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Book of Abstracts

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Timing / 1

Tracking the time: Single pixel 50µm pitch 3D cell time resolution map

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The proven radiation hardness of 3D technologies up to fluencies exceeding $1x10^{16}n_{eq}/cm^2$ makes them a prime candidate for next generation high energy physics experiments. In addition, the decoupling of the charge generation and drift volumes unique in these structures, provides excellent timing characteristics without radiation hardness comprise or the need for additional amplification layers. In this study, results are presented using 160GeV SPS pions to examine the time resolution uniformity, efficiency and fill factor for a single cell 50µm pitch structure. The various technical aspects, including synchronisation with the EUDAQ system and instrumentation integration are also discussed and the analysis framework is presented.

Experiments / 2

ATLAS ITk Pixel quad module test beam measurements

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For the HL-LHC upgrade, the current tracking system of the ATLAS experiment will be replaced by an all-silicon system, called the Inner Tracker (ITk), consisting of an inner Pixel Detector and an outer Strip Detector.

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The ITk Pixel Detector has two types of modules foreseen: triplet modules with 3D sensors in the innermost

In 2021, for the first time the properties of quad modules were measured in test-beams. The data reconstru

This talk presents the ATLAS ITk Pixel Detector test-beam data analysis together with the properties of th
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Experiments / 4

The ATLAS High-Granularity Timing Detector: test beam campaigns and results

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The expected increase of the particle flux at the high luminosity phase of the LHC (HL-LHC) with instantaneous luminosities up to L ⊠ 7.5×1034 cm−2 s-1 will have a severe impact on the ATLAS detector performance. The pile-up is expected to increase on average to 200 interactions per bunch crossing. The reconstruction and trigger performance for electrons, photons as well as jets and transverse missing energy will be severely degraded in the end-cap and forward region, where the liquid Argon based electromagnetic calorimeter has coarser granularity and the inner tracker has poorer momentum resolution compared to the central region.
The High Granularity Timing Detector (HGTD), a new timing detector for ATLAS, will be installed in front of the liquid Argon end-cap calorimeters for pile-up mitigation and for bunch per bunch luminosity measurements. This detector will cover the pseudo-rapidity range from 2.4 to about 4.0. Two silicon sensors double sided layers will provide a precision timing information for minimum ionizing particles with a time resolution better than 50-70 ps per hit (i.e 30-50 ps per track) in order to assign the particle to the correct vertex. Each readout cell has a transverse size of 1.3×1.3 mm2 leading to a highly granular detector with about 3 millions of readout electronics channels. Low Gain Avalanche Detectors (LGAD) technology was chosen as it provides an internal gain good enough to reach large signal over noise ratio needed for excellent time resolution. A dedicated ASIC for the HGTD detector, ALTIROC, is being developed in several phases producing prototype versions of 2×2, 5×5 and 15×15 channels. HGTD modules are hybrids of the LGAD and ALTIROC connected through flip-chip bump bonding process.
Several test beam campaigns have been conducted at CERN SPS H6 and at DESY T22 beamlines in the past years. Irradiated LGAD prototypes for the HGTD project have been tested from different technologies, manufacturers and geometries: single pads and 2×2, 5×5 arrays with a pad size of 1.3×1.3 mm2. The operational stability at different bias voltages and its performance in terms of charge collection, time resolution, efficiency and uniformity at fluences up to 2.5e15 neq/cm2 is studied. HGTD mini-modules of 5×5 arrays have been tested and their performance with beam is evaluated.

Facilities / **5**

Commissioning and First Run for the CERN Proton Irradiation Facility (IRRAD) after the Long Shutdown 2

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The CERN Proton Irradiation Facility (IRRAD) is a reference facility for performing irradiation experiments and qualification of tracking and calorimetry detectors, important for the upgrade of CERN Large Hadron Collider (HL-LHC) and for the R&D on future CERN accelerators. After the CERN Long Shutdown 2, the IRRAD facility has undergone through several changes on hardware and software systems as well as at the infrastructure level. This latter includes a completely new beamline to deliver the irradiation beam as well as improvements at the beam diagnostic level.
In this talk, the current upgrades will be presented including new beam instrumentation, data management and control systems. Moreover, the first proton beam commissioning and IRRAD operation after the Long Shutdown 2 will be discussed as well as the plan about the future IRRAD operation in 2022. Details will be also provided about preliminary tests performed with heavy ions on the new beamline.
In addition, status updates about the two online databases of worldwide Irradiation and Test Beam Facilities will be presented.

Experiments / **6**

Study of the ATLAS Tile Calorimeter response to beams of particles using Phase II upgrade readout

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The Large Hadron Collider (LHC) Phase II upgrade aims to increase the instantaneous accelerator luminosity.
A new readout system of the ATLAS Tile Calorimeter (TileCal) is needed to meet the trigger's requirements, to cope with the higher radiation levels and the ageing of the current electronics. It has to handle longer latencies of up to 35 µs at such high pileup levels.
Prototypes of the upgrade TileCal electronics have been tested using the beam from the Super Proton Synchrotron (SPS) accelerator at CERN. Data were collected in 2016-2018 with beams of muons, electrons and hadrons at various incident energies and impact angles. Furthermore, data were collected during 2021 beam test campaigns where the final version of Phase II upgrade readout was tested.
This presentation summarizes the beam test campaigns, the upgrades of the calorimeter electronics, the trigger and particle identification systems. The results obtained analyzing muon, electron and hadron data are discussed.

Facilities / **7**

The CERN Gamma Irradiation Facility GIF++ during Run 3 and beyond

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The upcoming High-Luminosity upgrade of the CERN Large Hadron Collider (HL-LHC) and the R&D on future accelerators (FCC) require radiation hardness tests and detector qualifications. The reference facilities at CERN for muon gas detectors is the GIF++, located on the H4 beam-line in the SPS North Area.
The last years were dominated by the mass production tests for the ATLAS Phase 1 upgrade, qualification tests for ALICE TPC chambers, ageing test of muon chambers and the search for eco-friendly gas mixtures. With several mayor improvements to the facility and the muon beam production, we now entered Run 3, and added the dedicated muon beam periods to our work program. In this presentation we will give an overview of the facility, describe recent improvements, and present the ongoing test program. We will also discuss the possibility to operate the facility beyond the Long Shutdown 3 (LS3) and the necessary improvements to be made.

Experiments / **8**

Ultra Thin Secondary Electron Emission Sensors for Beam Monitoring

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The Extra Low Energy Antiproton (ELENA) is the new deceleration ring installed in the Antimatter Factory at CERN. Thanks to the introduction of ELENA, the antimatter experiments will receive an antiproton beam with an energy down to 100 keV, allowing improved performance and opening the door to new and exciting discoveries.
On the other hand, such a low energy beam required the development of new beam monitoring devices, capable of detecting the antiprotons without stopping them, while at the same time fulfilling the purpose of reducing their energy to below the trapping value of 10 keV.
We describe the development and the characterization of a new beam monitoring detector, based on Secondary Electrons Emission, with a sensitive foil with a thickness as low as 110 nm. The detector, developed by the IRRAD team at CERN and by the AEgIS Collaboration, was tested with a 24 GeV proton beam and with 100 keV antiprotons.

Hands-On Tutorial / 9

Hands-On: Silicon Detector Monte Carlo Simulations with Allpix Squared

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Scope of the tutorial

The goal of this interactive tutorial is to understand the usage of basic functionalities of the Allpix Squared simulation framework, and methods to extract some of the relevant quantities for sensor studies. Participants are encouraged to follow along on their own computers. A task and instructions will be provided and walked through, covering the basic concepts of configuring a simulation and a detector geometry, and extracting and interpreting histograms. We will also touch upon incorporating detailed results from TCAD into the simulations.
Some prior knowledge on the framework is helpful, but not required.

Preparation

Please install the latest release version of Allpix Squared on your computer, or make sure you have access to a working version online before the tutorial.

Detailed instructions for installation can be found in the manual or on the website (https://cern.ch/allpix-squared) and GitLab (https://gitlab.cern.ch/allpix-squared/allpix-squared)

Simulation / 10

Tangerine: Monte Carlo simulations of MAPS in a 65nm imaging process

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The rapid evolution of High Energy Physics experiments demands the development of improved detectors. The Tangerine project's goal is to develop the next generation of small collection electrode monolithic silicon pixel detectors using the 65nm CMOS imaging process which offers a higher logic density and overall lower power consumption compared to previously used processes. One objective of this project is to construct a telescope to potentially be used at the DESY test beam facility. In monolithic sensors the sensitive volume and readout is in a single chip, which enables a lower material, and reduced cost and production effort compared to hybrid sensors. In order to understand the processes and parameters that are involved in the developments in the new 65 nm technology, a combination of TCAD and Monte Carlo (MC) simulations are used. Allpix Squared utilizes the realistic electric field and doping profiles provided by the TCAD simulations and by the use of MC methods, obtains important quantities such as efficiency, cluster size, and resolution. These results can later be compared to results from test beam experiments.

This presentation will cover the design and setup of the Monte Carlo simulations and present the results obtained so far.

Sensors / **11**

TANGERINE - First test-beam result on MAPS prototypes in 65 nm process

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The characteristics of the Monolithic Active Pixel Sensors such as small thicknesses, pixel pitches and cost have made this detector type increasingly attractive for applications in high energy physics in recent years. The TANGERINE project at DESY aims to push research in this field in order to develop a fully integrated 65 nm CMOS pixel chip for future application in beam-test facilities or Higgs factories, aiming for a spatial resolution below 3 μm and a time resolution on the order of 1 ns.
First 65 nm CMOS test chips with 4 pixels of 16 μm pitch and analog readout are investigated. Initial analysis of data obtained at the DESY II, CERN SPS, and MAMI beam-test facilities are reported. A 10 GSa/s oscilloscope is used to record the analog pulses, allowing for detailed waveform analysis.

Experiments / **12**

Future perspective of the FOOT experiment for neutrons identification

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The FOOT (FragmentatiOn Of Target) collaboration aims at improving cancer treatments in particle therapy and optimizing passive countermeasures in space radioprotection by studying the interaction of typical beams with reference targets. On the one hand, particle therapy employs proton and carbon beams to deliver a uniform dose in the tumor region, minimizing the damage to the surrounding healthy tissues. On the other hand, space radioprotection deals with the dose delivered to the astronauts by the space radiation field interacting with any material composing the spacecraft. In both cases, the interaction of the beam with the patient body or the shielding materials lead to nuclear fragmentation with significative neutrons production. Therefore, the characterization of both neutral and charged secondary particles produced in the nuclear beam-target interactions has to be considered both in the plan of an effective and safe medical treatment and in the risk assessment of a long-lasting interplanetary mission (i.e., Mars human exploration). Specifically, the most missing information is about neutrons production, for instance data in the literature are scarce and reported with few details. As a matter of fact, neutrons are an unavoidable drawback of hadron therapy and they have been suggested by NASA and other space agencies to have a dominant role in the potential restriction of boundaries of space exploration.

So far, the FOOT experiment has focused on the characterization of the charged fragments production and the measurement with 5% accuracy of the nuclear fragmentation cross sections interesting in tumor therapy and space radioprotection. However, the future perspective of the FOOT collaboration is to start several experimental campaigns devoted to the evaluation of neutron-production cross sections relevant in the same fields. The feasibility of these experiments relies upon the availability of neutron detectors with particle discrimination capability, and able to operate in an experimental environment highly contaminated by the presence of background, like a liquid scintillator for instance. The telescope system achieved by coupling such detector with a thin plastic scintillator will ensure the discrimination between charged and neutral particles.
In this contribution, I will present the possible upgrades of the FOOT experiment to extend the research focus on neutron production, as well as the preliminary results of measurements performed at GSI (Germany).

Overview Lectures / 13

Beam Generation for Test Beams

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The lecture covers the basics of the secondary and tertiary beam generation for the test beams at CERN. It covers the basics of beam-matter interaction and summarises the processes of secondary particles production at the target stations. It introduces the Atherton parametrisation and the particle zoo available at CERN North Area. Subsequently, it covers the design of transfer beam lines, beam optics and equipment types used for beam size and divergence setup, momentum selection, collimation etc. The tools of particle type selection and enrichment are introduced, such as converters, absorbers, radiators, synchrotron radiation, pion decay and muon polarization. The presentation ends with a brief overview over the beam instrumentation utilized for test beams diagnostics.

DAQ Systems / 14

A Trigger/Timing Logic Unit (TLU) For AIDAInnova

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Beam-lines supported by the EUDET, AIDA and AIDA-2020 projects provided a standard hardware and software interface for triggering and synchronization between any beam-telescope installed on the beam-line. The hardware used is called a Trigger/Timing Logic Unit (TLU).

The AIDA-Innova project will provide a new TLU with a higher specification than the existing EUDET and AIDA(-2020) TLUs while maintaining a backward compatible hardware interface.

The most important upgrade is improving the timing resolution from O(1ns) to O(10ps).

Initial specifications for the AIDA-Innova TLU are discussed together with plans for implementation.

Calorimetry / **15**

Latest Beam Tests of CMS HGCAL Tilemodule Prototypes

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For the HL-LHC phase, the calorimeter endcap of the CMS detector will be upgraded with a High Granularity Calorimeter (HGCAL), a sampling calorimeter which will use silicon sensors as well as scintillator tiles read out by silicon photomultipliers (SiPMs) as active material (SiPM-on-tile). The complete HGCAL will be operated at -30 degC. The SiPMs will be used in areas where the expected radiation dose during the lifetime of the detector is up to 5*10^{13} neq/cm^2. The design of the SiPM-on-tile part is inspired by the CALICE AHCAL.

The basic detector unit in the SiPM-on-tile part is the tilemodule, consisting of a PCB with one or two HGCROC ASICs, reading out up to 96 tiles with SiPMs. To acquire the data as well as to send the fast and slow control commands, monitor temperature and voltages from the tilemodules a dedicated DAQ system has been designed and implemented. This DAQ system was tested alongside the latest generation of tilemodules at the October 2021 testbeam at DESY as well as tests at -30 degC were conducted using a climate chamber. Results from these tests will be reported.

Beam Telescopes / **16**

EUDET-Type Beam Telescopes and Beyond

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Beam telescopes have become integral to the infrasctructure of many test beam facilities today. At the DESY II Test Beam the EUDET-type beam telescopes have represented the standard for the better part of a decade by now. The monolithic architecture of the MIMOSA26 pixel sensor combined with the small pitch (18.4 μm) makes it particularly suited for tracking low momentum particles.
In the first part of this talk an update on the current status of the EUDET-type beam telescopes will be given.
Despite their success up until now, keeping up with increasing demands in the field of detector R&D calls for an upgrade. High particle rates and the requirement for precise time information exceed the

capabilities of the MIMOSA26 sensor with its ˜ 115 µs long readout cycle. One upgrade approach is the integration of an additional dedicated timing layer, several options of which are currently under study. A compatible approach is the replacement of the MIMOSA26 sensors by newer generation pixel sensors, which is additionally motivated by the possibility of the current telescopes reaching their end-of-life in the near term.
The second part of the talk will present the efforts being made at DESY to upgrade the EUDET-style beam telescopes as well as an outlook on future possibilities.

Facilities / 17

CERN North Area Multi-Purpose Superconducting Magnet Facility

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In the context of EP R&D, CERN is developing a multi-purpose superconducting magnet test facility to be used for future detector and electronic device testing at the North Area beam-test area. The facility will serve as a replacement of the existing M1 and Morpurgo magnets that have been in operation since the late 70s. The facility is envisioned to serve all the testing requirements for the following 50 years together with the proton beam of the Super Proton Synchrotron (SPS).

The magnet will have a central field of 4 Tesla with a free-bore volume of 1 cubic metre. The magnet will take either the form of a split solenoid, allowing dual use as a dipole or solenoid, or a skateboard tilted racetrack design, allowing dipole function. It is envisioned to use Niobium Titanium Rutherford cables with a Nickel-Aluminium stabiliser. The operation temperature will be 4.5 K with liquid Helium cooling. The stray fields are being minimised to be below 12 mT at a distance of 5 m from the central point. The magnet will also incorporate bespoke Persistent Current Switches studied and developed in-house and well as possible inclusion of cryo-coolers.

The North Area Superconducting Magnet facility is an important project for the testing and development of future detectors and electronics at CERN, specifically components that will utilised in the Future Circular Collider (FCC), the new 100 km collider to be built at CERN. This innovative facility therefore serves as an important step for the future activities of CERN and the future of colliders.

Sensors / 18

Test Beam Results of highly irradiated 3D and planar pixel sensors interconnected to RD53A readout chip

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The High Luminosity upgrade of the CERN Large Hadron Collider (HL-LHC) calls for new high-radiation tolerant silicon pixel sensors, capable of withstanding fluences up to 2.3E16 neq/cm2 (1MeV equivalent neutrons). In this presentation results obtained in beam tests experiments with 3D and planar pixel sensors interconnected with the RD53A readout chip are reported. RD53A is the first prototype in 65nm technology issued from RD53 collaboration for the future readout chip to be used in the upgraded pixel detectors. The interconnected modules have been tested on an electron beam at DESY, before and after irradiation, which was performed in KIT Irradiation Center, up to an equivalent fluence of 2.4E16 neq/cm2. The sensors were made in FBK foundry in Trento, Italy, and their development was done in collaboration with INFN (Istituto Nazionale di Fisica Nucleare, Italy). Analysis of collected data shows hit detection efficiencies around 99% measured after irradiation. All results are obtained in the framework of the CMS R&D activities.

Simulation / 19

Device simulations of a MAPS in 65nm CMOS Imaging Technology dedicated for test beam measurements

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Monolithic CMOS sensors have found their way through imaging technologies into High Energy Physics thanks to multiple advantages in particle detection. Their main characteristic is the integration of an active sensor and readout in a single chip, which provides a reduction in production effort, costs and material. The Tangerine project aims to develop the next generation of silicon pixel sensors intended as reference detectors in test beam measurements. The goal is to achieve excellent time and spatial resolution using a 65 nm CMOS imaging technology with a small collection electrode. It offers a significant improvement in the logic density of the pixels, the power consumption, the material budget and the S/N in comparison to previously studied technologies. In virtue of this, the first sensor is envisioned to potentially be used as a telescope in the DESY test beam facility. Both device (TCAD) and Monte Carlo simulations (Allpix^2) are needed to develop the understanding of this technology and provide important insight into performance parameters of the sensor, which can be tested afterwards in laboratory and test beam experiments. This contribution will present the latest developments in device simulation results of a 65 nm CMOS sensor with a small collection electrode.

Experiments / 20

Performance of the FASER tracker using testbeam data

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FASER, or the Forward Search Experiment, is a new experiment at CERN designed to complement the LHC's ongoing physics programme, extending its discovery potential to light and weakly-interacting particles that may be produced copiously at the LHC in the far-forward region. New particles targeted by FASER, such as long-lived dark photons or dark scalars, are characterised by a signature with two oppositely-charged tracks or two photons in the multi-TeV range that emanate from a common vertex inside the detector. The experiment is composed of a silicon-strip tracking-based

spectrometer using three dipole magnets with a 20-cm aperture, supplemented by four scintillator stations and an electromagnetic calorimeter to allow for energy measurements. The full detector was successfully installed in March 2021 in an LHC side-tunnel 480 meters downstream from the interaction point in the ATLAS detector. FASER is planned to be operational for the upcoming LHC Run 3.

In 2021 a test beam campaign was carried out using one of the CERN SPS beam lines, utilizing one of the tracking stations (24x24cm), scintillators, and the calorimeter of the experiment. During the test beam, a large statistical sample of electron and muon tracks ranging from 10 to 300 GeV have been recorded while scanning over the experimental setup. We will present the performance and alignment of the tracking station during the test beam campaign.

Sensors / 21

Digital Pixel Test Structure characterization with the ALPIDE telescope

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The ALPIDE telescope is a continuously evolving tracking telescope based on the TowerJazz 180 nm CMOS ALICE PIxel DEtector (ALPIDE). The ALPIDE is a high efficiency, high spatial resolution monolithic active pixel sensor designed for the recently commissioned ALICE Inner Tracker System (ITS2).
This telescope is one of the main R&D tools for the test and characterization of new sensors and devices in view of the future tracker upgrades.
One such sensor is the Digital Pixel Test Structure (DPTS), produced using the TPSCo 65 nm CMOS imaging process. It consists of a 32 by 32 matrix of 15 um by 15 um pixels featuring time-based encoding of a hit position.
Both non-irradiated and irradiated DPTS performance is assessed with 5.4 GeV/c and 3.4 GeV/c electron tracks measured with the ALPIDE telescope at DESY Test Beam Facility.
In this talk, the test beam measurements with the ALPIDE telescope and the analysis of the DPTS performances will be presented.

Calorimetry / 22

Exploring the Intrinsic Time Resolution of the SiPM-on-Tile Technology

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The SiPM-on-Tile technology, where small plastic scintillator tiles are directly read out with SiPMs, has been developed for the CALICE Analog Hadron Calorimeter (AHCAL), and has been adopted for parts of the hadronic section of the CMS HGCAL. For future electron-positron colliders, a single cell time stamping on the sub-nanosecond level for energy deposits corresponding to single minimum-ionizing particles is desired to provide background rejection and to support pattern recognition and energy reconstruction with particle flow algorithms. To study the intrinsic time resolution achievable with this technology, detailed measurements have been performed in beam tests at DESY. For this program, a setup designed for maximum flexibility to minimize the time needed for access to the beam area and changes to the setup has been constructed. Four scintillator tiles are arranged as

a "beam telescope", allowing the investigation of various scintillator materials and tile geometries. This setup is integrated in an overall support structure and equipped with a compact system that provides SiPM, front-end amplifier power and signal routing. A precise digitizer reads out the full analog waveform to resolve the time structure of the detector response in an offline analysis. In this contribution, we will discuss details of the experimental setup and its calibration, and report on first analyses of the data taken at DESY in October 2021.

Facilities / 23

CERN Secondary Beam lines and Experimental Areas

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The CERN beam lines of the North and the East Area are designed to deliver beams of secondary and tertiary particles as well as attenuated primary protons and ions from the SPS and PS accelerators. Typically, hadrons, electrons, and muons in the energy range up to 360 GeV/c at a maximum flux of 10ˆ7 - 10ˆ8 particles per SPS extraction are served to the experimental areas. Following the Long Shutdown 2, these beam started again in 2021. This talk will present the features of the different beam lines and beams serving various fixed target experiments and test beam areas, including beam properties, available infrastructure for tests and beam instrumentation, e.g. the installed beam telescopes. The beam control software will also be briefly introduced. The East Area has been just renovated and a first look into the performance of the newly available beams will be given, as well.

DAQ Systems / 24

First experience with a HGCROCv3 silicon module at the SPS

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The endcap calorimeters of CMS will be upgraded a single High Granularity Calorimeter (HGCAL) for the HL-LHC. The HGCAL is a sampling calorimeter that will use silicon sensors as well as scintillator tiles as active material and be operated at -30 C. The silicon section will have several sensor thicknesses and there will be multiple sensor geometries based on 8" wafers. The readout of the sensors is performed by an ASIC (HGCROC) that measures the amplitude and timing of the signals. The amplitude is measured in a large dynamic range that needs to cover both single MIPs and TeV shower deposits and the timing precision for energetic deposits should be under 30 ps.

In the space of a few months in 2021, the HGCROCv3 was commissioned, assembled into a silicon module, and exposed to electron beams in the SPS H2 line. The module was operated for about a week in a chamber at 0 C and the signal from MIPs was seen for the first time even with the asynchronous nature of the beam. In this contribution we will present and discuss the experience of going from single HGCROCs from the foundry that did not work out of the box, all the way through to seeing MIP signals, including aspects of the Zynq-based readout system, the firmware developed to deal with the asynchronous beam timing, and the software that performed online monitoring using contemporary COTS technologies.

Overview Lectures / **25**

Transition Radiation Detectors

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Transition radiation detectors is one of the not destructive particle Identification techniques widely used in high energy and cosmic-ray physics.
The change of the electromagnetic field of a charged particle at a transition between media with different refractive indices leads to the emission of electromagnetic radiation, so-called transition radiation (TR). In the optical range transition radiation is emitted in the forward and backward directions and it is used usually for a beam position diagnostics in accelerators. However, in the keV energy range TR is emitted at small angles to the particle and its yield has sort of threshold effect as a function of a particle Lorentz factor. This effect used in the transition radiation detectors (TRD) to separate particles of the same momentum which have different masses.
In this talk I'll present a basic properties of the transition radiation starting from the TR characteristics at a singe transition boundary then going to interference phenomena and their dependence on the coherence conditions leading to evolution of the angular and the energy TR spectra. Dependence of these characteristics on the Lorentz factor will be discussed. Then basic principles of the TRD operation will be presented with examples of their use in the high energy and cosmic-ray experiments. Finally, new TRD developments and trends with be presented and discussed.

DAQ Systems / **26**

Next-generation electronics for the gaseous beam telescope of RD51

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RD51 is a CERN-based research collaboration, focusing on the development and advancement of Micro-Pattern Gaseous Detectors (MPGDs). One of the major outcomes of these activities was the development of a joint multi-purpose electronic readout system, the Scalable Readout System (SRS). It allows to read out small R&D set-ups up to mid-sized experiments with various front-end ASICs

(APV25 and Timepix as most successful examples). The SRS is used for test beam campaigns and laboratory measurements since its introduction in 2009 by many RD51 teams.

In recent years the analogue and digital BNL/ATLAS VMM3a was integrated into the SRS. With its rich set of features (e.g. a multi-channel self-triggered continuous readout, a high-rate capability of 9 Mhits/s per ASIC, a 10-bit charge information and a time information with nanosecond resolution) the combination of VMM3a and SRS is particularly interesting for the readout of a beam telescope.

As part of its activities, RD51 organises up to three times per year a joint test beam campaign at the H4 beamline of CERN's Super Proton Synchrotron. For these test beam campaigns, the collaboration provides a GEM-based beam telescope with 10x10 cm² active area. During the past two RD51 test beams (July and October 2021), VMM3a/SRS was successfully tested as new electronics for its beam telescope. The telescope (detectors, FE and DAQ) aims to provide MHz rate-capability, spatial resolutions of 50 µm or better and time resolutions in the nanosecond regime. In this presentation, the first results are shown, focusing on the commissioning of the system, the tracking efficiency, spatial resolution and time resolution studies.

Simulation / **27**

Allpix Squared - Version 2.0 and Onwards

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Allpix Squared is a versatile, open-source simulation framework for silicon pixel detectors. Its goal is to ease the implementation of detailed simulations for both single sensors and more complex setups with multiple detectors. While originally created for silicon detectors in high-energy physics, it is capable of simulating a wide range of detector types for various application scenarios, e.g. through its interface to Geant4 to describe the interaction of particles with matter, and the different algorithms for charge transport and digitization. The simulation chain is arranged with the help of intuitive configuration files and an extensible system of modules, which implement the individual simulation steps. Detailed electric field maps imported from TCAD simulations can be used to accurately model the drift behavior of charge carriers, and an implementation of the Shockley-Ramo theorem enables time-resolved signal formation studies, adding a new level of detail to Monte Carlo simulations of particle detectors.

Recently, Allpix Squared has seen major improvements to its core framework to take full advantage of multi- and many-core processor architectures for simulating events fully parallel. Furthermore, new sensor geometries such as hexagonal pixels have been introduced, further extending the application range. This seminar provides an overview of the framework and its components, highlighting the versatility and some of the recent developments.

Calorimetry / **28**

Energy reconstruction of electrons and pions in the HGCAL beam test prototype using Graph Neural Networks

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Calorimetry at the High Luminosity-Large Hadron Collider faces two enormous challenges particularly in the forward direction: radiation tolerance and unprecedented in-time event pileup. To meet these challenges, the CMS experiment has decided to replace its current endcap calorimeters with a High Granularity Calorimeter (HGCAL), featuring a previously unrealized transverse and longitudinal segmentation, for both the electromagnetic and hadronic compartments. As part of the development of this calorimeter, a series of beam tests have been conducted using prototype segmented silicon detectors. In the beam test conducted at the CERN SPS in October 2018, the performance of a prototype calorimeter equipped with ≈12,000 channels of silicon sensors complemented with a CALICE AHCAL prototype, a scintillator-based sampling calorimeter, mimicking the proposed design of the HGCAL scintillator part was studied with beams of high-energy electrons, pions and muons with momenta ranging from 20 to 300 GeV/c.

The ultimate calorimetric performance of the HGCAL can potentially be realized using advanced deep-learning algorithms that exploit the detailed low-level hit information that effectively images the shower development in three spatial dimensions, while also measuring the corresponding energy deposition in the active elements. We have developed a novel machine-learning architecture based on dynamic graph neural networks using these low-level detector hits as input features and applied it to reconstruct the energy of electrons and pions with the HGCAL beam test prototype. The results show a very significant improvement in the relative energy resolution as compared to a simpler rules based reconstruction technique.

In this presentation we will cover this new machine-learning based reconstruction technique in detail and summarize the results obtained for both the energy response and resolution to electromagnetic and hadronic showers.

Hands-On Tutorial / 29

Making the most of your test-beam time - Understanding the interplay between the new AIDA-TLU and EUDAQ2 to optimally match your DAQ system

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The AIDA trigger logic unit and EUDAQ2 provide a common infrastructure platform to integrate a large variety of devices with the EUDET-type reference telescopes at test beams. Since test-beam time is always limited, users rely on a stable and common interface for their devices. The tutorial will provide a solid basis to optimally prepare your next successful test beam campaign.

The tutorial is split into three parts:

In the beginning, the software framework is introduced and the basic principles of software integration are discussed, along with the basic principles of data storage. Afterwards, all required software will be installed.

In the second step, we will discuss the functionality of the trigger logic unit and demonstrate its functionality:

- How can the readout be triggered
- Modes of communication with user devices
- Realization of the interplay between soft and hardware

Finally, we will connect two scintillators/PMTs to trigger on cosmic particles and demonstrate the impact of the modes on the trigger rates, DUTs based on a raspberry Pi.

A repository with all required scripts, libraries etc will be provided beforehand
No expert knowledge is required to participate. Nevertheless, additional information can be found via the following links:

EUDAQ2
Telescopes at DESY
AIDA TLU

Timing / 30

ATTRACT FASTPIX Monolithic Pixel Sensor Demonstrator for sub-Nanosecond Timing in Future Vertex and Tracking Applications

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Vertex and tracking detectors for future high-energy physics experiments face stringent requirements in view of their spatial and temporal measurement performance as well as the projected experimental conditions.
Within the ATTRACT FASTPIX project, a monolithic pixel sensor demonstrator chip has been developed in a modified 180 nm CMOS imaging process technology, targeting sub-nanosecond timing precision for single ionising particles. It features a small collection-electrode design and contains 32 mini-matrices of 68 hexagonal pixels each, with pixel pitches ranging from 8.66 µm to 20 µm. Various design variations are explored, aiming at an increase in speed and uniformity of charge collection across the pixel area.
This contribution explores arising challenges in characterizing the state-of-the-art pixel sensor demonstrator FASTPIX by discussing the preparation, setup and results of beam tests at the CERN SPS. The talk will cover the CLICdp Timepix3-based beam telescope setup, including upgrades for picosecond time measurements as well as performance results from recent test-beam measurements.

Experiments / 31

Testbeam studies of irradiated modules for the ATLAS ITk Strip upgrade

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In order to cope with the occupancy and radiation doses expected at the High-Luminosity LHC, the ATLAS experiment will replace its Inner Detector with an all-silicon Inner Tracker (ITk), containing pixel and strip subsystems. The strip subsystem will be built from modules, consisting of one n+-in-p silicon sensor, one or two PCB hybrids containing the front-end electronics, and one powerboard with high voltage, low voltage, and monitoring electronics. The sensors in the central region of the detector will use a simple rectangular geometry, while those in the forward region will use a radial geometry with built-in stereo angle.
To validate the expected performance of the ITk strip detector, a series of testbeam campaigns has been performed over several years at the DESY-II testbeam facility. Tracking was provided by EUDET telescopes, consisting of six Mimosa26 pixel planes. An additional pixel or strip plane was used to improve the timing resolution of the telescope. Tracks are reconstructed using the General Broken Lines algorithm, resulting in a spatial resolution of several microns. During 2021 the focus has been on assessing the module performance post-irradiation, using the final production versions of the sensors and front-end electronics. Three modules were built from irradiated components, including the first "split" module containing two sensors to be tested at testbeam. Measurements were performed of the charge collection, signal efficiency, and noise occupancy of the modules, as well as tracking performance in various sensor regions. The results give confidence in the operability of the detector across its lifetime.

Career Paths / 32

Knowledge transfer in the High Energy Physics domain

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Historically, one can point to innovations that were a result of earlier efforts to build detectors for particle physics experiments or to work together more effectively. Two such developments, indispensable in our everyday life are the invention of the world wide web and the touch screen at CERN; combined in nearly all our phones.
Nowadays, we could be asked to show what societal benefits can be expected beforehand. To deal with these kind of questions, we need to be conscious of where current or future developments could be applied in other fields. The aim of this contribution is to trigger this mindset in an interactive manner.

Experiments / 33

Silicon Pixel-Strip module characterisation for the CMS Outer Tracker Phase II Upgrade

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The Large Hadron Collider (LHC) will undergo a major "High Luminosity"upgrade with the goal of delivering a peak instantaneous luminosity of about $5 - 7.5 \times 10^{34} cm^{-2} s^{-1}$ by 2027. In order for the CMS experiment to cope with the higher radiation levels and data rates, the current CMS Silicon Tracker will be replaced. The upgraded Outer Tracker will introduce a new module concept, made of two vertically stacked silicon sensors, which will exploit the strong magnetic field inside the CMS detector to select high transverse momentum particles locally and send the corresponding information to the CMS Level-1 triggering system.

This talk will focus on one of the two foreseen designs, namely the Silicon Pixel-Strip (PS) module. The module is made of a $10 \times 5cm^2$ strip sensor, with $2.5cm$ long strips and 100μm pitch, stacked on top of a macro pixel sensor with $1400 \times 100\mu m$ macro pixels bump-bonded to dedicated macro pixel ASICs. The sensor stack is surrounded by peripheral front-end, power and readout hybrids in charge of strip sensor readout and data concentration, power distribution and optical data transmission, respectively.

After an introduction to the concept and design of a transverse momentum discriminating module, with a mention of the Pixel-Strip module assembly and preparation, the talk will mainly cover the description of the DAQ test system and first results of test-beam characterisation performed at the DESY II Test Beam Facility, focusing on detection and momentum discrimination performance.

Hands-On Tutorial / 34

The Corryvreckan Test-Beam Reconstruction Framework — Hands-on

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Corryvreckan is a software framework dedicated to the analysis of test-beam data. It employs a modular concept, providing algorithms for typical analysis steps like pixel masking, clustering, tracking, alignment and for the reconstruction of commonly investigated observables like detection efficiency, spatial and temporal resolution or material budget. This approach allows for a flexible configuration and adaption to a broad range of setups and devices, and explicitly includes the EUDAQ2 framework and the AIDA TLU.

This tutorial provides an introduction to the Corryvreckan framework, the use of different analysis modules and their configuration. A key point of Corryvreckan — the flexible event building mechanism — will be covered for a typical setup, making use of EUDAQ2 and the AIDA TLU. Finally, the use of Corryvreckan as a tool for online monitoring will be covered.

Experiments / 35

A test beam for the cluster counting technique

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Particle identification is one of the crucial and difficult task for the high energy physics experiments, like the future FCC-ee, CEPC, SCTF. The ionization of matter by charged particles is the primary mechanism used for particle identification (dE/dx), but the large uncertainties in the total energy deposition represent a limit to the particle separation capabilities. The cluster counting technique (dN/dx) takes advantage from the primary ionization \textit{Poissonian} nature and offers a more statistically significant way to infer the mass information. To investigate the potential of the cluster counting techniques on physics events a simulation of the ionization clusters generation is needed. To this purpose, we developed an algorithm which can use the energy deposit information provided by Geant4 software tool to reproduce, in a fast and convenient way, the clusters number distribution and the cluster size distribution. The results obtained confirm that the cluster counting technique allows to reach a resolution 2 times better than the traditional dE/dx method. To validate the simulations results, we performed a first test beam at CERN with a pack of drift tubes, by using a muon beam of 165 GeV, by collecting data with two gas mixtures, which are 90% He and 10% iC_4H_{10} and 80% He and 20% iC_4H_{10}, at different gas gain and angle configurations.
The final goal of the test beam will be the possibility to study:
- the counting efficiency as a function of gas mixture, gain, geometrical configuration (cell size, sense wires size), arrival time of the first cluster
- the cluster density as a function of ionization length and angle
- the cluster dimension as a function of gain and cell size
- the definition of the optimal condition for the next test (next spring) whose goal will be the measurement of the relativistic rise of dN/dx and dE/dx.

Timing / 36

MONOLITH –picosecond time stamping in fully monolithic highly-granular pixel sensors

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The MONOLITH H2020 ERC Advanced project aims at the development of fully monolithic highly granular pixel sensors with picosecond time stamping capabilities. To reach a picosecond precise sensor response, a thin gain layer has been implemented deep inside a high-resistivity epitaxial layer. By moving the gain layer away from the pixel implantation, the pixel size can be reduced down to 50 µm, allowing to simultaneously reach a high spatial precision. Making use of a SiGe BiCMOS 130 nm process technology, a fast and low noise frontend has been realized. First prototypes with different doping levels and different complexity of in-pixel circuitry have been produced in this technology to investigate and optimize their performance in terms of e.g. sensor gain and time-stamping capability. Laboratory and test-beam measurements have been made, with a focus on sensor gain, detection efficiency, and time resolution. This talk will introduce the MONOLITH project and summarise the main measurement results.

Beam Telescopes / 37

MALTA Monolithic Pixel Sensor Telescope : New Developments and Recent Measurements

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MALTA is part of the Depleted Monolithic Active Pixel sensors designed in TowerJazz 180nm imaging technology. The MALTA sensor has been produced on Cz substrates in view of optimising the signal for efficiency and time resolution. A custom telescope with MALTA planes has been developed for a testbeam campaign at SPS (CERN) using up to six MALTA tracking planes and the ability to host several devices under test (DUT). The telescope system has a dedicated custom readout, online monitoring integrated into DAQ with realtime hit map, time distribution and event hit multiplicity. It furthermore hosts a dedicated fully configurable trigger system giving the possibility to trigger on coincidence between telescope planes and reference from scintillators. The excellent time resolution performance allows for fast track reconstruction, due to the possibility to retain a low hit multiplicity per event which reduces the combinatorics. The contribution will review the architecture of the system and its performance during the 2021 testbeam campaign at SPS North Area and will present preliminary results on the new generation MALTA2 chips.

Timing / 38

40 picoseconds time resolution analysis from test beam of monolithic pixel sensors.

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"The MONOLITH ERC Advanced project targets the development of very thin monolithic pixel sensors capable of reaching picosecond-level resolution combined with high granularity. To achieve such performance the project profits from the 130nm SiGe BiCMOS technology by IHP to produce very fast, low noise and low power front-end electronics. Small prototypes have been tested at the H8 SPS beam line at CERN. Time resolutions better than 40 ps and efficiencies above 99 % have been measured. This talk will briefly introduce the sensor technology and focus on the time walk correction used to measure the time resolution of these devices. "

Calorimetry / 39

Beam Tests of CALICE AHCAL prototypes

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The Analogue Hadron Calorimeter (AHCAL) developed by the CALICE collaboration is a scalable engineering prototype for a detector at future electron-positron energy frontier colliders. It is a sampling calorimeter of steel absorber plates and 3*3 cmˆ2
plastic scintillator tiles individually read out by silicon photomultipliers (SiPMs) as active material. The front-end ASICS (SPIROC2E) are integrated into the active layers of the calorimeter. They are designed for minimal power consumption by rapidly cycling the power according to the beam structure of a linear accelerator.

After building and operating a large prototype of 38 active layers with nearly 22000 readout channels in 2018, we are now focussing on two further developments:
1) an alternative scintillator geometry with mega-tiles instead of tiles individually wrapped in reflective foil, and
2) an alternative readout ASIC (KLauS), which allows operation both with power cycling and with continuous readout, as required for operation at circular electron-positron colliders.
Both developments have successfully studied in beam tests at DESY in 2021.

This presentation gives an overview of the recent AHCAL beam tests.

Experiments / 40

Test Beam Analysis of a Silicon-Strip Module for the CMS Phase-II Tracker Upgrade

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The foreseen Large Hadron Collider upgrade is expected to deliver an integrated luminosity that is one order of magnitude larger after 2027. Rare processes and new phenomena may be observed in this high luminosity era. The Phase-II Outer Tracker upgrade of the CMS experiment is required to surmount higher radiation and increased event rate. Transverse momentum (P_T) discrimination is introduced in the design and will contribute to the Level-1 Trigger. A CMS 2S silicon strip module with P_T discrimination concept was built by the DESY Outer Tracker group and has undergone a test beam experiment at the DESY test beam facility.

The talk will briefly summarize the assembly of the DESY 2S module, sensor studies and the data acquisition scheme during the beam test. The main focus will be on the results from recent test beam measurements. The analysis will be done based on corryvreckan framework, a modular concept of test beam reconstruction chain. Hit efficiency of the sensors under a bias scan, the performance over the large module area, and on-module P_T discrimination functionality will be presented.

Beam Telescopes / 41

The INSULAB beam test setup

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The INSULAB beam test setup is made up by different detectors for precision tracking, trigger setup, multiplicity counting and energy measurements. The tracking system consists in a set of double-sided microstrip silicon telescopes with a high spatial resolution (˜ 5 um) and large area single-sided microstrip silicon detector (resolution down to ˜ 30 um) for the precise measurements of the incoming particles tracks and the beam divergence; different plastic scintillators read out by PMTs are suitable for the trigger system and to be used as multiplicity counters; a set of electromagnetic calorimeters (homogeneous BGO or Lead glass and sampling lead-scintillator shashlik) read out by PMTs for a precise energy measurements (with energy resolution down to 5%/sqrt(E) TBC) of photons or electrons/positrons.
The detectors are read out by custom VME boards (silicon detectors) or commercial digitizers of the CAEN V1730 family (scintillators or calorimeters).
The data acquistion, written in C with Tcl/Tk as GUI, allows to program and monitor different trigger configurations, acquire data and process them online with a stripping system producing DST (summary files) with all relevant informations suitable for easy data analysis in ROOT or python.
There is undergoing work to improve the interconnection of modules (optical fiber readout of silicon detectors) and to develop custom digitizers to improve the acquisition speed.

DAQ Systems / 42

Status of the Caribou DAQ System

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Developing a new silicon detector requires significant effort for preparing the readout hardware and software for the prototype to be operated in the laboratory and test beams. The Caribou DAQ framework significantly reduces the development effort and cost for such readout systems. By utilizing modern system-on-chip (SoC) platforms, it combines programmable logic and a processing system and thereby brings unprecedented flexibility to the DAQ design. A universal interface card connects the SoC with the detector prototype, housing power supplies for biasing as well as DACs and ADCs for setting and measuring operational parameters, test pulses, etc. Through this versatile hardware and the modular design, the turnaround time for supporting new detectors is minimized. The system is completed by a set of configurable firmware blocks for commonly used functionality as well as the DAQ software Peary.
This talk gives an overview of the Caribou system and presents recent applications and developments, such as the integration of new detector chips: FASTPIX is a monolithic pixel sensor demonstrator chip with sub-nanosecond time resolution implemented in a modified 180 nm CMOS imaging process. The DPTS and APTS are prototype chips using a modified 65 nm process. An oscilloscope based readout implemented in Caribou is used for laboratory and beam tests.

Sensors / 43

Test beam studies of passive CMOS strip sensors

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Future particle physics experiments are motivated by the increase in luminosity and thus the need for intelligent tracking detectors providing fast track and momentum information to select events of interest. The next generation tracking detectors are mostly all silicon detectors and thus finding a cost effective solution to maximize the output is important. Therefore the commercial CMOS technology for silicon strip sensors is a prime candidate as it allows the use of large and high-resistive wafers and also provides the advantage of easier production and faster fabrication.

In this contribution, the test beam measurements of novel passive CMOS silicon strip sensors performed at the DESY-II test beam facility are presented.. The sensor is processed by a European foundry, in a 150 nm CMOS technology and has three different strips design to study. The sensors have two different strip lengths and are formed by stitching of individual reticles. The main focus of this test beam measurement on the passive CMOS sensors is to study the charge collection, to determine the hit detection efficiency and to examine the performance of the stitching.

Overview Lectures / 44

A high-energy electron FLASH therapy facility

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A very hot topic in radiation oncology is so-called FLASH therapy which involves delivering an entire radiation treatment in a few hundred ms, or less. This fast delivery can reduce toxicity to healthy tissue while maintaining tumor control expanding the parameter space for treatment. The effect has been observed in experiments and clinical translation is now underway. As part of this effort, Lausanne Hospital (CHUV) and CERN have formed a collaboration to design and build a clinical FLASH-capable facility for treatment of large, deep-seated tumors using high-energy, 100 MeV-range, electrons accelerated with electron linac technology developed by the CLIC linear collider study.

Experiments / 45

ATLAS ITk Planar Pixel Sensors: Test Beam Measurements of Irradiated Devices with Various Punchthrough Bias Structures

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The Phase-II upgrade of the LHC during Long Shutdown 3 (LS3) aims to reach a peak instantaneous luminosity of $7.5 \times 10^{34} \mathrm{cm}^{-2}\mathrm{s}^{-1}$, which corresponds to an average of about 200 inelastic proton-proton collisions per beam-crossing. To cope with these conditions, the ATLAS tracking system will be replaced by an all-silicon Inner Tracker (ITk). The ITk will be operational for more than ten years, during which time ATLAS is expected to record a total dataset of $4000\,\mathrm{fb}^{-1}$. The pixel detector of the ITk is based on hybrid planar pixel modules with new silicon sensors and readout chips. This talks focuses on test beam campaigns carried out at the CERN SPS and DESY in order study the pixel position and efficiencies for the on-going R\&D of ITk pixel modules. Results for several silicon sensor designs with different punch through structures and the first large structure prototype front-end readout chip, RD53A, will be presented.

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Beam test of the GEM detectors for the Phase-2 upgrade of CMS

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The High-Luminosity LHC (HL-LHC) will deliver proton-proton collisions at 5-7.5 times the nominal LHC luminosity, with an expected number of 140-200 pp-interactions per bunch crossing. To maintain the performance of muon triggering and reconstruction under high background radiation, the forward part of the Muon spectrometer of the CMS experiment will be upgraded with Gas Electron Multiplier (GEM) and improved RPC (iRPC) detectors. A first GEM station (GE1/1) was installed during long-shutdown 2 LS-2), a 2nd station (GE2/1) of Triple-GEM detectors will be installed in the year end technical stops of 2023-2024 or 2024-2025, while a new 6-layer station (ME0) will be installed in the third long shutdown (LS3) 2026-2028. The lessons learnt with the first large-area GEM station have lead to improvements in detector and electronics design. For the first time we made a test of the full readout chain, using final detectors, electronics and DAQ. A production GE2/1 chamber was tested with muons and pions at CERN SPS toghether with a prototype ME0 chamber. The detectors were equipped with their final front-end electronics, sending data over optical fibers to the FPGA DAQ board operating the standard CMS DAQ software. A new beam telescope based on 4 Triple-GEM detectors with fine pitch and 70um spatial resolution obtained through digital readout was tested. We will present GEM chamber and telescope performance during beam tests, with particular emphasis on spatial resolution and rate capability.

Experiments / **47**

Electric field as a crucial parameter for LGAD's safe, danger and irreversible breakdown region: Highlighted outcomes from the sensor stability study using ELI SEB Femtosecond TEST Beam Station

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In this presentation we highlight the most significant outcomes from the systematic study of heavily Irradiated LGAD using the femtosecond laser test beam facility at ELI Beamlines. Instability and LGAD's deaths associated to Single Event Burnout (SEB) from Highly Ionising Particles (HIP) are tested. Questions such as what the safe margin for operation is; is the sensor mortality a threshold effect and whether some vendors already produced LGADs that when irradiated at critical ATLAS fluency of 2.5e15 neq/cm2 cope well with limits recently imposed by SEB, will be discussed. The impact of findings in the context of ETL (CMS) and HGTD (ATLAS) will also be presented.

Overview Lectures / 48

Applications of the Medipix and Timepix ASICs

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Hybrid pixel detectors were first developed to address the needs of particle tracking at the heart of the large LHC experiments. The key property of these detectors is the ability to detect particles with a high signal to noise ratio even at very high speed permitting clean reconstruction of the LHC events. In the Medipix project we adapted the same hybrid pixel approach firstly to X-ray photon counting and then to spectroscopic X-ray imaging. With the Timepix detectors we measure the arrival time of particles (these days to withing 200ps) as well as the charge collected per pixel. Our devices have found applications in widely varying fields. These include use in classrooms to teach radiation physics, radiation monitoring at the International Space Station, electron microscopy and different kinds of medical imaging.

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Fermilab Test Beam Facility

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The Fermilab Test Beam Facility is a world class facility for testing and characterizing particle detectors. With two operational low intensity beam lines, the facility can deliver a variety of particle types and momenta ranging from 120 GeV protons in the primary beam line down to 200 MeV particles in the tertiary beam line. In order to meet the needs of future detectors, the facility is working on new upgrades to provide better particle tracking and timing. Facility capabilities, scheduling, and plans will be discussed in this talk.

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The DESY II Test Beam Facility

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The DESY II Test Beam Facility was in operation from March to December in 2021, starting with local and national users before continuing from May on in normal mode welcoming international groups. After the winter shutdown, the facility resumed operation in February 2022.
In this contribution, a review over the test beam period in 2021 and the current status is given. This includes first results from tests for a potential new beam line using the direct electron beam. Furthermore, an outlook on the season 2022 and our plans for the future of the facility will be presented.

Experiments / 54

The monolithic ASIC for the high precision preshower detector of the FASER experiment at the LHC

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The FASER experiment at the LHC will be instrumented with a high precision W-Si preshower to identify and reconstruct electromagnetic showers produced by two O(TeV) photons at distances down to 200µm.
The new detector will feature a monolithic silicon ASIC with hexagonal pixels of 65 µm side, with extended dynamic range for the charge measurement and capability to store the charge information for thousands of pixels per event. The ASIC will integrate SiGe HBT-based fast front-end electronics with O(100) ps time resolution. Analog memories inside the pixel area will be employed to allow for a frame-based event readout with minimum dead area. A description of the pre-shower and its expected performance will be presented together with the design of the monolithic ASIC and the testbeam results of prototypes.

Beam Telescopes / 55

First tracks and initial timing results with Timepix4 ASIC

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A single arm beam telescope based on the recently developed Timepix4 ASIC was built in order to perform first tests of synchronous multiple-detector readout and track reconstruction. The Timepix4 is a hybrid pixel detector readout ASIC designed to record time-of-arrival (TOA) and time-over-threshold (TOT) simultaneously in each pixel. It has a 448x512 pixel matrix with square pixels at a 55 µm pitch. The TOA is digitised with a 195 ps TDC bin size and the TOT is proportional to the charge collected by the silicon sensor. The telescope is composed of four planes with n-on-p silicon sensors. Two of these planes are instrumented with 300 μm thick sensors tilted with respect to the beam, to provide high quality spatial measurements, while the remaining two have 100 μm thick sensors to achieve a better time response. Each detector assembly (sensor + Timepix4 ASIC) is cooled by a 3D printed titanium block directly attached to the test PCB, through which a cooling fluid is circulated. Both the cooling block and PCB have a circular cut-out to minimise the amount of material traversed by incident particles. The assemblies are readout by SPIDR4 systems. In addition to the Timepix4-based detectors, scintillators were placed in the beam acceptance (2 upstream and 1 downstream of the telescope) in order to give a reference timing measurement. The signals from the scintillators are treated with a constant fraction discriminator for optimal temporal resolution. The discriminated signal is digitised by TDCs in the Timepix4 ASIC with the same resolution as the pixels. First tracks were reconstructed using information from all four planes, which allows the assessment of temporal resolution using high energy particles. In this presentation, the initial results of the timing and spatial resolution of this telescope and plans for the complete telescope will be shown.

Timing / 56

A Beam ToF Reference System with 10 ps resolution

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Test beams are frequently used for developing high resolution Time-of-Flight (ToF) equipment. To investigate the timing properties of detectors under test, a reliable and reproducible time reference counter (TRC) would be an important asset for a test beam facility. Frequently ToF detectors are calibrated only occasionally and it may be difficult to guarantee that their calibration is maintained for the whole period of measurement. On the other side using a distinct "time reference counter" to characterize the time resolution of the timing detector under test, would provide the ability of permanently monitoring the calibration of the reference counter itself. To achieve this goal we have assembled a scheme with 3 timing counters based on Cherenkov radiation from quartz bars and a quartz block readout with MCP-PMT photodetectors, which insure excellent timing properties. By combining the 3 time measurements it is possible to extract the resolution (better than 10 ps) of the TRC counter (with quartz block), and use it as reference for any other device installed on the beam. This method has been tested at CERN (H8 beam in SPS North Hall) and in an electron beam at DESY, where the TRC was used as permanently calibrated time reference system, to study other types of timing detectors. To ensure the high quality of the time measurement based on this system, we have investigated the behaviour of the 3 counters with Monte Carlo simulations, and experimentally, demonstrating the possibility of using the redundancy of the measurements to keep under control also the potential correlations between the time measurements of the 3 counters. Typical configurations for this TRC system are discussed.

Simulation / 57

Monte Carlo simulations of a beam telescope setup based on the 65 nm CMOS Imaging Technology

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Monolithic CMOS sensors enable the development of detectors with a low material budget and a low fabrication cost. Moreover, using a small collection electrode results in a small sensor capacitance, a low analogue power consumption, and a large signal-to-noise ratio. These characteristics have become very attractive in the development of new silicon sensors for charged particle tracking at future experiments. One of the goals of the Tangerine Project (Towards Next Generation Silicon Detectors) is to develop a telescope setup consisting of detector prototypes designed in a novel 65 nm CMOS imaging process. This contribution describes the first steps and verifications in the design of such a telescope using the Allpix Squared and Corryvreckan frameworks for simulation and analysis.

Sensors / 58

Test beam characterization of sensor prototypes for the CMS MTD barrel timing layer

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The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive upgrade program to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). A new timing detector in CMS will measure minimum ionizing particles (MIPs) with a time resolution of 30-40 ps for MIP signals at a rate of 2.5 Mhit/s per channel at the beginning of HL-LHC operation. The precision time information from this MIP Timing Detector (MTD) will be used to reduce the effects of the high levels of pileup expected at the HL-LHC, bringing new capabilities to the CMS detector. The central barrel part of the MTD detector, the Barrel Timing Layer (BTL), will be based on LYSO:Ce crystals read out with silicon photomultipliers (SiPMs). The BTL will use elongated crystal bars, read out by a SiPM on each end of the crystal, to maximize detector performance within the constraints of space, cost, and channel count. This geometry enables covering large surfaces with a minimal active area of the photodetectors, thus reducing noise and power consumption. We will present an overview of the MTD BTL design and recent results on the characterisation of BTL sensor prototypes with beams of high energy particles.

Beam Telescopes / 59

The Fermilab Test Beam Silicon Telescope upgrade

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The Fermilab Test Beam Facility (FTBF) featured an all-silicon telescope based on pixel detectors from the phase-0 of the CMS pixel detector. In the past few years, the demand for more precision tracking pushed the facility to upgrade the pixel telescope with newer and more precise silicon strip detectors. In the past few months, the facility decided to simplify the system removing the old pixel detectors and improve the resolution adding four extra pixel layers based on the RD53A prototypes. The evolution of the telescope over the years and the description and performance of the upgraded one will be described in this talk.

Facilities / 60

Irradiation Test Area at Fermilab

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An Irradiation Test Area(ITA) has been operating at Fermilab since 2021 with a beam delivering 400 MeV protons at an intensity up to 2.7e15 protons per hour. This talk will cover lessons learned and present status of the facility, user application process, and future upgrade plans.

Sensors / 61

Stability of irradiated LGAD sensors in the Fermilab high-rate proton beam facility

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Low-gain avalanche diodes (LGADs) will be employed in the CMS MIP Timing Detector (MTD) upgrade to mitigate the high levels of pileup expected in the High Luminosity phase of the LHC. Over the last several years, LGAD sensors with radiation tolerant gain implants have been developed, successfully providing gain even after the fluences expected at the HL-LHC, in excess of 1 x 10ˆ15 neq/cmˆ2. However, it has been observed that highly-irradiated sensors operated at large bias voltage can be susceptible to single event burnout (SEB) when exposed to highly ionizing particles at beam tests. We present a series of measurements at the Fermilab Test Beam Facility to both understand the SEB mechanism and develop strategies for mitigation. We utilize a new, ultra-high rate beamline facility at FNAL to successfully operate irradiated LGAD sensors for a total flux comparable to the one year flux at the HL-LHC. We find that the SEB mechanism is mitigated by a slight reduction in bias voltage, with little to no impact on the CMS MTD performance.

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Development of the ATLAS Liquid Argon Calorimeter Readout Electronics for the HL-LHC

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A new era of hadron collisions will start around 2029 with the High-Luminosity LHC which will allow to collect ten times more data than what has been collected during 10 years of operation at LHC. This will be achieved by higher instantaneous luminosity at the price of higher number of collisions per bunch crossing.
In order to withstand the high expected radiation doses, the ATLAS Liquid Argon Calorimeter readout electronics will be upgraded.
The electronic readout chain is made of 4 main components.
1: New front-end boards will allow to amplify, shape and digitise the calorimeter's ionisation signal on two gains over a dynamic range of 16 bits and 11 bit precision. Low noise below Minimum Ionising Particle (MIP), i.e. below 120 nA for 45 ns peaking time, and maximum non-linearity of two per mil are required. Custom preamplifiers and shapers are being developed to meet these requirements using 65 nm and 130 nm CMOS technologies. They shall be stable under irradiation until 1.4kGy (TID) and 4.1x10ˆ13 new/cmˆ2 (NIEL). Two concurrent preamp-shaper ASICs were developed and, "ALFE", the best one has been chosen. The test results of the latest version of this ASIC will be presented. "COLUTA", a new ADC chip is also being designed. A production test setup is being prepared and integration tests of the different components (including lpGBT links developed by CERN) on a 32-channels front-end board are ongoing, and results of this integration will be shown.
2: New calibration boards will allow the precise calibration of all 182468 channels of the calorimeter over a 16 bits dynamic range. A non-linearity of one per mil and non-uniformity between channels of 0.25% with a pulse rise time smaller than 1ns shall be achieved. In addition, the custom calibration ASICs shall be stable under irradiation with same levels as preamp-shaper and ADC chips. The HV SOI CMOS XFAB 180nm technology is used for the pulser ASIC, "CLAROC", while the TSMC 130 nm technology is used for the DAC part, "LADOC". The latest versions of those 2 ASICs which recently passed the production readiness review (PDR) with their respective performances will be presented.
3: New ATCA compliant signal processing boards ("LASP") will receive the detector data at 40 MHz where comprising FPGAs connected through lpGBT high-speed links will perform energy and time reconstruction. In total, the off-detector electronics receive 345 Tbps of data via 33000 links at 10 Gbps. For the first time, online machine learning techniques are considered to be used in these FPGAs. From the original data, reduced data is sent with low latency to the hardware trigger system, while the full data are buffered until the reception of trigger accept signals. The latest development status of the board as well as the firmware will be shown.
4: A new timing and control system, "LATS", will connect to the aforementioned components. Its current design status will also be shown.

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ATLAS LAr Calorimeter Commissioning for LHC Run-3

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The Liquid Argon Calorimeters are employed by ATLAS for all electromagnetic calorimetry in the pseudo-rapidity region $|\eta| < 3.2$, and for hadronic and forward calorimetry in the region from $|\eta| = 1.5$

to |η| = 4.9. They also provide inputs to the first level of the ATLAS trigger. After successful period of data taking during the LHC Run-2 between 2015 and 2018 the ATLAS detector entered into the a long period of shutdown. In 2022 the LHC will restart and the Run-3 period should see an increase of luminosity and pile-up up to 80 interaction per bunch crossing.

To cope with this harsher conditions, a new trigger readout path has been installed during the long shutdown. This new path should improve significantly the triggering performances on electromagnetic objects. This will be achieved by increasing the granularity of the objects available at trigger level by up to a factor of ten.

The installation of this new trigger readout chain required also the update of the legacy system. More than 1500 boards of the precision readout have been extracted from the ATLAS pit, refurbished and re-installed. The legacy analog trigger readout that will remain during the LHC Run-3 as a backup of the new digital trigger system has also been updated.

For the new system 124 new on-detector boards have been added. Those boards that are operating in a radiative environment are digitizing the calorimeter trigger signals at 40MHz. The digital signal is sent to the off-detector system and processed online to provide the measured energy value for each unit of readout. In total up to 31Tbps are analyzed by the processing system and more than 62Tbps are generated for downstream reconstruction. To minimize the triggering latency the processing system had to be installed underground. The limited available space imposed a very compact hardware structure. To achieve a compact system, large FPGAs with high throughput have been mounted on ATCA mezzanines cards. In total no more than 3 ATCA shelves are used to process the signal from approximately 34000 channels.

Given that modern technologies have been used compared to the previous system, all the monitoring and control infrastructure is being adapted and commissioned as well.

This contribution will present the challenges of the installation, the commissioning and the milestones still to be completed towards the full operation of both the legacy and the new readout paths for the LHC Run-3.

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Eco-friendly gas mixtures for future RPC detectors

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Resistive Plate Chambers are operated in several experiments tipically with large fractions of Tetrafluoroethane (C2H2F4) commonly known as R134a, a gas with a high Global Warming Potential (GWP) that has been recently banned by the European Union.
Within the HEP Community, many studies are ongoing to find a good replacement for such component for RPCs working in avalanche mode. One interesting alternative is the Tetrafluoropropene (C3H2F4) called HFO1234ze with a GWP of 6 that has been shown to have reasonable performance with respect to the R134a.
Since a few years a joint collaboration between ALICE, ATLAS, CMS, LHCb/SHiP and CERN groups is in place with the goal to study the performance of RPCs operated with eco-friendly gas mixtures under irradiation at GIF++.
The performance of several chambers with different layout and electronics has been studied during dedicated beam tests, with and without gamma irradiation at GIF++. The RPCs have been operated with different gas mixtures based on CO2 and HFO1234ze gases.
Results of these tests together with the future plans for aging studies of the chambers will be presented.

Facilities / 66

R-Weg : A new high-intensity electron beamline at DESY II

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The R-Weg is a former transfer beamline from the DESY II synchrotron to DORIS. Recently, it has been recommissioned to serve as a high-rate electron beam line. The full DESY II beam with up to 1.5×10^{10} e^- per bunch can be dumped at a rate of 12.5 Hz. The available high rates allow not only for precise detector tests, but also electron irradiation campaigns.
To ensure safe and controlled operation, it is necessary to understand the beam parameters and radiation field in detail. Therefore, the R-Weg is studied using a Monte-Carlo simulation framework for the interaction and transport of particles in materials: FLUKA. Typically, it is optimized for the study of radiation and beams.
Using FLUKA, the radiation backgrounds, neutrons and gamma from the beam dump are simulated and verified by an appropriate measurement device such as a radiation monitor. In addition, the beam stability at different extraction timings, which is influenced by the instability in the mains frequency, is going to be simulated while the study of beam profile is going to be conducted.
In this presentation, an overview of the recent progressing simulation and measurement is given.

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Hands-On: Silicon Detector Monte Carlo Simulations with Allpix Squared

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Scope of the tutorial

The goal of this interactive tutorial is to understand the usage of basic functionalities of the Allpix Squared simulation framework, and methods to extract some of the relevant quantities for sensor studies. Participants are encouraged to follow along on their own computers. A task and instructions will be provided and walked through, covering the basic concepts of configuring a simulation and a detector geometry, and extracting and interpreting histograms. We will also touch upon incorporating detailed results from TCAD into the simulations.
Some prior knowledge on the framework is helpful, but not required.

Preparation

Please install the latest release version of Allpix Squared on your computer, or make sure you have access to a working version online before the tutorial.

Detailed instructions for installation can be found in the manual or on the website (https://cern.ch/allpix-squared) and GitLab (https://gitlab.cern.ch/allpix-squared/allpix-squared)

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The Corryvreckan Test-Beam Reconstruction Framework — Hands-on

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Corryvreckan is a software framework dedicated to the analysis of test-beam data. It employs a modular concept, providing algorithms for typical analysis steps like pixel masking, clustering, tracking, alignment and for the reconstruction of commonly investigated observables like detection efficiency, spatial and temporal resolution or material budget. This approach allows for a flexible configuration and adaption to a broad range of setups and devices, and explicitly includes the EUDAQ2 framework and the AIDA TLU.

This tutorial provides an introduction to the Corryvreckan framework, the use of different analysis modules and their configuration. A key point of Corryvreckan — the flexible event building mechanism — will be covered for a typical setup, making use of EUDAQ2 and the AIDA TLU. Finally, the use of Corryvreckan as a tool for online monitoring will be covered.

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Making the most of your test-beam time - Understanding the interplay between the new AIDA-TLU and EUDAQ2 to optimally match your DAQ system

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The AIDA trigger logic unit and EUDAQ2 provide a common infrastructure platform to integrate a large variety of devices with the EUDET-type reference telescopes at test beams. Since test-beam time is always limited, users rely on a stable and common interface for their devices. The tutorial will provide a solid basis to optimally prepare your next successful test beam campaign.

The tutorial is split into three parts:

In the beginning, the software framework is introduced and the basic principles of software integration are discussed, along with the basic principles of data storage. Afterwards, all required software will be installed.

In the second step, we will discuss the functionality of the trigger logic unit and demonstrate its functionality:

- How can the readout be triggered
- Modes of communication with user devices
- Realization of the interplay between soft and hardware

Finally, we will connect two scintillators/PMTs to trigger on cosmic particles and demonstrate the impact of the modes on the trigger rates, DUTs based on a raspberry Pi.

A repository with all required scripts, libraries etc will be provided beforehand
No expert knowledge is required to participate. Nevertheless, additional information can be found via the following links:

EUDAQ2
Telescopes at DESY
AIDA TLU

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Official Welcome Address

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Welcome from the IAC

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Welcome & Information from local organisers

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Introduction to Hands-on Sessions

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Hands on: Knowledge Transfer in the High Energy Physics domain

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BL4S / 75

A BL4S Experiment: EXTRA - Electron X-ray Transition RAdiation

EXTRA - Electron X-ray Transition RAdiation - is the experiment of one of the 2021 winning teams of the Beamline for Schools (BL4S) competition.

In this contribution, the students will present their experiment, show results and share their experiences from their participation in BL4S