12th Beam Telescopes and Test Beams Workshop

Monday, 15 April 2024 - Friday, 19 April 2024

Edinburgh

Book of Abstracts

Contents

Beam telescopes / 1

The EPFL Scintillating Fibre Telescope

Authors: Ettore Zaffaroni[1]; Federico Ronchetti[1]; Guido Haefeli[1]

[1] *EPFL - Ecole Polytechnique Federale Lausanne (CH)*

Corresponding Authors: f.ronchetti@cern.ch, ettore.zaffaroni@cern.ch, guido.haefeli@epfl.ch

The EPFL Scintillating Fibre Telescope is composed of 4 X-Y modules with an active surface of 13x13 cm2. It is made of 250 um diameter scintillating fibres readout with SiPM arrays and its front-end electronics is based on the TOFPET2 ASIC. The telescope suits very well the requirements for detector tests. It has per plane an excellent hit detection efficiency (>98%) and spatial resolution (<100 um) and a time resolution of <250 ps. The large active area allows the telescope to be moved in the beam with the detector under test (example LHCb ECAL) and the compact design allows to set it up in a custom arrangement given by the detector under test. Since there is no gas or cooling required, installation is relatively simple. The telescope DAQ runs in asynchronous or triggered mode and can handle particle rates of a few 10ˆ4 Hz.

Test beam analysis / 2

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

Authors: Irena Nikolic[1]; Theodoros Manoussos[2]

[1] *LPNHE, Université Paris Cité*

[2] *CERN*

Corresponding Authors: theodoros.manoussos@cern.ch, irena.nikolic@cern.ch

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 DESY and CERN SPS H6 beamline in 2022 and 2023. The performance of irradiated Carbon-enriched LGAD sensors has been studied. Module prototypes of 15×15 arrays with a pad size of 1.3×1.3 mm2 for the HGTD project have been tested. Their performance with charged-particle beams before irradiation is evaluated. A summary of the results from LGAD-only and hybrids will be presented.

Poster session / 4

Development of Detector and Trigger System for 1.6 GeV Proton Test Beam at CSNS

Author: Yuhang Guo[1]

Co-authors: Hantao Jing ; Rui Fan [1]

[1] *Institute of High Energy Physics, CAS*

Corresponding Authors: guoyh@ihep.ac.cn, fanrr@ihep.ac.cn, jinght@ihep.ac.cn

The High-energy Proton Experiment Station (HPES) is currently being constructed as part of the CSNS-II project. The 1.6 GeV protons are extracted from the Rapid Cycling Synchrotron of CSNS and directed to the HPES in the form of "single particle beam". Test terminals have been designed within the HPES to facilitate the completion of beam tests. The primary objective of the HPES test terminals is to serve as an advanced detector test platform for the development of High Energy Physics in China. As such, a beam telescope is designed to achieve a proton tracking accuracy of < 10 μm and a proton energy measurement system is designed to achieve an energy resolution of < 1% at 1.6 GeV. Moreover, the HPES is expected to play an important role in various other fields, including high energy proton imaging and the pre-testing of aerospace experiments. This presentation will provide an overview of the design progress and prospects of the HPES test terminal.

DAQ systems / 5

The AIDA-Innova TLU. A Trigger/Timing Logic Unit for Beam-lines

Author: David Cussans[1]

[1] *University of Bristol (GB)*

Corresponding Author: david.cussans@cern.ch

In beam-lines providing particles to test High Energy Physics detectors there is a need to provide a way of synchronizing the "device under test" with instrumentation such as a beam telescope installed in the beam-line.

In order to ease use of beam test facilities the EU funded EUDET,AIDA,AIDA-2020 and now AIDA-Innova projects have developed Trigger/Timing Logic Units (TLUs) that aim to simplify integration.

We describe the TLU being developed as part of AIDA-Innova. The precision for tagging beam particles will be improved from O(1ns) in previous generations to TLU to O(100ps).

Sensors / 6

Test Beam on monolithic pixel sensors test structures in the 65 nm technology for the ALICE ITS3 upgrade

Author: Stefania Perciballi[1]

[1] *Universita e INFN Torino (IT)*

Corresponding Author: stefania.perciballi@cern.ch

The ALICE ITS3 (Inner Tracking System 3) upgrade project together with the CERN EP R&D on monolithic sensors are exploring the Tower Partner Semiconductor Co. 65 nm ISC process.
The ITS3 project aims to build the first fully cylindrical tracker by using wafer scale, ultra thin (less than 50 µm) bent MAPS with a material budget down to 0.07% radiation length per layer.
Four different pixel test structures were designed to validate the sensor technology through an extensive characterization both with laboratory and in-beam measurements.
In particular, this work will focus on the Analogue Pixel Test Structure - Operational Amplifier (APTS-OPAMP), which is equipped with a fast in-pixel OPAMP buffer to explore the sensor timing performance.
To perform the timing measurements, a test beam with positive hadrons (120 GeV/c) was performed in June 2023 at CERN-SPS facility.
This work will show the integration of the two different readout systems for OPAMP structure: an Oscilloscope with 40 GS/s sampling frequency and 13 GHz bandwidth, and a readout board that has a 4 MHz sampling rate. A summary of the results will also be presented: a time resolution of about 75 ps demonstrates a big improvement compared with the 180 nm technology fastest sensors, without any loss in terms of charge collection efficiency. Moreover, by selecting only the tracks passing under the electrode, a time resolution of 50 ps can be achieved.

7

MALTA Monolithic Pixel Sensor Telescope : New developments and characterisation results

Author: Ignacio Asensi Tortajada[1]

Co-author: Carlos Solans Sanchez [1]

[1] *CERN*

Corresponding Authors: carlos.solans@cern.ch, ignacio.asensi@cern.ch

The MALTA sensor is a Depleted Monolithic Active Pixel Sensor (DMAPS) fabricated in Tower Semiconductor 180 nm CMOS imaging sensor technology. This sensor, produced on both high resistivity epitaxial and Cz substrates, is designed for enhanced signal efficiency and time resolution.

A custom-built telescope, with up to six MALTA tracking planes, has been developed for a test-beam campaign at SPS (CERN). This system features a dedicated custom readout, online monitoring integrated into DAQ providing realtime hit maps, time distribution and event hit multiplicity. Additionally, it incorporates a dedicated advanced configurable trigger system that enables triggering based on coincidences between the telescope planes and scintillator references.

The excellent time resolution performance facilitates rapid fast track reconstruction, due to its ability to maintain low hit multiplicity per event which reduces the combinatorics. This contribution will discuss the versatility of the telescope in testing various DUTs exemplified by Calypso and LGAD sensors. It will also cover results from spatial resolution studies and the novel rotational studies conducted inside an expanded cold box, underlining the system's versatility and technological advancements.

Sensors / 8

Charge Collection Studies for HV-MAPS

Author: Ruben Kolb[1]

[1] *Heidelberg University (DE)*

Corresponding Author: ruben.kolb@cern.ch

The High-Voltage Monolithic Active Pixel Sensor (HV-MAPS) technology, designed for high-rate applications, integrates precise spatial and time resolution by consolidating active detector volume and readout functions into a single chip. The TelePix1, an HV-MAPS test chip, incorporates in-pixel electronics, including an amplifier and a comparator.

This study explores the charge deposition and collection processes in HV-MAPS to guide further design considerations. The emphasis of this presentation is to disentangle the contributions of drift and diffusion to the signal. To achieve this objective, the Time-over-Threshold (ToT) and cluster size of sensors with varying thicknesses are examined, exploring their dependence on the depletion depth. Offline calibration is essential due to pixel-to-pixel variations, ensuring accurate sensor comparisons. The calibrated signal is investigated for a 4 GeV electron beam and electrons emitted from a Strontium-90 source. A significant contribution of diffusion to the signal size is observed for small depletion volumes.

Poster session / 9

First test beam insights for ATLAS ITk strip modules with Cold Noise

Author: Yajun He[1]

Co-authors: John Stakely Keller [2]; Lennart Huth [3]

[1] *Deutsches Elektronen-Synchrotron DESY*

[2] *Carleton University (CA)*

[3] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: yajun.he@cern.ch, lennart.huth@cern.ch, john.stakely.keller@cern.ch

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 or two n+-in-p silicon sensors, 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 have more comprehensive studies on the module behaviours and to validate the expected performance of the ITk strip detector and, a series of testbeam campaigns has been performed over several years at the DESY-II and CERN SPS testbeam facilities. This contribution focuses on the first test beam results for the short strip module with the issue called COLD NOISE. The module under test is irradiated at $1.1 \times 10^{15} n_{eq}/cm^2$. These results help us understand how much cold noise must be reduced to have proper tracking at end of lifetime.

Hands-on tutorials / 10

The Corryvreckan Test-Beam Reconstruction Framework — Hands-on

Author: Finn Feindt[1]

Co-authors: Naomi Afiriyie Davis [2]; Sara Ruiz Daza [2]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *DESY*

Corresponding Authors: naomi.davis@desy.de, finn.feindt@desy.de, ruizdaza@mail.desy.de

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 hit 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.

Sensors / 11

Testbeam results of single event effect studies on prototype memory chips for the ALICE ITS3 upgrade

Author: Timea Szollosova[1]

[1] *Czech Technical University in Prague (CZ)*

Corresponding Author: timea.szollosova@cern.ch

The ITS3 (Inner Tracking System 3) is a new innovative vertex detector planned to be installed between 2026 and 2028 during the next Long Shutdown 3 to replace the three innermost layers of the current Inner Tracking System of the ALICE experiment at the LHC as from Run4. The detector will consist of wafer-scale ultra-thin silicon Monolithic Active Pixels Sensors sensors bent to half-cylindrical shape with radii corresponding to radial distances of 18, 24 and 30 mm from the beam axis.
Within the R&D efforts to characterize the 65 nm CMOS Imaging technology used for these prototype structures in terms of radiation tolerance, two dedicated memory chips (SEU) were designed to test the Single Event Effects (SEE) sensitivity of the prototypes. To observe SEE, we exposed the SEU chips to both heavy ion and proton beams to measure the latch-up and Single Event Upset sensitivity, respectively. This contribution will present the results of those tests and discuss their impact on future sensor designs.

Beam telescopes / 13

Beam Telescopes at the DESY II Test Beam

Author: Adrian Herkert[1]

[1] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Author: adrian.herkert@desy.de

Beam tests often rely on the precise reconstruction of particle tracks as a reference measurement. Therefore, the DESY II Test Beam facility provides beam telescopes to its users. They have to be flexible regarding the integration of a device under test and consist of a minimum amount of material to not disturb the comparatively low-energy beam (
$lesssim 6$ GeV). These requirements are fulfilled by the well-established EUDET-type telescopes, which DESY operates two copies of. A successor of these telescopes is currently being developed based on ALPIDE sensors. A first prototype, called Adenium, is already in continuous user operation.
This presentation will discuss the ins and outs of using one of the beam telescopes provided by

the DESY II Test Beam facility and report on the status of DESY's ALPIDE-based telescope developments.

Test beam analysis / 14

A Digital SiPM as 4D tracking prototype

Authors: Daniil Rastorguev[None]; Finn Feindt[1]; Gianpiero Vignola[1]; Inge Diehl[None]; Ingrid-Maria Gregor[2]; Karsten Hansen[3]; Simon Spannagel[1]; Stephan Lachnit[1]; Tomas Vanat[1]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *DESY & Bonn University*

[3] *DESY*

Corresponding Authors: daniil.rastorguev@desy.de, finn.feindt@desy.de, karsten.hansen@desy.de, ingrid.gregor@desy.de, tomas.vanat@cern.ch, stephan.lachnit@cern.ch, gianpiero.vignola@cern.ch, inge.diehl@desy.de, simon.spannagel@cern.ch

CMOS foundries have recently introduced Single Photon Avalanches Diodes SPADs into process design kits, allowing for easy implementation of monolithic SiPMs with custom designed ASIC. In CMOS SPAD arrays, many features typical of monolithic pixel detectors can be implemented, enriching the capabilities of widely used analog SiPMs. In-pixel digitization, masking, full hitmap readout, and large area sensors are some of the peculiar features of digital SiPMs. These qualities, typical for tracking detectors, combined with SPADs' intrinsic timing performance on the order of 10 ps, make monolithic SiPMs a good candidate for 4D-tracking in contexts where excellent spatial and temporal capabilities are required in the same detector.

A prototype of a digital SiPM was designed at DESY using LFoundry 150 nm CMOS technology. These dSiPMs have been tested at the DESY II test-beam facility, to investigate MIP detection efficiency, spatial and temporal resolution. This contribution will illustrate the test beam setup and analysis approach used to investigate the 4D-tracking performance of the DESY digital SiPM. The results of the latest measurements campaigns and future perspectives will be discussed.

Facilities / 15

The Frascati Beam Test Facility Status and prospective

Authors: Claudio Di Giulio[None]; Luca Gennaro Foggetta[1]

Co-authors: Clara Taruggi ; Domenico Di Giovenale [2]; Eleonora Diociaiuti ; bruno buonomo [2]

[1] *INFN*

[2] *INFN-LNF*

Corresponding Authors: claudio.digiulio@lnf.infn.it, luca.foggetta@lnf.infn.it, domenico.digiovanale@lnf.infn.it, eleonora.diociaiuti@lnf.infn.it, bruno.buonomo@lnf.infn.it, clara.taruggi@lnf.infn.it

After the first year of operation of the second line of the Frascati Beam Test Facility BTF a summary of the performance will be provided.
The diagnostics system and the performances obtained in the two beamlines will be presented and the future activity of the facility will be discussed.

Facilities / 16

PRIMA : A New High-Intensity Electron Beamline at DESY II

Authors: Dennis Haupt[1]; Dohun Kim[None]; Felix Sefkow[1]; Heiko Ehrlichmann[1]; Lennart Huth[1]; Marcel Stanitzki[1]; Sven Ackermann[1]

[1] *DESY*

Corresponding Authors: lennart.huth@cern.ch, dohun.kim@desy.de, marcel.stanitzki@desy.de, felix.sefkow@desy.de, dennis.haupt@desy.de, sven.ackermann@desy.de, heiko.ehrlichmann@desy.de

The PRIMary-beam test Area (PRIMA), formerly an extraction beamline from the DESY II synchrotron to DORIS, is currently being commissioned to serve as a high-rate electron beamline. By utilizing electrons in DESY II that would not have been by PETRA III, a synchrotron radiation facility, and just dumped, the full DESY II beam with up to 3×10^{10} electrons per bunch can be available for detector testing and irradiation campaigns.
To ensure a safe and controlled operation, it is necessary to understand the beam parameters and radiation field in detail. Therefore, the PRIMA irradiation environment has been studied using a Monte Carlo simulation framework for the interaction and transport of particles in materials: FLUKA. Using FLUKA the radiation background, neutrons and gammas generated from electron interactions with materials present in the facility, has been simulated and is being verified by measurement. In addition, beam instabilities during extraction have been taken into account.
We will provide an overview of recent simulation and measurement progress and showcase opportunities for future usage.

Poster session / 17

Simulation of a test-beam setup for the characterization of innovative photodetectors for Ring-Imaging Cherenkov applications

Authors: Alessandro Saputi[1]; Angelo Cotta Ramusino[1]; Donato Vincenzi[2]; Gabriele Romolini[1]; Gianfranco Paterno[None]; Lorenzo Capriotti[1]; Massimiliano Fiorini[1]; Nicolo Vladi Biesuz[1]; Riccardo Bolzonella[3]; Viola Cavallini[1]

[1] *Universita e INFN, Ferrara (IT)*

[2] *Infn ferrara, Università di ferrara*

[3] *University of Ferrara and INFN*

Corresponding Authors: lorenzo.capriotti@cern.ch, viola.cavallini@cern.ch, nicolo.vladi.biesuz@cern.ch, vincenzi@fe.infn.it, paterno@fe.infn.it, angelo.cotta.ramusino@cern.ch, alessandro.saputi@cern.ch, massimiliano.fiorini@cern.ch, riccardo.bolzonella@cern.ch, gabriele.romolini@cern.ch

A new hybrid photodetector, based on a vacuum tube containing a transmission photocatode, a microchannel plate and a CMOS pixelated read-out anode (the Timepix4 ASIC) is under development in the framework of the 4DPHOTON ERC-funded project.
This detector will allow to image single photons up to a maximum rate of 1 billion photons per second over an area of $\sim$7 cm^2, reaching simultaneously excellent spatial (5-10 μm) and timing (50-100 ps) resolutions.

A test-beam is planned at the CERN SPS North Area in order to characterize the performance of the first detector prototypes using a Ring-Imaging Cherenkov configuration.
The setup consists of a tracking telescope made of two Timepix4 ASICs bump-bonded semiconductor-based pixel detectors, a solid radiator for the production of Cherenkov photons, followed by an optical section that allows to focus the emitted Cherenkov photons into a ring on a set of photodetectors under study.

The Geant4 simulation of the whole experimental test-beam setup is presented. The design of the optical section that follows Cherenkov photons production is optimized using Ansys Zemax.

The analysis of the simulated data is also presented, in particular the performance in terms of tracking resolution, Cherenkov angle resolution and the photon timing resolution, which is expected to be of the order of 10˜ps per single track.

Facilities / 18

Coordinating the future challenging user needs and improvements of test beam and irradiation facility infrastructures at CERN

Authors: Eva Barbara Holzer[1]; Federico Ravotti[1]; Pierre Pelissou[1]

Co-authors: Blerina Gkotse [1]; Martin R. Jaekel [1]; Martin Schwinzerl [1]

[1] *CERN*

Corresponding Authors: pierre.pelissou@cern.ch, martin.jaekel@cern.ch, blerina.gkotse@cern.ch, federico.ravotti@cern.ch, barbara.holzer@cern.ch, martin.schwinzerl@cern.ch

The ability to study the open mysteries about the universe strongly relies on the capability of innovating high-energy physics instrumentation and research infrastructures. The diversity of physics programs supported by CERN requires to provide access to a wide variety of particle beams and radiation fields at CERN and at worldwide research institutes to fulfill user's needs. Hence, the necessity to support financially and technically test-beam and irradiation user requests and R&D activities for both the near- and longer term.
CERN has extensive experience in taking part in international scientific projects such as the EURO-LABS project lately. In these projects, CERN is often involved in managing transnational access and user's scheduling among facilities, operating within its accelerator complex. The irradiation facilities GIF++, IRRAD, CHARM, as well as the PS East Area (EA) and SPS North Area (NA) are reference facilities meant to meet the R&D objectives mentioned above.
This contribution presents the most important developments and improvements related to the coordination of the CERN Irradiation and Test Beam facilities during 2023 as well as it will give an outlook for 2024 and 2025 until the start of the CERN Long Shutdown 3.

Test beam analysis / 19

Qualification of pixel detectors for the upgrade of the ATLAS Inner Detector with beams tests

Author: Juan Ignacio Carlotto[1]

Co-author: Martina Ressegotti [2]

[1] *IFAE - Barcelona (ES)*

[2] *INFN e Universita Genova (IT)*

Corresponding Author: martina.ressegotti@cern.ch

The ATLAS Inner Detector will be completely replaced with an all-silicon Inner Tracker (ITk) to withstand the harsh operational conditions of the High Luminosity LHC at CERN.
The ITk pixel detector will be located in the innermost part of the ITk. It will be instrumented with different sensor technologies according to the expected total fluence, which ranges up to $1.9 \cdot 10^{16}$ $\mathrm{n}_{eq}/\mathrm{cm}^2$ (safety factor of 1.5 included), and the required performance. Pixel sensors with 3D technology will instrument the innermost layer (L0), planar n-in-p sensors 100 µm and 150 µm thick will instrument respectively the second innermost layer (L1) and the outer layers (L2-L4). Additionally, planar sensors will have a pixel size of 50x50 µm^2, while 3D sensors with pixel size of 50×50 µm^2 and 25×100 µm^2 will be used. Eventually, the production and hybridization of pixel detectors is distributed across several vendors and institutes.

A large effort to study the variety of pre-production pixel detectors with different technology, design, and produced by different vendors is ongoing. An overview of the results obtained with beam tests and the progress of the beam test setup is given.

Hands-on tutorials / **20**

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

Authors: Daniil Rastorguev[None]; Håkan Wennlöf[1]; Manuel Alejandro Del Rio Viera[1]; Stephan Lachnit[1]

[1] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: stephan.lachnit@cern.ch, manuel.alejandro.del.rio.viera@cern.ch, h.wennlof@cern.ch, daniil.rastorguev@desy.de

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. There will also be the possibility of asking questions and discussing the framework.
Some prior knowledge of Allpix Squared 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://allpix-squared.docs.cern.ch/) and GitLab (https://gitlab.cern.ch/allpix-squared/allpix-squared)

Facilities / **21**

CERN Secondary Beamlines and Test Beams facilities overview

Authors: Alice Marie Goillot[None]; Anna Baratto Roldan[1]; Bastien Rae[1]; Dipanwita Banerjee[1]; Elisabetta Giulia Parozzi[1]; Emily Marie Andersen[2]; Fabian Metzger[1]; Florian Wolfgang Stummer[3]; Johannes Bernhard[1]; Laurie Nevay[1]; Luke Aidan Dyks[1]; Maarten Van Dijk[1]; Marc Andre Jebramcik[1]; Markus Brugger[1]; Nikolaos Charitonidis[1]; Rob Murphy[3]; Silvia Schuh-Erhard[1]

[1] *CERN*

[2] *University of Bergen (NO)*

[3] *University of London (GB)*

Corresponding Authors: dipanwitha.banerjee@cern.ch, marc.andre.jebramcik@cern.ch, alice.marie.goillot@cern.ch, luke.dyks@cern.ch, elisabetta.giulia.parozzi@cern.ch, emily.marie.andersen@cern.ch, anna.baratto.roldan@cern.ch, maarten.van.dijk@cern.ch, laurie.nevay@cern.ch, murphy.robert@cern.ch, florian.wolfgang.stummer@cern.ch, johannes.bernhard@cern.ch, bastien.rae@cern.ch, silvia.schuh@cern.ch, fabian.metzger@cern.ch, nikolaos.charitonidis@cern.ch, markus.brugger@cern.ch

The CERN secondary beamlines 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 for fixed target experiments and beam tests. Protons with $24\,\mathrm{GeV}/c$ at the PS and with $400\,\mathrm{GeV}/c$ at the SPS produce typically hadrons, electrons, and muons within a wide range of momenta between $0.1\,\mathrm{GeV}/c$ and $360\,\mathrm{GeV}/c$ at fluxes from several 100 up to 10^9 particles per spill that are provided at several experimental areas throughout the complex.
This talk will present the features of the different beam lines and beams serving the various fixed target experiments and test beam areas, including beam properties, available infrastructure for tests and beam instrumentation, e.g. the installed beam telescopes. Measurements of the beam performance from 2023 are shown following the recent extensive consolidation activities and beamline improvements throughout. Future plans are also presented including beam control software upgrades during LS3.

BL4S / **22**

Team Myriad Magnets - A Radially and Rotationally Adjustable Magnetic Mangle for High Energy Particle Beams

Authors: Achyuta Rajaram[1]; Aubrey Zhang[2]; Daniel Jeon[3]; Isabella Vesely[3]; Ishaan Vohra[1]; Peter Morand[1]; William Lu[1]; William Soh[1]

Co-authors: Berare Gokturk [4]; Martin Schwinzerl [5]

[1] *Phillips Exeter Academy*

[2] *University of Chicago*

[3] *Massachusetts Institute of Technology*

[4] *Bogazici University (TR)*

[5] *CERN*

Corresponding Authors: whlu@exeter.edu, aubreyz@uchicago.edu, ivohra@exeter.edu, ivesely@mit.edu, dhjeon@mit.edu, wsoh@exeter.edu, arajaram@exeter.edu, pmorand@exeter.edu

Our magnetic mangle, a multifunctional variant of the Halbach cylinder designed for 100MeV – 10GeV electron beams, was nominated as one of the winners of the 2023 Beamline for School (BL4S) competition. As a result, we were selected to testing it on the T10 beamline of CERN, Geneva, in September 2023. Analysis of the experimental results shows deflections well within the margin of error of our GEANT4 simulations and confirms the viability of our magnetic mangle as a low-cost alternative to electromagnets. The compact (20cmx20cmx35cm, less than 5 kg) and low-cost mangle consists of 8 diametrically-magnetized magnets encased and arranged in a circle; it was entirely designed by us at our high school, Philips Exeter Academy, where the first prototype was 3D printed. Each magnet can be rotated to generate a dipole or a quadrupole field inside the array, and the magnets can be moved radially inward or outward to modify the field's strength. The very weak magnetic field outside the array makes the mangle safe to use near other electronics, and a viable alternative to electromagnets for narrowing or deflecting particle beams.

Poster session / **23**

Sub-GeV particle identification and tagged photon beam for the Water Cherenkov Test Experiment

Author: Alie Craplet[1]

[1] *Imperial College (GB)*

Corresponding Author: alie.craplet@cern.ch

The Water Cherenkov Test Experiment (WCTE) will be installed in CERN's recently upgraded T9 "Test Beam"Area in Summer 2024. The upgrade to the East Area, completed in 2022, allows the T9 beamline to reach lower beam momenta than previously possible, now down to ~100MeV/c. The WCTE has three goals: to prototype photosensor and calibration systems for Hyper-Kamiokande, to develop new calibration and reconstruction methods for water Cherenkov detectors and to measure lepton and hadron scattering on Oxygen.

The WCTE collaboration performed a 3-week-long beam test in July 2023 to test WCTE's beam telescope in the momentum range of 200-1000MeV/c. The collaboration uses newly developed aerogel Cherenkov counters with an index of refraction between 1.006 and 1.15 to perform an efficient separation of pions from muons in the sub-GeV range, which had not been done before. This makes a test beam where pions and muons are tagged with good efficiency without having to rely on a tertiary beam.

Additionally, the collaboration developed a new compact tagged photon beamline composed of a Neodymium (N52) Halbach array permanent magnet with a peak magnetic field of 1.7T and a hodoscope array placed downstream of the magnet. The combination of the aerogel Cherenkov threshold counters and tagged photon beamline provides sub-GeV p, e, pi, mu and gamma test beams with momentum between 200 and 1000MeV/c. Using this setup, the collaboration was able to estimate the beam flux of the CERN T9 beam.

Beam telescopes / 24

Latest results and improvements of the RD51 VMM3a/SRS gaseous beam telescope

Author: Lucian Scharenberg[1]

Co-authors: August Brask ; Djunes Janssens [2]; Dorothea Pfeiffer [3]; Eraldo Oliveri [3]; Florian Maximilian Brunbauer [3]; Francisco Garcia [4]; Giorgio Orlandini [5]; Hans Muller [6]; Jerome Samarati [7]; Karl Jonathan Floethner [6]; Leszek Ropelewski [3]; Marta Lisowska [3]; Miranda Van Stenis [3]; Rob Veenhof [3]

[1] *CERN, University of Bonn (DE)*

[2] *Vrije Universiteit Brussel (BE)*

[3] *CERN*

[4] *Helsinki Institute of Physics (FI)*

[5] *Friedrich Alexander Univ. Erlangen (DE)*

[6] *University of Bonn (DE)*

[7] *ESS - European Spallation Source (SE)*

Corresponding Authors: karl.jonathan.floethner@cern.ch, hans.muller@cern.ch, lucian.scharenberg@cern.ch, francisco.garcia@cern.ch, leszek.ropelewski@cern.ch, dorothea.pfeiffer@cern.ch, marta.lisowska@cern.ch, giorgio.orlandini@cern.ch, jerome.samarati@cern.ch, djunes.janssens@cern.ch, august.brask@cern.ch, eraldo.oliveri@cern.ch, florian.maximilian.brunbauer@cern.ch, rob.veenhof@cern.ch, miranda.van.stenis@cern.ch

The RD51 collaboration focuses on the R&D of Micro-Pattern Gaseous Detectors (MPGDs). Included in their activities are joint test beam campaigns at a semi-permanent facility at the H4 beam line of CERN's Super Proton Synchrotron (SPS). As part of the test beam infrastructure, two beam telescopes with 10 x 10 cm² active area are provided. One telescope employs MicroMegas detectors for tracking and the other one uses Gas Electron Multipliers (GEM). Both of them are read out with the RD51 Scalable Readout System (SRS), with two options for the front-end ASICs: the APV25 and the more recent ATLAS/BNL VMM3a. This allows to read out up to 5k channels with typically around 500 to 1000 channels per detector.

The results presented here have been obtained with the GEM telescope (around 50 µm spatial resolution) that is combined with scintillators and Photomultiplier-Tubes (PMTs) for timing (around 1 ns time resolution). It is read out, including the NIM-logic connected to the PMTs, with the VMM3a.

With the front-end electronics providing also the charge information, a simultaneous detector characterisation in energy, space and time is possible. Due to the continuous self-triggered readout scheme, particle interaction rates up to the MHz regime can be recorded.

Following the successful commissioning of the beam telescope in the last years, in this presentation, the latest improvements and detector characterisation results will be shown. On the telescope's side, the main focus was the development of a new powering scheme for the front-end electronics, enabling in particular the use of a telescope lever arm of around 20 m. The detector studies focussed on characterising GEMs with higher-granularity amplification structures, showing that they improve the detector's spatial resolution. In addition, the results from characterising a prototype GEM detector for the AMBER experiment and resistive MPGDs with a single amplification stage (μRWELL and MicroMegas) will be presented.

With the RD51 collaboration ceasing operation end of 2023 and being succeeded by the DRD1 collaboration, the telescopes will be used in the future for the DRD1 test beam campaigns. This includes continuing the improvements of the telescopes, e.g. by the ongoing implementation of externally triggered readout modes for the VMM3a front-end.

Sensors / 25

Laboratory Characterization of an H2M Monolithic Pixel Detector Prototype

Author: Judith Schlaadt[None]

Co-authors: Ana Dorda [1]; Christian Reckleben [2]; Dominik Dannheim [3]; Eric Buschmann [4]; Finn Feindt [2]; Gianpiero Vignola [2]; Håkan Wennlöf [2]; Ingrid-Maria Gregor [5]; Iraklis Kremastiotis [3]; Karsten Hansen [6]; Lennart Huth [2]; Lucia Masetti [7]; Michael Campbell [3]; Philipp Gadow [3]; Rafael Ballabriga Sune [3]; Raimon Casanova Mohr [8]; Sara Ruiz Daza ; Simon Spannagel [2]; Stefano Maffessanti ; Tomas Vanat [2]; Younes Otarid [3]

[1] *KIT - Karlsruhe Institute of Technology (DE)*

[2] *Deutsches Elektronen-Synchrotron (DE)*

[3] *CERN*

[4] *Brookhaven National Laboratory (US)*

[5] *DESY & Bonn University*

[6] *DESY*

[7] *Johannes Gutenberg Universitaet Mainz (DE)*

[8] *IFAE - Barcelona (ES)*

Corresponding Authors: eric.buschmann@cern.ch, stefano.maffessanti@cern.ch, christian.reckleben@desy.de, judith.schlaadt@desy.de, michael.campbell@cern.ch, finn.feindt@desy.de, ingrid.gregor@desy.de, younes.otarid@cern.ch, h.wennlof@cern.ch, simon.spannagel@cern.ch, karsten.hansen@desy.de, lucia.masetti@cern.ch, iraklis.kremastiotis@cern.ch, tomas.vanat@cern.ch, lennart.huth@cern.ch, gianpiero.vignola@cern.ch, rafael.ballabriga@cern.ch, dominik.dannheim@cern.ch, ana.dorda.martin@cern.ch, paul.philipp.gadow@cern.ch, raimon.casanova.mohr@cern.ch, ruizdaza@mail.desy.de

Research and development of monolithic active pixel sensors (MAPS) with applications in future lepton colliders and beam telescopes face various challenges regarding time and position resolution while maintaining a low material budget and high rate capabilities. In this context, the H2M (hybrid-to-monolithic) project represents the joint effort of CERN, DESY and IFAE to design and test a monolithic chip with an integrated hybrid pixel detector architecture. This sensor was designed and fabricated in a 65nm CMOS imaging process and consists of 64×16 square pixels with a 35um pitch, which results in a total active area of 2.24×0.56 mm^2. The n-gap layout of the sensitive area of this chip was previously investigated in the Tangerine project and ensures an improved charge collection from pixel edges and corners.
This contribution shows preliminary results of the laboratory characterization of an H2M prototype. A particular focus was put on the implementation of a trimming procedure by making use of the tuning DAC, as this front-end parameter allows for the threshold adjustment for individual pixels with a 4-bit resolution. Different procedures to minimize the threshold dispersion for the whole pixel matrix were tested, and the impact of the bias current of the tuning DAC was studied.

Simulation / **26**

Simulation of Hexagonal Pixel Configurations in Monolithic Active Pixel Sensors

Author: Larissa Mendes[None]

Co-authors: Adriana Simancas [1]; Anastasiia Velyka ; Håkan Wennlöf ; Ingrid-Maria Gregor [2]; Lennart Huth [1]; Simon Spannagel [1]; Yajun He [3]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *DESY & Bonn University*

[3] *Deutsches Elektronen-Synchrotron DESY*

Corresponding Authors: hakan.wennlof@desy.de, larissa.mendes@desy.de, lennart.huth@cern.ch, anastasiia.velyka@desy.de, simon.spannagel@cern.ch, ingrid.gregor@desy.de, yajun.he@cern.ch, adriana.simancas@cern.ch

One of the DESY Tangerine Project is to evaluate monolithic active pixel sensors (MAPS) that are produced with small collection electrodes and in a 65 nm CMOS imaging technology. Consequently, precise simulations have proven essential for characterizing and predicting sensor performance, leading to improved performance designs.

To accomplish this kind of characterization, a simulation strategy can combine Monte Carlo simulation with electrostatic field simulations using Technology Computer-Aided Design (TCAD). The conventional square/rectangular pixel arrangements offer convenient fabrication and readout electronics, along with well-established data processing and analysis methods. However, there is a growing interest in the use of hexagonal pixel detectors as some different prototypes have been developed. The presented study investigates a hexagonal pixel grid arrangement to demonstrate potential benefits over square or rectangular pixel layouts.

Efficiency, cluster size, and spatial resolution are used to evaluate these different configurations, and the square and hexagonal pixel geometries are compared. Transient simulations in detectors are also executed to model the time-dependent behavior of detectors in response to incident particles of hexagonal pixels. The investigations undertaken in this work underscore the potential of the hexagonal pixel grid to enhance the performance of MAPS in high-energy physics experiments.

Poster session / **27**

Test Beam characterization of the H2M chip designed in a 65 nm CMOS imaging process

Author: Sara Ruiz Daza[1]

Co-authors: Ana Dorda [2]; Christian Reckleben [1]; Dominik Dannheim [3]; Eric Buschmann [4]; Finn Feindt [1]; Gianpiero Vignola ; Håkan Wennlöf ; Ingrid-Maria Gregor [5]; Iraklis Kremastiotis [3]; Judith Schlaadt ; Karsten Hansen [6]; Lennart Huth [1]; Michael Campbell [3]; Philipp Gadow [3]; Rafael Ballabriga Sune [3]; Raimon Casanova Mohr [7]; Simon Spannagel [1]; Stefano Maffessanti ; Tomas Vanat [1]; Younes Otarid [3]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *KIT - Karlsruhe Institute of Technology (DE)*

[3] *CERN*

[4] *Brookhaven National Laboratory (US)*

[5] *DESY & Bonn University*

[6] *DESY*

[7] *IFAE - Barcelona (ES)*

Corresponding Authors: gianpiero.vignola@desy.de, tomas.vanat@cern.ch, hakan.wennlof@desy.de, dominik.dannheim@cern.ch, eric.buschmann@cern.ch, raimon.casanova.mohr@cern.ch, finn.feindt@desy.de, simon.spannagel@cern.ch, judith.schlaadt@desy.de, karsten.hansen@desy.de, paul.philipp.gadow@cern.ch, michael.campbell@cern.ch, stefano.maffessanti@desy.de, rafael.ballabriga@cern.ch, ana.dorda.martin@cern.ch, iraklis.kremastiotis@cern.ch, sara.ruiz.daza@desy.de, christian.reckleben@desy.de, younes.otarid@cern.ch, ingrid.gregor@desy.de, lennart.huth@cern.ch

Monolithic active pixel sensors (MAPS) manufactured in a 65 nm CMOS imaging process are attractive candidates for tracking charged particles at future lepton and electron-ion colliders, as well as for beam telescopes. To investigate this technology and explore the design challenges of porting a hybrid pixel detector architecture into a monolithic chip, the H2M (Hybrid-to-Monolithic) test chip has been developed. The chip matrix consists of 64×16 square pixels with a size of 35×35 µm2 (matrix area of ~1.25 mm2), and the sensitive region is designed in the so-called n-gap layout to enhance fast charge collection.

Test-beam measurements have been carried out to characterize two of the four available acquisition modes: Time-Over-Threshold (ToT) at SPS and Time-Of-Arrival (ToA) at DESY. This contribution describes the setup and DAQ system used for these measurements. Sensor performance results in terms of detection efficiency, spatial resolution, and time resolution will be shown.

Test beam analysis / 28

Test Beam Characterisation of stitched CMOS Strip Sensors

Authors: Arturo Rodriguez Rodriguez[None]; Birkan Sari[None]; Dennis Sperlich[1]; Fabian Huegging[2]; Fabian Simon Lex[1]; Ingrid-Maria Gregor[3]; Iveta Zatocilova[1]; Jan-Hendrik Arling[4]; Jens Weingarten[5]; Jochen Christian Dingfelder[2]; Karl Jakobs[1]; Kevin Alexander Kroeninger[5]; Leena Diehl[6]; Marc Hauser[1]; Marta Baselga[5]; Michael Karagounis[7]; Naomi Afiriyie Davis[4]; Niels Sorgenfrei[1]; Roland Koppenhöfer[1]; Simon Spannagel[4]; Tianyang Wang[None]; Tomasz Hemperek[2]; Ulrich Parzefall[1]

[1] *Albert Ludwigs Universitaet Freiburg (DE)*

[2] *University of Bonn (DE)*

[3] *DESY & Bonn University*

[4] *Deutsches Elektronen-Synchrotron (DE)*

[5] *Technische Universitaet Dortmund (DE)*

[6] *CERN*

[7] *Fachhochschule Dortmund Univ. of Applied Sciences and Arts (DE)*

Corresponding Authors: ingrid.gregor@desy.de, karl.jakobs@uni-freiburg.de, naomi.afiriyie.davis@cern.ch, ulrich.parzefall@cern.ch, jochen.christian.dingfelder@cern.ch, iveta.zatocilova@cern.ch, kevin.alexander.kroeninger@cern.ch, roland.koppenhofer@cern.ch, dennis.sperlich@cern.ch, leena.diehl@cern.ch, arturo.rodriguez.rodriguez@cern.ch, michael.karagounis@cern.ch, niels.sorgenfrei@cern.ch, simon.spannagel@cern.ch, jan-hendrik.arling@cern.ch, fabian.simon.lex@cer tianyang.wang@cern.ch, themperek@cern.ch, birkan.sari@tu-dortmund.de, fabian.huegging@cern.ch, marc.hauser@cern.ch, jens.weingarten@cern.ch, marta.baselga@cern.ch

In high-energy physics, there is a need to investigate silicon sensor concepts that offer large-area coverage and cost-efficiency.
Sensors based on CMOS imaging technologies present an alternative silicon sensor concept for particle tracking detectors.
As this technology is a standardised industry process, it can provide a lower sensor production cost and access to fast and large-scale production from various vendors.

The CMOS Strips project is investigating passive CMOS strip sensors fabricated by LFoundry in a 150 nm technology.
By employing the technique of stitching, two different strip formats of the sensor have been realised.
The implant design varies in doping concentration and width of the strip implant, making it possible to study various depletion concepts and electric field configurations.

The sensor performance is evaluated based on several test beam campaigns conducted at the DESY II test beam facility. In addition, the strip sensors have been electrically characterised in the laboratory.

This contribution presents detailed test beam data analysis results for different sensor layouts, focusing on the signal distribution, spatial resolution and hit detection efficiency.

Poster session / 29

Results for Online Track-fitting in Hardware at 40 MHz

Author: Michael McGinnis[1]

[1] *Northwestern University (US)*

Corresponding Author: michael.gilmer.mc.ginnis@cern.ch

Central to particle physics experiments using high intensity beams is event selection to allow DAQ systems to cope with high data rates. This is true for the MUonE experiment, both for its final configuration and upcoming test beams. Online track-fitting for event selection will be implemented directly on FPGAs, using High-Level Synthesis to convert C++ code into an HDL description to then run on the FPGA. In the fall of 2023, during a beam test at the M2 beamline at CERN, an initial hardware tracking implementation was tested in parallel to the mainline DAQ. Results from this test will be presented, including agreement with offline reconstruction, algorithm performance, as well as improvements on the tested algorithm which decrease latency and resource use. Results from an event selection using the patterns of stubs in adjacent tracking stations, which was tested offline using test beam data, will also be presented.

Facilities / 30

The DESY II Test Beam Facility - Present and Future

Authors: Marcel Stanitzki[1]; Norbert Meyners[2]; Ralf Diener[None]; Sven Ackermann[1]

[1] *DESY*

[2] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: sven.ackermann@desy.de, marcel.stanitzki@desy.de, norbert.meyners@desy.de, ralf.diener@desy.de

The DESY II Test Beam Facility is looking back at another successful year.
In this contribution, a review is given over the test beam period 2023 and the running period 2024. This includes the current status of the facility as well as recent developments of the infrastructure and improvements for the user community.
In addition, studies on the future of the facility are presented against the background of an upgrade of the accelerator complex for the planned Petra IV synchrotron source. Different upgrade plans for test beams at the existing synchrotron or at a completely new synchrotron will be introduced, highlighting their advantages and disadvantages.

Poster session / 31

A Material Budget Measurement of an ATLAS ITk Pixel Module via Multiple Scattering at the CERN Proton Synchrotron

Authors: Antonin Lindner[1]; Brian Moser[2]; Simon Florian Koch[3]

Co-authors: Carlos Solans Sanchez [2]; Daniela Bortoletto [3]; Valerio Dao [2]; Yingjie Wei [4]

[1] *Palacky University (CZ)*

[2] *CERN*

[3] *University of Oxford (GB)*

[4] *Albert Ludwigs Universitaet Freiburg (DE)*

Corresponding Authors: daniela.bortoletto@cern.ch, simon.florian.koch@cern.ch, lindner.antonin@cern.ch, valerio.dao@cern.ch, yingjie.wei@cern.ch, carlos.solans@cern.ch, brian.moser@cern.ch

Modern pixel detectors are being built to withstand the ever higher collision rates and pile-up of colliders designed to push luminosity and intensity limits. The ITk is a new silicon tracker for the ATLAS experiment designed to increase detector resolution, readout capacity, and radiation hardness, and the five innermost layers will be built of hybrid pixel modules. The material budget of the modules and support structures strongly influences the tracking and vertexing performance of the detector. During the R&D phase, the material budget of detector components is usually estimated from material content expectations for individual components, and is only verified after commissioning in dedicated runs of the detector.

We present a measurement of the radiation length of an ATLAS ITk pixel module performed at a testbeam at the CERN Proton Synchrotron using the multiple scattering of low-energy positrons within the module volume. Using a four-plane telescope of thin monolithic pixel detectors from the MALTA collaboration, scattering datasets were recorded at various beam energies and telescope configurations. Kink angle distributions are extracted from tracks derived both with and without information from the ITk pixel module. These are fit to extract the RMS scattering angle which can be converted to a fractional radiation length via the inverse highland formula, resulting in a 2D map of the module's radiation length with O(10%) uncertainty and sub-mm resolution. Following a comparison of the results to empirical estimates, we explore the different beam energies, tracking configurations, and methodological choices made, to give a wider commentary on the potential and flexibility of the chosen method for material budget estimates of both position-sensitive and non-instrumented subjects.

Test beam analysis / 32

Beam test of a baseline vertex detector prototype for CEPC

Authors: Shuqi Li[1]; Tianya Wu[1]; Zhijun Liang[1]

[1] *Chinese Academy of Sciences (CN)*

Corresponding Authors: wuty@ihep.ac.cn, zhijun.liang@cern.ch, lishuqi@ihep.ac.cn

The Circular Electron Positron Collide (CEPC) has been proposed to enable more thorough and precise measurements of the properties of Higgs, W and Z bosons, as well as to search for new physics. In response to the stringent performance presented by the vertex detector for the CEPC, a baseline vertex detector prototype was designed and tested using a 6 GeV electron beam at DESY~\uppercase\expandafter{\romar
Test Beam Line 21. The baseline vertex detector prototype is designed with a cylindrical barrel structure that houses six double-sided ladders. Each side of the ladder includes TaichuPix-3 sensors based on Monolithic Active Pixel Sensor (MAPS) technology, a flex printed cable and a carbon fiber support structure. Additionally, the readout electronics and the Data Acquisition (DAQ) system were verified during this beam test. The performance of the prototype was evaluated using an electron beam that traversed directly the six ladders from one side. Offline data analysis indicates a spatial resolution of about \SI{5}{\um}, with a detection efficiency exceeding \SI{99}{\%} and an impact parameter resolution also near \SI{5}{\um}. The promising results from this baseline vertex detector prototype mark a significant step toward realizing the optimal vertex detector for the CEPC.

Beam telescopes / 33

Results from the Timepix4 Telescope

Authors: Daan Jasper Oppenhuis[None]; David Bacher[1]; Efren Rodriguez Rodriguez[2]; Elena Dall'Occo[3]; Ganrong Wang[4]; Kazuyoshi Carvalho Akiba[5]; Kevin Heijhoff[6]; Martin Van Beuzekom[6]; Paula Collins[7]; Timothy David Evans[8]; Tommaso Pajero[7]; Victor Coco[7]

[1] *University of Oxford (GB)*

[2] *Universidade de Santiago de Compostela (ES)*

[3] *Technische Universitaet Dortmund (DE)*

[4] *Central China Normal University CCNU (CN)*

[5] *Nikhef*

[6] *Nikhef National institute for subatomic physics (NL)*

[7] *CERN*

[8] *University of Manchester (GB)*

Corresponding Authors: elena.dall'occo@cern.ch, timothy.david.evans@cern.ch, tommaso.pajero@cern.ch, doppenhu@nikhef.nl, k.heijhoff@nikhef.nl, paula.collins@cern.ch, efren.rodriguez.rodriguez@cern.ch, kazu.akiba@cern.ch, martin.van.beuzekom@cern.ch, ganrong.wang@cern.ch, victor.coco@cern.ch, david.lukas.bacher@cern.ch

A beam telescope based on the Timepix4 ASIC was built in order to perform tests of synchronous multiple-detector readout and track reconstruction with fast timing capability.
The telescope consists of eight planes with n-on-p silicon sensors, each bump bonded to a Timepix4 ASIC. Four of these planes are instrumented with 300 µm thick planar sensors, and they are tilted with respect to the be incidence to provide high quality spatial measurements. The other four planes have 100 µm thick sensors to achieve a better time response.
The Timepix4 is designed to record both the time of arrival (ToA) and the time over threshold (ToT) for each discriminated signal. It has a 448×512 pixel matrix with square pixels at a 55 µm pitch. Each superpixel, a group of two by four pixels, has a 640 MHz voltage controlled oscillator (VCO). The VCO has four phase shifted copies, which results in a ToA digitisation with time bins of 195 ps. The ToT is proportional to the charge collected by the silicon sensor, and is used to improve spatial resolution based on charge sharing. The ToT is also used to correct for timewalk and improve the ToA resolution. After VCO and timewalk corrections the timing resolution of each plane improves significantly. The measurements can be combined to achieve a more precise time stamp on a track.
In this presentation a detailed overview of the most recent results in temporal and spatial resolutions obtained by the telescope will be shown.

Experiments / 34

Development of a High-Resolution, High-Dynamic-Range Charge Detector for Ion Beam Monitoring

Author: Oleksandr Starodubtsev[1]

Co-authors: Eugenio Berti [1]; Lorenzo Pacini [2]; Monica Scaringella [3]; Nicola Mori [4]; Pietro Betti [5]

[1] *Universita e INFN, Firenze (IT)*

[2] *INFN, Firenze (IT)*

[3] *INFN Firenze (IT)*

[4] *INFN Florence*

[5] *Department of Physics and Astronomy, University of Florence and INFN sezione di Firenze*

Corresponding Authors: m.scaringella@cern.ch, nicola.mori@cern.ch, aleksandr.starodubtsev@cern.ch, eugenio.berti@cern.ch, lorenzo.pacini@fi.infn.it, pietro.betti@unifi.it

This paper introduces a novel concept for a charge detector featuring high resolution and a wide dynamic range. The prototype of this detector was specifically designed and constructed to serve the ion beam monitoring requirements of the High-Energy cosmic-Radiation Detection (HERD) experiment during beam tests conducted at CERN SPS facilities.

The prototype incorporates a series of silicon pad sensors and utilizes the same readout electronics employed in the HERD Calo photodiode system. Initial testing and experimentation with the prototype have demonstrated exceptional performance, showcasing both high resolution and a dynamic range that enables the measurement of nuclei with atomic numbers ranging from 1 to 80.

An integral aspect of the prototype's success lies in its compatibility with fast and practically real-time data analysis, making it suitable for online applications. In this presentation, we will share the achieved results from the prototype's testing phase, highlighting its capabilities and performance metrics. Furthermore, we will discuss the potential applications of this charge detector in the broader context of the HERD experiment and outline our ideas for future development and refinement.

Test beam analysis / 35

Test-beam qualification of the PS modules for the CMS Phase-2 Outer Tracker

Author: Daniil Rastorguev[1]

Co-authors: Andreas Nürnberg [1]; Paul Schütze [1]; Lea Stockmeier [2]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *KIT - Karlsruhe Institute of Technology (DE)*

Corresponding Authors: daniil.rastorguev@cern.ch, andreas.nurnberg@cern.ch, paul.schuetze@desy.de, lea.stockmeier@cern.ch

The LHC is to enter a High Luminosity era in 2029, and many systems are to be upgraded or replaced in order to overcome challenges brought up by the vastly increasing luminosity. The corresponding Phase-2 upgrade of the CMS experiment is scheduled for Long Shutdown 3 in 2026. This includes installation of the entirely new Outer Tracker, consisting of two types of double-sensor modules, namely, pixel-strip (PS) and strip-strip (2S). As of spring 2024, production of such modules has reached a kick-off stage, essentially meaning that demonstrator modules have been built with close-to-final components to verify the design and production processes and to perform integration tests.

This talk covers specific aspects of the design and production of PS modules, including the novel functionality of the on-module track angle discrimination, and the procedure of precision mechanical assembly, which is crucial for the aforementioned feature. Subsequently, results of the module qualification at the DESY-II Test Beam Facility are presented, comprising particle detection efficiency studies and tests on the angle discrimination.

Poster session / 36

Caribou - A versatile data acquisition system for silicon pixel detector prototyping

Author: Younes Otarid[1]

Co-authors: Dominik Dannheim [1]; Eric Buschmann [2]; Simon Spannagel [3]; Tomas Vanat [3]

[1] *CERN*

[2] *Brookhaven National Laboratory (US)*

[3] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: tomas.vanat@cern.ch, eric.buschmann@cern.ch, younes.otarid@cern.ch, dominik.dannheim@cern.ch, simon.spannagel@cern.ch

Caribou is a versatile data acquisition system used in multiple collaborative frameworks (CERN EP R&D, DRD3, AIDAinnova) for both bench-top and test-beam qualification of novel silicon pixel detector prototypes. The system is built around a common hardware, firmware and software base shared accross different projects, thereby drastically reducing the development effort and cost. The current version consists of a custom Control and Readout (CaR) board and a commercial Xilinx Zynq 7000 series Sytem-on-Chip (SoC) platform. The CaR board provides a hardware environment featuring various services such as powering, slow-control and high-speed data links that can be used by the target detector prototype. The SoC platform is based on a ZC706 evaluation board running a fully featured Yocto-based Linux distribution (Poky) and a custom data acquisition software (Peary). Migration to a Zynq UltraScale+ architecture is ongoing with the additional objective of merging the SoC and the CaR board into a single hardware platform. This talk describes the current Caribou system architecture, its capabilities, examples of projects where it is used, and the foreseen system upgrade.

Test beam analysis / 37

Test Beam Results on 3D pixel sensors for the CMS Tracker Upgrade at the High-Luminosity LHC

Author: Rudy Ceccarelli[1]

[1] *Universita e INFN, Firenze (IT)*

Corresponding Author: rudy.ceccarelli@cern.ch

The High Luminosity upgrade of the CERN Large Hadron Collider (HL-LHC) calls for new high-radiation tolerant silicon pixel sensors, capable of withstanding, in the innermost tracker layer, fluences up to 2.3E16 neq/cm2 (1MeV equivalent neutrons). An extensive R&D program aiming at 3D pixel sensors, built with a top-side only process, has been put in place in CMS in collaboration with FBK (Trento, Italy) and CNM (Barcelona, Spain) foundries. A number of sensors were interconnected with the CROC readout chip; CROC is the prototype, in 65nm technology, of the pixel readout chip which will be used in the HL-LHC inner trackers. The modules have been tested on beam at CERN and DESY, before and after irradiation up to an equivalent fluence of about 1.5E16 neq/cm2. Analysis of collected data shows great performance, with hit detection efficiencies around 98% measured after irradiation.

Experiments / 38

The Silicon Tracking System of the E16 experiment at J-PARC: commissioning and results from the test beam

Authors: Adrian Rodriguez Rodriguez[1]; Alberica Toia[2]; Dairon Rodríguez Garcés[2]; Joerg Lehnert[1]; Kazuya Aoki[3]; Kyoichiro Ozawa[3]; Maksym Teklishyn[4]; Rento Yamada[5]; Shuta Ochiai[6]

[1] *GSI*

[2] *GSI and Goethe University of Frankfurt*

[3] *High Energy Accelerator Research Organization (KEK)*

[4] *GSI and INR of NASU*

[5] *Hiroshima University*

[6] *Kyoto University*

Corresponding Author: d.rodriguezgarces@gsi.de

The J-PARC E16 experiment has the goal to search for signatures of the spontanoeusly broken chiral symmetry and its (partial) restoration, through the study in-medium modification of the vector

mesons, particulary the phi meson, decaying via di-electron channel, with a high intensity 30 GeV proton beam interacting with C and Cu targets at rates up to 10 MHz. For this purpose, the experiment will use modules constructed using the same technology and procedures as the modules of the Silicon Tracking System (STS) of the CBM experiment.

A total of 10 modules were assembled, tested, characterized and then; installed in the E16 detector setup. For preparation the detector for the beamtest, we commissioned the detectors by measuring ENC and calibration performance. In the beamtime 3 modules operated and were iluminated by electron beam of 3 GeV momentum.

This work will show the results of commissioning and operation of the E16 modules, as well as the status of the data analysis and the insights that we have gained from it, in view the upcoming series production of STS modules.

Test beam analysis / 39

A Beam Monitor For The AMS-02 Layer0 Tracker Upgrade

Authors: Alessio Ubaldi[1]; Dexing Miao[2]; Gianluigi Silvestre[1]; Hongyu Zhang[3]; Hsinyi Chou[None]; Jianchun Wang[4]; Liu Cong[5]; Lorenzo Mussolin[1]; Maria Ionica[6]; Matteo Duranti[1]; Mattia Barbanera[1]; Maura Graziani[1]; Mingjie Feng[4]; Pingcheng Liu[7]; Qinze Li[4]; Shuqi Sheng[4]; Tiange Li[4]; Valerio Formato[8]; Xiaojie Jiang[4]; Xudong Cai[9]; Yaozu Jiang[1]; Zhiyu Xiang[4]; Zijun Xu[4]

[1] *Universita e INFN, Perugia (IT)*

[2] *The Institute of High Energy Physics of the Chinese Academy of Sciences (CN)*

[3] *FDU*

[4] *Chinese Academy of Sciences (CN)*

[5] *SDIAT*

[6] *INFN Perugia, via A. Pascoli 23c, Perugia, I-06100, Italy*

[7] *Shandong Institute of Advanced Technology (SDIAT) (CN)*

[8] *INFN - Sezione di Roma Tor Vergata*

[9] *Massachusetts Inst. of Technology (US)*

Corresponding Authors: jwang@ihep.ac.cn, dexing.miao@cern.ch, matteo.duranti@cern.ch, tiange.li@cern.ch, mingjie.feng@cern.ch, liqz@ihep.ac.cn, shuqi.sheng@cern.ch, mattia.barbanera@cern.ch, zhiyu.xiang@cern.ch, maura.graziani@cern. gianluigi.silvestre@cern.ch, zijun.xu@cern.ch, valerio.formato@cern.ch, lorenzo.mussolin@cern.ch, xudong.cai@cern.ch, pingcheng.liu@cern.ch, xiaojie.jiang@cern.ch, hsinchou@stat.sinica.edu.tw, yaozu.jiang@pg.infn.it, alessio.ubaldi@cern.ch

The Alpha Magnetic Spectrometer (AMS-02) detector operates on the International Space Station. It performs high precision measurements of cosmic ray composition and fluxes, searches for antimatter and dark matter. To increase the detection acceptance and improve its heavy ion identification power, the AMS collaboration plan to add a new layer (L0) of silicon tracker on top of AMS-02. The detector consists of 2 planes, 72 silicon strip detector ladders. Each ladder has 8, 10, or 12 silicon strip detector sensors (SSDs) connected in serial, producing an effective strip length of about 1 meter. The total sensitive area is about $8m^2$.

In order to study the detector ladder in cosmic rays and particle beams, and calibrate the L0 tracker with particle beams before launching to the space, a beam monitor has been produced. The monitor consists of 10 single-SSD modules with a readout electronics system similar to that of the L0 detector. The beam monitor alone had been used in testbeams using electron beam at IHEP to characterize the SSD, which was custom designed for the AMS L0 upgrade. The beam monitor has also been used to test prototype ladders using proton, muon and heavy ion beams at CERN.

In this talk details of the beam monitor and its performance will be described. The tracking and alignment methods based on GBL and Millepede-II packages will also be introduced. Results from the SSD characterization from the testbeam at IHEP will also be presented.

Experiments / 40

A large-area prototype SiPM readout plane for the dRICH detector of ePIC at the EIC: test at the CERN-PS facility

Author: Marco Giacalone[1]

Co-authors: Luigi Pio Rignanese ; Nicola Rubini [1]; Roberto Preghenella [2]

[1] *Universita e INFN, Bologna (IT)*

[2] *INFN, Bologna (IT)*

Corresponding Authors: marco.giacalone@cern.ch, rignanes@bo.infn.it, roberto.preghenella@bo.infn.it, nicola.rubini@cern.ch

Silicon photomultipliers (SiPMs) have been selected as the photodetector technology for the dual-radiator RICH (dRICH) detector of the ePIC experiment at the future Electron-Ion Collider (EIC). A large-area prototype readout surface, consisting of a total of 1280 3 x 3 mm² SiPM sensors, was recently built and installed as part of the dRICH prototype during a beam test in October 2023 at CERN-PS. The SiPM prototype readout is based on a novel EIC-driven prototype photodetection unit (PDU) developed by INFN. This concept integrates 256 3x3 mm² Hamamatsu SiPM sensors and corresponding services (cooling and front-end electronics) into the prototype PDU volume of approximately 5 x 5 x 14 cm³. The front-end and the readout electronics are based on the second version of the ALCOR chip developed by INFN Torino. Eight PDUs have been assembled and tested in the dRICH prototype and, in this presentation, the features of the PDUs and their performance within the prototype will be discussed. The results from the beam test at CERN-PS, with both positive and negative hadrons, will be presented to highlight the performance of the new SiPM detector readout surface. An alternative analysis approach based on machine learning for Cherenkov image reconstruction has been explored: results compared to classical ring reconstruction algorithms will be also reported.

Beam telescopes / 41

Test beam performance of sensor modules for the CMS Barrel Timing Layer

Author: Claudio Quaranta[1]

[1] *Sapienza Universita e INFN, Roma I (IT)*

Corresponding Author: claudio.quaranta@cern.ch

The MIP Timing Detector (MTD) is a new sub-detector planned for the Phase 2 upgrade of the Compact Muon Solenoid (CMS) experiment at the CERN LHC. The MTD is designed to measure the time-of-arrival of charged particles with a resolution of 30-60 ps. The precision time information from MTD will reduce the effects of the high levels of pileup expected at the HL-LHC, bringing new capabilities to the CMS detector. The sensor technology chosen for the central part of the MTD, the Barrel Timing Layer (BTL), consists of scintillating LYSO:Ce crystal bars read out by silicon photomultipliers. In this talk, we will present an overview of the BTL design and discuss recent results of beam test campaigns conducted in 2023 at CERN and FNAL on final module prototypes, both non-irradiated and irradiated to a neutron fluence of 2×10^{14} 1MeV n_{eq}/cm^2, as expected by the end of HL-LHC operations.

Test beam analysis / 42

electronCT - The Bright Side of Multiple Coulomb Scattering

Author: Paul Schütze[1]

Co-authors: Adrian Herkert [1]; Florian Burkart ; Sara Ruiz Daza [1]; Simon Spannagel [1]

[1] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: florian.burkart@desy.de, simon.spannagel@cern.ch, adrian.herkert@desy.de, sara.ruiz.daza@desy.de, paul.schuetze@desy.de

Multiple Coulomb scattering of charged particles in matter is in high energy physics often seen as a nuisance due to its stochastic nature and the concomitant deterioration of tracking and momentum resolution. In this contribution studies on a technique are presented utilising this effect for the purpose of a medical imaging method, electronCT.
This technique applies radiation detectors developed in high energy physics to determine the scattering power of highly relativistic electrons in any sample, phantom or patient to determine the properties of the traversed material, offering the capabilities of two- and three-dimensional imaging.

In the context of radiation therapy with electrons of energies in the range of 100 to 250 MeV, called Very-High Energy Electron (VHEE), this technique has the potential of applying the same accelerator for treatment as for imaging, where the latter can mean a full diagnostic measurement or a high-precision location of a tumour.

Studies towards this technique have been performed at the ARES linear accelerator at DESY using silicon pixel detectors for radiation detection. In this contribution we present the principles of the imaging method electronCT and the experimental setup, as well as results in terms of two- and three-dimensional imaging of phantoms in a test beam-like environment.

DAQ systems / 43

Commissioning and study of a CMS 2S module with 40MHz read-out

Author: Martin Delcourt[1]

[1] *Vrije Universiteit Brussel (BE)*

Corresponding Author: martin.delcourt@cern.ch

In order to maintain its outstanding performance under the challenging conditions brought by the high-luminosity LHC, the CMS collaboration is preparing the production of a new outer tracker detector. The upgraded detector modules will feature two silicon sensors and the ability of reading out correlated clusters, or stubs, compatible with high transverse momentum particles at the full 40MHz collision rate. With the detector design being finalized and mass production planned to start during the second half of 2024, the scalability of the read-out system and the study of the commissioning and characterization of the detector in realistic conditions are ever-more pressing.

In this context, a joint beam-test was organised in collaboration with the MUonE collaboration where twelve modules were placed in an asynchronous muon beam line reaching particle rates of about 50MHz, with the full stub stream being recorded to disk triggerless. The setup and read-out chain will be outlined, the commissioning procedures and operational challenges will be discussed and resulting system performance will be presented. From these results, the future prospects for both experiments will be discussed, as well as the milestones reached and still lying ahead before the full systems could be deployed.

Calorimetry / 44

Summary of HGCAL beam tests in 2023

Author: Geliang Liu[1]

[1] *Centre National de la Recherche Scientifique (FR)*

Corresponding Author: geliang.liu@cern.ch

As part of its HL-LHC upgrade program, CMS is developing a High Granularity Calorimeter (HGCAL) to replace the existing endcap calorimeters. The HGCAL will be realized as a sampling calorimeter equipped with silicon and SiPM-on-tile modules. For the validation of the HCGAL, prototype of various silicon modules types have been exposed to beam of electrons, muons and pions at the CERN SPS H4 beam line. In 2023, the full electronic chain was assembled and tested for the first time. The front-end electronics, including readout and concentrator ASICs, were controlled and readout by a prototype board of the final back-end. The experimental setup and first results will be discussed.

Poster session / 45

Ions beam test of silicon micro-strip detectors for the AMS-02 upgrade

Authors: Alessio Ubaldi[1]; Gianluigi Silvestre[2]

Co-authors: Dexing Miao [3]; Lorenzo Pacini [4]; Maria Movileanu [1]; Matteo Duranti [1]; Mattia Barbanera [1]; Maura Graziani [1]; Mingjie Feng ; Nicola Mori [5]; Oleksandr Starodubtsev [6]; Pingcheng Liu ; Sebastiano Detti [6]; Shuqi Sheng ; Tiange Li ; Valerio Formato [7]; Xiaojie Jiang ; Yaozu Jiang [1]; Zijun Xu

[1] *Universita e INFN, Perugia (IT)*

[2] *INFN, Perugia (IT)*

[3] *Institute of High Energy Physics, Beijing, China*

[4] *INFN, Firenze (IT)*

[5] *INFN Florence*

[6] *Universita e INFN, Firenze (IT)*

[7] *INFN - Sezione di Roma Tor Vergata*

Corresponding Authors: zijun.xu@cern.ch, xiaojie.jiang@cern.ch, tiange.li@cern.ch, shuqi.sheng@cern.ch, pingcheng.liu@cern.ch, mingjie.feng@cern.ch, dexing.miao@cern.ch, gianluigi.silvestre@cern.ch, alessio.ubaldi@cern.ch, matteo.duranti@cern.ch, yaozu.jiang@pg.infn.it, valerio.formato@cern.ch, maura.graziani@cern.ch, maria.ionica@cern.ch, aleksandr.starodubtsev@cern.ch, nicola.mori@cern.ch, sebastiano.detti@cern.ch, mattia.barbanera@cern.ch, lorenzo.pacini@fi.infn.it

The Alpha Magnetic Spectrometer (AMS) is a space-borne experiment with the unique capability of distinguishing matter from anti-matter, thanks to its capability of measuring the charge sign from the track deflection within its magnetic field. The AMS Collaboration decided to upgrade the silicon tracker with the installation of an additional tracking layer on the top of the existing instrument. The work presented shows the results of a preliminary study on the performance of the new Silicon tracker layer, the Layer 0 (L0). Two silicon ladder prototypes have been exposed to a fragmented ions beam at the super-proton-synchrotron (SPS) of the CERN and to a Carbon beam at Centro Nazionale di Adroterapia Oncologica (CNAO) in Pavia, to characterize its charge resolution and the readout electronics. Moreover, different configurations of the setup have been tested to evaluate the effects of the meachanical structure that will enclose the complete Layer 0. A beam telescope composed of nine detectors, similar to the ones under test, have been used to characterize the beam upstream of the Device Under Test (DUT) and fragmentation in the downstream region. A high dynamic range, photodiodes based charge tagger detector was also used in combination with the beam telescope to identify the beam composition.

DAQ systems / 46

Development of a flexible SCADA system for test beam environments

Authors: Simon Spannagel[1]; Stephan Lachnit[1]

Co-authors: Annika Vauth [2]; Hanno Perrey [3]; Håkan Wennlöf [1]; Lene Kristian Bryngemark [4]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *Universität Hamburg*

[3] *Lund University*

[4] *Lund University (SE)*

Corresponding Authors: annika.vauth@uni-hamburg.de, h.wennlof@cern.ch, hanno.perrey@nuclear.lu.se, stephan.lachnit@cern.ch, lene.bryngemark@cern.ch, simon.spannagel@cern.ch

The qualification of new detectors in test beam environments presents a dynamic setting that demands the stable operation of diverse devices equipped with different Data Acquisition (DAQ) systems. This complexity necessitates a system capable of controlling the data taking, monitoring the experimental setup, facilitating seamless configuration, and easy integration of new devices.

These requirements closely parallel the demands of a Supervisory Control And Data Acquisition (SCADA) system. Collaborative efforts between DESY, DVel, Lund University, and the University of Hamburg have led to the exploration of SCADA system concepts tailored for laboratory and test beam environments, resulting in the development of a new framework named Constellation.

In this contribution, a first implementation of a satellite (an element of a constellation) will be showcased. The concepts of Constellation, its current status, and an overview of the project will be presented.

Test beam analysis / 47

CMS ETROC beam telescope with test beam results from CERN and DESY and initial integration with AIDA telescope

Author: Murtaza Safdari[1]

[1] *Fermi National Accelerator Lab. (US)*

Corresponding Author: murtaza.safdari@cern.ch

The Endcap Timing ReadOut Chip (ETROC) for the CMS MIP Timing Detector is designed to process signals from Low-Gain Avalanche Diodes (LGAD) with a time resolution of 40-50ps per hit. The ETROC2 is the first full size (16x16) prototype design and full functionality design, and in this talk we present the results from the CMS ETROC suitcase style beam telescope results at CERN and DESY to study the timing performance of the ETROC2 chips bump-bonded with 16x16 FBK and HPK LGAD sensors. The ETROC telescope is organized with a self-referential system composed of up to 4 layers/chips without the use of other detectors to study the timing performance. We also present the first successful demonstration of integration of the ETROC with the AIDA telescope platform, with successful beam data acquisition at DESY triggered by the AIDA TLU2 (trigger logic unit) in Dec 2023, with the ETROC chip operated synchronously with the AIDA telescope, paving the way to fully integrate ETROC into the AIDA telescope platform in the future.

Simulation / 48

Timing studies of MAPS in 65 nm imaging process

Authors: Adriana Simancas[1]; Anastasiia Velyka[1]; Christian Reckleben[1]; Daniil Rastorguev[1]; Finn Feindt[1]; Gianpiero Vignola[1]; Håkan Wennlöf[1]; Ingrid-Maria Gregor[2]; Judith Schlaadt[None]; Larissa Mendes[None]; Lennart Huth[1]; Manuel Alejandro Del Rio Viera[1]; Sara Ruiz Daza[1]; Simon Spannagel[1]; Walter Snoeys[3]; Yajun He[4]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *DESY & Bonn University*

[3] *CERN*

[4] *Deutsches Elektronen-Synchrotron DESY*

Corresponding Authors: lennart.huth@cern.ch, gianpiero.vignola@cern.ch, christian.reckleben@desy.de, ingrid.gregor@desy.de, larissa.mendes@desy.de, finn.feindt@desy.de, daniil.rastorguev@cern.ch, judith.schlaadt@desy.de, h.wennlof@cern.ch, manuel.alejandro.del.rio.viera@cern.ch, walter.snoeys@cern.ch, yajun.he@cern.ch, anastasiia.velyka@cern.ch, simon.spannagel@cern.ch, sara.ruiz.daza@desy.de, adriana.simancas@cern.ch

The goal of the TANGERINE project is to develop the next generation of monolithic silicon pixel detectors using a 65 nm CMOS imaging process, which offers a higher logic density and overall lower power consumption compared to currently utilized feature sizes.

The Analogue Pixel Test Structure (APTS) are sensors designed and developed by ALICE with readout boards developed by CERN EP R&D using a 65 nm imaging process to study the capabilities of this technology. In order to study the temporal development of charge collection, the sensor is tested at the DESY-II test beam facility. For each hit produced by an incident particle, the analogue signal output is recorded using an oscilloscope and analyzed offline, including information from the track reconstruction. The results of this analysis are compared with studies obtained through Technology Computer-Aided Design (TCAD) and Monte Carlo (MC) simulations. Through the use of generic doping profiles, the electric fields and electrostatic potentials are calculated with TCAD and imported into the Allpix Squared framework which allows high statistic and realistic simulations.

In this contribution, the sensor and setup, results obtained at the DESY-II Test Beam facility, laboratory characterization measurements using Fe-55 and a comparison with simulations will be presented

Poster session / 50

Quality Control for MuPix11 for the Mu3e Pixel Detector

Author: Lelia Fuchs[1]

[1] *Heidelberg University (DE)*

Corresponding Author: anna.lelia.maria.fuchs@cern.ch

The Mu3e experiment aims to observe charged lepton flavour violation in the form of the $\mu^+ \rightarrow e^+e^-e^+$ decay. The identification of the decay requires precise spatial and timing resolutions. This will be achieved using ultra-thin High-Voltage Monolithic Active Pixel Sensors (HV-MAPS). This technology combines readout electronics and active detector volume on one sensor, and can be thinned down to 50 µm. The Mu3e tracking detector will be composed of MuPix11 HV-MAPS at thicknesses of 50 µm and 70 µm. A quality control is essential to ensure the functionality of the sensors before installation.

The quality control procedure developed for the MuPix11 sensors evaluates essential functions such as HV biasing, powering, global configuration and data readout. For pre-production of the Mu3e vertex detector, the quality control is carried out on both 50 µm and 70 µm sensors. The testing output characteristic to a functional sensor is identified, and used to develop the testing and evaluation strategies. In addition, the tests are expanded for investigation of frequent failure modes, and improvements are made to reduce errors during testing and evaluation. The quality control yield and the failure profiles are presented for 50 µm and 70 µm MuPix11 sensors.

Facilities / 51

Studies on the Future DESY Test Beam Facility

Author: Sven Ackermann[1]

Co-authors: Marcel Stanitzki [2]; Ralf Diener ; Norbert Meyners [3]; Heiko Ehrlichmann

[1] *Deutsches Elektronen-Synchrotron (DESY)*

[2] *DESY*

[3] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: norbert.meyners@desy.de, marcel.stanitzki@desy.de, heiko.ehrlichmann@desy.de, ralf.diener@desy.de, sven.ackermann@desy.de

DESY operates the 3rd generation synchrotron radiation facility PETRA III. The DESY II booster is used to inject electrons into the PETRA storage ring either for the initial fill or top-up operation. When it is not used for these purposes, DESY II drives three target-based test beams exploiting the pair production principle. The next update of the PETRA storage ring will change the requirements for the injected beam significantly and will require different modes of operation.
In this contribution we present different upgrade plans for test beams at the existing synchrotron as well as at a new synchrotron that has been discussed in the scope of the PETRA IV project. The advantages and disadvantages will be evaluated and the results of initial studies will be shown.

Sensors / 52

Characterizing of MIMOSIS-1 CMOS Monolithic Active Pixel Sensor Using a 25 MeV Proton Beam at Cyrce

Authors: Abdelkader HIMMI[1]; Ali Murteza ALTINGUN[2]; Andrei Dorokhov[3]; Auguste Guillaume Besson[4]; Christian Joachim Schmidt[5]; Christian Peter Muntz[6]; Christine Guo Hu[4]; Claude Pierre Colledani[4]; Franz Matejcek[7]; Frederic Morel[4]; Grégory Bertolone[None]; Hasan Darwish[None]; Isabelle Valin[None]; Jan Michel[6]; Jerome Baudot[8]; Joachim Stroth[9]; Joshua Benedict Arnoldi-Meadows[6]; Julio Andary[10]; Kimmo Kalevi JAASKELAINEN[None]; Mathieu Goffe[4]; Matthieu Specht[2]; Michael Deveaux[5]; Michal Koziel[6]; Oliver Keller[11]; Roma Bugiel[4]; Szymon Bugiel[12]; Tabatha Dufour[None]; Thanh Hung PHAM[13]; Ziad El Bitar[4]

[1] *University of Strasbourg*

[2] *CNRS -Centre national de la recherche scientifique*

[3] *IPHC, Strasbourg*

[4] *Centre National de la Recherche Scientifique (FR)*

[5] *GSI - Helmholtzzentrum fur Schwerionenforschung GmbH (DE)*

[6] *Goethe University Frankfurt (DE)*

[7] *Goethe-Universität Frankfurt, Institut für Kernphysik*

[8] *IPHC - Strasbourg*

[9] *Goethe-University and GSI*

[10] *GSI*

[11] *GSI/FAIR*

[12] *CERN*

[13] *CNRS*

Corresponding Authors: ziad.el.bitar@cern.ch, baudot@in2p3.fr, franz.matejcek@stud.uni-frankfurt.de, andrei.dorokhov@iphc.cnrs joshua.benedict.arnoldi-meadows@cern.ch, christine.guo.hu@cern.ch, michael.deveaux@cern.ch, abdelkader.himmi@ires.in2p3.fr, j.stroth@gsi.de, isabelle.valin@iphc.cnrs.fr, ali-murteza.altingun@iphc.cnrs.fr, kimmo.jaaskelainen@iphc.cnrs.fr, szymon.bugiel@cern.ch, auguste.guillaume.besson@cern.ch, michal.koziel@cern.ch, frederic.morel@iphc.cnrs.fr, hung.pham@iphc.cnrs.f j.andary@gsi.de, mathieu.goffe@cern.ch, c.muentz@cern.ch, jan.michel@cern.ch, claude.pierre.colledani@cern.ch, matthieu.specht@iphc.cnrs.fr, c.j.schmidt@gsi.de, oliver.michael.keller@cern.ch, roma.dasgupta@cern.ch, tabatha.dufour@etu.unistra.fr, h.darwish@gsi.de, gregory.bertolone@iphc.cnrs.fr

MIMOSIS, a CMOS Monolithic Active Pixel Sensor (MAPS), is currently under development at the Institut Pluridisciplinaire Hubert Curien (IPHC), Strasbourg, and it will be integrated into the Micro Vertex Detector (MVD) of the upcoming FAIR/GSI experiment, Compressed Baryonic Matter (CBM). The primary objective of the MVD is to provide precise particle tracking in a high-density track environment. To achieve this, MIMOSIS aims to deliver a spatial resolution of approximately 5 μm, a time resolution of 5 μs, a maximum rate capability of around 80 MHz/cmˆ2, and radiation tolerance exceeding 10ˆ13 neq/cmˆ2 and 5 Mrad.

The first full-scale prototype sensor, MIMOSIS-1, underwent testing at the CYRCé cyclotron facility at IPHC, which delivers a proton beam with energies ranging from 16 to 25 MeV. In this presentation, we will discuss the test results of the MIMOSIS-1 using a 25 MeV proton beam, with intensities reaching up to 3 pA and beam sizes as small as 2 mm, achieved through the use of collimators. The performance of the sensor was investigated regarding cluster size, and irradiation hardness, and limitations in data bandwidth due to high intensities. Furthermore, we will demonstrate the suitability of the CYRCé platform for testing our sensors and ability of our sensor to be used for beam monitoring and characterization.

Calorimetry / 53

On-beam test for the LHC Phase-II CMS Electromagnetic PbWO4 calorimeter

Author: Giulia Lavizzari[1]

Co-author: On behalf of CMS (ECAL)

[1] *Università degli Studi e INFN Milano (IT)*

Corresponding Author: giulia.lavizzari@cern.ch

The High-Luminosity phase of the CERN Large Hadron Collider will pose new challenges for the detectors. The Electromagnetic Calorimeter (ECAL) of the CMS experiment will be equipped with a completely new readout electronics to cope with increase in the number of pp collisions per bunch crossing, as high as 200, and higher noise induced by radiation. Two on-beam vertical integration tests were performed at the CERN H4 facility using near-final components, installed in an ECAL Supermodule identical to the 36 Supermodules the barrel is made of. The data acquisition chain and the results of the test beam will be presented.

Infrastructure and software / 54

CLICdp Timepix3 Telescope: Improvements and Monitoring

Authors: Justus Braach[1]; Peter Svihra[2]

Co-authors: Dominik Dannheim [2]; Eric Buschmann [3]; Philipp Gadow [2]; Younes Otarid [2]

[1] *CERN, Hamburg University (DE)*

[2] *CERN*

[3] *Brookhaven National Laboratory (US)*

Corresponding Authors: peter.svihra@cern.ch, younes.otarid@cern.ch, paul.philipp.gadow@cern.ch, eric.buschmann@cern.ch, justus.braach@cern.ch, dominik.dannheim@cern.ch

This contribution reports on recent upgrades made to the CLICdp Timepix3 beam telescope installed in the H6 beam line of the CERN SPS test-beam facility. The focus is given to mechanical improvements and the establishment of an environmental monitoring system. Data from recent test-beam campaigns are used to demonstrate the achieved improvements both in data quality and with the operation of the setup.

The performed mechanical enhancements result in better control over the alignment of its planes and scintillators. To achieve better time resolution, microchannel plate photomultiplier tubes (MCP-PMTs) are being commissioned as part of the ongoing upgrades. All improvements are verified using reconstructed particle beams and using the Corryvreckan analysis framework.

An environment and data monitoring system based on Grafana and Raspberry Pis has also been established and tested. This system is designed to track conditions like data rates, temperature, and humidity, which can impact the telescope performance. Importantly, the design of this monitoring system allows for simple expansion to other parts of the infrastructure, such as High Voltage (HV) crates, demonstrating its versatility.

Sensors / 55

Impact of incidence angles on MuPix10 performance

Author: Annie Meneses Gonzalez[1]

[1] *Heidelberg University (DE)*

Corresponding Author: annie.meneses.gonzalez@cern.ch

High Voltage Monolithic Active Pixel Sensors (HV-MAPS) have emerged as a promising technology for silicon tracking detectors in particle physics. HV-MAPS, selected as the technology for the Mu3e Pixel Tracker and under investigation for potential implementation in future detector applications, offers good efficiency, position, and time resolution while keeping the material budget minimal. In many of these applications, particles may enter the sensor at different incidence angles. This variability influences the cluster size and the collected charge, depending on the in-pixel incidence position, sensor thickness, and the depth of the depletion zone. Therefore, studying their performance at different incidence angles can help determine their limitations and capabilities.

This talk presents sub-pixel results from DESY test beam rotation studies using MuPix10 sensors, one of the HV-MAPS prototypes developed for the Mu3e experiment, with different sensor thicknesses and resistivities. The study aimed to gain insights into the relationship between cluster size and efficiency under different thresholds and voltage configurations. Additionally, the findings of this research contribute to enhancing the understanding of the impact of diffusion and drift on sensor efficiency for the HV-MAPS technology.

Poster session / 56

TelePix2 - Fast Timing and Triggering With a Single Sensor

Author: Arianna Wintle[1]

Co-authors: Andre Schoening [2]; David Maximilian Immig [2]; Felix Sefkow [1]; Heiko Augustin [2]; Ivan Peric [3]; Lennart Huth [1]; Marcel Stanitzki [4]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *Heidelberg University (DE)*

[3] *KIT - Karlsruhe Institute of Technology (DE)*

[4] *DESY*

Corresponding Authors: marcel.stanitzki@desy.de, augustin.heiko@physi.uni-heidelberg.de, ivan.peric@kit.edu, immig@physi.uni-heidelberg.de, felix.sefkow@desy.de, arianna.wintle@desy.de, schoning@mail.desy.de, lennart.huth@cern.ch

The DESY II Test Beam facility offers electron beams with a user selectable momentum from 1-6 GeV, typically used for detector and sensor characterisation. The facility offers beam telescopes as precise reference tracking systems. These provide a very high spatial resolution. However, their readout time is long relative to the rate of incident electrons. This frequently results in more than one electron crossing the system within a single readout frame. Without an additional segmented timing layer, it becomes impossible to assign tracks to specific triggers.

Devices Under Test (DUTs) of varying sizes are characterised at the DESY II Test Beam facility. A size discrepancy between the trigger and the DUT leads to inefficient data taking by recording events where the electron has not intersected the DUT. To overcome this, a configurable region of interest trigger is needed.

TelePix2 is a High Voltage Monolithic Active Pixel Sensor (HV-MAPS); it provides both fast timing with a timestamp of 4 ns and a fast trigger output with a configurable region of interest. Here, characterisation results of TelePix2 are presented based on the latest test beam measurements. A time resolution for the timestamp below 5 ns was found across the full sensor at an efficiency above 99%. The time resolution of the trigger output from TelePix is below 2 ns. With these positive characterisation results and first successful runs with test users, TelePix2 is close to becoming part of the regular user infrastructure at the DESY test beam facility.

Poster session / **57**

Particle Physics Test-beam Facility at the Scottish Centre for the Application of Plasma-based Accelerators (SCAPA)

Author: Dino Jaroszynski[None]

Co-authors: Dima Maneuski [1]; Mark Richard James Williams [2]; Richard Bates [1]

[1] *University of Glasgow (GB)*

[2] *The University of Edinburgh (GB)*

Corresponding Authors: dzmitry.maneuski@cern.ch, richard.bates@glasgow.ac.uk, dino@phys.strath.ac.uk, mark.williams@cern.ch

Particle physics requires new detector technologies for experiments beyond the HL-LHC. This relies on access to facilities for irradiation and characterisation in detector development. A key characterisation facility is provision of a GeV particles (electrons/pions) test-beam passed through a telescope to measure key performance metrics of detectors (such as detection efficiency, spatial and timing resolutions). Such facilities exist at a handful of international laboratories and access to these is often oversubscribed (CERN, DESY and SLAC). In this work we propose the development of a pilot beamline and test-beam telescope at the Scottish Centre for the Application of Plasma-based Accelerators (SCAPA) at Strathclyde University. We propose to produce a working 2 GeV electron beamline based on a laser-driven accelerator for use by the particle and nuclear physics communities, which would accelerate detector development for future experiments, and enable the development of a design for a second phase beamline at higher energies (4 GeV) and higher repetition rates (10 Hz). The project will also develop an ultra-low mass beam telescope with picosecond timing resolution, usable with the 2 GeV beams. Monolithic CMOS and back thinned TimePix4 detector planes will be investigated for the beam telescope. Here we will discuss the proposed facility, its advantages and limitations, and beam telescope options to gauge interest from the community.

Infrastructure and software / **58**

Development of versatile online monitoring for EUDAQ2

Authors: Andreas Loeschcke Centeno[1]; Lennart Huth[2]

Co-author: Fabrizio Salvatore [1]

[1] *University of Sussex (GB)*

[2] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: lennart.huth@cern.ch, p.f.salvatore@sussex.ac.uk, andreas.loeschcke.centeno@cern.ch

During test beam data taking, being able to monitor the quality of the incoming data in real time is of crucial importance. Hence, many test beam users implement their own monitoring tools tailored to their needs. One goal of the AIDAinnova project is to develop common test beam infrastructure, including a versatile online monitoring tool capable of reading any data recorded by EUDAQ2, such that a wide user range can profit from this tool. Some of the limitations existing monitoring tools experience are the lack of flexible event building and no opportunity to do track reconstruction from beam telescope data.
To adress these issues and exploit existing synergies with EUDAQ2, the widely used test beam data reconstruction and analysis software 'corryvreckan' is used as base for the monitoring tool. In this presentation we describe the integration into EUDAQ2 in such a way that minimal user input is required.
We present the latest status of development and release of this software. We also showcase setups in which this monitoring has been used successfully in a test beam scenario, such as monitoring of silicon photomultipliers during a test beam of the dual-readout calorimetry group at the SPS at CERN.

Poster session / 59

Tracking studies with cosmic rays using the ATLAS ITk end-cap system test

Authors: Jan-Hendrik Arling[1]; Maximilian Caspar[2]

Co-author: ITk Strips End-Cap System Test community

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *DESY*

Corresponding Author: jan-hendrik.arling@cern.ch

The new ATLAS Inner Tracker (ITk) detector is an all-silicon tracking detector replacing the currently installed Inner Detector (ID) for the high-luminosity phase of the LHC. The ITk detector design foresees a pixel and a strip sub-detector, both of which are subdivided into a barrel and end-cap sections. Focusing on the strip end-cap sections, the silicon microstrip sensors use a radial strip geometry that resembles a polar coordinate system and features an already defined stereo angle in the design. Detector modules, consisting of the active sensor, plus the directly glued on readout and power electronics, are grouped on larger local support structures, called petals. These are again arranged in discs out of which six of these are forming one end-cap in the global structure with a total number of 196 petals.
To demonstrate the full detector concept, the ITk strip detector collaboration is pursuing full system tests for the barrel and end-cap parts. Here, the latter is commissioned at DESY Hamburg and consists of a slice of the full detector structure which can be populated with up to 12 petals. Among several planned electrical characterisation measurements, it is also envisioned to take cosmic ray data with this setup to verify tracking and overall detector performance.
For this purpose, the end-cap system test is simulated within the simulation framework Allpix2 and tracking studies are performed within the track reconstruction framework Corryvreckan. As a first step, the implementation of the radial strip geometry was consolidated and the new feature of generating cosmic rays in the simulation was implemented. With this, first studies of the expected tracking performance of the system tests in various configurations were performed and will be compared to experimental test results in the actual lab setup.

Sensors / 60

Picosec: optimization of a fast timing detector for its application at a future muon collider experiment

Authors: Chiara Aime'[1]; Cristina Riccardi[1]; Ilaria Vai[1]; Matteo Brunoldi[1]; Paola Salvini[1]; Paolo Vitulo[1]; Simone Calzaferri[2]

[1] *Pavia University and INFN (IT)*

[2] *Università degli studi di Pavia - INFN Pavia*

Corresponding Authors: matteo.brunoldi01@universitadipavia.it, ilaria.vai@cern.ch, simone.calzaferri01@universitadipavia.it, paola.salvini@cern.ch, paolo.vitulo@cern.ch, cristina.riccardi@cern.ch, chiara.aime'@cern.ch

The Micropattern Gaseous Detectors (MPGDs) boast excellent spatial resolution performance. However, they typically exhibit modest time resolution due to fluctuations in the position where ionization occurs within the gas. Picosec addresses this issue by operating based on the amplification, via a Micromegas, of electrons generated by the conversion of Cherenkov light produced from an incident particle on a radiator crystal. Picosec achieves resolutions on the order of tens of picoseconds in this manner. The ongoing study aims at optimizing this technology for its application in future experiments at the Muon Collider. This optimization involves evaluating performance using different radiators, various photocathodes, and new-generation gas mixtures that also have a reduced environmental impact. Additionally, the study will outline future prospects, particularly focusing on the scalability of this technology.

DAQ systems / 61

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

Author: Stergios Kazakos[1]

Co-author: Augusto Santiago Cerqueira [2]

[1] *Michigan State University (US)*

[2] *Federal University of Juiz de Fora (BR)*

Corresponding Authors: stergios.kazakos@cern.ch, augusto.santiago.cerqueira@cern.ch

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 aging of the current electronics. It has to handle longer latencies of up to 35 µs at such high pileup levels. The upgrade TileCal electronics have been tested during test beam campaigns from the Super Proton Synchrotron (SPS) accelerator at CERN. Data were collected in 2015-2018 and 2021-2023, with beams of muons, electrons and hadrons at various incident energies and impact angles. 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.

Test beam analysis / 62

Beam tests for the PIONEER experiment

Author: Stefan Hochrein[None]

Co-author: Jennifer Ott [1]

[1] *University of California,Santa Cruz (US)*

Corresponding Authors: shochrein@student.ethz.ch, jeott@ucsc.edu

PIONEER is a next-generation experiment proposed at the Paul Scherrer Institute to perform high precision measurements of rare pion decays. By improving the precision on the charged-pion branching ratio to electrons vs. muons and the pion beta decay by an order of magnitude, PIONEER will provide a pristine test of Lepton Flavour Universality and the Cabibbo angle anomaly. In addition, various exotic rare decays involving sterile neutrinos and axions will be searched for with unprecedented sensitivity.
The experiment design benefits from experience with the PIENU and PEN experiments at TRIUMF and at PSI. Excellent energy and time resolutions, greatly increased calorimeter depth, high-speed detector and electronics response, large solid angle coverage, and complete event reconstruction are all critical aspects of the approach.
In the PIONEER experiment design, an intense pion beam is stopped in a segmented, instrumented (active) target (ATAR). The proposed technology for the ATAR is based on low-gain avalanche detectors (LGADs), which can provide precise spatial and temporal resolution for particle tracks and thus separate even very closely spaced decays and decay products. The proposed detector will also include a ˜2π sr, 25-X0 (radiation length) electromagnetic calorimeter. Two alternative designs for the calorimeter - liquid Xe or LYSO:Ce crystal scintillators - are being explored. An additional cylindrical tracker surrounding the ATAR, based on micro-patterned gas detector technology (μ-RWELL), may be used to link the locations of pions stopping in the target to showers in the calorimeter.
This contribution will present results from several beam test campaigns aimed at the investigation of different aspects of the experiment setup: simulation and beam diagnostics of the PSI PiE5 charged pion beamline including temporal and energy distribution of π^+, μ^+ and e^+ with a segmented scintillator + SiPM readout; response of silicon AC-LGAD sensors at the same beamline; tests of gain suppression for highly ionizing particles at the University of Washington CENPA Tandem accelerator; characterization of LYSO crystal calorimeter prototypes, as well as trigger and digitization systems at the PSI PiM1 beamline. The near-future plans for further test beam data analysis and next beam test studies will be outlined.

Sensors / 63

Performance studies of AC coupled Low Gain Avalanche Pixel Detectors at Diamond Light Source

Author: Neil Moffat[1]

[1] *Consejo Superior de Investigaciones Cientificas (CSIC) (ES)*

Corresponding Author: neil.moffat@cern.ch

This work presents significant strides in the fabrication and characterization of LGAD devices, specifically leveraging the innovative AC-Coupled LGAD (AC-LGAD) technology. Building on the expertise gained in controlling the LGAD fabrication process at CNM, our focus has shifted towards highly segmented devices with improved features, including a 100% fill factor and enhanced uniform gain across pixels when compared to standard LGAD architecture, specifically for applications the Medipix family of readout ASICs.

To thoroughly understand and evaluate the inter-pixel response of these devices, a highly collimated monochromatic X-ray beam at Diamond Light Source (B16) with an energy of 15 keV was employed. Comprehensive 2D scans were performed, allowing for an in-depth study of pixel response in relation to beam position and, consequently, the calculation of spatial resolution.

The results reveal a spatial resolution of approximately 10 μm, a finding consistent with simulations. A simulation model was developed to predict spatial resolution as a function of gain (SNR), providing a valuable tool for anticipating device performance under varying conditions.

This work signifies a comprehensive approach to LGAD technology, encompassing fabrication, characterization utilizing advanced X-ray techniques, and predictive simulation modelling. The achieved

spatial resolution, validated by simulation results, underscores the effectiveness of the AC-LGAD technology and its potential impact on high-performance detector applications.

BL4S / 66

Team Particular Perspective - Measuring The Particle Composition of the T10 Beamline

Authors: Abdul Wahab Akram[None]; Muhammad Abdullah Masood[None]; Muhammad Asadohoo Abdali[None]; Muhammad Hasnain Haider[None]; Muhammad Mansoor Afzal Maitla[None]; Muhammad Saad Bilal[None]; Muhammad Salman Tarar[None]; Muhammad Zohaib Abbas[None]; Wasif Ahmed[None]

Co-authors: Berare Gokturk [1]; Martin Schwinzerl [2]

[1] *Bogazici University (TR)*

[2] *CERN*

Corresponding Author: muhammadzohaibabbas53@gmail.com

This presentation describes the measurement of the beam composition in one of the experimental halls of CERN, the East Hall. This study was conducted in Autumn 2023 as part of being one of the three winning teams globally for the CERN Beamline For Schools. We have designed an experimental setup using different particle detectors to measure the rate, position, particles, and energy of the particle beam. We've collected data at 12 different momentum values, employing both positive and negative polarity beams. Our goal is to measure the number of protons, electrons, kaons, pions, muons, as well as trace amounts of antiparticles such as deutrons. We achieve this by analysing datasets obtained from the particle detectors and implementing data analysis, simulation, and theoretical measures to assist our experiment. Lastly, we present our results with statistical distributions of the composition of the beam.

Experiments / 67

A Silicon Pixel Tracker for Future μSR Experiments

Authors: Lukas Mandok[1]; Lukas Mandok[2]

[1] *Heidelberg University (DE)*

[2] *University of Heidelberg*

Corresponding Authors: lukas.mandok@cern.ch, mandok@physi.uni-heidelberg.de

Muon spin rotation (μSR) is a long existing baseline technique in condensed matter research, facilitating the exploration of magnetic and superconducting phenomena. Traditional reliance on scintillator-based detectors, limited in rate and spatial resolution, hinders the investigation of novel quantum materials. The use of ultra-thin silicon pixel sensors for precise track reconstruction has the potential to revolutionize μSR spectrometry.
A first prototype of a silicon-based μSR spectrometer has been constructed, using a telescope setup with four layers of quad modules made from MuPix11 sensors and a central μSR sample. Initial studies were conducted at a polarized muon beamline at PSI.
The testbeam analysis framework Corryvreckan is used to efficiently track the incoming muons and emitted decay positrons.
First results demonstrate muon spin precession measurements comparable to traditional methods, while eliminating accidental background and enabling resolution of details on a 1 mm scale on the sample.
This technology shows great potential for efficient, high-rate investigations of multi

Facilities / 68

A New Test Beamline at Photon Factory Advanced Ring (PF-AR) in KEK

Authors: Isamu Nakamura[1]; Shoji Uno[2]

[1] *Department of Physics*

[2] *KEK*

Corresponding Authors: shoji.uno@kek.jp, isamu.nakamura@kek.jp

KEK has constructed a new test beamline at Photon Factory Advanced Ring (PF-AR). The electron accelerator ring has been used for PF users for a long time. Recently, carbon targets are installed to extract high energy electrons and to build the test beam line for particle and nuclear physicists. The top-up injection is performed for the accelerator ring. Therefore, electrons are continuously extracted without any bunch structures for 24 hours. The present beam rate is 1 kHz order and further improvement is expected. The user operation started just one year ago. KEK accepted around 20 proposals for 3 periods (5 months in total) so far. Some proposals are educational ones. In the workshop, the features of the beamline are introduced and some obtained results in test experiments are presented.

Experiments / 69

LHCb RICH test beam campaigns for future upgrades

Authors: Constantinos Vrahas[1]; Federica Oliva[1]

[1] *The University of Edinburgh (GB)*

Corresponding Authors: federica.oliva@cern.ch, s1621622@sms.ed.ac.uk

The LHCb experiment is one of the four large detectors at the Large Hadron Collider (LHC) at CERN, performing searches for new physics through studies of CP-violation and rare decays of heavy-flavour hadrons. The RICH (Ring Imaging Cherenkov) sub-detectors assume a critical role in particle identification. At present, intensive test beam campaigns, lead by the RICH group, are actively underway to assess the efficacy of prototypes designed for forthcoming Upgrades.
Upgrade Ib is primarily oriented towards the incorporation of timestamps to Cherenkov photons, aiming to enhance temporal precision. Simultaneously, Upgrade II is dedicated to the exploration of alternative photon detectors. The experimental setup at CERN SPS will be detailed, with a specific emphasis on one of the leading candidates for the role of a photon detector, the Large Area Picosecond Photon Detector (LAPPD), supplied by INCOM (US).

Facilities / 70

Future instrumentation upgrades at the Fermilab Test Beam Facility and Irradiation Test Area

Author: Nathaniel Joseph Pastika[1]

[1] *Fermi National Accelerator Lab. (US)*

Corresponding Author: nathaniel.joseph.pastika@cern.ch

Fermilab plays host to the Fermilab Test Beam Facility(FTBF) and the Irradiation Test Area (ITA). The FTBF is one of the highest energy facilities in the world which is dedicated to helping experimenters develop, test, and calibrate particle detectors. The Fermilab accelerator complex delivers a 120 GeV primary proton beam and secondary/tertiary beams of varying momenta and particle content. The ITA provides access to high intensity (up to 2.7e15/hr) 400 MeV protons directly from the FNAL linac. FTBF and ITA provide beamline instrumentation, sources, ancillary equipment, and technical support needed to run successful experiments. This talk will cover the basics of the FTBF and ITA facilities with an emphasis on the status and plans for upgrades to the facility instrumentation.

BL4S / 71

Team Wire Wizards - Wire chambers prototyping

Author: Leon Se[None]

Co-author: Antoine Laudrain [1]

[1] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: quedst24@gmail.com, antoine.laudrain@cern.ch

As part of the Beamline for Schools competition, we have created our own of wire chambers design and built five prototypes that we tested at the DESY-II testbeam facility. The chambers are designed such that they can be built with tools typically found in maker labs and use widely available materials.
Our detector consisted of two pairs of chambers with each plane in rotated by 90 degrees, thus providing two points in space and allowing for visualisation of particle tracks. We tested the chambers with various gases and high-voltage to characterise their operating point. The supporting team at DESY provided us with the data-acquisition system and helped us writing a data analysis in python.
Our final goal is to publish the design in open-source, with a simplified data-acquisition system that can cope with lower rates (for example from cosmics).
In this talk, we will explain the design process of the chambers and show the results of their tests at the DESY-II testbeam.

Hands-on tutorials / 72

The Corryvreckan Test-Beam Reconstruction Framework — Hands-on

Author: Finn Feindt[1]

Co-authors: Naomi Afiriyie Davis [2]; Sara Ruiz Daza [2]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *DESY*

Corresponding Authors: ruizdaza@mail.desy.de, finn.feindt@desy.de, naomi.davis@desy.de

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 hit 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.

Hands-on tutorials / 73

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

Authors: Daniil Rastorguev[None]; Håkan Wennlöf[1]; Manuel Alejandro Del Rio Viera[1]; Stephan Lachnit[1]

[1] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Authors: daniil.rastorguev@desy.de, h.wennlof@cern.ch, manuel.alejandro.del.rio.viera@cern.ch, stephan.lachnit@cern.ch

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. There will also be the possibility of asking questions and discussing the framework.
Some prior knowledge of Allpix Squared 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://allpix-squared.docs.cern.ch/) and GitLab (https://gitlab.cern.ch/allpix-squared/allpix-squared)

BL4S / 74

Introduction to the BL4S competition

Authors: Antoine Laudrain[1]; Berare Gokturk[2]; Martin Schwinzerl[3]; Sarah Zoechling[3]

Co-authors: Marcel Stanitzki [4]; Markus Joos [3]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *Bogazici University (TR)*

[3] *CERN*

[4] *DESY*

Corresponding Author: sarah.zoechling@cern.ch

Lectures / 75

Physics Opportunities and Challenges at Future Multi-TeV Muon Collider

Author: Donatella Lucchesi[1]

[1] *Universita e INFN, Padova (IT)*

Corresponding Author: donatella.lucchesi@cern.ch

A multi-TeV muon collider represents an extraordinary opportunity for groundbreaking discoveries and precise Standard Model measurements. By colliding muons, the entire center-of-mass energy becomes available for high-energy reactions, allowing for the exploration of extremely short length scales. Additionally, multi-TeV muons have a high probability of emitting electroweak radiation, effectively transforming the muon collider into a vector boson collider and opening new path for studying electroweak physics.
However, muons being unstable particles, present several significant challenges for both the accelerator and the detector. Protective measures are necessary to shield both of them from the high fluxes of particles generated by muon decay products interacting with infrastructure components. Furthermore, the development of a new method for beam cooling is essential since traditional techniques are designed for use with stable particles. An extensive R&D program has been defined to address these technological challenges.
The lecture will offer insights into the primary physics potentials alongside the associated experimental challenges, and it will provide an overview of the status of the collider facility.

Lectures / **76**

An in-vivo monitoring system for ion-beam radiotherapy based on tracking of charged nuclear fragments with 28 Timepix3 detectors

Corresponding Author: laurent.kelleter@dkfz-heidelberg.de

Cancer is a leading cause of death worldwide, with about 10 million fatalities every year. A large fraction of cancer patients receives radiotherapy in the course of their treatment, of which the vast majority is treated with X-rays. Ion-beam radiotherapy offers steeper dose gradients and a higher biological effectiveness (ability to neutralise cancerous cells) compared with conventional X-ray radiotherapy. In order to improve the general effectiveness of radiotherapy, the treatment is split into fractions which are administered daily over several weeks. However, variations in the daily patient setup as well as potential anatomical changes over the treatment course have a greater impact on the quality of ion beams than X-rays, because of their steep dose gradients. It is therefore highly desirable to develop a feedback system that monitors the dose distribution in-vivo (i.e. in the patient) without applying additional dose and with minimal time and resource cost. Secondary radiation escaping the patient during therapy could form the basis of such a monitoring system.
At the German Cancer Research Centre in Heidelberg, we developed a monitoring system based on 28 hybrid silicon pixel detectors (Timepix3) to harvest the information carried by the nuclear fragments that are produced when the ion beam disintegrates into lighter ions. The system was characterised in extensive test beams with patient models as well as in Monte Carlo simulations. By comparing the detected fragment tracks of consecutive treatment fractions, the system was shown to be capable of detecting and locating anatomical changes and thus measure changes in the in-vivo dose distribution. Encouraged by these results, the monitoring system is now being used in the in-vivo-monitoring (InViMo) clinical trial with head-and-neck cancer patients at the Heidelberg Ion Beam Therapy Centre. In this contribution I will present preliminary results of the first patient cohort monitored with the novel system.

Lectures / **77**

Introduction to TDAQ and its scaling principles

Corresponding Author: francesca.pastore@cern.ch

This lecture is an introduction to the Trigger and DAQ (TDAQ) systems for small and medium HEP experiments. After introducing the main role of TDAQ and its requirements, it goes through the basic TDAQ concepts, like digitisation, latency, deadtime, busy logic and derandomization. Each component of the TDAQ framework is described with the corresponding technology choices, following the scaling from small to medium scale systems, spotting any bottle-neck and proposing possible evolution.

Welcome and closing / 78

Welcome from university host

Corresponding Author: c.leonidopoulos@cern.ch

Welcome and closing / 79

Welcome from IAC

Author: Younes Otarid[1]

[1] *CERN*

Corresponding Author: younes.otarid@cern.ch

Welcome and closing / 80

Welcome from LOC

Corresponding Author: federica.oliva@cern.ch

Welcome and closing / 81

Tutorial introduction

Author: Peter Svihra[1]

[1] *CERN*

Corresponding Author: peter.svihra@cern.ch

Lectures / 83

Neutrino Beams

Corresponding Author: johannes.bernhard@cern.ch

Neutrinos are the only particles that easily elude the Standard Model description. Due to their non-zero mass, effects like neutrino oscillations have been observed, which are clear indicators of Beyond Standard Model physics. With so many unknowns, accelerator neutrino beams offer a clean testbed for experiments that would like to further understand the underlying physics. We will shortly introduce neutrinos and their characteristics, talk about experimental techniques on neutrino detection, then look at the concept of neutrino beams with some examples, and finally, via a short deviation to the CERN test beam facilities for neutrino detector R&D, go to the latest developments on monitored and tagged neutrino beams.

Welcome and closing / 84

Global testbeam & irradiation schedule

Authors: Eva Barbara Holzer[1]; Ralf Diener[None]

[1] *CERN*

Corresponding Authors: ralf.diener@desy.de, barbara.holzer@cern.ch

85

Workshop photo

Welcome and closing / 86

Closing

Corresponding Author: paul.schuetze@desy.de