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Book of Abstracts

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3D integration

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A New Generation of Detectors for Future Neutron Science Instrumentation

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A New Generation of Detectors for Future Neutron Science Instrumentation

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Neutron scattering science - the study of materials using neutrons - is in an exciting period, with new large facilities under construction in China (Chinese Spallation Neutron Source), the US (second target station at the Spallation Neutron Source) and Europe (European Spallation Source). Additionally, large upgrades in the numbers of instruments are planned at major facilities in the US, Japan, Russia and Europe. These upgrades create a much greater demand for detectors in terms of numbers of instruments and their solid angle coverage in the coming decade than in the previous one. Additionally, the requirements of a new generation of instrumentation naturally pushes the boundaries of state-of-the-art in terms of performance. Previous generations of performant neutron detectors used the Helium-3 isotope as the material sensitive to neutrons; however, since 2009, the supply of Helium-3 is increasingly rare and the prices have risen considerably- the so-called “Helium-3 Crisis”.

Along with other disciplines reliant upon Helium-3 gas, the neutron scattering community has devoted significant effort into detector development. The aim was to mitigate the usage and demand for Helium-3 by developing replacement technologies, but also to match the challenging performance requirements for the new generation of instruments with creative technical solutions. This talk presents an overview of the status and outlook of these developments, and the performance of this new generation of neutron detectors for large scale facilities, with particular emphasis on the developments for the European Spallation Source. A perspective towards high resolution, high rate devices is given.

Current detectors: operational experience / 3

ALICE ITS: the Run 1 to Run 2 transition and recent operational experience

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ALICE ITS: the Run1 to Run2 transition and recent operational experience

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The characterization of the Quark-Gluon Plasma (QGP) produced during ultra-relativistic heavy-ion collisions is the main goal of the ALICE experiment at the CERN LHC. The ALICE Inner Tracking System (ITS) plays a key role in the study of the short-living hadrons through the primary and secondary vertex reconstruction. It consists of six cylindrical layers of silicon detectors based on three different technologies: two innermost layers of pixel detectors, two middle layers of drift detectors and two outermost layers of strip detectors. It covers the central pseudo- rapidity range of $|\eta|<0.9$ and the distance from the beam line ranges from 3.9 cm of the innermost layer to 43 cm of the outermost layer. During the Run1 data tacking the ITS has provided ALICE with tracking and charged particle identification capabilities, as well as a contribution to the definition of the Level0 trigger signal. In particular at low pT the event reconstruction relies on the ITS performance as tracks do not reach the outer tracking detectors. In this contribution, after a brief description of the features of three sub-detector systems and the respective performances during Run 1, the consolidation activities carried out during the long shutdown period (LS1) and the re-commissioning to prepare the detector for the data taking during Run 2 will be presented.

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AMS Tracking

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AMS-02 is a high precision magnetic spectrometer for cosmic rays in the GeV to TeV energy range. Its tracker consists of nine layers of double-sided silicon microstrip sensors. They are used to locate the trajectories of cosmic rays in the 0.14 T field of a cylindrical magnet, thus measuring their rigidity and charge sign. In addition, they deliver a high resolution measurement of the absolute charge |Z|. The detector has been designed to operate in space with a position resolution of about 10 μm for each hit and charge identification capabilities up to Z=26. In this talk I describe the performance in orbit of this detector component and its impact on the overall performance of the spectrometer.

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AMS tracking

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Vertexing and Tracking Methods / 35

ATLAS FTK: Fast Track Trigger

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ATLAS FTK: Fast Track Trigger

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An overview of the ATLAS Fast Tracker processor is presented, reporting the design of the system, its expected performance, and the integration status. The next LHC runs, with a significant increase in instantaneous luminosity, will provide a big challenge to the trigger and data acquisition systems of all the experiments. An intensive use of the tracking information at the trigger level will be important to keep high efficiency in interesting events, despite the increase in multiple p-p collisions per bunch crossing (pile-up). In order to increase the use of tracks within the High Level Trigger (HLT), the ATLAS experiment planned the installation of an
hardware processor dedicated to tracking: the Fast TracKer (FTK) processor. The FTK is designed to perform full scan track reconstruction at every Level-1 accept. To achieve this goal, the FTK uses a fully parallel architecture, with algorithms designed to exploit the computing power of custom VLSI chips, the Associative Memory, as well as modern FPGAs. The FTK processor will provide enough computing power to reconstruct tracks with $p_T > 1$ GeV in the whole tracking volume. The tracks will be available at the beginning of all the trigger selections, allowing to develop new more pileup resilient strategies. The FTK system will be installed in 7 racks of high density electronics, with about 8000 AM chips and 2000 FPGAs, providing full tracking with an event rate of up to 100 KHz and an average latency of 100 μs. Preliminary studies on tracking and trigger performance will be presented, showing the overall tracking performance and the potential benefits in the selection of τ, b-jets, and primary vertex determination. The status of the final hardware prototypes and the installation schedule will be presented, as well as the possible evolutions for the HL-LHC.

Current detectors: operational experience / 0

ATLAS inner detector: the Run 1 to Run 2 transition, and first experience from Run 2

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ATLAS inner detector: the Run 1 to Run 2 transition, and first experience of Run 2

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The ATLAS experiment is equipped with a tracking system, the Inner Detector, built using different technologies, silicon planar sensors (pixel and micro-strip) and gaseous drift- tubes, all embedded in a 2T solenoidal magnetic field. For the LHC Run II, the system has been upgraded; taking advantage of the long showdown, the Pixel Detector was extracted from the experiment and brought to surface, to equip it with new service quarter panels, to repair modules and to ease installation of the Insertable B-Layer (IBL), a fourth layer of pixel detectors, installed in May 2014 between the existing Pixel Detector and a new smaller radius beam-pipe at a radius of 3.3 cm from the beam axis. To cope with the high radiation and pixel occupancy due to the proximity to the interaction point and the increase of Luminosity that LHC will face in Run-2, a new read-out chip within CMOS 130nm and two different silicon sensor pixel technologies (planar and 3D) have been developed. SCT and TRT systems consolidation was also carried out during long shutdown in 2013-2014. The DAQ system was expanded to cope with L1 trigger of 100 KHz at high pileup, new TXs were installed, the cooling system was refurbished. An overview of the refurbishing of the Inner Detector and of the IBL project as well as early performance tests using cosmic and beam data will be presented.

Detectors in preparation I / 4

ATLAS pixel upgrade for the HL-LHC

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ATLAS pixel upgrade for the HL-LHC

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From 2024, the HL-LHC will provide unprecedented pp luminosities to ATLAS, resulting in an additional integrated luminosity of around 2500 fb-1 over ten years. This will present a unique opportunity to substantially extend the mass reach in searches for many signatures of new physics, in several cases well into the multi-TeV region, and to significantly extend the study of the properties of the Higgs boson. The increased luminosity and the accumulated radiation damage will render the current Inner Tracker no longer suitable for long term operations. It will need to be replaced with a new all silicon tracker to maintain tracking performance in the high occupancy environment and to cope with the increase of approximately a factor of ten in the total radiation fluence. New technologies are used to ensure that the system can survive this harsh radiation environment and to optimise the material distribution. Present ideas and solutions for the pixel detector will be discussed in this talk.

Detectors in preparation I / 8

ATLAS strip detector upgrade for the HL-LHC

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ATLAS strip detector upgrade for the HL-LHC

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From 2024, the HL-LHC will provide unprecedented pp luminosities to ATLAS, resulting in an additional integrated luminosity of around 2500 fb-1 over ten years. To withstand the much harsher radiation and occupancy conditions of the HL-LHC necessitates a complete replacement of the present ID. The new all-silicon tracker design is driven by the performance requirements that cannot be met by the present ID. The sensors are of finer granularity than the existing tracker, to meet the challenges of very high pile-up and to be able to reconstruct tracks in the core of multi- TeV jets. In addition, the replacement tracker has to be much more radiation hard and the readout links need to provide much greater bandwidth. Present ideas and solutions for the strip detector and current R&D program will be discussed in this talk.

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Advanced TCT Techniques

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Transient Current Technique with a narrow laser beam impinging perpendicularly to the detector edge (Edge-TCT) is a powerful method for investigating properties of silicon detectors. It produces localized ionization in the detector volume. IR light (λ = 1064 nm) has a long penetration depth in silicon and charge carriers are released along the beam path. Drift of electrons and holes can be studied by observing induced current with wide bandwidth amplifier. Initial rise of signal probes the electric field, while the integral of the signal measures collection of charge carriers generated at known depth of the detector.. Results obtained with nonirradiated and irradiated strip detectors and with a laser beam directed perpendicular and parallel to the strips will be presented. Measurements with CMOS sensors will also be reported.

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Advanced TCT techniques

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R&D and Detector Applications II / 40

Alignment of the ATLAS Inner Detector Upgraded for the LHC Run II

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Alignment of the ATLAS Inner Detector Upgraded for the LHC Run II

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ATLAS is a multipurpose experiment at the LHC proton-proton collider. Its physics goals require high resolution, unbiased measurement of all charged particle kinematic parameters. These critically depend on the layout and performance of the tracking system, notably quality of its offline alignment. ATLAS is equipped with a tracking system built using different technologies, silicon planar sensors (pixel and micro-strip) and gaseous drift- tubes, all embedded in a 2T solenoidal magnetic field. For the LHC Run II, the system has been upgraded with the installation of a new pixel layer, the Insertable B-layer (IBL). Offline track alignment of the ATLAS tracking system has to deal with about 700,000 degrees of freedom (DoF) defining its geometrical parameters. The task requires using very large data sets and represents a considerable numerical challenge in terms of both CPU time and precision. The adopted strategy uses a hierarchical approach to alignment, combining local and global least squares techniques. An outline of the track based alignment approach and its implementation within the ATLAS software will be presented. Special attention will be paid to integration to the alignment framework of the IBL, which plays the key role in precise reconstruction of the collider luminous region, interaction vertices and identification of long-lived heavy flavor states. Techniques allowing to pinpoint and eliminate tracking systematics due to alignment as well as strategies to deal with time-dependent variations will be briefly covered. The first results from Cosmic Ray commissioning runs and status from proton-proton collision in LHC Run II will be discussed.

Non-HEP applications / 33

Antimatter annihilation detection with AEGIS using siilicon detectors

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Antimatter annihilation detection with AEGIS using silicon detectors

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AEgIS
(Antimatter
Experiment:
Gravity,

Interferometry, Spectroscopy) is an antimatter experiment based at CERN, whose primary goal is to carry out the first direct measurement of the Earth's gravitational acceleration on antimatter. AEgIS will attempt to measure the gravitational acceleration for antihydrogen with 1% relative precision, which would be the first precision test of the Weak Equivalence Principle for antimatter. The principle of the experiment is based on the formation of antihydrogen through a charge exchange reaction between laser excited (Rydberg) positronium and cold (100 mK) antiprotons. The antihydrogen atoms will be accelerated by an inhomogeneous electric field (Stark acceleration) to form a pulsed cold beam. The free fall of the antihydrogen due to Earth's gravity will be measured using a moiré deflectometer and a hybrid position detector. This detector will consist of an active silicon part, where the annihilation of antihydrogen takes place, followed by an emulsion part coupled to a fiber time--of--flight detector. This overview presents the current results from the R&D efforts for the construction of the silicon position detector. Low energy antiproton annihilations in silicon were studied in detail using different silicon sensor technologies. A first comparison between experimental data and Monte Carlo simulations for low energy antiproton annihilation is also reported, suggesting areas where the improvement of simulation models is possible. The outcome of these tests defined the basis for the final design parameters of the silicon position detector. This detector will consist of a 50 µm thick silicon strip sensor bonded to an application specific integrated circuit (ASIC) with self-triggering readout capabilities and a timing resolution in the order of µs.

Detectors in preparation II / 31

BELLE-2 Pixel detector upgrade

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BELLE-2 Pixel detector upgrade

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The DEPFET technology is the baseline for the innermost detector of the Belle II experiment at the e+e- SuperKEKB collider at KEK. This technology integrates signal detection and a first phase of signal amplification in a single silicon structure with a 75 µm thin pixel array. This feature provides a very accurate position measurement, with an overall material budget of 0.2% radiation length and reduces the impact of multiple scattering for tracks with low transversal momentum. Furthermore, the physics goals of the experiment impose challenging requirements to this technology, but DEPFET with its excellent signal-noise-ratio, its lower power consumption and its non destructive readout has proven to be a suitable solution for the Belle II PXD necessities. The vertex pixel detector will consists of two DEPFET layers at radii of 14 mm and 22 mm with 8 and 12 modules respectively. The pixel sizes will vary, between 50x50 – 55 μm^2 at the fist layer and between 50x70 – 85 μm^2 at the second layer, to optimize the charge sharing efficiency. Moreover the four-fold readout in rolling shutter mode provides a readout speed of 20 µs/frame. All of these features, the sensor concept and the electronics involved will be presented in detail.

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BELLE-2 silicon vertex detector upgrade

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BELLE-II silicon vertex detector upgrade

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BELLE II is an experiment in KEK (Tsukuba, Japan) that will explore heavy flavour physics (B, charm and tau) from early 2018 with unprecedented precision. Charged particles are tracked (going from the interaction point to the outside) by a two-layer DEPFET pixel device (PXD), a four-layer silicon strip detector (SVD) and the central drift chamber (CDC). The design and the construction of the SVD are challenging in many ways: The detector has about 200k analog channels, which are readout by about 5,000 APV25 ASICs. These frontend readout chips have a short shaping time of about 50 ns and thus can cope with the backgrounds expected at Belle II. At the same time, they are sensitive to capacitive noise, which requires that some of the chips are mounted in the active region of the detector. To minimise material in the acceptance region, carbon fibre structures and CO2 cooling (to reduce the cooling pipe diameter) are used. In this talk, I will review the design of the Belle II SVD, the current state of the production and first results on the detector performance obtained in test beam experiments.

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CMS Tracker: the Run 1 to Run 2 transition and first experience of Run 2

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The CMS inner detector is the largest silicon tracker ever built. Located around the center of CMS where the LHC particle beams are brought into collision, it consists of a hybrid pixel detector with 66 million channels and a 200 mÂ² silicon strip detector with about 10 million read-out channels. The tracking detector provides high-resolution measurements of charged particles passing through a 3.8 T magnetic field and is also crucial for vertex reconstruction. The presentation briefly summarizes the operational experience gained with this detector during the first three years of LHC operation (Run 1) including performance measurements. The focus lies on the work carried out during the first long shutdown of LHC to prepare the detector for the high-radiation and high-luminosity environment of Run 2. The most important tasks were the repair of the detector and preparations for operating the detector at significantly lower temperature. First experience with 2015 operation of the detector is also presented.

Vertexing and Tracking Methods / 41

CMS developments for track-triggers

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CMS developments for track-triggers

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The High Luminosity LHC (HL-LHC) is expected to deliver luminosities of 5x10^34 cm^2/s, with an average of about 140 overlapping proton-proton collisions per bunch crossing. These extreme pileup conditions place stringent requirements on the trigger system to be able to cope with the resulting event rates. A key component of the CMS upgrade for HL-LHC is a track trigger system which would identify tracks with transverse momentum above 2 GeV already at the first-level trigger. This talk presents the status of proposals for implementing the L1 tracking in conjunction with the planned upgrade for the silicon tracker of the CMS experiment. The expected performance and the use of L1 tracks for triggering is discussed.

Detectors in preparation I / 5

CMS pixel upgrade for the HL-LHC

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CMS pixel upgrade for the HL-LHC

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In 2023, the LHC will be upgraded to the HL-LHC, increasing the luminosity to 5 x 10^34 cmâ2 sâ1. The increased luminosity will present new challenges in higher data rates and increased radiation. The CMS Phase 2 Pixel upgrade will require a high bandwidth readout system and high radiation tolerance for sensors and on-detector ASICs. Several technologies for the upgrade sensors are being considered, including thin planar and 3D options. DC-DC conversion or serial powering schemes are under consideration to accommodate significant constraints on the system. These prospective designs, as well as new layout geometries that include very forward pixel discs, will be presented.

Detectors in preparation I / 9

CMS strip detector upgrade for the HL-LHC

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CMS strip detector upgrade for the HL-LHC

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A significant upgrade of the LHC accelerator is planned to become operational mid of the next decade. This High Luminosity LHC will increase the design luminosity by a factor of five to about 5 x 10^34 cm^(-2)s^(-1) or even beyond, making an upgrade of the detectors unavoidable. To cope with this environment, the outer tracker of the CMS experiment has to face an increase in particle density inducing more radiation damage and higher occupancy. Furthermore, the tracker has to provide information to the level one hardware trigger.

The CMS Tracker Collaboration has developed a concept for a new tracking system, which uses intelligent dual sensor modules with high granularity. The talk will give an overview on the layout of the proposed outer tracker and will closely review the design of the modules. Special emphasis will be placed on the developments in sensor design and production.

Current detectors: operational experience / 1

CMS tracker: Run 1 to Run 2 transition, and first experience with Run 2

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Chronopixel Project Status

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A monolithic CMOS pixel detector with time stamping capability (Chronopixel) is being developed, in collaboration with the Sarnoff Corporation (which was recently renamed into SRI International). The design goals are based on the requirements of an ILC vertex detector. The main feature of the design is that each hit is accompanied by a time tag with sufficient precision to assign it to a particular bunch crossing of the ILC (thus the name Chronopixel). This reduces the occupancy to negligible levels, even in the innermost vertex detector layer, yielding a robust vertex detector which operates at the background levels significantly in excess of those currently foreseen for the ILC. Chronopixel differs from the similar detectors developed by other groups by the fact, that it is monolithic and is using standard CMOS process. The first set of prototype devices was fabricated in 2008, and tests results were reported in 2010. The second prototype was fabricated in 2012 with test results reported in 2013. The third prototype was fabricated in 2014. Main goal of the third prototype was the test of possible solutions for the problem, discovered in prototype 2. The problem was traced to the TSMC design rules for 90 nm technology, and led to unacceptable large value of the sensor diode capacitance. Six different layouts for the sensor diode were tested in prototype 3, and tests have shown that high capacitance problem was solved.

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Chronopixel project status

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Current detectors: operational experience / 59

Current and prospective performance of the LHCb tracking system

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Current and prospective performance of the LHCb tracking system

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The LHCb tracking system consists of a Vertex Locator around the interaction point, a tracking station with four layers of silicon strip detectors in front of the magnet, and three tracking stations, using either straw-tubes or silicon strip detectors, behind the magnet. This system allows to reconstruct charged particles with a high efficiency (typically > 95% for particles with momentum > 5 GeV) and an excellent momentum resolution (0.5% for particles with momentum < 20 GeV). The high momentum resolution results in very narrow mass peaks, leading to a very good signal-to-background ratio in such key channels as Bs -> mu mu. Furthermore an optimal decay time resolution is an essential element in the studies of time dependent CP violation. Thanks to the excellent performance of the tracking system, a decay time resolution of ~50 fs is obtained, allowing to resolve the fast B0s oscillation with a mixing frequency of 17.7 ps-1. In this talk, we will give an overview of the track reconstruction in LHCb and review its performance in Run I of the LHC. We will highlight the challenges and improvements of the track reconstruction for the data taking period from 2015 on, discussing efforts to improve the timing in the online reconstruction as well as approaches to unify the online and offline reconstruction. The upgrade of the LHCb experiment will run at an increased instantaneous luminosity of 2x10^33 cm^-2 s^-1 with a fully software based trigger, allowing to read out the detector at a rate of 40MHz. For this purpose, the full tracking system will be newly developed. We will present the performance of the tracking system for the LHCb upgrade, highlighting the improvements with respect to the current tracking system of LHCb, and review the track finding strategy. Special emphasize will be put on the need for fast track reconstruction in the software trigger, also giving examples of the potential use of parallelism in the pattern recognition. Finally, we will give some prospects of the physics performance with the LHCb upgrade for channels relying on excellent tracking capabilities.

Vertexing at future accelerators / 28

Current developments by SiD and ILD

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Current developments by SiD and ILD

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The International Linear Collider (ILC) has been very prominently mentioned in the international strategy documents for HEP and here is a strong interest in Japan to become the host country for the ILC. Two detectors have been proposed for the ILC, the SiD and ILD concepts. They have been validated by an international advisory committee and Detailed Baseline Designs have been presented in 2012. While both detectors are built for particle flow, their approach to tracking is quite distinct. While ILD uses a combination of a TPC with silicon, SiD has an all-silicon approach to tracking with a fully integrated tracker. I will first give an overview about both concepts and then review the recent technology developments for both vertex and tracker sensors as well as the state of the reconstruction software suites. I'll conclude with a short summary on the ILC status in Japan.

Non-HEP applications / 14

Detector developments in photon science

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Detector developments in photon science

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Spurred on by the recent and planned upgrades to storage rings such as PETRA III, NSLS II, Diamond, ESRF, APS, etc., along with the growing number of free electron lasers (FEL), there has been a burst of activity in developing new detectors for these facilities. Given the wide range of photon energies, diverse set of experimental techniques employed, and varied beams delivered by the accelerators, an expansive set of detectors with different characteristics needs to be designed and constructed. In particular the dichotomy between the time structures of rings and FELs, often necessitates the implementation of parallel detectors with similar functionality. An overview of progress in the performance of x-ray cameras for these challenging environments will be presented.

R&D and detector applications I / 64

Developments in CMOS for strip detectors

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Developments in CMOS for strip detectors

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ATLAS is currently studying the use of CMOS MAPS devices as a replacement for the baseline silicon strip sensors for the Phase-II Strip Tracker Upgrade. One of the key aspects is to establish whether the radiation hardness is suitable for the HL-LHC environment. Two different technologies are being studied: High-Voltage CMOS and High-Resistivity CMOS. Several test chips have already been manufactured. We present the latest results from non-irradiated and irradiated sensors including test beam results and give an outlook on the next steps.

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Developments in Neural Vision Technology

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The visual system is a remarkable neural network that is able to extract vital information about the external visual world. The conversion of the dynamic visual input into processed electrical signals is performed by the retina, an extraordinary biological pixel detector that lines the back of the eye and transmits coded information to the brain. The brain does further processing and generates visual perceptions.
In this talk, after an introduction to the visual system, I will describe the technology and experimental methods we have developed and employ, in close collaboration with neurobiologists, to probe both the retina and the brain. These methods are based on large-scale multielectrode array systems that can record, and in some cases stimulate, the electrical activity of a large population of neurons. This project was inspired by the development of silicon microstrip detectors for high energy physics experiments.

Non-HEP applications / 15

Developments in neural vision technology

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R&D and detector applications I / 37

HR-CMOS Developments

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HR-CMOS Developments

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CMOS Monolithic Active Pixel Sensors (MAPS) are starting to be investigated for particle physics experiments. In order to make MAPS the solution of choice for more experiments, we are developing sensors able to withstand high levels of radiation such as those required by the extremely harsh environments found in the Large Hadron Collider (LHC) experiments. A very rad-hard MAPS will also provide benefit in terms of imaging speed. CMOS MAPS designed in a deep-implant "INMAPS" process are flexible in design and have been shown to work for experiments such as Alice at the LHC. High-resistivity substrates, i.e. of order one kOhm-cm, are used to provide a depleted region for charge collection, even with the small voltages normally available in CMOS. An electric field is present in the depletion region,

thus speeding up charge collection and reducing the spread of charge between pixels. This in turn is beneficial for the detection efficiency as the average signal over noise ratio for a signal pixel is increased. The reduced charge collection time also means the sensors is less affected by the lattice damage generated by Non Ionising Energy Loss (NIEL). I will present the status of the HR-CMOS work at RAL, and plans for the future.

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HV-CMOS Developments

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In the framework of the ATLAS Inner Tracker Upgrade (ITk) project, the ATLAS CMOS collaboration is pursuing a R&D effort to demonstrate the capabilities of modern High-Voltage and High-Resisitivity CMOS (HV/HR-CMOS) technologies in terms of particle detection. The use of commercial large scale CMOS production facilities and the possibility to integrate amplification and logic inside the sensor open the door to large cost reduction for the construction of large area tracking and vertexing detectors. In this presentation, I will introduce the concept of particle detection using HV/HR-CMOS sensors and present the latest results from the collaboration in terms of laboratory and test beam characterization.

R&D and detector applications I / 26

HV-CMOS developments

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Detectors in preparation I / 6

LHCb VELO upgrade

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LHCb VELO upgrade

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The upgrade of the LHCb experiment, planned for 2018, will transform the experiment to a trigger-less system reading out the full detector at 40 MHz event rate. All data reduction algorithms will be executed in a high-level software farm with access to the complete event

information. This will enable the detector to run at luminosities of 2 x 10^33 /cm^2/s and probe physics beyond the Standard Model in the heavy flavour sector with unprecedented precision. The Vertex Locator (VELO) is the silicon vertex detector surrounding the interaction region. The current detector will be replaced with a hybrid pixel system equipped with electronics capable of reading out at 40 MHz, designed to withstand the irradiation expected at an integrated luminosity of 50 fb-1 and beyond. The upgraded VELO will form an integral part of the software trigger, and must provide fast pattern recognition and track reconstruction while maintaining the exceptional resolution of the current detector. The detector will be composed of silicon pixel sensors with 55x55 um^2 pitch, read out by the VeloPix ASIC which is being developed based on the TimePix/MediPix family. The hottest region will have pixel hit rates of 900 Mhits/s yielding a total data rate more than 3 Tbit/s for the upgraded VELO. The detector modules are located in a separate vacuum, separated from the beam vacuum by a thin custom made foil. The foil will be manufactured through milling and possibly thinned further by chemical etching. The detector halves are retracted when the beams are injected
and closed at stable beams, positioning the first sensitive pixel at 5.1 mm from the beams. The high data rates require development of low-mass, high-speed, flexible electrical serial links bringing the data out of the vacuum where electrical-to-optical conversion is
performed. The material budget will be minimised by the use of evaporative CO_2 coolant circulating in microchannels within 400 um thick silicon substrates. Microchannel cooling brings many advantages: very efficient heat transfer with almost no temperature gradients across the module, no CTE mismatch with silicon components, and low material contribution. This is a breakthrough technology being developed for LHCb. The 40 MHz readout will also bring significant conceptual changes to the way in which the upgrade trigger is operated. Work is in progress to incorporate momentum and impact parameter information into the trigger at the earliest possible stage, using the fast pattern recognition capabilities of the upgraded detector. The current status of the VELO upgrade will be described together with a presentation of recent test results, including operation of irradiated sensor and ASIC assemblies in testbeam and lab environments.

Current detectors: operational experience / 2

LHCb silicon detectors: Run 1 to Run 2 transition, and first experience with Run 2

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LHCb silicon detectors: Run 1 to Run 2 transition, and first experience with Run 2

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LHCb is a dedicated experiment to study New Physics in the decays of heavy
hadrons at the Large Hadron Collider (LHC) at CERN. The detector includes a
high precision tracking system consisting of a silicon-strip vertex detector
(VELO) surrounding the pp interaction region, a large-area silicon-strip
detector located upstream of a dipole magnet (TT), and three stations of
silicon-strip detectors (IT) and straw drift tubes placed downstream (OT).
The operational transition of the silicon detectors VELO, TT and IT from LHC
Run 1 to Run 2 and first Run 2 experiences will be presented. During the long shutdown of the LHC the silicon detectors have been maintained in a safe state and operated regularly to validate changes in the control infrastructure, new operational procedures, updates to the alarm systems and monitoring software. In addition, there have been some infrastructure

related challenges due to maintenance performed in the vicinity of the silicon detectors that will be discussed. The LHCb silicon detectors are well prepared for LHC Run 2 and have already recorded tracks from injection line tests and low energy collisions. The results obtained from analyzing this data and the current status and plans for new operational procedures of the LHCb silicon detectors required in LHC Run 2 will be outlined.

Detectors in preparation I / 10

LHCb upstream tracker upgrade

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LHCb upstream tracker upgrade

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The upgraded LHCb detector is planned to run at an instantaneous luminosity of 2 × 1032cm−2s−1 and will have 40 MHz readout. In order to cope with the higher data rate, all the components of the LHCb tracking system are being replaced. In particular, the silicon microstrip detector system located upstream of the dipole magnet, (TT), is going to be replaced by the Upstream Tracker (UT). This system consists of four silicon microstrip planes, read out with custom made electronics (SALT128), currently being developed. The silicon- SALT128 hybrid circuits are connected with near-detector electronics via low mass flex cables. In order to maintain the silicon detectors at the required temperature, cooling is provided by an evaporative CO2 system. Hybrids are mounted on low mass reinforced carbon fiber sandwiches called "staves." Considerable progress has been achieved on the design of most of the components required for this system. In addition a program of irradiation and test beam studies was started last year. Key findings will be summarized.

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Lessons from the Fermi LAT experience for high precision trackers for future space missions

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Lessons from the Fermi LAT experience for high precision trackers for future space missions

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Designing trackers for future gamma-ray telescopes to operate in the MeV to GeV range requires making tradeoffs for optimizing the scientific performance. In particular, the choice of available detector technologies combined with the limited space and power available to space-based missions suggest that trade-offs between the collecting area, the field of view, and the spatial and spectral resolution will be required. In this contribution I will summarize some lessons learned from the performance optimization of the Fermi Large Area Telescope, and discuss how they may be applicable to the design of trackers for future instruments.

Electronics and Integration / 36

Monolithic Active Pixel Sensors

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Monolithic Active Pixel Sensors

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After more than a decade of R&D, CMOS Monolithic Active Pixel Sensors (MAPS) have proven to offer concrete answers to the demanding requirements of subatomic physics experiments. Their main advantages result from their low material budget, their very high granularity and their integrated signal processing circuitry, which allows coping with high particle rates. Moreover, they offer a competitive radiation tolerance and may be produced for low costs. Sensors of the MIMOSA series have offered an opportunity for nuclear and particle physics experiments to address with improved sensitivity physics studies requiring an accurate reconstruction of short living and soft particles. The STAR-PXL detector is the first vertex detector based on MAPS produced in 0.35 µm CMOS technology. While this experiment is successfully taking data, it was found that the 0.35µm CMOS technology is not suited for upcoming applications like the CBM vertex detector and the ALICE inner tracker system, which require faster and more radiation tolerant sensors. The exploration of a deeper submicron
CMOS technology was therefore initiated and it was shown that MAPS can be envisaged for detectors exposed to particularly demanding running conditions. The talk will overview achieved performances of MIMOSA / MISTRAL sensors and focus on their most recent developments, addressing the CBM-MVD, ALICE-ITS
and ILD vertex detector.

Vertexing and Tracking Methods / 39

Novel methods and expected Run II performance of ATLAS track reconstruction in dense environments

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Novel methods and expected Run II performance of ATLAS track reconstruction in dense environments

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Detailed understanding and optimal track reconstruction performance of ATLAS in the core of high pT objects is paramount for a number of techniques such as jet energy and mass calibration, jet flavour tagging, and hadronic tau identification as well as measurements of physics quantities like jet fragmentation functions. These dense environments are characterized by charged particle separations on the order of the granularity of ATLAS's inner detector. With the insertion of a new innermost layer in this tracking detector, which allows measurements closer to the interaction point, and an increase in the centre of mass energy, these difficult environments will become even more relevant in Run II, such as in searches for heavy resonances. Novel algorithmic developments to the ATLAS track reconstruction software targeting these topologies as well as the expected improved performance will be presented.

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Novel real-time alignment and calibration of the LHCb Detector in Run2

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LHCb has introduced a novel real-time detector alignment and calibration strategy for LHC Run 2. Data collected at the start of the fill will be processed in a few minutes and used to update the alignment, while the calibration constants will be evaluated for each run. This procedure will improve the quality of the online alignment. For example, the vertex locator is retracted and reinserted for stable beam collisions in each fill to be centred on the primary vertex position in the transverse plane. Consequently its position changes on a fill-by-fill basis. Critically, this new real-time alignment and calibration procedure allows identical constants to be used in the online and offline reconstruction, thus improving the correlation between triggered and offline selected events. This offers the opportunity to optimise the event selection in the trigger by applying stronger constraints. The required computing time constraints are met thanks to a new dedicated framework using the multi-core farm infrastructure for the trigger. The motivation for a real-time alignment and calibration of the LHCb detector is discussed from both the operational and physics performance points of view. Specific challenges of this novel configuration are discussed, as well as the working procedures of the framework and its performance.

R&D and Detector Applications II / 45

Novel real-time alignment and calibration of the LHCb detector in Run 2

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Pilot System for the Phase 1 Pixel Upgrade

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The CMS phase 1 pixel upgrade is planned for installation in 2016-2017, incorporating a new front-end ASICs with digital 400 Mbps data links to handle a higher instantaneous luminosity of up to 2.5 x 10^34 cm^-2 s^-1 and trigger rates of 100 kHz with bunch spacing scenarios of 25 or 50 ns. The new digital readout requires new back-end electronics incorporating faster optical receivers and firmware for decoding the new data format. Additionally the phase 1 upgrade is powered from DC-DC converters installed inside CMS close to the modules. To gain experience with this new readout chain and DC-DC converters in realistic operating conditions (trigger rates, backgrounds, high data occupancy, and possible single-event upsets) a pilot detector system comprising 8 sensor modules, service electronics, optical links, and back-end electronics has been prepared using pre-production parts and installed with the present forward pixel detector in 2014 during LS1. The pilot system will be operated concurrently with the present pixel detector in 2015-2016 to validate the data acquisition and powering design and advance online control system development for a rapid deployment of the full detector in 2017. This contribution will report on the phase 1 pilot system experience leading into Run 2 of the LHC.

Detectors in preparation II / 44

Pilot System for the Phase 1 Pixel Upgrade of CMS

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Qualification of pixel detector modules for the forward sector of the CMS vertex detector

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Qualification of pixel detector modules for the forward sector of the CMS vertex detector

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The phase 1 upgrade of the CMS pixel detector will replace the existing pixel detector at the end of 2016 in an extended technical stop. The phase 1 upgrade includes four barrel layers and three forward disks, providing robust tracking and vertexing for LHC luminosities up to 2.5 x 10^34 cm-2 s-1 prior to the HL-LHC era. The upgrade incorporates new readout chips and front-end electronics for higher data rates, DC-DC powering, and dual-phase CO2 cooling to achieve performance exceeding that of the present detector with a lower material budget. The design of the forward detector is presented along with present status of mechanical construction, module assembly, and module qualification. The procedures for module testing and quality assurance are described in some detail.

Radiation Hardness / 20

RD42: diamond detectors

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RD42: diamond detectors

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The RD42 Collaboration at CERN is investigating Chemical Vapor Deposition (CVD) diamond as a material for tracking detectors operating in extreme radiation environments. This talk will present an overview of latest the developments from RD42. Results from diamond sensor based beam monitors in the ATLAS and CMS experiments at the CERN Large Hadron Collider (LHC) will be presented and the status of diamond based luminosity monitors for the upcoming LHC run will be described. Charge collection measurements of latest diamond detector material from several diamond manufacturers will be presented for the first time. Recent beam test measurements of the pulse height dependence on the incoming charged particle flux for single-crystal and poly-crystalline diamond sensors will be shown. Finally, the overall radiation hardness of diamond sensors and future plans will be reviewed.

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RD50: Simulation of radiation-induced defects

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Mainly due to their outstanding performance the position sensitive silicon detectors are widely used in the tracking systems of High Energy Physics experiments such as the ALICE, ATLAS, CMS and LHCb at LHC, the world's largest particle physics accelerator at CERN, Geneva. The foreseen upgrade of the LHC to its high luminosity (HL) phase (HL-LHC scheduled for 2023), will enable the use of maximal physics potential of the facility. After 10 years of operation the expected fluence of above 1015 neqcm−2 for strip sensors ~20 cm from the vertex will expose the tracking system at HL-LHC to a radiation environment that is beyond the capacity of the present system design. Thus, for the required upgrade of the all-silicon central trackers extensive measurements and simulation studies for silicon sensors of different designs and materials with sufficient radiation tolerance have been initiated within the RD50 Collaboration.

Complementing measurements, simulations are in vital role for e.g. device structure optimiza- tion or predicting the electric fields and trapping in the silicon sensors. When numerical simulations are able to verify experimental results they will also gain predictive power, resulting in reduced time and cost budget in detector design and testing. The main objective of the device simulations in the RD50 Collaboration is to develop an approach to model and predict the performance of the irradiated silicon detectors (diode, strip, pixel, columnar 3D) using professional software.
The simulation of radiation damage in the silicon bulk is based on the effective mid gap levels (a deep acceptor and a deep donor level). The main idea of the model that was first proposed in 2001 and entitled later as the "PTI model" is that the two peaks in the E(z) profile of the both proton and neutron irradiated detectors can be explained via the interaction of the carriers from the bulk generated current with the electron traps and simultaneously with the hole traps. The first successfully developed quantitative models, namely the proton model and the neutron model, for the simulation of the detector characteristics like leakage current, full depletion voltage and charge collection efficiency (CCE) were built on the base of the PTI model. Recent implementations of additional traps at the SiO2/Si interface or close to it have expanded the scope of the simulations to include experimentally agreeing surface properties such as the interstrip resistance and capacitance, and the position dependency of CCE for strip sensors irradiated up to 1.5 × 1015 neqcm−2.
Insights to the development processes of the defect models and comparisons of the simulation results with measurements of several detector technologies and silicon materials at radiation levels expected for the HL-LHC will be presented.

Radiation Hardness / 19

RD50: radiation-hard technology developments

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RD50: radiation-hard technology developments

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The next upgrades of the HL-LHC (High Luminosity-Large Hadron Collider) are scheduled to reach fluences of 2e16neq/cm2. Silicon detectors will be expose to high fluences of radiation, and RD50 (Radiation Hard Semiconductor Devices For High Luminosity Colliders) is a CERN R&D collaboration devoted to develop radiation hard silicon detectors for the HL-LHC. The collaboration explore different fields structured in different areas: defect and material characterization explore the macroscopic properties of materials before and after irradiation, detector characterization test the devices in different techniques, new detector structures develop new devices such as Low Gain Avalanche Detectors LGAD or 3D detectors and full detector systems integrates the electronic to the detector and study the performance under high fluences. The last updates of the collaboration outcomes will be presented.

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RD50: simulation of radiation-induced defects

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Electronics and Integration / 21

RD53: new developments

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RD53: new developments

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The current status and plans of RD53 will be presented. This will include radiation testing results of the 65nm process, test chip submissions, and plans for a reticle size chip.

Radiation Hardness / 91

Radiation damage monitoring of the ATLAS pixel detector

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Radiation damage monitoring of the ATLAS pixel detector

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Radiation damage to the ATLAS pixel detector is measured continuously by a dedicated system for monitoring leakage current in a representative sample of the modules. Measurements for the full 2011-2012 run are presented and compared to predictions by a theoretical model. The data are used to infer the impact of the current upon the lifetime of the detector.

R&D and detector applications I / 92

Recent Progress on 3D Silicon Detectors

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Recent Progress on 3D Silicon Detectors

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3D silicon detectors, in which the electrodes penetrate the sensor bulk perpendicular to the surface, have recently undergone a rapid development from R&D over industrialisation to their first installation in a real HEP experiment. Right now the ATLAS Insertable B-Layer (IBL) is taking first collision data with 3D pixel detectors. At the same time, preparations are advancing to install 3D pixel detectors in forward trackers such as the ATLAS Forward Proton (AFP) detector, which might be installed as early as the end of this year, or the CMS-TOTEM PPS. For those experiments, the main requirements are a slim edge and the ability to cope with non-uniform irradiation. Both has been shown to be fulfilled by 3D pixel detectors. For the HL-LHC pixel upgrades of the major experiments (ATLAS, CMS, LHCb), 3D detectors are a promising candidate for the innermost pixel layers to cope with harsh radiation environments up to fluences of 2e16 n_{eq}/cm^2 thanks to their excellent radiation hardness at low operational voltages and power dissipation and moderate temperatures. This presentation will give an overview on the recent developments of 3D detectors related to these projects and the future plans.

Vertexing and Tracking Methods / 34

Recent developments in vertexing and tracking methods

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Recent developments in vertexing and tracking methods

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After a long shutdown, LHC is resuming operation with a center-of-mass energy of 13 TeV. In order to reach the target luminosity not only the collision frequency, but also the beam intensity will be higher than in Run 1. As a consequence, the average number of events underlying the signal events (pile-up) will rise from about 15 to about 25. The LHC collaborations have used the shutdown period to improve their tracking and vertexing in order to meet the more demanding requirements. I will give a summary of the most important developments. The LHC collaborations, in particular ATLAS and CMS, already have plans to upgrade their inner tracking devices for the high-luminosity phase of the LHC, scheduled to begin in the next decade. Besides having to deal with an even higher amount of pile-up, these devices are designed to trigger on high-momentum tracks and will thus require real-time track finding. I will describe the current activities in this field. Finally, I will give a brief outline of tracking and vertexing in future experiments such as Belle II and CBM.

Detectors in preparation II / 11

STAR silicon upgrade

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STAR silicon upgrade

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A primary goal of the high luminosity era at RHIC will be the study of heavy quark behavior in Quark Gluon Plasma. The integration of high precision silicon-based tracking in the form of the Heavy Flavor Tracker for the STAR Experiment should enable the reconstruction and identification of charmed hadron decays, working in concert with STAR's Time Projection Chamber to determine momenta and displacement of decay daughters from the primary collision vertex. To reach the precision demands, the new detectors must be calibrated and sufficiently accounted in tracking to observe charmed hadrons with high signal-to-noise. In this presentation we will review the STAR Collaboration's developments and achievements in this critical effort.

R&D and detector applications I / 27

Semiconductor neutron detectors

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Semiconductor neutron detectors

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Solid-state neutron detectors have many applications in different fields, such as security, medical imaging, cultural heritage, forensics, and high energy and nuclear physics. The shortage and the consequent increasing cost of 3He gas, on which most neutron detector systems were based for

decades, has played an important role in boosting the development of silicon based devices featuring high aspect-ratio cavities filled with neutron converter materials (typically based on 10B or 6Li). In order to achieve good performance, both in term of neutron detection efficiency and suppression of gamma-ray sensitivity, the key aspects are the optimization of the size of the cavities and of the gap regions in between them. Moreover, the deposition techniques of converter materials should be optimized to ensure conformal filling of small cavities and good stability. Very good results have so far been obtained by different research groups in Europe (e.g., Delft University, University of Prague, CNM Barcelona) but most of all in the USA (e.g., University of Kansas, Lawrence Livermore National Laboratory, Rensselaer Polytechnic Institute), with efficiency values up to ~50% using only a single detector layer. The state of the art in semiconductor neutron detectors will be reviewed, with emphasis on silicon based devices. Moreover, the R&D activity carried out in the framework of the INFN HYDE (HYbrid DEtector for neutrons) Project will be reported, covering design and technological aspects, simulations, and selected experimental results. In particular, a new sensor structure, aimed at high detection efficiency while minimizing the process complexity will be introduced.

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SiPMs as tracking detectors

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Summary and closeout / 22

Summary and outlook

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Detectors in preparation II / 13

The NA62 Gigatracker

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The NA62 Gigatracker

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The Gigatracker is an hybrid silicon pixel detector built for the NA62 experiment aiming at measuring the branching fraction of the ultra-rare kaon decay $K^+ \to \pi^+ \nu\bar{\nu}$ at the CERN SPS. The detector has to track particles in a beam with a flux reaching 1.3 MHz/mm^2 and provide single-hit timing with 200 ps RMS resolution for a total material budget of less than 0.5% X_0 per station. The tracker comprises three 63.1 mm $\times$ 29.3 mm stations installed in 10^{-6}mbar vacuum and cooled with liquid C6F14 circulating through microchannels etched inside 130 um thick silicon plates. Each station is composed of a 200 um thick silicon sensor readout by 2$\times$5 custom 100 um thick ASIC, called TDCPix. Each chip contains 40$\times$45 asynchronous pixels, each 300 um $\times$ 300 um, and is instrumented with 100

ps bin time-to-digital converters. In order to cope with the high rate, the TDCPix is self-triggered and data are sent out through four 3.2 Gb/s serialisers. We will describe the detector and the results from the 2014 NA62 run.

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The Phase 1 Upgrade of the CMS Vertex Detector

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The present CMS pixel detector was originally designed for a luminosity of 1 x 10^34 cm-2s-1 and a pileup (number of inelastic interaction per bunch crossing) of 25 in 25 ns bunch spacing. These beam parameters will be reached in the middle of the LHC data taking period 2015-2017 (with an additional increase in the center of mass energy up to the value of 13-14 TeV) and then, peak luminosity will keep increasing until 2018 when it will reach the value of 1.5 x 10^34 cm-2s-1. The present detector will remain operative until the end of 2016 and will be replaced with an upgraded pixel system that will be described in this presentation before Long Shutdown 2 (LS2). The design of the upgraded CMS pixel detector allows to cope with the yet higher peak luminosities after LS2 reaching 2 x 10^34 cm-2s-1 around 2021 and pileup of 50 or 100 at 25ns or 50ns beam spacing, respectively. The new upgraded detector will have higher tracking efficiency and lower mass with four barrel layers and three forward/backward disks to provide a hit coverage up to absolute pseudorapidities of 2.5. In this presentation the new pixel detector will be described focusing mostly on the barrel detector design, construction and expected performances. Preliminary tests on detector module production will also be presented.

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The Phase I Upgrade of the CMS Vertex Detector

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Detectors in preparation I / 7

The Upgrade of the Inner Tracking System of ALICE

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The Upgrade of the Inner Tracking System of ALICE

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The upgrade of the Inner Tracking System (ITS) of ALICE is planned for the second long shutdown of the LHC in 2018-2019. The main motivation for the upgrade is the fulfillment of the requirements of the ALICE physics program for run 3 and 4 of the LHC, which requires improved tracking capability and impact parameter resolution at very low transverse momentum, as well as a substantial increase in the readout rate. To fulfill these requirements the current ITS will be replaced by seven layers of state-of-the-art Monolithic Active Pixel Sensors and the new detector will be moved as close as 22 mm to the interaction point. Several prototypes of the sensor have been developed to test different aspects of the sensor design including prototypes with analog and digital readout, as well as small and final size sensors. The talk will give an overview of the current status of the research and development with a focus on the pixel sensor and the characterization of the latest prototypes.

R&D and detector applications I / 25

Ultra-fast silicon detectors

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Ultra-fast silicon detectors

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Ultra-fast silicon detectors are a recent detector type using high resistivity n-on-p wafers and including an extra implantation step to create a high field region that amplifies drifting electrons. The target gain is approximately a factor of ten, allowing high rate operation and good time resolution at the same time as good position resolution is achieved. The best time resolution is expected to be achieved for thin detectors, for example 50 microns thick sensors. This talk will cover how the ultra-fast detectors work, some measurements made to date, and performance expectation based on simulations. Also the extensive prototyping program recently launched to explore the choice of detector parameters will be described. The prototyping program should yield significant new information in the next six months and provide validation for the simulation program that has been developed.

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VELOPIX: A high rate pixel ASIC for the LHCb VELO upgrade

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The LHCb Vertex Detector (VELO) will be upgraded in 2018 along with the other subsystems of LHCb in order to enable full detector readout at 40 MHz. LHCb will run without a hardware trigger and all data will be fed directly to the software triggering algorithms in the CPU farm. The upgraded

VELO is a lightweight silicon hybrid pixel detector with 55 um square pixels, operating in vacuum in close proximity to the LHC beams. The readout will be provided by a dedicated front end ASIC, dubbed VeloPix, matched to the LHCb luminosity requirements. The occupancy across the chip is very non uniform, and the radiation levels reach an integrated 400 MRad over the lifetime of the detector in the most irradiated regions. VeloPix is a binary pixel chip with a matrix of 256 x 256 pixels, covering an area of 2 cm^2. It is designed in a 130 nm CMOS technology, and is closely related to the Timepix3, from the Medipix family of ASICs. The principal challenge that the chip has to meet is a hit rate of up to 900 Mhits/s/ASIC, resulting in a data rate of more than 16 Gbit/s. Combining pixels into groups of 2x4 super-pixels enables the use of shared logic and a reduction of bandwidth due to combined address and timestamp information. The pixel hits are combined with other simultaneous hits in the same super-pixel, timestamped, and immediately driven off-chip via custom designed 5.12 Gbit/s serialisers. The analog front end must be sufficiently fast to accurately timestamp the data, with a small enough dead time to minimise data loss in the most occupied regions of the chip. The power consumption of the analog front end is about 5 uW per pixel, and the total power consumption of the ASIC is less than 2 W. An extensive testbeam and lab test campaign is underway in order to characterise prototype upgrade VELO sensors and simultaneously study the performance of the Timepix3 chip in a high track rate environment. These measurements provide valuable input to the VeloPix project. The VeloPix ASIC design is nearing completion and the chip is expected to be submitted in the autumn. The current status of the ASIC design, performance simulations and prototyping will be described, along with recent lab and testbeam results.

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Vertex Detector R&D for CLIC

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A vertex detector is under development for CLIC, a future linear electron-positron collider with a maximum centre of mass energy of 3 TeV. In order to perform precision physics measurements in a challenging environment, the CLIC vertex detector must have excellent spatial resolution, full geometrical coverage extending to low polar angles, extremely low mass, low occupancy facilitated by time-tagging, and sufficient heat removal from sensors and readout. These considerations, together with the beam structure of CLIC, push the technological requirements to the limits. A detector concept based on hybrid pixel-detector technology is under development. It comprises fast, low-power and small-pitch readout ASICs implemented in 65 nm CMOS technology (CLICpix) coupled to ultra-thin (50 um) planar or active HV-CMOS sensors via low-mass interconnects. Prototype devices have been tested in the lab and with beams. The power dissipation of the readout chips is drastically reduced by means of power pulsing, allowing for a low-mass cooling system based on forced air flow

through an optimised arrangement of detection layers. This talk reviews the requirements for the CLIC vertex detector and gives an overview of recent R&D achievements in the domains of sensors and readout ASICs, data-acquisition systems and detector integration. First results with an innovative hybridisation concept based on capacitive coupling between active sensors and readout ASICs will be presented.

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Vertex detector R&D for CLIC

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