TALENT Initial Training Network

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28 October 2013

CERN

TALENT in a nutshell

- Marie Curie Initial Training Network in the context of the ATLAS Tracker Upgrade program
- TALENT runs January 1, 2012 until December 31, 2015
- 4.5 M Euro, EC FP7 Marie Curie Action
- TALENT offers 15 positions for the Early-stage researchers (PhD, 3 y) and 2 positions for Experienced researchers (Post-doc, 2y)

TALENT Network

3 Research facilities, 7 Universities, 8 Industrial partners

- CERN, Switzerland
- Fraunhofer IZM, Berlin, Germany
- Centre de Physique de Particules de Marseille, France

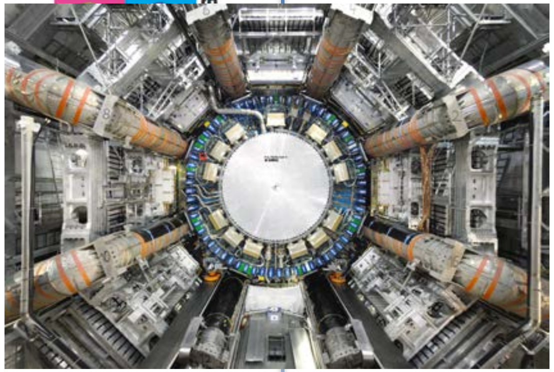
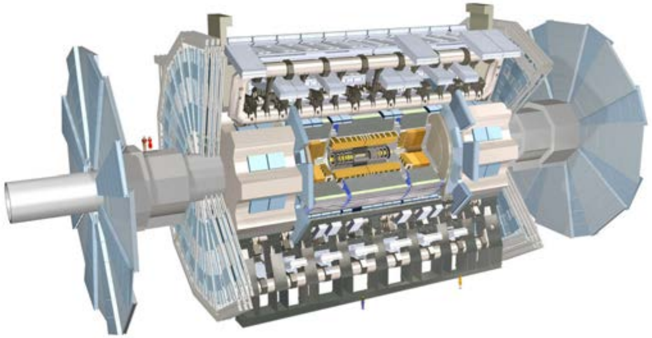
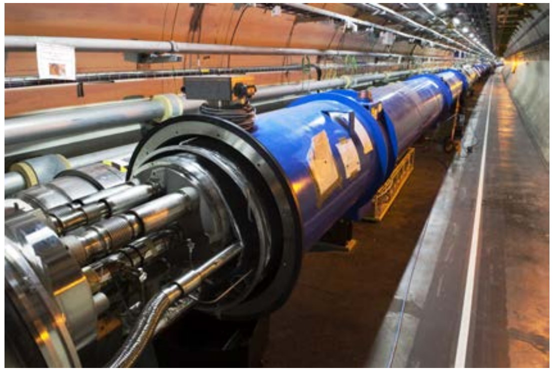
- Wirtschafts Universität Wien, Austria
- NIKHEF, Amsterdam, The Netherlands
- Universität Bonn, Germany
- Bergische Universität Wuppertal, Germany
- Université de Genève,Switzerland
- University of Oslo, Norway
- Institute de Fisica d'Altes Energies, Spain

- IBA Dosimetry GmbH, Germany
- Composite Design SA, Switzerland
- Bgator Oy, Finland
- Centro Nacional de Microelectrónica, Spain
- CIVIDEC Instrumentation GmbH, Austria
- A.D.A.M SA, Switzerland
- CiS Forschungsinstitut für Mikrosensorik und Photovoltaik GmbH, Germany
- Atostek Oy, Finland

TALENT Researchers

WP	Title	WP leader	ESR/ER positions	Hiring institutions
2	Development of very radiation-hard precision pixel sensors	CERN	ESR 1 ESR 2 ESR 3	CiS University of Bonn CERN
3	Development of radiation-hard high-density electronics; interconnection with sensors	University of Bonn	ESR 4 ESR 5 ESR 6	University of Wuppertal University of Bonn CERN
4	New mechanical integration methods	Nikhef	ESR 7 ESR 8 ESR 9 ER 1	Nikhef University of Wuppertal Nikhef University of Geneva
5	Detector performance and system integration	University of Oslo	ESR 10 ESR 11 ER 2 ESR 12 ESR 13	CERN University of Geneva Atostek University of Oslo CERN
6	Dissemination, knowledge transfer and external research funding	Vienna university of Economics and Business	ESR 14 ESR 15	Vienna university of economics and business Vienna university of economics and business

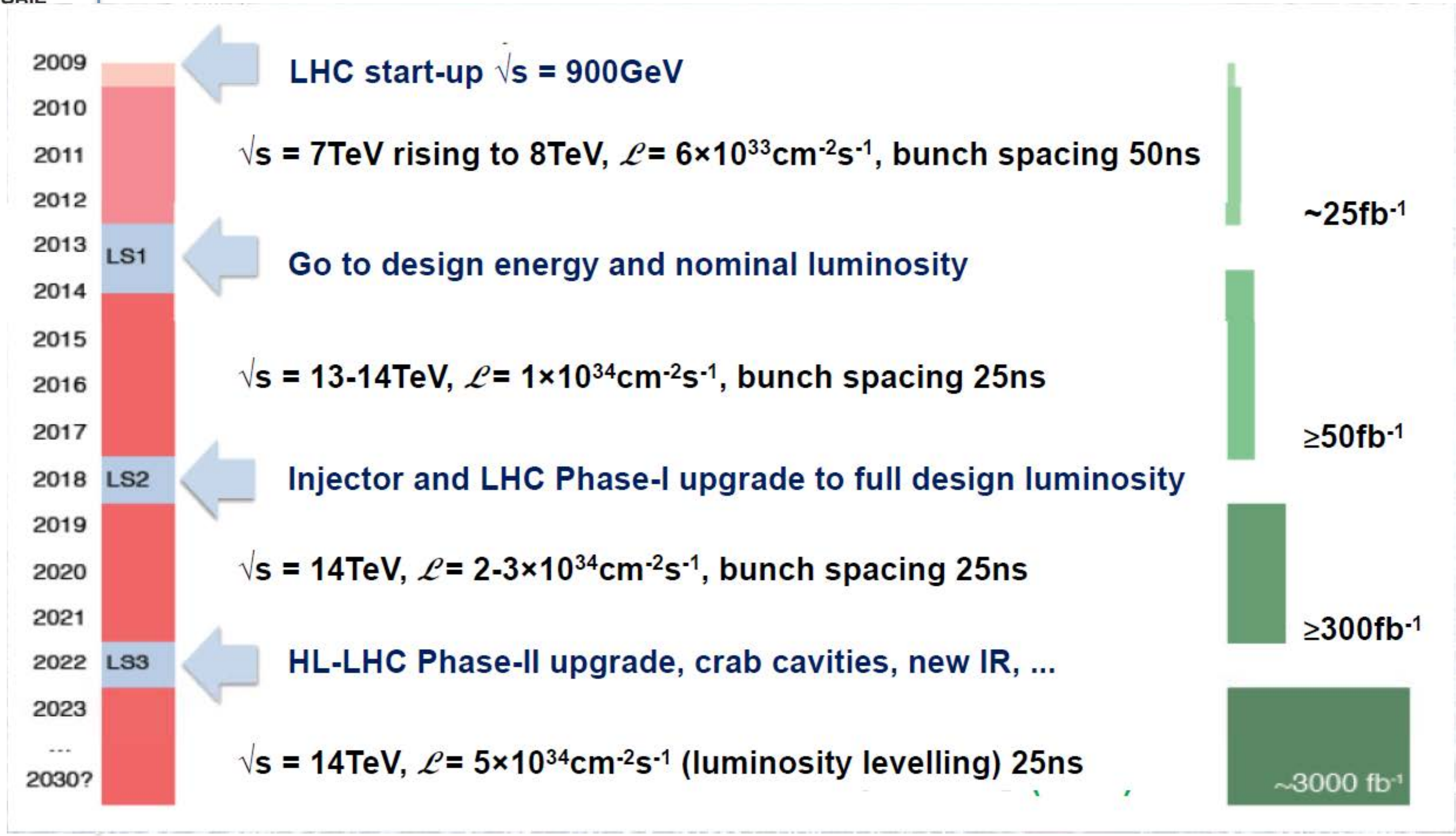
The ATLAS experiment

- The **ATLAS experiment at the Large Hadron Collider (LHC)**
- 2900 scientists from more than 37 countries collaborate in design, construction and data analysis
  - 172 institutes and universities
  - ~ 500 industrial partners during design and construction
- web site: http://www.atlas.ch/

The LHC upgrade program

- From now to HL-LHC:



LHC start-up $\sqrt{s}$ = 900GeV

$\sqrt{s}$ = 7TeV rising to 8TeV, $\mathcal{L}$= 6×10^{33}cm^{-2}s^{-1}, bunch spacing 50ns

Go to design energy and nominal luminosity

$\sqrt{s}$ = 13-14TeV, $\mathcal{L}$= 1×10^{34}cm^{-2}s^{-1}, bunch spacing 25ns

Injector and LHC Phase-I upgrade to full design luminosity

$\sqrt{s}$ = 14TeV, $\mathcal{L}$= 2-3×10^{34}cm^{-2}s^{-1}, bunch spacing 25ns

HL-LHC Phase-II upgrade, crab cavities, new IR, ...

$\sqrt{s}$ = 14TeV, $\mathcal{L}$= 5×10^{34}cm^{-2}s^{-1} (luminosity levelling) 25ns

The ATLAS Tracker upgrade

- Phase-0 Upgrade (2013-14):

The new “Insertable B-Layer” (IBL) will extend the pixel detector system to a 4-layer system with finer segmentation and at smaller radius

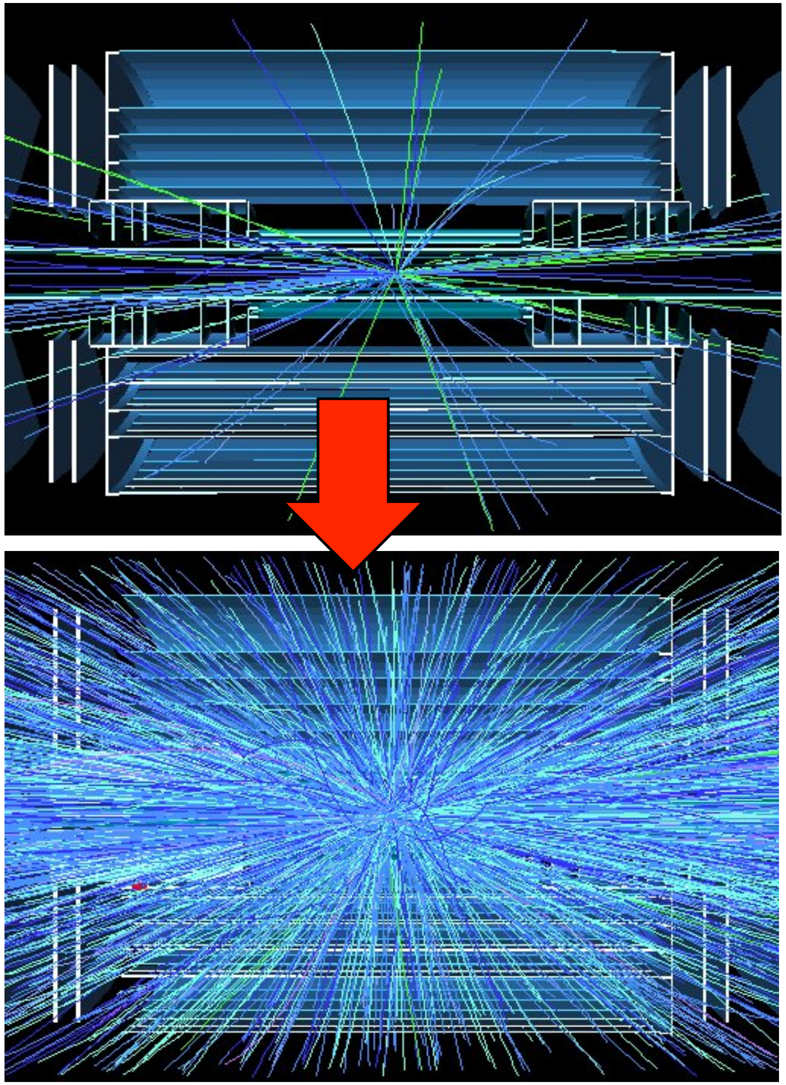
- Phase-2 Upgrade (2022):

Complete new ATLAS tracker for pixels and strip detectors

Challenges for the future

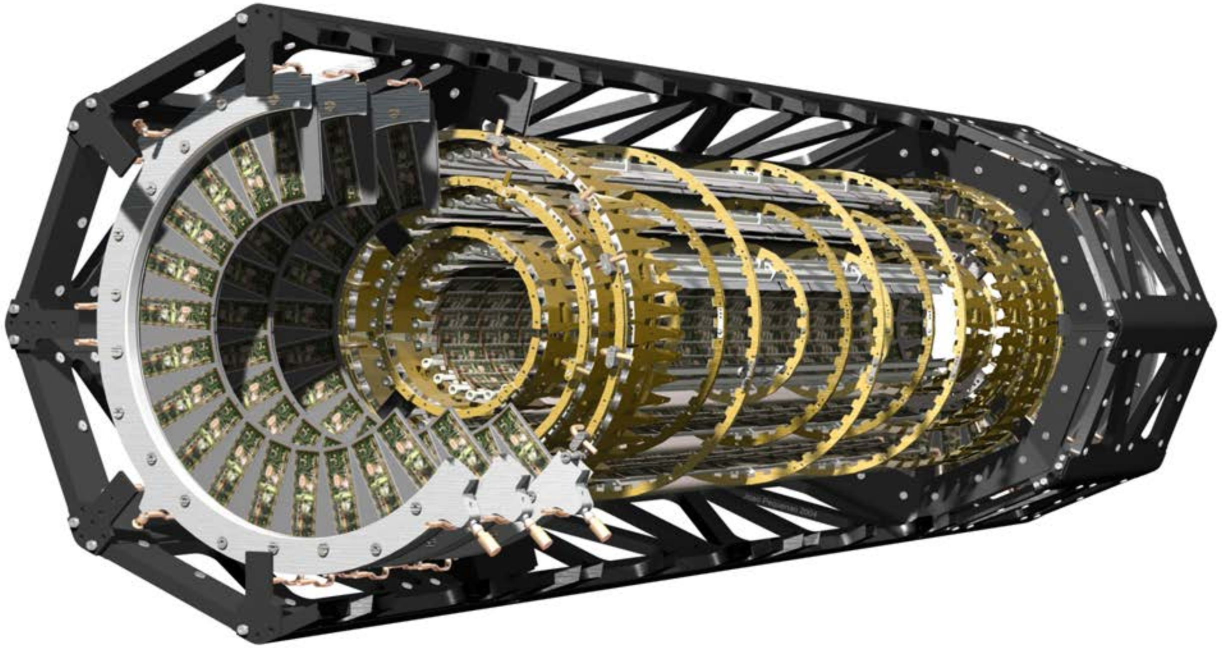
- Increased luminosity requires
  - Higher hit-rate capability
  - Higher segmentation
  - Higher radiation hardness
  - Lighter detectors

- Radiation hardness improvement compared to now
  - IBL approx. factor 5
  - Phase-2 approx. factor 10-30



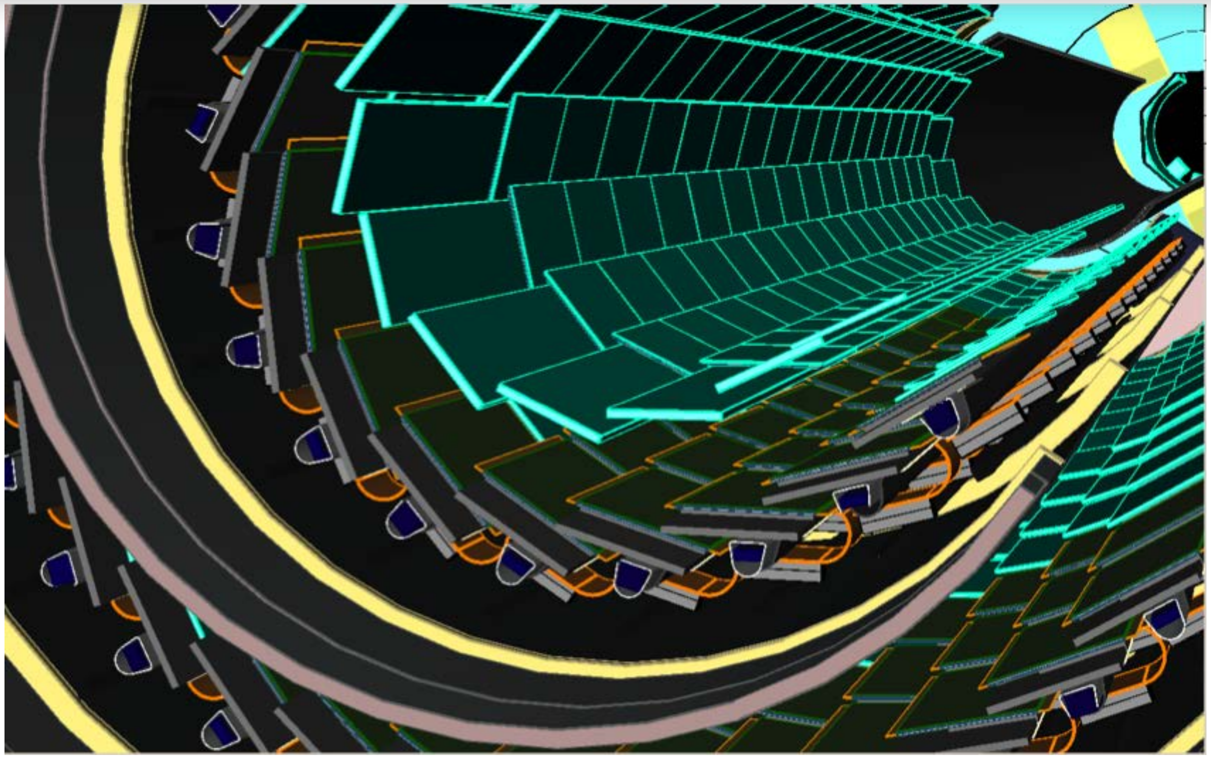
The ATLAS Pixel

- 3-barrel layers + 2x3 disks with planar n-in-n silicon pixel sensors
- 80 million pixels readout with FE-I3 pixel chip (pad size 400x50 μm)
- Radiation hardness ~ 50Mrad , 1 x 10^{15} n_{eq}/cm^2



The Insertable B-Layer “IBL”

- Provide ATLAS with a 4 Layer Pixel Tracker from 2014 onwards
- Maintain and improve physics performance (b-tagging, light jet rejection) until HL-LHC
- Insertion of new pixel inside current pixel detector: Insertable B Layer IBL.
- IBL sensors at ~34mm radius: 250 Mrad TID and 5.10^{15} n_{eq}/cm^2 NIEL.

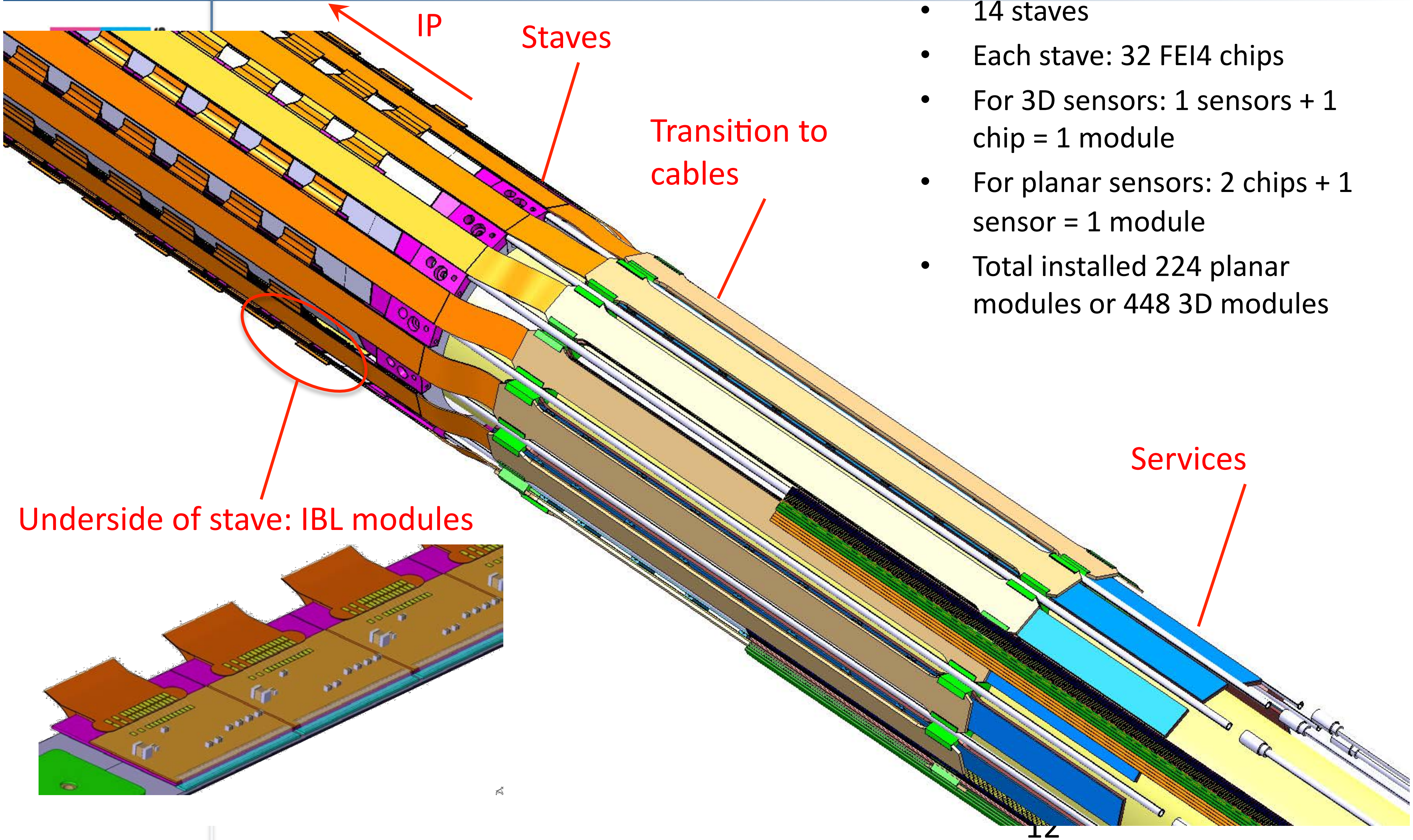


IBL key goals

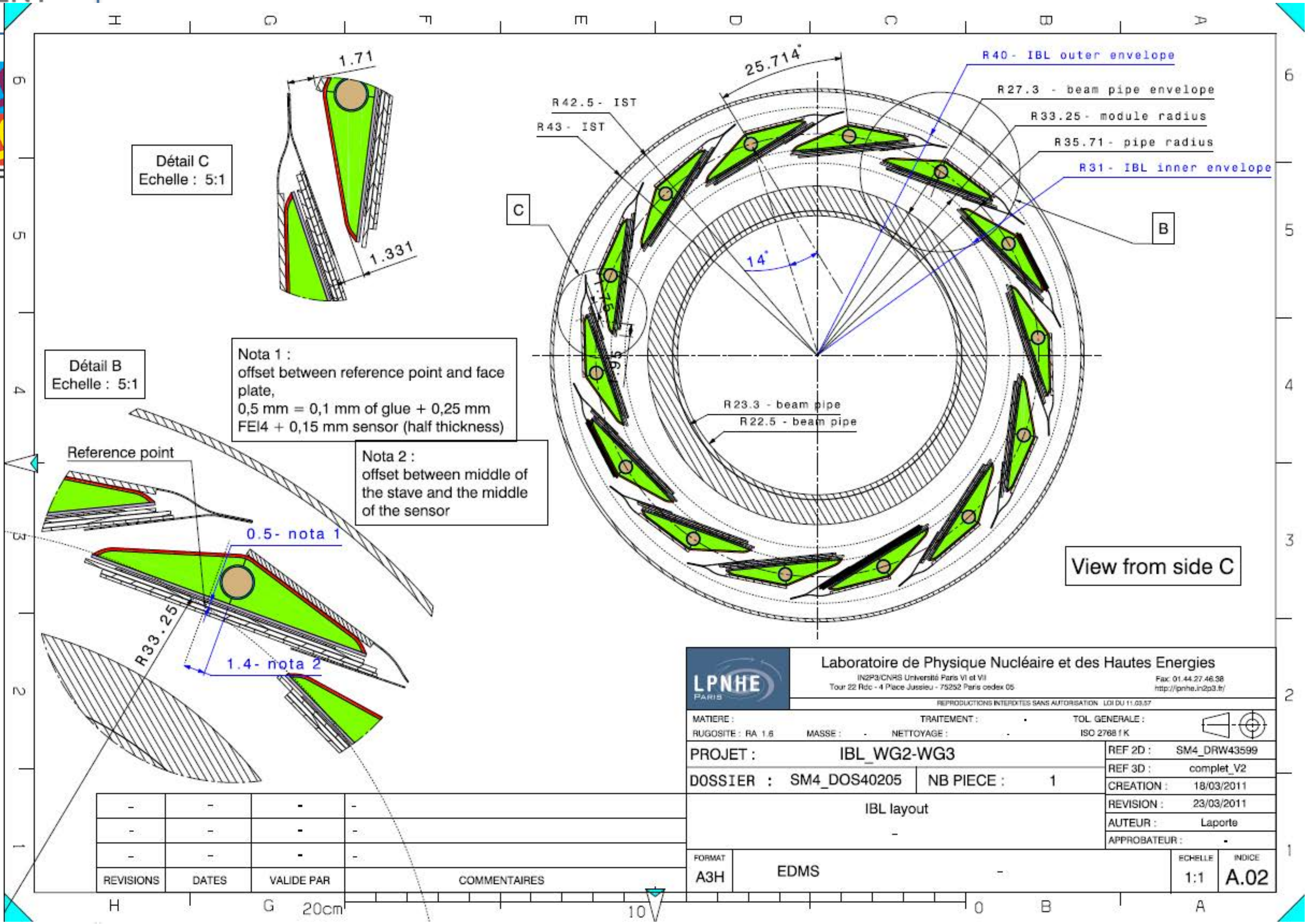
- Sensors with higher radiation hardness:
  - Improve radiation hardness by factor 5 ($5 \times 10^{15}\ n_{eq}/cm^2$)
- New readout chip with fine segmentation, more active area and improved hit-rate capability
  - New readout architecture and smaller cell size 250x50 μm
  - Large single-chip (21x19mm2)
- Lighter detector: less radiation length in support and cooling
  - Improve radiation length per layer from 2.7% to ~ 1.5% to minimize multiple scattering in closest layer
  - Requires lighter and less material for support and cooling
  - High efficiency CO_2 cooling at -40C coolant temperature
- New off-detector readout system
  - Matched to FE-I4 pixel chip & Increase readout speed by factor 2

Stave and module arrangement

- 14 staves
- Each stave: 32 FEI4 chips
- For 3D sensors: 1 sensors + 1 chip = 1 module
- For planar sensors: 2 chips + 1 sensor = 1 module
- Total installed 224 planar modules or 448 3D modules



IBL: 14 staves around beam pipe



Nota 1 :
offset between reference point and face plate,
0,5 mm = 0,1 mm of glue + 0,25 mm FEI4 + 0,15 mm sensor (half thickness)

Nota 2 :
offset between middle of the stave and the middle of the sensor

-	-	-	-
-	-	-	-
-	-	-	-
REVISIONS	DATES	VALIDE PAR	COMMENTAIRES

LPNHE PARIS

Laboratoire de Physique Nucléaire et des Hautes Energies
IN2P3/CNRS Université Paris VI et VII
Tour 22 Rdc - 4 Place Jussieu - 75252 Paris cedex 05
Fax: 01.44.27.46.38
http://lpnhe.in2p3.fr/

REPRODUCTIONS INTERDITES SANS AUTORISATION LOI DU 11.03.57

MATIERE :
TRAITEMENT : -
TOL. GENERALE :
RUGOSITE : RA 1.6
MASSE : -
NETTOYAGE : -
ISO 2768 f K

PROJET : IBL_WG2-WG3
DOSSIER : SM4_DOS40205
NB PIECE : 1

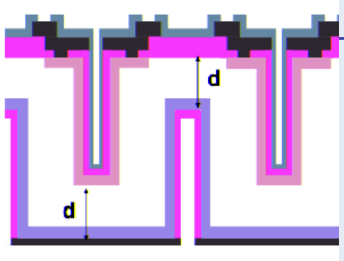
IBL layout
-

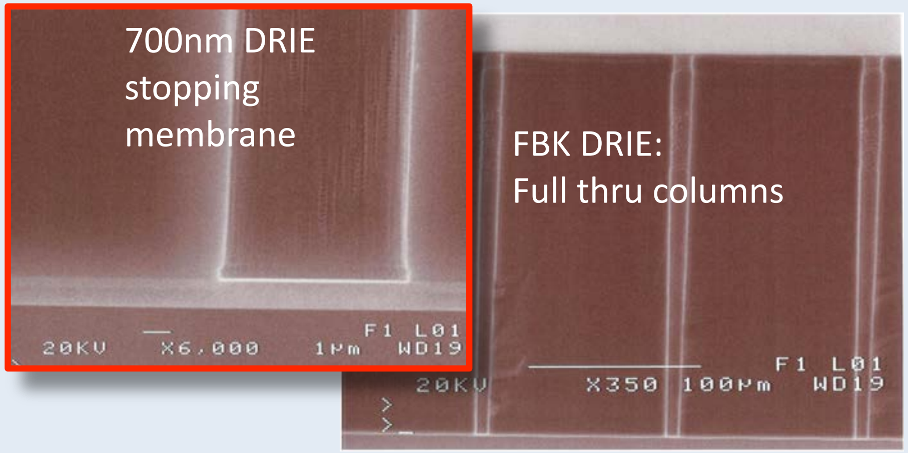
REF 2D : SM4_DRW43599
REF 3D : complet_V2
CREATION : 18/03/2011
REVISION : 23/03/2011
AUTEUR : Laporte
APPROBATEUR : -

FORMAT A3H
EDMS
-
ECHELLE 1:1
INDICE A.02

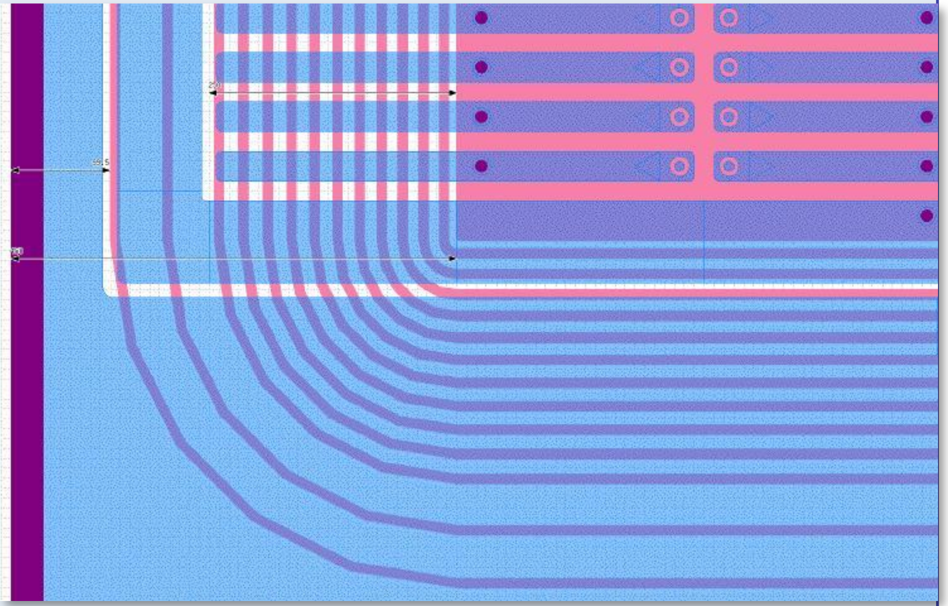
Silicon Sensor : 3D and Planar

3D slim edge (CNM, FBK)	Planar n-n Slim Edge Design (CiS)
○ column through ~full bulk 2 electrodes per pixel ○ depletion horizontally (short depletion width leads to low bias voltage) ○ Manufacturing yield now being tested with pre-production runs by CNM and FBK	○ minimize inactive edge by shifting guard rings underneath active pixel region . ➔ 200 – 250 μm inactive edge achievable ○ test signal after full IBL irradiation now ○ manufactured by CiS similar present Pixel



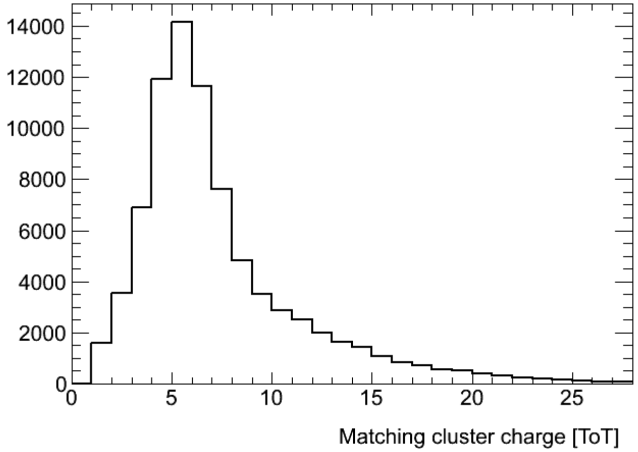

700nm DRIE stopping membrane

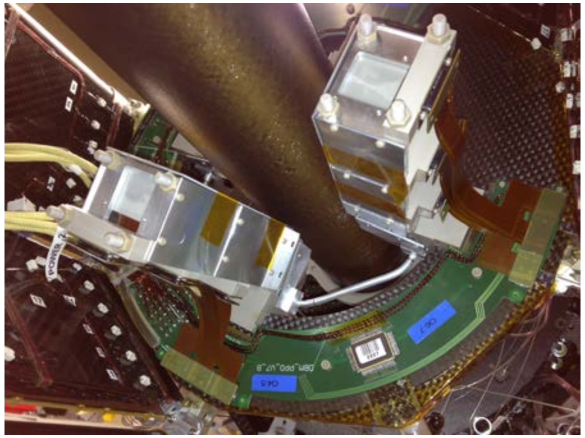
FBK DRIE: Full thru columns



CVD diamonds in Beam Monitor

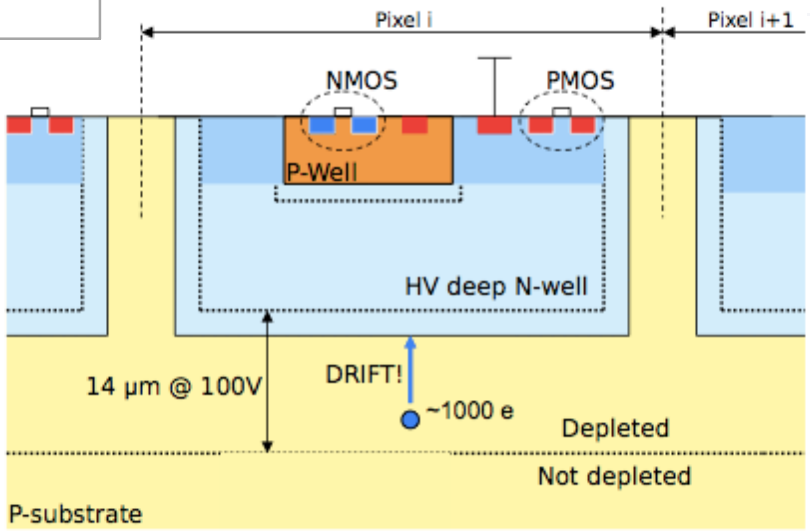
- The Diamond Beam Monitor (DBM) for ATLAS
- Monitors the luminosity for each bunch in real time
    - 24 DBM modules arranged in 8 telescopes
    - 21x18 mm^2 polycrystalline CVD diamonds
    - FE-I4 ATLAS IBL pixel chip
    - 336x80 = 26880 channels, 50x250 μm^2





Depleted CMOS sensors

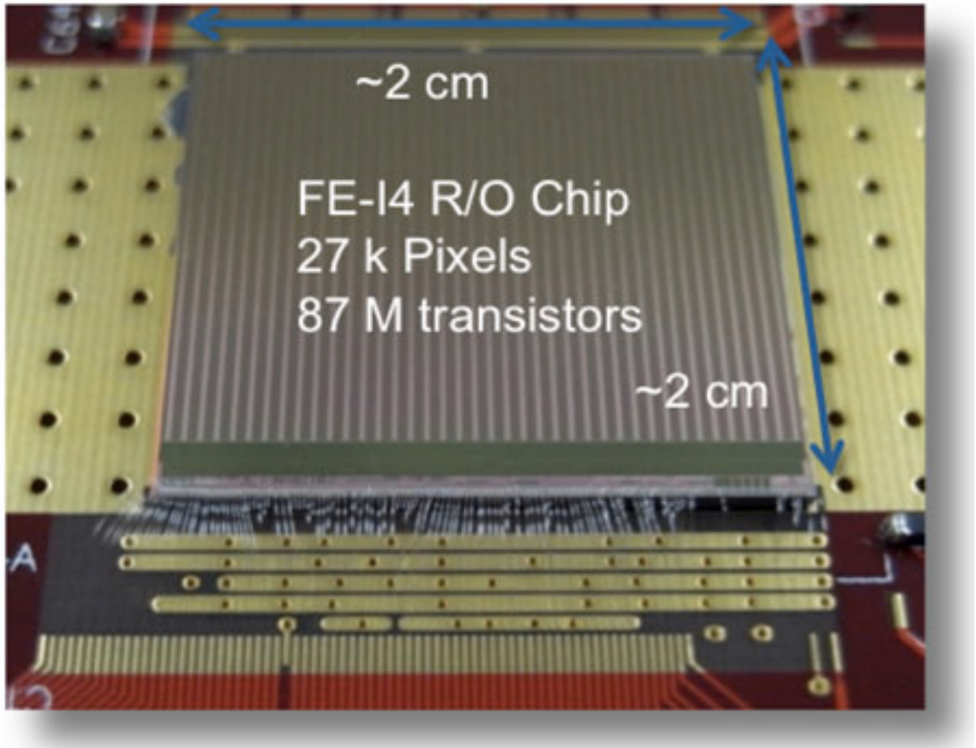
- Traditionally used specialty process to fabricate silicon sensors on high-resistivity silicon – costly and not many vendors for larger volumes
- CMOS sensors are used for imagers in camers, i.e. for photon detection at low energies -> large volume at lower price
- Combine processes to allow charged particle detection: **Depleted HV-CMOS sensors**



- Create depleted volume under n-well -> this serves as volume for particle detection
- Electronics is include in sensor pixel -> “Smart Pixel” allows first processing of information on sensor
- In some processes all sensor and electronics can then be integrate on same chip
- **Depleted Monolythic Active Pixel Sensor (DMPAS)**

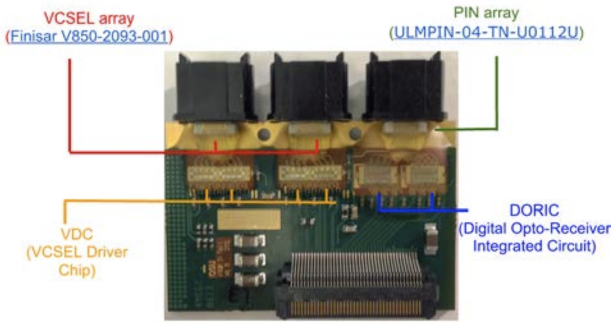
New generation Pixel FE chip

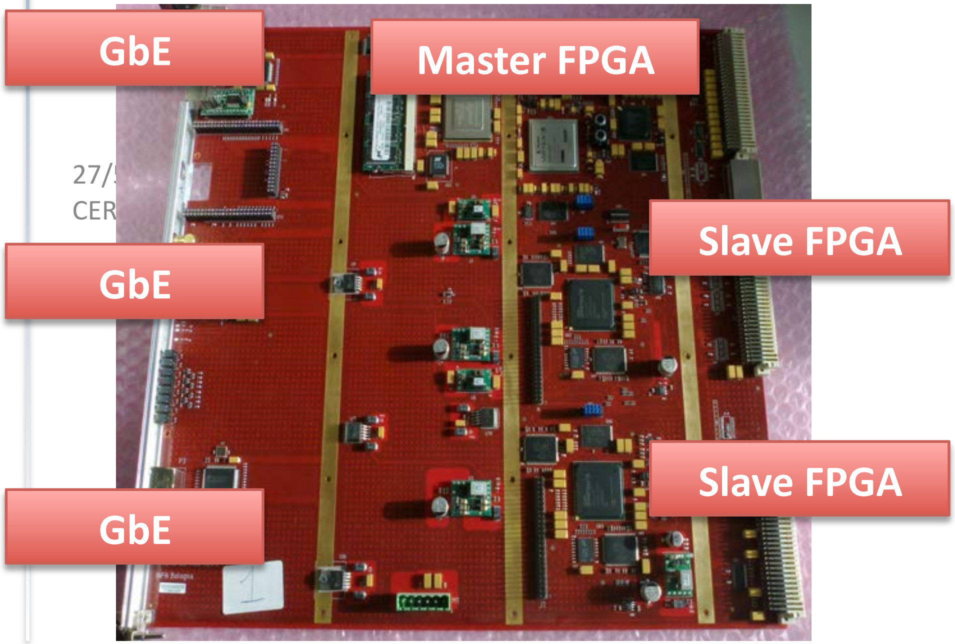
- The ATLAS FE-I4 pixel readout chip in IBM 130nm CMOS
  - New architecture for higher efficiency at high hit rates
  - Smaller pad side to improve pattern recognition and impact parameter resolution
  - Higher radiation hardness (~300Mrad)

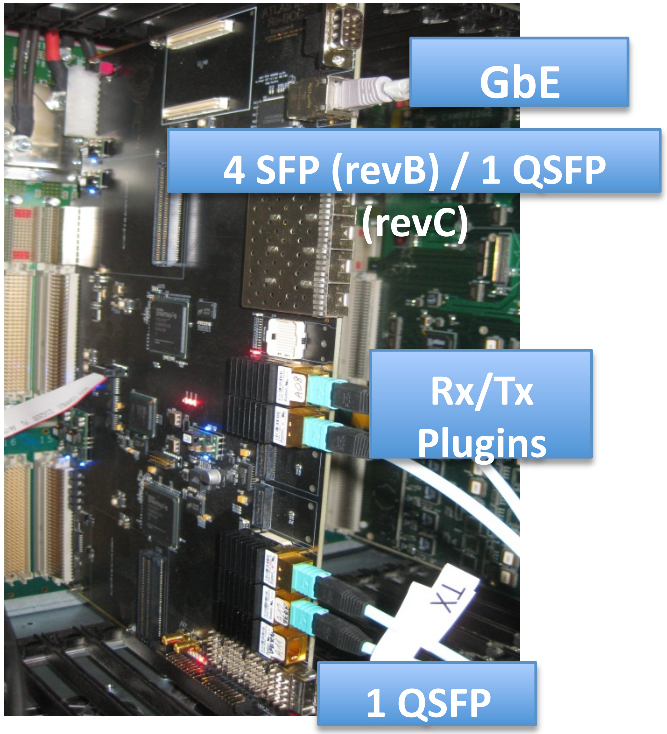


Detector readout: new system

- **Readout Driver (ROD) upgrade to twice speed (160Mb/s):**
  - **ROD firmware design is ongoing**
- **The design of a full DAQ chain simulation environment has started**
- **Back-of-Crate card (BOC): makes optical data/cmd link from control room to IBL modules**
- **Detector opto-link:**
  - Placed near IBL inside ATLAS detectors
  - Converts electrical data/cmd/clk LVDS signal to opto signal for transmission to counting room (~100m)

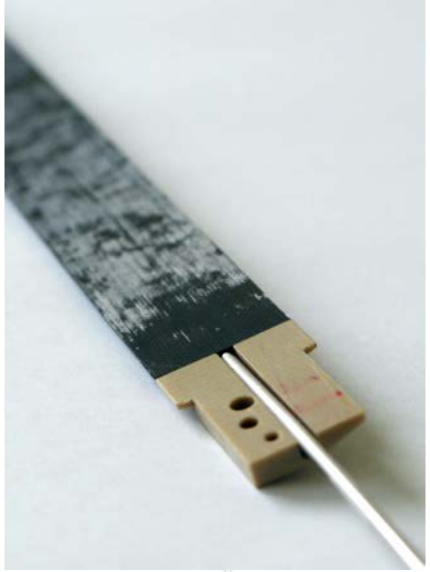


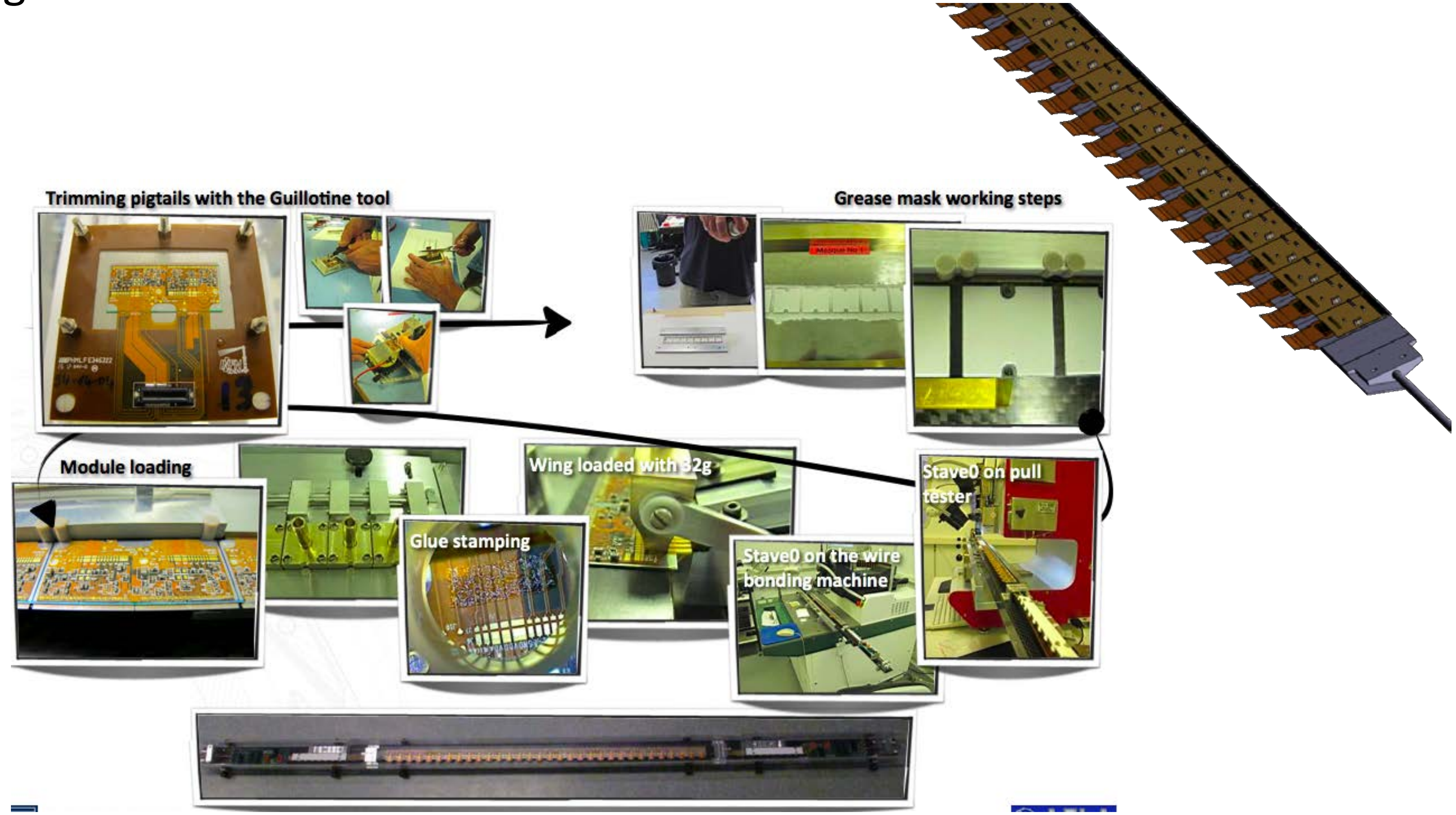




Carbon-Fibre supports

- Carbon-fibre support structure with minimal material
- Optimize stiffness and thermal conductivity as well as match thermal expansions
- Qualify material for use in high-radiation environments (300Mrad at IBL)
- Cool detectors with CO2 system at -40C coolant temperature to minimize leakage currents on sensors





IBL integration: Staves and beam pipe

New ATLAS VI beam pipe: ready for integration

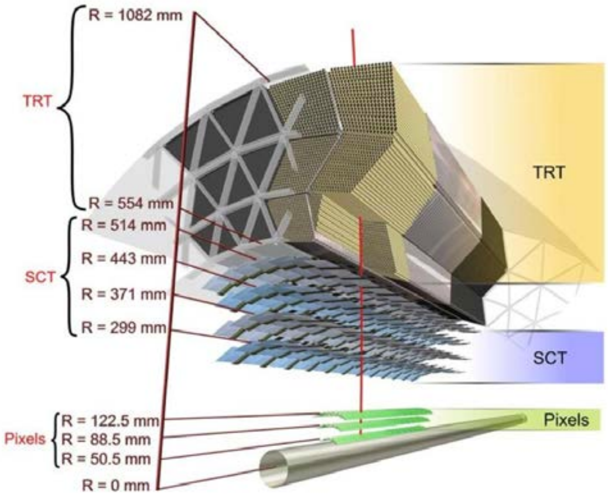
1.) Setup beam pipe on tool in ATLAS SR1

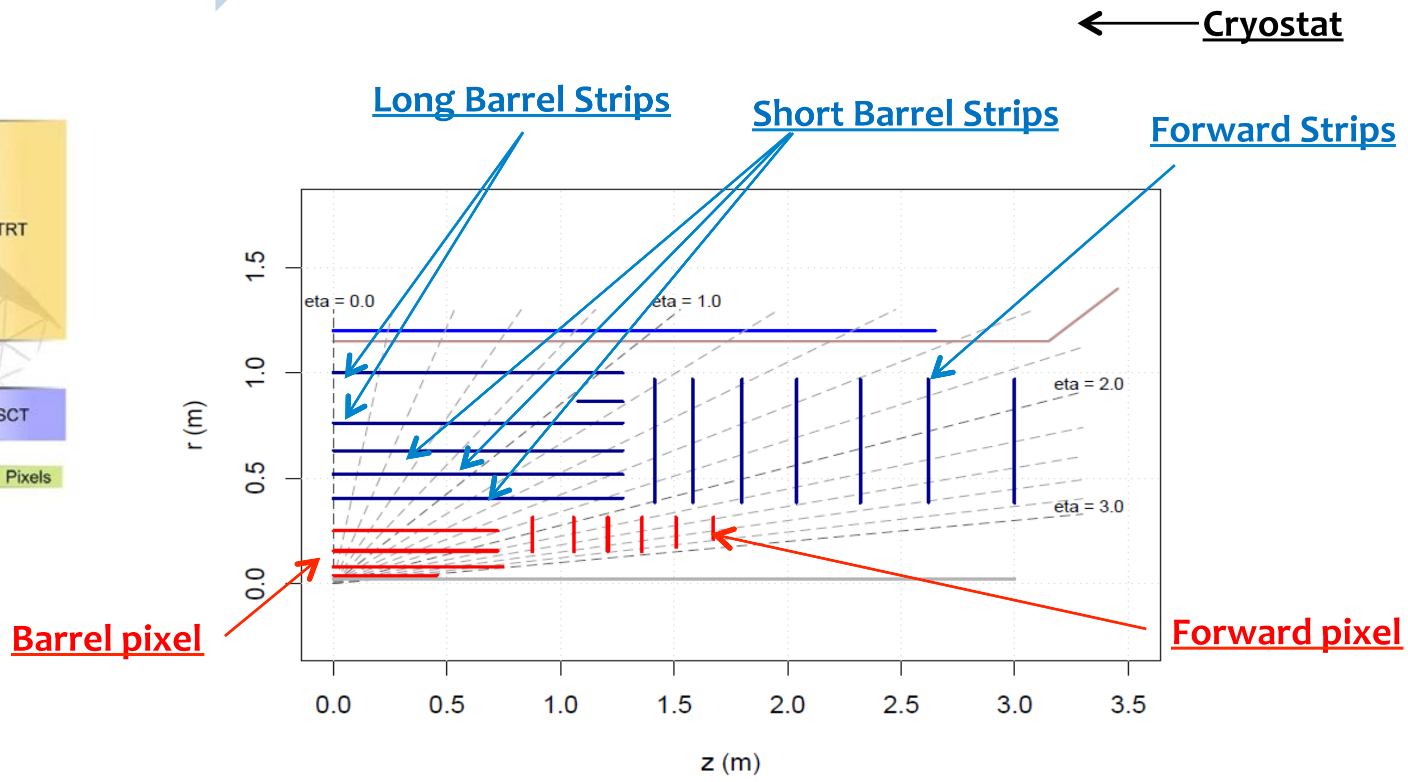
2.) mount each stave around beam pipe, connect to services, test

Transfer of beampipe to support

Integration with beam pipe (in SR1 at CERN)

ATLAS Tracker for 2022->





Cryostat

Long Barrel Strips

Short Barrel Strips

Forward Strips

Barrel pixel

Forward pixel

All Silicon tracker for Phase 2 (TRT would not cope with occupancy)

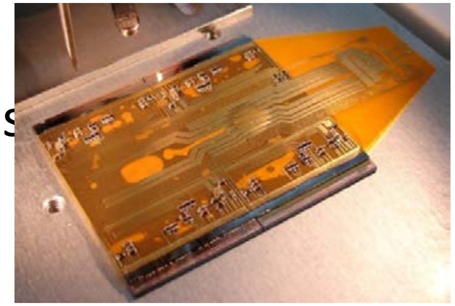
Baseline layout of the new ATLAS inner tracker for HL-LHC

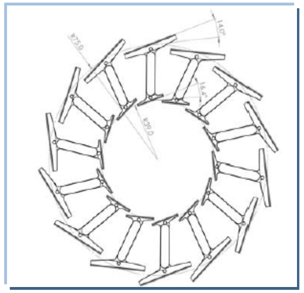
Aim to have at least 14 silicon hits everywhere (robust tracking)

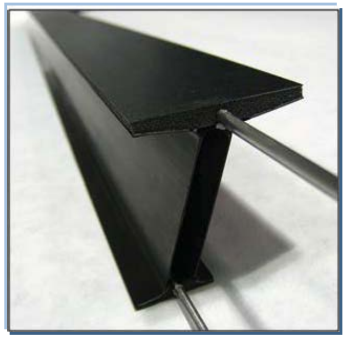
New All-silicon Inner Tracker

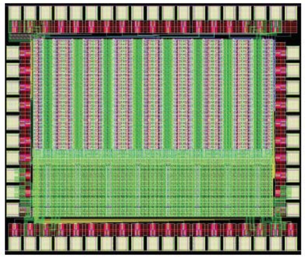
Pixel Detector

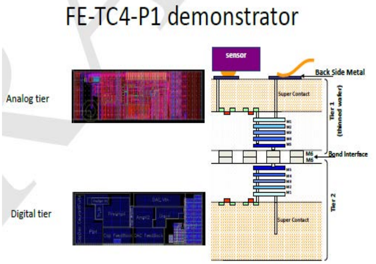
- Pixel sensors in several technologies proved to high doses (planar/3D/diamond shown to $2\times10^{16} n_{eq}/cm^2$)
- IBL pixel (50×250µm) OK for outer pixel layers, but can go down to 25µm×125µm pixels with 65 nm CMOS
- Test structures in 65nm produced and even studies after irradiation
- Larger area sensors quads/sextuplets produced on 150mm diameter wafers with several foundries
- Quad pixel module produced, being tested and results look promising







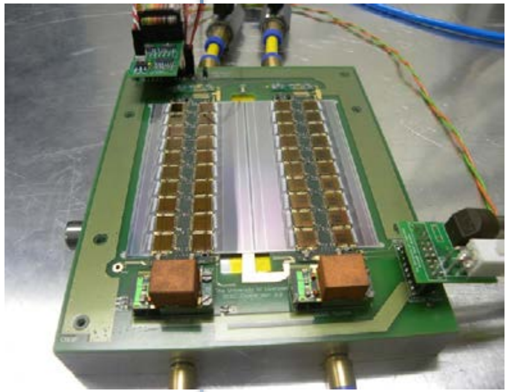


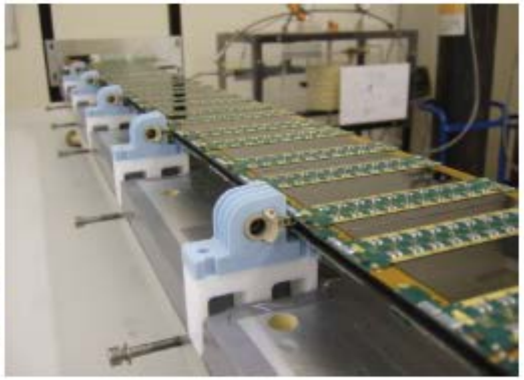


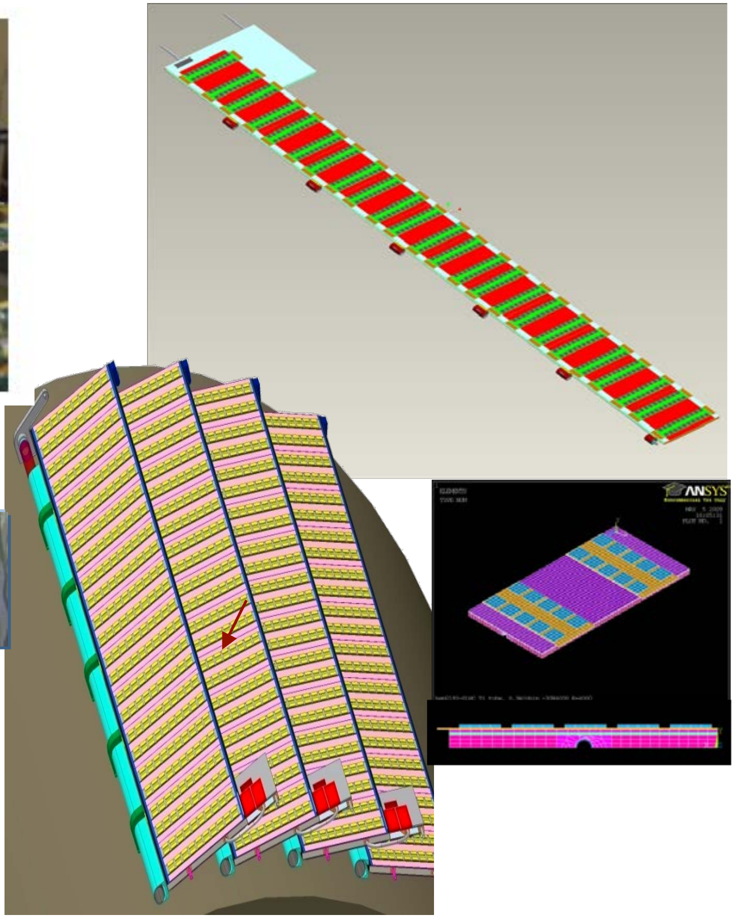
New All-silicon Inner Tracker

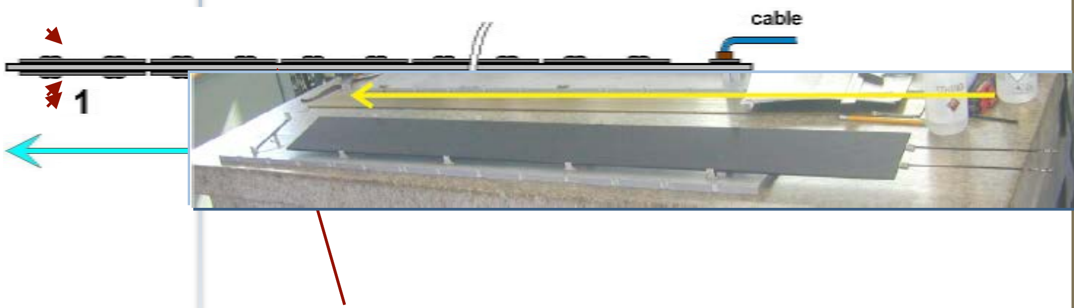
Strip Detector

- Strip stave/padel = Hybrid glued to Sensor glued to bus tape glued to cooling substrate



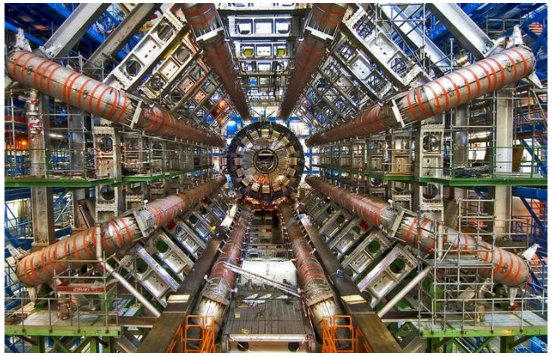






TALENT Research

- Provides research to **upgrade the LHC at CERN** by developing new state-of-the-art technologies for a new precision pixel detector for the ATLAS experiment, the Insertable B-layer detector (IBL), and for future precision tracking detectors.



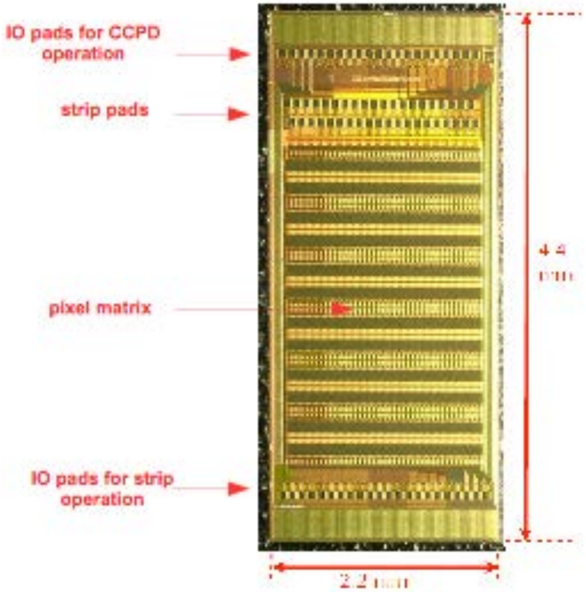
- The TALENT research topics are
    - Radiation-hard precision pixel sensors
    - High-density electronics and interconnection
    - New mechanical supports and detector cooling
    - System integration and performance

- TALENT has also a special focus on dissemination, knowledge transfer and external research funding.

- Scientific work in TALENT is organized around 5 Work Packages

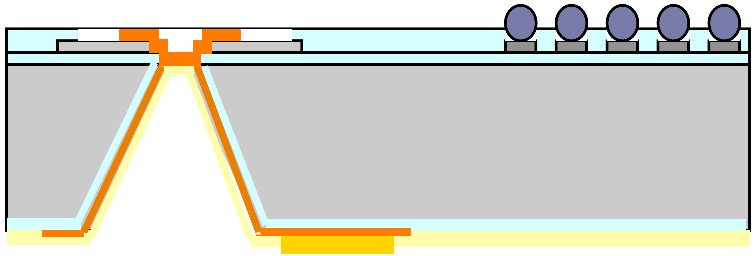
WP2: Precision Sensors

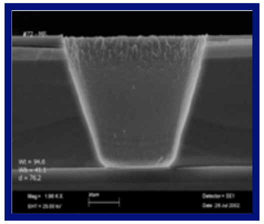
- Optimizing different designs for IBL
- sensor technologies under investigation: silicon planar and CMOS, silicon 3D and CVD diamonds
- Measure charge collection properties
- Investigate radiation hardness
- Study designs for pixel detectors’ and beam monitors

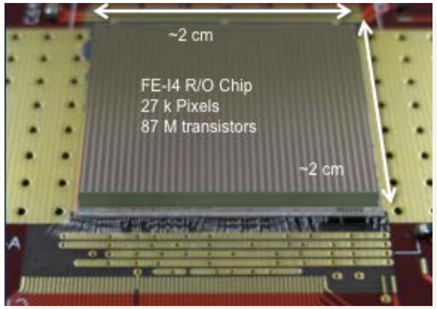


WP3: Electronics and Interconnection

- New data transmission and off-detector readout system
- Qualification and system testing of readout and powering systems
- New pixel front-end readout ASICs and DMAPS
- Research in 3D integration methods (through-silicon-vias) for future high-density pixel detectors
- New powering schemes for future trackers

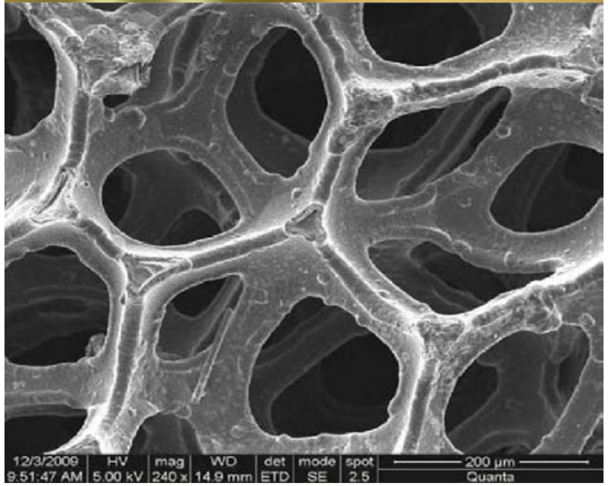






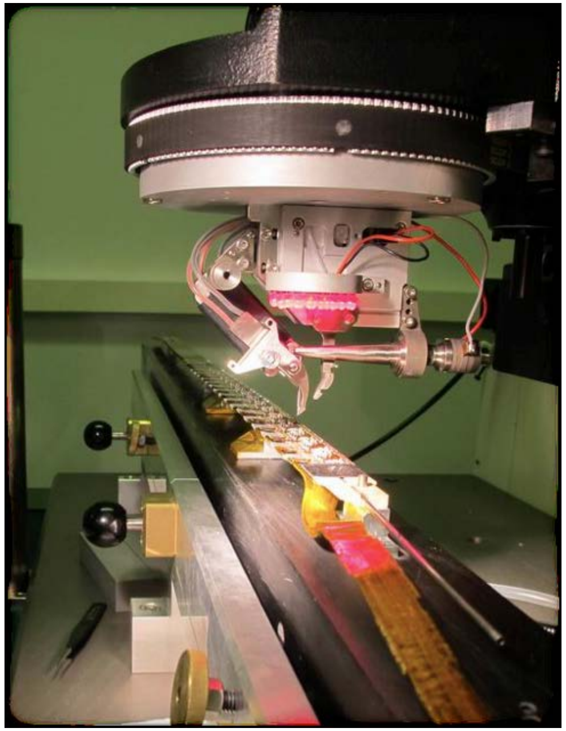
WP4: Mechanics and Cooling

- Design of **light-weight stiff composite structures** for detector support
- Qualification of materials
- Measurements of thermo-mechanical properties on support prototypes
- Design and construction of high-efficiency **CO2 cooling system**
- Common CAD software procedures for integration



WP 5: System integration

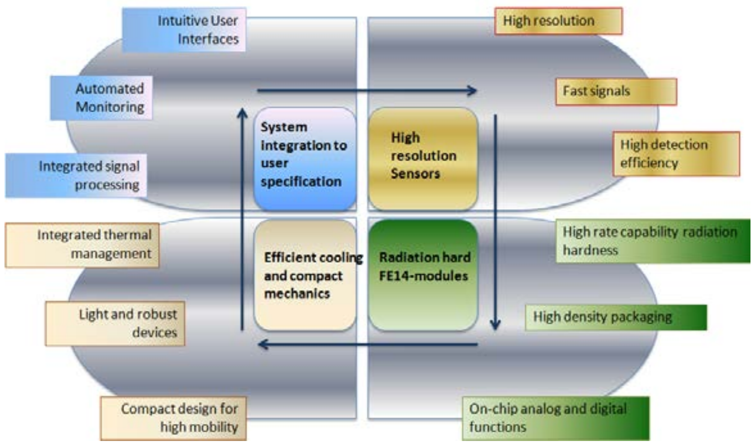
- **Prototypes**
    - Design and construction of prototypes for the IBL detector integration – qualification of thermal and mechanical properties
- **Signal processing software**
    - Development and optimization of signal processing software
- **Offline data analysis software**
    - Software to decode and analyse data to reconstruct hit position in pixel detector
- **Integration of modules on staves**
    - Integration of modules on staves and qualification of staves
- **Integration of staves**
    - Integration of staves to the full detector system and detector commissioning
- **Overall IBL performance characterization**



WP 6: Knowledge Exchange

- Study current **technology needs** in ATLAS
- Create map of external **R&D funding** instruments
- **Benchmark** available knowledge and technology transfer methods
- Stimulate **knowledge exchange with industrial partners**
- Business study to find **industrial applications**

- **TALENT:** Linking the technologies' core benefits



Questions? Comments?