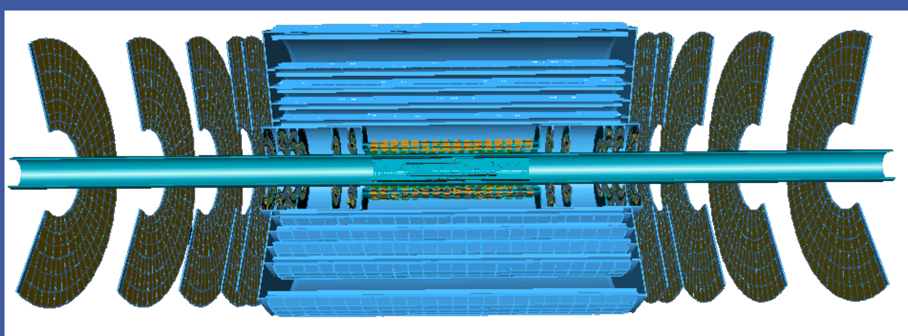
Status of the DESY ATLAS Upgrade Activities

Ingrid-Maria Gregor

- LHC Upgrade Schedule
- IBL Activities
- Endcap Strip Activities



ATLAS Inner Detector - UTOPIA Layout (>2020)

PETAL2014.

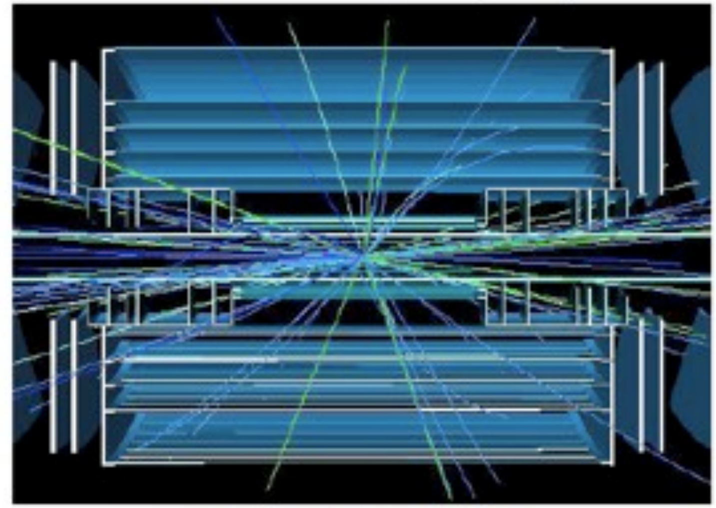
Why Upgrade?

- The new discoveries hoped for will need a lot of data to understand their nature
  - Higgs parameters
  - SUSY – spectroscopy
  - Triple gauge couplings
  - VV scattering at ~1 TeV
- In addition, the potential is significantly extended for (more difficult) physics discoveries

Detector Challenges

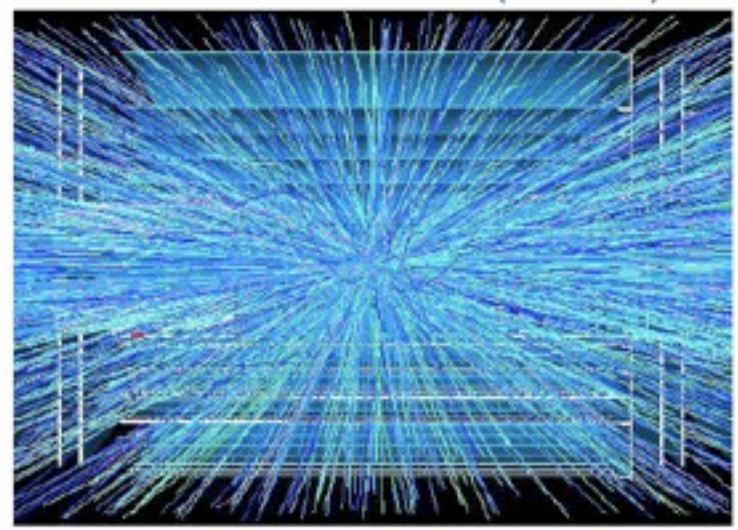
- **event pile-up, hit rates, occupancies ...**
  - improve on: material, trigger, pattern recognition, data BW, data storage
- **radiation damage**
  - improve on:materials, electronics, links, ageing, …

$0.2 \times 10^{34}\ cm^{-2}s^{-1}$ (2013)



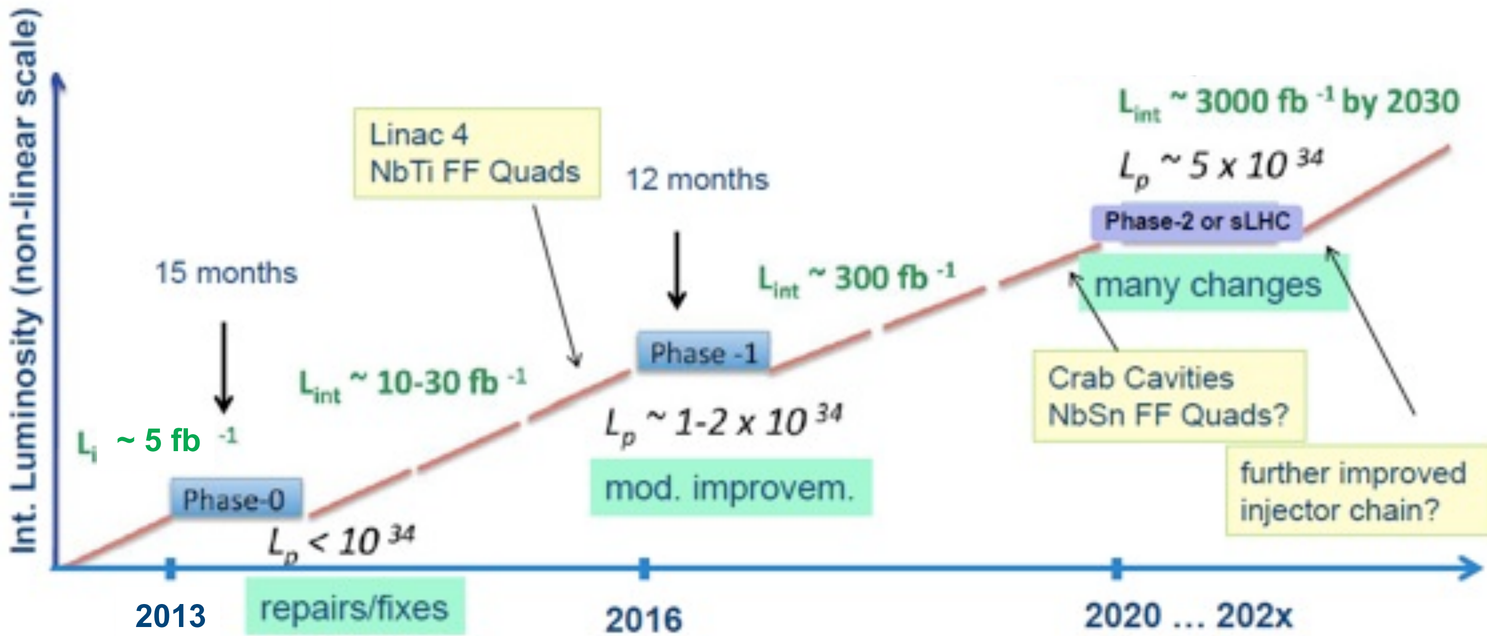
5 collisions per BX

$1 \times 10^{35}\ cm^{-2}s^{-1}$(>2025 ?)



400 collisions per BX (100 with luminosity levelling)

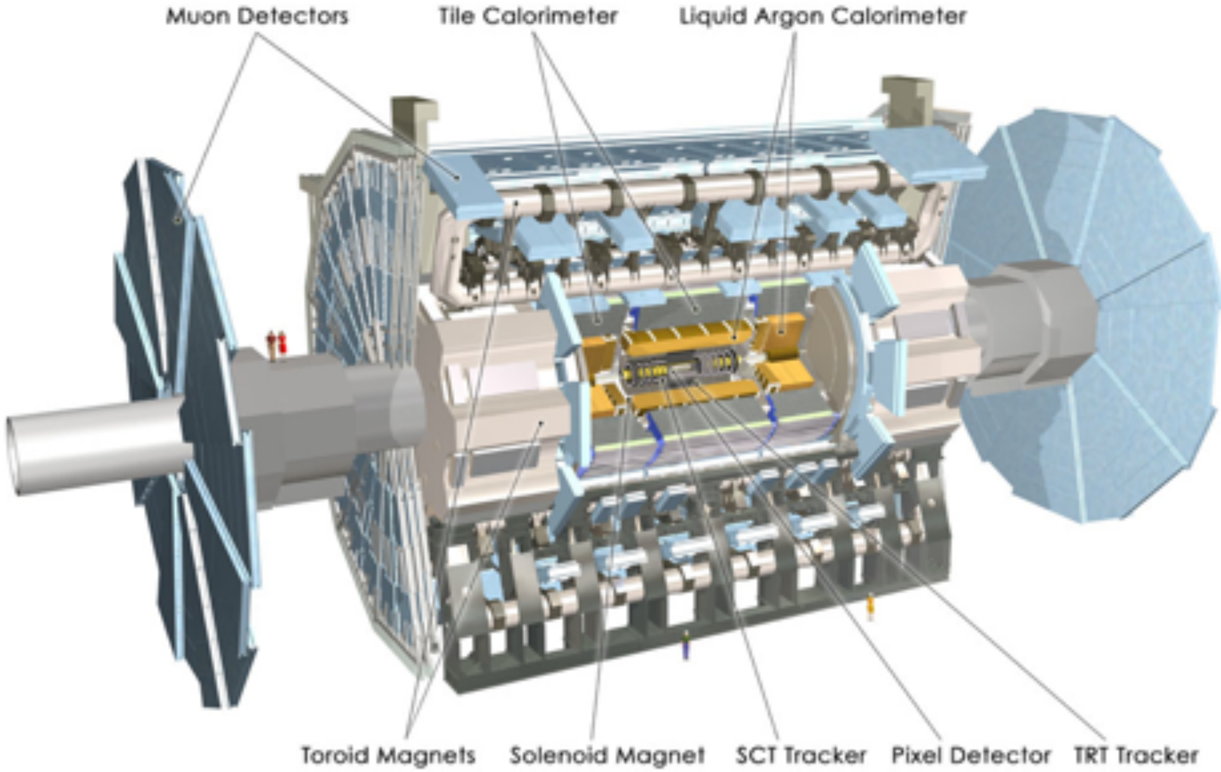
Tentative Schedule LHC Upgrade



- LHC schedule was just revised (see Bulletin last night)
- Main change: LHC is going to run in 2012
- The beam energy will likely remain 3.5 TeV in 2011, based on a careful assessment of risks vs benefits.
- 15 months shutdown shifted to 2013

Tentative ATLAS Plans

- Schedule as planned until recently
- Phase 0 (2012):
  - Pixel: opto-electronics repair
  - Muon/forward: Beam-pipe -> Beryllium
  - Infrastructure consolidation



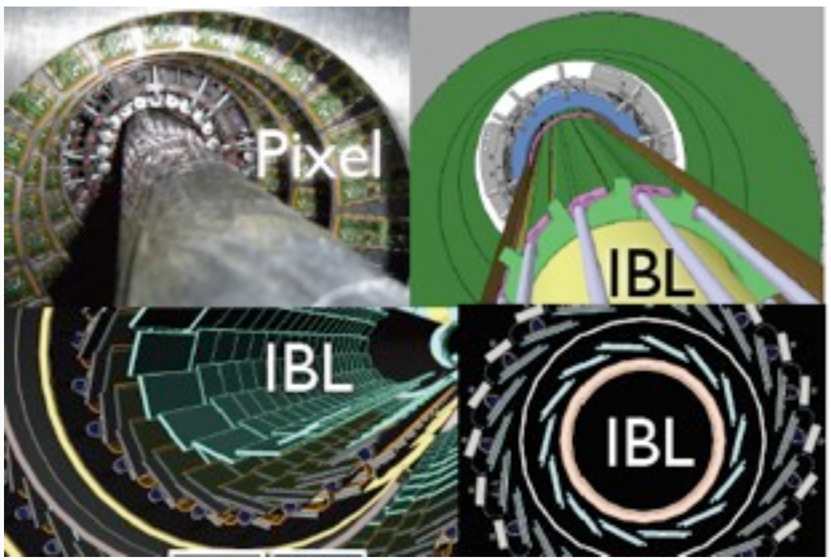
- Phase 1 (>2016):
  - **Pixel: Insertable B-Layer (IBL) ??**
  - Muon: additional SCS layers
  - TDAQ: moderate upgrades, improved level-2 triggers
  - minor consolidations: TRT HV PS, LAr LV PS, ...
- Phase 2 (>2020):
  - **ID: new tracker**
  - LAr: barrel electronics and new forward elements
  - Tile Calorimeter: new electronics
  - Muons: new forward layers
  - TDAQ: major upgrades

Phase I: Insertable B-Layer (IBL)

New innermost layer around smaller beam-pipe, 14 staves, 160 MHz readout, evaporative cooling (CO_2)

Expected improvement

- IP res Z: 100µm->~60µm
- IP res RΦ : 10µm -> 7µm
- B-tagging: Light Jet rejection factor improves by factor~2
- BUT: to maintain Pixel Detector performance with inserted layer the material budget is critical.



- The heart of the detector - three different sensor options under study:
  - Planar sensors
  - 3D sensors
  - Diamond sensors

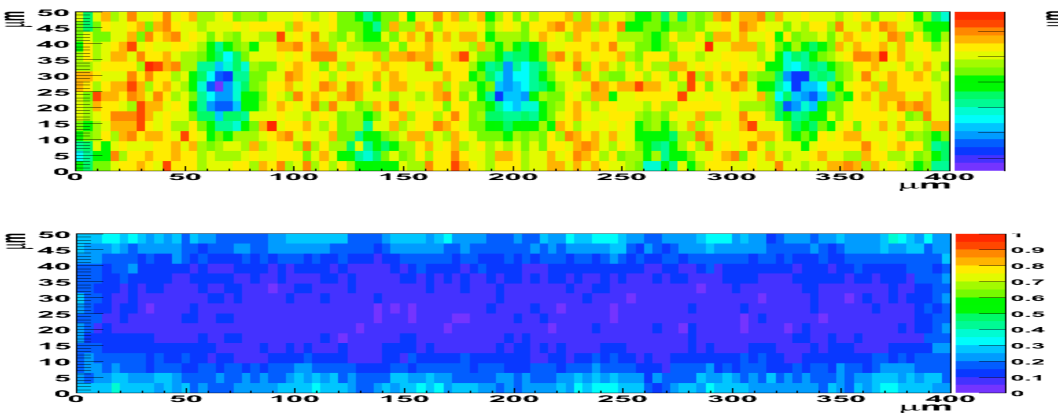
➡ to choose the right sensor type all sensors need to be tested under the same conditions

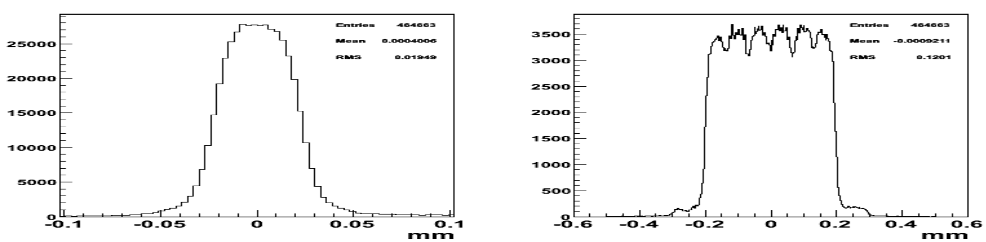
- New Front End chip needed to be ready for higher occupancy and radiation environment

➡ to be ready for a production this year -> test beam as soon as possible

DESY Contribution to IBL

- Procurement and testing of optical links
- Provision and running of EUDET telescope
  - hardware support
  - data taking and analysis
  - maintenance of analysis software
  - extension of software for ATLAS pixel sensors





EUDET telescope

- Ready for FE-I4 IBL test beams at **DESY**
- February: first test beam of FE-I4
- April: test beam of irradiated FE-I4
- Summer: a number of test beams of sensors at CERN (with EUDET telescope)

➡ important input to sensor decision and chip assessment

PETAL2014.

Phase II: Strip ENDCAP

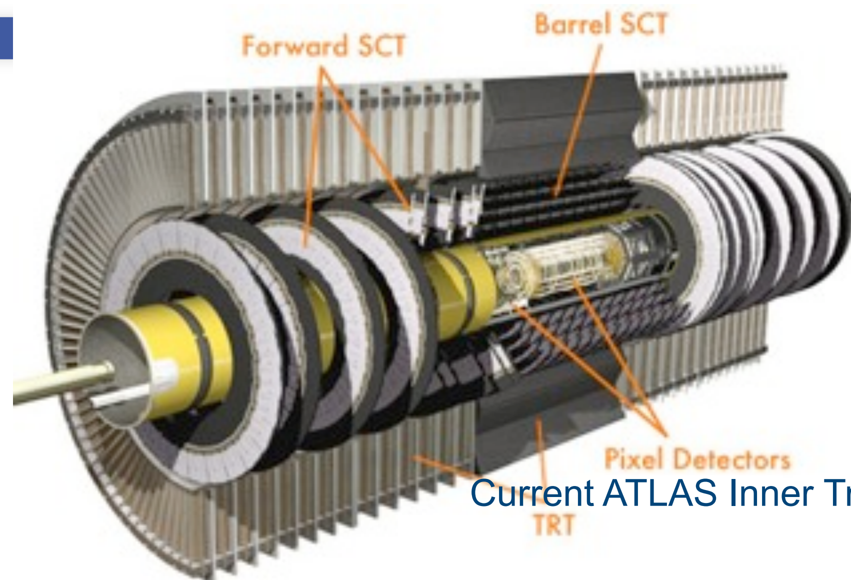
- New Silicon strip detector will consists of barrel and two end caps
- The diameter of the end cap discs increases to 2 m (~double of current diameter)

- DESY is preparing for high-visibility large-scale upgrade projects.
- In ATLAS: main assembly site for one full end cap -> highly welcome with ATLAS management and strip detector upgrade community

- 5 discs on each side
  ➔R_{out}= 95.0cm
  ➔R_{in} = 33.7cm for all but the last disc.

  ➔Short strip sensors up to R~60cm (2cm)
  ➔Long strips up to Rout (6cm)

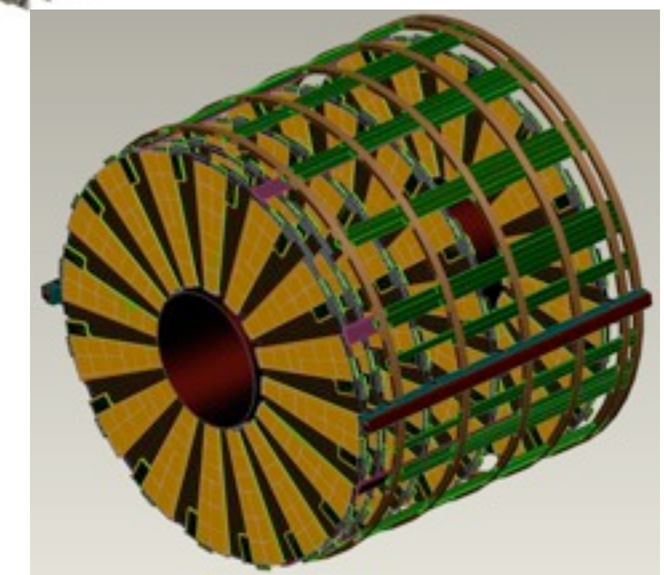
One endcap about 30 m^2 silicon !!
5 discs = 160 petals = 1440 modules



2 m

Current ATLAS Inner Tracker

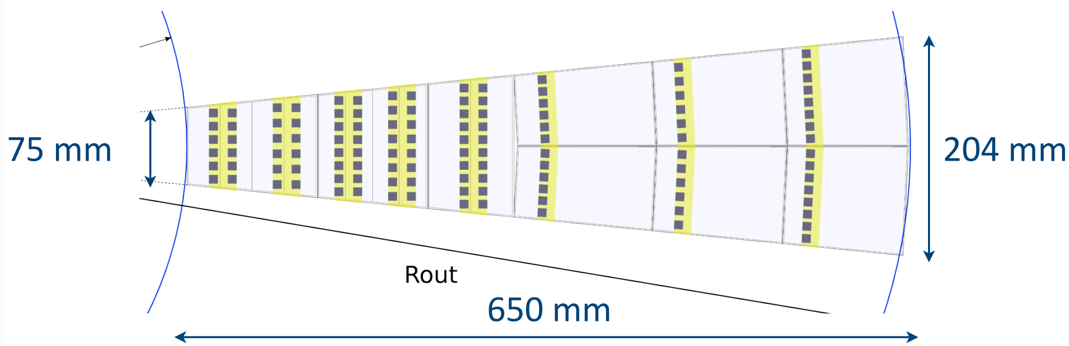
2 m



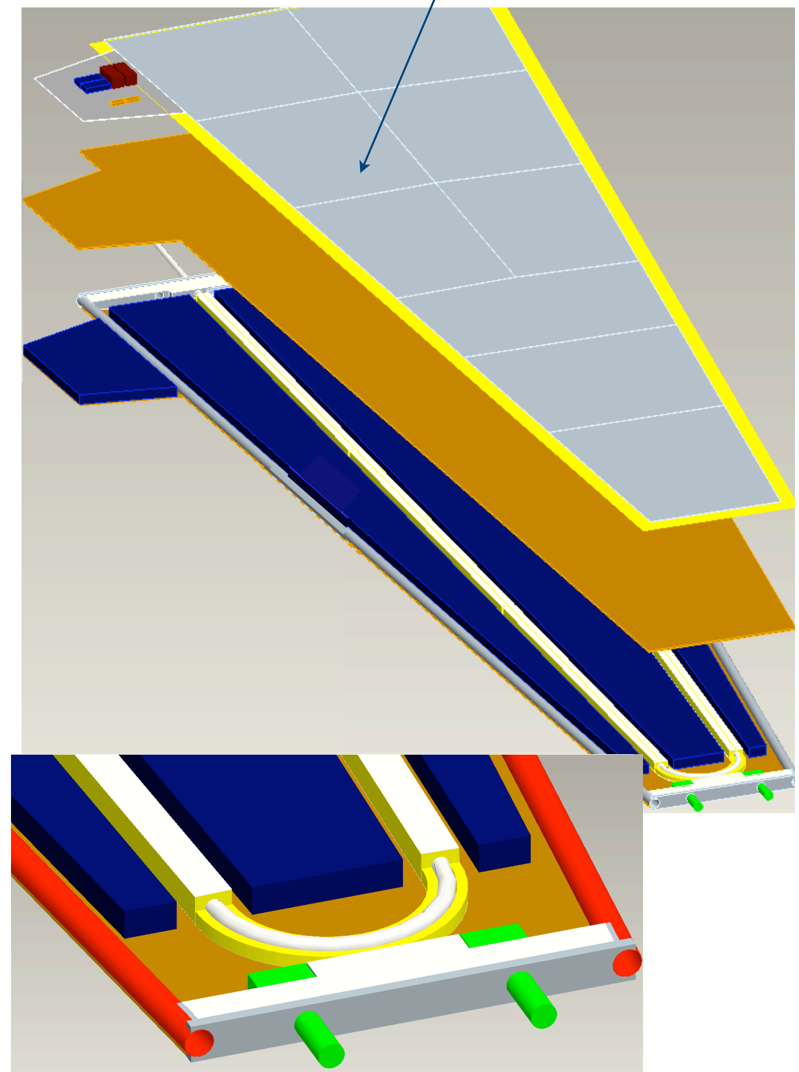
Possible Strip Endcap Design

What is a petal ?

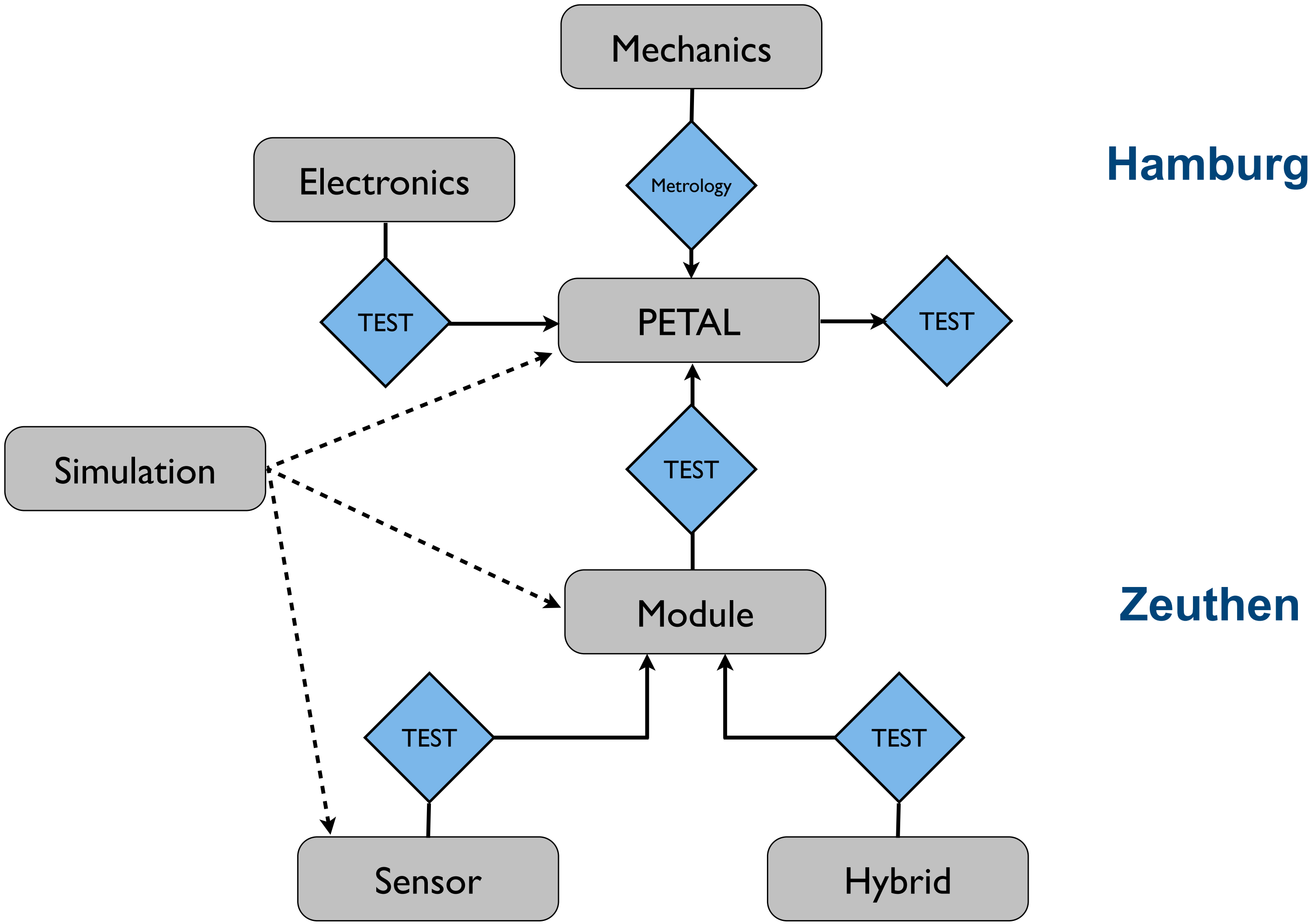
- **Hybrid** = capton board with FE chips (ABCNext, connection via wire bonds)
- **Module** = silicon sensor with readout hybrid (connection via wire bonds)
- **Petal** = petal core structure + cooling + electrical services (power, data, TTC) + modules:
  - 2 Carbon Facings + Honeycomb sandwich core (6mm)
  - Carbon Fibre tubes on sides
  - Independent CO_2 cooling pipe
  - Independent e- services + Bus cable
  - Control card on side
  - 2 x 9 modules



Hybrid positions and dimensions



DESY Contribution

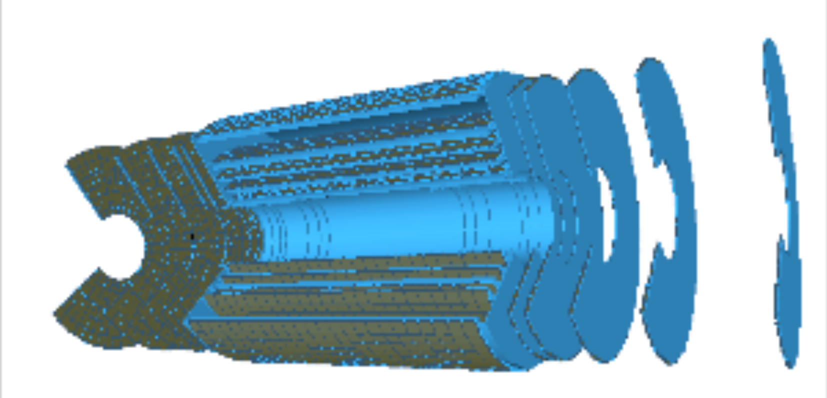


MC Simulations

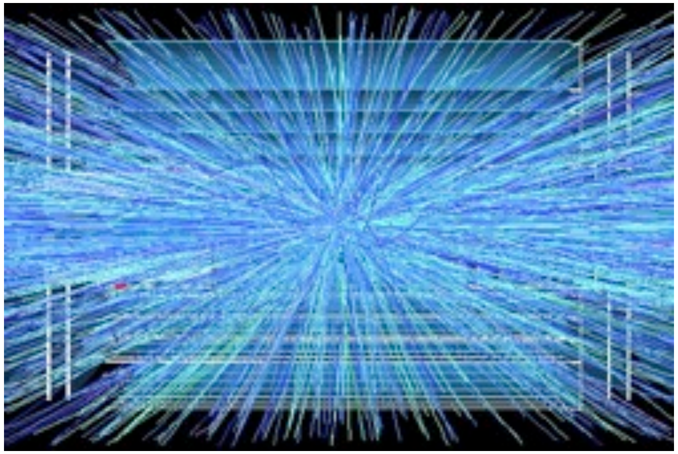
- Recently new sub-group within ATLAS organised to push the simulation efforts towards a new inner tracker for HL-LHC
- Optimise physics performance in the technological and other boundaries -> simulation is a crucial effort
- DESY will contribute significantly to this effort (new team formed recently)

- Current HL-LHC detector implementation
  - Producing simulated data sample
  - Performance plots: efficiency, fake rate, etc...

- Goal is to devise an optimal layout for the strip endcap
  - Aim to achieve performance comparable to current detector



SLHC-19-13 SCT



Simulated SLHC event with L= $10x10^{34}$ $cm^{-2}s^{-1}$

Detector Modules

Sensors

- Based on experiences with with prototype sensors for the barrel strip detector upgrade (STAVE09) -> knowledge transfer to end cap sensor design
- EndCap sensor design is more complicated due to petal shape => very expensive and probably too much for this prototype phase

- Sensors for STAVE09 and later for PETAL2014 will be tested in Zeuthen and also wire bonded to the hybrids

Hybrids

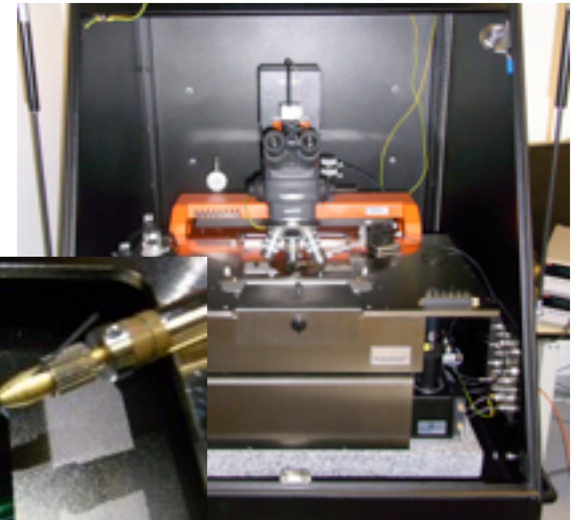
- Polyimide hybrids with ABCNext chips will be connected via wire bonds to the sensor
- University of Freiburg will design the first prototype for the endcap

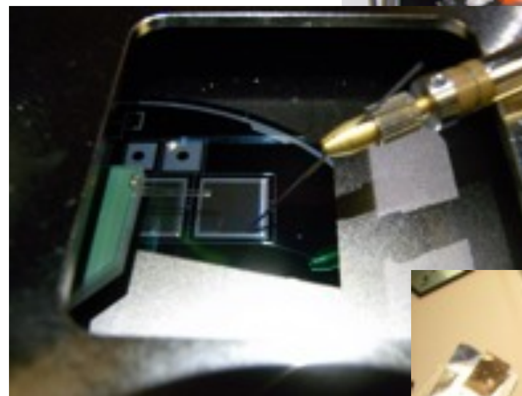
Module of current endcap strip detector

Setup in Zeuthen

Characterisation / test (verify vendor specifications) of sensors:

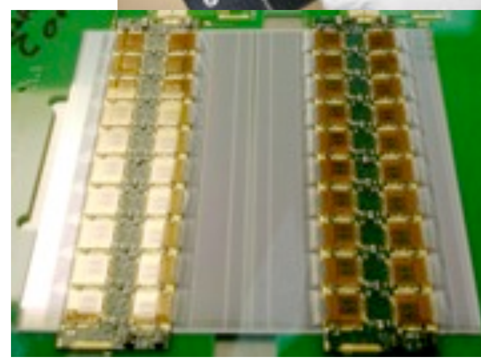
- 10 full-size strip sensors available + 4 mechanical prototypes
- IV / CV measurements using new semi-automatic probe station installed in October / November; software development ongoing, first automated measurements before Christmas





Strip sensor module production

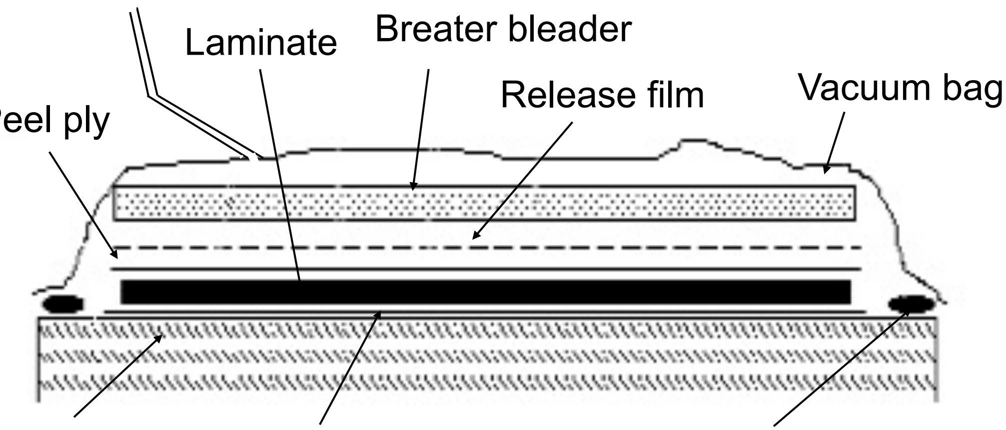
- Design adaption of mechanical tools for in-house production at Zeuthen
- Hybrids will arrive by end of January, too → start of gluing / wire bonding tests
- Setup of DAQ system and tests with single read-out chip ongoing

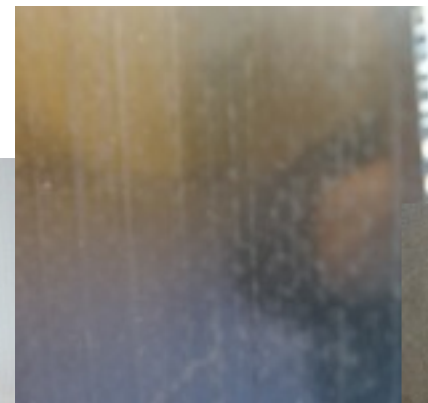


Efficiency studies of different powering options for petals

Petal Mechanics

- Measurements and finite element analysis of mechanical properties
- First petal mechanical prototype was build
- Next prototype will closed to design (including honeycomb, pocofoam and cooling pipe)
- Focusing on thermal measurements
- Collaboration with NIKHEF and Valencia to find optimal design of petal





Surface without release film

Surface (release film used)

Summary

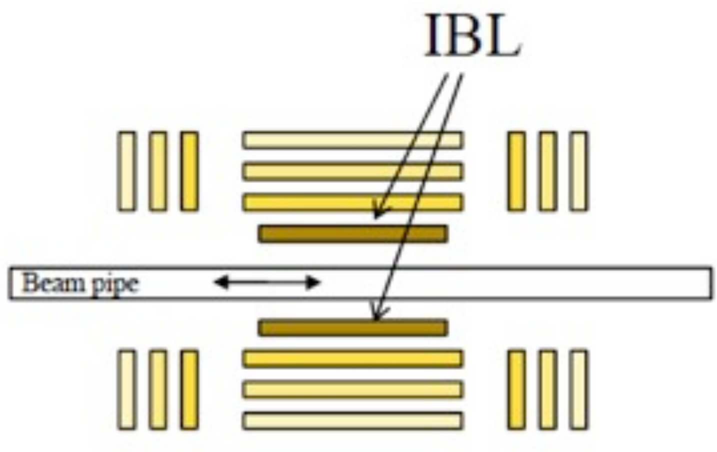
- DESY ATLAS group is active in many areas from operation to upgrade projects
- The test beam efforts will help to select the right sensor for the insertable B-Layer
- The MC team for the Upgrade team grew nicely in the recent months, now we have the possibility to shape the future ATLAS Inner Tracker
- The mechanics is focusing on thermal studies for the petal design
- In February we will have all parts together to build the first full silicon module
- The ATLAS Upgrade team will be strengthened by additional members
- **The LHC Upgrade activities will be a good opportunity to have a visible DESY impact in ATLAS also in the detector construction**

Why is a new B-Layer needed ?

Hardware wise

Radius = 50 mm						
Year	Integrated luminosity (fb^{-1})	Φ_{eq} [10^{14} $n_{eq}cm^{-2}$]	V_D (initial) Volts	V_D (max) Volts	V_D (annealed) Volts	Charge efficiency €
2009 +1	6	0.14	62	12	15	0.99
2010 +1	18	0.42	14	23	16	0.97
2011 +1	48	1.13	19	70	51	0.92
2012 +1	108	2.56 (3.85)	59 (87)	155 (230)	118 (174)	0.85
8 month shutdown						
2013 +1	198	4.73	131	276	220	0.78
2014 +1	318	7.61	238	430	354	0.70
2015 +1	468	11.21	376	616	521	0.61
2016 +1	648	15.52 (23.28)	546 (784)	833 (1214)	718 (1039)	0.49 (0.36)

Table taken from BLTF recommendations, one year added



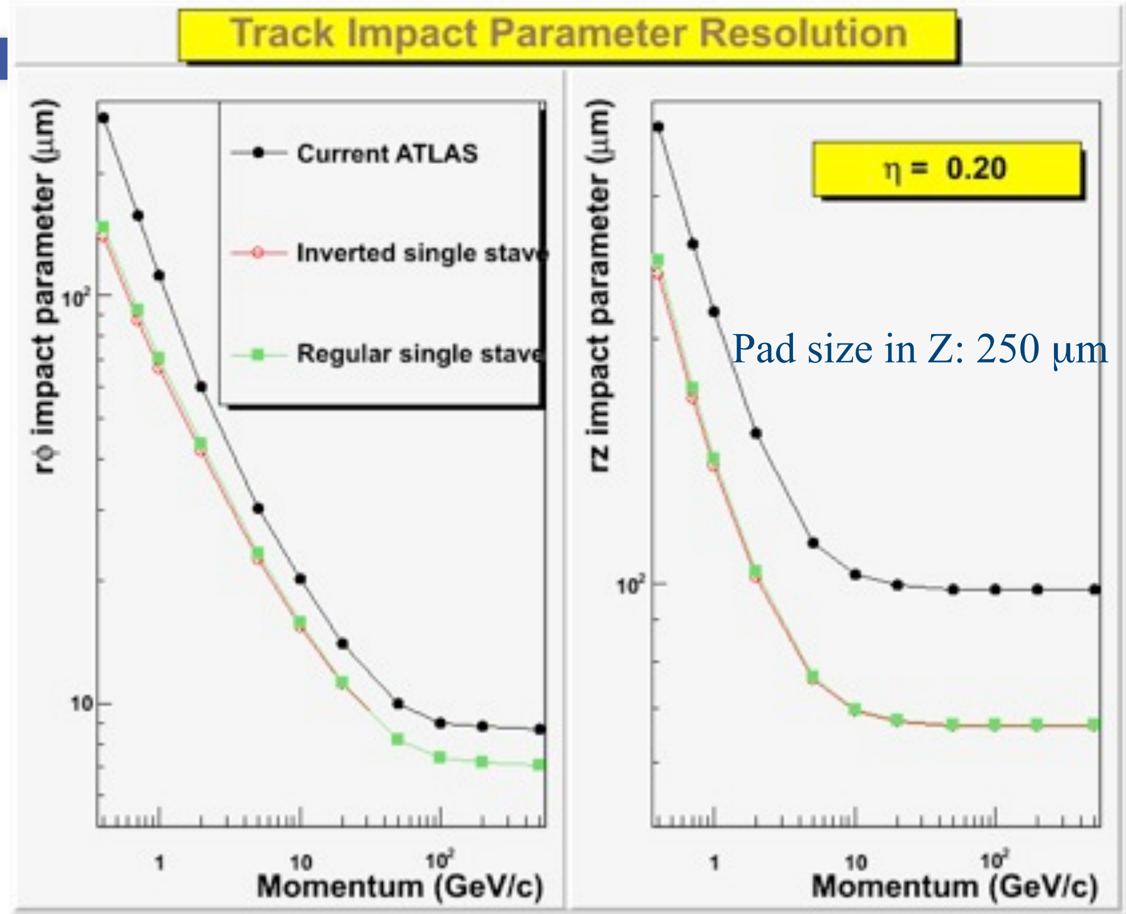
- “Soft” failure
  - degradation of sensor due to radiation damage
  - example: sensor would survive until 2013, but not until 2017
  - as long LHC not running it is very difficult to estimate this
- “Hard” failure –> some fraction of the detector stops functioning
  - cooling system failure that requires a detector warm up -> impact on sensor
  - failure of an opto-board -> no connection to part of detector
  - ....

IBL Performance

Physics wise

- IP res Z: 100µm->~60µm
- IP res RΦ : 10µm -> 7µm
- B-tagging: Light Jet rejection factor improves by factor ~2
- BUT: to maintain Pixel Detector performance with inserted layer the material budget is critical.

Component	% X_0
beam-pipe	0.6
New-BL @ R=3.5 cm	1.5
Old BL @ R=5 cm	2.7
L1 @ R=8 cm	2.7
L2 + Serv. @ R=12 cm	3.5
Total	*11.0*



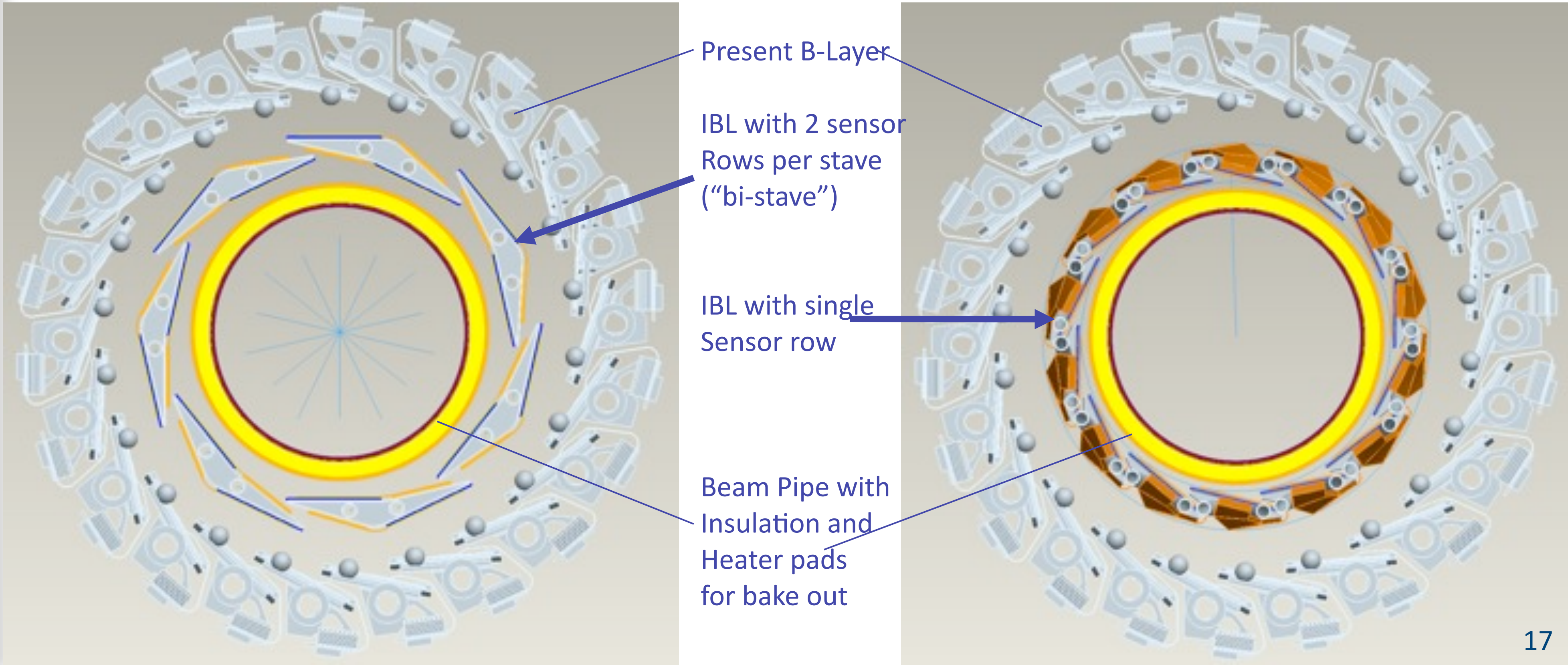
Pad size in Z: 250 µm

example: 100um Silicon = 0.11% X_0 (ILC)

Layouts under Study

- 14 staves, each with 32 FE-I4 Frontend chips
- Sensor surface ~ **only 0.2m²**
- 16 degree tilt angle
- ~35 mm sensor radius
- ~33 Inner Radius, 41.5 Outer Radius

- Uses newly developed FE chip: FE-I4
- Pad size 50x250µm
- Chip size 20.1x19.6mm
- Radiation hardness >200Mrad
- Beam pipe IR 25mm (tbc)



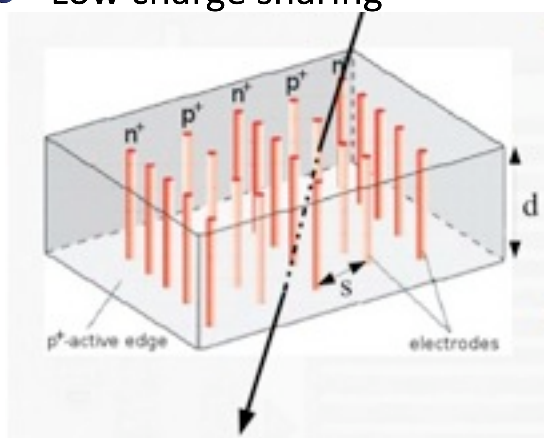
Three different approaches

Planar Sensor

- current design is an n-in-n planar sensor
- silicon diode
- different designs under study (n-in-n; n-in-p ....)
- radiation hardness proven up to 2.4 . 10^{16} p/cm^2
- problem: HV might need to exceed 1000V

3D Silicon

- Both electrode types are processed inside the detector bulk instead of being implanted on the wafer's surface.
- Max. drift and depletion distance set by electrode spacing
- Reduced collection time and depletion voltage
- Low charge sharing



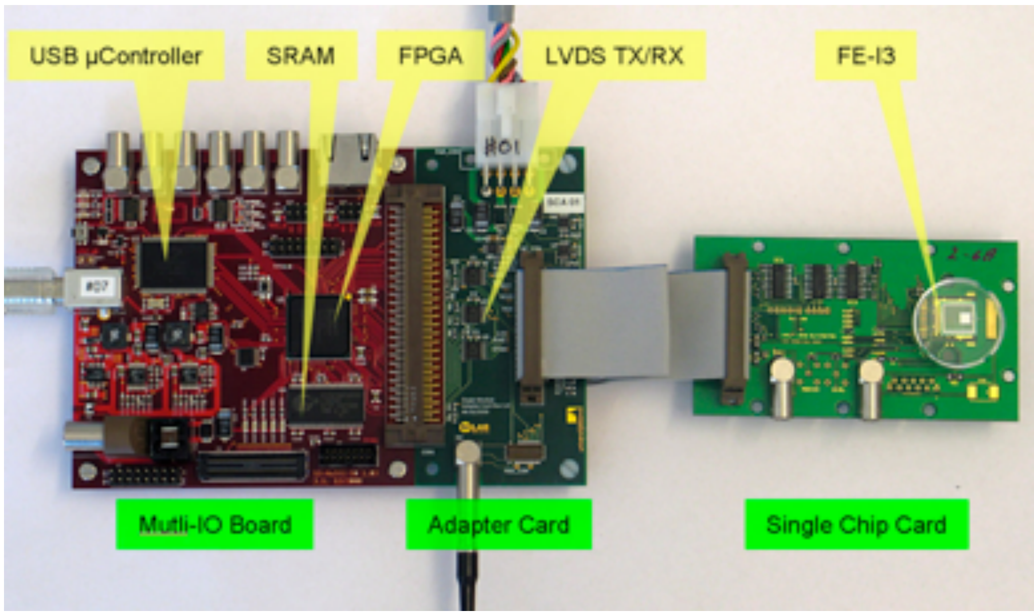
CVD (Diamond)

- Poly crystalline and single crystal
- Low leakage current, low noise, low capacitance
- Radiation hard material
- Operation at room temperature possible
- Drawback: 50% signal compared to silicon for same X_0, but better S/N ratio (no dark current)

None of the three technologies is proven to be suitable or to be excluded

The FE chip

- New architecture to reduce inefficiencies to be ready for higher occupancy
- Great fraction (~90%) devoted to pixel array
- Lower power/pixel & higher hit rate: store hits locally in pixel and distribute the trigger
- Increased rad hard



USBPix readout board

- One of the biggest chips in HEP
- Submitted July 2010; delivery Sept. 23
- Intensive testing under way -> so far very positive
- Final FE-I4B production in <1 year

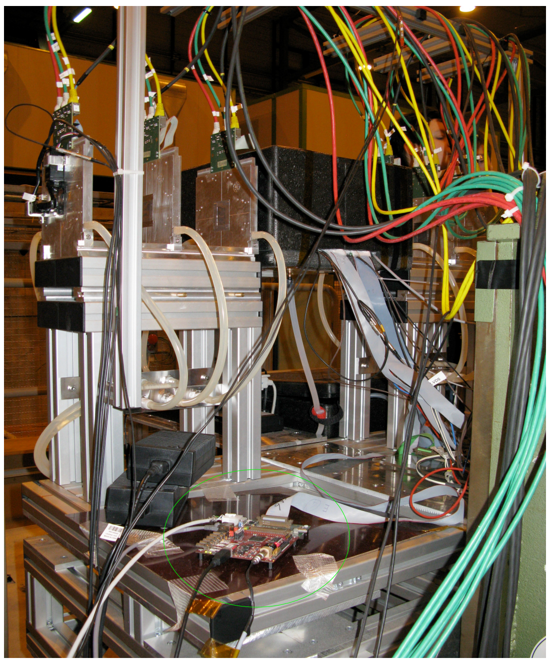
- **IBL 2013** -> production as soon as possible (no time for errors)

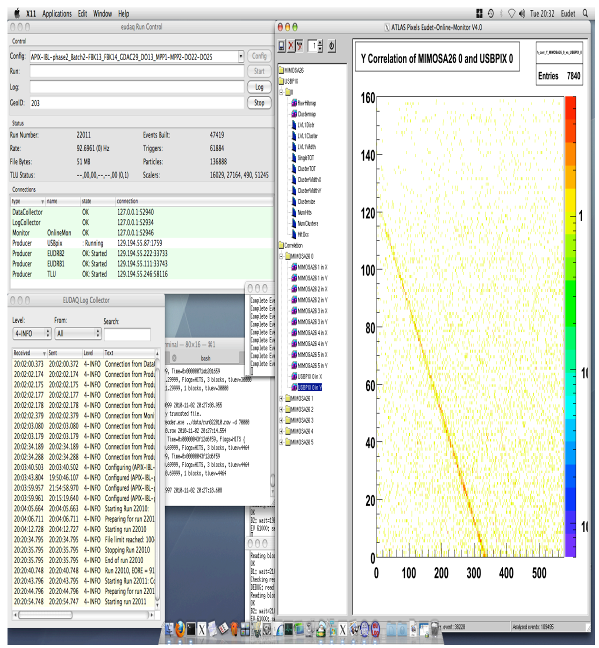
USBPix Implementation in EUDAQ

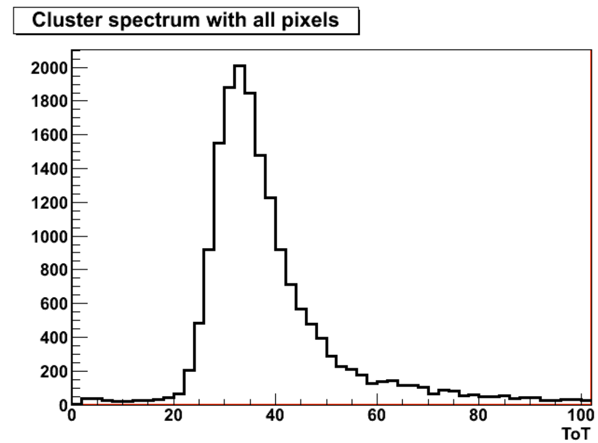
- USBpix – an alternative to common TurboDAQ (TPLL, TPCC) system
- Will be used for IBL testbeams (FE-I4) in 2011
- Was integrated in the EUDET Telescope and tested during first IBL testbeam in November 2011

The setup

Online monitoring and offline analysis







- System was running very stably
- Offline analysis results reasonable