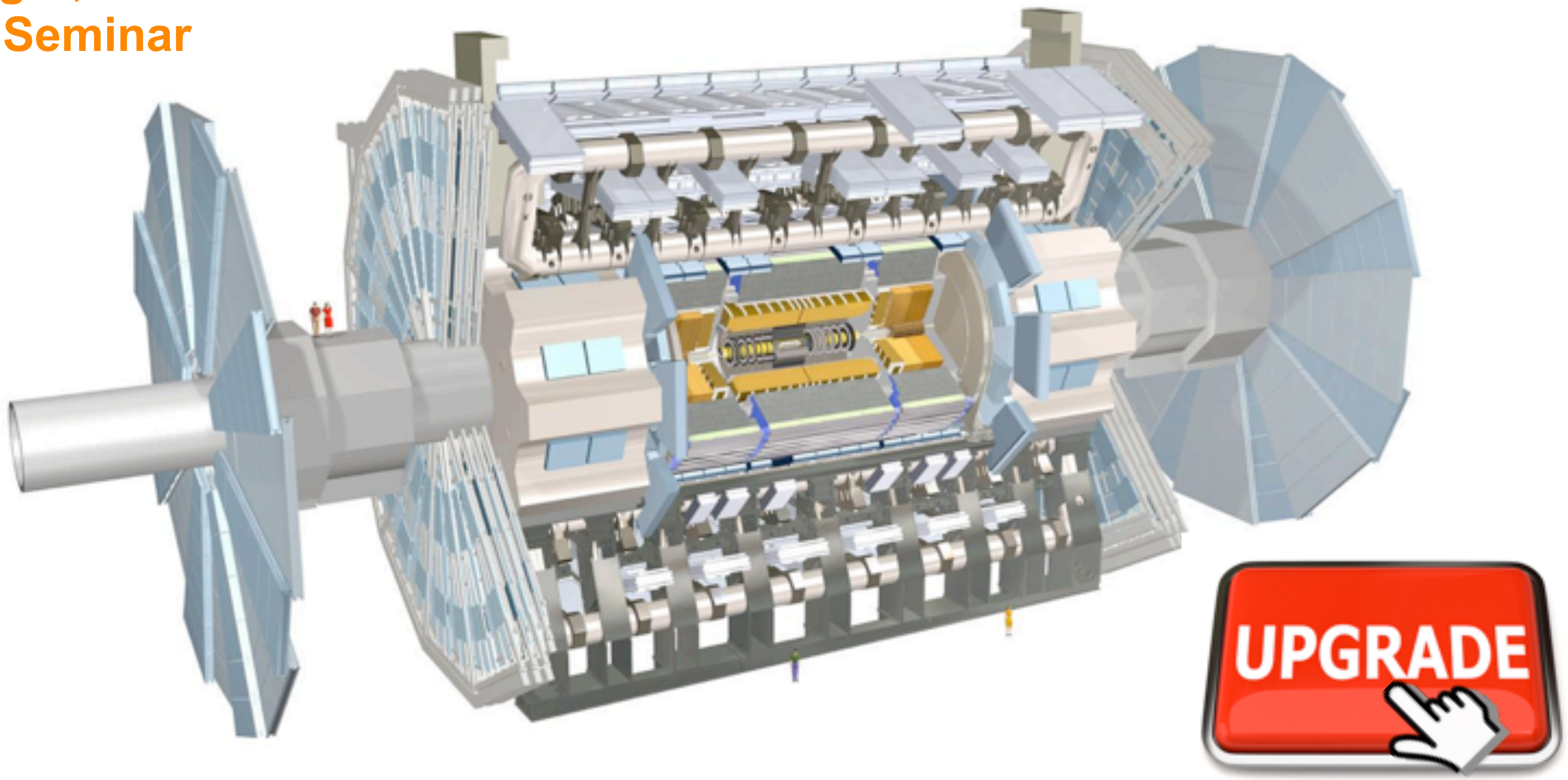
The ATLAS Upgrade.

Ingrid-Maria Gregor, DESY
Instrumentation Seminar
DESY



Thanks to: Tony Affolder, Phil Allport, Nigel Hessey, Andrey Loginov, Marzio Nessi, Christoph Rembser, Nick Styles, Peter Vankov….

HELMHOLTZ GEMEINSCHAFT

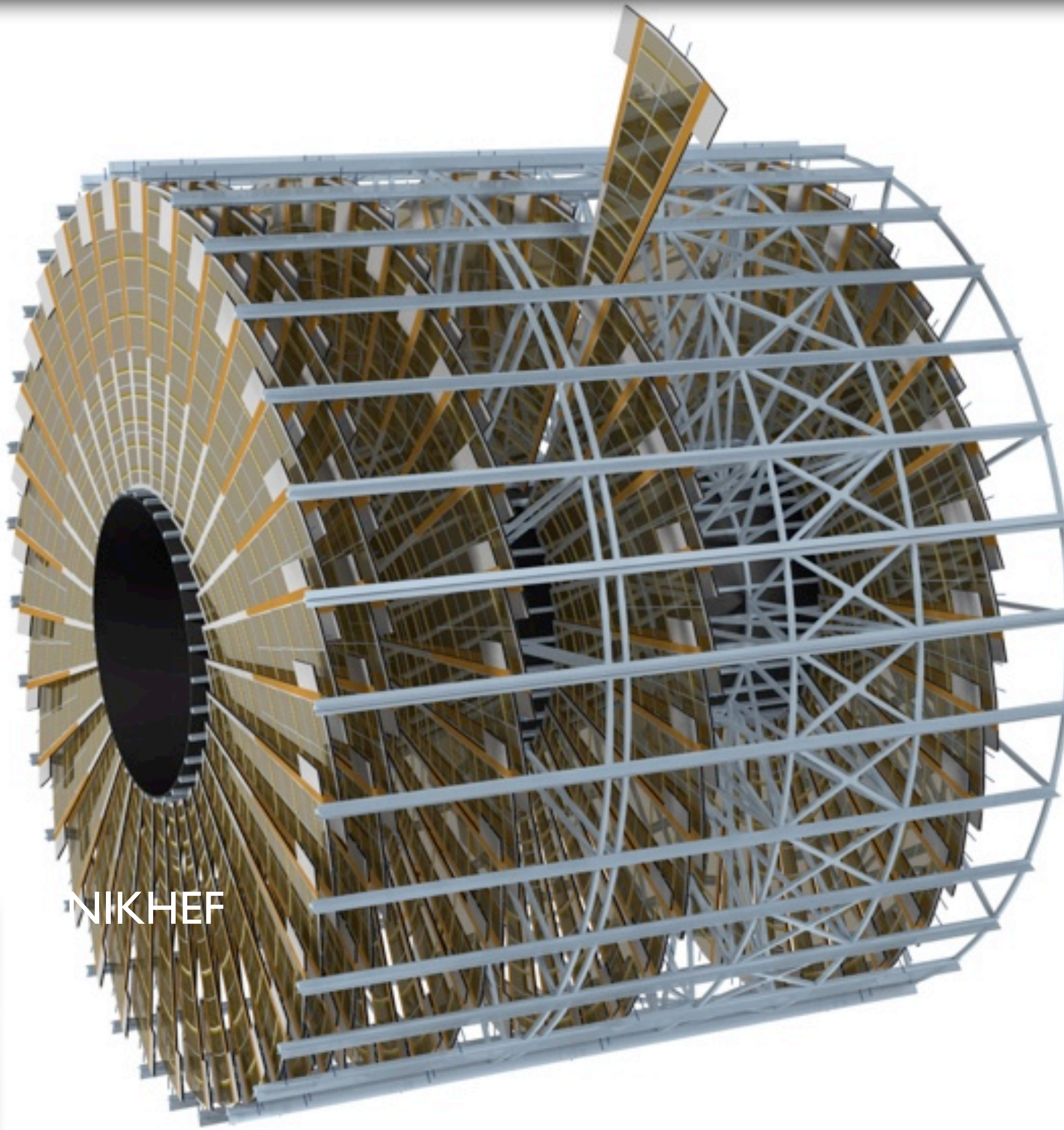
DESY

Overview

- Introduction
- LHC Upgrade
- ATLAS Phase 0 - Phase 2
- Conclusion

Disclaimer:

- too much material to cover in 45 minutes
- will focus only on few programs
- personally biased ….



Introduction

HEP Detector Recap

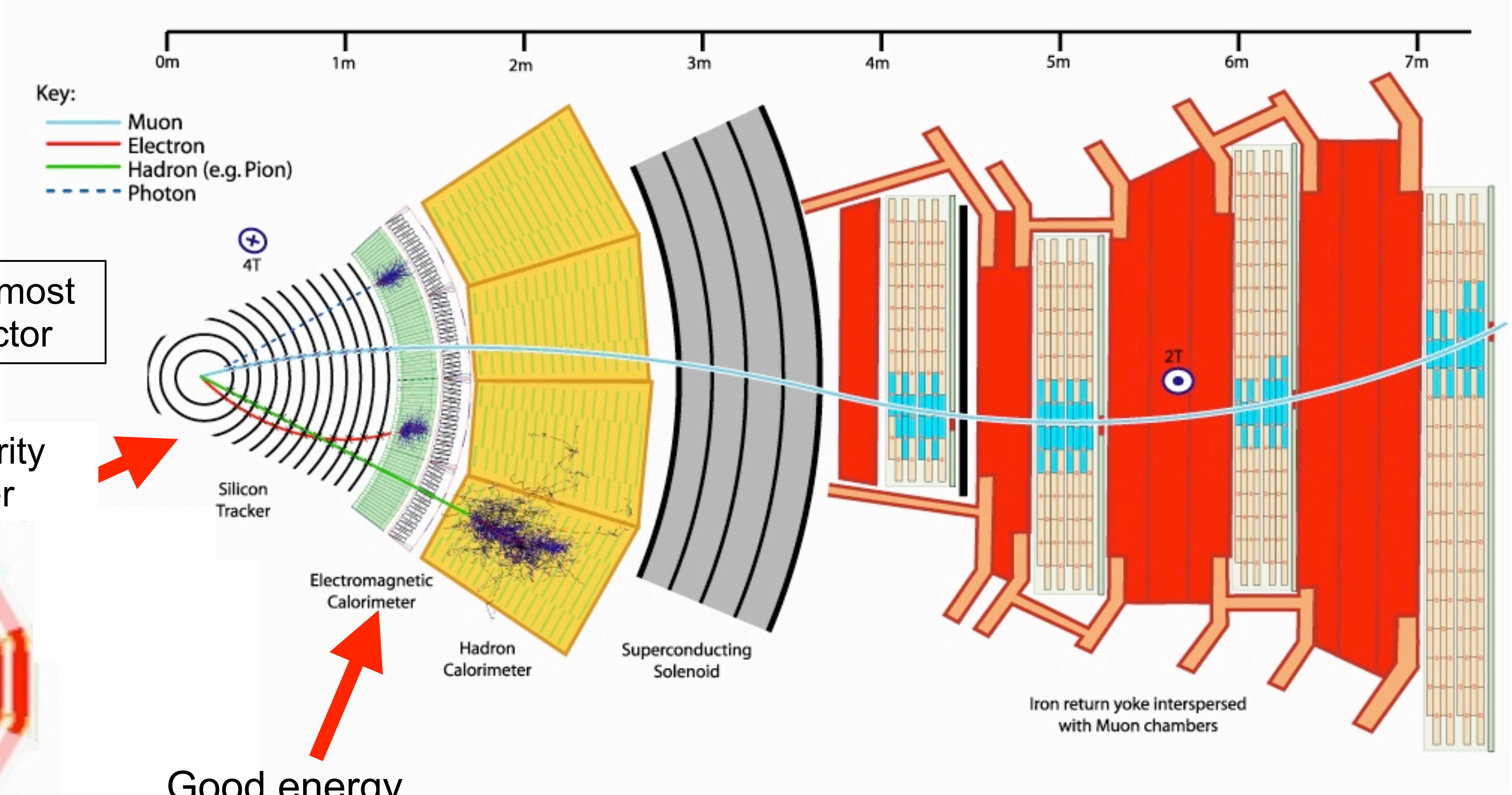
Tracker: Momentum of charged particles due to magnetic field and precise measurement of track

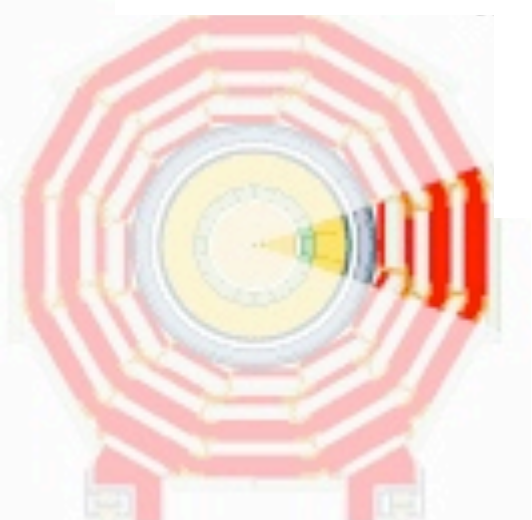
Calorimeter: Energy measurement of photons, electronics and hadrons through total absorption

Muon-Detectors: Identification and precise momentum measurement of muons outside of the magnet

Vertex: Innermost tracking detector

High granularity for the tracker





Transverse slice through CMS

Good energy resolution up to highest energies

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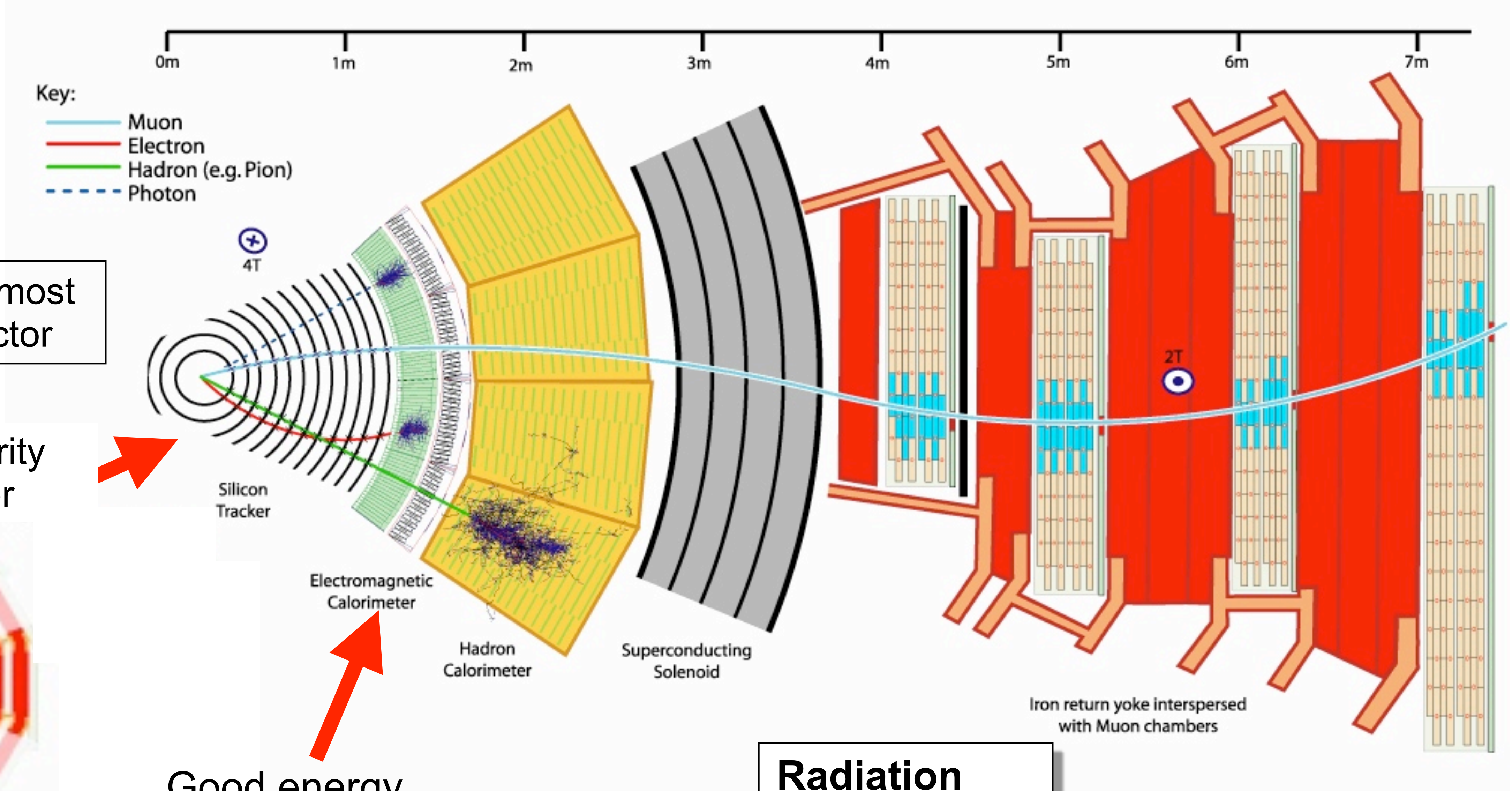
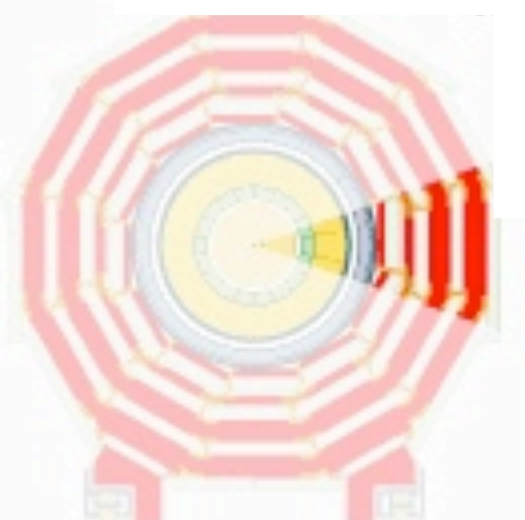




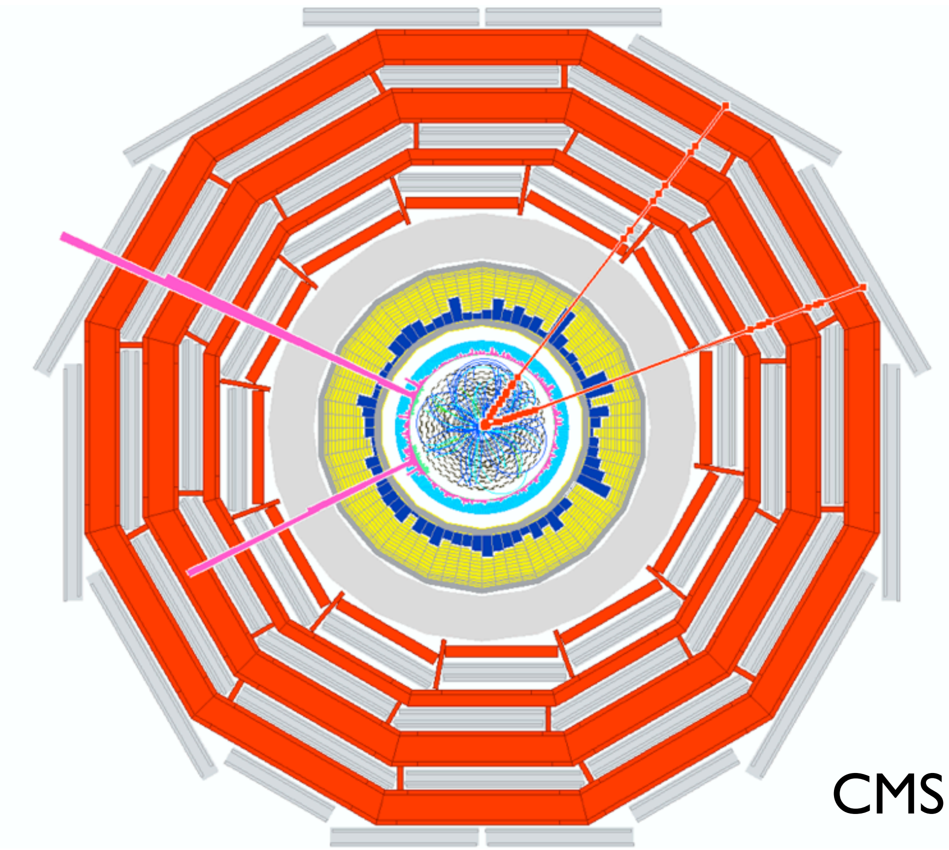
Transverse slice through CMS

Good energy resolution up to highest energies

Radiation hard (hadron collider)

What is a Trigger ?

- Collisions every 25 ns with many simultaneous interactions
- A lot of information stored in the detectors - we need all information
- Electronics too slow to read out all information for **every** collision
- But: a lot of the interactions are very well known - we only want rare events
- “Trigger” is a system that uses simple criteria to rapidly decide which events to keep when only a small fraction of the total can be recorded.



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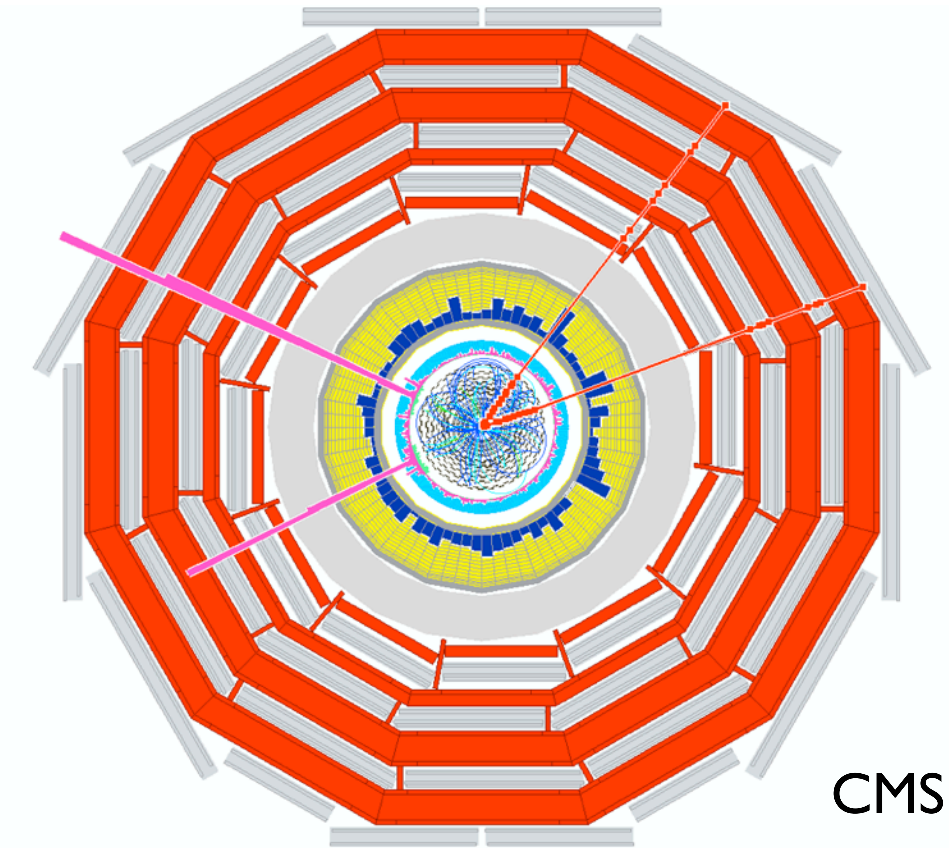
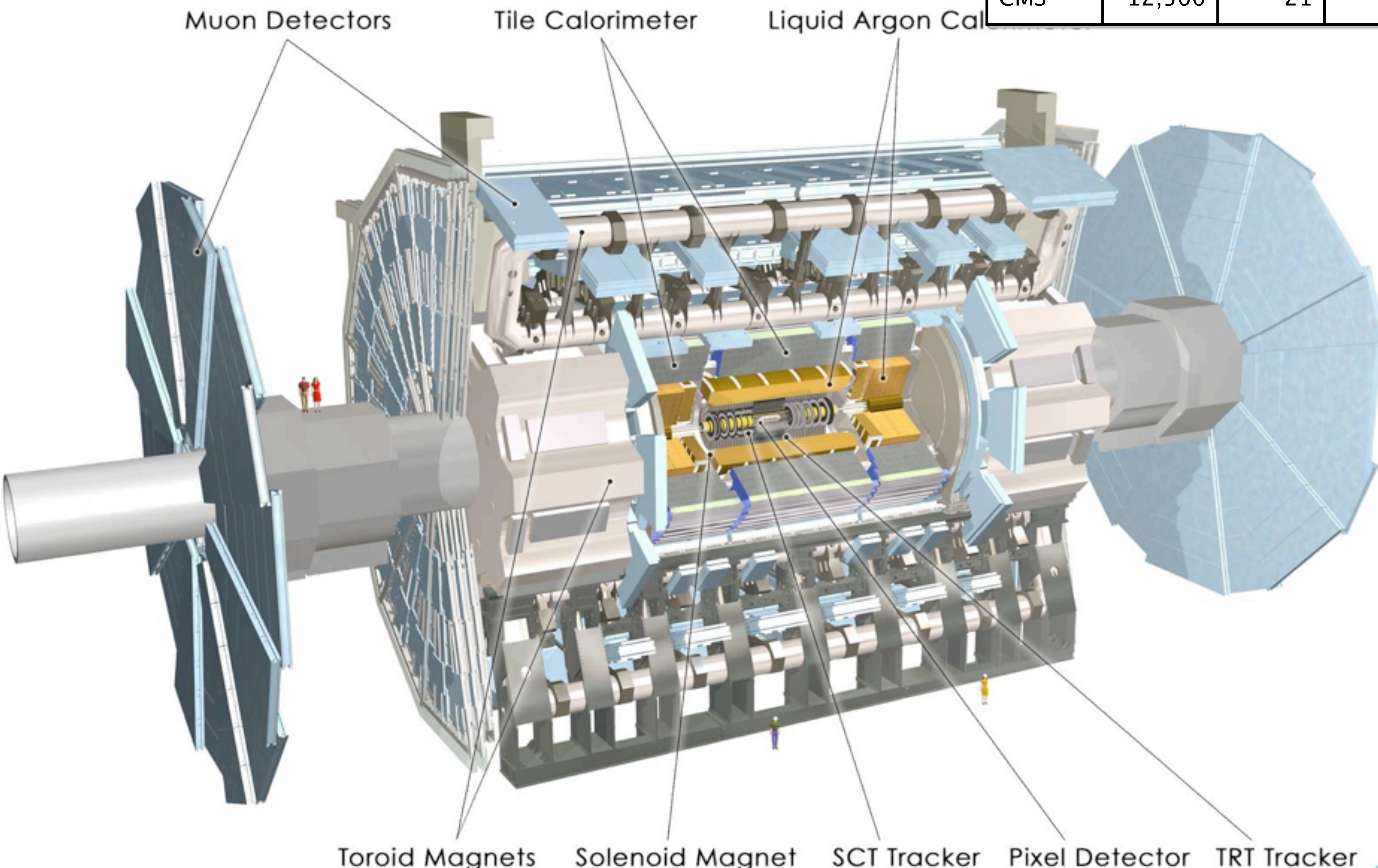


- Want to know the information of green cars
  - number of passengers
  - speed
  - weight
  - …..
- Trigger = system detecting the color and initiating the information transfer all information

The ATLAS Detector

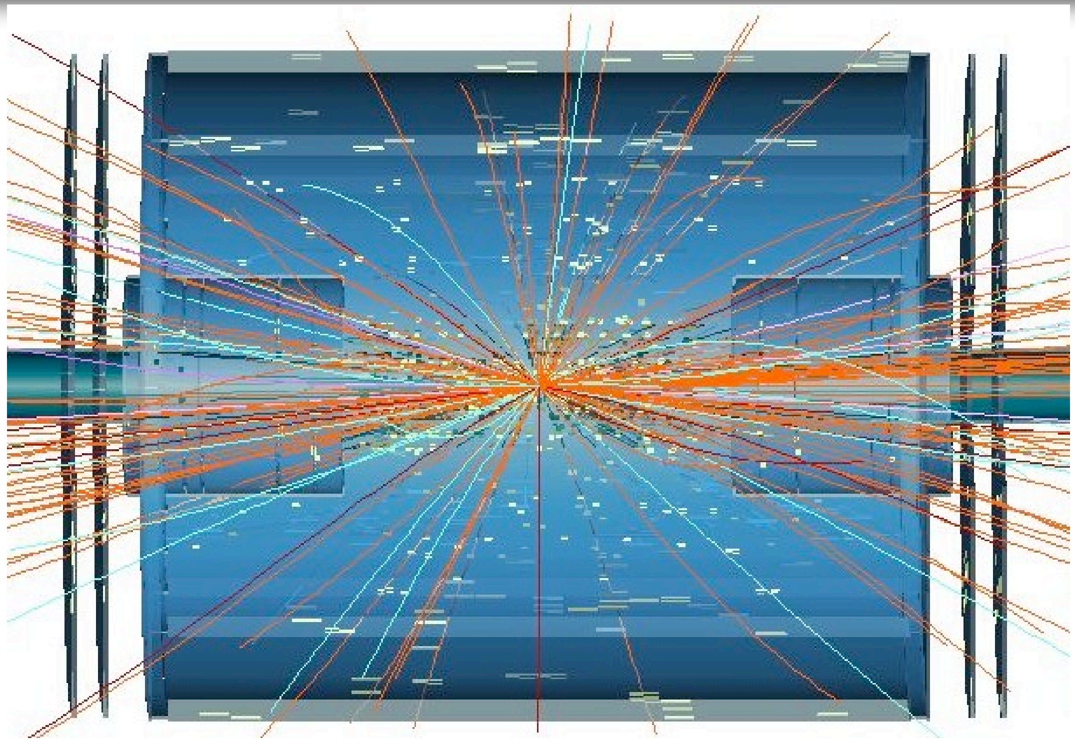
	Weight (tons)	Length (m)	Height (m)
ATLAS	7,000	42	22
CMS	12,500	21	15



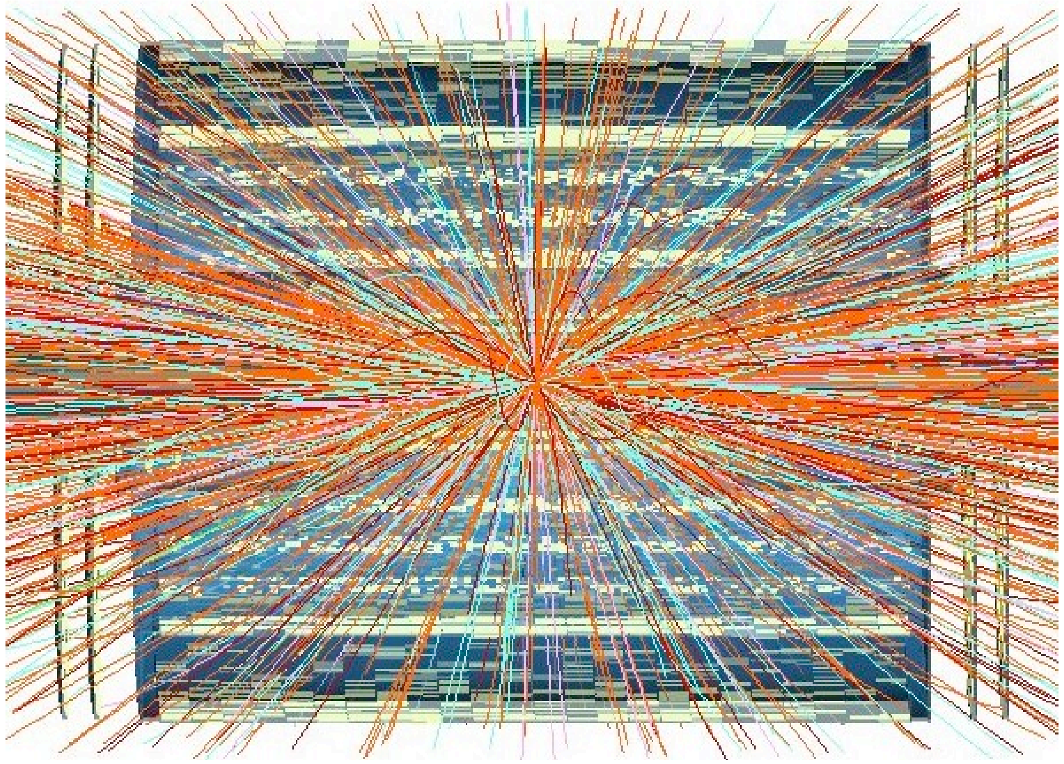
Why Upgrade?

- Higgs boson
  - Assuming it is found, determine its properties, primarily its couplings to fermions and bosons.
  - If it is excluded, WW scattering measurements will become essential to unveil the electroweak symmetry breaking mechanism.
- Looking for New Physics ….
- In addition, the potential is significantly extended for (more difficult) physics discoveries

- Event pile-up, hit rates, occupancies ...
  - improve on: material, trigger, pattern recognition, data BW, data storage
- **Radiation damage**
  - current detectors are designed for a few hundred fb^{-1}
  - improve on:materials, electronics, links, aging, …



LHC in 2011: $1x10^{33}$ $1/cm^2s$



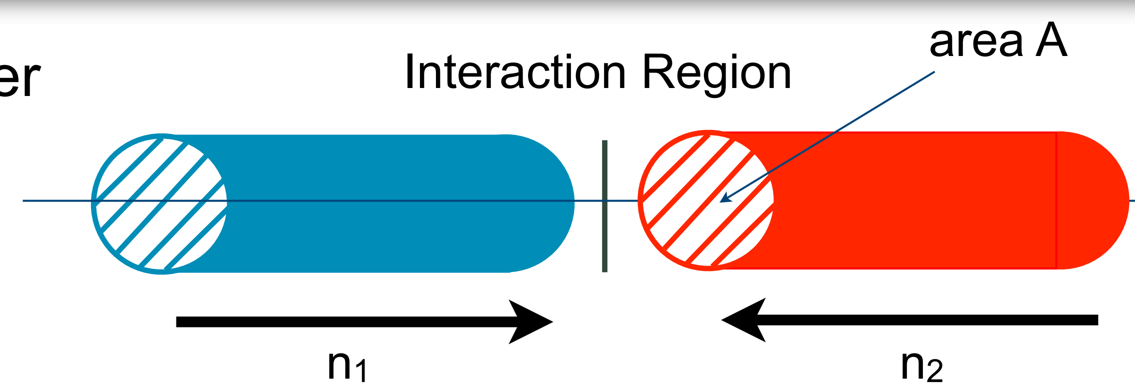
HL-LHC: $5x10^{34}$ $1/cm^2s$

LHC Machine Upgrade

"So to achieve high luminosity, all one has to do is make high population bunches of low emittance to collide at high frequency at locations where the beam optics provides as low values of the amplitude functions as possible."
PDG 2010, chapter 25

LHC Machine Upgrade in a Nutshell

- Luminosity is the number of particles per unit area per unit time times the opacity of the target/detector
- Simply: a figure-of merit for the amount of data
- Goal: increase the luminosity by factors (in steps)



Total beam current. Limited by:
- Uncontrolled beam loss!!
- E-cloud and other instabilities
- Action: Linac4

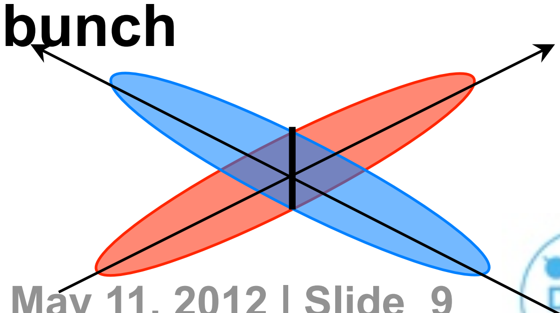
Brightness, limited by
- Injector chain
- Max tune-shift

Maximize number of bunches

$$\mathcal{L} = \left(\frac{\gamma f_{rev}}{4\pi}\right)\frac{n_b N_b}{\beta^\star}\left[\left(\left(\frac{N_b}{\epsilon_N}\right) R_\phi\right)\right]$$

Reduce β*, limited by
- magnet technology -> Nb3Ti
- chromatic effects

Geometric factor, related to crossing angle and bunch length

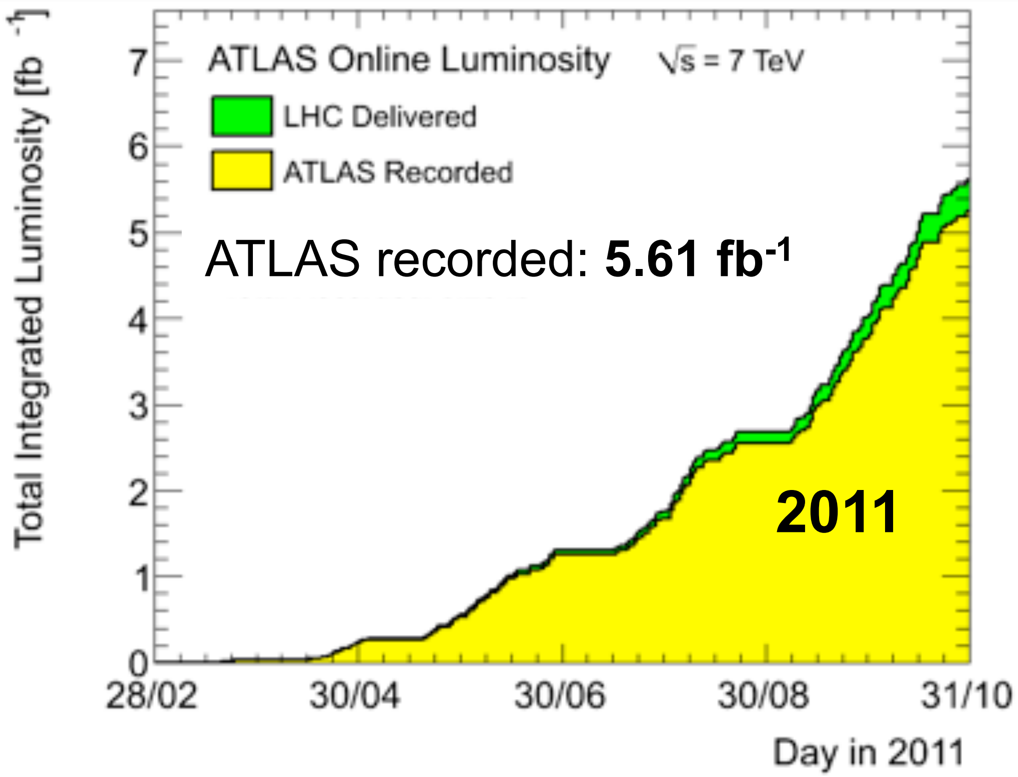


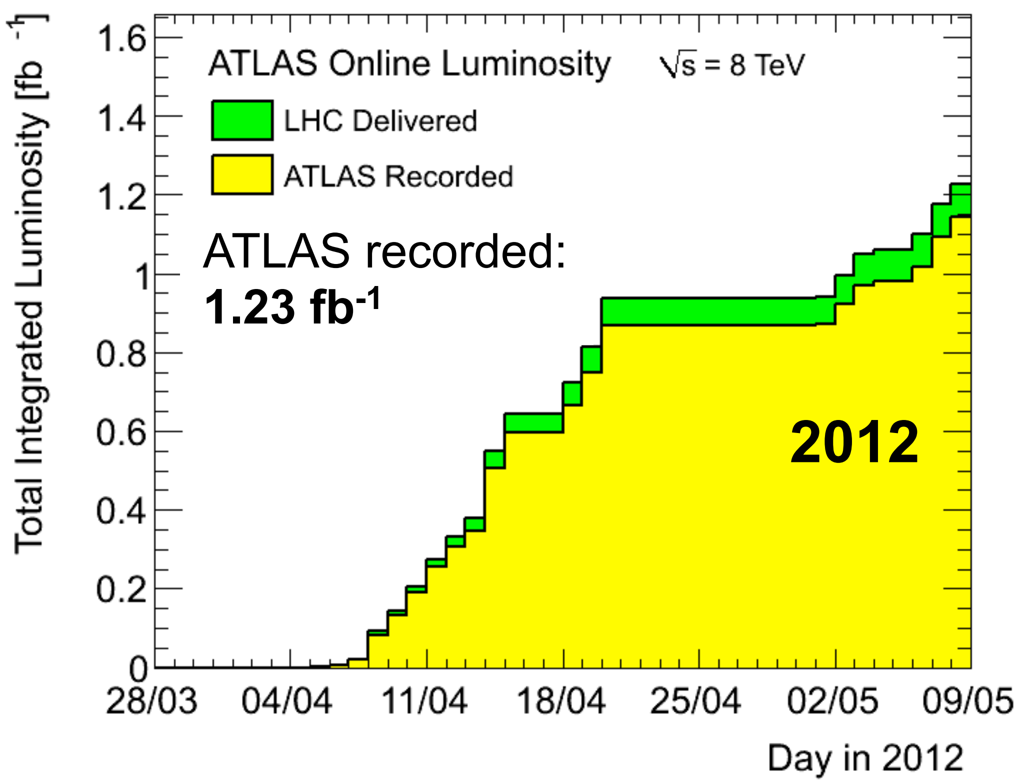
Current LHC Status

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResults#2012_pp_Collisions

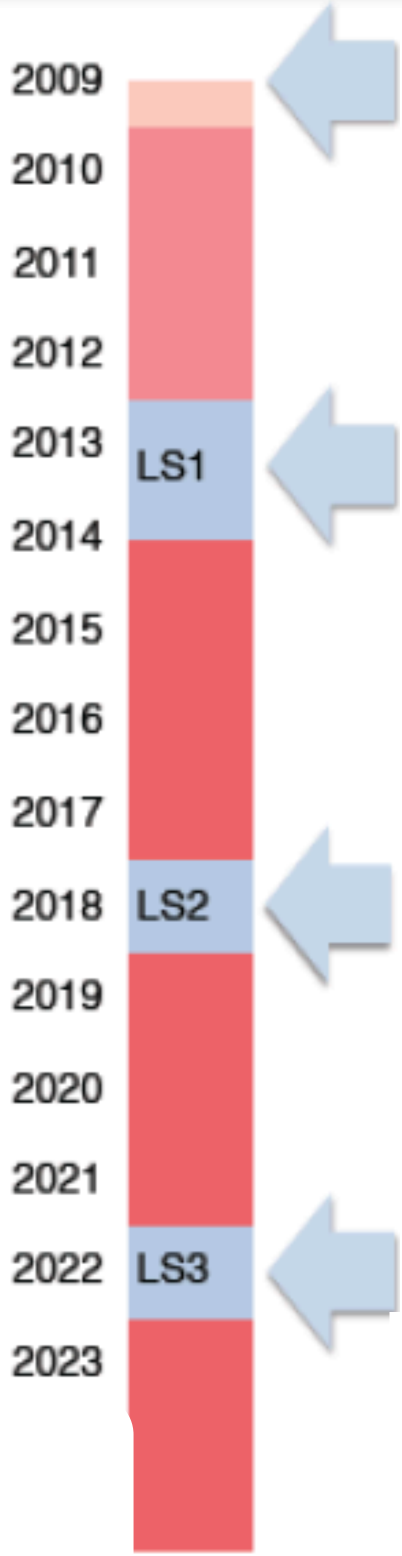
	LHC Design	May 2012
Momentum at collision [TeV/c]	7	**4**
Luminosity [cm-2s-1]	1.00E+34	5.50E+33
Number of bunches per beam	2808	1380
Bunch intensity	1.15E+11	**1.25E+11**

- **In short:** The performance of LHC is excellent !!
- Within a few weeks the machine ramped to standard performance at a higher energy than before (8TeV centre of mass)
- Hopes are up to reach 20 fb^{-1} in 2012...





(Possible) LHC Time-Line



✧ LHC startup, $\sqrt{s}$ = 900 GeV

$\sqrt{s}$=7~8 TeV, L=6x10^{33} cm^{-2} s^{-1}, bunch spacing 50 ns

Go to design energy, nominal luminosity

$\sqrt{s}$=13~14 TeV, L~1x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

ATLAS: Phase 0 detector upgrade

Injector and LHC Phase-1 upgrade to full design luminosity

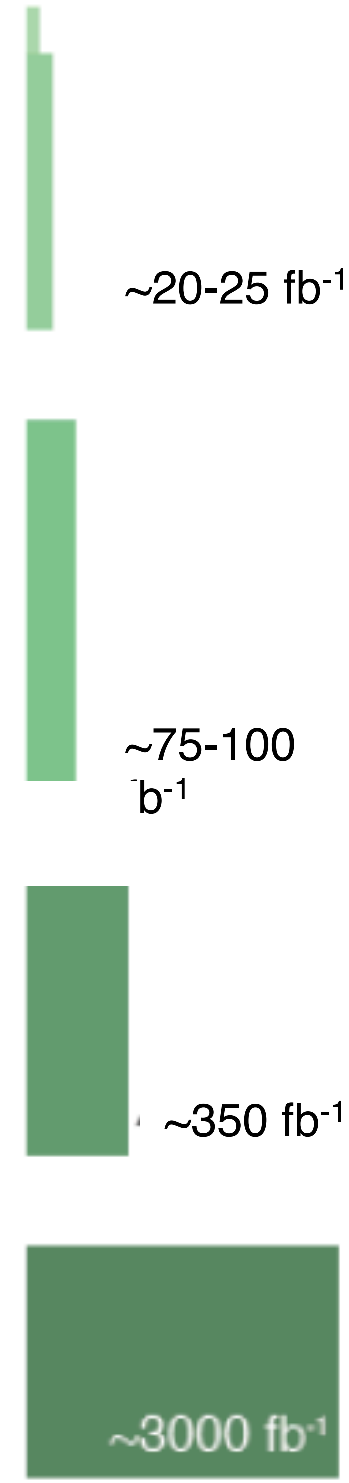
$\sqrt{s}$=14 TeV, L~2x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

Phase 1

HL-LHC Phase-2 upgrade, IR, crab cavities?

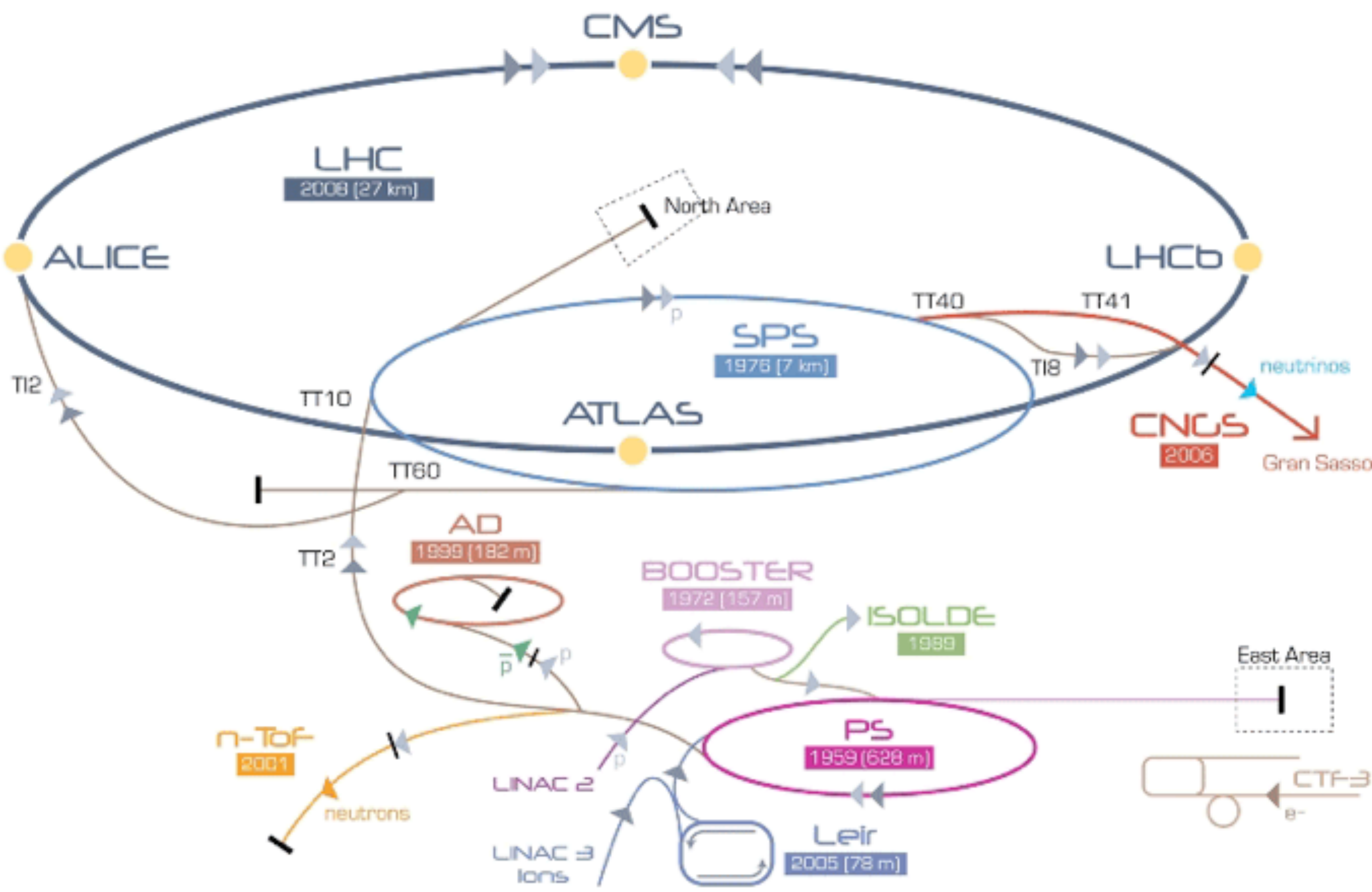
$\sqrt{s}$=14 TeV, L=5x10^{34} cm^{-2} s^{-1}, luminosity levelling

Phase 2



As shown at "Chamonix 2012"

Interaction Region Upgrades



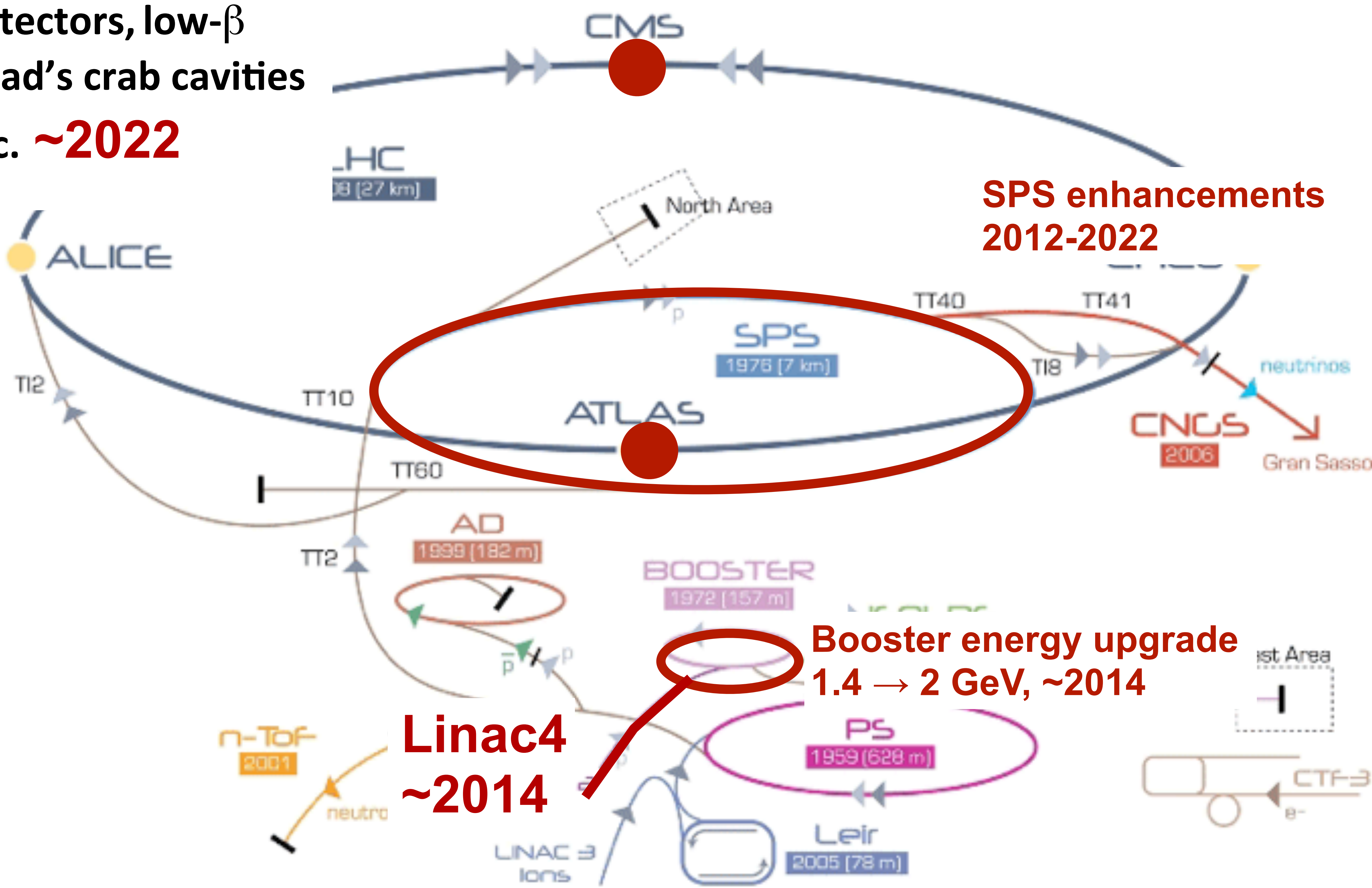
Interaction Region Upgrades

detectors, low-β quad's crab cavities etc. **~2022**

SPS enhancements 2012-2022

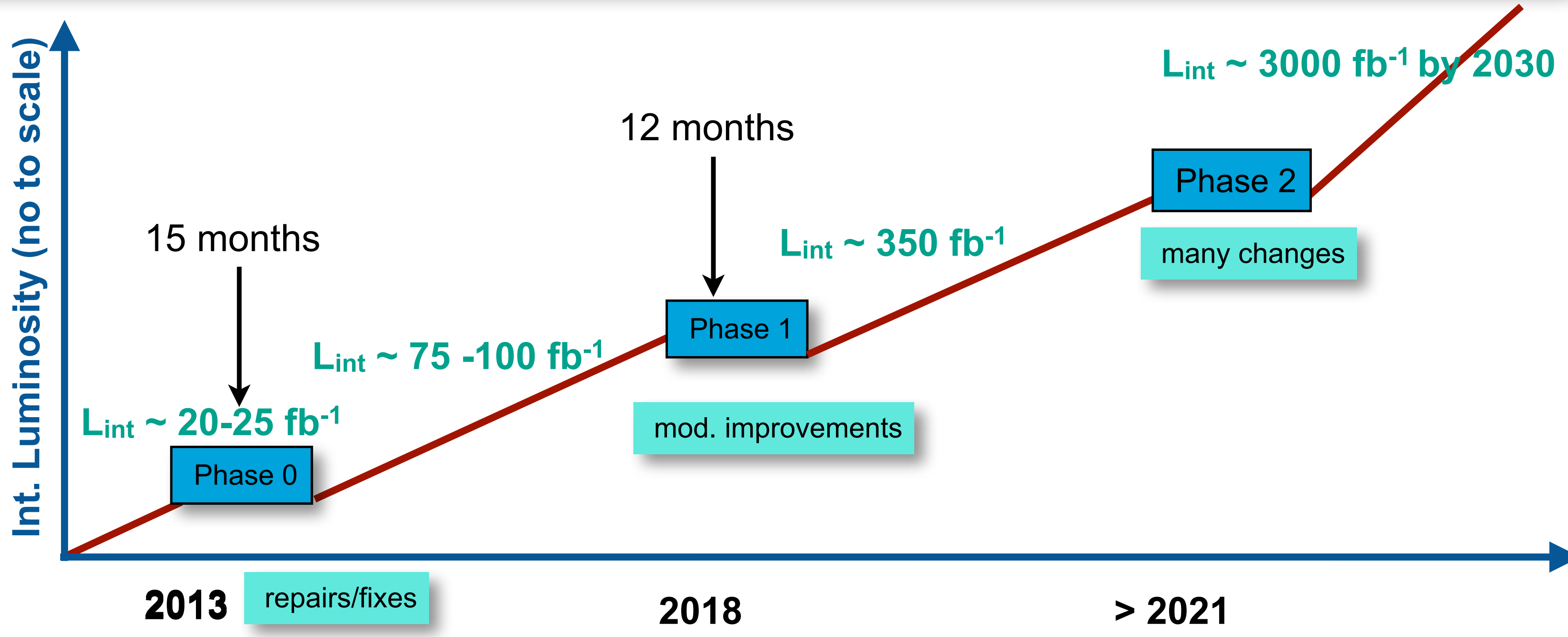
Booster energy upgrade 1.4 → 2 GeV, ~2014

Linac4 ~2014



Tentative Schedule and ATLAS Plans

- **Phase 0 (2013):**
  - **Pixel: Insertable B-Layer (IBL)**
  - Pixel: opto-electronics repair
  - Beam-pipe -> Beryllium
  - Infrastructure consolidation
  - Muon/forward upgrade
  - nSQP



- **Phase 1 (2018):**
  - **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

Assumptions on Global Requirements

- Radiation damage scales with the integrated luminosity
- Performance of detector is influenced by number of simultaneous interactions
- While designing the new detectors following parameters have to be kept in mind to ensure a successful running

LHC up to 2021		
	Estimated value	**Safer value**
Peak luminosity	$2*10^{34}$	$3*10^{34}$
Integrated Lumi expected	$300fb^{-1}$	**$400fb^{-1}$**
Mean number of interactions per crossing	46	69
Safety factor to be used in the radiation dose calculation	2	2
HL-LHC after 2022		
Peak luminosity	$5*10^{34}$	$7*10^{34}$
Integrated Lumi expected	$2500fb^{-1}$	**$3000fb^{-1}$**
Int. Luminosity per year expected	$250fb^{-1}$	$300fb^{-1}$
Mean number of interactions per crossing	140	200
Safety factor to be used in the radiation dose calculation	2	2

order of magnitude

Phil Allport

Phase 0 Upgrade (2013/2014 Shutdown LS1)

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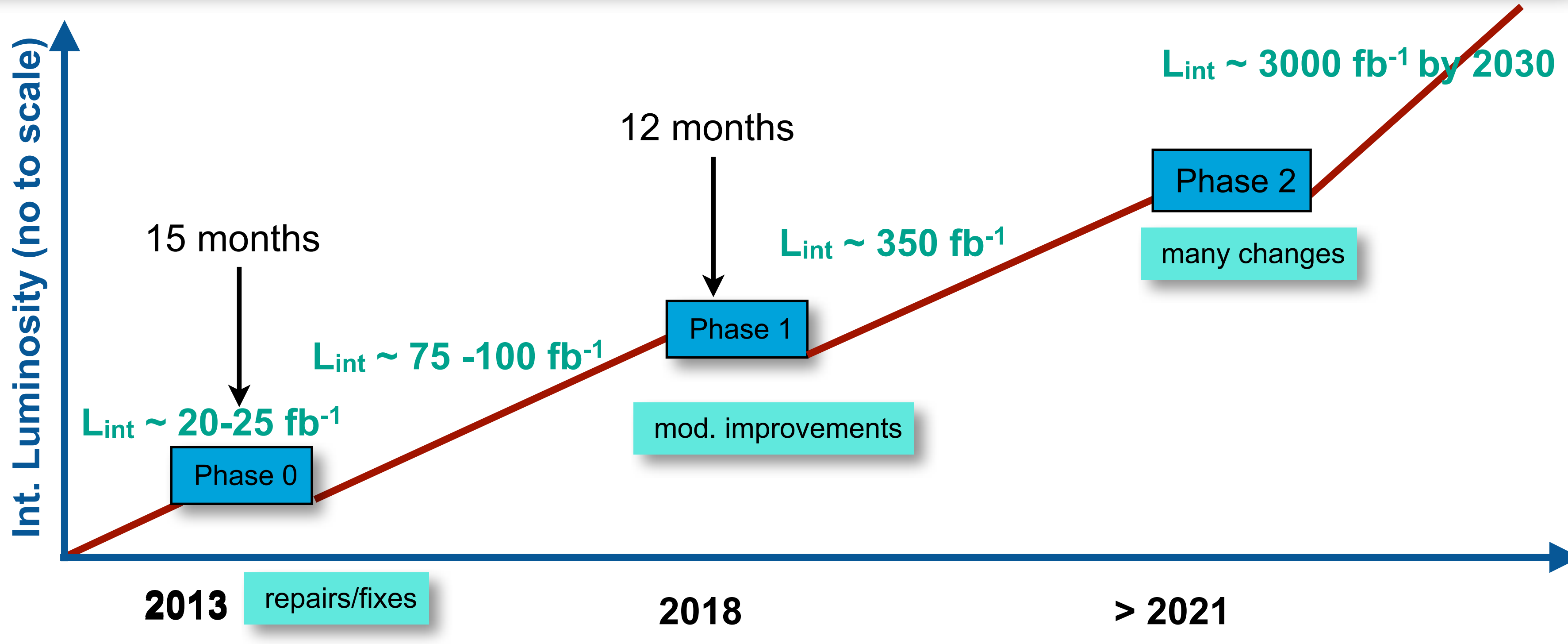

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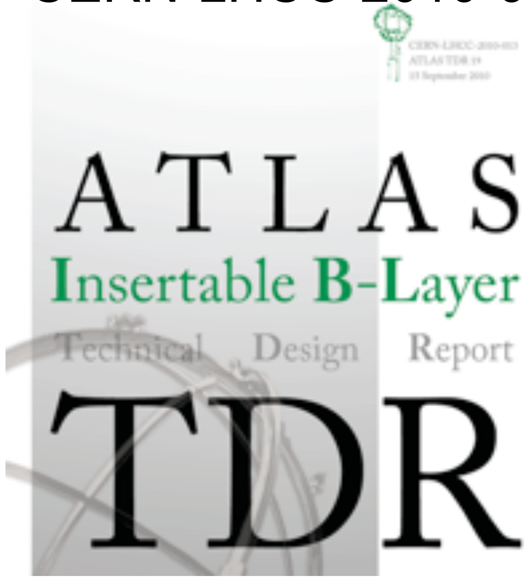
The Insertable B-Layer (IBL)

CERN-LHCC-2010-013



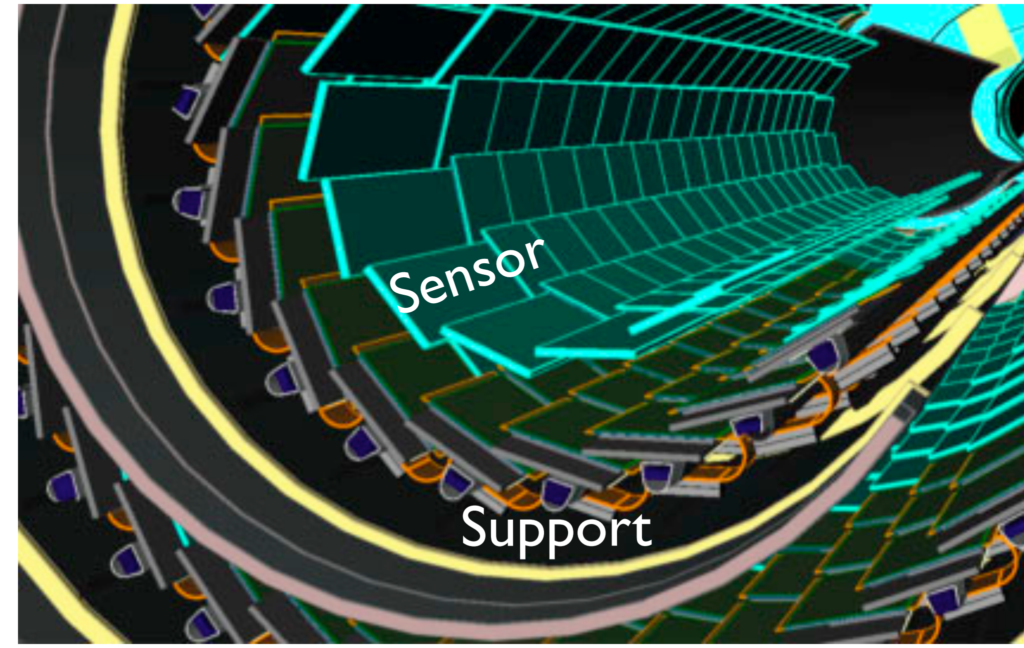
- Present pixel detector will develop inefficiencies and damages in time (radiation damage, failures ….)
- Also designed for a peak luminosity of 10^{34} cm^{-2} s^{-1}. Higher luminosity will induce pileup and readout inefficiencies -> potentially affecting the performance.
- Improve performance of current pixel detector by adding an additional inner layer close to the beam pipe.

- **Tracking precision:** Being closer to the interaction point improves the quality of impact parameter resolution (higher precision in the vertex position measurement)
- **Beam pipe replacement:** Actual beam pipe is installed together with the detector. The new, smaller beam pipe will only be connected to the IBL allowing faster removal.
- Technological step towards HL-LHC !!

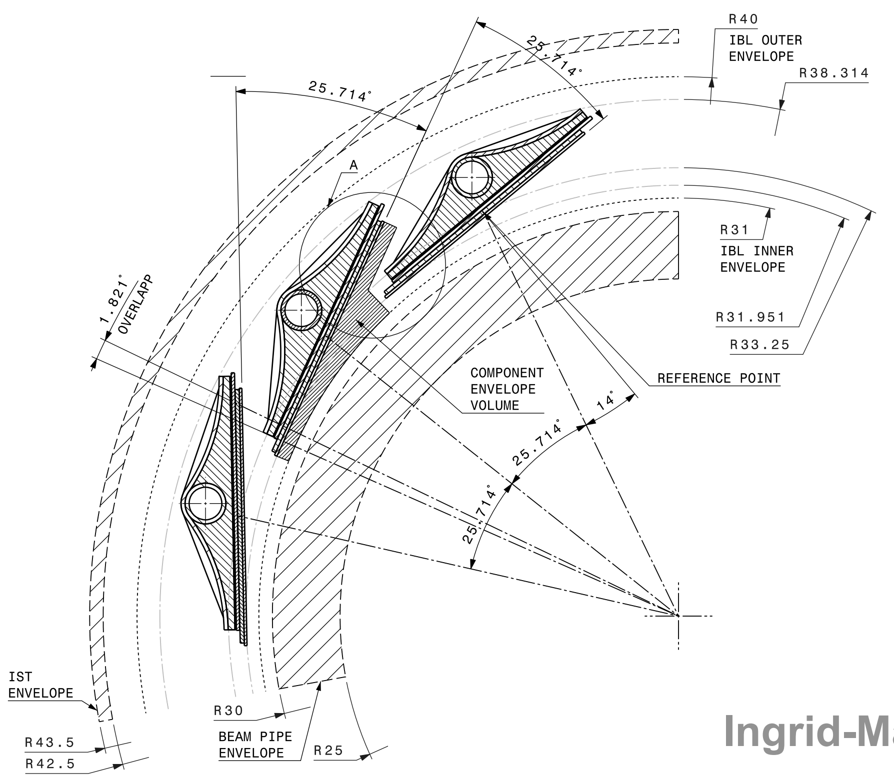
Present Beam Pipe & B-Layer

IBL: A Technological Challenge

- Amount of material in detector has direct impact on overall detector performance
- Additional layer inserted increases material budget
  - sensor and support material needs to be minimized
  - the detector has to be powered, read-out and cooled

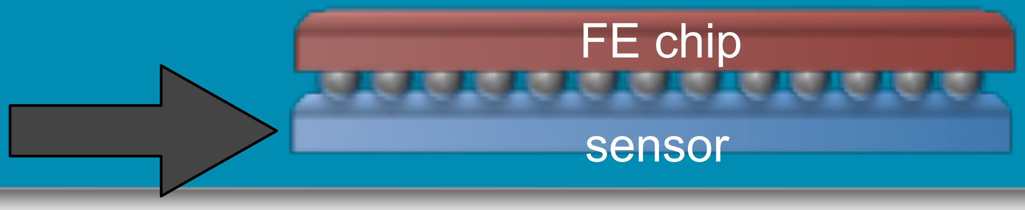


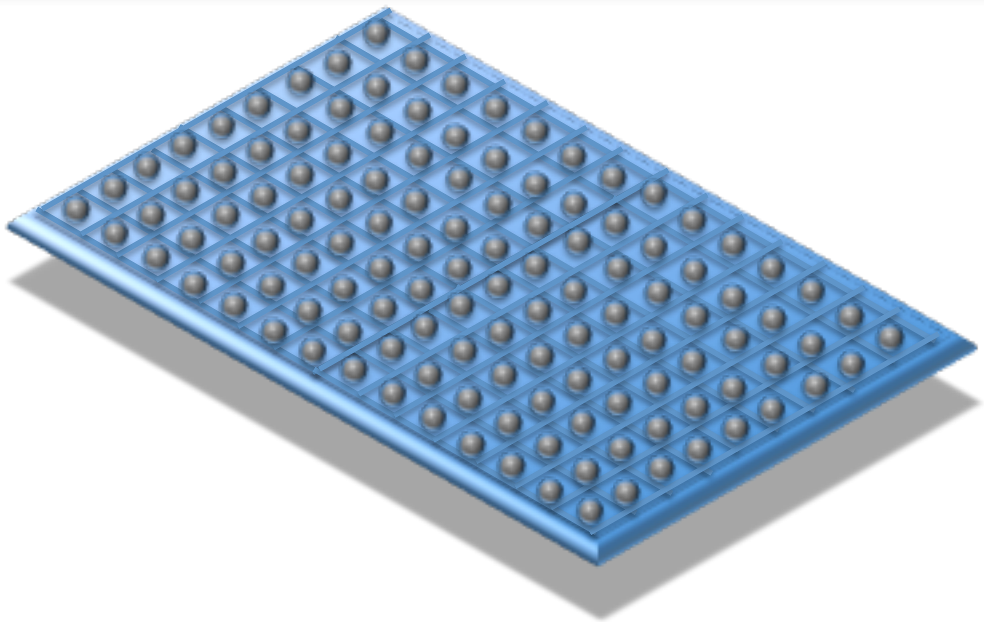
- New stave design in carbon foam structure
  - low material budget, while building excellent heat path to cooling pipe



- Reduced material budget: 0.015 X_0
- Coverage: z = 60cm, $|\eta| < 2.5$
- Sensors @33mm (now@50.5mm) => smaller beam pipe (29 -> 25mm)
- 14 staves with phi overlap
- No eta overlap due to clearance => minimize modules edge

Active Sensor





Hybrid Pixel Chip Assembly:

- sensor and FE chip are produced separately
- connected via bump bonding

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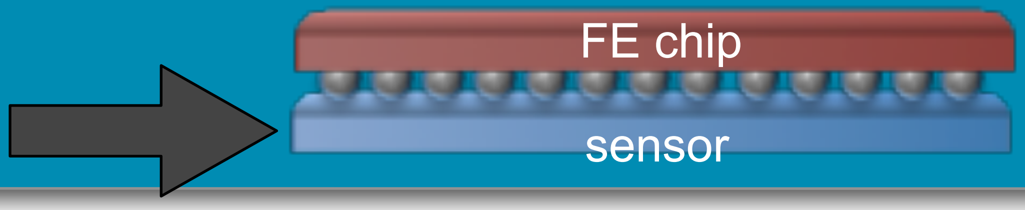

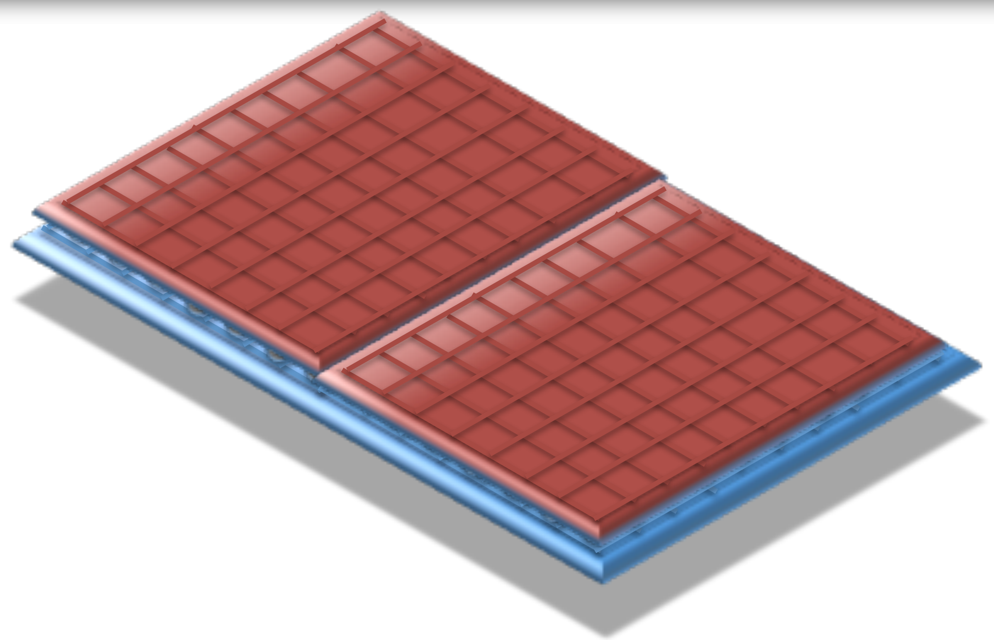

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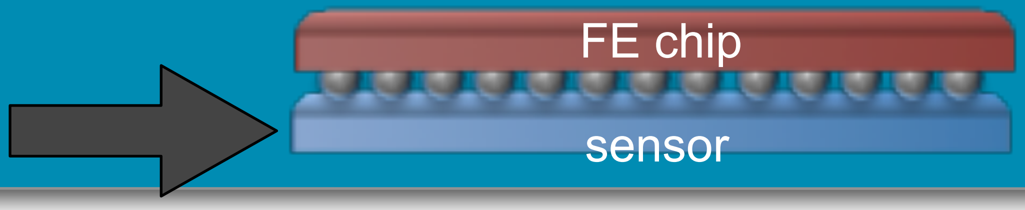

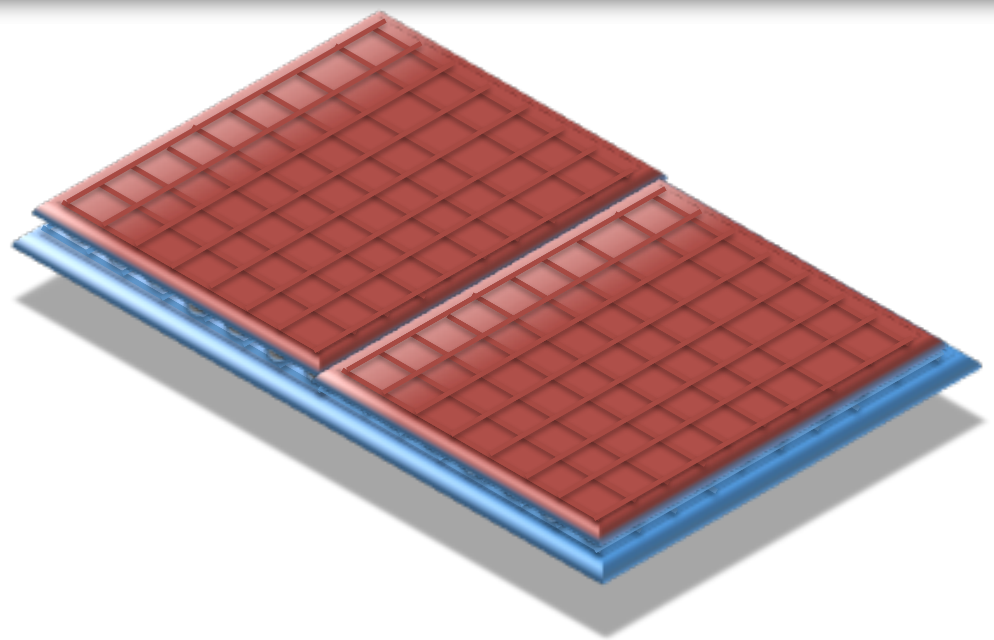

Hybrid Pixel Chip Assembly:
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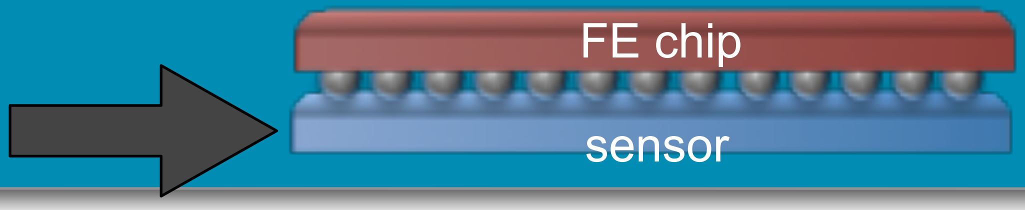
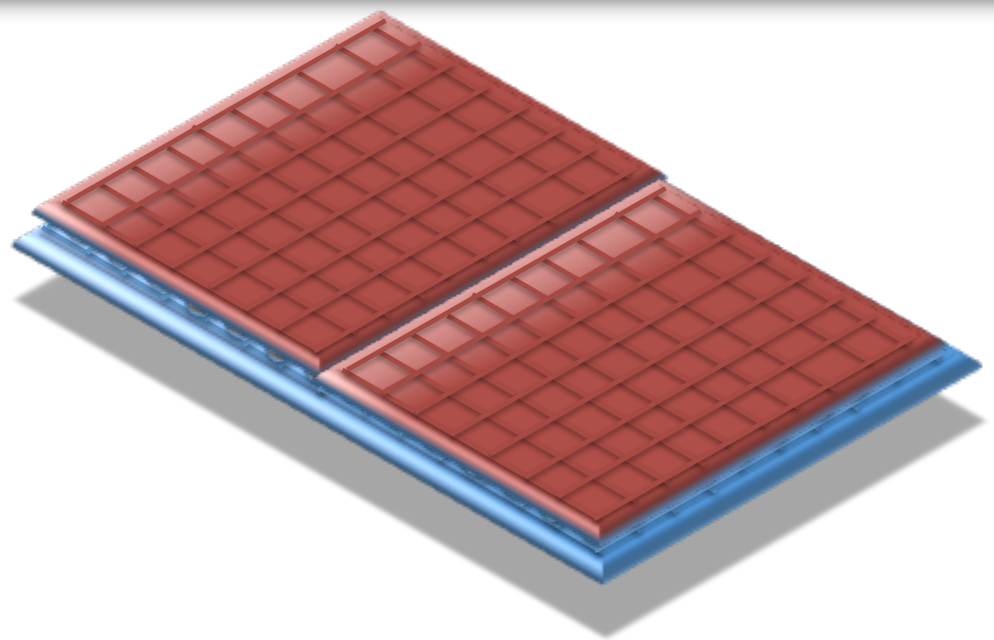
Planar Sensor

- “classic” sensor design
- oxygenated n-in-n
- 200µm thick
- Minimize inactive edge by shifting guard-ring underneath pixels (215 µm)
- Radiation hardness proven up to 2.4 . 10^{16} p/cm^2
- Problem: HV might need to exceed 1000V

Active Sensor





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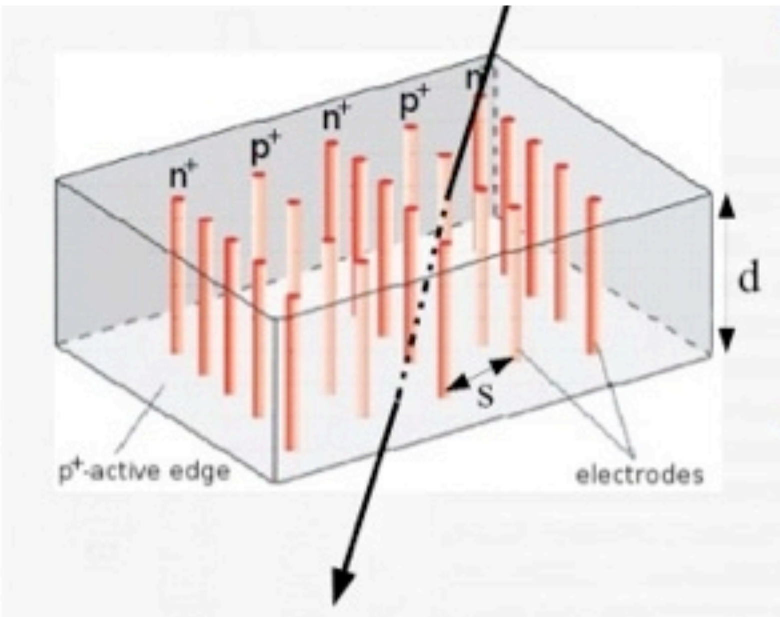

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3D Silicon

- Both electrode types are processed inside the detector bulk
- Max. drift and depletion distance set by electrode spacing
- Reduced collection time and depletion voltage
- Low charge sharing

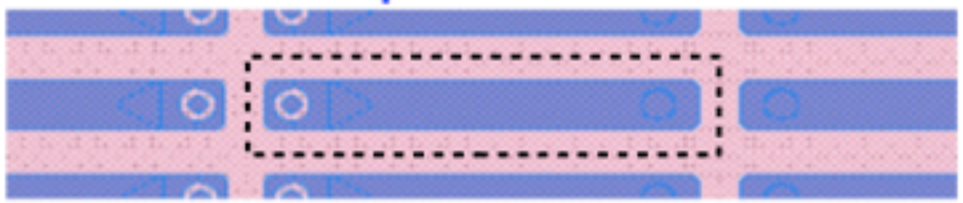
IBL baseline:

– 75 planar sensors

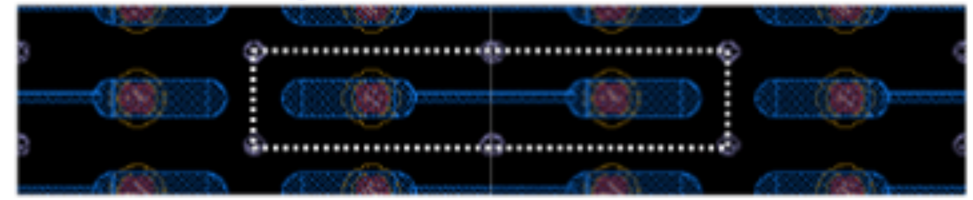
– 25 (3D sensors@large eta)

Test Beam: new after review

Planar pixel sensors

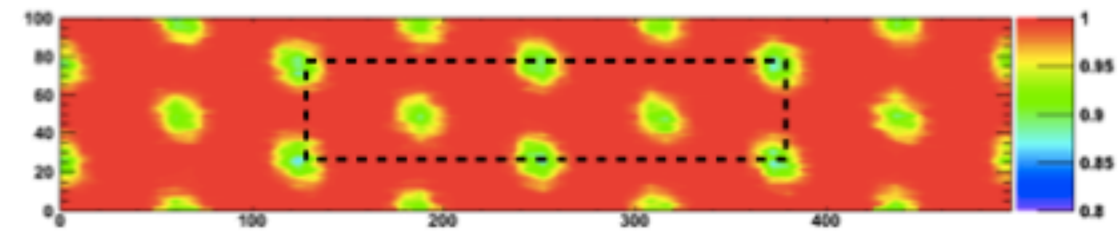


3D pixel sensors



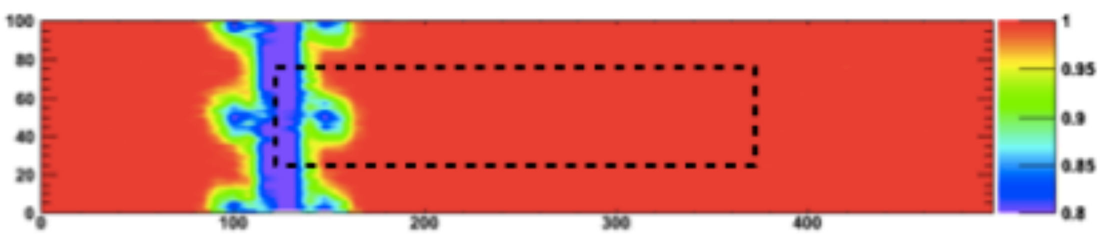
0 deg

SCC40 PPS, un-irrad, HV=150V, Eff.=99.95%

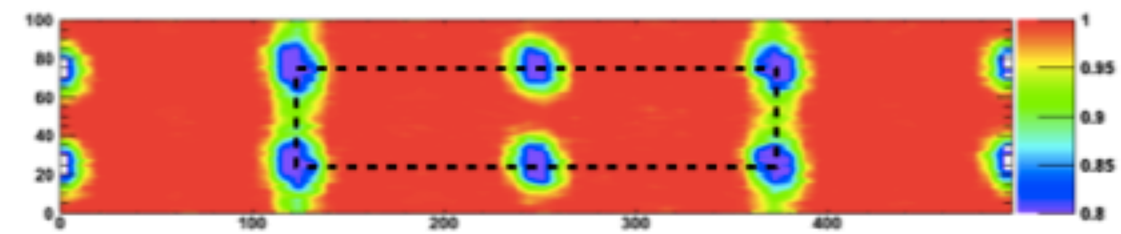


SCC105 FBK-3D, un-irrad, HV=20V, Eff.=98.77%

0 deg

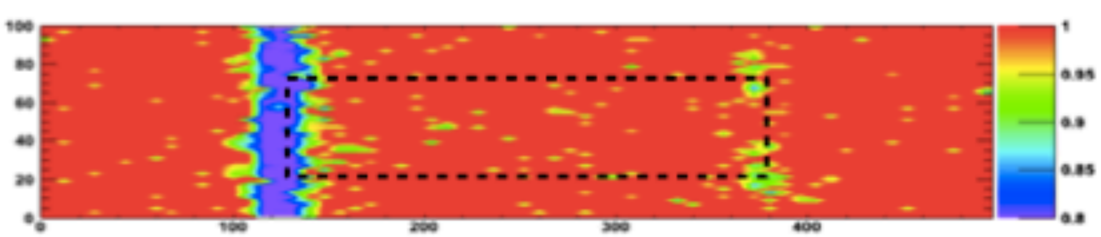


LUB4 PPS, n-irrad, HV=1000V, Eff.=97.90%

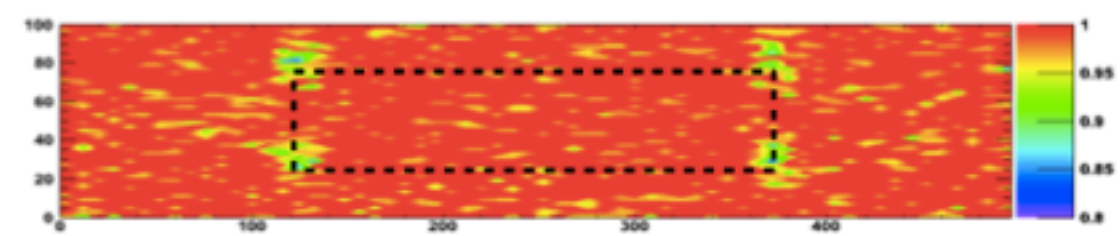


SCC81 CNM-3D, n-irrad HV=160V, Eff.=97.46%

15 deg



SCC60 PPS, p-irrad, HV = 940V, Eff.=97.65%

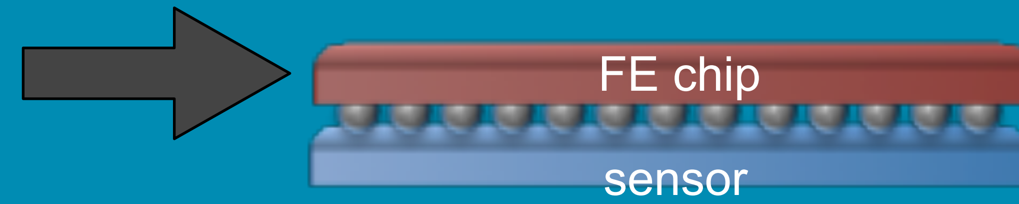


SCC34 CNM-3D, p-irrad, HV = 160V, Eff.=98.96%

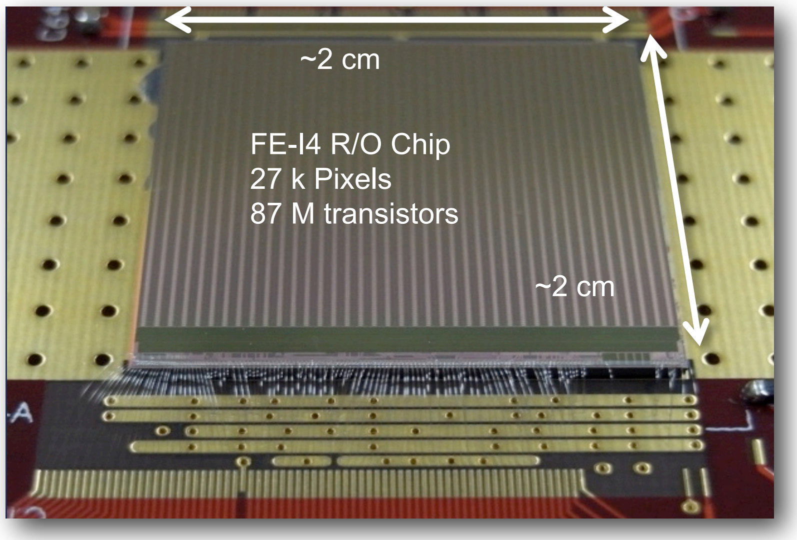
Comment: Autumn 2011 test beam confirmed requirements after full dose.

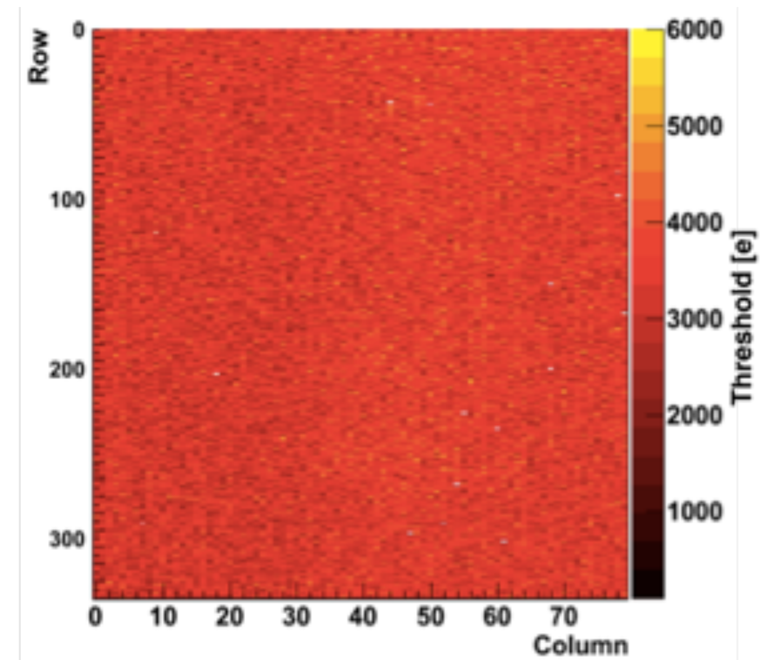
Threshold: 1600 e
p-irrad: $5x10^{15}$ n_{eq}/cm^2 with 24 MeV protons
n-irrad: $5x10^{15}$ n_{eq}/cm^2 by nuclear reactor

New Front End Chip FE-I4



- Reasons for a new front-end chip
  - Increased radiation hardness (> 250 MRad)
  - Greater fraction of the footprint devoted to pixel array
    - Move the memory inside the array
  - Lower power
    - Don't move the hits around unless triggered
  - Able to take higher hit rate
    - Store the hits locally and distribute the trigger
  - Still able to resolve the hits at higher rate
    - Smaller pixels and faster recovery time
  - No need for extra control chip
    - Significant digital logic blocks on array periphery





FE-I4B Threshold scan

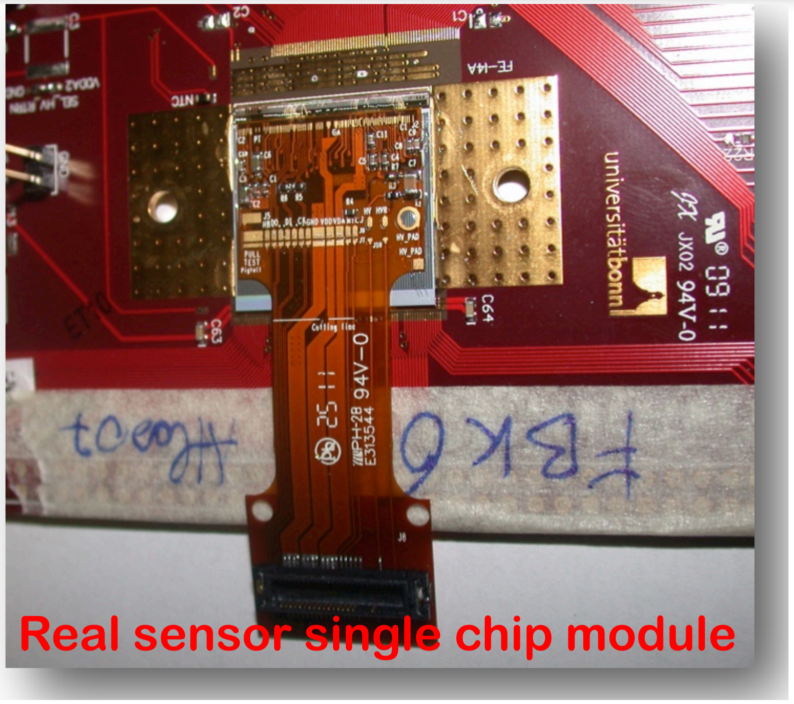
=> 19 x 20 mm^2 130 nm CMOS process, based on an array of 80 by 336 pixels (each 50 x 250 μm^2)

Improved version B was received and used for various tests

Modules & Staves - status April 2012

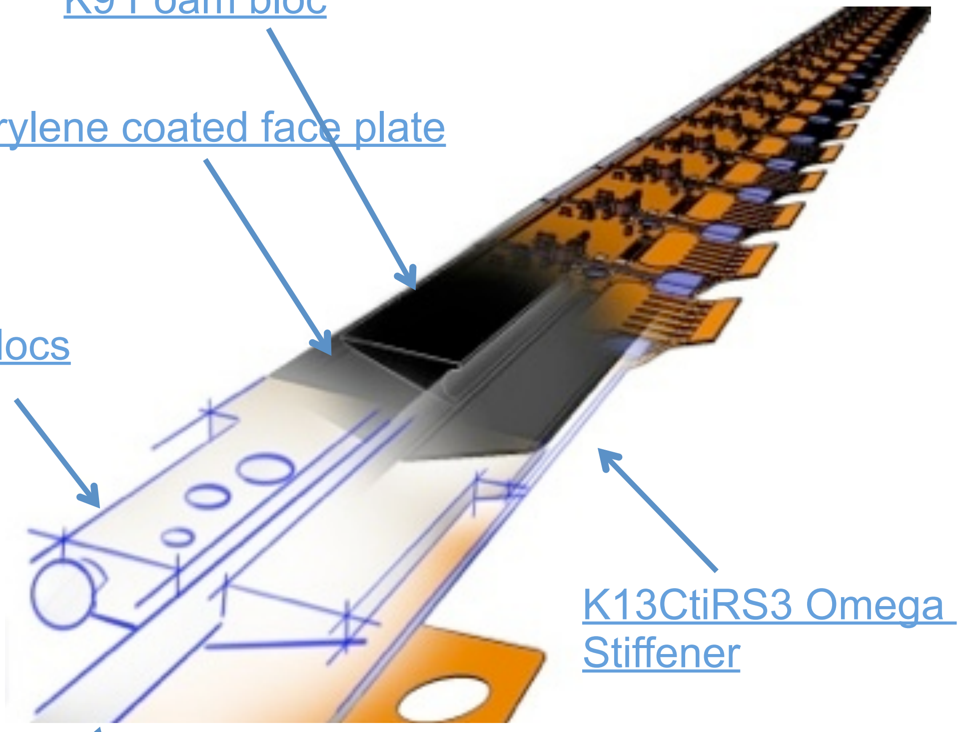
Modules:

- First flex modules made and characterized.
- Sensors and FE-I4B being prepared for bump bonding.
- Module production will start next month.


Real sensor single chip module

Stave prototypes:

- 6 final prototypes made (1.5 mm pipe, faceplate with parylene)
- Full Stave PRR including Stave loading early July
- Planned to produce 33 staves (already started) → load 24 (14 needed for IBL)

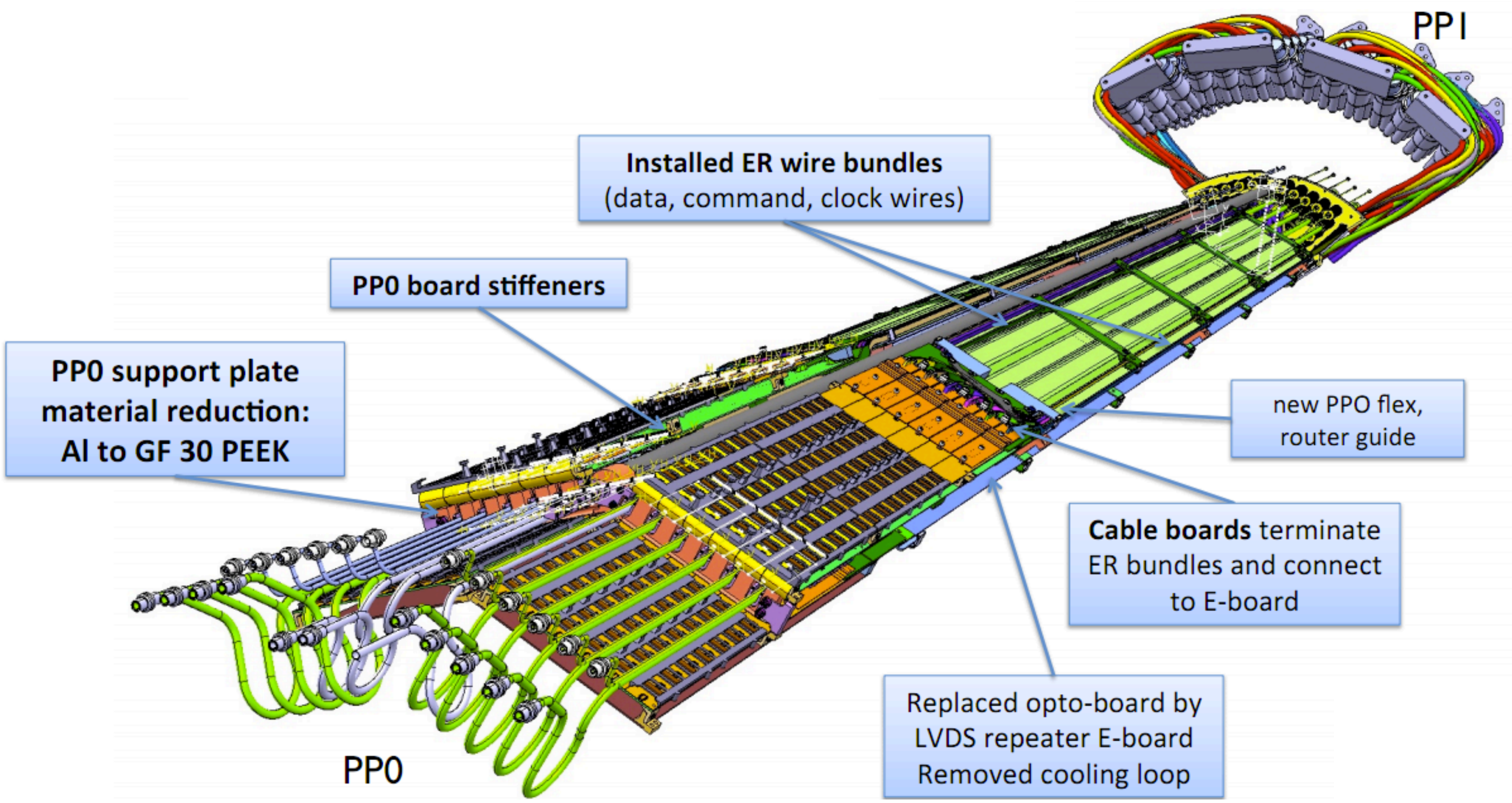


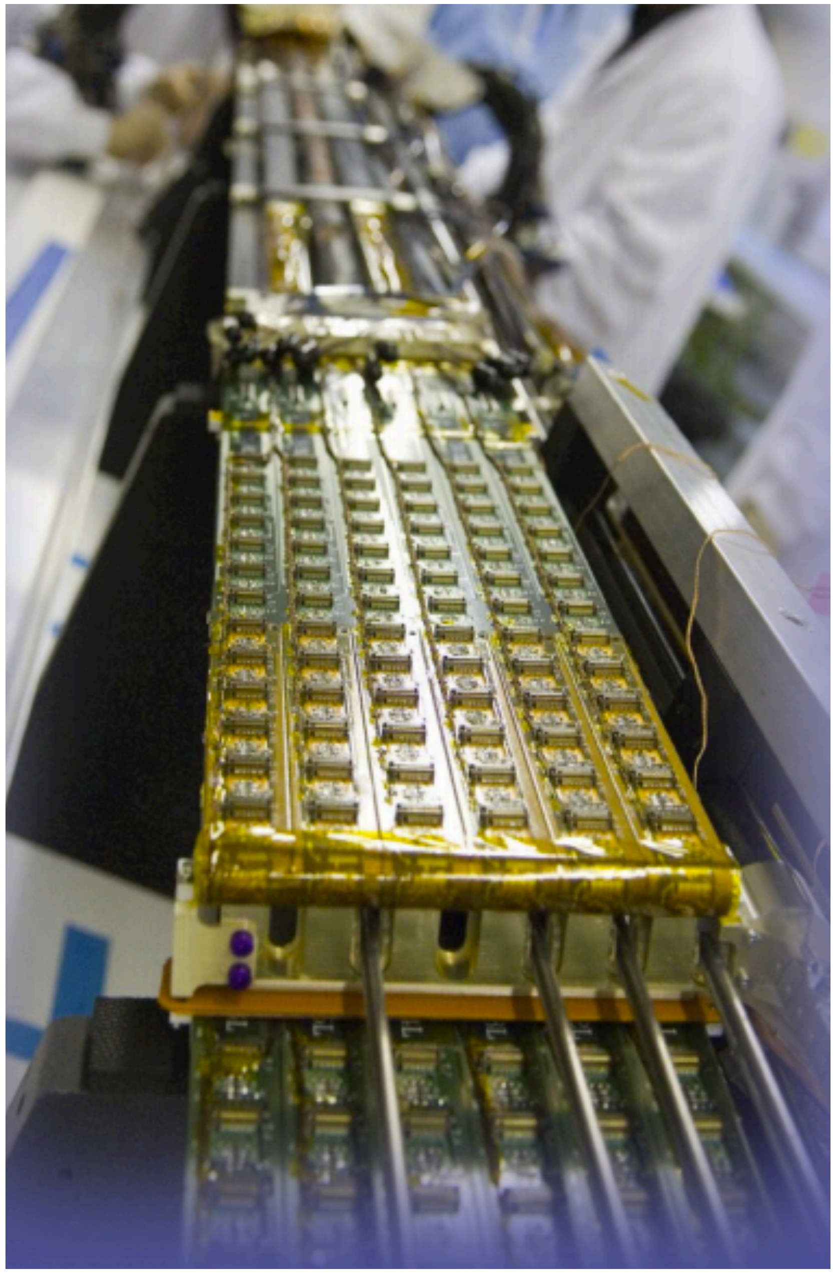
IBL community is very busy, but project is on schedule !

New Service Quater Panel

Be ready to take the final decision if to extract and repair or not the pixel detector on the surface during 2012 (first half)

- New service layout for all pixel service (nSQP)"
- Redundant and safer location for fibers transmitters"
- Doubling of the readout bandwidth in view of Phase 1 upgrade"
- **Diamond Beam Monitor attached to nSQP**
  - Uses Diamond Si detectors produced for IBL trials
  - Will provide very fast monitoring of beam in high rate environment

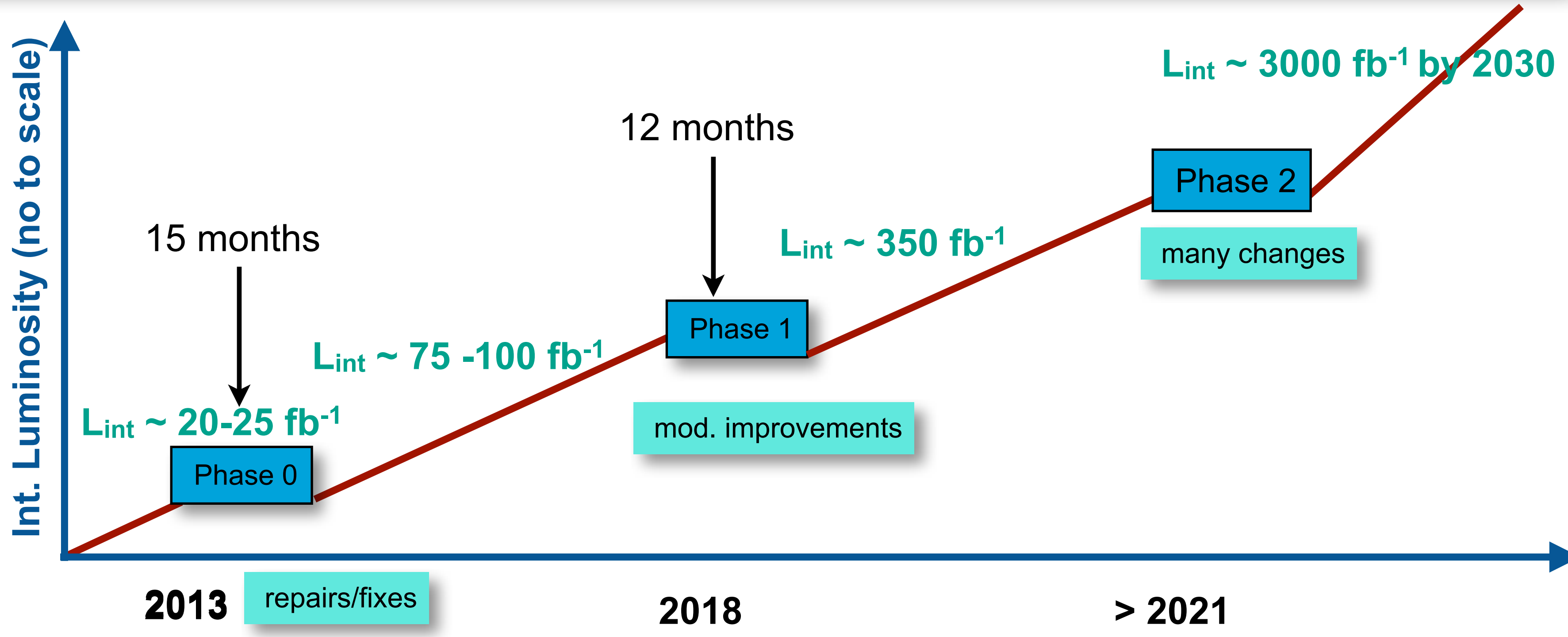




Phase 1 Upgrade
(2018 Shutdown LS2)

Tentative Schedule and ATLAS Plans

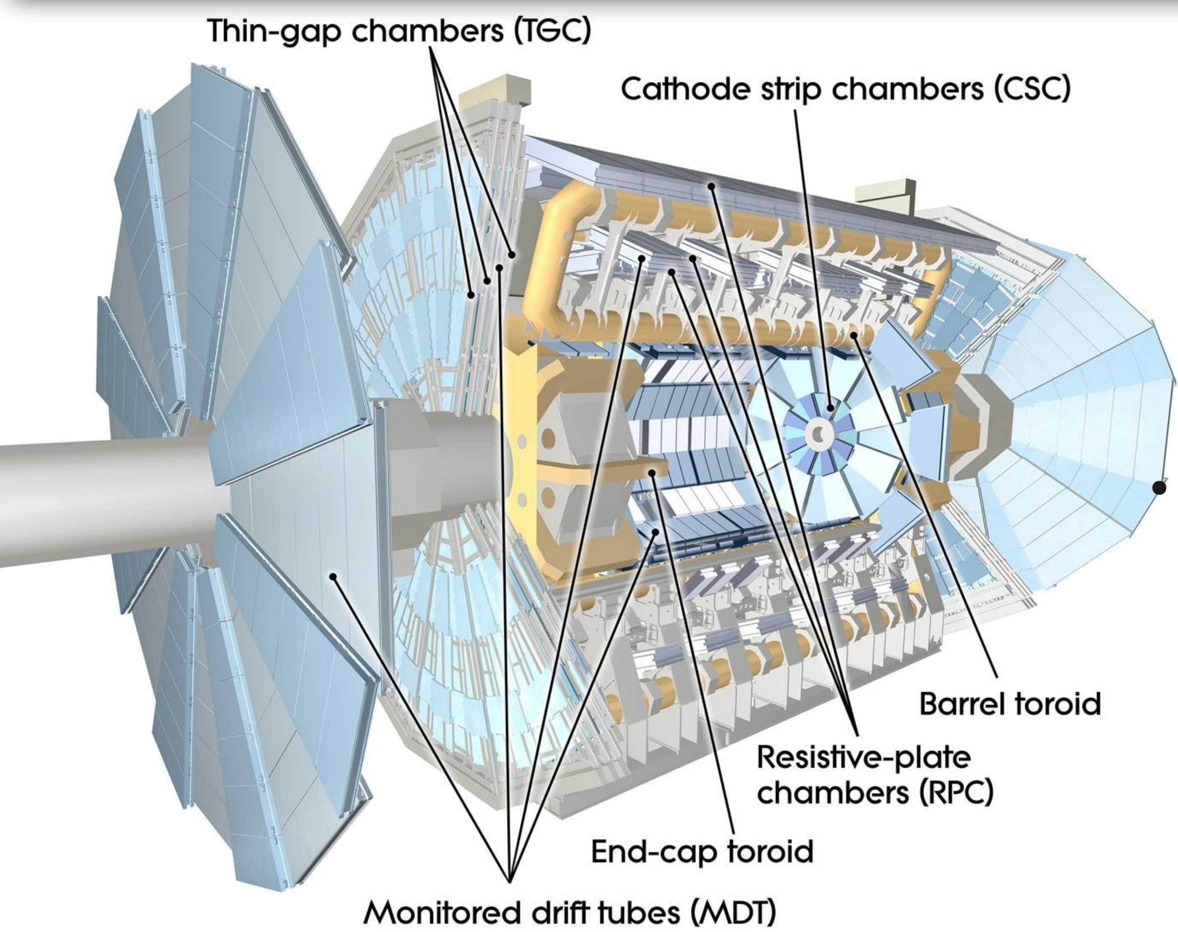
- **Phase 0 (2013):**
  - **Pixel: Insertable B-Layer (IBL)**
  - Pixel: opto-electronics repair
  - Beam-pipe -> Beryllium
  - Infrastructure consolidation
  - Muon/forward upgrade
  - nSQP



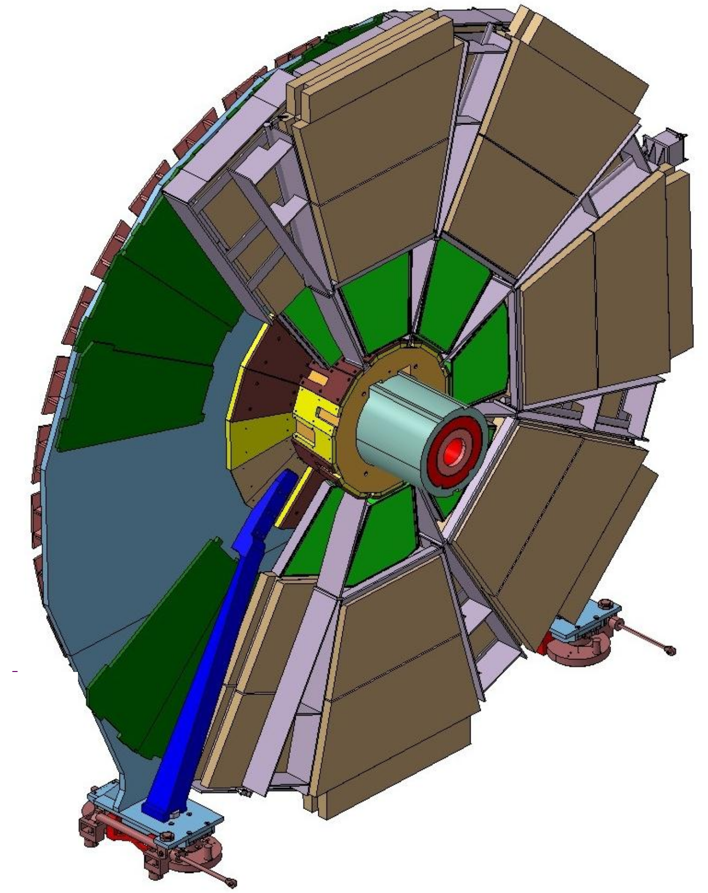
- **Phase 1 (2018):**
  - **Muon: additional SCS layers**
  - Fast track trigger at "Level-1.5"
  - Higher granularity in Level-1 trigger
  - New diffractive physics detector stations
  - All upgrades should be compatible with Phase 2 !

- **Phase 2 (>2020):**
  - **ID: new tracker**
  - LAr: barrel electronics and new forward elements
  - Tile Calorimeter: new electronics
  - Muons: new forward layers
  - TDAQ: major upgrades

Muon System of Current ATLAS Detector



- Muon spectrometer was designed to work at the design luminosity 1×10^{34}
- Unexpected high trigger rate was observed in the muon endcap region
- Due to trigger chamber resolution limitations
- New small wheel muon chambers will be added to reduce the fake rate equipped with precision tracker that works up to the ultimate luminosity, $5\text{-}7 \times 10^{34}$

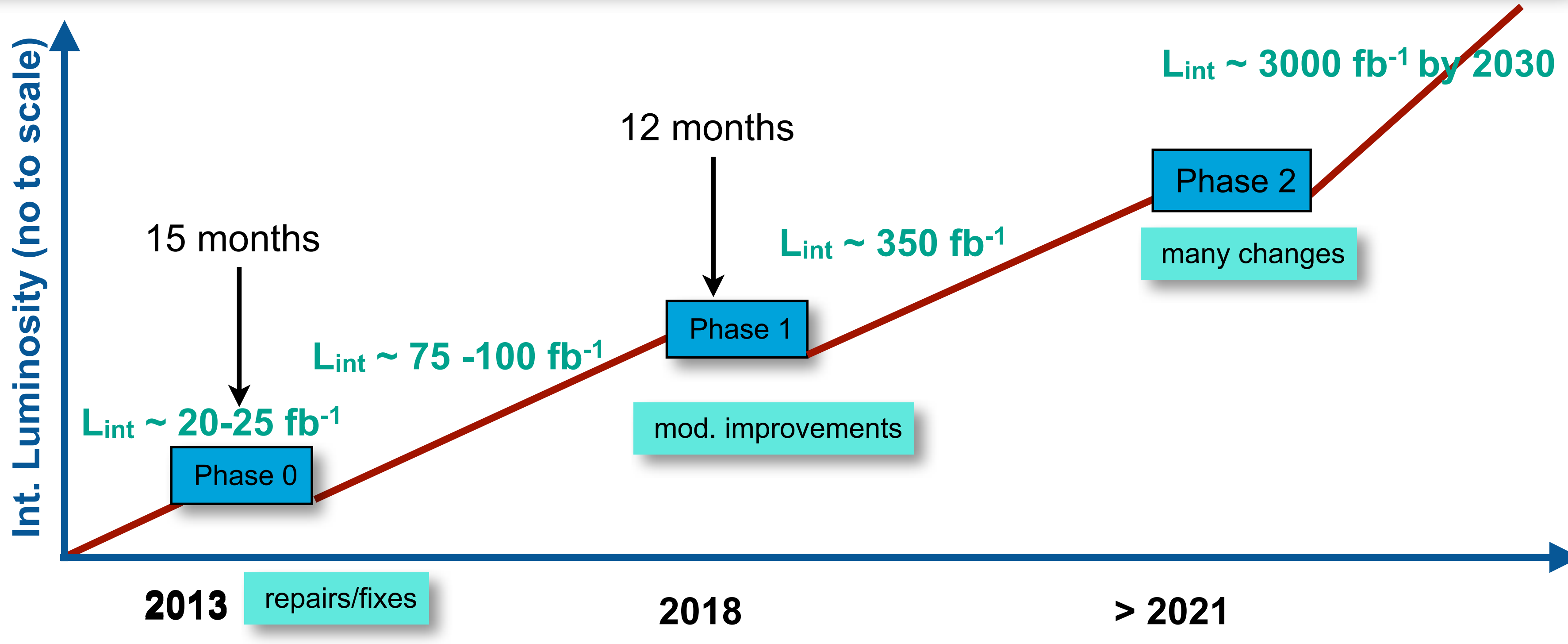


Possible Technologies

- sMDT (Muon Drift Tubes): Small tubes (15 mm tube : much shorter drift time)
- sTGC (Thin Gap Chambers): reduced cathode resistivity => rate capability has been increased substantially up to 30 kHz/cm^2
- RPC (Resistive Plate Chambers)
- Micromegas (MM)

Phase 2 Upgrade
(2022 Shutdown LS3)

Tentative Schedule and ATLAS Plans



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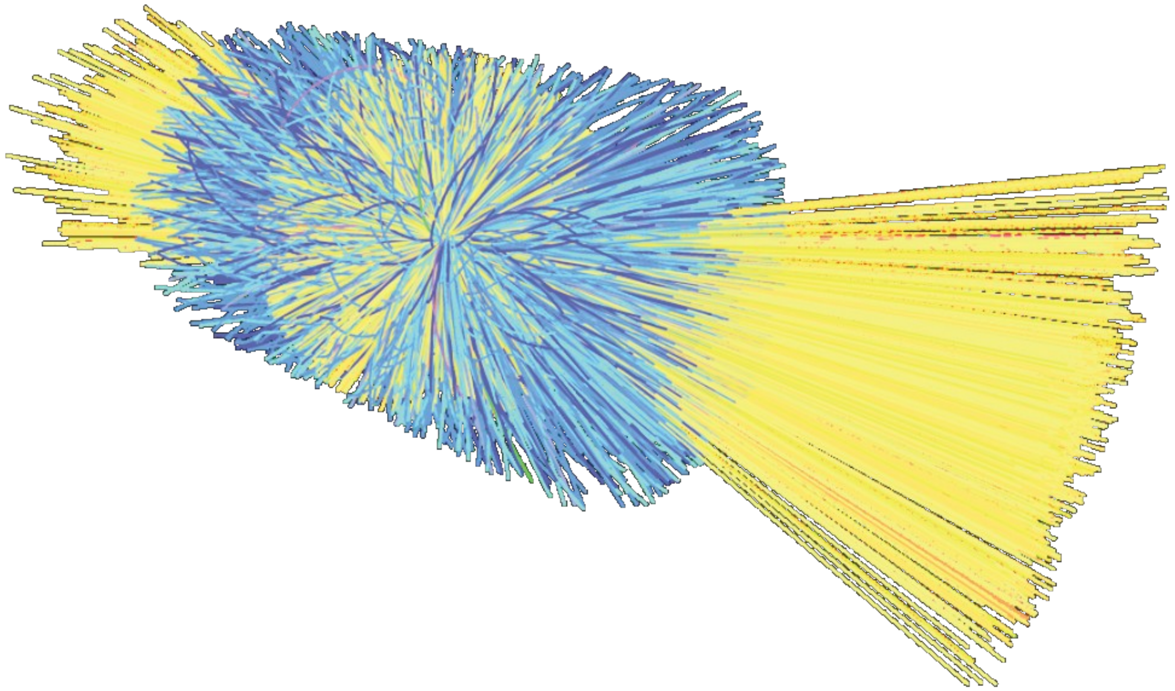
Upgrading the ATLAS Experiment

- To keep ATLAS (and CMS) running beyond ~10 years requires tracker replacement
- Current trackers designed to survive up to 10MRad in strip detectors (≤ 700 fb^{-1})
- For the luminosity-upgrade the new trackers will have to cope with:
  - much higher integrated doses (a factor of 10 more)
  - much higher occupancy levels (up to 200 collisions per beam crossing)
  - Installation inside an existing 4π coverage experiment



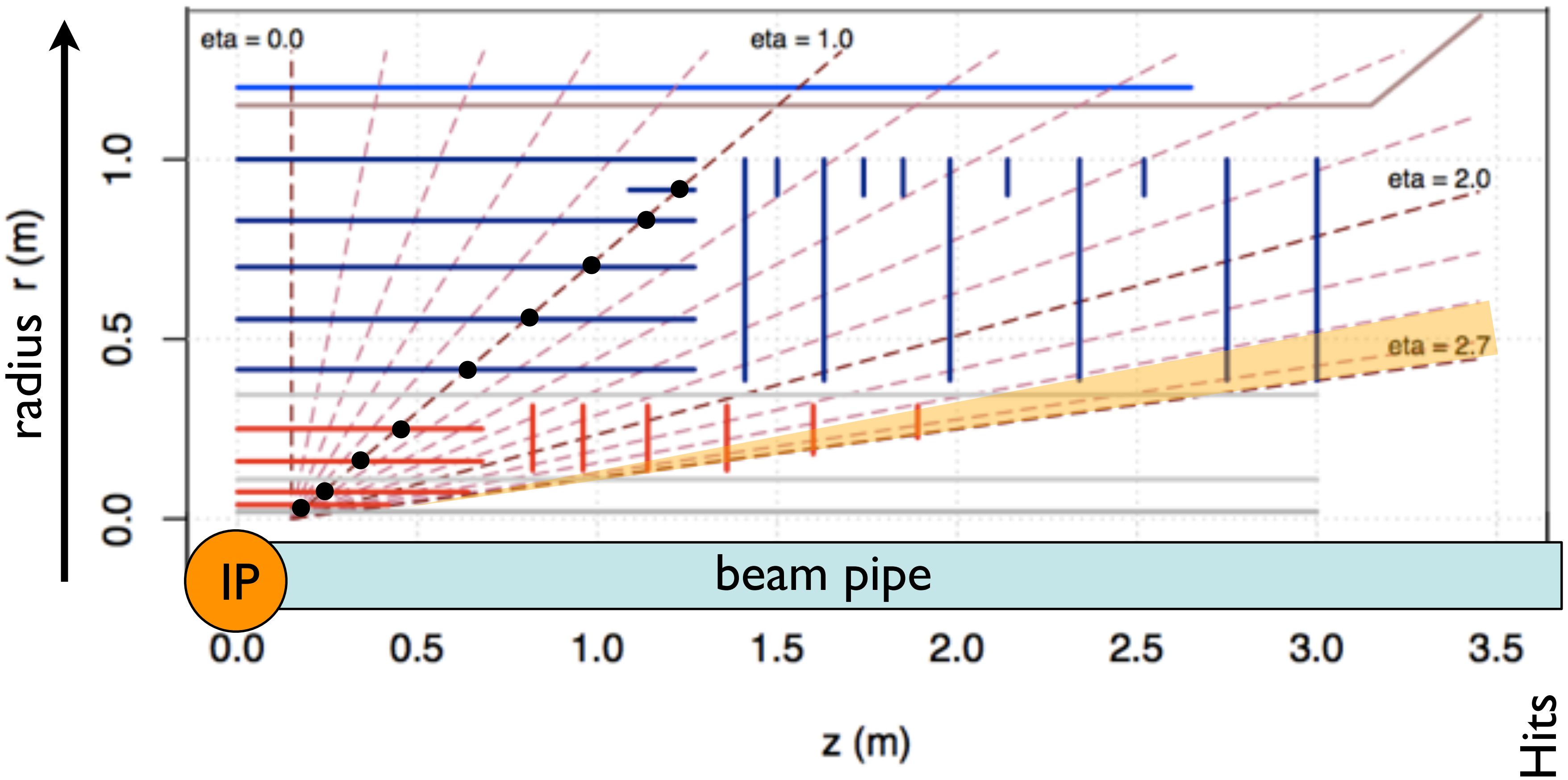
- Budgets are likely to be such that replacement trackers cannot cost more than the ones they replace - while needing higher performance to cope with the extreme environment

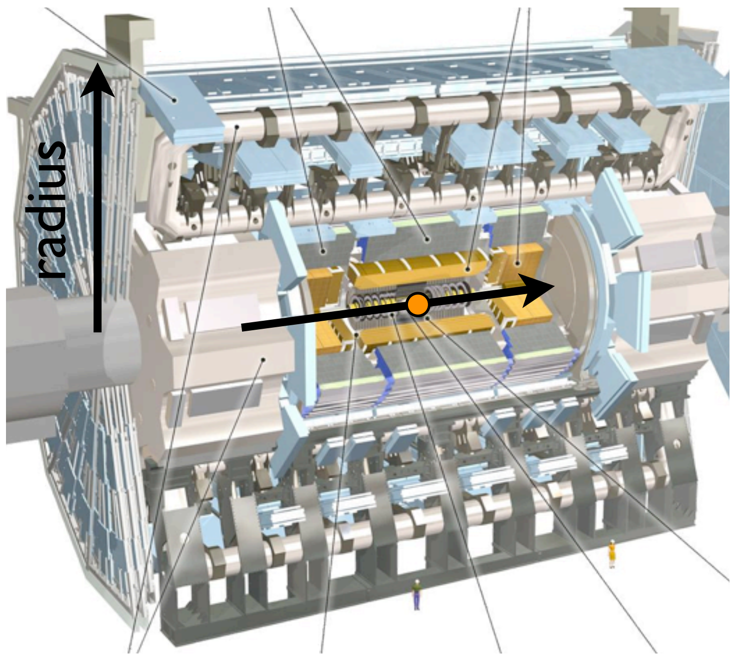
To complete a new tracker by ~2020, require Technical Design Report 2014/15

(Note the ATLAS Tracker TDR: April 1997; CMS Tracker TDR: April 1998)

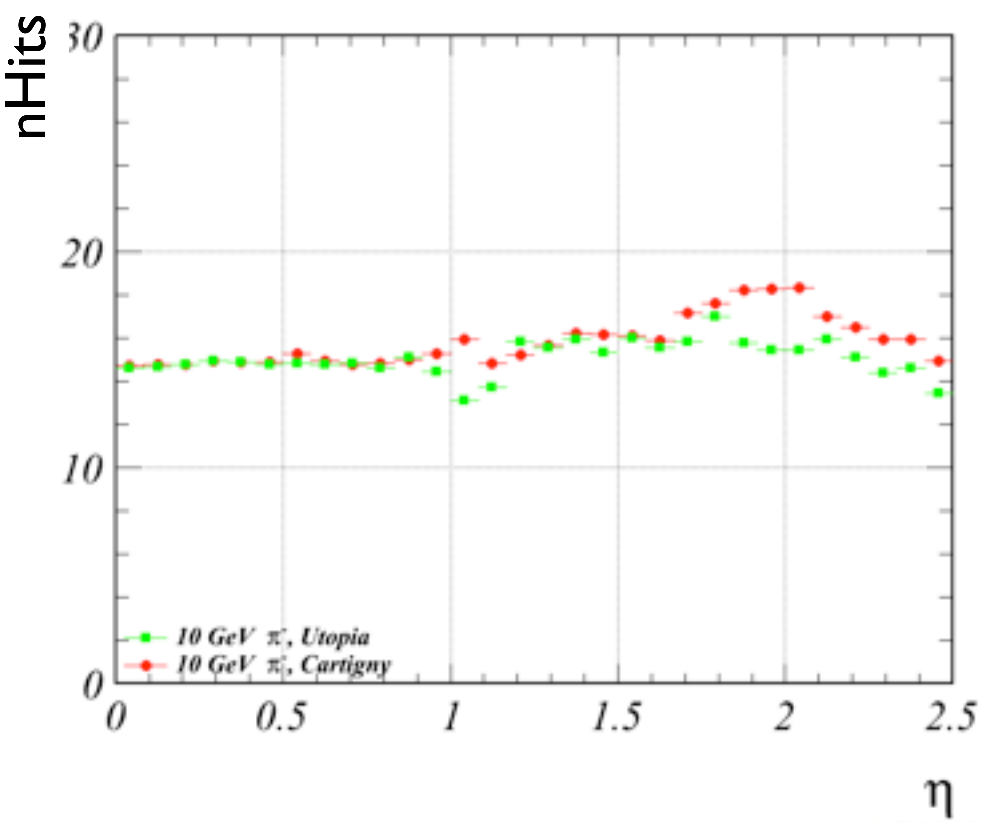
New Layout "Cartigny" - the first meter

A quarter of the ATLAS Inner Detector



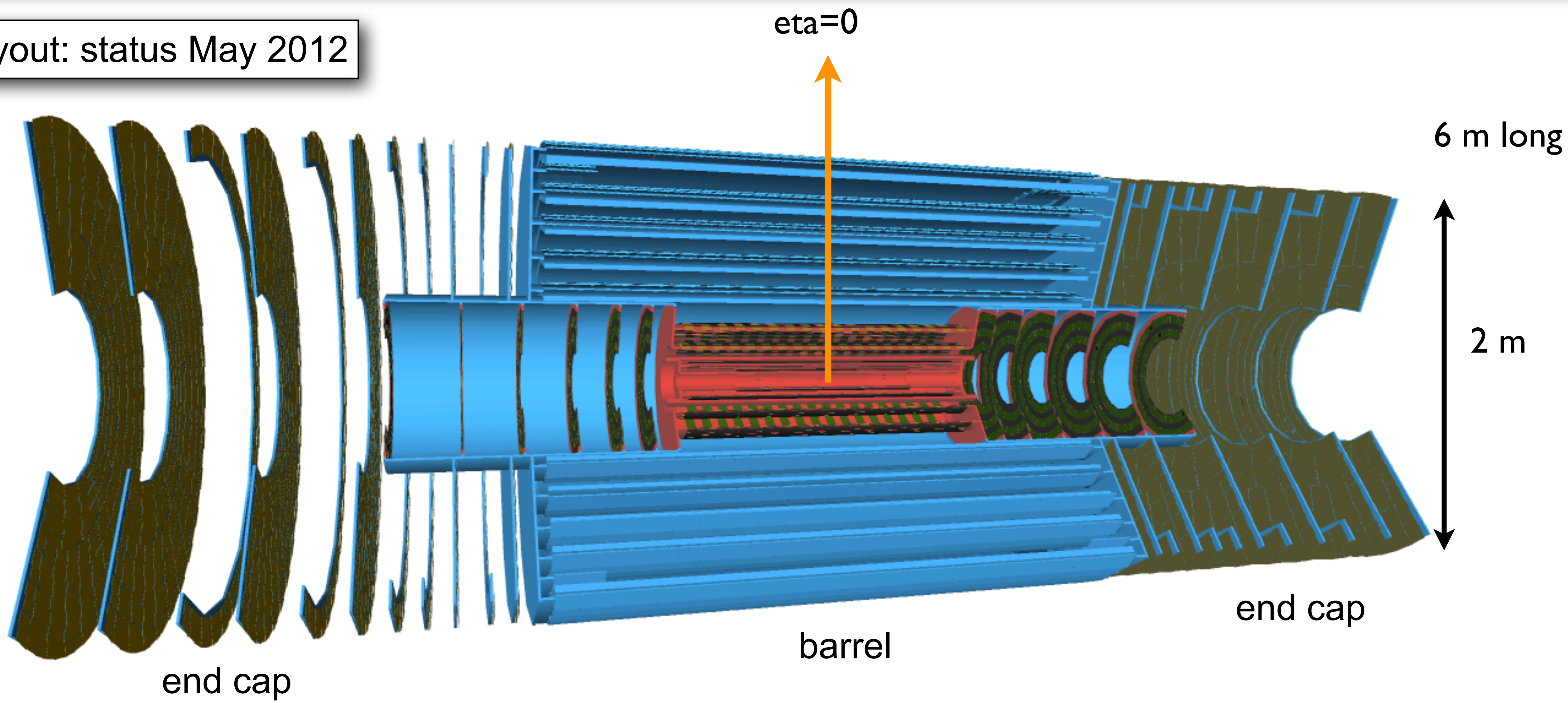


- Tracking at the HL-LHC conditions: need 11 hits and all silicon tracker
- Full coverage for $|\eta| < 2.5$, Pixels cover $|\eta| < 2.7$ (forward muon identification)
- Minimize hit gaps: Strip disk z_{max} = 3m , endcap disklets, small layer in barrel; endcap gap
- Increase radius of last Pixel layer to 25-30cm (better double track resolution)

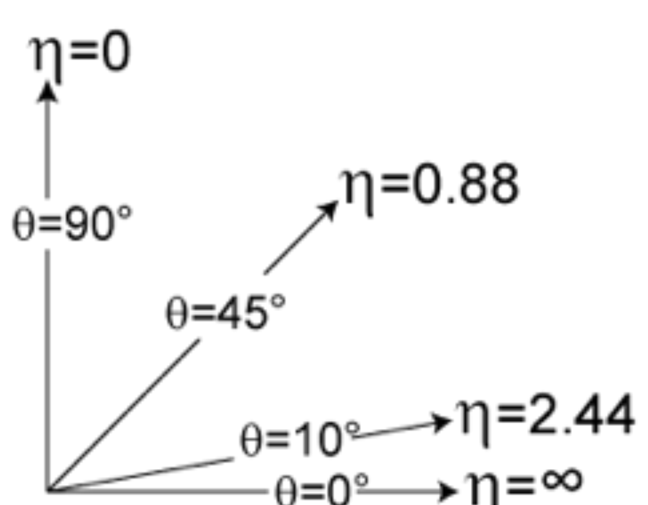


The new Tracker for ATLAS

layout: status May 2012



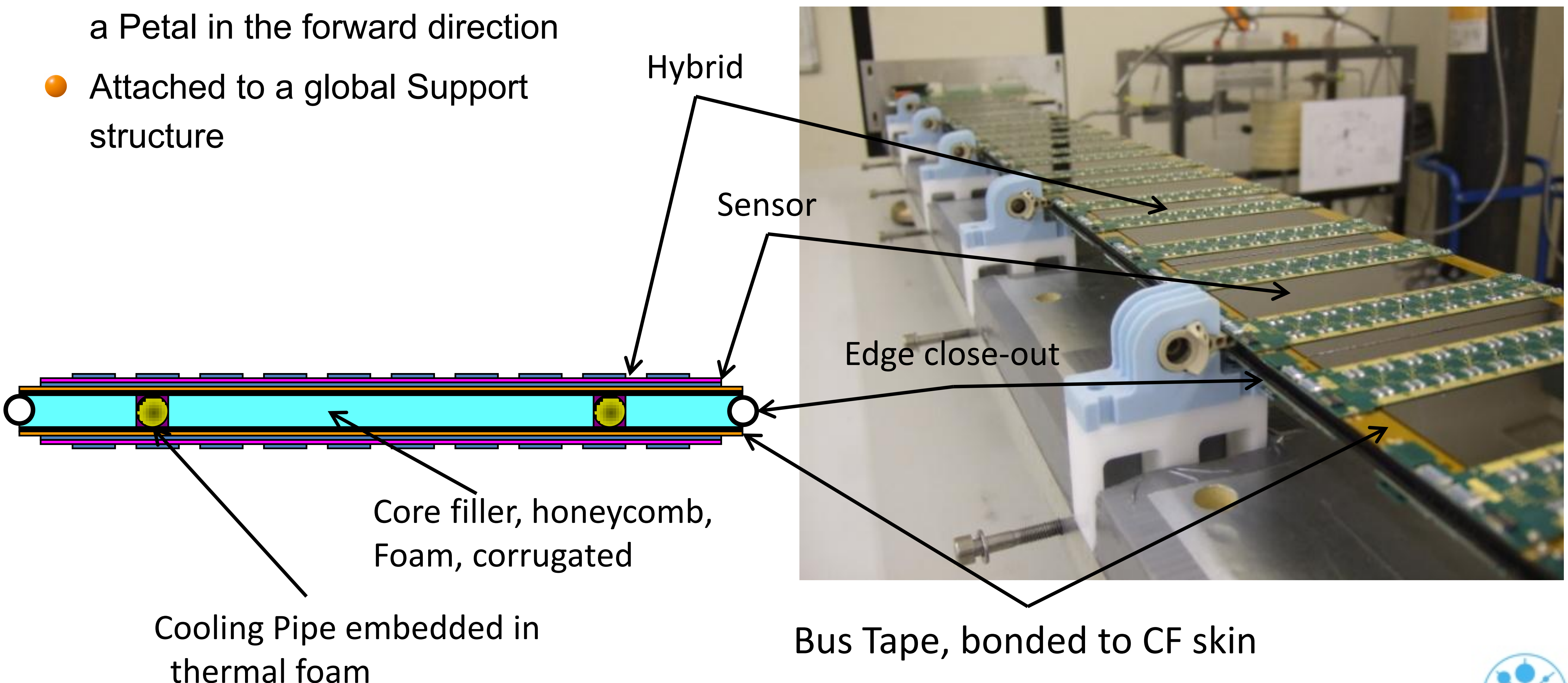
- Pixel: 4 barrel layer plus 6 disks on each side
  - 80 -> 400 million pixels (~7m^2),
- and 5 double sided Strip layers plus 5 strip disks on each side
  - 6 -> 45 million strips (~200m^2)
- In this talk: concentrate on strip detector



Strip Detector Stave Design

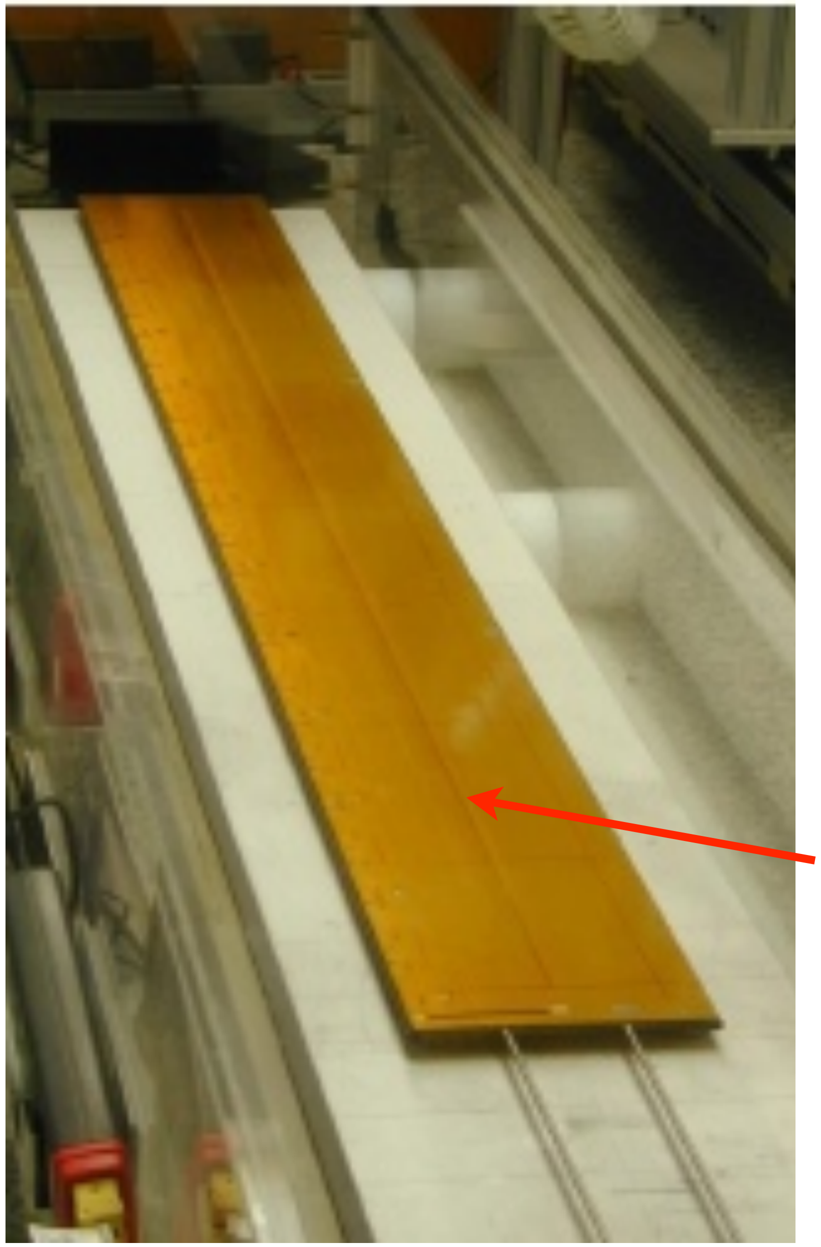
- Silicon Modules directly bonded to a cooled carbon fibre plate.
- A sandwich construction for high structural rigidity with low mass.
- Services integrated into plate including power control and data transmission.

- Called a Stave in barrel region and a Petal in the forward direction
- Attached to a global Support structure

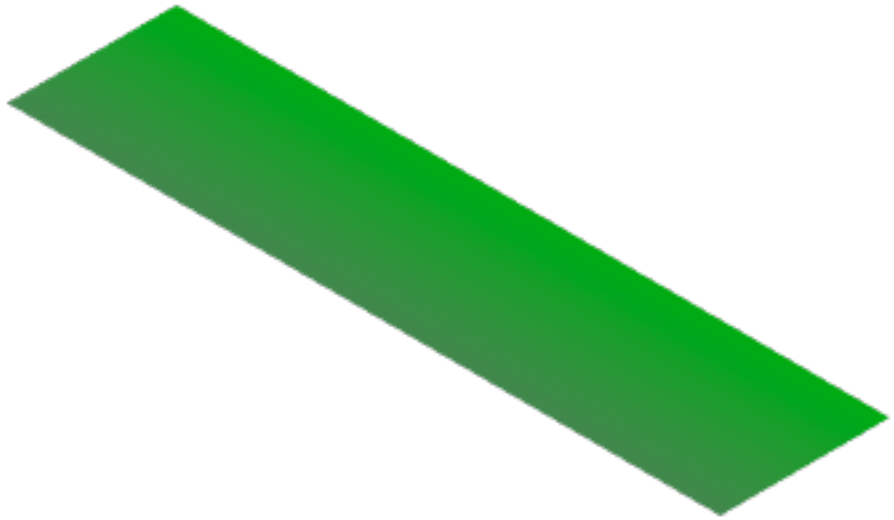


Carbon Structure with Cooling

- Stave/Petal Core: composite structure consisting of CF facings laminated to foam/ honeycomb filler with embedded cooling pipes.
- Explicit use of advanced thermal materials.



Stave Concept (1)



- **Hybrid** = kapton board with FE chips (ABCNext, connection via wire bonds)
- **Module** = silicon sensor with readout hybrid (connection via wire bonds)
- **stave** = core structure + cooling + electrical services (power, data, TTC) + modules

- Tested chips are glued on to hybrids
  - wire bonded, tested ….
- The hybrid are then glued on top of sensors
  - wire bonded, tested ….
- This “module” is directly glued on top of the kapton bus tape

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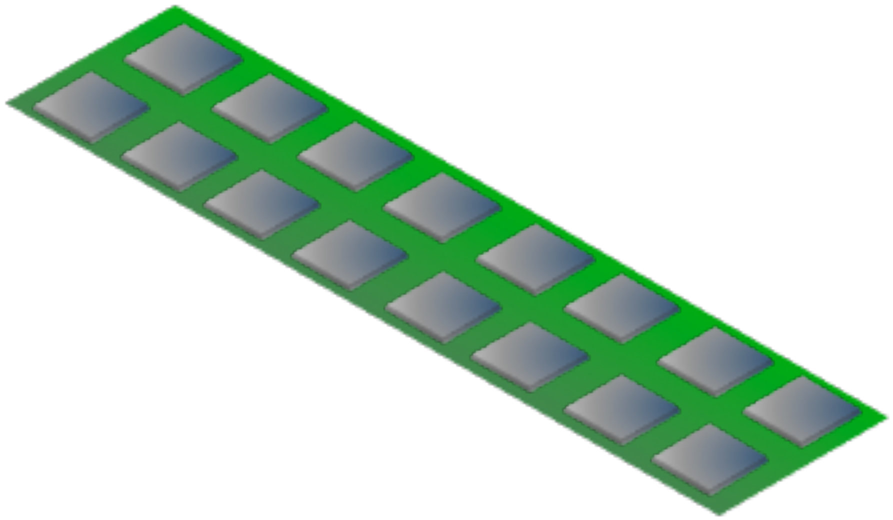

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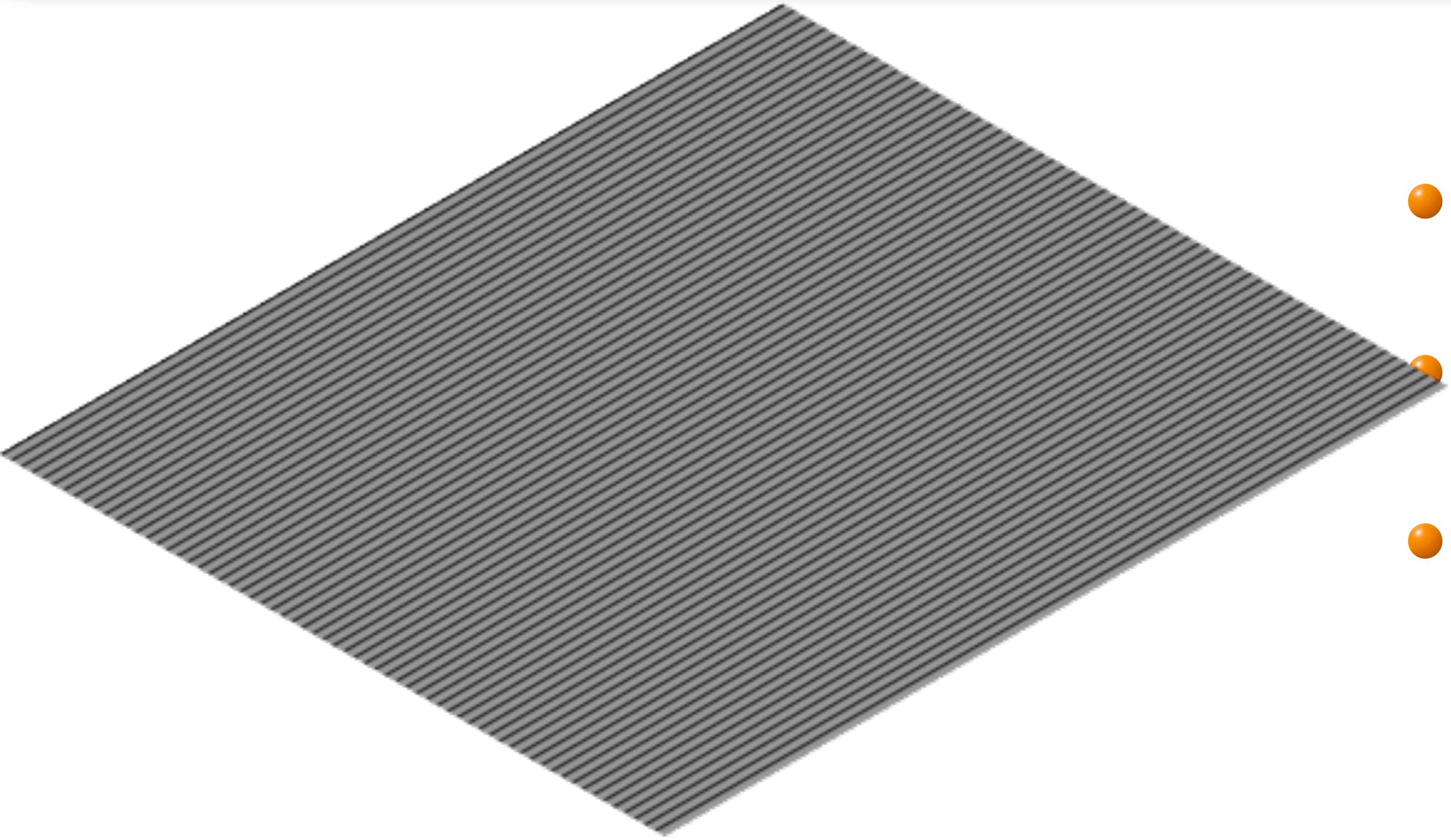

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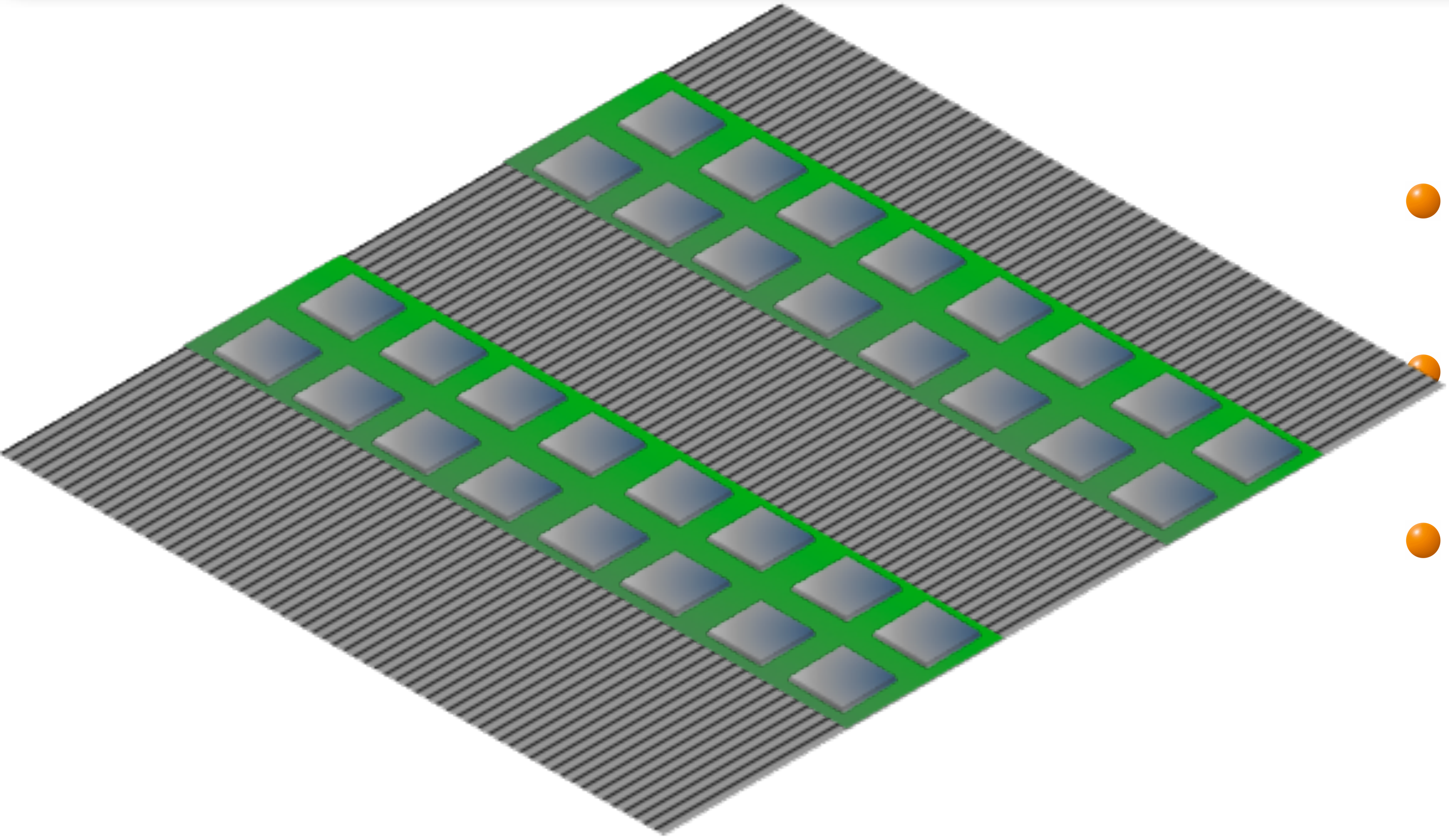

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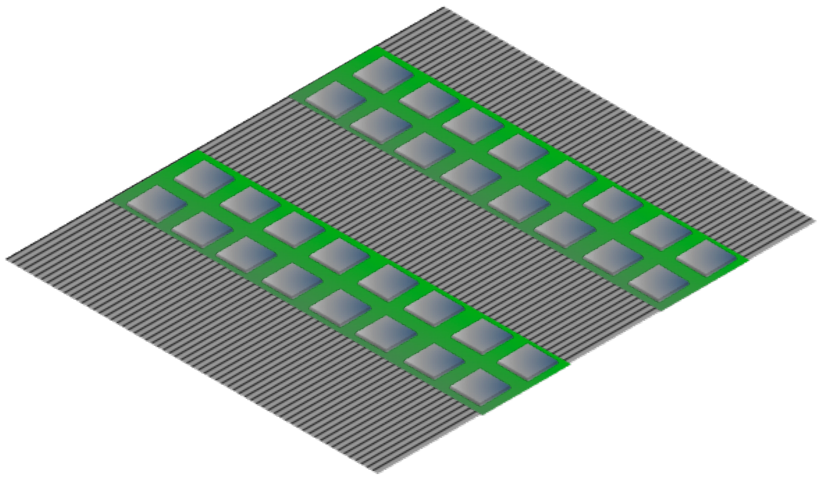

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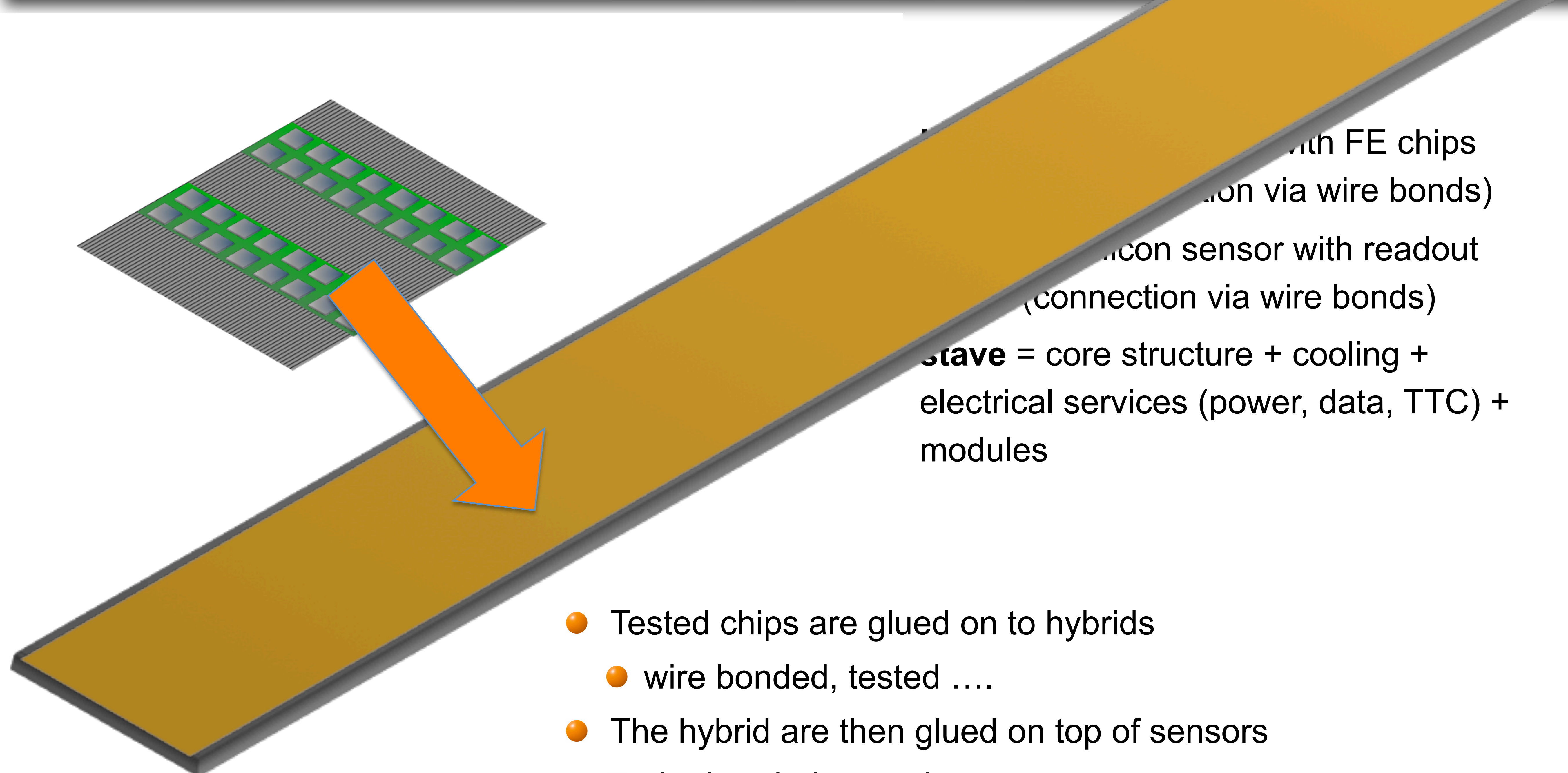

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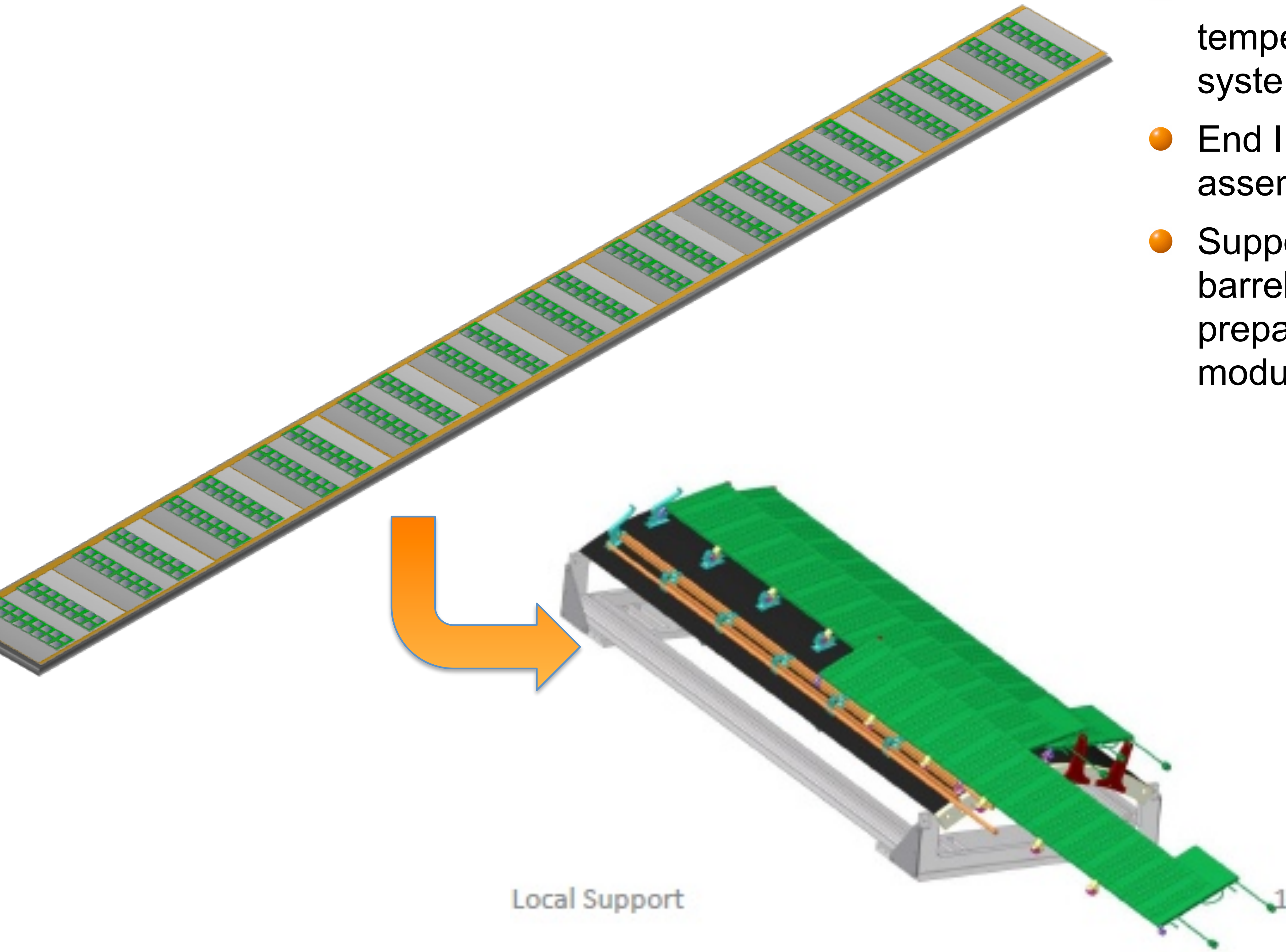
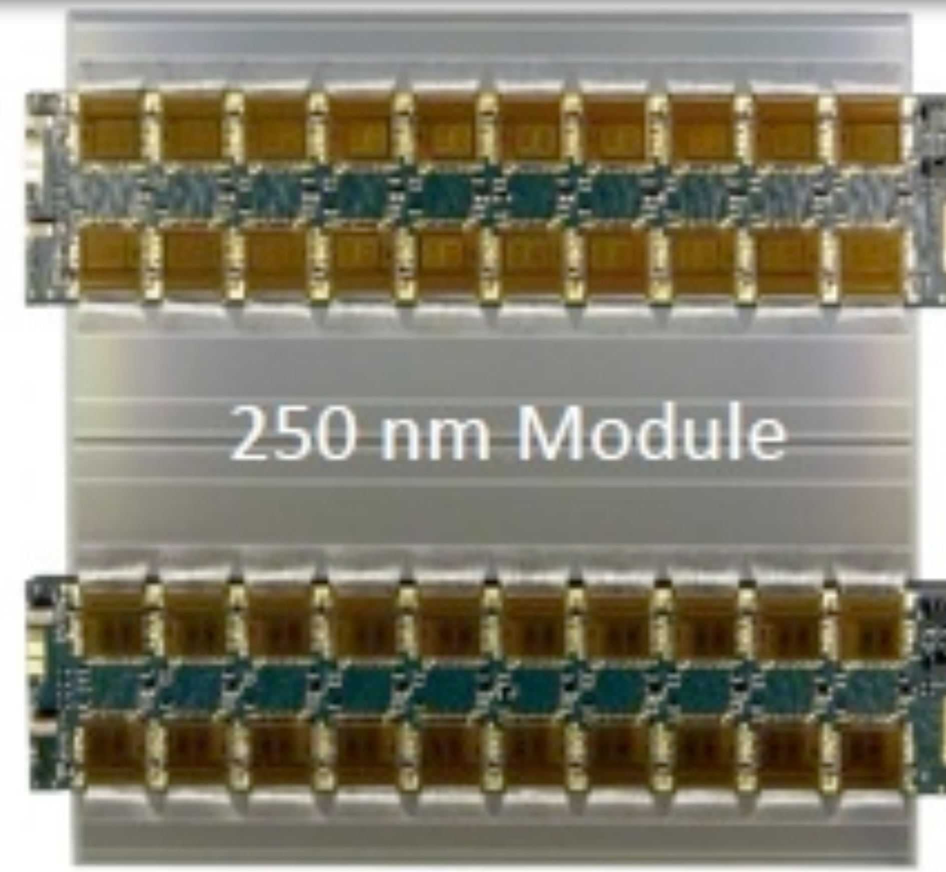
Stave Concept (2)



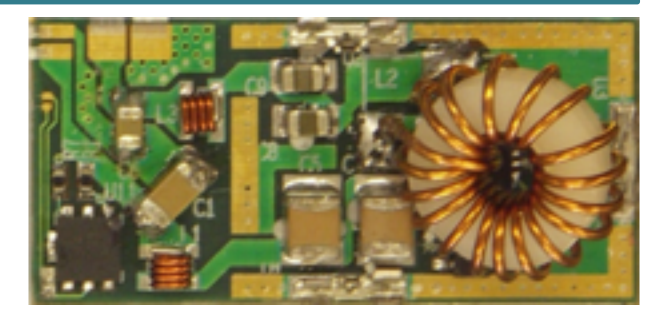
- Cooling: baseline is CO_2, with temperature set by pixel system
- End Insertion: ease of assembly and access
- Support Structure: thin CF barrels, with brackets, simpler preparation than with single modules

Modules and Electronics

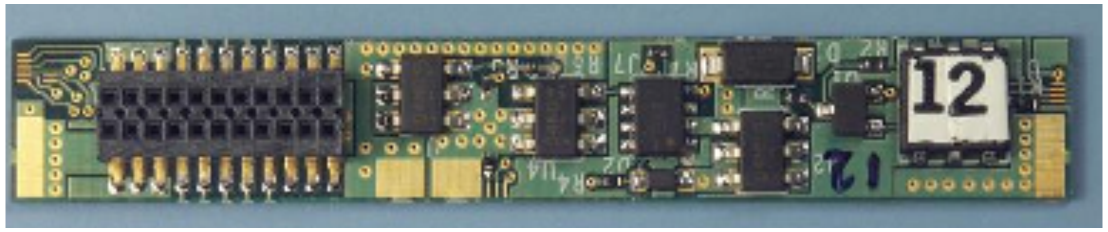
- **Sensors**: n in p single sided design, 98 x 98 mm, long & short strip designs, detailed design not yet finalized
- **ASICS:** a 130 nm CMOS chipset
  - ABCn130: binary readout architecture (like SCT) but new protocol, 256 inputs for smaller hybrids, ROI and fast trigger block
  - Hybrid Control Chip: interface and module controller
- **Powering:** to reduce material (and space) smart powering options are mandatory
  - LV: Serial or parallel powering is under investigation; additional powering and protection chipset, prototyped and new versions in development
  - HV: multiplex using HV switches



STV-10 DC-DC Convertor

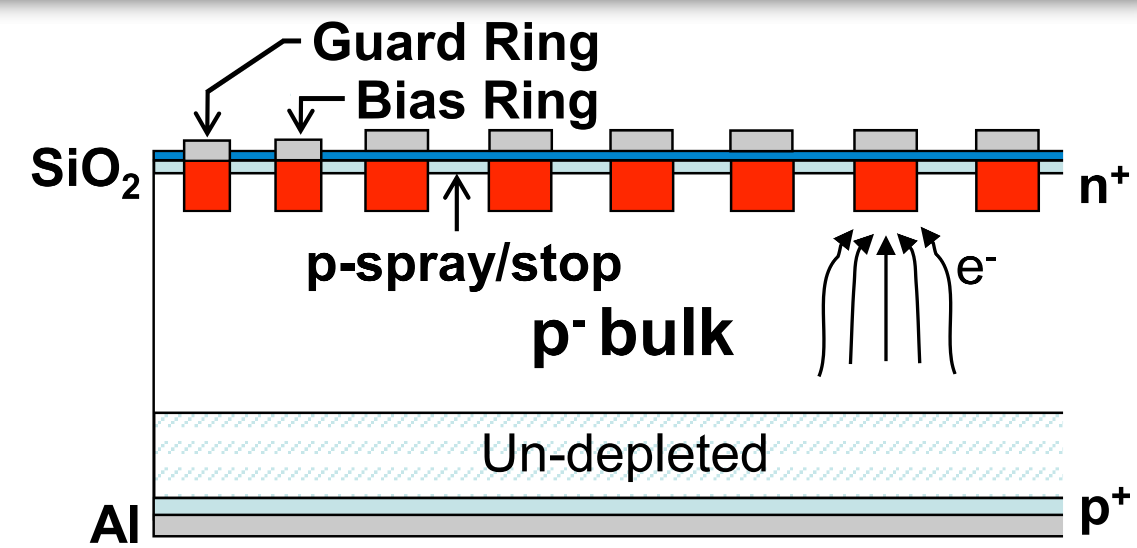


Serial Power Protection Board

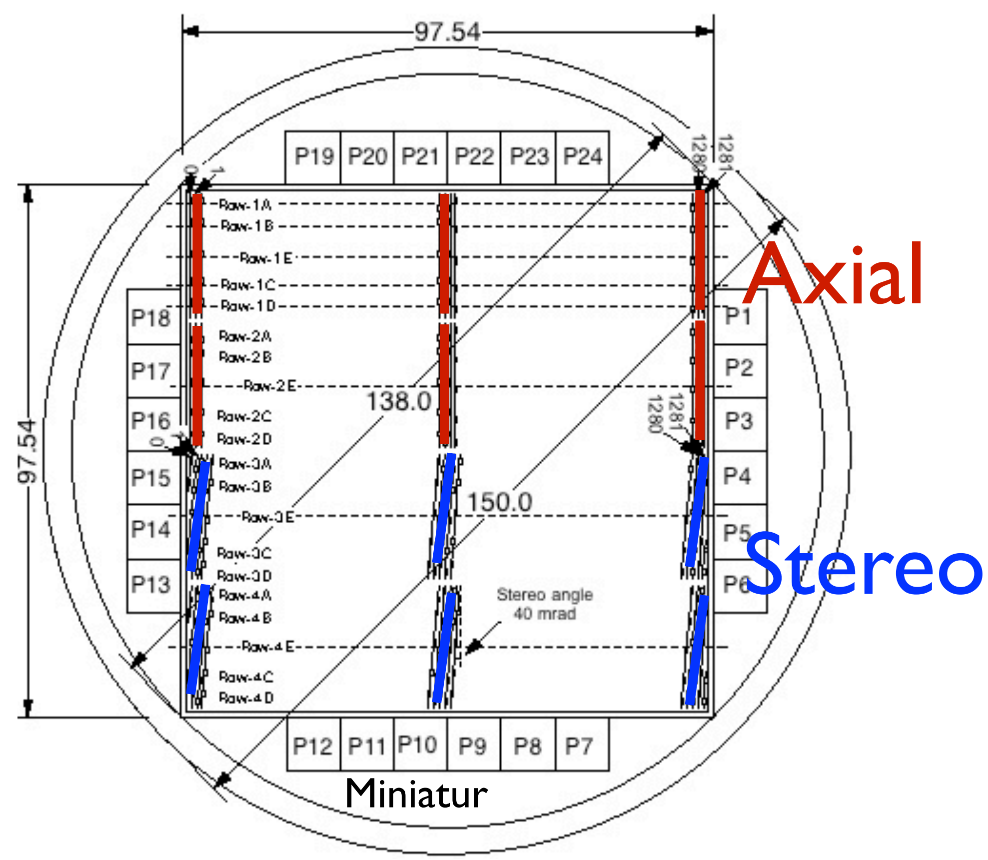


Radiation Hard Sensors

- **n^+-strip in p-type substrate (n-in-p)**
  - Collects electrons like current n-in-n pixels
    - Faster signal, reduced charge trapping
  - Always depletes from the segmented side
    - Good signal even under-depleted
  - Single-sided process
    - much cheaper than n-in-n
    - More foundries and available capacity world-wide
  - Easier handling/testing due to lack of patterned back-side implant



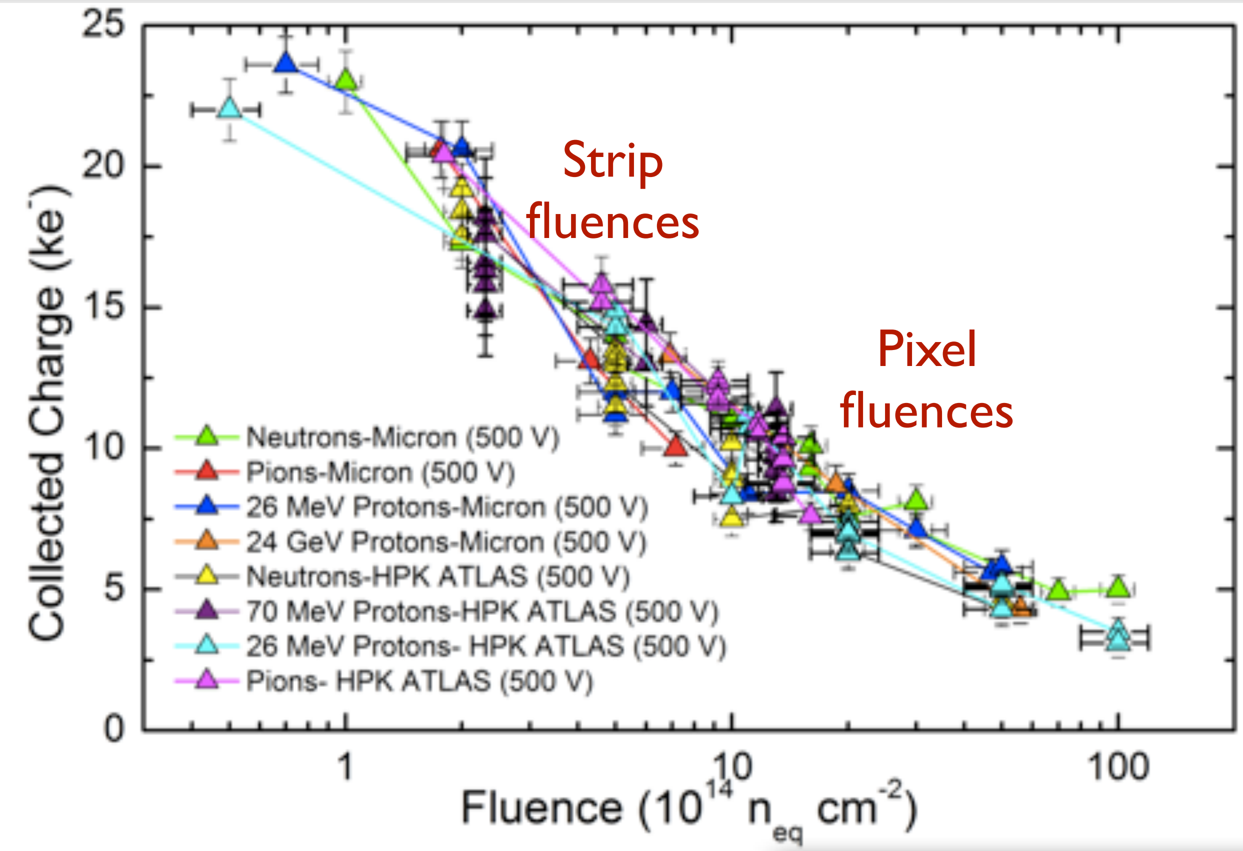
- Collaboration of ATLAS with Hamamatsu Photonics (HPK) to develop 9.75x9.75 cm² devices (6 inch wafers)
  - 4 segments (2 axial, 2 stereo), 1280 strip each, 74.5 µm pitch, ~320 µm thick
  - FZ1 <100> and FZ2 <100> material studied
  - Miniature sensors (1x1 cm²) for irradiation studies



See N. Unno, et. al., Nucl. Inst. Meth. A, Vol. 636 (2011) S24-S30 for details

Sensor Irradiation Tests

- Miniature devices irradiated to strip barrel radiation level with neutrons, pions, protons
- Charge collection measured with ^{90}Sr β-source
- Consistent results between different groups/ equipment
- S/N greater than 10:1 for strip sensor types with expected noise performance
  - S/N>21 (short strips), S/N>14 (long strips)
  - ~600-800 e^- short strips, ~800-1000 e^- long strips



plot: Tony Affolder

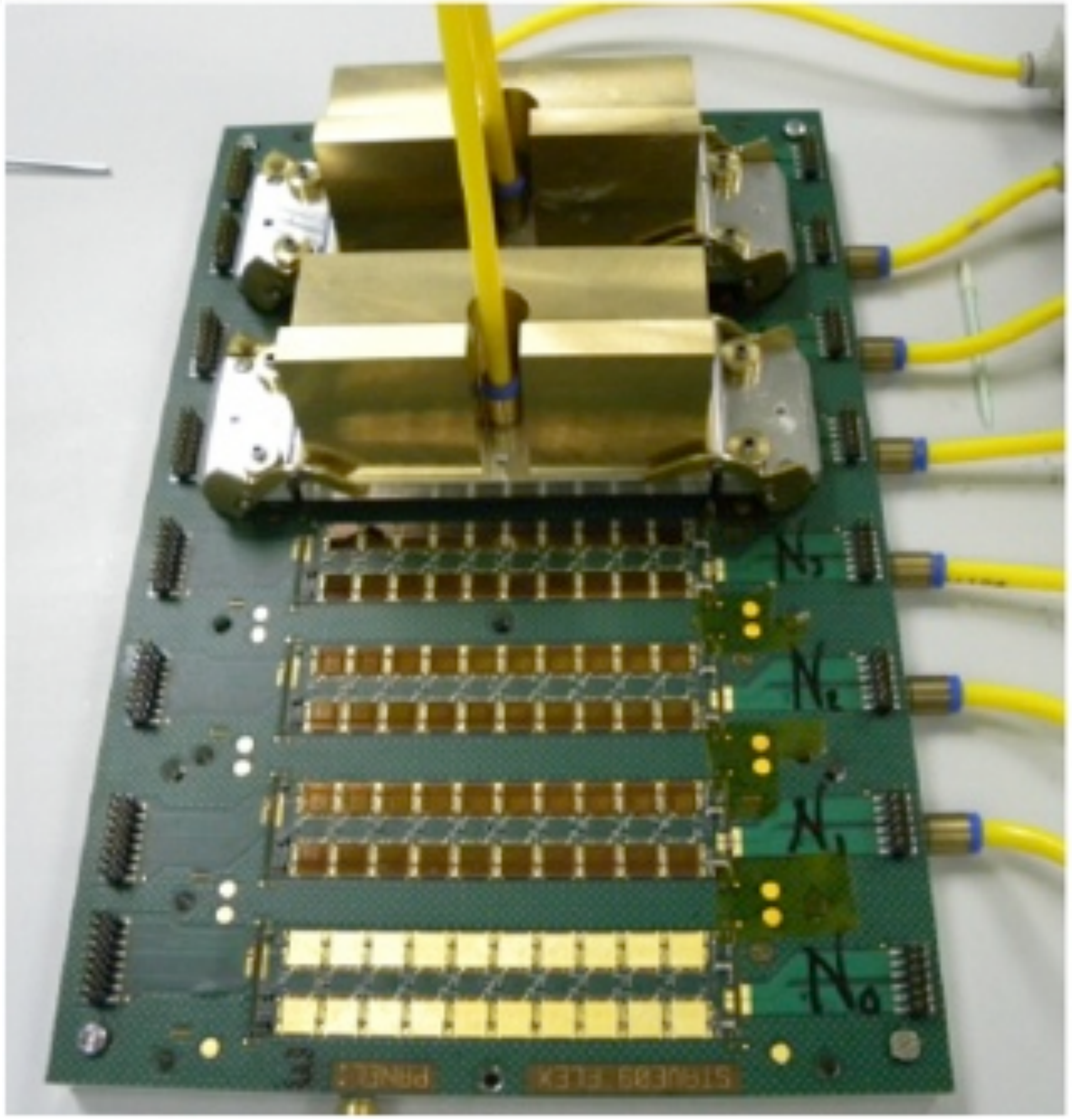
	Specification	Measurement
Leakage Current	<200 μA at 600 V	200– 370nA
Full Depletion Voltage	<500 V	190 – 245V
Coupling Capacitance (1kHz)	>20 pF/cm	24 – 30pF
Polysilicon Resistance	1.5+/-0.5MΩ	1.3 -1.6MΩ
Current through dielectric	I_{diel} < 10 nA	< 5nA
Strip Current	No explicit limit	< 2nA
Interstrip Capacitance (100kHz)	<1.1pF/cm (3 probe)	0.7 – 0.8pF
Interstrip Resistance	> 10x R_{bias}~15 MΩ	>19 GΩ

All specifications already met!!

A. Affolder, P. Allport, G. Casse, Nucl. Instr. Meth. A 623 (2010) 177-179
I. Mandic et al., Nucl. Instr. Meth. A626 (2011) 101-105J. Bohm, et. al., Nucl. Inst. Meth. A, Vol. 636 (2011) S104-S110 for details

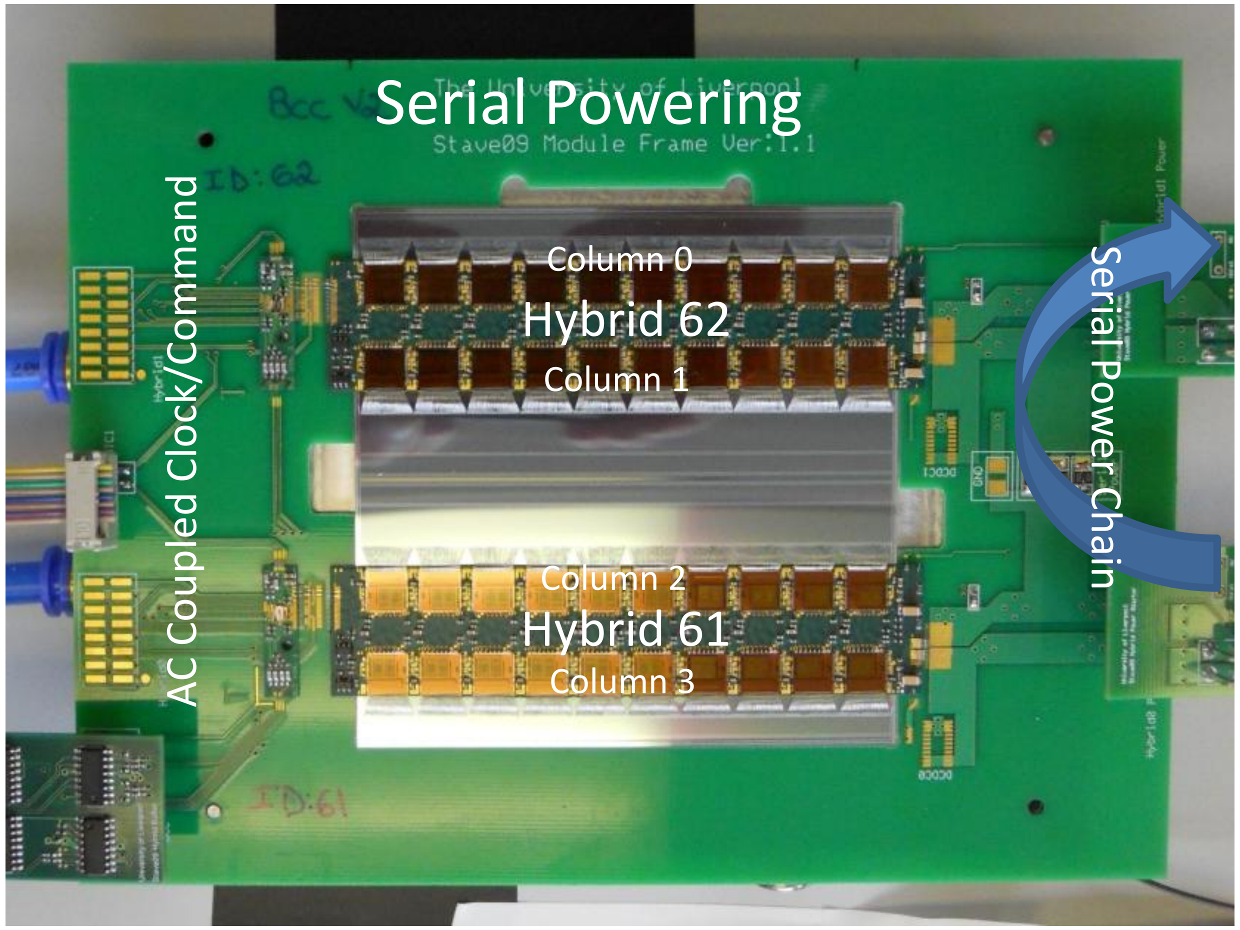
Hybrid “Mass” Production

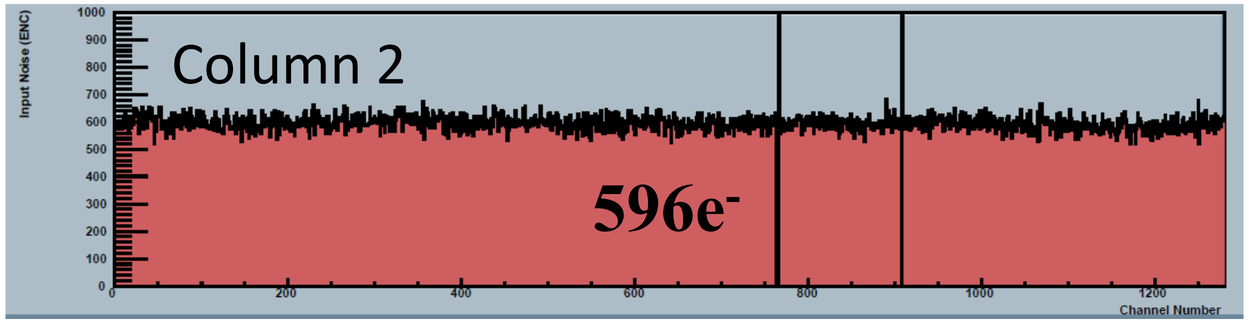
- Focus R&D on realistic configurations & components as early as possible
- First pass at industrialization of hybrids:
  - Panelization (8 per panel):
    - Flex selectively laminated to FR4
    - FR4 acts as temporary substrate during assembly, wire bonding and testing
  - Mass attachment/wire bonding of custom ASICs
- Flex uses conservative design rules (~20000 hybrids to be installed):
  ↳ High yield, large volume, low price
- Hybrids+ASICs tested in panel
  - With final ASIC set (ABCn-130nm, HCC, power), all hybrids in the panel tested with one data I/O and one power connection

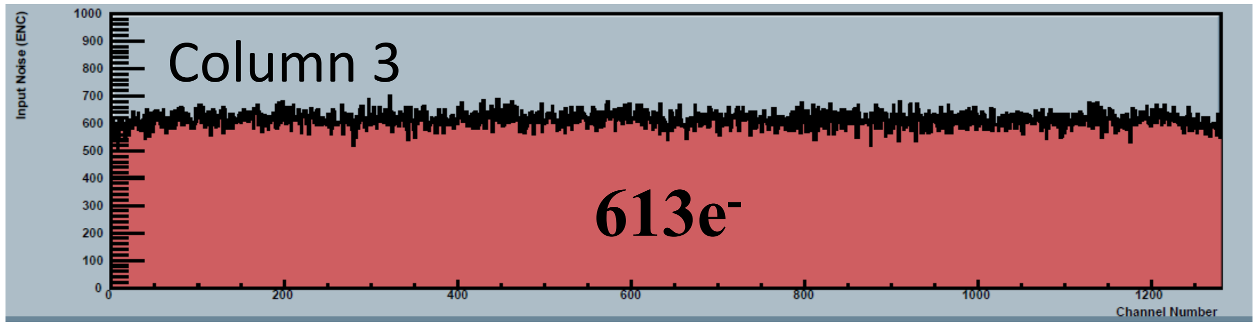


Stave Module Tests

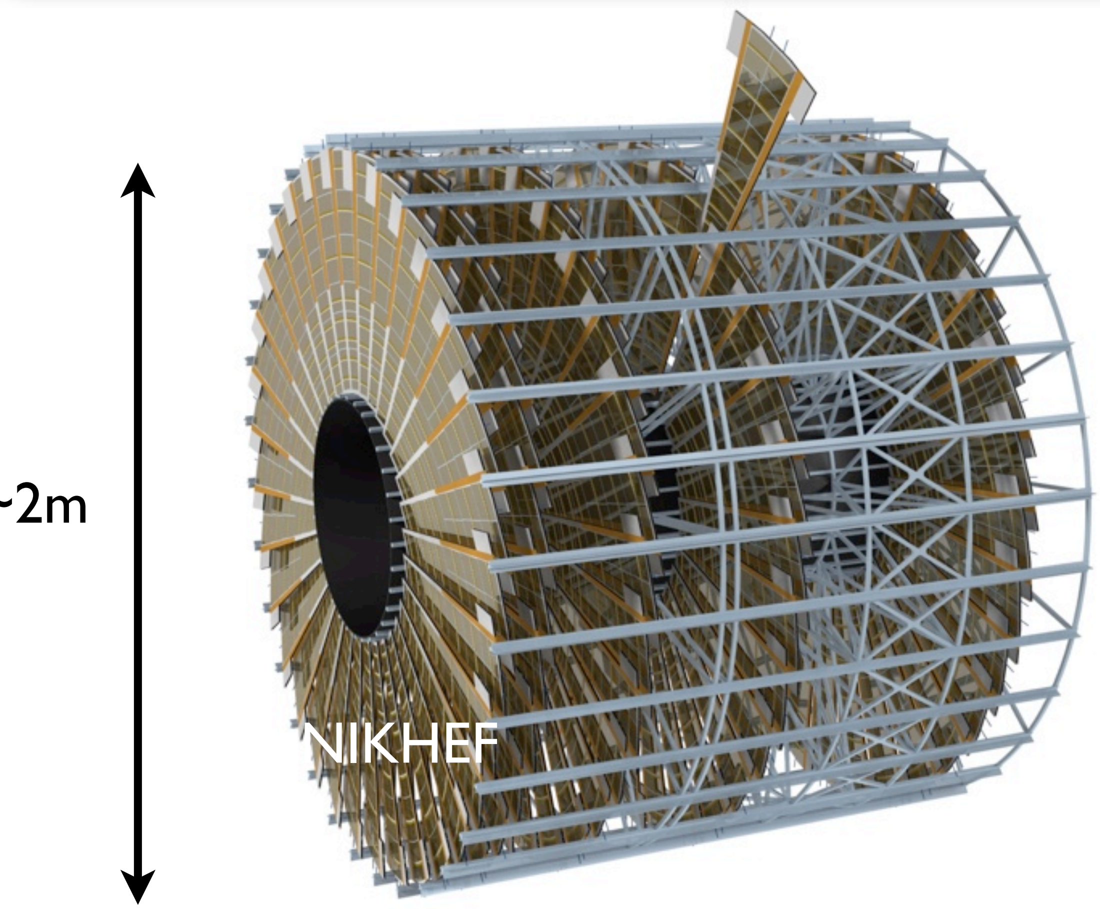
- Stave modules are tested in PCB frames
  - Cheap, flexible test bed for different power/shielding/grounding configurations
- Parallel powering, serial powering, and DC-DC converters have all been evaluated
  - All give expected noise performance
- Gluing the hybrid onto the sensor's surface increases the load capacitance by 0.4 pF and 0.6 pF for inner/outer columns with nominal 120 um glue thickness
  - ~600 e- inner columns
  - ~620 e- outer columns

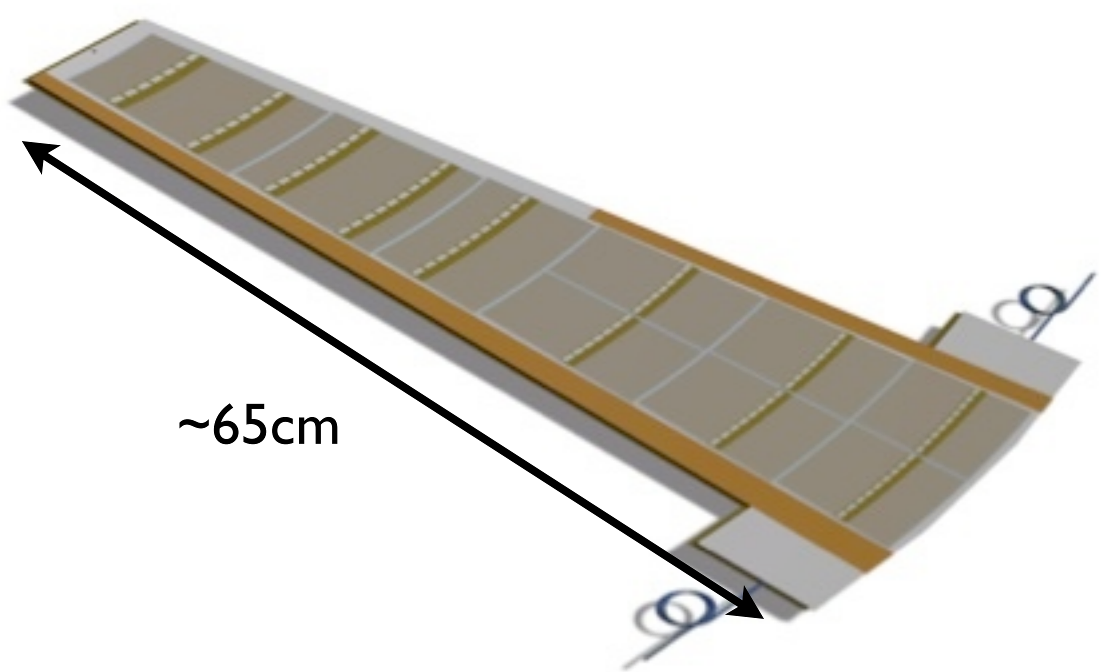






And the End Caps ….





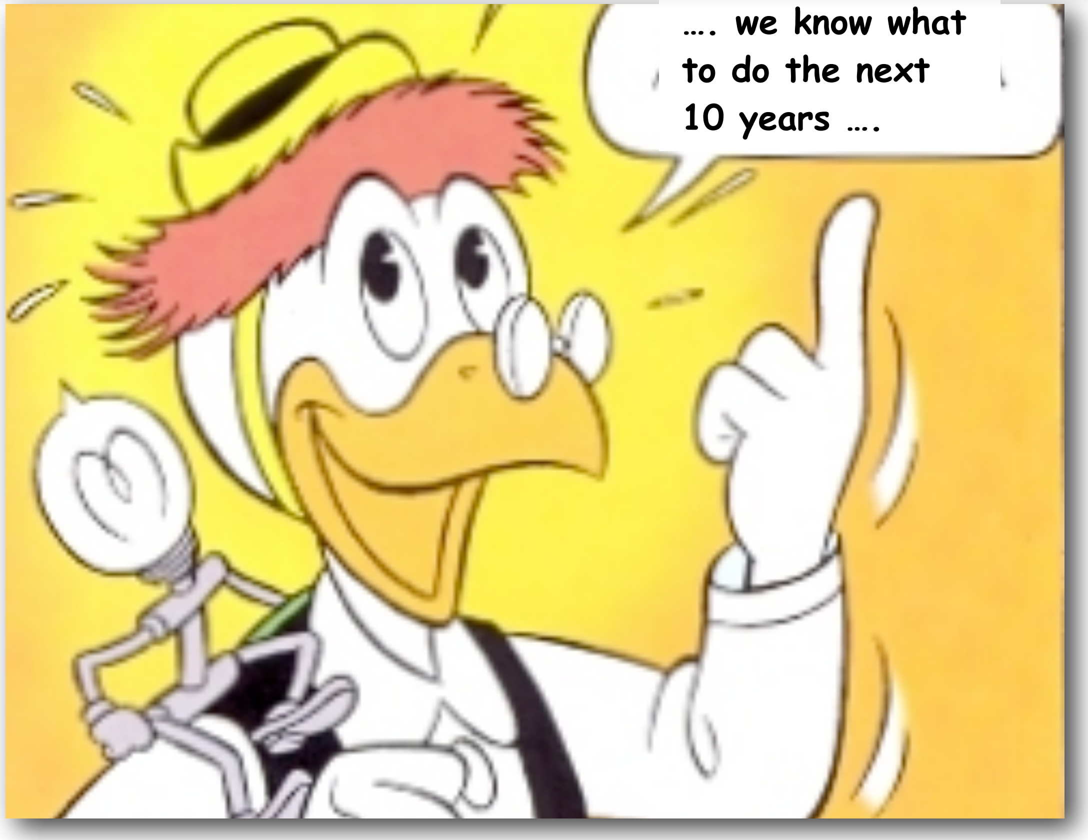
- To “close” barrel two end caps are needed
- Strips pointing to centre of beam pipe
- “Petal” seems currently the optimal design

- The petal concept follows closely the barrel stave concept
- 6 discs on each end cap with 32 petals per disc
- 6 Sensor rings
- First petal cores have been produced – Flat to better than 100 um
- First endcap hybrids tested
  - Same performance as barrel hybrid
- n-in-p sensor prototypes submitted to CNM to make petal-let using 4” wafers

- DESY is planning to build one full end-cap with ~30m^2 of Silicon

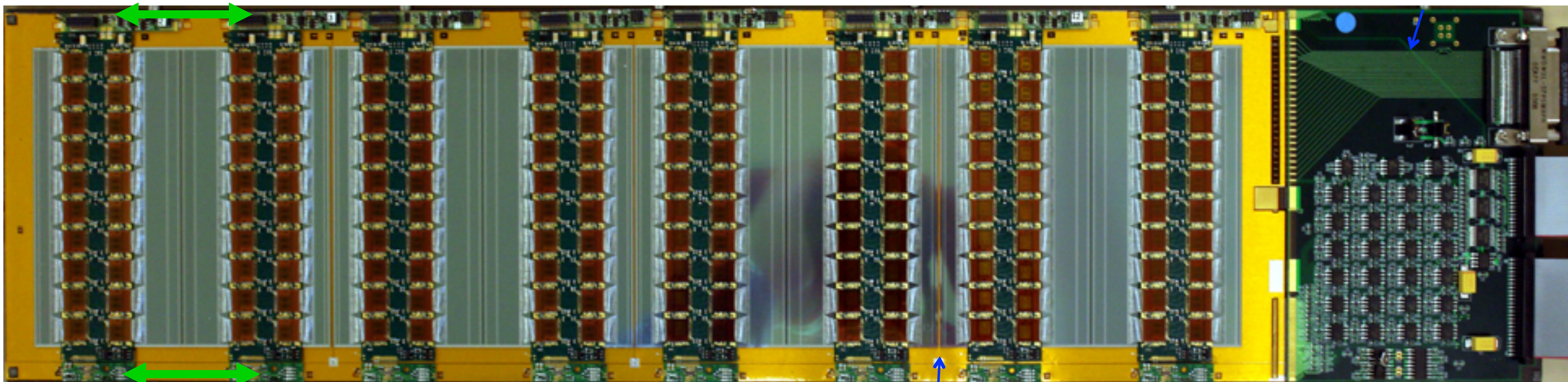
Summary

- The current schedule for the LHC foresees running well into the next decade to accumulate up to 3000 fb^{-1}
- ATLAS will use the different shutdowns for detector consolidation and new detectors
- In the first LHC shutdown (2013) an additional pixel layer will be installed -> challenging project

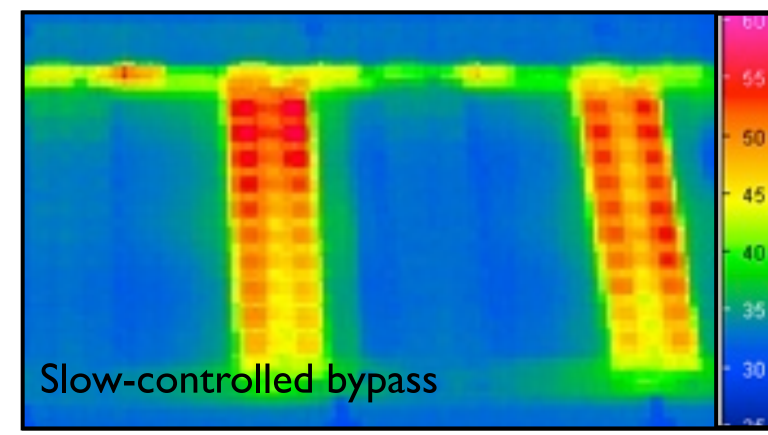


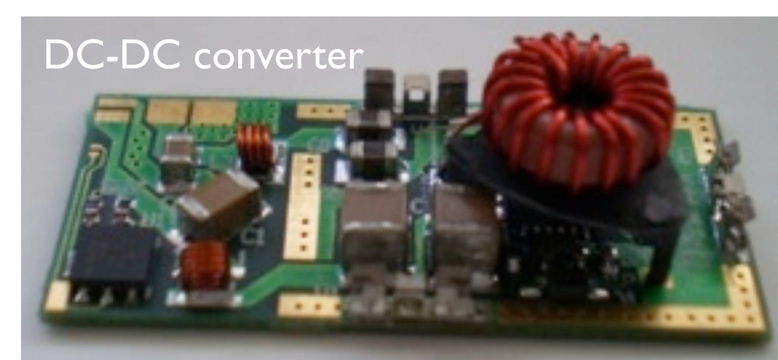
- The current ATLAS Inner Detector are designed to withstand few hundred fb^{-1} -> must be replaced with an all-silicon tracker for HL-LHC operation (Phase 2 upgrade)
- Such a High Luminosity LHC requires granularity and radiation hardness in the tracking detectors that are, again, a factor of 10 greater than before.
- Full-size prototypes are planned to be finished this year with the next generation of the 130 nm ASICs for the strip tracker under design

Stavelets

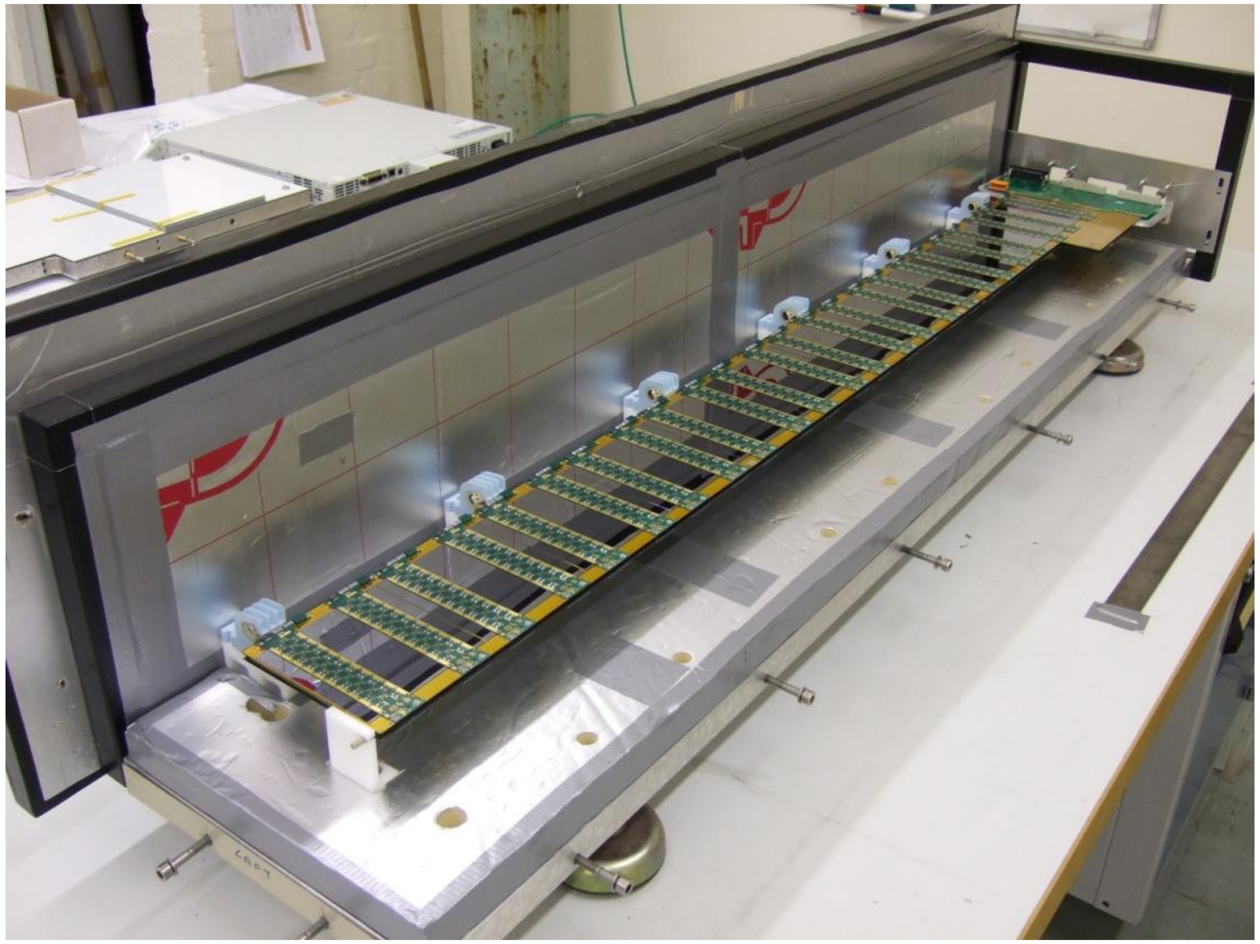


- Shortened stave built as electrical test-bed
  - Shielding, grounding, serial and DC-DC powering, …
- First stavelet serial powered
  - Power Protection Board (PPB) has automated over-voltage protection and slow-controlled (DCS) hybrid bypassing
  - DC-DC stavelet under construction
- Uses Basic Control Chip (BCC) for data I/O
  - Generates 80MHz data clock from 40MHz BC clock
  - 160Mbit/s multiplexed data per hybrid

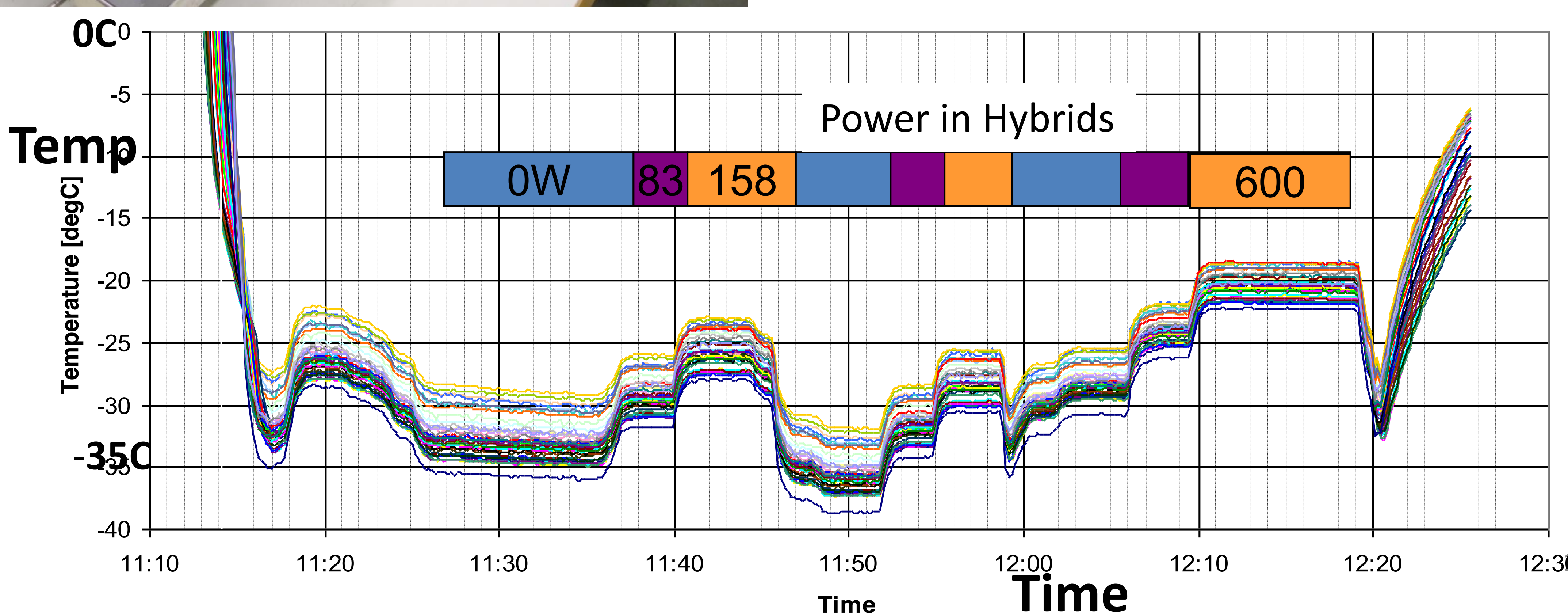




Thermo-mechanical Stave



- Full-sized 250nm serial powered Stave
- Accurate co-cured core
    - Dummy modules
        - Silicon wafers
        - Hybrids
        - Resistors replace ASICS
- Pt1000 on each hybrid
- Properly edge-mounted
- CO_2 cooled to -28C - -35C



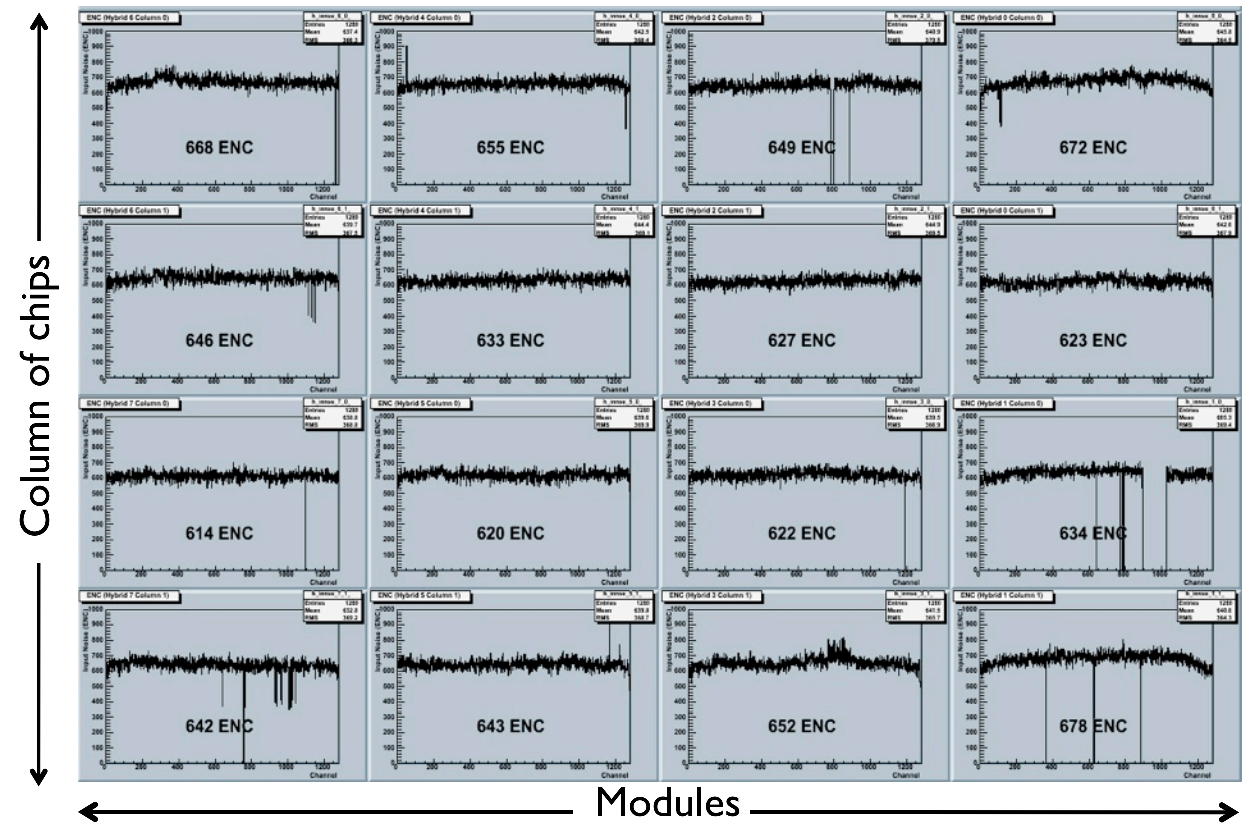
Recent R&D Accomplishments

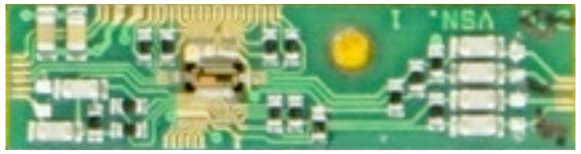
- Full electrical test and characterization of serial and DC-DC systems
- DC-DC circuitry mass reduction progress
- CERN B180 test facility up and running
- Hybrids/modules assembly, ~8 sites up-and-running, ~20 DAQ test stands
- Studies of powering optimization and cabling, reported at AUW, task force
- Development of “Petalet” program
- 2011 Sept mechanical materials and FEA workshop
- Precision requirement meeting
- Modeling and characterization of petal mechanical cores
- Co-curing of facings and bus tapes with optimized lay-ups
- Production of test of 250nm chipset
- Studies of HV switches
- Design progress on 130 nm chipset
- Inclusion of L1 track trigger functions into the 130 nm chipset
- Full R&D schedule and LOI organization and assignments in place
- …..

Serial Powered Stavelet Electrical Results

- Uses on-hybrid shunt control circuit
- Stavelet noise approaching single module tests
  - Roughly ~20 e^- higher
  - Bypassing hybrids does not affect noise performance
- All technologies necessary for serial powering of stave have been prototyped and shown to work (and compatible with 130 nm CMOS)
  - Constant current source, SP protection and regulation, multi-drop LVDS
    - Currently optimizing location of components, size of SP chains
- Minimal impact on material budget
  - Estimated to be ~0.03 averaged over the stave

Stavelet Noise using Serial Power

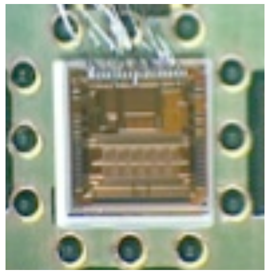




AC-coupled mLVDS

Serial Power Protection
(discrete components)

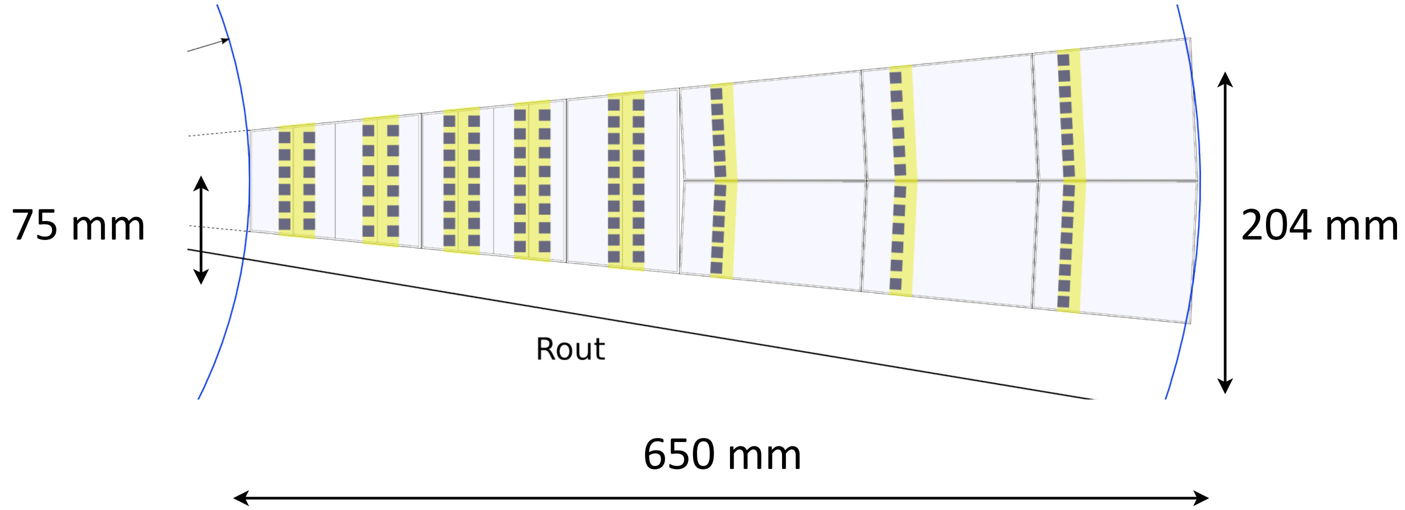
Custom Current Source



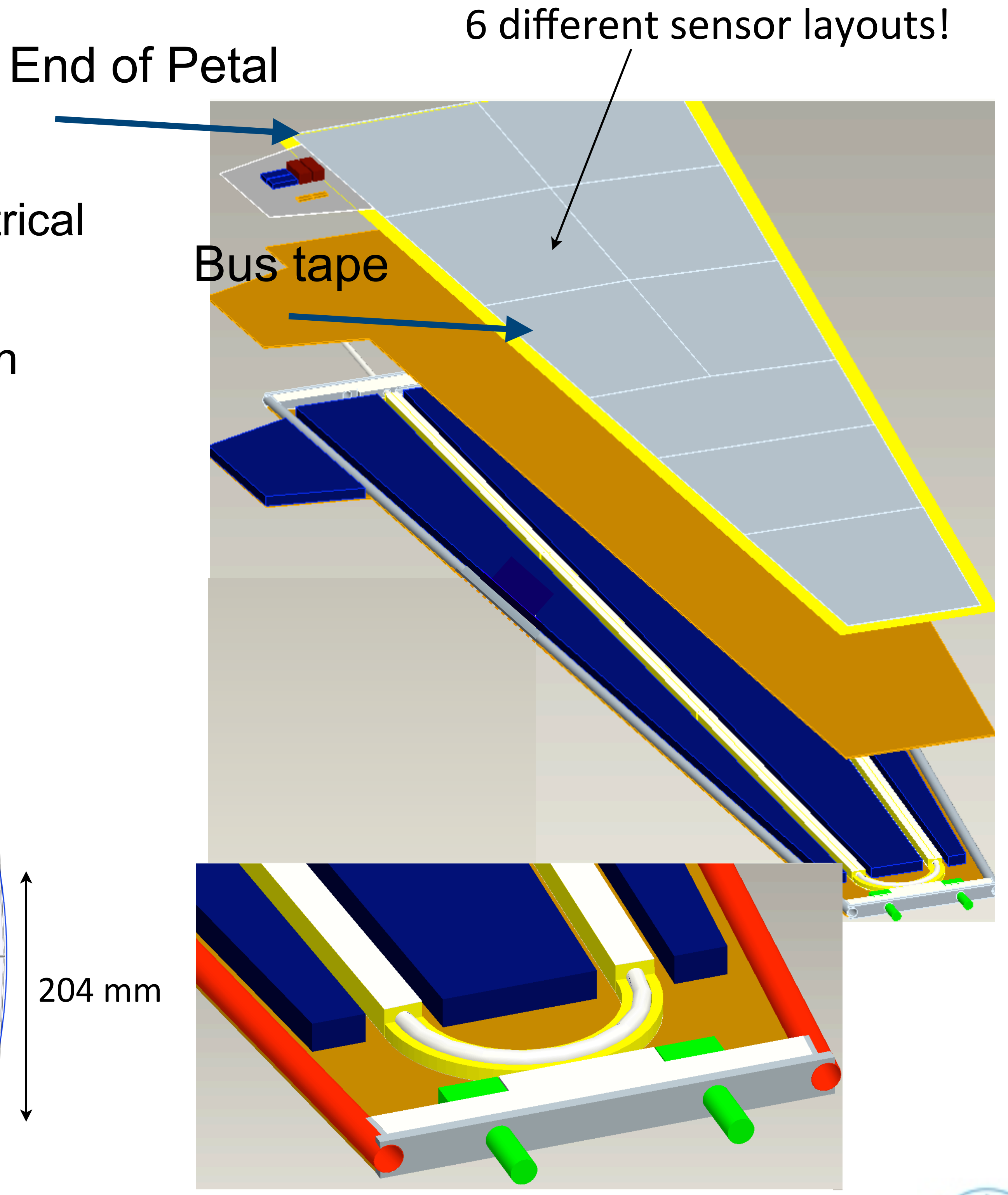
Serial Power Protection
(130 nm prototype)

What is a petal

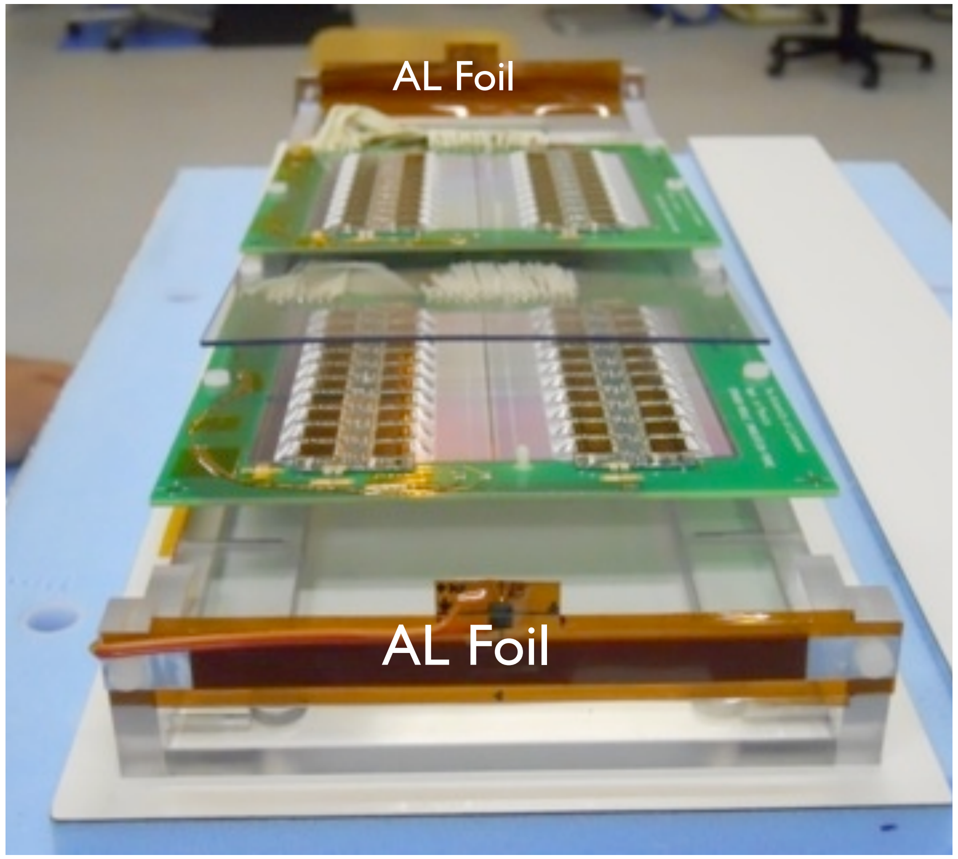
- **Hybrid** = kapton board with FE chips (ABCNext, connection via wire bonds)
- **Module** = silicon sensor with readout hybrid (connection via wire bonds)
- **Petal** = petal core structure + cooling + electrical services (power, data, TTC) + modules:
  - 2 Carbon Facings + Honeycomb sandwich core (6mm)
  - Carbon Fibre tubes on sides
  - Independent CO_2 cooling pipe
  - Independent e- services + Bus cable
  - Control card on side
  - 2x9 modules



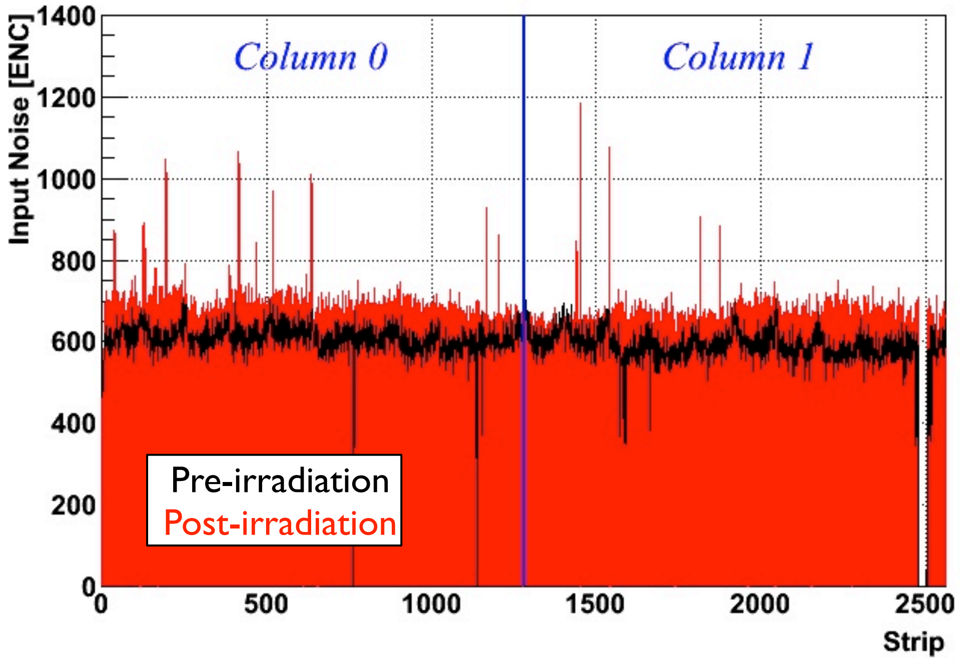
Hybrid positions and dimensions



Strip Module Irradiation



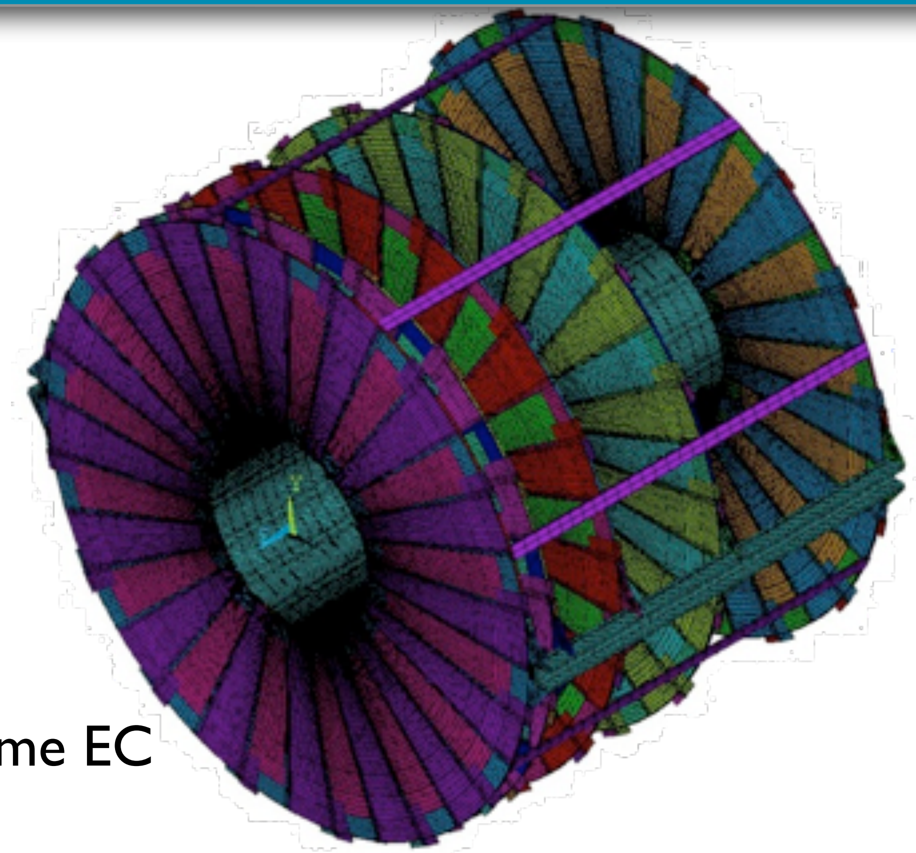
- Irradiated at CERN-PS irradiation facility
  - 24 GeV proton beam scanned over inclined modules
  - Module biased, powered, and clocked during irradiation
  - Total dose of 1.9×10^{15} n_{eq} cm^{-2} achieved
    - Max predicted fluence for barrel modules is 1.2×10^{15} n_{eq} cm^{-2}
- Sensor and module behave as expected
  - Noise increase consistent with shot noise expectations
- Rather difficult study as full devices tend to get “hot”



Noise	Column 0	Column 1
Pre-Irrad	610 e^-	589 e^-
Post-Irrad	675 e^-	650 e^-
Difference	65 e^-	61 e^-
Expected	670 e^-	640 e^-

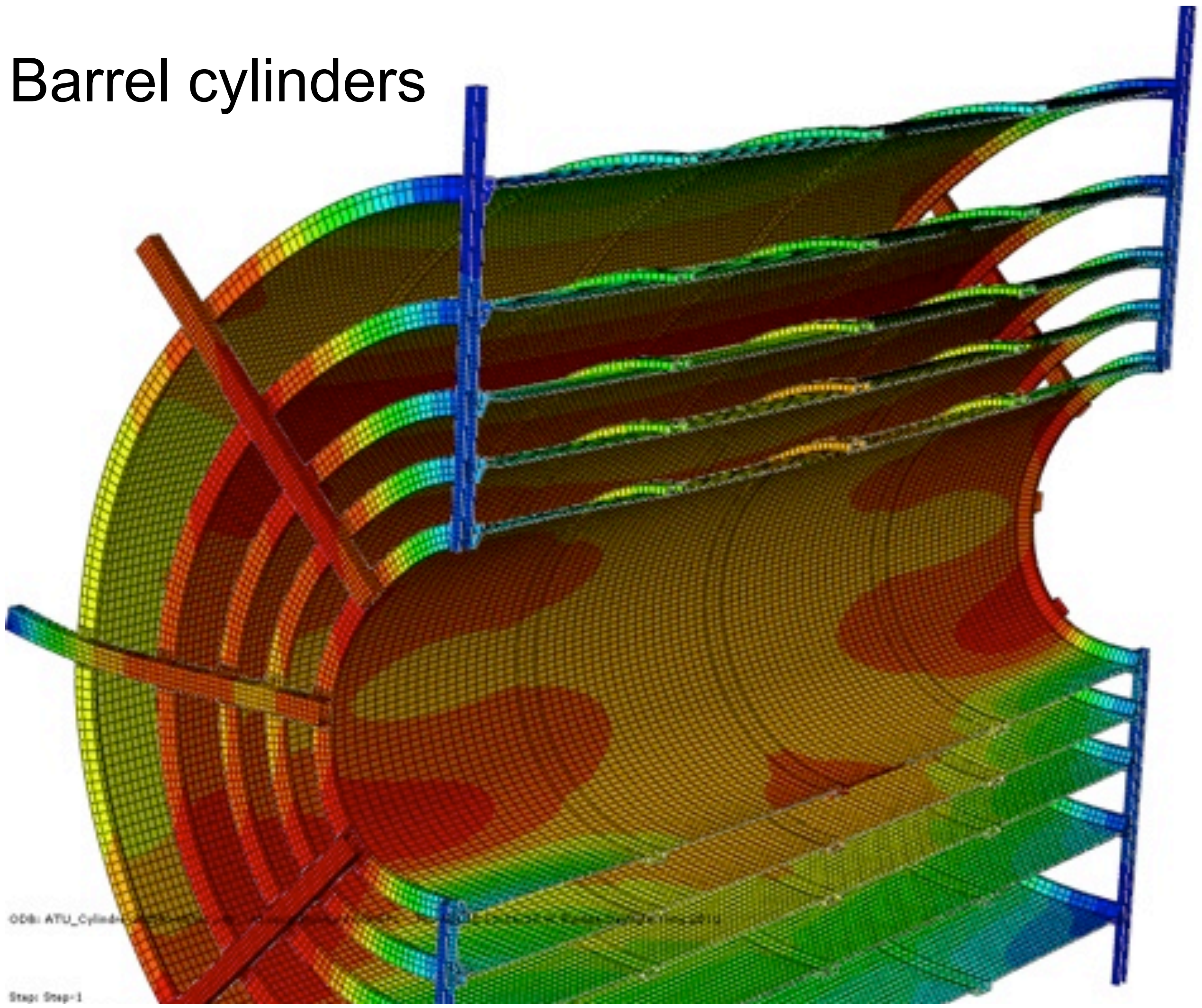
Mechanical Support Structures

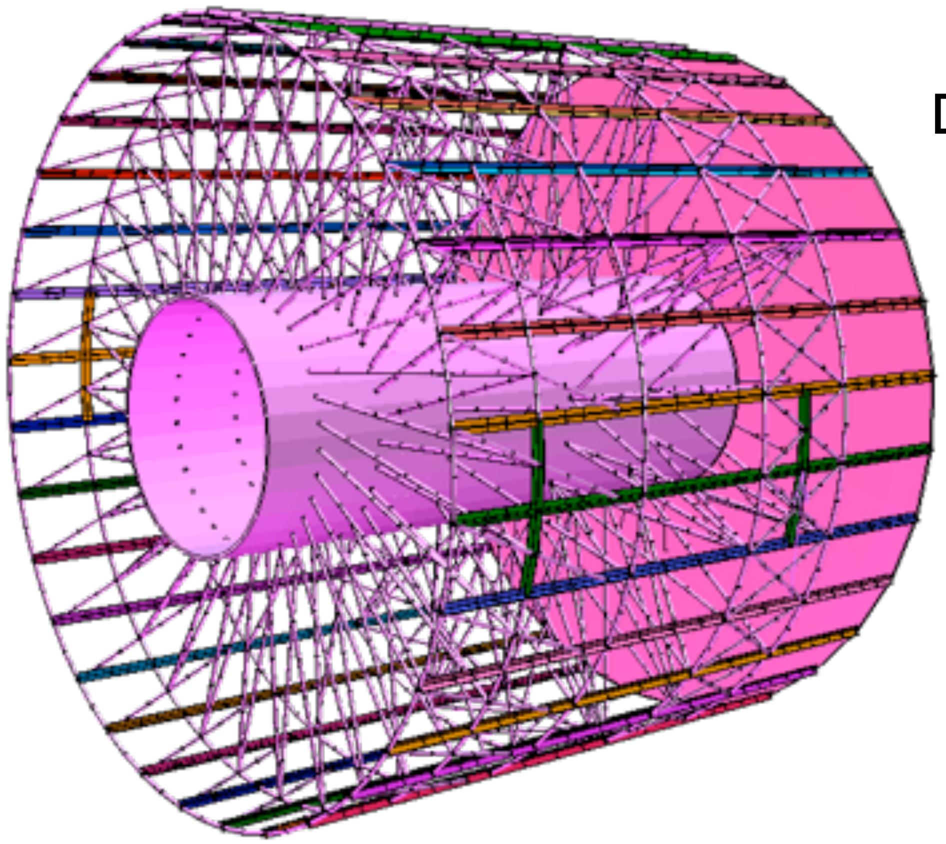
- Barrel structures: first studies of barrels, similar to SCT
- Endcap structures: Different approaches under study (disks or space-frame structures)
- Structures need to satisfy stability requirements and will strive to constrain weak mode deformations



Spaceframe EC

Barrel cylinders

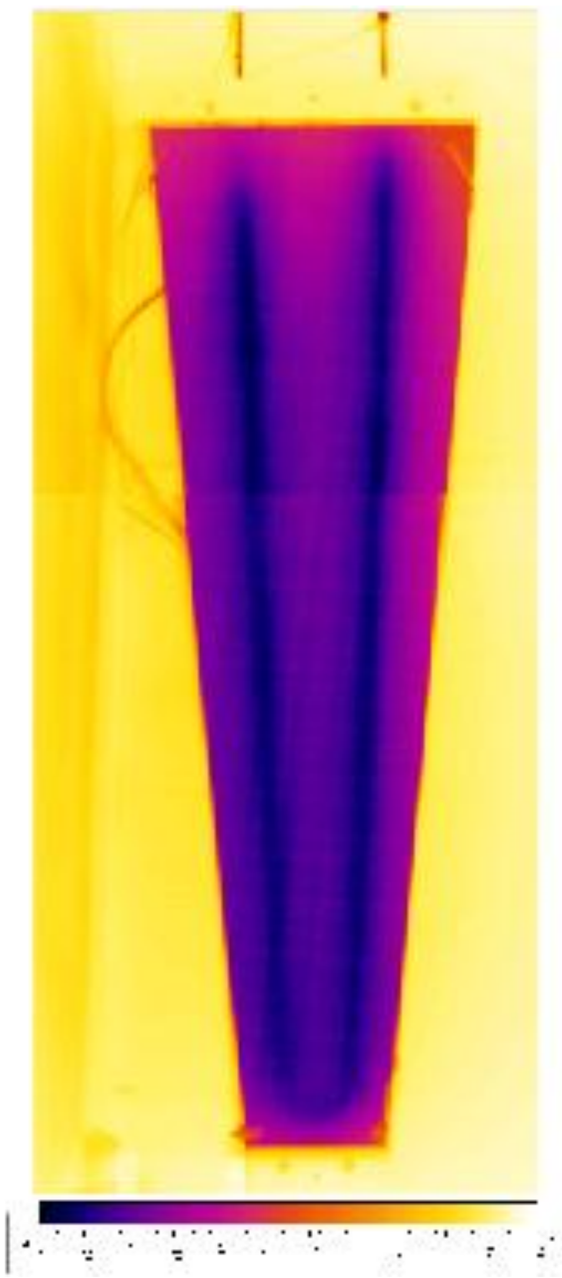




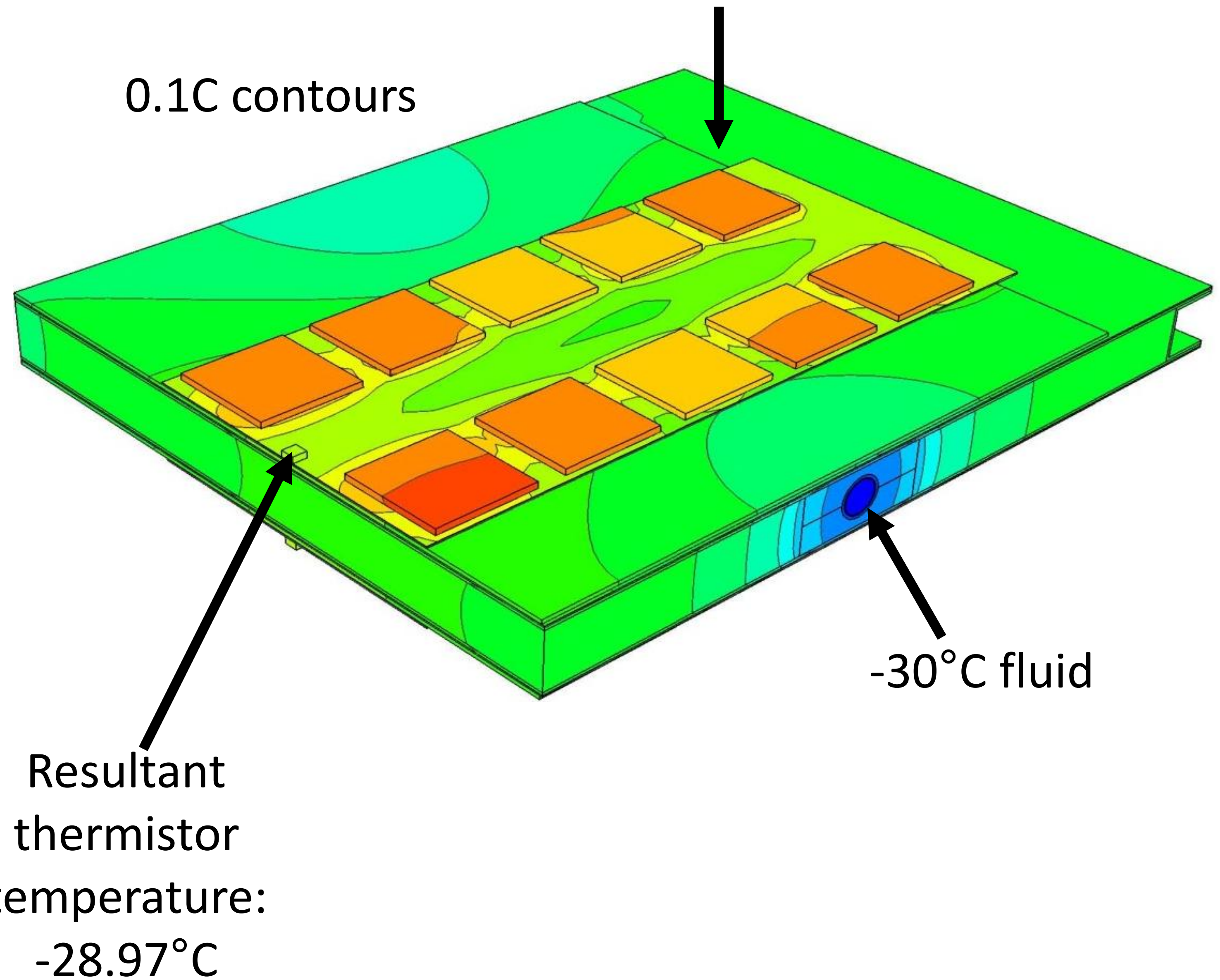
Disk EC

FEM and measurements

- Stave TM FEA and measurement agree
- Very uniform heat transfer



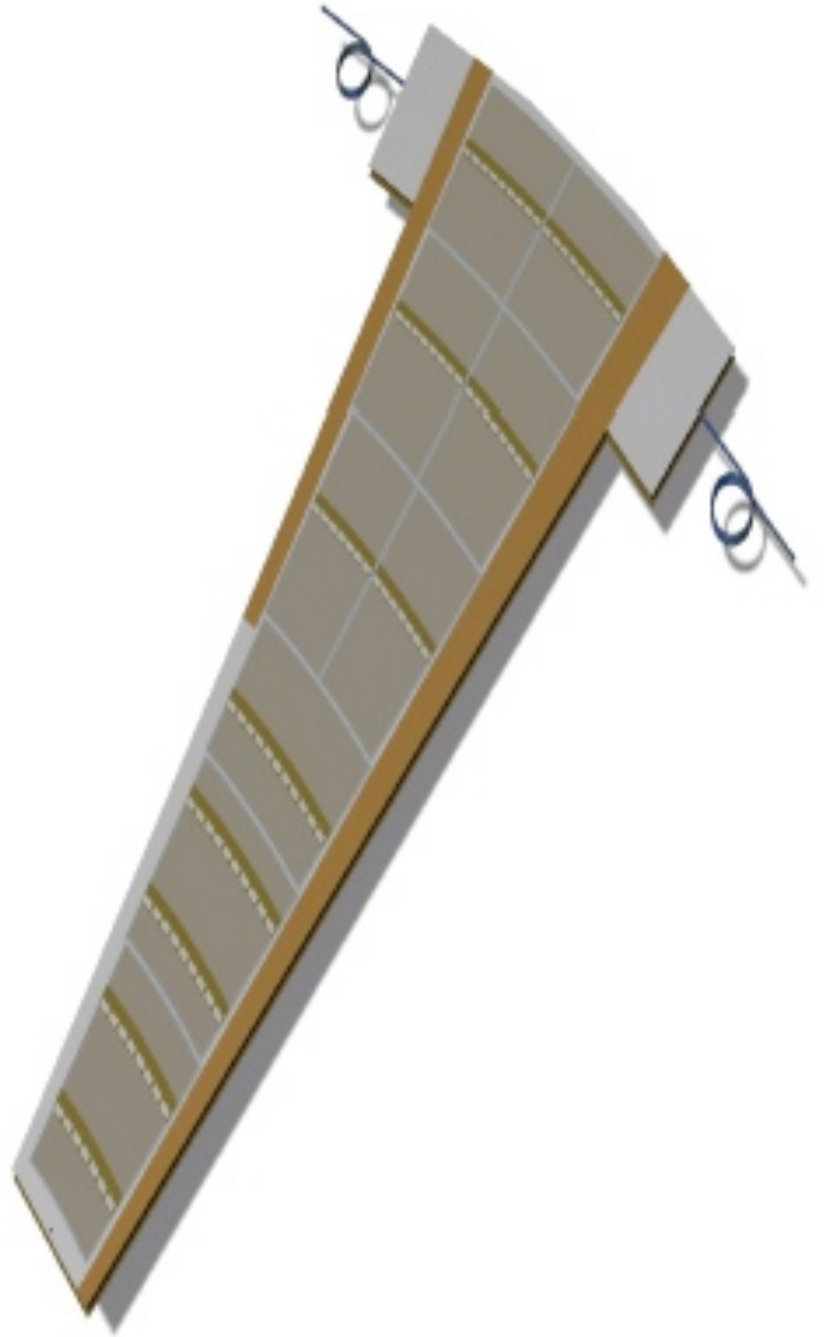
IR image of a Petal Core Prototype
Showing excellent uniformity of cooling in the 'harder' geometry.



Strip pitch etc

Sensor ring	Hybrid	Numb. chips	Pitch (micron)
1	Inner	7	78.8
1	Outer	8	78.6
2	Inner	9	78.7
2	Outer	10	78.6
3		11	78.7
4		7	74.2
5		8	76.1
6		9	76.8

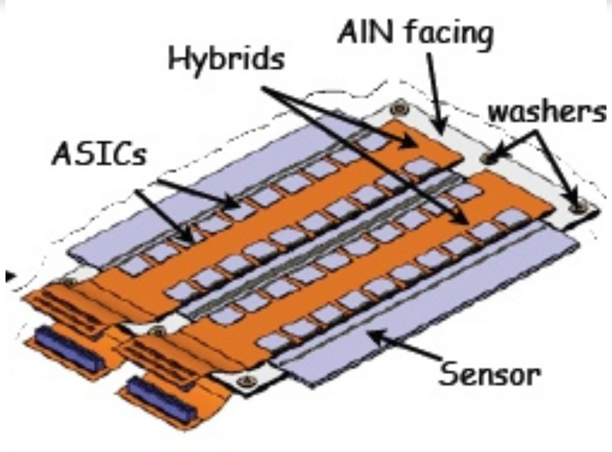
- UTOPIA layout
- In the current design we have 6 different sensor type, leading to 8-11 different hybrid designs

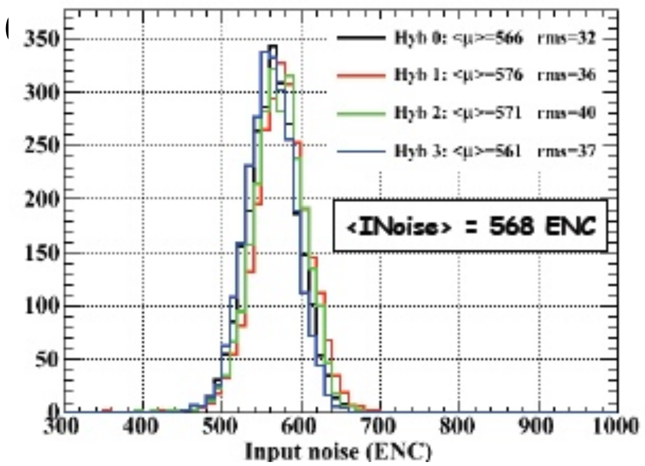


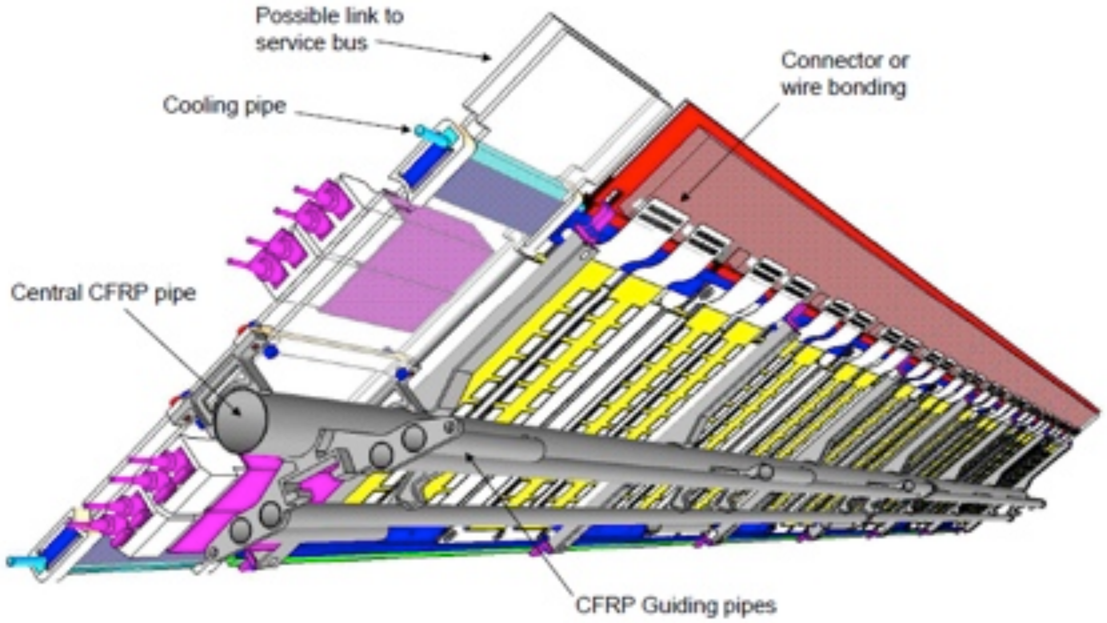
Possible petal design

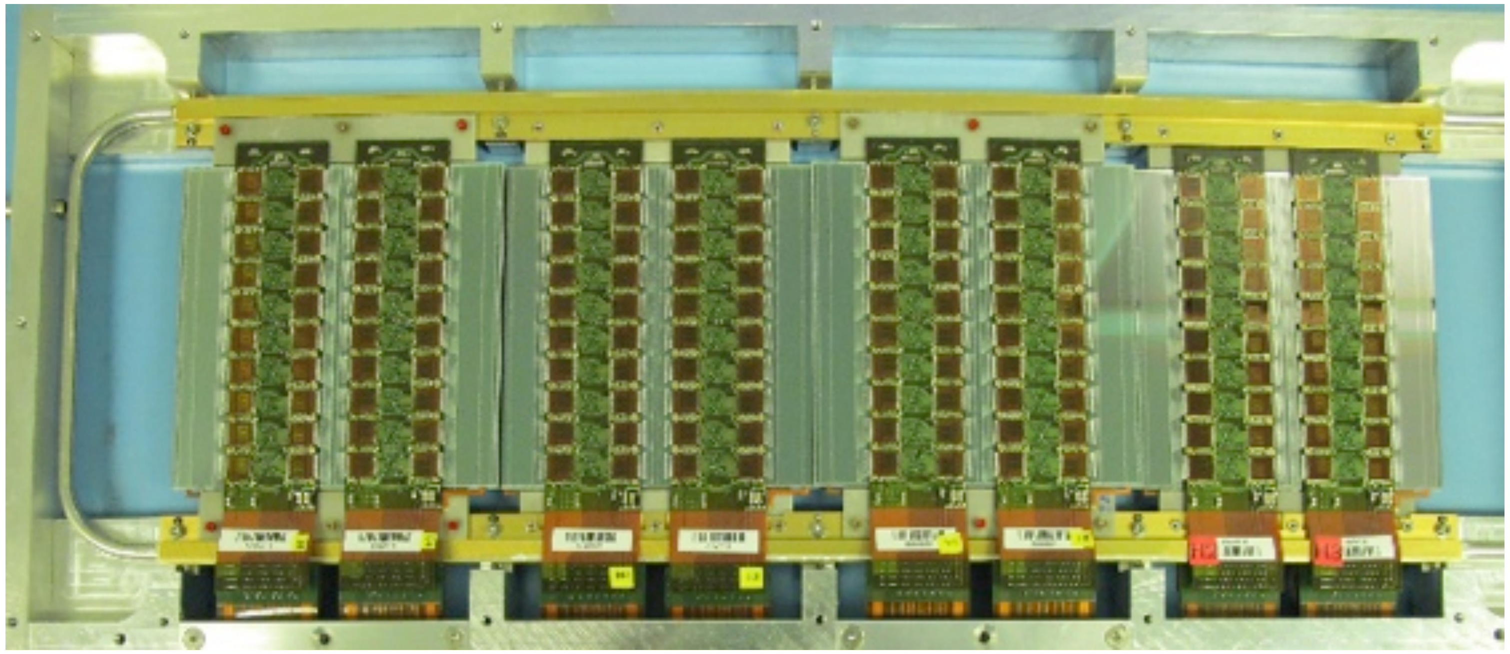
Alternative Solution: Super-Module

- Modular concept: cooling, local structure, service bus, power interface are decoupled from the modules
- Overlapping coverage in Z
- Rework – Possible up to the commissioning after integration
- Design includes carbon-carbon hybrid bridge
  - Hybrid could be also glued as for stave modules to redu material









Possible Technologies (Active Element)

Section	Radius (cm)	Area (m^2) (*1)	Fluence (neq/cm^{-2}) (*2)	Technologies/Vendor capability
B-Layer	3.7	~0.2	$\sim 2.2 \times 10^{16}$	Diamond, 3D, Planar, GOSSIP, Exotic, … (highly radiation-tolerant)
Inner Pixel	7.5	~0.8	$\sim 6 \times 10^{15}$	3D, Planar, … (medium area - low cost)
Outer Pixels	15.5 – 19.5	~5.6	$\sim 2 \times 10^{15}$	Planar (large area – low cost) Large-scale production capability
Strips	30 e.g.	~200	$\sim 1 \times 10^{15}$	Strips (large area – low cost) Large-scale production capability

Notes:
(*1) Utopia H, and including +30 contingency
(*2) Fluences assumption with 3000 fb-1 and with safety factor 2