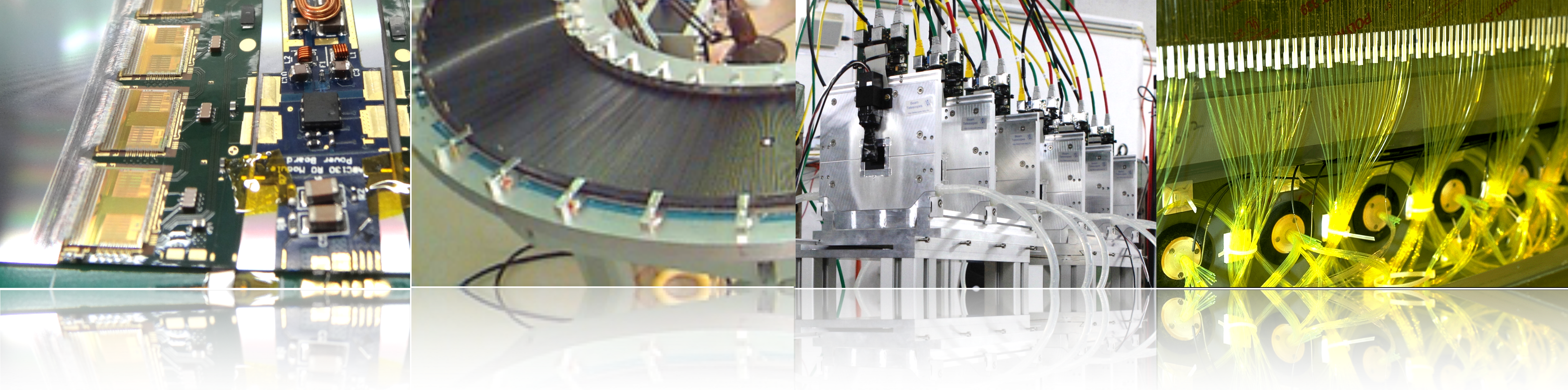

The ATLAS Detector and ITS Upgrades

Part 2

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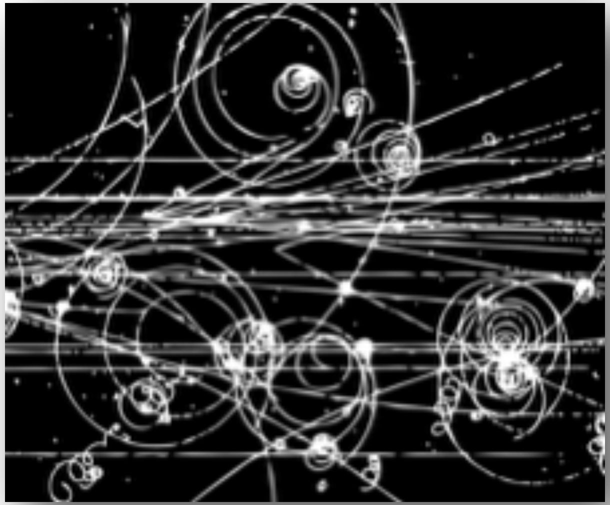
Frauenchiemsee
September 21, 2018

Symmetry Breaking

Introduction

- Detectors for particle physics are very complex
- A lot of physics is behind the detection of particles:
  - Particle physics
  - Material science
  - Electronics
  - Thermodynamics
  - Mechanics
  - ….



picture: CERN

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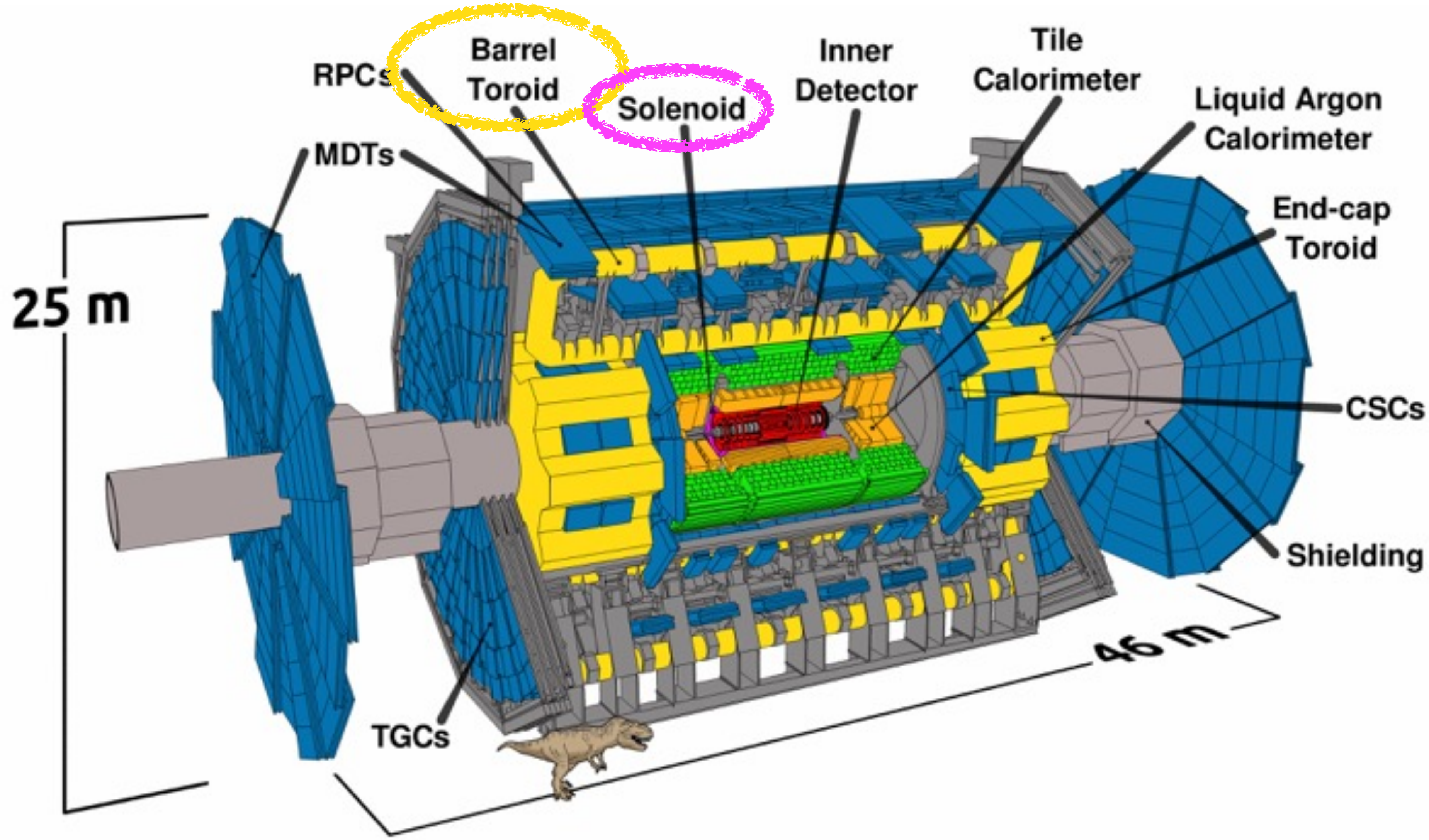
Outline

- Introduction
- ATLAS Detector
  - Inner Detector
  - Calorimeters
  - Muon System
  - Overall performance
- ATLAS Upgrades
  - Motivation Upgrade
  - New Small Wheel
  - New Inner Tracker
  - Calorimeter Upgrades
- Summary

Monday

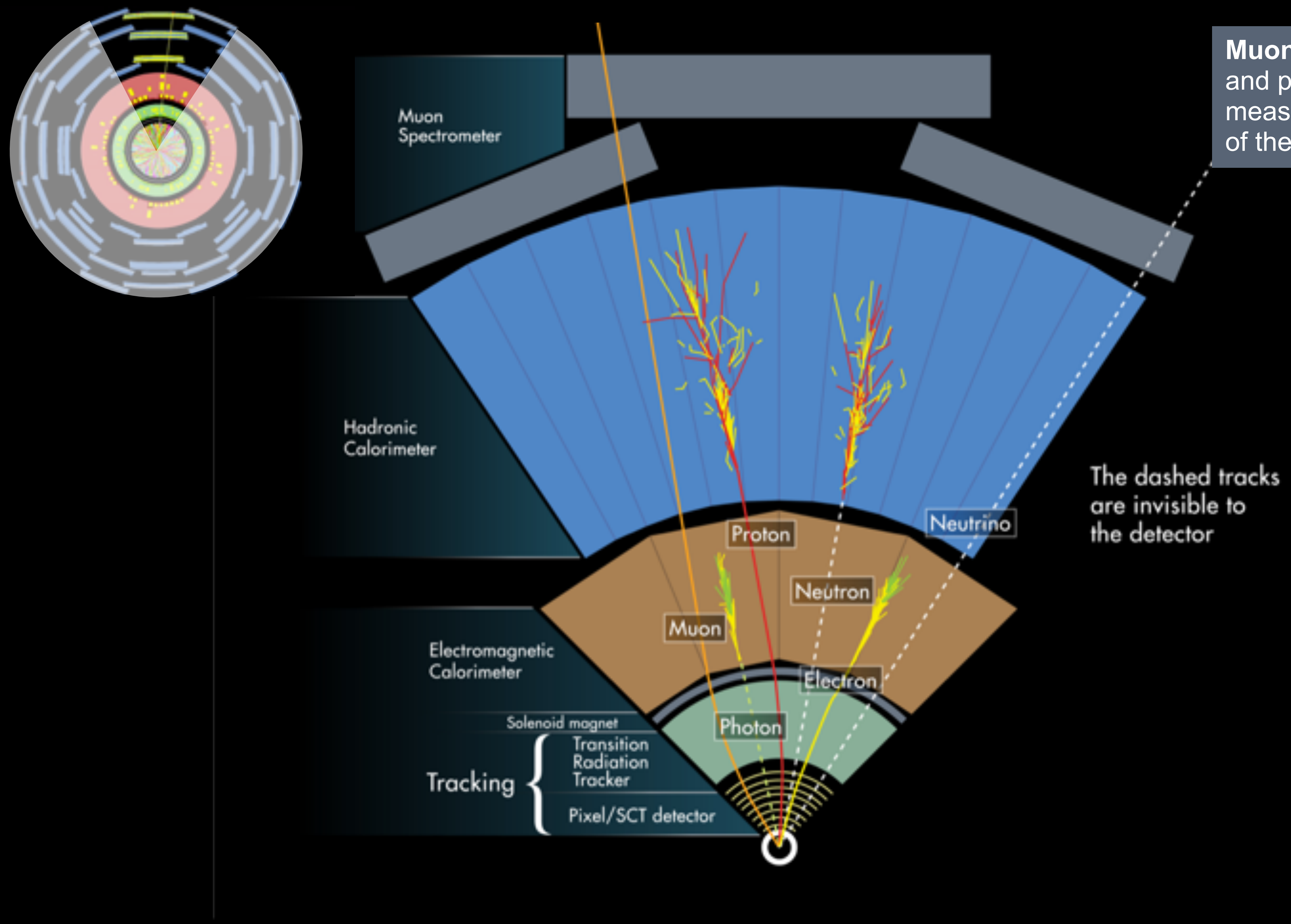
Friday

ATLAS detector



ATLAS Muon Spectrometer

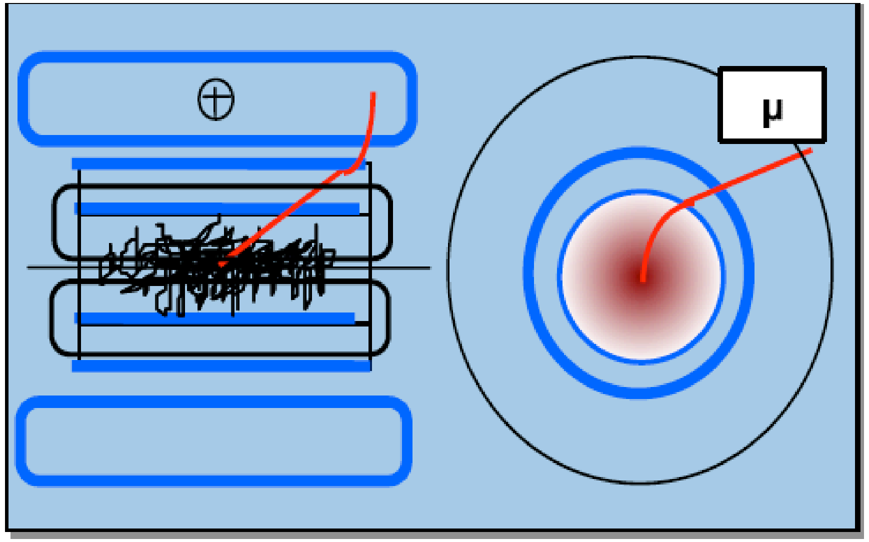
Muon-Detectors: Identification and precise momentum measurement of muons outside of the magnet

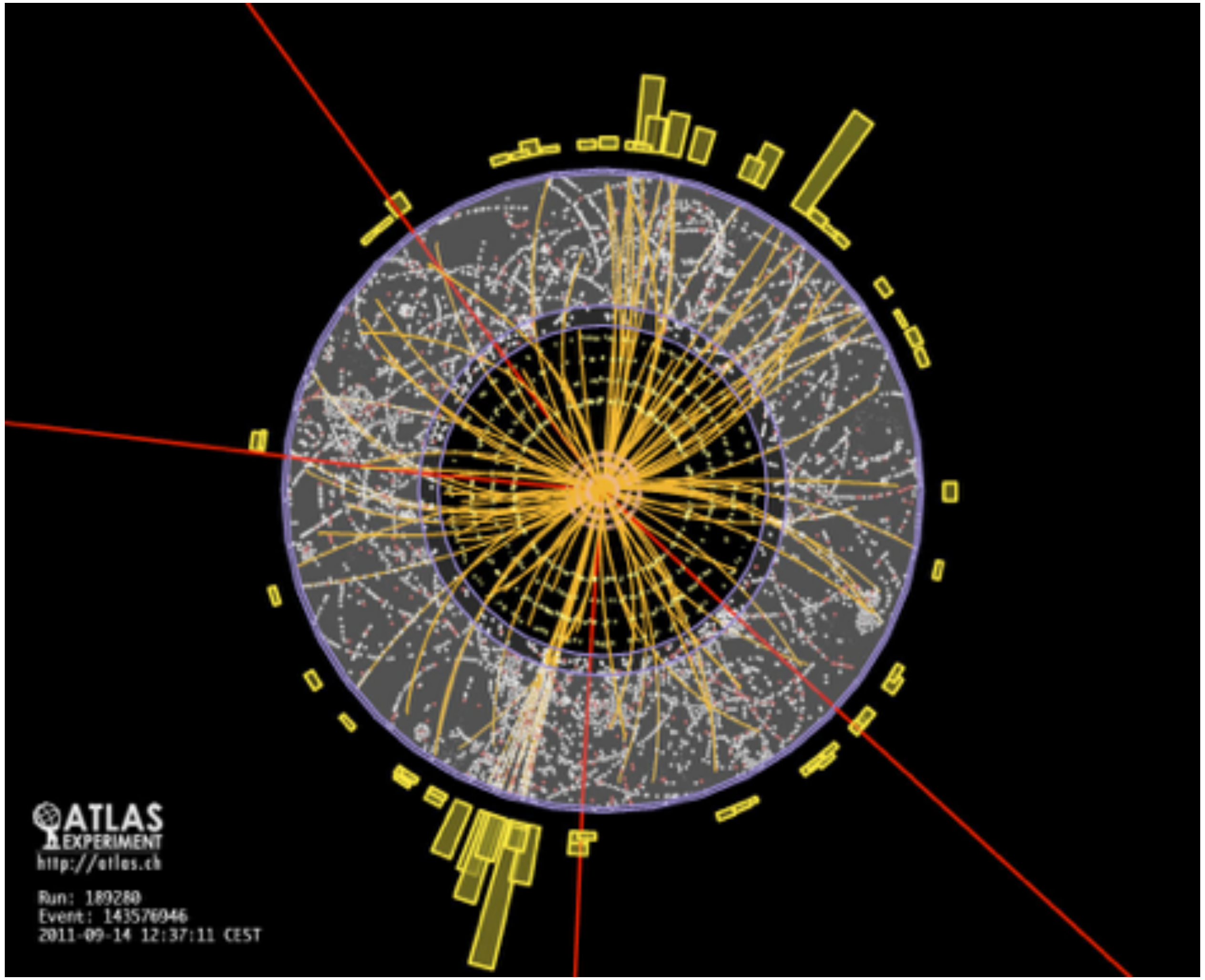


Detecting Muons

- Muons are important signatures in ATLAS.
- Example: candidate event for Higgs decay to four muons.
- Combine tracking information with fact that muons penetrate material.
- Calorimeter is “natural” filter for muons.

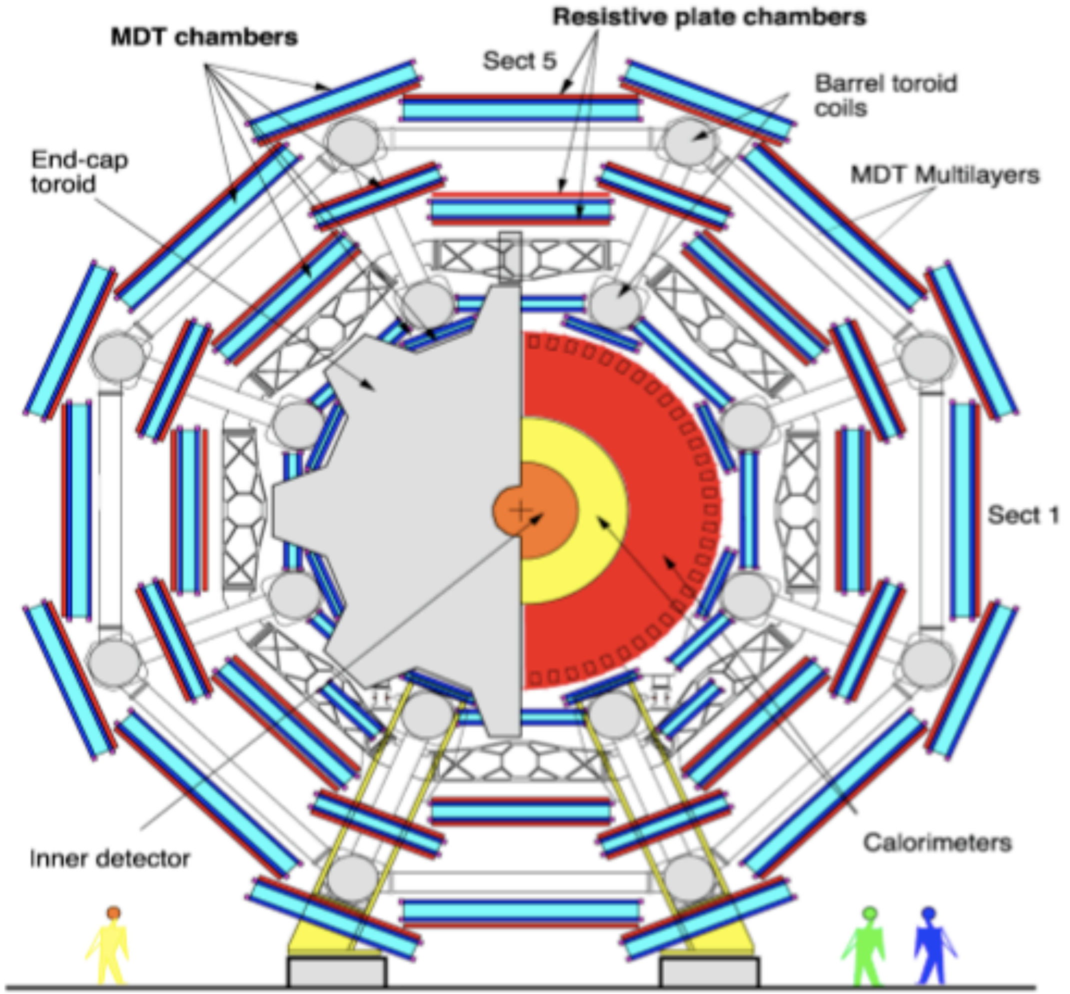
ATLAS: another tracker outside of the magnet





Muon Detectors

- Identification and precise momentum measurement of muons outside of the magnet
- Benchmark design for muon detectors: momentum measurement better than 10% up to 1 TeV.
  - $\Delta pT/pT \approx 1/BL^2$
- Typical track in Muon System has ≈ 20 hits
- A muon tracks can be:
  - “standalone” purely based on MS
  - “combined” btw MS and ID
- The standalone capability can be crucial at high luminosity when ID is “very crowded”
- The momentum measurement is dominated by
  - ID @ low p_T
  - MS @ high p_T

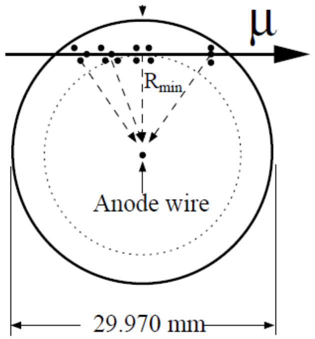


ATLAS

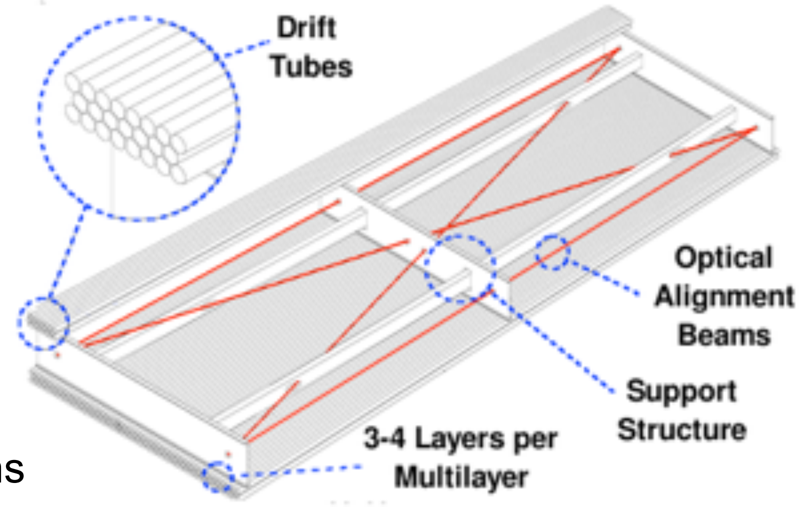
- independent muon system -> excellent stand capabilities

Precision Chambers

1) Monitored Drift Tubes (MDT)



Drift Tube

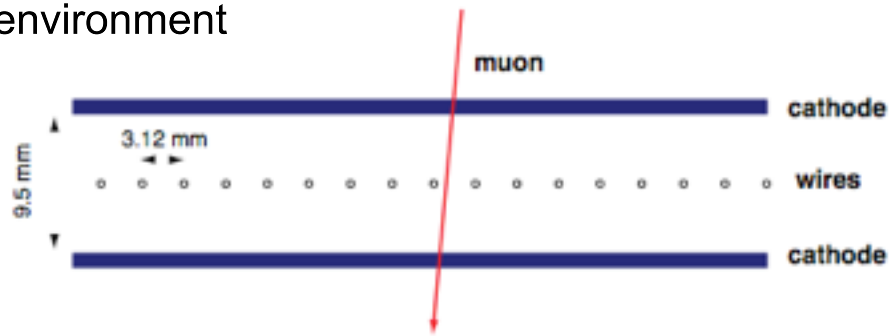


High-pressure drift tubes
$\sigma(R) \approx 100\mu m$, $T_{drift} \approx 700ns$

- Gas-filled drift tubes with central wire
- Signal read out on both ends
- Spatial resolution increased by recording drift time.
- Three concentric barrel layers plus end-cap (eta=2.7).
- Total of 355000 tubes.

2) Cathode Strip Chambers

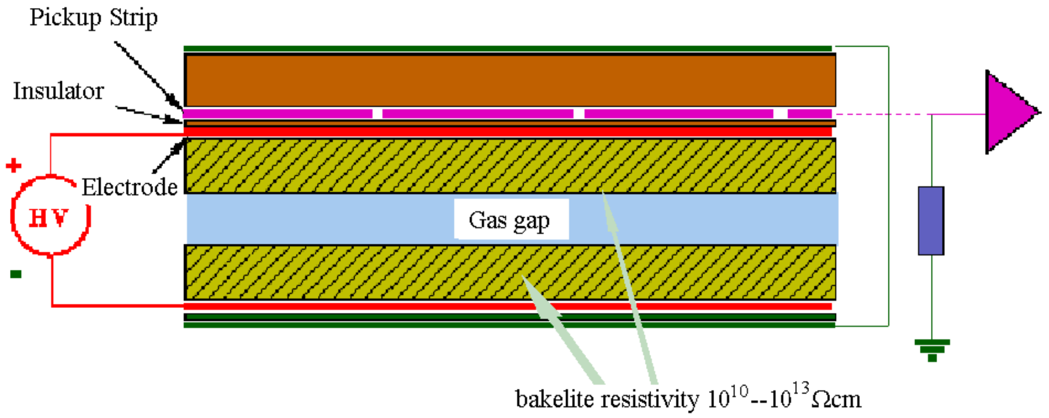
Operation in high rate environment
$\sigma(R) \approx 60\mu m T_{drift} \approx 20ns$



- Array of anode wires crossed with copper cathode strips within gas volume.
- Short drift distances.
- Suited for high eta

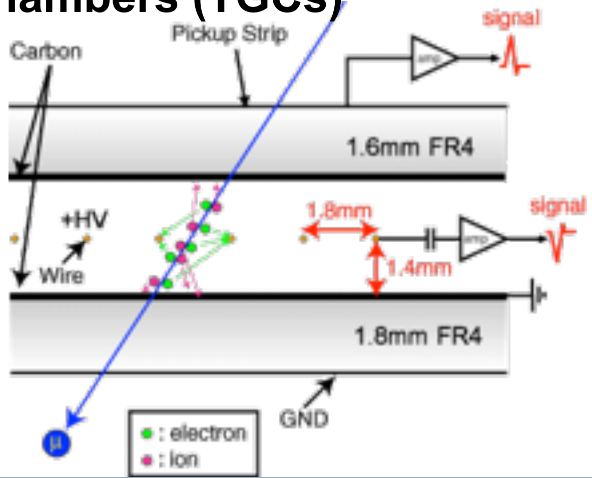
Trigger Chambers

1) Resistive Plate Chambers (RPCs)



- Robust detector with up to 5ns time resolution
- Charge carriers drift towards anode and get multiplied by electric field (avalanche).
- Applied high voltage at parallel plate electrodes leads to uniform electric field in the gas gap.
- The propagation of the growing number of charges induces a signal on a read out electrode.
- In ATLAS the Barrel is equipped with RPCs.

2) Thin Gap Chambers (TGCs)



- Derivative of MWPCs
- Operation in saturated mode. Signal amplitude limited by by the resistivity of the graphite layer
- In ATLAS the End-cap is equipped with TGCs.

Magnet, Trigger, Data Processing

A magnet for a LHC experiment

- **Wish list**
  - Big: long lever arm for tracking
  - High magnetic field
  - Low material budget or outside detector (radiation length, absorption)
  - Serve as mechanical support
  - Reliable operation
  - Cheap
  - ….

momentum resolution:
$\Delta p_T/p_T \approx 1/BL^2$

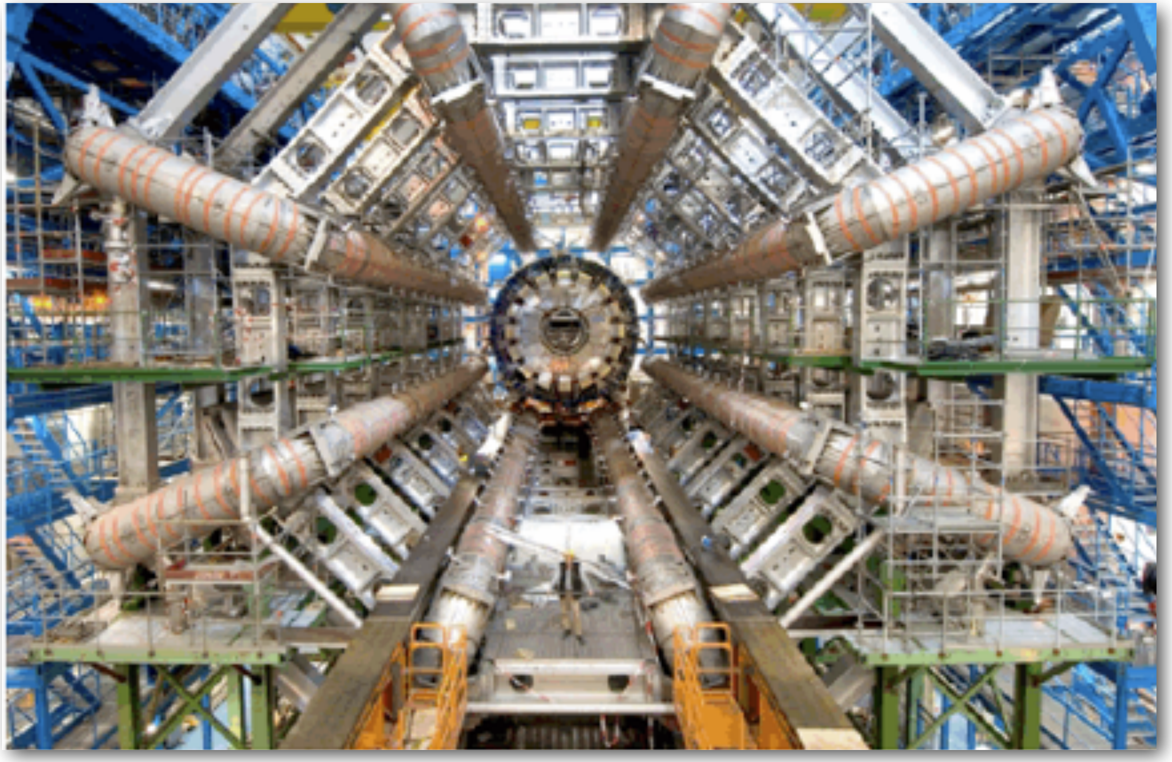
Eierlegende Wollmilchsau

- **ATLAS decision**
  - achieve a high-precision stand-alone momentum measurement of muons
  - need magnetic field in muon region -> large radius magnet

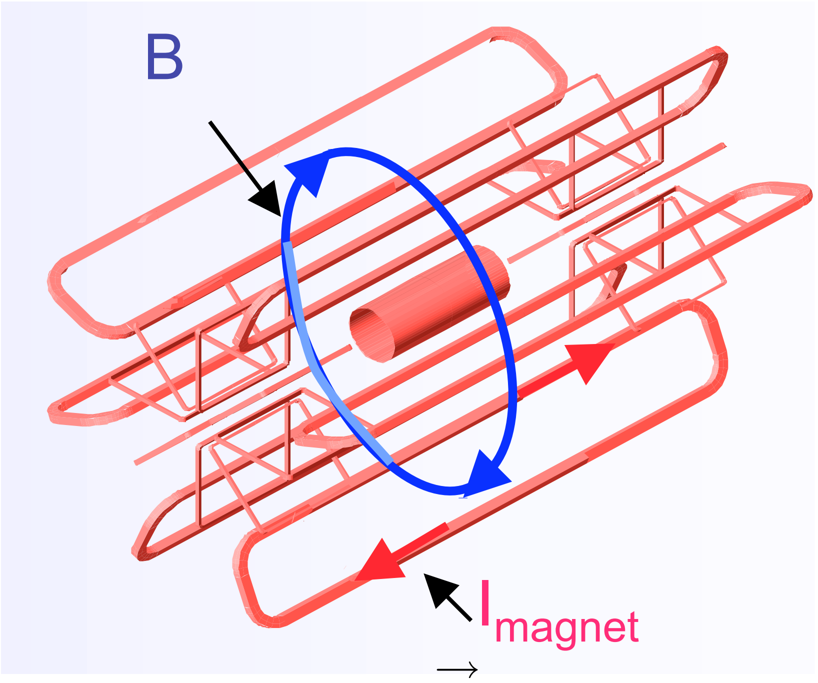
- **CMS decision**
  - single magnet with the highest possible field in inner tracker (momentum resolution)
  - muon detector outside of magnet

Magnet-Concepts: ATLAS -> Toroid

- Central Toroid field within Muon-System: 4 T
  - Closed field, no yoke
  - Complex field
- 2 T Solenoid-field for trackers



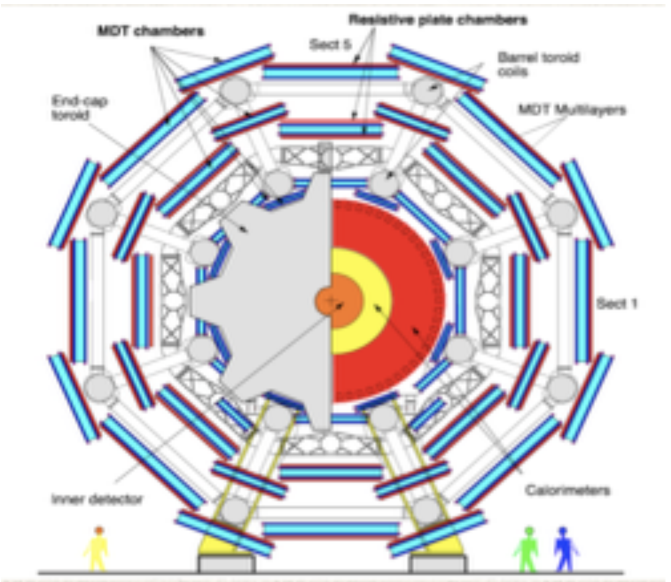
The largest magnet in the world



+ field always perpendicular to p
+ relative large field over large volume
- non uniform field
- complex structure (detector hard to access)

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 (currently) 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.

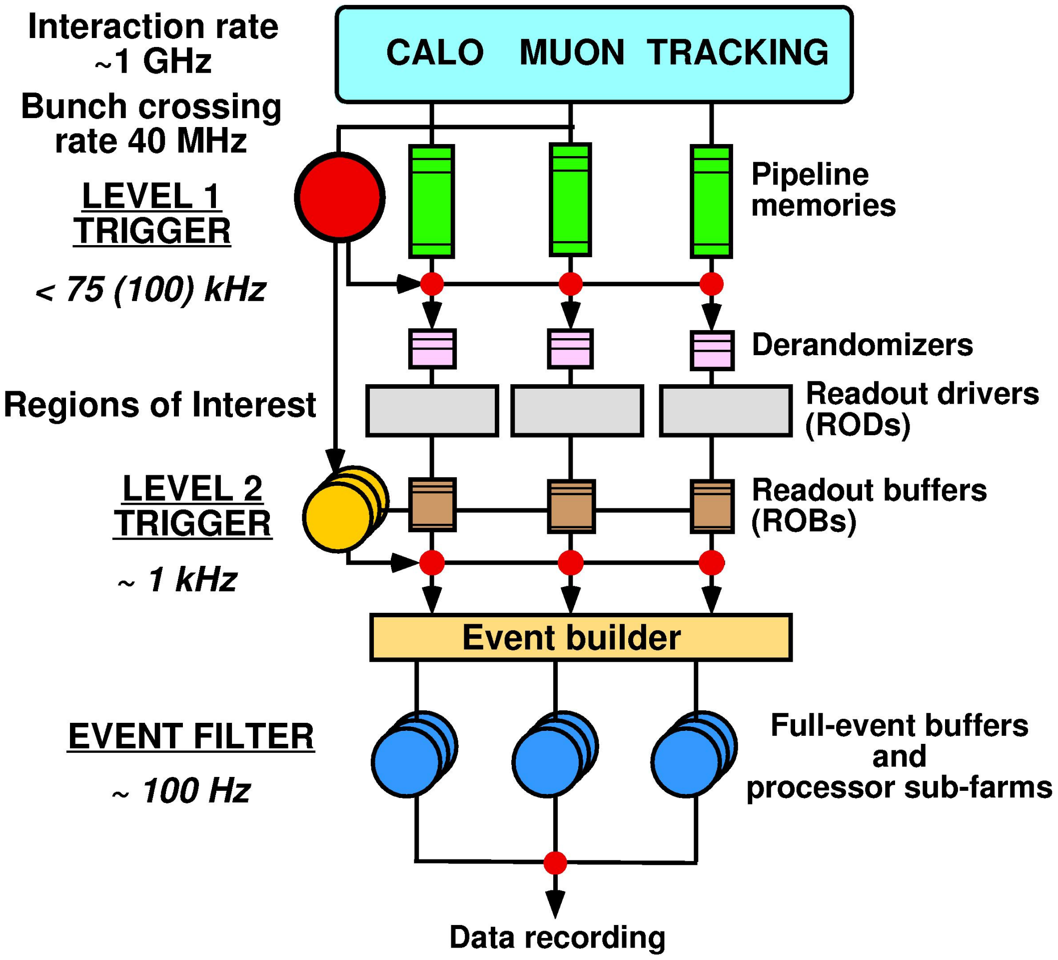


Fast detector systems detect possible interesting signature and trigger the inner detector systems to be read out. Other events are discarded.

- 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

ATLAS Trigger

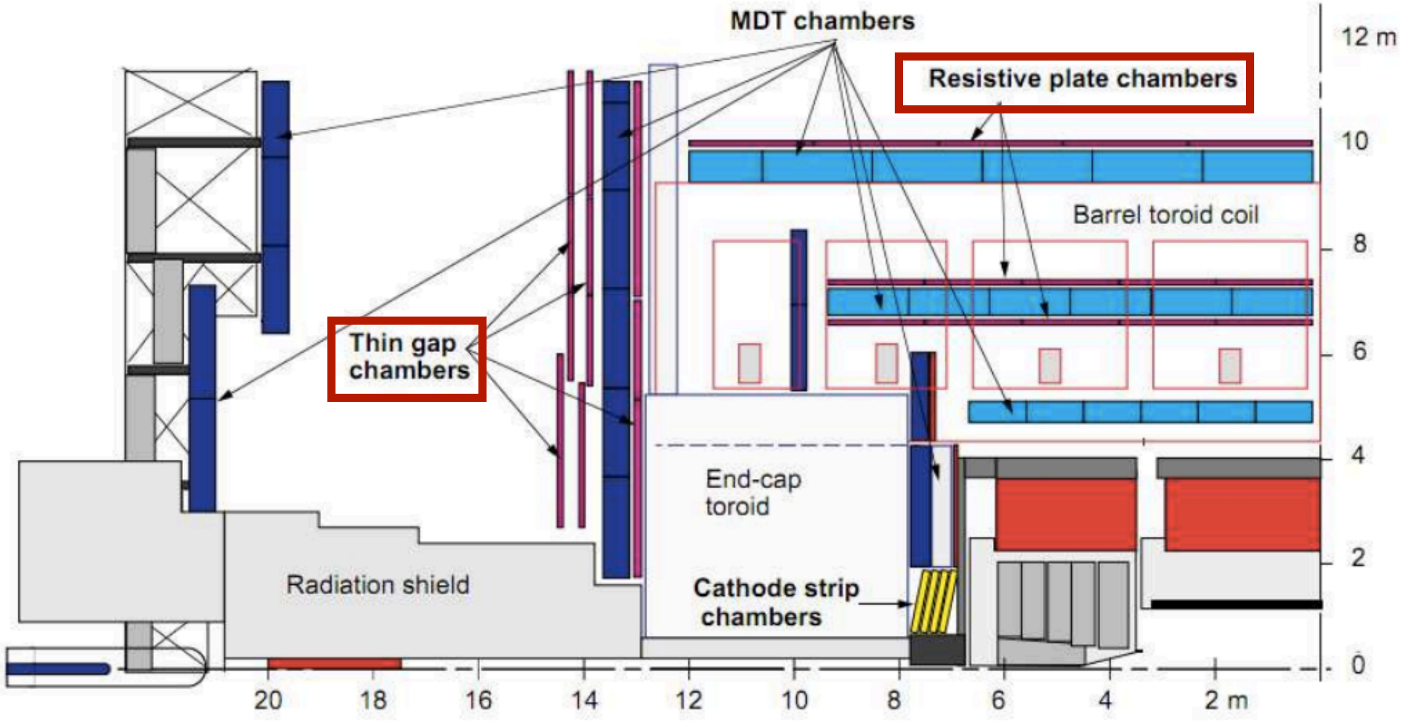
- Level-1:
  - Implemented in hardware
  - Muon + calorimeter based
  - Coarse granularity
  - e/γ, μ, π, τ, jet candidate selection
  - Define regions of interest (ROIs)
- Level-2:
  - Implemented in software
  - Seeded by level-1 ROIs, full granularity
  - Inner Detector – Calo track matching
- Event Filter:
  - Implemented in software
  - Offline-like algorithms for physics signatures
  - Refine LV2 decision
  - Full event building



- Collision rate 40MHz
- Level 1 accepts up to 75kHz
- Recorded ~300 Hz

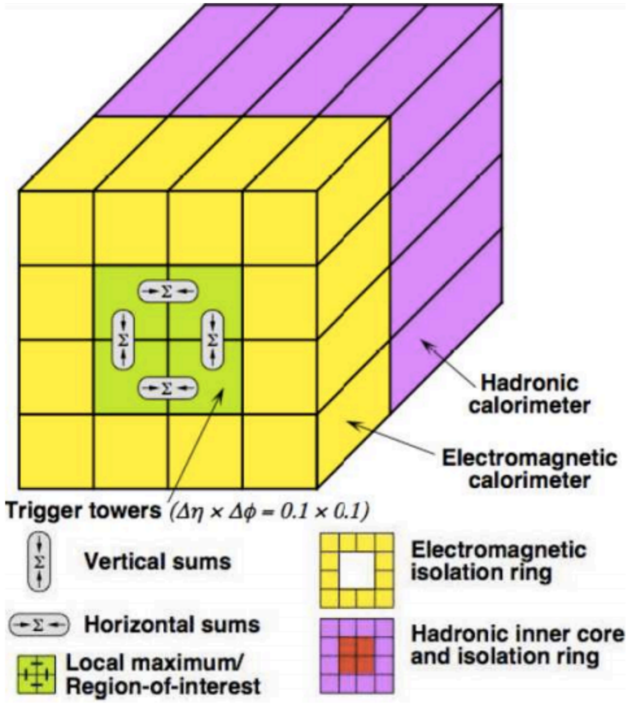
factor ~130000

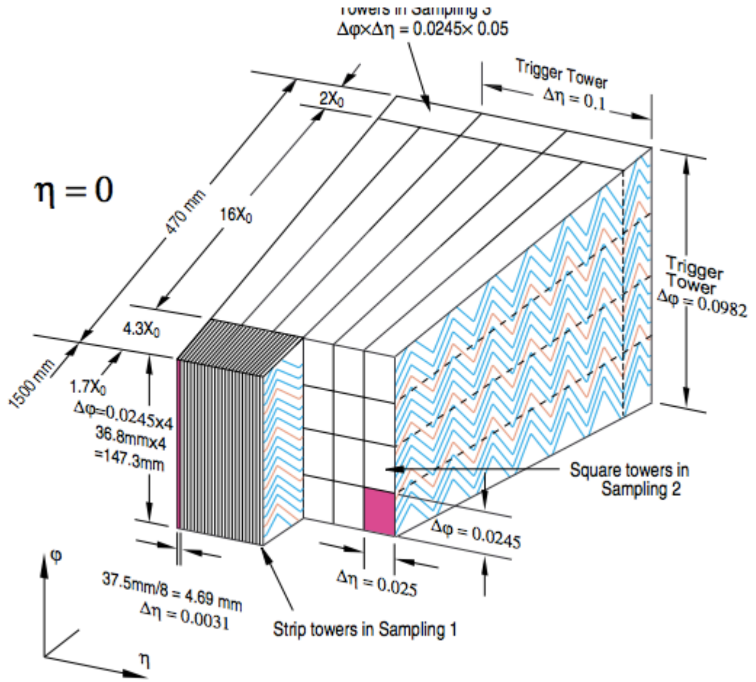
Horizontal View



- L1 Trigger:
  - Fast Resistive Plate and Thin Gap Chambers
  - Hardware pattern recognition
- High Level Trigger: L2 & EF Trigger:
  - Use slower more precise MDT chambers
  - Combine with inner detector track
  - L2 uses simplified B-field model
  - Event Filter uses full offline software

Calo Trigger

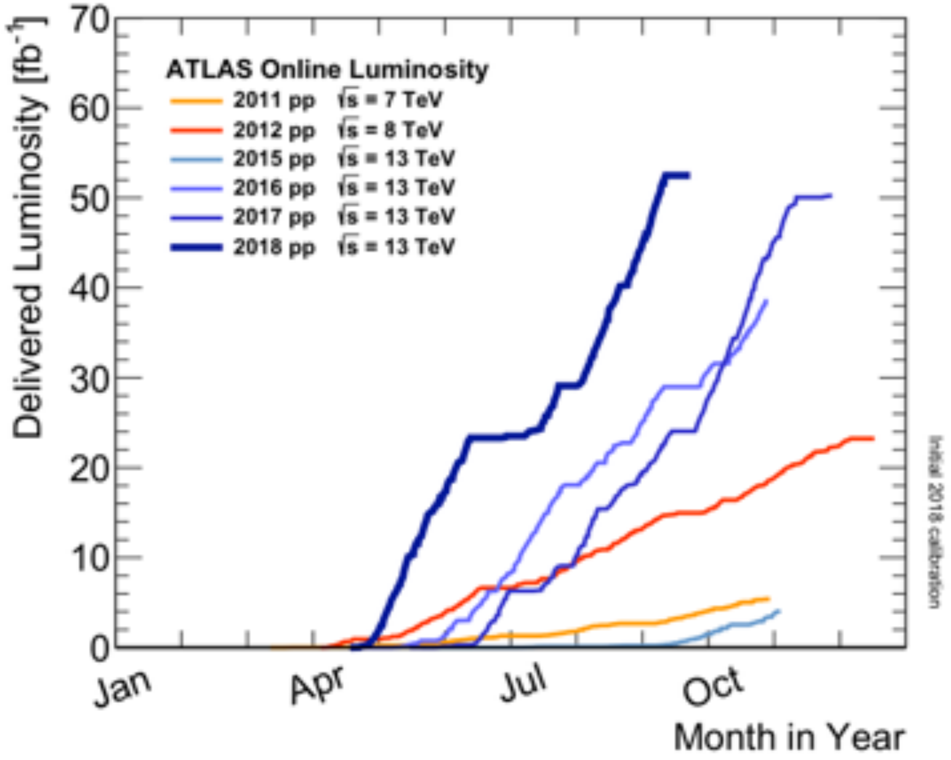


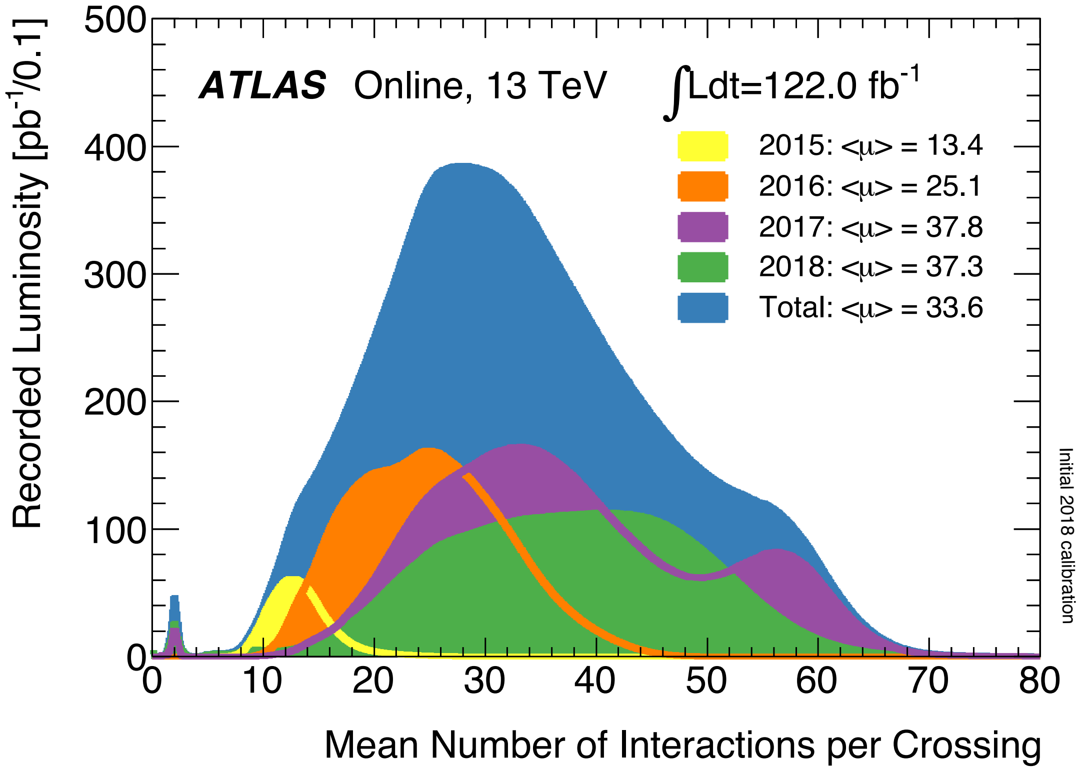


- L1 Trigger: analog sums over...
  - 0.1x0.1 for e/gamma and taus
  - ~0.2x~0.2 for jets, MET, sumET
- L2 & Event Filter Trigger:
  - Full detector granularity same digitisation as offline
  - Track-shower matching
  - Detailed shower shape cuts
  - Reclustering jets
- Overall trigger performance
  - Achieve very high efficiencies even with high pile-up conditions
  - Reaching the limits ….

ATLAS Detector Performance

Data Taking with ATLAS

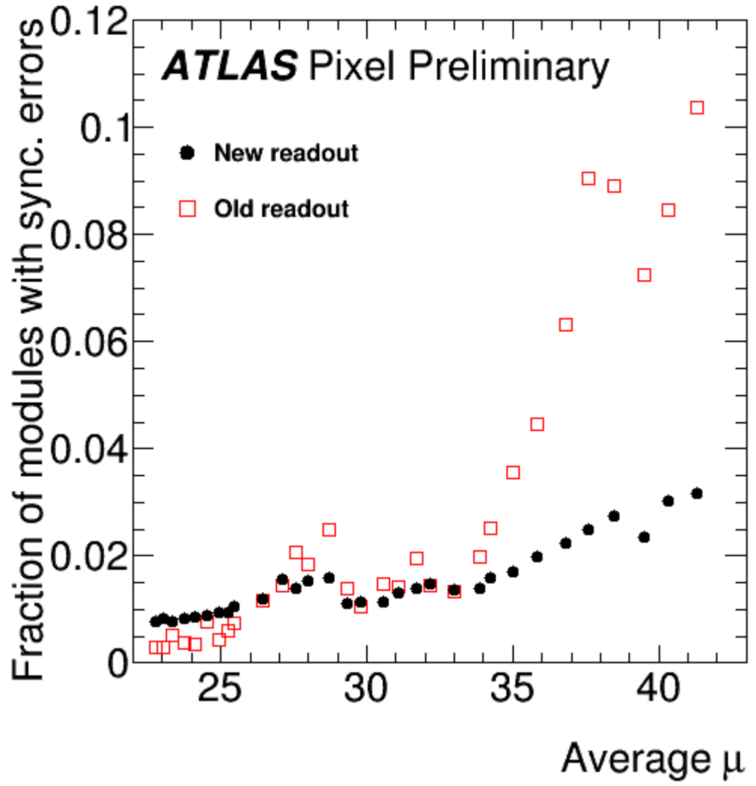


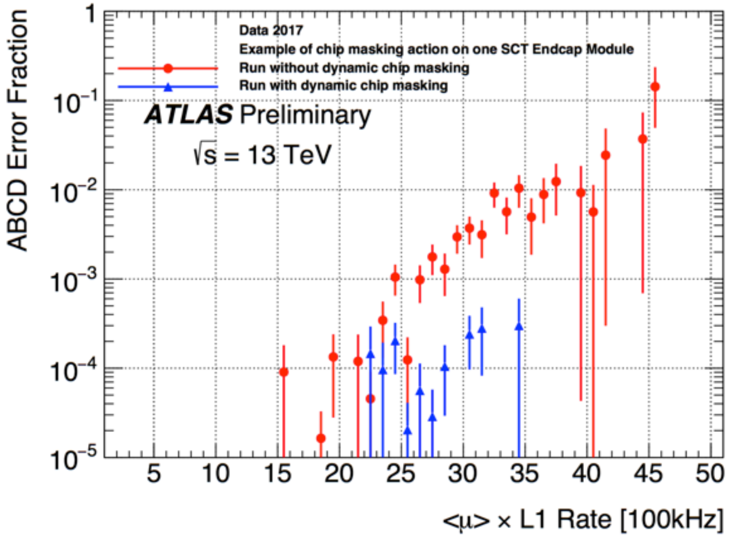


- Instantaneous peak luminosities around 2 10^{34} cm^{-2} s^{-1} i.e. exceeding the LHC design luminosity by a factor of two.
- LHC is able to run with a full machine in 2018, 2556 bunches.
- Pile-up is high, however, ATLAS is capable to take this high luminosity (μ ~ 58, just at the limit)

Inner Detector Performance

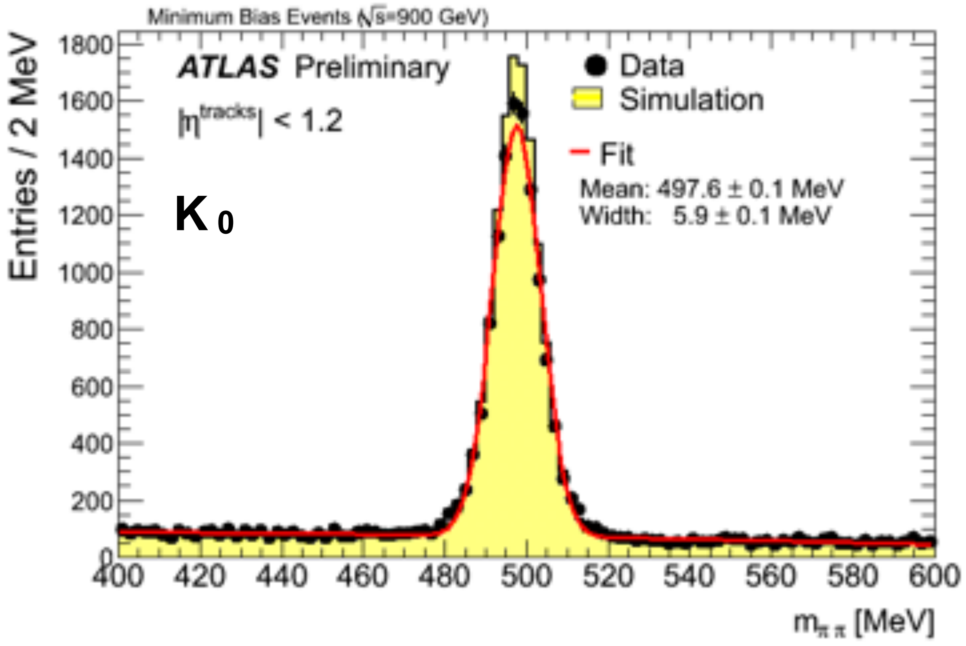
- Pixel detector
  - Hardware/firmware/software upgrades to cope with high pile-up
  - Reduction of deadtime (1.2%->0.2%)
- SCT
  - Very stable operation
  - Dynamic chip masking to cope with high <μ>
- TRT
  - Hardware and firmware upgrades to cope sustain high occupancy
  - Increase of bandwidth and compression ratio

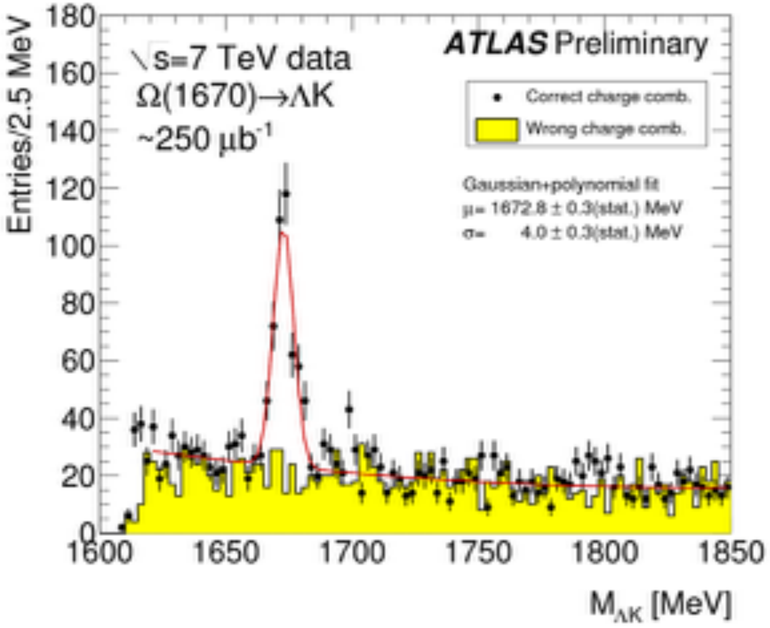




Inner Detector Performance

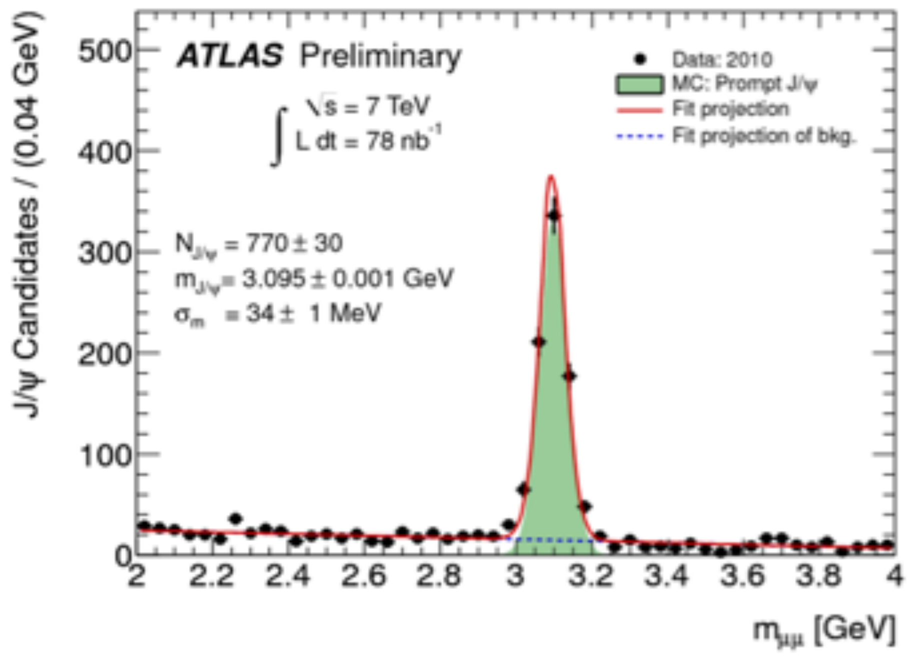
- Observed all most classic resonances
  - K_s, K*, φ, Λ, Ω, Ξ, D, D* and J/Ψ
  - The mass values agree with the PDG values, the resolutions with the MC expectations.
- Momentum scale known to permil level in this range
  - Is precisely determined via known resonances
  - Resolution as expected (dominated by multiple scattering)
  - Good performance of ATLAS tracker and tracking/vertexing algorithm

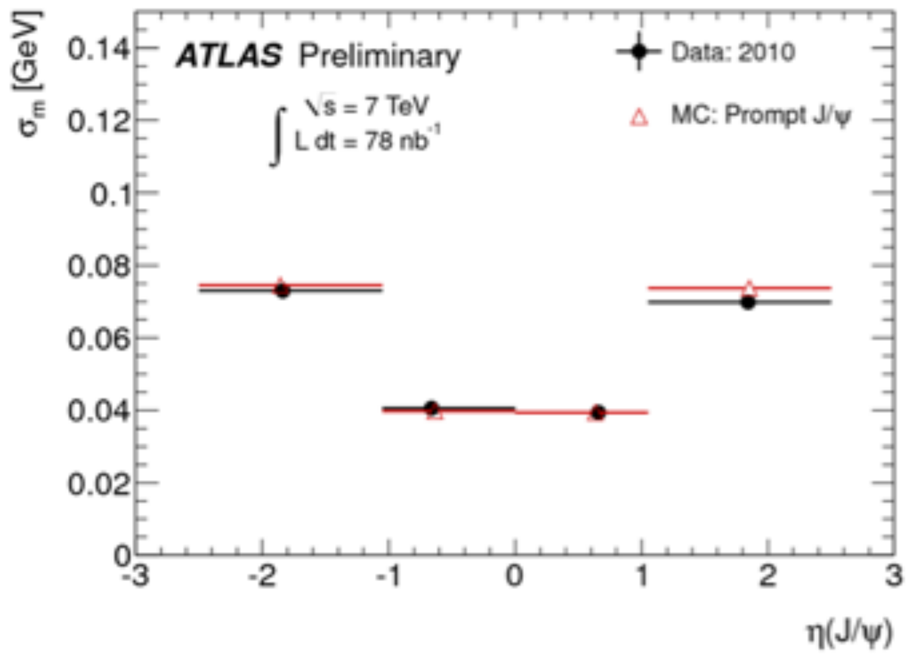




Inner Detector Performance

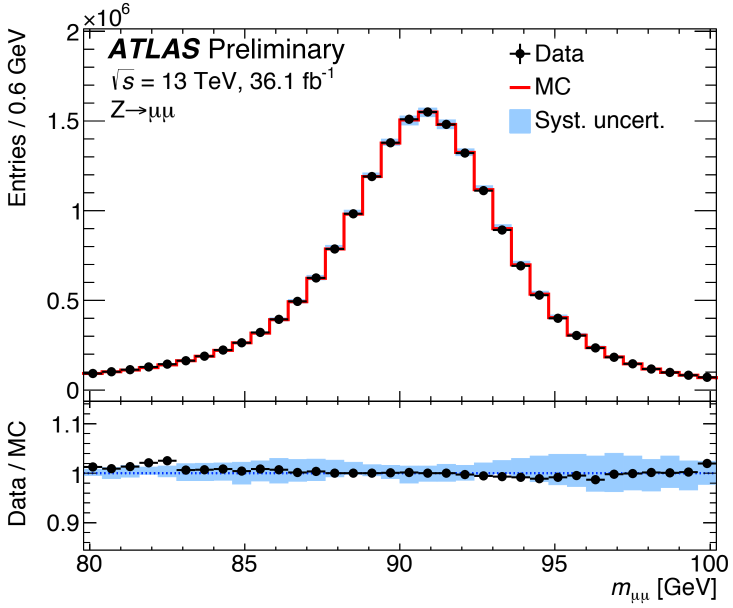
- Particles with higher masses (e.g. J/Psi, Z) are used to assess momentum scale and resolution in higher energy regimes
  - Example: J/Psi mass resolution
  - Momentum scale known to 1% level up to ~100GeV
- Offline reconstruction efficiencies determined e.g. via ‘tag and probe’ techniques
  - Inner Detector reconstruction efficiency for muons above 20GeV confirmed to be better than 99%

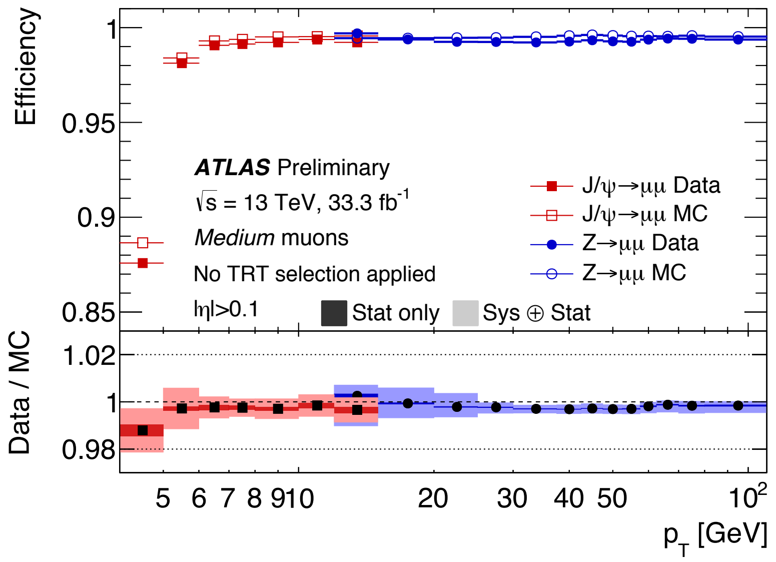




Muon System

- Good performance of combined Inner Detector and Muon Spectrometer reconstruction
  - At low pt, Inner detector is dominating overall muon momentum resolution (~2% resolution >10GeV, dominated by multiple scattering)
  - Nice agreement between reconstruction efficiency from J/psi data and Z -> mu mu data
- Muon Spectrometer performance can be assessed via
  - (Cosmic muons)
  - Di-muon decays of known particles (Z->mu mu)

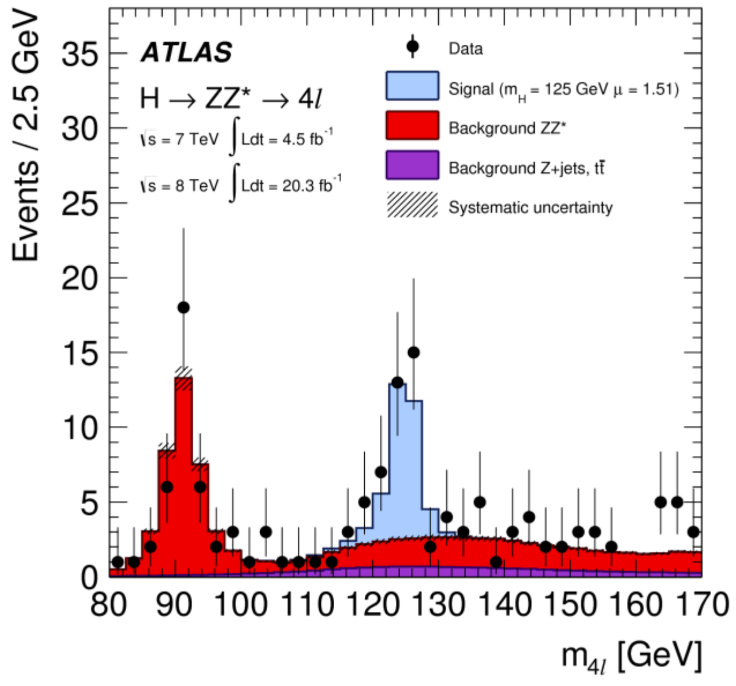


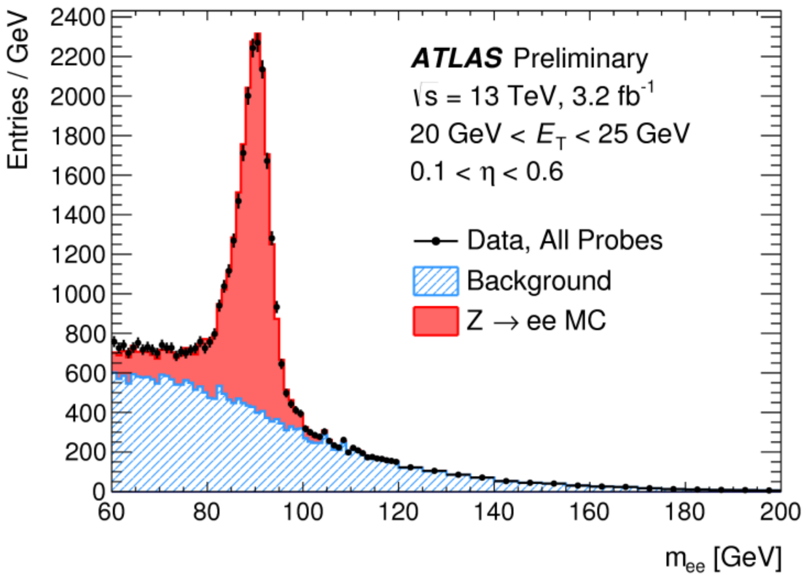


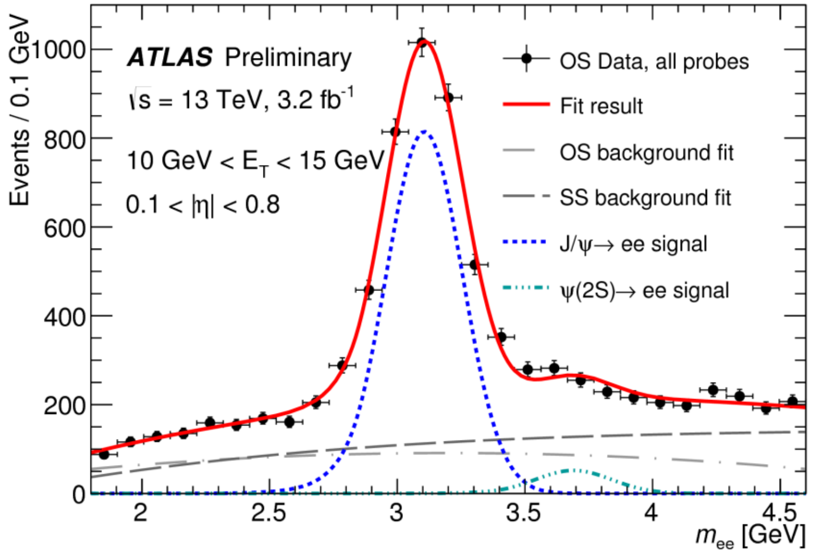
- Momentum scale known to 1%
- Momentum resolution known to rel. 10%
- Reconstruction efficiency known to <1%

Electrons and Photons

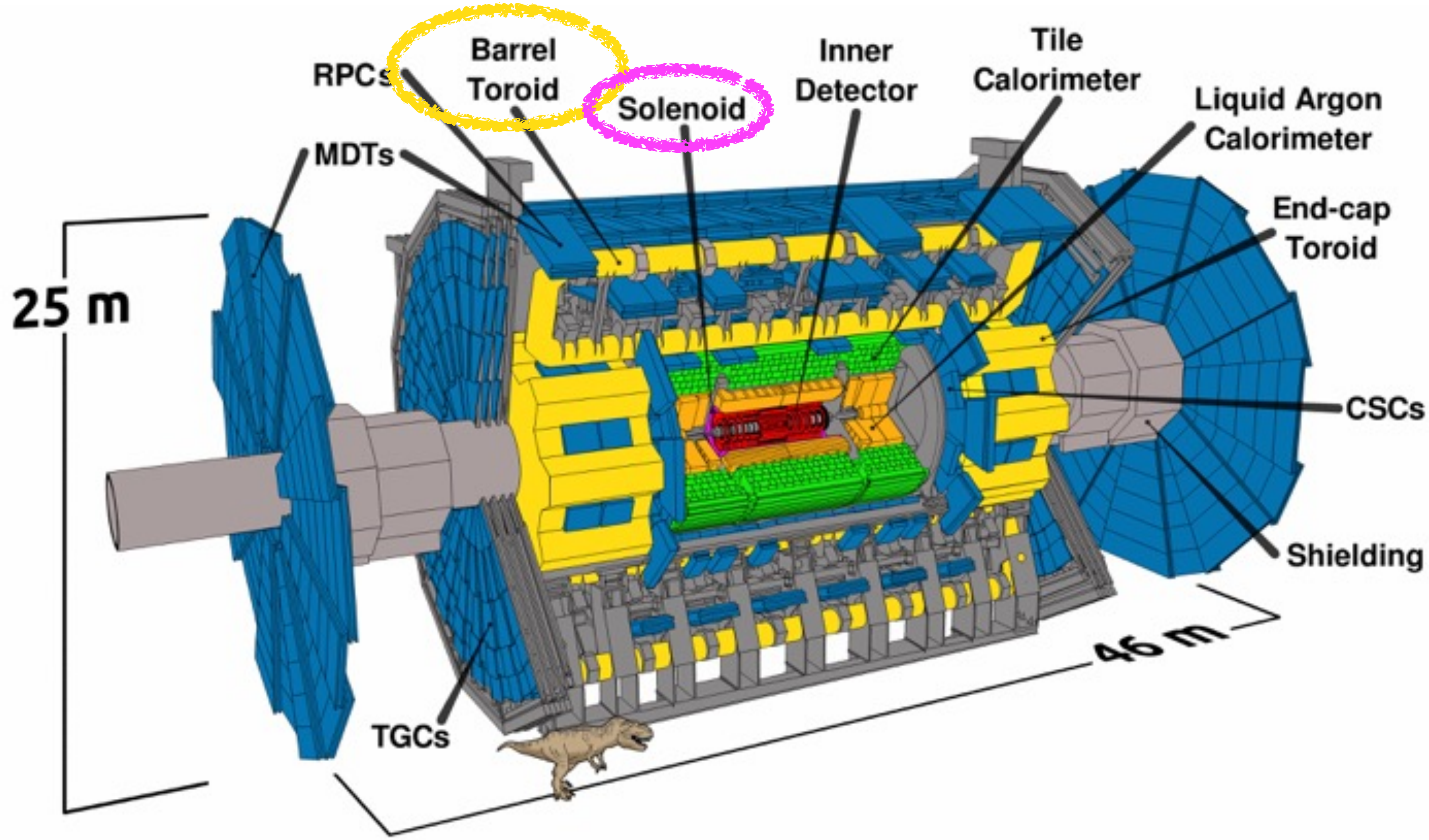
- Electrons and photons are interesting probes in proton-proton collisions
- Crucial for all analyses:
  - high reconstruction efficiencies, good background reduction and energy calibration
- Electrons: Energy cluster in EM calo and matching track in ID
- Photons: Energy cluster without track or matched track from conversion.







ATLAS detector

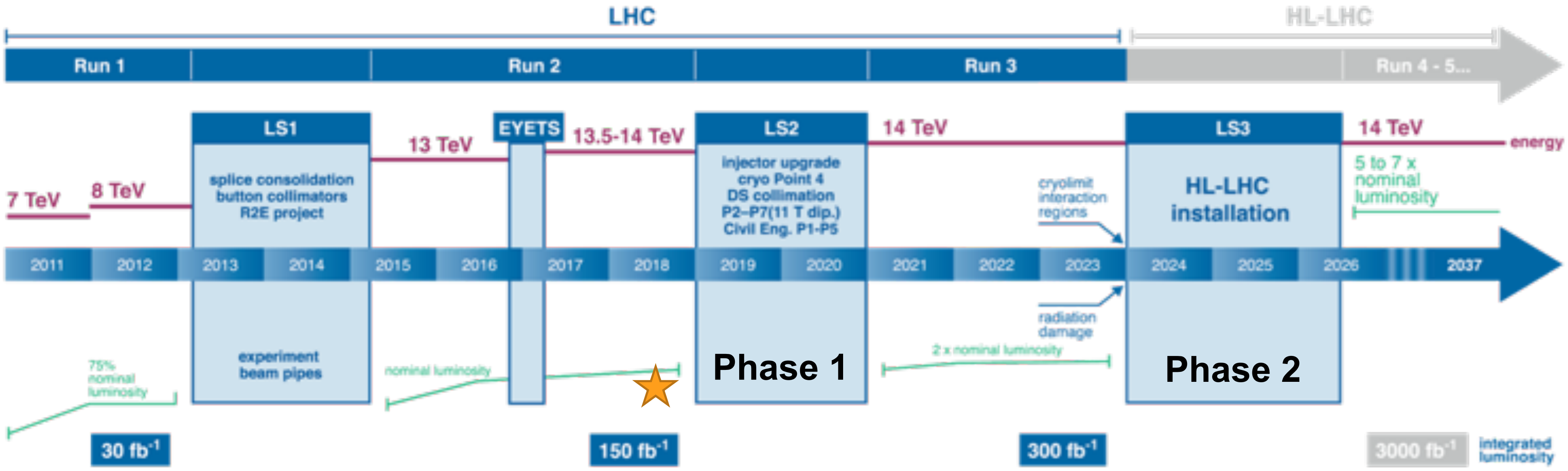


A new ATLAS Detector

High-Luminosity LHC

Frédérick Bordry, Chamonix Workshop 2017
https://indico.cern.ch/event/580313/

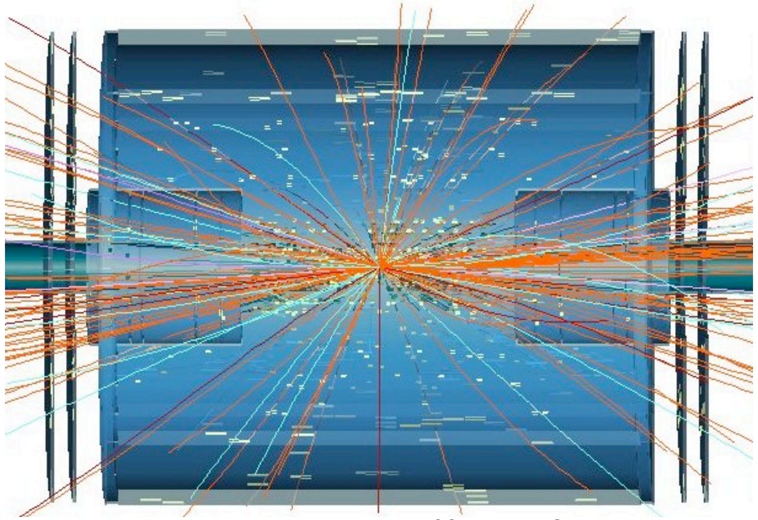
LHC Schedule



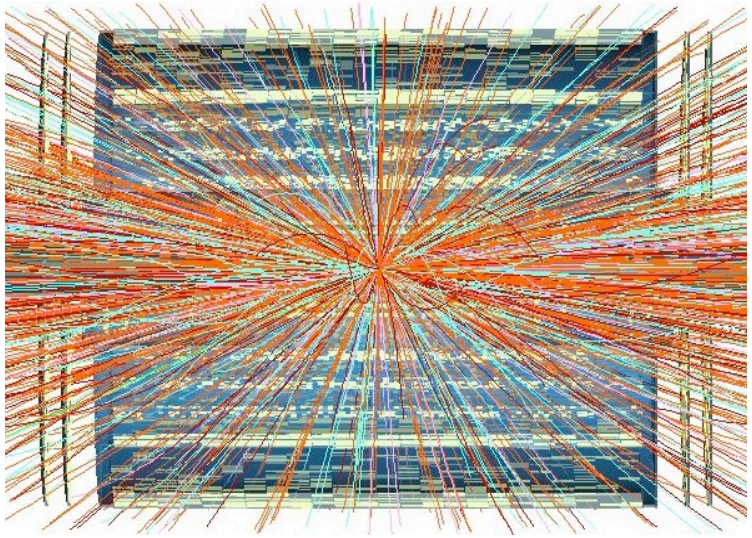
- Exploit full potential of LHC and to collect up to 4000fb^{-1}
- Goals for HL-LHC: $\sqrt{s}$ = 14 TeV, ultimate luminosity: 7.5 x 10^{34} cm^{-2} s^{-1}, 200 interactions/crossing,
- Upgrades of accelerator and detectors are necessary to reach this ambitious goal.

Why Upgrade?

- **Primary motivation** of all upgrades is to maximise physics reach
  - Precision measurements of Higgs couplings and other SM processes
  - Make first measurement of Higgs self-coupling (very challenging)
  - Search for/investigate signals of phenomena beyond the Standard Model
- **The Means**
  - LHC demonstrated the ability to deliver beyond expectations
  - Future LHC upgrades offer the opportunity for an order of magnitude greater data samples
  - Improved detector technologies and strong R&D investments available
- **The Challenge**
  - Preserving or even enhancing the current performances in a challenging environment of high instantaneous luminosity and high pile-up
  - Design choices for detector upgrades driven by physics goals, but also existing constraints.



LHC in 2011: $1\text{x}10^{33}$ $1/\text{cm}^2\text{s}$



HL-LHC: $5\text{x}10^{34}$ $1/\text{cm}^2\text{s}$

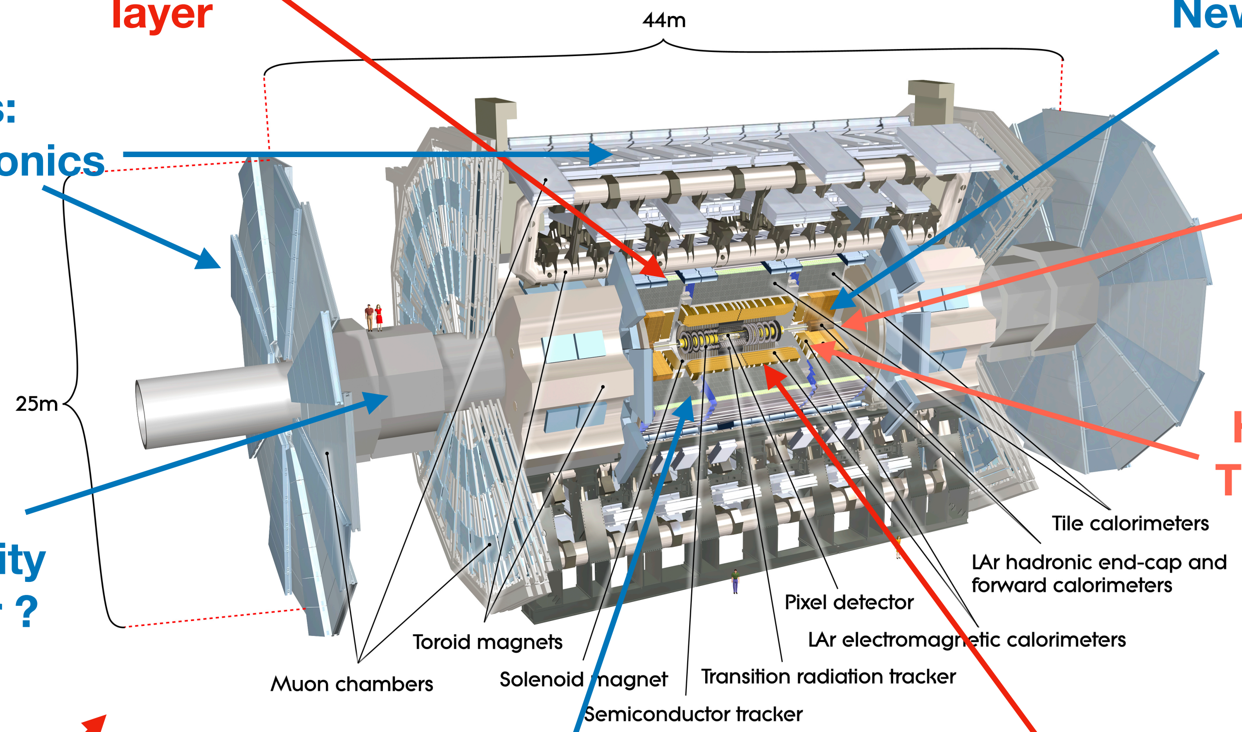
ATLAS for the HL-LHC

New Muon Barrel-Inner layer

Liquid Argon Calorimeter
(EM + EndCap Hadronic)
New electronics

Muons:
new electronics

Large eta
Muon tagger ?



High Granularity
Timing Detector ?

New
luminosity
monitor ?

New Trigger
and DAQ
System

Tile Hadronic Calorimeter
New electronics

New all-silicon
Inner Tracker

ATLAS Upgrade Matrix

- **Will not be replaced:**
  - Active and passive material in calorimeters
  - Magnets
  - Most of cables
- **Limits**:
  - Inner Detector area radiation controlled area
  - Scheduled time
  - Money …

Subsystem	Phase 1	Phase 2
Silicon Pixel	–	New Tracker
Silicon Strips	–	New Tracker
Electromagnetic Calorimeter	Finer Granularity in Trigger	New Electronics, Forward Cal
Hadronic Calorimeter	–	New Electronics, Forward Cal
Muon System	Small Wheels (Forward)	–
Trigger	Topological Triggers, Fast Track Trigger	Complete Replacement

New Inner Tracker
ATLAS ITk

A New Inner Tracker is Needed ... Why ?

- Current ATLAS Inner Detector (ID) works excellently to provide precision charged particle tracking with high efficiency.
- **Radiation damage - detector designed for 10 years**
  - Pixels designed for ~400fb^{-1}
  - Strips ~700 fb^{-1}
  - HL-LHC should deliver **4000fb^{-1}**
  - Fluences up to $2x10^{16}$MeV n_{eq} /cm^2 (> factor 10)
  - **New sensor & readout require more radiation hardness**
- **Bandwidth saturation**
  - Inner Detector designed for pile up of 50 at $2x10^{34}cm^{-2}s^{-1}$
  - HL-LHC goes to pile up of ~200 at $7.5x10^{34}cm^{-2}s^{-1}$
  - Readout need to be able to cope with this
- **Detector Occupancy**
  - Finer granularity is required to keep ITk performance at the same level as current ATLAS ID (Max hit density ~0.64/mm^2 (0.16%) Pix; ~0.005/cm^2 (1.2%) Strips)

ttbar event with 140 pile-up events (ATLAS simulation)

Improving the Tracking System

- Complex task to design a new tracking system for a running experiment
  - Size, cables and many other parameters are not changeable
  - Measures to improve one tracking parameter might have negative impact on other parameter
  - Prize tag important parameter

Modification

Performance

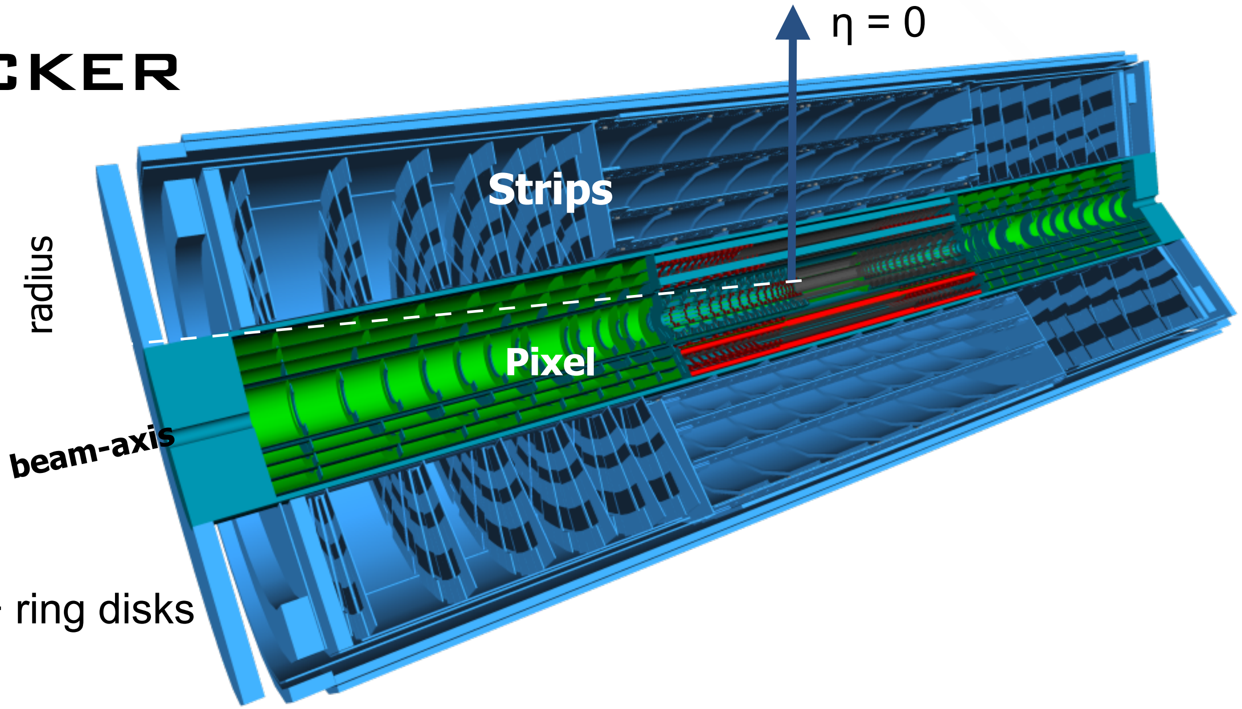
	Increase granularity at large radii	Increase granularity close to IP (pixels)	Increase number of pixellated layers	Reduce material
Fast and efficient pattern recognition in high pileup	X	X	X	
Improve momentum resolution at low pT				X
Improve momentum resolution at high pT	X			
Improve tracking efficiency	X			X
Improve impact parameter resolution		X		
Improve two-track separation		X		
Reduce photon conversions				X

New ATLAS Inner Tracker

- **Design goal:** ITk should have the same or better performance as the current detector
  - Even at harsh HL-LHC conditions.

Layout 2018

- All-silicon design
- Pixel:
  - 5 barrel layers (short barrel + inclined modules) + ring disks
- Strips:
  - 4 barrel layers + 6 end-cap disks



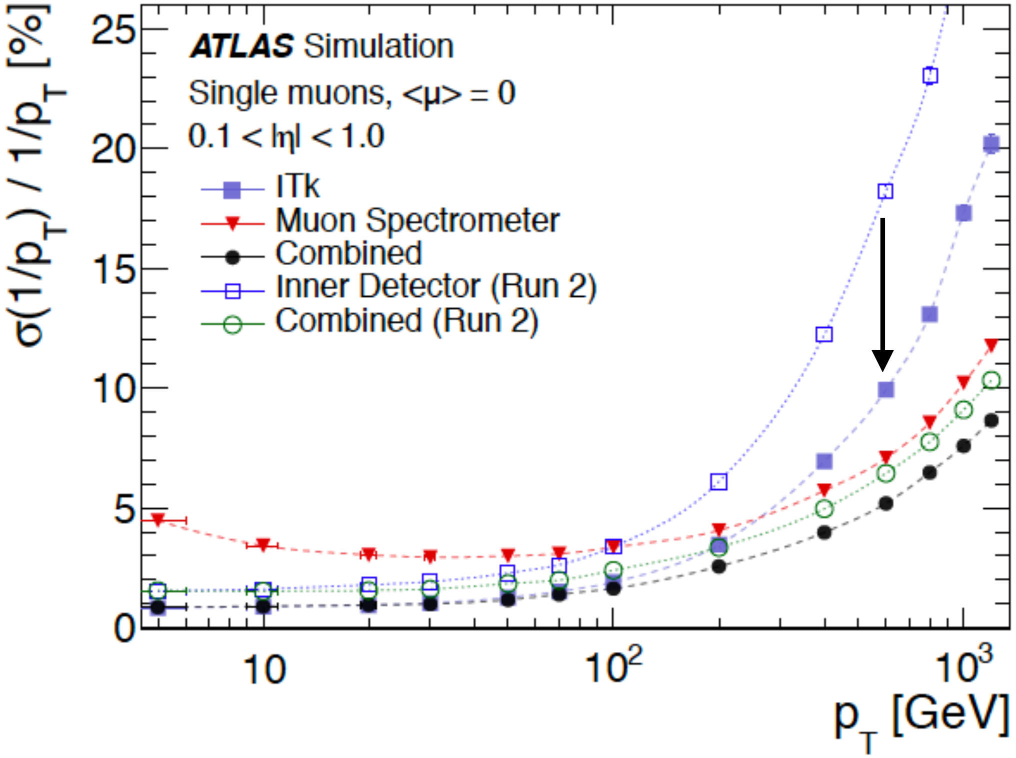
	Pixel	Strips
Active area	~13m^2	165m^2
Segmentation	50x50µm^2 (25x100µm^2)	75.5µm (Barrel) 69 to 85µm (Disk)
# modules	10276	17888
# channels	~5x10^9	~6x10^7

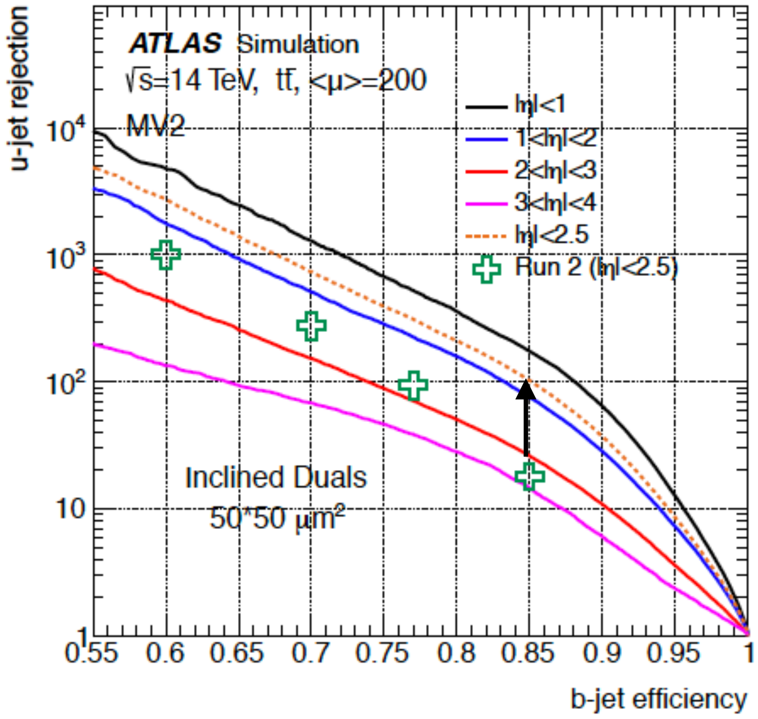
Biggest changes compared to current tracker:

- Pixels system extends out to larger radii
- More pixel hits in forward direction to improve tracking
- Smaller pixels and short inner strips to increase granularity
- Outer active radius slightly larger to improve momentum resolution

ITk Performance - Simulation

- Very high efficiency (>99% for muons) and negligible fake rates (10^{-5} in tt events) at the highest pileup levels (200).
- Improved momentum resolution at high and medium p^t .
- Large improvement in b-tagging and pileup rejection due to better resolution on track impact parameter.

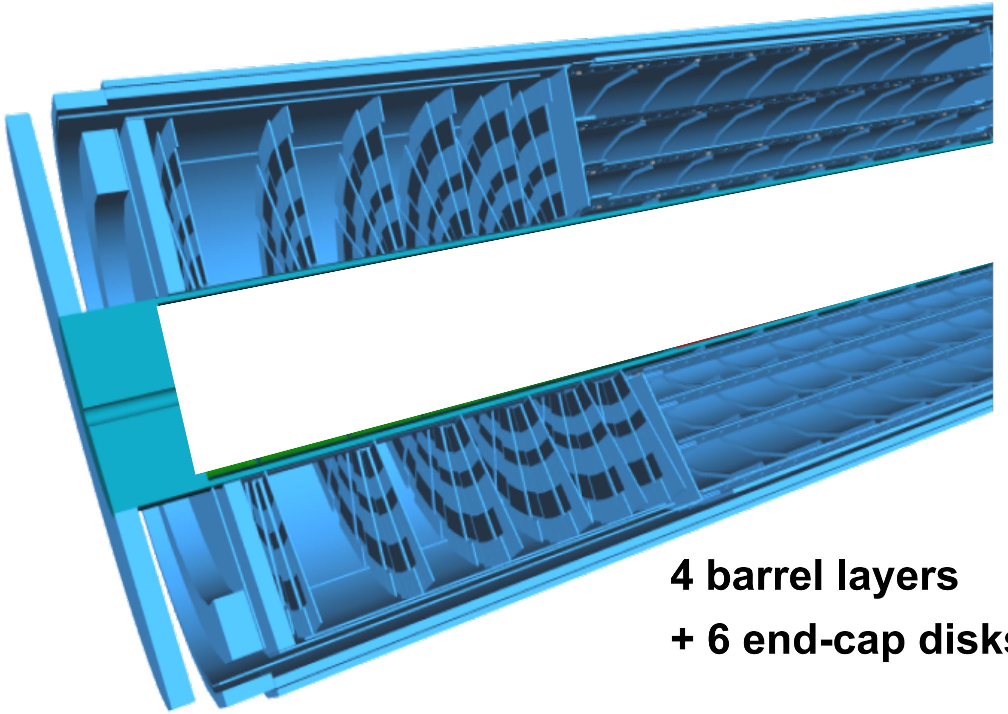


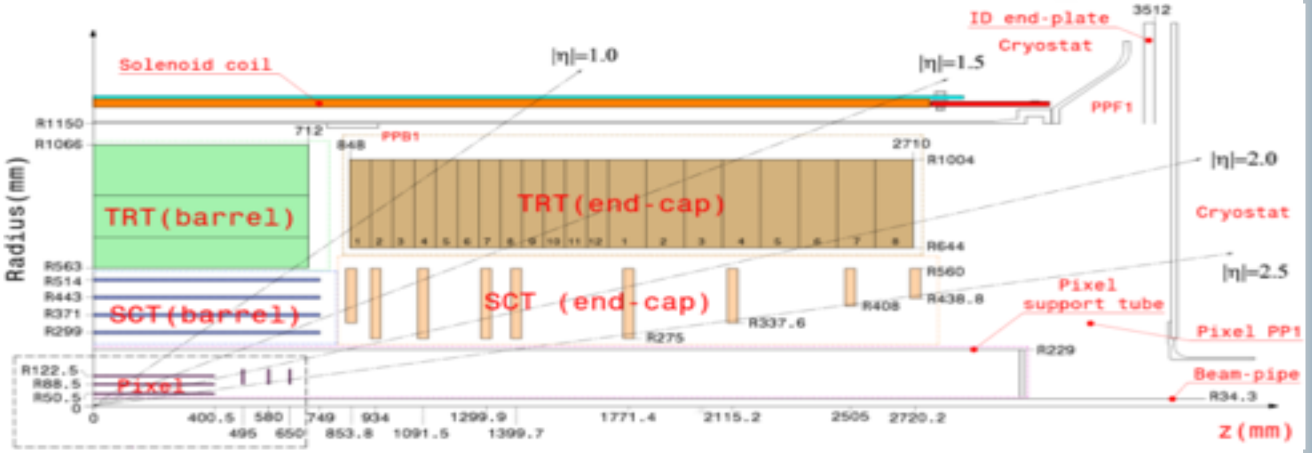


Very small selection of studies - worked on the layout for years!

A Huge Strip Detector

The Strips Detector

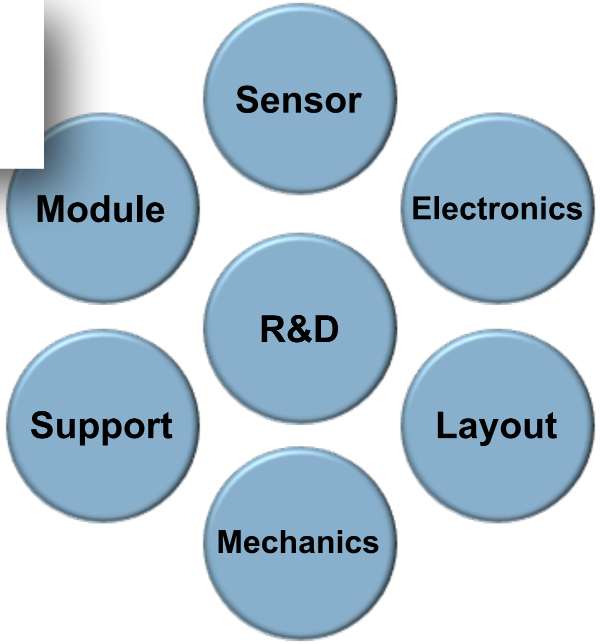




4 barrel layers

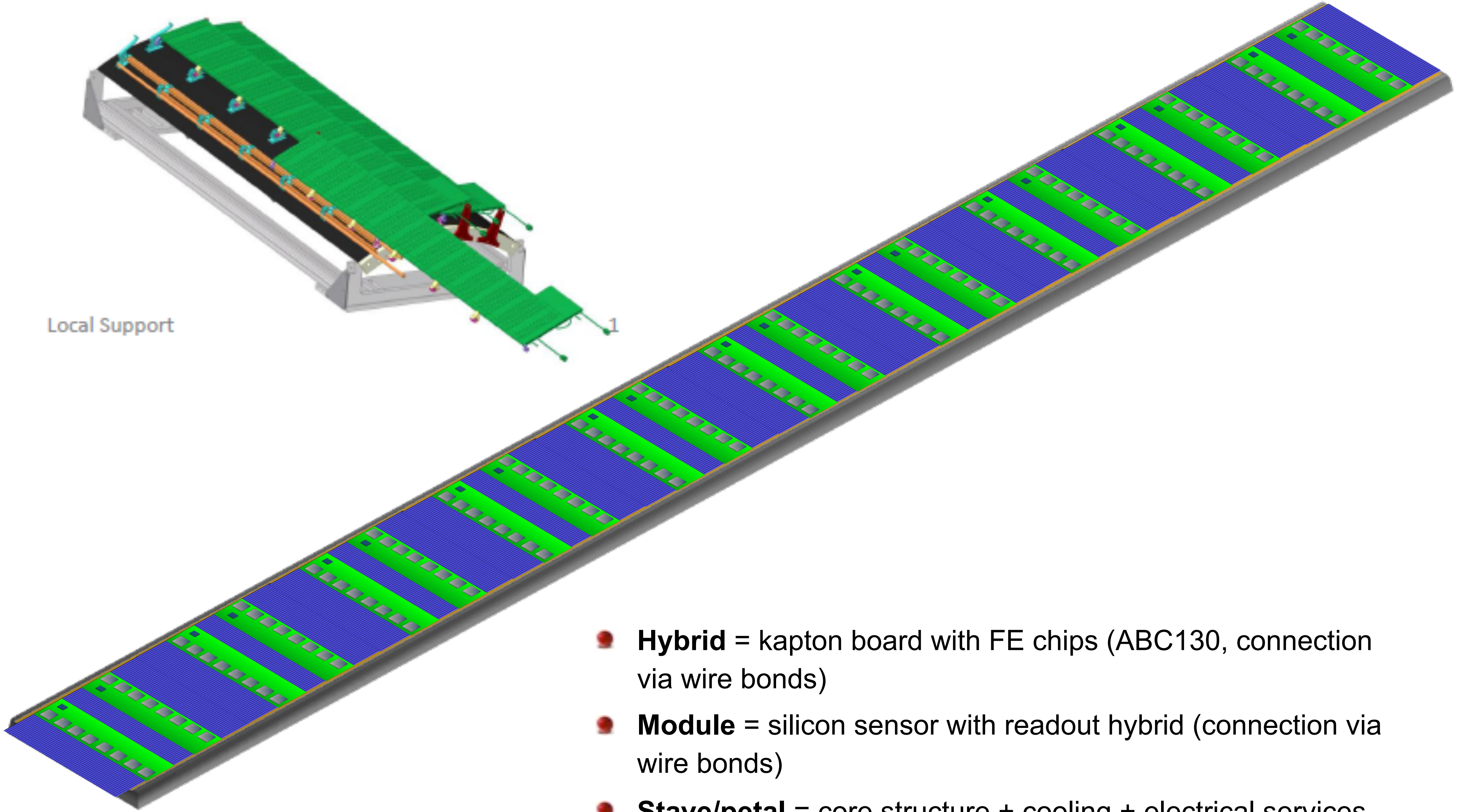
+ 6 end-cap disks

Last 7 years - R&D from early prototypes to TDR



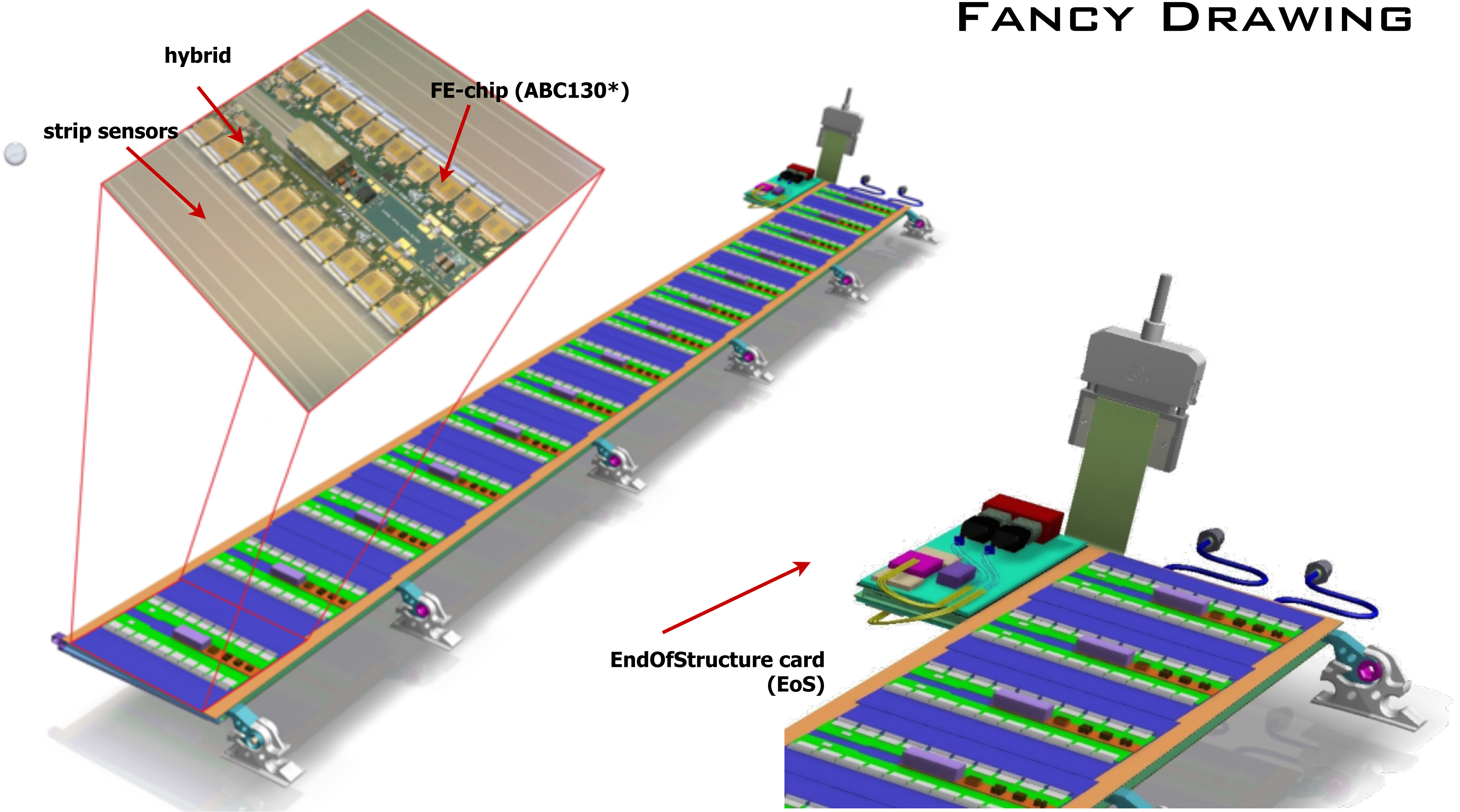
- Developed concept applicable for **barrel and end-cap.**
  - Silicon modules glued directly onto a cooled carbon fibre plank.
  - Kapton service tapes co-cured onto carbon fibre skins providing the electrical connections.
  - Designed to reduce radiation length.

ATLAS Strips: Stave/Petal Concept

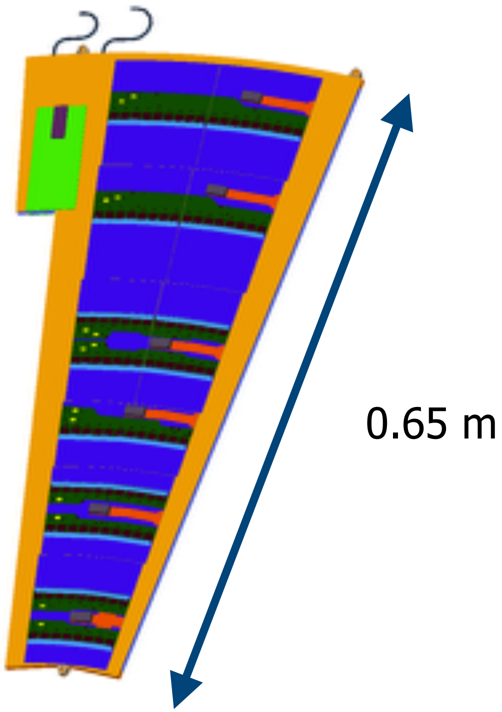


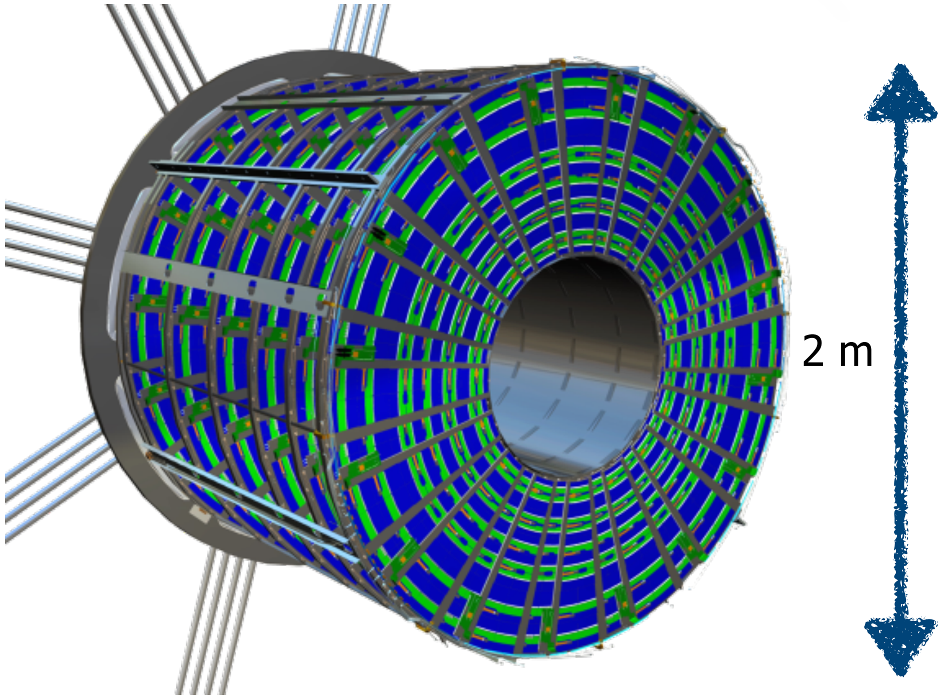
- **Hybrid** = kapton board with FE chips (ABC130, connection via wire bonds)
- **Module** = silicon sensor with readout hybrid (connection via wire bonds)
- **Stave/petal** = core structure + cooling + electrical services (power, data, TTC) + modules

Fancy Drawing



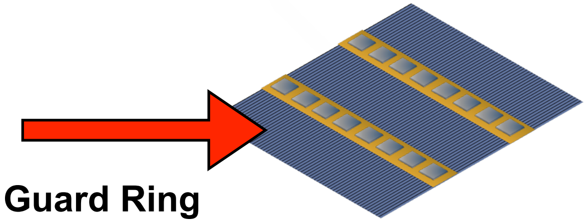
End-caps



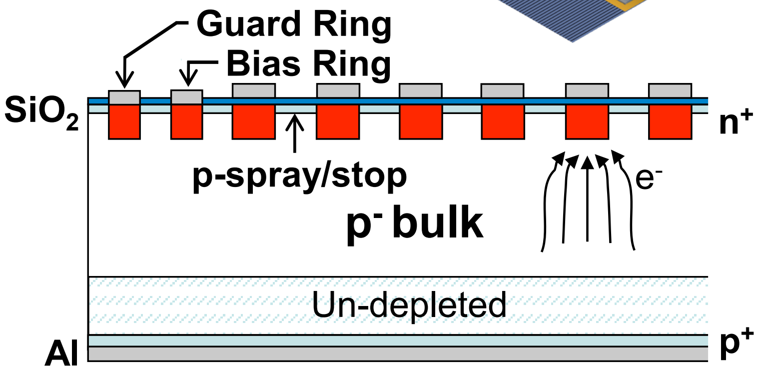


- End-caps are more challenging due to their geometrical constraints
  - pointing strips: same phi coordinate measurement along the strip length
  - same concept as in barrel -> build disks out of wedge shaped petals covered by **six** different sensor shapes
  - more complicated layout for the electronics as we have two modules besides each other
- Advantages:
  - side-insertion - petals accessible for a very long time
  - technical solutions for barrel and end-caps mostly the same
  - especially module production is exactly the same across barrel and end-cap

Silicon Strips Sensors

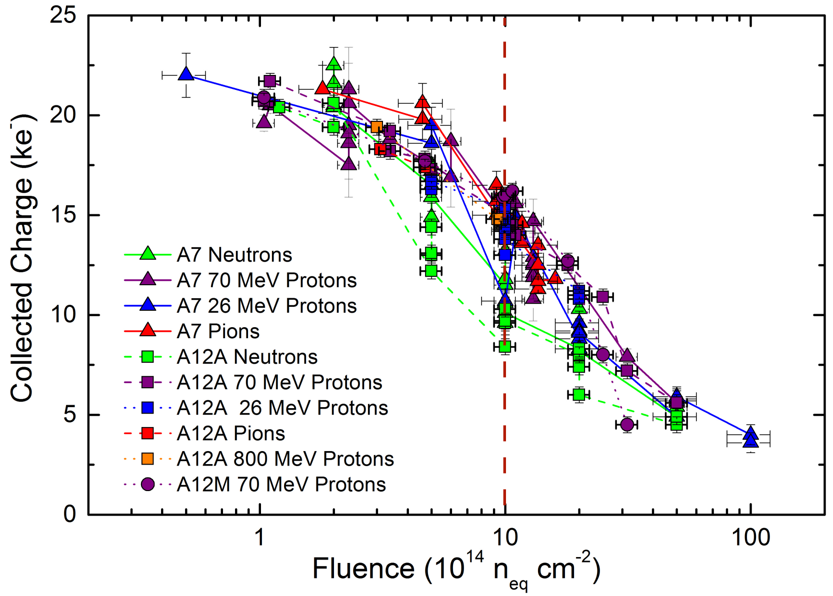


- Sensor parameters defined: **n-in-p with p-stop isolation**
  - Collects electrons
    -> faster signal, reduced charge trapping
  - Always depletes from the segmented side:
    good signal even under-depleted
- Single-sided process
  - Cheaper than n-in-n
  - More foundries and available capacity world-wide
- Radiation damage most important issue



Cross-section through sensor

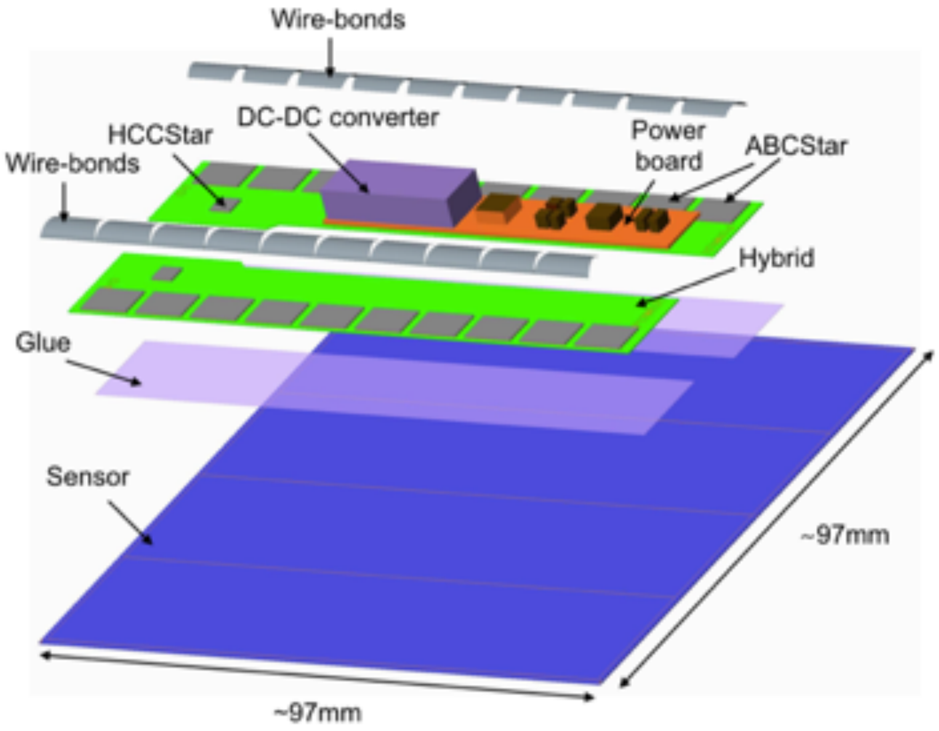
Sensor	
Substrate material	p type FZ
Thickness	300-320 µm
Resistance	> 3kΩ cm
Collected charge after 1×10^{15} n_{eq} /	> 7500 e^- per MIP



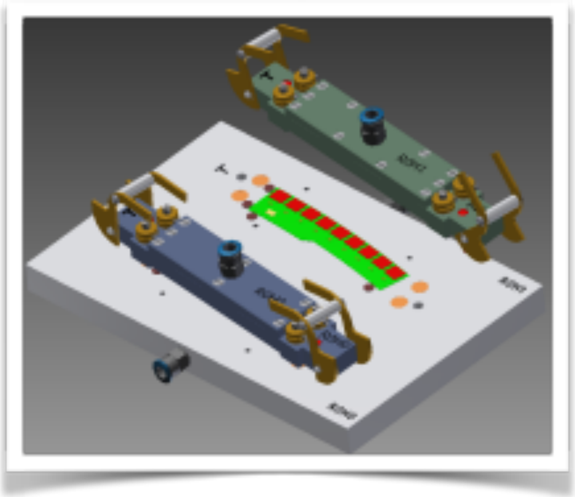
Collected charge versus irradiation

The Module

Module = silicon sensor with readout hybrid (connection via wire bonds)



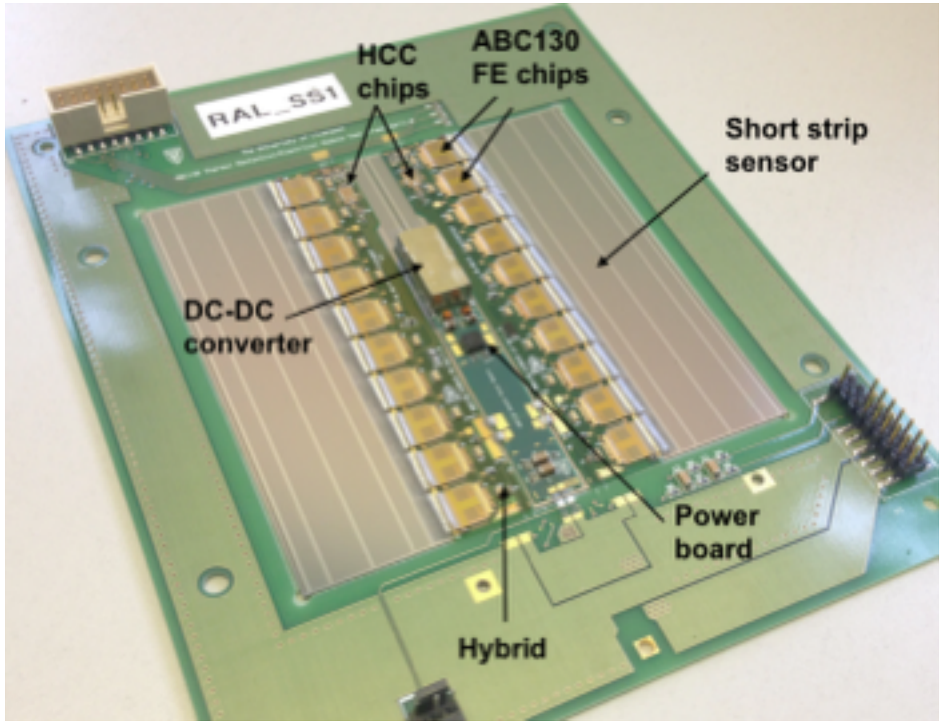
Short Strip module
Barrel



- Even so we have multiple different module “types” they are all based on exactly the same concept and production steps.
- Frame for module production is identical (barrel and end-cap), “just” the tooling has to be switched.

Modules - The Real Thing

- By now we built more than 150 modules of various types at 15 different sites
  - Good start - need to build ~20.000



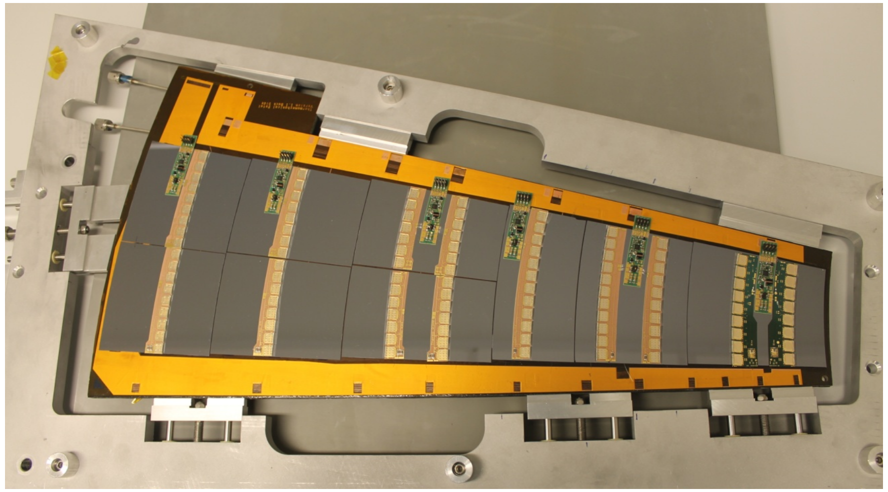
Barrel short strip module

End-cap R0 module

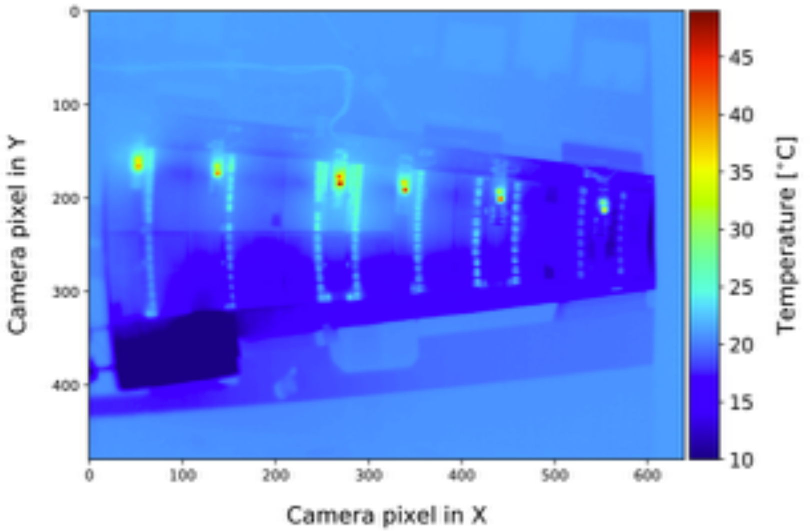
- About to build another ~100 prototype modules for the barrel and ~100 for the end-cap
  - To be used for full stave assemblies and ramping up end-cap sites

Towards a Full Detector

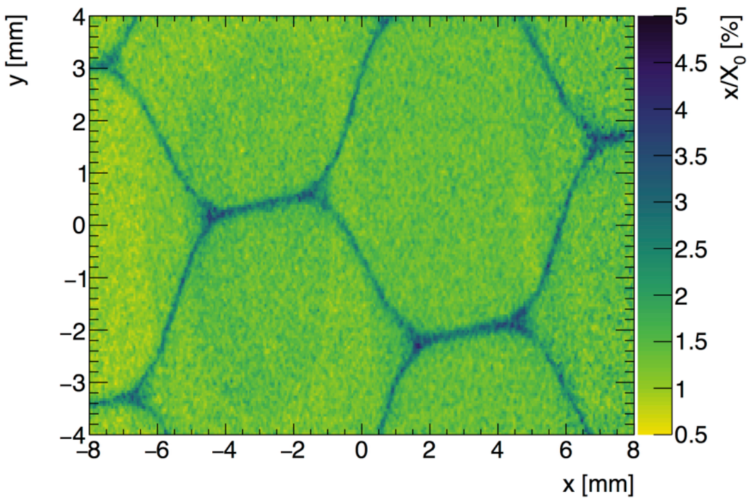
- Prototyping full staves and petals
- Complete quality assurance and control procedures
- FEA calculations and IR measurements
- Readout developments (End of substructure cards)
- Integration tools
- Start pre-production in 2019.
- Installation 2024.



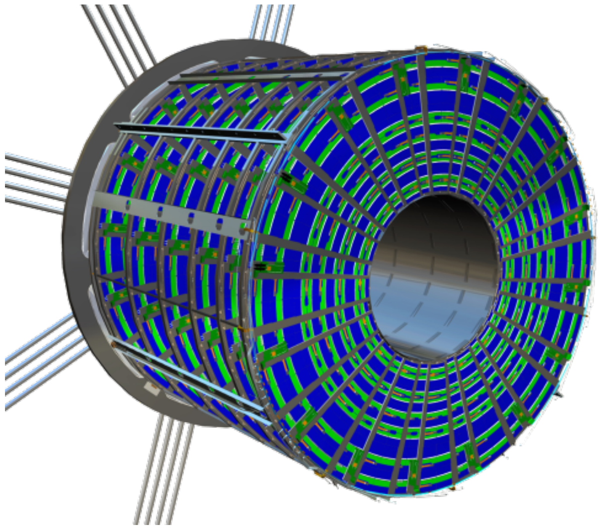
Thermo-mechanical prototype @DESY



IR picture of thermo-mechanical prototype



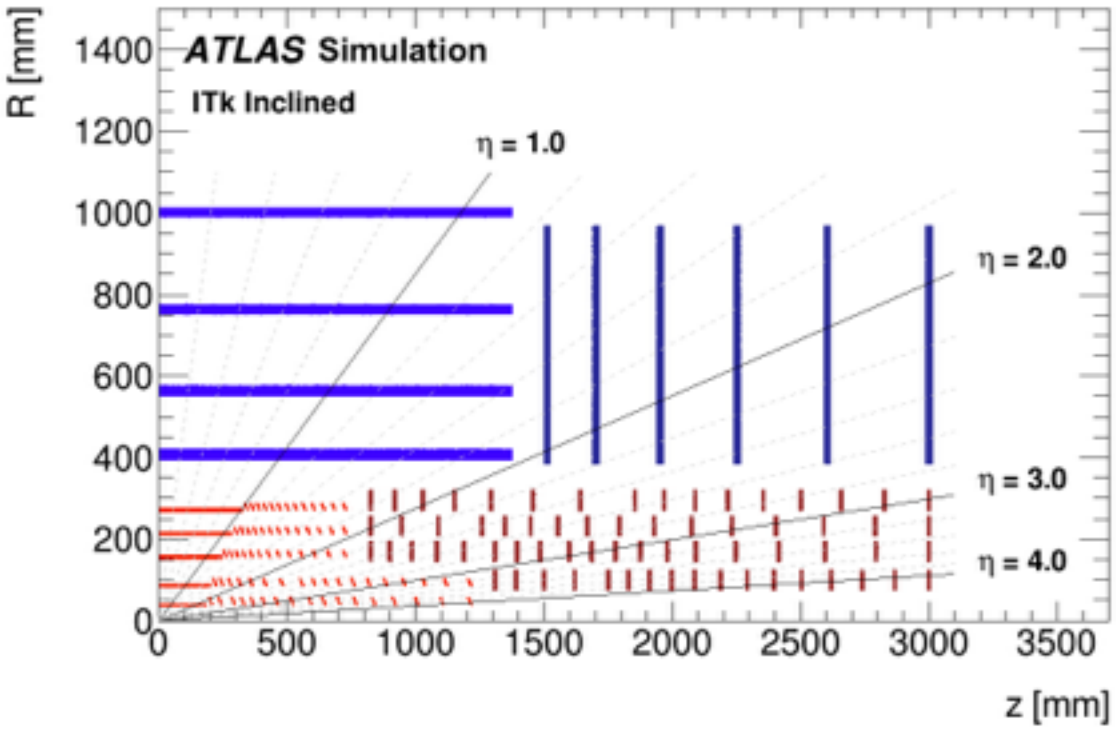
x/X_0 measurement of petal segment



The Pixel Detector

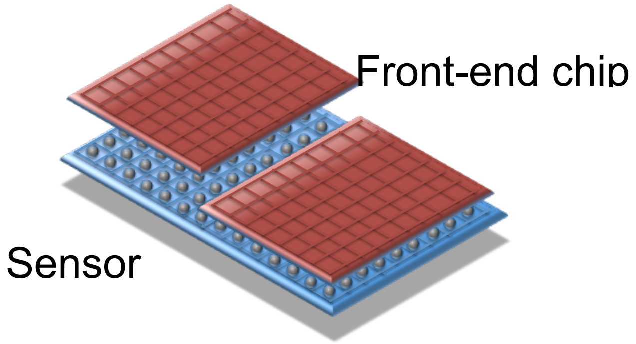
Pixel Detector Layout

- Benefits of forward tracker extension:
  - Reject pile-up jets
  - Extend lepton coverage
  - Extend b-tagging
  - Better E_T^{miss} resolution
- Improves multiple physics channels
  - Vector-boson scattering, Vector boson fusion
  - High lepton-multiplicity channels
  - ...



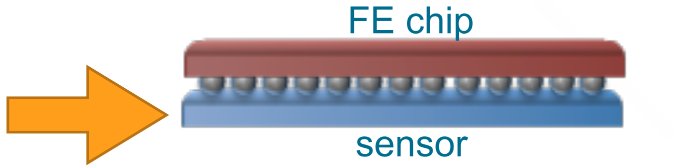
Optimisation of layout for high eta coverage

- Innermost central layer structure needs to cover full pseudo-rapidity range
  - closest possible measurement to IP minimise extrapolation distances for best impact parameter resolution between measurements (hits)
  - minimises passive material before the first two measurements in forward region



Hybrid pixel detector

Sensors for Hybrid Pixels



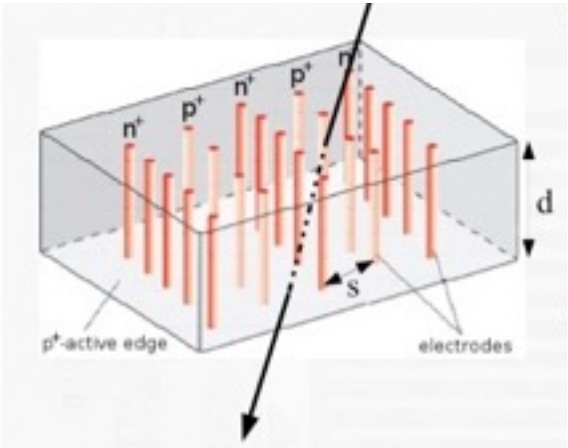
Planar Sensor

- 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

Very strong R&D efforts to develop sensors for HL-LHC applications!

3D Silicon

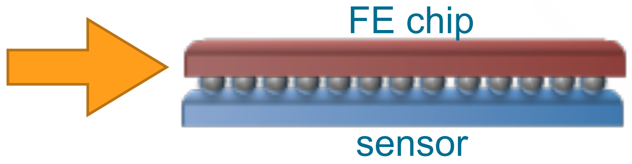
- Both electrode types are processed inside the detector bulk instead of being implanted on the wafer's surface.
- Max. drift and depletion distance set by electrode spacing
- Reduced collection time and depletion voltage
- Low charge sharing



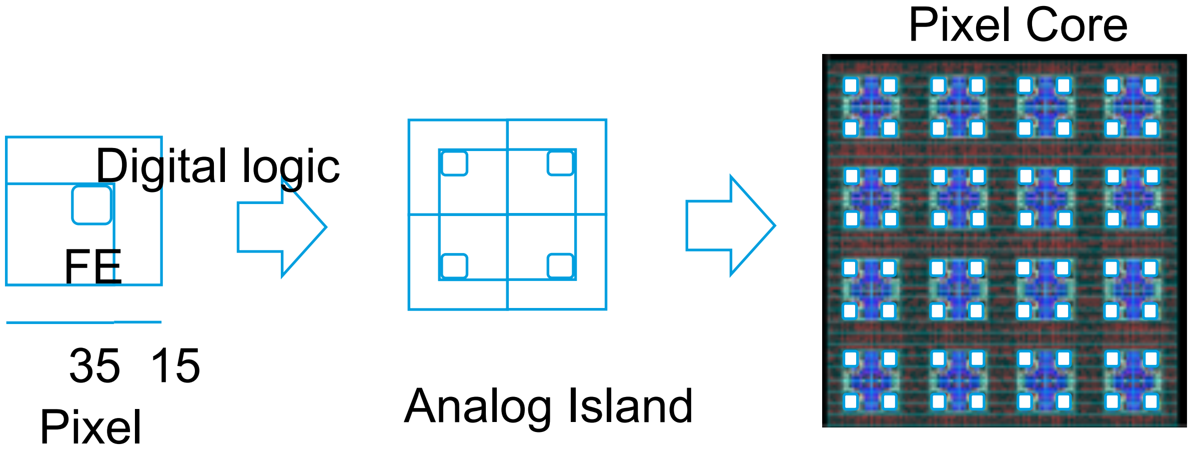
CVD (Diamond)

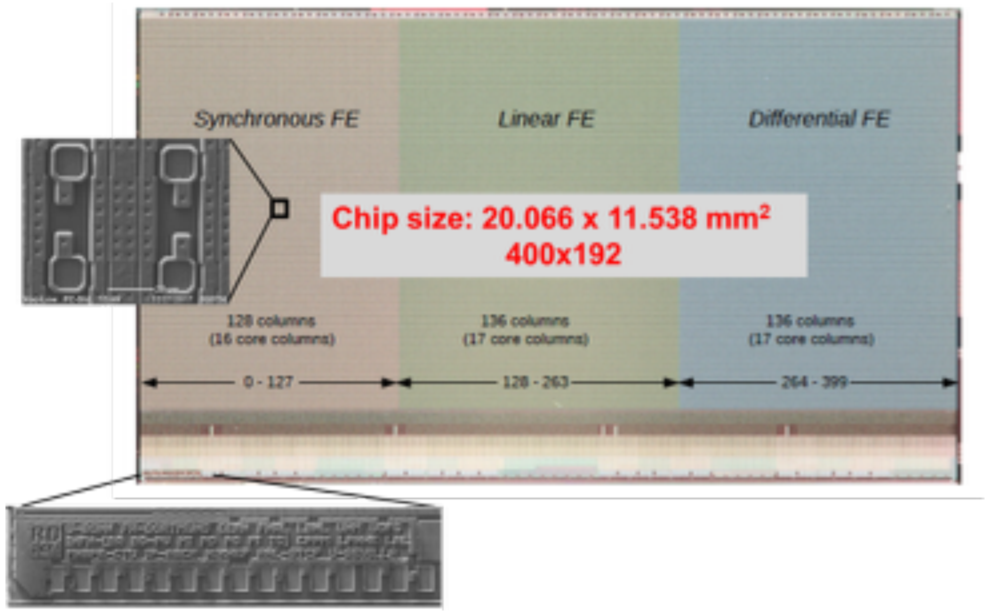
- Poly crystalline and single crystal
- Low leakage current, low noise, low capacitance
- Radiation hard material
- Operation at room temperature possible
- Drawback: 50% signal compared to silicon for same X_0 , but better S/N ratio (no dark current)

Pixel FE chip



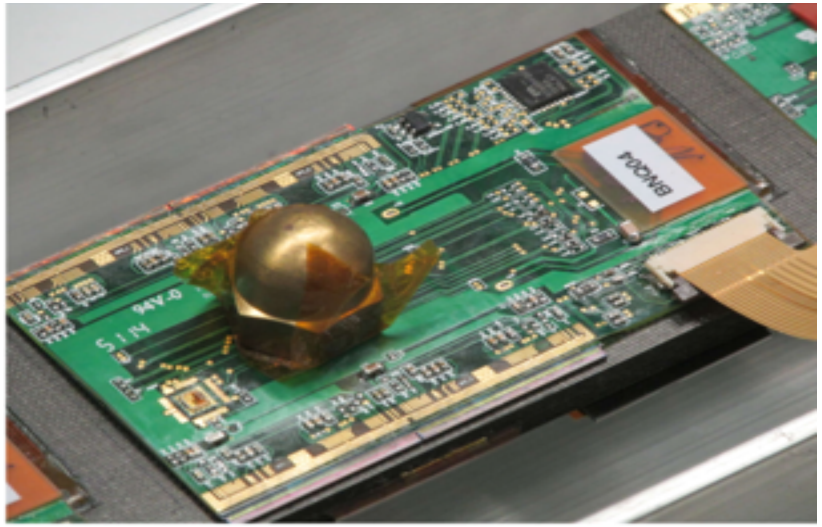
- Radiation tolerance, low power consumption per channel, low noise
- Format & power similar to FE-I4 (current pixel chip)
- “New” CMOS node and vendor
  - 65 nm with TSMC
- Joint development ATLAS & CMS
  - RD53 collaboration – share resources
  - Several prototypes fabricated and tested
- Radiation tolerance challenge
  - Damage mechanism empirically characterised
  - Produce design specs for 1 Grad (500 MRad) target
- Pixel layout
  - 50x50 μm^2 with 4-pixel analogue section in three flavours
  - 50 μm minimum pitch to allow “standard” flip-chip

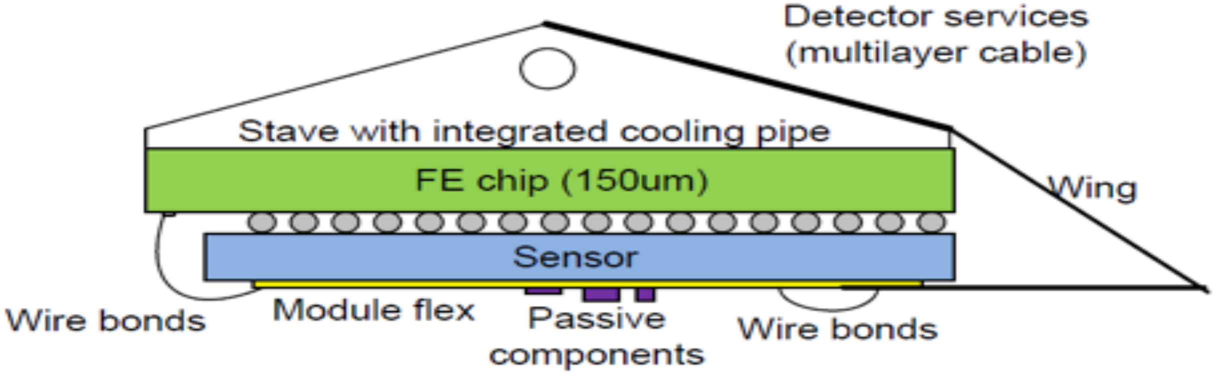


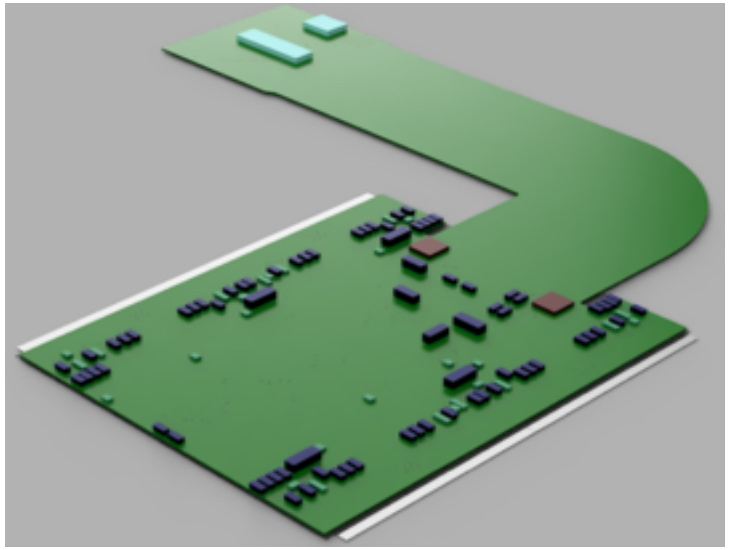


Pixel Module

- Basic building block is the pixel module:
  - Bare module assembly consisting of sensor and FE-chip(s)
  - Flex hybrid for interconnection of data power line to the local support services
  - Connection between FE, sensors and flex is done via wire-bonds
- For ITk about 10,000 modules are needed (quad-, double and single chip modules)



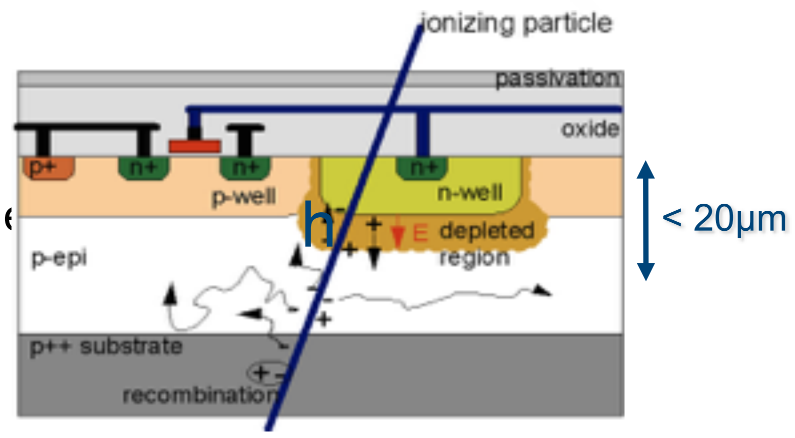




- Project fully approved
- Preproduction starting 2020.

New Alternative: CMOS

- "Classical" CMOS sensors:
  - Signal charge collection mainly by diffusion -> moderate radiation tole
    suppressed by trapping < 10^{15} n_{eq}/cm^2)
  - Typically no backside processes



"Classic" CMOS sensor based on diffusion (Mimosa)

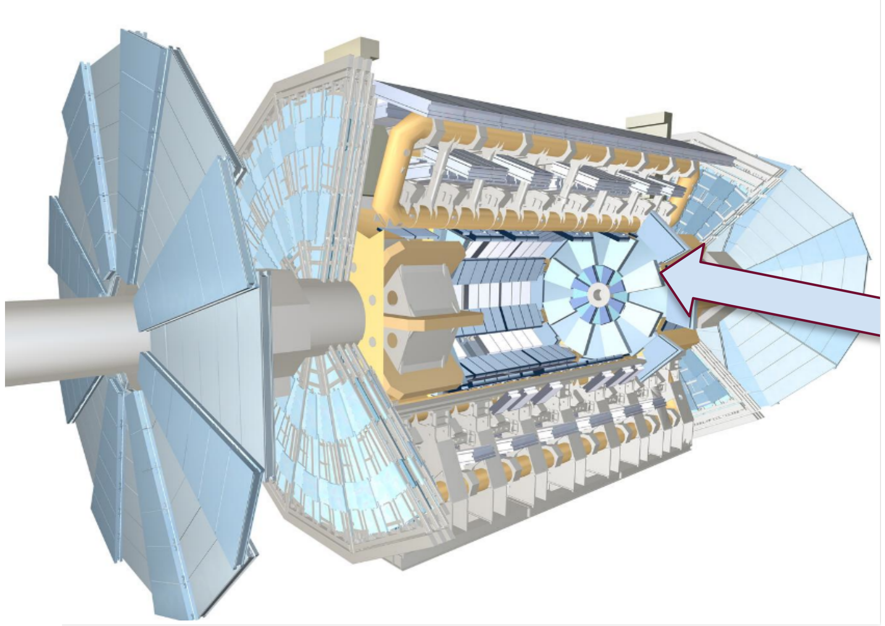
- Main **challenge for HL-LHC**: need combination of
  - Tolerance to displacement damage (depletion)
  - Integration of complex circuitry without efficiency loss
  - Keep using commercial technology

- Availability of high resistivity sensors (l
  backside connections for HV (HV-CMC
  for use at HL-LHC.
- Foundries offer both → Depleted MA
  developed for ATLAS ITk Pixels.

- **Next steps:**
  - Completion of radiation-damage studies
  - Verification in test beams
  - Scaling from single modules to full system
  - Final decision on usage of CMOS in ATLAS Pixels (end of 2019)

Muon System

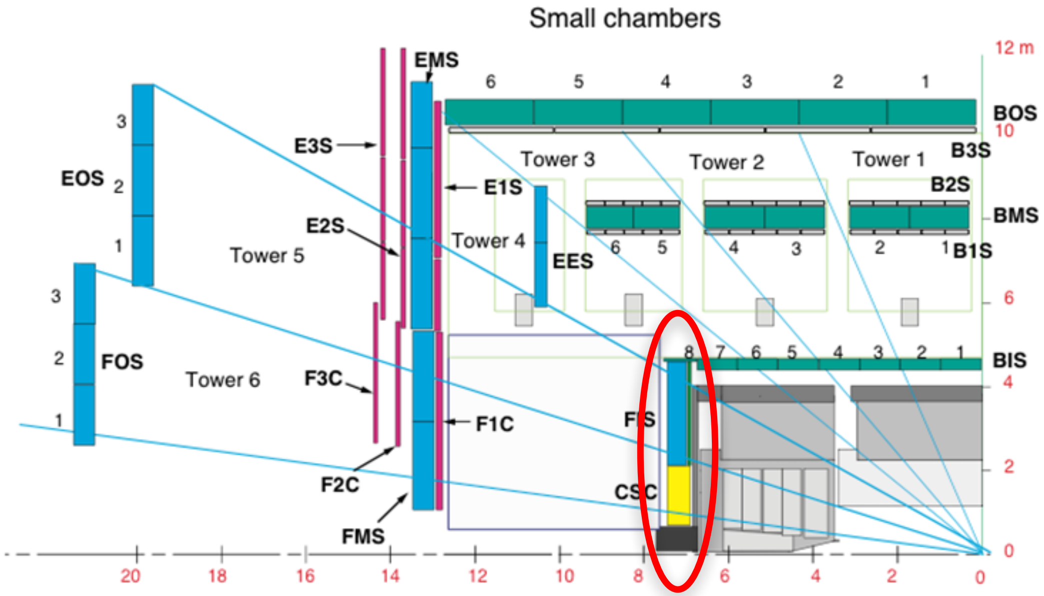
Phase-1: New Small Wheel



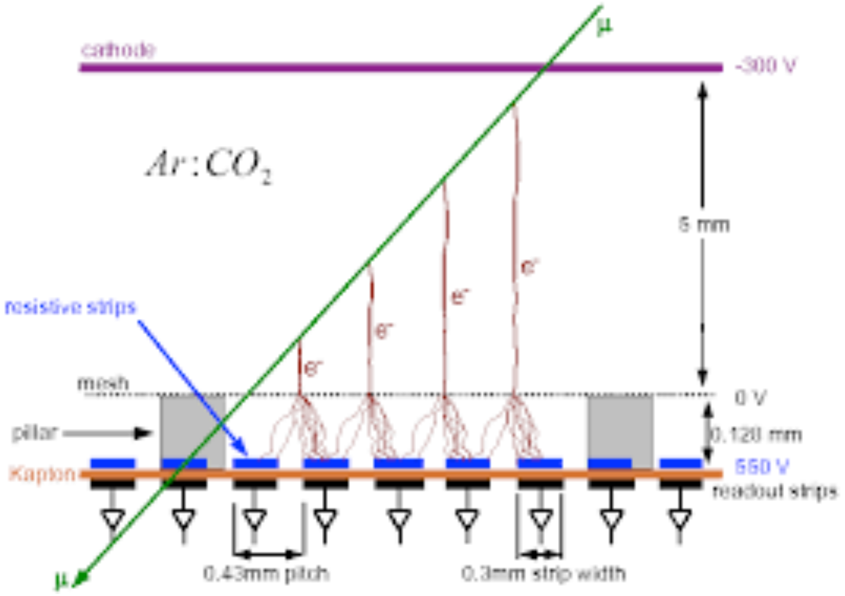
- Consequences of luminosity rising beyond design values for forward muon wheels
  - Degradation of the tracking performance (efficiency / resolution)
  - L1 muon trigger available bandwidth exceeded unless thresholds are raised

- Replace Muon Small Wheels with New Muon Small Wheels (NSW)
  - Improved tracking and trigger capabilities meets Phase-2 requirements
    - compatible with <μ>=200, up to L~7x10^{34} cm^{-2}s^{-1}

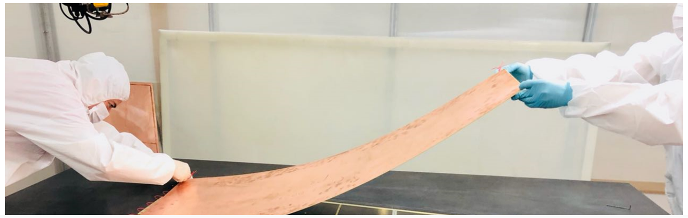
Coverage:
Tracking up to η = 2.7
Triggering up to η = 2.4

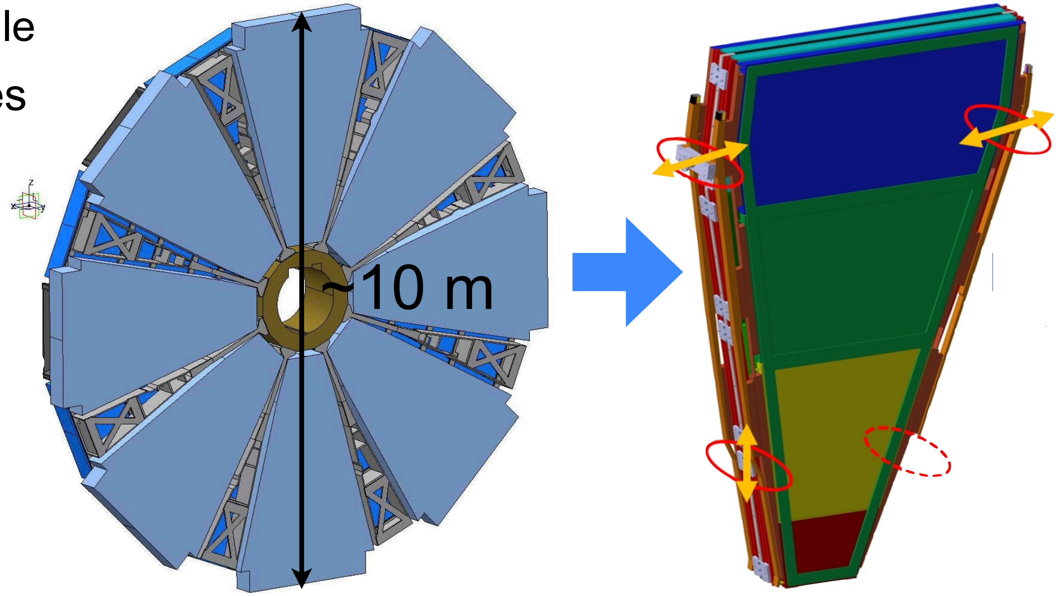


Phase-1: New Small Wheel



- Precision: MicroMegas
  - Space resolution < 100 μm independent of incidence angle
  - High granularity -> good track separation
  - High rate capability due to small gas amplification region and small space charge effect
- Timing: Small strip Thin Gap Chambers (sTGC)
  - Space resolution < 100 μm independent of incidence angle
  - Space resolution < 100 μm independent of incidence angle
  - Bunch ID with good timing resolution to suppress fakes
    Track vectors with < 1 mrad angular resolution



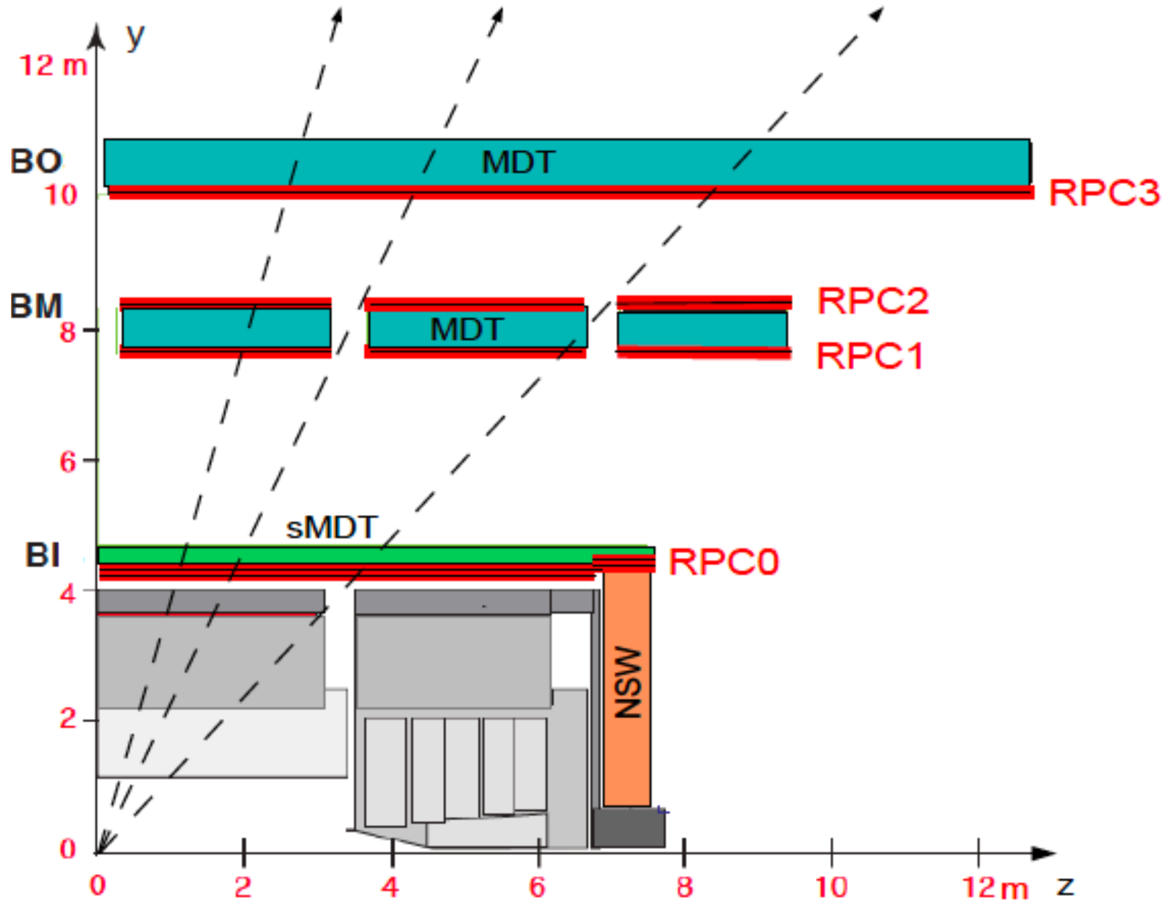


- Detector in production.
- Installation scheduled for end of next year.

Total area of 1200 m^2

Phase-2: Improve Trigger Capabilities

- Barrel Inner layer upgrade
  - Add inner layer of resistive plate chambers (RPCs) to improve barrel trigger
  - Partial replacement of monitored drift tubes (MDT) with small tubes (sMDT)
- New Front-End electronics for precision chambers (MDT)
- New trigger and readout electronics for trigger chambers (RPC and TGC)
- New TGC inner chambers (EIL4) for 1<|eta| <1.3

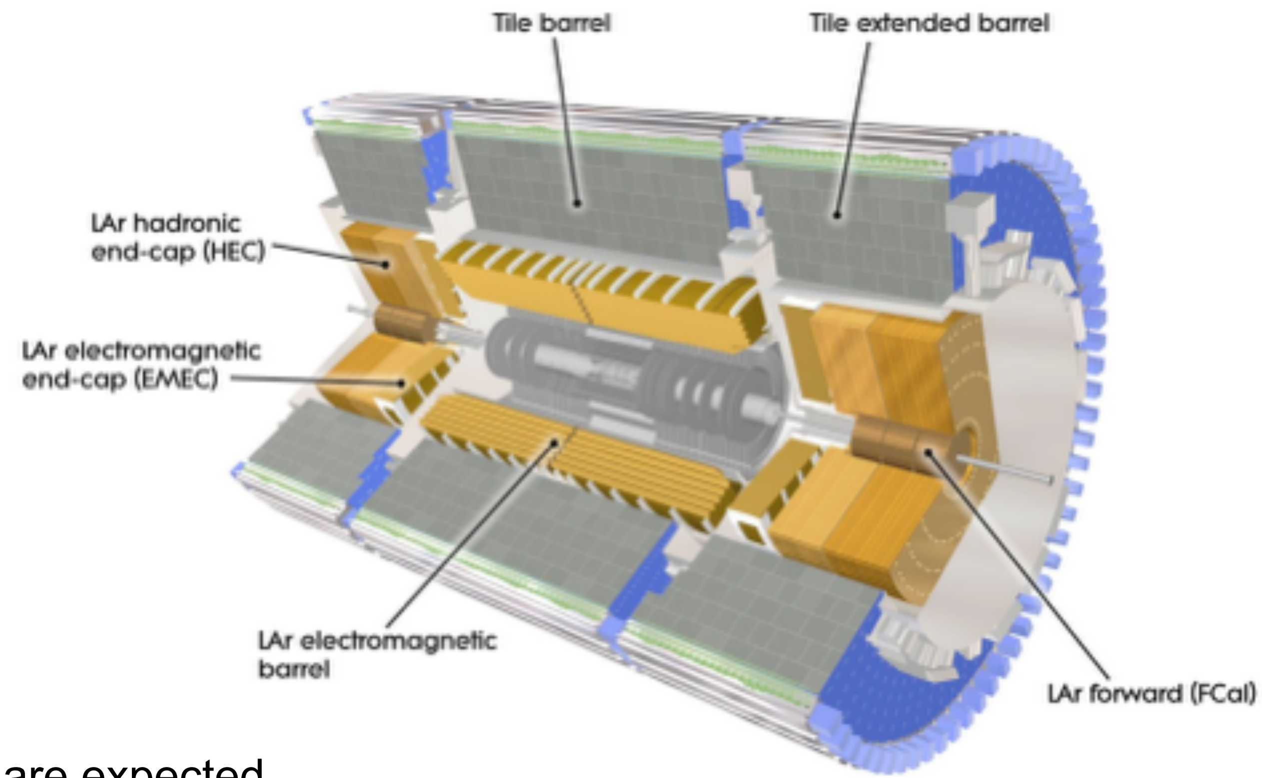


- Project fully approved.
- Production starting 2020.

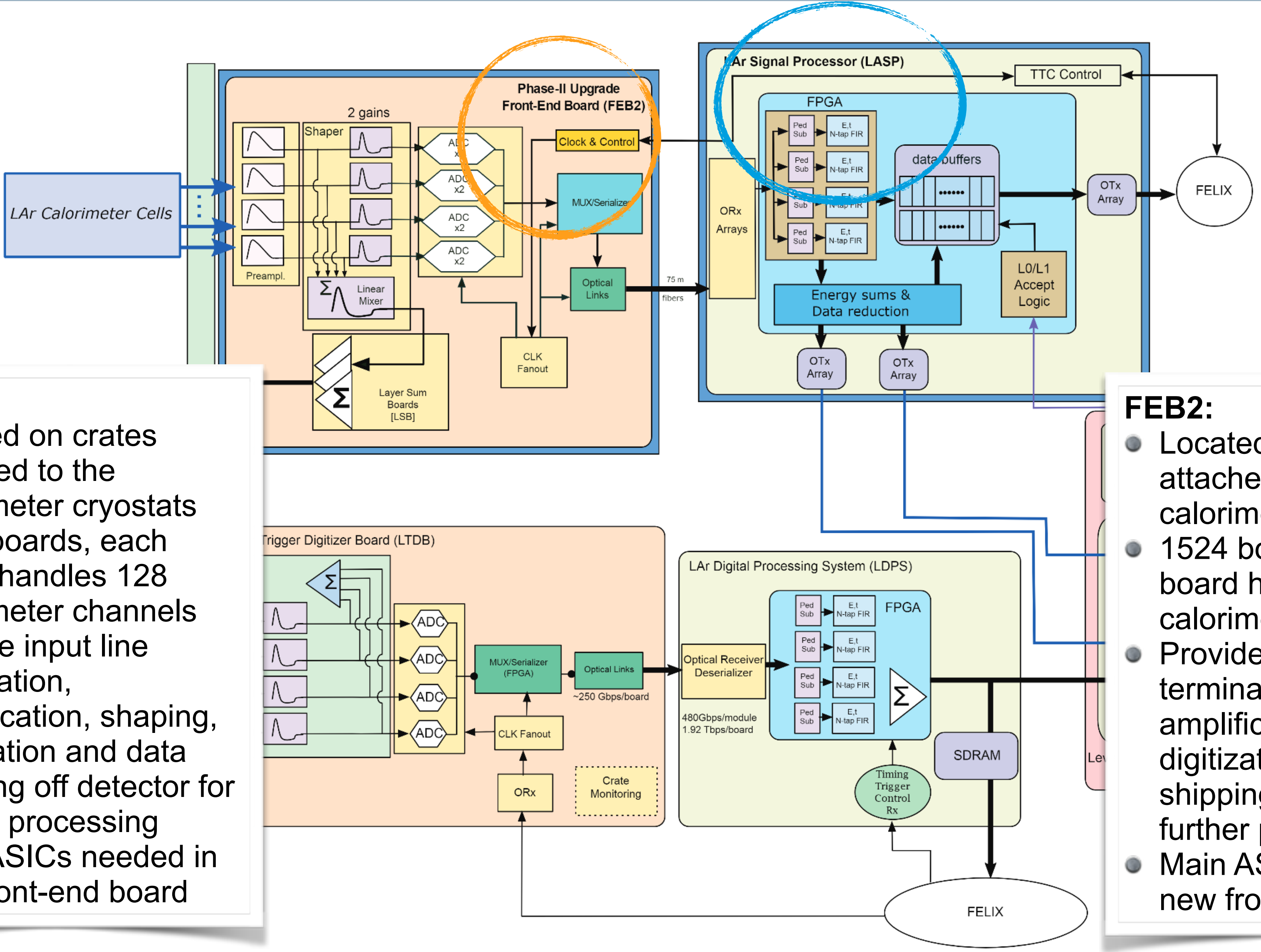
Calorimeter

Calorimeter Upgrade

- Tile Calorimeters
  - No change to detector needed
  - Full replacement of front-end and back-end electronics
    - New read-out architecture: Full digitisation of data at 40MHz and transmission to off-detector system, digital information to level L1/L0 trigger.



- The LAr calorimeters (active and passive layers) are expected to operate reliably during the HL-LHC data taking period
  - But the current electronics is not compatible with operations at HL-LHC
  - Radiation resistance: replace components with versions more rad-tolerant
  - Ageing: some components would have ~20 yrs operation: Difficult to maintain and repair
  - Trigger: the ATLAS trigger system will be upgraded to cope with the expected pile-up, making the present LAr readout electronics incompatible.



FEB2:

- Located on crates attached to the calorimeter cryostats
- 1524 boards, each board handles 128 calorimeter channels
- Provide input line termination, amplification, shaping, digitization and data shipping off detector for further processing
- Main ASICs needed in new front-end board

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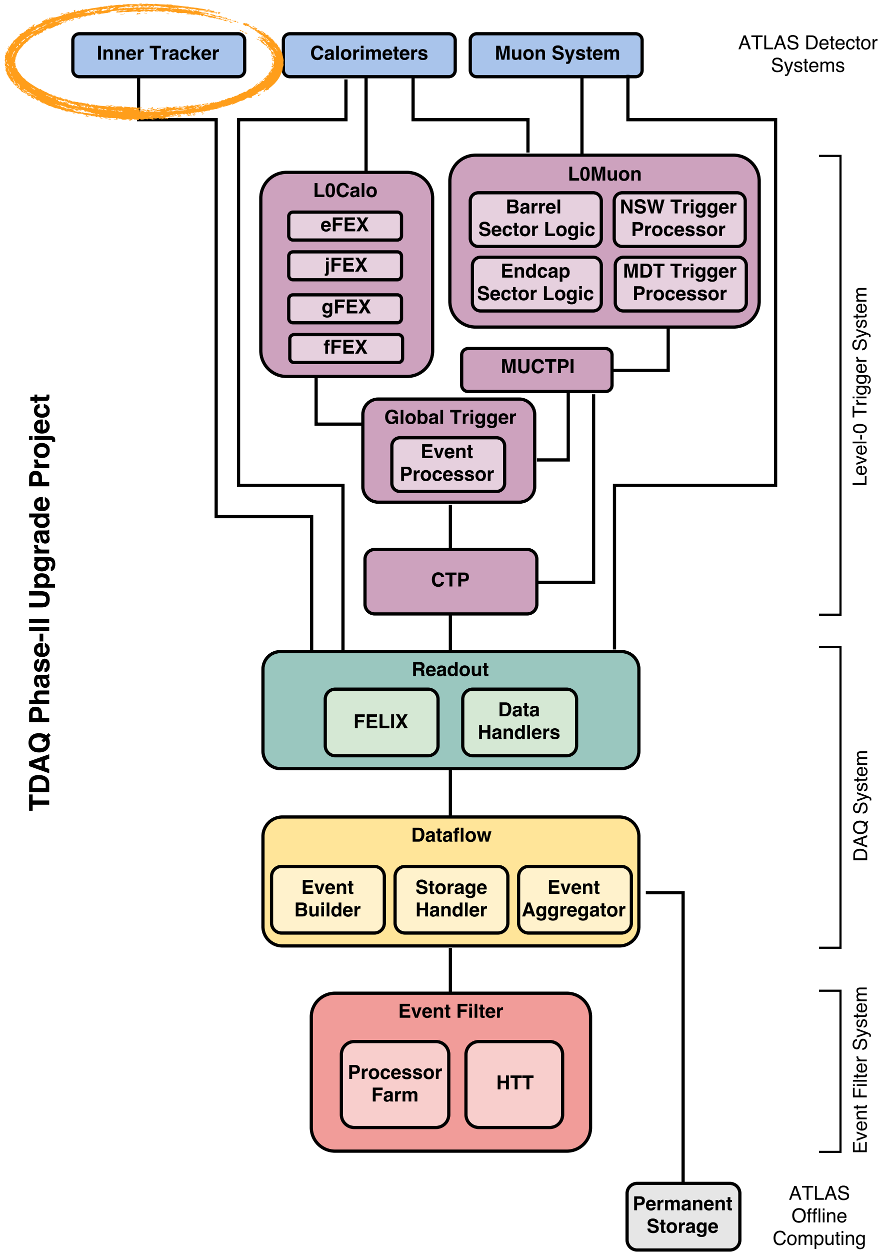
HL-LHC Trigger

HL-LHC Trigger

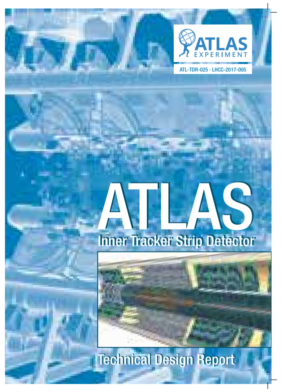
- With ultimate luminosity of 7.5 x 10^{34} cm^{-2} s^{-1} and 200 interactions/crossing the current trigger system can not cope.
- Keeping p_t thresholds low with trigger rates at manageable level is crucial to exploit the high luminosity potential.
- Three TDAQ Systems:
  - Level-0 Trigger
  - Data Acquisition
  - Event Filter
- Exploit progress in network and FPGA* technologies to:
  - **Add tracking information in trigger**
  - Increase trigger rate
  - Improve the quality of object reconstruction at trigger level
  - Introduce more sophisticated multi-object topological selections

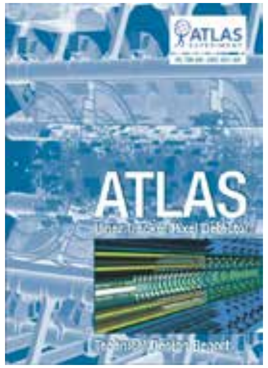


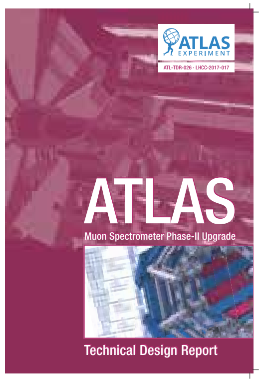
*Field Programmable Gate Array

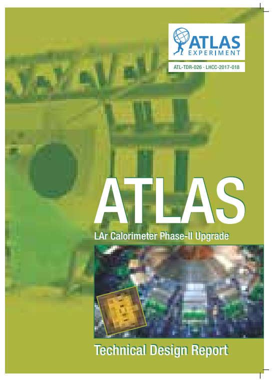
Summary

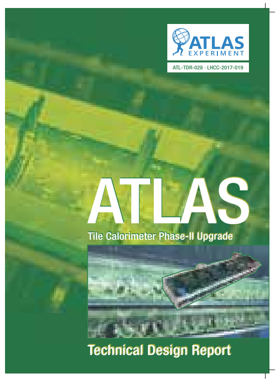
- The ATLAS Detector is a fascinating “machine” built over 10 years by people from more than 30 countries.
  - It was designed to entangle complex physics signals in the difficult LHC environment.
- The current LHC schedule foresees running well into the next decade to accumulate up to 4000 fb-1
- ATLAS will use the different shutdowns for detector consolidation and new detectors.
- The next generation ATLAS detector will be even more fascinating than the current detector.

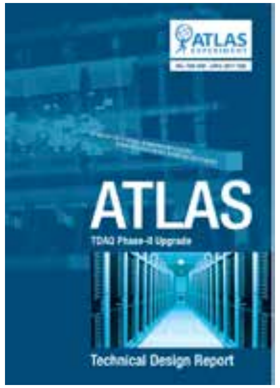












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