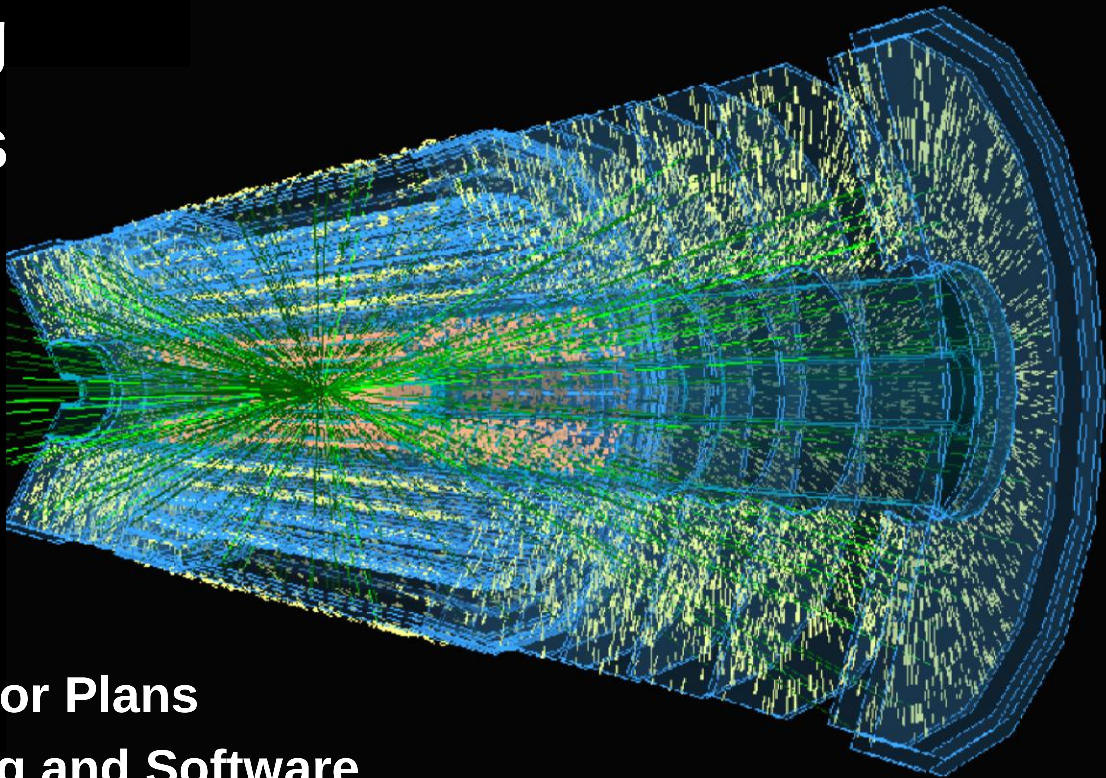
ATLAS Upgrade Overall

Phil Allport
(On behalf of the ATLAS Collaboration)

18/3/14

- Physics at the HL-LHC
- HL-LHC Planning
- ATLAS Upgrades
  - Phase-0
  - Phase-I
  - Phase-II
    - New Tracker
      - Pixels
      - Strips
    - Other Sub-detector Plans
    - TDAQ, Computing and Software
- Conclusions



HL-LHC Planning

- The stated target of the European strategy set the overall framework *"Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma."* (Adopted by CERN Council May 2013, see http://council.web.cern.ch/council/en/EuropeanStrategy/esc-e-106.pdf).
- All 4 experiments, the accelerator and the theory community were represented at the October 2013 ECFA HL-LHC Experiments Workshop at Aix-les-Bains http://indico.cern.ch/conferenceDisplay.py?confId=252045
- The report from this to ECFA can be found at https://cds.cern.ch/record/1631032 which focusses on the detector requirements and physics reach with 3000fb^{-1}
- There were also presentations on accelerator upgrade preparations but these have been to some extent superseded by more recent workshops:
  - "The Review of LHC and Injector Upgrade Plans Workshop" from 29th to 31st October at Archamps, France (**RLUIP**: https://indico.cern.ch/conferenceDisplay.py?ovw=True&confId=260492)
  - "The 3rd **Joint HiLumi LHC_LARP** Annual Workshop" from 11th to 15th November at Daresbury (STFC) Laboratory, UK (https://indico.cern.ch/conferenceDisplay.py?ovw=True&confId=257368)

The next in the ECFA HL-LHC workshop is planned for 21st -23rd October 2014

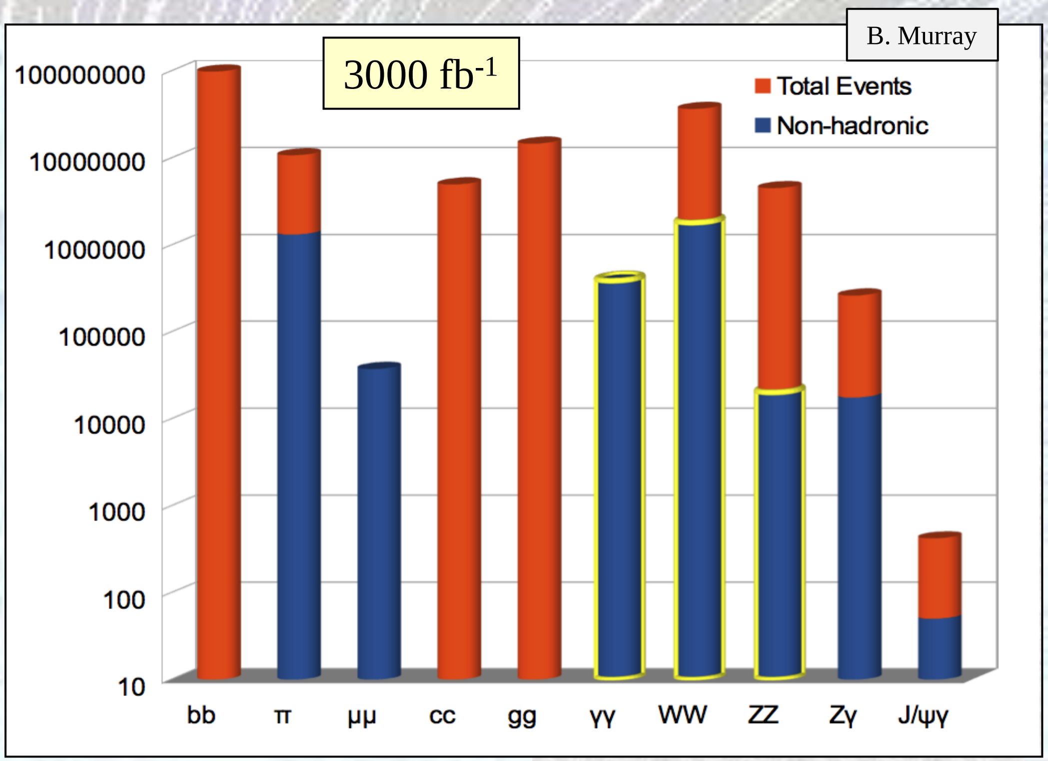
Physics Studies

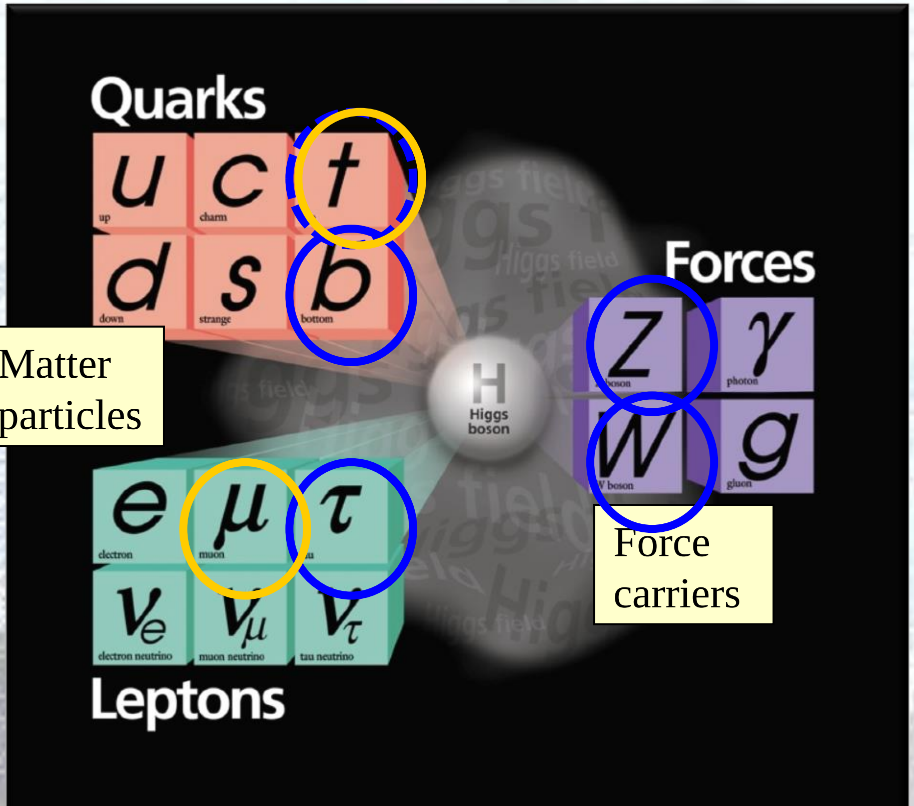
Aim to measure as many Higgs couplings to fermions and bosons as possible to really test if this is the SM Higgs or a pointer to the BSM physics we know has to exist

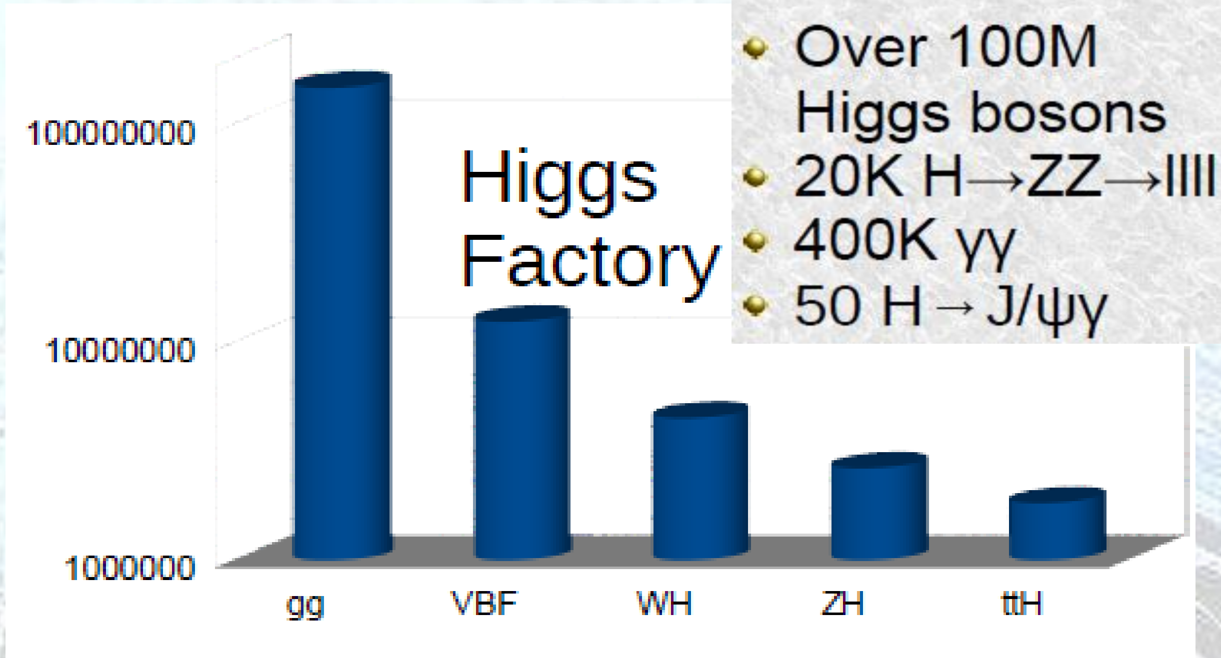
HL-LHC (3000 fb^{-1}): a true Higgs factory:

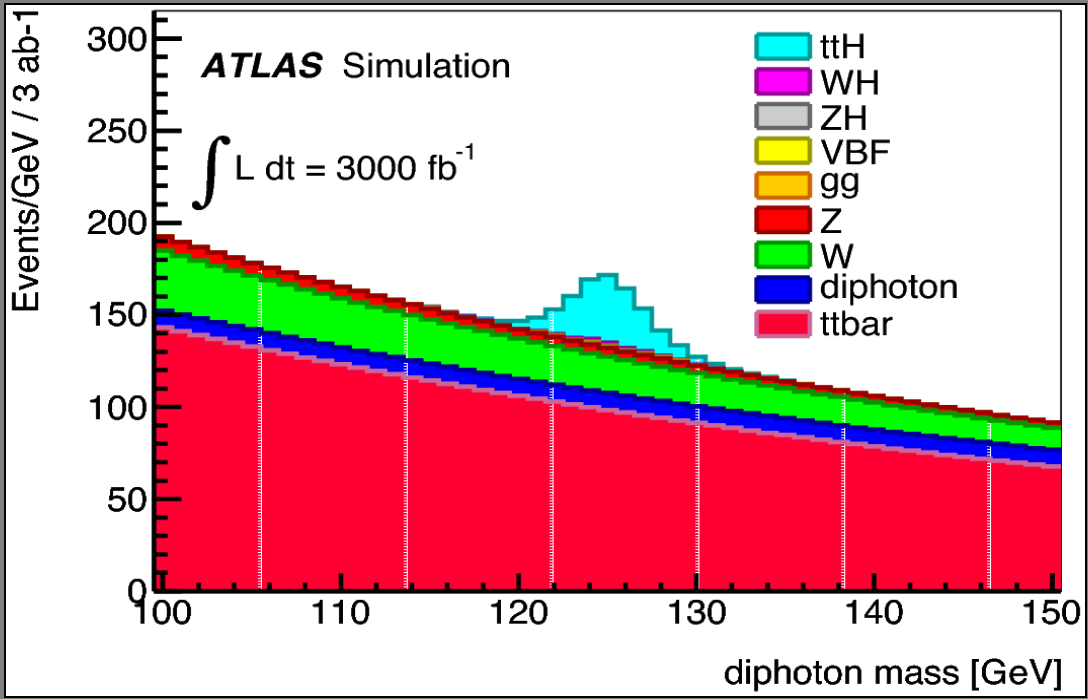
- ❑ > 170M Higgs events produced
- ❑ > 3M useful for precise measurements (more than or similar to ILC/CLIC/TLEP)

LHC $gg \rightarrow H$ (50pb); $e^+e^- \rightarrow ZH$ (0.2-0.3pb)

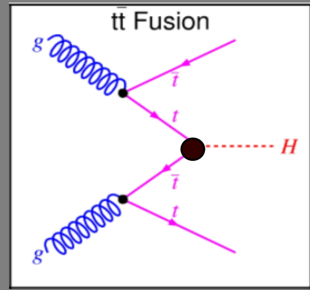




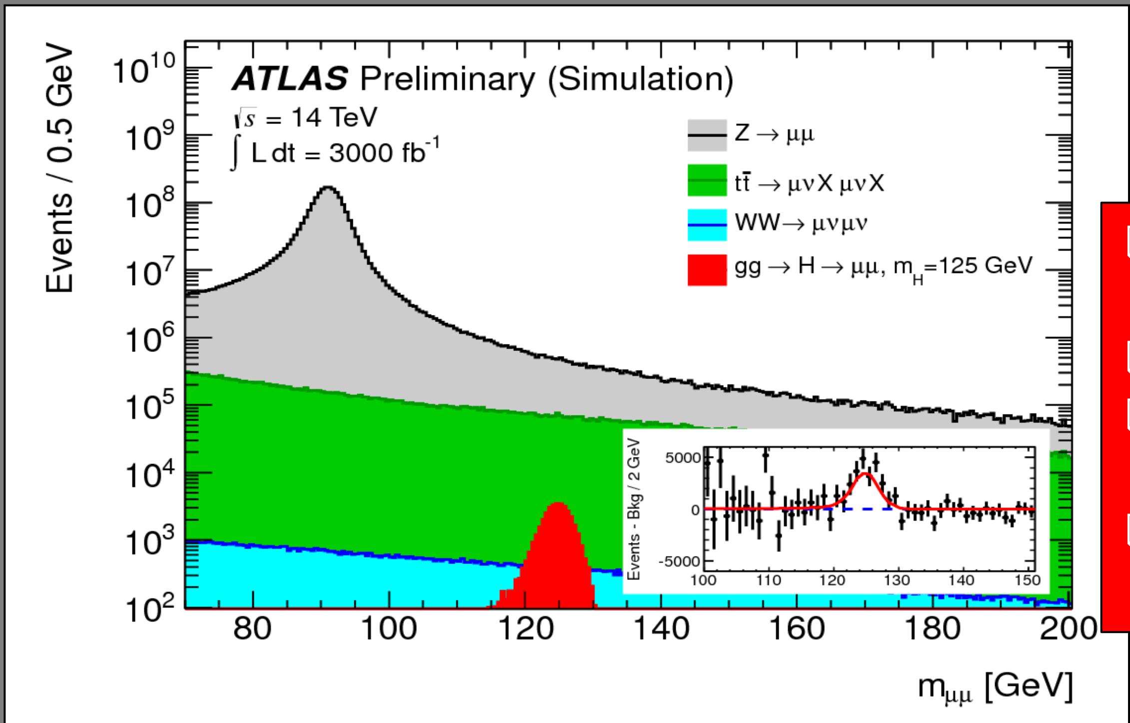




ttH production
with H → γγ

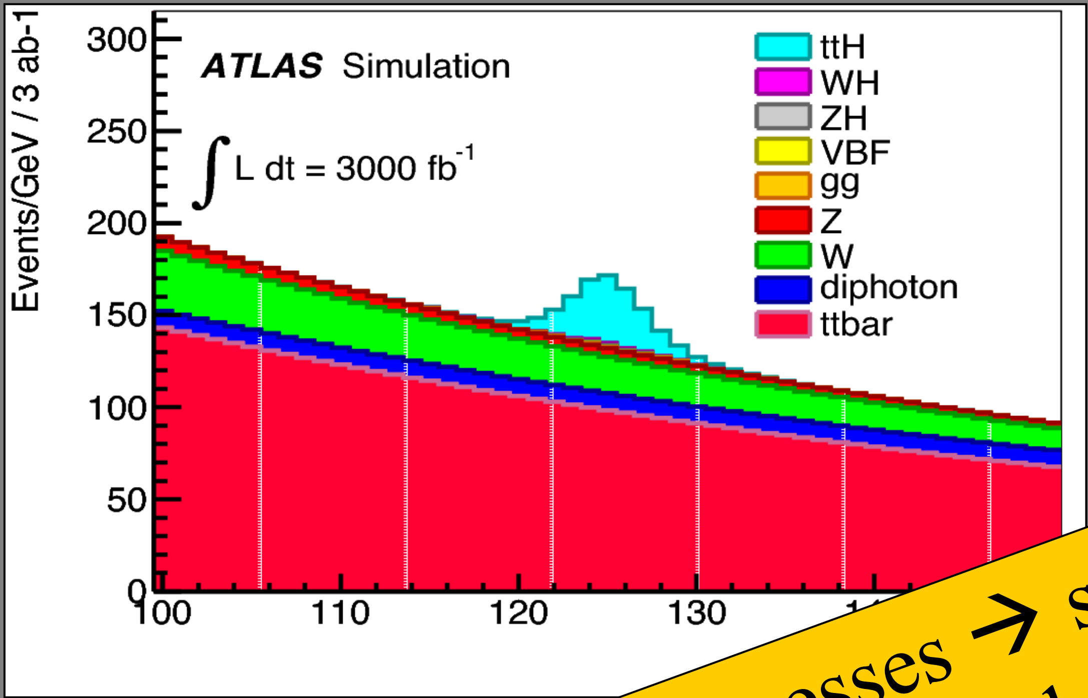


- Gives direct access to Higgs-top coupling (intriguing as top is heavy)
- Today's sensitivity: 6xSM cross-section
- With 3000 fb^{-1} expect 200 signal events (S/B ~ 0.2) and > 5σ
- Higgs-top coupling can be measured to about 10%

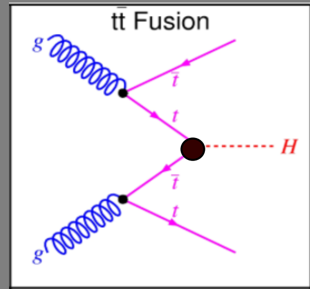


H → μμ

- Gives direct access to Higgs couplings to fermions of the second generation.
- Today's sensitivity: 8xSM cross-section
- With 3000 fb^{-1} expect 17000 signal events (but: S/B ~ 0.3%) and ~ 7σ significance
- Higgs-muon coupling can be measured to about 10%

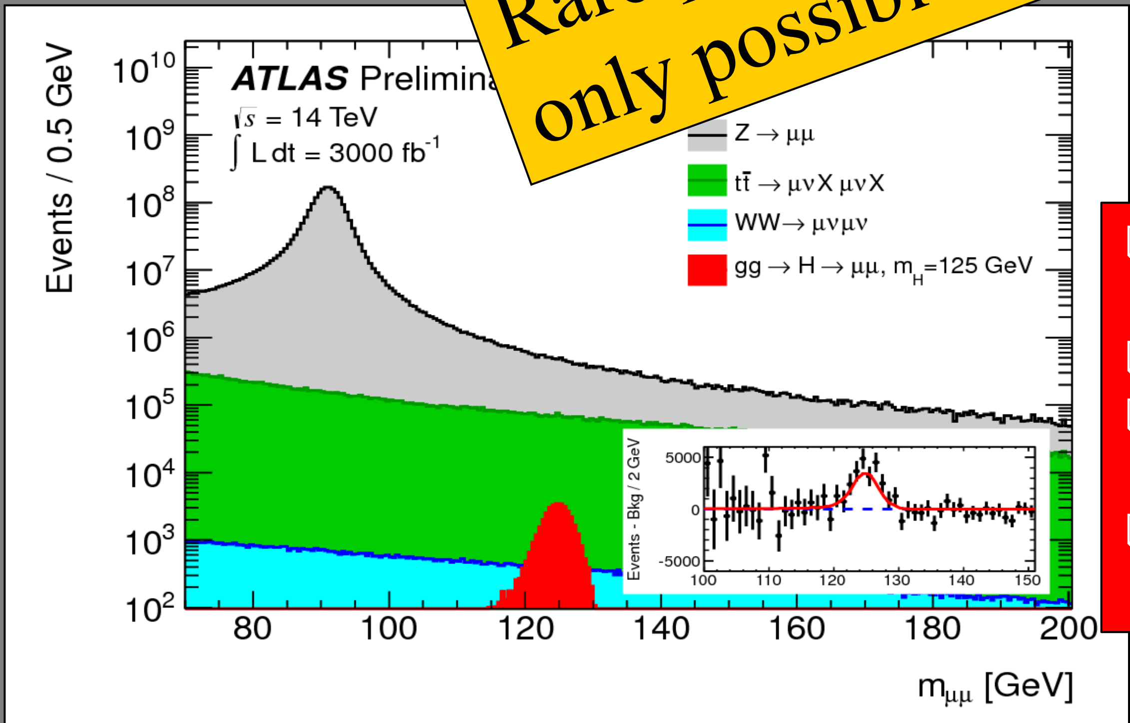


ttH production with H → γγ



- ❑ Gives direct acce… o Higgs-top coupling (i… s top is heavy)
- ❑ T… SM cross-section … 200 signal …) and > 5σ … p coupling can be … easured to about 10%

Rare processes → sensitive studies only possible with 3000 fb^{-1}



H → μμ

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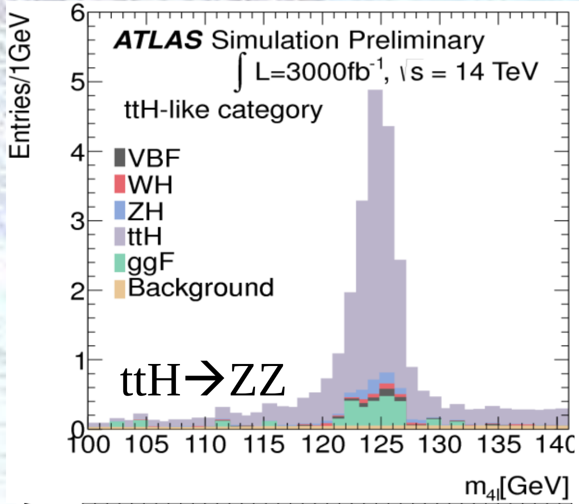
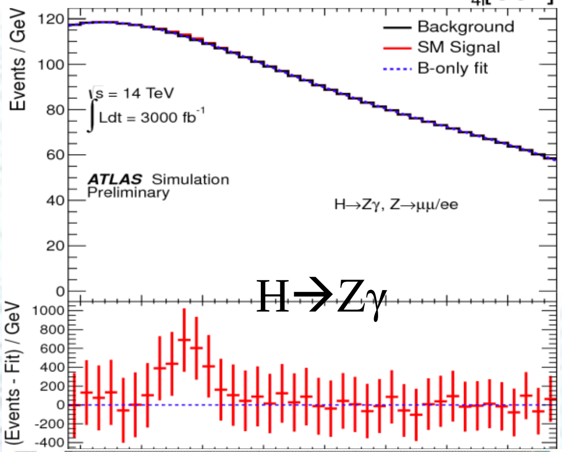
- ❑ Higgs-muon coupling can be measured to about 10%

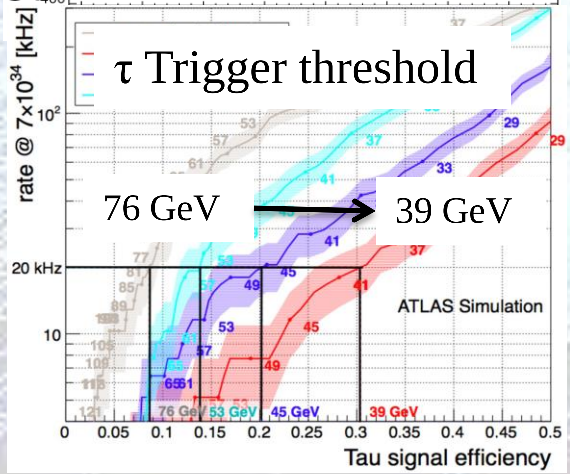
Physics Studies at Aix-les-Bains



ttH→ZZ

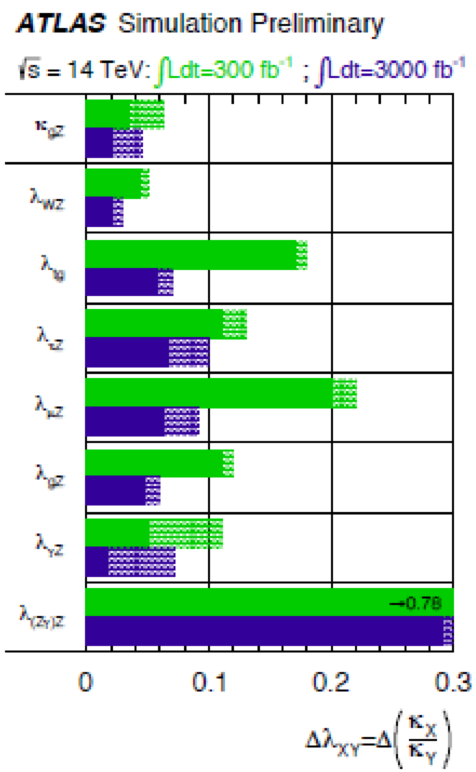


H→Zγ

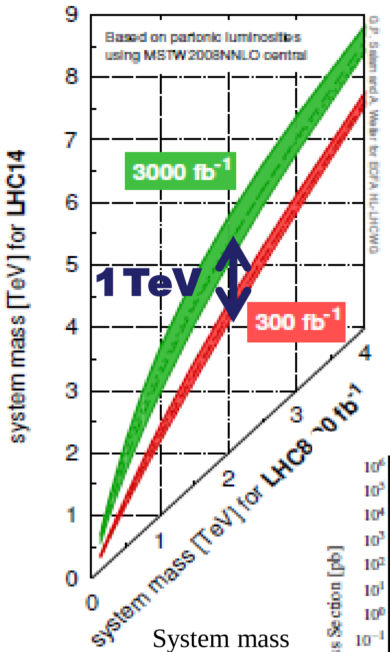


τ Trigger threshold

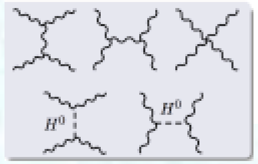
76 GeV → 39 GeV

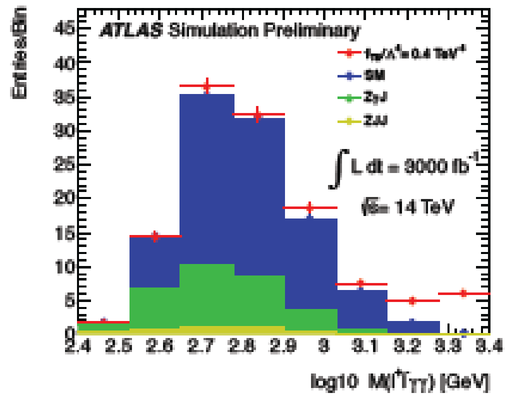


Improvements in coupling ratios with HL-LHC. (Range depends on handling of systematics and theoretical uncertainties)

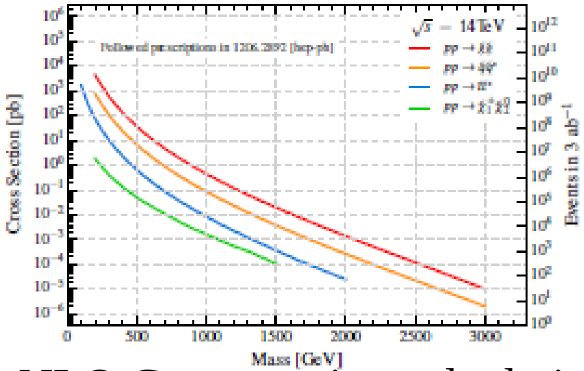


System mass probed so far

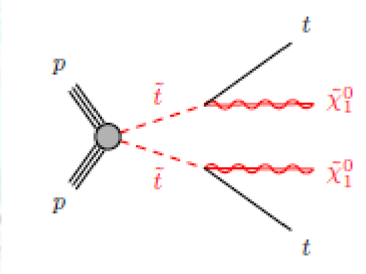




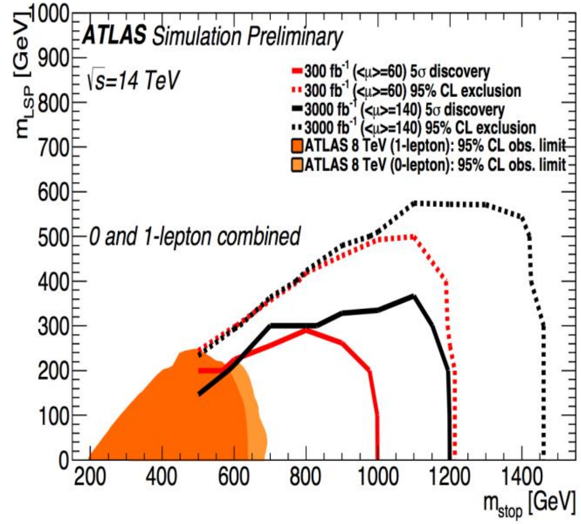
Vector boson anomalous couplings



NLO Cross-section calculations



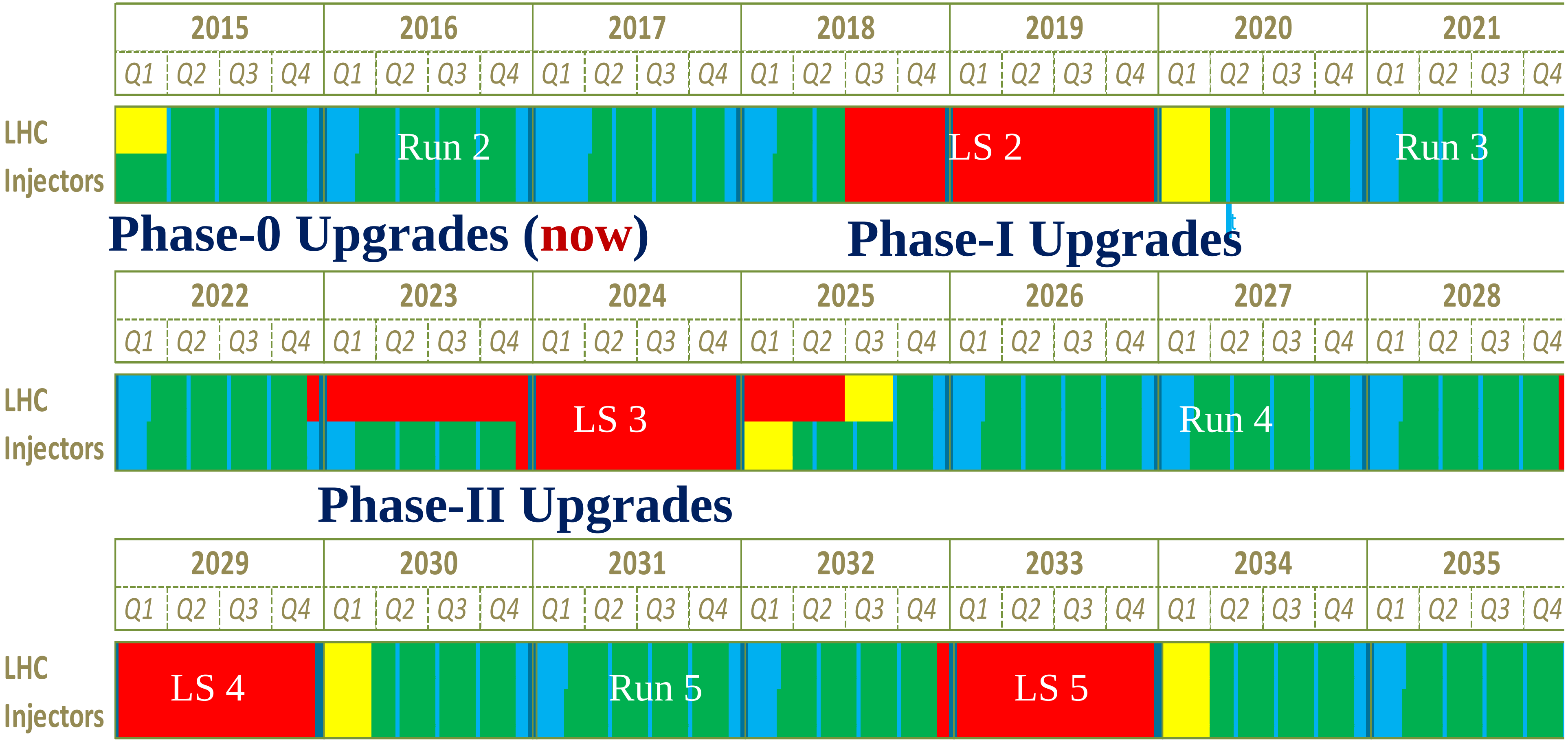
H→ττ trigger threshold improvements with track trigger at L1



New LHC schedule beyond LS1

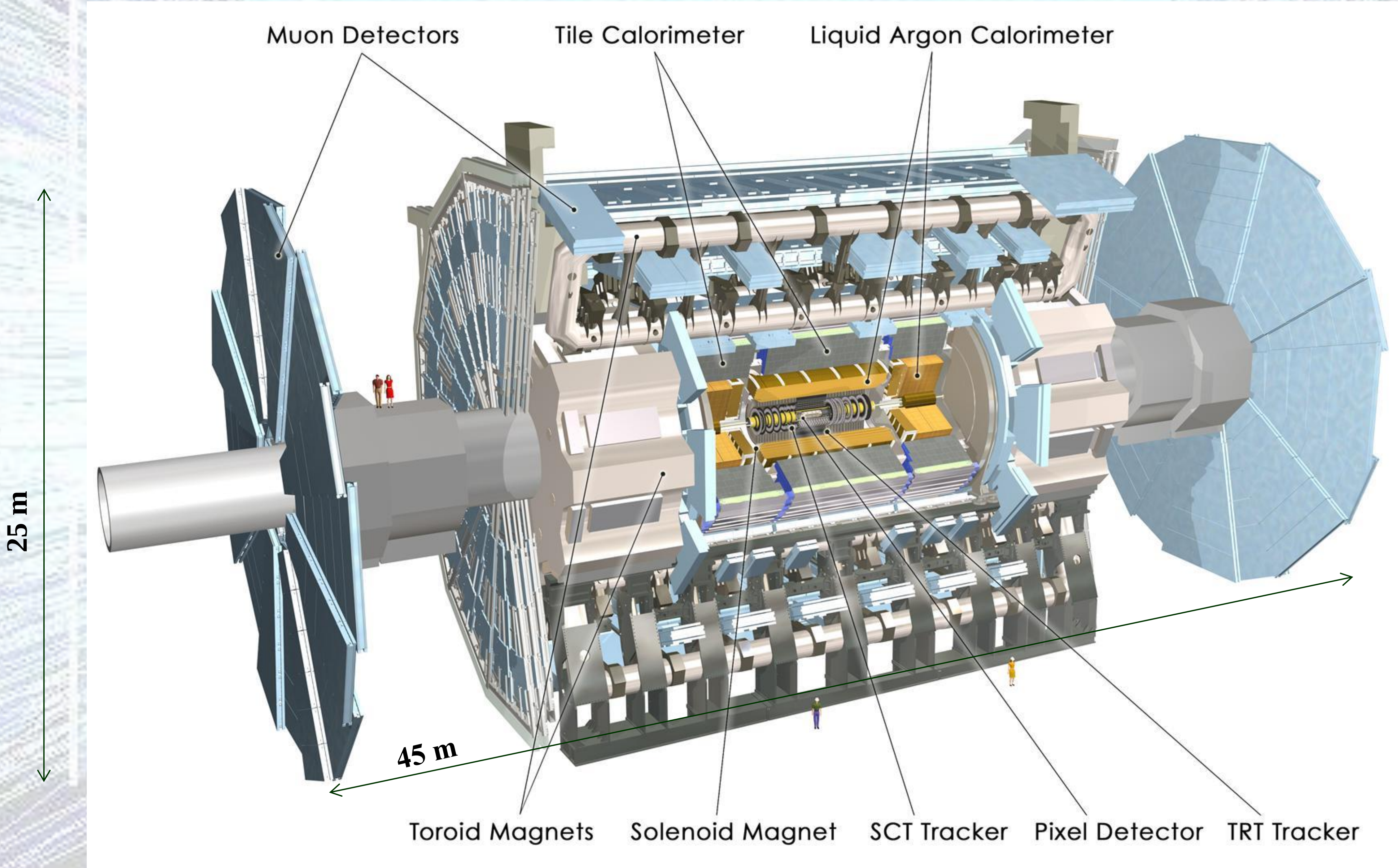
Only EYETS (19 weeks) (no Linac4 connection during Run2)

LS2	starting in 2018 (July)	18 months + 3months BC (Beam Commissioning)
LS3	LHC: starting in 2023 =>	30 months + 3 BC
	injectors: in 2024 =>	13 months + 3 BC



LHC schedule approved by CERN management and LHC experiments spokespersons and technical coordinators
Monday 2nd December 2013

The ATLAS Experiment

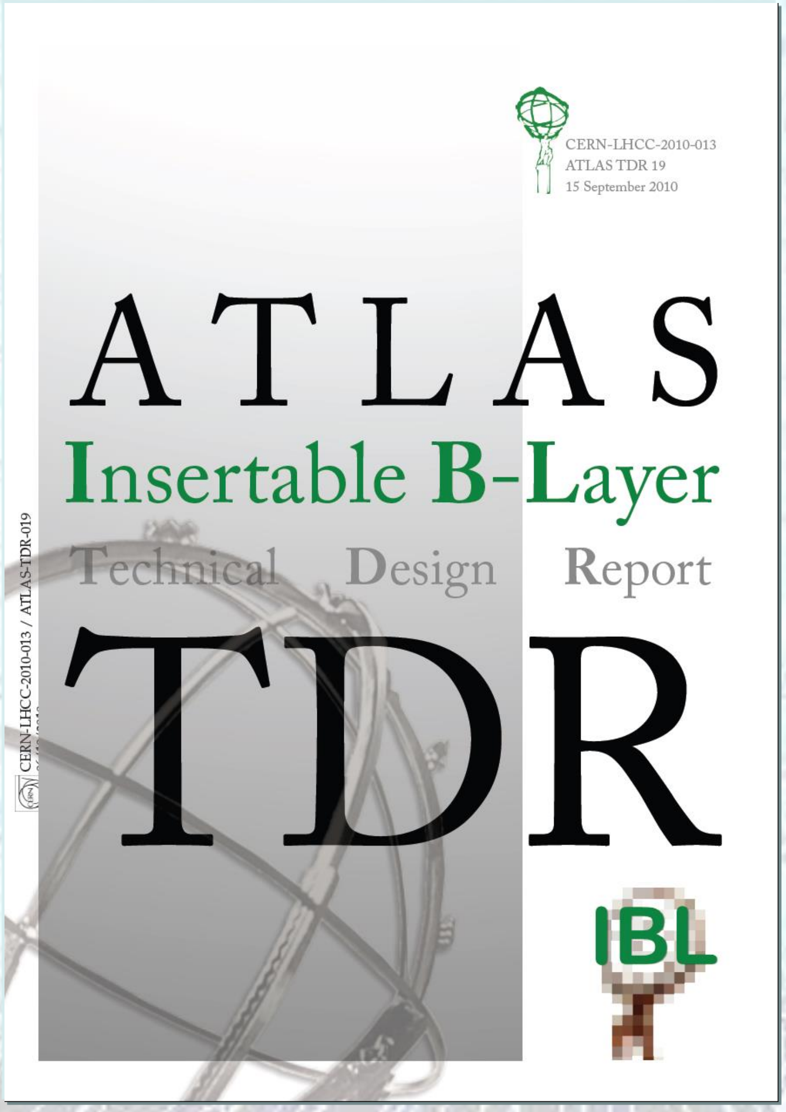


Current Shutdown Phase-0

- New insertable pixel b-layer (IBL) + new pixel services (nSQP) + new small Be pipe
- New Aluminum beam pipes to prevent activation problem and reduce muon BG
- New evaporative cooling plant for Pixel and SCT + IBL CO_2 cooling plant
- Replace all calorimeter Low Voltage Power Supplies
- Finish the installation of the EE muon chambers staged in 2003 + additional electronics for chambers in the feet and elevators region + RPC gas consolidation
- New CSC RODs (get to 100kHz) and additional RODs for pixel and strip systems
- Dual output HOLAs installed for FTK access to pixel and strip data
- Up to 1kHz total data output rate to storage
- Upgrade the magnets cryogenics and decouple toroid and solenoid cryogenics
- Add specific neutron shielding where necessary (eg behind endcap toroid, USA15)
- Revisit the entire electricity supply network (UPS in particular)
- Where possible prepare Phase-I and minor upgrade services etc
- Re-align the barrel calorimeter and ID + consolidation of infrastructure and services + general maintenance
- Some early installation of (Phase-I) trigger upgrades which are required for above design luminosity operation are being anticipated for run 2:
  - CTP: CTPCore and CTPOut
  - Muon endcap trigger with current small wheel (reduce fake rate)
  - Tile outer layer trigger (to help L1 muon in transition region)
  - nMCM (needed for bunch train correction)
  - CMX and L1Topo

Current Shutdown Phase-0

- **New insertable pixel b-layer (IBL)** + **new pixel services (nSQP) + new small Be pipe**



ATLAS COLLABORATION CERN-RRB-2012-028-Appendix 1

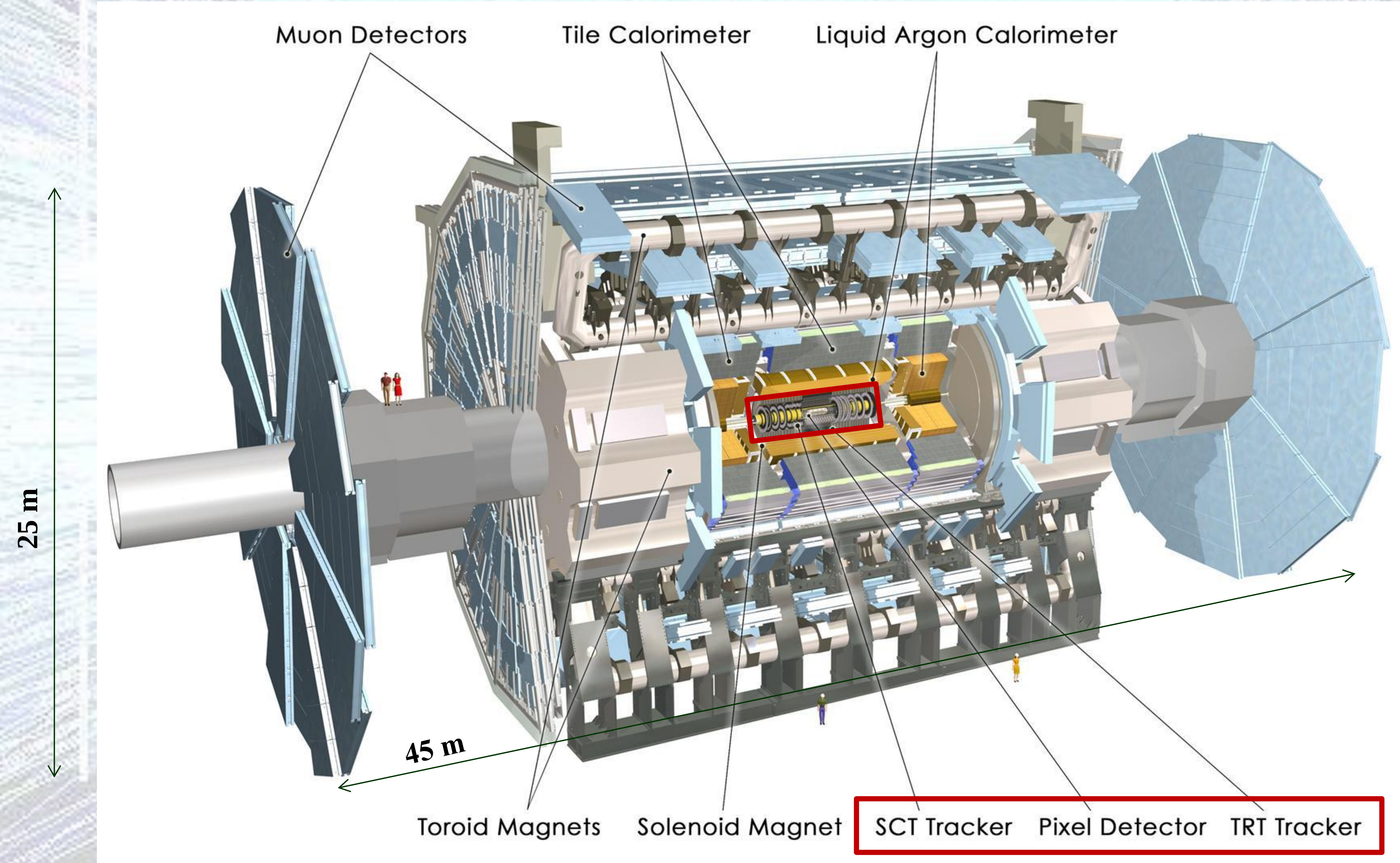
Addendum No. 01

to the
Memorandum of Understanding
for Collaboration in the Construction of the
ATLAS Detector

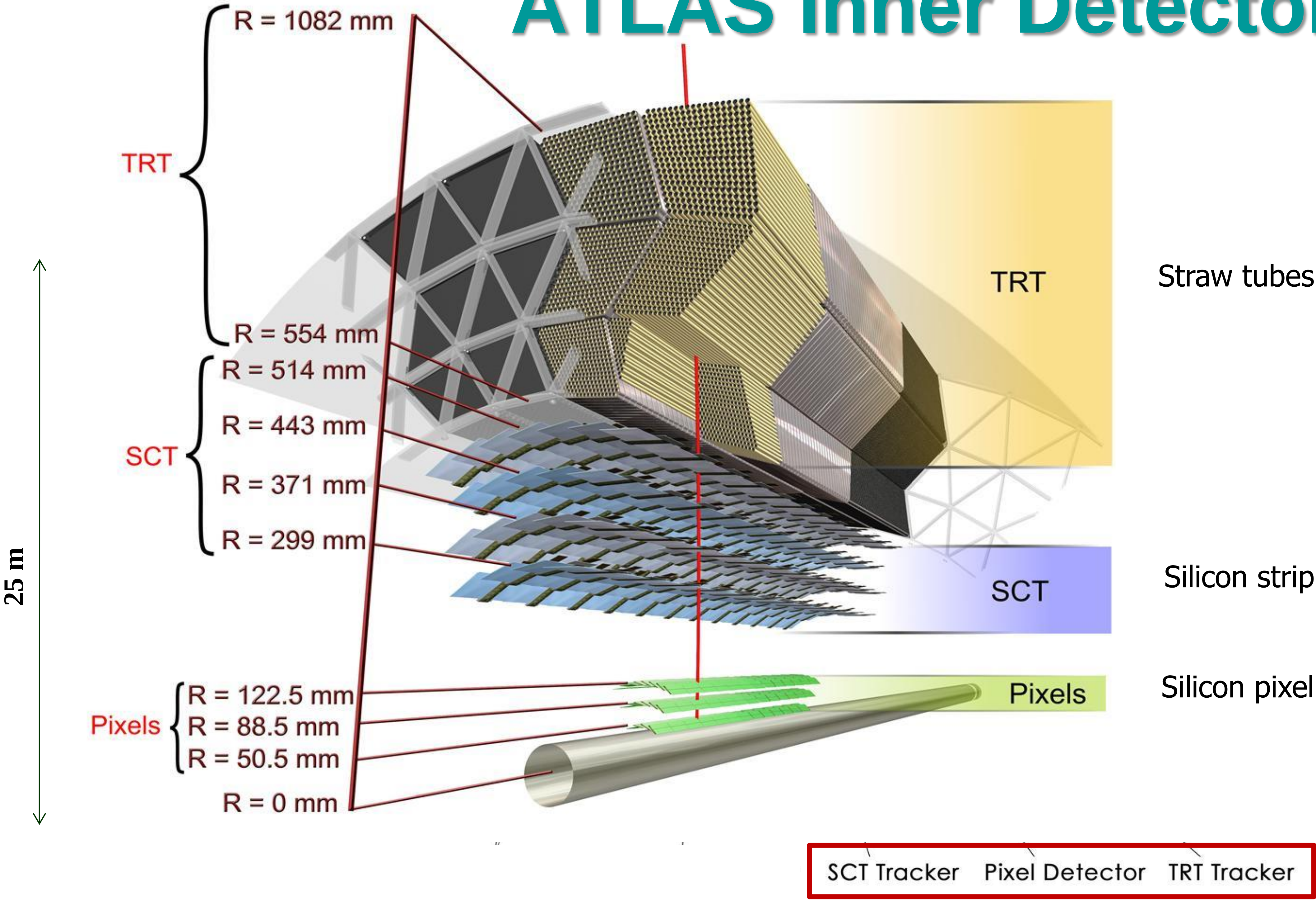
Construction of the ATLAS Insertable B-Layer (IBL)
Sub-Detector

Work Responsibility	
Barcelona	Prototype: 3D, Planar; Production: contribution
Bonn	Prototype: 3D, Planar, Diamond; Production: contribution
CERN	Prototype: 3D, Planar, Diamond; Production: contribution
Dortmund (/MPI)	Prototype: Planar; production: wafer QC
KEK	Prototype: Planar; Production: contribution
Liverpool	Prototype: Planar; Production: contribution
Ljubljana	Prototype: Diamond
LPNHE/Orsay	Prototype: Planar; Production: contribution
Manchester/Glasgow	Prototype: 3D; Production: contribution; QC supervision (Manchester)
New Mexico	Prototype: 3D, Planar, Diamond; Production (silicon): contribution
Ohio SU	Prototype: Diamond
Oslo/Bergen	Prototype: 3D; Production: contribution
Prague AS	Prototype: Planar; Production: contribution
Santa Cruz	Prototype: Planar, (3D); Production: contribution
SLAC/Stony Brook	Prototype: 3D; Production: contribution
Toronto(/Carleton)	Prototype: Diamond
Udine(/Trento)	Prototype: 3D, Planar; Production: contribution

ATLAS: Inner Tracking Detectors



ATLAS Inner Detector



Straw tubes

Silicon strip

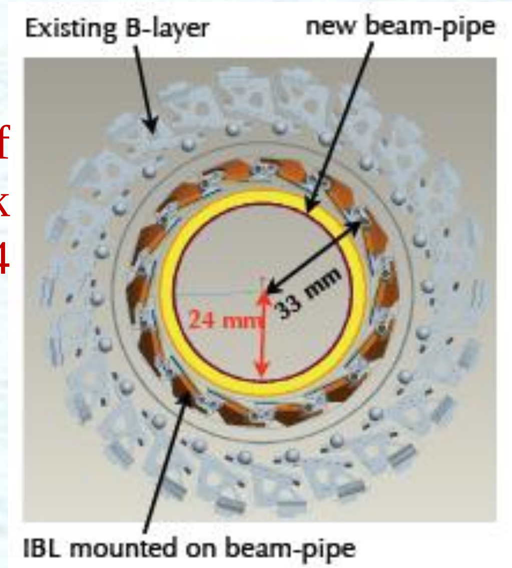
Silicon pixel

Insertable B-Layer

- New pixel layer around new smaller beam pipe
- Current pixel package was brought to surface allowing
  - IBL support tube insertion at surface
  - New services installed to fix problems and improve R/O bandwidth
  - New diamond beam monitors with IBL (FE-I4) ASICs

- Now reinserted and being recabled
- IBL modules and stave status
  - **14 staves required, 20 available with 18 suitable for installation**
  - **Staves being assembled to Inner Positioning Tube**

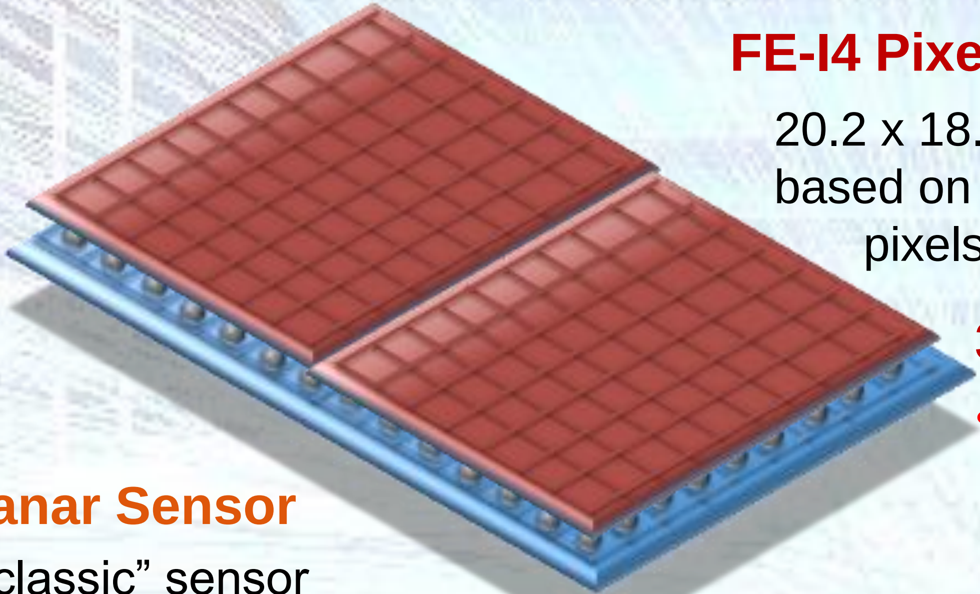
See talk of Tobias Flick 09.00 19/3/14



- Integration and installation
  - Extensive trials using test stands
  - Detailed schedule for remainder of shutdown
  - 5th May planned installation

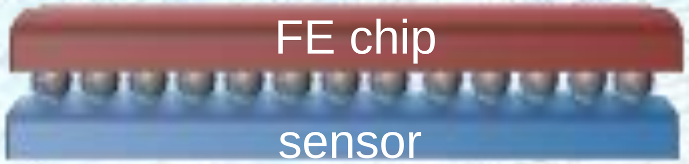
- Off-detector
  - New RODs can read-out 32 FE-I4 ASICs at a rate of 160 Mbit/s using 4 S-Links (also supports the dual output required for FTK)

Insertable B-Layer



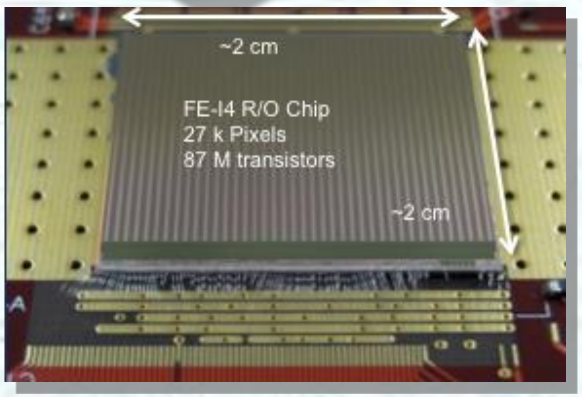
FE-I4 Pixel Chip (26880 channels)

20.2 x 18.8 mm^2 130 nm CMOS process, based on an array of 80 by 336 pixels (each 250 x 50 μm^2)



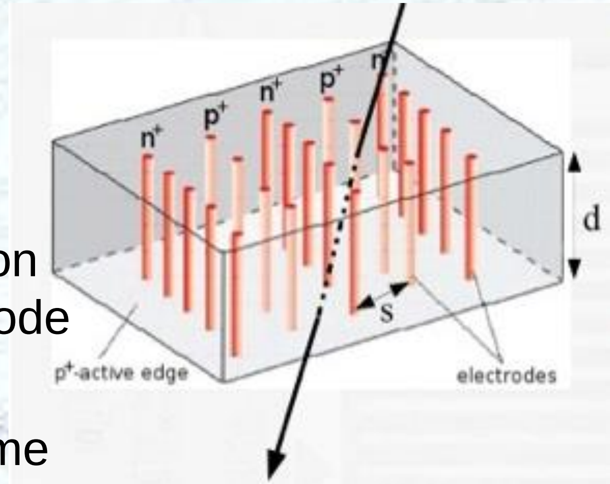
Planar Sensor

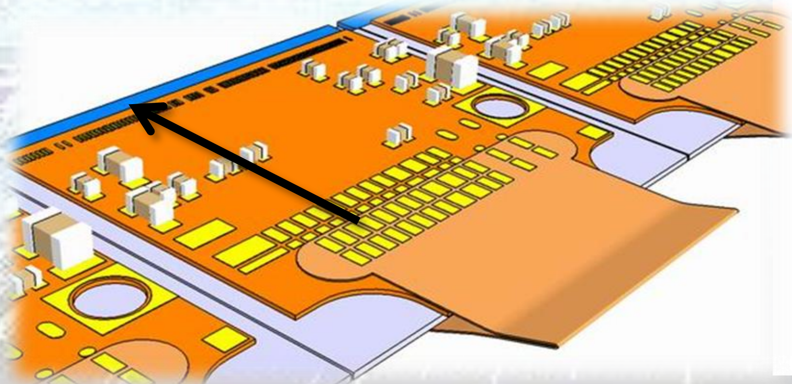
- "classic" sensor design
- oxygenated n-in-n
- 200μm thick
- Minimize inactive edge by shifting guard-ring under pixels (215 μm)
- Radiation hardness proven up to 2.4×10^{16} p/cm^2

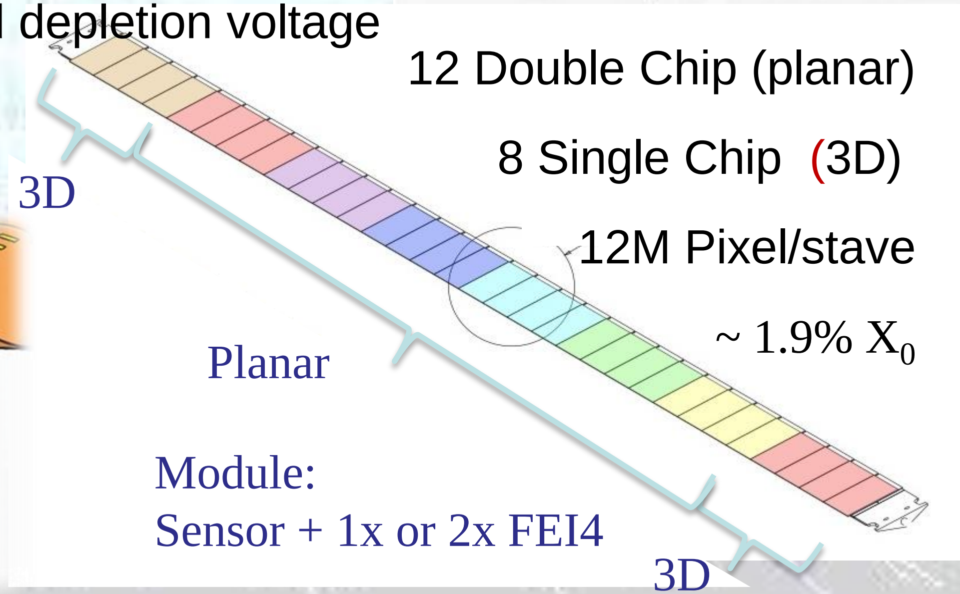


3D Sensor

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







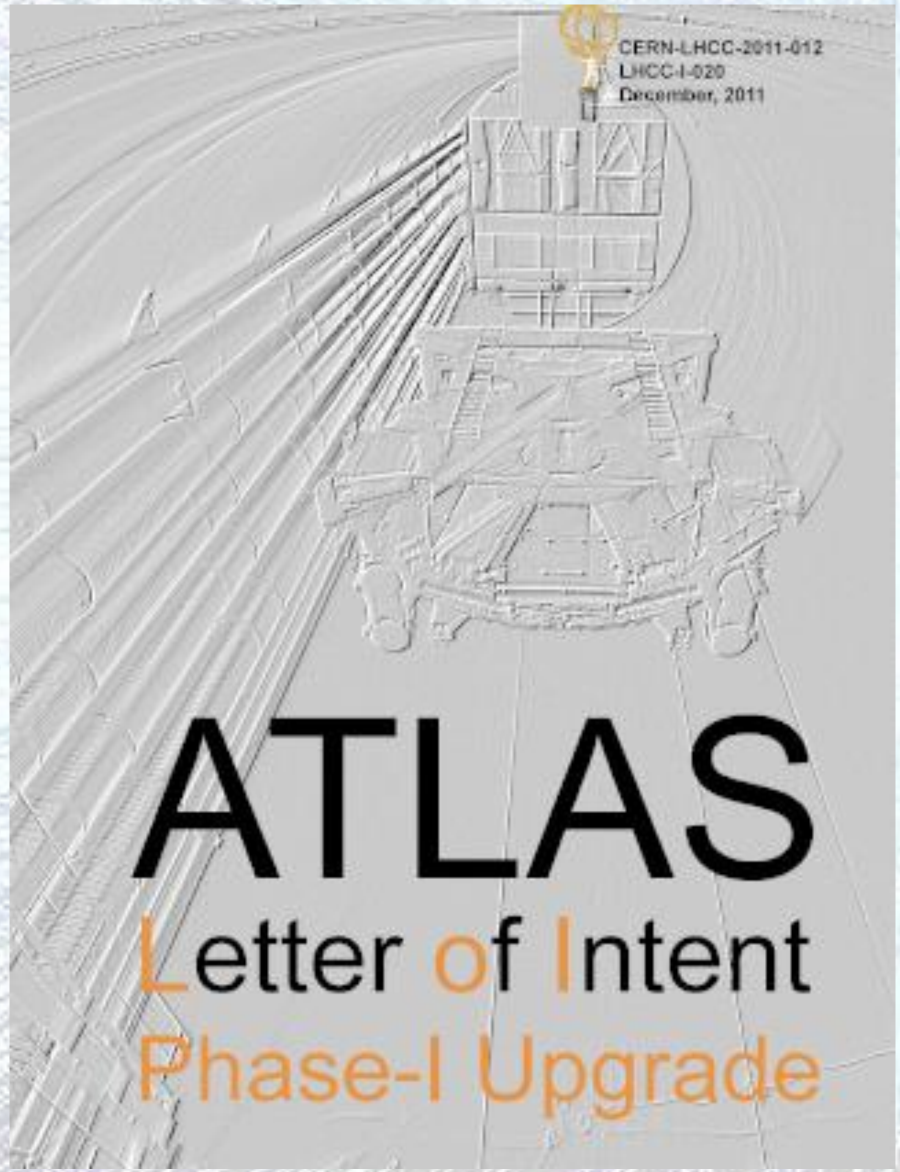
12 Double Chip (planar)

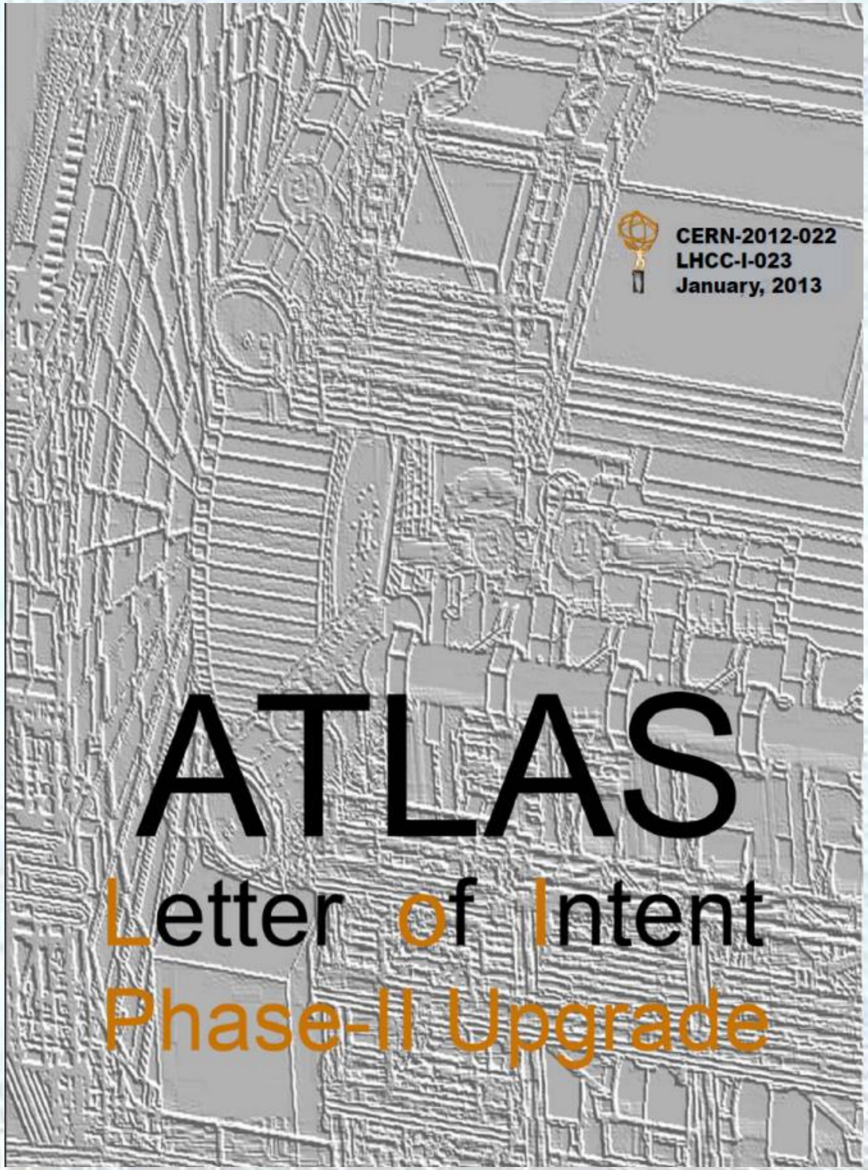
8 Single Chip (3D)

12M Pixel/stave

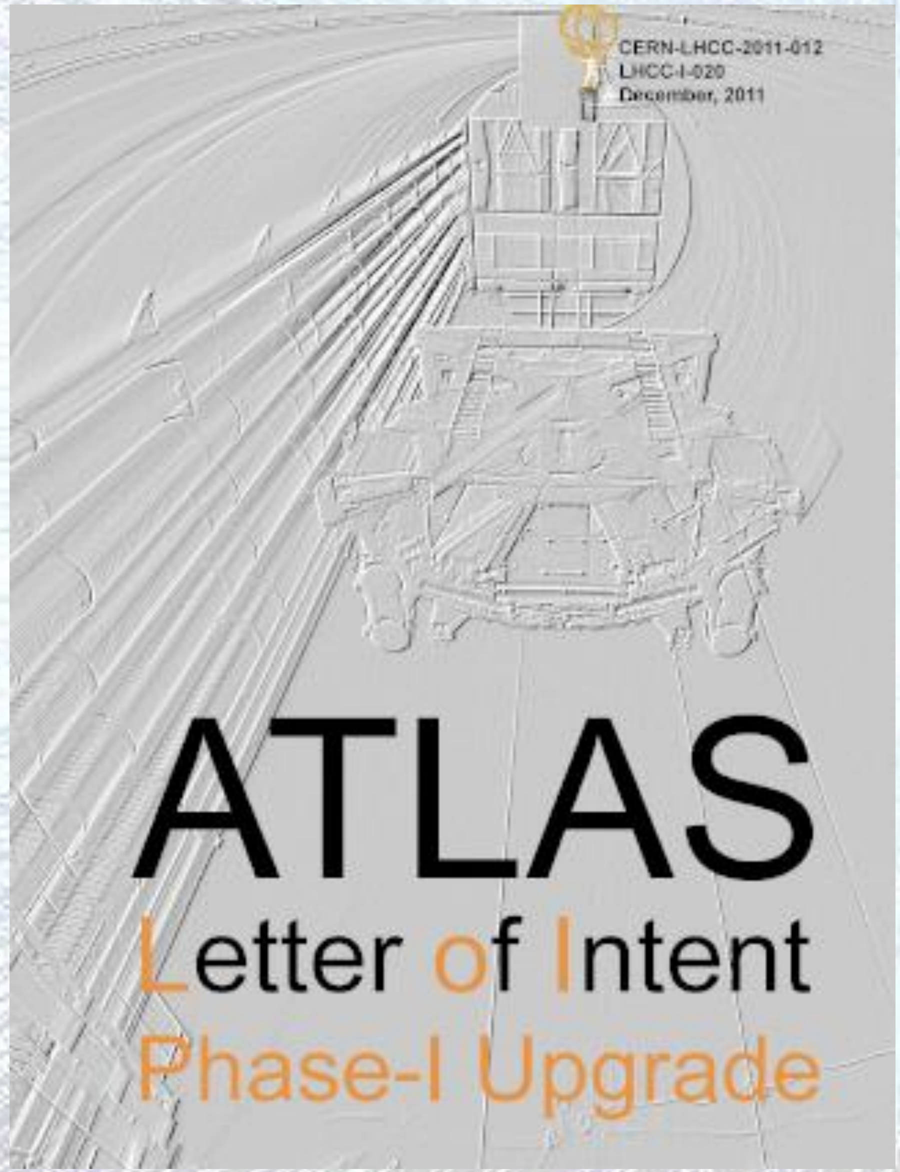
~ 1.9% X_0

Future Upgrade Planning





Future Upgrade Planning



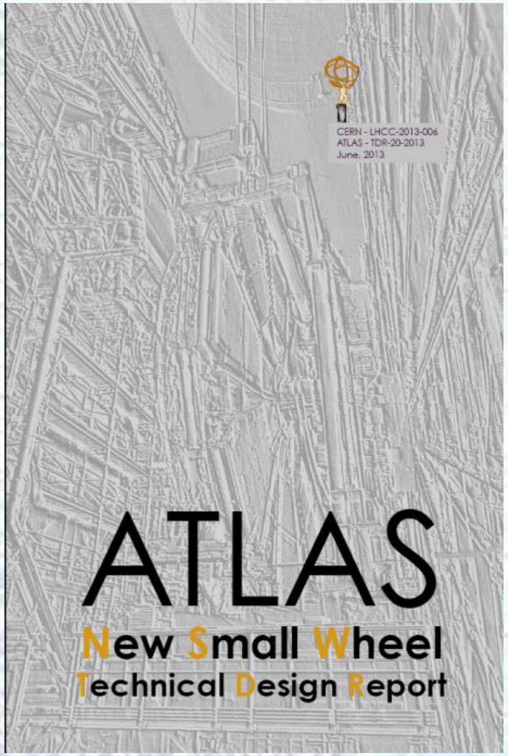
Phase-I Upgrade

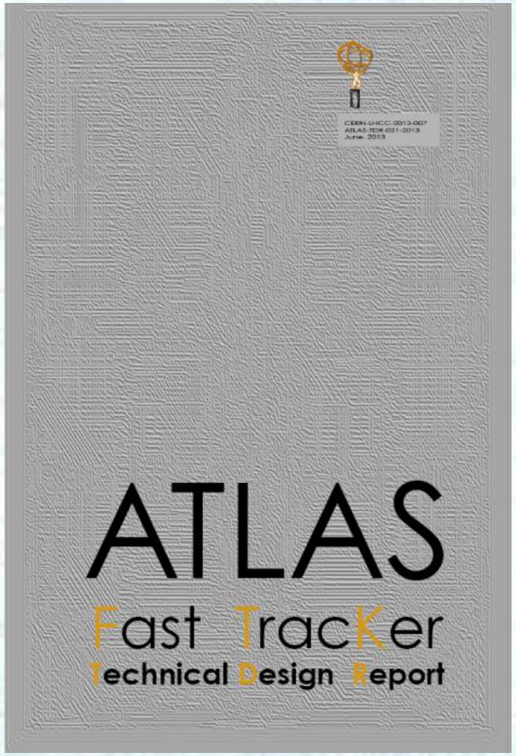
(LS2)

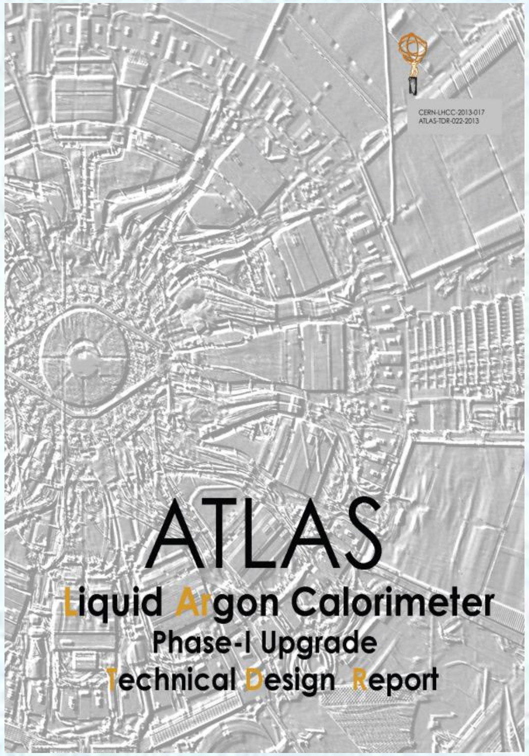
Starts Middle 2018

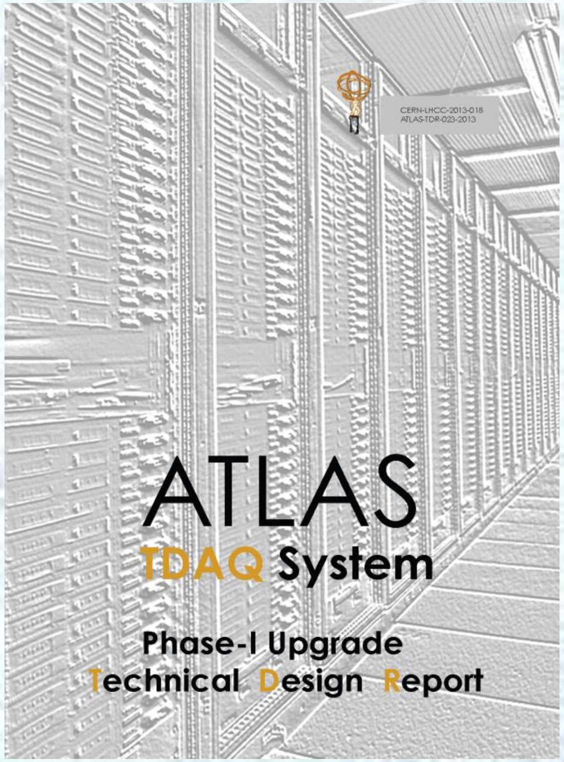
Future Upgrade Planning

In 2013, four TDRs for Phase-I construction projects were prepared within ATLAS, approved by the CB and submitted to the LHCC





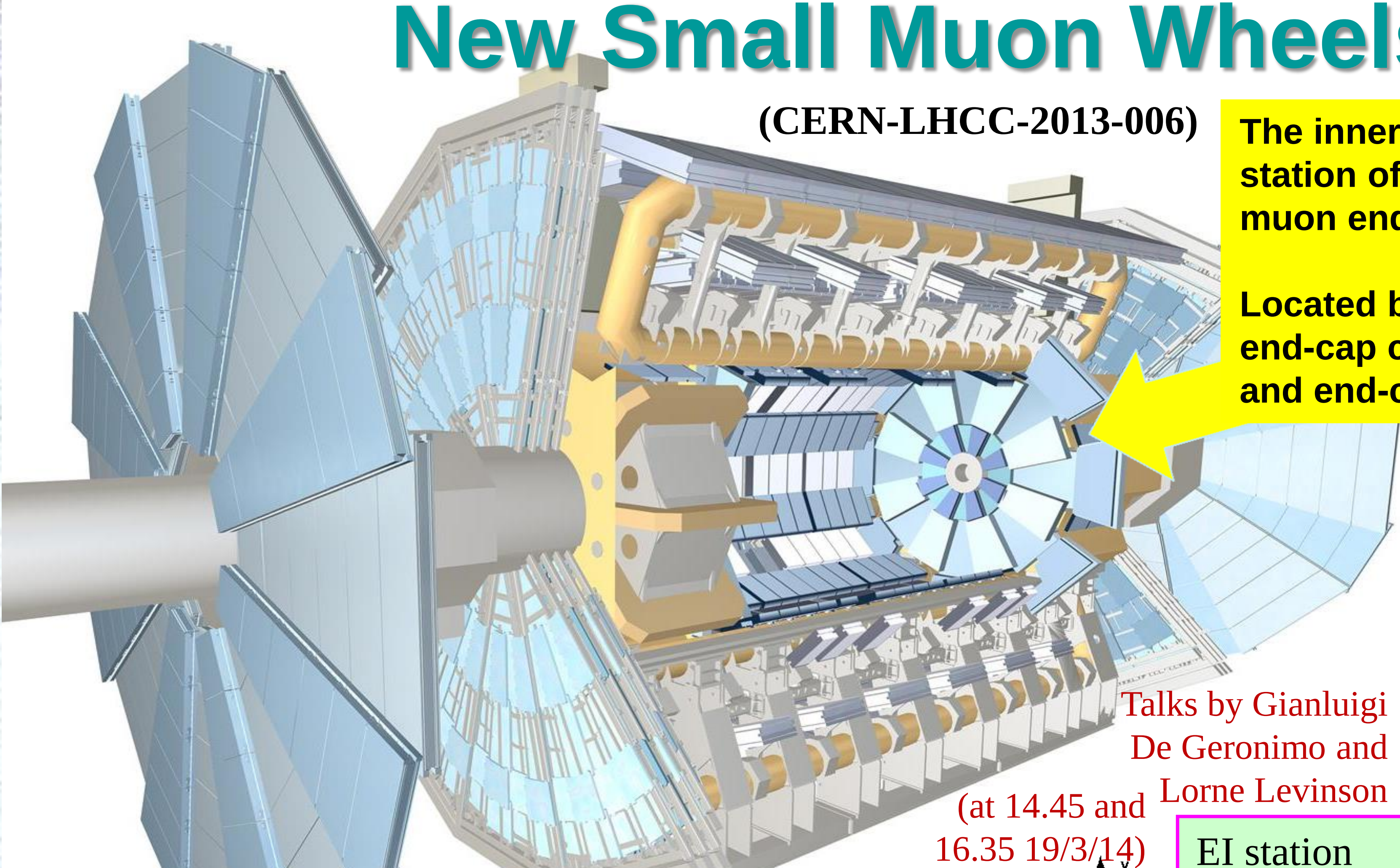




All four are now fully approved by the LHCC

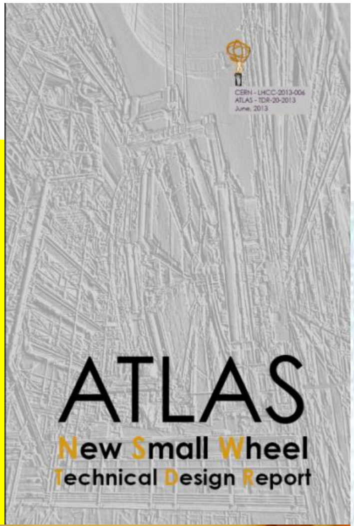
New Small Muon Wheels

(CERN-LHCC-2013-006)



The innermost station of the muon end-cap

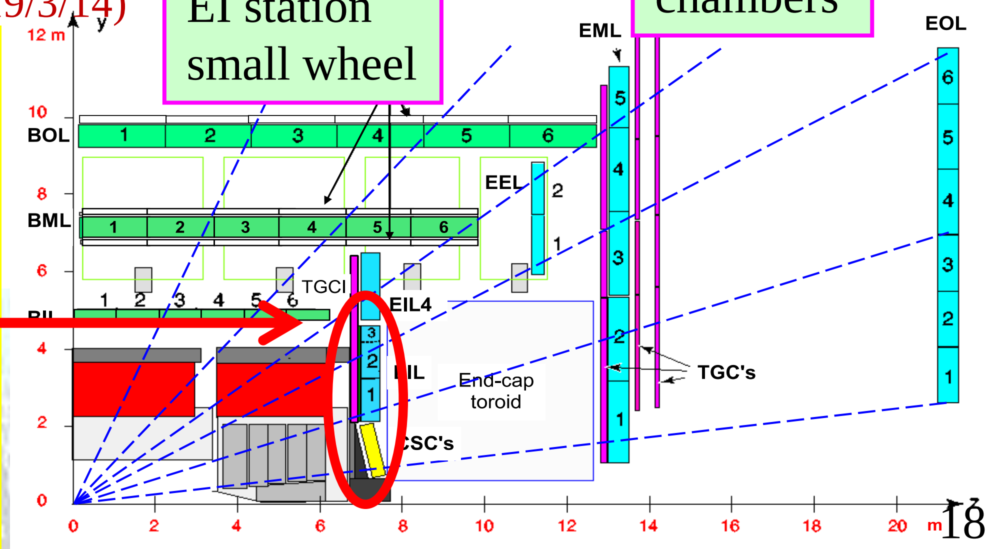
Located between end-cap calorimeter and end-cap toroid



Talks by Gianluigi De Geronimo and Lorne Levinson (at 14.45 and 16.35 19/3/14)

EI station small wheel

L1 trigger chambers



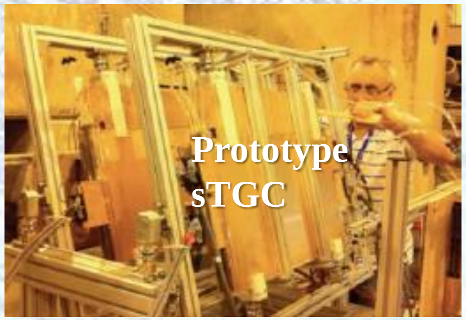
- In furthest forward direction, chamber efficiencies fall with hit rate as luminosity goes well above the design values
- Rate of L1 muon triggers exceeds available bandwidth unless thresholds raised

→ Replace "small" muon wheels

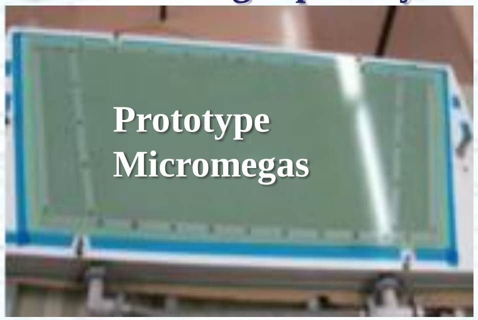
- Kill fake muon triggers by requiring high quality (σ_θ~ 1mrad) pointing to interaction region
- Precision chambers in both sTGC and micromegas technologies for robustness to Phase-II luminosities

New Small Muon Wheels

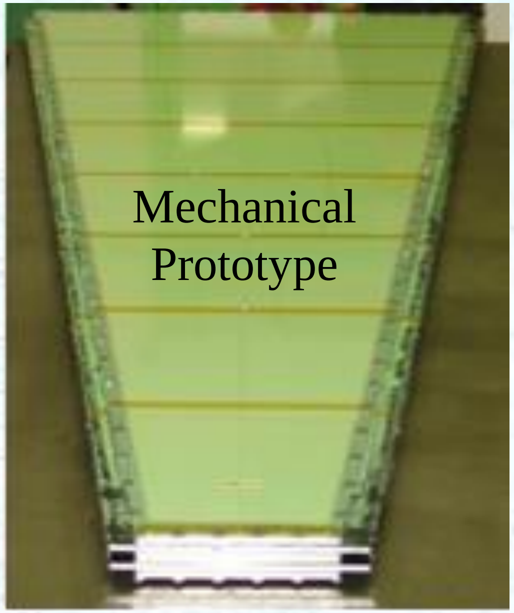
(CERN-LHCC-2013-006)

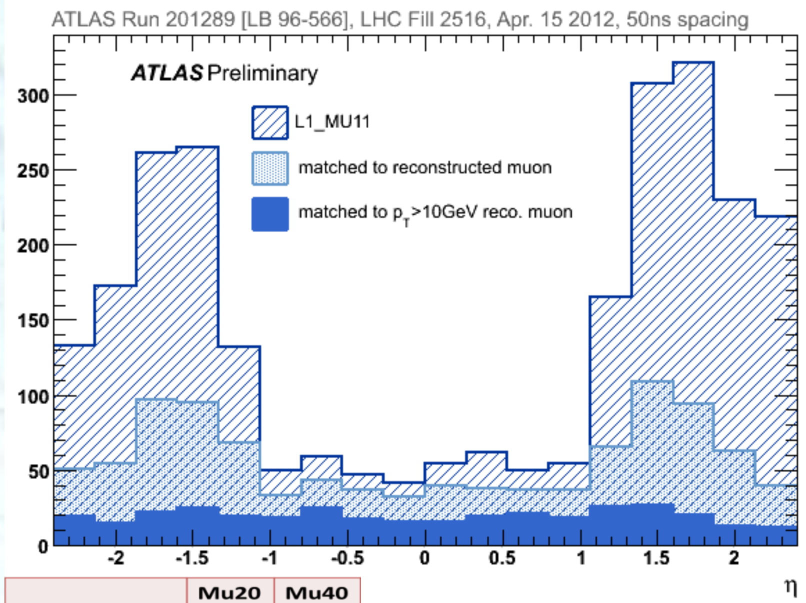


sTGC: trigger chambers with tracking capability

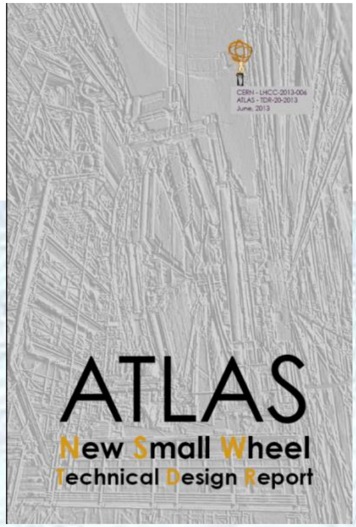


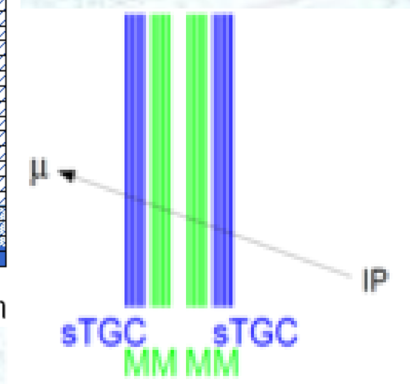
MM: precision tracking with triggering potential

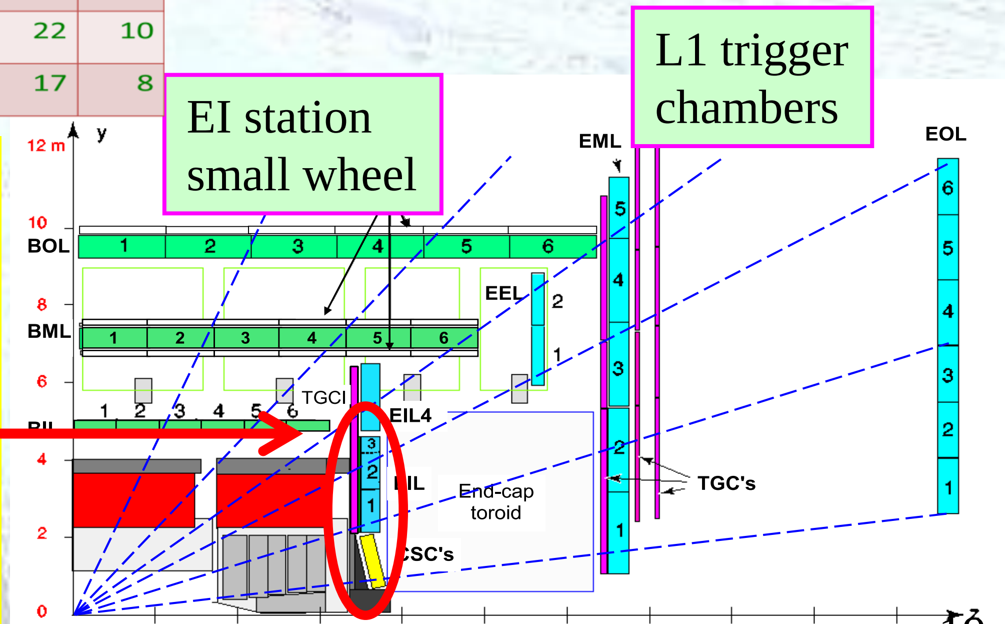




	Mu20	Mu40
Without NSW	60	29
With NSW	22	10
NSW + phase-0	17	8







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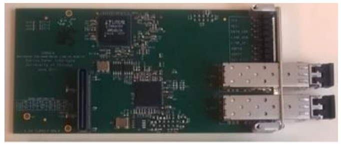
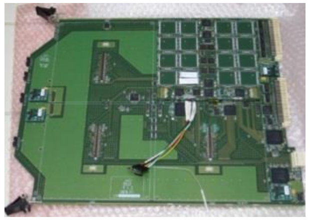
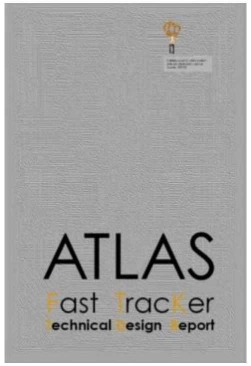
Fast TracKer (FTK)

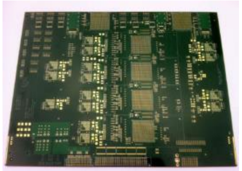
(CERN-LHCC-2013-007)

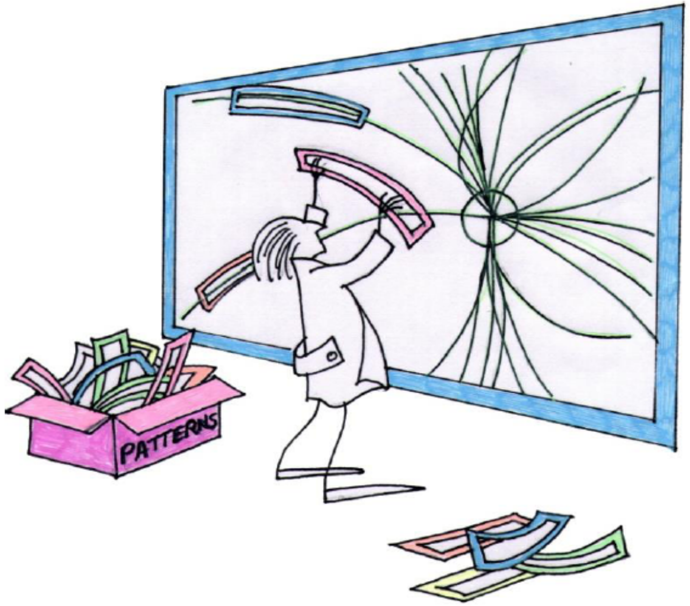


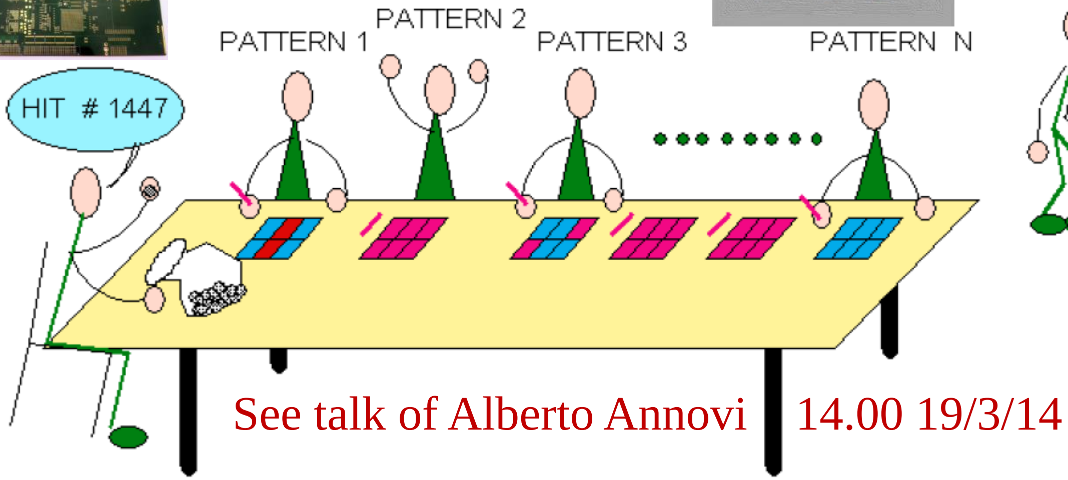


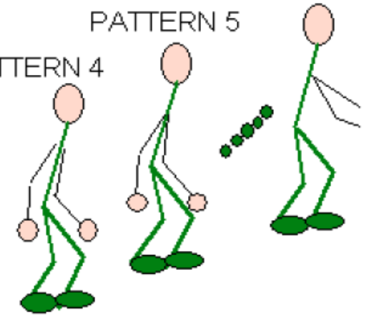


- Rapid pattern recognition









See talk of Alberto Annovi 14.00 19/3/14

  - A pattern consists of a Super-Strip in each layer (10s of pixels/strips wide).
  - Uses HEP-specific content addressable memory (CAM) custom chip.
  - Patterns determined from full ATLAS simulation.
  - ~ 10^9 patterns see each hit almost simultaneously.
  - When hits have all been sent off detector, pattern recognition is ~ done.

    → This is then followed by FPGA based track fitting (1 fit/ns)

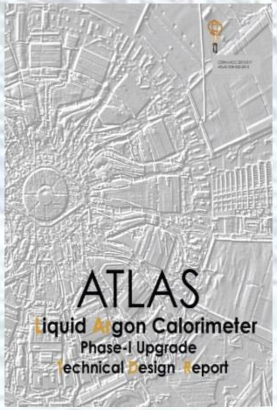
Many boards in pre-production and pre-final CAM chip version submitted

Designed for installation in 2016 to provide track information at start of HLT

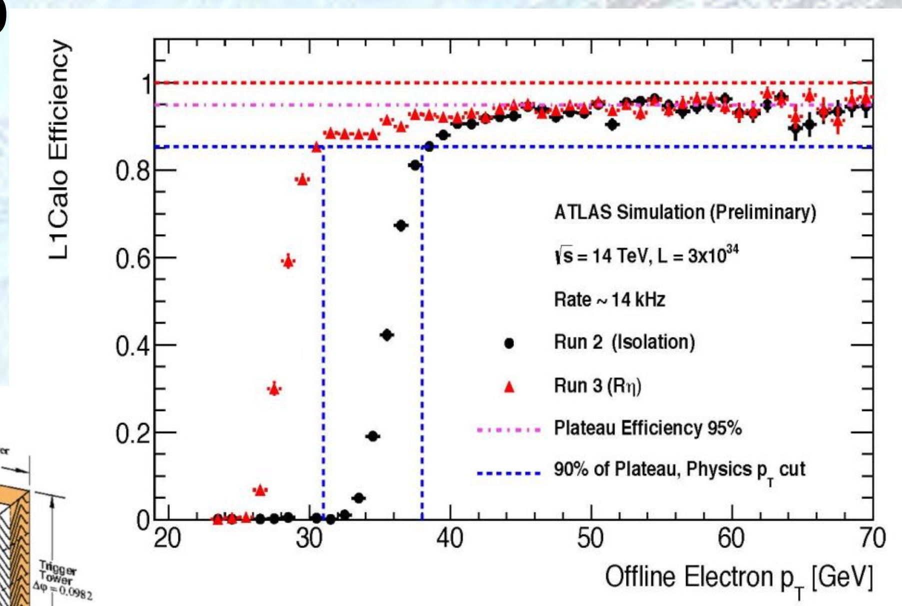
(For Phase-II need to speed up to fit tracks in RoI as input to Level-1.)

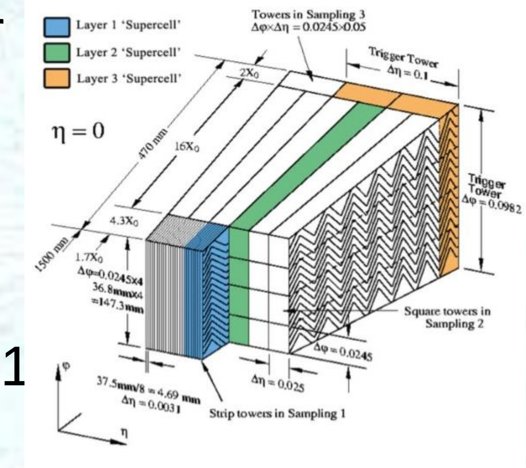
LAr Electronics Upgrades

(CERN-LHCC-2013-0017)

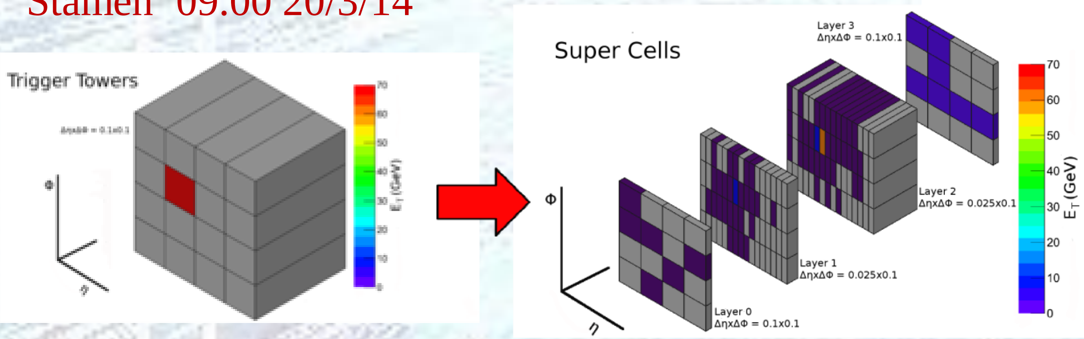


- Key target (as for New Small Wheel) is to maintain high efficiency for Level-1 triggering on low P_T objects
- In the LAr calorimeter this implies changes to the front-end electronics to allow greater granularity to be exploited at Level-1

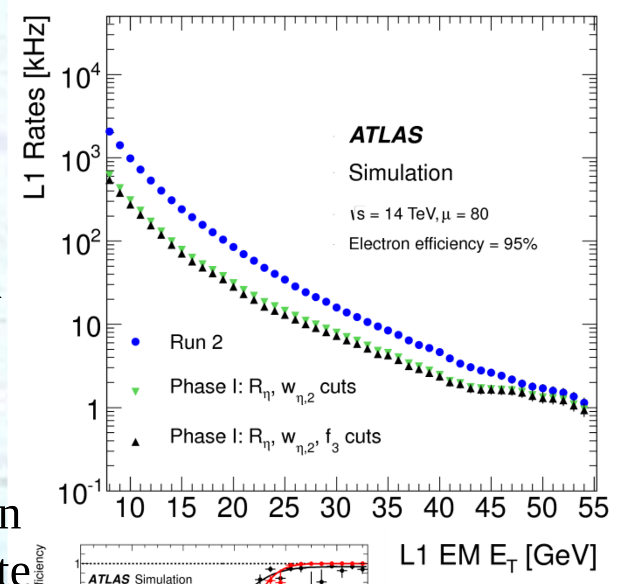


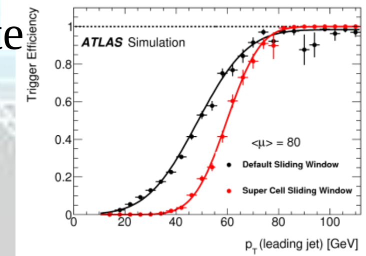


See talk by Rainer Stamen 09.00 20/3/14

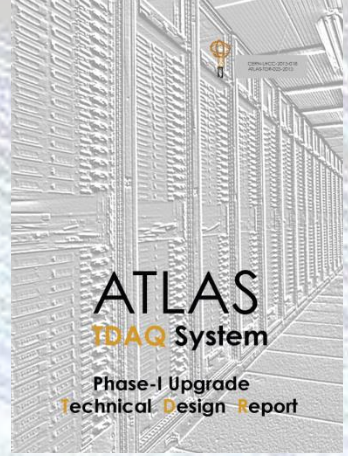


Different parameters based on greater segmentation in η, φ and depth as well as greater resolution allow significant improvements in threshold for a given L1 rate





(Phase-I Level-1 designed to be able to become Level-0 at Phase-II.)

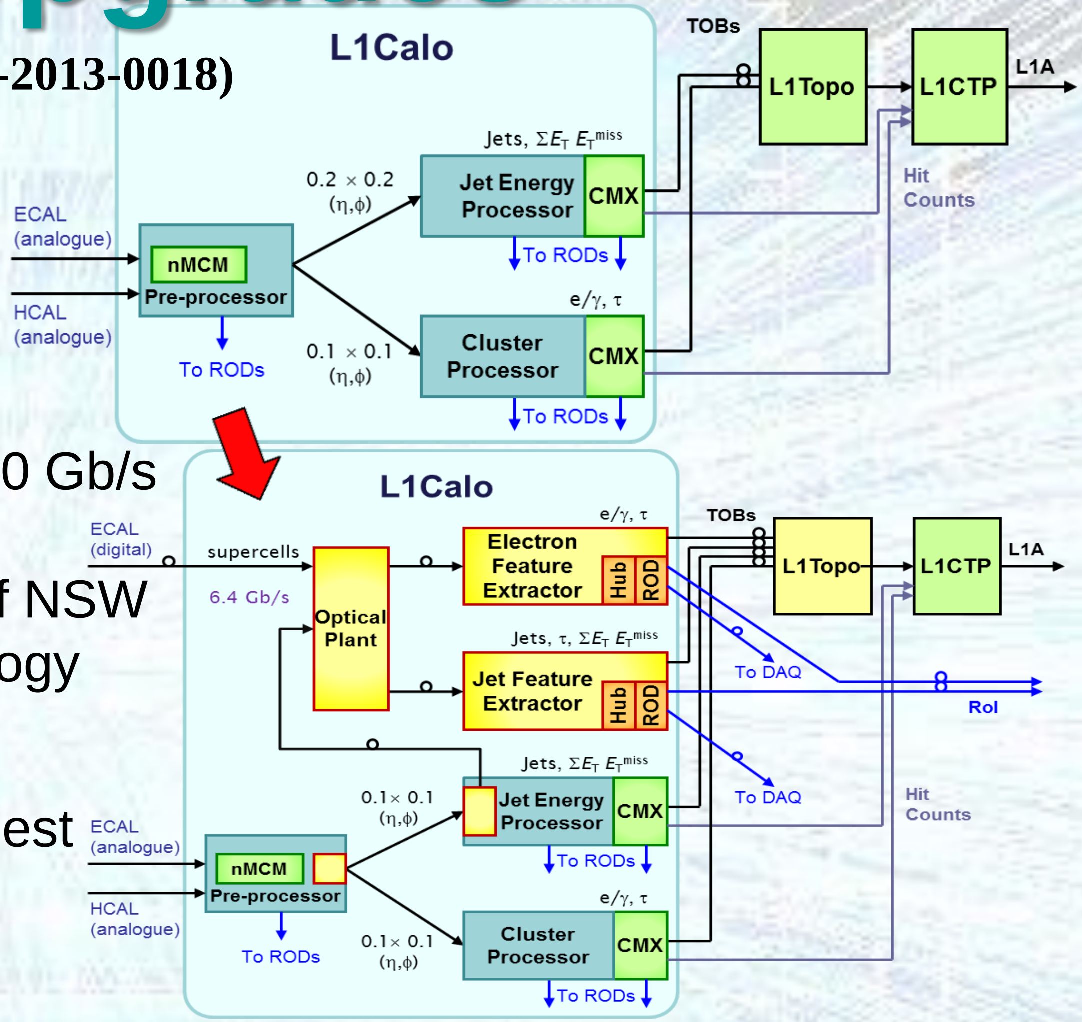


TDAQ Upgrades

(CERN-LHCC-2013-0018)

Level-1:

- Phase I: completely new L1 electron and jet triggers.
  - Exploiting greater η, φ and depth segmentation
  - Complex ATCA modules: 6-10 Gb/s signal distribution on boards
- New MUCTPI: incorporation of NSW and full granularity to L1Topology



See talk by David Francis
15.30 20/3/14

HLT:

- Increase DataFlow throughput
  → higher request rates, more data per request
- Maintain rejection & limit rise of CPU times

Dataflow:

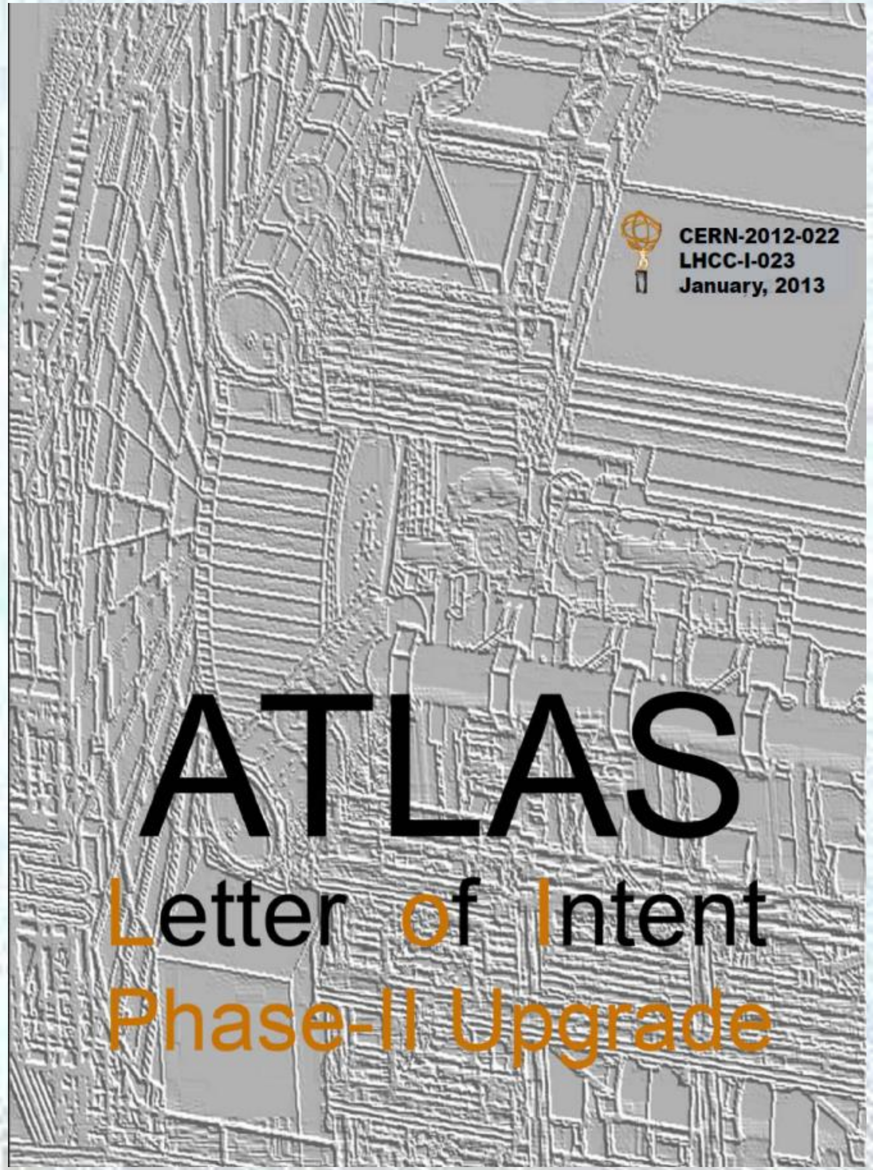
- Provide read-out for new and upgraded detectors: FTK, NSW, LAr, L1Calo
  - FELIX: receives detector data via FE links (GBT) and multiplexes to commodity network technology
- **HLT core software:**
- Upgrading HLT steering software and trigger chains
- Provide for new detectors: FTK, NSW, …
- Minimize *cost* of Trigger selection (cost ∝ data rate & trigger rates & CPU)

Future Upgrade Planning

Phase-II Upgrade

(LS3)

Starts End 2022



Future Upgrade Planning

Phase-II Upgrade

(LS3)

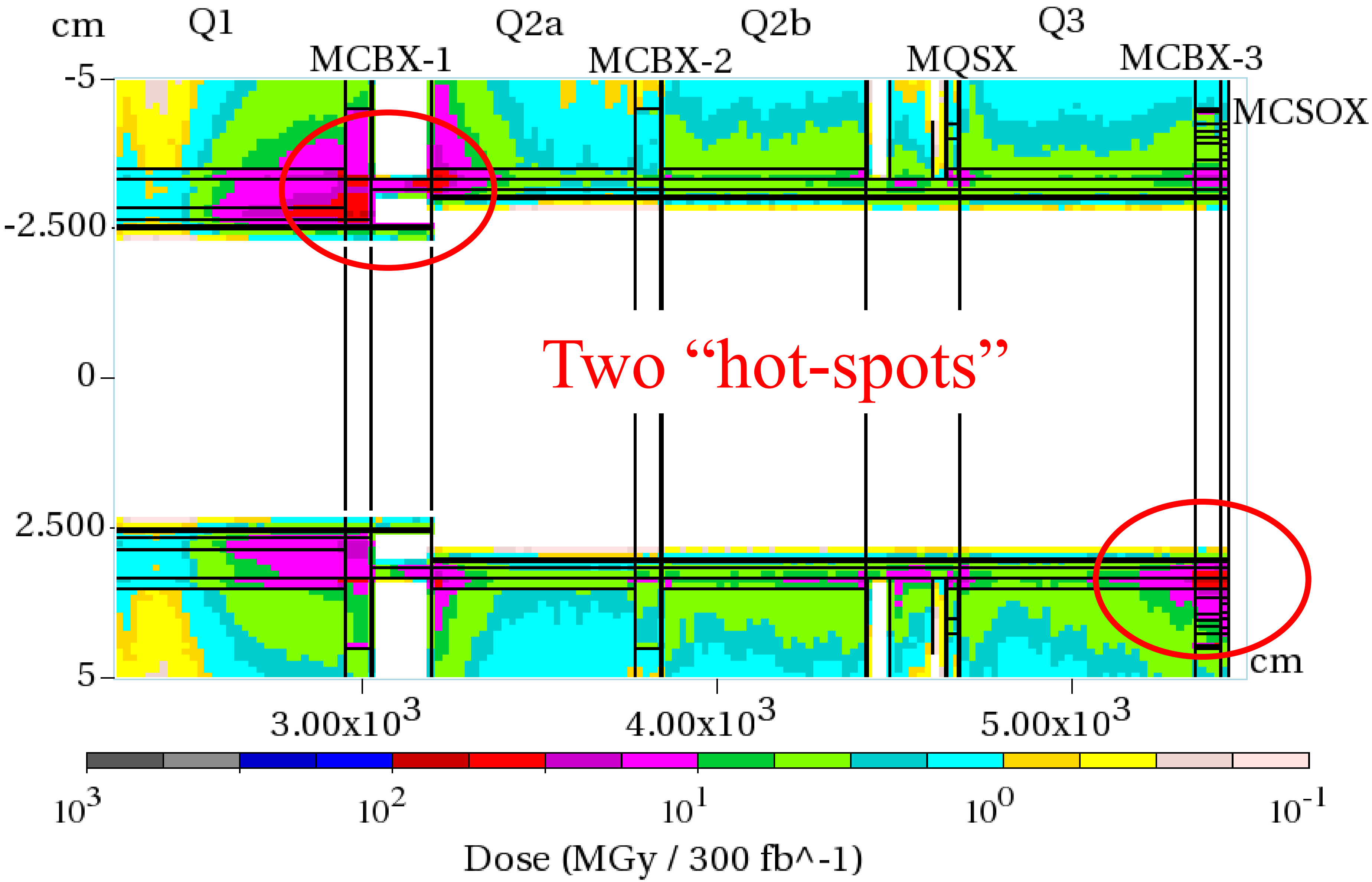
Starts End 2022

Parameter	25ns
N_b	2.2E+11
n_b	2808
N_{tot}	6.2E+14
beam current [A]	1.11
x-ing angle [μrad]	590
beam separation [σ]	12.5
β^* [m]	0.15
ε_n [μm]	2.50
ε_L [eVs]	2.51
energy spread	1.20E-04
bunch length [m]	7.50E-02
IBS horizontal [h]	18.5
IBS longitudinal [h]	20.4
Piwinski parameter	3.12
Reduction factor 'R1*H1' at full crossing angle (no crabbing)	0.306
Reduction factor 'H0' at zero crossing angle (full crabbing)	0.905
beam-beam / IP without Crab Cavity	3.3E-03
beam-beam / IP with Crab cavity	1.1E-02
Peak Luminosity without levelling [$cm^{-2}\ s^{-1}$]	7.4E+34
Virtual Luminosity: Lpeak*H0/R1/H1 [$cm^{-2}\ s^{-1}$]	21.9E+34
Events / crossing without levelling	210
Levelled Luminosity [$cm^{-2}\ s^{-1}$]	5E+34
Events / crossing (with leveling for HL-LHC)	140
Leveling time [h] (assuming no emittance growth)	9.0

(L. Rossi: http://indico.cern.ch/event/257368/session/0/contribution/3)

Radiation dose in the present triplet (300 fb^{-1})

L. Bottura



F. Cerutti, et al., WP10: Energy Deposition and Radiation Damage in Triplet Magnets, April 2013

https://indico.fnal.gov/conferenceDisplay.py?confId=6164

Radiation dose in the present triplet (300 fb^{-1})

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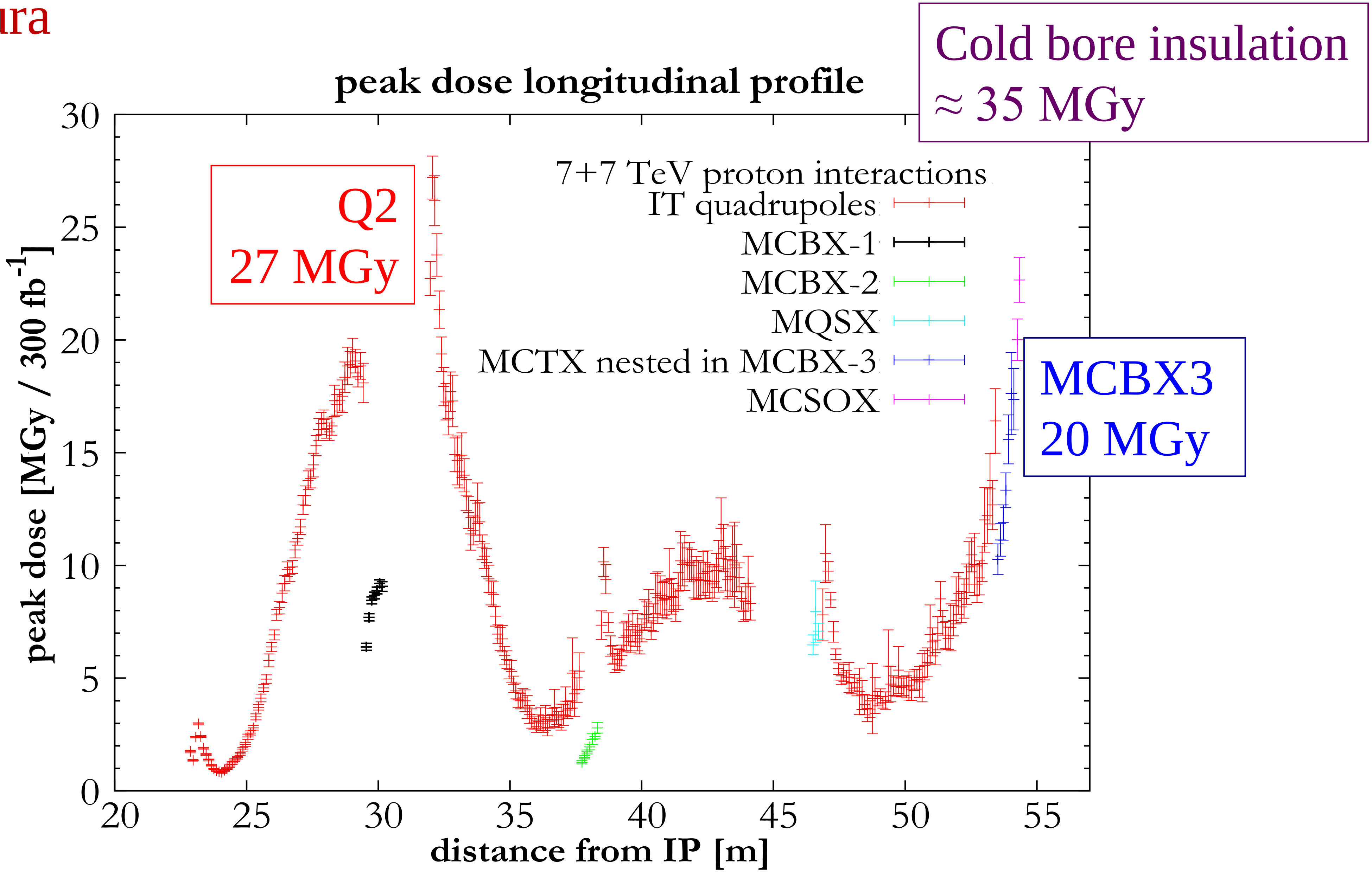


F. Cerutti, et al., WP10: Energy Deposition and Radiation Damage in Triplet Magnets, April 2013

https://indico.fnal.gov/conferenceDisplay.py?confId=6164

RLIUP Summary on LHC Inner Triplets

L. Bottura https://indico.cern.ch/conferenceDisplay.py?ovw=True&confId=260492

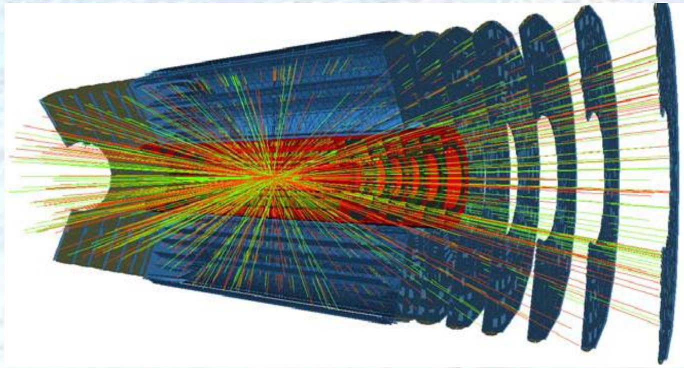
- Expected dose by LS3 (300 fb^{-1}) with 50 % uncertainty[(3)]
  - Range of 27 [18…40] MGy in the Q2
  - Range of 20 [13…30] MGy in the MCBX
- Bonding strength (shear) of epoxies is strongly degraded (80 %) above 20 MGy
- Fracture strength of insulating materials degrades by about 50 % in the range of 20 MGy (G11) to 50 MGy (epoxies, kapton)
- Insulations (polyimide) become brittle above 50 MGy
- Triplet magnets may experience mechanically-induced insulation failure in the range of 300 fb^{-1} (LS3 ± 1 year)
  - Premature quenches (cracks in end spacers)
  - Insulation degradation (monitor on line[(4)])
  - Mechanical failure (nested coils in MCBX)

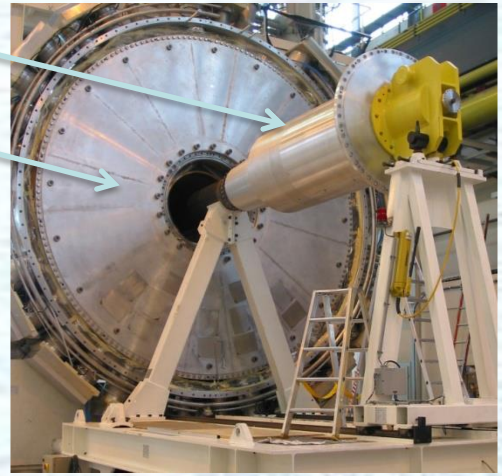
Phase-II Detector Upgrades

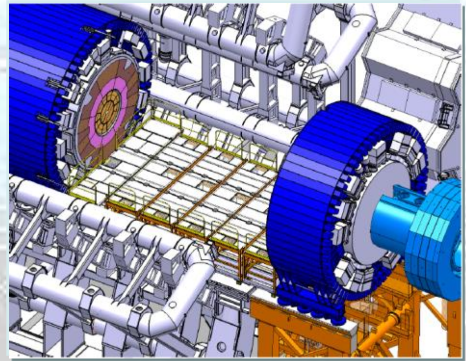
Integrated radiation levels (up to 2-3×$10^{16}n_{eq}/cm^2$) and plan to cope with up to 200 interactions every 25ns

Implications of this include:

- **New Inner Detector (strips and pixels)**
- **Trigger and data acquisition upgrades**
- **L1 Track Trigger**
- **New LAr front-end and back-end electronics**
- **Possible upgrades of HEC and FCal**
- **New Tiles front-end and back-end electronics**
- **Muon Barrel and Big Wheel trigger electronics**
- **Possible TGC upgrade to inner part of Big Wheels**
- **Forward detector upgrades**
- **TAS and shielding upgrade**
- **Various infrastructure upgrades**
- **Common activities (installation, safety, …)**
- **Software and Computing**





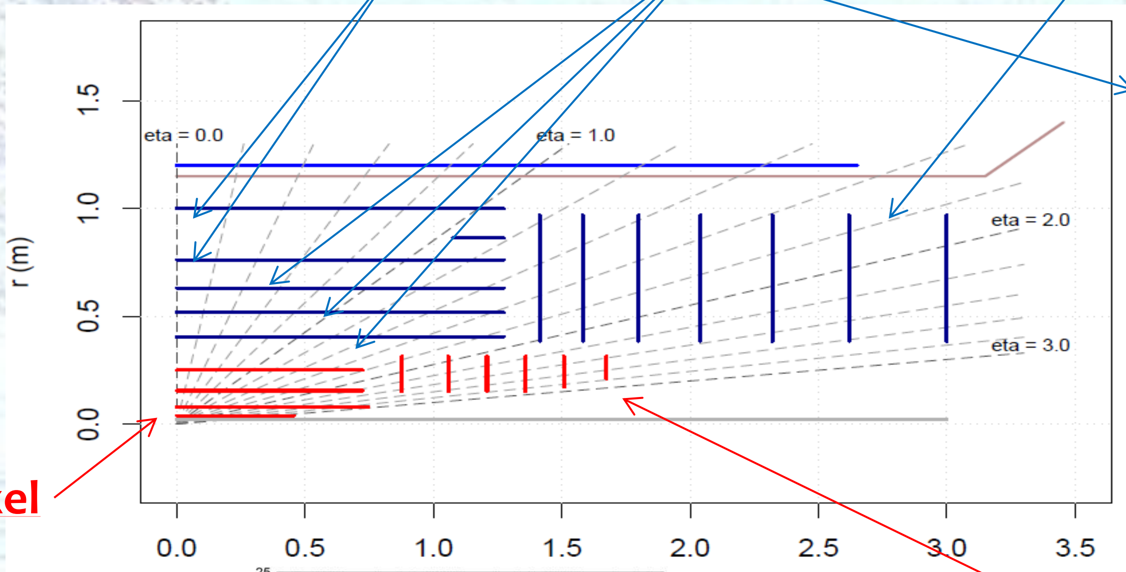


ATLAS: New All-silicon Inner Tracker

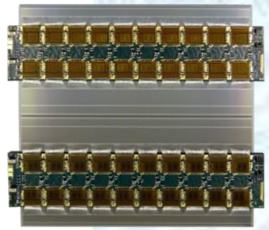
Long Barrel Strips

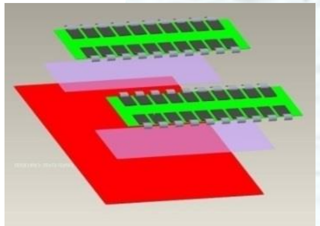
Short Barrel Strips

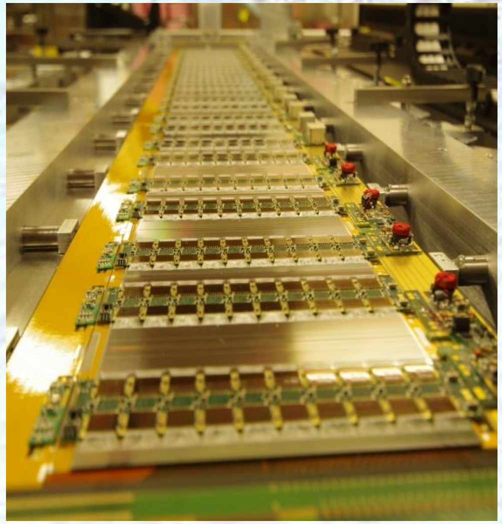
Forward Strips



Barrel pixel

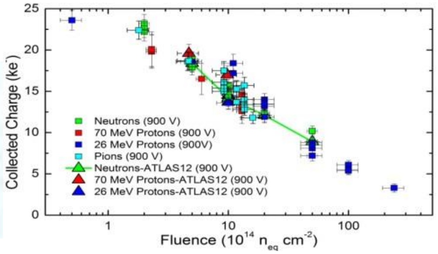






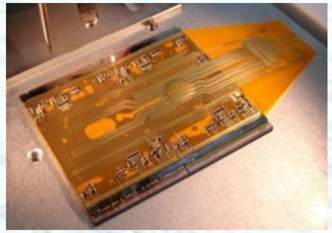
Microstrip Stave Prototype

Signal vs dose (1 MeV n equivalent)

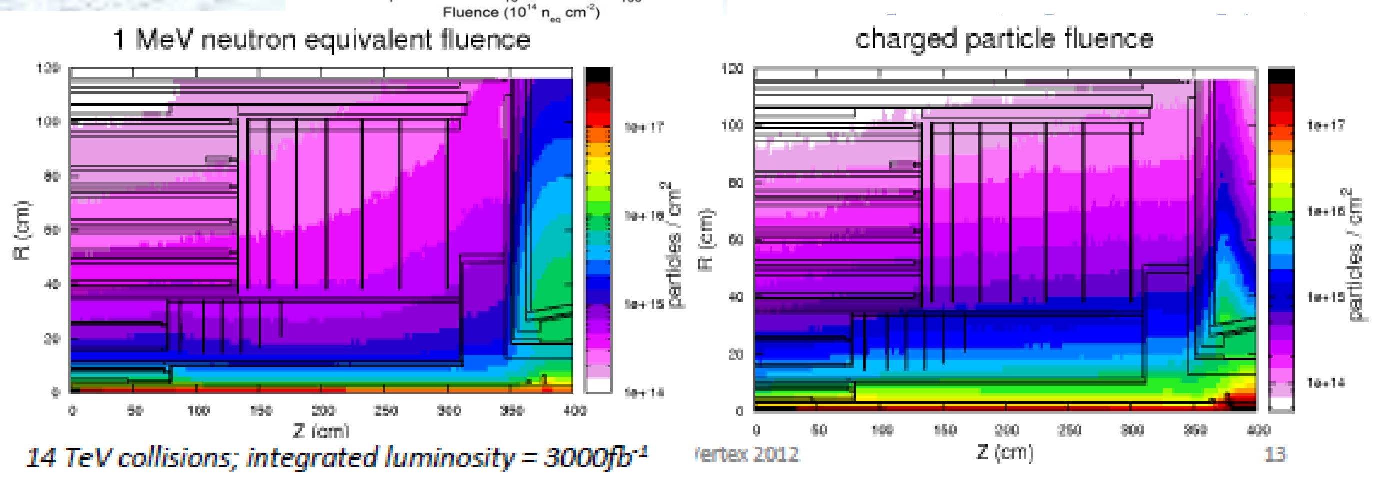


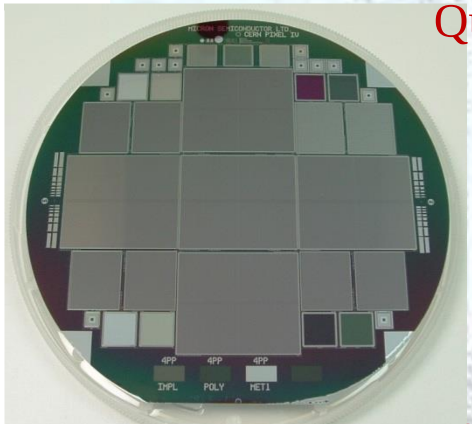
Baseline layout of the new ATLAS inner tracker for HL-LHC Aim to have at least 14 silicon hits

Forward pixel



Quad Pixel Module





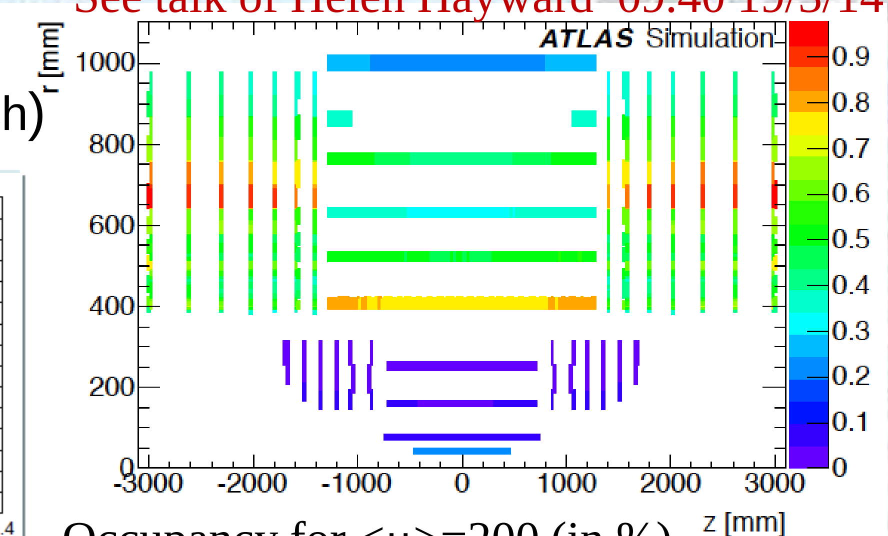
Quad Pixel Sensor Wafer

Baseline Tracker Performance

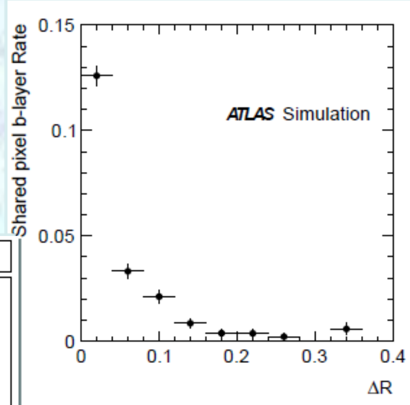
See talk of Helen Hayward 09.40 19/3/14

- New Inner Detector Improved granularity

  (Smaller pixels and 2.45cm and 4.9cm strips (74.5µm pitch)
  - ➢ Improved radiation hardness
  - ➢ Reduced material
  - ➢ Extended forward coverage
  - ➢ Robust tracking (14 layers)

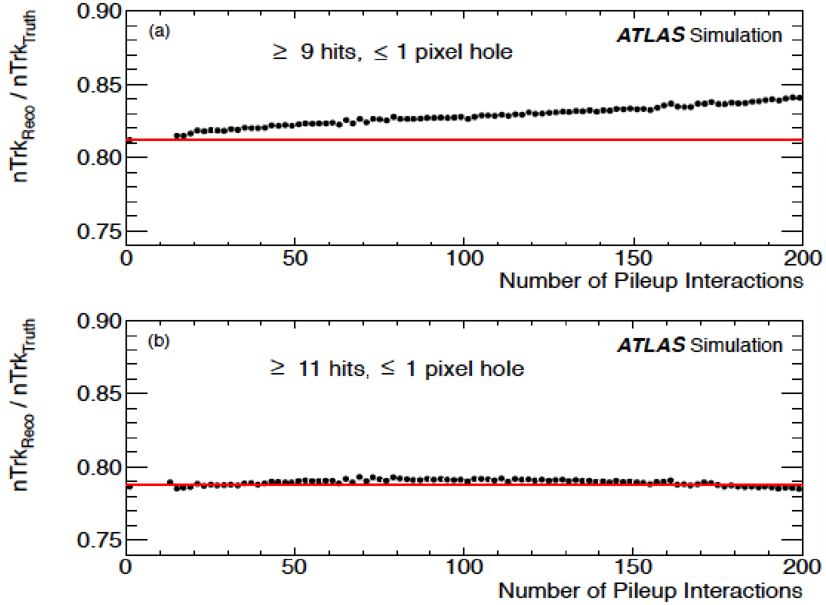


Occupancy for <μ>=200 (in %)

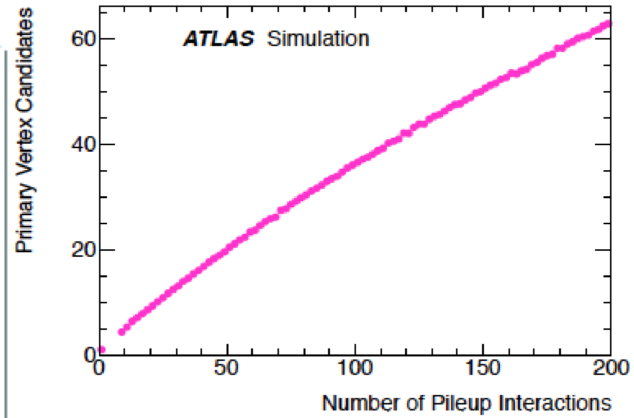


parameter	layer 1	layer 2	layers 3 + 4	disks
chips (ϕ x z)	FE-5 2x1	FE-5 2x2	FE-I4 2x2	FE-I4 2x3
pixel size (μm^2)	25 x 150	25 x150	50x 250	50x 250
nb of pixels in ϕ	672	1348 +12 ganged	672 + 6 ganged	672 + 6 ganged
nb. of double columns in z	68	68	40	60
length of sensor at gap (μm)	300	300	450	450
distance to module edge (μm)	150	150	500	500
distance active to cut edge (μm)	100	100	100	100
active size (mm^2)	16.8 x 41.1	34.0 x 41.1	33.9 x 40.4	33.9x60.8
physical size (mm^2)	18.8 x 41.3	38.0 x 41.3	38.0 x 41.1	38.0x61.3
power (W)	0.9	1.8	1.8	2.7

Track parameter $\|\eta\| < 0.5$	Existing ID with IBL no pile-up $\sigma_x(\infty)$	Phase-II tracker 200 events pile-up $\sigma_x(\infty)$
Inverse transverse momentum (q/p_T) [/TeV]	0.3	0.2
Transverse impact parameter (d_0) [μm]	8	8
Longitudinal impact parameter (z_0) [μm]	65	50



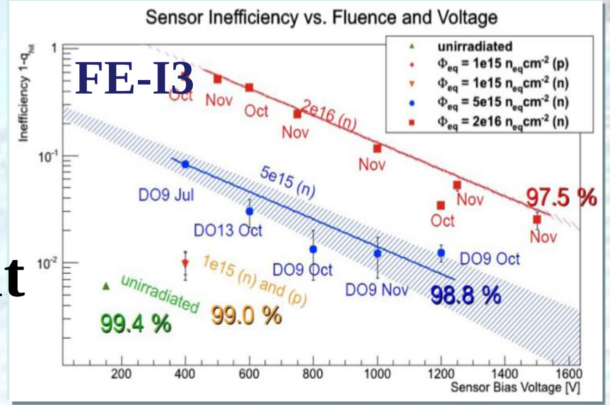
Detector:	Silicon area [m^2]	Channels [10^6]
Pixel barrel	5.1	445
Pixel end-cap	3.1	193
Pixel total	**8.2**	**638**
Strip barrel	122	47
Strip end-cap	71	27
Strip total	**193**	**74**



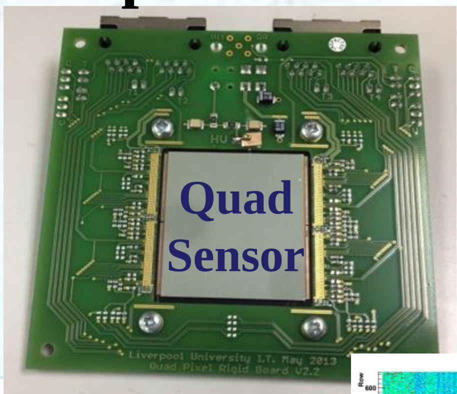
New All-silicon Inner Tracker

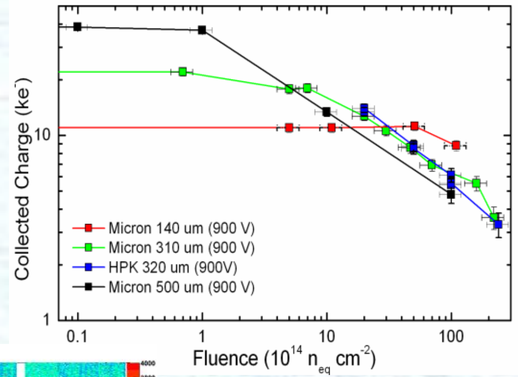
See talk of Helen Hayward 09.40 19/3/14

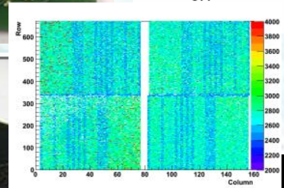
Pixel Detector



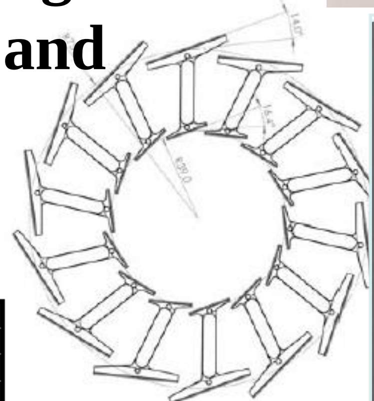
- n-in-n, n-in-p planar, 3D and diamond sensors proved to doses up to $2\times10^{16} n_{eq}/cm^2$ and 1Grad
- IBL pixel size (50×250μm) OK for outer pixel layers, but target down to 25μm×150μm pixels with 65 nm CMOS
- Test structures in 65nm produced and studied after irradiation
- Larger area sensors (n-in-p) quads/sextuplets produced on 150mm diameter wafers with several foundries
- Irradiated quad pixel modules studies in test-beam and results look promising
- Novel technologies: HR/HVCMOS for possible use as outer pixel or higher radii
- Prototyping of local supports and concepts for service routings have been studied

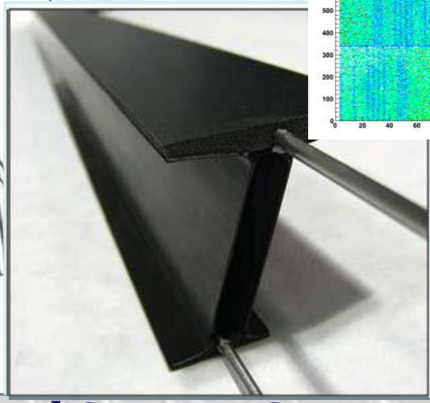




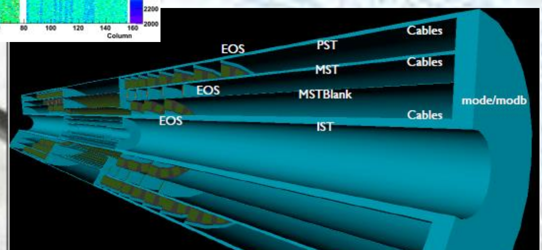


Irradiated quad at 3000e threshold



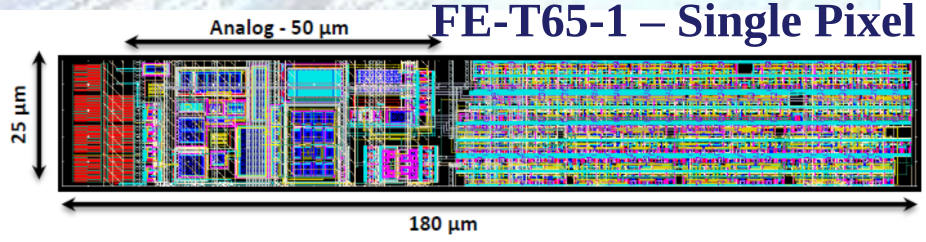


Possible Barrel Support Concept



Forward Pixel Services

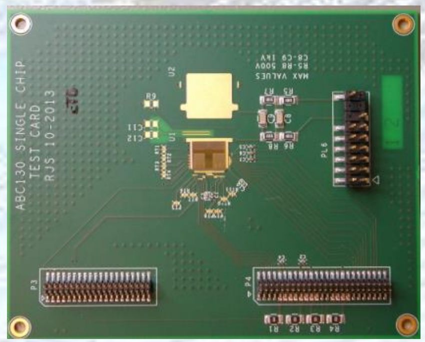
FE-T65-1 – Single Pixel



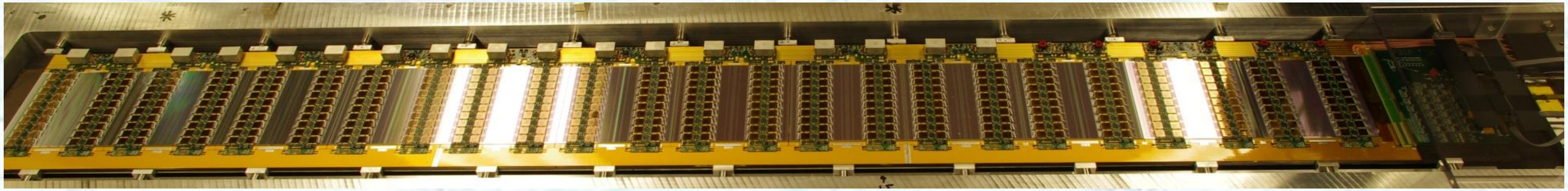
New All-silicon Inner Tracker

Strip Detector

See talk of Peter Phillips 10.40 19/3/14

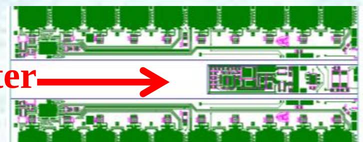


- **New prototype n-in-p sensors delivered with 4 rows of 2.4cm long strips at 74.5µm pitch**
- **New (256 channel) 130nm CMOS ASIC received and under study (some issues)**
- **Many strip modules (single and double sided) prototyped with 250nm ASICs**
- **Large area stave DC-DC prototype (120cm×10cm) produced and under study**

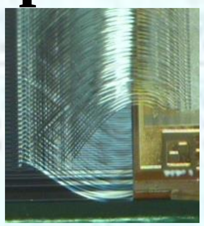


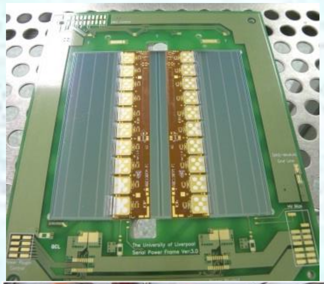
- **Serial and DC-DC powering studied in detail on short versions of 250nm stave**
- **Several other new chips (HCC, HV multiplex, SP, DC-DC,..)**
- **Hybrid/module designs to use these completed**

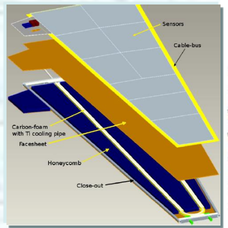
Module with on-board DC-DC converter
(Federico Faccio 16.30 17/2/14)

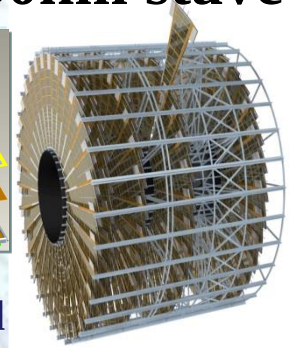


4 row wire bonds









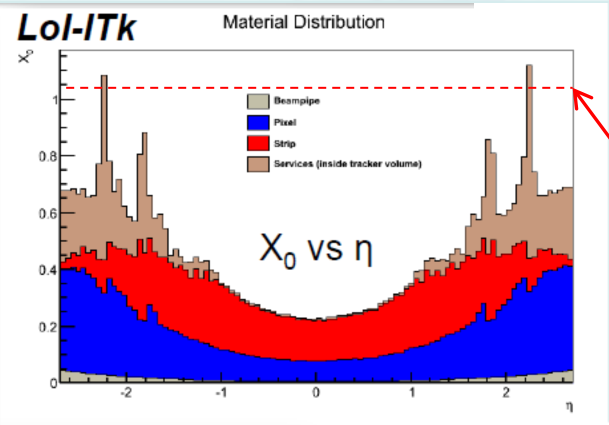
8 double-sided module 250nm super-module

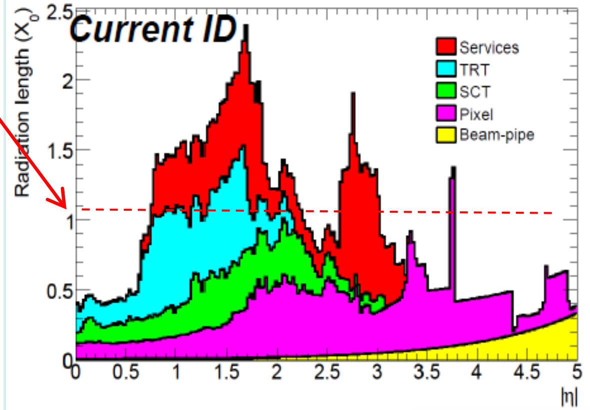
- **Local supports extensively prototyped and further material reduction achieved**
- **Progress in Petal and Stave support designs**
- **End-of-stave card for 130nm developed**

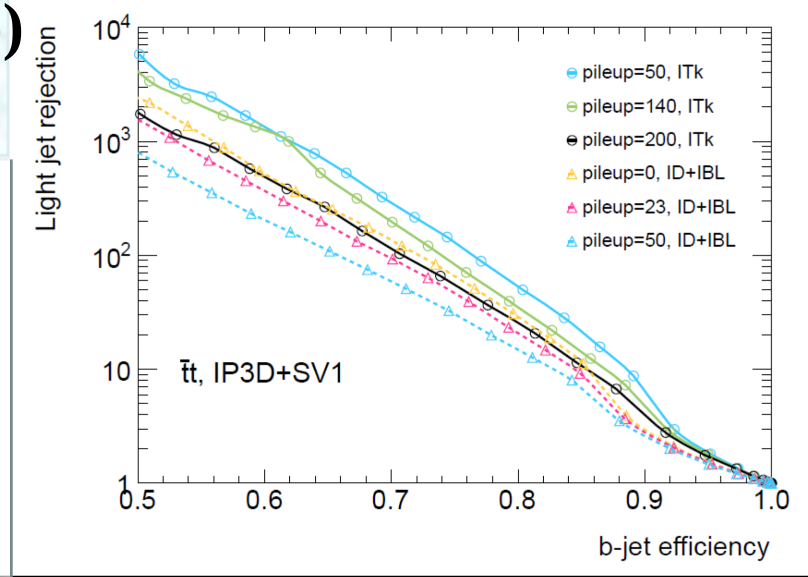
New All-silicon Inner Tracker

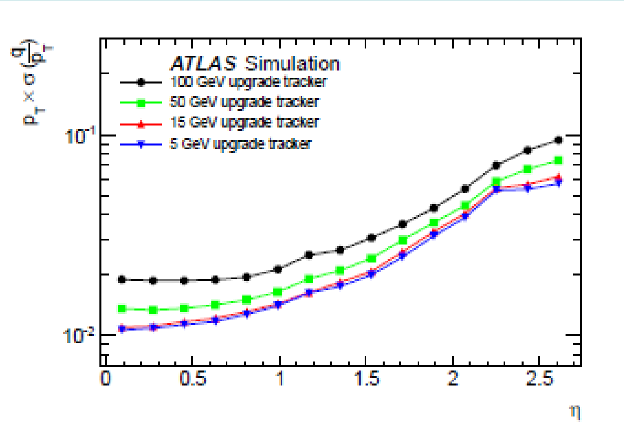
Integration and Performance

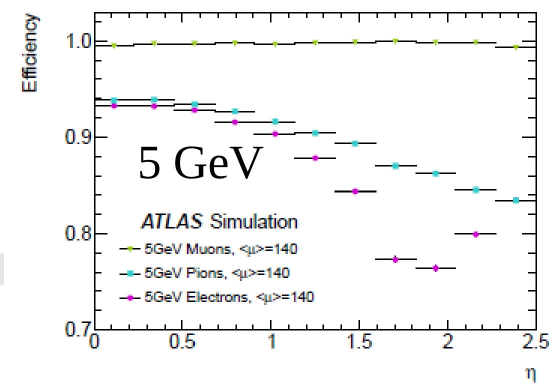
- Cooling, services, integration, removal, installation etc all being studied and key is understanding <u>activation</u> issues
- Optoelectronics (GBT) being working on in common with other experiments
- DAQ/DCS exists for prototype operation but not yet designs for final system
- Detailed performance studies (140 pile-up) and alternative layouts considered

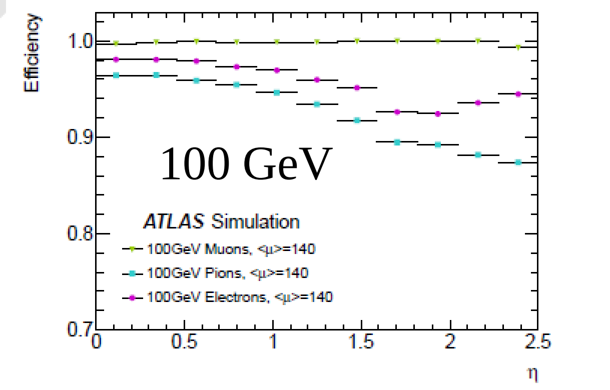












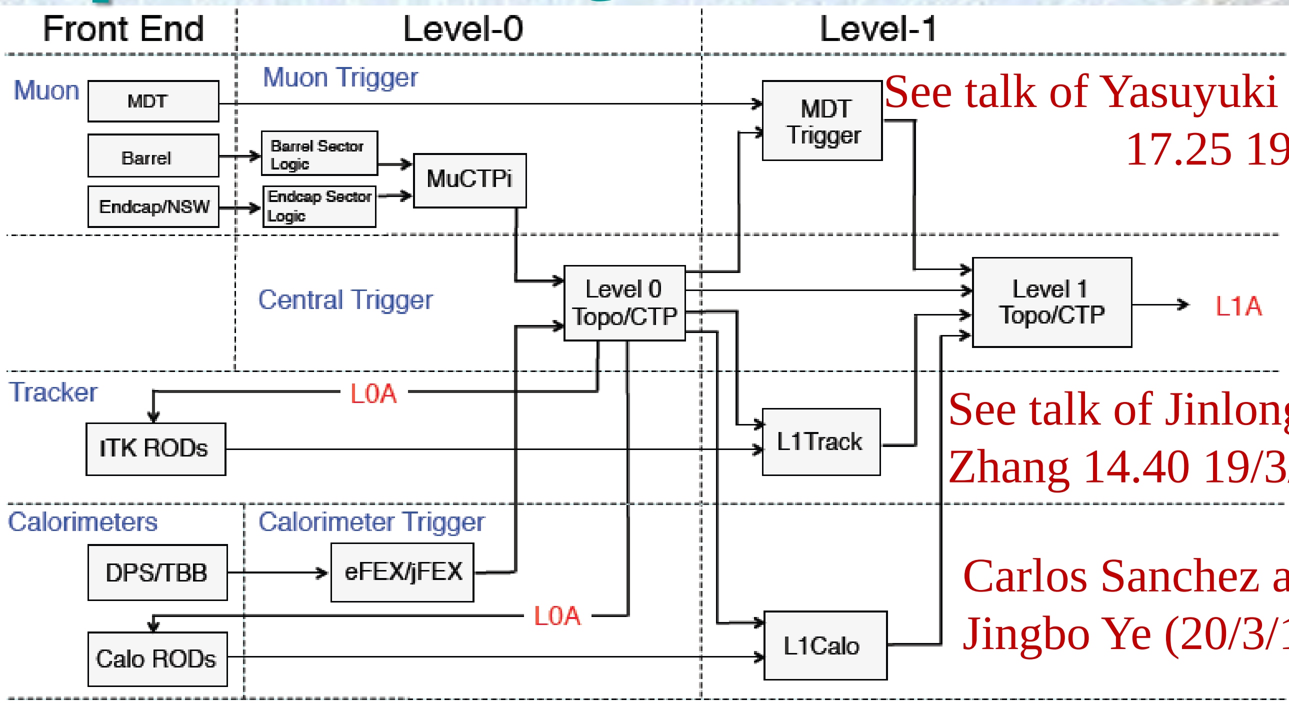
Phase-II Split TDAQ L1 Scheme

Simulation studies show that including a track trigger complements muon and EM triggers

- Improves muon P_T resolution
- Improves EM identification by matching to track

Implemented as 2-level scheme reusing Phase-I L1 trigger improvements for new L0

LOA scheme and buffering fully integrated in ABCn130 ASIC

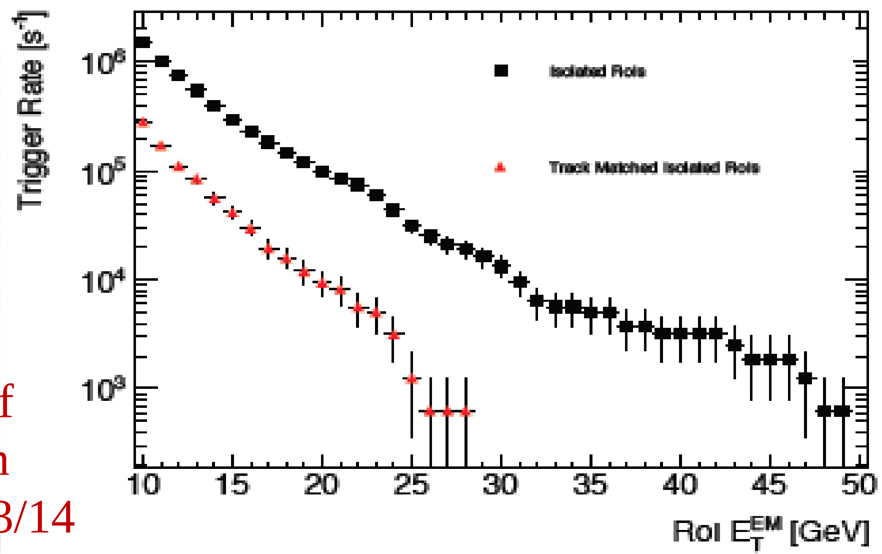


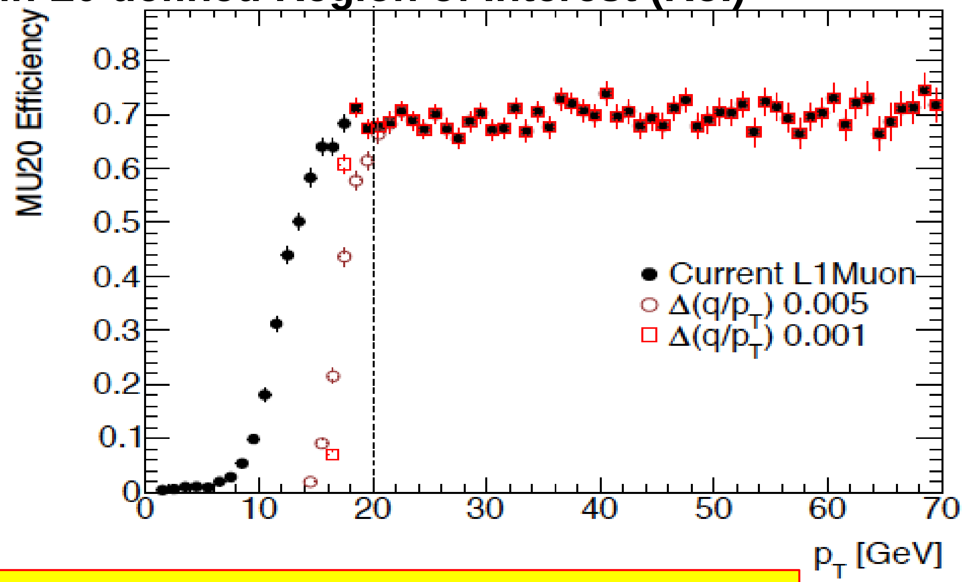
See talk of Yasuyuki Horii 17.25 19/3/14

See talk of Jinlong Zhang 14.40 19/3/14

Carlos Sanchez and Jingbo Ye (20/3/14)

FTK technology could be used to perform fast track fit in L0 defined Region of Interest (RoI)



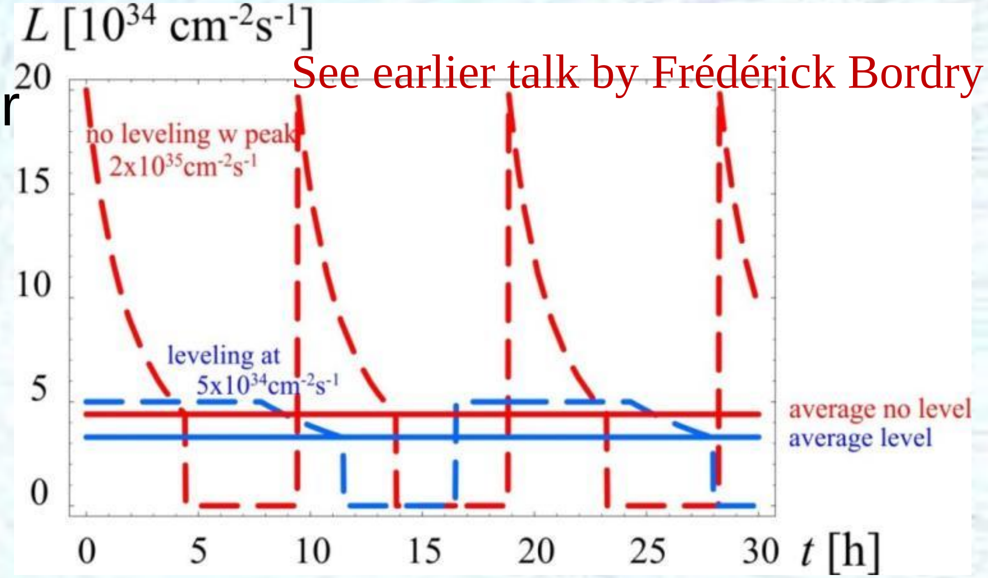


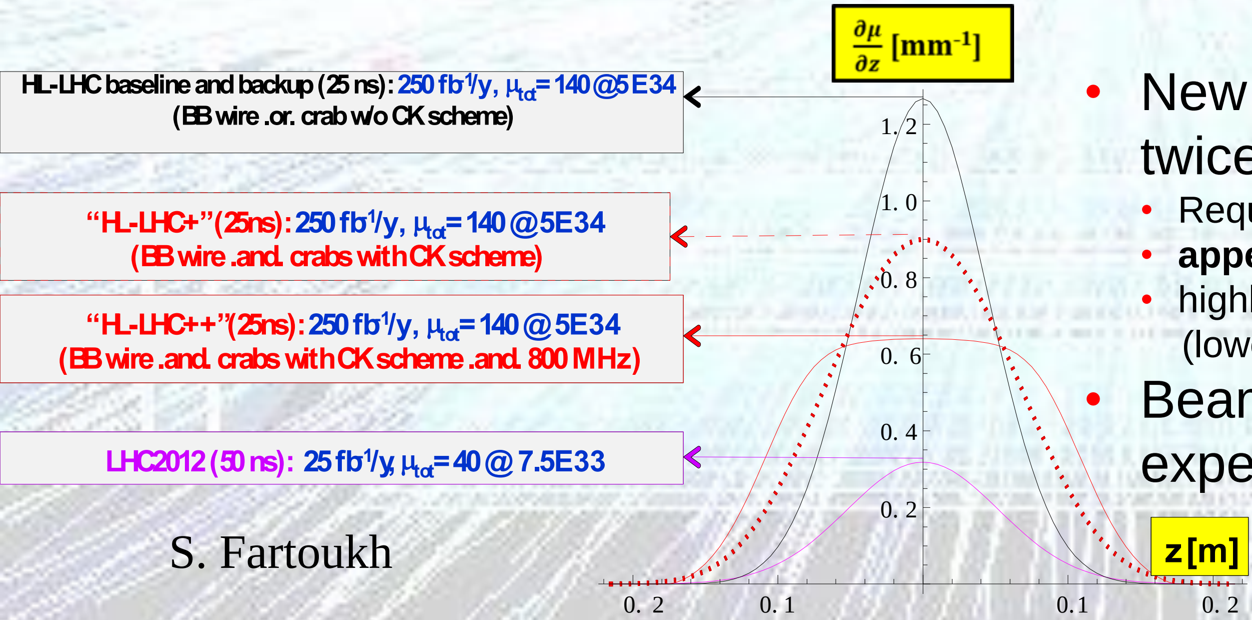
See talk of Ian Brawn 14.30 20/3/14

Note this scheme impacts the electronics in all systems and provides possibilities to exploit the L0/L1 structure to have more extensive information from all sub-detectors at L1

Interface with Accelerator

- In the context of the 3000fb^{-1} by "around 2030", given that levelling at 5×10^{34} cm^{-2}s^{-1} is based on an effective luminosity of 2×10^{35} cm^{-2}s^{-1}, this raises the question of the ultimate acceptable pile-up (average # collisions each 25ns)
- The "crab-kissing" scheme offers an extended interaction region in z with lower pile-up density (better vertex finding)
- The question arises for mean pile-up, <μ>, = 140 (5×10^{34} cm^{-2}s^{-1}, 25ns); if the vertex density could drop from 1.3/mm to 0.7/mm could <μ> be even higher?



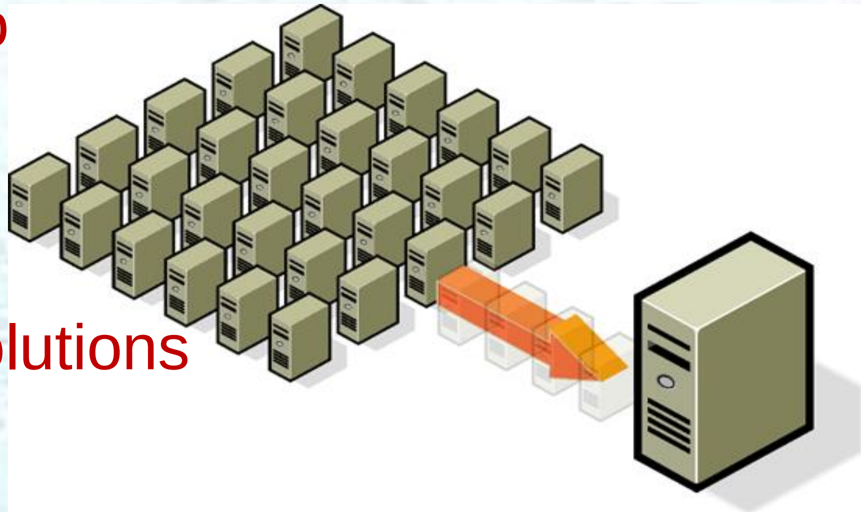


S. Fartoukh

- New Triplets at Interaction Region will have twice present aperture
  - Requires modification of absorbers in the interaction region
  - **appears compatible with small radius beam pipe**
  - highly desirable to anticipate work in LS2 (lower activation - time gained for LS3)
- Beam loss risks (for new crab cavities and experiments)
  - Appear manageable from preliminary studies –
  - More (common) work needed

Computing and Software

- Resources needed for computing at HL-LHC are large - but not unprecedented.
  - However, depending on technology assumptions, flat resources can only provide a factor of 2 to 10 times less CPU power than needed
    - Cloud federation may be a way to build the next Grid
    - Possible usage of specialized track processing (eg use of GPUs as for HLT)
    - Multi-core processors will need major software developments to minimize computing demands
  - The use of more specialized hardware to optimize overall costs implies the need for frameworks able to seamlessly adapt and use much more heterogeneous computing resources
  - CERN WLCG provides a possible framework for development of future solutions
  - All LHC experiments could benefit from better coordinated efforts to develop new programming techniques



Virtualization is the key technology behind the Cloud

Conclusions

- ATLAS has a coherent plan for upgrades through the coming decade to meet the challenges up to and including the HL-LHC era, which are embodied in two LoIs and four TDRs which have been through full LHCC approval
- The understanding of the full physics potential of the HL-LHC is advancing rapidly, with greatly increased activity on both detector and accelerator preparations following the adoption by CERN Council of the Updated European Strategy for Particle Physics, with the HL-LHC as its highest priority
- There are designs for a replacement tracker that should withstand both the pile-up and radiation conditions at the HL-LHC, with performance able to not just fully recover, but also improve on, the current capabilities at low pile-up.
- Major R&D programmes are targeting all the upgrades needed for ATLAS to operate at luminosities far above the initial design requirements.

However, it is critical for these programmes to proceed rapidly that there be adequate resources now to develop optimized, fully cost-effective solutions.

Back-up

CERN-Council-S/106
Original: English
7 May 2013

ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE

CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Action to be taken | *Voting Procedure*

For Approval	**EUROPEAN STRATEGY SESSION OF COUNCIL** 16th Session - 30 May 2013 **European Commission** **Berlaymont Building - Brussels**	Simple Majority of Member States represented and voting

The European Strategy for Particle Physics Update 2013

Having finalised its text by consensus at its Session of 22 March 2013, the Council is now invited to formally adopt the Update of the European Strategy for Particle Physics set out in this document.

1

Higgs working group report

Conveners: Sally Dawson (BNL), Andrei Gritsan (Johns Hopkins), Heather Logan (Carleton), Jianming Qian (Michigan), Chris Tully (Princeton), Rick Van Kooten (Indiana)

Authors: A. Ajaib, A. Anastassov, I. Anderson, O. Bake, V. Barger, T. Barklow, B. Batell, M. Battaglia, S. Berge, A. Blondel, S. Bolognesi, J. Brau, E.Brownson, M. Cahill-Rowley, C. Calancha-Paredes, C.-Y. Chen, W. Chou, R. Clare, D. Cline, N. Craig, K. Cranmer, M. de Gruttola, A. Elagin, R. Essig, L. Everett, E. Feng, K. Fujii, J. Gainer, Y. Gao, I. Gogoladze, S. Gori, R. Goncalo, N. Graf, C. Grojean, S. Guindon, T. Han, G. Hanson, R. Harnik, B. Heinemann, S. Heinemeyer, U. Heintz, J. Hewett, Y. Ilchenko, A. Ismail, V. Jain, P. Janot, S. Kawada, R. Kehoe, M. Klute, A. Kotwal, K. Krueger, G. Kukartsev, K. Kumar, J. Kunkle, I. Lewis, Y. Li, L. Linssen, E. Lipeles, R. Lipton, T. Liss, J. List, T. Liu, Z. Liu, I. Low, T. Ma, P. Mackenzie, B. Mellado, K. Melnikov, G. Moortgat-Pick, G. Mourou, M. Narain, J. Nielsen, N. Okada, H. Okawa, J. Olsen, P. Onyisi, N. Parashar, M. Peskin, F. Petriello, T. Plehn, C. Pollard, C. Potter, K. Prokofiev, M. Rauch, T. Rizzo, T. Robens, V. Rodriguez, P. Roloff, R. Ruiz, V. Sanz, J. Sayre, Q. Shafi, G. Shaughnessy, M. Sher, F. Simon, N. Solyak, J. Stupak, S. Su, T. Tanabe, T. Tajima, V. Telnov, J. Tian, S. Thomas, M. Thomson, C. Un, M. Velasco, C. Wagner, S. Wang, A. Whitbeck, W. Yao, H. Yokoya, S. Zenz, D. Zerwas, Y. Zhang, Y. Zhou

arxiv.org/pdf/1310.8361v1

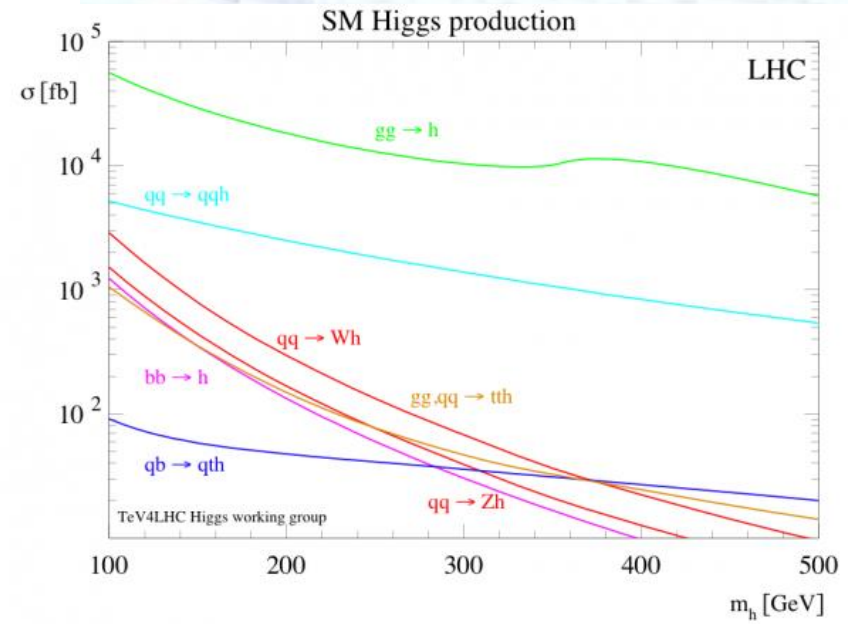
Snowmass 2013

Abstract

This report summarizes the work of the Energy Frontier Higgs Boson working group of the 2013 Community Summer Study (Snowmass). We identify the key elements of a precision Higgs physics program and document the physics potential of future experimental facilities as elucidated during the Snowmass study. We study Higgs couplings to gauge boson and fermion pairs, double Higgs production for the Higgs self-coupling, its quantum numbers and *CP*-mixing in Higgs couplings, the Higgs mass and total width, and prospects for direct searches for additional Higgs bosons in extensions of the Standard Model. Our report includes projections of measurement capabilities from detailed studies of the Compact Linear Collider (CLIC), a Gamma-Gamma Collider, the International Linear Collider (ILC), the Large Hadron Collider High-Luminosity Upgrade (HL-LHC), Very Large Hadron Colliders up to 100 TeV (VLHC), a Muon Collider, and a Triple-Large Electron Positron Collider (TLEP).

Table 1-15. *Dominant Higgs boson production cross sections at various e^+e^- collision energies. Cross sections are calculated [74] including initial-state radiation, but not beamstrahlung effects, for unpolarized beams and the enhancement due to polarized beams ($P(e^-, e^+) = (-0.8, 0.3)$ for 250, 350, and 500 GeV, baseline for the ILC; $(-0.8, 0.2)$ for 1000 GeV, baseline for the ILC; $(-0.8, 0.0)$ for 1.4 and 3.0 TeV, typical for CLIC.)*

Cross sections in fb $m_H = 125$ GeV							
Mode	$\sqrt{s}$ (GeV) =	250	350	500	1000	1400	3000
ZH	unpolar.	211	134	64.5	16.1	8.48	2.00
	polar.	318	198	95.5	22.3	10.0	2.37
$\nu_e\bar{\nu}_e H$	unpolar.	20.8	34.1	71.5	195	278	448
	polar.	36.6	72.5	163	425	496	862
$e^+e^- H$	unpolar.	7.68	7.36	8.86	20.1	27.3	48.9
	polar.	11.2	10.4	11.7	24.7	32.9	56.5



HL-LHC matrix: equipment, time, cost

LS2 - 1 y (14 months access)		**LS3 - 2 y (26 months access)**					
	PIC		**US1**	**US2**	**Cost (MCHF)**		**In kind**
	LS2	*LS3*	*LS3*	*LS3*			**in part**
P4 new cryoplant	Y				15		
H SC link P7	Y				5		
IR (IT,D1, TAS)	%	Y			210		**YES**
P1-P5 cryoplant	%	Y			75		
SC link (EPC&DFBX on surface)	%	Y			40		
Collimators IR		Y			10		
Collimators MoGr	%	Y			15		
Collimators for INJ &TCLA Q4/Q5)		Y			5		
DS cryocoll.(11T) P2	Y				20	395	
LRBB comp.wires			Y		10		
DS cryocoll.(11T) P7			Y		25		
DS cryocoll (11 T) P1-P5			Y		40		
SC link (EPC&DFB on surface) for MS			Y		20	95	
MS new layout (P1-P5) and Q5 in P6				Y	30		**YES**
Machine & Magnet QPS (Availability)				Y	25		
CC cavity P1-P5				Y	95		**YES**
SCRF 2nd Harmonic				Y			
Crystal Coll				Y ?			**YES ?**
Halo control (e-lens)				Y ?			**YES**
High Band Feedback System				Y ?		150	
Studies					10		
Other systems (Studies, Vacuum, Diagnostics, Remote handling					30		
Infrastructure, Logistics, Integration,Installation HWC					130	170	
Total					**810**	**810**	

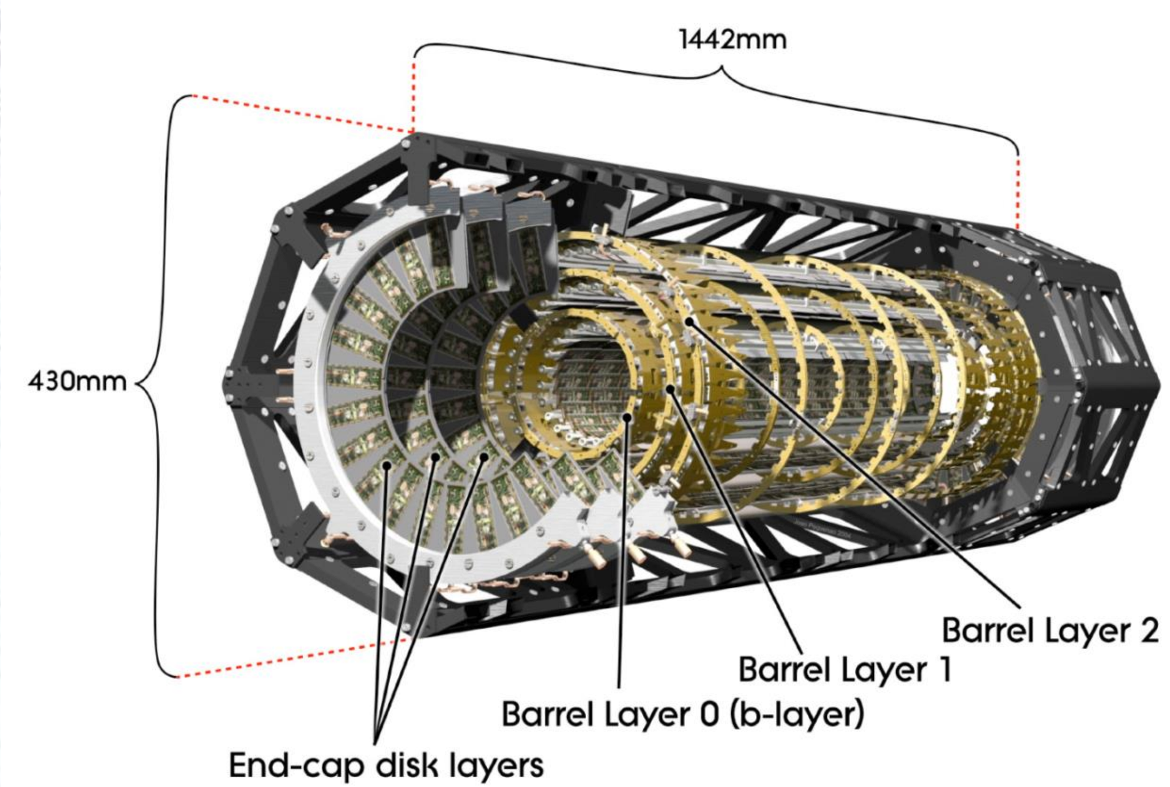
High Luminosity LHC

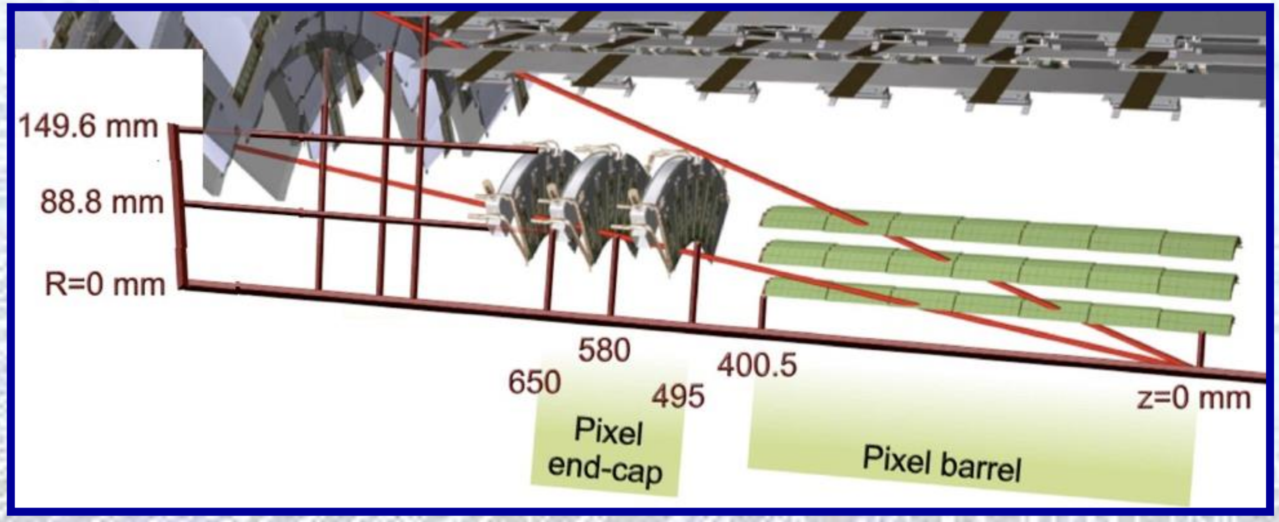
Conclusions

- **The upgrade is robust for 250 (300) fb^{-1}/y**
  - Means to maintain or increase availability are under study
- **All hardware is more robust for 3000 fb^{-1} than it is today for 300 fb^{-1}**
- **Design Study finished by 2015 with the TDR**
- Margins are there and – once established and proved:
  - Possible to decrease pile-up density and/or increase to 350 fb^{-1} ($7 \cdot 10^{34}$ of L_{level}) thanks **to crab kiss (CC in II & ⊥ planes) and β^* of 10 cm (large aperture IT & ATS)**
  - **Increase data collection to > 4000 fb^{-1}??**

High Luminosity LHC

The ATLAS Pixel Detector

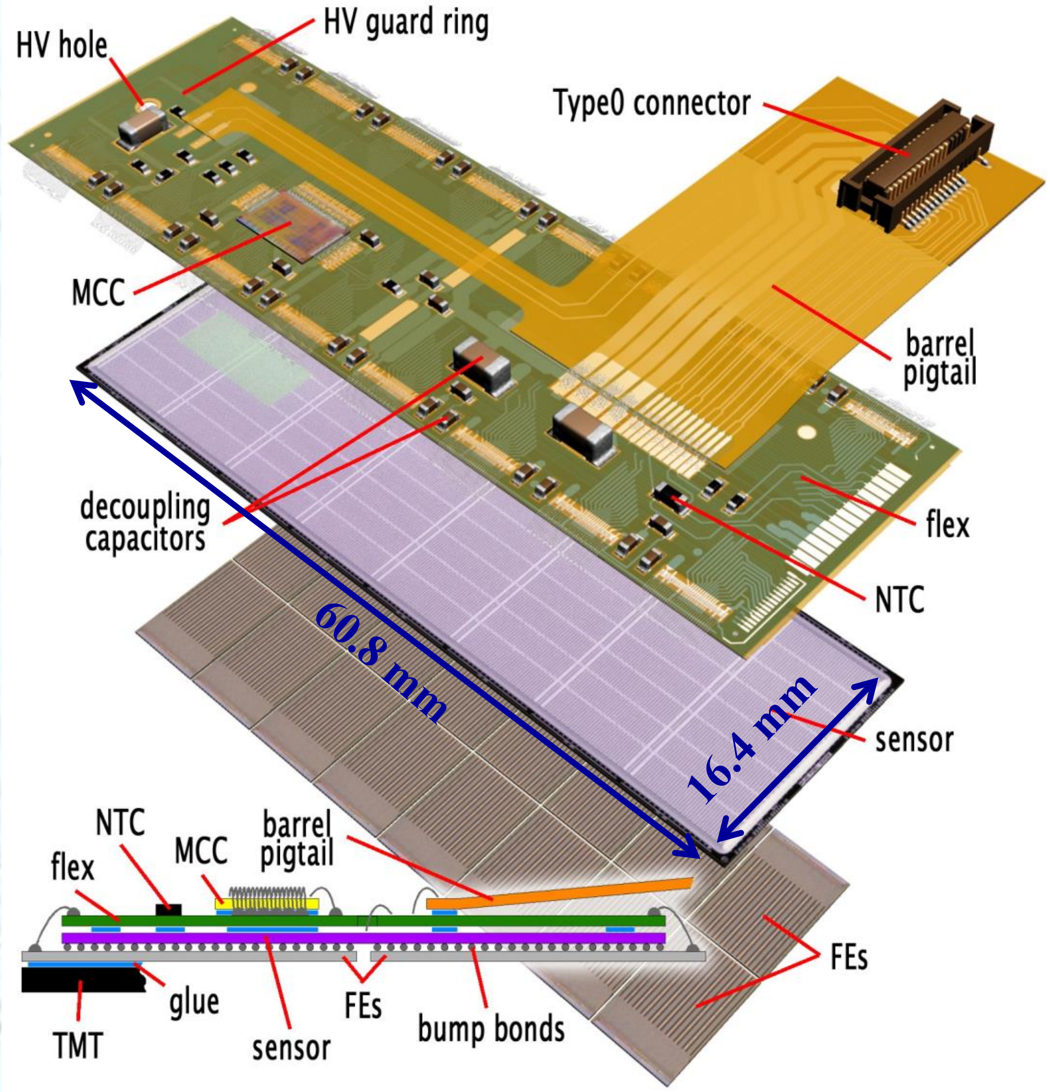




- **Three barrel layers:**
  - R= 5 cm (B-Layer), 9 cm (Layer-1), 12 cm (Layer-2)
  - modules tilted by 20º in the Rϕ plane to overcompensate the Lorentz angle.
- **Two endcaps:**
  - three disks each
  - 48 modules/disk
- **Three precise measurement points up to |η|<2.5:**
  - RΦ resolution:10 μm
  - η (R or z) resolution: 115 μm
- 1456 barrel modules and 288 forward modules, for a total of 80 million channels and a sensitive area of 1.7 m^2.
  - Environmental temperature about -10 ºC
  - 2 T solenoidal magnetic field.

Module Overview

- **Sensor**
  - 47232 n-on-n pixels with moderated p-spray insulation
  - 250 μm thickness
  - 50 μm (RΦ) × 400 μm (η)
  - 328 rows (x_{local}) × 144 columns (y_{local})
- **16 FE chips**
  - bump bonded to sensor
- **Flex Hybrid**
  - passive components
  - Module Controller Chip to perform distribution of commands and event building.
- **Radiation-hard design:**
  - Dose >500 Gy
  - NIEL >10^{15} n_{eq}/cm^2 fluence

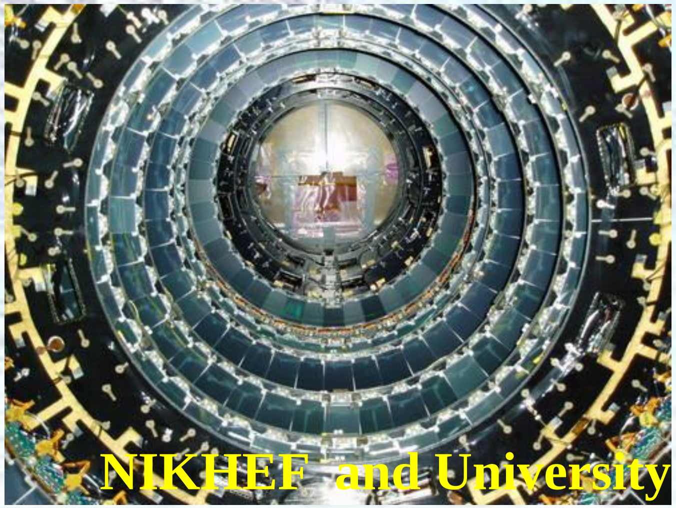


ATLAS Silicon Strip Detectors

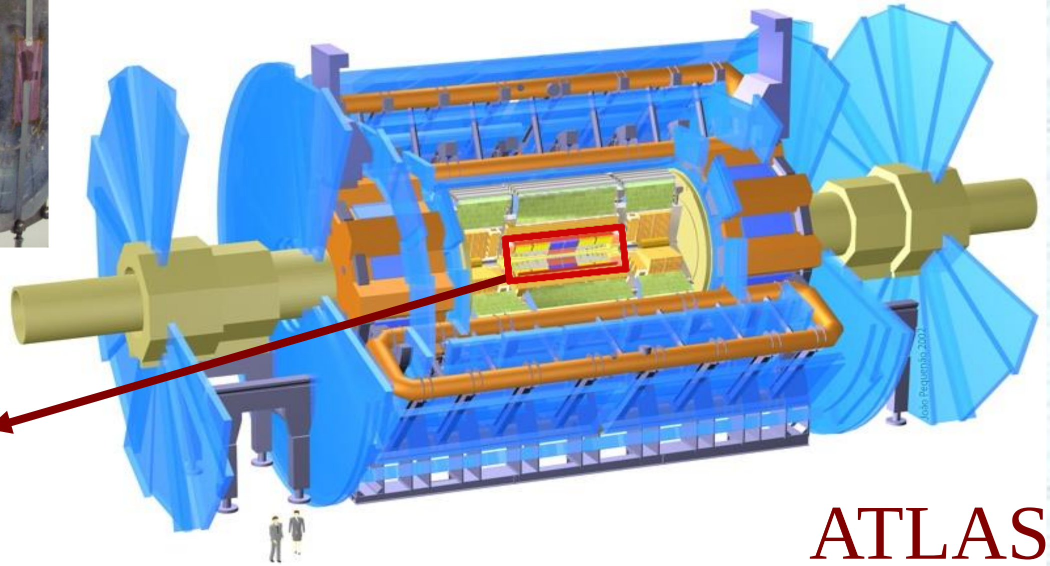
4 barrels (2112 modules) and 2×9 disc end-caps (1976 modules)

61m^2 of silicon micro-strip detectors

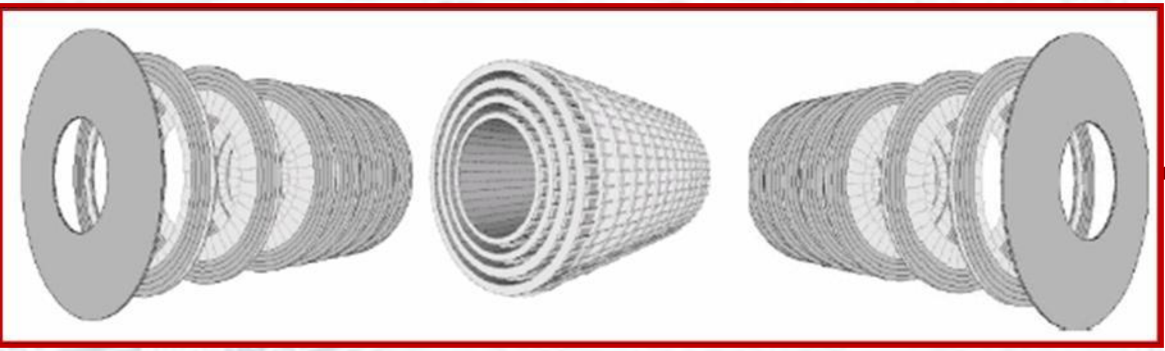
~20,000 separate 6cm×6cm sensors

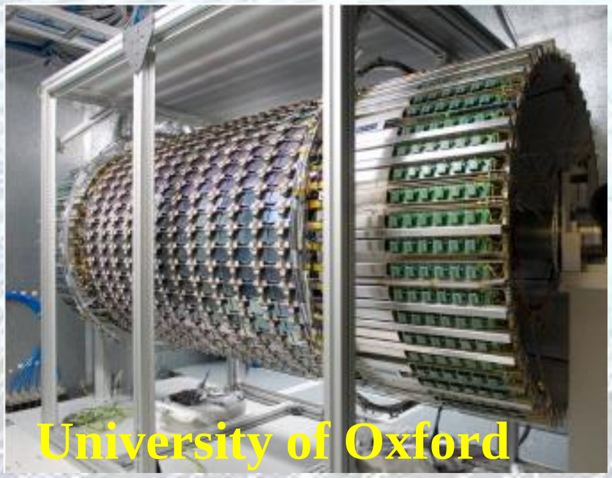


NIKHEF and University of Liverpool



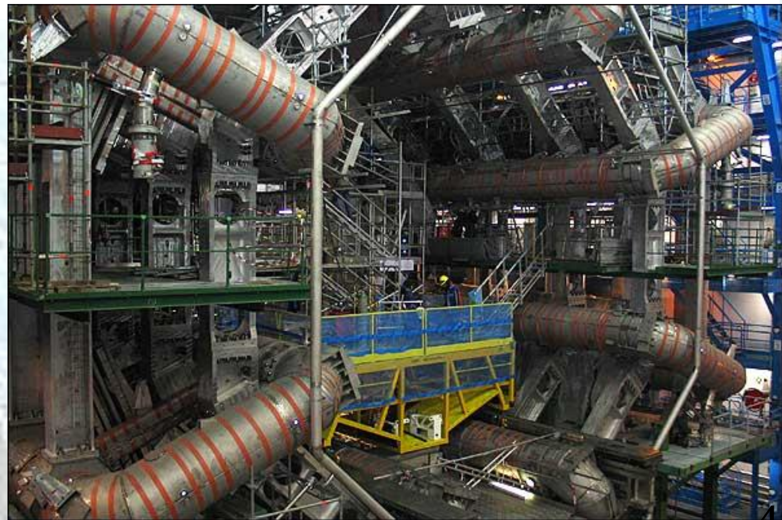
ATLAS





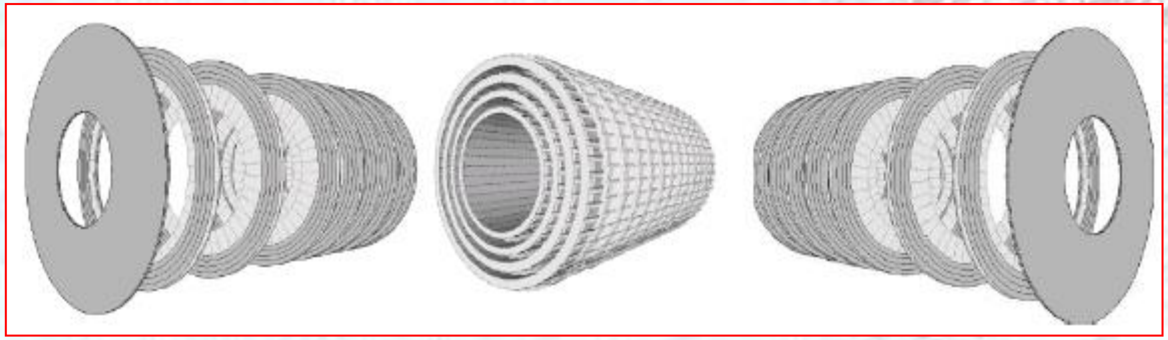
University of Oxford

CERN

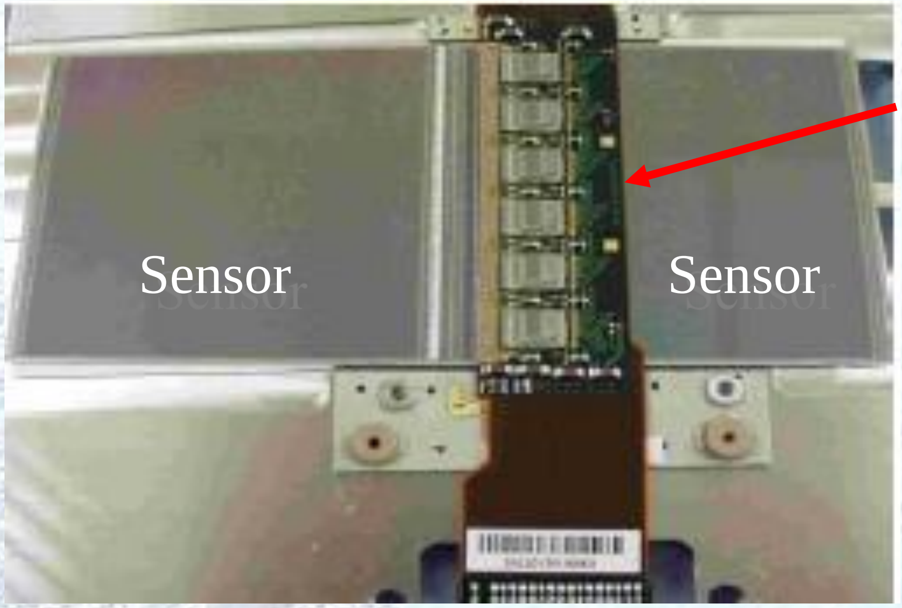


Current SCT ATLAS Module Designs

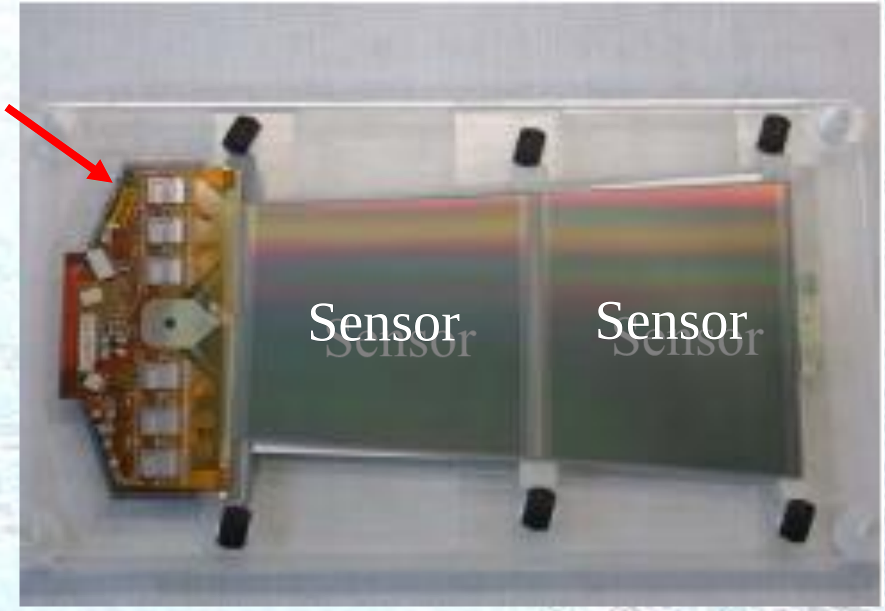
ATLAS Tracker Based on Barrel and Disc Supports



Effectively two styles of double-sided modules (2×6cm long) each sensor ~6cm wide (768 strips of 80μm pitch per side)



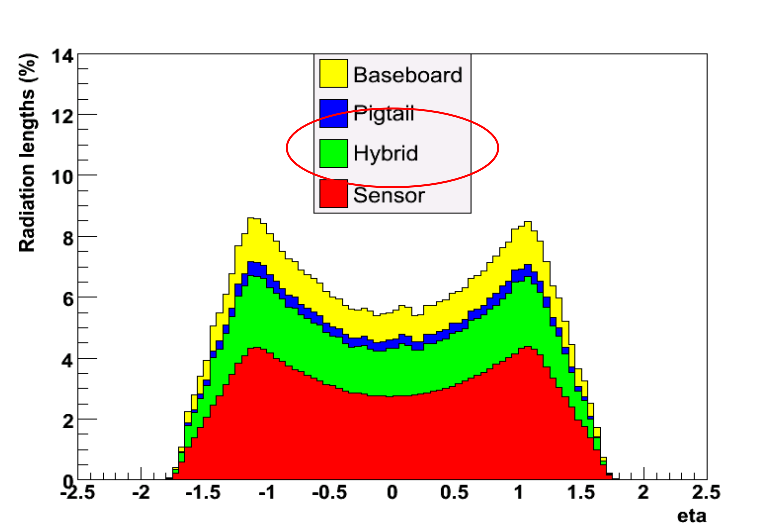
Hybrid cards carrying read-out chips and multilayer interconnect circuit



Barrel Modules
(Hybrid bridge above sensors)

Forward Modules
(Hybrid at module end)

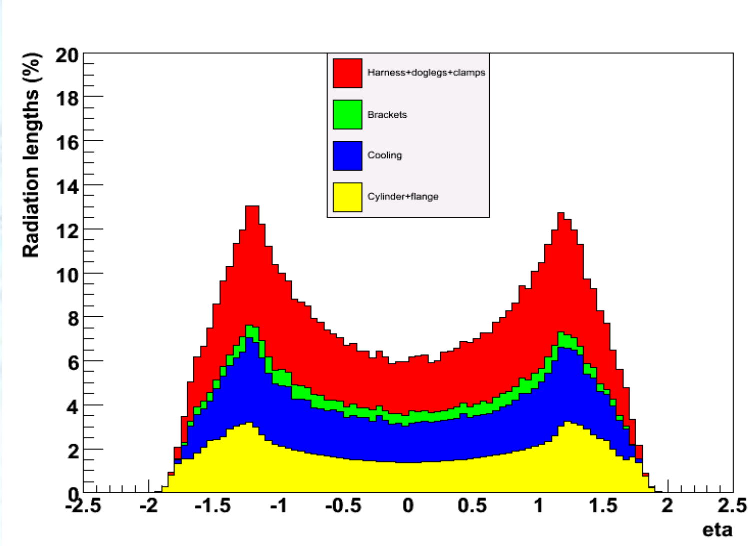
Current Silicon Microstrip (SCT) Material



Current Silicon Tracker
(4 barrel strip layers)

Module Material

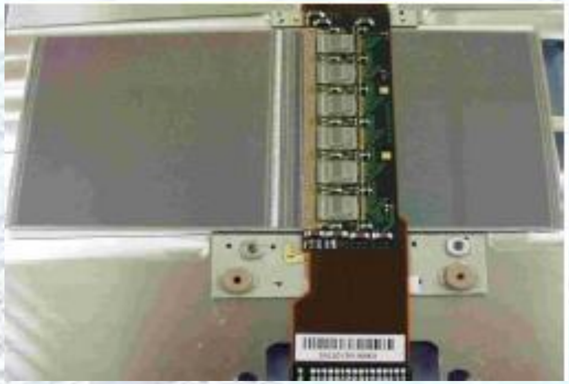
Support Material



Old ATLAS Barrel Module

12 ASIC of 300µm thickness for double-sided module read-out

(*ie* just 6 read-out chips per side)



"The barrel modules of the ATLAS semiconductor tracker". Nucl.Instrum.Meth.A568:642-671,2006.

Table 1
Radiation lengths and weights estimated for the SCT barrel module

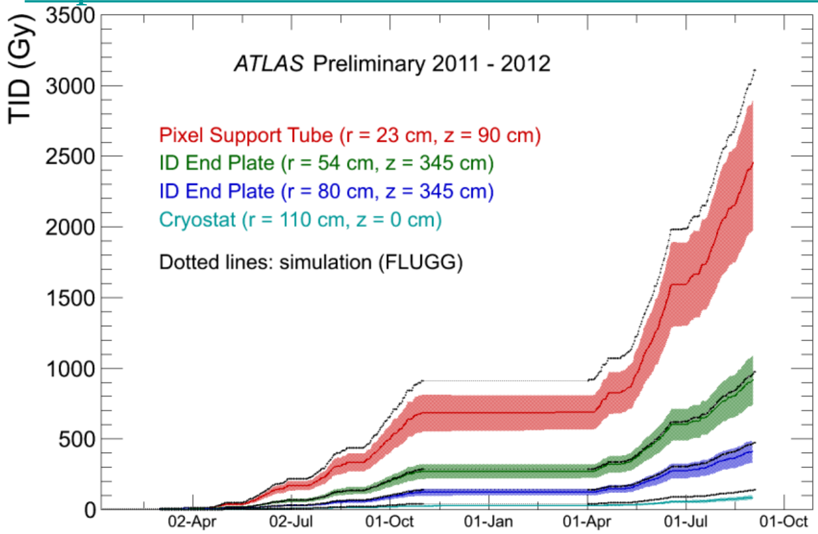
Component	Radiation length [%Xo]	Weight [gr]	Fraction [%]
Silicon sensors and adhesives	0.612	10.9	44
Baseboard and BeO facings	0.194	6.7	27
ASIC's and adhesives	0.063	1.0	4
Cu/Polyimide/CC hybrid	0.221	4.7	19
Surface mount components	0.076	1.6	6
Total	1.17	24.9	100

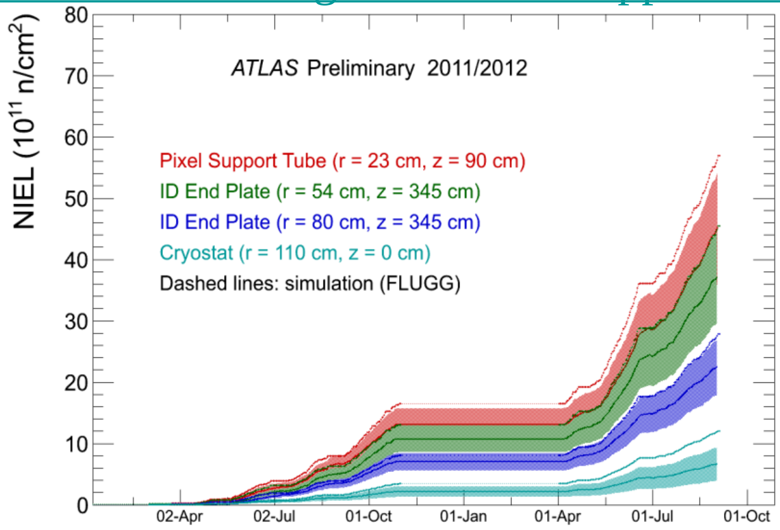
New ATLAS sLHC-Tracker Module will have 80 ASICs in two hybrid fingers for just one-sided read-out

Hybrid area per module roughly ×2 at HL-LHC: much higher R/O granularity

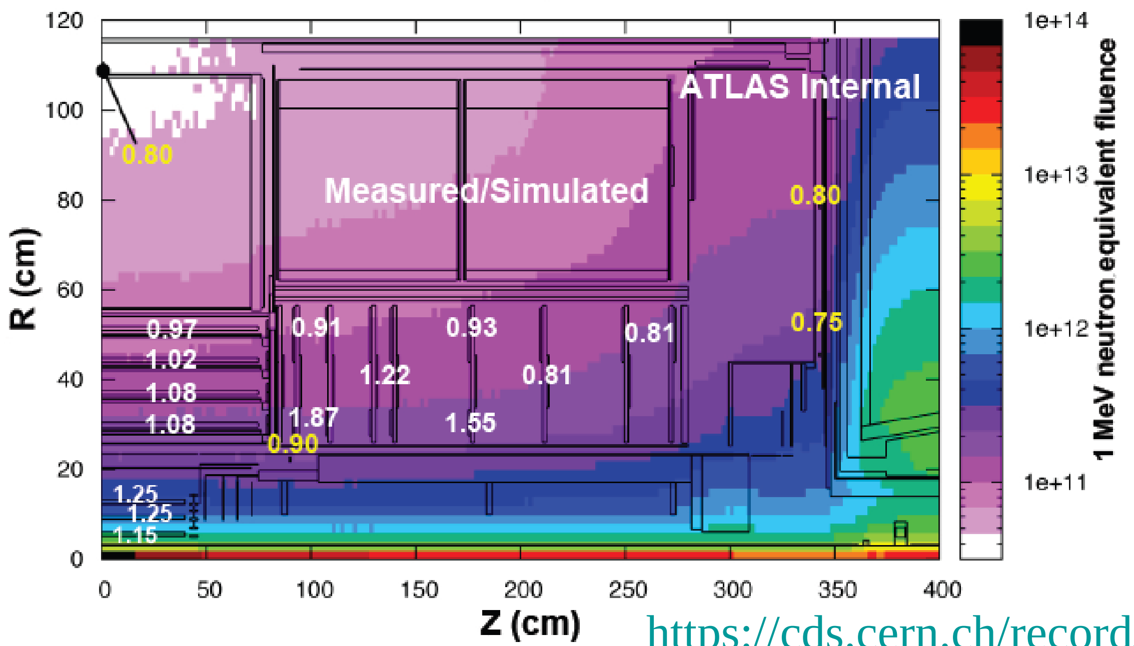
Current Detector Radiation Simulation

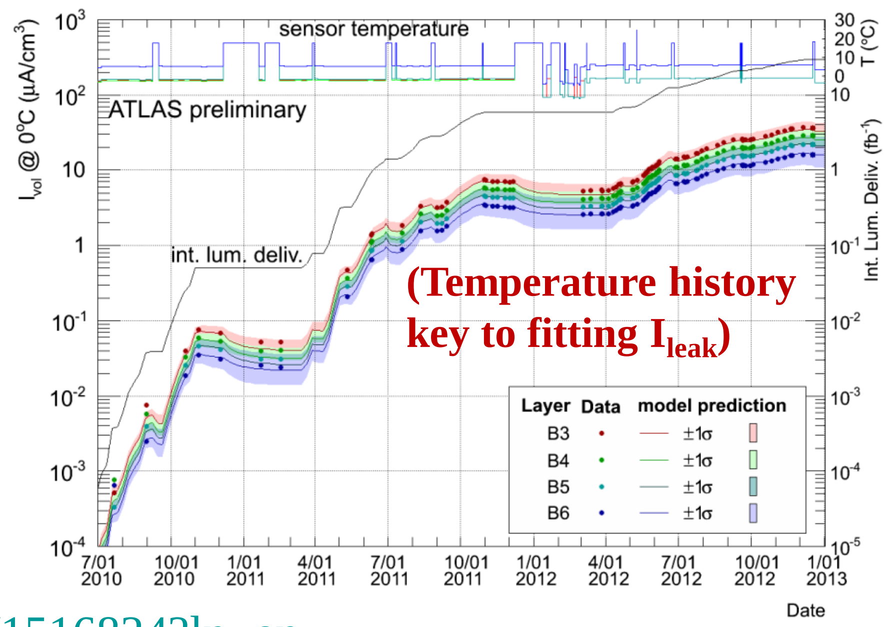
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SCTPublicResults#Figures
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsPixel#Radiation_damage_plots
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/InDetTrackingPerformanceApprovedPlots#Alignment





Simulation results fit with data to much better than a factor of 2
(and safety factor of 2 was assumed in dose specifications)



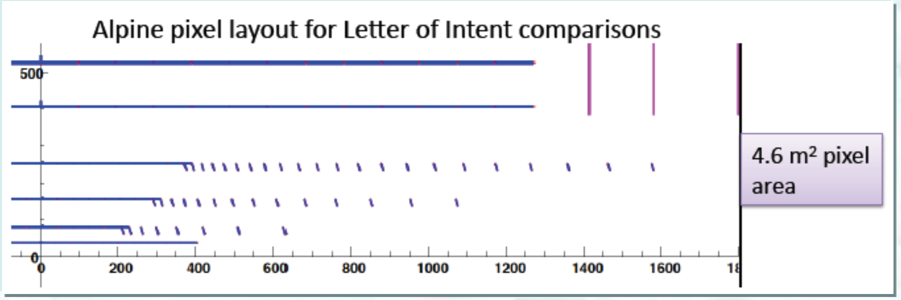


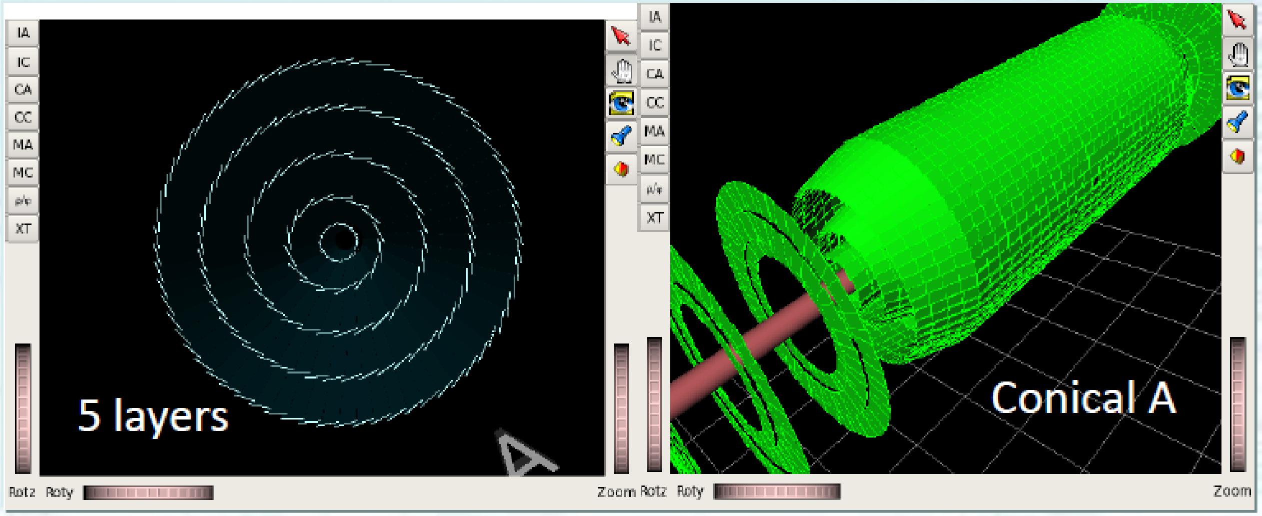
(Temperature history key to fitting I_{leak})

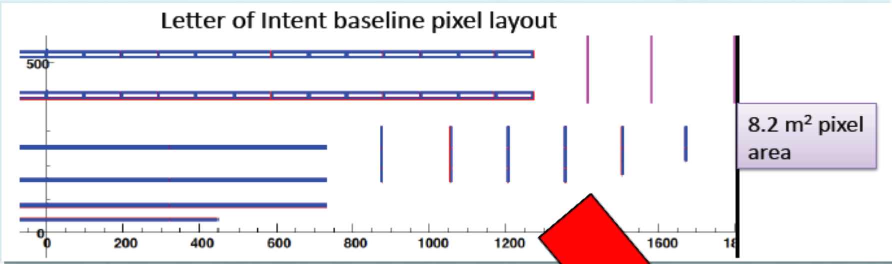
https://cds.cern.ch/record/1516824?ln=en

New All-silicon Inner Tracker

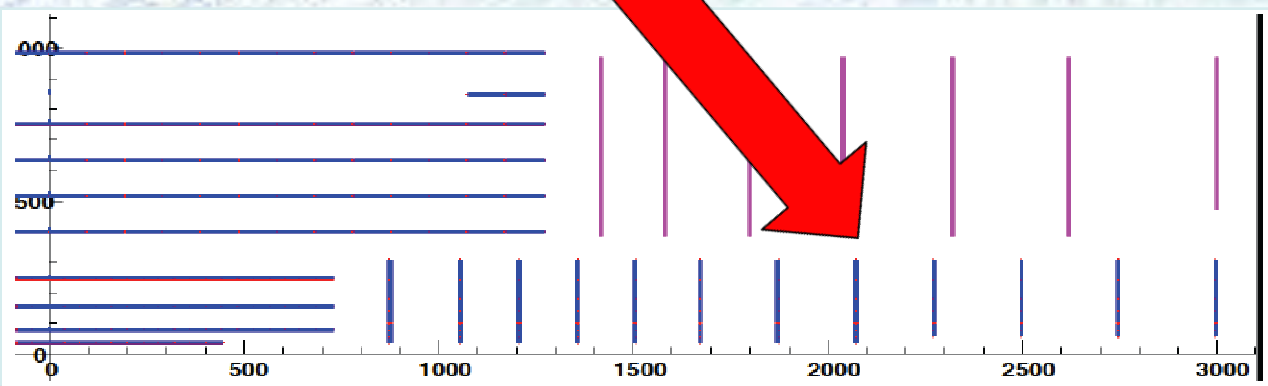
- **Alternative layouts being considered which include either a further pixel layer or inclined pixel sensors attached to the same barrels (Alpine layout)**

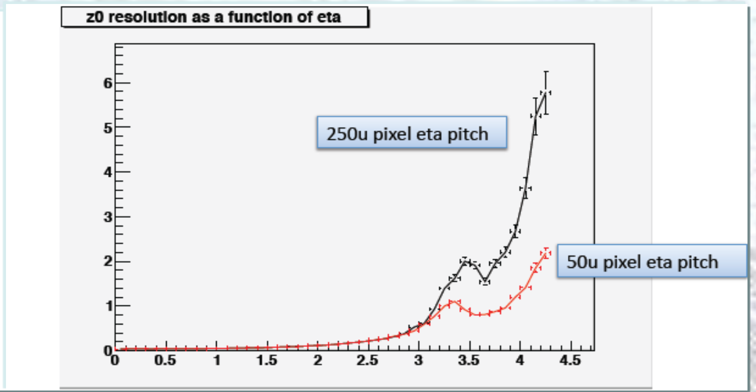




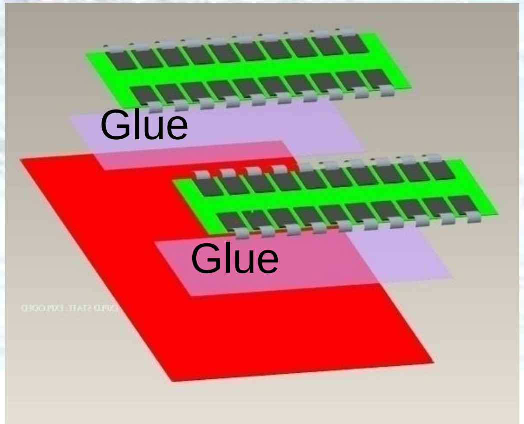


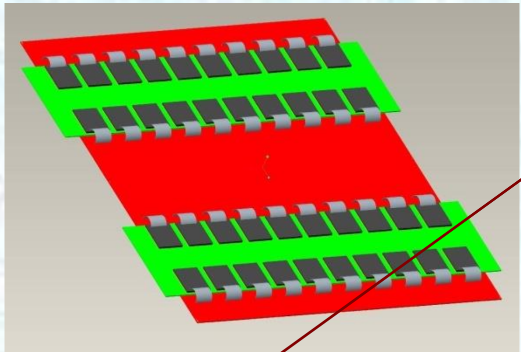
Extended η coverage needs more detailed physics motivation

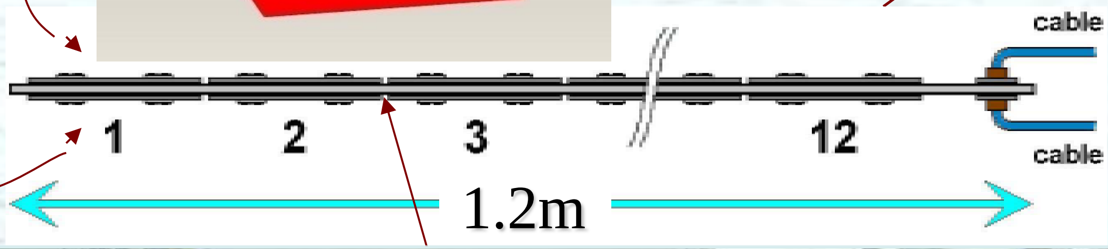


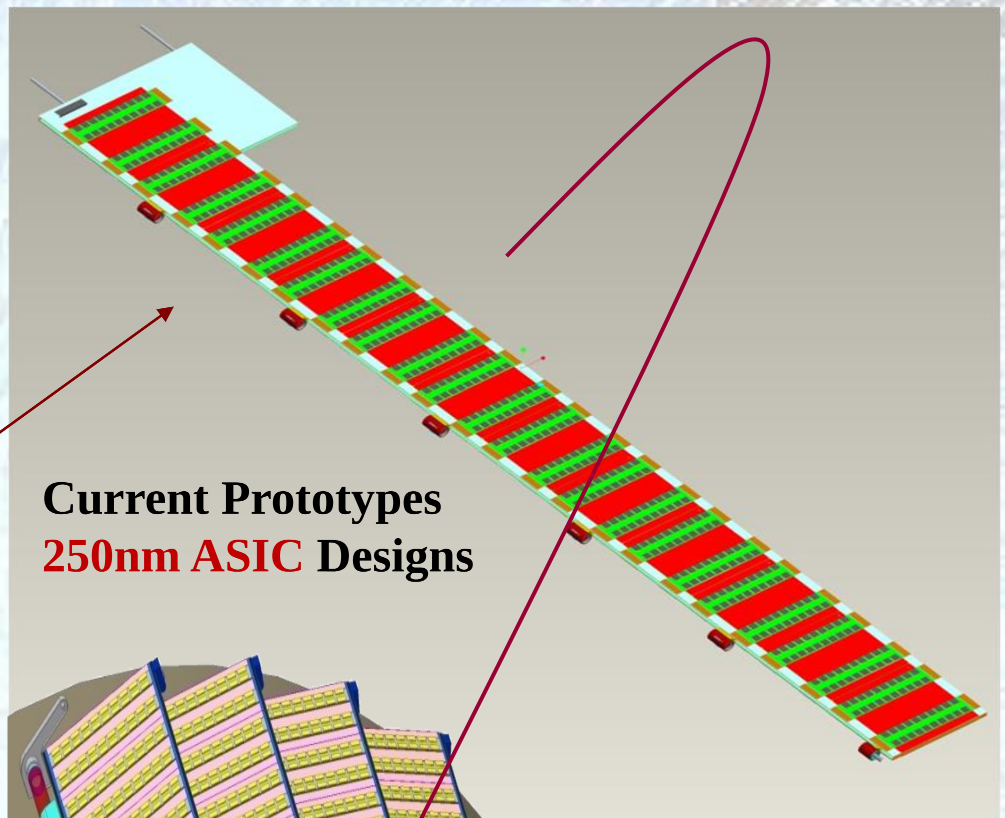


Stave: Hybrids glued to Sensors glued to Bus Tape glued to Cooling Substrate

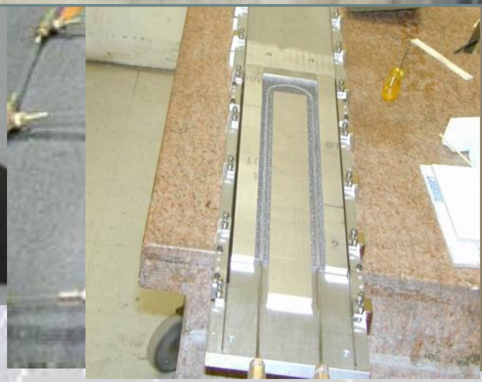


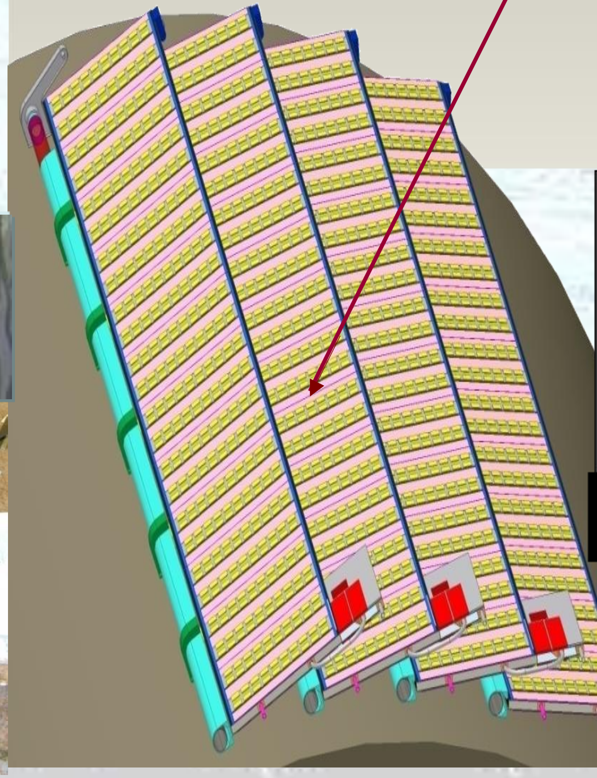


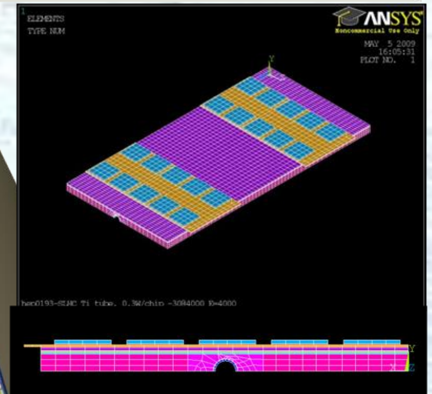


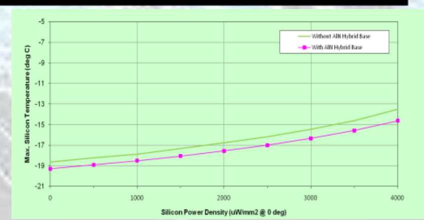


Current Prototypes
250nm ASIC Designs

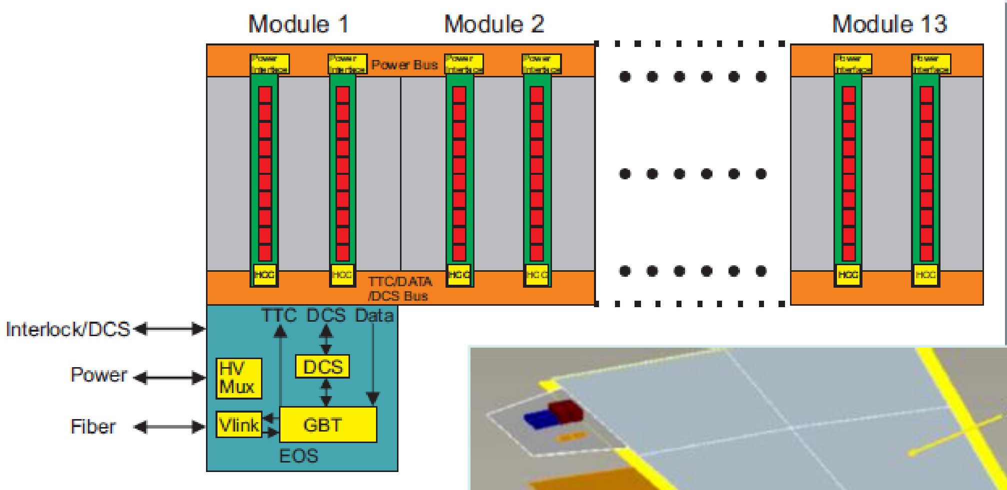


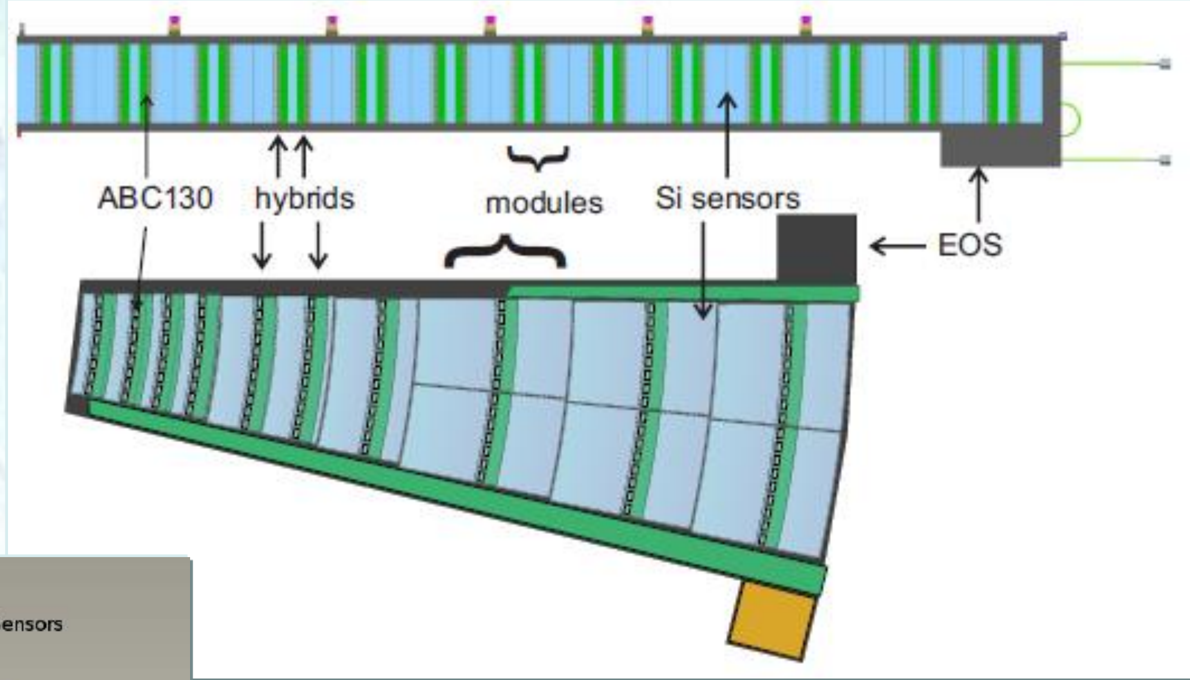






Stave: Hybrids glued to Sensors glued to Bus Tape glued to Cooling Substrate





Module, Stave and Petal concepts with 130nm ASIC: 256 channels so each row of ASICs address two rows of strips