ATLAS Upgrade Projects

Brief Overview of ATLAS Upgrade
Schedule
New Inner Detector
R&D Projects
Reminder of ATLAS 3D Needs

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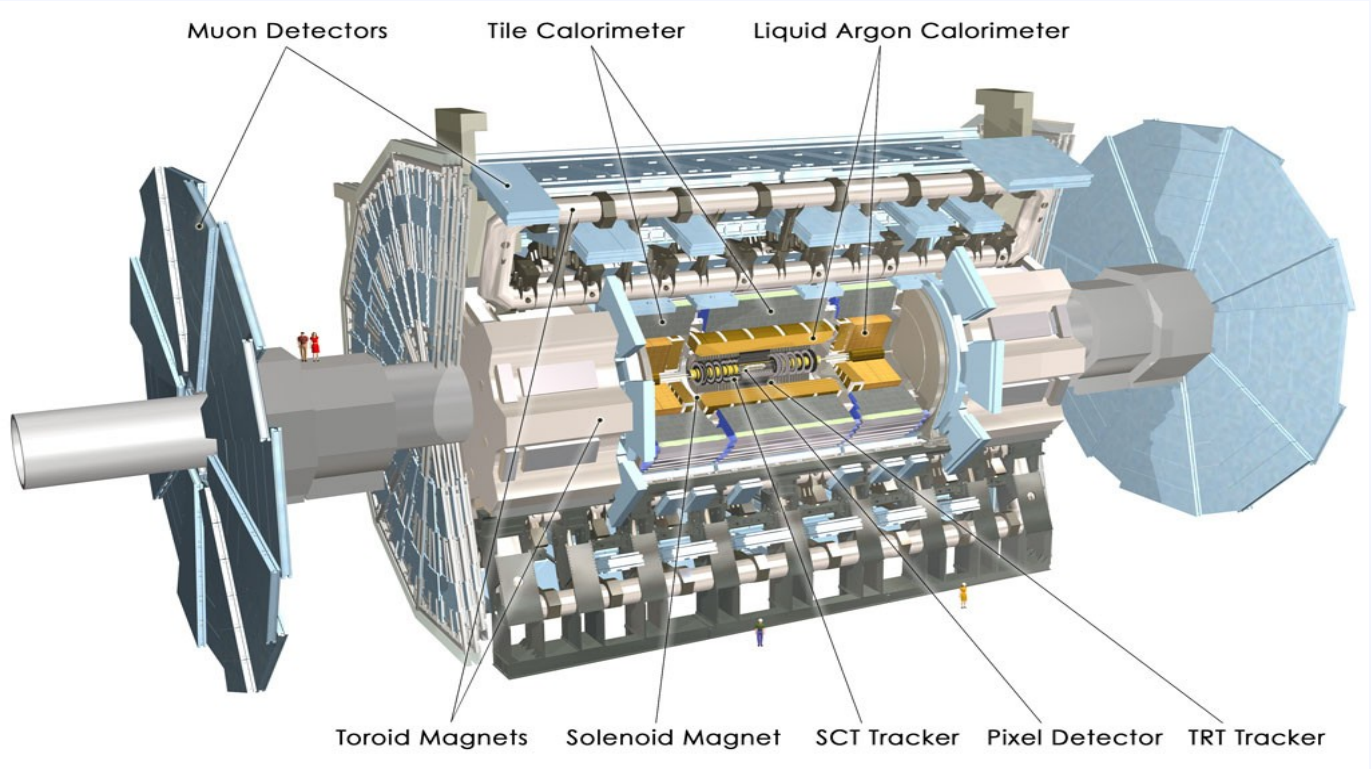


Upgrade Overview

- Some physics channels have very low event rates so need high integrated luminosity; also gives higher mass reach, etc.
  - Desire for higher luminosity from Atlas and CMS
- Machine can increase luminosity (in steps) by a factor ~10: “sLHC”
  - Detectors have to be upgraded to cope
- In any case some parts of detectors and machine will have reached end-of-life (radiation damage)
  - Replacement of focussing magnets for IP and various parts of detector necessary
- Aim of Atlas Upgrade:
  - Keep as much as possible of original upgrade while maintaining similar sub-system performance at the sLHC rate
- Expected conditions: peak of 400 pile-up events per 50 ns bunch crossing; high vertex density in z (~30 mm sigma-z IP)
    - Very high track density in inner detector; high pile-up in calorimeters

What changes...major items:

- Muon system: if backgrounds are as predicted, only chambers in the forward region need to be changed to other higher-rate technologies. Other chambers can work with e.g. new higher band-width electronics
- Tiles: The scintillators only degrade slowly with radiation, so the basic hadron calorimeter will not change. Limited to new electronics.
- LAr: Mostly OK - rad hard technology. But forward calorimeter may have many problems - under study (protvino testbeam); and probably something new for FCAL.
- ID: Radiation damage to several regions of pixels and strips. High occupancy would occur with current tracker, giving low efficiency and high fake track rate. **Renew the whole ID**.
- Trigger: Baseline is to keep accept rates same at each level (still means ~10x more data transmission and higher rejection rates). Under study if there are better strategies. Also look at fast track trigger.

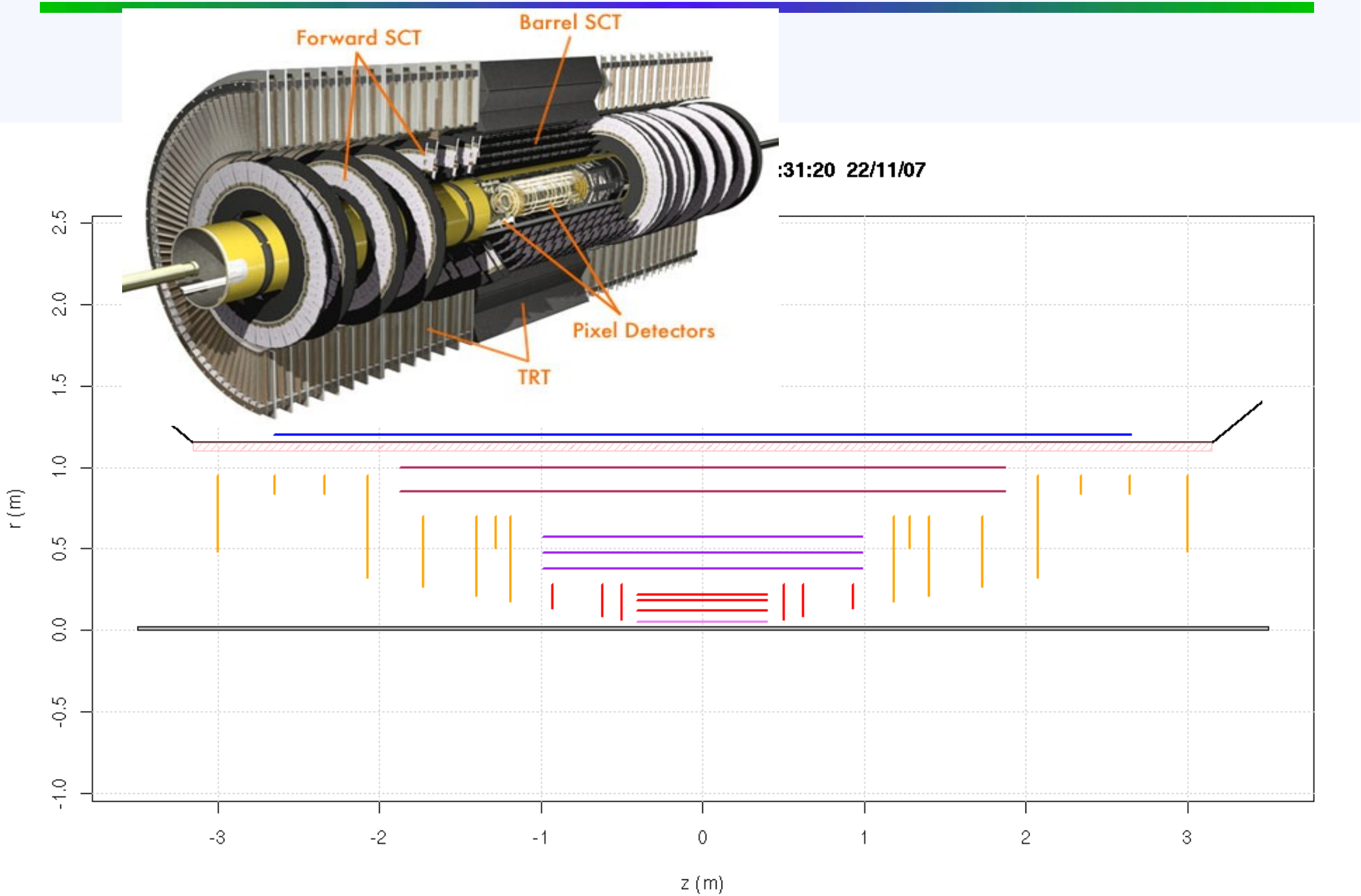
Schedule

- Driven by development of LHC luminosity
- IP magnets and ID reach radiation damage limit at 700 fb-1
  - Could be as early as 2014, but more realistically 2015 and could be later
- We have to aim to be ready for earliest possible, while staying flexible if we find we have more time
  - Will be much clearer once we have seen how the LHC starts up (2008)
- Current goal is to install new ID in 2015 (no data taking) and be ready for data taking in 2016 (Much shorter than ILC)
  - Very ambitious; the current ID took much longer. If luminosity builds up slower, we should be ready to take advantage of the extra time
  - Summary:
    - 2010: TDR (concepts fixed). R&D winding down (~3 years).
      - Pixel build time may not be so long as strips, so may have more time available for R&D
    - Procure and assemble parts 2011 - 2013
    - Surface assembly of large structures 2012 - 2014
    - Install in pit 2015
    - Data taking 2016

New ID

- All Silicon: the current straws cannot cope with the sLHC rates.
- Long strips (~100 mm) in place of TRT; short strips (~25 mm) in place of current SCT strip detector; pixels with one extra layer.
- B-layer:
  - Current n-in-n sensors not rad-hard enough for b-layer at ~3 cm radius
    - Investigate other technologies - 3D sensors, thin-Si, diamond, Gossip
- Currently we have a “Strawman” layout (easy to rearrange)
  - 18,000 strip sensors of 1280 strips; 160 M pixels.
- Conditions:
  - Very high hit rate (>10^8/cm^2), high radiation damage (100 MRad, 10^{16} n/cm^2)
    - Need rad-hard, SEU-hard electronics
  - Inaccessible and difficult to maintain
    - High reliability
  - Tracking in high density needs very high efficiency and granularity for good reconstruction; **small pixels in z for vertex discrimination**
    - Very low dead-channel rate

Old ID to New Strawman



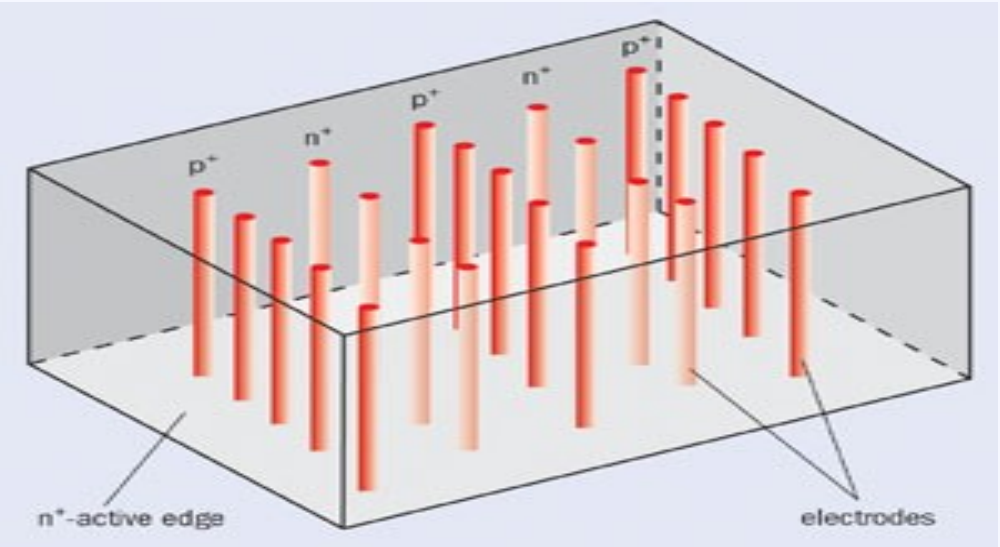
Organisation of R & D Projects

- ATLAS has in place an Upgrade Steering Group and an Upgrade Project Office.
  - These organise several working groups (electronics, engineering, cooling…)
- Plus a system of R&D proposals with approval process
  - Proposal review: Consider if proposals are relevant to ATLAS
  - Steer them to be efficient, avoid duplication of effort, encourage collaboration
  - Invite/encourage proposals where needed
  - 23 proposals received so far, 7 fully approved, most of the rest headed for approval (often after some interaction with the proponents)
  - Mostly short term, basic research
  - Useful for funding for many researchers
  - People/Groups/Institutes welcome to join the Projects
    - Contact me or the project spokesperson

Short name	Title	Principle contacts	Status
			28/11/07
Opto	Radiation Test Programme for the ATLAS Opto-Electronic Readout System for the SLHC for ATLAS upgrades	Cigdem Issever	Approved by EB
Staves	Development and Integration of Modular Assemblies with Reduced Services for the ATLAS Silicon Strip Tracking Layers	C. Haber, M. Gilchriese	Approved by EB
ABC-Next	Proposal to develop ABC-Next, a readout ASIC for the S-ATLAS Silicon Tracker Module Design	F. Anghinolfi, W. Dabrowski	Approved by EB
Radiation BG	Radiation background benchmarking at the LHC and simulations for an ATLAS upgrade at the SLHC	Ian Dawson	Approved by EB
n-on-p sensors	Development of non-inverting Silicon strip detectors for the ATLAS ID upgrade	Hartmut Sadrozinski	Approved by EB
SiGe chips	Evaluation of Silicon-Germanium (SiGe) Bipolar Technologies for Use in an Upgraded ATLAS Detector	Alex Grillo, S. Rescia	Approved by EB
3D sensors	Development, Testing, and Industrialization of 3D Active-Edge Silicon Radiation Sensors with Extreme Radiation Hardness: Results, Plans	Sherwood Parker now Cinzia Da Via	Approved by EB
Modules	Research towards the Module and Services Structure Design for the ATLAS Inner Tracker at the Super LHC	Nobu Unno	Recommended for approval by USG; awaiting CB comments
Powering	Research and Development of power distribution schemes for the ATLAS Silicon Tracker Upgrade	Marc Weber	Reviewer's report received; awaiting USG discussion.
TRT	R&D of segmented straw tracker detector for the ATLAS Inner Detector Upgrade	Vladimir Peshekhonov	Awaiting final reviewers report
Gossip	R&D proposal to develop the gaseous pixel detector Gossip for the ATLAS Inner Tracker at the Super LHC	H van der Graaf	Expression of interest received
SoS	Expression of Interest: Evaluations on the Silicon on Sapphire 0.25 micron technology for ASIC developments in the ATLAS electronics readout upgrade	Ping Gui and Jingbo Ye	Reviewers report received
Thin pixels	R&D on thin pixel sensors and a novel interconnection technology for 3D integration of sensors and electronics	H-G. Moser	Reviewed; making follow up list
Muon Micromegas	R&D project on micropattern muon chambers	V. Polychronakos, J. Wotschack	Under review by USG
TGC	R&D on optimizing a detector based on TGC technology to provide tracking and trigger capabilities in the MUON Small-Wheel region at SLHC	G. Mikenberg	Expression of interest received
MDTReadout	Upgrade of the MDT Readout Chain for the SLHC	R. Richter	Expression of interest received
MDTGas	R&D for gas mixtures for the MDT detectors of the Muon Spectrometer	P. Branchini	Expression of interest received
Selective Readout	Upgrade of the MDT Electronics for SLHC using Selective Readout	R. Richter	Expression of interest received
High Rate MDT	R&D on Precision Drift-Tube Detectors for Very High Background Rates at SLHC	R. Richter	Expression of interest received
Diamond	Diamond Pixel Modules for the High Luminosity ATLAS Inner Detector Upgrade	M. Mikkuz	Under review by USG
ID Alignment	ID Alignment Using the Silicon Sensors	H. Kroha	EoI Received
Fast Track Trigger	FTK, a hardware track finder	M. Shochet	Under review by USG
Optolink	The Versatile Link Common Project	Francois Vasey	Proposal received

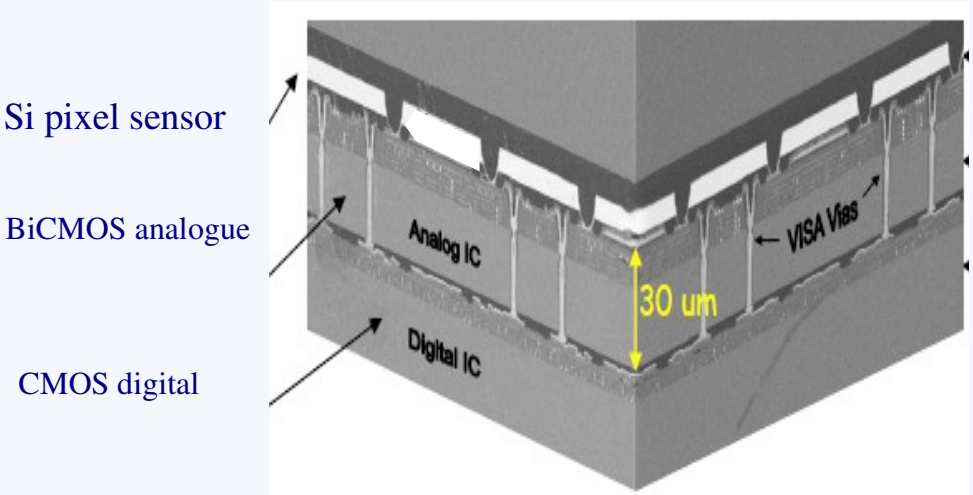
Relevant examples of R&D Projects - 3D Edgeless Sensors

- Vertical pillars of n and p type
- Full thickness of Si (300 microns)
  - large signal
- Small drift distance (50 micron)
  - high charge collection efficiency even after 10^{16} n/cm^2
- No guard ring structure
  - Sensitive to the edge
  - Allows butting together multi-chip modules with very small dead area
  - Interesting to have readout chips with no dead are too (e.g. avoid column logic at side)
  - Hence 3D electronics interest
- Working to industrialise the production



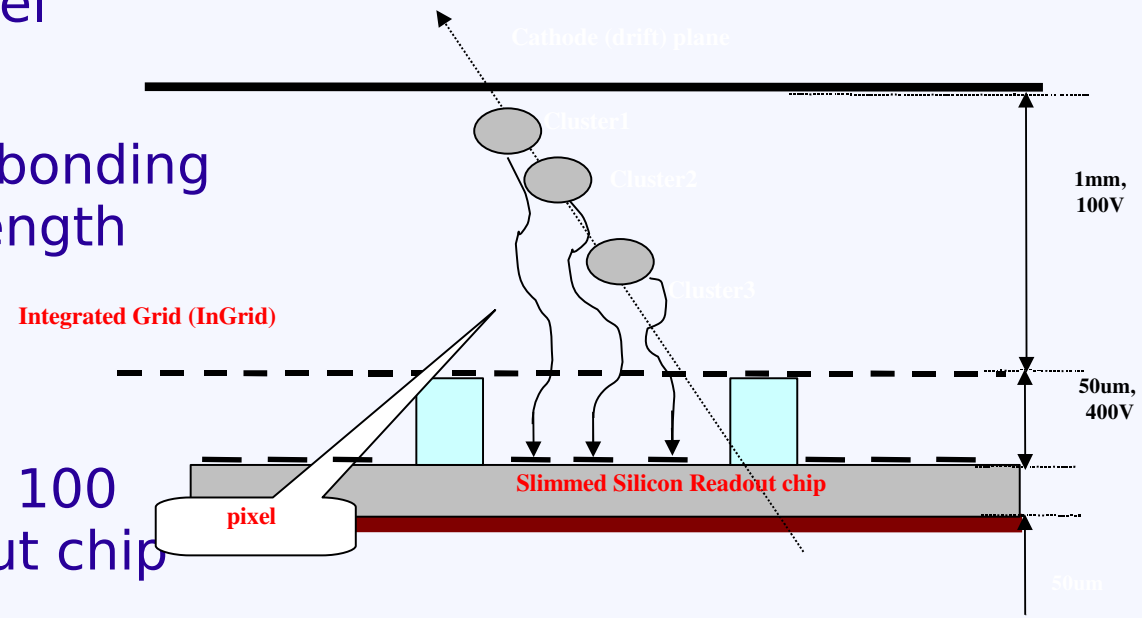
R&D: Thin Si

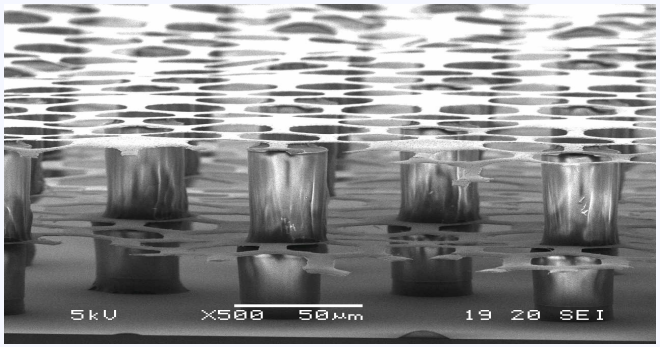
- (As presented by L. Andricek)
- Develop thin sensors for high charge collection efficiency with low bias voltage
- + 3D integration
- + SLID interconnect as an alternative to bump bonding
- Ultimate in low radiation thickness silicon detectors?
- Short pixel size possible
- Ambitious, and partners needed



Gossip

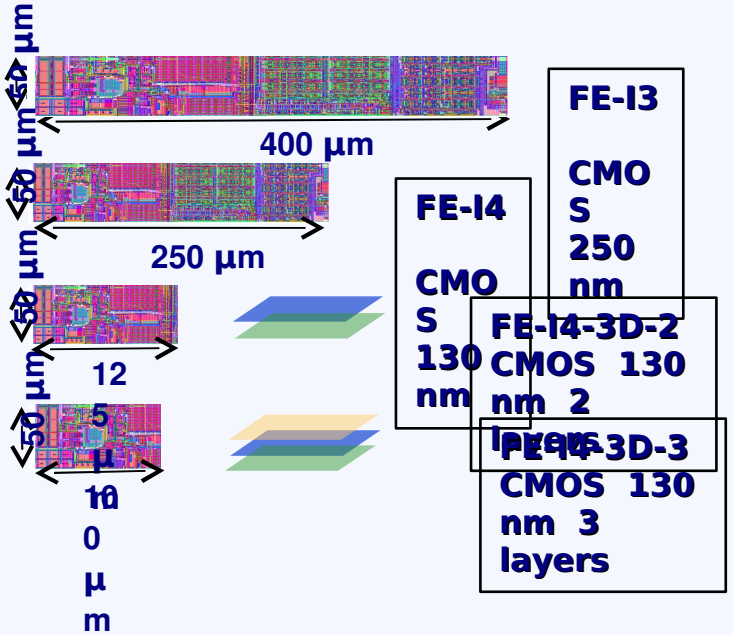
- Gas detector on thinned pixel readout chip
- No silicon sensor; no bump bonding – cheap and low radiation length
- ~1.2 mm drift gap
- Al grid made by wafer post-processing techniques, 50 – 100 micron above a pixel readout chip
- The gas containment structure above the readout chip makes it attractive to use 3D integration to bring connections to the other side of the readout chip
  - Work on-going for vias with Gossip chip





Summary 3d Integration Needs at ATLAS

- Standard Planar pixels and the R&D projects mentioned can all benefit from 3D Integration.
- Goals were given by Sacha:
  - Thin chips --> low radiation length
  - Bringing bond connections to rear side for easier layout
  - Smaller pixel size: shorter pixels are very important at the sLHC to separate the vertices of the 400 pile-up events
  - Possibility to use different technologies for analogue and digital parts of the pixel readout (e.g. SiGe analogue for lower power)
  - Interconnections are a major cost driver: reducing costs would allow more pixel use
  - Space for more electronics can reduce power. Power costs radiation length for cooling and power lines.



Chip Development

- All these developments need more or less specialisation in chips
  - Different sensors have different characteristics
- E.g. creating space on standard pixel readout chips for vias needs layout modifications
- --> Atlas Upgrade needs more chip designers

Summary

- Entering R&D phase for the ATLAS Upgrade
- 3D Integration is very interesting for the new pixel detector
- Several R&D projects approved and looking into it
- We need more effort for it, including chip designers
- Timescale: ~3 years R&D, more if LHC is slower than hoped for