CERN-ECFA-NuPECC Workshop on the LHeC

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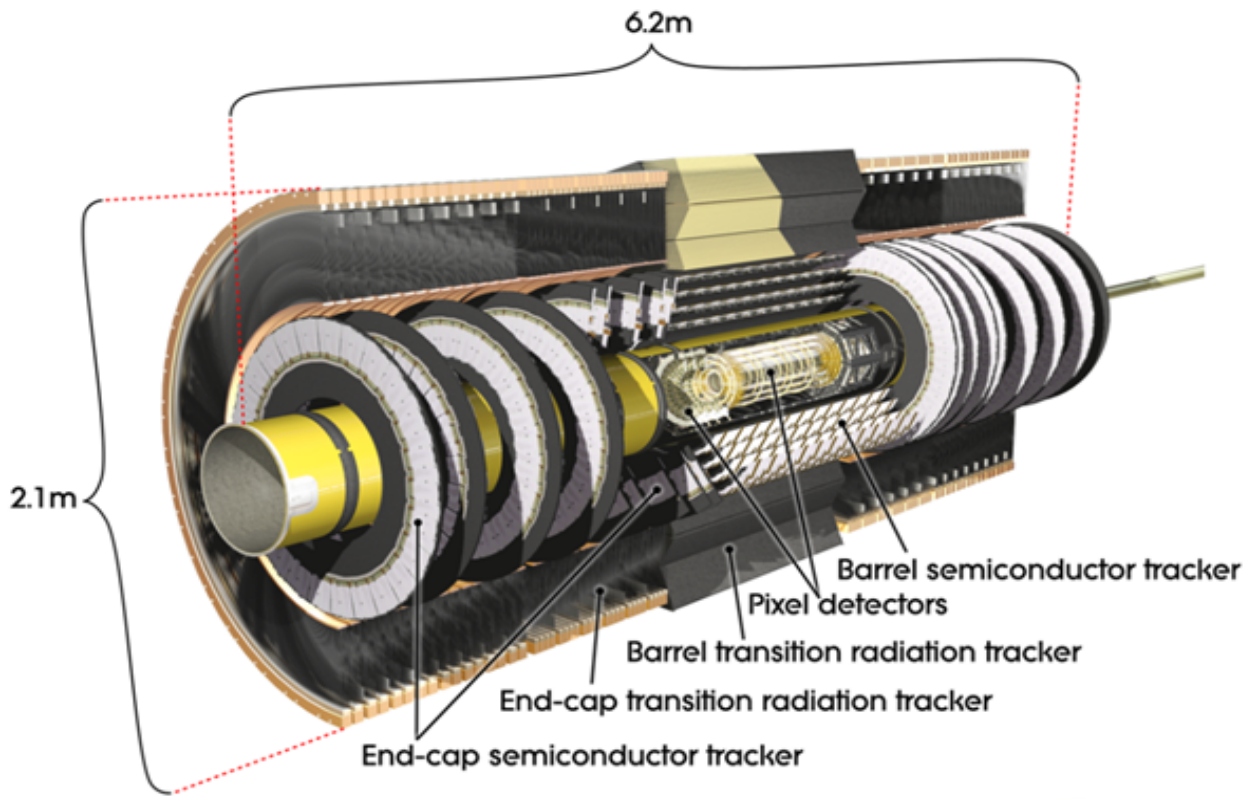
LHeC Tracker Design viewed from ATLAS

- General requirements
- Sensor technology
- Frontend architecture
- Data Link, Integration
- Powering and cooling
- Support structure

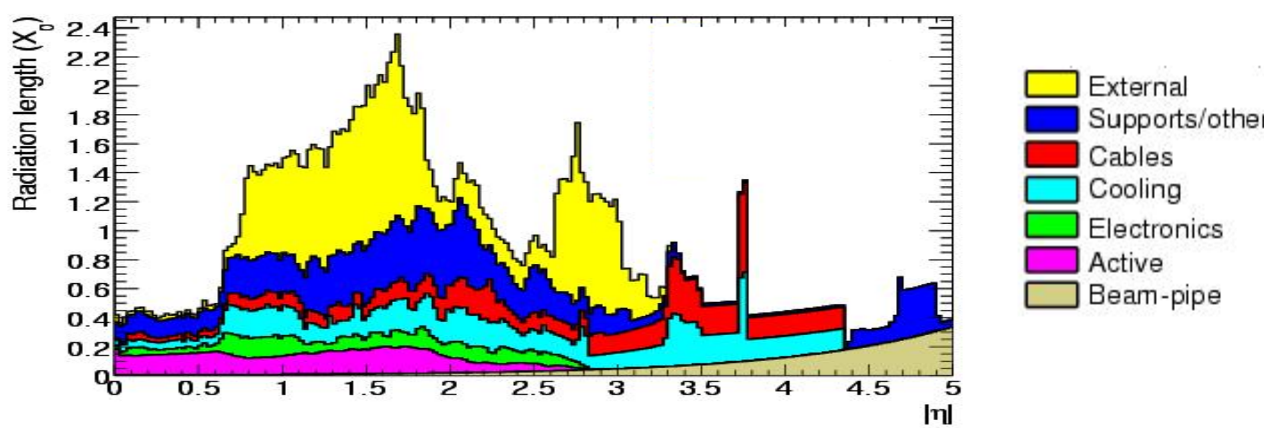
Chavannes-de-Bogis, Switzerland

June 14th, 2012

Present ATLAS tracking system

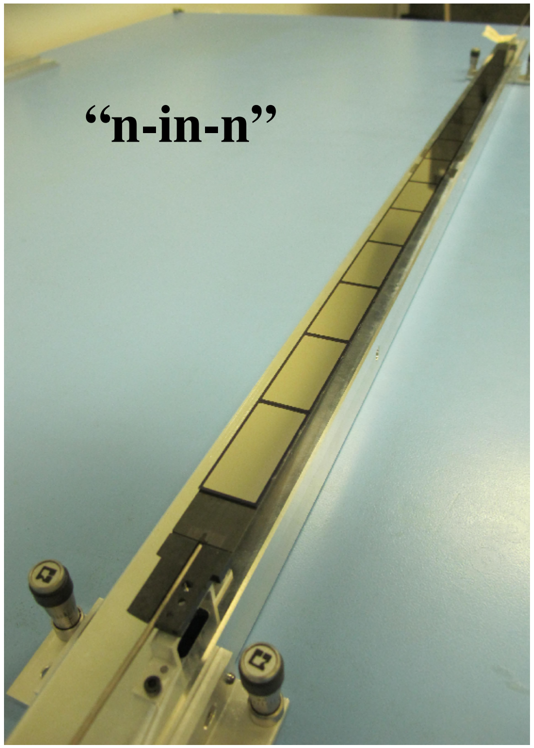


Full φ coverage, Compromised θ range due to material concentration at flanges

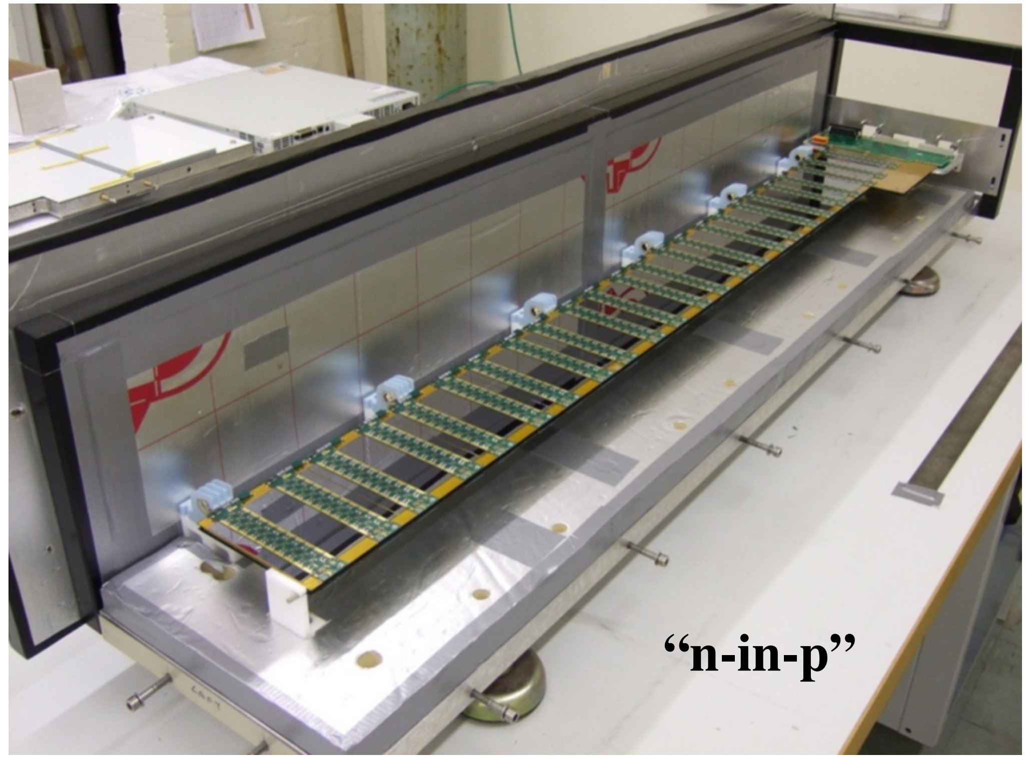


Components for the Tracker Upgrade

Pixel modules on stave



Strip modules on stave



16 sensor assemblies with 32 FE-I4 pixel readout ASICs on each stave. Pixel granularity is 50x250 um (for regular channels) and 50x450 um in gaps between two ROCs.

12 sensor assemblies with 480 ABC-N strip readout ASICs on each stave. Strip granularity is 22mm x 74.5 um

LHeC tracker Layout

Purpose: best possible spectroscopy

Target X/X_0 in the LHeC CDR paper is 1.5-2.0%

$-4.8 < \eta < 5.5$

Proposed LHeC tracker dimensions:

Length ~ 5.7 m (similar to length of ATLAS tracker)
Max R ~ 0.4 m (2.5 times smaller than of ATLAS tracker)

High density of material (X/X_0 could be worse at low and large η values) → ATLAS components should be considered with care !

Alternatively, new modules could be built from available ROCs and with customised sensors to reduce service material, especially at very low and high η values.

Sensor Technology

Planar

is better in terms of achievable resolution

(IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 58, NO. 3, JUNE 2011)

Advantages of the "n-in-p" process

Compared to "p-in-n" detectors: Radiation hardness

Compared to "n-in-n" detectors:

- **Possibility of back-thinning for low material budget**
- **Low manufacturing costs (single-side processing)**
- **Easy mechanical handling of the backplane**
- **Bulk type does not invert - can be operated under-depleted,**
  - relaxed temperature conditions,
  - simpler data analysis.

Detector Granularity

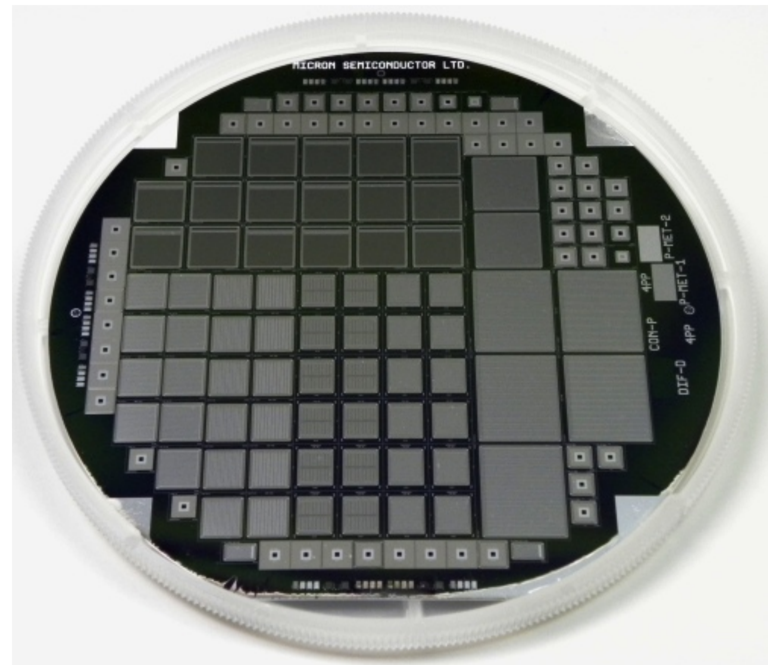
For pixels:

Granularity is determined by available ROCs.

For the strip detectors:

Physicists should specify the minimum length, width and pitch of implants from MC tracker resolution studies.

To help experts with device modelling, the University of Liverpool is committed to measurements of strip and pixel detectors for the ATLAS upgrade with different implant geometry and various intermediate strip options.



Various pixel and strip sensors on 6-inch wafers (thicknesses range from 50um to 600um) produced by Micron Semiconductor Ltd in different processes.

Frontend Architecture

Analogue ? Binary

Coordinate resolution ~ η distribution, pitch, S/N^{-1}

FE-I4 pixel ROCs has ToT processing in each channel.

Advantages: high readout speed achievable

Disadvantages: compromised latency and resolution, elevated power consumption.

ABC-N chip for strips has a binary output.

APV25 (CMS) or Beetle V1.5 (LHCb) are better candidates for the readout of strips. The latter features a self-trigger and multiple output ports for the faster readout.

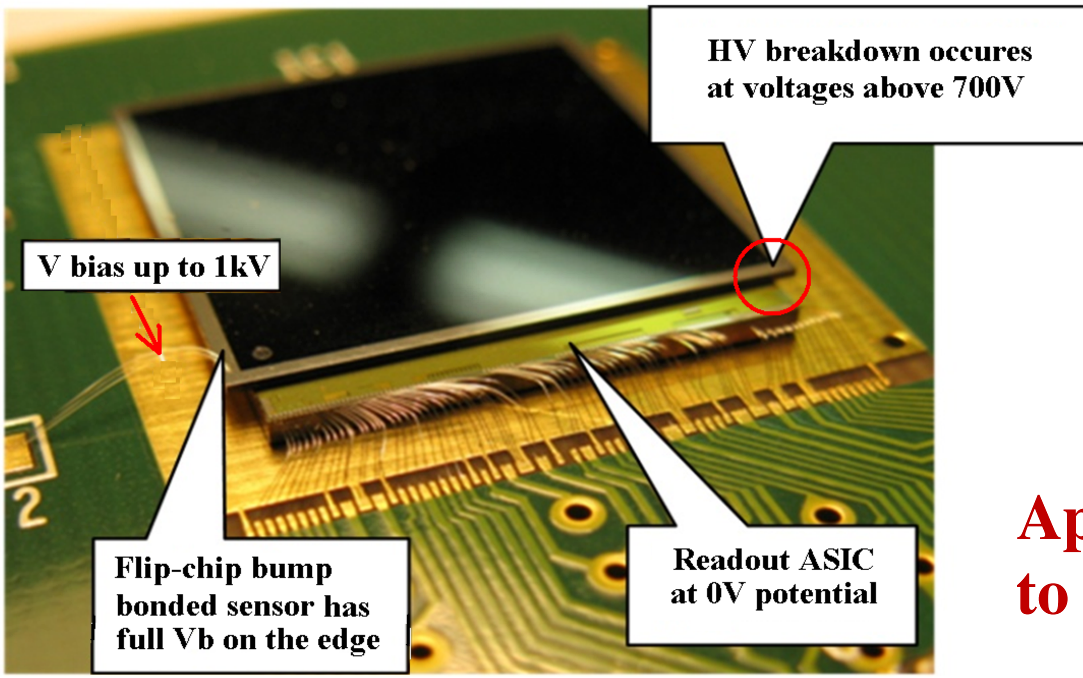
Alternatively, new ROC for strips with ToT or analogue pipeline could be developed, if necessary.

Frontend Perspectives

1. Deeply Depleted Channel technology offers a breakthrough in power consumption and CMOS scaling (more functionality)

www.suvolta.com

2. Through Silicon Vias are highly desirable for the pixel ROC



TSVs could replace wire bonds allowing ASIC confine within sensor. This should solve HV sparking problem for planar technology.

Application of TSVs has to become the taskforce!

Data Up Link

Optical ? "Galvanic"

Requirements: reliable, low mass, low power

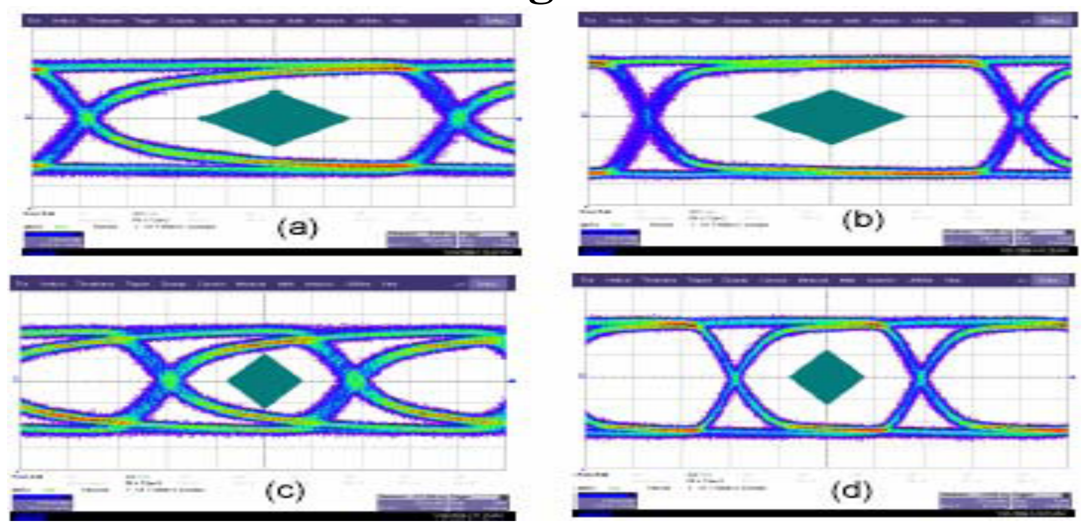
Studies of micro-twisted pairs for the ATLAS upgrade:

Minimum speed requirements:

Analogue output:
40 MHz bandwidth

Digital (6 bit) output
240 MHz bandwidth

140 cm Length 60 cm



640 MHz

1.3 GHz

NUCLEAR SCIENCE SYMPOSIUM CONFERENCE RECORD, 2006 IEEE, VOL. 2, p. 717-720

Frontend Powering

Serial	?	DC-DC
Module control has to dial with line ruptures		Module control has to dial with short circuits

The latter is more likely, otherwise why do we need fuses at all

Serial or DC-DC power options show alternating popularity in the past few years depending on the manpower available.

Serial powering would allow for reducing cable material in the LHeC volume and thus it has to become a task force.

Impact on the mechanical concept:

ROCs should be mounted onto electrically isolated and thermally conductive substrate (additional thermal interface reduces cooling efficiency)

Cooling requirements

Low voltage:

100mA/chip x 2.5V x 2000 / m2 → 0.5 kW/m2 (strips)
100mA/chip x 2.5V / 2.5 cm2 → 1 kW/m2 (pixels)

(estimates based on the current ROCs for the ATLAS upgrade)

High voltage (for sensor dose 1e14 neq):

10..100 μA/cm2 x 500 V → 0.5 kW/m2 (@ 0 deg. C)

Convection: 0.2 kW/m2 (@ 0 deg. C)

CPT (1.4 m2) → 2.5 kW
CST (8.1 m2) → 10 kW
CFT, CBT (1.8 m2) → 2.2 kW each
FST (3.3 m2) → 4 kW
BST (2.0 m2) → 2.5 kW

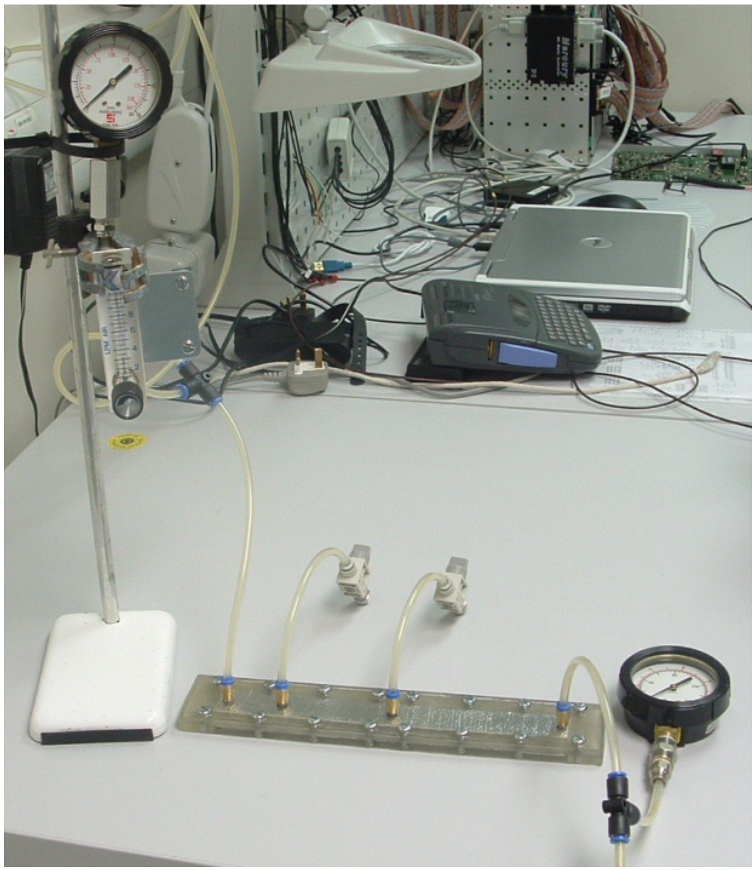
assuming all modules are equipped with pixel and strixel sensors only

~ 25 kW in total

(+50% overhead for el. and thermal interfaces)

Support Structure

Low anticipated radiation dose – no need for cooling sensors below 0C



Silicon carbide (SiC) foamcould be suitable for the low-mass CO2 cooling through support structure

Airflow resistivity of ERG aerospace SiC foam (P=15%) is 2600 +/- 400 Pa*s/cm2 @ 5 bar

Impression: this foam causes very small resistance to the air flow.

Summary

Technology developments for HL-LHC/ILC experiments to be used with care (yet unknown figures for X/X0). Cosmetic re-design of detector modules might be needed.

ATLAS upgrade assumes just improvements to existing detector, but ongoing preparations face already tight delivery schedule.

R&D manpower needs synchronisation and enforcement.

Preliminary meeting in Liverpool in December 2011:
The LHeC apparatus installation and commissioning could begin during the 3rd large LHC shutdown in 2022.

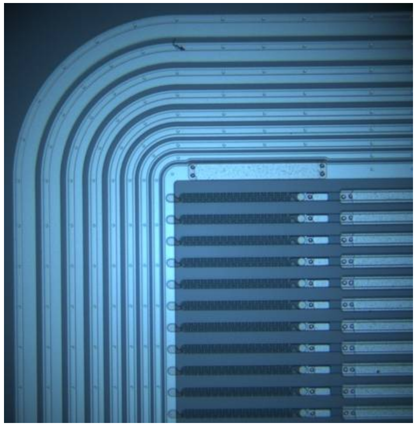
The secret of getting ahead is getting started

Backup

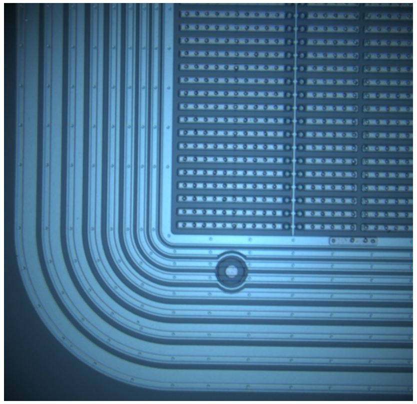
Planar Sensor R&D for the ATLAS upgrade

Design goals: spatial resolution and efficiency

Strip detector



Pixel detector



Readout implants (strips or pixels):
- granularity, fill factor for particle detection
- analogue / binary readout options

Implant termination (guard structure)

Design features:
- field plates, biasing scheme (punch-through, polysilicon resistors, current termination ring), geometry of bonding and test contacts, etc.

Dicing:
- saw cut, laser cut, scribing and breaking

Operating conditions and maintenance:
- radiation dose, bias voltage, temperature profile (annealing)