The Diamond Beam Monitor as part of ATLAS IBL upgrade

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for the Diamond Pixel Collaboration

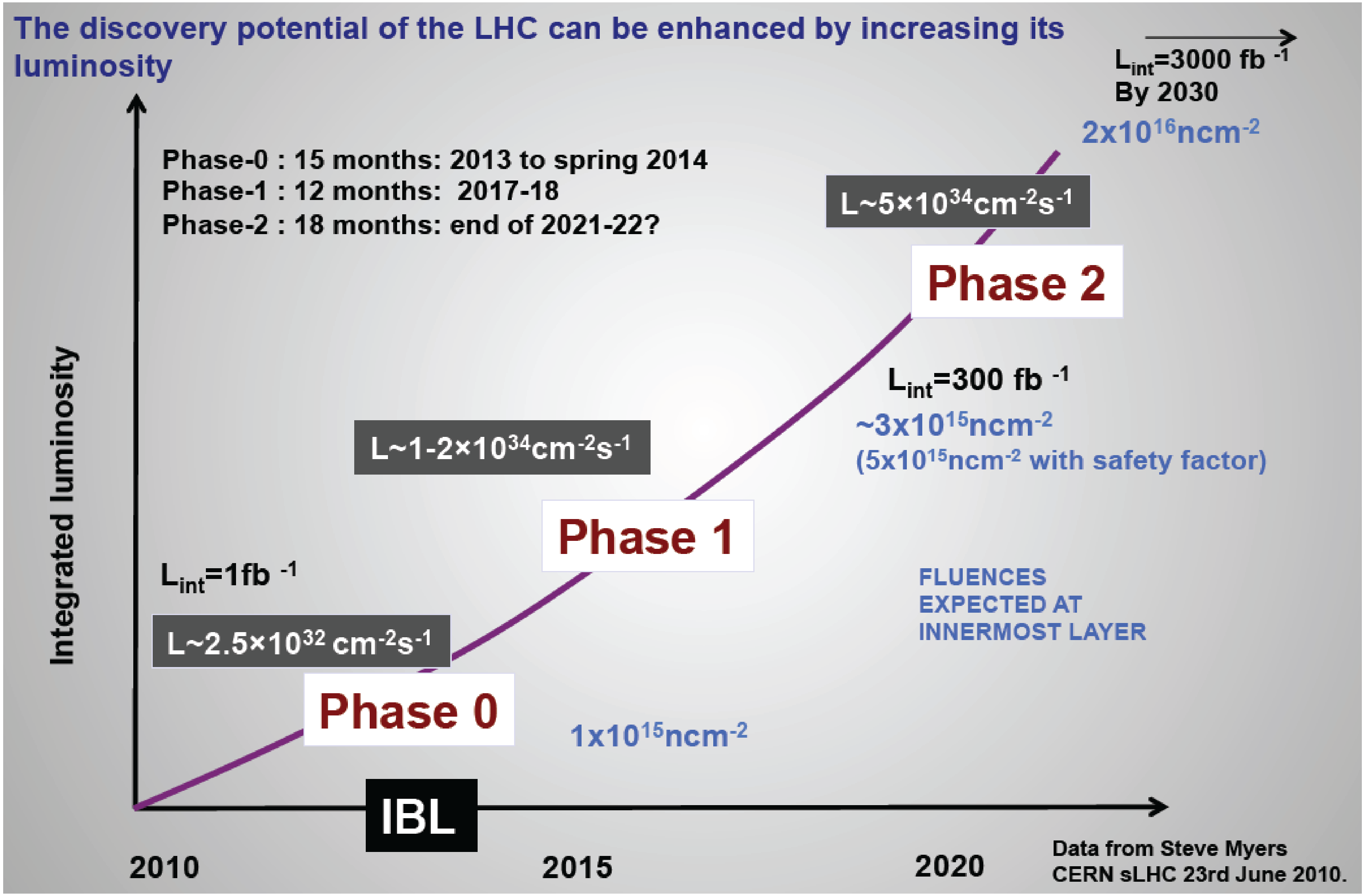
Outlook

- ATLAS Upgrade
- The DBM Project
- Diamond Results
- Future Plans

First Part

ATLAS UPGRADE

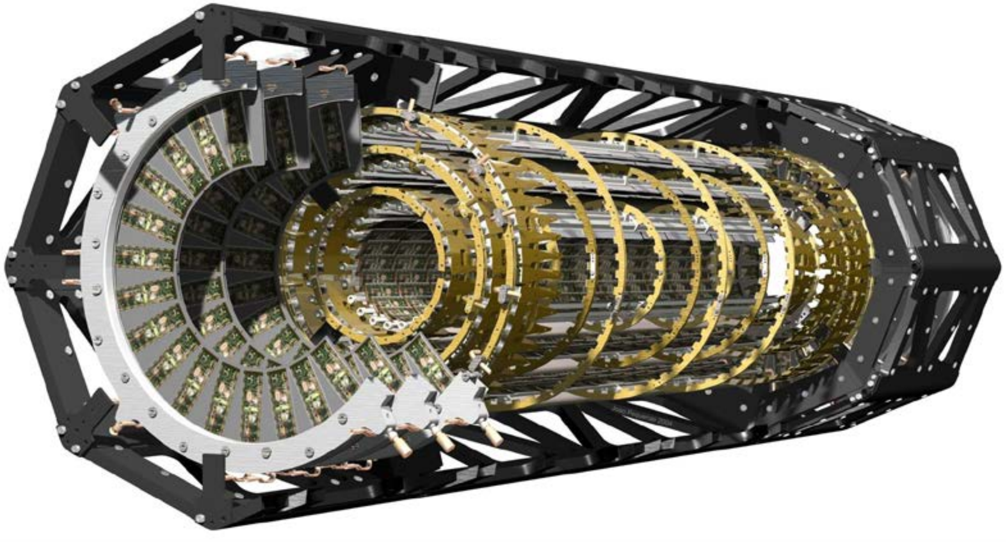
Upgrade Phases

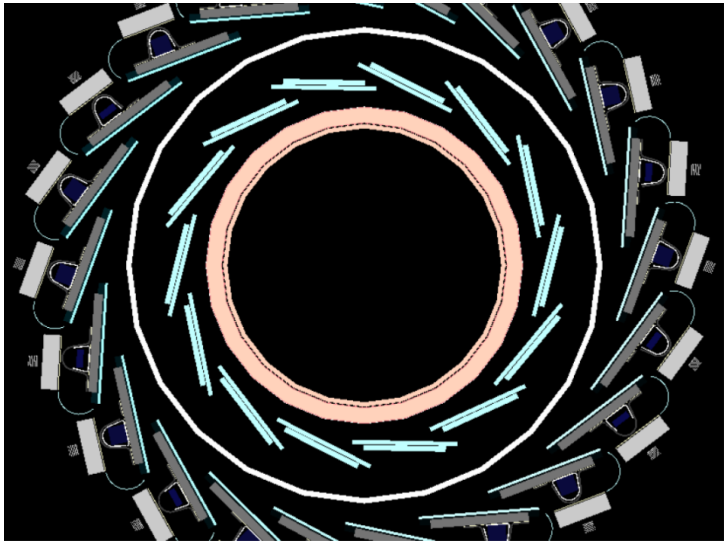


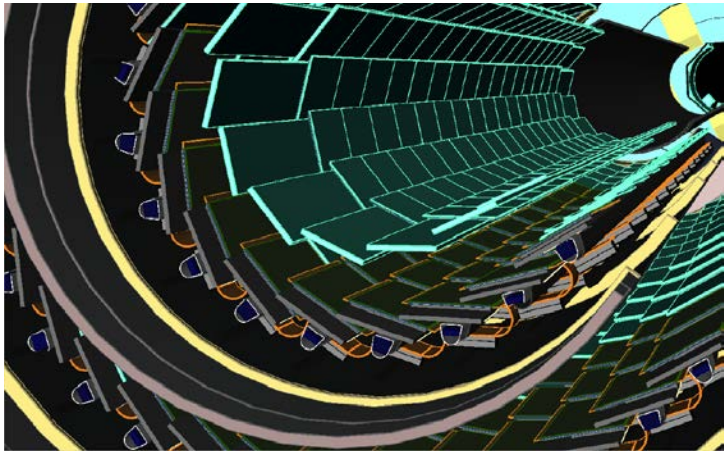
P. Grenier "Silicon sensor technologies for ATLAS IBL upgrade" 2011

Phase 0 – IBL Upgrade

- Advanced IBL installation in 2013 instead of 2016





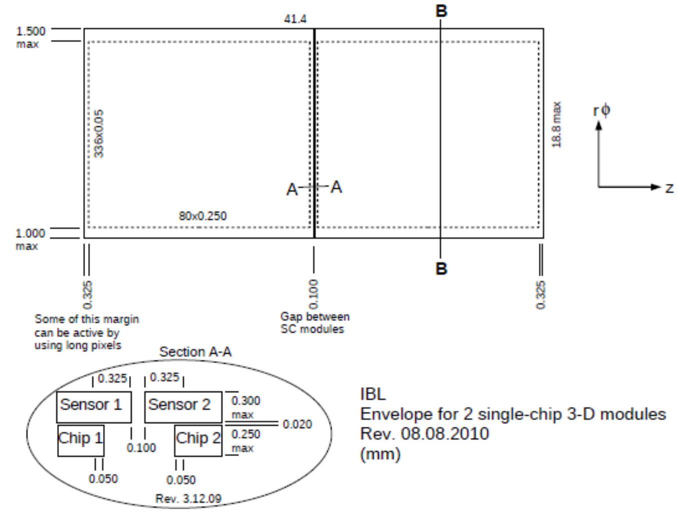


- New thinner beam pipe with a reduced outer radius
- Free space for additional pixel layer
  -> Insertable B-Layer
- New Front-End chip (FE-I4)
- Different sensor candidate technologies
  - Planar Silicon, 3D Silicon, Diamond Pixel

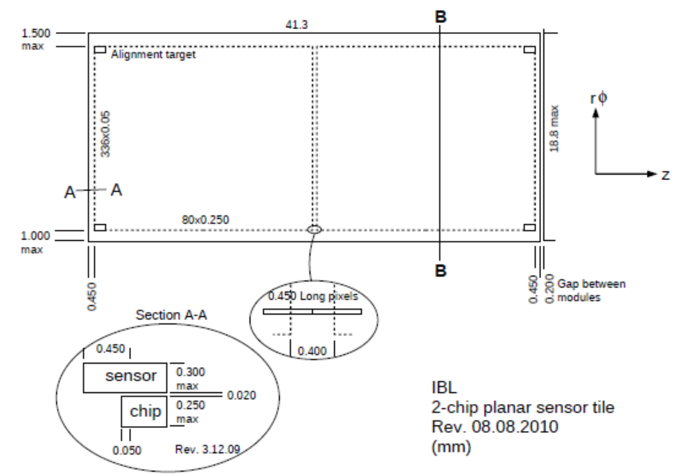
IBL specifications

- Insertable B-Layer (IBL)
  - 14 staves with 224 modules -> 6.02×10^2 pixel
  - Radius: 31.0mm to 40.0mm
- Design Requirements:
  - Fluence: $5 \times 10^{15}\ n_{eq}\ cm^{-2}$
  - TID: 250 Mrad
- Modules
  - FE-I4 chip size: ~20x20 mm^2 with 336x80 pixel
  - Pixel size: 50 µm x 250 µm
  - Single or double FE-I4 modules

Single FE-I4 module



Double FE-I4 module



Application for FE-I4 diamond modules

- 20 FE-I4 diamond modules for sensor qualification
  - Operation threshold around 800 electrons
  - 4 FE-I4 diamond modules are already available for laboratory and test beam measurements
  - 10 sensors are ready for bump bonding and characterization

24 FE-I4 diamond modules for installation as Diamond Beam Monitor

Second Part

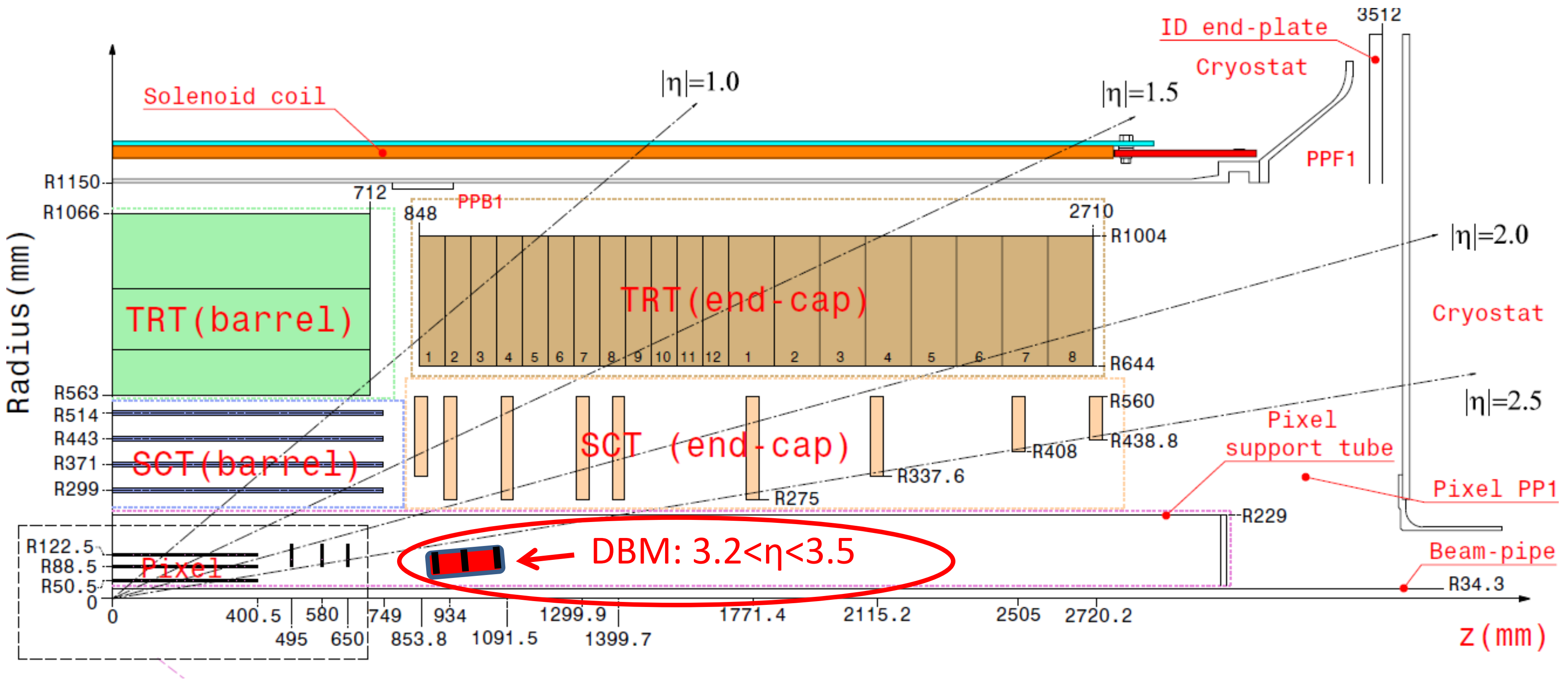
THE DBM PROJECT

DBM - Diamond Beam Monitor

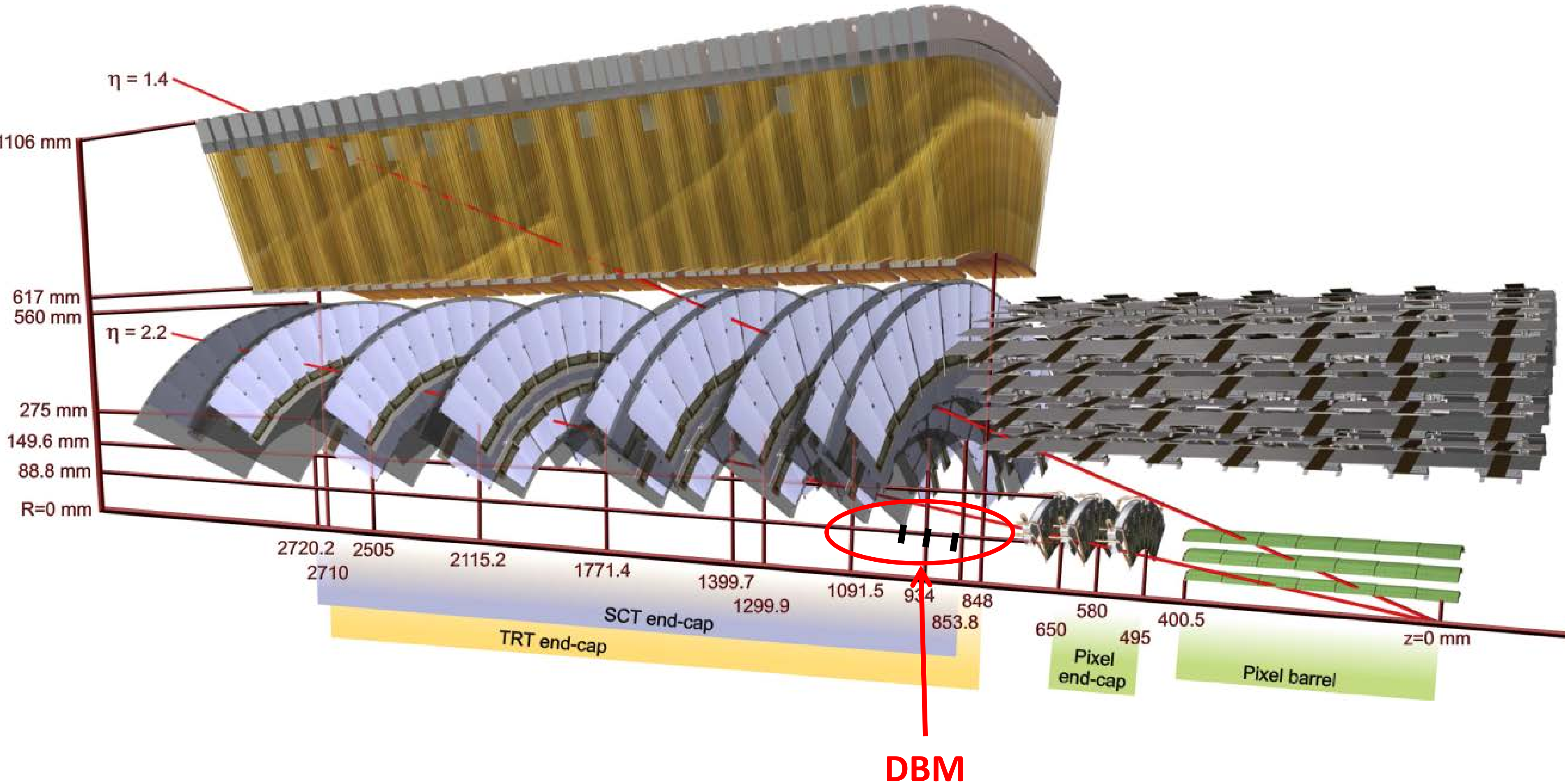
- What is the DBM?
  - Eight 3-Modul Diamond Beam Telescopes in ATLAS
    - 24 FE-I4 diamond modules
- Purpose
  - Bunch by Bunch luminosity monitor
    - Finer segmentation and larger acceptance than BCM
    - No saturation
  - Bunch by Bunch beam spot monitor
    - Triple telescope for tracking
    - Distinguishes hits form beam halo tracks
- Design Considerations
  - Acceptance $3.2 < \eta < 3.5$ (ATLAS Inner Detector acceptance: $\eta < 2.5$)
  - Use Phase 0 upgrade efforts to get access to the Pixel Detector

DBM – Layout I

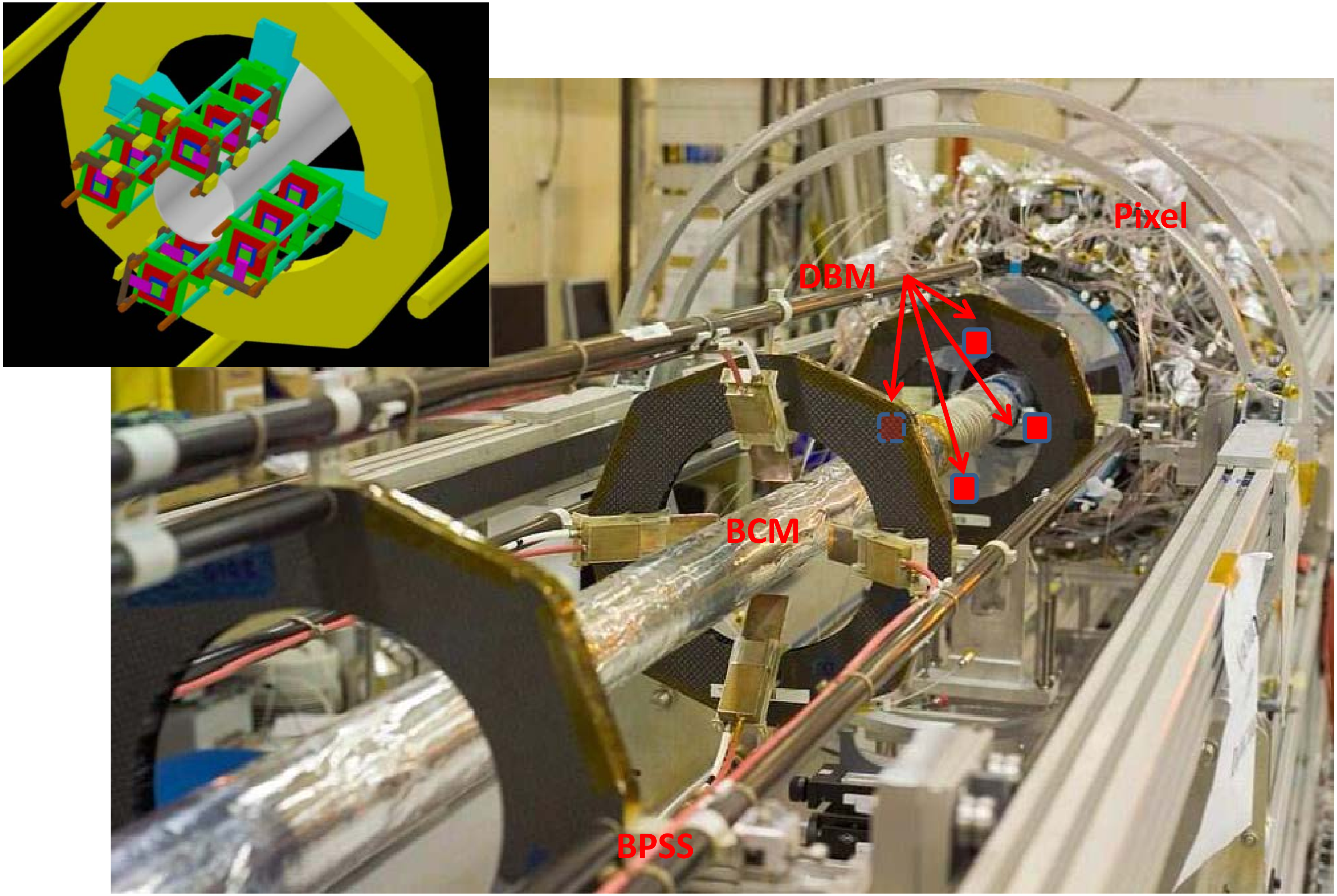
- Distance from the vertex: 90cm – 100cm



DBM – Layout II



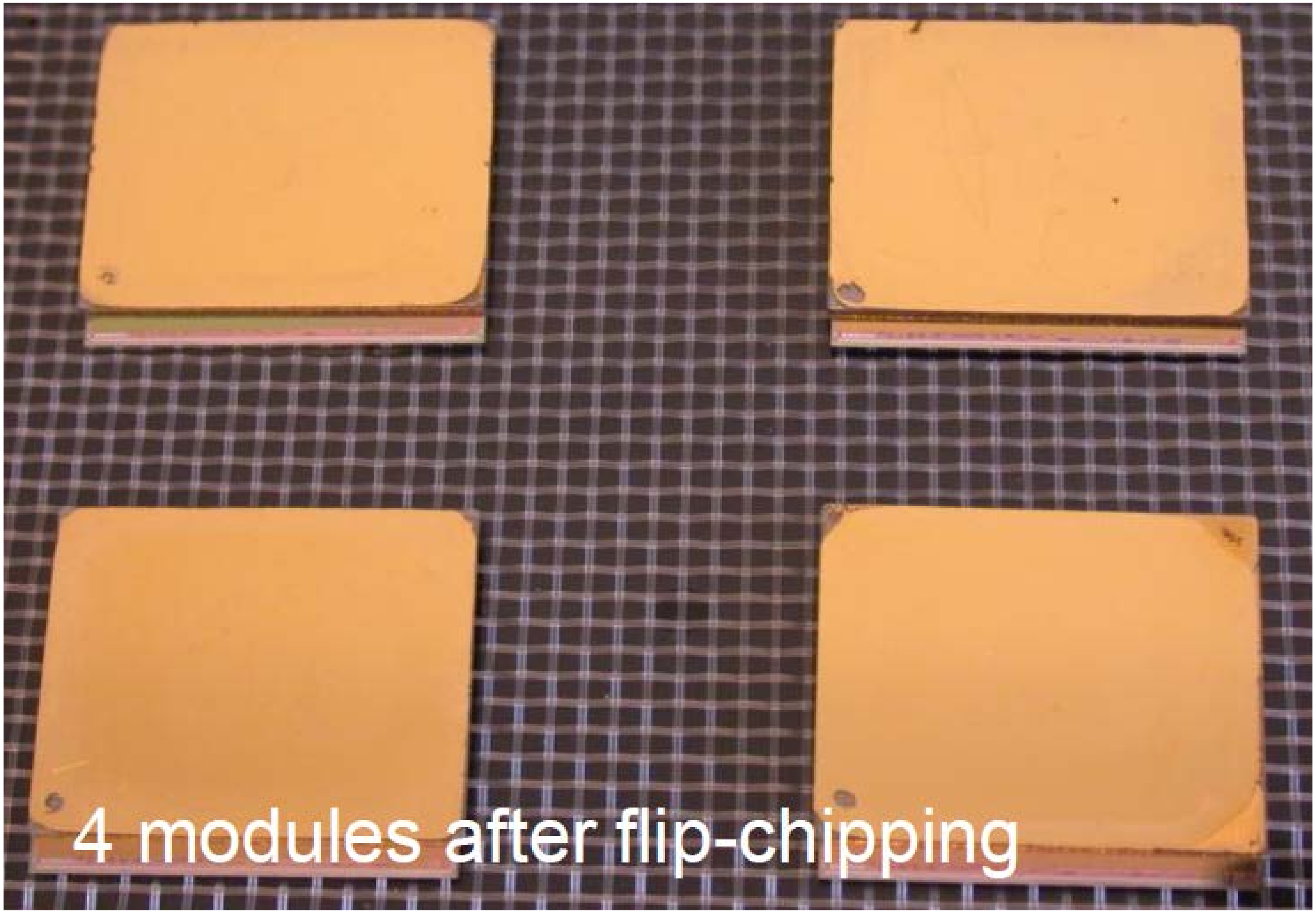
DBM – Layout III



DBM specifications

Properties	Specifications
Sensor Size	21 mm x 18 mm (active area 20mm x 16.8mm)
Sensor Thickness	400-500 µm
Minimum charge collection distance	200 µm
Minimum average charge	7200 electrons
Minimum collection distance / charge after $2x10^{15}$ cm^{-2}	100 µm; 3600 electrons
Minimum signal/threshold after $2x10^{15}$ cm^{-2}	3
Maximum operation voltage	1000 V
Maximum total leakage current at 1000 V	100 nA

FE-I4 diamond modules



DBM operation

Two DAQ modes in parallel

- ATLAS trigger
  - DBM data for the ATLAS data stream
- Quasi-random trigger sampling all bunches
  - Bandwidth limit of the readout 160 MB/s
  - Assumed ~100bits/module, 1 link/module
  - 30% uptimes yields for 0.5 M events/s
  - Private stream for data-rich events

Performance estimate - Luminosity

- Efficiency
  - DBM has 5.4 higher acceptance than BCM
  - ~0.09 hits per telescope (plane) per p-p interaction
- Basic performance figures
  - Assumption
    - Hits in all modules in a telescope highly correlated
    - Hits in different telescopes uncorrelated
- Luminosity assessment
  - 0.7 hits in system at μ=1, polling at 0.5 M/s yields 350000 hits spread over 3564 BCID's
    - 100 hits/s per (full) BCID
    - 1 % precision in ~100 s, compatible with ATLAS LB
  - Operation at μ»1 indicates statistical precision on bunch-by-bunch luminosity well below 1 % per lumi-block

Performance estimate – Beam Spot

- Resolution along beam axis at interaction point (z=0mm)
- Take 2 measurements 10 cm apart at $z_{1,2}$ ~ 90 cm
  - $\delta z_{1,2}$ ~ 500 μm/√(12) – sensor thickness
  - δr ~ 250 μm/√(12) – long pixel side
- Track straight line in r-z projection, look for z of intercept with axis
- $\delta z \sim z_{1,2} \sqrt{(2)}\, \delta r/(r_1 - r_2) \sim 13$ mm
  - Looks adequate to locate interaction spot and eventual background sources
- Algorithms for beam spot localization in development by OSU and Bonn

DBM production

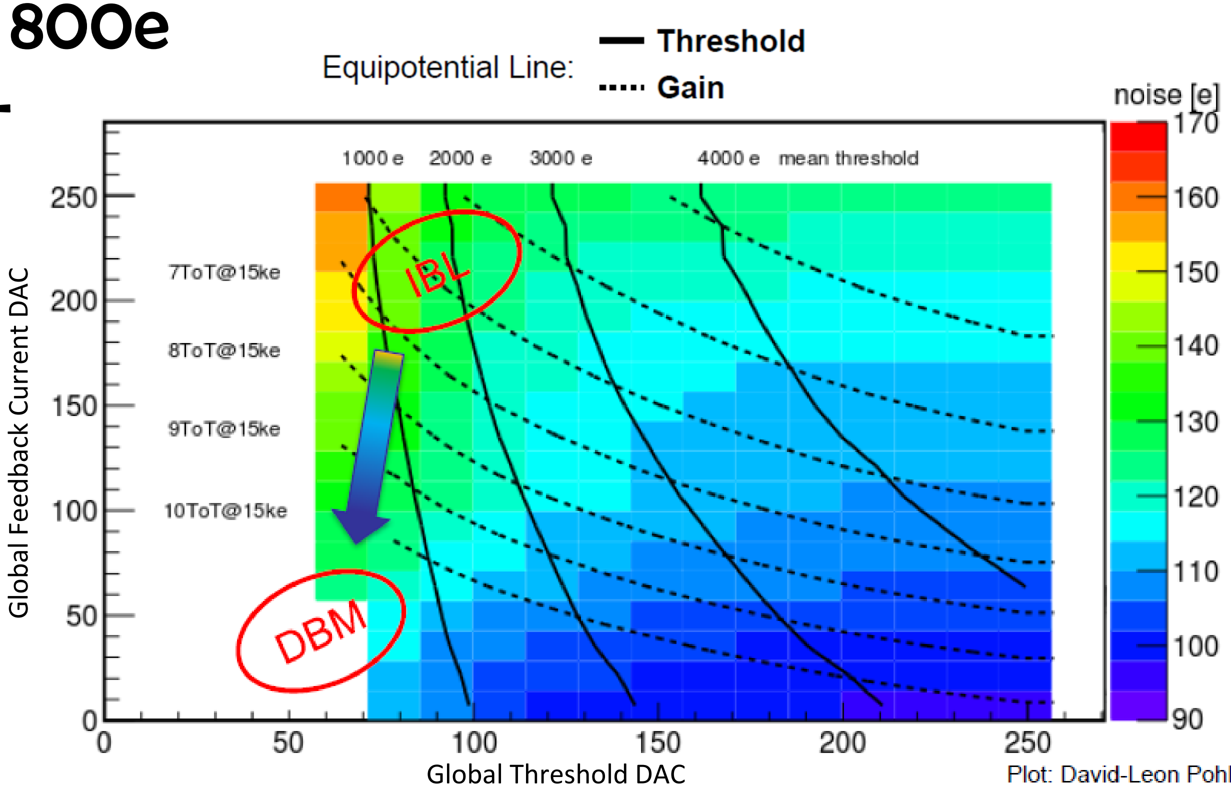
- Baseline: 24 modules to be installed
- Production model: aim for 30 good modules
- Loss of 25 % during module assembly
  - Need parts to assemble 40 modules
    - 40 sensors, FE-I4's, flip-chippings, flexes etc.
  - More than 20 sensors in hand for IBL qualification
- DBM adds of 24 IBL modules to the existing modules
  - Requires an additional ~5 % of most IBL components
- Major cost drivers
  - DBM specific parts
    - Sensors: ~20/45 already procured
    - Bump bonding: 40 % in qualification
  - IBL identical parts to be negotiated case by case
    - 5 % is in most cases much smaller than the spares level

Third Part

DIAMOND RESULTS

Threshold/Noise characterization

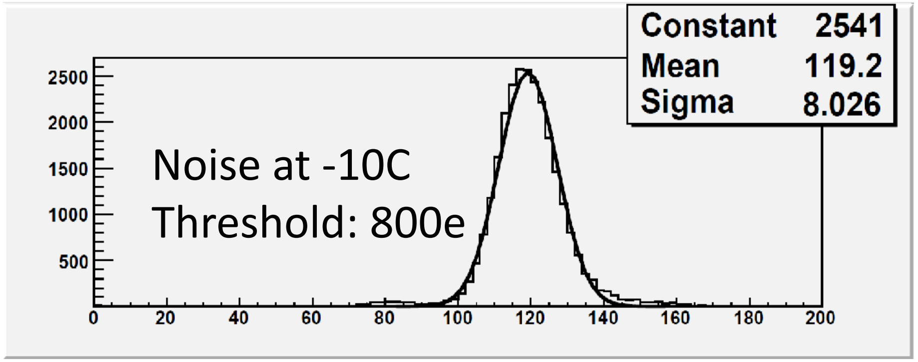
- DBM tuning is at the edge of Front-End capabilities
- Target Threshold: 800e
- Target Gain: 8ToT for 5000e

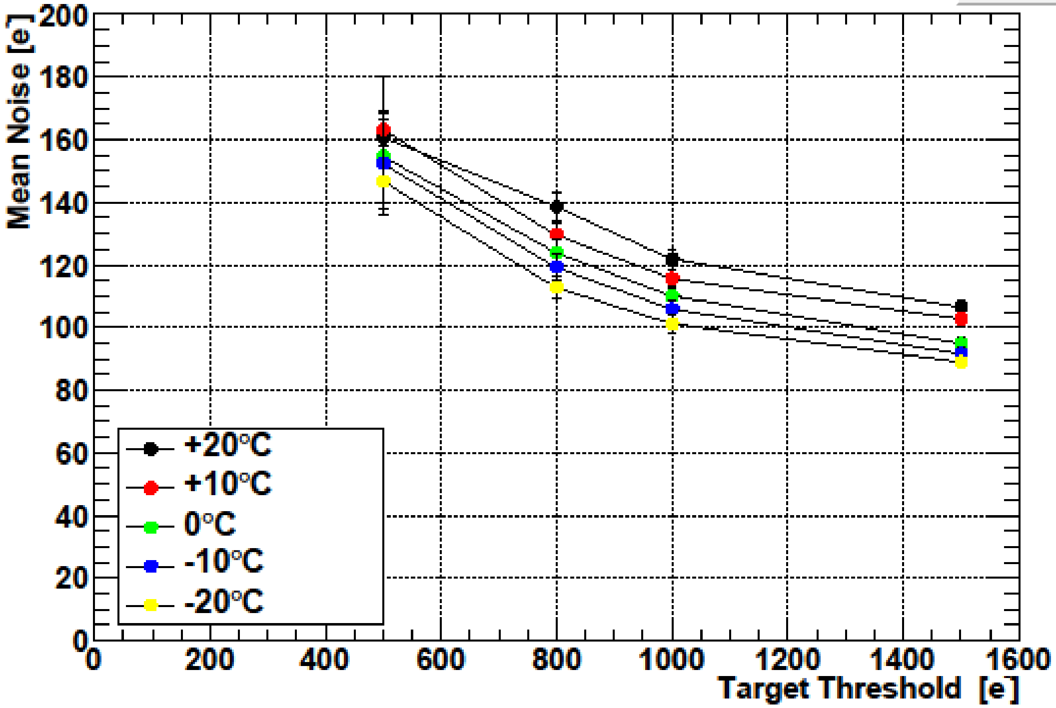


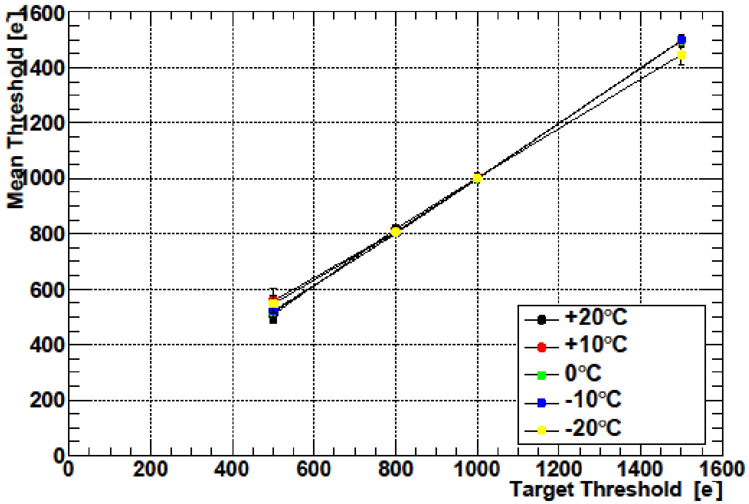
Plot: David-Leon Pohl

Threshold/Noise vs. Temperature

- Noise decreases with Temperature
- Front-End noise: ~80e

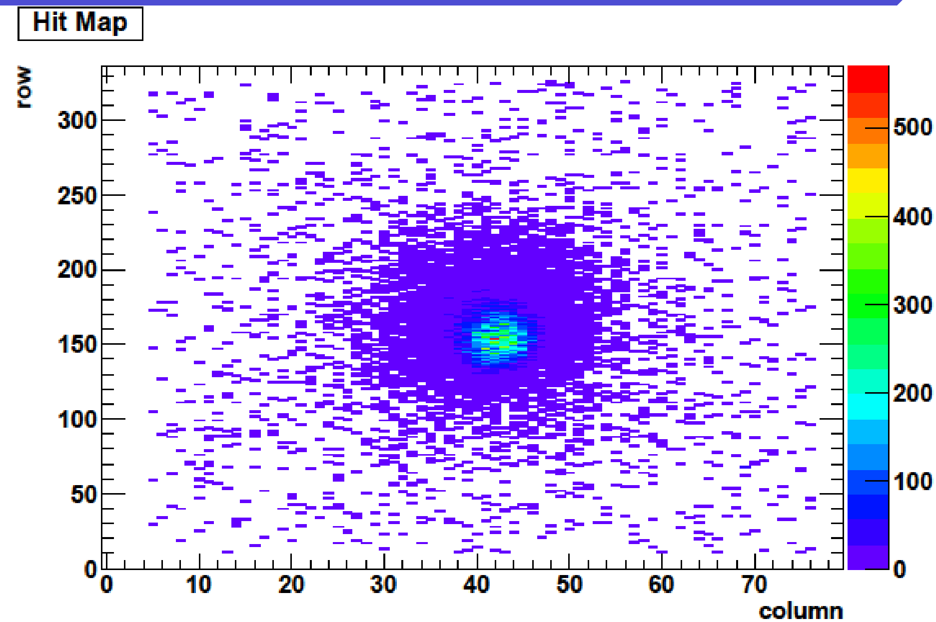


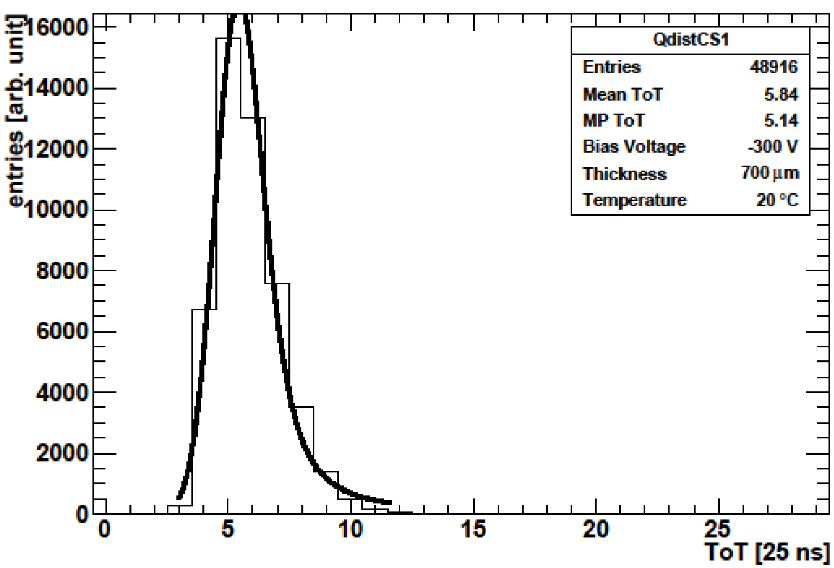


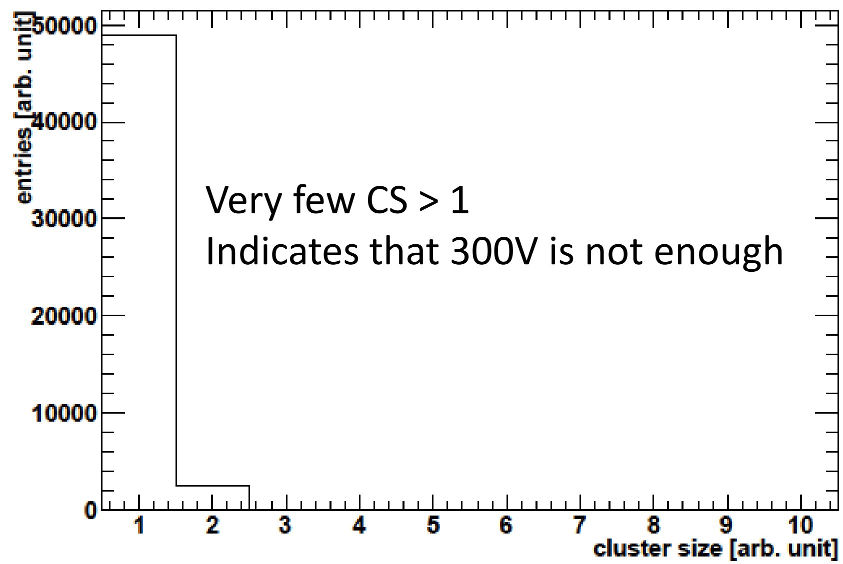


Source analysis – Sr90

- Conditions:
  - Threshold: 1500e
  - Bias voltage: 300V
- Results:
  - Nice correlation
  - Clear beam spot
  - Bias voltage is too low

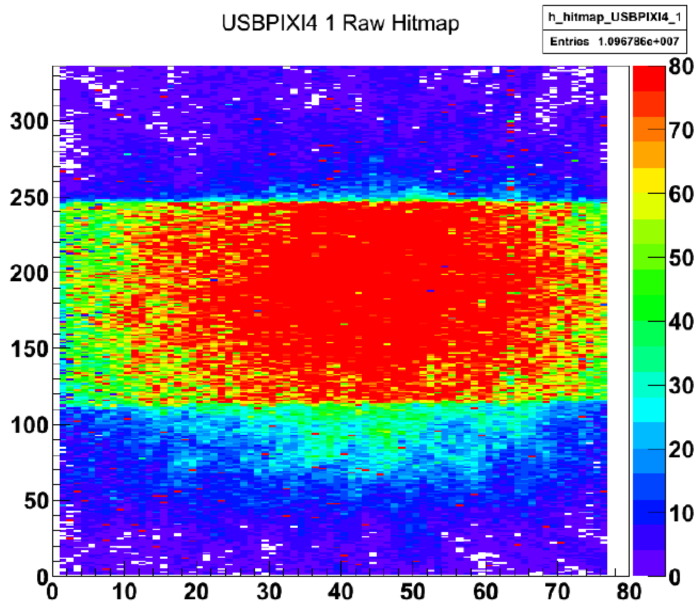




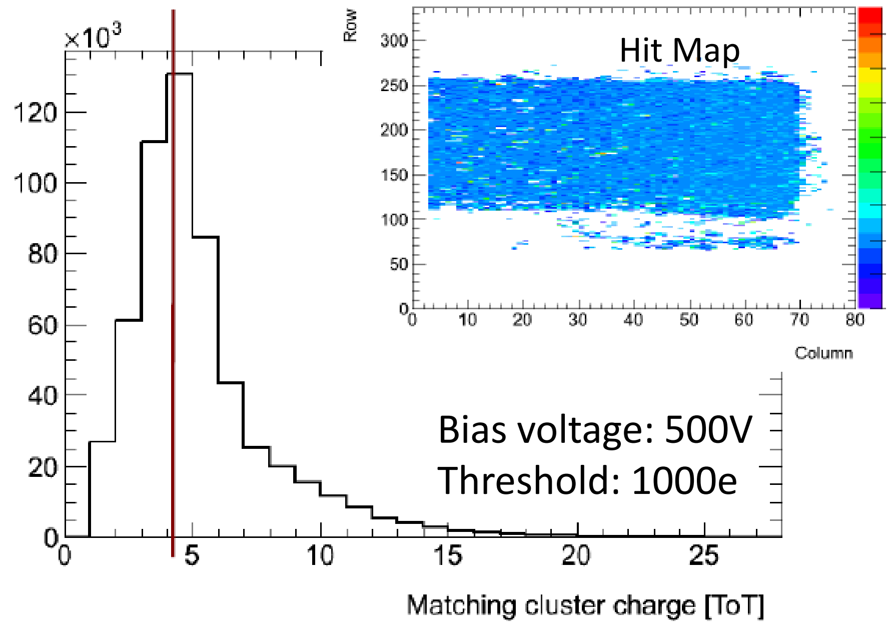


Test Beam results

- 2011: several test beam periods at CERN SPS
- Data analysis not completed
- TB results confirm source measurements



First 500e Threshold Run in October 2011 DBM Testbeam



Forth Part

FUTURE PLANS

Future Plans

- Plans for 2011
  - Additional lab measurements at higher bias voltages
  - Additional test beam measurements with second version of FE-I4 chip
  - Further development of DBM setup

Diamond Pixel Collaboration

- Universität Bonn
- CERN Geneva
- Universität Göttingen
- Institut Jozef Stefan Ljubljana
- Ohio State University
- University of Toronto

Thanks for your attention