ATLAS Diamond Beam Monitor

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DBM Institutes

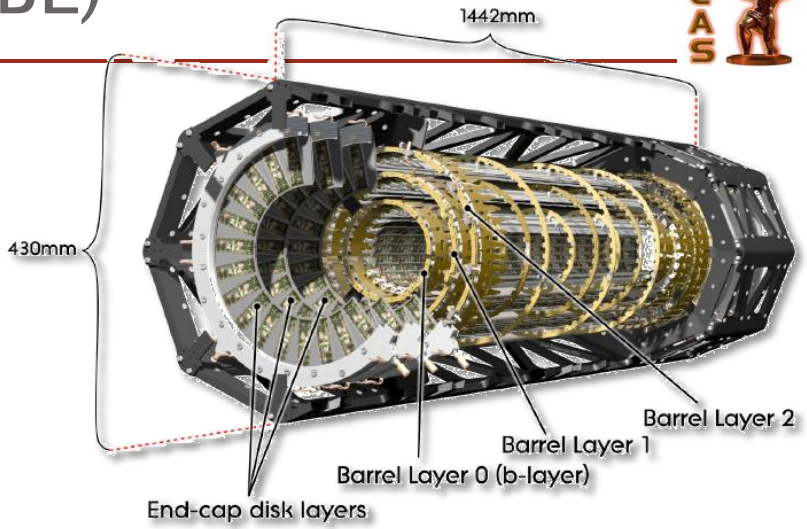
- University of Bonn
- CERN
- University of Göttingen
- J. Stefan Institute, Ljubljana
- New Mexico
- Ohio State University
- University of Toronto

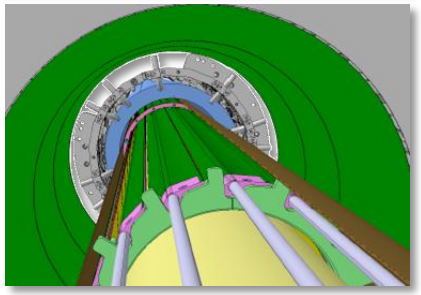
DBM – dependences

- DBM existence closely connected to two projects:
- ATLAS Insertable B-Layer (IBL)
  - additional layer of pixel detector installed on shrunk beam-pipe
- New Services Quarter Panel (nSQP)
  - project to move the opto-links of current pixel detector outside of the inner detector volume for easier access

ATLAS Insertable B-Layer (IBL)

- Current pixel detector
  - 3 layers
  - 10^{15} n/cm^2 benchmark
  - 10^{34} cm^{-2}s^{-1} instantaneous luminosity
  - Inner B-layer planned replaceable
- Facts
  - No hope replacing a layer in ~1y
  - LHC plans n x10^{34} cm^{-2}s^{-1} in 2019+
- Solution
  - Shrink beam pipe
  - Add insertable B-layer



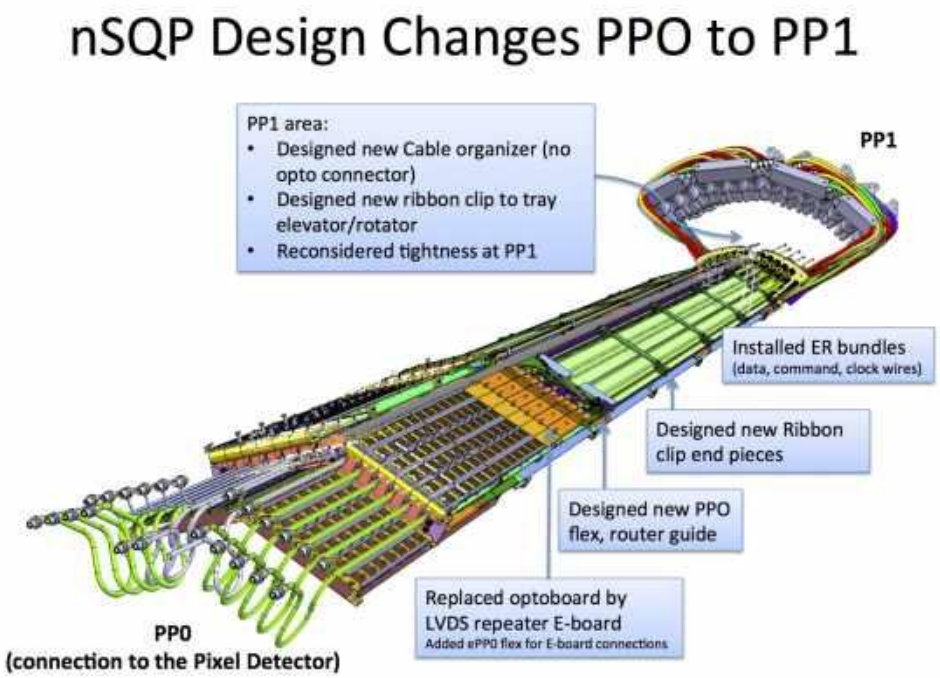


IBL Schedule

- Originally IBL planned for installation in 2016 shutdown
- Chamonix 2011→ LHC splice refurbishing in 2013/14
- ATLAS reaction – Fast Track IBL
  - Installation in 2013
  - Stave loading Feb 2012, all modules on staves end 2012
  - Twice the needed # of modules (& sensors) required by mid 2012
  - Schedule just in time, no contingency whatsoever !
- Sensor review July 2011: **¾/¼ planar/3D**
  - 3D the ¼ at large η
  - 100 % planar as backup, full quantity produced & bonded
  - Diamond out of the game since Jan 2011 → DBM

nSQP

- The ATLAS Pixel nSQP (new Services Quarter Panels)
  - reproducing the Pixel services
  - add long-term reliability to the operation of the Pixel Detector
- The current on-detector optoboards replaced by new optoboards located at ID End-Plate
- **Probably** installed on the Pixel detector during the next LHC shutdown (2013/14).

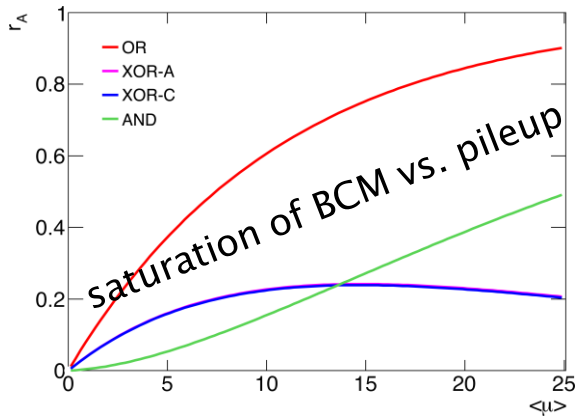


DBM – conception

- IBL qualification modules are single FE-I4 chip pixel modules
  - 50 μm x 250 μm pixels, 336 x 80 on an FE-I4 chip (16.8 x 20 mm^2)
- A very promising tracking device
- All (most) services & back-end are being developed for the IBL (and adopted by DBM)
- Take a ride on this wave
  - Build the ATLAS Diamond Beam Monitor (DBM)

DBM – purpose

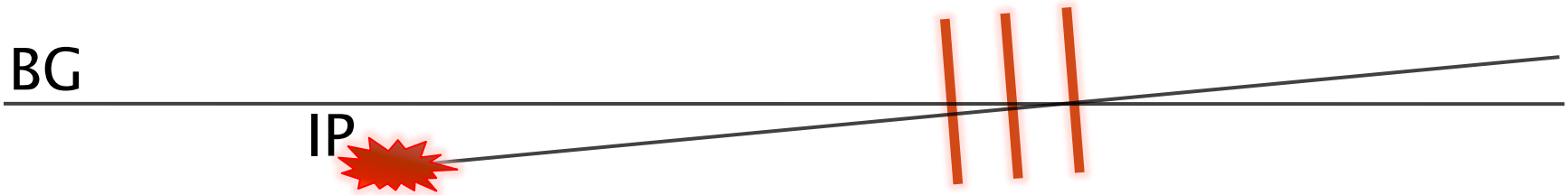
- Bunch-by-bunch luminosity monitor (aim < 1 % per BC per LB)
  - Finer segmentation and larger acceptance than Beam Condition Monitor (currently main ATLAS luminosity monitor)
  - saturation not a problem
  - internal stability monitoring



- Bunch-by-bunch beam spot monitor
  - Need three-module telescopes for tracking
  - Can distinguish hits from beam halo tracks
  - Unbiased sample, acceptance extends far along beam axis

DBM – goals

- Luminosity
  - monitor luminosity delivered to ATLAS for individual BCIDs
  - aim for % level accuracy in lumiblock (1-2 minutes)
- Beam Spot
  - unbiased (trigger) beam spot monitoring
  - aim for ~1cm accuracy per event
- Background monitoring
  - topology of BG different than IP interactions



- Track Trigger test-bed
  - possible test-bed for ideas (pattern reco., tracking,…)

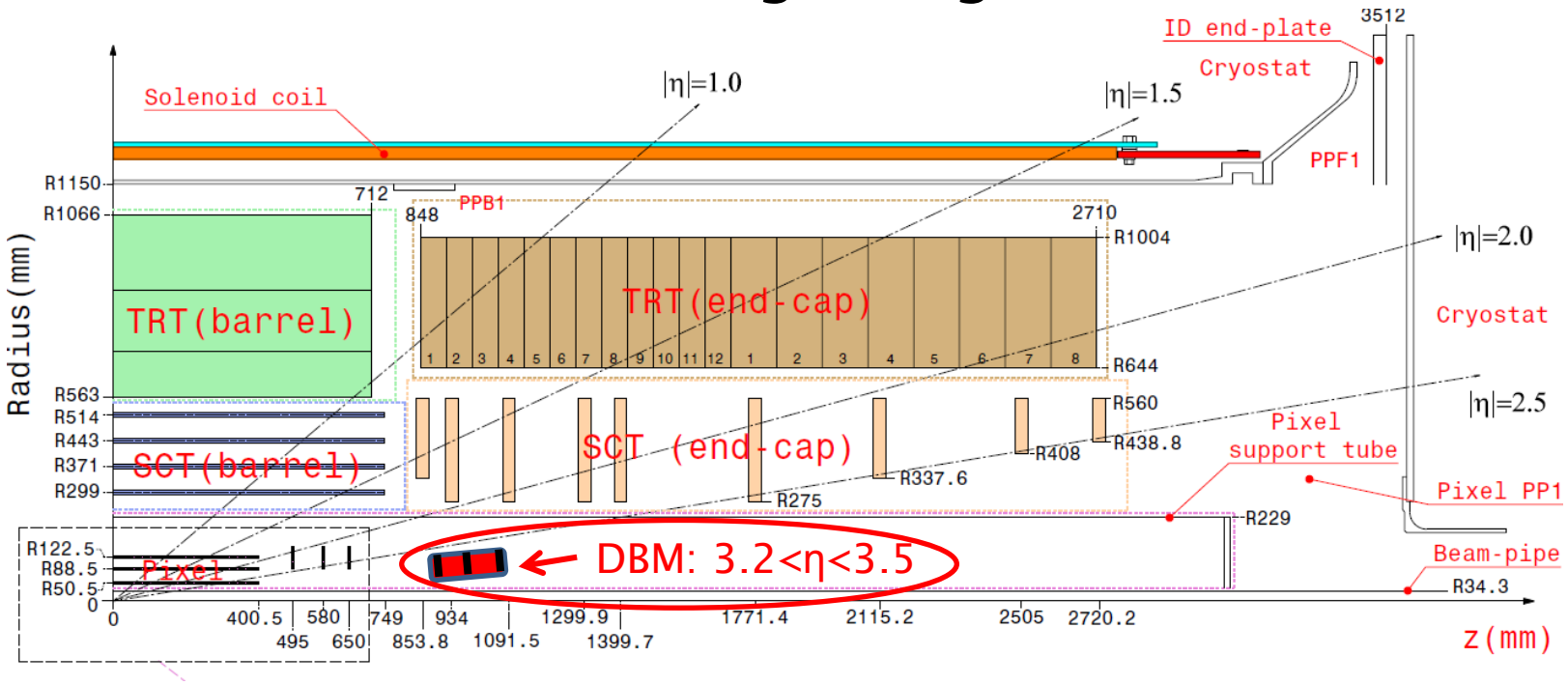
← all need more input from simulation (rate, occupancy,…)

DBM – design

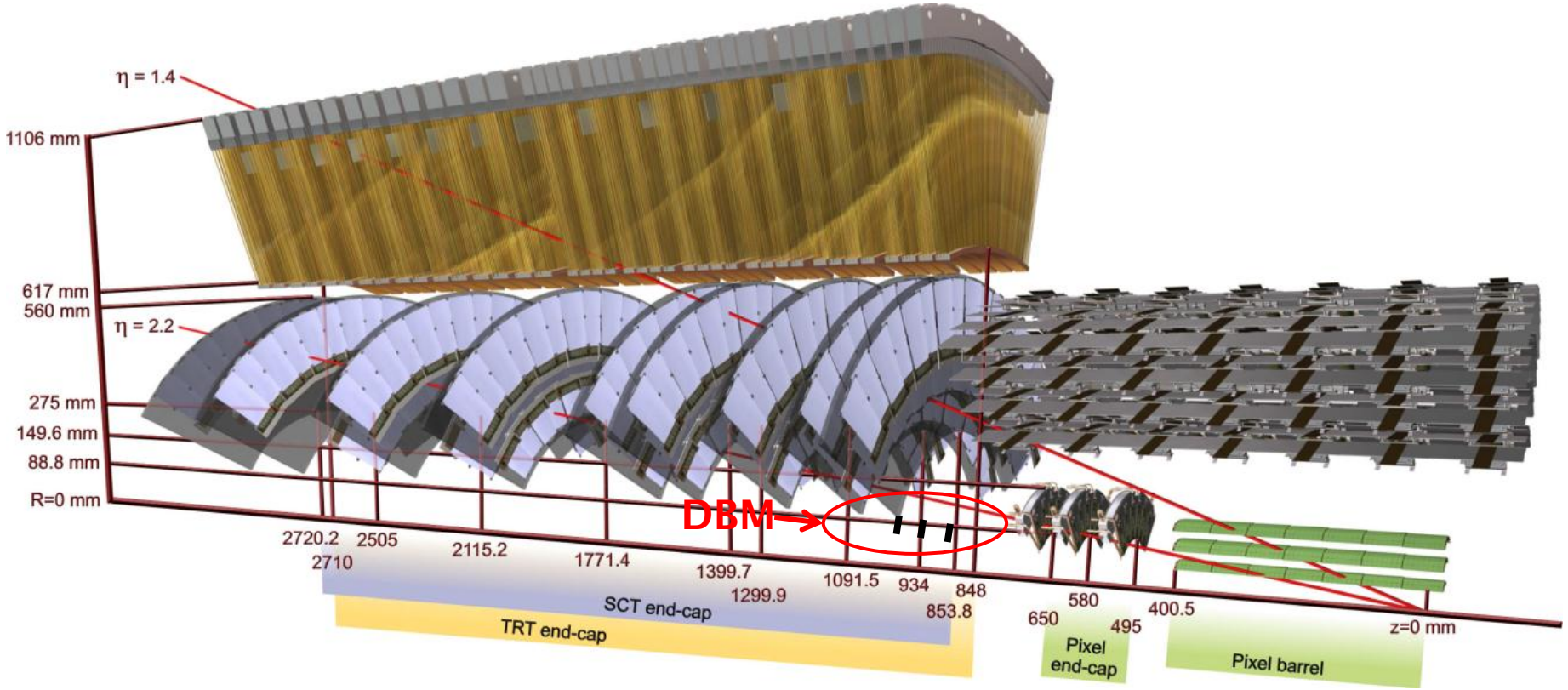
- Design considerations
  - Baseline: four telescopes of 3 IBL modules per side → 24 total
  - Avoid IBL insertion volume and ID acceptance (η>2.5)
    - In front of BCM (η~4.2); limited overlap
  - Place in pixel support structure close to detector and beam pipe
- Only possible if nSQP project brings pixels out in 2013
- Back-up plan is being considered if nSQP project will not be realized

DBM – geometry

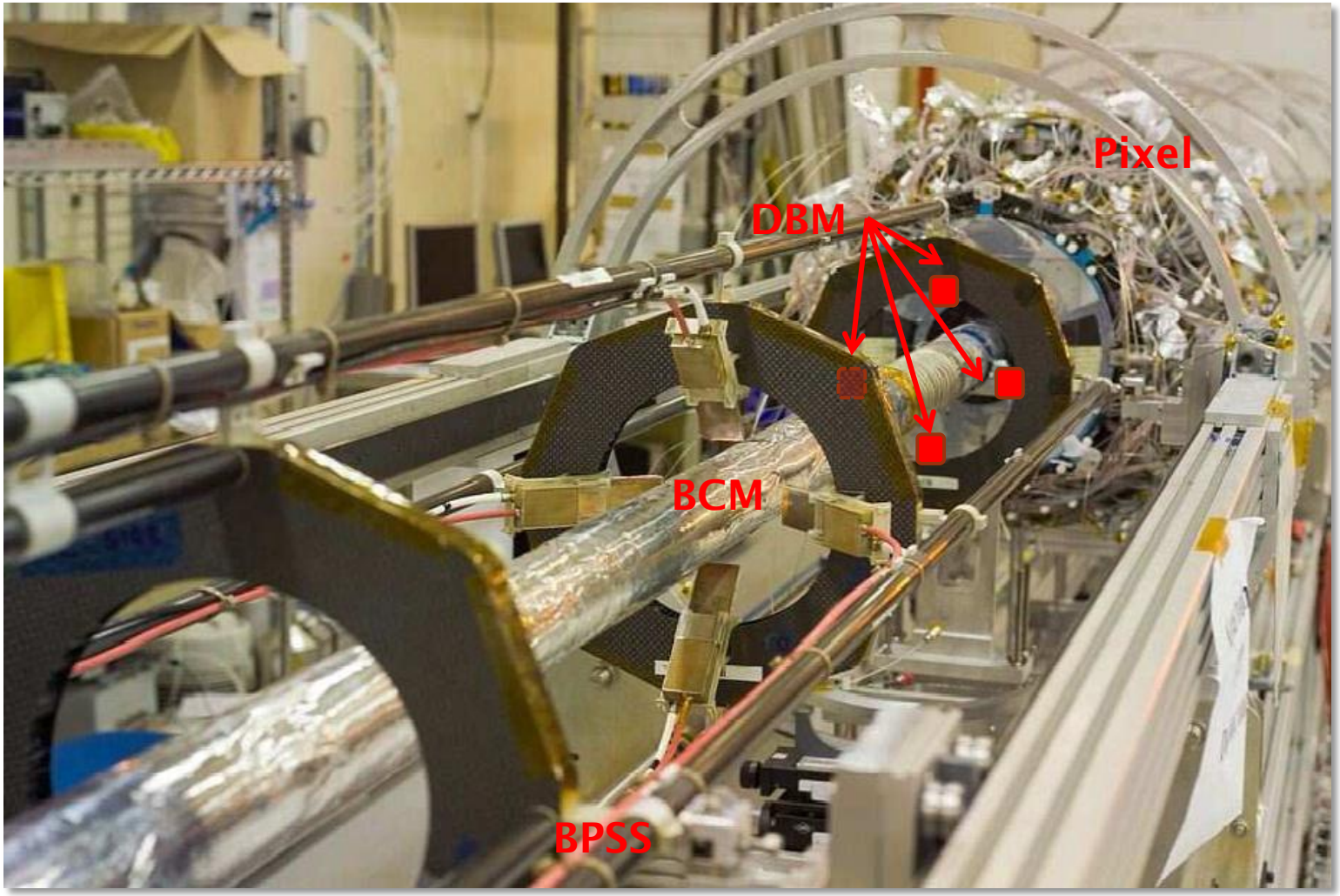
- Part of pixel volume, but needs IBL-type services
  - e.g. 1000 V for detector bias
  - Services inventory being included in nSQP
- nSQP sets installation date for DBM – July 2013
- Alternative location = beginning of 2014



DBM – installation



DBM – installation



DBM – within IBL

- Apart from sensors, mechanics and read-out modifications DBM just adds 24 IBL single chip modules to the existing 448
  - Services: two half-staves in addition to 2x14 of IBL
  - Requires an additional ~5 % of most IBL components
- Resources partly available under detector-specific part of IBL MoU
- DBM is now included as one of IBL work packages

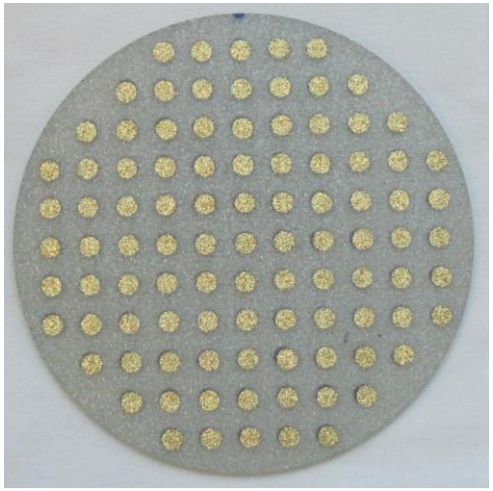
DBM – module production

- Baseline: 24 modules to be installed
- Production model: aim for 30 good modules
- Loss of 25 % during module assembly
  - Need parts to assemble 40+5=45 modules
    - 45 sensors, FE-I4's, flip-chippings, flexes etc.
    - 5 for irradiation studies
  - Diamonds are reusable!!! ☺
    - After testing with 1st version of FE-I4A diamond sensors will be re-used for final modules with FE-I4B

DBM - diamond sensors

- Two suppliers: DDL(E6) and II-VI
- Order 10 detectors from DDL (done)
- Order wafer from II-VI for June delivery (10-20 parts)
- Thin 23 existing thick parts
- Have 3+1 parts (correct thickness) at IZM

new wafer from DDL



quote from II-IV →

II-VI INFRARED ...the world leader in CO_2 laser optics

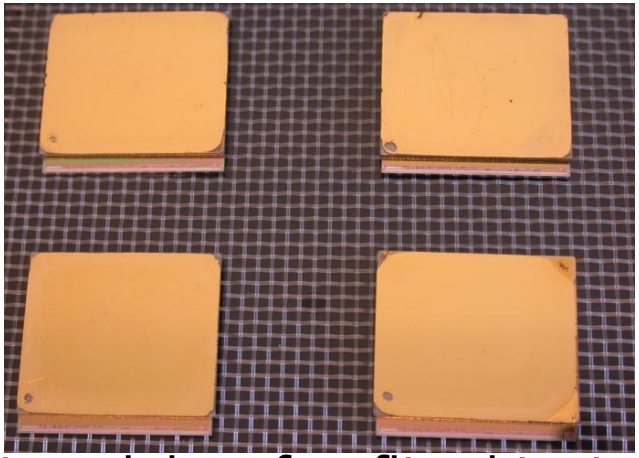
Part Description

SPECIFICATIONS FOLLOW

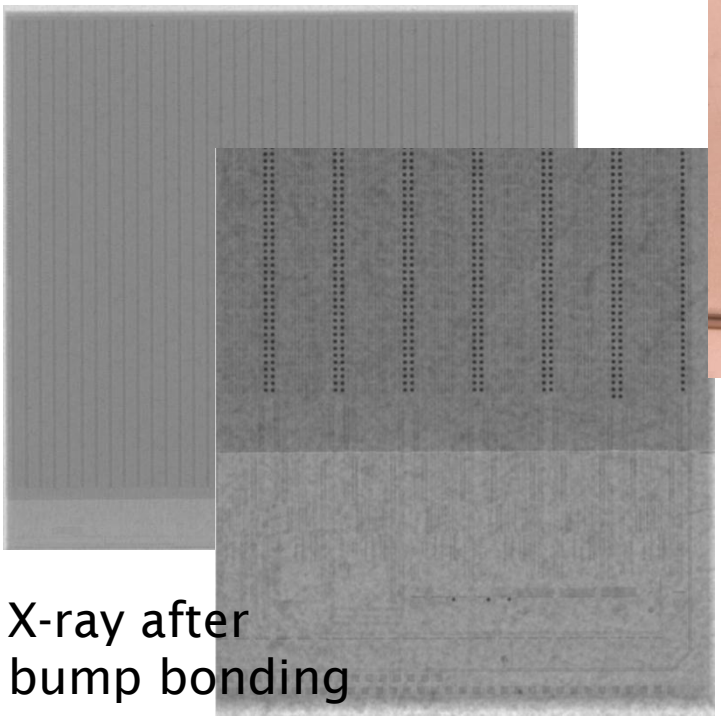
Thickness: 0.500 +/- 0.050mm
Length: 21.000 +/- 0.200mm
Width: 18.000 +/- 0.200mm
Growth surface planarized with minimum possible material removal
Nucleation surface thinned to final thickness
Surface Roughness: Ra <5nm for both faces (average of 20 measurements on each side)
Wedge: <5 arcmin
Edge Chips: <0.1mm
Serialization: Nucleation surface marked with 0.2mm characters within 0.7mm of edge (~8 characters)
Charge collection distance of polished part: >250um (measured by OSU)

First DBM modules

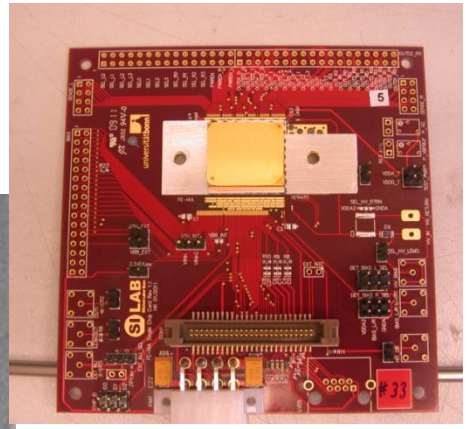
- Four DBM modules built at IZM
- 21x18 mm^2 pCVD from DDL
- FE-I4 ATLAS IBL pixel chip
- 336x80 = 26880 channels, 50x250 μm^2
- Largest ASIC/diamond flip chip assembly



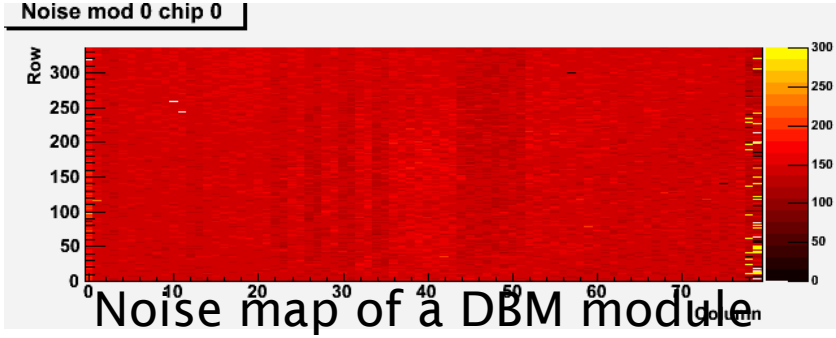
4 modules after flip-chipping



X-ray after bump bonding



Module on test board

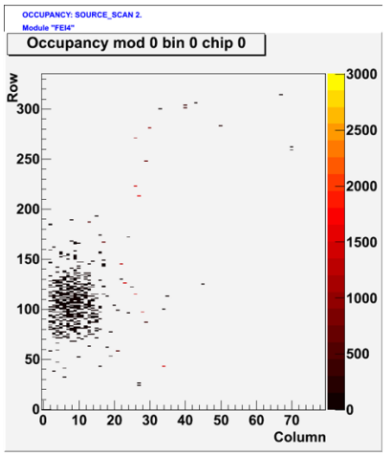


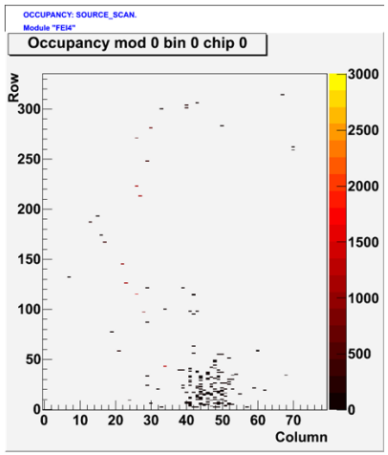
Noise map of a DBM module

DBM – first results

- Source test
- Modules tested with ^{90}Sr using USBPix
- The bump-bonds at edges are alive despite the worry of relatively large (~3 $10^{-6}K^{-1}$) CTE mismatch between diamond and Si

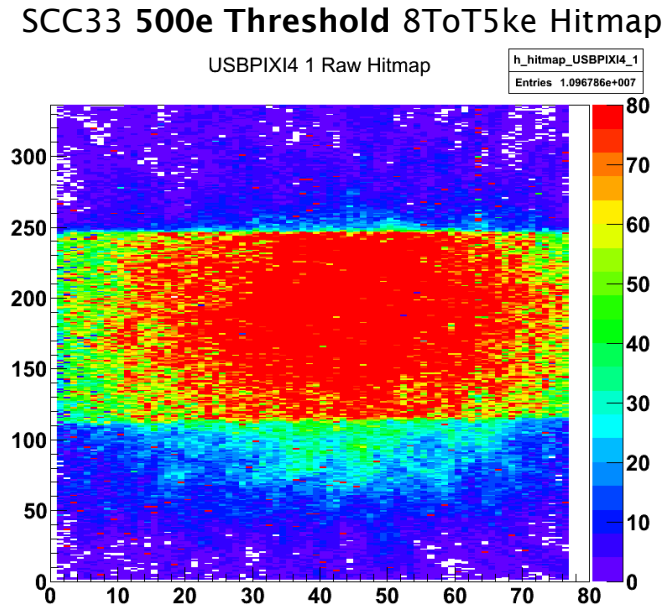
Two plots from edges:

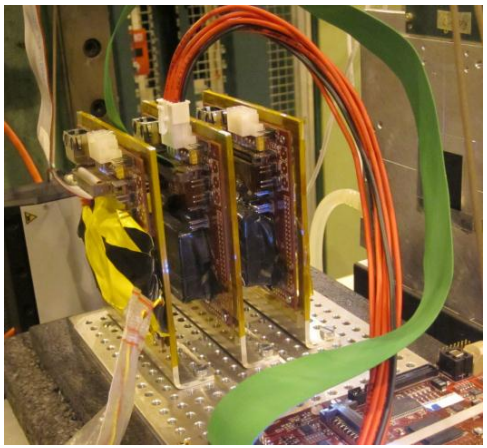


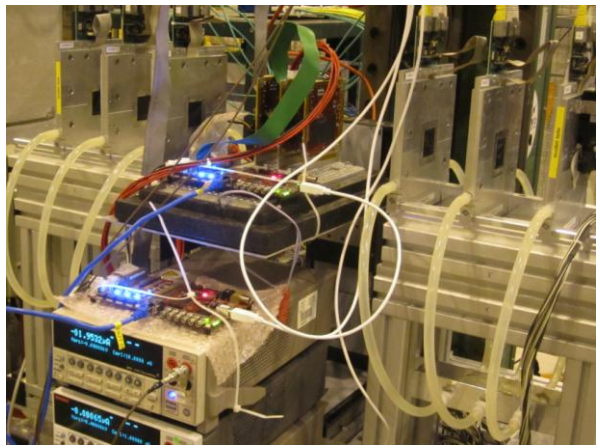


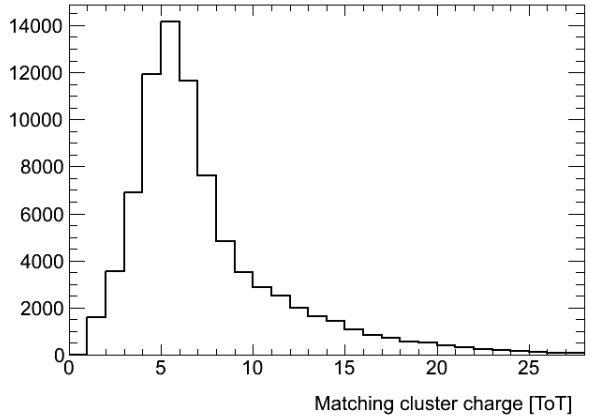
DBM – test beam

- 3 test-beam campaigns
  - Jul, Aug, Oct
- FE-I4 tuning accomplished @ 500 e
  - With 8ToT5ke
  - Is probably ~1000 e because of offset







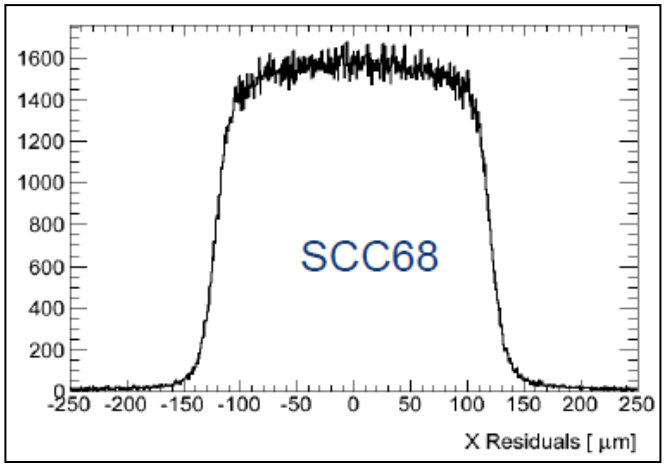


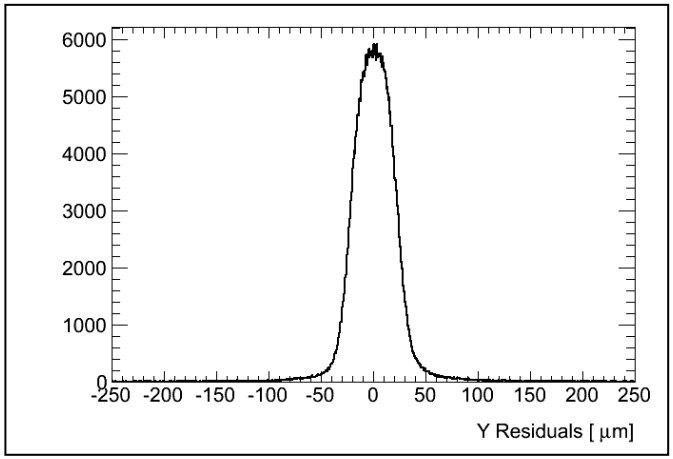
First test-beam results

- ATLAS Pixel TB setup works for DBM
- trigger rate @CERN ~400 Hz during spill
  → 1M triggers in 3.5 – 4 hours
- diamond TB schedule slightly more complex than Si, due to pumping
- sample tuning more critical than for Si
  - much lower thresholds
  - much lower feedback current
- we learned a lot:
  - noise occupancy excessively high, most likely due to metallization
  - no indication, that efficiency is unreasonably low
  - in-pixel TOT distribution unexpected, not yet understood (might be an artifact of the high noise occupancy)

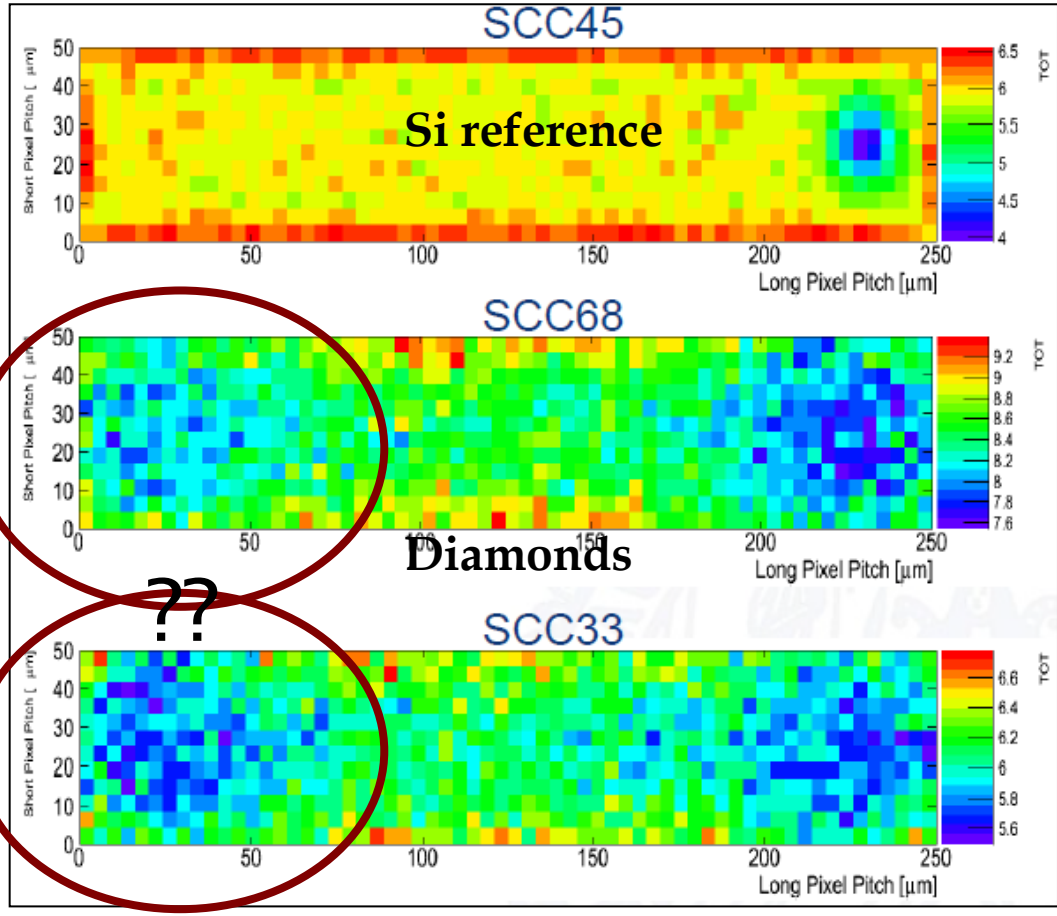
First test-beam results

Residuals look ok



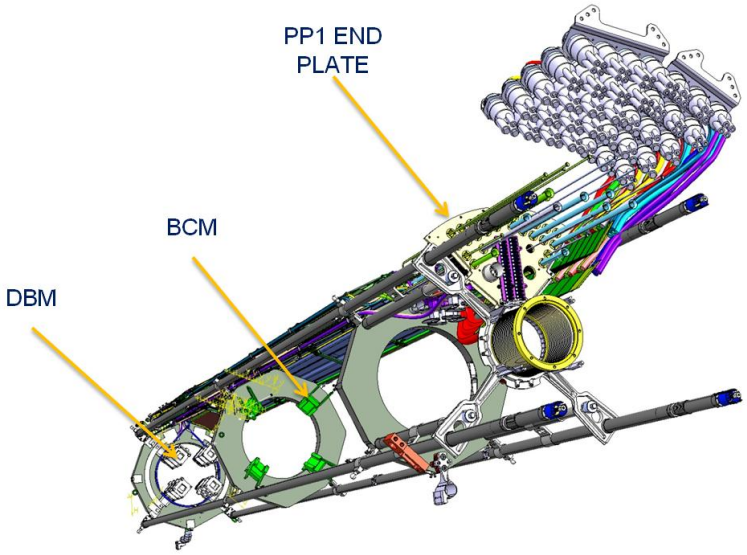


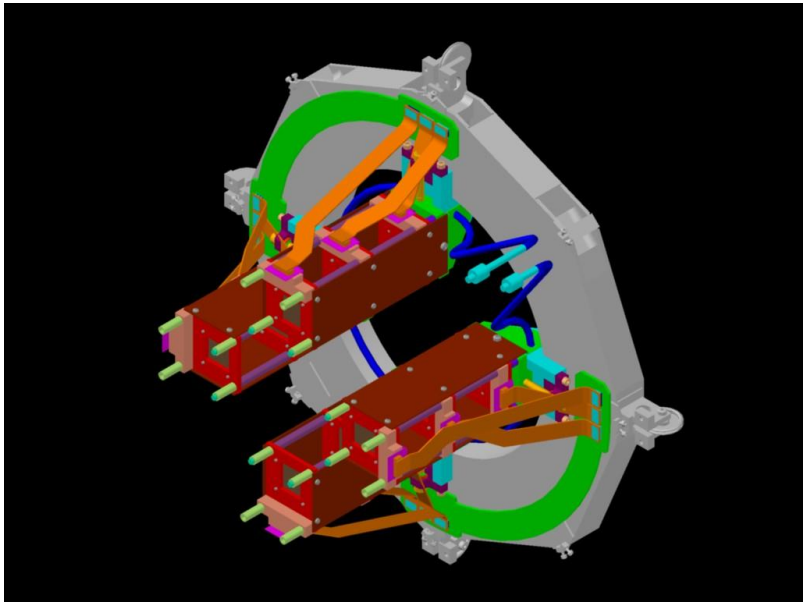
TOT distribution



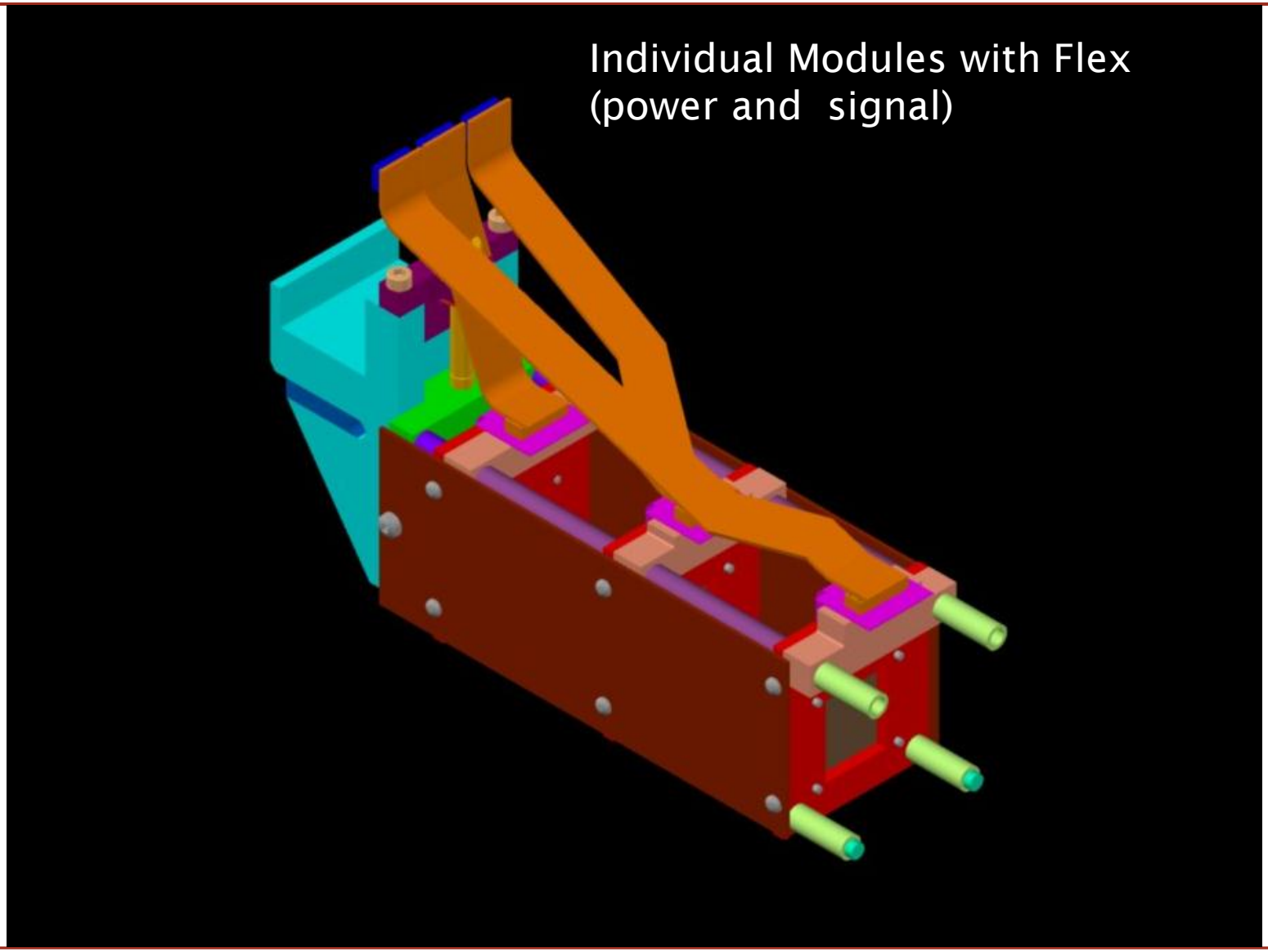
DBM – services

- Defined interfaces with nSQP team
- No showstoppers, agreed to work sharing
  - Services routing done, **big thanks** to nSQP team
  - DBM is treated as (half)stave 15 of IBL
- Cooling loops (DBM needs to be thermally neutral)



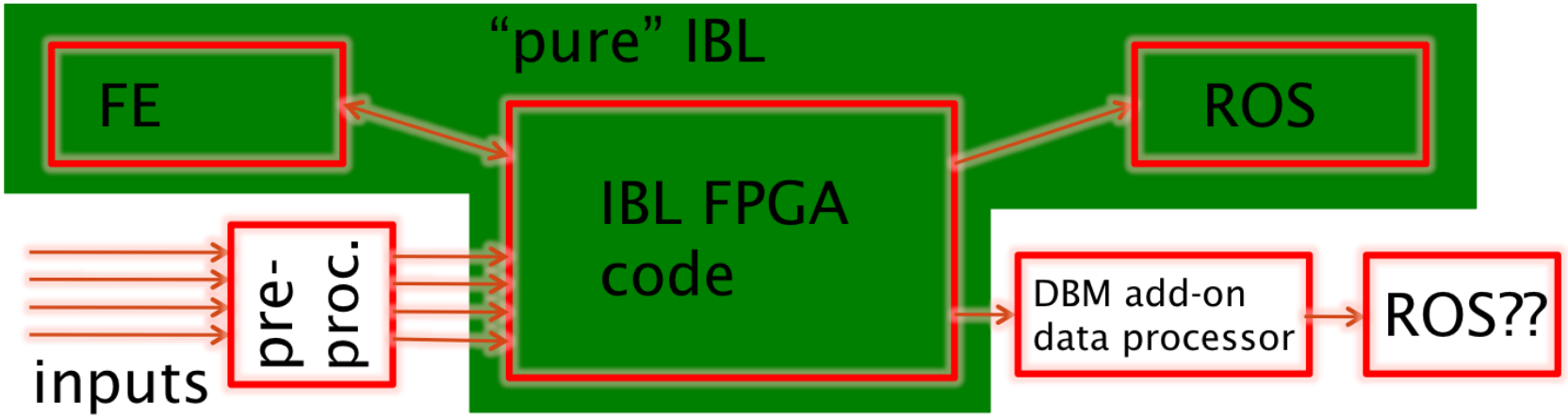


DBM – telescope design



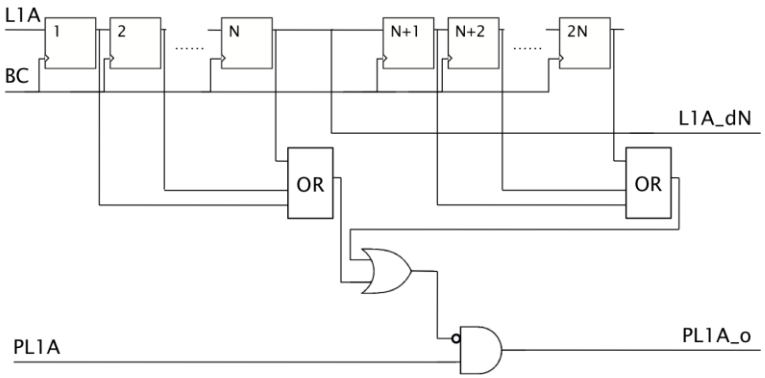
DBM – back-end

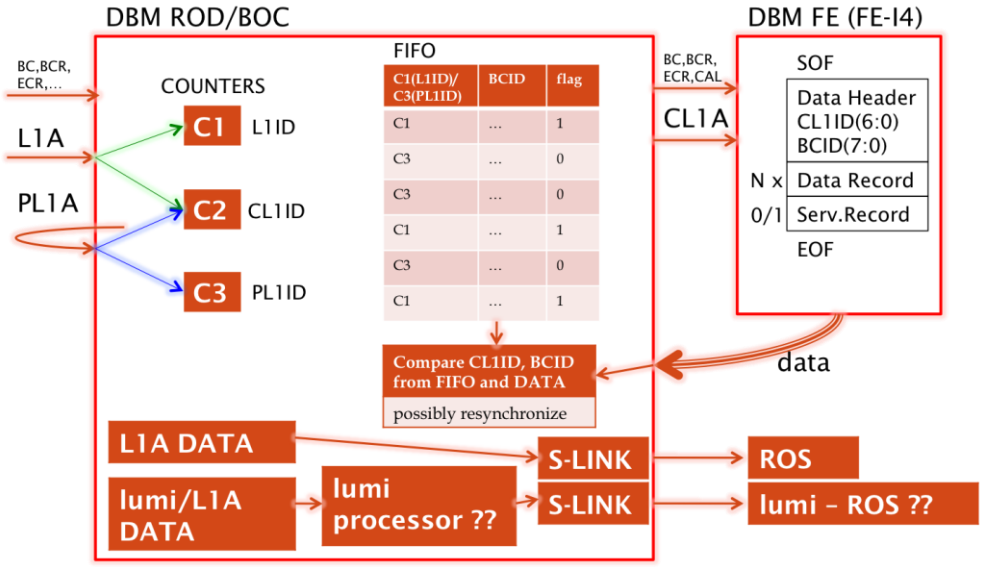
- Use identical hardware for Read out Driver (ROD) as IBL
- Reuse IBL-ROD firmware code as much as possible
- If possible add only additional blocks needed for DBM functionality – in form of "add-on"s



DBM – readout/triggers

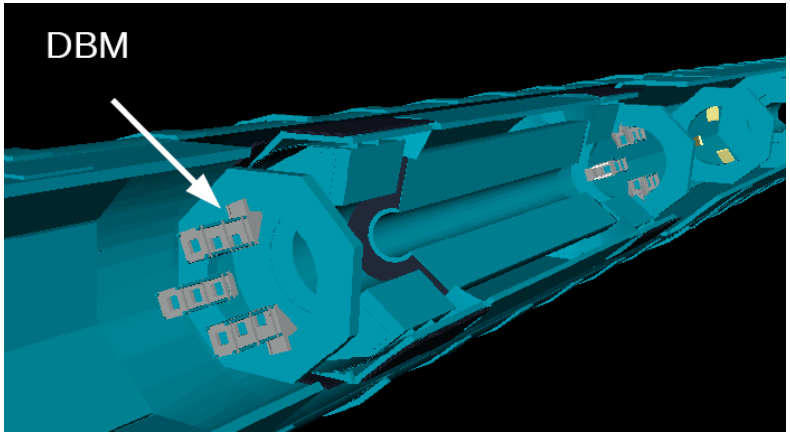
- Normal IBL-like readout at ATLAS wide level-1 trigger signals
- In addition fill the bandwidth with pseudo-random triggers (monitor luminosity and beam-spot reconstruction)
- Prioritizing mechanism for ATLAS L1 triggers over pseudo-random triggers
- Possibility to use hit-bus information from FE-I4



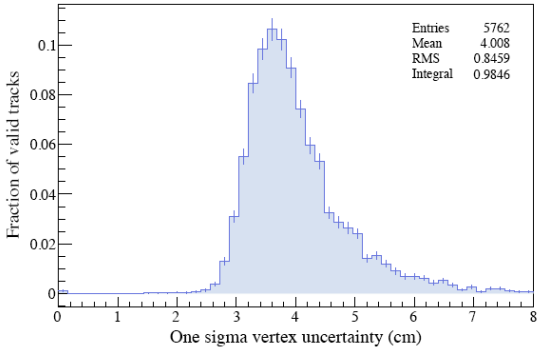


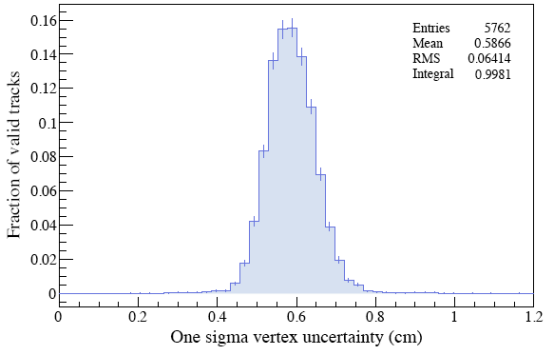
DBM – off-line

- Simulation studies underway



- Decided to focus on *z* of vertex, momentum resolution bad anyway → turn precise pixel side in *r*





Conclusion

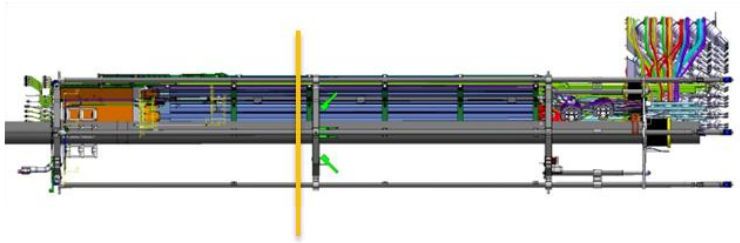
- DBM picking up momentum
- DBM integration into IBL and nSQP well under way
- Components being procured
- Number of modules produced and exercised

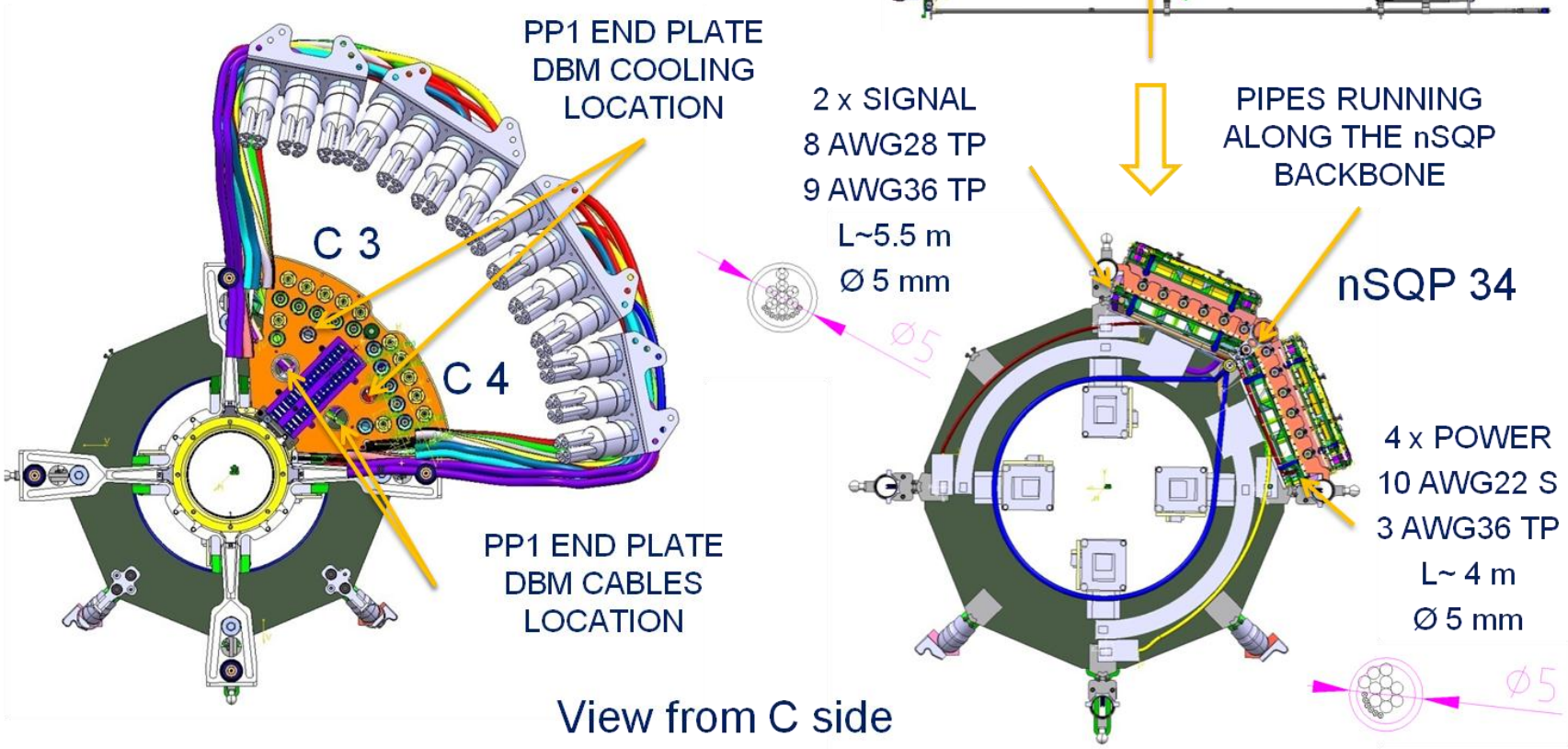
Back-up

DBM – sensor specifications

DBM – electrical services

- **2 SIGNALS BUNDLES nSQP C3**
- **4 POWER BUNDLES nSQP C4**





DBM – cooling

- **FITTINGS LOCATION**