Converging on tracker baseline 2.0

F. Bossu, D. Elia, L. Gonella, M. Posik
with input from Ernst, Nick, Rey, Shujie

ATHENA integration meeting
29 September 2020

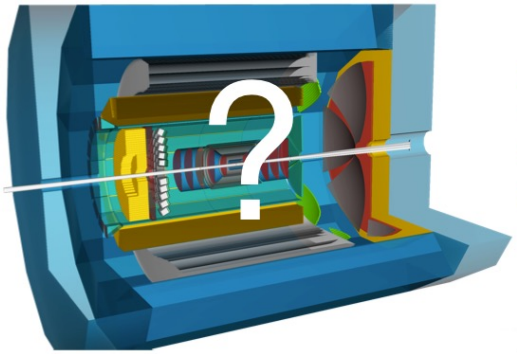
Introduction

- Aspects that have been considered to converge on the detector concept for the ATHENA proposal (baseline 2.0) are
  - Physics
  - Integration
  - Cost

- Plus… all the knowledge and technology developments from many years of eRD6 and eRD16/18/25

The Goal of the I/GD Subgroup is …

Design this:



and:

- Meet all physics requirements
- Low risk
- Upgradable
- Cost effective
- Superior to other concepts

with:

- Detector Working Groups
- Engineers
- Project
- Software Group
- DD4HEP
- Physics Working Groups
- Patience
- Little Time

In a constructive and friendly way

2

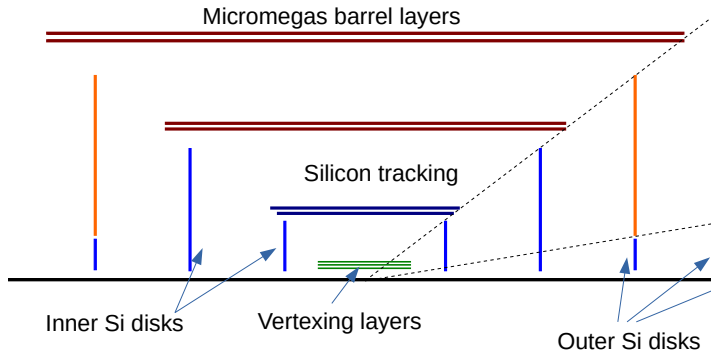
Thomas Ullrich, https://indico.bnl.gov/event/13175/contributions/54419/

Barrel layout

Si pixel pitch 10 um for vtx and barrel layers

Tracking WG Input for Next Iteration: Barrel

- **Barrel**: pretty settled by now - converging on hybrid setup
  - 3 D-MAPS Vertex layer
  - 2 D-MAPS tracking layer
  - 4 (2x2) MMG layer
  - No MPGD layer after DIRC since ECAL's first layer is Si (AstroPix) layer with $\sigma \approx 500/\sqrt{12}\ \mu\text{m} = 144\ \mu\text{m}$
  - Design leaves plenty of room for possible future upgrades
    - ToF (AC-LGAD/LAPPD)
    - miniTPC (GridPix)
    - high-p_T solution (RICH)



- Covers $-1.1 < \eta < 1.1$
- Minimal mass except at edges due to service (FEE, cables, …)

Thomas Ullrich, https://indico.bnl.gov/event/13175/contributions/54419/

Si Vertex	Radius (mm)	Length (cm)	% X/X0
Layer 1	33	28	0.05
Layer 2	44.1	28	0.05
Layer 3	55.1	28	0.05

- Three vtx layers for redundancy and low pT-threshold
- Radii from 1st engineering CAD model release based on possible stitched sensor size in phi
- Length = 28 cm: max length of a single sensor on wafer, allows for services on one side only; helps low material in negative direction

Si Barrel	Radius (cm)	Length (cm)	% X/X0
Layer 1	13.38	35.74	0.55
Layer 2	18	48.08	0.55

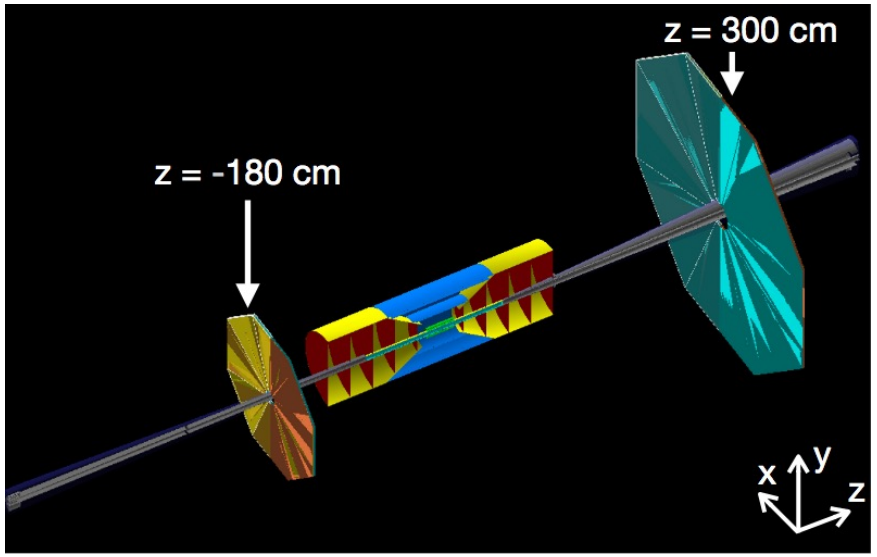
- 0.55% X/X0 might be conservative; Rey showed significant performance improvement for lower material in these layers; material optimisations to be looked into considering RD104 services reduction, inputs from engineers, etc. not necessarily for the proposal

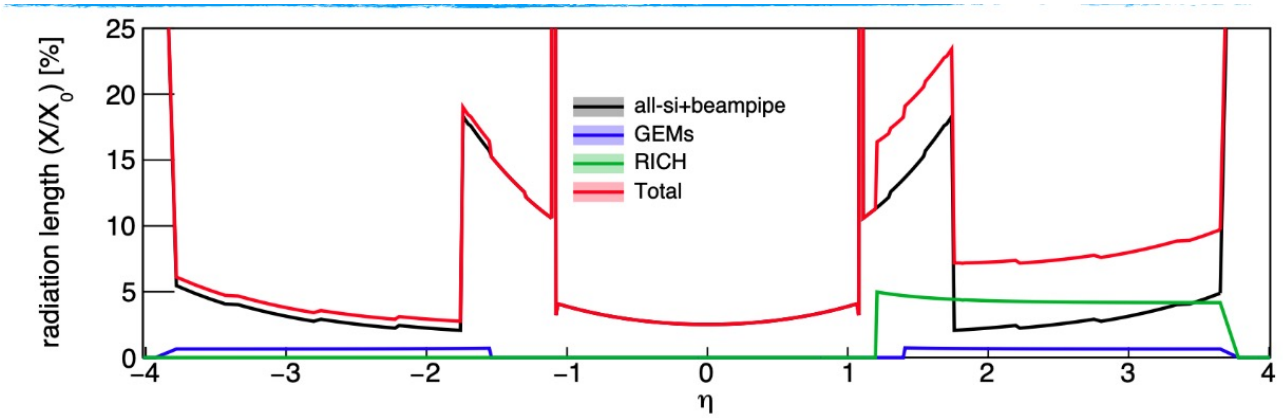
Barrel MPGD Tracker (MM)	Radius (cm)	Length (cm)	Area (m^2)	Resolution (um)	% X/X0
Layer 1	47.72	127.47	3.82	150	0.4
Layer 2	49.57	127.47	3.97		
Layer 3	75.61	201.98	9.59		
Layer 4	77.47	201.98	9.83		

- Cheaper than silicon, no detrimental effect on performance
- Further optimisation of number of layers requires pattern recognition in presence of background, not for the proposal

Forward/backward regions: a bit of history

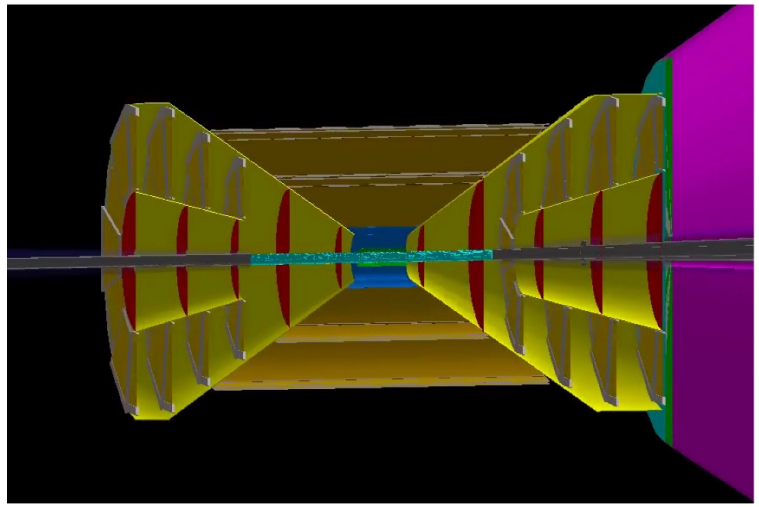
- Critical to reduce material in front of EMCal, especially in the backward direction
- The concern with all-silicon **was** the material 1 < |eta| < 2
  - Otherwise, good for performance, cost and integration

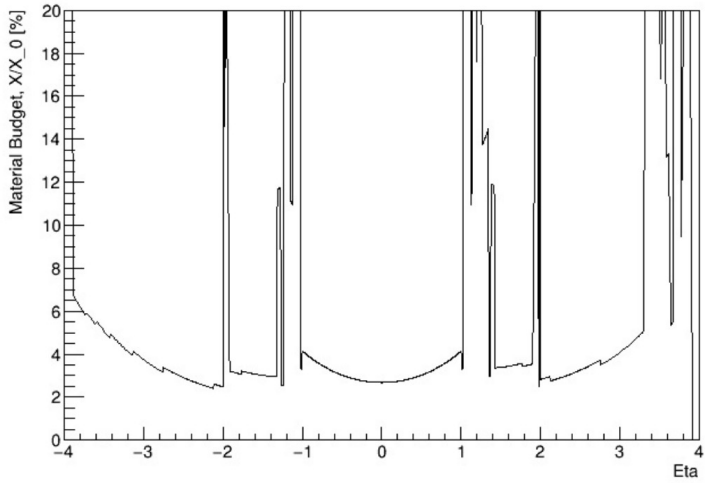




Forward/backward regions: a bit of history

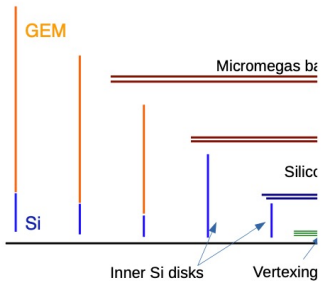
- A projective configuration was introduced to reduce material over broad eta range
  - An all-Si projective tracker would do an excellent job meeting the physics requirements, but may get too expensive (~1+ meter disks at large |z|)
  - An all MPGD projective tracker will not meet the physics requirements
  - A hybrid Si-MPGD is best compromise though it will still have some services and support material in front of ECAL but it has to be as projective as possible for the two technologies to concentrate the high material thickness in clearly identified regions in phi rather than spread all across large eta range.





Tracking WG Input for Next Iteration: Fwd/Bkwd (I)

- **Fwb.Bckwd:** new projective layout
- Mix of Si disk and low mass GEM disks
- Bigger Inner Silicon disks
  - cost saving
- Overlap among technologies
  - cross-calibration, better control of systematics
- Extended forward and backward Si disks for better Bdl
- Extended silicon disks up to ± 175cm may be essential for increasing the pseudorapidity coverage



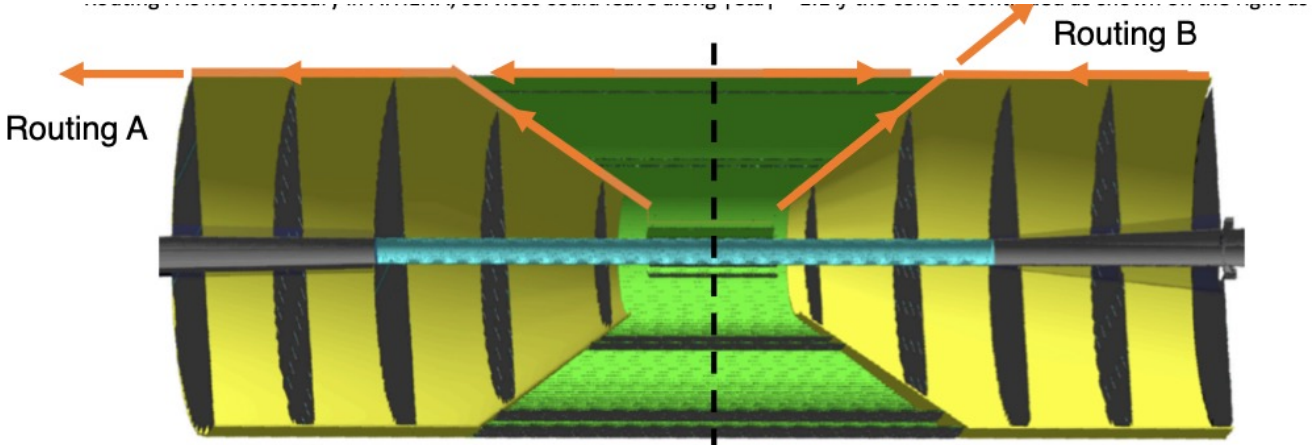
- Issues
  - disk position and diameter not optimized (see talk by E. Sichtermann at tracking meeting Sep 14)
  - Integration, service routing: not clear current layout is even possible

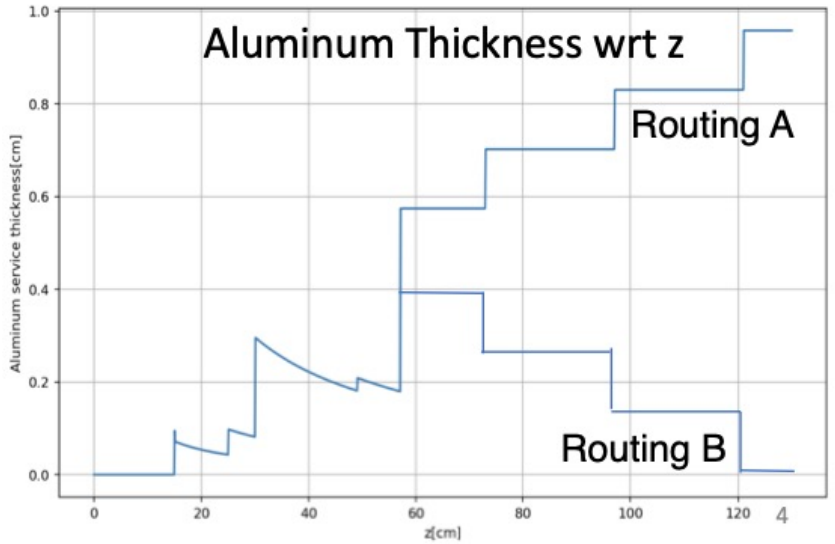
13

Thomas Ullrich, https://indico.bnl.gov/event/13175/contributions/54419/

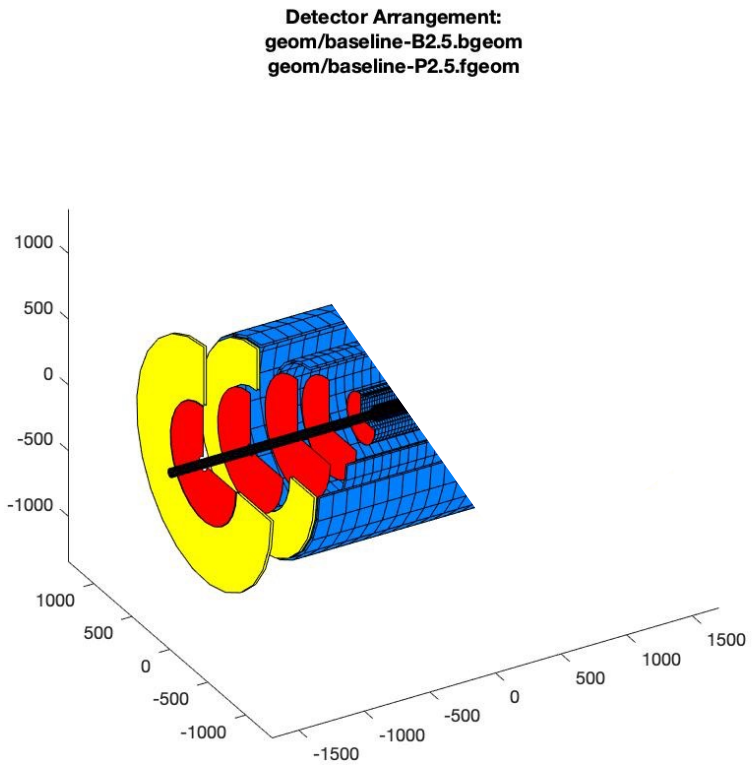
Forward/backward regions: last week developments/findings

- Projective configuration
  - Meeting with engineers on 23 September; integration and service routing far from trivial, it would require significant engineering work to establish integration feasibility, not possible on the timescale of the proposal; the cost for integration could also become significant; different support materials could be needed for different structures
- All-silicon configuration
  - See Ernst's talk at Tracking WG meeting 28 September https://indico.bnl.gov/event/12601/
  - Bottomline: material in the all-silicon for 1 < |eta| < 2 can be reduced by choosing a different routing configuration for the services (use routing B instead of A)
    - Also remember that RD104 addresses further services reduction so that will help further





Forward/backward regions: new configuration



* -150 cm should be possible, checking position of mRICH

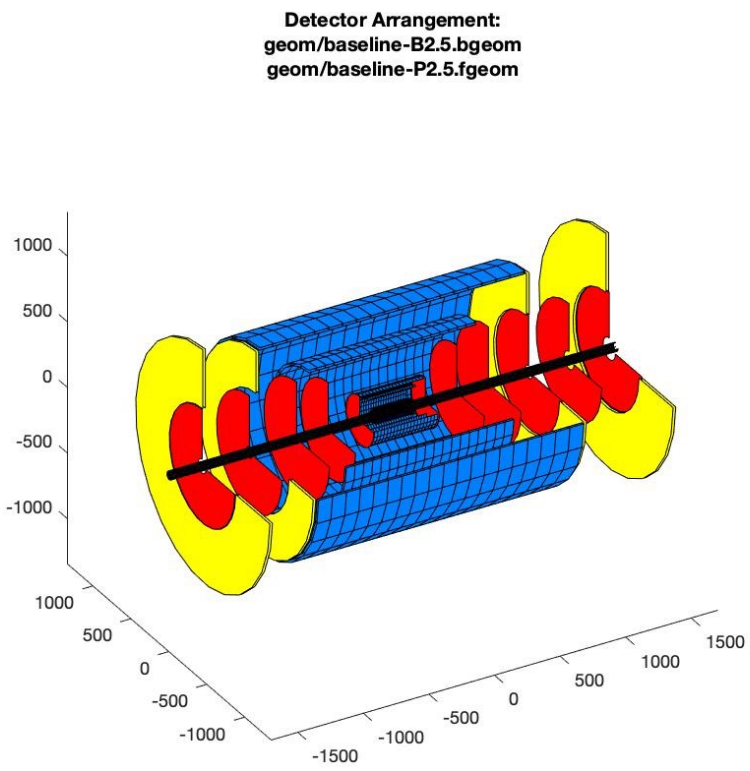
** Resolution can be improved for this small size GEMs

- Backward region
  - Five silicon disks, 10 um pixel pitch
  - Disks 1 to 3 in the same position as all-silicon
  - Disk 5 at -145 cm* (was -121cm in all-silicon)
    - Better Bdl
    - Increased the pseudorapidity coverage
  - Disk 4 equidistant from 3 and 5
  - 2x GEM rings to increase number of points in 1.1 < |eta| < 1.7
    - Z position chose to cap / close up the MPGD barrel and the overall tracking volume
    - No overlap needed between Si and GEM

Si Disks	Z Position (cm)	Inner Radius (cm)	Outer Radius (cm)	% X/X0
Rear Disk 5	-145		43.23	0.24
Rear Disk 4	-109		43.23	0.24
Rear Disk 3	-73	3.5	43.23	0.24
Rear Disk 2	-49	3.18	36.26	0.24
Rear Disk 1	-25	3.18	18.5	0.24

GEM Rings	Z Position (cm)	Inner Radius (cm)	Outer Radius (cm)	% X/X0	Resolution [um]**
Rear Disk 1	-102	43.5	75.5	0.4	250 x 50
Rear Disk 2	-144.5	43.5	88.5	0.4	250 x 50

Forward/backward regions: new configuration



* +170 cm should be possible, checking position of dRICH
** Resolution can be improved for this small size GEMs

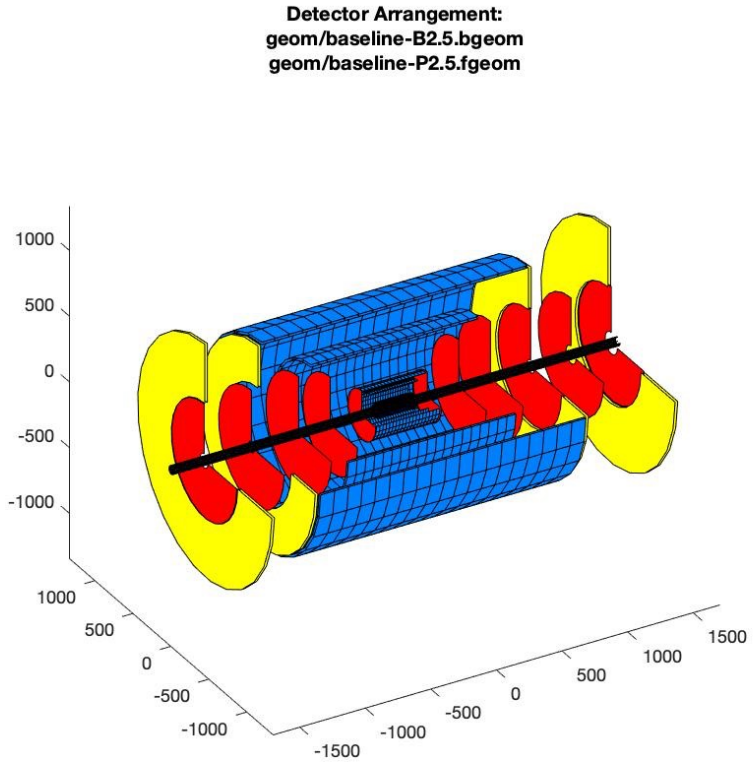
- Forward region
  - Six silicon disks, 10 um pixel pitch
  - Disks 1 to 3 in the same position as all-silicon
  - Disk 6 at +165* cm (was +121cm in all-silicon)
    - Better Bdl
    - Increased the pseudorapidity coverage
  - Disks 3 to 6 equidistant
  - 2x GEM rings to increase number of points in 1.1 < |eta| < 1.7
    - Z position chose to cap / close up the MPGD barrel and the overall tracking volume
    - No overlap needed between Si and GEM

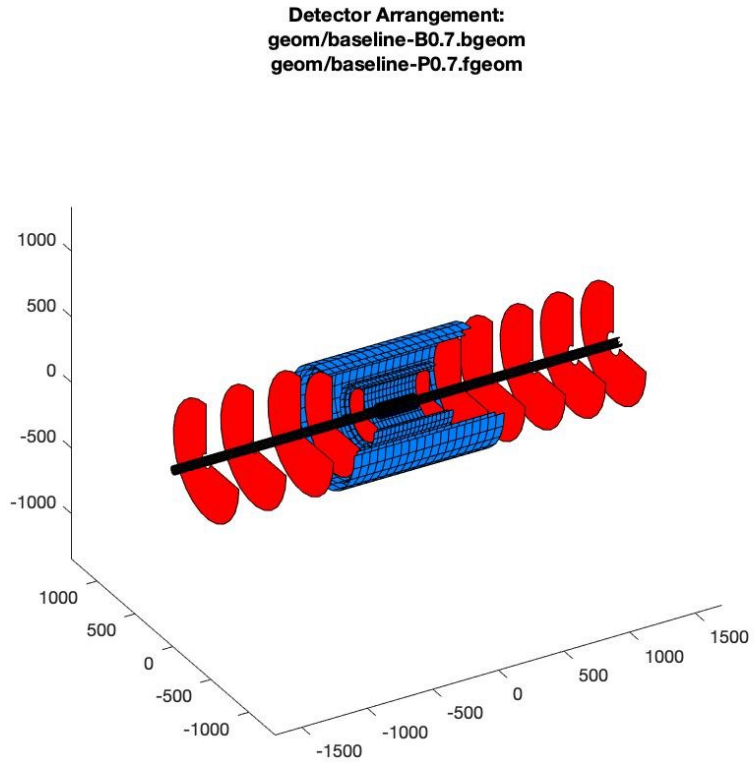
Si Disks	Z Position (cm)	Inner Radius (cm)	Outer Radius (cm)	% X/X0
Fwd Disk 6	165		43.23	0.24
Fwd Disk 5			43.23	0.24
Fwd Disk 4			43.23	0.24
Fwd Disk 3	73	3.5	43.23	0.24
Fwd Disk 2	49	3.18	36.26	0.24
Fwd Disk 1	25	3.18	18.5	0.24

GEM Rings	Z Position (cm)***	Inner Radius (cm)	Outer Radius (cm)	% X/X0	Resolution [um]**
Fwd Disk 1	+102	43.5	75.5	0.4	250 x 50
Fwd Disk 2	+164.5	43.5	88.5	0.4	250 x 50

E. Sichtermann

Baseline Tracking Configurations for ATHENA





Hybrid Tracker Concept has been updated for

- overall length, now -1.45m < z < 1.65m,
- vertexing barrel, still 3 layers but now 280mm length,
- cylindrical inner silicon subsystem(s),
- 2x4 GEM disks to complement tracking at large radii,
- 2+2 MM in the barrel

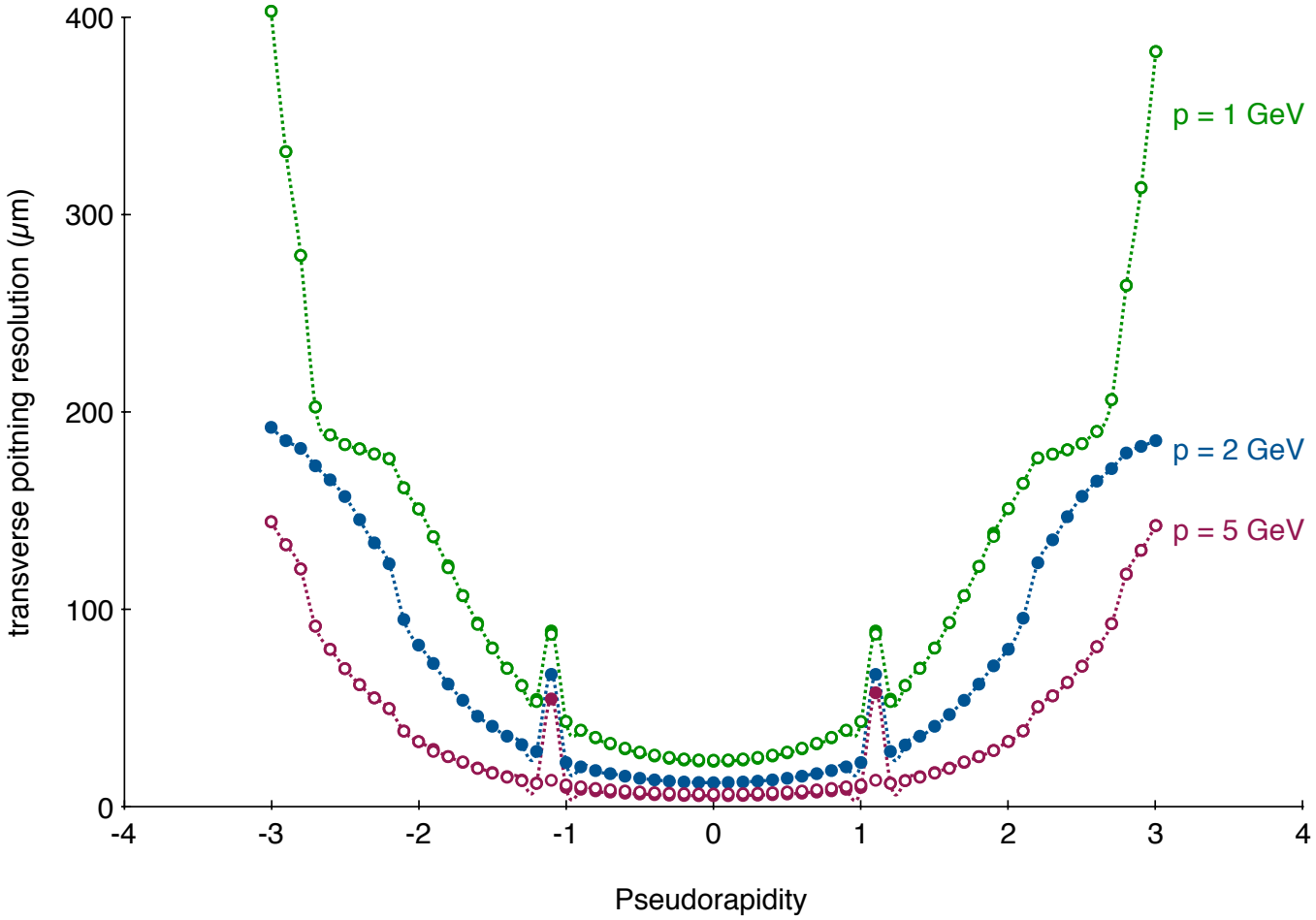
All Silicon Tracker Concept has been updated for

- overall length, now -1.45m < z < 1.65m, 1 addtl. disk at large z,
- vertexing barrel, now 3 layers and 280mm length,

E. Sichtermann

Baseline Tracking Configurations for ATHENA

Vertexing layers and inner disks are identical; single-track DCA performance is near-identical:

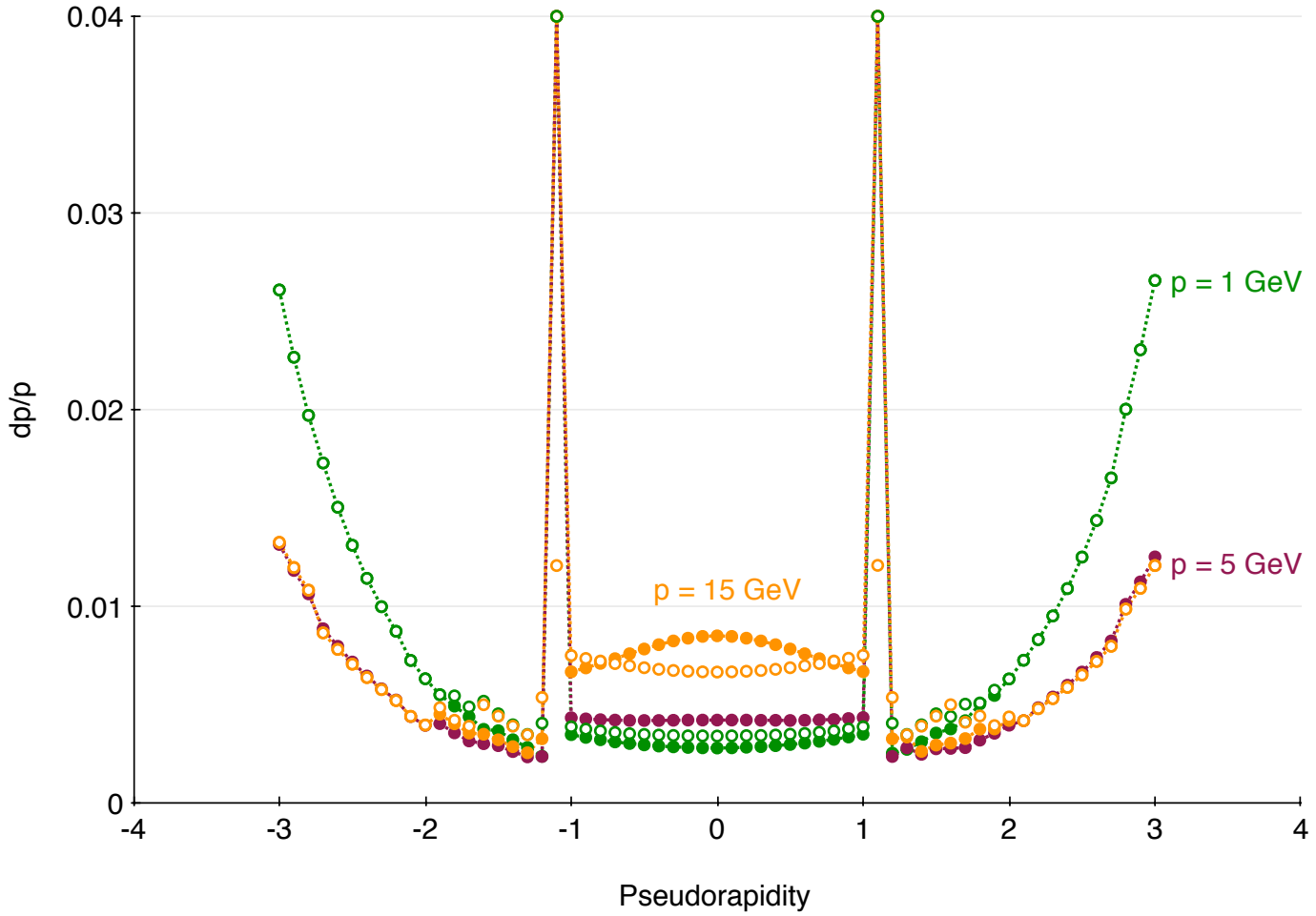


filled symbols – hybrid
open symbols – all-silicon

Note, these fast-simulations are obviously very, very preliminary.

Baseline Tracking Configurations for ATHENA

Tracking layers and disks are, obviously, somewhat different; performance is comparable.

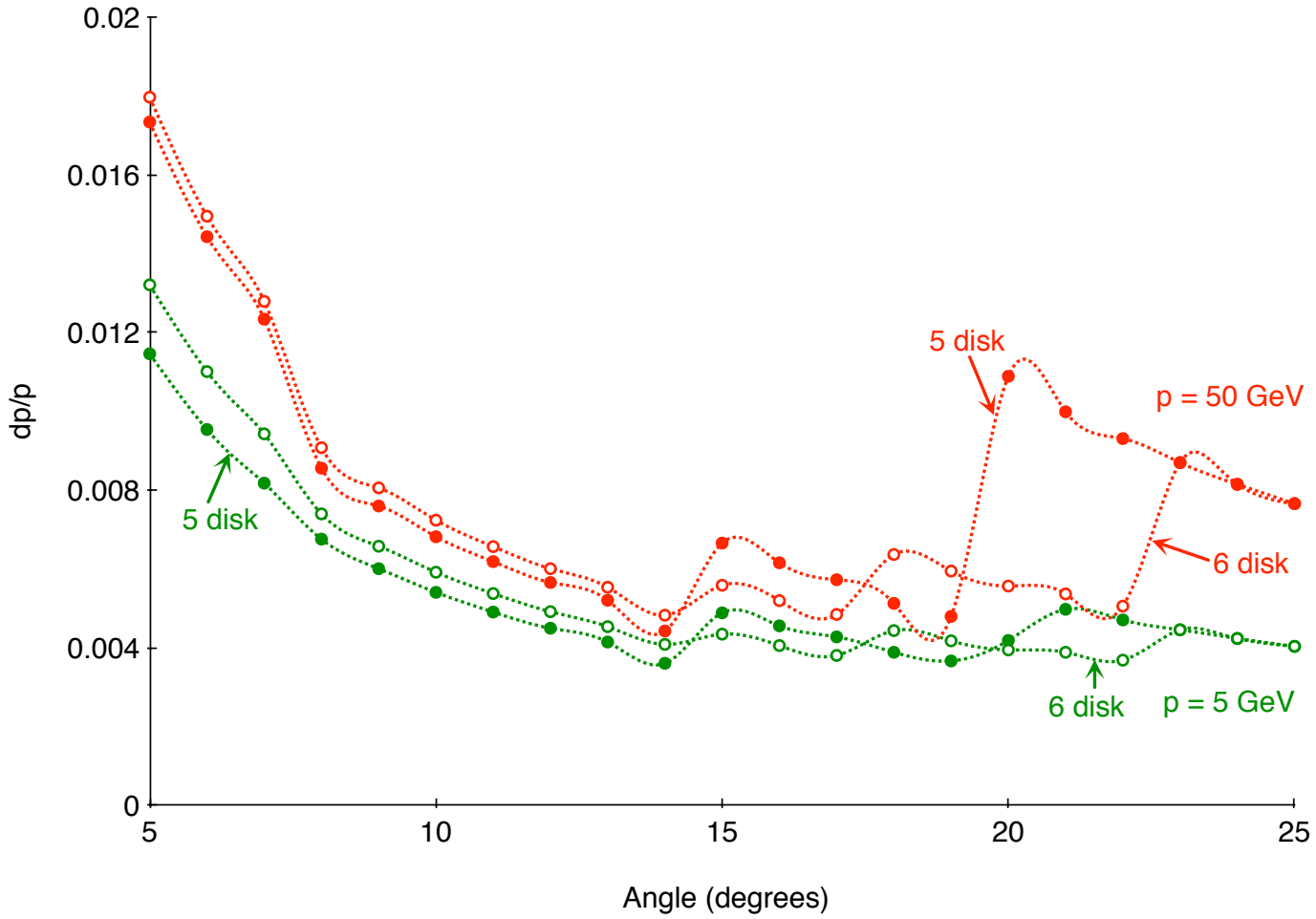


filled symbols – hybrid
open symbols – all-silicon

Note, these fast-simulations are obviously very, very preliminary.

Baseline Tracking Configurations for ATHENA

6 disks in the hadron direction appears favorable (**all-silicon results only**):



filled symbols – 5-disks
open symbols – 6-disks

Note, these fast-simulations are obviously very, very preliminary.

Conclusion

- We believe the current design works for physics, integration and cost (and keeps everybody happy)

- What is missing before giving the configuration to the SW WG
  - Benchmark plots in Fun4All
    - Consider also large GEM behind mRICH and behind dRICH
  - (Hopefully brief) Check with engineers about integration of the two GEMs rings
  - Define support and services thickness along cone and cylinders with optimised routing
  - Test with the shifted magnetic field

- We expect we can be ready by mid of next week, that should be in time for when the SW WG plans to work on the next configuration

Outcome of the meeting

- Barrel and forward region – OK

- For backward region – to check
  - Adding GEM rings adds material in the negative direction
  - How much larger would a silicon disk need to be to give the extra tracking points in 1.1 < |eta| < 1.7? And what material would this larger disk have?
  - If we keep the GEM rings, would the material to support the silicon disks in front of the GEM be tolerable?
  - If we do not converge within one week, no GEM disks in the backward region (for the proposal)