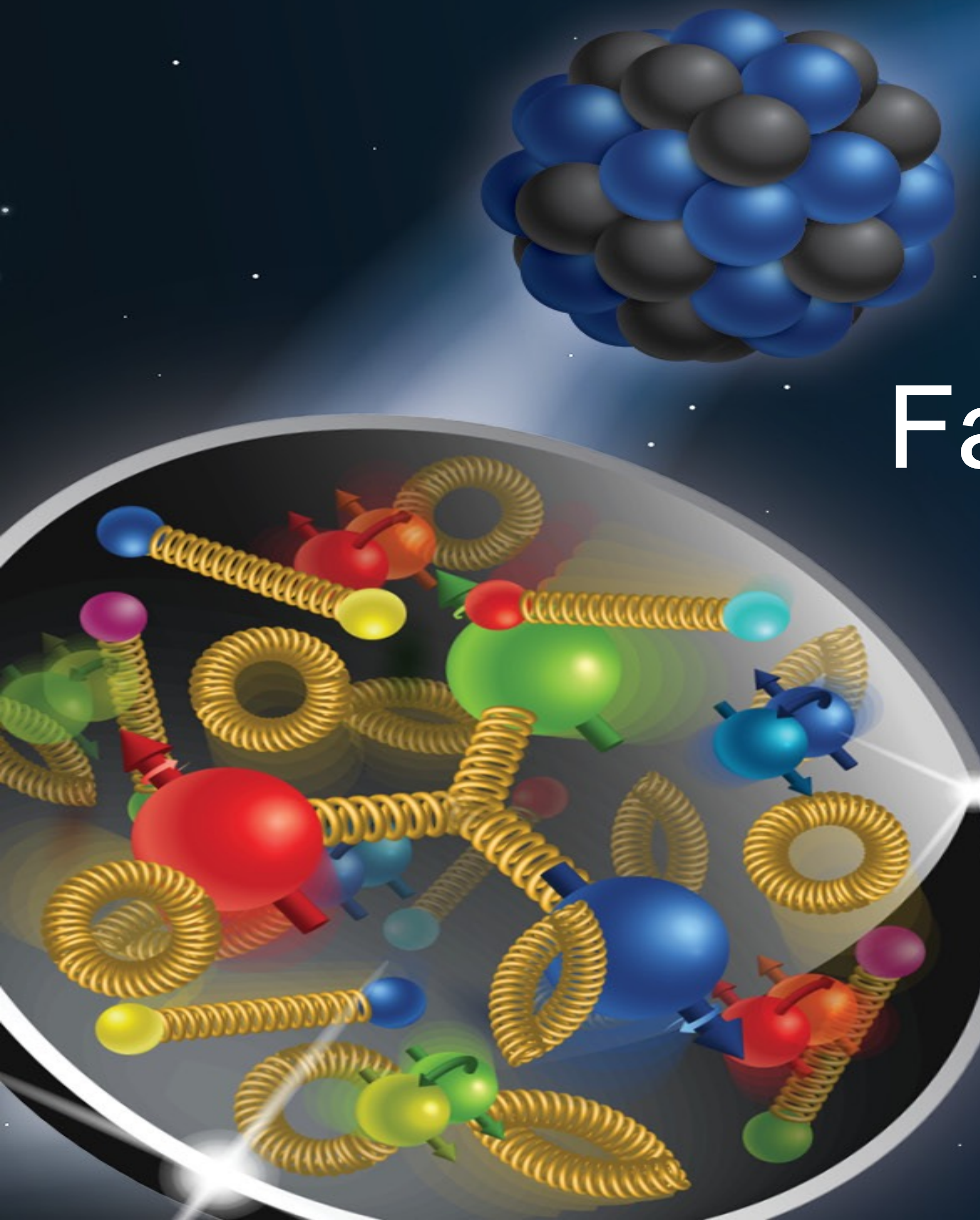


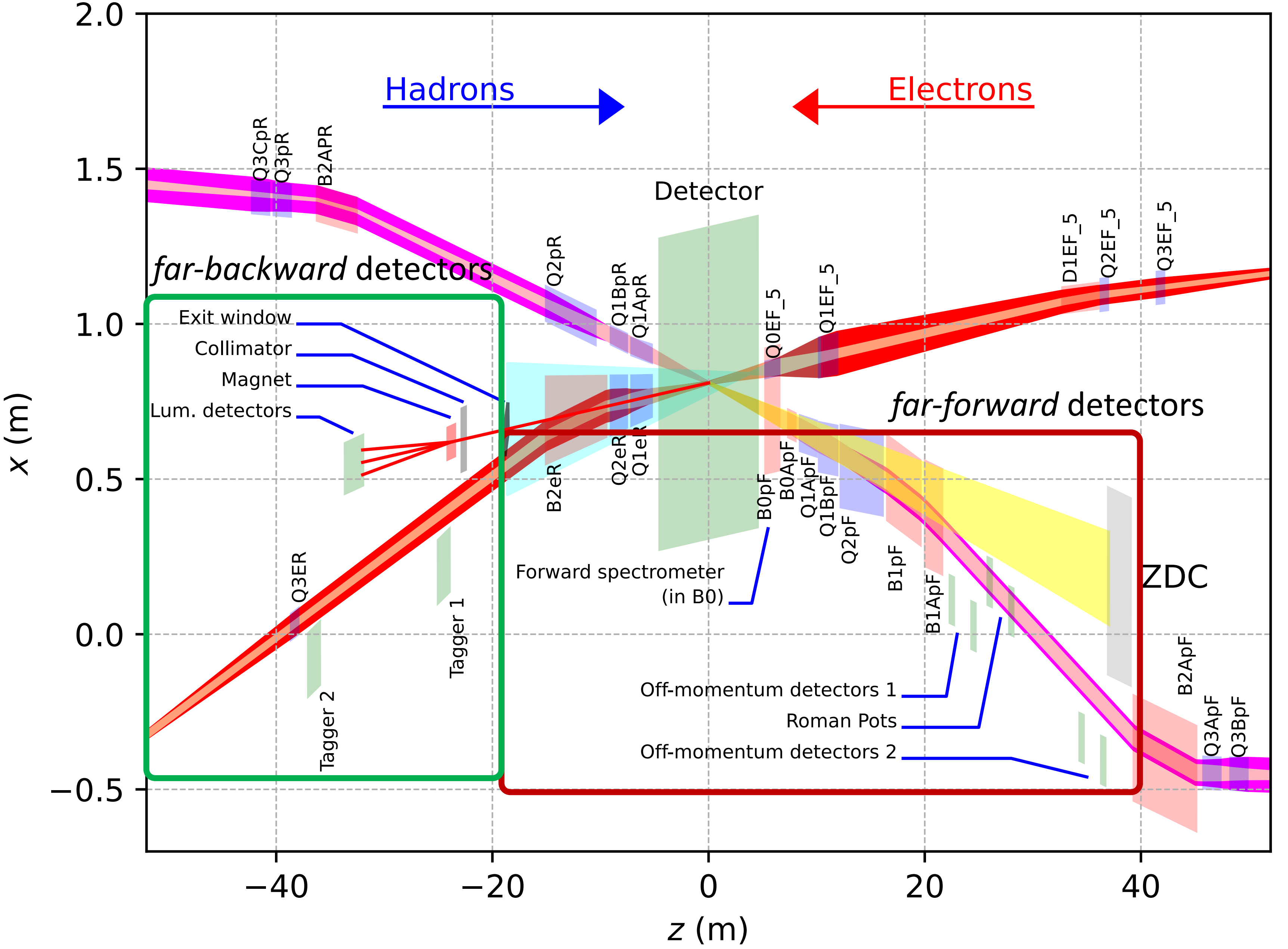
Far-Forward and Far-Backward Detectors at ATHENA

Alex Jentsch (BNL)

on behalf of the ATHENA Collaboration

EICUG Meeting, August 2nd – 7th, 2021

EIC Interaction Region Layout (IP6)



ATHENA Far-Backward Conveners

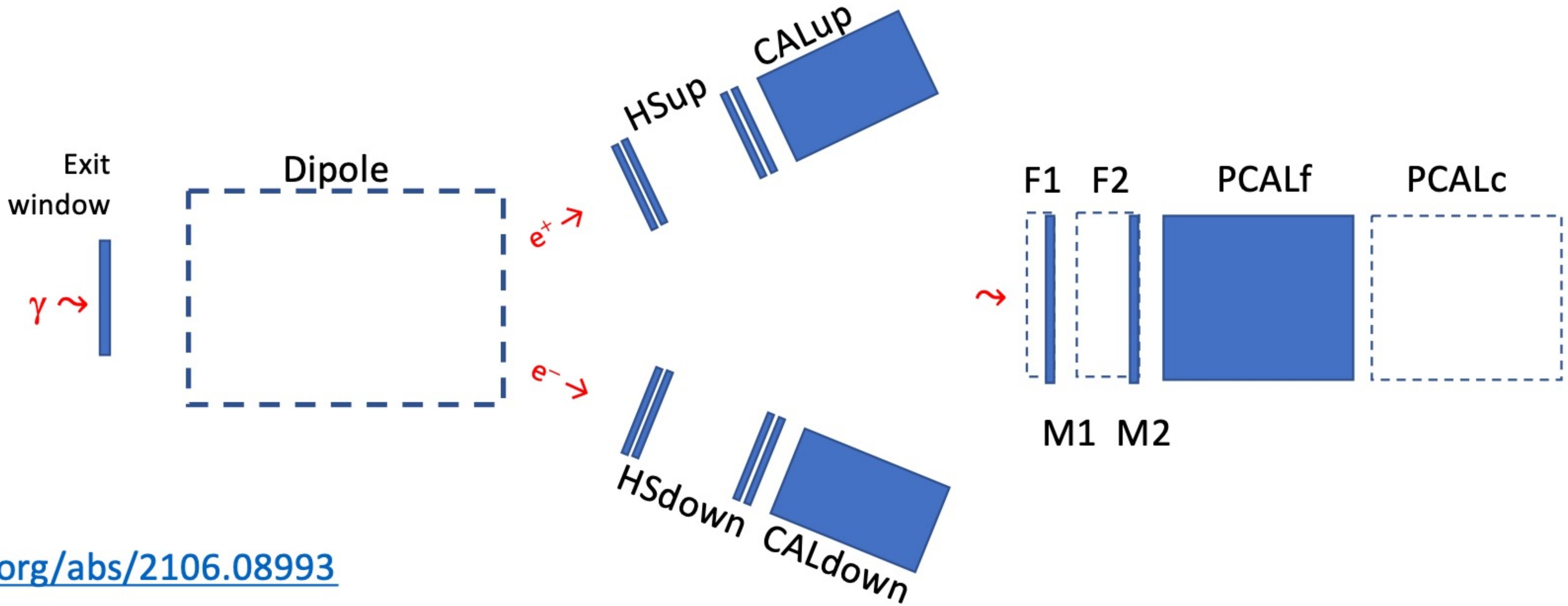
- Jaroslav Adam (Jarda)
- Krzysztof Piotrzkowski

ATHENA Far-Forward Conveners

- John Arrington
- Alex Jentsch

Luminosity Monitor

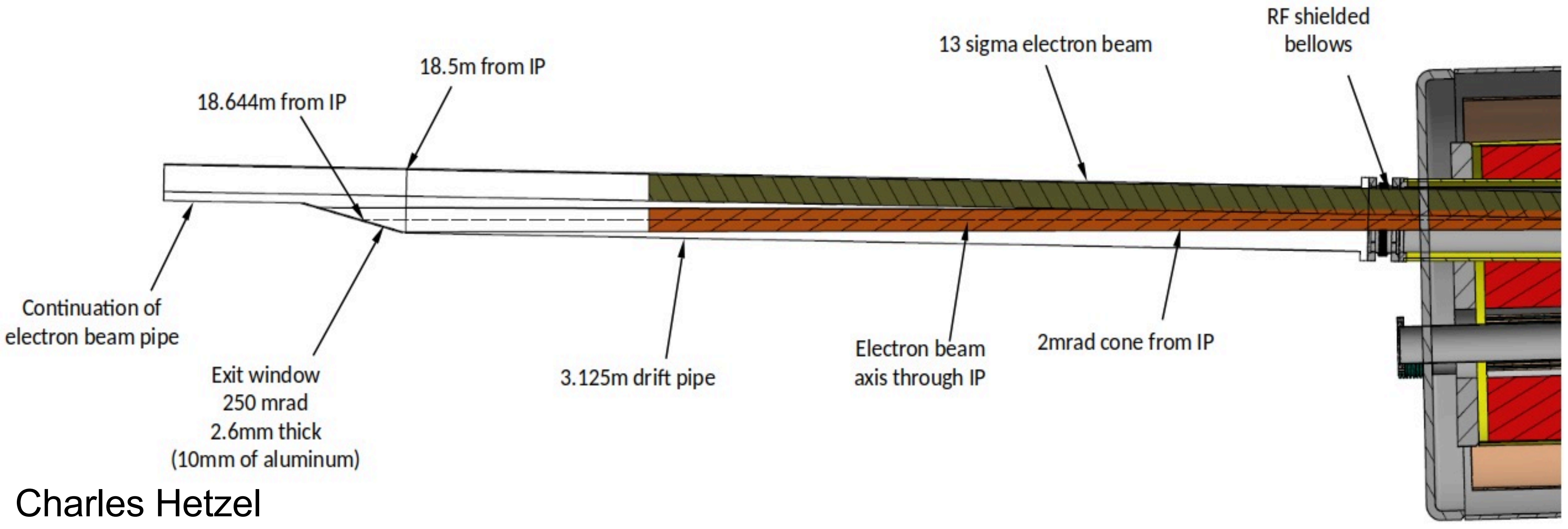
- Must make measurement in challenging environment.
  - High synchrotron radiation, high bremsstrahlung rates (~10 GHz), etc.
- Need ~1% for absolute luminosity measurement, ~10^{-4} for relative luminosity measurement.
- Can make direct photon measurement, or indirect via pair conversion in exit window, where e^+e^- pair is steered toward two calorimeters opposite a dipole magnet.
- Direct photon calorimeter includes moveable SR filters/monitors (F1 and F2), and has configurations for high (PCALf) and low (PCALc) luminosity running.



https://arxiv.org/abs/2106.08993

Exit window for luminosity monitor

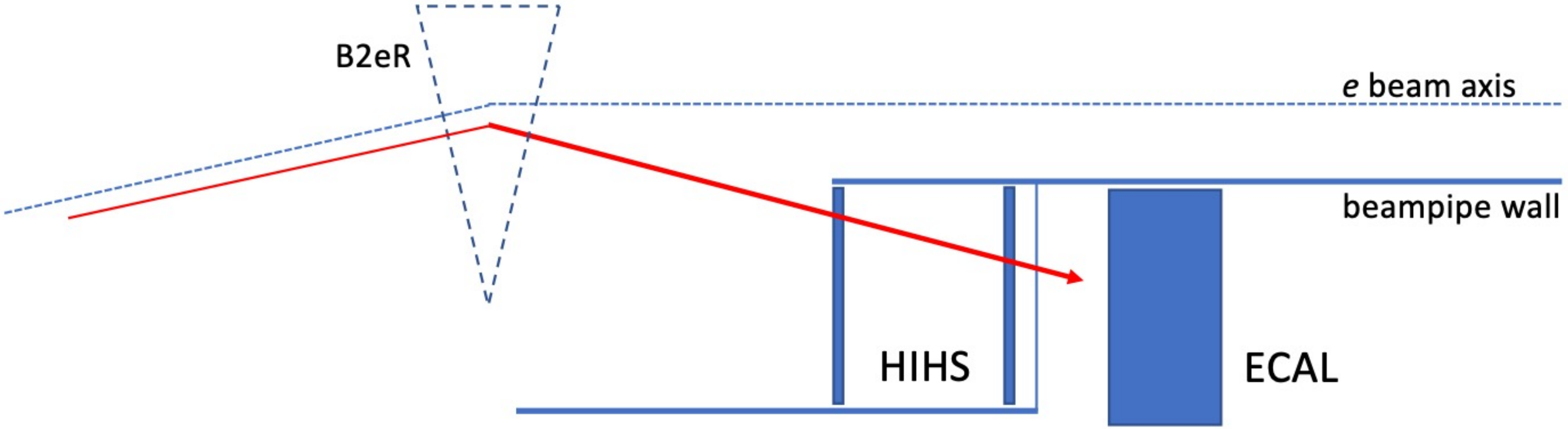
- Part of outgoing electron beam pipe
- Conversion layer for bremsstrahlung photons
- Tilt angle vs. electron (and photon) beam axis against synchrotron radiation



Charles Hetzel

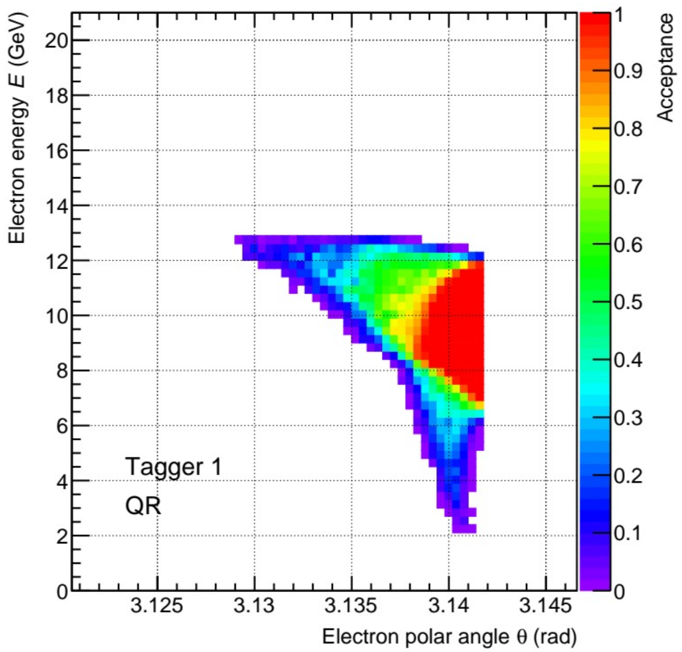
Low-Q^2 Taggers

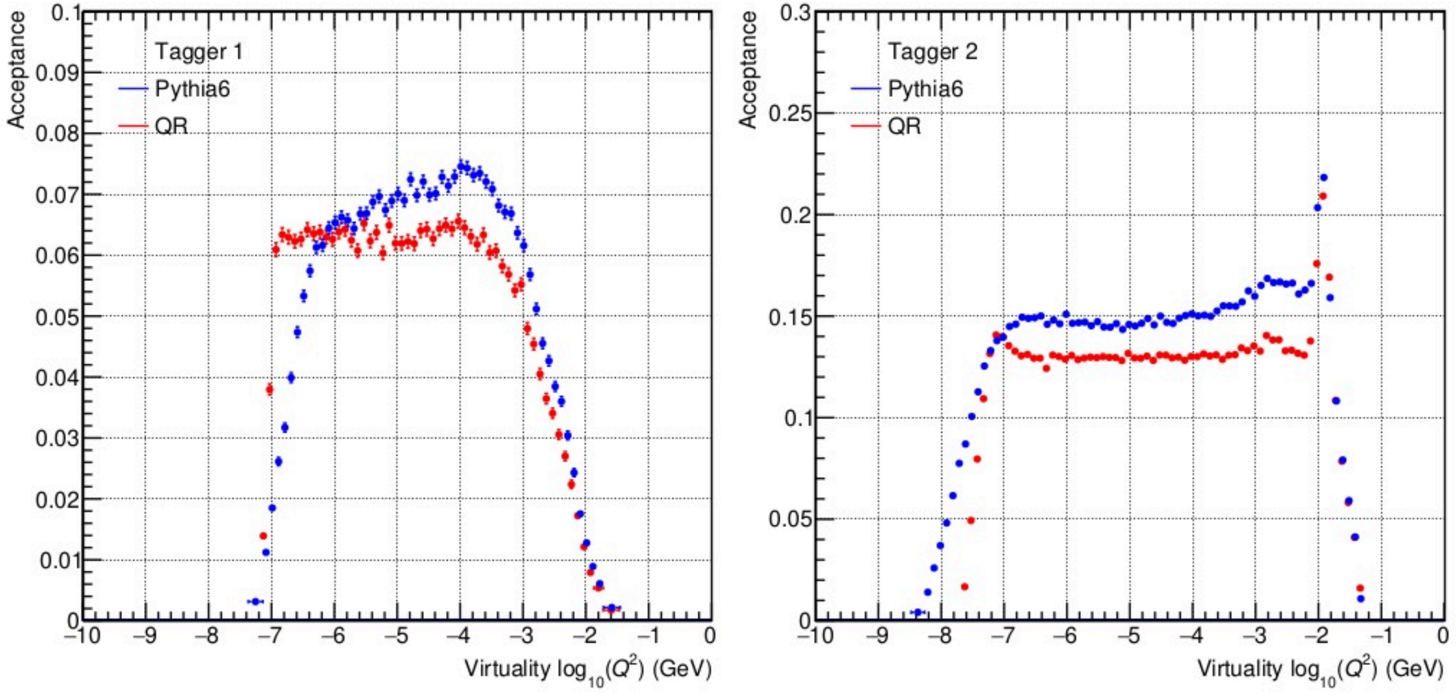
- Two taggers for reconstructing electrons from low-Q^2 ($< 10^{-1}$ GeV^2) reactions.
- Combination of EM calorimetry for energy reconstruction, and silicon layers (High Resolution Hodoscope – HIHS) for position and angular resolution.



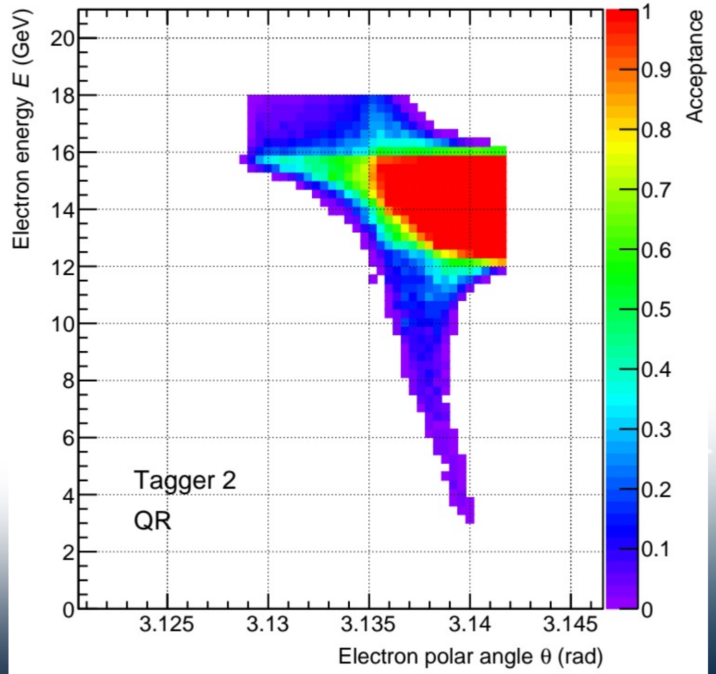
Performance for low-Q2 tagger

- Tagger 1 and 2 are placed closer (further) from the IP
- Overlap in Q2 acceptance (< 0.1 GeV^2)
- Complementary in electron energy (higher energies reach Tagger 2)
- Consistent for Pythia6 and quasi-real photoproduction (QR)



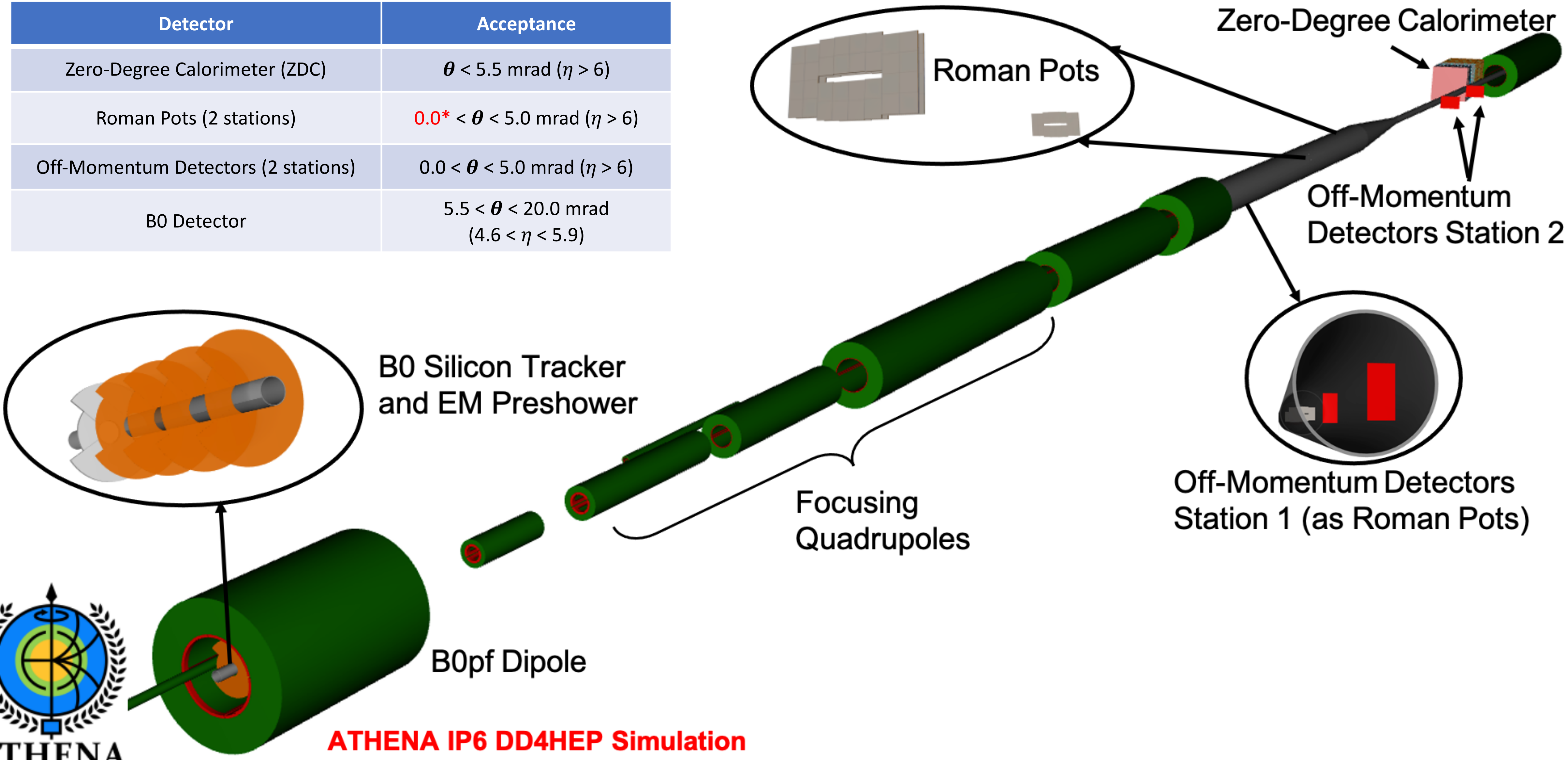


(a) Tagger 1 (b) Tagger 2



Far-Forward IR and Detectors

Detector	Acceptance
Zero-Degree Calorimeter (ZDC)	θ < 5.5 mrad (η > 6)
Roman Pots (2 stations)	0.0* < θ < 5.0 mrad (η > 6)
Off-Momentum Detectors (2 stations)	0.0 < θ < 5.0 mrad (η > 6)
B0 Detector	5.5 < θ < 20.0 mrad (4.6 < η < 5.9)



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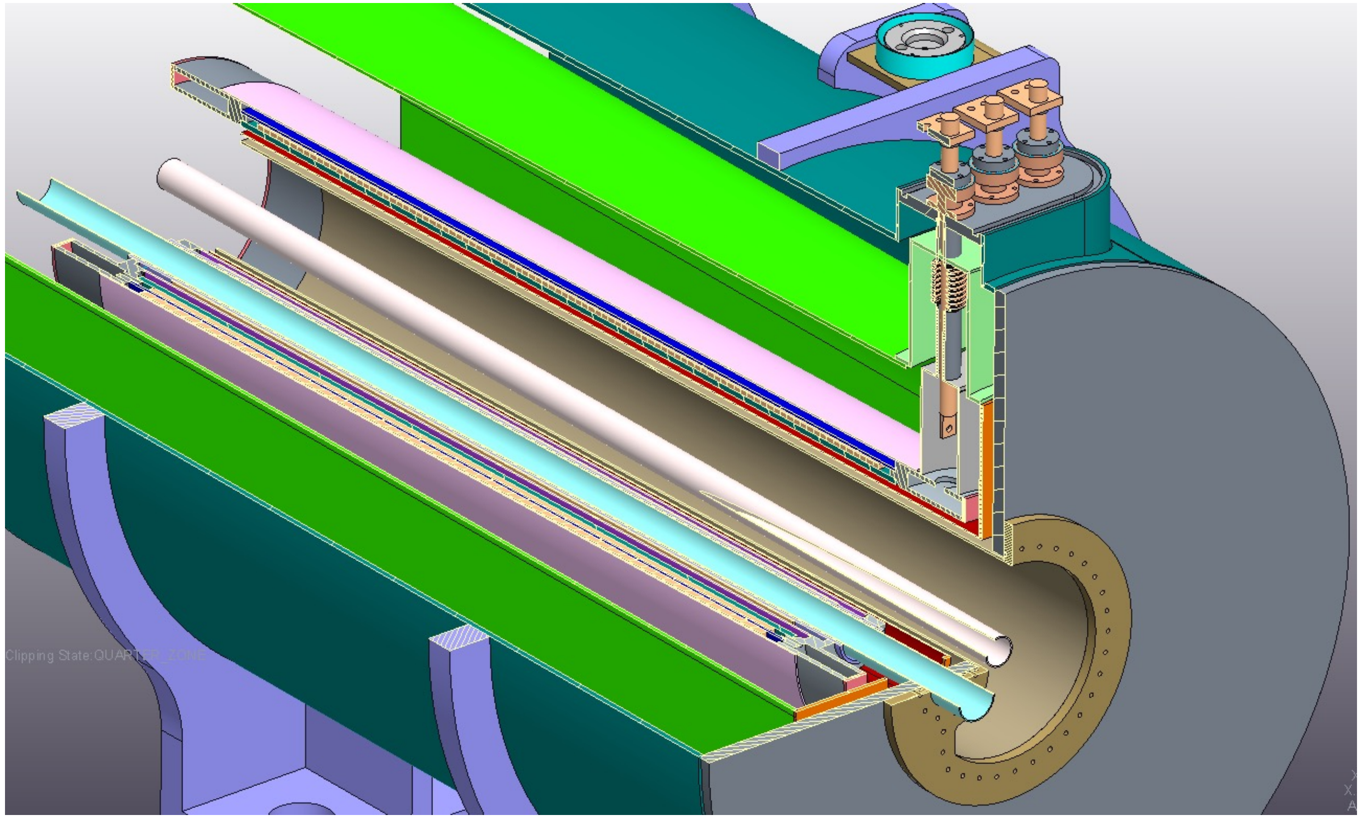
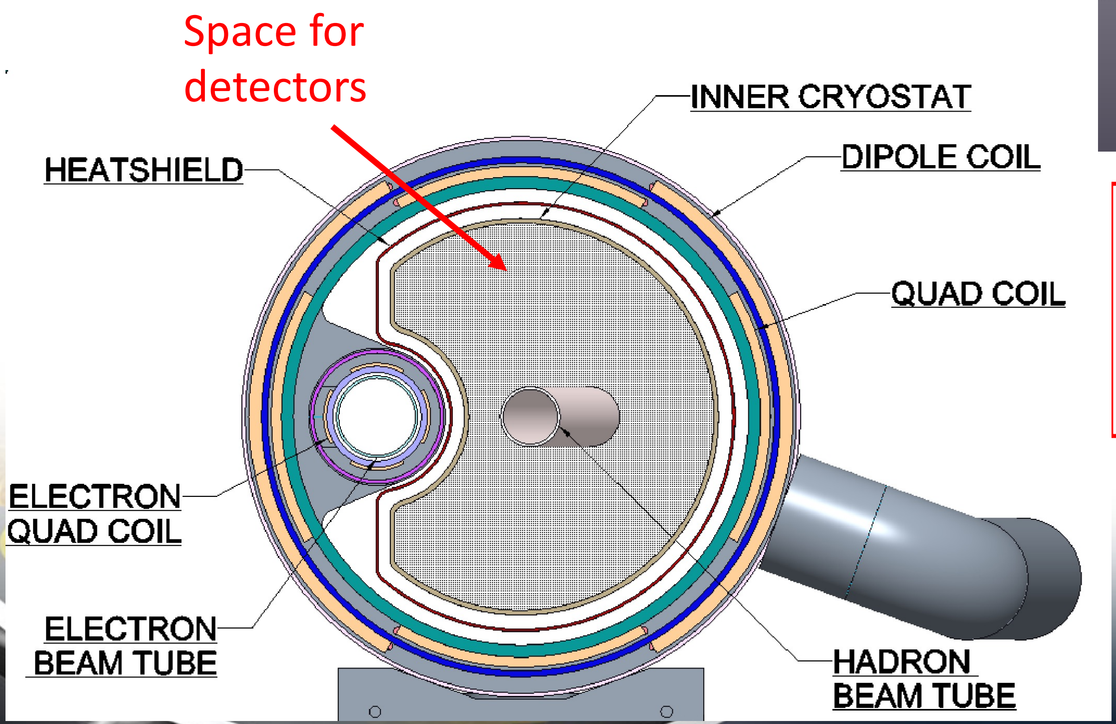
B0-detectors

(5.5 < θ < 20.0 mrad)

- Charged particle reconstruction and photon tagging.
  - Precise tracking -> need smaller pixels (20-50um) than for the RP + vertex constraint.
  - Require timing layer for the crab rotation and background rejection.
  - Four tracking layers + silicon preshower detector for photon tagging.

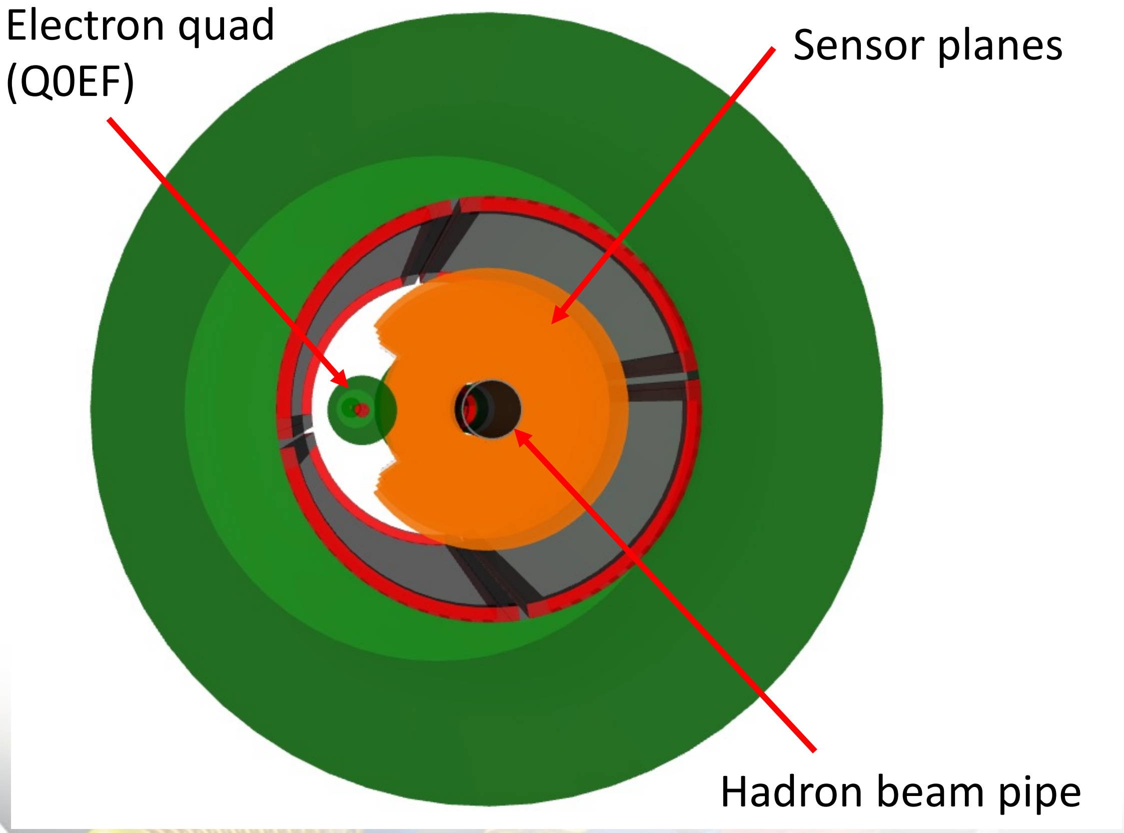




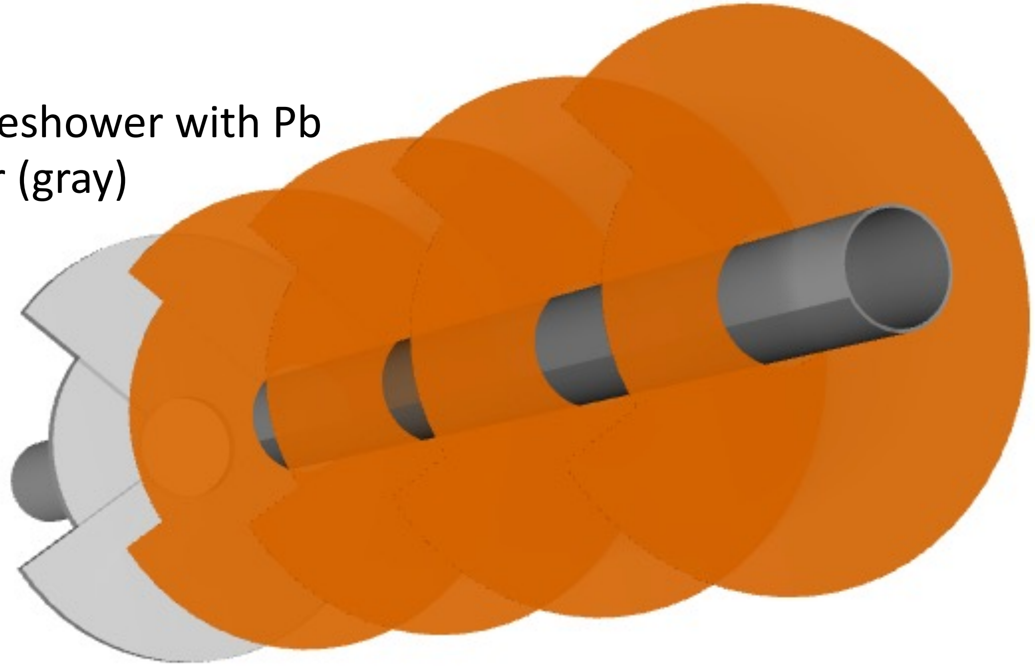
- Higher granularity detectors needed in this area (MAPS, or something similar) with layers of fast-timing detectors (e.g. LGADs), or timepix (provides high resolution space and timing information).

B0-detectors

(5.5 < θ < 20.0 mrad)



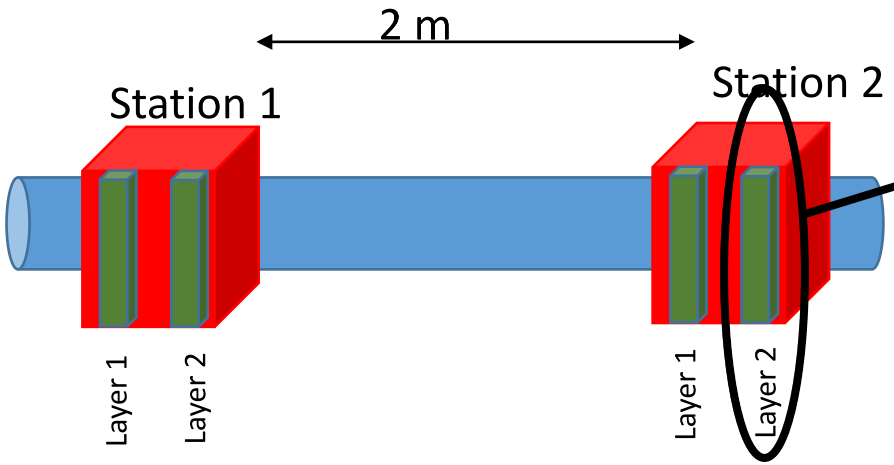
ATHENA DD4HEP Simulation

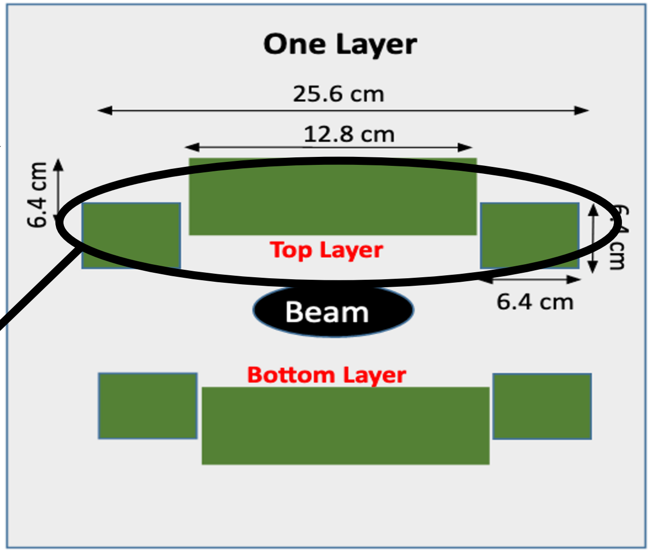


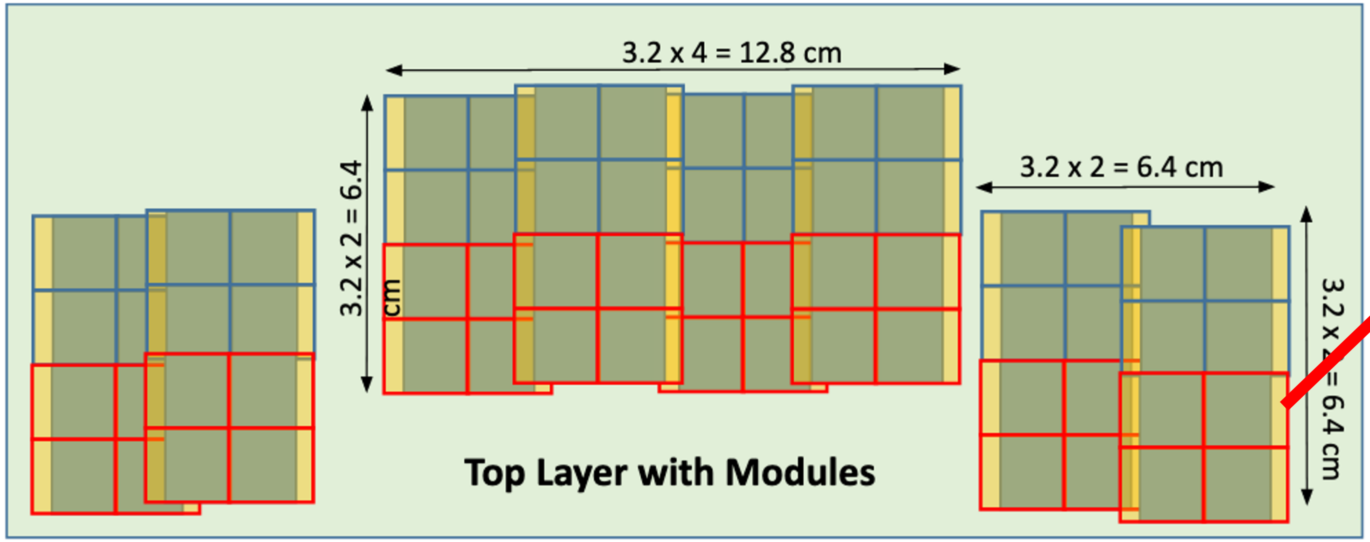
- Higher granularity detectors needed in this area (MAPS, or something similar) with layers of fast-timing detectors (e.g. LGADs), or timepix (provides high resolution space and timing information).
- Tagging photons important in differentiating between coherent and incoherent heavy-nuclear scattering.
- Silicon preshower with one radiation length Pb converted layer included in setup.

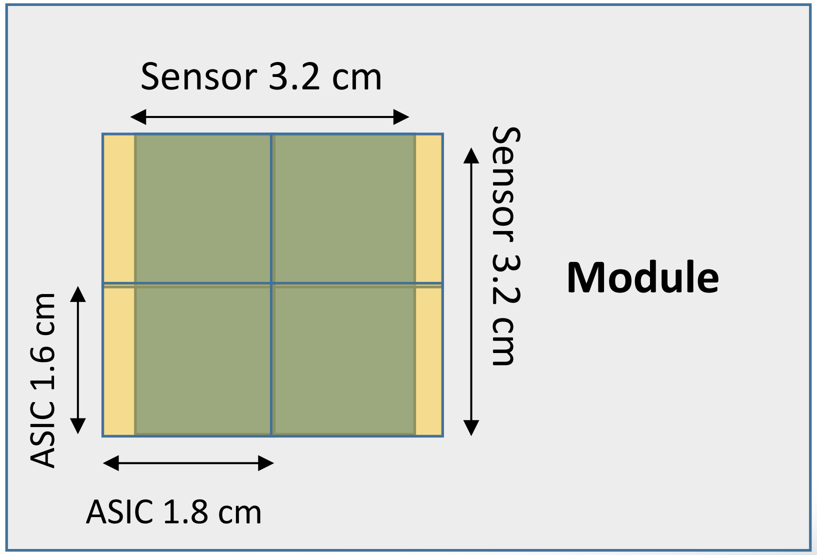
Roman Pots

- Updated layout with current design for AC-LGAD sensor + ASIC.





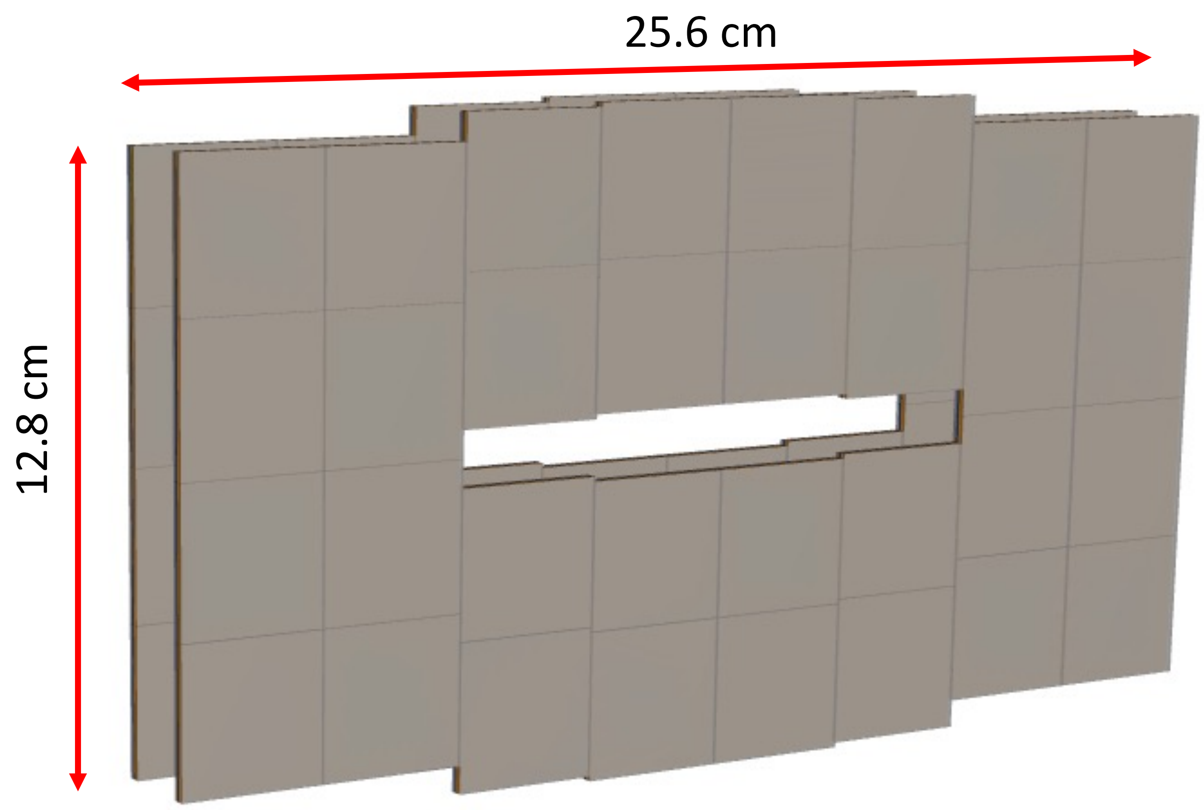




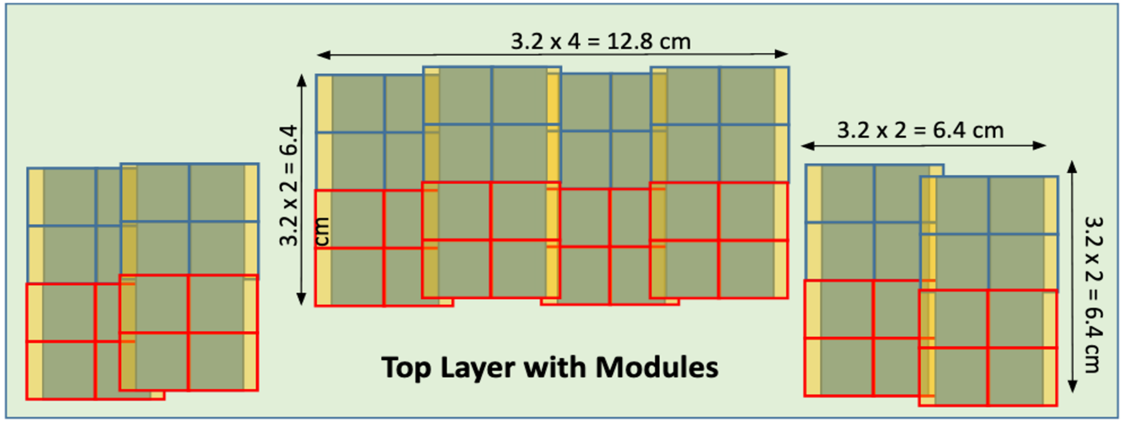
- Current R&D aimed at customizing ASIC readout chip (ALTIROC) for use with AC-LGADs.

Based on eRD24 R&D work.

Roman Pots



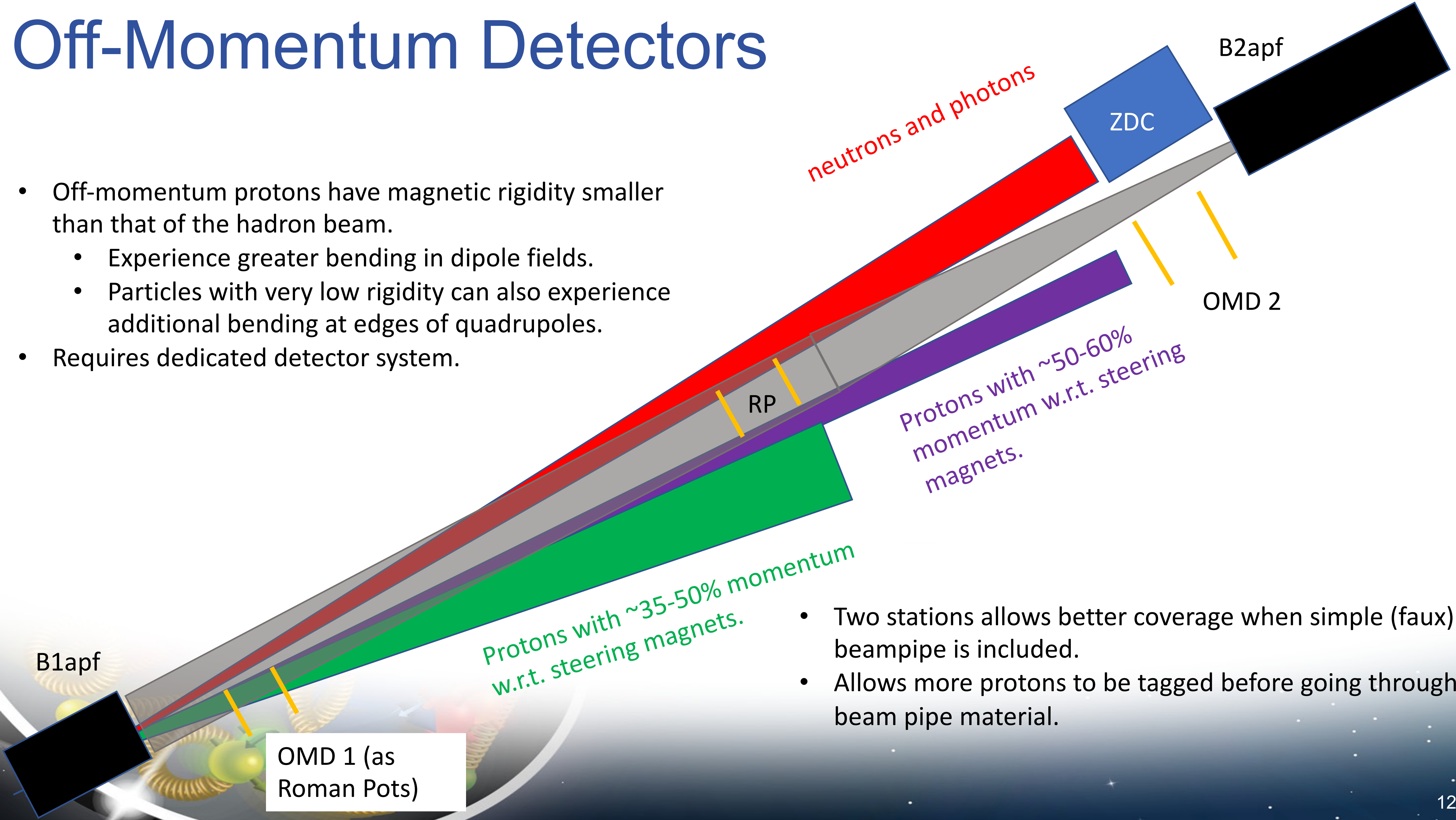
ATHENA DD4HEP Simulation



- AC-LGAD sensor provides both fine pixilation (500um square pixels), and fast timing (~30ps).
- "Potless" design concept with thin RF foils surrounding detector components.
- AC-LGAD silicon sensor bump-bonded to ASIC readout chip.
- Cooling via either thermal strips or closed-loop gas + heat exchanger, similar to VELO setup at LHCb.
    - More discussion with machine group required.
- Individual 3.2 cm by 6.4 cm modules independently movable vertically for different optics configurations.

Off-Momentum Detectors

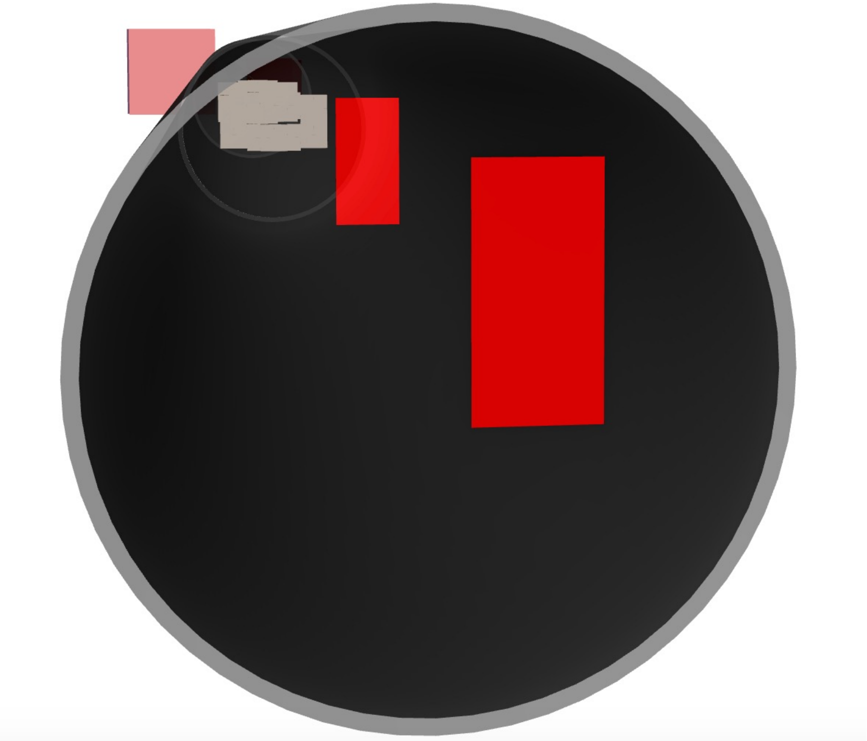
- Off-momentum protons have magnetic rigidity smaller than that of the hadron beam.
  - Experience greater bending in dipole fields.
  - Particles with very low rigidity can also experience additional bending at edges of quadrupoles.
- Requires dedicated detector system.



- Two stations allows better coverage when simple (faux) beampipe is included.
- Allows more protons to be tagged before going through beam pipe material.

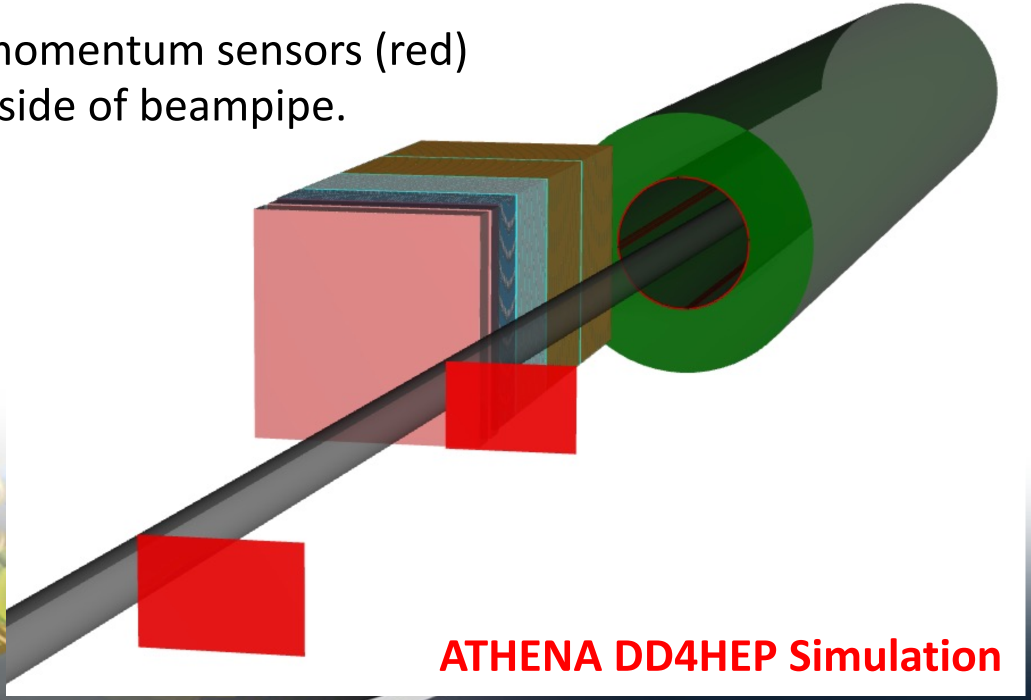
Off-Momentum Detectors

- **<u>Solution with two stations:</u>**
  - First station injected into beamline as horizontal Roman Pot system.
  - Second station situated further downstream near the ZDC, but on the opposite side of the beam pipe.



Station 1: Off-momentum sensors (red) inside beam pipe vacuum.

Station 2: Off-momentum sensors (red) completely outside of beampipe.



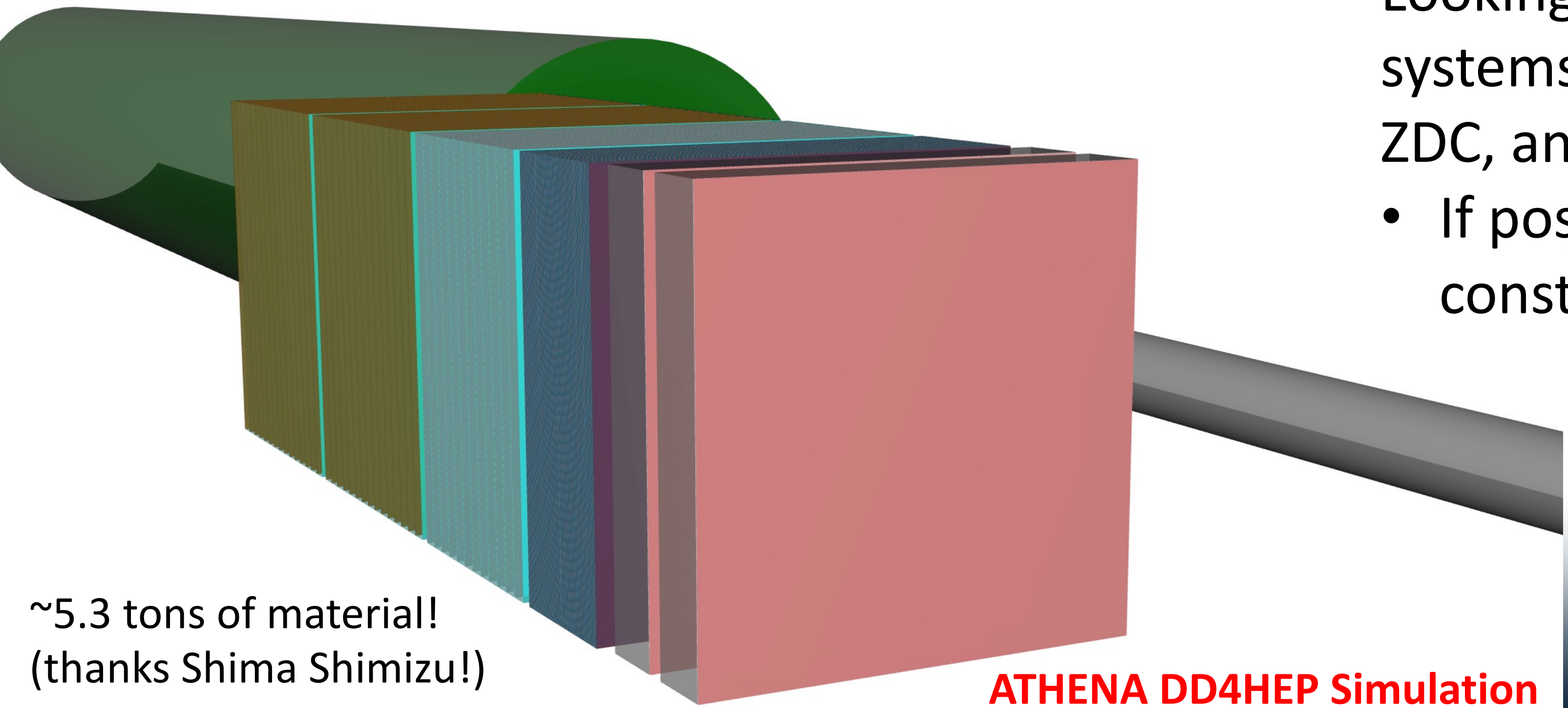
Zero-Degree Calorimeter

eRD27 Focused on development
(U. Kansas, RIKEN, et al.)

- Based on ALICE FoCal Concept.
  - First section: silicon for charged particle veto.
  - Second section: $PbWO_4$ EMCAL (~27cm thickness) + W (~22.5cm thickness) and Pb (~48cm thickness) layers with silicon sampling.
  - Third section: HCAL comprised of Pb scintillator (~96cm thickness).
- 60cm x 60cm x 2m

Looking into possible overlap in EMCAL systems for application in Low-Q2 tagger, ZDC, and potentially the B0 detector.

- If possible, could save on R&D and construction costs.



~5.3 tons of material!
(thanks Shima Shimizu!)

ATHENA DD4HEP Simulation

DD4HEP Implementation by Jihee Kim.

Summary and Takeaways

- All FF detectors implemented in full ATHENA DD4HEP framework.
  - Some work to include a few more engineering considerations underway.
- Validation tests underway to benchmark detector performance against previous studies from the Yellow Report in EicRoot.
- Investigating possible overlaps in technology use between FF and FB subsystems to reduce cost.

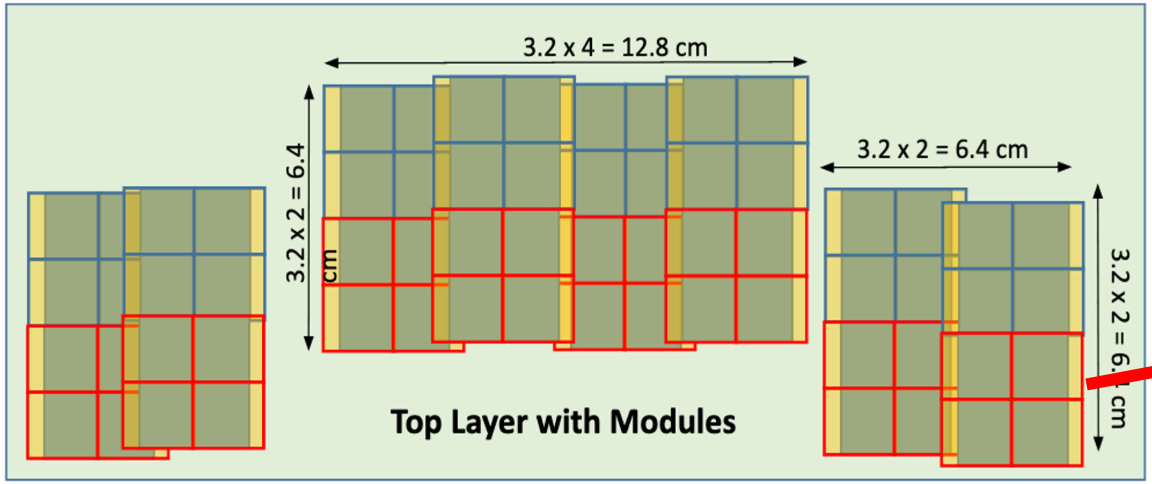
Backup

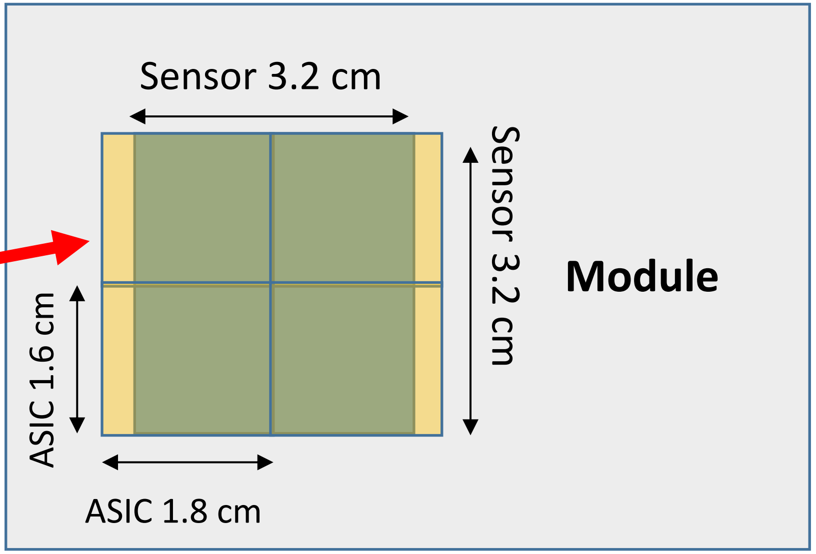
Roman Pots

- Active sensor area very large (26cm x 13cm).
- “Potless” design could make better use of space.
- With AC-LGADS + ALTIROC ASIC, current estimates of power dissipation around 400-500 watts for entire subsystem, so roughly 100 watts/layer.
  - With potless design, leveraging experience from LHCb VELO for cooling would allow for cooling of the electronics within the vacuum.
- Support structure only to be placed between hadron pipe and wall to avoid interference with the ZDC.

Roman Pots

- Updated layout with current design for AC-LGAD sensor + ASIC.



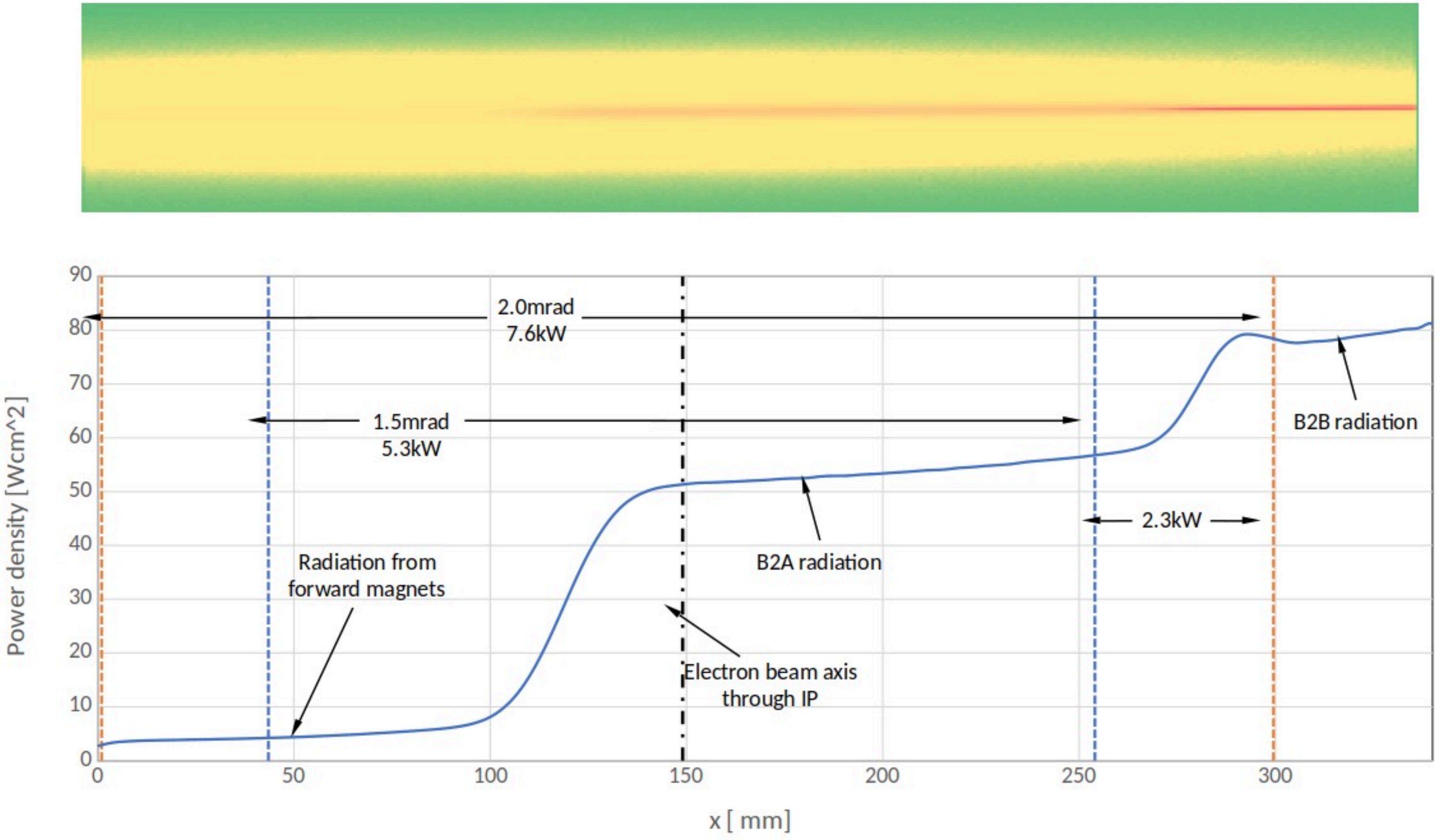


- Current R&D aimed at customizing ASIC readout chip (ALTIROC) for use with AC-LGADs.

ASIC size	ASIC Pixel pitch	# Ch. per ASIC	# ASICs per module	Sensor area	# Mod. per layer	Total # ASICs	Total # Ch.	Total Si Area
1.6x1.8 cm^2	500 μm	32x32	4	3.2x3.2 cm^2	32	512	524,288	1,311 cm^2

Power by synchrotron radiation on the exit window

- Power density imposed by synchrotron radiation
- 1.5 mrad and 2.0 mrad indicate possible acceptance to bremsstrahlung photons



Charles Hetzel

Bremsstrahlung cross section in photon energy and polar angle

- Large cross sections especially in e-Au, dedicated event generator, arXiv:2105.10570
- Angular divergence has a strong effect at small angles