EIC Detector 1 Far-Forward Kick-off Meeting

John Arrington (LBNL), Yuji Goto (RIKEN),
Alex Jentsch (BNL), Michael Murray (U. Kansas)

Basic "charge" for all DWGs

The overall goal of the detector WG's is to optimize the ECCE reference design towards a technical design within the constraints listed above. In working towards this goal, the DWG's should collaborate with existing detector consortia (EICSC, EEEMCAL, MPGD, DIRC, DRICH, AC-LGADs, etc.), all detector R&D efforts relevant for Detector-1, and any additional efforts within the EIC scientific community.

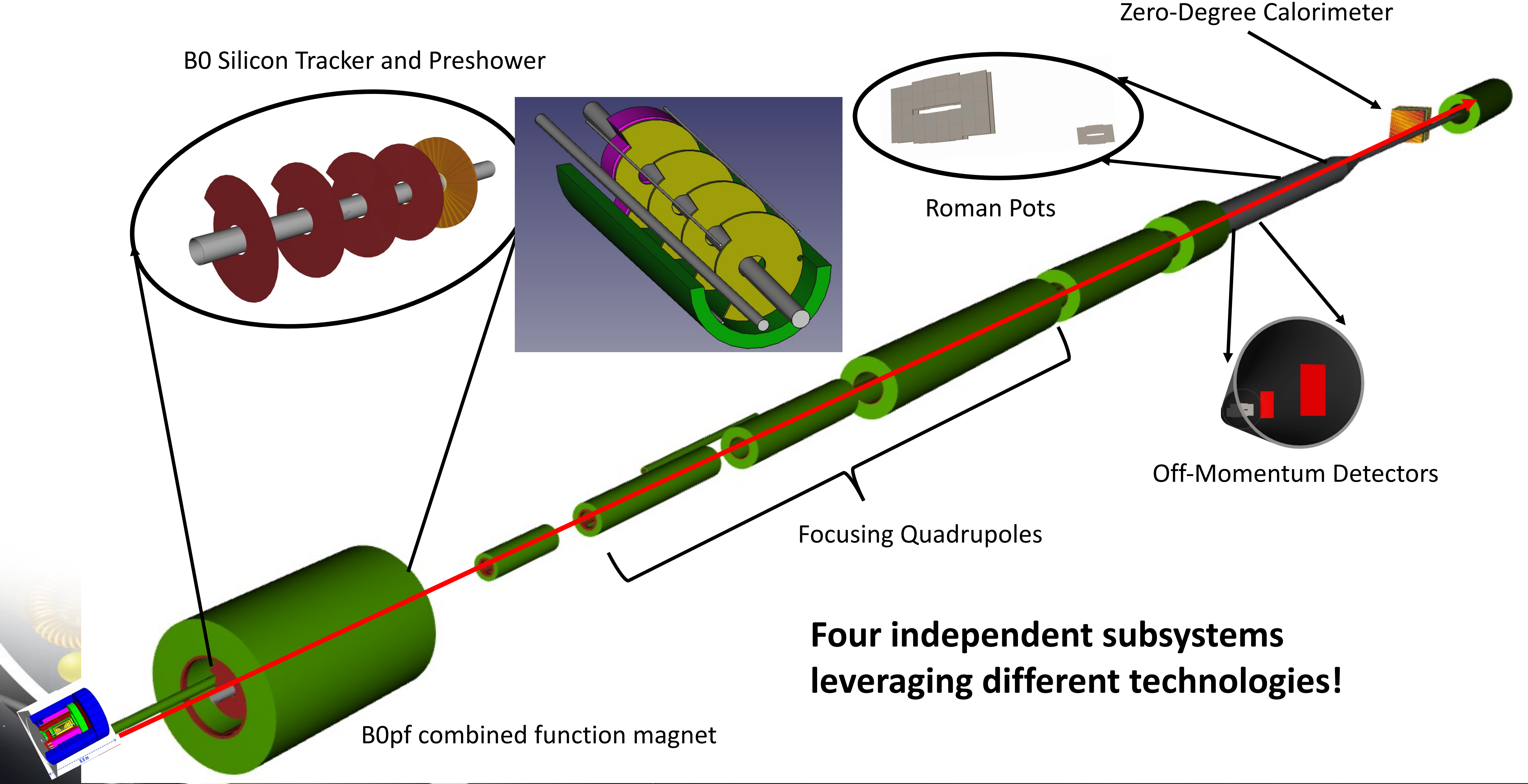
- All working groups will work closely with the Global detector / integration working group and the EIC project towards a technical design that optimizes the global detector performance, taking into account global integration and physics performance.
- Each joint WG should hold at least one kickoff meeting where the designs of each proposal are presented in detail. It is critically important that WG members understand the scientific and technical reasoning behind different design choices before engaging in optimization discussions.
- The WG conveners will lead a discussion to identify any non-trivial differences and/or aspects in need of further optimization.
- For each non-trivial difference working groups will then work to prepare a pro/con list accounting for technical performance, risk and cost. The resolution of non-trivial differences should be discussed in close consultation with the Global detector/integration WG, physics working groups, the EIC project, relevant detector consortia and R&D efforts.

The Quirks of the FF DWGs

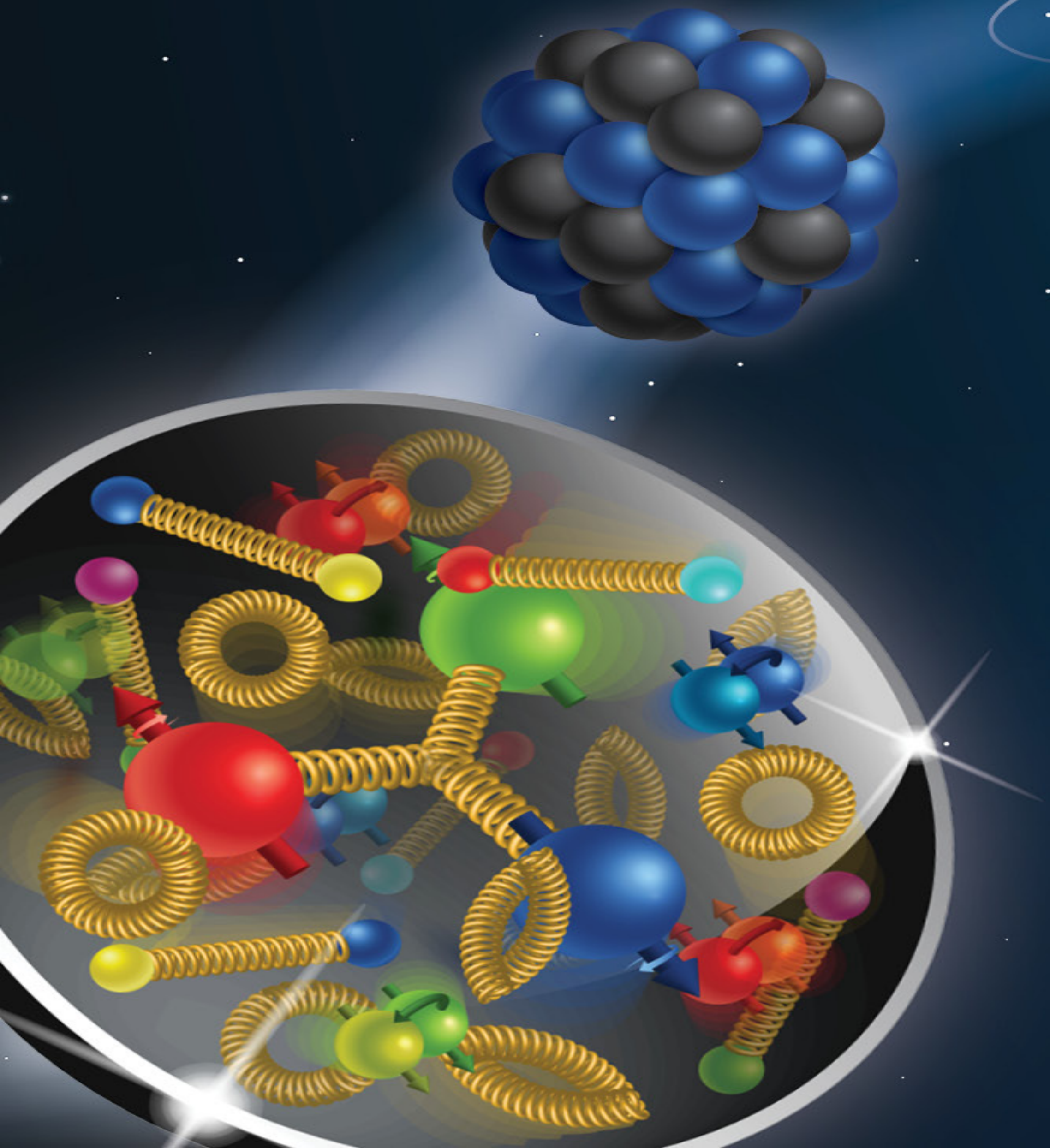
- Roman Pots and Off-Momentum Detector Design essentially the same.
- B0 tracking system design essentially the same (except perhaps silicon technology).
- ECCE B0 design included a full PWO4 EMCAL (obviously ideal), while ATHENA design had a simple photon-tagging preshower.
  - Integration/space issues.
- ECCE ZDC design different from ATHENA design.
  - ECCE design based on eRD27 (et al.) R&D – always expected to be baseline, ATHENA design an alternate/cheaper design which can meet energy resolution requirements.

Take-home message: There are no showstoppers here. All proposed options meet requirements for physics. Our job is work with the integration/machine group to begin dealing with engineering constraints.

The Far-Forward Detectors

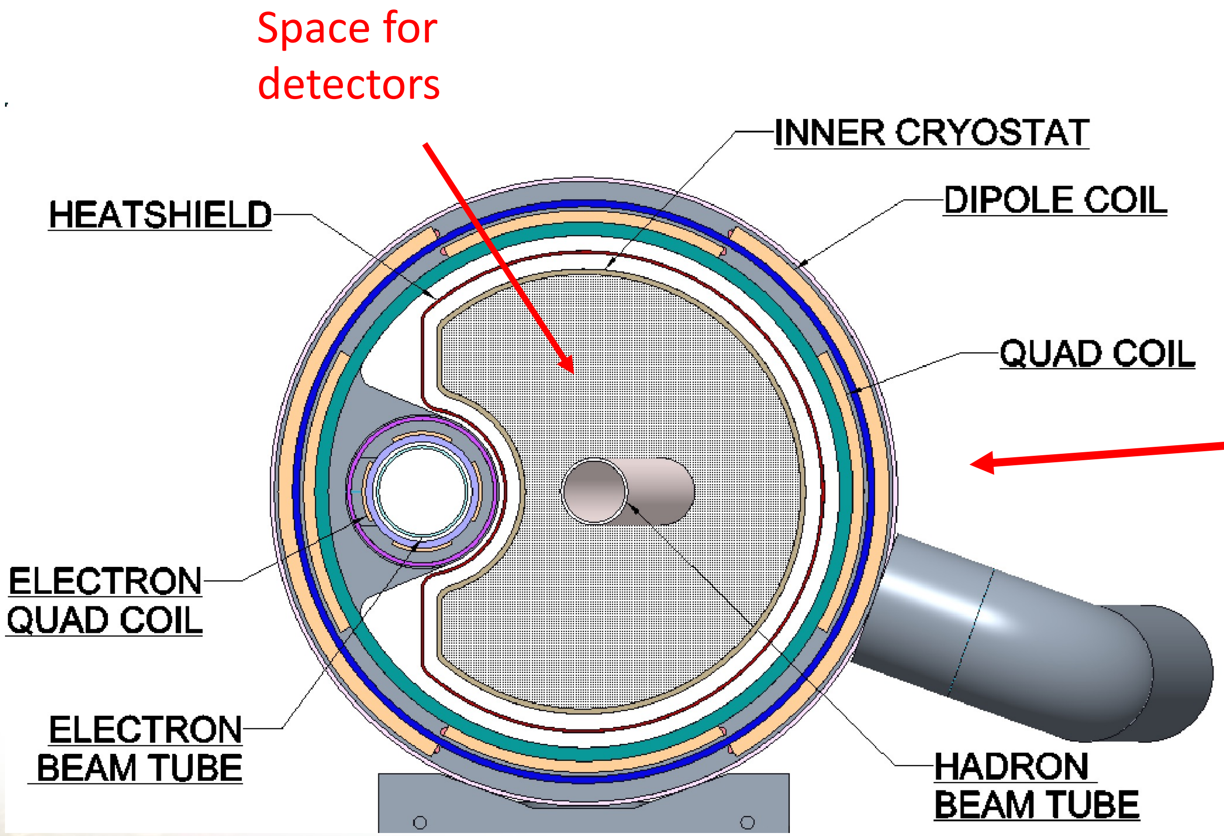


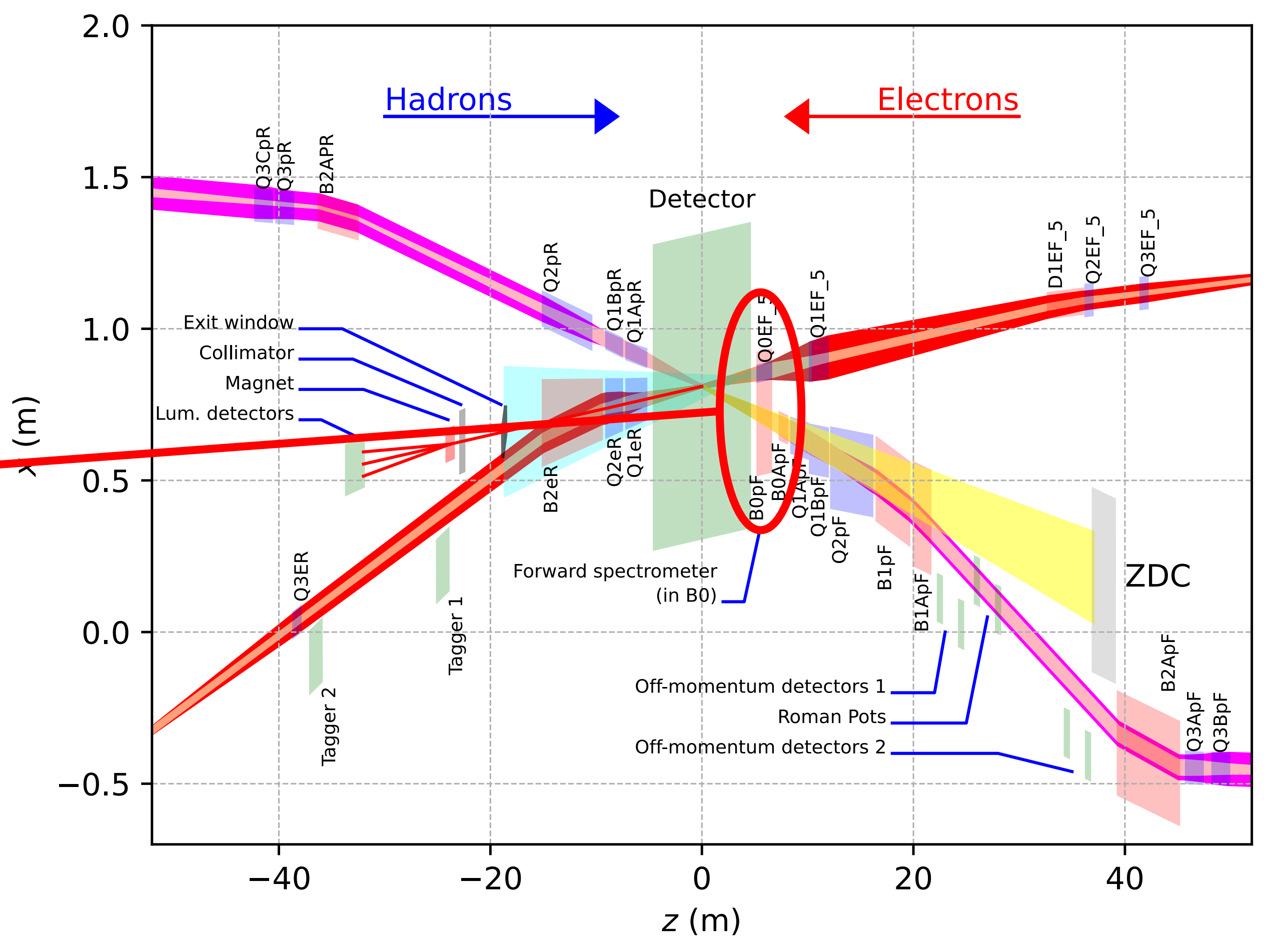
Four independent subsystems leveraging different technologies!



Far-Forward Detector Subsystems

B0-detectors (tracking)

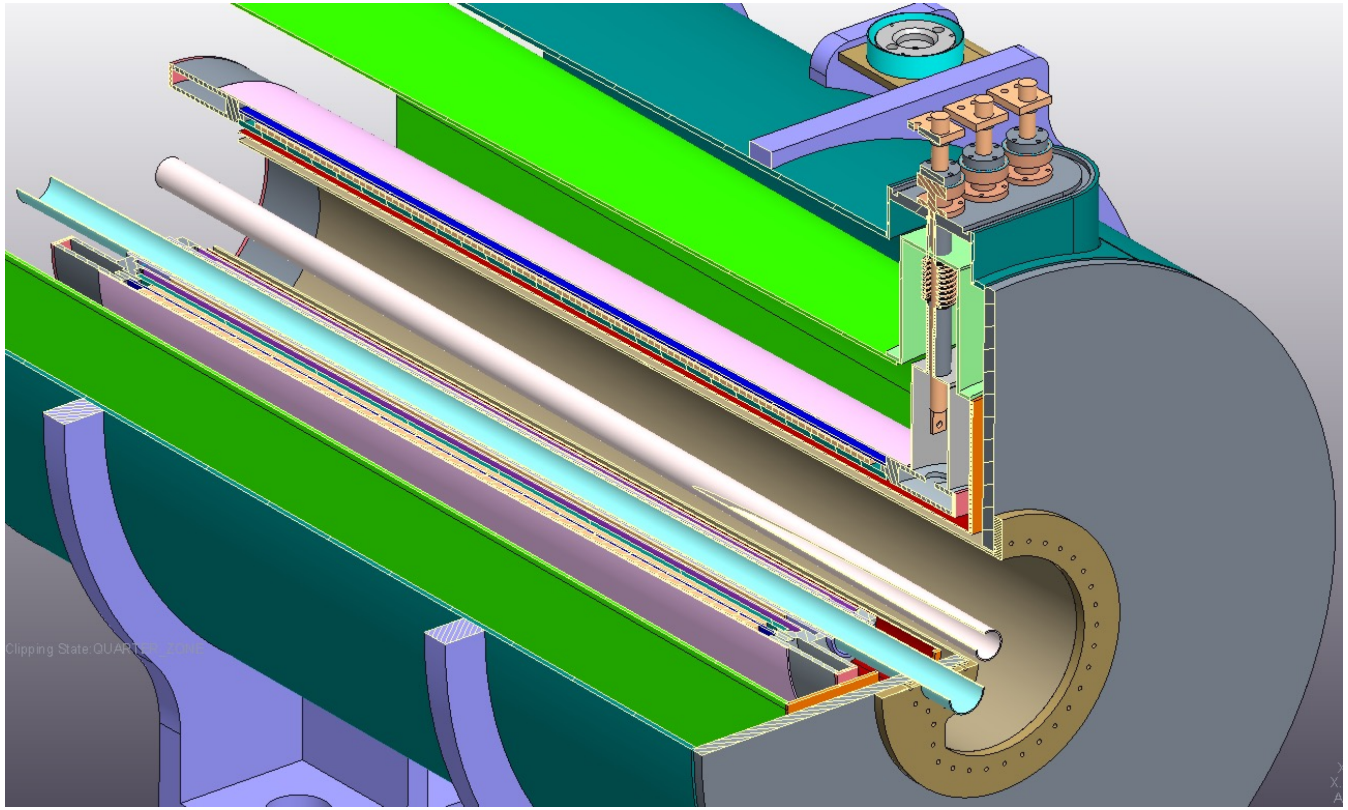


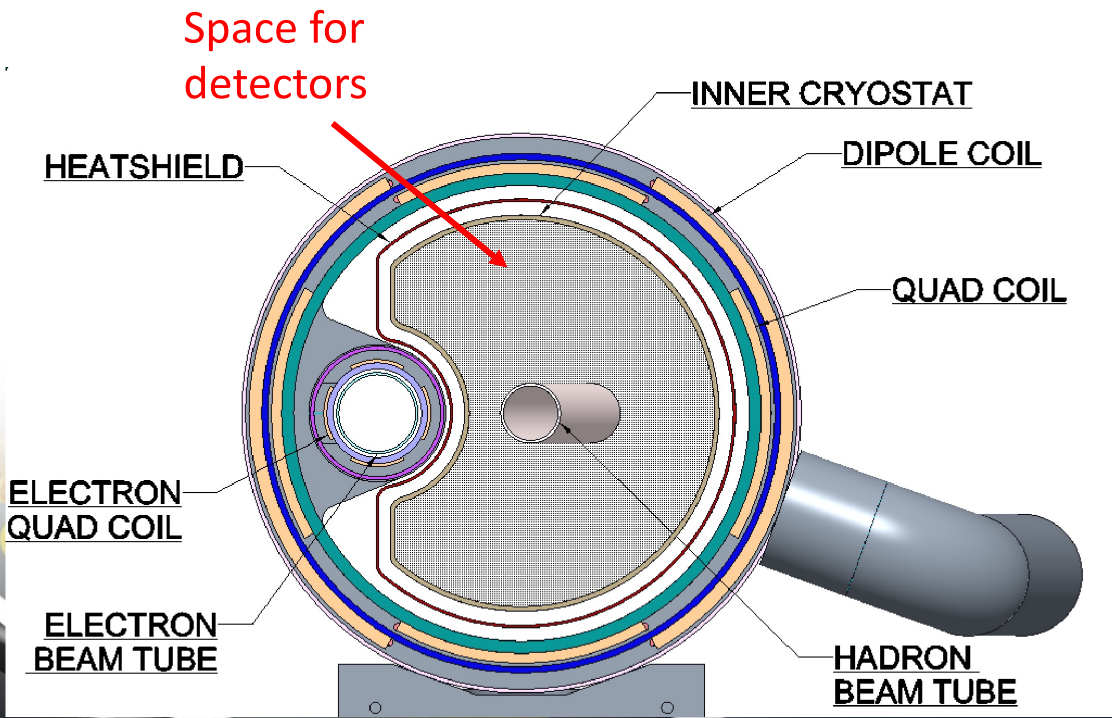


B0-detectors (tracking)

(5.5 < $\boldsymbol{\theta}$ < 20.0 mrad)

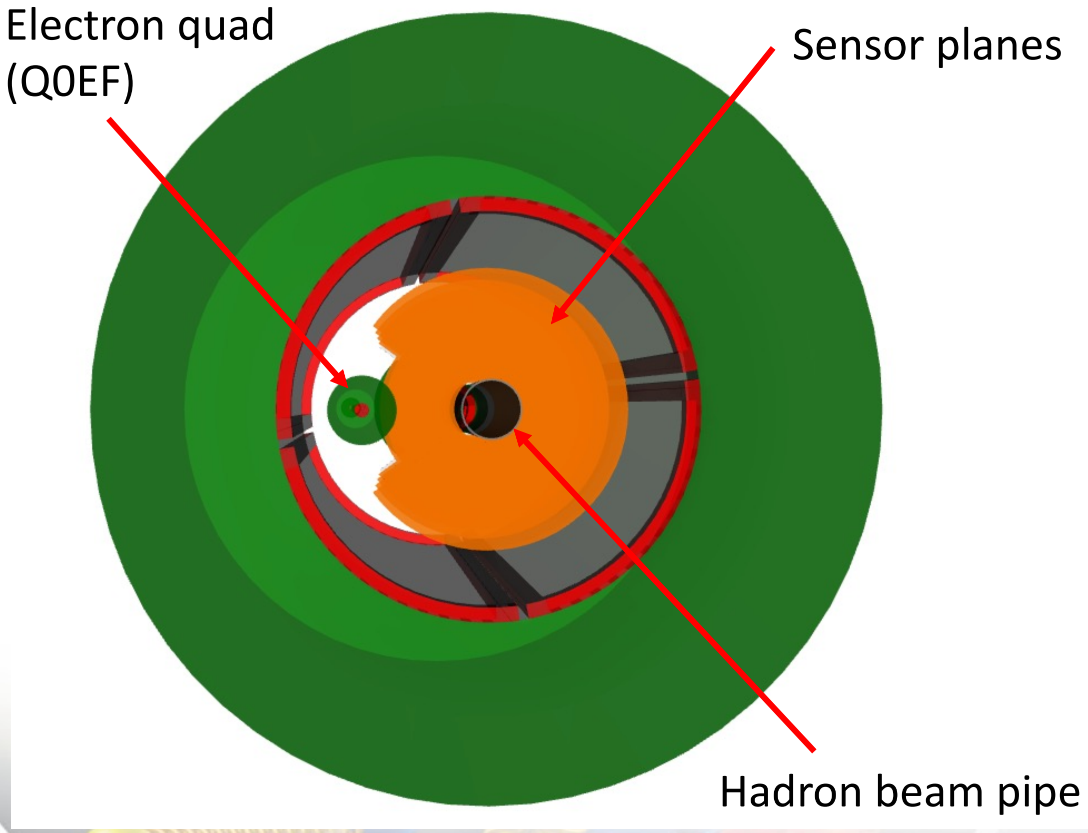
- Charged particle reconstruction and photon tagging.
  - Precise tracking -> need smaller pixels (20-50um) than for the RP + vertex constraint.
  - Require timing layer for the crab rotation and background rejection.
  - Four tracking layers + photon detection (preshower or EMCAL).



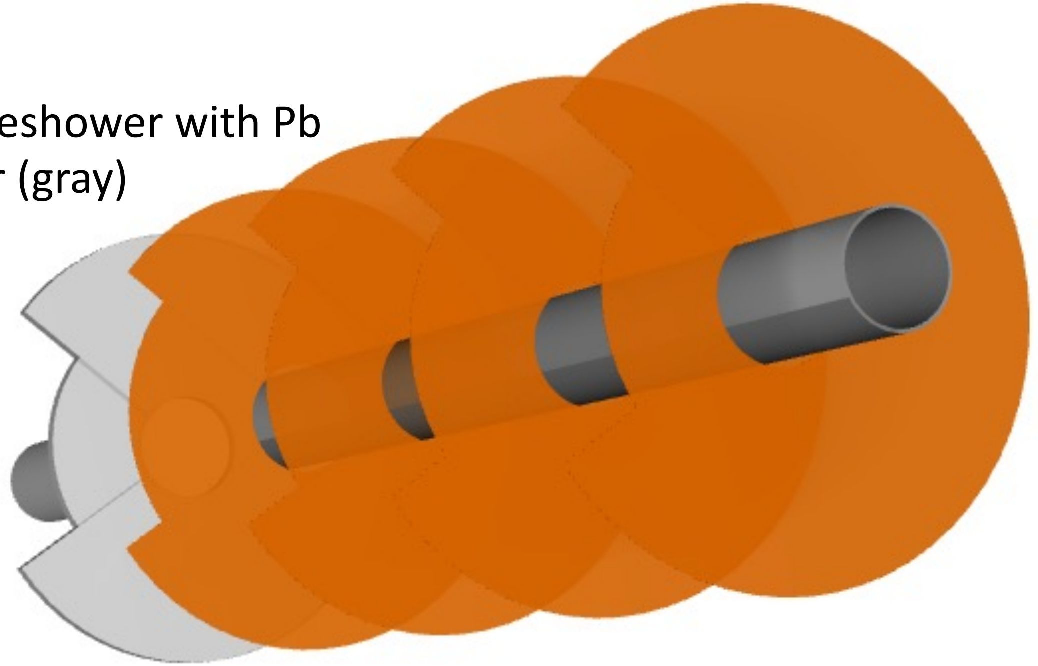


B0-detectors (tracking)

(5.5 < θ < 20.0 mrad)

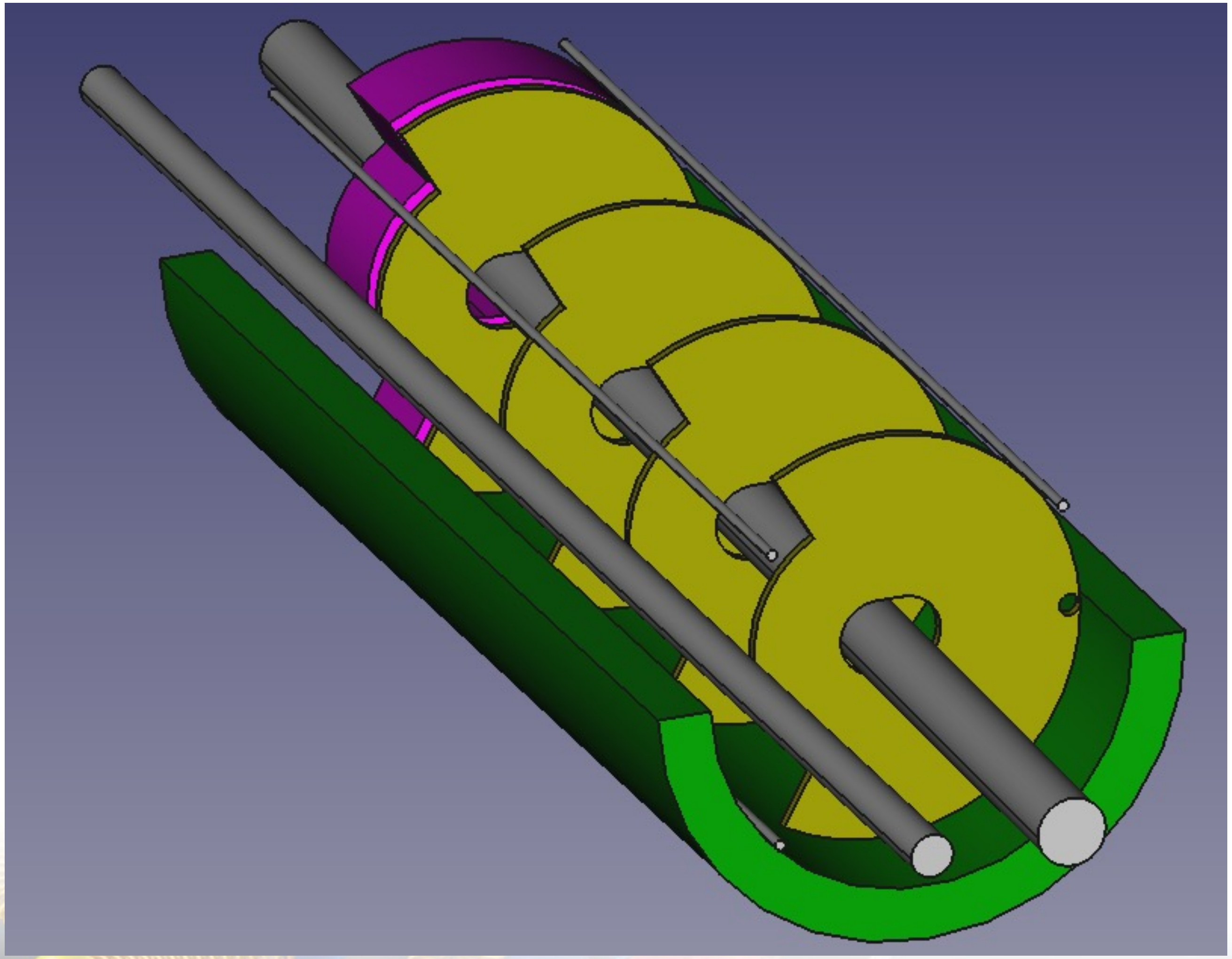


DD4HEP Simulation



- Higher granularity silicon (e.g. MAPS) required.
- Tagging photons important in differentiating between coherent and incoherent heavy-nuclear scattering.
  - **Space is a major concern here – an EMCAL is highly preferred, but may only have space for a preshower.**

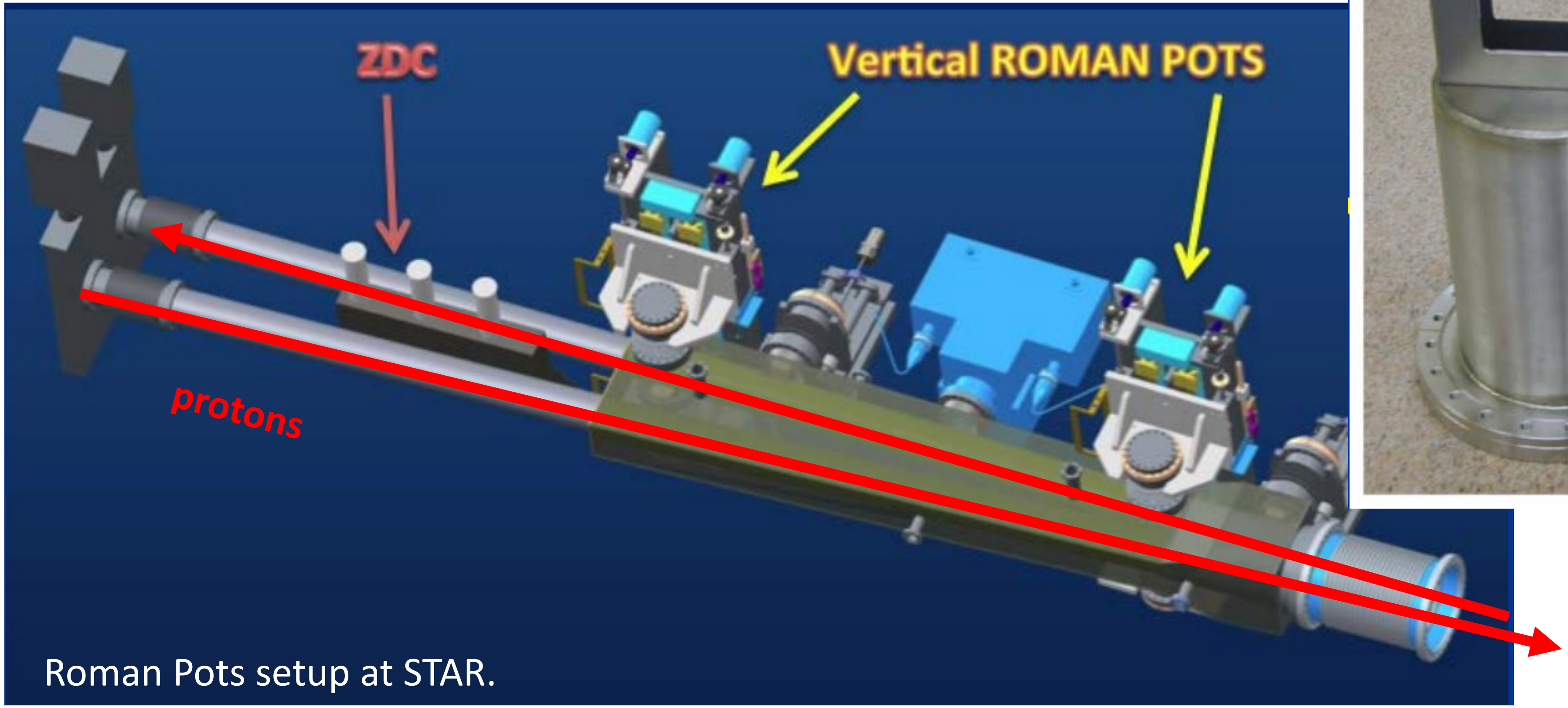
B0-detectors (calorimetry)



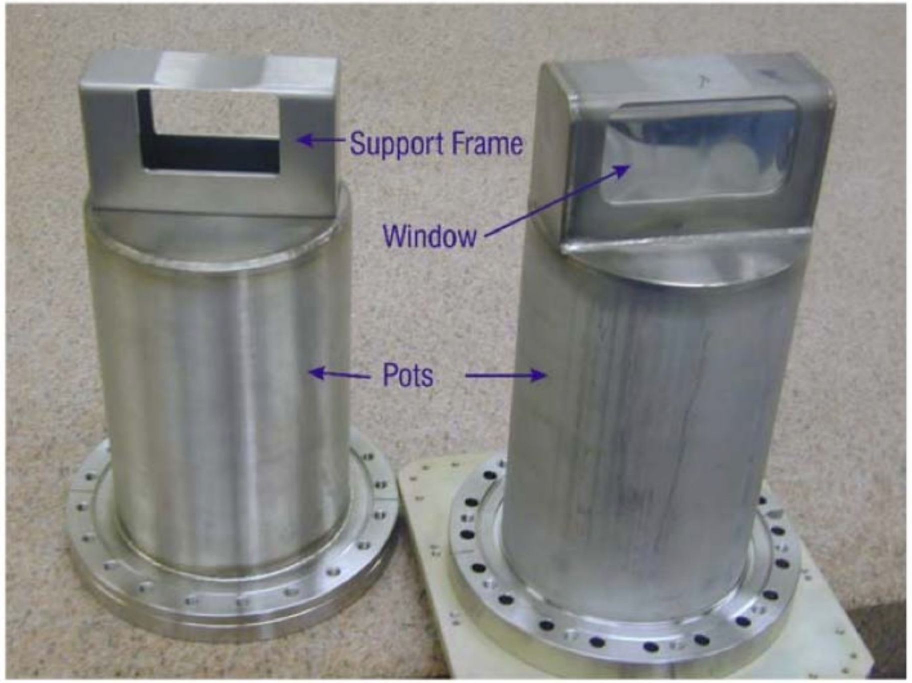
- For studies of *u*-Channel (Backward-angle) exclusive electroproduction, need capability to reconstruct photons from π^0 decays.
  - Physics beyond the EIC white paper!
- Would require full EMCAL with high granularity and energy resolution.
  - ➢ PbWO4 used in ECCE studies.
- Longitudinal space in B0pf magnet limited.
  - Would be a great candidate for an upgrade or for IP8 complementarity!

Thanks to Bill Li for the figure!

Roman Pots

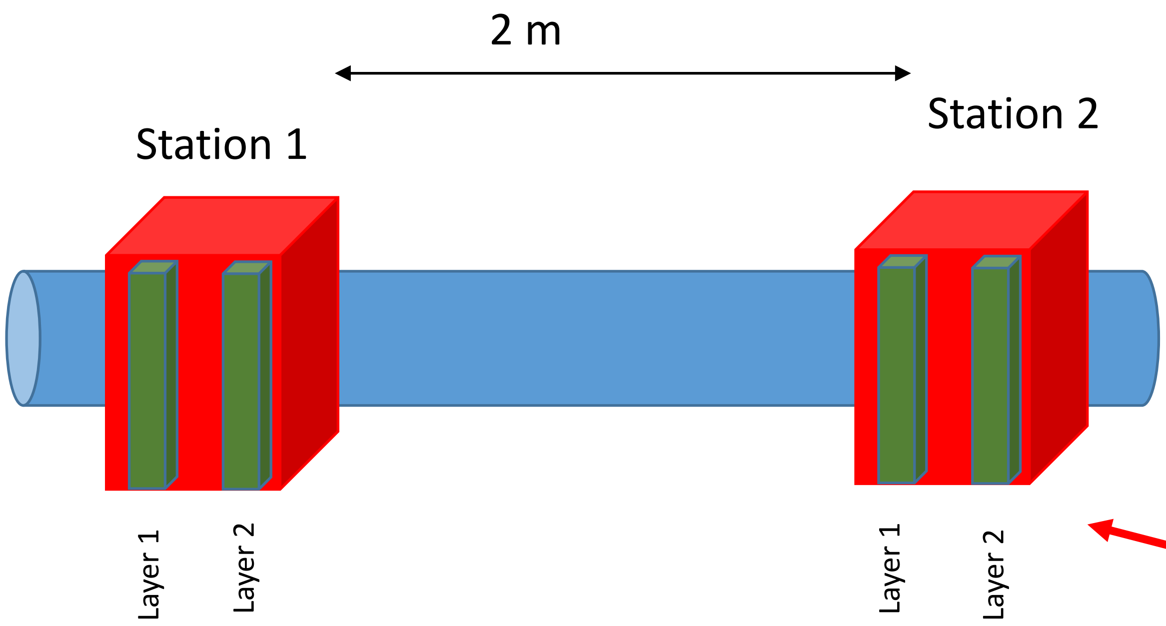


Roman Pots setup at STAR.

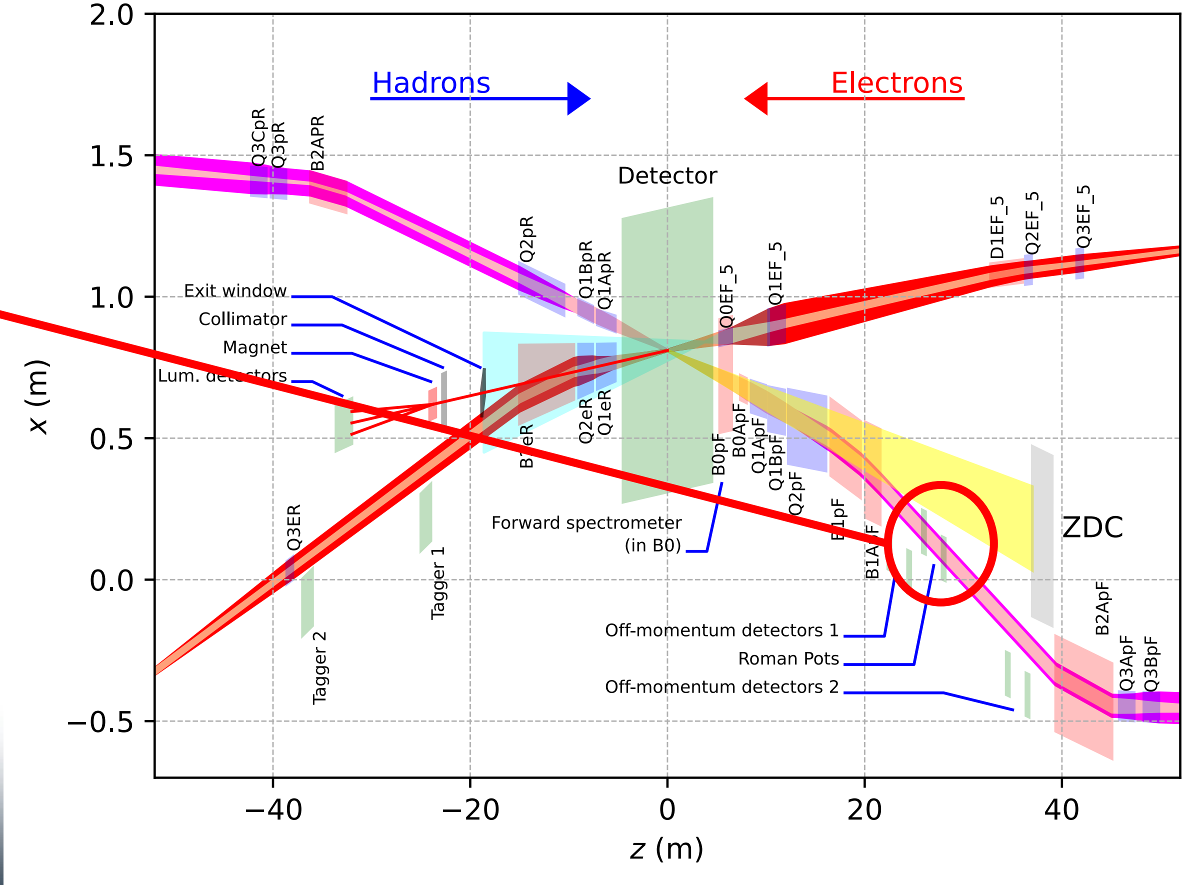


- Silicon detectors sit inside a "pot" with a thin-window to tag protons scattered at small angles (e.g. near the beam).

Roman Pots @ the EIC

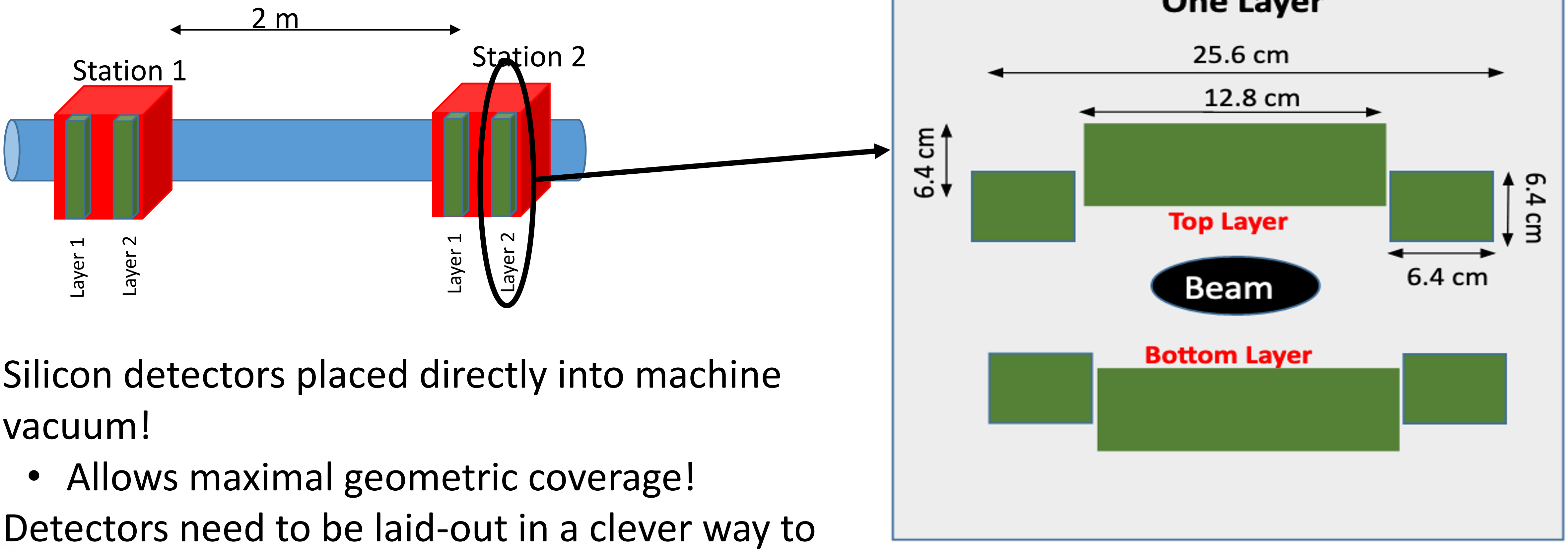


- Two stations, separated by 2 meters, each with two layers (minimum) of silicon detectors.



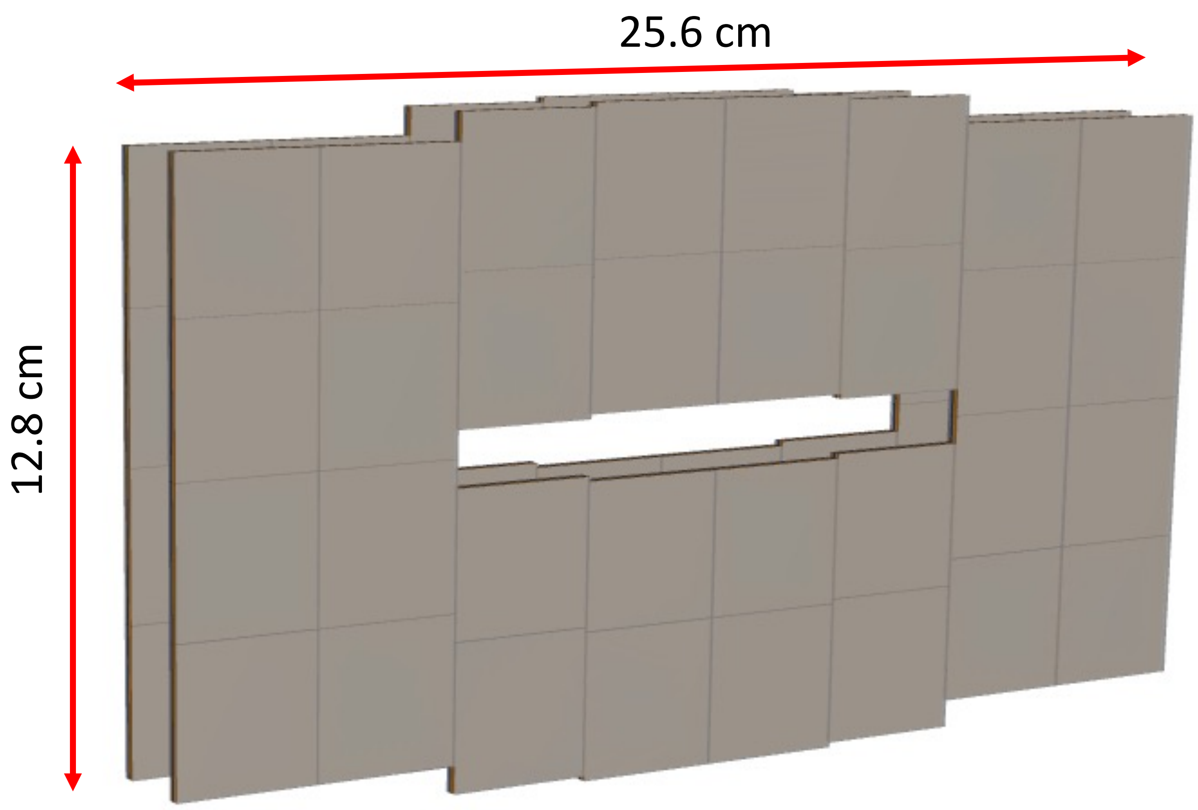
Roman Pots @ the EIC

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

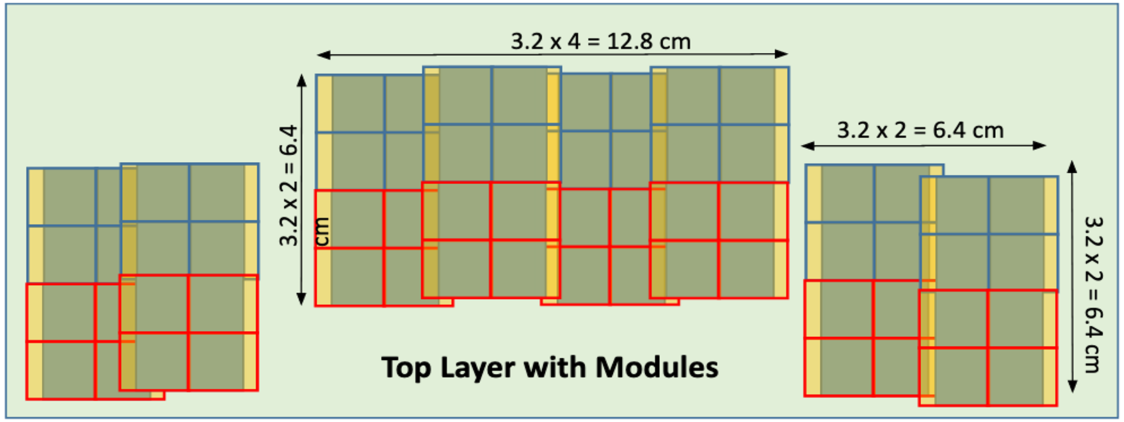


- Silicon detectors placed directly into machine vacuum!
  - Allows maximal geometric coverage!
- Detectors need to be laid-out in a clever way to allow for best coverage of final-state particles.

Roman Pots @ the EIC



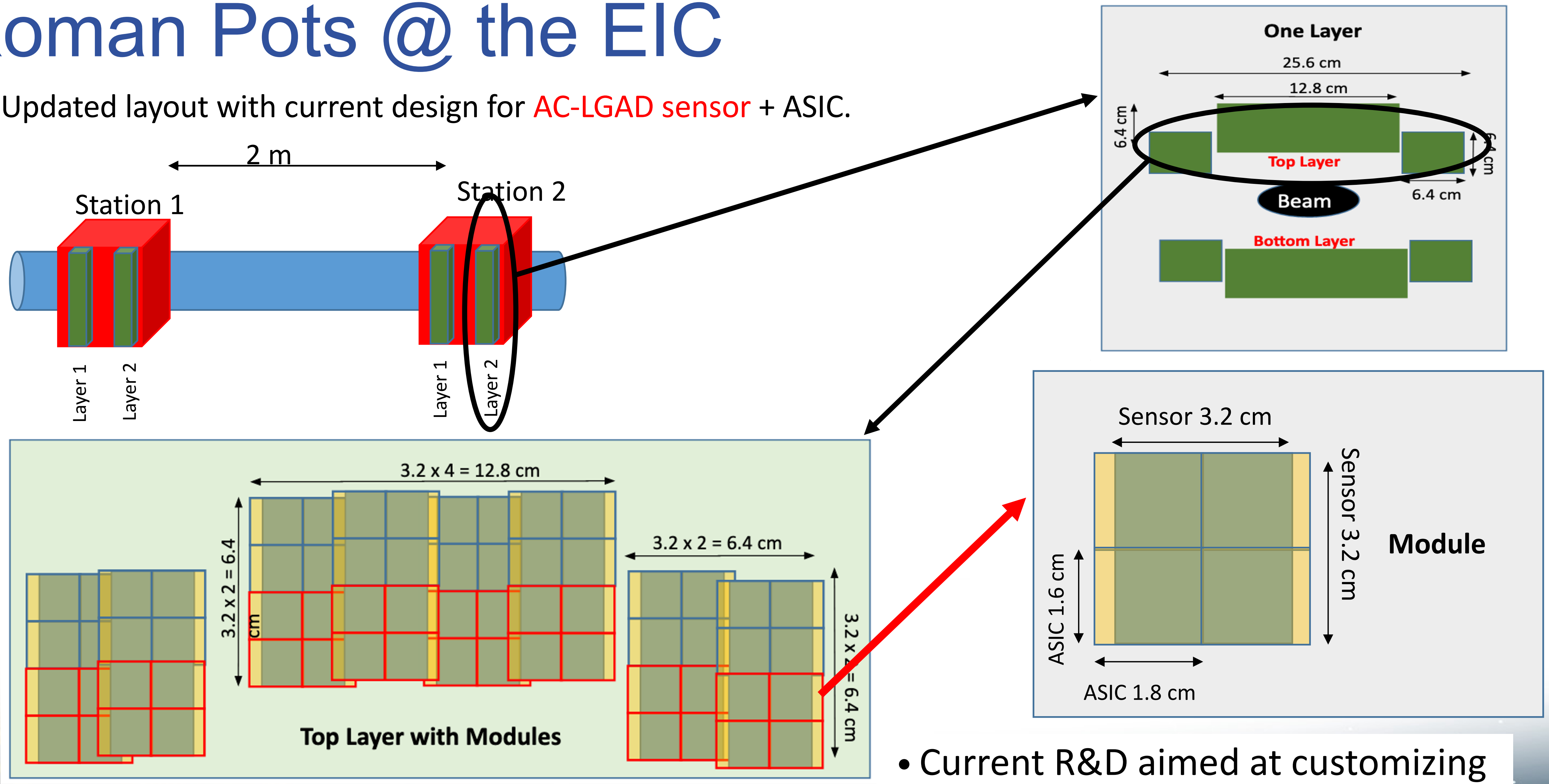
DD4HEP Simulation



- **<u>Two main options</u>**
  - ➢ AC-LGAD sensor provides both fine pixilation (500um square pixels), and fast timing (~30ps).
  - ➢ MAPS + LYSO timing layer.
- "Potless" design concept with thin RF foils surrounding detector components.

Roman Pots @ the EIC

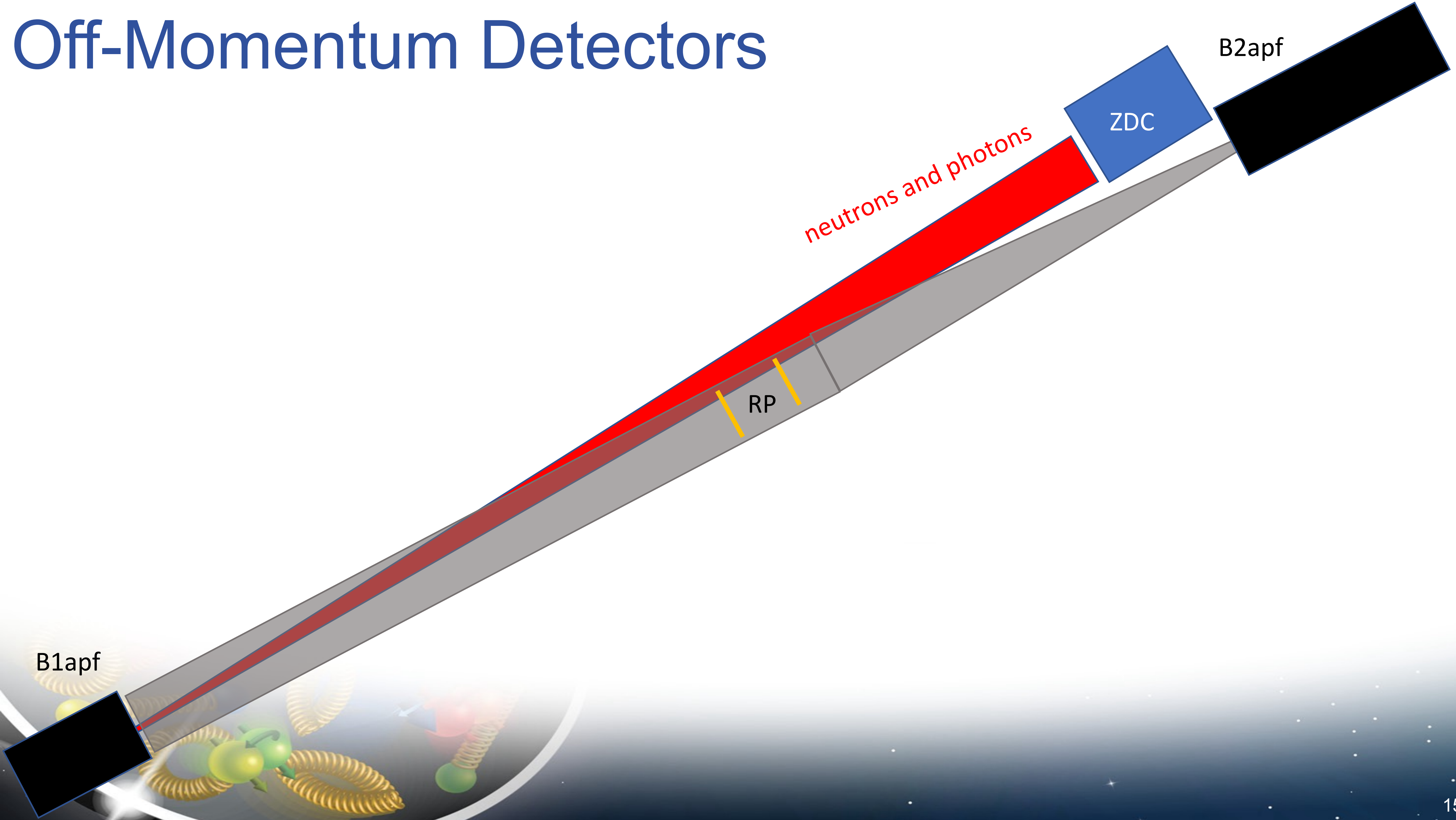
- Updated layout with current design for AC-LGAD sensor + ASIC.



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

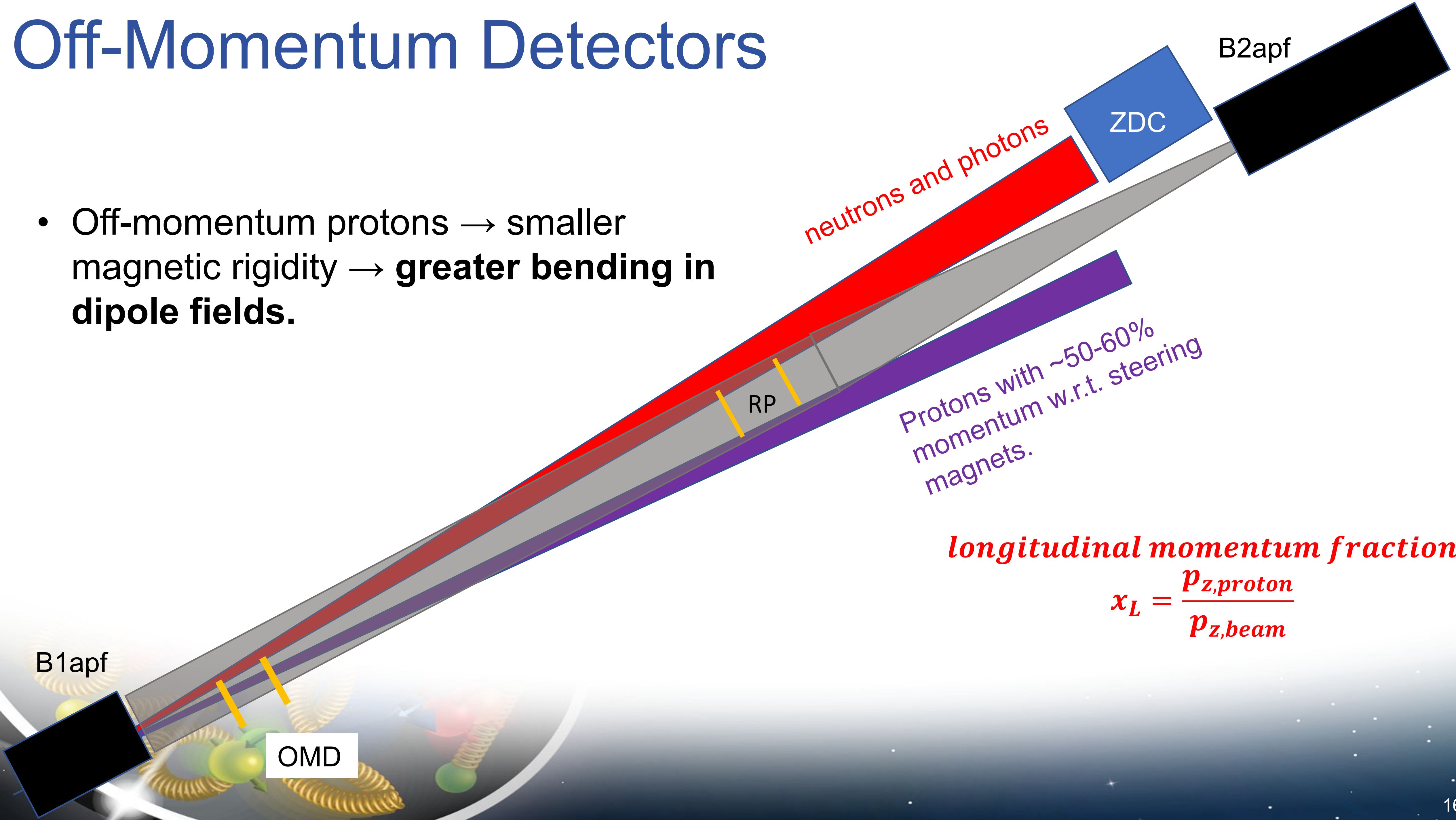
Based on eRD24 R&D work.

Off-Momentum Detectors



Off-Momentum Detectors

- Off-momentum protons → smaller magnetic rigidity → **greater bending in dipole fields.**



longitudinal momentum fraction

$$x_L = \frac{p_{z,proton}}{p_{z,beam}}$$

Off-Momentum Detectors

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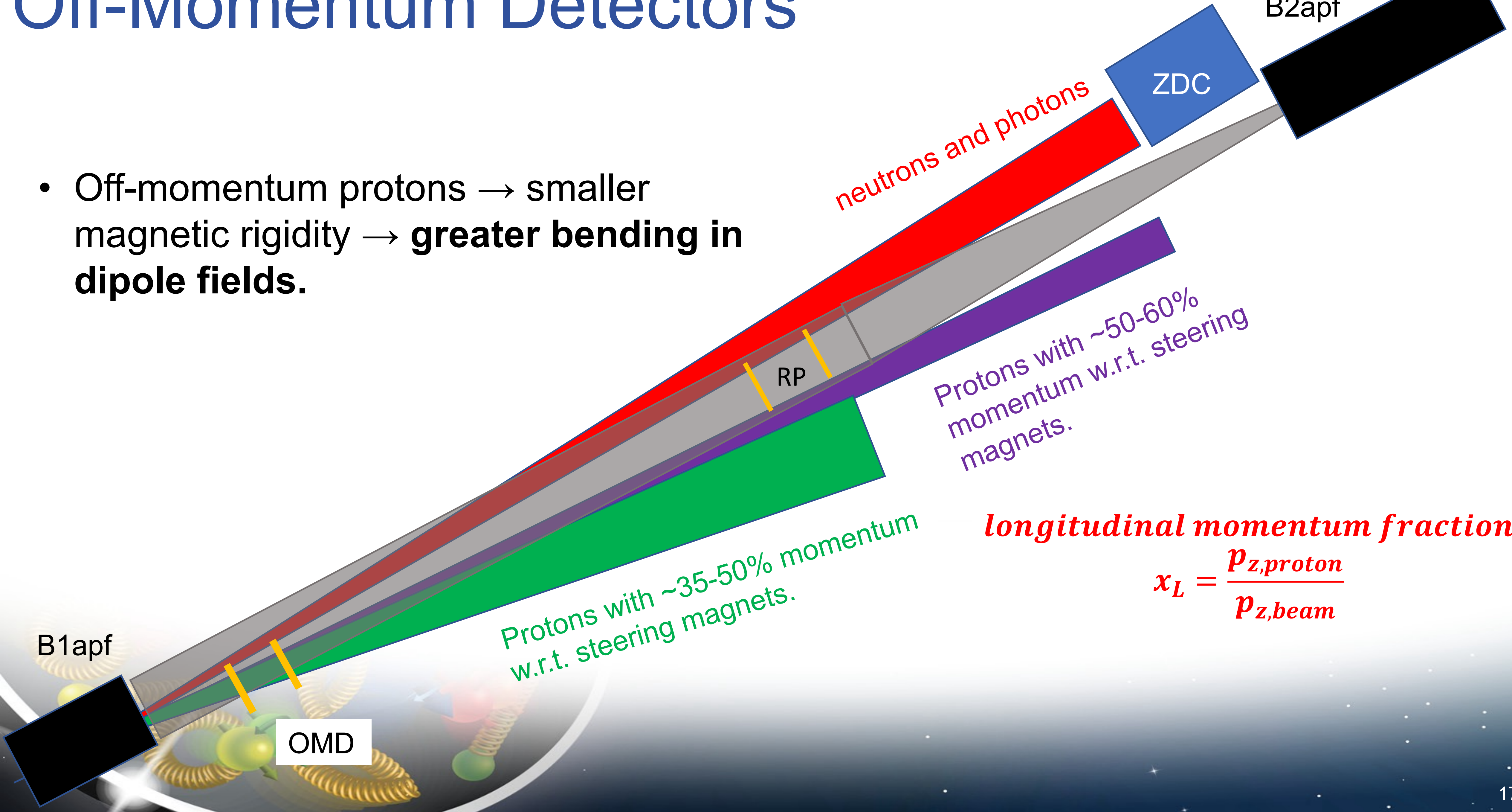
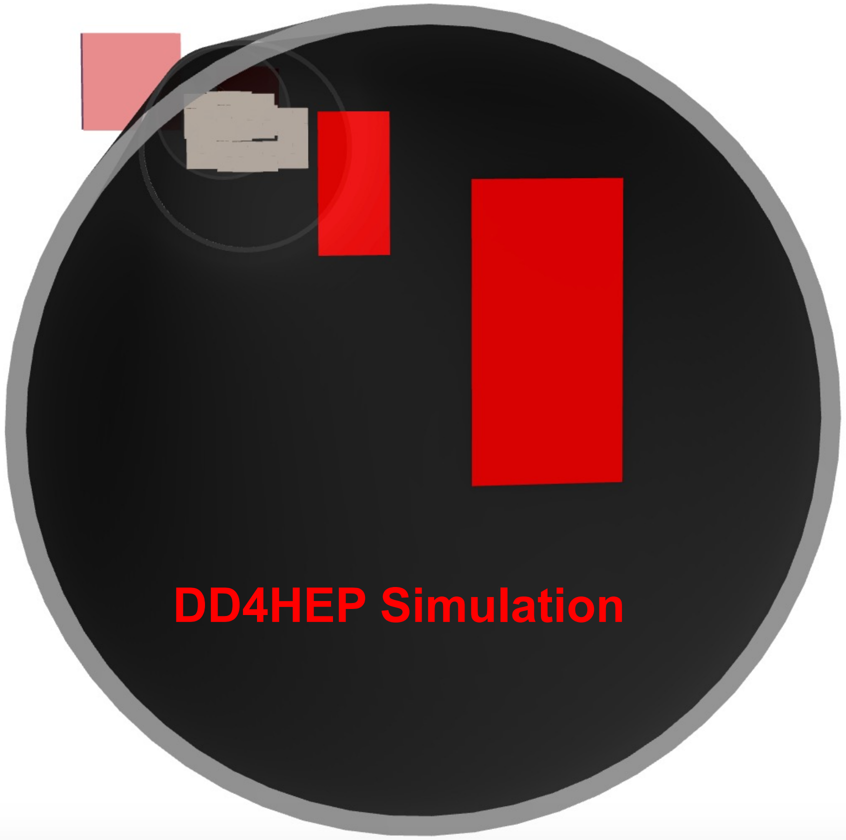


longitudinal momentum fraction

$$x_L = \frac{p_{z,proton}}{p_{z,beam}}$$

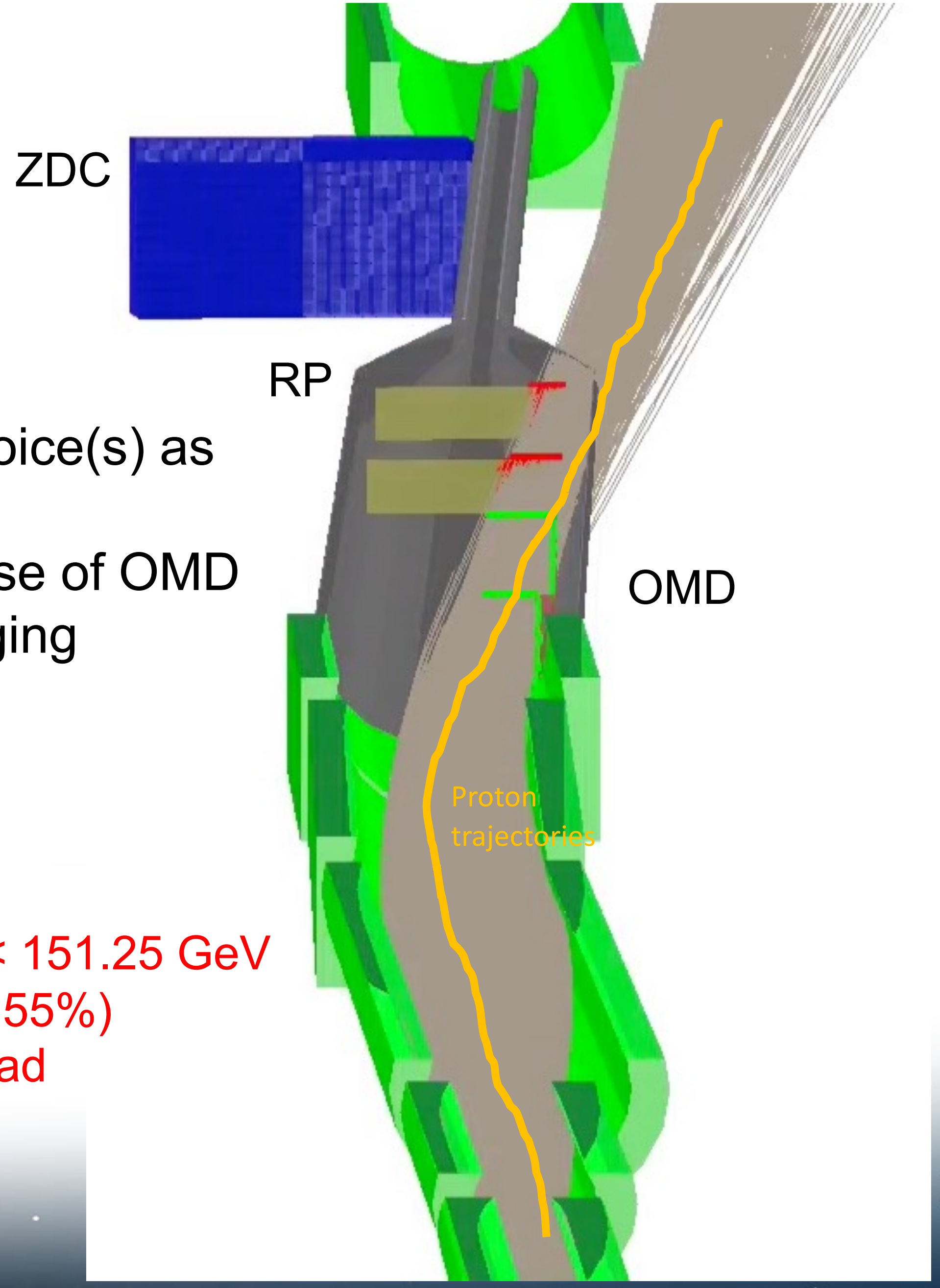
Off-Momentum Detectors



Off-momentum detectors implemented as horizontal "Roman Pots" style sensors.

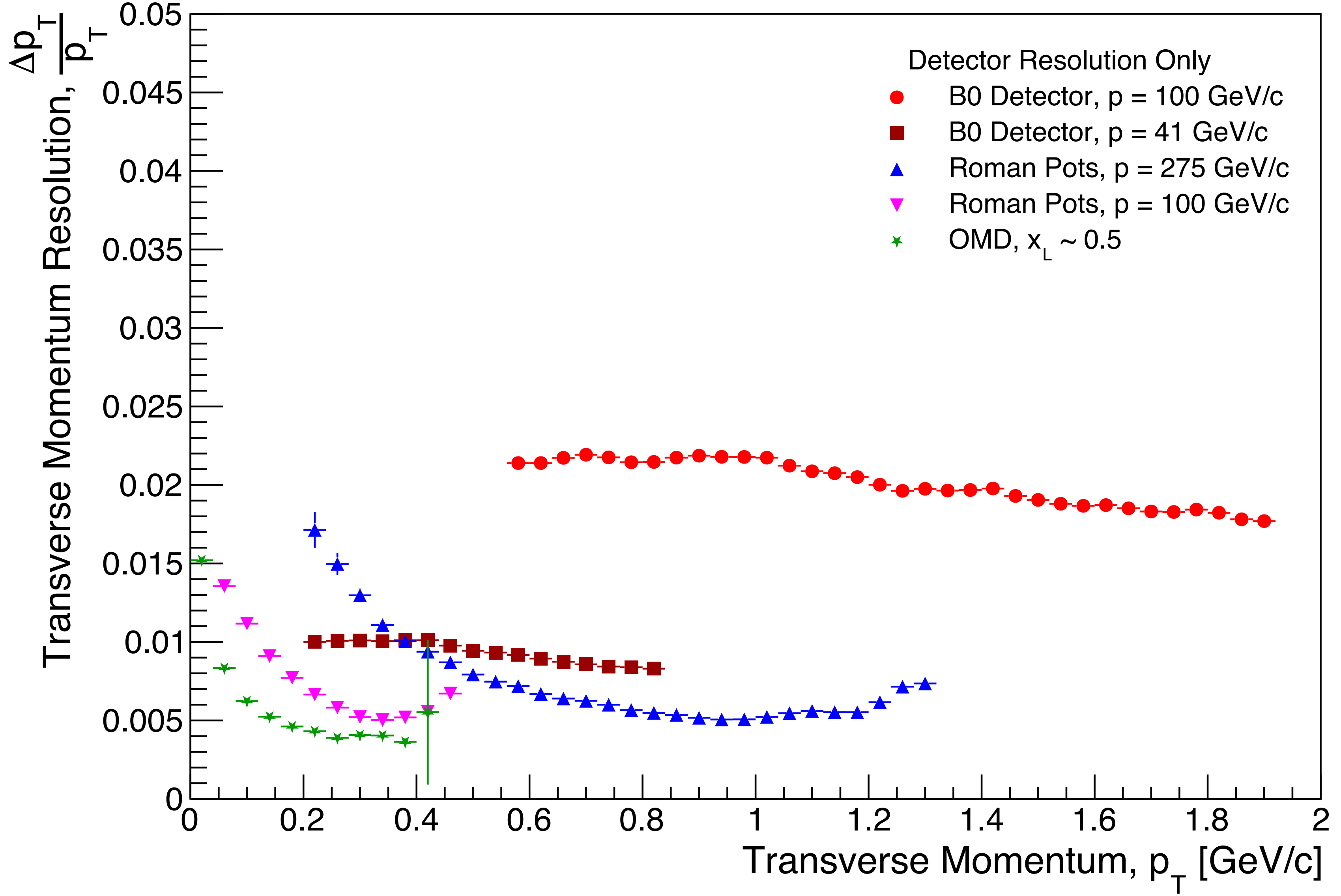
- Same technology choice(s) as for the Roman Pots.
- Need to also study use of OMD on other side for tagging negative pions.

Protons
123.75 < E < 151.25 GeV
(45% < xL < 55%)
0 < θ < 5 mrad



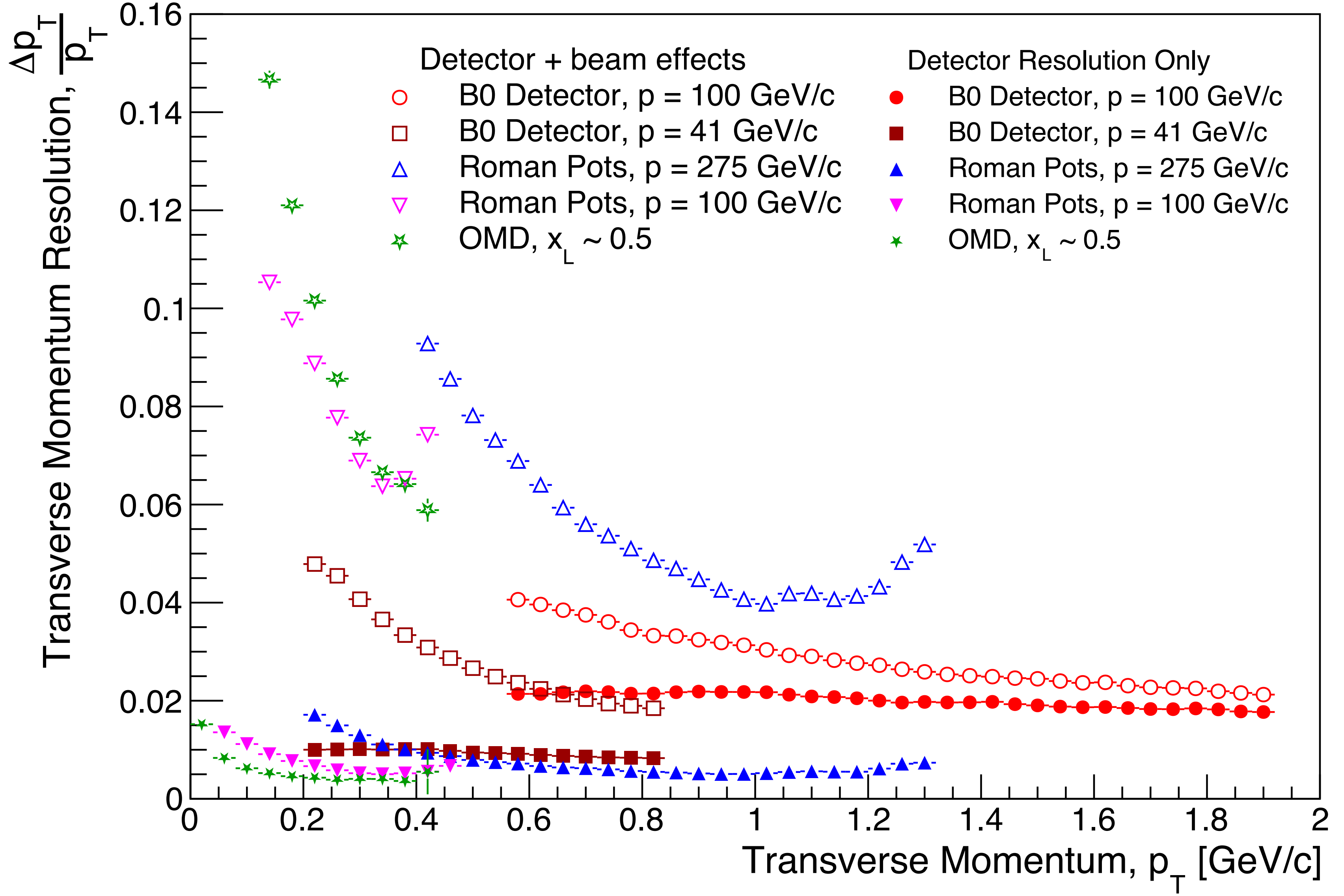
EICROOT GEANT4 simulation.

Summary of Detector Performance (Trackers)



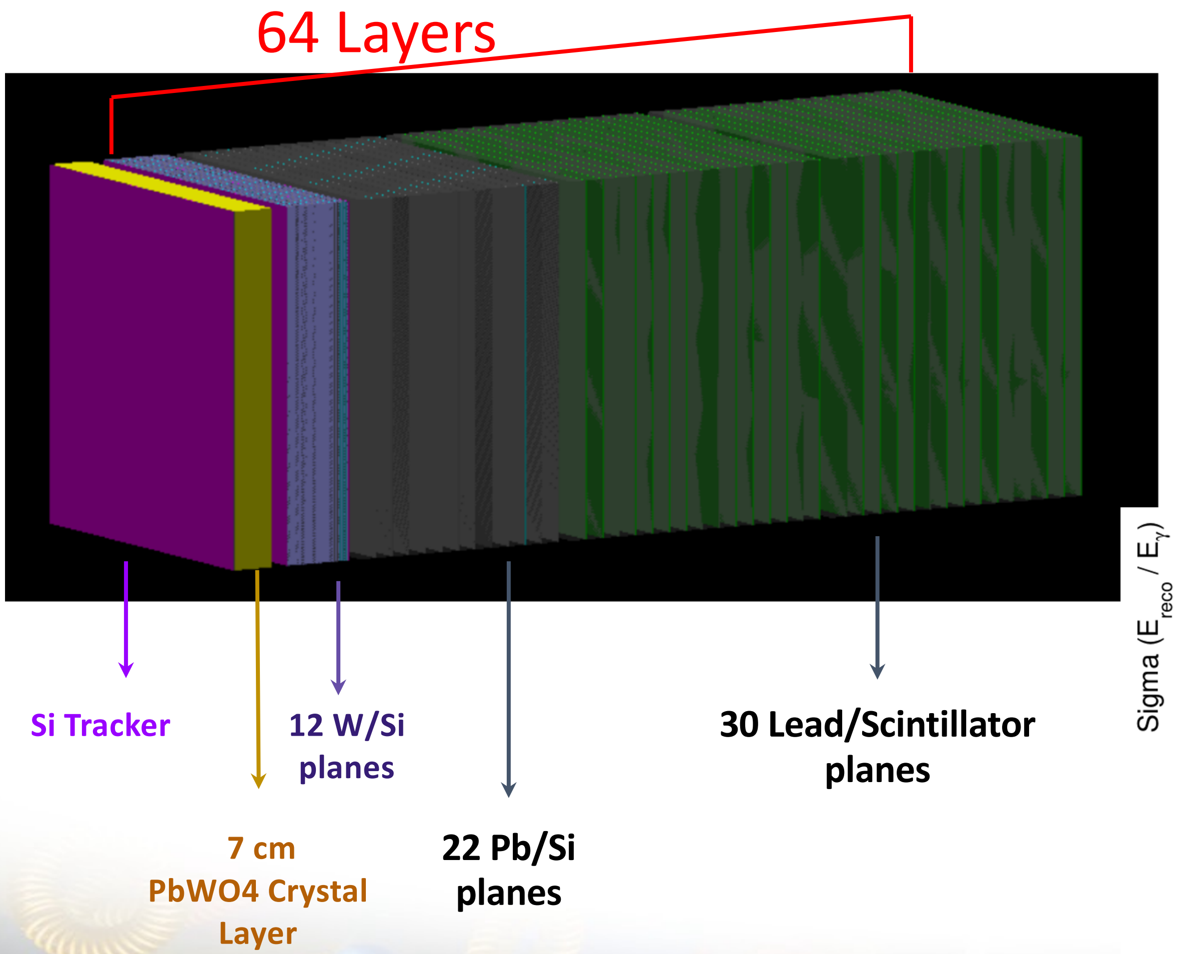
- Includes realistic considerations for pixel sizes and materials
  - More work needed on support structure and associated impacts.
- Roman Pots and Off-Momentum detectors suffer from additional smearing due to improper transfer matrix reconstruction.
  - This problem is close to being solved!

Summary of Detector Performance (Trackers)



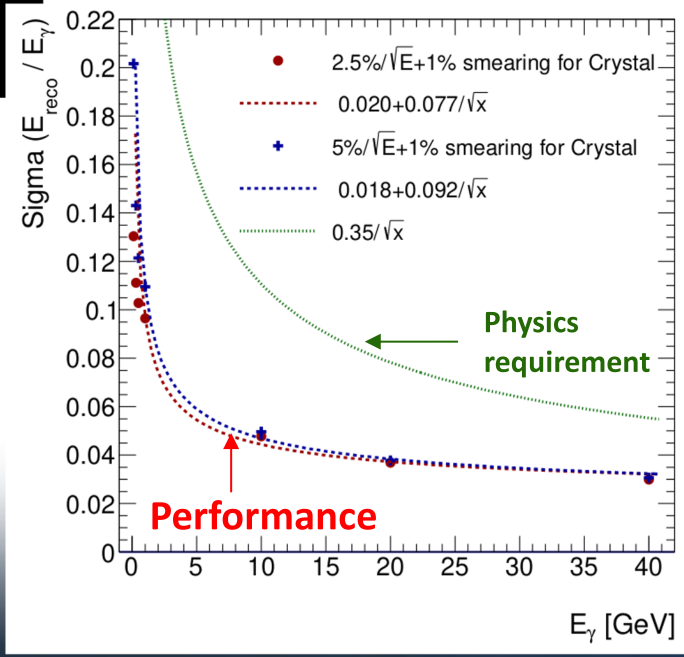
- All beam effects included!
  - Angular divergence.
  - Crossing angle.
  - Crab rotation/vertex smearing.

Zero-Degree Calorimeter (primary option)

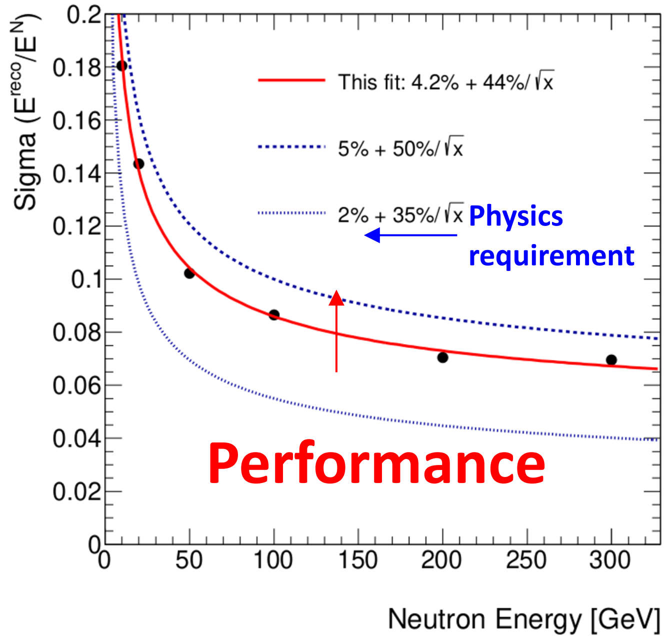


- **Zero Degree Calorimeter (improved ALICE design):**
  - **Dimension: 60 cm x 60 cm x 168 cm**
  - **30 m from IR**
  - **Detect spectator nucleon**
  - **Acceptance: +4.5 mrad, -5.5mrad**
  - **Position resolution ~1.3mm at 40 GeV**

Photon energy resolution



Neutron energy resolution

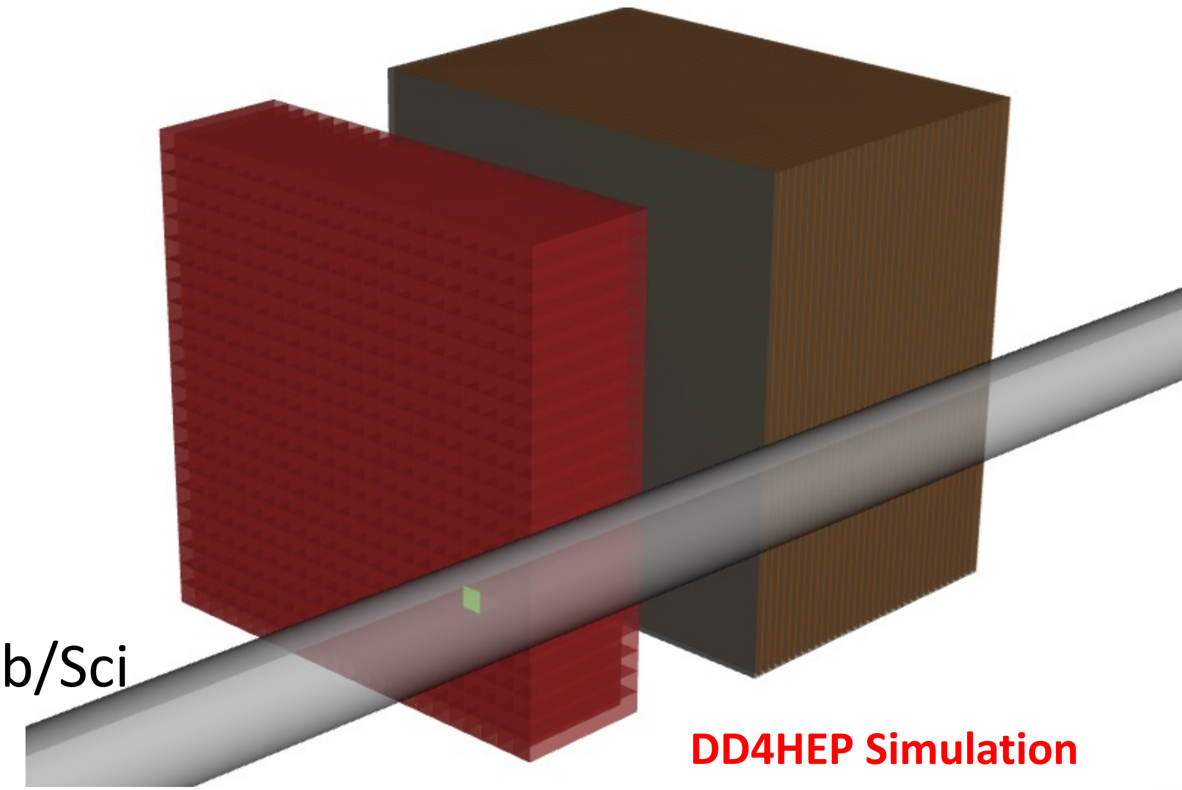


Credit to Shima Shimizu (Kobe U. , Japan)

Thanks to Bill Li for providing the slide!

Zero-Degree Calorimeter (backup/IP8 option)

Multi-functional design including EMCAL and HCAL, with imaging layers to improve pT/angular resolution for neutrons.



DD4HEP Simulation

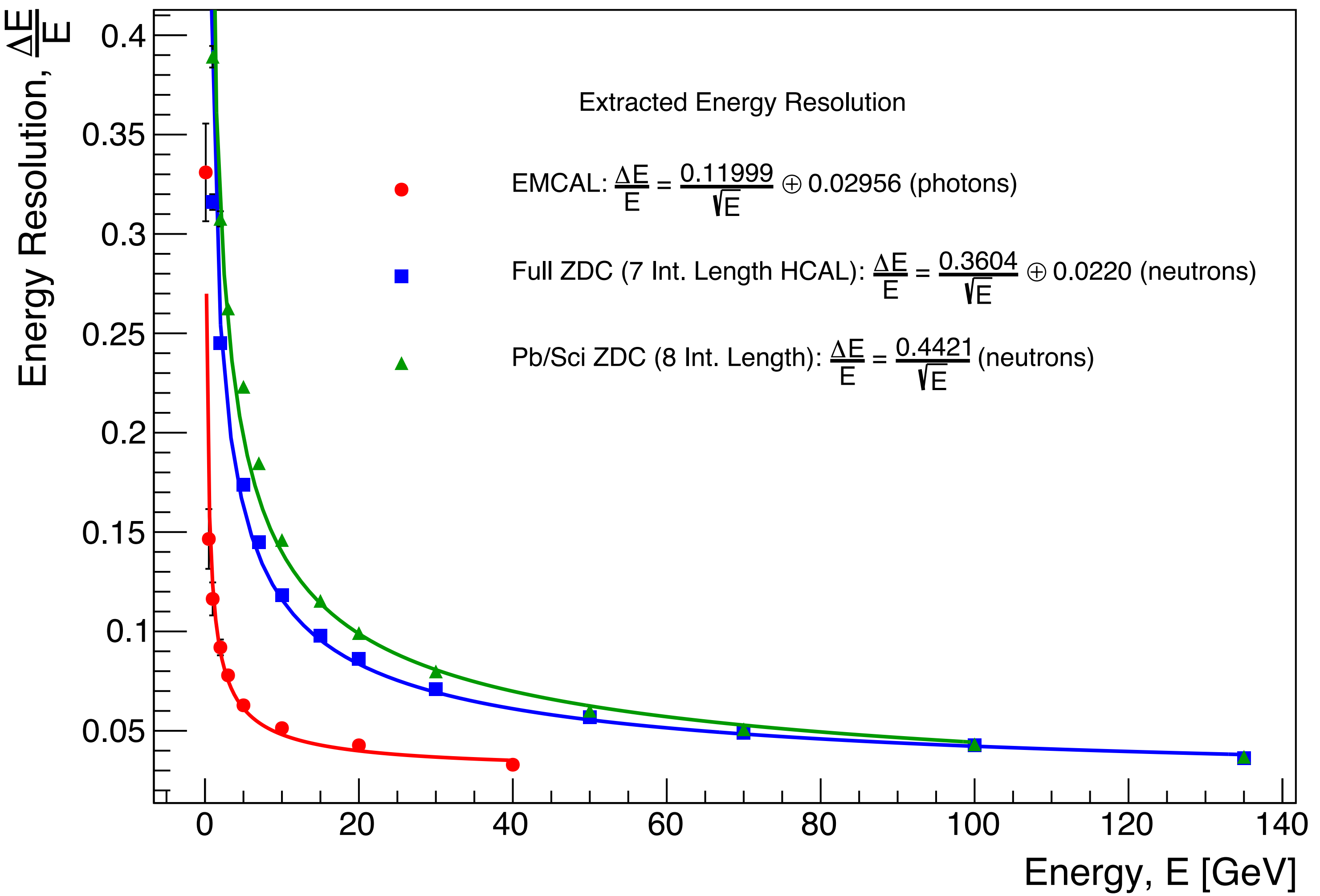
EMCAL (W/SciFi):

- Scintillating fibers embedded in W powder.
- Photon energy resolution $\frac{12\%}{\sqrt{E}} \oplus 3\%$.
- $23X_0$ and $1\lambda_I$

HCAL (Pb/Sci):

- Neutron energy resolution $\frac{36\%}{\sqrt{E}} \oplus 2.2\%$ - using Pb/Sci sampling HCAL with $7\lambda_I$, plus EMCAL section.
- Imaging layers could be silicon or scintillating fibers.
  - Need to better establish how many are needed and at what level of granularity to produce needed resolution.

ATHENA ZDC Performance (E resolution)



- **<u>Alt. ZDC</u>**
  - Comparisons made with simulations for pure Pb/Sci.
    - Performance in GEANT4 simulations consistent with test beam studies for similar construction.
  - Performance will worsen for particles with larger polar angles due to transverse leakage.

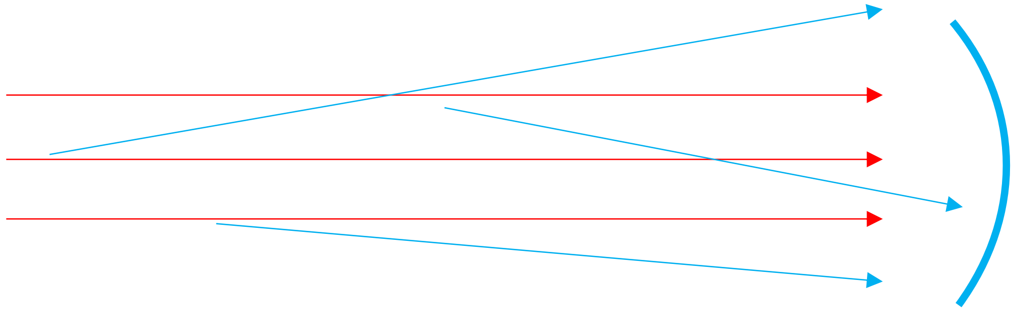
Summary and Takeaways

- Roman Pots, Off-Momentum Detectors, and B0 tracking in good shape between the two groups.
  - Need to think about the alternate technology choice pending R&D outcomes.
- B0 EMCAL is clearly ideal, but space in the B0 magnet bore is limited, and will shrink.
- ECCE ZDC design is the baseline and meets the requirements.
- More realistic engineering considerations need to be added to simulations as design of IR vacuum system and magnets progresses toward CD-2/3a.
  - Lots of experience in performing these simulations, so this work will progress rapidly as engineering design matures.
  - Already well-established line of communication between detector and physics parties and the EIC machine/IR development group ⇒ Crucial for success!!!

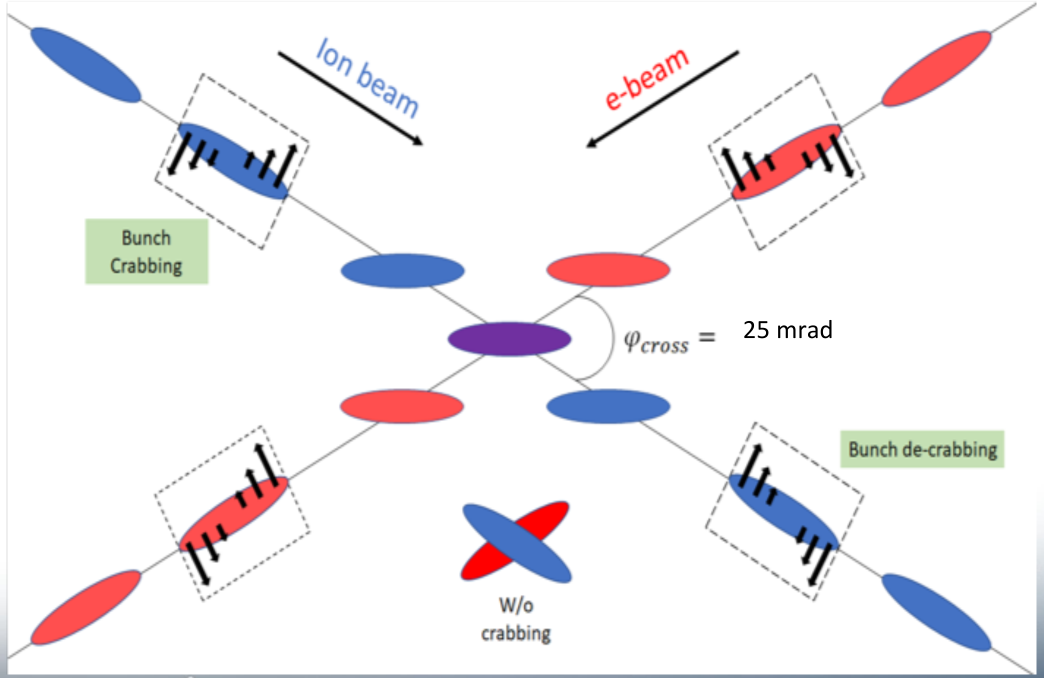
Backup

Digression: particle beams

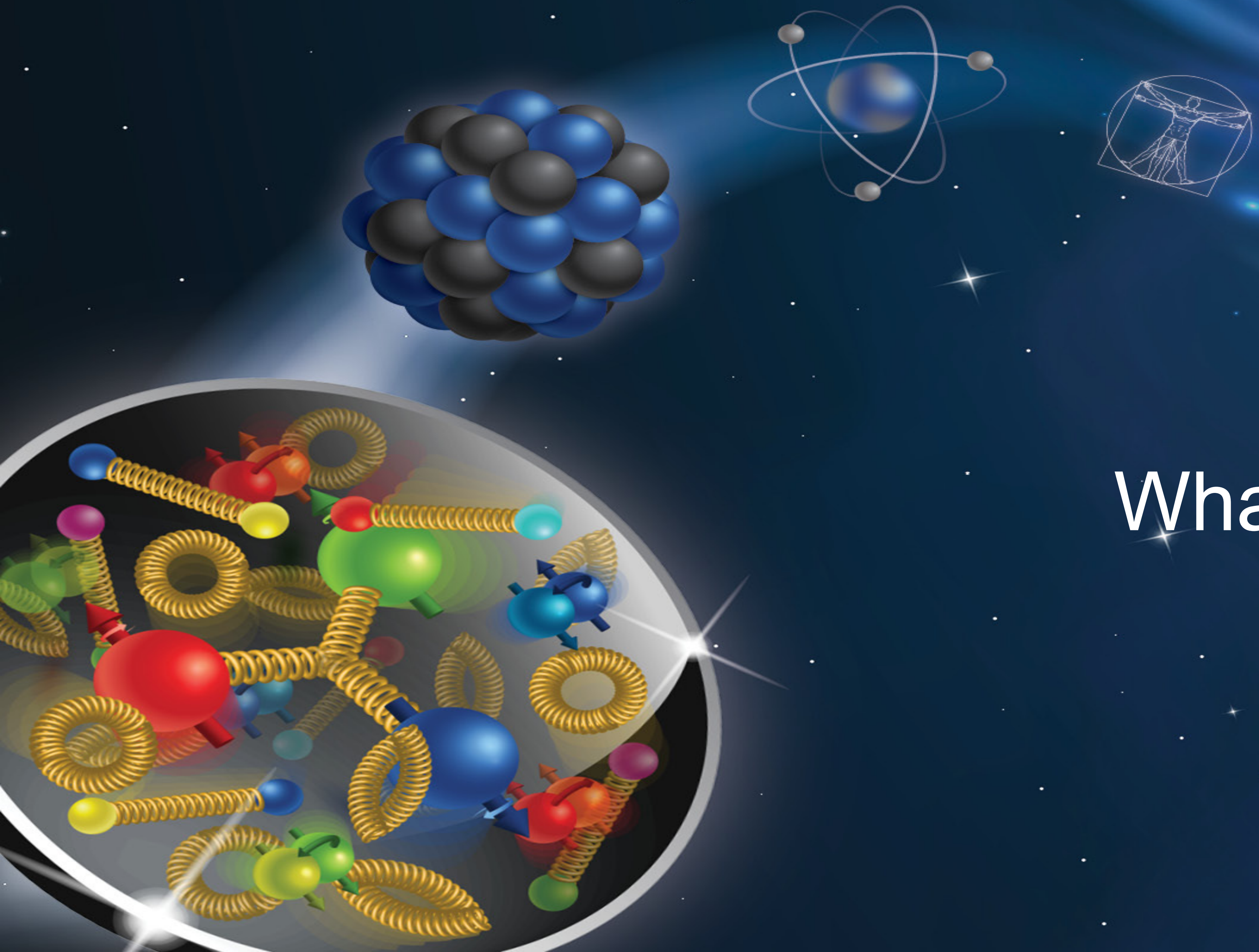
- Angular divergence
  - Angular "spread" of the beam away from the central trajectory.
  - Gives some small initial transverse momentum to the beam particles.



- Crab cavity rotation
  - Can perform rotations of the beam bunches in 2D.
  - Used to account for the luminosity drop due to the crossing angle – allows for head-on collisions to still take place.

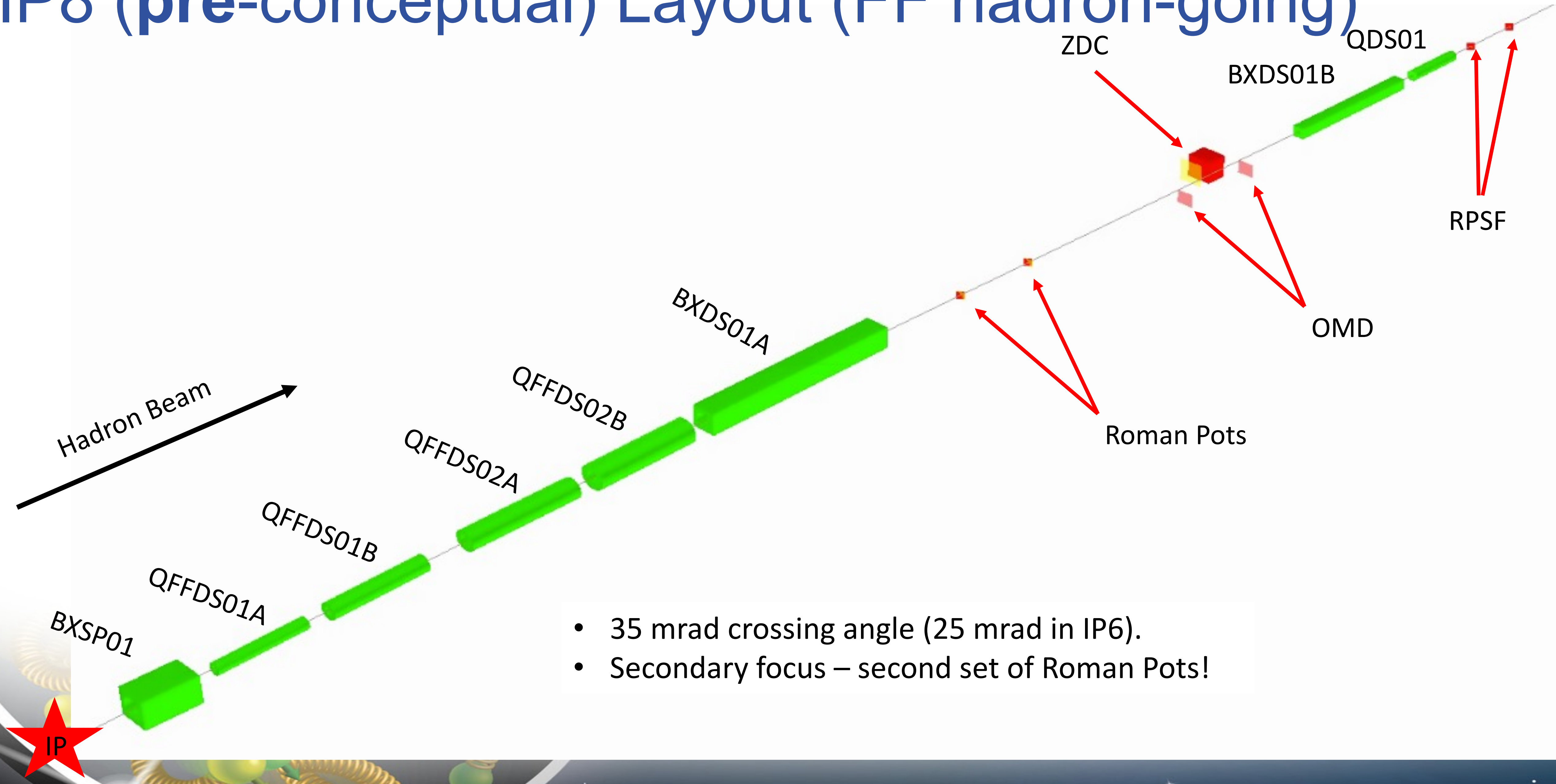


These effects introduce smearing in our momentum reconstruction.



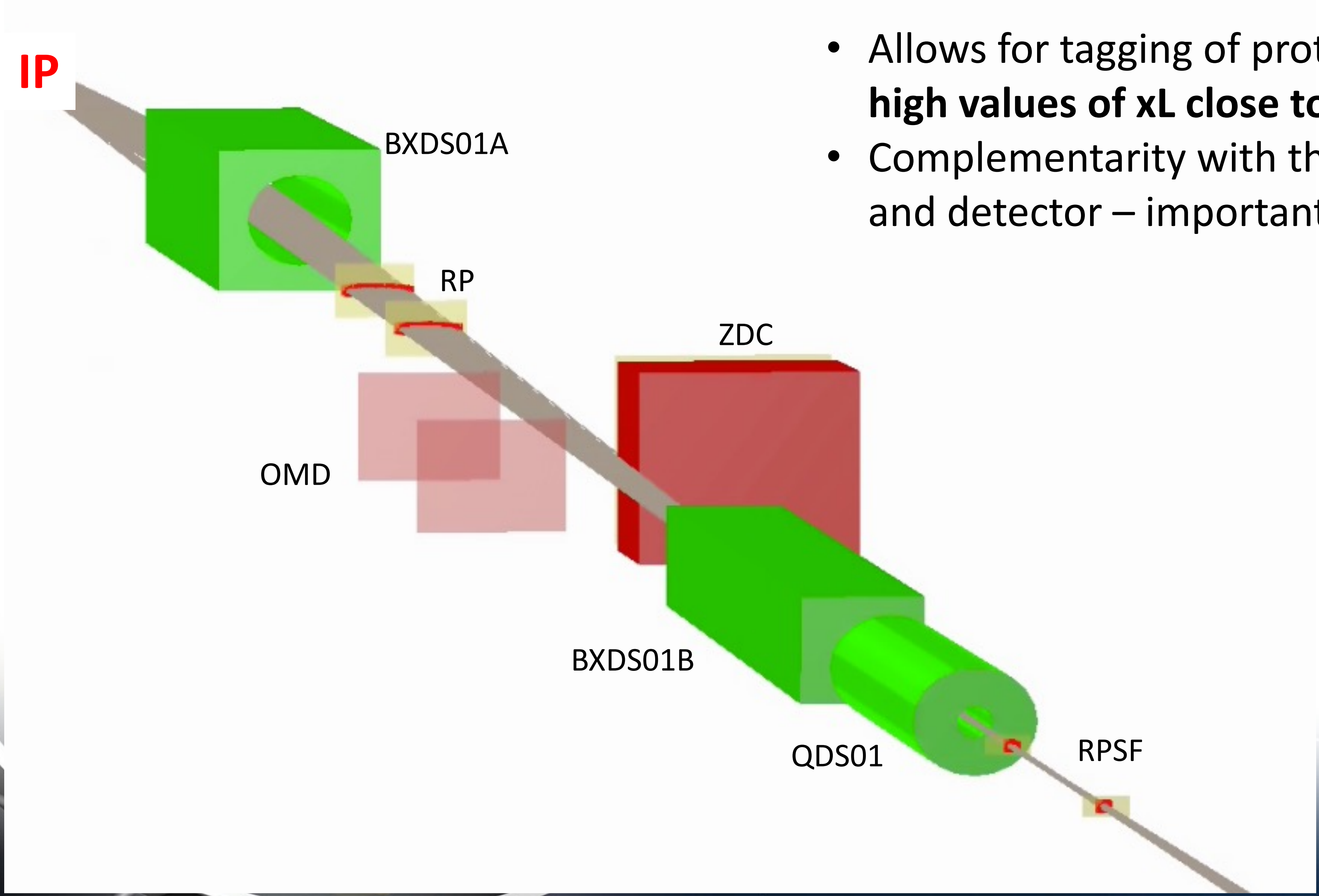
What about IP8?

IP8 (**pre**-conceptual) Layout (FF hadron-going)



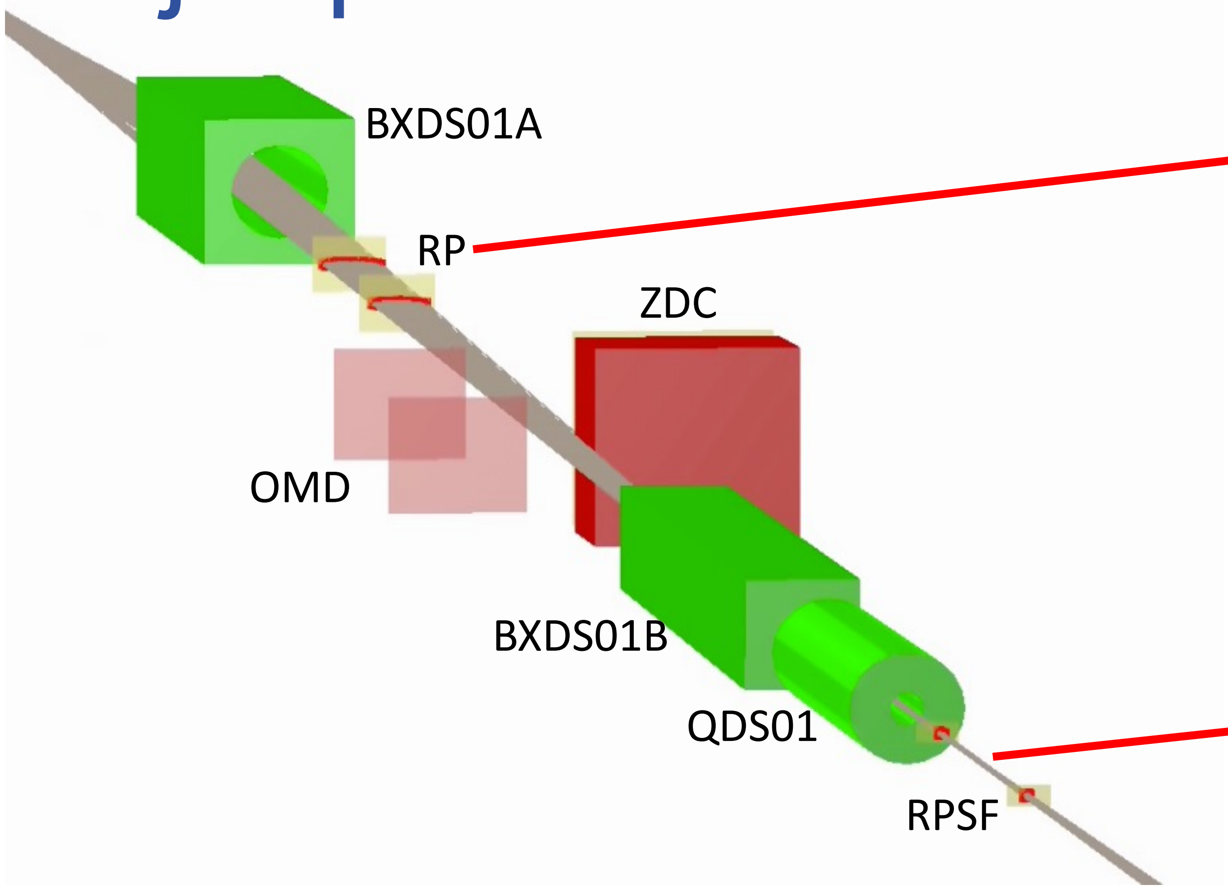
- 35 mrad crossing angle (25 mrad in IP6).
- Secondary focus – second set of Roman Pots!

Major potential benefit: Secondary Focus



- Allows for tagging of protons and nuclei at very **high values of xL close to one** (pT ~ 0).
- Complementarity with the IP6 configuration and detector – important for the EIC!

Major potential benefit: Secondary Focus



$$x_L = \frac{p_{z,particle}}{p_{beam}}$$