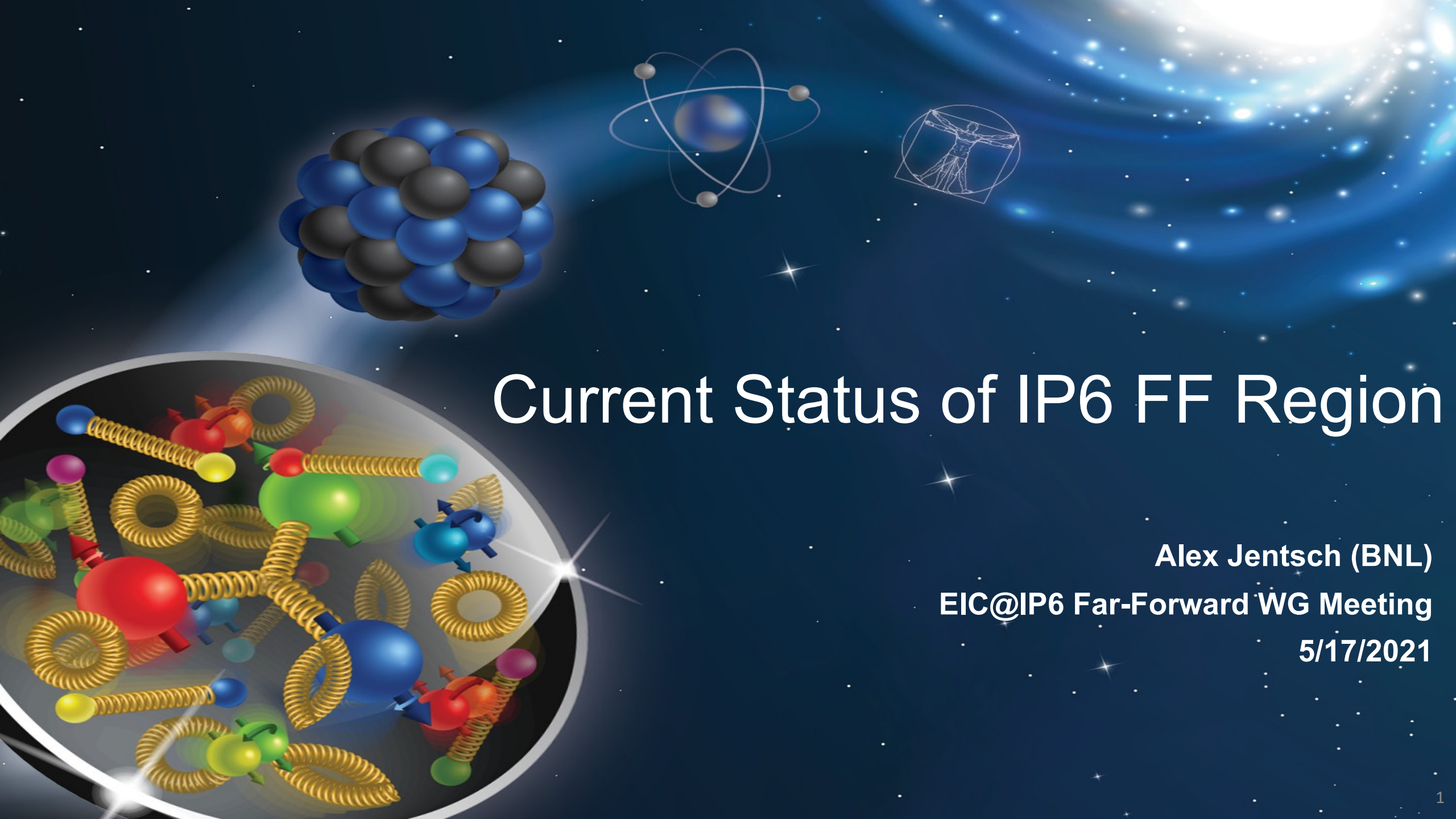


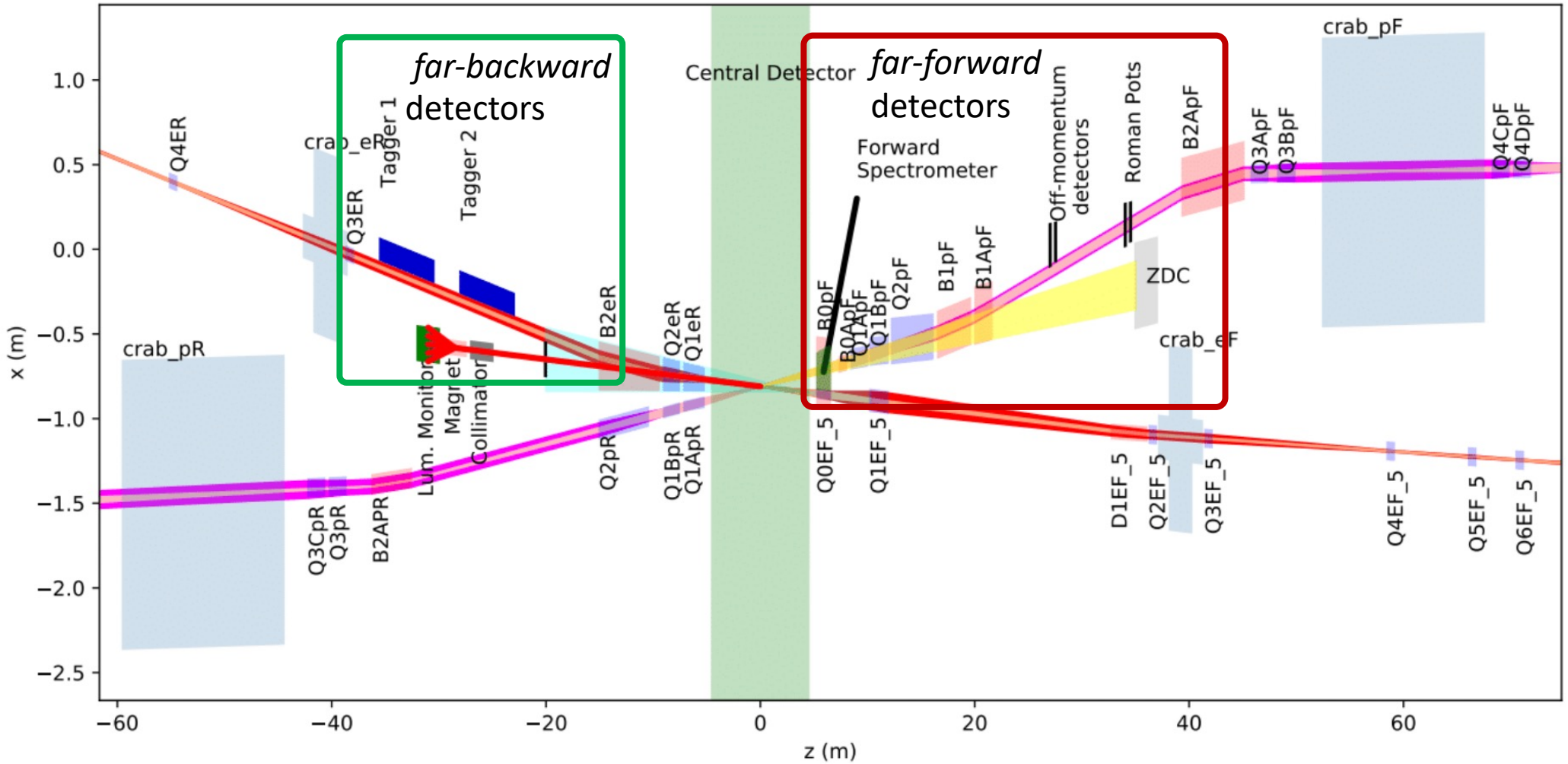
Current Status of IP6 FF Region

Alex Jentsch (BNL)

EIC@IP6 Far-Forward WG Meeting

5/17/2021

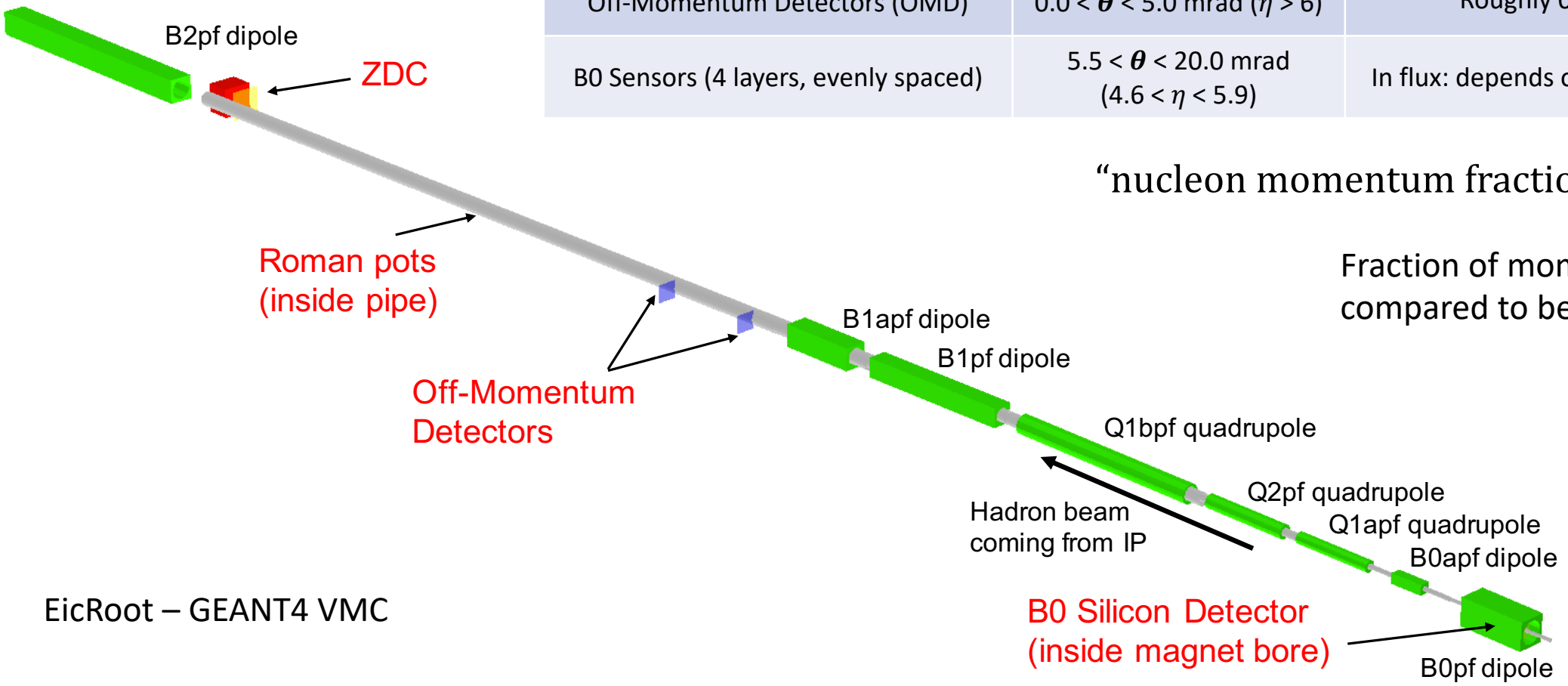
EIC Interaction Region Layout



- Central detector spans 9 meters and is machine-component free (except for beam pipe).
- Hadron-going and electron-going directions after central detector fully instrumented.
- Hadron and electron beam cross with an angle of 25 mrad.

FF Hadron-Going Direction & Acceptance

Detector	Acceptance	Notes
Zero-Degree Calorimeter (ZDC)	$\boldsymbol{\theta}$ < 5.5 mrad (η > 6)	About 4.0 mrad at φ ~ π
Roman Pots (2 stations)	0.0* < $\boldsymbol{\theta}$ < 5.0 mrad (η > 6)	$0.65 < \frac{p_{z,nucleon}}{p_{z,beam}} < 1.0$ *10σ cut
Off-Momentum Detectors (OMD)	0.0 < $\boldsymbol{\theta}$ < 5.0 mrad (η > 6)	Roughly $0.3 < \frac{p_{z,nucleon}}{p_{z,beam}} < 0.6$
B0 Sensors (4 layers, evenly spaced)	5.5 < $\boldsymbol{\theta}$ < 20.0 mrad (4.6 < η < 5.9)	In flux: depends on pipe and electron quad.

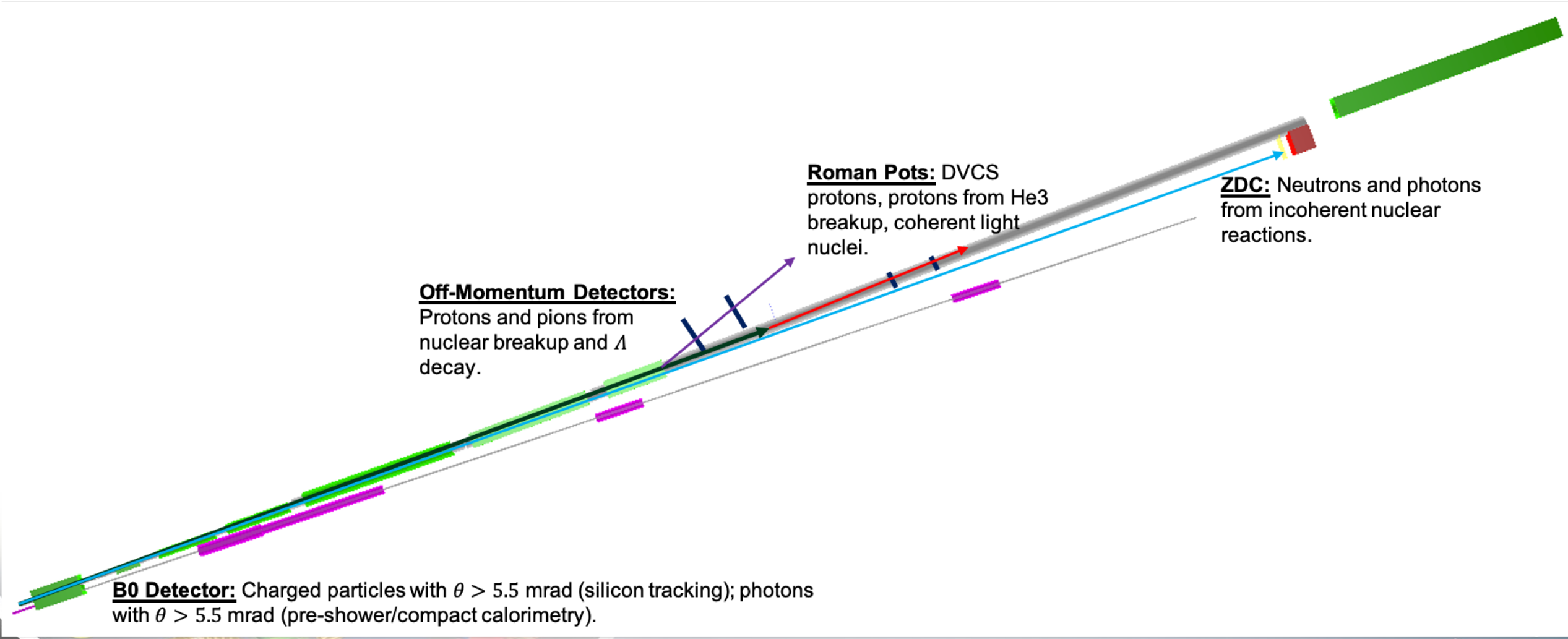


$$\text{“nucleon momentum fraction”} = \frac{p_{z,nucleon}}{p_{z,beam}}$$

Fraction of momentum for nucleon compared to beam.

EicRoot – GEANT4 VMC

FF Hadron-Going Direction & Acceptance



What has been done up to now (i.e. YR)?

- Establishment of basic detector acceptances for all 4 subsystems.
  - Well-understood, unlikely to undergo any kind of major changes.
- Establishment of needed performance of detectors.
  - Pixel sizes, timing needs, etc. fairly well-established and impact studied for numerous physics channels (e+p DVCS, e+d spectator tagging, e+He3 spectator tagging, incoherent vetoing in heavy nuclei, etc.).
- Estimation of impacts of (some) beam effects.
  - Crab cavity rotation of bunch translates to vertex smearing.
  - Angular divergence increases (transverse) momentum smearing, but gives us more luminosity. Reducing divergence improves acceptance and smearing, and provides subsequent reduced luminosity (~ factor of 2).
- All of these details are in the Yellow Report in Ch. 11., and in the EIC CDR.
  - YR: (https://arxiv.org/abs/2103.05419)
  - CDR: (https://www.bnl.gov/ec/files/EIC_CDR_Final.pdf).

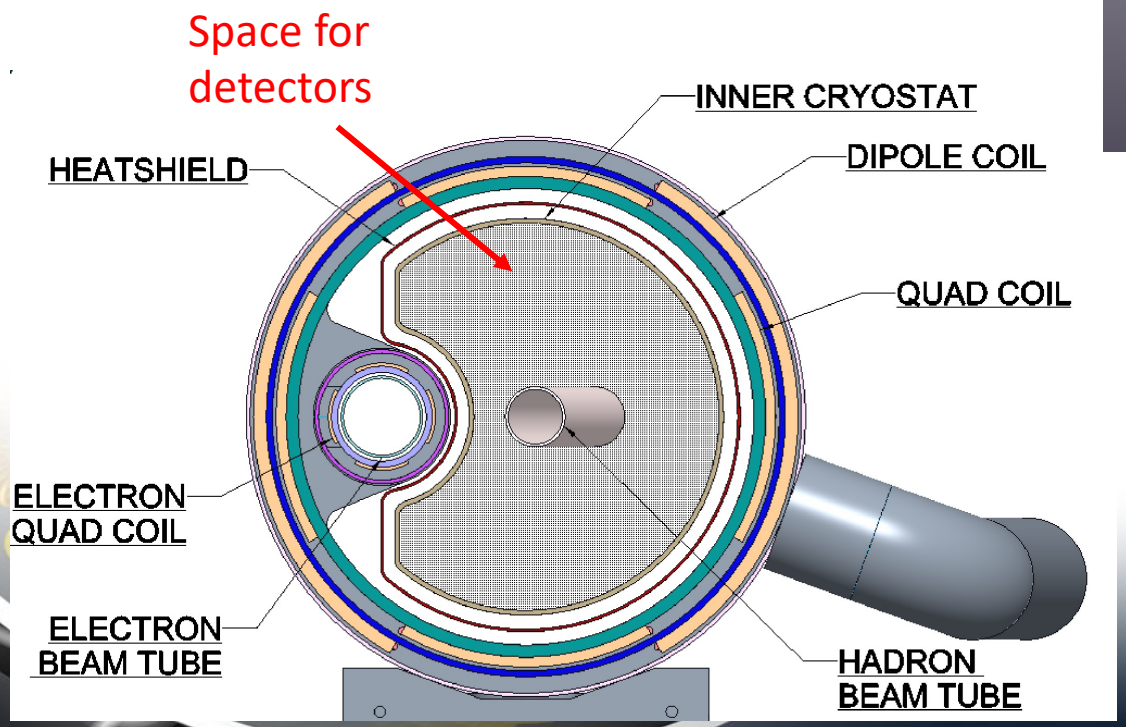
What is missing or currently in progress?

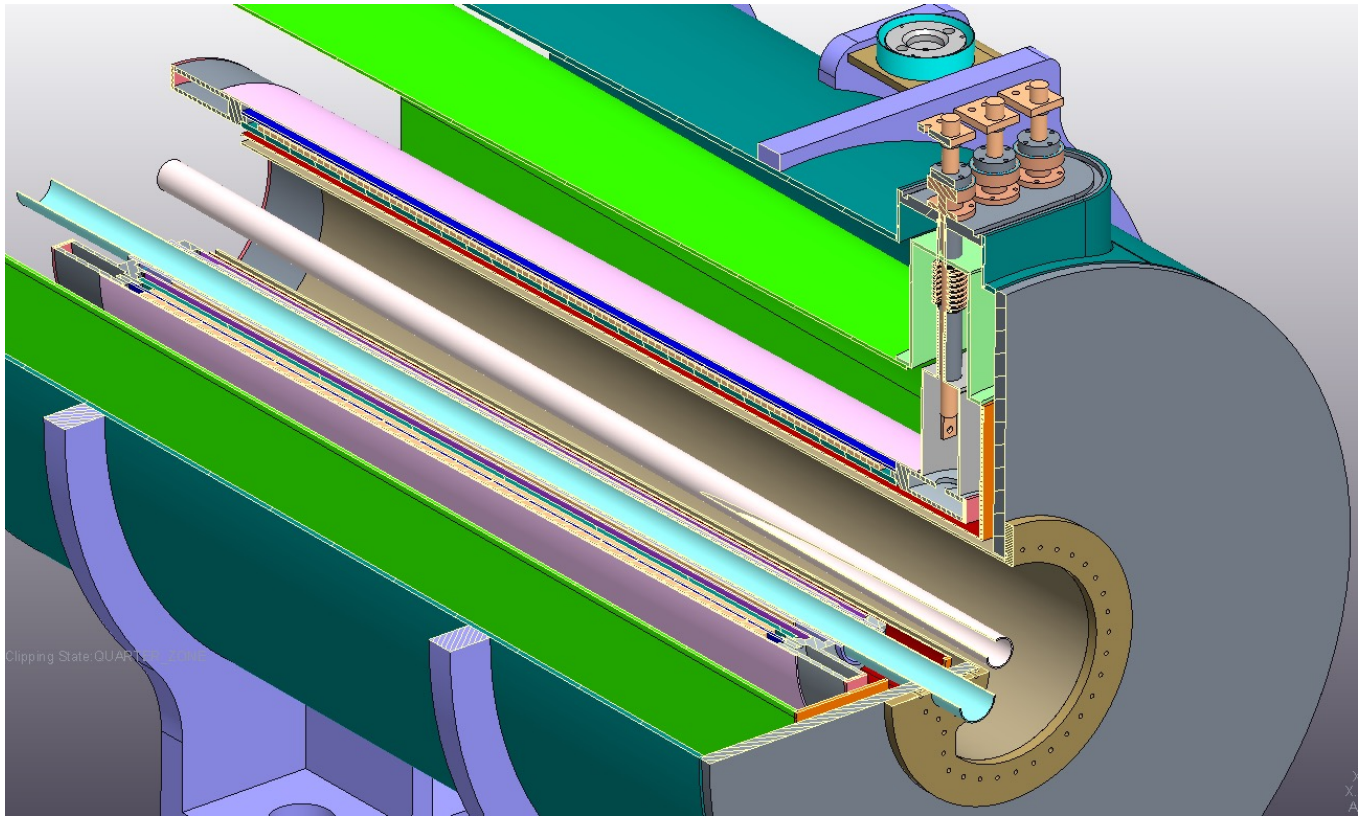
- Beam pipe design (project work – input from relevant parties).
  - Some preliminary ideas have been worked on, and impact assessed (especially on the efficiency of incoherent vetoing in heavy nuclei).
  - The beam pipe in this region is highly challenging.
- Services and support estimates.
  - ZDC and OMD less crucial since they sit outside the beam pipe.
- Optimizations still underway for IP6.
  - e.g. 50cm shift of magnets to give more central detector space still being finalized.
  - Nothing will have drastic negative impact - all optimizations aimed at improvements.

B0-detectors

(5.5 < θ < 20.0 mrad)

- Charged particle reconstruction.
  - Precise tracking -> need smaller pixels (50um) than for the RP.
  - Require timing layer for the crab rotation and background rejection.
  - Shape and # of layers of B0 tracker needs to be further evaluated.



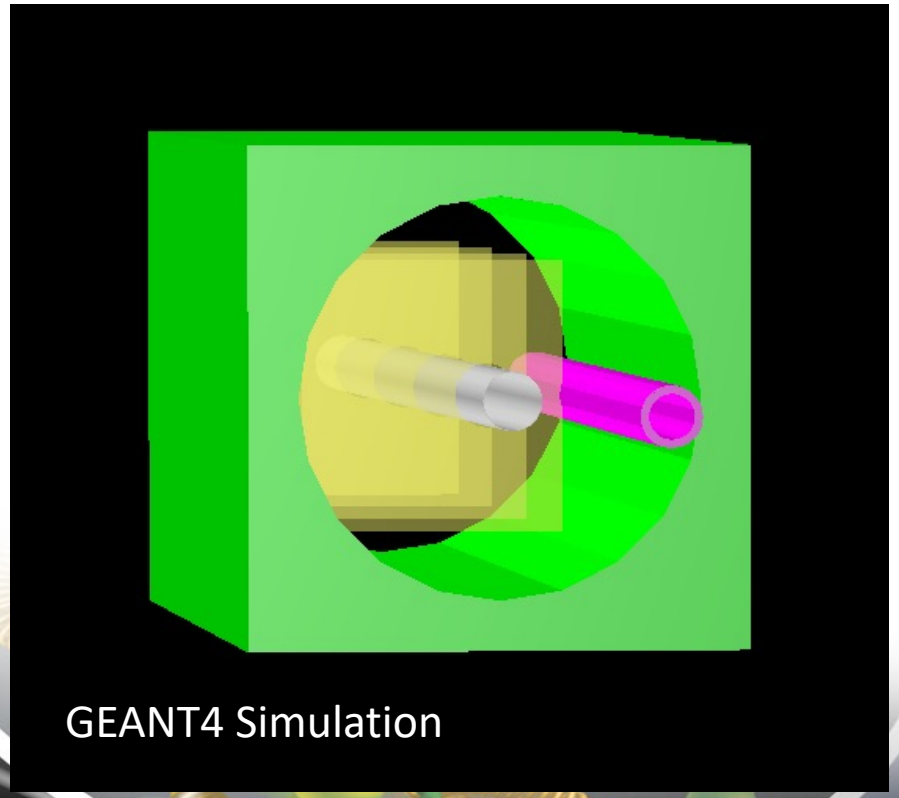


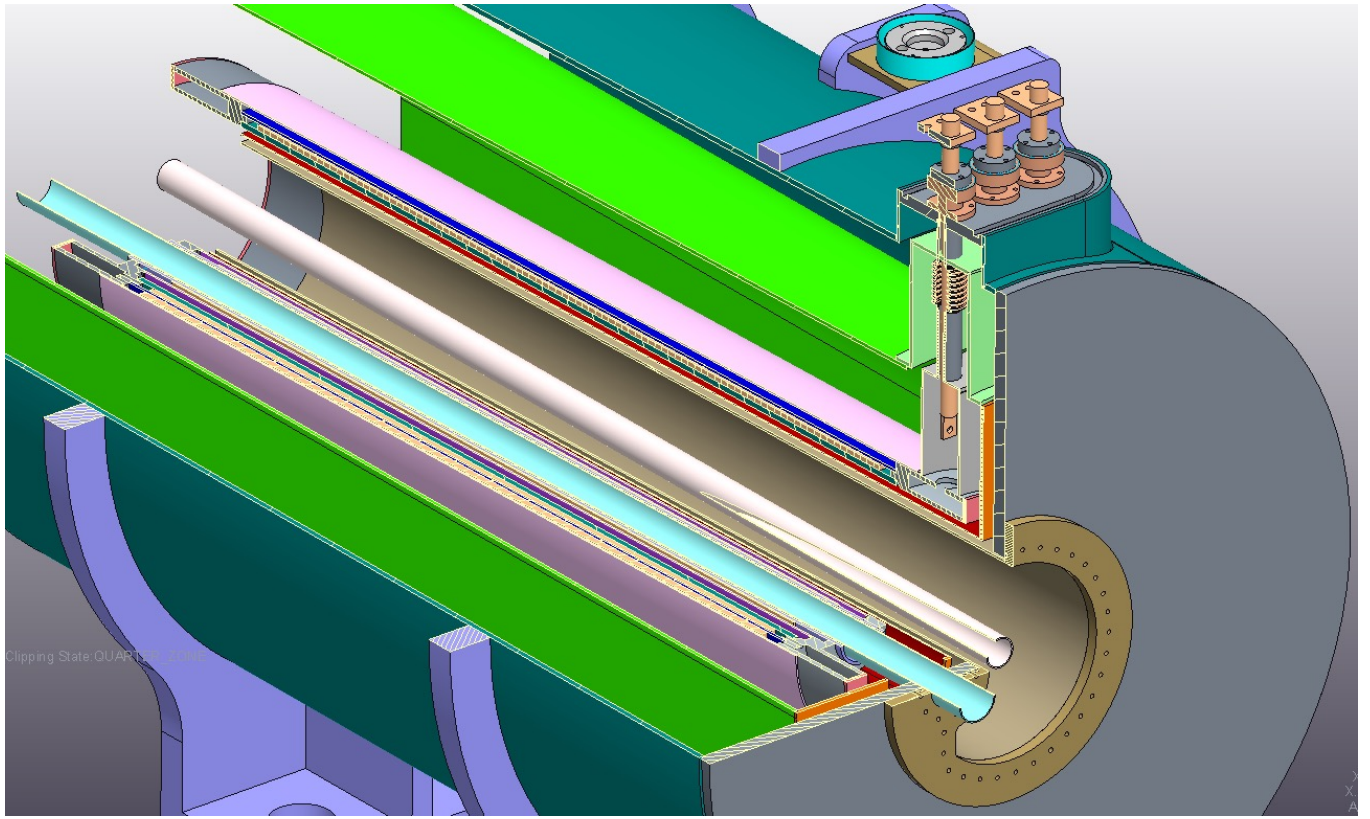
- Higher granularity detectors needed in this area (MAPS, or something similar) with layers of fast-timing detectors (e.g. LGADs), or timepix (provides high resolution space and timing information), depending on sensor layout and size.
- **Decision on technology options needs to be made!**

B0-detectors

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

- ~1.2 meters of longitudinal space in bore.
- Could potentially have several layers of silicon for tracking, and a few layers after for some EM calorimetry (compact).





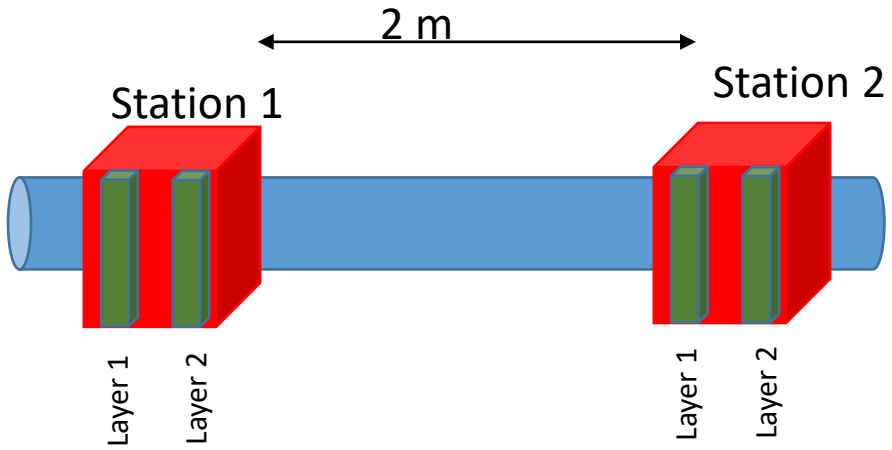
- Tagging photons is also important in differentiating between coherent and incoherent heavy-nuclear scattering.
- Potential inclusion of small EMCAL or preshower detector in the B0 bore.
- Further study needed to assess.
- Tagging photons further down-stream (ZDC) highly technically challenging.

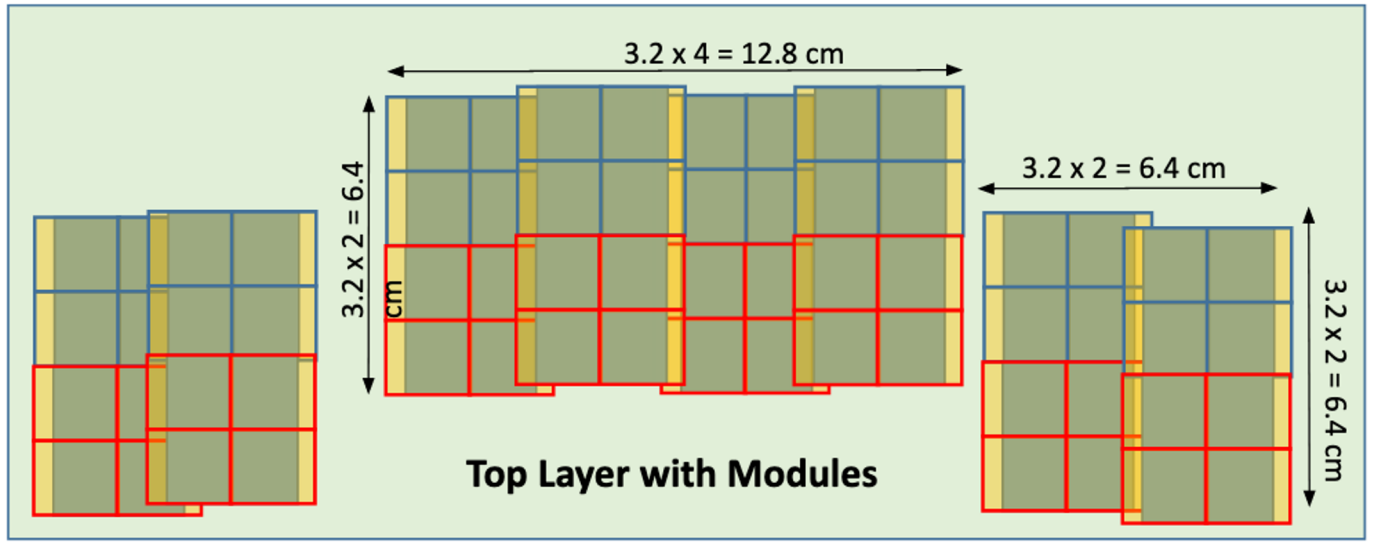
B0 Detectors

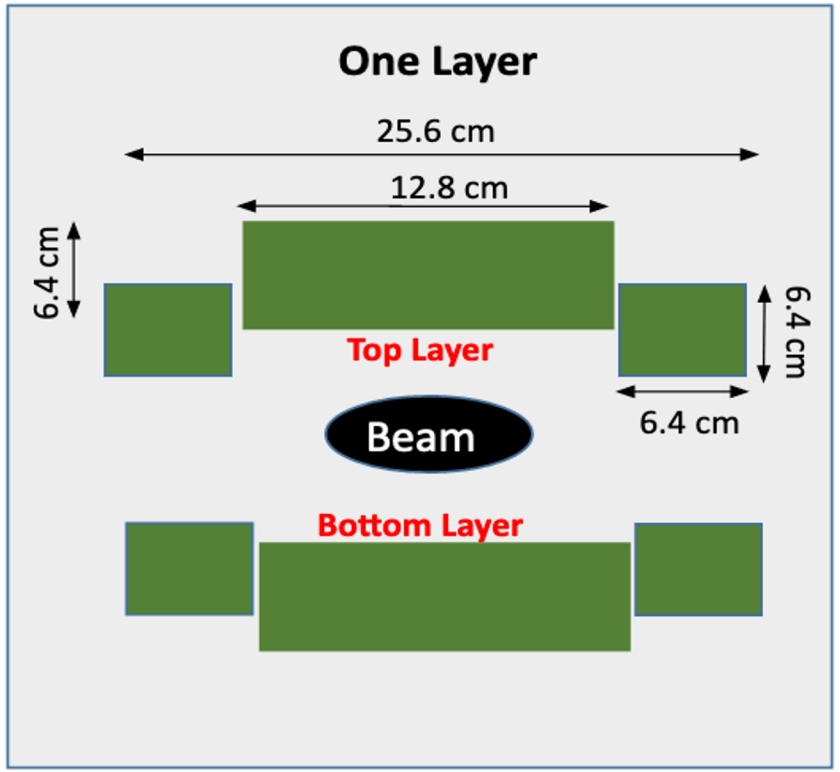
- What technology is ideal here?
  - Need smaller pixels (~50um) than for RP. MAPS? Others?
  - Still need to have timing, so a separate layer.
- Support structure for tracking layers.
  - Some ideas are already in discussion based on STAR Forward Upgrade (silicon tracking).
  - Need to allow removal of detectors in a relatively simply way.
- Preshower, compact EMCAL?
  - We have 1.2 meters of space, maybe a bit less, longitudinally.
  - How small can we really go?

Roman Pots

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

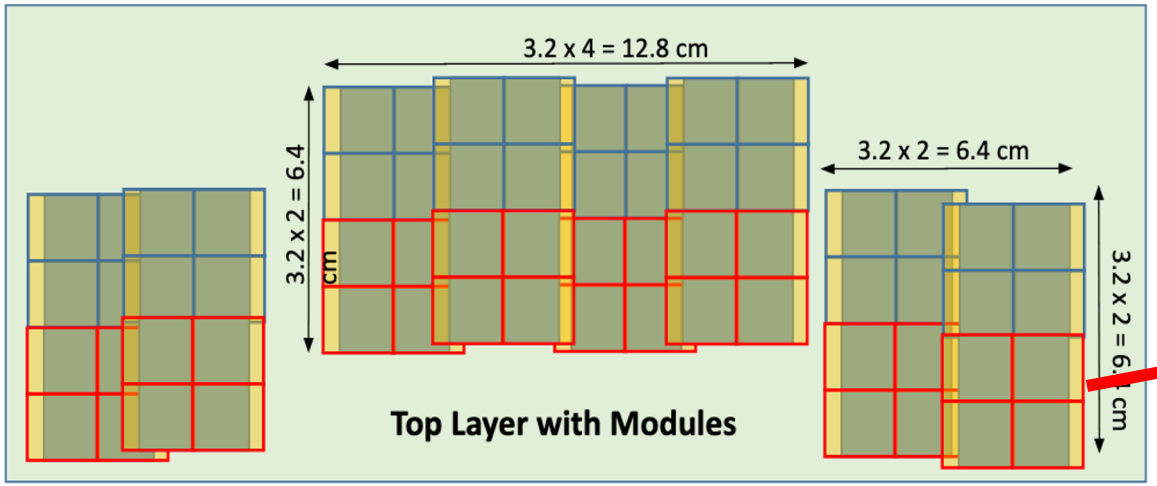


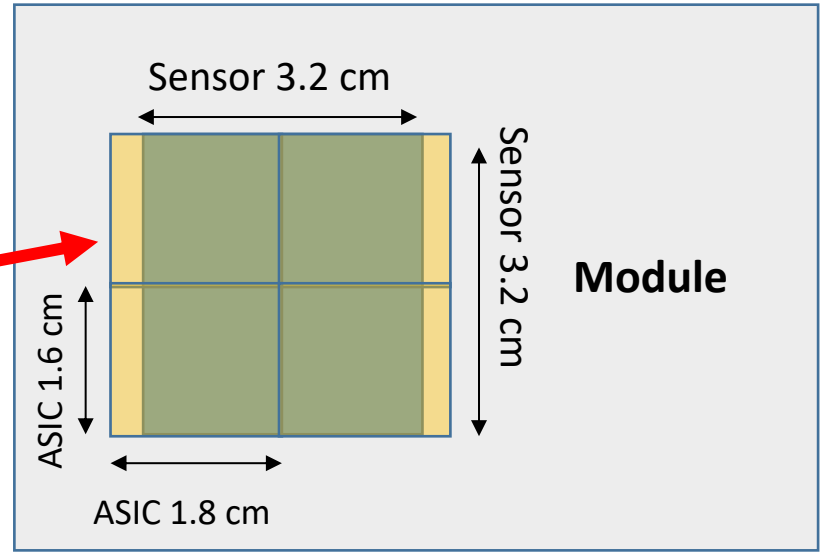




Roman Pots

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





- As further developments are made, more of the realistic considerations can be included in the simulations as we move toward a TDR design.

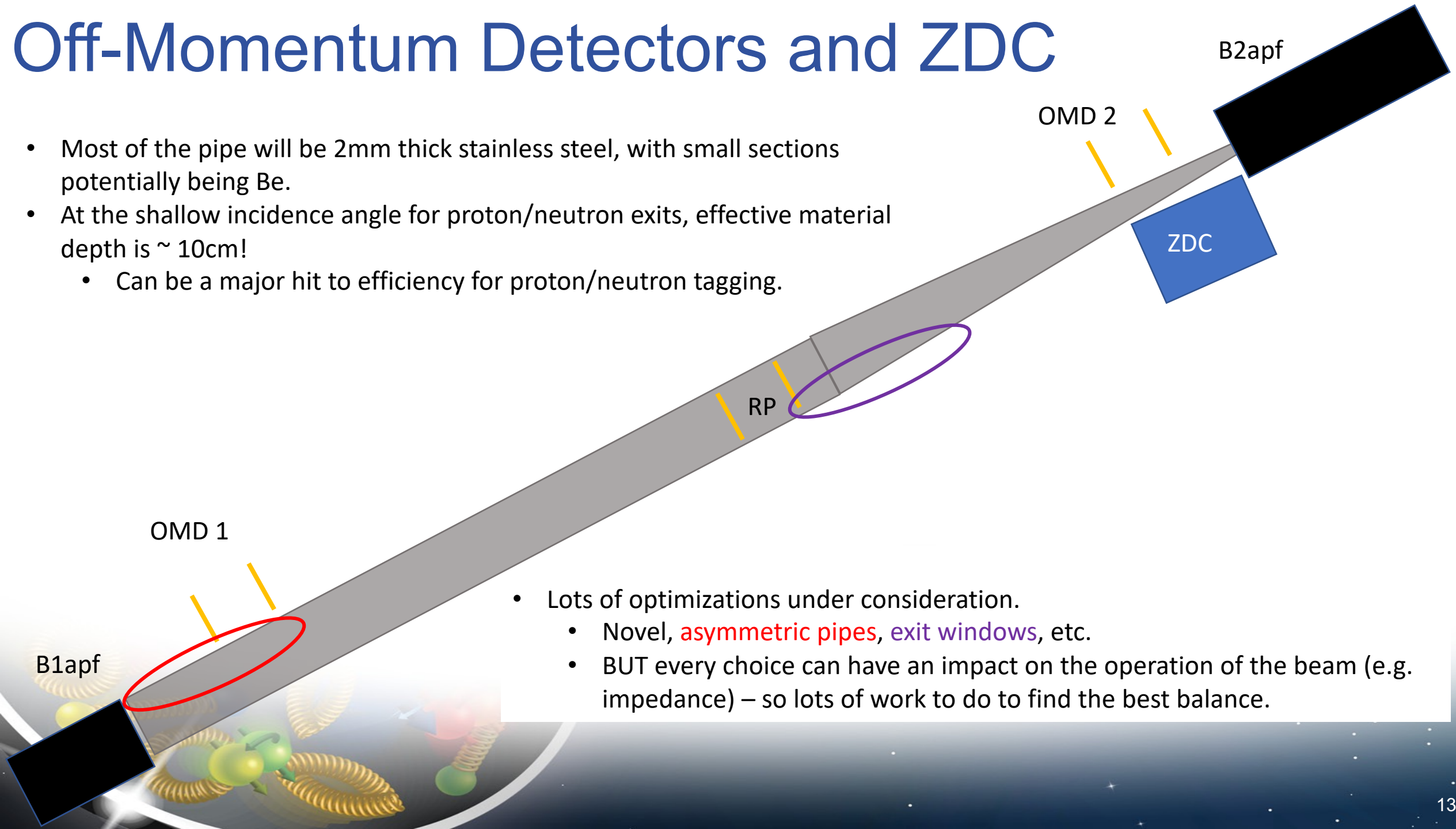
ASIC size	ASIC Pixel pitch	# Ch. per ASIC	# ASICs per module	Sensor area	# Mod. per layer	Total # ASICs	Total # Ch.	Total Si Area
1.6x1.8 cm^2	500 μm	32x32	4	3.2x3.2 cm^2	32	512	524,288	1,311 cm^2

Roman Pots

- Active sensor area very large.
- With AC-LGADS + ALTIROC ASIC, current estimates of power dissipation around 400-500 watts for entire subsystem, so roughly 100 watts/layer.
  - Cooling needs? What if we decide (as we hope) to go with a “pot-less” design? Thermal cooling?
- eRD24 is dedicated to this already, and are working on trying to solve some of the issue currently on the table, but more input is highly appreciated.
- Need to make some estimates of support structure and insertion tooling – at least to judge possible impact on other things (e.g. tagging neutrons and photons in the ZDC – will the RP infrastructure potentially be in the way?).

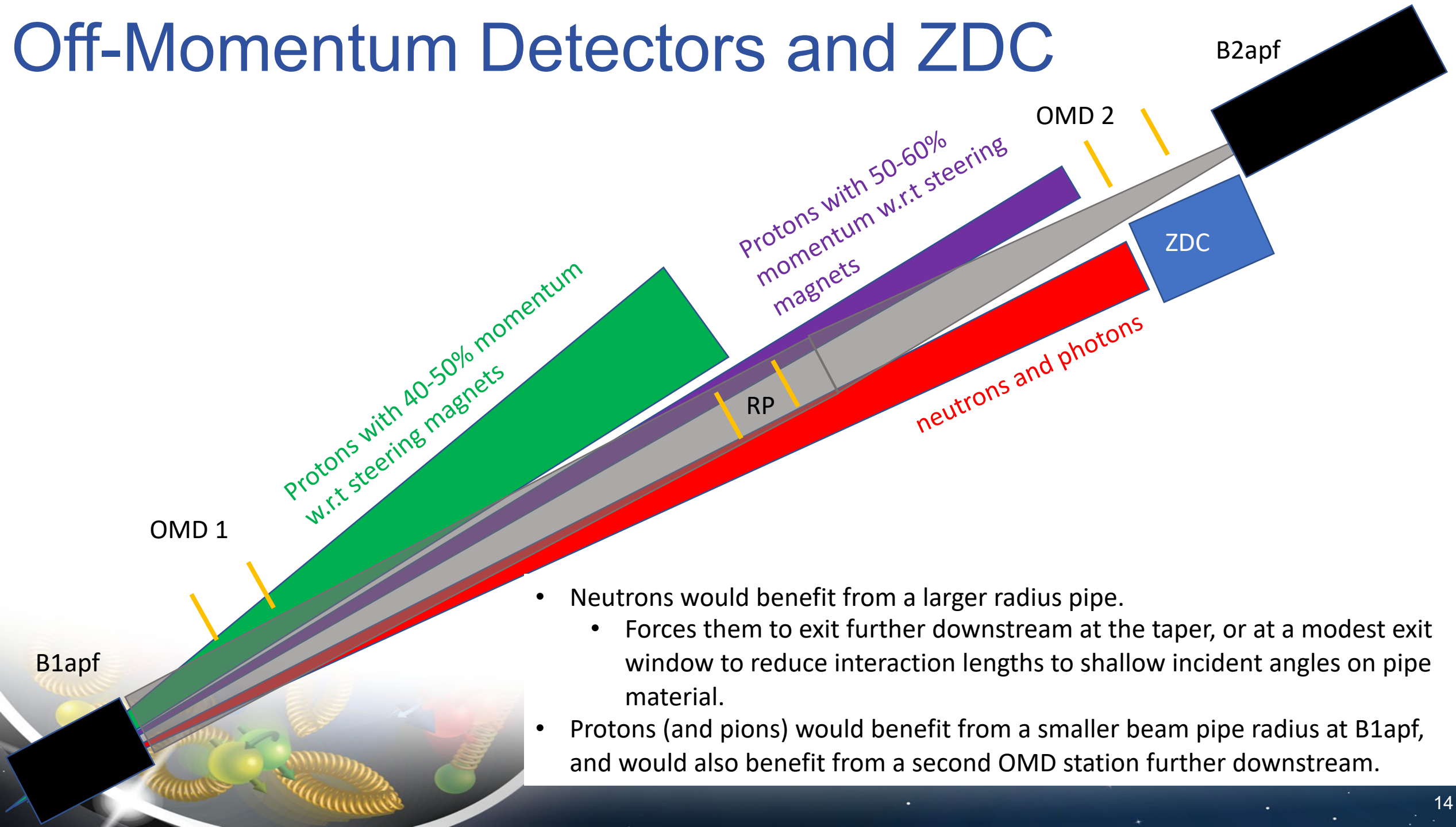
Off-Momentum Detectors and ZDC

- Most of the pipe will be 2mm thick stainless steel, with small sections potentially being Be.
- At the shallow incidence angle for proton/neutron exits, effective material depth is ~ 10cm!
  - Can be a major hit to efficiency for proton/neutron tagging.



- Lots of optimizations under consideration.
  - Novel, asymmetric pipes, exit windows, etc.
  - BUT every choice can have an impact on the operation of the beam (e.g. impedance) – so lots of work to do to find the best balance.

Off-Momentum Detectors and ZDC



- Neutrons would benefit from a larger radius pipe.
  - Forces them to exit further downstream at the taper, or at a modest exit window to reduce interaction lengths to shallow incident angles on pipe material.
- Protons (and pions) would benefit from a smaller beam pipe radius at B1apf, and would also benefit from a second OMD station further downstream.

Takeaways

- Basic detector requirements fairly well-understood and established.
  - Two EIC R&D projects dedicated to the EIC FF region (eRD24 – Roman Pots; eRD27 – ZDC).
  - But, input on other options would be appreciated!
- More work needed on beam pipe design + integration + performance impacts.
- B0 needs work to finalize required support structure, best technology choices, and potential for preshower/compact EMCAL.
- Work needs to be done to understand services, support, cooling, etc. for all subsystems.
- Not every detail can or will be solved in the proposal timeline – the goal here is to be as detailed as we can be, and make reasonable, conservative estimates where required to reflect the challenges (and associated costs) accurately.
- Need to identify key channels to re-simulate in the full EIC@IP6 detector simulations.
  - e+p DVCS, spectator tagging with light nuclei, etc.
  - Luckily, small event samples (< 1M events) will be sufficient for most studies.