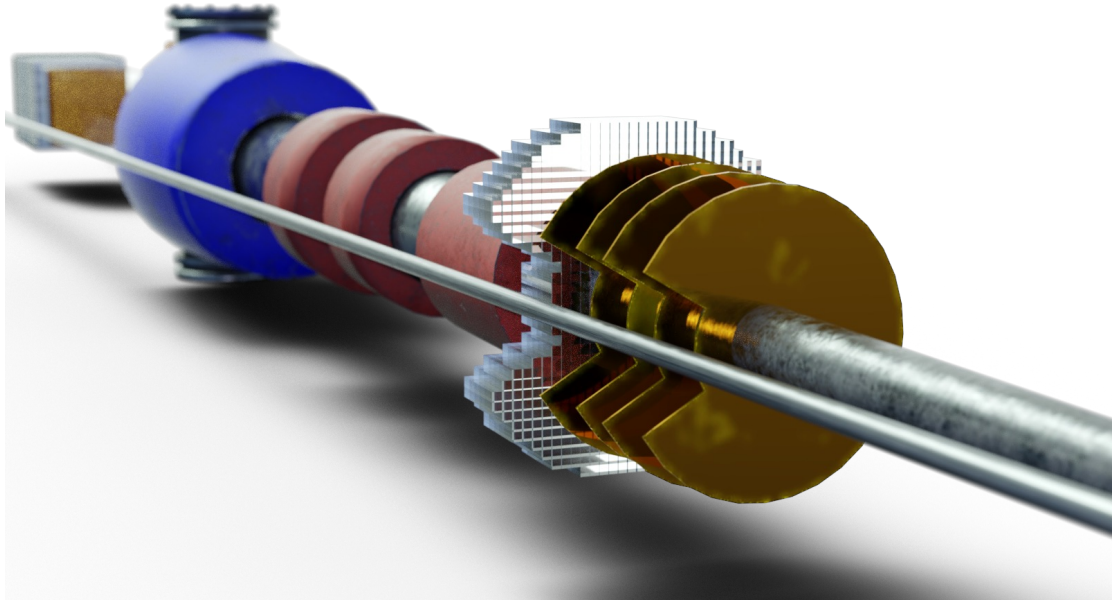


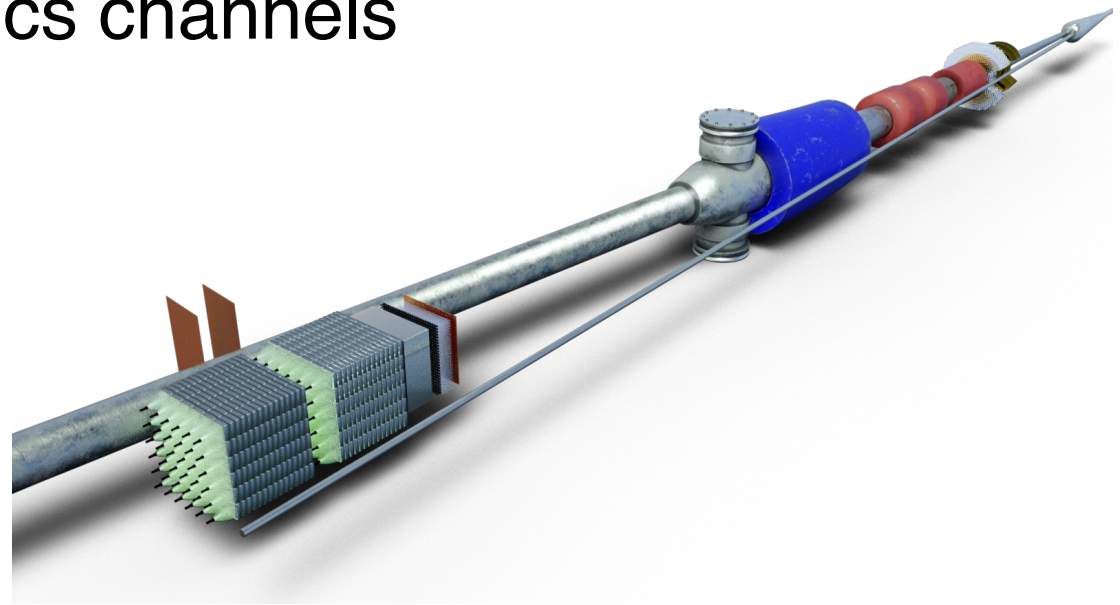
EicC Far Forward (FF) Detector

- Yutie Liang, Aiqiang Guo, Ting Lin and Weizhi Xiong

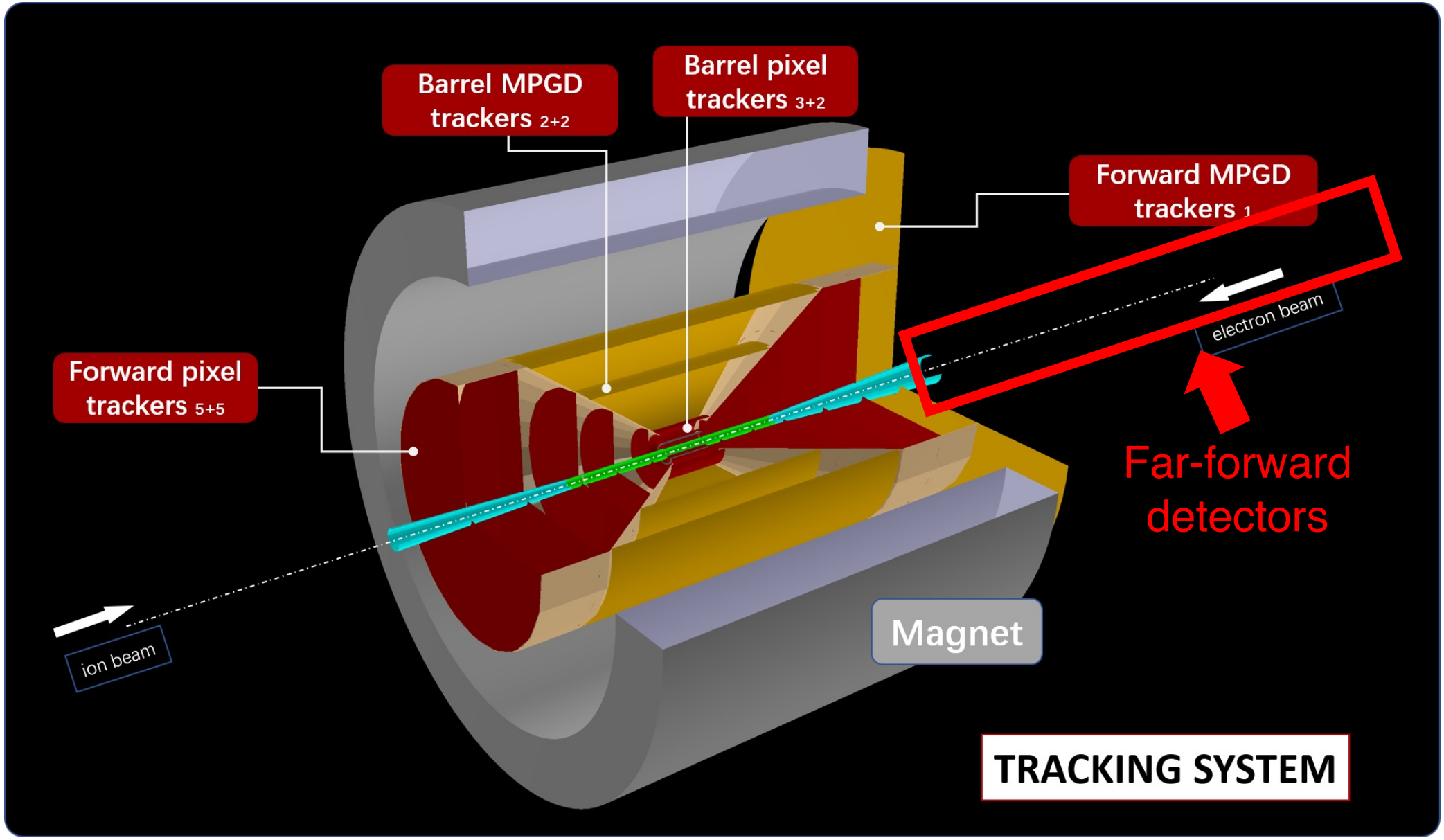
- Workshop on near-threshold J/ψ photoproduction
- Feb. 19th – 23rd 2024

Outline

- Overview of Far-Forward detector and related physics
- Current Design and Kinematic Coverage of EicC-FF
- Performance for selected physics channels
- Summary

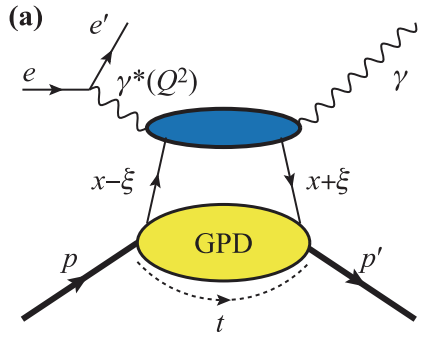


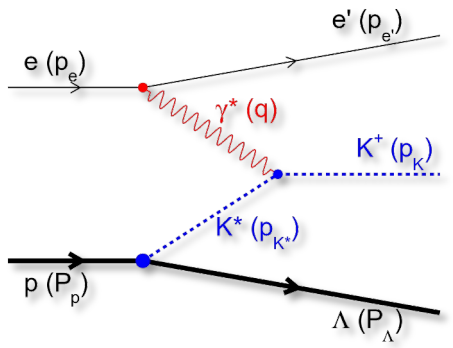
EicC Far Forward Detectors

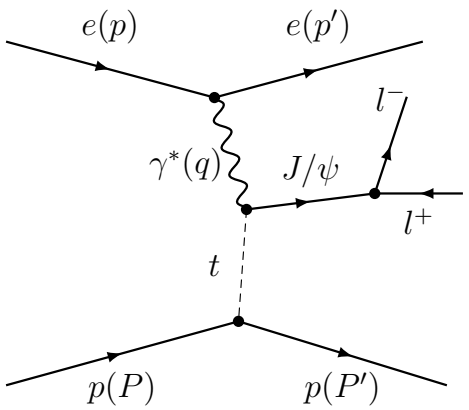


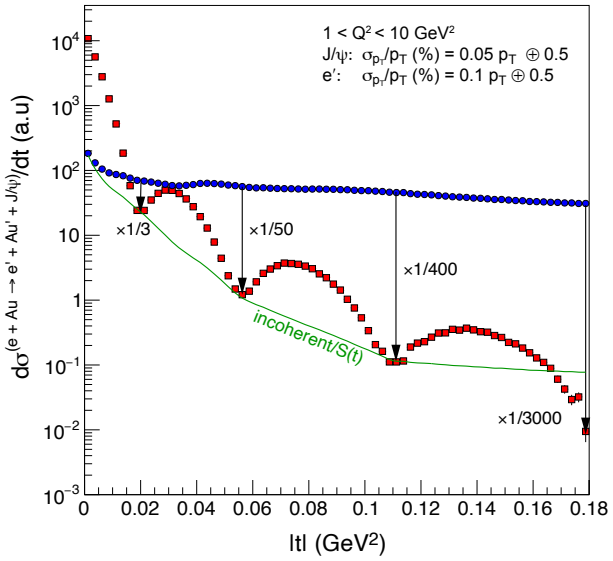
Related Physics for Far Forward Detectors

- Deeply virtual Compton scattering (DVCS)
- Exotic states: X 3872, Zc 3900…
- Meson form factor, structure functions, GPD…
- Diffractive measurements
- Spectator tagging for tagged DIS, SIDIS, SRC…
- J/ψ production near threshold
- …

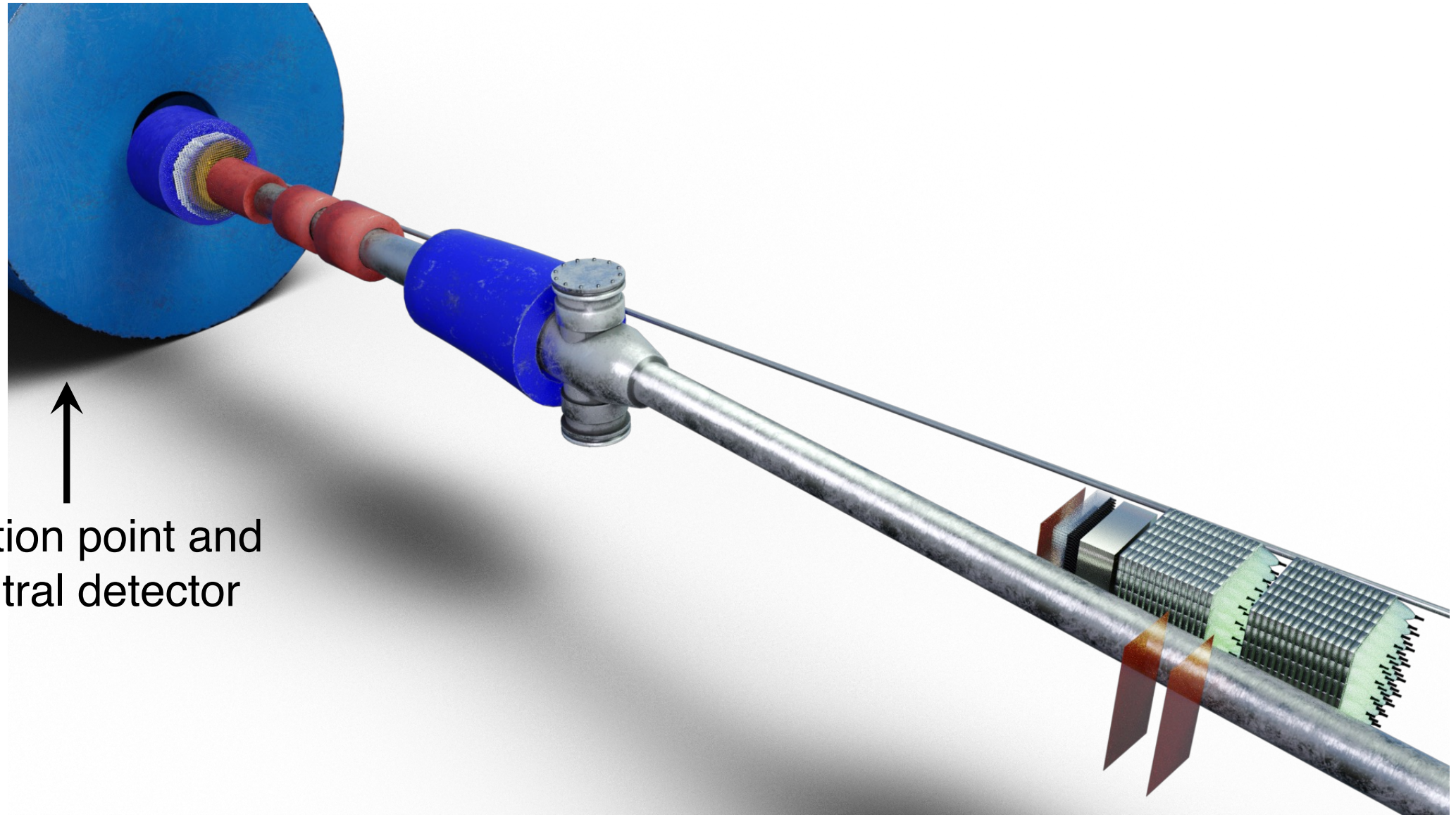




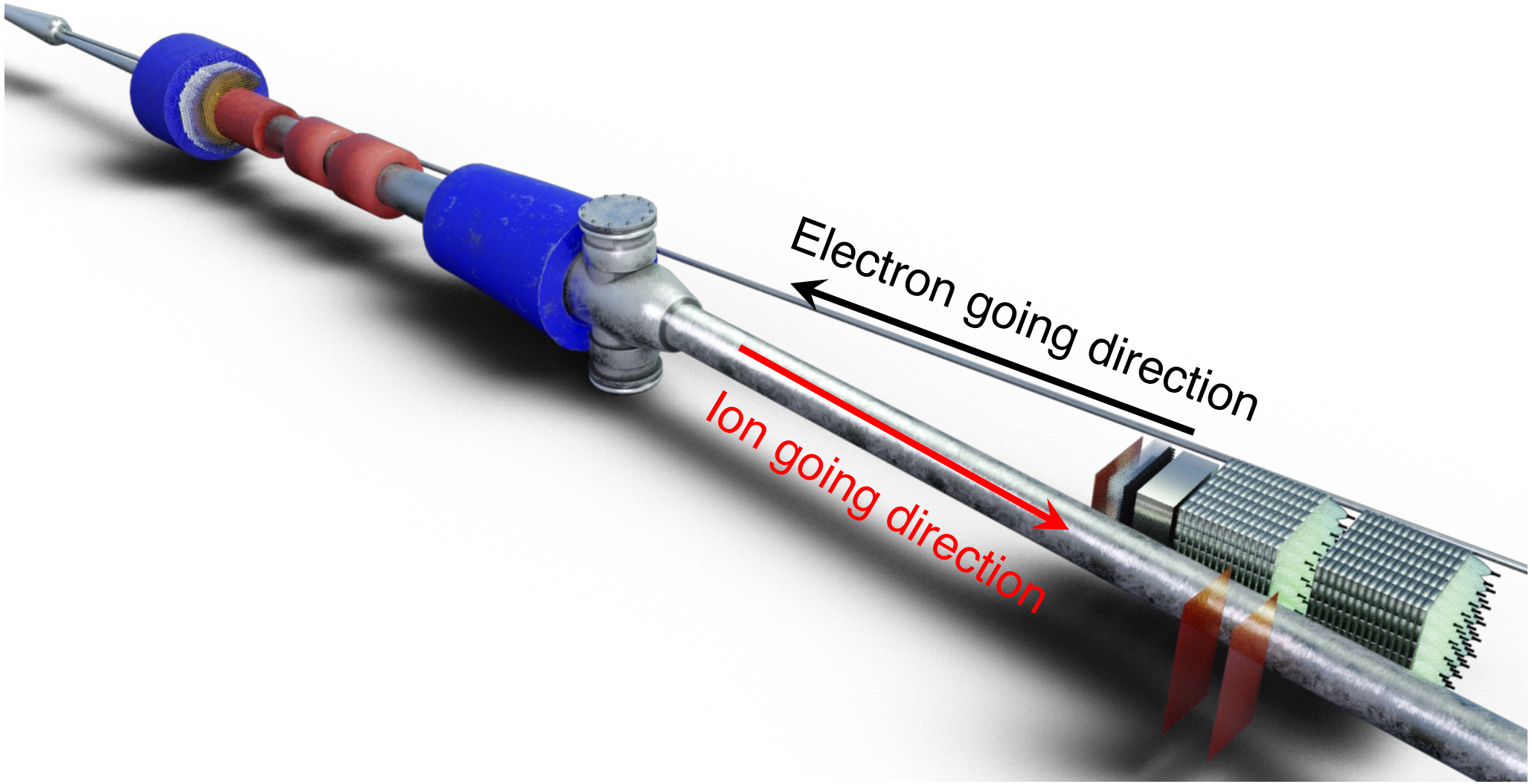




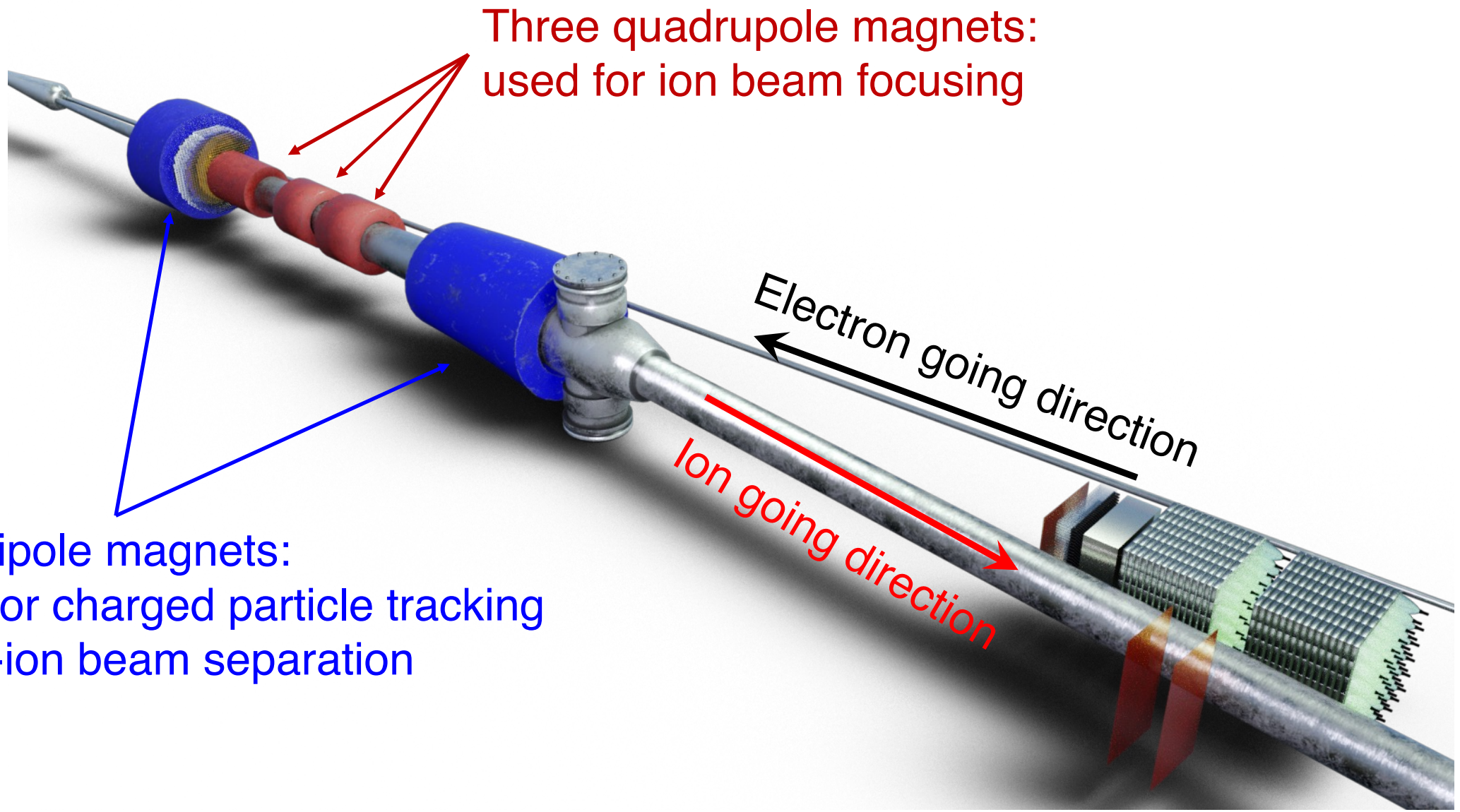
Current Design for EicC Far-Forward (FF) Region



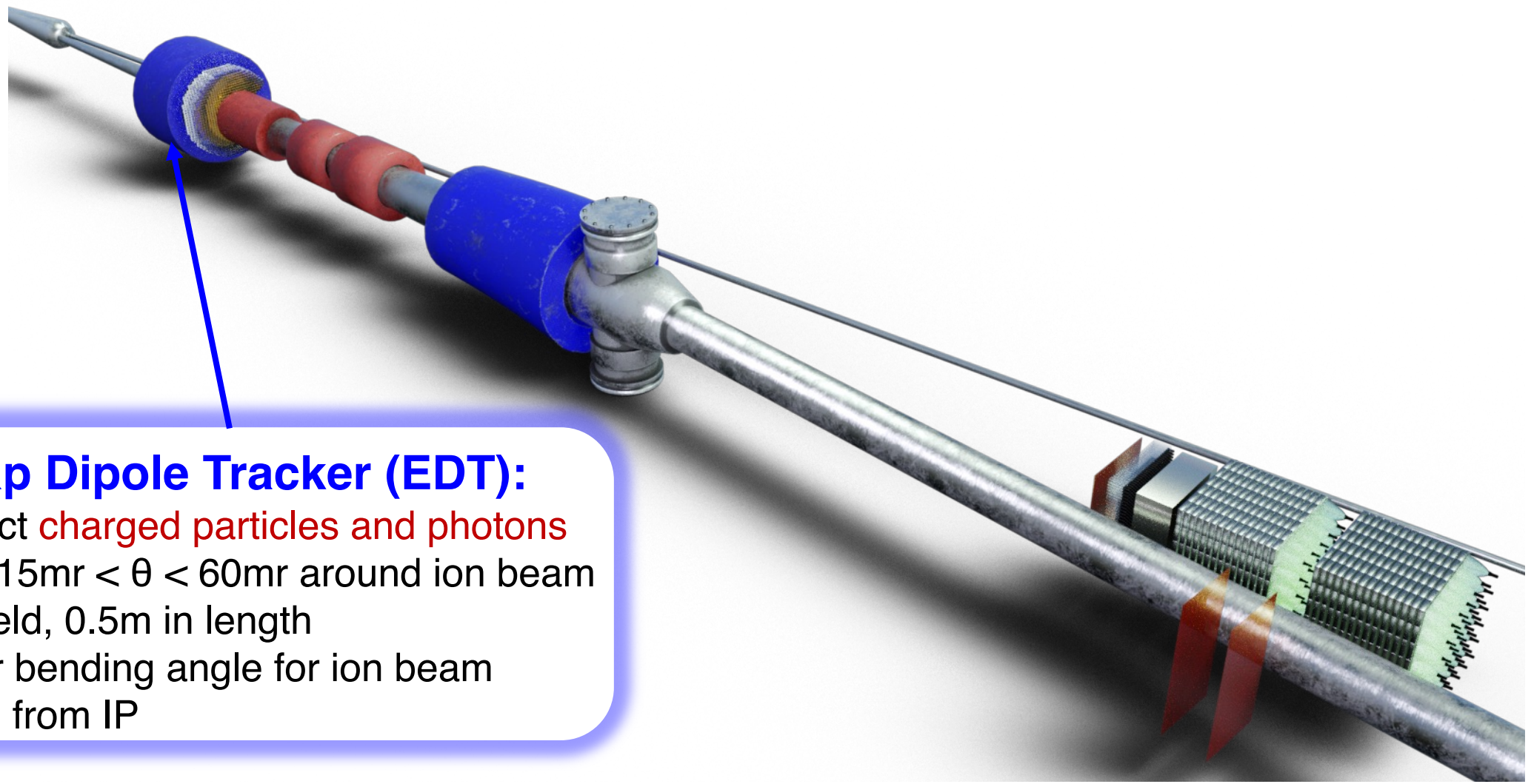
Current Design for EicC Far-Forward (FF) Region



Current Design for EicC Far-Forward (FF) Region



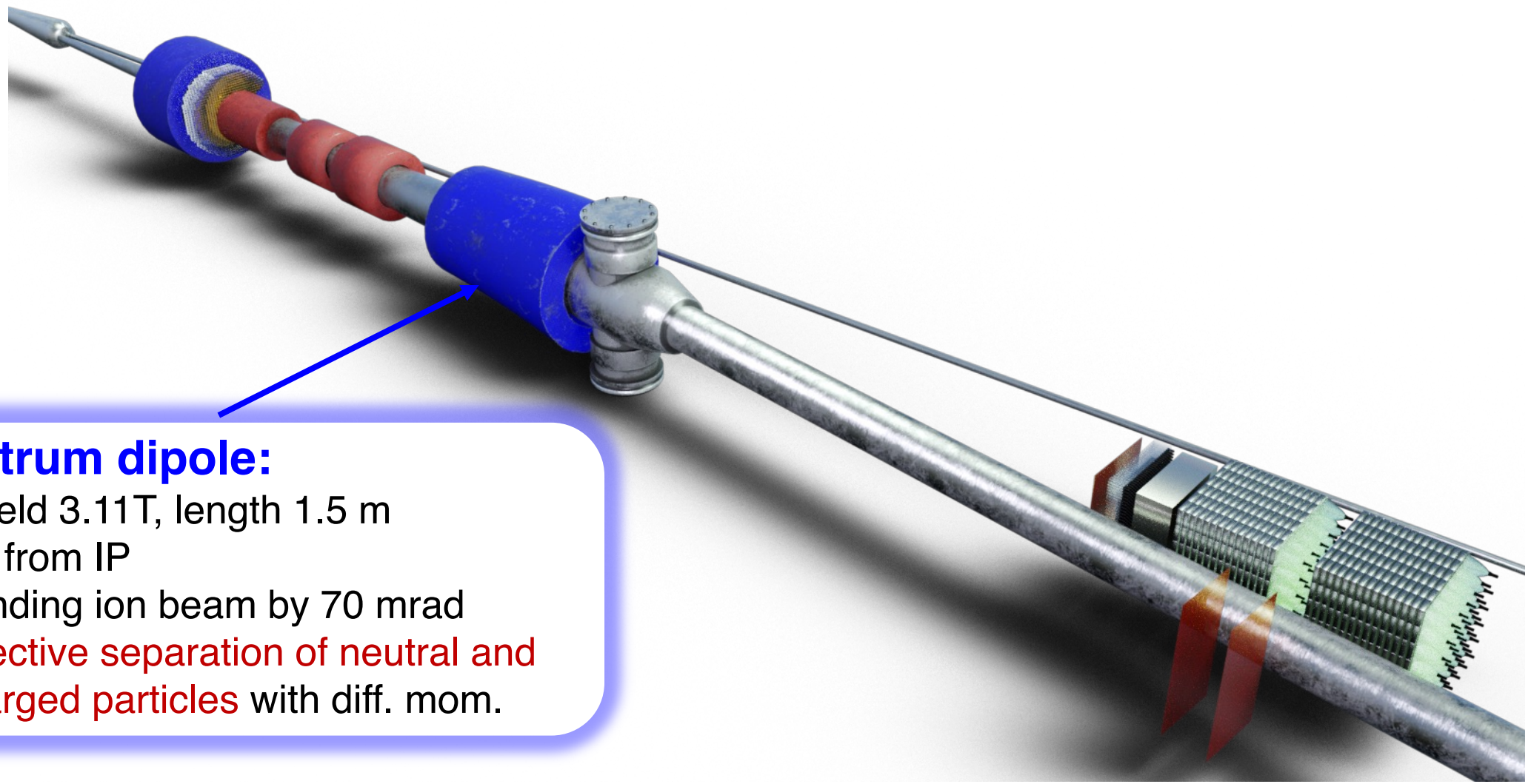
Current Design for EicC Far-Forward (FF) Region



Endcap Dipole Tracker (EDT):

- Detect charged particles and photons with $15mr < \theta < 60mr$ around ion beam
- 2T field, 0.5m in length
- 15mr bending angle for ion beam
- 4.8m from IP

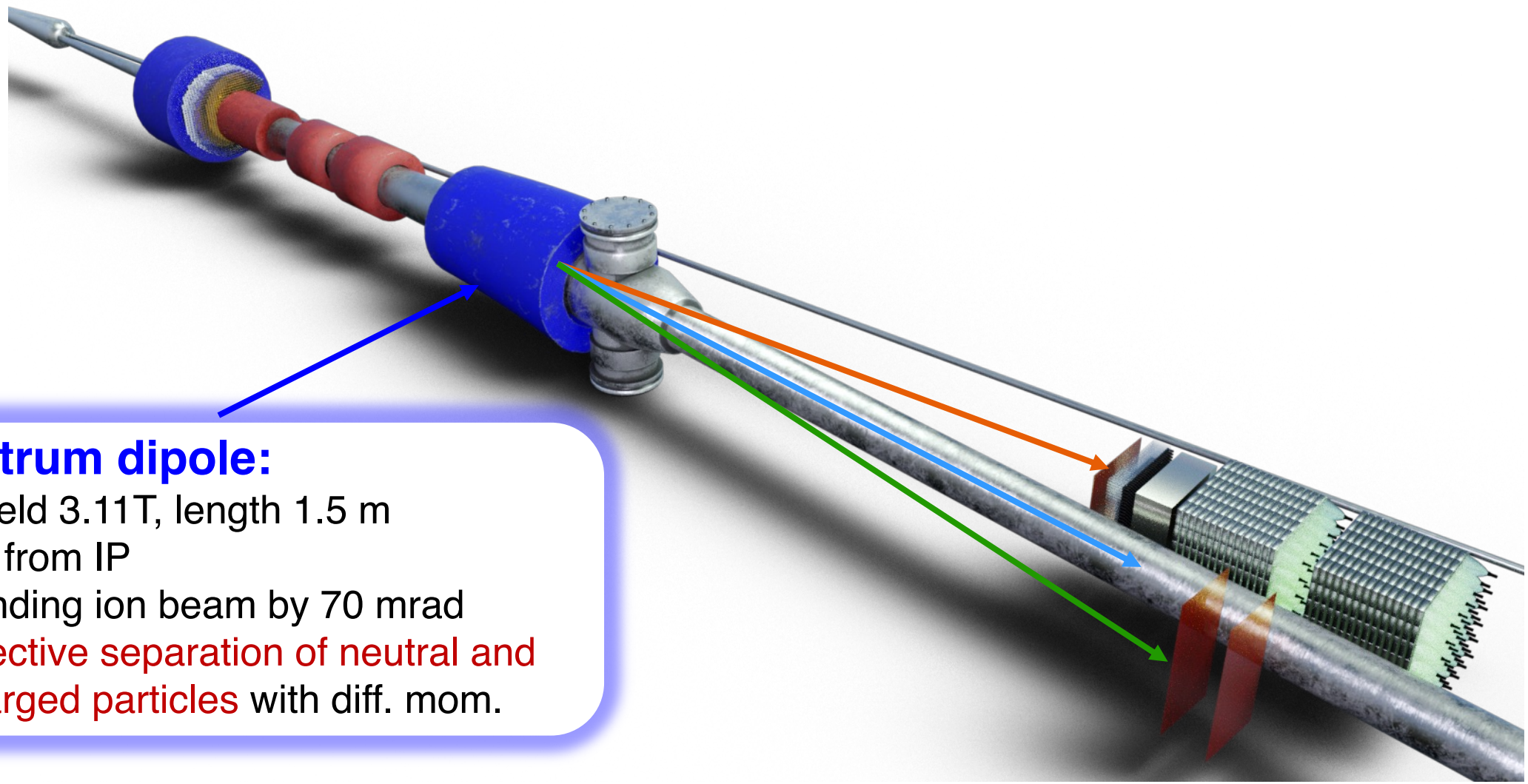
Current Design for EicC Far-Forward (FF) Region



Spectrum dipole:

- B field 3.11T, length 1.5 m
- 9m from IP
- Bending ion beam by 70 mrad
- Effective separation of neutral and charged particles with diff. mom.

Current Design for EicC Far-Forward (FF) Region



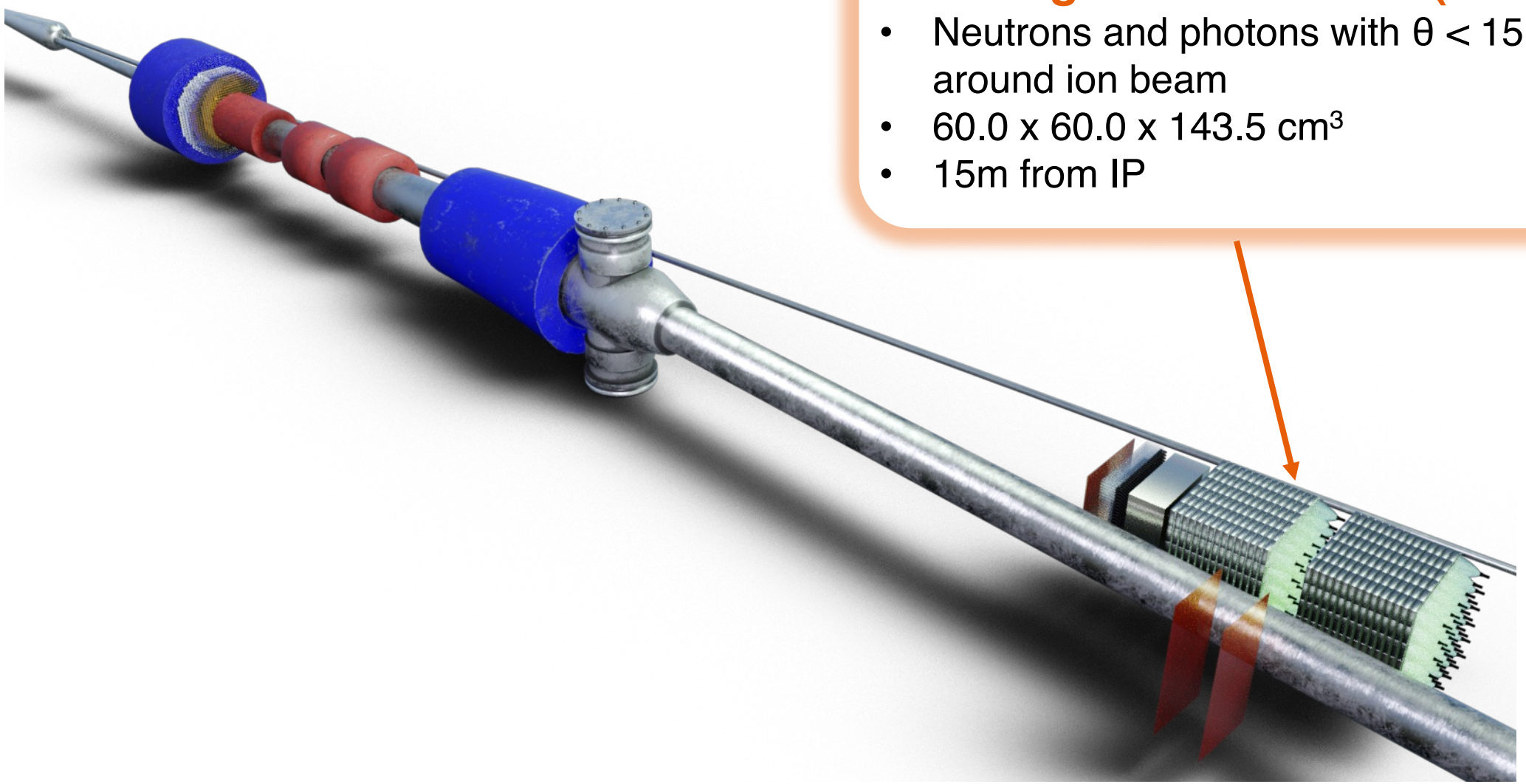
Spectrum dipole:

- B field 3.11T, length 1.5 m
- 9m from IP
- Bending ion beam by 70 mrad
- Effective separation of neutral and charged particles with diff. mom.

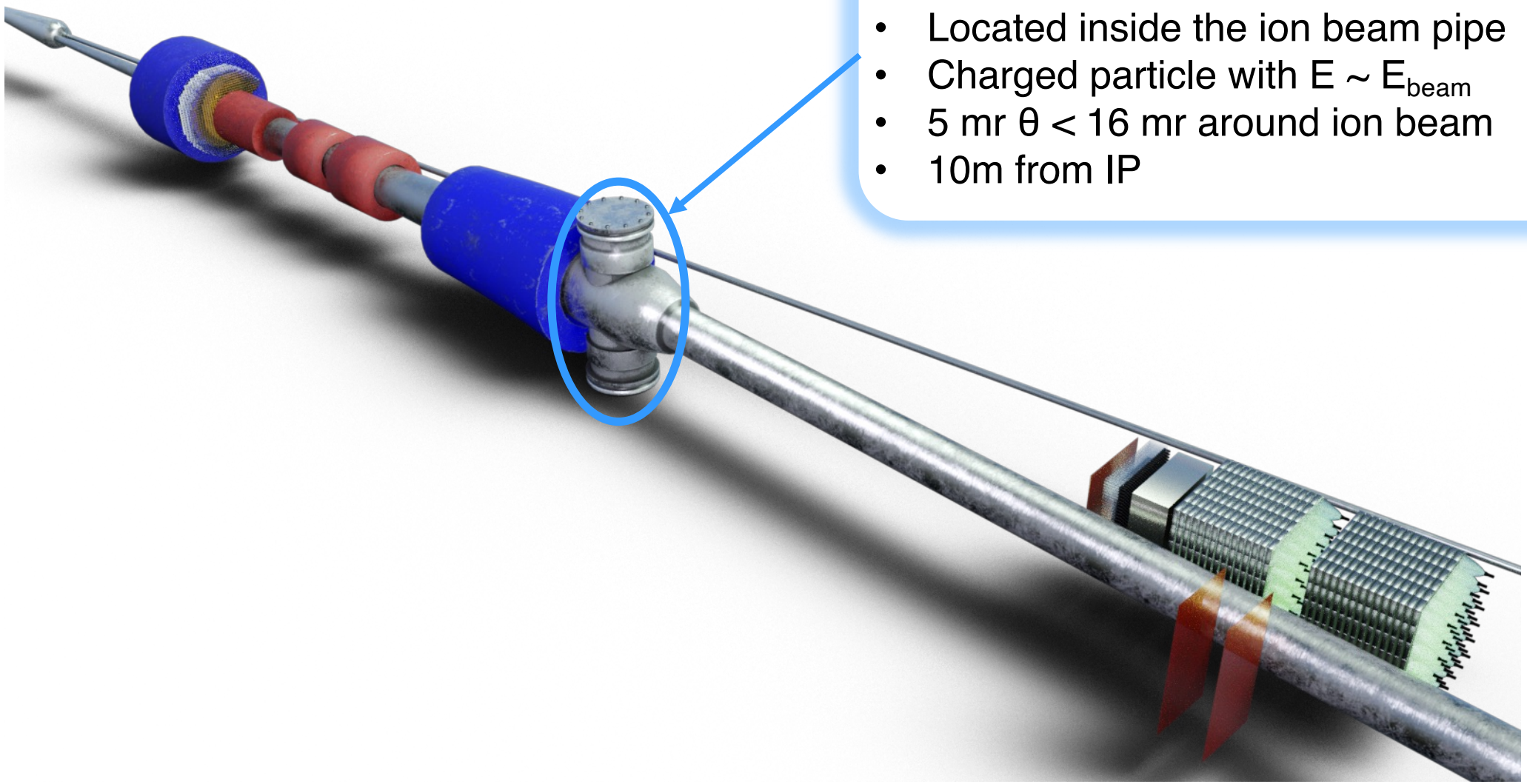
Current Design for EicC Far-Forward (FF) Region

Zero degree calorimeter (ZDC):

- Neutrons and photons with $\theta < 15$ mr around ion beam
- 60.0 x 60.0 x 143.5 cm^3
- 15m from IP



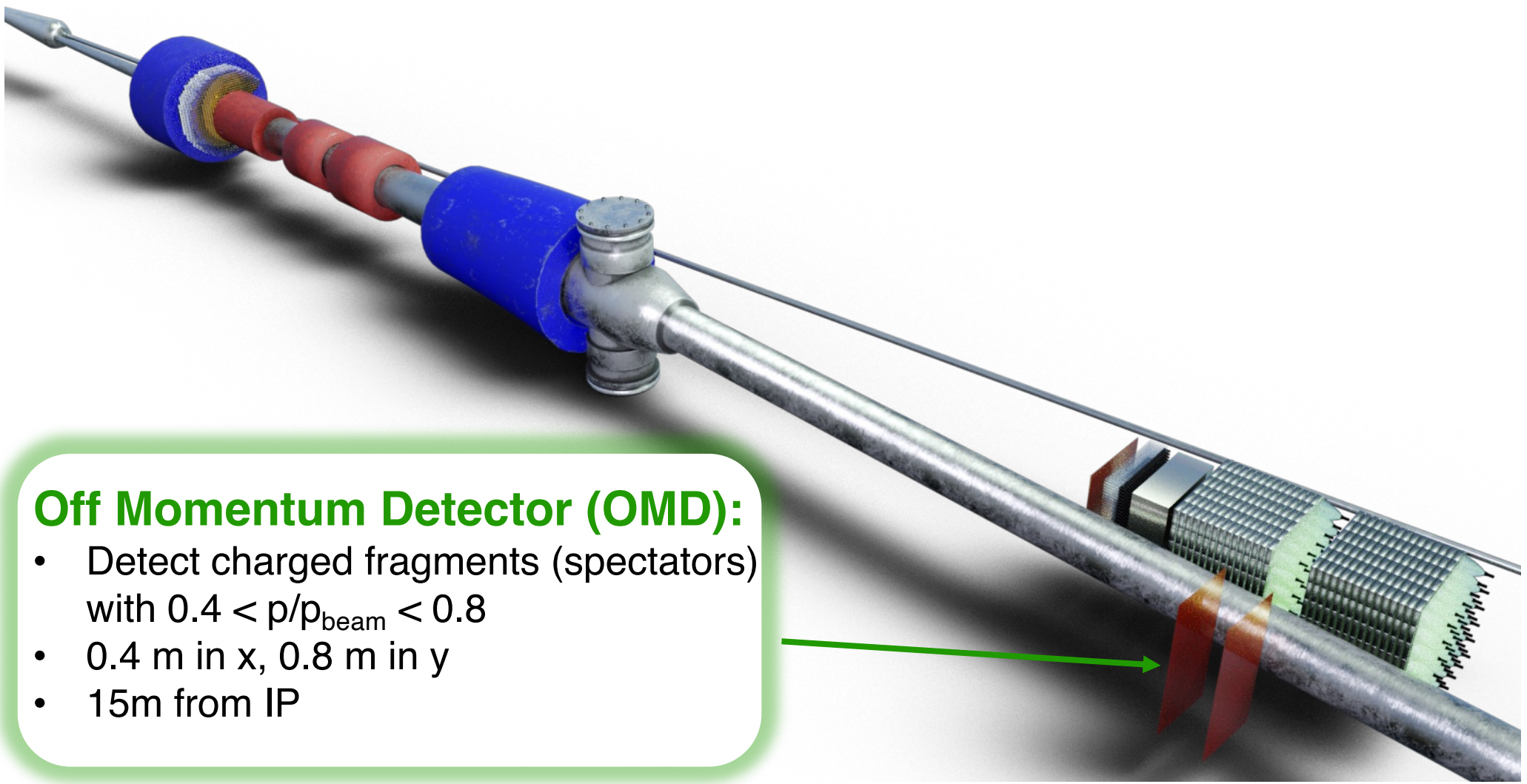
Current Design for EicC Far-Forward (FF) Region



Roman Pot Station:

- Located inside the ion beam pipe
- Charged particle with $E \sim E_{beam}$
- 5 mr θ < 16 mr around ion beam
- 10m from IP

Current Design for EicC Far-Forward (FF) Region

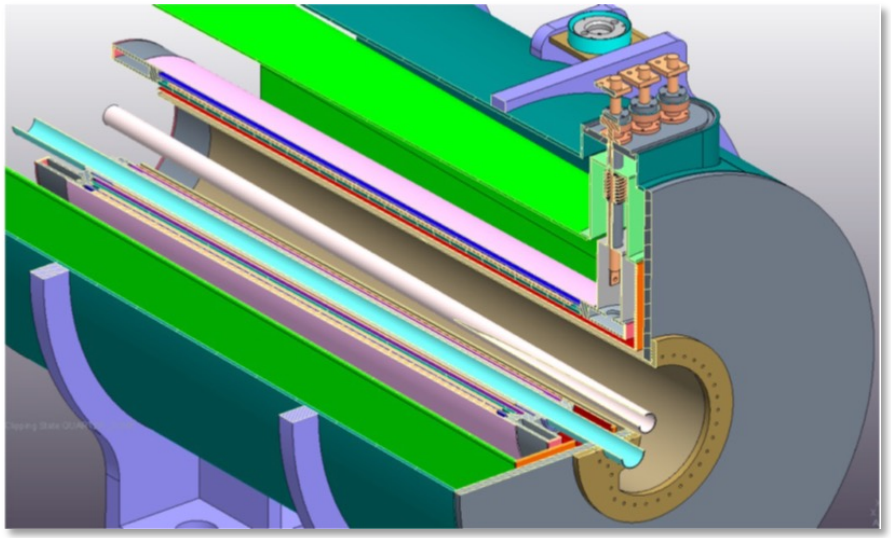


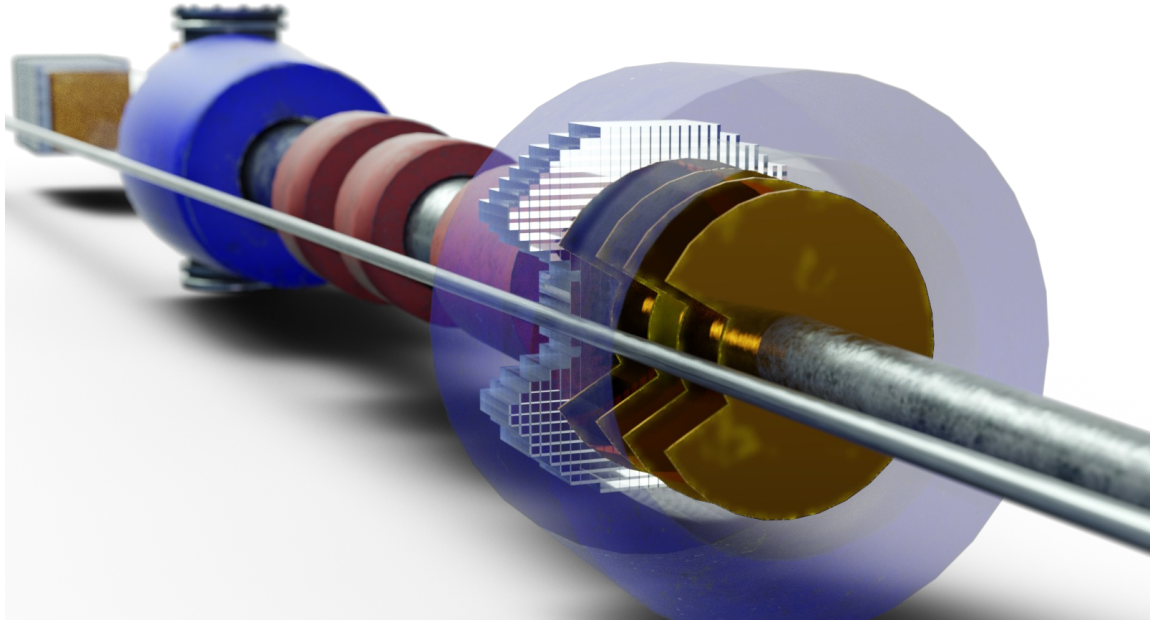
Off Momentum Detector (OMD):

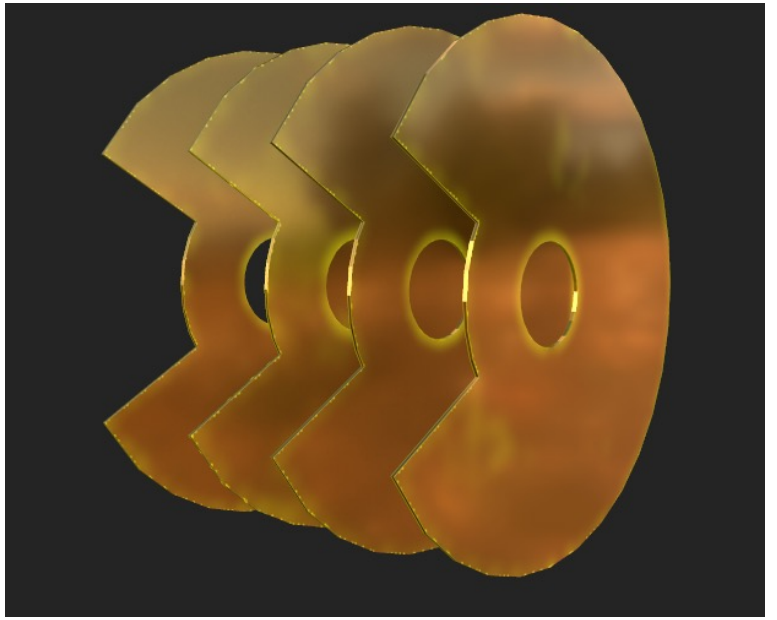
- Detect charged fragments (spectators) with $0.4 < p/p_{beam} < 0.8$
- 0.4 m in x, 0.8 m in y
- 15m from IP

Endcap Dipole Trackers (EDT)

- Four silicon trackers (MAPS, AC-LGAD)
- Charged particle tracking in 16 mr < θ < 60 mr
- Full ϕ coverage for θ < 35 mr
- Require gaps for θ > 35 mr and -30^o < ϕ < 30^o to allow electron beam pass through

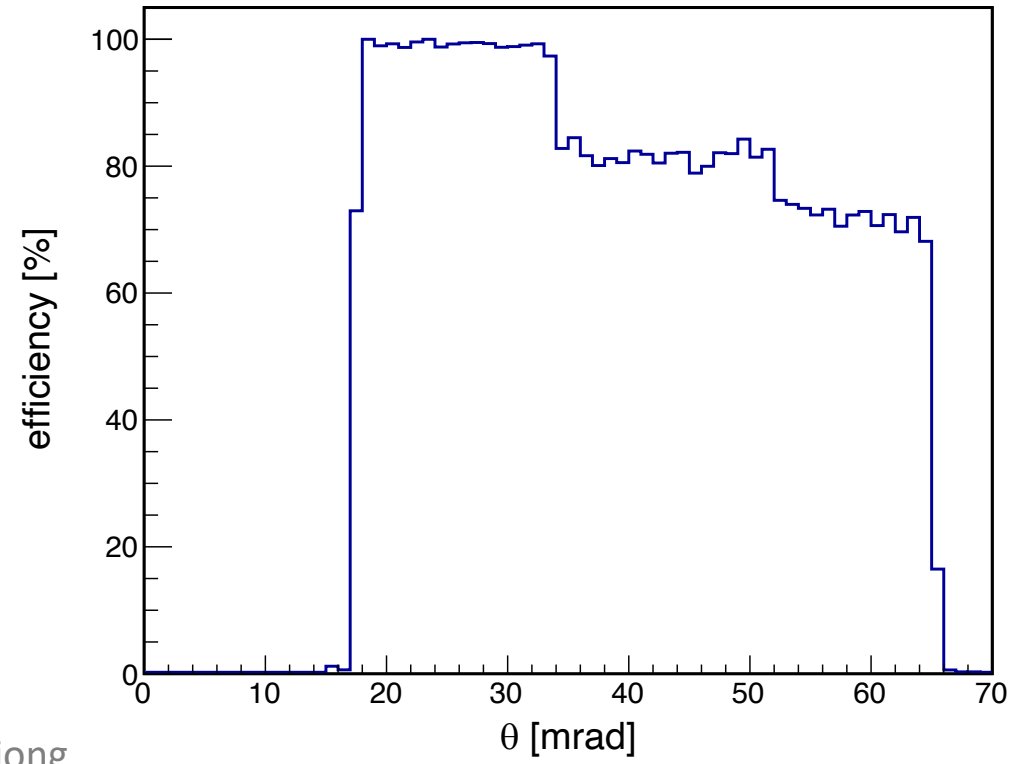


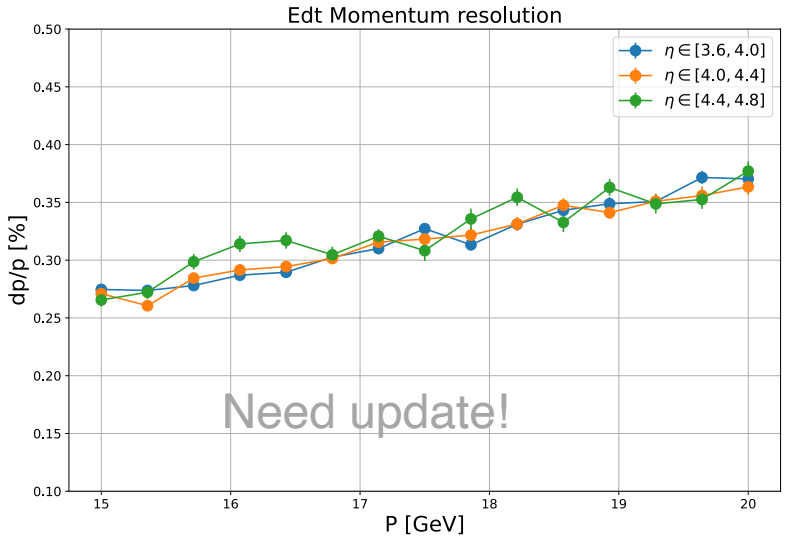


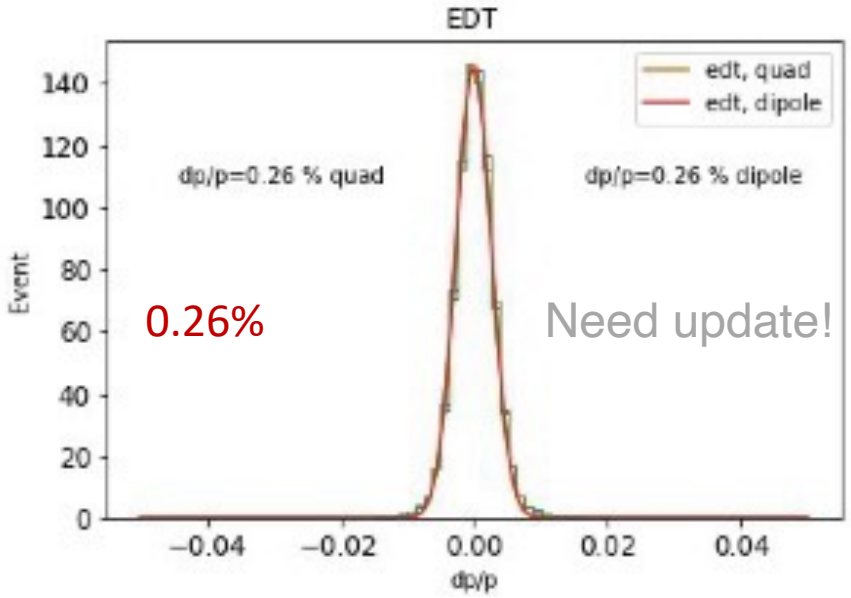


Endcap Dipole Trackers (EDT)

- Acc. and recon. by Y. Liang & A. Guo
- Resolution outdated, need to update (reduced EDT dipole field by 50% recently)

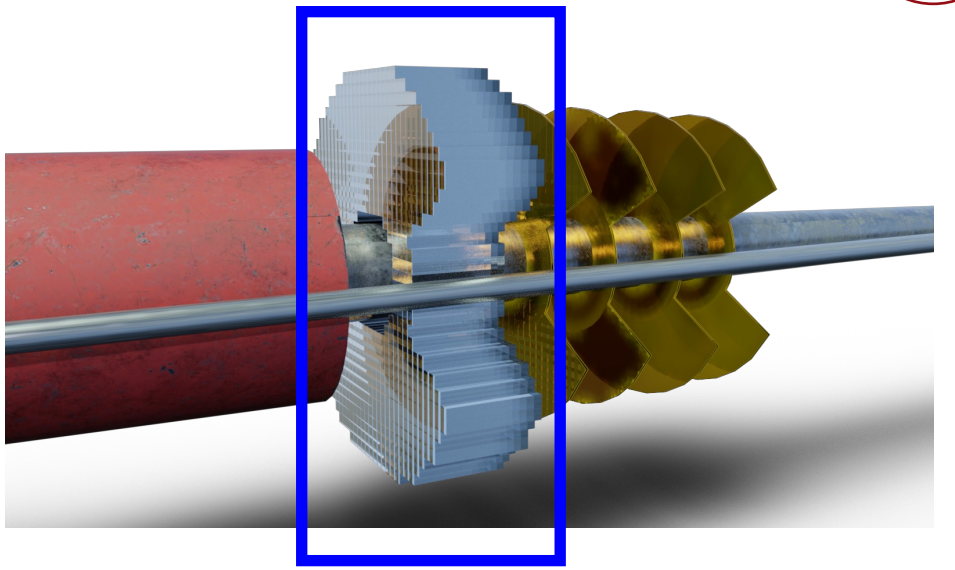




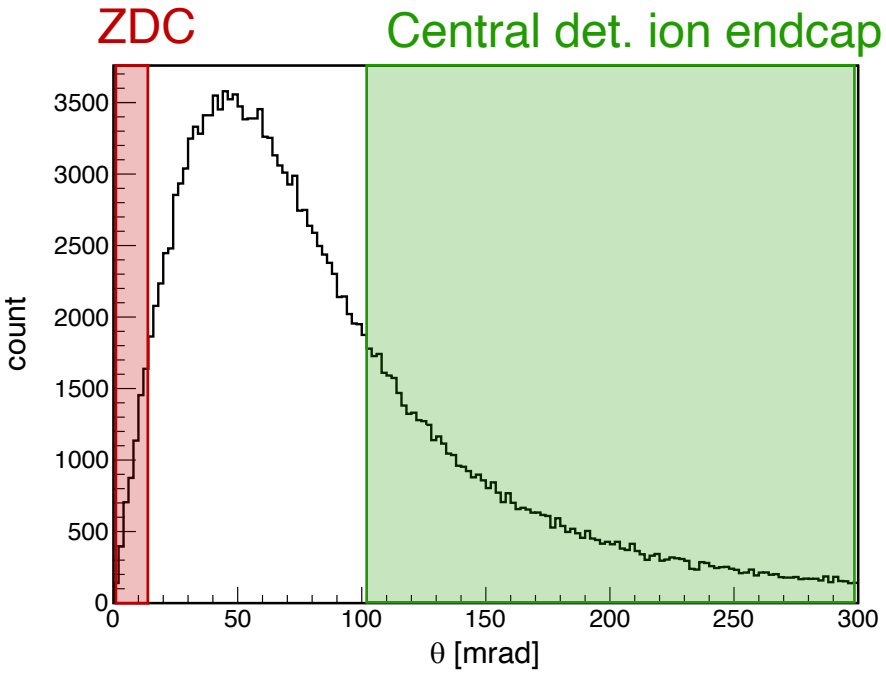


Endcap Dipole Trackers (EDT)

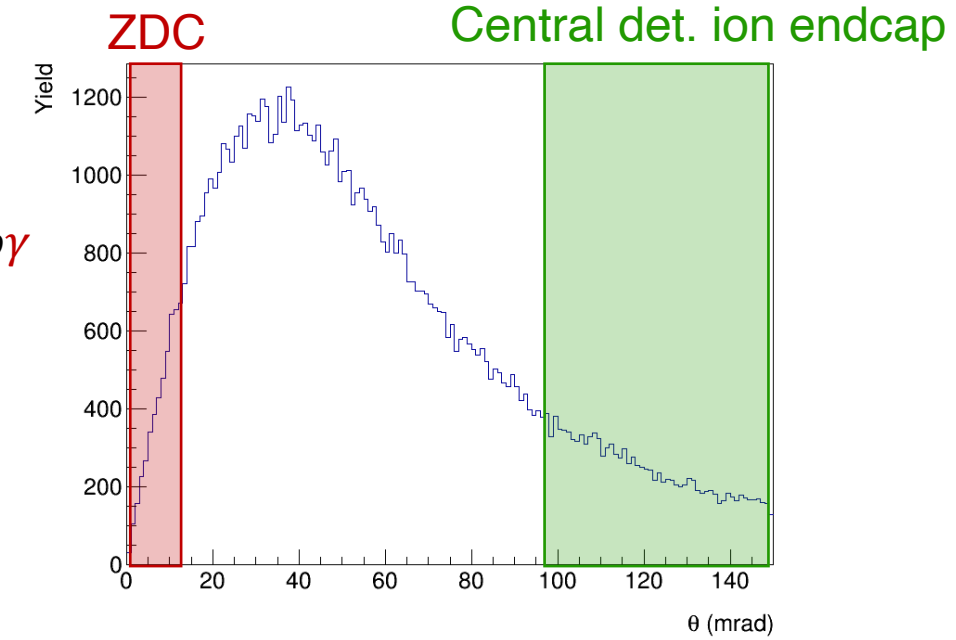
- Motivation: many meson decay photons peak in this range
- Need compact EM calorimeter (only ~30cm available space in z due to quad. magnets)
- Reasonable candidate: $PbWO_4$
- Acceptance: 20 mr < θ < 60 mr



$ep \to e\Lambda K^+$
$\Lambda \to n\pi^0$
$\pi^0 \to \gamma\gamma$

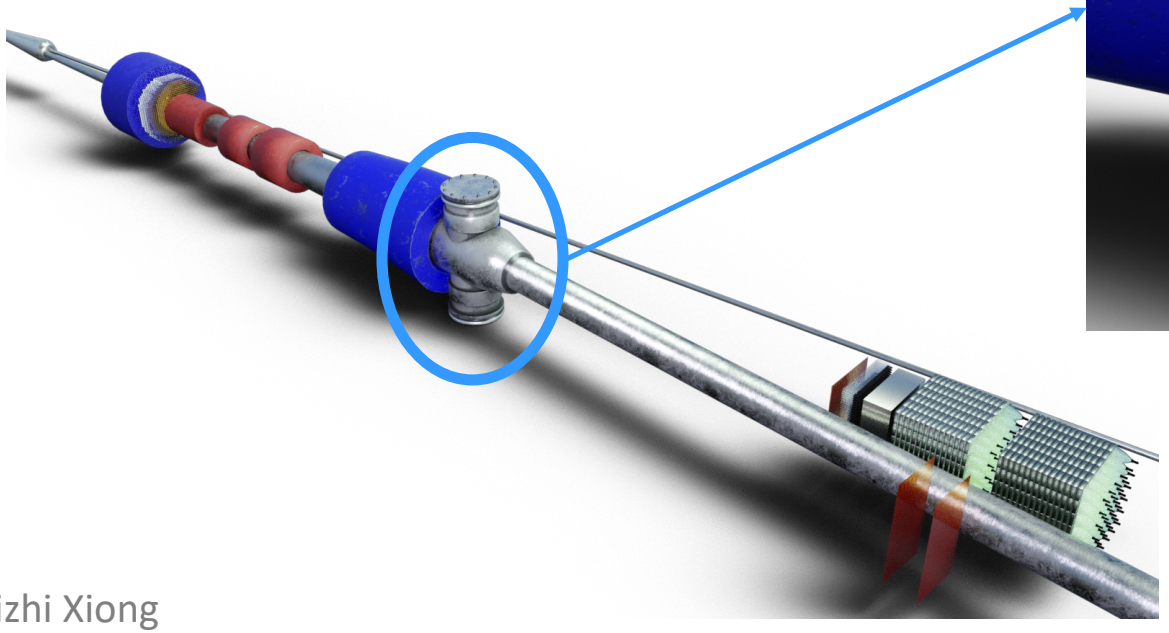


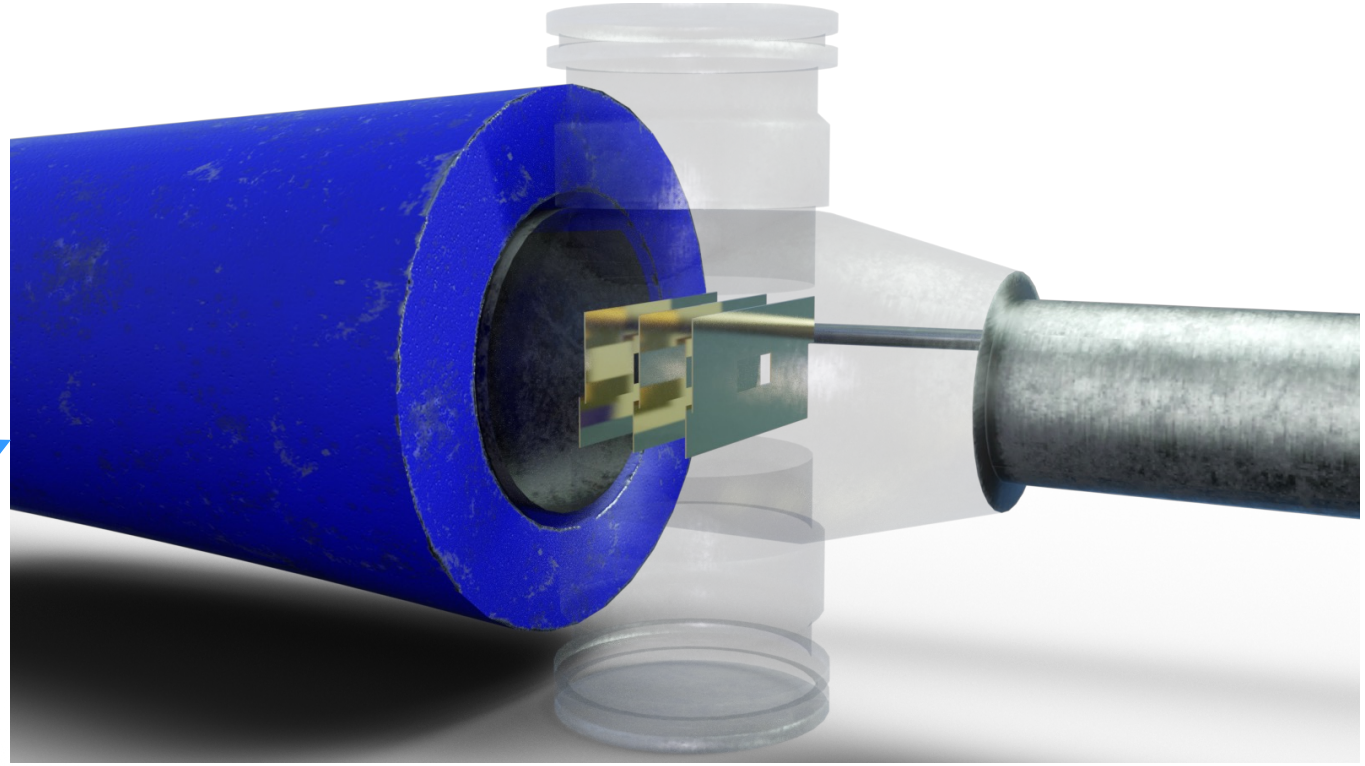
$ep \to ep\rho\gamma$
$\rho \to \gamma\gamma$



Roman Pot Station (RPS)

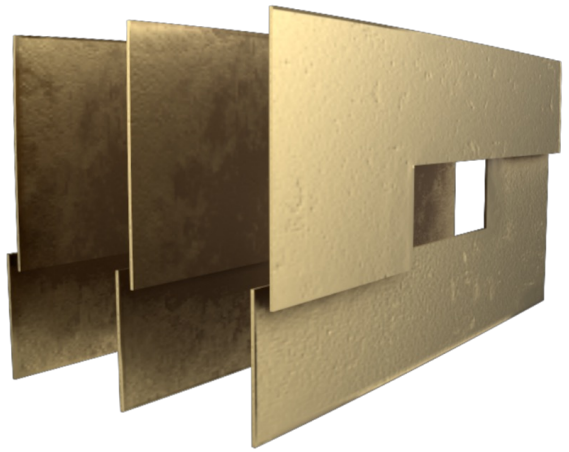
- Roman pot station: 2-3 silicon trackers (MAPS + AC-LGAD) placed inside the ion beam pipe
- Small holes in the middie to allow ion beam passes through
- Each tracker made of two movable L-shape planes, making the hole size tunable



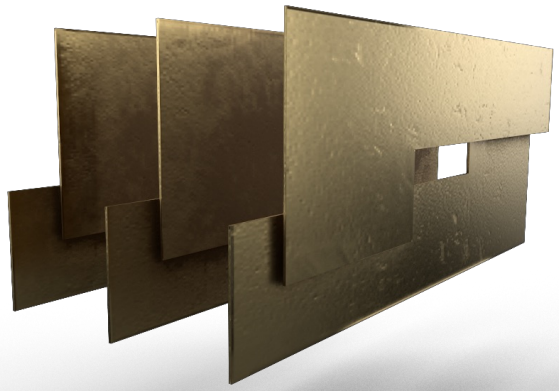


Roman Pot Station (RPS)

High lumi. configuration



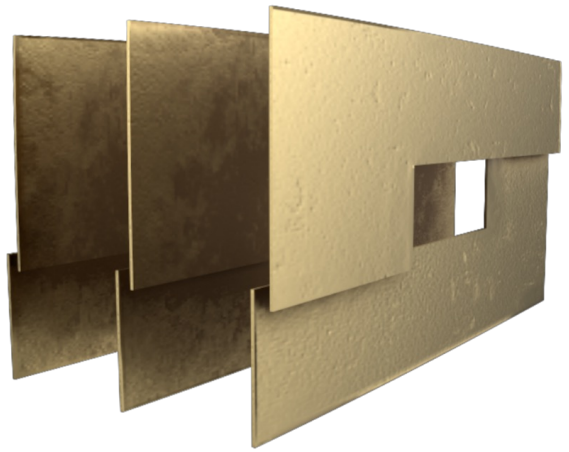
Low lumi. configuration



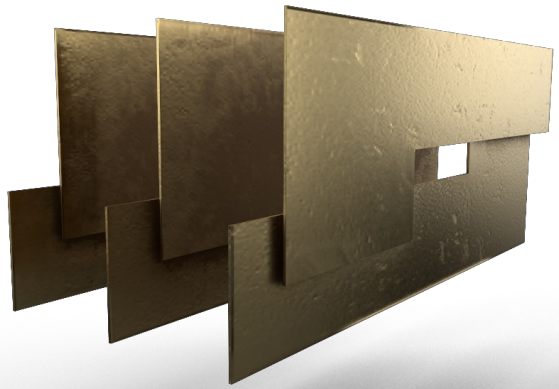
- With EicC high luminosity ~$4x10^{33}$ cm^{-2} s^{-1}
  - larger beam spot size at RPS
  - central hole needs minimum (18cm / 10cm in x / y)
  - Only cover down to ~10 mrad
- With EicC high luminosity ~$1x10^{33}$ cm^{-2} s^{-1}
  - smaller beam spot size at RPS
  - central hole needs minimum (8cm / 4cm in x / y)
  - Can cover down to 5 mrad
- Possible way to reach ultra-forward angles:
  - spend 10~20% of run time to run low-lumi. setting, reaching angles ~5 mrad

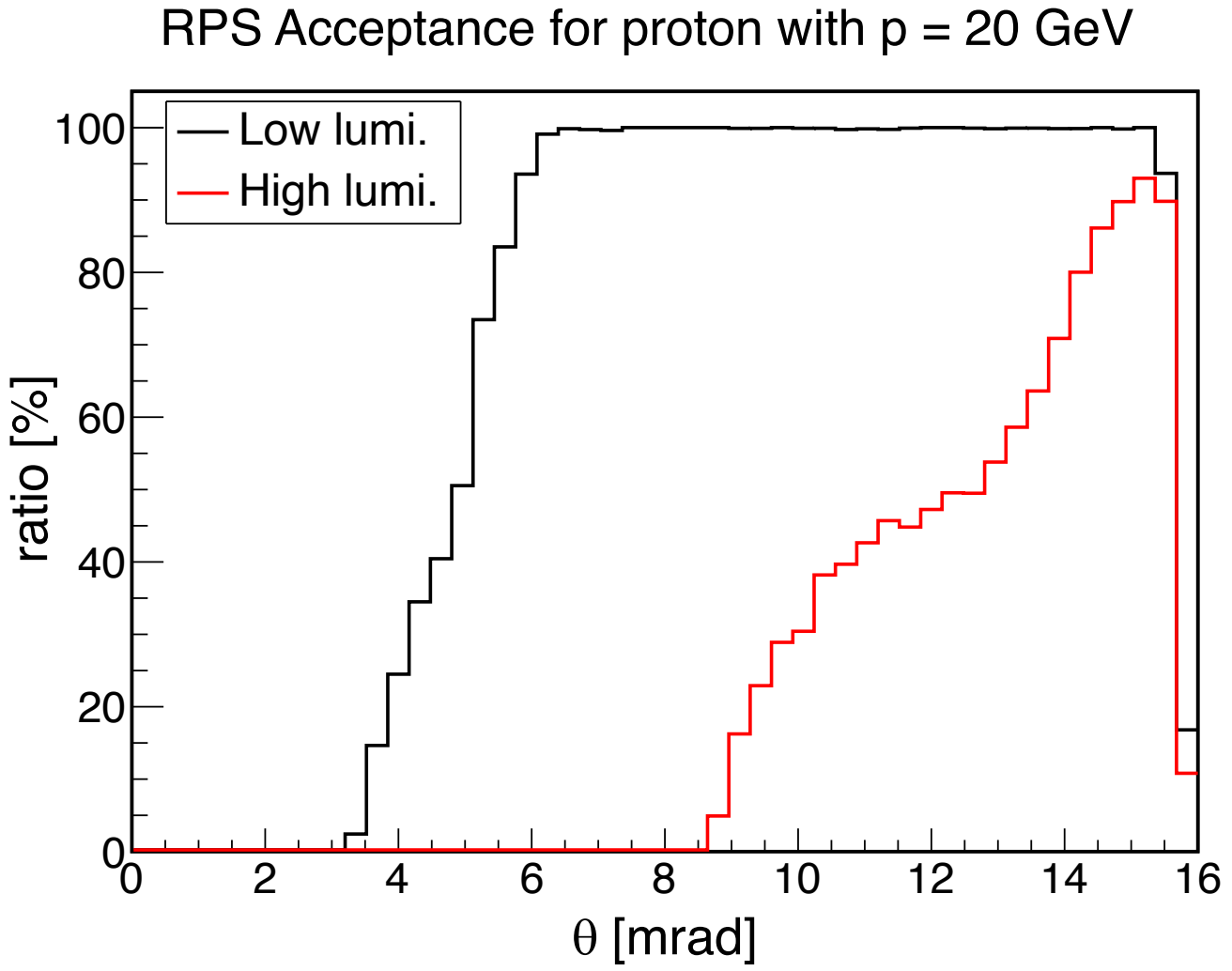
Roman Pot Station (RPS)

High lumi. configuration



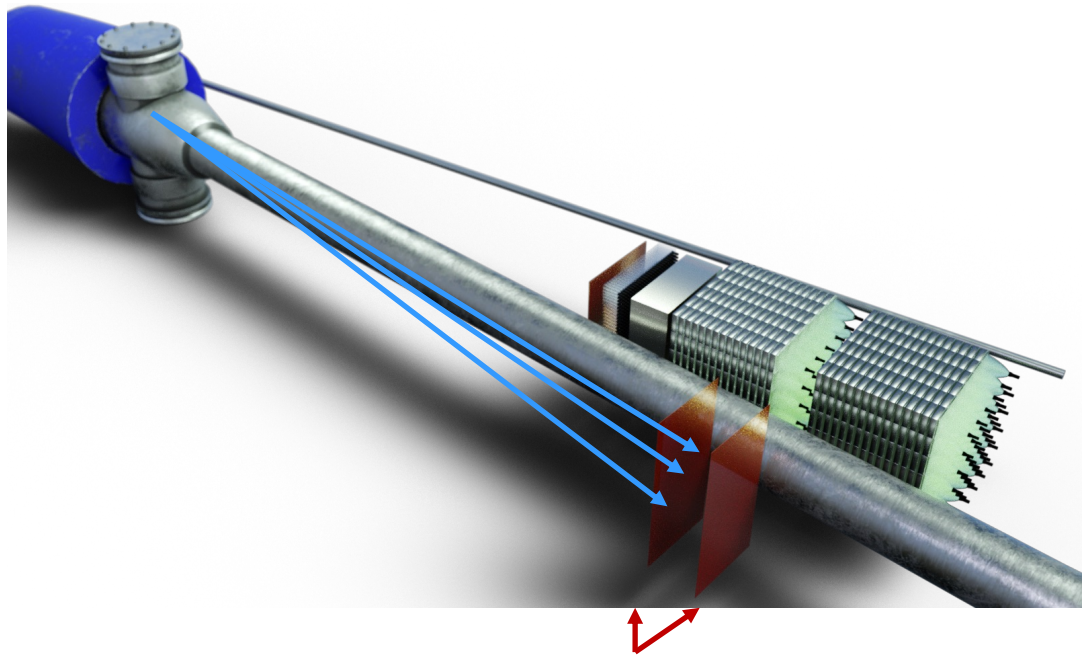
Low lumi. configuration



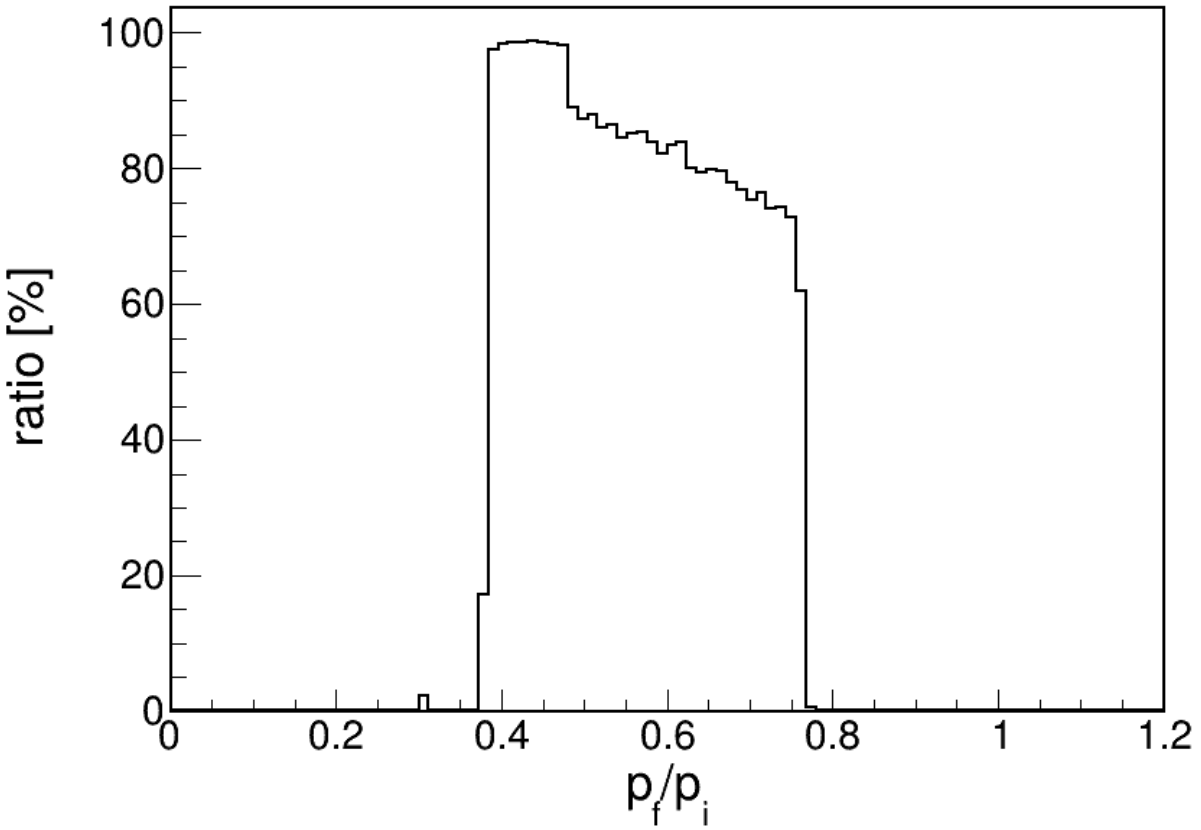


Off Momentum Detector (OMD)

- Purpose of OMD is for charged spectator tagging
- Envisioned technology: MAPS + AC-LGAD or MPGD + AC-LGAD
- Capable of detector charge particles with $0.4 < p_f / p_i < 0.75$



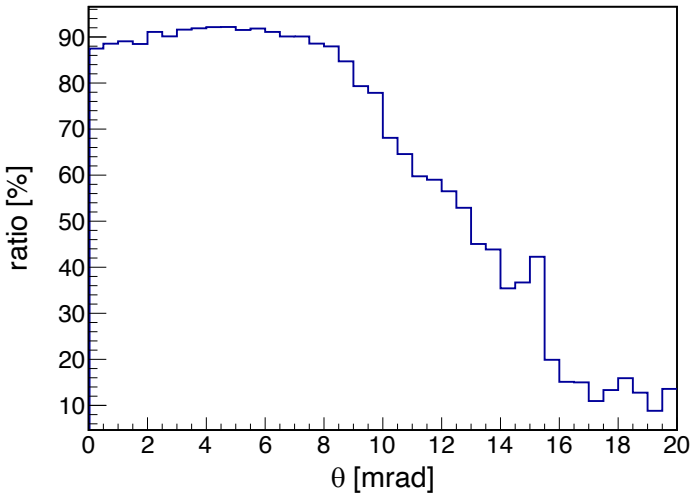
Off-momentum detectors



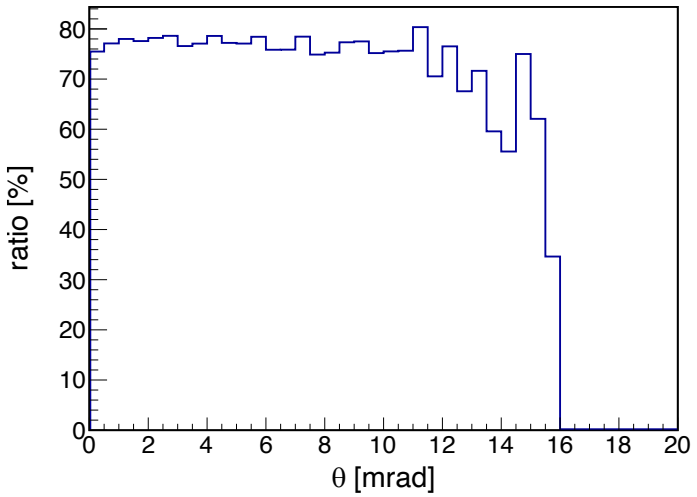
Off Momentum Detector (OMD)

- Majority of spectators from D and He-3 can pass through spectrum dipole and reach OMD
- D works, means He-4, Li-6, C-12 will also work
- ^{3}H may need further optimization

deutron 12.9GeV/A

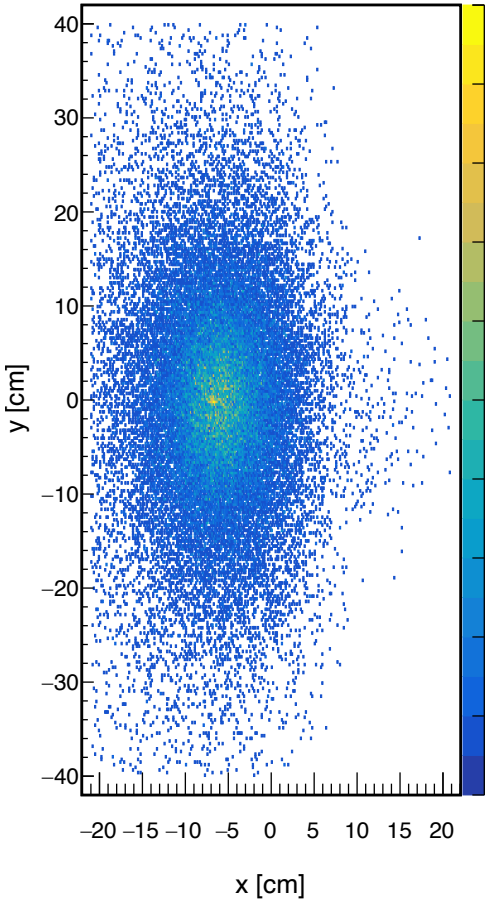


He-3 17.2GeV/A

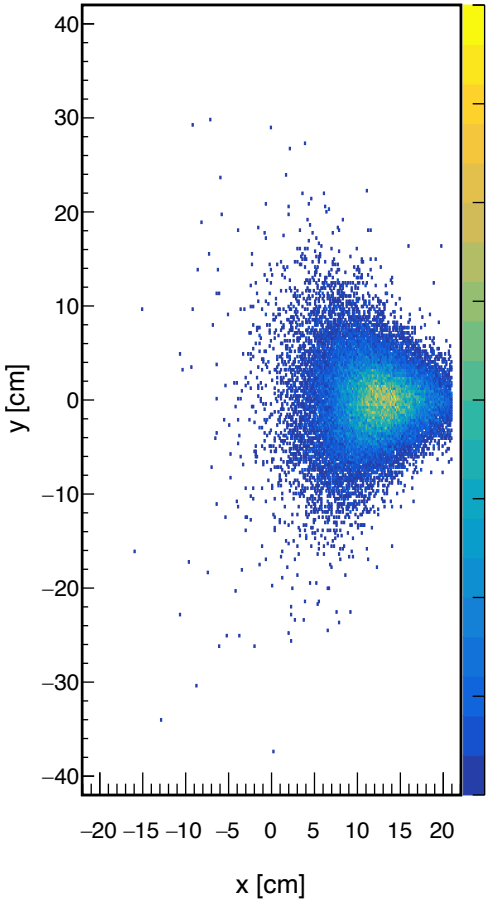


Hit position on OMD from spectator protons

deutron 12.9GeV/A



He-3 17.2GeV/A

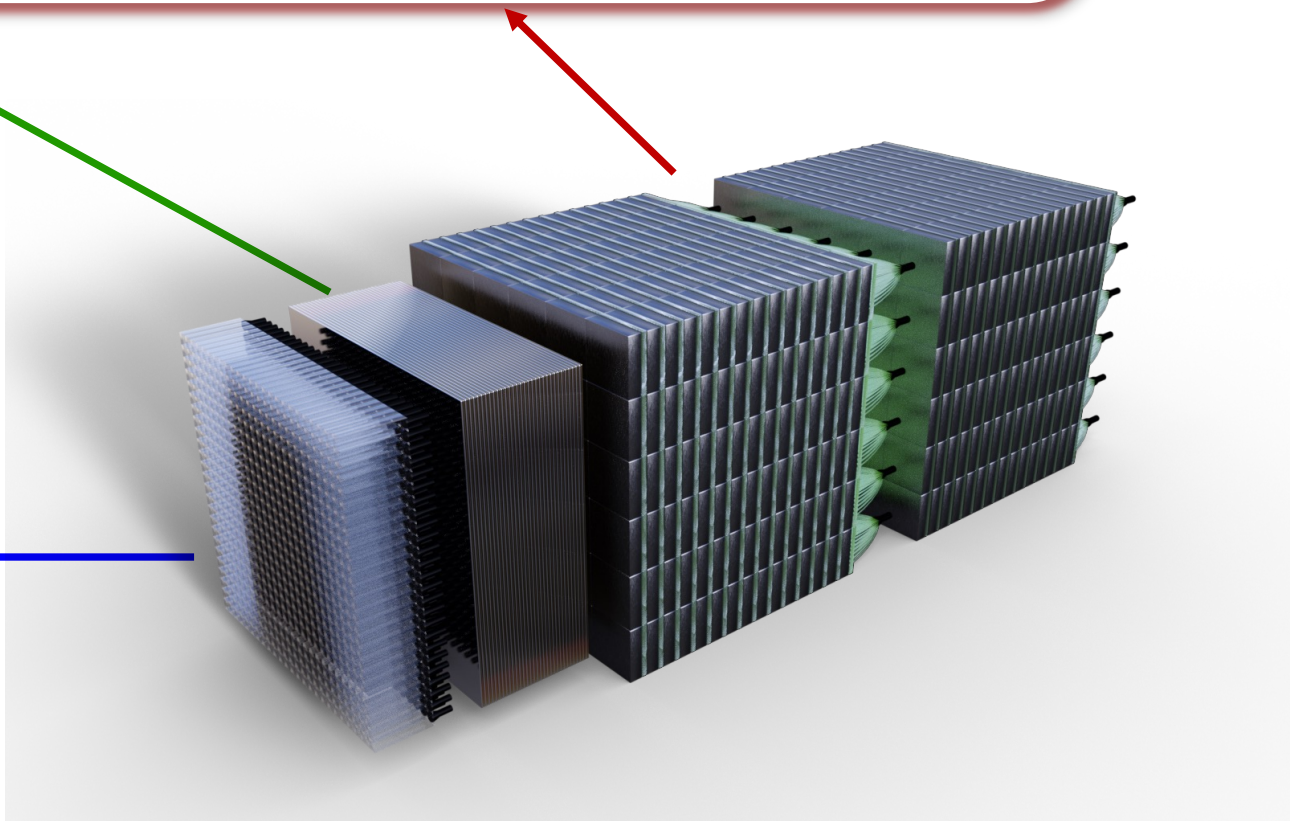


Zero Degree Calorimeter (ZDC)

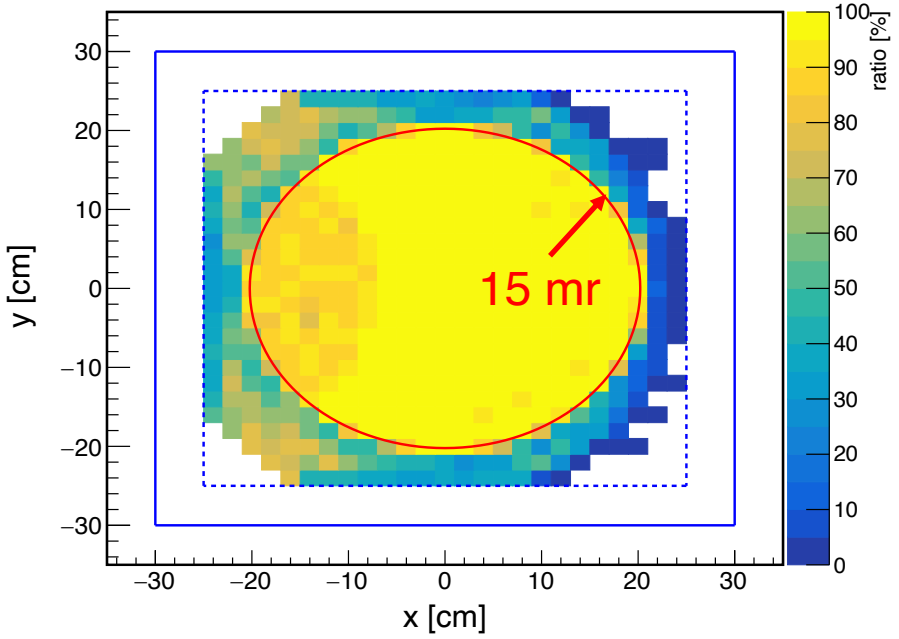
2 PbSci detectors:
- **Energy measurement for neutron**
- each layer 25.6mm lead + 6.4mm scintillator
- 15 layers for each detector
- in total 60cm x 60cm x 48cm for each detector

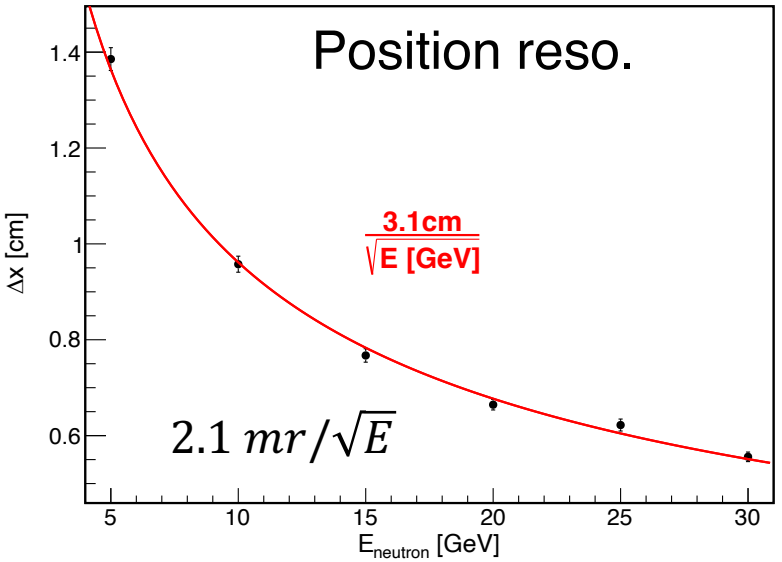
WSi detectors:
- **Imaging calo., pos recon., PID**
- each layer 3.5mm W + 320um Si
- in total 42 layers
- Si layer readout 1cm x 1cm for now
- in total 50.6 cm x 50.6 cm x 22.5cm

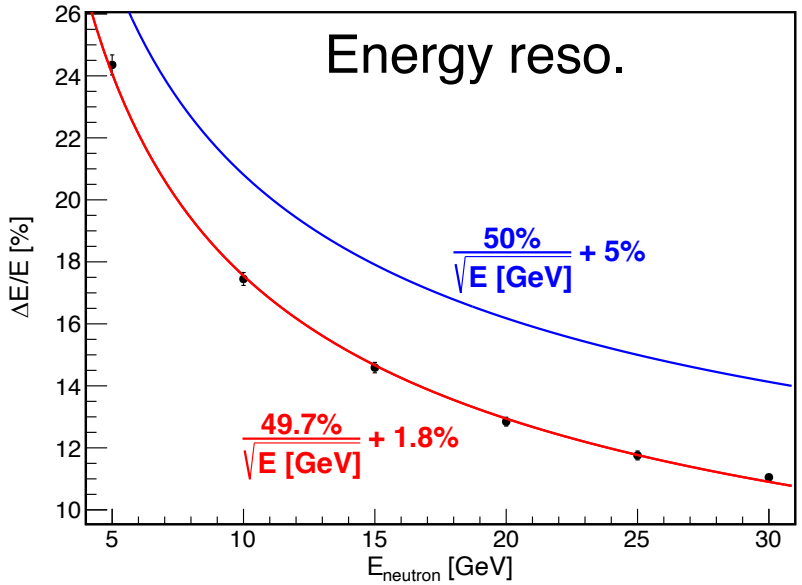
PbWO4 detectors:
- **For photon detection**
- each module 2.2 cm x 2.2 cm x 10 cm
- in total 50.6 cm x 50.6 cm x 10.0 cm

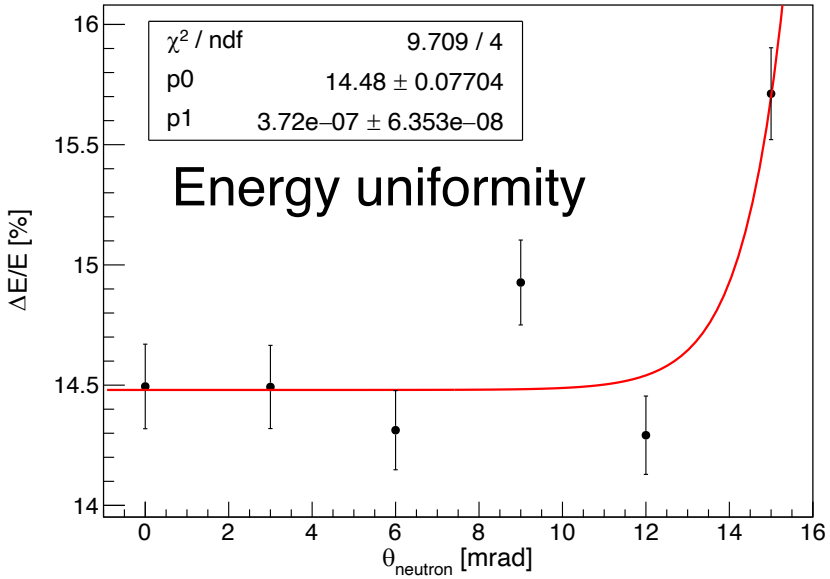


Zero Degree Calorimeter (ZDC)



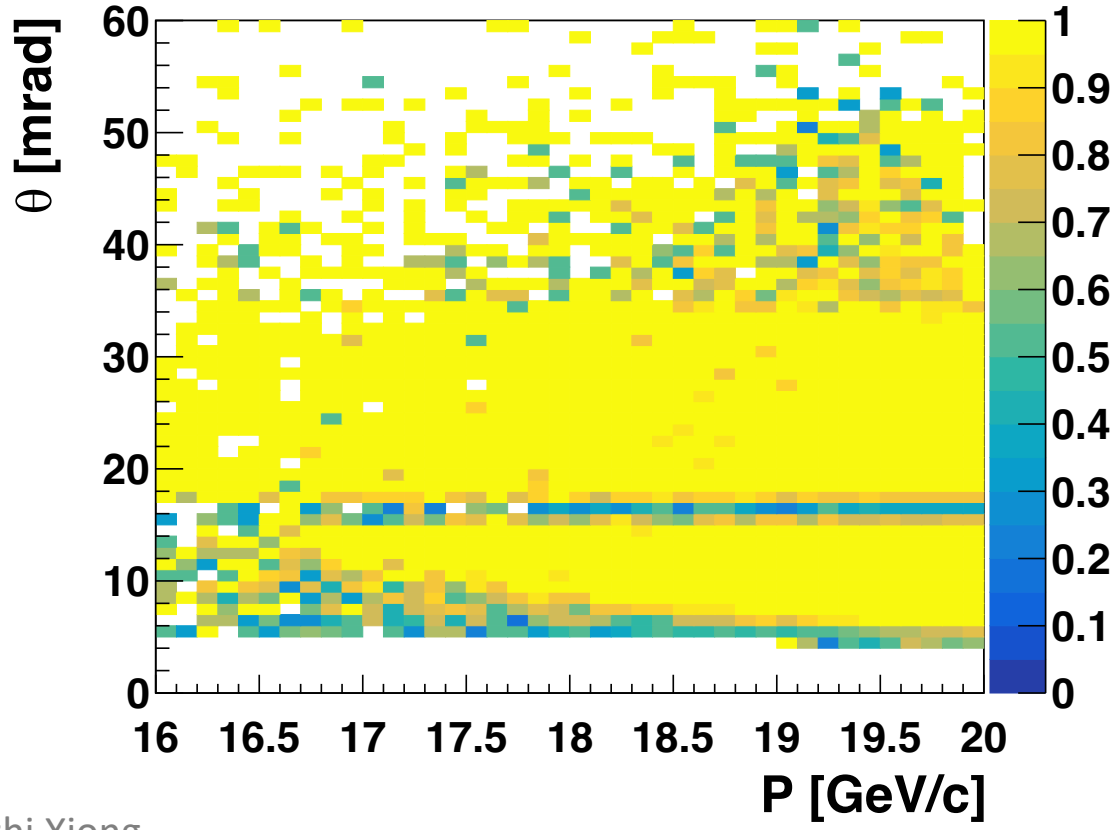


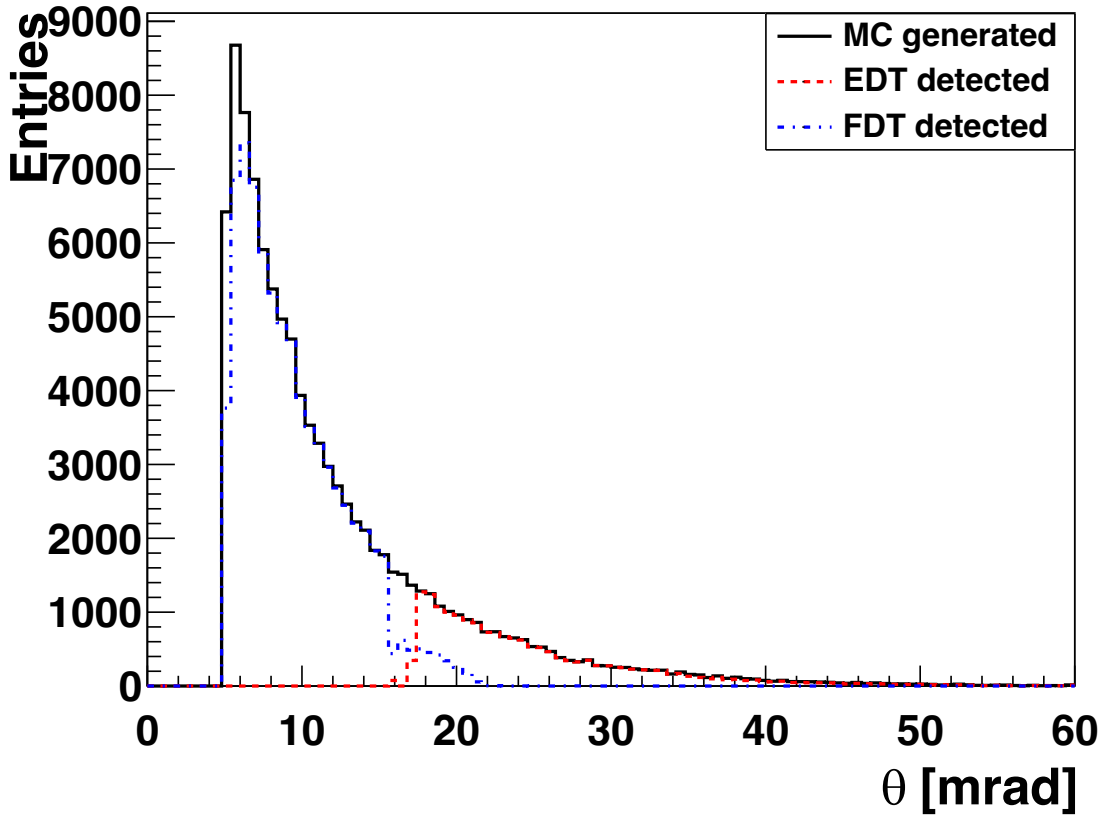




Detecting Protons from DVCS

- A high-energy proton with small scattering angle produced in the final state
- Mostly detected by RPS and EDT
- Complex acceptance for FDT due to beam pipes and intricate magnet fields
- May gain improvement by using Roman pots for FDT





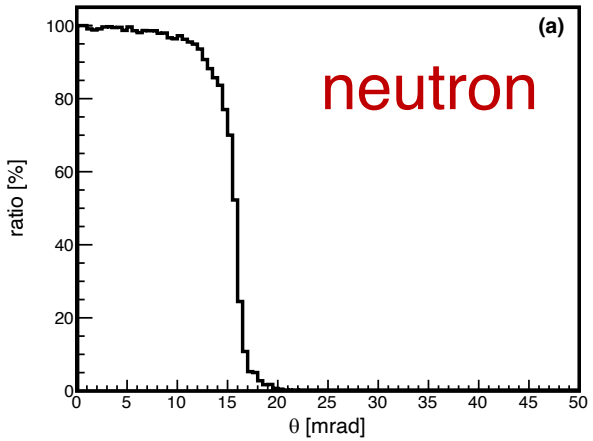
Forward Λ Detection

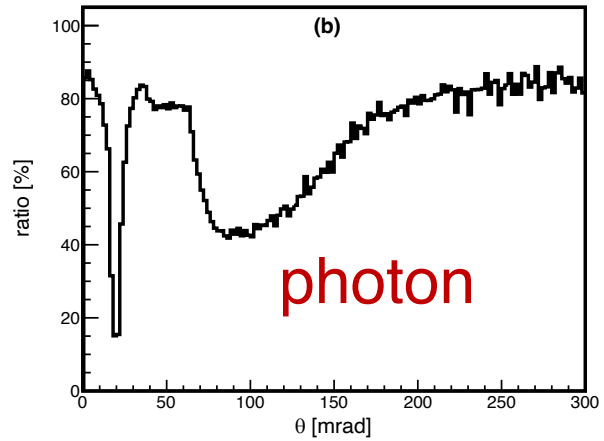
- Crucial for kaon form factor and structure-function study using Sullivan process: $ep \rightarrow e\Lambda K^+/X$

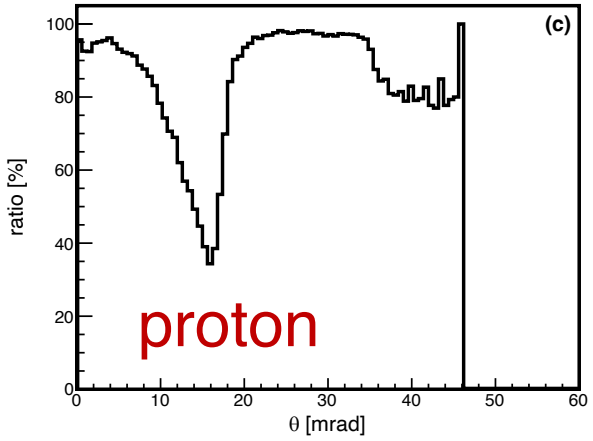
- Λs go mostly forward, as well as their decay products
  1. neutral channel: $\Lambda \rightarrow n\pi^0$, with BR 36%
  2. charged channel: $\Lambda \rightarrow p\pi^-$, with BR 64%

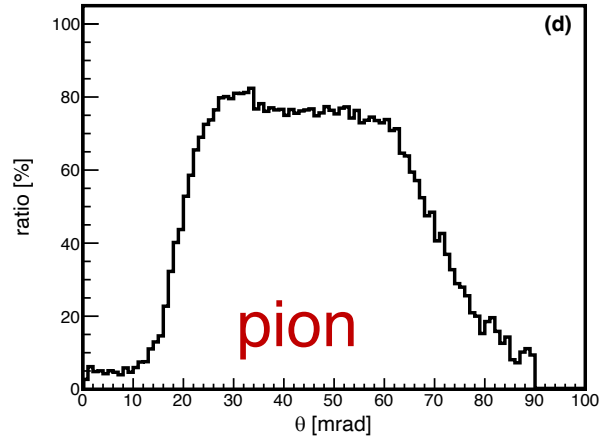
- Require all FF detectors work collectively

- Obvious advantage for EicC, compared to EIC
  - ➢ overall efficiency ~ 40% (EIC 1% ~ 20%)



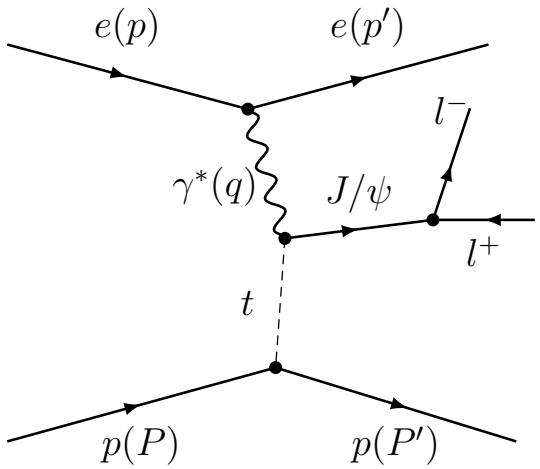




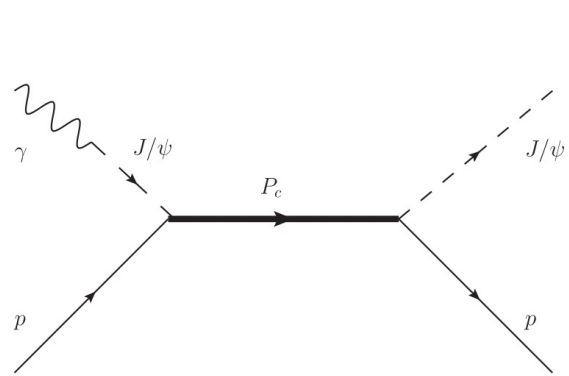


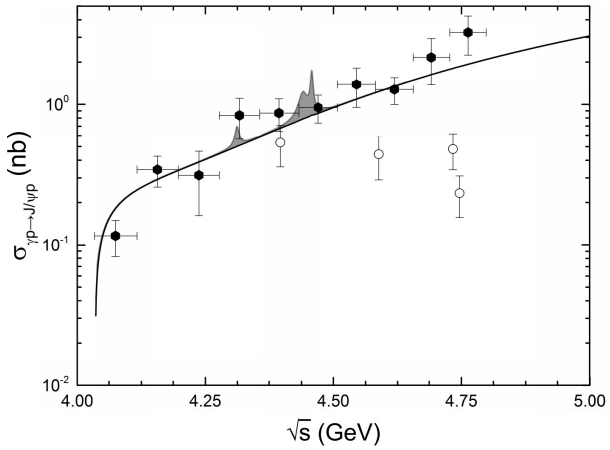
Near Threshold J/ψ Production

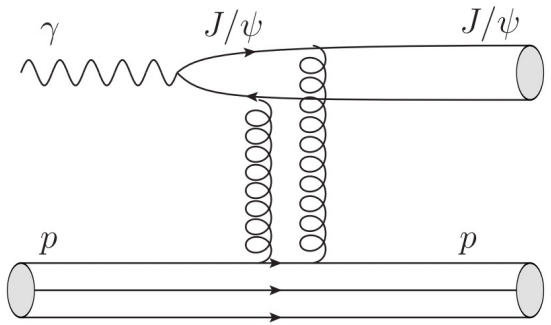
- Can be used to probe rich physics topics:
  1. Gravitational form factor (GFF)
  2. Origin of proton mass
  3. Exploring pentaquark states
  4. Revealing the J/ψ production mechanism
  5. …

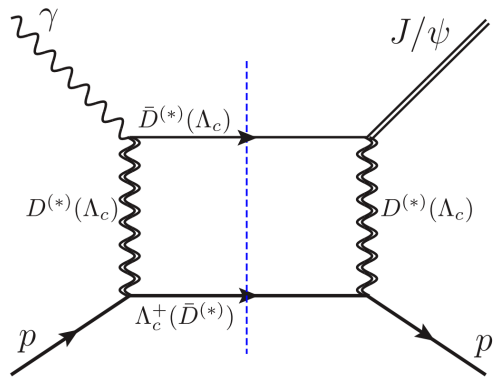


X. Wang et al. arXiv: 2311.07008







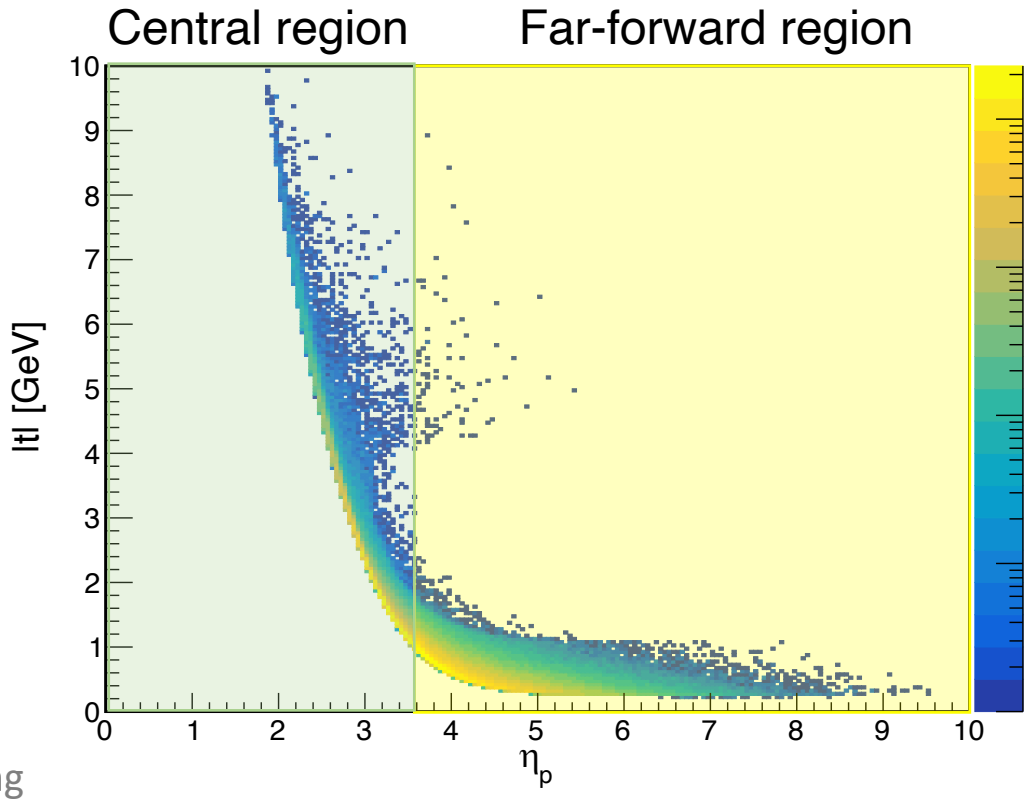


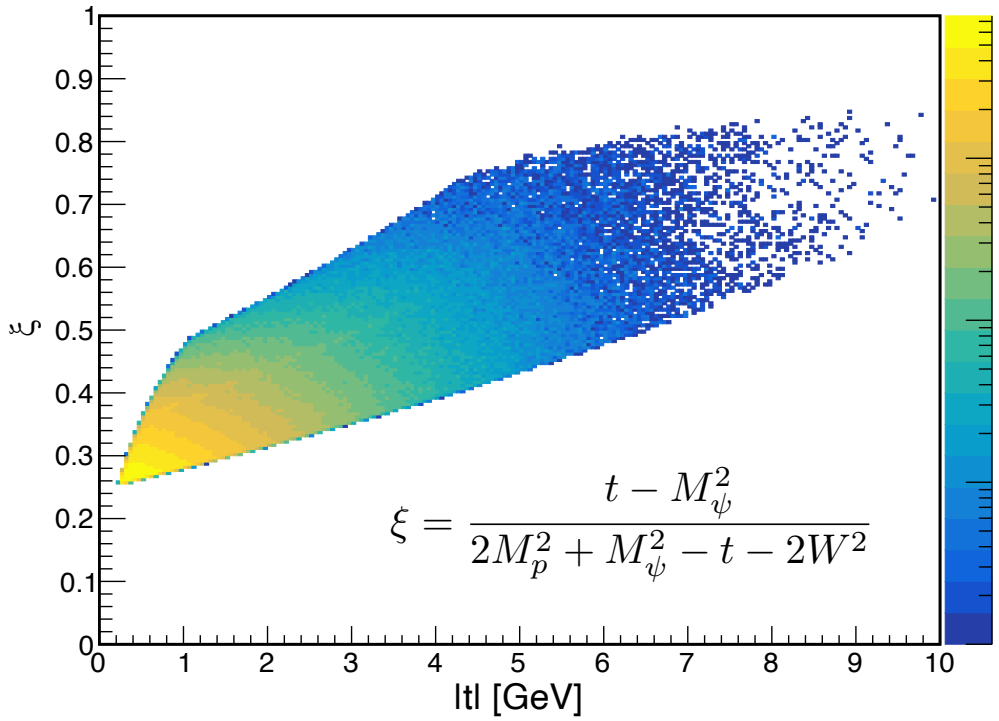
(Eur. Phys. J. C 80 (2020) 1053)

Near Threshold J/ψ Production

- Using $ep \to epJ/\psi$ generator developed for EicC (X. Wang et al. arXiv: 2311.07008)
  - Based on the eSTARlight generator
  - Improved fitting and kinematics for the threshold region

- Need detection of all final-state particles
- For W < 5 GeV and Q^2 < 1GeV^2 with 3.5GeV electron x 20 GeV proton setting:

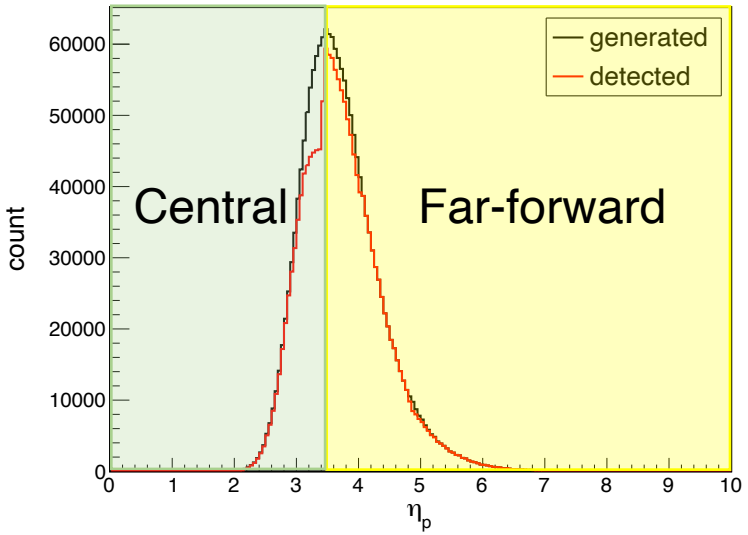


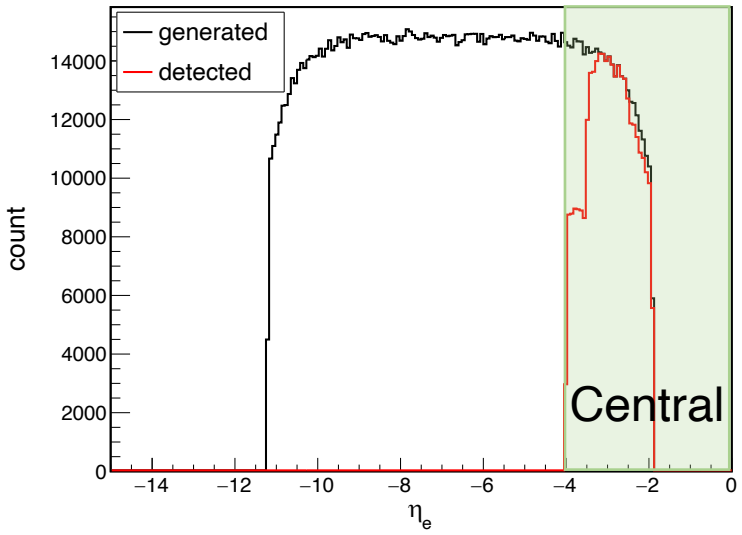


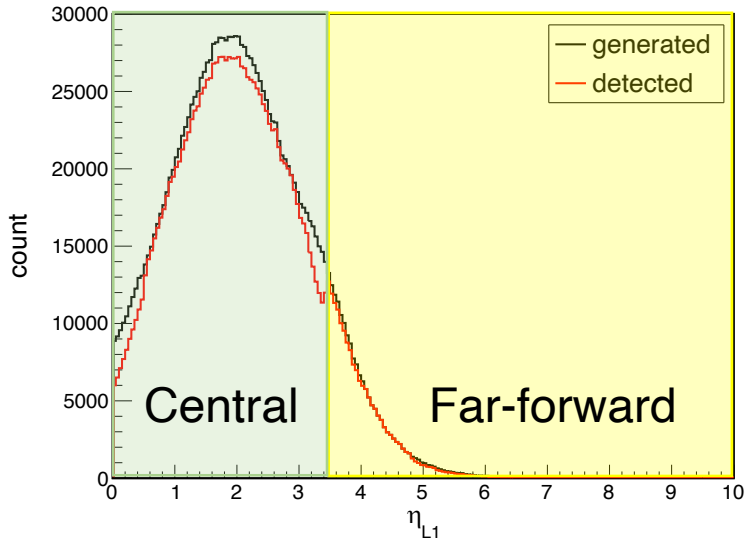
Near Threshold J/ψ Production

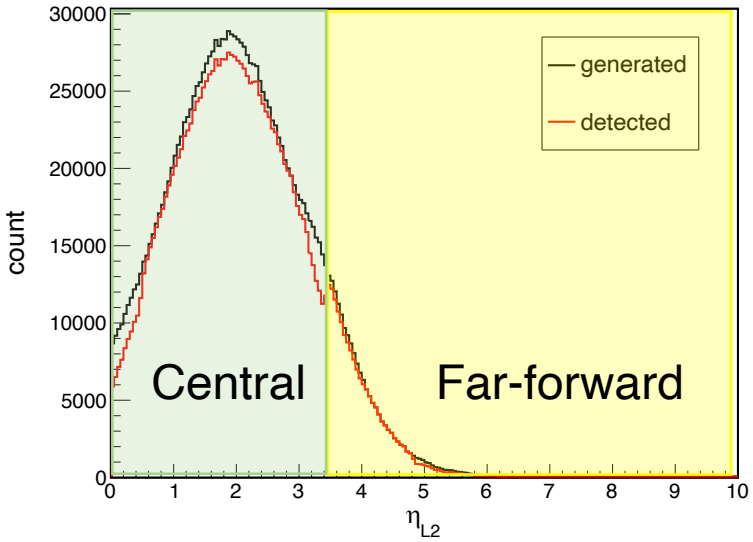
- Excellent acceptance for p and di-leptons, if combine both FF and central
  - ➢ central detector momentum reso. could be slightly worse

➢ Bottleneck on the scattered electron:
  - ➢ No far-backward detector yet





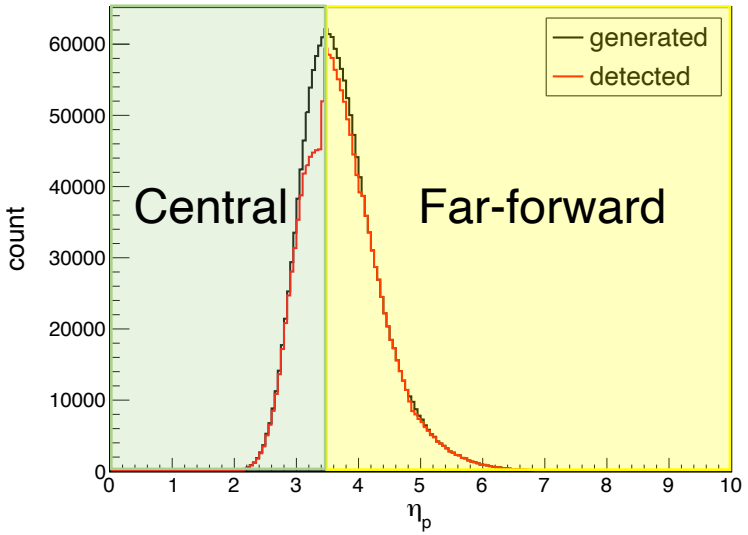




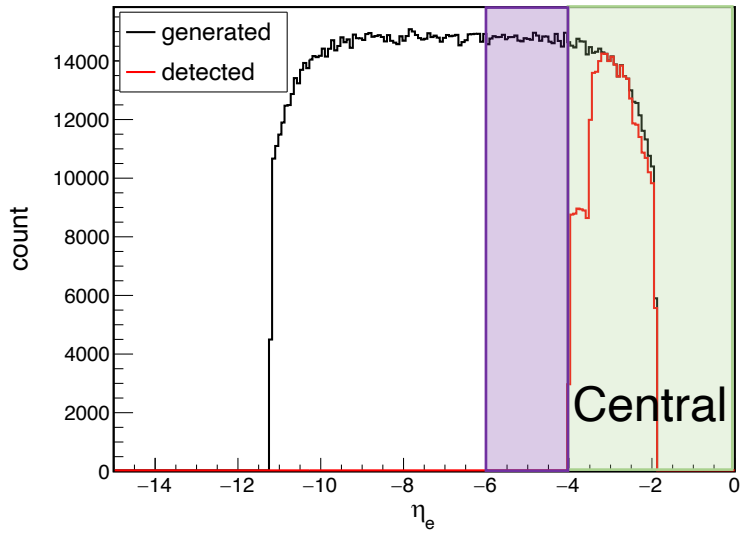
Near Threshold J/ψ Production

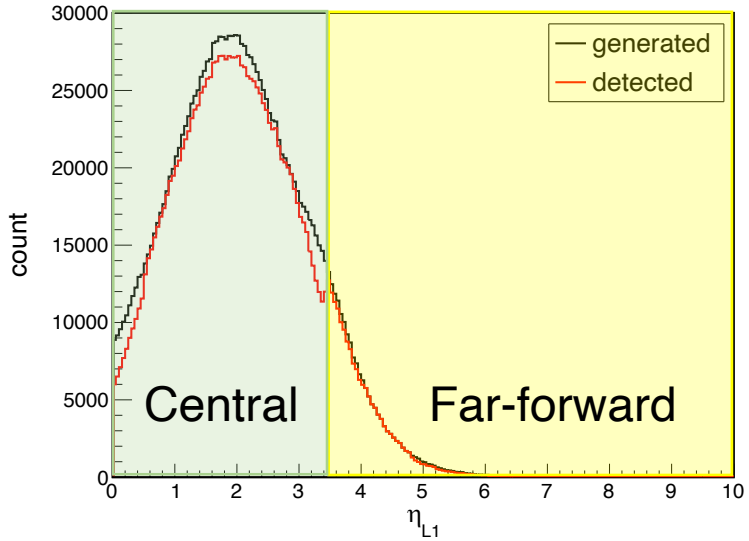
- Excellent acceptance for p and di-leptons, if combine both FF and central
  - ➢ central detector momentum reso. could be slightly worse

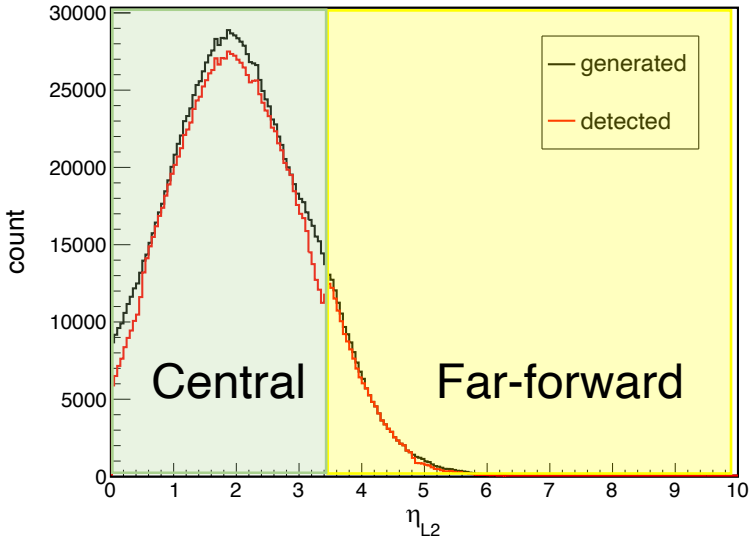
➢ Bottleneck on the scattered electron:
  - ➢ No far-backward detector yet
  - ➢ Prelim. design exists, need further development
  - ➢ Could improve stat. by factor of 2



Potential far-backward det.



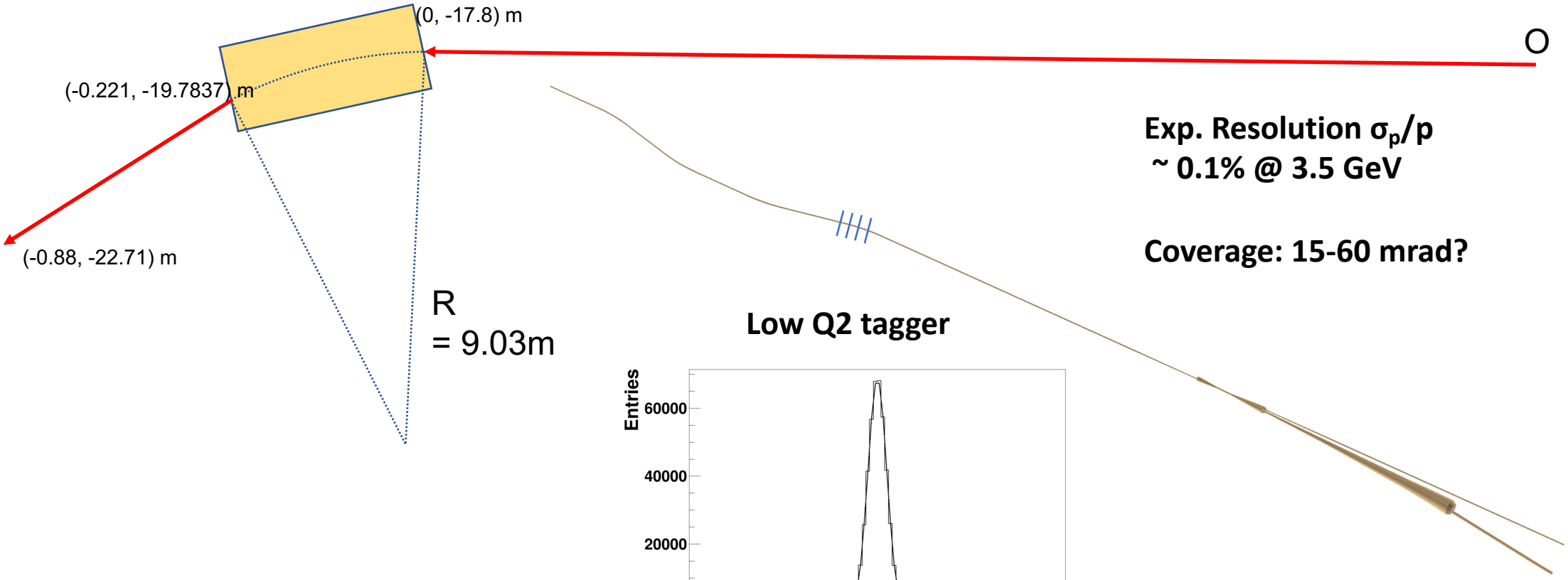




Forward detector in electron going direction

Slides from Yutie Liang

Dipole: z = -18.8 m
B = 1.29 T L_z = 1.9837 m
R2 = 9.03 m
Bending angle = 221 mrad



Exp. Resolution σ_p/p
~ 0.1% @ 3.5 GeV

Coverage: 15-60 mrad?

Low Q2 tagger

Summary

- A robust and fully equipped EicC far-forward detector complex:
  - EDT: charged particle and γ with 16 mr < θ < 60 mr
  - RPS: charged particle with $p \sim p_{beam}$ and 5 mr < θ < 16 mr
  - ZDC: neutron and γ with θ < 15 mr
  - OMD: charged spectator with $0.4 < p'/p_{beam} < 0.8$

- Essential for a wide range of physics measurements:
  - DVCS, meson structure, exotic states, diffractive measurements…
  - Near threshold J/ψ production: detection final state proton and di-lepton, especially for low W

- Detector optimization and physics projection on-going:
  - Helps very welcome and urgently needed

- EicC exclusive measurement and FF detector working group:
  - Fengkun Guo (fkguo@itp.ac.cn) Jiajun Wu (wujiajun@ucas.ac.cn), Xu Cao (caoxu@impcas.ac.cn)
  - Yutie Liang (liangyt@impcas.ac.cn) and Weizhi Xiong (xiongw@sdu.edu.cn)

Zero Degree Calorimeter (ZDC)