The XXXI International Workshop on Deep Inelastic Scattering (DIS2024)

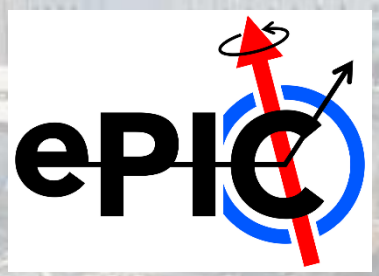
Physics Perspectives with the ePIC Far-Forward and Far-Backward detectors

10 April 2023

Michael Pitt*

The University of Kansas

* *also with the Ben Gurion University of the Negev*

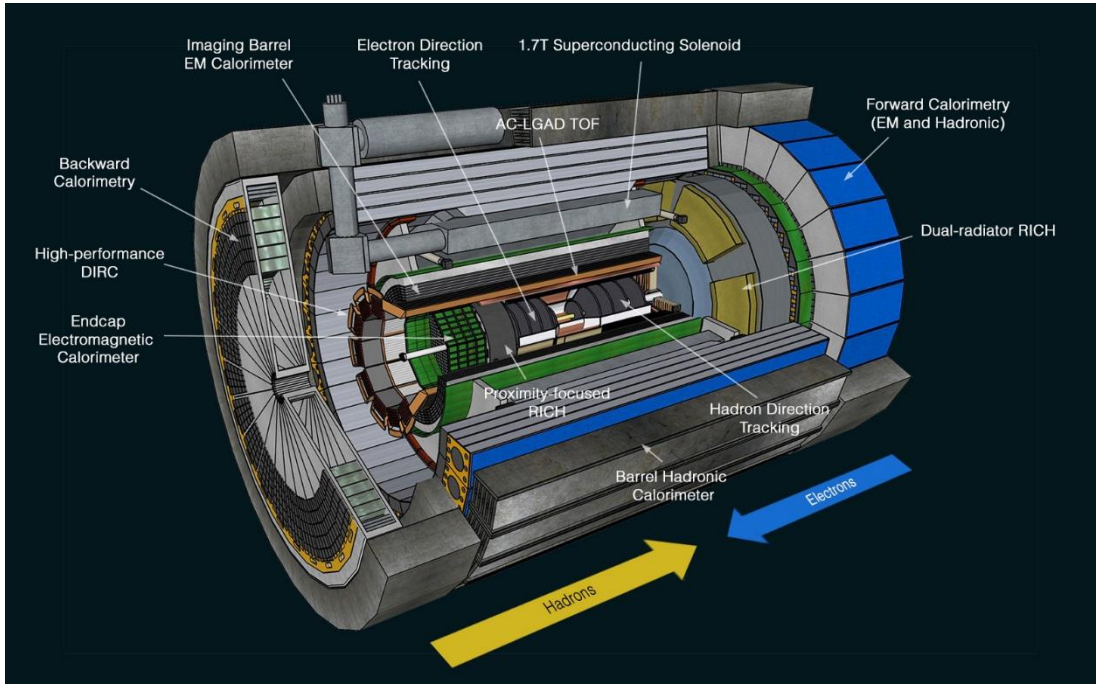


On behalf of the ePIC Collaboration

U.S. DEPARTMENT OF ENERGY | Office of Science
Grant DE-SC0023908

The ePIC detector at the Electron-Ion collider (EIC)

https://www.bnl.gov/eic/epic.php



- The ePIC experiment, scheduled to start in the early 2030s with the main goal to understand the visible matter
- It comprises:
  - A 10-meter-long cylindrical barrel detector

More about ePIC in Shujie Li talk:
https://lpsc-indico.in2p3.fr/event/3268/contributions/7417/

The ePIC detector at the Electron-Ion collider (EIC)

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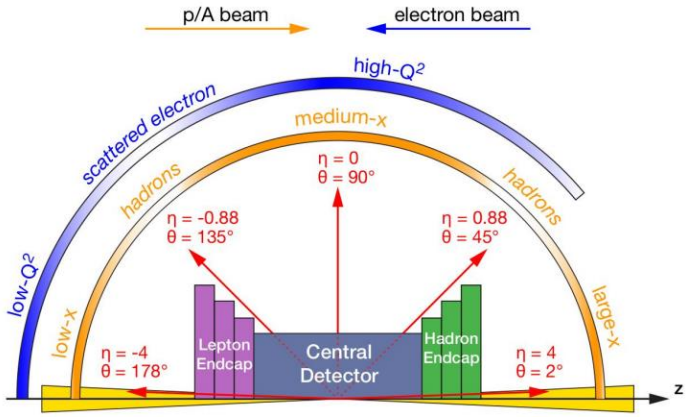

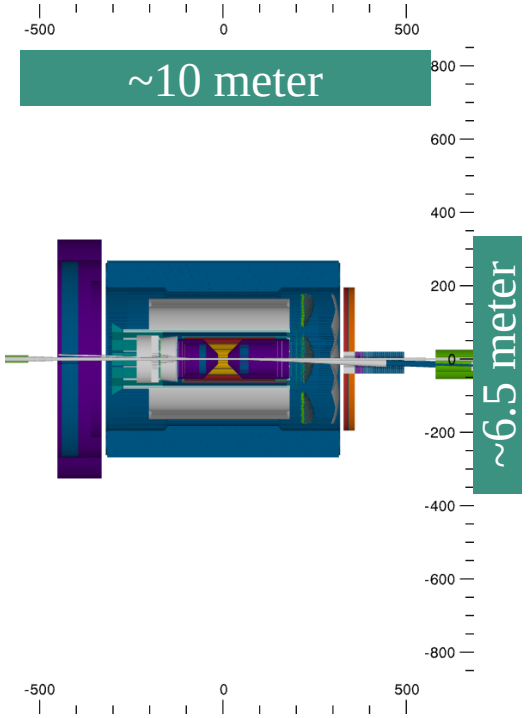

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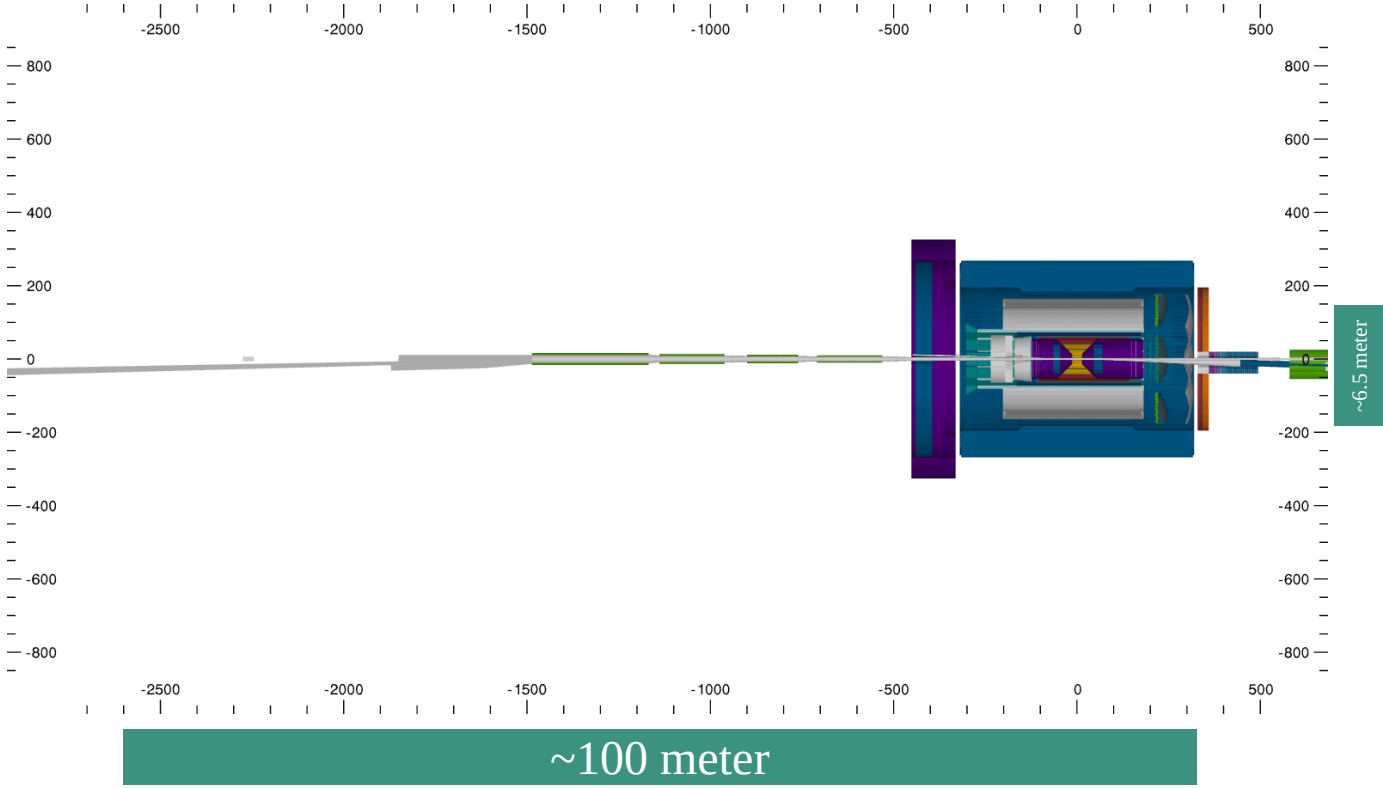
  - An additional detector array that extends ~50m in each direction aiming for a full coverage



The ePIC detector at the Electron-Ion collider (EIC)

- The extended detector's array required to enable primary physics objectives:

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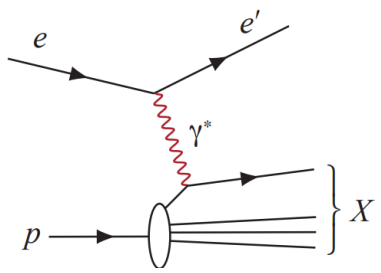
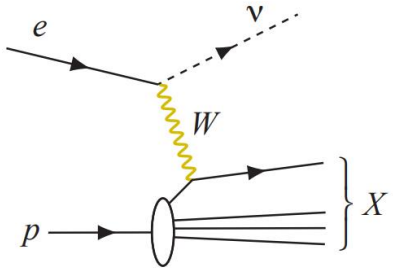
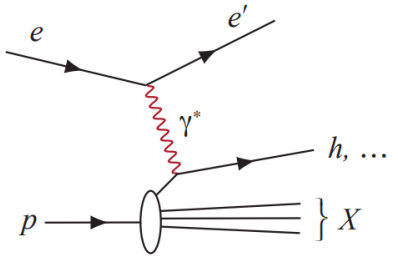
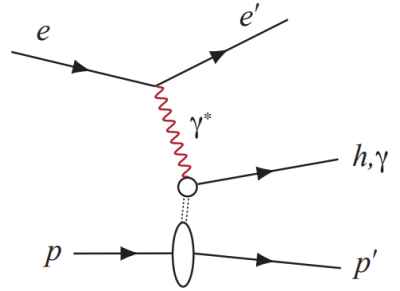


NC+CC Inclusive DIS (~1 fb^{-1})





Semi-Inclusive DIS (~10 fb^{-1})



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Far-Backward detectors

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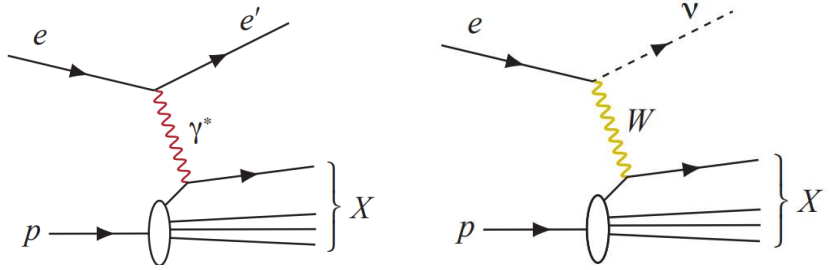

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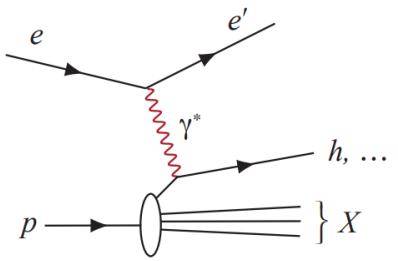

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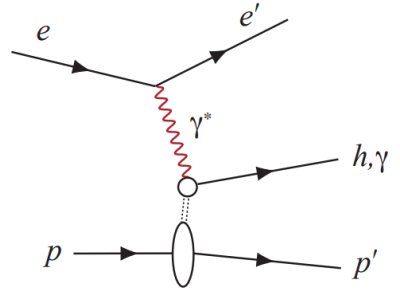

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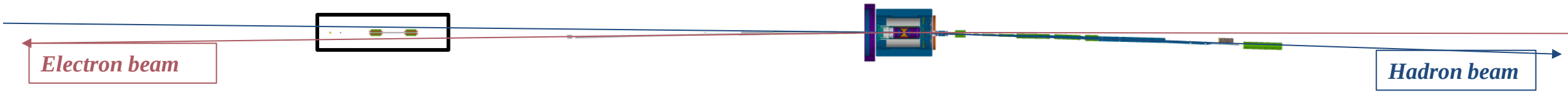

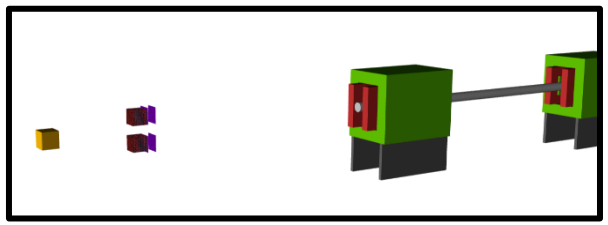

Luminosity monitor

Far-Backward detectors

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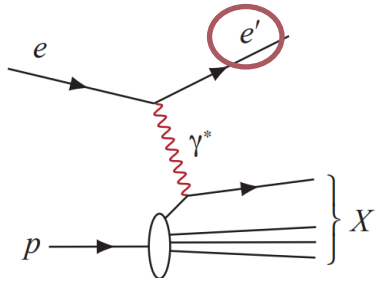

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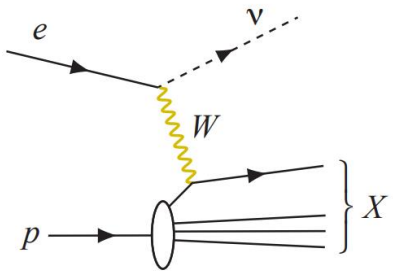

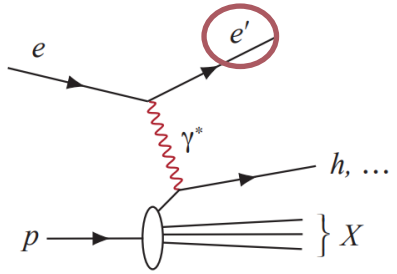

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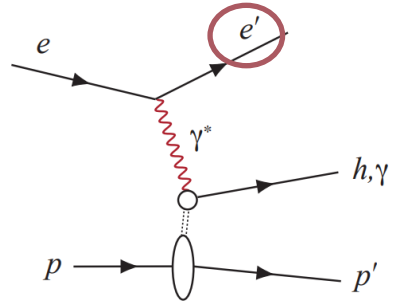

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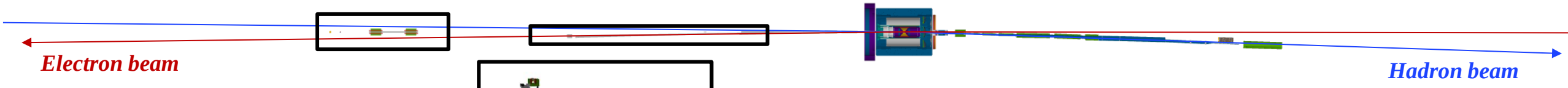

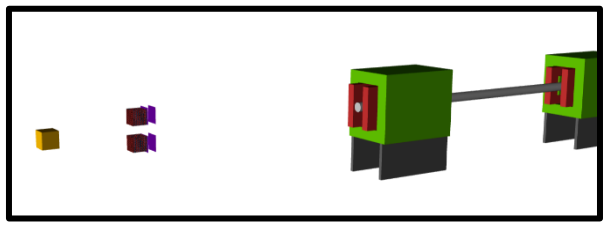

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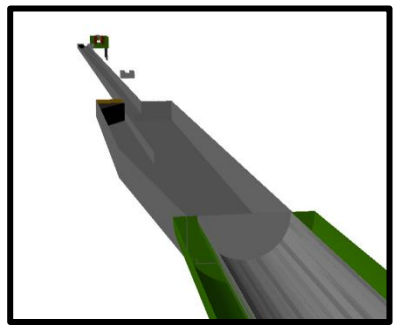

Low Q^2 taggers

Far-Backward and Far-Forward detectors

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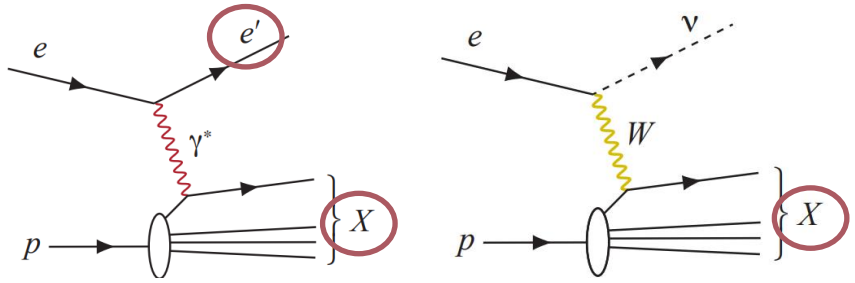

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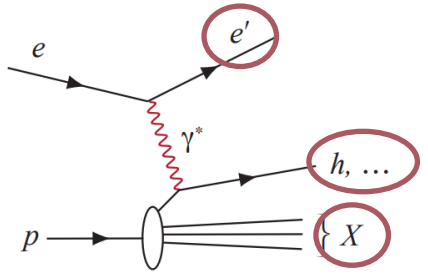

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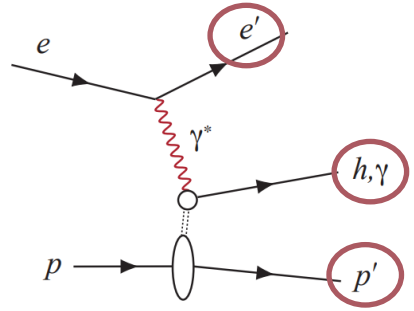

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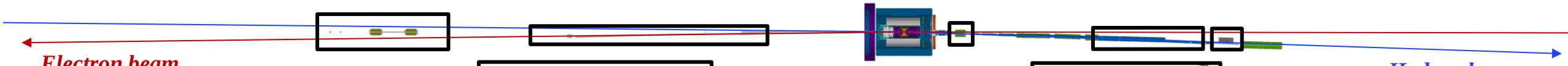

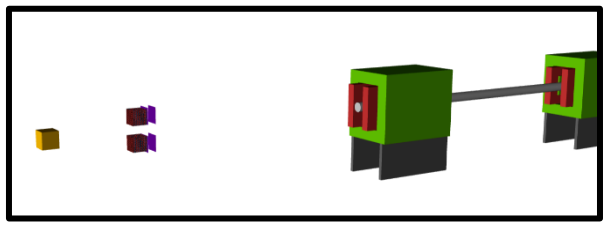

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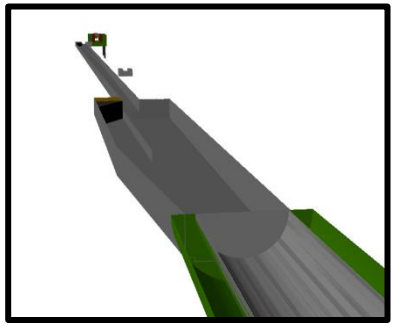

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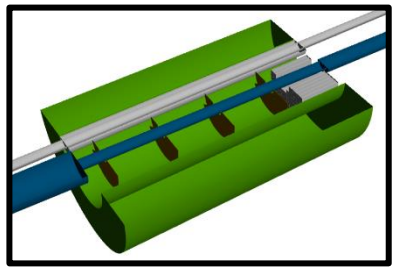
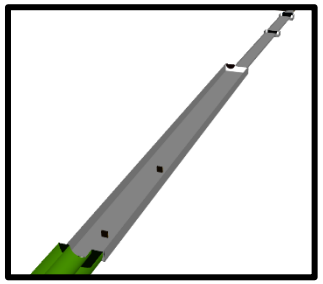
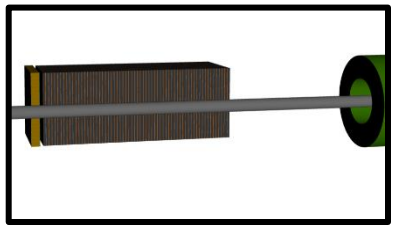


B0 detector



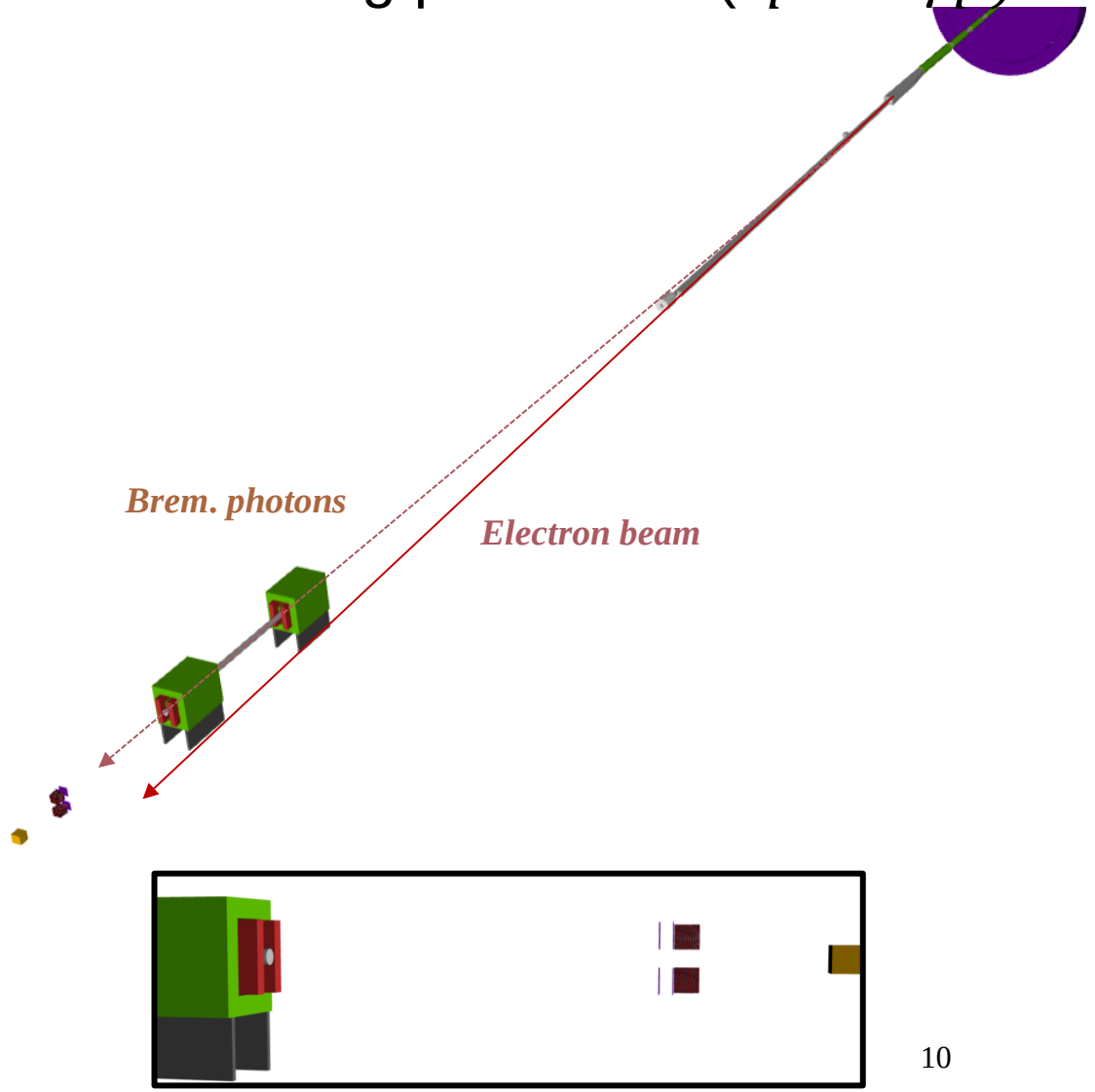
Forward beamline trackers



ZDC

Luminosity monitor

- Precise luminosity determination (<1%), from Bremsstrahlung processes ($ep \rightarrow e\gamma p$)



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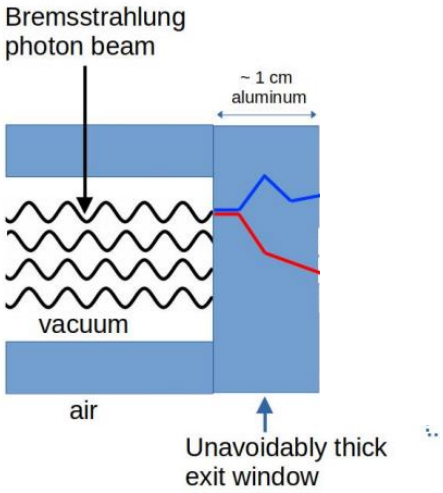

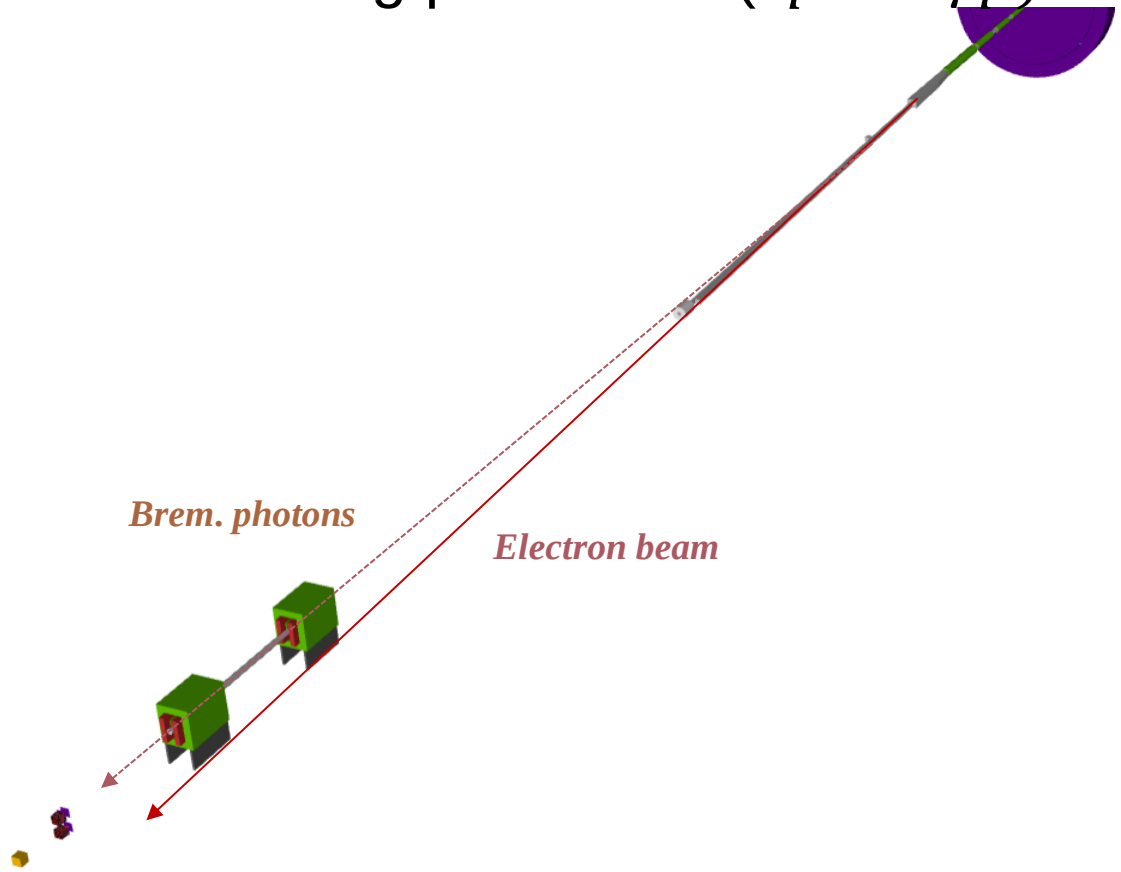

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- Precise luminosity determination (<1%), from Bremsstrahlung processes ($ep \rightarrow e\gamma p$)
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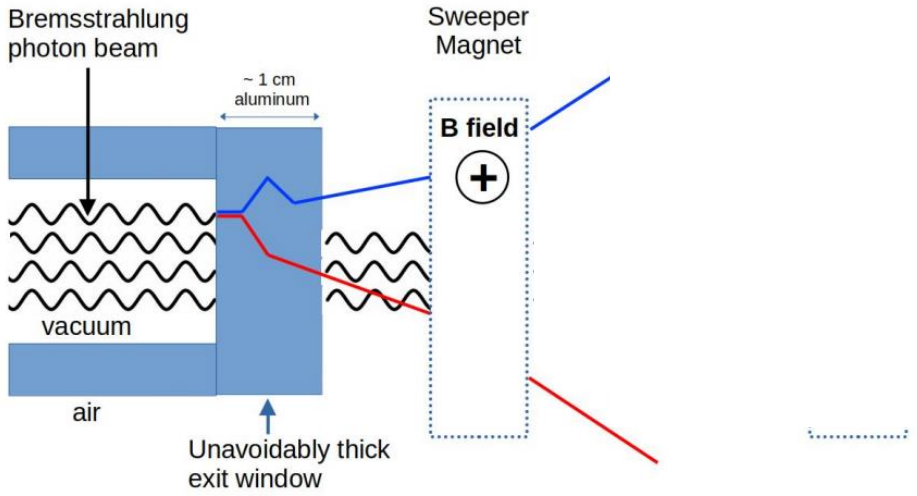

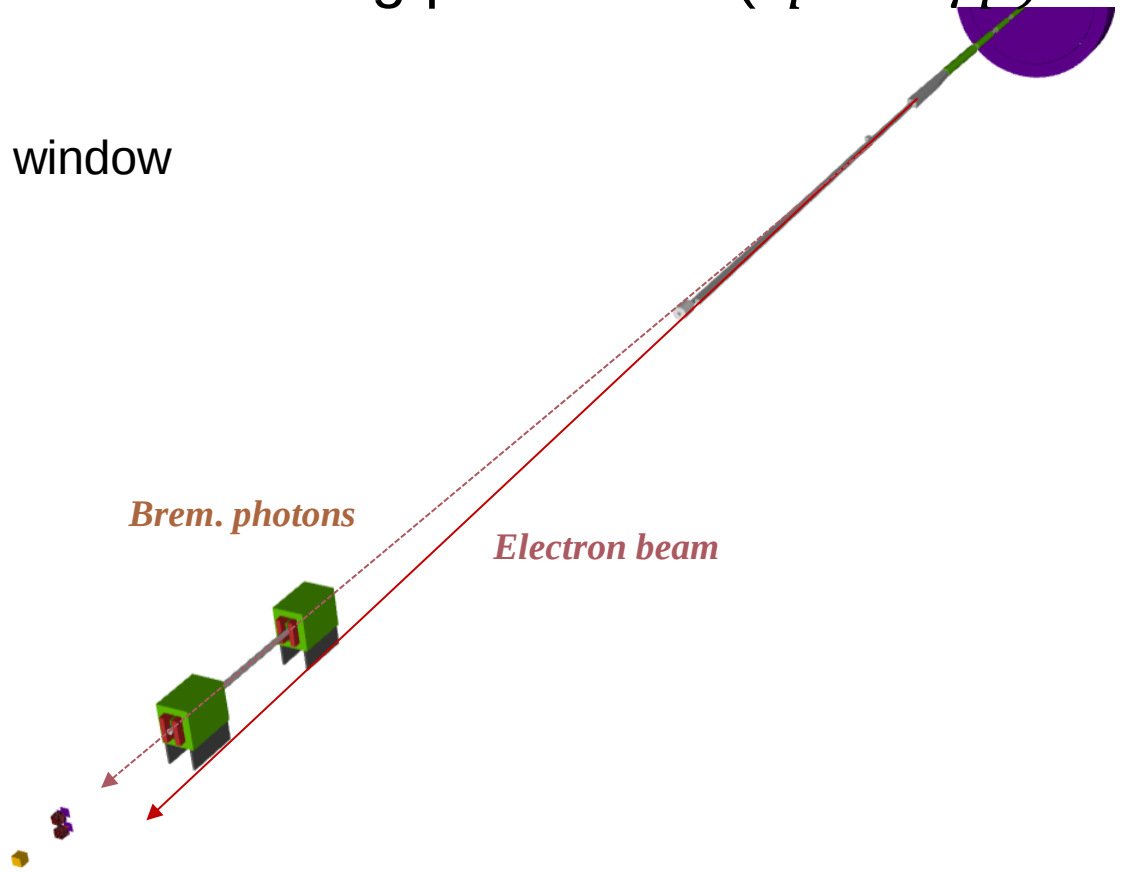

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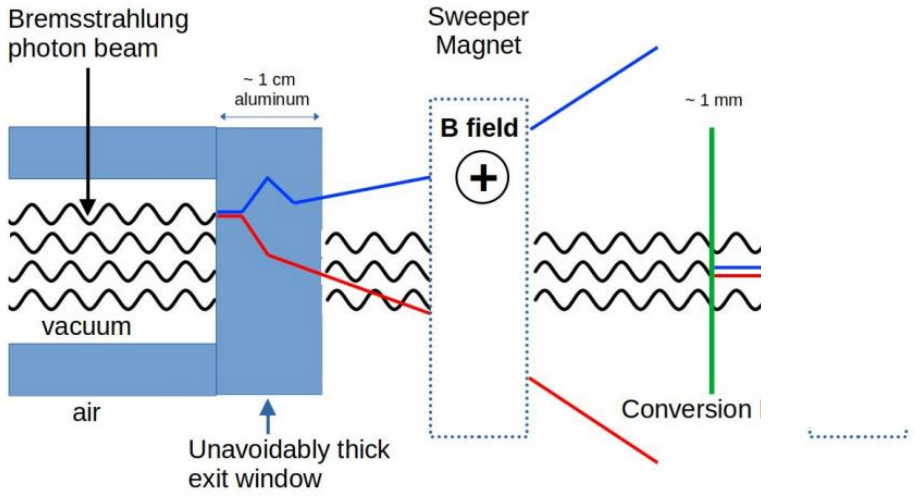

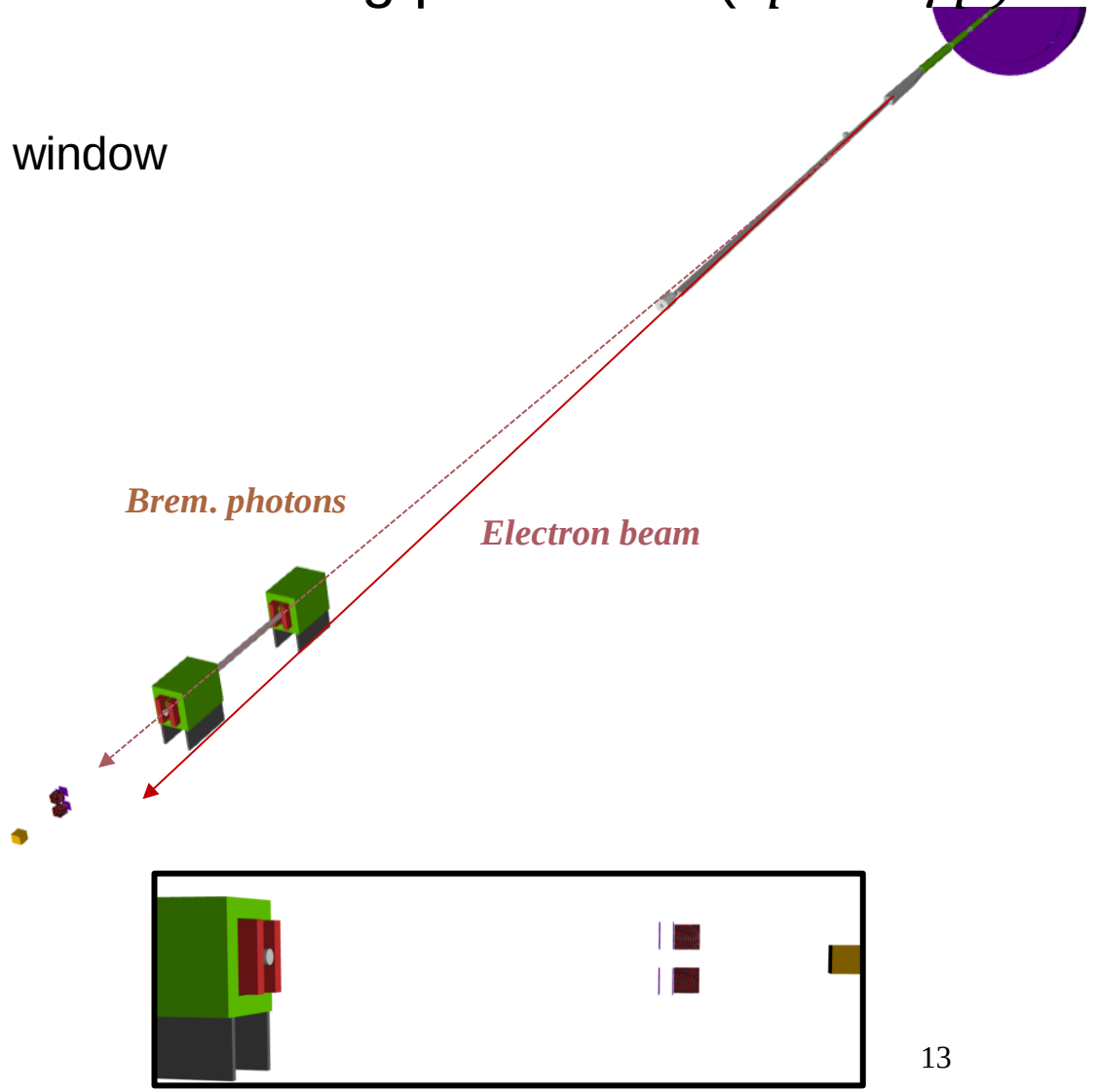

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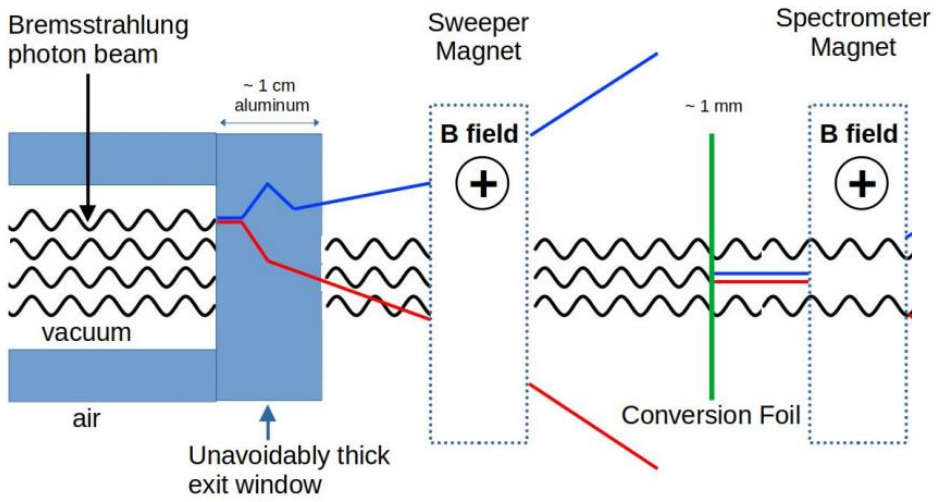

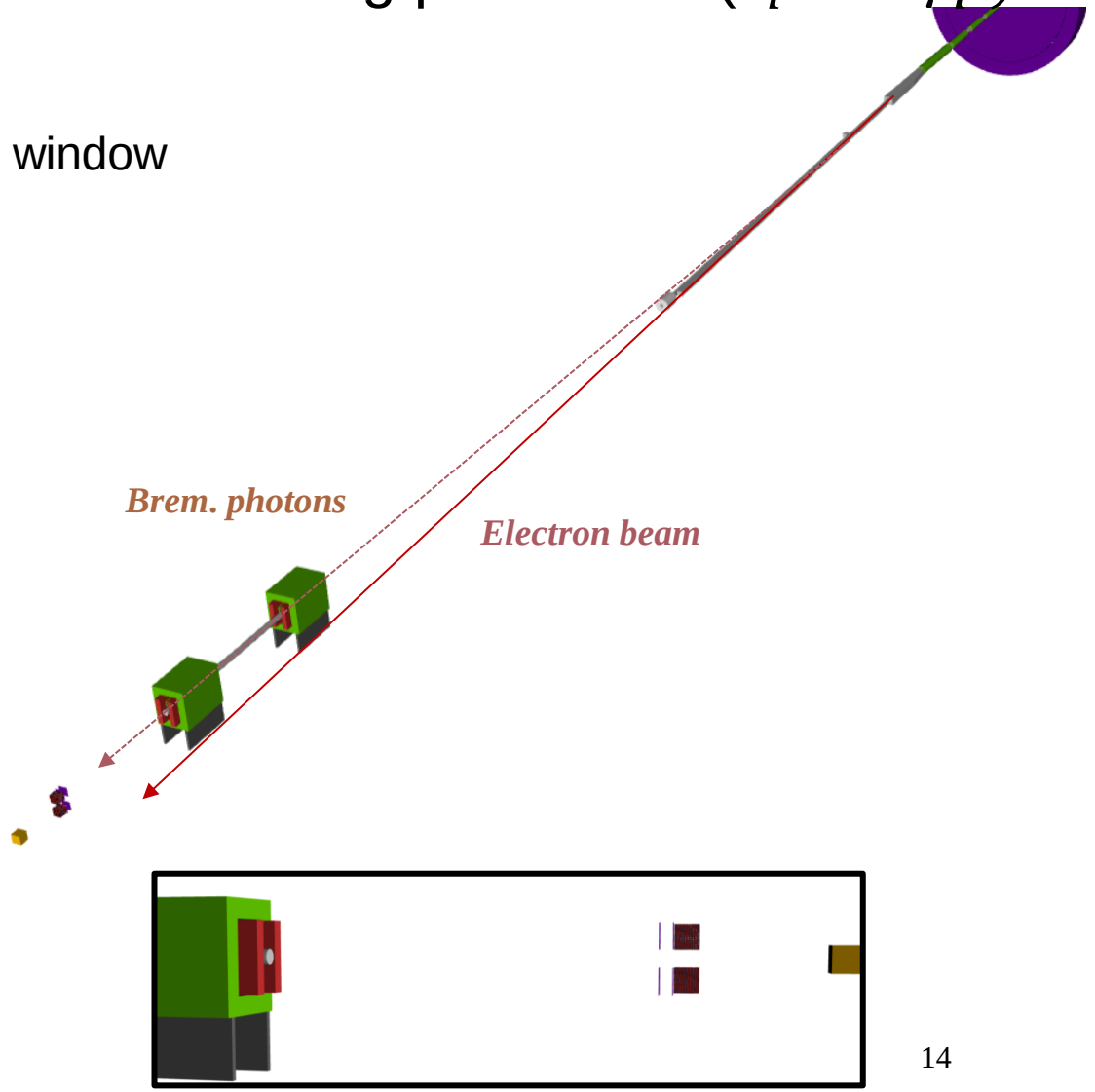

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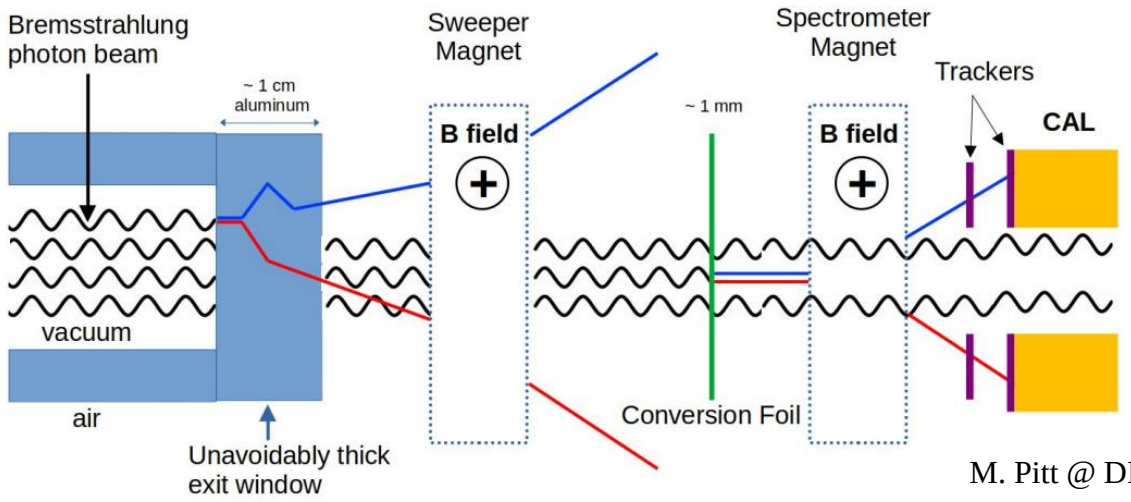
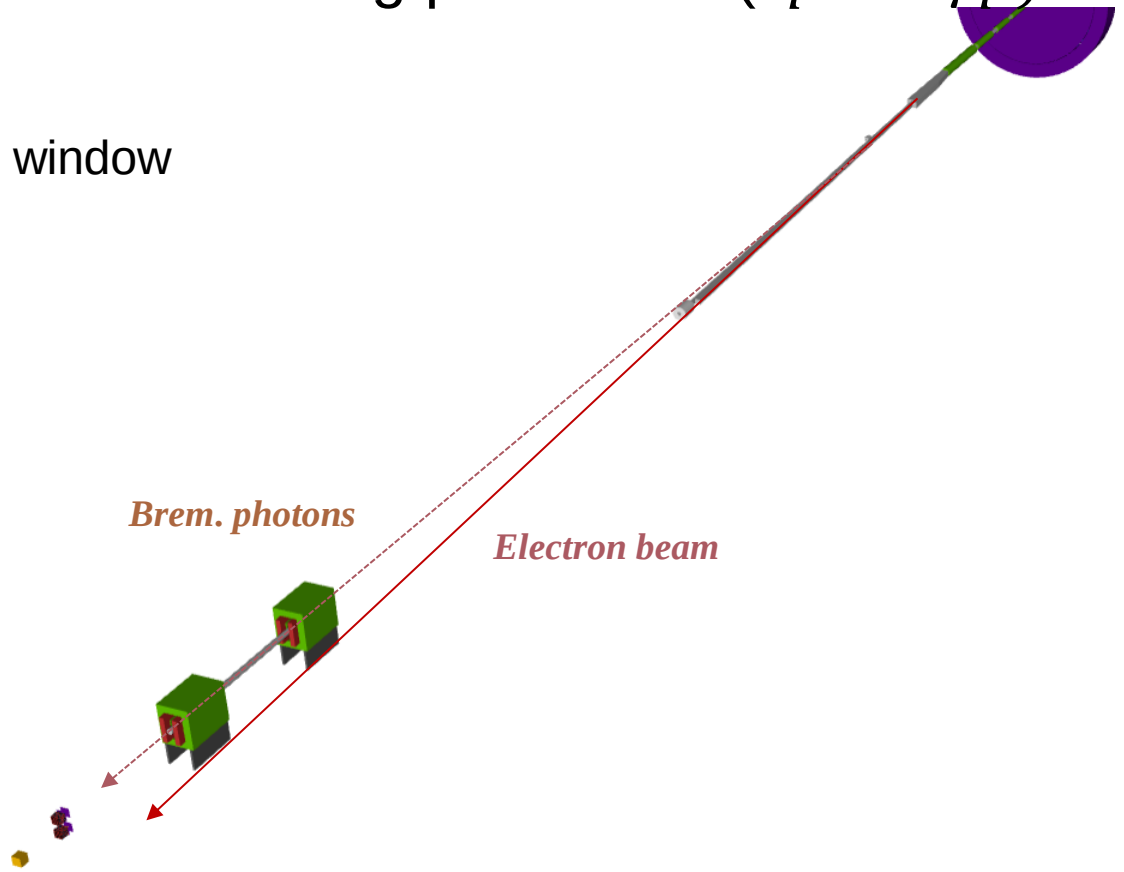
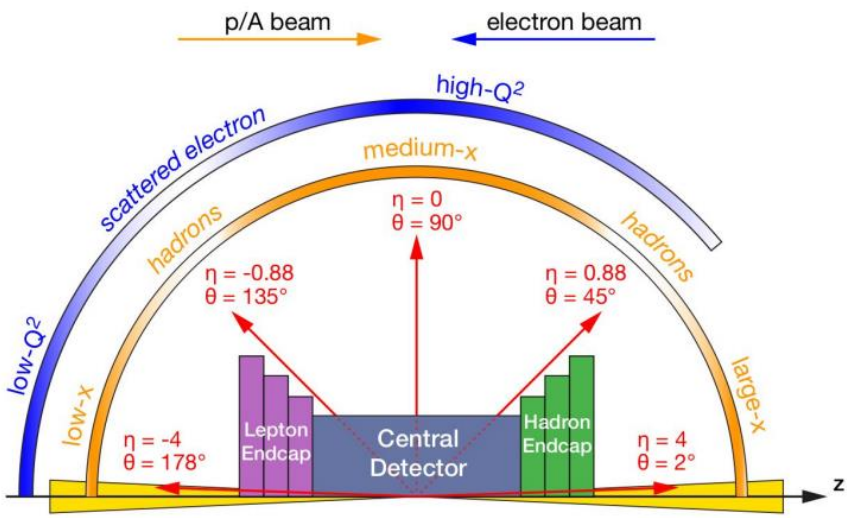
  - Pair spectrometer:
    - ✓ Tracker: AC-LGAD strips with 20um resolution
    - ✓ Calorimeter: Scintillating Fiber, $23X_0$

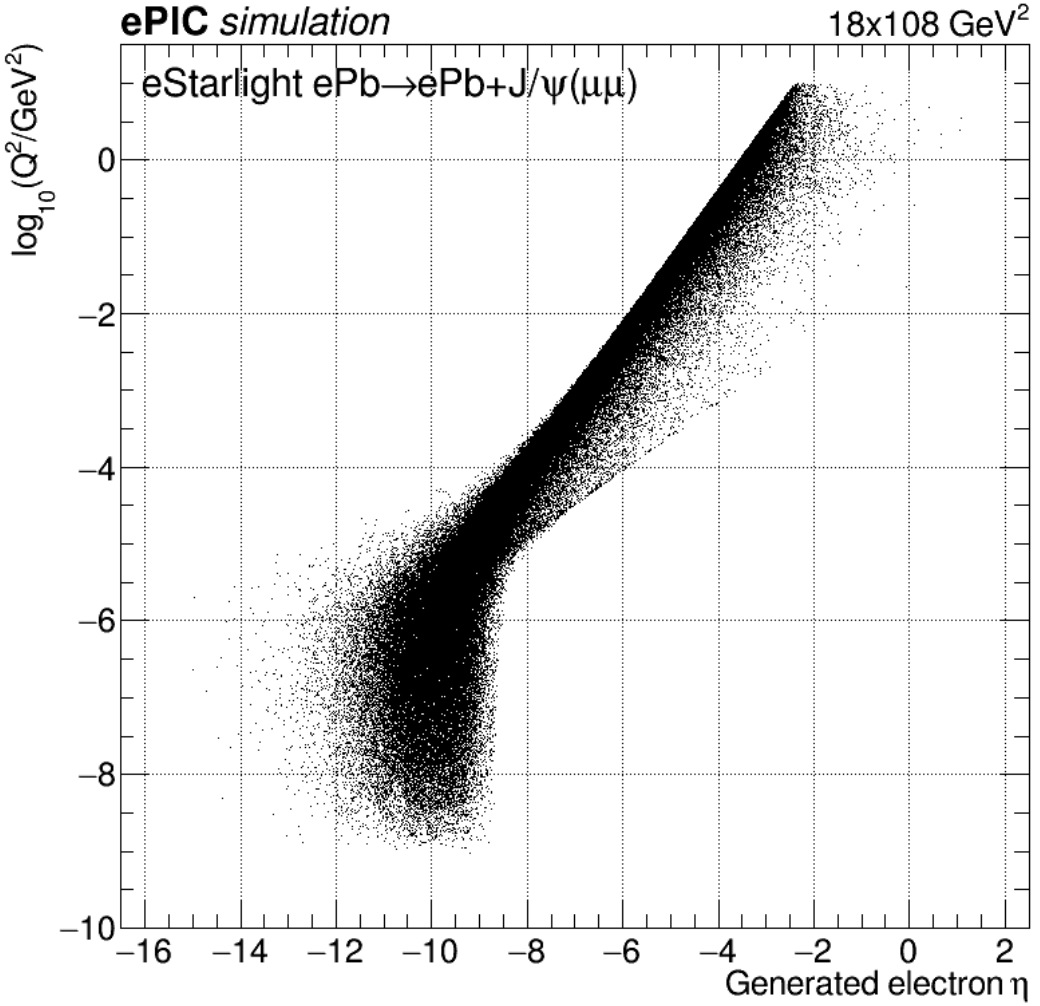




Low Q^2 electron tagger

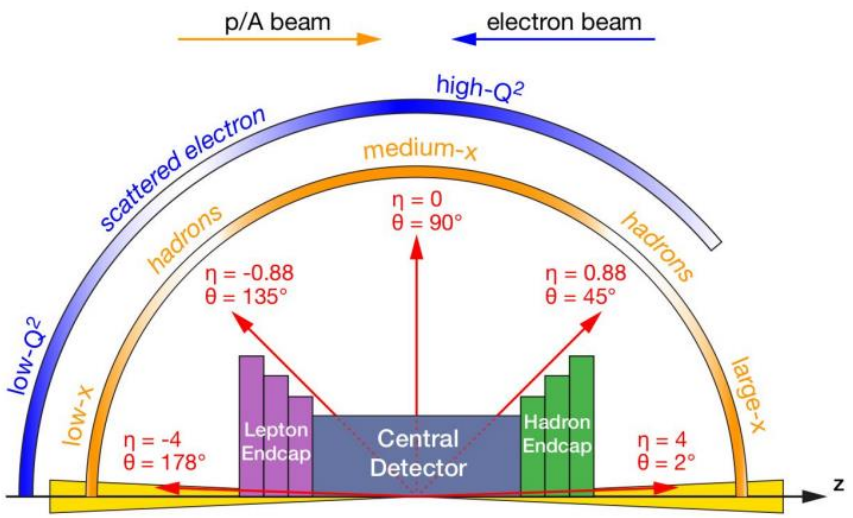
- Photon virtuality (Q^2) is reflected in the scattering angle of the outgoing electron

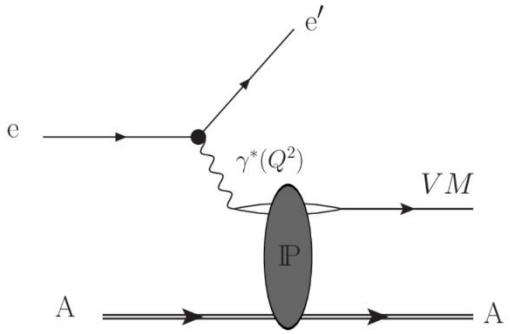


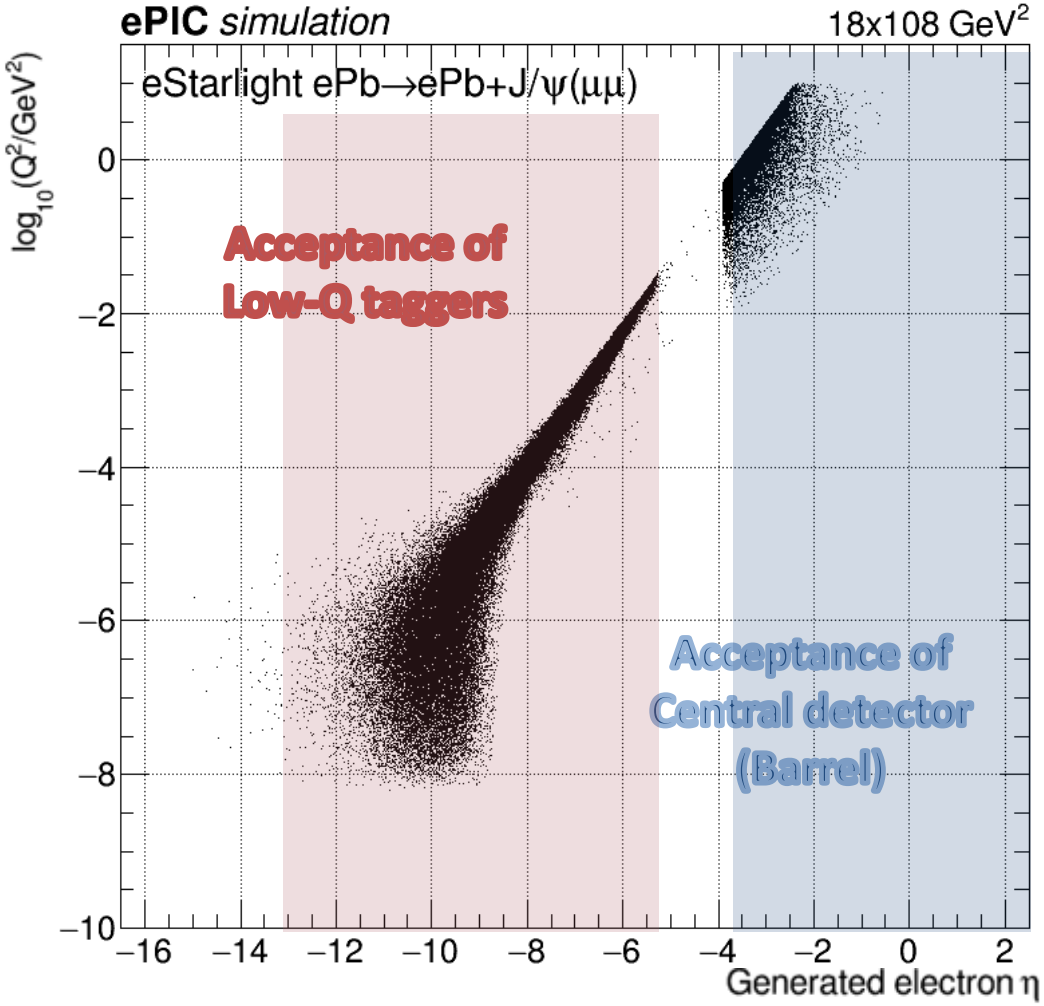


Low Q^2 electron tagger

- Central detector acceptance: $Q^2 > 0.1$ GeV^2 outgoing electrons

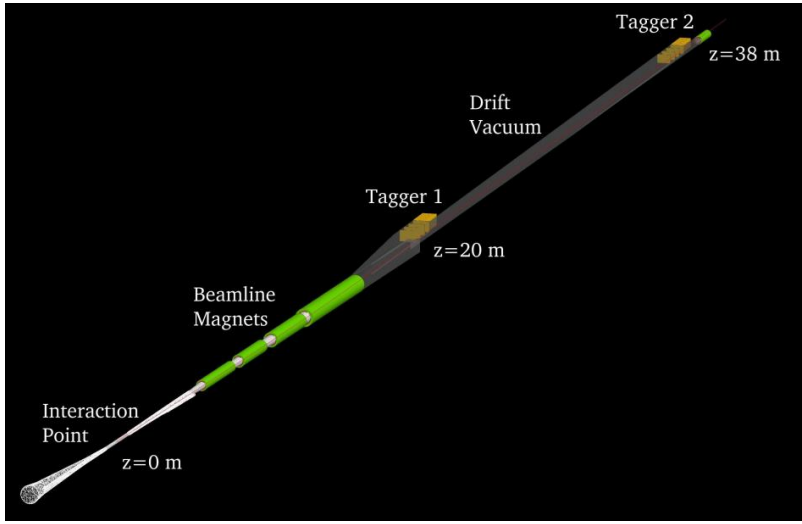


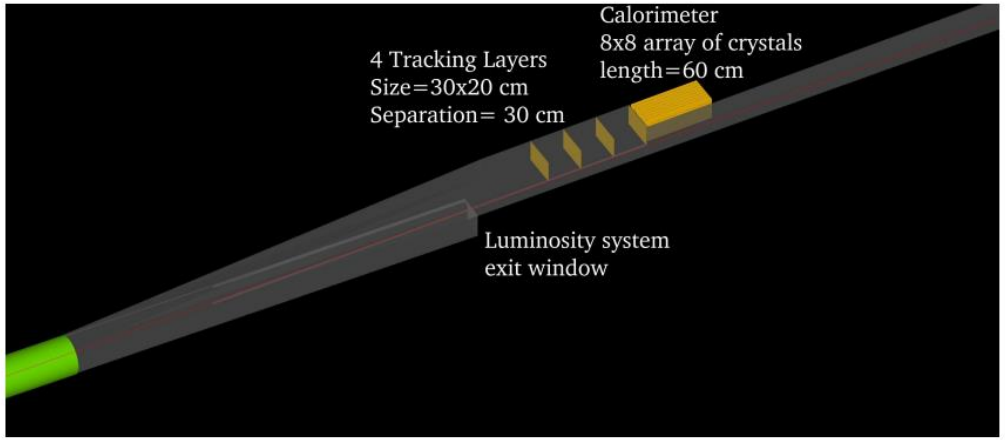


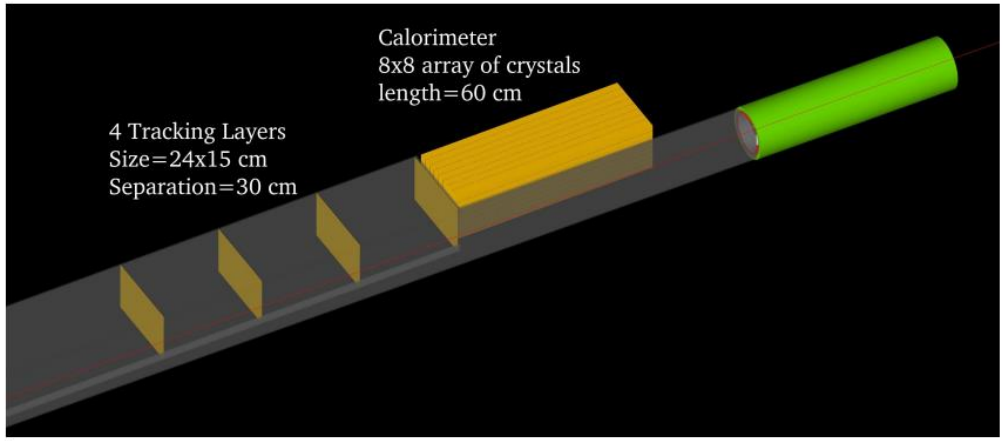


Low Q^2 electron tagger

- Central detector acceptance: $Q^2 > 0.1$ GeV^2 outgoing electrons
- Allow quasi real (Q<<1) physics
  - 2 taggers:
    - ✓ Pixel-based 4 trackers (Timepix4), with rate capability of > 10 tracks per bunch
    - ✓ Calorimeters (for calibration)
  - Challenges: high, non-uniform Brem. background

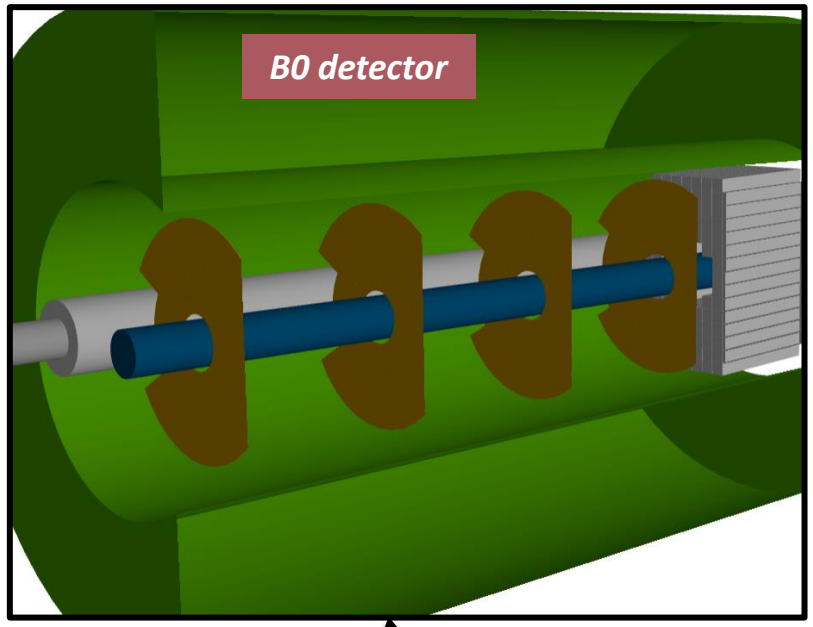






https://arxiv.org/abs/2305.02079

The Far-Forward detectors



Hadron beam

ZDC

B2apf

B1apf

Focusing quadrupoles

Off-momentum Detectors (OMD)

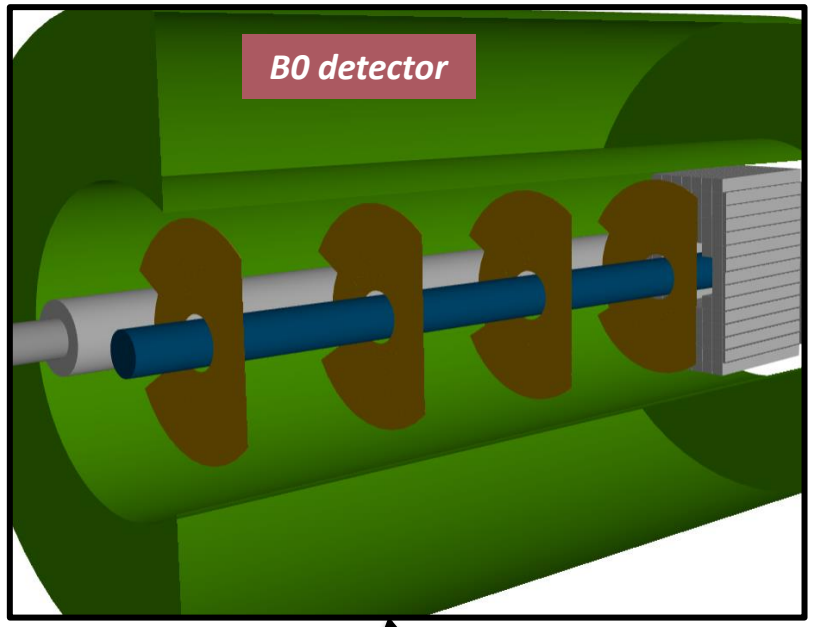
Roman Pots

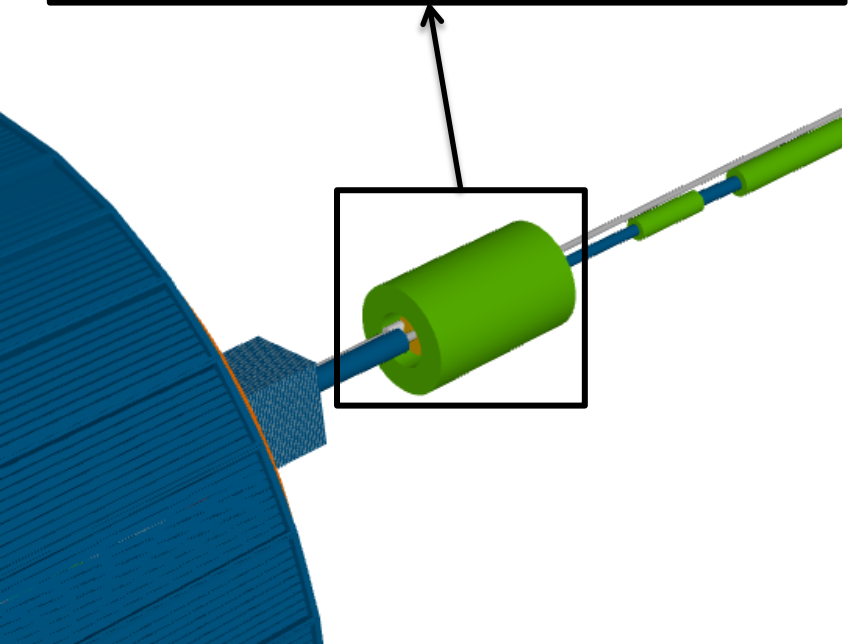
Forward beamline trackers

B0pf combined function magnet

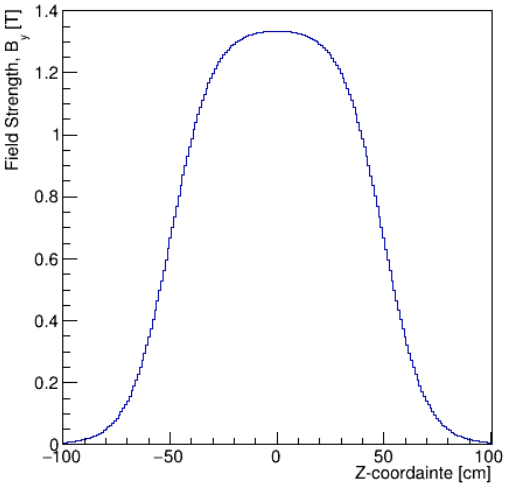
Detector	Acceptance
Zero-Degree Calorimeter (ZDC)	θ < 5.5 mrad (η > 6)
Roman Pots (2 stations)	0.0* < θ < 5.0 mrad (η > 6)
Off-Momentum Detectors (2 stations)	0.0 < θ < 5.0 mrad (η > 6)
B0 Detector	5.5 < θ < 20 mrad (4.6 < η < 5.9)

The Far-Forward detectors





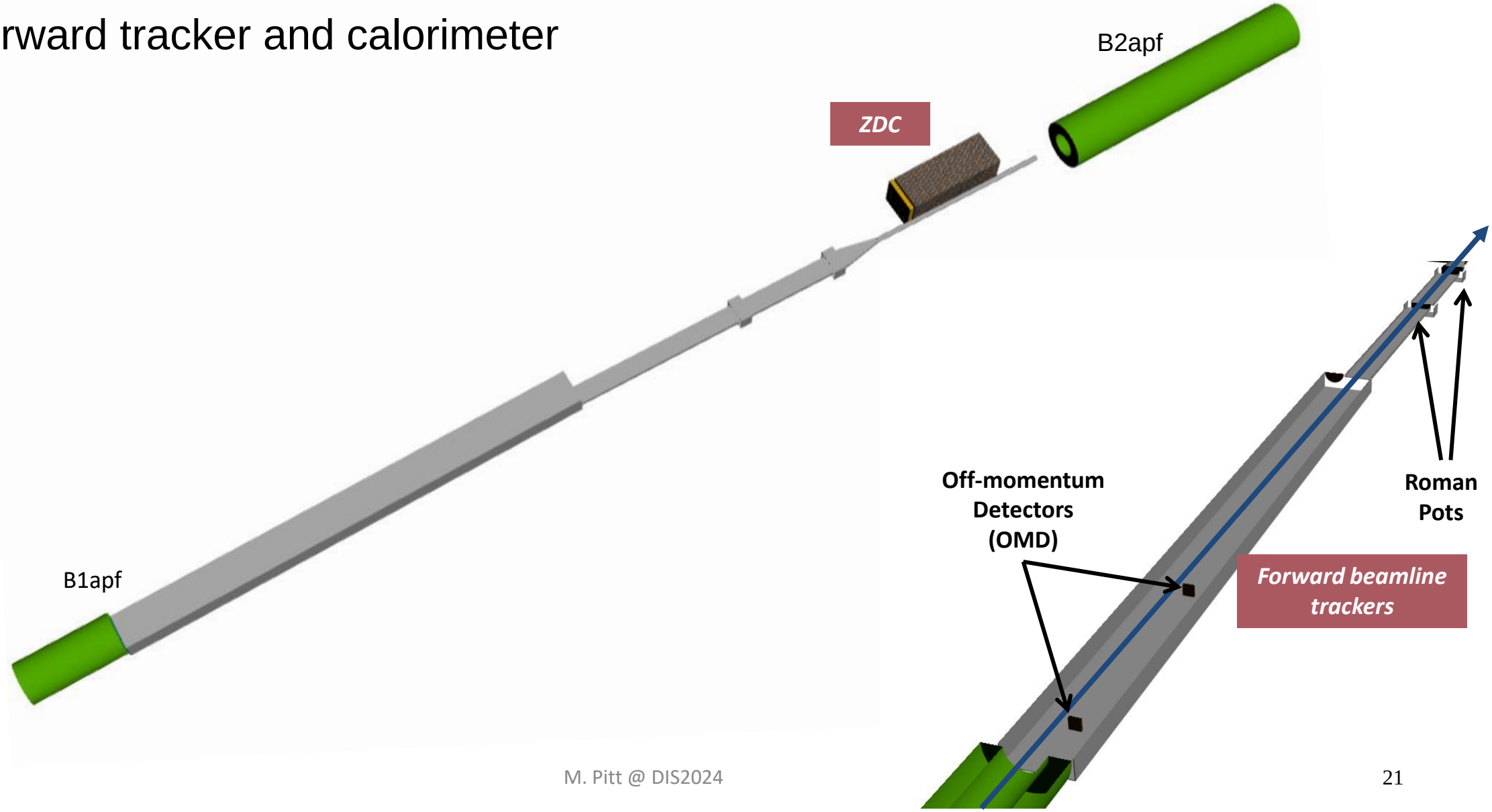
- Acceptance 5.5 < θ < 20 mrad
- Very low material budget in 5 < η < 5.5
  - ➢ Si Tracker: 4 Layer of AC-LGAD
  - ➢ EM Calorimeter: 20 cm LYSO crystals



- **Photons:**
  - ➢ High acceptance in a broad energy range (> 50 MeV), including ~MeV de-excitation photons
  - ➢ Energy resolution of 6-7%
  - ➢ Position resolution of ~3 mm
- **Protons:**
  - ➢ Momentum resolution (dp/p) of ~ 2-4%
- **Neutrons:**
  - ➢ 50% detection efficiency (λ is almost 1)

The Far-Forward detectors

- Very Forward tracker and calorimeter



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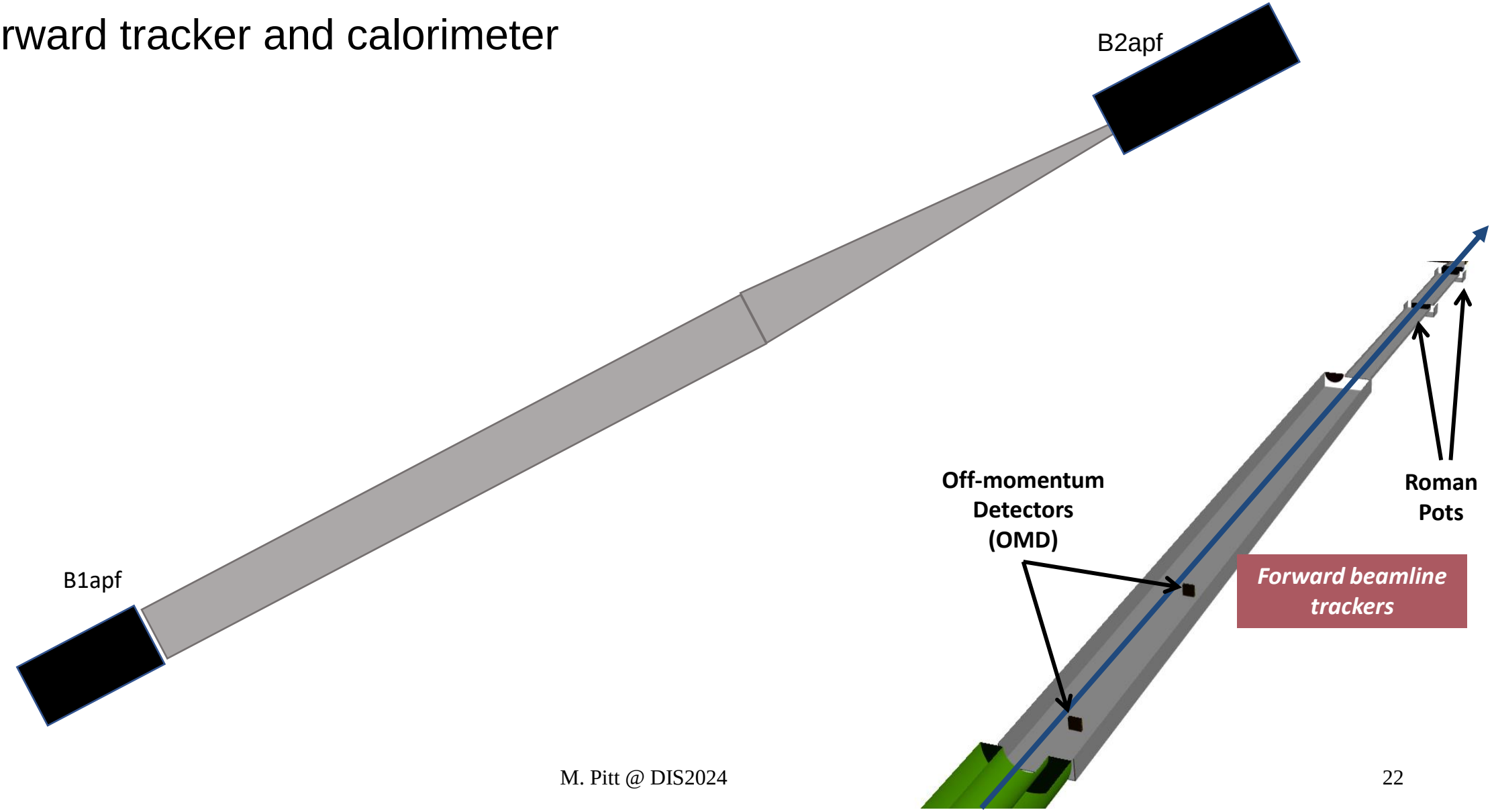
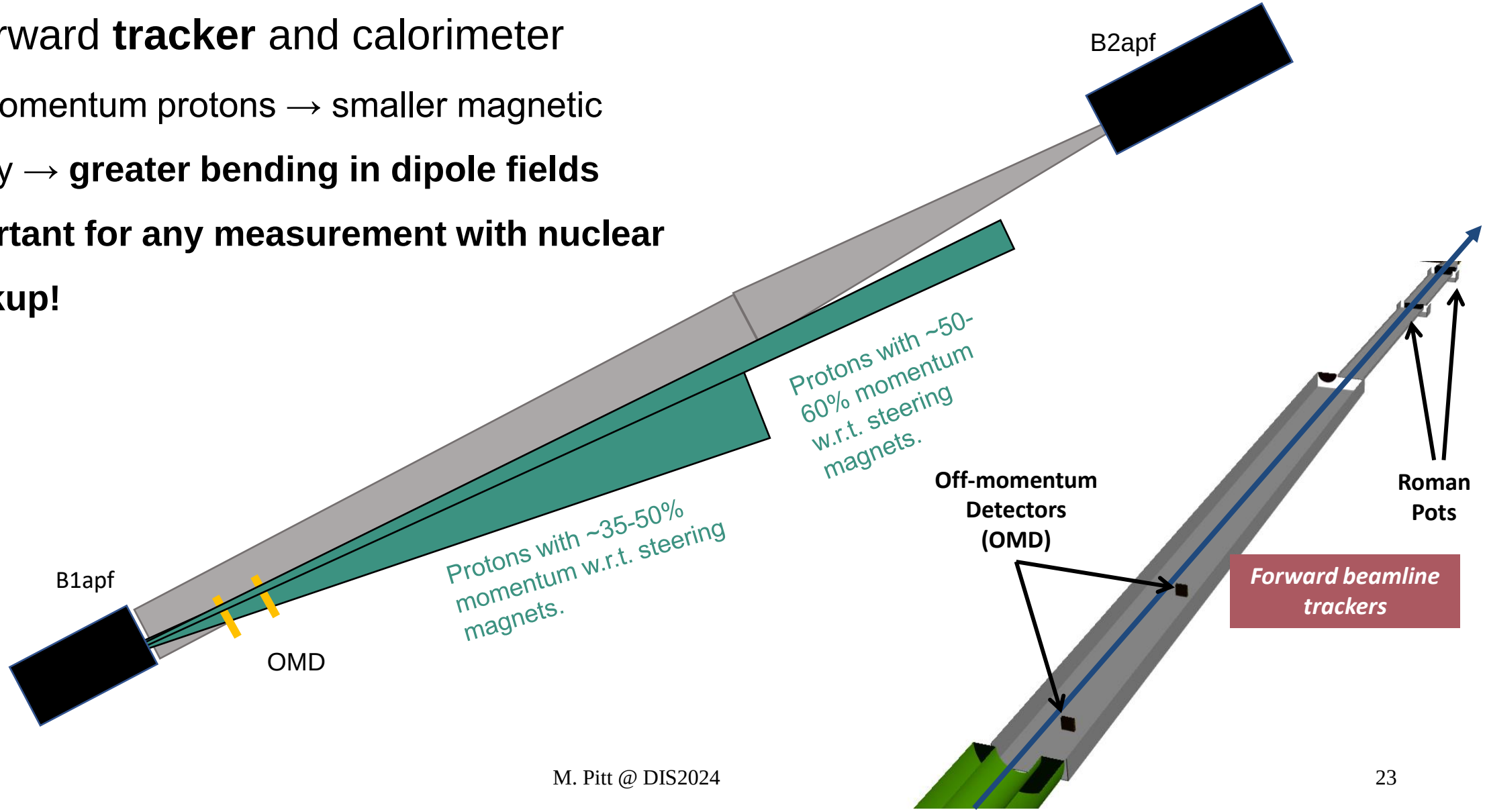


The Far-Forward detectors

- Very Forward **tracker** and calorimeter
  - Off-momentum protons → smaller magnetic rigidity → **greater bending in dipole fields**
  - **Important for any measurement with nuclear breakup!**



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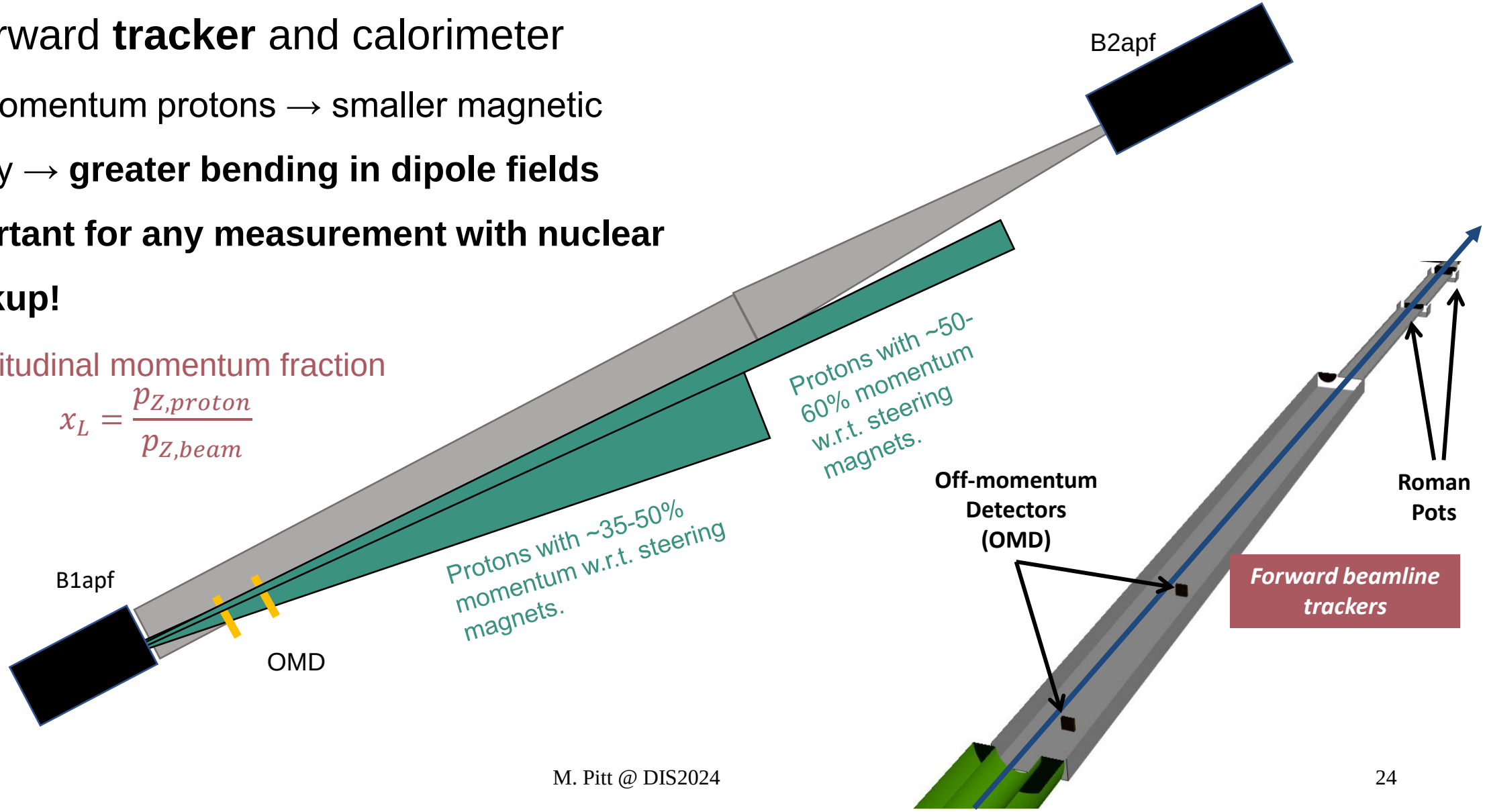
Longitudinal momentum fraction

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



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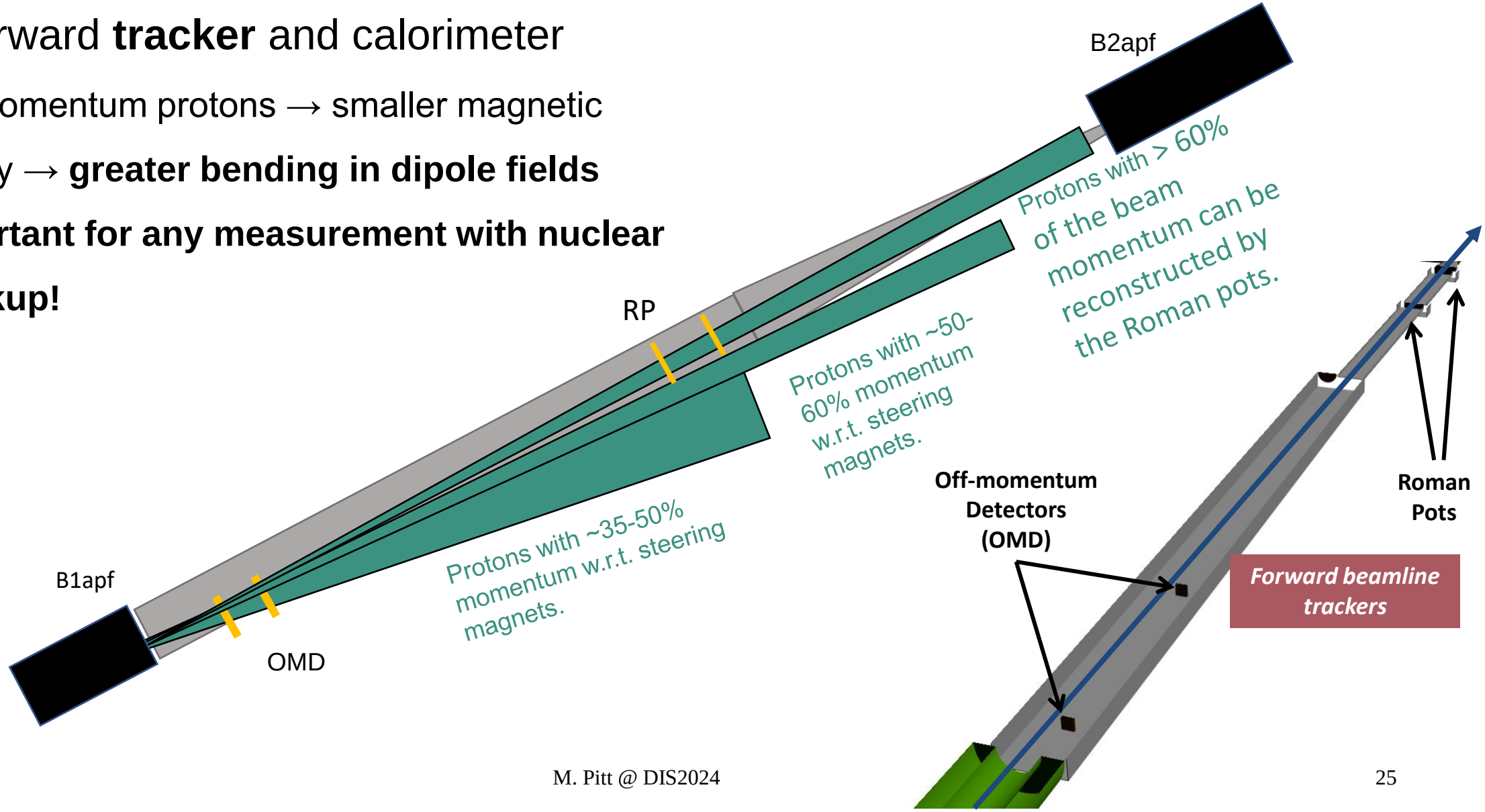
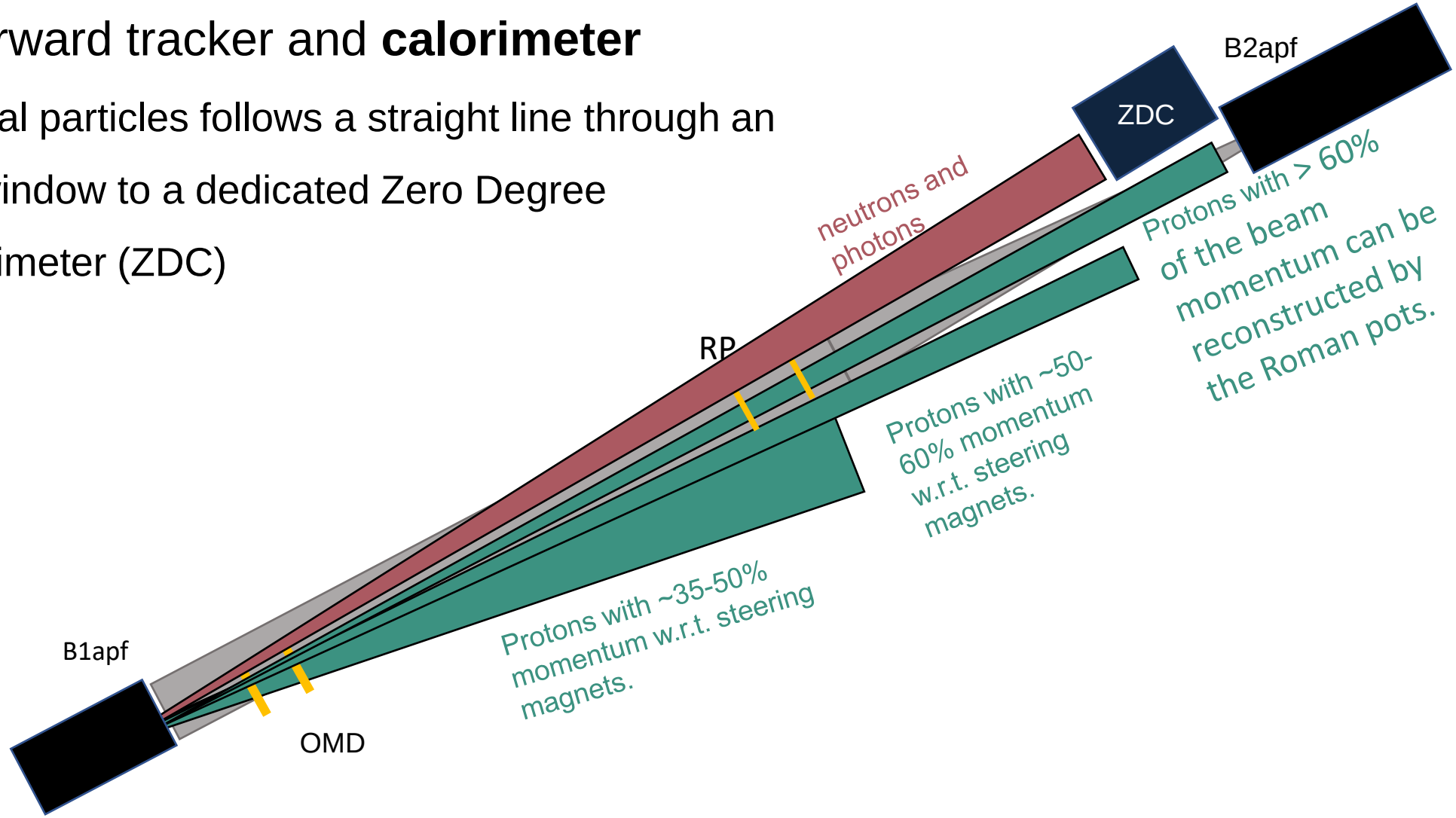


The Far-Forward detectors

- Very Forward tracker and **calorimeter**
  - Neutral particles follows a straight line through an exit window to a dedicated Zero Degree Calorimeter (ZDC)



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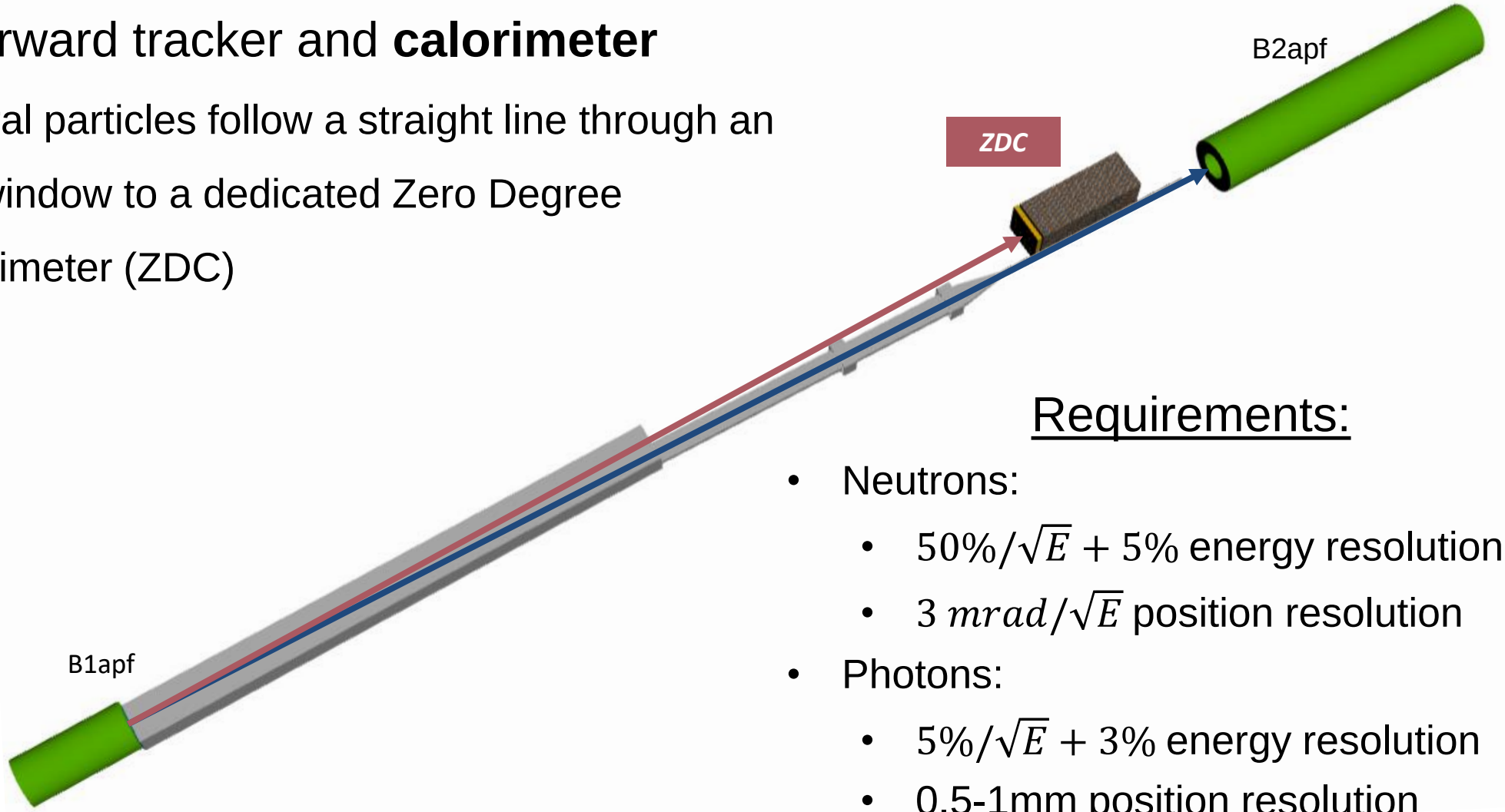
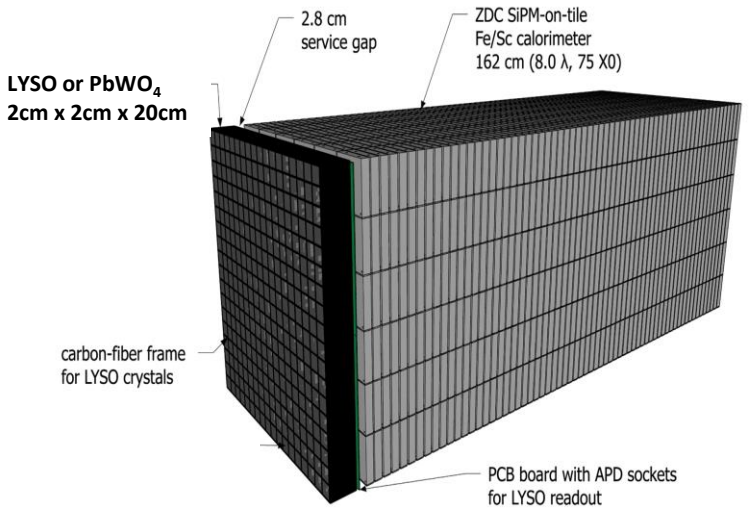


Requirements:

- Neutrons:
  - $50\%/\sqrt{E} + 5\%$ energy resolution
  - $3\ mrad/\sqrt{E}$ position resolution
- Photons:
  - $5\%/\sqrt{E} + 3\%$ energy resolution
  - 0.5-1mm position resolution

The Far-Forward detectors

- Zero Degree Calorimeter (ZDC)
  - EM section – 20 cm long LYSO or $PbWO_4$ crystals



The Far-Forward detectors

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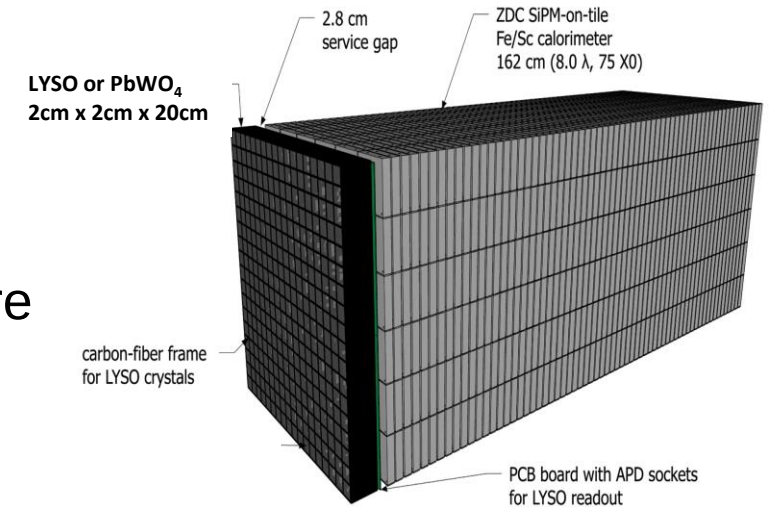
  - Hadronic section – similar to forward hadron calorimeter (see more on ePIC calorimeters in Henry Klest talk)



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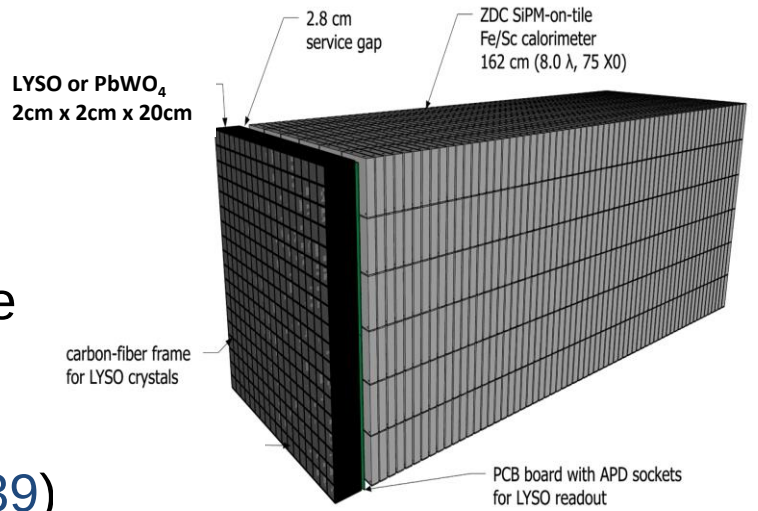
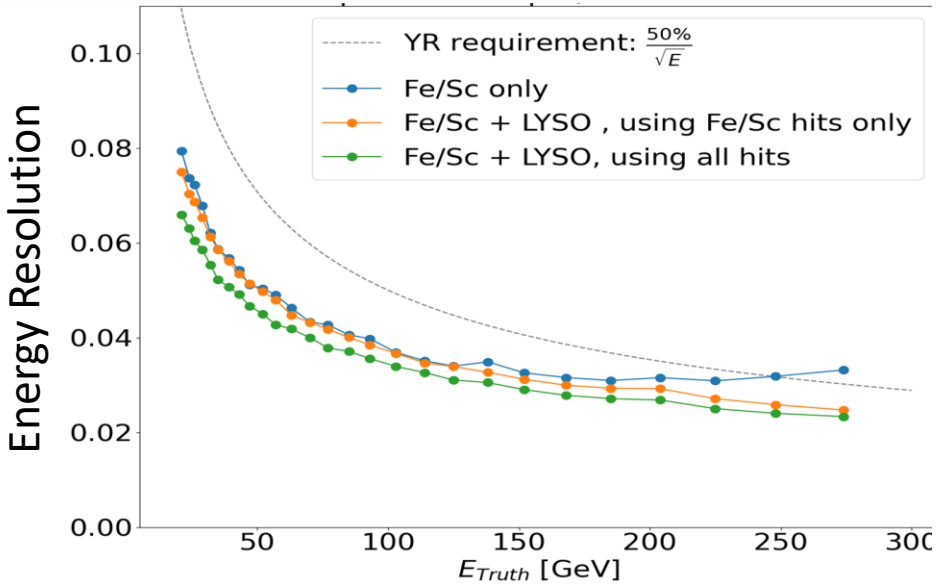
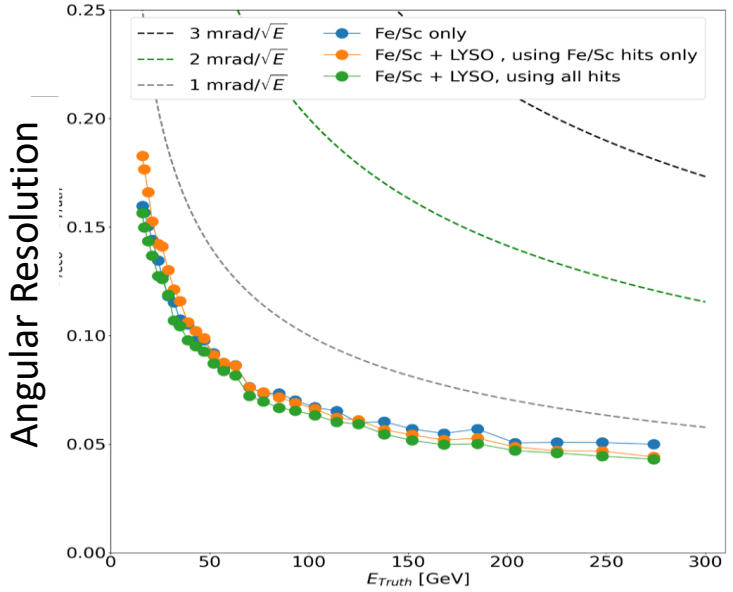
  - ML based reconstruction using the HEXPLIT algorithm (2308.06939)



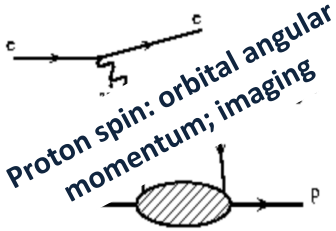




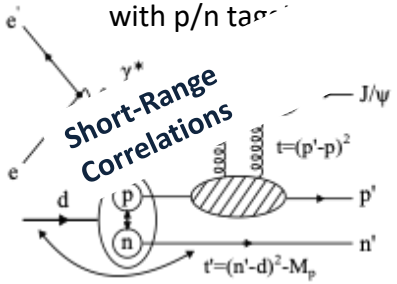
Physics perspectives

- Far-Forward and Far-Backward detectors also enable a broader physics program than was initially envisioned, enhancing the EIC's research potential:

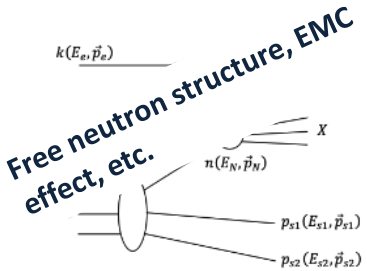
e+p DVCS



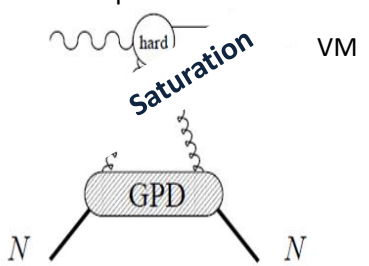
e+d exclusive J/Psi with p/n tag



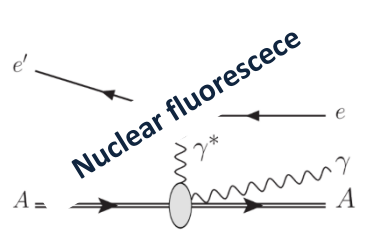
spectator tagging in light nuclei



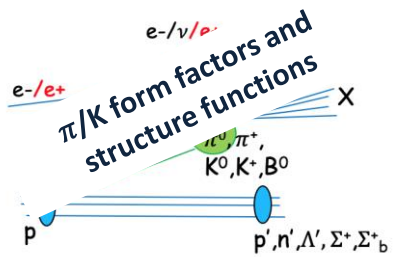
coherent/incoherent VM production in



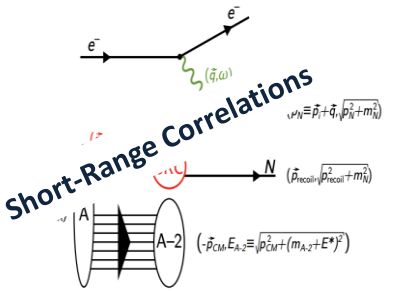
Ion-deexitation in eA collisions



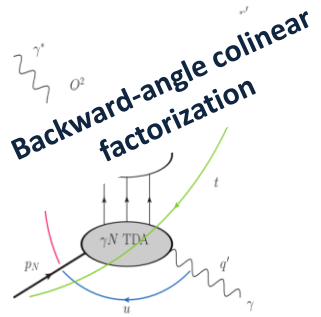
Sullivan process



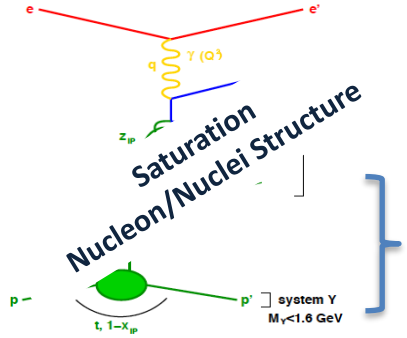
Quasi-elastic electron scattering



u-channel backward exclusive electroproduction

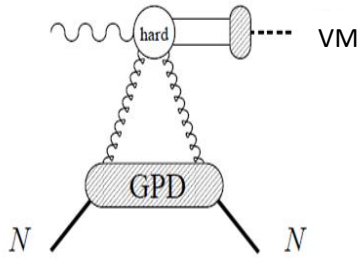


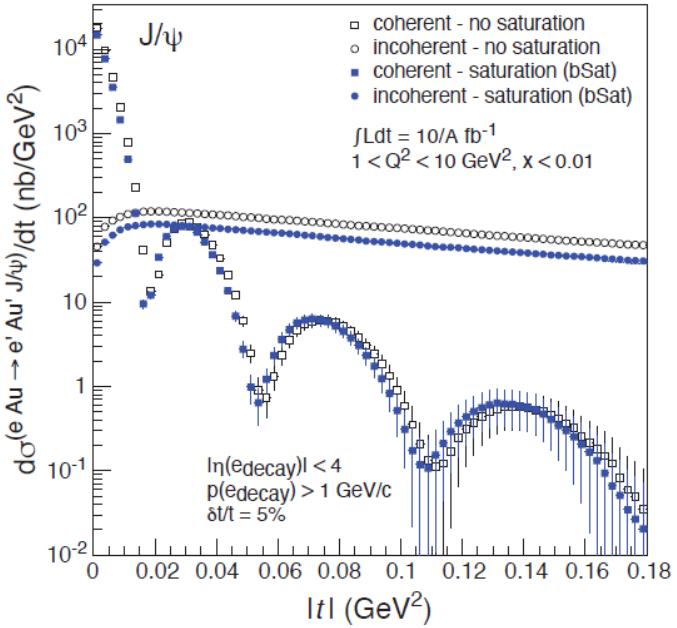
Diffraction



Physics perspectives (examples)

- Coherent VM production (Saturation)
  - Challenge: Large backgrounds (incoherent production processes)





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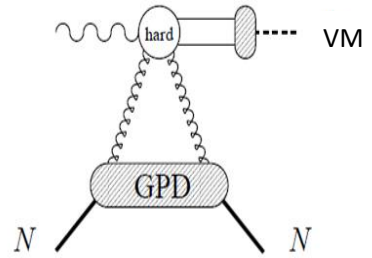
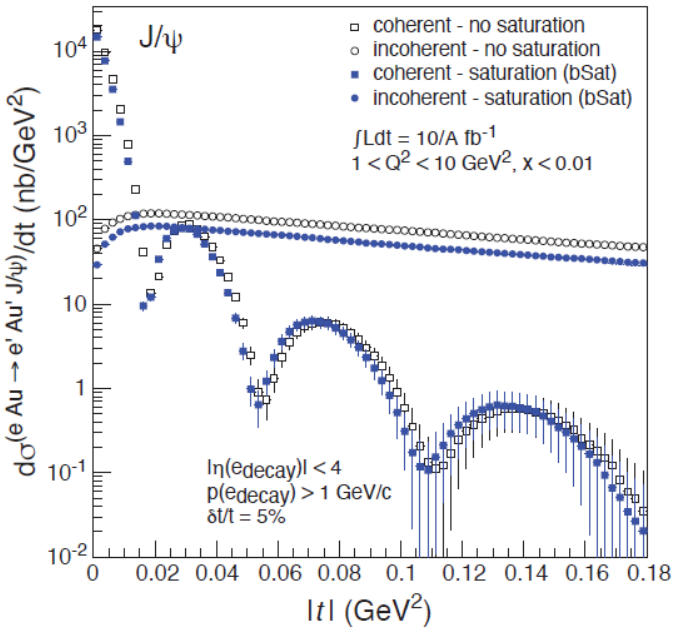
Physics perspectives (examples)

- Coherent VM production in eA collisions
  - Challenge: Large backgrounds (incoherent production processes)
  - The forward detectors array allows strong background rejection





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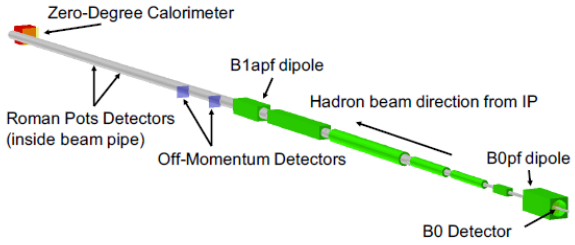
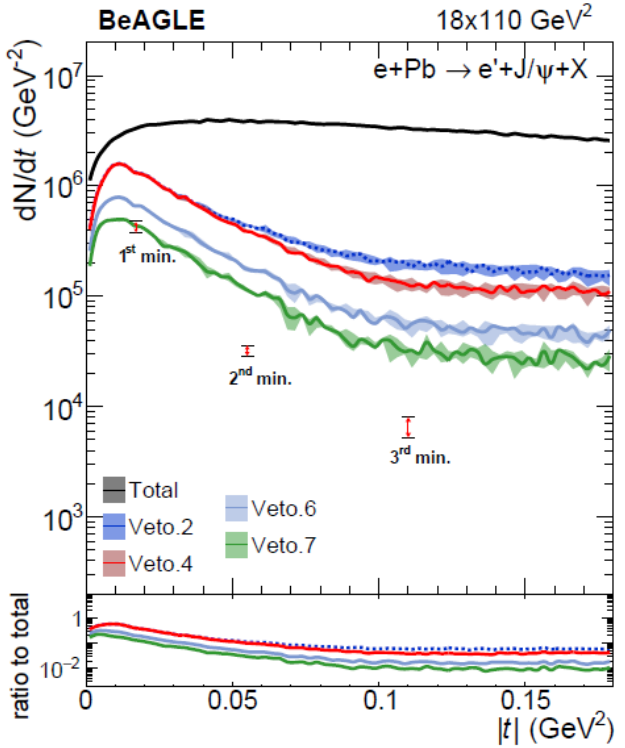


- Veto.1: no activity other than e^- and J/ψ in the main detector ($|\eta| < 4.0$ and $p_T > 100$ MeV/c) ;
- Veto.2: Veto.1 and no neutron in ZDC;
- Veto.3: Veto.2 and no proton in RP;
- Veto.4: Veto.3 and no proton in OMDs;
- Veto.5: Veto.4 and no proton in B0;
- Veto.6: Veto.5 and no photon in B0;
- Veto.7: Veto.6 and no photon with $E > 50$ MeV in ZDC.

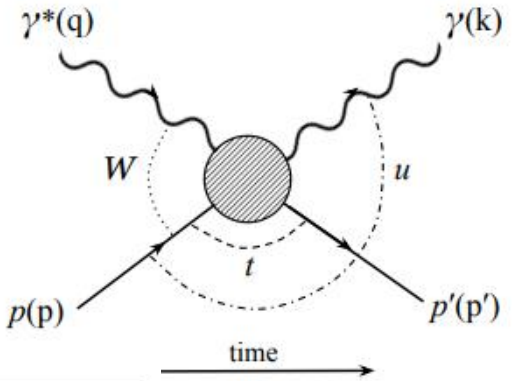
=

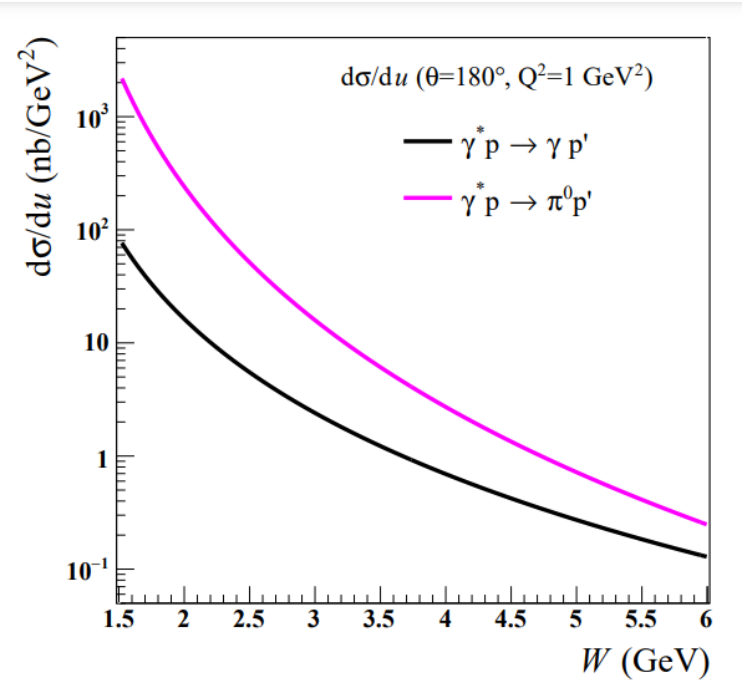


PRD **104** (2021) 11, 114030

Physics perspectives (examples)

- Virtual Compton scattering (u-channel)
- Challenge: Large backgrounds from π^0 production
- Background rejection – well-segmented ZDC ($\Delta x^{\gamma\gamma} \approx 70 \cdot m_\pi / E_{beam}$ [meter])





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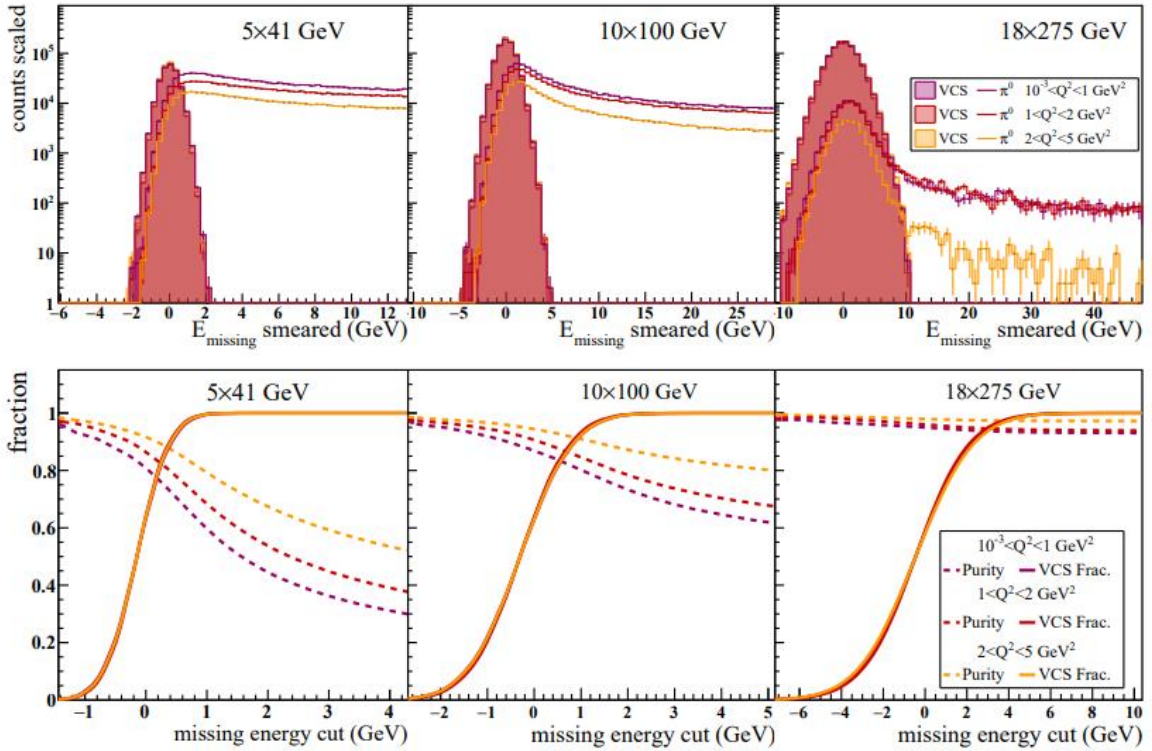


Summary

- All Far-Forward and Far-Backward detector acceptances and detector performance are well-understood with currently available information
- There is an impressive extension of the nominal physics program[1] foreseen with the current detectors
- A large focus has been placed now on simulation studies of various processes in preparation for the ePIC Technical Design Report (TDR)

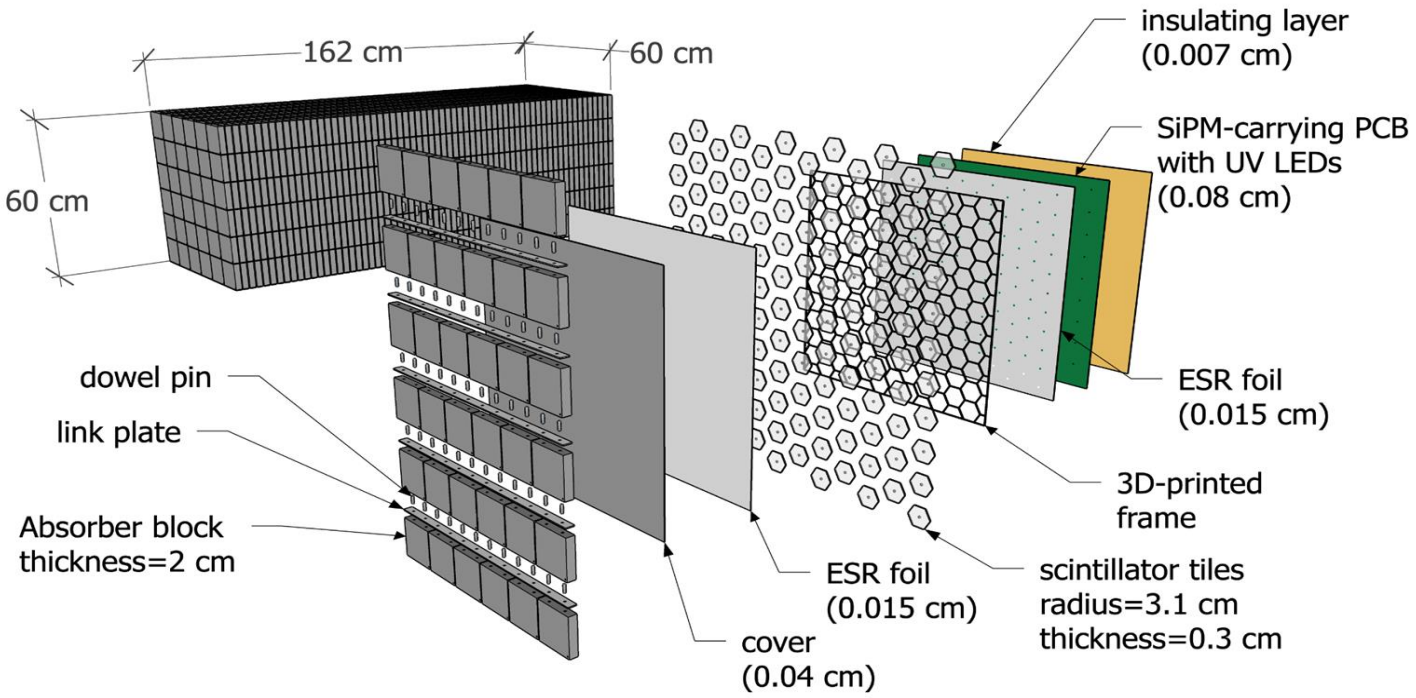
Coming soon[2]: the full list of the physics projections for the ePIC detector

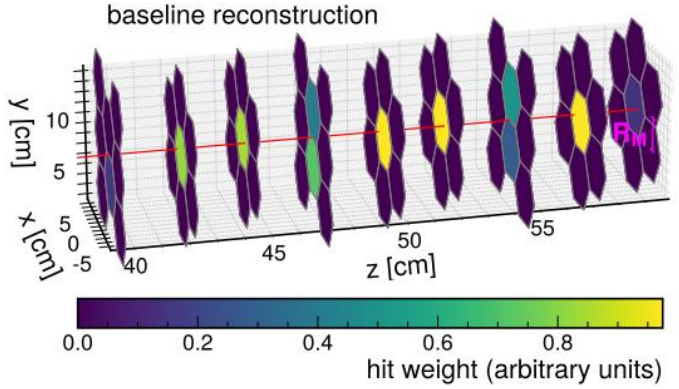
[1] EIC Yellow report (Nucl. Phys. A 1026 (2022) 122447)
[2] Early 2025

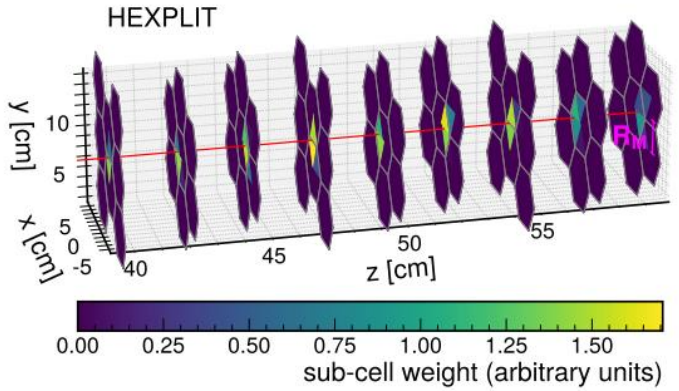
Backup

The Far-Forward detectors

- Zero Degree Calorimeter (ZDC)
  - Hadronic section – similar to forward hadron calorimeter (see more in Henry Klest talk)
  - ML based reconstruction using the HEXPLIT algorithm (2308.06939)







Other DIS talks

- EIC, HL-LHC, Forward physics (Mon 14:40)

https://lpsc-indico.in2p3.fr/event/3268/contributions/7216/

- Overview of the ePIC Detector (Wed 10:20)

https://lpsc-indico.in2p3.fr/event/3268/contributions/7417/

- Particle Identification with the ePIC detector at the EIC (Wed 11:00)

https://lpsc-indico.in2p3.fr/event/3268/contributions/7571/

- Calorimetry for the ePIC Experiment (Wed 12:00)

https://lpsc-indico.in2p3.fr/event/3268/contributions/7433/

- A 2nd Detector for the Electron-Ion Collider (Wed 12:20)

https://lpsc-indico.in2p3.fr/event/3268/contributions/7439/