EicC Far Forward Detector Update

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

- EicC 3rd CDR Workshop
- October 21st – 23rd 2022

Outline

- EIC far forward detector and related physics
- Current progress on EicC far forward design
    1. EDT and FDT update
    2. ZDC update
- Summary on current status and outlook

EIC Far Forward Detector

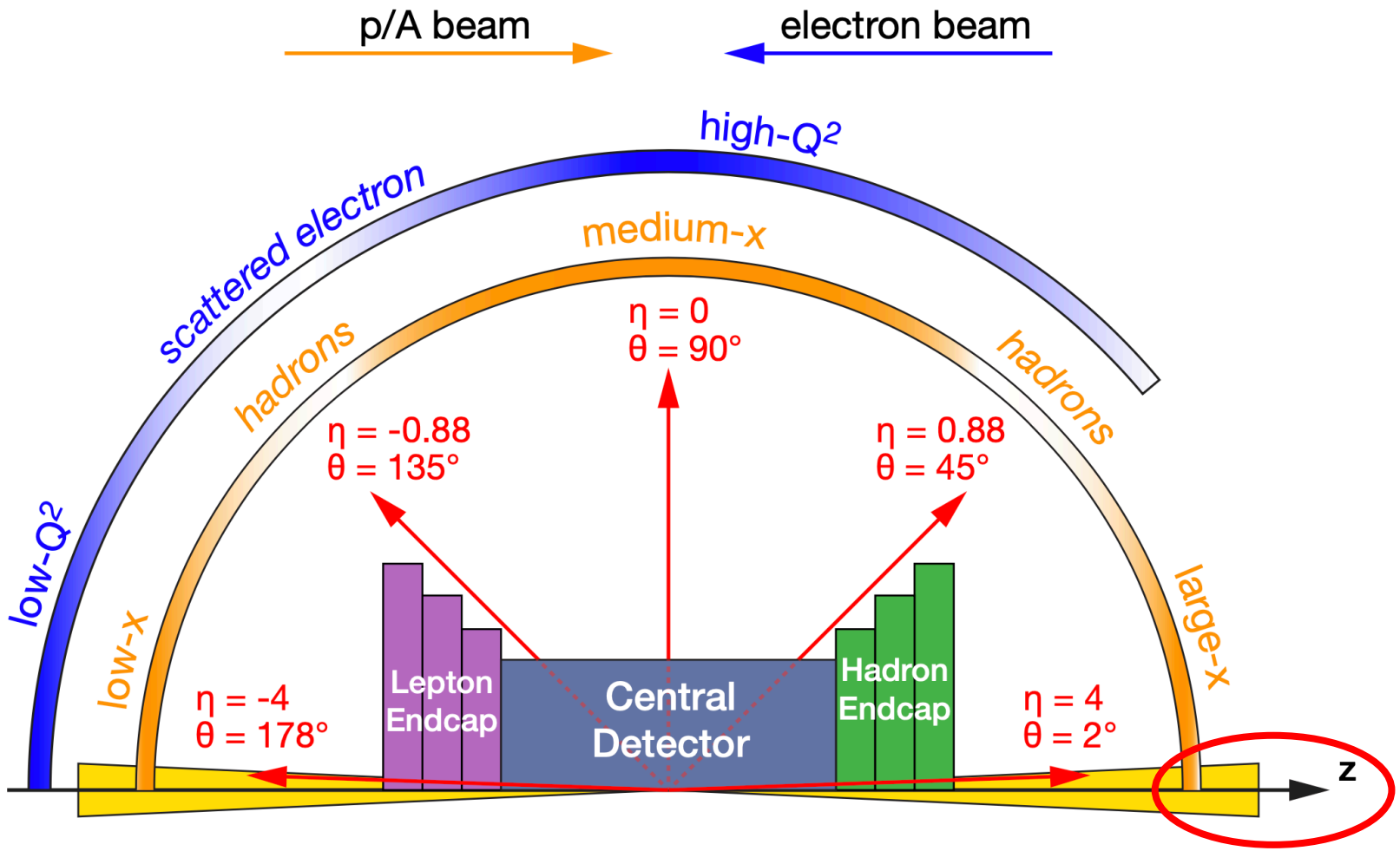
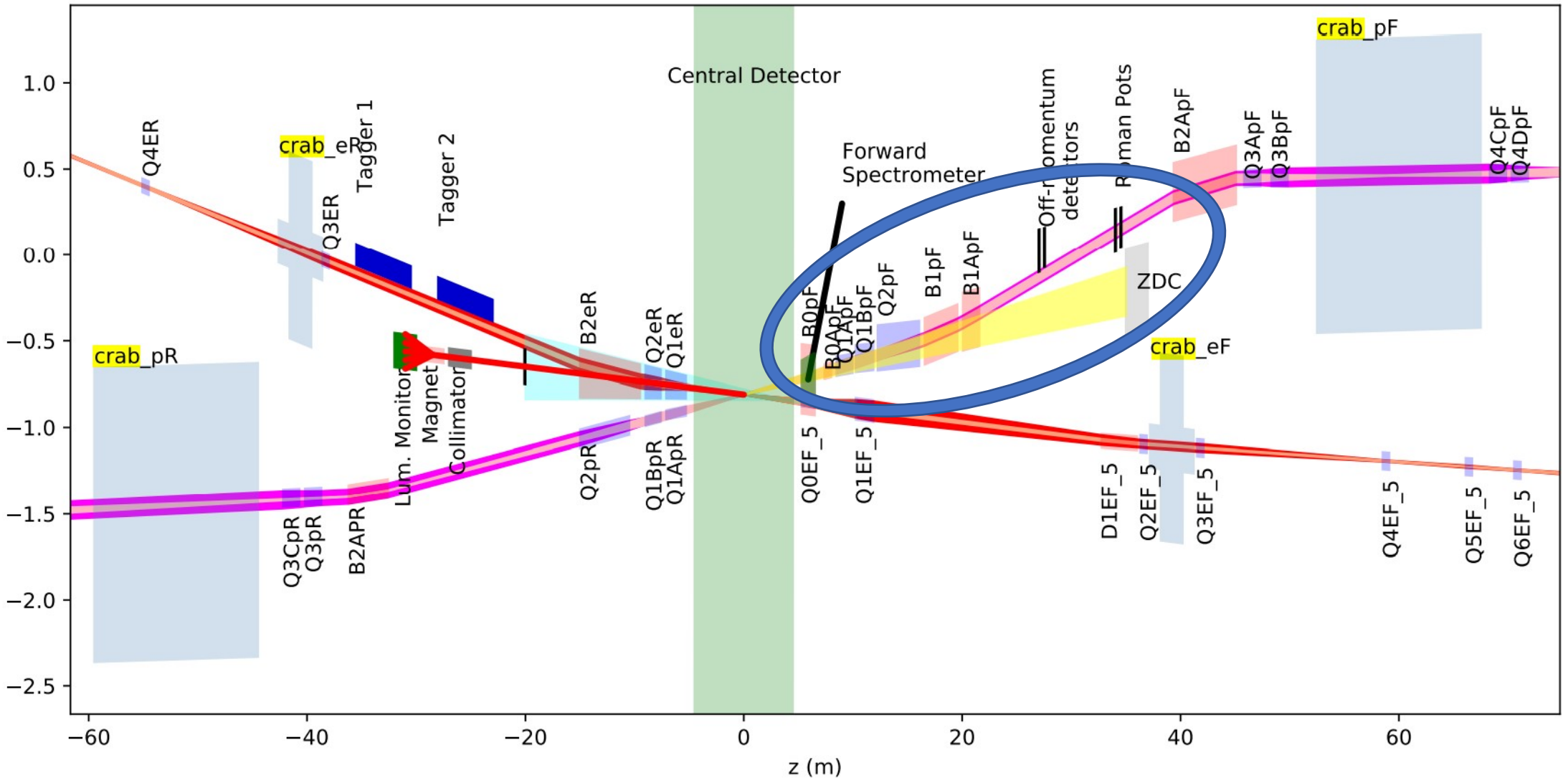


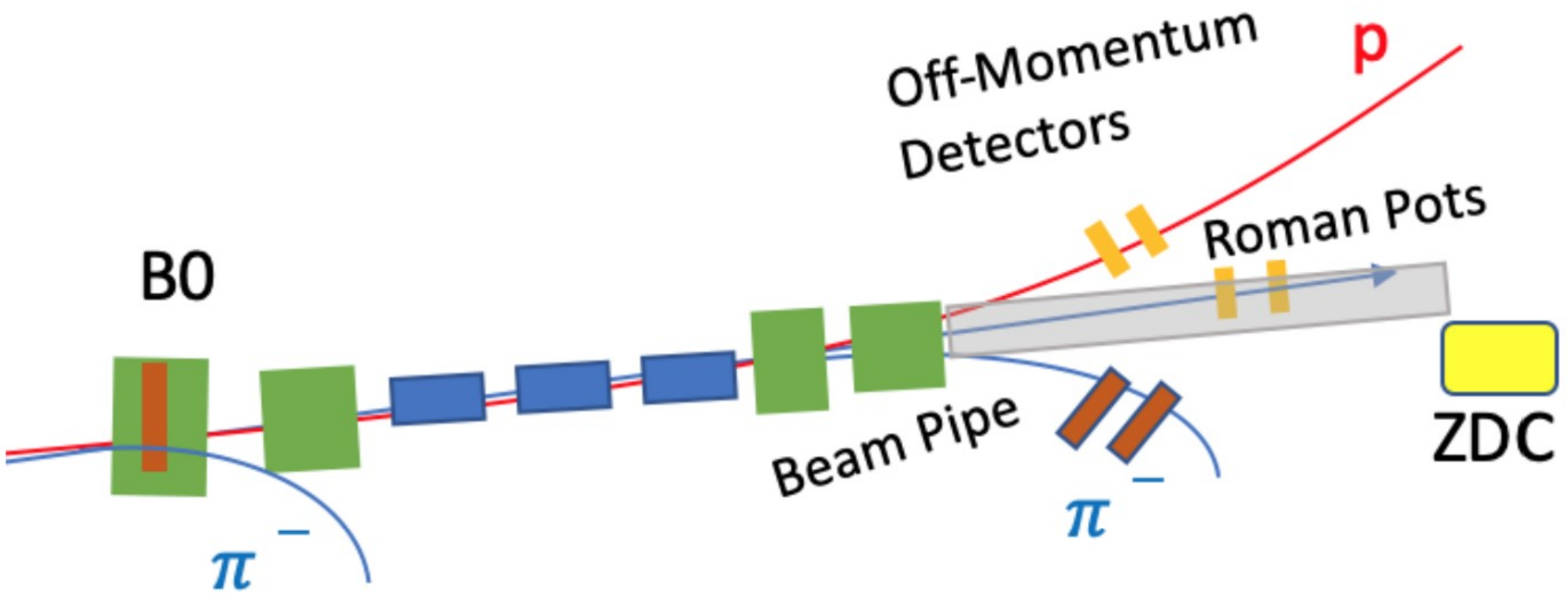
Figure 2.2: Schematic showing the distribution of the scattered lepton and hadrons for different $x - Q^2$ regions over the detector polar angle / pseudorapidity coverage.

Far-forward region

EIC Far Forward Detector

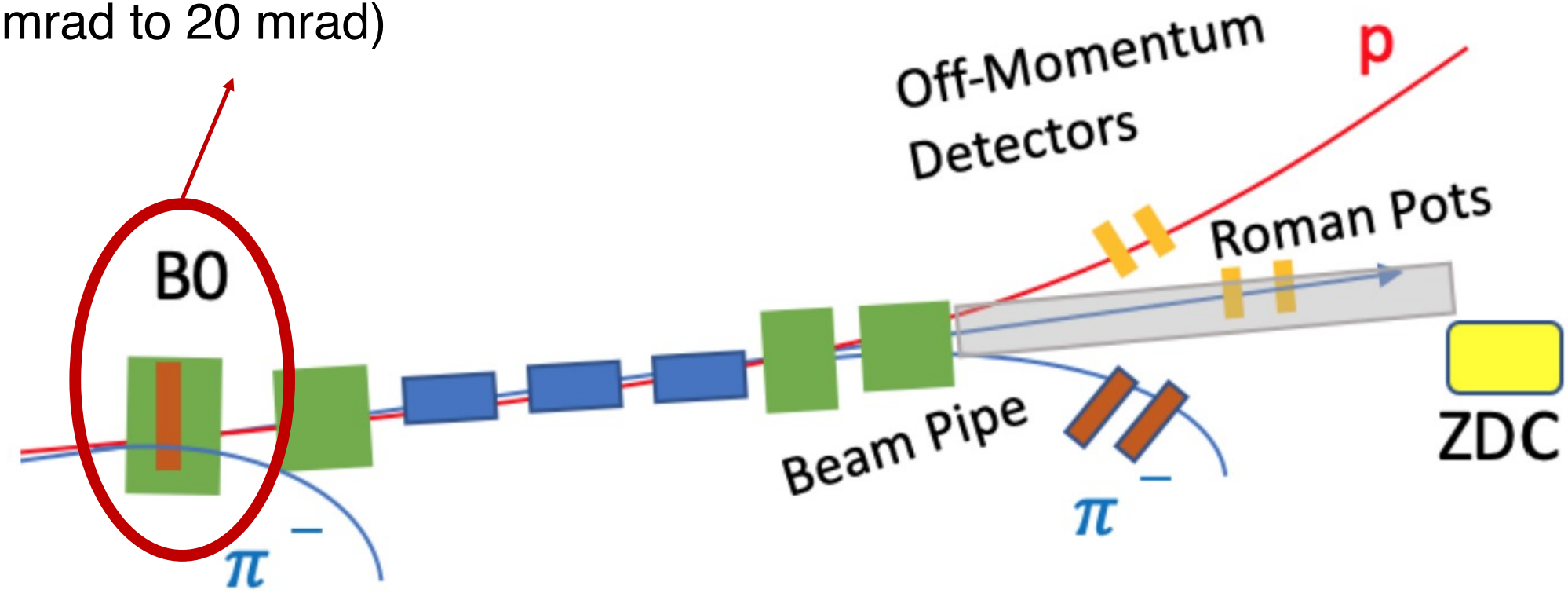


EIC Far Forward Detector



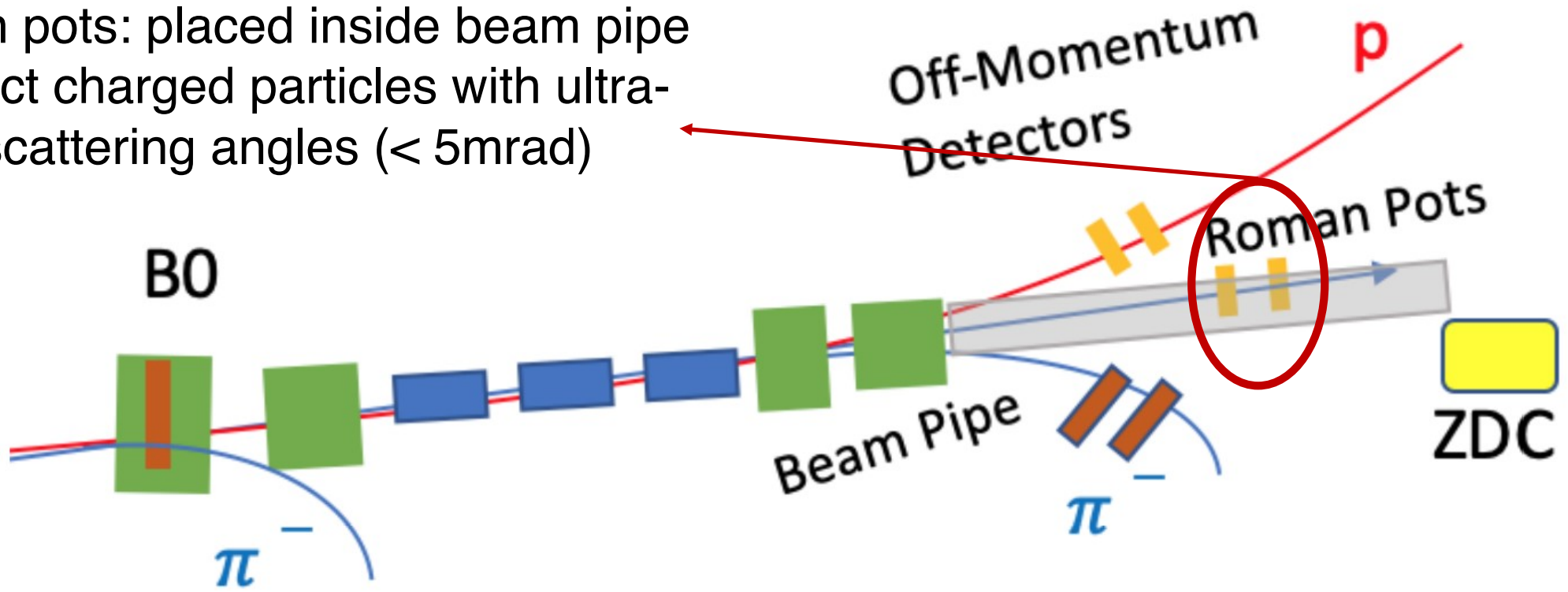
EIC Far Forward Detector

B0 spectrometer: detecting charged particles in the forward angular region (5.5 mrad to 20 mrad)

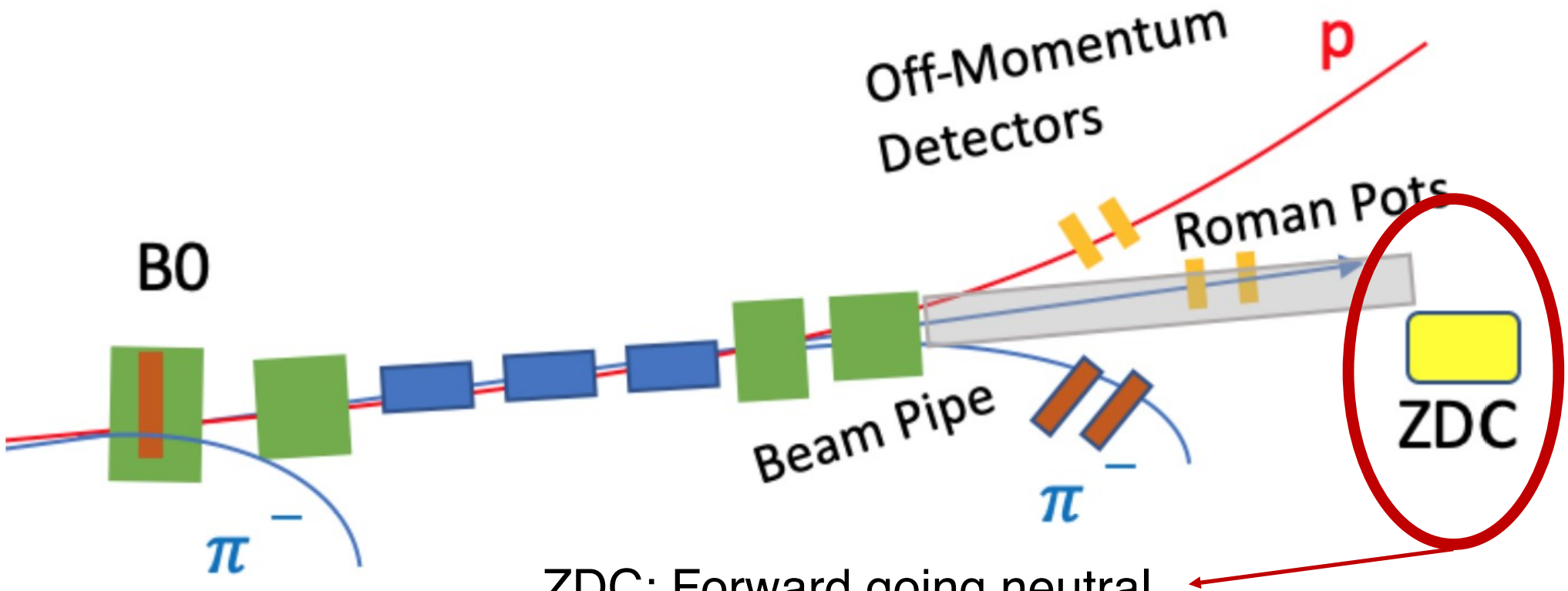


EIC Far Forward Detector

Roman pots: placed inside beam pipe to detect charged particles with ultra-small scattering angles (< 5mrad)



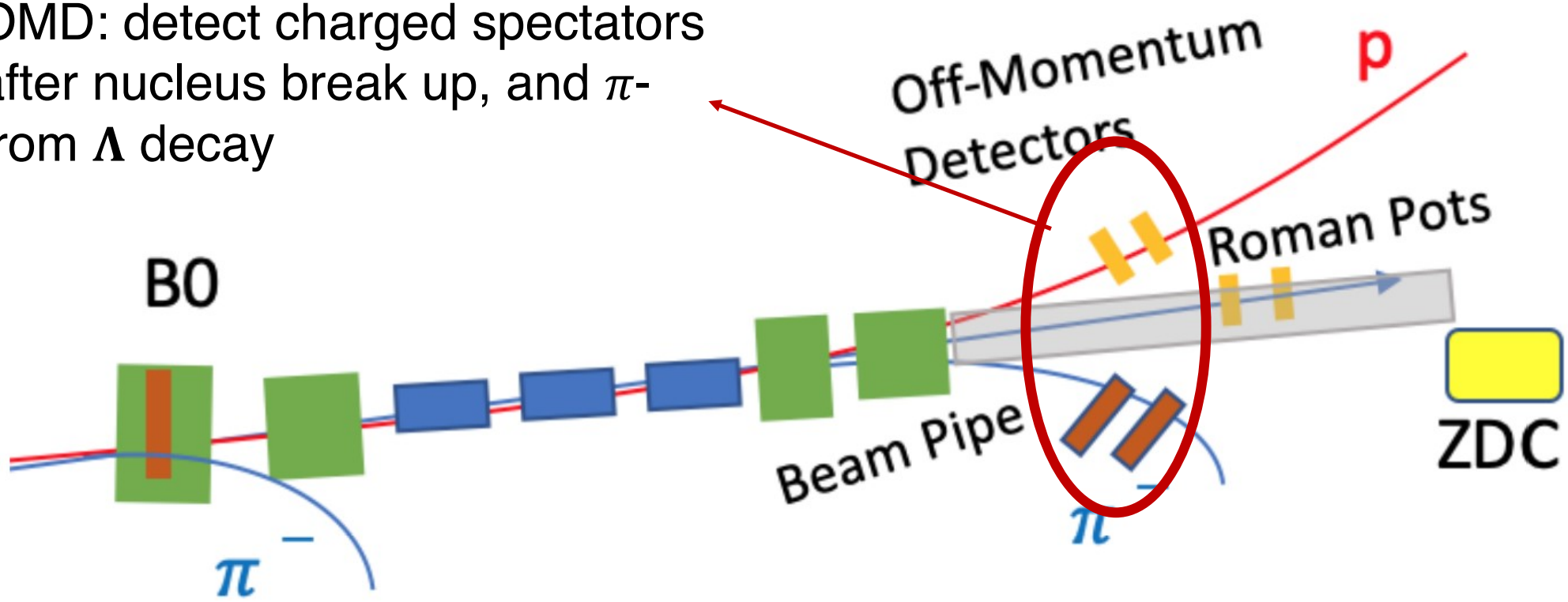
EIC Far Forward Detector



ZDC: Forward going neutral particles such as neutrons and gammas (<5.5 mrad)

EIC Far Forward Detector

OMD: detect charged spectators after nucleus break up, and π- from Λ decay



Related Physics for Far Forward Detectors

- **Deeply virtual Compton scattering (DVCS):**
  - Roman pot, B0 for (e+p and e+light nuclei)
  - Also need ZDC for neutron DVCS
  - Generator: MILOU and TOPEG
- **Exclusive vector meson production in e+p**:
  - Roman pot and B0
  - Generator: lAger

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- **Deeply virtual Compton scattering (DVCS):**
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  - Generator: MILOU and TOPEG
- **Exclusive vector meson production in e+p**:
  - Roman pot and B0
  - Generator: lAger
- **Exclusive vector meson production in *e*+A:** Incoherent/coherent separation:
  - Roman pot, B0 and OMD**:** charged fragment;
  - ZDC**:** detecting decay photons from the nuclear
  - Generator: Sartre, BeAGLE, eSTARLight
- ***u*-channel exclusive electroproduction of π^0**:
  - **ZDC for gamma detection from π^0** decay

Related Physics for Far Forward Detectors

- **Meson structure**
  - **Sullivan process for pion structure: $e + p \rightarrow e' + X + n$**
    - ZDC for neutron detection
  - **Sullivan process for kaon structure: $e + p \rightarrow e' + X + \Lambda$**
    - **$\Lambda \rightarrow n + \pi^0$** needs ZDC for neutron and gamma detection
    - **$\Lambda \rightarrow p + \pi-$** needs B0, OMD and Roman pot
  - **Exclusive $e + p \rightarrow e' + \pi^+ + n$**
    - ZDC for neutron detection
  - Generator: DEMPGen

Related Physics for Far Forward Detectors

- **Meson structure**
  - **Sullivan process for pion structure: $e + p \rightarrow e' + X + n$**
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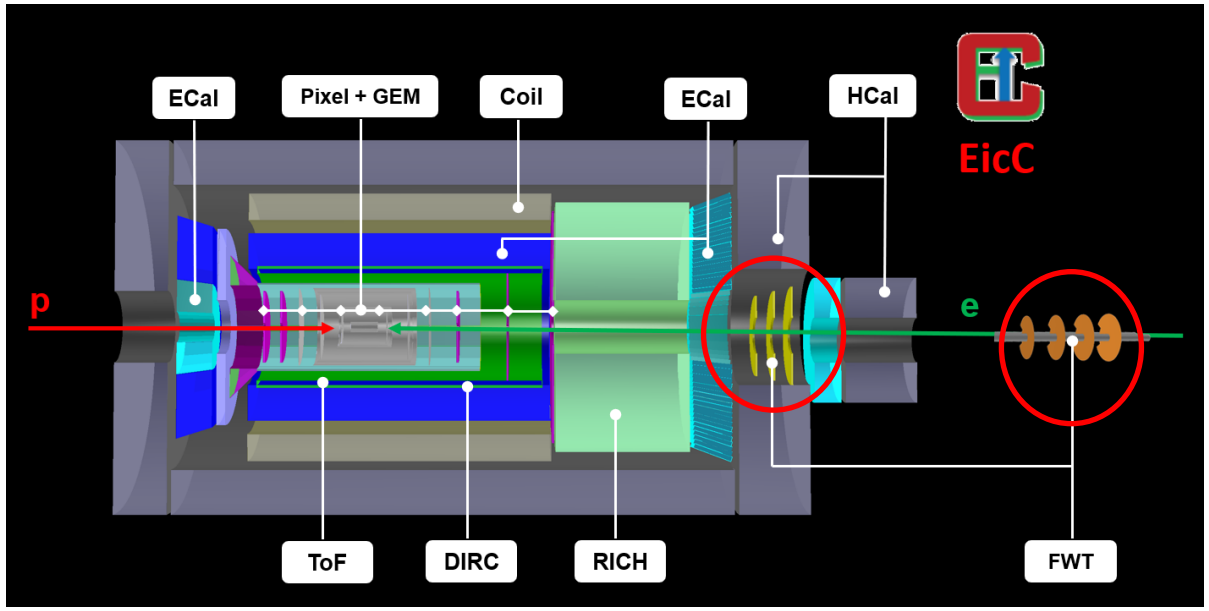
  - **Sullivan process for kaon structure: $e + p \rightarrow e' + X + \Lambda$**
    - **$\Lambda \rightarrow n + \pi^0$** needs ZDC for neutron and gamma detection
    - **$\Lambda \rightarrow p + \pi-$** needs B0, OMD and Roman pot
  - **Exclusive $e + p \rightarrow e' + \pi^+ + n$**
    - ZDC for neutron detection
  - Generator: DEMPGen
- **Deuteron DIS with spectator tagging:** Free neutron structure and nuclear modifications
  - B0, Roman pot and OMD for proton tagging
  - ZDC for neutron tagging
  - Generator: BeAGLE

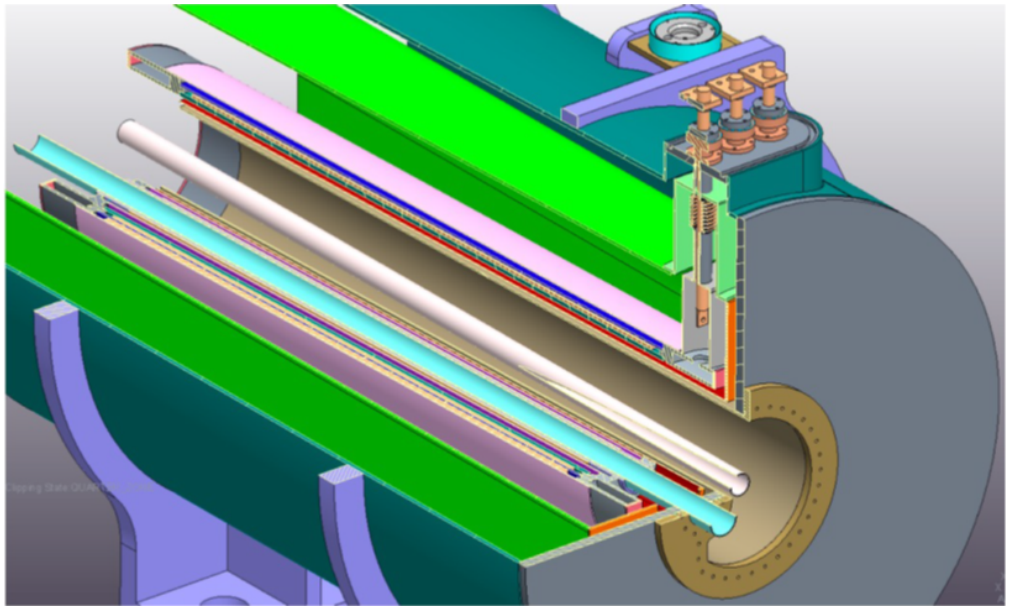
Related Physics for Far Forward Detectors

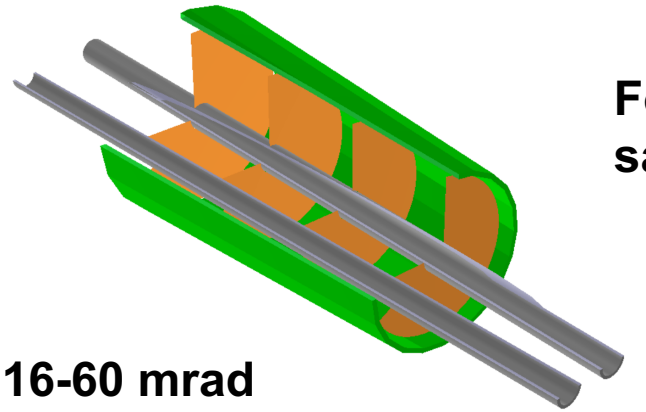
- **Diffractive J/Ψ production on the deuteron with spectator tagging**
  - B0, Roman pot and OMD for proton tagging
  - ZDC for neutron tagging
  - Generator: BeAGLE
- **Double tagging for A=3 nuclei:** double tagging DIS and SIDIS, short range correlation
  - B0, Roman pot and OMD for proton tagging
  - ZDC for neutron tagging
  - Generator: CLASDIS, BeAGLE
- ……

EicC Far Forward Detectors

B0pf magnet



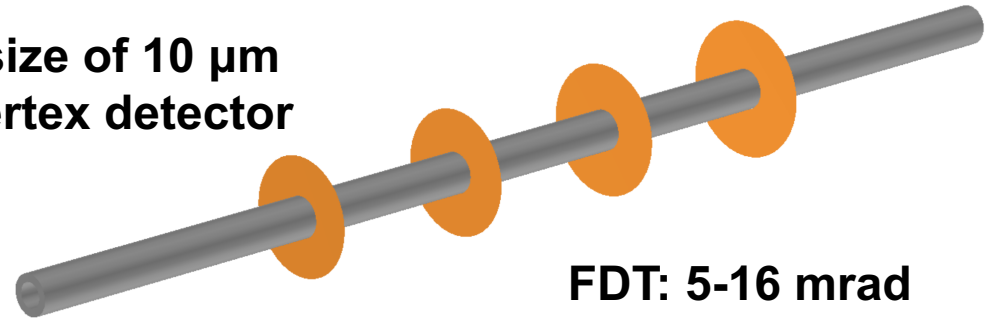




EDT: 16-60 mrad

EDT (Endcap Dipole Tracking)

Four disks with pixel size of 10 μm
same as the central vertex detector



FDT: 5-16 mrad

FDT (Forward Dipole Tracking)

Slides from Yutie

1st and 2nd Dipole for Tracking

Dipole 1: z = 5 m B = 2.52 T L = 0.8 m

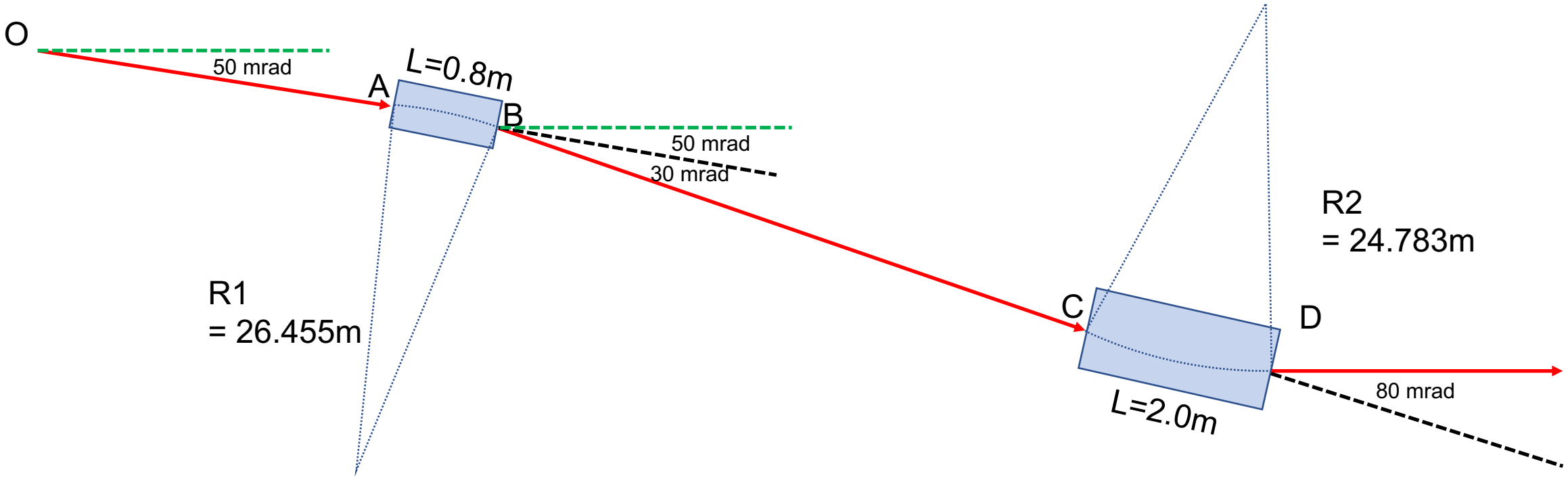
R1 = p*10/3./B1 = 20GeV*10/3./2.52 = 26.455 m

Bending angle = asin(L/R) = 0.03 rad = 30 mrad

Dipole 2: z = 12 m B = -2.69 T L = 2.0 m

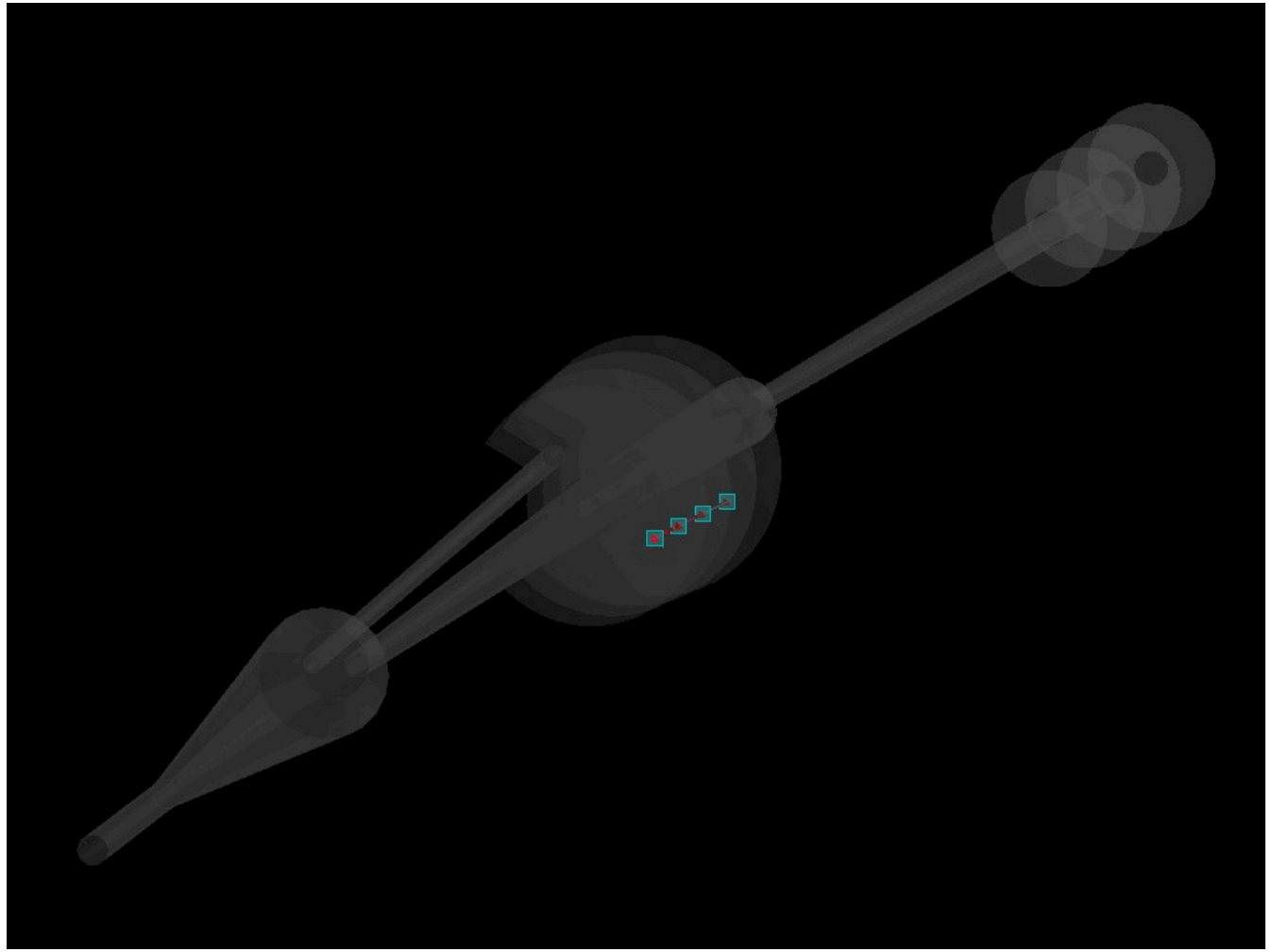
R2 = p*10/3./B2 = 20GeV*10/3./2.69 = 24.783 m

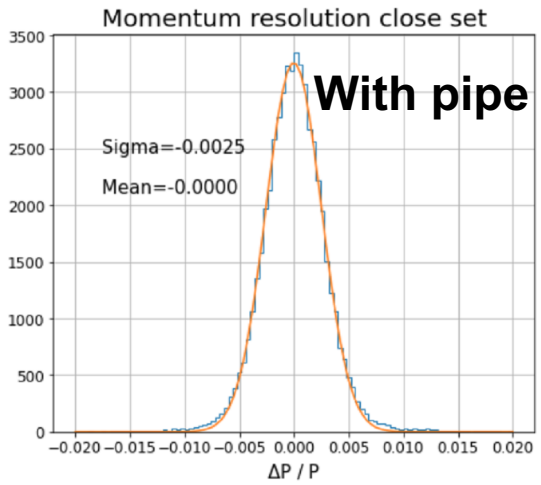
Bending angle = asin(L/R) ~ 0.08 rad = 80 mrad



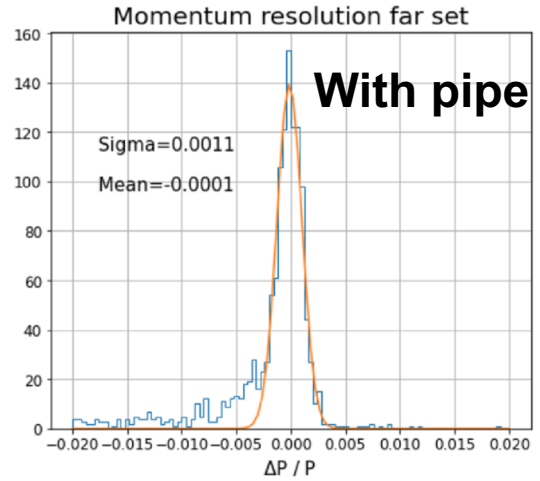
Slides from Yutie

EDT and FDT Momentum Resolution





EDT:
dp/p~0.3%
@ 20 GeV

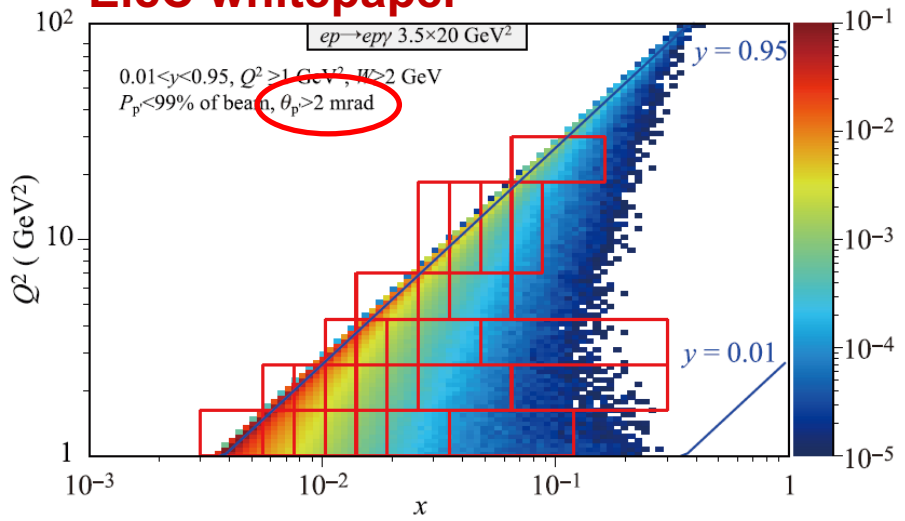


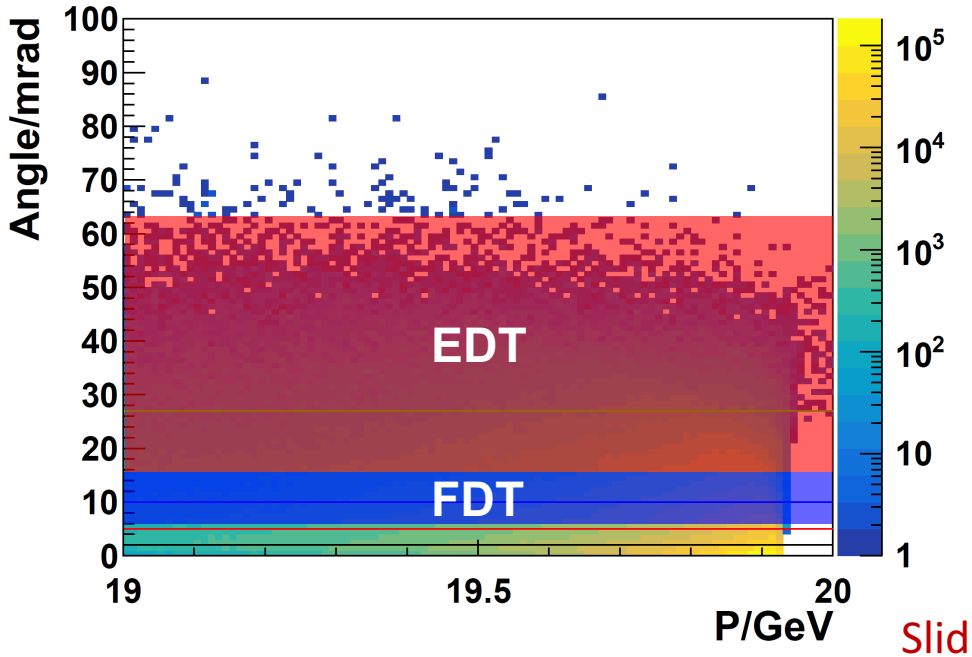
FDT:
dp/p~0.1%
@ 20 GeV

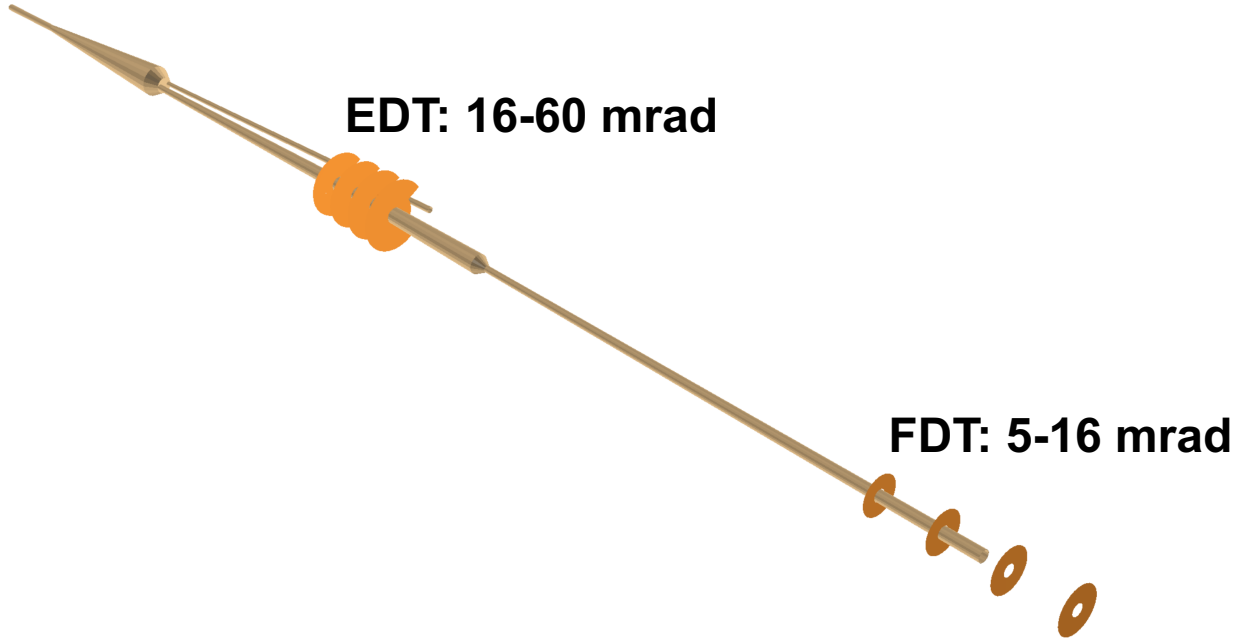
Slides from Yutie

Far Forward for DVCS

EicC whitepaper





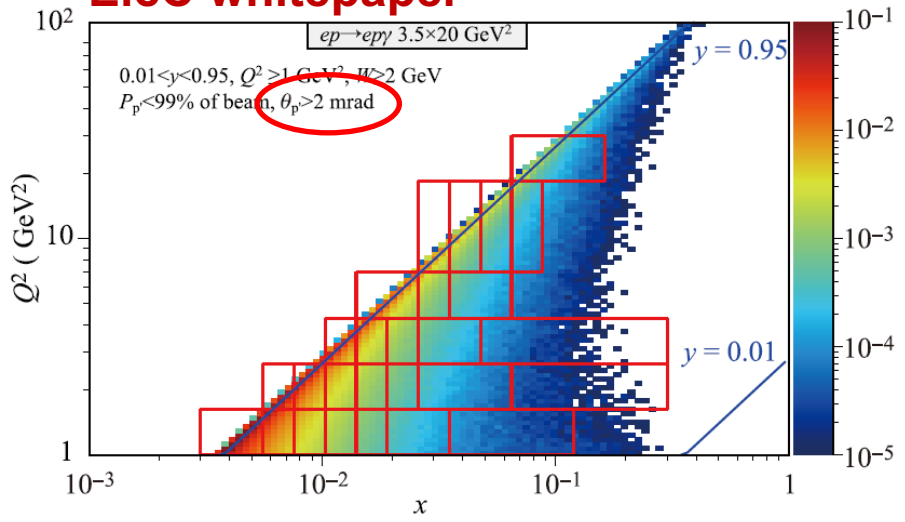


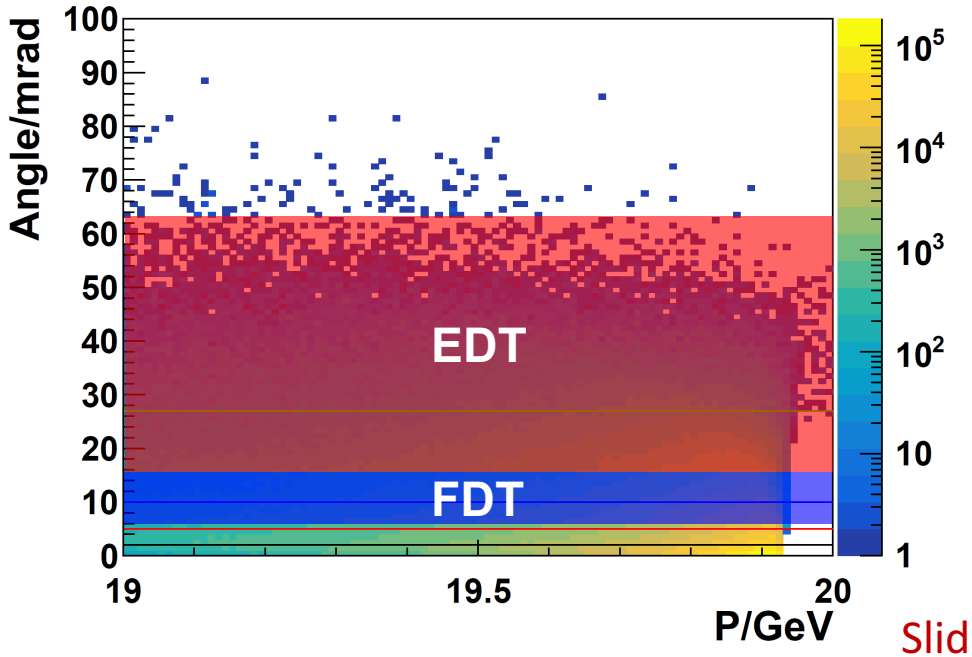
mrad :	DVCS ratio relative to 2 mrad
16-34:	9.3%
16-60:	**9.9%**
5-16:	**45.3%**
2-5 :	44.7%

Slides from Yutie

Far Forward for DVCS

EicC whitepaper





At current EicC beam element design, the minimum angle is 27 mrad.

The angle can be optimized to 10~20 mrad, but with a sacrifice of the luminosity.

An angle dependent luminosity chart will be provided by the accelerator colleagues.

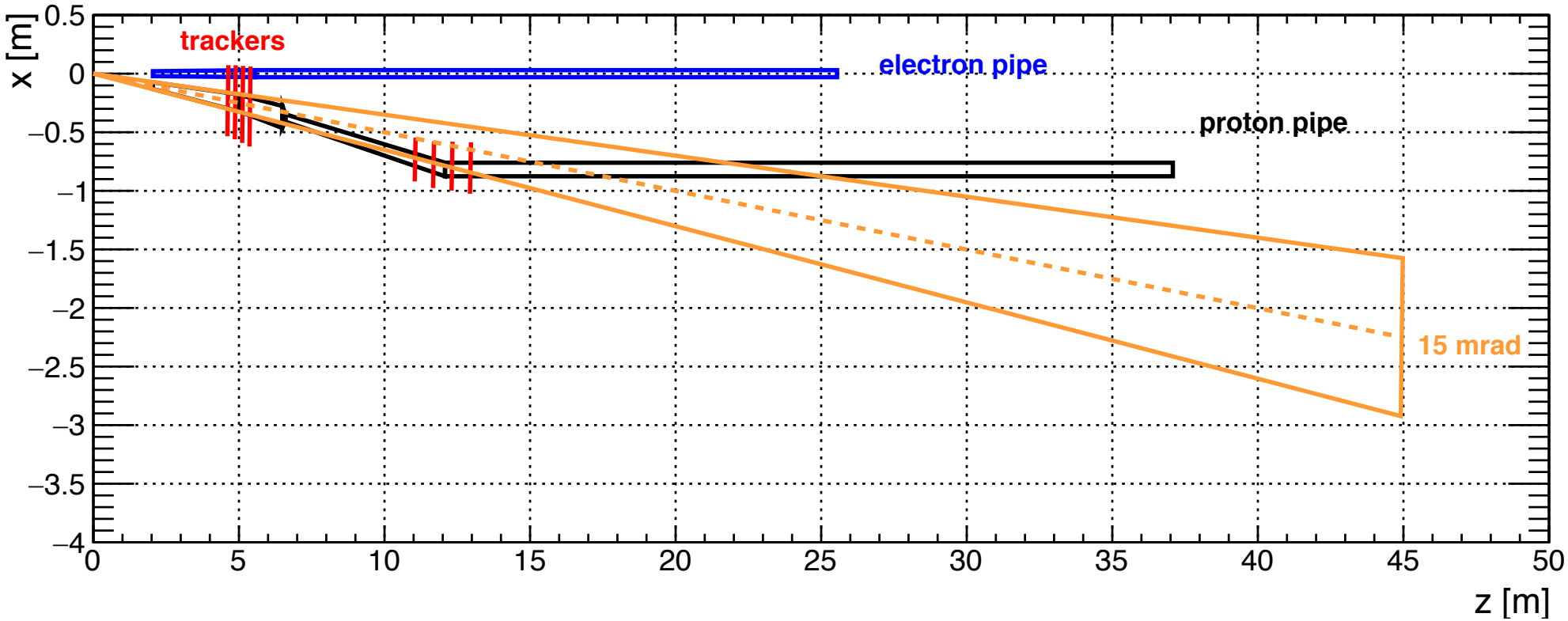
- **In case of minimum angle at ~15 mrad, FDT is not needed. The detection of DVCS will be affected.**
- **May also consider lower the luminosity in order to reach smaller scattering angles**

mrad :	DVCS ratio relative to 2 mrad
16-60:	9.9%
5-16:	45.3%
2-5 :	44.7%

Slides from Yutie

Putting ZDC in Far Forward

- Consider for now a +/- 15 mrad neutron cone (~3 times larger than EIC ZDC)



- Things to keep in mind for ZDC possible location:
  1. Cannot intersect with beam pipes
  2. Cannot block the acceptance of FDT
  3. Cannot be too far away from IP (due to crab cavity)

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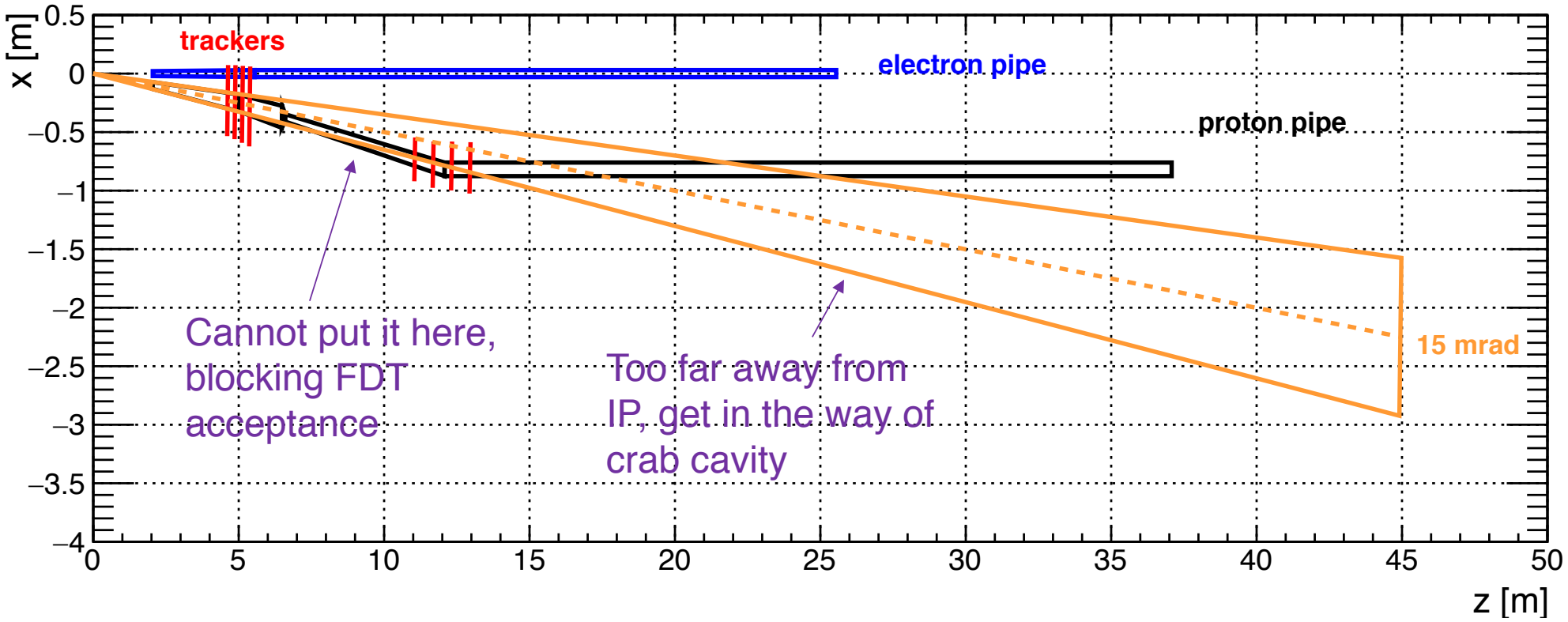

- Things to keep in mind for ZDC possible location:
  1. Cannot intersect with beam pipes
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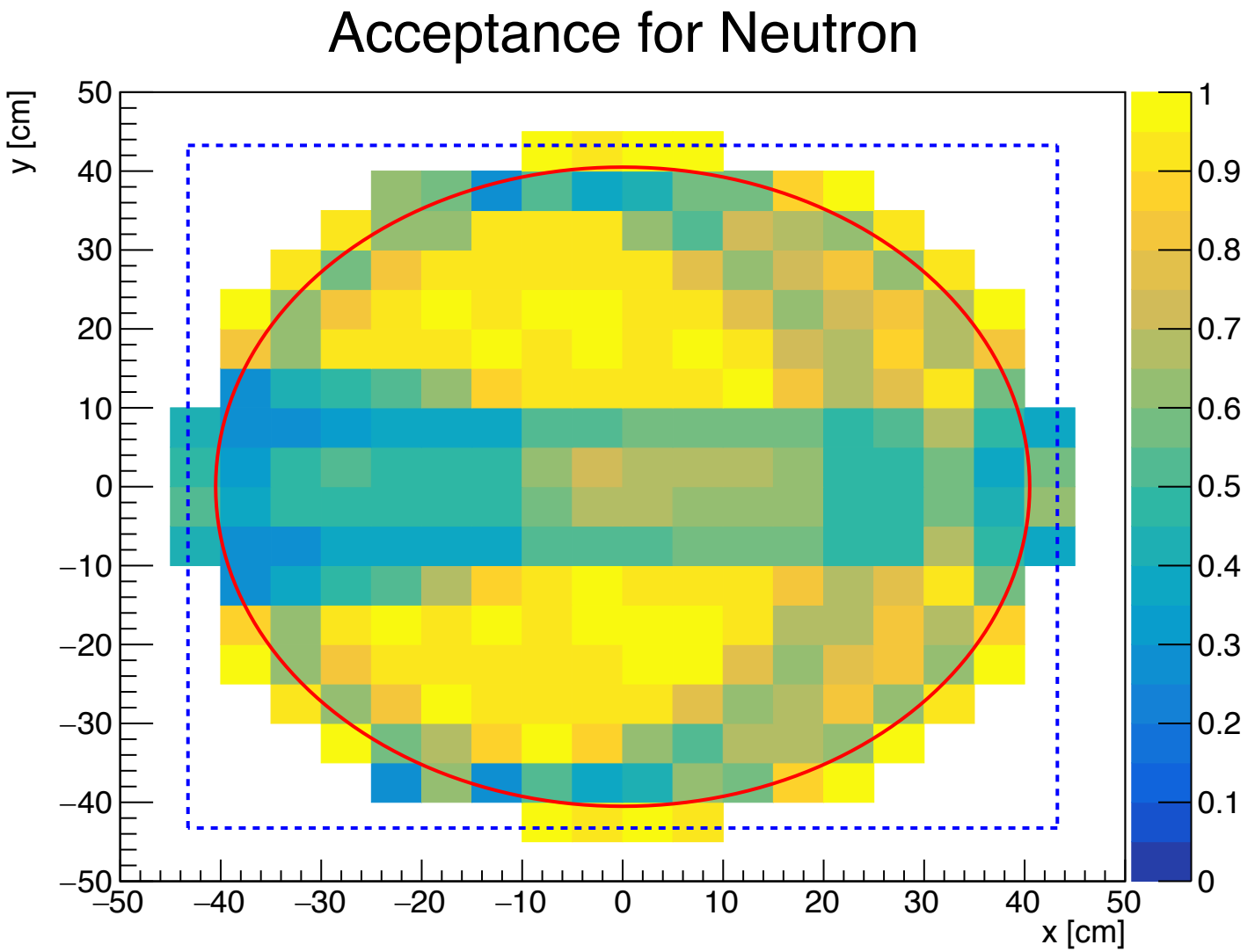
  3. Cannot be too far away from IP (due to crab cavity)

Material Effect for ZDC

- About 50% neutron loss after passing through beam pipes
  - (3x2) mm / sin(50mrad) = 120mm
- Loss due to material will be even more for other particles (i.e. photons)



Modifying the Current Far Forward Design

- With current far forward beam line design, no proper place for ZDC

- We discussed with Lei Wang about possible modifications in the FF region
  1. We can have additional dipoles to bend the ion beam before FDT by ~80 mrad
  2. There is a few meters of room to place additional dipoles to compensate additional bending

Modifying the Current Far Forward Design

Dipole 1: z = 5 m B = 2.52 T L = 0.8 m

R1 = p*10/3./B1 = 20GeV*10/3./2.52 = 26.455 m

Bending angle = asin(L/R) = 0.03 rad = 30 mrad

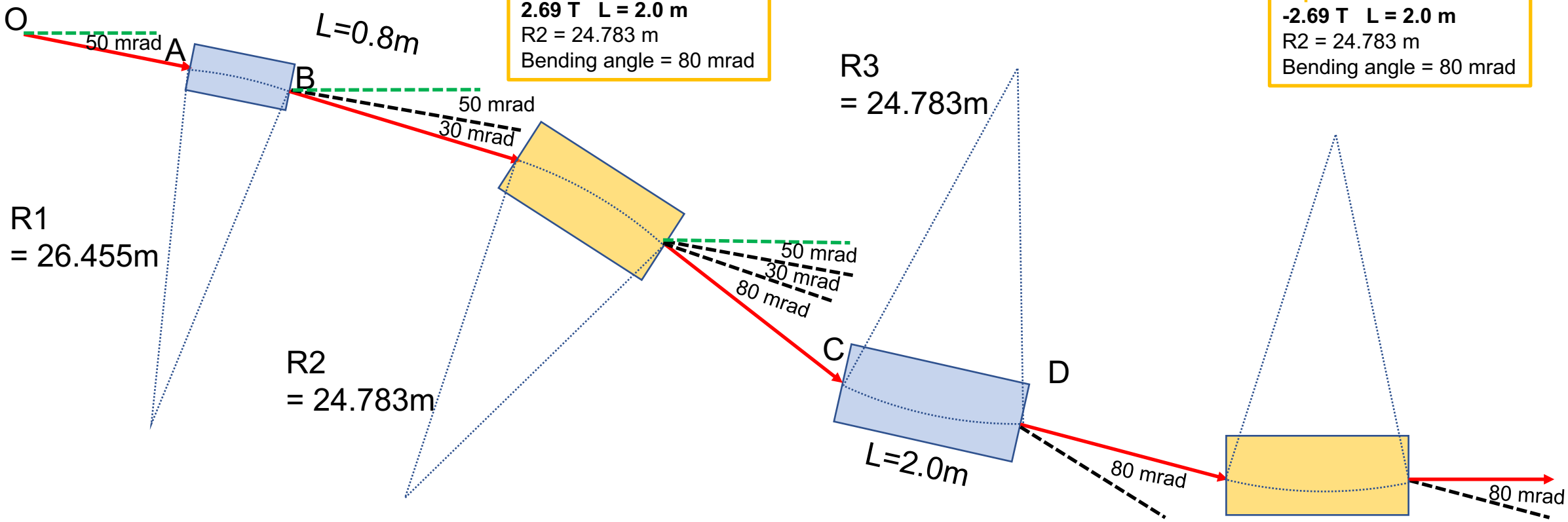
Dipole 3: z = 12 m B = -2.69 T L = 2.0 m

R2 = p*10/3./B2 = 20GeV*10/3./2.69 = 24.783 m

Bending angle = asin(L/R) ~ 0.08 rad = 80 mrad

Dipole 2: z = 7 m B = 2.69 T L = 2.0 m
R2 = 24.783 m
Bending angle = 80 mrad

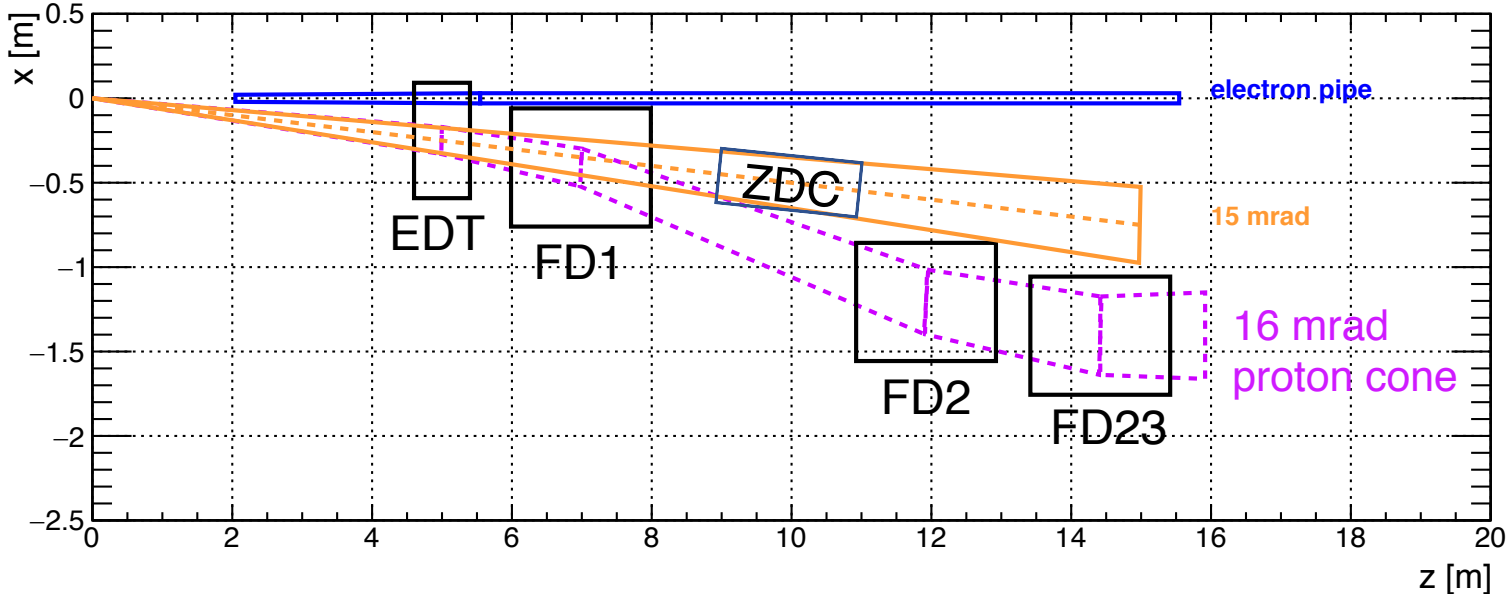
Dipole 4: z > 13 m B = -2.69 T L = 2.0 m
R2 = 24.783 m
Bending angle = 80 mrad

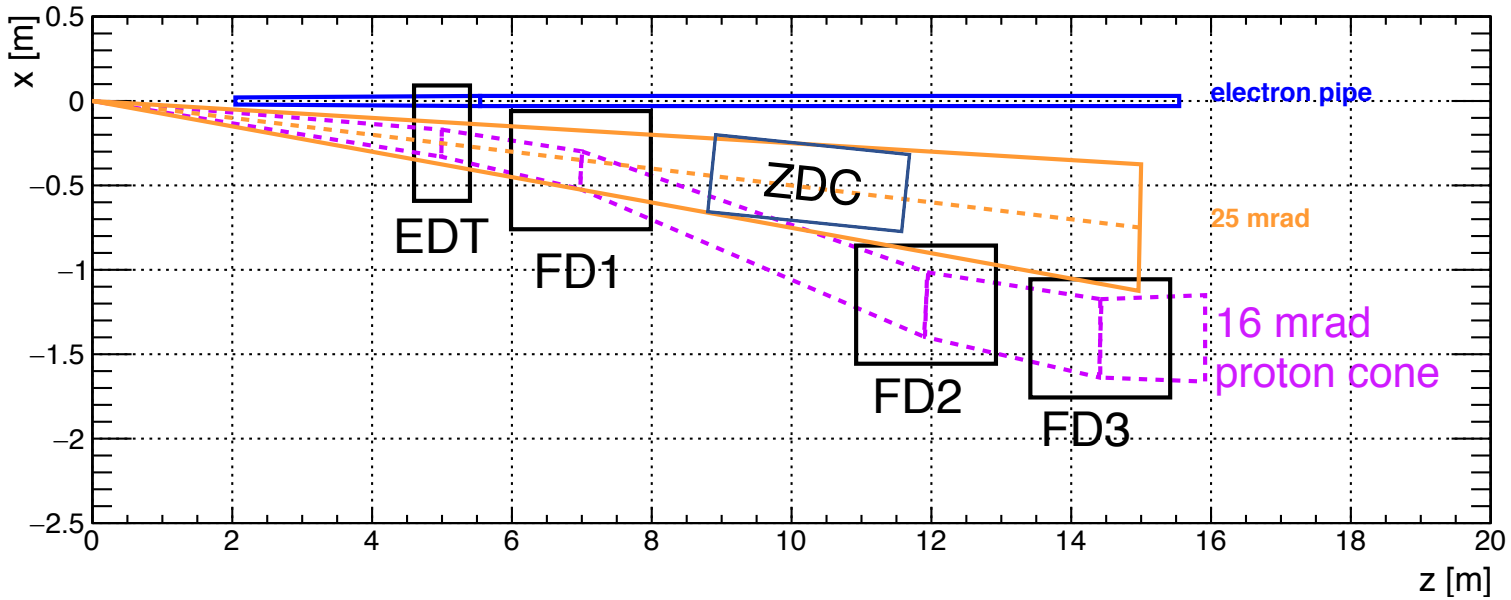


Slides from Yutie

ZDC in New FF Configuration

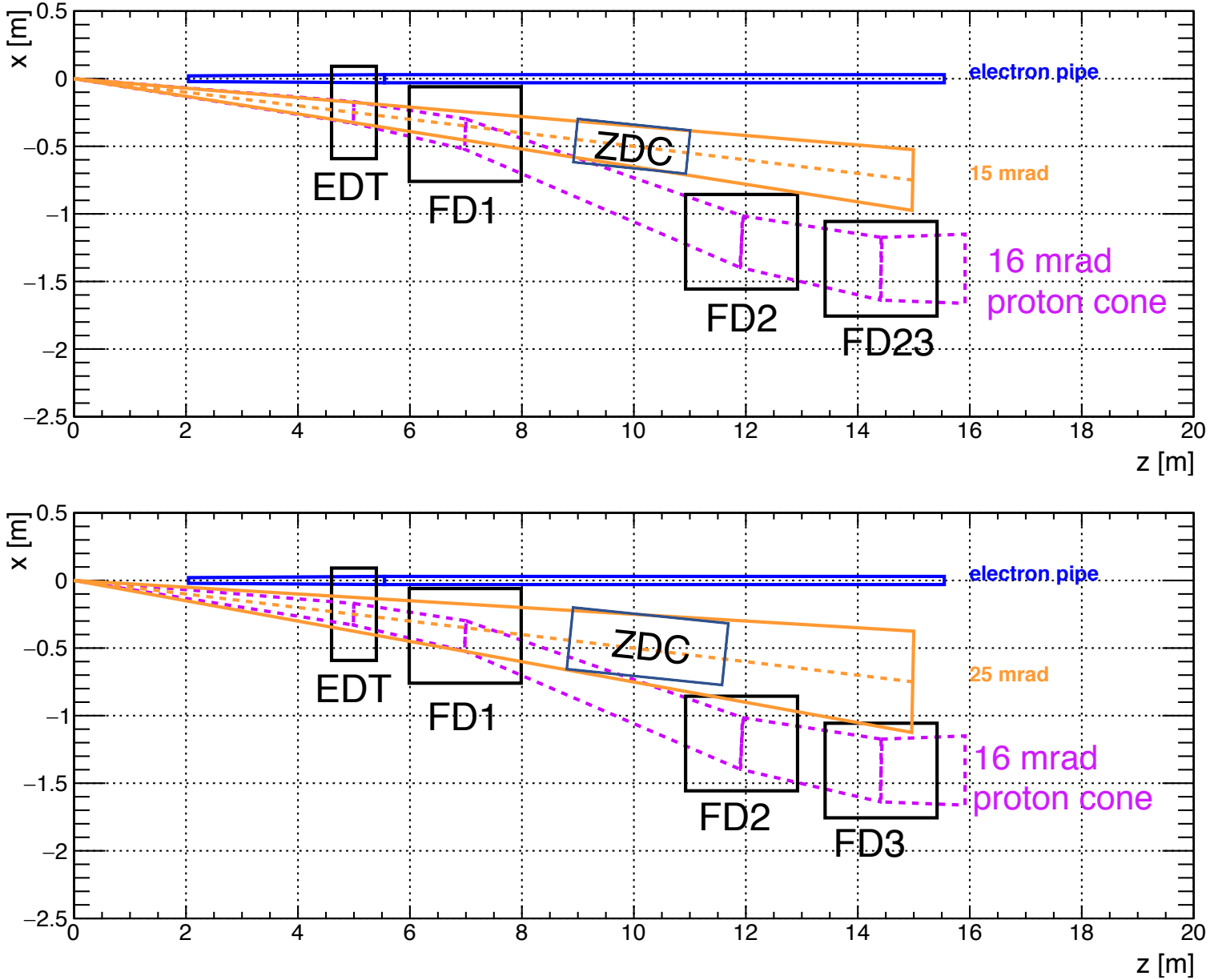
- Have a location, ~10m from IP for ZDC
- Should be able to place a +/-15 to 25 mrad ZDC
  - 30cm x 30cm for +/- 15 mrad cone
  - 50cm x 50cm for +/- 25 mrad cone





ZDC in New FF Configuration

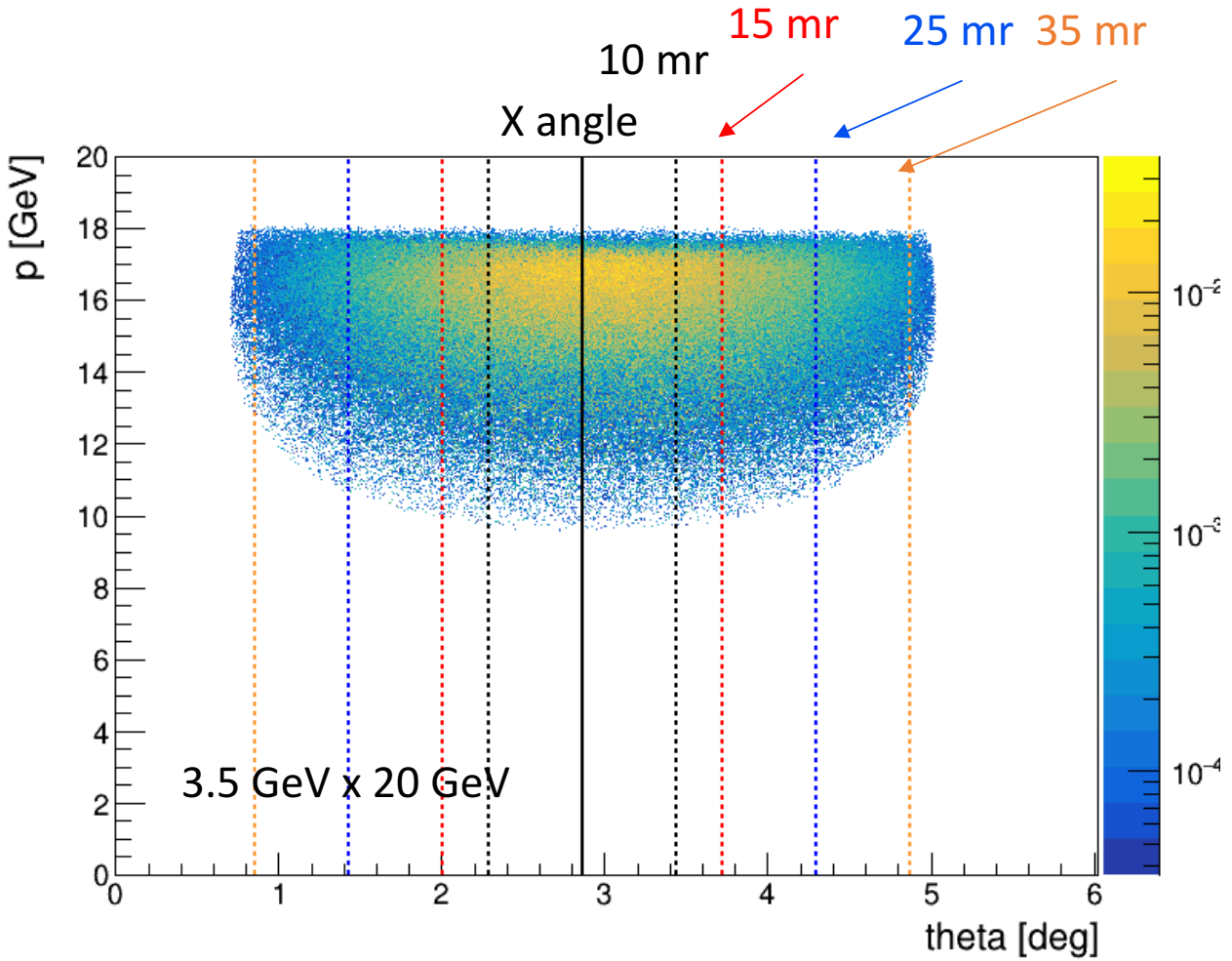
- Things we need to consider:
  1. Move FDT from FD2 location to FD1 location
  2. Move FD2/3 slightly down stream to make more room for ZDC
  3. FD1 magnet radius and thickness
  4. Will there be any quadrupoles between FD1 and FD2



ZDC in New FF Configuration

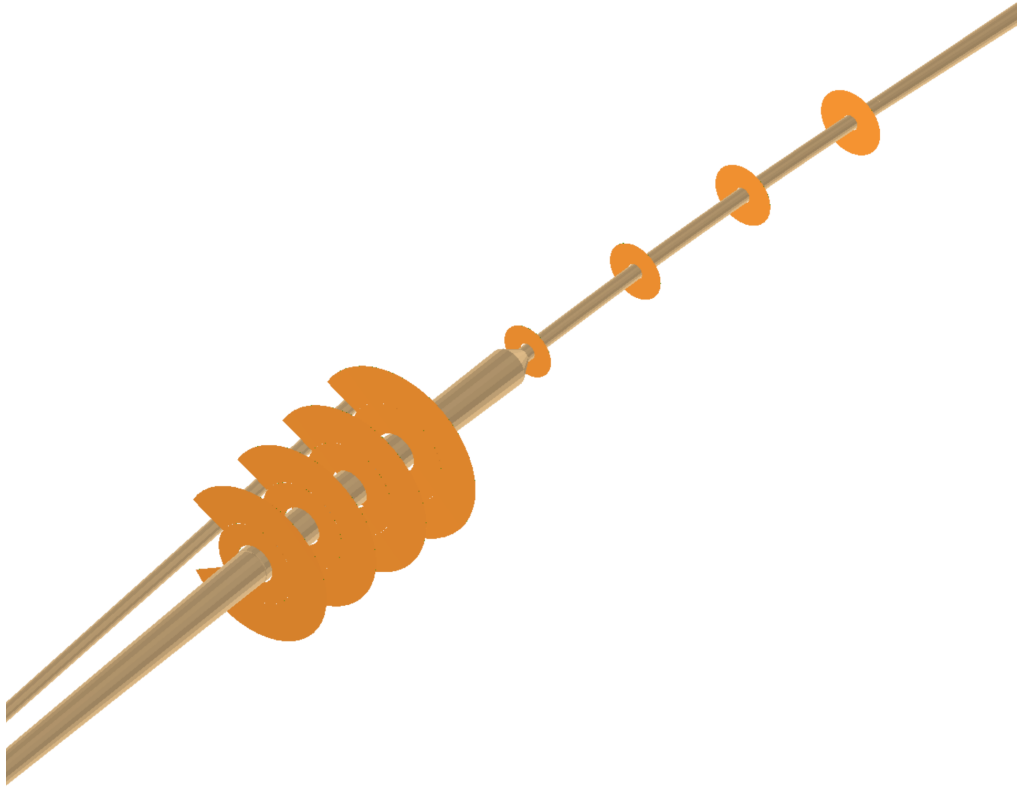
- Using DEMPGen to generate exclusive $e + p \rightarrow e' + \pi^+ + n$
- Ratio between event within an angular cut over all events given by the generator

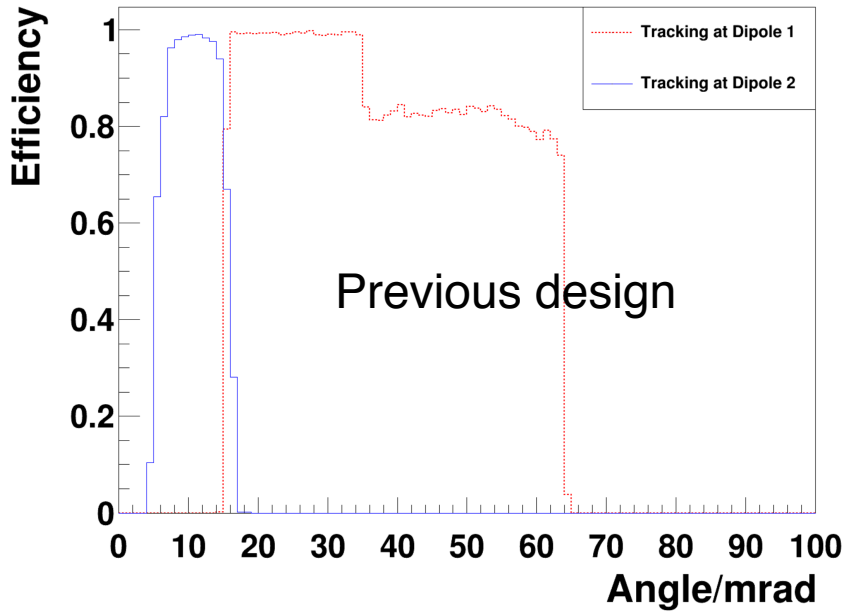
Angular Cut [mrad]	Ratio [%]
+/- 10	55.9
+/- 15	74.3
+/- 25	93.8
+/- 35	99.7

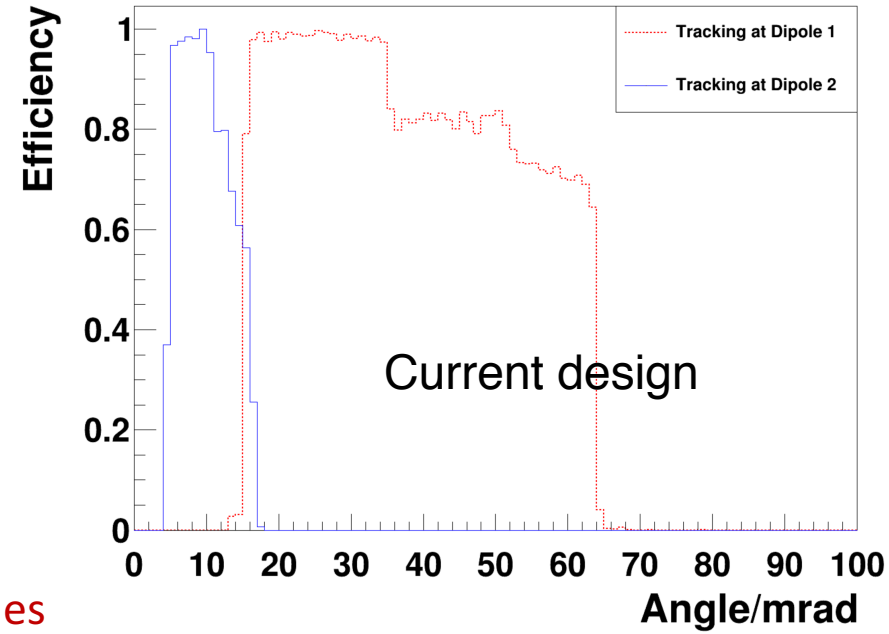


FDT in New FF Configuration

- Since we have 3 identical dipoles after EDT, we can move FDT trackers closer to EDT (to FD1 location)







From Yutie's slides

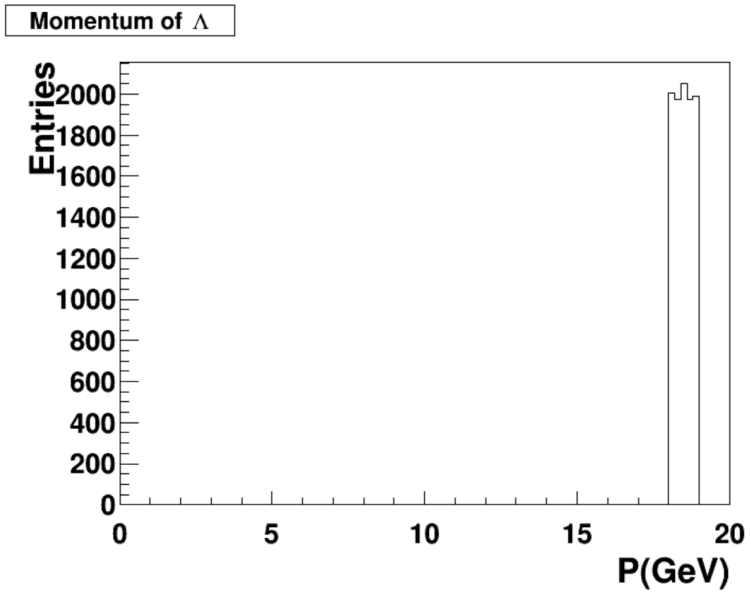
Summary and Outlook

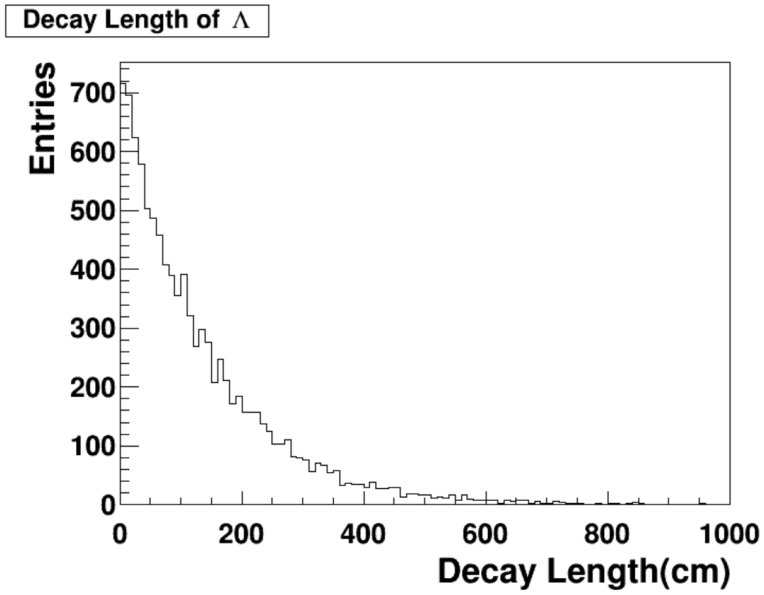
- Need new beamline configuration to make room for ZDC
  - Add additional dipole to further bend the ion beam
  - Have room to place ZDC at ~10m from IP
  - Acceptance studied using DEMPGen, but will revisit when people fix low energy issue
  - Will need accelerator colleagues to confirm the new configuration
- EDT and FDT acceptance and resolution studied using *e+p* DVCS
  - ➢ Will need optimization and update for the new beamline configuration

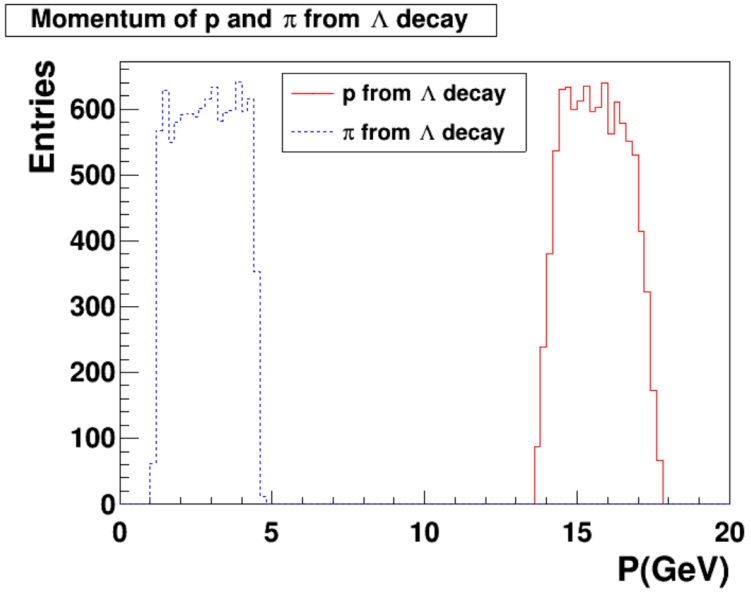
- Plan to explore BeAGLE for further FF detector study and optimization, as well as the location of OMD and Roman Pot

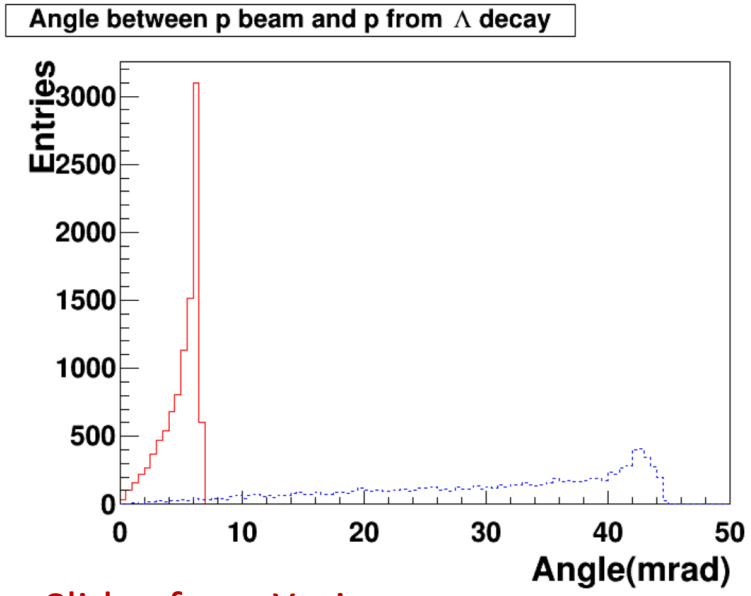
Backup

First Look at Λ Reconstruction with FF Detectors









10000 events
Lambda → p π
Momentum 18-19 GeV

pion:

$\varepsilon_{(N\_edt\_hit >= 3)} = 52\%$

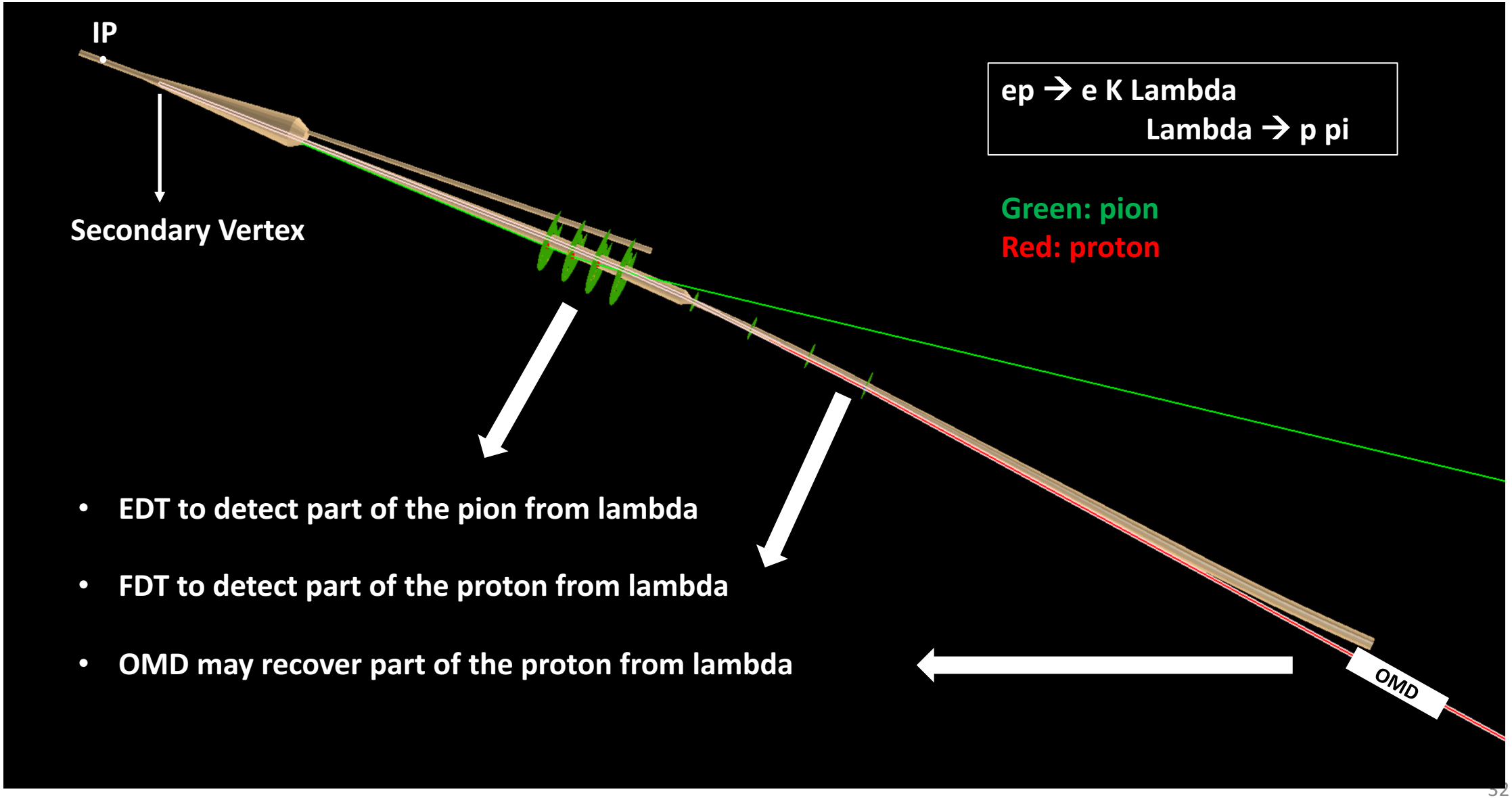
proton:

$\varepsilon_{(N\_fdt\_hit >= 3)} = 53\%$

Both pion and proton:
ε= 29%

Slides from Yutie

First Look at Λ Reconstruction with FF Detectors



Slides from Yutie