An idea for a conceptual design for the EIC detector at IR8

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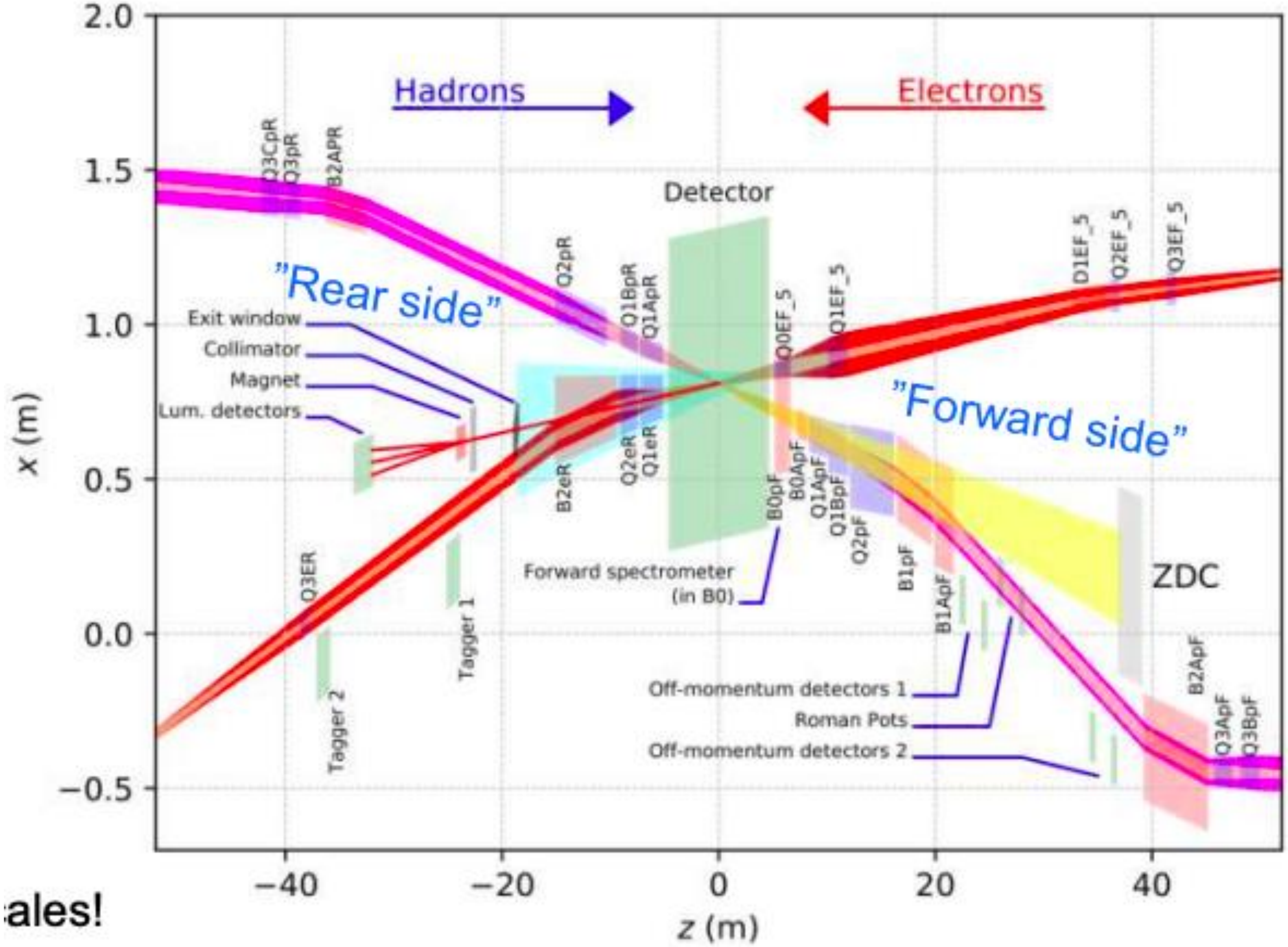


Hadrons
Electrons
Detector
"Rear side"
"Forward side"
Exit window
Collimator
Magnet
Lum. detectors
Q3CpR
Q3pR
B2APR
Q2pR
Q1BpR
Q1ApR
B2eR
Q2eR
Q1eR
Q0EF_5
Q1EF_5
D1EF_5
Q2EF_5
Q3EF_5
B0pF
B0ApF
Q1ApF
Q1BpF
Q2pF
B1pF
B1ApF
B2ApF
Q3ApF
Q3BpF
Q3ER
Tagger 1
Tagger 2
Forward spectrometer
(in B0)
ZDC
Off-momentum detectors 1
Roman Pots
Off-momentum detectors 2
x (m)
z (m)
2.0
1.5
1.0
0.5
0.0
−0.5
−40
−20
0
20
40

ales!

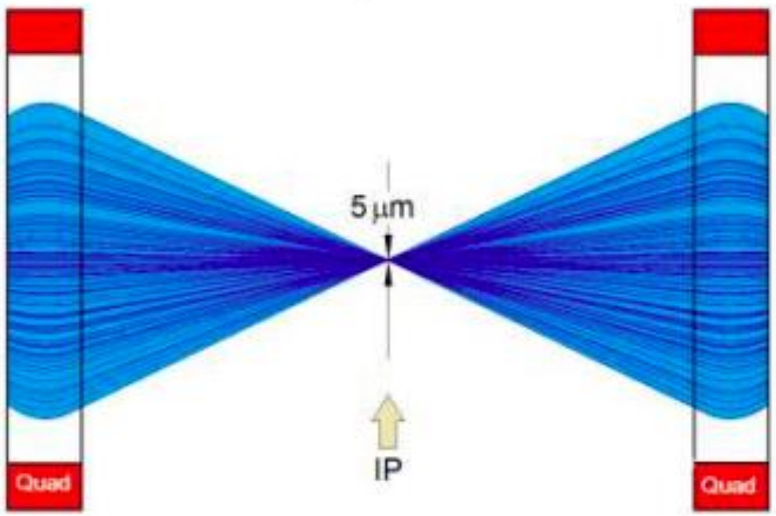
Luminosity

$$L \propto f_{\rm coll} N_1 N_2 / \sigma_x^\star \sigma_y^\star$$

$f_{\rm coll}$: collision frequency

$N_{1,2}$: particles per bunch

$\sigma_{x,y}^\star$: (equal) beam sizes at IP



- **Maximize collision frequency (~100 MHz)**
  - Limited by kicker rise times
  - Limited by parasitic collisions, injection system, etc.
- **Maximize particles per bunch (~10^{11})**
  - Limited by sources, space charge
  - Limited by collective effects
    - Interaction of beam with impedances
    - Also total currents: $I_{1,2}=q_{1,2}N_{1,2}f_{coll}$ ~1-3A
- **Minimize beam sizes at IP (~100/10 um)**
  - Limited by IR focusing, magnets
  - Limited by chromatic dynamic aperture
  - Limited by emittance growth (IBS)

$$\beta(s)=\beta(IP) + \frac{s^2}{\beta(IP)}$$

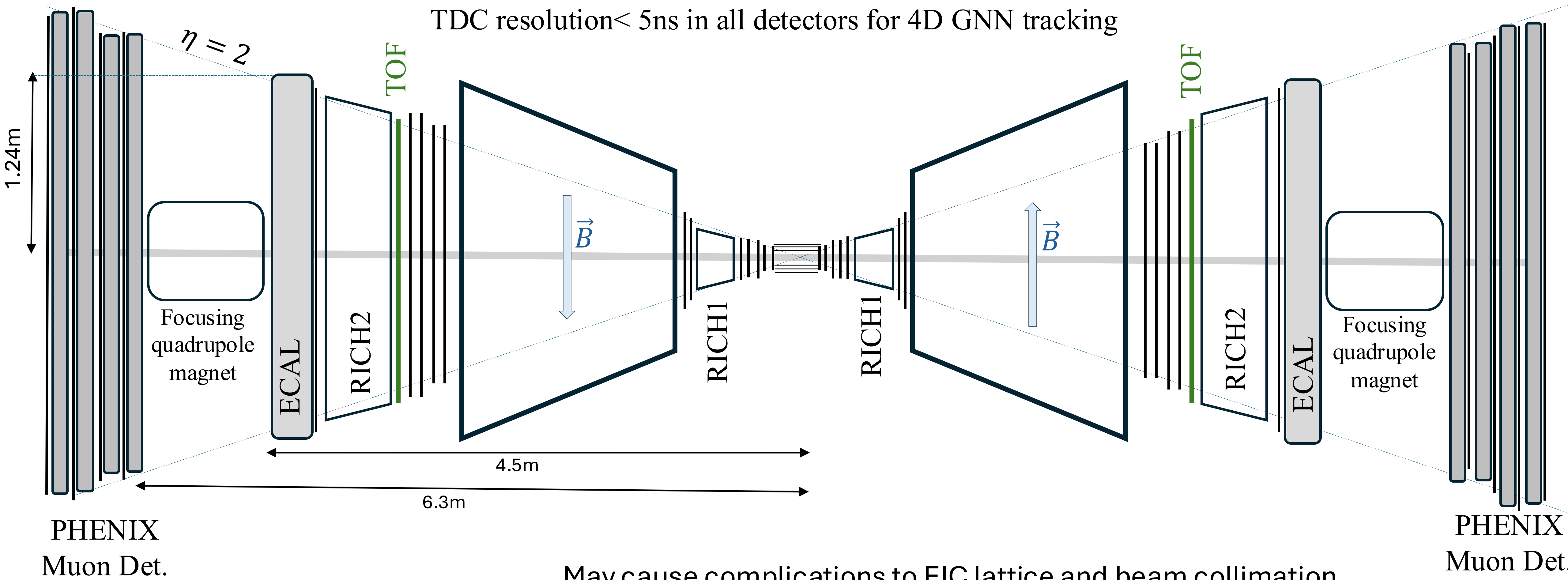
- The RMS beam size $\sigma=\sqrt{\varepsilon\beta(s)}$ grows approximately linearly with distance from the IP

FROG: Forward Region Observation of Gluons

$2.0 < |\eta| < 4.8$ (limited by R=3cm beam pipe)

$\frac{\delta p}{p} < 0.5$

TDC resolution< 5ns in all detectors for 4D GNN tracking



May cause complications to EIC lattice and beam collimation.

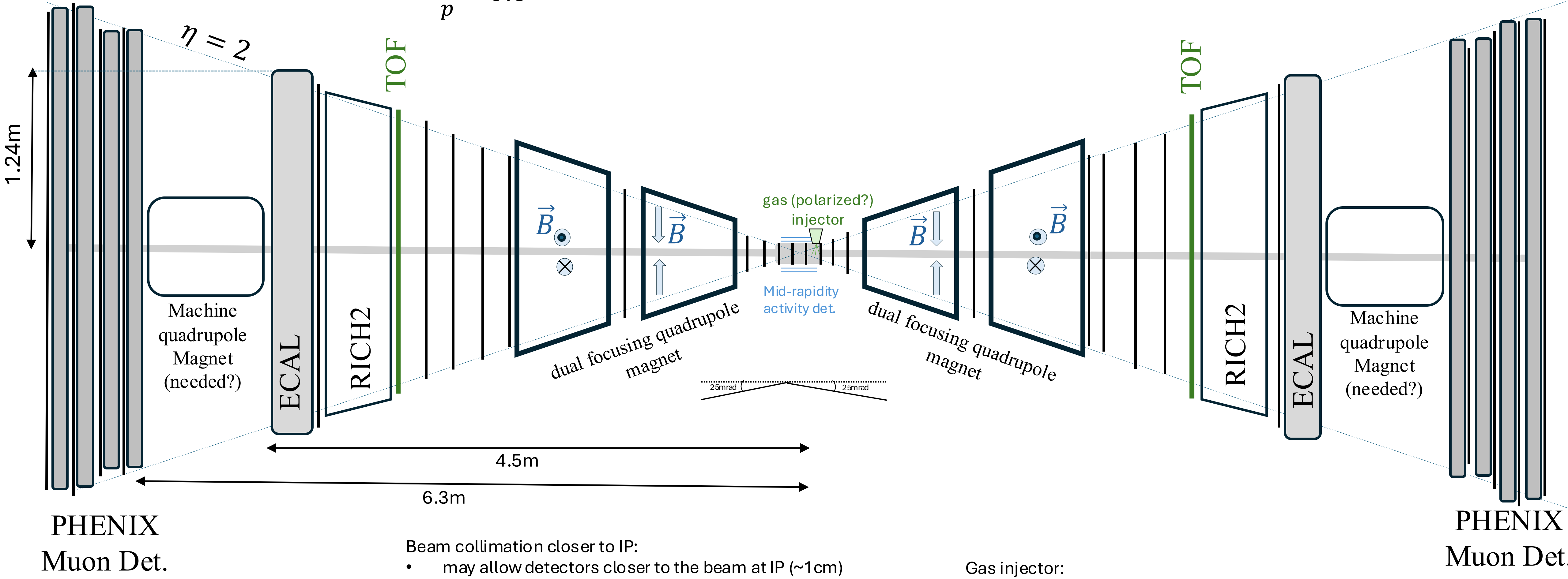
TOF could replace RICH1 for soft particle PID.

FROG: Forward Region Observation of Gluons

2.0< $|\eta|$ < 4.8 (limited by R=3cm beam pipe at |Z|=2m)

TDC resolution< 5ns in all detectors for beam BG suppression and 4D GNN tracking

$\frac{\delta p}{p} < 0.5$



TOF for soft particle PID.

Beam collimation closer to IP:

- may allow detectors closer to the beam at IP (~1cm)
- will increase luminosity
- Will require a ~60cm aperture quadrupole magnet
- Field and detectors direction tilted in 25mrad to minimize electron beam dispersion (to be discussed with magnet division)

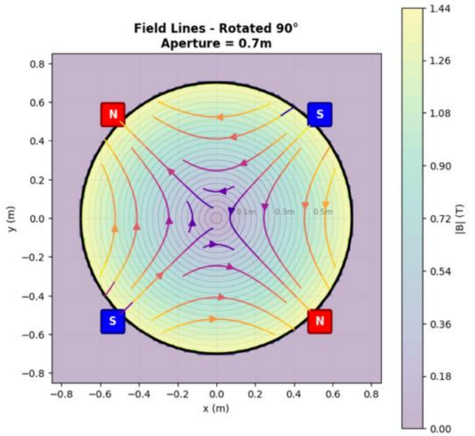
Gas injector:

- Luminosity measurement < 1%
- Fixed target
- Polarized gas would open a new spin program at EIC

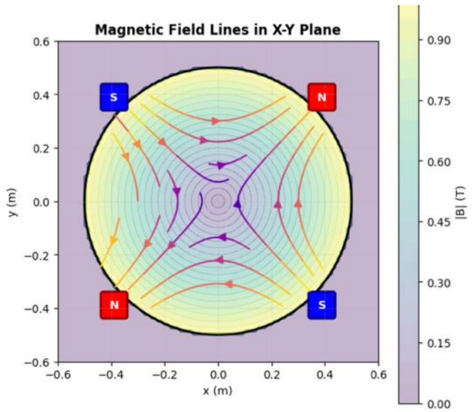
Quadrupole magnets

50cm long each
50cm and 70cm radius
1 T at pole tip

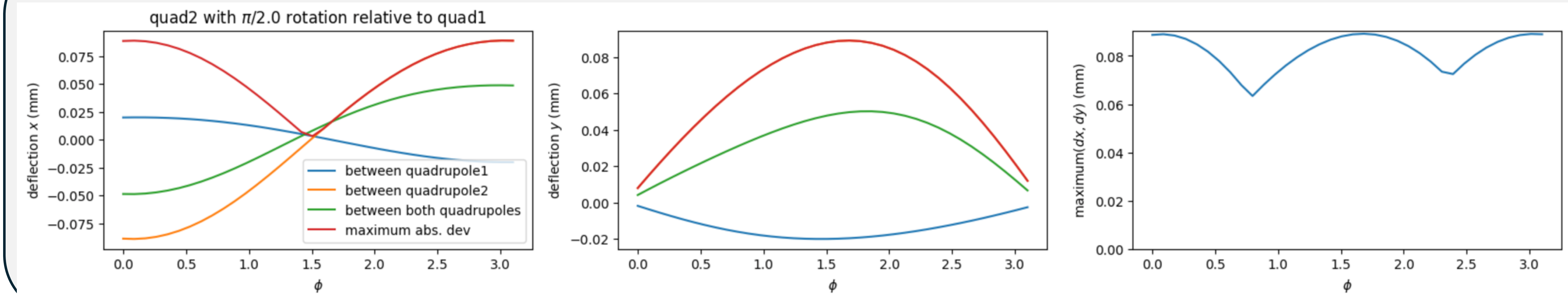
Quadrupole 2



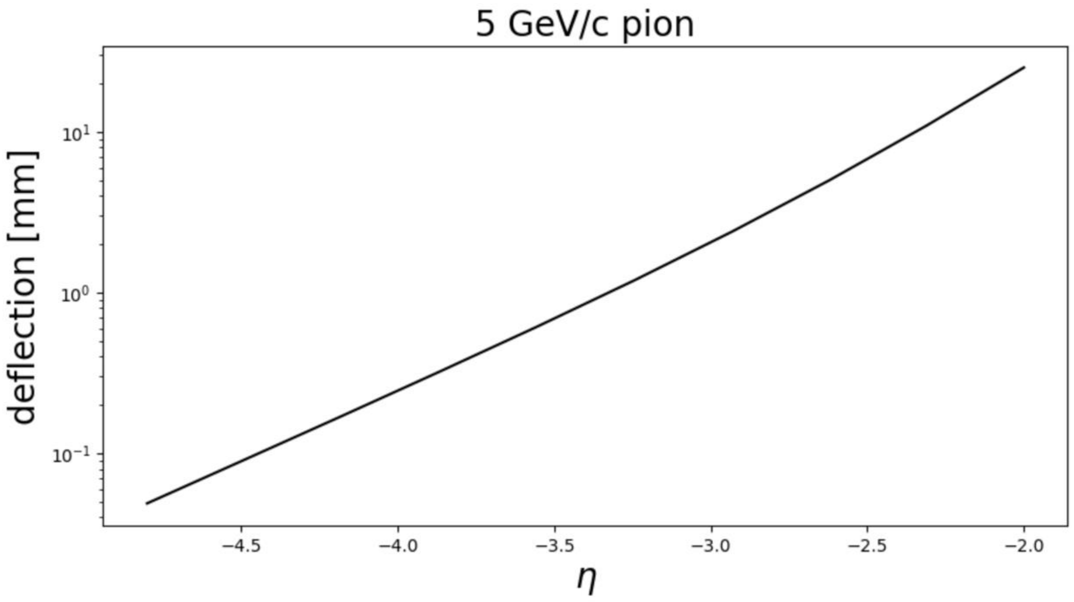
Quadrupole close to IP



5 GeV/c pion deflection at $\eta = -4.5$



- Deflection has strong dependence with azimuthal angle when using a single quadrupole
- Tracking combining deflection from two rotated quadrupoles minimizes the azimuthal dependence.
- A **graphical neural network (GNN)** seems a doable solution for FROG tracking
- Space resolution at the largest rapidity and highest p_T in that region on the order of $50\mu m$

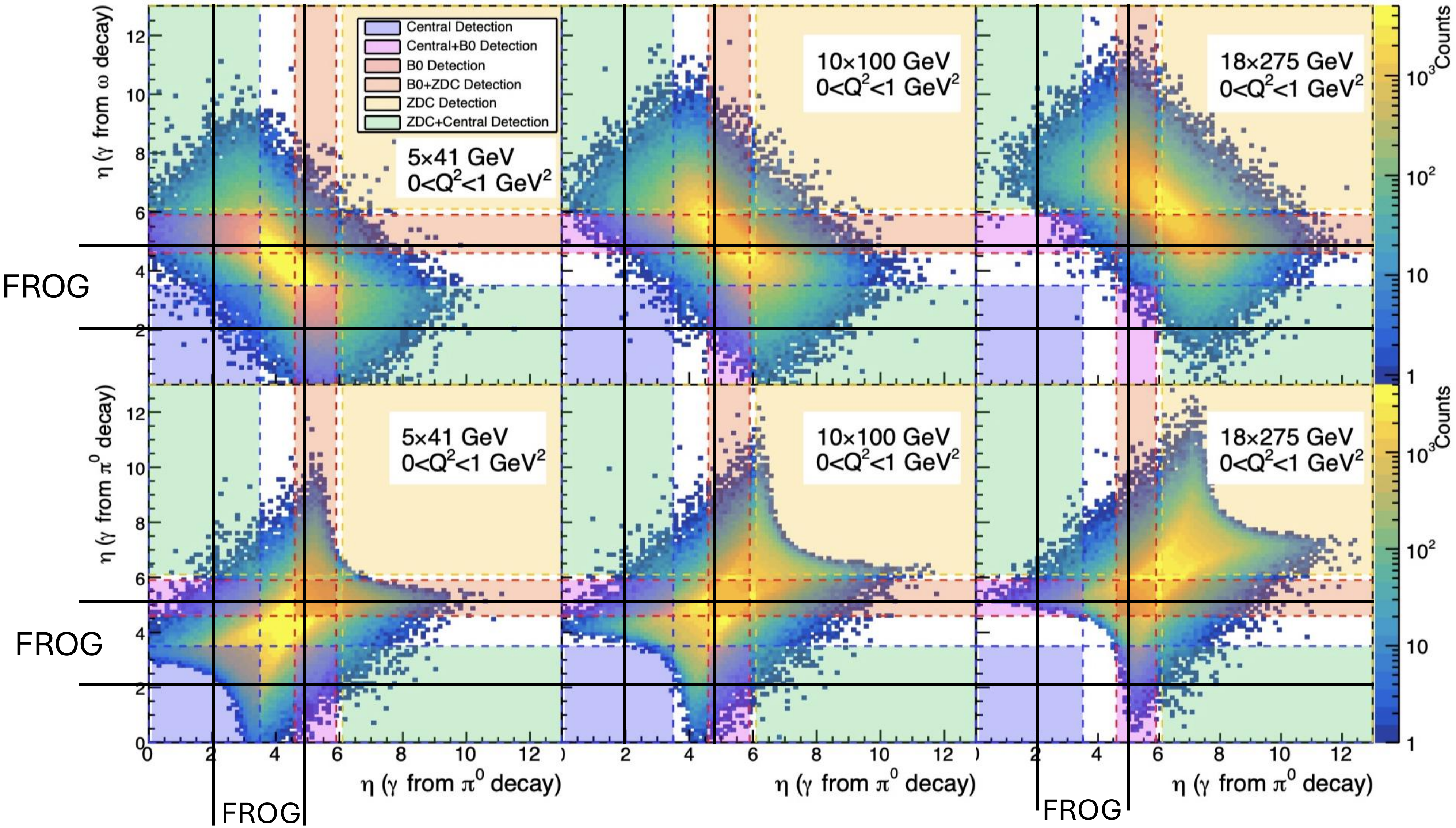


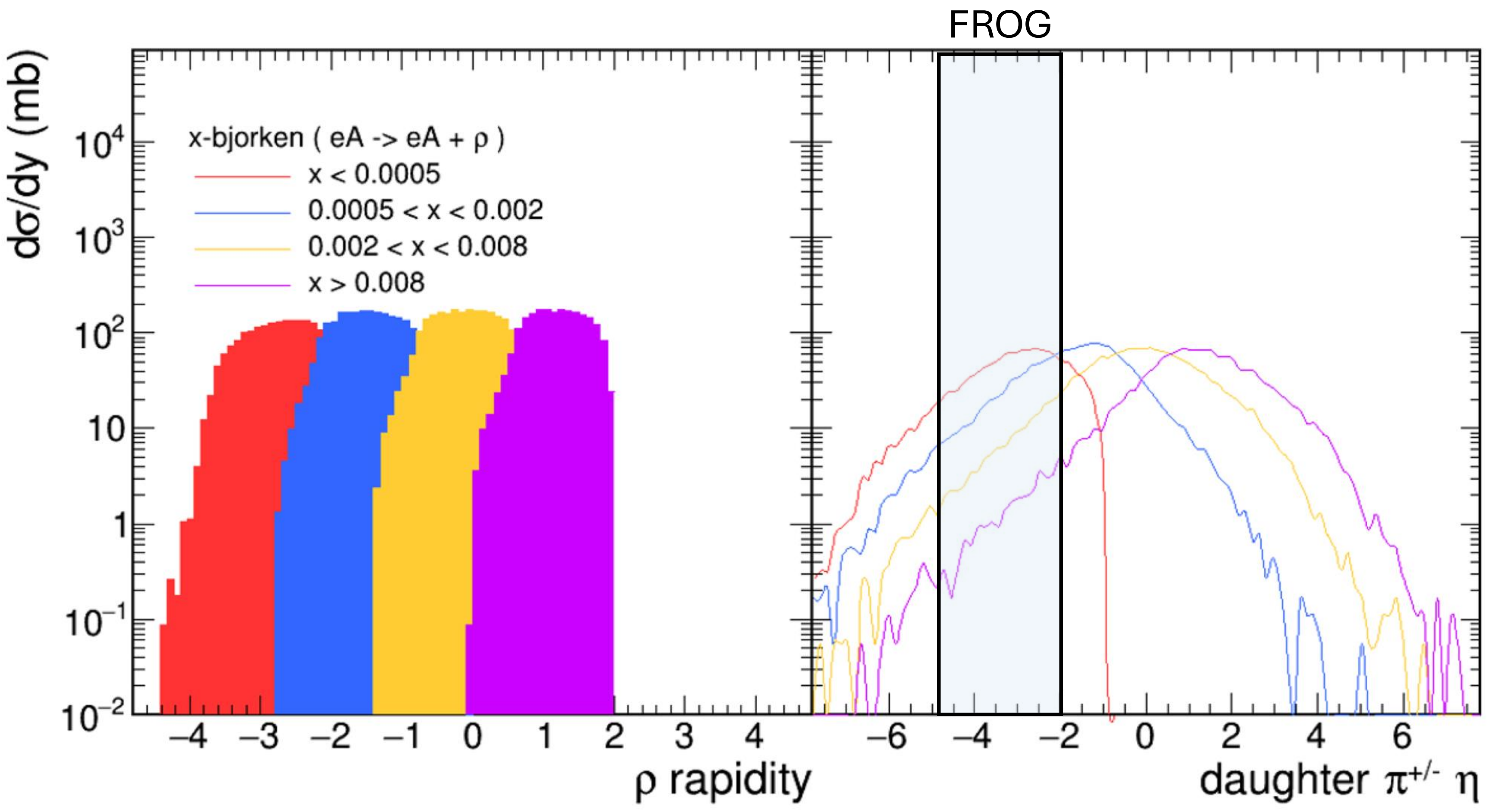
- Charged particle deflection exponentially decreases with $|\eta|$ but it still is under conventional silicon detector resolution.

- Can explore other combination of magnets and tracking to maximize B-field at $\eta \sim 4$ keeping B=0 at the beam electron direction.

- Interaction with magnets department in BNL is crucial

Exclusive ω production





Access to Bjorken-x < $5x10^{-4}$

Clear access to the gluon saturated regime

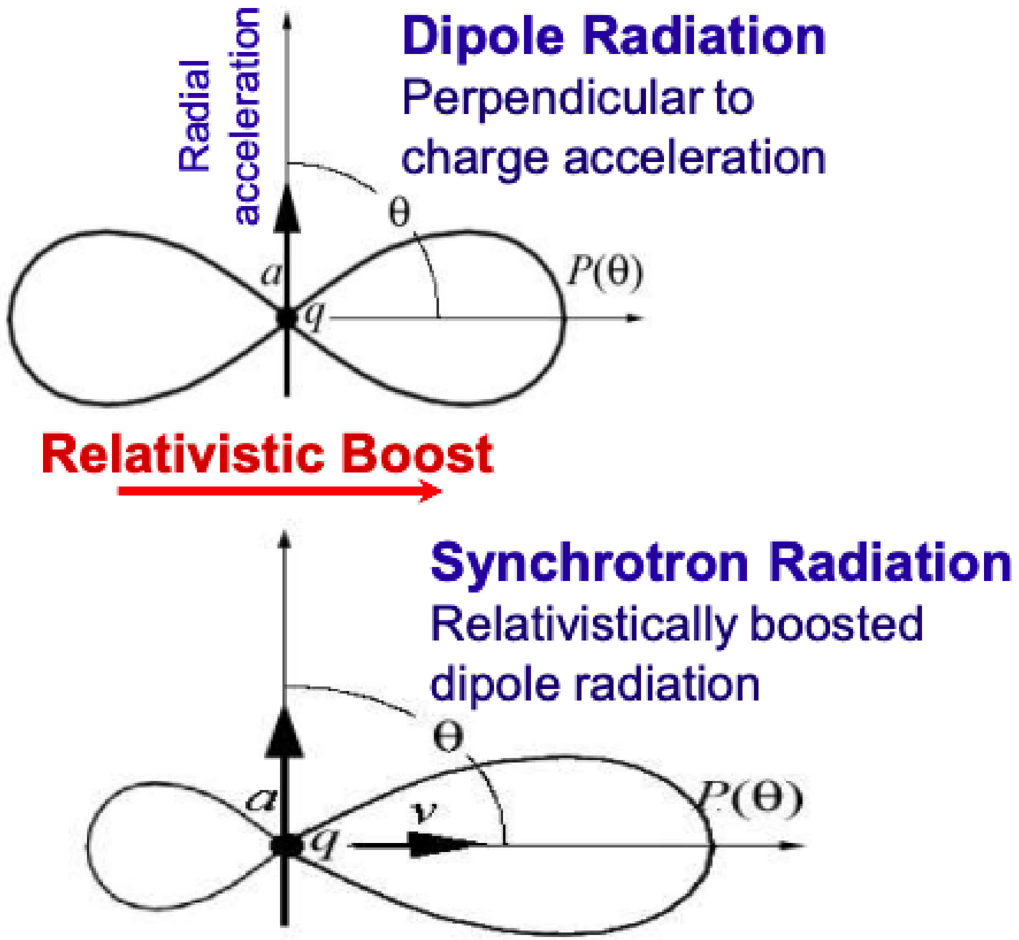
Conclusions and thought

- A forward and backward detector at IR8 would provide
  - Direct access to very small-x and large-x, exploring the boundaries of EIC
  - Integrated with the accelerator magnets, maximizing luminosity and beam collimation
  - A LHCb VELO inspired vertex detector inside a modified beam pipe to get as close as 1cm from the beam for heavy flavor physics at very large rapidity
  - Enables a fixed target program opening the door for new physics at EIC:
    - HI at very small energies, continuing one of the current STAR programs
    - High-lumi transverse spin asymmetry measurements with hadron collisions
  - Broad pt range PID with RICH+TOF
  - Utilizes the PHENIX muon detector for quarkonia an tau physics. Will require a new readout.
  - A relatively compact detector totally design for
    - AI-based streaming and tracking
    - Fast readout for 4D tracking in order to minimize hit contribution from beam background and synchrotron radiation
- A conceptual design based on quadrupoles seems not impossible. A better design improving the field close to the beam pipe would be desirable.
- A far-forward spectrometer could also make tracking at this region easier
- The detector could be built in steps given the funding limitations: one arm at the time for example
- Would like to have follow-ups on this concept for a future LDRD proposal at LANL

BACKUP SLIDES

Lumi Limitations: Electron SR Power

- Accelerated charged particles emit photons
  - Electrons in synchrotron: radially accelerated
  - **Synchrotron radiation** emitted in forward cone
    - Cone opening angle $\propto 1/\gamma$
    - Radiated power $P_\gamma = \frac{2}{3}\frac{e^2 c}{4\pi\epsilon_0}\frac{(\gamma\beta)^4}{\rho^2}$
  - γ scaling **much** worse for electrons
    - 18 GeV e: γ=3.5x10^4 vs 255 GeV p: γ=3x10^2
- **Design: 9 MW** @ 18 GeV (facility limit 10 MW)
- **Expensive:** Power must be provided by SRF



EPIC