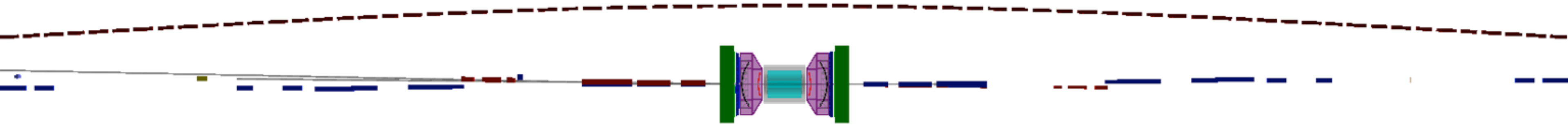


R&D Proposal for an electron polarimeter, a luminosity monitor, and a low Q^2-tagger: eRD12 Status Update

Richard Petti for the BNL EIC group

EIC Generic Detector R&D Advisory Meeting

July 2015

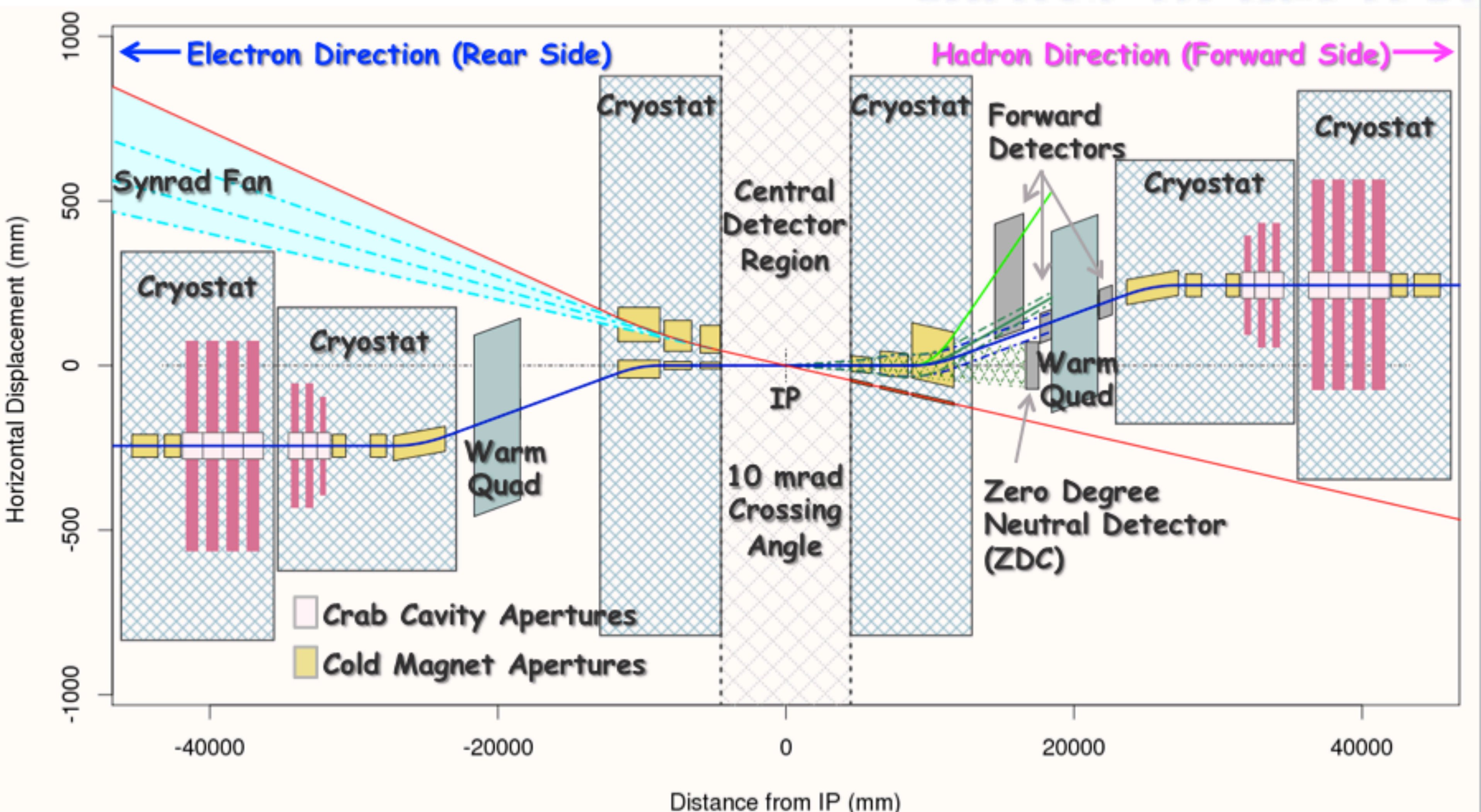
Outline

- overview of the IR design and simulation framework
- new stuff
  - general software improvements
  - luminosity monitor
  - extension of low Q^2-tagger study
  - extension of roman pot study
- to do list

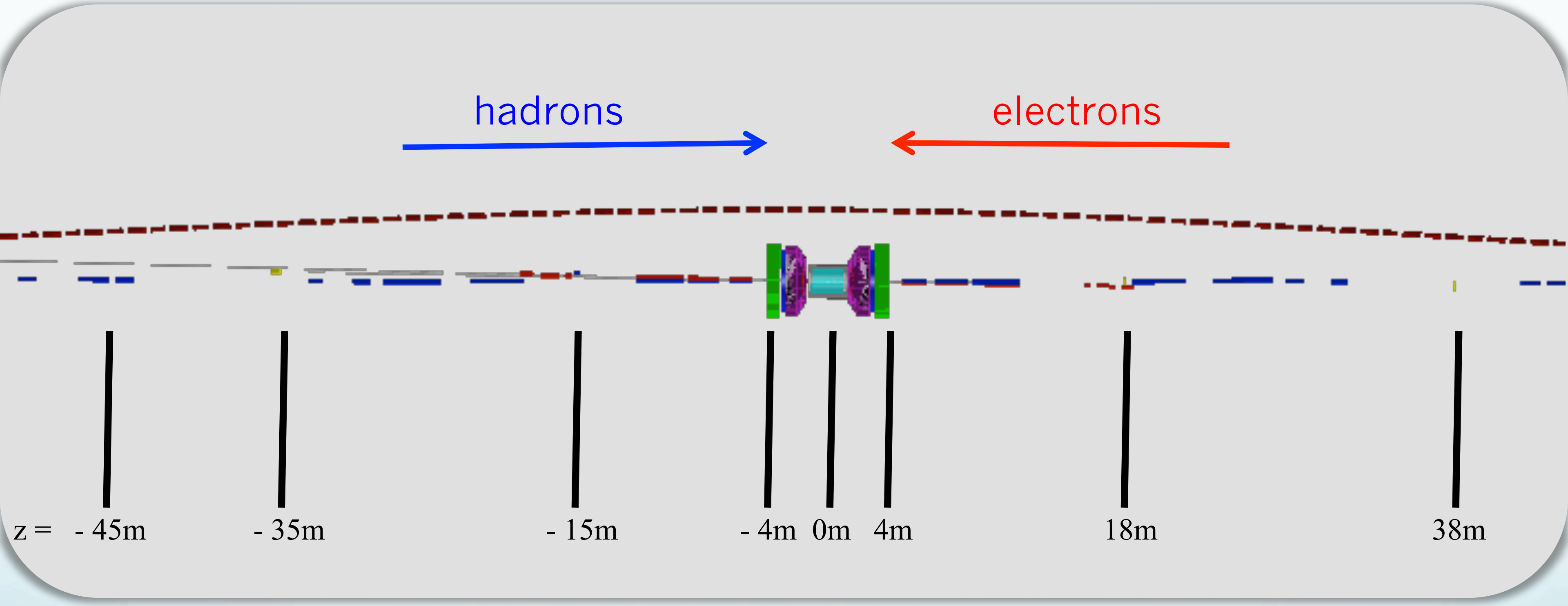
EicRoot simulation setup

- EicRoot is the EIC implementation of the FairRoot framework
  https://wiki.bnl.gov/eic/index.php/Eicroot
- main features:
  - use ROOT for detector geometry implementation, data handling and analysis
  - use GEANT (3 or 4) for particle tracking and interaction with materials
  - import beam line elements and magnetic field maps from files obtained by C-AD

Schematic of the eRHIC IR design



The IR setup in EicRoot

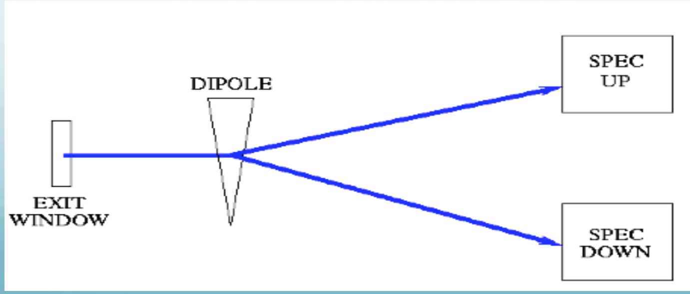


General Software Improvements

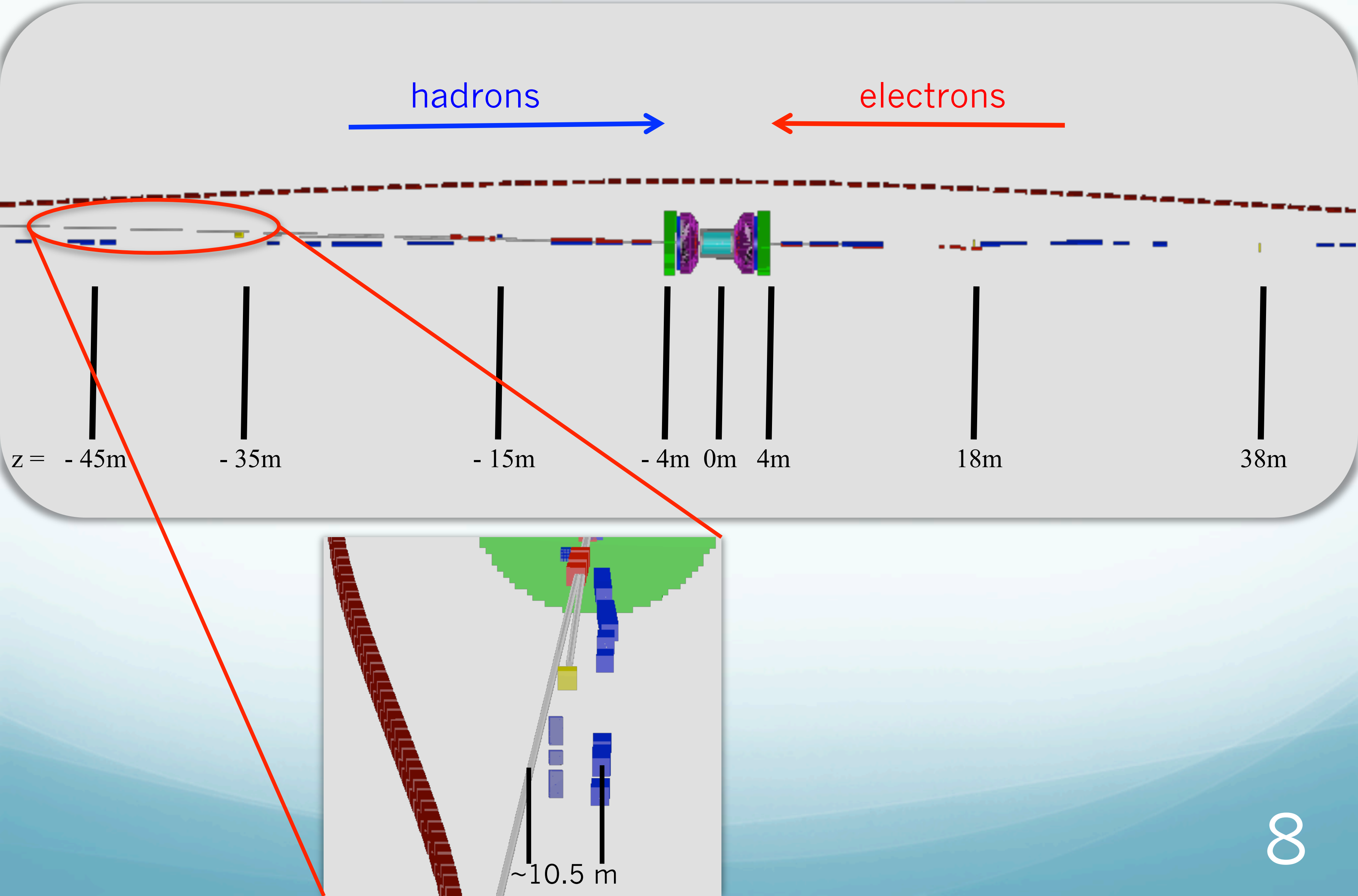
- EicRoot
  - magnetic field scaling
    - the field implementations from C-AD are for 20x250 GeV ep collisions
    - code importing the fields has been modified to allow one to scale the field for doing simulations with different energies
    - see the wiki page for details https://wiki.bnl.gov/eic/index.php/Eicroot#Realistic_IR_Magnet_Setup
- eicsmear (BuildTree module)
  - BuildTree module converts MC files from different generators to a unified EICTrees (ROOT based) for analysis
  - now can add in smearing of vertex position in x,y,z given a distribution and width
  - also can add the effect of the crossing angle and angular beam divergence

Luminosity Measurement

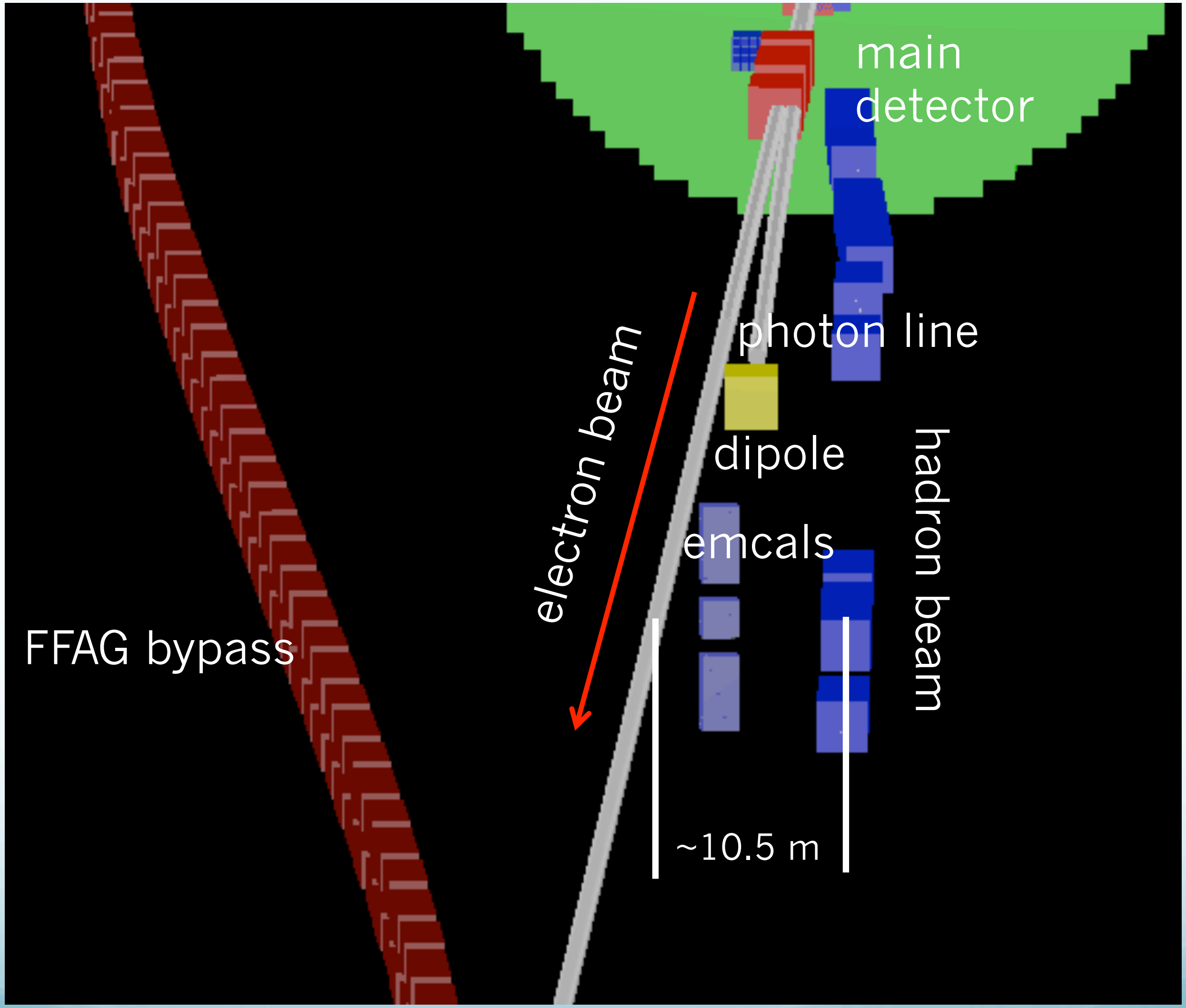
- measure luminosity via e+p ➔ e+p+γ
  - well known pure QED process
  - large cross-section
- need to know the luminosity better than 1%
- model after ZEUS (HERAII) design and measurement
- system needs to be fast enough to give feedback to machine on luminosity steering
- main goal of the current study, ensure there is room in the current IR design from C-AD
- two lumi measurements for important cross-check
  - central emcal for direct photon measurement
  - pair spectrometer measures converted photons in upper and lower emcals
  - each have independent systematics with different backgrounds



Luminosity Monitor Implementation



Luminosity Monitor Implementation



Investigating the size of the bremsstrahlung photon cone

- Want to ensure that the bremsstrahlung photon cone has good acceptance in the IR design
- Look at simulations from e+p ➔ e+p+ γ (unpolarized) from DJANGOH
- also compare to toy simulation of photons pulled from the Bethe-Heitler calculation
- fold in effect of beam optics
  - angle smearing from angular beam divergence
  - steering of vertex position also studied

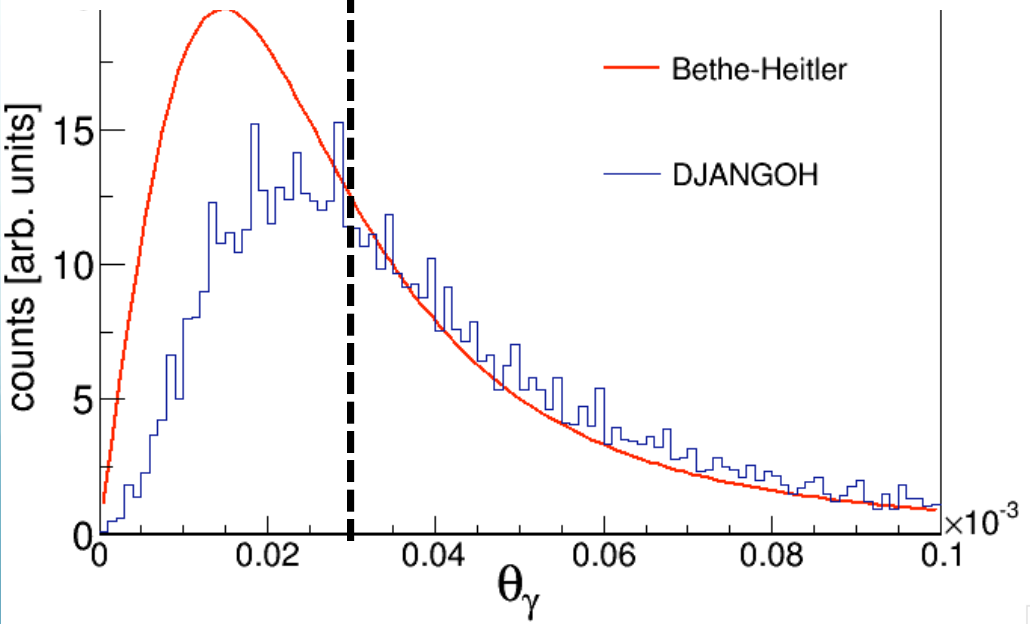
Lumi monitor study – the e+p ➔ e+p+γ process

- Two estimates of the expected angular distribution of Bremsstrahlung photons
  - Bethe-Heitler calculation

$$\frac{d\sigma}{d\Theta_\gamma} \approx \frac{\Theta_\gamma}{\left(\left(m_e/E_e\right)^2 + \Theta_\gamma^2\right)^2}$$

  - DJANGOH simulation
    - MC generator for DIS and bremsstrahlung processes

Note: relative scaling (please ignore numbers on yaxis)



- typical angle of emission is less than 0.03mrad
- roughly factor of 10 less than contribution from beam divergence for top energy ep collisions (see next slide)
- +/- 4mrad cone is the approximate space available

Luminosity monitor study – beam optics

- calculation of the angular beam divergence (in radians)

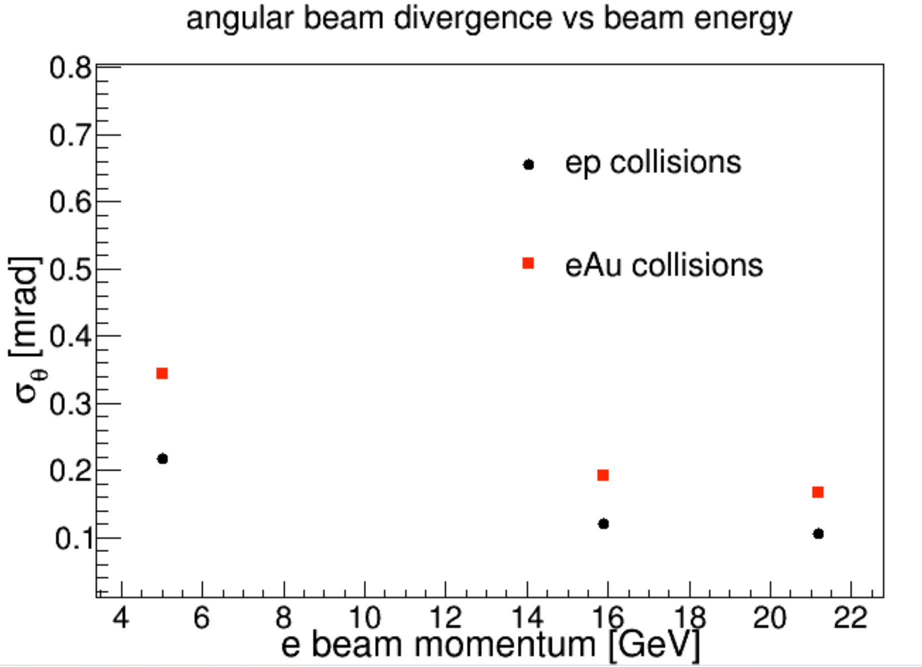
$$\sigma_\theta = \sqrt{\frac{\varepsilon}{\beta^* \gamma}}$$

  - sigma_theta = angular beam divergence
  - epsilon = (normalized) emittance (taken from table 3-1 of the eRHIC design report)
  - gamma = lorentz factor
  - beta* = beam optics parameter at IP (5cm taken from table 3-1)

- for 20x250 GeV e+p collisions

$$\sigma_\theta = \sqrt{\frac{23\times10^{-6}}{0.05*5\times10^{4}}} = 0.1 mrad$$

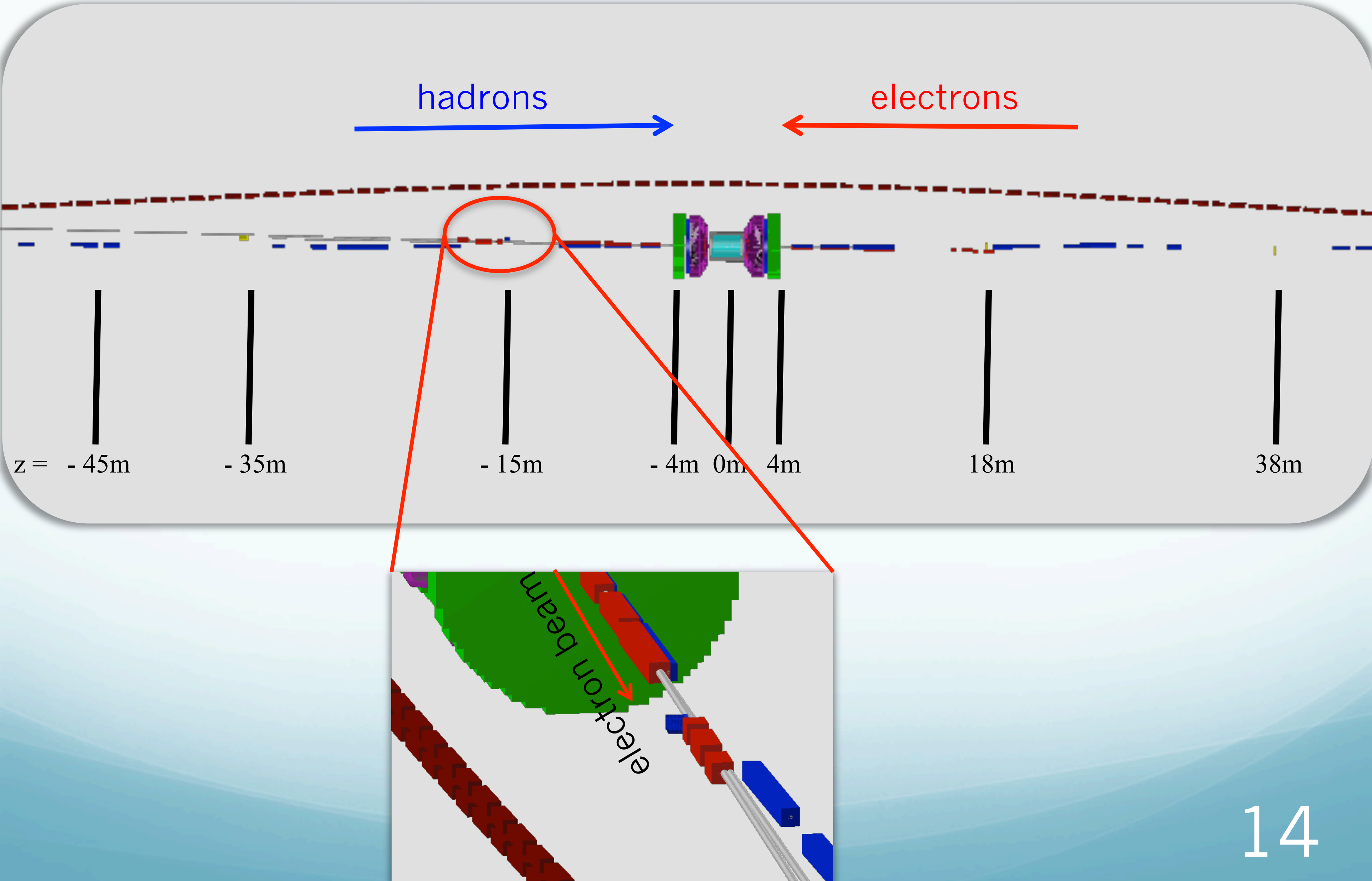
- for other beam conditions



Conclusion for Lumi Monitor Study

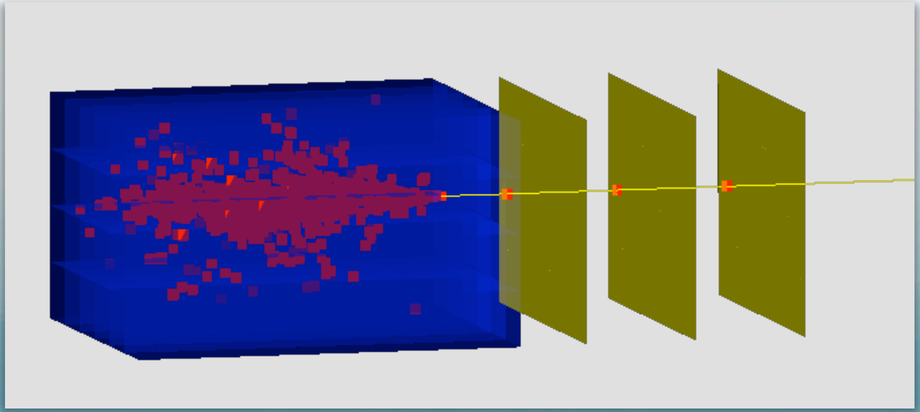
- studies show that the beam conditions dominate the expected cone size of bremsstrahlung photons
- have sufficient acceptance within the current IR design

Low Q^2-tagger Implementation

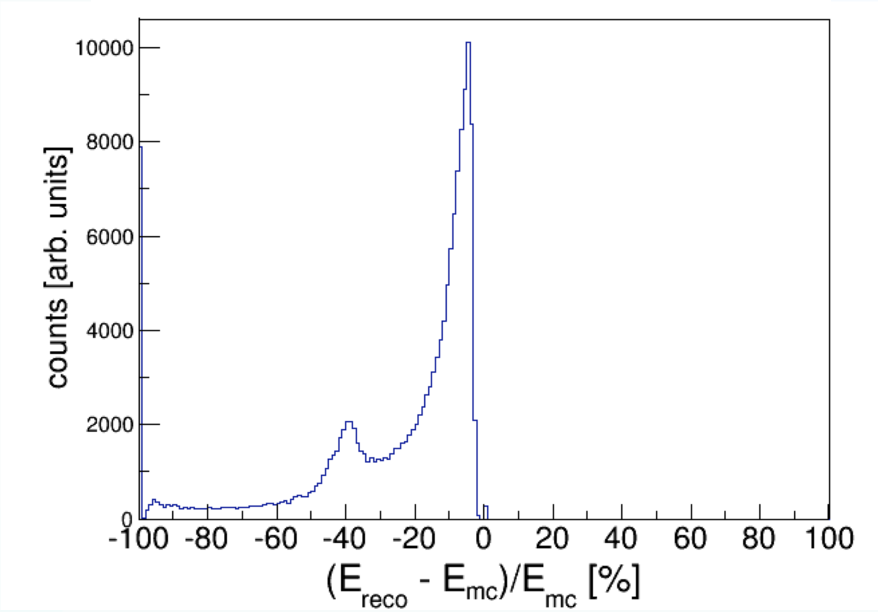


Update on low Q^2-tagger

- low Q^2-tagger will be used to capture electrons that miss main detector and come from low Q^2 ($<0.1 GeV^2$) events
  - physics topic example: photoproduction and PDF for photons
- located 2.5 cm from the beam center outside of the beam pipe
- add a third layer for redundancy in track reconstruction
- more realistic simulations underway
  - previously implemented a scattering angle reconstruction using perfect MC hits
  - now run the hit digitization step and cluster formation in emcal

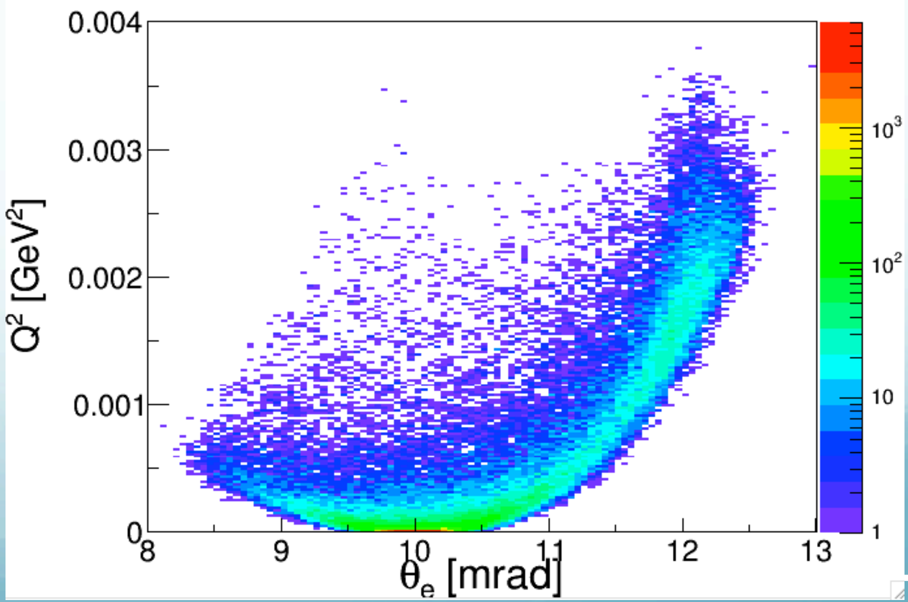


Energy reconstruction and Q^2 coverage in the low Q^2-tagger



- pythia events
- energy is typically under-estimated due to leaking from edge
- can be corrected for
- still need to take into account multiple scattering in beam pipe
  - to do: detailed beam pipe design

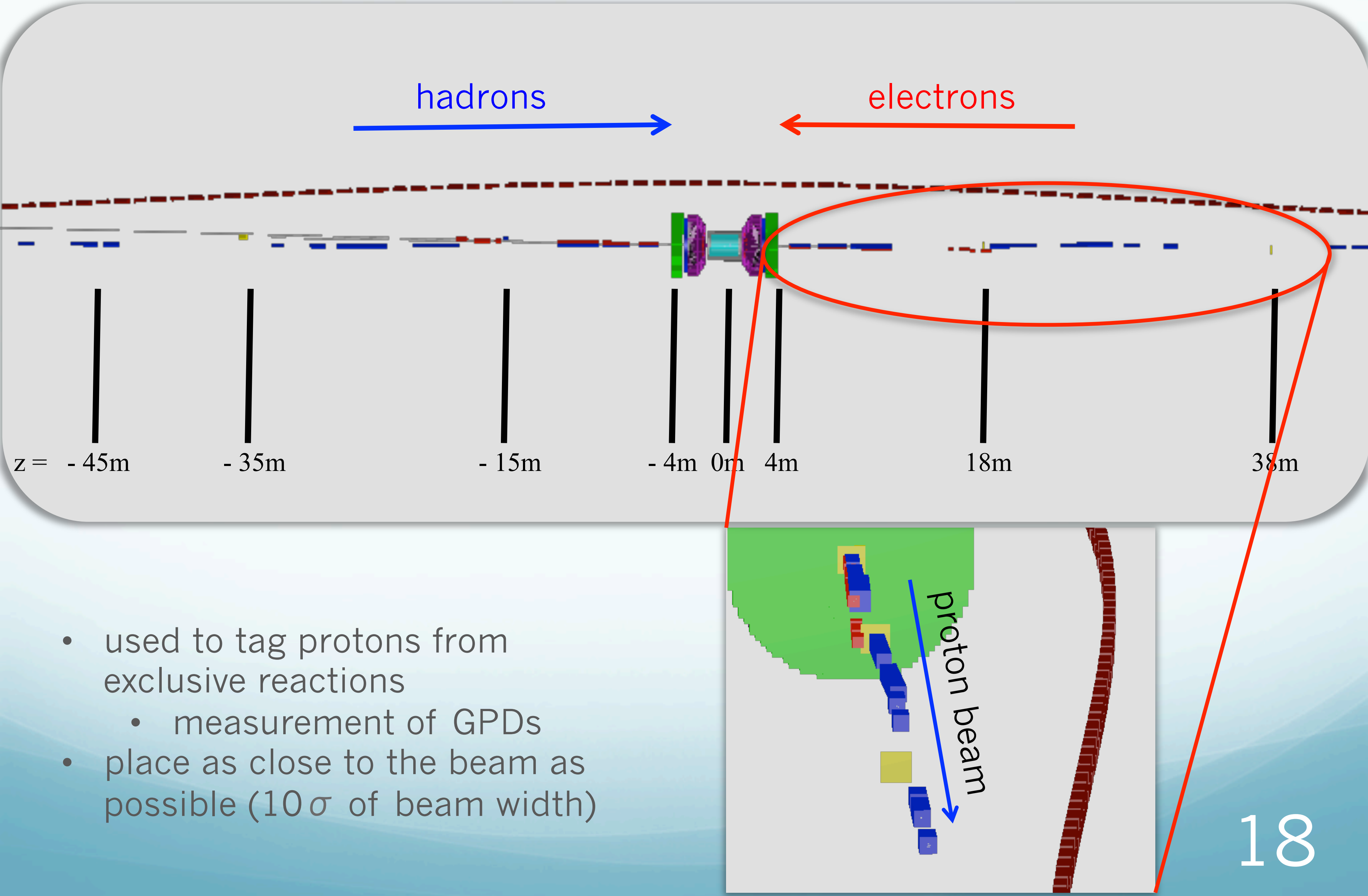
- pythia events
- require:
  - $E_{reco} > 0.5\text{GeV}$
  - $|(E_{reco} - E_{mc})/E_{mc}| < 20\%$



Conclusion for Low Q^2-tagger Study

- studies show reasonable energy reconstruction
- good coverage down to low Q^2

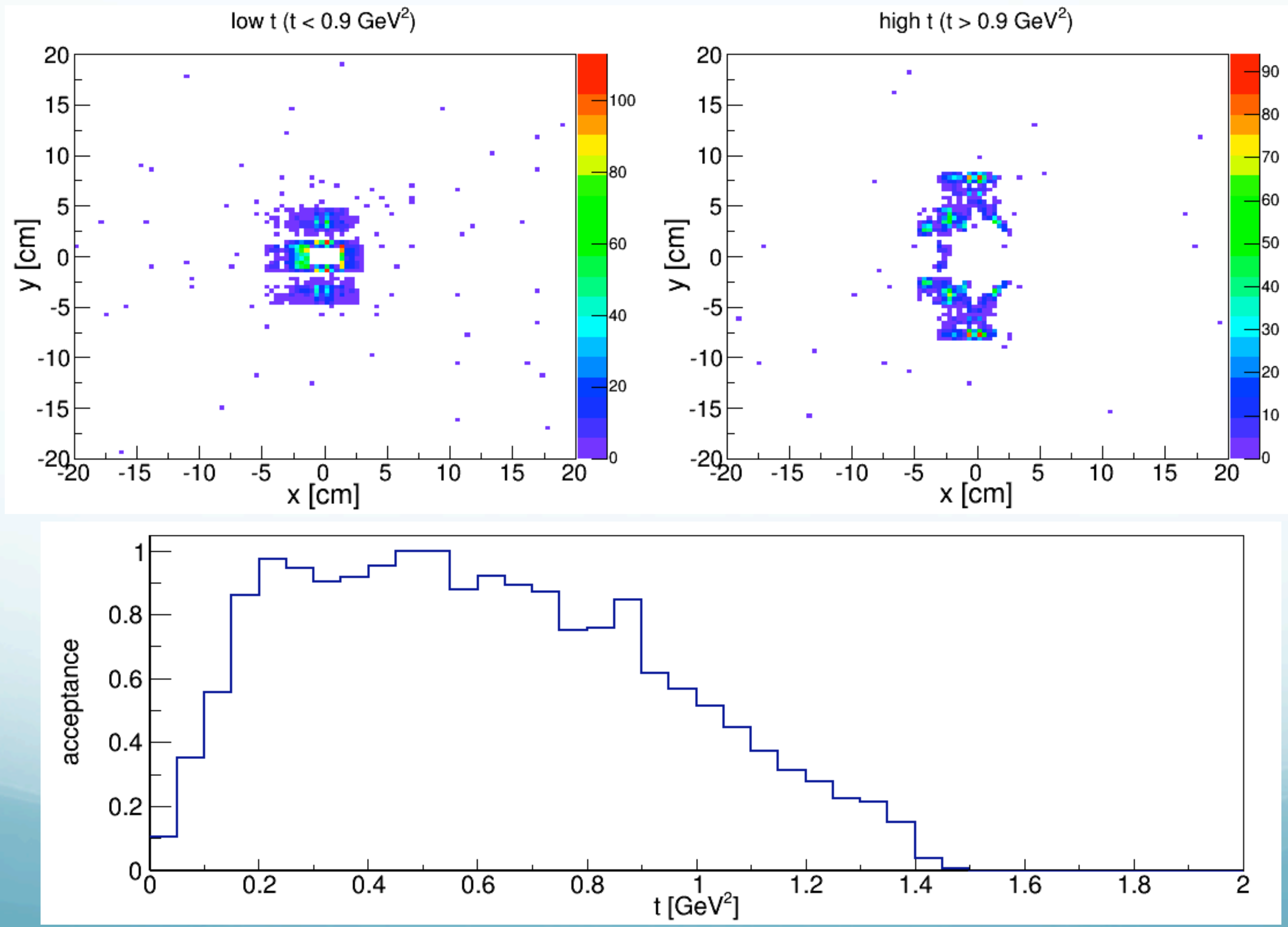
Roman Pot Implementation



- used to tag protons from exclusive reactions
  - measurement of GPDs
- place as close to the beam as possible (10 σ of beam width)

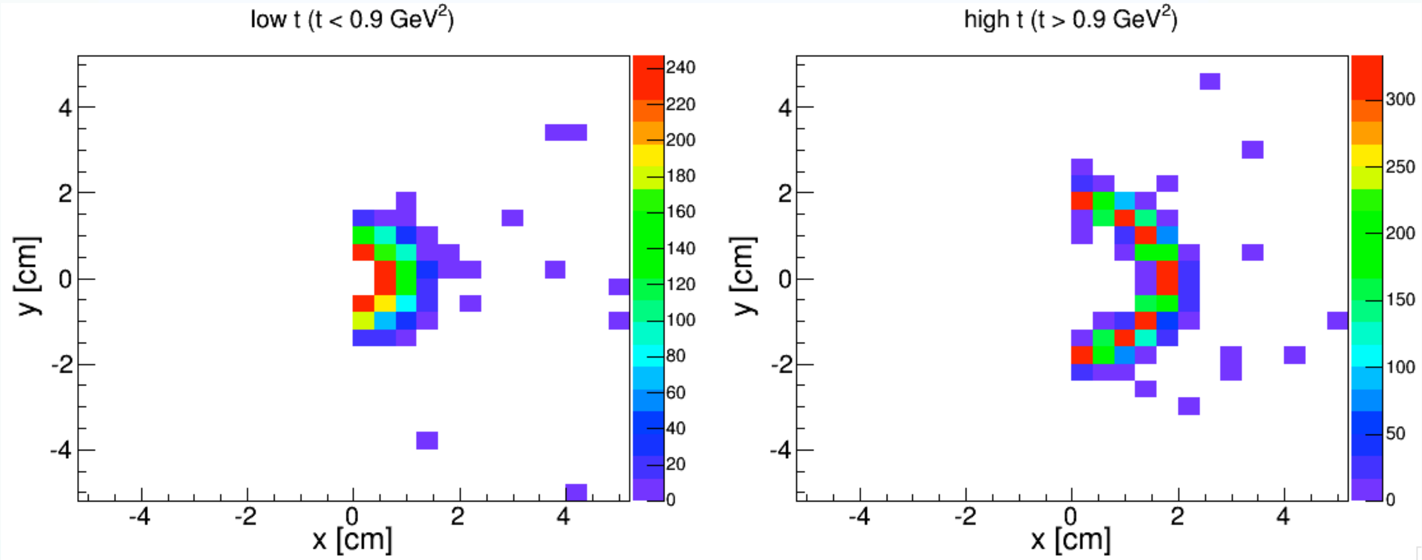
roman pot acceptance: one station at 18m

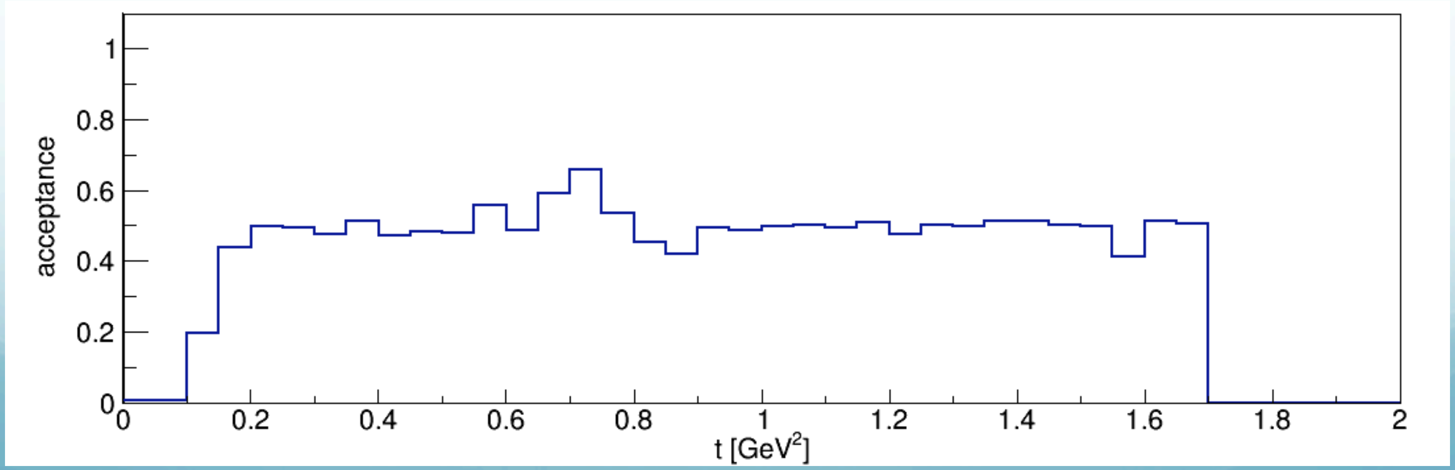
- feed in MILOU simulations of DVCS events
  - following studies have no beam effects taken into account and event production at (0,0,0)
  - coordinates relative to the center of the beam



Addition of a close station at 4.25m

- necessary for acceptance at high t (most statistics starved phase space)
- electron beam prevents full 360^0 acceptance





Conclusion for Roman Pot Study

- studies show good overall coverage in t in current IR design
- but lose somewhat at high t
- need to consider a station very close to the main detector

Electron Polarimetry

- use compton-scattering process for measurement (as was done at HERA)
- important to integrate polarimeter into the machine lattice from the beginning to minimize backgrounds
  - Need to find the optimal place for the detectors
  - reduce backgrounds from Bremsstrahlung and synchrotron radiation
    - place is a short section with gentle bending
  - maximize Compton rate
    - small crossing angle with beam
    - place in an area with a small electron beam width and divergence
  - measure as close as possible to the IP
  - measure in between spin rotators

to do for the next year

- electron polarimetry!
- calculation of polarized e+p ➔ e+p+γ cross-section
- integrate ZDC into the design
- investigate MDISIM to improve field map importing
  - being developed by FCC group
  - interfaces MAD-X with ROOT and GEANT
- background studies (for example synchrotron radiation)
- all studies so far focused on top energy running
  - extend studies to lower energies
- current studies performed with v2.1 of machine design
  - need to iterate with a newer version (there is a v3.* in existence with some of the concerns about apertures rectified)
- financial funding
  - original request 2 y of postdoc $115,508/yr + $10k/y travel funds
  - started August 2014 → remaining request 1 y of postdoc $115,508 + $10k travel funds

Summary

- Major progress made in simulations of the axillary detectors in the IR
  - basic lumi monitor design and implementation in the simulation framework complete
    - MC studies indicate that there is sufficient space for the system
  - basic low Q^2-tagger design and implementation in the simulation framework complete
    - performing more detailed simulations of the performance of the design based on physics
  - roman pot acceptance studies confirm a need for a station before the first set of magnets to have access to high t
- Next step in the project is to pursue studies related to the polarimeter
  - initial design and placement around the ring
- integrate polarized e+p ➔ e+p+γ event generation into DJANGOH

Man Power

- Elke Aschenauer (BNL physics)
- Alexander Kiselev (BNL physics)
- Vladimir Litvinenko (BNL C-AD)
- Brett Parker (BNL magnet division)
- Richard Petti (BNL physics)
- Vadim Ptitsyn (BNL C-AD)
- William Schmidke (BNL physics)
- Hubert Spiesberger
- Dejan Trbojevic (BNL C-AD)

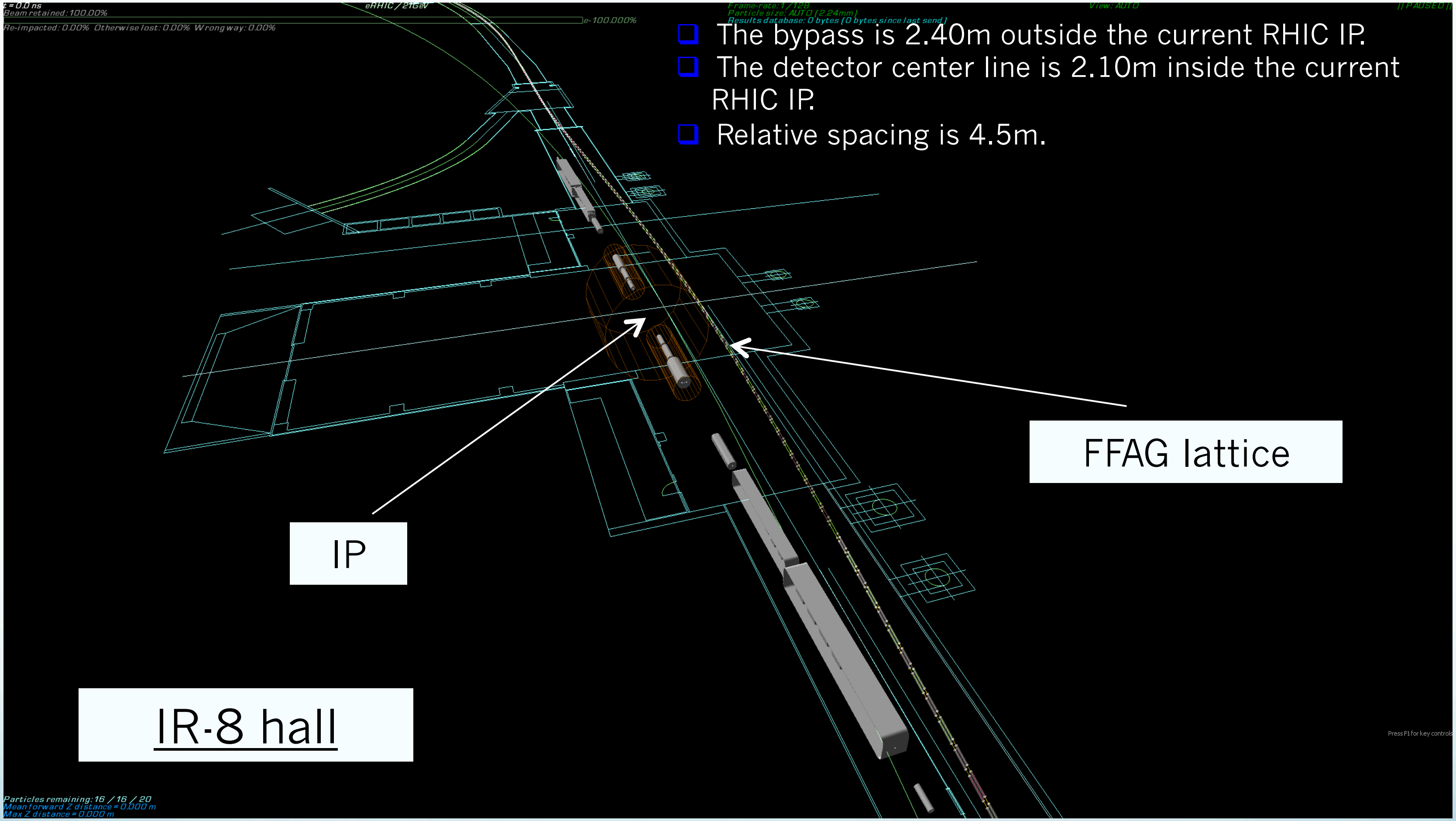
Backups

Summary at last meeting

- post-doc hired
- framework set up to exchange machine beam line elements and field maps from C-AD to EicRoot simulation
- major progress in implementing working design for low Q^2-tagger in the EicRoot simulation framework
  - initial geometry, design, and location
  - acceptance studies
    - given recommendations to C-AD to improve apertures
  - simple reconstruction algorithm to determine scattering angle
- added roman pot studies to the list
  - implemented a roman pot station at 18m and studied acceptance
  - current IR design causes loss of high t protons in first magnet
  - brought this to the attention of C-AD

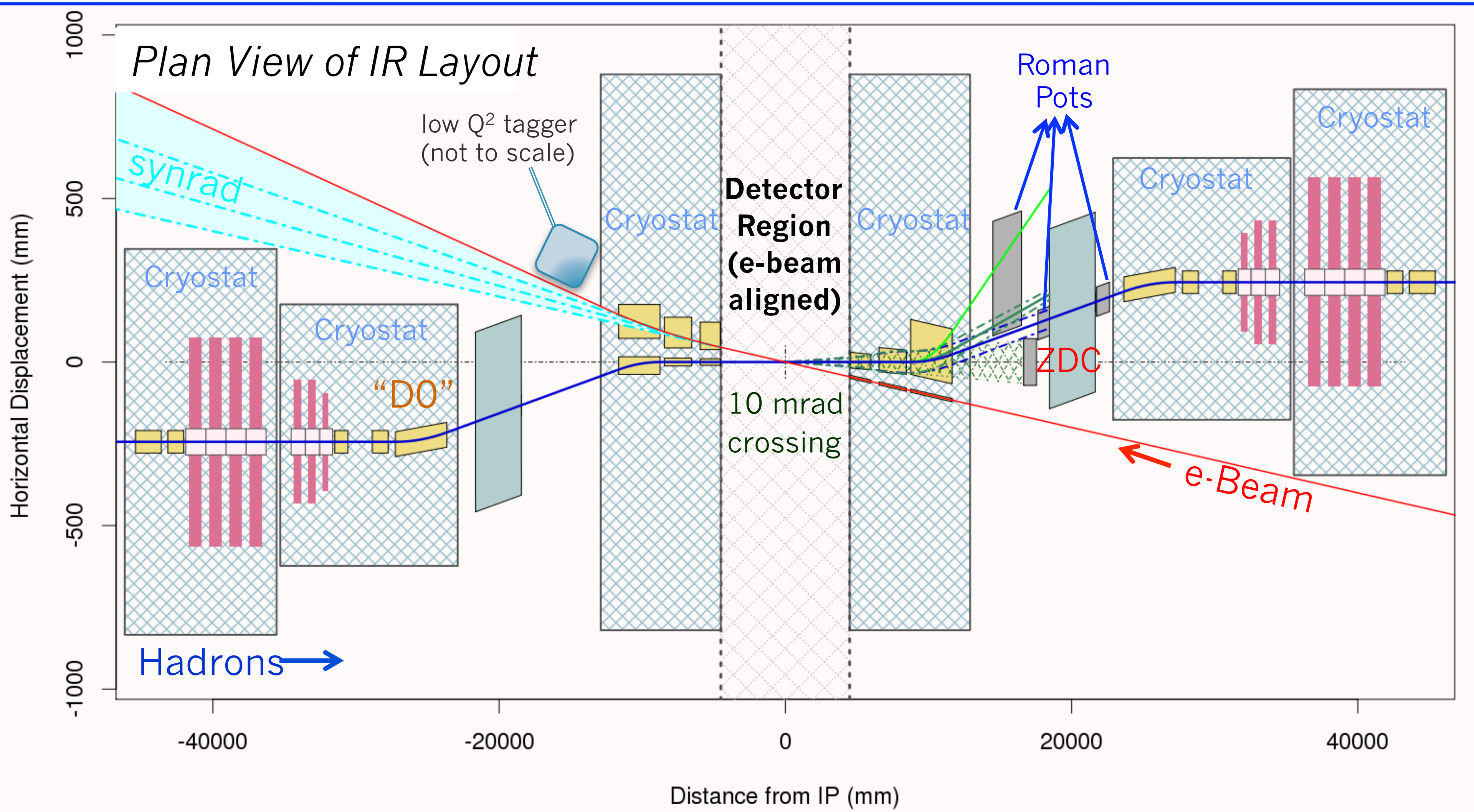
by Stephen Brooks

Schematic of the eRHIC IR design



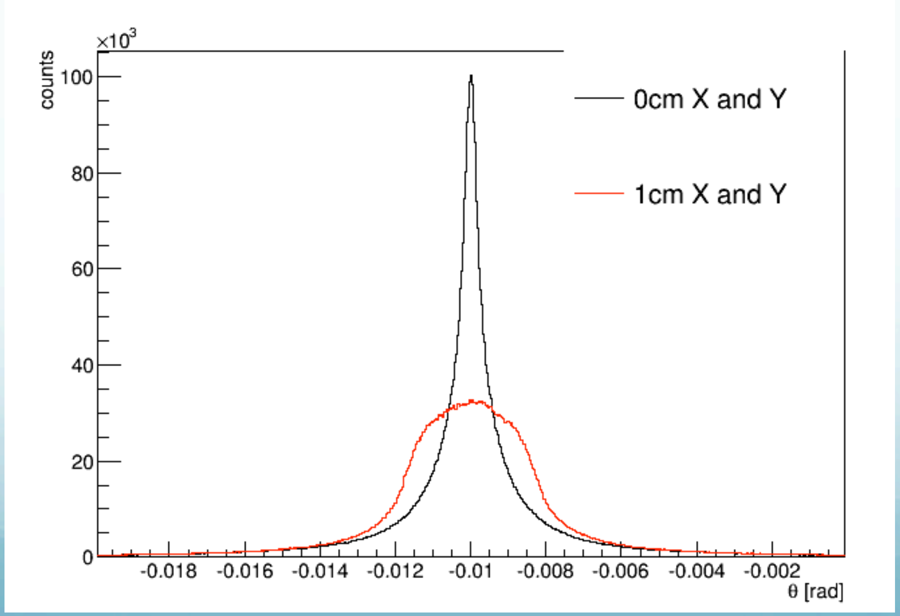
→ space constraints need to be taken into account in detector, e-polarimeter, lumi-monitor and tagger design design

Schematic of the eRHIC IR design



Luminosity monitor study – additional effect of beam steering

- considering the added effect if the IP moves a bit and is off center
- look at DJANGOH e+p ➔ e+p+γ events fed into EicRoot
- extreme assumption to test limits
  - both curves include crossing angle (10mrad) and angular beam divergence (0.1mrad) and a flat z vertex spread of +/- 2.5cm (corresponding to proton beam bunch length)
  - black has all events at (0,0) vertex
  - red has events with (x,y) vertex distributed flat with +/- 0.5cm
- note that in this definition, the electron going direction is 0 degrees

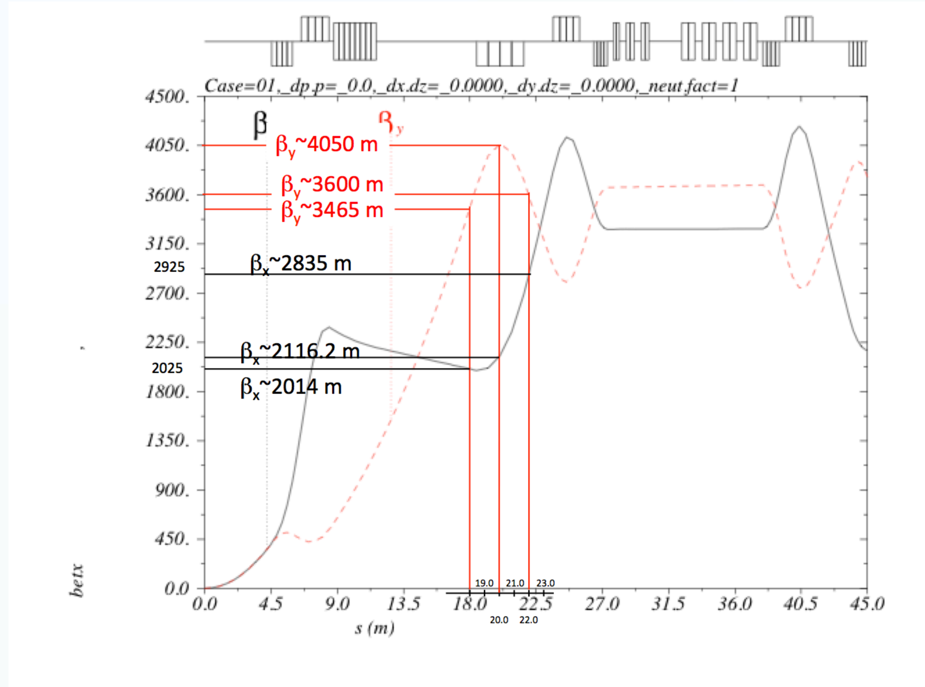


Crunching some numbers...how close can we place the RP to the beam?

- place 10σ from beam so as not to disrupt the beam
- how to calculate beam width RMS

$$\sigma_{x,y} = \sqrt{\frac{\beta_{x,y}\varepsilon_n}{\gamma}}$$

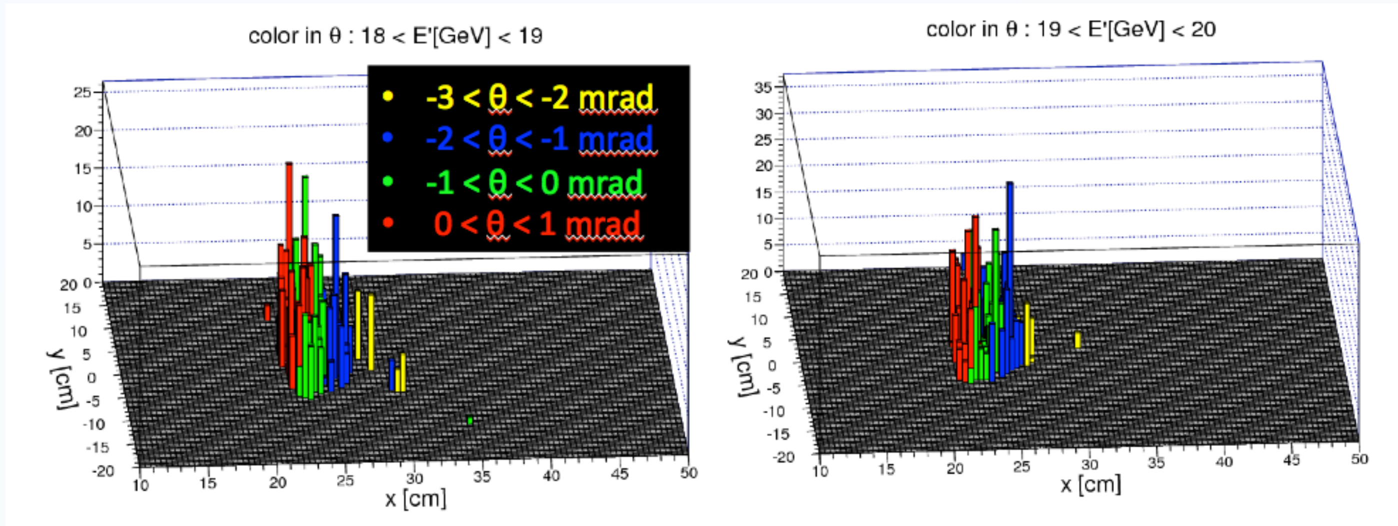
- for 250 GeV proton beam
  - gamma = 270
  - epsilon_n = 0.2x10^-6 m



z location [m]	beta_x [m]	10*sigma_x [cm]	beta_y [m]	10*sigma_y [cm]
4.25	425	0.56	425	0.56
14.5	2116.2	1.25	2250	1.29
18	2014	1.22	3465	1.6
38	3465	1.6	3465	1.6

Aperture acceptance for low Q^2-tagger

nominal design



rotated aperture