Physics capabilities at the MEIC at JLab

Pawel Nadel-Turonski

Jefferson Lab

for the MEIC group

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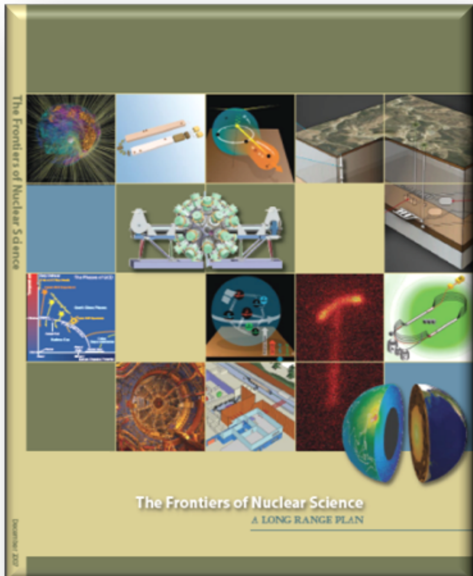
Outline

Introduction and overview

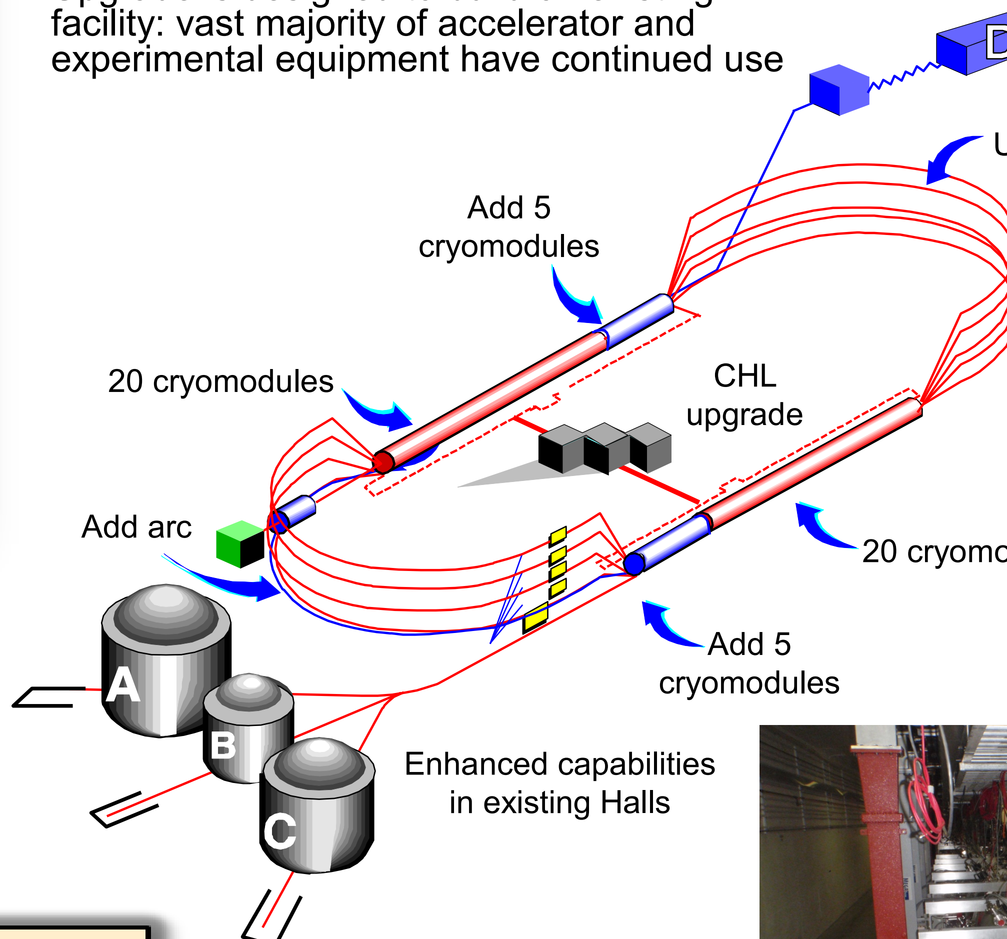
Update on Detector

Some physics highlights

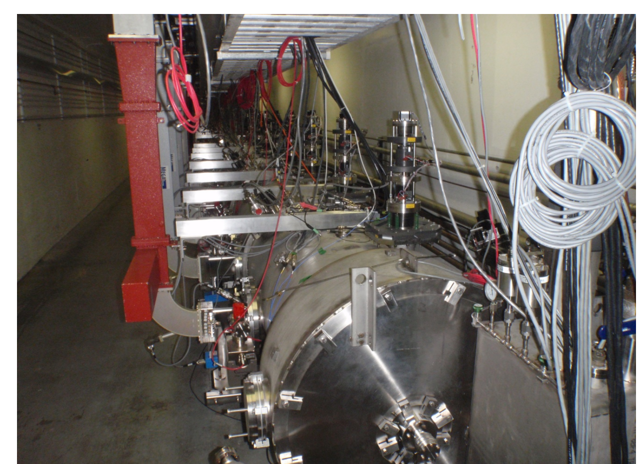
JLab 12 GeV upgrade – probing the valence quarks



Upgrade is designed to build on existing facility: vast majority of accelerator and experimental equipment have continued use



The completion of the 12 GeV Upgrade of CEBAF was ranked the highest priority in the 2007 NSAC Long Range Plan.



New C100 cryomodules in linac tunnel

Scope of the project includes:
- Doubling the accelerator beam energy
- New experimental Hall and beamline
- Upgrades to existing Experimental Halls

EIC – probing the sea

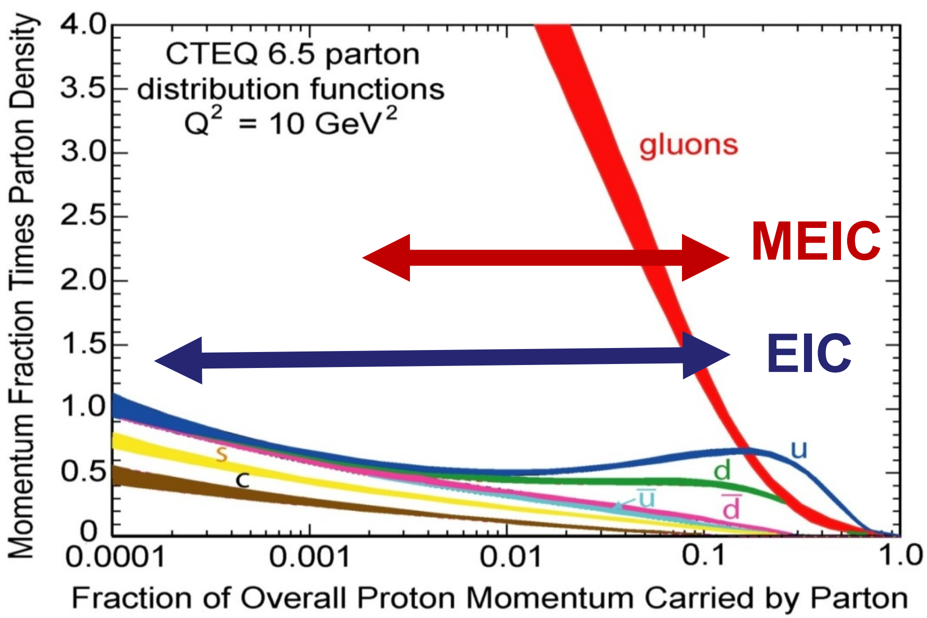
(“Medium-Energy”) MEIC@JLab energy choices driven by:

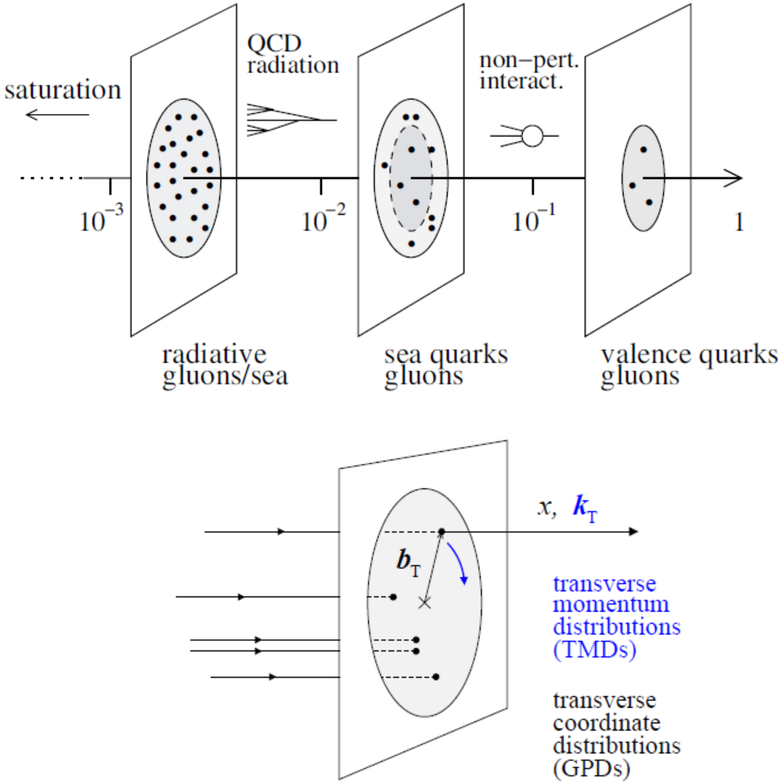
access to sea quarks and gluons

→ s = few 100 – few 1000 allows access to gluons, shadowing

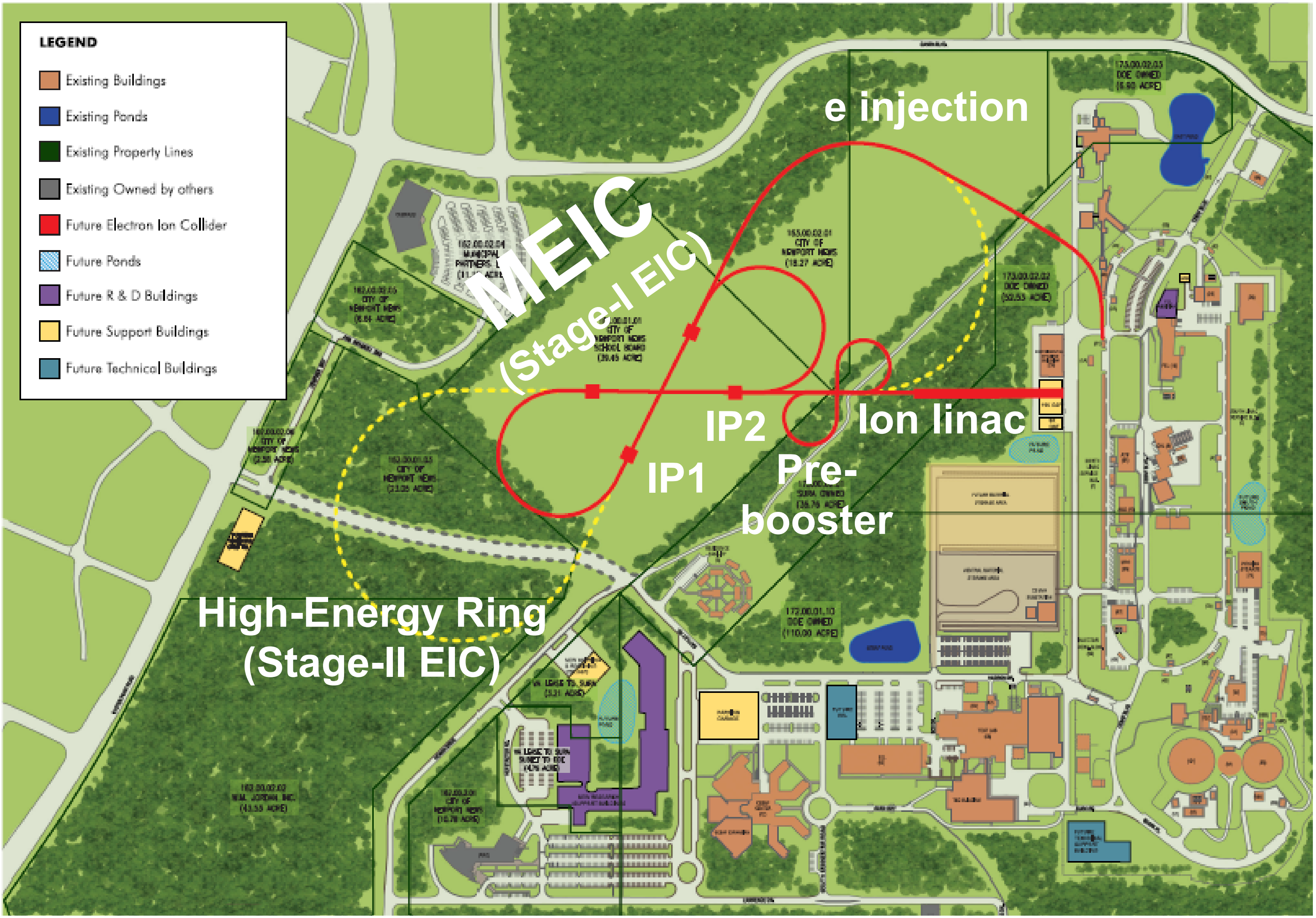
Polarization + good acceptance to detect spectators & fragments

An EIC aims to study the <u>sea quarks and gluon-dominated matter</u>.





MEIC – accelerator layout at JLab

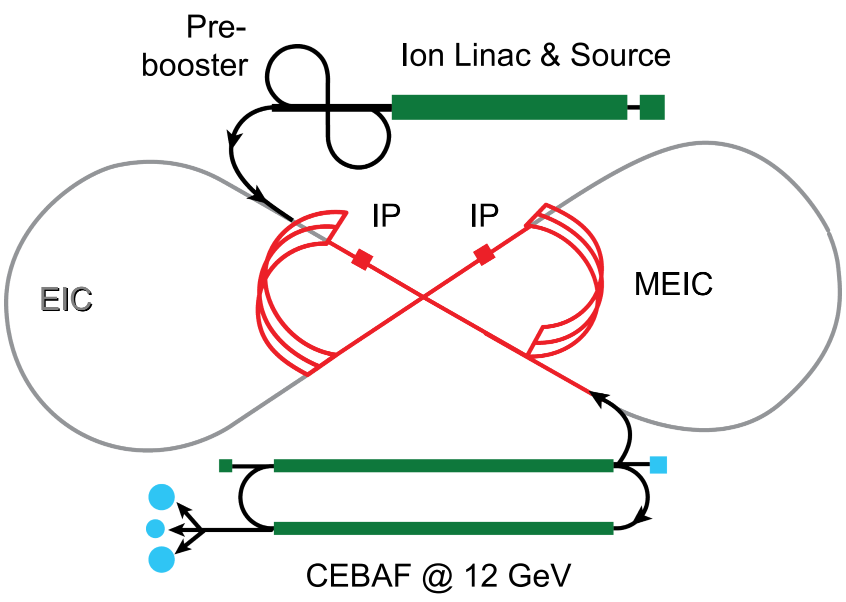


- The MEIC has the same circumference as CEBAF

MEIC – a figure-8 ring-ring collider

The design makes possible:

- Simultaneous use of two full-acceptance detectors
  - total beam-beam tune shift < 0.03
- Longitudinal and *transverse* polarization of light ions
  - protons, ***deuterium***, ^{3}He, ...
- Longitudinally polarized leptons
  - electrons and ***positrons***
- Running fixed-target experiments in parallel with collider



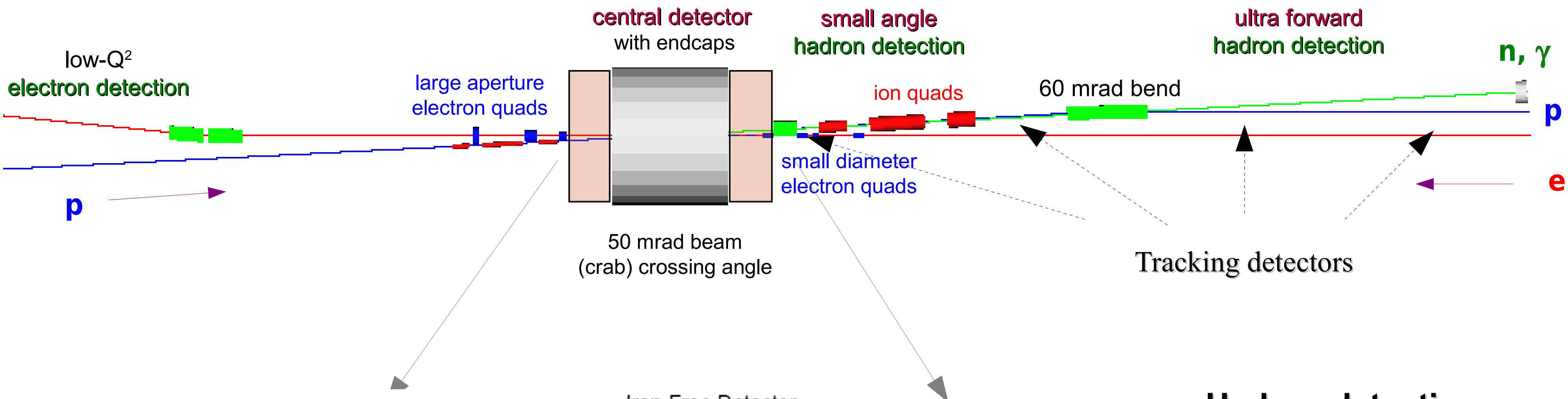
- Reduced R&D challenges
  - Regular electron cooling
  - Regular electron source
  - No multi-pass ERL
  - No space-charge compensation

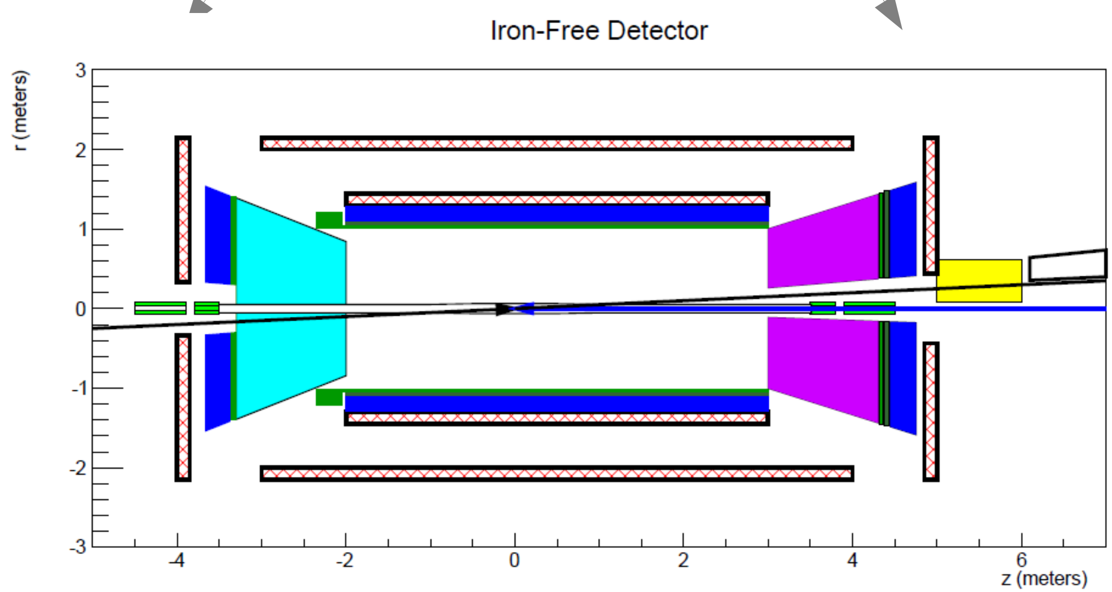
→ talk by Y. Zhang

Full-acceptance detector concept

(from GEANT4)

No other magnets or apertures between IP and FP!





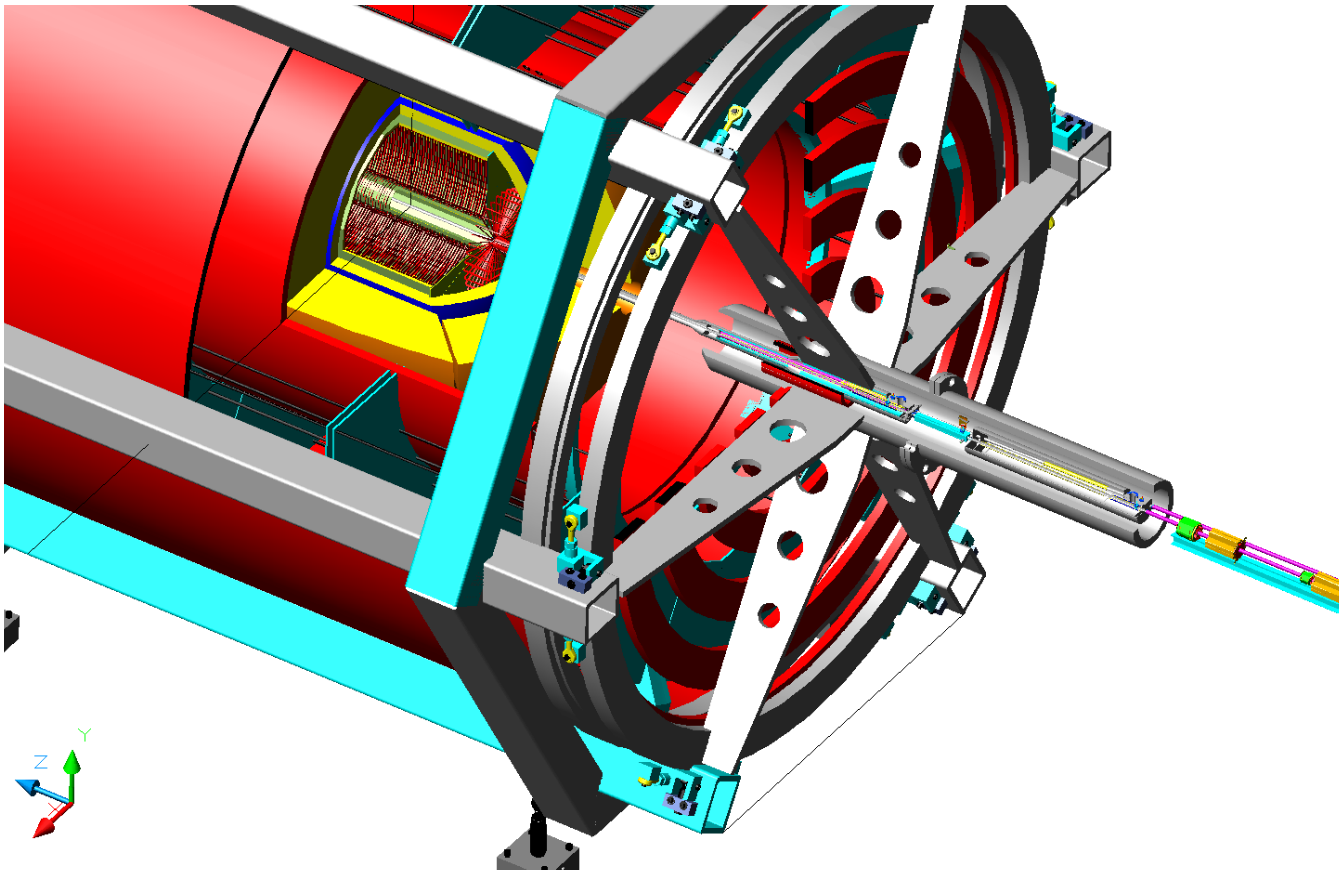
Hadron detection in three stages:

1. Encap with 50 mrad crossing angle

2. Small dipole covering angles up to a few degrees

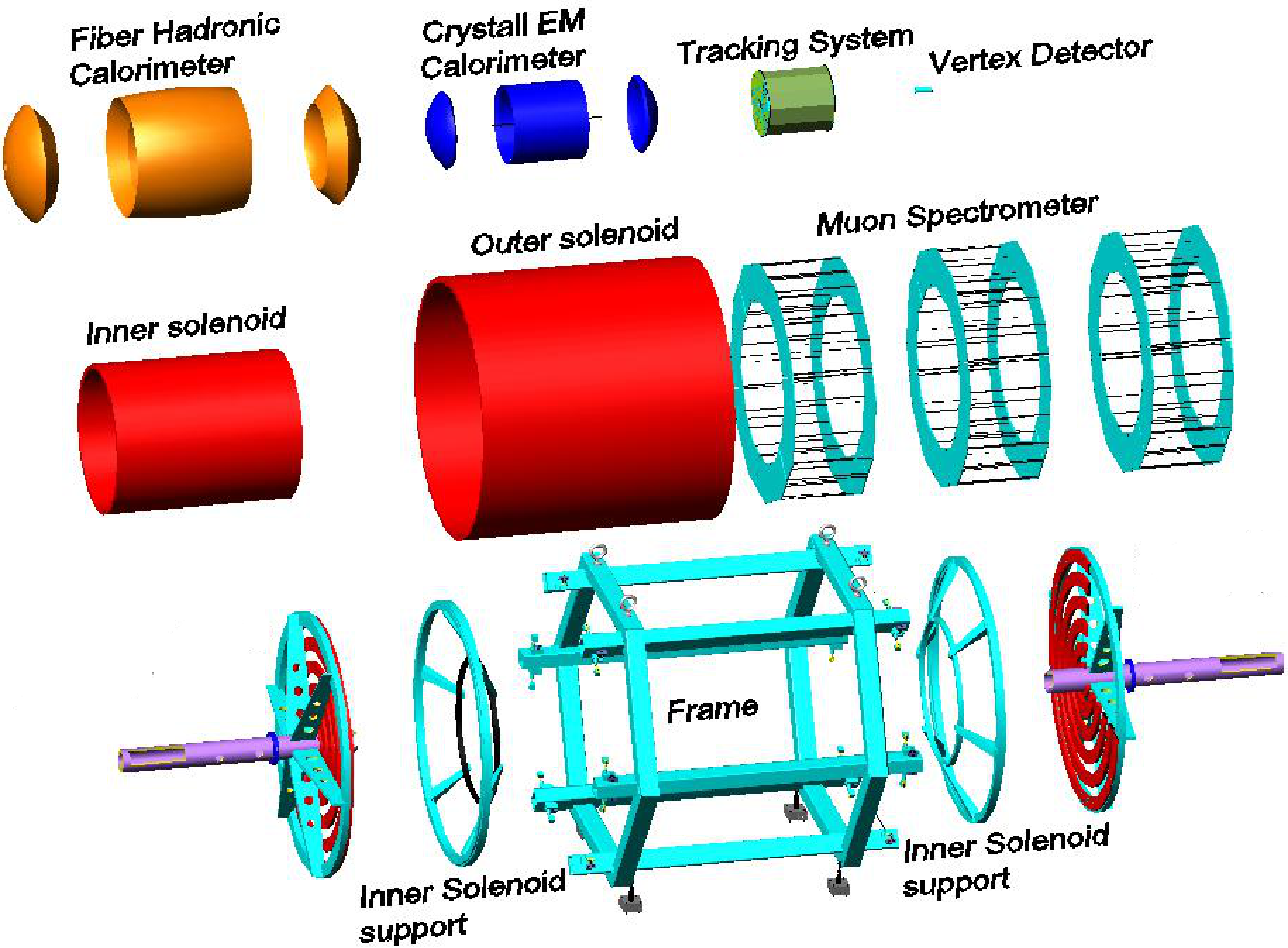
3. Ultra-forward, up to one degree, for particles passing the accelerator quads

Central detector – ILC “4th” detector concept



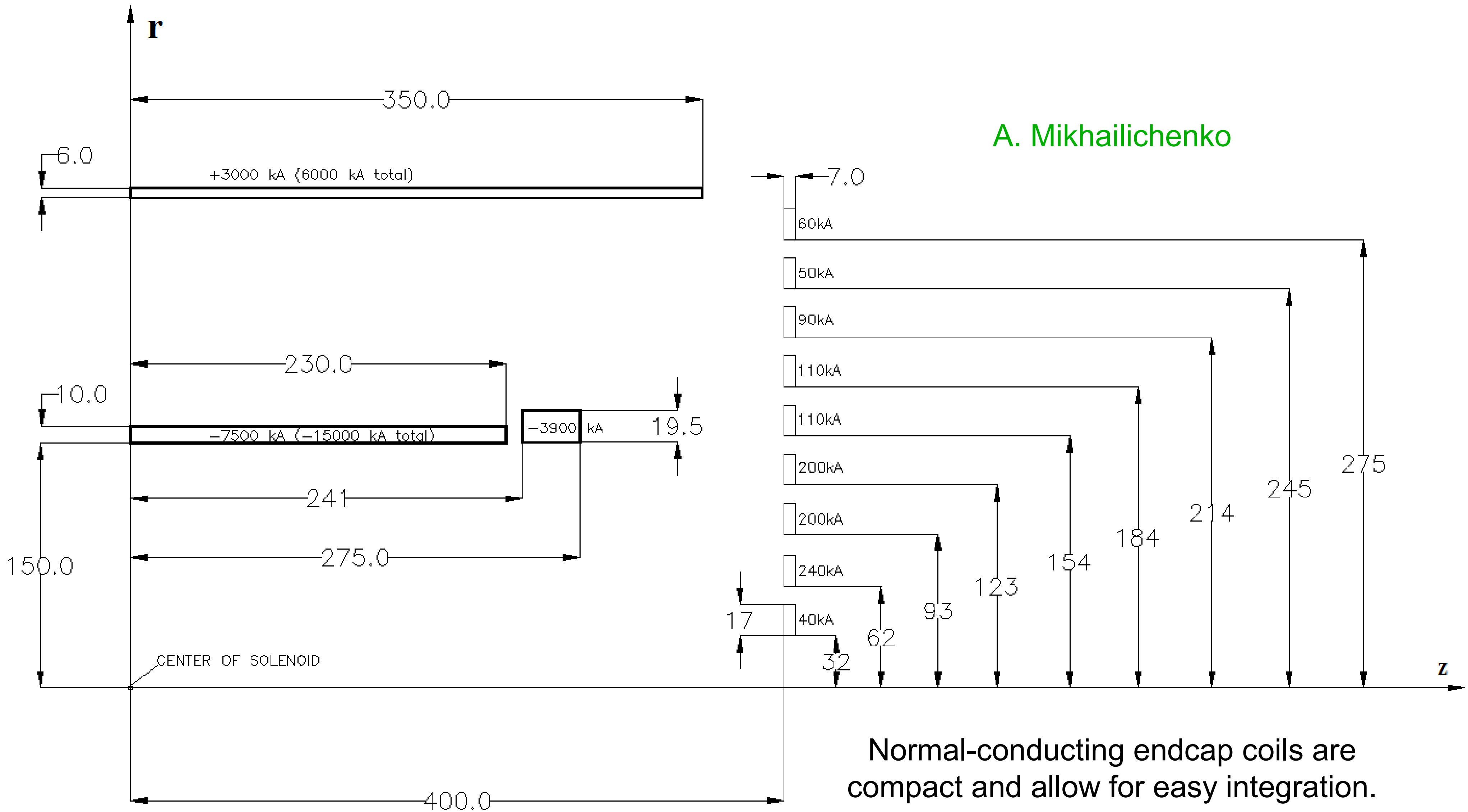
- An iron-free dual-solenoid based central detector approach from the ILC „4th“ concept LoI has many attractive features.
- The dual-solenoid concept is applied to the MEIC detector in collaboration with the ILC team.
  - The MEIC detector is about 1/2 of the ILC one (1/8 of the volume), and has field lower (3 T).

ILC „4th“ detector concept – components



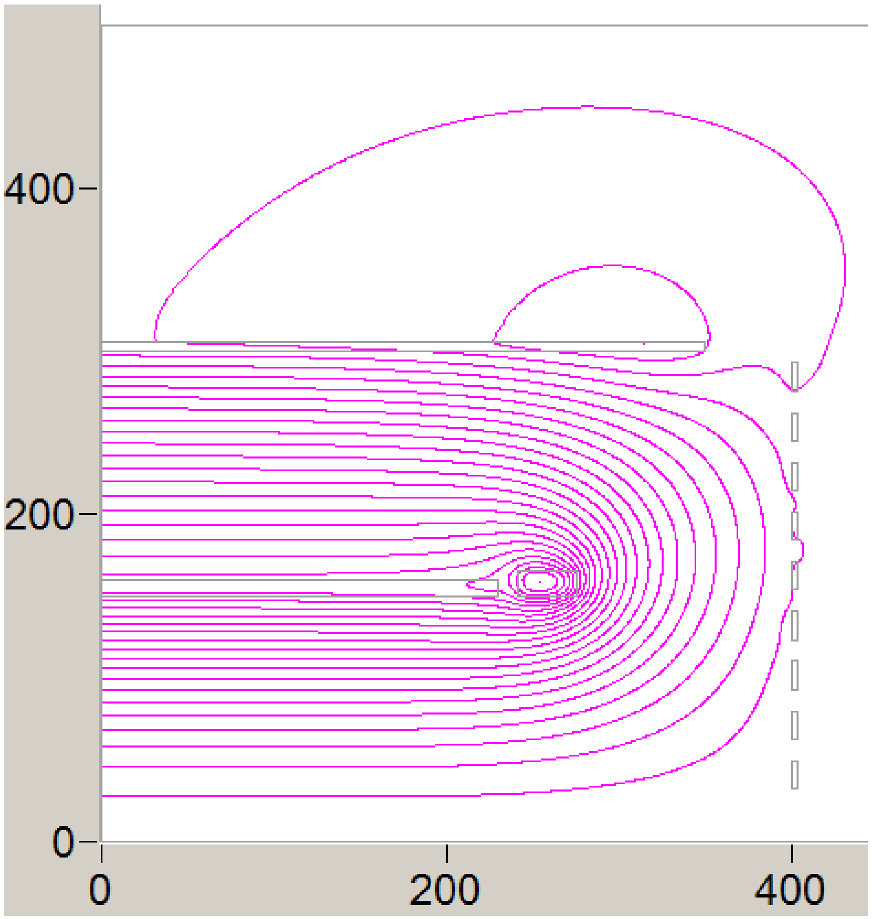
First iteration dual-solenoid design for MEIC IP 1

A. Mikhailichenko



Normal-conducting endcap coils are compact and allow for easy integration.

Fields in the 3 T solenoid for the MEIC



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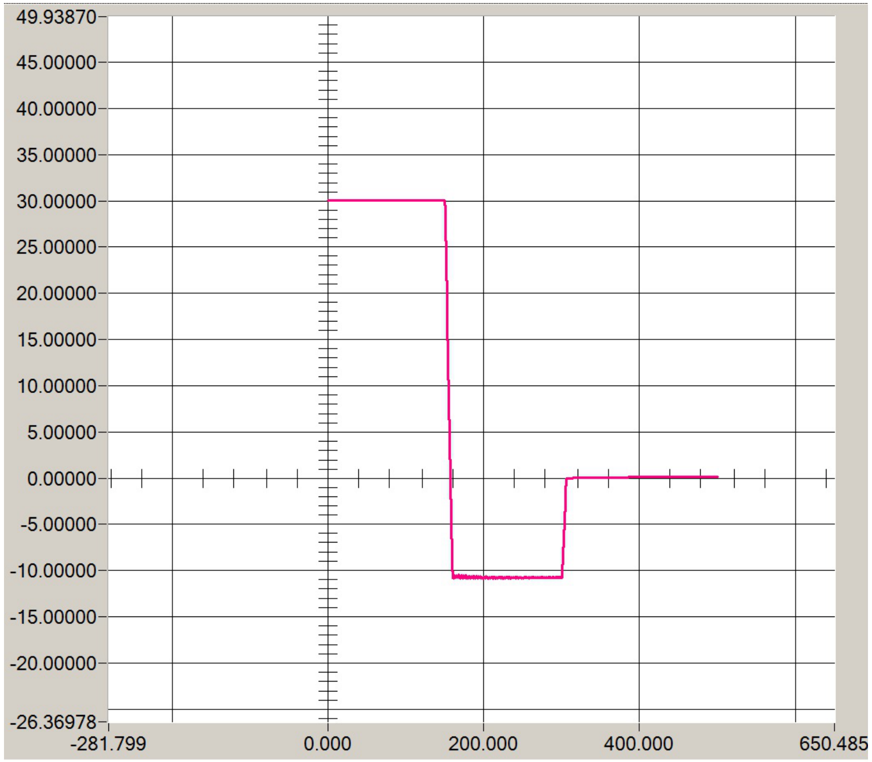
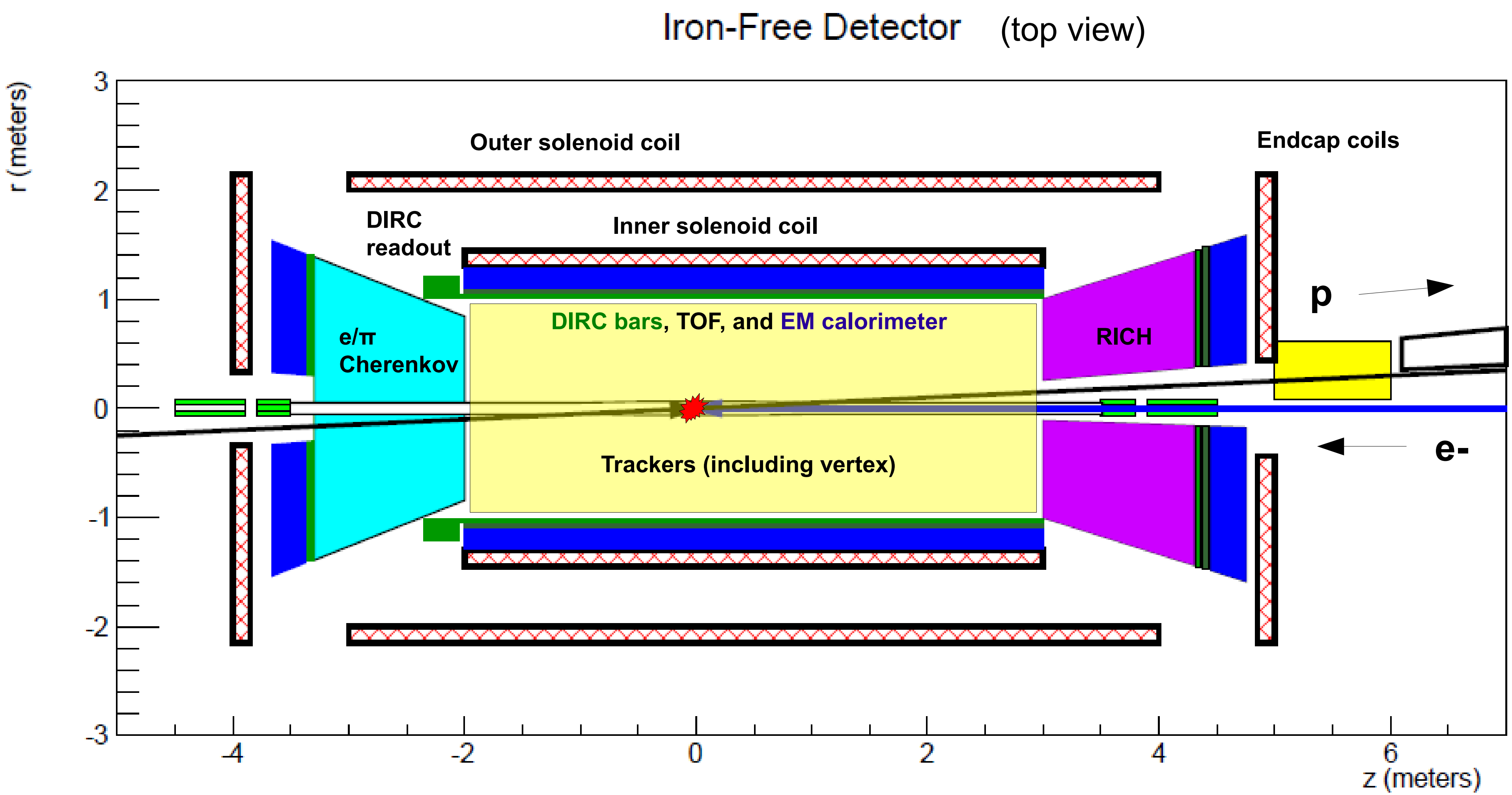


Radial field outside of outer coil vanishes quickly

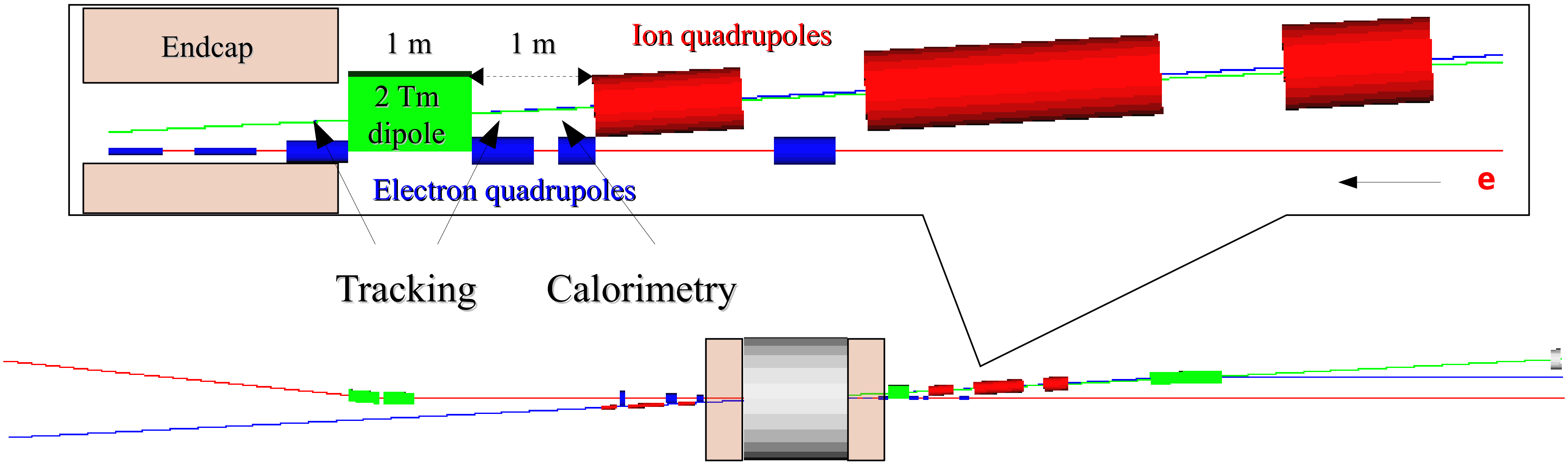
- Field in tracking volume has high uniformity
- Field vanishes quickly outside of detector volume
  - Endcap wall layout and currents can be tailored to requirements

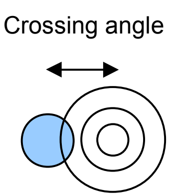
MEIC IP 1 central detector based on dual-solenoid



- Dual-solenoid allows for a compact, low mass detector
  - Easy endcap integration (line-of-sight) and good access
  - Easy integration with small-angle detectors on outgoing ion side (*right*)

Hadron detection between endcap and ion quads





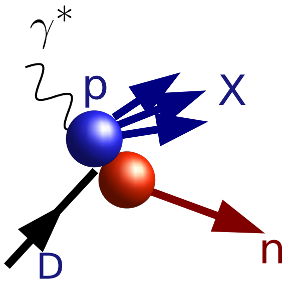
- Large crossing angle (50 mrad)
  - Moves spot of poor resolution along solenoid axis into the periphery
  - Minimizes shadow from electron FFQs

- Dipole before quadrupoles further improves resolution in the few-degree range

Ultra-forward hadron detection – requirements

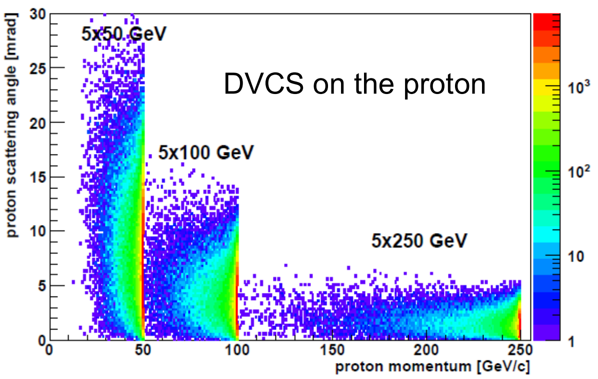
1. Good acceptance for ion fragments (rigidity different from beam)

- Large downstream magnet apertures
- Small downstream magnet gradients (realistic peak fields)
- Roman pots not needed



2. Good acceptance for recoil baryons (rigidity similar to beam)

- Small beam size at second focus (to get close to the beam)
- Large dispersion (to separate scattered particles from the beam)
- Roman pots important

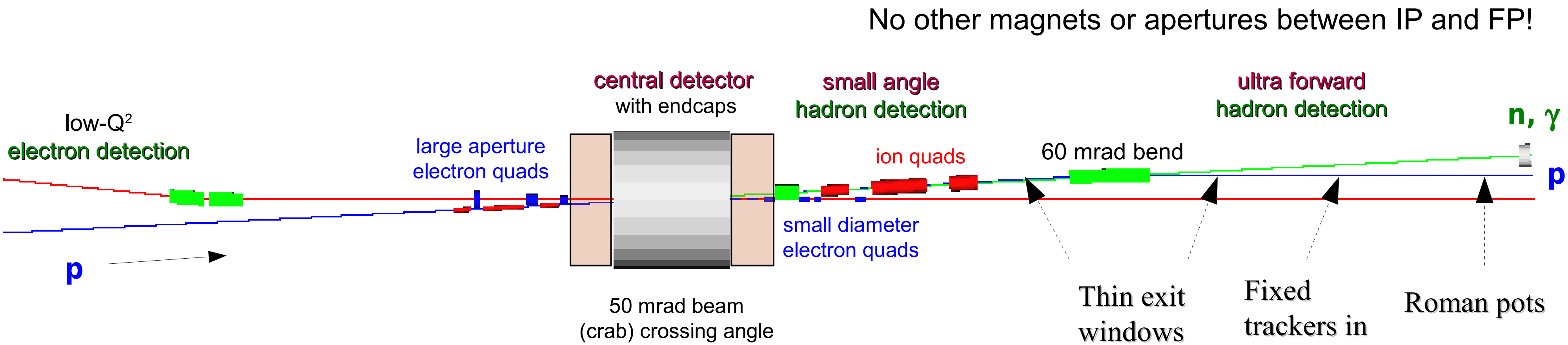


3. Good momentum- and angular resolution

- Large dispersion (*e.g.*, 60 mrad bending dipole)
- Long, instrumented magnet-free drift space

4. Sufficient separation between beam lines (~1 m)

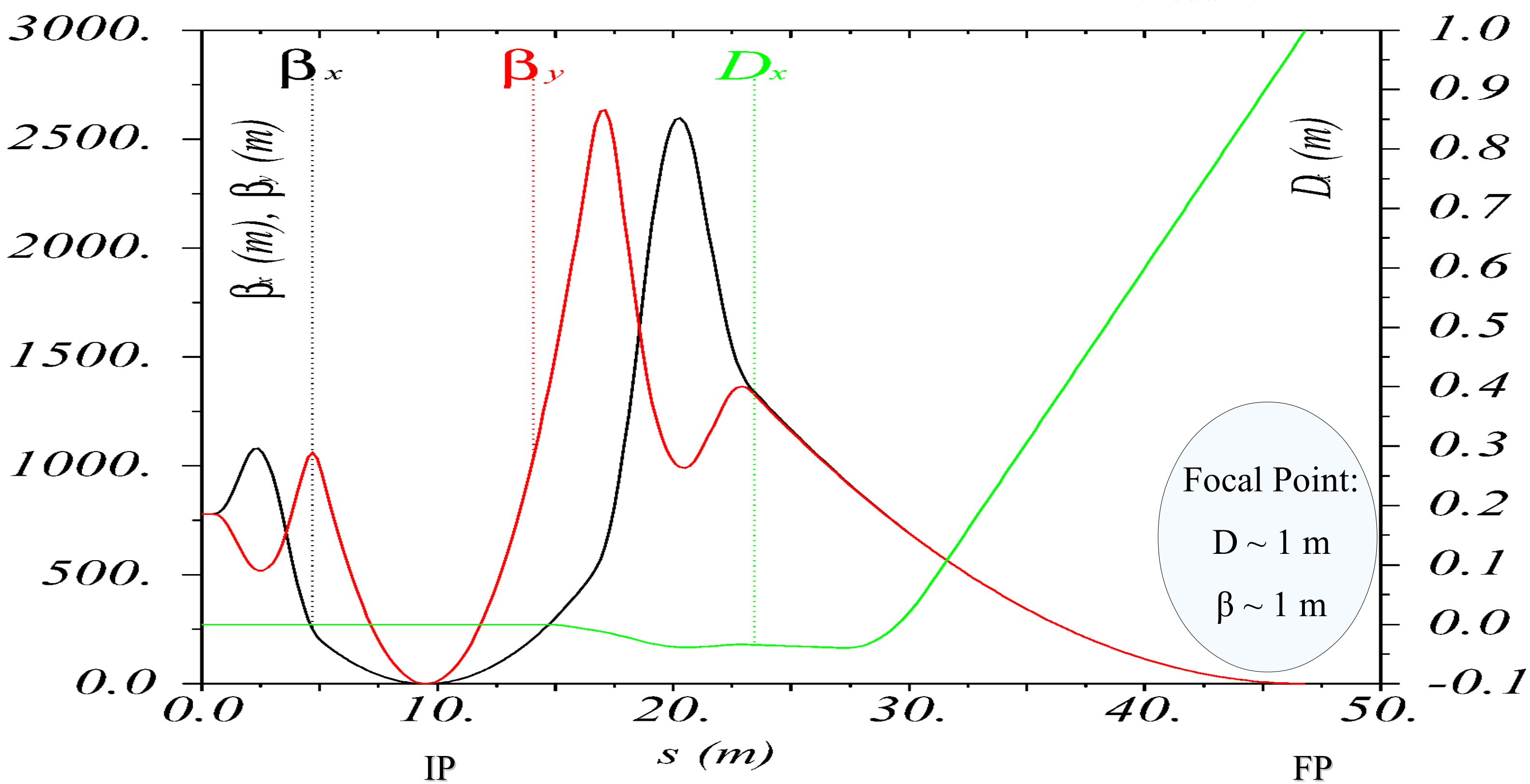
A fully integrated interaction region



Recoil baryon detection:

Small beam size (β function) and large dispersion at the secondary focal point give superb resolution and great acceptance at very small angles

Excellent t-coverage for all kinematics!

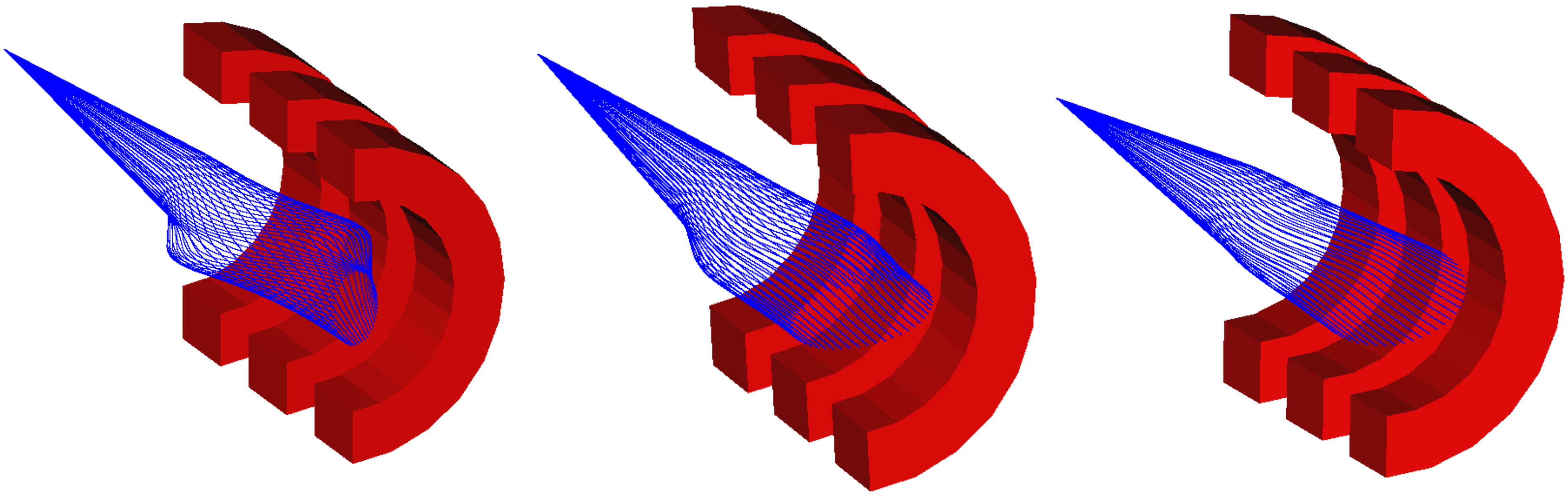


Tracking of ultra-forward charged particles

Δp/p = -0.5
(spectator protons
from deuterium)

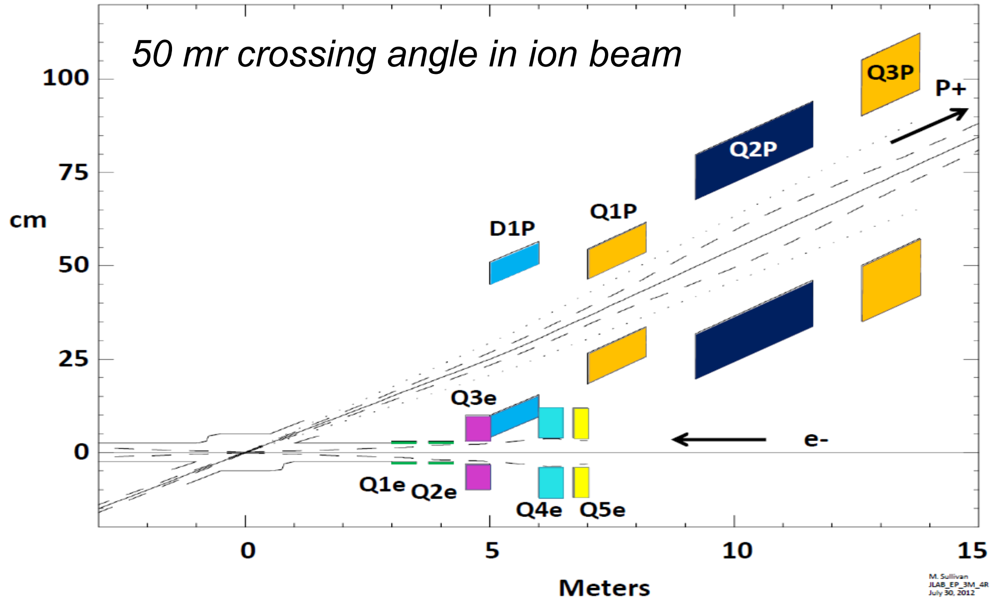
Δp/p = 0.0
(exclusive / diffractive
recoil protons)

Δp/p = 0.5
(neutron-rich nuclear
fragments)

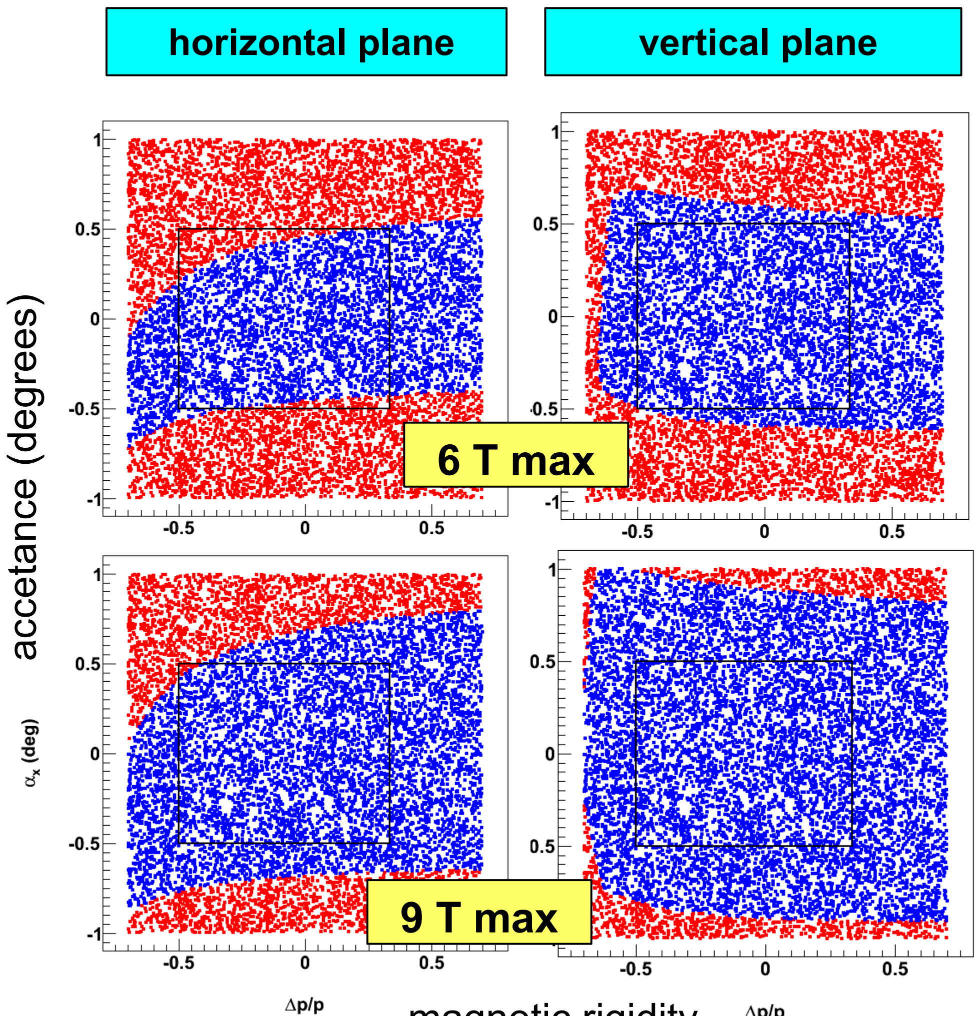


- Design provides full acceptance for *all* nuclear fragments
  - Low gradient quads make possible the necessary large apertures
  - Can be achieved with realistic peak fields (= gradient * aperture radius)
    - Easier with lower maximum energy – benefits from JLab two-ring staging

Ultra-forward charged-hadron acceptance



Forward acceptance vs.magnetic rigidity



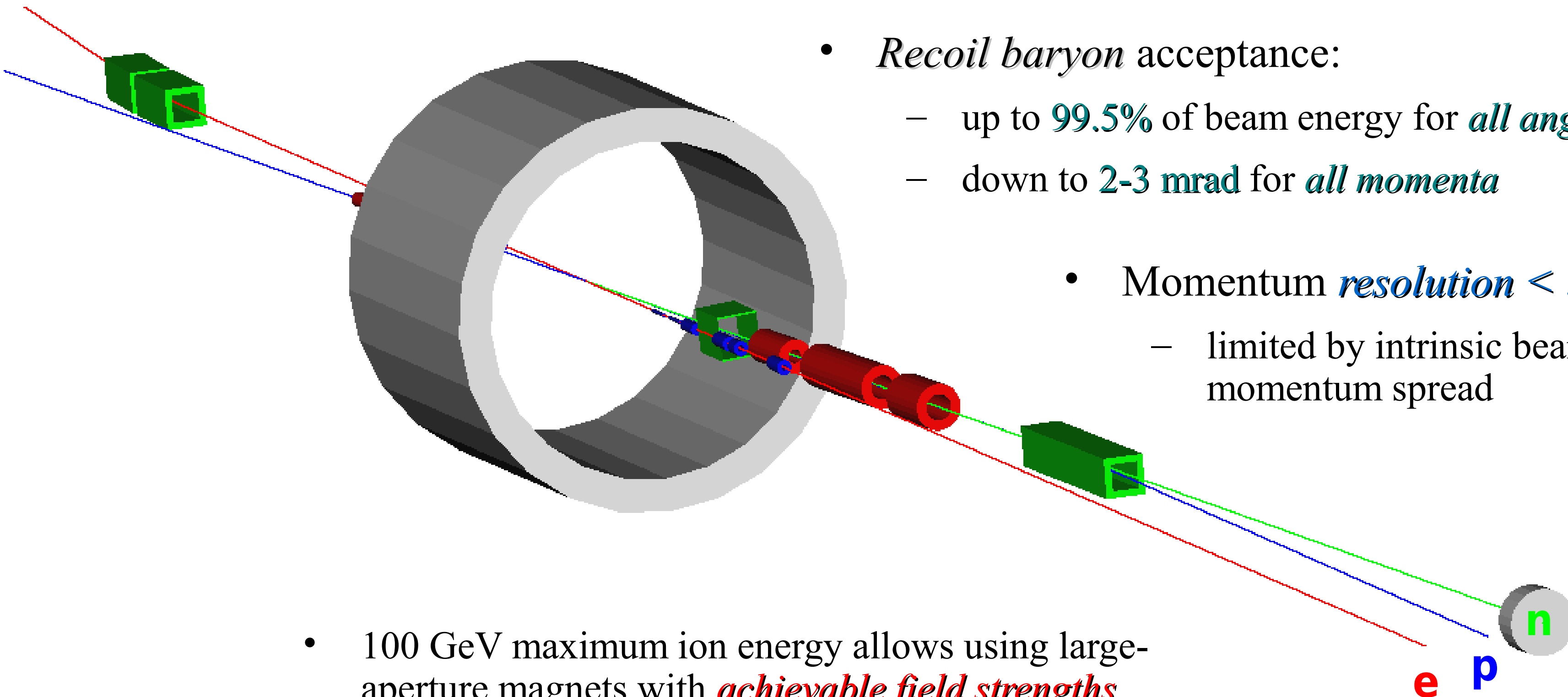
Red: Detection before ion quadrupoles

Blue: Detection after ion quadrupoles

- The angle is the original scattering angle at the IP

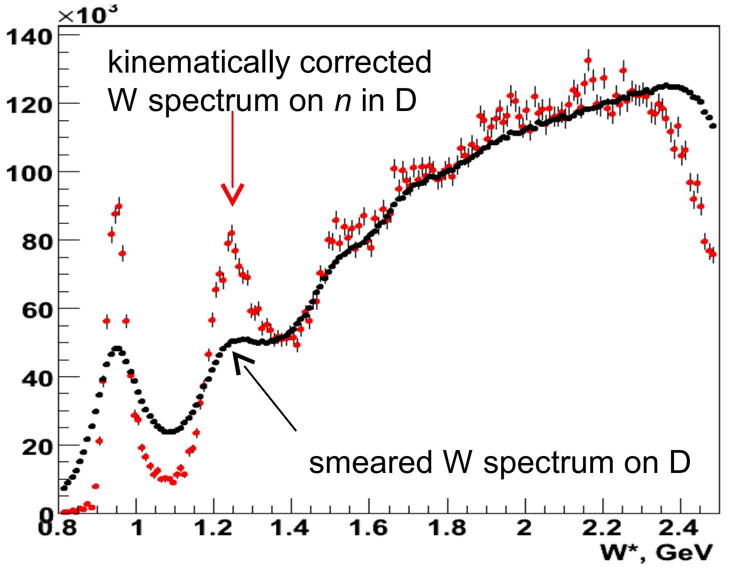
Ultra-forward hadron detection – summary

- *Neutron* detection in a 25 mrad cone ***down to zero degrees***
- Excellent acceptance for ***all ion fragments***
- *Recoil baryon* acceptance:
  - up to **99.5%** of beam energy for ***all angles***
  - down to **2-3 mrad** for ***all momenta***
- Momentum ***resolution < 3x10^{-4}***
  - limited by intrinsic beam momentum spread

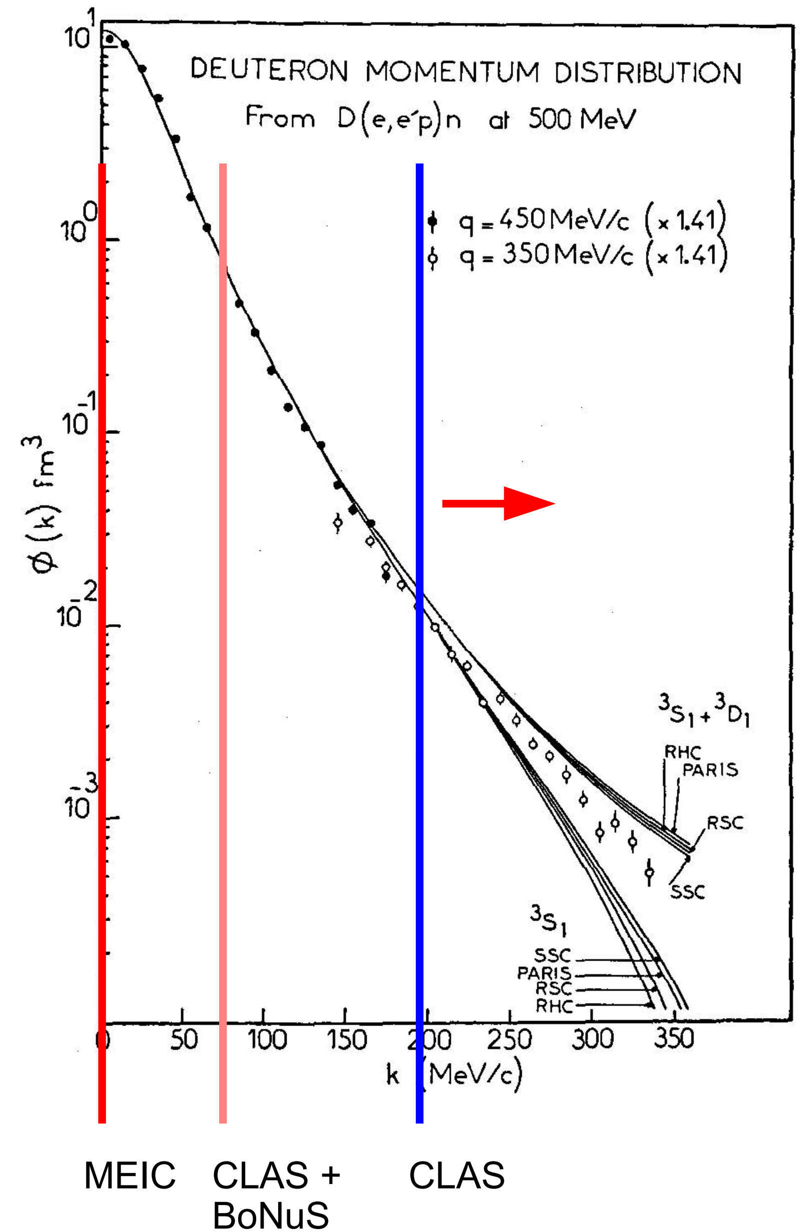


- 100 GeV maximum ion energy allows using large-aperture magnets with ***achievable field strengths***

Neutron structure through spectator tagging

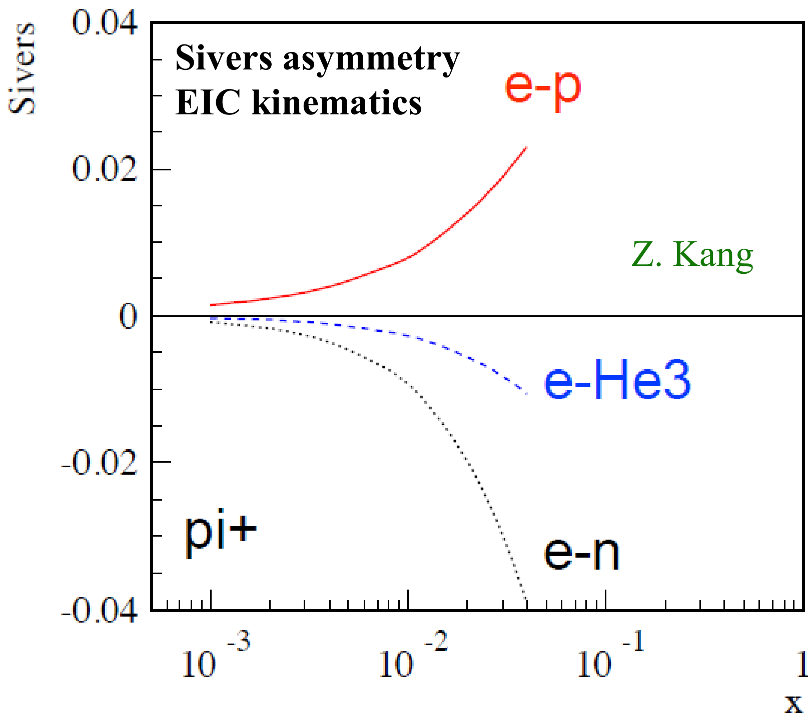


CLAS BoNuS data with tagged spectators



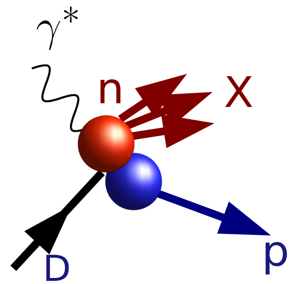
- In fixed-target experiments, scattering on *bound neutrons* is complicated
  - Fermi motion, nuclear effects
  - Low-momentum spectators
  - No polarization
- The MEIC is designed from the outset to tag spectators, and all nuclear fragments.

Spectator tagging with polarized deuterium

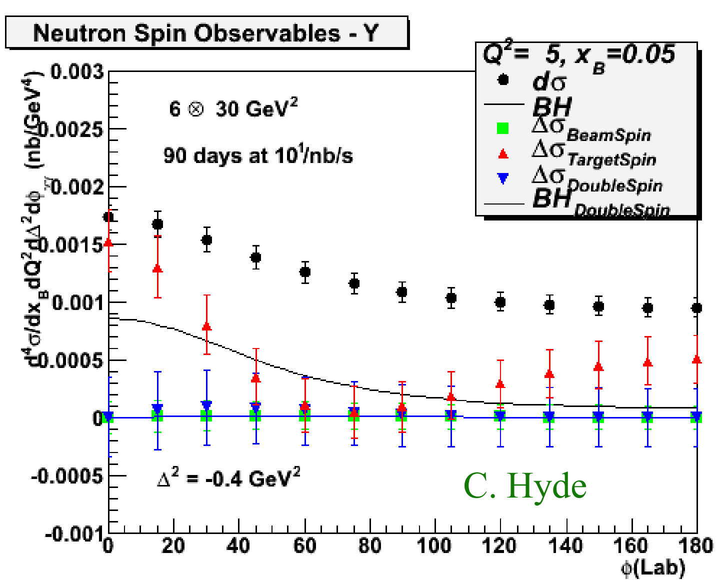


„If one could tag neutron, it typically leads to larger asymmetries“

Z. Kang



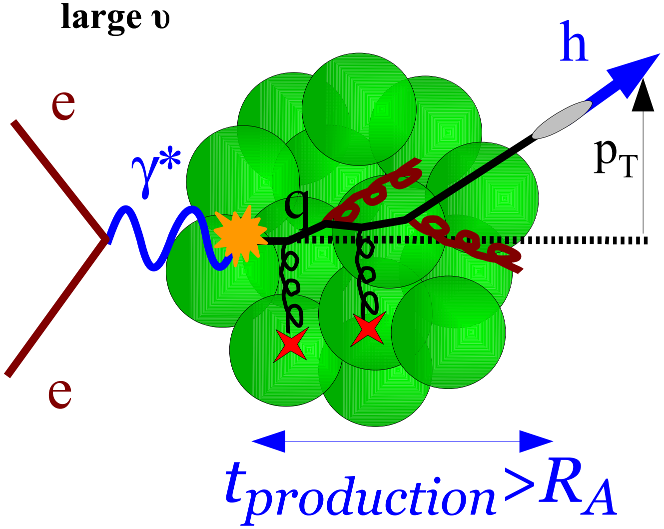
- Polarized neutrons are important for probing d-quarks through **SIDIS**

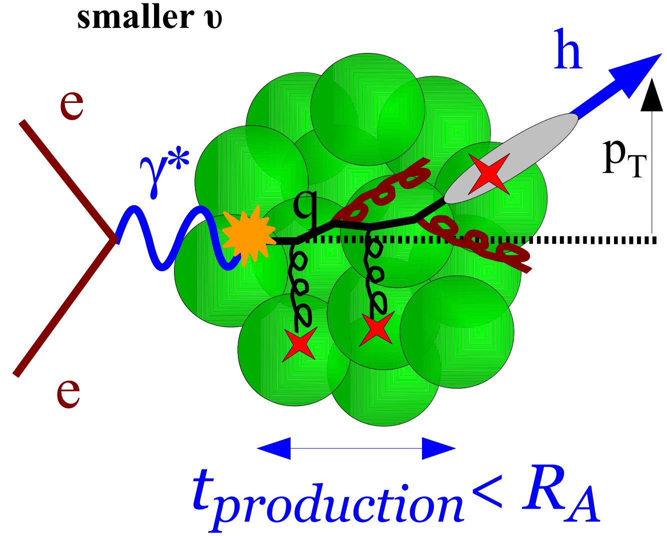


- Deeply Virtual Compton Scattering (DVCS) on a neutron target
- Tagged, polarized *neutrons* are essential for the GPD program

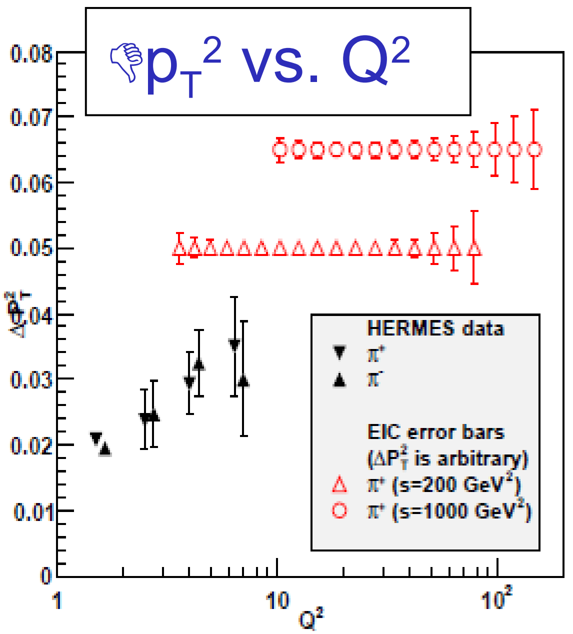
LDRD proposal submitted at JLab for polarized light nuclei at the EIC

Quark propagation in matter (hadronization)

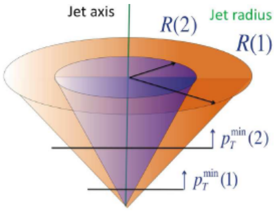




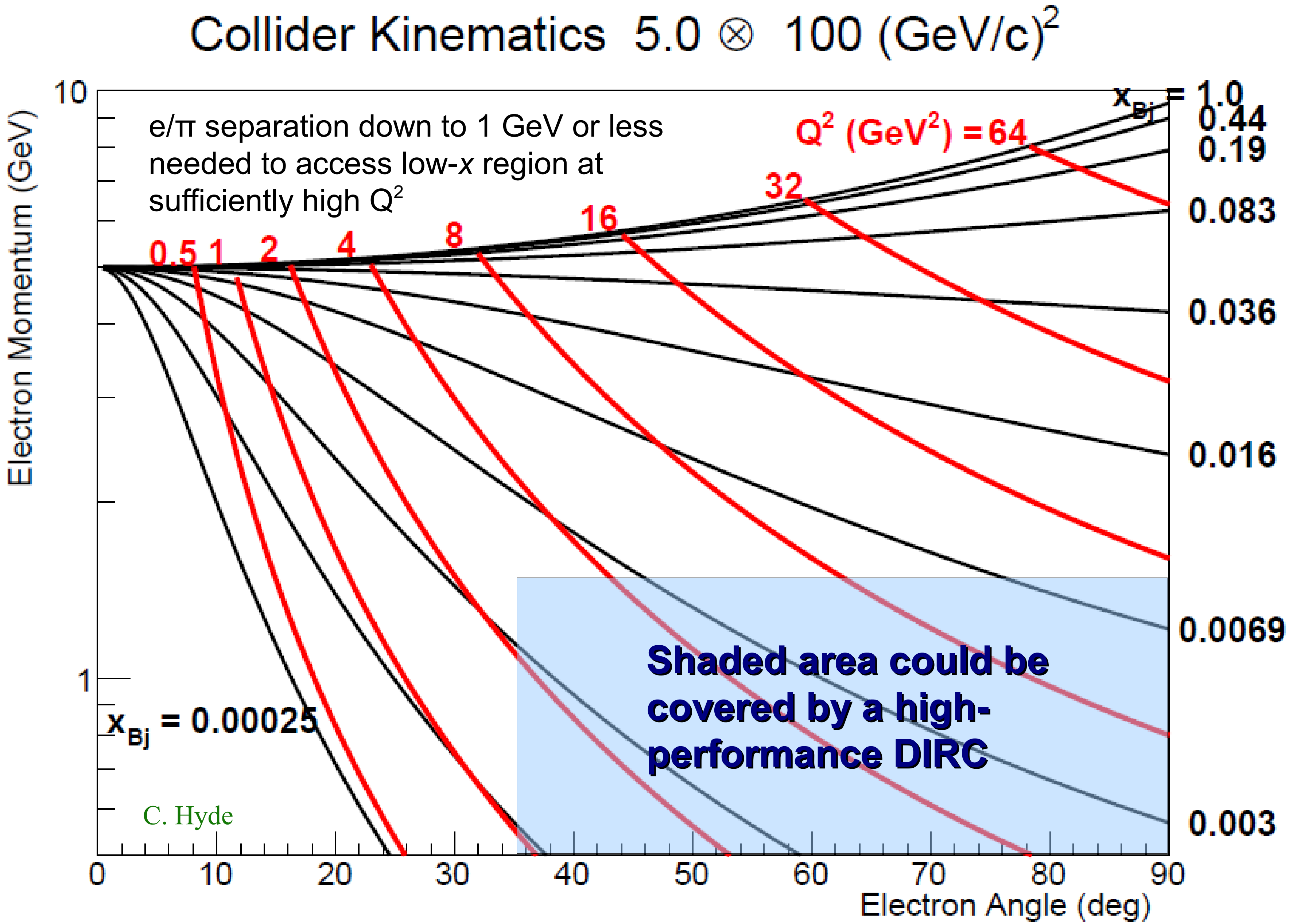
Accardi, Dupre



- Broadening of p_T distribution
- Heavy flavors: B, D mesons, J/Ψ …
- Hadron jets at $s > 1000\ GeV^2$
- ***What happens to the nucleus?***
  - *Fragments hold the key to what happened „along the way"*



Electron identification at low p (and x)



Generic detector R&D for an EIC (in collaboration with BNL)

Summary

The MEIC offers a fully integrated interaction region

- The possibility to design the storage ring around the detector requirements allows unprecedented detection capabilities and takes full advantage of unique accelerator featured (*e.g.*, vector- and tensor polarized deuterium)

Good progress on detector design

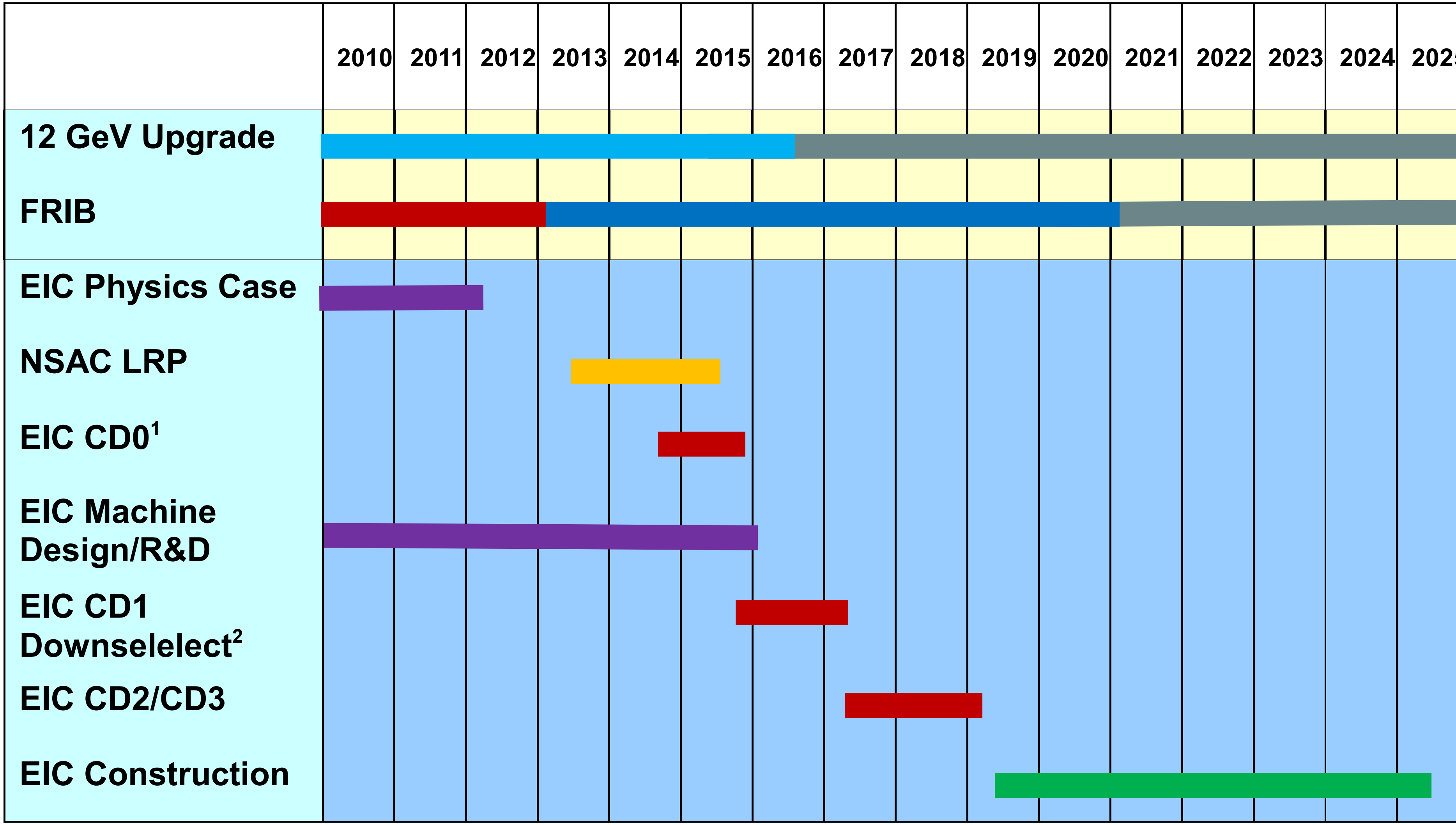
- Promising collaboration on central detector with HEP

Physics and R&D efforts to understand key issues

- Physics effort for polarized light nuclei and forward tagging under way
- Generic EIC detector R&D program in second year

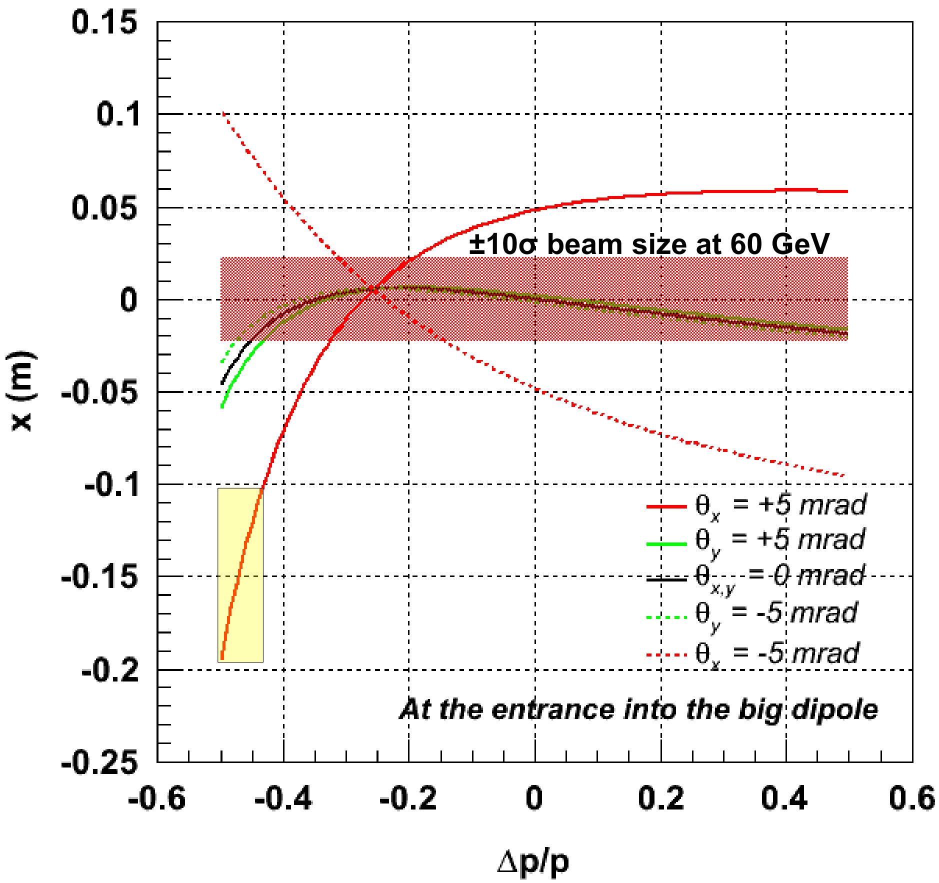
Backup

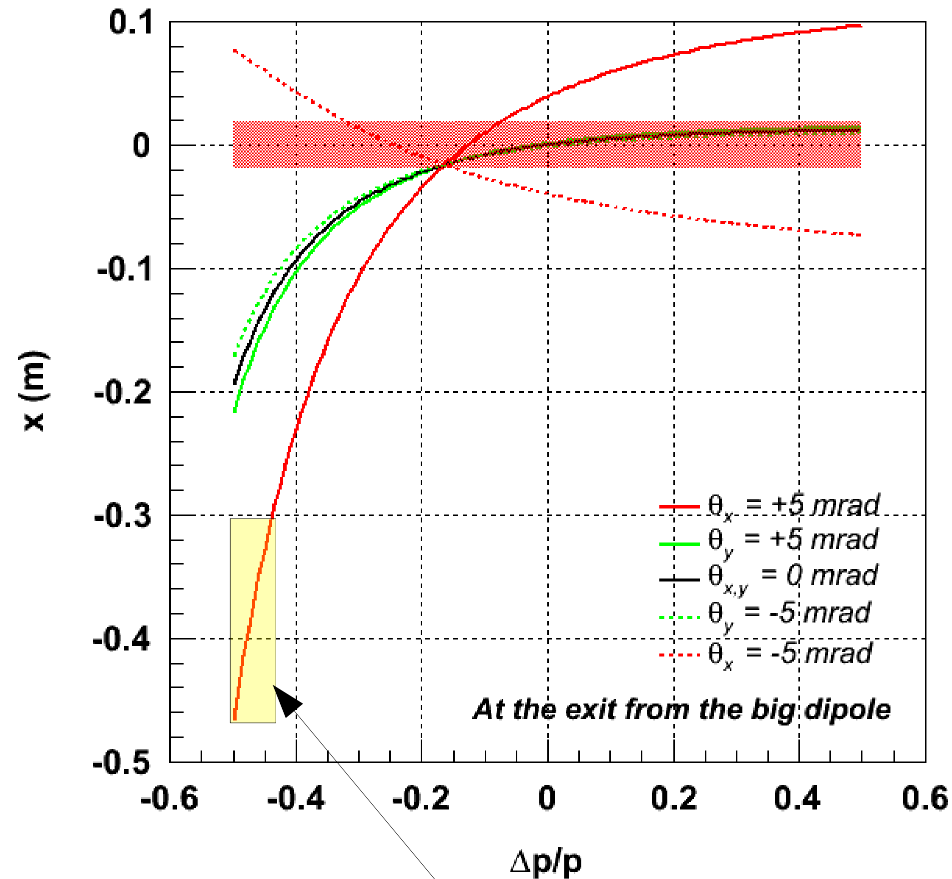
EIC timeline



1) Assumes endorsement for an EIC at the next NSAC Long Range Plan
2) Assumes relevant accelerator R&D for down-select process done around 2016

Ion acceptance and resolution at the 20 Tm dipole

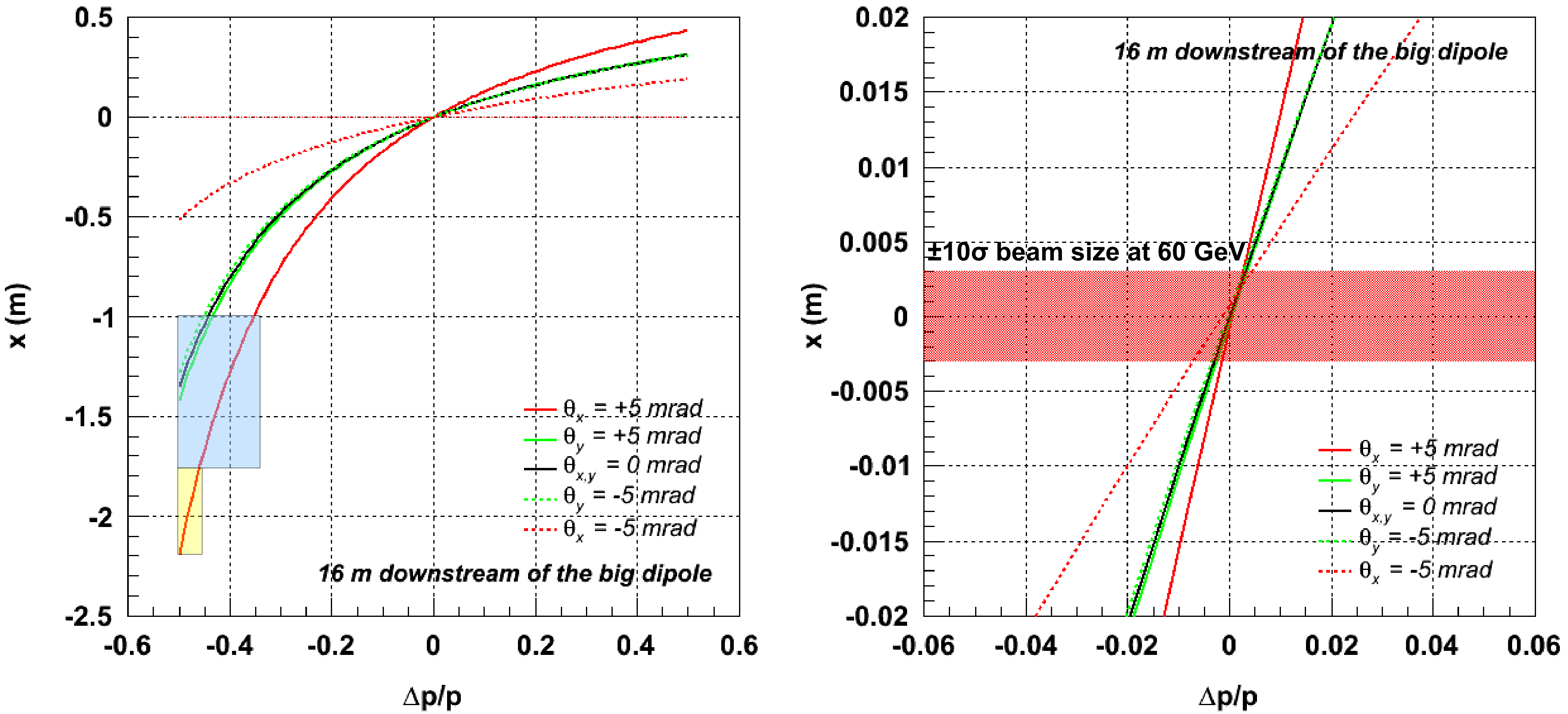




Detected between ion quads and 20 Tm dipole

- A dipole aperture of ~30 cm is sufficient for all particles with $\Delta p/p > -0.45$ or $\Theta_x < +4$ mrad.
- Momentum resolution is given by the slope of the line

Ion acceptance and resolution at the focal point



- Large deflections allow precise tracking over long distances with cheaper detectors
  - Particles with deflections > 1 m will be detected closer to the dipole