Detector Integration and Performance of MEIC at JLAB

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Workshop on EIC Detector R&D Simulations
BNL, October 9, 2012

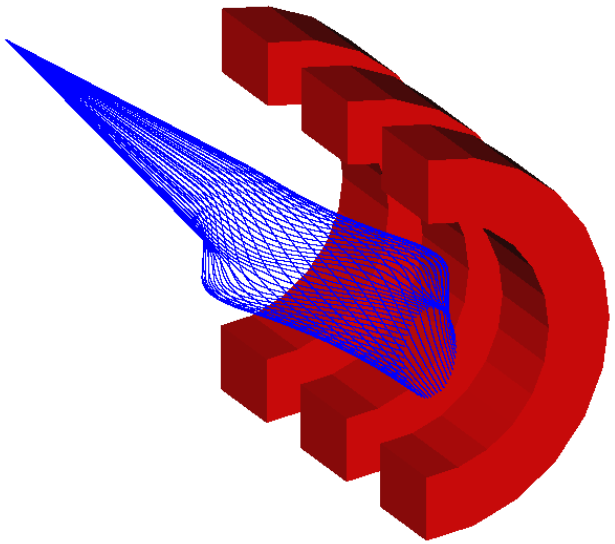
Outline

- G4beamline/GEANT4 Model
- Ion and Electron Detector Region
  - Optics
  - Magnet Parameters
  - Acceptance, Momentum and Angle Resolution
- Outlook

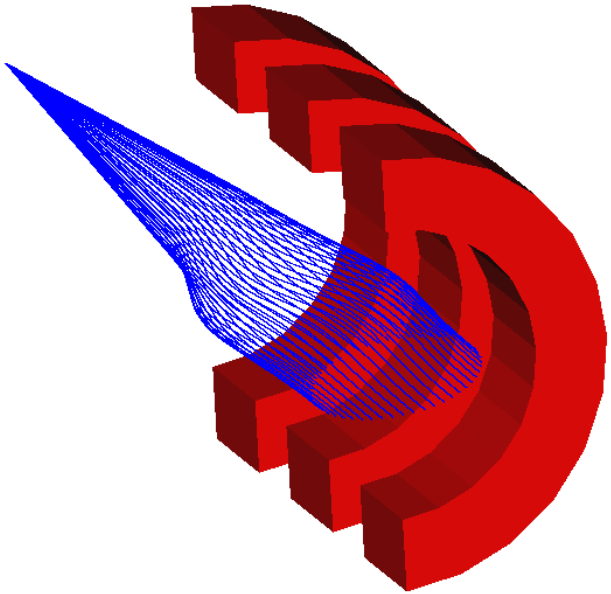
G4beamline Simulations

- **GEANT 4 toolkit for beam line simulations**
- **Realistic simulations of complete system at later design stages**
- **Not very well suited for optimization tasks**

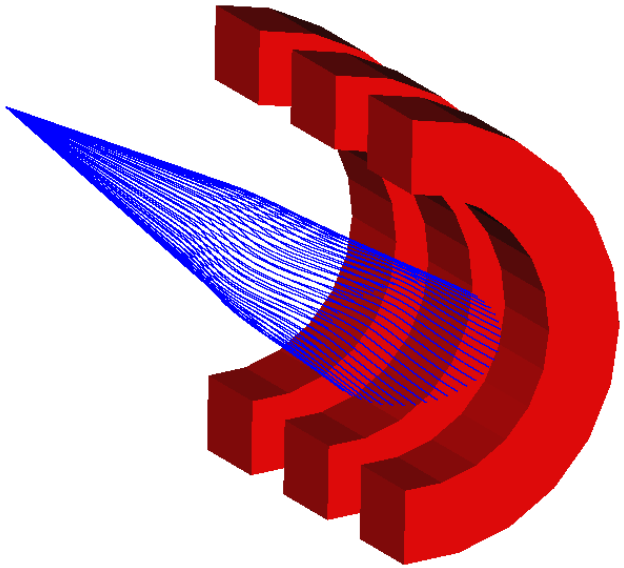
$\Delta p/p = -0.5$



$\Delta p/p = 0.0$

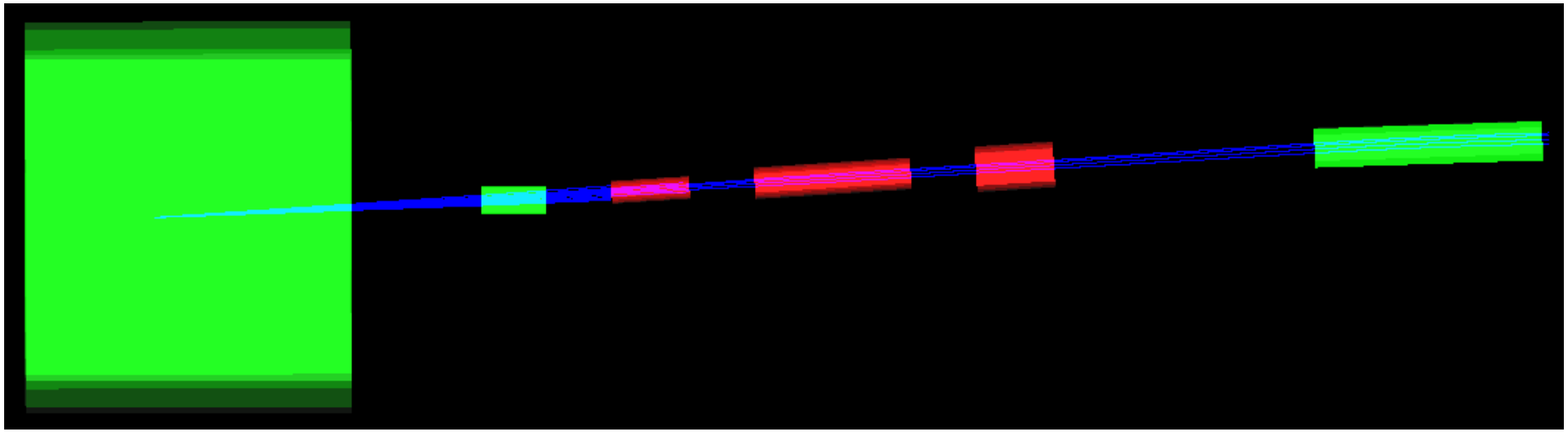


$\Delta p/p = 0.5$



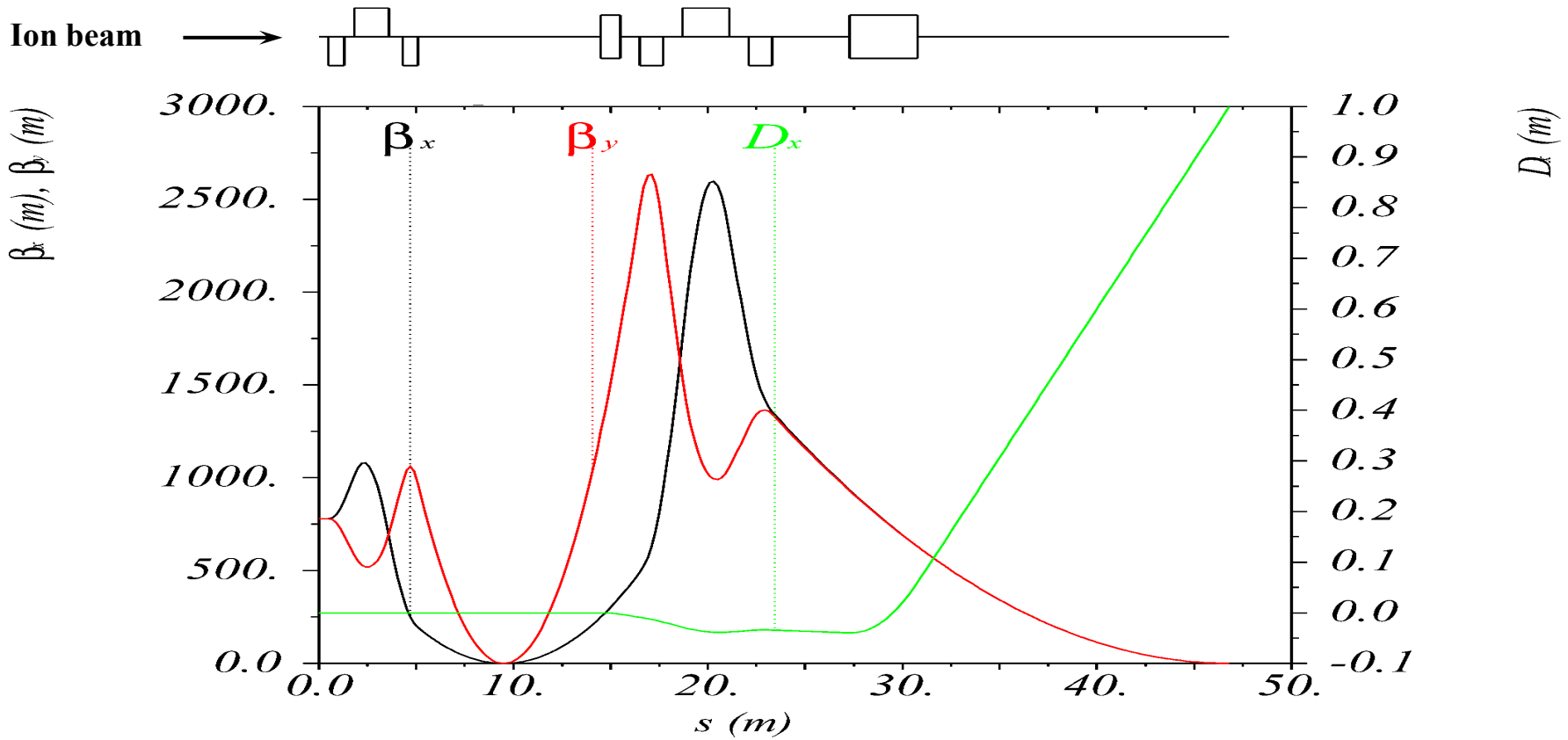
GEANT4 Model

- Detector solenoid
  - 4 T field at the center, 5 m long, 2.5 m inner radius, IP 2 m downstream from edge
- Small spectrometer dipole in front of the FFB
  - 2 T (@ 100 GeV/c), 1 m long, hard-edge uniform field
  - Interaction plane and dipole are rotated around z to compensate orbit offset
- FFB
- Big spectrometer dipole
  - 4 m downstream of the FFB, sector bend, 3.5 m long,
    60 mrad bending angle (21 Tm, 6 T @ 100 GeV/c), ±40 cm square aperture



Ion Detector Region Optics

- **Downstream FFB: quad lengths = 1.2, 2.4, 1.2 m, quad strengths @ 100 GeV/c = -89.0, 51.1, -35.7 T/m**
- **2 T (@ 100 GeV/c) outward-bending dipole in front of the final focus**
- **6 T (@ 100 GeV/c) inward-bending dipole 4 m downstream of the final focus**



Ion Magnet Parameters

- **50 mrad beam crossing angle**

Name	Type	Max B (T)	Max $\partial B_y/\partial x$ (T/m)	Length (m)	Inner radius (cm)	Outer radius (cm)	Distance from IP* (m)	Beam separation** (cm)	Notes
Detector solenoid	SC	4	N/A	5	250				
Downstream ion side									
Ion spectrometer dipole 1	SC	2	N/A	1	20	Limited on e beam side by beam separation	5	25	~60 mrad field rotation Lambertson?
Downstream ion quad 1	SC	9	89.0	1.2	10.1		7	35	+h/v orbit corrector?
Downstream ion quad 2	SC	9	51.1	2.4	17.6		9.2	46	+h/v orbit corrector?
Downstream ion quad 3	SC	7	35.7	1.2	19.6		12.6	63	+h/v orbit corrector?
Ion spectrometer dipole 2	SC	6	N/A	3.5	40		17.8	89	rectangular or sector?
Upstream ion side									
Upstream ion quad 1	SC	5.4	180.5	0.8	3	10	4.4	22	+h/v orbit corrector?
Upstream ion quad 2	SC	3.4	85.7	1.8	4	11	5.9	29.5	+h/v orbit corrector?
Upstream ion quad 3	SC	2.5	63.0	0.8	4	11	8.2	41	+h/v orbit corrector?

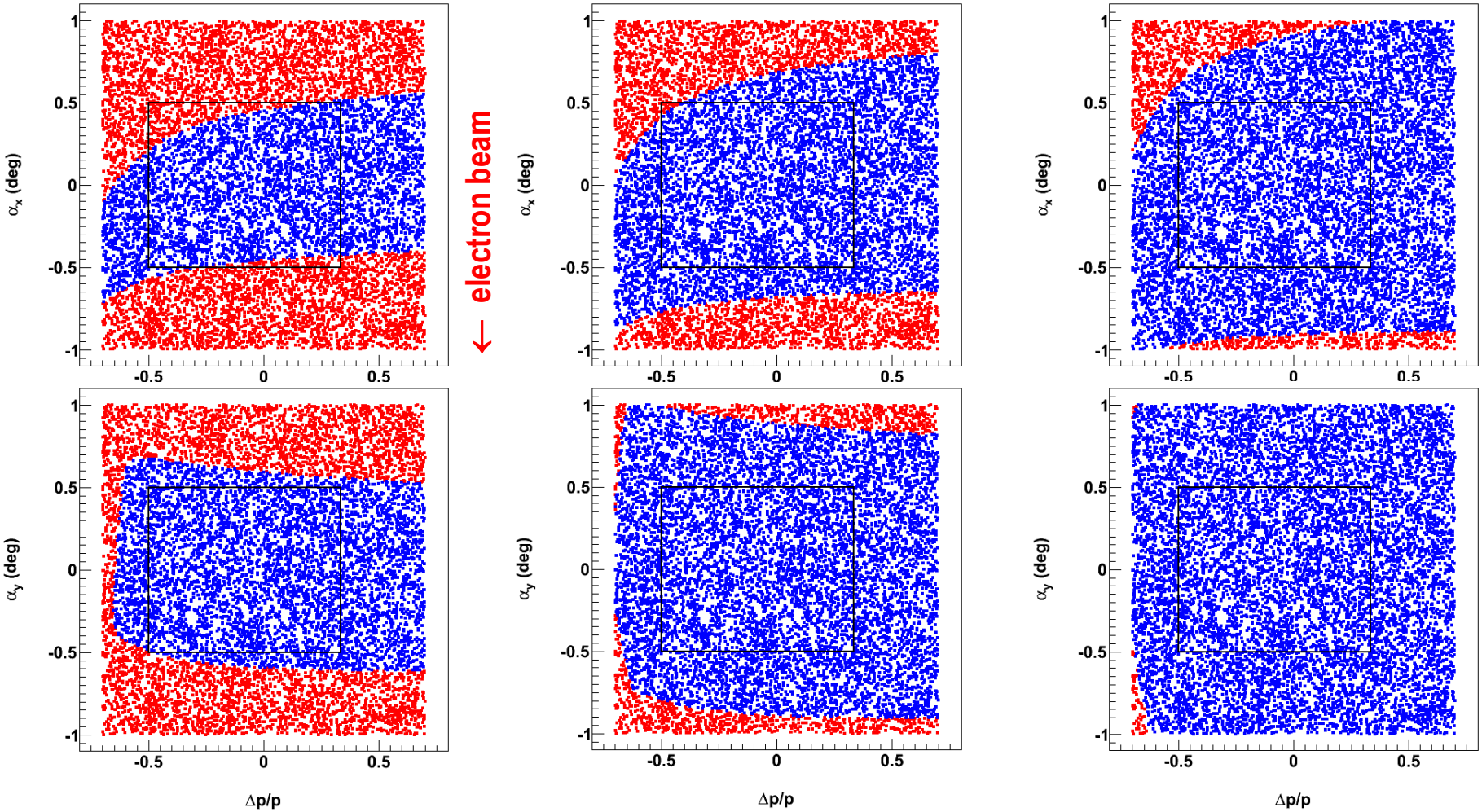
* The distance is from the IP to the magnet side facing the IP

** The electron and ion beam separation is at the magnet side facing the IP

Downstream Ion FFB Acceptance for Protons

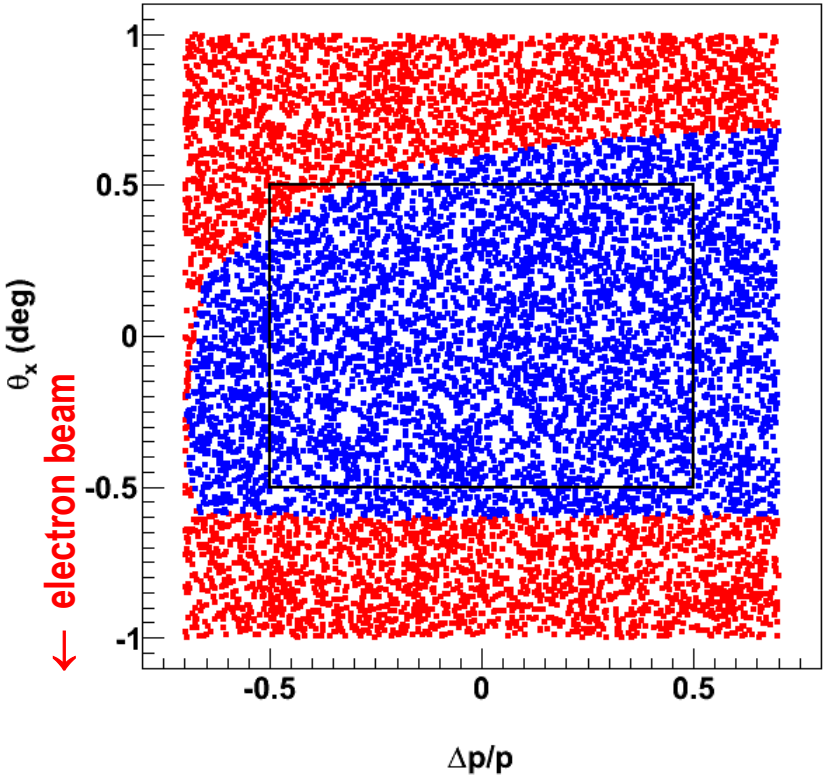
- **Quad apertures = B max / (field gradient @ 100 GeV/c)**

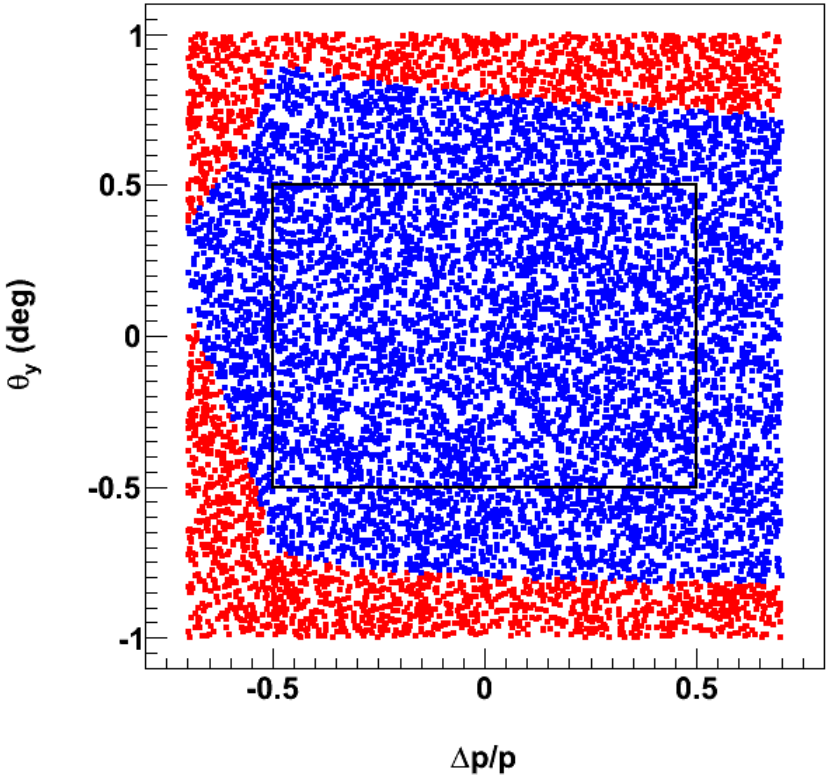
6 T max | **9 T max** | **12 T max**



Downstream Ion FFB Acceptance for Protons

- **Uniform spreads: ±0.7 in Δp/p and ±1° in horizontal/vertical angle**
- **Apertures: Quads = 9, 9, 7 T / ($\partial B_y / \partial x$ @ 100 GeV/c)**

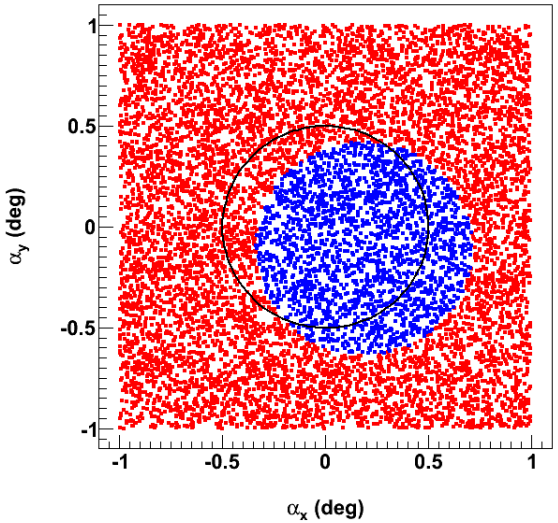




Downstream Ion FFB Acceptance for Neutrons

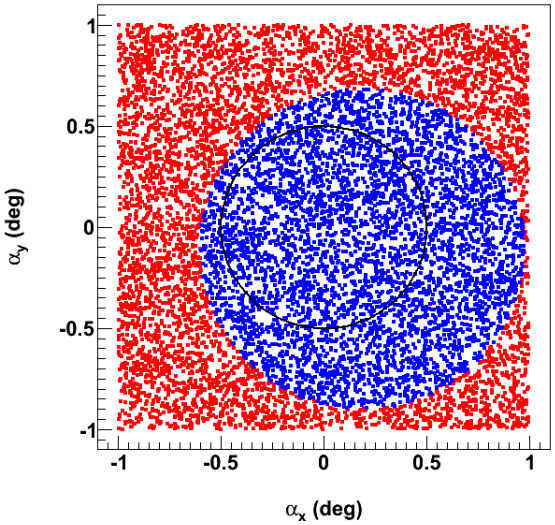
- **Neutrons uniformly distributed within ±1° horizontal & vertical angles around proton beam**
- **Each quad aperture = B max / (field gradient @ 100 GeV/c)**

6 T max

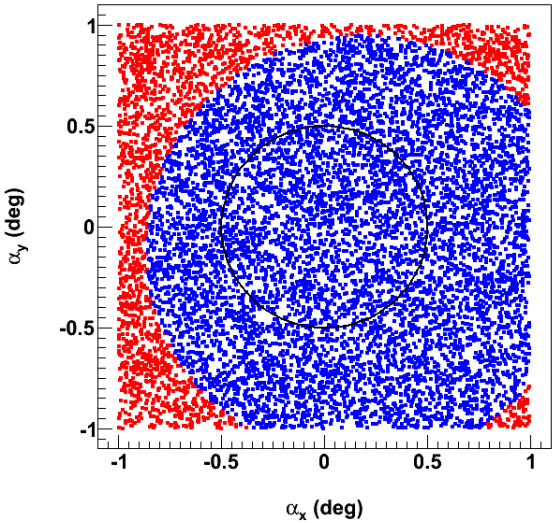


← electron beam

9 T max

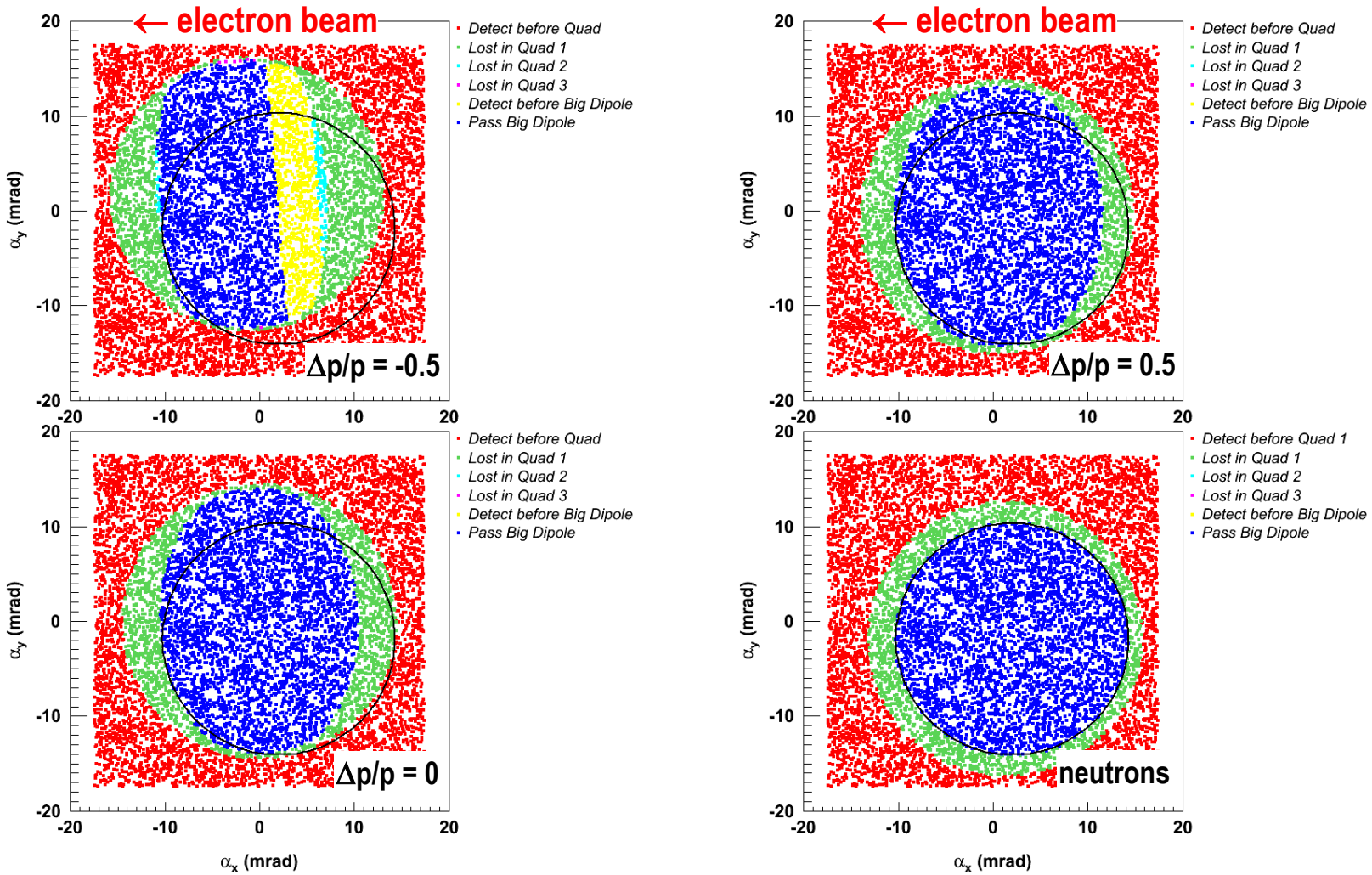


12 T max



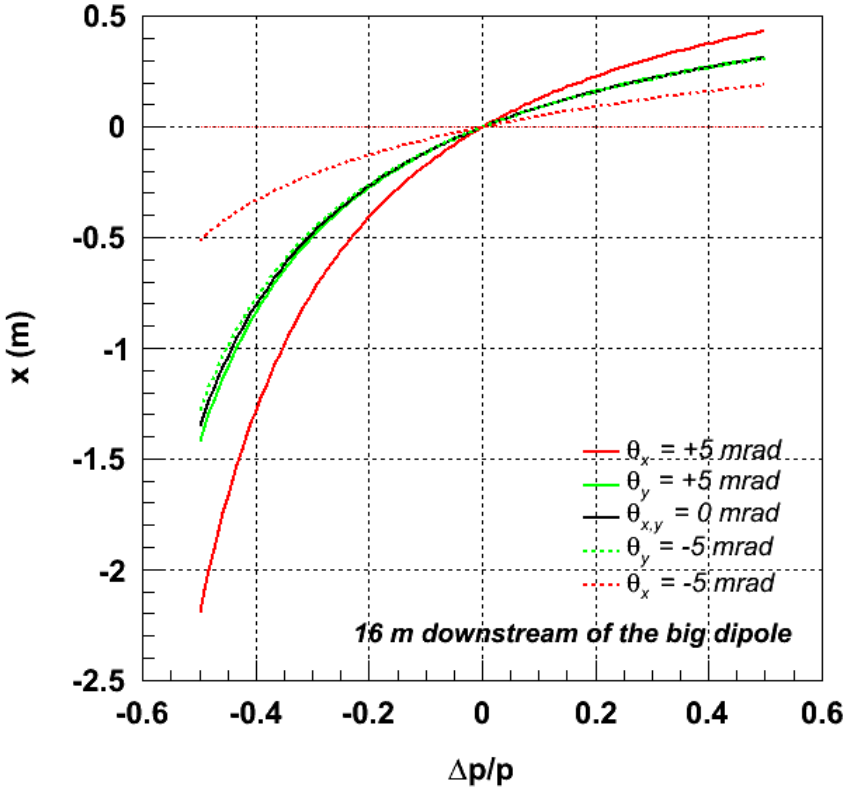
Acceptance of Downstream Ion Final Focus

- **Uniform distribution horizontally & vertically within ±1° around protons**
- **Apertures: Quads = 9, 9, 7 T / ($\partial B_y / \partial x$ @ 100 GeV/c), Big Dipole = -30/+50 × ±40 cm**



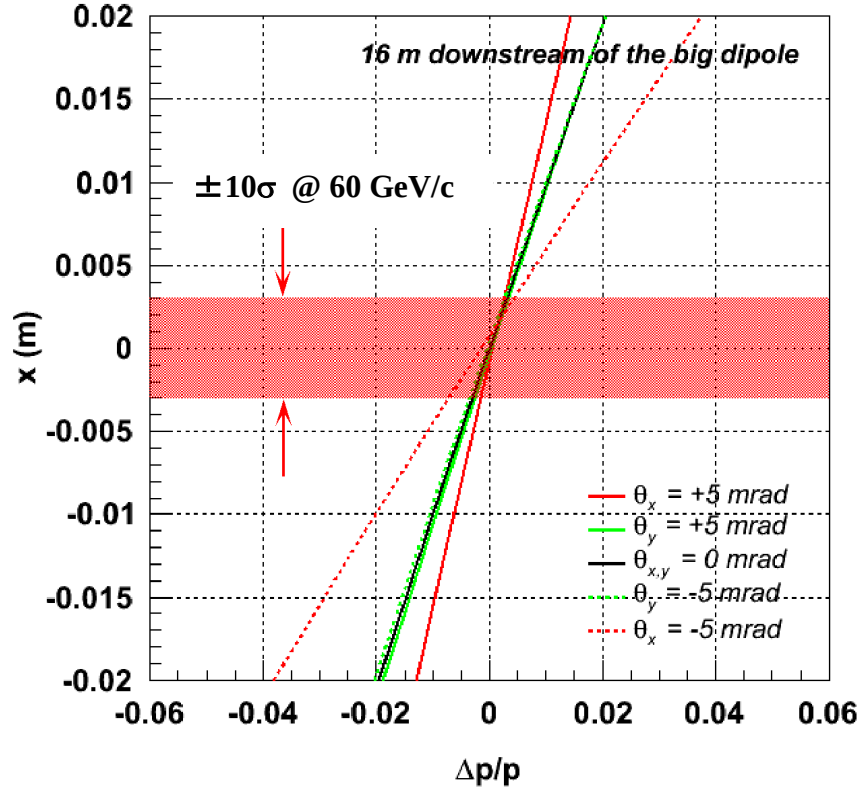
Forward Ion Momentum & Angle Resolution

- **Protons with Δp/p spread launched at different angles to nominal trajectory**



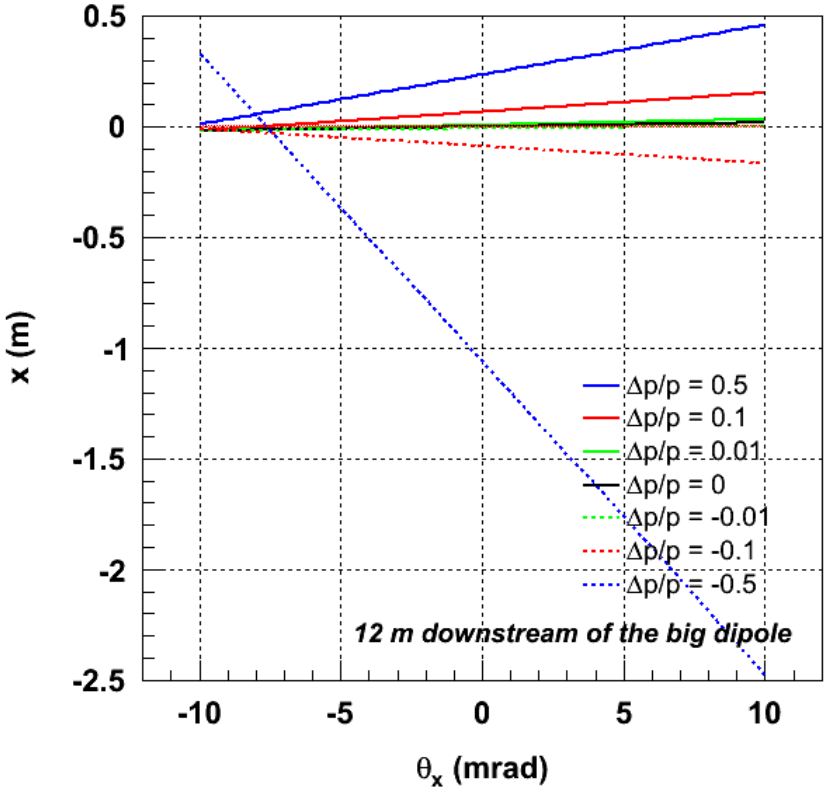
← electron beam

|Δp/p| > 0.005 @ $\theta_{x,y}$ = 0



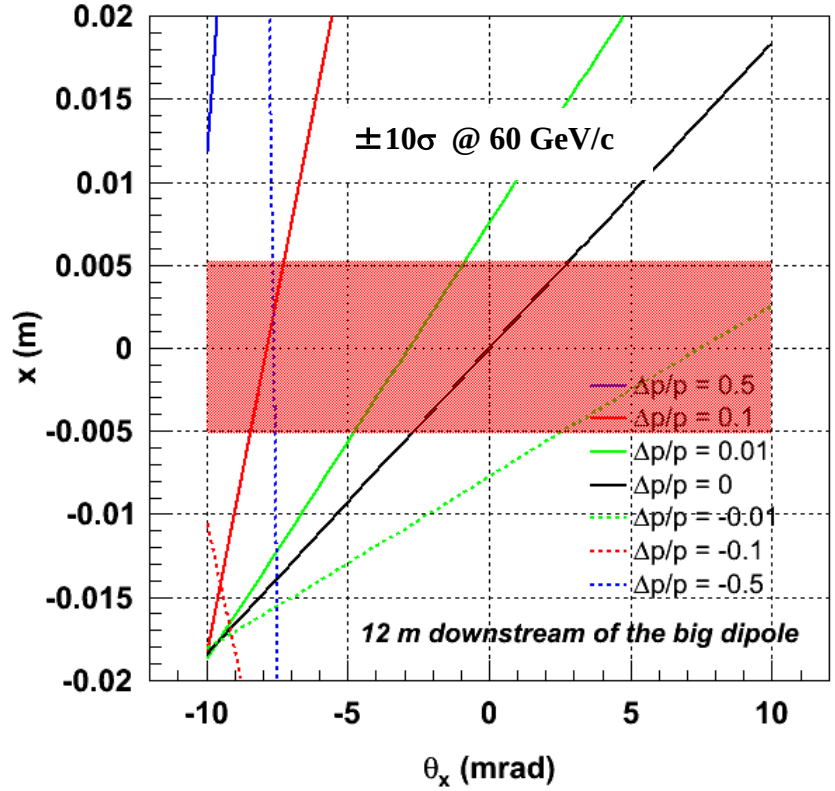
Forward Ion Momentum & Angle Resolution

- **Protons with different Δp/p launched with θ_x spread around nominal trajectory**



← electron beam

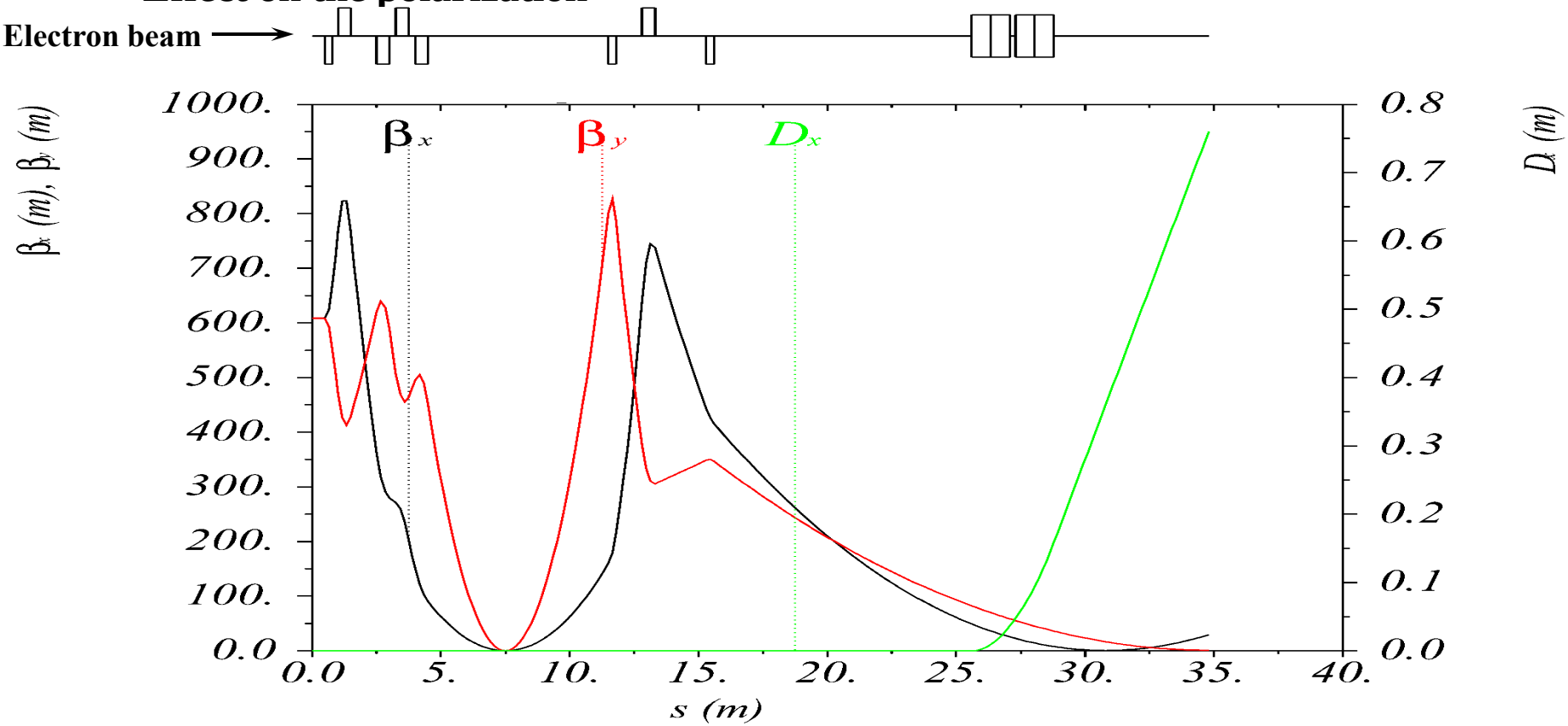
$|\theta_x| > 3$ mrad @ Δp/p = 0



← electron beam

Electron Detector Region Optics

- Similar to ion detector design
- Detector solenoid is not included
- Still need to address:
  - Transverse coupling
  - Effect on the polarization



Electron Magnet Parameters

- **50 mrad beam crossing angle**

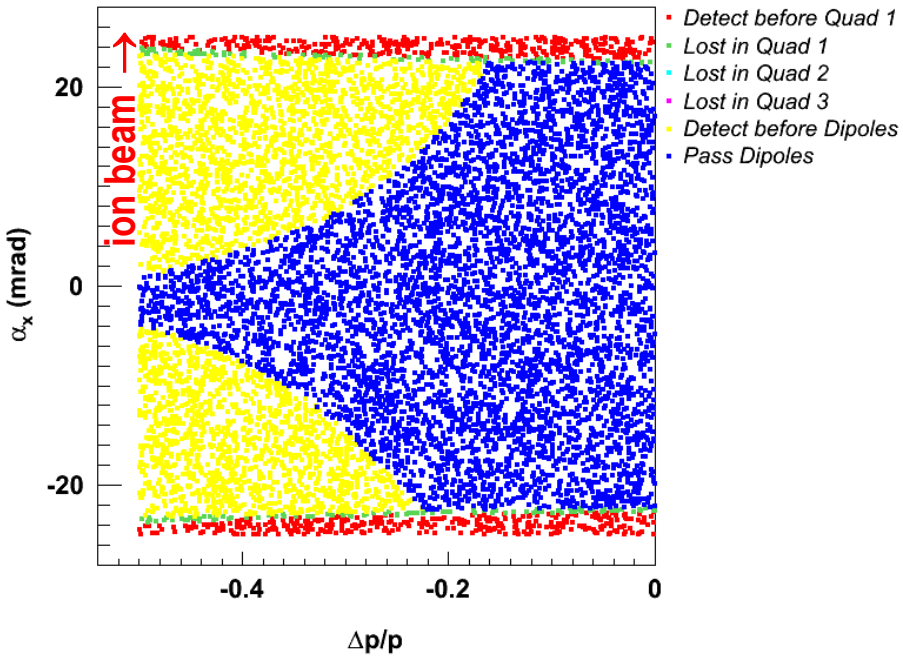
Name	Type	Max B (T)	Max $\partial B_y/\partial x$ (T/m)	Length (m)	Inner radius (cm)	Outer radius (cm)	Distance from IP* (m)	Beam separation** (cm)	Notes
Downstream electron side									
Downstream electron quad 1	SC	6	67.1	0.3	9	Limited on ion beam side by beam separation	4	20	
Downstream electron quad 2	SC	6	37.3	0.5	16		5.3	25.5	
Downstream electron quad 3	SC	3	10.2	0.3	30		7.8	39	
Electron spectrometer dipole 1	warm	1.2	N/A	1.5	20		18.1	90.5	
Electron spectrometer dipole 2	warm	1.2	N/A	1.5	20		19.8	99	Merge dipoles 1 & 2?
Upstream electron side									
Upstream electron quad 1	permanent	0.3	15	0.5	2	3	3	15	
Upstream electron quad 2	permanent	0.3	15	0.5	2	3	3.75	18.8	
Upstream electron quad 3	SC	0.7	34.0	0.5	2	9	4.5	22.5	
Upstream electron quad 4	SC	1.8	45.6	0.5	4	11	6	30	
Upstream electron quad 5	SC	1.5	38.0	0.3	4	11	6.7	33.5	

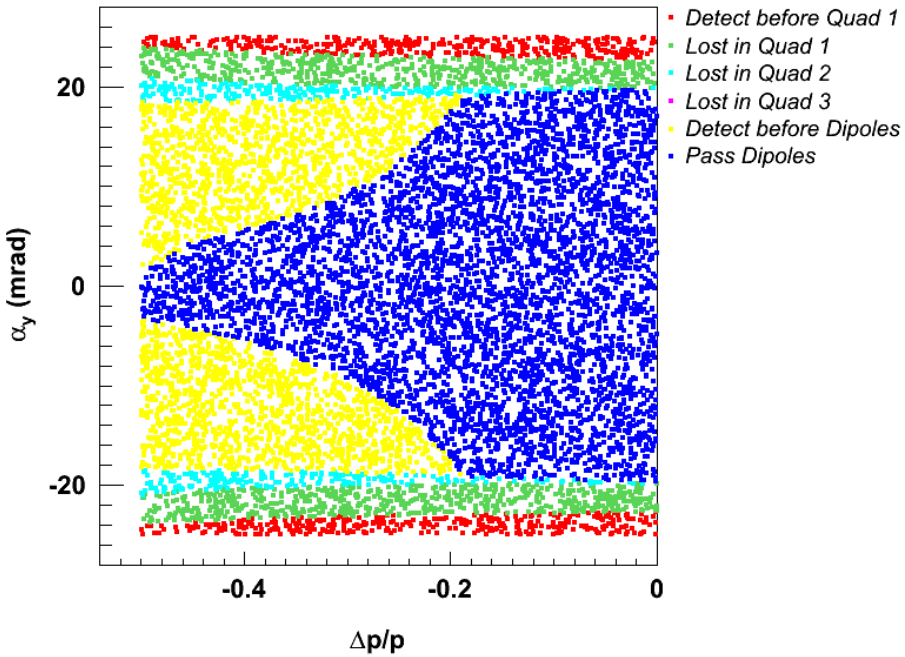
* The distance is from the IP to the magnet side facing the IP

** The electron and ion beam separation is at the magnet side facing the IP

Acceptance of Downstream Electron Final Focus

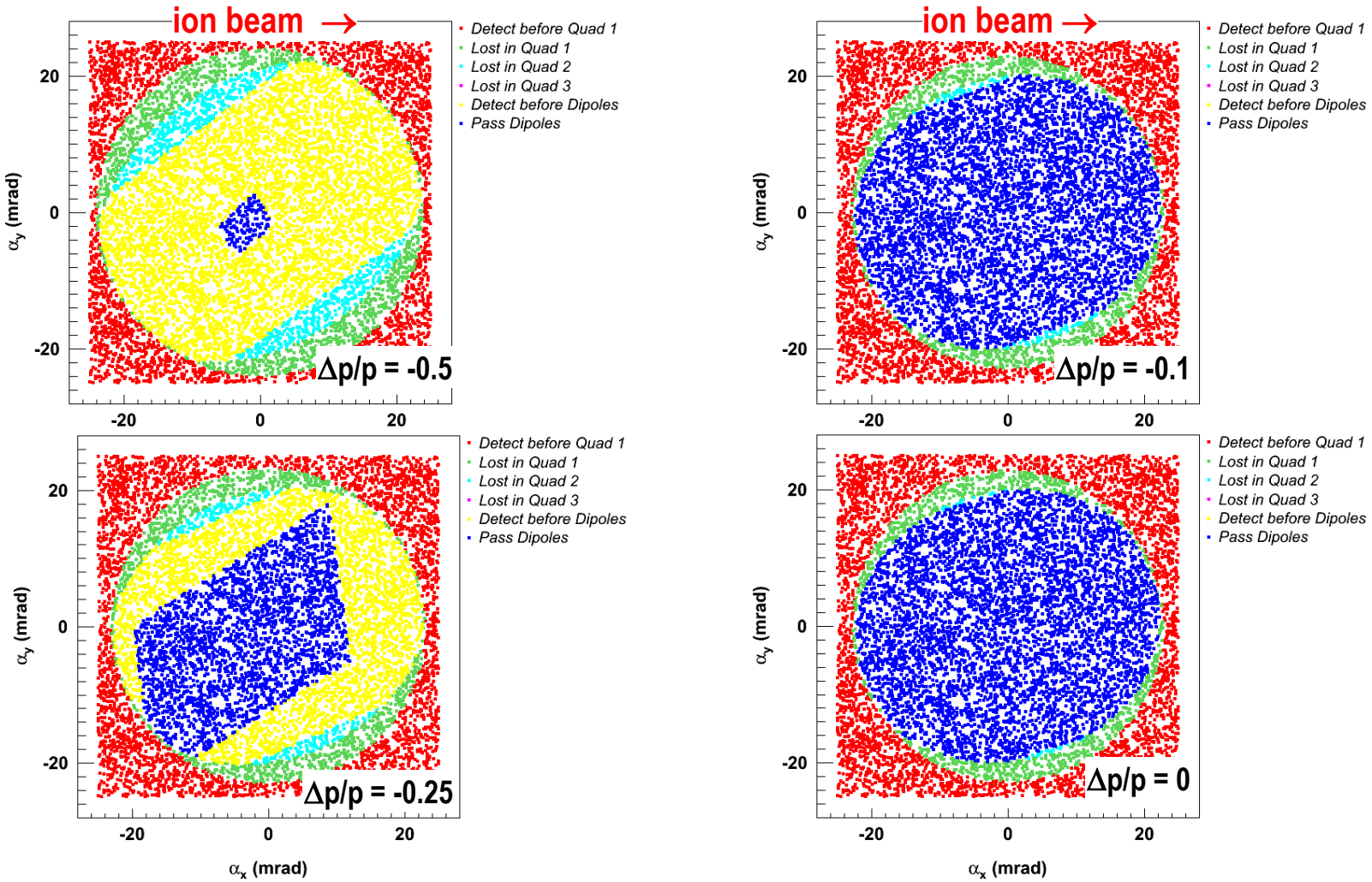
- 5 GeV/c e^-, uniform spreads: -0.5/0 in $\Delta p/p$ and ±25 mrad in horizontal/vertical angle
- Apertures: Quads = 6, 6, 3 T / ($\partial B_y / \partial x$ @ 11 GeV/c), Dipoles = ±20 × ±20 cm





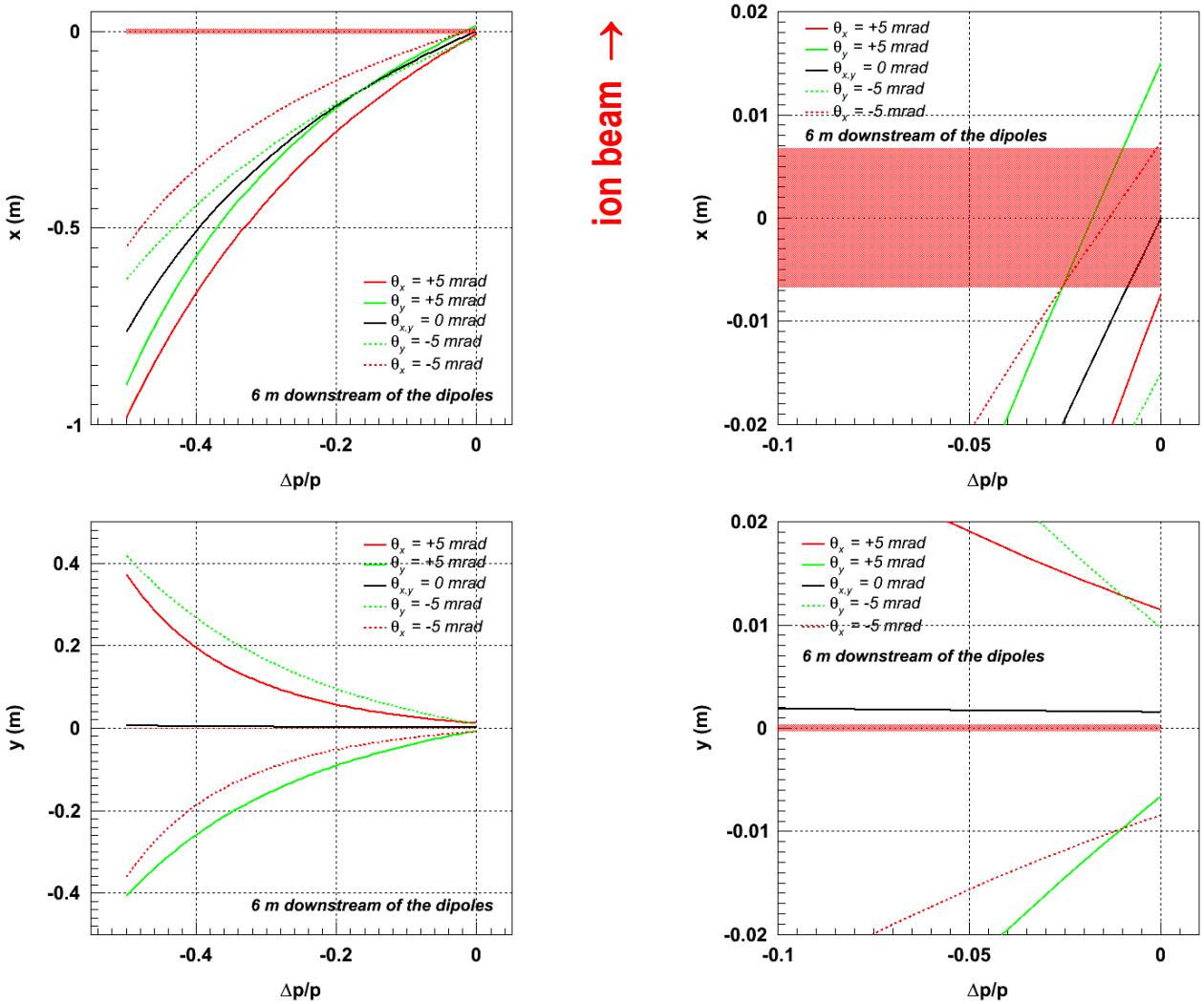
Acceptance of Downstream Electron Final Focus

- Uniform e^- distribution horizontally & vertically within ±25 mrad around 5 GeV/c beam
- Apertures: Quads = 6, 6, 3 T / ($\partial B_y / \partial x$ @ 11 GeV/c), Dipoles = ±20 × ±20 cm



Forward Electron Momentum & Angle Resolution

- **Electrons with Δp/p spread launched at different angles to nominal 5 GeV/c trajectory**

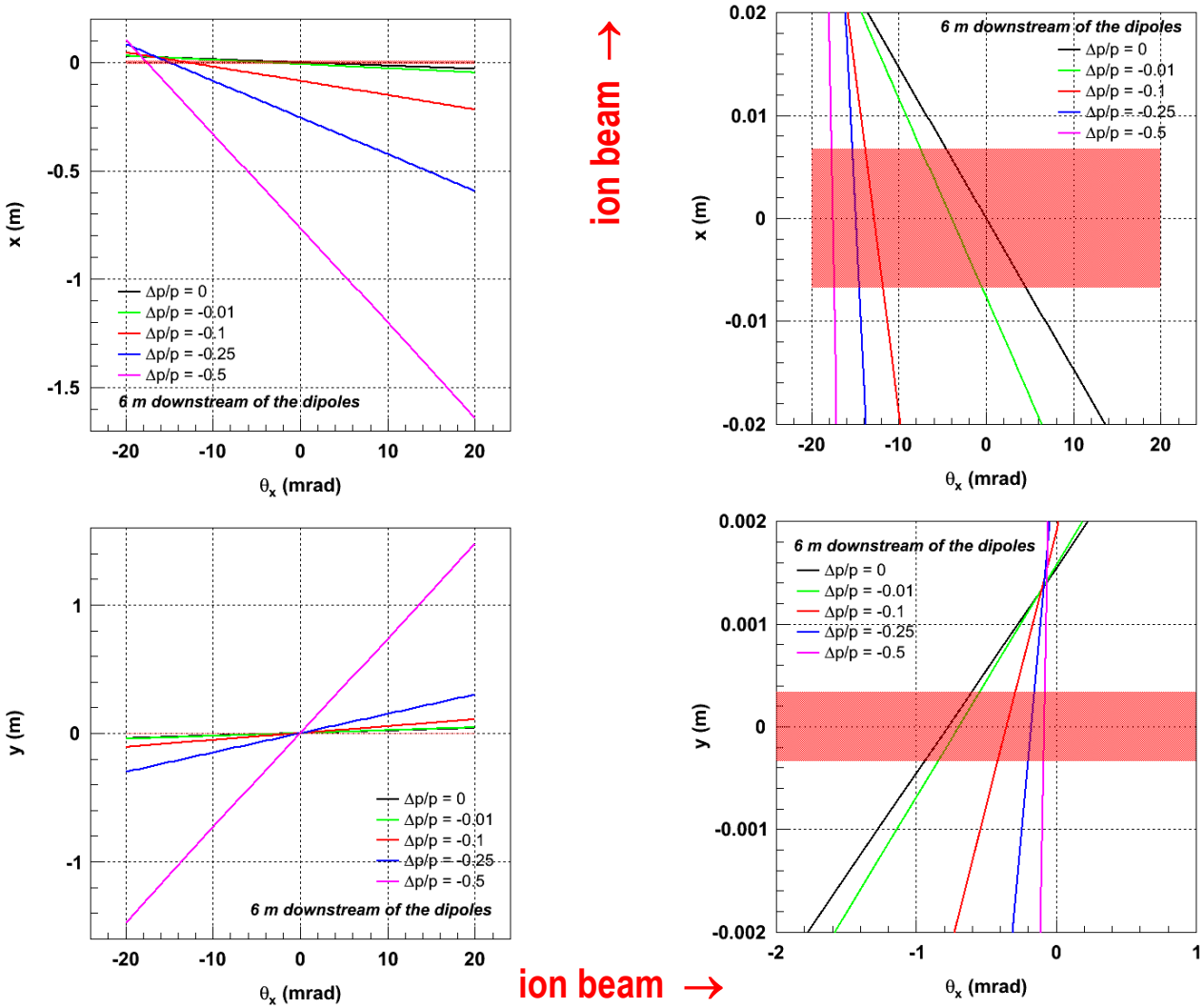


ion beam →

|Δp/p| > 0.01
@ $\theta_{x,y}$ = 0

Forward Electron Momentum & Angle Resolution

- **Electrons with different Δp/p launched with θ_x spread around nominal 5 GeV/c trajectory**



$|\theta_x| > 0.4\text{-}4$ mrad
@ $\Delta p/p = 0$

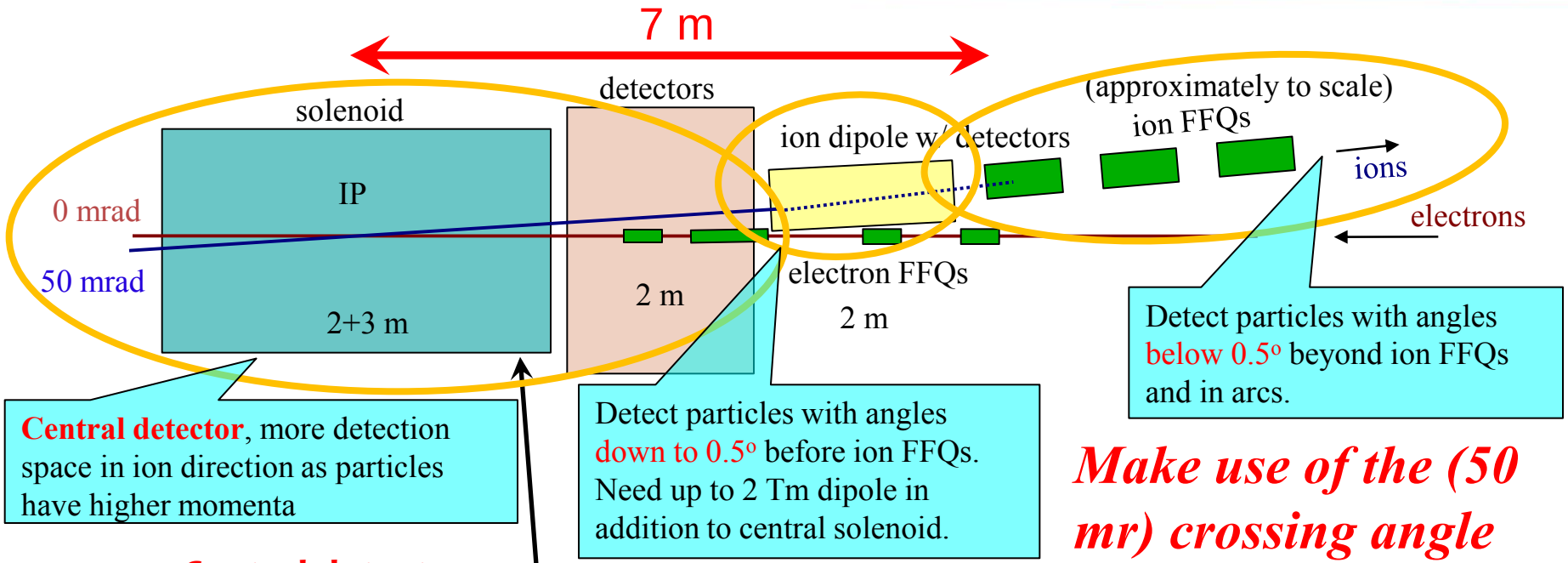
Immediate Outlook and R&D

- Continue optimizing interaction region linear optics for detector integration
- Continue optimizing the forward detection system for electron and ion beams
- Develop a control scheme of synchrotron radiation power in the IR
- Continue work on estimation of detector backgrounds
- Evaluate engineering requirements of the detector region magnets
- Develop a concept for a luminosity monitor
- Develop a concept for orbit control to maintain collisions
- Develop compensation of coherent ion orbit offset in the detector solenoid
- Develop compensation of coupling introduced by the detector solenoid
- Compensate polarization rotation introduced by the interaction region magnets
- Consider integration of the detector region design into the chromaticity compensation scheme
- Develop a vacuum specification and plan for the IR
- Investigate effects of magnet field errors and misalignments in the interaction region

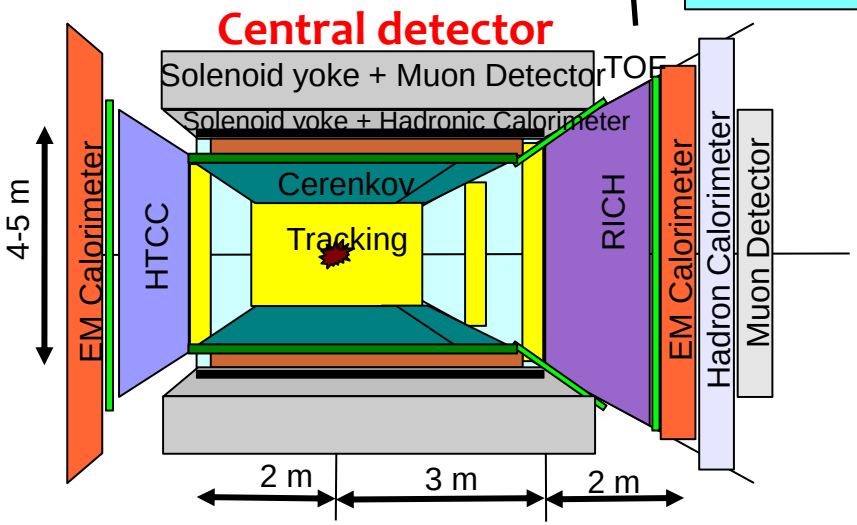
Thank you for your attention !

Back Up

MEIC Primary "Full-Acceptance" Detector

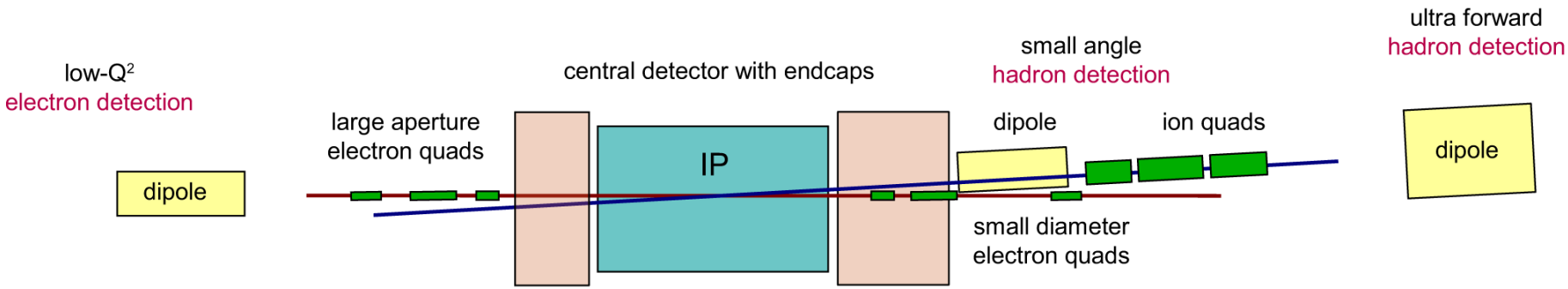
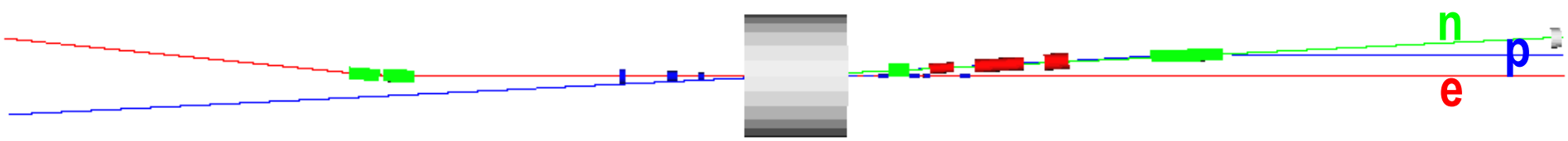


Make use of the (50 mr) crossing angle for ions!



Distance IP – electron FFQs = 3.5 m
Distance IP – ion FFQs = 7.0 m
(Driven by push to 0.5° detection before ion FFQs)

Pawel Nadel-Turonski & Rolf Ent

Upstream Ion / Downstream Electron Side

- **Electron FFB**
  - **4 m distance to IP**
  - **1° polar angle acceptance**
  - **Superconducting quads (solenoid fringe field, small size, large aperture)**
  - **Electron beam focused inside spectrometer dipole**
- **Ion FFB**
  - **First quad immediately after first electron quad at ~4.5-5 m**
  - **Ion quads interleaved with electron quads**