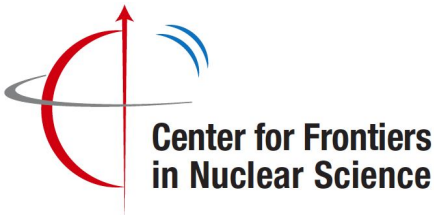
IR8 Forward Instrumentation

Wenliang (Bill) Li

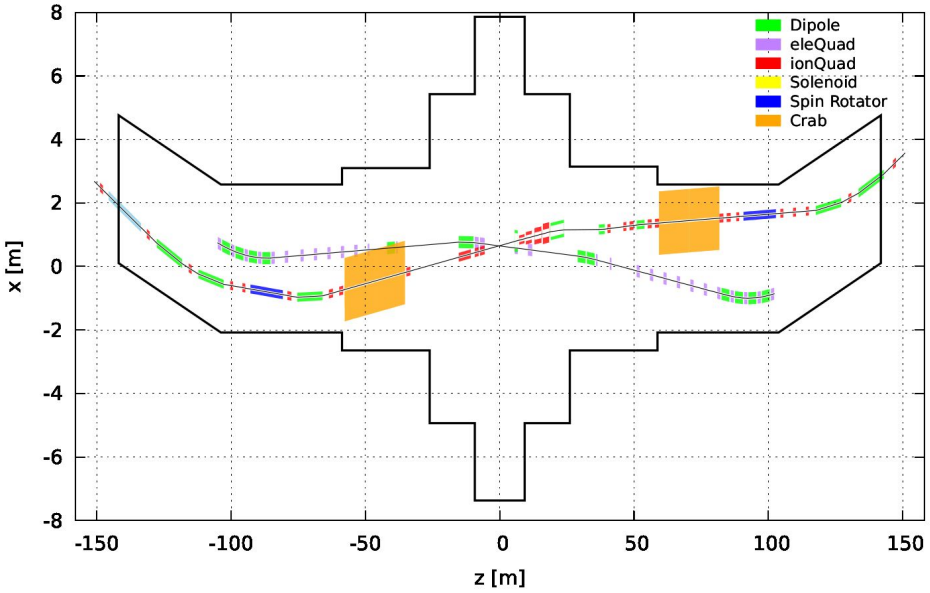
March 21, 2023



Outline Line

- **Official information of IP8**
- **Forward instrumentation**
- **Some practical consideration**

Official Project Information

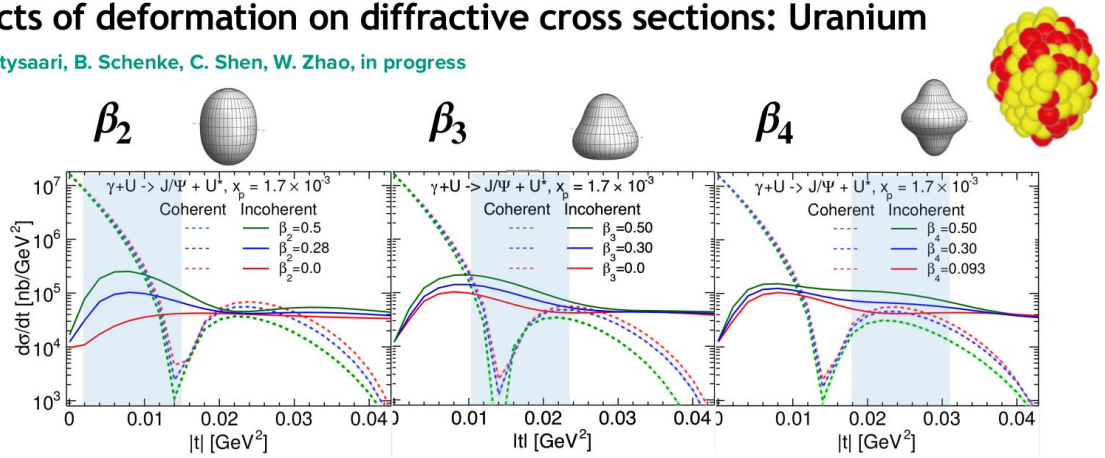


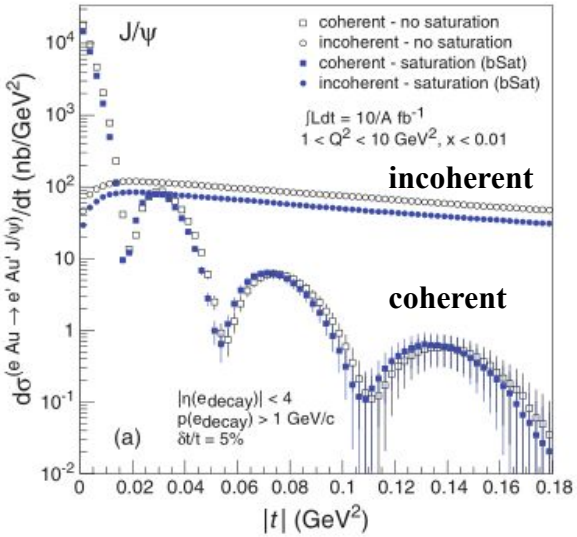
- **Official Information:** https://wiki.bnl.gov/eic-detector-2/index.php?title=Project_Information
  - Contact person: Bamunuvita Gamage (randika@jlab.org)
  - Further optimization is needed! (See example in later slides)

Simulations of coherent diffraction with ^{90}Pb

Effects of deformation on diffractive cross sections: Uranium

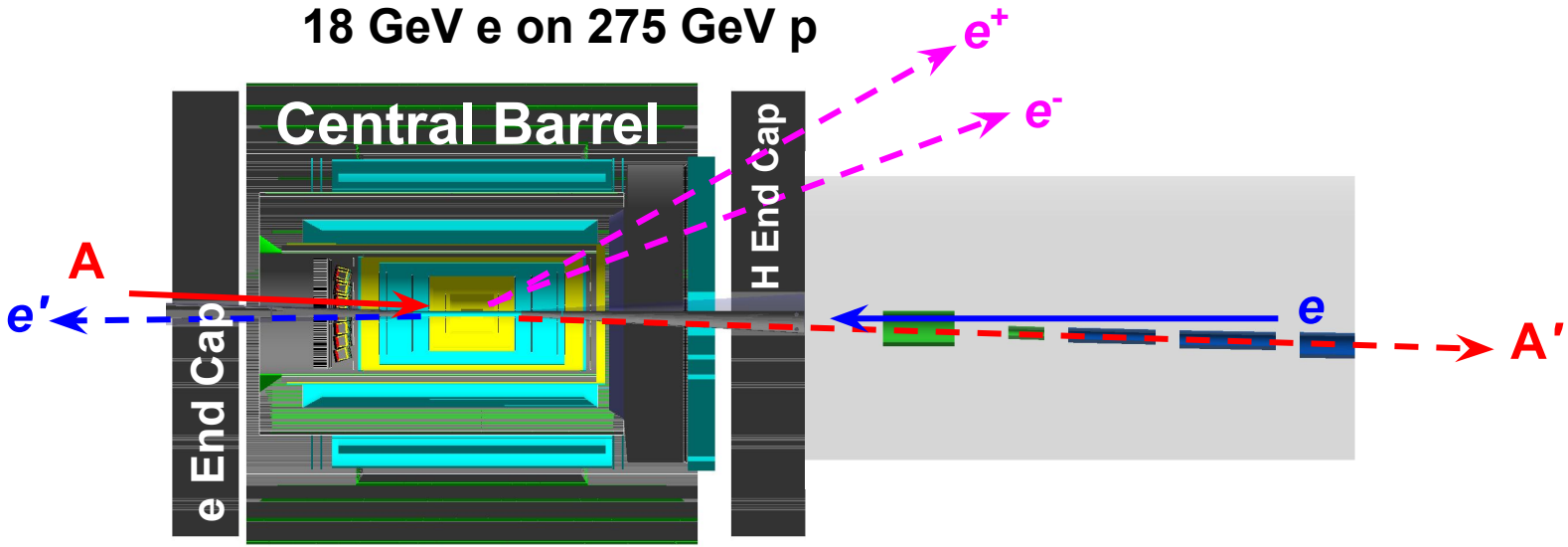
H. Mäntysaari, B. Schenke, C. Shen, W. Zhao, in progress





- **Diffractive Processes (no color exchange)**
  - Dips: “glumpiness” of gluon.
  - Coherent and incoherent: shape of heavy nuclei.

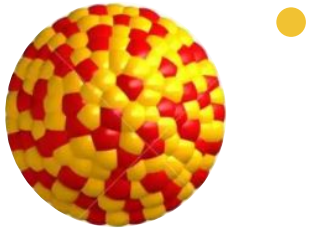
e+A Scattering General Theme



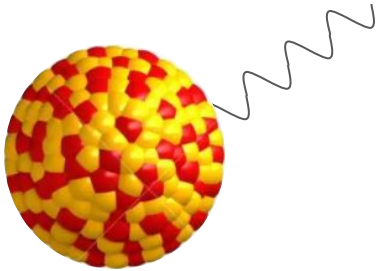
- **Scattered electron (e')**: $\eta \rightarrow -\infty$, far backward region, low Q^2 tagger
- **Decayed J/$\psi \rightarrow e^+e^-$**: $-1.5 < \eta < 3.5$, Central detector
- **Recoiled A (A')**: $\eta \sim 6$, far forward region

What does A′ do In the Beam Pipe?

A′



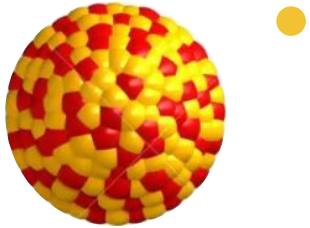
Neutron Evaporation



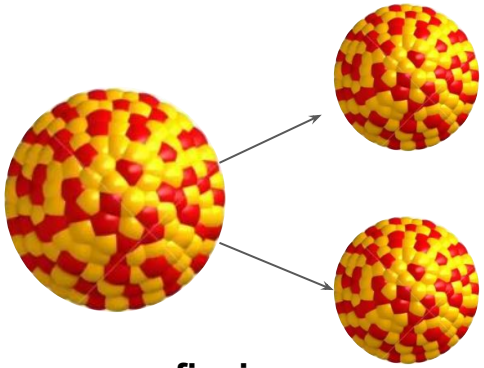
Gamma de-excitation

- eA Diffractive study, forward detector must:
  - Tag A′
  - Veto events due to neutron evaporation and gamma de-excitation

A′ Decay is not all bad !

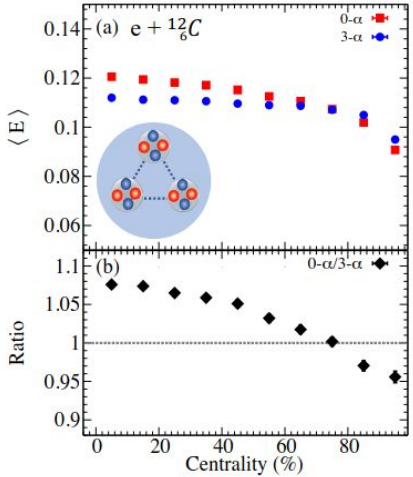


Neutron Evaporation



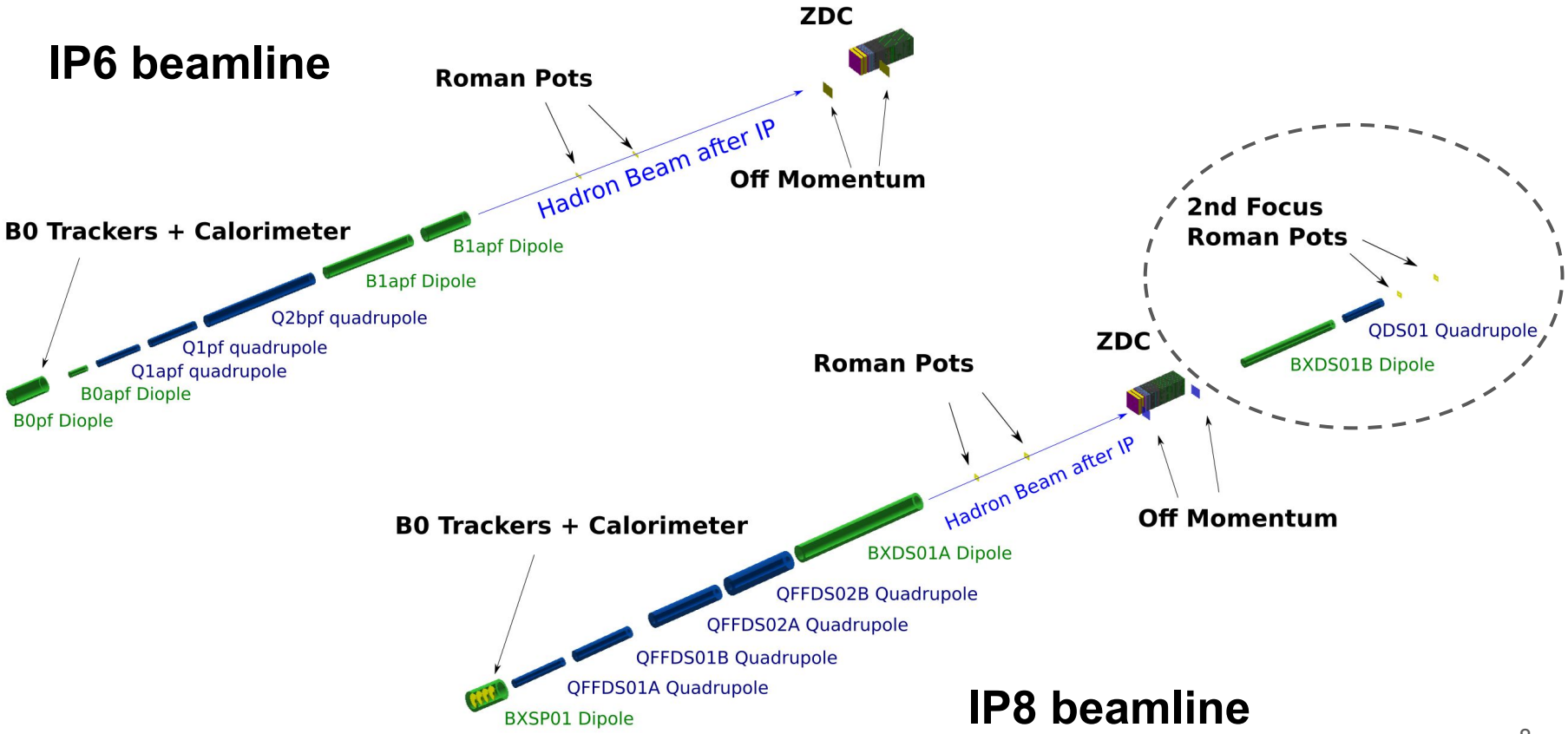
fission

- Evaporated neutron energy deposition study by Niseem Magdy, Jia, et. al.

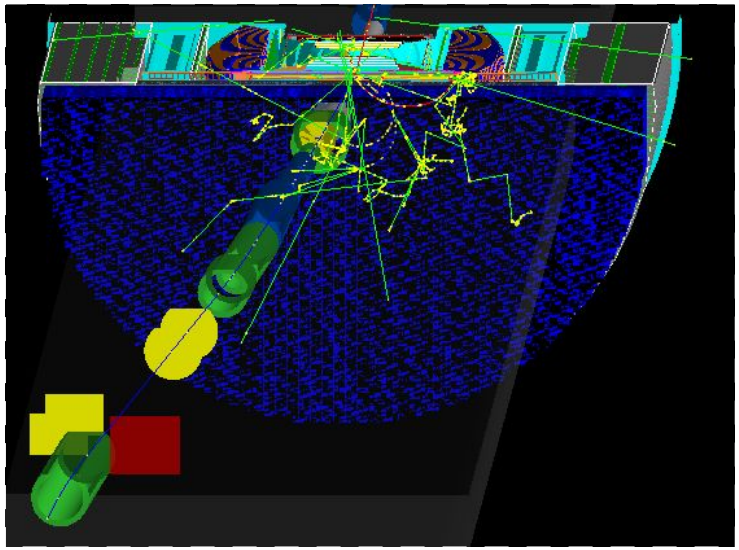


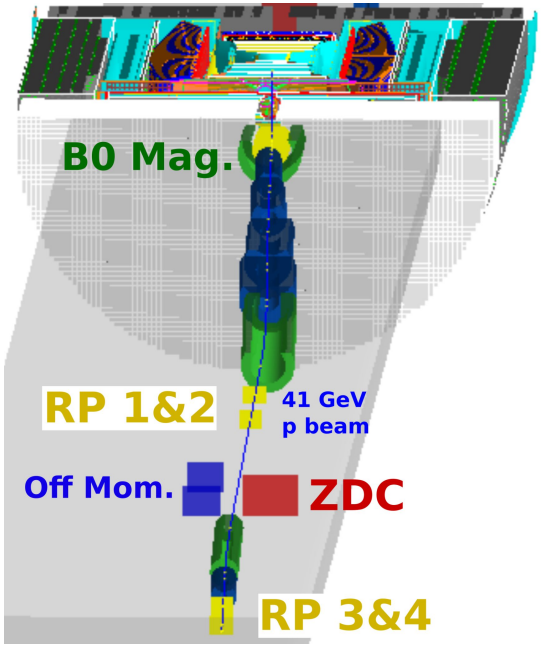
- Evaporated neutron energy deposition study by B. Moran, et. al.
  - See later slide

IP6 vs IP8: almost identify but different



IP6 vs IP8: almost identify but different





IP6:

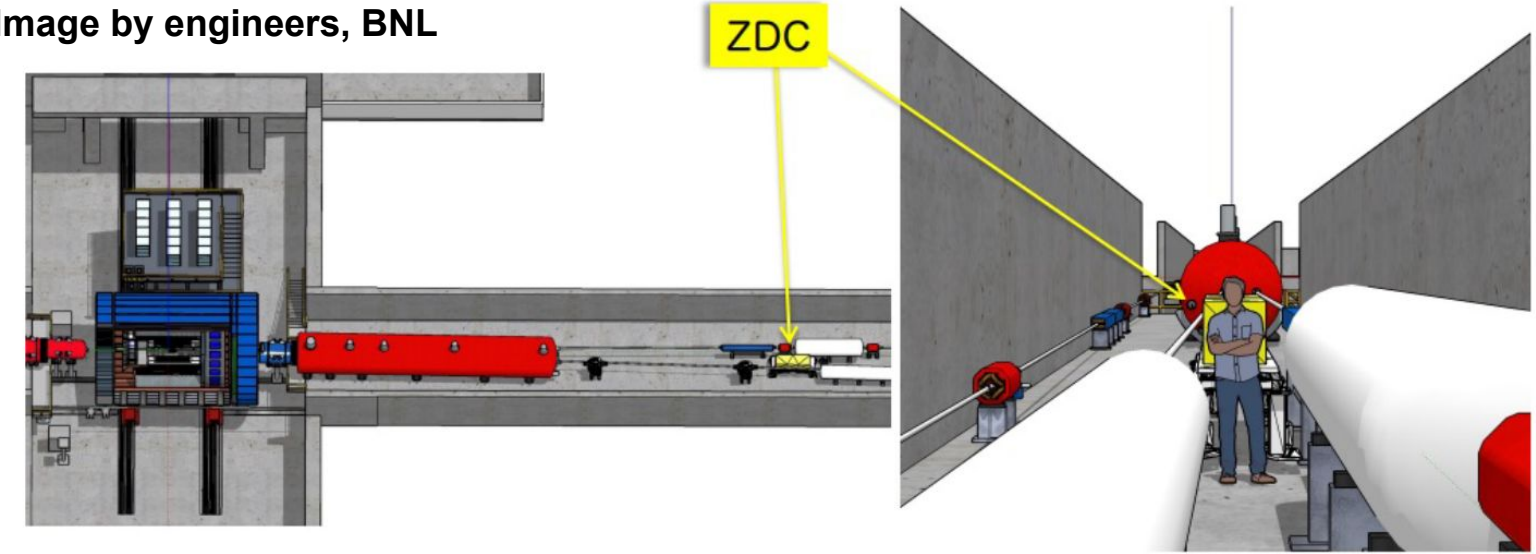
- 25 mrad e+p crossing angle
- ZDC Acceptance: -4.5 to +5.5

IP8:

- 35 mrad e+p crossing angle
- Second focus
- ZDC Acceptance: +-5 official design
  - potentially +-7

Zero Degree Calorimeter

Image by engineers, BNL



- **ZDC**
  - Sensitive to soft photon and neutron
  - IP6 ZDC +-5mrad acceptance
  - IP8 benefit from higher acceptance?

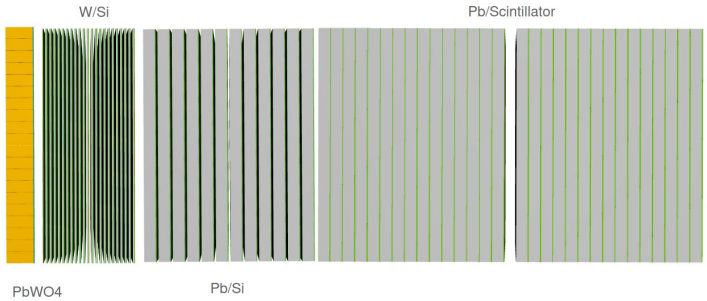


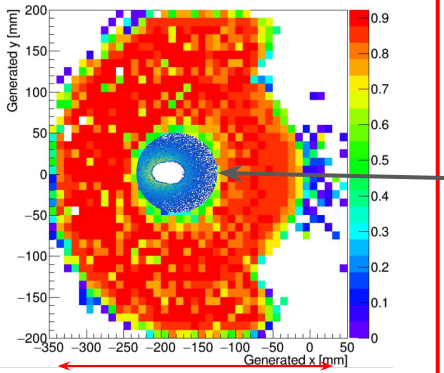
Image by D. Misra, PNNL

In terms of Far Forward Acceptance: B0 is the Key

- The increase to ZDC acceptance from +-5 to +-7 marginally increases the recoil nucleon acceptance:
  - e+p 5x41 GeV pion structure study: 20% increase in terms of nucleon detection efficiency
- Instrumentation of a full calorimeter inside B0 will significantly boost the forward acceptance: from +- 5 mrad to +-28 mrad !
- Due to special constraints, full Calorimeter might be a “no-go”

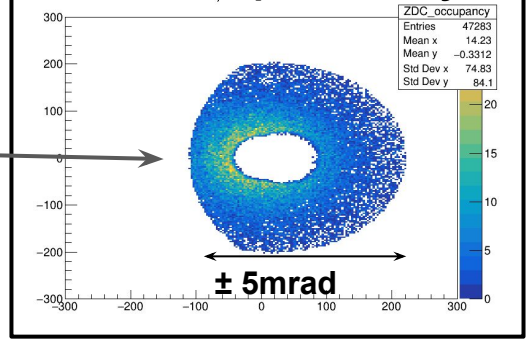
B0 Calorimeter

ZDC + B0 calorimeter

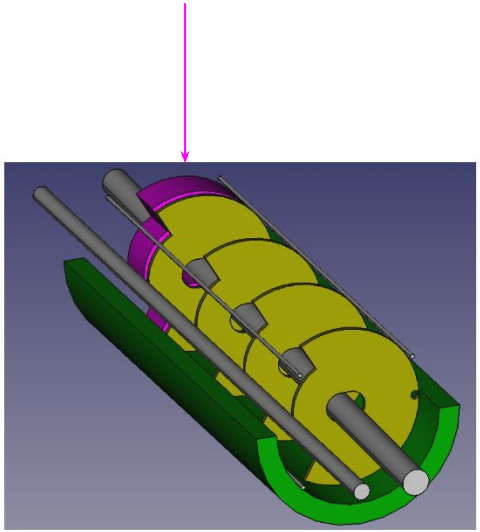


± 28mrad !

ZDC Acceptance only



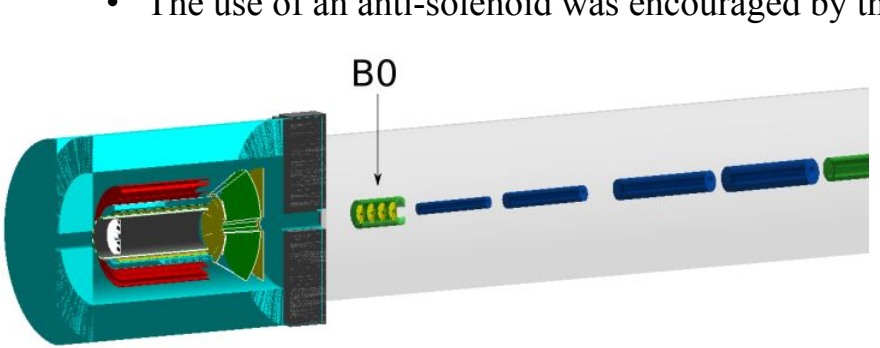
± 5mrad

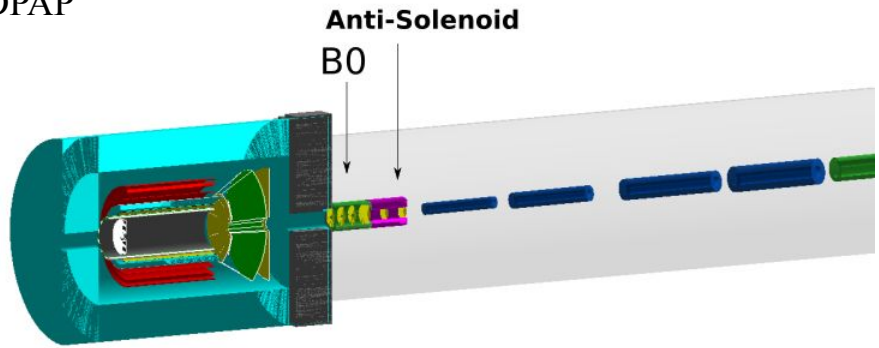


Slides borrow from P. Nadel-Turonski

Motivation – overview

- Compensation of the field of the detector solenoid is necessary, and can be done either using a large number of skew quads or an anti-solenoid on each side of the detector, each compensating half the field.
  - Anti-solenoid: solenoid with opposite polarity to the main detector solenoid
  - Skew quad: quadrupole magnet / winding rotated by 45 degrees in azimuth
- The use of an anti-solenoid offers significant benefits for the accelerator and provides additional space behind the small B0 dipole for improved detection in the 5-20 mrad range.
  - An anti-solenoid was part of the original (JLab) IR concept that IR8 is based on
  - The use of an anti-solenoid was encouraged by the DPAP





- An anti-solenoid can fit in the space in front of the ion FFQs (blue), located 7.5 m from the IP.

Off Momentum Tracker

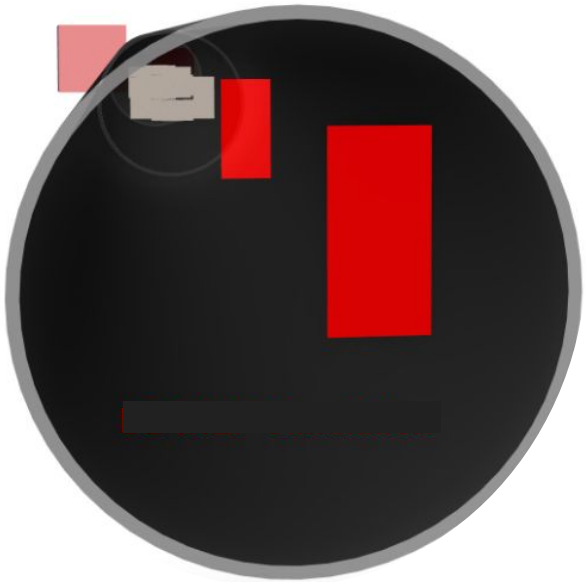
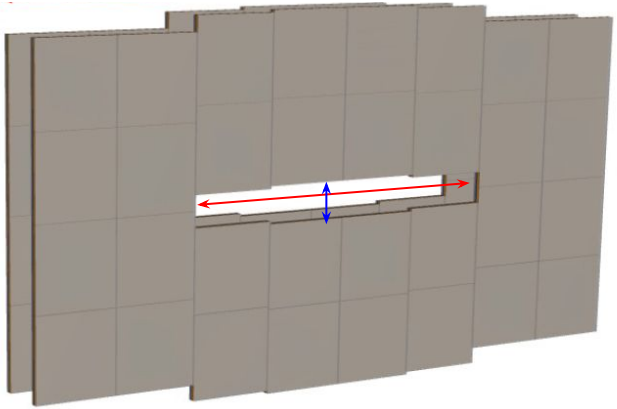


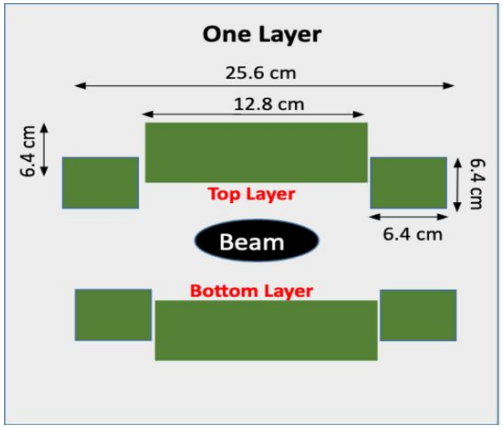
Image by A. Jentsch, BNL

- Roman pot without slits.
- Offsetted to one direction
- Protons tagging:
  - 123.75 < E < 151.25 GeV
  - 45% < $p_{z,proton}/p_{z,beam}$ < 55%
- Tagging decay remnants from Λ or Σ

Roman Pots

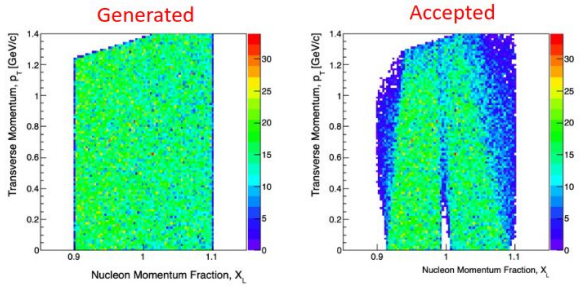
Image by A. Jentsch, BNL





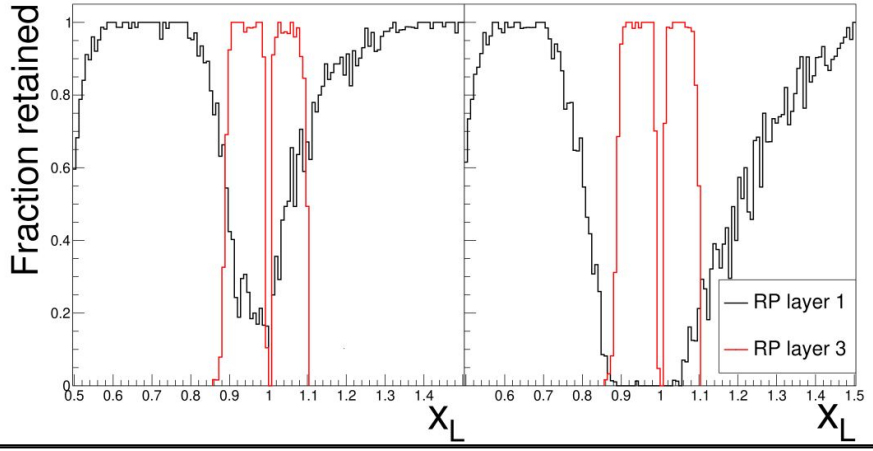
- **Primary consideration:**
  - Slit opening 10σ wider than the beam width.

	Slit width	Slit height
IP6 RP 1&2	8.8 cm	1.2 cm
IP8 1&2	6.2 cm	0.8 cm
IP8 3&4 (2nd focus)	0.7 cm	0.2 cm



Acceptance study by Alex Jentsch, see full study: https://wiki.bnl.gov/eic-detector-2/images/8/86/IP8_HSR_lattice_performance_10_13_22_v3.pdf

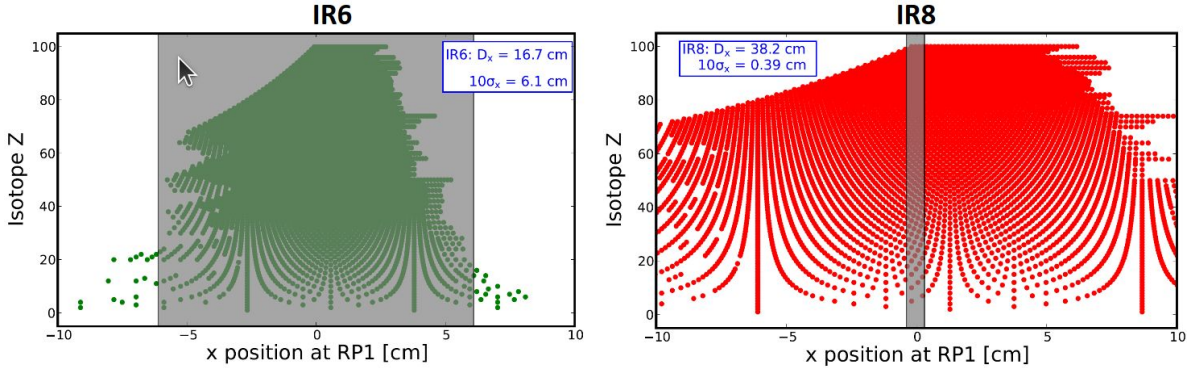
In terms of PD acceptance



Rigidity fraction of eA diffractive process:

- with 2nd focus: black + red
- without 2nd focus: black

Study by M. Baker and others

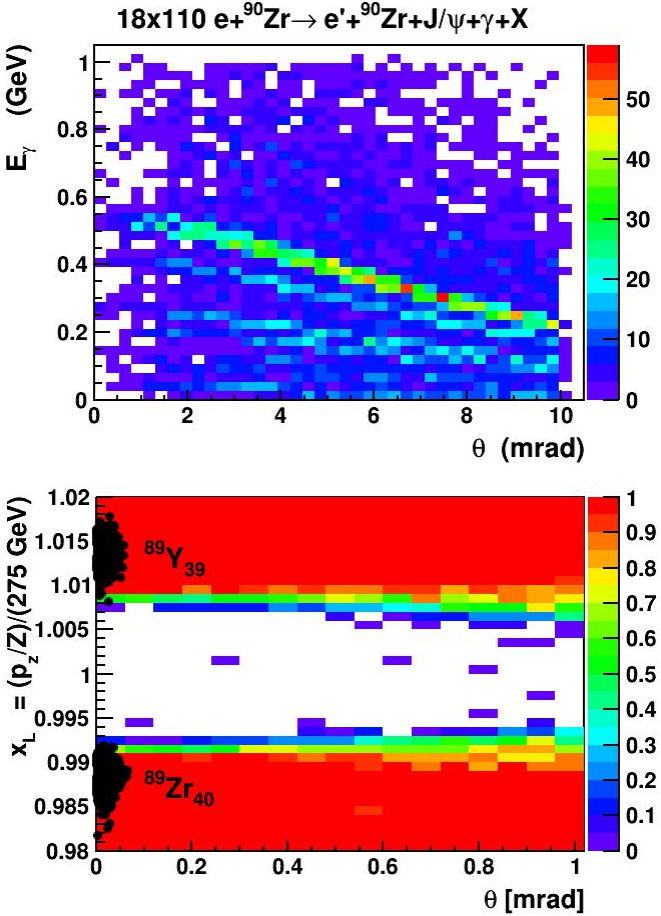


Heavy isotop detection at Roman Pot

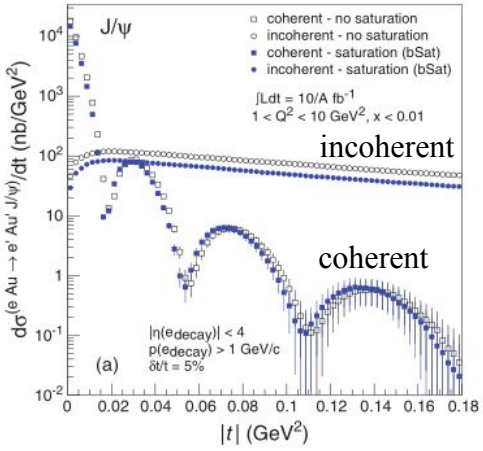
Study by B. Moran and others

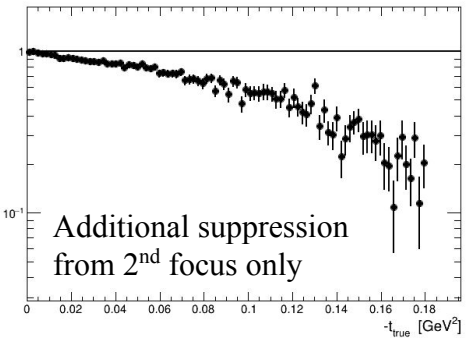
Slides borrow from P. Nadel-Turonski

Simulations of coherent diffraction with ^{90}Zr



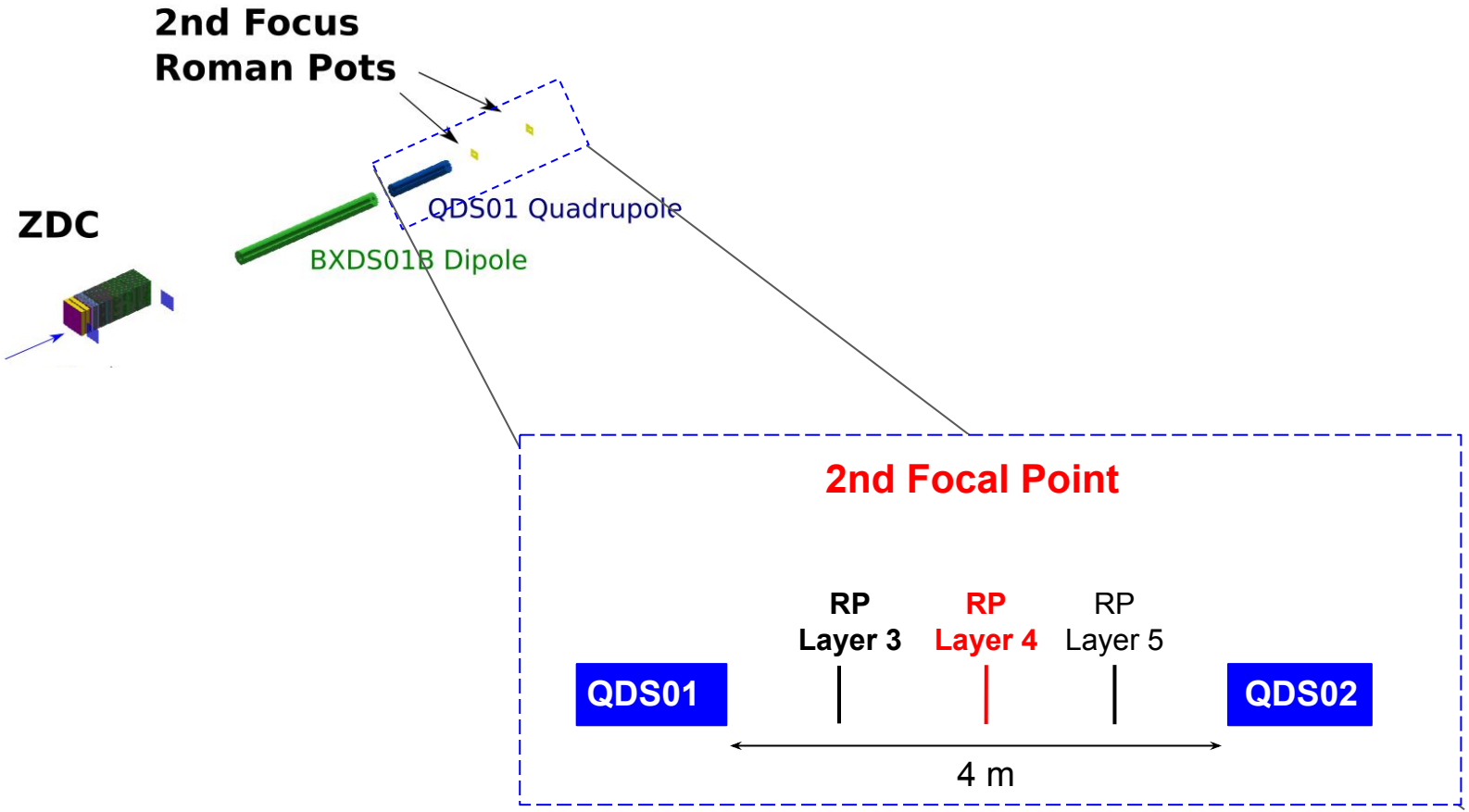
- Extended forward photon detection is synergetic with the 2nd focus in IR8.
- ^{90}Zr is ideal for benchmarking:
  - The ability to tag A-1 nuclei in the 2nd focus and detect a large fraction of nuclear photons has the potential to significantly improve the suppression of incoherent backgrounds in coherent diffraction.
  - The photon detection will also help to distinguish reactions where the final nucleus was in the ground state or an excited state.
  - The figures on the left show the photons and A-1 fragments from ^{90}Zr
  - The figures on the right show the additional suppression at high t from the 2nd focus



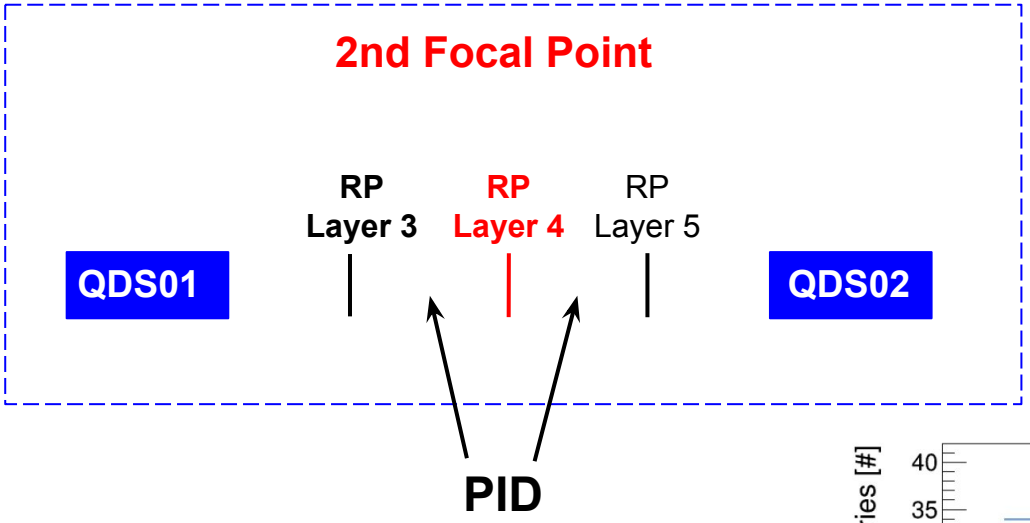


Study by M. Baker and others

A Closer Look at the 2nd Focus Area

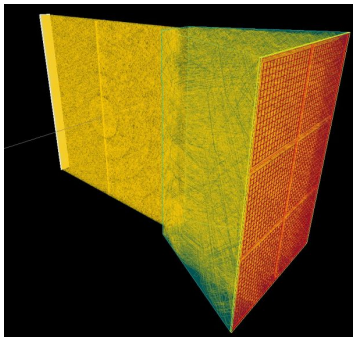


Ideas: Adding PID? Z-Tagging Mini DIRC Concept (C. Hyde)

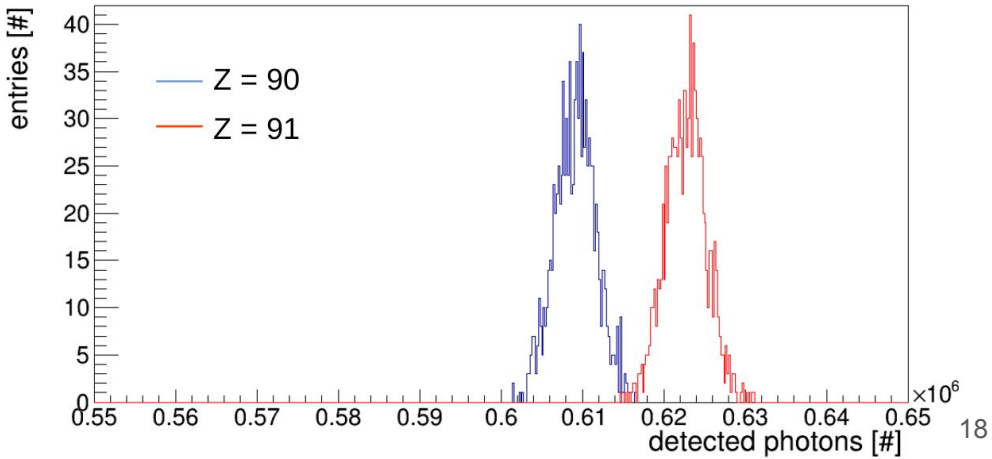


- **Z-Tagging Mini DIRC** (C. Hyde)
  - Photon counter

$$\frac{dN}{dX} \approx z^2\,(0.013/\mathrm{cm}) = \frac{106}{\mathrm{cm}} \text{ for } z = 90$$

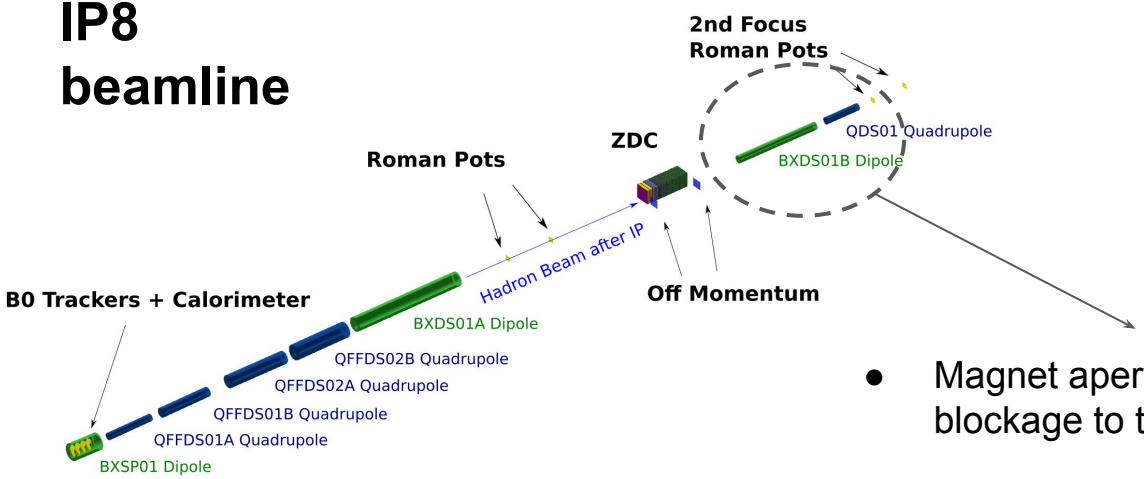


Ray trace simulation by
C.Hyde and R. Dzhygadlo



IP8: Practical Issues

IP8 beamline



- Magnet aperture of BXDS01B and QDS01 creates blockage to the physics event acceptance
- Further optimization needs to be done ASAP

IP8 Forward Detector Suggestion

Detector	Acceptance	Requirement
ZDC	θ < 5.5 mrad (η > 6)	35%/√E ~1mm position resolution
RP 1&2	0.0* < θ < 5.0 mrad (η > 6)	
RP 3&4	0.0* < θ < 5.0 mrad (η > 6)	
Off Momentum	0.0* < θ < 5.0 mrad (η > 6)	
B0 tracker + Calorimeter	5.5 < θ < 25.0 mrad (4.6 < η < 5.9)	Full Calorimeter
PID at 2nd focus	0.0* < θ < 5.0 mrad (η > 6)	Z tagger photon counter

Thank you for your attention!