Spectator proton tagging in e/p + ^{3}He

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Outline

- Spectator, forward proton tagging for eRHIC and RHIC: What's involved
- Utilizing Roman Pot detectors in
  - $e+{}^3He$ at EIC
  - $p+{}^3He$ at STAR/RHIC

Forward protons in the key measurements for EIC

- Diffractive proton in exclusive Deeply Virtual Compton Scattering (DVCS) process ($ep \rightarrow e\gamma p$): access to the spatial distribution of partons in the transverse plane: GPD (polarized, unpolarized)
- Spectator protons in polarized $e+{}^3He$ in inclusive DIS for polarized neutron structure function $g_1^n(x,Q^2)$ and flavor separation in semi-inclusive DIS
- ...

Forward protons in current and future RHIC physics

- Protons in elastic p+p: studying structure of Pomeron (and Odderon)
- Inelastic diffractive protons in central process: $p+p \rightarrow p+M_X+p$ to study constituent gluonic degree of freedom
- Spectator protons in polarized $p+{}^3He$
- ...

Forward protons

- Scattered with ~O(mrad): Need Roman Pot to detect
- Large angle (high-t) acceptance mainly limited by magnet aperture
- Small angle (low-t) acceptance limited by beam envelop (~10σ)
- Reconstruction resolution limited by
  - beam angular divergence (~O(50μrad))
  - uncertainties in vertex (x,y,z) and transport

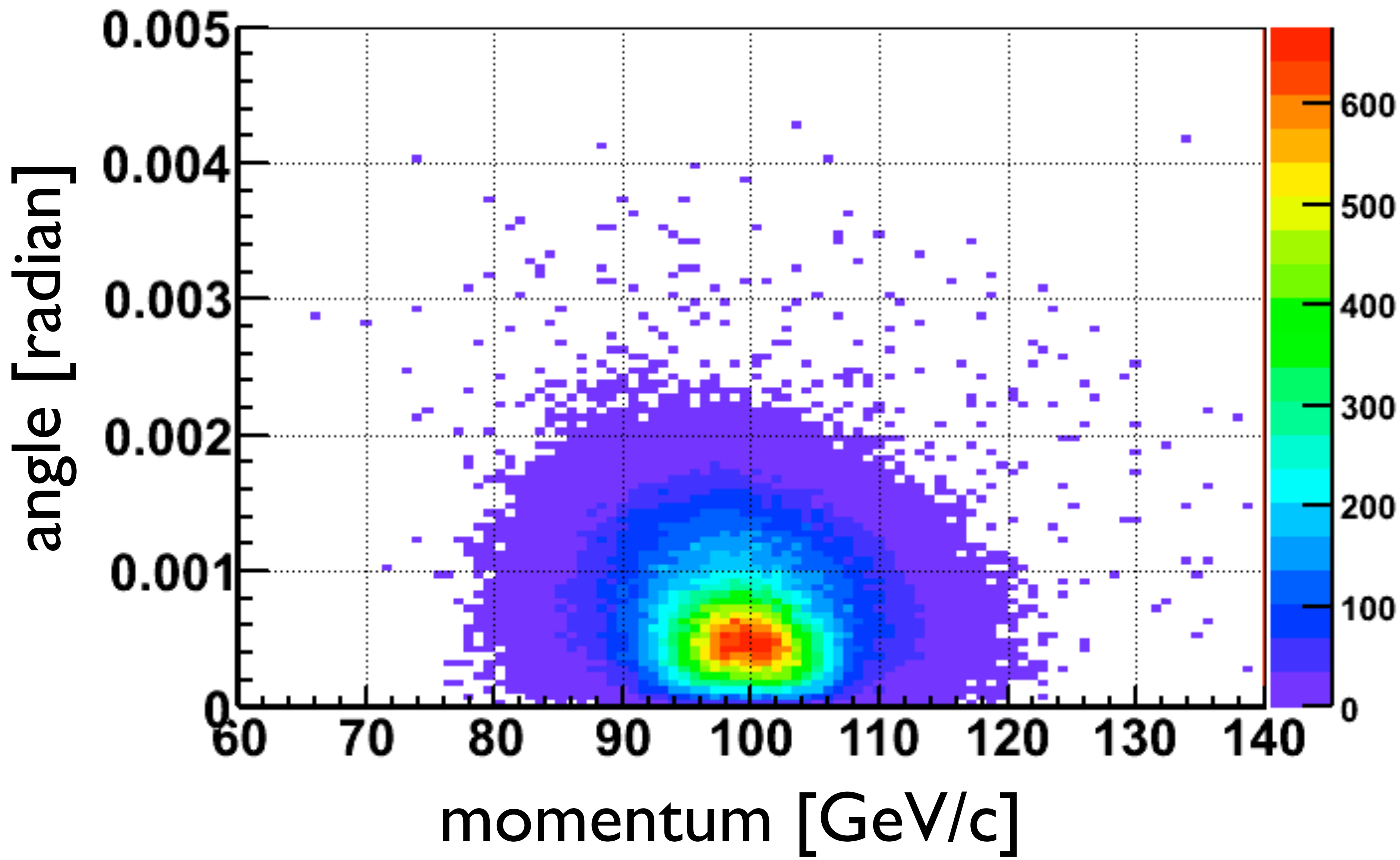
Tagging spectators in ^{3}He

- Crucial for identifying processes with a neutron "target" [e(p)+n] in e(p)+^{3}He
- Spectator neutron (<~3 mrad) can be measured by ZDC
- Tagging spectator protons from ^{3}He
  - Relying on separation from magnetic rigidity (B_r) changes
    ^{3}He: p = 3/2:1
  - No need to reconstruct momentum but need clean identification
    - position+directional measurement desirable
- Can a common detector be utilized for tagging forward proton from DVCS and the spectator protons from ^{3}He?

Simulation

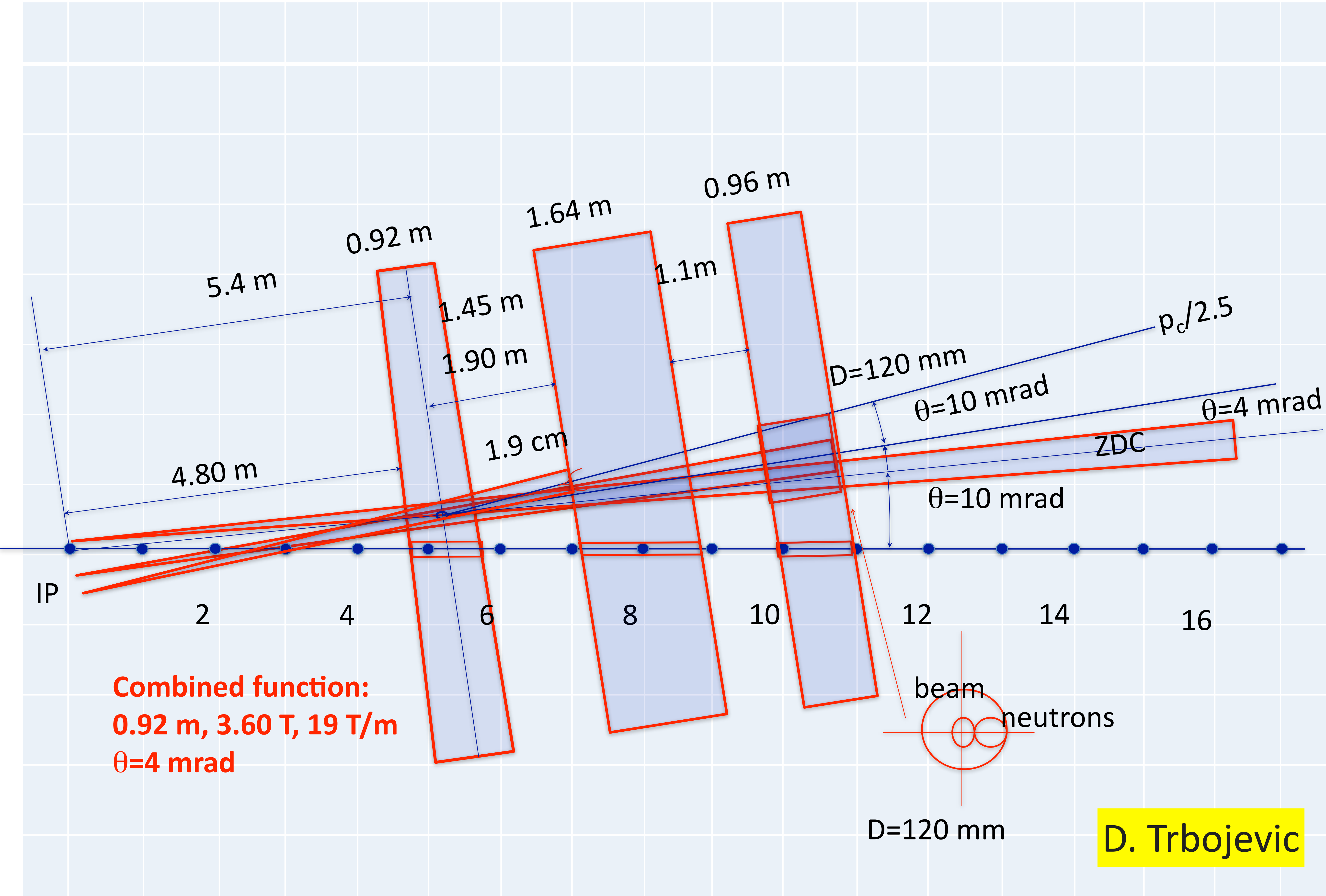
- Event: DPMJET III with FLUKA implemented
  - Simulated internuclear cascades in spectator pre-fragments and break-up of excited nuclei
  - $e(5)+^3He(100)$ $0<Q^2<20$ GeV^2 (spectator distributions depend on ^3He energy)
- Beam transport: HECTOR (beam simulator)
  - with the "latest" EIC Optics
  - with current RHIC Optics (with DX): for $p+^3He$
- Detector: Roman Pot (RP)
  - 4 sided (2 Up/Down 2 Left/Right) active area of 10cmx7cm (flexible)
  - RP at 20m for EIC
  - RP at 15.3m for RHIC
  - Using a common setup used for detecting diffractive protons in DVCS (See http://www.rhic.bnl.gov/~jhlee/proton_tagging_in_DVCS.pdf)

Spectator protons from ^{3}He



- Momentum smearing mainly due to Fermi motion + Lorentz boost
- Angle <~3mrad (>99.9%)

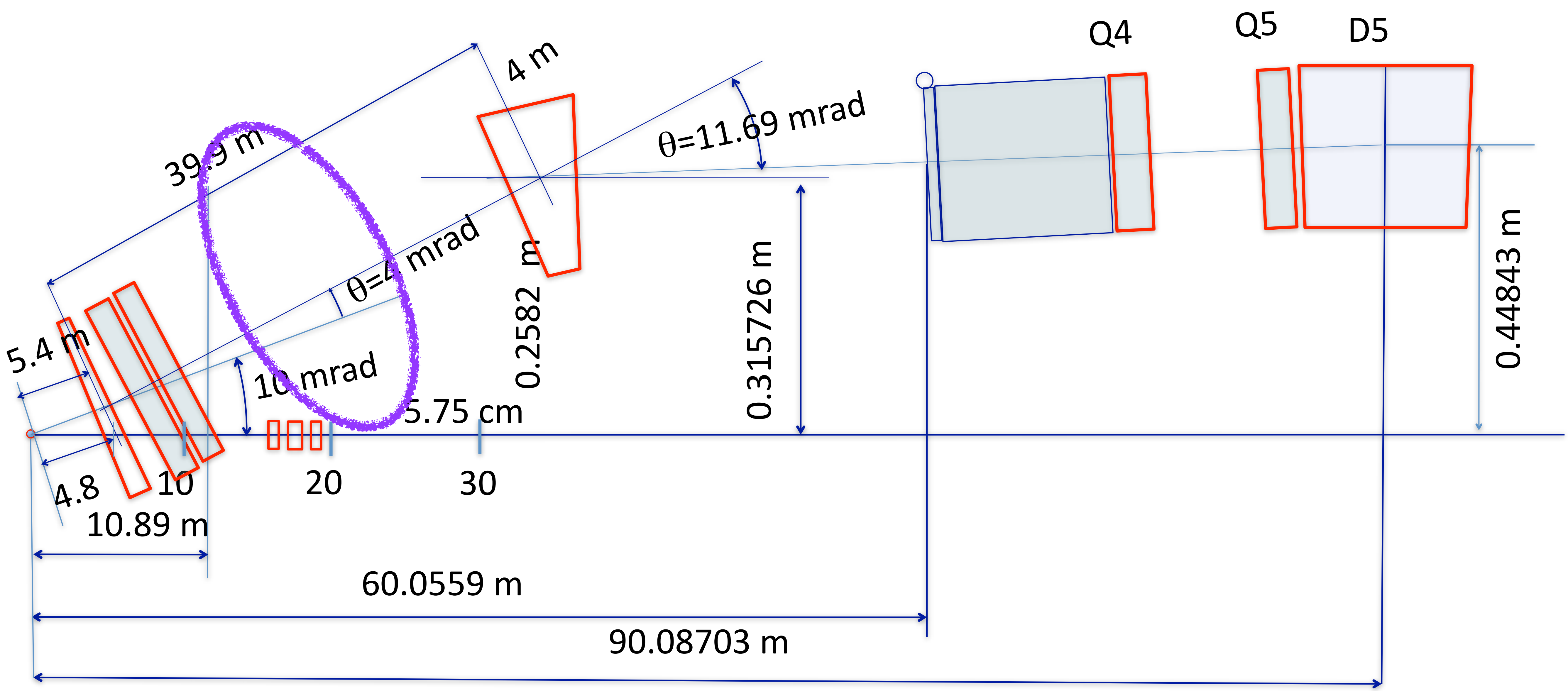
IP configuration for eRHIC (December 22, 2010)



Combined function:
0.92 m, 3.60 T, 19 T/m
θ=4 mrad

D. Trbojevic

IP configuration for eRHIC (December 22, 2010)



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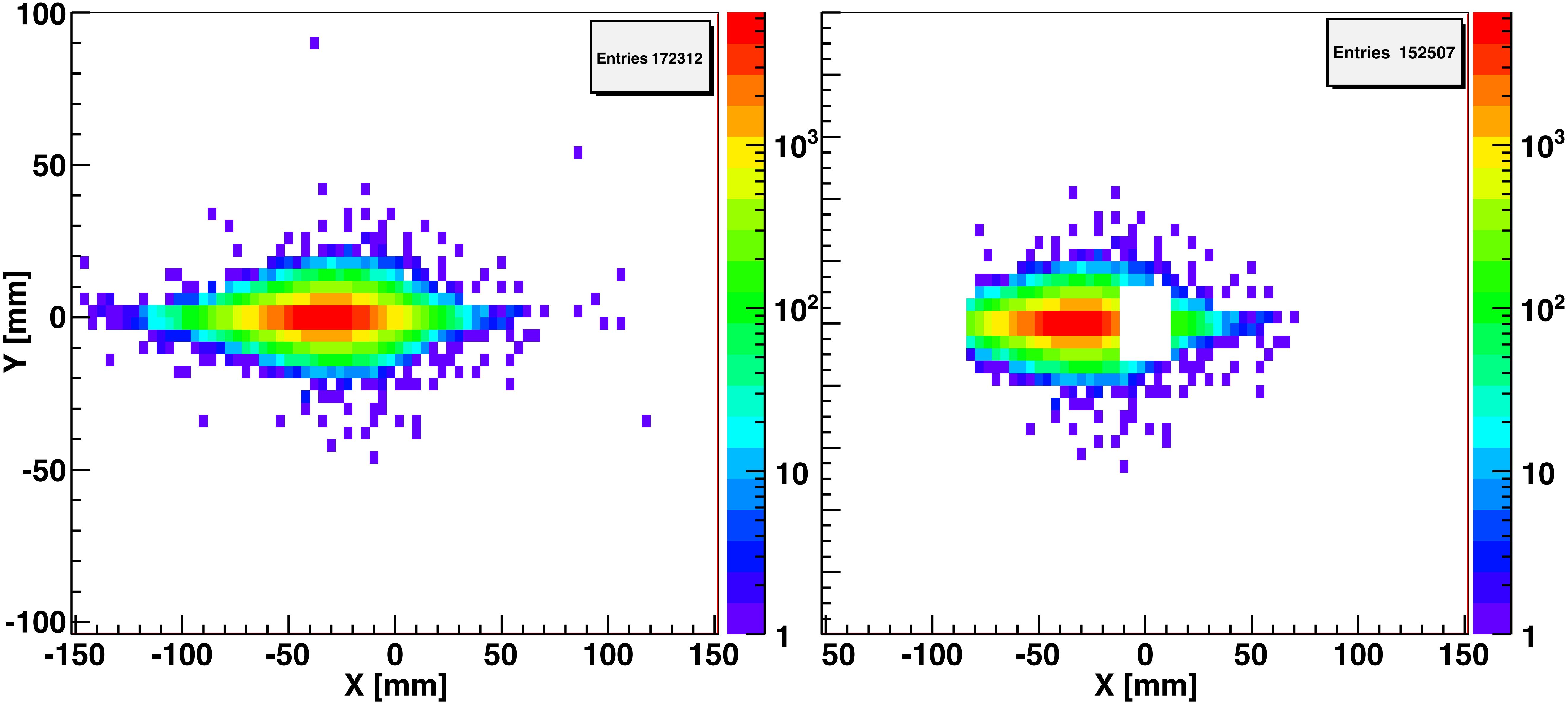
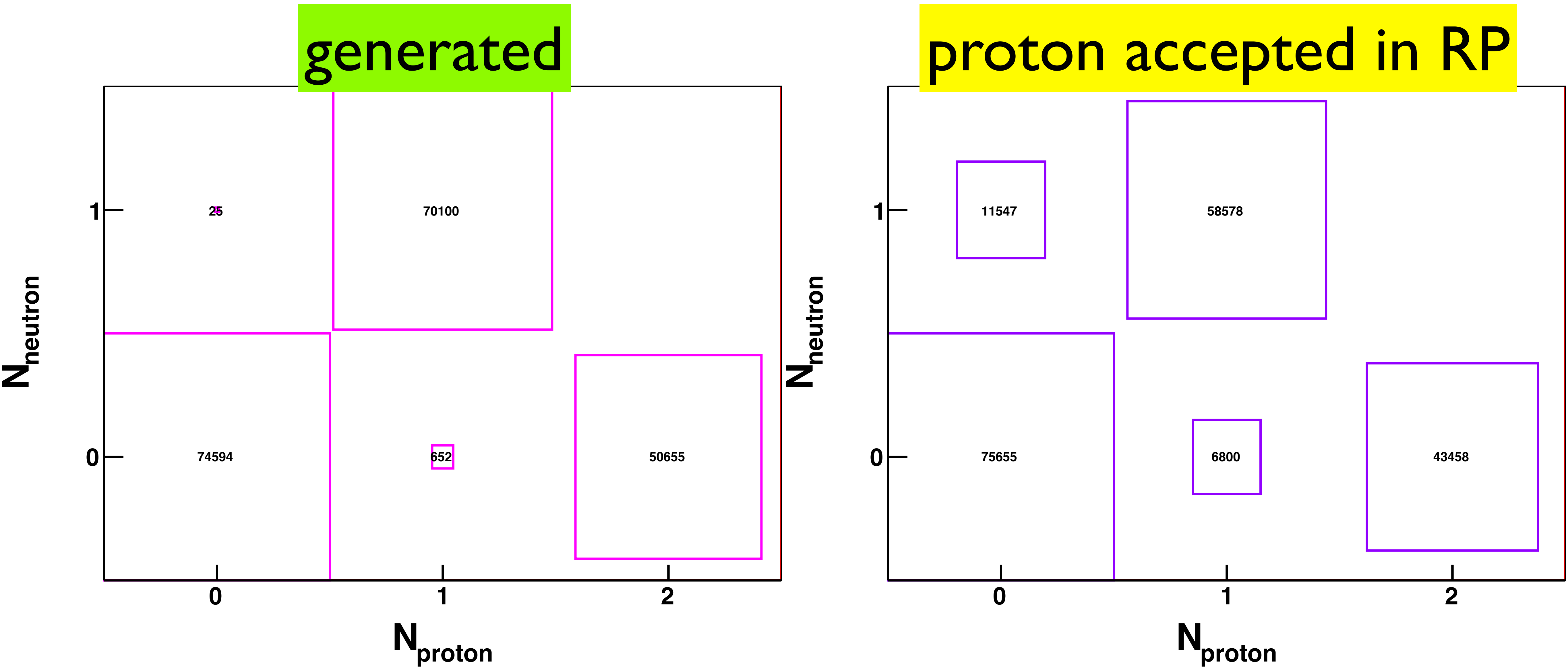
Acceptance of RP at 20m



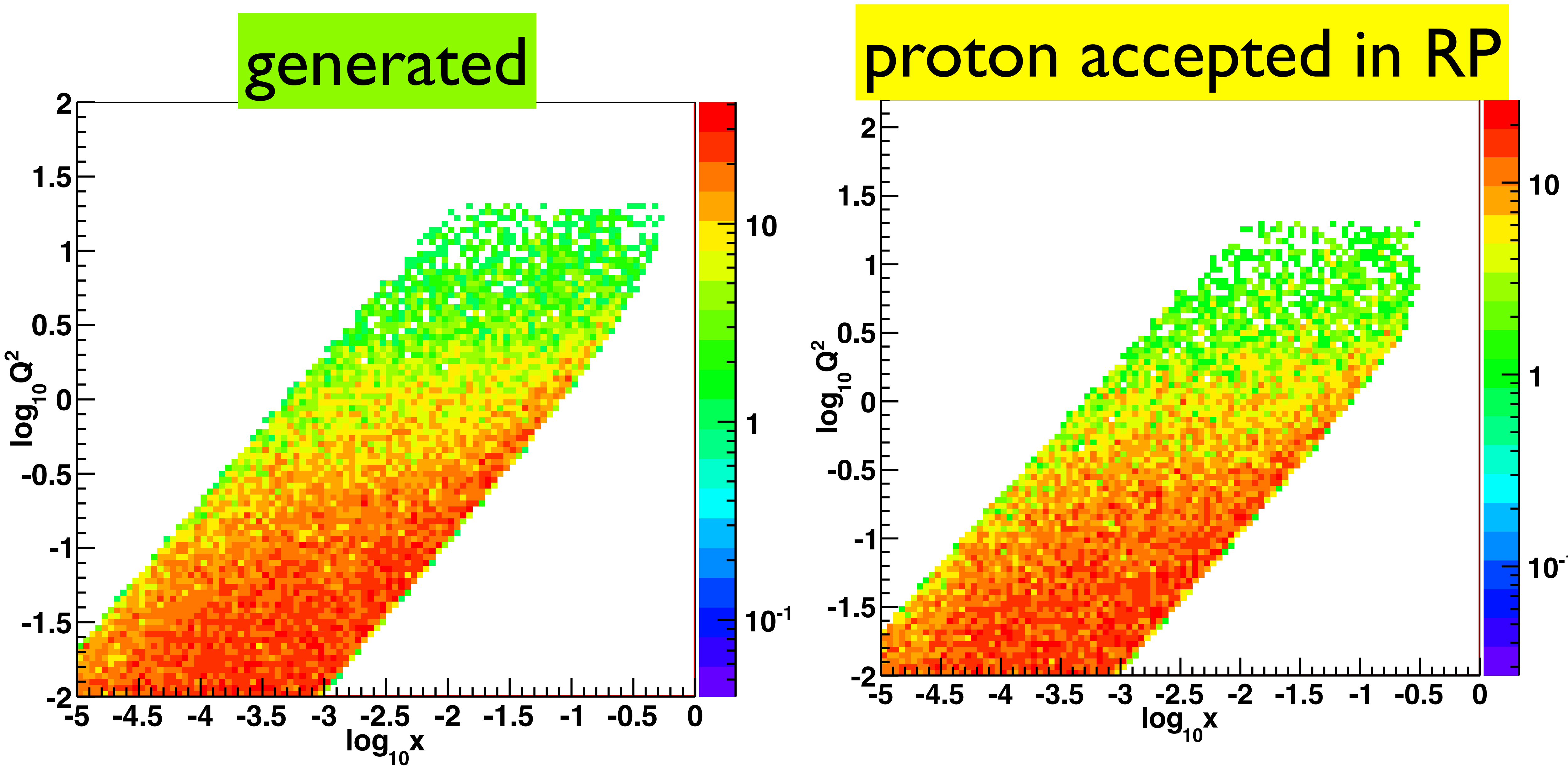
- Spectator proton acceptance in RP ~ 90% with the assumed design

$N_{neutron}$ vs N_{proton}



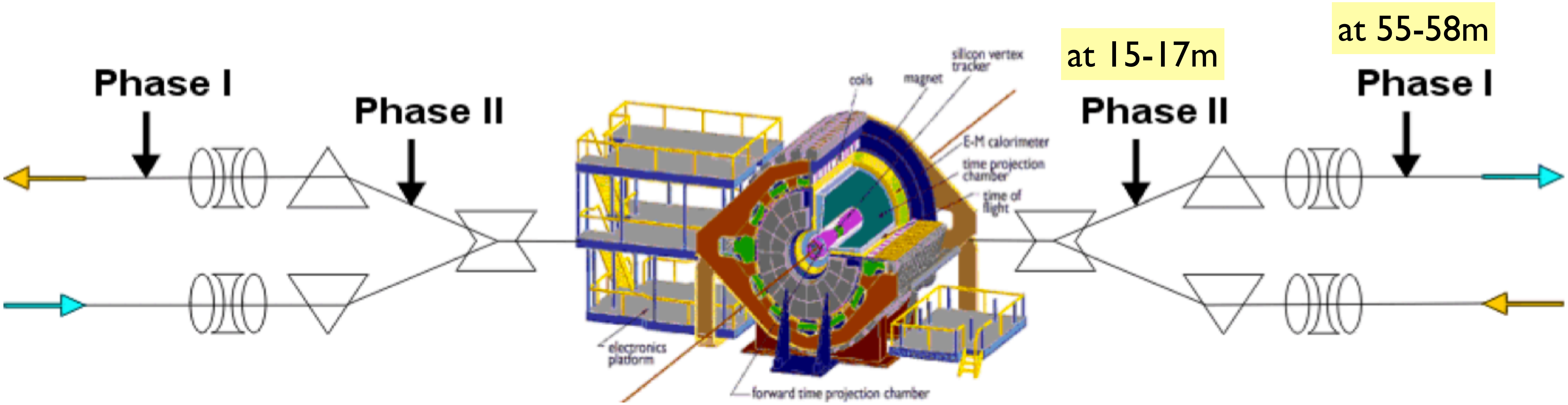
- Unambiguously identified e+p event vs e+n event:
  1 p +1 n vs 1 p + 1 p = 30% vs 22%

Q^2 vs x in e+^{3}He (DPMJET III)



- RP acceptance: No significant bias in Q^2-x

Forward Proton Tagging at STAR/RHIC

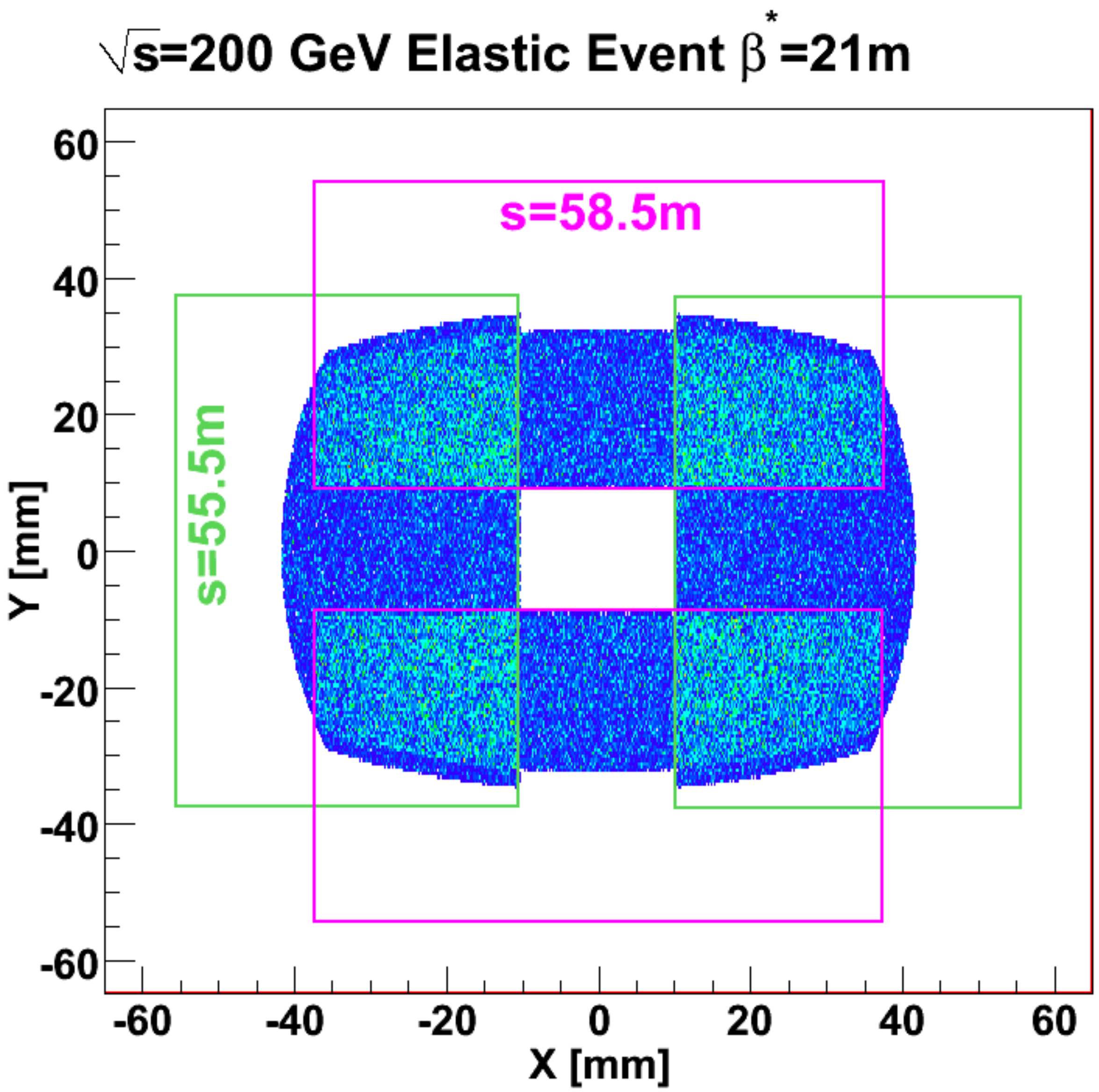


- Roman Pot detectors to measure forward scattered protons in diffractive processes
  - Staged implementation to cover wide kinematic coverage

  Phase I (Installed): for low-t coverage

  Phase II (planned) : for higher-t coverage

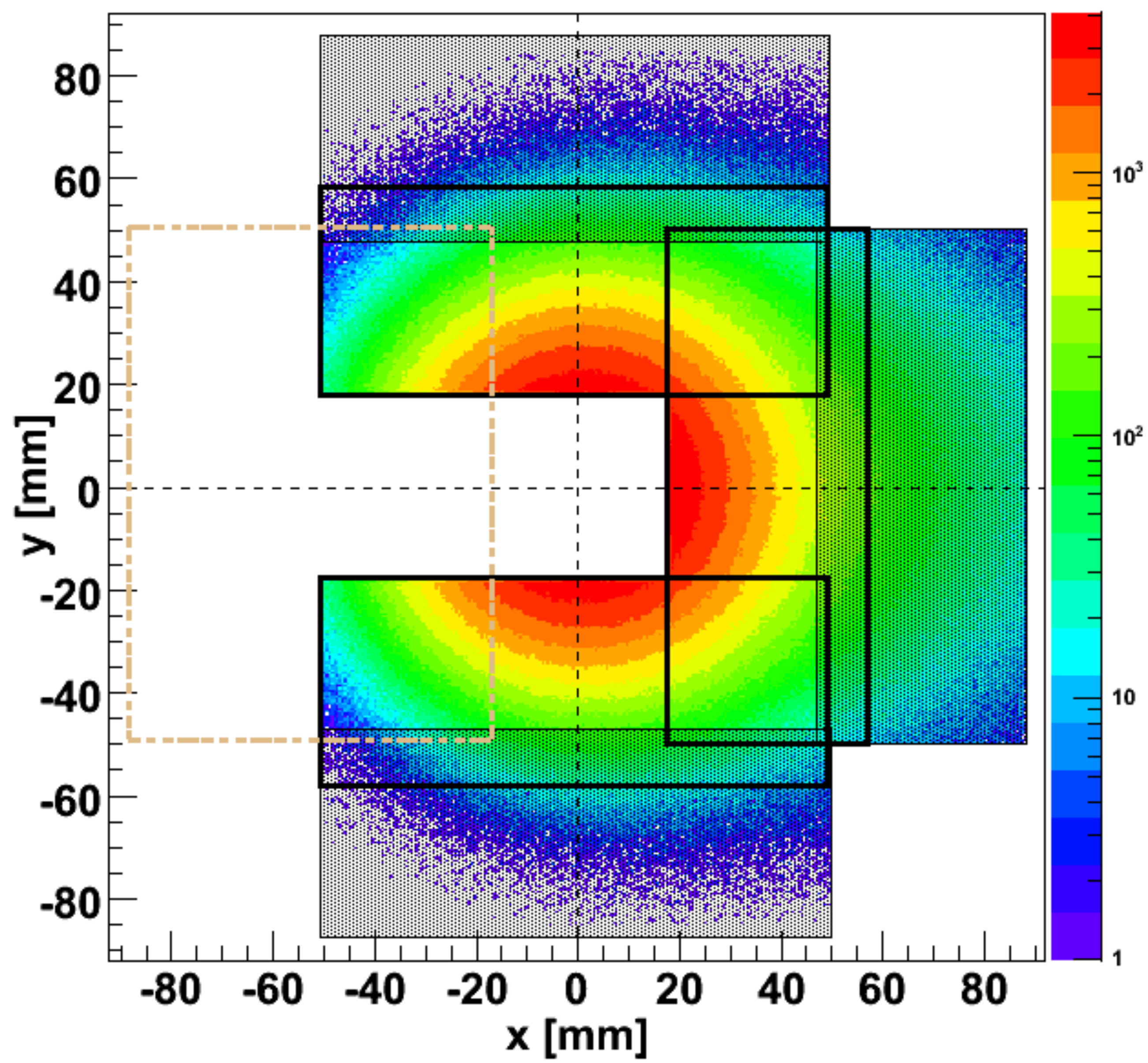
Roman Pots at STAR (Phase I)



Beam transport simulation using Hector

- Phase I: 8 Roman pots at ±55.5, ±58.5m from the IP
- Require special beam tune :large β^* (21m for $\sqrt{s}$=200 GeV) for minimal angular divergence
- Successful run in 2009: Analysis in progress focusing on small-t processes ($0.002<|t|<0.03$ GeV^2)

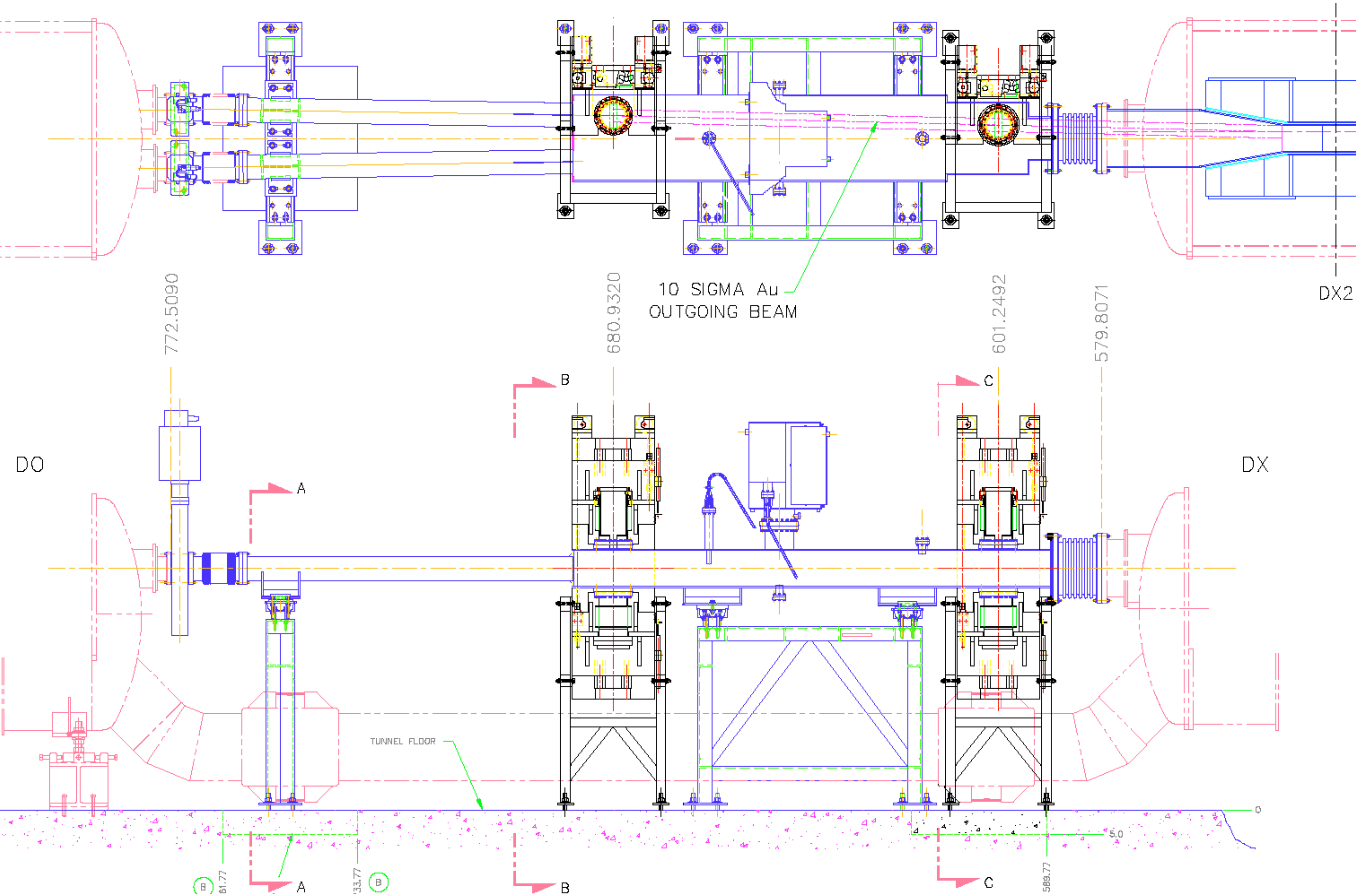
Roman Pots (Phase II)



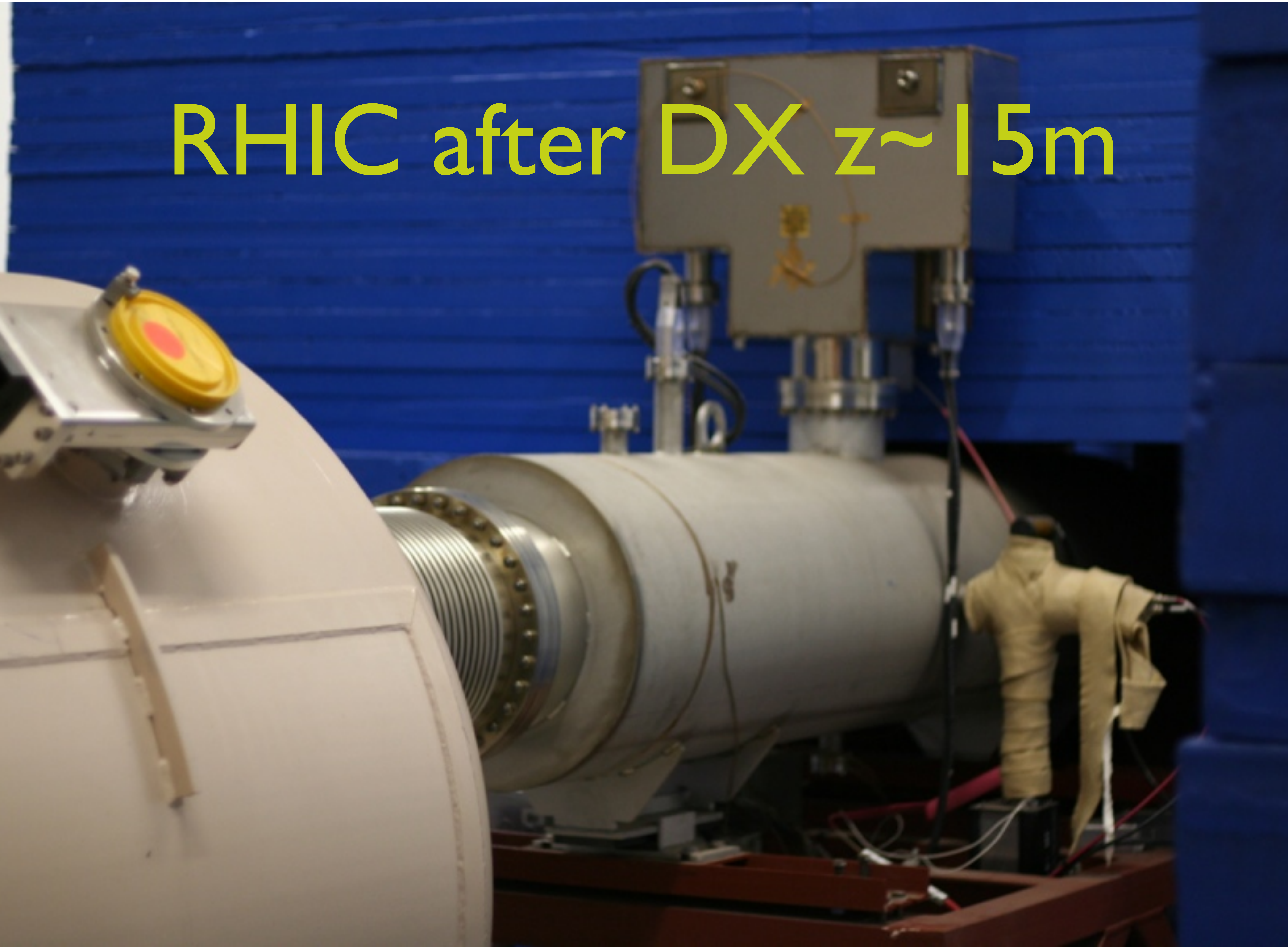
- Phase II: 8(12) Roman Pots at ±15 and ±17m
- Planed to be implemented in 2011-2012
- Doesn't require special beam optics: main set-up for central DPE processes requiring wide-t coverage and high-luminosity
- 2π coverage in ϕ will be limited due to machine constraint (incoming beam)

Current "Design" for RP Phase II

shorter by 1.25" for CF flange interface to DX-DO chamber. Alternatively can extend strongback and kinematics to accommodate CF flange inter
o in DX-DO chamber to keep Roman Pot design the same at both stations. Alternatively can redesign RP brackets at RP (601).
ype frame will be required in place of existing Roman Pot support pedestal to avoid interference with VJR below.
rf-screening shown. Adding a screen can be simple to complex depending on requirements. The most simple rf-screen will be a perforated sh
essed to an oval upon box closure. The simplest rf-shield design will only rounds the longitudinal sharp inside corners.

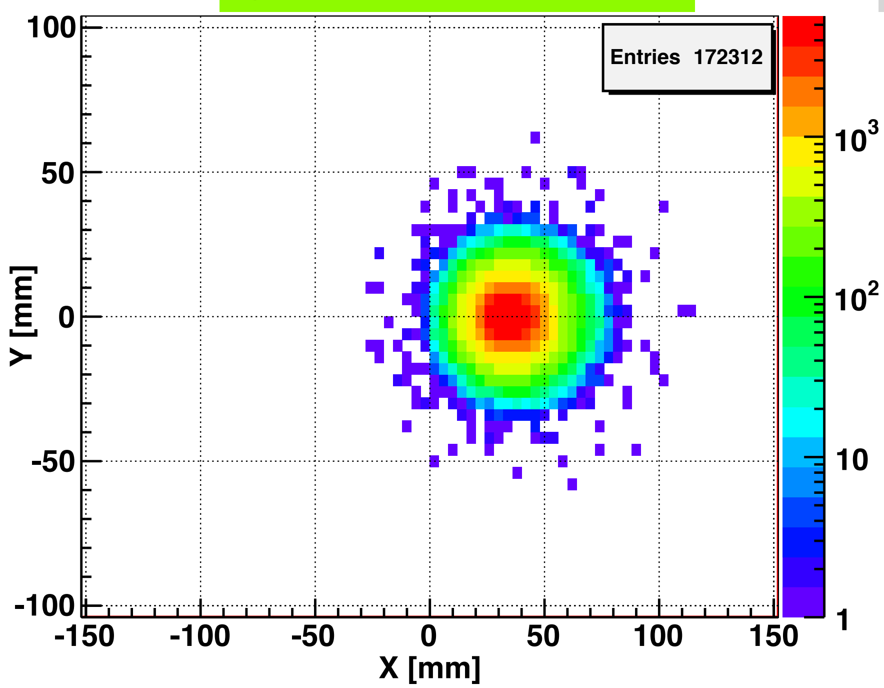


RHIC after DX z~15m

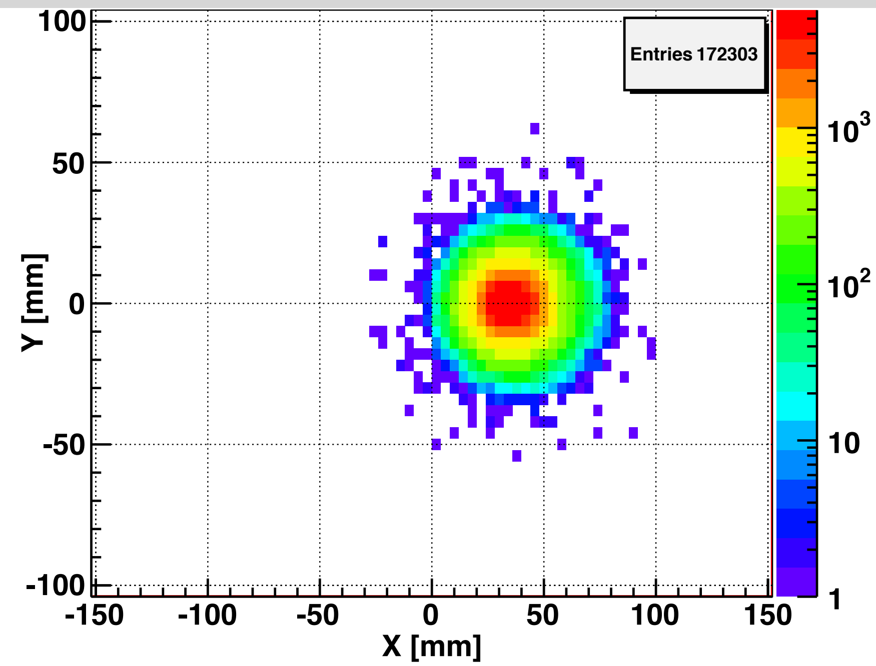


Spectator proton from ^{3}He with the current RHIC optics

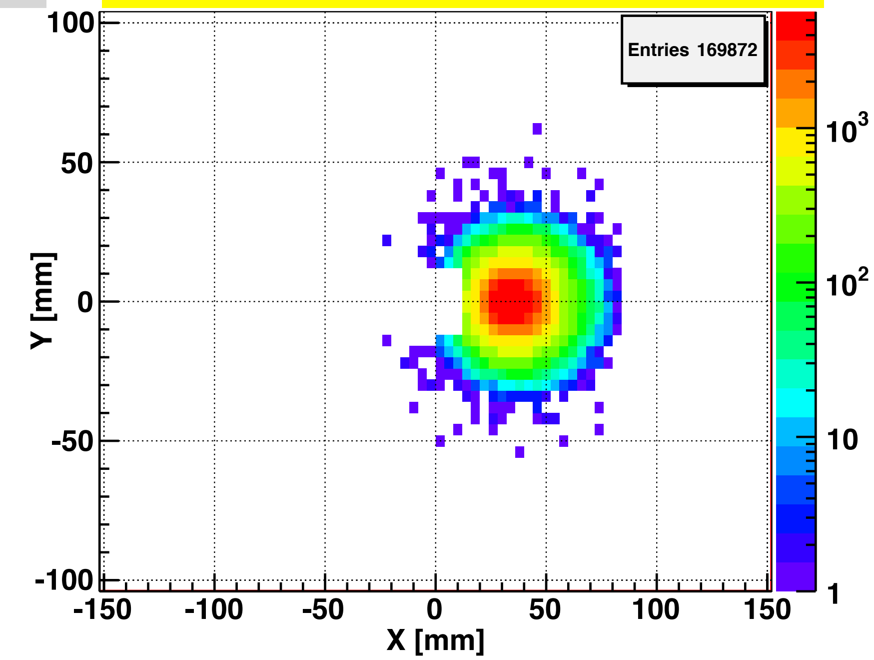
generated



Passed DX aperture

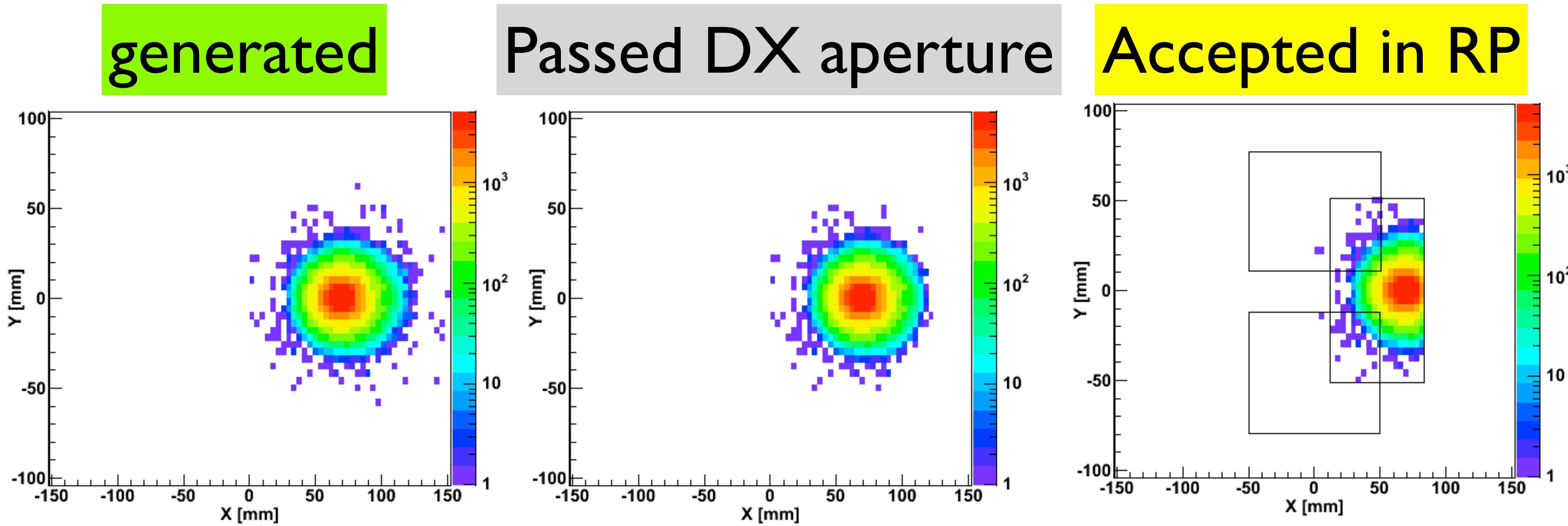


Accepted in RP



- The same RP configuration with the current RHIC optics (at z ~ 15m between DX and D0)
- Acceptance ~ 98%

"Spectator" proton from deuteron with the current RHIC optics



- Rigidity (d:p =2:1)
- The same RP configuration with the current RHIC optics (at z ~ 15m between DX and D0)
- Detector size and position can be optimized for optimal acceptance

Summary

- Spectator tagging necessary for identifying target nucleon in e/p+^{3}He
- Deflected spectator protons due to different rigidity can be detected using Roman Pots
- A common detector system ("forward proton spectrometer") can be utilized for measuring diffractive protons and spectator protons in ^{3}He
- Currently assumed detector design can be optimized for better acceptance and efficiency
- High luminosity and background effects in p+^{3}He need to be studied

“protons, protons, ^{3}He...”

"Particles, particles, particles."