Exclusive vector meson J/ψ study using ePIC simulation

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Motivation

- One of golden channels for EIC 2nd detector
  - Study coherent/Incoherent **Vector Meson production** (ex. J/ψ) to investigate nuclear diffractive pattern inside ion
  - Compare two di-lepton channels of $J/\psi \rightarrow e^+e^-$ **and** $\mu^+\mu^-$

- **Complementary** to ePIC and **cross-checking**

- More interested in muon channel
  - **Cleaner signal** in quarkonium reconstruction compared to di-electron
  - **Reduce ambiguity** to scattered electrons

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Simulation

- **Event Generator**
  - Sartre 18×110 GeV **coherent** $eAu \rightarrow J/\psi(ee)$
  - BeAGLE 18×108.4 GeV **incoherent** $ePb \rightarrow J/\psi(\mu\mu)$
- **ePIC full simulation framework**
  - World volume filled with “**Air**”
  - Magnetic field ~ 1.7T
  - Tracking based on truth seeding
  - Focus on central detector

Input data files used
S3/eictest/EPIC/EVGEN/EXCLUSIVE/DIFFRACTIVE_JPSI_ABCONV/Sartre/Coherent/sartre_bnonsat_Au_jpsi_ab_eAu_1.hepmc3.tree.root
S3/eictest/EPIC/EVGEN/EXCLUSIVE/DIFFRACTIVE_JPSI_ABCONV/BeAGLE/ePb_18x108.41_tau10_B1.1_Jpsi_highstats/ePb_18x108.41_tune3_tau10_B1.1_extracted_Jmu_1.hepmc

Data Selections and Reconstruction

- Muon Detection from di-muon channel
  - **Track-based momentum** and PID
- Electron Selection from di-electron channel
  - Use PID to pair opposite di-electron
  - If the reconstructed mass is within 2 standard deviations, the e+ and e- are labeled as "$\boldsymbol{J/\psi}$ decayed" di-electron
  - If $\boldsymbol{\eta} < -\mathbf{1.5}$, **use ECAL energy** instead of momentum from tracking
- Reconstruction
  - $\boldsymbol{Q^2} = -(e_{beam} - e_{scattered}).M2()$
  - **t** from **method L** (estimate scattered ion beam to incorporate beam effect)
  - Events with $\mathbf{Q^2} \geq \mathbf{1}$ GeV^2 and $\boldsymbol{J/\psi}$ $|\boldsymbol{\eta}| \leq \mathbf{1.5}$

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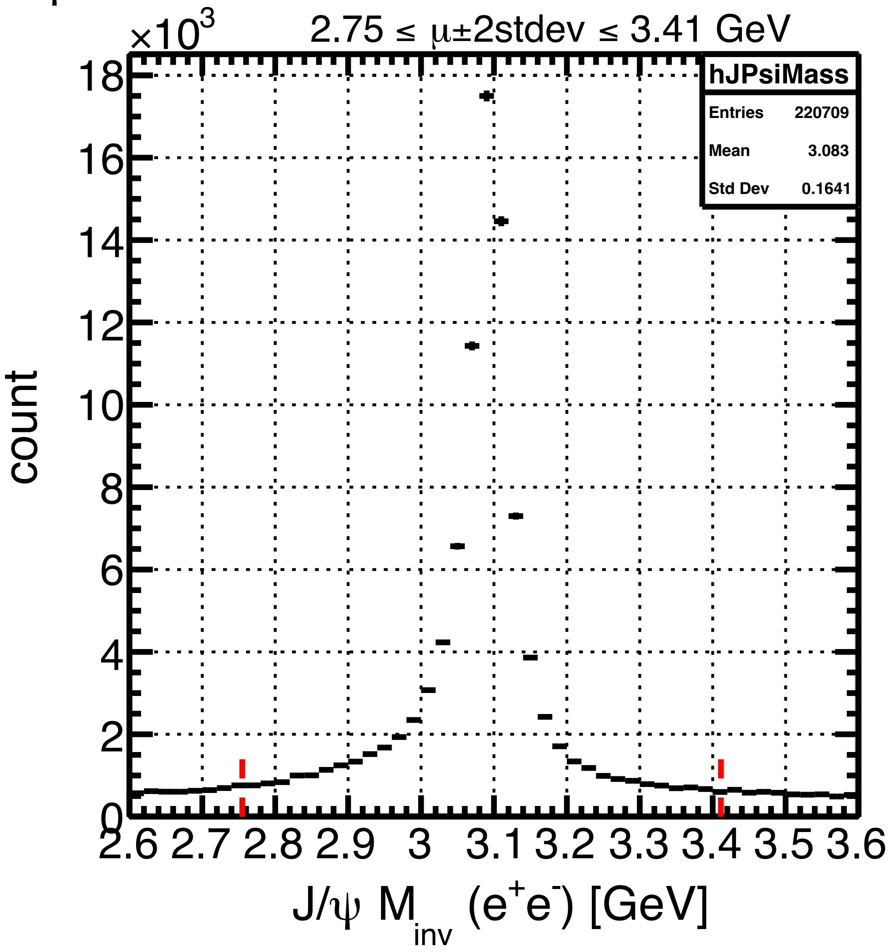
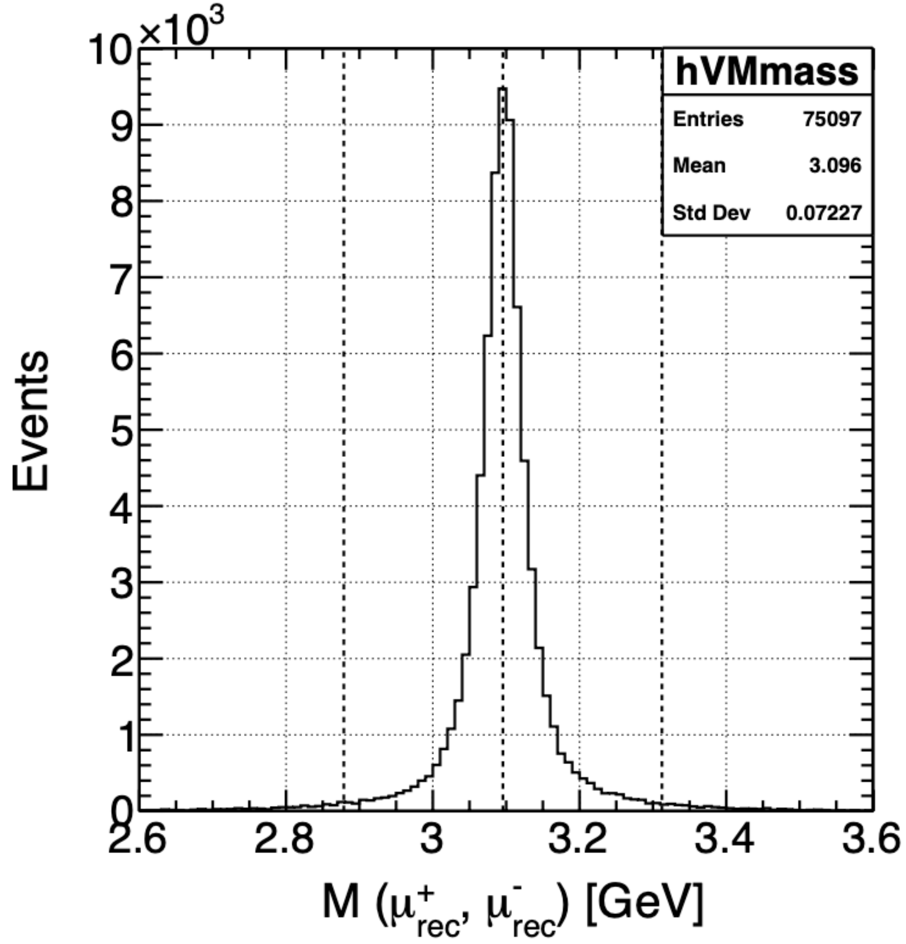
Mass Reconstruction

$J/\psi(ee)$

J/ψ Mass:

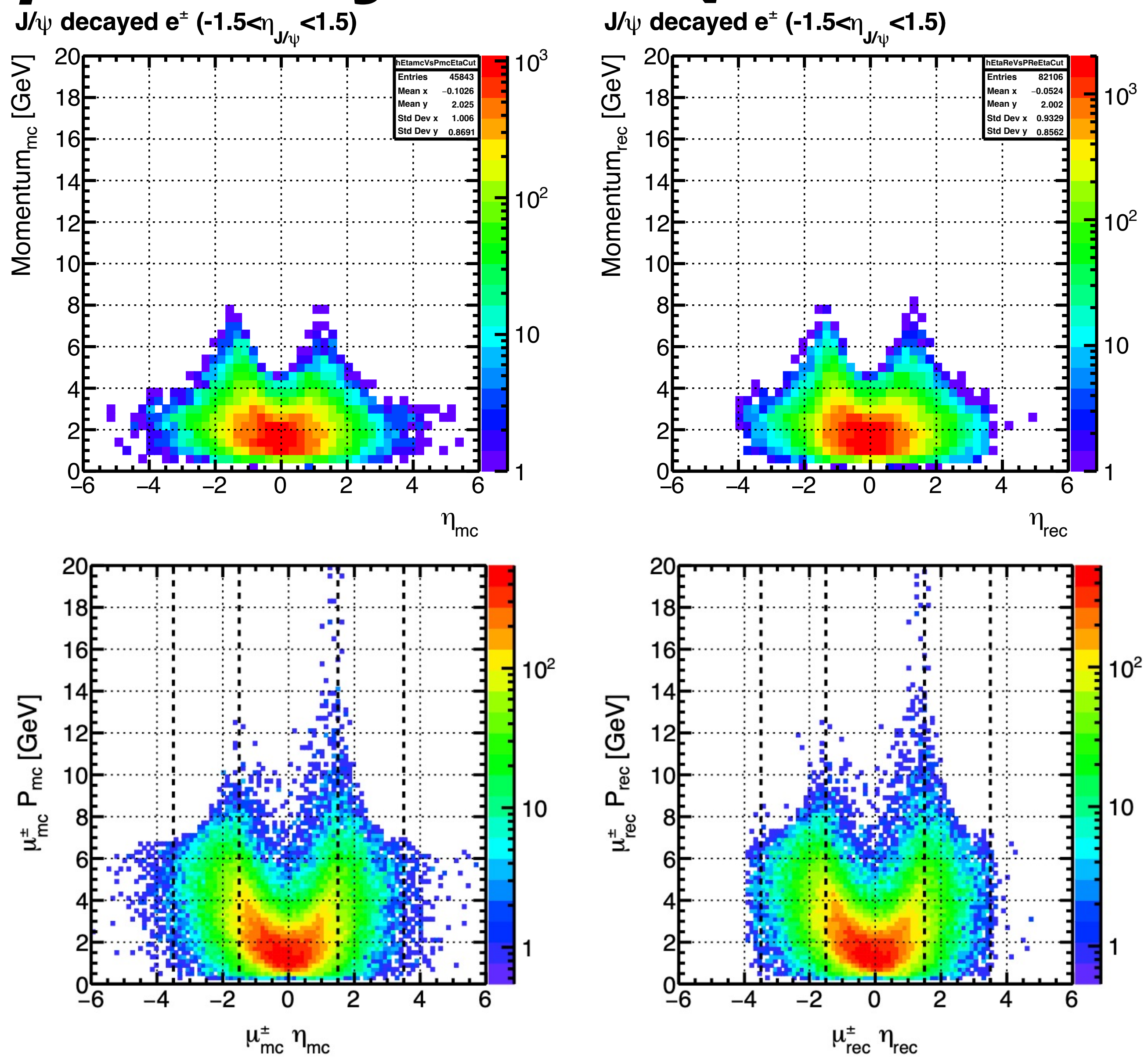


$J/\psi(\mu\mu)$



In di-electron channel, it has asymmetric radiative tail. On the other hand, di-muon channel shows more clean mass distribution with a half of di-electron rms.

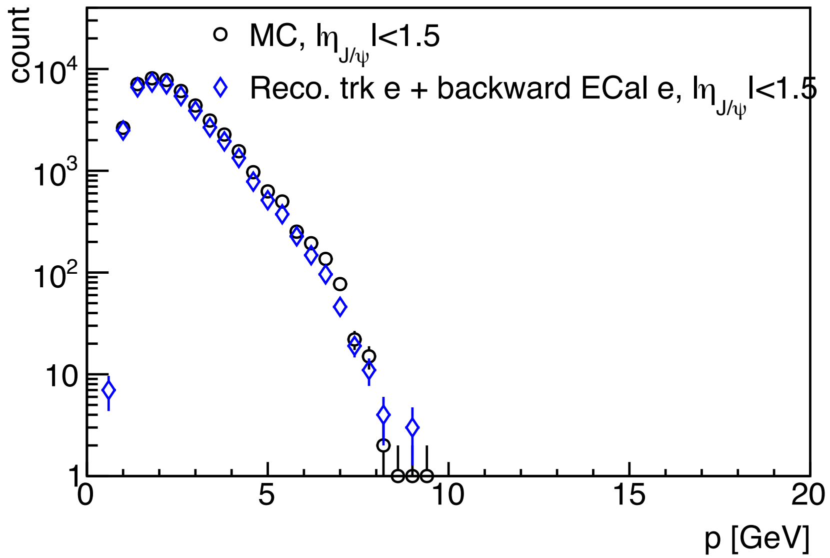
J/ψ Decayed $e^{\pm}/\mu^{\pm}$ Kinematics

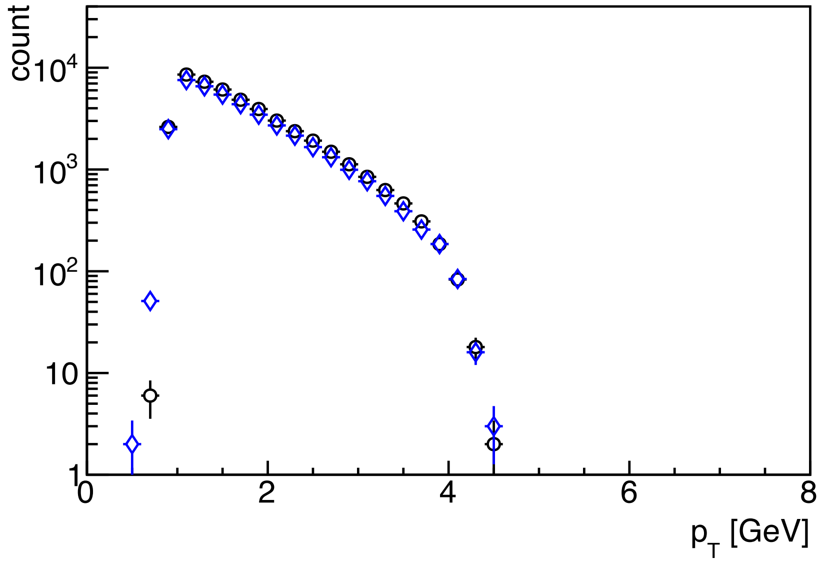


- **Kinematic of di-lepton is similar**
  - Cut on $|\eta_{J/\psi}| \leq 1.5$
- Di-electron
  - Track-based momentum ($|\eta_e| < 1.5$)
  - ECAL energy ($|\eta_e| > -1.5$)
- Di-muon
  - Track-based momentum ($|\eta_\mu| < 3.5$)

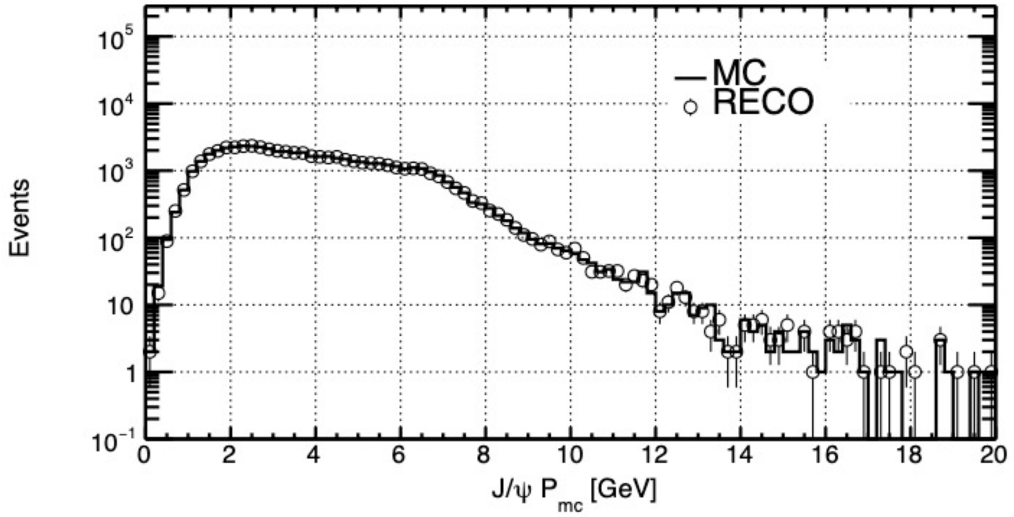
J/ψ Reconstruction

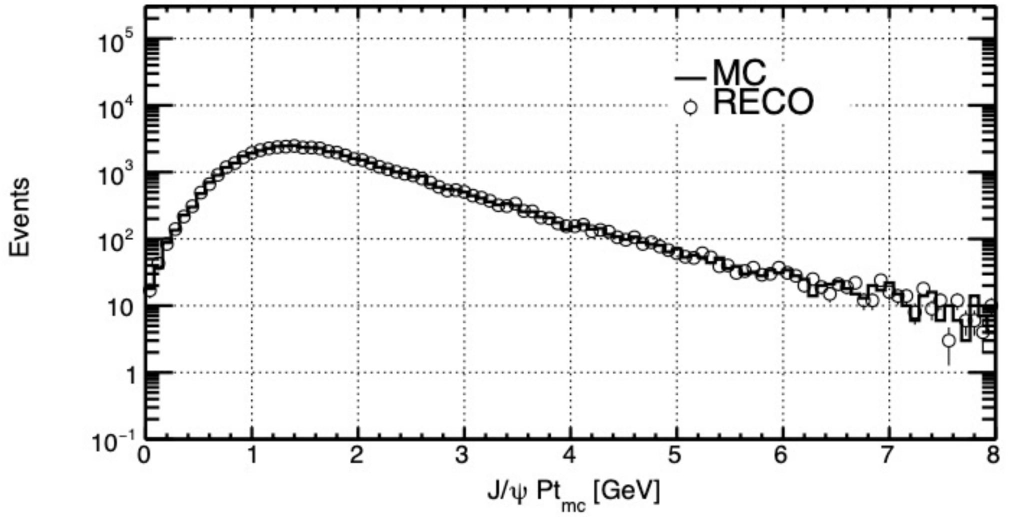
$J/\psi(ee)$





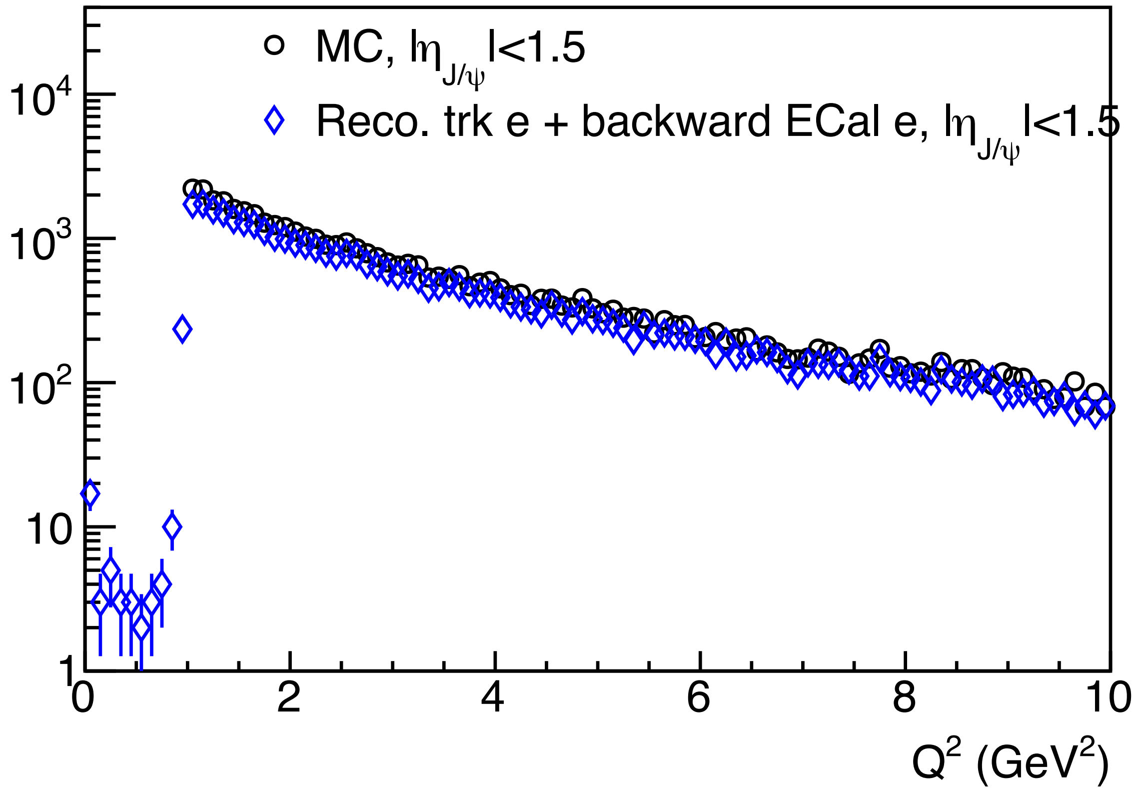
$J/\psi(\mu\mu)$



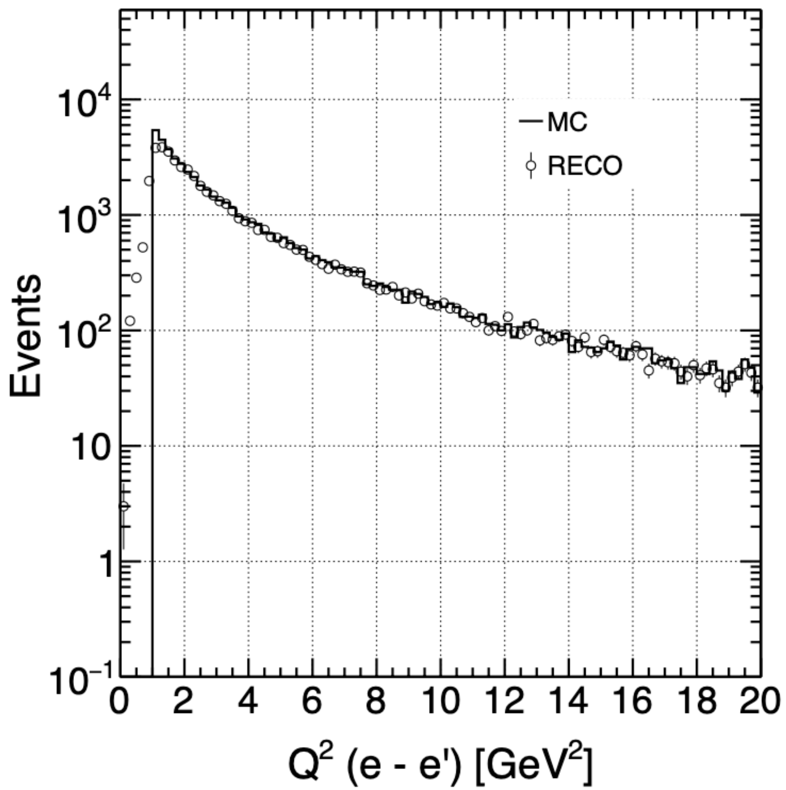


Q^2 Distribution

$J/\psi(ee)$



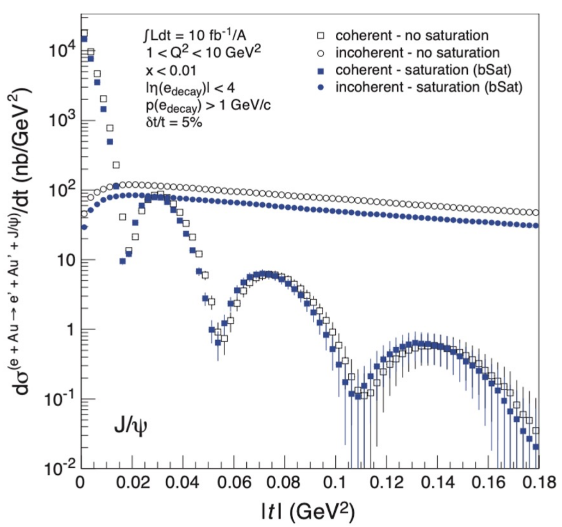
$J/\psi(\mu\mu)$



Cut on events (Q^2 < 1) treated as mis-reconstruction to calculate t

t Distribution

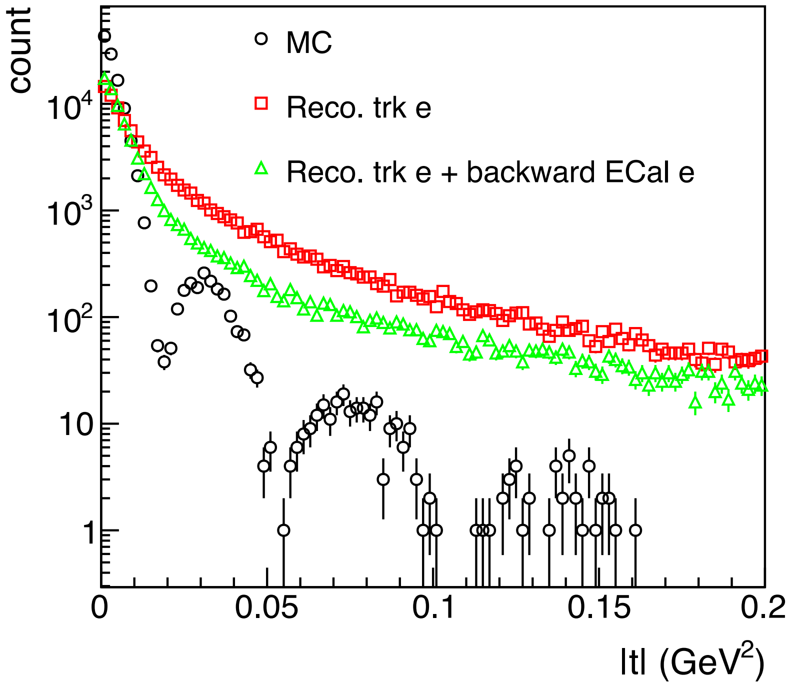
Diffractive e+Au collisions (Sartre)
from EIC White paper



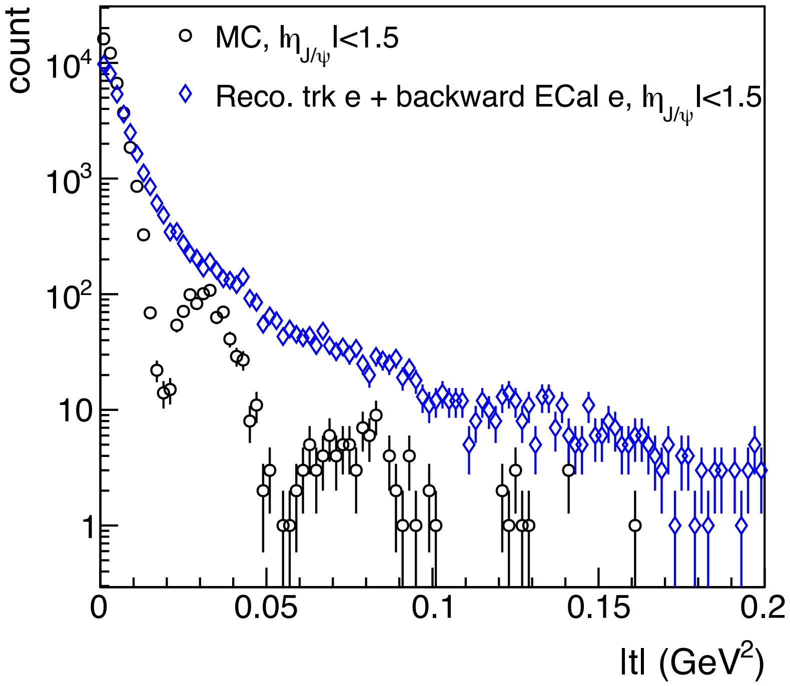
Coherent $J/\psi(ee)$

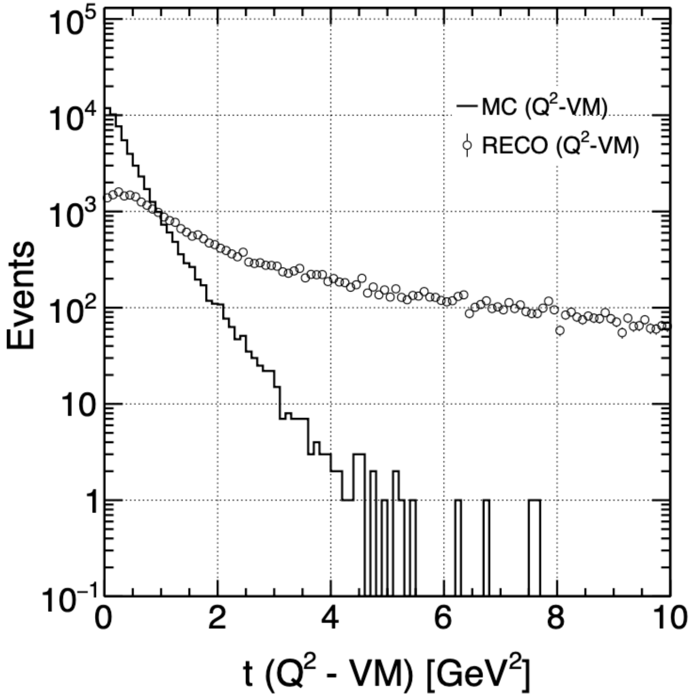
Incoherent $J/\psi(\mu\mu)$

$1 < Q^2 < 10$ GeV^2



$1 < Q^2 < 10$ GeV^2



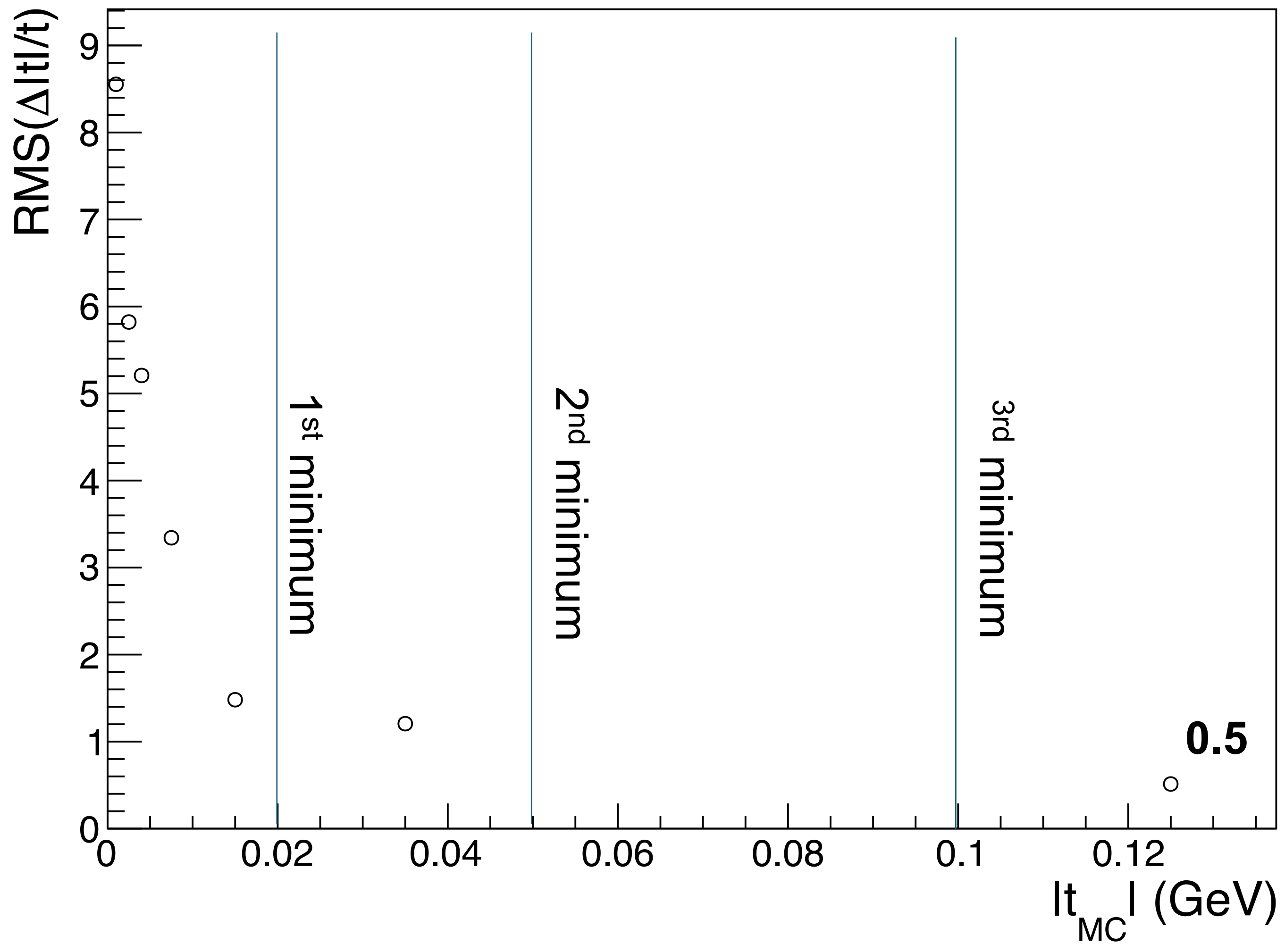


Reduced background at high |t| with the $|\eta_{J/\psi}| < 1.5$ selection

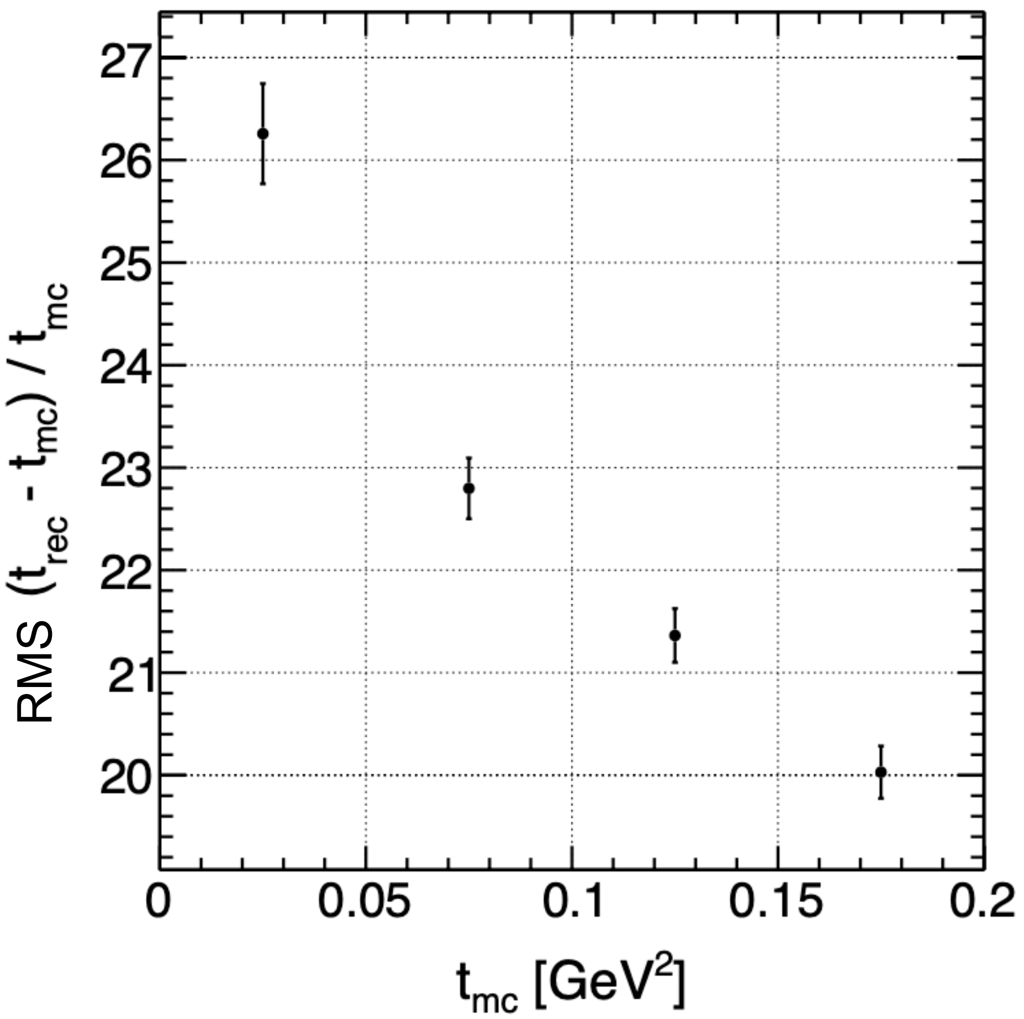
t was calculated using Method L for coherent di-electron channel, not for incoherent di-muon channel

t Resolution

$J/\psi(ee)$ Method L used



$J/\psi(\mu\mu)$



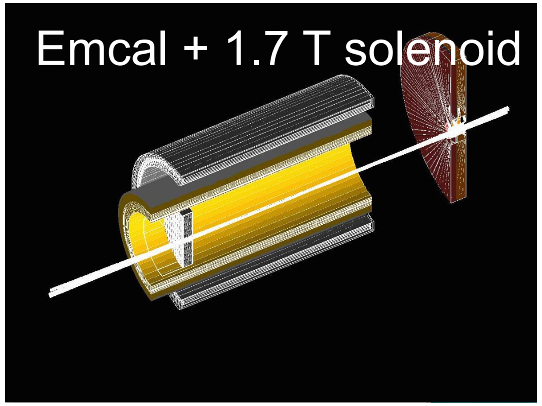
Summary

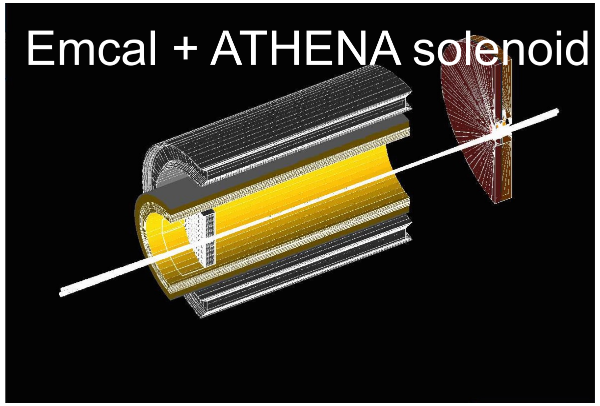
- **Use coherent J/ψ as a golden channel to study the needs of the 2nd EIC detector**
- One of the goal is to compare coherent $J/\psi \rightarrow e^{+}e^{-}$ and $J/\psi \rightarrow \mu^{+}\mu^{-}$ study
- By focusing on J/Psi within barrel region with coherent di-electron channel, it helps reducing background in higher t, but it is hardly describing diffractive pattern.

- Currently analyzing coherent $J/\psi \rightarrow \mu^{+}\mu^{-}$ events to **evaluate advantage of using di-muon channels**

Next Steps Toward EIC 2nd Detector

Scatter Electrons + Muons

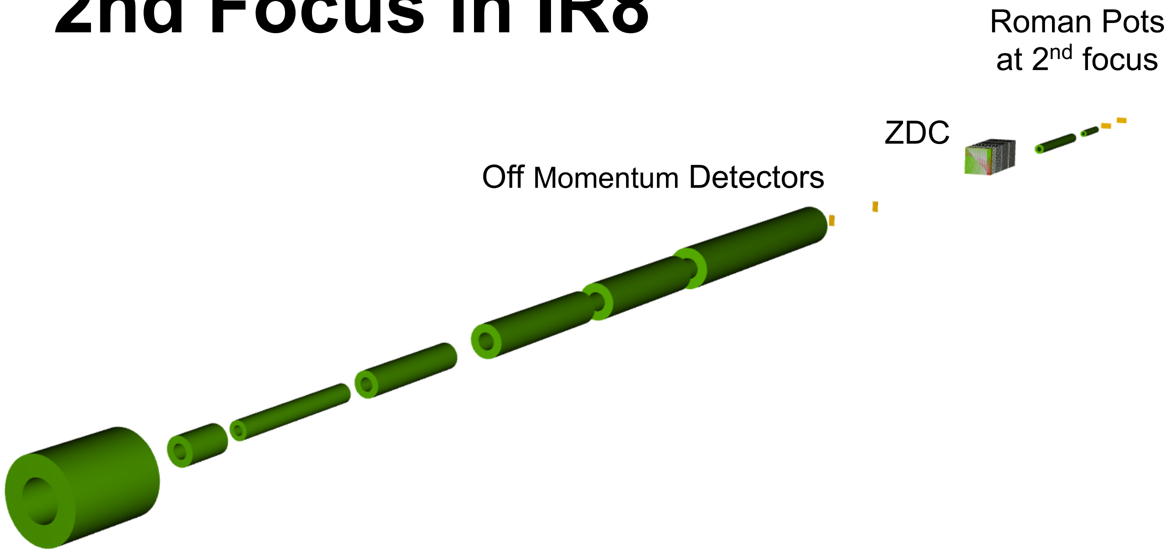




Modify detector setup in simulations
Replace ePIC **solenoid** with ATHENA solenoid
Replace Hcals with **KLM**

Focus on better detecting scattered electrons' energy/momentum and muon ID
- **Tracker improvement + barrel KLM type detector**

2nd Focus in IR8

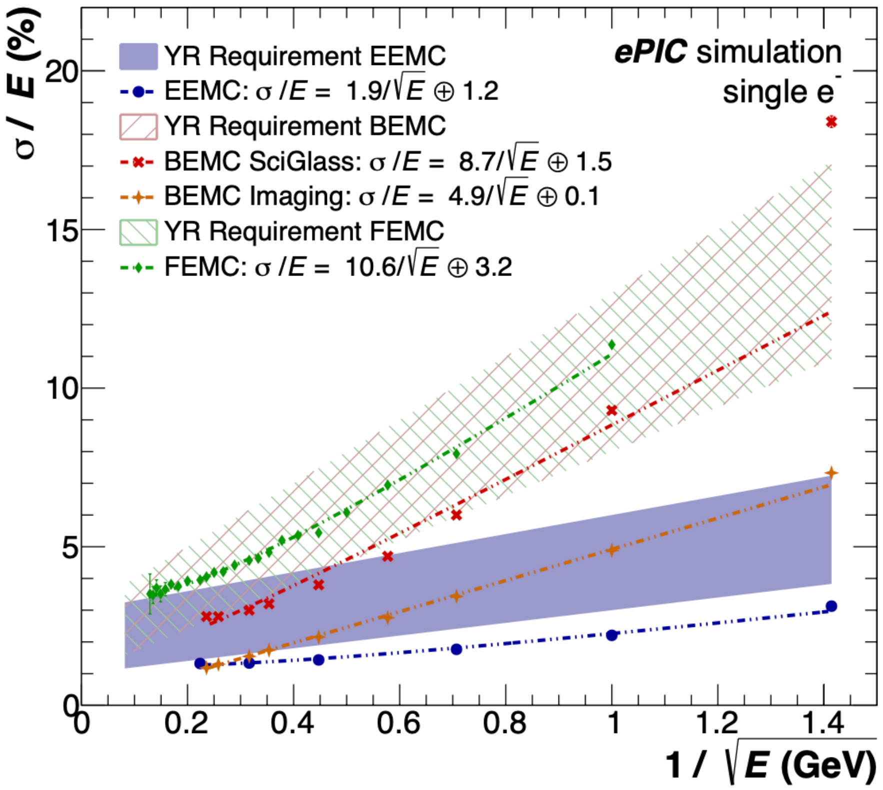


Implemented **IP8 IR** and **Far-forward detector** setup in DD4hep simulations
- Need to work on optimization of detector layout

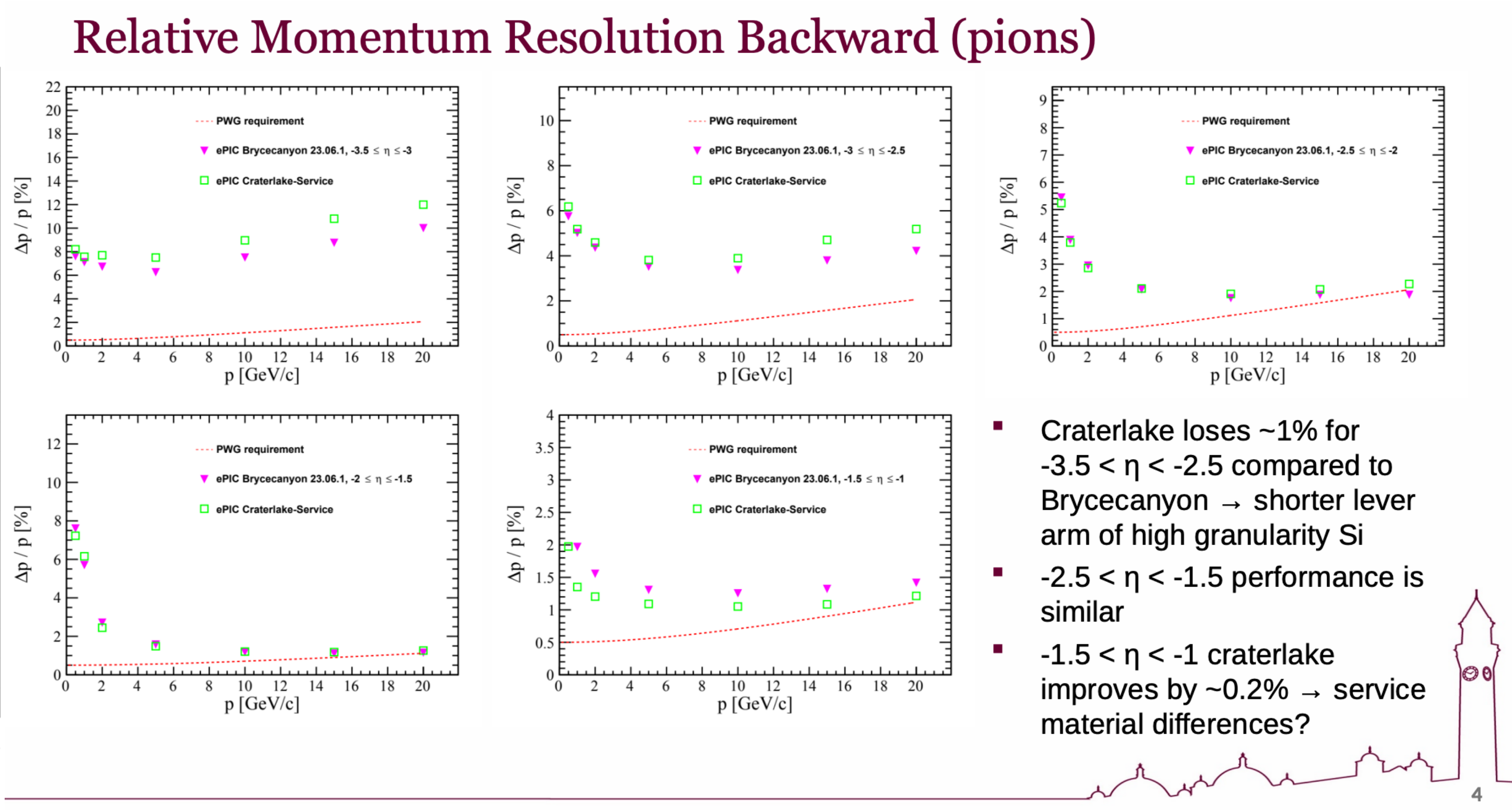
Focus on **incoherent veto to understand background** and acceptance/detection efficiency

Backup Slides

Tracking/Energy Resolution in Backward

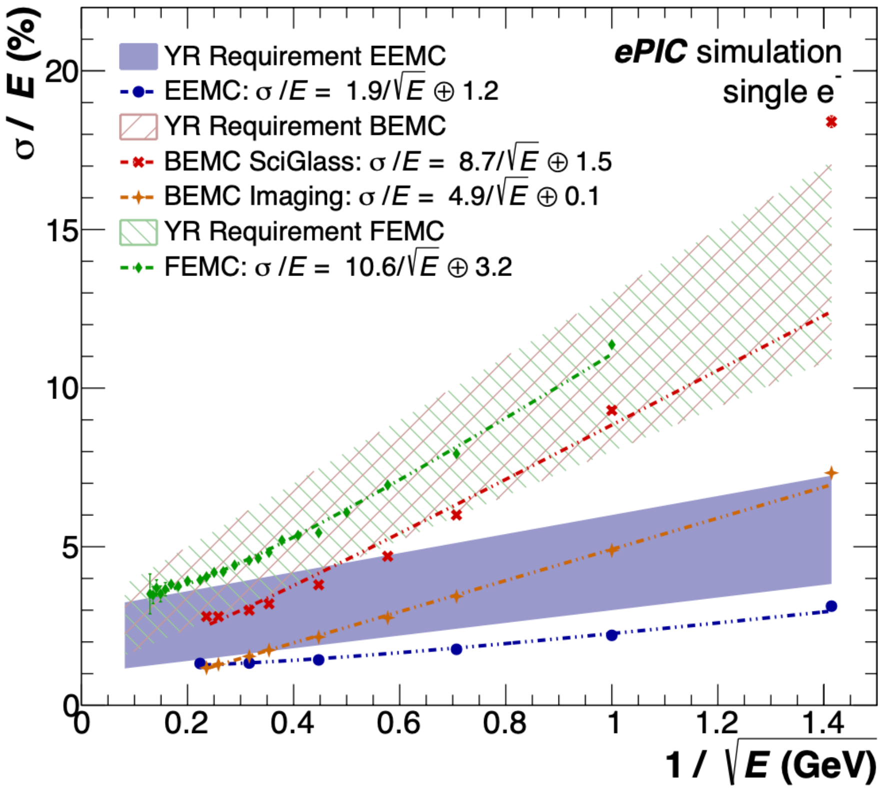


From Friederike Bock



From Stephan Maple

Tracking/Energy in Central



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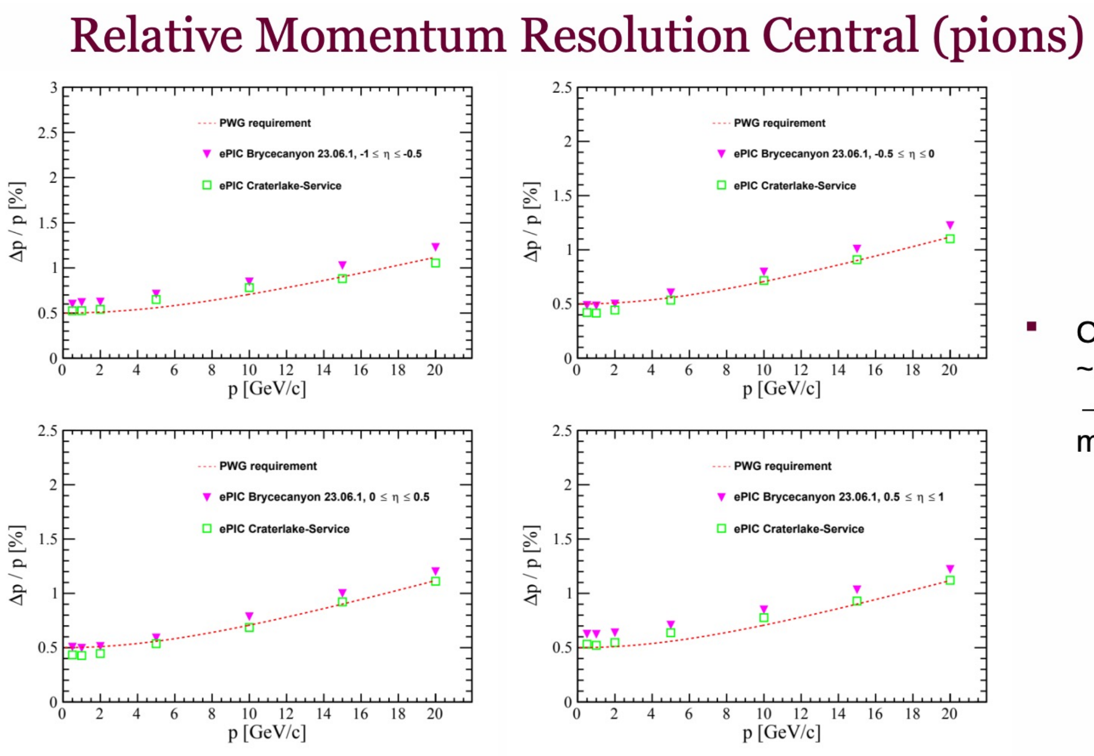

From Stephan Maple

- Craterlake improves dp/p by ~0.1% in central region → removal of L2 support material

t Resolution