Capabilities of the ECCE detector proposal for small-x physics

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IJCLab, Université Paris-Saclay

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EIC Center at Jefferson Lab

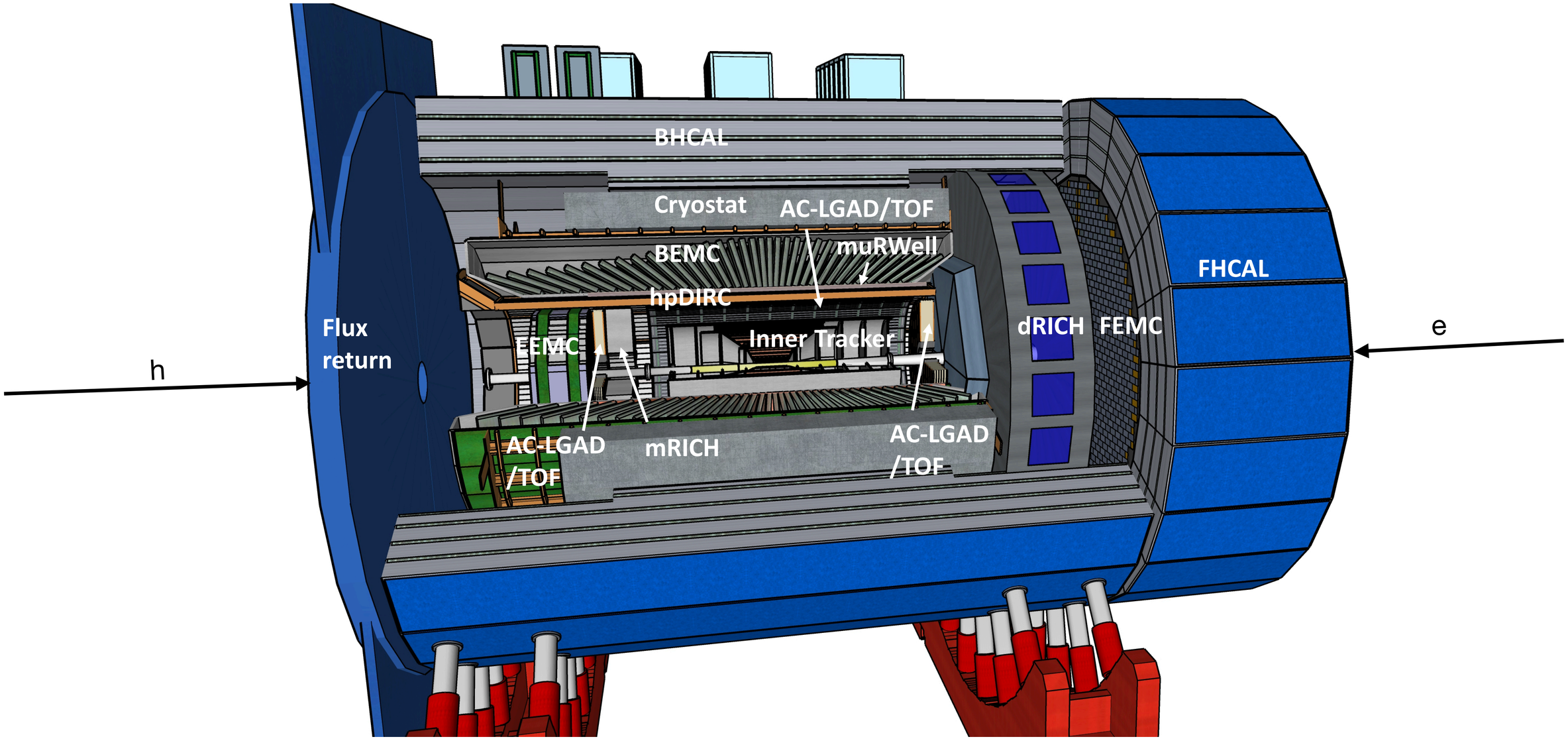
Small-x physics in the EIC era
December 15-17, 2021
RIKEN BNL Research centre, online

Outline

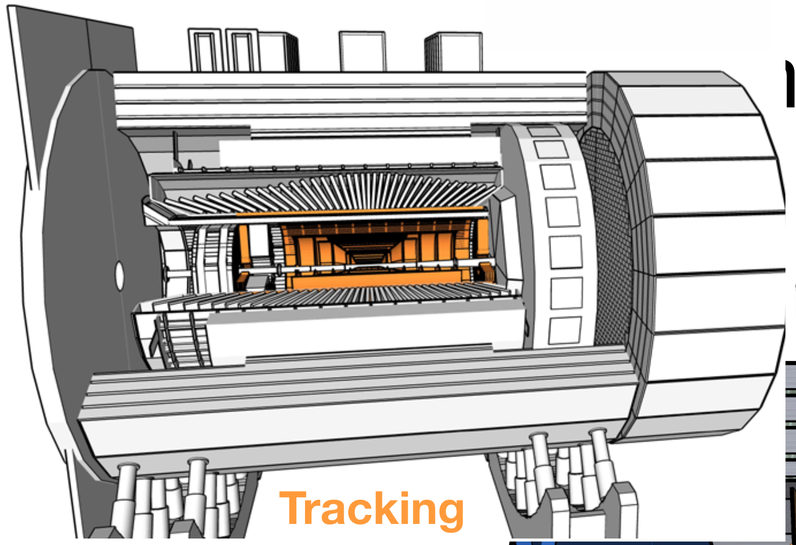
- Scattering off nucleon:
  - Spin structure: inclusive and semi-inclusive DIS
  - 3D tomography: momentum and position space

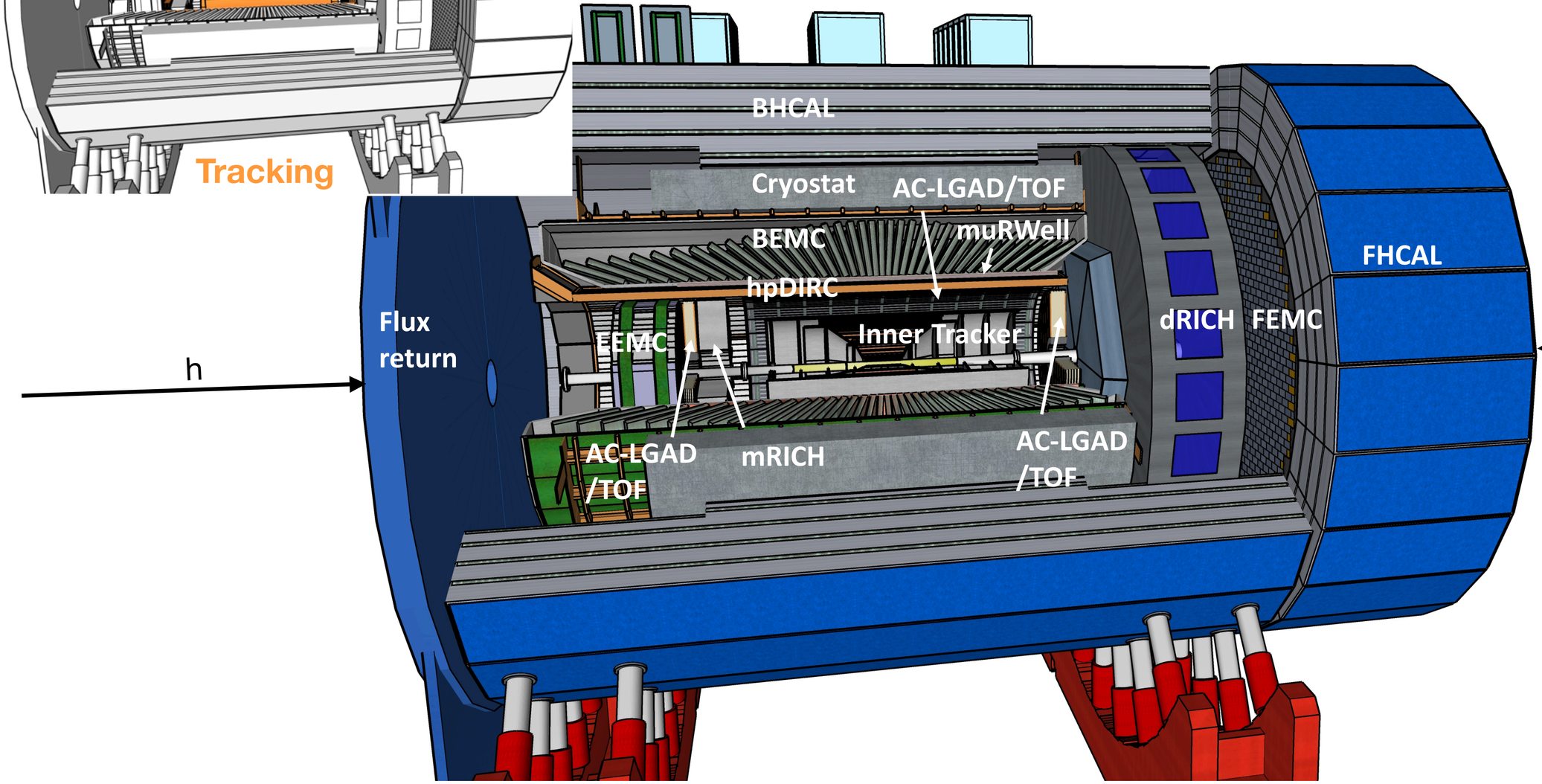
- Scattering off nuclei:
  - Dihadron correlations
  - Exclusive/diffractive

ECCE – EIC Comprehensive Chromodynamics Experiment

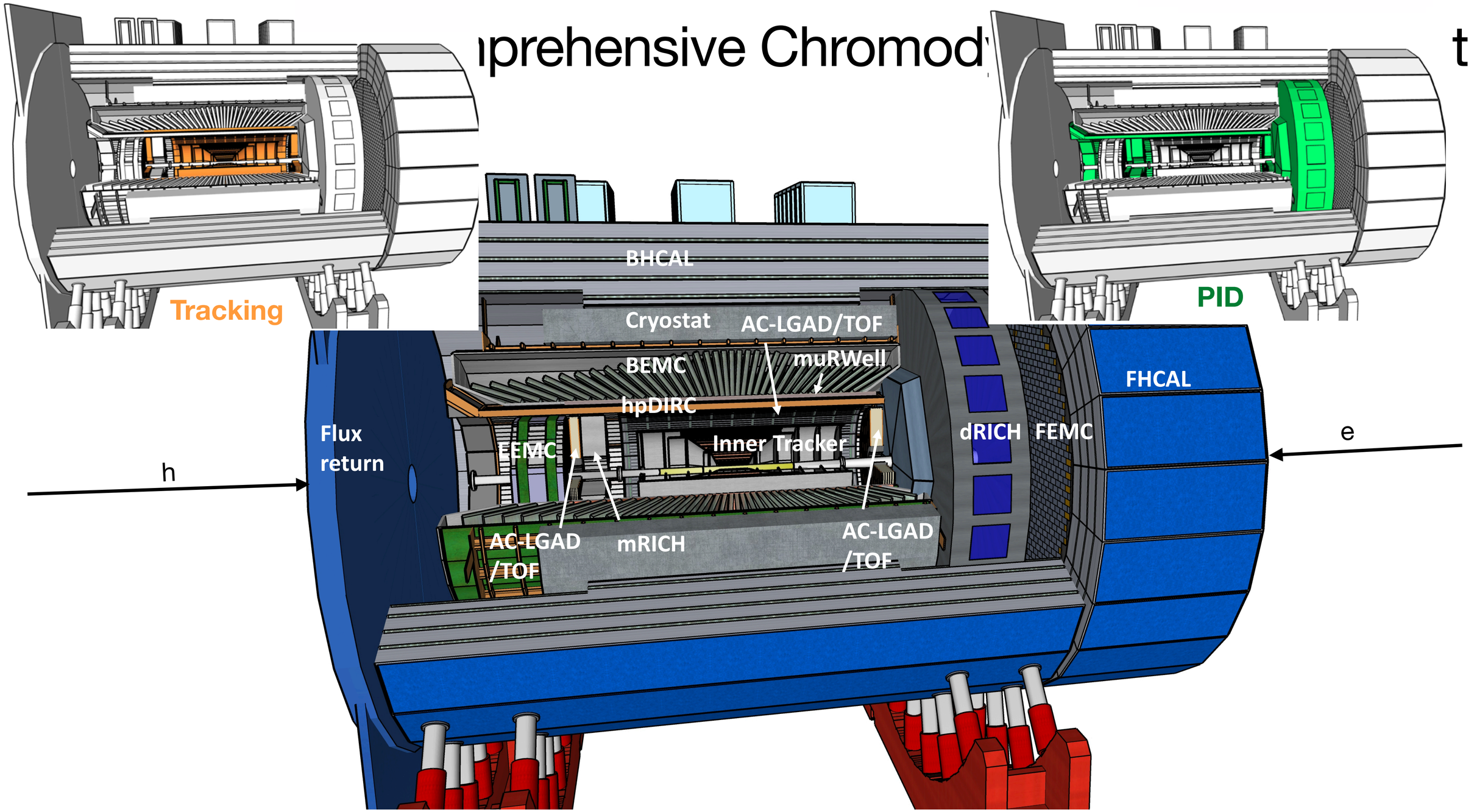


ıprehensive Chromodynamics Experiment





ıprehensive Chromod t



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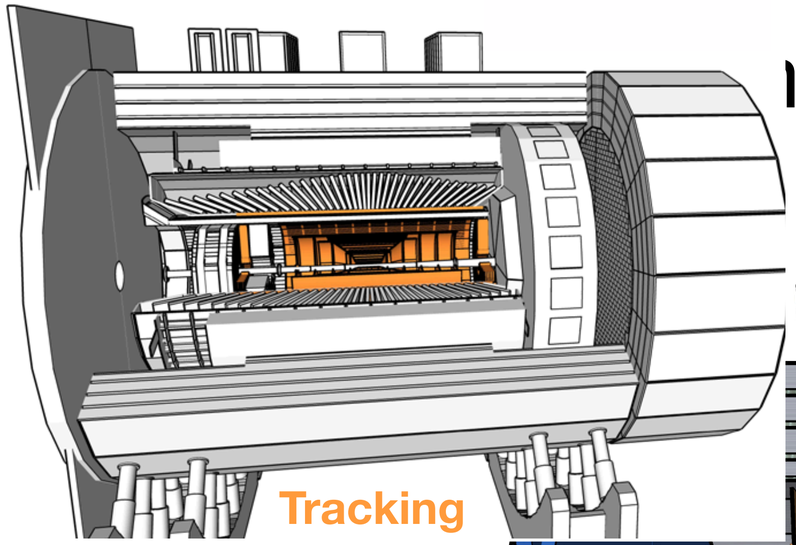

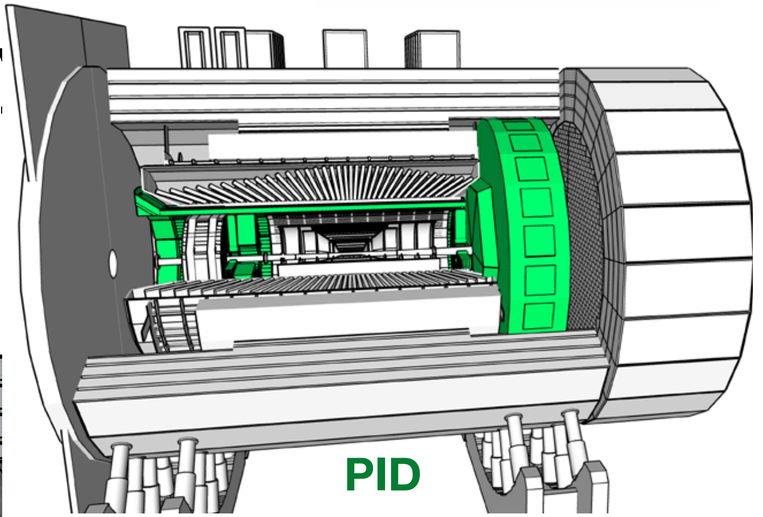

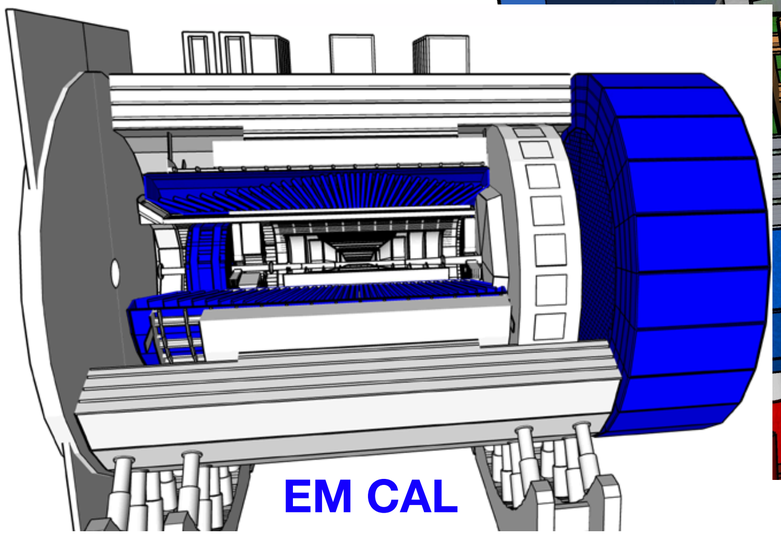

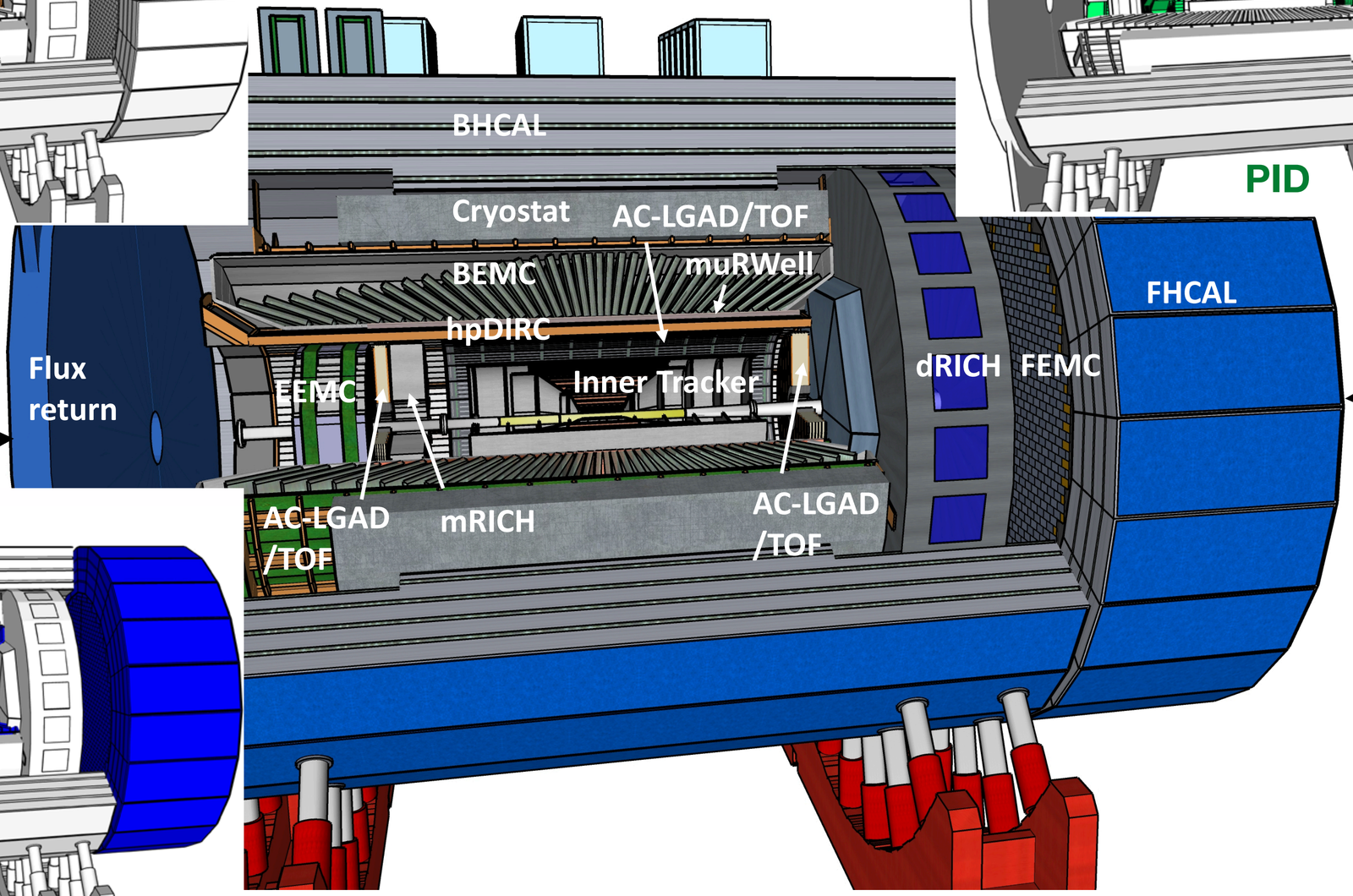

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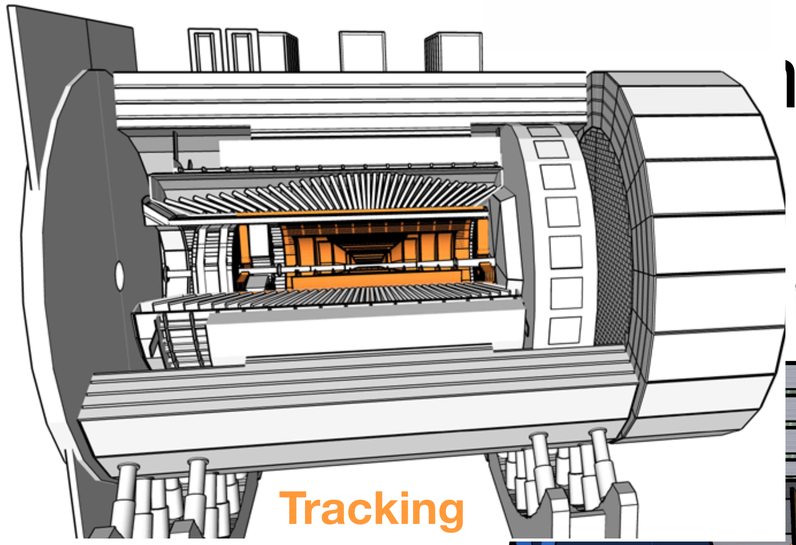

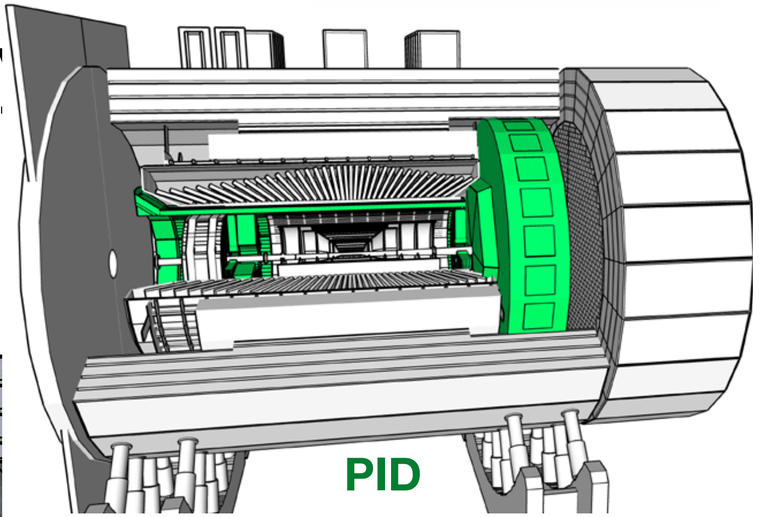

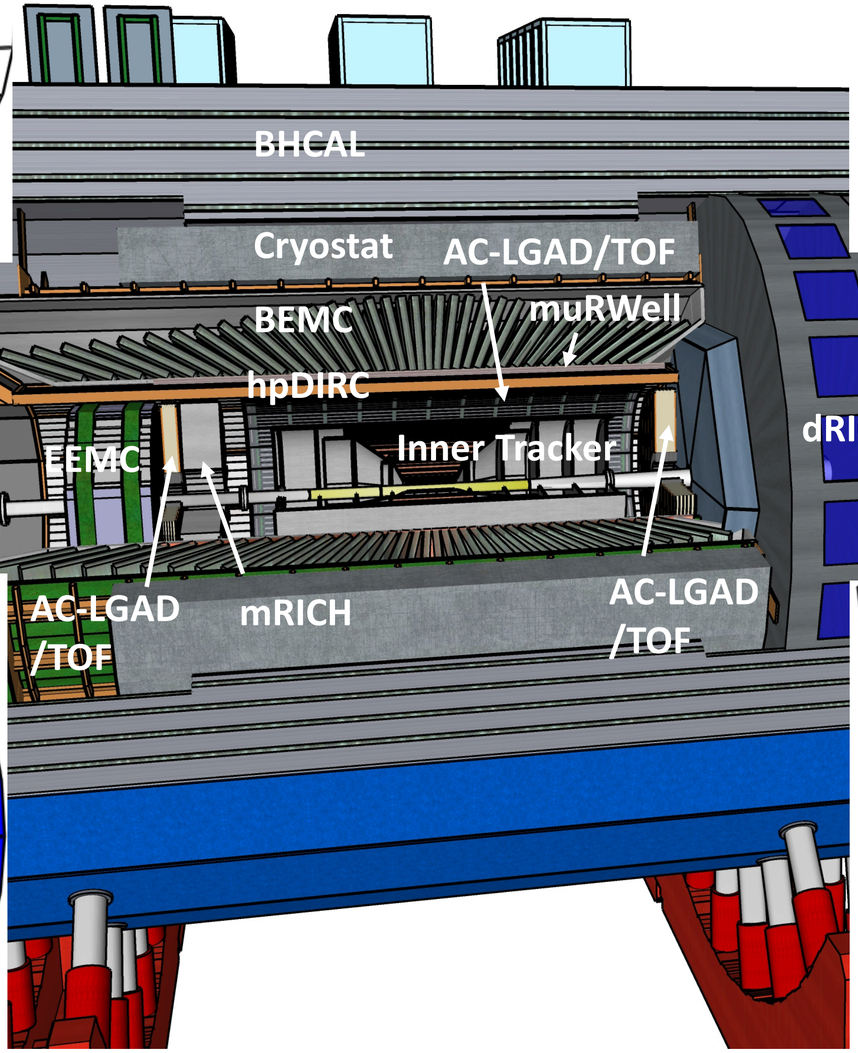

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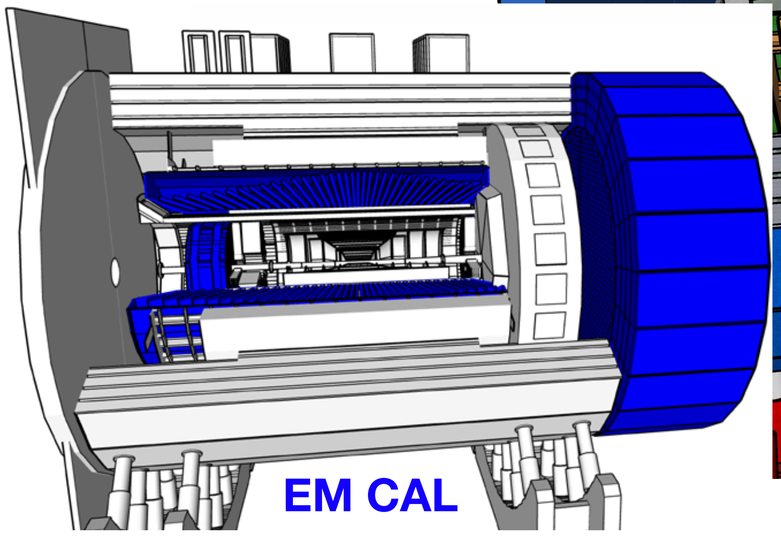

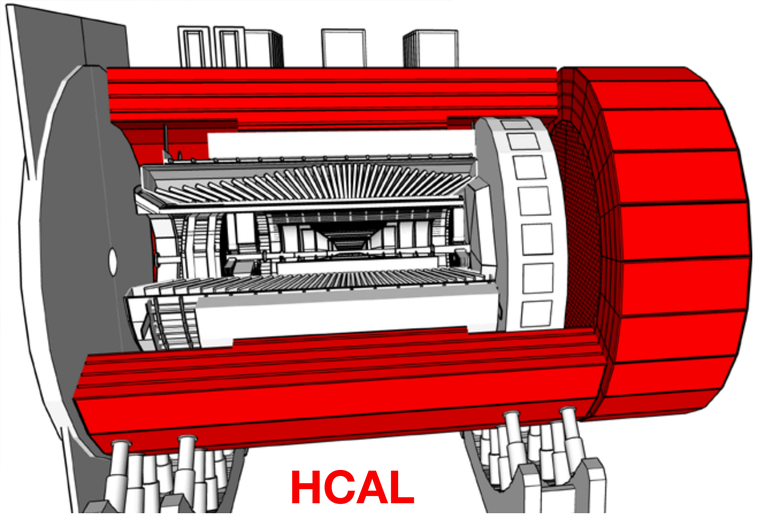

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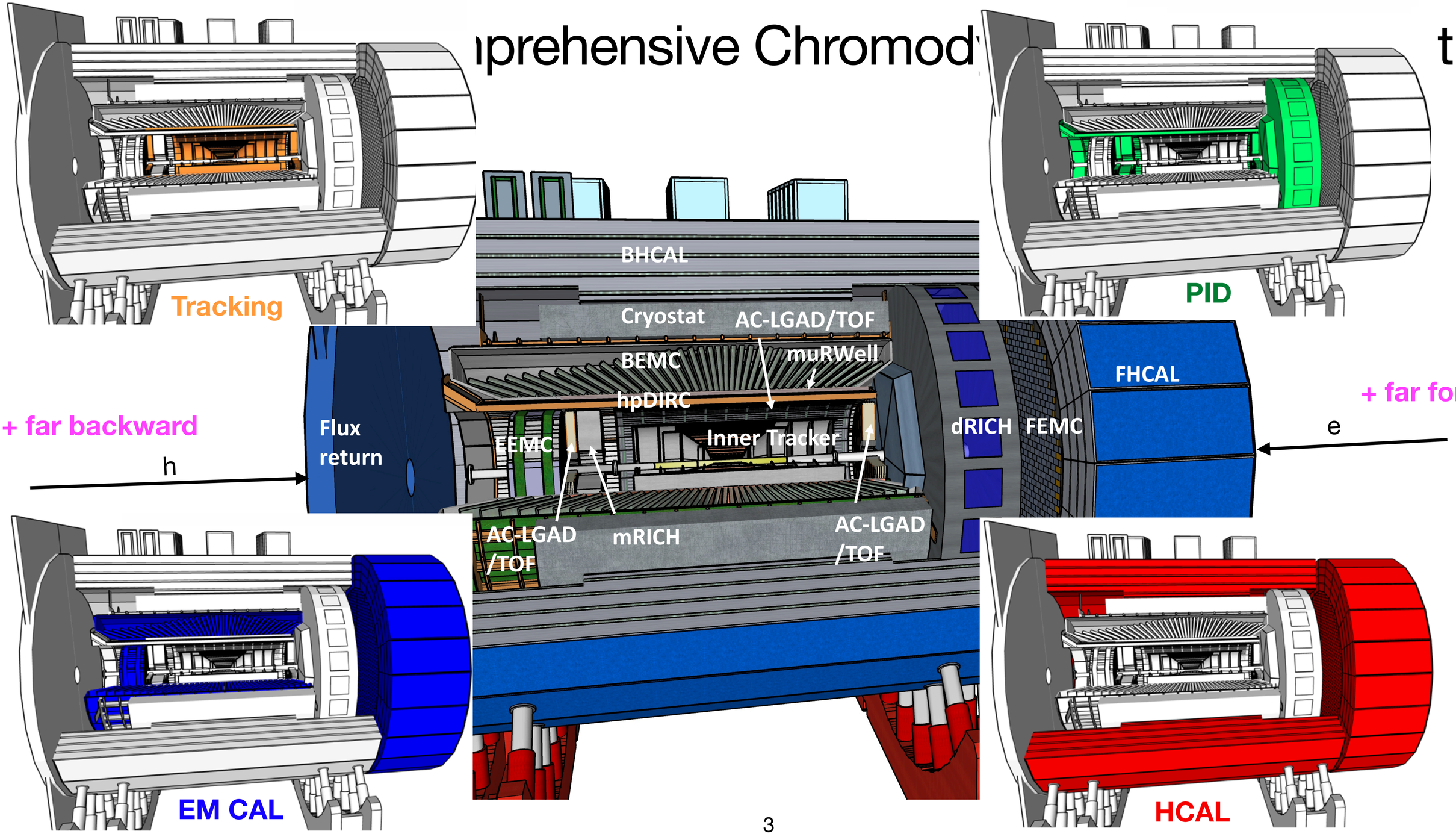
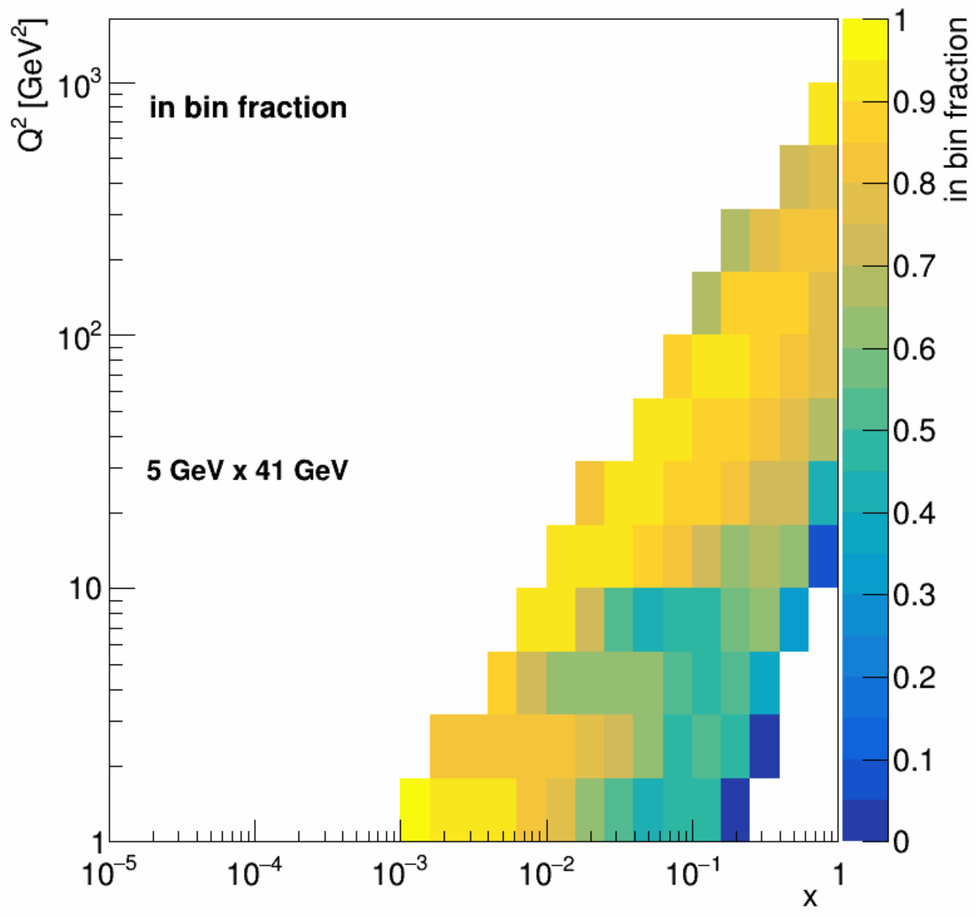
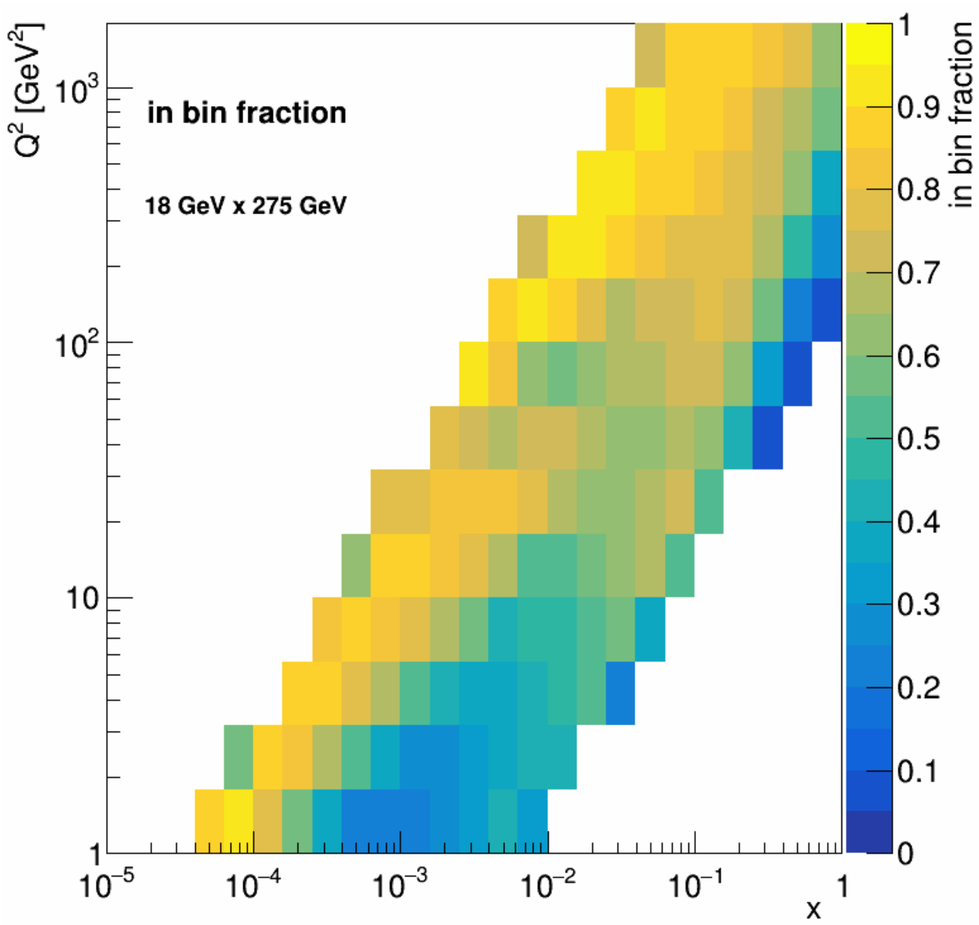


Kinematic coverage for (semi-)inclusive DIS





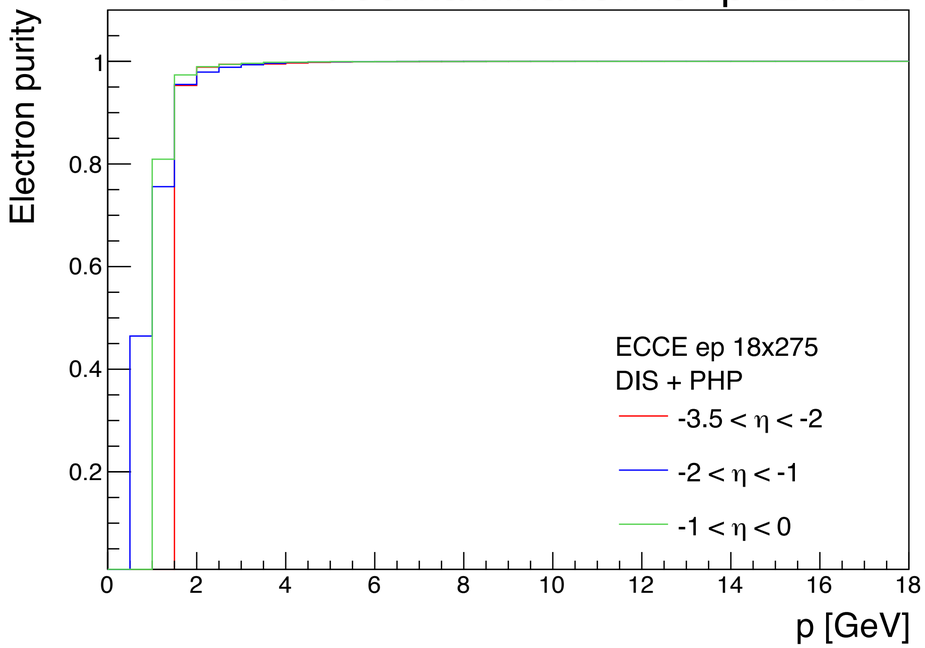
Reconstruction of DIS variables via scattered lepton (high y) or double-angle method (low y)

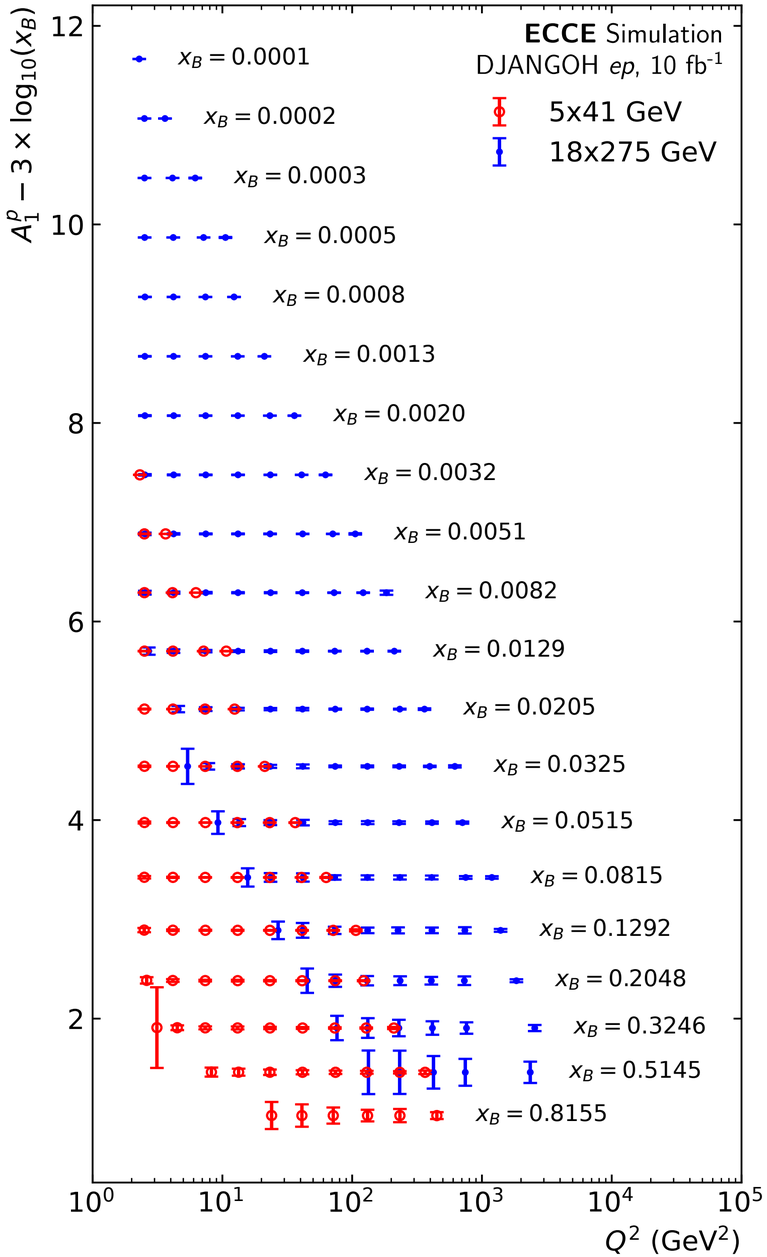
Spin structure: inclusive measurements on p

→ access to gluon spin

e- purity via EMCAL:

<2% π contamination for p>2 GeV





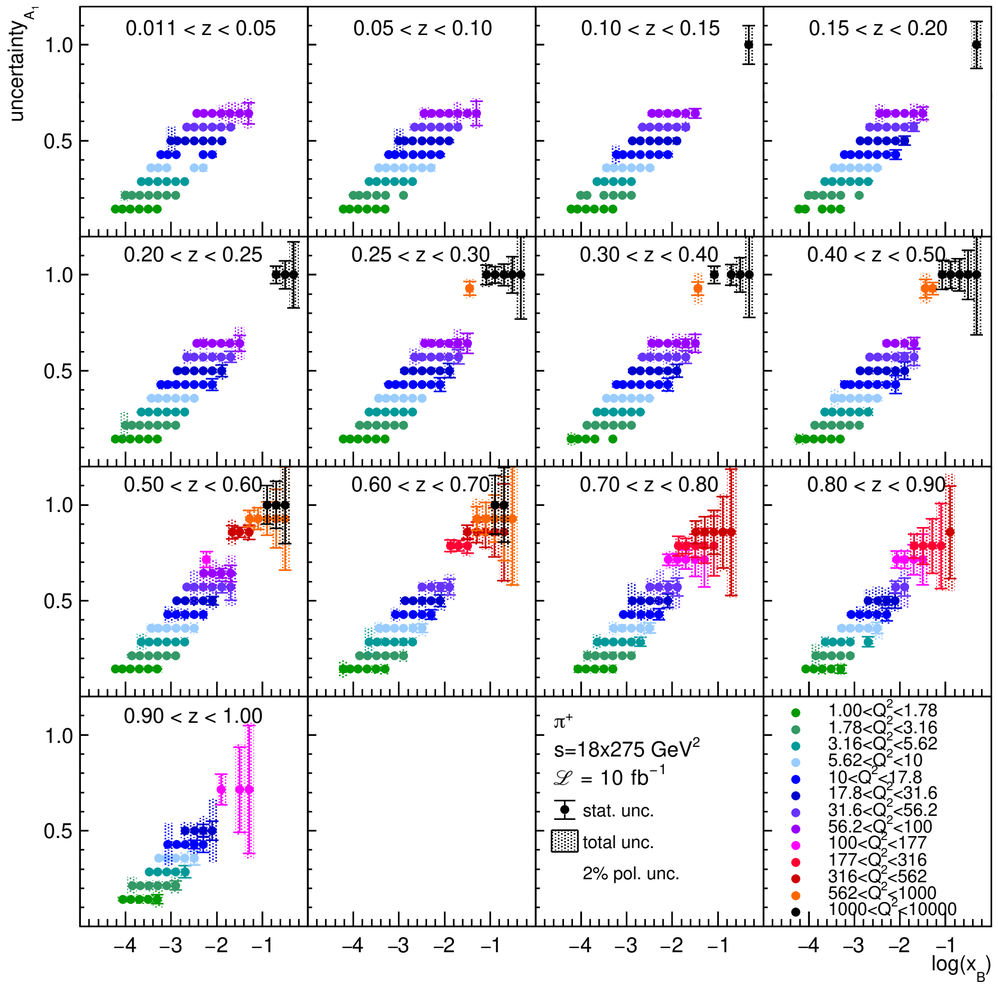
stat. unc.+ unfolding

via tracking of scattered lepton only

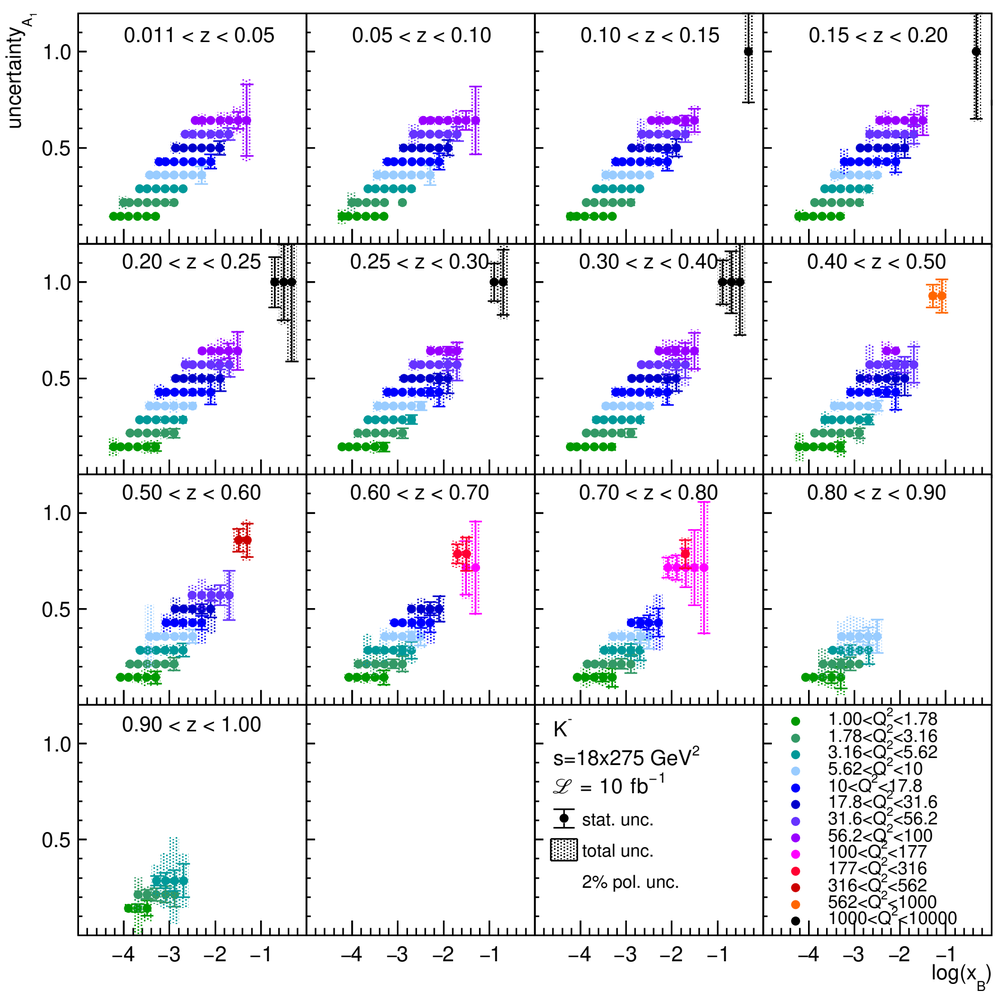
Spin structure: semi-inclusive measurements on p

→ access to sea-quark spin

u, d sea quarks



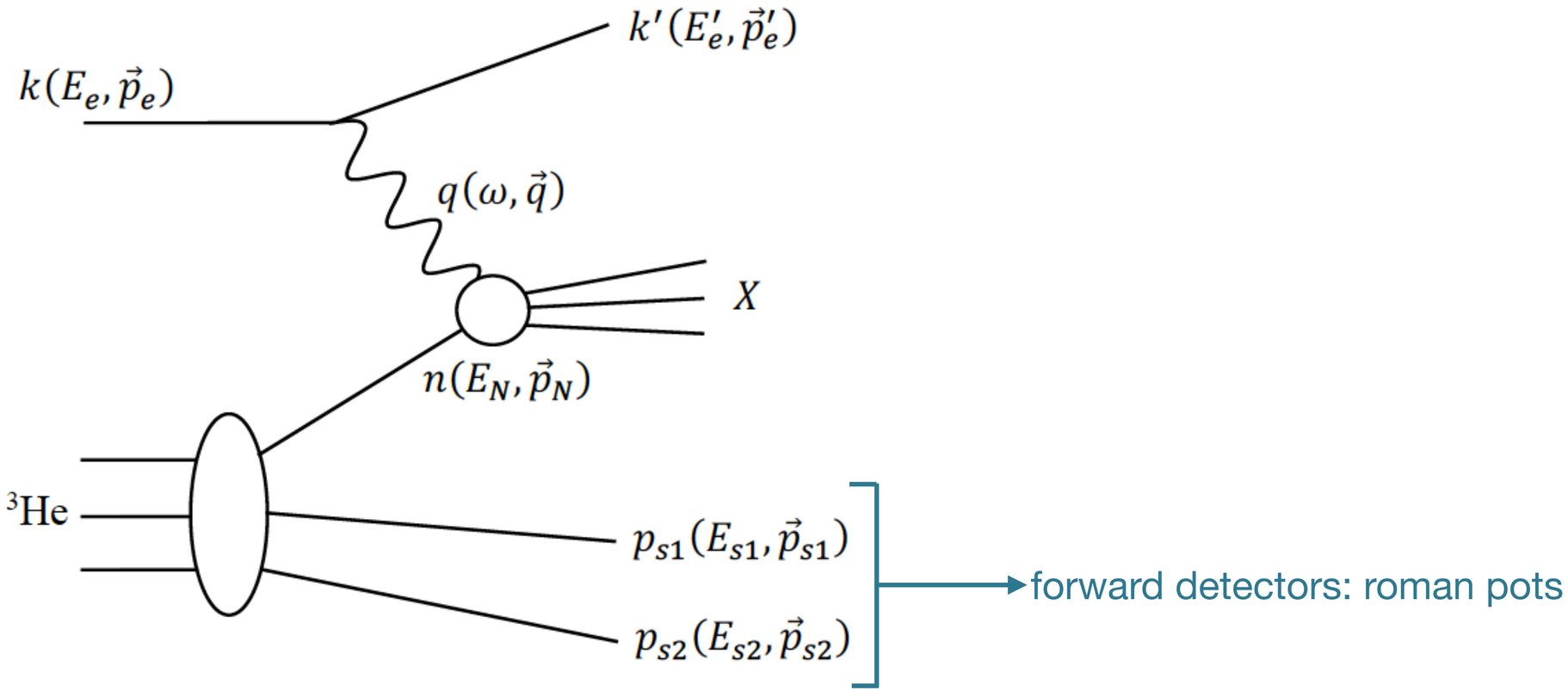
strange quarks



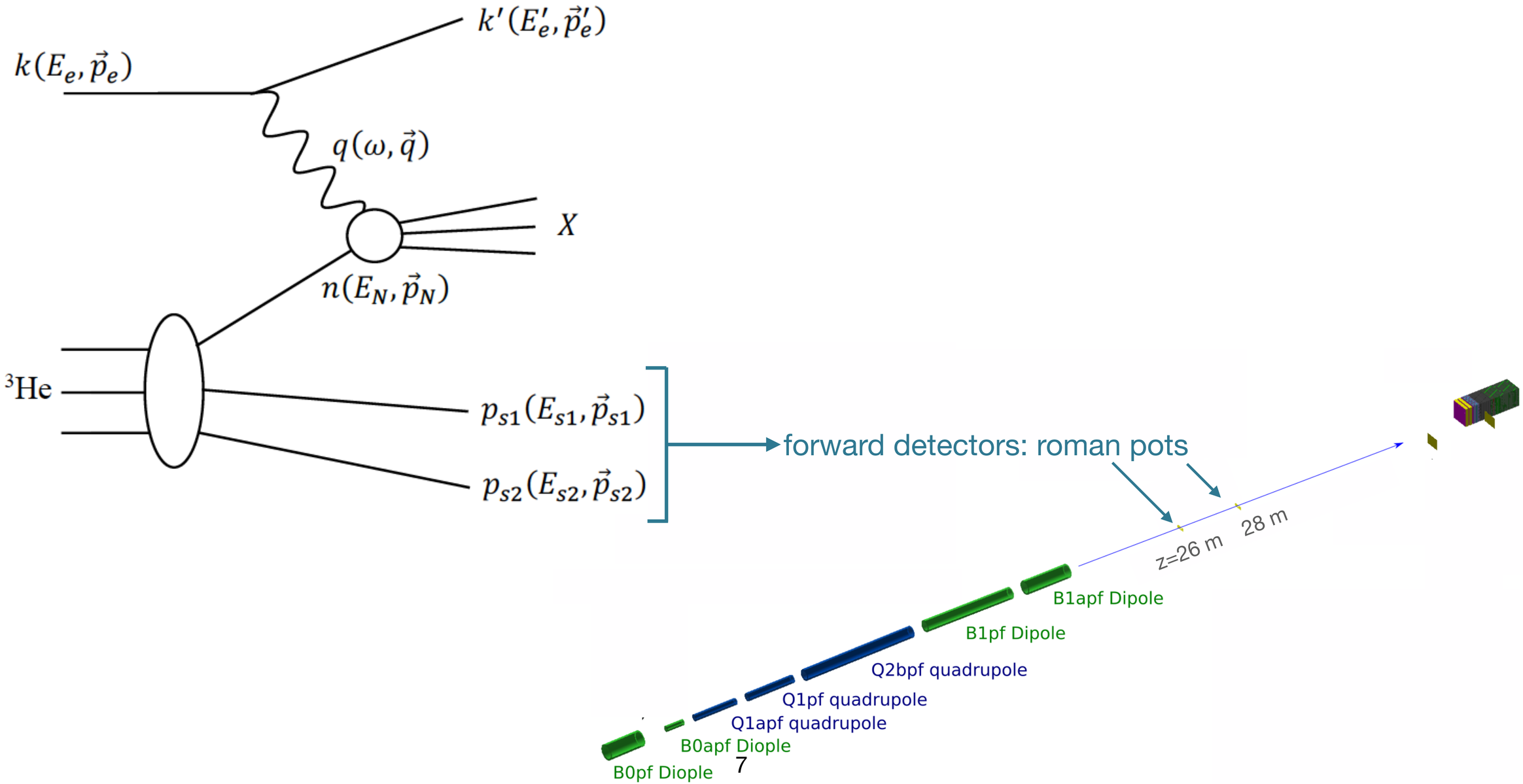
via tracking of scattered lepton only

sys. unc.= diff(gen.,rec.)

Spin structure: inclusive on n via double-p tagging



Spin structure: inclusive on n via double-p tagging



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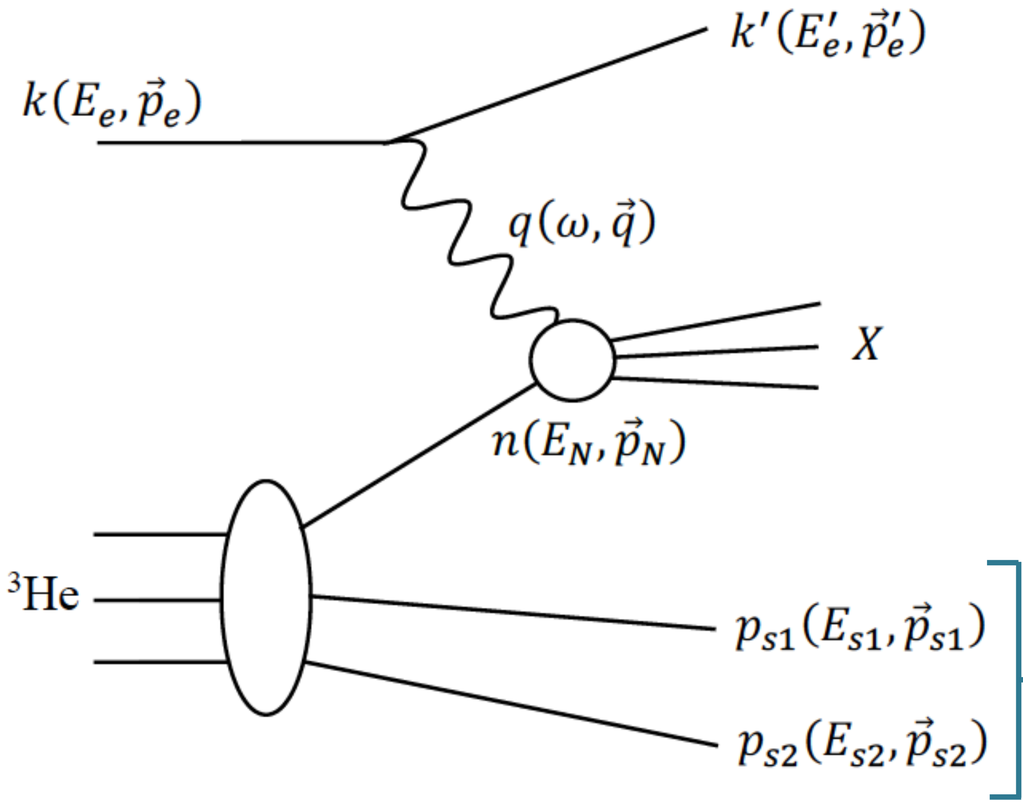
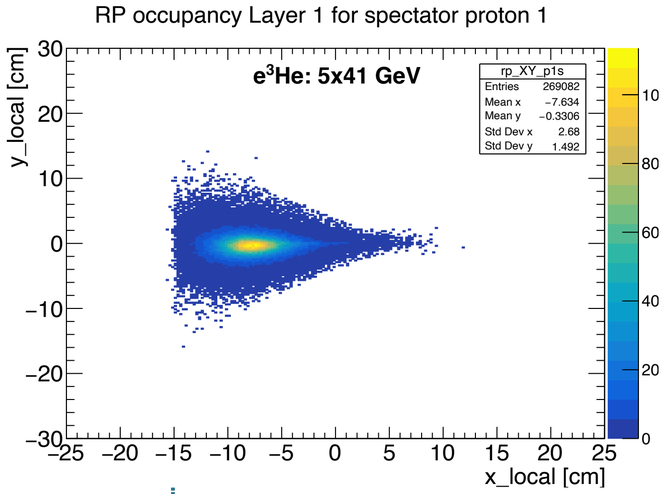
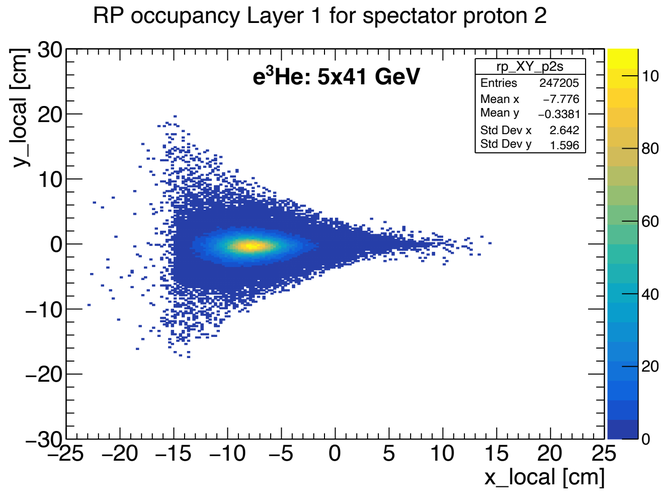
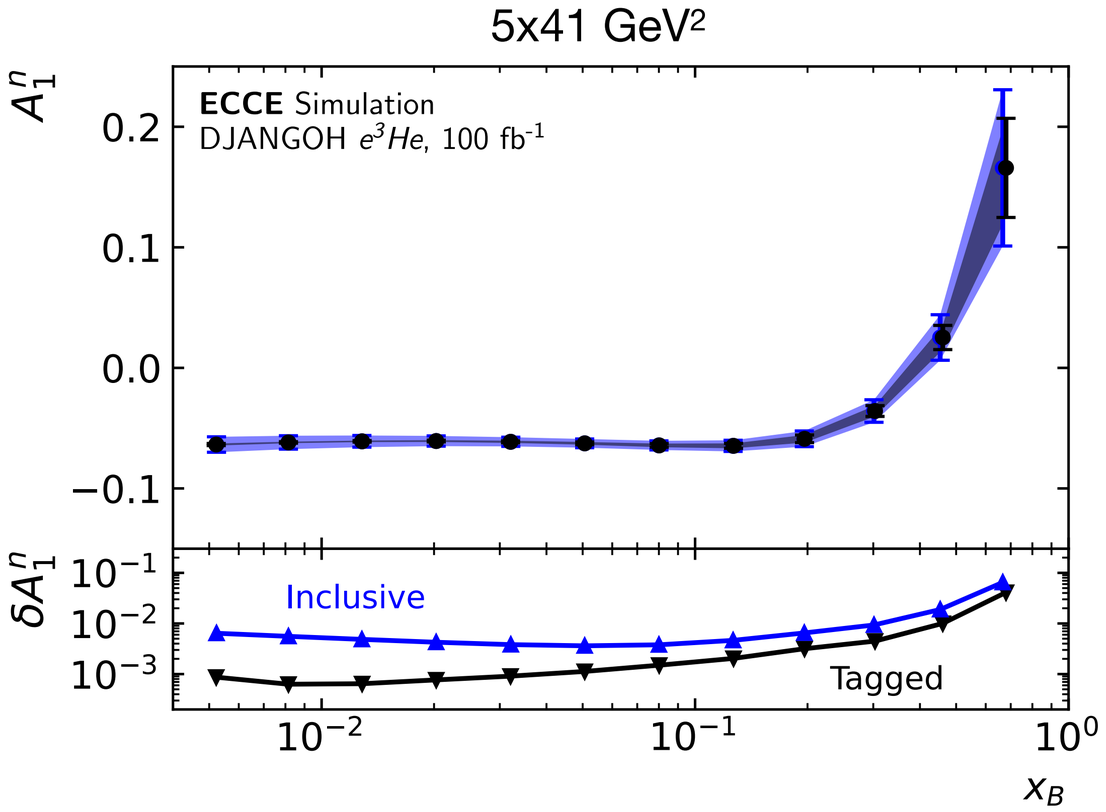


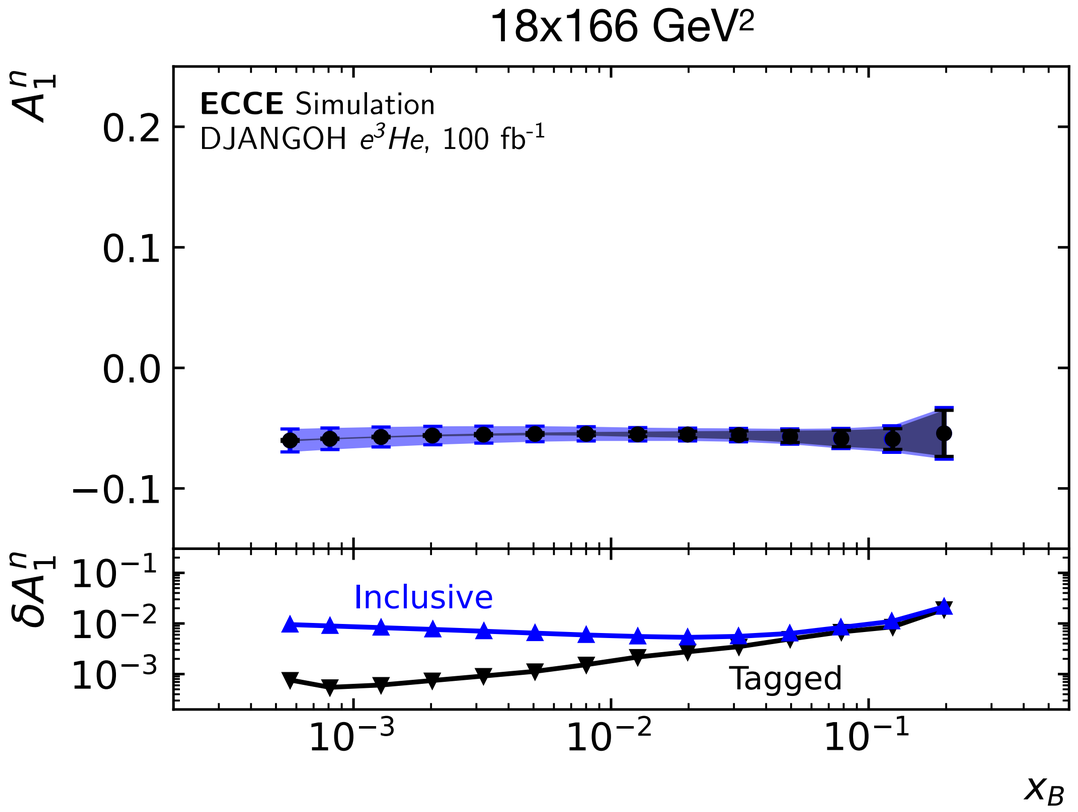
forward detectors: roman pots





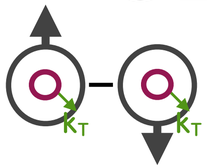
Spin structure: inclusive on n via double-p tagging



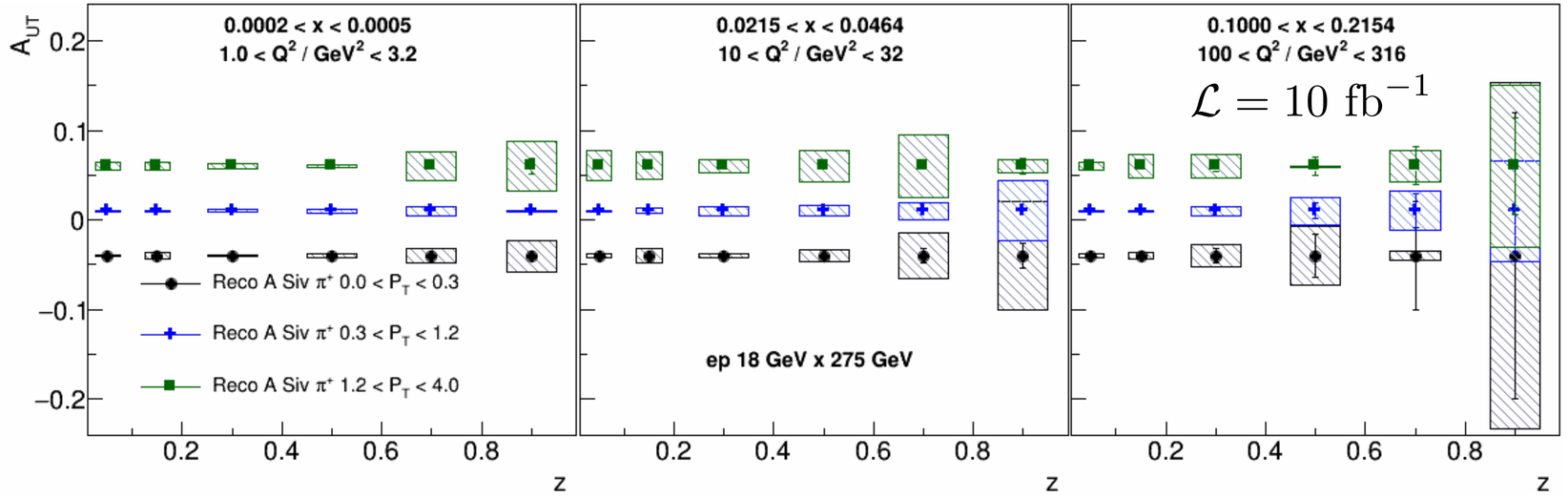


Factor of 10 reduction in uncertainty at low x

3D momentum structure: Sivers



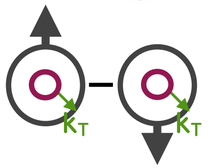
Sivers asymmetry



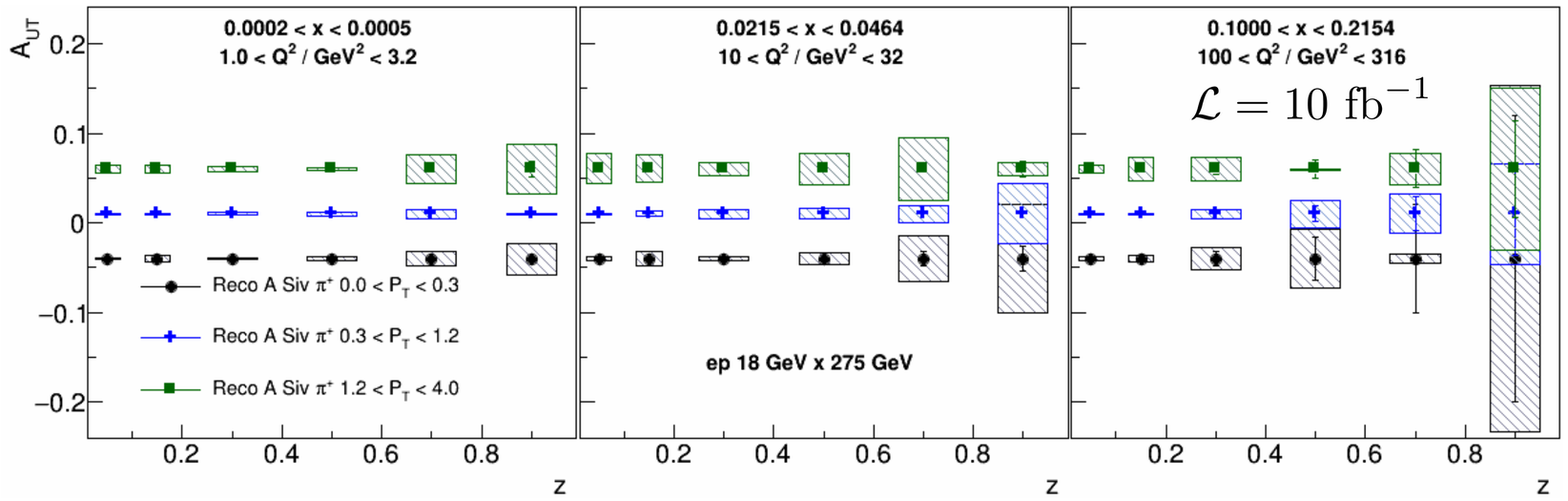
via tracking of scattered lepton only

sys. unc.= diff(gen.,rec.)

3D momentum structure: Sivers



Sivers asymmetry



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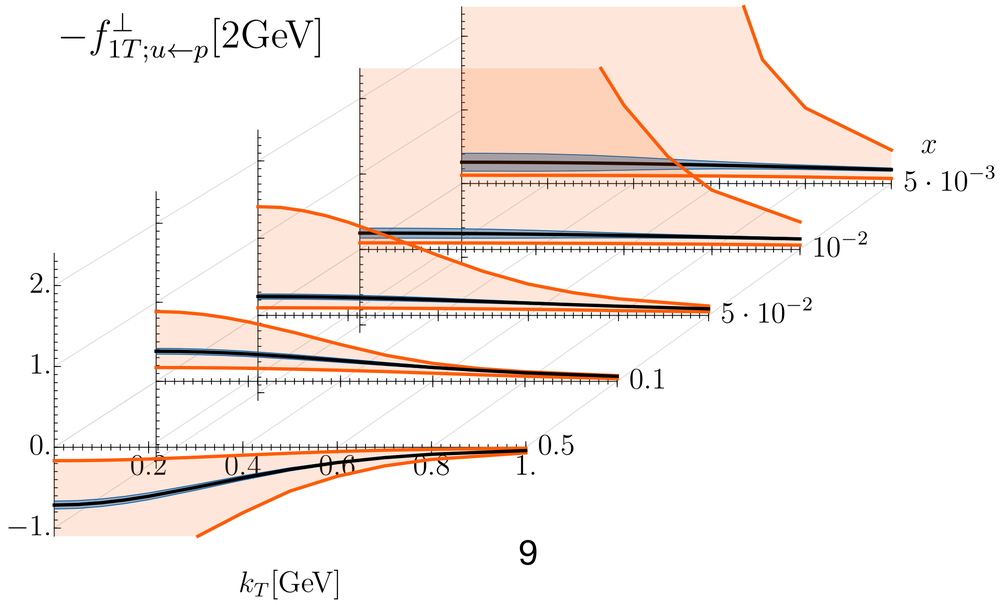

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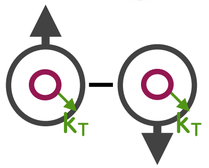
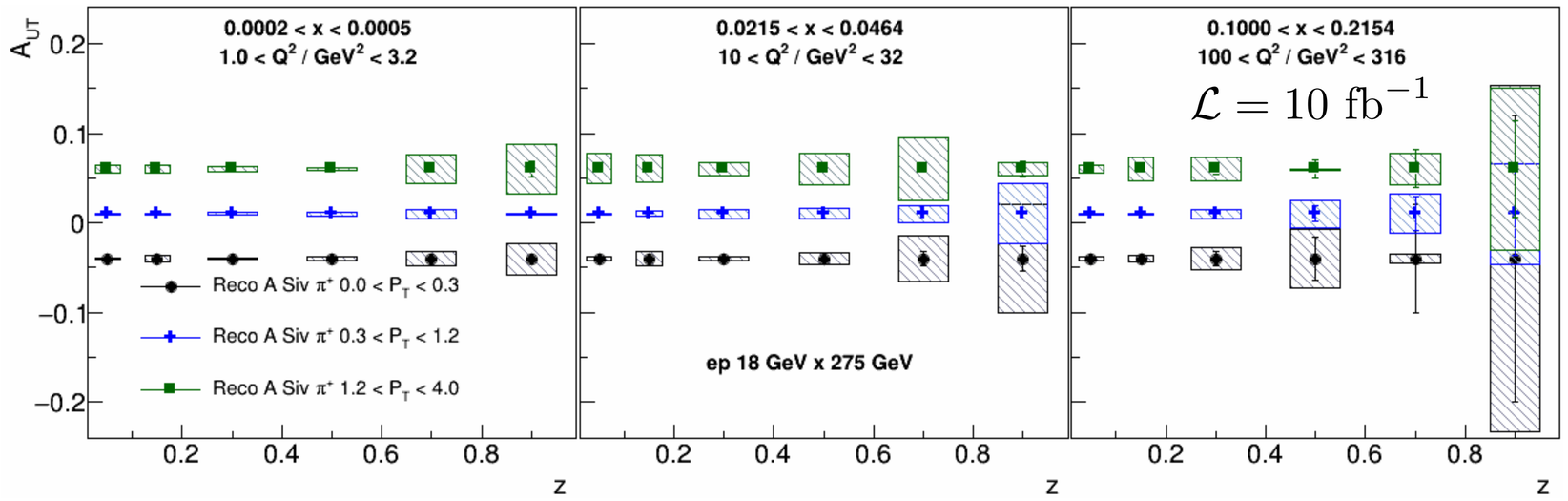


Sivers asymmetry



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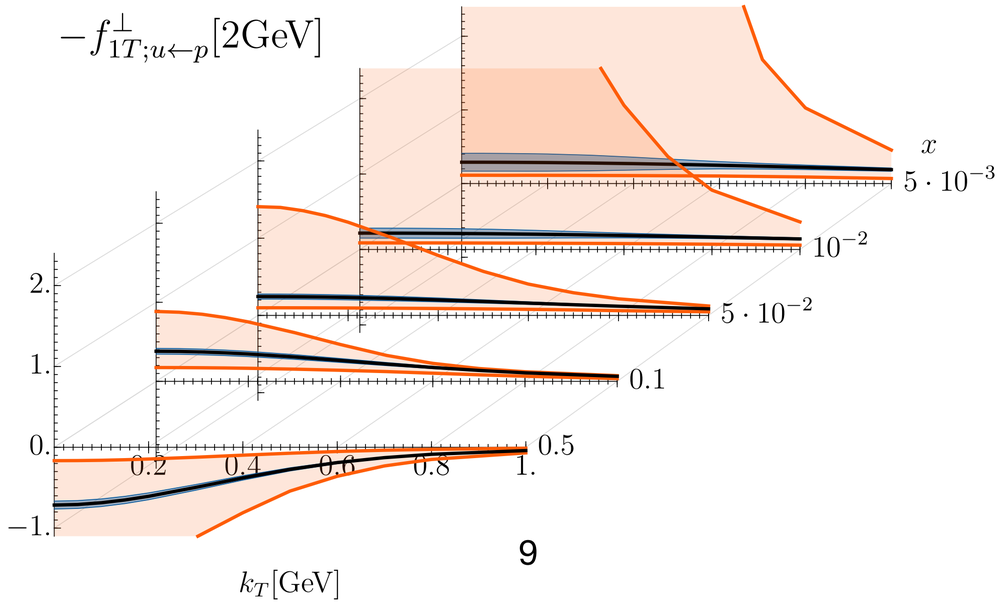
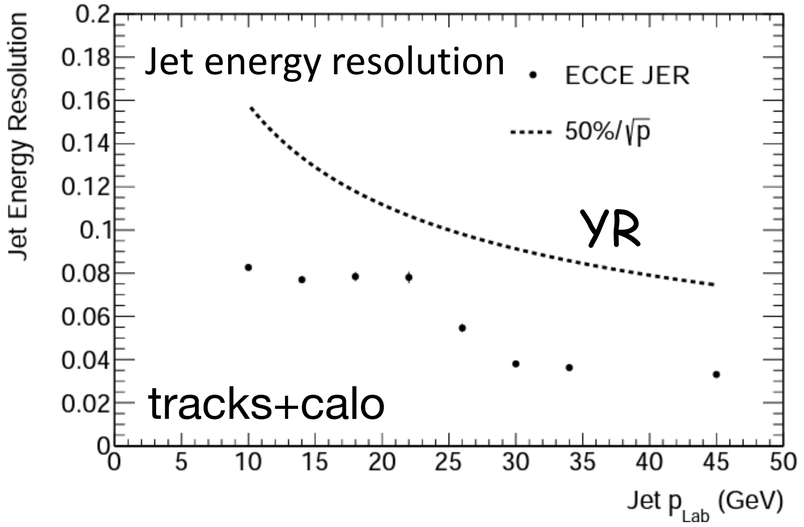


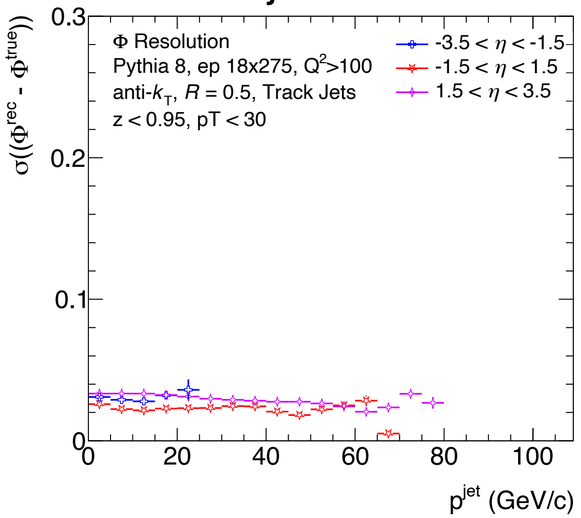
gluon Sivers via pair production of open heavy flavours, of jets, …

Jet and heavy-flavour reconstruction

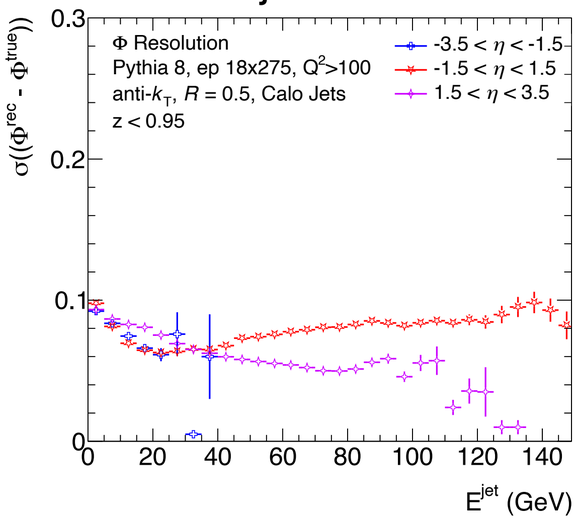
Jets



Track jet resolution

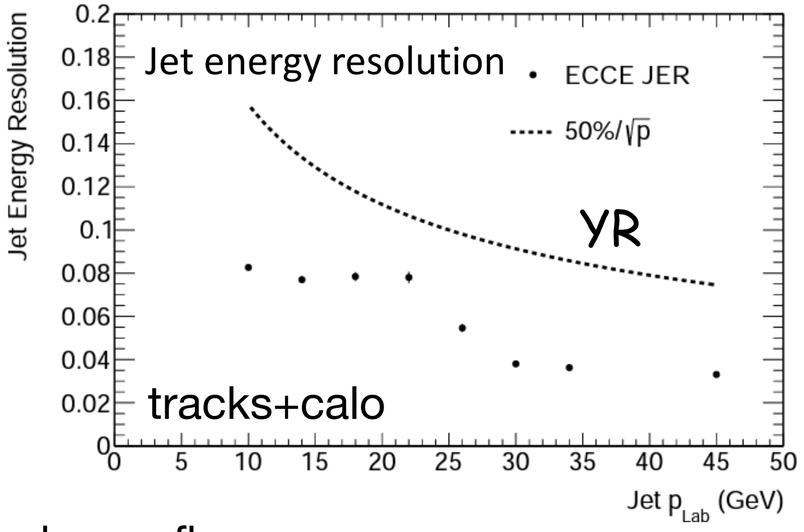


Calo jet resolution

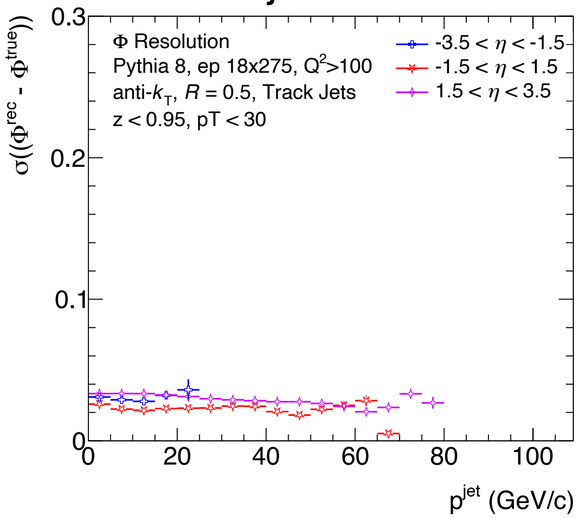


Jet and heavy-flavour reconstruction

Jets



Track jet resolution



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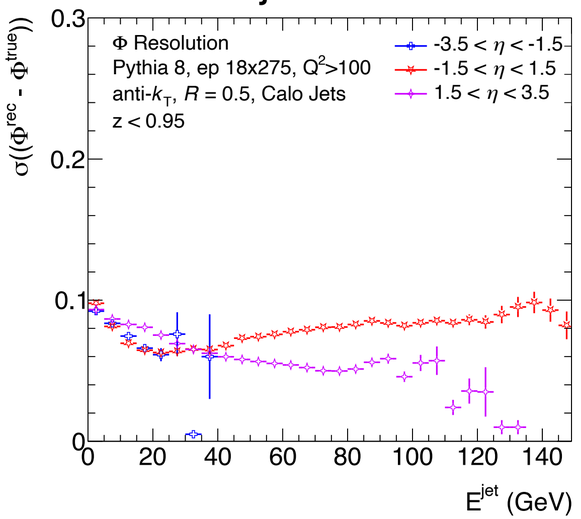
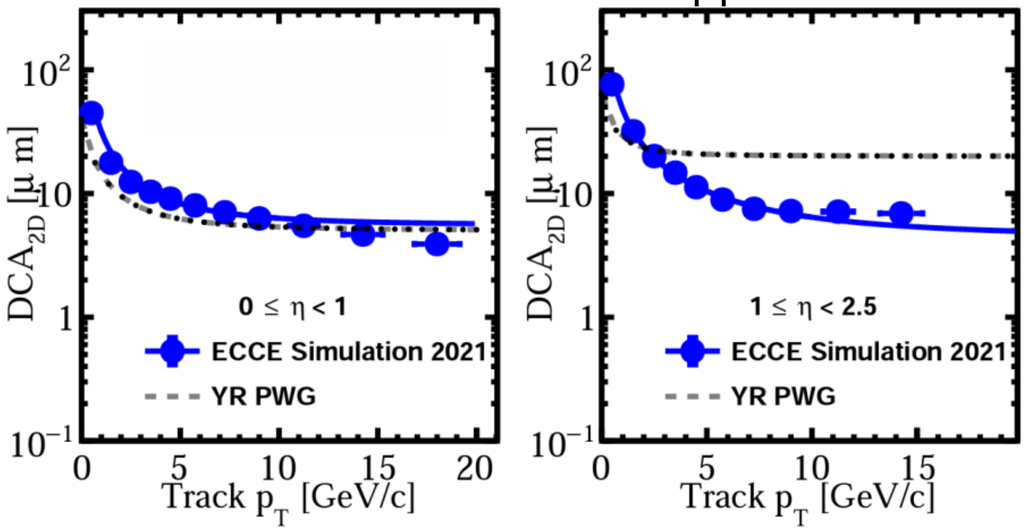


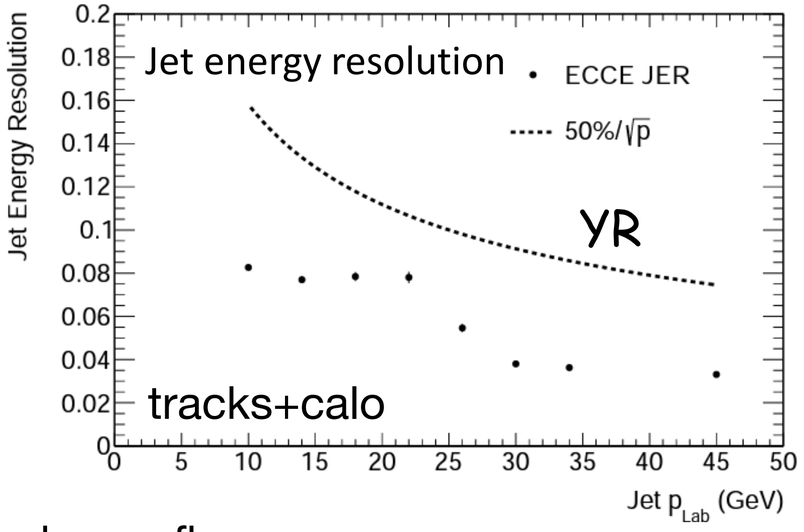
Open heavy flavours

Distance of closest approach

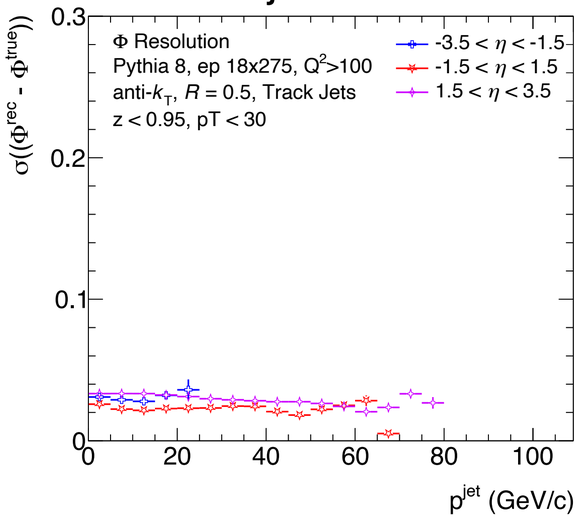


Jet and heavy-flavour reconstruction

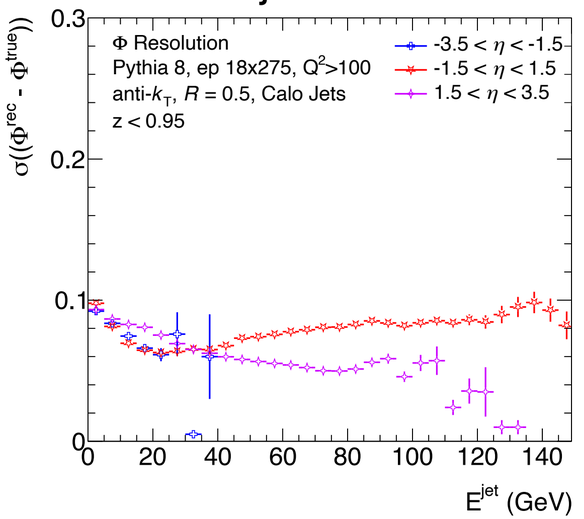
Jets



Track jet resolution



Calo jet resolution



Open heavy flavours

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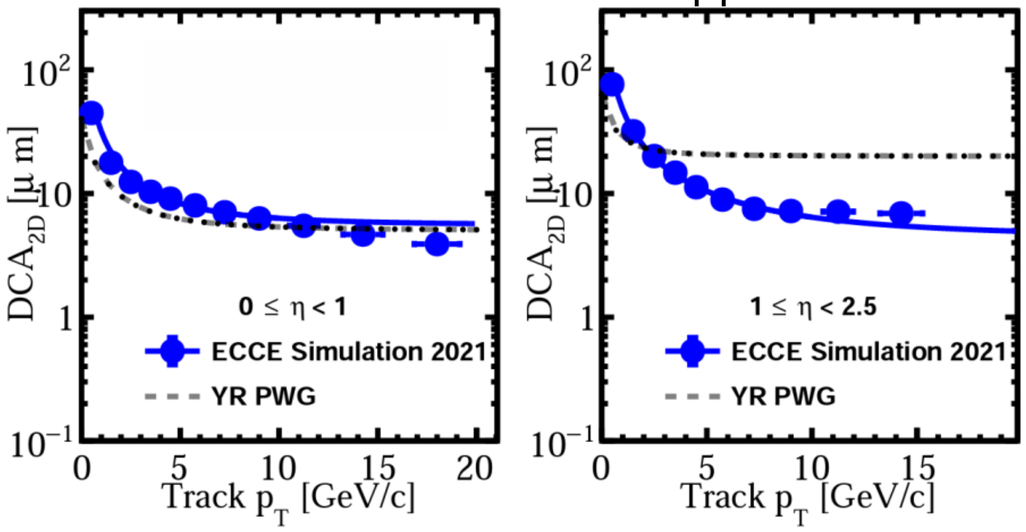
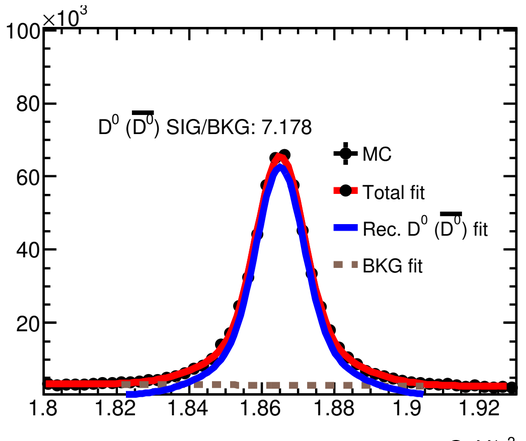
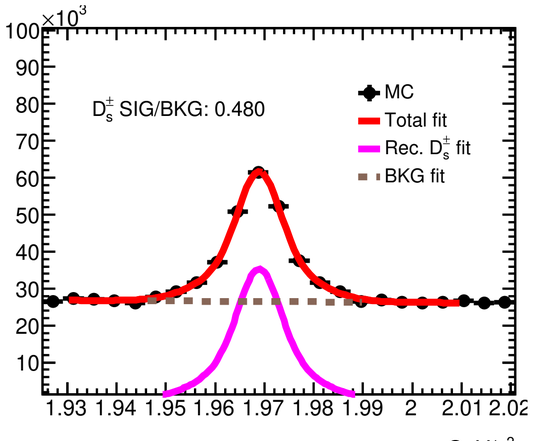
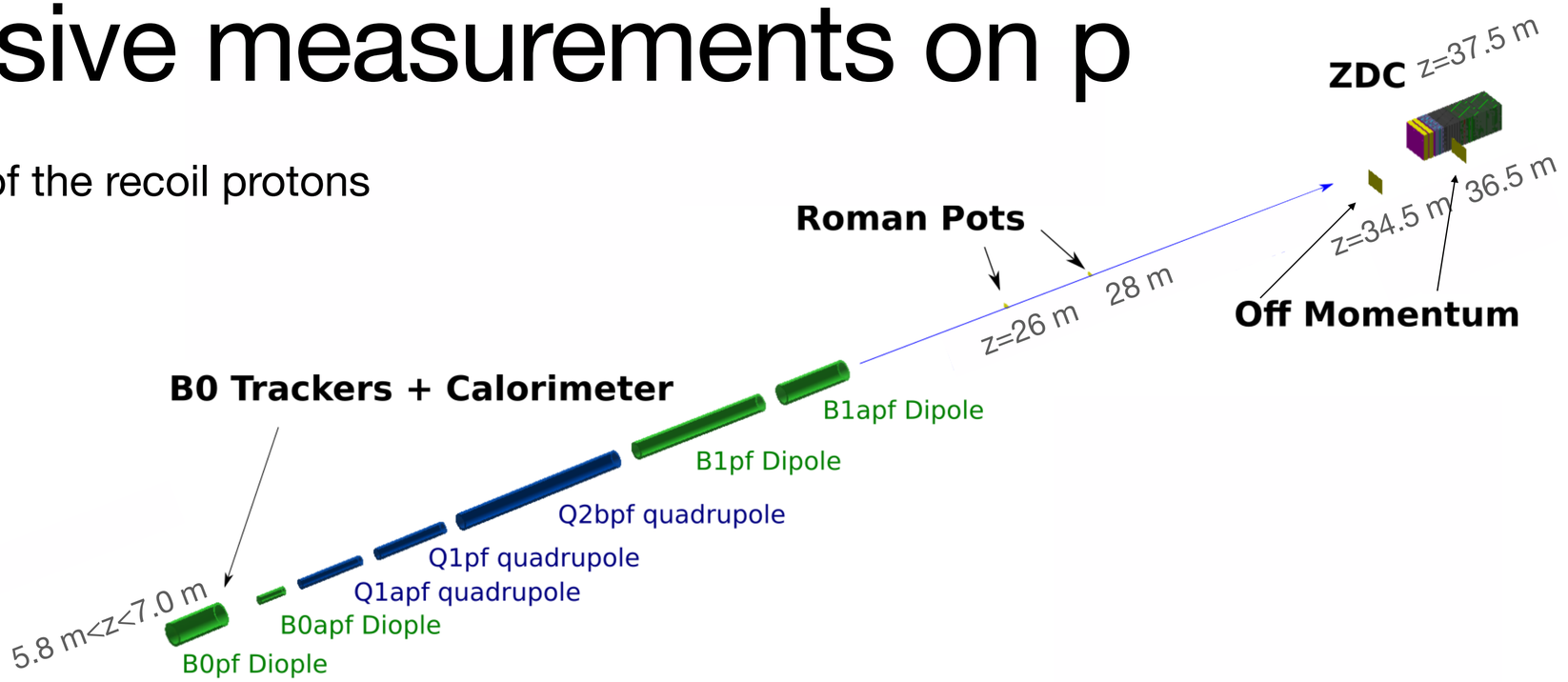


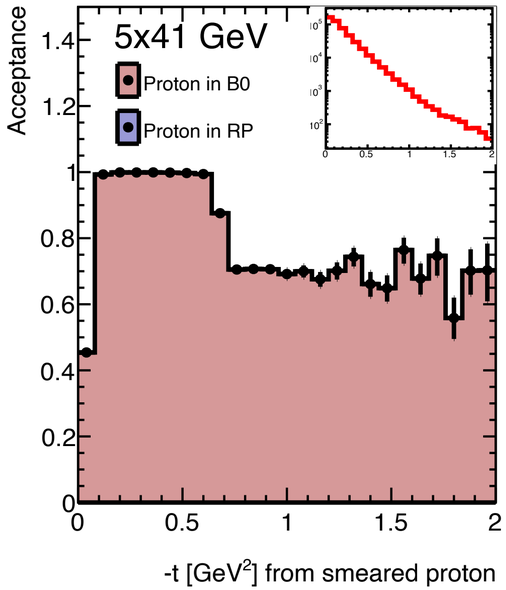


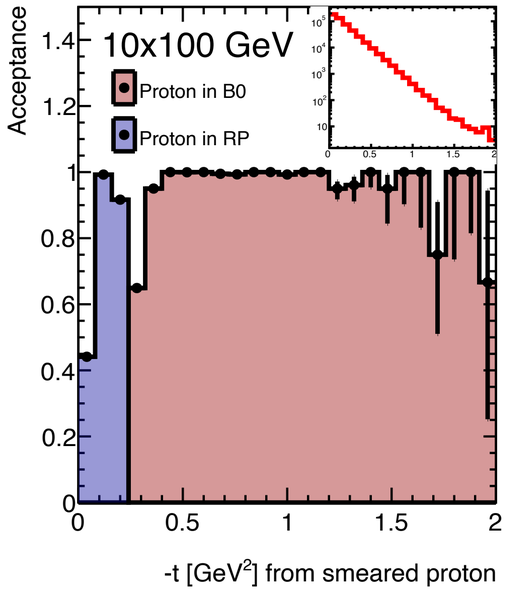


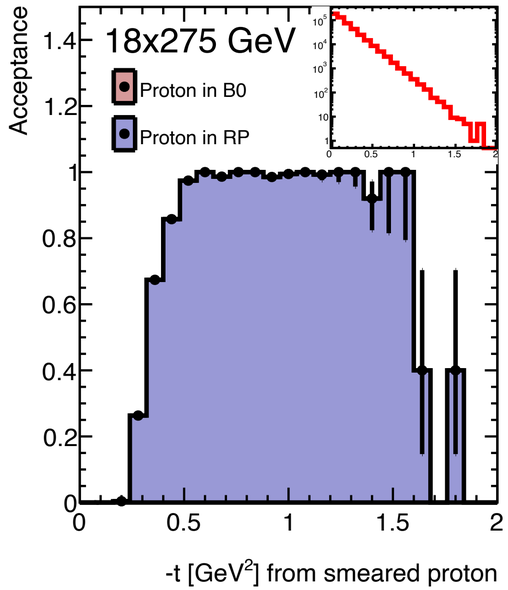
Exclusive measurements on p

Detection of the recoil protons



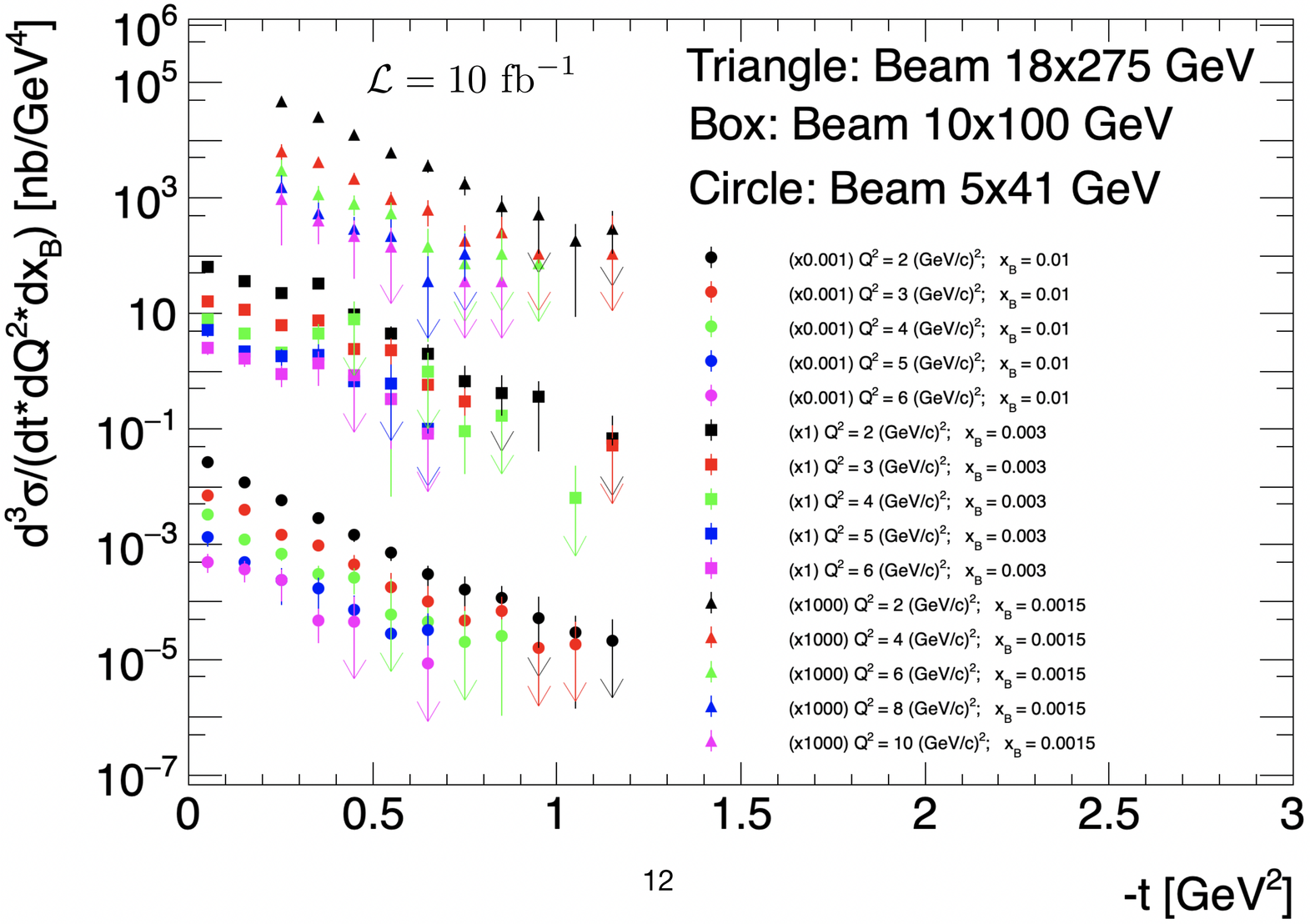






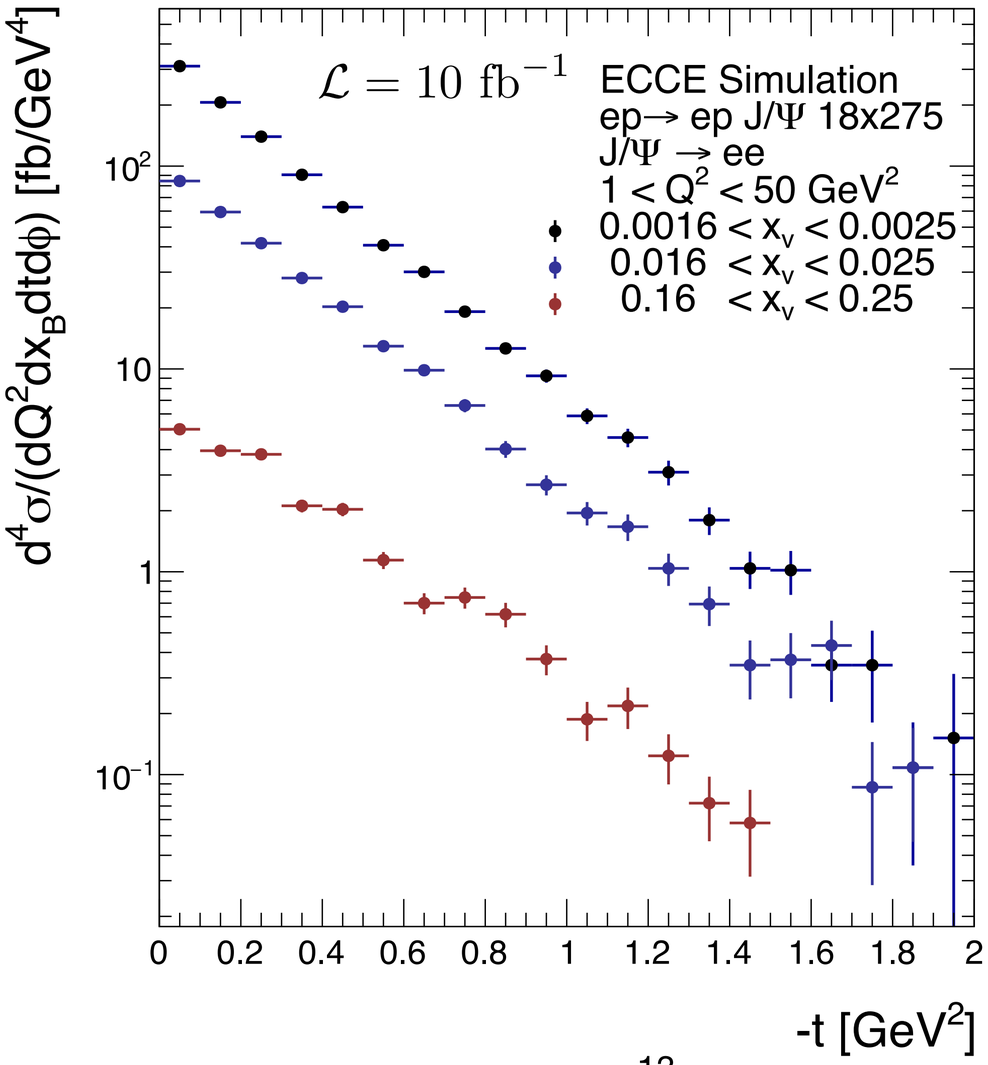
Deeply virtual Compton scattering on p

→ sensitive to quark (and gluon) GPDs



Exclusive J/ψ electroproduction on p

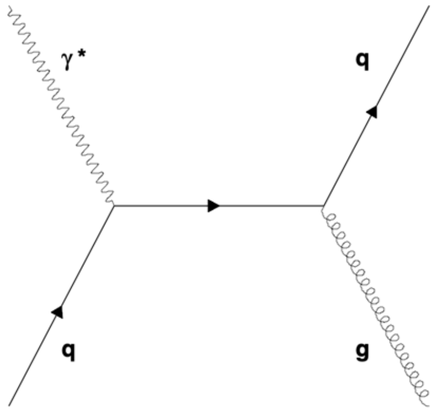
→ excellent to probe gluon GPDs

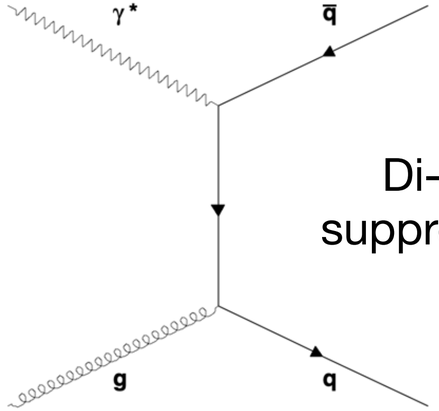


Probing the nuclear medium

- Additional requirements for certain channels of interest:
  - Diffractive/exclusive measurements:
    - veto of events where nuclei break up → use entire far-forward detector systems
    - low-t for nuclei → reconstruction via scattered lepton and exclusively produced vector meson/photon

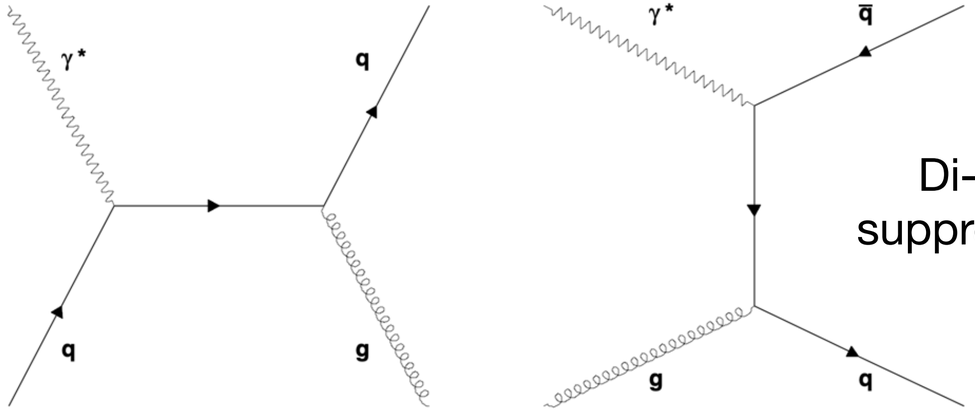
Di-hadron production from jets





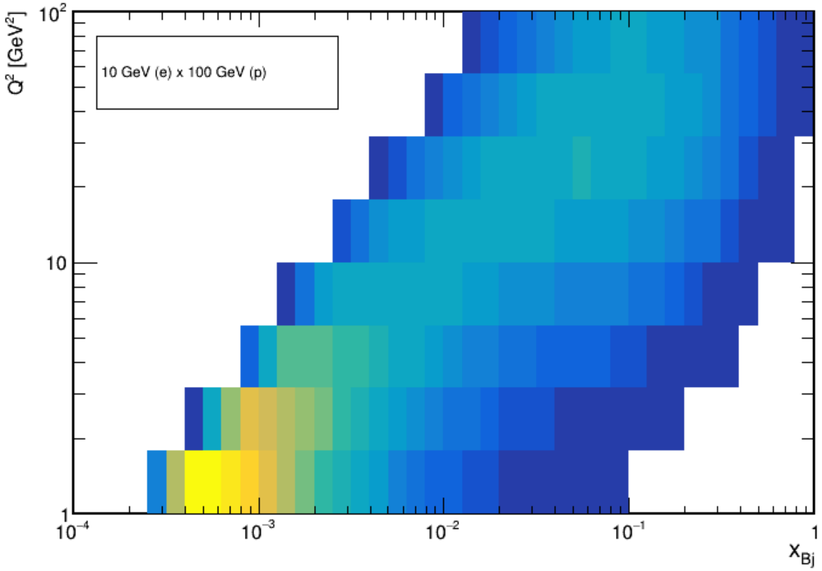
Di-jet correlations → search for signs of saturation:
suppression of back-to-back dijet correlations in nucleus

Di-hadron production from jets

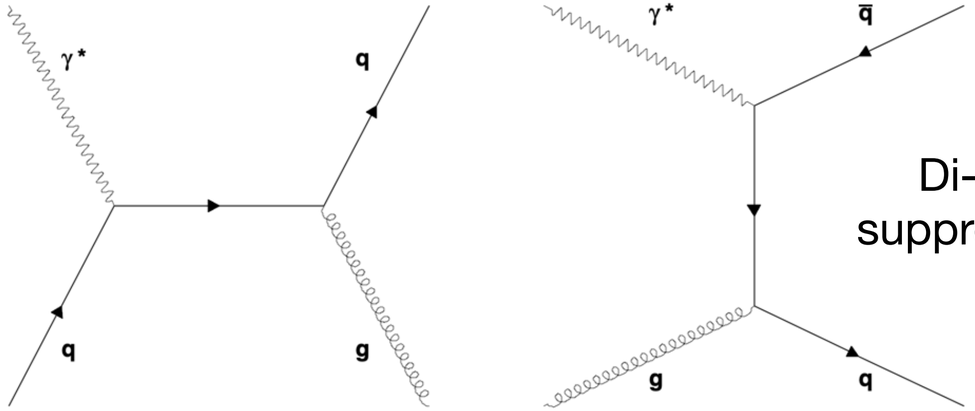


Di-jet correlations → search for signs of saturation:
suppression of back-to-back dijet correlations in nucleus

$p_T^{\text{trig}} > p_T^{\text{assoc}} > 1 \text{ GeV}$ and $|\eta| < 3.5$



Di-hadron production from jets



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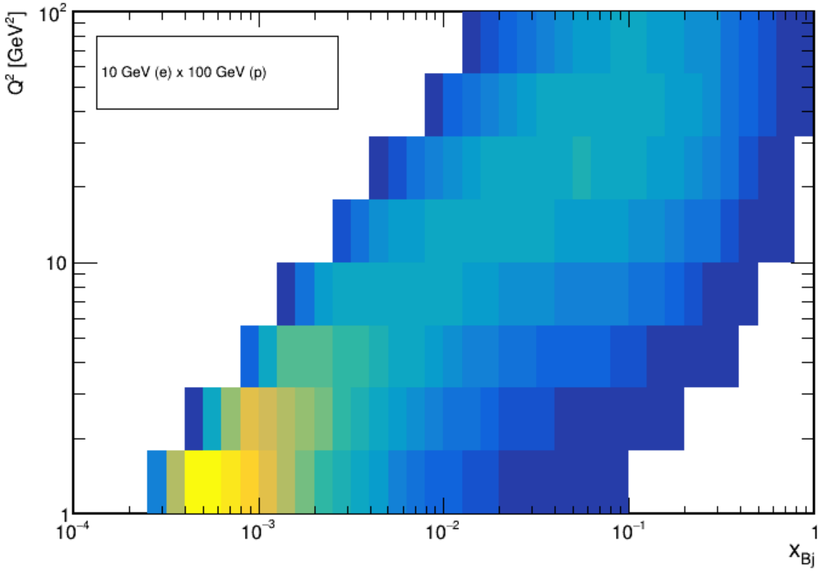
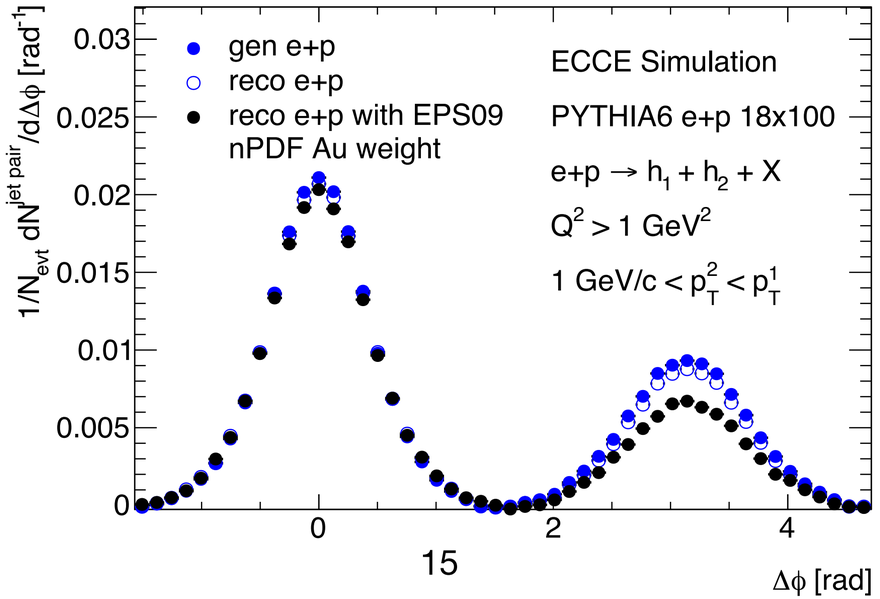
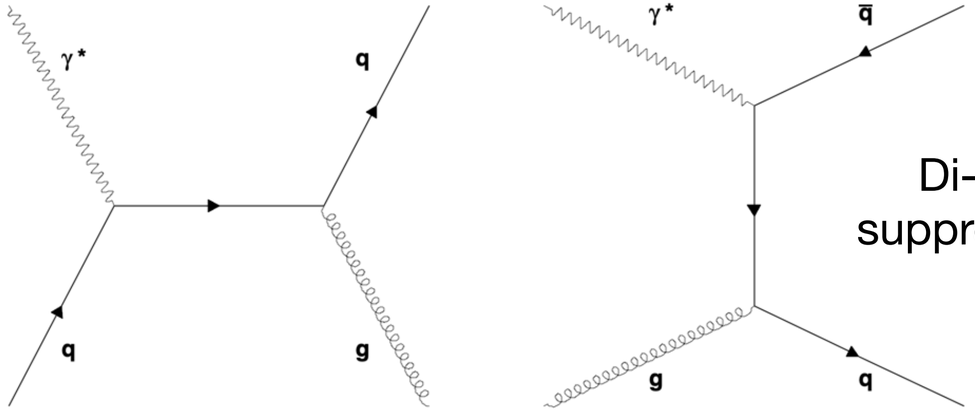




Di-hadron production from jets



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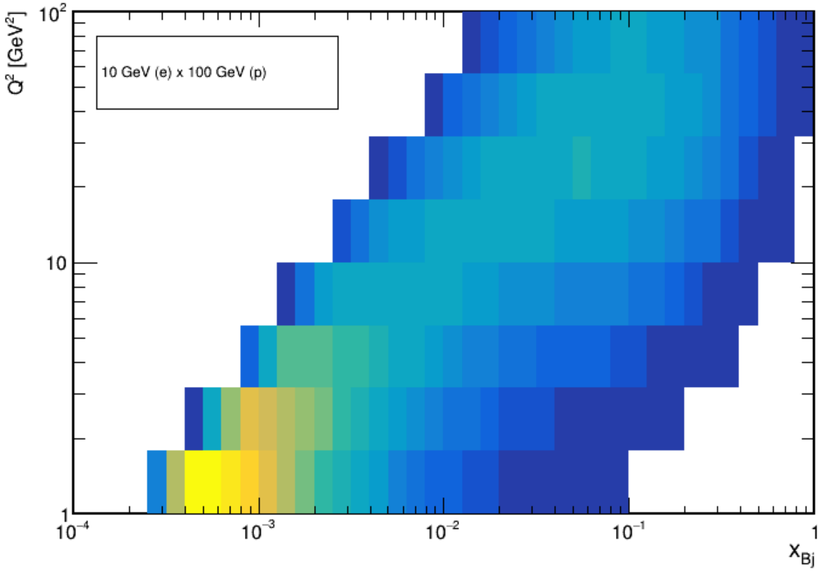
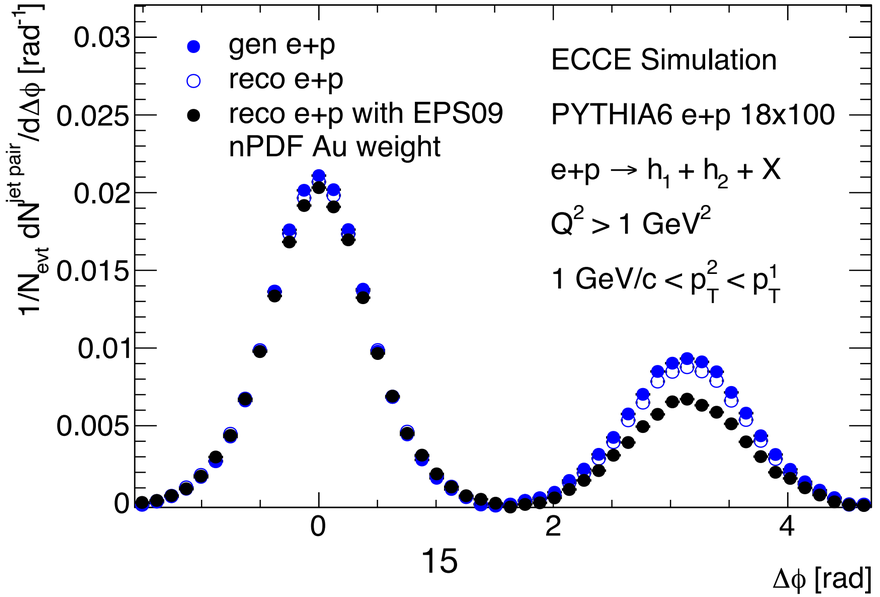
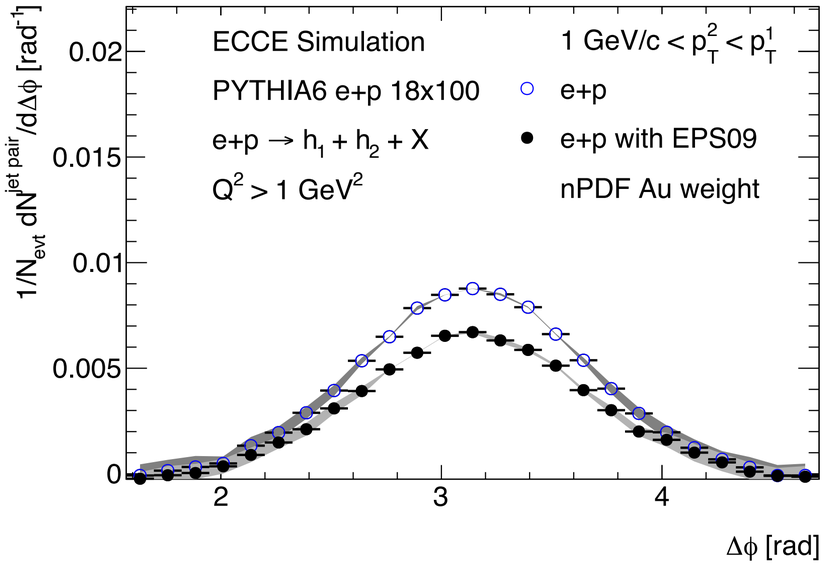




For π/2<Δφ<3π/2 difference eA–ep
>
systematic uncertainties (grey band)
systematic=diff. (gen.,rec.)



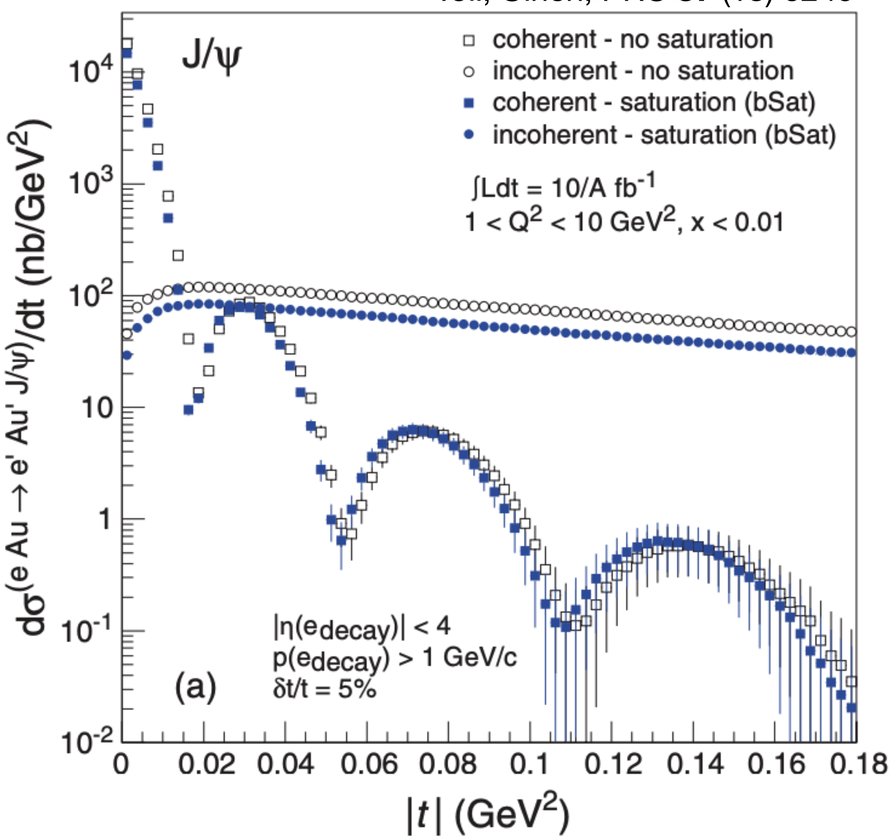
Diffractive eA

→ probe gluon saturation

→ nuclear imaging in position space

→ resolving minima is crucial

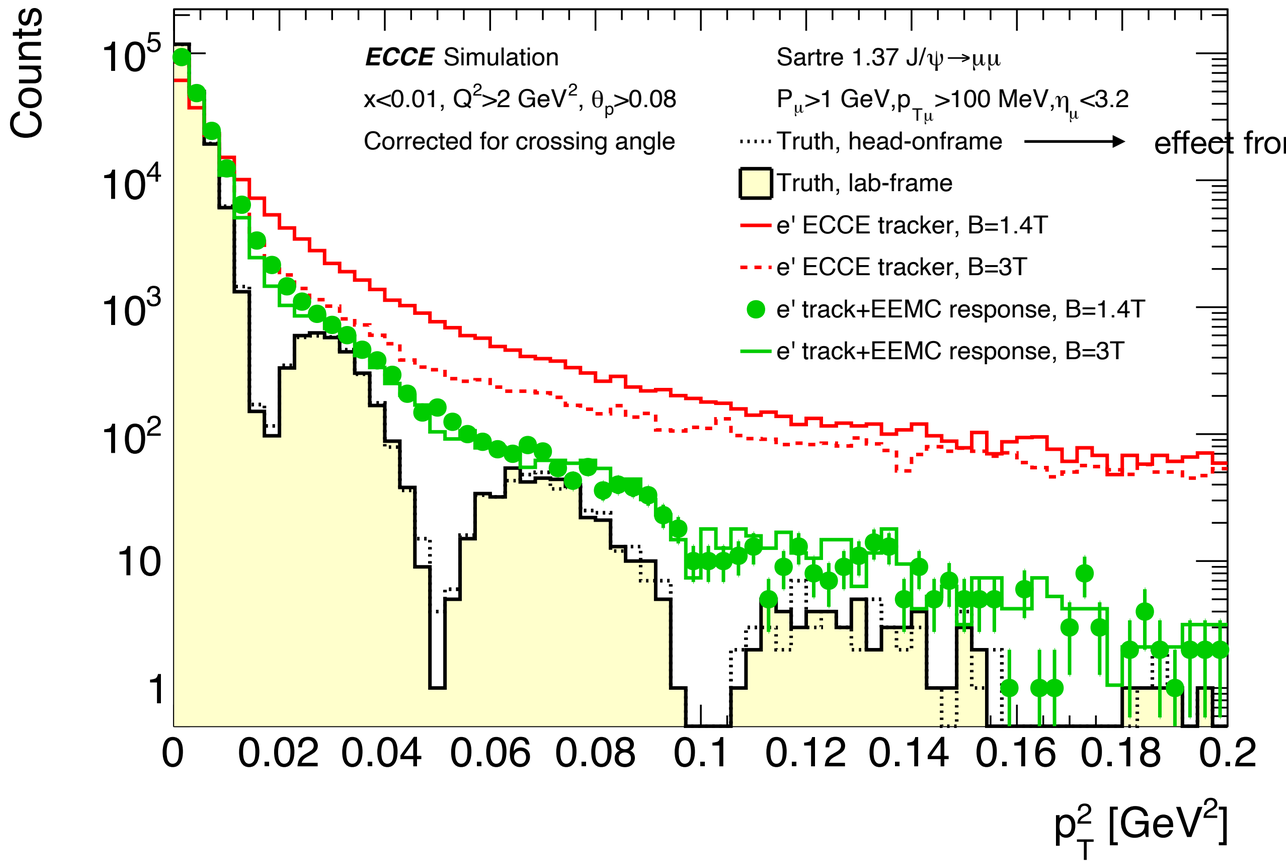
Toll, Ulrich, PRC **87** (13) 0249



Need 90%, 99%, and > 99.8% veto efficiency for incoherent production, for the respective minima at increasing t.

Need precise determination of t.

Diffractive eA: study of exclusive J/ψ production in ePb

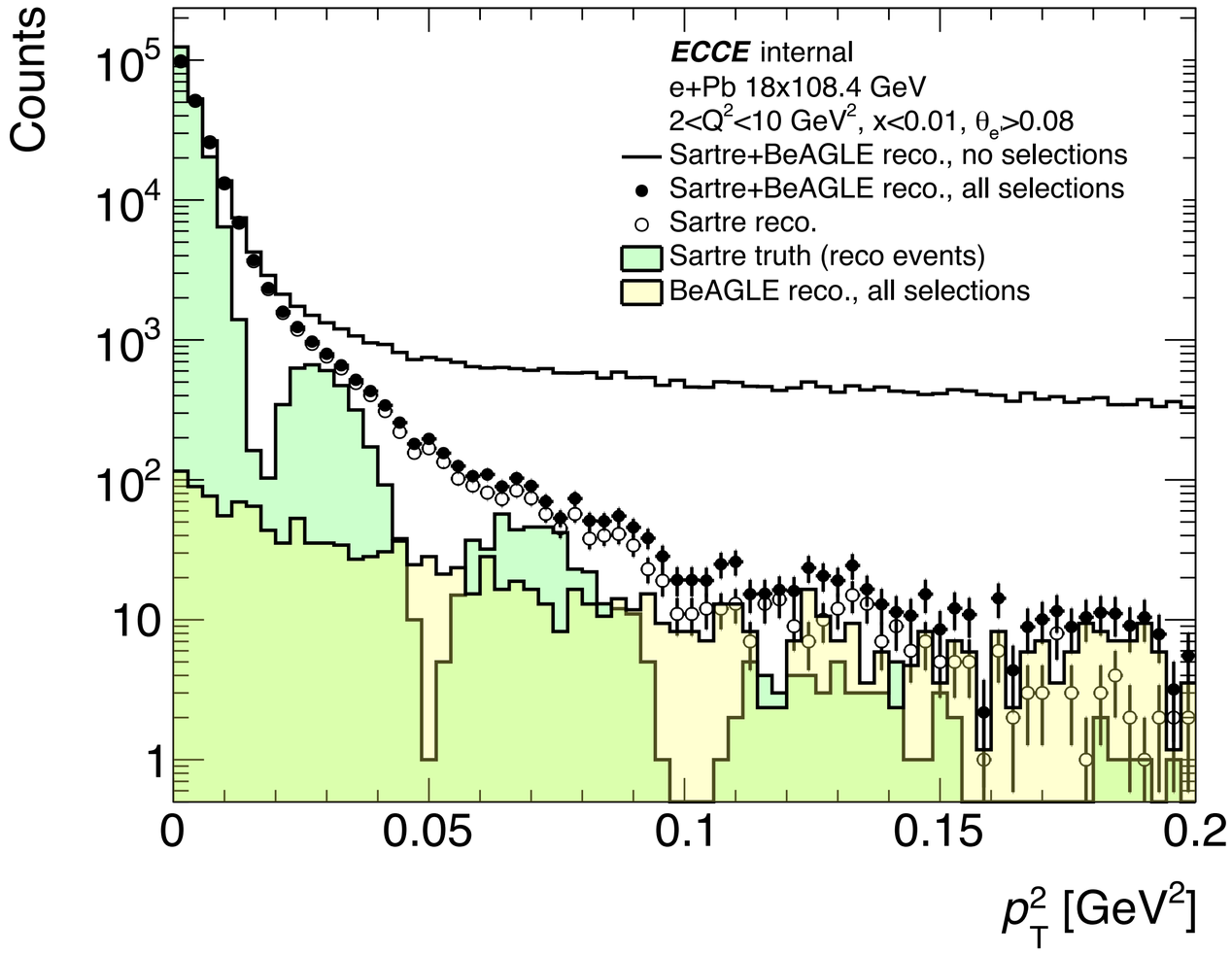


effect from crab and beam divergences

- t via scattered lepton and reconstructed vector meson

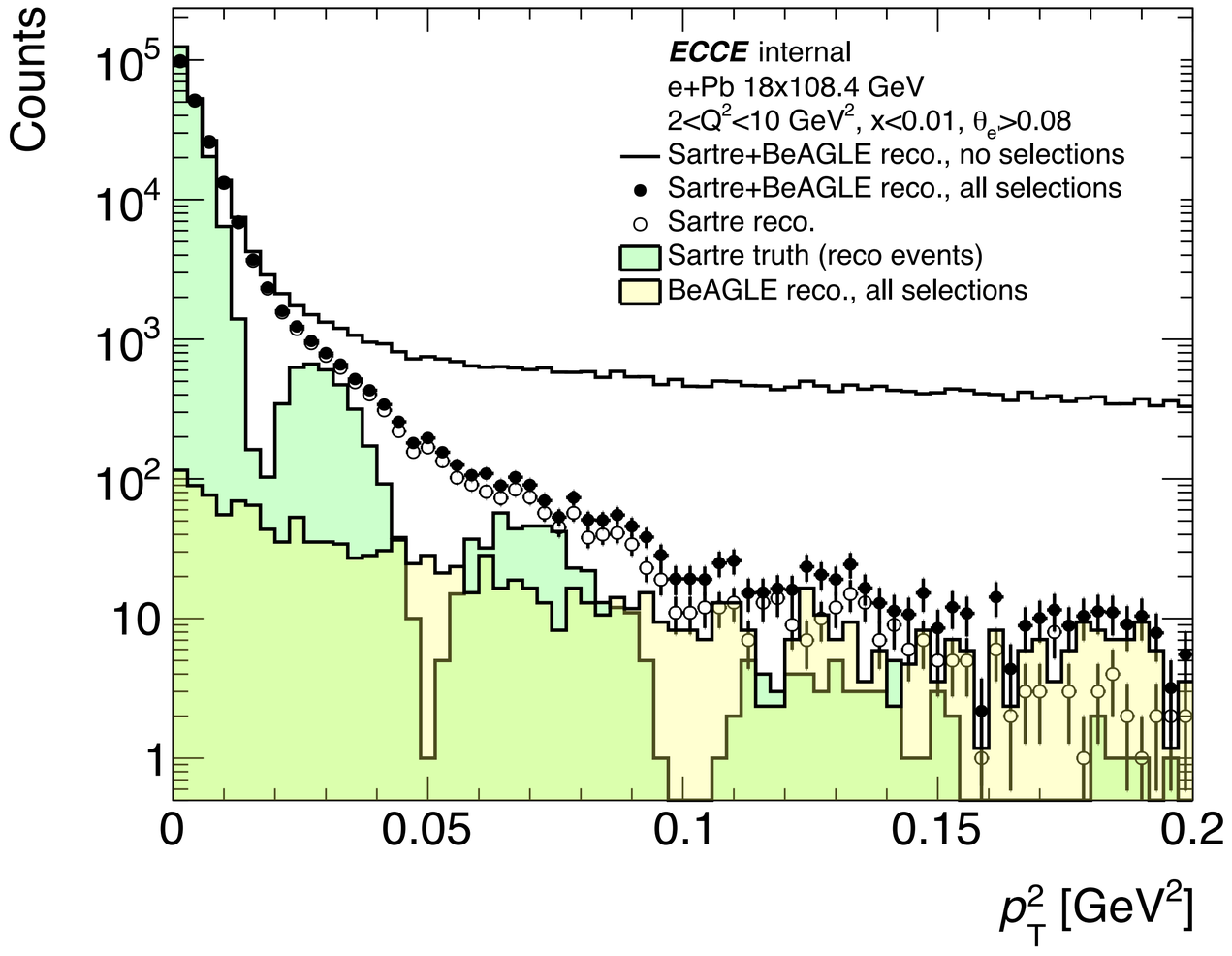
$$p_T^2 \approx (\vec{p}_{J/\psi,T} + \vec{p}_{e',T})^2$$

Diffractive eA: study of exclusive J/ψ production in ePb



- exactly three tracks in ECCE detector
- requirement on far-forward detector signals

Diffractive eA: study of exclusive J/ψ production in ePb



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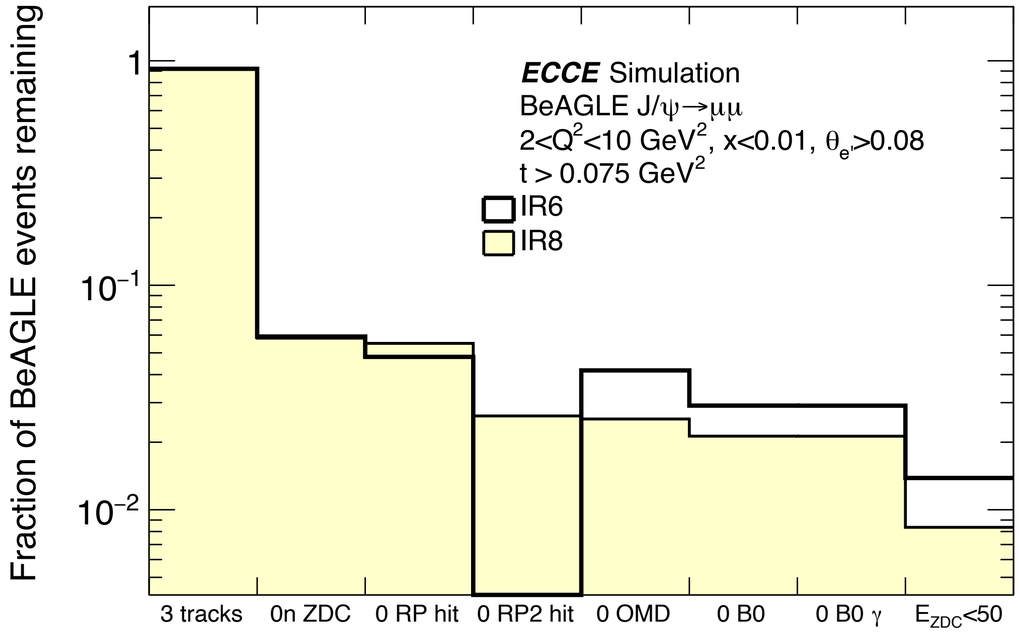
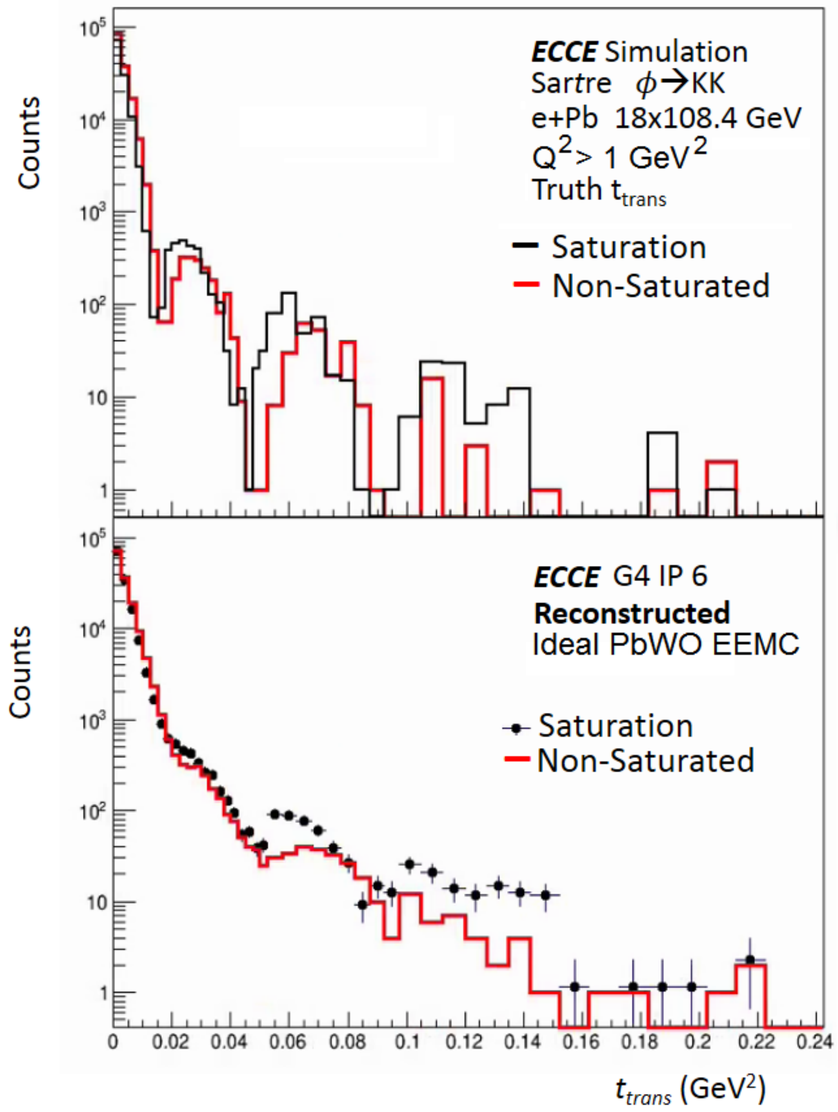
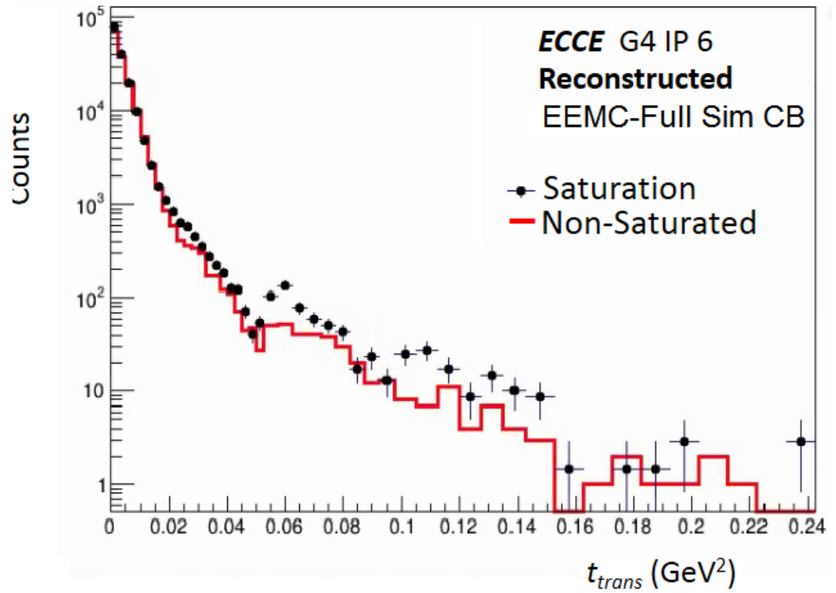


Diffractive eA: study of exclusive ϕ production in ePb

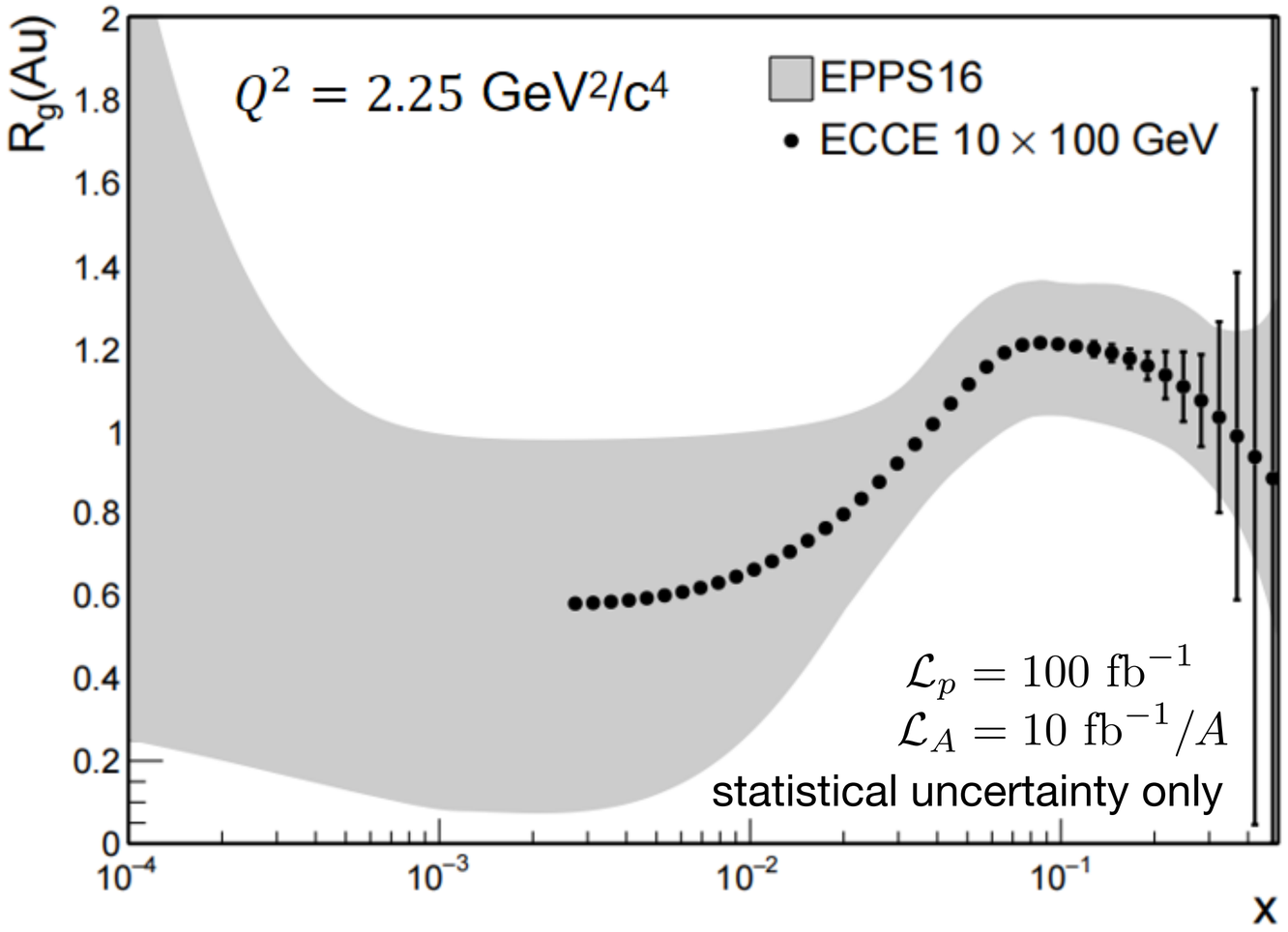
→ higher sensitivity to gluon saturation than J/ψ



- Search for saturation via shift in t spectrum
- Optimisation of detector configuration and analysis: expected performance in between ‘EEMC-Full Sim’ and ‘Ideal EEMC’



Exclusive J/ψ photo-production in ep and eAu



At low x_B: approximate access to gluon PDF

$$\left.\frac{d\sigma}{dt}\right|_{t=0} \propto [g(x_B)]^2$$

M. G. Ryskin, Z. Phys. C57 (1993) 89–92;
S. P. Jones et al., arXiv:1609.09738

- ratio eAu and ep measurements → constrain nuclear PDFs in low x region where uncertainties at present are large

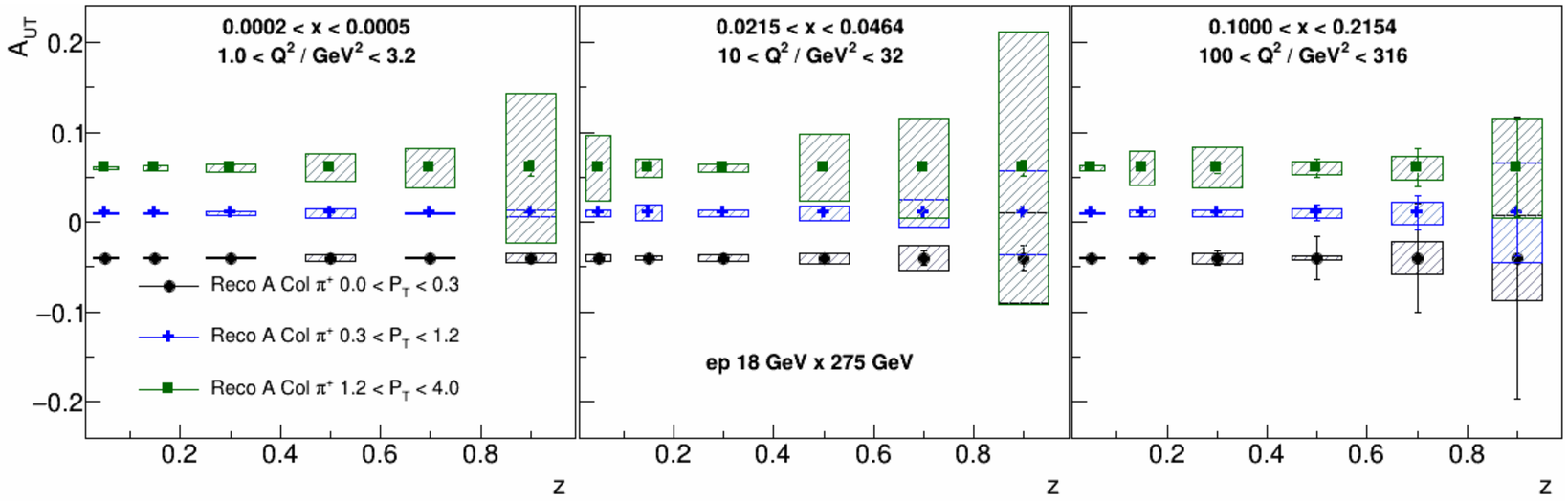
Summary

- ECCE can address various low-x physics topics through:
  - Precise inclusive (spin-dependent) DIS measurements via high-resolution EM calorimeters.
  - Measurements for 3D (spin-dependent) tomography in momentum space provided by good Cherenkov-based and TOF AC-LGAD hadron PID detectors and tracking.
  - Very good jet resolution via 1.4 T field, thin magnet, good hadron calorimetry:
    - Semi-inclusive DIS: 3D momentum tomography
    - Study of nuclear matter via heavy-flavour production and di-hadron correlations in jets.
  - Diffractive and exclusive measurements with coherent/incoherent separation via very precise EM calorimeters and forward detector system.

Back up

Spin structure: transversity

Collins asymmetry

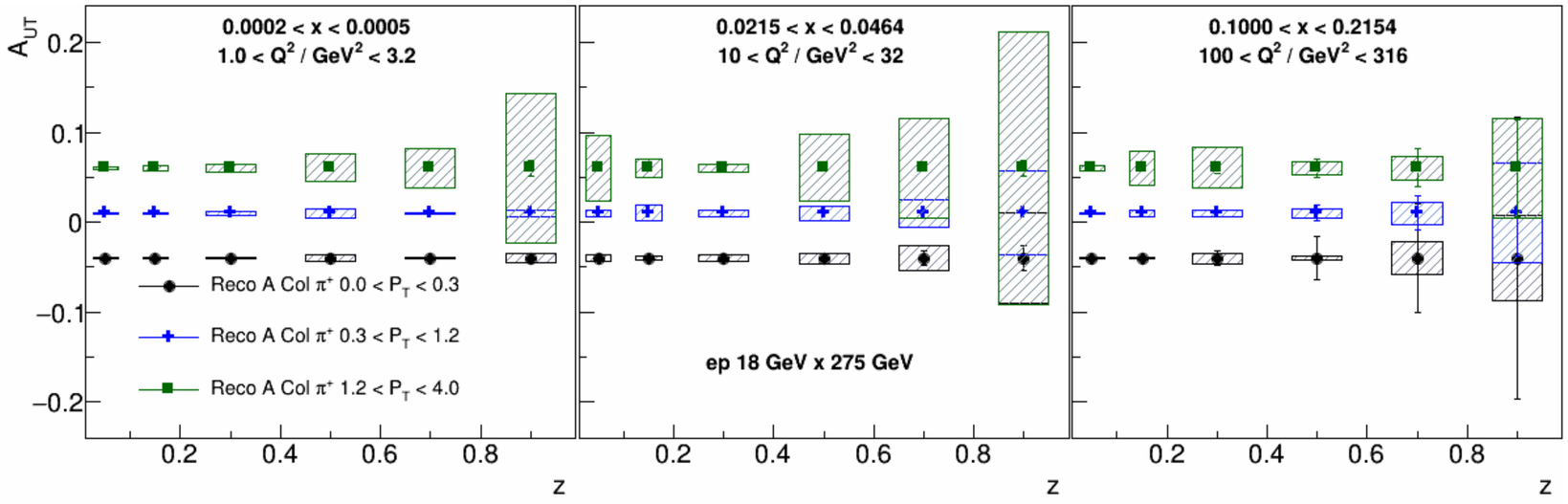


via scattered lepton only

sys. unc.= diff(gen.,rec.)

Spin structure: transversity

Collins asymmetry



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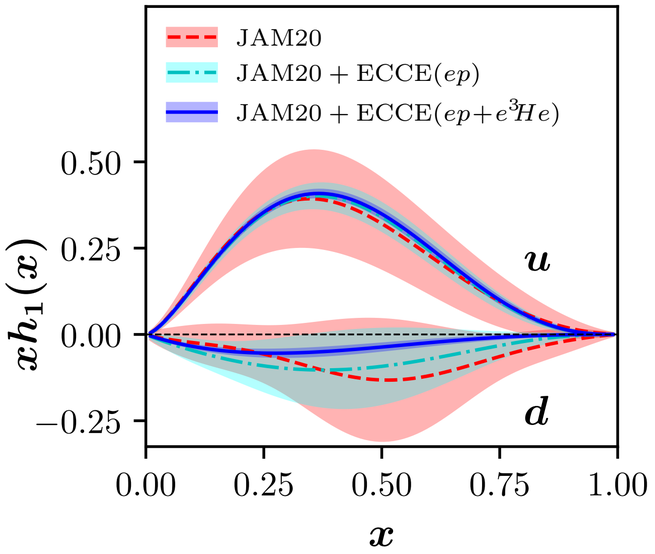
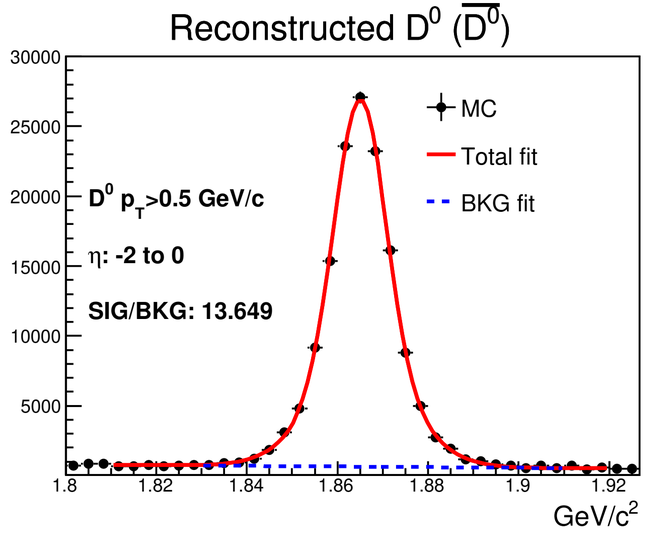
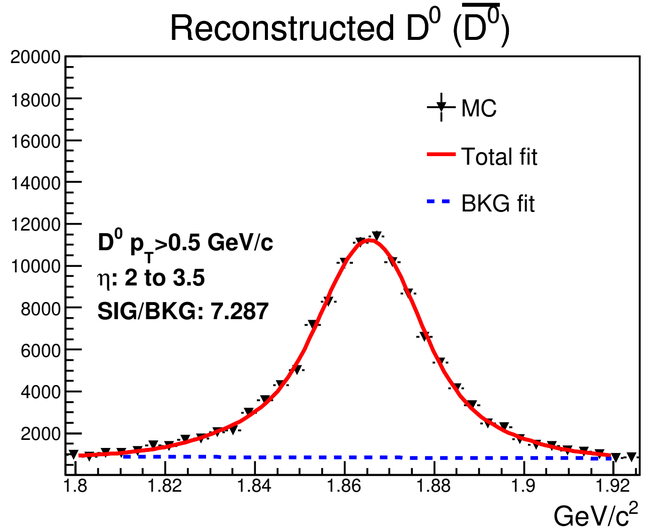
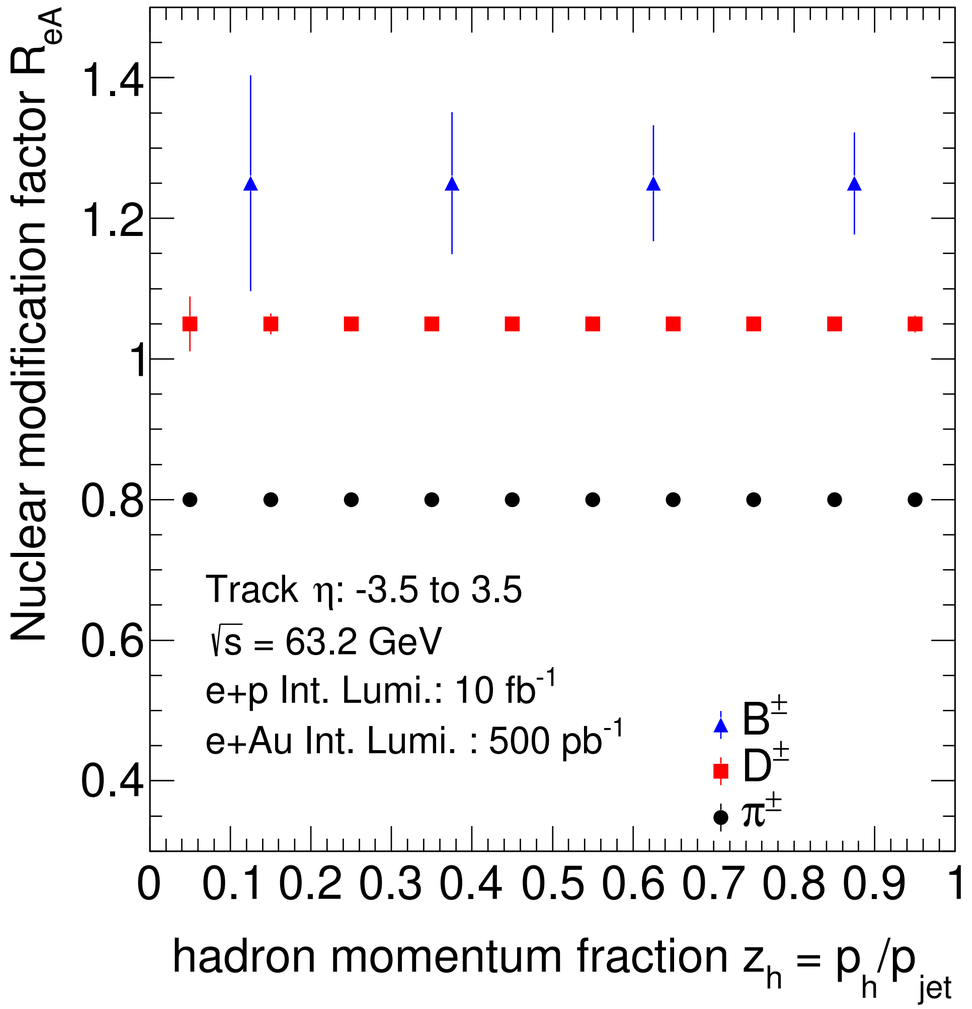


Open heavy-flavour production



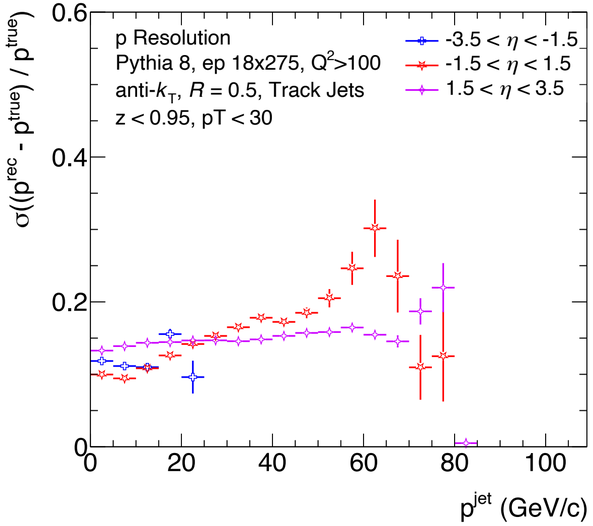


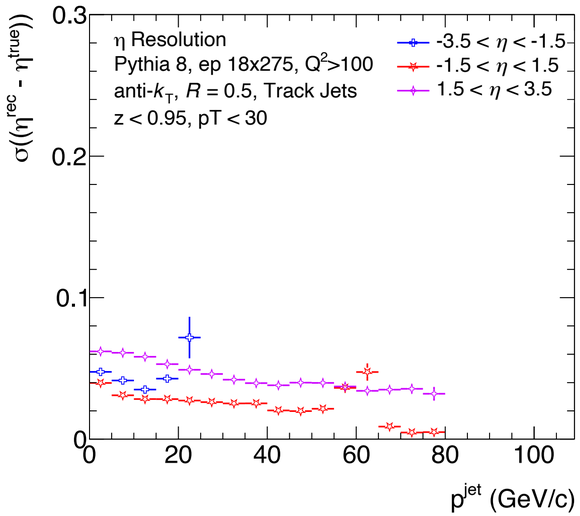
statistical uncertainty only

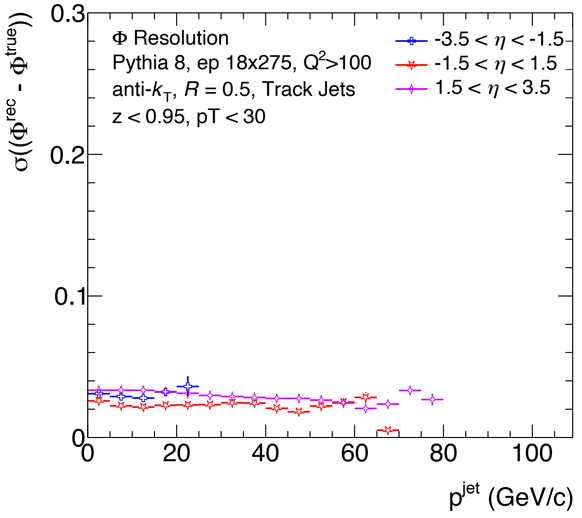


Jet resolution

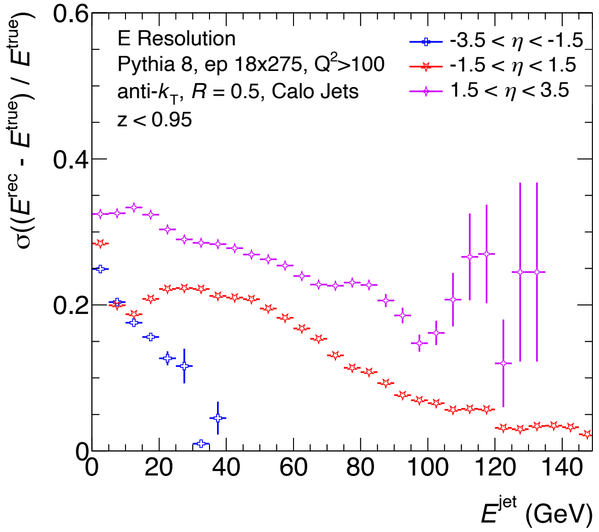
- Track jet resolution

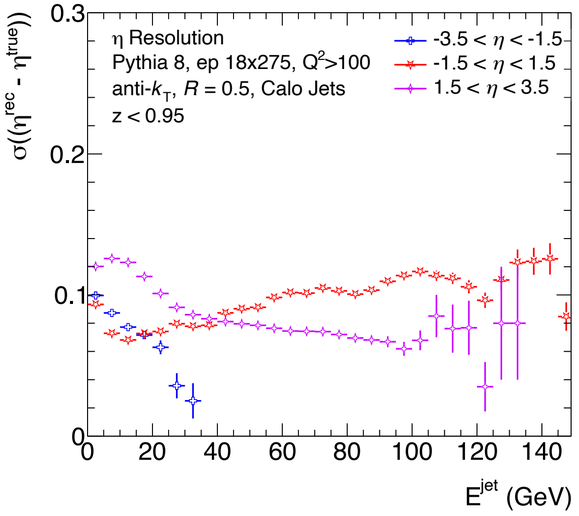


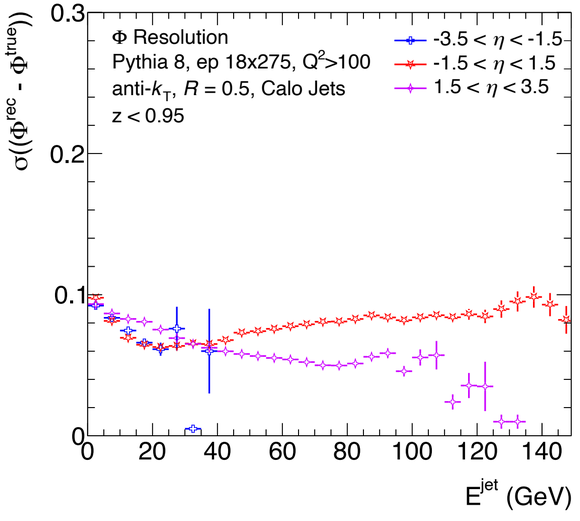




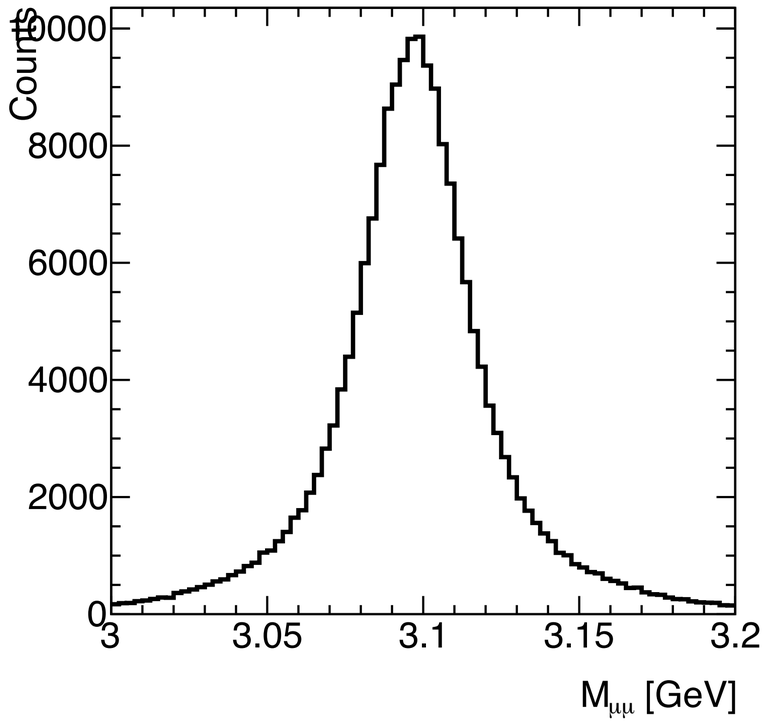
- Calo jet resolution

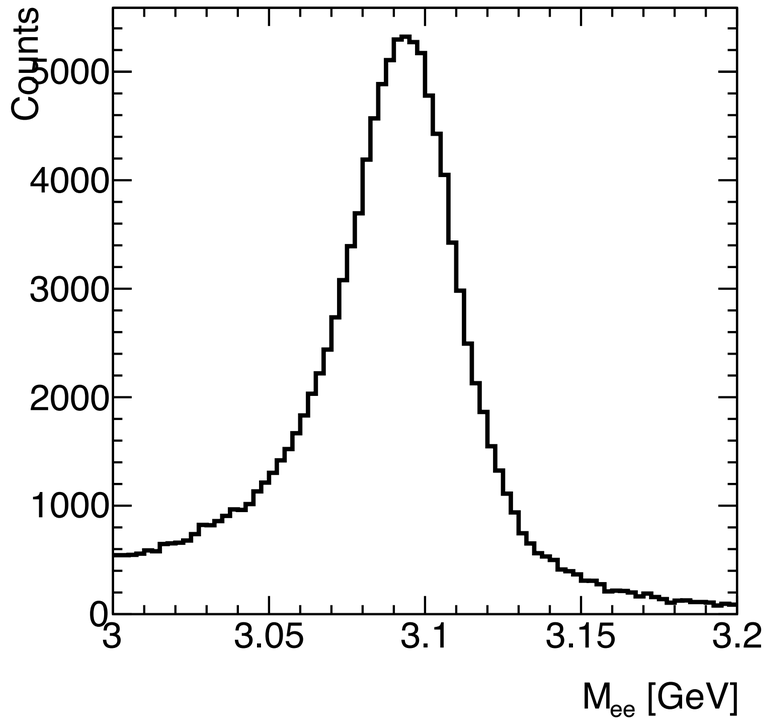






Diffractive eA: study of exclusive J/ψ production in ePb

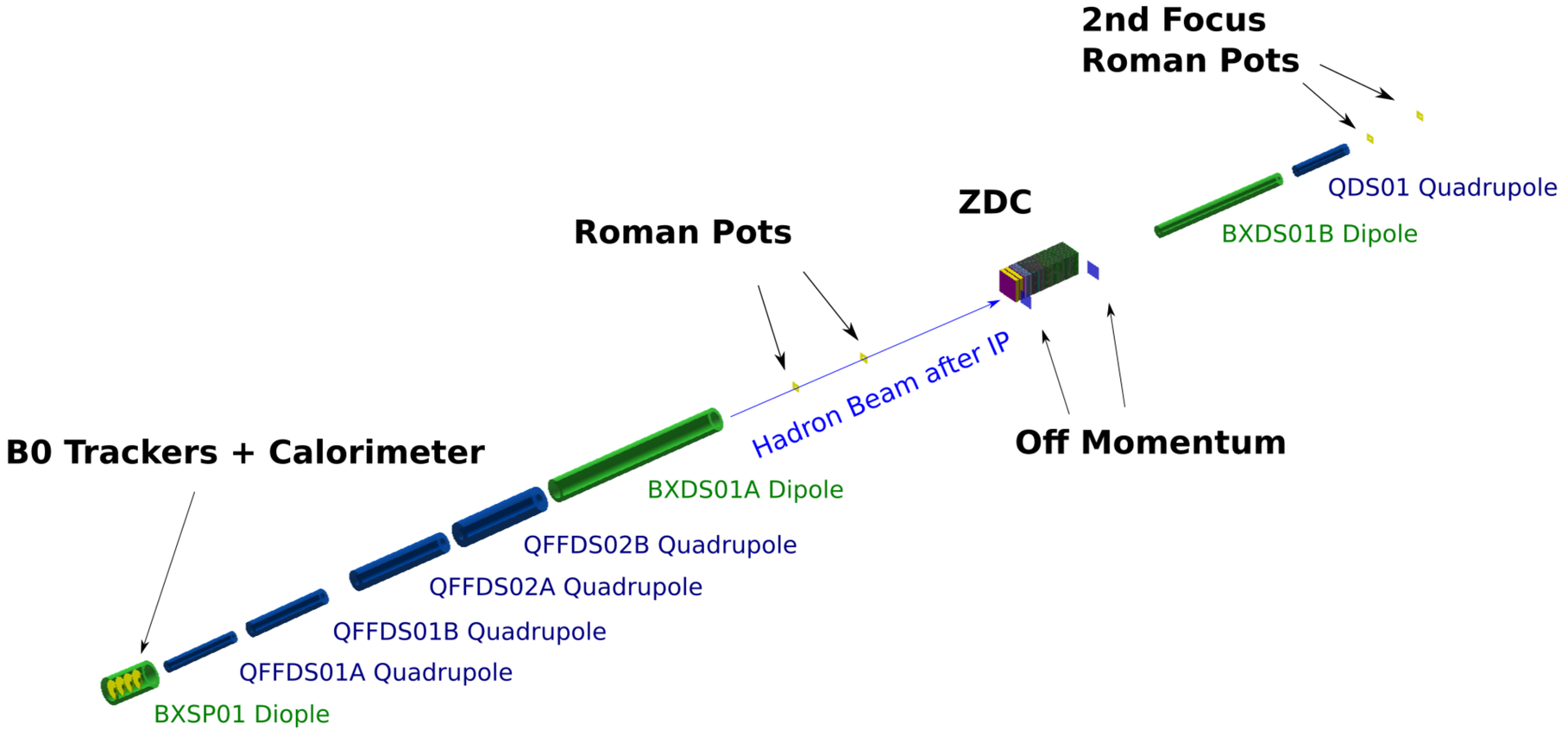




Sartre (coherent) + Beagle (incoherent)

true PID

IP 8


2nd Focus
Roman Pots
QDS01 Quadrupole
BXDS01B Dipole
ZDC
Roman Pots
Hadron Beam after IP
Off Momentum
B0 Trackers + Calorimeter
BXDS01A Dipole
QFFDS02B Quadrupole
QFFDS02A Quadrupole
QFFDS01B Quadrupole
QFFDS01A Quadrupole
BXSP01 Diople

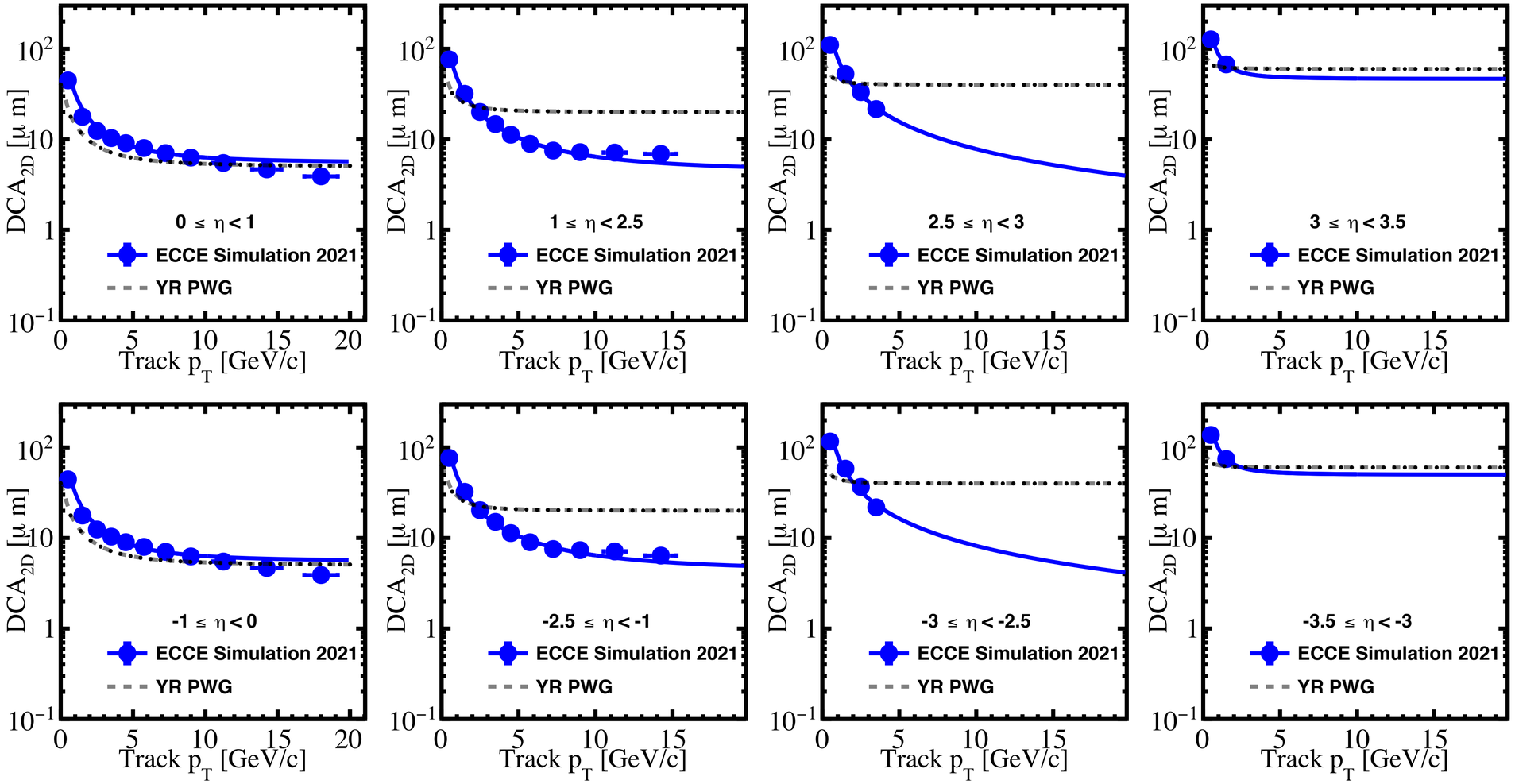


Figure 2.8: Pion DCA_{2D} resolutions (data points), which is compared to the EIC YR PWG requirement (dashed lines). The ECCE DCA resolution is consistent with YR requirements.