PHYSICS WITH ELECTROWEAK PROBES AT THE ELECTRON-ION COLLIDER

NILS FEEGE

CIPANP 2018

Palm Springs, California, May 29 - June 3, 2018

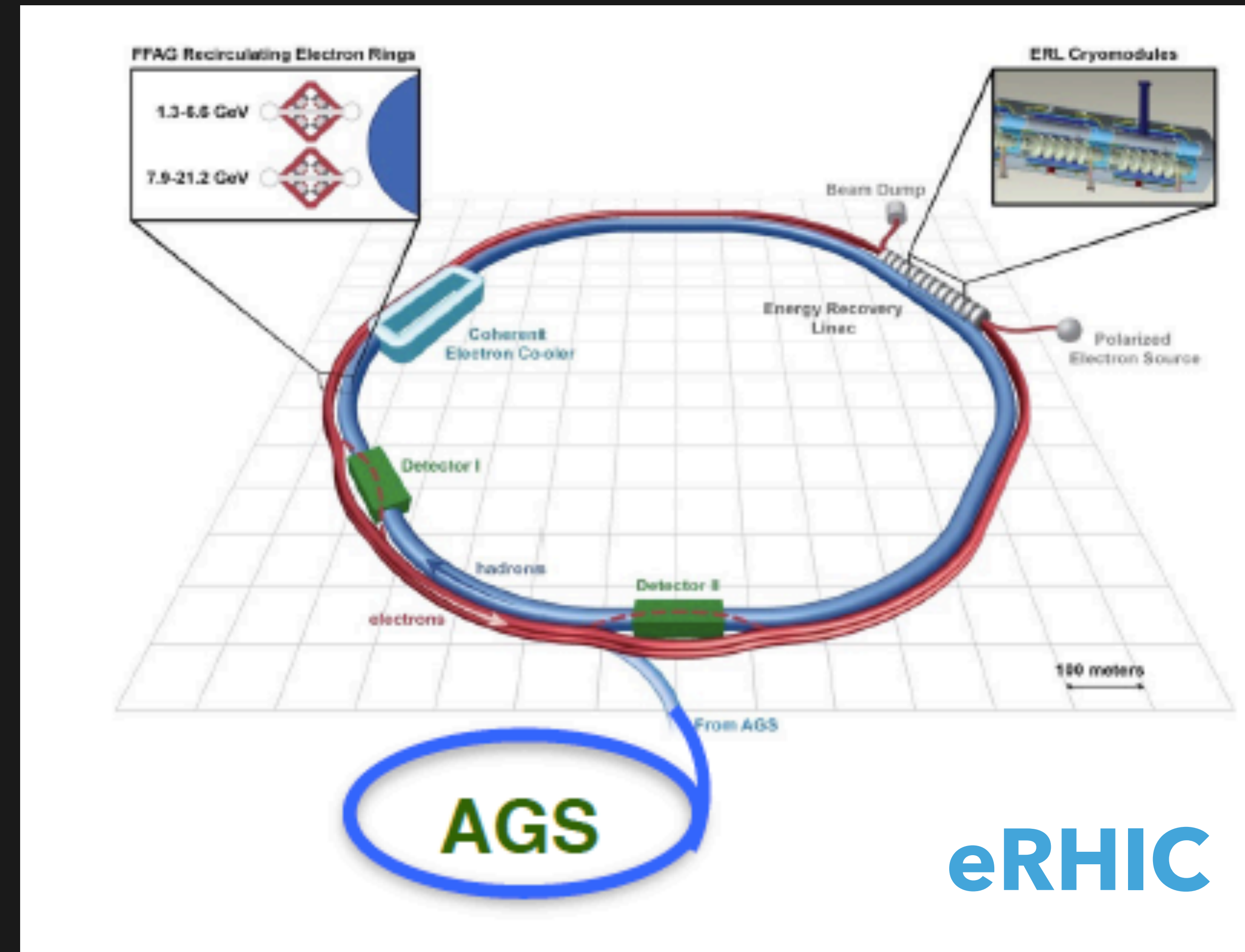
Stony Brook University

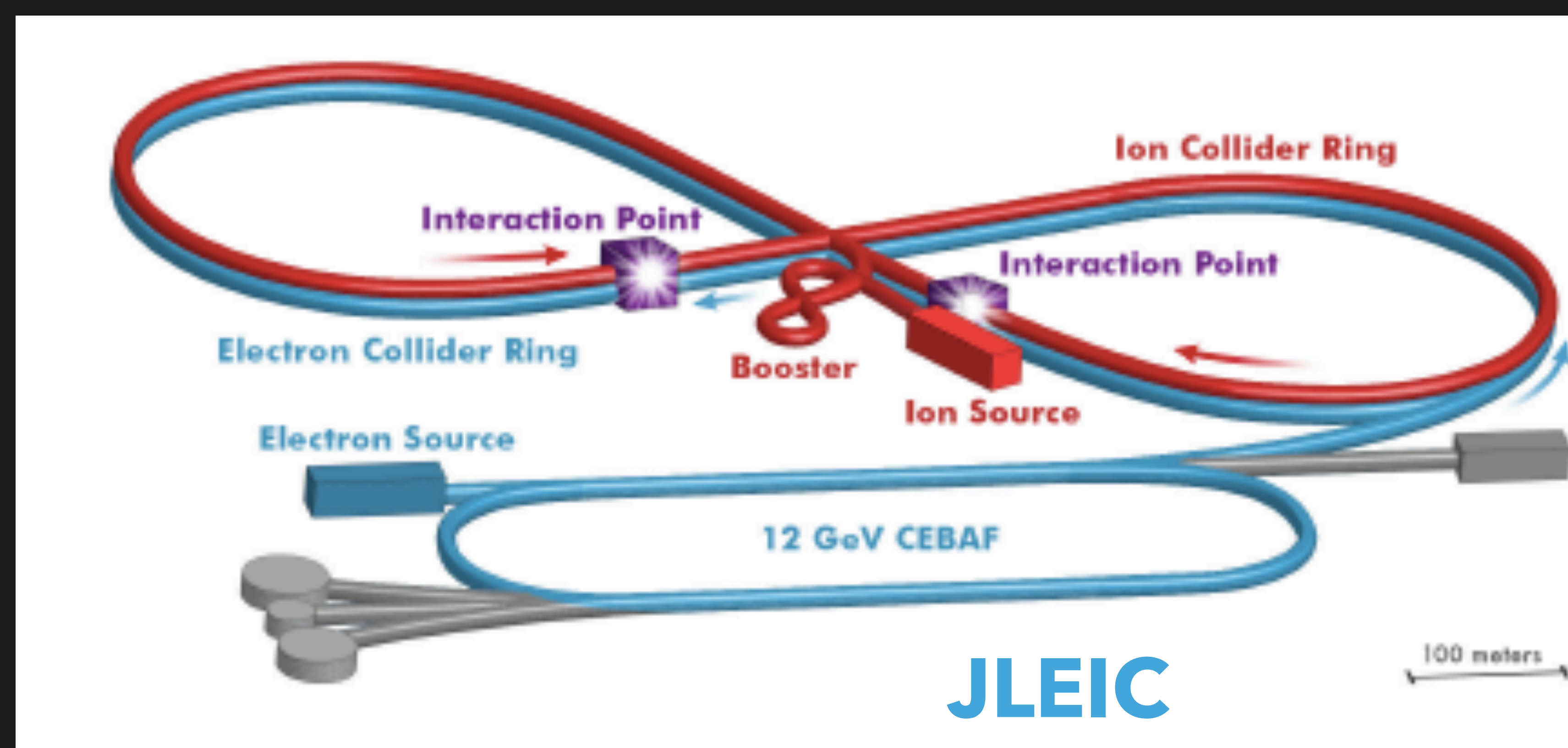
Electrons
Protons
Deuterium, ^{3}He
Nuclei up to Uranium

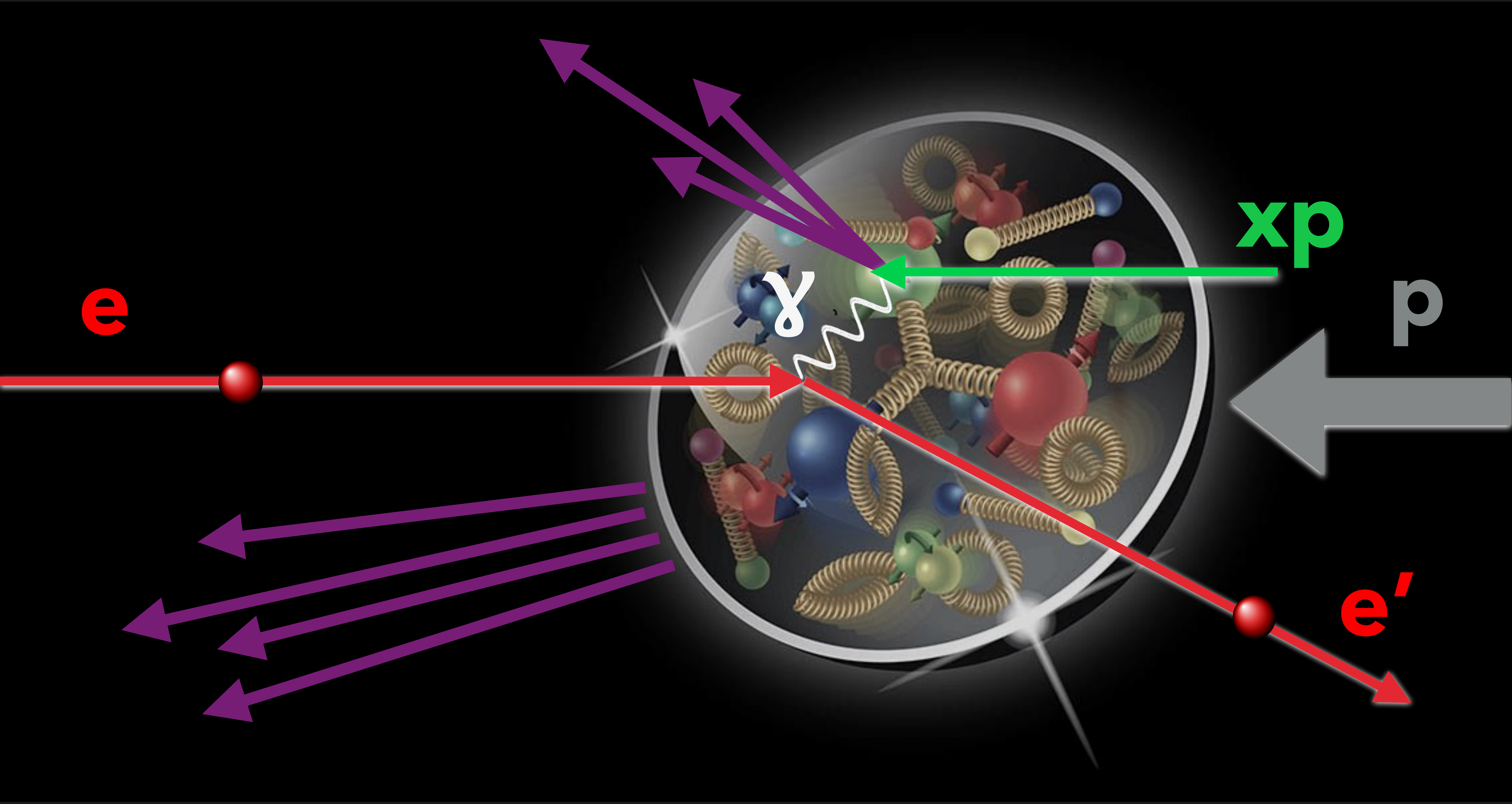
} **Spin Polarized!**

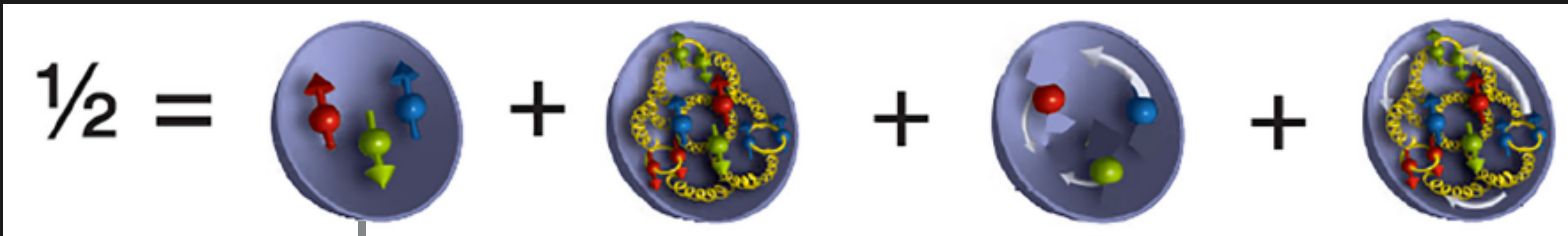
$\sqrt{s}$ = 32 GeV … **141 GeV**

$L_{ep} = 10^{33}$ … $\mathbf{10^{34}}$ cm^{-2}s^{-1}

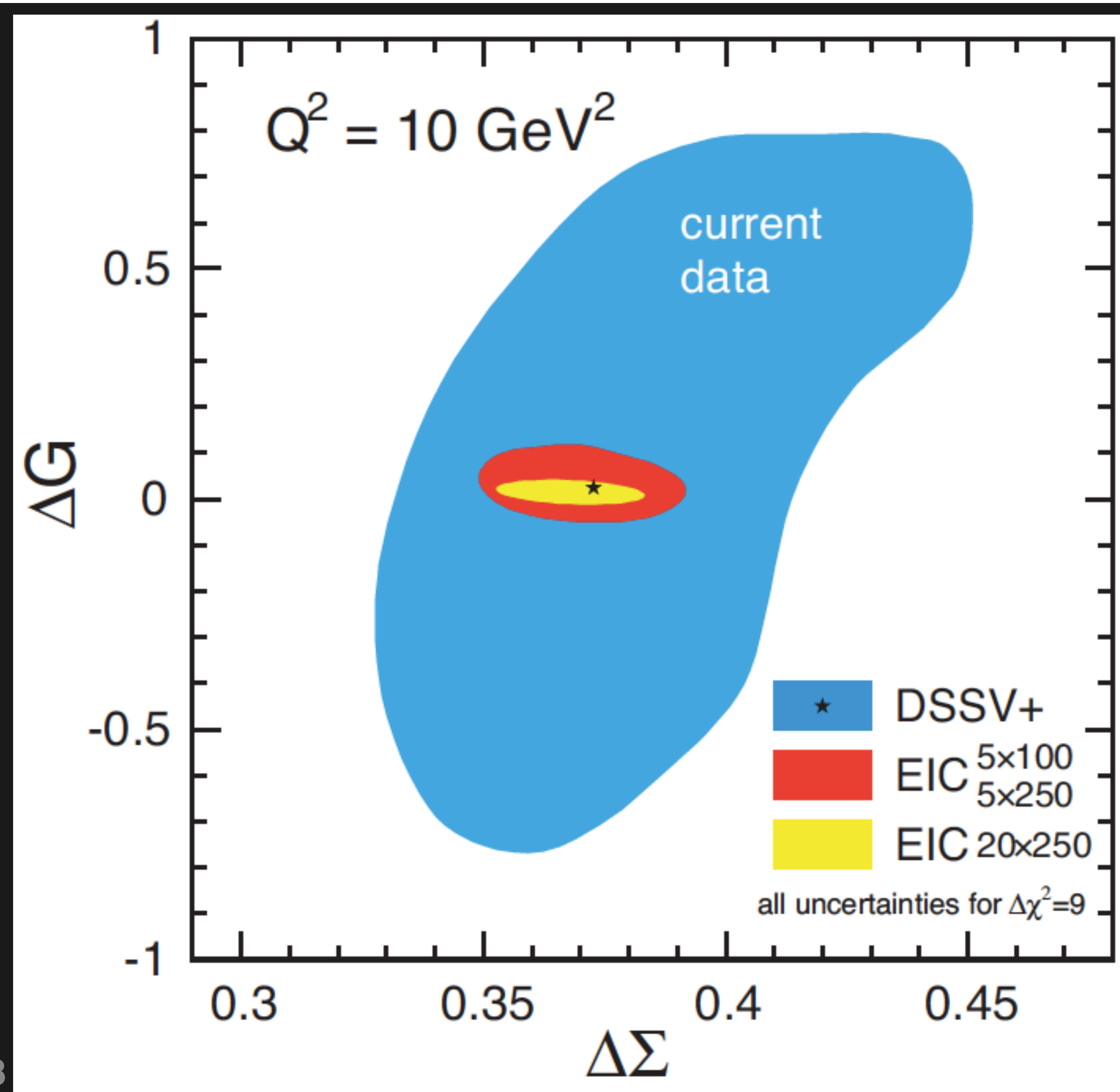





xp
e
γ
p
e′

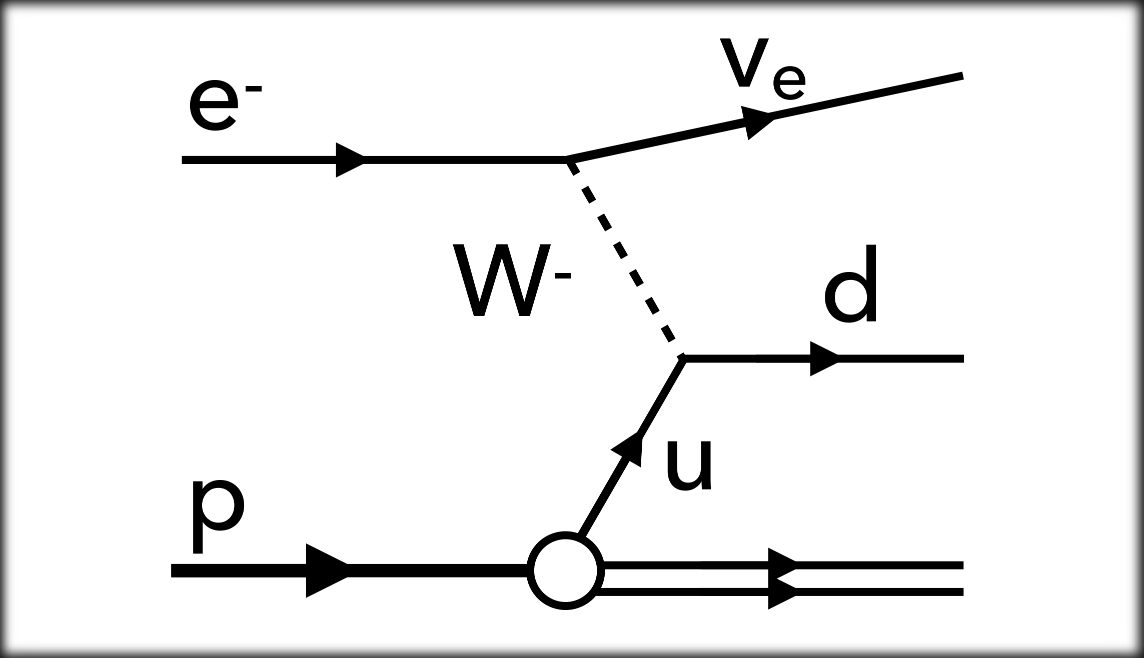


$$\sum_f \Delta q_f + \Delta \bar{q}_f$$



Eur.Phys.J. A52 (2016) no.9, 268

ASYMMETRIES IN CHARGED CURRENT DIS ACCESS NEW FLAVOR COMBINATIONS.



$$A^{W^-,p} = \frac{2\, b\, g_1^{W^-,p} - a\, g_5^{W^-,p}}{a\, F_1^{W^-} + b\, F_3^{W^-}}$$

a, b: kinematics factors

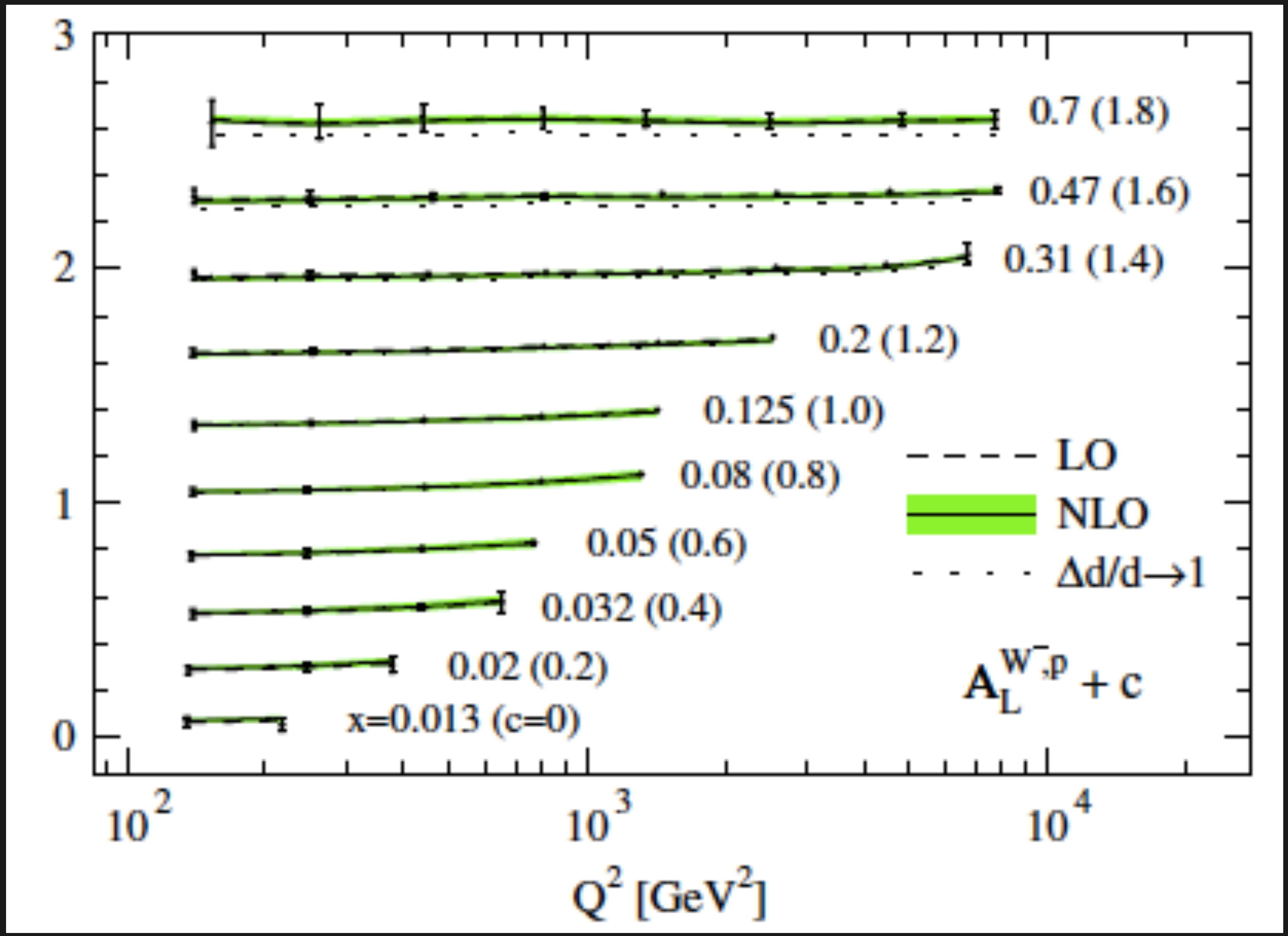
F_1^{W-}, F_3^{W-}: unpolarized structure functions

$$g_1^{W^-,p}(x) = \Delta u(x) + \Delta \bar{d}(x) + \Delta c(x) + \Delta \bar{s}(x)$$

$$g_5^{W^-,p}(x) = -\Delta u(x) + \Delta \bar{d}(x) - \Delta c(x) + \Delta \bar{s}(x)$$

THE ASYMMETRIES IMPROVE THE FLAVOR DECOMPOSITION OF NUCLEON SPIN CONTRIBUTIONS IN GLOBAL FITS.

Phys. Rev. D 88, 114025 (2013)



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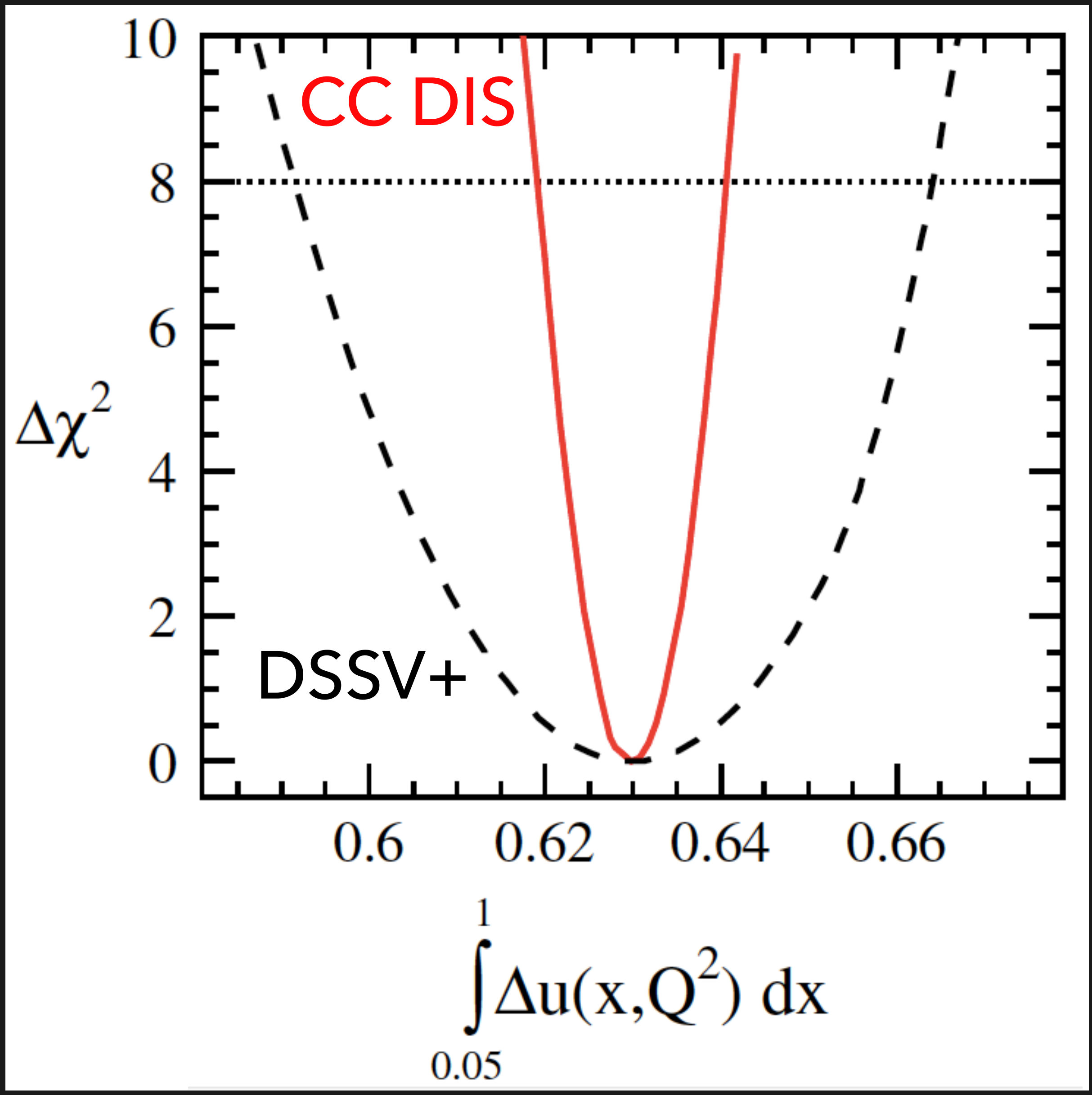


10 fb^{-1}

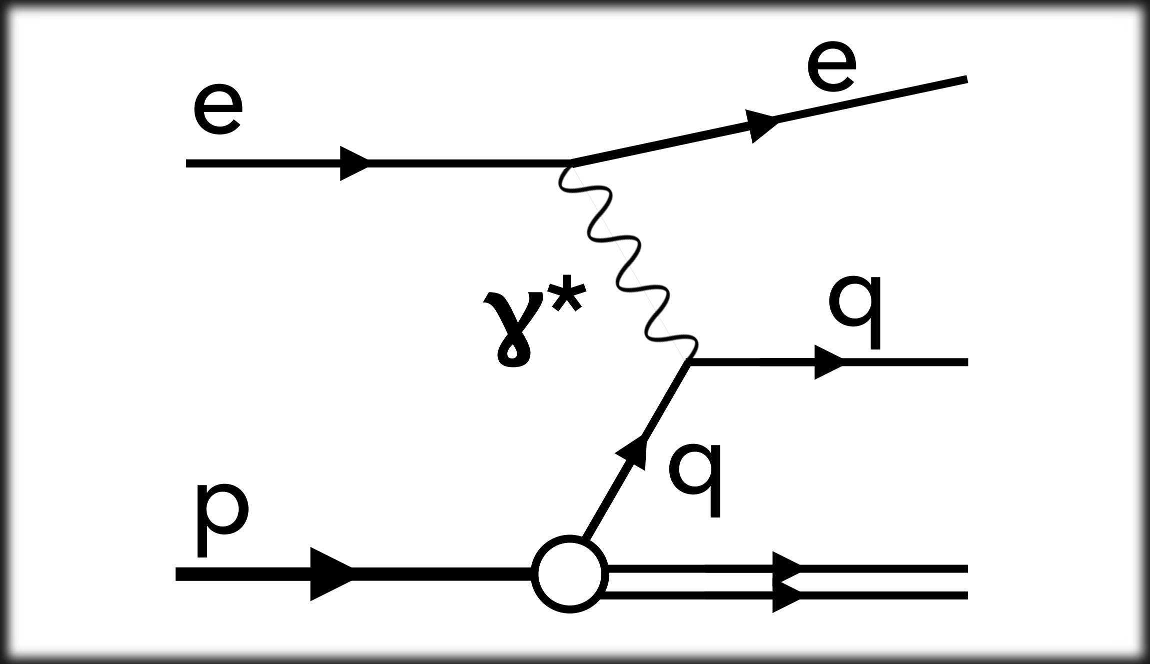
PARITY VIOLATING ASYMMETRIES ACCESS INTERFERENCE STRUCTURE FUNCTIONS.

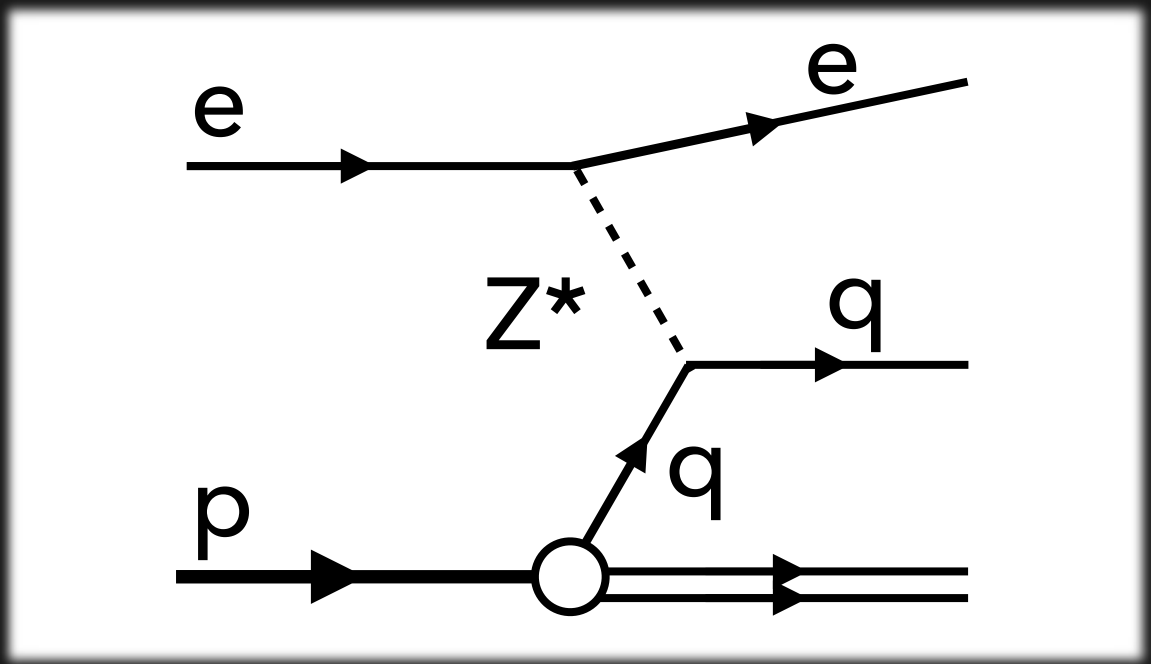
Polarized electrons, unpolarized hadrons:

$$A_{PV}^{electron} = \frac{G_F\, Q^2}{2\sqrt{2}\pi\alpha}\left[g_A^e\, \frac{F_1^{\gamma Z}}{F_1^{\gamma}} + g_V^e\, \frac{Y_-}{2Y_+}\, \frac{F_3^{\gamma Z}}{F_1^{\gamma}}\right]$$

Polarized hadrons, unpolarized electrons:

$$A_{PV}^{hadron} = \frac{G_F\, Q^2}{2\sqrt{2}\pi\alpha}\left[g_V^e\, \frac{g_5^{\gamma Z}}{F_1^{\gamma}} + g_A^e\, \frac{Y_-}{Y_+}\, \frac{g_1^{\gamma Z}}{F_1^{\gamma}}\right]$$





INTERFERENCE STRUCTURE FUNCTIONS ACCESS NEW FLAVOR COMBINATIONS.

Polarized electrons, unpolarized hadrons:

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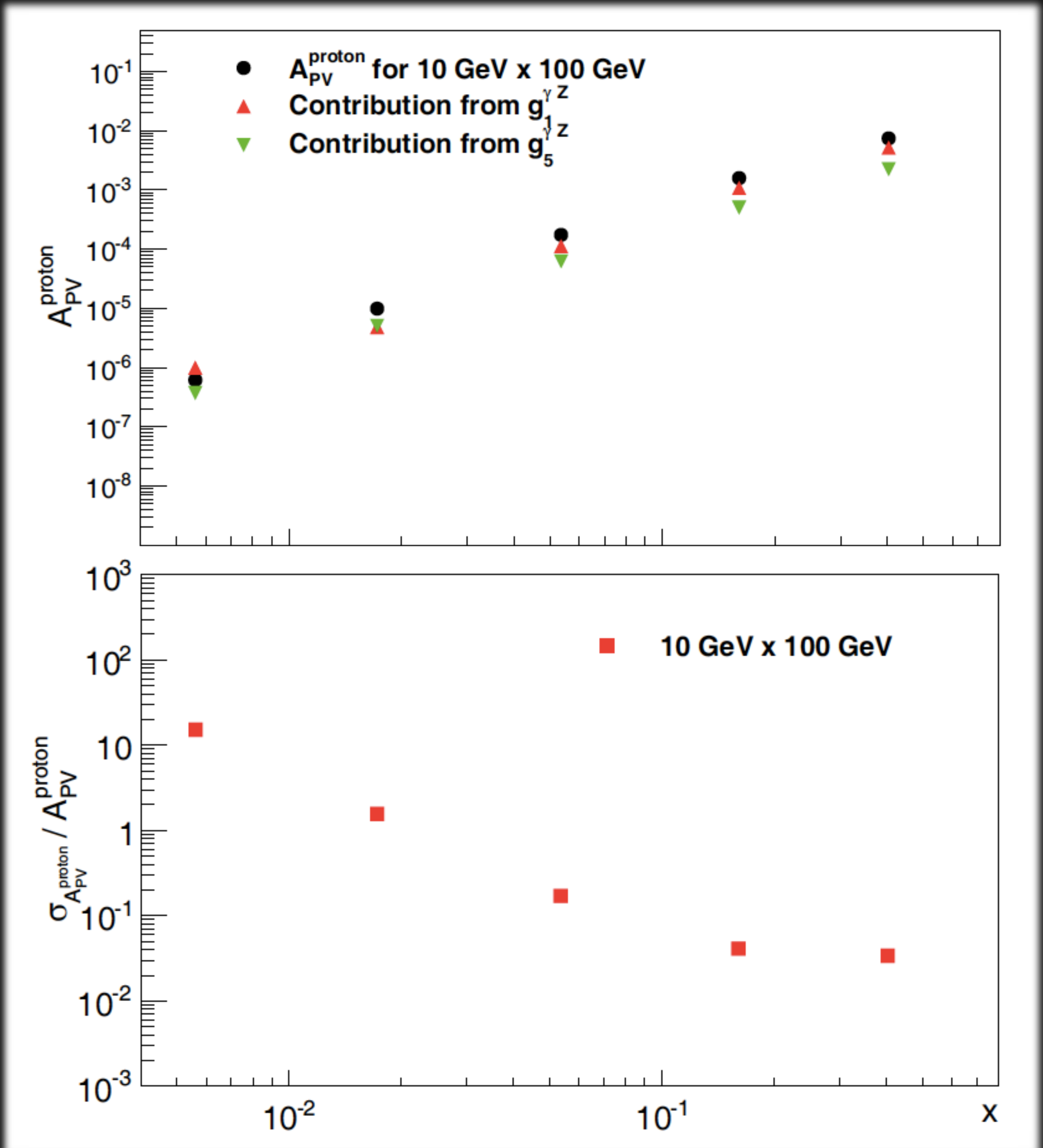
Polarized hadrons, unpolarized electrons:

$$A_{PV}^{hadron} = \frac{G_F\, Q^2}{2\sqrt{2}\pi\alpha}\left[g_V^e\, \frac{g_5^{\gamma Z}}{F_1^{\gamma}} + g_A^e\, \frac{Y_-}{Y_+}\, \frac{g_1^{\gamma Z}}{F_1^{\gamma}}\right]$$

$$g_1^{\gamma Z,p} \approx \frac{1}{9}\left(\Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} + \Delta s + \Delta\bar{s} + \Delta c + \Delta\bar{c}\right)$$

$$g_5^{\gamma Z,p} \approx \frac{1}{3}\left(\Delta u_V + \Delta c - \Delta\bar{c}\right) + \frac{1}{6}\left(\Delta d_V + \Delta s - \Delta\bar{s}\right)$$

HIGH-LUMINOSITY EIC CAN MEASURE PARITY VIOLATING ASYMMETRIES.

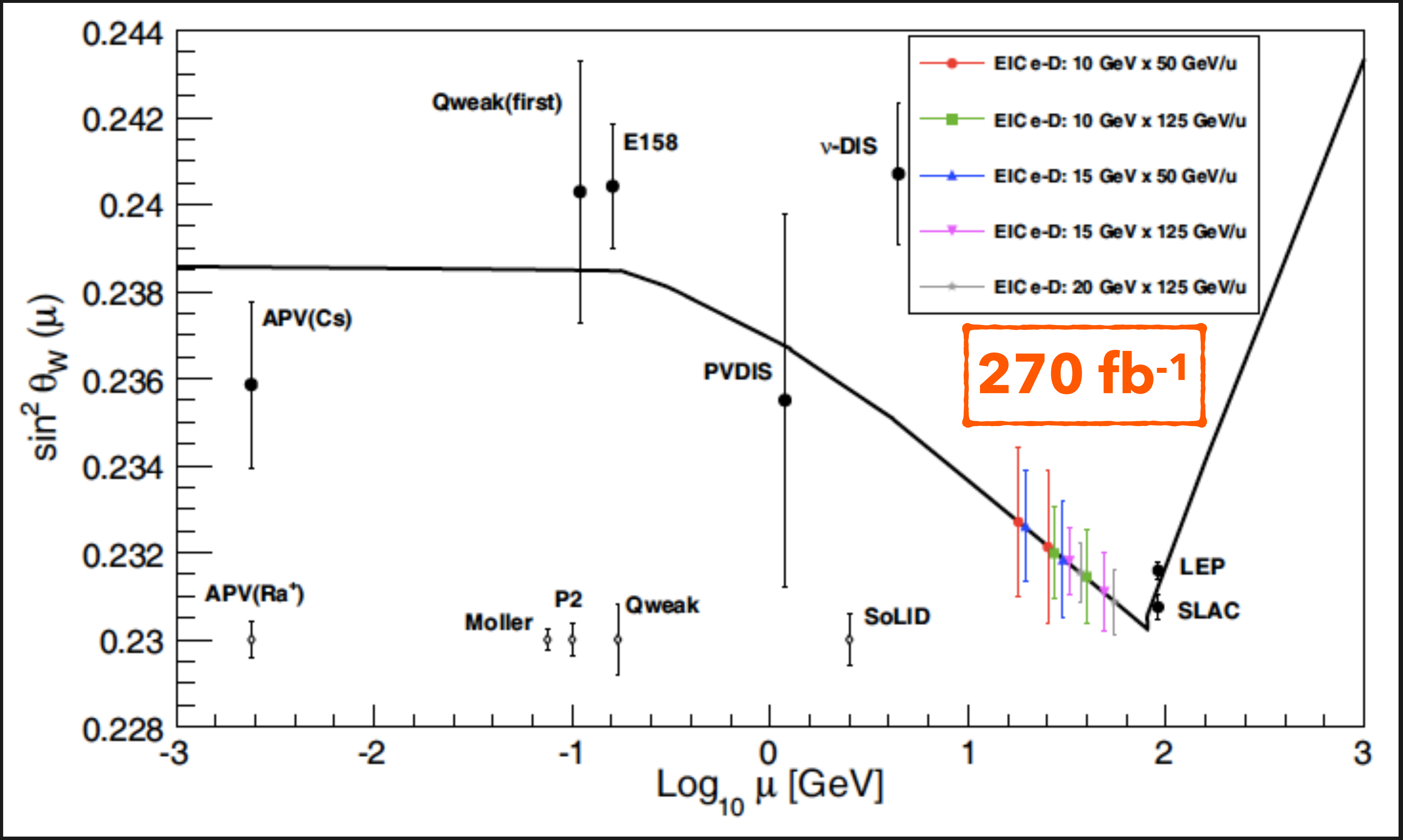


500 fb^{-1}

Eur. Phys. J. A (2017) 53: 55

DEUTERON TARGET:

$$A_{PV}^{electron} \sim \frac{20}{3} \sin^2 \theta_W - 1$$



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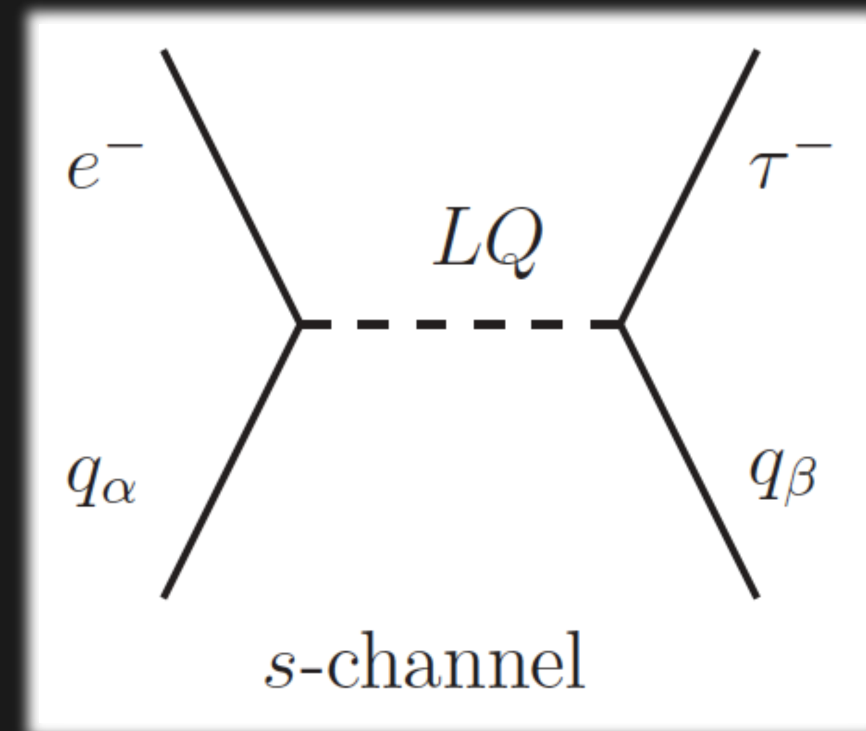
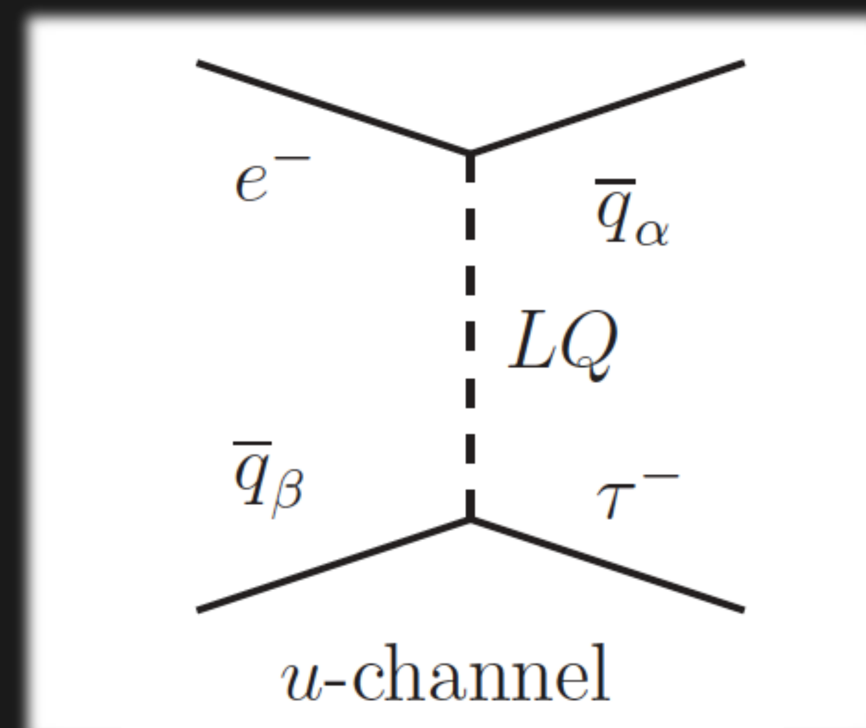
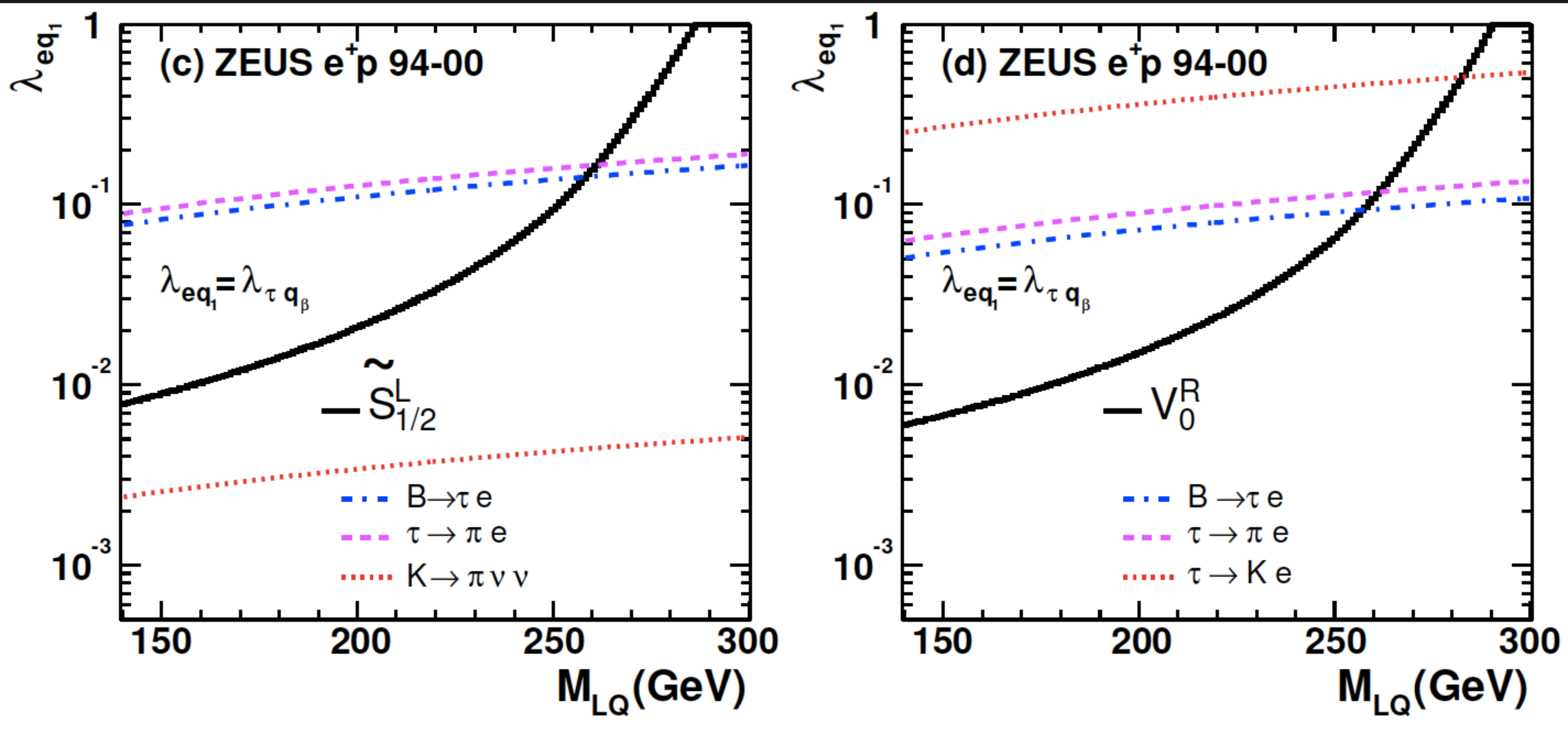
E → TAU CHARGED LEPTON FLAVOR VIOLATION VIA LEPTOQUARKS.

Griffin = Eagle + Lion





LEPTOQUARK EXCLUSION LIMITS FROM HERA.



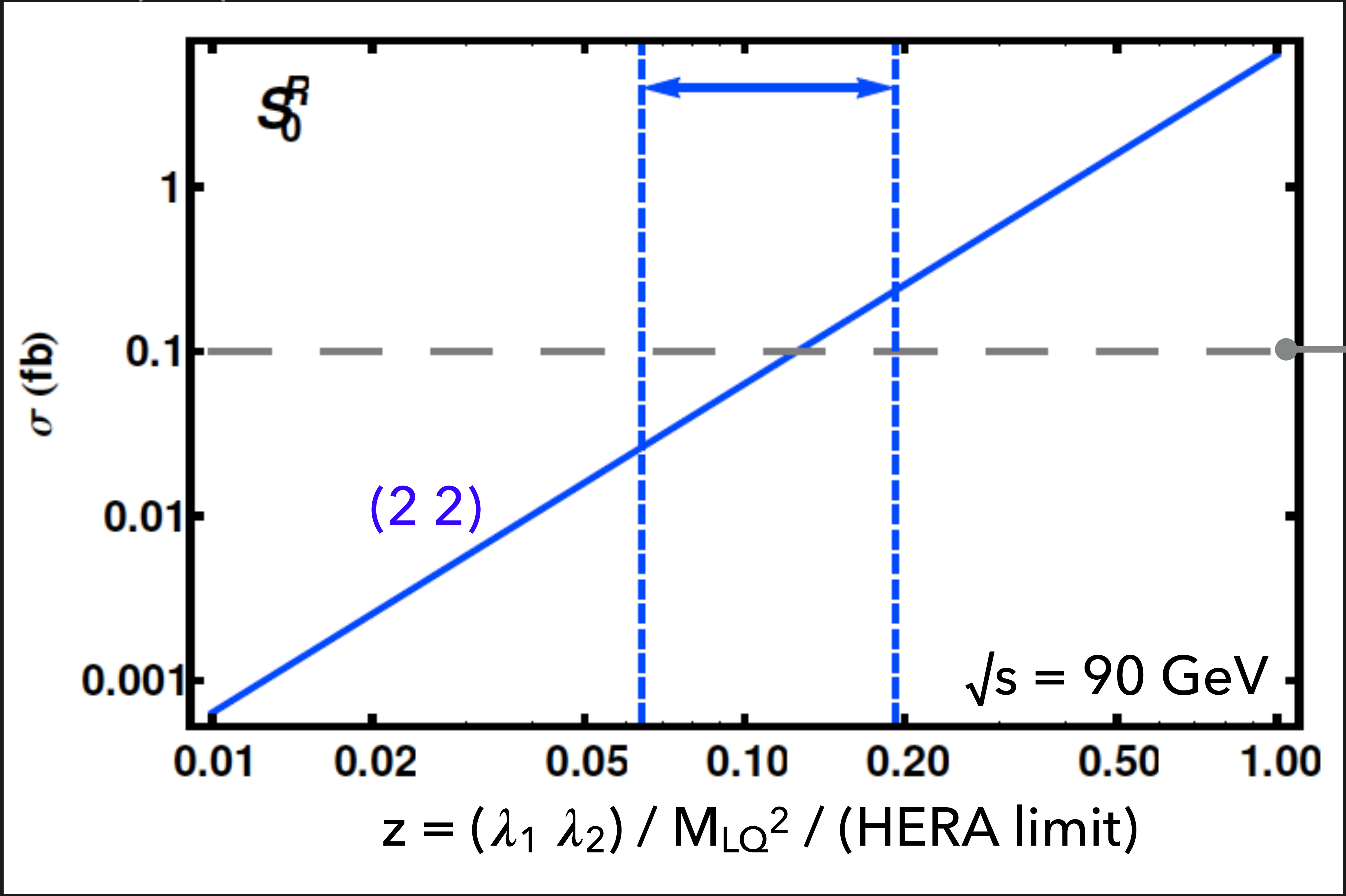
C. Veelken (H1, Zeus) (2007)

POTENTIAL TO IMPROVE LIMITS AT EIC.

10 years at $L = 10^{33}$ cm^{-2}s^{-1}

1 year at $L = 10^{34}$ cm^{-2}s^{-1}

JHEP 05 (2012) 047



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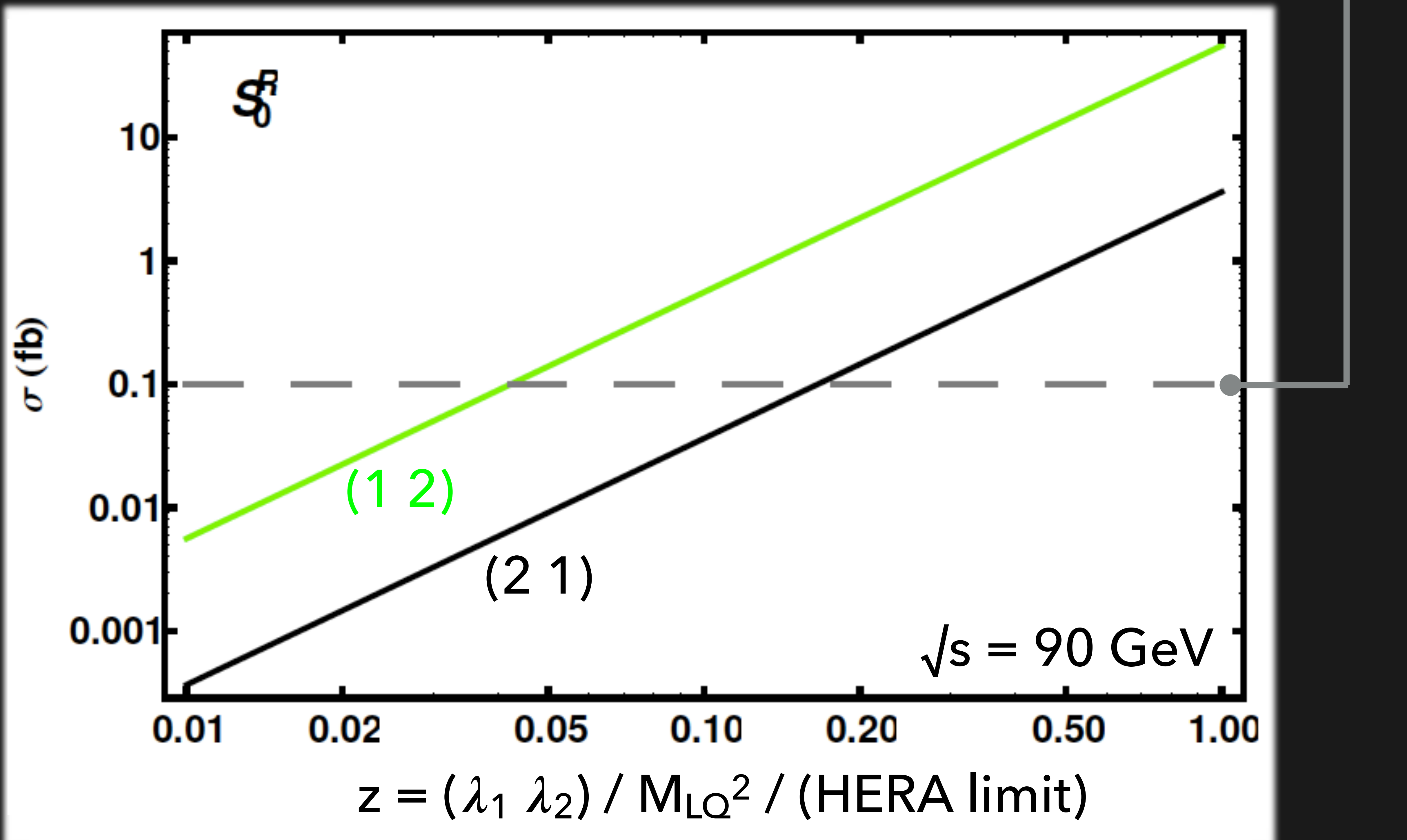
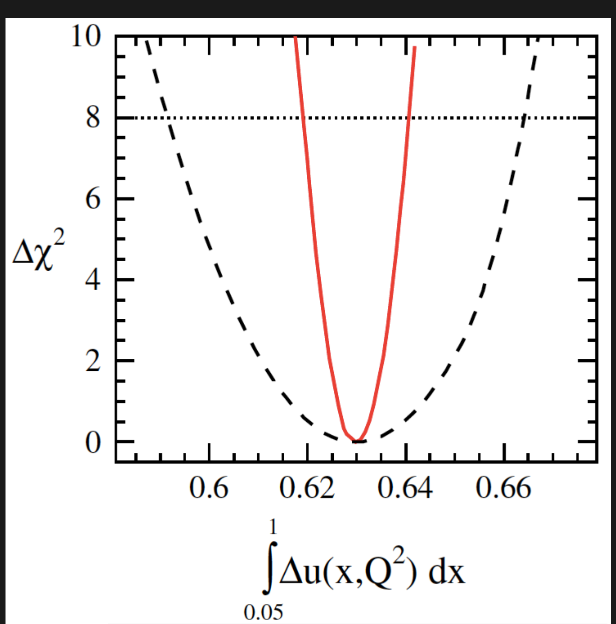
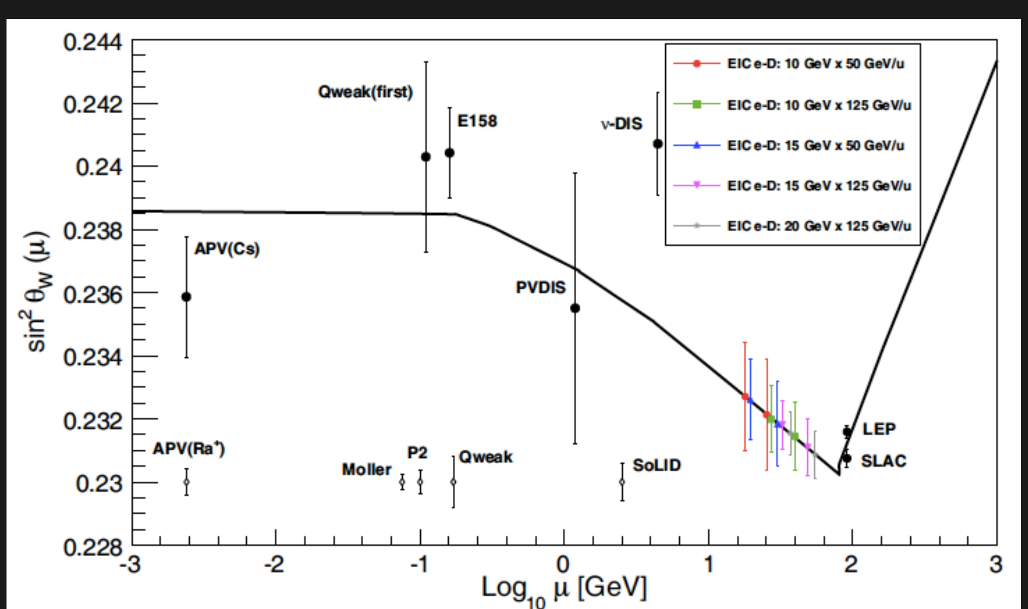
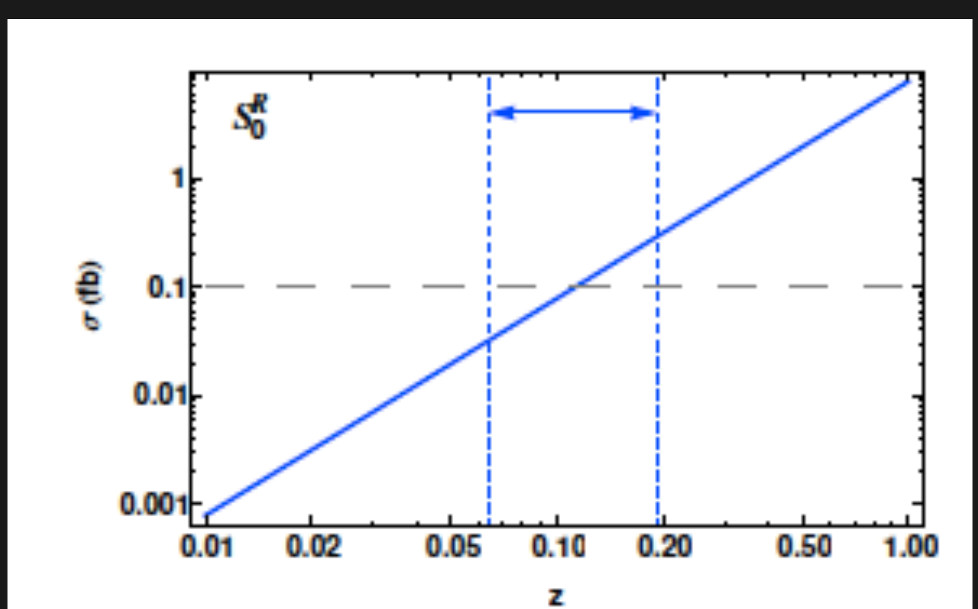


The Electron-Ion Collider will:

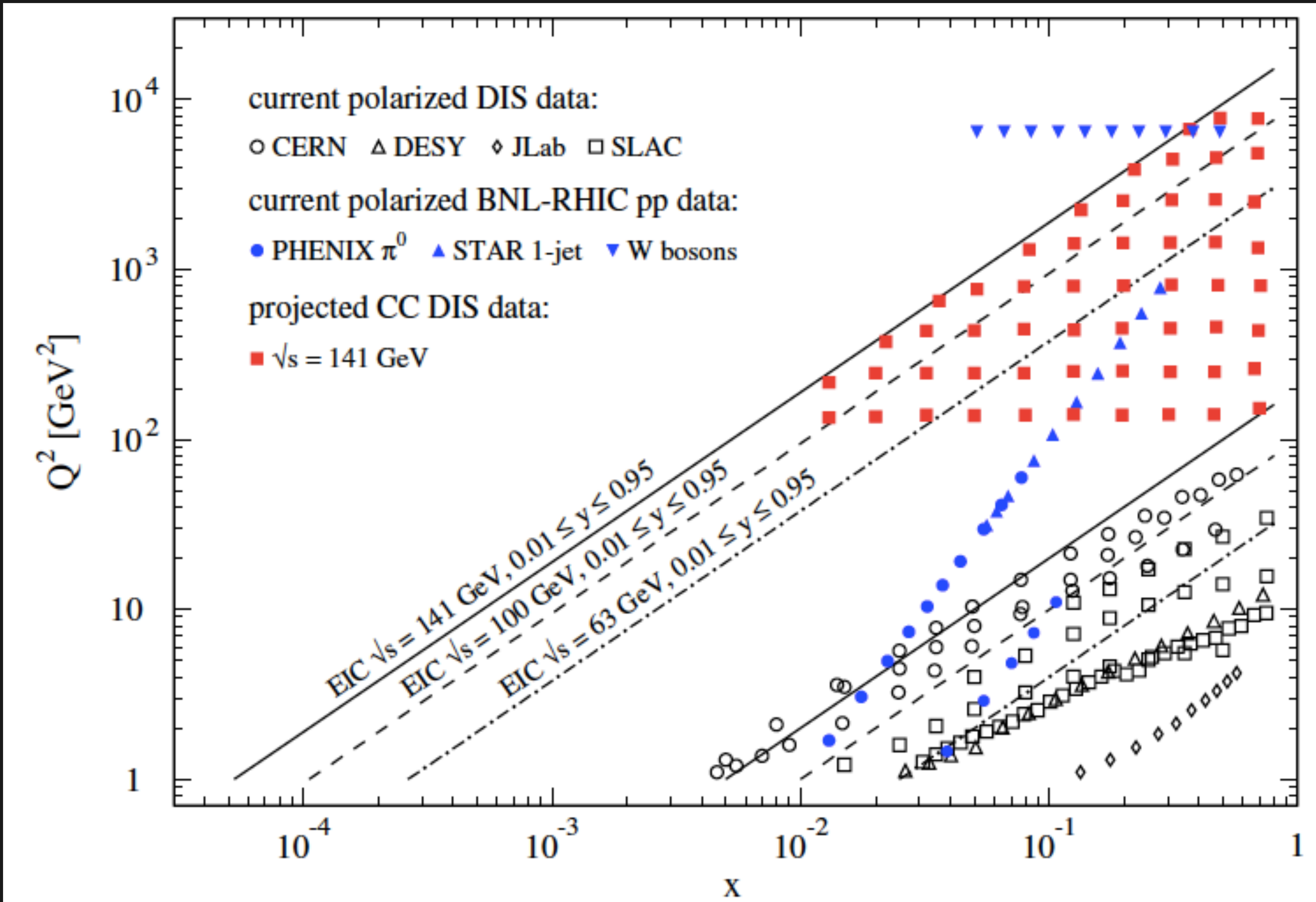
- ➡ Constrain nucleon structure functions and separate quark flavor contributions to the nucleon spin using deep inelastic scattering meditated by γ, W, and Z,
- ➡ Measure the Standard Model weak mixing angle in a new kinematics range, and
- ➡ Potentially improve experimental limits for electron-to-tau charged lepton flavor violation in search of Physics Beyond the Standard Model.







ADDITIONAL SLIDES



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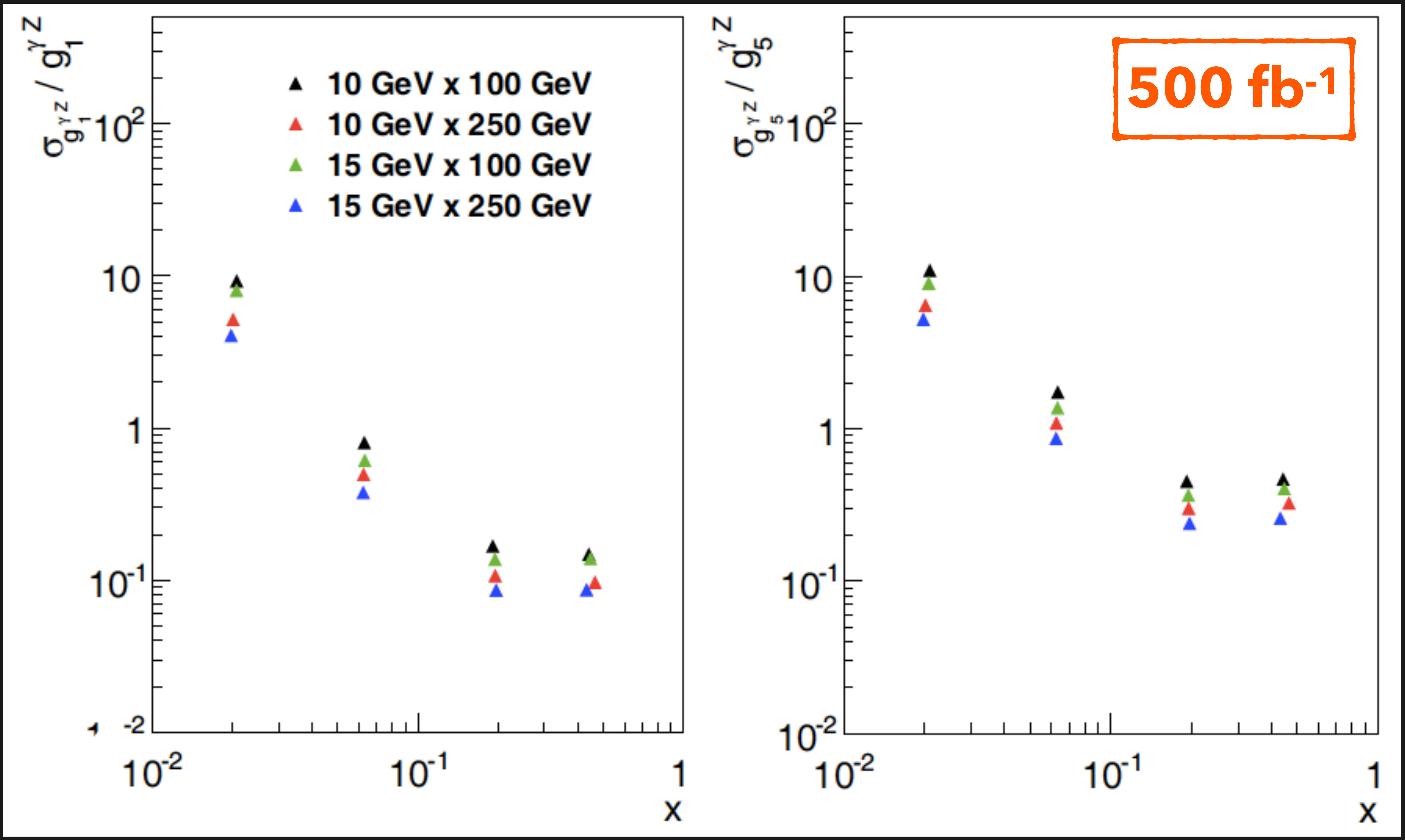
HIGH-LUMINOSITY EIC CAN CONSTRAIN INTERFERENCE STRUCTURE FUNCTIONS.



Eur. Phys. J. A (2017) 53: 55

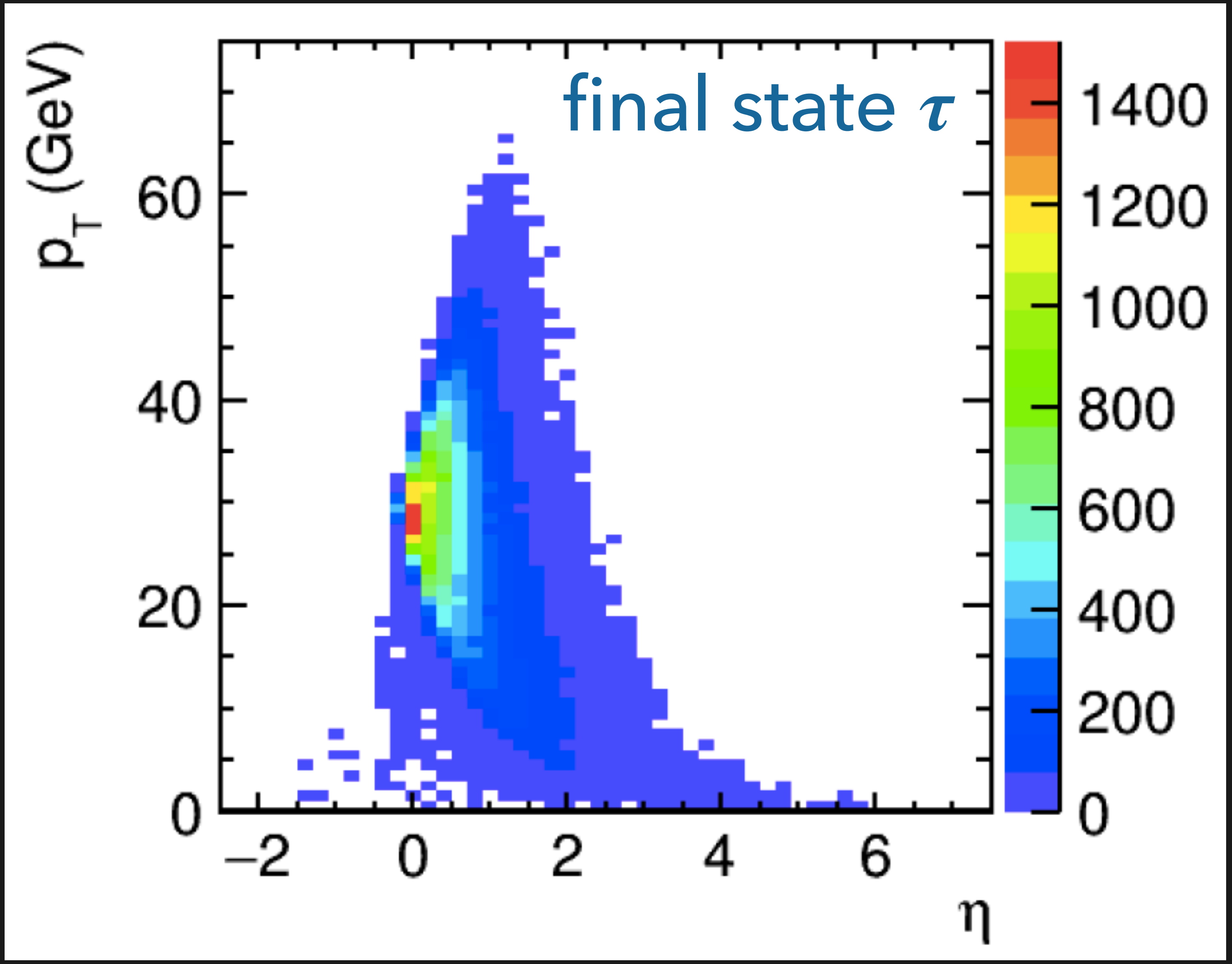
E → TAU LFV AT EIC

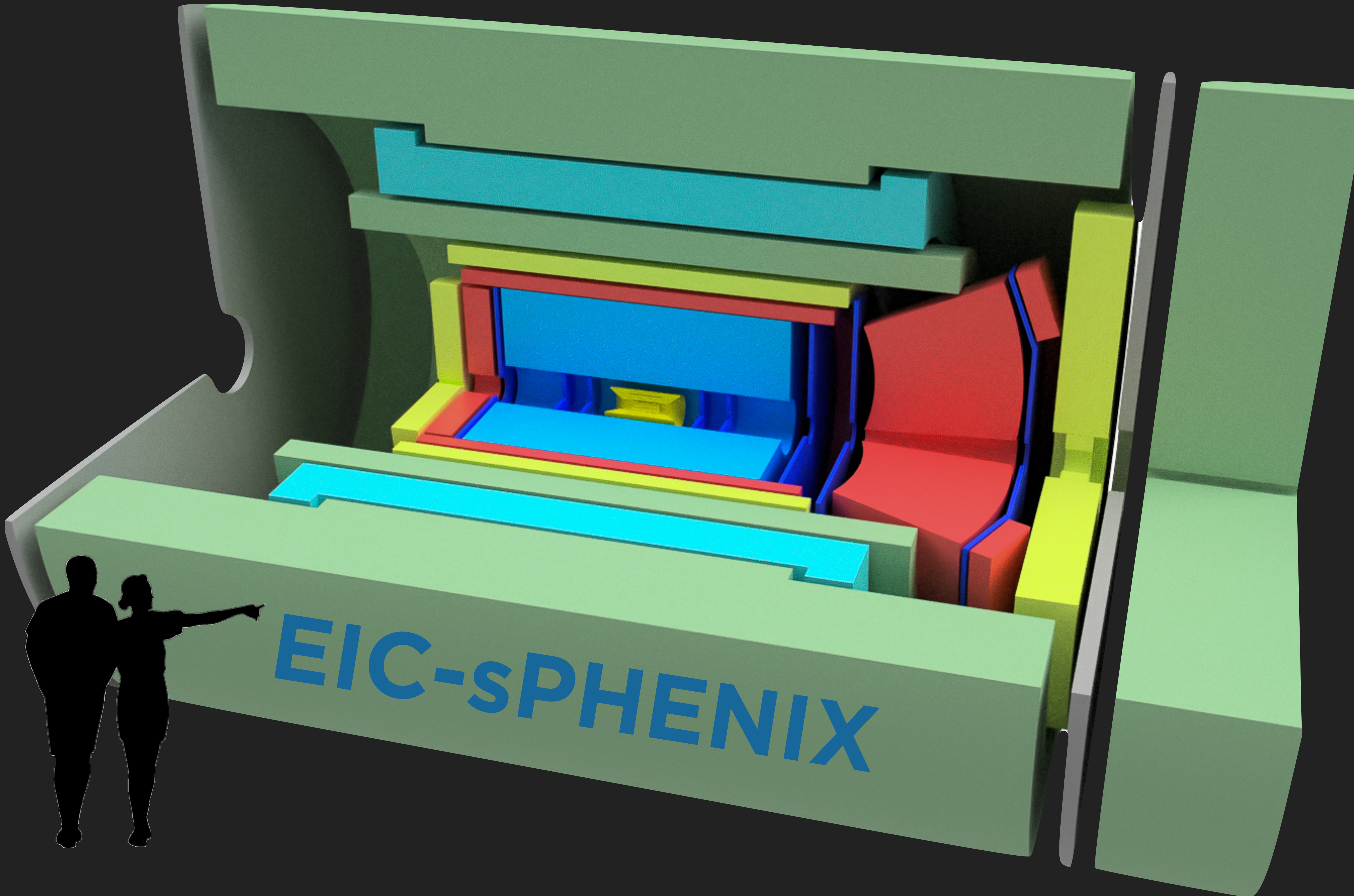
- Limits in experimental searches for LFV(1,3) are significantly worse than those for LFV(1,2).
- Some BSM models specifically allow and enhance LFV(1,3) over LFV(1,2), for example:
  - Minimal Super-symmetric Seesaw model.
    J. Ellis et al, Phys. Rev. D66 115013 (2002)
  - SU(5) GUT with leptoquarks.
    I. Dorsner et al., Nucl. Phys. B723 53 (2005); P. Fileviez Perez et al., Nucl. Phys. B819 139 (2009)
- Study by Gonderinger & Musolf (2010): EIC with 10 fb^{-1} e-p at $\sqrt{s}$ = 90 GeV could improve leptoquark limits.
  - Assumes 100% detector and analysis efficiencies.
    M. Gonderinger & M. Ramsey Musolf, JHEP 1011 (045) (2010); D. Boer et al., arXiv:1108.1713
- It is a great feasibility study to test an EIC detector with.

GENERATING MONTE CARLO EVENTS USING LQGENEP.

LQGENEP: Leptoquark generator for e-p processes using Buchmuller-Ruckl-Wyler model *(L. Bellagamba, Comp. Phys. Comm. 141, 83 (2001))*

- Mass M_{LQ} = 1936.5 GeV
- Coupling $\lambda_{11} = \lambda_{31} = 0.3$
- d-quark in initial and final state (s-channel)
- τ is final state lepton
- $\sqrt{s}$ = 141 GeV





Solenoid

Flux return

Central tracking

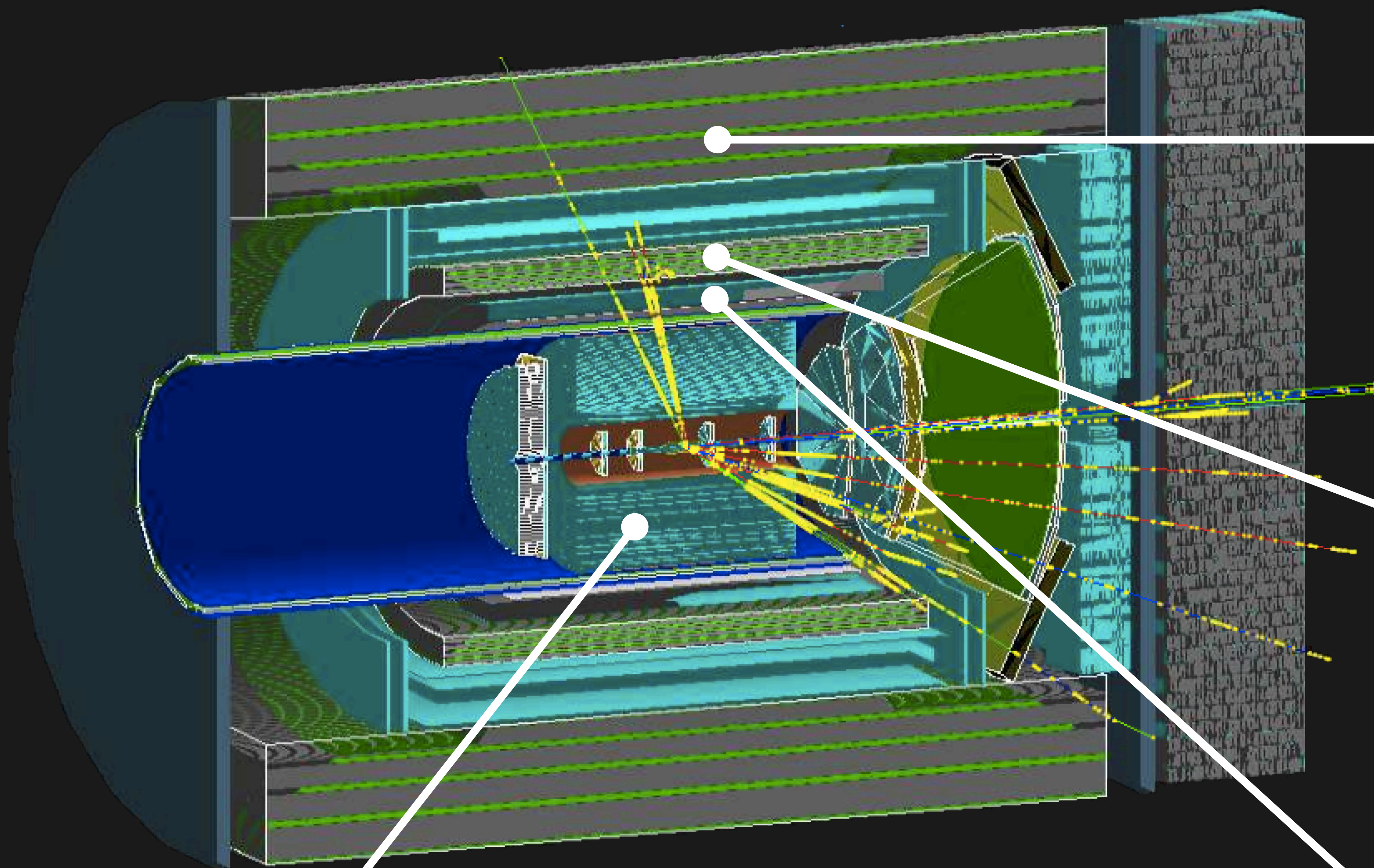
Electromagnetic calorimeter

Forward tracking

Hadron calorimeter

Particle ID

FULL GEANT4 DETECTOR SIMULATION.



HCAL: Fe + scintillator (0.1 x 0.1)

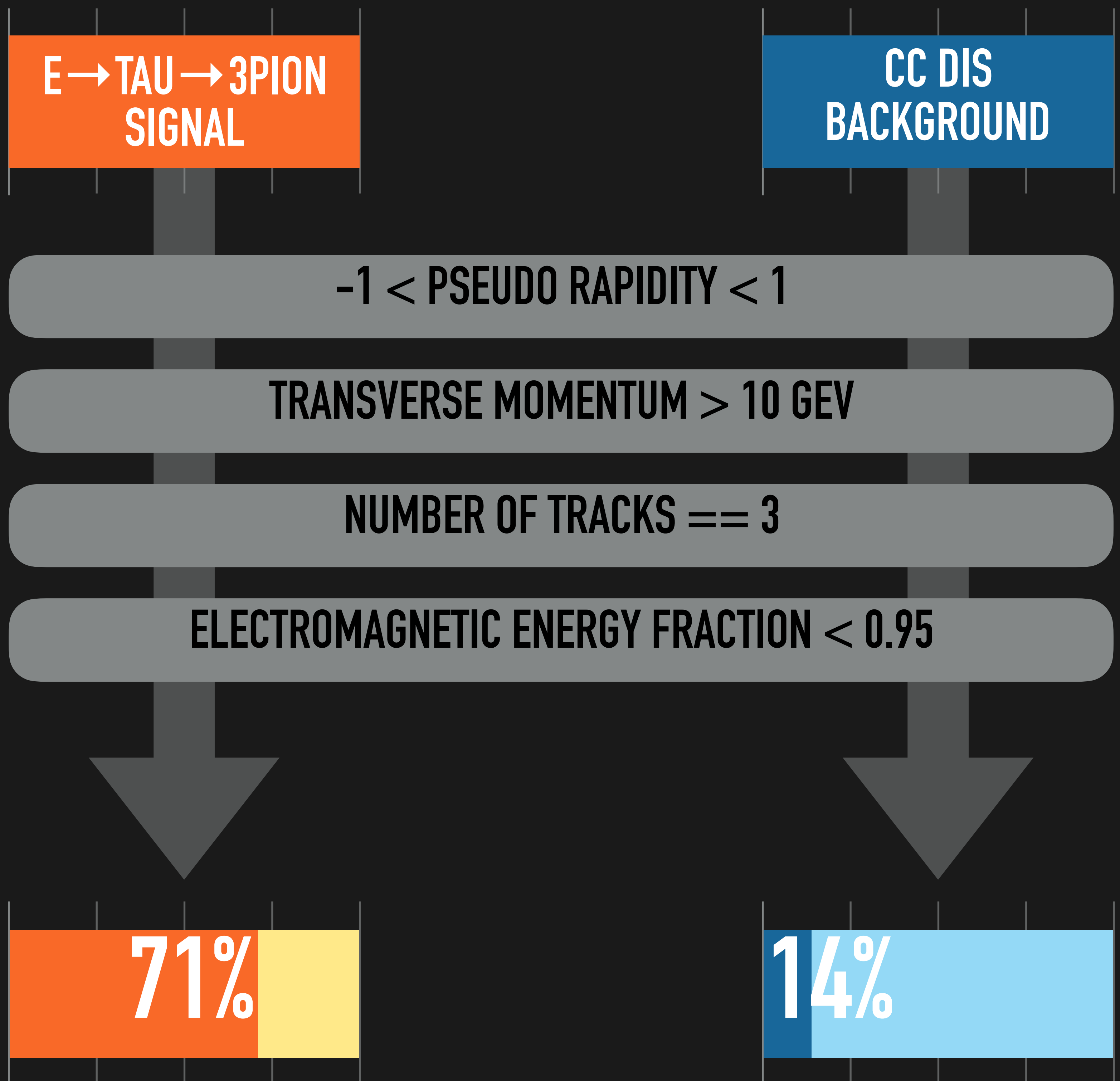
HCAL: Stainless steel + scintillator (0.1 x 0.1)

ECAL : W + scintillating fibre (0.025 x 0.025)

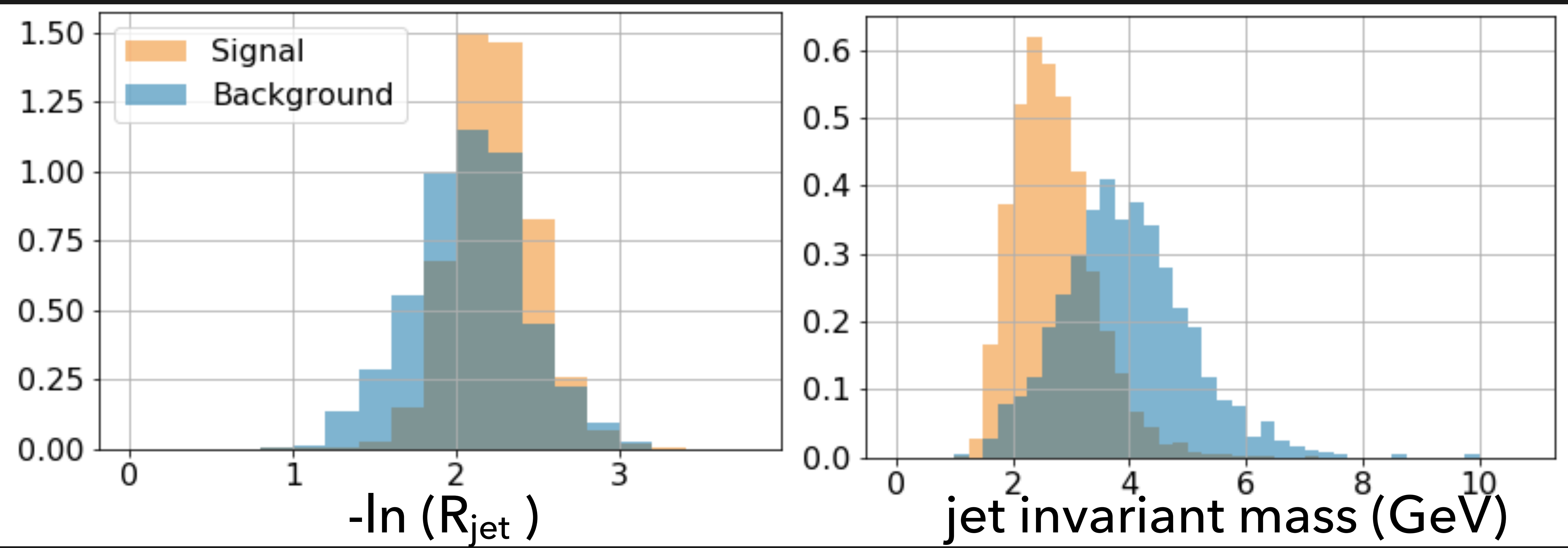
Continuous readout TPC

3-layer MAPS vertex detector

EIC-SPHENIX: SELECTION OF TAU CANDIDATE JETS (GEANT4).



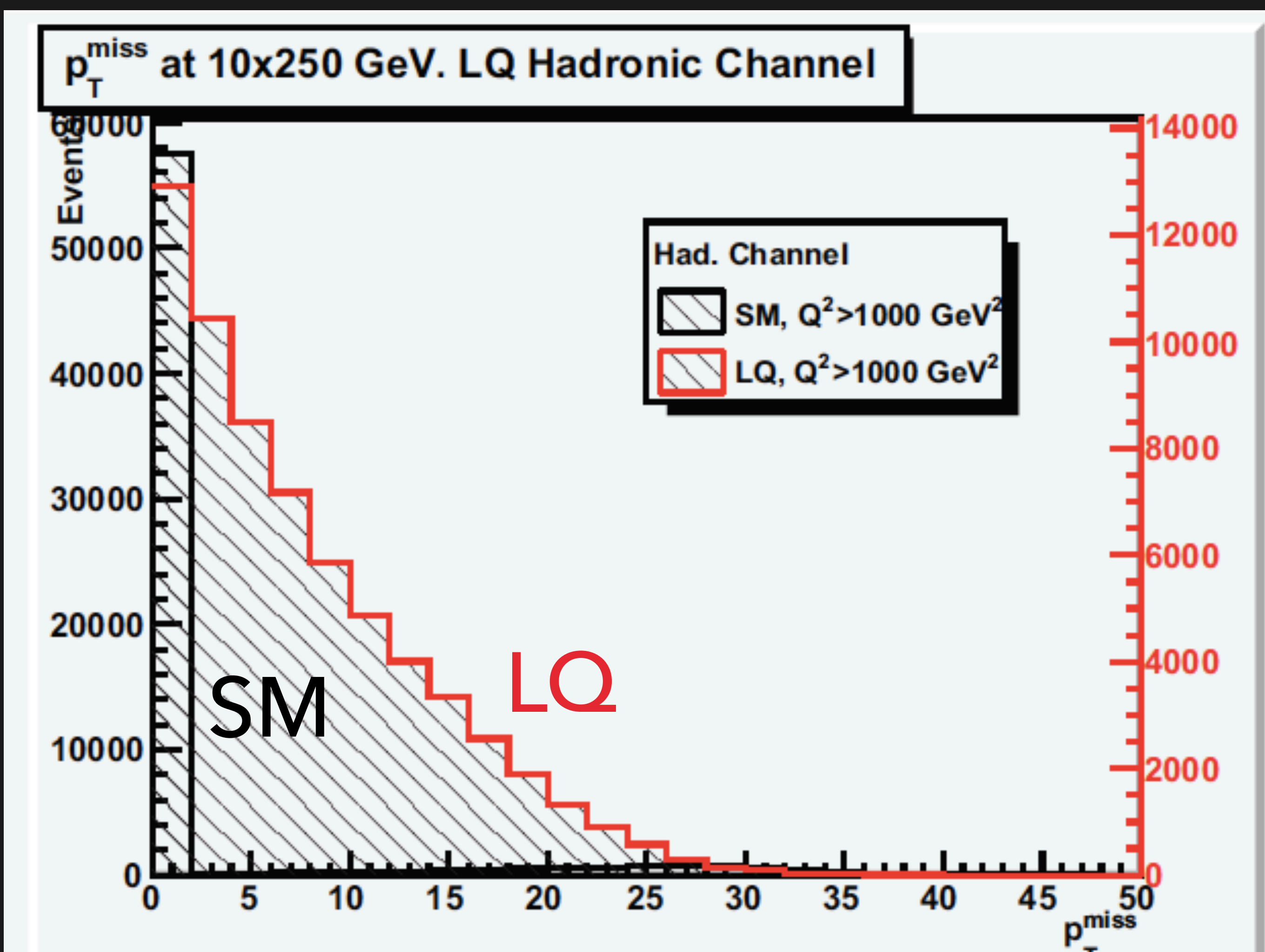
EIC-SPHENIX: OBSERVABLES TO IDENTIFY TAU JETS (GEANT4).

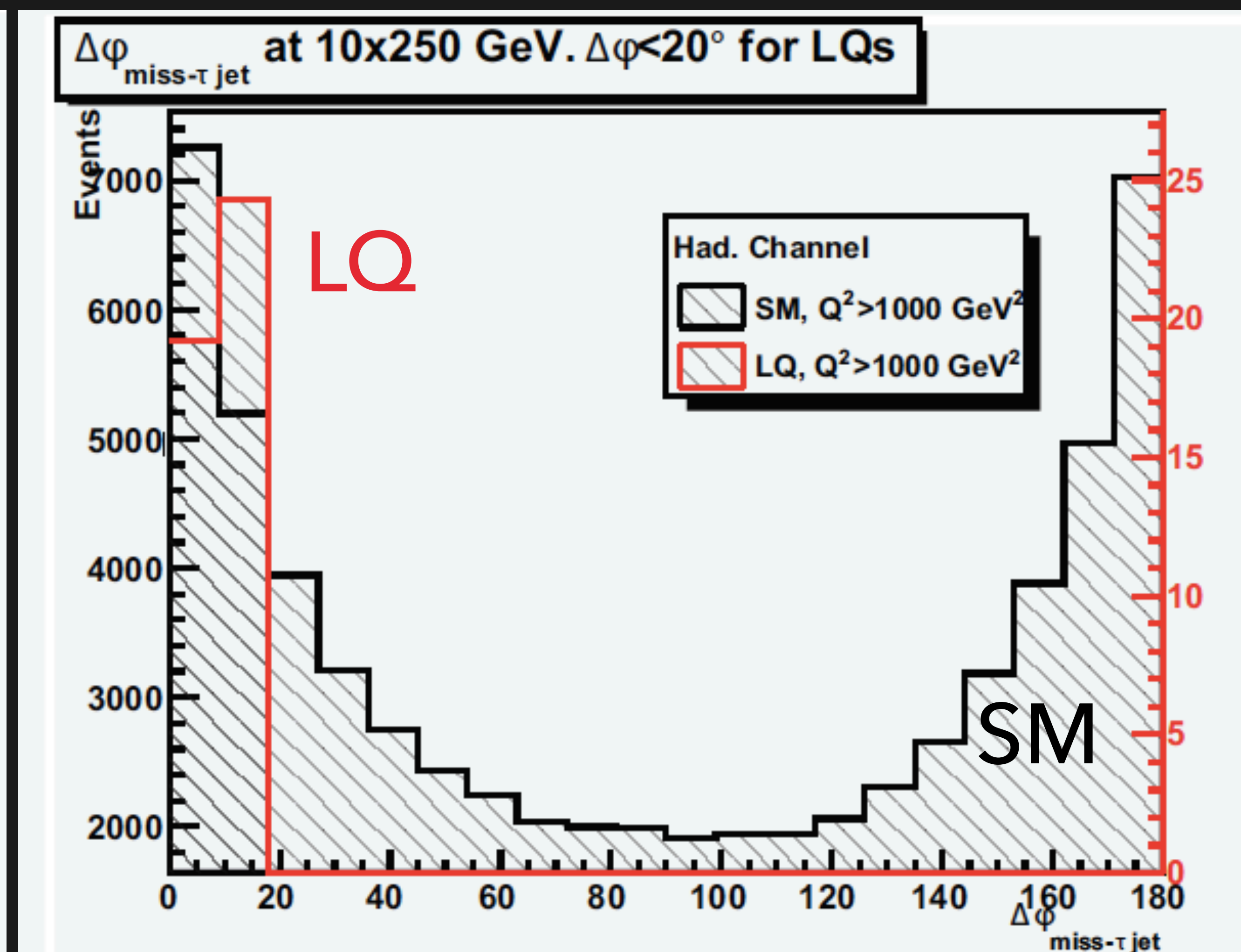


SEPARATING LEPTOQUARK EVENTS FROM STANDARD MODEL BACKGROUND.

$M_{LQ} = 200$ GeV, $\lambda_{11} = \lambda_{31} = 0.3$, $\sqrt{s} = 100$ GeV

arXiv:1108.1713





Analysis efficiencies ($M_{LQ} >> \sqrt{s}$): 4–20% (ZEUS)
3-13% (H1)

ZEUS, Eur. Phys. J. C 44, 463–479 (2005)

H1, Eur. Phys. J. C 52, 833–847 (2007)