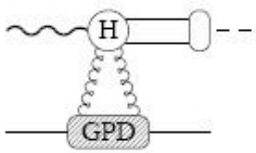
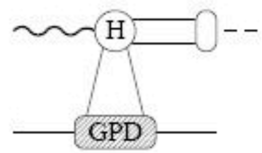
Exclusive reactions at an electron-ion collider

Tanja Horn (JLab)

EIC collaboration meeting, 11 December 2008

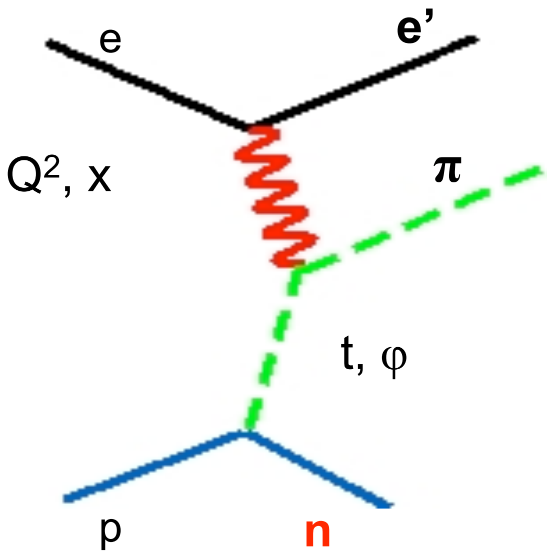
- Exclusive Processes Overview
- Experimental challenges
- Outlook

Categories of Exclusive Processes

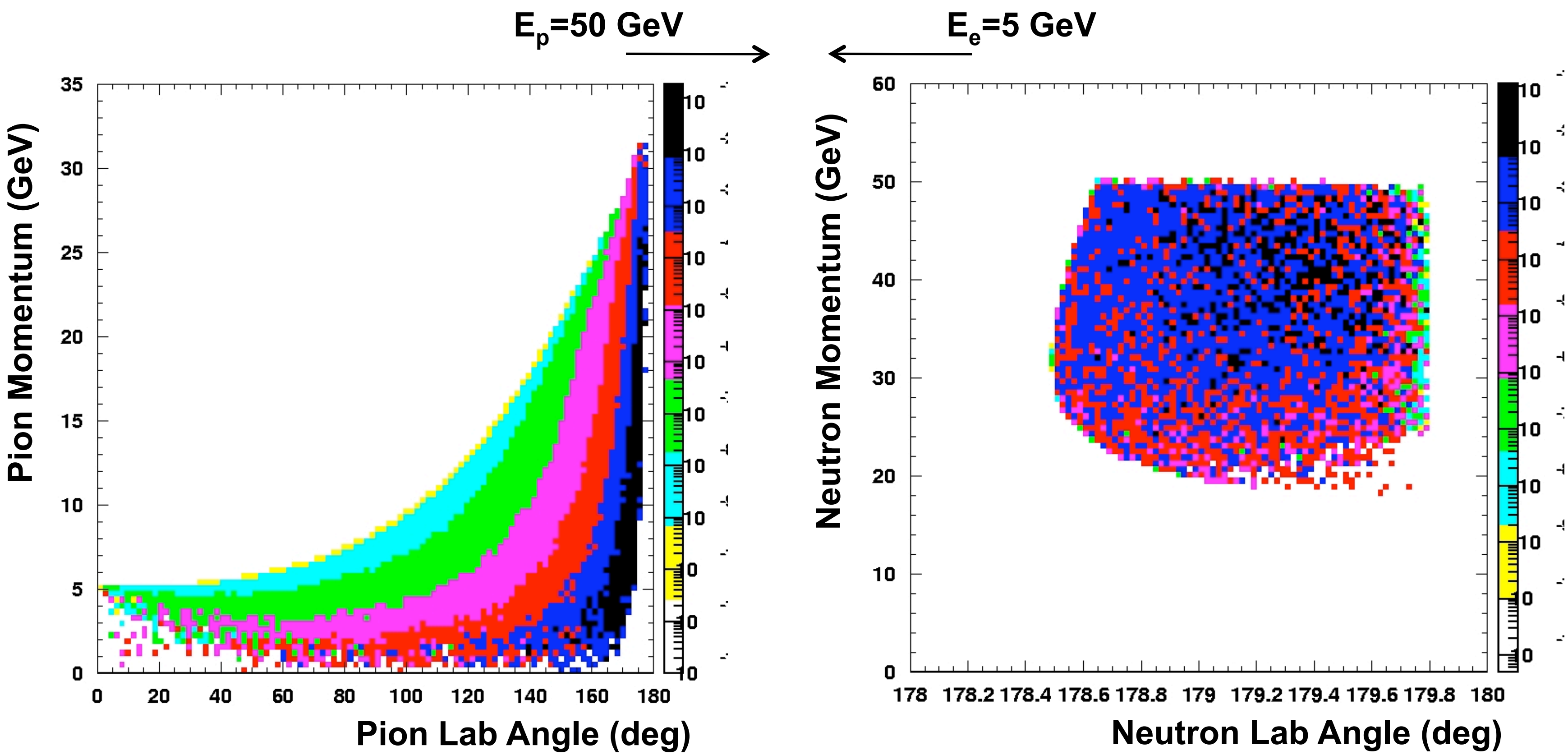
	"diffractive" (vacuum exchange)	"non-diffractive" (quantum number exchange)
Channel	$\gamma p,\ \rho^0 p,\ J/\psi\, p, \ldots$	$\pi^+ p,\ \pi^0 p,\ K\Lambda,\ \rho^+ n, \ldots$
GPDs	 gluon	 non-singlet quark
Cross section	rises with energy	drops with energy
Interest	gluon imaging of nucleon	spin/flavor structure of quark GPDs

Experimental Challenges

- Exclusivity (channel selection)
- Particle identification
- L/T separations
- Luminosity

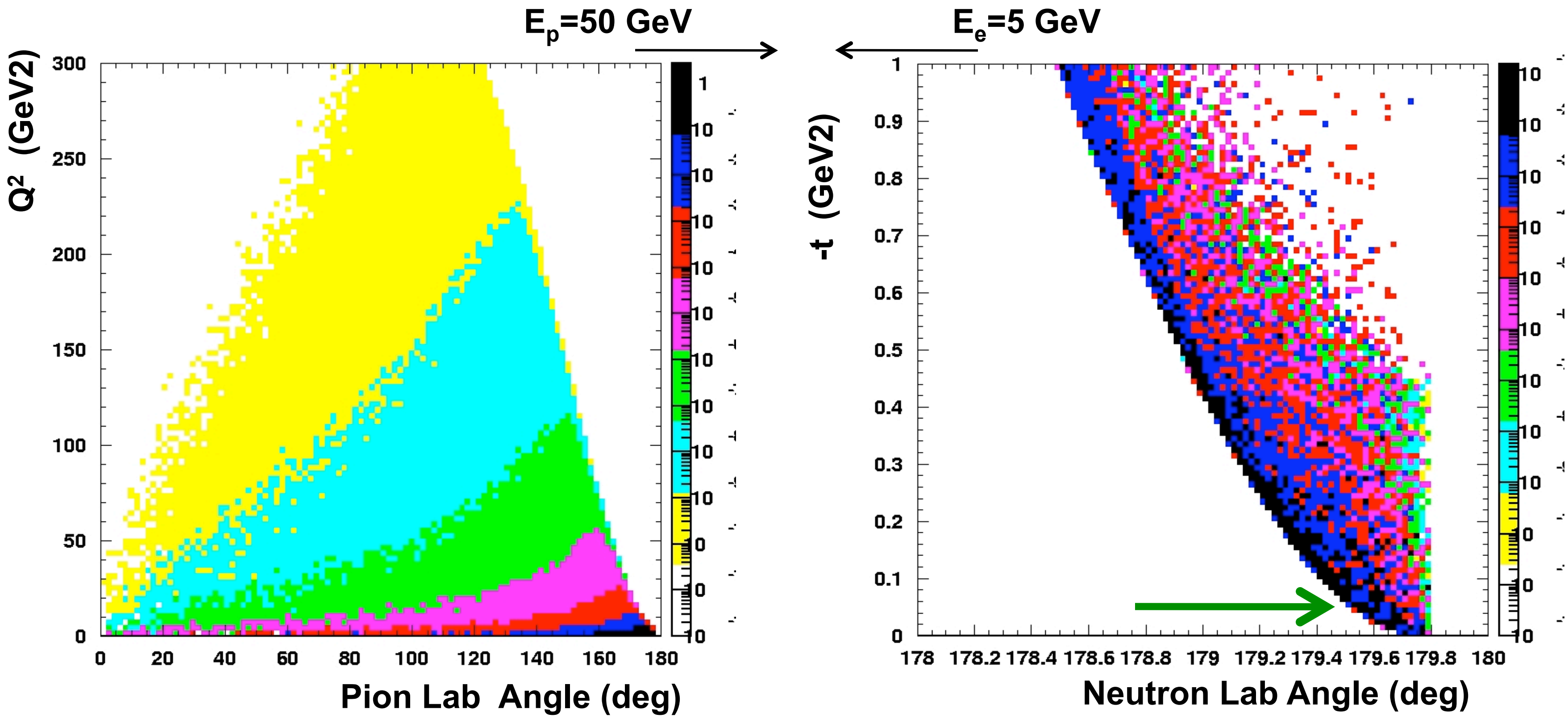


Exclusivity: $^{1}H(e,e'\pi^{+})n$ or multi-pion production?



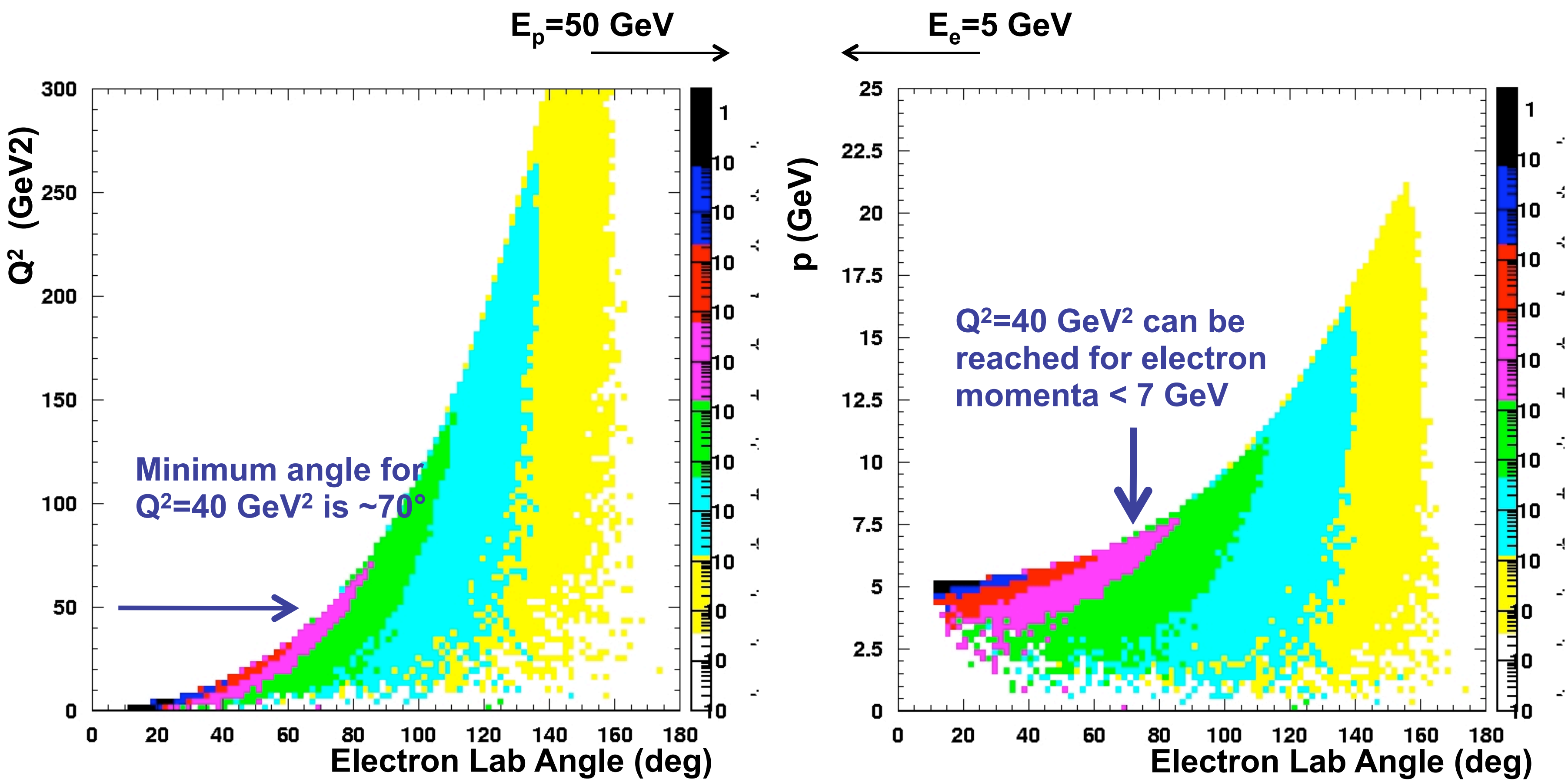
- Large c.m. boost in baryon direction
  - hadrons are produced with high momentum at small angles
  - can we distinguish events with an additional π^0?

$^1H(e,e'\pi^+)n$ – Q^2 and t-dependence of hadrons



- Low *-t* neutrons never leave the beam pipe – a zero-degree detector is needed
  - energy resolution is poor
  - useful angular resolution requires a long flight path
- For high Q^2, pion detection is required over a large angular range

$^{1}H(e,e'\pi^{+})n$ – scattered electron kinematics

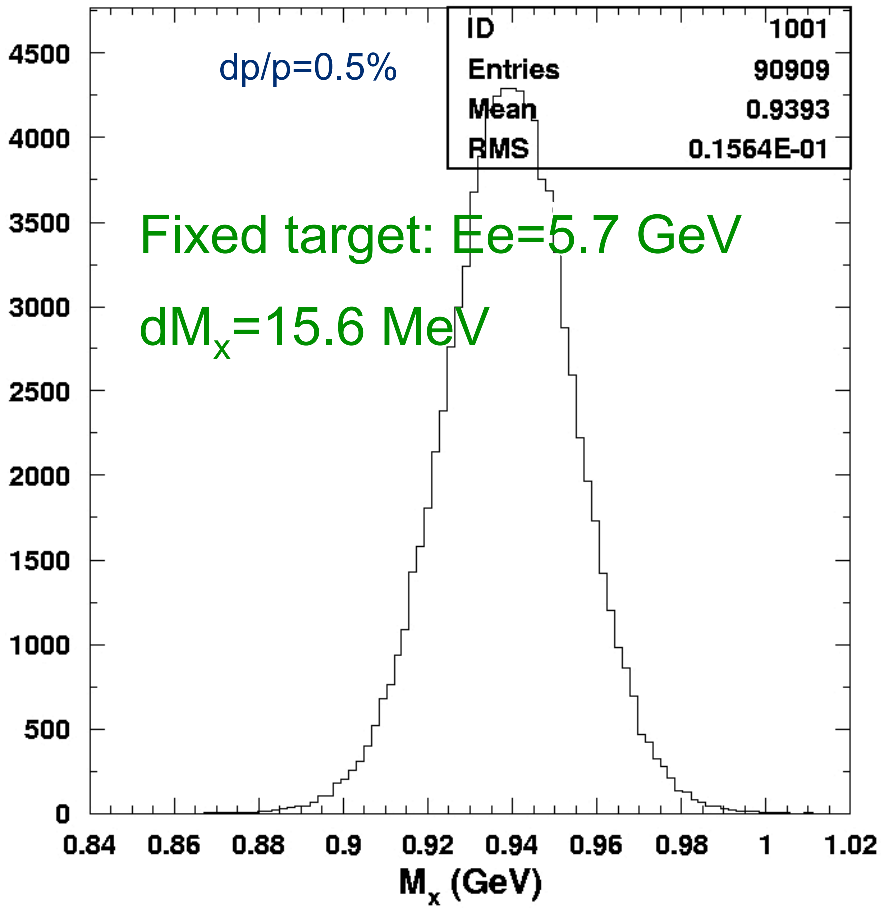


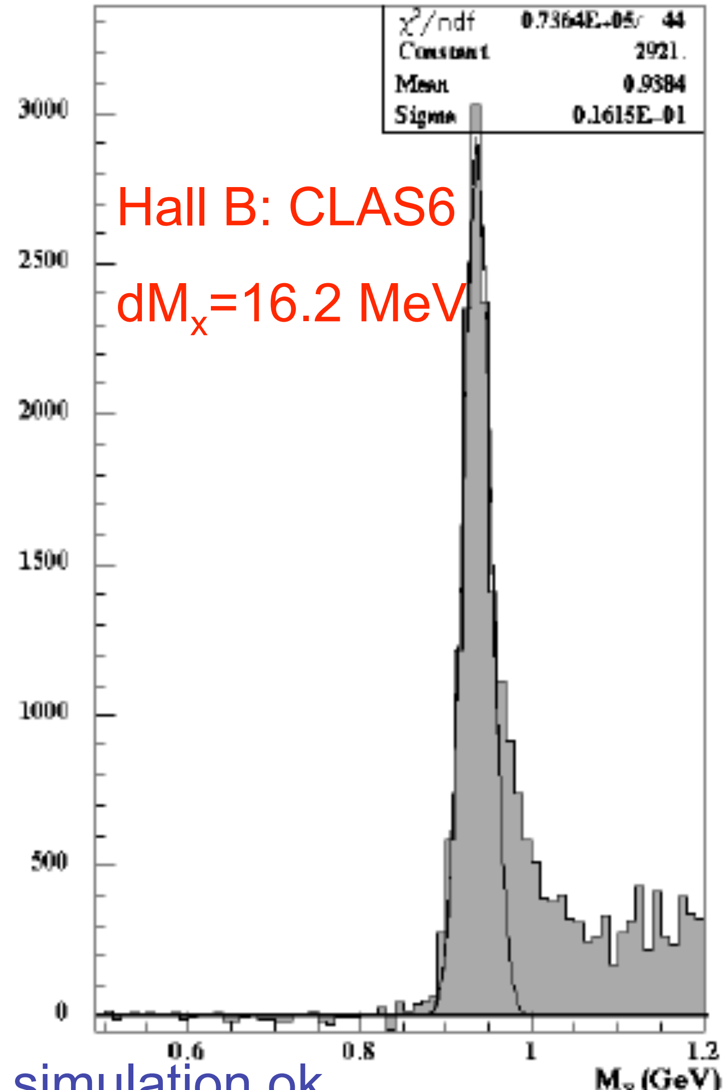
- Most electrons scatter at small angles, but correspond to low Q^2
- High-Q^2 electrons require detection (and identification) over large angular range

Methods to ensure exclusivity

- Detector as a veto
  - relies on detector hermeticity to reject events with additional particles
  - requires very good (forward) acceptance – not easy with large c.m. boost
- Missing mass of baryon (neutron)
  - electron and meson momenta are measured
  - missing mass resolution depends on detector resolution, particle momentum, and available phase space
  - deteriorates rapidly with momentum and c.m. energy
- Kinematic fits
  - detect all three particles
  - forward baryon acceptance limited by magnets sizes and apertures
  - poor resolution (momentum or angle) means no constraint!
  - longitudinal momentum particularly challenging (forward-going π^0 rejection)

M_x Resolution – fixed target

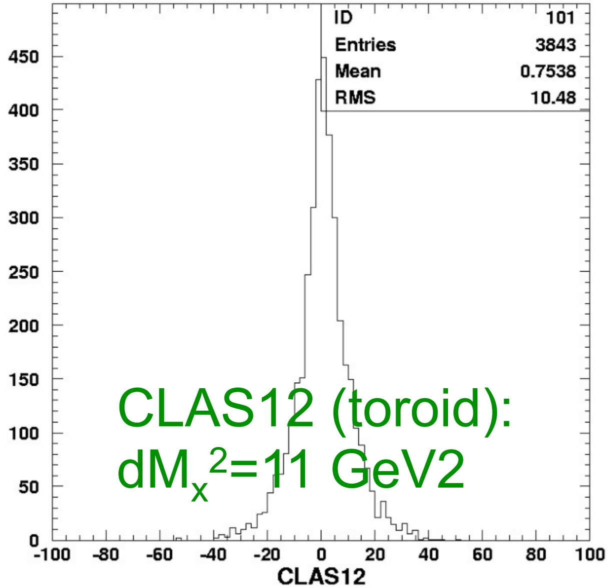


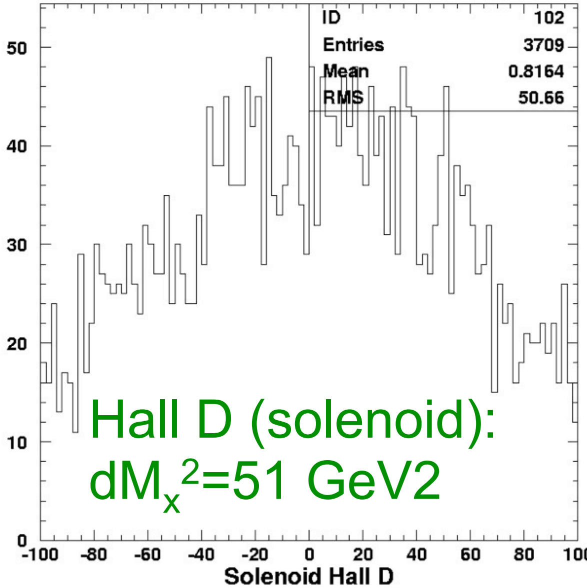


Conclusion: in good agreement with data → simulation ok

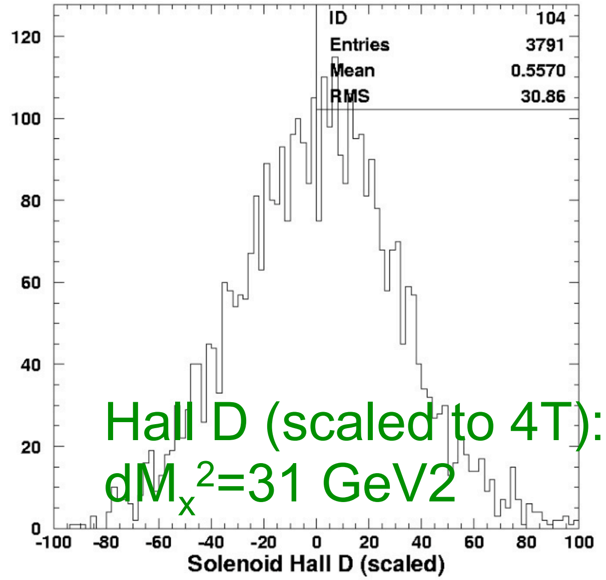
Simulated dM_x^2 distributions for 5 on 50 kinematics

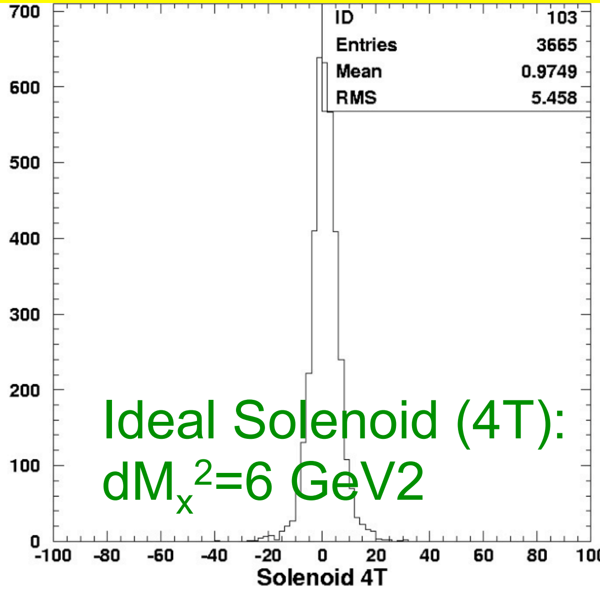
$\Theta_\pi < 30°$





Conclusion: missing mass technique will not guarantee exclusivity in these kinematics

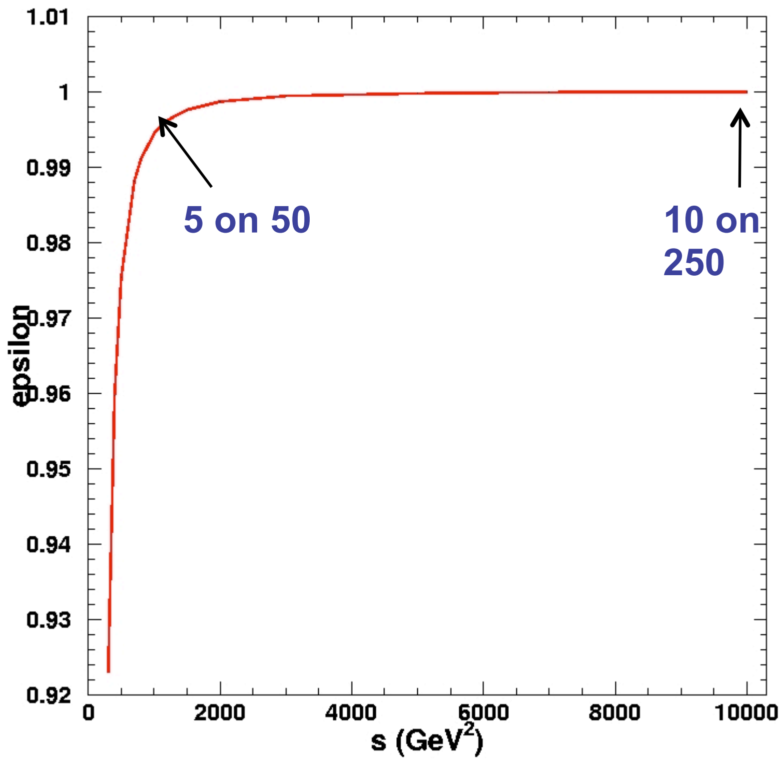




L/T separations in exclusive π+ production

- L/T separations require sufficiently large Δε to avoid magnification of the systematic uncertainty in the separation
- Virtual photon polarization, ε, goes to unity at high √s

Q^2=10 GeV^2, x=0.1, -t=0.1



- Requires special low energies for at least one ε point and cannot be done with the standard EIC

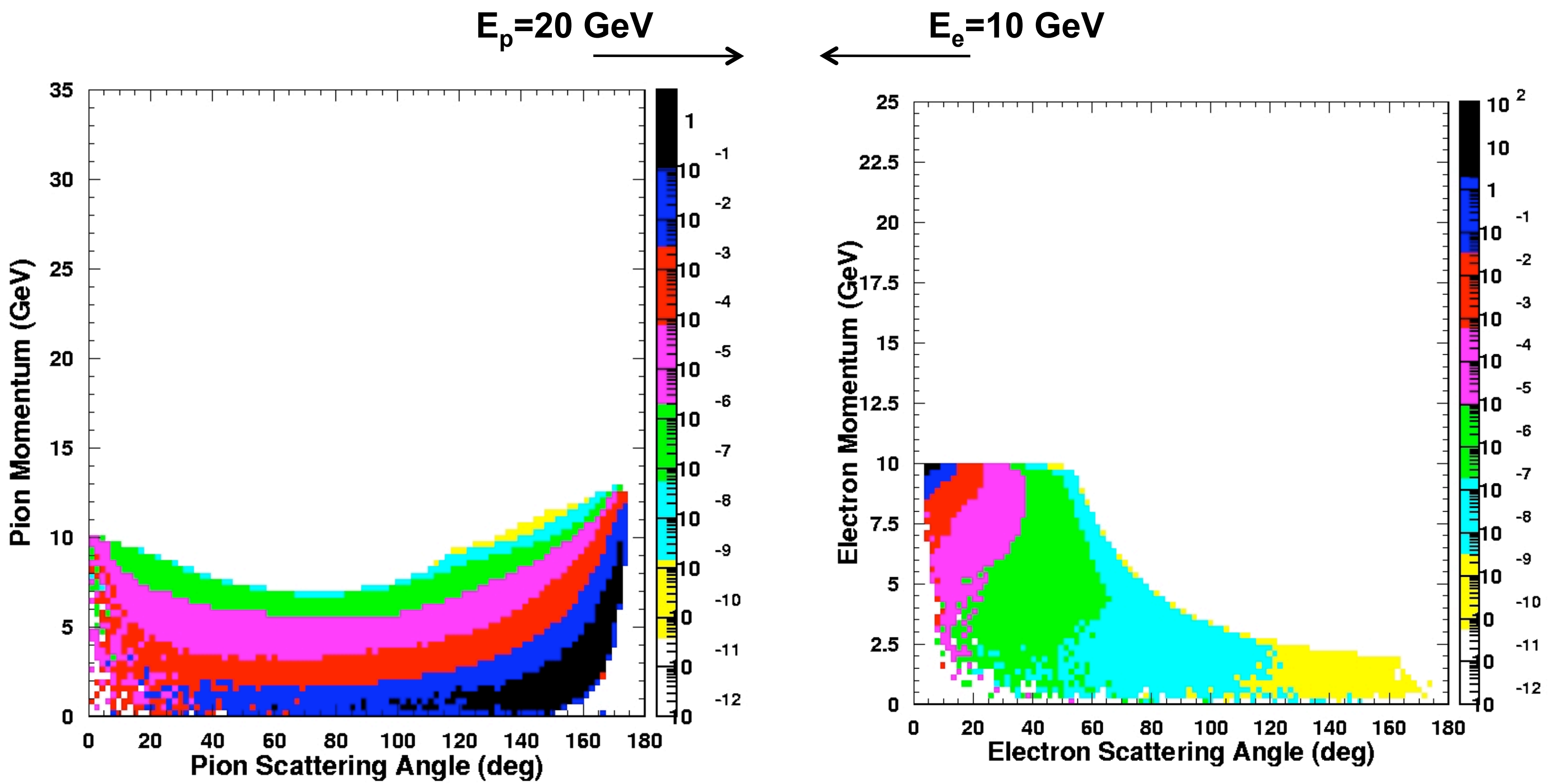
Luminosity considerations

- To lower the minimum energy of a high-energy EIC would require a relaxed final focus to fit magnet apertures and could impose space charge limits due to the size of the ring.
- The luminosity penalty in multi-purpose high-energy ring can be a factor of 10 at the maximum energy (250 GeV).
- The luminosity, which is proportional to the ion momentum, could thus be a factor 100 lower at 10% of the maximum energy (25 GeV).
- Is there another way?

An alternative approach

- The luminosity issue can be resolved by using a smaller ion ring for the lower energies.
- The experimental challenges can be addressed with a different choice of kinematics
  - Example: 10 GeV on 20 GeV electron-ion collisions
- A nearly symmetric collider would have the benefits of:
  - Lowest lab momenta for a given s
  - Optimal momentum resolution
  - Good particle identification
  - Improved acceptance

$^1H(e,e'\pi^+)n$ kinematics



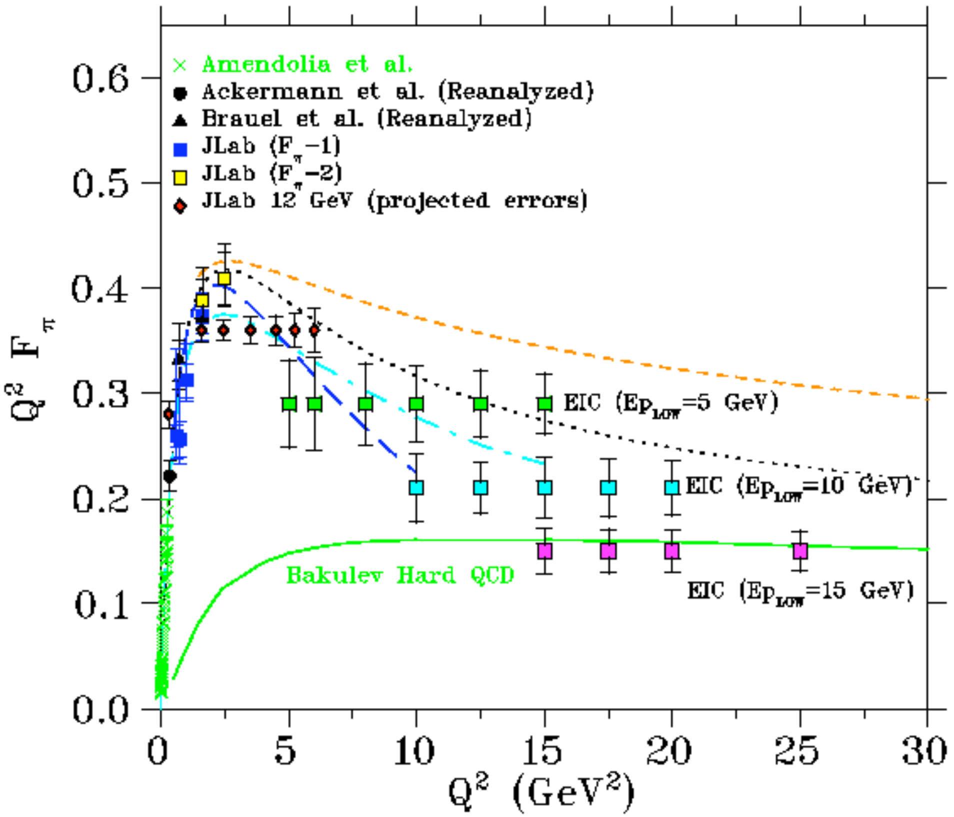
- Large

Conclusion

- Measurements of exclusive reactions face various experimental challenges
- These challenges can be addressed with a different choice of kinematics
- A symmetric collider would offer additional benefits

Backup

Kinematic Reach (Pion Form Factor)



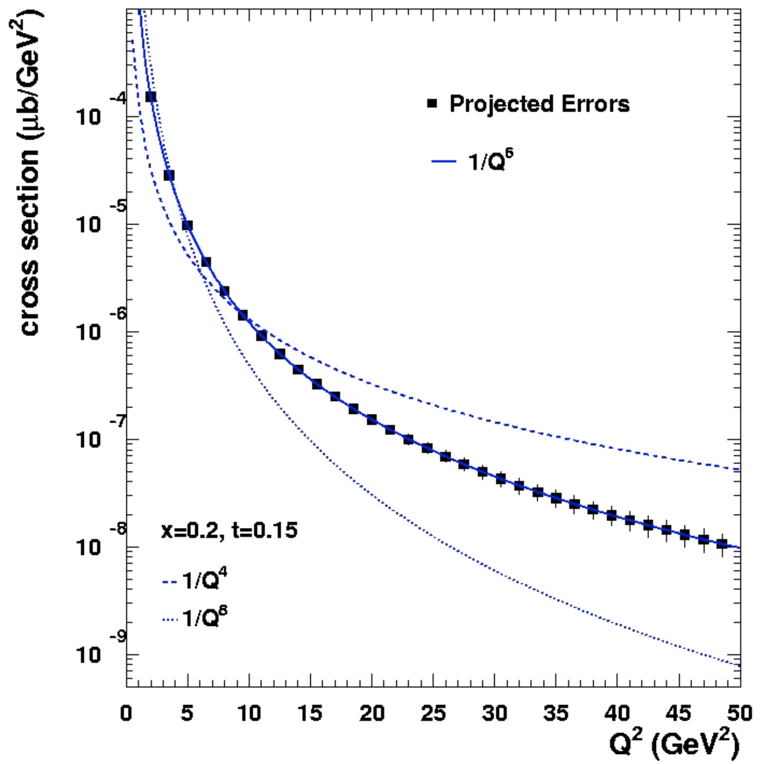
Assumptions:

- **High ε:** 5(e^-) on 50(p).
- **Low ε** proton energies as noted.
- Δε~0.22.
- Scattered electron detection over 4π.
- **Recoil neutrons detected at θ<0.35° with high efficiency.**
- Statistical unc: $\Delta\sigma_L/\sigma_L$~5%
- Systematic unc: 6%/Δε.
- **Approximately one year at L=10^{34}.**

Excellent potential to study the **QCD transition** nearly over the whole range from the strong QCD regime to the hard QCD regime.

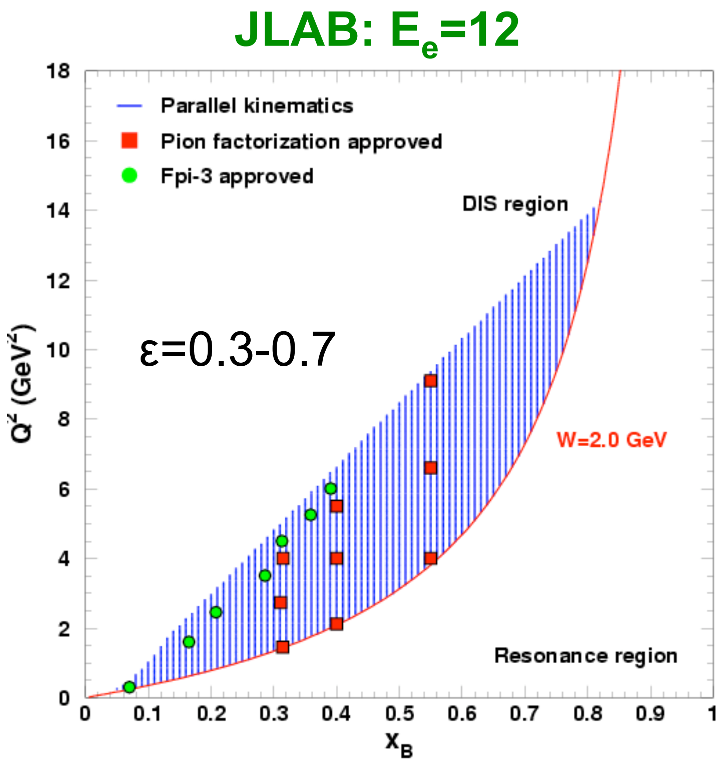
Projected uncertainties for Q^{-n} scaling

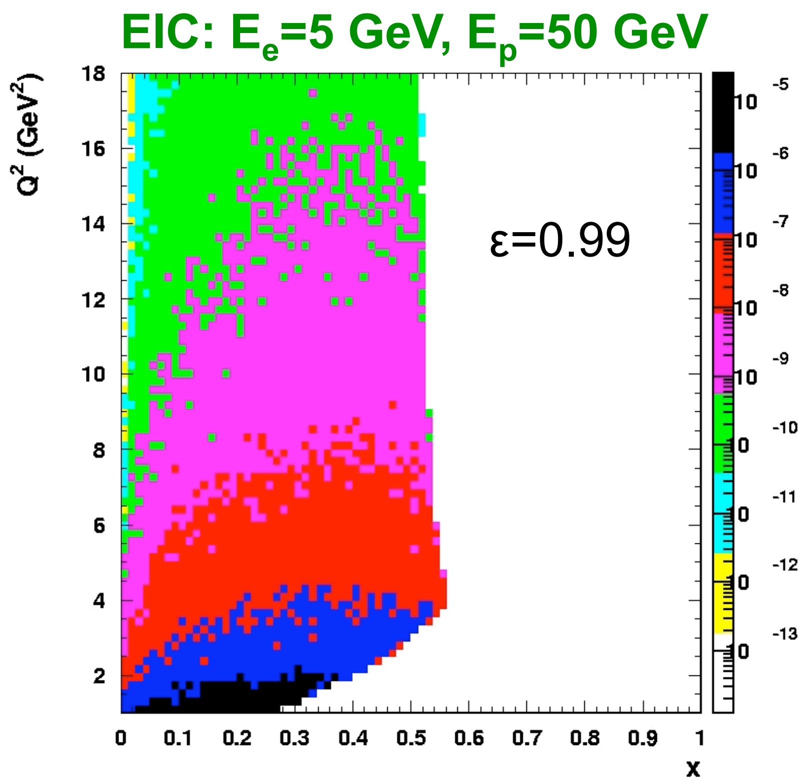
EIC: Ee=5 GeV, Ep=50 GeV



- Transition region 5-15 GeV² well mapped out even with narrow fixed x and t
  - careful with detector requirements

Low ε data from Jlab12?

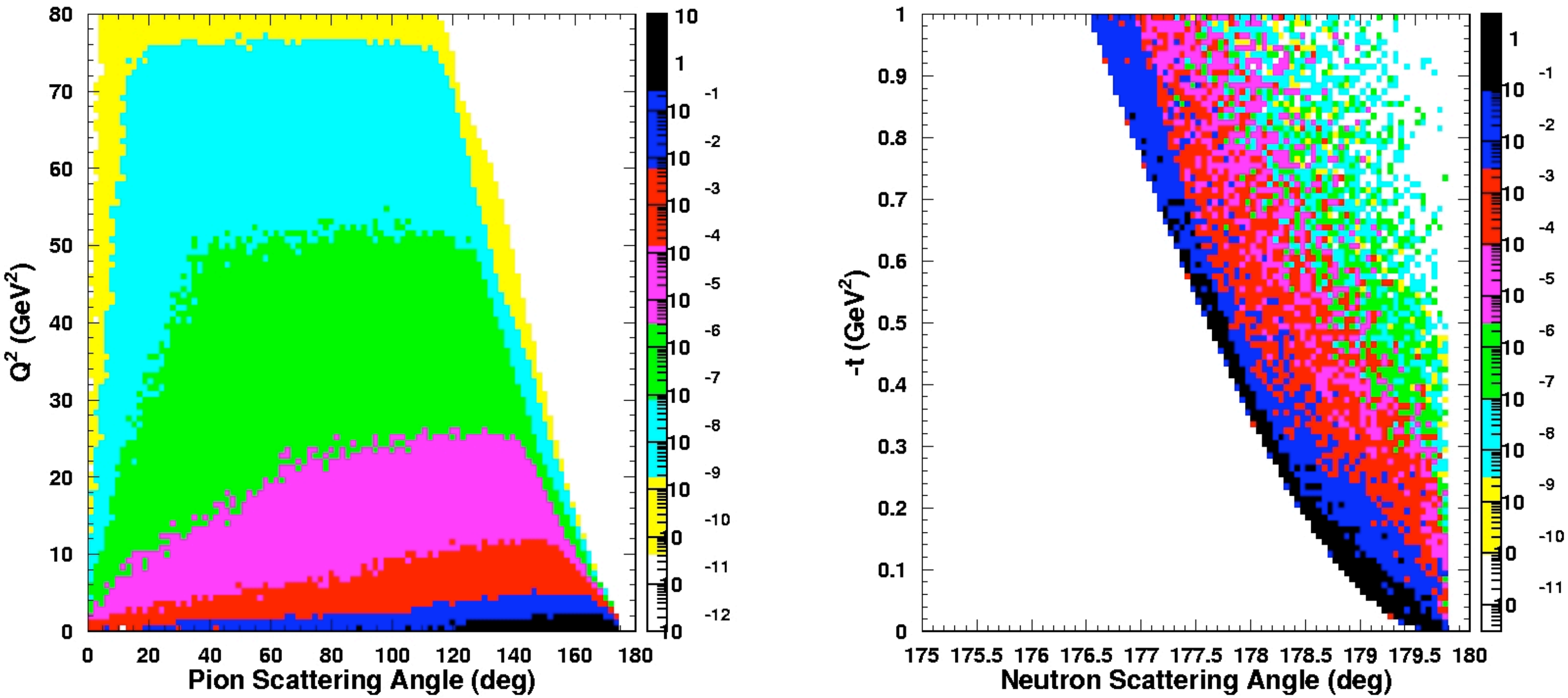




- L/T separations at EIC will benefit from Jlab12 measurements

$^1H(e,e'\pi^+)n$ – Q^2 and t-dependence

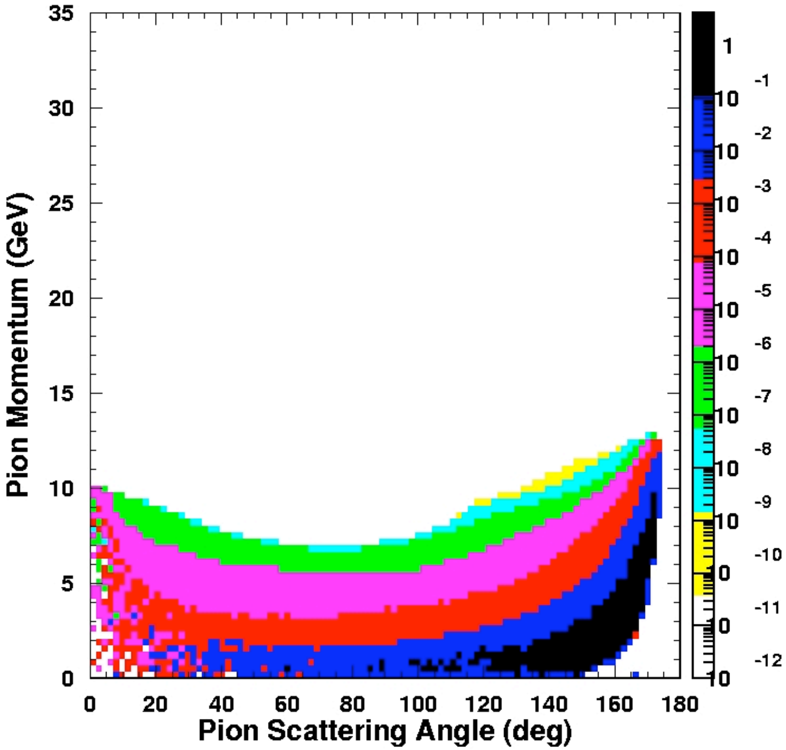
E_p=20 GeV → ← E_e=10 GeV

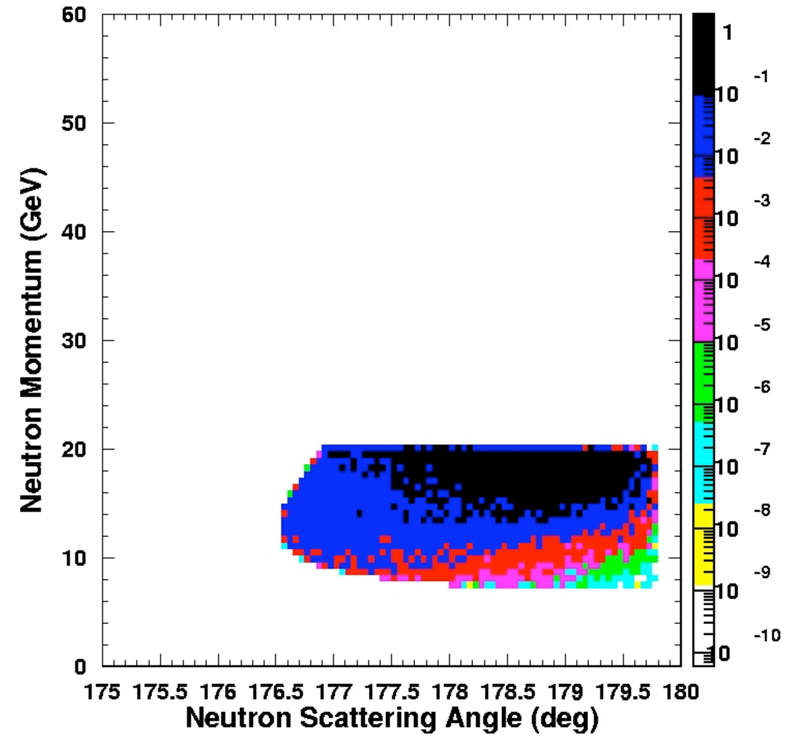


- Low

$^{1}H(e,e'\pi^{+})n$ scattered kinematics

E_p=20 GeV → ← E_e=10 GeV

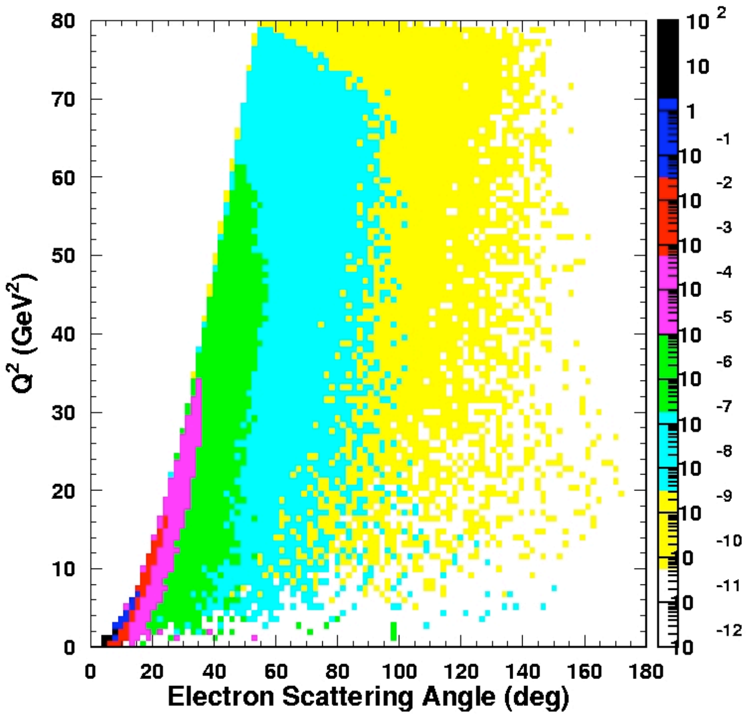


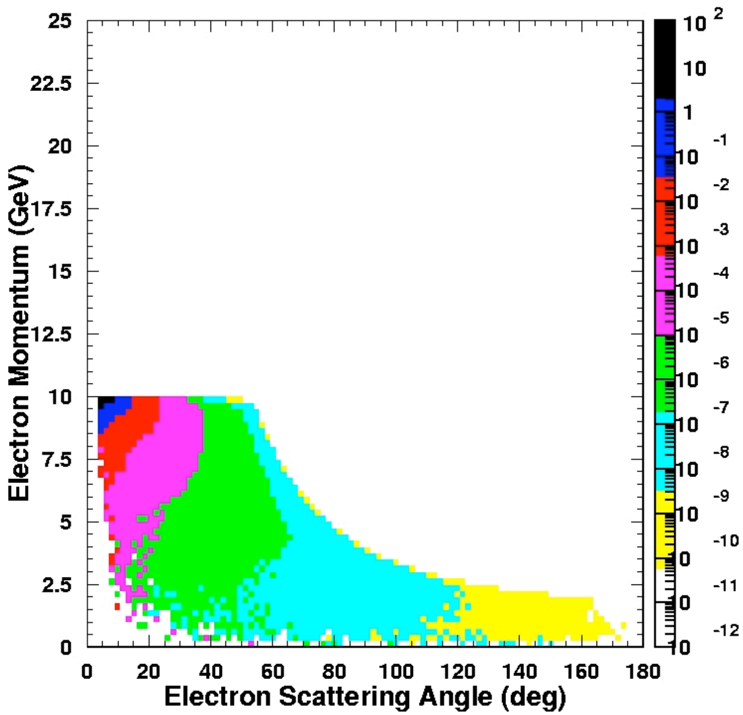


- Large

$^{1}H(e,e'\pi^{+})n$ – scattered electron kinematics

E_p=20 GeV → ← E_e=10 GeV





- Most