RG-D CT Studies

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On behalf of the CLAS Collaboration

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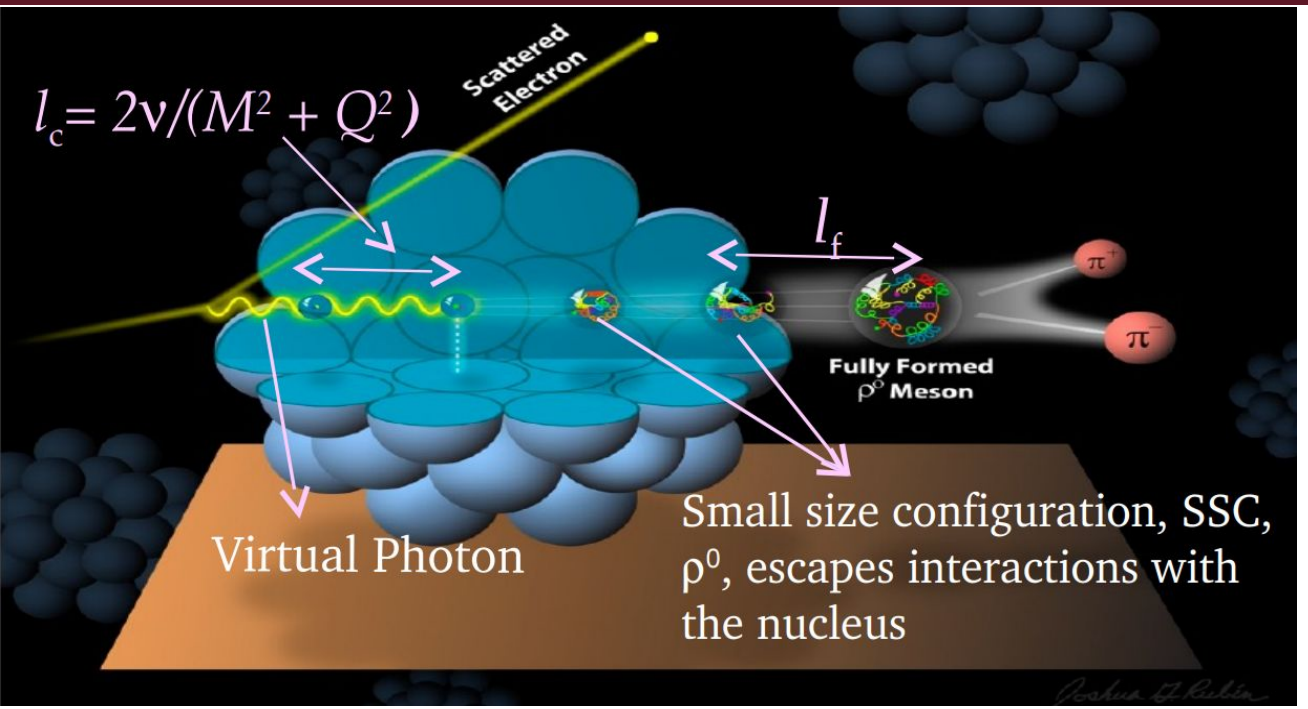
Outline

- Color Transparency (CT) Phenomenon
  - Brief Introduction
  - RG-D Experimental Setup
- RG-D CT Experiment Status
  - Initial Particle IDentification
  - Ongoing Analysis and Preliminary Results
- Summary and Outlook

Brief Introduction: Experimental Observable



Coherence length, l_c: the lifetime of the qq-bar pair

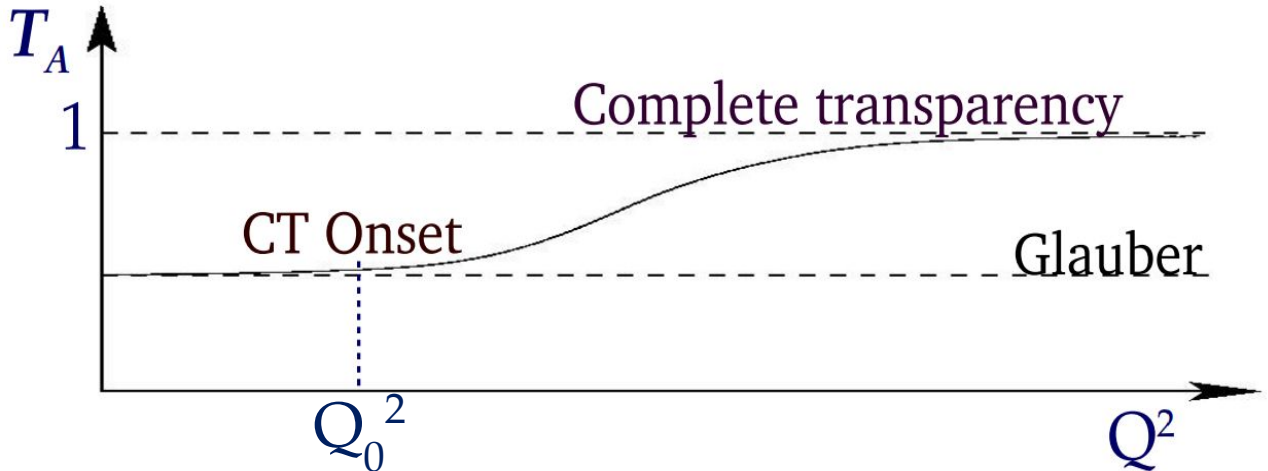
Formation time, l_f: the time needed for the SSC to evolve to an on-shell ρ^0 meon

The CT signature is the increase of the medium "nuclear" transparency, T_A, as a function of the four-momentum transfer squared, Q^2, where

$$T_A = \frac{\sigma_A}{A\sigma_N}$$

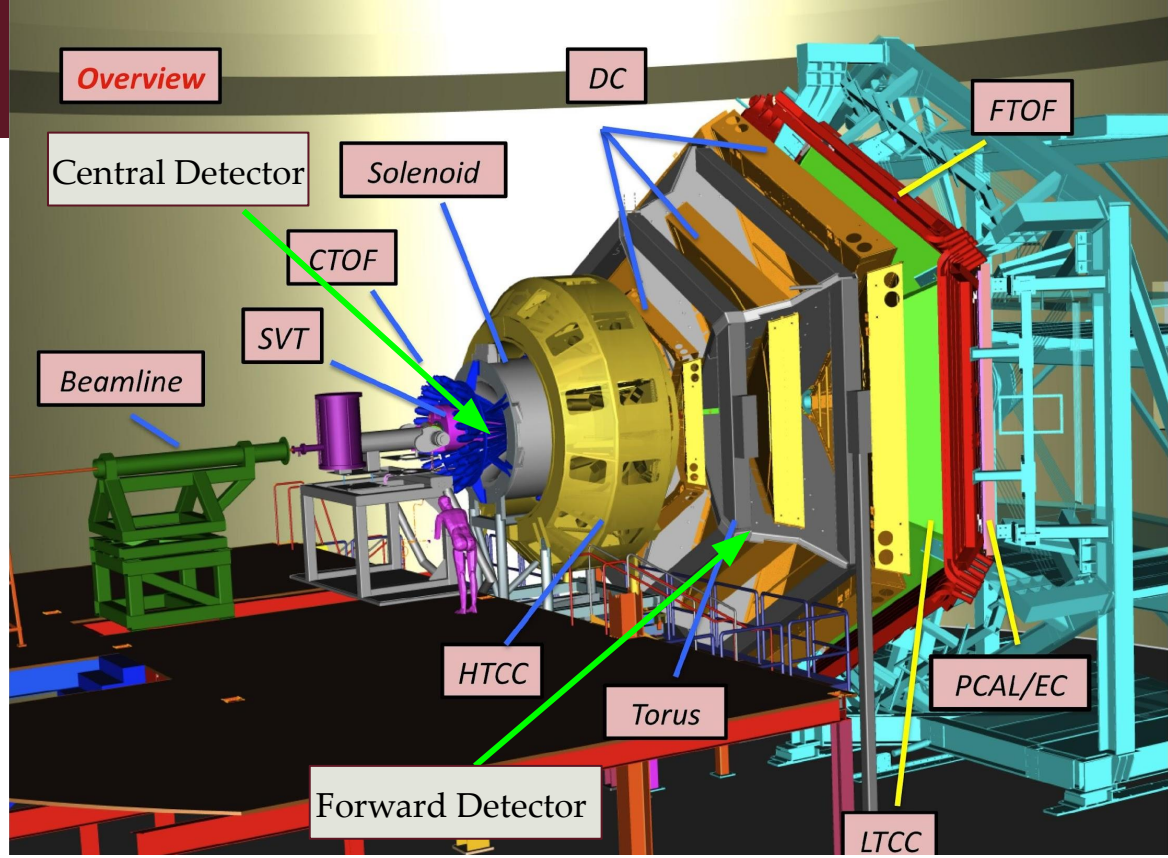
σ_A is the nuclear cross section

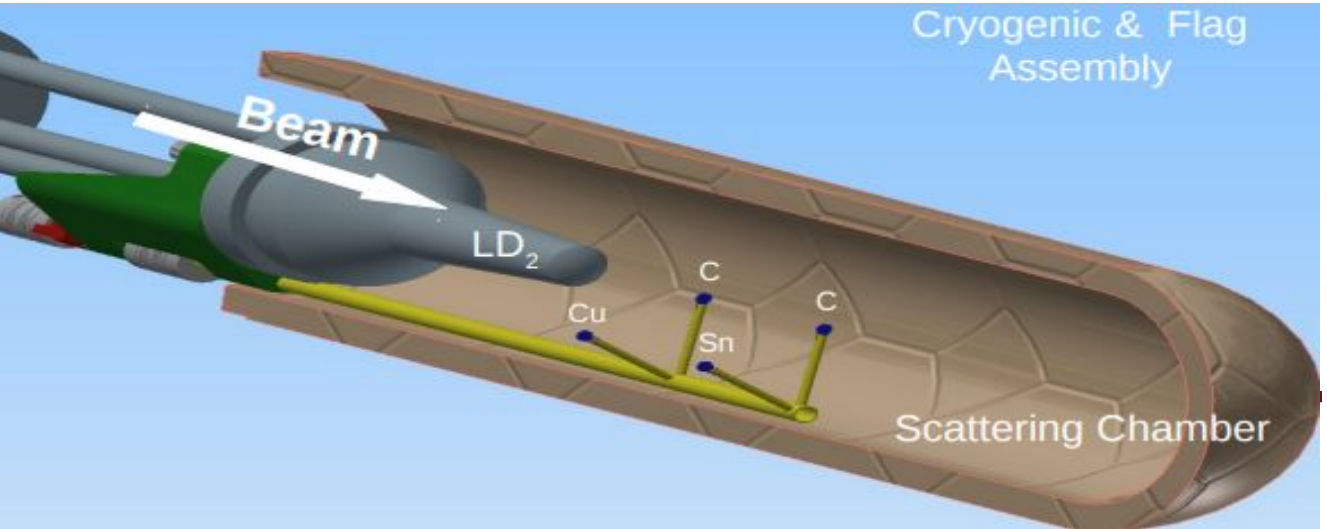
σ_N is the free (nucleon) cross section

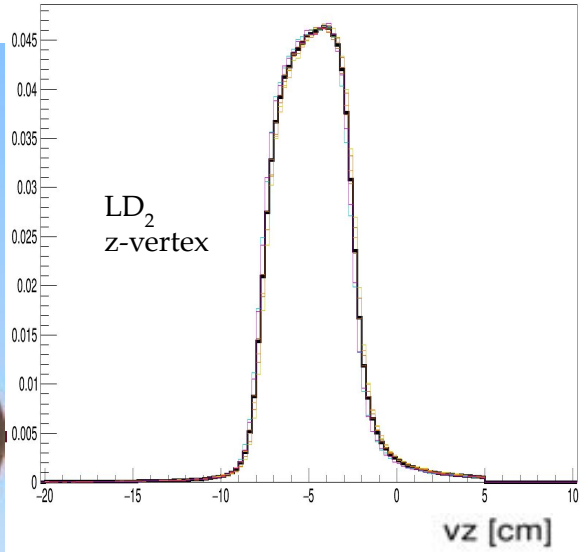


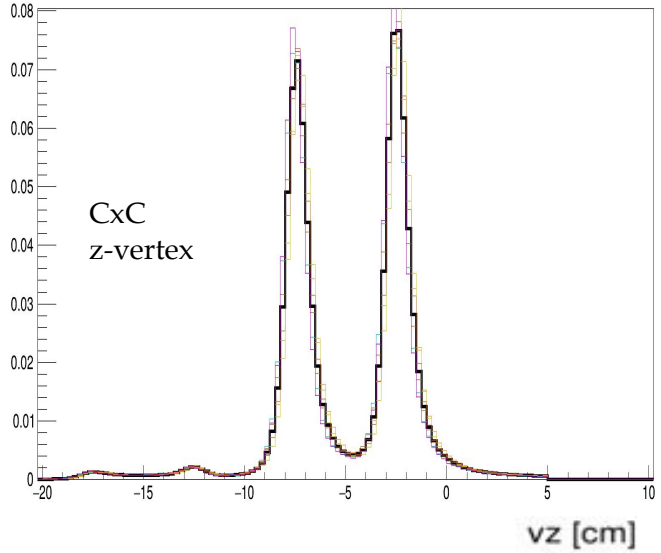
RG-D Experimental Setup

- Used a polarized electron beam with an energy of 10.5 GeV
- Standard CLAS12 configuration with FT-OFF
- 5-cm-long LD_2 cell in the newly built cryogenic system positioned at -5 cm relative to the CLAS12 center
- Remotely controlled 5-cm-apart solid-foil (C, Cu, and Sn) flag assembly centered @ -5 cm









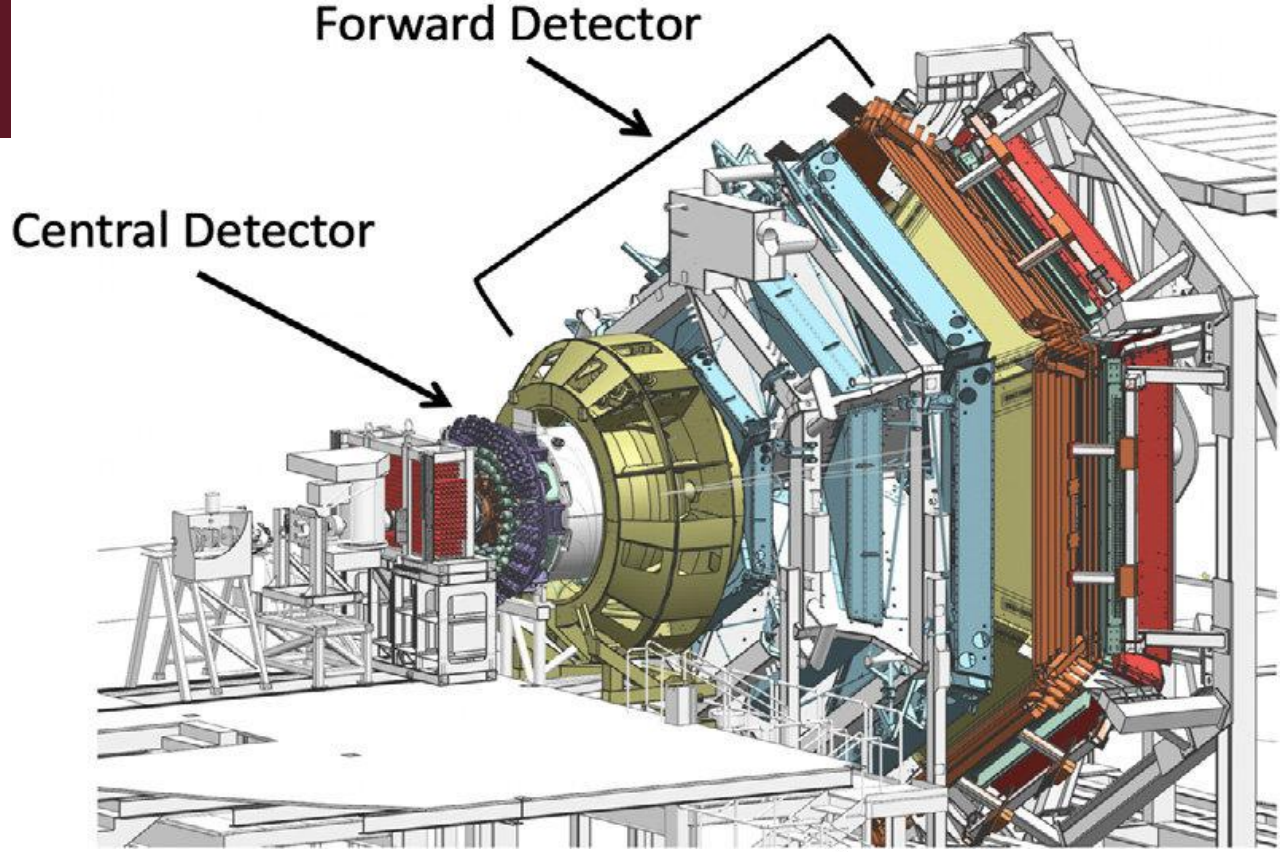
Initial Particle Identification

- χ^2 is precision of reconstructed particle trajectories

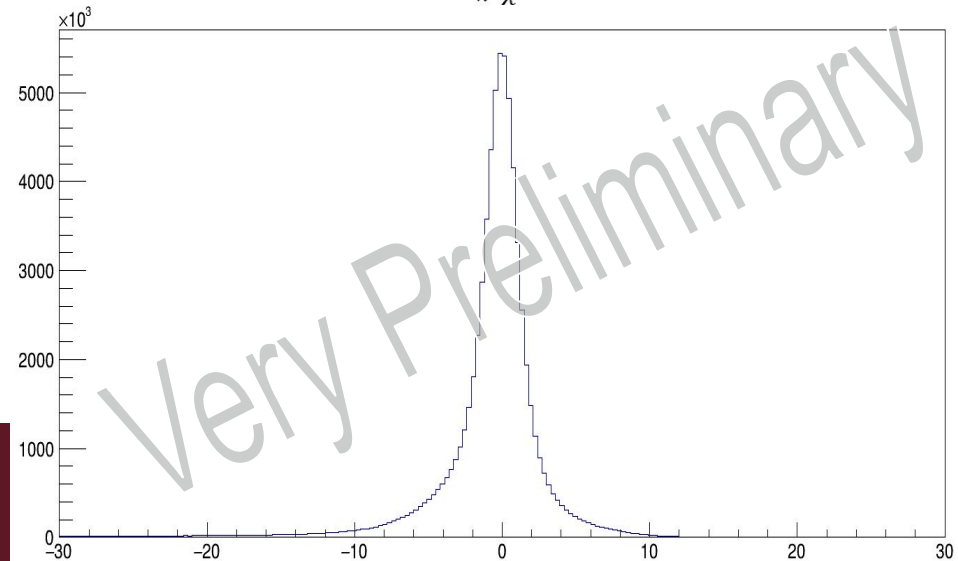
- Electron Selection
  - PID = 11
  - Particle must be in the forward detector
  - $-5 \leq \chi^2 \leq 5$

- π^+ Selection
  - PID = 211
  - $-10 \leq \chi^2 \leq 10$

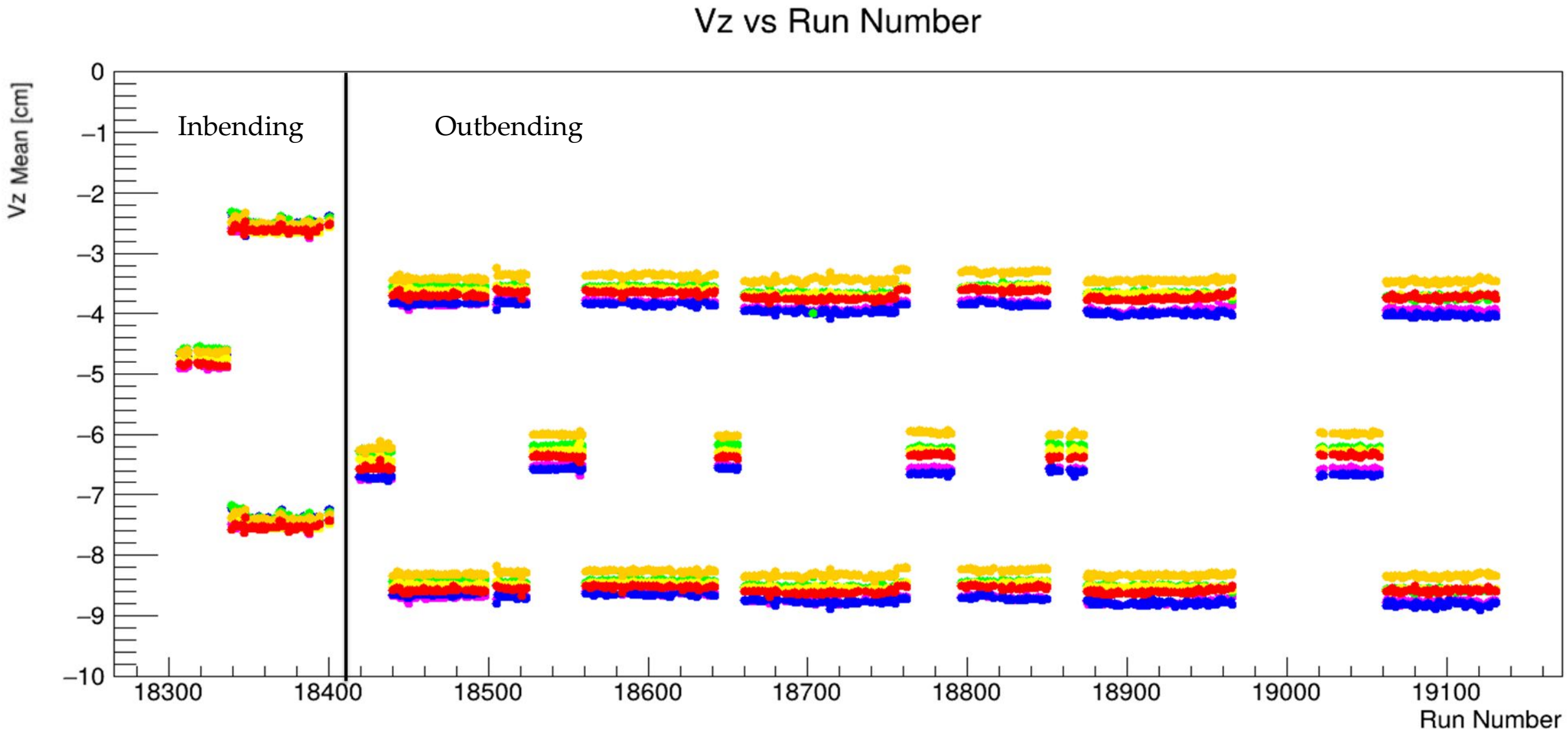
- π^- Selection
  - PID = -211
  - $-10 \leq \chi^2 \leq 10$



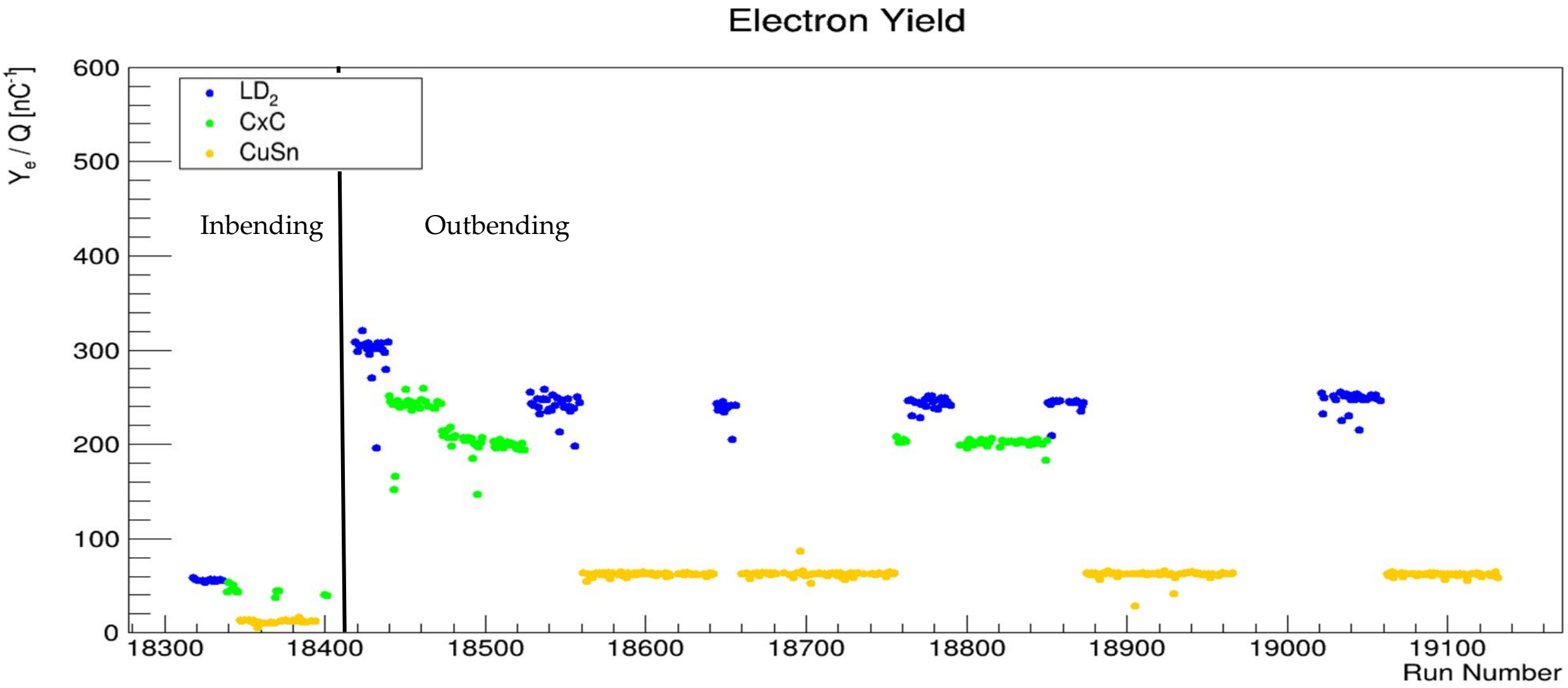
$\pi^+ \chi^2$



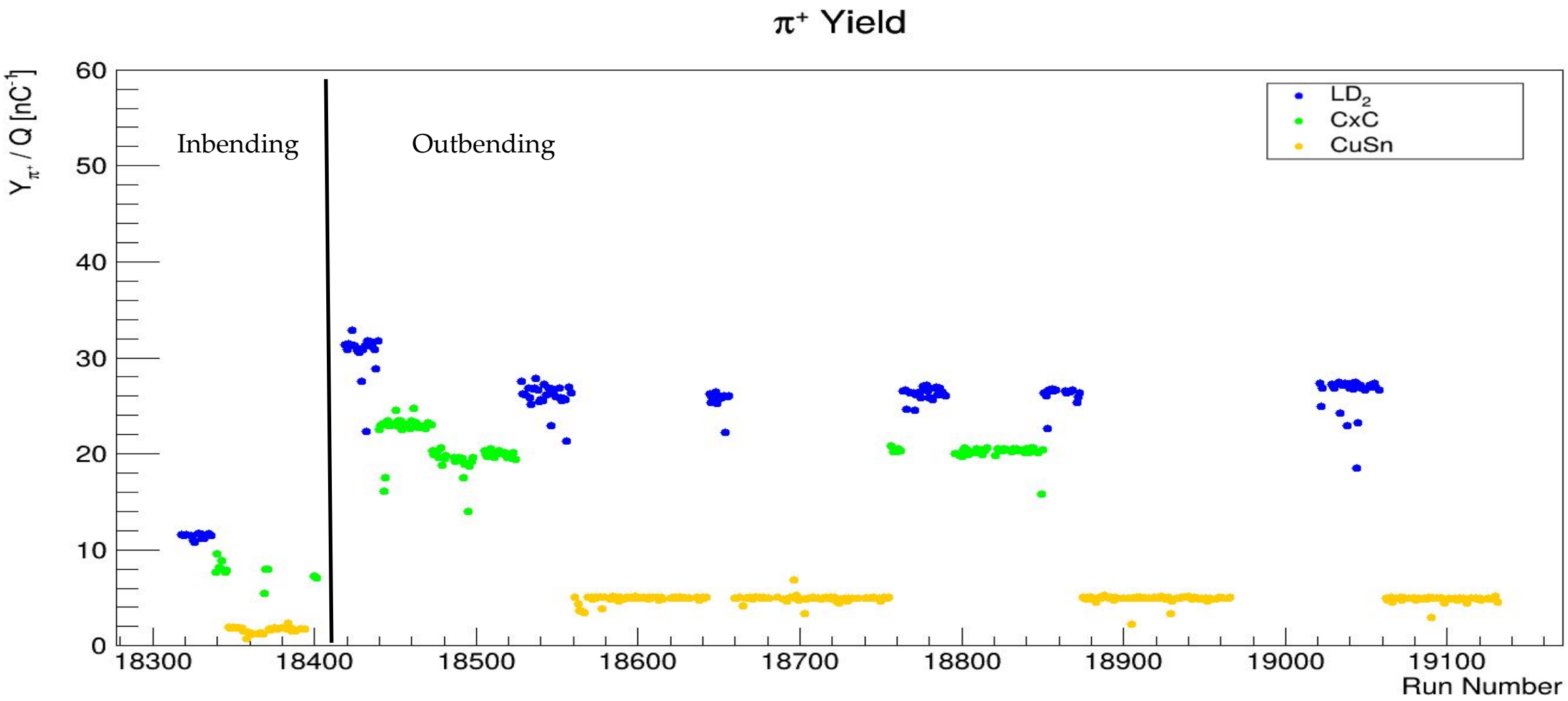
Sector-dependent z-Vertex Timeline



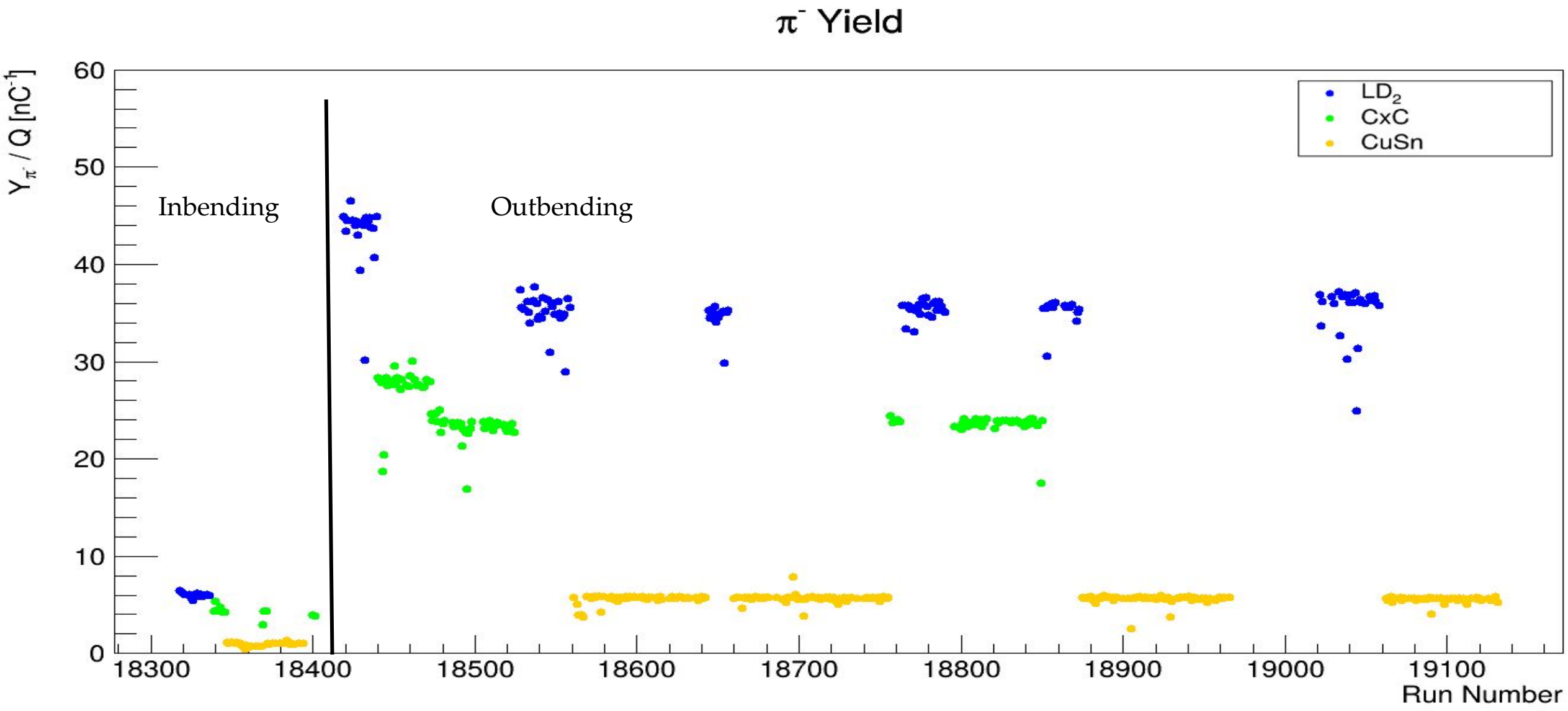
Particle Yield: Electrons



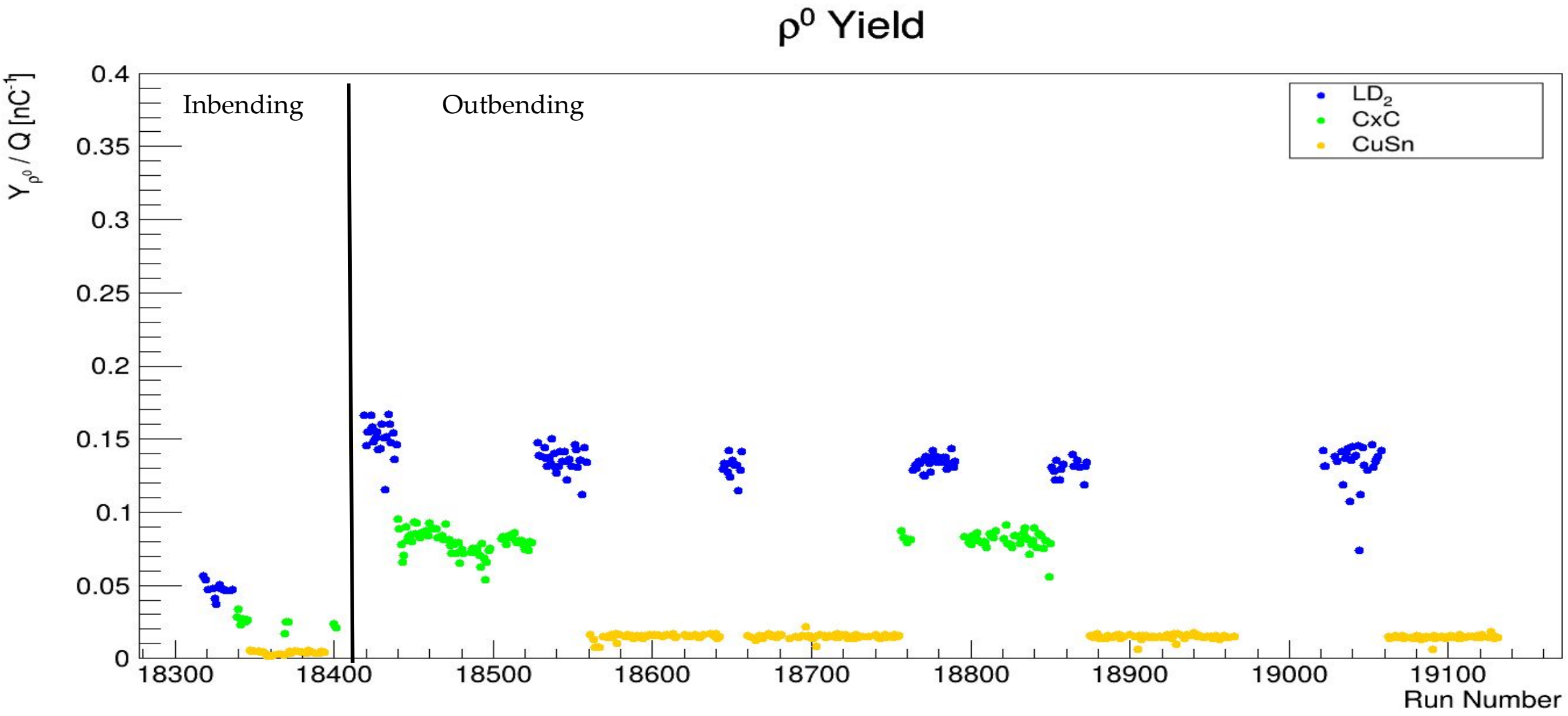
Particle Yield: Positive Pions



Particle Yield: Negative Pions

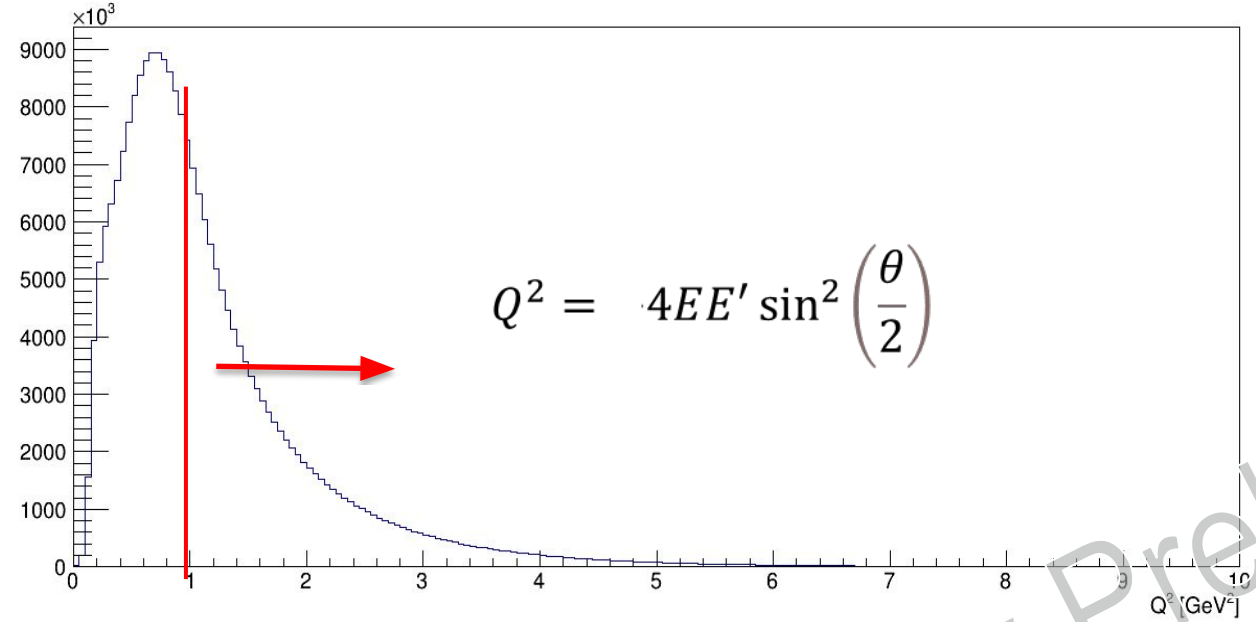


Particle Yield: ρ^0

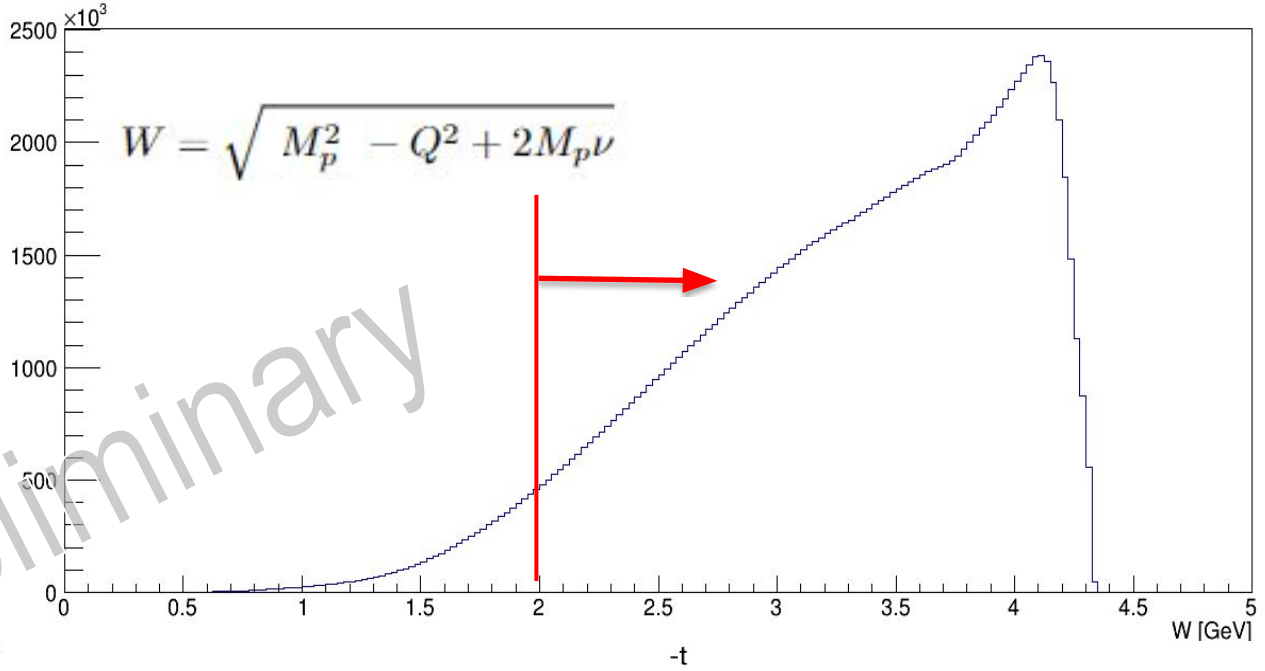


RG-D: Ongoing CT Analysis

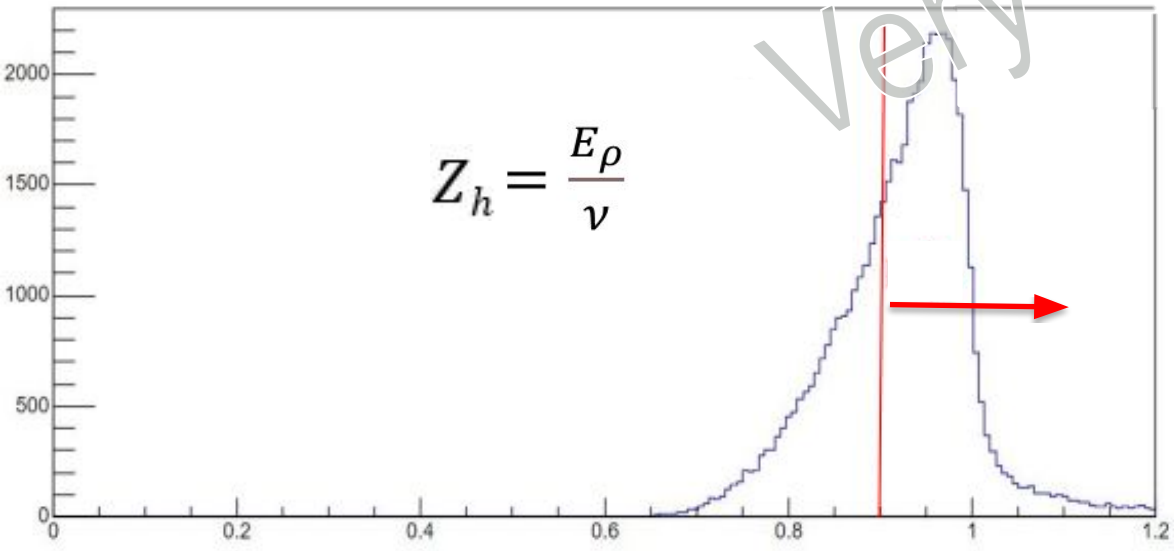
- Kinematics for exclusive diffractive and incoherent ρ^0 electroproduction off nuclei



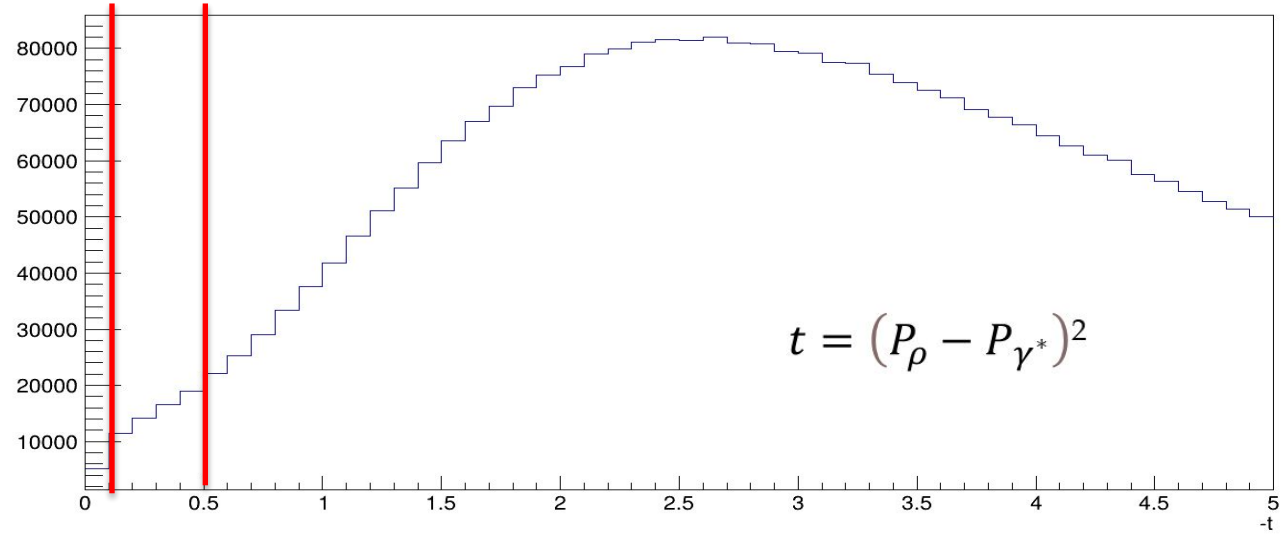
$$Q^2 = 4EE'\sin^2\left(\frac{\theta}{2}\right)$$



$$W = \sqrt{M_p^2 - Q^2 + 2M_p\nu}$$

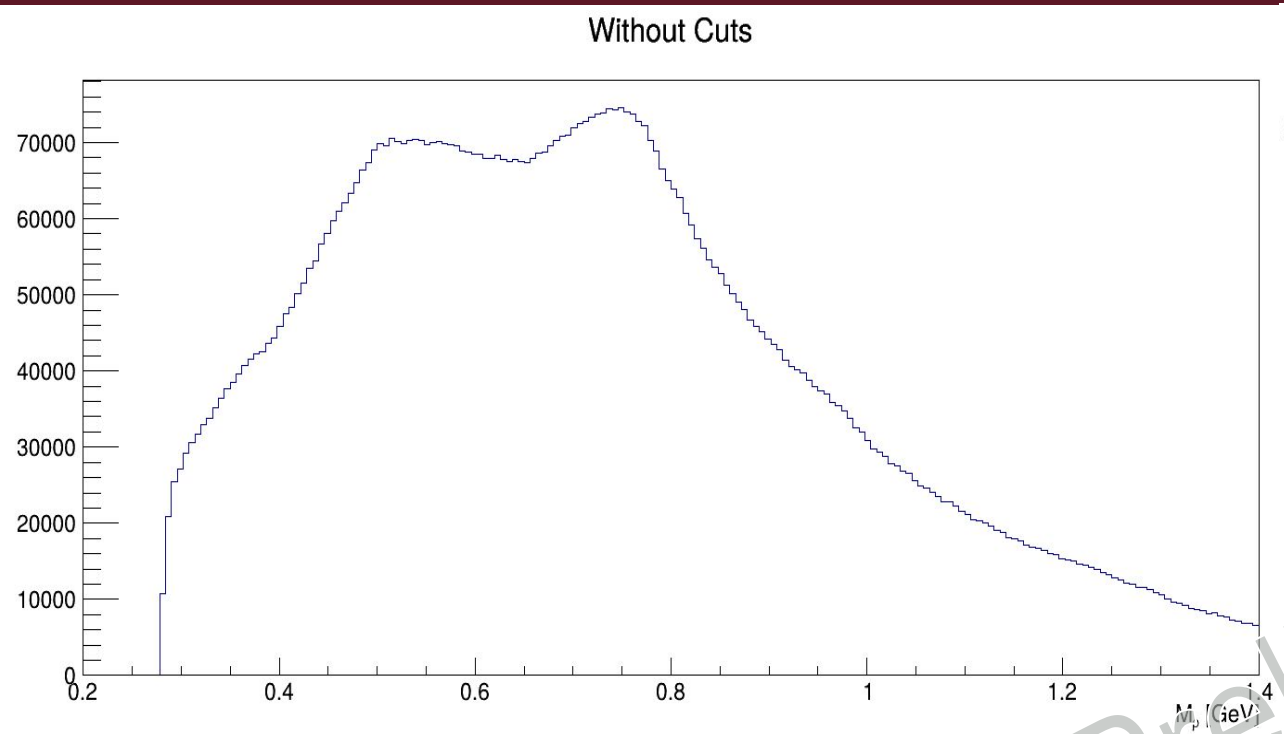


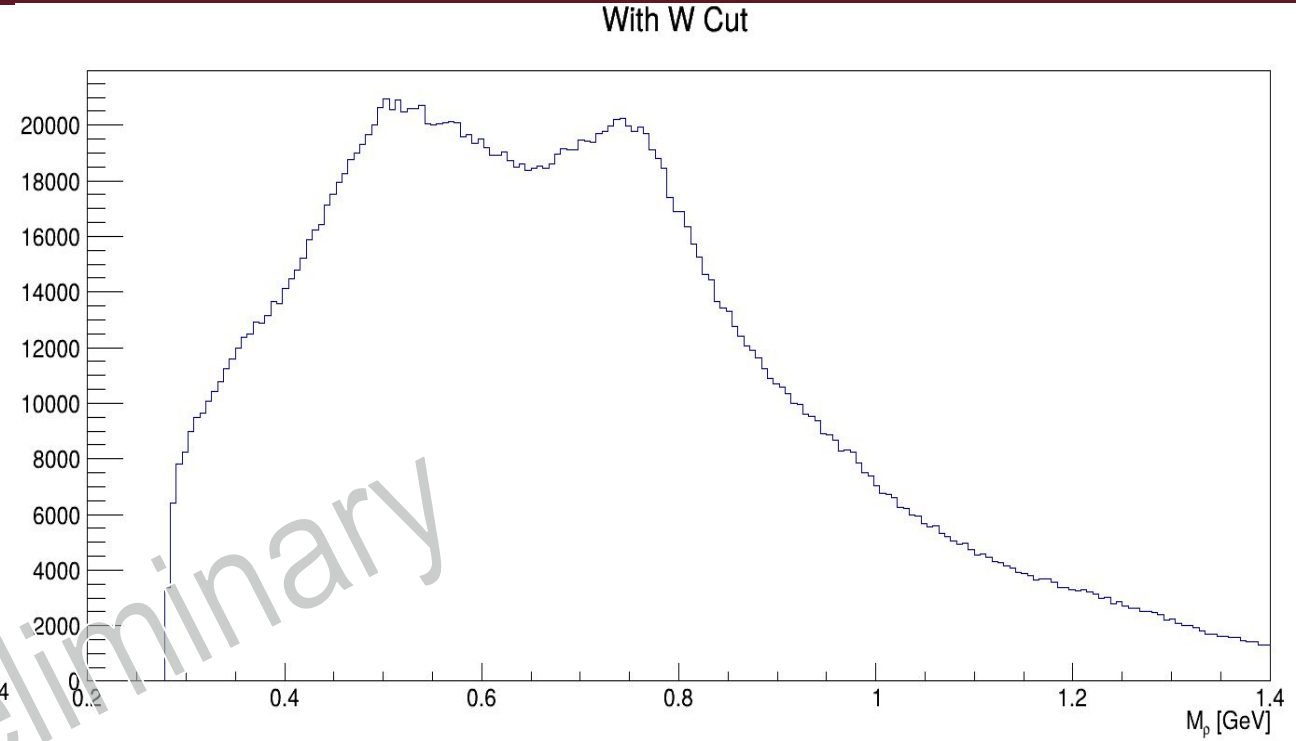
$$Z_h = \frac{E_\rho}{\nu}$$

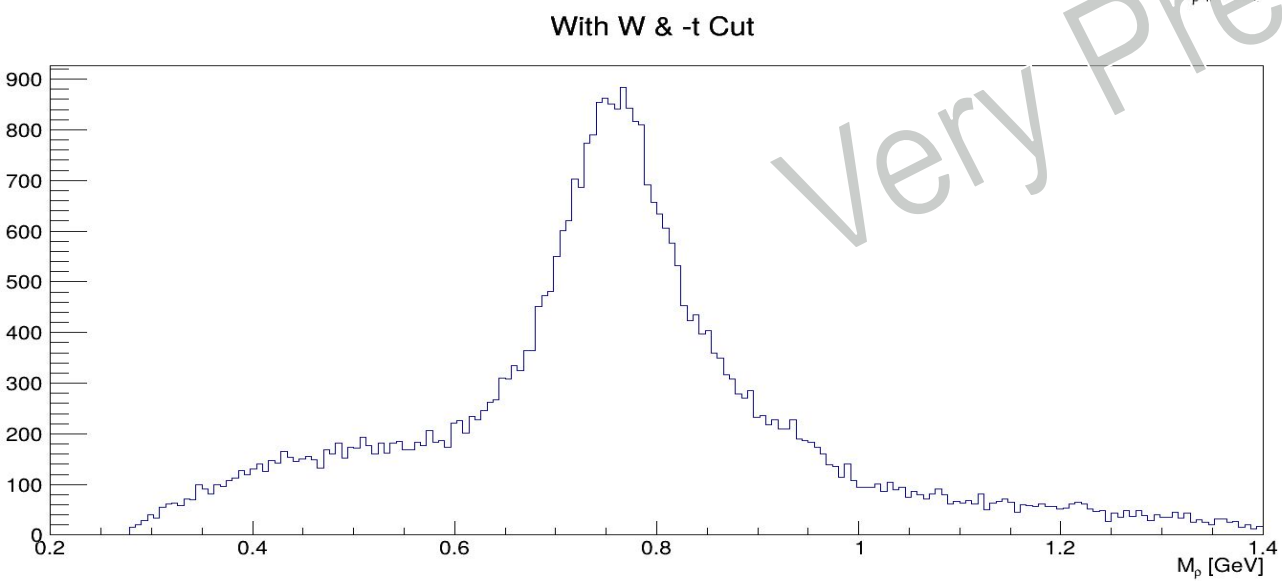


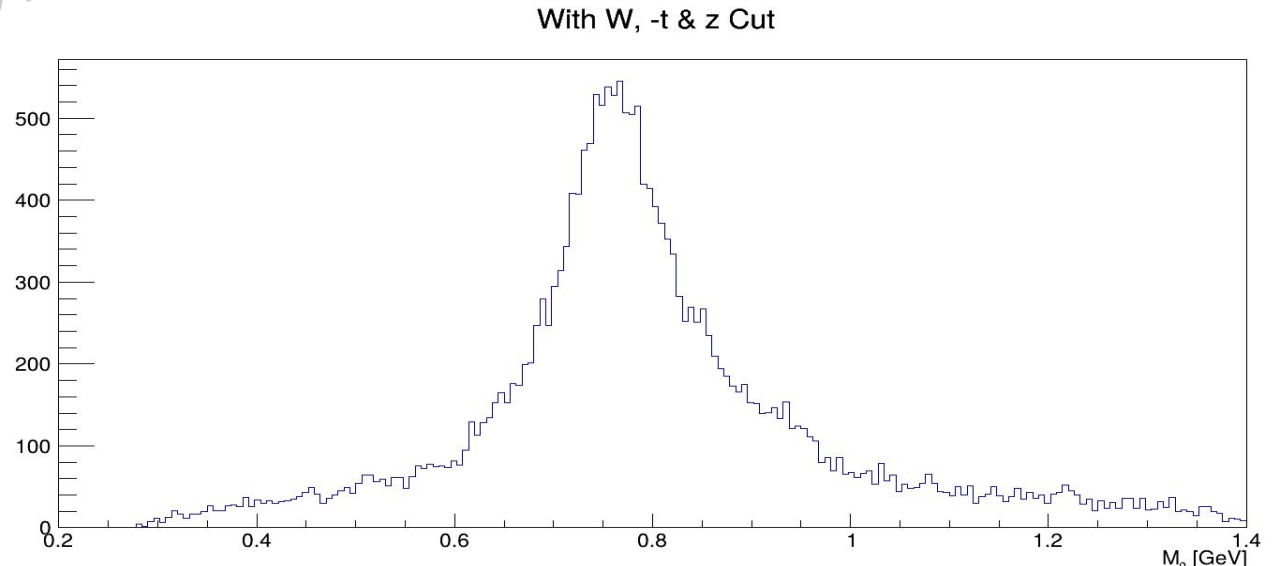
$$t = (P_\rho - P_{\gamma^*})^2$$

RG-D: Ongoing CT Analysis

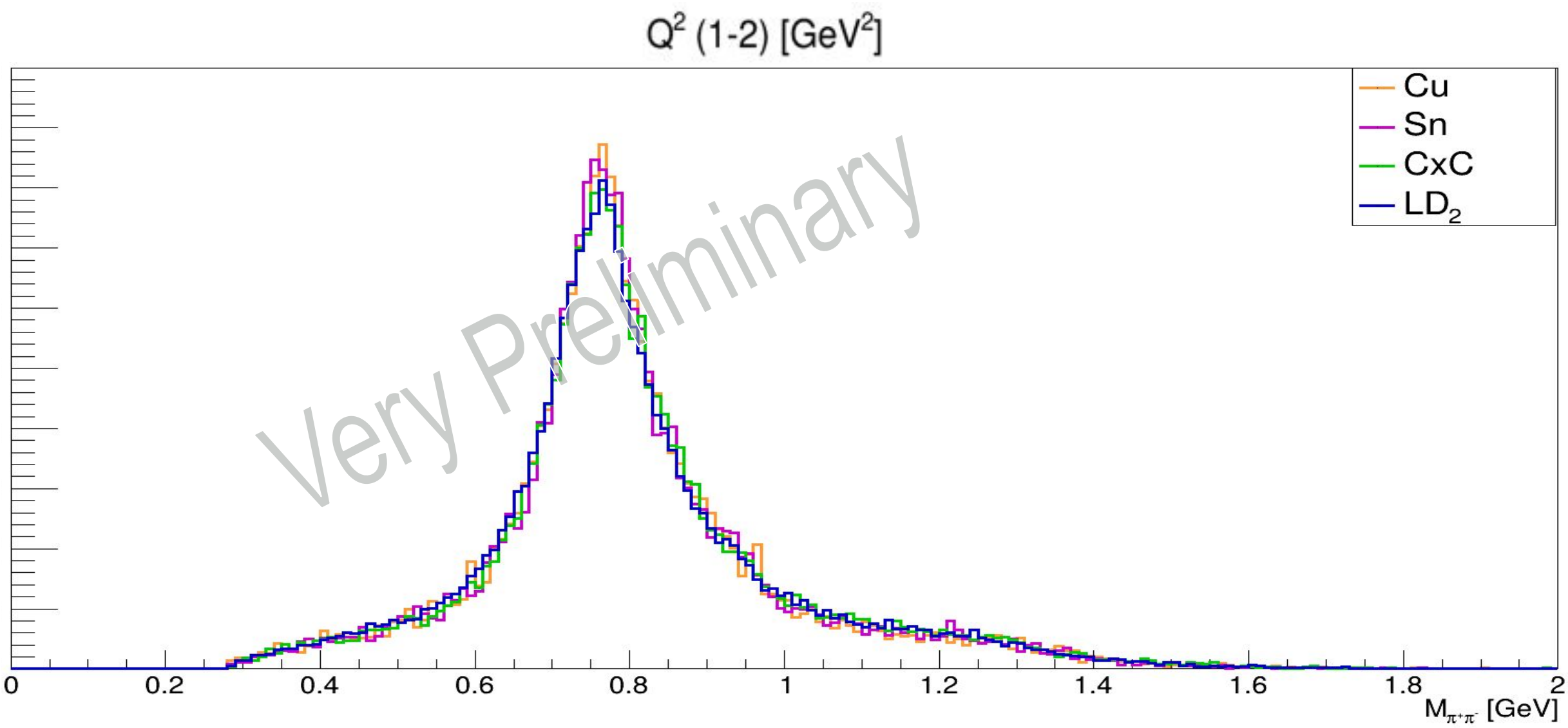




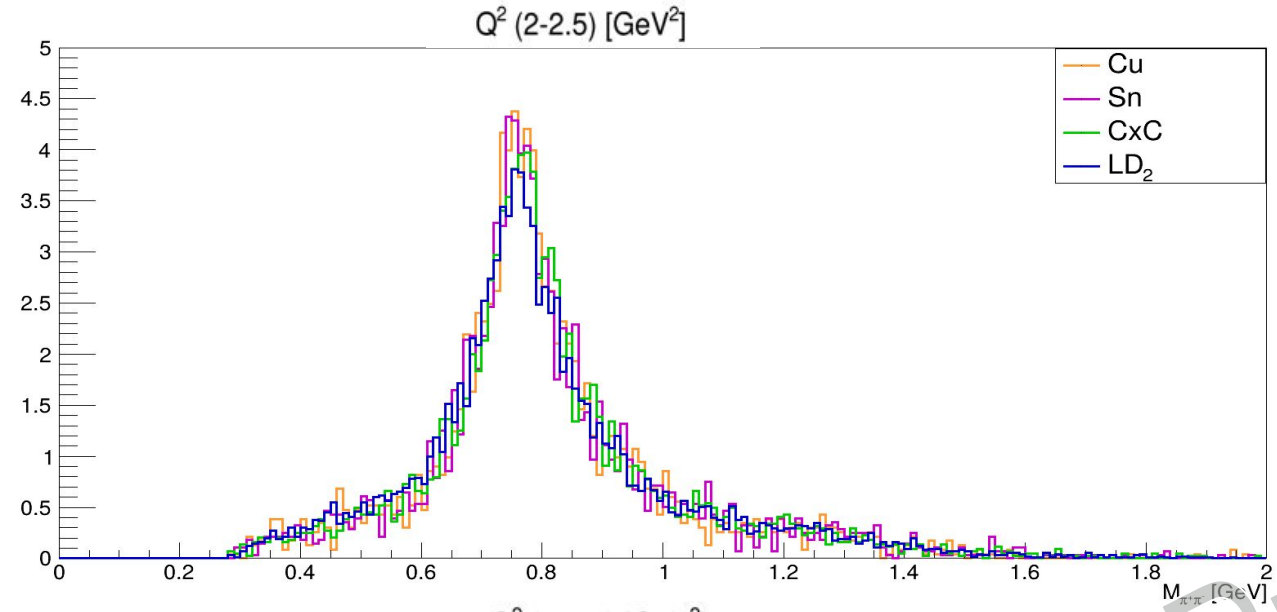


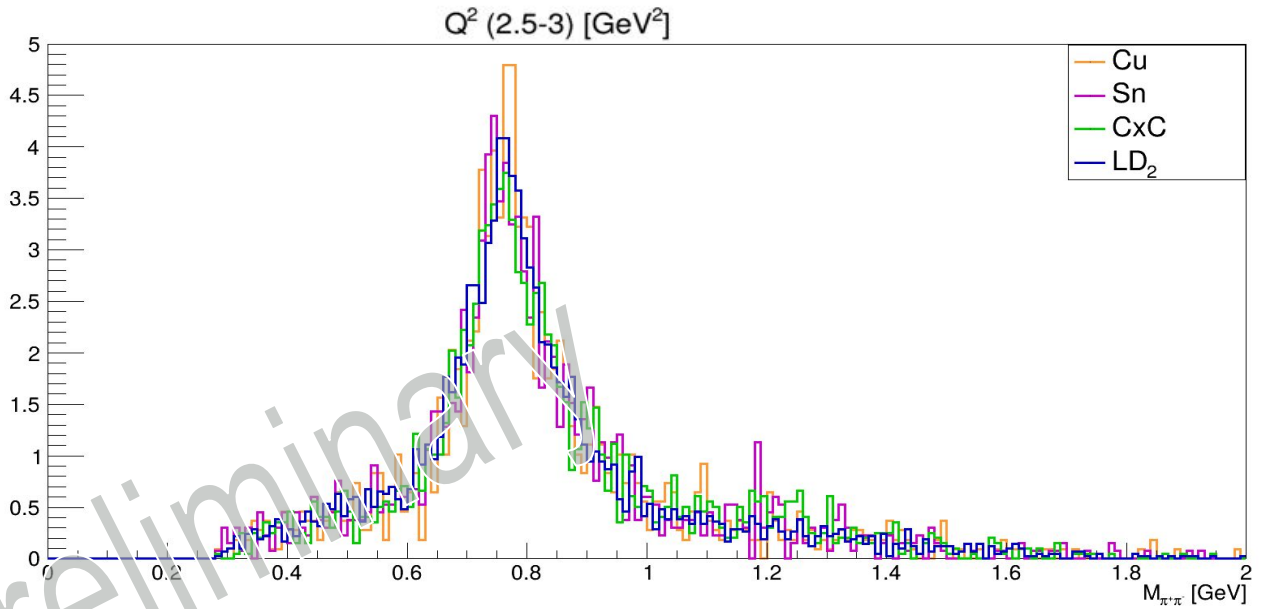


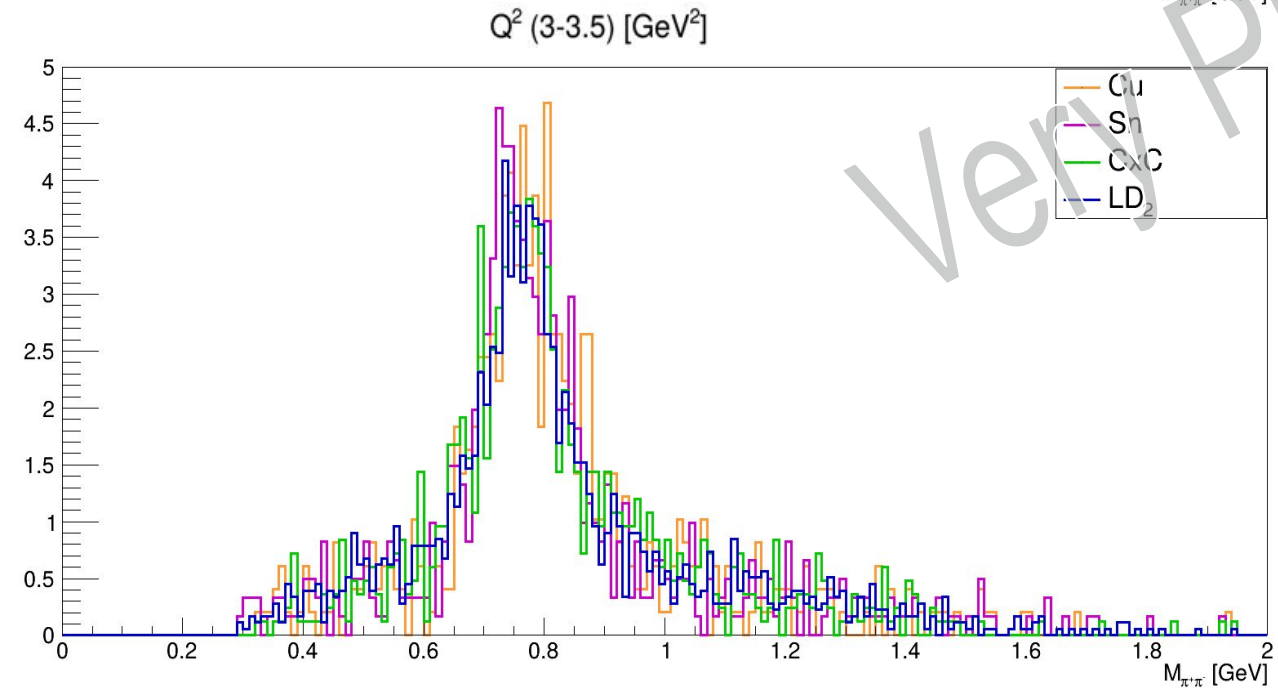
RG-D CT Analysis: Invariant Mass Comparison

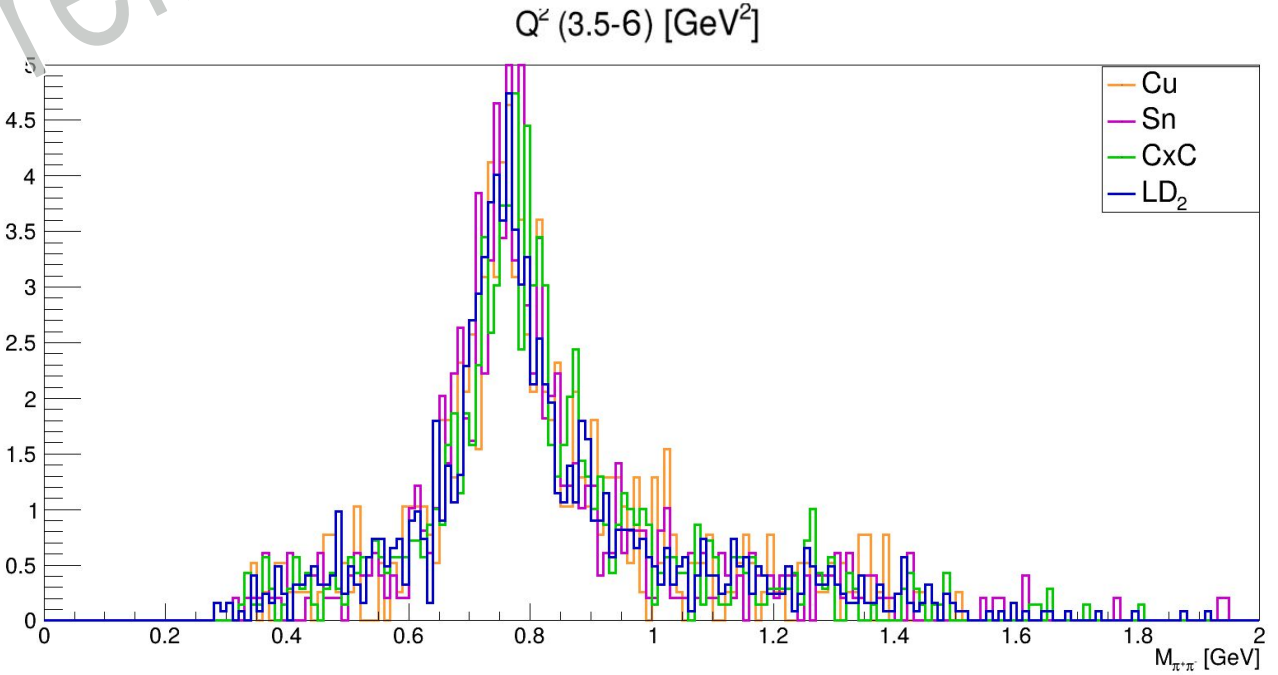


RG-D CT Experiment Status: Invariant Mass Comparison



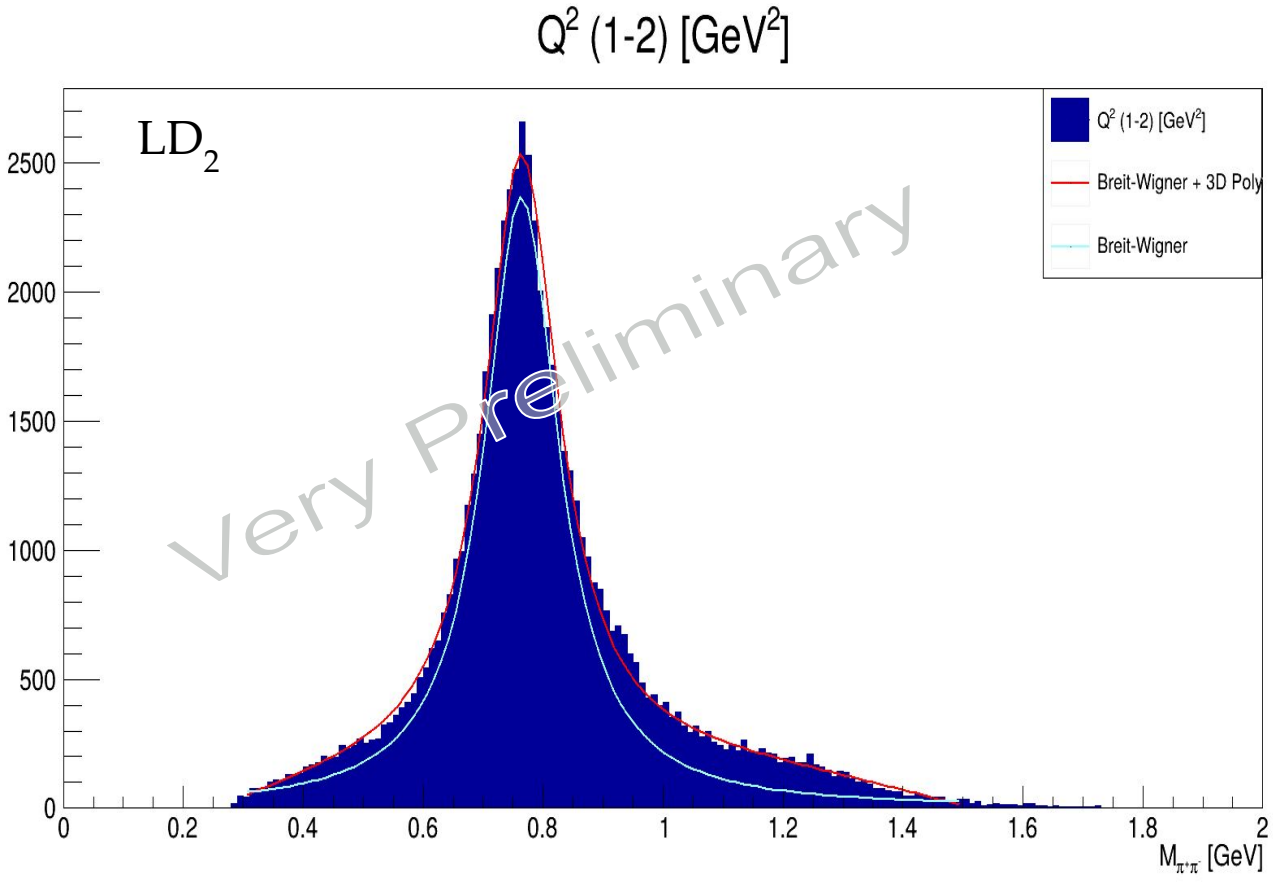


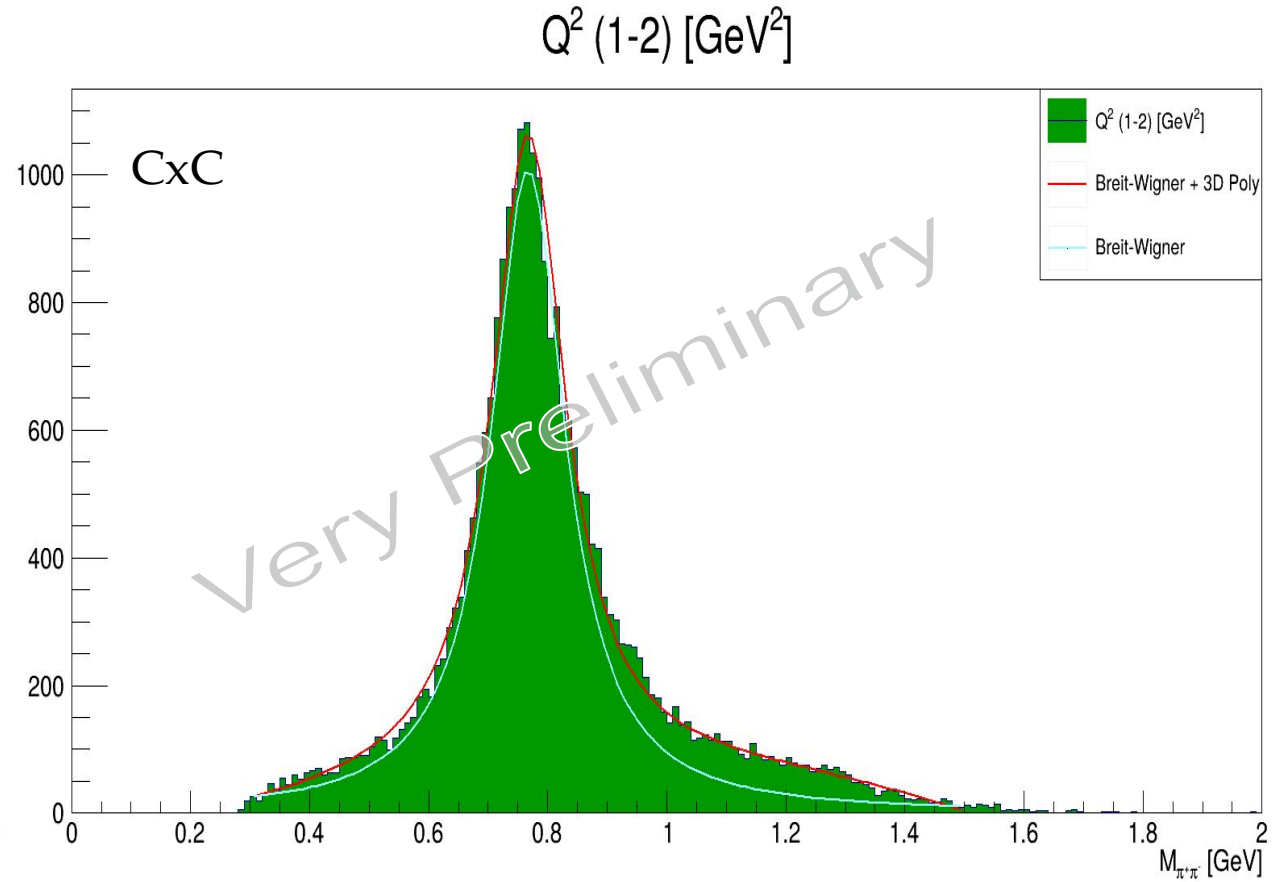


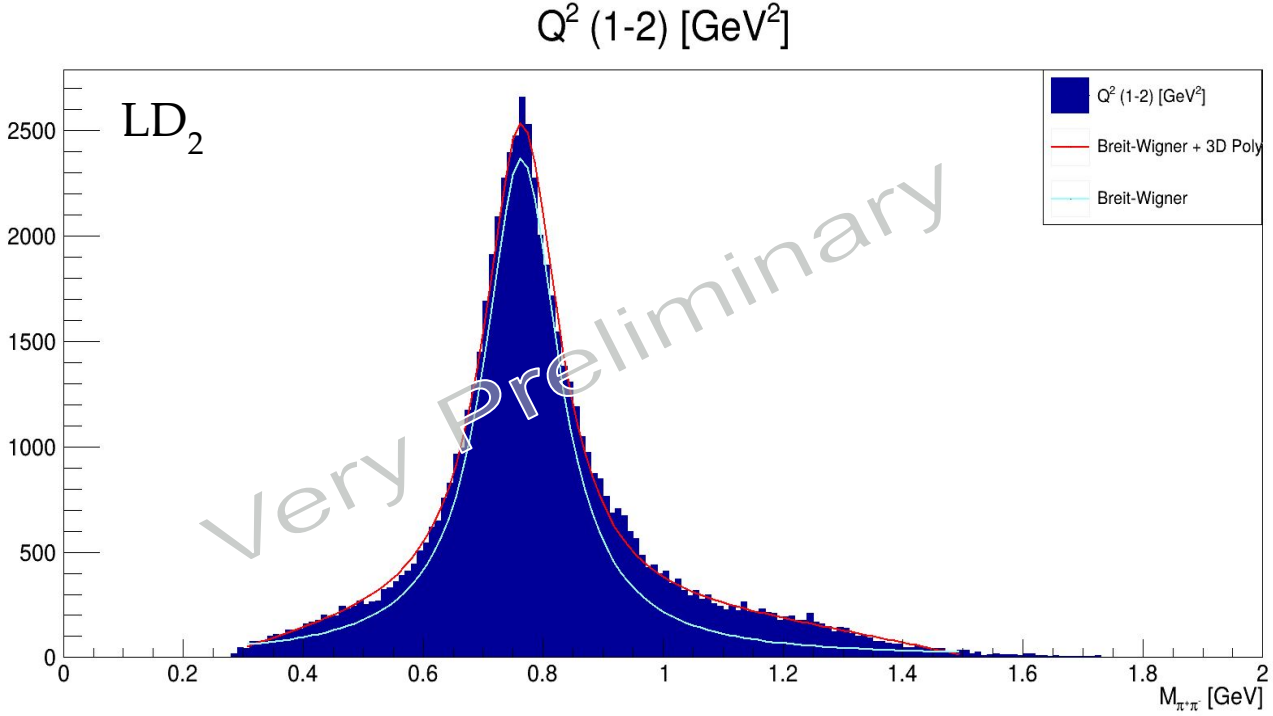


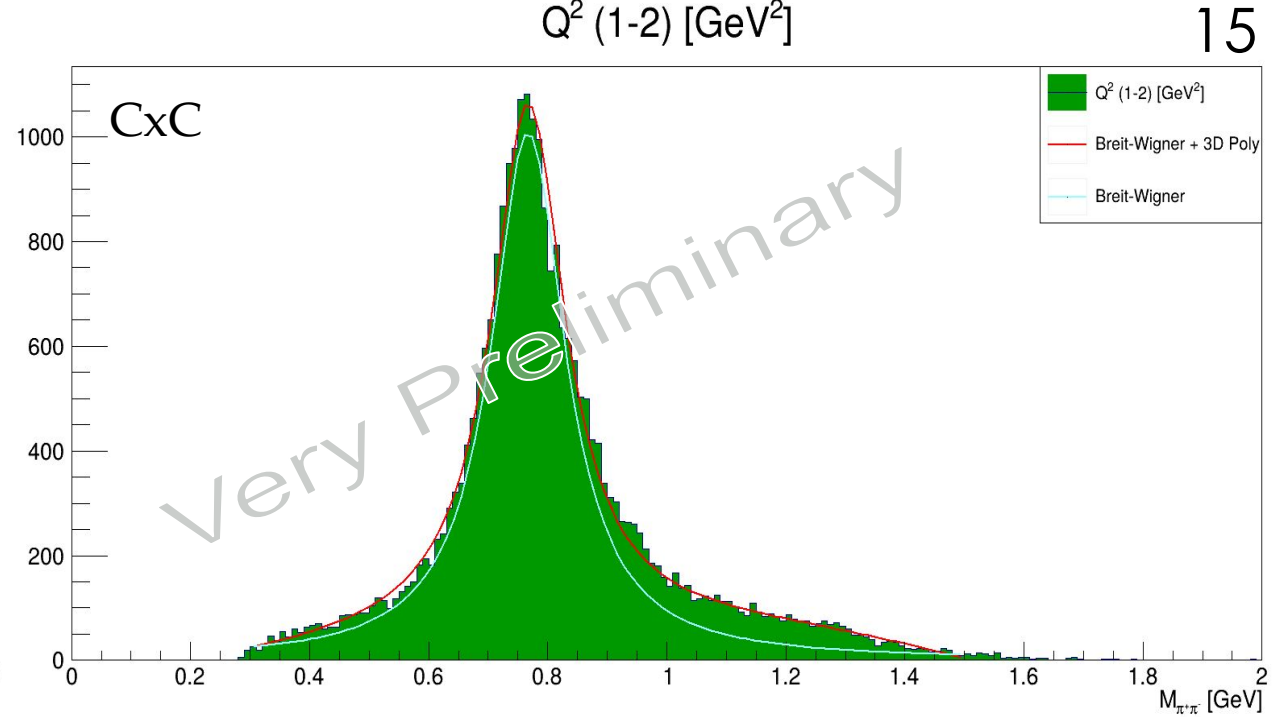
RG-D CT Analysis Status: $\pi^+\pi^-$ Invariant Mass Fit

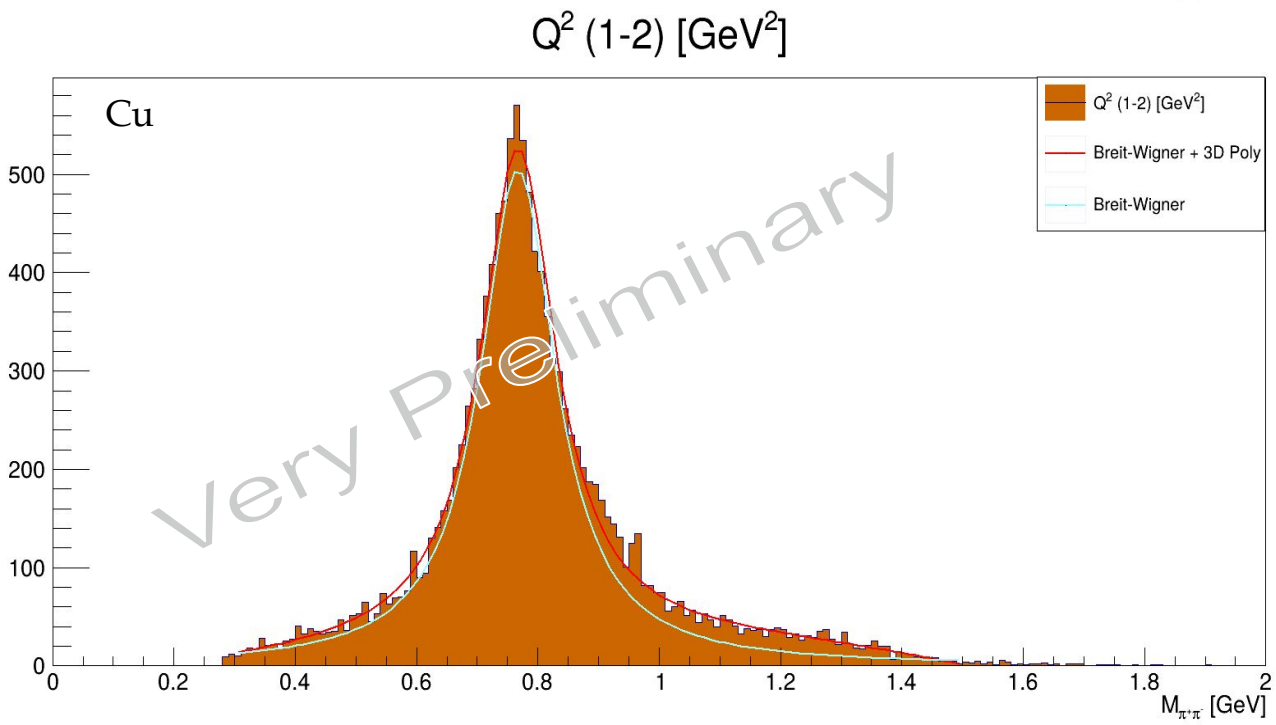
- $\pi^+\pi^-$ mass distributions for various Q^2 bins and less than 10% of all datasets
- A very preliminary fit using a simple Breit Wigner for the signal and a 3-D polynomial (*temporarily*) function for the background underneath the peak

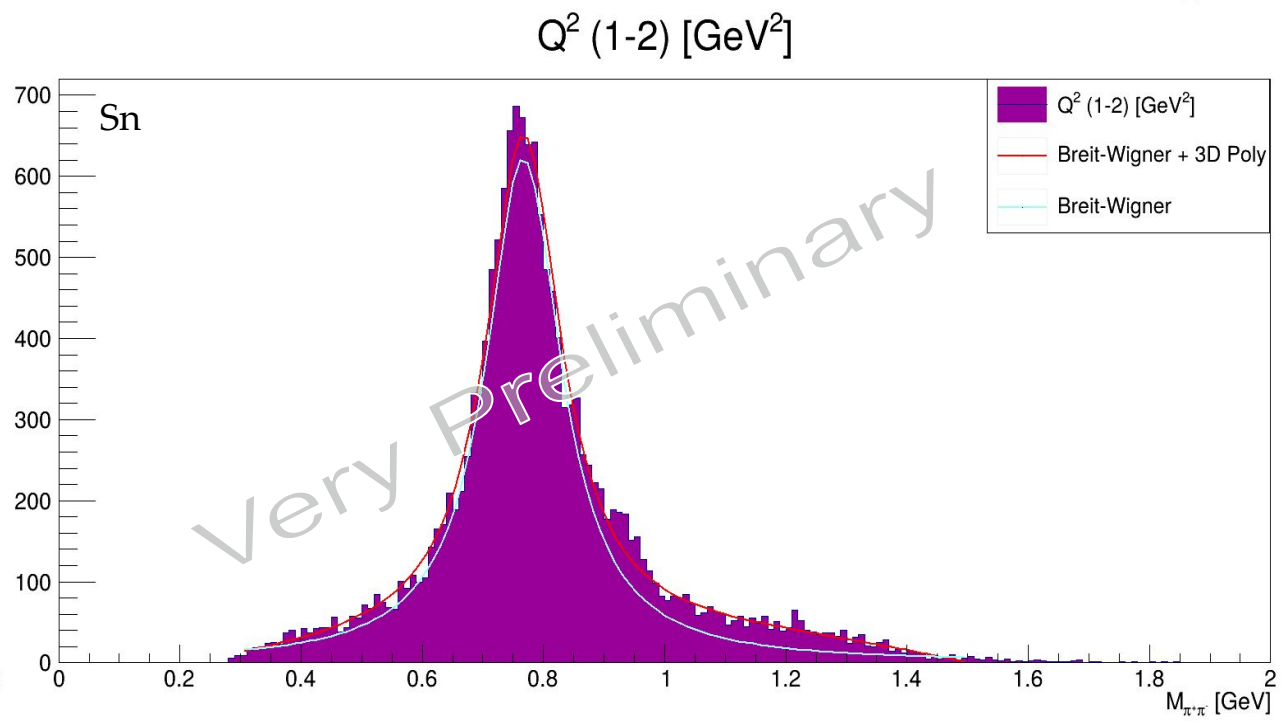


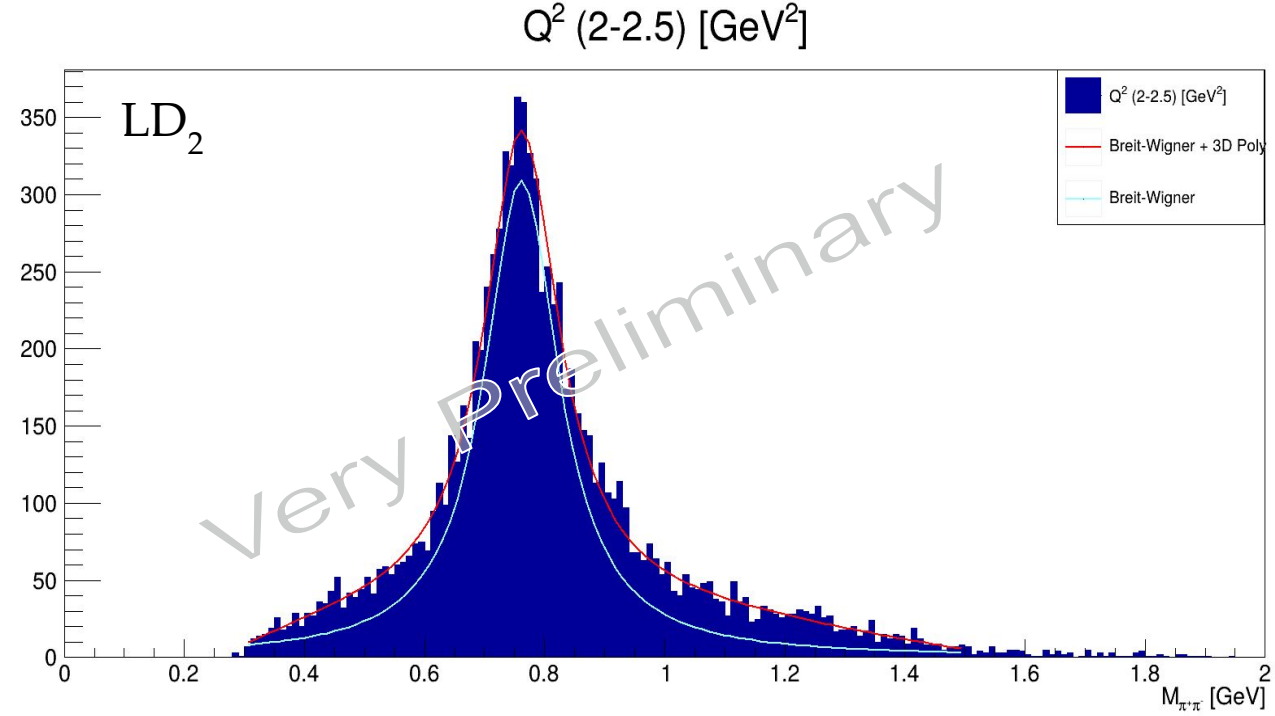


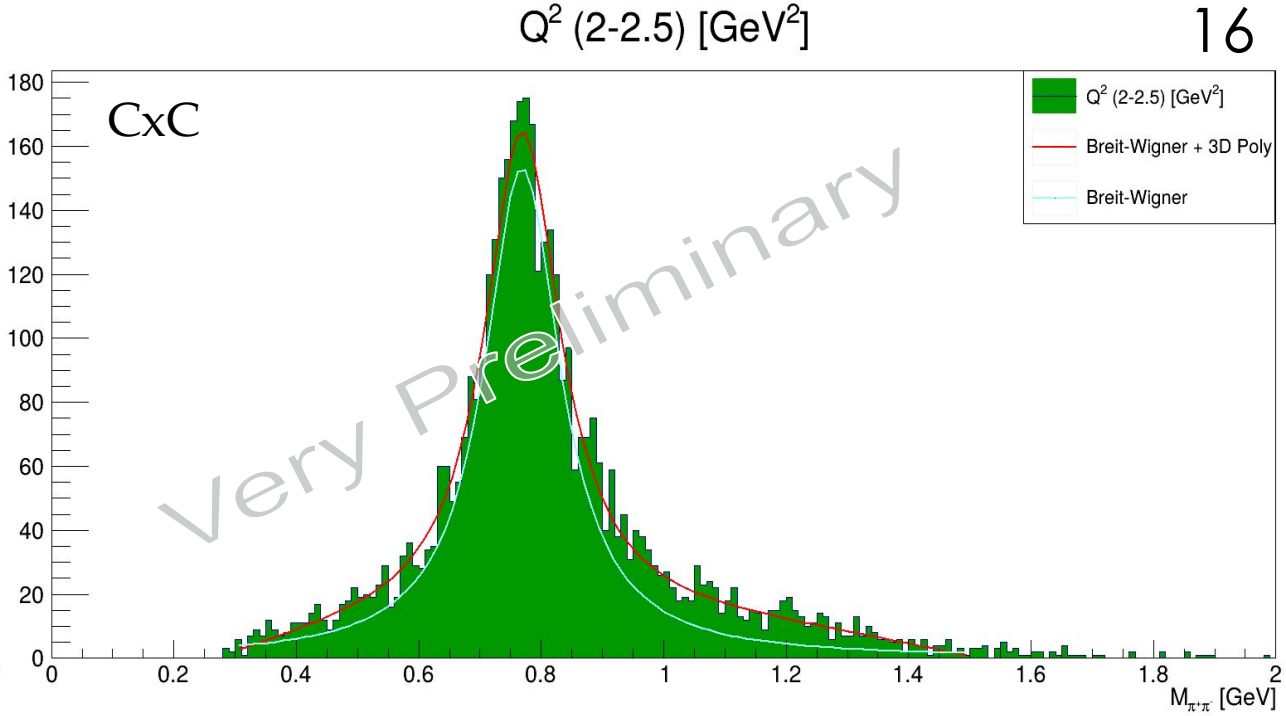

Q² (1-2) [GeV²]
LD2
Q² (1-2) [GeV²]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
Mπ⁺π⁻ [GeV]

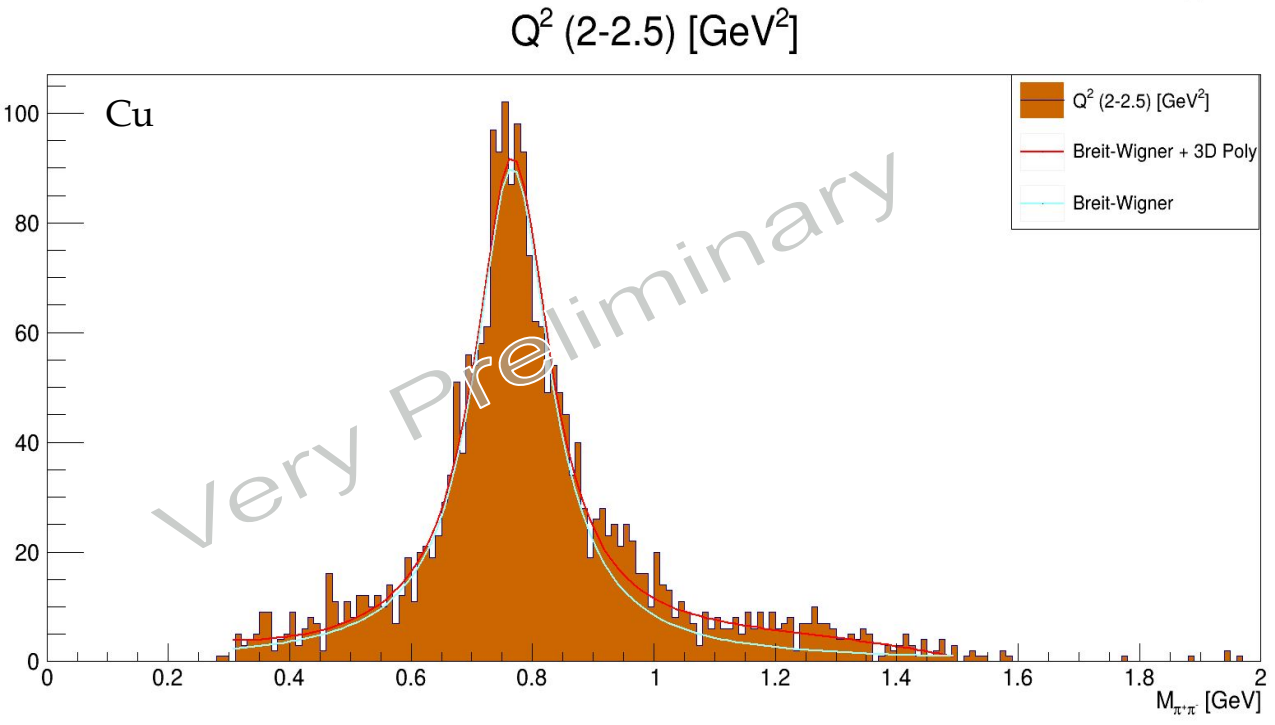

Q² (1-2) [GeV²]
CxC
Q² (1-2) [GeV²]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
Mπ⁺π⁻ [GeV]

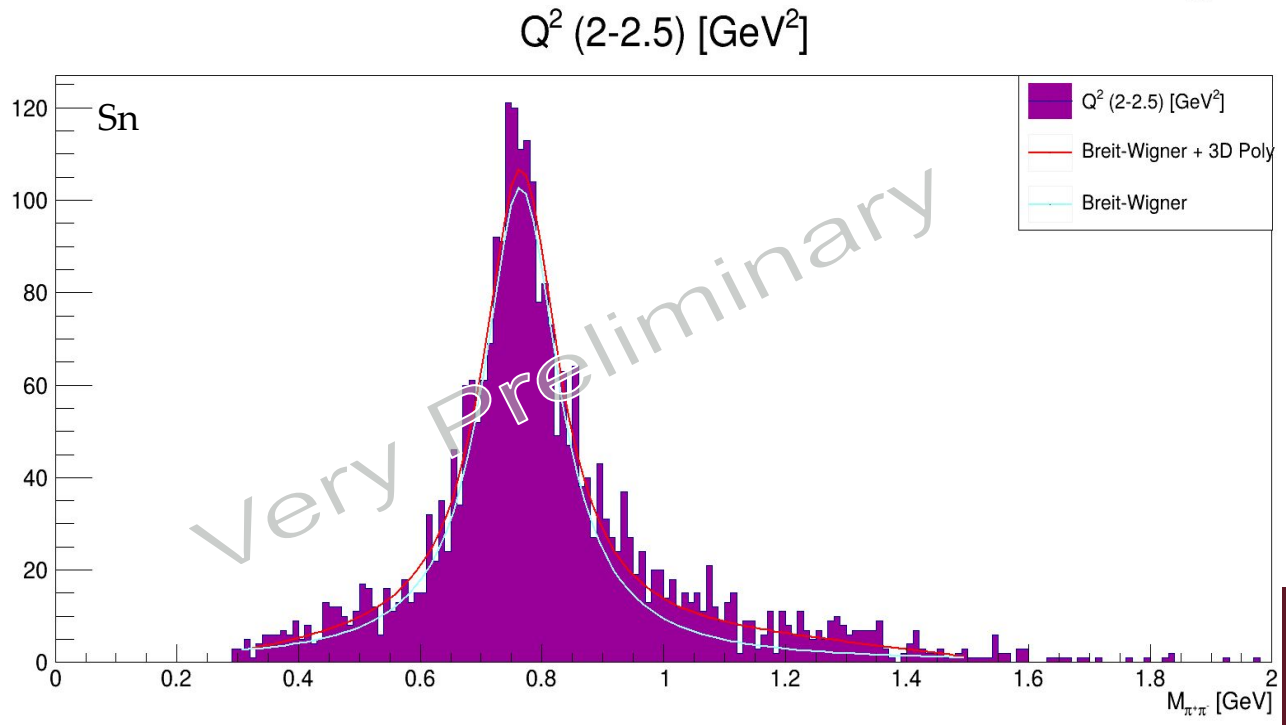

Q² (1-2) [GeV²]
Cu
Q² (1-2) [GeV²]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
Mπ⁺π⁻ [GeV]

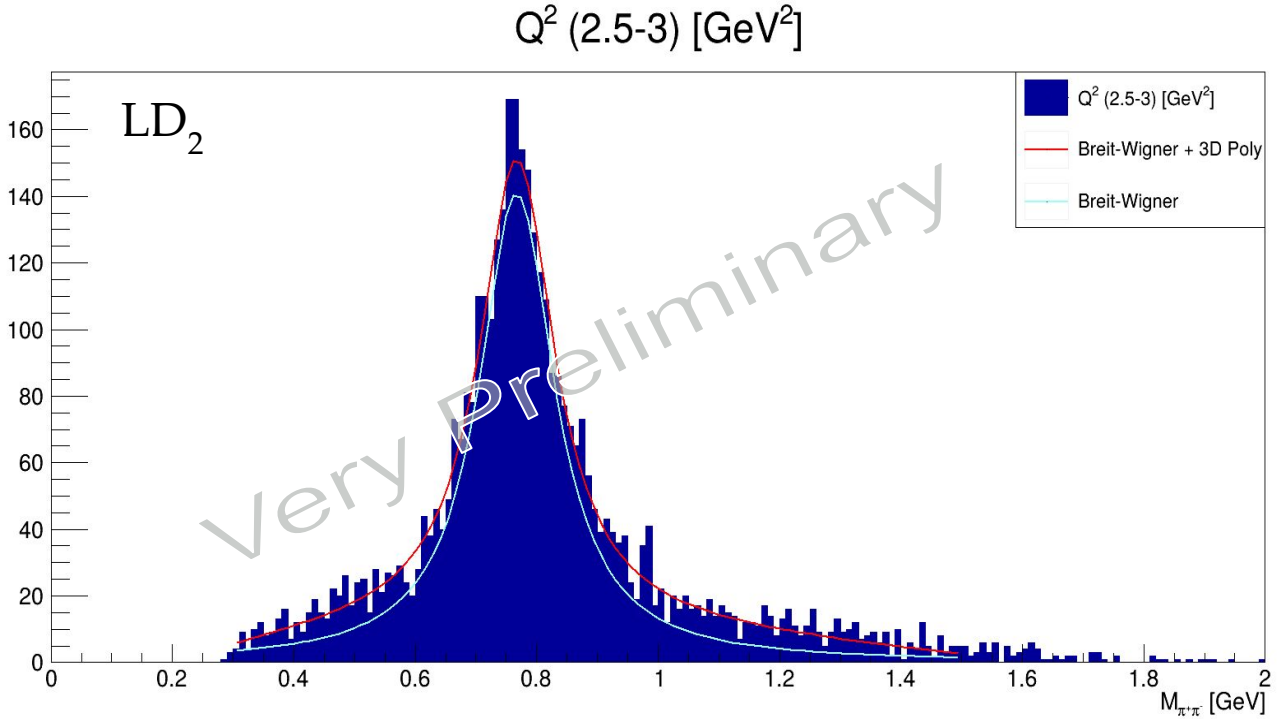

Q² (1-2) [GeV²]
Sn
Q² (1-2) [GeV²]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
Mπ⁺π⁻ [GeV]

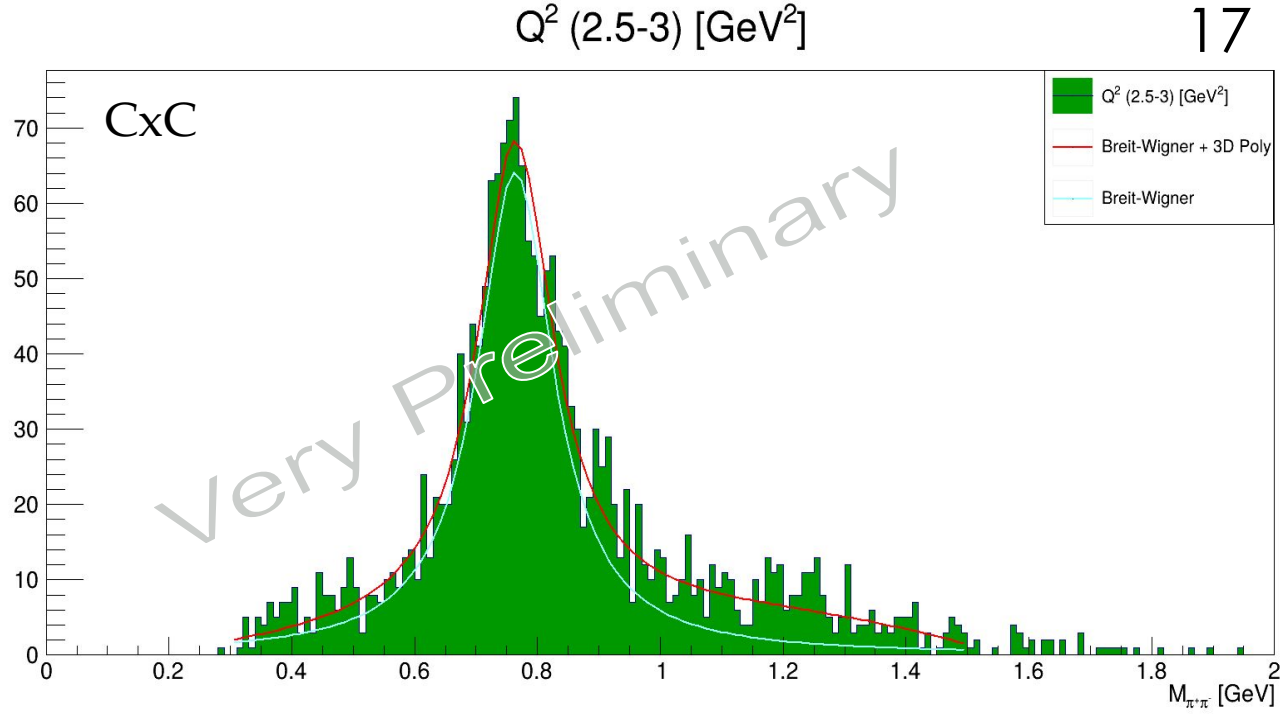

Q^2 (2-2.5) [GeV^2]
LD_2
Q^2 (2-2.5) [GeV^2]
Breit-Wigner + 3D Poly
Breit-Wigner
$M_{\pi^+\pi^-}$ [GeV]
Very Preliminary


Q^2 (2-2.5) [GeV^2]
CxC
Q^2 (2-2.5) [GeV^2]
Breit-Wigner + 3D Poly
Breit-Wigner
$M_{\pi^+\pi^-}$ [GeV]
Very Preliminary


Q^2 (2-2.5) [GeV^2]
Cu
Q^2 (2-2.5) [GeV^2]
Breit-Wigner + 3D Poly
Breit-Wigner
$M_{\pi^+\pi^-}$ [GeV]
Very Preliminary


Q^2 (2-2.5) [GeV^2]
Sn
Q^2 (2-2.5) [GeV^2]
Breit-Wigner + 3D Poly
Breit-Wigner
$M_{\pi^+\pi^-}$ [GeV]
Very Preliminary


Q^2 (2.5-3) [GeV^2]
LD_2
Q^2 (2.5-3) [GeV^2]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
$M_{\pi^+\pi^-}$ [GeV]


Q^2 (2.5-3) [GeV^2]
CxC
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Breit-Wigner + 3D Poly
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Very Preliminary
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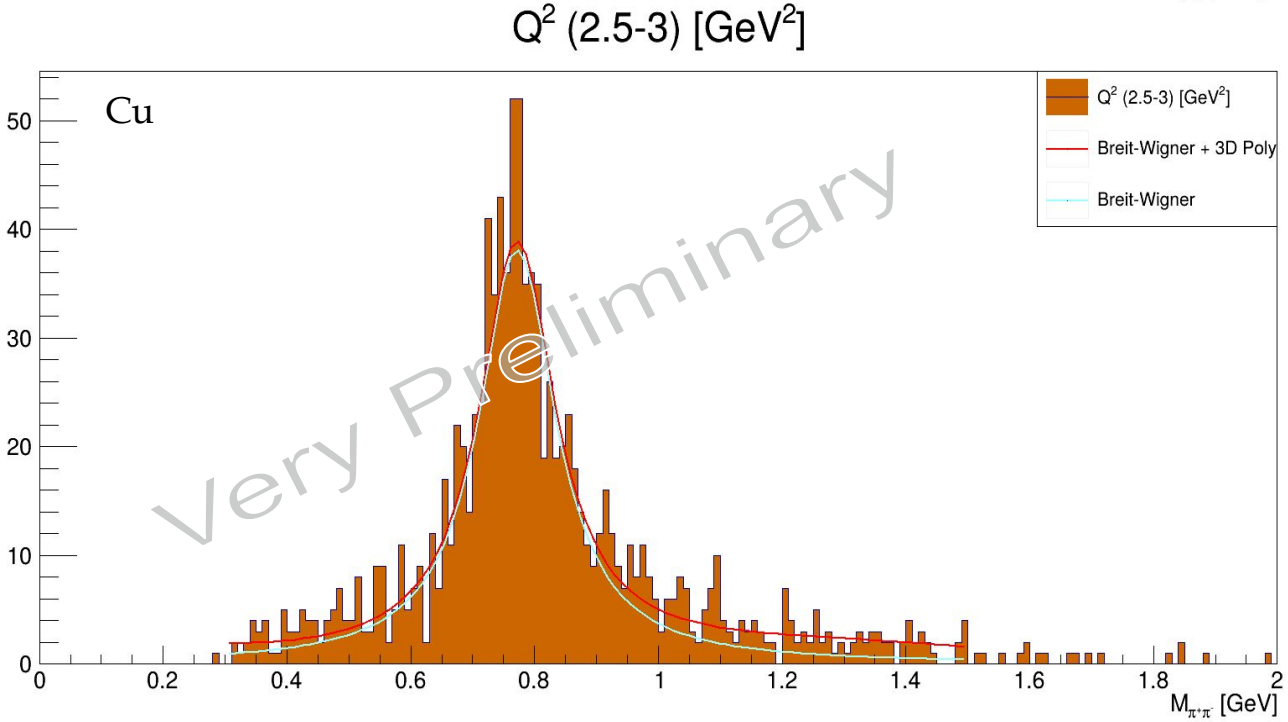
Q^2 (2.5-3) [GeV^2]
Cu
Q^2 (2.5-3) [GeV^2]
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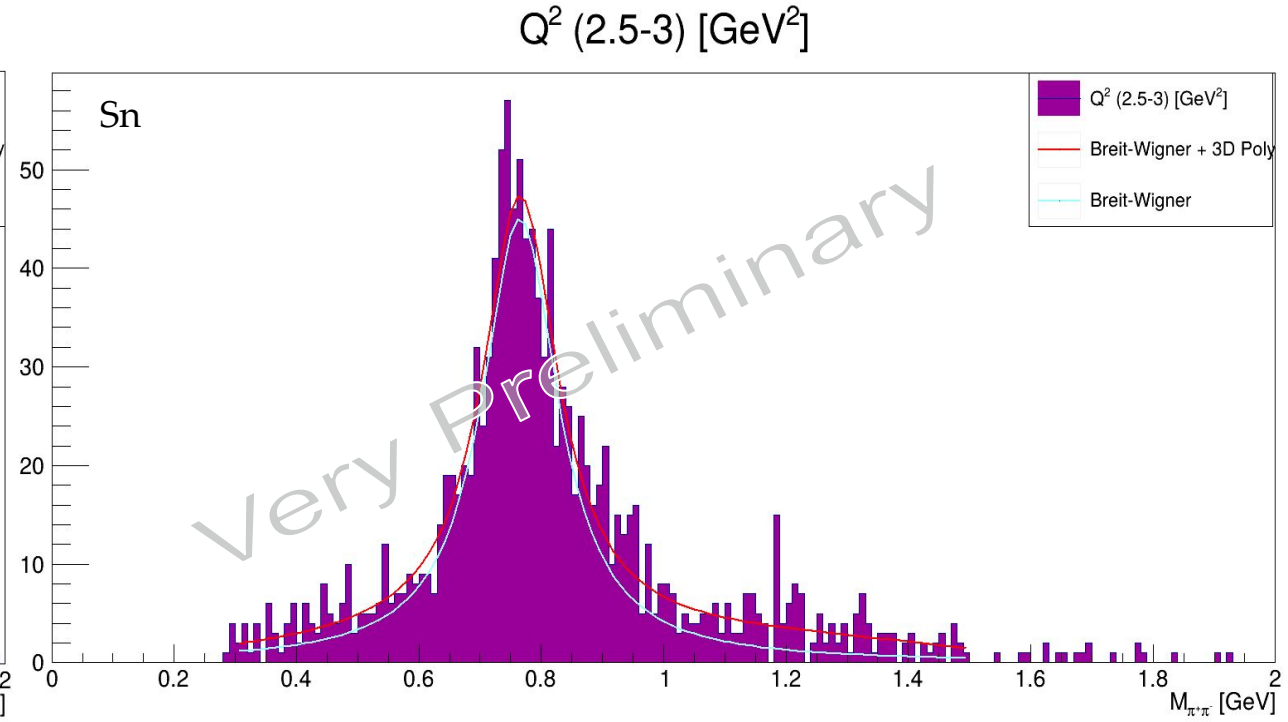
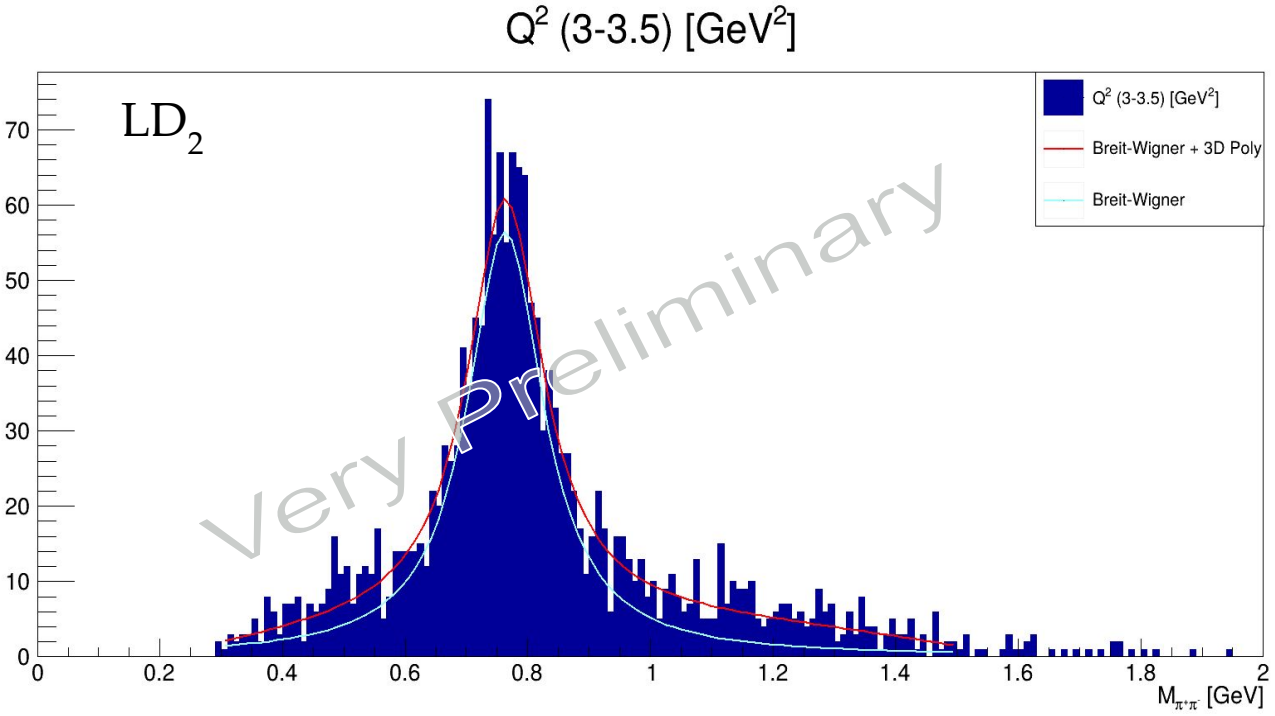
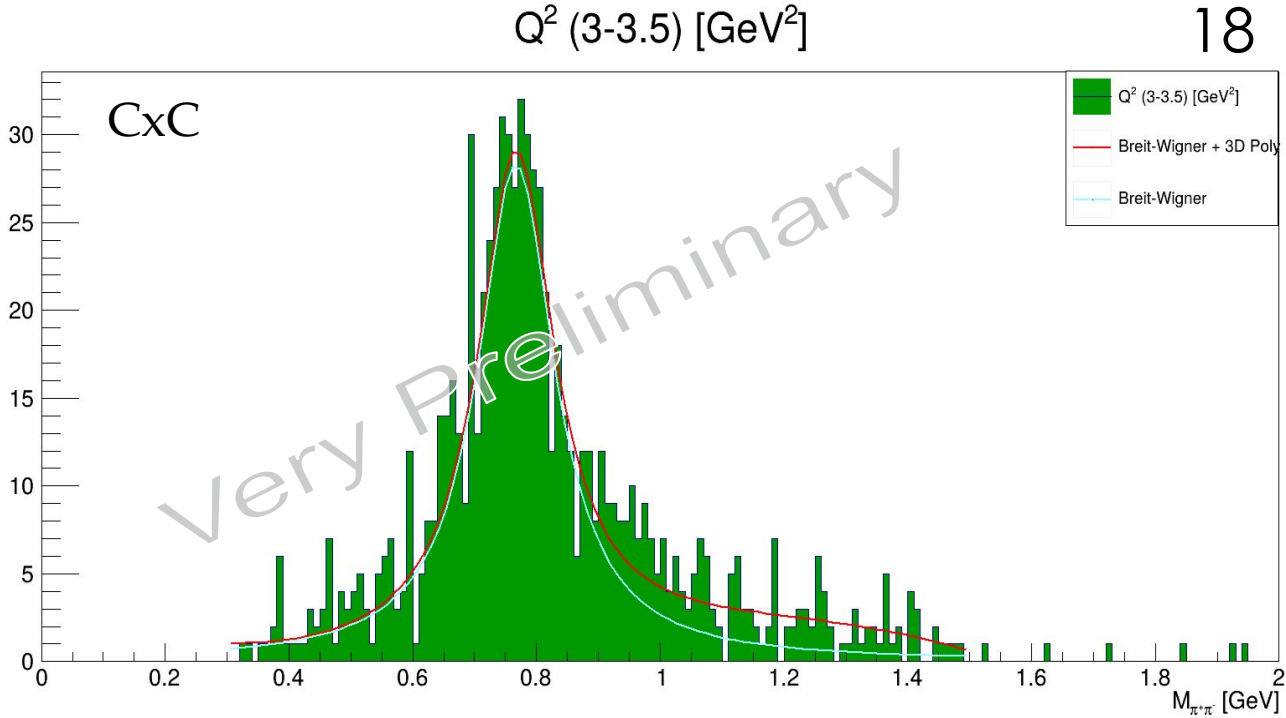
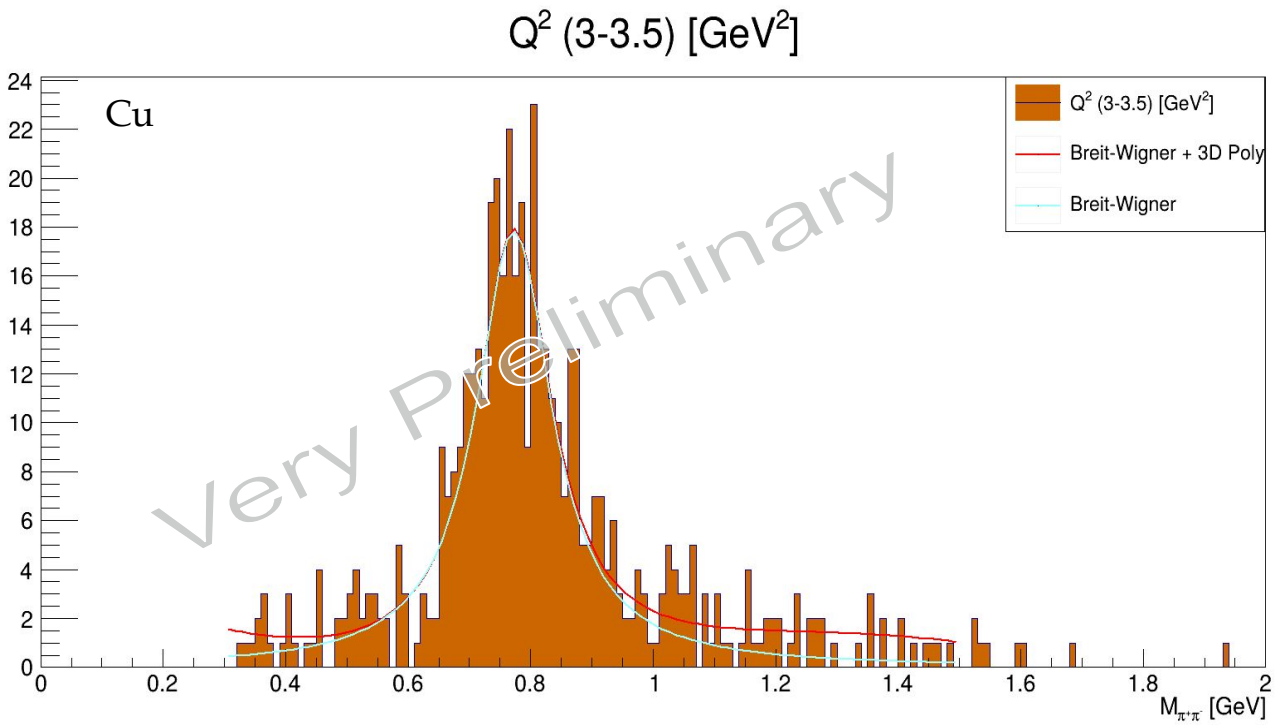
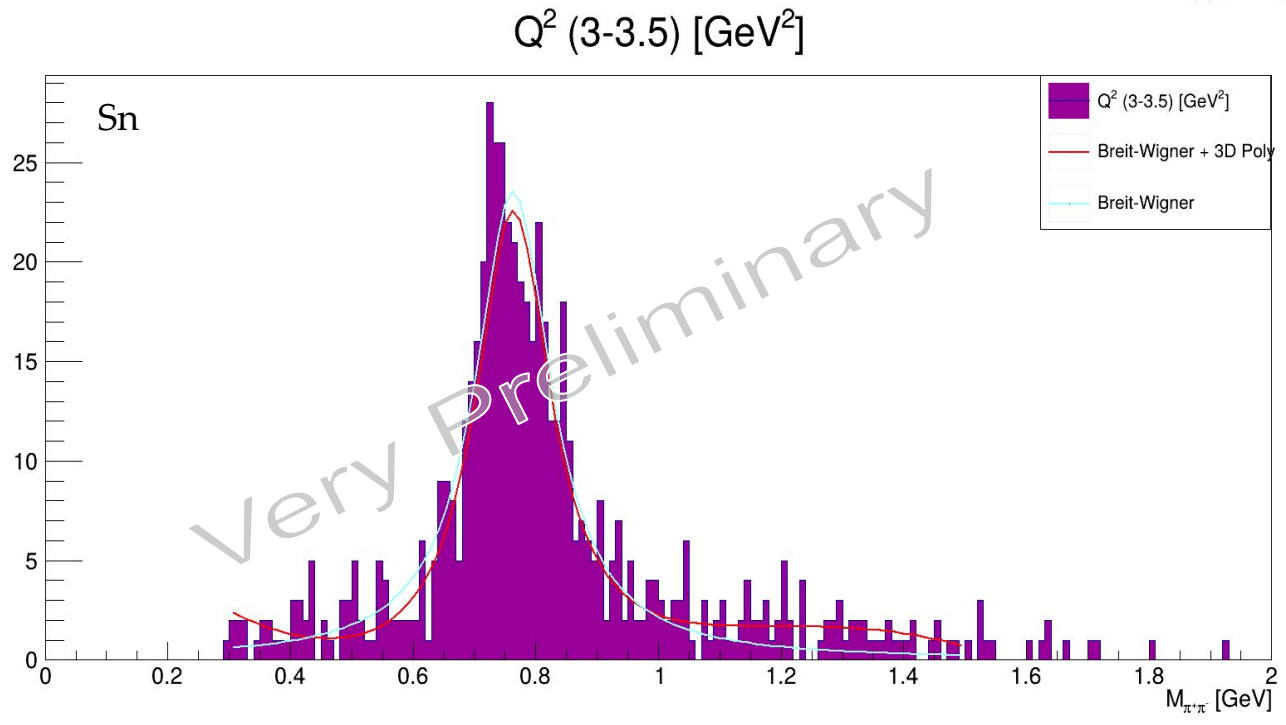
Breit-Wigner
Very Preliminary
$M_{\pi^+\pi^-}$ [GeV]

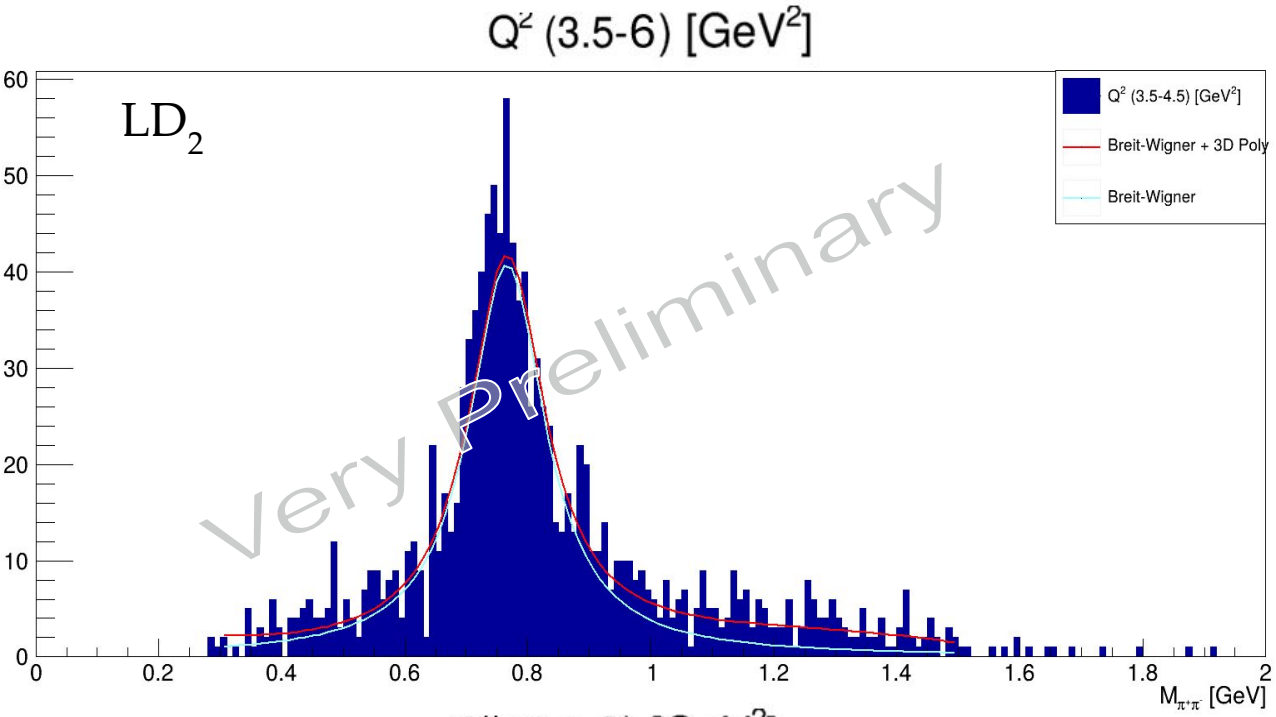

Q^2 (2.5-3) [GeV^2]
Sn
Q^2 (2.5-3) [GeV^2]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
$M_{\pi^+\pi^-}$ [GeV]

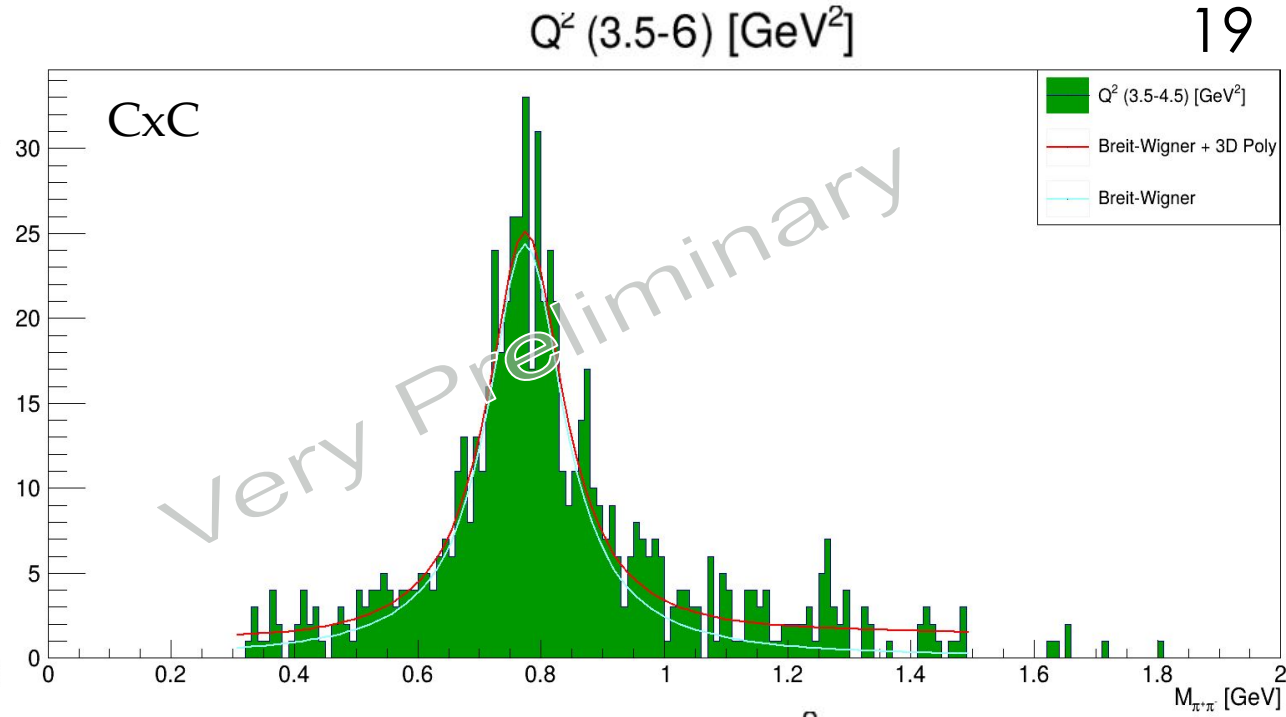

Q^2 (3-3.5) [GeV^2]
LD_2
Q^2 (3-3.5) [GeV^2]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
$M_{\pi^+\pi^-}$ [GeV]

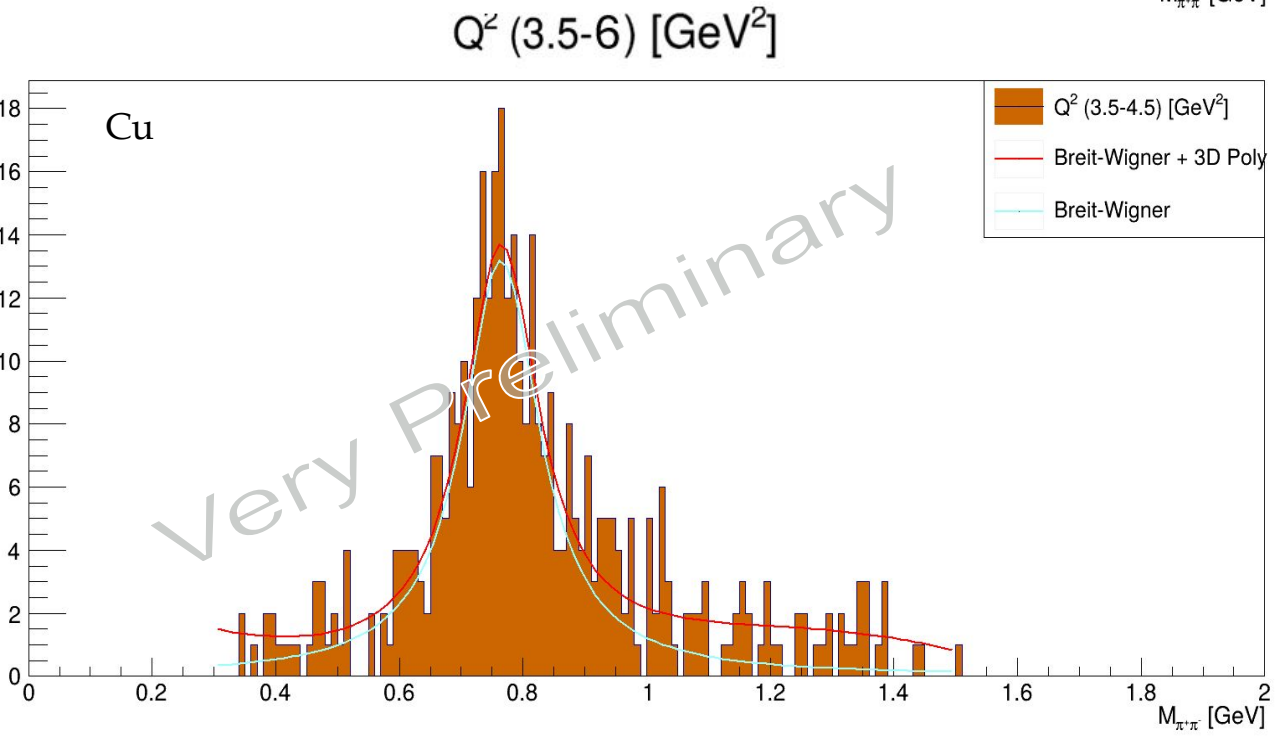

Q^2 (3-3.5) [GeV^2]
CxC
Q^2 (3-3.5) [GeV^2]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
$M_{\pi^+\pi^-}$ [GeV]

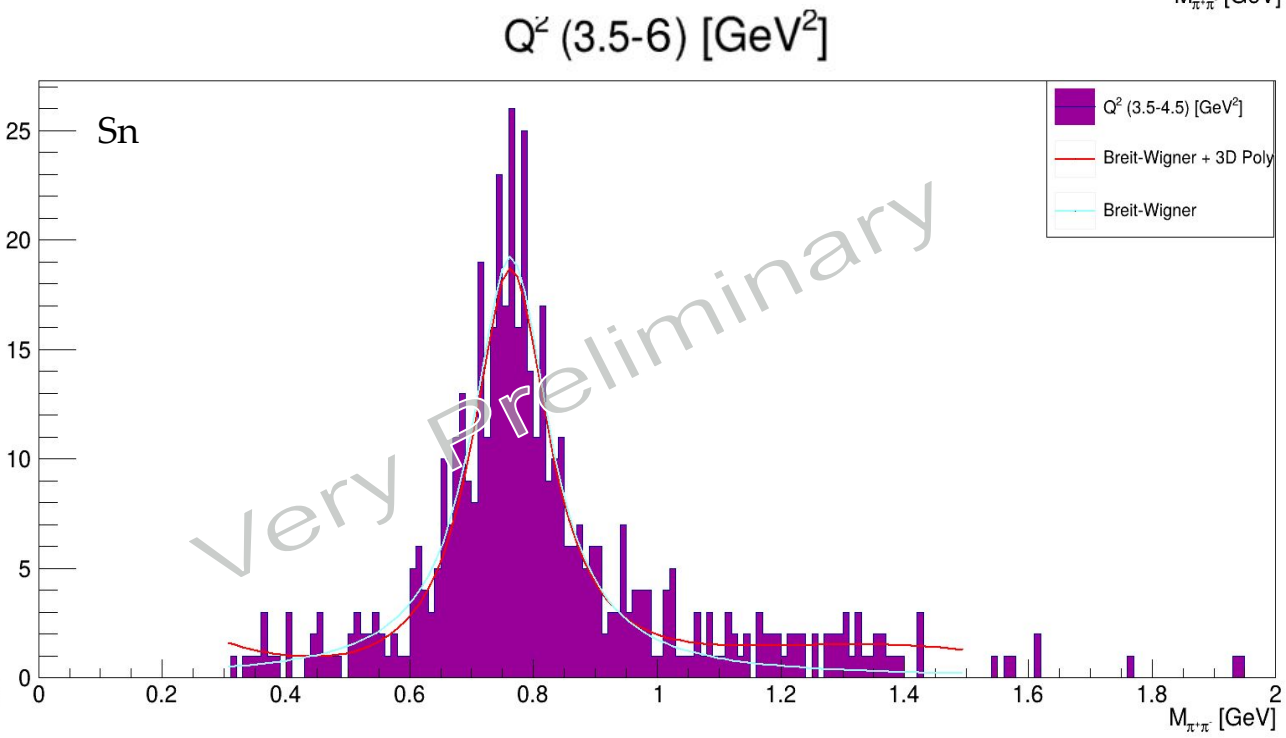

Q^2 (3-3.5) [GeV^2]
Cu
Q^2 (3-3.5) [GeV^2]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
$M_{\pi^+\pi^-}$ [GeV]


Q^2 (3-3.5) [GeV^2]
Sn
Q^2 (3-3.5) [GeV^2]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
$M_{\pi^+\pi^-}$ [GeV]


Q² (3.5-6) [GeV²]
LD2
Q² (3.5-4.5) [GeV²]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
Mπ+π- [GeV]


Q² (3.5-6) [GeV²]
CxC
Q² (3.5-4.5) [GeV²]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
Mπ+π- [GeV]


Q² (3.5-6) [GeV²]
Cu
Q² (3.5-4.5) [GeV²]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
Mπ+π- [GeV]


Q² (3.5-6) [GeV²]
Sn
Q² (3.5-4.5) [GeV²]
Breit-Wigner + 3D Poly
Breit-Wigner
Very Preliminary
Mπ+π- [GeV]

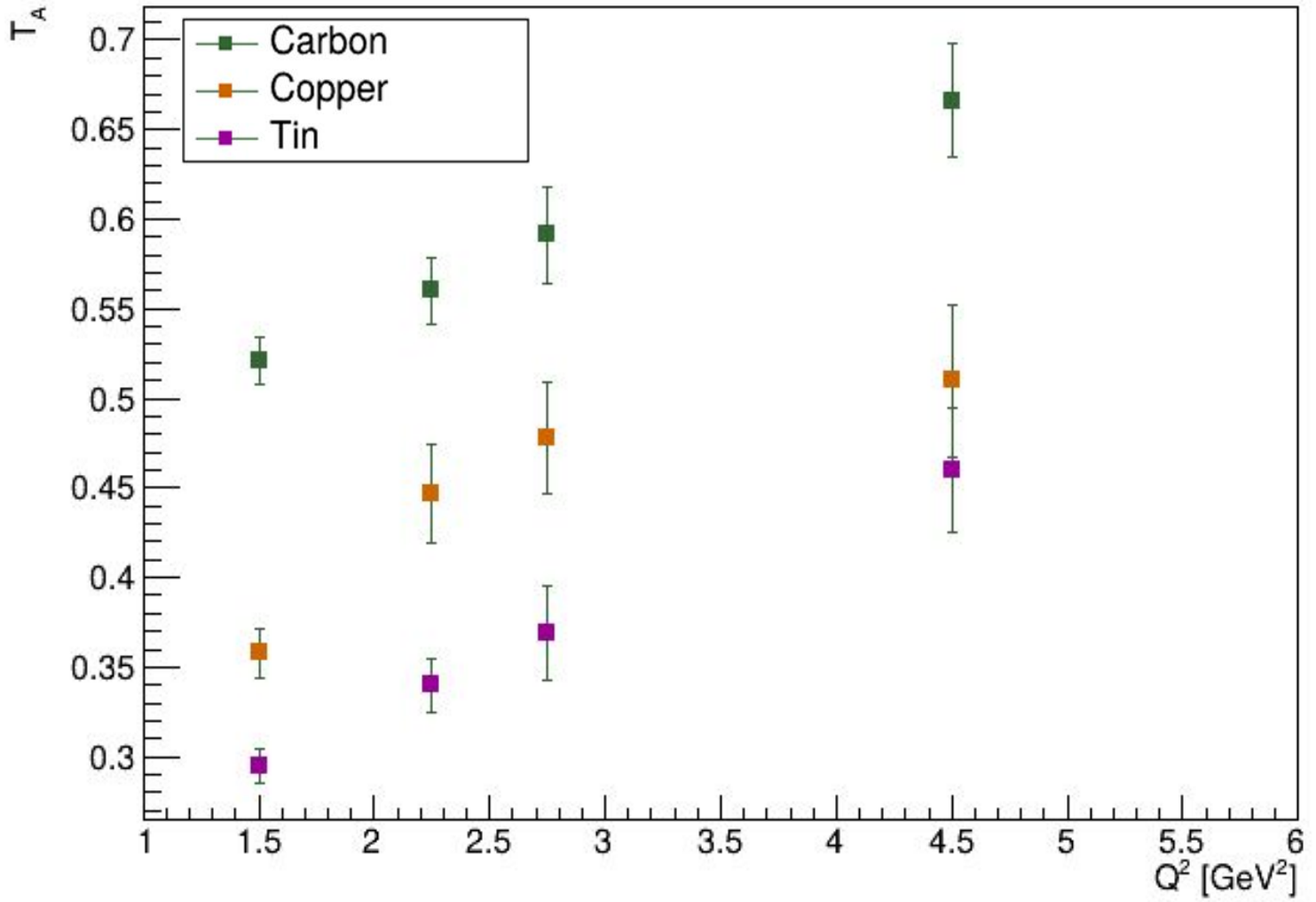
Preliminary Nuclear Transparency Results

- Nuclear transparency is extracted as

$$T_A = \frac{N_s^\rho}{N_D^\rho}\left(\frac{t_D \times \rho_D}{t_s \times \rho_s}\right)$$

where,

- N_S^ρ is the ρ^0 yield from solid target
- N_D^ρ is the ρ^0 yield from LD_2 target
- t_S is the solid target thickness
- t_D is the LD_2 target thickness
- ρ_S is the solid target density
- ρ_D is the LD_2 density



Summary and Outlook

- Refine particle identification, vertex, and fiducial cuts and corrections
- Perform background subtraction using our ρ^0 event generator and the CLAS12 GEant-4 Monte Carlo package
- Extract the preliminary nuclear transparency results for the three nuclei, C, Cu, and Sn, after applying various cuts and corrections
- Identify various sources of systematic uncertainties related to the CT study in ρ^0 electroproduction off nuclei

Thank you

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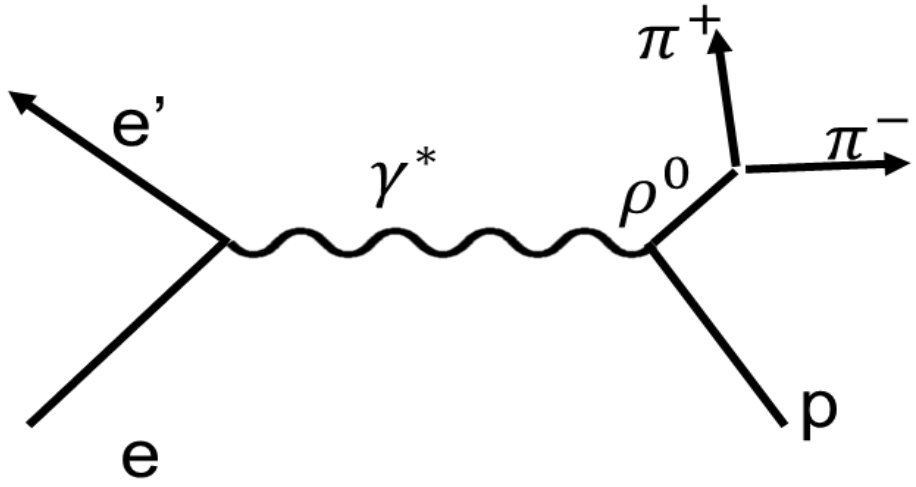
Backup Slides

RG-D CT Kinematics



- $\nu = E - E'$: Energy of the virtual photon
- $Q^2 = -(P_e - P_{e'})^2 = 4EE'sin^2\left(\frac{\theta}{2}\right)$: Transfer momentum squared
- $t = (P_{\gamma^*} - P_\rho)^2$: Momentum transfer squared to target proton
- $W^2 = (P_p + P_{\gamma^*})^2 = -Q^2 + Mp^2 + 2Mp\nu$: Invariant mass squared of hadronic final state
- $Z_h = E_\rho/\nu$: Observed hadron energy fraction