Deep Processes Working Group Report

CLAS Collaboration Meeting
Jefferson Lab, 21st June2019

PAC Reviews

Analysis	Data	Lead Author	In progress
Tagged Neutron DVCS with BONuS12 in CLAS12	**RGF**	**M. Hattawy**	Submitted to PAC
Exclusive photo-production of Photon-Meson Pair at Large Invariant Mass	**RGB++**	**D. Sokhan**	Anticipated by CAA

Ad Hoc Reviews

Analysis	Data	Lead Author	In progress
Exploring the structure of the proton via semi-inclusive pion electro-production	**e1f**	**N. Harrison** **K. Joo**	2nd round done on Jan 19

Analysis Reviews

Analysis	Data	Author	In progress
Extraction of $A_{LU}^{\sin\phi}$ moments from hard exclusive π^+ off the unpolarized hydrogen target in a wide range of kinematics	**e1f**	**S. Diehl**	3rd round done on Jun 19
First Observations of Beam Spin Asymmetries for K+	**e1f**	**D. Riser**	1st round done on Sep 18
Di-hadron beam spin asymmetry in SIDIS electro production	**eg1-dvcs**	**M. Mirazita**	Analysis under revision
Beam asymmetries in exclusive π^+ electro production for W> 1.7 GeV from e16	**e16**	**P. Bosted** **K. Park**	Extended scope
Semi-inclusive pion production	**e16**	**M. Osipenko**	Working on a better alignment

Measurement of proton spin structure g_1^p and its moments	**eg4**	**X. Zheng**	Going to start soon

Analysis Reviews

Analysis	Data	Author	In progress
Deep-virtual production of the ρ^+ meson off the proton	**e1-dvcs**	**A. Fradi**	Ahmed willing to continue
Exclusive electro-production of the f0(980) and f2(1270) on the proton with CLAS	**e1f**	**B. Garillon** **S. Niccolai**	Brice busy with other project
Time-like Compton scattering	**g12**	**I. Abayrak**	Last record 2015

CAA Reviews

Analysis	Data	Author	In progress
Observation of transverse polarization of Lambda hyperons in the current frgamentation from unpolarized targets	**RGA**	**A. Vossen** **C. Dilks**	1st round done on Oct 18
Boer-Mulders effect and helicity dependent fragmentation functions in hadron pair production off unpolarized targets	**RGA**	**A. Vossen** **C. Dilks**	1st round done on Oct 18

DPWG Meeting

08:30 **DPWG Business** *10'*
Speaker: Mr. Marco Contalbrigo (INFN Ferrara)
Material: Slides

08:40 **The spin structure of the proton at low Q2 from CLAS EG4** *30'*
Speaker: Dr. Xiaochao Zheng (University of Virginia)
Material: Slides

09:10 **Di-hadron BSA** *25'*
Speaker: Christopher Dilks (DUKE)
Material: Slides

09:35 **Dihadron multiplicity studies with clas12** *25'*
Speaker: Dr. Harut Avagyan (Jefferson Lab)
Material: Slides

10:30 **Efficiency study of the central for protons** *20'*
Speaker: Mr. Pierre Chatagnon (ORSAY)
Material: Slides

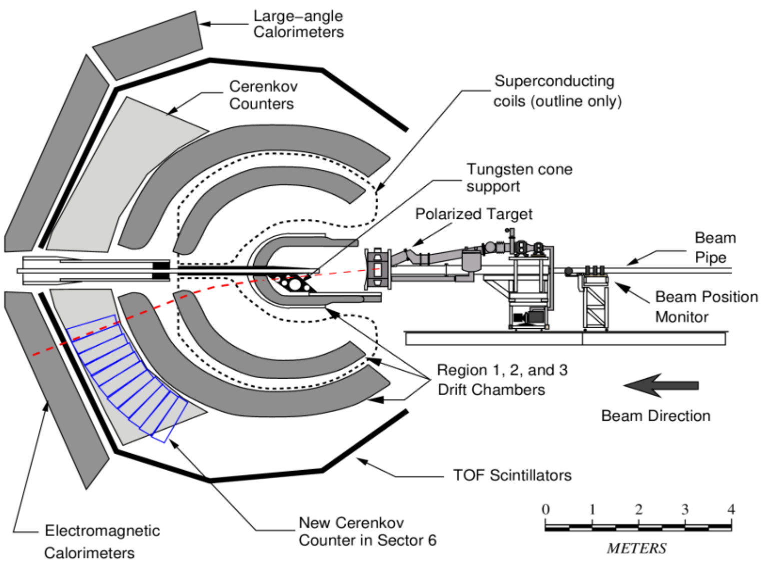
10:50 **Charged-particles veto in the CD using only CTOF and CND** *20'*
Speaker: Katheryne Price (ORSAY)
Material: Slides

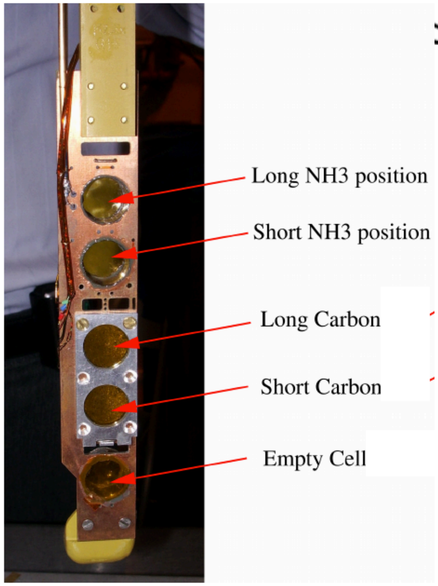
11:10 **DVCS at 10 GeV** *20'*
Speaker: Guillaume CHRISTIAENS (SACLAY)
Material: Slides

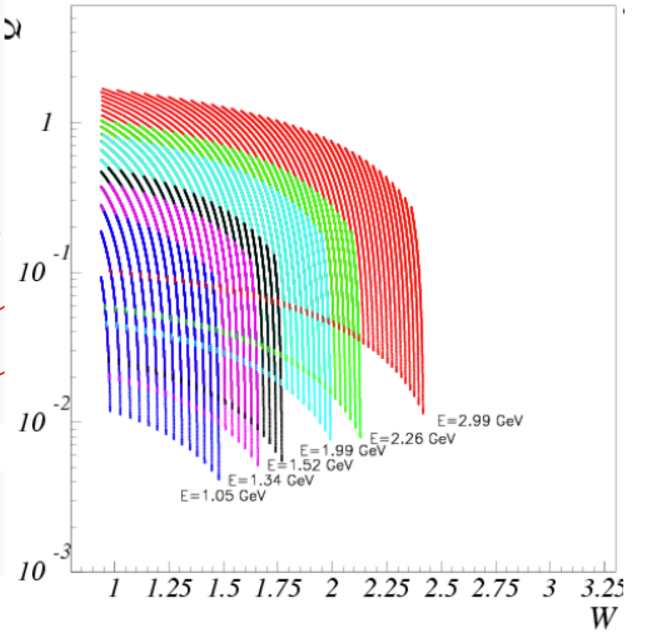
11:30 **DVCS at 6 and 7 GeV** *20'*
Speaker: Joshua Artem Tan (Kyungpook National University And Jefferson Lab)
Material: Slides

Measurement of proton spin structure g_1^p and its moments from CLAS EG4 data

Xiaochao Zheng
University of Virginia







- GDH Sum Rule (virtual photon):

$$I_{TT}(Q^2) = \frac{M^2}{8\pi^2\alpha}\int_{\nu_{th}}^{\infty}\frac{K}{\nu}\frac{\sigma_{TT}}{\nu}d\nu = \frac{2M^2}{Q^2}\int_0^{x_{th}} A_1 F_1 dx \xrightarrow[Q^2\to 0]{} -\frac{2\alpha\pi^2\kappa^2}{M^2}$$

Hadronic degrees of freedom

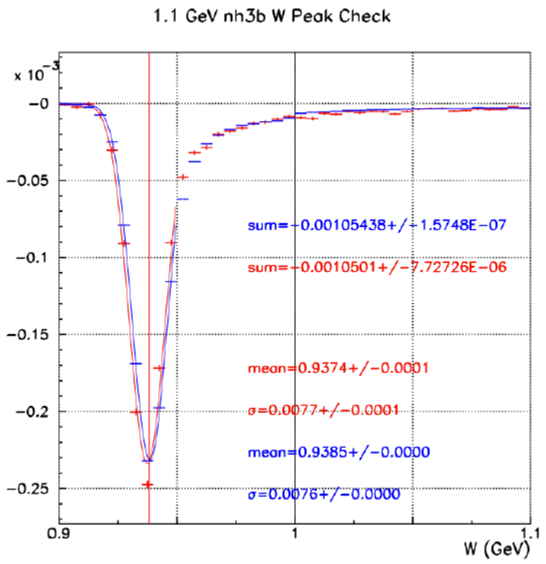
Q^2 →

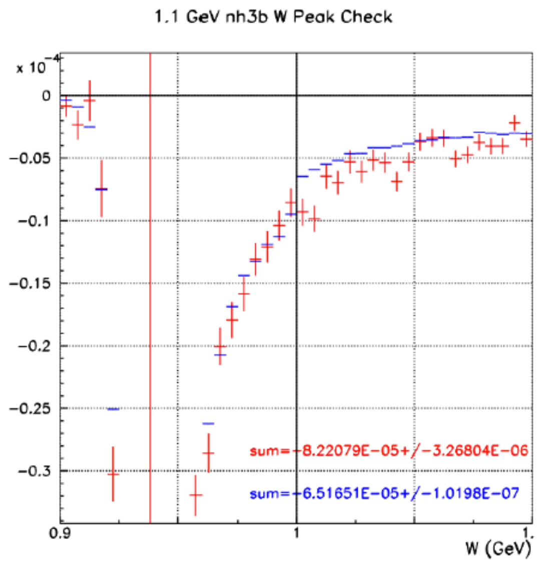
Chiral perturbation theory (χpt) — OPE, pQCD

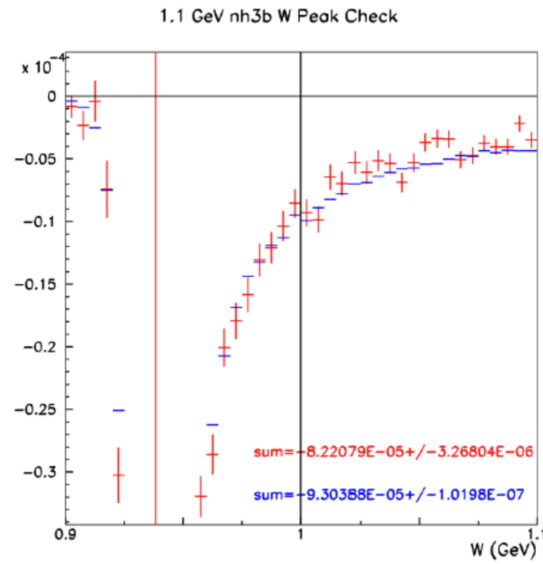
Lattice QCD, SDE, AdS/QCD

Partonic degrees of freedom

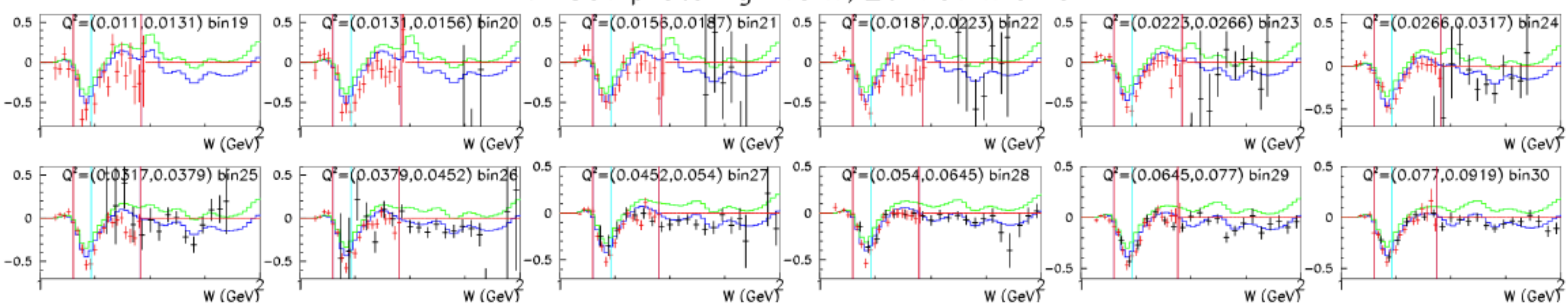
Elastic + inelastic detailed simulation







1.1 GeV proton g1 vs W, 20 MeV W bins



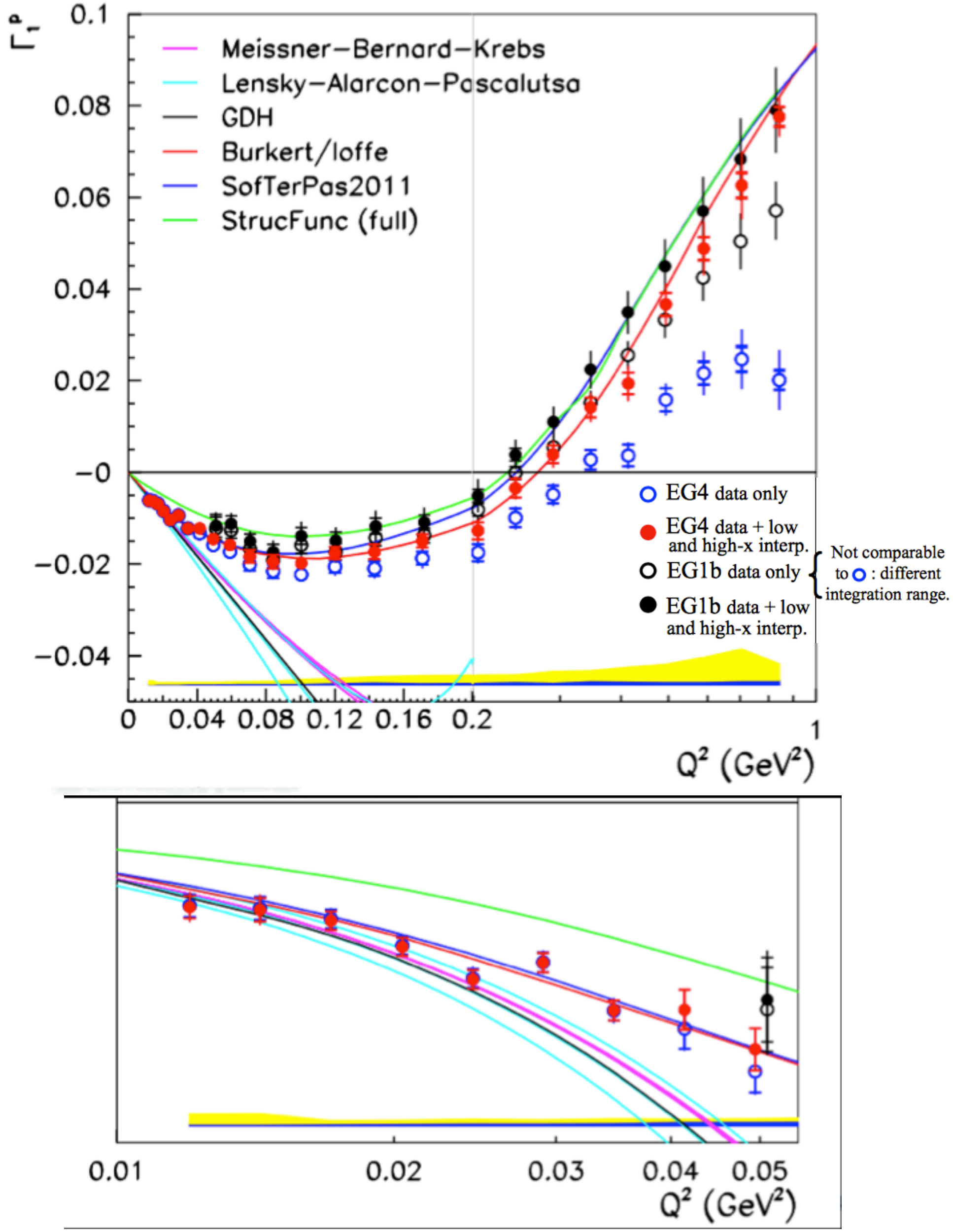
Systematic Uncertainties (bucket list)

- Radiative tail
- Target packing fraction – by repeating simulation → extraction
- CC efficiency – by repeating extraction using CC-uncorrected simulation
- Elastic normalization – by changing normalization → repeating extraction
- – statistical uncertainty
- – disagreement between data and simulated peak area (<2E-3)
- – elastic F.F. – 1%+1%*Eb in GeV
- Background: – similar to normalization
- – pion and pair production background: <1% in polarized yield
- – ^{15}N: 0.7% to inelastic polarized yield
- – (^{15}N elastic: low Q2 bins excluded from elastic normalization
- Reconstruction (shift in W) – by shifting W → repeating extraction

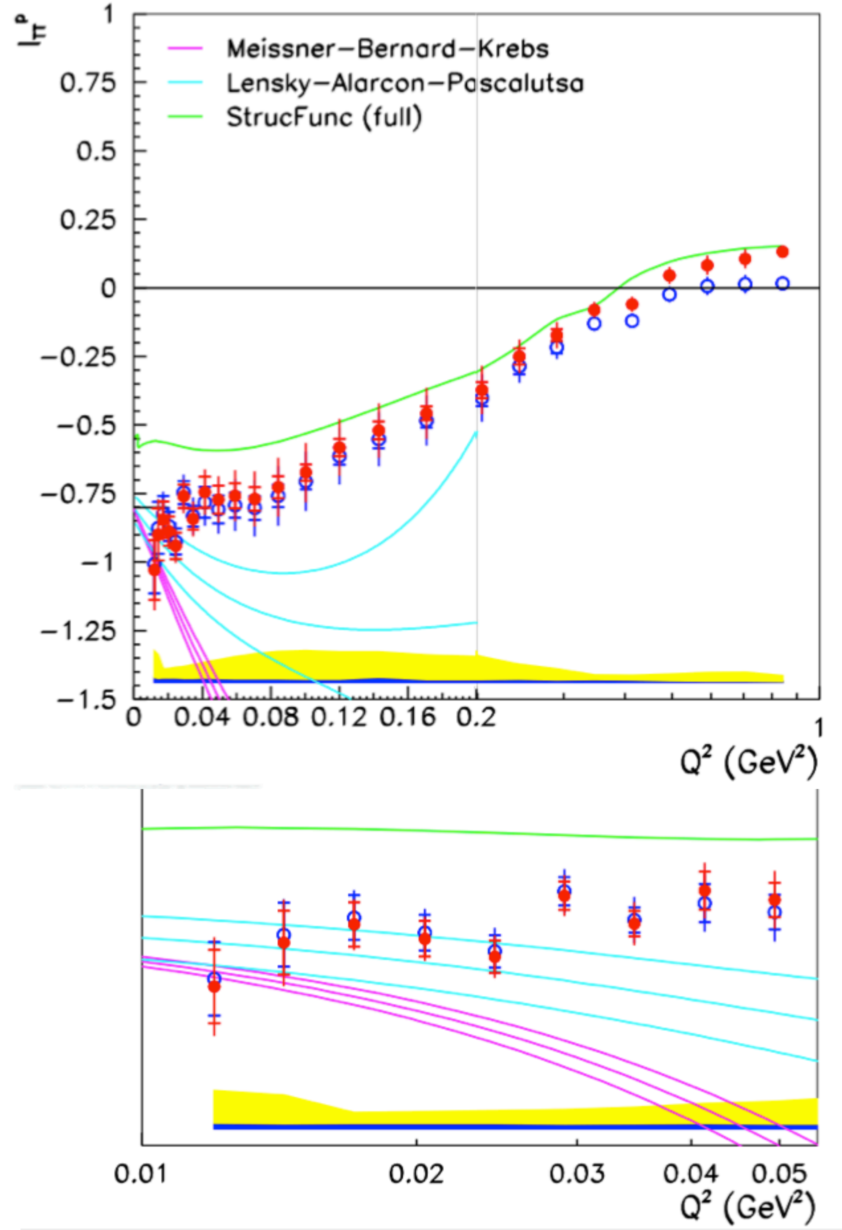
- Model uncertainties: studied by varying inelastic simulation six times (F1,2; R; A1 res; A2 res, A1 DIS; A2 DIS) → repeating extraction

$$\Gamma_1(Q^2) = \int_{0.001}^{x_{\rm lo}} g_1^{\rm mod}(x,Q^2)dx + \int_{x_{\rm lo}}^{x_{\rm hi}} g_1^{\rm EG4\ data}(x,Q^2)dx + \int_{x_{\rm hi}}^{x_{th}} g_1^{\rm mod}(x,Q^2)dx$$

proton g1 integral

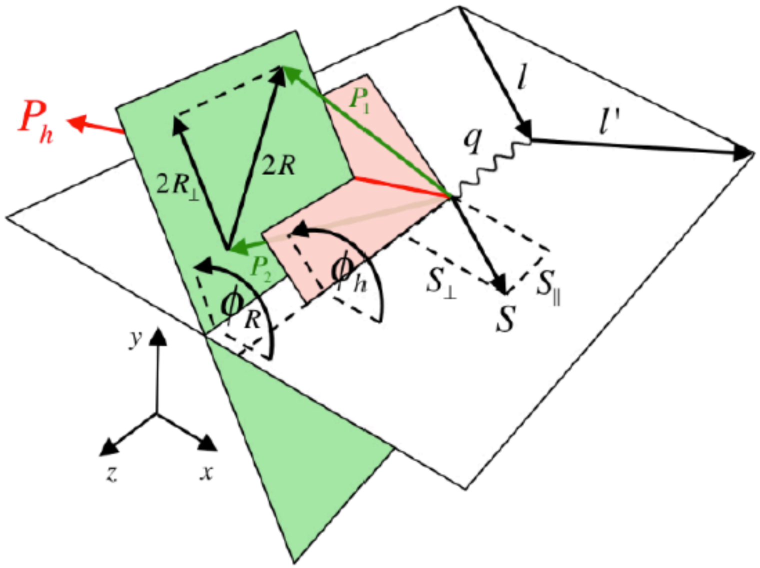


proton A1F1 integral



Dihadron Analysis Update

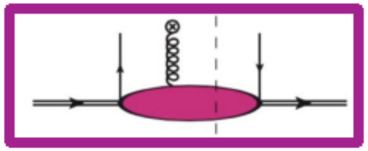
Christopher Dilks DUKE



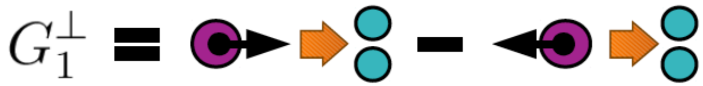
BSA for

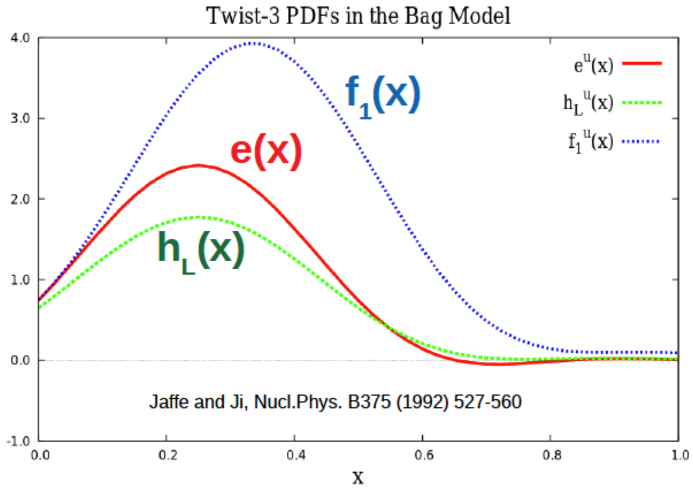
transverse color-Lorentz force over the struck quark

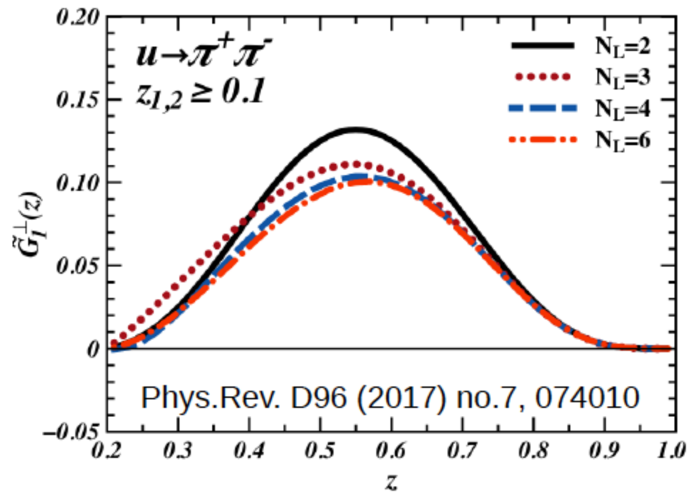
Twist-3
PDF e(x)



Handedness / Helicity-Dependent DiFF

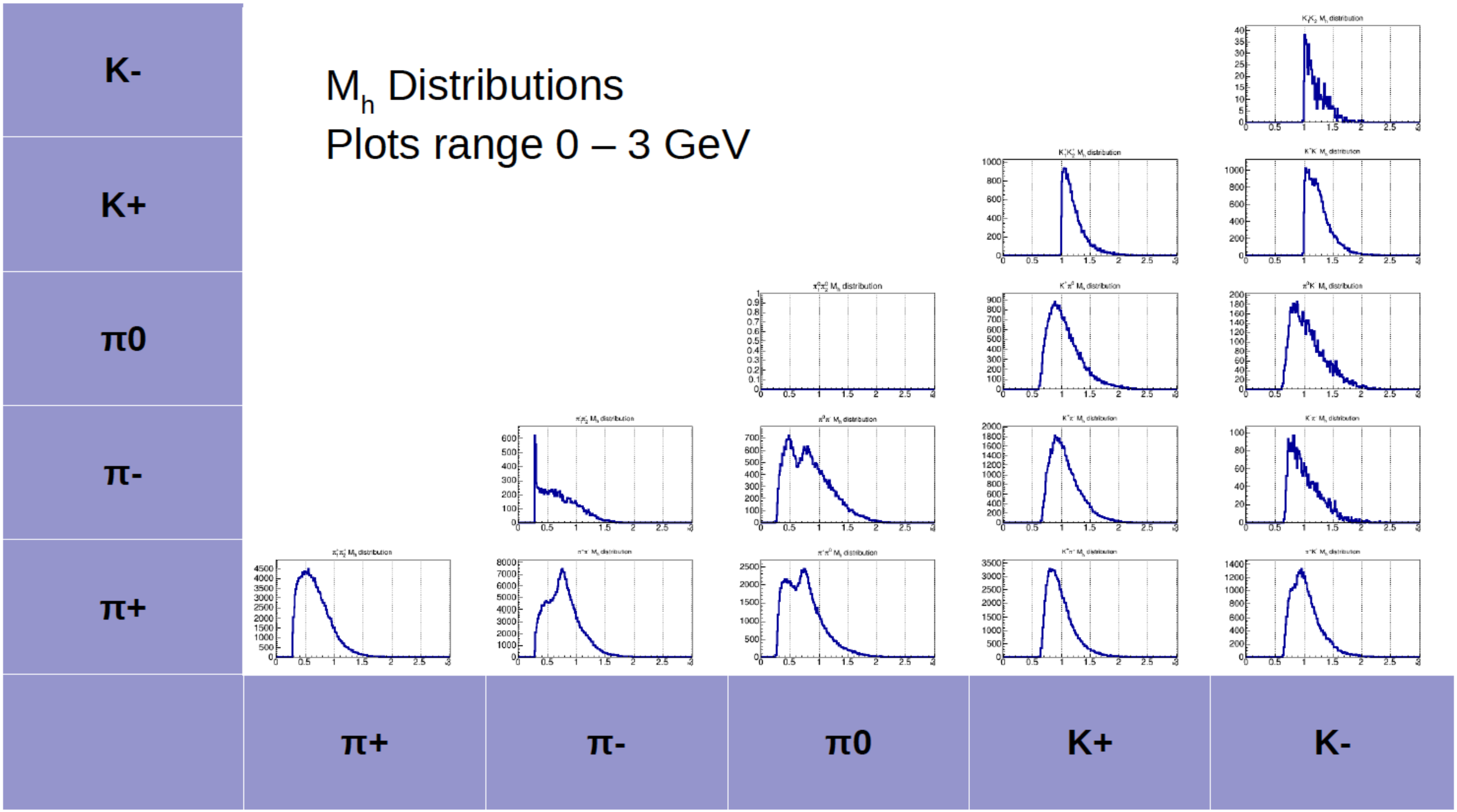






Various meson combinations

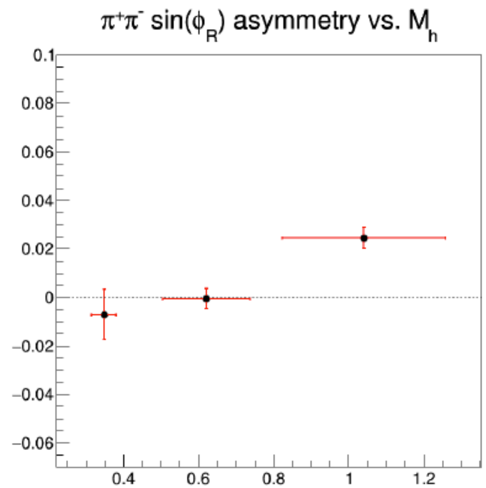
M_h Distributions
Plots range 0 – 3 GeV

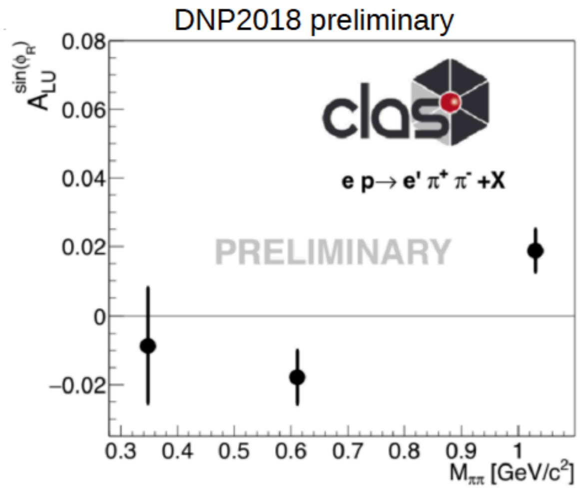


Sinϕ_R Asymmetry: π+ π-

$$A_{LU}\left[\sin\phi_R\right] \propto \boxed{e(x)}\ H_1^{\sphericalangle}(z, M_h, \cos\theta)$$

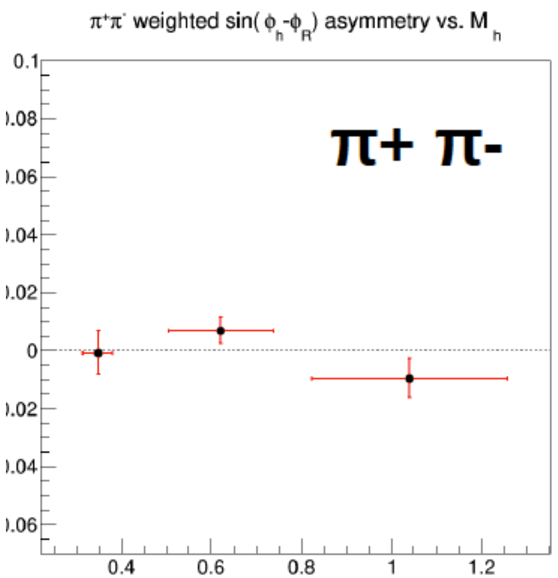
Not all cuts that were used for DNP2018 preliminary are applied, e.g., fiducial cuts

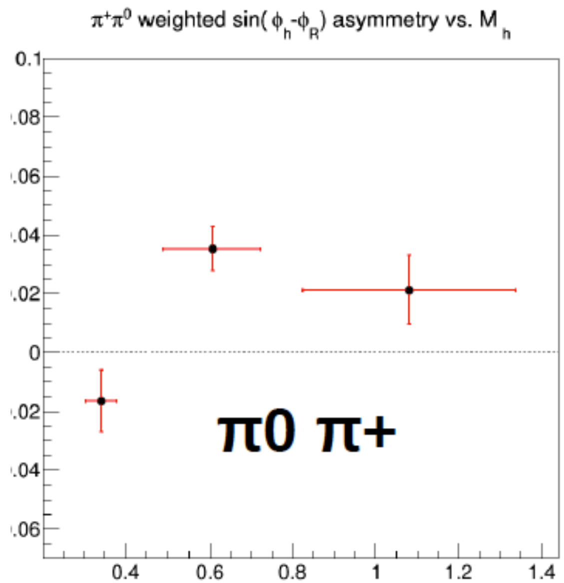


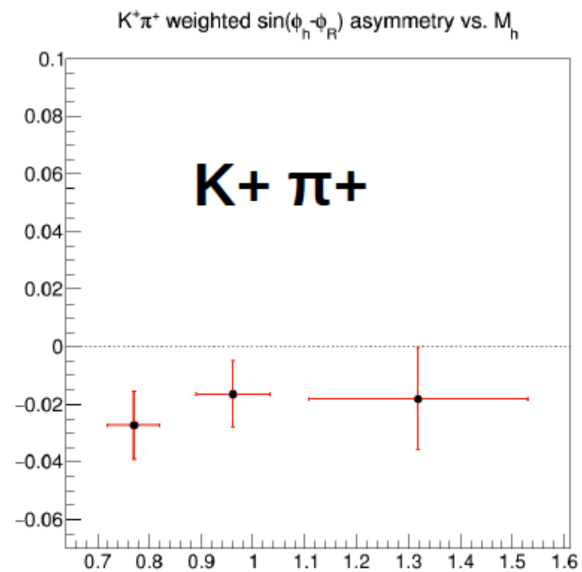


$P_h^\perp$Sin(ϕ_h–ϕ_R) / M_h Asymmetry: π+ π-

$$A_{LU}\left[P_h^\perp \sin(\phi_h - \phi_R)/M_h\right] \propto f_1(x) \cdot \boxed{G_1^\perp(z, M_h)}$$

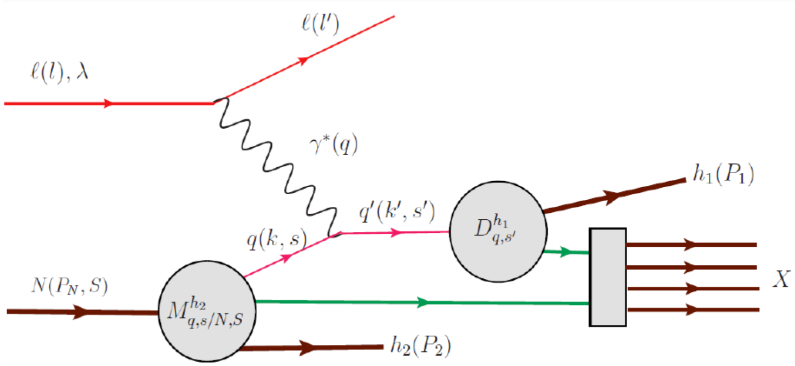


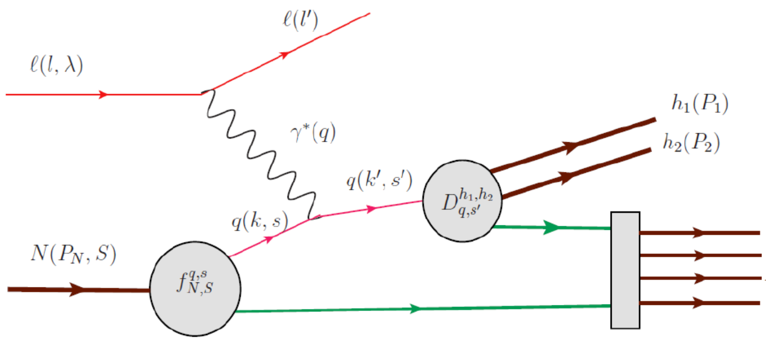




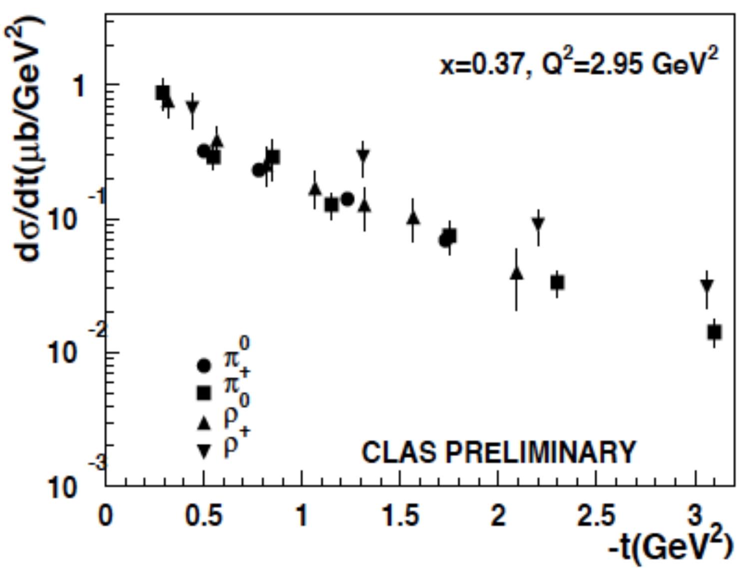
Dihadron multiplicity studies with clas12

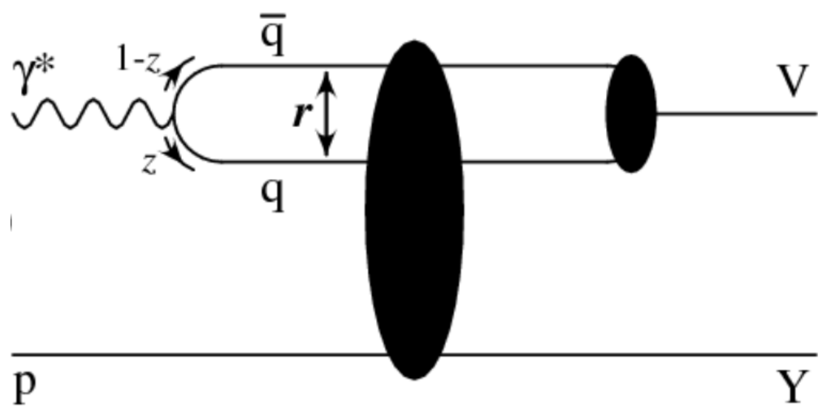
Harut Avakian (JLab)





2h production in SIDIS provides access to correlations inaccessible in simple SIDIS

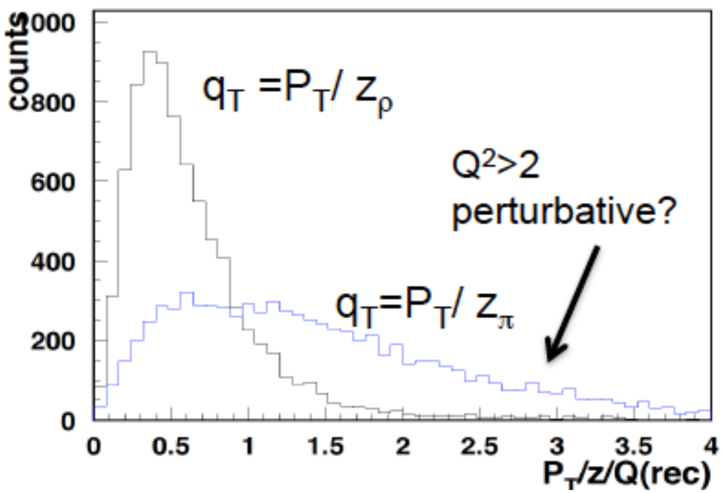




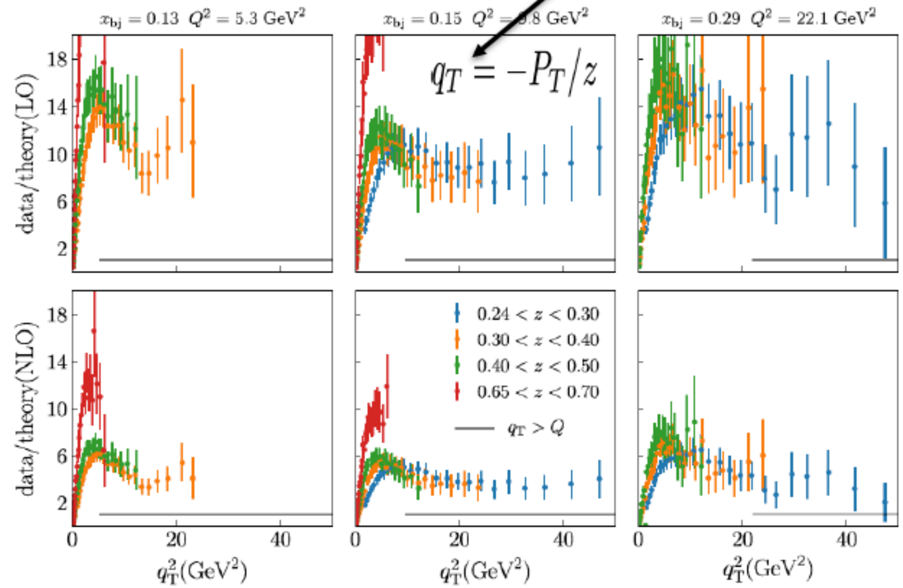
$\rho+ > \rho^0$ → Diffractive production suppressed at large t production mechanism most likely is similar to SIDIS (color transparency?)

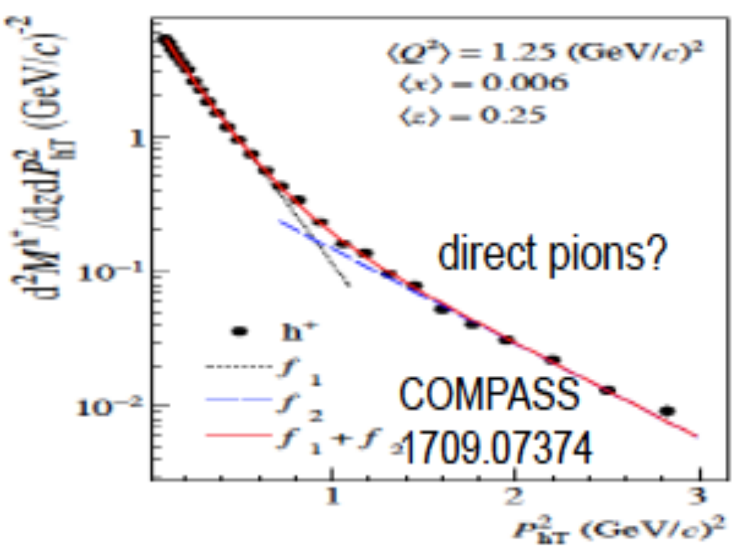
Implications for interpretation

Matching with high pT (perturbative) regime

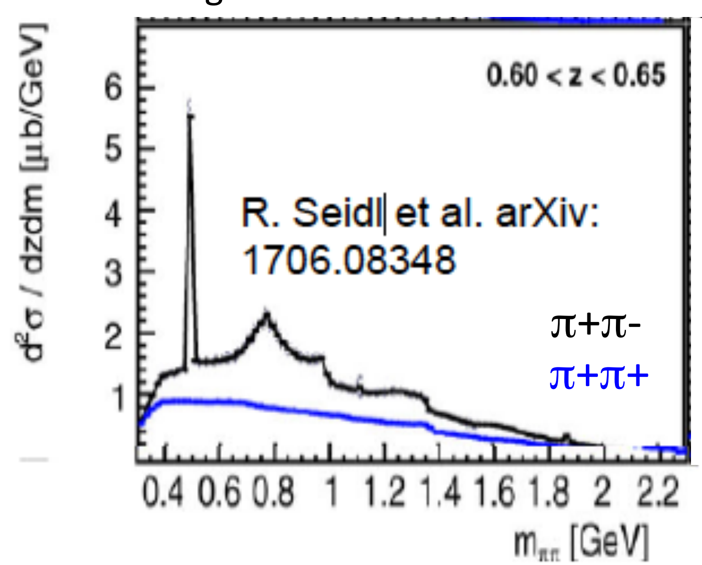


quark transverse momentum

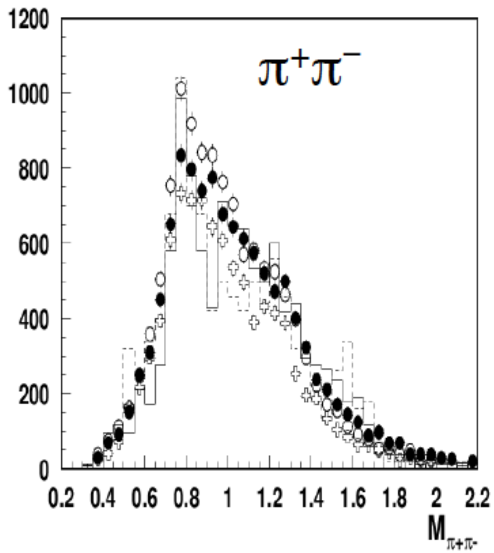


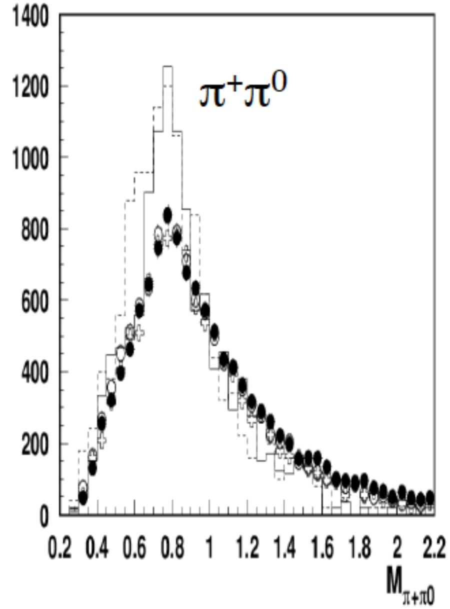


Fragmentation Functions

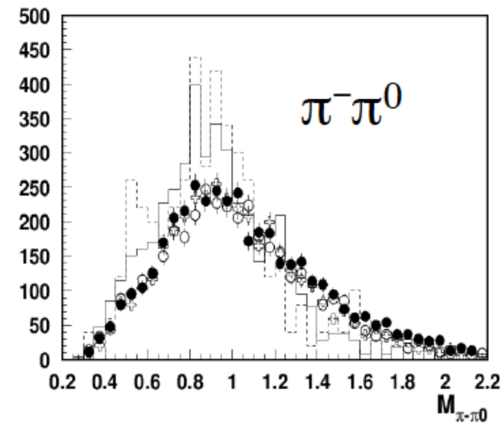


DATA vs MC tuning



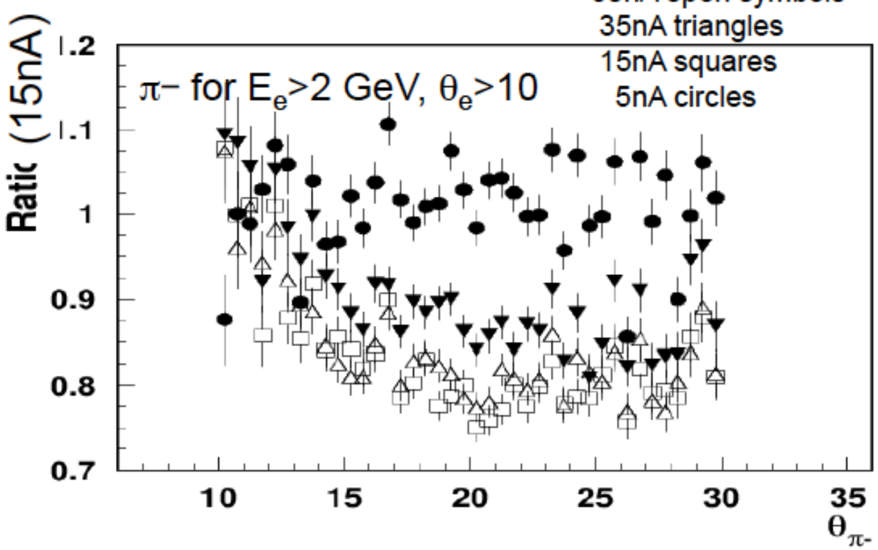


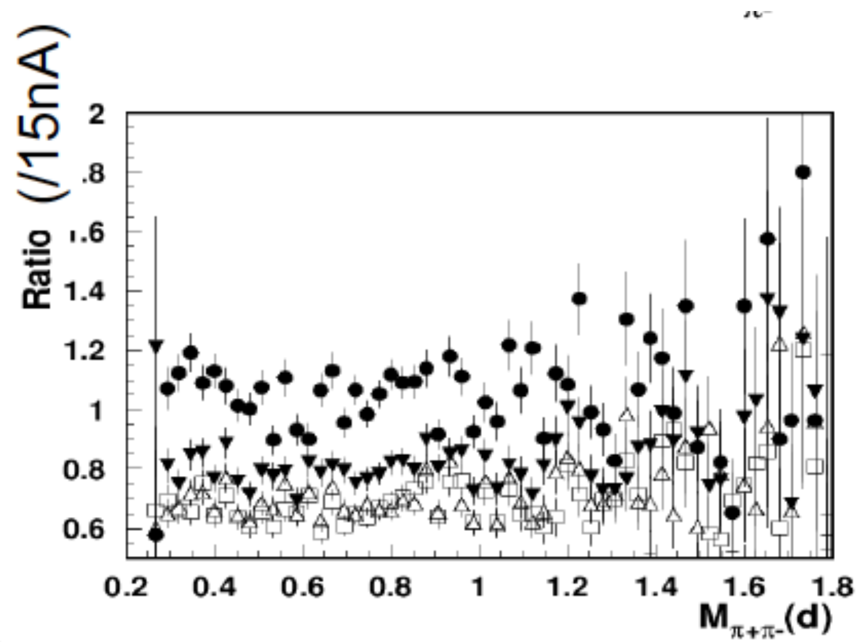
Number of ρ+ very significant



Yileld vs luminosity

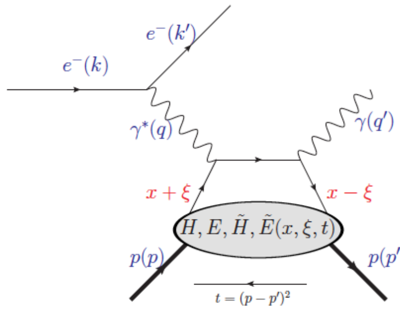
50nA open symbols
35nA triangles
15nA squares
5nA circles



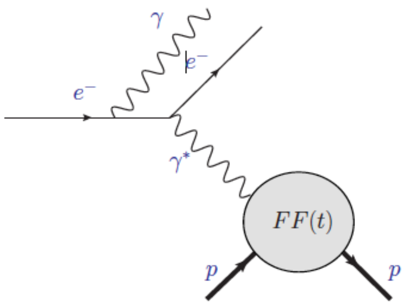


Deeply Virtual Compton Scattering at 10.6 GeV with CLAS12

Guillaume Christiaens
University of Glasgow, CEA Saclay

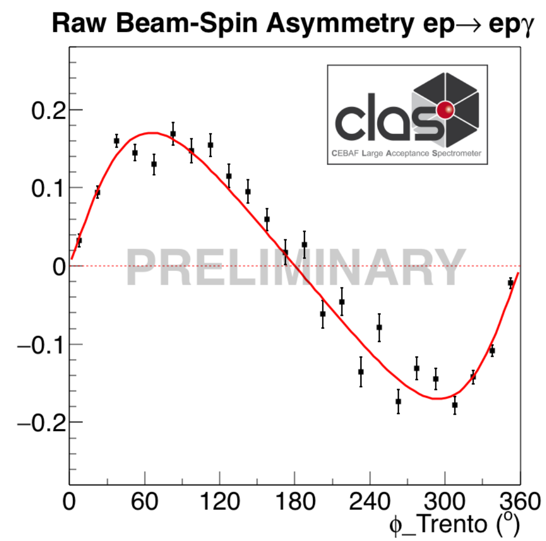


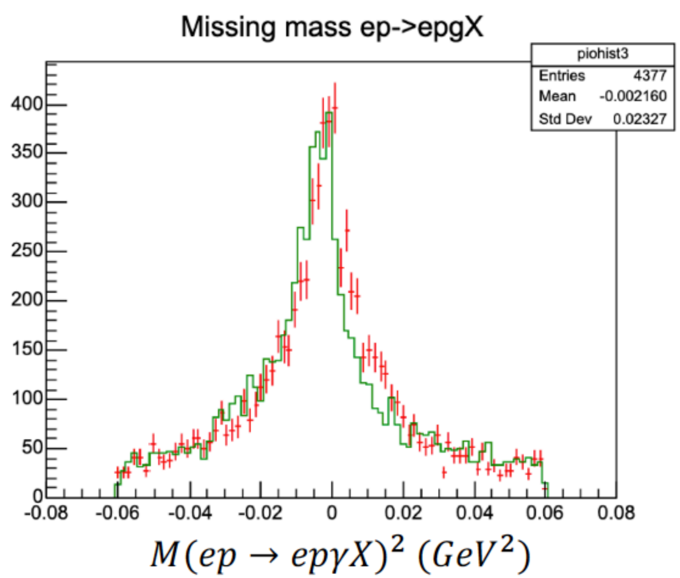
DVCS at leading order

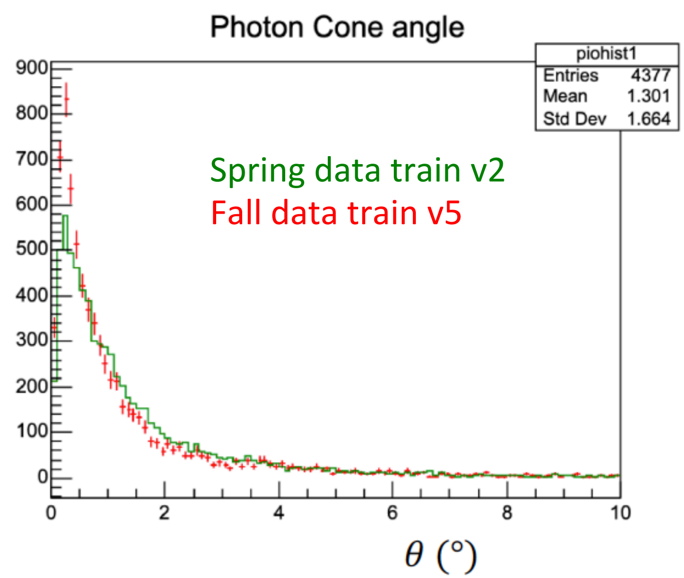


BH at leading order

$$s_1^{\mathcal{I}} \propto Im(F_1\mathcal{H} + \xi(F_1+F_2)\tilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E})$$

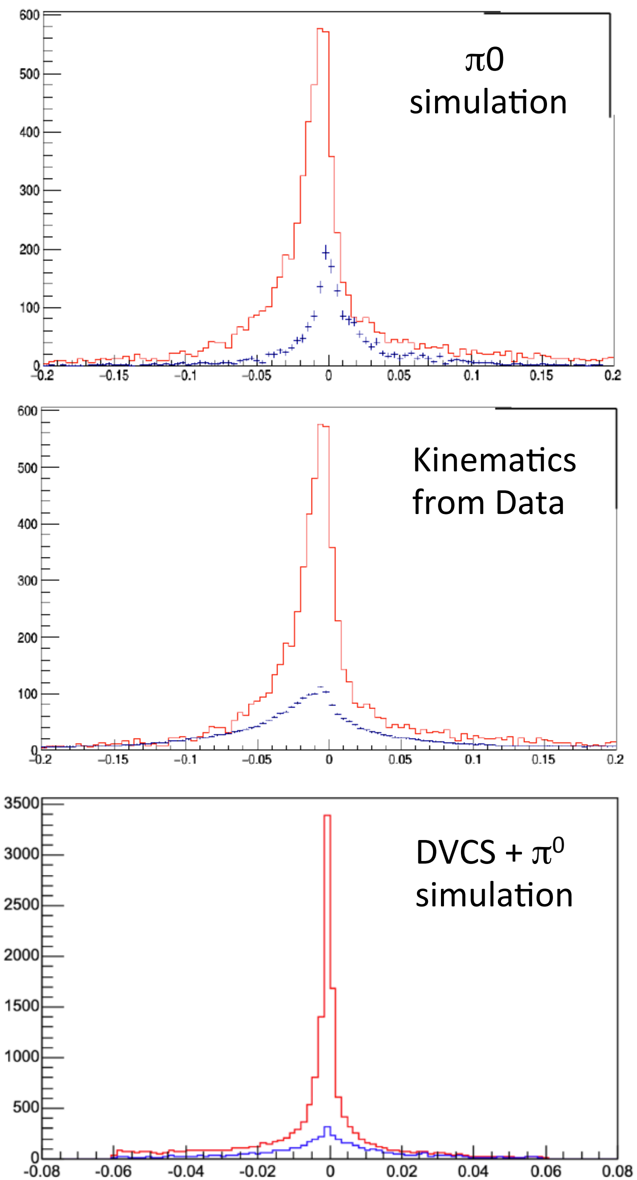


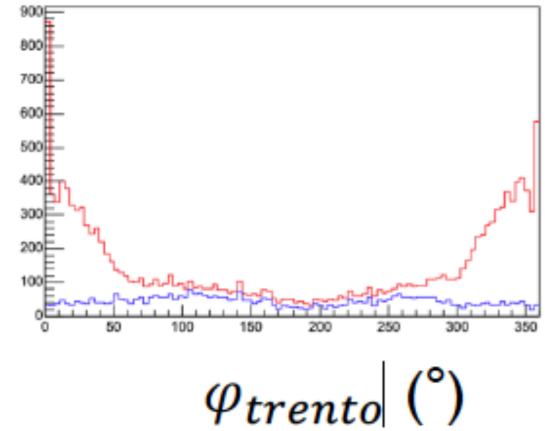


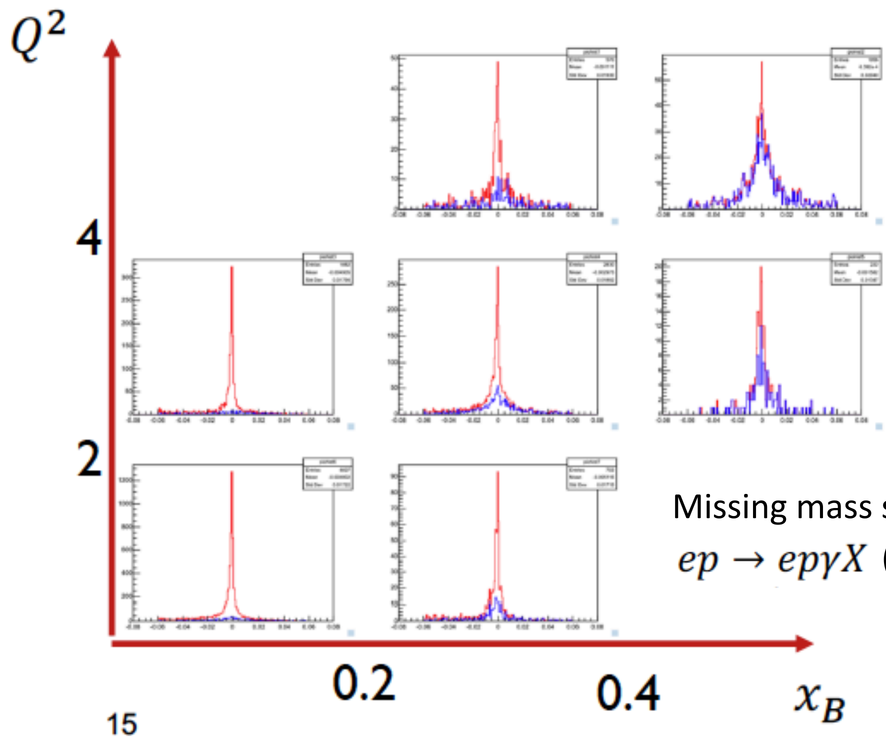


π^0 contamination

Missing mass squared $ep \rightarrow ep\gamma X$ (GeV^2)







Missing mass squared
$ep \rightarrow ep\gamma X$ (GeV²)

BH- π^0 Generator – Algorithm

Issue 1 : Metropolis algorithm …

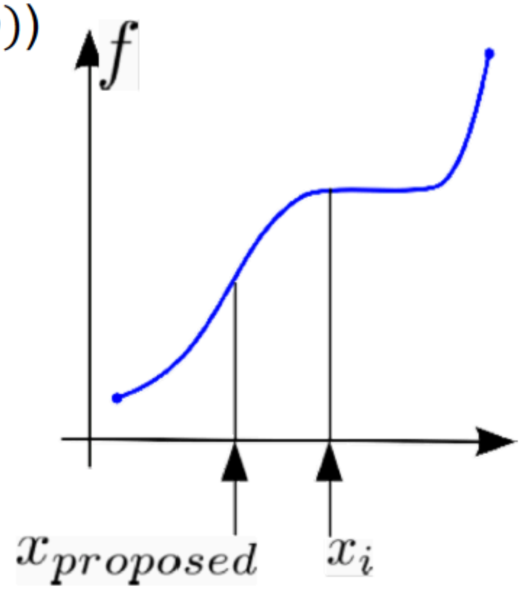
1 – x_i random starting point (4D: $x = (Q^2, x_B, t, \varphi)$)

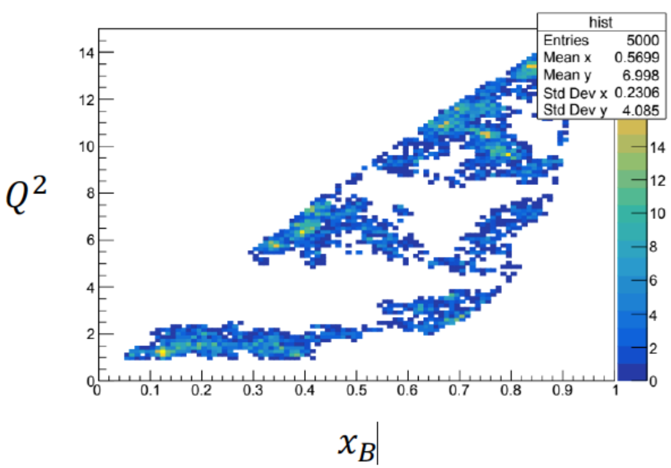
2 – x_{prop} new point on a gaussian around x_i

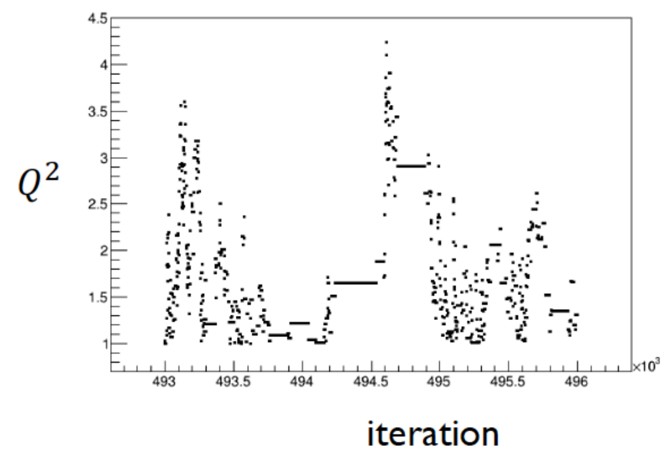
3 – Draw a random number $A \sim U_{[0,1]}$

- if $A < \frac{f(x_{prop})}{f(x_i)}$, $x_{i+1} = x_{prop}$
- else, $x_{i+1} = x_i$

4 – Save x_{i+1}, set $x_i = x_{i+1}$ and restart step 2





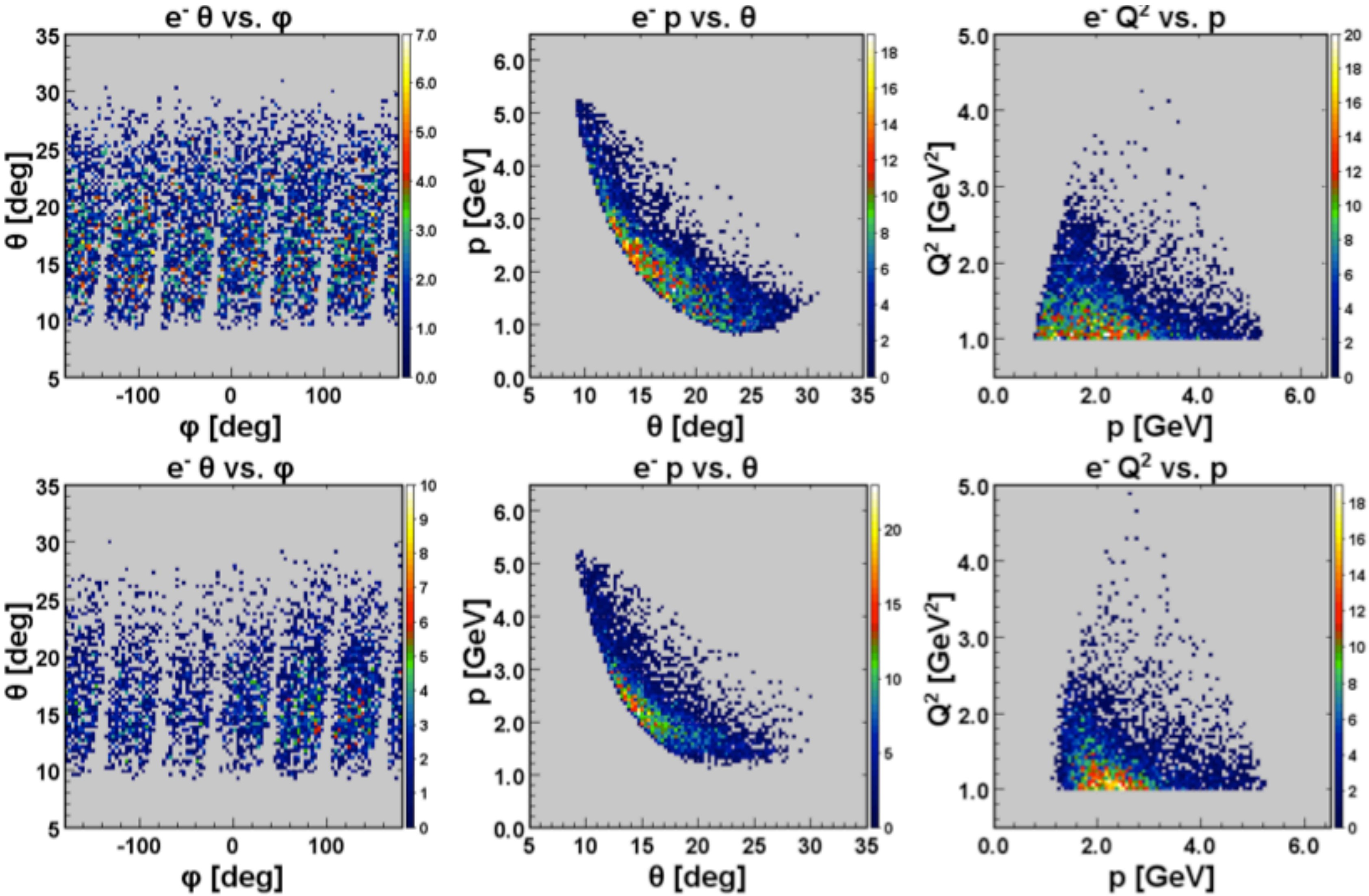


RG-K DVCS at 7.5 GeV

Joshua Artem Tan KNU

DVCS MC

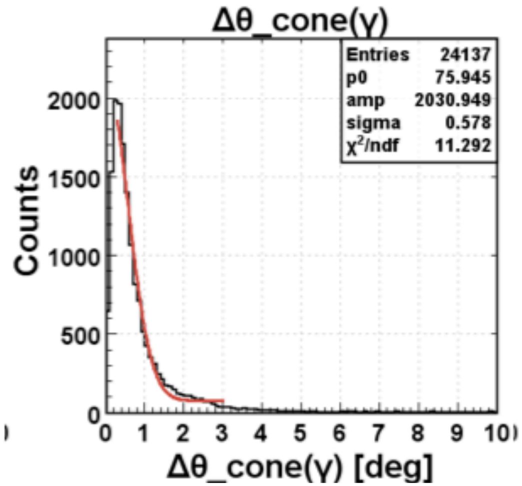
DATA

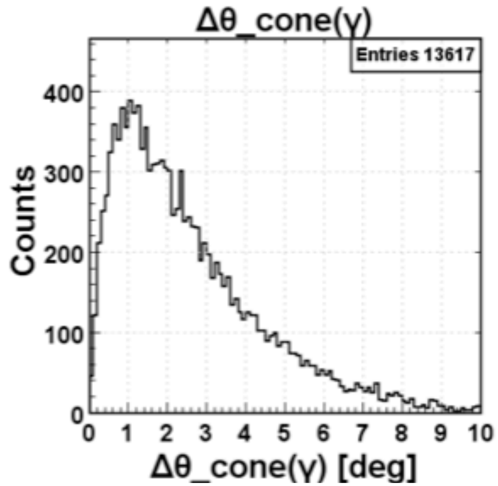


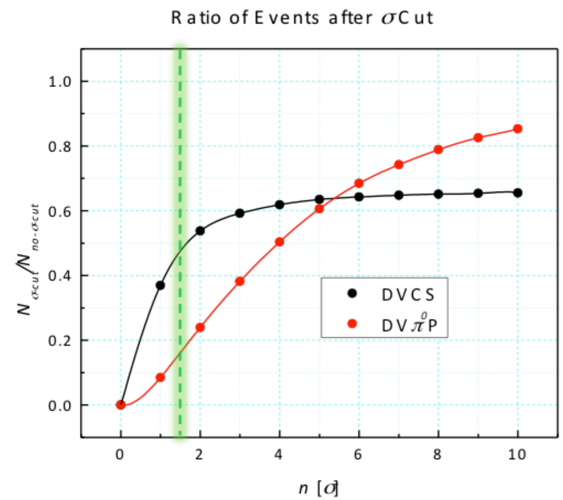
DVCS and DVπ^0P Separation at 7.5 GeV

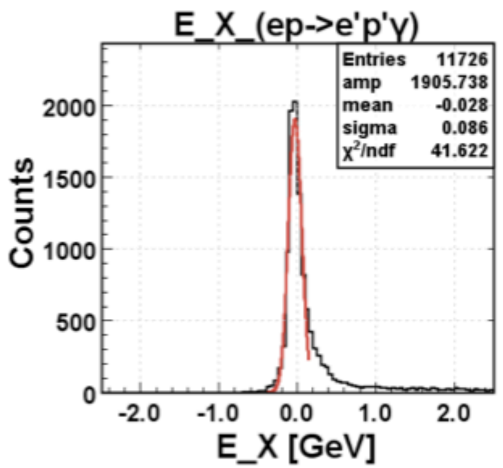
DVCS

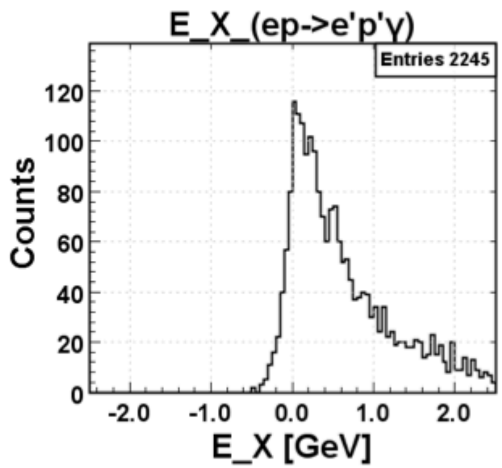
DVπ^0 P

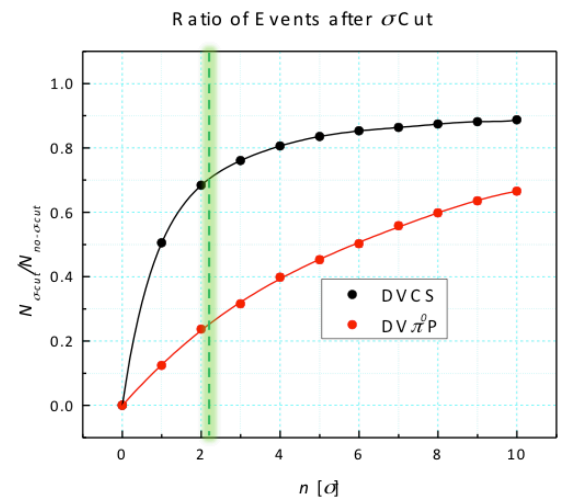








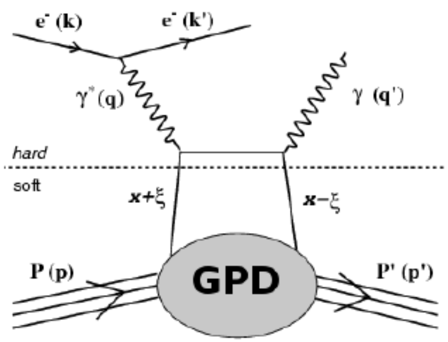




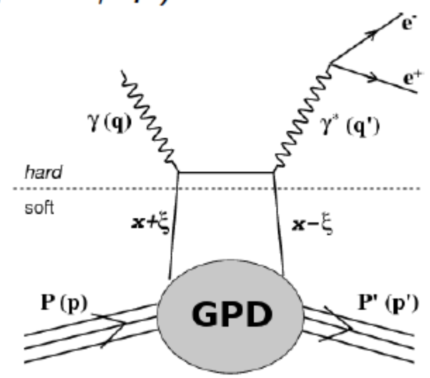
TCS with CLAS12 at Jefferson Lab

Pierre Chatagnon and the ee analysis group
Institut de Physique Nucleaire d'Orsay

DVCS ($\gamma^* p \rightarrow \gamma p$)

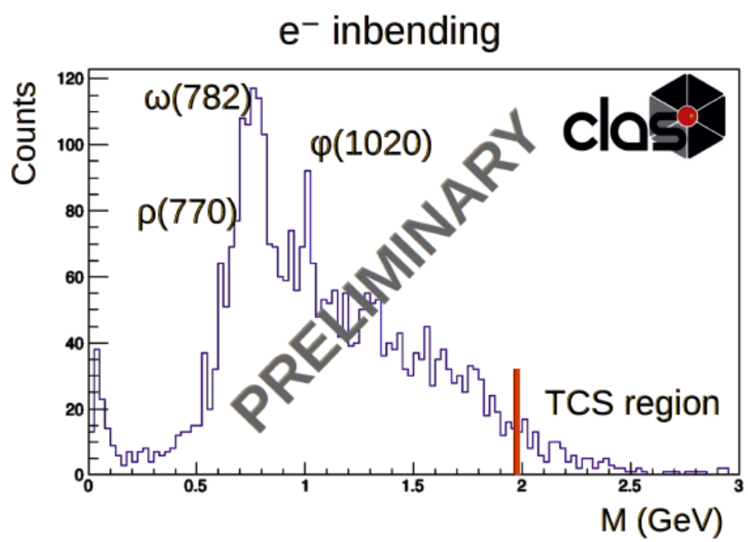


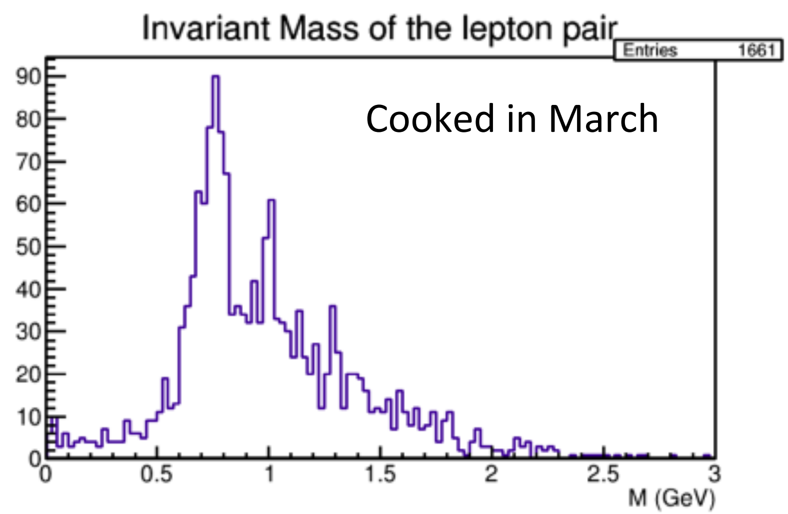
TCS ($\gamma p \rightarrow \gamma^* p$)



Compton Form Factors

$$\mathcal{H} = \sum_q e_q^2 \left\{ \mathcal{P} \int_{-1}^{1} dx H^q(x,\xi,t) \left[\frac{1}{\xi - x} - \frac{1}{\xi + x} \right] + i\pi \left[H^q(\xi,\xi,t) - H^q(-\xi,\xi,t) \right] \right\}$$

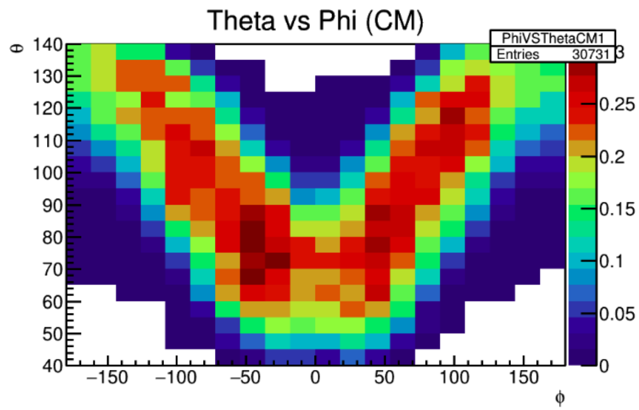


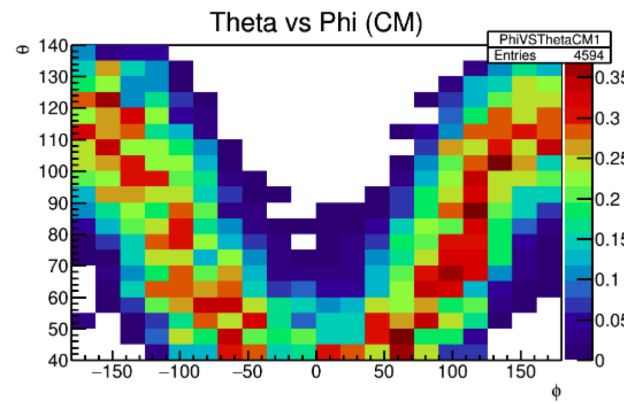


Acceptance correction (R. Paremuzyan)

$$R' = \frac{\sum_{\phi} cos(\phi) Y_{\phi}}{\sum_{\phi} Y_{\phi}}$$

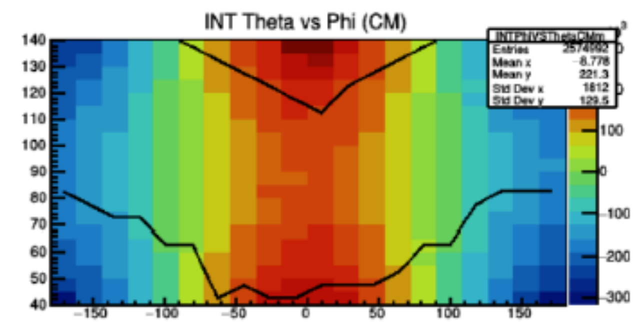
$$Y_{\phi} = \sum_{\theta} \frac{L}{L_0} N_{\theta}^{\phi} \frac{1}{A_{\theta}^{\phi}}$$

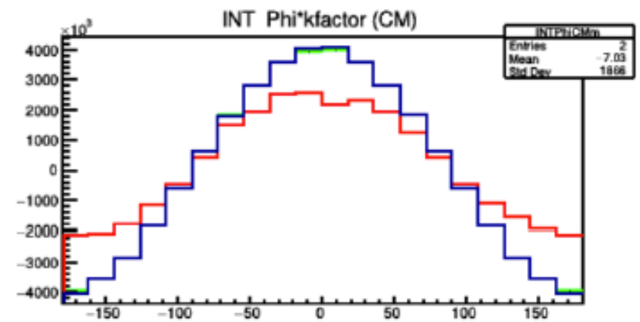




$$\frac{dS_{Tot}}{dQ'^2 dt d\phi} = S_{BH} + A \cdot ReM^{--} \cdot cos(\phi)$$

$$A = \int_{\pi/4}^{3\pi/4} d\theta \cdot a = -\frac{\alpha_{em}^3}{4\pi s^2} \frac{1}{-t} \frac{M}{Q'} \frac{1}{\tau\sqrt{1-\tau}} \int_{\pi/4}^{3\pi/4} (1 + cos^2(\theta)) d\theta$$





Integrated number of events

in acceptance limit

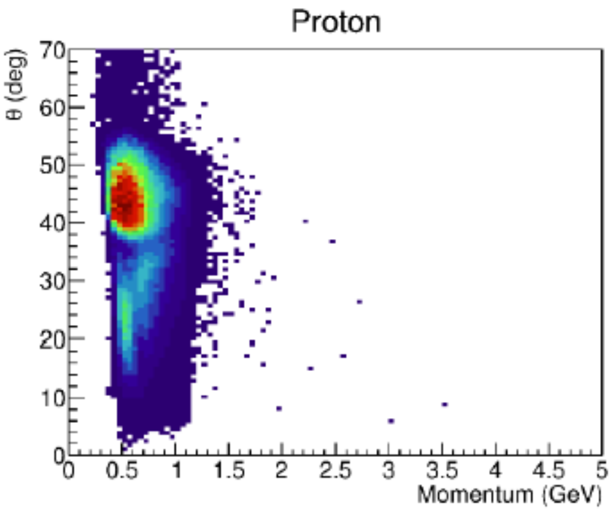
within $40deg < \theta < 140deg$

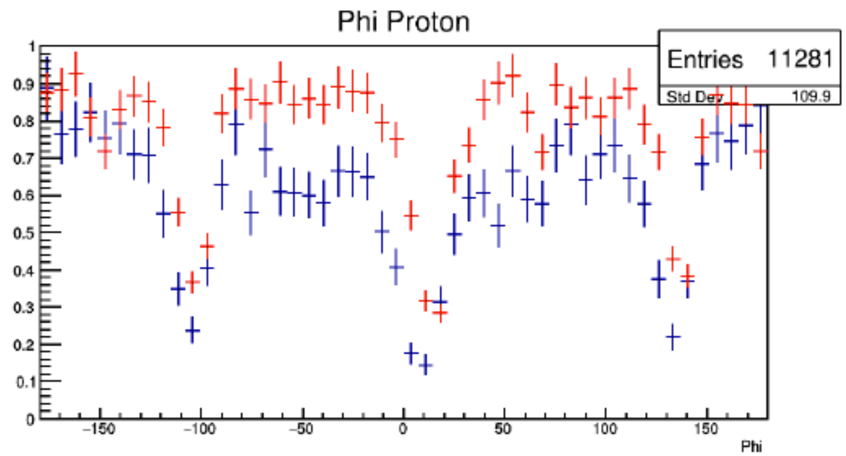
extrapolated.

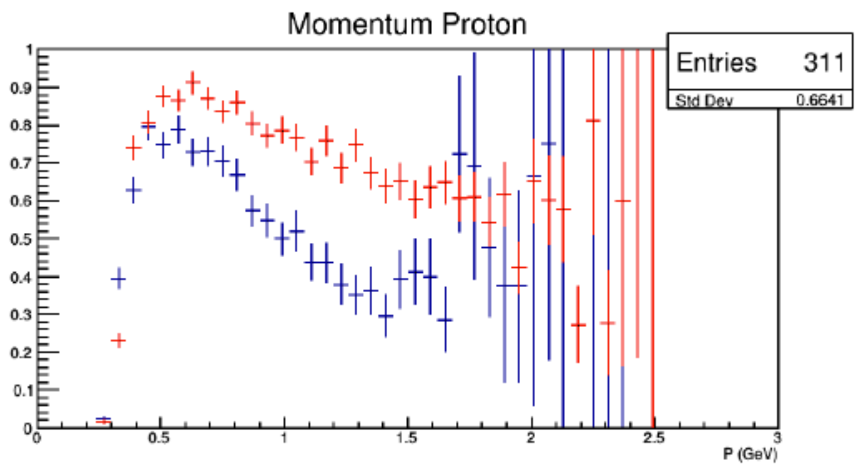
Proton efficiency in the central detector

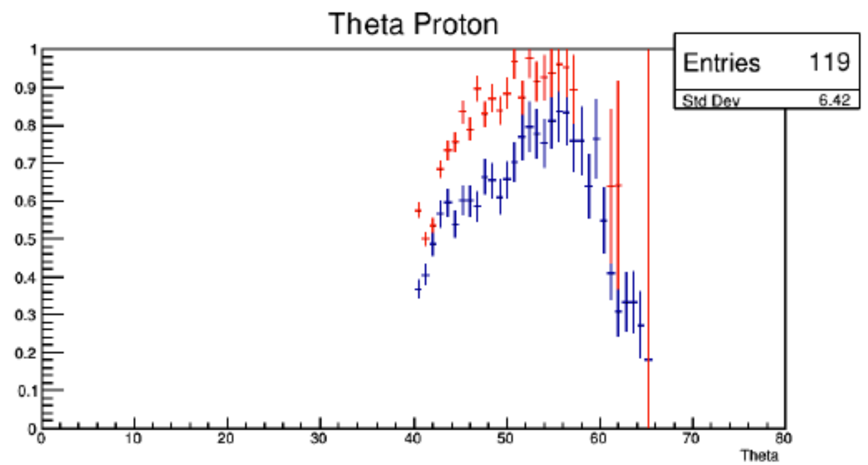
$$Efficiency = \frac{ep \rightarrow ep\pi^+\pi^-}{ep \rightarrow e(p)\pi^+\pi^-}$$

Data efficiency   MC efficiency





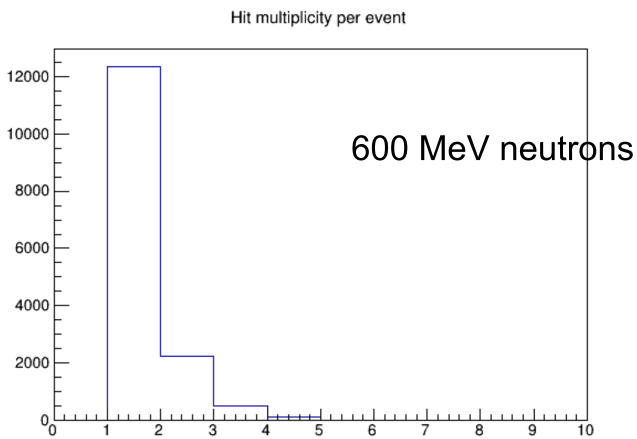


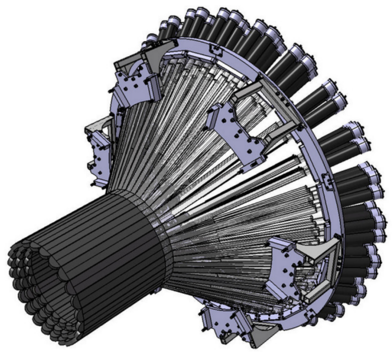


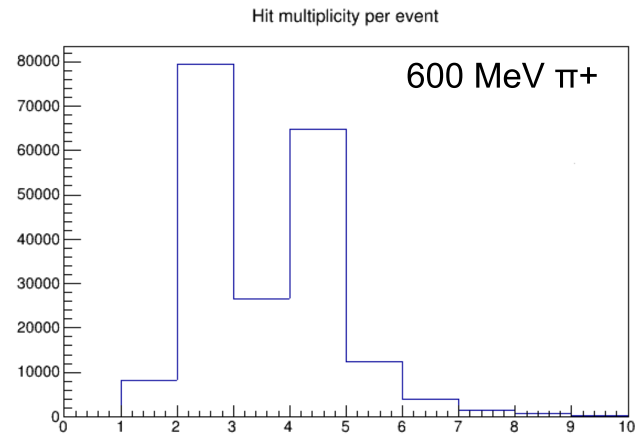
A Charged Particle Veto in the Central Detector Using Only CND and CTOF

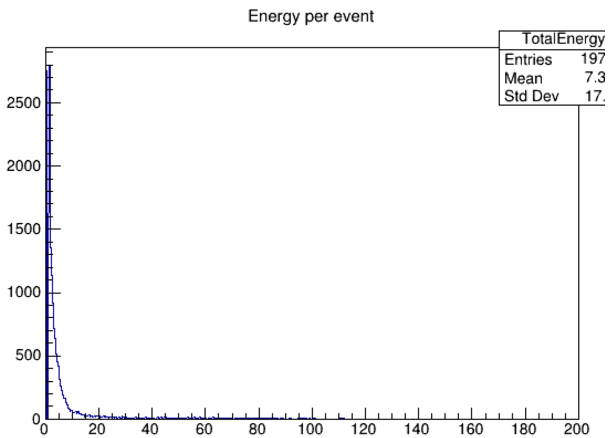
Katheryne Price
IPN Orsay

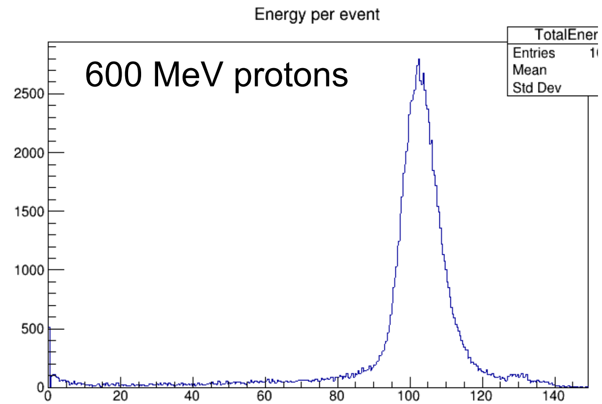
- Tracking in the CVT is neither 100% efficient nor uniform
  - → CND sees charged particle contamination

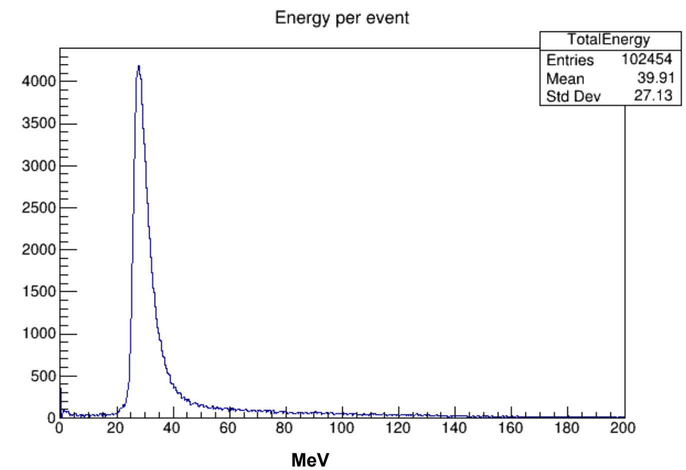




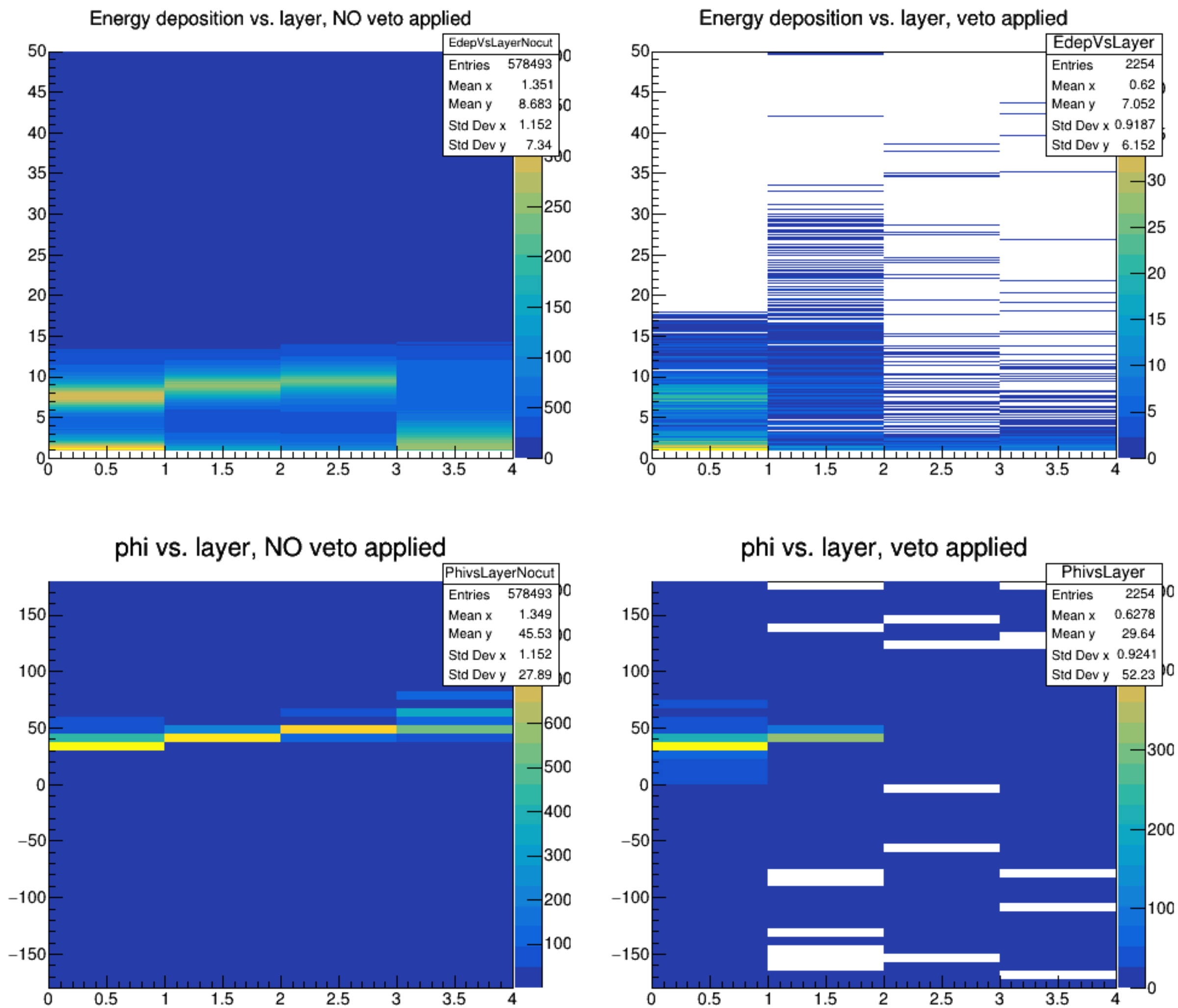








Results



total detected	Cut 47	%	
12346	11553	93.58%	←n
12656	11750	92.84%	
13228	12125	91.66%	
14118	12866	91.13%	
14516	13126	90.42%	
16092	14343	89.13%	
17359	15166	87.37%	
96876	1689	1.74%	←p
99222	695	0.70%	
99510	540	0.54%	
99656	409	0.41%	
99697	403	0.40%	
99741	437	0.44%	
99754	417	0.42%	
99155	1242	1.25%	←π+
99561	956	0.96%	
99691	699	0.70%	
99770	675	0.68%	
99824	706	0.71%	
99816	445	0.45%	
99865	358	0.36%	