CLAS Collaboration meeting

Deeply Virtual Compton Scattering at 10.6 GeV with CLAS12

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Thursday, June 20, 2019

Outline

- 1 - Introduction
- 2 - Previous main analysis steps and results
- 3 - π^0 contamination
- 4 – BH-π^0 generator
- 5 – Quick look at the new data
- Conclusion

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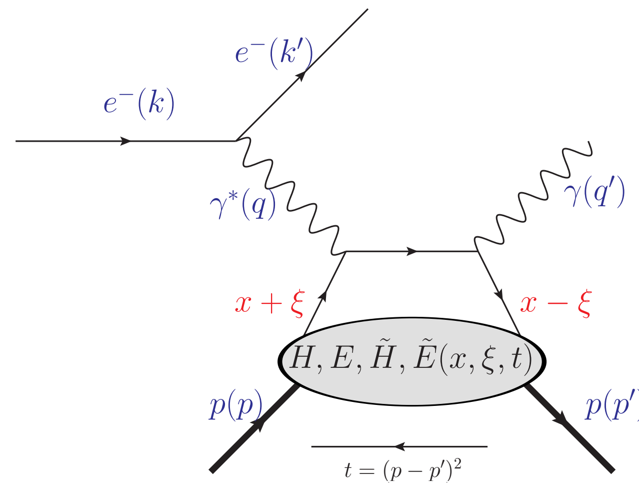
Deeply Virtual Compton Scattering

Deeply Virtual Compton Scattering $ep \to ep\gamma$

- GPDs appear in the DVCS amplitude through Compton Form Factors (CFF) such as:

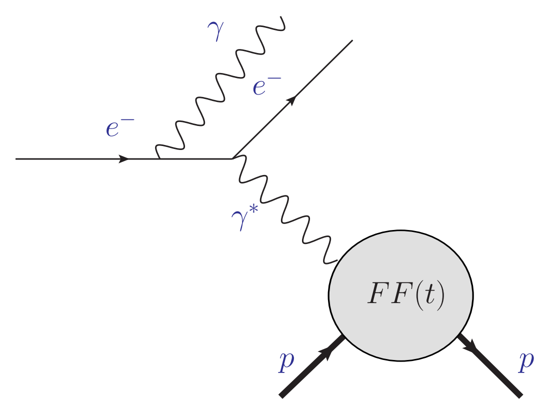
$$\mathcal{H} = \int_{-1}^{1} H(x,\xi,t)\left(\frac{1}{\xi - x - i\epsilon} - \frac{1}{\xi + x - i\epsilon}\right)dx$$



DVCS at leading order

- Experimentally we measure photon leptoproduction: interference of **DVCS and Bethe-Heitler** (BH)

$$\sigma_{(}ep \to ep\gamma) = |DVCS|^2 + |BH|^2 + Interference$$



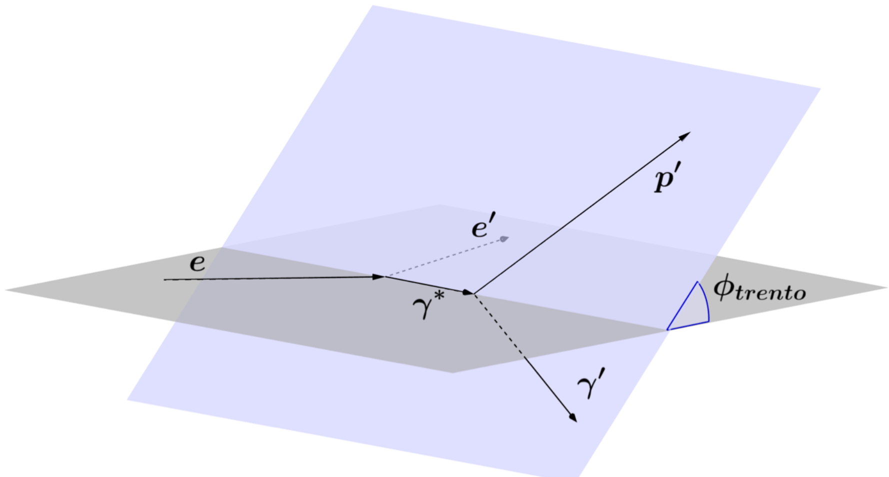
BH at leading order

Beam-spin asymmetry

- Extraction of GPDs from DVCS with polarized lepton beam and unpolarized target

- Photon leptoproduction
  beam-spin asymmetry:

$$A_{LU} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$$



- At leading order the asymmetry is:

$$A_{LU} \simeq \frac{A \sin(\phi_{trento})}{1 + B\cos(\phi_{trento})} \qquad A = \frac{s_1^{\mathcal{I}}}{\kappa c_0^{BH} + c_0^{\mathcal{I}}} \qquad B = \frac{\kappa c_1^{BH} + c_1^{\mathcal{I}}}{\kappa c_0^{BH} + c_0^{\mathcal{I}}}$$

κ known function of kinematical variables

$c_1^{\mathcal{I}},\ c_0^{\mathcal{I}},\ s_1^{\mathcal{I}}$ combinations of CFF

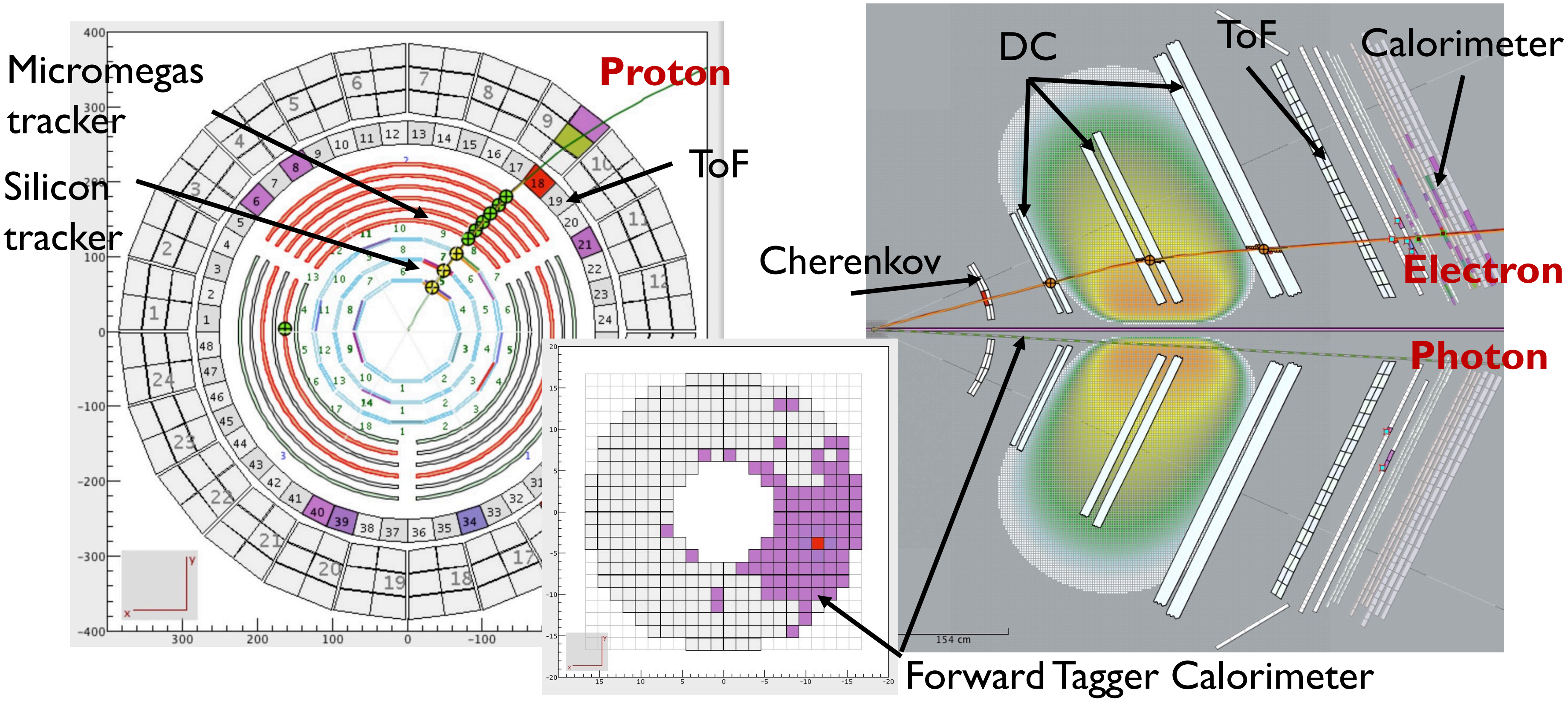
$$s_1^{\mathcal{I}} \propto Im(F_1\mathcal{H} + \xi(F_1 + F_2)\tilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E})$$

F_1, F_2 form factors

DVCS event in CLAS12

Typical DVCS event:

- Electron in the forward detector (torus, DC, ToF, Cherenkov, Calorimeter)
- Photon in the forward tagger (calorimeter)
- Proton in the central detector (solenoid, Silicon, Micromegas and ToF)



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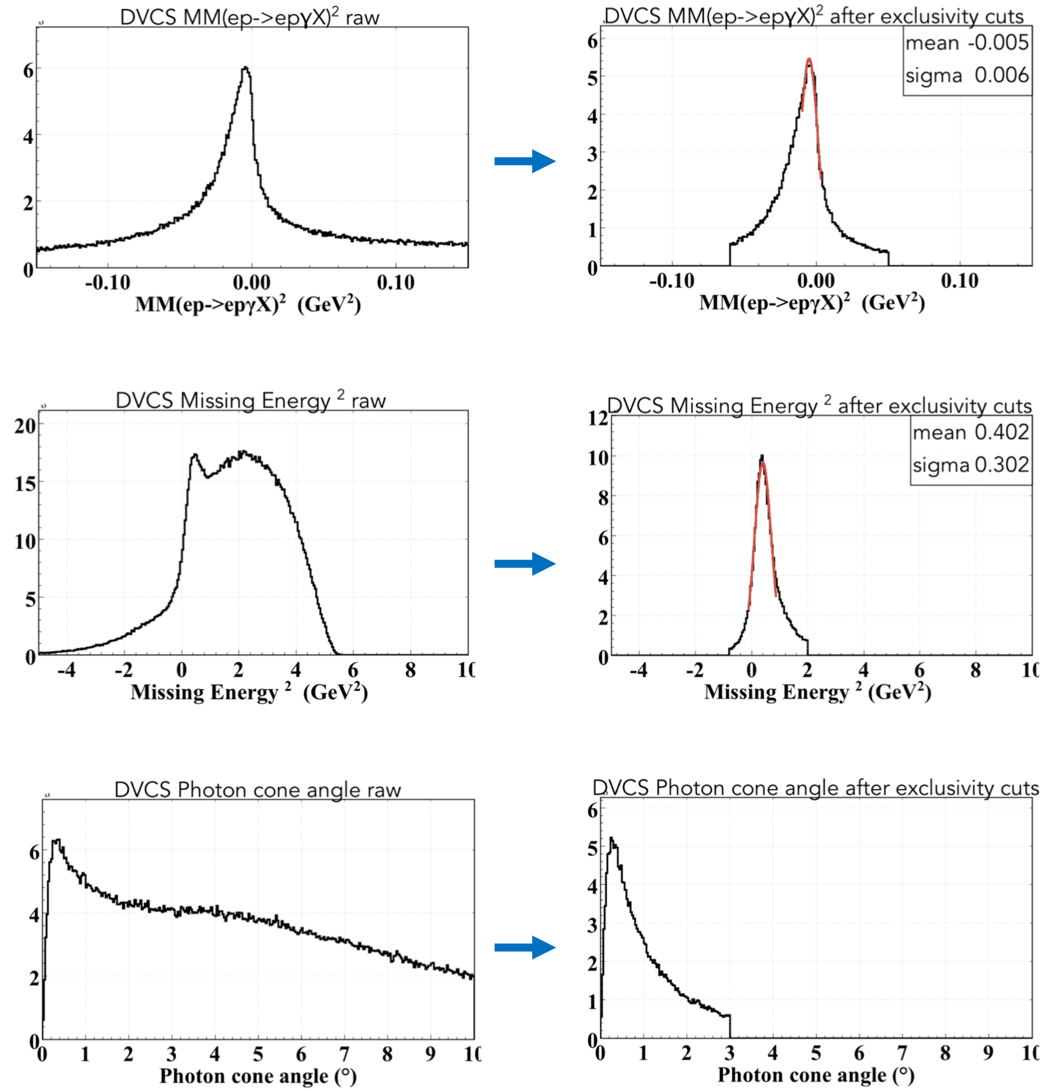
Preliminary selection and exclusivity

Final state with:

- High energy **electron** > *2GeV*
- High energy **photon** > *3 GeV*
- **Proton**
- $Q^2 = -q^2 > 1\ GeV^2$
- $W^2 = (p+q)^2 > 4\ GeV^2$

Selection of exclusive DVCS events:

- **Missing mass** $ep \rightarrow ep\gamma X$
- **Missing energy** $ep \rightarrow ep\gamma X$
- **Cone angle**: angle between measured and computed photon (using proton and electron)



First look at beam-spin asymmetry

Preliminary asymmetry:

$$A_{LU} = \frac{1}{P}\frac{N^{+}(\phi_{trento}) - N^{-}(\phi_{trento})}{N^{+}(\phi_{trento}) + N^{-}(\phi_{trento})}$$

P polarization

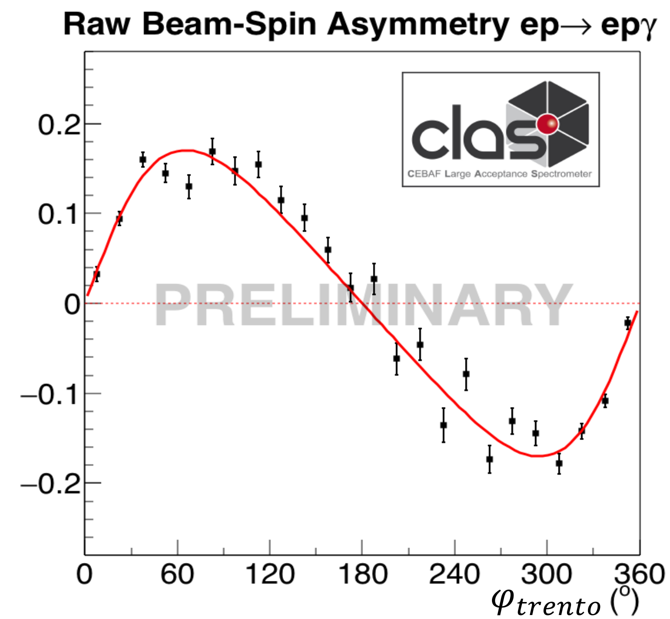
N^{+} / N^{-} number of events with helicity + / -

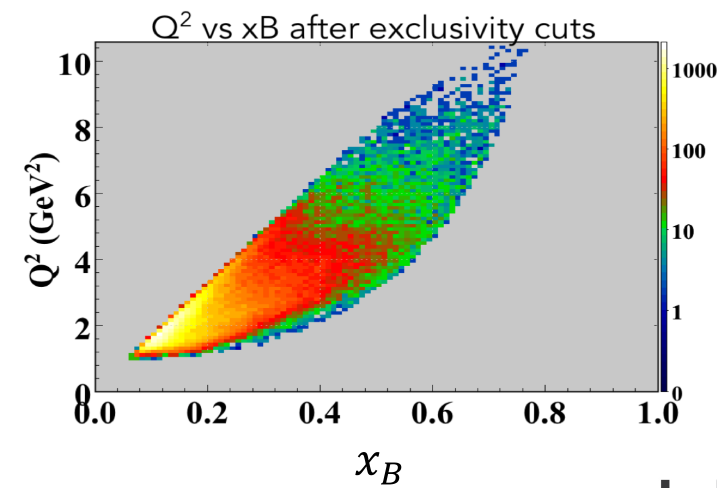
Residual background not yet subtracted

Only statistical errors

Integrated over all kinematic domain

About 3% of RG-A statistics





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π^0 contamination

Pion electroproduction $ep \rightarrow ep\pi^0 \rightarrow ep\gamma\gamma$

If one of these happen:
- one photon is not detected
- one photon has too low energy
- the two photons are too close to be distinguished

Then we might take a pion event for a DVCS event → contamination

Effect of this contamination
- π^0 have no or a very low asymmetry
- only appear in the denominator

→ Contamination **reduces the asymmetry**

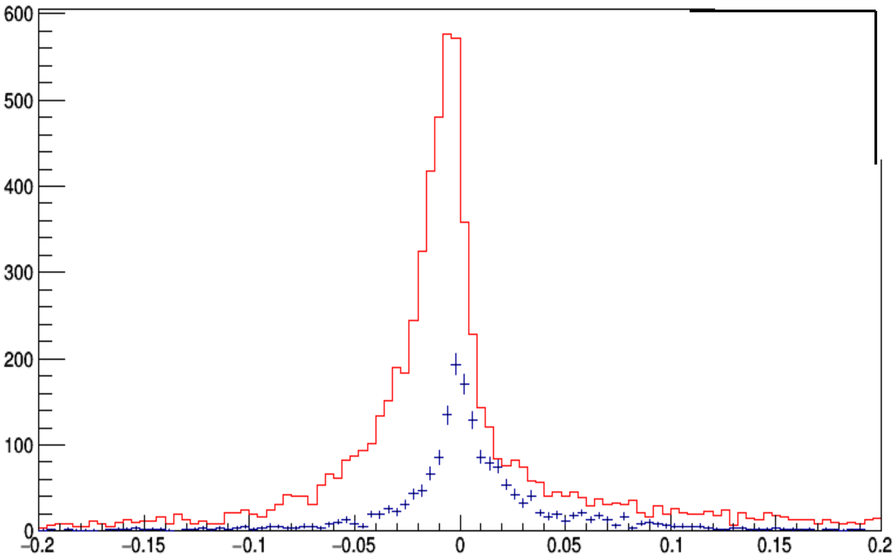
$$A_{LU} = \frac{1}{P}\frac{N^+(\phi_{trento}) - N^-(\phi_{trento})}{N^+(\phi_{trento}) + N^-(\phi_{trento})}$$

π^0 contamination – Method 1

Goal: estimate π^0 contamination
with a π^0 simulation

- Simulate π^0 with dynamics
- Compute number of π^0 in data and in the simulation (in a clean region) to find the scaling factor
- Scale simulation to the data

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



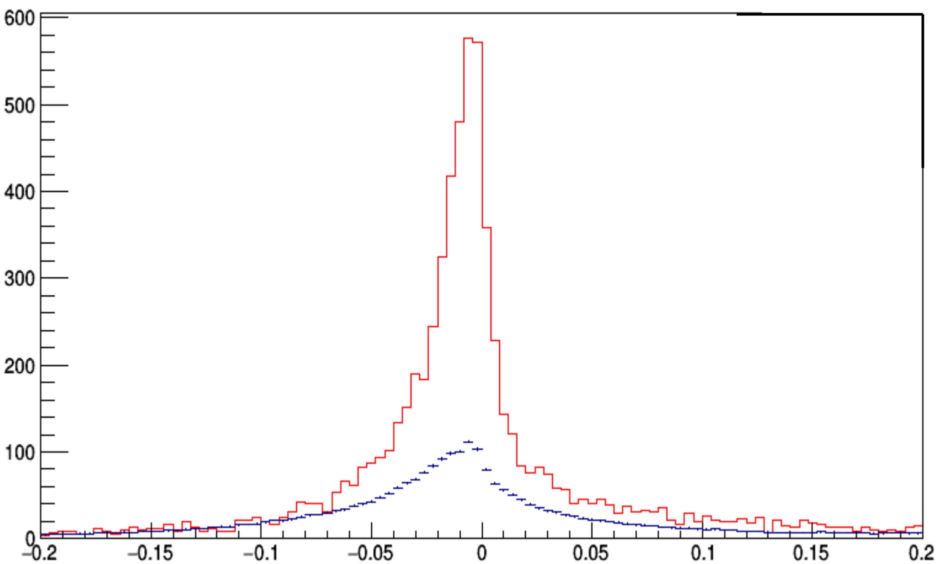
Preliminary pion contamination
(red: total signal, blue contamination)

π^0 contamination – Method 2

Goal: estimate π^0 contamination **with dynamics from the data**

- Identify π^0 in the data
- Simulate decay of these pions (each pion is randomly decayed multiple times)
- The events with photons within exclusivity cuts become DVCS background

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



Preliminary pion contamination
(red: total signal, blue contamination)

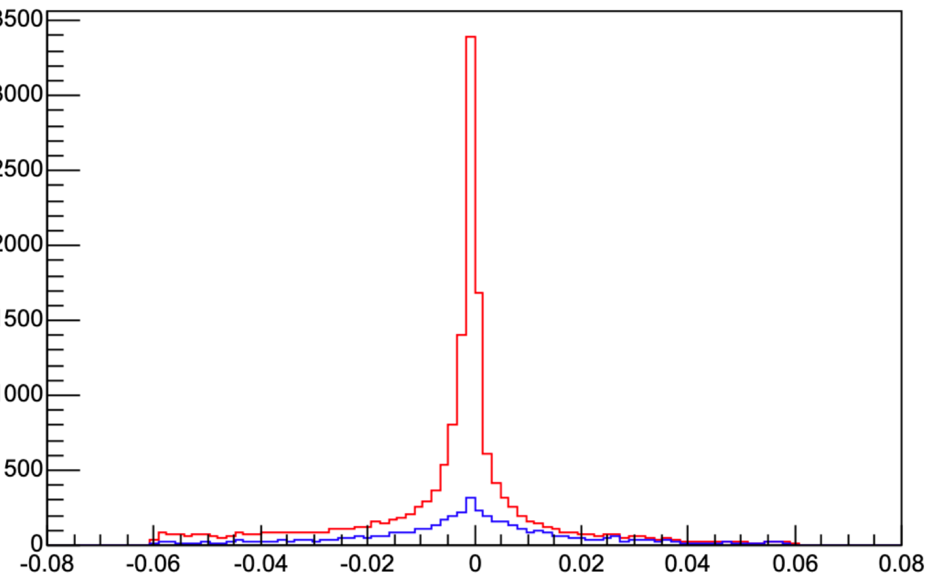
π^0 contamination – Method 3

Goal: estimate π^0 contamination using a DVCS + π^0 simulation

- Generate both DVCS and π^0 with dynamics
- Background consist of all the events that are not DVCS

Warning: Issue with simulation/reconstruction
Pid had to be based on MC banks

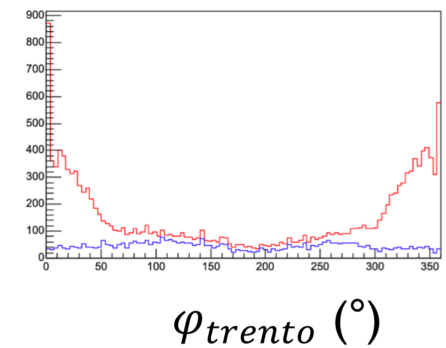
Missing mass squared $ep \to ep\gamma X$ (GeV^2)



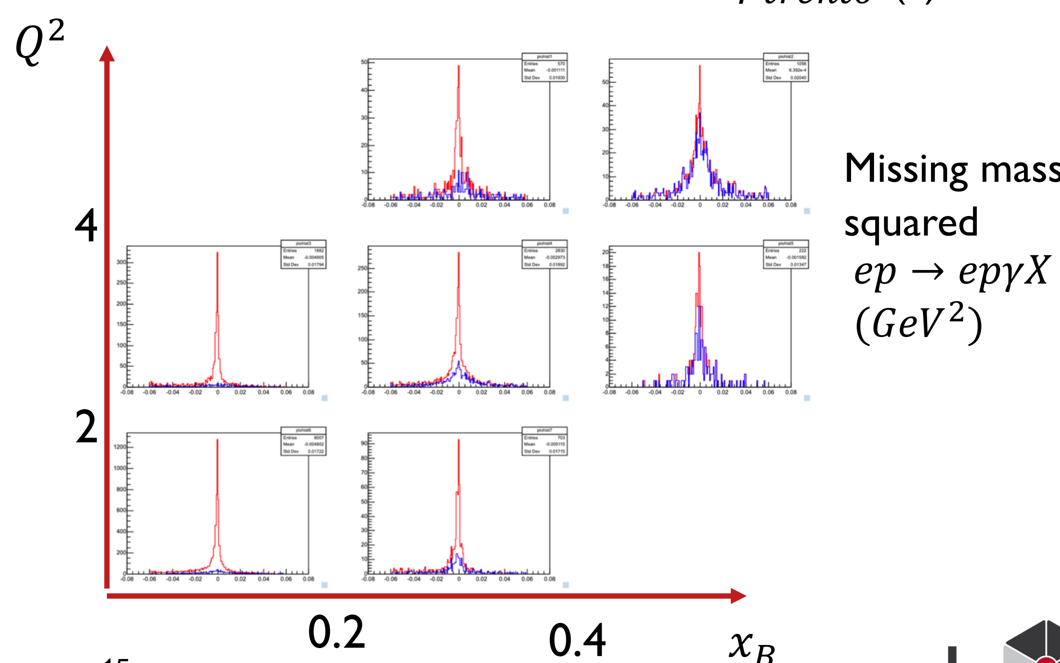
Preliminary pion contamination
(red: total signal, blue contamination)

π^0 contamination – Conclusions

- Very preliminary but overall good **agreement** between all 3 method
  - **About 30% with the current exclusivity cuts**



- Depends on the kinematics
  - φ dependence
  - Q2/xB dependence



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BH- π^0 Generator – Goals and issues

Goal of the algorithm

- Be able to generate DVCS and Pi0 flat or from cross-section
  - pure DVCS with cross section
  - pure Pi0 with cross section
  - **DVCS and Pi0 together with a correct cross-section ratio**

Issues

- 1 - BH cross-section is extremely high in some regions
  - Accept-reject algorithm is difficult to implement and extremely slow
- 2- How to generate 2 processes at “the same time” and on a slightly different 4D phase-space ?

BH- π^0 Generator – Algorithm

Issue 1 : Metropolis algorithm …

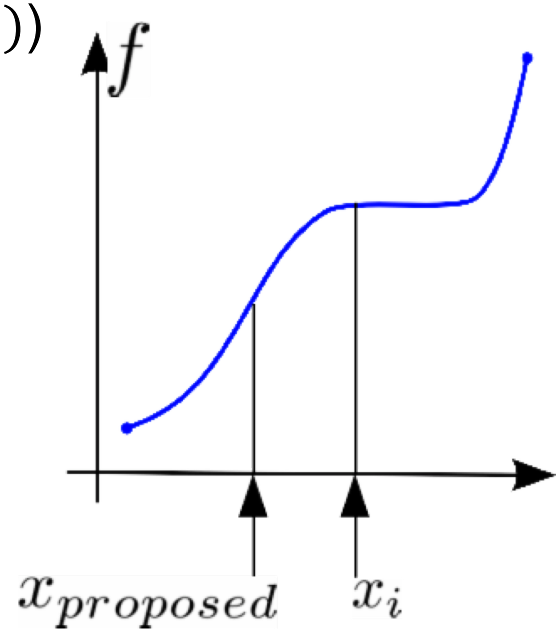
1 – x_i random starting point (4D: $x = (Q^2, x_B, t, \varphi)$)

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

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

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

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



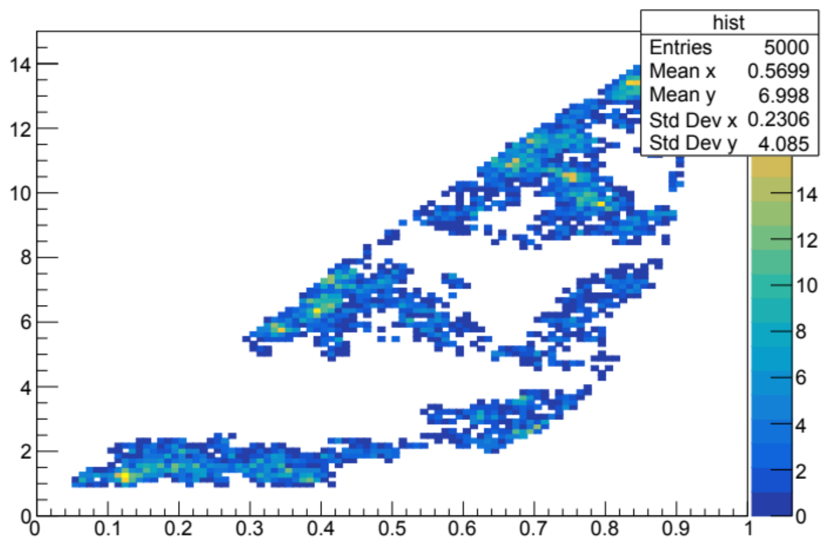
Issue 2 : … applied on the sums of the cross sections

Use $f(x) = \sigma_{BH}(x) + \sigma_{\pi^0}(x)$

BH- π^0 Generator – Example

Example of sequence of the algorithm (with flat cross section)

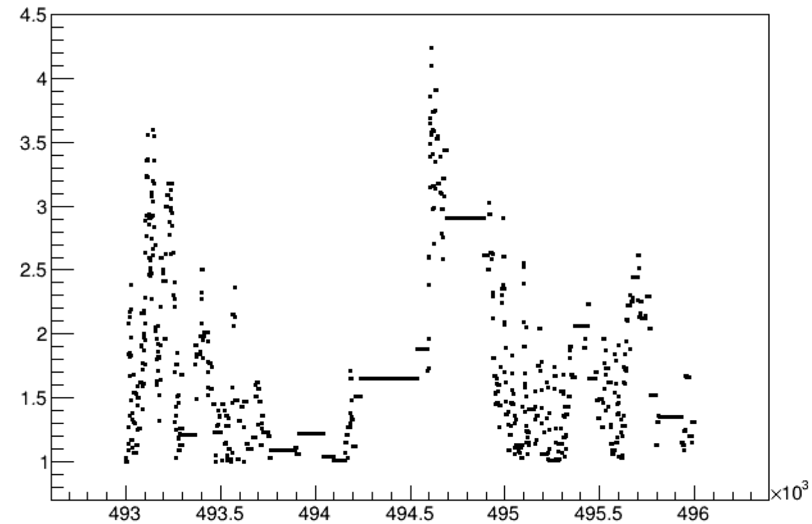
Q^2



x_B

Example of Q^2evolution for 3000 iterations (with real cross-section)

Q^2



iteration

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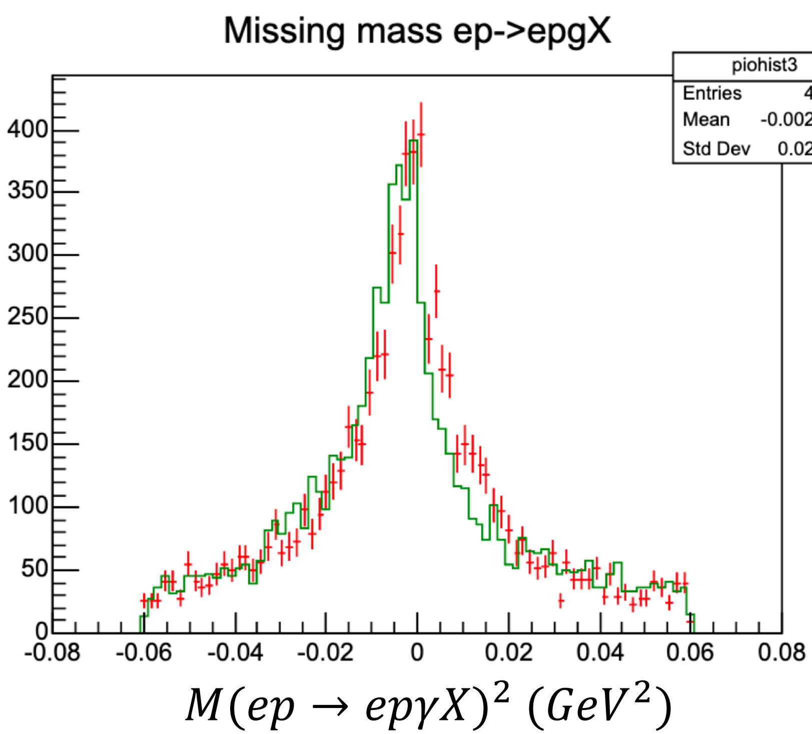
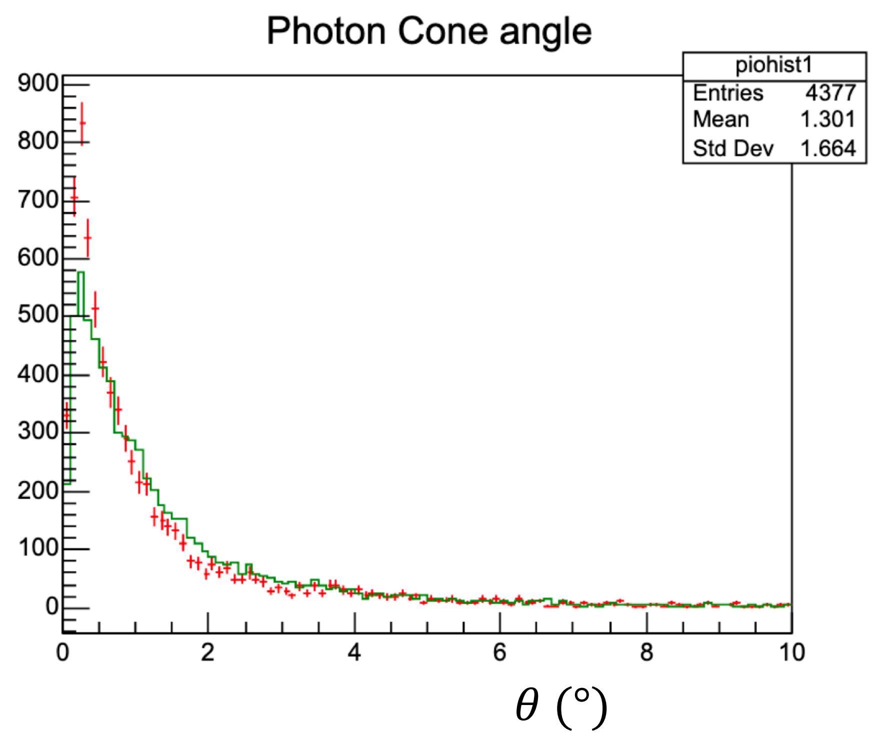
A quick look at the new cooked data

Green = **spring data train v2** (this winter)
Red = **fall data train v5** (last week)

→ Not really comparable (spring vs fall) but great overall improvement





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Conclusion

- **π^0 contamination** is being analyzed and understood
  - 3 different methods giving consistent results

- **DVCS + π^0 simulation** has been done
  - joint **DVCS + π^0** simulation
  - Metropolis algorithm can be useful

- **Ready to analyze** a new set of cooked data
  - We can expect **nice improvements** by looking at **newly cooked fall data compared to spring DNP data**

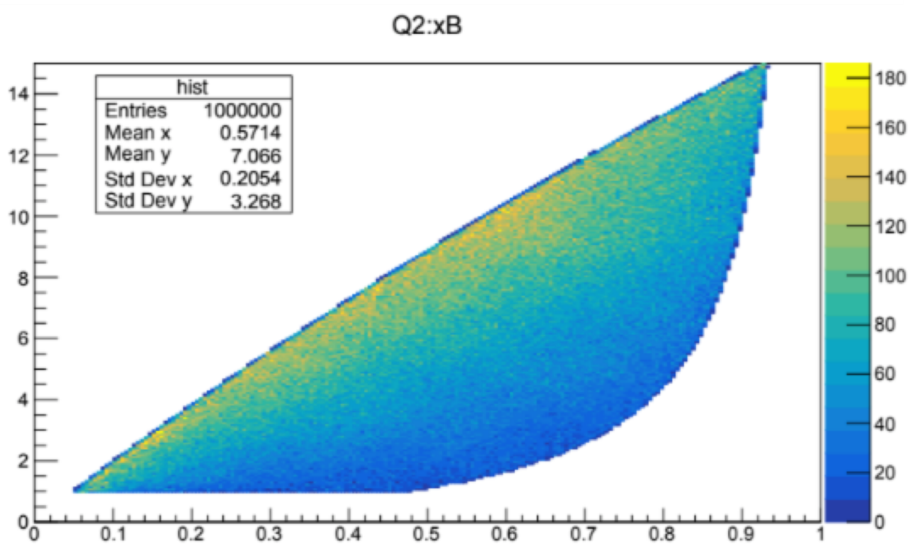
- Would like to be able to do some **background merging**
  - Gemc background merging tool does not seem enough (example adc from data $\neq$ adc from simulation for several detectors)
- Clas12Tools to read HIPO4

Thanks !!

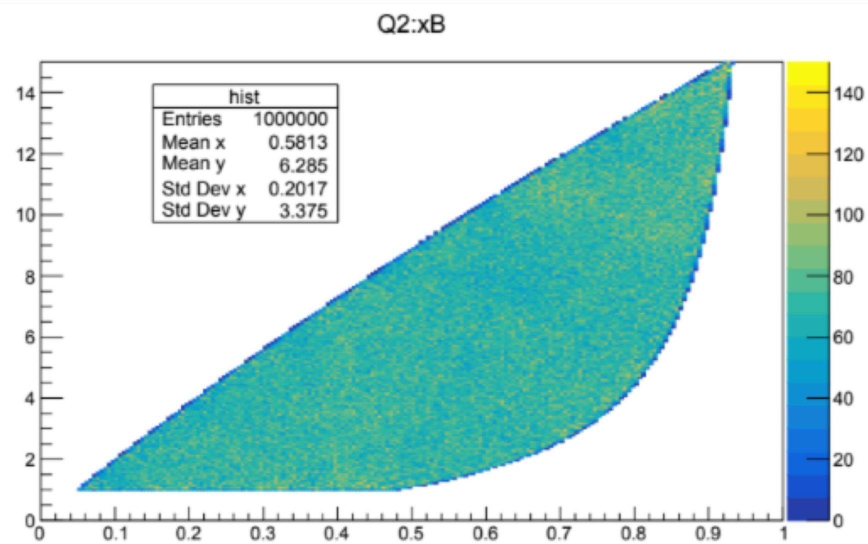
Backup

BH- π^0 Generator

Simulation flat (4-Dimension flat) using Metropolis algorithm



Simulation flat (without t range) using Metropolis algorithm



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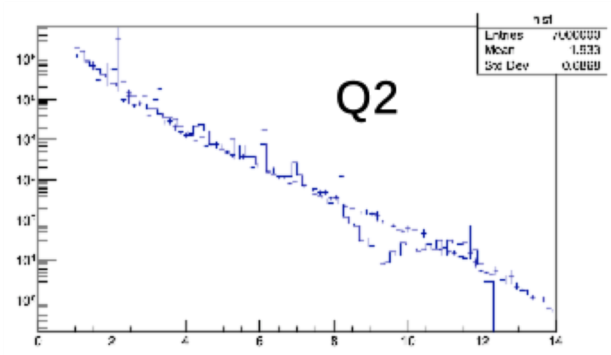
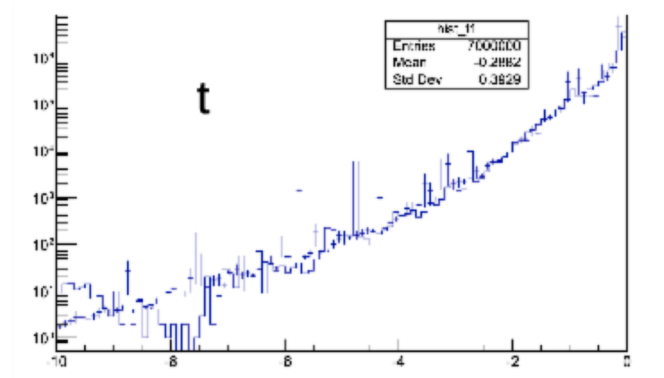
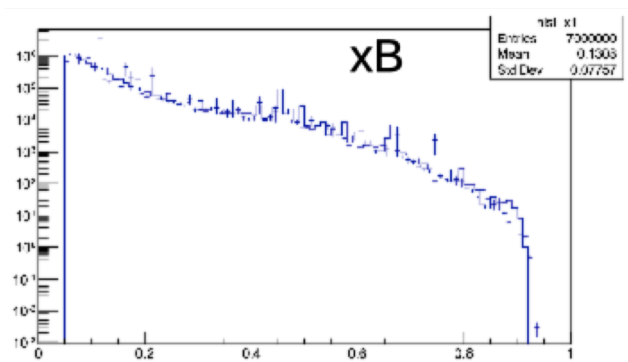
BH- π^0 Generator

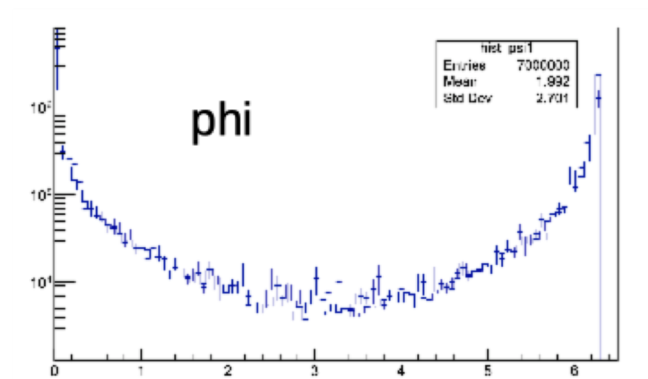
- crosses: distribution flat weighted
using accept-reject method

- lines: distribution according to a cross-section
using Metropolis method



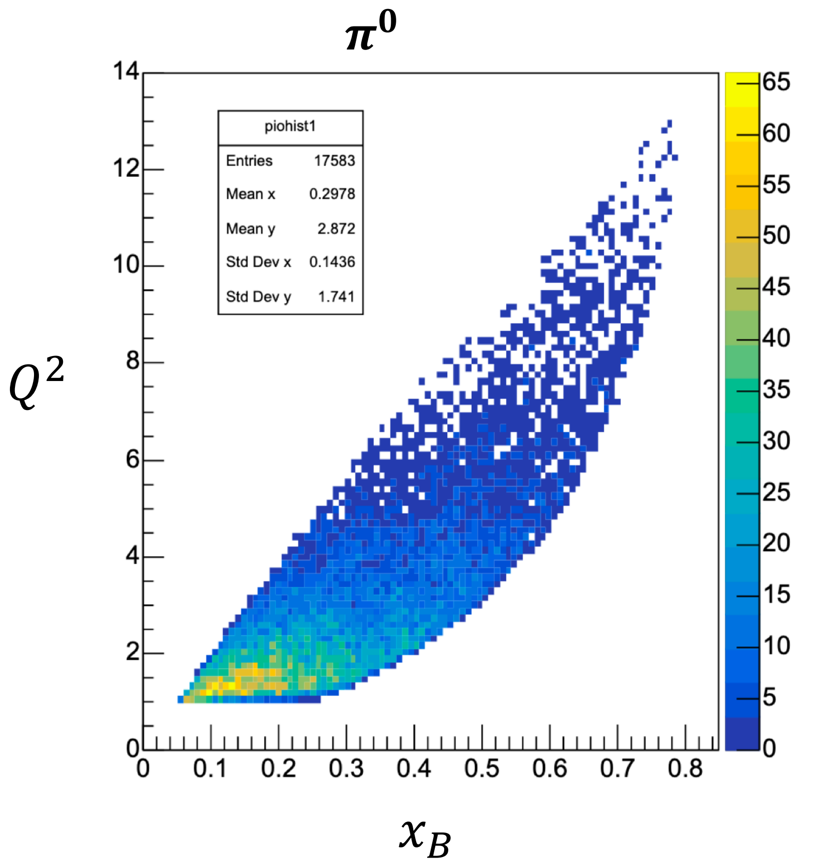


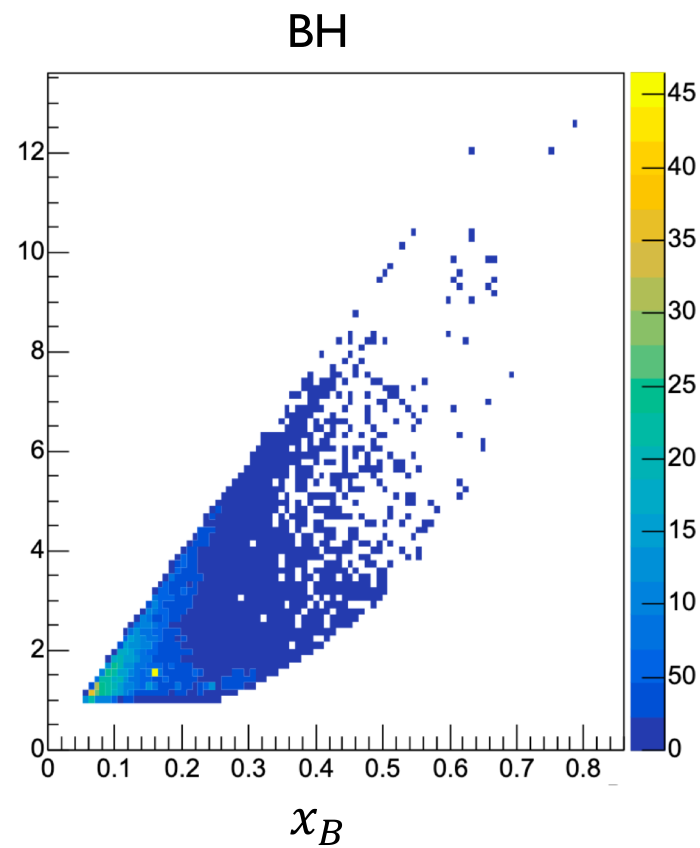




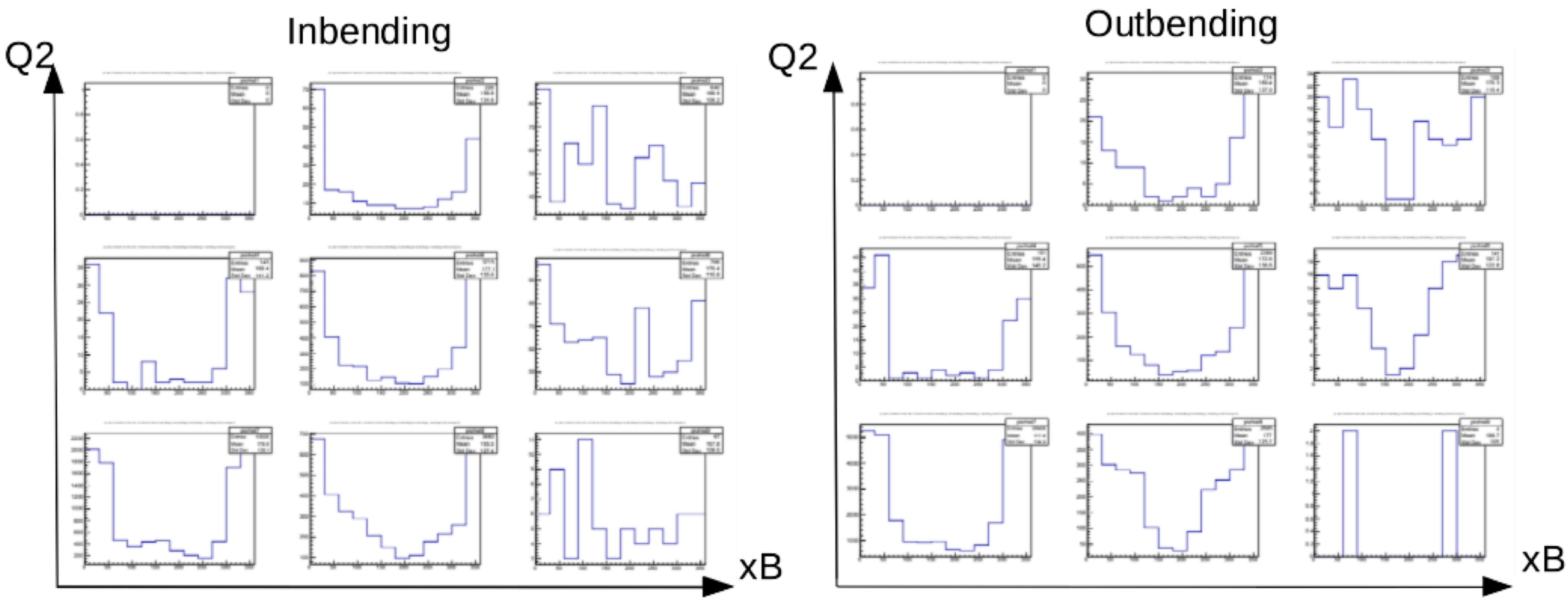
BH- π^0 Generator

- Distributions after reconstruction for 1M BH- π^0 events





BH- π^0 Generator



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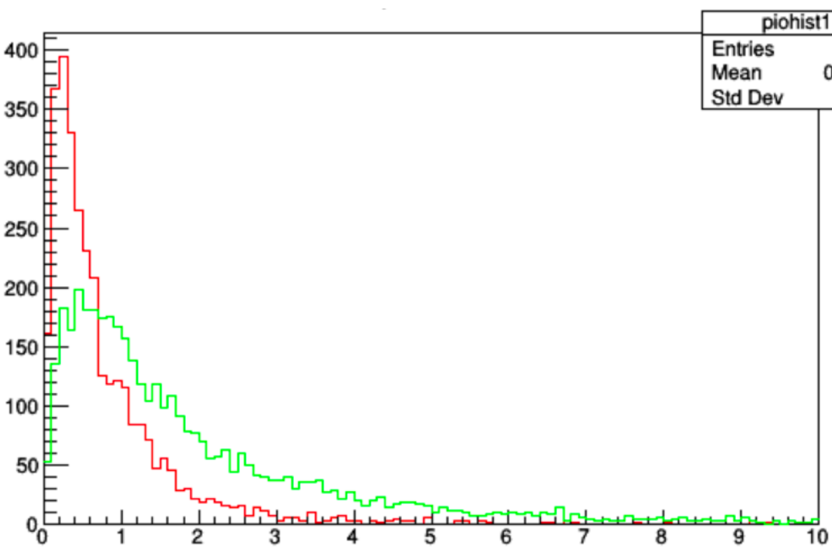
Number of particles from data

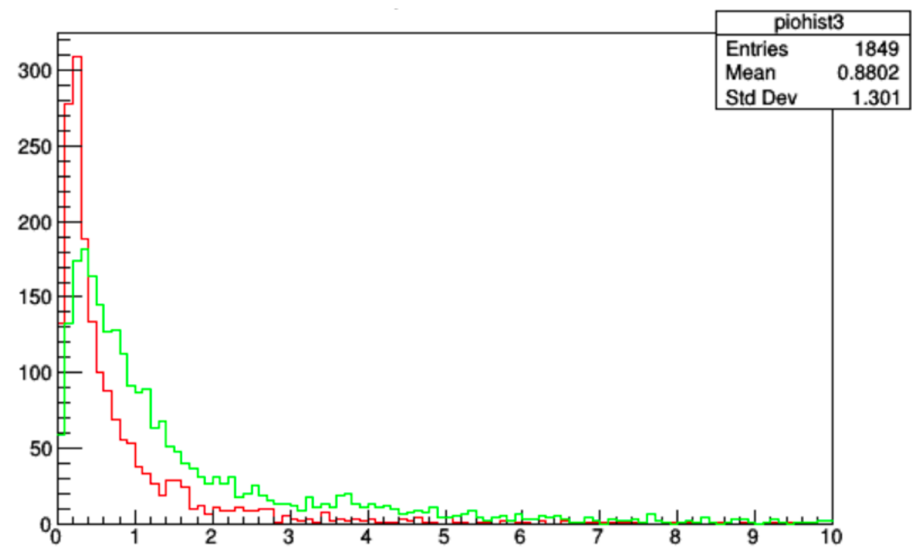
A quick look at the new cooked data

Left = **spring data train v2** (this winter)
Right = **fall data train v5** (last week)

Red = photon in **FT**
Green = photon in **FD**



Photon cone angle (°)



Photon cone angle (°)