Calorimeter simulations

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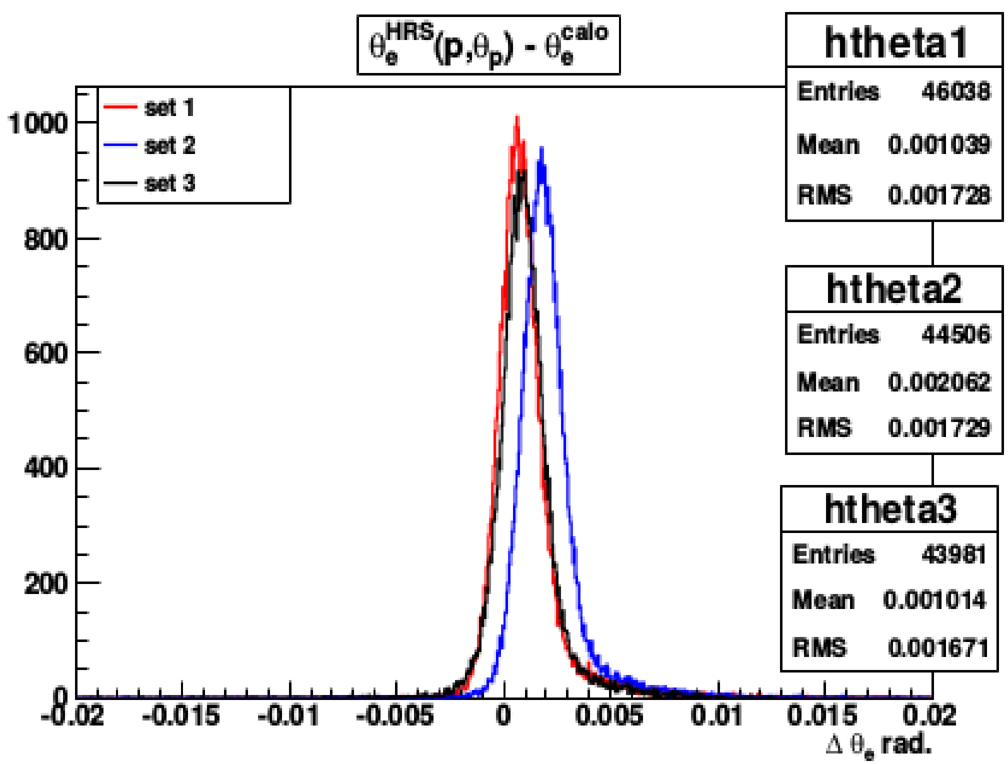
Introduction

A previous study with elastic runs (Fall 2014) showed that the calorimeter was not exactly where it was thought to be.

Introduction

- Comparing e scattering angle measured by calorimeter, and computed from p in spectrometer : angles (mean values) are not equal !
- When we move the calorimeter : there is an incertitude on its exact position.



1mrad shift for a calorimeter at 6m

~ 6mm shift of calorimeter position

Rough Estimation :

1m distance ~ 1mm error on position

(Study made by Mongi Dlamini)

Introduction

- Not really an issue for elastic runs...

  … But it is (possibly) an issue for DVCS !

- What is the effect of a shift of the position of the calorimeter on the DVCS cross-section computation ?

  → effect negligible ?

  → need to measure precisely calorimeter position every time it is moved ?

  → If yes, are there fast methods ?

Outline

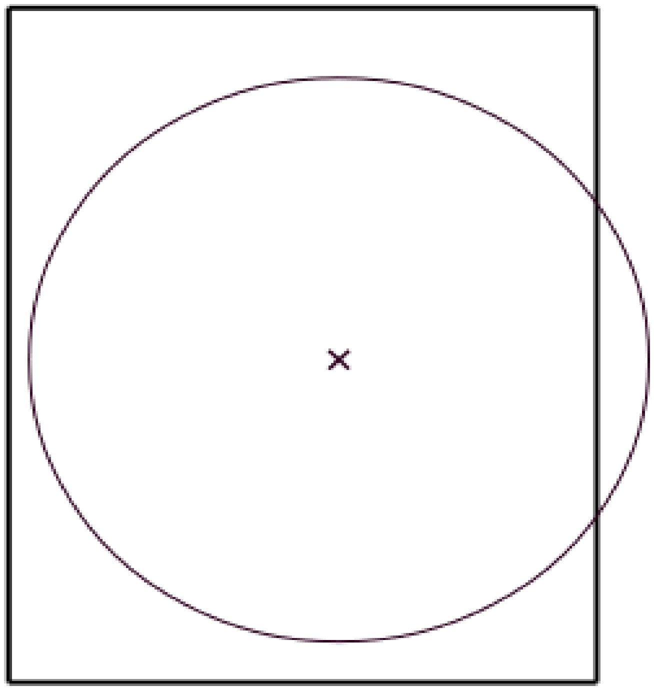
- Effects of a shift of the position of the calorimeter on cross-section computation.
- Possible methods to measure the exact position of the calorimeter.

Effects of a shift of the position of the calorimeter on cross-section computation

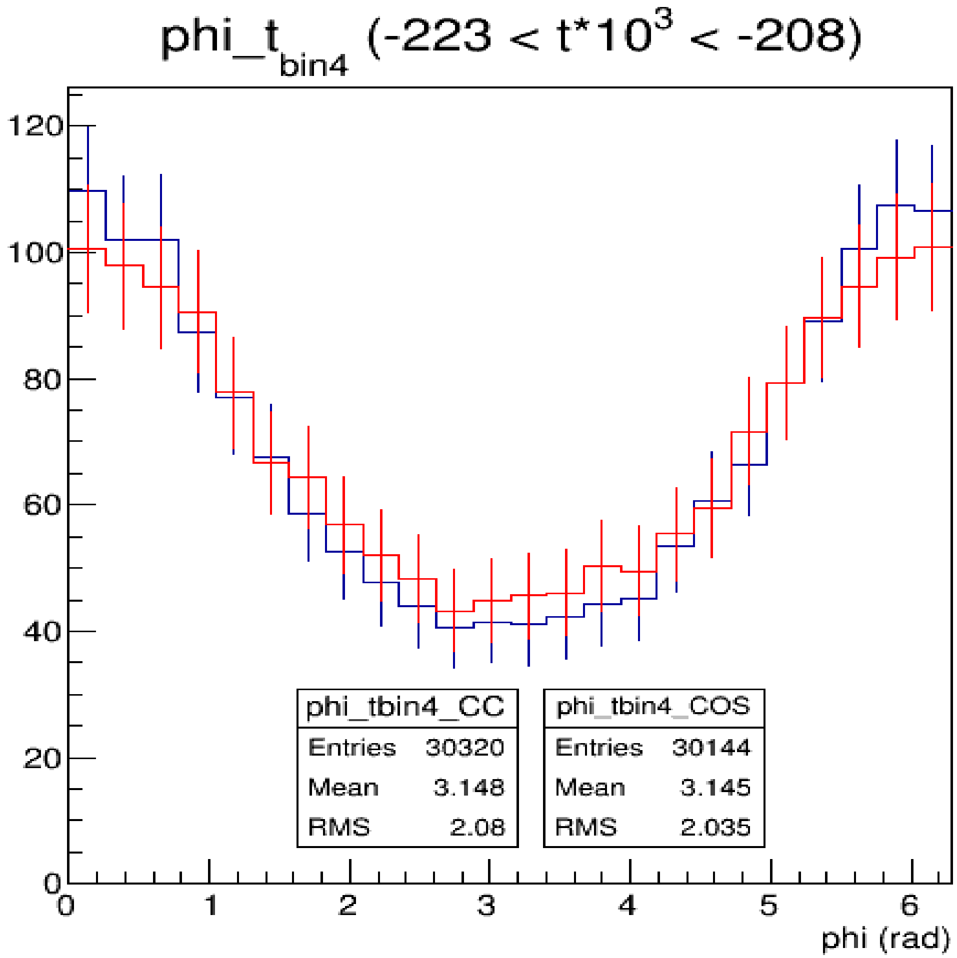
Simulation of a shift of the position

- Geant4 simulation : shifted calorimeter position to simulate an error on its position.
- Simulated DVCS events, same kinematics as this spring.
- Selection of a range of t where the acceptance of the calorimeter is flat.
- Cuts, subtraction of BH, analysis...

  → histograms of the number of events per bin in t and phi (azimuthal angle).



Effects on cross section



Shift of the position of the calorimeter :

→ deformation of the histogram

→ error on the value of the cross-section as a function of phi.

(Unfortunate since information on GPD is extracted from this dependence)

Quantification of this error ?

$$a + b * cos(\Phi) + c * cos(2 * \Phi) + d * cos(3 * \Phi)$$

Results

- For a shift of 2mm, with a calorimeter at 1,5m from target (realistic shift) :

  mean value of b : 30

  mean statistical error on b : 2,3

  mean variation of b due to shift : 2

Reminder : b is the amplitude of the cos(Φ) term.

Results

- For a shift of 6mm, with a calorimeter at 1,5m from target (pessimistic shift) :

  mean value of b : 30

  mean statistical error on b : 2,3

  mean variation of b due to shift : 4,5

Reminder : b is the amplitude of the cos(Φ) term.

Conclusion

The error on b, due to the error on the position of the calorimeter, is of the same order of magnitude as its statistical error.

Compared to other error sources : small effect

But not negligible...

Possibilities to correct the position of the calorimeter

Methods to measure exact position

- Geometrical survey (long, dependent on experts availability)
- $ep \rightarrow ep$ elastic scattering runs (HRS polarization inversion quite long)

  Cross-check calorimeter position with scattered proton's angle and momentum detected in the HRS

  → **Have to check that elastic settings are accessible !**

- π^0 two photons decay (data taken simultaneously to DVCS runs : fast)

  → variations of the π^0 invariant mass ?

  → variations of $ep \rightarrow e\, \pi^0\, X$ missing mass ?

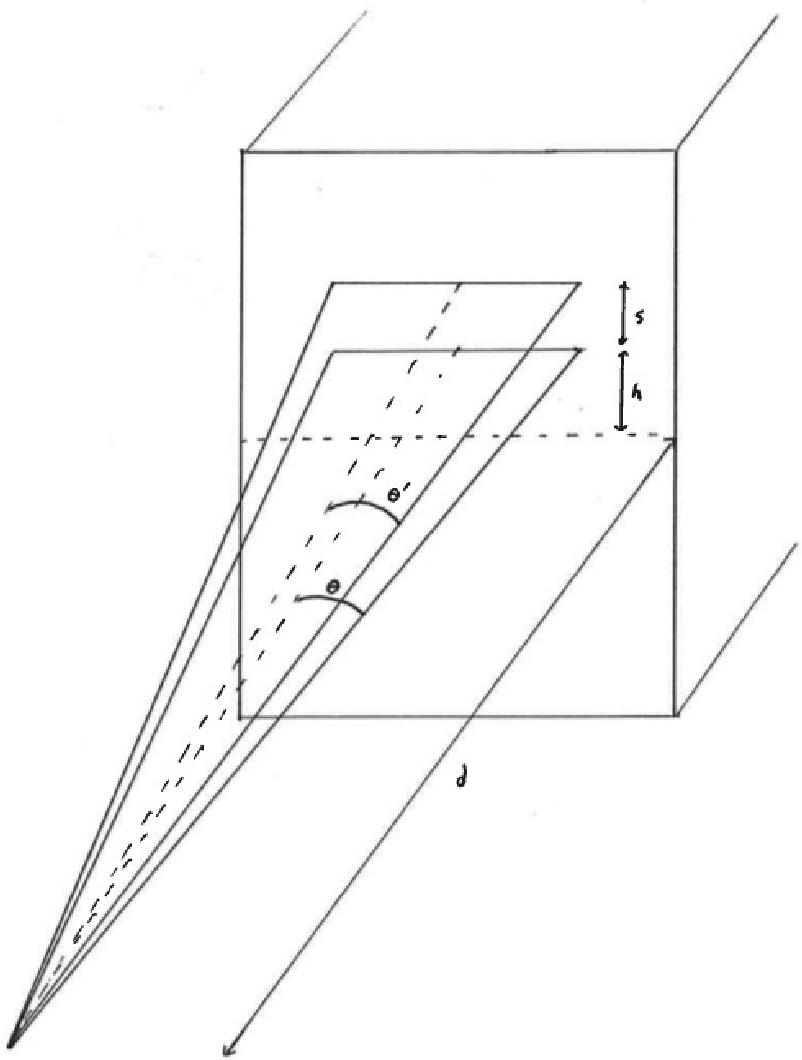
  → **Have to check that it is possible !**

π^0 invariant mass – angle variations

- Geometrical considerations to estimate if possible
- 2 limit cases have been considered :
  - Calorimeter position shift : vertical
  - Calorimeter position shift : horizontal

π^0 invariant mass – angle variations

- Case 1 :



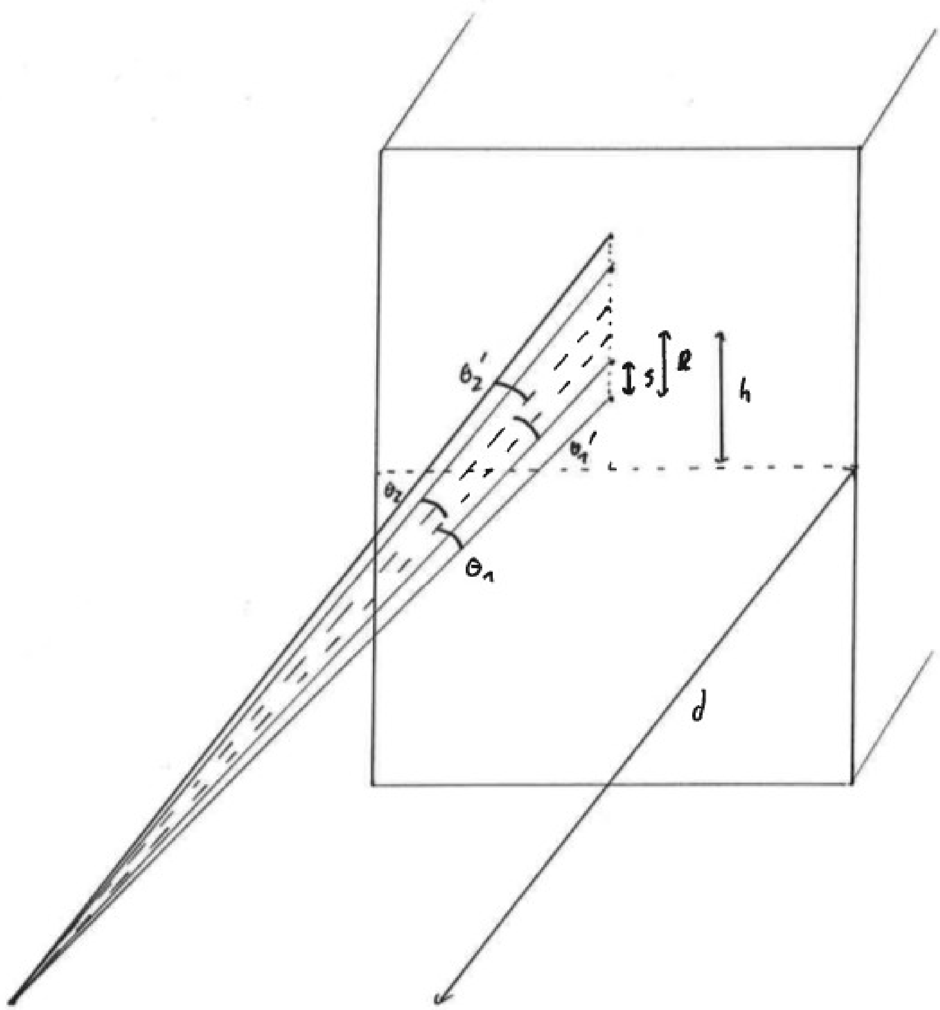
$$\frac{\tan\theta' - \tan\theta}{\tan\theta'} = 1 - \frac{\sqrt{d^2+h^2+s^2+2hs}}{\sqrt{d^2+h^2}}$$

With s = 2mm, d = 1.5m and h = 20cm :

$$\frac{\tan\theta' - \tan\theta}{\tan\theta'} = -1.76 * 10^{-4}$$

π^0 invariant mass – angle variations

- Case 2 :



$$\theta_1 = \arctan\frac{h}{d} - \arctan\frac{h-l}{d}$$

$$\theta_1' = \arctan\frac{h+s}{d} - \arctan\frac{h+s-l}{d}$$

$$\theta_2 = \arctan\frac{h+l}{d} - \arctan\frac{h}{d}$$

$$\theta_2' = \arctan\frac{h+s+l}{d} - \arctan\frac{h+s}{d}$$

With s = 2mm, d = 1.5m, h = 10cm

and l = 5cm:

$\theta_1 - \theta_1' = -2.57 * 10^{-4}$ degree

$\theta_2 - \theta_2' = -4.22 * 10^{-4}$ degree

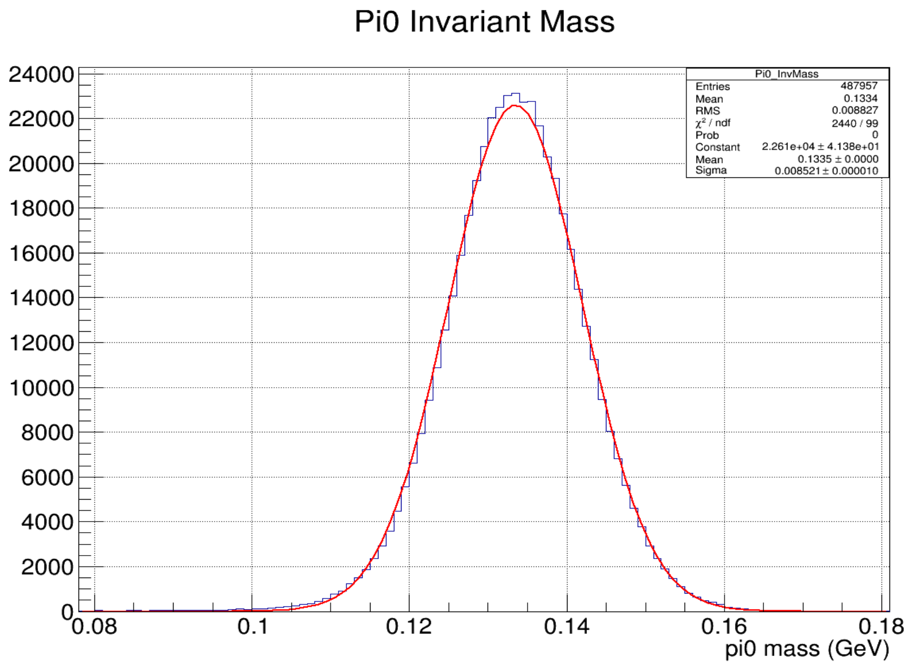
π^0 invariant mass – angle variations

Conclusion : angles' variations are too small to be detected and used.

Invariant and Missing Mass

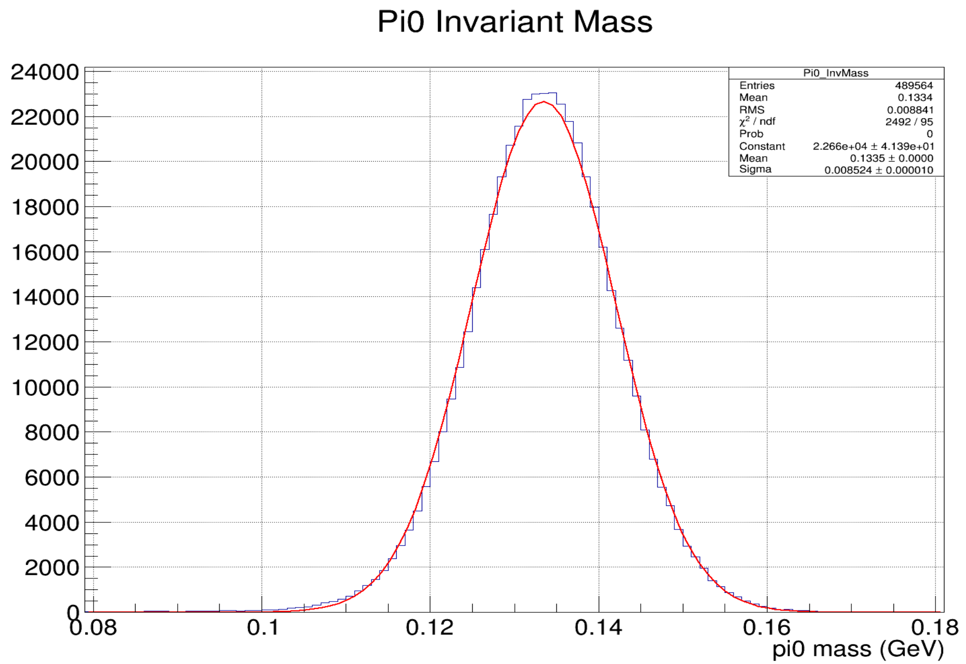
- Geant4 simulation ep → e π^0 X
- One simulation with calorimeter at exact position, one with calorimeter position shifted (6mm, with calorimeter at 1.5m from target : exagerated shift)
- Usual cuts...

π^0 Invariant Mass



Exact position

mean = 0.1335, sigma = 0.008521

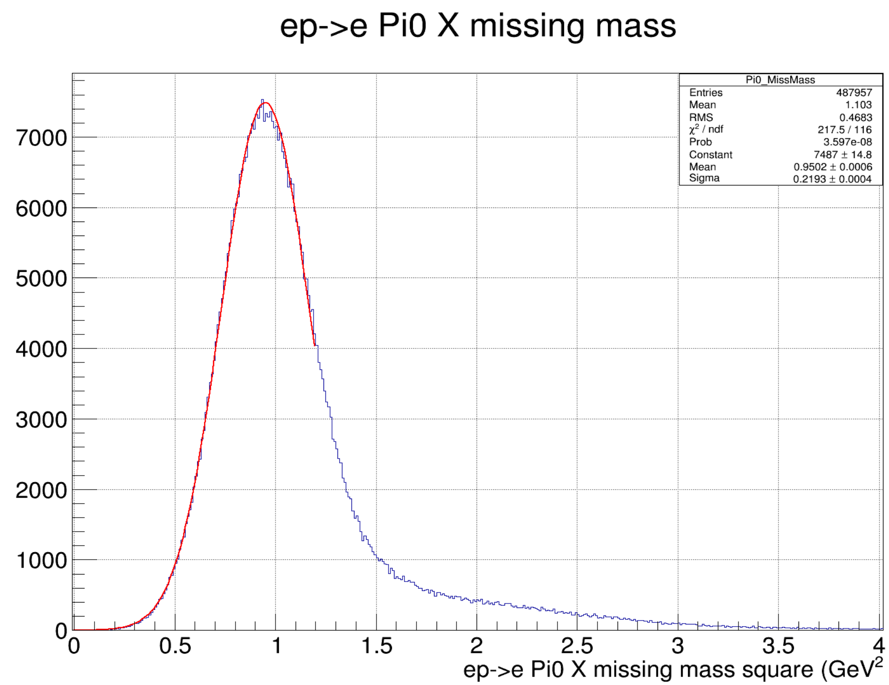


Position offset

mean = 0.1335, sigma = 0.008524

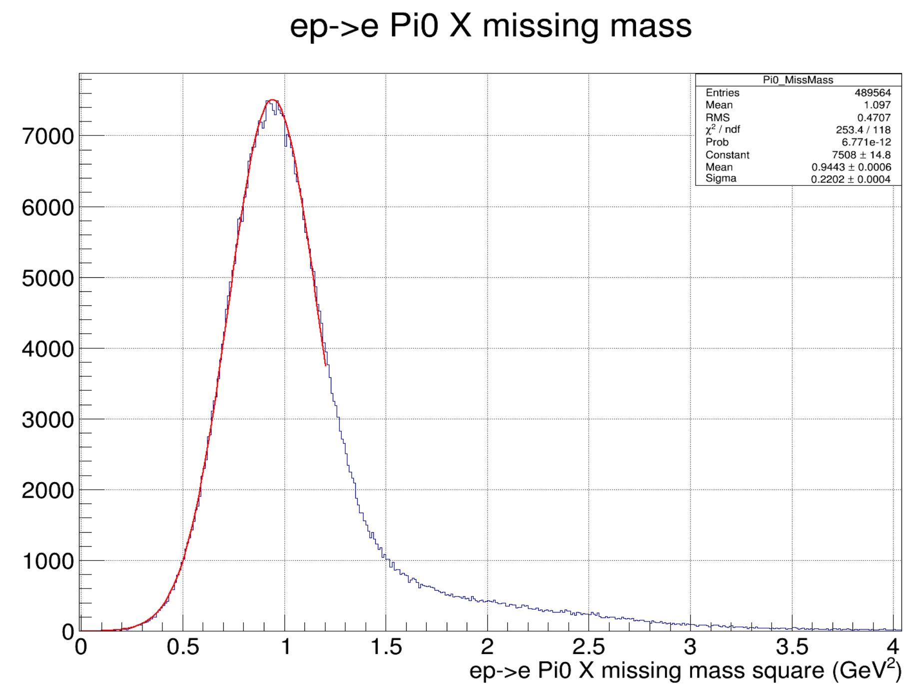
No noticeable differences

ep$\rightarrow$eπ^0X Missing Mass



Exact position

mean = 0.9502, sigma = 0.2193



Position offset

mean = 0.9443, sigma = 0.2202

Idem : No significant differences

π^0 – Conclusion

We won't be able to use π^0 to measure the exact position of the calorimeter.

ep→ep elastic scattering

- Calorimeter position fixed (at DVCS setting).
- Beam energy fixed (at DVCS setting).
- Computed analyticaly LHRS central angle and momentum to check that they are accessible.
- Computed elastic cross section to check that we can detect enough elastic events in a reasonnable amount of time.

$$\cos\theta_e = \frac{M^2 - M\sqrt{M^2+p^2}}{E(E+M-\sqrt{M^2+p^2})} + 1$$

$$\cos\theta_p = \frac{E\sqrt{M^2+p^2} - M(E+M-\sqrt{M^2+p^2})}{Ep}$$

ep→ep elastic scattering

From DVCS setting			proposition for elastic run					
E (GeV)	D calo (m)	θ calo (deg)	p HRS (GeV)	θ HRS (deg)	σ1 (nb/str)	σ2 (nb/str)	time	
6,6	1,5	11,7	1,512	50,54	29,54	3,2	1min 50s	
8,8	2	10,3	1,872	46,91	12,84	1,13	5min 10s	
11	2,5	10,8	2,67	39,74	1,64	0,18	32min 27s	
6,6	1,5	18,5	2,529	37,39	0,62	0,21	27min 48s	
8,8	2	14,5	2,81	37,14	0,61	0,13	44min 55s	
11	2,5	12,4	3,164	35,88	0,45	0,075	1h 17min 52s	
11	2,5	10,2	2,487	41,37	2,79	0,27	21min 38s	
8,8	1,5	17,8	3,2	34,03	0,22	0,066	1h 28min 30s	*
8,8	2	14,8	2,878	36,57	0,51	0,12	48min 40s	
11	2,5	13,1	3,2	35,63	0,42	0,071	1h 22min 16s	**
11	3	10,2	2,487	41,37	2,79	0,27	21min 38s	

*HRS momentum limitation. Electron angle = 16.24 deg. Distance electron – center of calo = 4.08 cm

**HRS momentum limitation. Electron angle = 12,51 deg. Distance electron – center of calo = 2,55 cm

σ1 is differential in cos(θelectron)

σ2 is differential in cos(θproton)

time : time required to get 10 000 events

We will be able to use ep→ep elastic scattering for each DVCS setting, with a reasonnable cross section.

Outlook

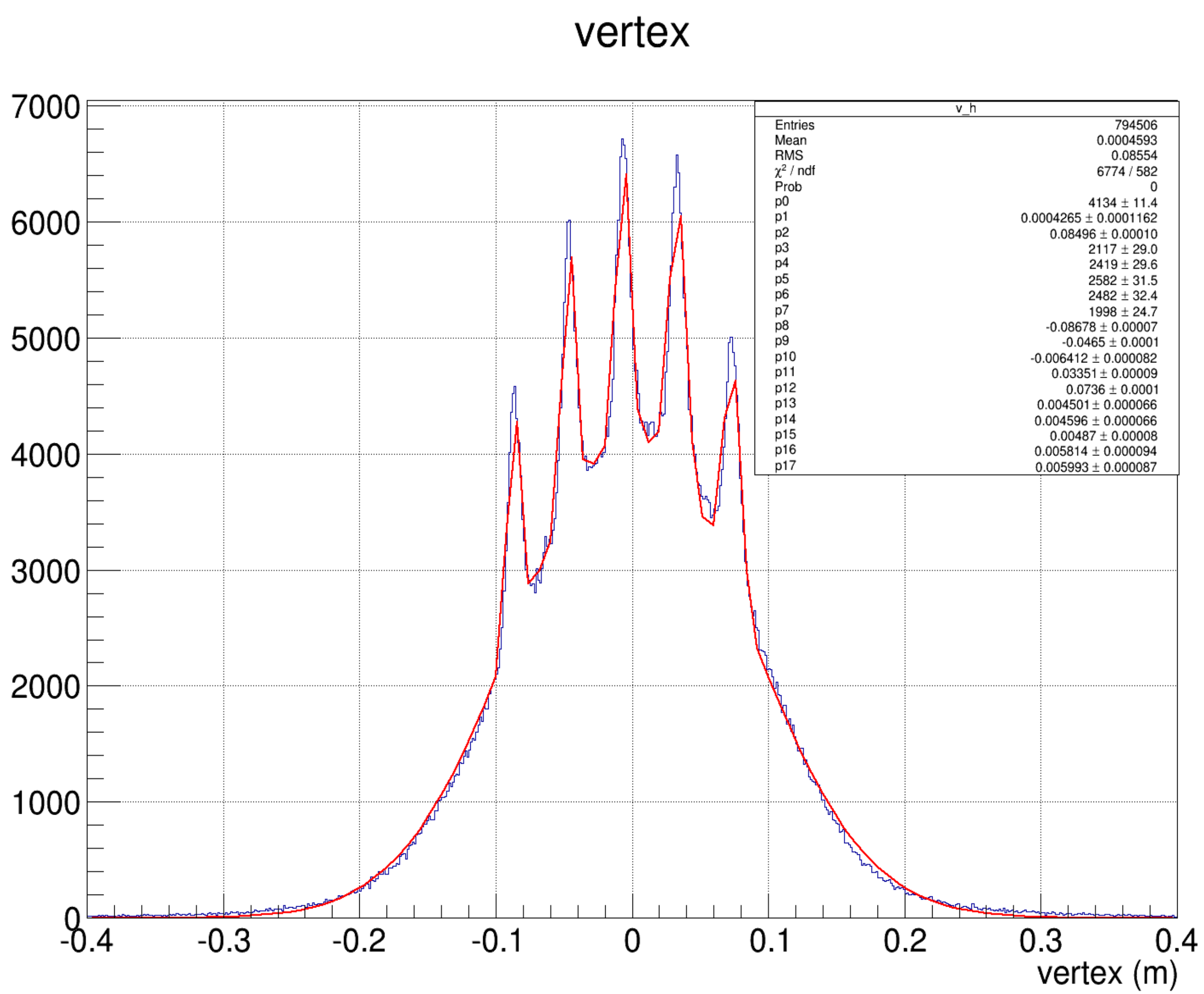
Outlook

- Spectrometer optics study (quadripole cannot reach maximum current, resolution loss, acceptance loss, issue for this spring).

Thank you for your attention !

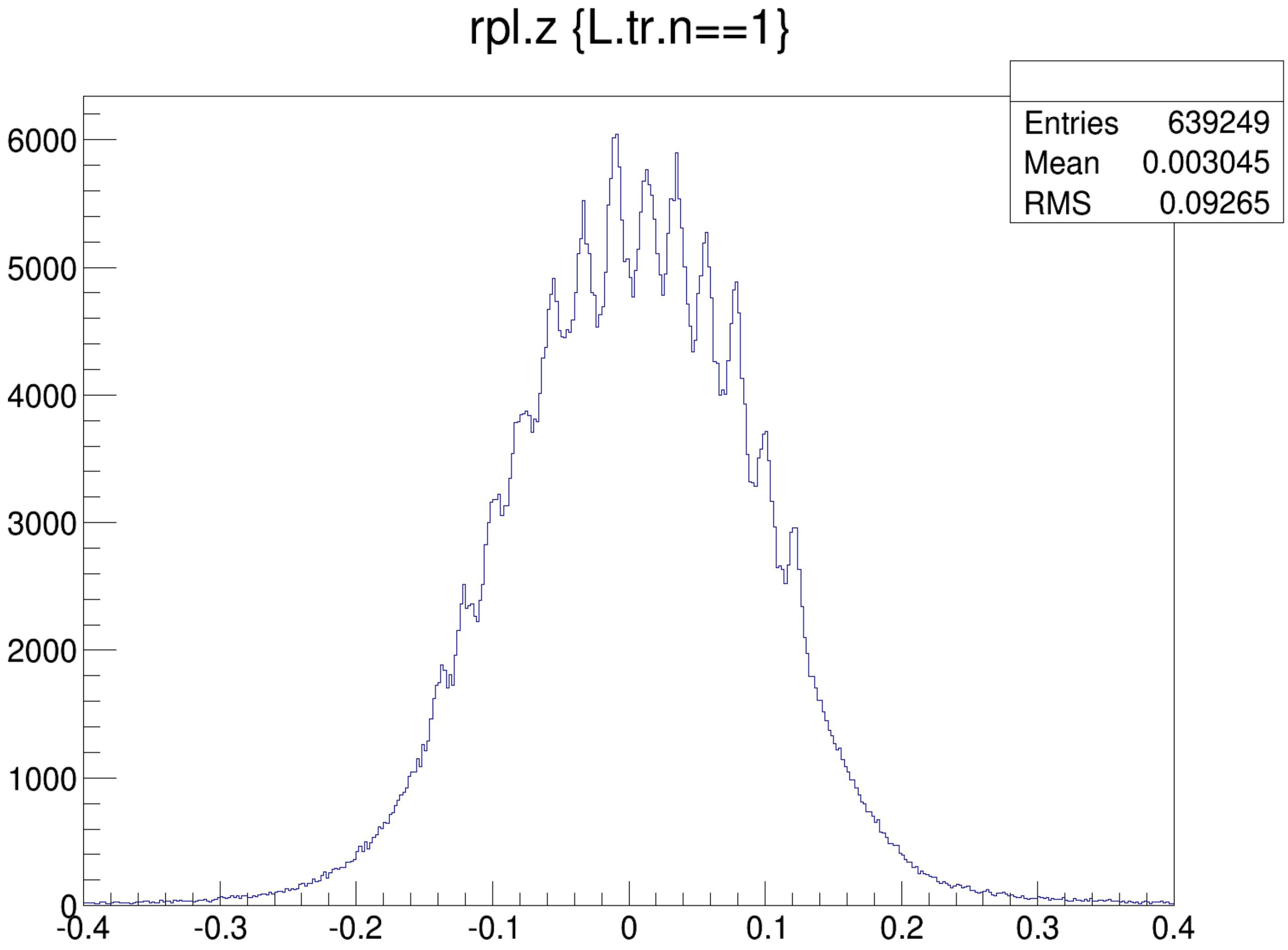
Addendum : HRS optics

HRS resolution



- Run LHRS 11352 (29 avril 2015) : Standard configuration

HRS resolution



- Run LHRS 11354 (29 avril 2015) : Q1 at 80%

HRS Acceptance

Cuts applied :

-0.15 < vertex < 0.15

number of traces = 1

-0.1 < theta < 0.08

-0.04 < phi < 0.04

-0.04 < dp < 0.04

Results :

Run 11352 ; N_hits = 606466 ; integrated charge (BCM u1) = 30570 uC ; N_hits/uC = 19.8386

Run 11354 ; N_hits = 475076 ; integrated charge (BCM u1) = 27040 uC ; N_hits/uC = 17.5694

→ 11.4% acceptance loss when Q1 at 80 %

Addendum : elastic run length estimation

Elastic run length estimation

$L = (Q * N_A * \rho * l) / (e * A_H)$ with : $Q = 10\ \mu C.s^{-1}$

$e = 1.602e^{-19}$ C
$N_A = 6.022e^{23}\ mol^{-1}$
$A_H = 1.0079\ g.mol^{-1}$
$\rho = 0.07229\ g.cm^{-3}$
$l = 13.5$ cm

$\Delta cos(\theta_{proton}) = 2\ (1-cos(\theta_{proton}))$ with : $\theta_{proton} = 28$ mr

$time = N / (L * \sigma_2 * \Delta cos(\theta))$ with : N = 10 000 events

σ_2 is a notation for $d\sigma/dcos(\theta_{proton})$