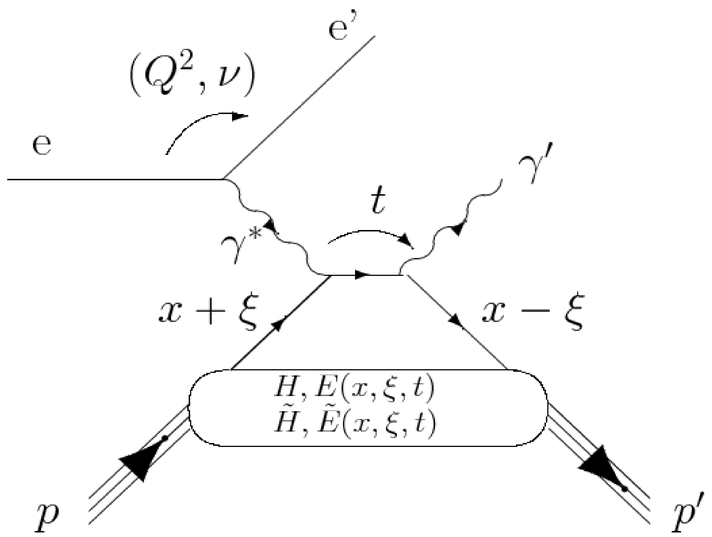
E07-007/E08-025: DVCS Experiment

Camille Desnault – Ph-D Student

DVCS Experiment (Data taking from October to December 2010)

DVCS Process :



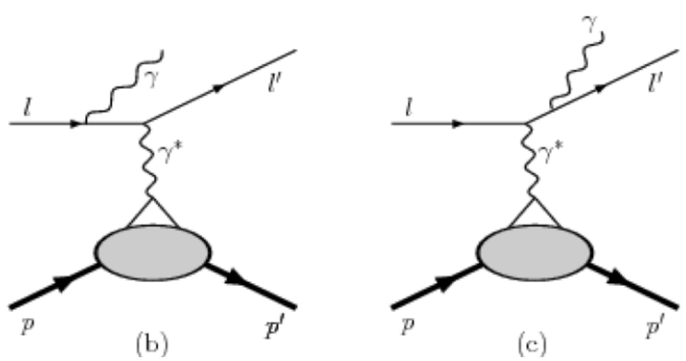
Handbag Diagram

<u>E07-007</u> : (LH2 target → Proton data)
Alejandro Marti **(all the kinematics)**

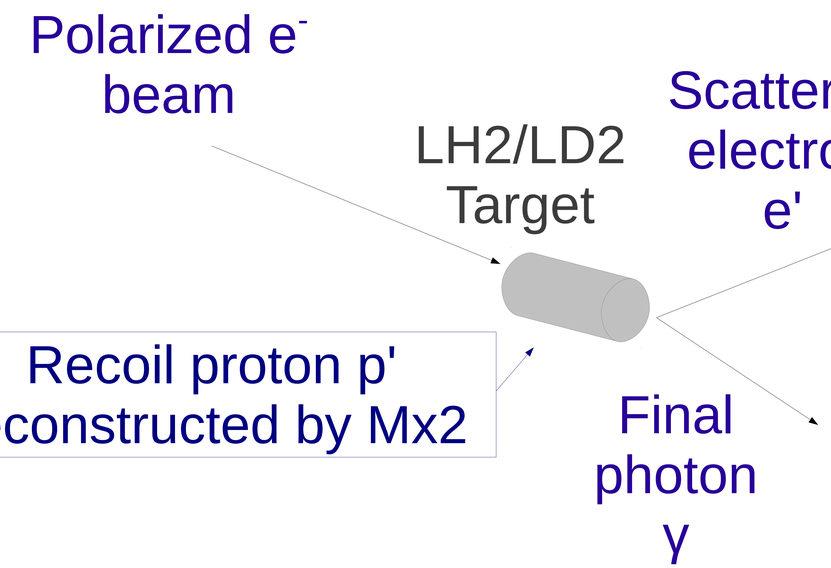
<u>E08-025</u> : (LH2/LD2 targets → Neutron data)
Meriem Ben Ali, Camille Desnault **(kin2 only)**

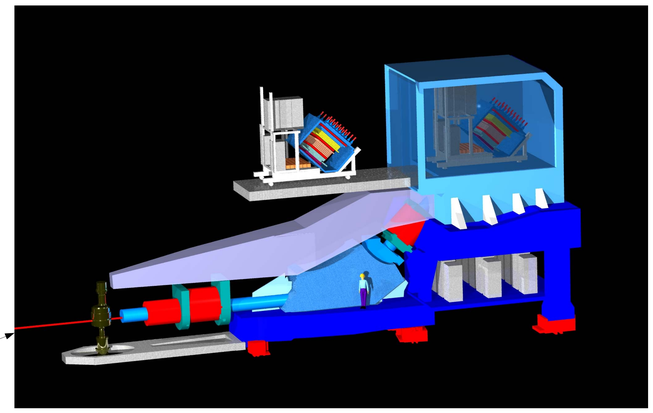
<u>π° electroproduction,</u>
<u>G4 simulation</u> :
Maxime Defurne

<u>G4 simulation</u> :
Rafayel Paremuzyan

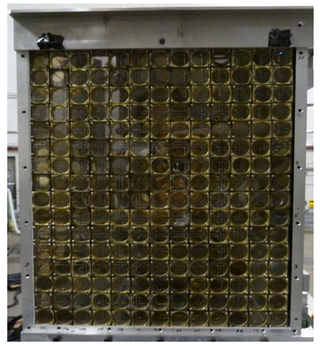


DVCS Setup :





High Resolution Spectrometer



Calorimeter PbF2 (Cerenkov)

	Kin 1		Kin 2		kin3	
Q^2(GeV^2)	1.5		1.75		2.0	
X_B	0.36		0.36		0.36	
E_{beam} (GeV^2)	3.36	5.55	4.45	5.55	4.45	5.55

<u>2 Beam energies for a Rosenbluth separation</u>

$$\sigma_1 = |BH|^2 + k_{1_{(Eb1)}} |DVCS|^2 + k'_{1_{(Eb1)}} Re(I)$$
$$\sigma_2 = |BH|^2 + k_{2_{(Eb2)}} |DVCS|^2 + k'_{2_{(Eb2)}} Re(I)$$

Data analysis

Maxime Defurne,
Hall A Collaboration Meeting
Friday 14 June 2013

Beam line
- Polarimetry (Compton + Moller) data (FINISHED), E. Fuchey
- Beam charge monitors (BCM) calibration (FINISHED), J. Roche

HRS
- Optics and mispointing checks (FINISHED), P. Bertin
- Drift chambers time offsets (FINISHED), C. Munoz
- Trigger/ detectors efficiency (FINISHED), M. Defurne, C. Hyde, M. Mazouz
- Normalization : DIS cross section (IN PROGRESS), M. Defurne

Calorimeter
- Calibrations (FINISHED), A. Marti, C. Desnault, M. Ben Ali
- Waveform analysis of PMT pulses (FINISHED), A. Marti
- Timing corrections (FINISHED), M. Mazouz

MC simulation
- GEANT4 written from scratch based on previous GEANT3 and their comparison, (FINISHED) R. Paremuzyan, M. Defurne

Physics analysis (IN PROGRESS)
- DVCS off proton, A. Marti
- DVCS off neutron, C. Desnault , M. Ben Ali
- $\pi 0$ electroproduction cross section, M. Defurne

Data analysis

Hall A Collaboration Meeting
Tuesday 17 December 2013

Beam line
- Polarimetry (Compton + Moller) data (FINISHED), E. Fuchey
- Beam charge monitors (BCM) calibration (FINISHED), J. Roche

HRS
- Optics and mispointing checks (FINISHED), P. Bertin
- Drift chambers time offsets (FINISHED), C. Munoz
- Trigger/ detectors efficiency (FINISHED), M. Defurne, C. Hyde, M. Mazouz
- Normalization : DIS cross section (FINISHED), M. Defurne

Calorimeter
- Calibrations (FINISHED), A. Marti, C. Desnault, M. Ben Ali
- Waveform analysis of PMT pulses (FINISHED), A. Marti
- Timing corrections (FINISHED), M. Mazouz

MC simulation
- GEANT4 written from scratch based on previous GEANT3 and their comparison, (FINISHED) R. Paremuzyan, M. Defurne

Physics analysis
- DVCS off proton (PRELIMINARY CROSS SECTION), A. Marti
- DVCS off neutron (FIRST DVCS NUMBER OF EVENTS), C. Desnault , M. Ben Ali
- $\pi 0$ electroproduction cross section (IN PROGRESS), M. Defurne

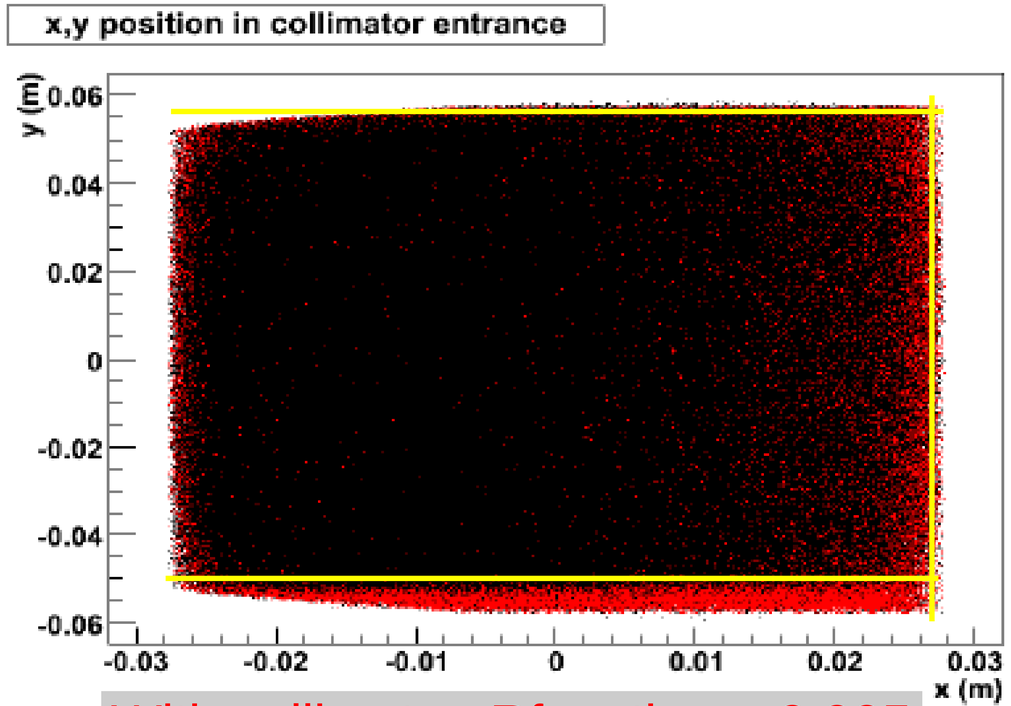
HRS Acceptance and Rfunction

HRS acceptance :

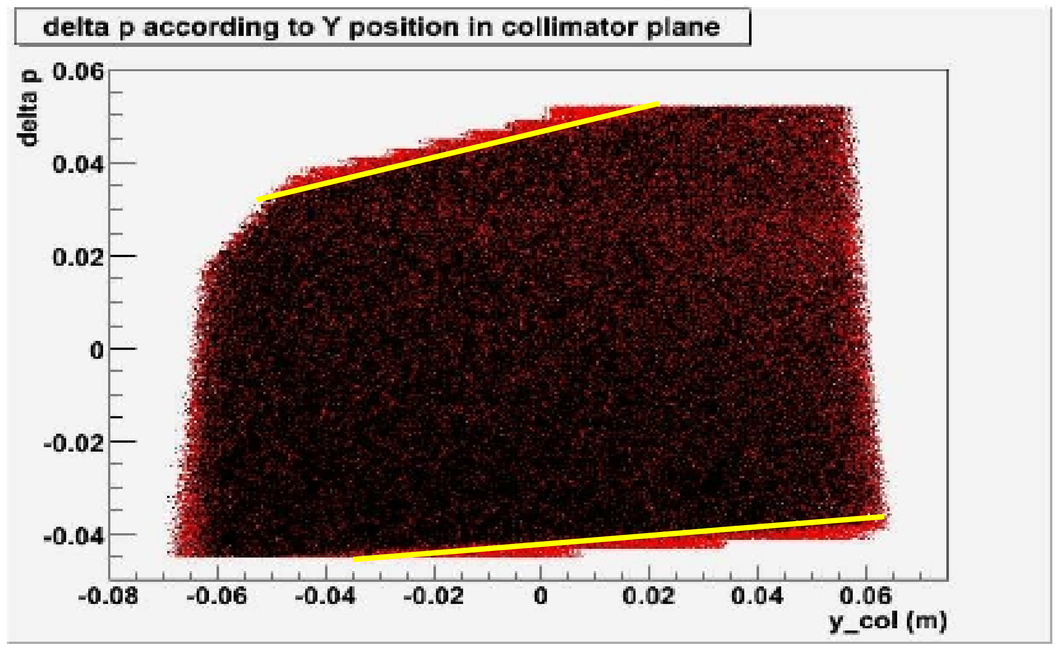
→ **Collimator** at the entrance of the HRS was **mis-located** (*left figure*).
→ **Rfunction** is calculated from the **HRS variables** (vertical angle θ, horizontal angle φ, difference in momentum dp/p, vertex) to determine its **acceptance**.
→ **Rfunction is not totally accurate** (*right figure*).

Black dots : data / Red dots : MC simulation

Defurne M.



With collimator, Rfunction > 0.005



Without collimator, Rfunction > 0.005

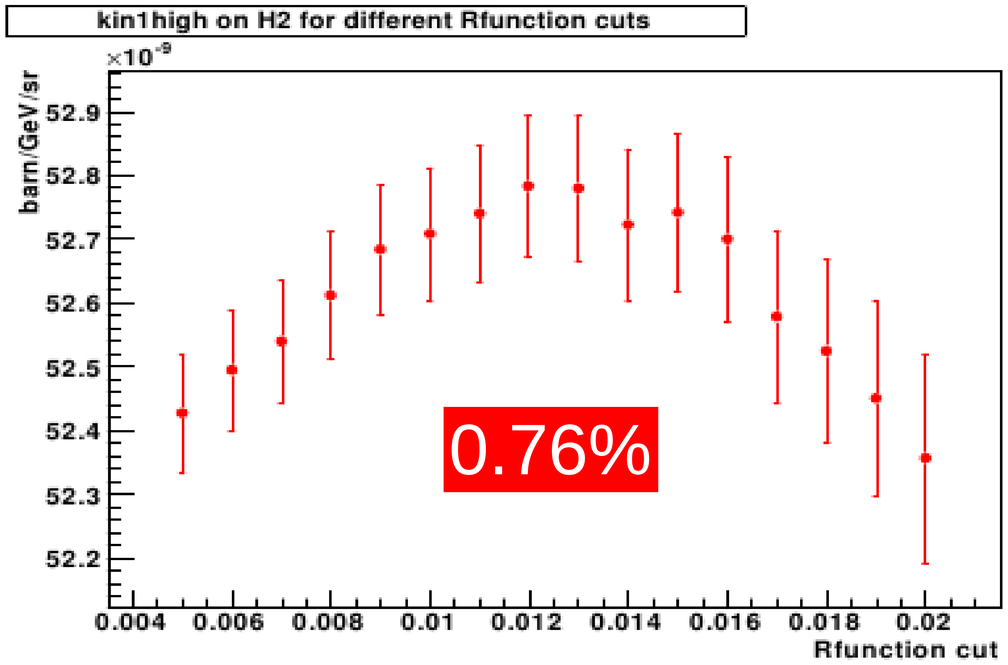
→ We will apply a **geometrical cut in the XY plane of the collimator**

→ We will apply a **cut in dp/p and Y direction of the HRS vertical plane**

DIS cross section results and cuts check

DIS cross-section :

Kinematic with collimator

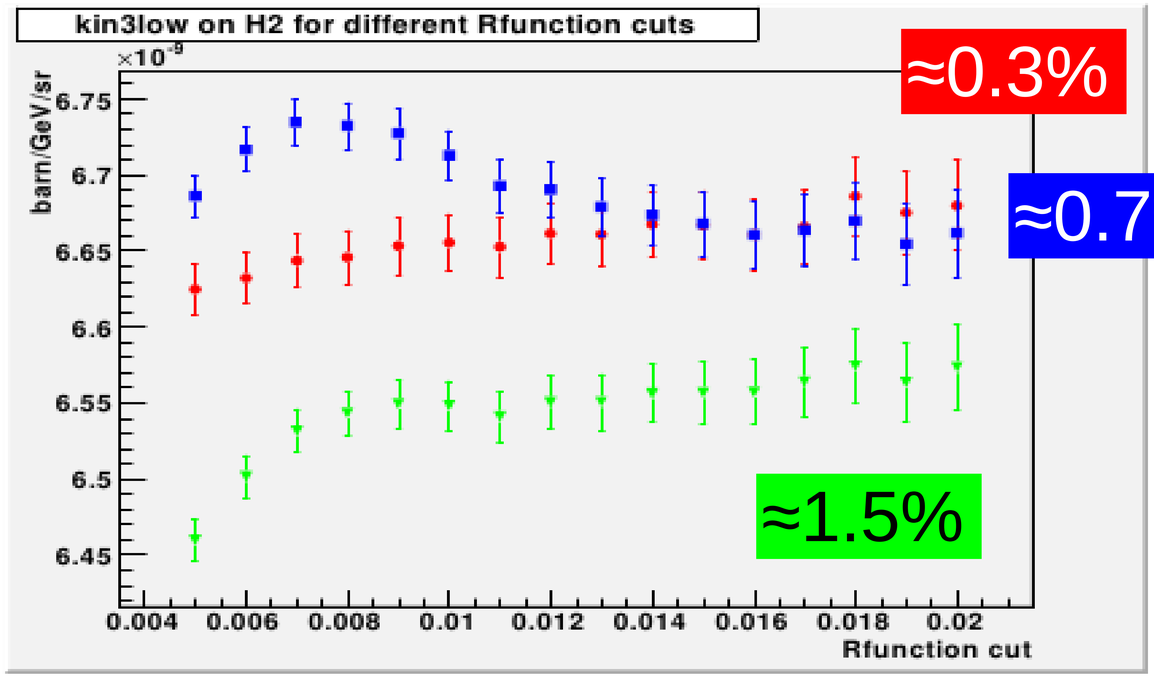


Defurne M.

Rfunction + XY + dp/p:Y

→ Variation of the DIS cross section with the Rfunction **lower than 1%**.

Kinematic without collimator



Rfunction

Rfunction + dp/p:Y

Rfunction + XY + dp/p:Y

→ Better **stabilization** of the DIS cross section with all the cuts.

DIS cross section results and normalization check

Check of the normalization and its stability in time by the DIS cross section results :

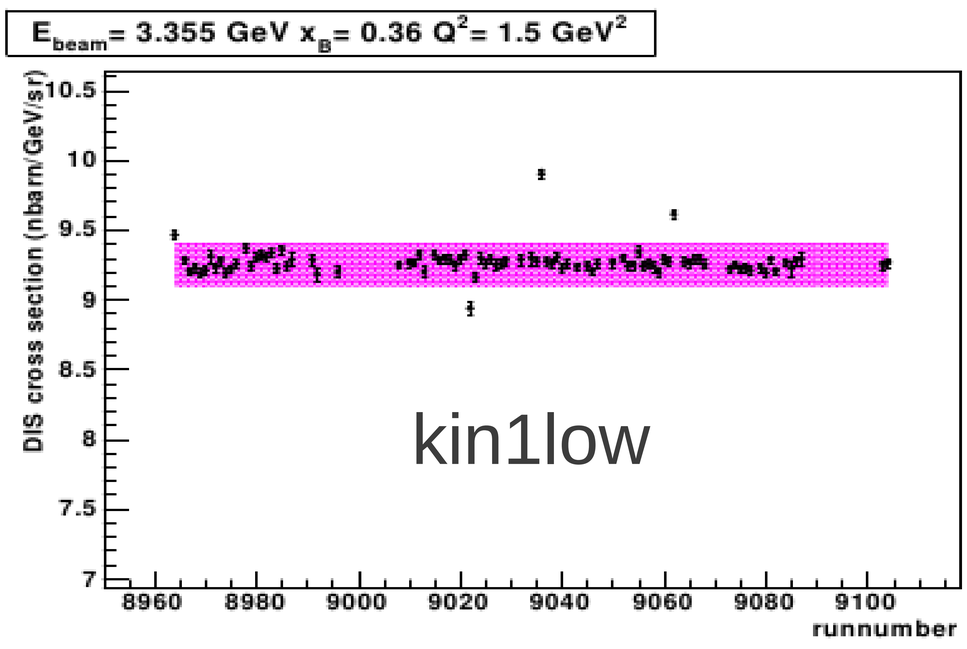
→ With a **comparison** between **our experimental DIS cross section** and a **theoretical DIS cross section** using a parametrization (*) , we can check :

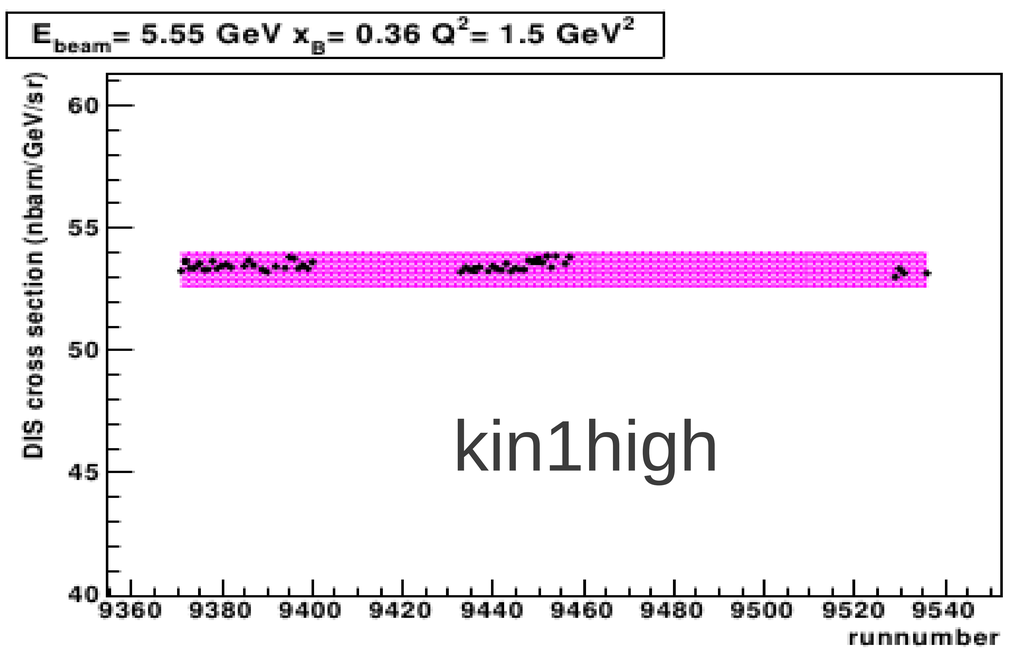
(*) Ingo Schienbein, Voica A. Radescu, G.P. Zeller, M. Eric Christy, C.E. Keppel, et al. A Review of Target Mass Corrections. *J.Phys.*, G35:053101, 2008.

1) The **reliability** of our normalization
2) The **stability in time** of our normalization on a whole kinematic.

Kinematics	$\frac{d\sigma^{TMC}}{d\Omega dE}$	$\frac{d\sigma^{TMC}_{exp}}{d\Omega dE}$	Relative difference (%)	Stability (%)
Kin1low	9	9.26	+2.8	1.6
Kin1high	55.2	53.3	-3.4	1.3
Kin2low	13.14	13.14	0	2
Kin2high	28.93	27.9	-3.4	1.3
Kin3low	6.6	6.9	+4.5	4
Kin3high	15.93	15.26	-4	2.2

Defurne M.





Contamination subtraction to the DVCS (ep → e'p'γ)

Raw data = DVCS + Accidentals + π° → **Contamination**

Raw data

1-cluster events (DVCS + π°)

2-clusters events (π° data)

π° random decays

Projection of the photons on the calorimeter surface

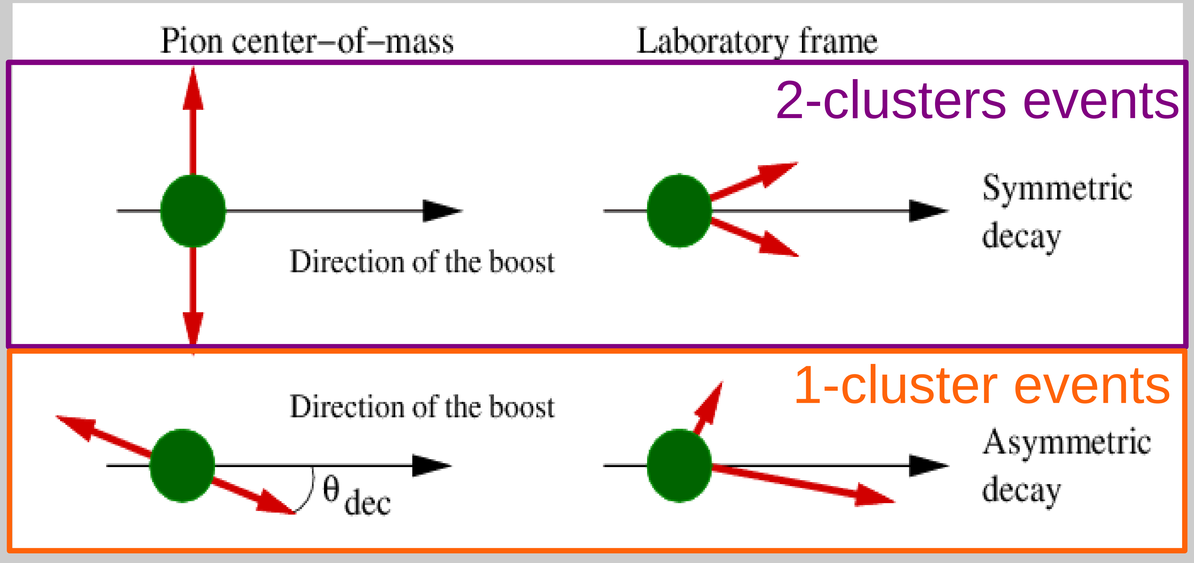
N0 : 0 cluster
N1 : 1 cluster
N2 : 2 clusters

1-cluster events (DVCS + π°)

−

N1 : 1 cluster

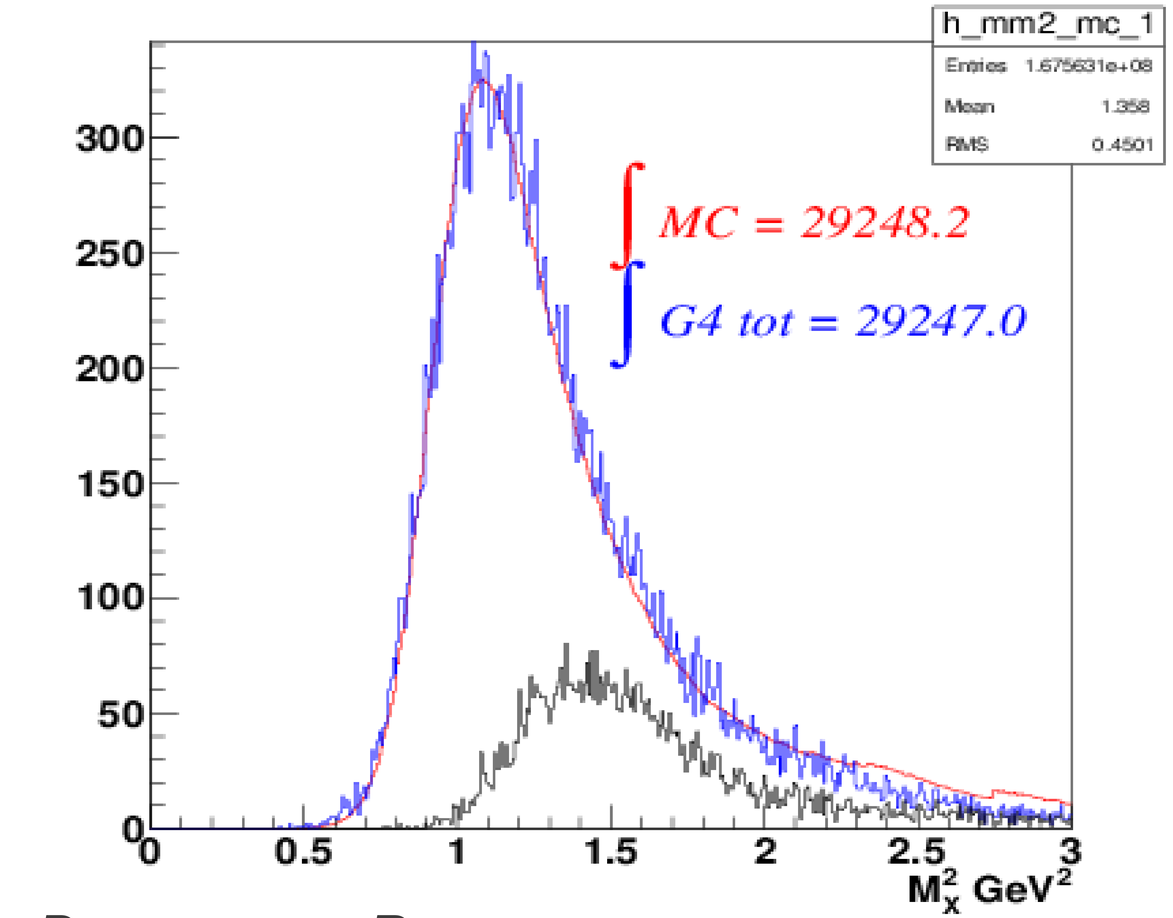
π°(ep → e'p'π° → e'p'γγ) :



Contamination when only **1 of the two photons from the π° decay** is detected by the calorimeter

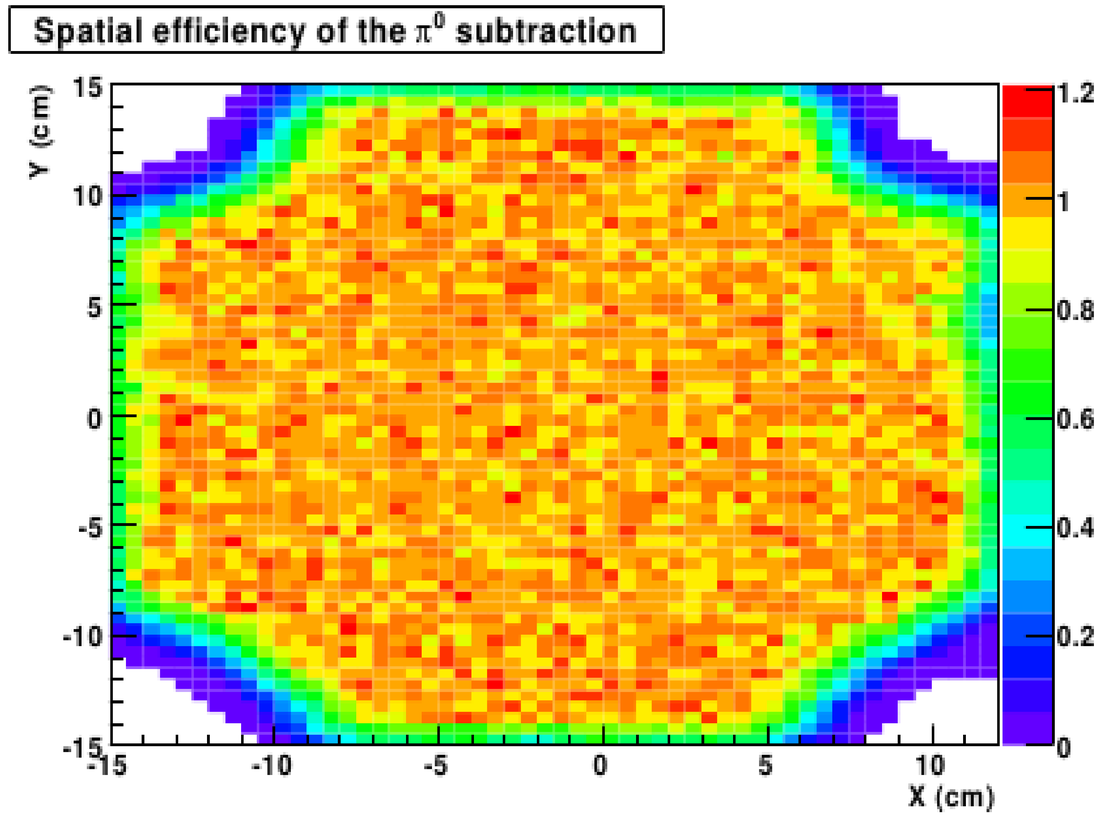
Test of exclusive π° subtraction method with G4 simulation

→ We check the **validity of the** π° subtraction method without any border effects by a G4 simulation.



Paremuzyan R.

→ We check the **validity of the π° subtraction method** by a ratio Nsubtracted/Nsimulated on the whole calorimeter surface.



Defurne M.

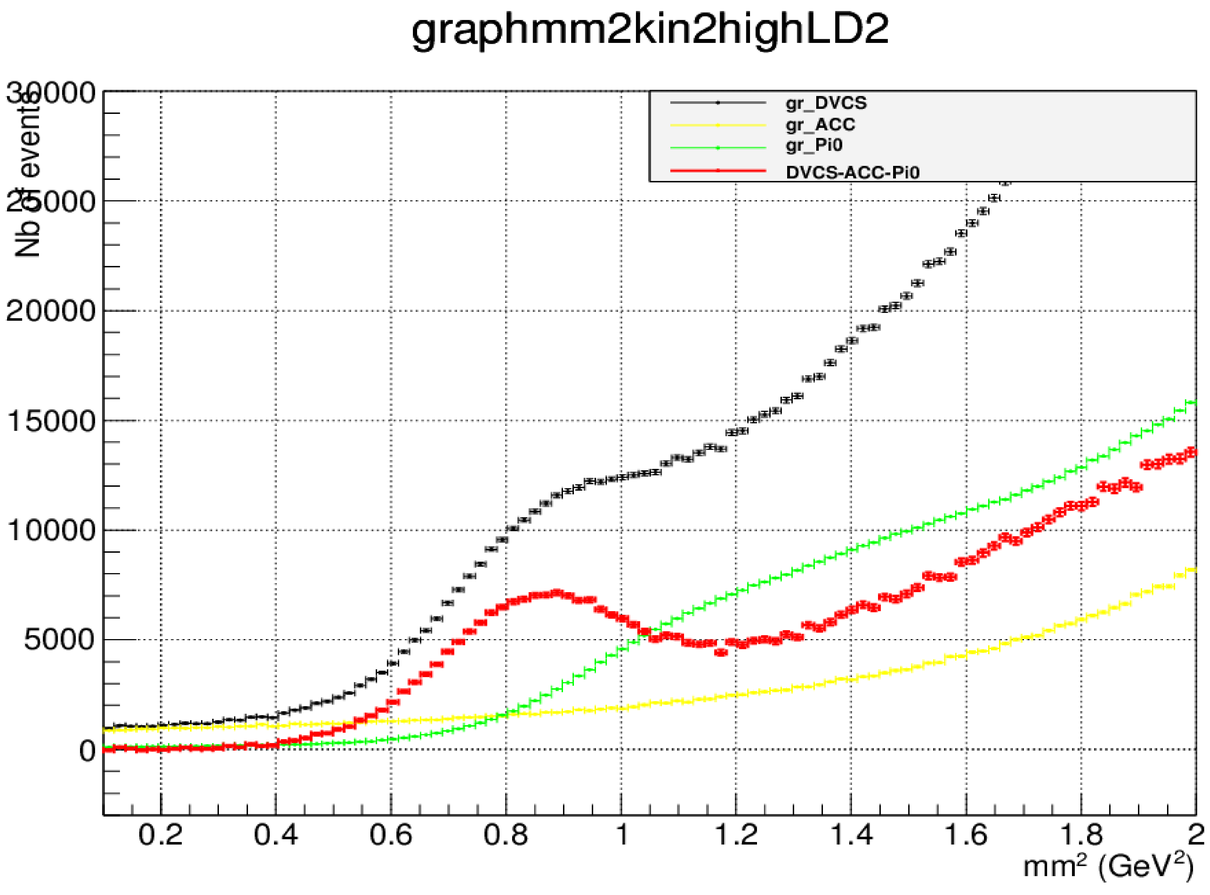
→ There is a **significant match** in the **central region** of the calorimeter between the simulation and the π° subtraction method (***left figure***) but **not in the edges** of the calorimeter (***right figure***).

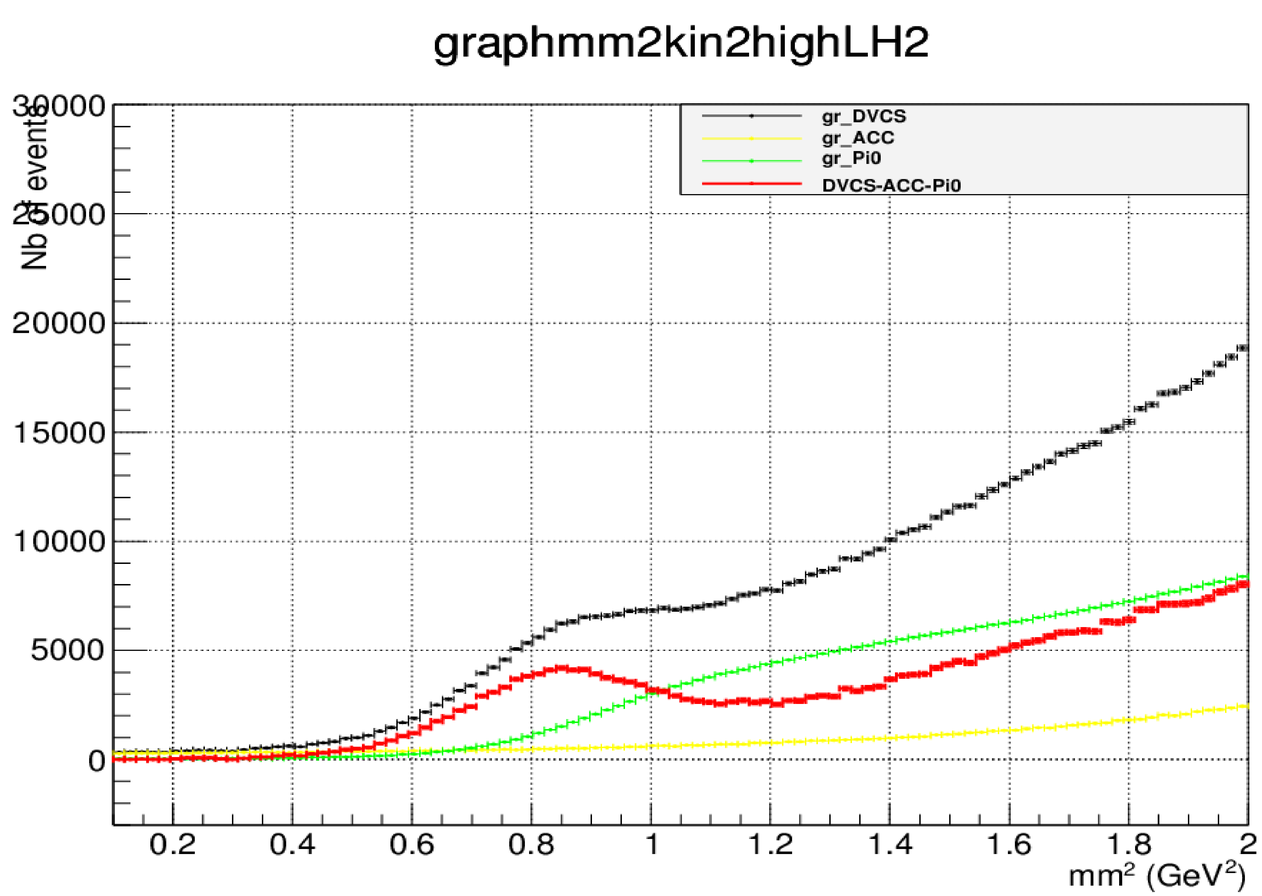
We need to apply a cut on the edges of the calorimeter

Contamination subtraction : Example with the neutron data

Raw data = DVCS + Accidentals + π°

We subtract the contamination from the raw data to get only the DVCS events



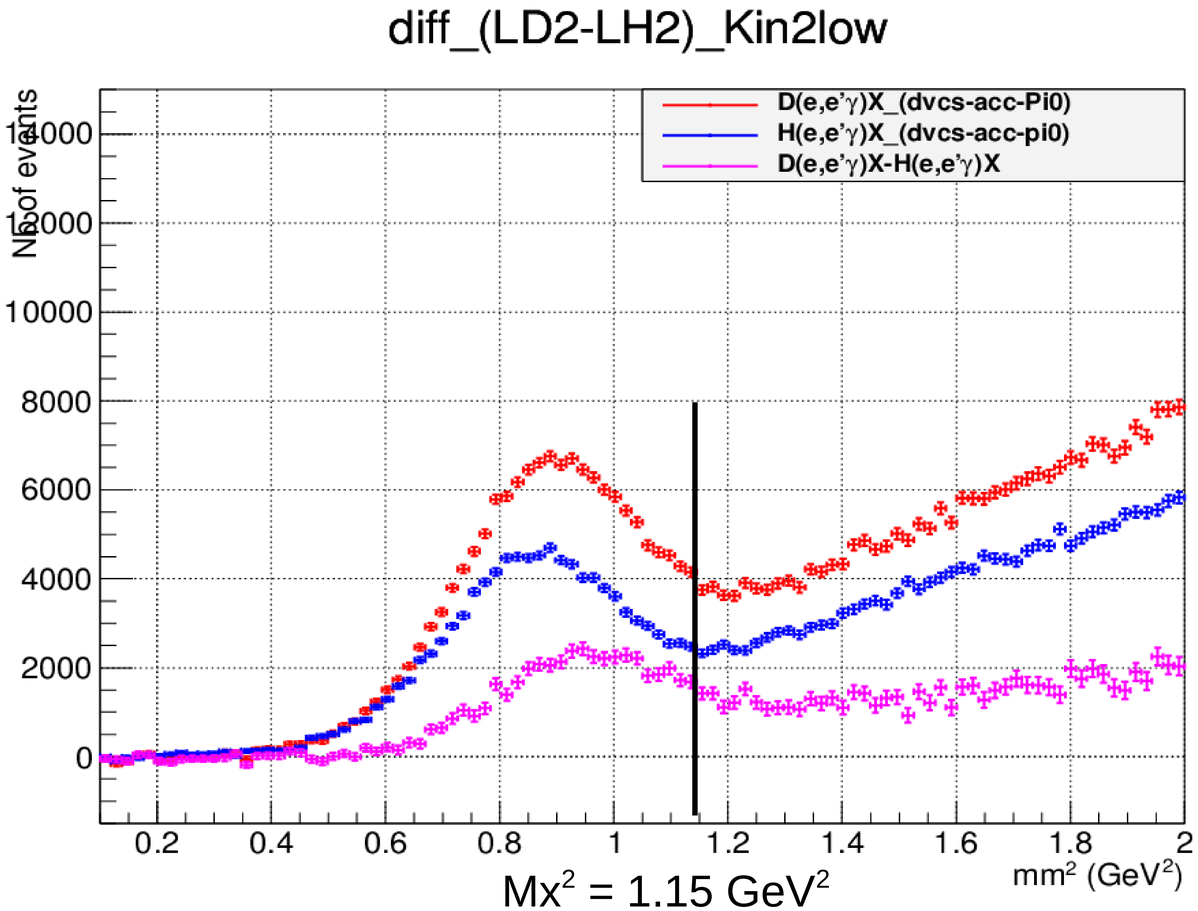


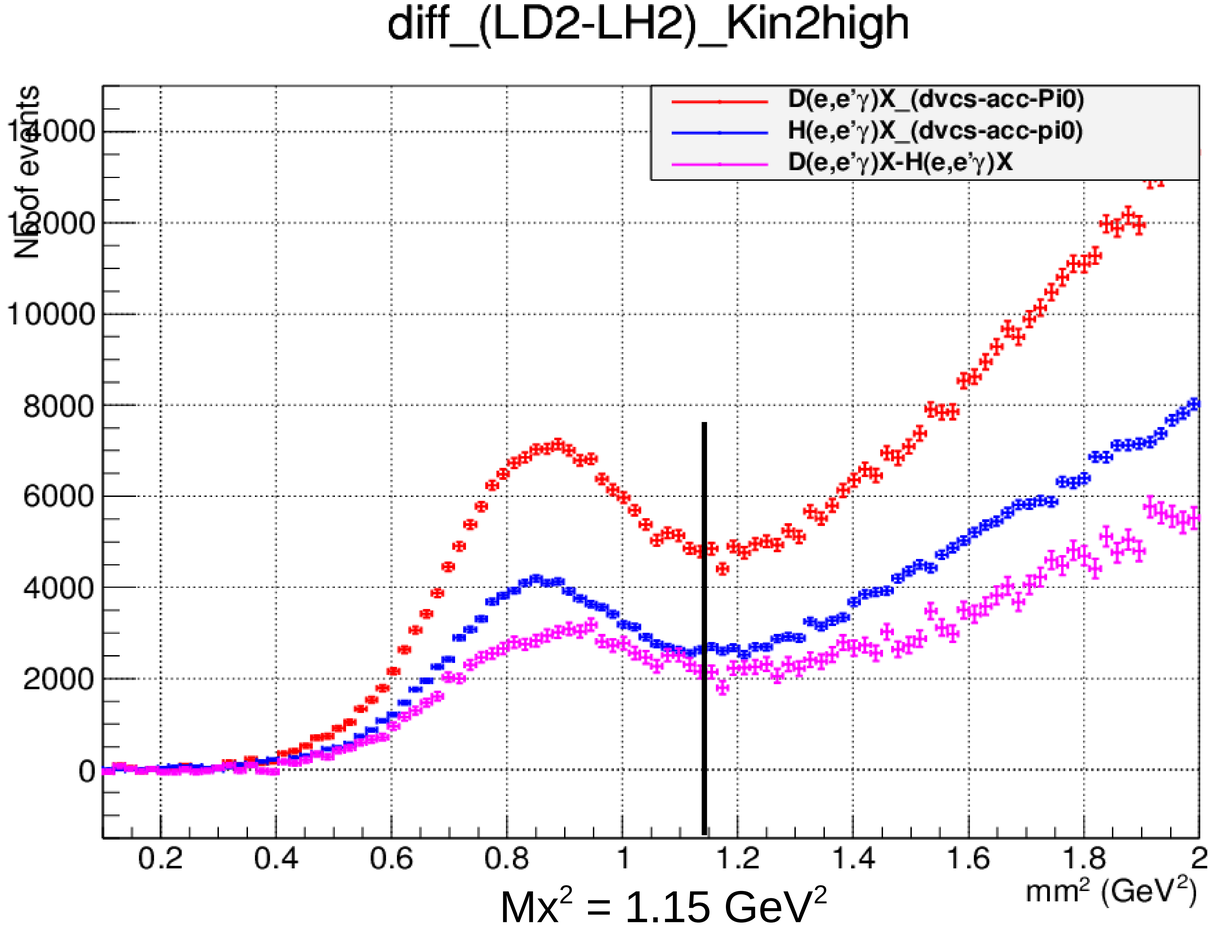
Ben Ali M.

LD2/LH2 Targets data subtraction to get neutron data

$$\text{DVCS } \mathbf{neutron} = \text{DVCS}_{\text{LD2-target}}\ (\mathbf{p+n}) - \text{DVCS}_{\text{LH2-target}}\ (\mathbf{p})$$

→ **Normalization** required for the targets subtraction by the **charge of each run**
→ Addition the **fermi motion** to the LH2's proton initially **at rest**

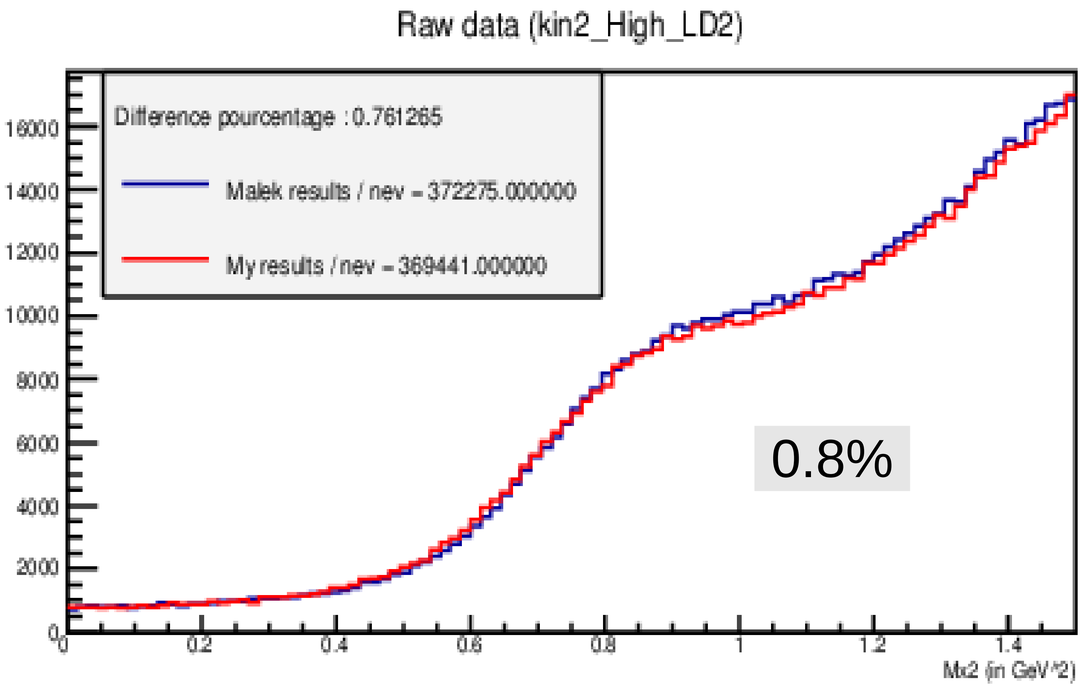


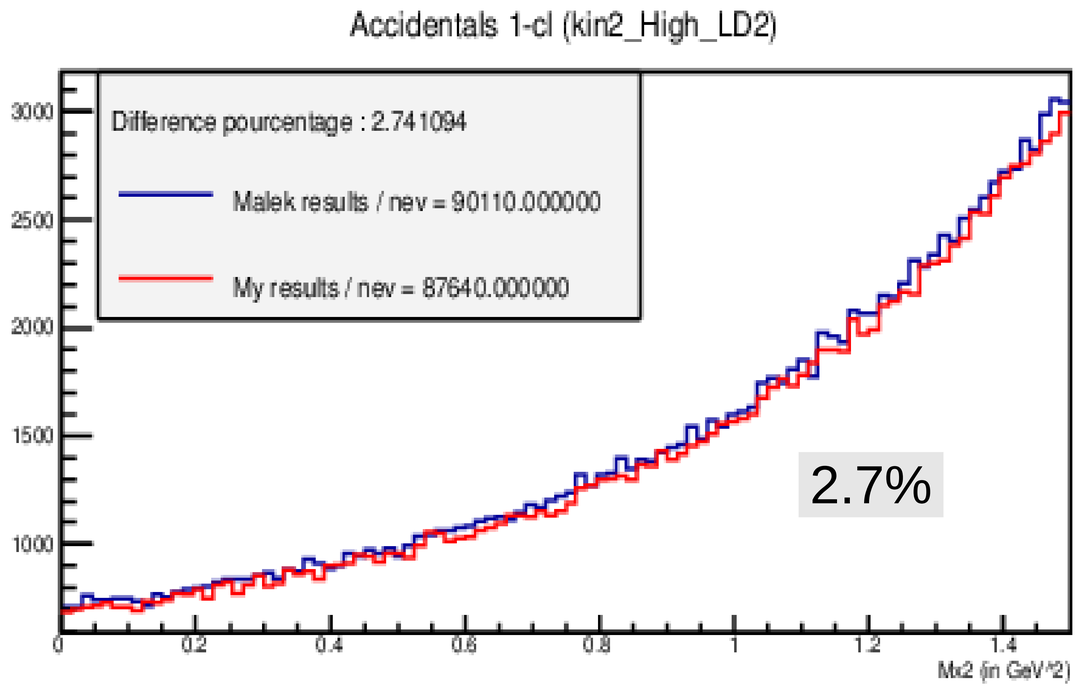


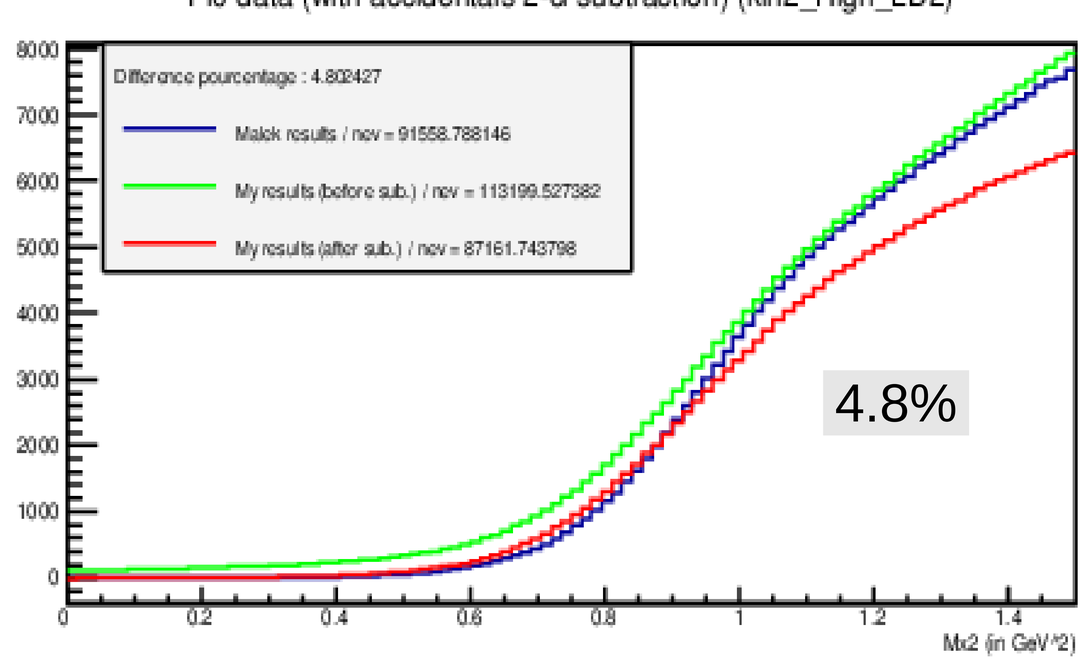
Ben Ali M.

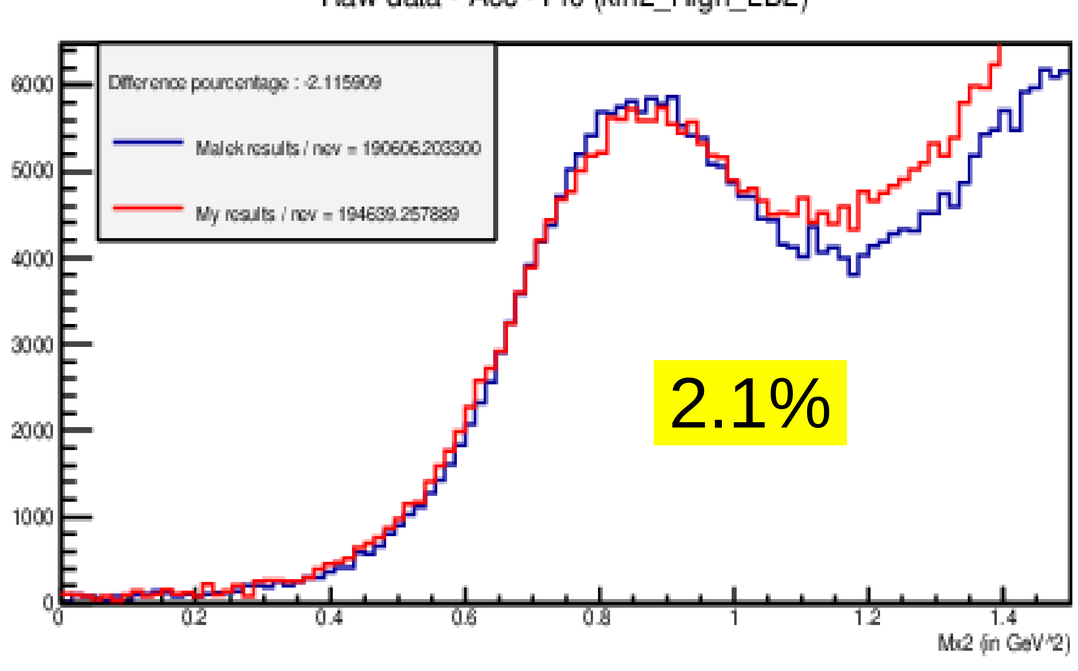
Comparison of 2 parallel analysis for the contamination subtraction :
Example with the neutron data

LD2 Target : M. Ben Ali results (blue) / My results (red)



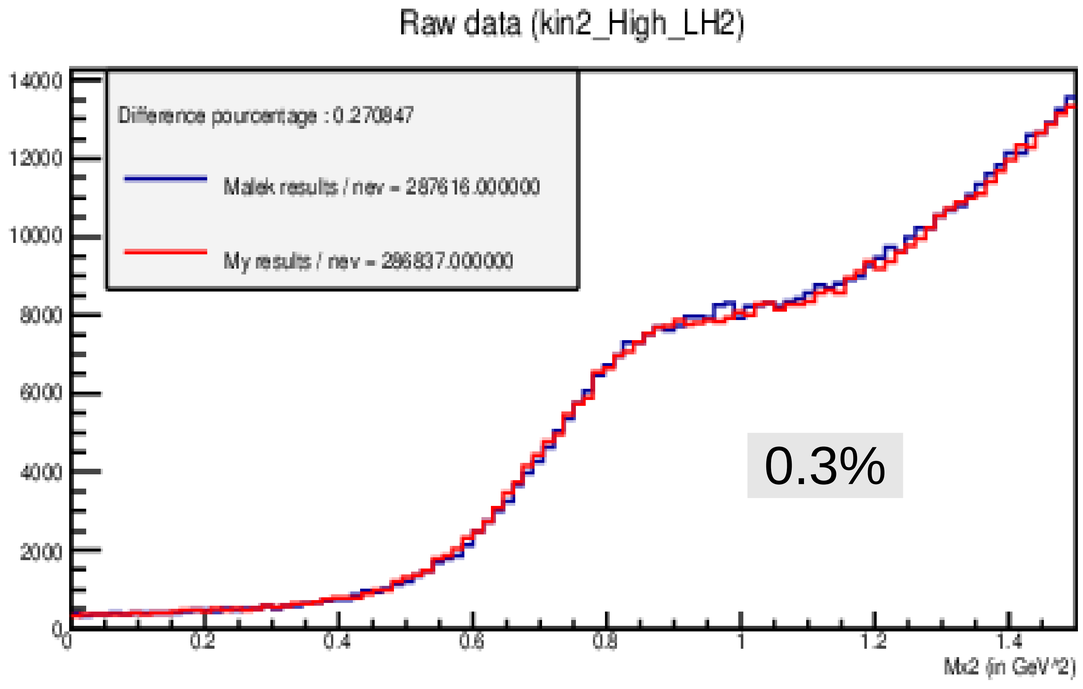


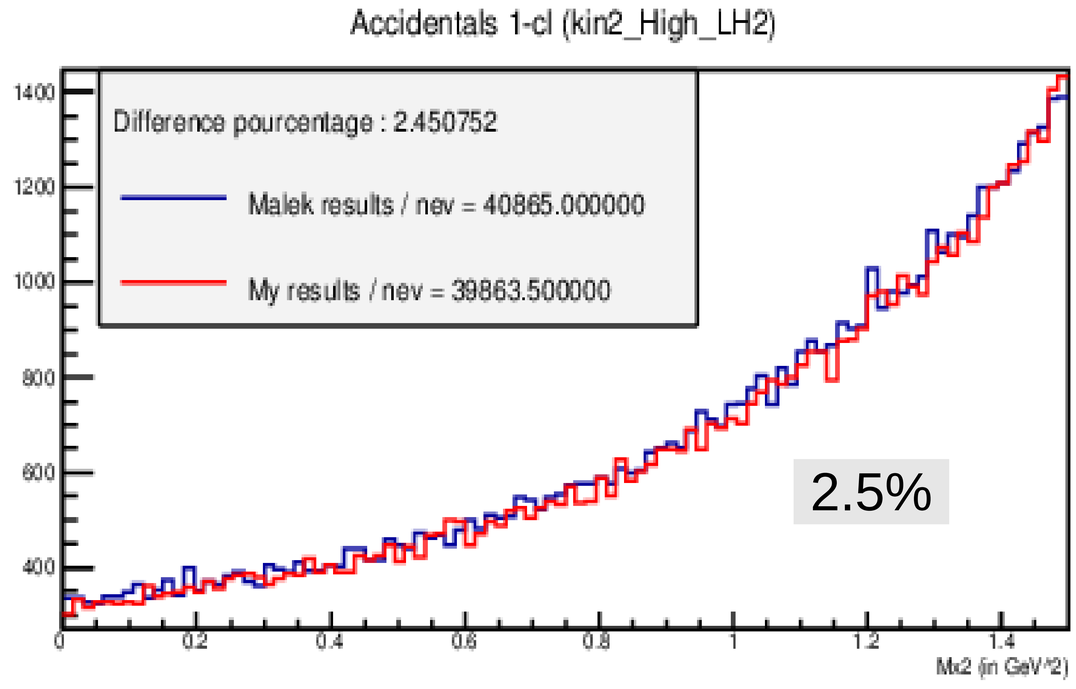


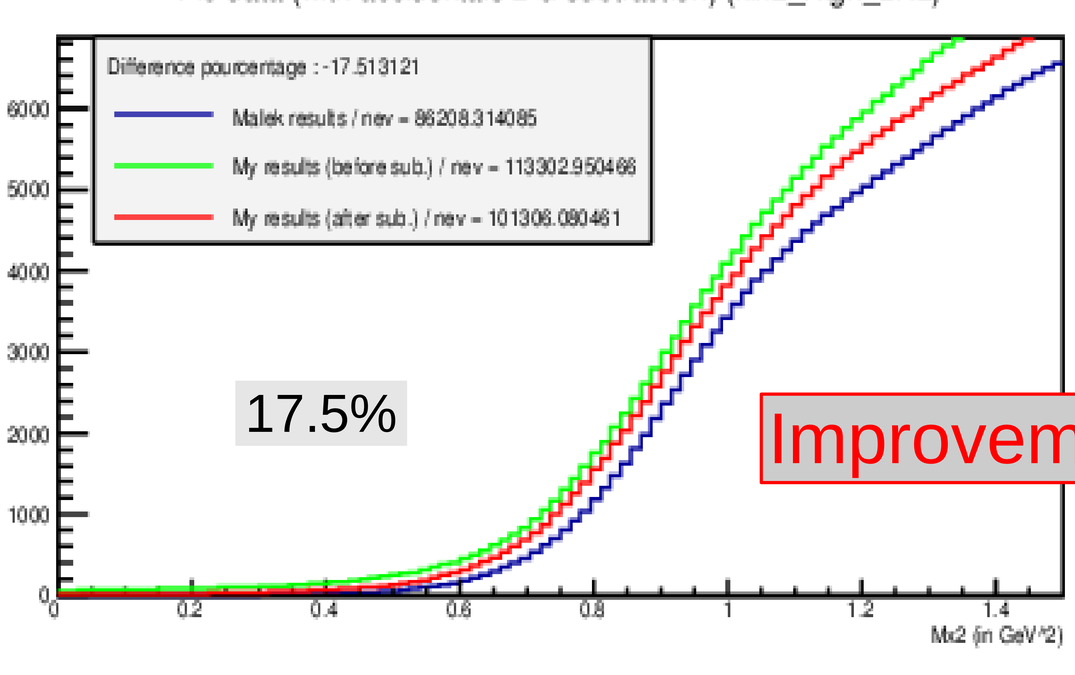


Comparison of 2 parallel analysis for the contamination subtraction :
Example with the neutron data

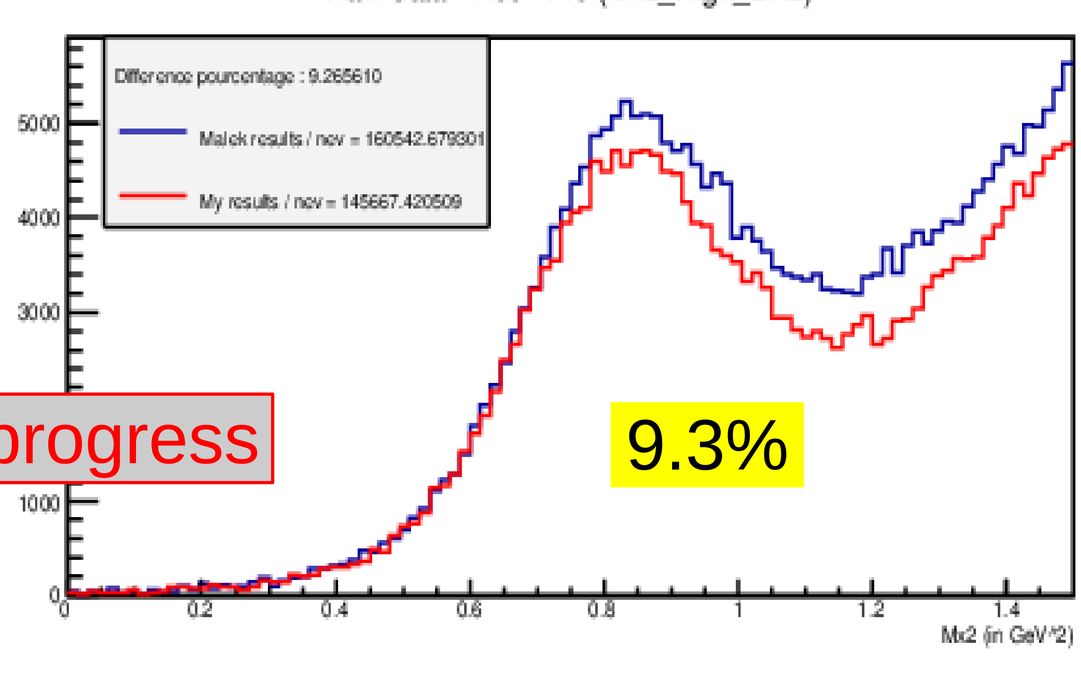
LH2 Target (with fermi motion) : M. Ben Ali results (blue) / My results (red)







Improvement in progress

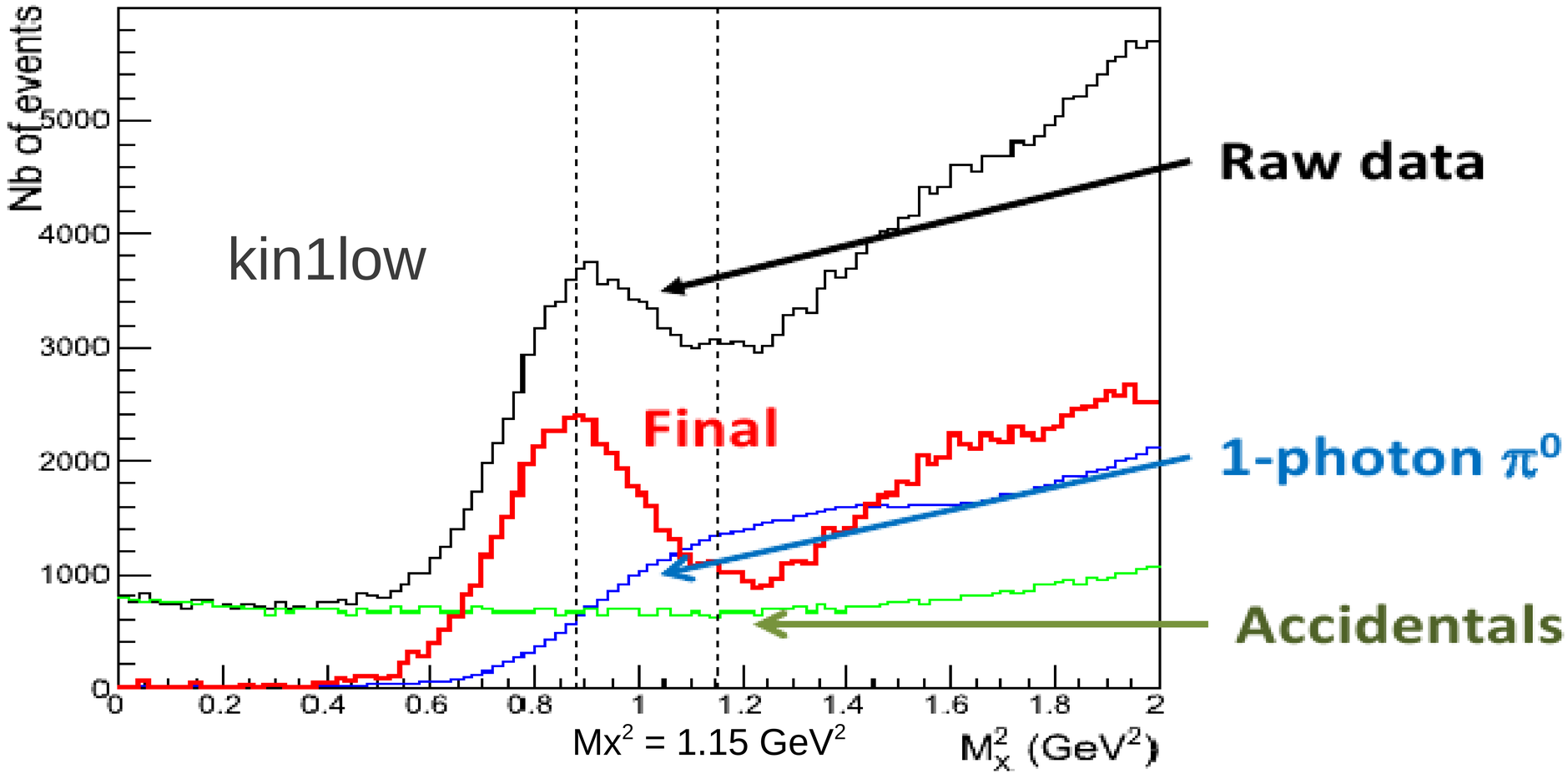


First DVCS proton cross-section

Cross section obtained according to the t and $\varphi_{\gamma\gamma^*}$ bins :

→ t proportional to $\theta_{\gamma\gamma^*}$ (polar angle between the final photon γ and the virtual photon γ*)

→ $\varphi_{\gamma\gamma^*}$ (azimutal angle between γ and γ*)



Marti A.

First DVCS proton cross-section

Photon electroproduction helicity-independent cross section :

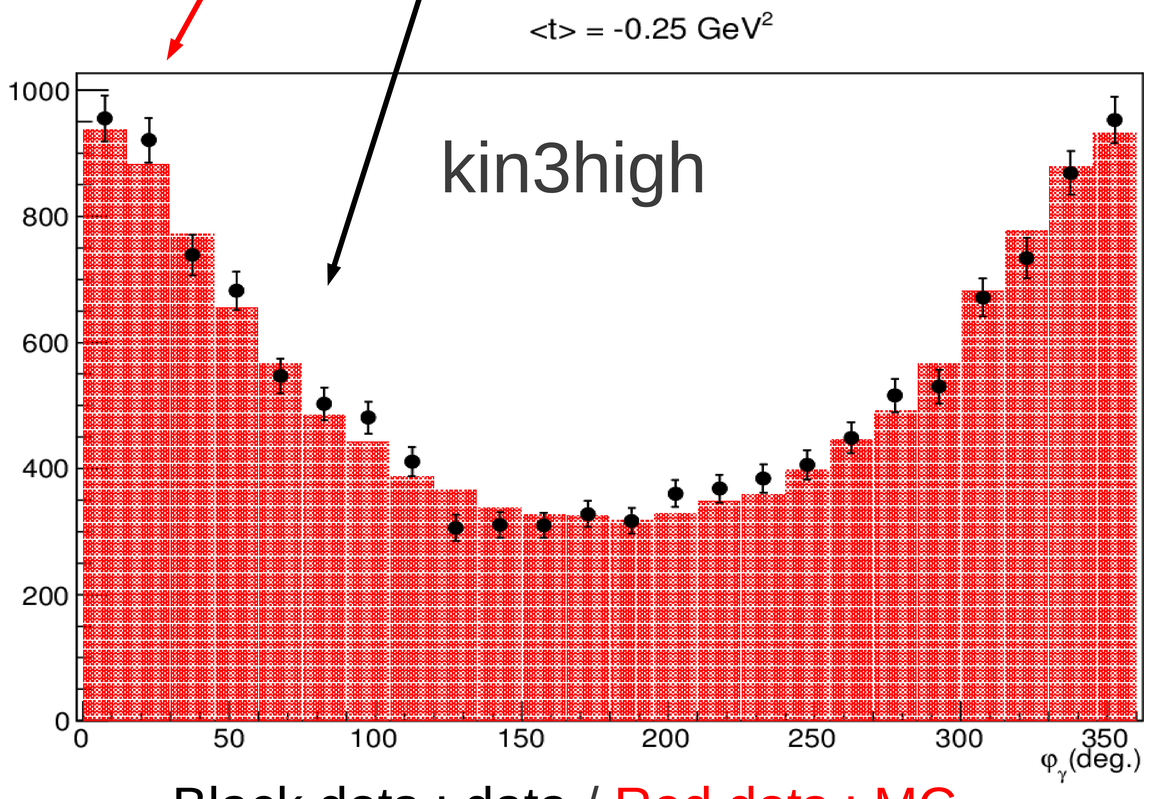
$$\frac{d^4\sigma}{dx\,d|\Delta^2|\,d\phi\,dQ^2} = \Gamma^G|\mathcal{T}_{BH}|^2 + \Gamma^1\mathcal{C}^{\mathcal{I}}_{unp}(\mathcal{F}) + \Gamma^2\Delta\mathcal{C}^{\mathcal{I}}_{unp}(\mathcal{F}) + \Gamma^3\mathcal{C}^{\mathcal{I}}_{unp}(\mathcal{F}^{eff})$$

Γ^i : kinematic factors (calculable in experimental setup simulation)

C^i ($= C^I, \Delta C^I, C^I_{eff}$) : Compton Form Factors obtained by fit on the data

$$\chi^2 = \frac{\left(N^{MC} - N^{Exp}\right)^2}{\sigma^2} \rightarrow N^{MC} = \int \frac{d\sigma}{d\Omega} d\Omega = \sum_{i=1}^{3} \left(\int \Gamma^i d\Omega\right) C^i$$

$$\frac{\delta\chi^2}{\delta C^i} = 0 \rightarrow \left\{ \begin{matrix} C^I \\ \Delta C^I \\ C^I_{eff} \end{matrix} \right\}$$



Black dots : data / Red dots : MC

Marti A.

To be continued ...

→ All the calibrations are finished.

→ The only remaining work is the data analysis :

→Improvement of the **cross check for the contamination subtraction** concerning the LH2 target.

→Final **DVCS off the proton cross section** very soon !!

→Extraction of the **DVCS off the neutron cross section** in 2014

→Extraction of the **π° electroproduction cross section** in 2014

Back up

DIS cross section results and normalization check

<u>Check of the normalization and its stability in time by the DIS cross section results</u> :

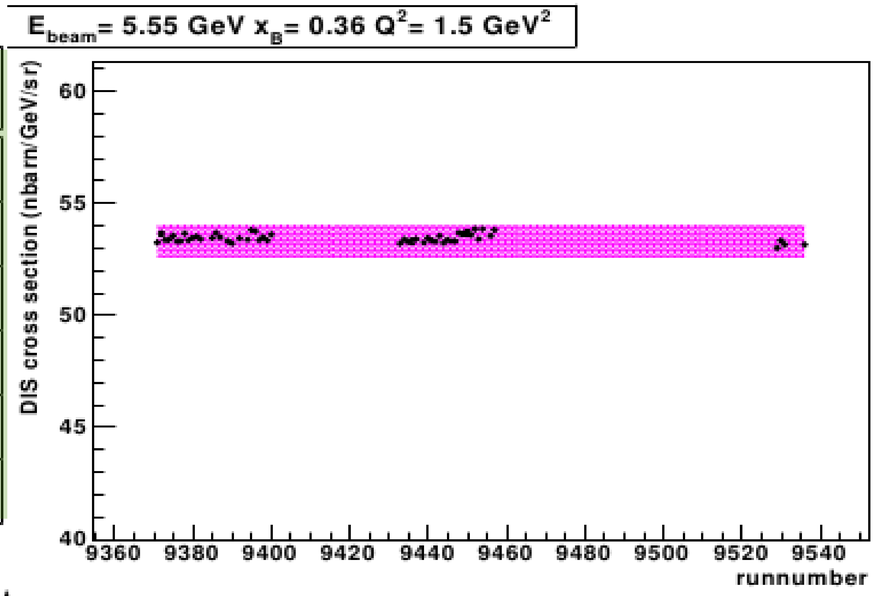
→ Only the detection of the **scattered electron in the HRS** occurs for the **DIS Process** .

→ **DIS cross section is related to the beam, acquisition electronics and HRS adjustments** (Luminosity/Charge of the beam, Dead Time of the acquisition system, HRS efficiency, HRS acceptance...) .

→ With a **comparison** between **our experimental DIS cross section** and a **theoretical DIS cross section** using a parametrization (*) , we can check :

1) The **reliability** of our normalization
2) The **stability in time** of our normalization on a whole kinematic.

Kinematics	$\frac{d\sigma^{TMC}}{d\Omega dE}$	$\frac{d\sigma^{TMC}_{exp}}{d\Omega dE}$	Relative difference (%)	Stability (%)
Kin1low	9	9.26	+2.8	1.6
Kin1high	55.2	53.3	-3.4	1.3
Kin2low	13.14	13.14	0	2
Kin2high	28.93	27.9	-3.4	1.3
Kin3low	6.6	6.9	+4.5	4
Kin3high	15.93	15.26	-4	2.2



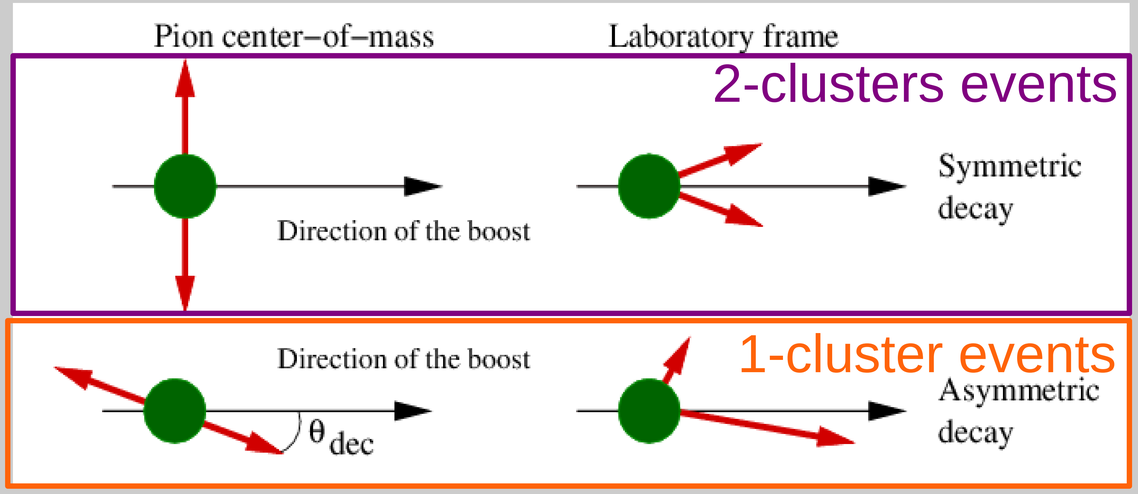
(*) Ingo Schienbein, Voica A. Radescu, G.P. Zeller, M. Eric Christy, C.E. Keppel, et al. A Review of Target Mass Corrections. *J.Phys.*, G35:053101, 2008.

Defurne M.

Contamination subtraction to the DVCS (ep → e'p'γ)

Raw data = DVCS + Accidentals + π° → **Contamination**

π°(ep → e'p'π° → e'p'γγ) :



Contamination when only **1 of the two photons from the π° decay** is detected by the calorimeter

Raw data

1-cluster events (DVCS + π°)

2-clusters events (π° data)

2000 π° random decays

N0 : 0 cluster
N1 : 1 cluster
N2 : 2 clusters

N1 : 1 cluster

1-cluster events (DVCS + π°)

Accidentals :

→ photons **not related to the trigger electron** are detected in the acquisition window (= not coming from the vertex)
→ **Uniform contamination in the time**

We **shift in time** the acquisition window to take **only accidentals events**

Test of exclusive π° subtraction method with G4 simulation

G4 π° generated

G4 1-cluster events | **G4 2-clusters events**

Black curve
1 cluster outside the fiducial region

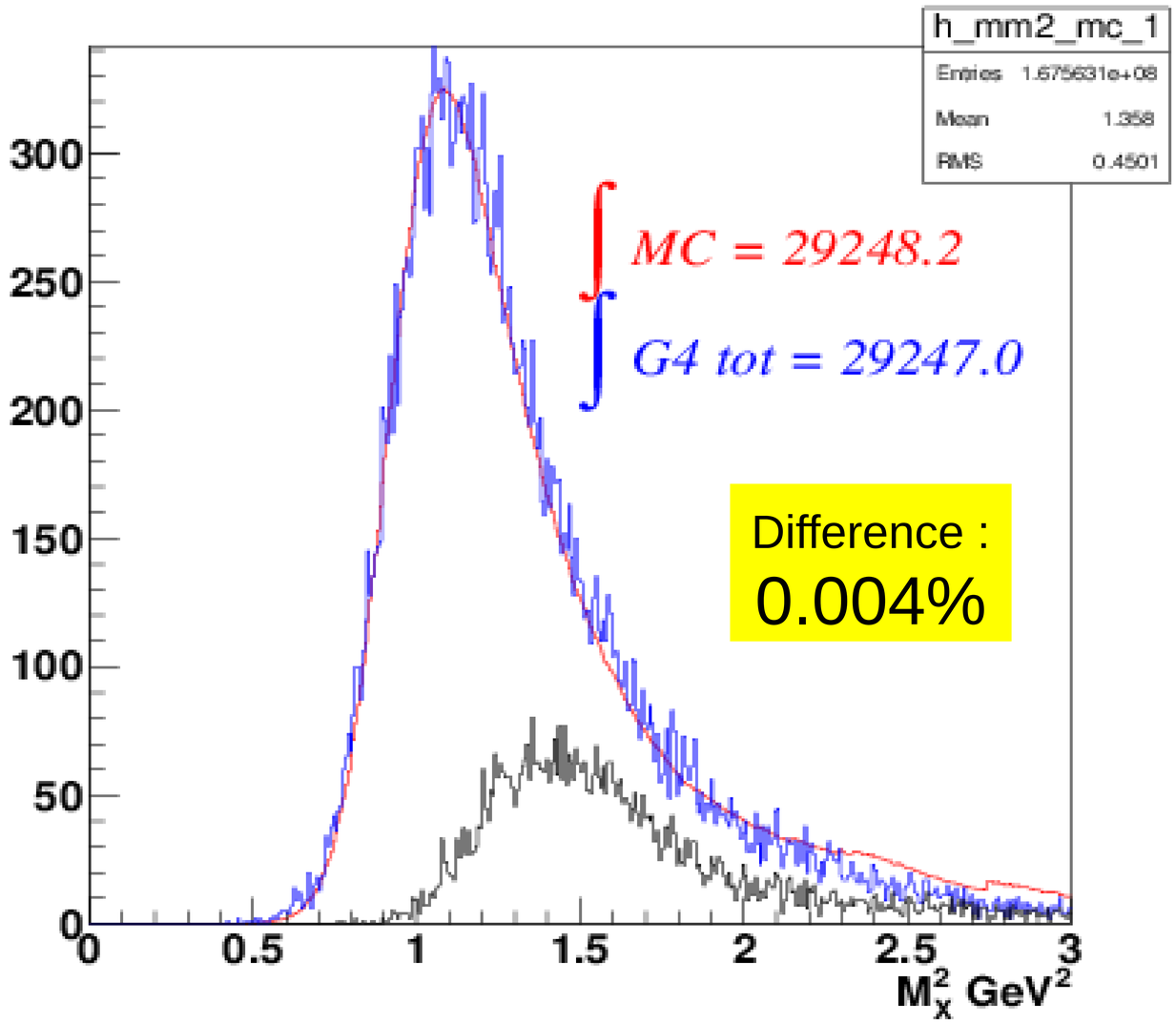
2 clusters in fiducial region

MonteCarlo

Blue curve
1 cluster events + black curve

Red curve
MC 1 cluster events

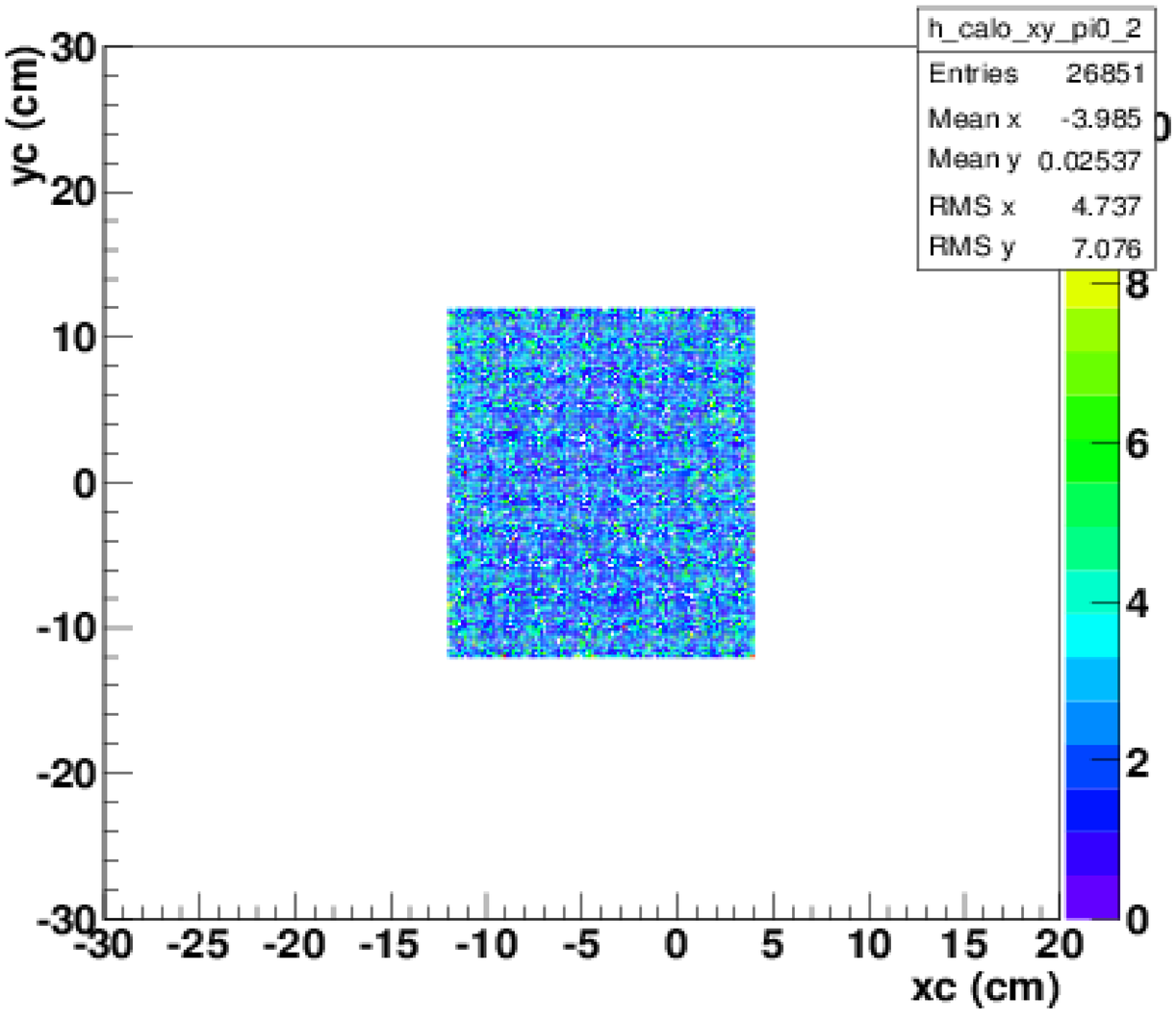
Paremuzyan R.

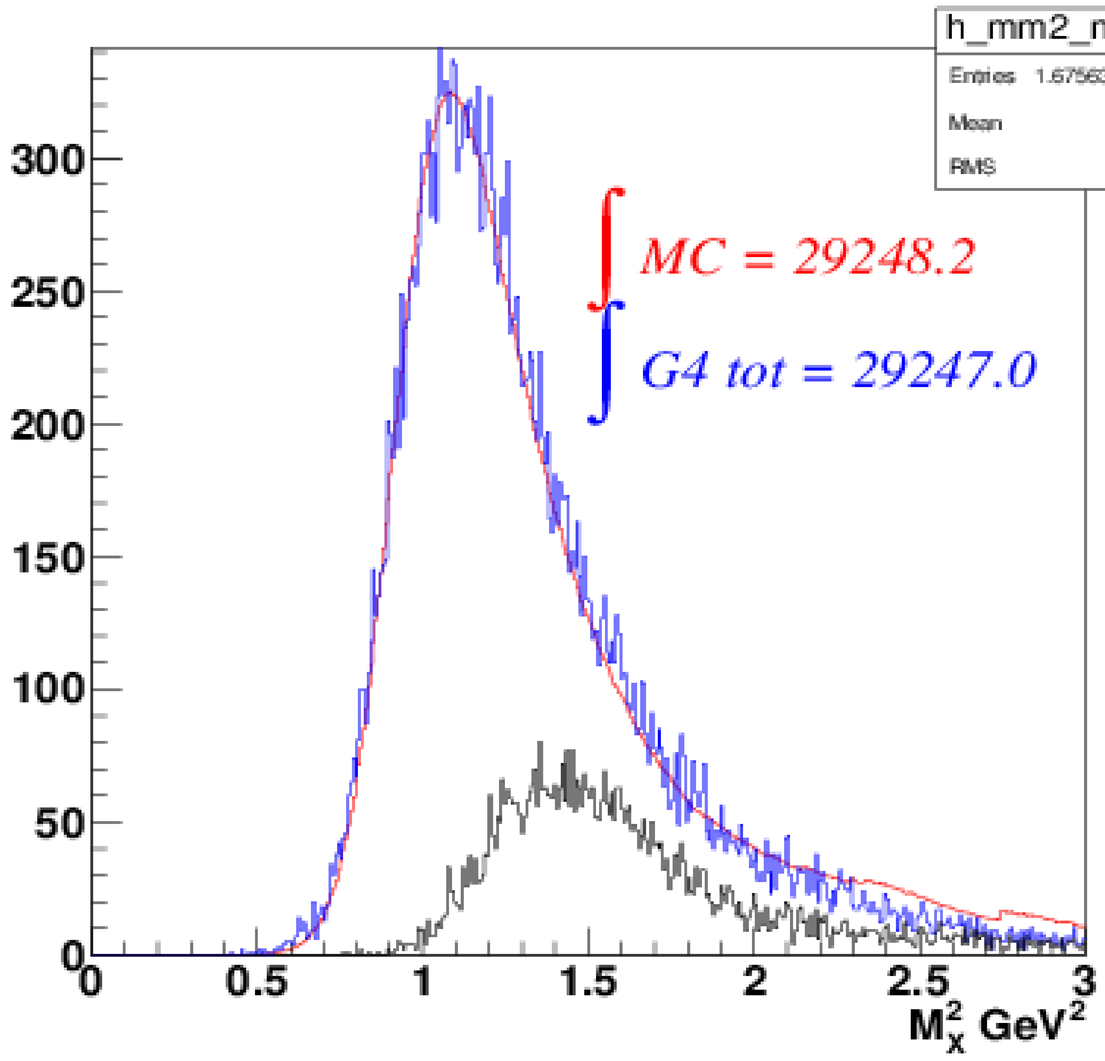


Test of exclusive π° subtraction method with G4 simulation

G4 π° (1-cluster and 2-clusters events)

Paremuzyan R.





→ XY coordinates of the **π° momentum direction is crossing the calorimeter** to ensures the detection of the two photons.

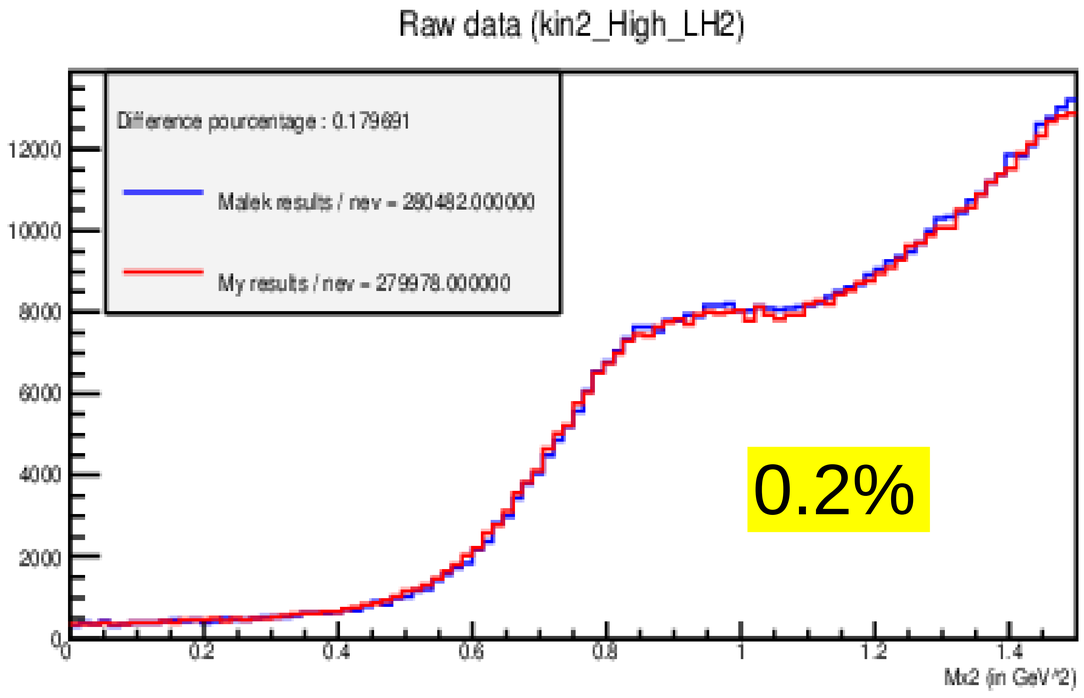
Black curve : one of the 2 clusters from the 2-clusters events is outside the fiducial region

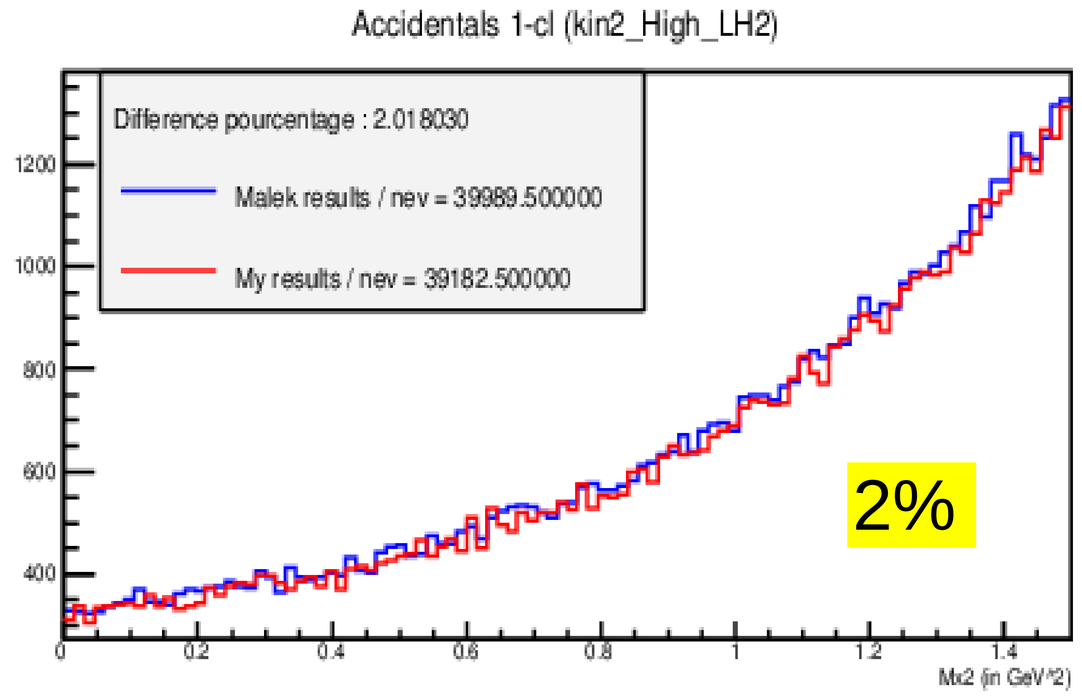
Blue curve : G4 1-cluster events + black curve

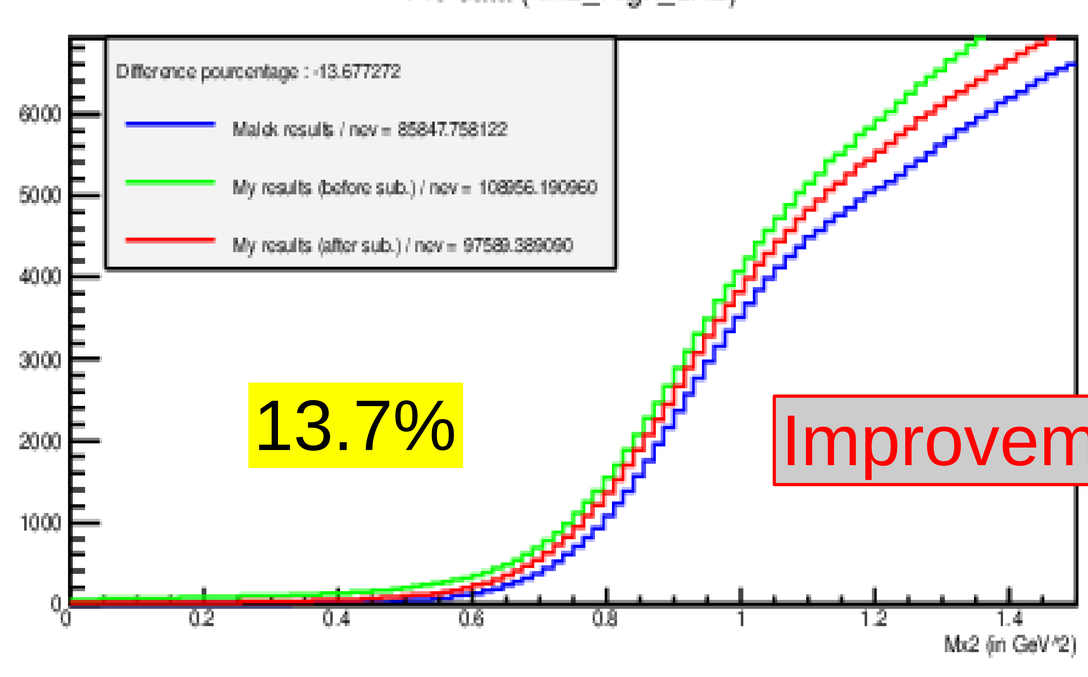
Red curve : 1-cluster events after MC from the G4 2-clusters events

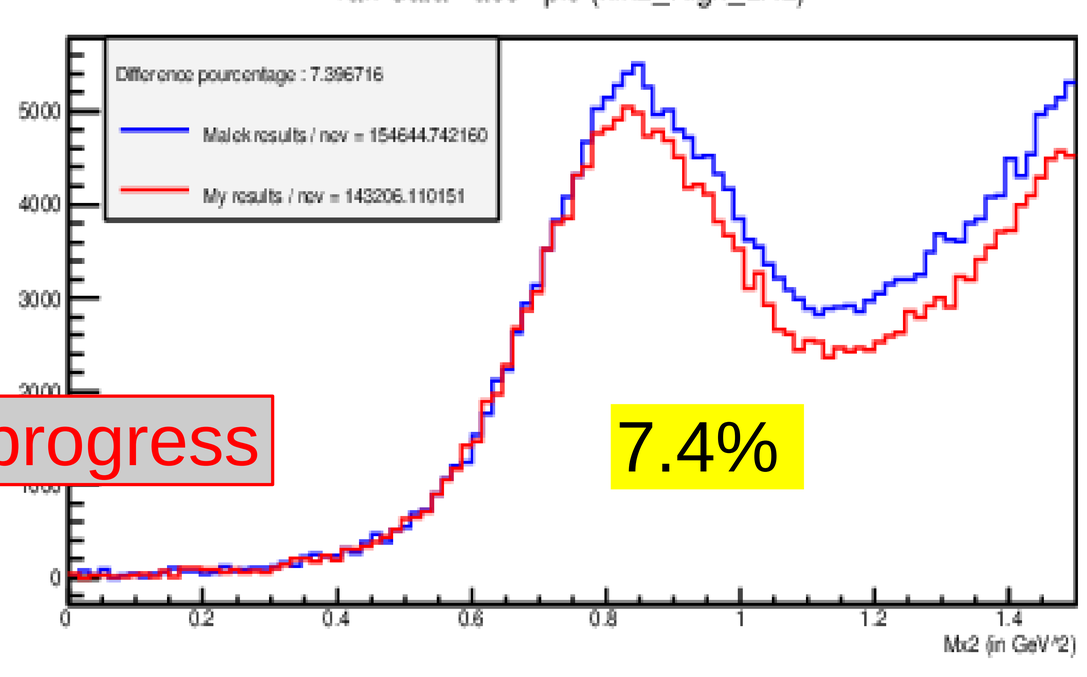
Cross check of the contamination subtraction : Example with the neutron data

LH2 Target (without fermi motion) : M. Ben Ali results (blue) / My cross check results (red)









Improvement in progress