Waveform analysis of NPS data and preliminary physics plots

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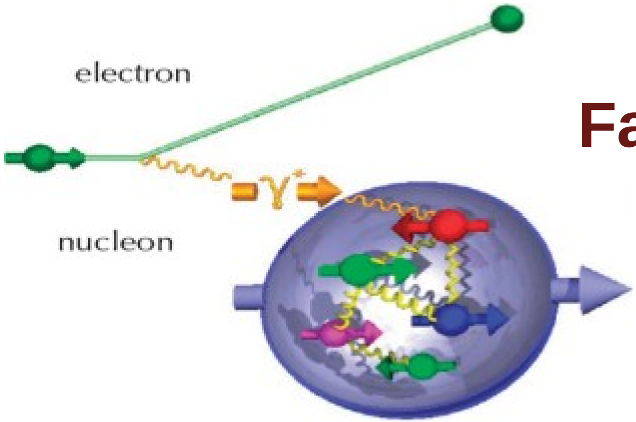
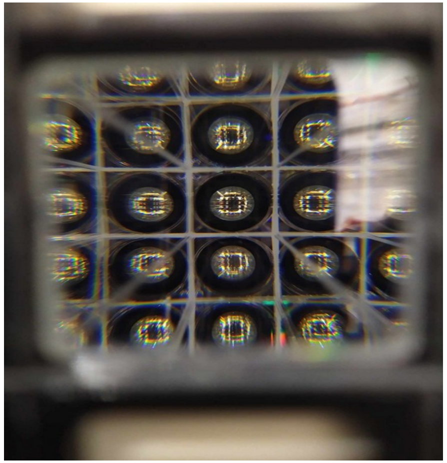
Tunisia





NPS Collaboration Meeting

18th of July 2024

Outlines

- **Waveform analysis**
- **Time resolution**
- **Energy Resolution**
- **Pi0 energy calibration**
- **e N → e ɣ N and e N → e π0 N analysis**

Waveform Analysis

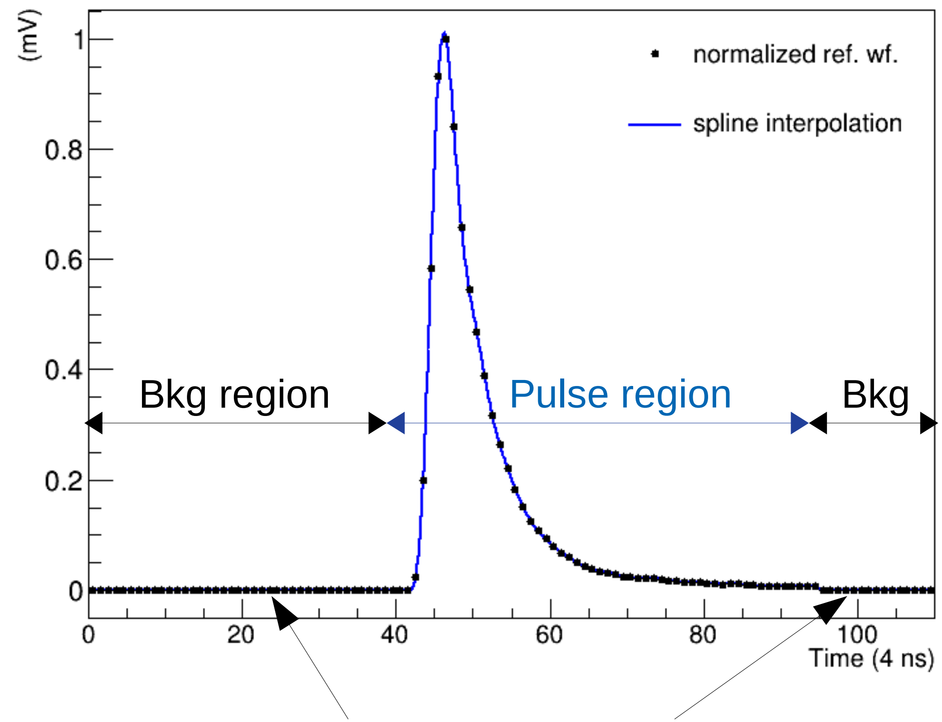
First step: Select from the elastic data a reference waveform for each NPS channel using certain criteria

- **Pulses should be:**

  - In **Coincidence** (+/- 5 samples)
  - **Highest** amplitude
  - **Lowest noise** in the Background
  - No **multiples** or **pile-up**

- **Add a constant vertical shift to have an average baseline equal to 0 mV**

- **Normalization of the ref. wf. to 1 mV amplitude**



Remove any fluctuation by setting all the ref. wf. samples to 0 mV in the bkg region

Waveform Analysis

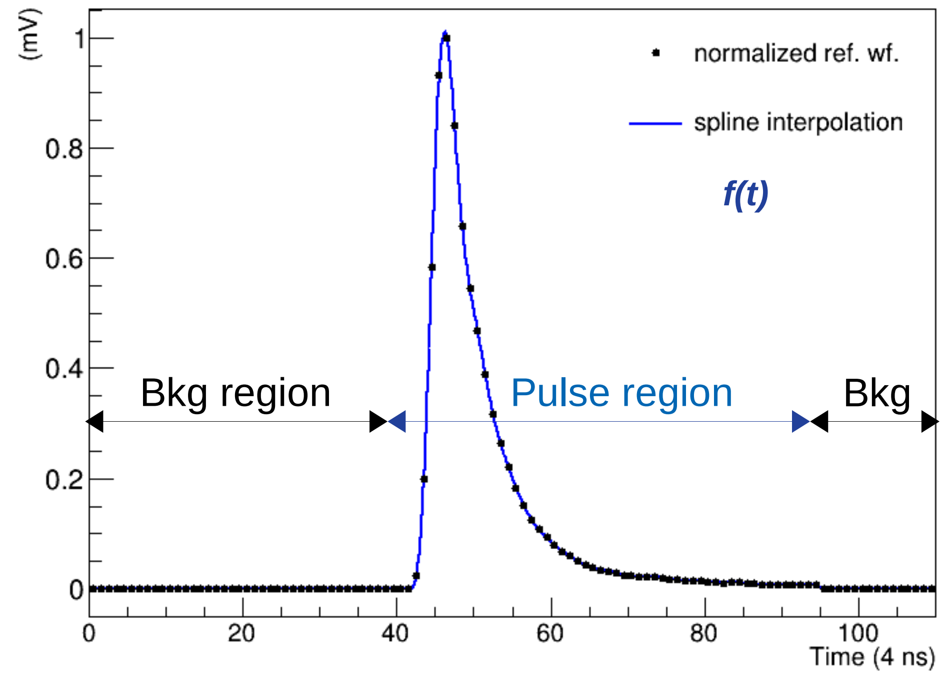
Second step: **Produce a Fit function for each block**

- **Interpolate the 110 samples of the ref. wf. with Spline to create a function *f(t)***

- **The fit function:**

$$F(t) = B + \sum_{i=1}^{Npulses} A_i \; f(t - t_i)$$

Baseline **Amplitude** **Time of pulse #i (4*ns) relatively to the ref wf time**

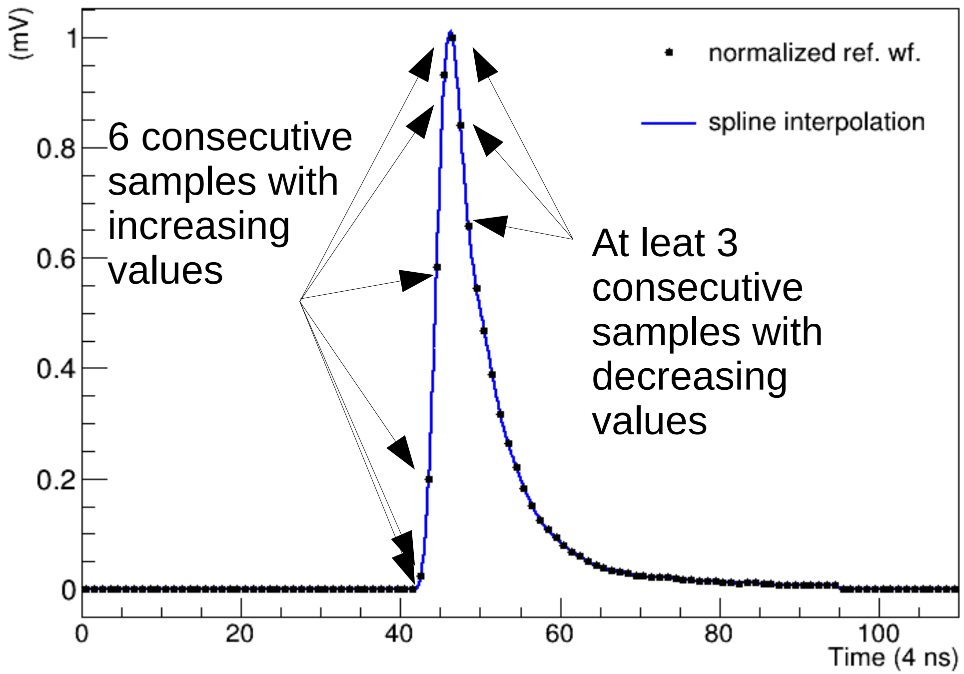


Waveform Analysis

Third step: Detect the number of pulses in the waveform, estimate the amplitude and time

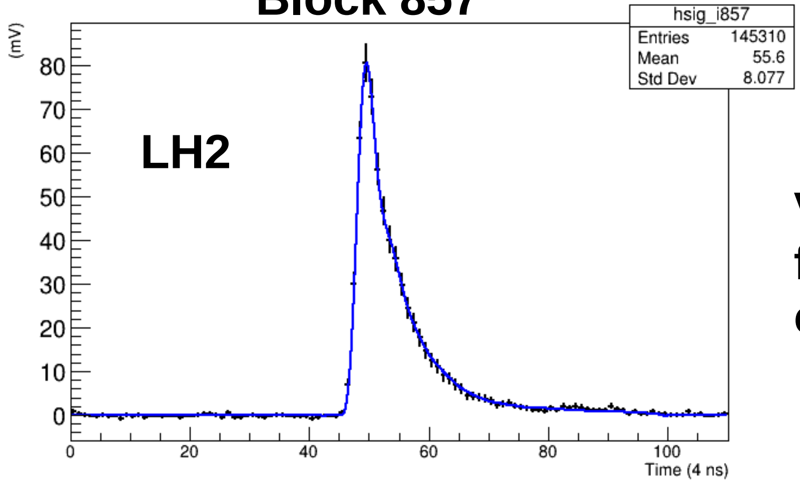
- **The identification of a pulse is based on 4 consecutive samples with increasing values followed by 2 consecutive samples with decreasing values**

- **The time and the rough estimate of the amplitude of the pulses found are used to help the fit**

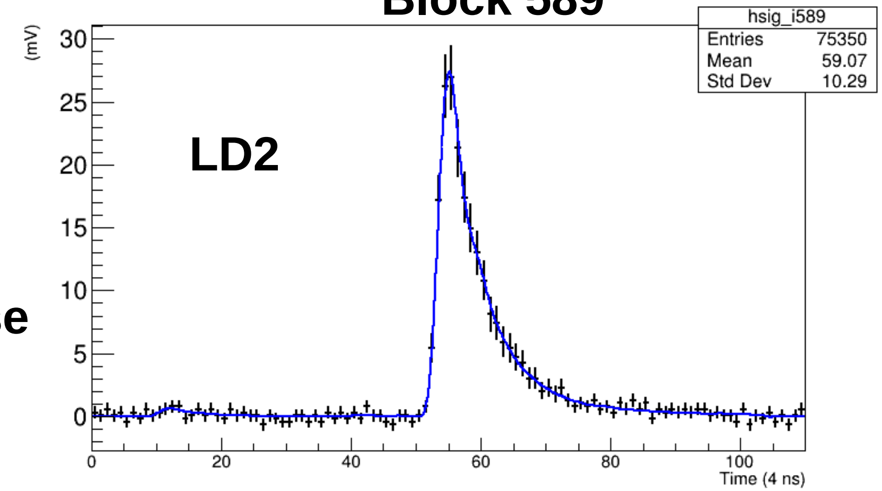


FITTED WAVEFORMS

Block 857

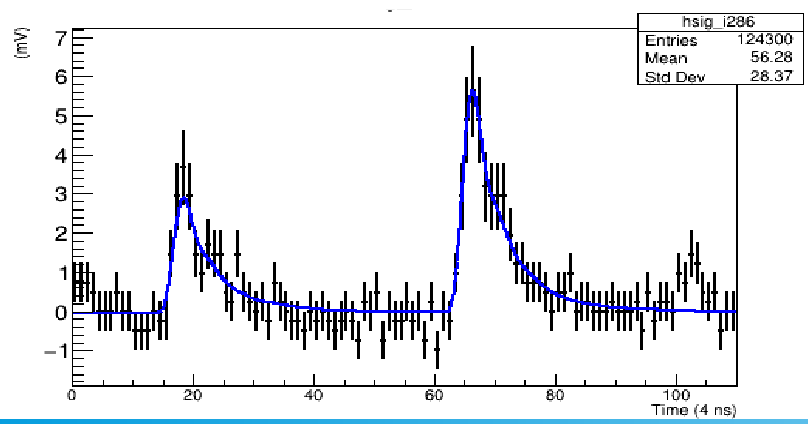


Block 589

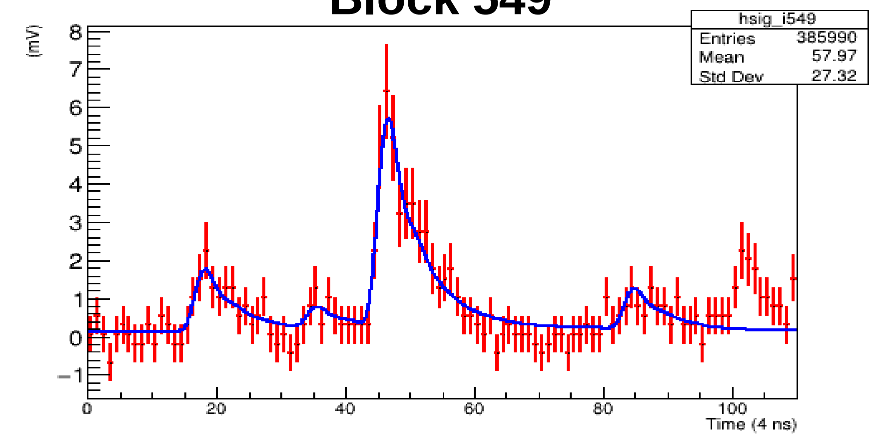


Very convenient fit for the coincidence pulse

Block 286

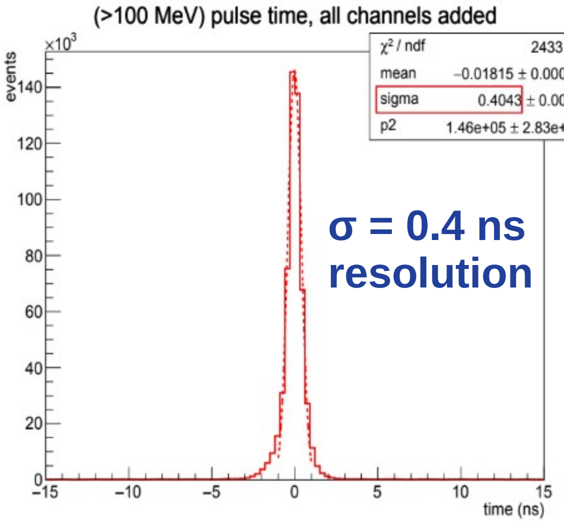


Block 549

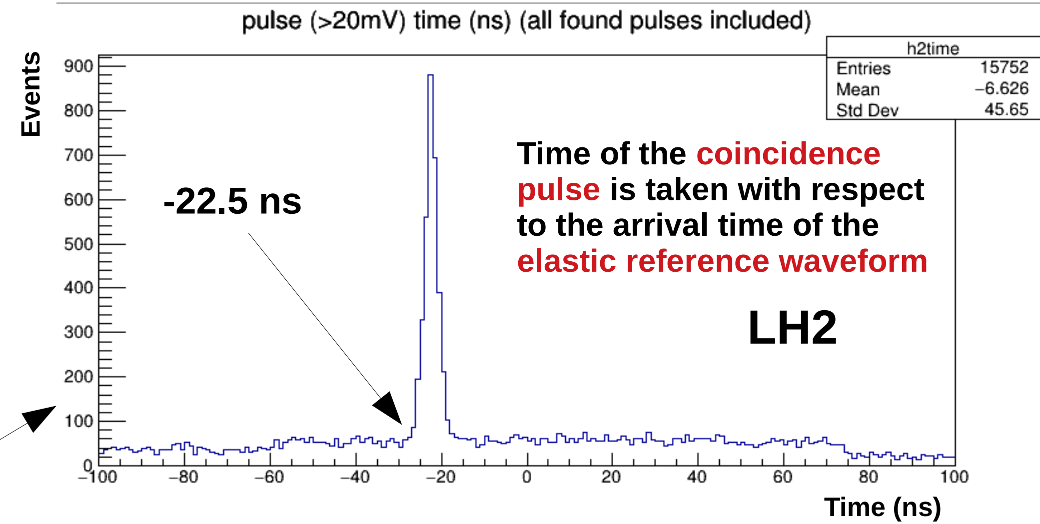


Multiple pulse fit

TIME RESOLUTION STUDY

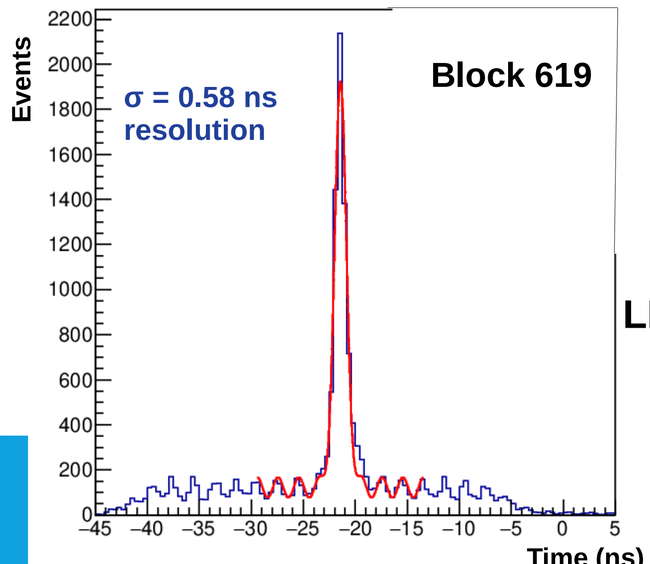


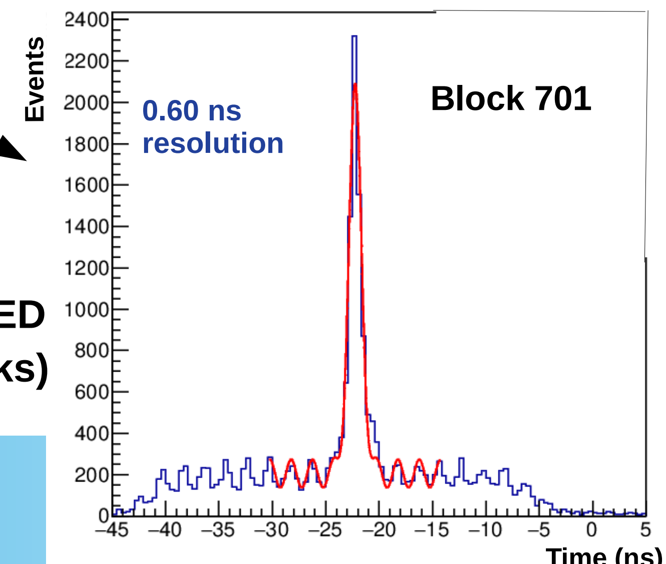
Elastics data



Production data

Pulses above 5 MeV





LD2 +LH2 RUNS COMBINED
(2 middle columns blocks)

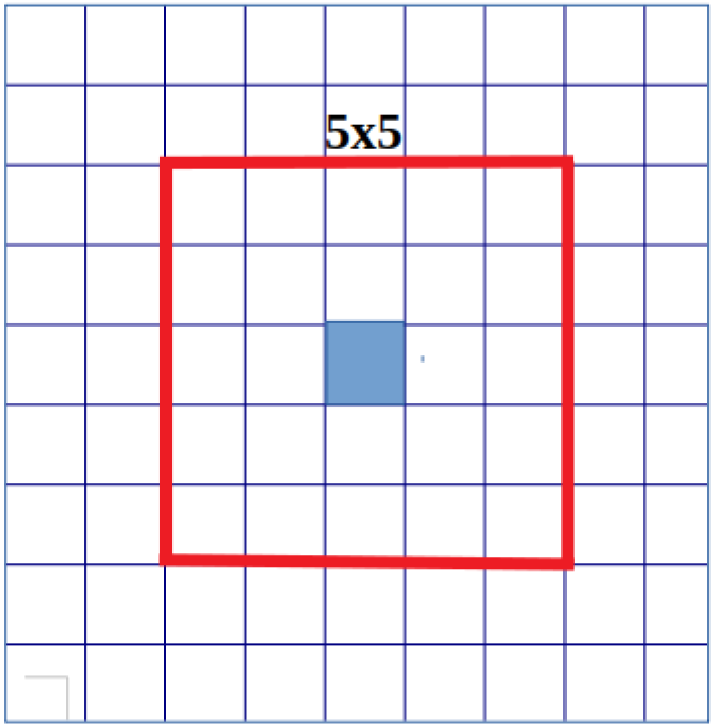
Clustering Scheme

Steps:

- **For each block:** **|time[i]|<5*rmstime[i]**
- **Search for the seed block**
- **Apply the 5x5 clustering**
- **Calculate the cluster energy and the impact position:**

$$E_i = C_i A_i \quad / \quad \vec{x} = \frac{\sum_i w_i \, \vec{x}_i}{\sum_i w_i} \quad / \quad w_i = \max\left\{0, \left[W_0 + \ln\left(\frac{E_i}{E}\right)\right]\right\}$$

$$W_0 = \ln\left(\frac{100\, E(\mathrm{GeV})}{2.02\, e^{-\frac{d}{r_M}} + \left[4.98\, e^{-\frac{d}{r_M}} + 0.30\right] E(\mathrm{GeV})}\right)$$



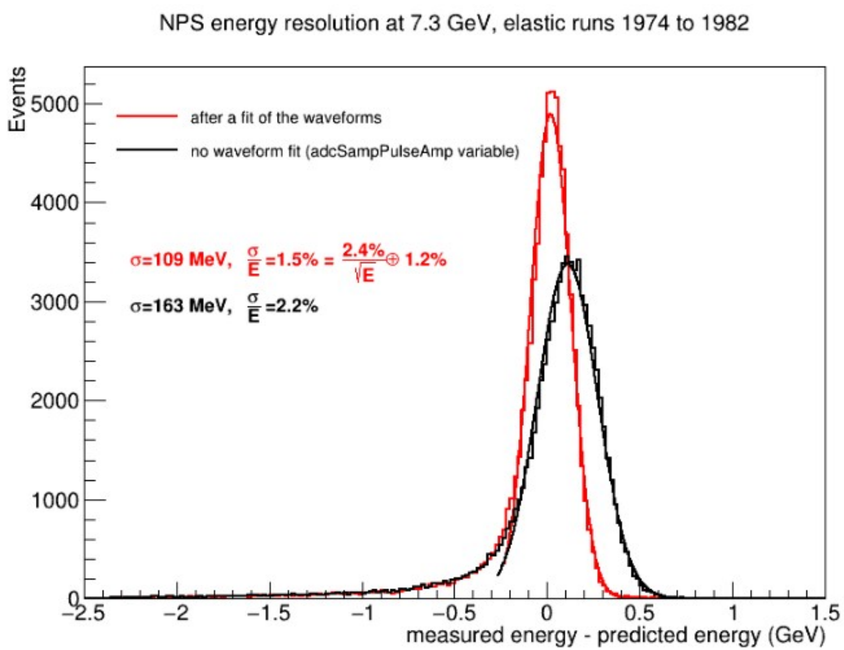
- **Calculate 4-vector using the shower depth (a) correction (G4 simulation)** →

$$a(cm) = \frac{0.00507955}{0.999238 - e^{(0.0010705 \times \mathrm{E}(GeV))}} + 9.31622$$

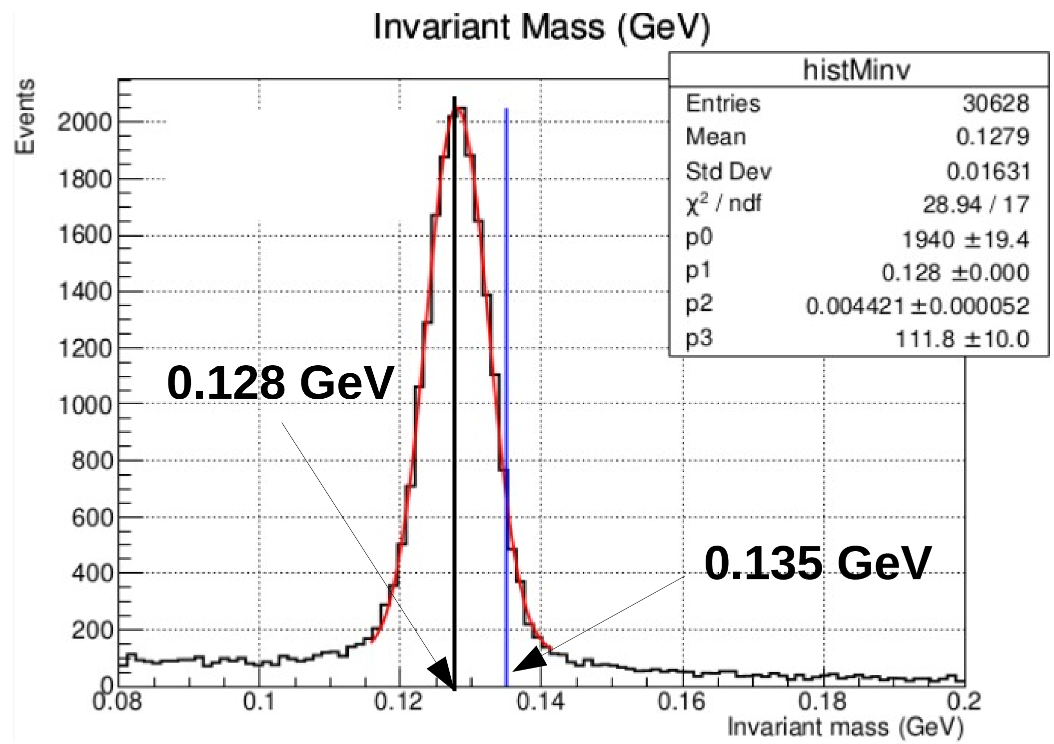
- **0.5 GeV as a cluster threshold**

Mazouz, M., L. Ghedira, and E. Voutier. "Determination of shower central position in laterally segmented lead-fluoride electromagnetic calorimeters." Journal of Instrumentation 11.07 (2016)

Energy Resolution



- **33% improvement in energy resolution at 7.3 GeV from elastic H(e,e'p) calibration runs after applying the waveform analysis**

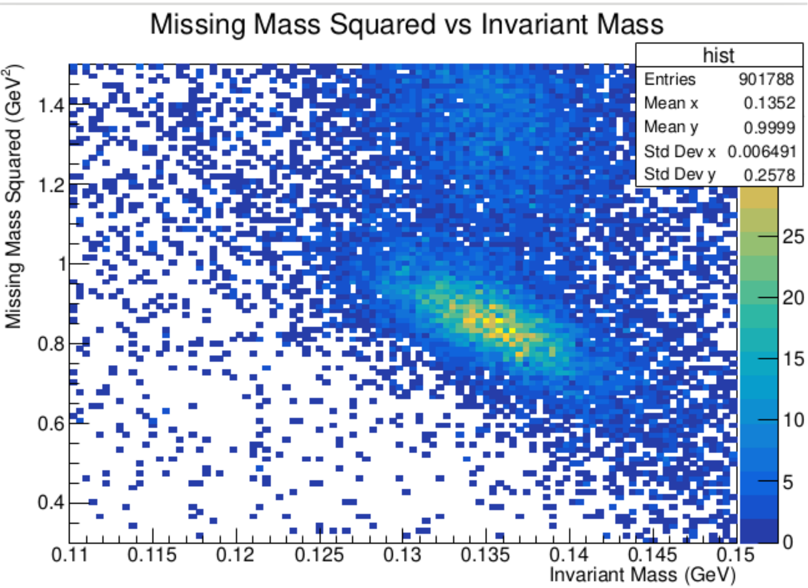


Not sufficient → Calibration using π0 is needed

π0 energy calibration

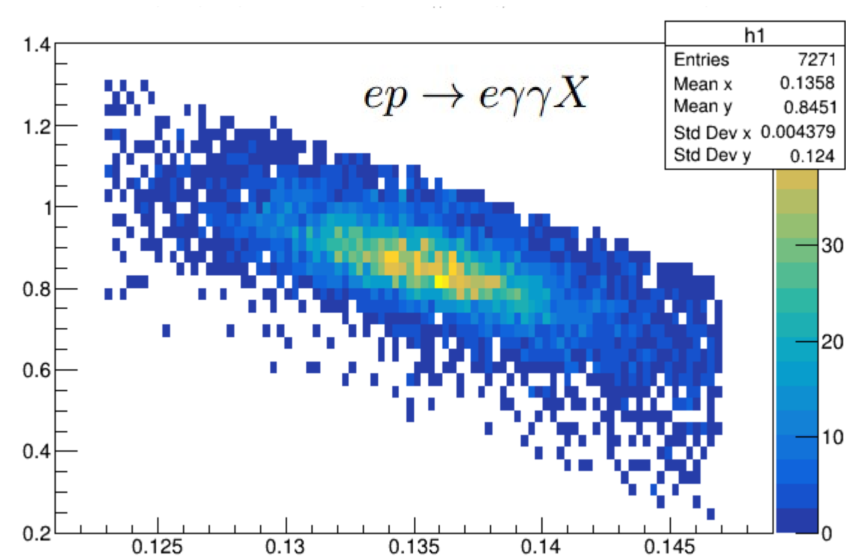
Method:

- **With exclusive π0 events, the expected energy of the π0 can be calculated using its scattering angle. A minimization between the measured energy and the expected π0 energy allows to calibrate the NPS channels**
- **We usually do 3 to 4 iterations before converging to the most suitable calibration coefficients**

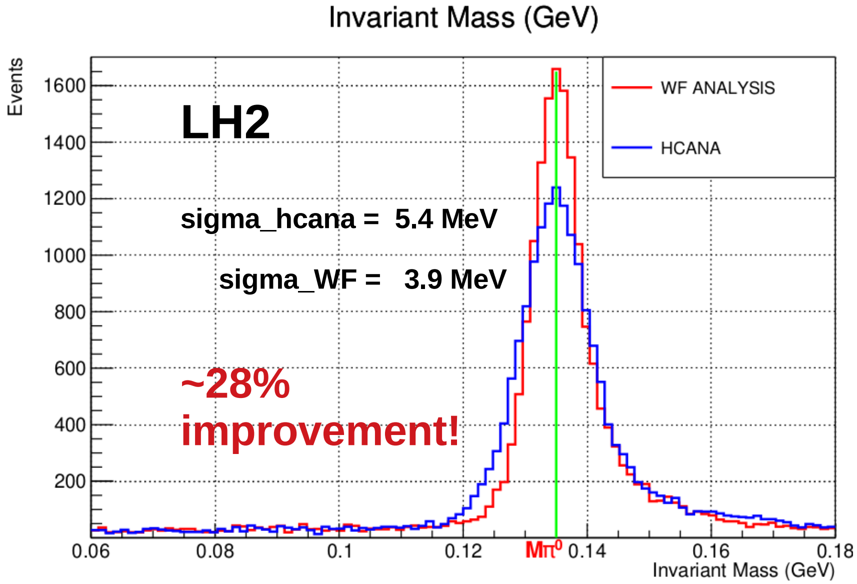


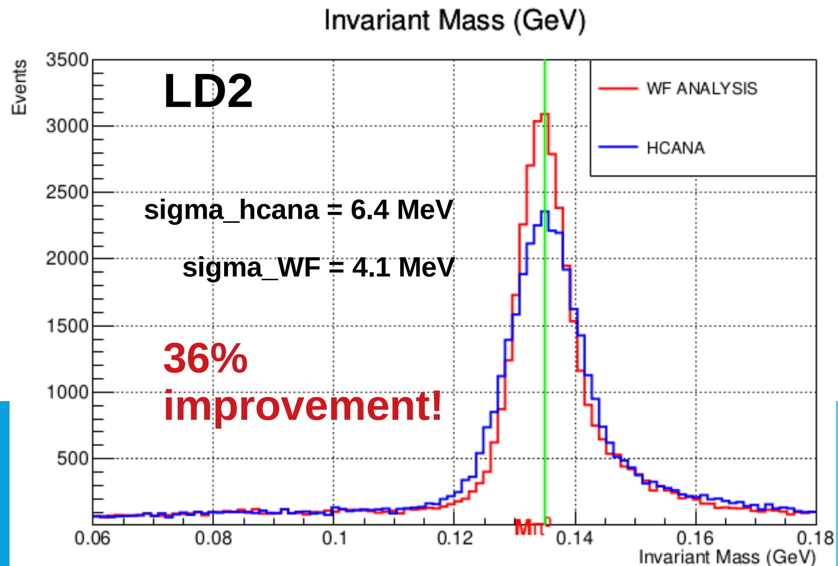
Exclusive events selection

2D cut

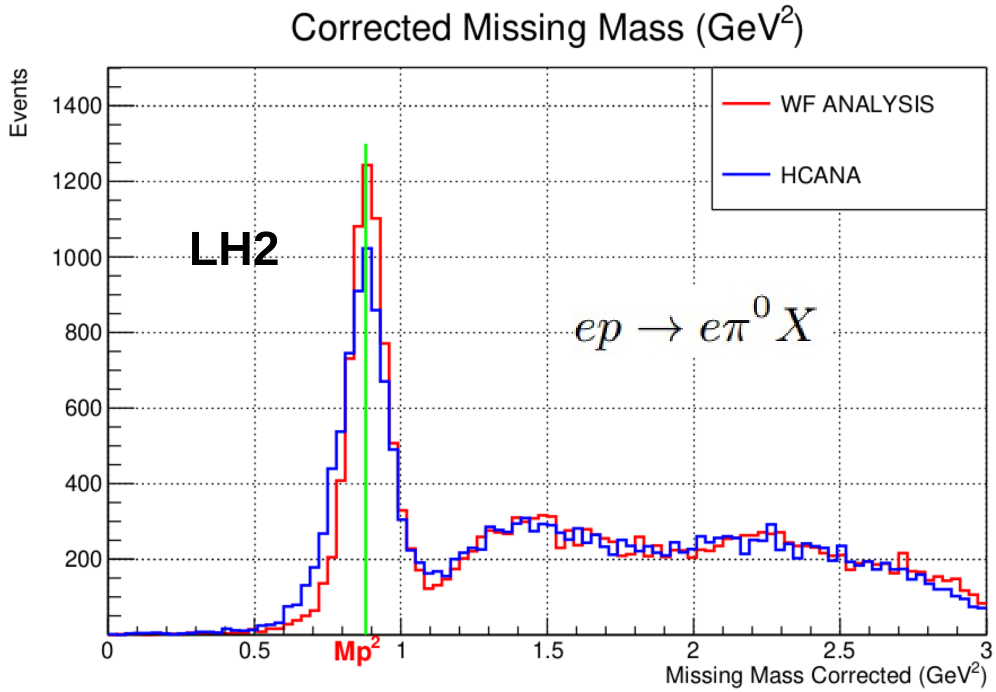


e p → e π0 p results



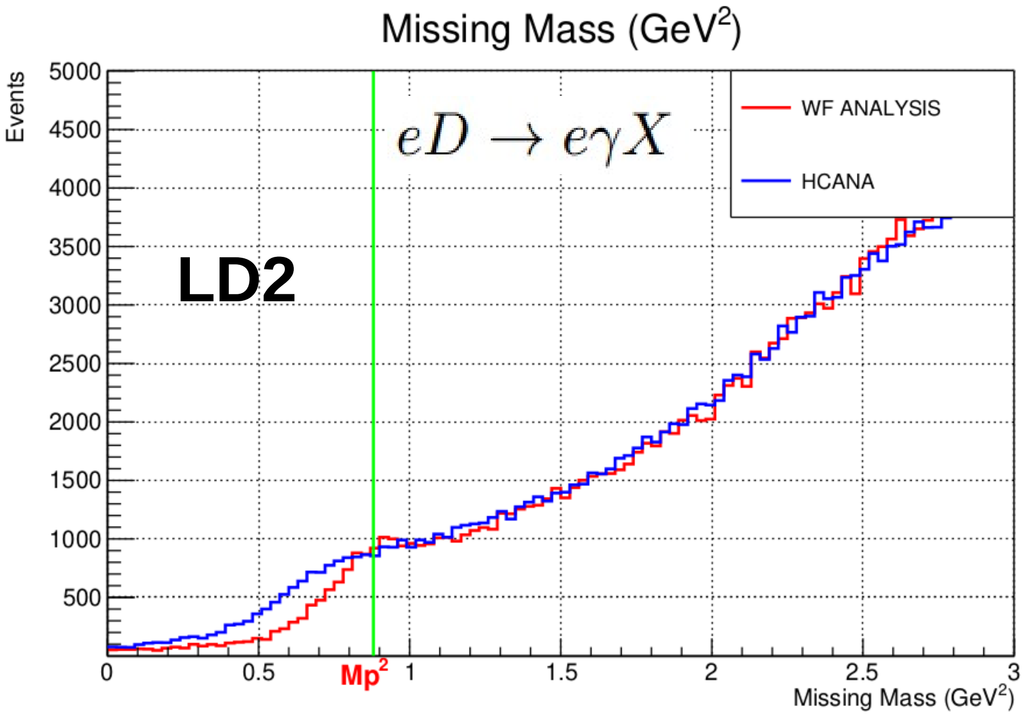


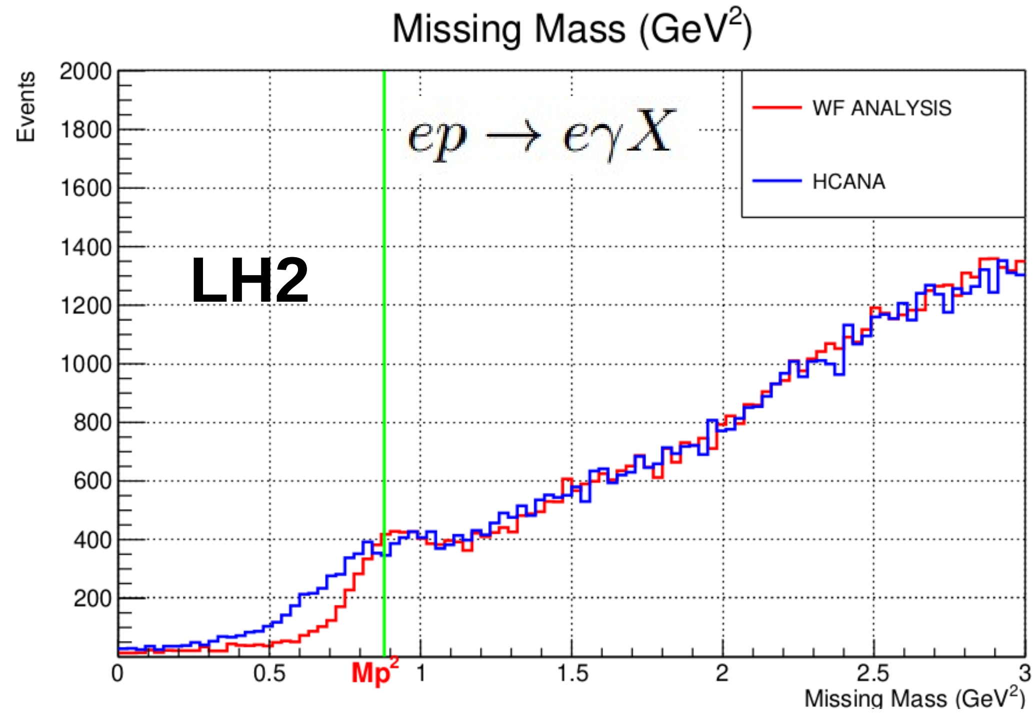
- Kinematics: KinC_x60_3
- 6 Runs for LH2: 2011, 2013, 2014, 2015, 2016 and 2017
- 4 Runs for LD2: 1990, 1991, 1992 and 1993
- Only the basic HMS cuts :
  |dp|<8% & |ph|<0.04 & |th|<0.08 & |react.z|<4



- Used the following relationship for the corrected missing mass: mm2+a*minv-b

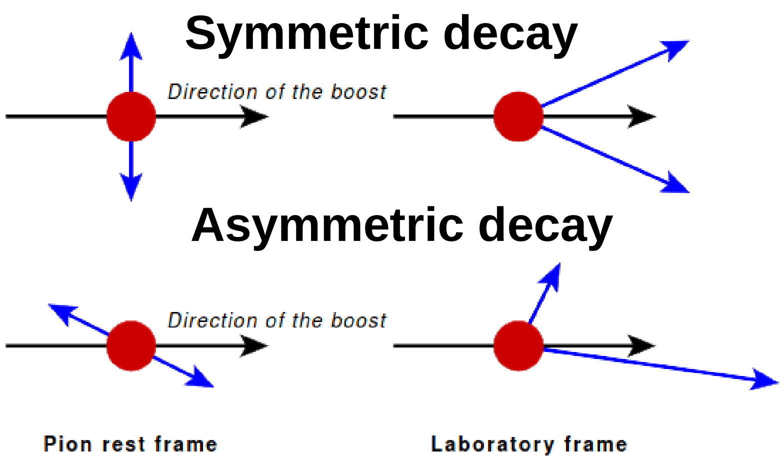
DVCS Missing Mass Plots





A noticeable improvement

DVCS Analysis
(Pi0 Contamination)



Method:

- 3 Main criteria for the π0 events selected from data:

- No edge block clusters
- Energy of the photons is above the trigger threshold
- A correct invariant mass

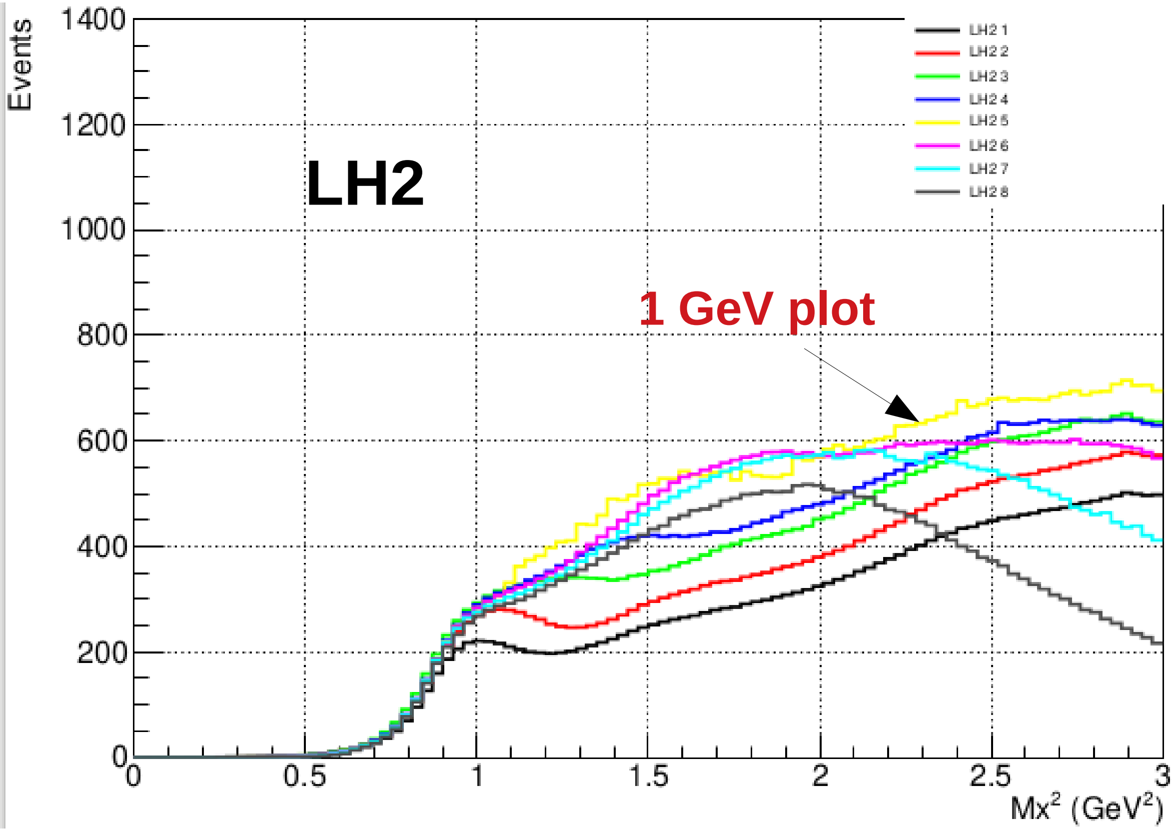
- Simulate the decays of each detected π0 by randomizing the photon angles 5000 times in the c.m. frame: cos θ [-1, 1] (θ= decay angle) Azimuthal angle [0, 2π]

- Divide the decays by number of photons generated:
  N0= events with no γ detected
  N1= events with 1 γ detected
  N2= events with 2 γ detected

- Each event with N1 is subtracted from the DVCS events and before hand multiplied by 2 factors:
  - a1 = 1/5000 and a2 =5000/N2 → **W = a1*a2 = 1/N2**

DVCS Analysis
(π0 Contamination)

Threshold Scan

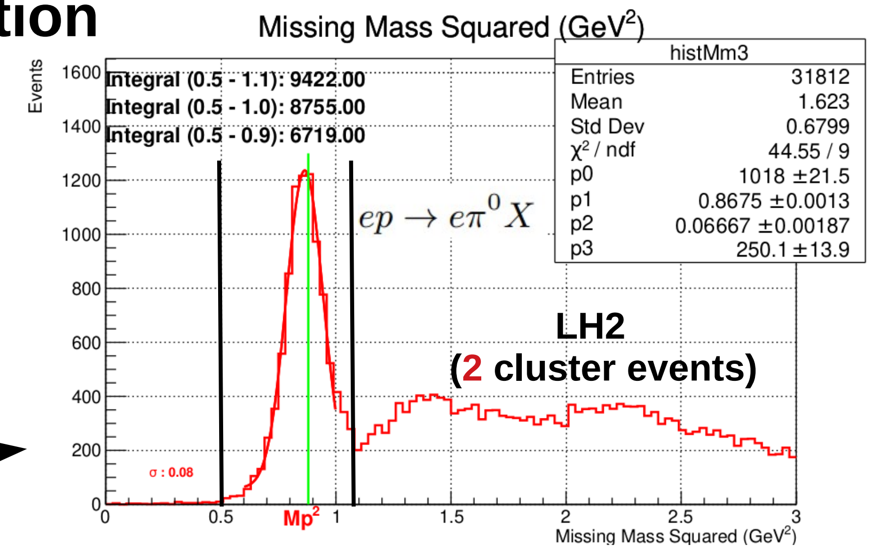


- **Steps of 0.1 GeV for the π0 threshold from 0.6 GeV (black plot) to 1.3 GeV (Grey plot)**
- **Chose the 1 GeV Threshold for both since it's stable+higher in [0.5, 1.5] GeV2**
- **LH2 trigger threshold: 0.75 GeV**

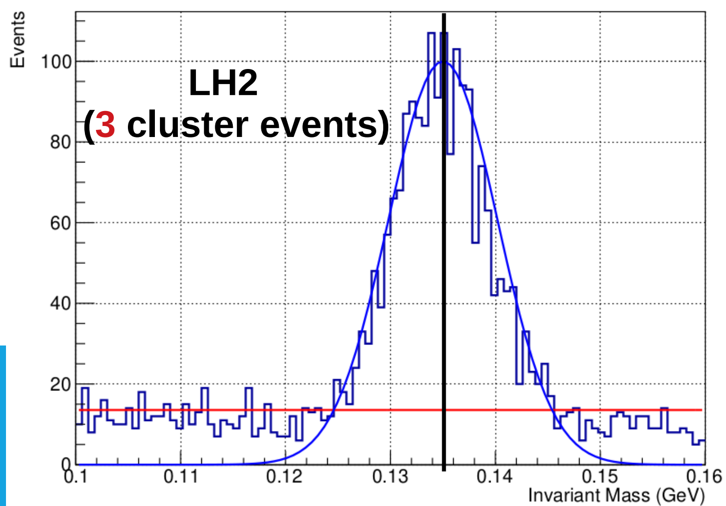
Multi-cluster correction

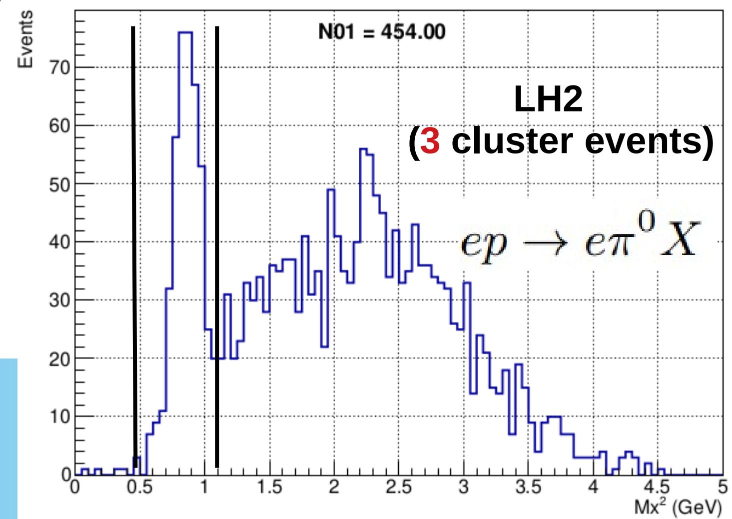
- Calculated the **yield** of **exclusive π0** events between **0.5 GeV2** and **1.1 GeV2** for the case of **2 cluster** events → **9422**

- For **3 clusters** event → **598 (6.43%)**
- For **4 clusters** event → **28 (0.29%)**
- **All the histogram** of different contributions are added to the **2 cluster Mx2 raw** spectrum



One of the combinations: **photon[0]+photon[1]**
(**E_photon[0]**>**E_photon[1]**>**E_photon[2]**)



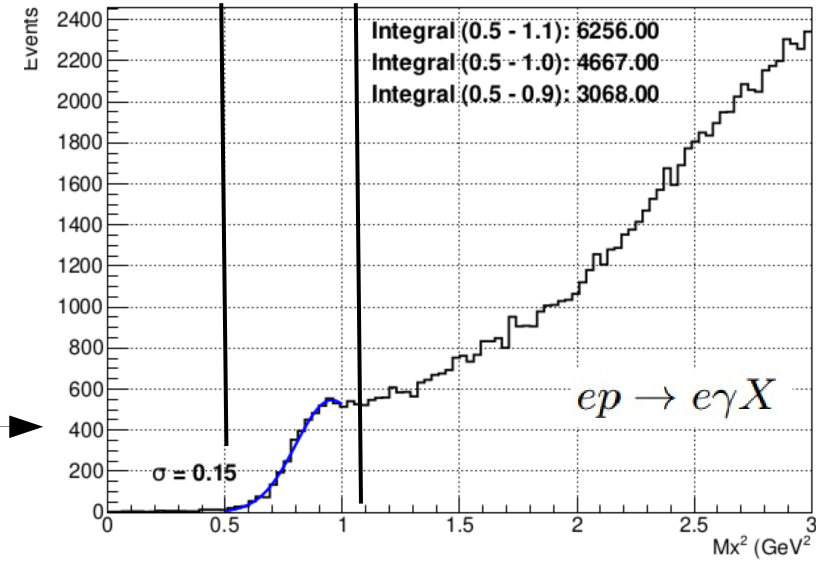


DVCS Analysis

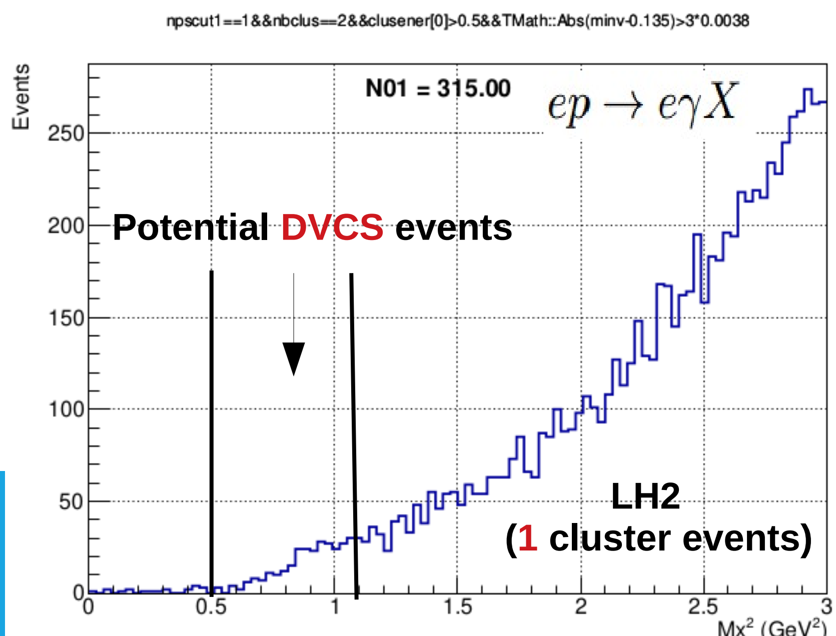
(DVCS Yield Study)

- Calculated the yield of DVCS events between 0.5 GeV2 and 1.1 GeV2 for the case of 1 cluster events → 6256

- For 2 clusters events → 315 (5.03%)
- For 3 clusters events → 17 (0.27%)
- All the histogram of different contributions are added to the 1 cluster Mx2 raw spectrum →



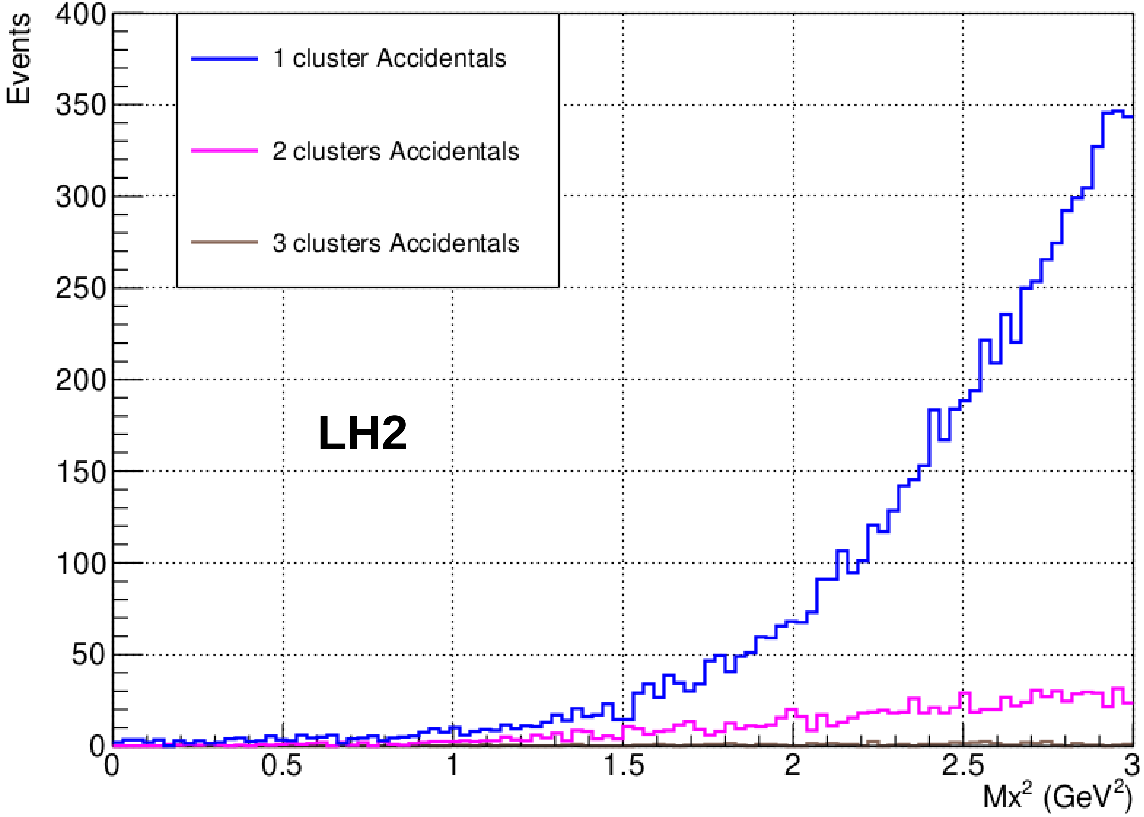
One Case:



- Each cluster in a multi-cluster event is systematically considered as a potential DVCS event if it does not originate from a π0 decay (the invariant mass of that photon when combined with another photon is different from the mass of π0)

DVCS Analysis

(DVCS Accidentals)



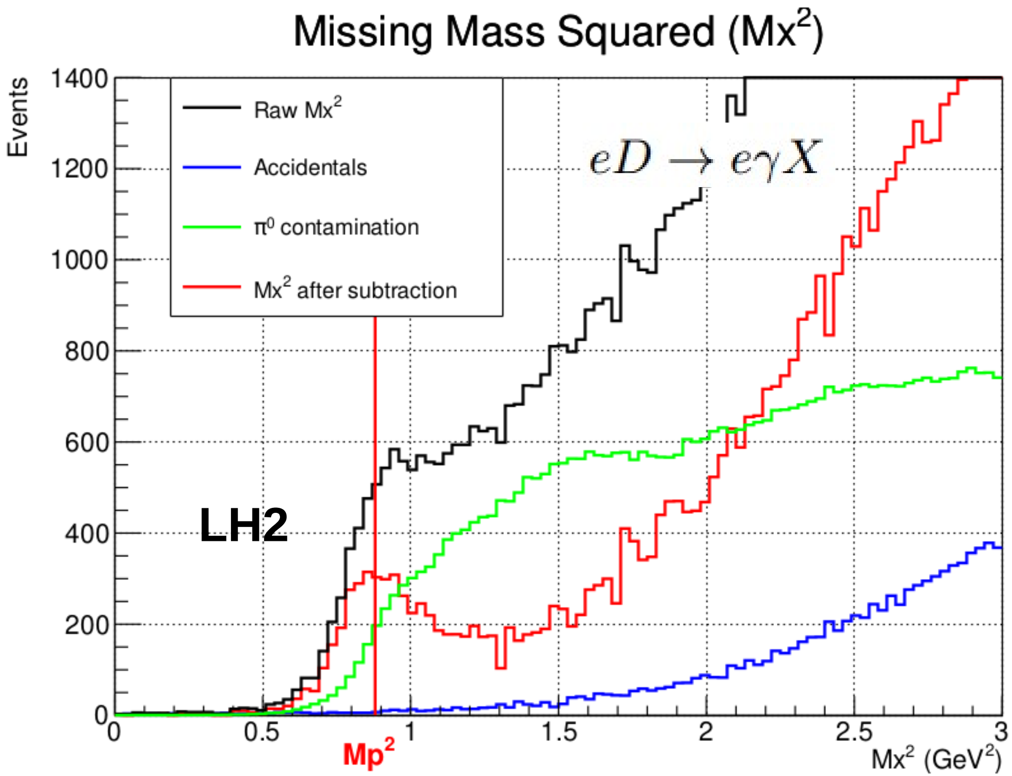
- **Window: +/- 10 ns from the coincidence pulse time**

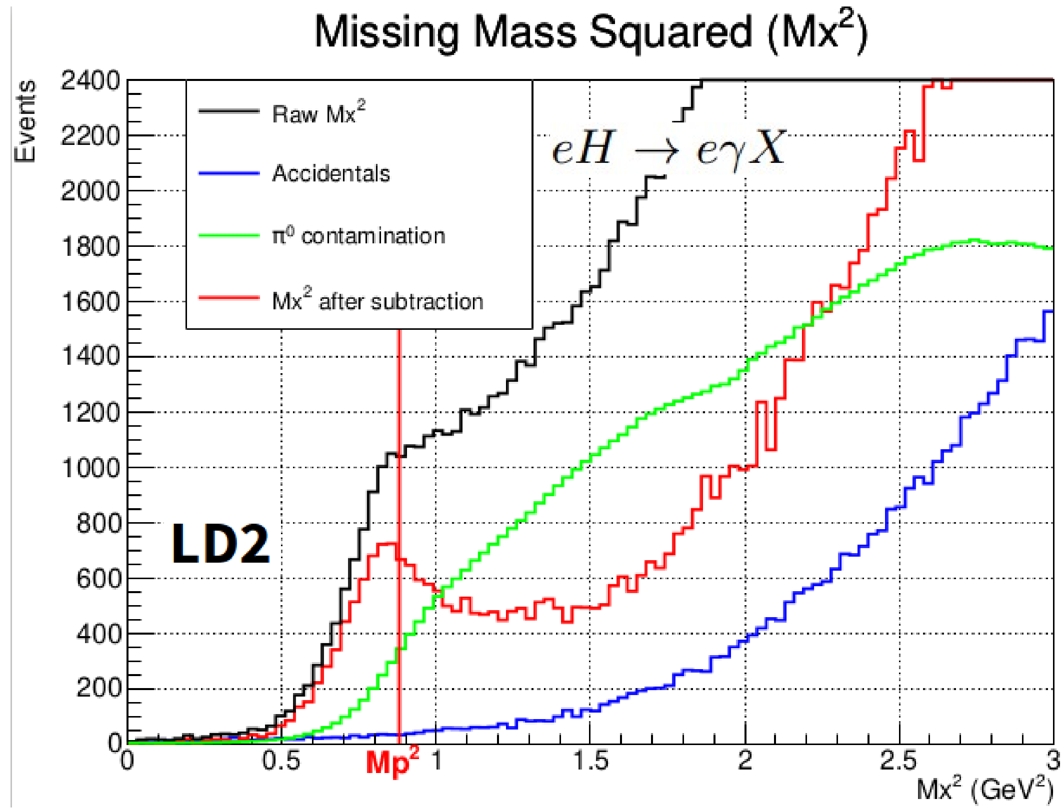
- **For each block:**
  |time[i]-10|<5*rmstime[i]
  |time[i]+10|<5*rmstime[i]

- **The accidentals are obtained with the same method used for the coincidence events :**

  - If cluster number 0 in 2-cluster events contributes to the coincidence Mx2 spectrum then its contribution is also determined and added to the total accidental Mx2 spectrum

Preliminary Results

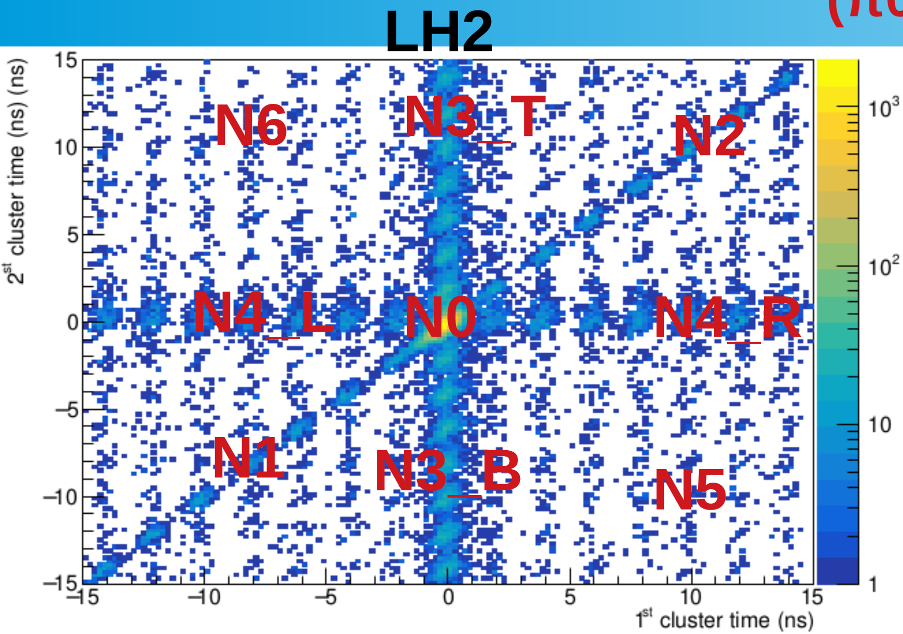


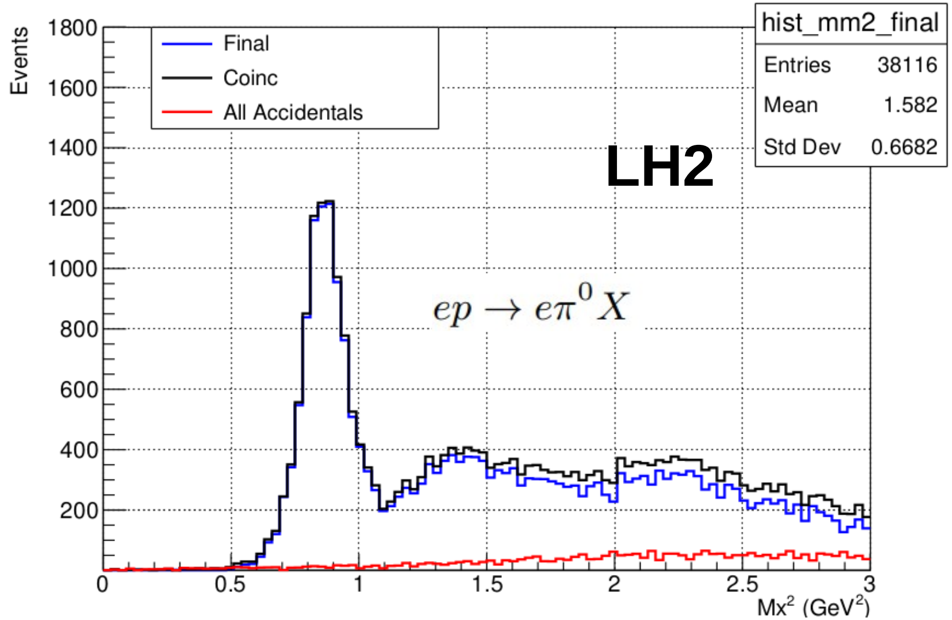


Better resolution and exclusivity than previous DVCS experiments

DVCS Analysis

(π0 Accidentals)



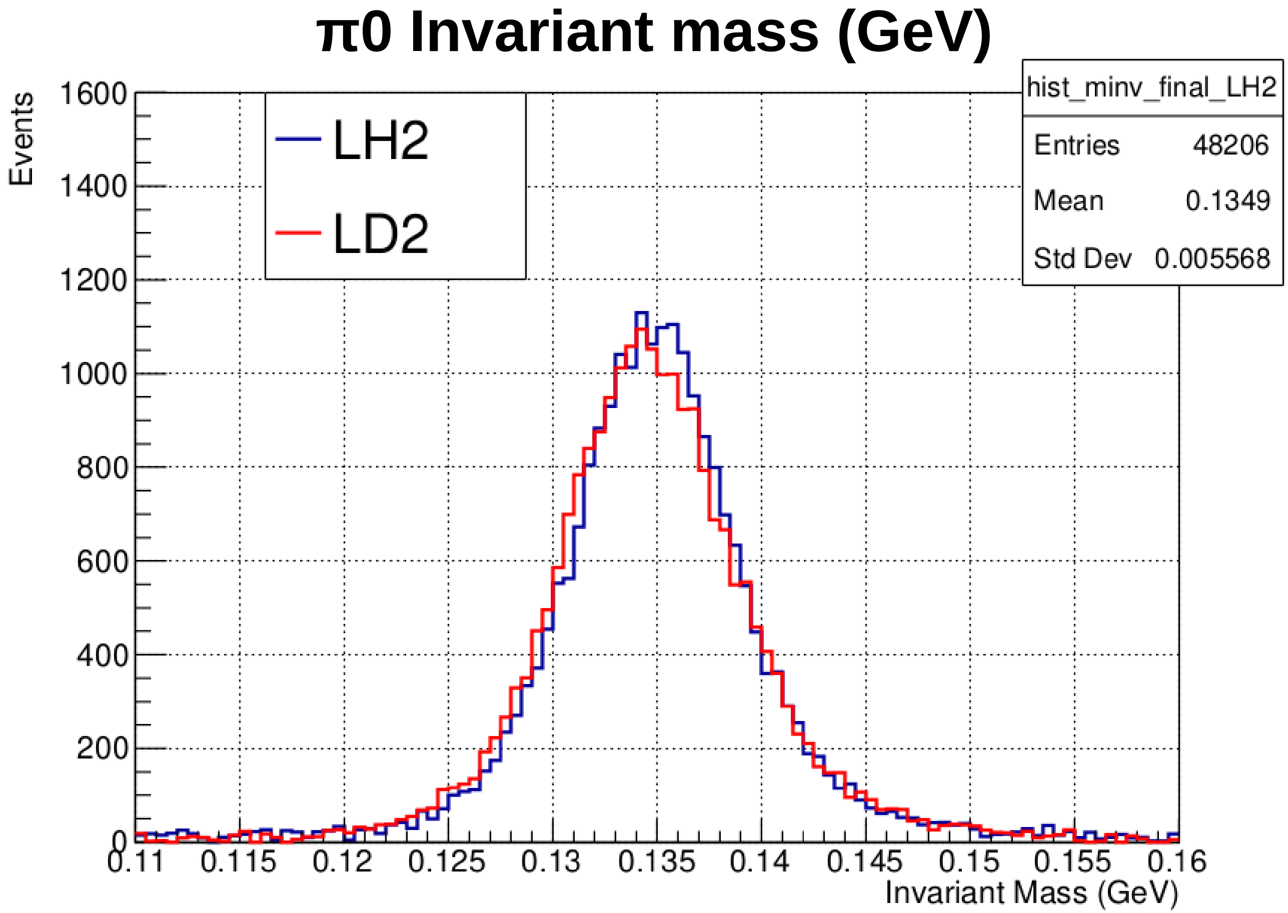


- **N0**: **2** photons are in **coincidence** with **each other** and with the **scattered electron**
- **N1** + **N2: 2** photons are in **coincidence** with **each other** but **not** in **coincidence** with the **scattered electron**
- **N3_T** + **N3_B** + **N4_L** + **N4_R:** both photons are **not in coincidence** with **each other** and only **one of them** is in **coincidence** with the **scattered electron**
- **N5** + **N6:** both photons are **neither in coincidence** with **each other** nor with the **scattered electron**

- **3 time frames:**
  - |time[i]|<5*rmstime[i]
  - |time[i]-10<5*rmstime[i]
  - |time[i]+10<5*rmstime[i]

All Accidentals = 0.5 * (N1+N2+N3_B+N4_L+N3_T+N4_R) - (N5+N6)

DVCS Analysis
(π0 Resolution Check)



- **Small differences between the 2 resolutions of the π0 invariant mass**
- **Will be multiplying the cluster energy of LD2 in order to bring it up to the same resolution by the following ratio: mean_LH2/mean_LD2**

Fermi Smearing

LH2 not smeared → $M_x^2 = (P_p')^2 = (q + P - q')^2$ **How to smear it?**

- **For the DVCS off the deutron reaction:**

$$\gamma^* + {}^2_1D \rightarrow \gamma + n' + p'$$

$P_d = (M_d, \mathbf{0})$ ← **Deuteron mass**

$$q + P_d = q' + P_n' + P_p'$$

With $= \left(\sqrt{M^2 + \mathbf{P}_f^2}, \mathbf{P}_f\right) + \left(\sqrt{M^2 + \mathbf{P}_f^2}, -\mathbf{P}_f\right) + \left(M_d - 2\sqrt{M_d^2 + \mathbf{P}_f^2}, \mathbf{0}\right)$ (**Nucleon mass**: M)

- **We can rewrite the previous equation as follows:**

$$q + P_n + P_p + P_{add} = q' + P_n' + P_p'$$

With $P_{add} = \left(M_d - 2\sqrt{M_d^2 + \mathbf{P}_f^2}, \mathbf{0}\right)$

- **The missing mass of the deuteron can be then written as follows:**

$$M_x^2 = (P_p' + P - P_p - P_{add})^2$$

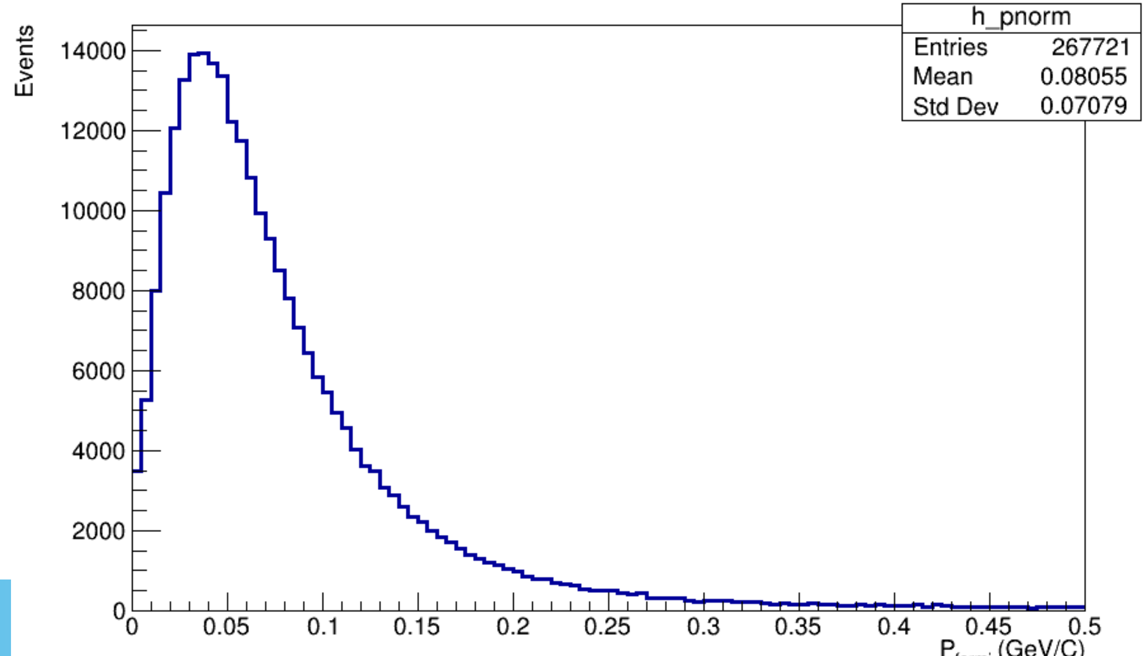
With $P = (M, \mathbf{0})$

- **Then we smear the LH2 data as follows:**

$$M_x^2 = (q + P - q' + P - P_p - P_{add})^2$$

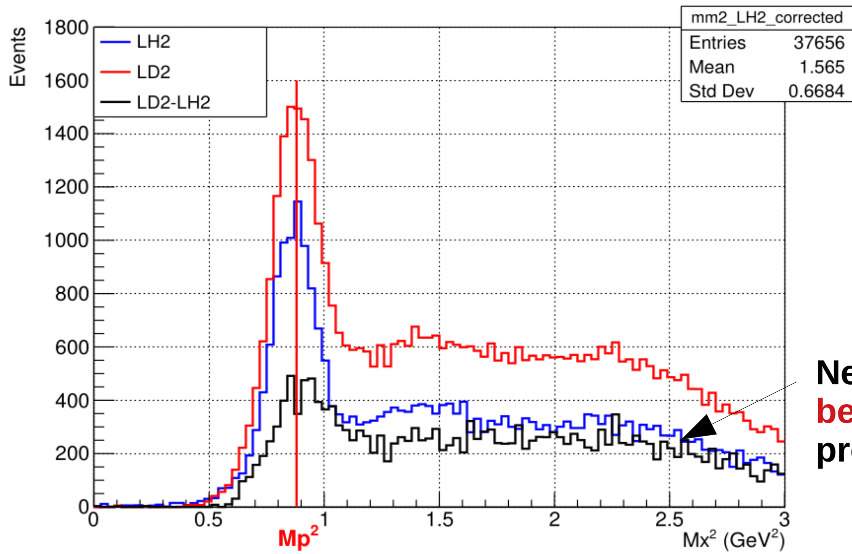
Smearing term: $P - P_p - P_{add}$

Fermi momentum distribution



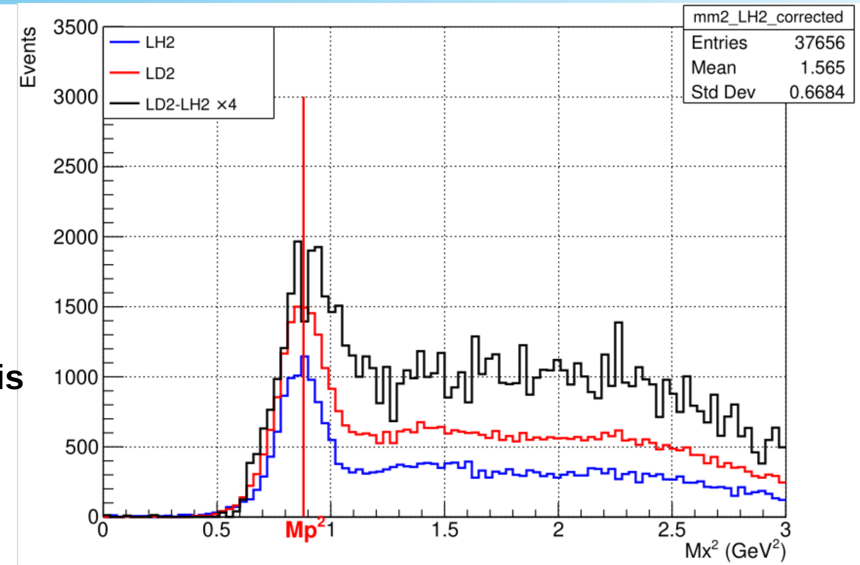
e N → e π0 N analysis

Corrected missing mass without any target correction

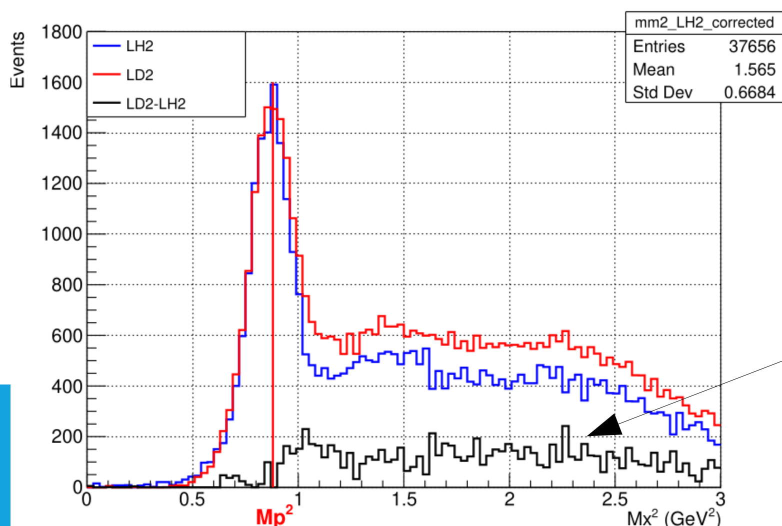


Multiplied the neutron peak by 4 →

Neutron peak is below the proton peak

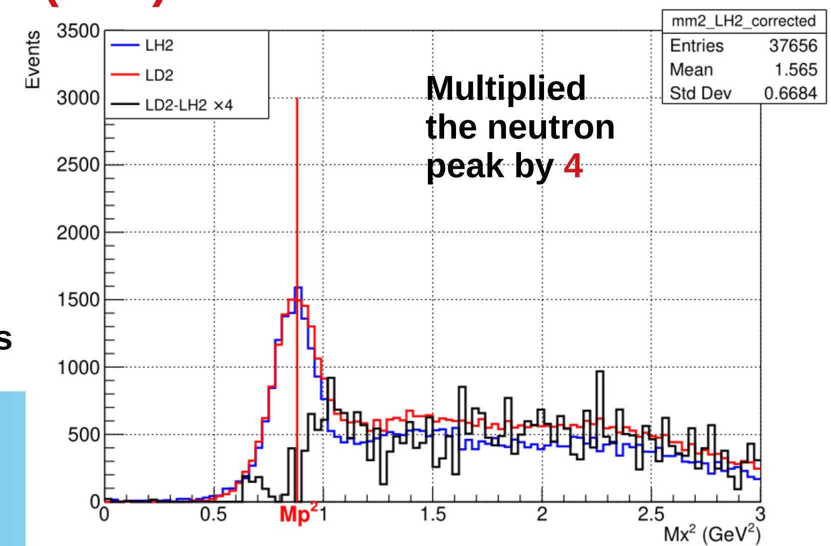


Corrected missing mass with (0.72) correction



Multiplied the neutron peak by 4 →

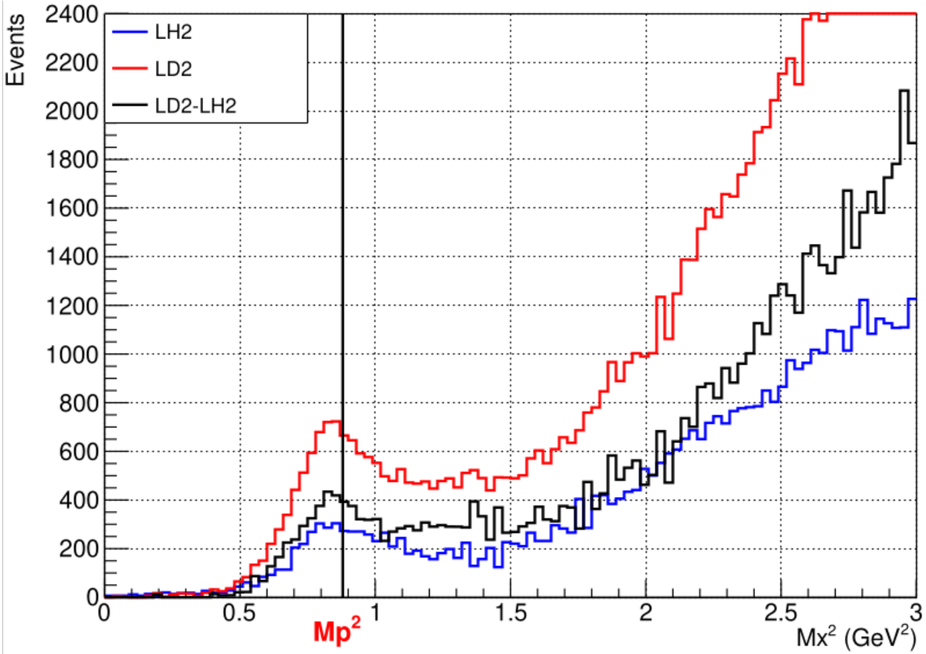
Neutron peak is Disappeared!



Multiplied the neutron peak by 4

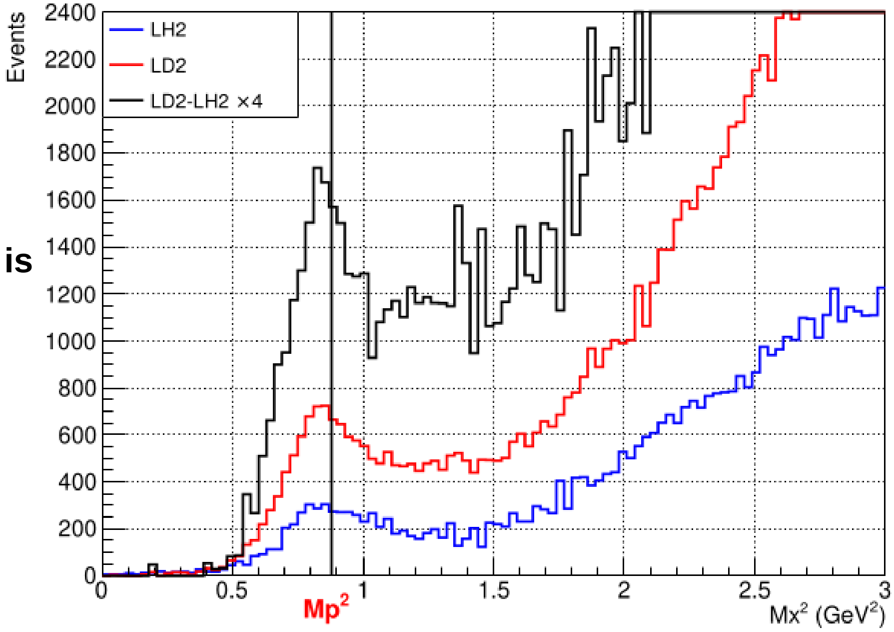
e N → e γ N analysis

DVCS missing mass squared without any correction



Multiplied the neutron peak by 4

Neutron peak is above the proton peak



Summary

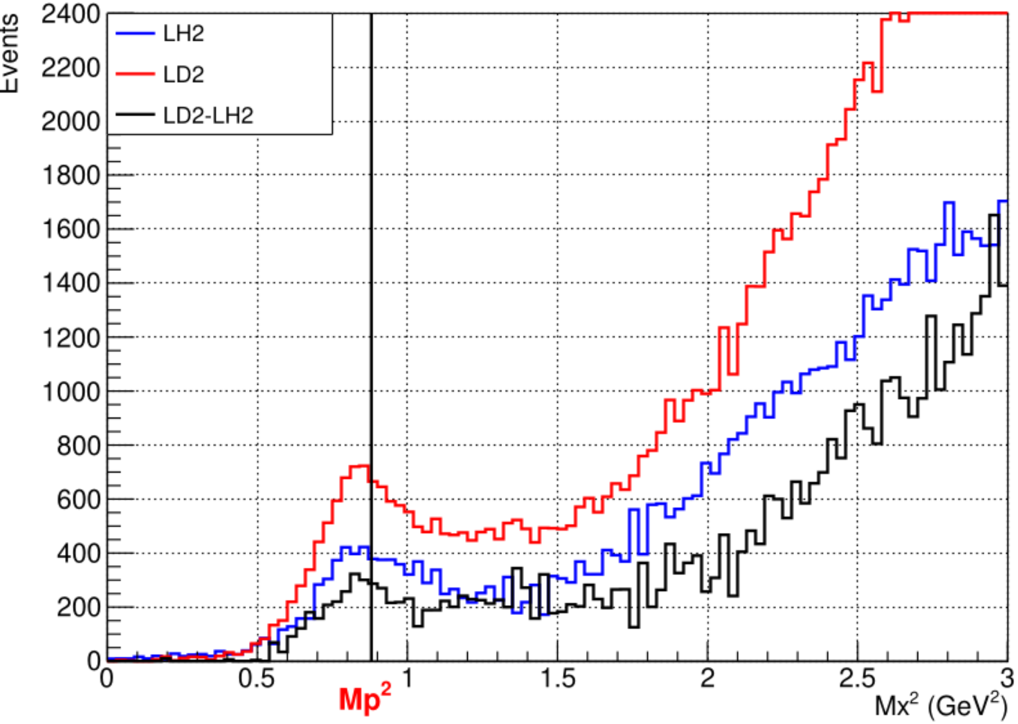
- **Waveform analysis is a crucial tool to extract the highest resolution possible obtained by the NPS calorimeter**

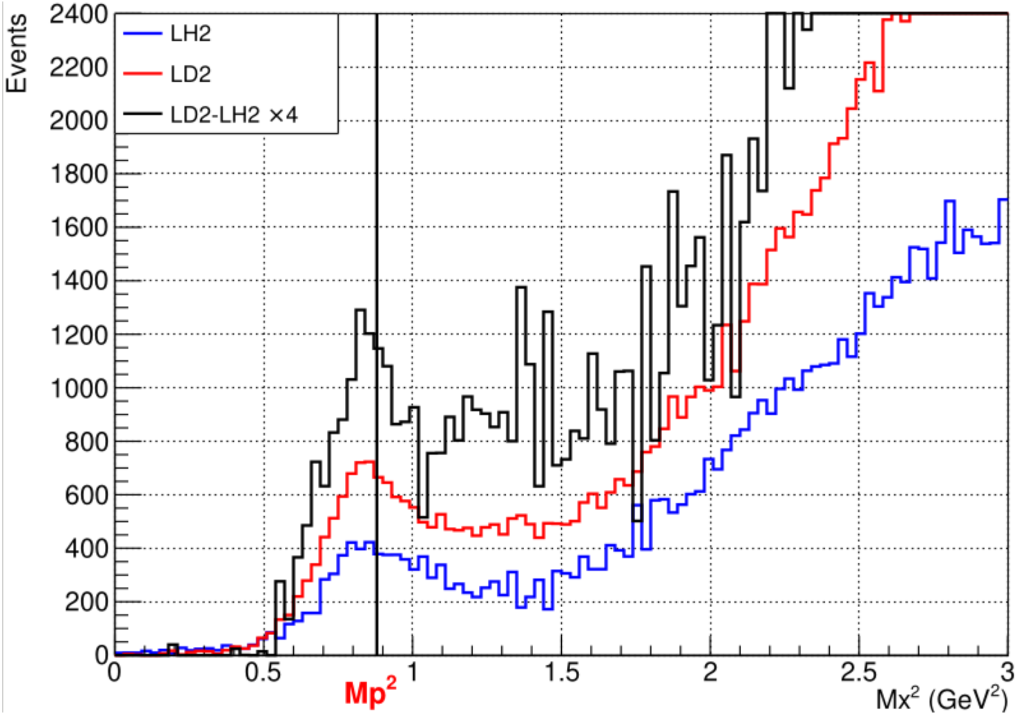
- **Better exclusivity and resolution than the previous DVCS experiments is already conducted**

- **More sophisticated analysis is ongoing...**

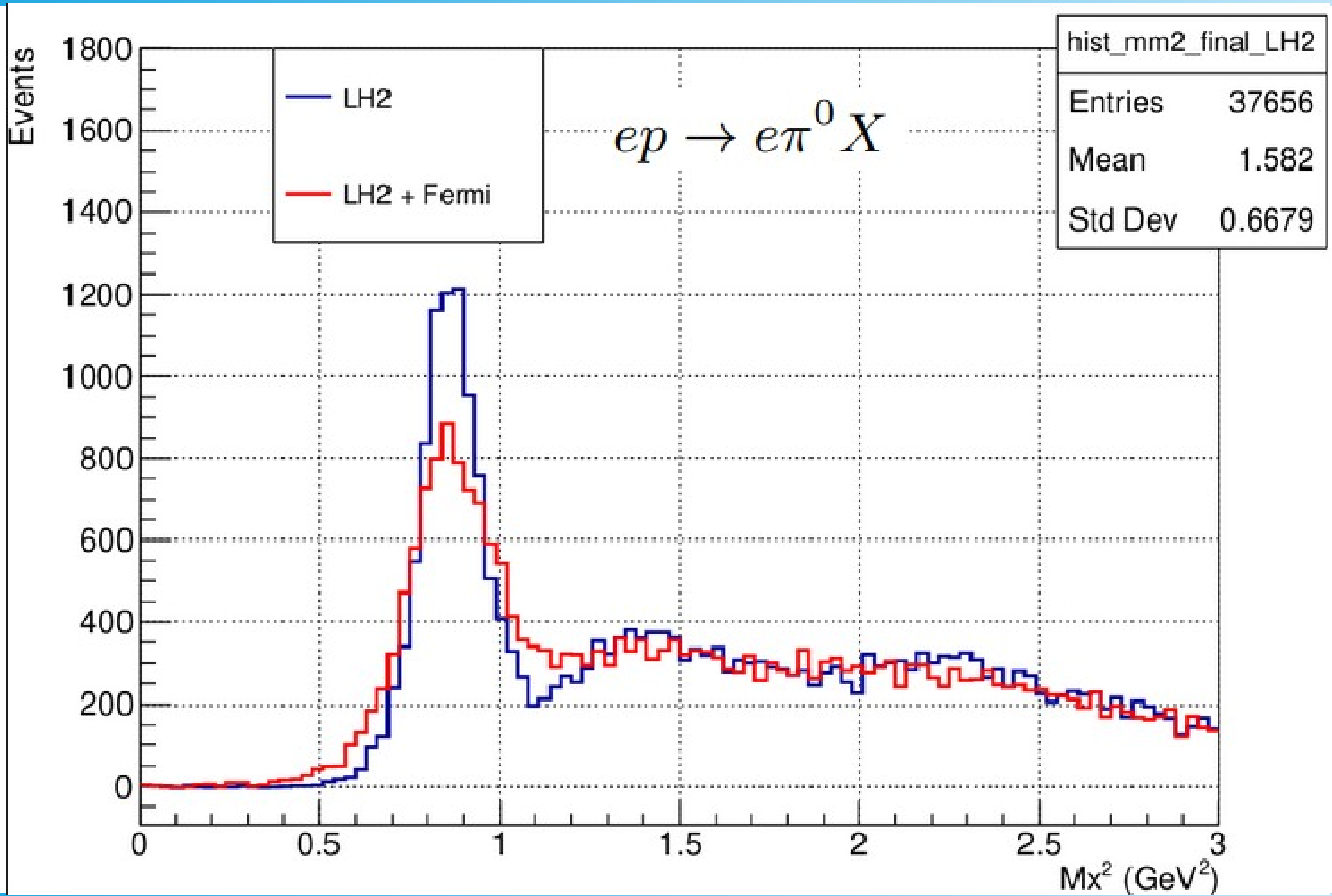
Back up Slides

DVCS with (0.72) correction



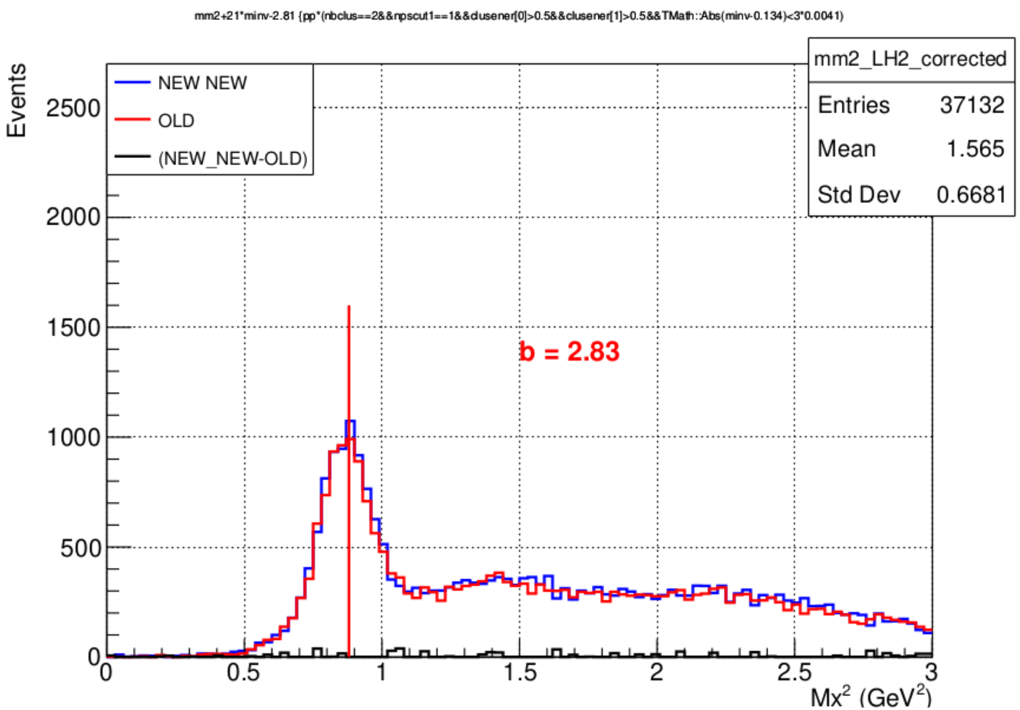


Fermi smearing effect

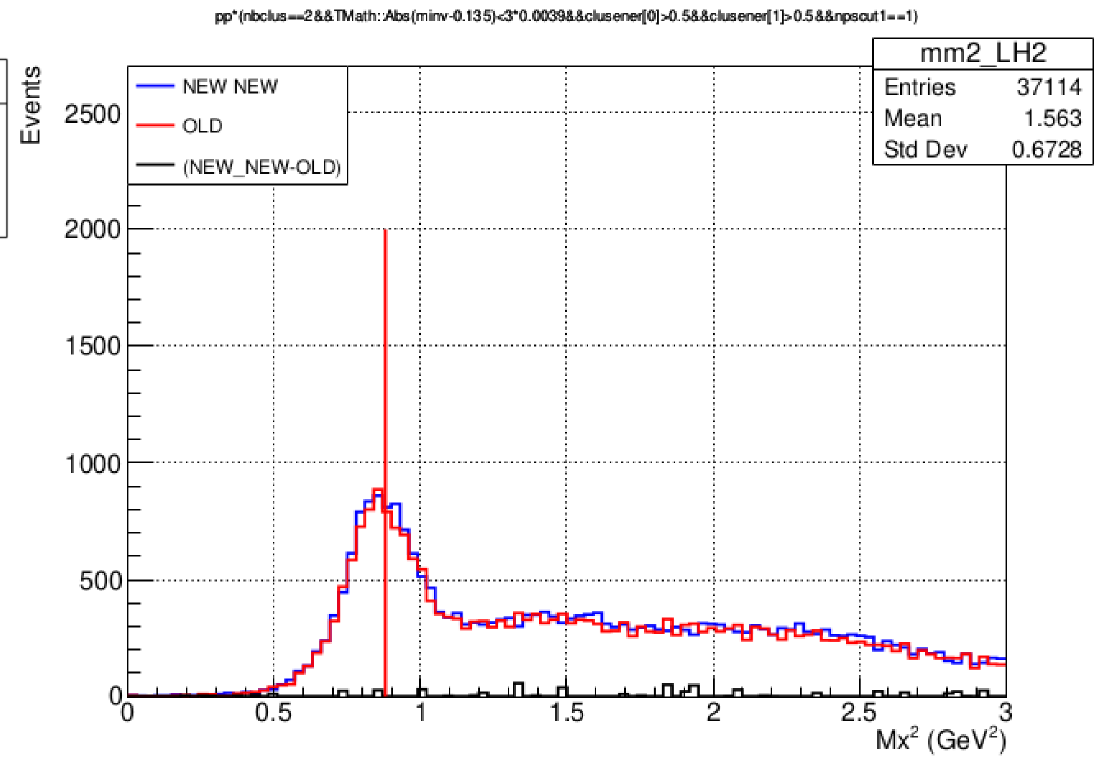


Comparison between old DVCS fermi smearing and the new method used

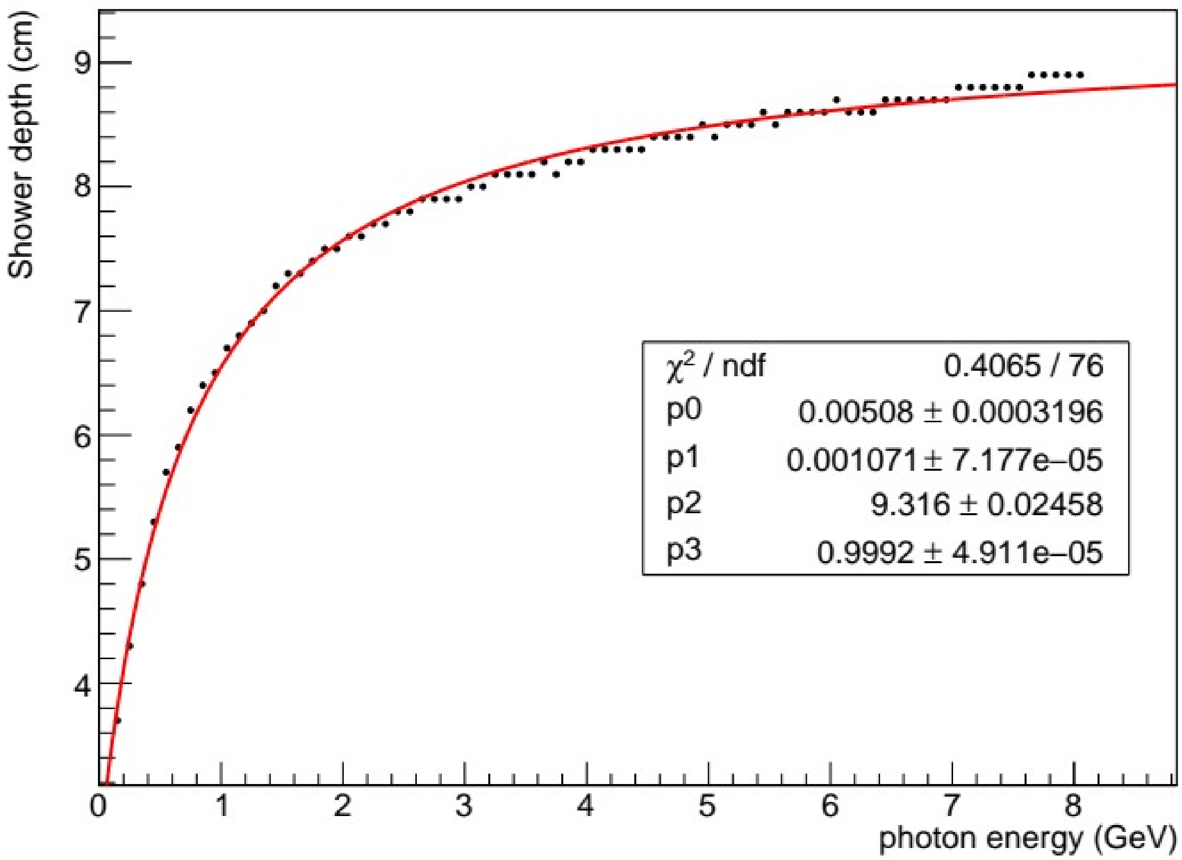
Corrected missing mass squared (GeV2)



Raw missing mass squared (GeV2)

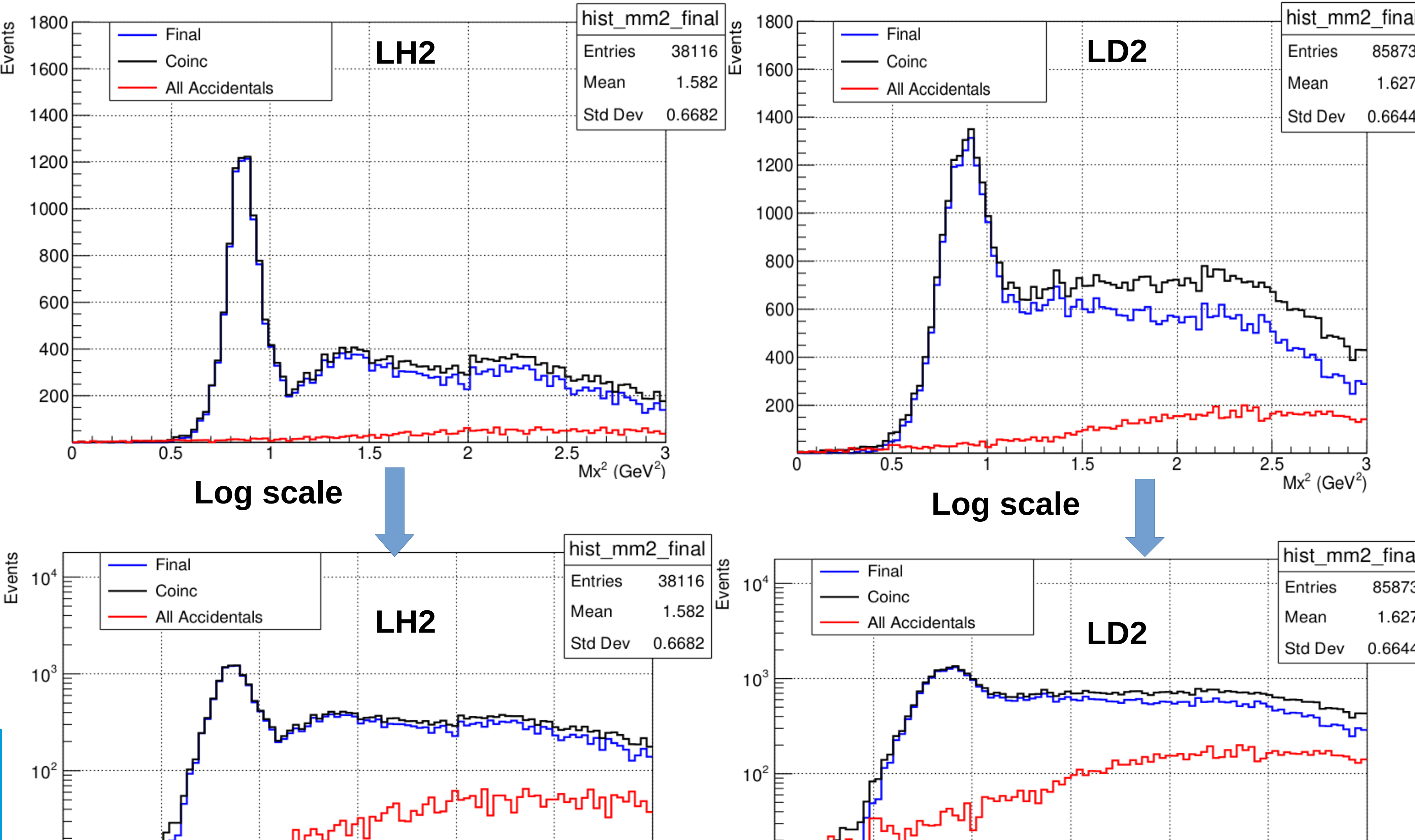


Shower depth correction

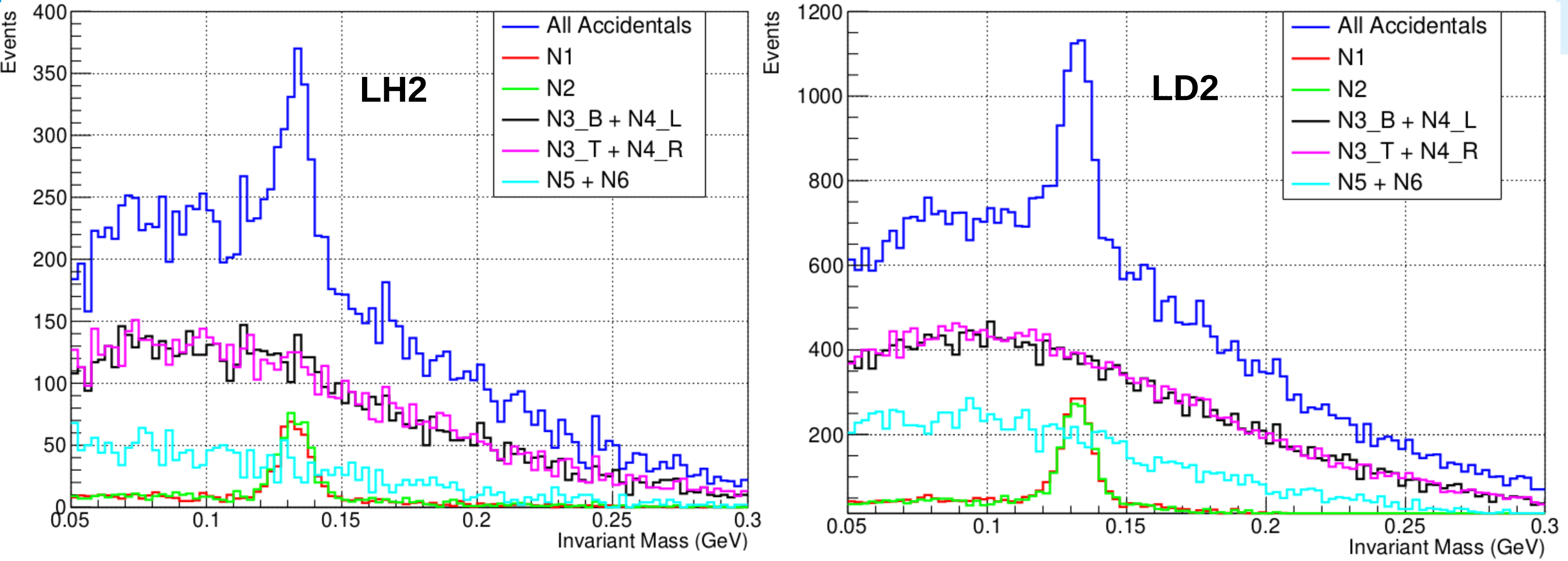


- **For each energy value, we determine "a" in such a way that the difference between the position xc (centroid position of the cluster) and x'c obtained by a Geante 4 simulation is centered around 0 and has the lowest RMS .**

Exclusive Pi0 Missing Mass Squared

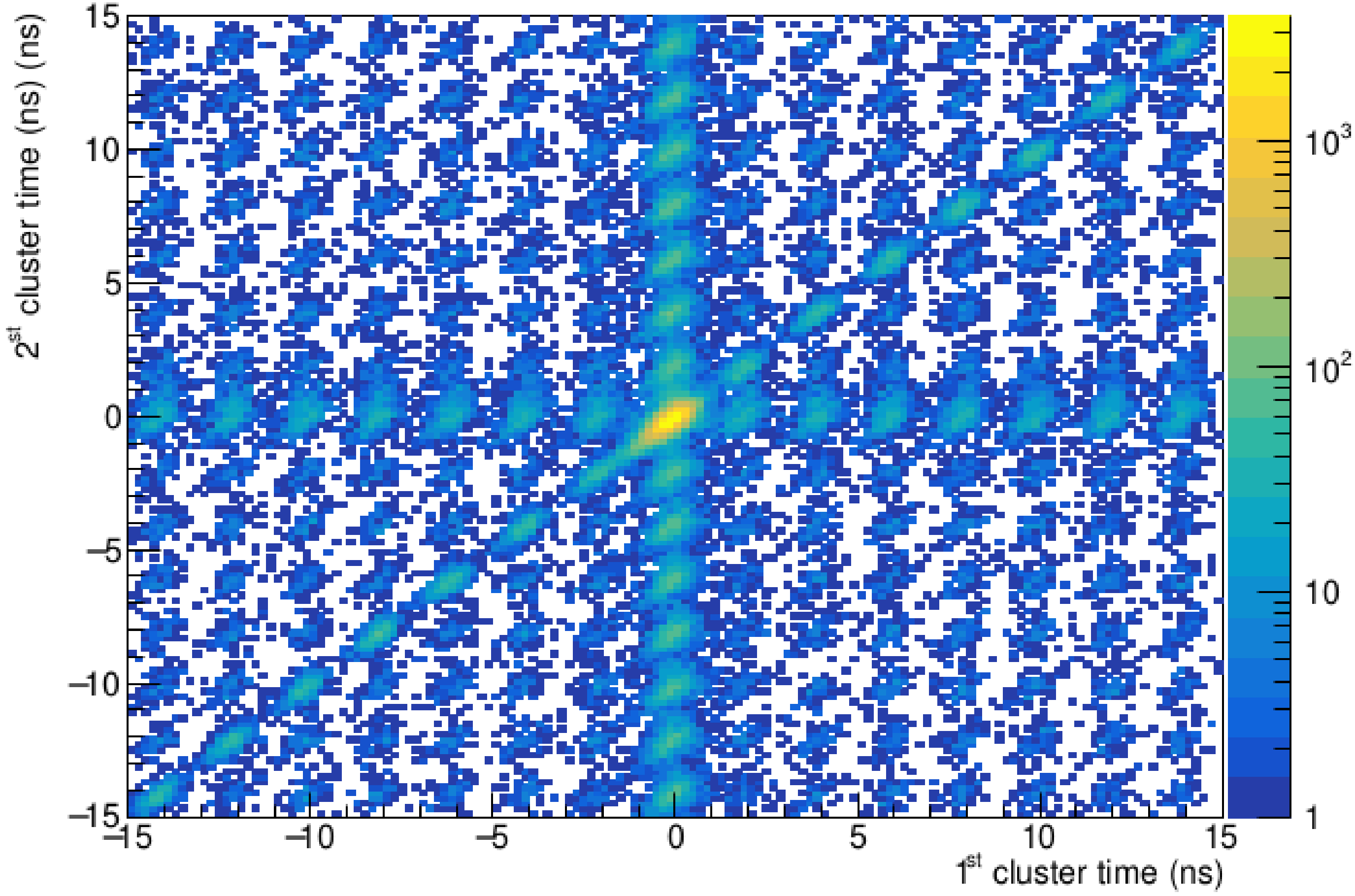


Exclusive Pi0 Invariant Mass

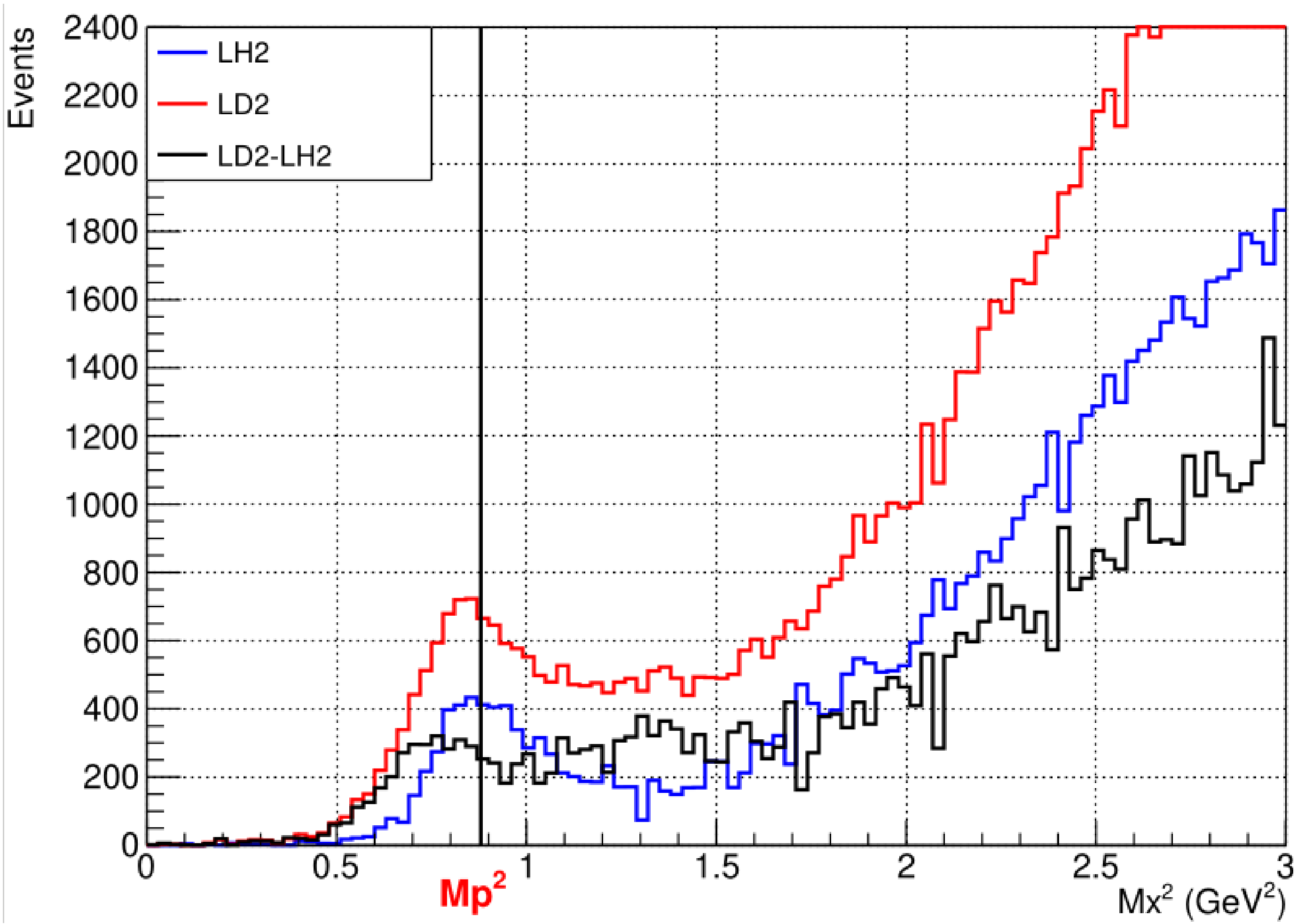


- **Red ==> N1**
- **Green ==> N2**
- **Black ==> N3_B (bottom) + N4_L (left)**
- **Pink ==> N3_T (Top) + N4_R (right)**
- **Sky Blue ==> N5 + N6**

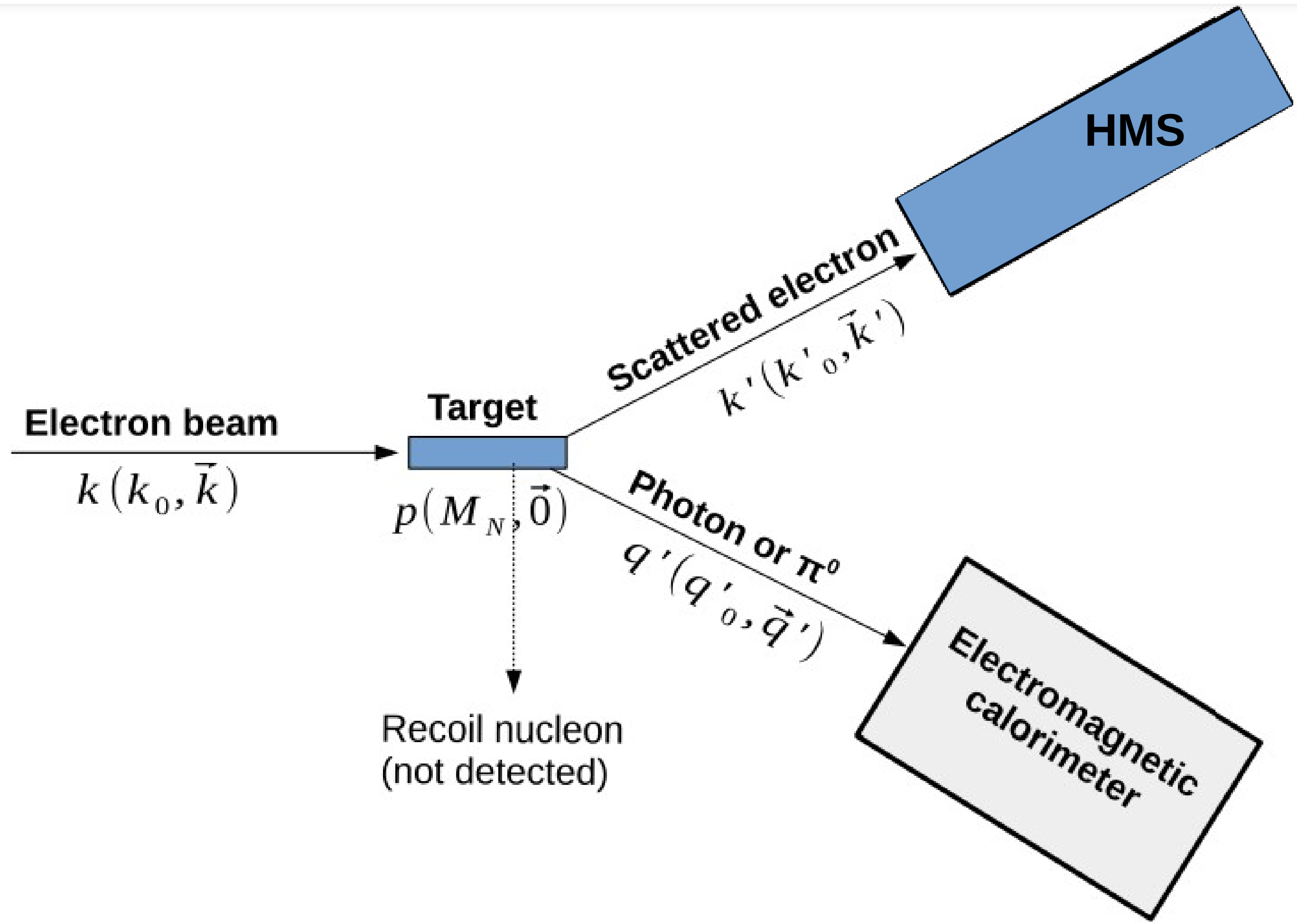
LD2 π0 ACCIDENTALS



DVCS missing mass squared with the factor 0.72 applied



π0 energy calibration



π0 energy calibration

Method:

$E_i'(j) = C_i' A_i(j)$ → $E_i(j) = \epsilon_i C_i' A_i(j) = \epsilon_i E_i'(j)$ With $C_i = \epsilon_i C_i'$ → Corrected calibration coefficient

- $E_i'(j)$: Deposited energy
- $E_i(j)$: Corrected Energy
- ϵ_i: Correction factor

1) Identification of $eN \rightarrow eN\pi^0$ reaction:

$|M_{\text{inv}} - M_{\text{peak}}| < 3\,\sigma_{M_{\text{inv}}}$ + $M_x^2 < M_{\text{peak}}^2 + \sigma_{M_x^2}$ → **2 main cuts applied**

$\sigma_{M_x^2}$: Missing mass squared resolution

With $M_{\text{inv}} = \sqrt{(q_1' + q_2')^2}$

2) Calculate the expected Pi0 energy:

$$M_N^2 = (k + p - k' - q_1' - q_2')^2 = (k + p - k')^2 + M_{\pi^0}^2 - 2(k_0 - k_0' + M_N)E_{\pi^0}^{\text{cal}} + 2\|\vec{q}\|\sqrt{(E_{\pi^0}^{\text{cal}})^2 - M_{\pi^0}^2}\cos\theta$$

Solution: $E_{\pi^0}^{\text{cal}} = \dfrac{-b + \sqrt{b^2 - 4ac}}{2a}$ **With**

$$a = 4(k_0 - k_0' + M_N)^2 - 4\|\vec{q}\|^2\cos^2\theta\,,$$

$$b = 4(k_0 - k_0' + M_N)\left[M_N^2 - (k - k' + p)^2 - M_{\pi^0}^2\right],$$

$$c = 4M_{\pi^0}^2\|\vec{q}\|^2\cos^2\theta + \left[M_N^2 - (k - k' + p)^2 - M_{\pi^0}^2\right]^2.$$

Mazouz, M. Energy calibration of laterally segmented electromagnetic calorimeters based on neutral pion detection. Nucl. Sci. Tech. 28, 155 (2017)

π0 energy calibration

3) Minimization:

- The following minimization between the calculated energy and the reconstructed one:

$$\chi^2 = \sum_{j=1}^{N_{\pi^0}} \left(E_{\pi^0}^{\mathrm{cal}}(j) - E_{\pi^0}^{\mathrm{rec}}(j)\right)^2$$

With N_{π^0} → Number of Pi0 events

$$E_{\pi^0}^{\mathrm{rec}}(j) = \sum_{i=1} \epsilon_i E'_i(j) d_i(j)$$ → Reconstructed energy

- We get the following linear set of equations:

$$\sum_{i=1} \left[\sum_{j=1}^{N_{\pi^0}} E'_i(j) d_i(j) E'_k(j) d_k(j)\right] \epsilon_i = \sum_{j=1}^{N_{\pi^0}} E_{\pi^0}^{\mathrm{cal}}(j) E'_k(j) d_k(j)$$

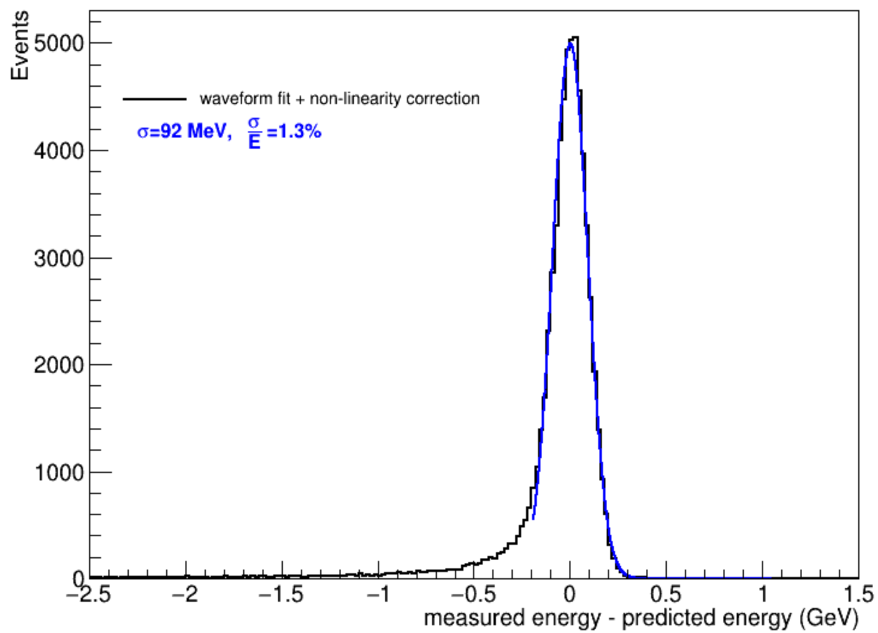
- The correction factors are obtained by inverting the following matrix:

$$\alpha_{ik} = \sum_{j=1}^{N_{\pi^0}} E'_i(j) d_i(j) E'_k(j) d_k(j)$$

Mazouz, M. Energy calibration of laterally segmented electromagnetic calorimeters based on neutral pion detection. Nucl. Sci. Tech. 28, 155 (2017)

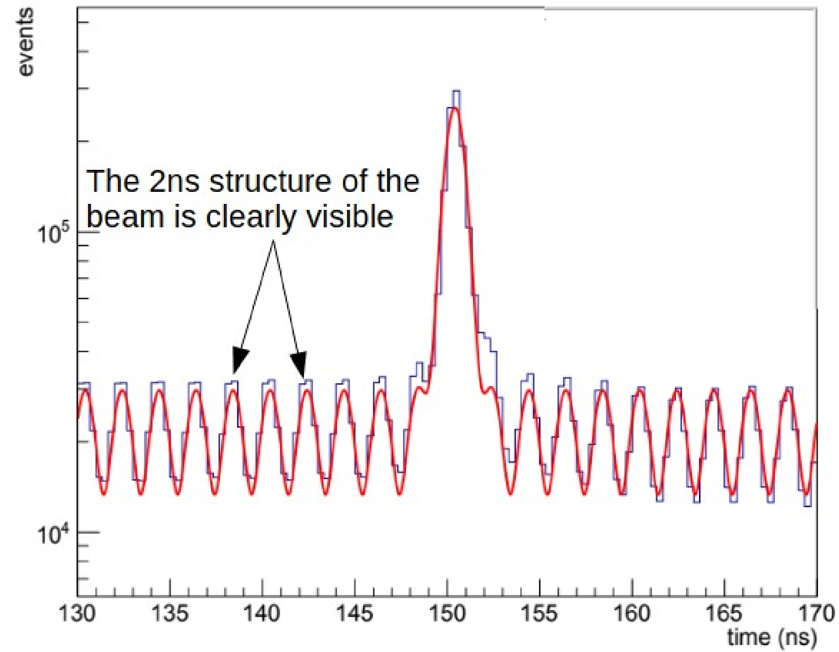
Detector Performance

Energy Resolution



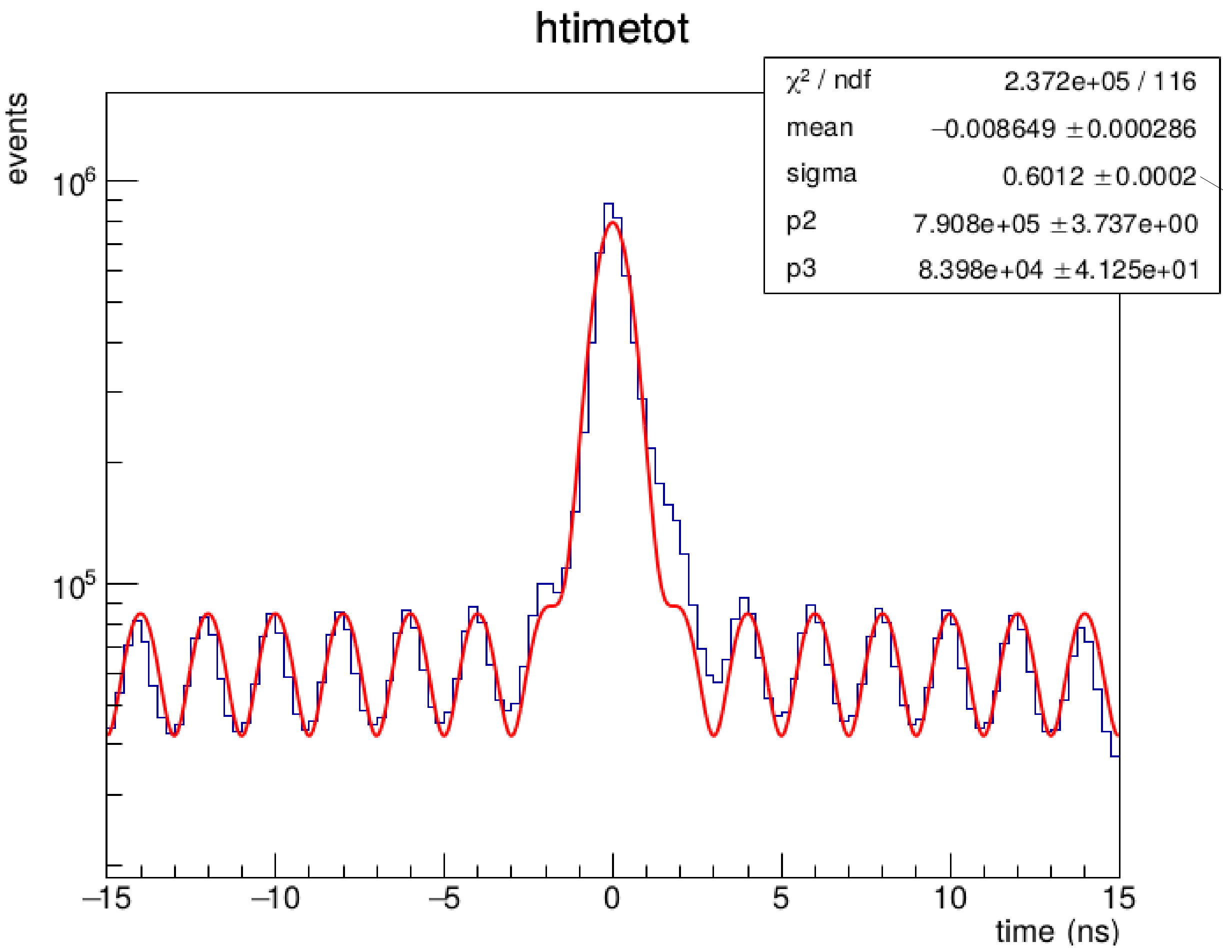
- **1.3% energy resolution at 7.3 GeV from elastic $\mathrm{H}(\mathrm{e},e'_{Calo}p_{HMS})$ calibration run, applying waveform analysis and a non linearity correction**

Time Resolution



- **A very good timing resolution (0.58 ns) is recorded**

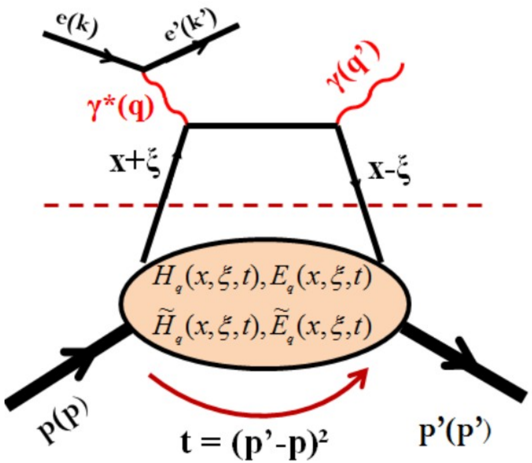
TIME RESOLUTION STUDY
(LD2+LH2 RUNS COMBINED)



0.6 ns resolution

From DVCS to GPDs

- **Factorization in Bjorken limit**



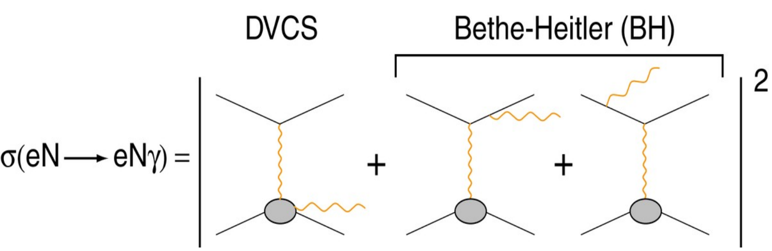
Handbag Diagram

Hard scattering process (Perturbative calculation)

PQCD factorization theorem

Soft process (non Perturbative calculation)

$$H^q, E^q, \widetilde{H}^q, \widetilde{E}^q(x,\xi,t)$$

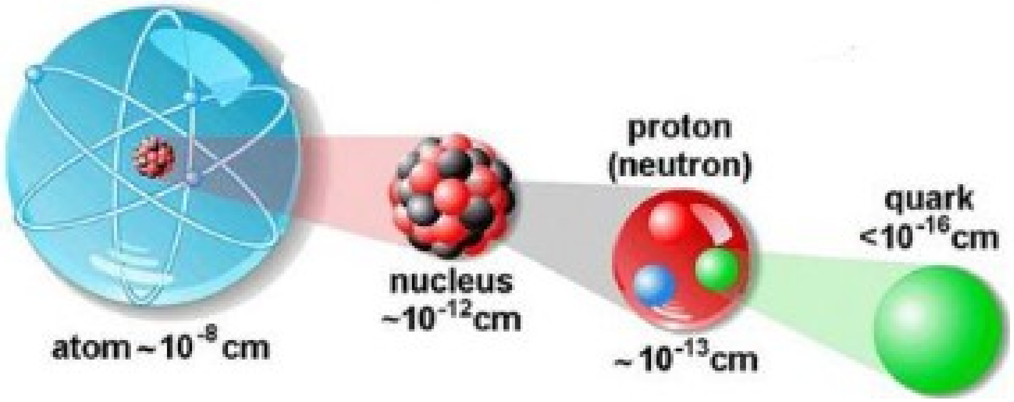


$$|\mathcal{T}|^2 = (\mathcal{T}_{DVCS} + \mathcal{T}_{BH})^2 = |\mathcal{T}_{BH}|^2 + |\mathcal{T}_{DVCS}|^2 + \mathcal{I}$$

$$\Im m(\mathcal{T}_{DVCS}) \propto -i\pi \left(GPD(\xi,\xi,t) \pm GPD(-\xi,\xi,t) \right)$$

$$\Re e(\mathcal{T}_{DVCS}) \propto P \int_{-1}^{1} dx \left(\frac{1}{x-\xi} \pm \frac{1}{x+\xi} \right) GPD(x,\xi,t)$$

Spin Crisis



Spin of all Quarks

½ =  ???

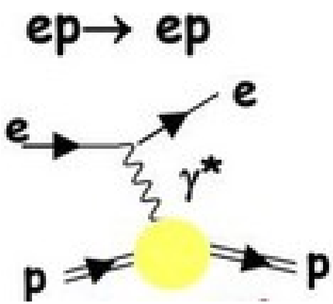
$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_Q + L_G$$

Orbital momentum of the quarks and gluons

Quarks contribution (u,d,s)

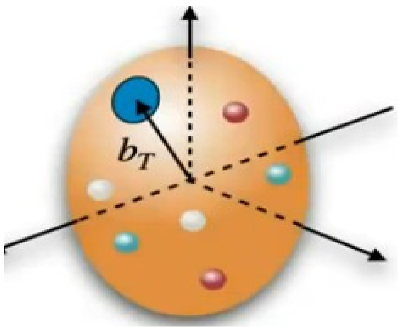
Gluons contribution

3D STRUCTURE OF THE NUCLEON

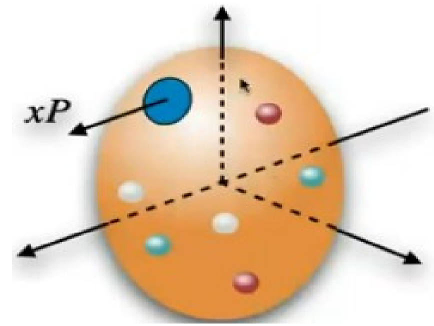


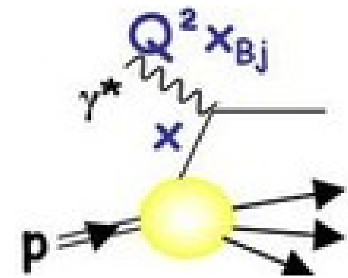
Elastic Scattering
(ep)

Form Factors

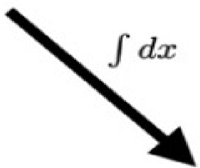


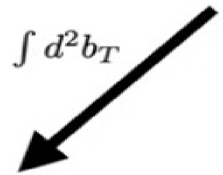
Partons Distribution Functions



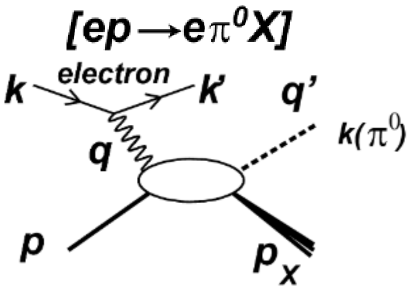


Deep Inelastic scattering
(DIS)

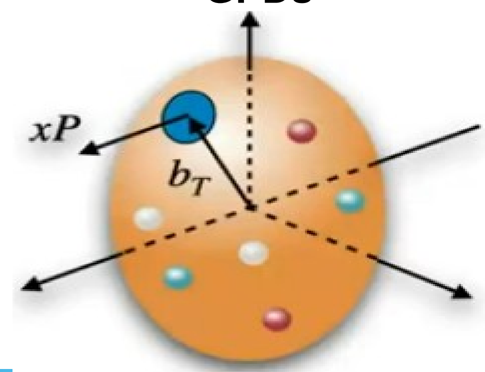




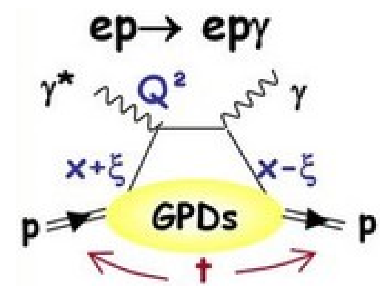
Exclusive Pi0 Meson
Electroproduction
(DVMP)



GPDs



Deeply Virtual Compton
Scattering
(DVCS)



Wigner Distributions and GPDs

General formalism for a quantum system

$$W(r,p) = \int_{-\infty}^{+\infty} dz e^{ipz} \psi^*(r - z/2)\psi(r + z/2)$$

Wigner Distribution

For the case of relativistic quarks and gluons

Dirac Matrix

$$W_\Gamma^q(r,k) = \frac{1}{2M}\int \frac{d^4q}{(2\pi)^4} < p'|\mathcal{W}_\Gamma^q(r,k)|p >$$

$$\mathcal{W}_\Gamma^q(r,k) = \int d^4z e^{ikz} \bar{\psi}^q(r - z/2)\Gamma\psi^q(r + z/2)$$

In the infinite momentum reference frame

$$F_\Gamma^q(P,x,\Delta) = \frac{P^+}{4\pi}\int dz^- e^{ixP^+z^-} < p'|\bar{\psi}(-z/2)\Gamma\psi(z/2)|p > |_{z^+=\vec{z}_\perp=0}$$

$$F^q_{\gamma^+}(x,\xi,t) = H^q(x,\xi,t)\bar{U}(p')\gamma^+U(p) + E^q(x,\xi,t)\bar{U}(p')\sigma^{+\nu}\frac{\Delta_\nu}{2M}U(p)$$

$$F^q_{\gamma^+\gamma^5}(x,\xi,t) = \tilde{H}^q(x,\xi,t)\bar{U}(p')\gamma^+\gamma^5U(p) + \tilde{E}^q(x,\xi,t)\bar{U}(p')\gamma^5\frac{\Delta^+}{2M}U(p)$$

Particle with S = 1/2

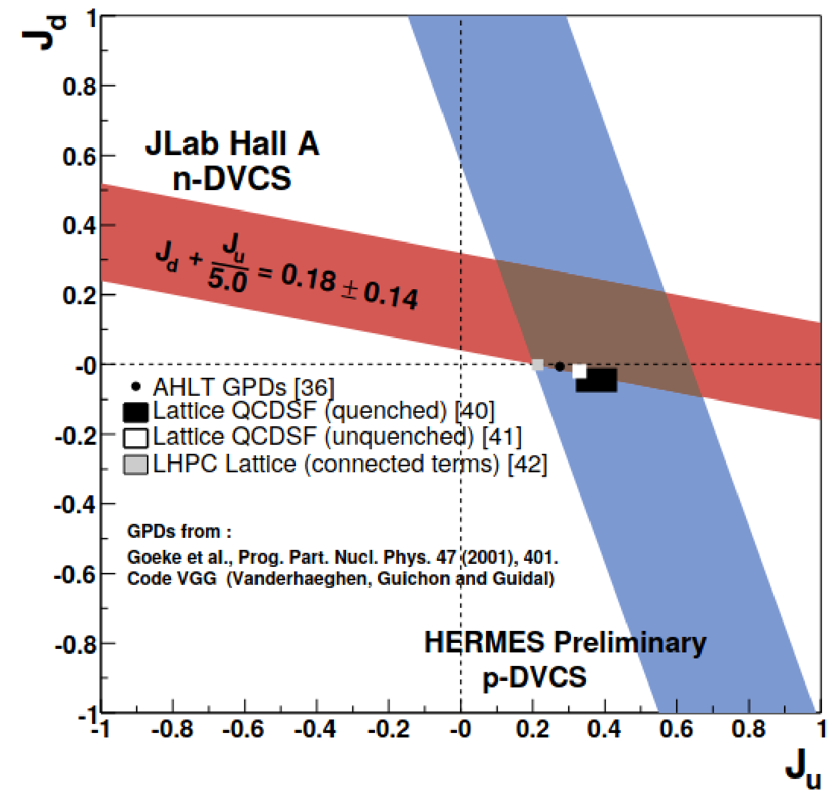
DVCS on the neutron

- Using the **Approximate isospin symmetry of QCD** we obtain the simplest way to perform a **flavor decomposition** of the **u** and **d** quark GPDs:

$$H^p = \frac{4}{9}H^u + \frac{1}{9}H^d \qquad H^n = \frac{1}{9}H^u + \frac{4}{9}H^d$$

- The **unpolarized** "n-DVCS" cross sections at **low t** have a direct relevance in the determination of the quark angular momentum via **Ji's sum rule**:

$$J^q = \frac{1}{2}\int_{-1}^{1} x dx [H^q(x,\xi,t=0) + E^q(x,\xi,t=0)] \quad \forall\xi$$



Mazouz et al. Physical review letters, 99(2007), 242501

n-DVCS and d-DVCS seperation
(Hall A results and upcoming steps)

- **Exclusive events are obtained with the missing mass technique after the subtraction of accidentals and the neutral pion contamination:**

Coherent elastic channel

incoherent quasi-elastic channels

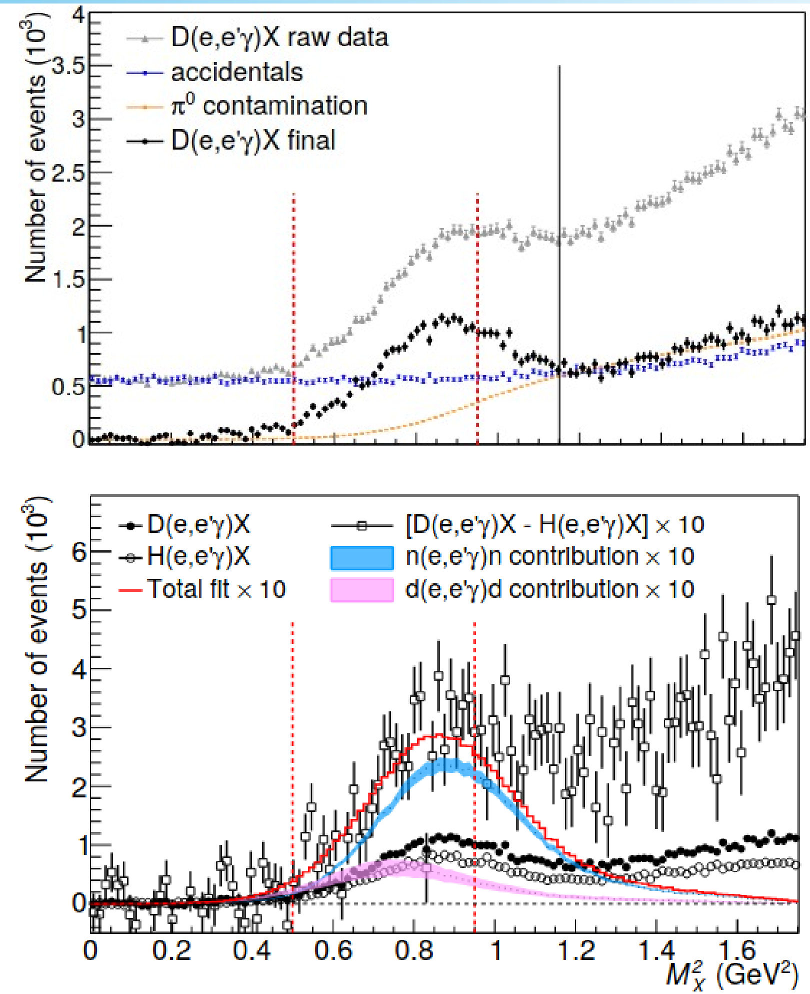
$$D(e,e'\gamma)X = d(e,e'\gamma)d + n(e,e'\gamma)n + p(e,e'\gamma)p$$

2 terms separated by missing mass

$$\Delta M_X^2 = t(1 - M_n/M_d) \approx t/2$$

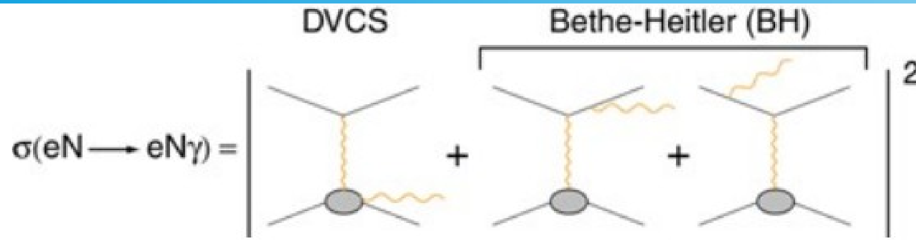
Subtracted from the LH2 data interleaved

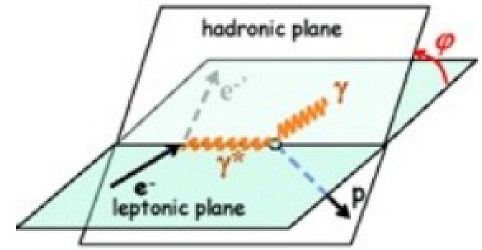
- **Separation between incoherent n(e,e'ɣ)n and coherent d(e,e'ɣ)d can be achieved with a fit of the exclusive region of the missing mass spectrum**



Benali et al. Nat Phys 16 (2020) 191

DVCS Cross Section





But using a polarized electron beam: **Asymmetry appears in Φ**

$$d^5\vec{\sigma} - d^5\overleftarrow{\sigma} \approx 2\,\mathrm{Im}(T^{BH}.T^{DVCS}) + \left[\left|\vec{T}^{DVCS}\right|^2 - \left|\overleftarrow{T}^{DVCS}\right|^2\right]$$

The **cross-section difference** accesses the Imaginary part of DVCS and therefore **GPDs at x=ξ**

Purely real and **fully calculable**

Small at Jlab enegies

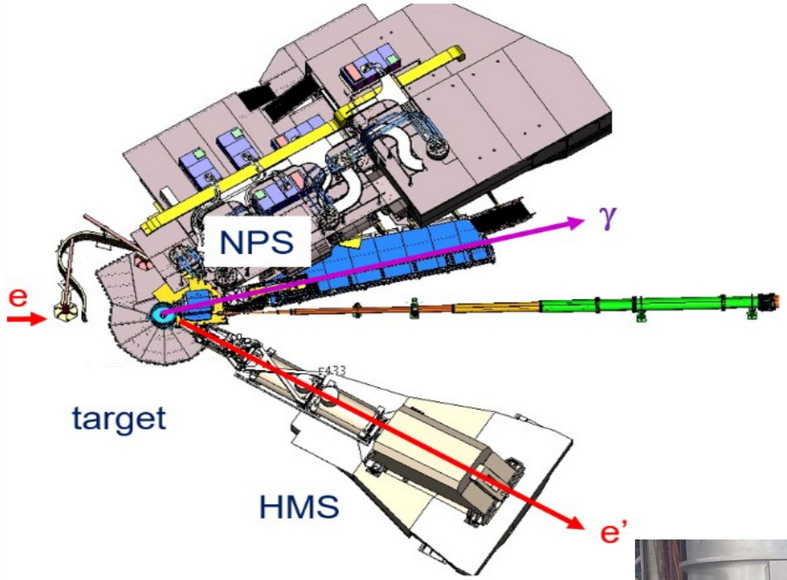
$$d^5\sigma \approx \left|T^{BH}\right|^2 + 2T^{BH}.\mathrm{Re}(T^{DVCS}) + \left|T^{DVCS}\right|^2$$

The **total cross-section** accesses the real part of DVCS and therefore an **integral of GPDs over x**

Kroll, Guichon, Diehl, Pire …

Experimental Setup

- The photon will be collected by the NPS **lead tungsten** calorimeter
- The **scattered electron** will be detected in the **HMS**
- The **recoil** particle off the LH2/LD2 target will be identified by **missing mass**



n-DVCS Kinematics

Data Taken in 2023

x_Bj	Kinematic Setting	Pass	Q2 (GeV^2)
0.36	KinC_x36_3	5	3.0
	KinC_x36_5	5	4.0
	KinC_x36_2	4	3.0
0.50	KinC_x50_2	5	3.4
	KinC_x50_3	5	4.8
	KinC_x50_1	4	3.4
0.6	KinC_x60_3	5	5.1
	KinC_x60_2	4	5.1

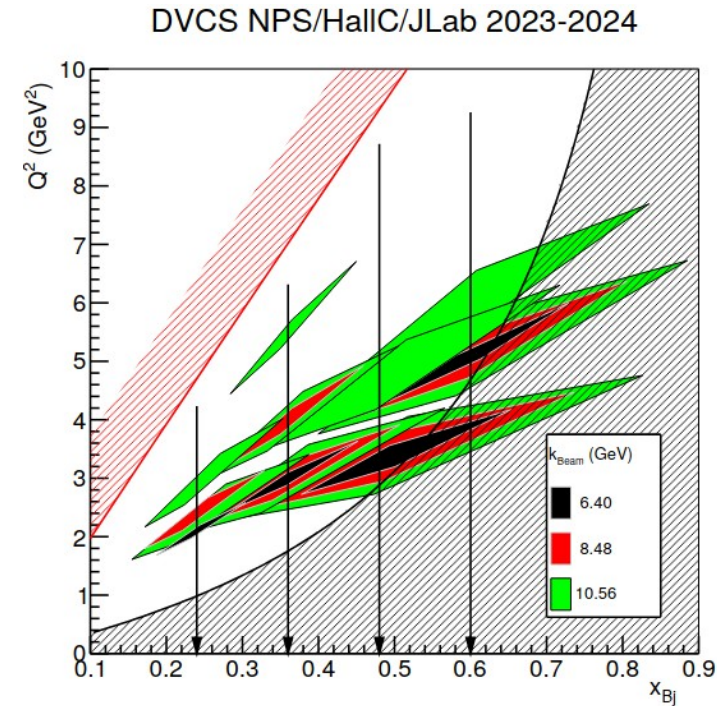
Data taken in 2024

x_Bj	Kinematic Setting	Pass	Q2 (GeV^2)
0.25	KinC_x25_1	5	2.1
	KinC_x25_2	5	2.4
	KinC_x25_3	4	2.4
	KinC_x25_4	3	3.0
0.36	KinC_x36_6	5	5.5
	KinC_x36_4	4	4.0
	KinC_x36_1	3	3.0
0.5	KinC_x50_0	3	3.4
0.6	KinC_x60_4	5	6.0
	KinC_x60_1	3	5.1

- **High xbj --> high |t| --> better separation**

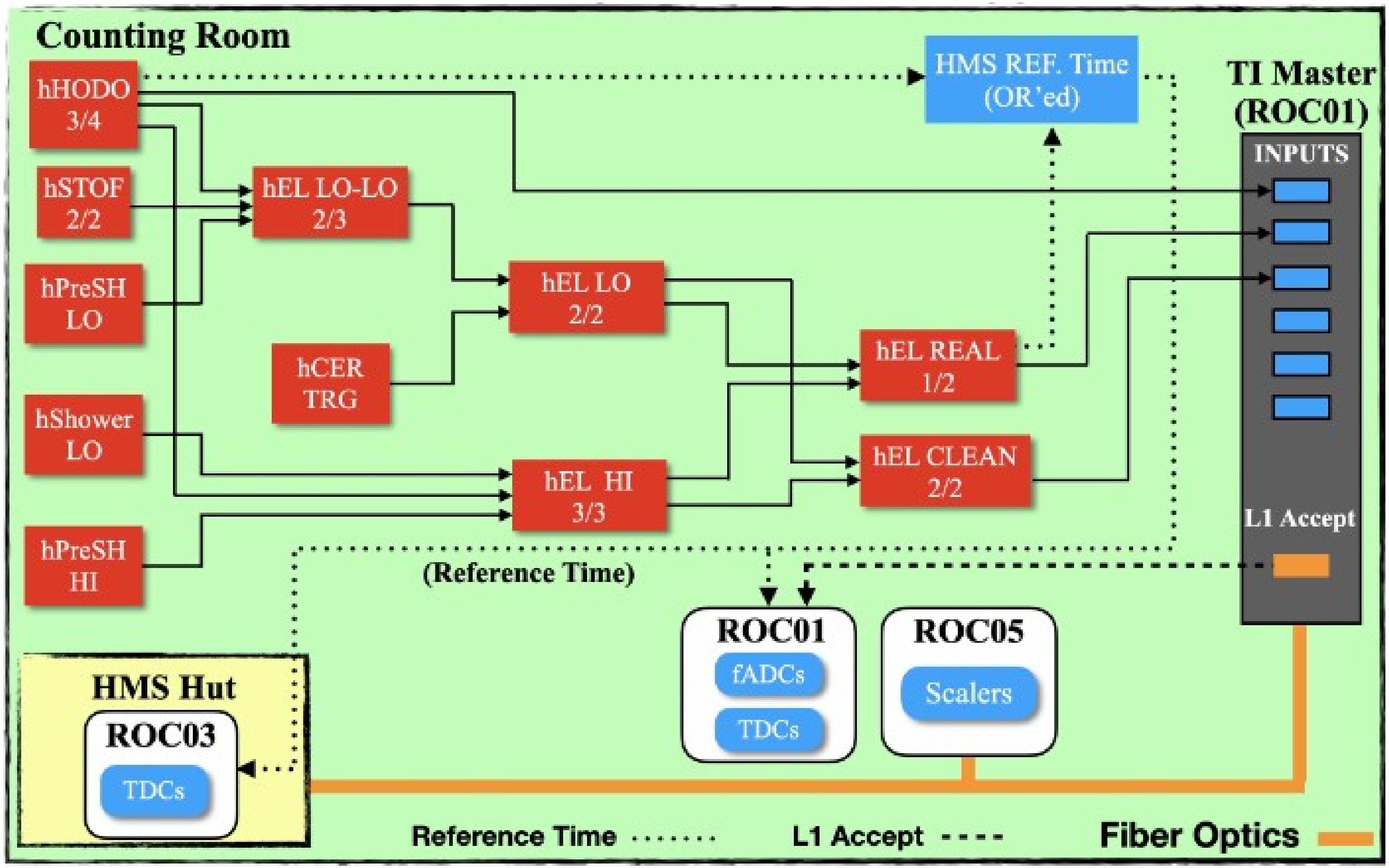
- **Different beam energies that will further give a better extraction of the different CFFs from the DVCS cross sections**

- **To reduce systematic uncertainties, LH2 and LD2 run periods are interleaved frequently (every few hours)**



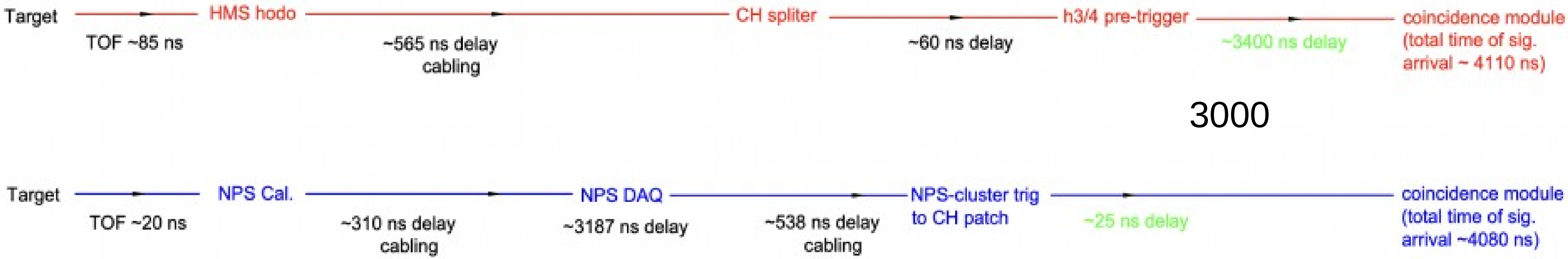
- **Sharp drop of the deuteron form factors as |t| increases**

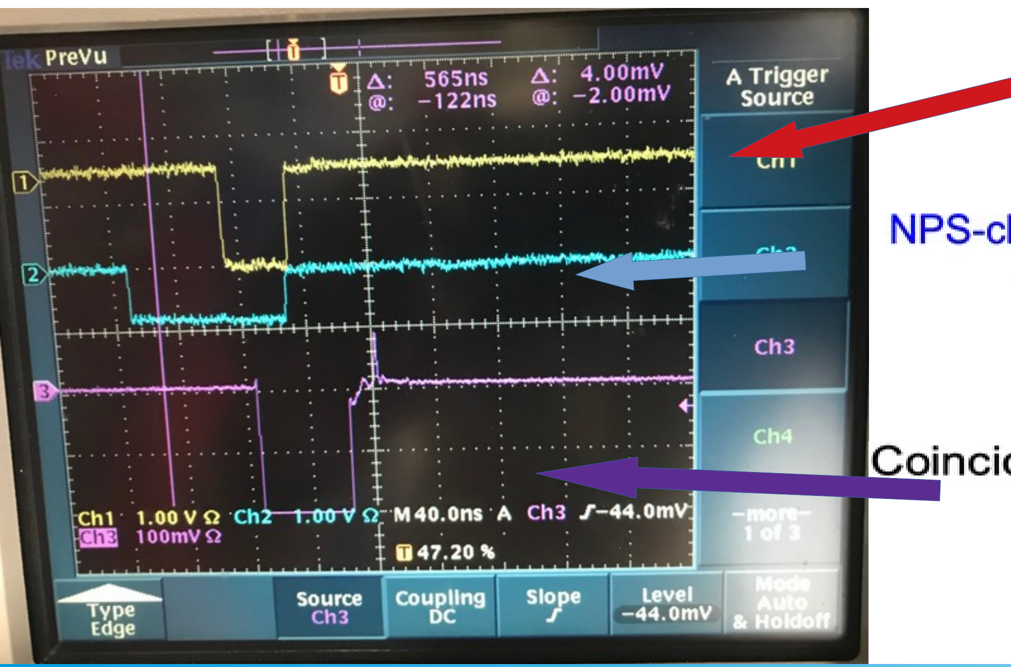
HMS Single Arm Pre-Trigger

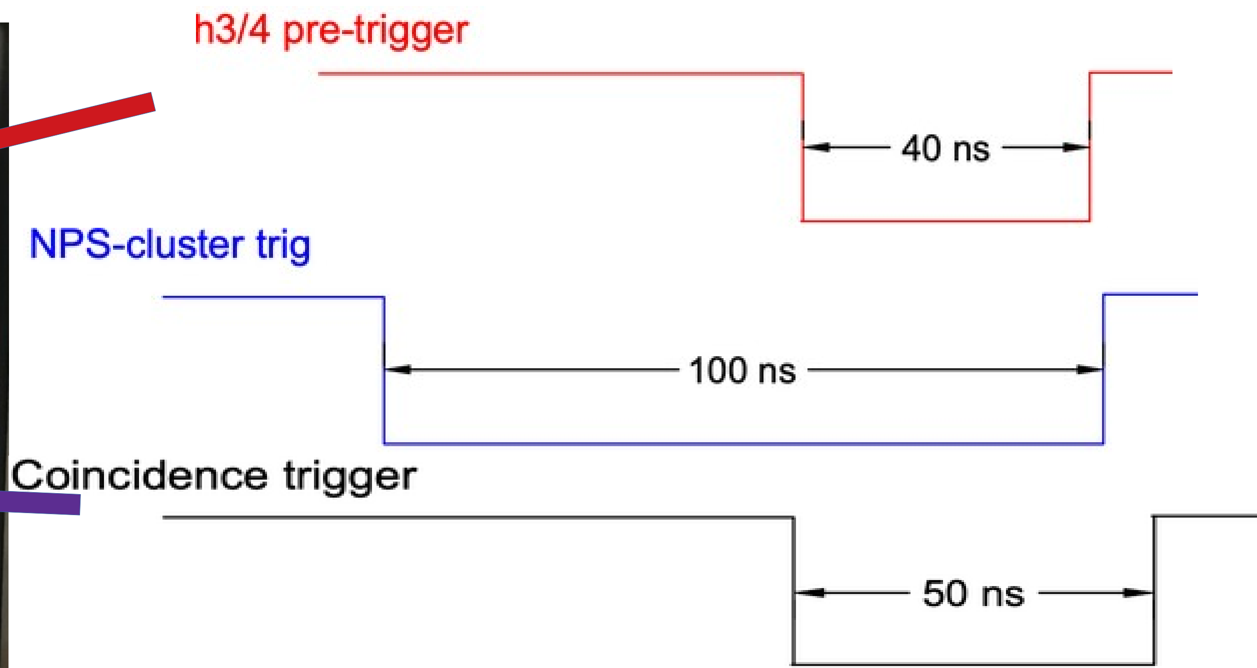


Credits to C.Yero

NPS/HMS Coincidence

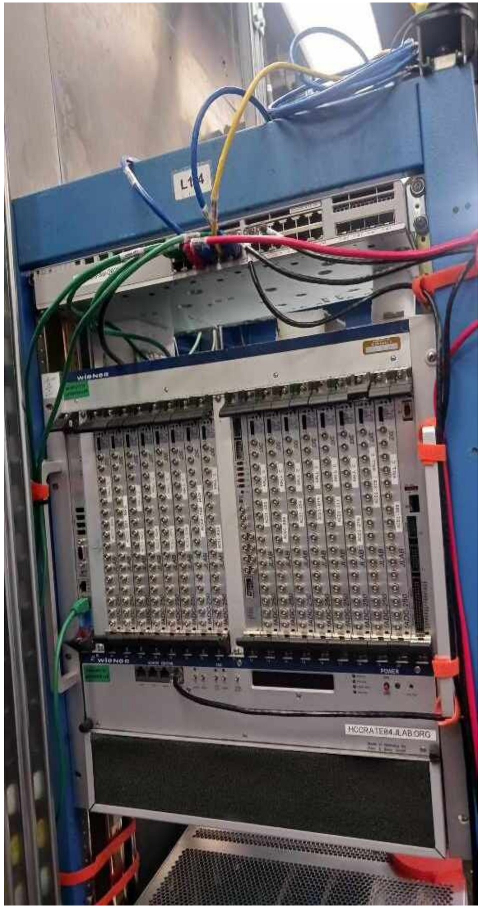






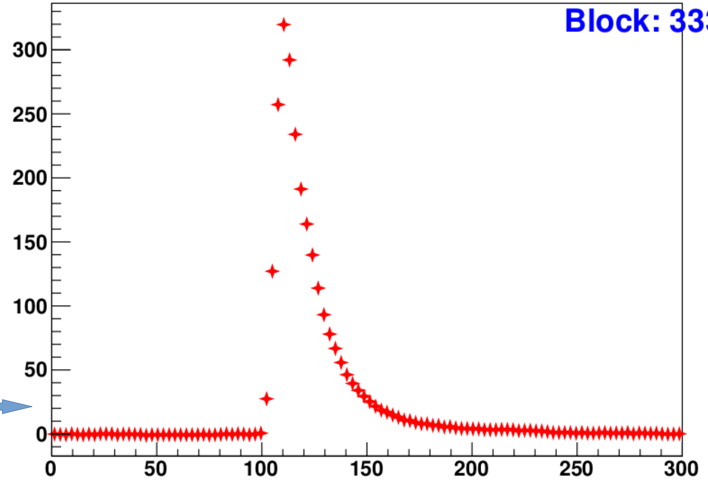
Credits to B.Michaels, J.Poudel, B.Raydo, C. Ghosh, Y. Zhang

How do we store the waveforms?



Data always streamed every 4 ns to the VTP

PEDESTAL
+
FADC
Threshold

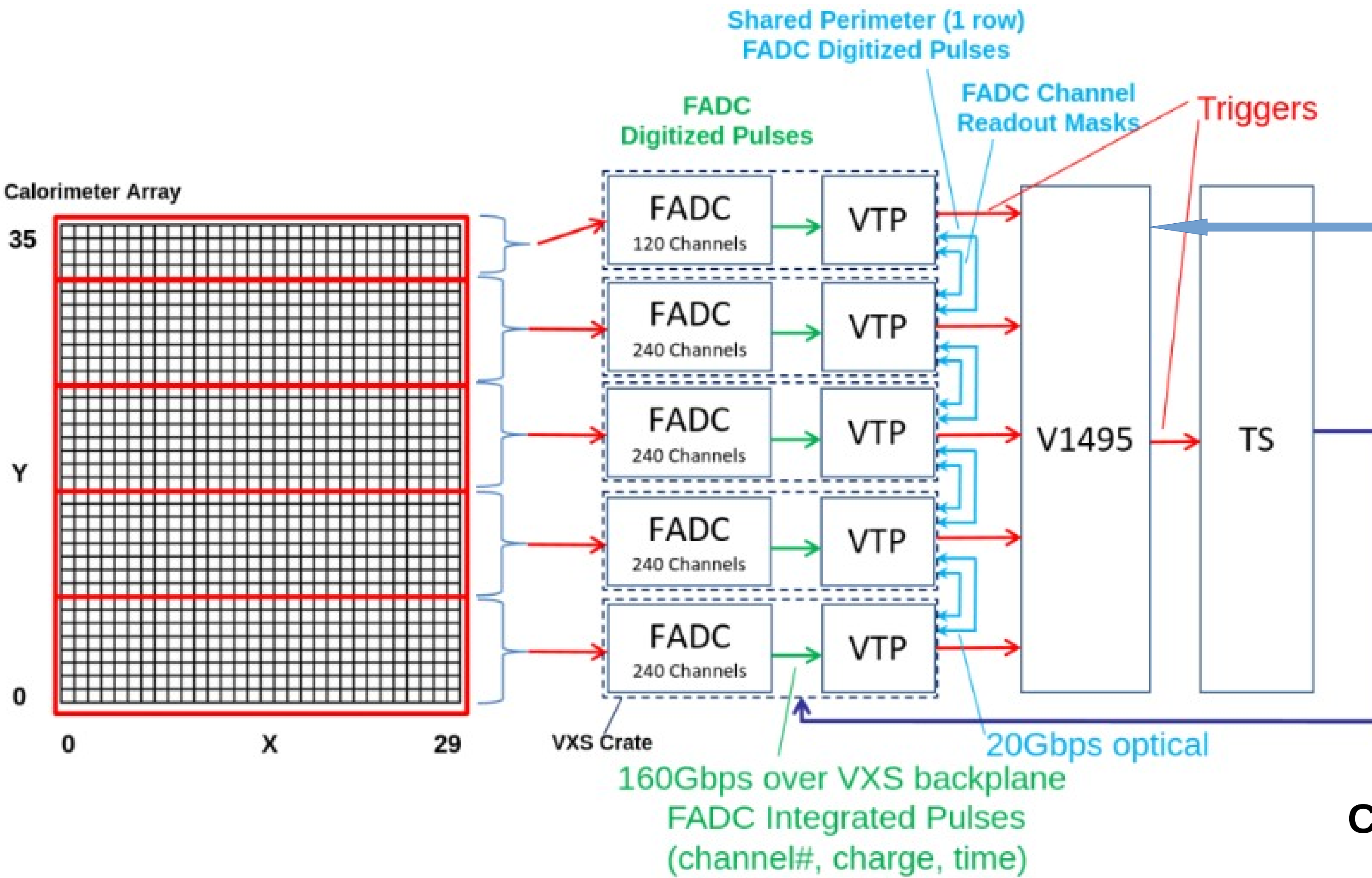


If sample > PEDESTAL+ Threshold ==>> HIT detected in the FADC

FADC computes the integral+ PED substraction + Gain applied ==>> Energy in MeV (13 bit) streamed to the VTP

Data Acquisition and electronics

- **Flash Analog to Digital Converter (FADC)**
- **VXS Trigger Processor (VTP)**



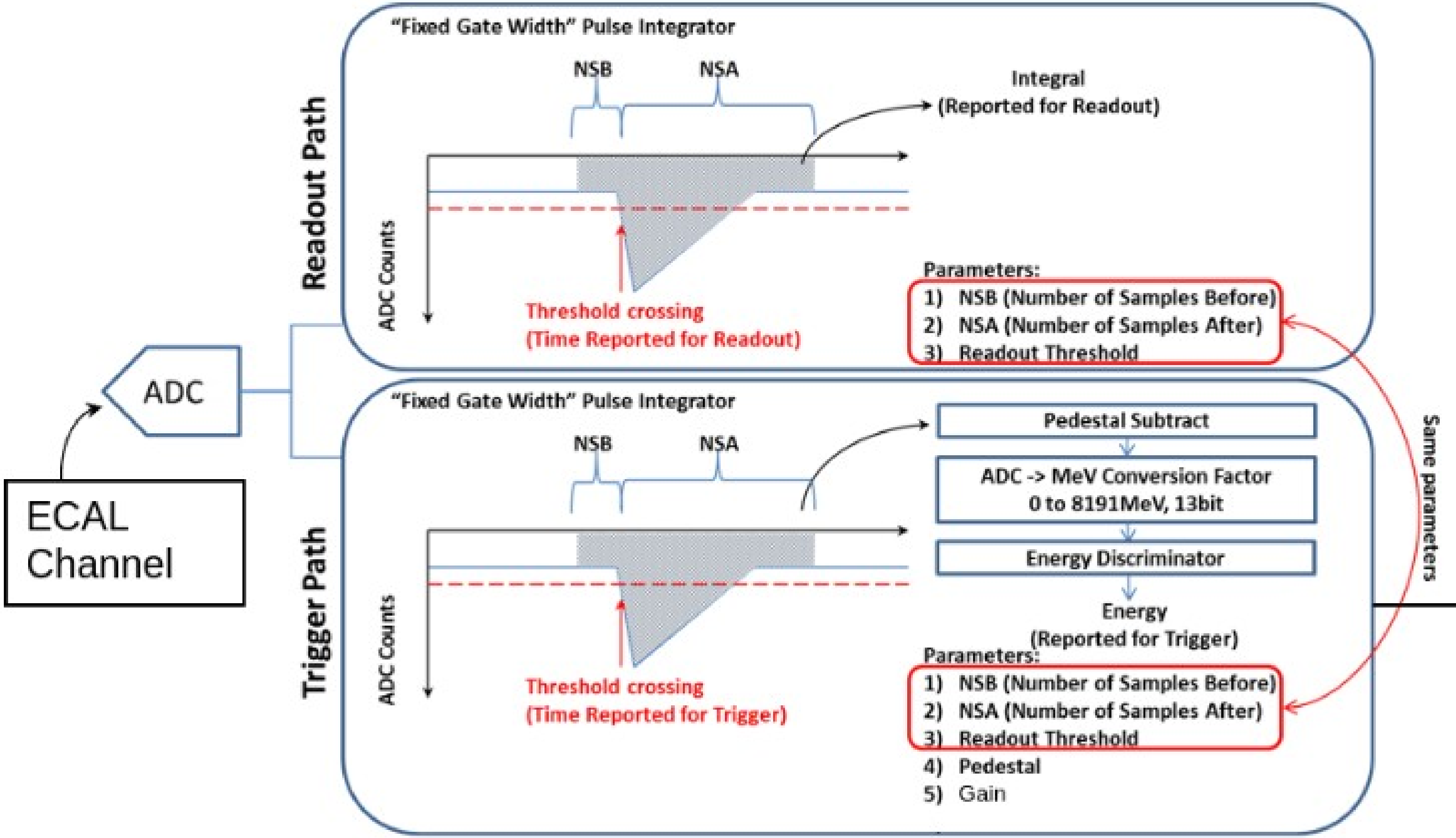
- **Compatible mezzanine connector exists that allow use of commercially available ECL/TTL/NIM/ADC/DAC modules**

L1A trigger latency estimated around 1μs

- Clustering of all views happens in parallel in about 64ns
- Most of the delay is in transporting information across the serial links
- L1A latency doesn't include additional delays due to TS->TI cable delays/latency settings

Credits to Ben Raydo

FADC Data Stream



Reports to VTP:

- 13bit energy (in MeV)
- 4ns timing
- Channel number
- 32ns double pulse resolution

Cluster Trigger

- **Single photon cluster trigger (S.P.T):**

1) The first Basic Steps by the VTP

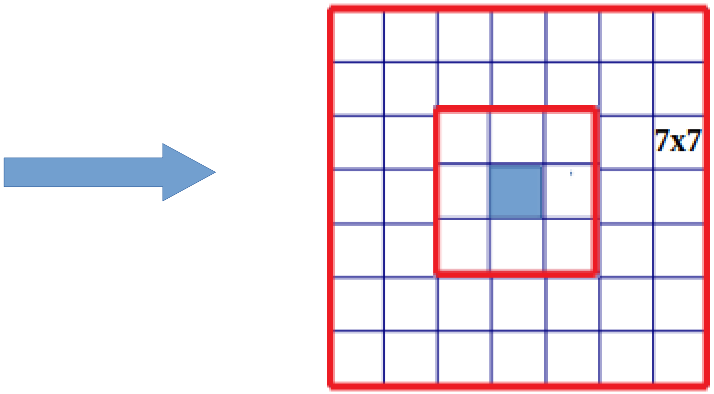
2) The Cluster Energy Is Above The S.P.T (1400 MeV)

==>> We have a DVCS cluster in hand

3) Readout threshold energy (500 MeV) is applied:

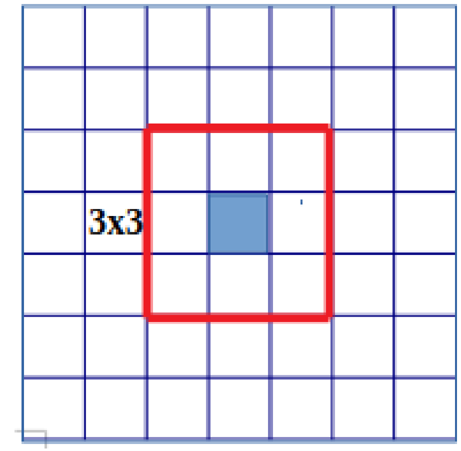
- We use the 7x7 Clustering around the seed block

- The VTP sends the readout channels masks in the 7x7 to the FADC in order to read out the raw wavefoms of these channels



VTP and Clusters reconstruction

- **VTP BASIC STEPS:**



1) If the seed Energy is above the threshold value (70 MeV) √

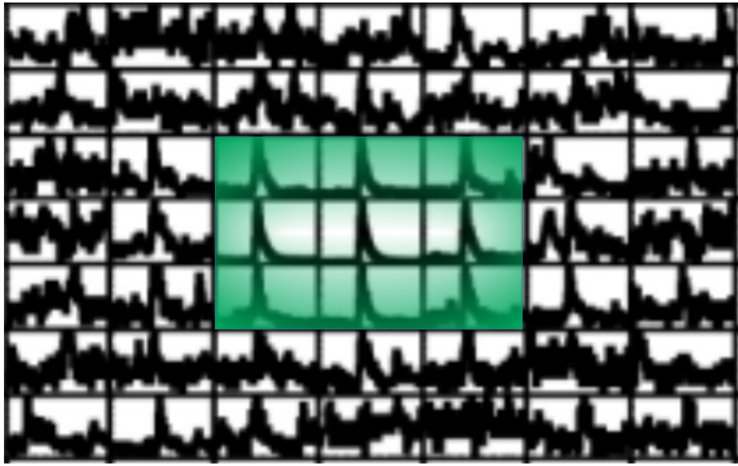
2) If the seed energy is a local maximum with respect to the 8 neighbors within the value of the time window (+- 20 ns from the seed) √

3) The Cluster Energy is calculated by summing up all the energies from the 9 blocks √

4) Information stored:

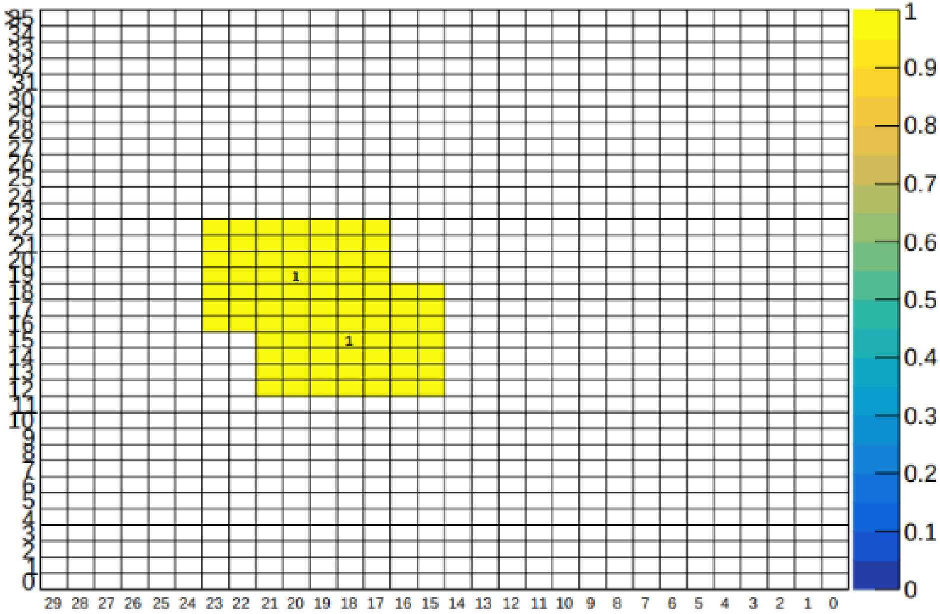
- **The x pos (column number), y pos (row number)**
- **Time of the seed block**
- **Total energy of the 3 by 3 cluster**

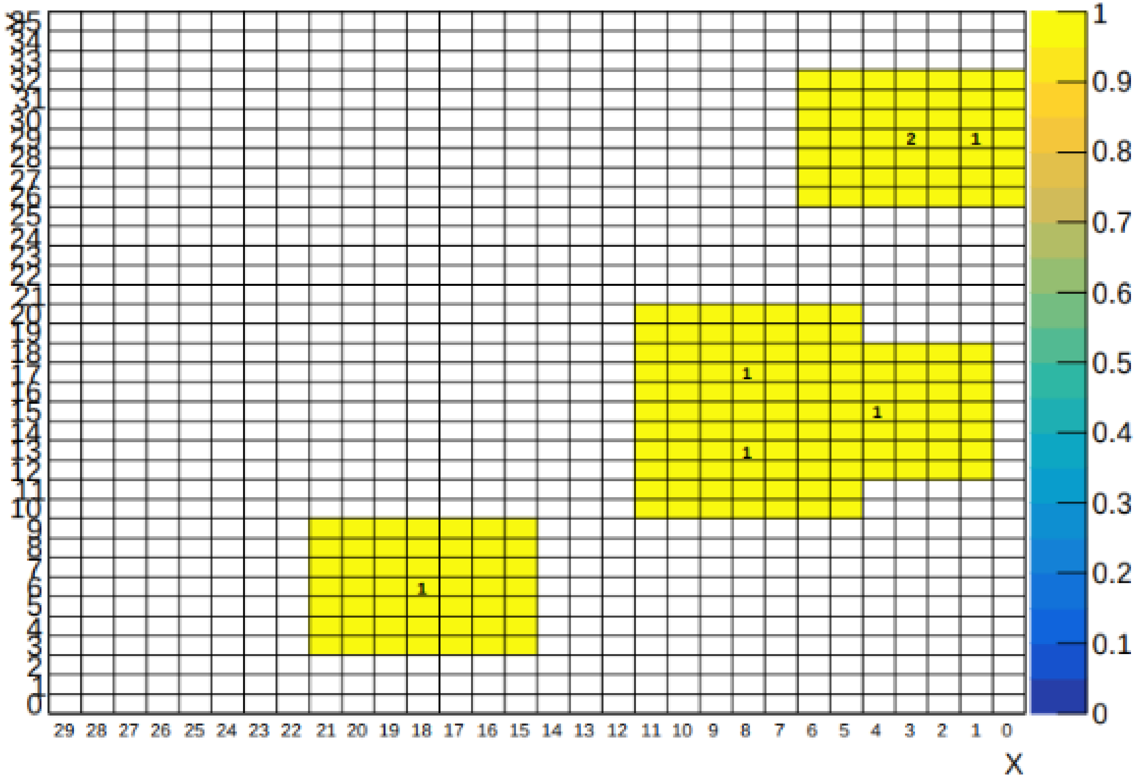
=> Coda file words => ROOTfile variables => Waveforms



VTP Performance

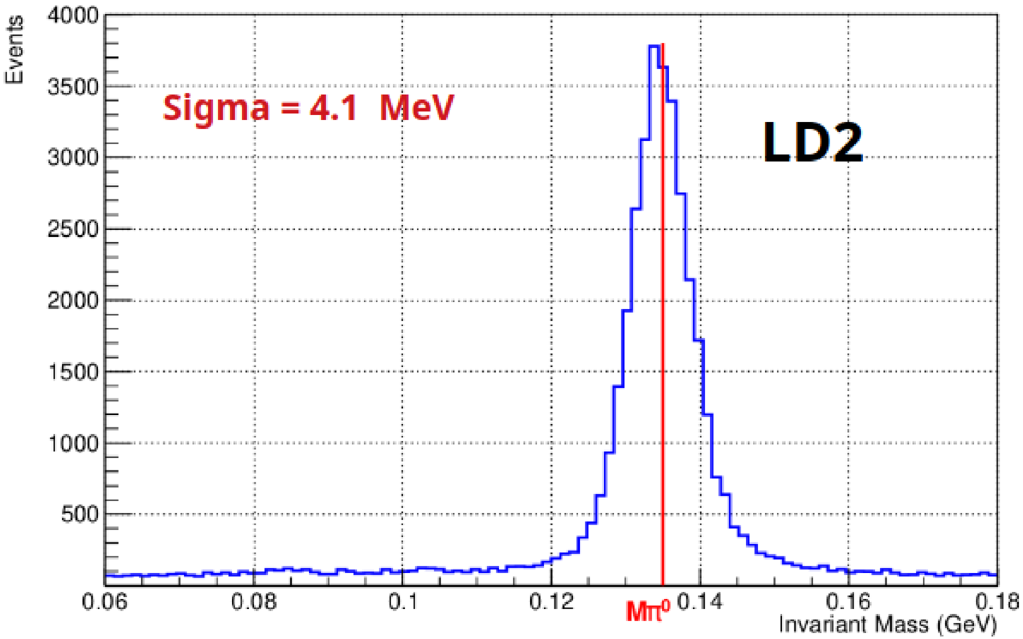
- **7x7** readout patterns for **separate** and **overlapping** cluster events
- A **significant reduce** in terms of the **data** stored

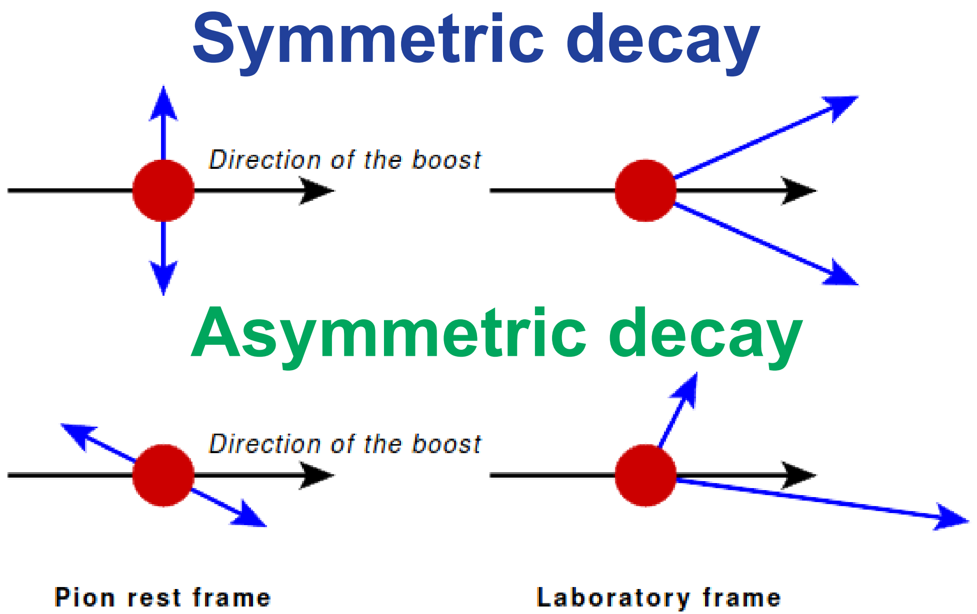




Preliminary Results

Exclusive neutral pion contamination





- Better resolution than the previous DVCS experiments

Thanks for everyone who contributed to the experiment

Thank you for your attention!