Exclusive/SIDIS π^0 Analysis at HallC JLab

Hall C Winter Collaboration Meeting 2026

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Flow of the talk

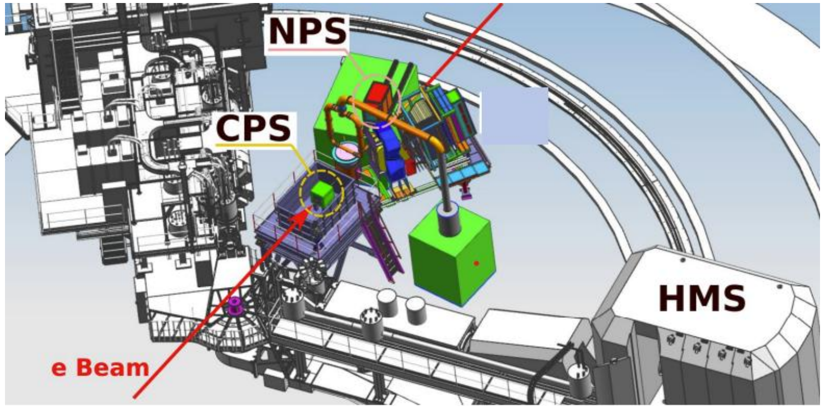
- Introduction and experimental setup
- Data and Event selection
- Background Subtraction
- Run trends
- Simulation and validation
- Conclusion

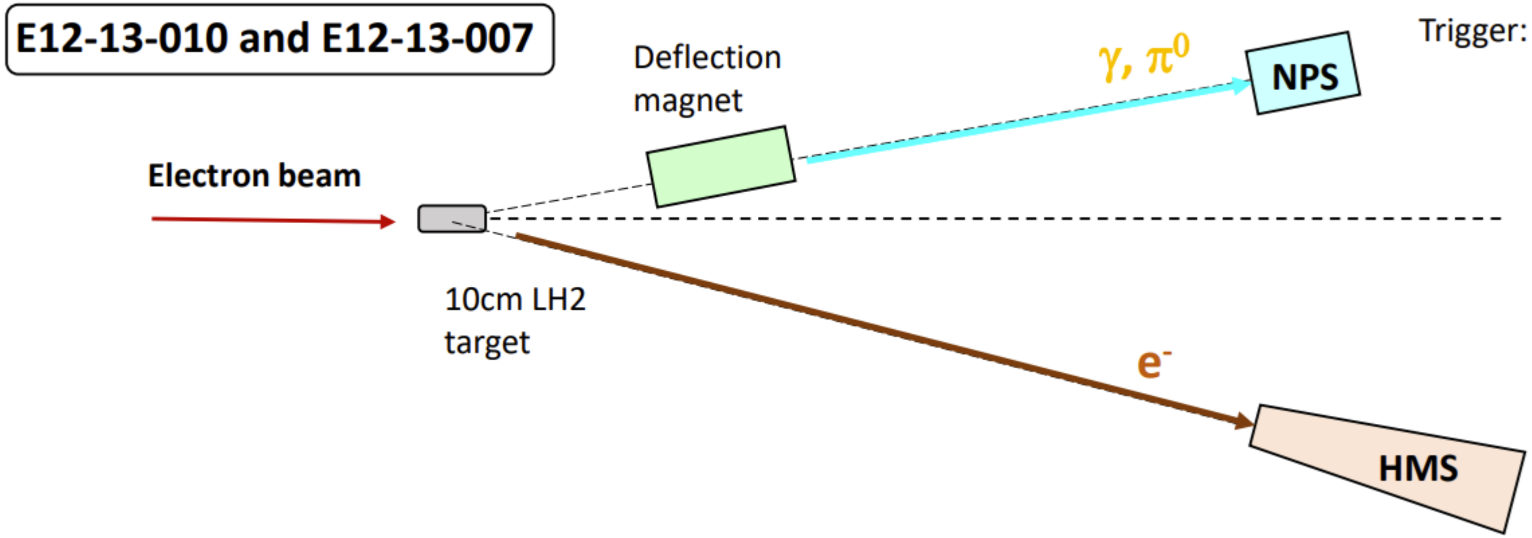
NPS Run Group 1a (Sept 2023 – May 2024)

- **<u>E12-13-010</u>**: Exclusive Deeply Virtual Compton and Neutral Pion Cross-Section Measurements in Hall C
- **E12-13-007**: Measurement of Semi-Inclusive π^0 Production as Validation of Factorization
- **E12-22-006**: Deeply Virtual Compton Scattering off the neutron with the Neutral Particle Spectrometer in Hall C
- **E12-23-014**: Measurements of the Ratio R = σ_L/σ_T , p/d ratios, Pt dependence, and azimuthal asymmetries in Semi-Inclusive DIS π^0 production form proton and deuteron targets using the NPS in Hall C

Neutral Particle Spectrometer in Hall C - Overview

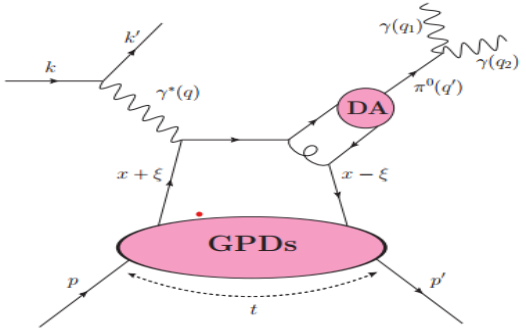
- Neutral Particle Spectrometer replaces one of the Hall C focussing spectrometers in the experiments
  - Angle reach between 5.5 and 60 degrees.
  - HMS has been recommissioned for 12 GeV
- Small angle, precision cross-sections, LT separation, high luminosity
- 1080 PbWO4 blocks.
- Radiation hard and temperature controlled frame.





Trigger: HMS, HMS+NPS

Physics Motivation: Exclusive π^0 Electroproduction



- Hall A experiment E07-007 [1] measured exclusive π^0 electroproduction cross sections at x_B=0.36 and Q^2=1.5, 1.75, 2.0 GeV^2.
- Achieved L/T separation of the differential cross section $d\sigma/dt$.
- Longitudinal component $d\sigma_L/dt$ was found to be small or consistent with zero, but compatible with leading-twist chiral-even GPD models.
- Theoretical models including transversity GPDs are also in agreement with the data, particularly at higher Q^2.
- Supports theoretical predictions involving chirally enhanced helicity-flip pion distribution amplitudes.
- Provides strong motivation to pursue π^0 studies at higher Q^2 and W to further explore transversity GPDs.

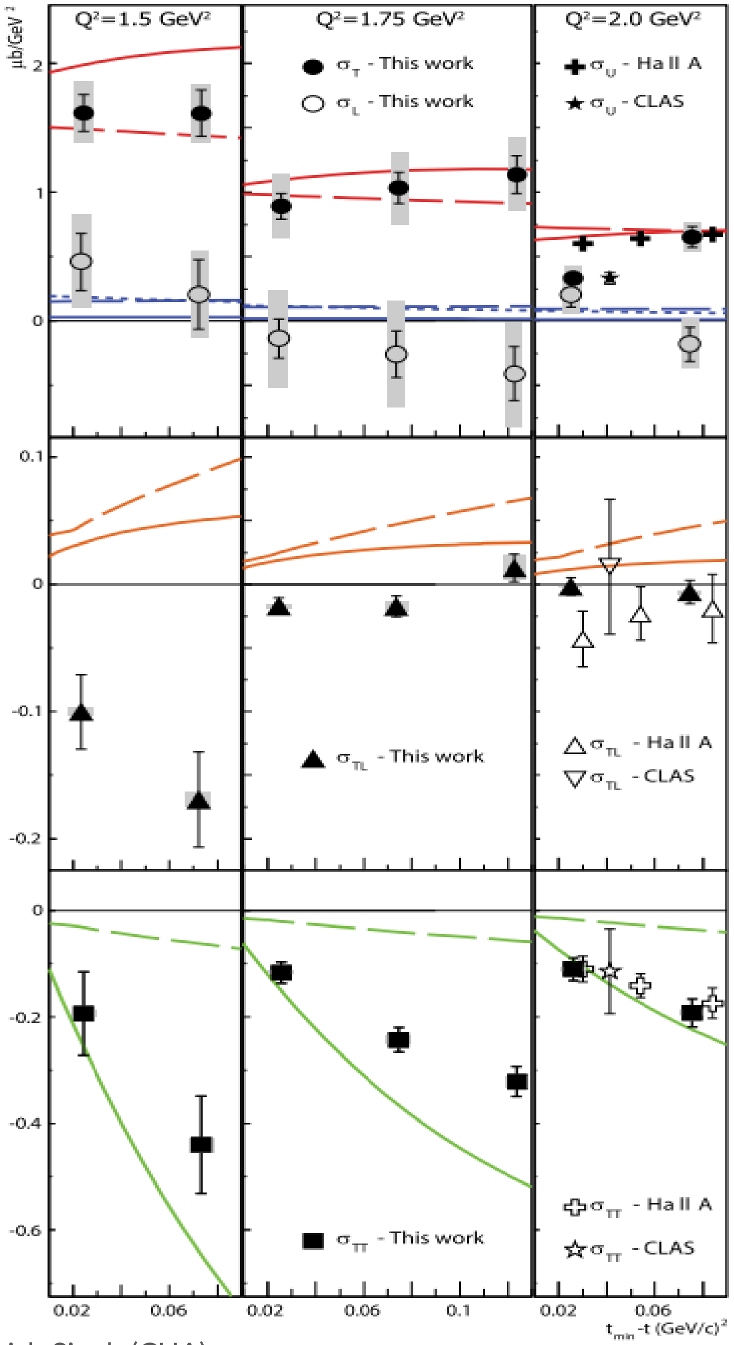
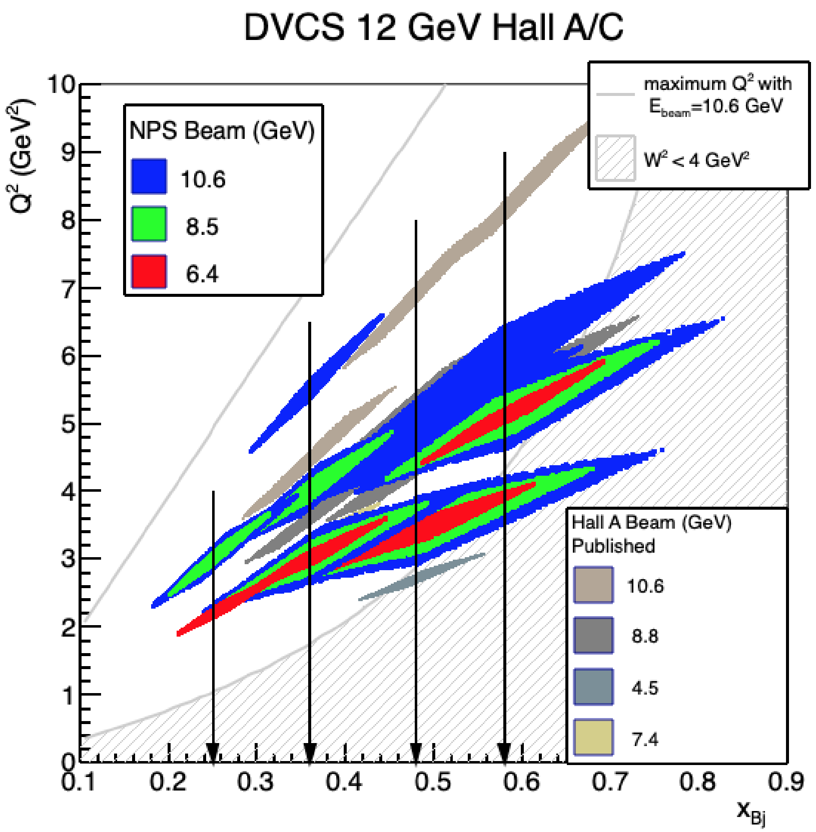


Figure: PhysRevLett.117.262001

Small dashed line: VGG (chiral even GPDs)
Solid and long dashed: alternative models with both chiral even and odd GPDs

Hall C kinematic complements earlier experiments



- Courtesy Charles Hyde and Julie Roche

Kinematic Setting	Beam Pass	Coulomb Goal Per Target	LH2 % of Goal	LD2 % of Goal
KinC_x36_1	3	1.2	119.33%	134.08%
KinC_x36_2	4	1.1	37.12%	20.67%
KinC_x36_2'	4	1.1	44.78%	25.22%
KinC_x36_2''	4	1.1	34.77%	25.17%
KinC_x36_3	5	0.6	107.21%	119.06%
KinC_x36_4	4	2.7	36.67%	19.16%
KinC_x36_5	5	1.4	121.88%	88.58%
KinC_x36_5'	5	0.5	137.28%	106.98%
KinC_x36_6	5	4.3	43.95%	36.85%
KinC_x50_0a	3	2	55.18%	48.35%
KinC_x50_0b	3	2	40.73%	47.39%
KinC_x50_1	4	1.9	100.14%	81.01%
KinC_x50_1'	4	1.9	94.84%	80.17%
KinC_x50_2	5	2.05	121.33%	89.67%
KinC_x50_2'	5	0.57	109.81%	90.19%
KinC_x50_2''	5	0.61	94.90%	104.86%
KinC_x50_3	5	4.85	117.56%	86.04%
KinC_x50_3'	5	0.68	80.86%	119.14%
KinC_x50_3''	5	0.7	88.31%	111.69%
KinC_x60_1	3	10	32.48%	29.36%
KinC_x60_2	4	4.75	24.59%	22.70%
KinC_x60_2'	4	4.75	18.67%	20.05%
KinC_x60_3	5	3.17	112.50%	99.41%
KinC_x60_3'	5	1.26	85.76%	114.24%
KinC_x60_3a	5	1.83	57.62%	82.17%
KinC_x60_3b	5	1.83	83.94%	72.65%
KinC_x60_4a	5	3.88	85.56%	77.40%
KinC_x60_4b	5	3.88	83.39%	77.13%
KinC_x25_1	3	0.5	53.14%	34.10%
KinC_x25_3	4	2.6	27.73%	18.02%
KinC_x25_4	5	2.6	41.78%	33.59%

x_b	Q^2 (GeV^2)	Energy (MeV)
0.24	2.1	6600
0.26	3.0	8800
0.26	3.1	11000
0.36	3.0	6600
0.36	3.0	8800
0.36	3.0	11000
0.36	4.0	8800
0.36	4.0	11000
0.36	5.5	11000
0.48	3.3	6600
0.48	3.4	8800
0.46	3.3	11000
0.48	4.8	11000
0.58	5.1	6600
0.58	5.1	4400
0.58	5.1	6600
0.58	6.0	8800

Data and Event selection

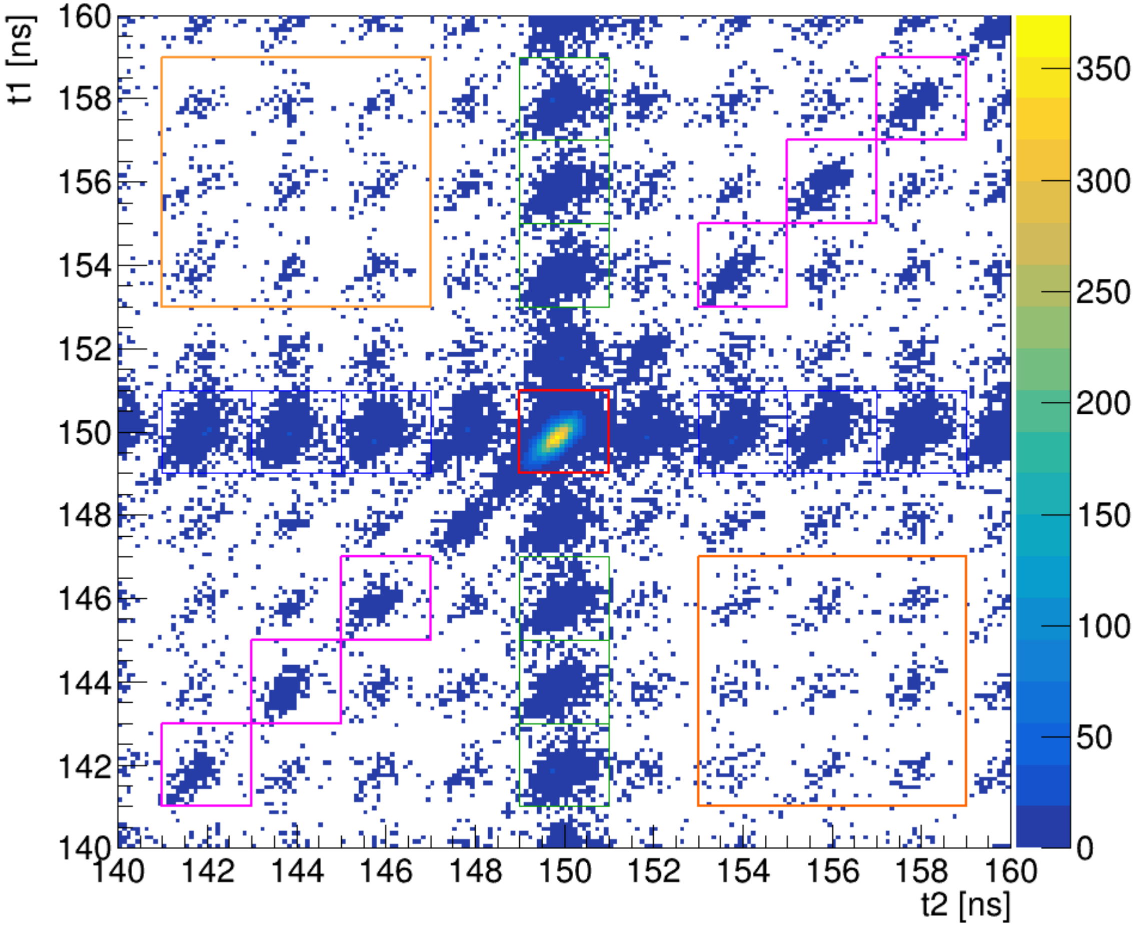
- kinC_x60_4b processed for LH2 with pass2 updated replay (waveform processing not yet included).

- Event selection:
  - HMS & NPS preliminary cuts applied as a workflow check — these cuts are intentionally conservative and will be tightened for final results.
    - EDTM TDC: `edtm_tdc < 0.1`
    - Reaction vertex: `-4 < z < +4 cm`
    - Momentum acceptance: `-15% < δ < +15%`
    - Track angles:
      - `-0.10 < θ < +0.10 rad`
      - `-0.04 < ϕ < +0.04 rad`
    - Čerenkov: `NPE > 1.5`
    - Calorimeter: `0.70 < E/p < 1.20`
    - Cluster energy: `E_cl > 0.8 GeV`
    - Cluster position:
      - `-30 < X_cl < +30 cm`
      - `-36 < Y_cl < +36 cm`
    - Cluster time window: `150 - Δt < T_cl < 150 + Δt`
  - Cluster merging kept optional at this stage (compare merged vs unmerged; future steps).
  - For events with >2 clusters, we apply a best-pair selection (algorithmic selection of the γγ pair most consistent with π^0 invariant mass).

- Background subtraction: Timing accidentals and combinatorial background

Background Subtraction:
Accidental subtraction using Timing spectrum

- The timing spectrum is used to identify accidental coincidences by examining regions outside the true coincidence peak.
- Sideband regions provide a data-driven estimate of accidental counts.
- The accidental template is normalized to the expected yield inside the coincidence window and subtracted event-by-event (or bin-by-bin).



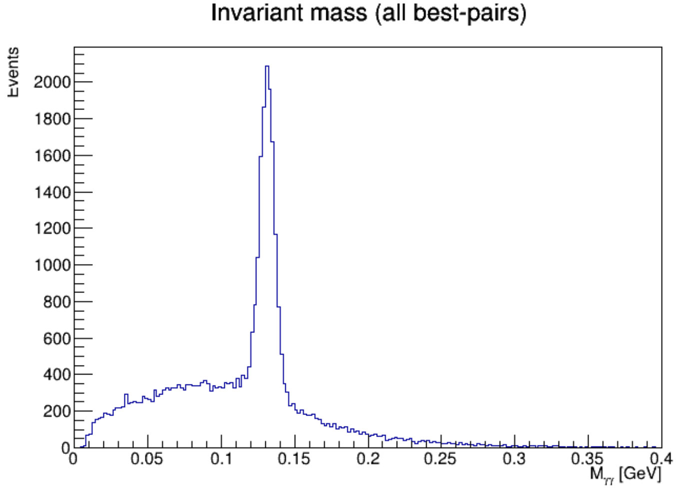
Accidental counts estimated as:

$$N_{\pi^0}^{Accidentals} = N_{e'^A\gamma_1^C\gamma_2^C} + \frac{1}{2}\left[N_{e'^C\gamma_1^C\gamma_2^A} + N_{e'^C\gamma_1^A\gamma_2^C}\right] - N_{e'^A\gamma_1^A\gamma_2^A}$$

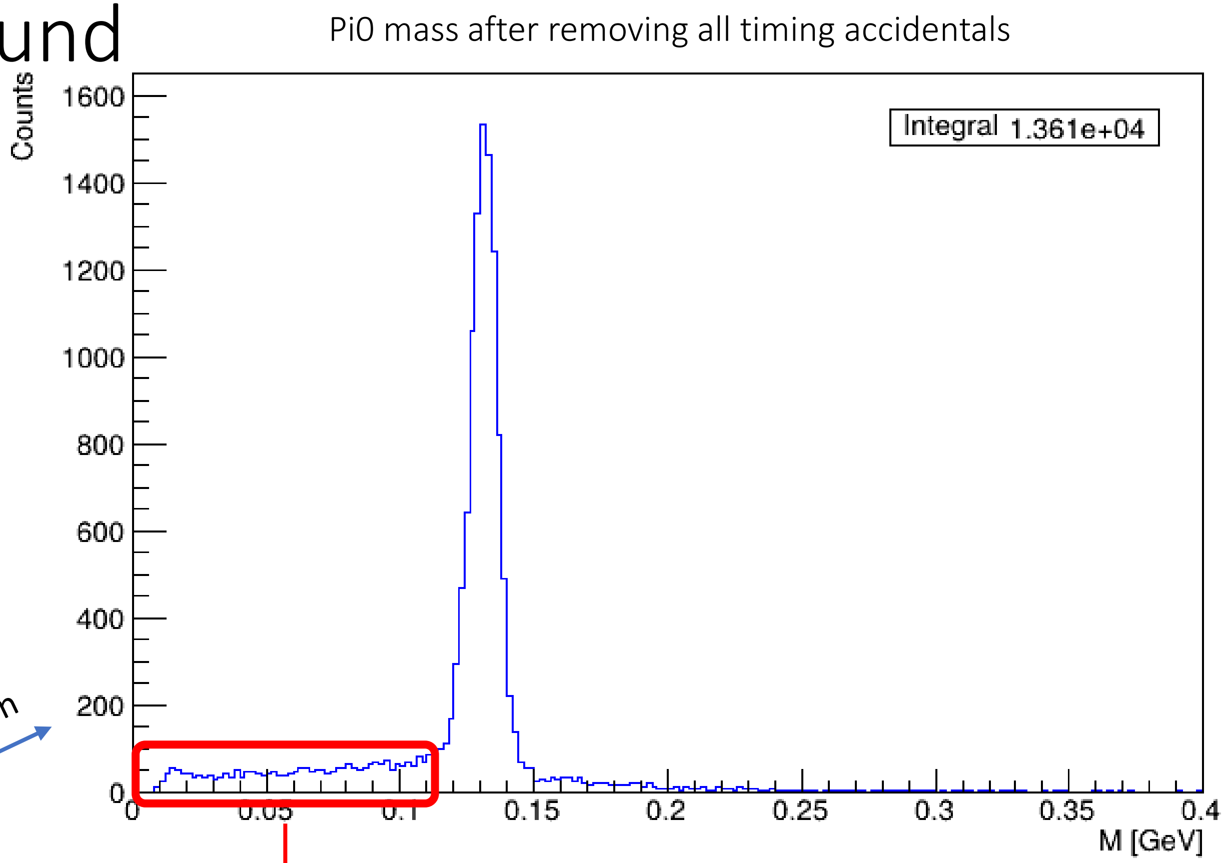
Background Subtraction: Residual combinatorial background

(more info)

- Timing-plane subtraction removes *timing* accidentals but **not all** combinatorial background.
- Remaining background arises from true-in-time but wrong-pair combinations (cluster splitting, pileup, multi-photon topologies).
- It sits under and around the π^0 peak and must be modeled to extract the signal yield.
- For this analysis we use a **simple polynomial** as a pragmatic, conservative model.

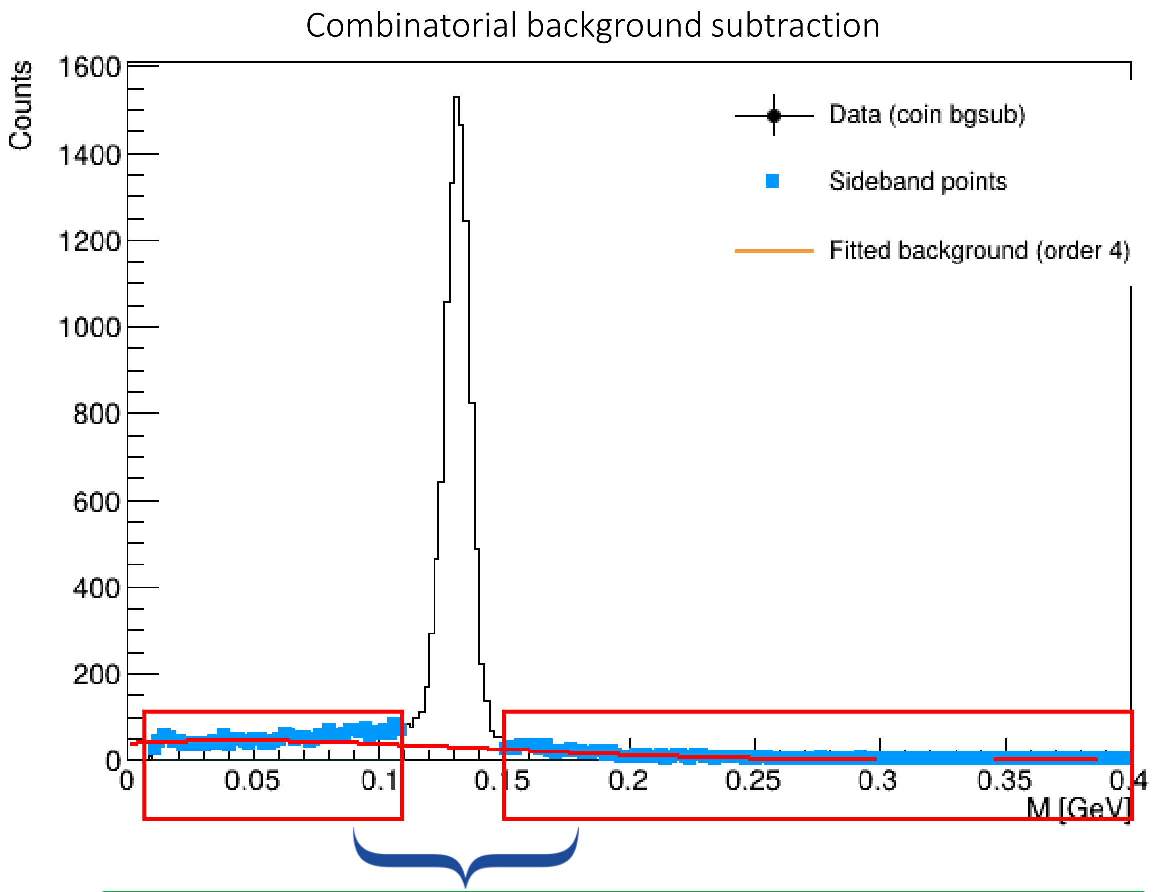


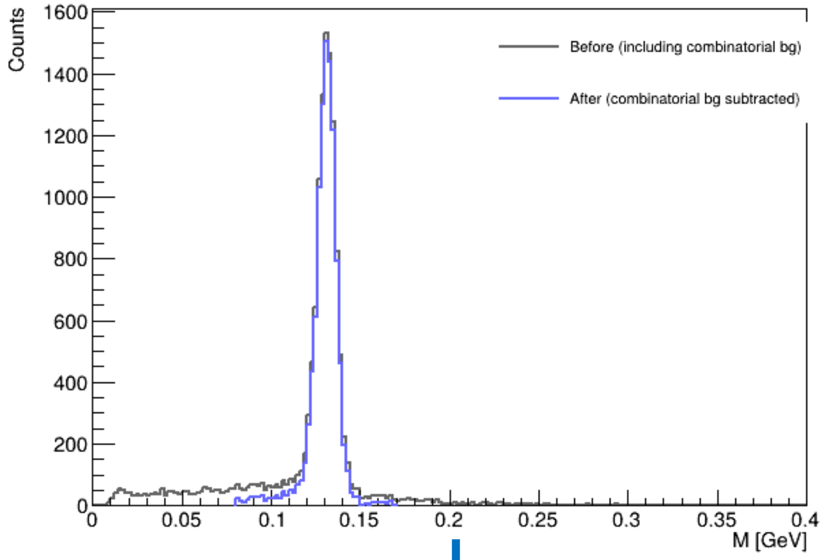
After timing acc. subtraction



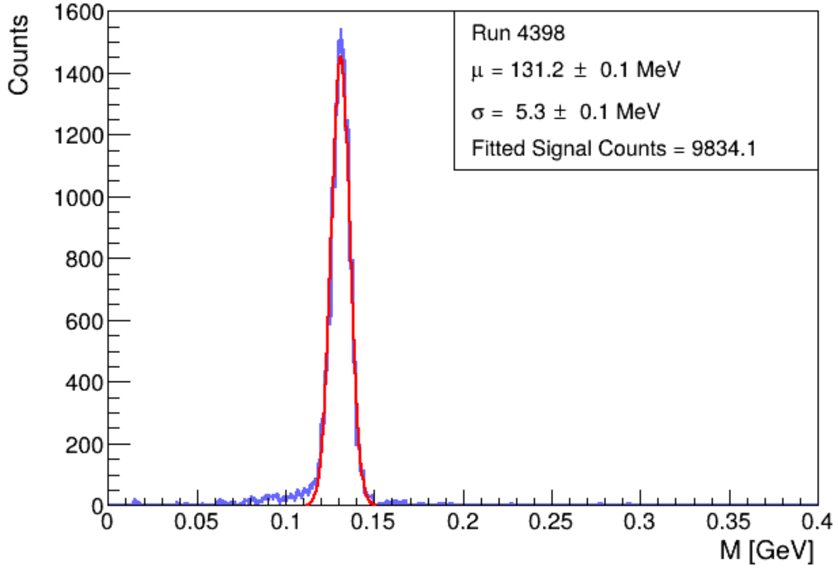
A smooth, non-peaking combinatorial background remains beneath the π^0 peak even after timing-accidental subtraction.

Background Subtraction: Combinatorial background subtraction





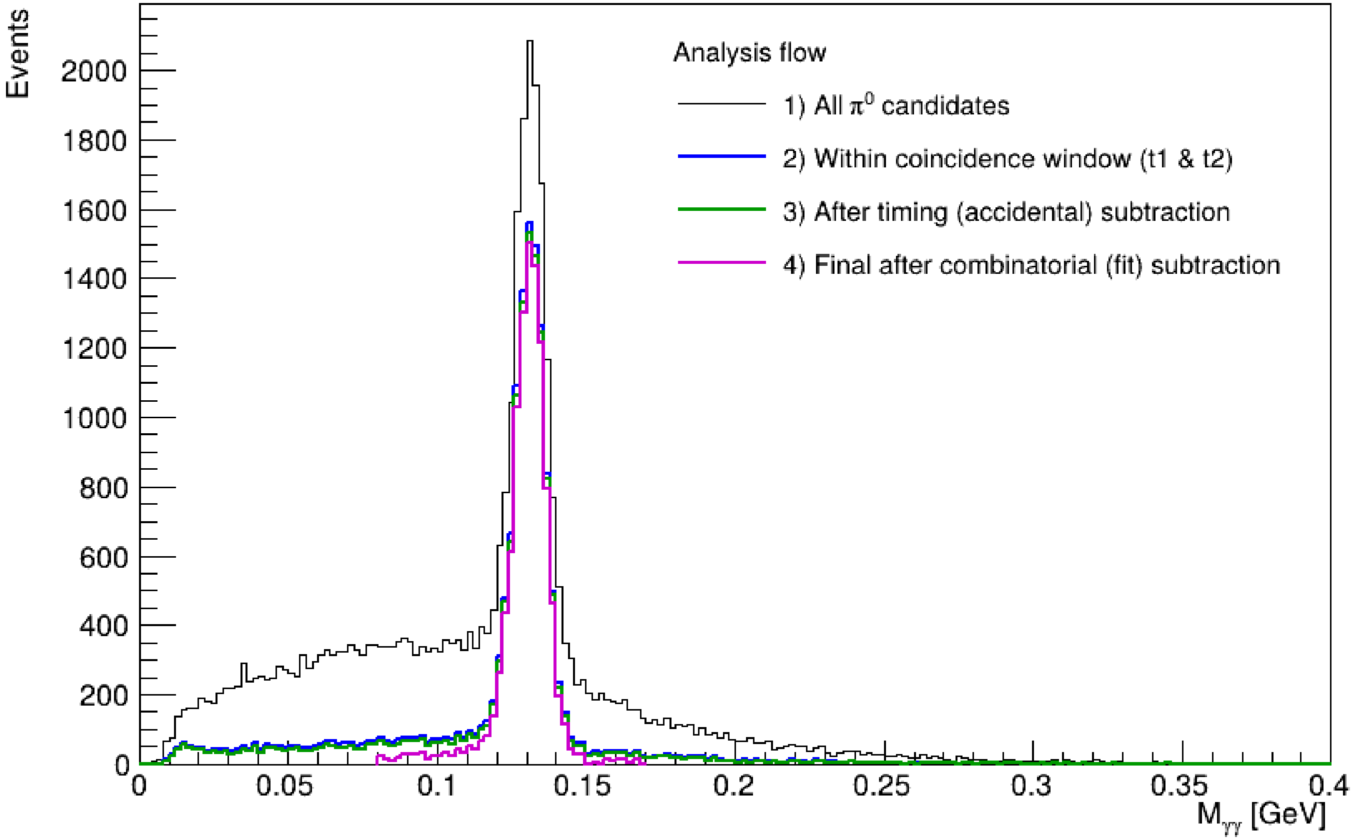
Combinatorial background subtracted.



The combinatorial background is modeled using only the sidebands, and the resulting fit is subtracted to obtain the final π^0 invariant mass histograms.

```
[nps::FitCombinatorialBGAndSubtract] run=4398 poly_order=4  chi2=407.11 ndf=170 chi2/ndf=2.39477
```

Background subtraction - Summary



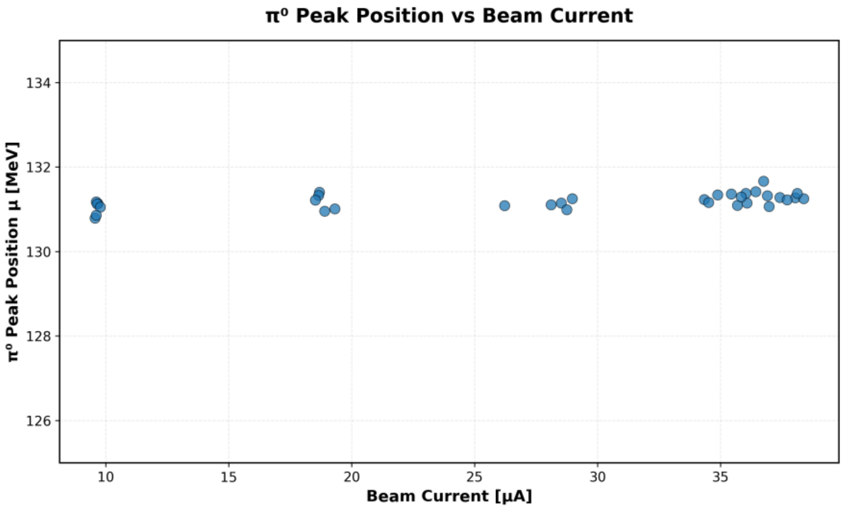
- **1. Timing selection:** Define prompt coincidence window.
- **2. Timing-accidental removal:** Model via sidebands and subtract.
- **3. Combinatorial removal:** Use invariant-mass sidebands.
- **4. Final signal:** Obtain accidental-free, combinatorial-free π^0 yields for cross-section extraction.

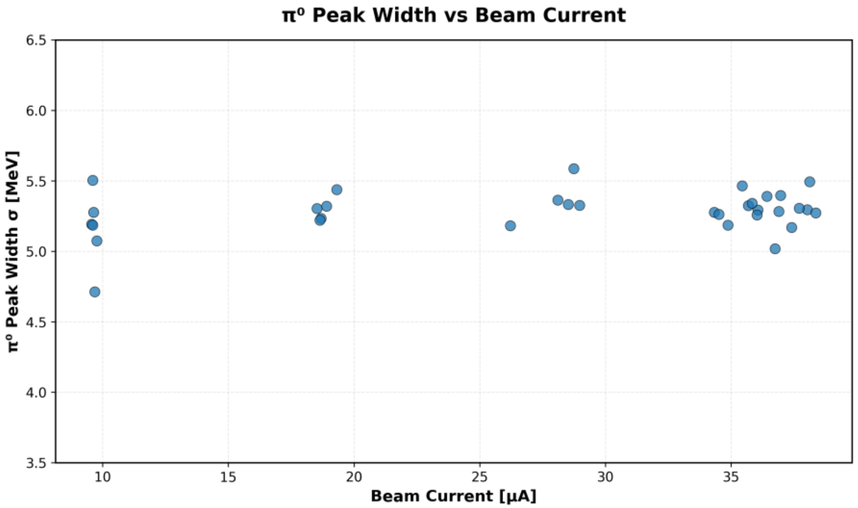
```
===== Run 4398 summary =====
 Total entries: 3222394
 Pass HMS: 1606270
 Pass HMS + NPS selection: 36360
 Coin raw (timing plane): 14550
 Estimated accidentals (time method): 946.389 +- 10.2601
 Comb. BG fit χ2/ndf: 2.395
 Pi0 fit μ (MeV): 131.158   σ (MeV): 5.264
 Pi0 signal counts (final): 9834.132
```

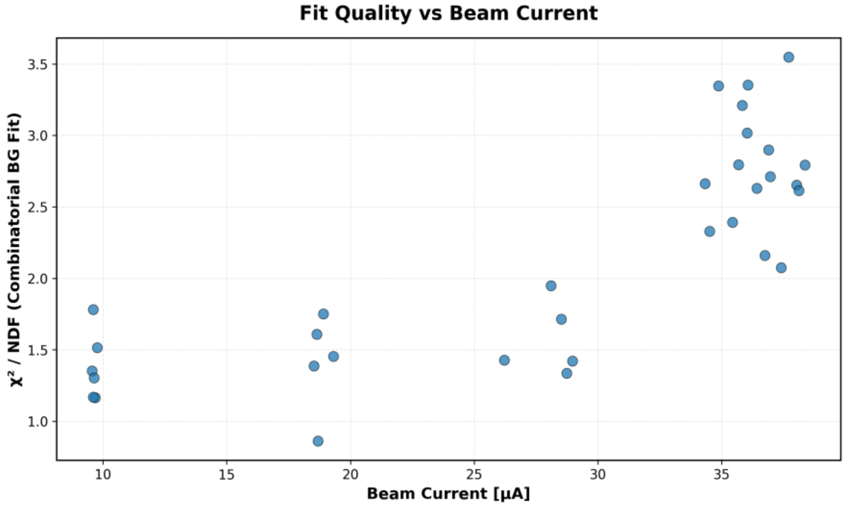
Run-by-Run Trends for x60_4b

- Top-left — π^0 peak position vs Current: Centroid is stable across runs and currents; observed range: **130.80 – 131.60 MeV/c²**.
- Top-right — π^0 peak width (σ) vs Current: Peak width is stable: **σ ≈ 5.0 – 5.50 MeV** for all currents.
- Bottom — χ^2/ndf vs Current: Fit quality degrades at high currents, with $\frac{\chi^2}{ndf}$ rising from ≈ 1-2 (10-30 uA) to ≈3.5 above 30 uA; origin under investigation.

- The stability of the peak position and width indicates a good run period with no major issues.
- The peak width is already below 5.5 MeV and is expected to improve further with waveform-based analysis and π^0 calibrated data.





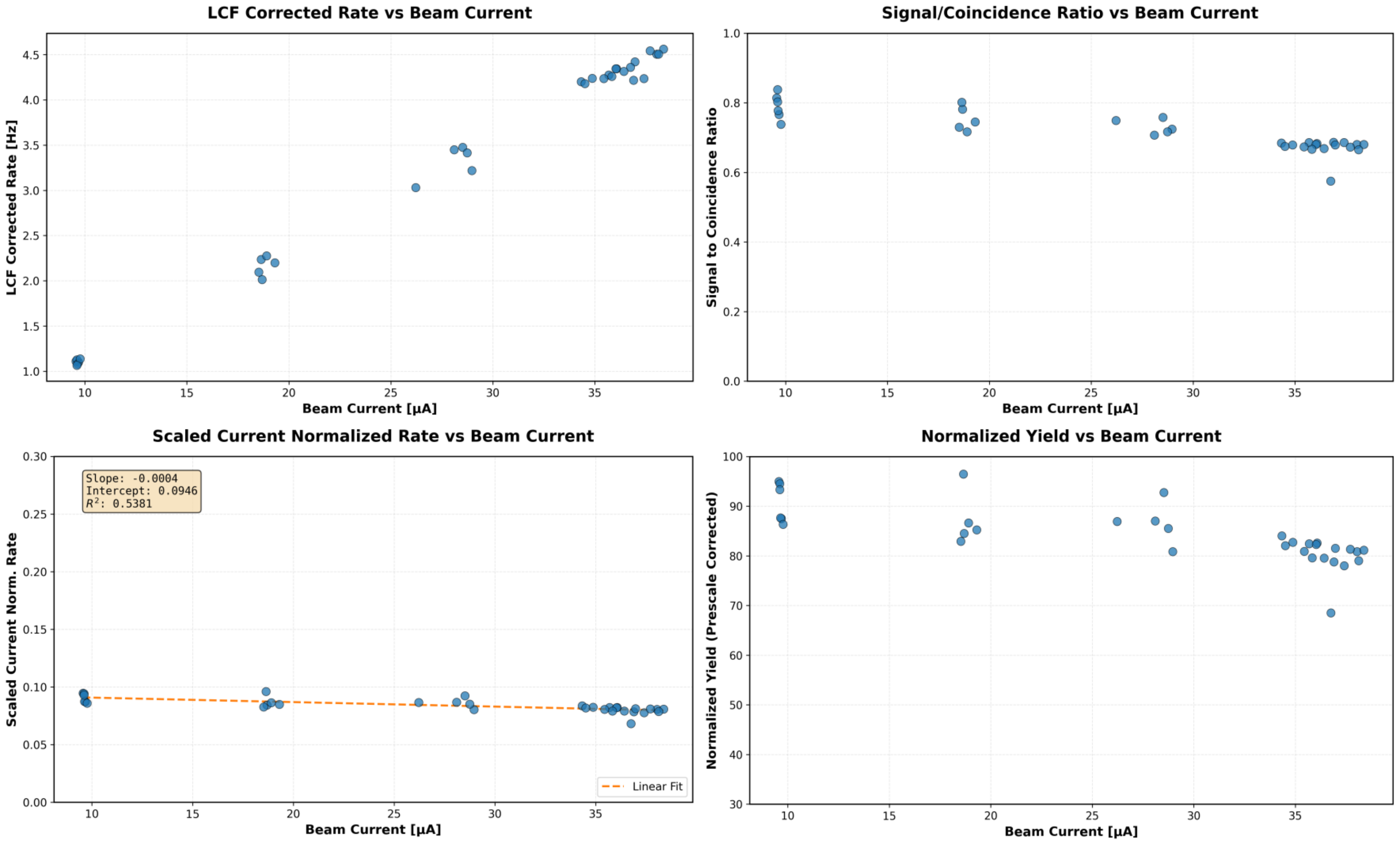


Run-by-Run Trends for x60_4b

(refer to slide 33 for rate def.)

- Top-left — Coincidence window event rate vs Current:
  Coincidence-window event rate increases roughly linearly with beam current.
- Top-right — Signal-to-Coin events vs Current:
  The π^0 signal fraction remains relatively stable (0.6-0.8).
- Bottom-left — π^0 Current normalized rate vs Current :
  The π^0 current normalized rate is almost current independent, as expected, with a very small –ve slope.
- Bottom-right — Normalized yield vs Current:
  A non-linear decreasing trend is observed in the normalized yield as a function of current.

- Luminosity corrections appear to be the main source of variation for the normalized yield. (correction in progress)
- More studies on the current dependance under progress.



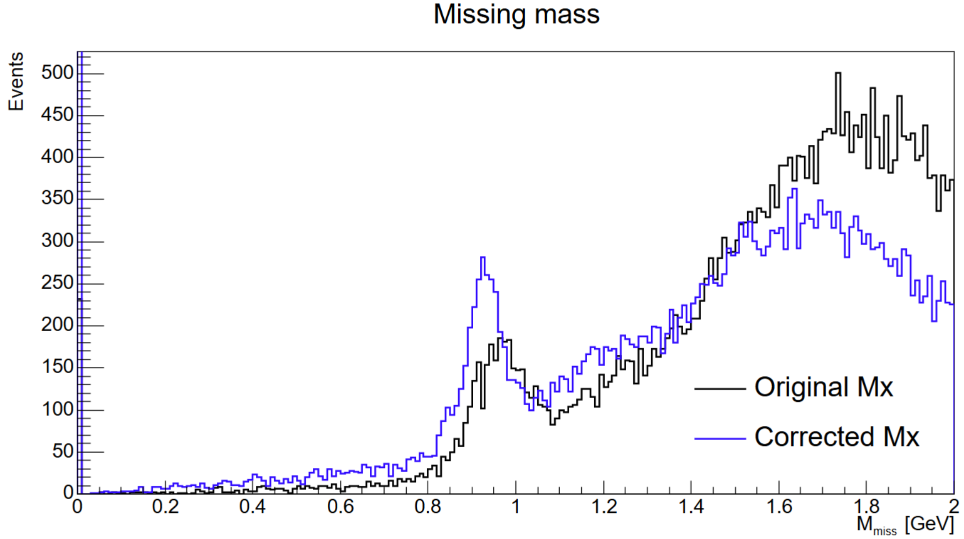
Missing mass correction

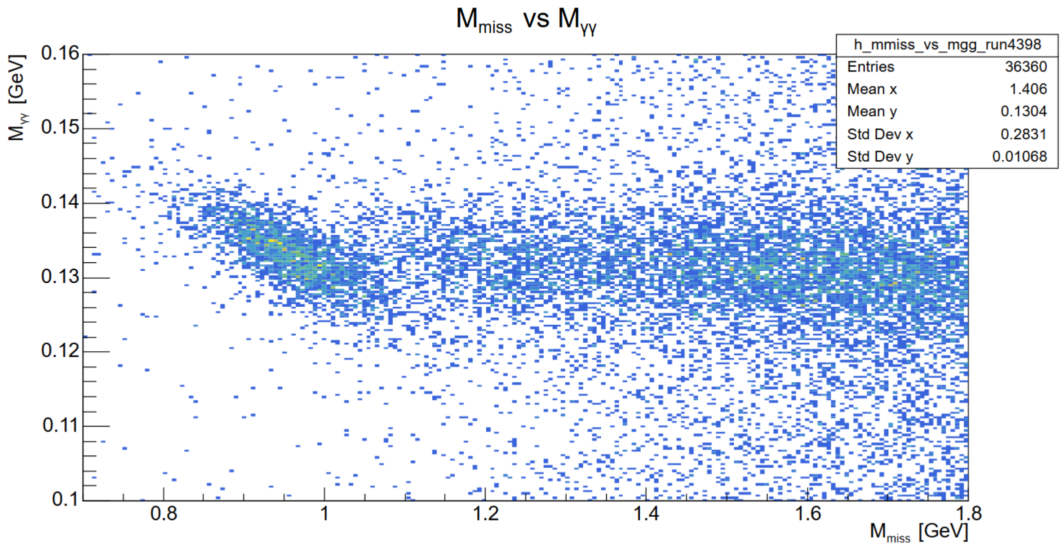
- Invariant mass and missing mass correlation is corrected event-by-event using the relation (report):

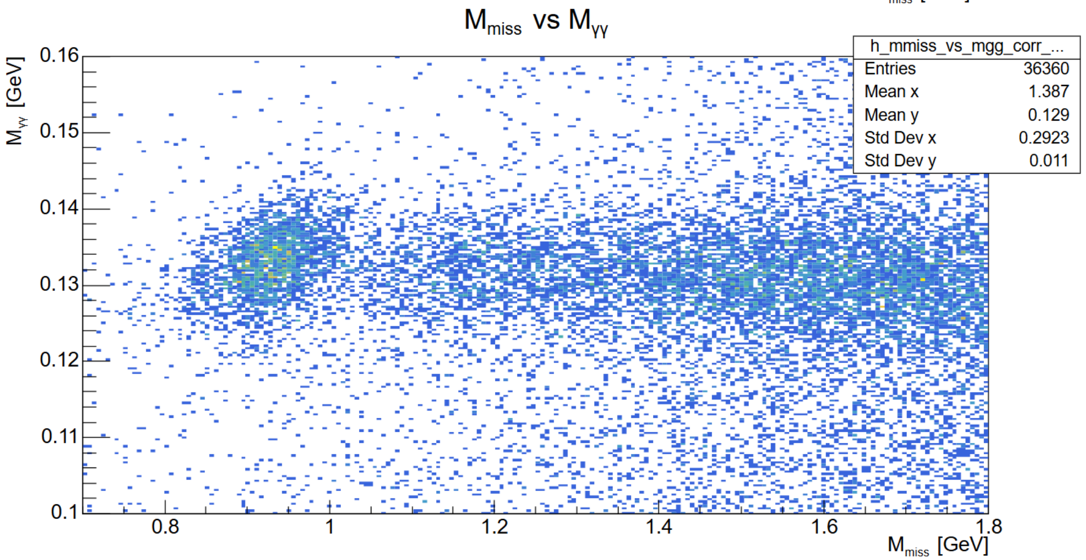
$$M^2_{x_{corr}} = M^2_x - \text{corrfac}\,(m_{inv} - m_{\pi^0})$$

where the corrfac is given as:

$$\frac{dM_x^2}{dm_{inv}} = \frac{2}{m_{inv}}\left[m_{inv}^2 - (E_1+E_2)\left(M_p + \nu + |\vec{q}|\cos\theta_{\gamma^*\pi^0}\frac{\sqrt{E_1^2+E_2^2+2E_1E_2\cos\theta_{\gamma\gamma}}}{E_1+E_2}\right)\right].$$

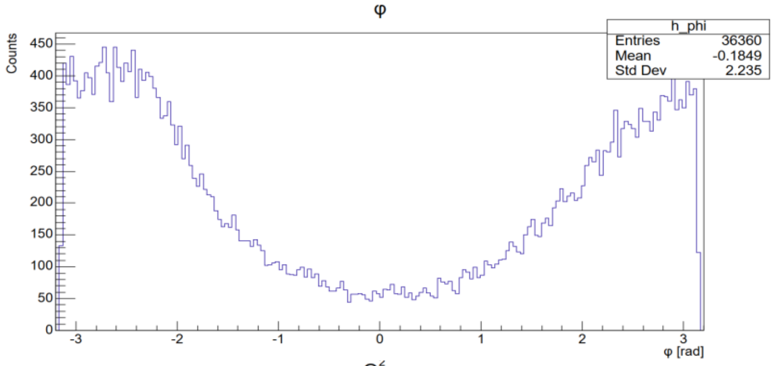


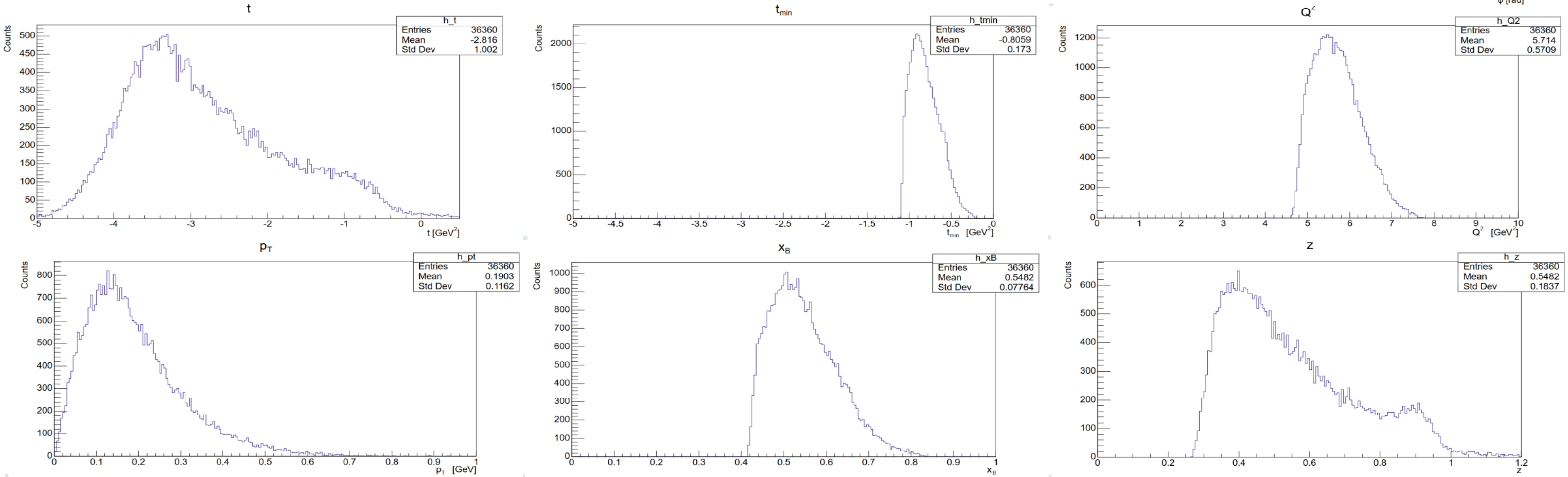




Physics Variables:

- Current plots show all events after initial HMS+NPS cuts (no per-bin weights applied).
- Next:
  - apply per-event weighting (slide 16) to get to the final yields
  - Verify weight implementation per bin with the simulations.

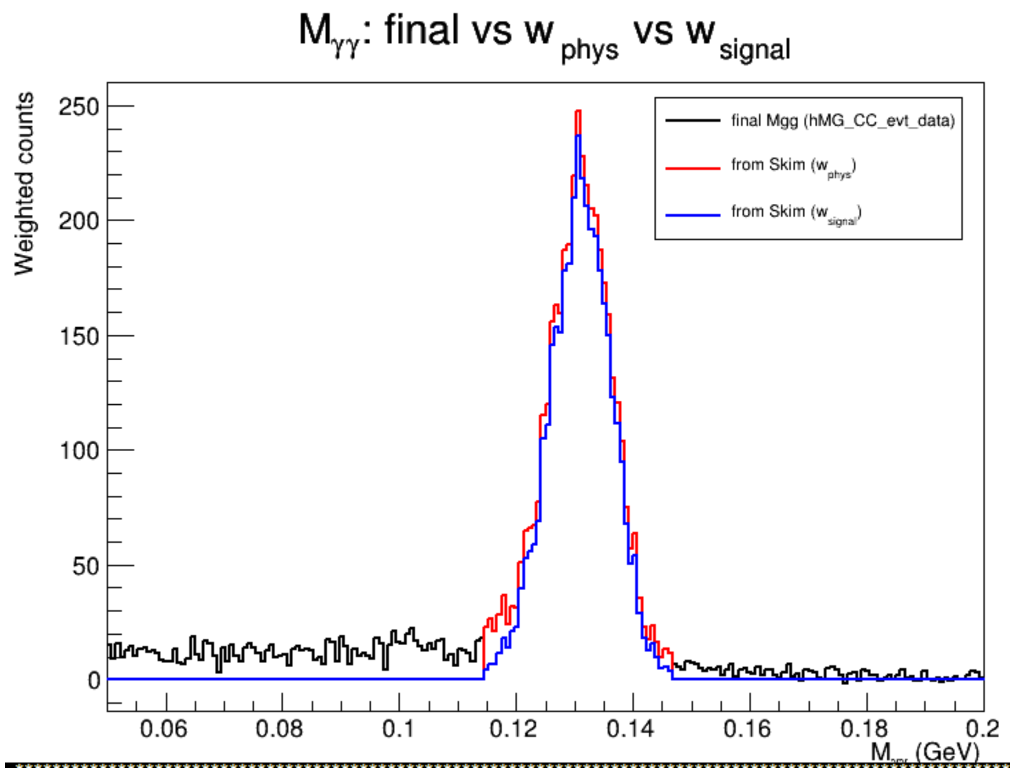




Skim Weights → Analysis

- After the full π^0 v5 production step, we write a compact **Skim** TTree that keeps just the information needed for physics plots and cross-section extraction, instead of dragging around the entire raw-event structure.

- Skim includes:
  - **eventnum** – original event identifier (for debugging / cross-checks).
  - **mgg** – invariant mass of the selected γγ pair.
  - **Mx / MxCorr –** (corrected) missing mass for the event.
  - **pass_pi0** – Boolean flag indicating whether the event lies in the π^0 mass window ($|M\gamma\gamma - \mu| \leq$ nsig·σ, currently nsig = 3).
  - **w_sig, w_phys, w_signal** – the three main analysis weights



Row	eventnum	mgg	w_sig	w_phys	w_signal	pass_pi0
0	98	0.129594105695	0.957511309770	0.176916656617	0.169211002248	1
1	273	0.131676593432	0.958368884094	0.180128528645	0.172582245567	1
2	421	0.115331951492	0.422468670328	0.173957036234	0.043462691327	1
3	446	0.130422182139	0.957511309770	0.179040620156	0.171461940435	1
4	486	0.120517910289	0.786611165430	0.147793037946	0.114751869048	1
5	551	0.131866669348	0.958368884094	0.168297721373	0.161191255009	1
6	873	0.130645647816	0.957511309770	0.179040620156	0.171461940435	1
7	878	0.133583571550	0.953648218905	0.165083736703	0.157605203666	1
8	988	0.138062938715	0.897709995912	0.186520423028	0.170594877840	1
9	1190	0.125735274049	0.924293976644	0.156572411457	0.144807079185	1
10	1397	0.132521963438	0.958368884094	0.168814293045	0.161497591179	1
11	1749	0.121197610086	0.786611165430	0.147793037946	0.114751869048	1
12	2178	0.134297720233	0.953648218905	0.171461486816	0.163195266323	1
13	2193	0.139019023642	0.897709995912	0.169828789497	0.152768035324	1
14	2510	0.136362699423	0.938865663675	0.166285100243	0.155544453357	1
15	2706	0.132392109397	0.958368884094	0.168297721373	0.161191255009	1

SIMC + Geant4 Framework for pi0 Production (HMS + NPS)

- developed by the NPS collaboration, with this integration by Avnish Singh

- SIMC (Simulation Hall C; standard for Hall C):
  - Generates the primary scattering events using cross-sections and radiative corrections.
  - Simulates HMS spectrometer acceptance and full HMS side kinematics.
  - Provides the event generator for the hadron side, serving as input to Geant4.
- Geant4 (NPS Detector Simulation):
  - Uses SIMC vertices and hadron momenta as primary particles.
  - Simulates particle transport and energy deposition in the NPS calorimeter.
  - Builds on prior work within the NPS collaboration: https://indico.jlab.org/event/946/contributions/16514/attachments/12609/20085/20250506_DVCS_simulation_Hao_Huang.pdf

- See slide 34 for differences between the two implementation.

Please feel free to reach out to me for more discussions on the same :D

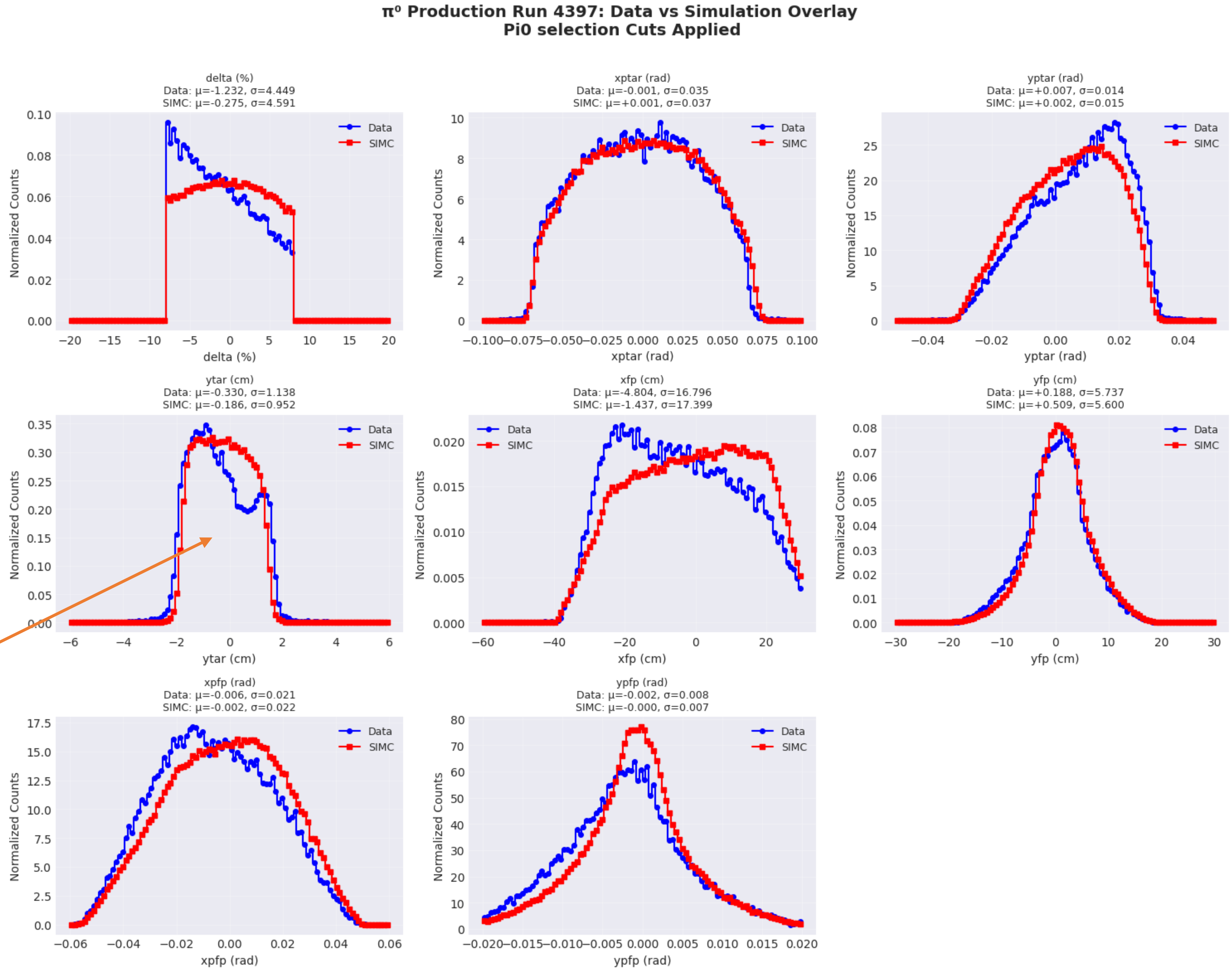
Extended Output and Diagnostic Branches

- Completed SIMC ↔ Geant4 integration (repo: HallC_SIMC_Geant); added detailed diagnostic branches to validate showering, clustering, and reconstruction.
- New branches (in addition to SIMC):
  - evtNb: Event number
  - edep: total energy deposited as registered by Geant
  - phot{1,2}_hit: primary photon hit flag; 0 or 1 for unregistered or registered hit, resp.
  - phot{1,2}_v{x,y,z}: generation vertex (SIMC)
  - phot{1,2}_hit_{x,y,z}: true Geant4 hit position on calorimeter face
  - phot{1,2}_clust_{x,y,z}: reconstructed cluster position (from the clustering algorithm)
  - phot{1,2}_Ecal: energy deposited by primary photon (true Geant value)
  - phot{1,2}_clustSize: cluster size associated with the respective primary photon
  - nClusters: number of reconstructed clusters
  - clust_E: ntuple of cluster energies
  - clust_{X,Y}: ntuple of cluster positions
  - clust_Size: ntuple of cluster sizes
- Phot1_Ecal (truth) vs clust_E (reco) differ because clustering algorithm uses total block energy without photon ID.
- NOTE: phot{1,2}_hit_{x,y,z}: mapping to physical calorimeter face in progress; other branches validated.
- Feedback welcome on additional branches and/or any discrepancies found in the code

HMS validation:

Data vs SIMC Kinematic comparisons

- Data:
  - π^0 selection cuts applied for comparison.
  - Binning weights after background subtraction not yet applied.
- Simulation:
  - SIMC cross-section weights applied to histograms.
  - Same kinematic cuts as used for data.
- Target contamination visible in the ytar distribution.
- Further kinematic tuning of the SIMC-Geant4 setup in progress.



NPS Response: Cluster Distributions (Simulation)

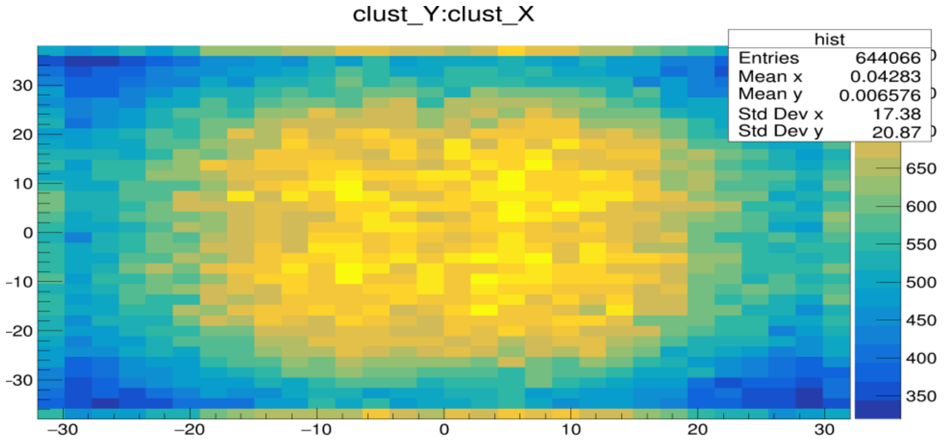


Fig. cluster positions for all the photon hits on the NPS face.

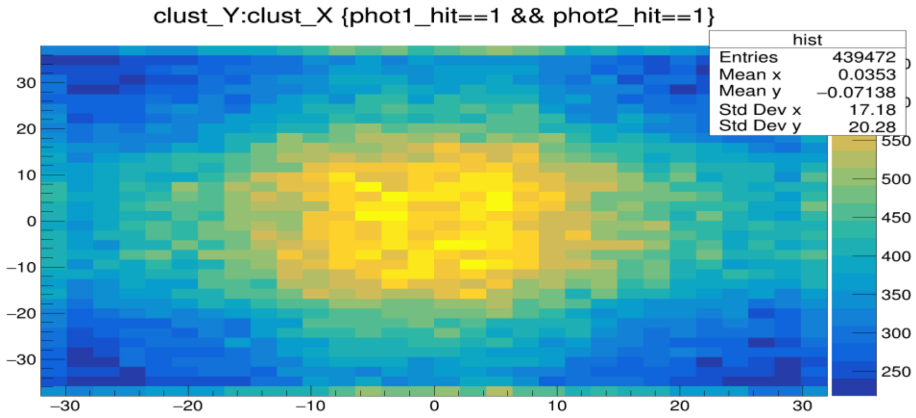


Fig. cluster positions for all the photon hits on the NPS face where both the photons registered a hit on the NPS face.

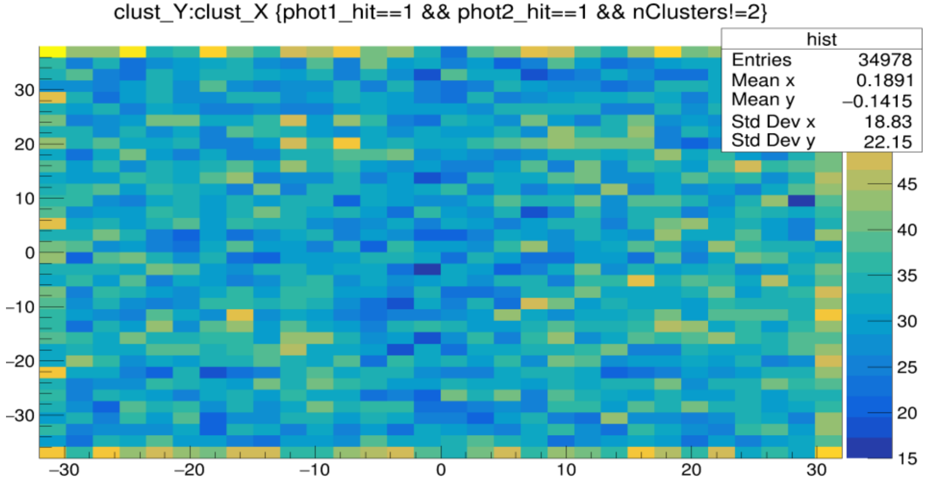
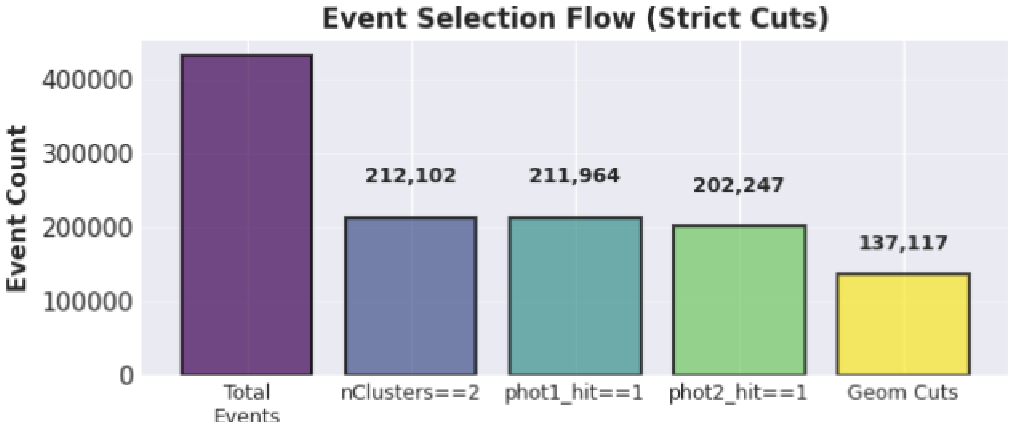


Fig. Cluster positions on the NPS face for events which both photons registered hits in the calorimeter but fewer than two clusters were reconstructed.

- Events are uniformly distributed over the NPS surface, as expected.
- phot1_hit, phot2_hit, and cluster multiplicity are used to study acceptance and reconstruction effects.
- Events with two photon hits but fewer than two clusters are mainly located near the NPS edges, indicating edge-related inefficiencies.

NPS π^0 Geometric Acceptance (Uniform illumination case)

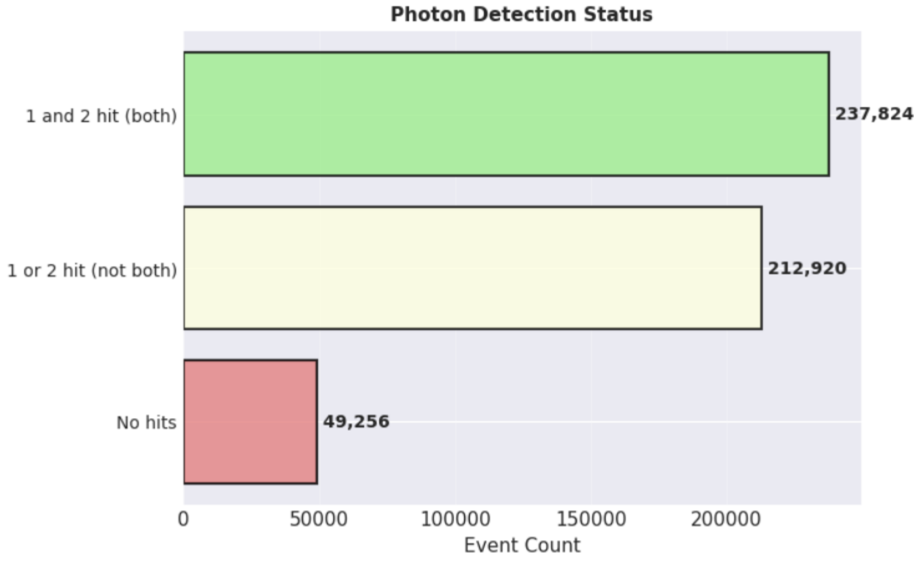


Selection Criteria & Acceptance

- Exactly two clusters: nClusters==2

- Both photons hit NPS: phot1_hit == 1 && phot2_hit == 1.

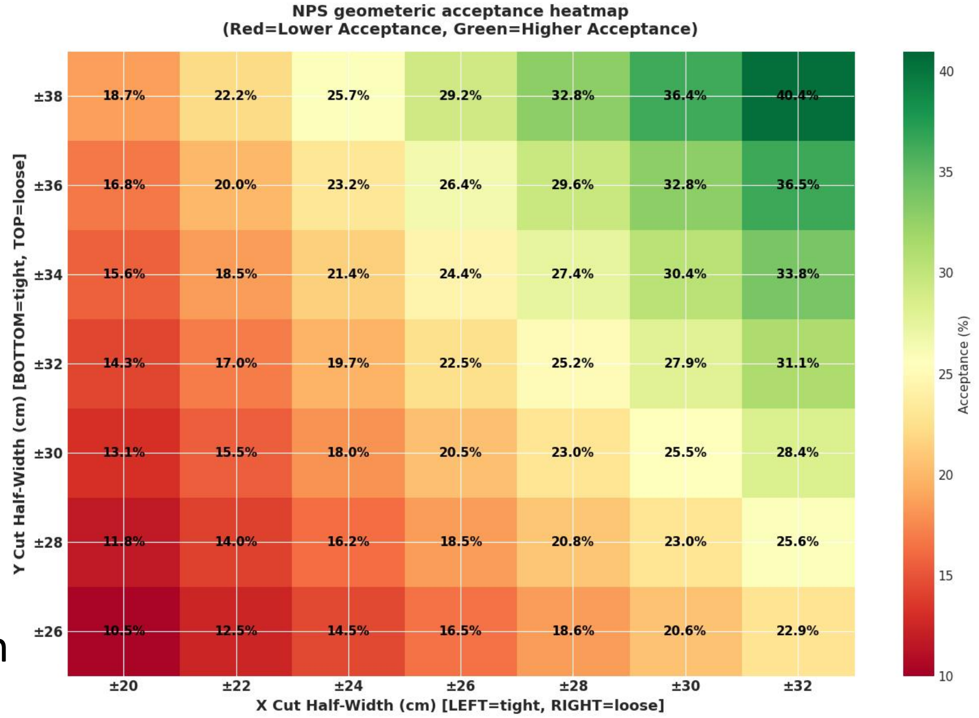
- Geometrical cuts on detector face (both clusters):
    - Loose: (x ∈ [-32,32], y ∈ [-38,38])
    - Strict: (x ∈ [-28,28], y∈ [-34,34])



Acceptance

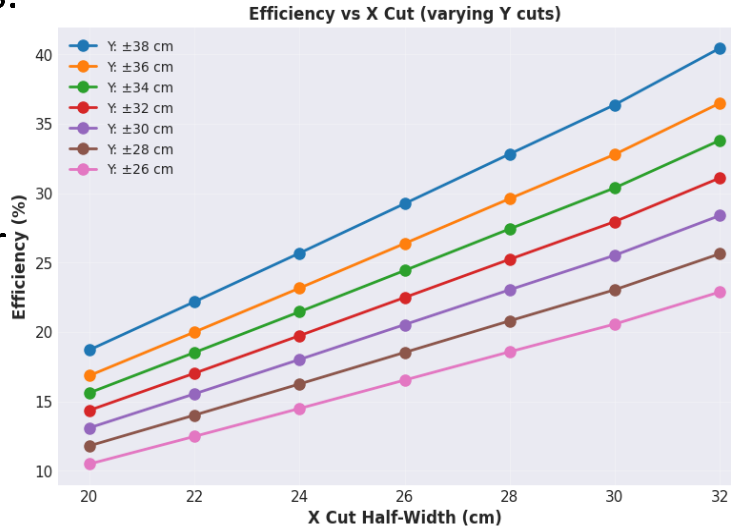
- $\varepsilon_{\{loose\}} = 40.45\%$
- $\varepsilon_{\{strict\}} = 27.42\%$

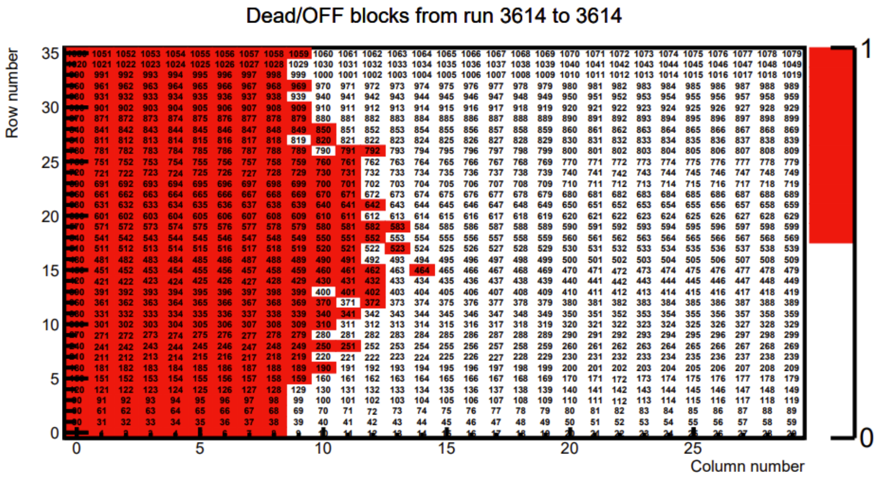
NPS π^0 Geometric Acceptance (Uniform illumination case)



- The simulated pi0 geometric acceptance quantifies the fraction of events lost as a function of NPS geometry.
- For the ideal case of a uniform photon distribution over the calorimeter surface (shown), the acceptance behavior is straightforward.
- In data, periods with dead or inefficient blocks and possible radiation damage can introduce non-uniform, geometry-dependent losses, leading to non-trivial acceptance effects.

- **In progress**:
  - Apply energy and position smearing to the simulated photons to reproduce the detector resolution observed in data.
  - Use the smeared simulation to obtain a more realistic estimate of the NPS geometric acceptance.





Conclusion

- **Preliminary data quality check:** Initial event selection and detector calibrations are stable; photon/electron reconstruction performance is consistent with expectations.
- **Pipeline readiness:** Analysis framework now handles multi-run datasets, per-run corrections, and outputs structured ntuples for physics observables.
- **MC integration validated:** SIMC+Geant4 workflow reproduces basic kinematic distributions; smearing procedures provide realistic resolutions for comparisons.

Next Steps

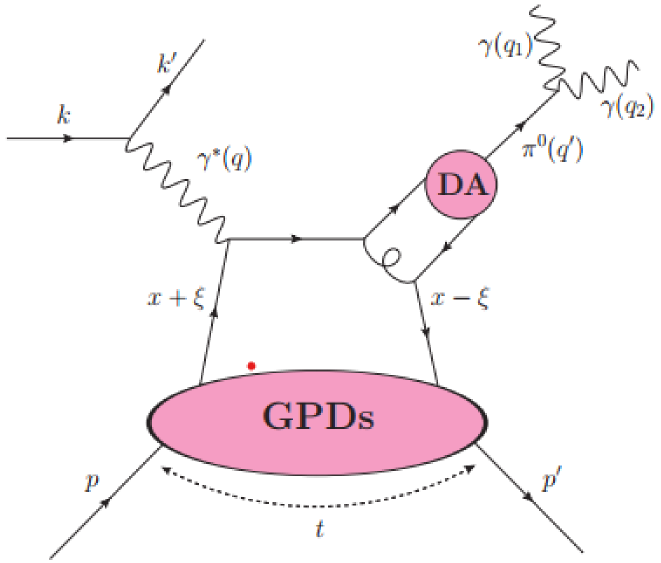
- **Finalize binned datasets:** Complete binning in Q^2, θ, ϕ, $-t$ for exclusive and SIDIS observables; produce intermediate physics distributions.
- **Efficiency & normalization refinements:** Fine-tune all efficiency and normalization corrections, and propagate uncertainties to the final yields.
- **MC-data tuning:** Optimize SIMC+Geant4 smearing parameters; include additional detector effects to better reproduce data.
- **Cross-checks & validation:** Compare results with collaborators' simulations and historic datasets to ensure consistency.
- **Preliminary physics results:** Generate preliminary cross-section estimates with propagated uncertainties.

Thanks for your time and attention! :D

Backup

Physics Motivation: Exclusive π^0 Electroproduction

- **Measurements** of exclusive π^0 electroproduction in the valence region have been performed by **Hall A** [1] and the **CLAS Collaboration** [3,4].
- Hall A results suggest **dominant contributions from transversely polarized virtual photons** (σ_T).
- **Significant LT and TT interference terms** were also observed, highlighting the complex structure of the reaction mechanism.
- Measuring **longitudinal-transverse (L/T) separated cross sections** offers a **clean probe of transversity effects** in pion electroproduction.
- L/T-separated π^0 predictions above the resonance region remain uncertain, with **limited experimental data available**.
- If a **large σ_T** is confirmed at higher Q^2 and W, it could open the door to a **detailed study of transversity GPDs**—an essential but elusive piece of the nucleon structure puzzle.
- Meanwhile, the **longitudinal cross section σ_L**, if isolated, could provide a **unique channel to access the usual chiral-even GPDs** via **neutral pion production**.



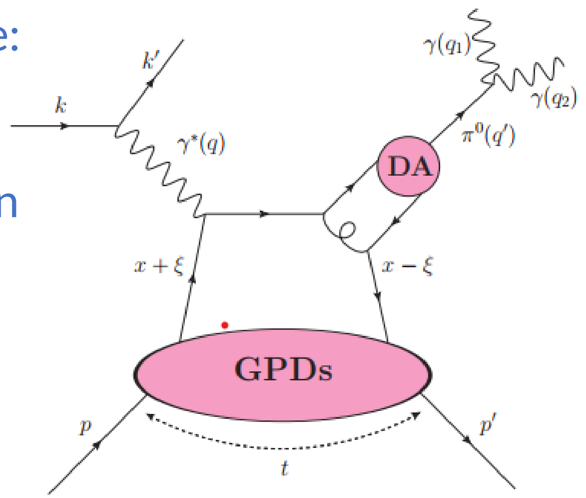
- PhysRevLett.117.262001

E12-13-010: Exclusive Deeply Virtual Compton and Neutral Pion Cross-Section Measurements in Hall C

Complement the kinematic settings of Hall A, by one or two conjugate setting. Increases the Q^2 reach to even higher values at fixed x_B. Expands the kinematic coverage to smaller values of x_B.

- π^0 electroproduction complements other channels for studying the nucleon structure:
  - **No diffractive ρ contributions**: Cleaner signal, reducing complications from vector mesons.
  - **No exclusive pole contributions**: Focuses the analysis purely on the production mechanisms without interference.
  - **Reduced resonance contributions**: Resonances play a smaller role, allowing access to more fundamental processes.

- Motivation for π^0 electroproduction towards GPDs:
  - Sensitive to transversity GPDs (H_T, E_T), which are less accessible in vector meson production.
  - Offers insights into parton helicity flipping (chiral-odd GPDs).
  - No need for polarized targets or beams to access these polarized distributions.



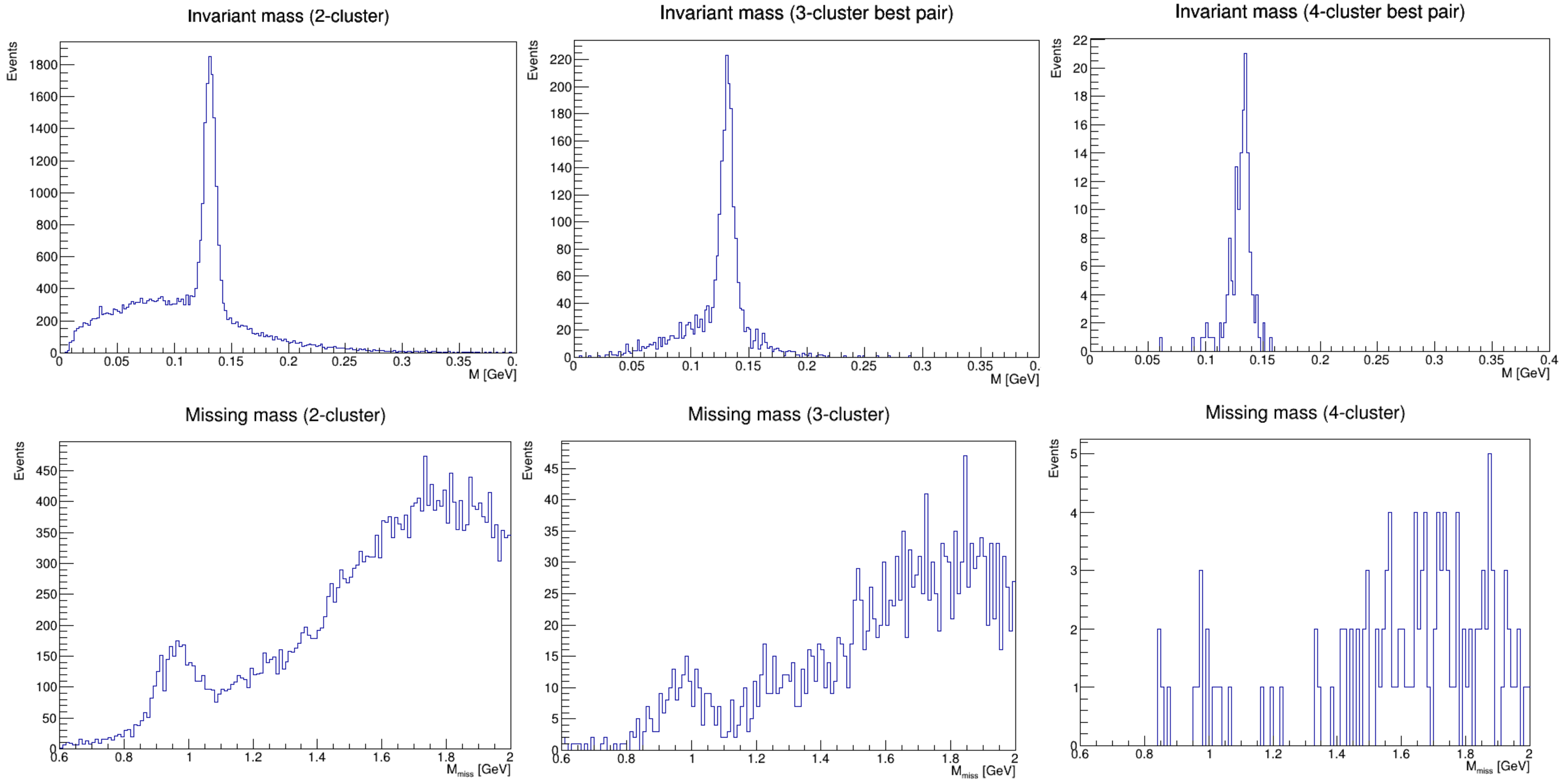
- PhysRevLett.117.262001

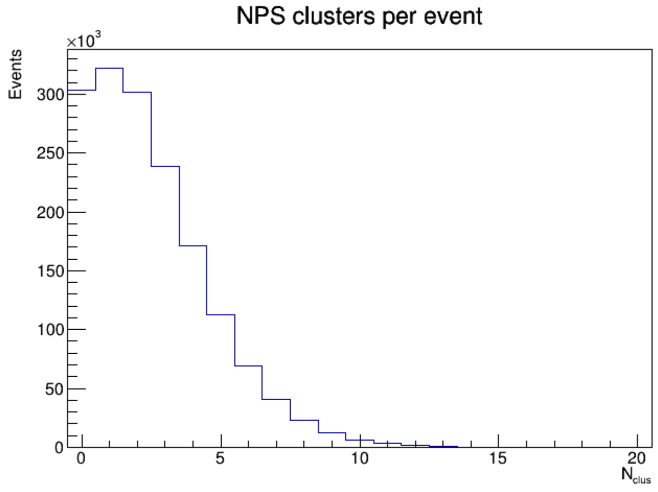
The three weights in the Skim

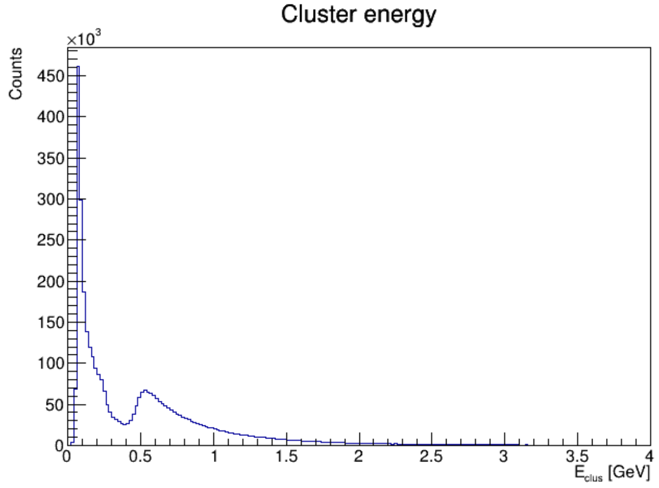
The three weights in the Skim

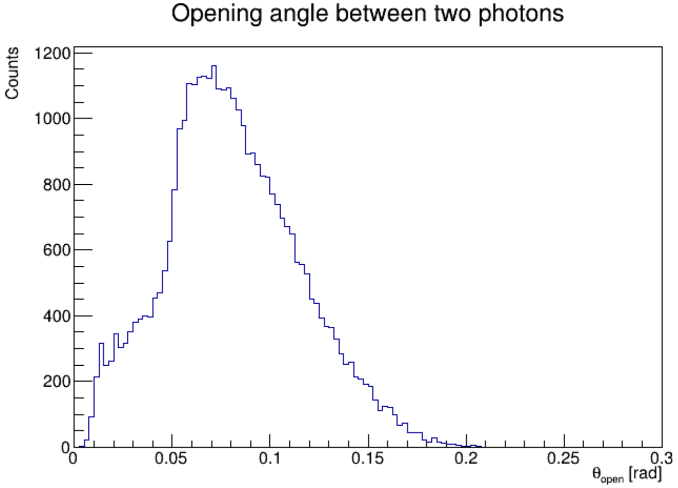
- **w_sig** – Template-A (combinatorial) signal weight
  - Built from the **A-method category mixing** (V/H/AD/AP) using the all-pairs template.
  - Encodes, for each event, the factor that turns the raw CC category counts into an estimate of the “true” CC π^0 contribution after accidental / category subtraction.
  - Use case: sanity checks of the A-method itself, or comparisons to older v5-style analyses.
- **w_phys** – “physics” weight (dummy + Option-A corrected)
  - For each Mγγ bin *j*, the production step builds the final dummy+Option-A–subtracted spectrum:
  - Use case: this is the **“physics-corrected” weight** that reproduces the final dummy+Option-A–subtracted Mγγ spectrum and is appropriate for unselected charge-normalized yields.
- **w_signal** – S+B–cleaned signal-only weight

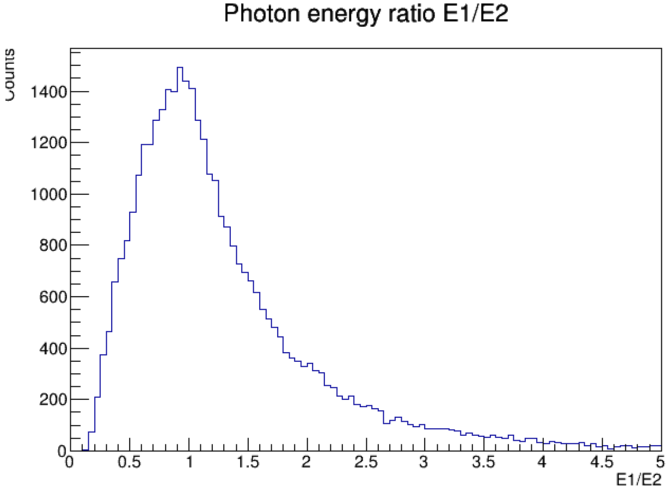
  From the S+B fit to the final Mγγ spectrum Fitted signal yield SjS_jSj
  - Fitted background yield BjB_jBj
  - Signal fraction (purity) fS(j)=Sj/(Sj+Bj)f_S(j) = S_j / (S_j + B_j)fS(j)=Sj/(Sj+Bj)
  - w_signal keeps **all** the earlier corrections (dummy, A-method, charge, etc.),
  - and additionally projects out only the **π^0 signal component** according to the S+B fit model.
  - Use case: any distribution (Mx, kinematics, etc.) where you want **signal-only** yields from the fit, with the irreducible under-peak background statistically removed.
  - Will be used for **final normalized yields** in analysis.

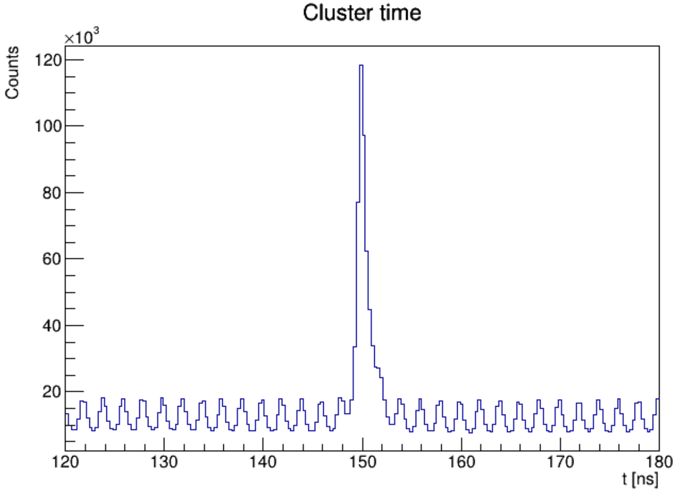

Invariant mass (2-cluster)
Invariant mass (3-cluster best pair)
Invariant mass (4-cluster best pair)
Events
M [GeV]
Missing mass (2-cluster)
Missing mass (3-cluster)
Missing mass (4-cluster)
Events
M_{miss} [GeV]





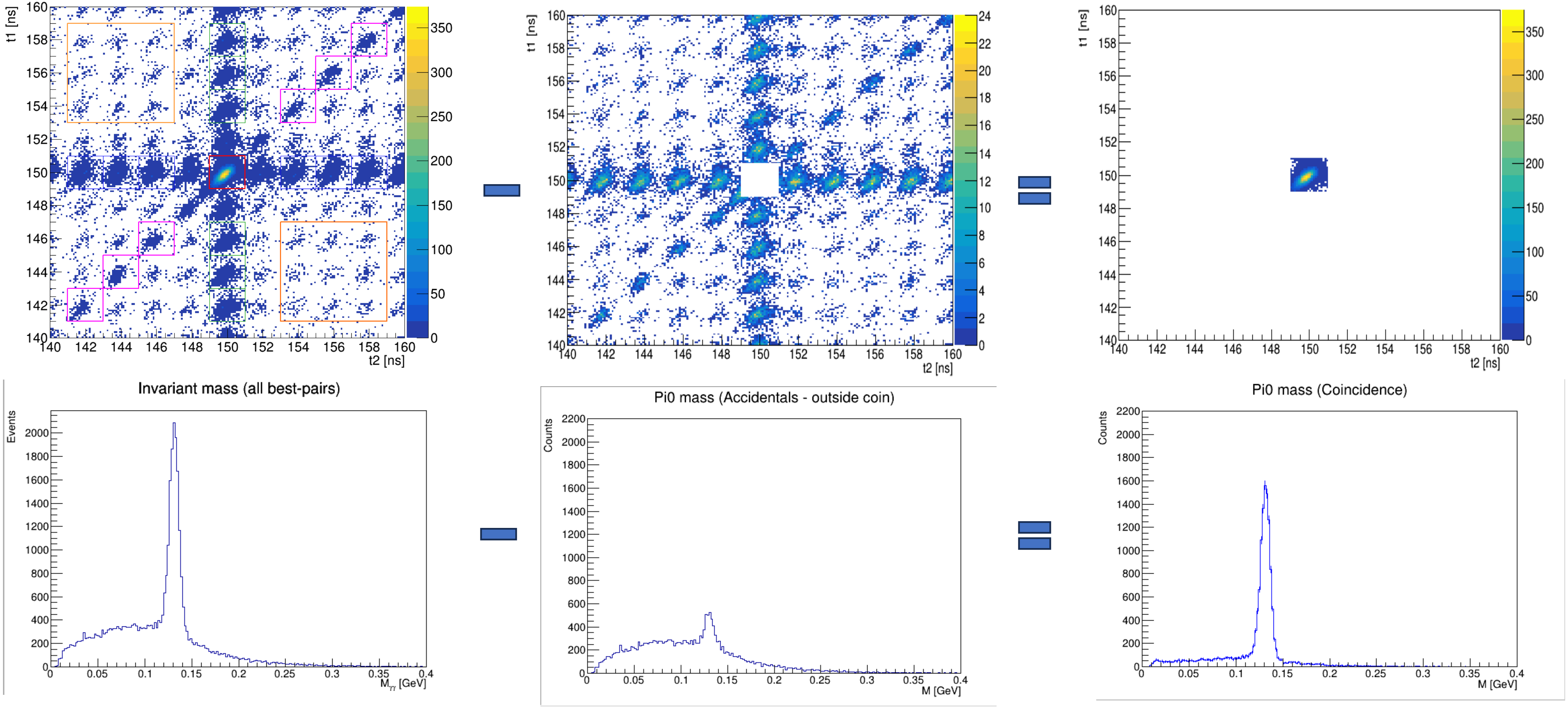






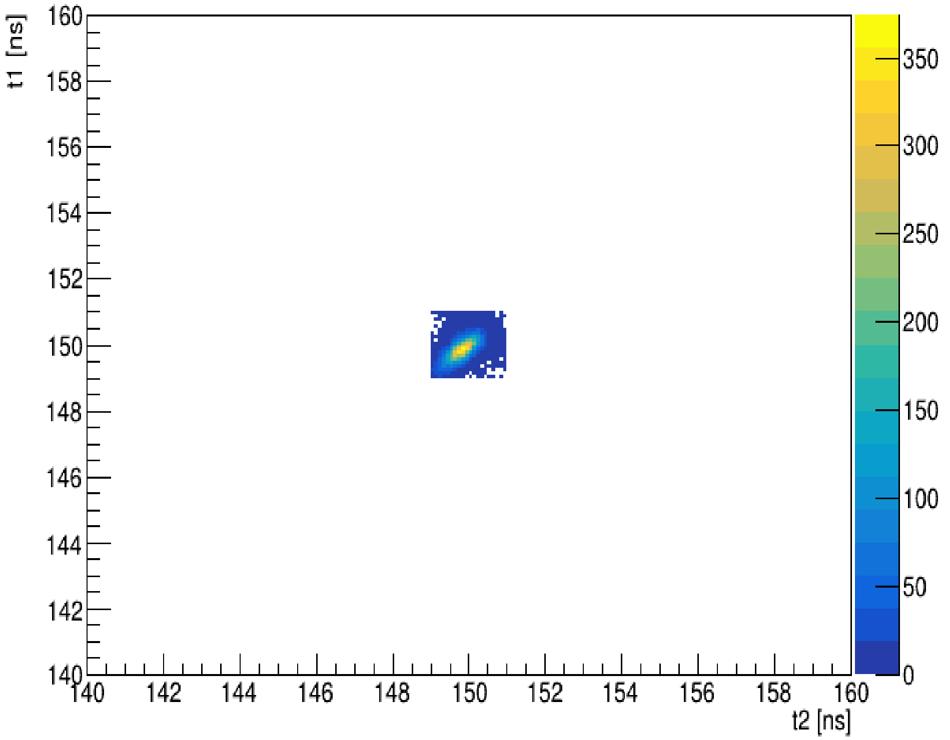

```
===== Run 4398 summary =====
 Total entries: 3222394
 Pass HMS: 1606270
 Pass HMS + NPS selection: 36360
 Coin raw (timing plane): 14550
 Estimated accidentals (time method): 946.389 +- 10.2601
 Comb. BG fit χ2/ndf: 2.395
 Pi0 fit μ (MeV): 131.158   σ (MeV): 5.264
 Pi0 signal counts (final): 9834.132
```

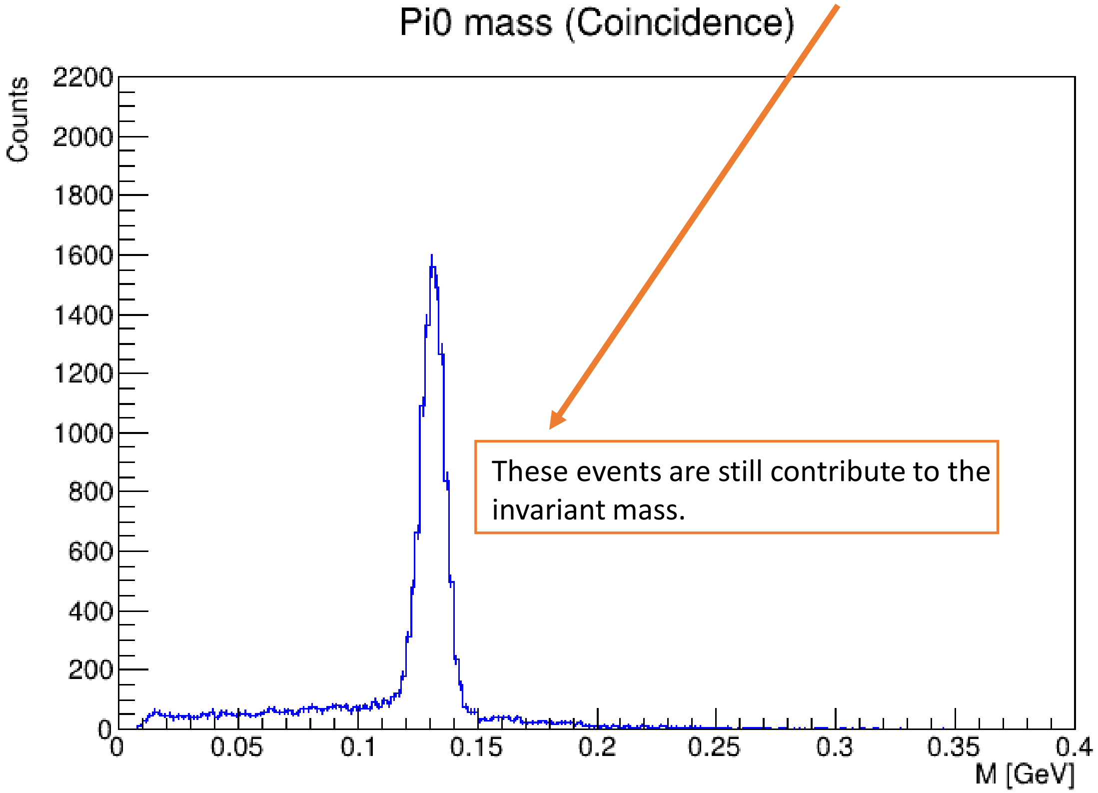
Step 1: Excluding Out-of-Window events



Step 2: Subtracting timing accidentals via sidebands

```
Run 4398 entries: 3222394
 run 4398 event 3222300 / 3222394
[nps::estimate_coincidence_background_default] Summary:
 Coincidence box: [149,151] x [149,151]
  raw coin counts = 14550   area (ns^2) = 4
 Diagonal sideband raw sum = 1370   total area = 24  normalized -> 228.333
 Horizontal sideband raw sum = 5187   total area = 24  normalized -> 864.5
 Vertical sideband raw sum = 4067   total area = 24  normalized -> 677.833
 Full accidental box1 raw = 478  area = 36  norm -> 53.1111
 Full accidental box2 raw = 478  area = 36  norm -> 53.1111
 Final estimated accidental counts in coin box = 946.389 +/- 10.2601
```

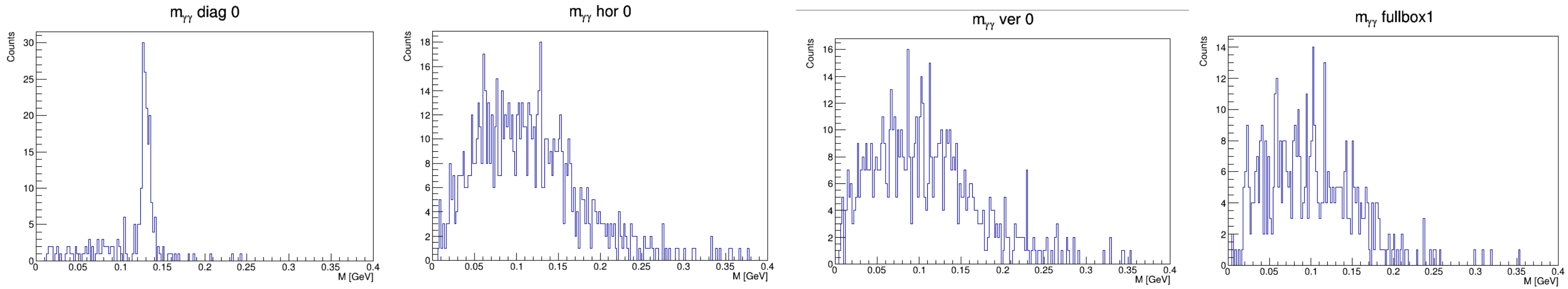




These events are still contribute to the invariant mass.

Step 2: Removal of the contribution to the coincidence window from (timing) accidental events estimated using the sidebands.

```
h_template = diag_sum * 1.0 + 0.5*(hor_sum + ver_sum) - 0.5*(full1 + full2)
```



Modeling Timing Accidentals in the coincidence window

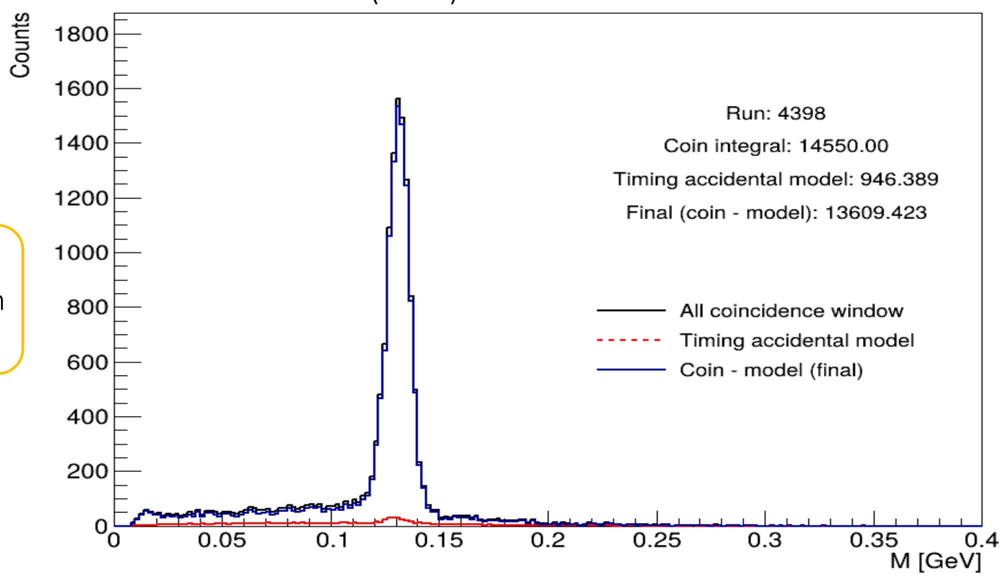
1. Timing accidentals within the coincidence window are **modeled using data from the out-of-coincidence window**.
2. The **model is scaled** so that its **integral reproduces the estimated accidental counts** in the coincidence window.

```
Final estimated accidental counts in coin box = 946.389
```

3. This approach ensures a **data-driven estimate** of accidental contributions without biasing the signal.

Subtract the estimated acc in the coin win

Pi0 mass (time) accidental subtraction



Rate definitions

(Ref. thesis Salina F. Ali)

$$Raw\ Rate\ (Hz) = \frac{Raw\ Counts}{Step\ time\ (s)}$$

$$LCF\ Corrected\ Rate\ (Hz) = \frac{Raw\ Counts}{Step\ time\ (s) \times LCF}$$

$$Current\ Normalized\ rate\ \left(\frac{\mu A}{Hz}\right) = \frac{LCF\ Corrected\ Rate(Hz)}{I(\mu A)}$$

(Ali 2018). The background containing all events (true coincidences, accidentals and random coincidences) scales with the beam current squared (I^2) and can be written as

$$Background\ (ns) = b \times I^2 \tag{3.50}$$

where b is a constant. The signal or real coincidences scale directly with the beam current shown in

$$Signal\ (ns) = a \times I \tag{3.51}$$

where a is a constant. The relationship between the signal, background and current I can be expressed by a ratio of signal to background:

$$\frac{Signal}{Background} = \frac{a \times I}{b \times I^2} = \frac{a}{b \times I} \tag{3.52}$$

Simplifying this signal to background ratio further to apply to the coincidence time distribution, we can write

$$\frac{Signal}{Background} = \frac{Background - Accidental\ peak}{Background} \tag{3.53}$$

where the accidental peak is shown in Fig. 3.19. The beam current dependence for the signal and accidentals is expressed by Eq. 3.52. The scaled DVCS current normalized rate was calculated by applying Eq. 3.53, and can be expressed by

$$Scaled\ Current\ Normalized\ rate\ \left(\frac{\mu A}{Hz}\right) = \frac{Raw\ Rate\ (Hz) \times Signal\ to\ Background\ ratio}{I\ (\mu A) \times LCF} \tag{3.54}$$

Differences from the DVCS group implementation

- DVCS framework: three components (standalone event generator + HMS MC + Geant4 for NPS); (git link)(presentation)
- This work: two-component unified pipeline — SIMC handles event generation, cross sections, radiative effects, and HMS, while Geant4 is dedicated to the full NPS detector simulation.(git link)
- The branch structure is also slightly different between the two implementations; effort is being made to make the branch structure close to the replay data files in the SIMC+Geant4 implementation.
- This integration uses the well tested SIMC for HallC for the workflow and ensures consistent physics modeling between HMS and NPS.

Prelim shape of Mgg background

- P. Bosted (elog)

- Used large SIDIS samples from the PEPSI (Lund) generator at 10.6 GeV on p and d targets to study the γγ invariant-mass spectrum for NPS acceptance (3.5 m, Eγ > 0.6 GeV).
- Observed a clear π^0 peak at 135 MeV with a background mainly from photons originating from two different π^0s in the same event.
- Background shape becomes less dependent on π^0 energy as the π^0 energy increases.
- Signal-to-background ratio improves rapidly with increasing π^0 energy (note log scale).
- No NPS energy resolution applied, so the true signal-to-background will be worse, especially at low π^0 energies.
- Despite this, the background shape is expected to be similar and can be used as a first approximation for modeling under the π^0 mass peak.