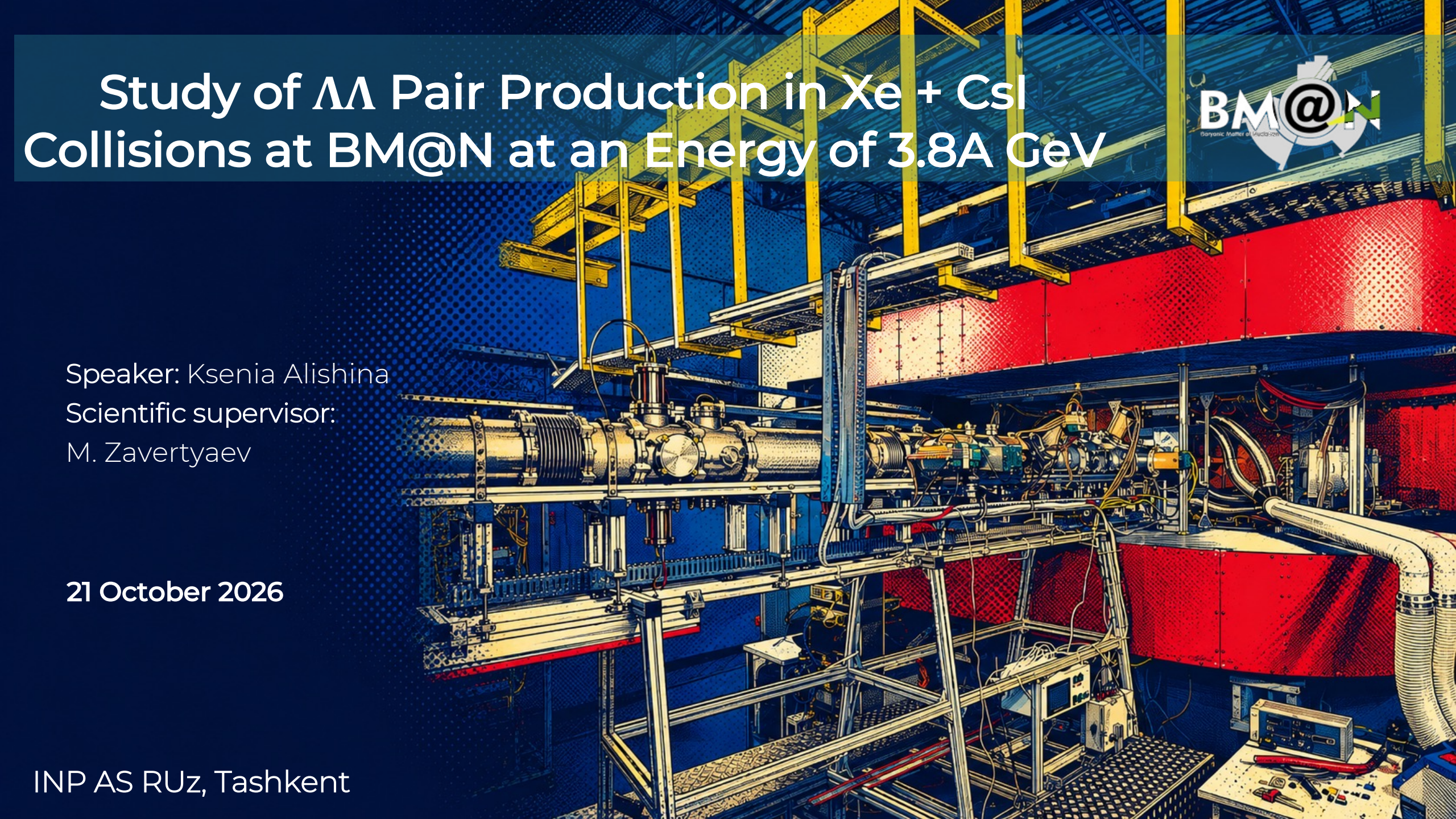
Study of ΛΛ Pair Production in Xe + CsI Collisions at BM@N at an Energy of 3.8A GeV



Speaker: Ksenia Alishina

Scientific supervisor:
M. Zavertyaev

21 October 2026

INP AS RUz, Tashkent

BM@N: Third Physics Paper



JHEP

Published for SISSA by Springer

Received: *April 21, 2026*
Accepted: *June 20, 2026*
Published: *August 6, 2026*

Production of Λ hyperons in 4.0A GeV and 4.5A GeV carbon-nucleus interactions at the Nuclotron

BM@N

The BM@N collaboration

K. Alishina et al.

Full author list at the end of the paper

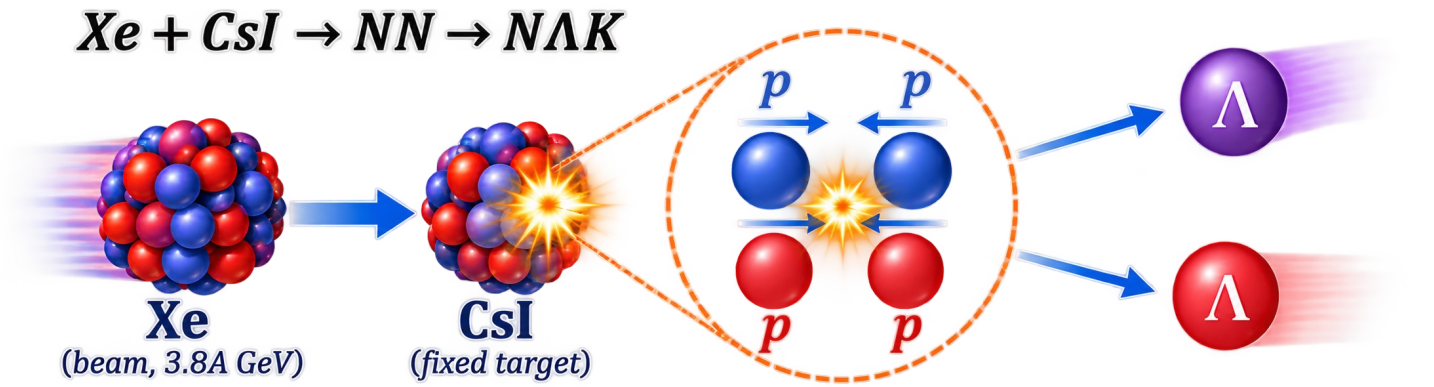
E-mail: bmn@jinr.ru

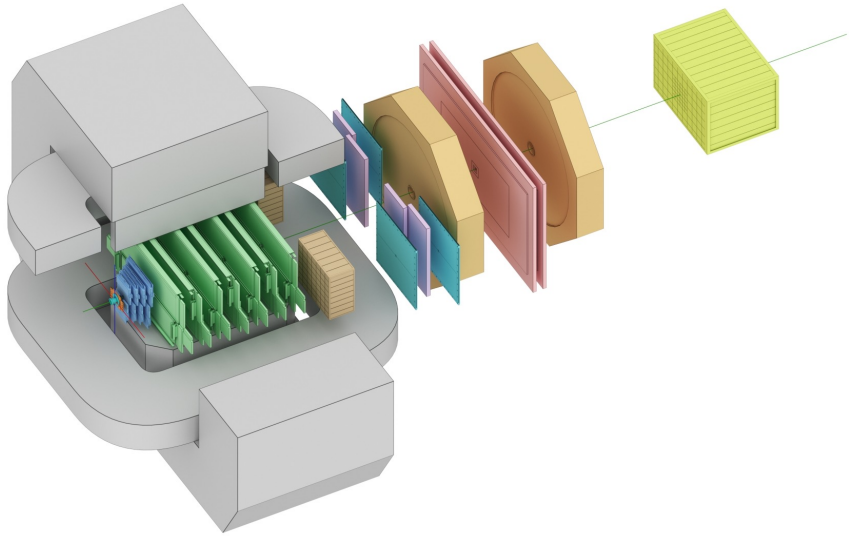
Abstract: The BM@N experiment (Baryonic Matter at the Nuclotron) is the first fixed-target experiment at the JINR NICA accelerator complex. In this work, data on the interactions of a carbon-ion beam with kinetic energies of 4.0A GeV and 4.5A GeV with C, Al, Cu, and Pb targets are used to measure transverse momentum spectra and rapidity distributions of Λ hyperon yields. The results are compared with the predictions of DCM-SMM, UrQMD, and PHSD transport models and with the Λ yield measurements in other experiments at similar collision energies.

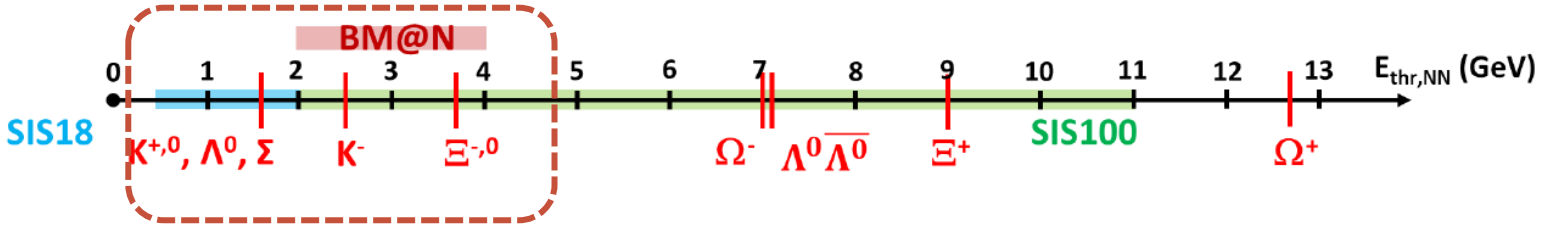
JHEP08(2026)048

And Next Steps ...

Physics motivation: ΛΛ production at BM@N







Configuration run 8,
Xe+CsI, 3.8A GeV

Why ΛΛ pairs?

- Strange particles probe dense baryonic matter;
- At 3.8A GeV, strangeness is produced near/below elementary thresholds;
- ΛΛ pair production provides additional constraints on strangeness-production mechanisms;

How probable is the production of two Λ hyperons in a single heavy-ion collision?

The first step of the analysis is the reconstruction of single Λ hyperons.

1. Selection of high-quality tracks.

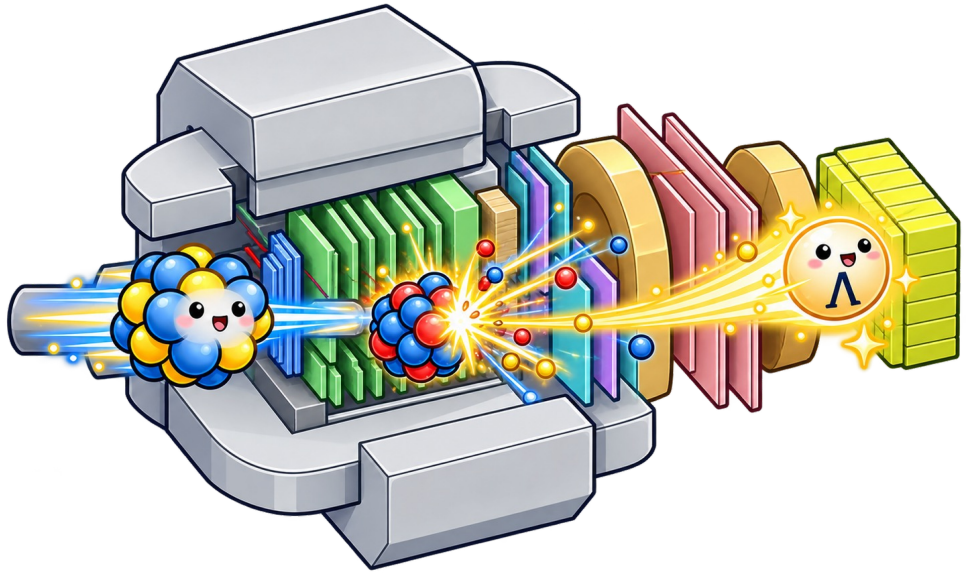
2. Use of the primary vertex coordinates (Xpv, Ypv, Zpv).

3. Construction of $\Lambda \rightarrow p\pi^-$ decay candidates from selected tracks.

4. Reconstruction of the secondary vertex (SV).

5. Application of topological and kinematic selection criteria.

6. Calculation of the invariant mass and construction of the mass spectrum.



Preliminary Selection Criteria for "Good" Tracks

1. Minimum number of hits $N_{hits} > 5$ per track;

2. Validity of track parameters: X, Y, Z, Tx, Ty, Q/p;

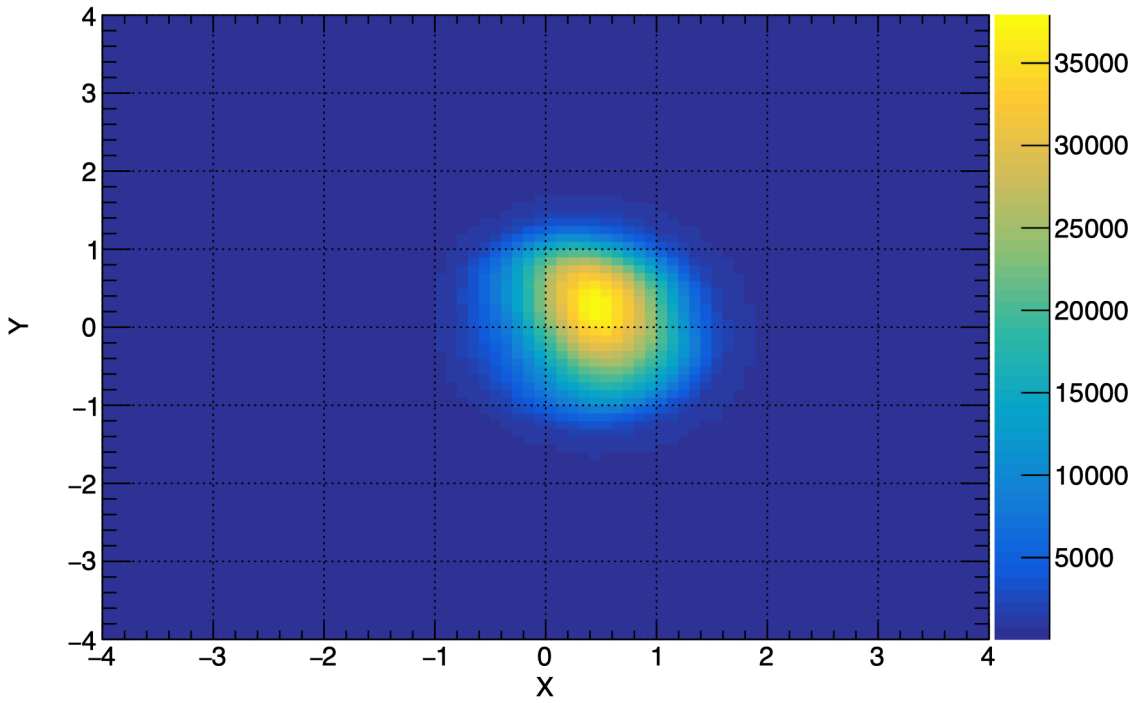
Tracks with incorrect or poorly reconstructed parameters are rejected.

3. Tracks are extrapolated to $Z = Z_{target}$.
The transverse distance to the beam axis is calculated as

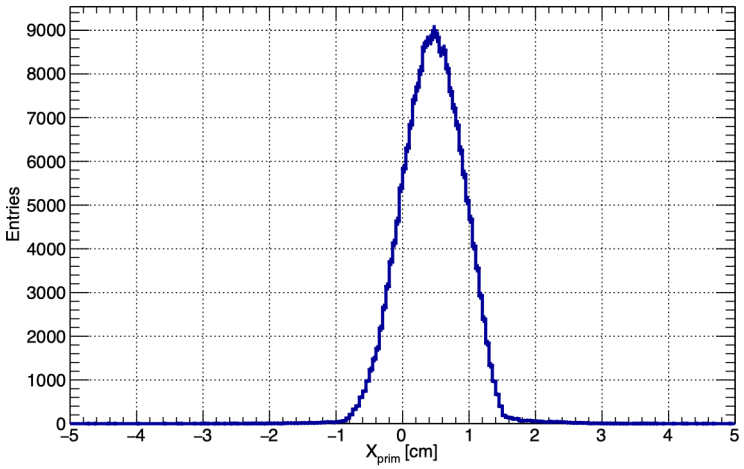
$$\text{dist} = \sqrt{(x_{target} - x_c)^2 + (y_{target} - y_c)^2} < 2 \text{ cm};$$

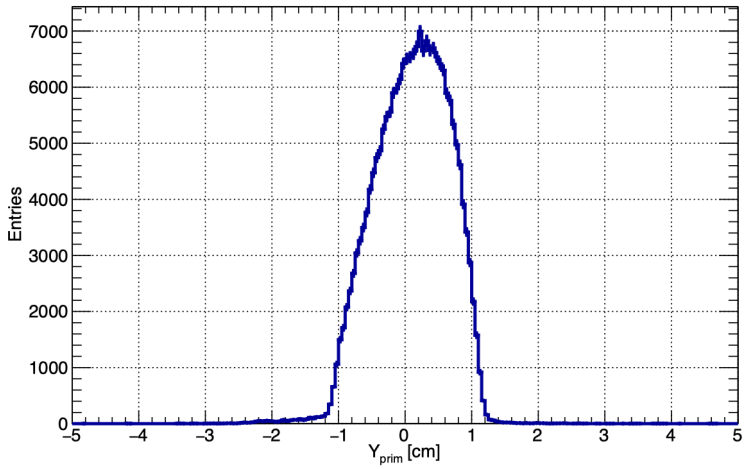
4. Fit quality requirement: $\chi^2/ndf < 10$;

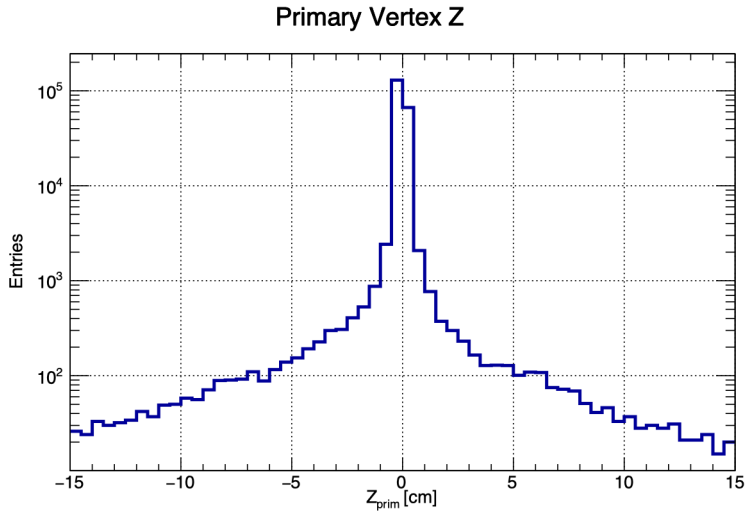
X/Y tracks at TG



Primary Vertex Determination







The primary vertex (PV) coordinates are taken from the standard reconstruction (primVtx).

Select events with: $N_{good_tracks} \geq 4$;

Constrain the interaction region along the Z axis: $|Z_{PV}| < Z_{cut}$

The PV is used as a reference point
for the calculation of secondary-vertex displacement and track impact parameters.

Construction of Λ → pπ⁻ decay candidates from selected tracks

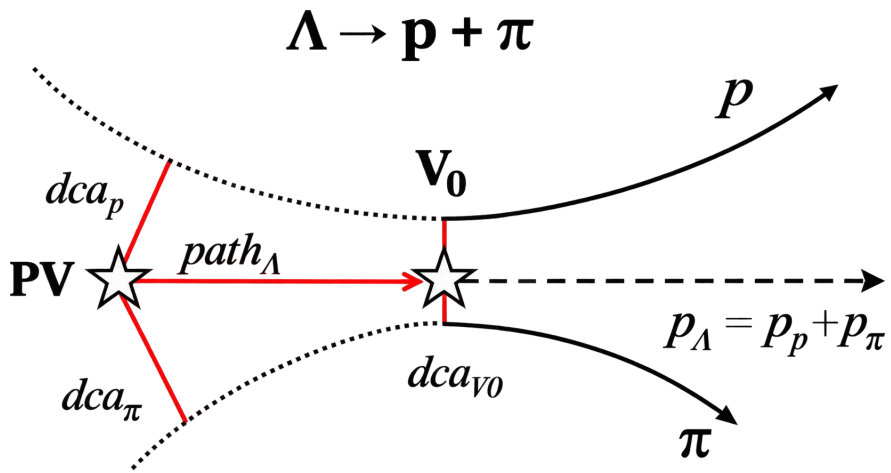
For each track in the list of selected tracks, the charge sign is determined from the parameter q/p :

Positive tracks (q>0) are treated as p candidates;

Negative tracks (q < 0) are treated as π^-candidates;

Selection criteria:

1) p_{pos}< 5 GeV/c, p_{neg}> 0.3 GeV/c;
2) $\mathrm{Log}(\Omega) > 3; \Omega = \mathrm{dca}_{+}^{\mathrm{PV}} \cdot \mathrm{dca}_{-}^{\mathrm{PV}} / (\mathrm{dca}_{\mathrm{V0}}^{\mathrm{PV}})^2 + 4 \cdot \mathrm{dca}_{\mathrm{V0}}^2$;
3) Armenteros–Podolanski plot(α);
4) cosT;
5) dca, path;



Event topology:

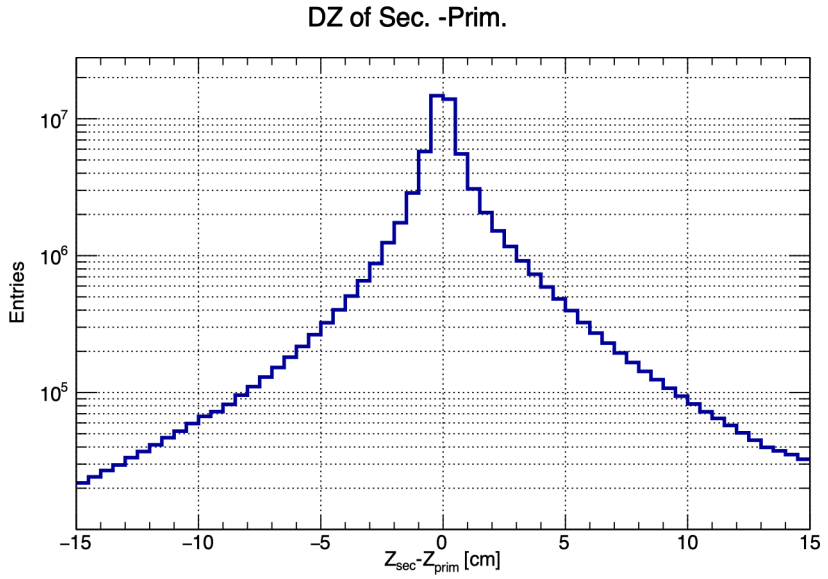
PV – primary vertex

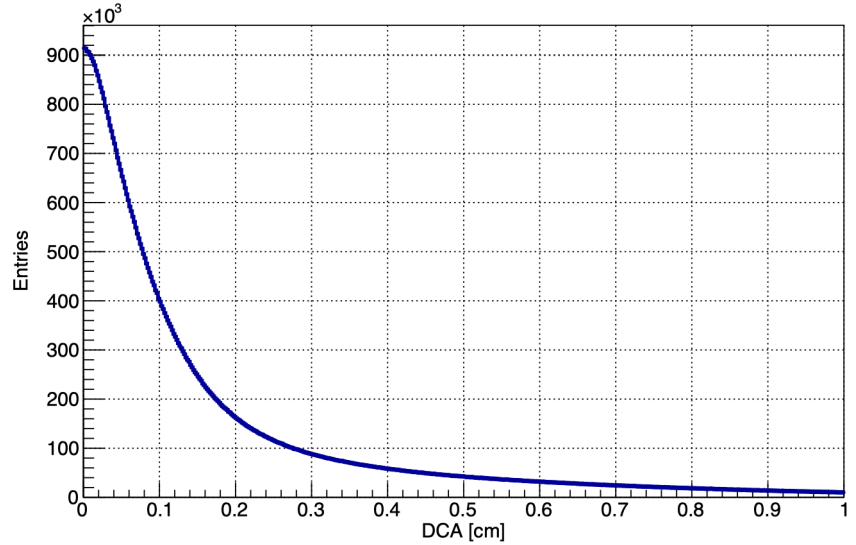
V0 – vertex of hyperon decay

dca – distance of the closest approach

path – decay length

Reconstruction of the Secondary Vertex (SV)



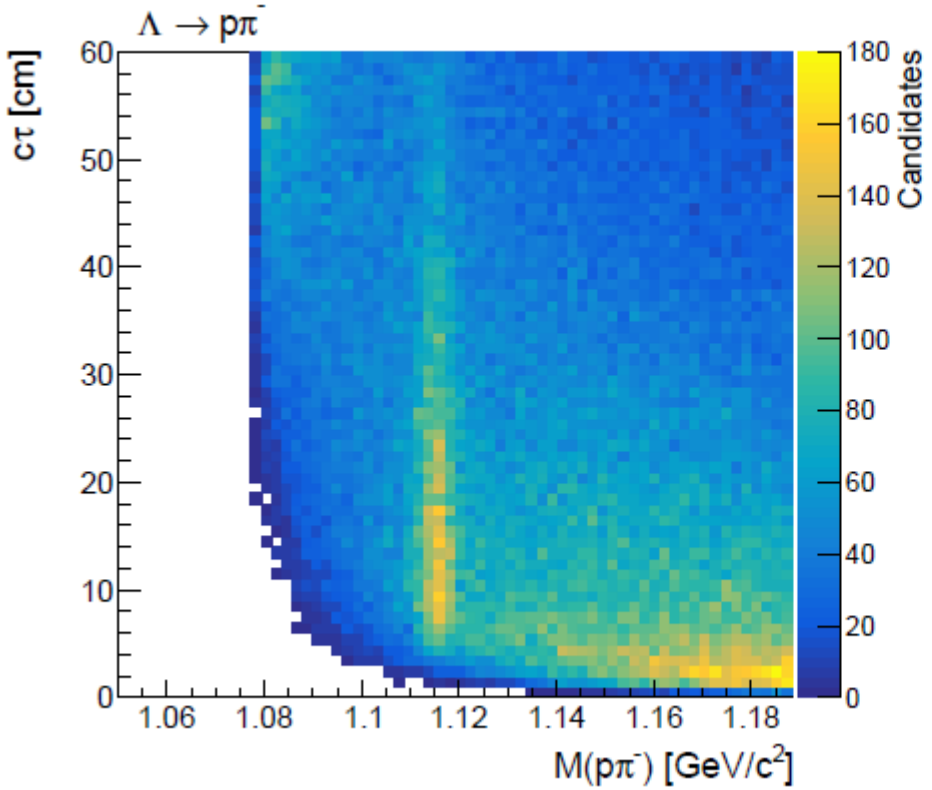


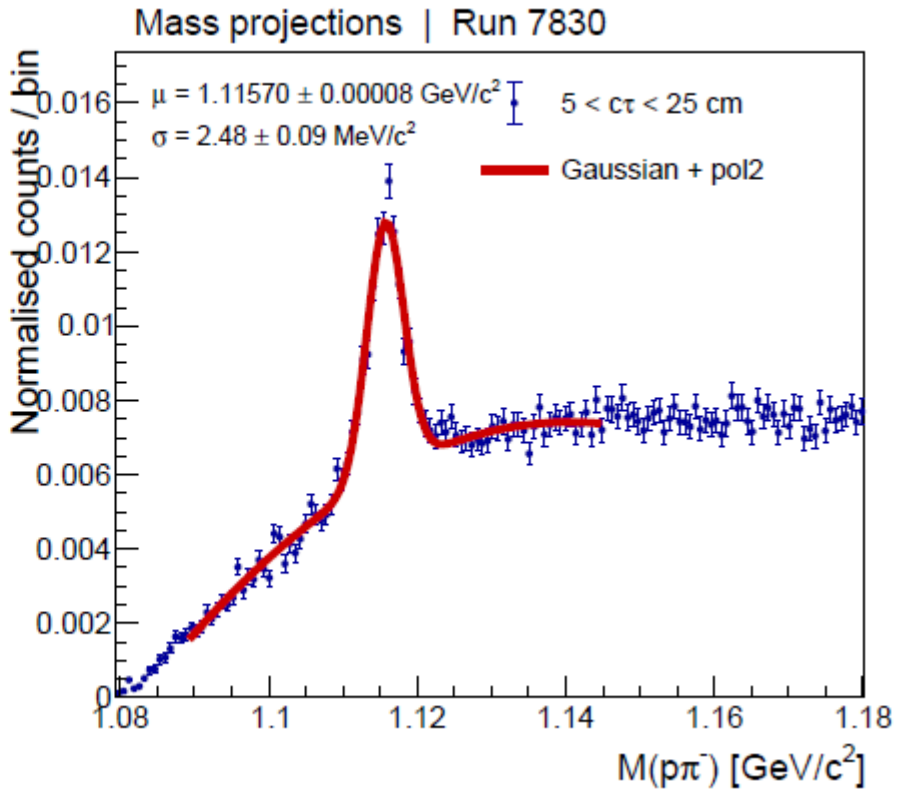
The SV is defined as the point of minimum distance between the daughter tracks (point of closest approach).

path = $Z_{SV} - Z_{PV} > 0$

A small value of the DCA indicates a well-reconstructed secondary vertex.

Signal Λ





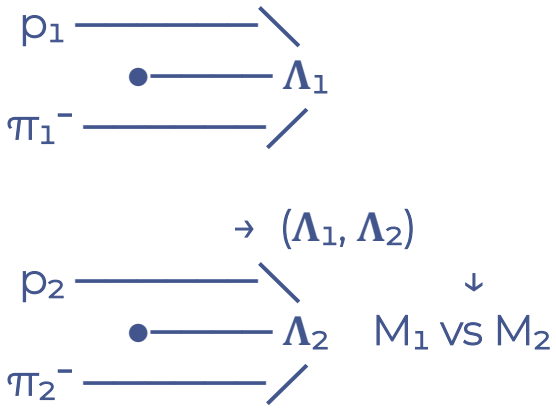
Left: M(pπ⁻) vs reconstructed cτ. **Right:** normalised mass spectra for all cτ and 5 < cτ < 25 cm.

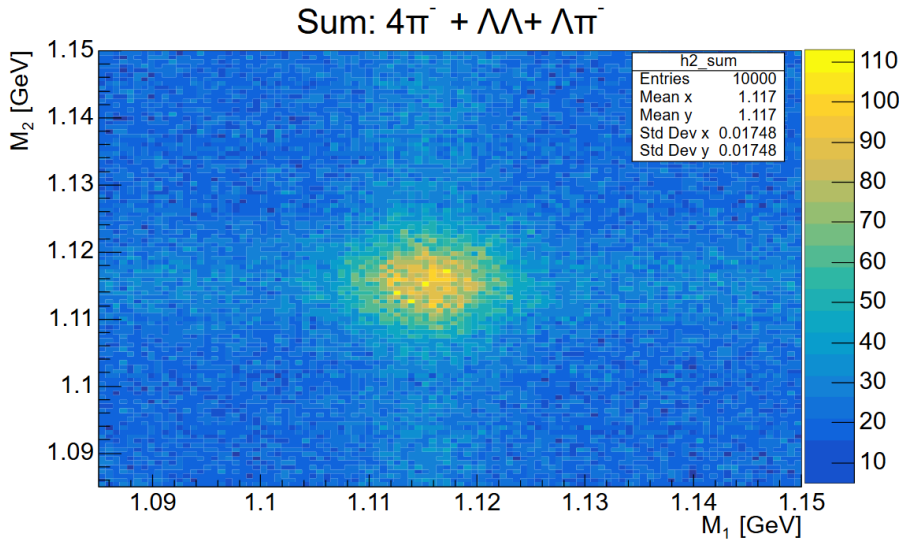
$c\tau = L\,{}^{m_\Lambda}/_{p_\Lambda}$, where L is the Λ hyperon decay length.

Lifetime extraction $\mathbf{{}^{dN}/_{dct} = {}^{N_0}/_{c\tau_\Lambda} \cdot \exp(-{}^{ct}/_{c\tau_\Lambda})}$

ΛΛ pair selection

ONE EVENT





Simulation of combinatorial background and ΛΛ signal

Pair selection:

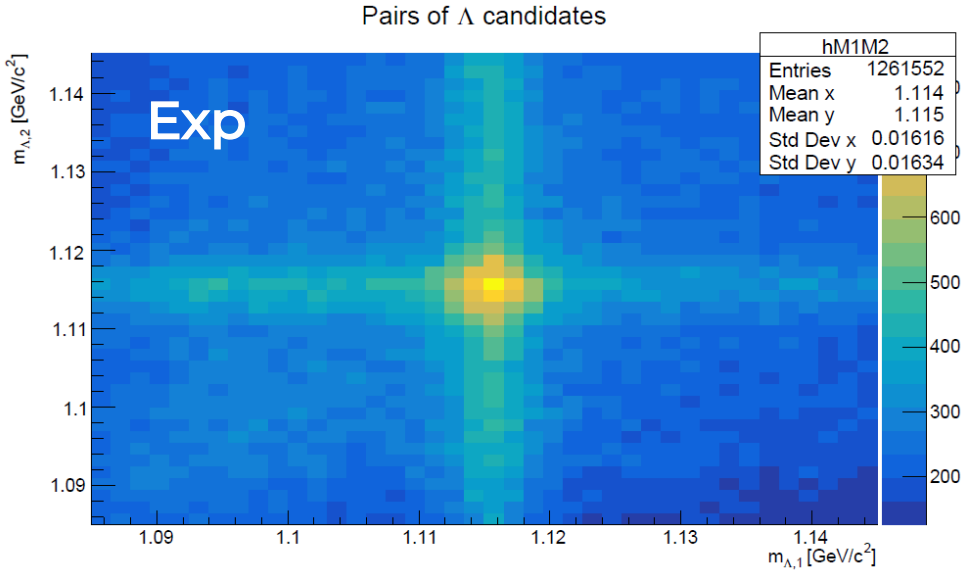
- Two Λ candidates in the same event;
- Each candidate passes the Λ selection cuts;
- The candidates do not share daughter tracks;
- Each unique ΛΛ combination is counted once;

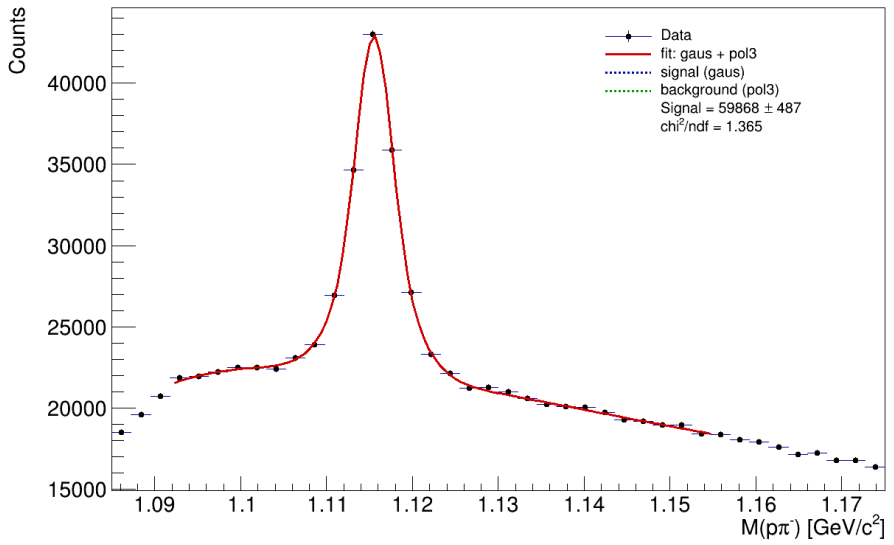
Fit procedure development (Gaussian + background):

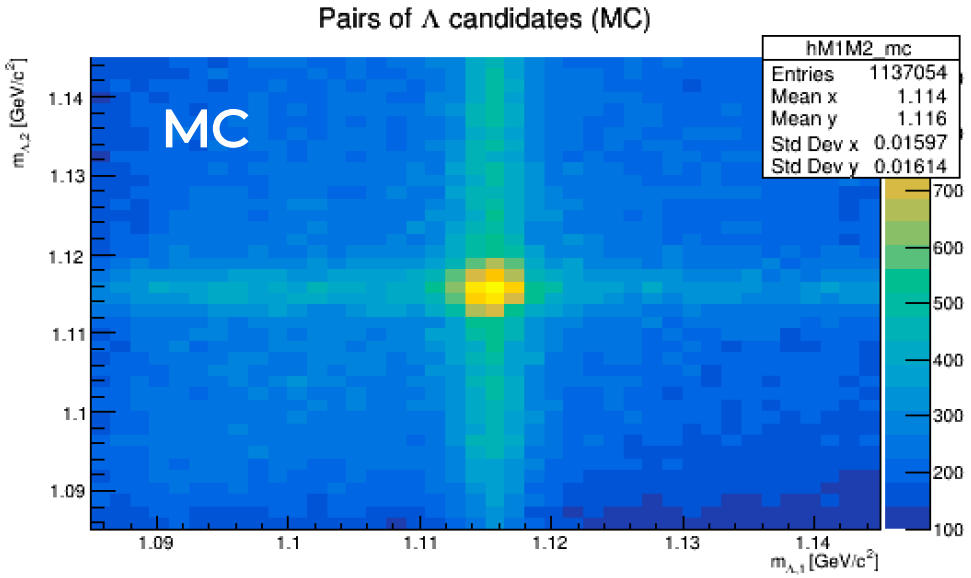
- Slice fit 2D histogram
- Refit sum signal histogram

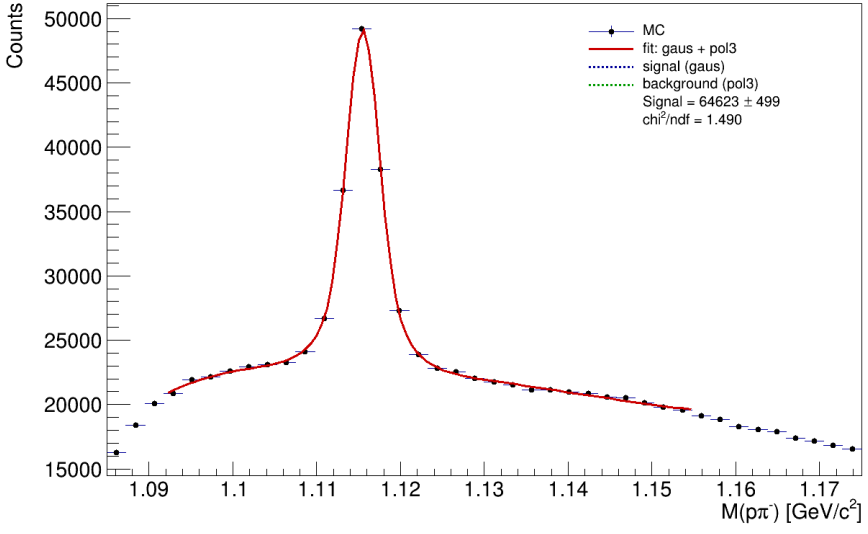
Extraction of true pair yield

Comparison of experimental data with MC samples
(data set from A. Zinchenko group)

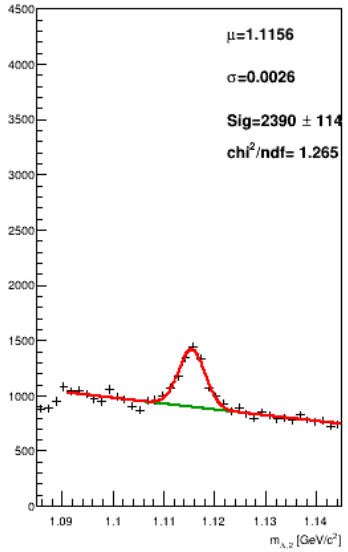


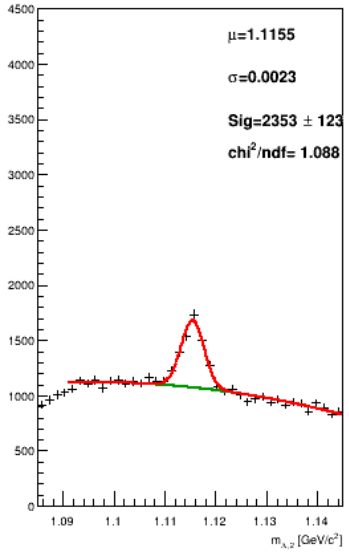


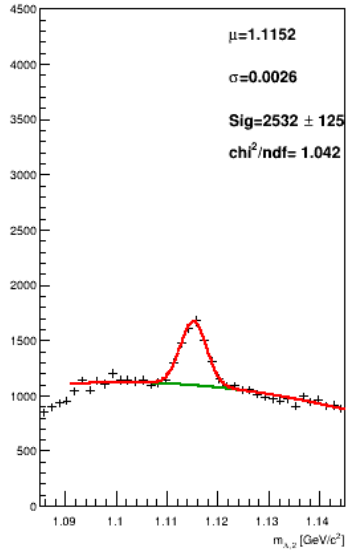


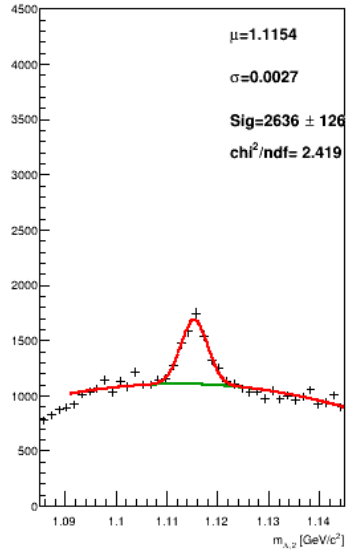


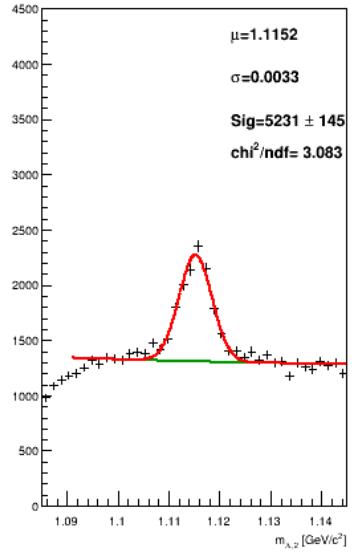
Apply fit method to Xe+CsI data

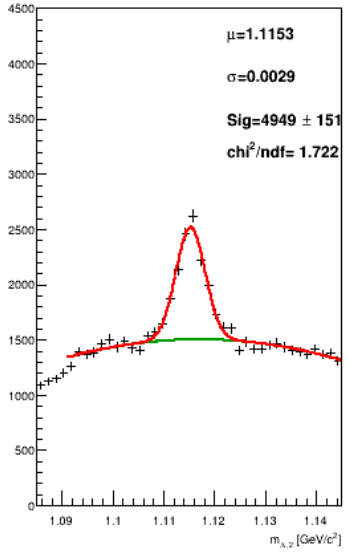


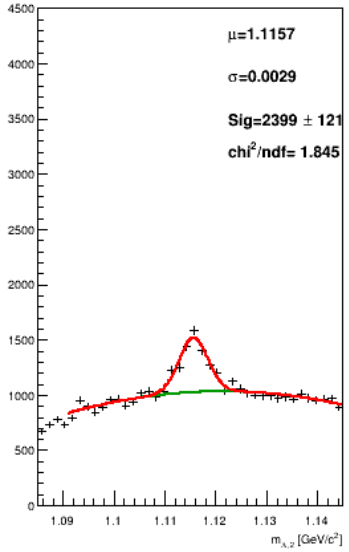


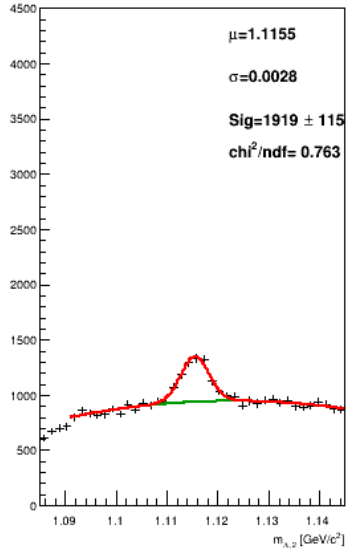


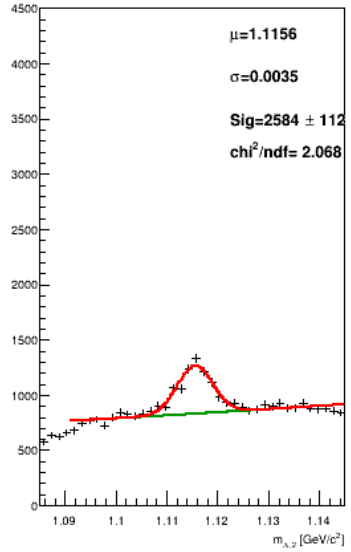


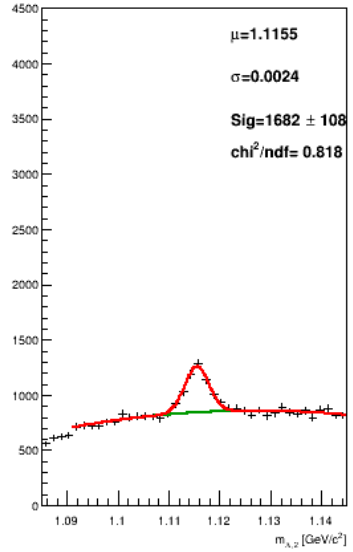




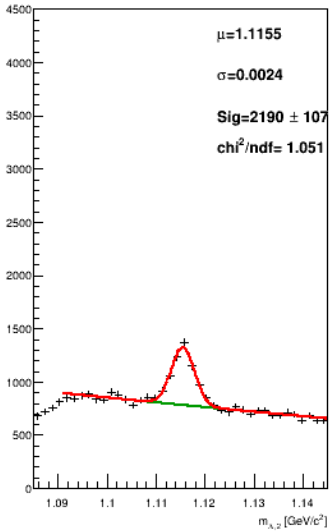


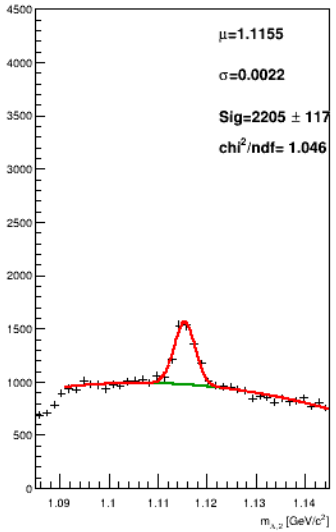


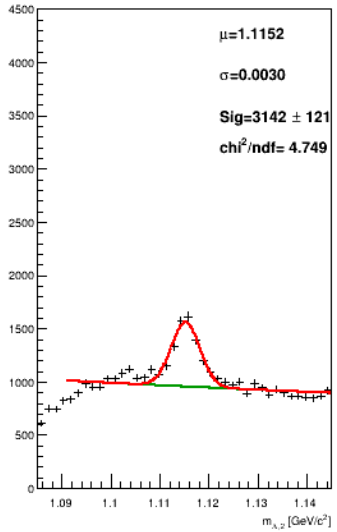


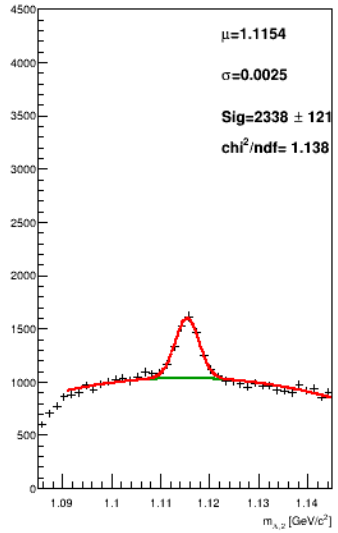


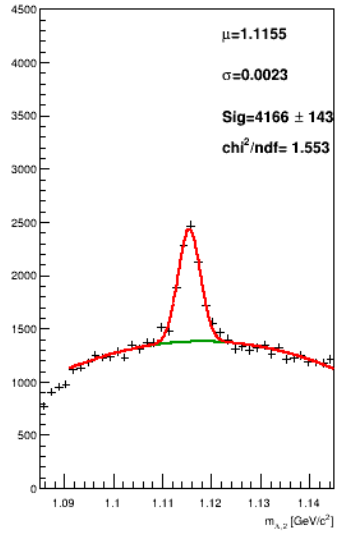
… Comparison fit method to MC simulation

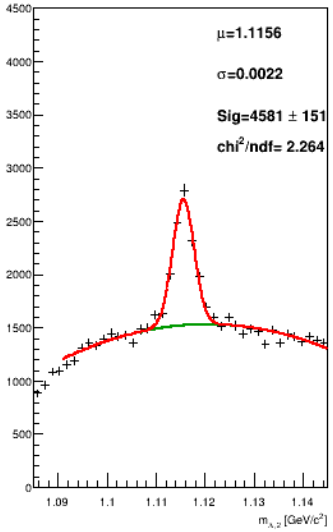


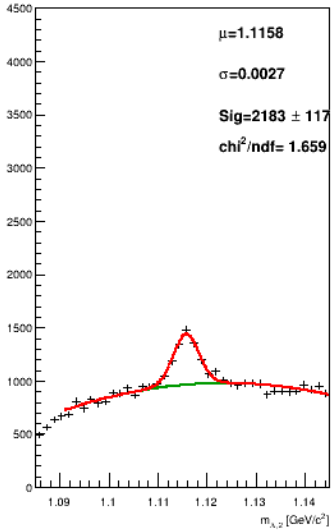


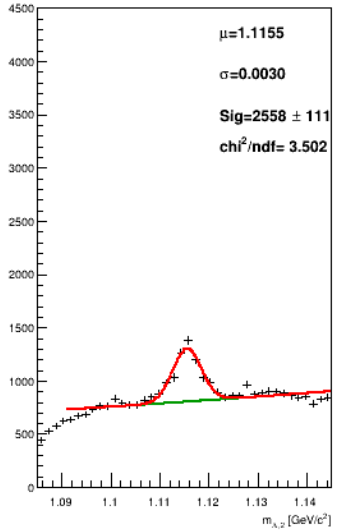


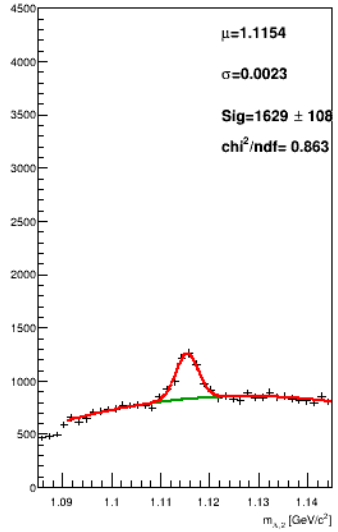


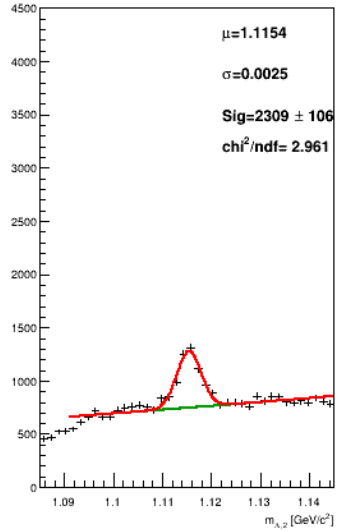




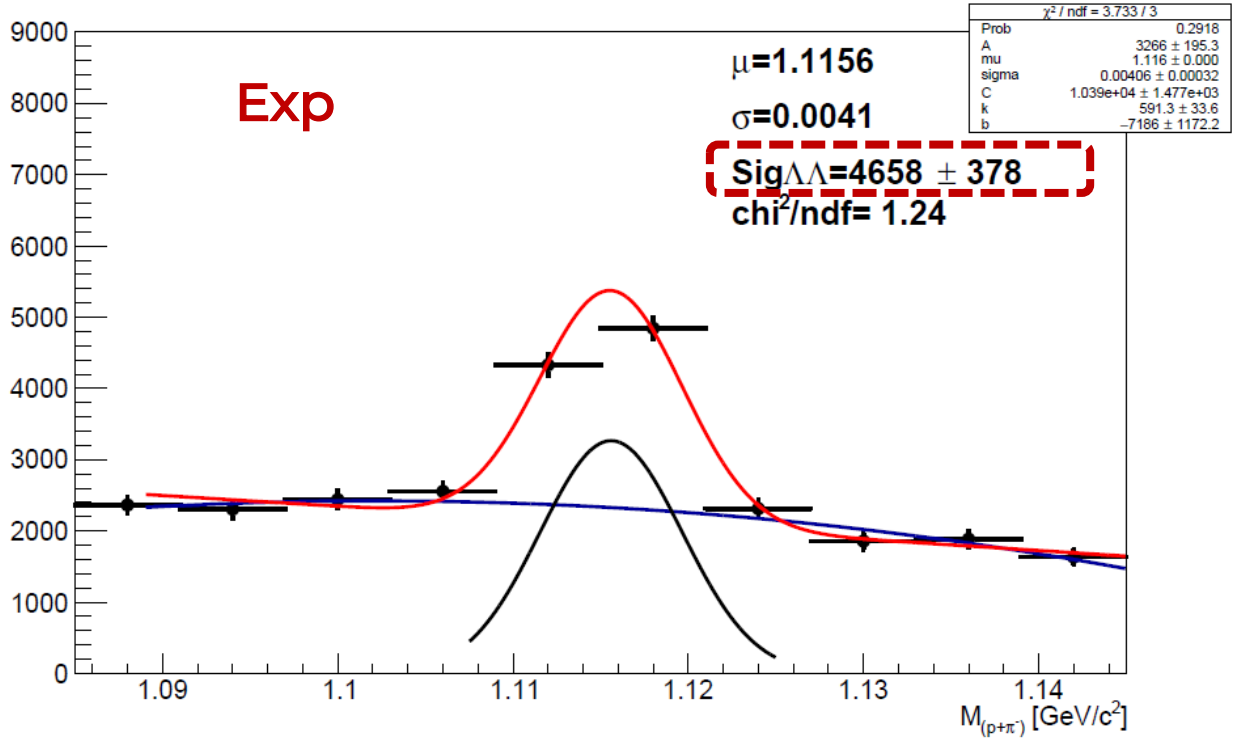


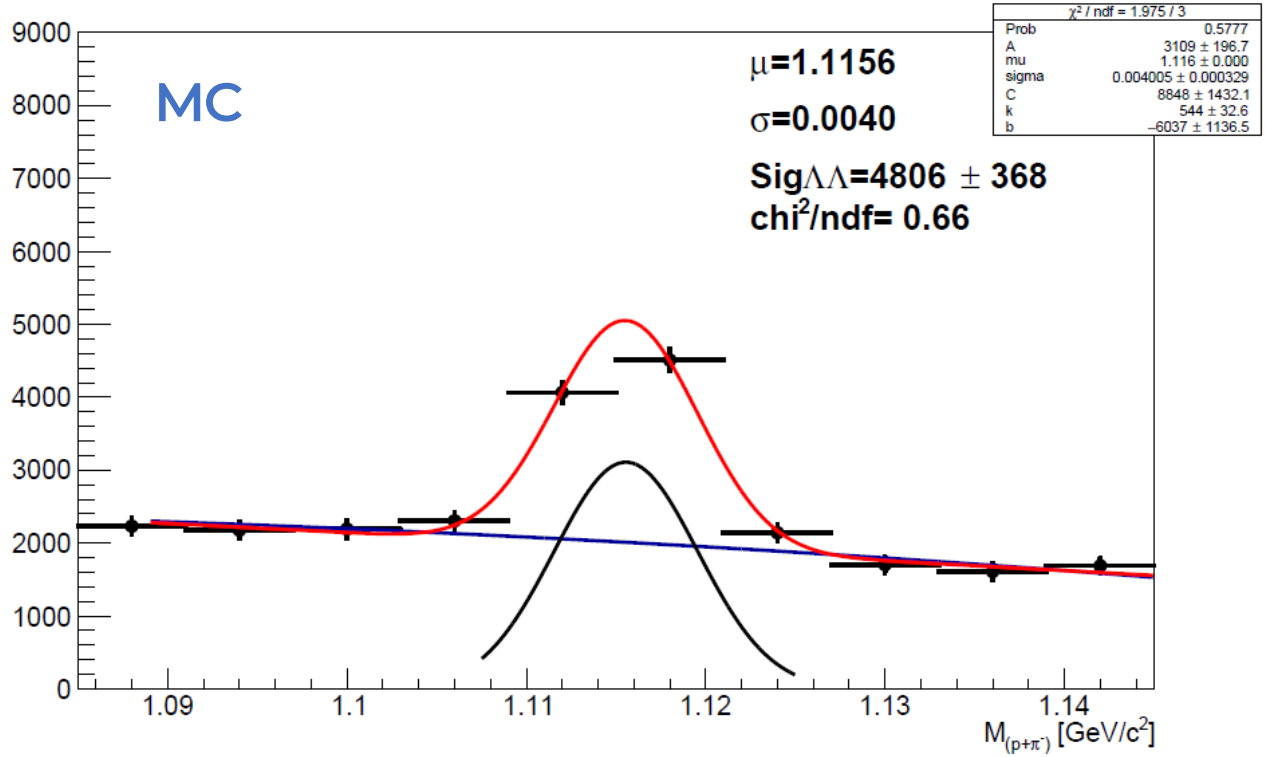






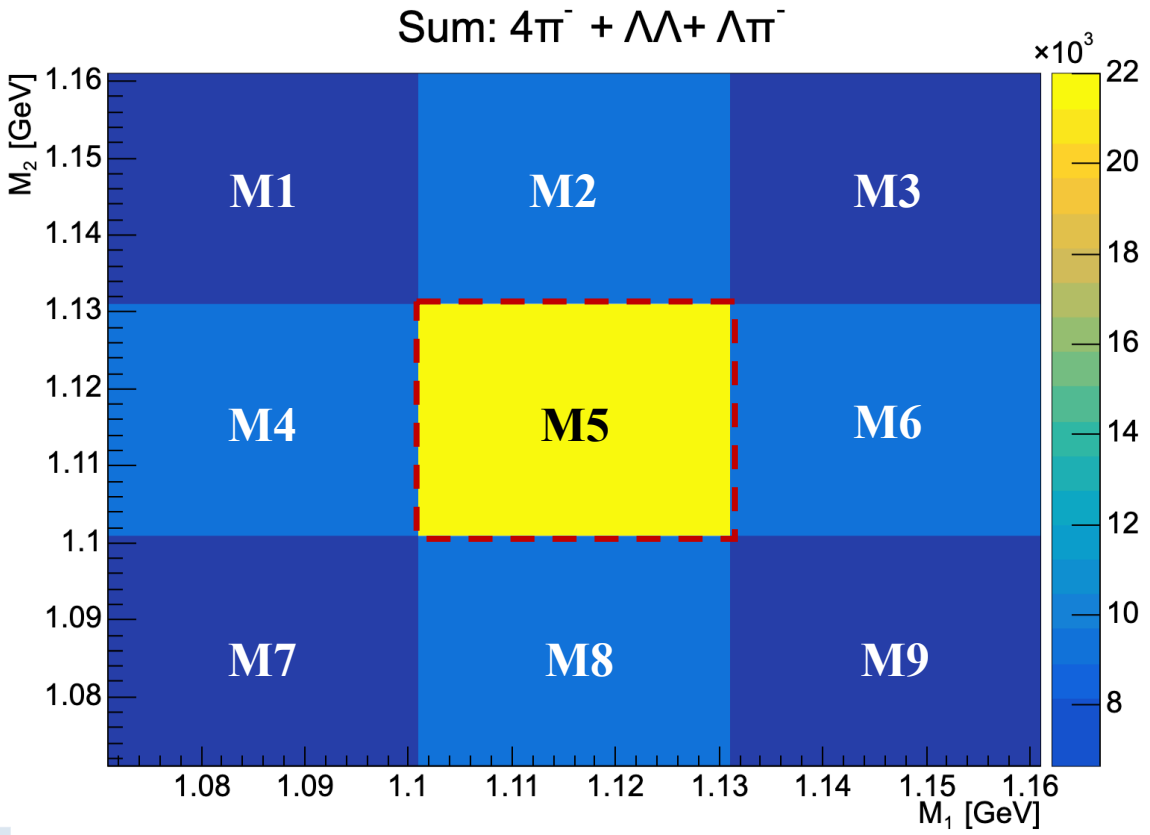
Refit of summed signal (Exp vs MC)





Fit model: Gaussian + polynomial background

Cross-check with alternative method (3×3 histogram method)



$N_{mean}(\Lambda) = 0.25(M_1 + M_3 + M_7 + M_9)$;

$M_2 = N_2 - N_{mean}$;

$M_4 = N_4 - N_{mean}$;

$M_5 = N_5 - N_{mean}$;

$M_6 = N_6 - N_{mean}$;

$M_8 = N_8 - N_{mean}$;

$L = 0.5(M_2 + M_4 + M_6 + M_8)$;

$D = M_5 - L$;

Extracted ΛΛ signal yield (uncorrected)

Fit: 4658 ± 378
number of ΛΛ pairs (Exp)

4800 ± 368
number of ΛΛ pairs (MC)

3×3 Hist: 5550 ± 230
number of ΛΛ pairs (Exp)

5504 ± 216
number of ΛΛ pairs (MC)

$N_{\Lambda\Lambda}/N_{\Lambda}$ 0.078(7.8%)
Ratio of the number of pairs to the total signal(Exp)

0.075(7.5 %)
Ratio of the number of pairs to the total signal(MC)

Single Λ Reconstruction Efficiency (DCM - SMM)

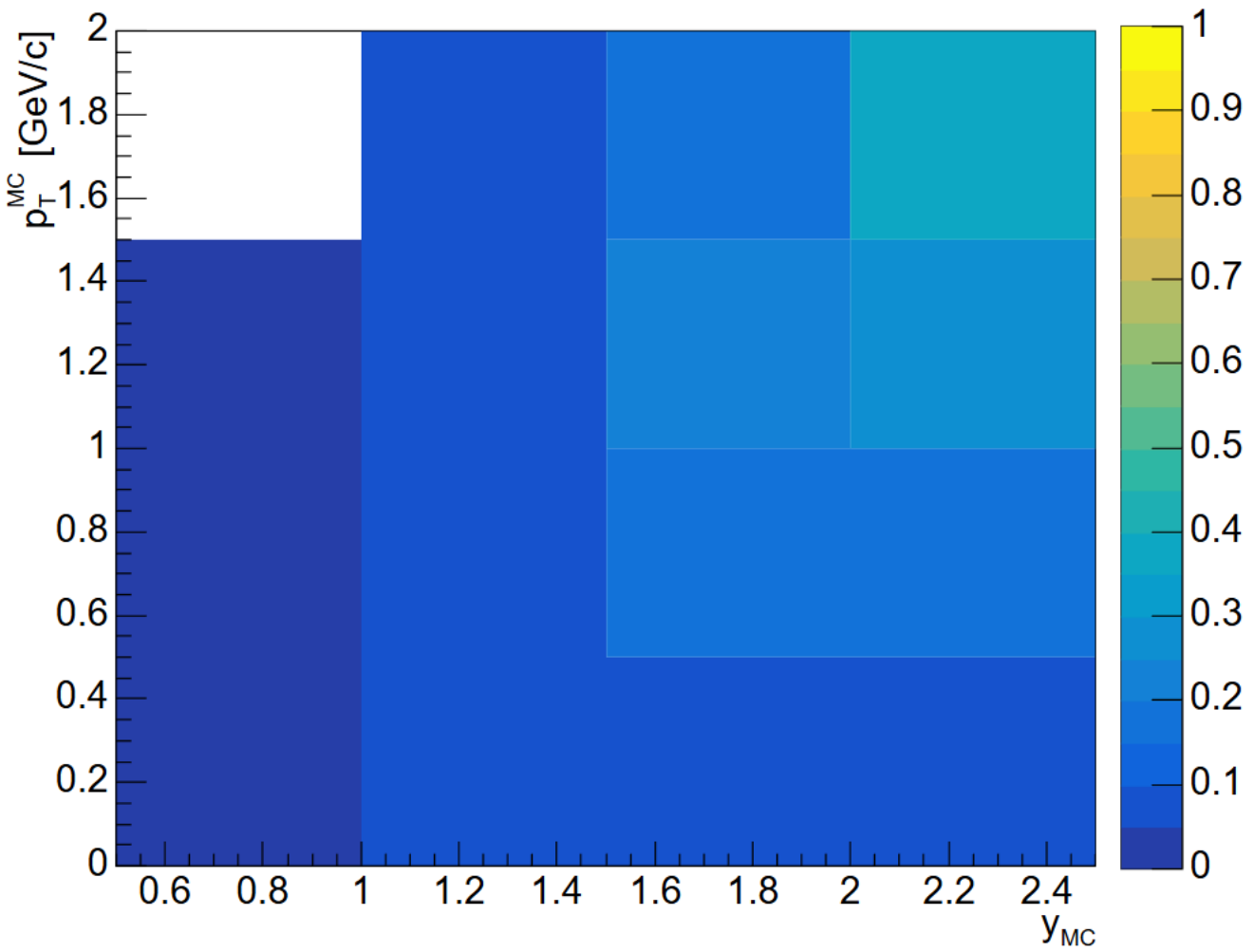
Kinematic measuring range (3.8A GeV):

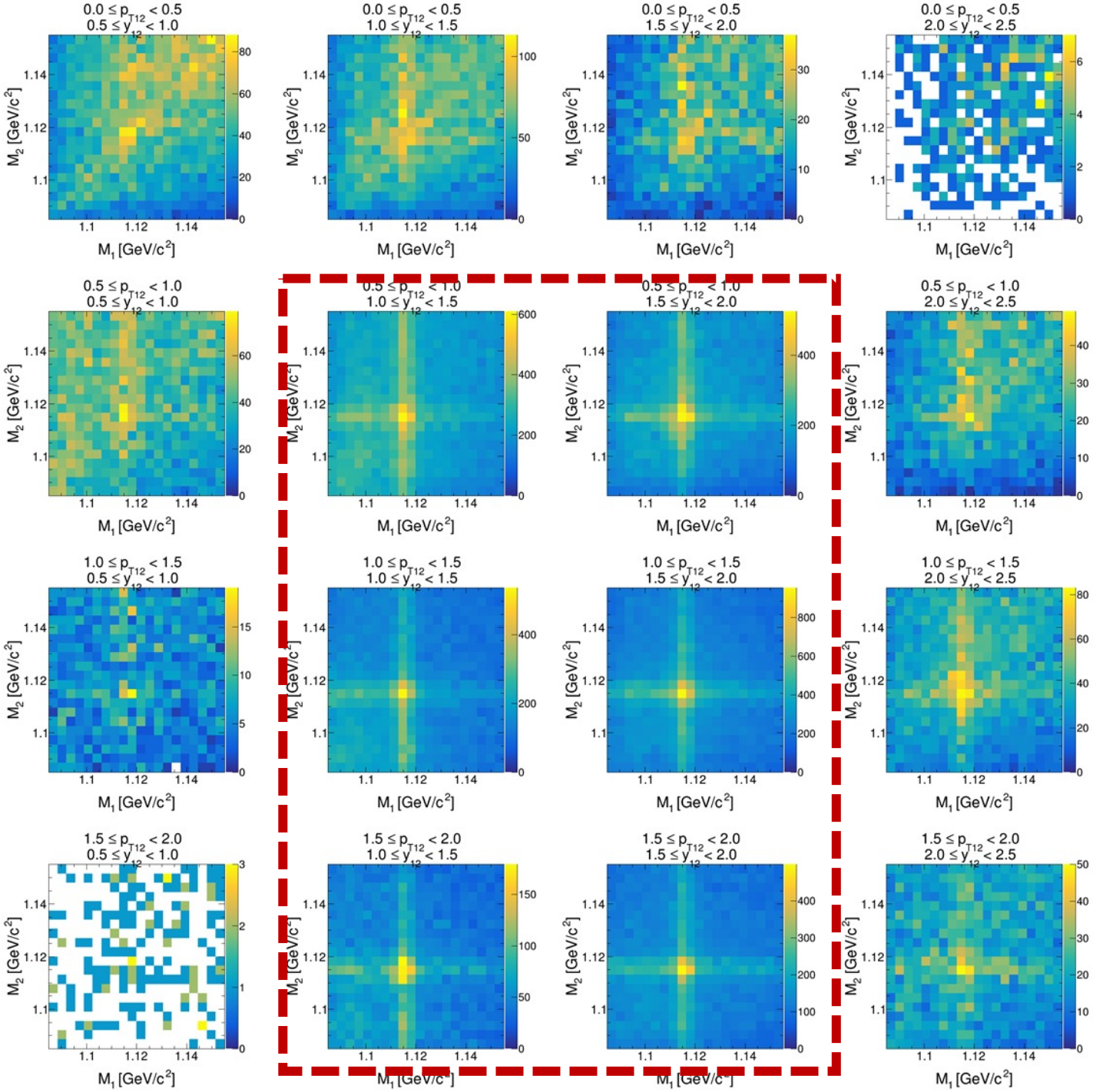
0.0 < p_T < 2.0 GeV/c
0.6 < y_{lab} < 2.5

$N_{gen}(y, p_T)$ includes all Λ hyperons generated in the MC simulation that fall within the corresponding (y, p_T)interval.

$N_{rec}(y, p_T)$ includes unique MC-validated Λ hyperons that have been successfully reconstructed and fall within the corresponding (y, p_T) interval.

$$\varepsilon_{acc} = N_{rec}(y, p_T) \Big/ N_{gen}(y, p_T)$$





ΛΛ signal in (y,pT) bins

- Promising signals are observed in the central kinematic bins.
- However, substantially more statistics are needed to proceed with the analysis.

Conclusions

The fitting method has been used to extract a preliminary $\Lambda\Lambda$ signal.
Possible $\Lambda\Lambda$ signals are seen in several kinematic bins.

Next Steps

Analyse more experimental data.
Improve the kinematic binning.
Check the reconstruction efficiency using MC simulations and apply corrections.

.

