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Performance study using the $\bar{p}p \to \bar{\Lambda}\Lambda$ reaction

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PANDA collaboration meeting

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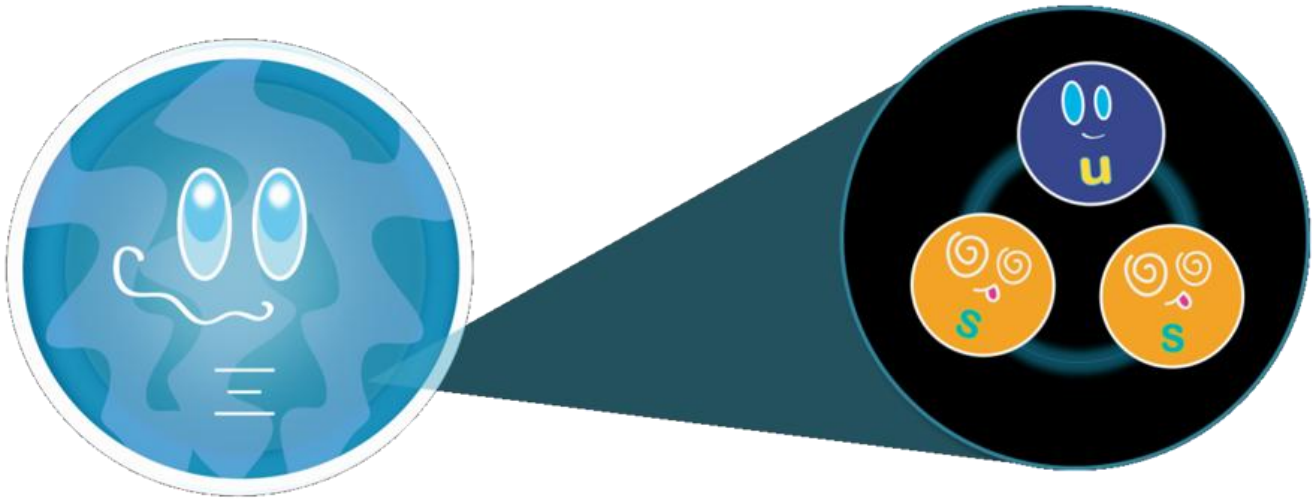
Outline

- Hyperon physics with PANDA
- The $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ reaction at 1.64 GeV
- The $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ reaction at 4 GeV
- Outlook: other hyperon channels



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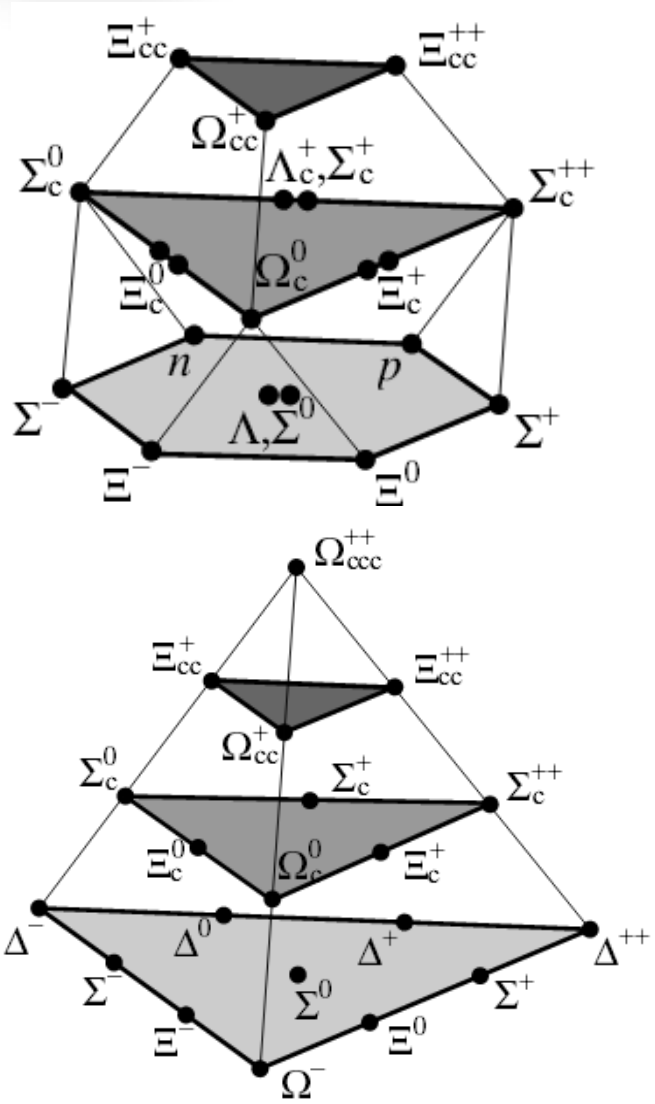
Hyperon physics with PANDA



- ”Map” of the ground state baryon octet and decuplet
- The role of spin in production of strangeness and charm
- CP violation in baryon decays?

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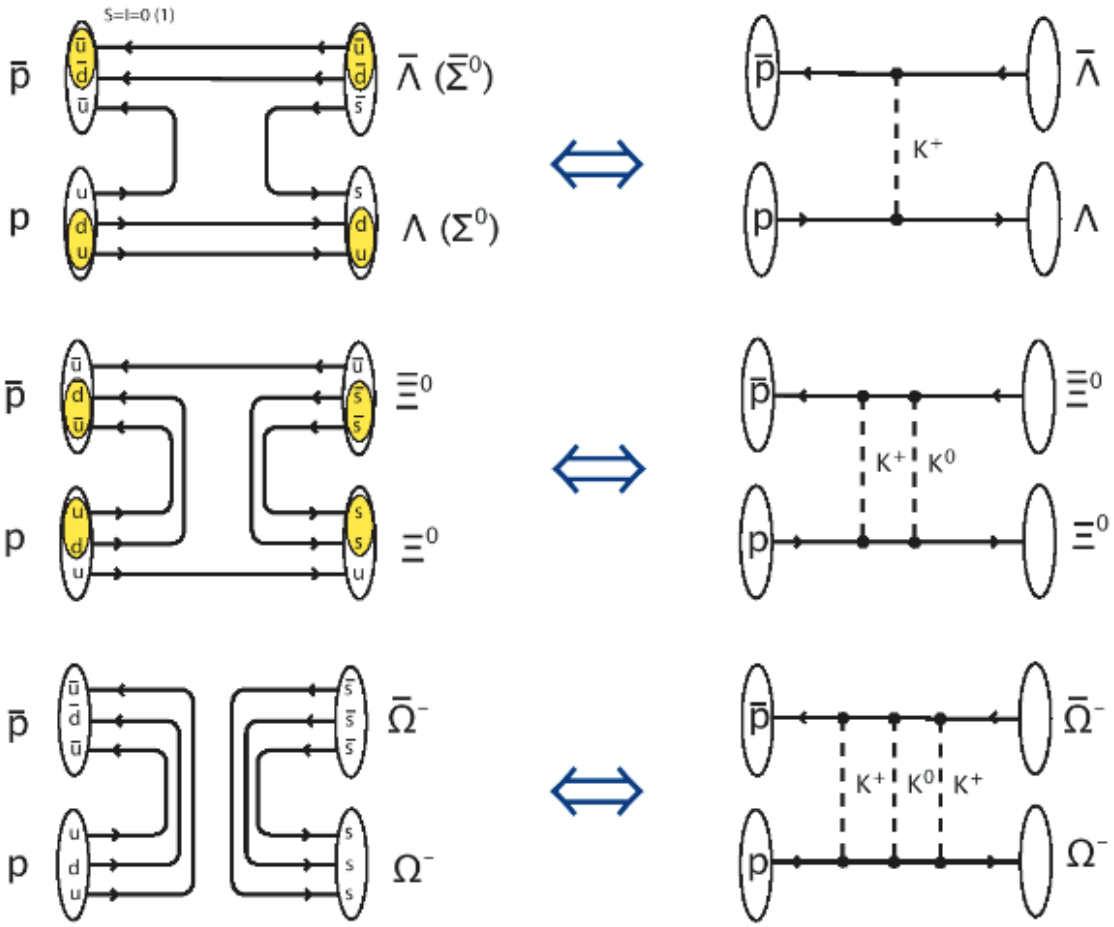
Hyperon physics with PANDA

- Relevant degrees of freedom: quarks and gluons or hadrons?
- Spin observables sensitive to production mechanism
- Differences between hyperons with different strangeness and charm?



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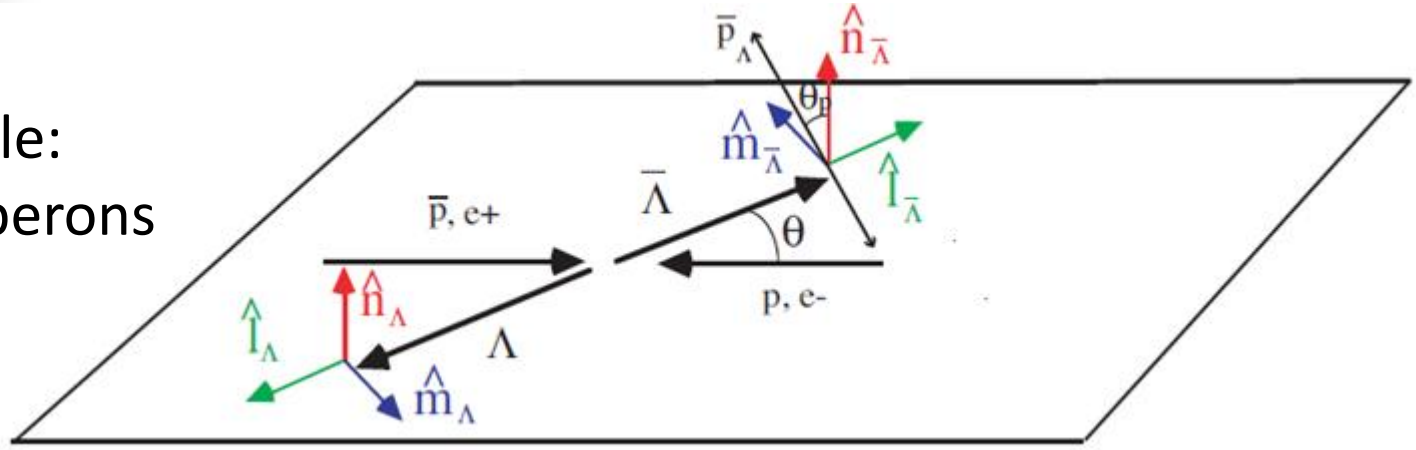
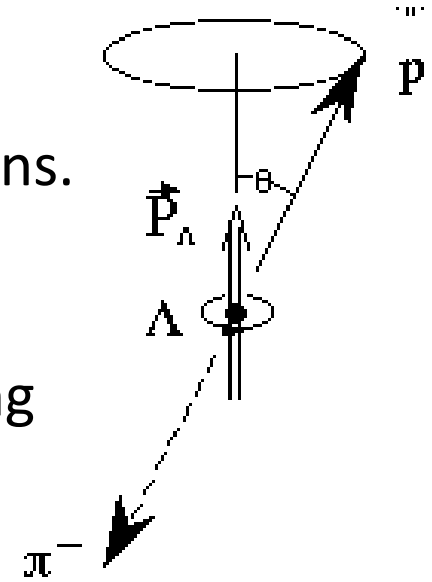
Hyperon physics with PANDA

Example:
Spin ½ hyperons



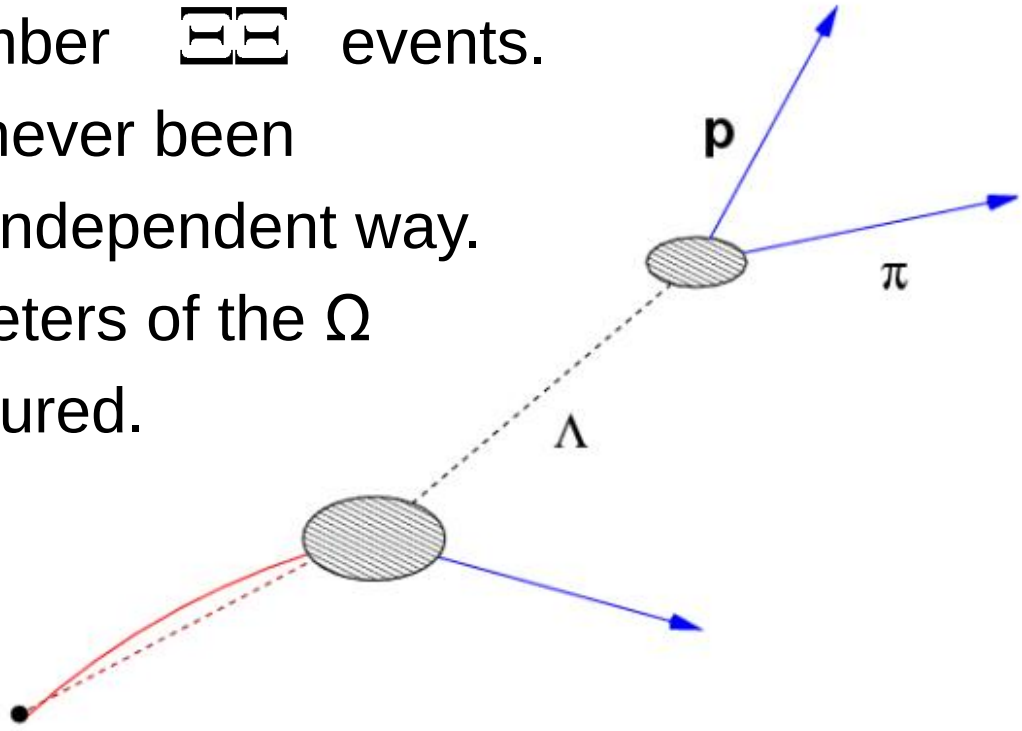
Unpolarised beam and target:

- Spin 1/2 hyperons: Polarisation and spin correlations.
- Spin 3/2 hyperons: 7 non-zero polarisation parameters (Thesis by E. Thomé).
- Polarisation accessible thanks to the parity violating weak decay.



Hyperon physics with PANDA

- PANDA is the only experiment where hyperon production in $\bar{p}p$ annihilations can be studied in the near future.
- $\bar{\Omega}\Omega$ and $\bar{\Lambda}_c\Lambda_c$ have never been seen before in this reaction
- Only a few bubble chamber $\bar{\Xi}\Xi$ events.
- The spin of the Ω has never been measured in a model-independent way.
- The polarisation parameters of the Ω have never been measured.



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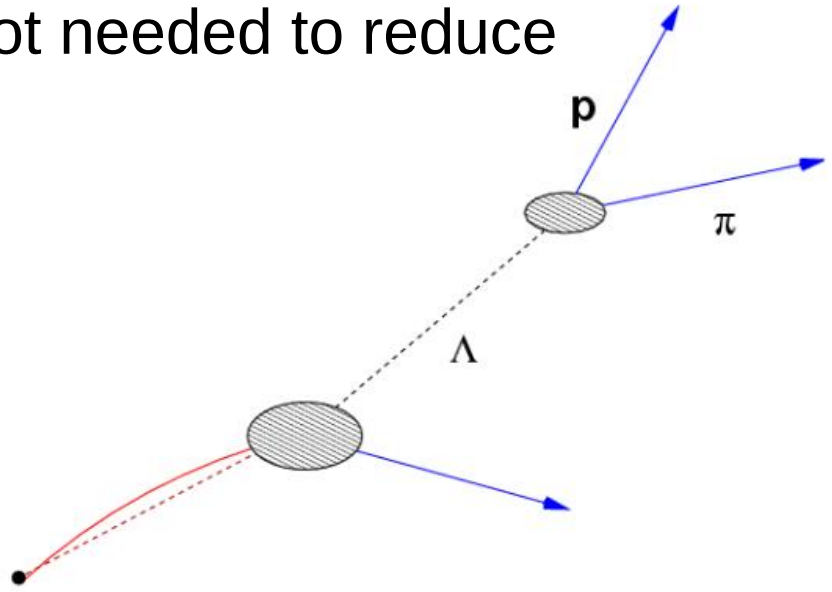
Prerequisities

- Weak decay → displaced vertices
  - Good spacial resolution required
  - More difficult to handle in reconstruction.
  - Background can be reduced to very low level.
- Many final state particles (4-6).
- Particle identification usually not needed to reduce background.



→ We depend on excellent tracking and vertexing but not necessarily PID and/or calorimetry.

The benchmark channel $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ at 1.64 GeV/c

- Well known from other experiments.
- Studied with old PANDA framwork (Thesis by S. Grape).
- Relevant since most heavier hyperons decay into hyperons.
- PANDAROOT still has difficulties to handle other hyperon channels.

$\bar{p}p \rightarrow$	$\bar{\Lambda}\Lambda$,	$\bar{\Sigma}^{-}\Sigma^{+}$,	$\bar{\Sigma}^{0}\Sigma^{0}$,	$\bar{\Sigma}^{-}\Sigma^{+}$,	$\bar{\Xi}^{0}\Xi^{0}$,	$\bar{\Xi}^{+}\Xi^{-}$,	$\bar{\Omega}^{+}\Omega^{-}$,	$\bar{\Lambda}_c^{-}\Lambda_c^{+}$
	↓	↓	↓	↓	↓	↓	↓	↓
	$p\pi^{-}$	$p\pi^{0}$	$\Lambda\gamma$	$n\pi$	$\Lambda\pi^{0}$	$\Lambda\pi$	ΛK	$\Lambda\pi$
	64%	52%	$\approx 100\%$	$\approx 100\%$	$\approx 100\%$	$\approx 100\%$	68%	$\approx 1\%$

Simulation of $p\bar{p} \rightarrow \Lambda\bar{\Lambda}$ at 1.64 GeV/c

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- Full simulation (sim, digi, reco, pid).
- Pandaroot revision 24660.
- Beam momentum 1.64 GeV/c.
- Forward peaking $\bar{\Lambda}$ distribution.
- Λ→pπ decay considered.
- No polarisation taken into account.
- Back propagation back to IP switched off.
- Ideal hypothesis in Kalman filter.
- 10000 events produced in each case.
- PID of FS particles taken from MC truth.

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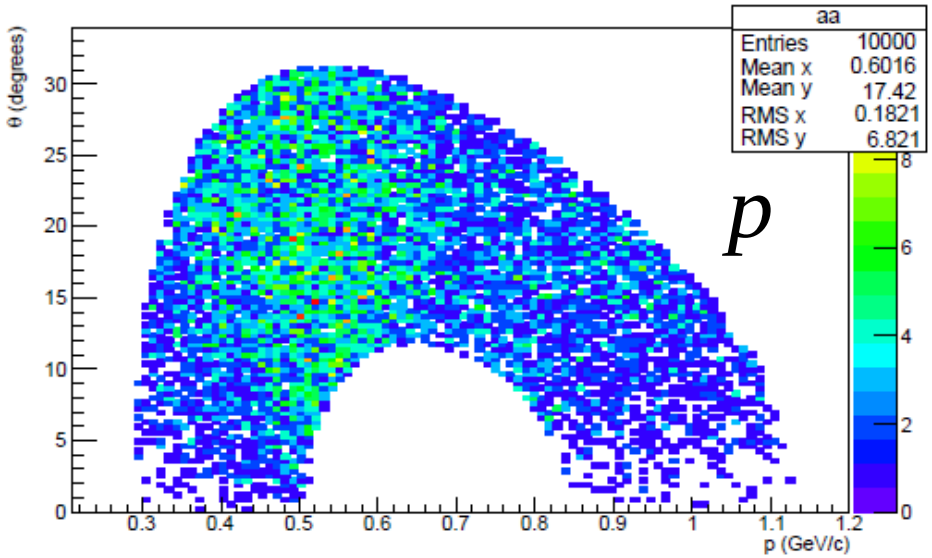
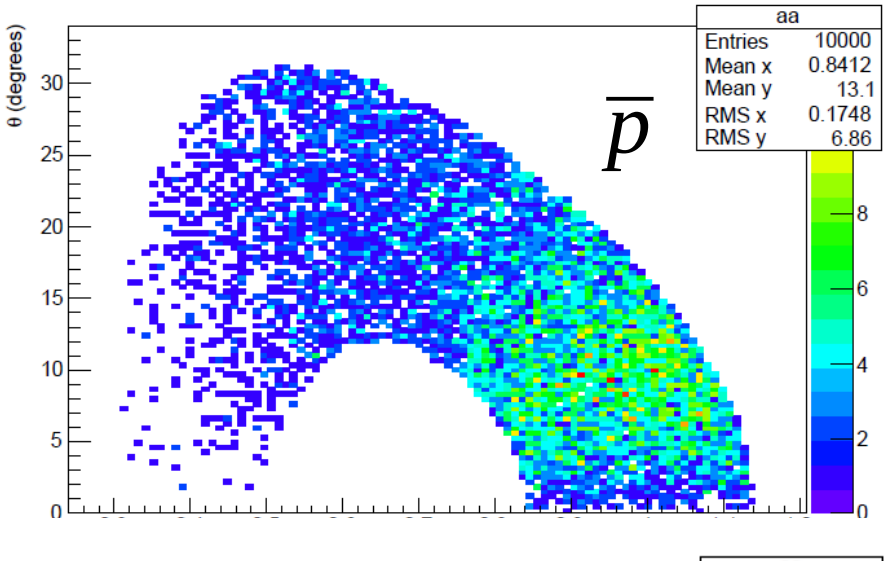
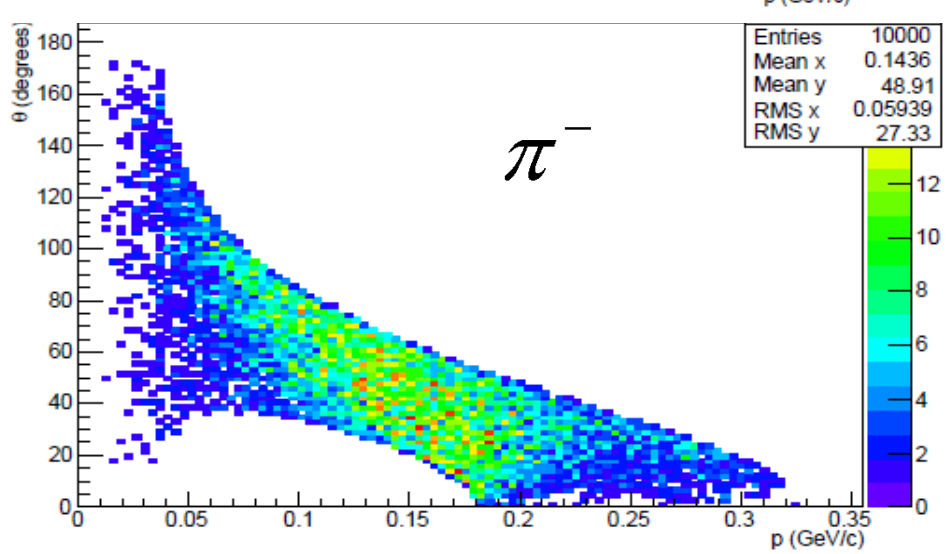
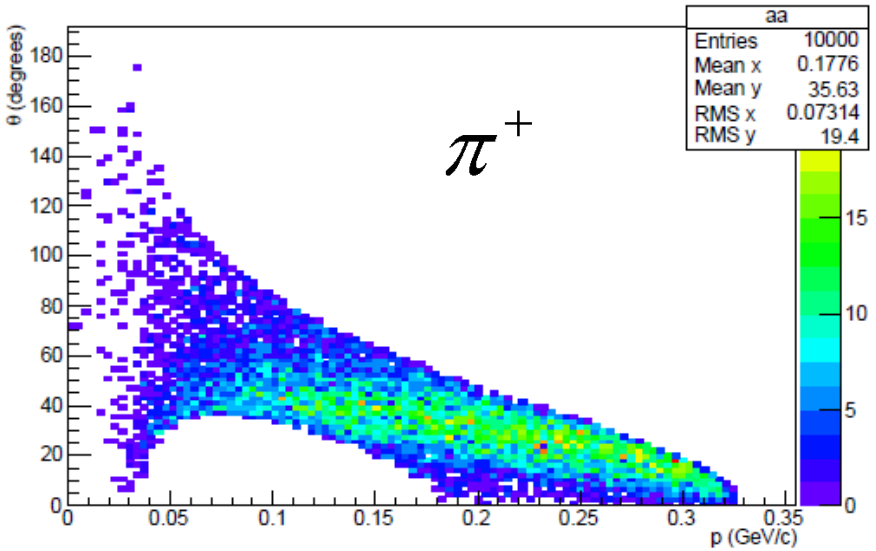
Phase space of the reaction









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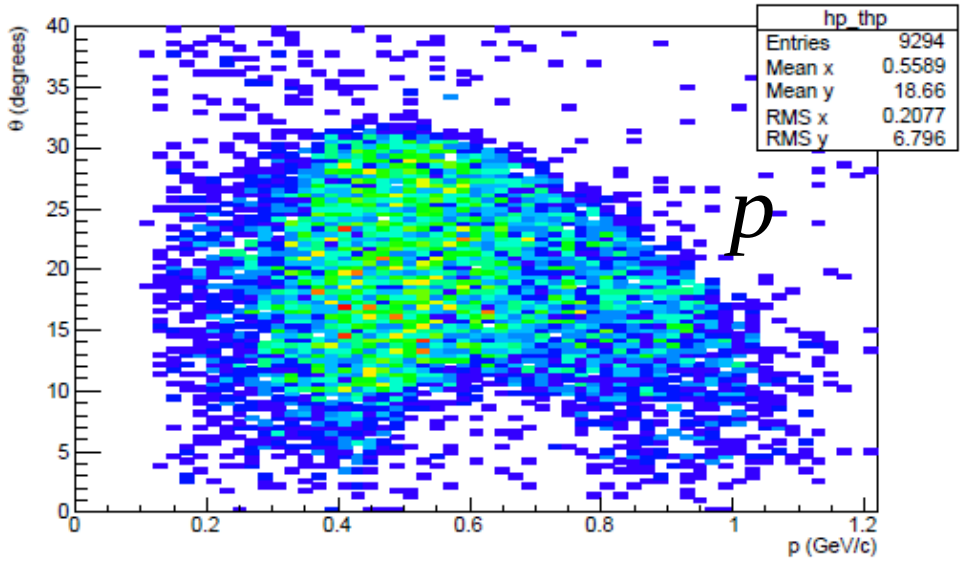
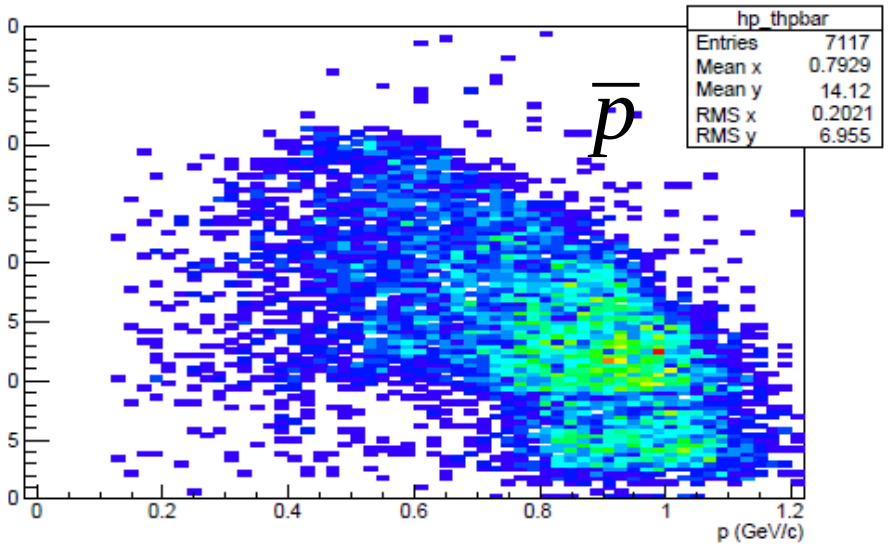
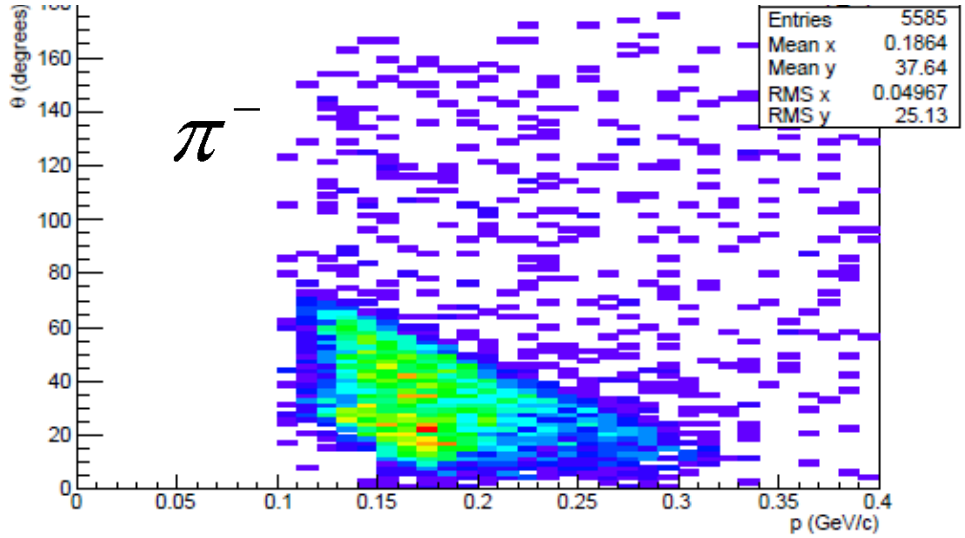
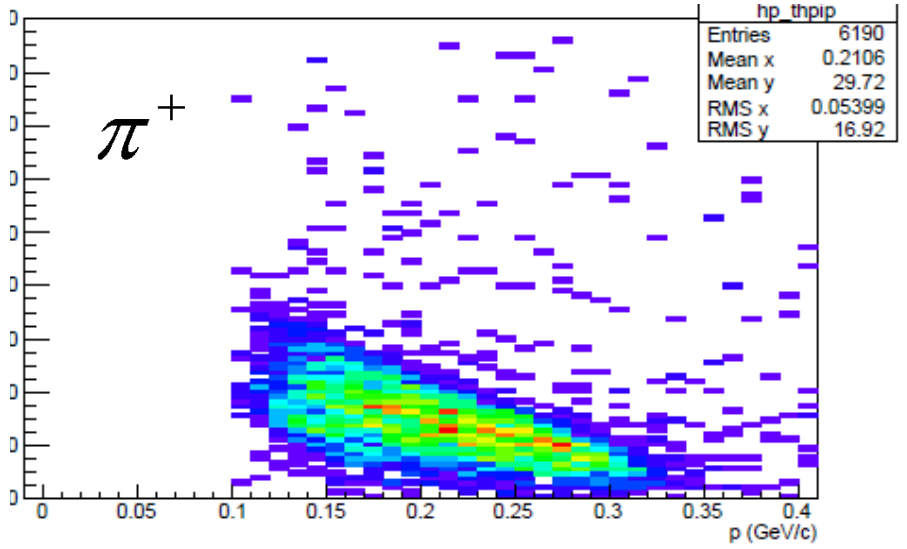
Reconstructed phase space, full setup









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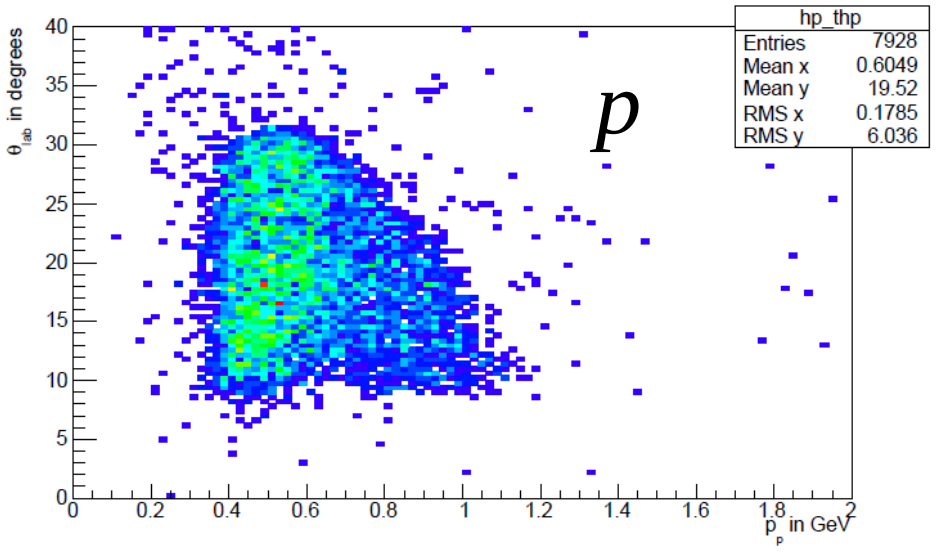
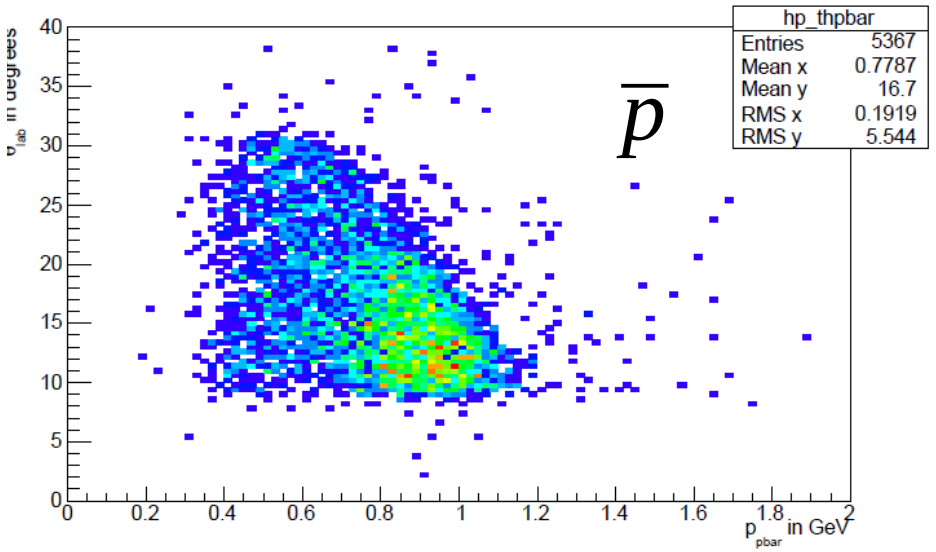
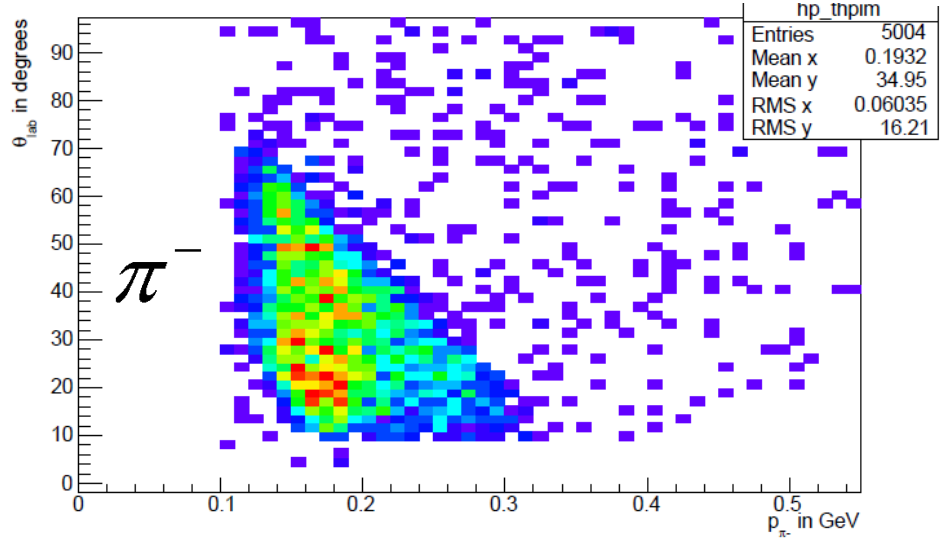
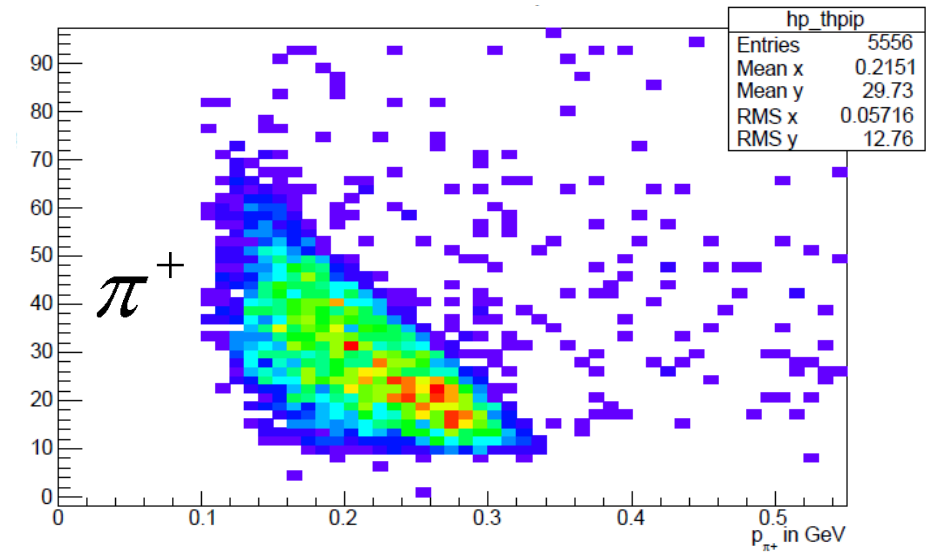
Reconstructed phase space, no FTS









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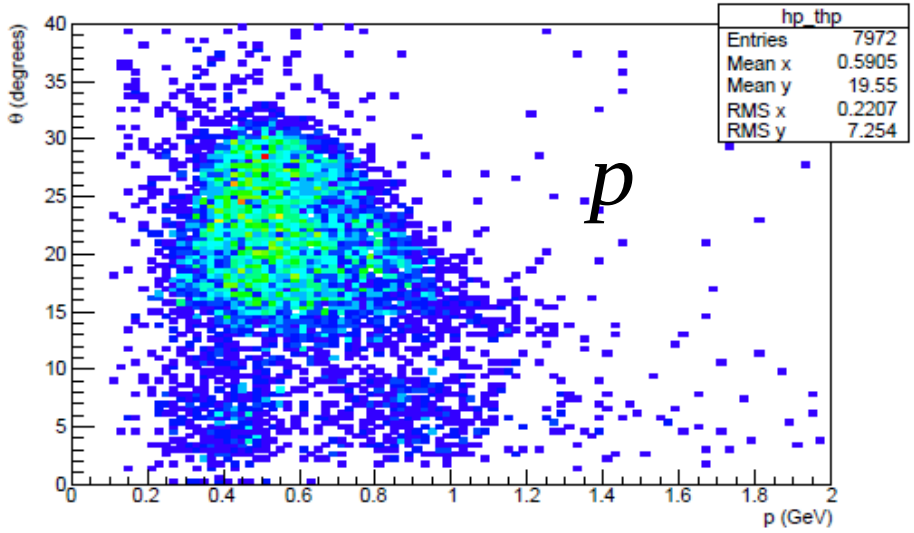
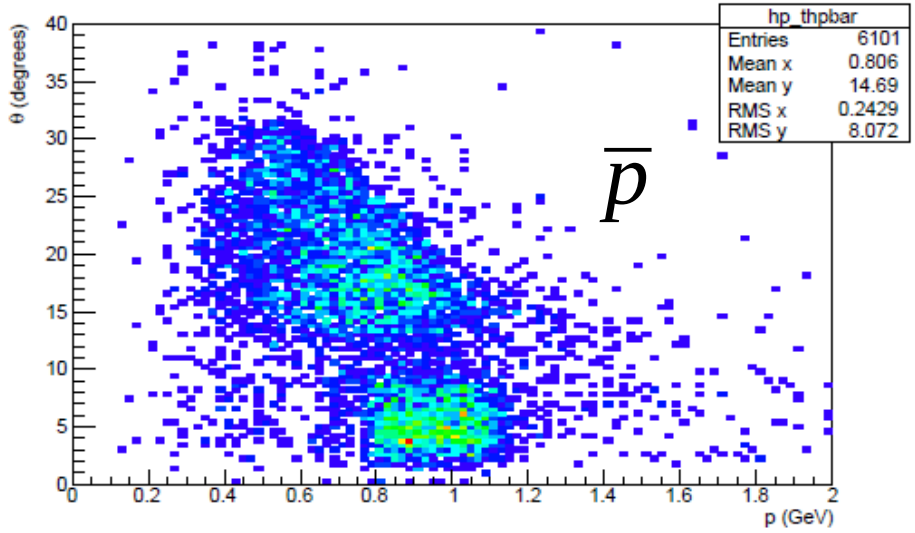
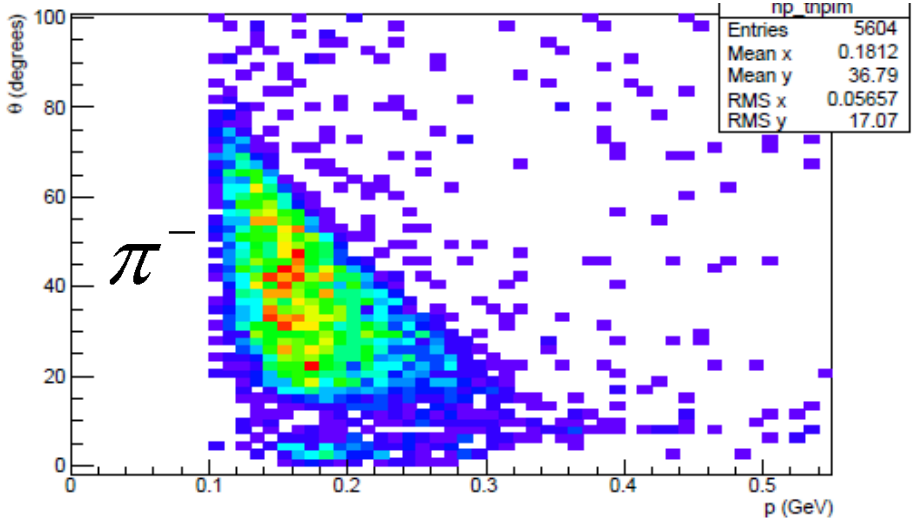
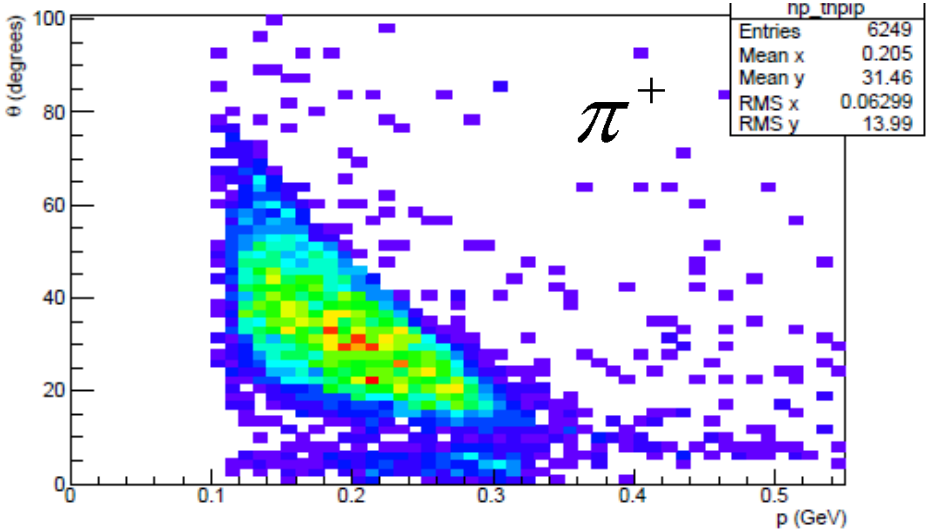
Reconstructed phase space, no MVD/GEM

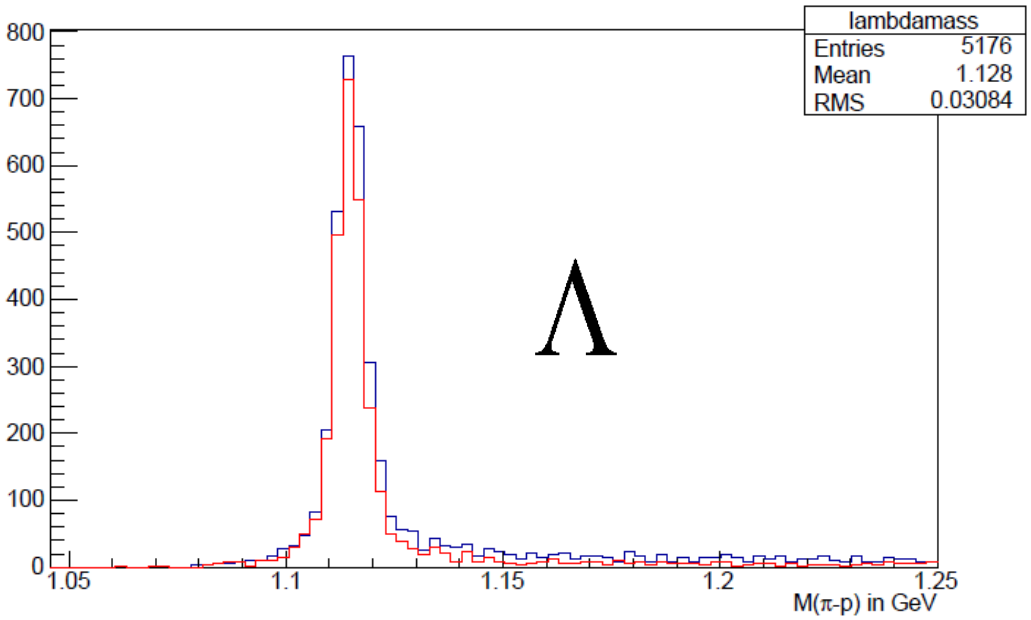




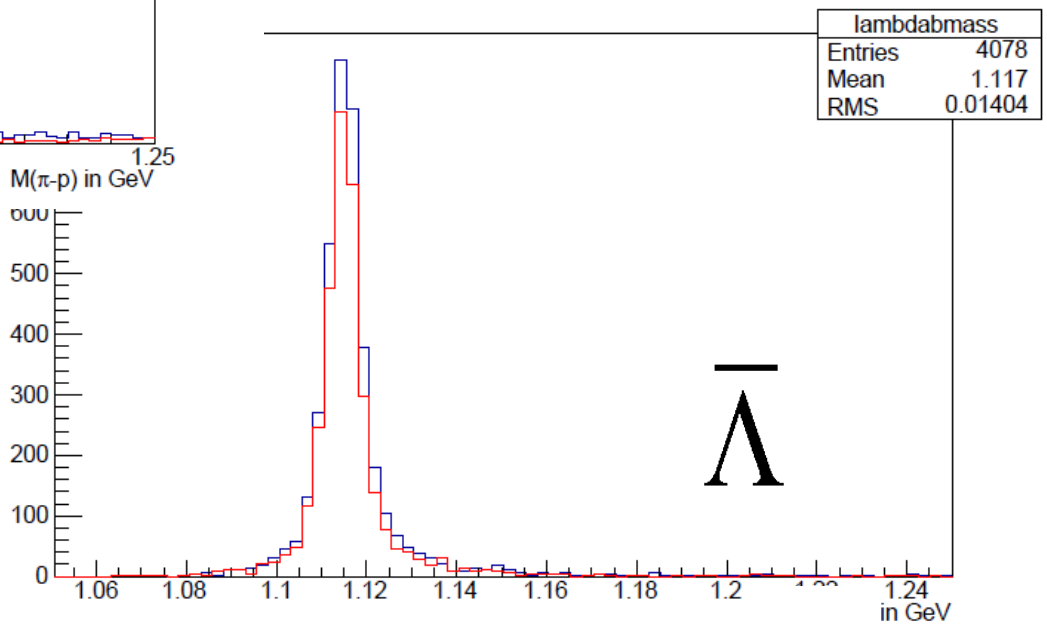




Reconstructed Λ mass (full setup)



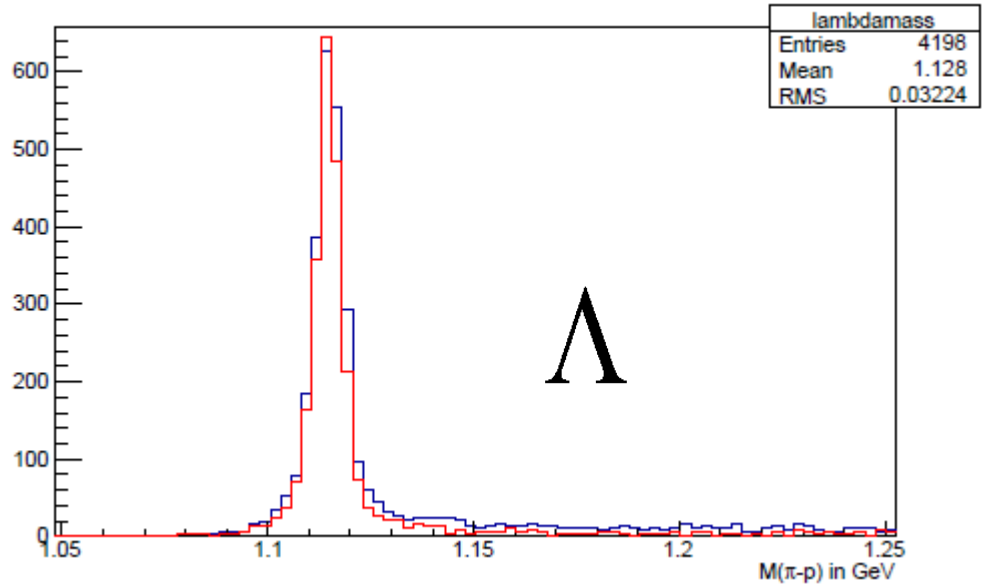
- ***pπ* mass**
- **Blue: Before vertex fit**
- **Red: after vertex fit**



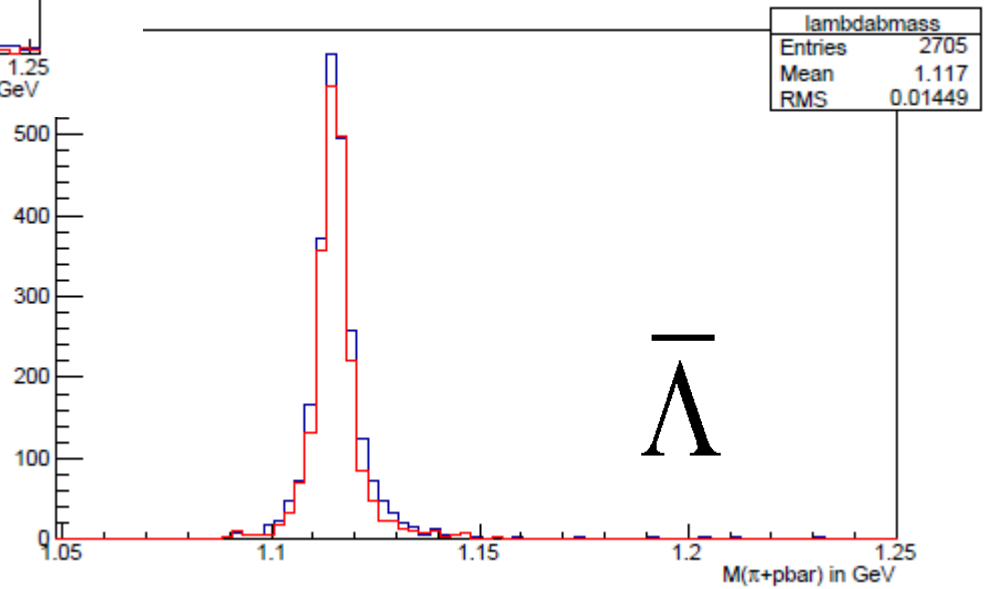
σ_{Λ} = 4.1 MeV, vertex fit 3.8 MeV.

$\sigma_{\Lambda bar}$ = 4.5 MeV, vertex fit 4.3 MeV.

Reconstructed Λ mass (no FTS)



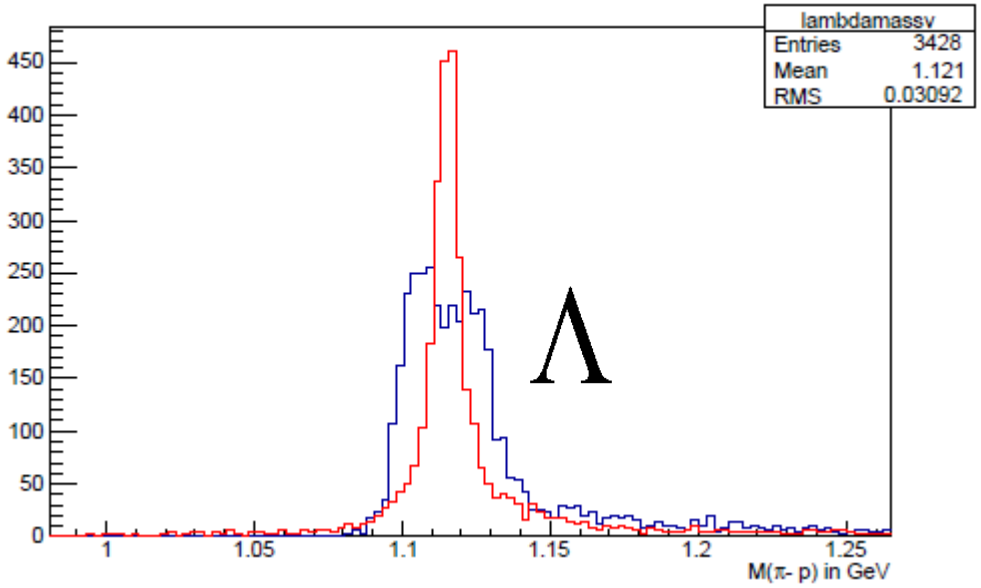
- ***pπ* mass**
- **Blue: Before vertex fit**
- **Red: after vertex fit**



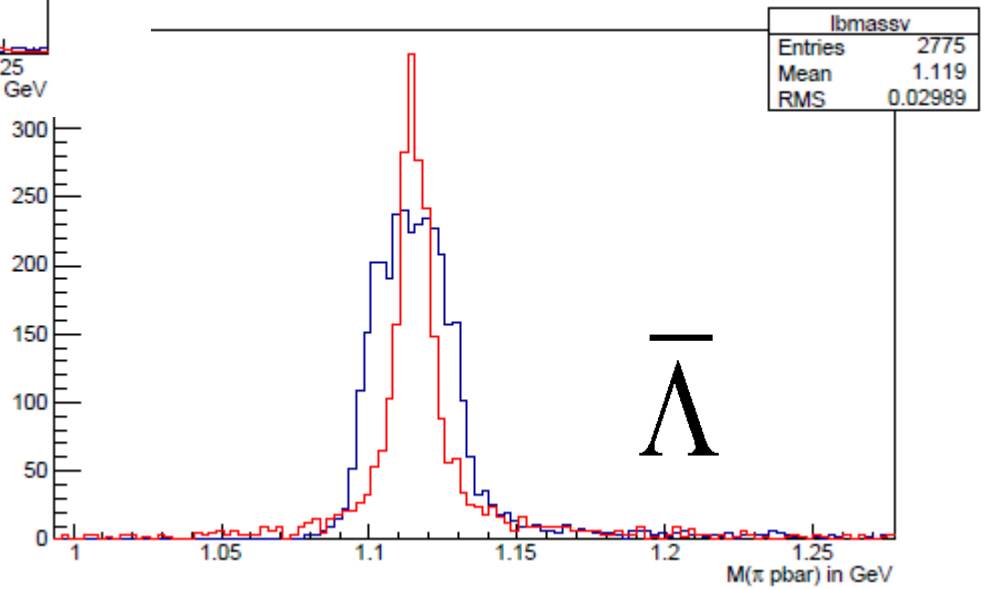
σ_{Λ} = 4.1 MeV, after vertex fit 3.7 MeV.

$\sigma_{\Lambda bar}$ = 4.4 MeV, after vertex fit 3.8 MeV

Reconstructed Λ mass (no MVD/GEM)



- ***pπ* mass**
- **Blue: Before vertex fit**
- **Red: after vertex fit**



σ_{Λ} after vertex fit 6.4 MeV.

$\sigma_{\Lambda bar}$ after vertex fit 7.5 MeV

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Case	Particle	Eff (%)	σ (MeV/c2)
Full	Λ	52	4.1
	Λbar	41	4.5
	Λ, vertex fit	35	3.8
	Λbar, v. fit	34	4.3
	ΛΛbar, v. fit	9.5	
No FTS	Λ	42	4.1
	Λbar	27	4.4
	Λ, vertex fit	29	3.7
	Λbar, v. fit	24	3.8
	ΛΛbar, v. fit	6.7	
No MVD/GEM	Λ	37	Not gaussian
	Λbar	36	Not gaussian
	Λ, vertex fit	30	6.4
	Λbar, v. fit	25	7.5
	ΛΛbar, v. fit	5.6	

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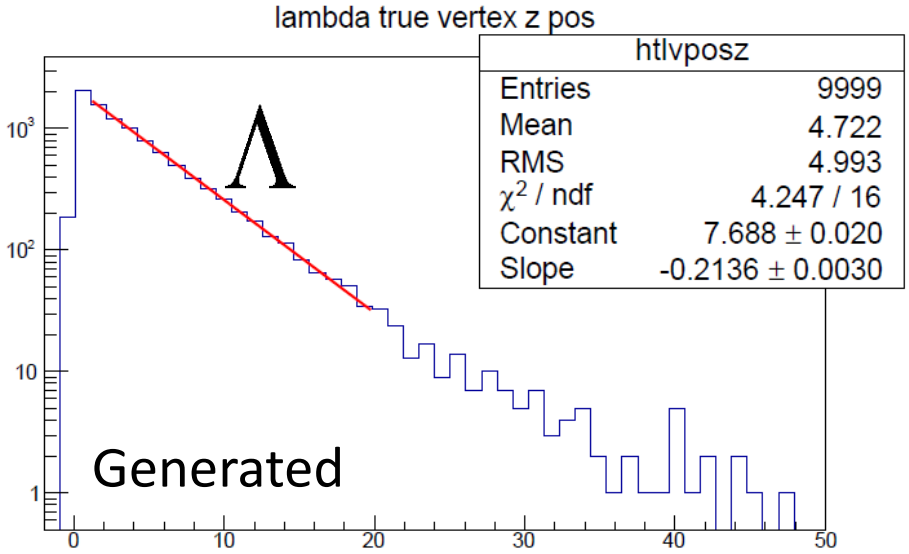
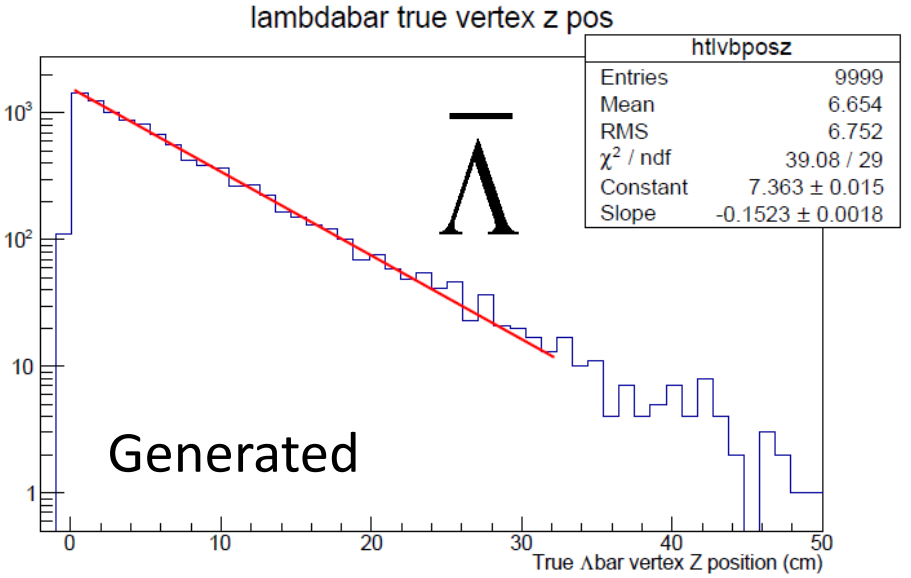
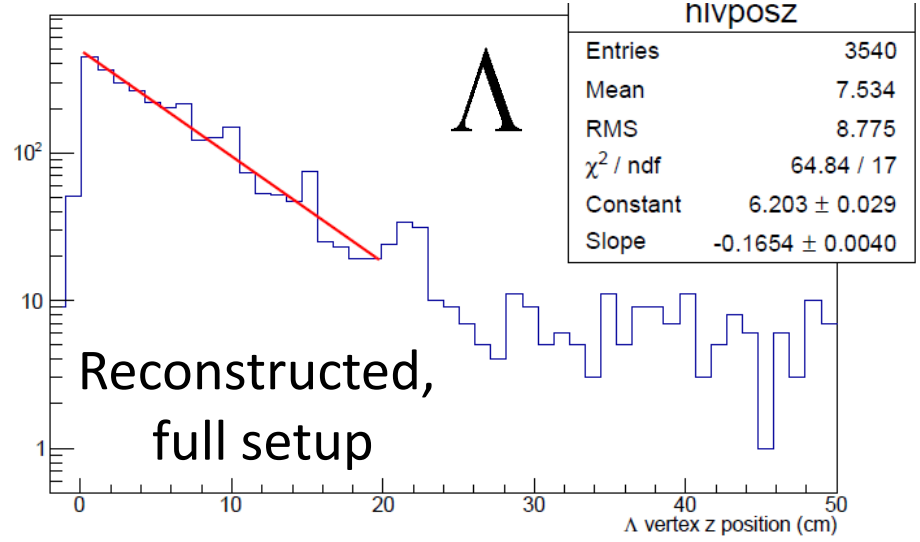
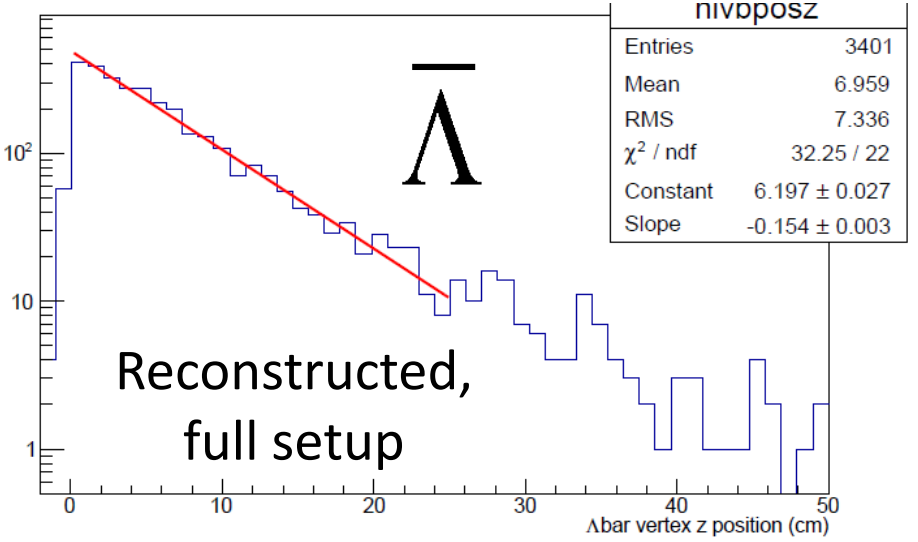
Vertex Z position









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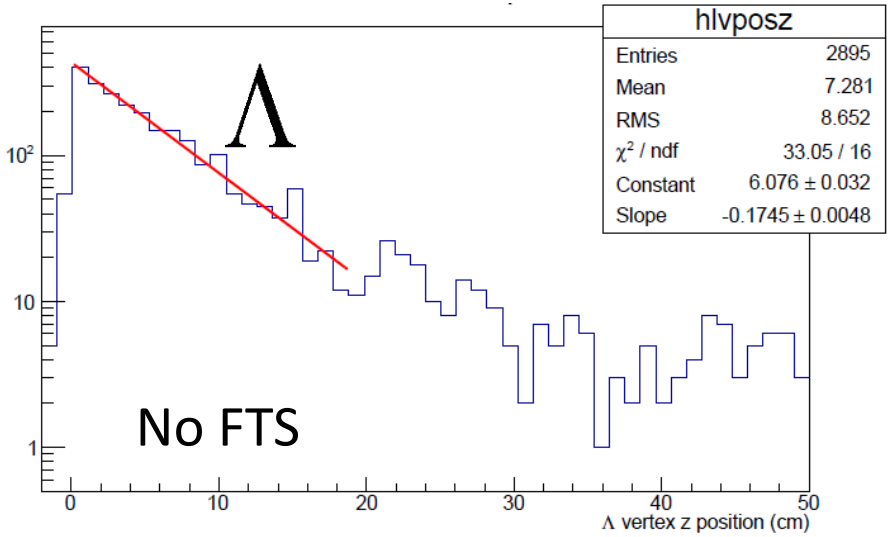
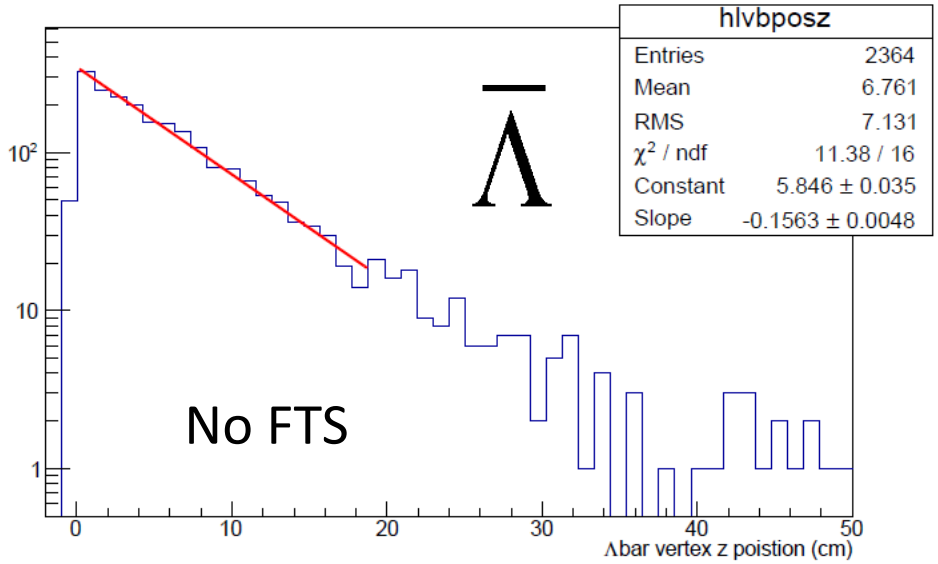
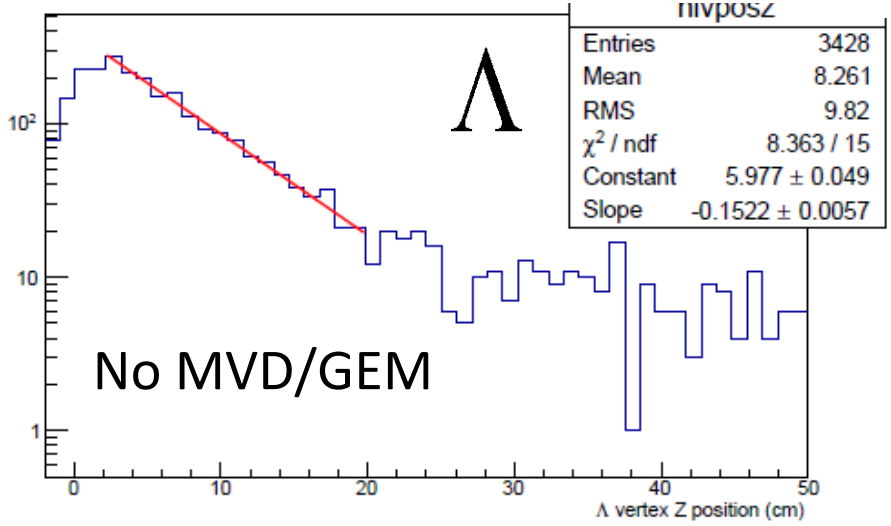
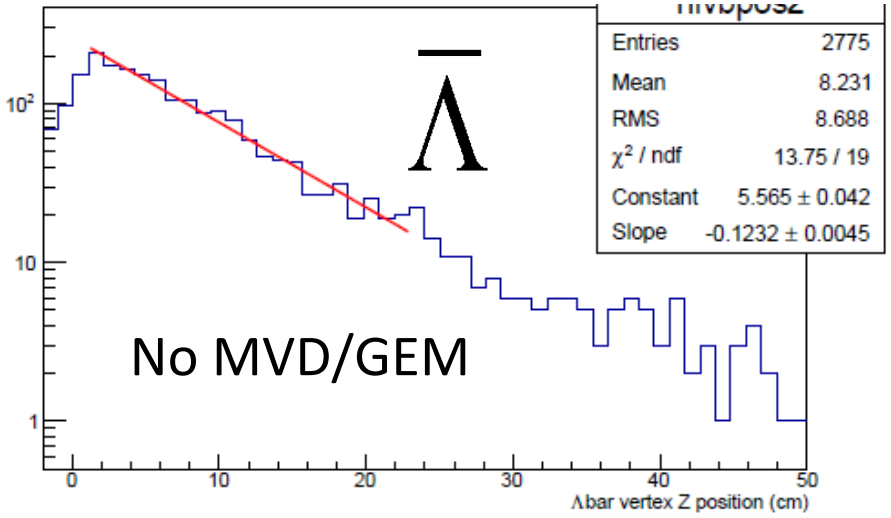
Vertex Z position

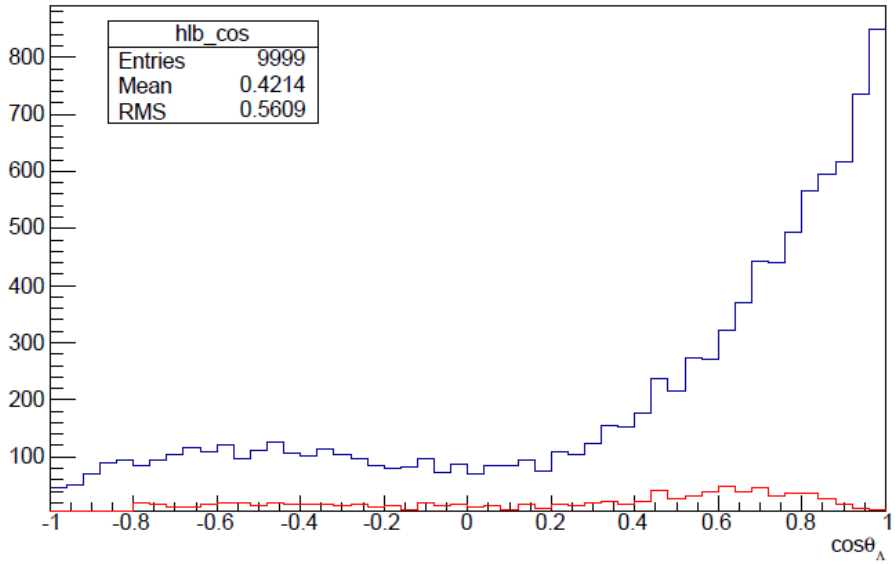






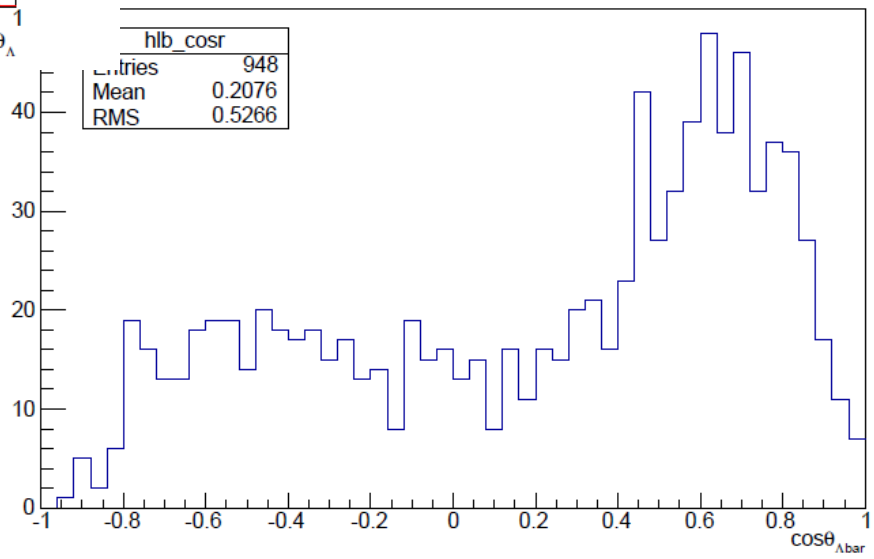


Angular distributions, full setup



$cos\vartheta^*_{\Lambda bar}$:
Acceptance losses in forward/backward direction due to reconstruction (will hopefully improve)

- **Blue: Generated distribution**
- **Red: reconstructed distribution**



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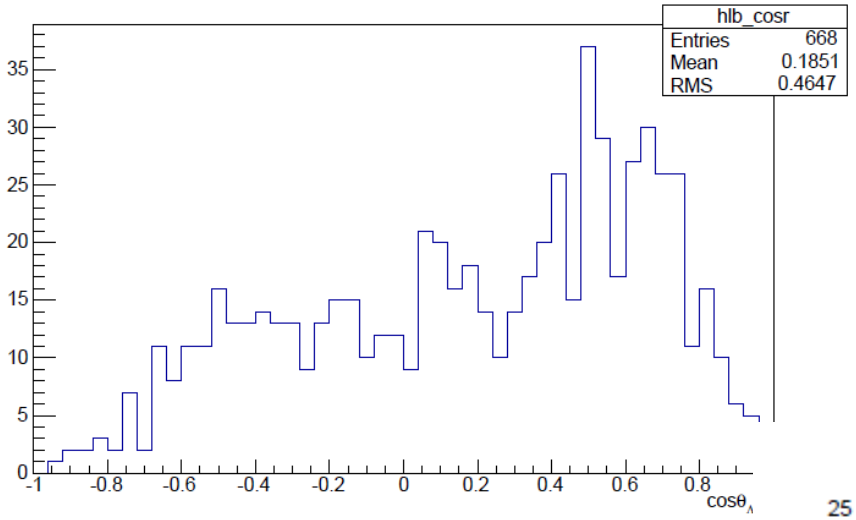
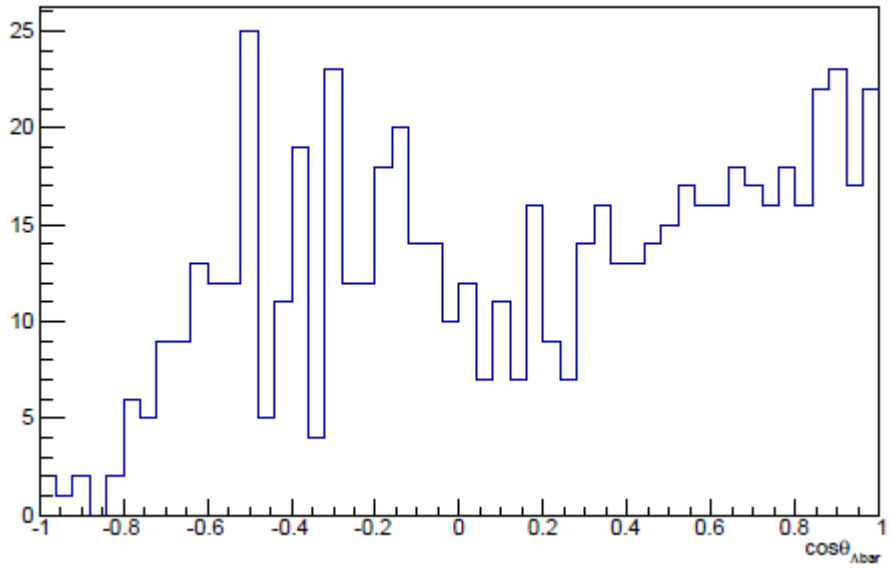
Angular distributions, sub-setups



No FTS

No MVD/GEM



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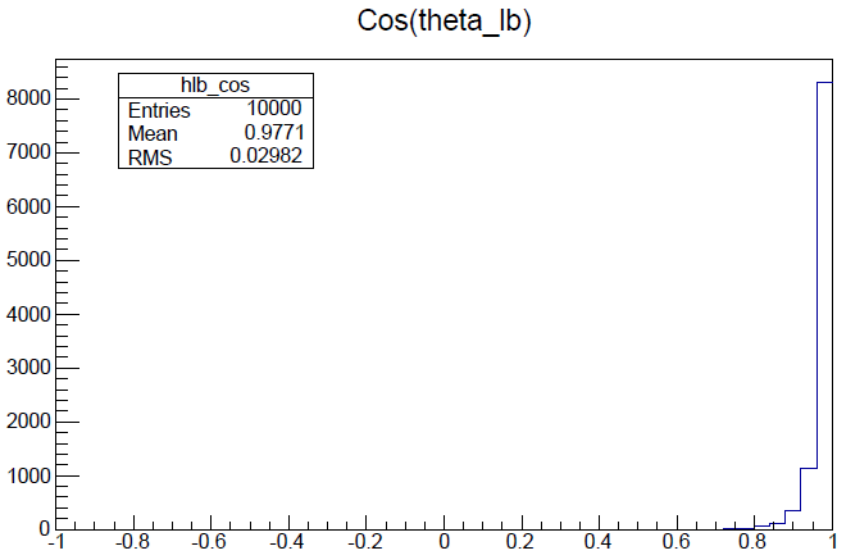
Summary, $p\bar{p} \to \Lambda\bar{\Lambda}$ at 1.64 GeV/c

- Acceptance for $\bar{\Lambda}\Lambda$ decreases from 9,5% to
  - 6.7% with no FTS
  - 5.6% with no MVD/GEM

- The mass and angular resolution without MVD/GEM will be too poor for ANY hyperon spin study!

The $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ channel at 4 GeV/c

- High cross section and (with full setup) good acceptance (Thesis by S. Grape).
- Optimal for CP violation studies.
- PANDAROOT performace too poor for this channel
  → only studied phase space
  of final state particles.
- Forward peaking $\bar{\Lambda}$ distribution was used in the generation.



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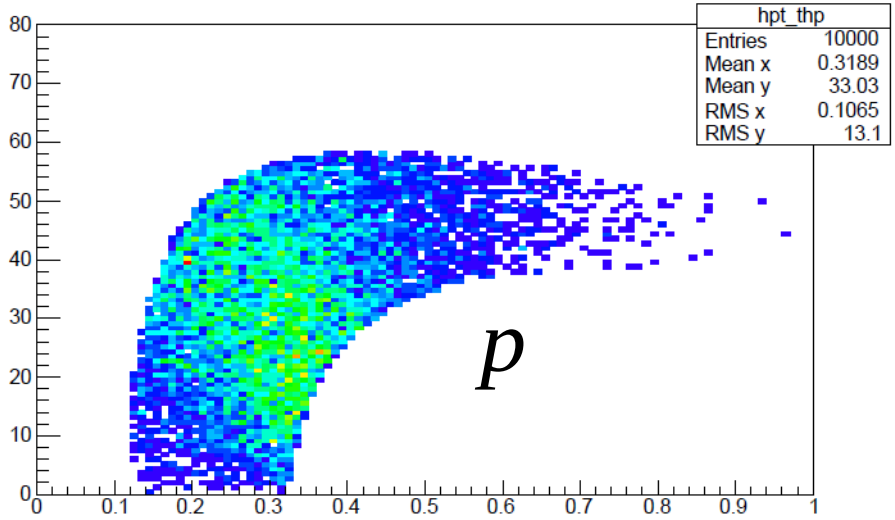
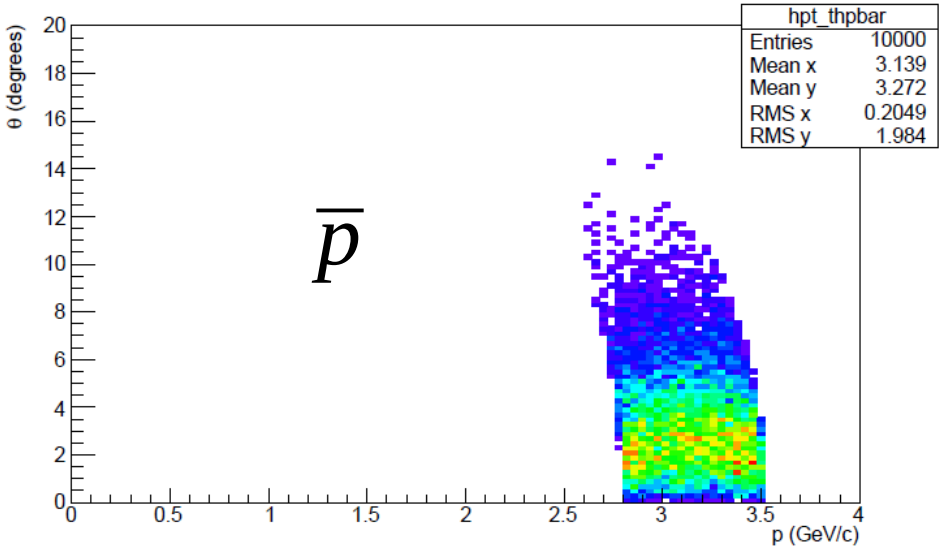
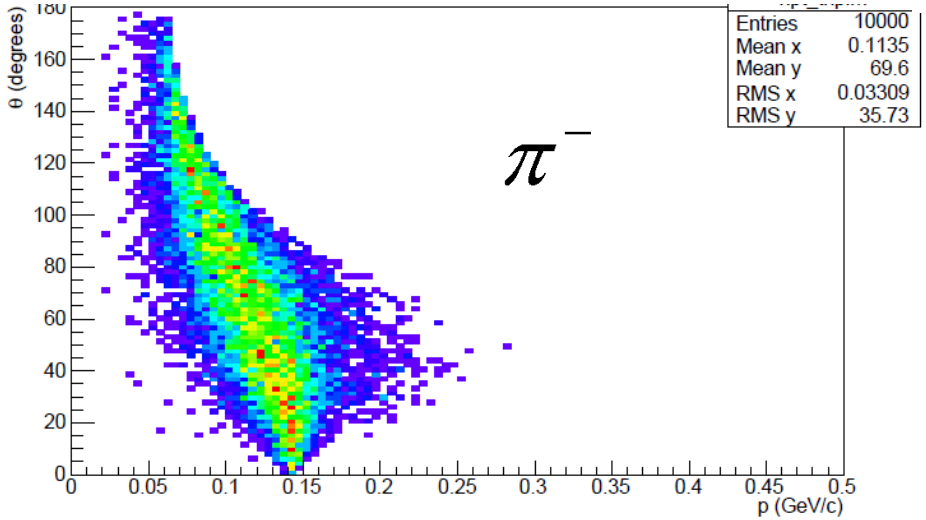
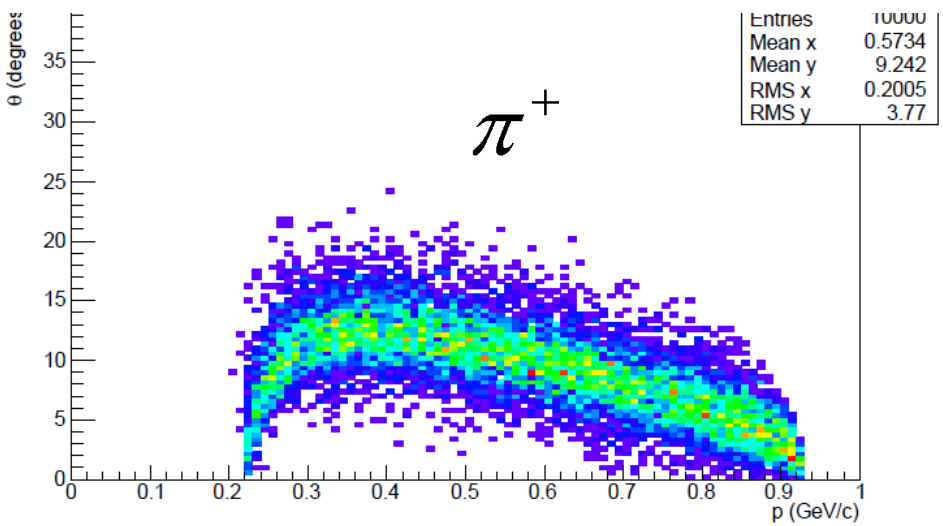
Phase space at 4 GeV/c









The $\bar{p}p \to \bar{\Lambda}\Lambda$ channel at 4 GeV/c

- In only 13% of the events, there are no particles in the forward direction ($\theta < 5^{o}$).
- At this energy it is impossible to study $\bar{\Lambda}\Lambda$ without the FTS.

Results from fast simulations

Setup	ΛΛbar efficiency (%)
Full (12345)	4.7
No FTS (1234)	0.8

- MVD/GEM required for the same reasons as before.

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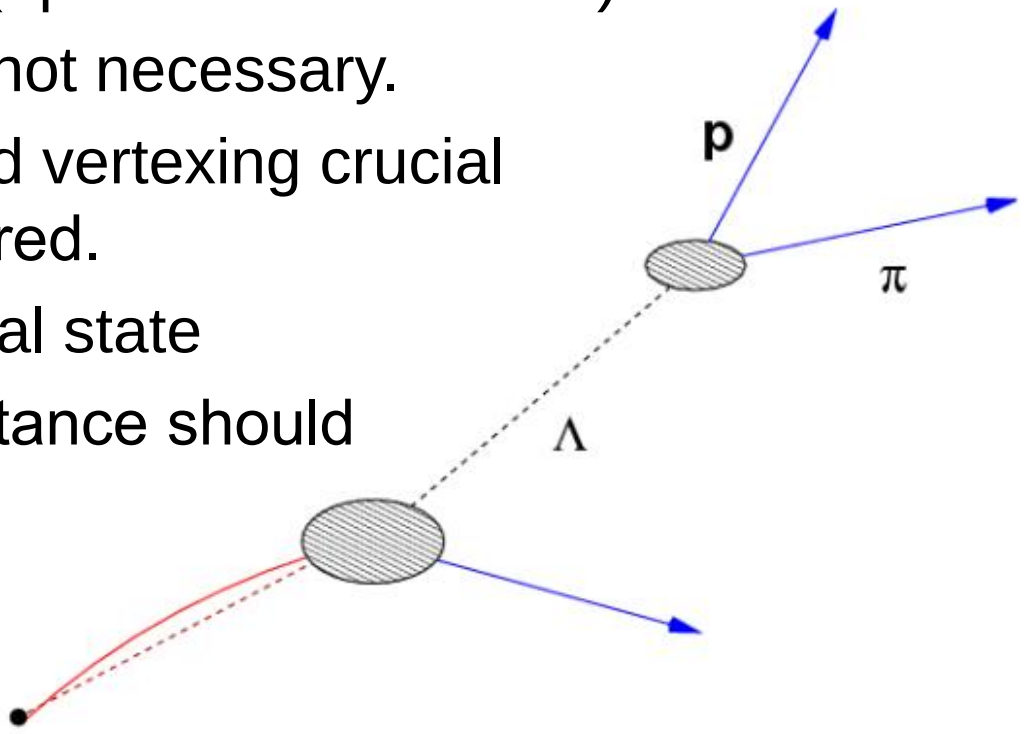
Other hyperon channels

- $\bar{p}p \to \bar{\Omega}\Omega$, $\bar{p}p \to \bar{\Xi}^{+}\Xi^{-}$ and $\bar{p}p \to \bar{\Lambda}_c\Lambda_c$.
- PANDAroot cannot yet handle these channels properly, but we know the following:
  - Displaced vertices (up to 200 cm from IP).
  - Calorimetry or PID not necessary.
  - Precise tracking and vertexing crucial
    → MVD/GEM required.
  - 6 particles in the final state

→ Holes in the acceptance should be avoided.



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The $\bar{p}p \rightarrow \bar{\Omega}\Omega$ channel at 12 GeV/c

- Never been observed before.
- $\Omega \rightarrow \Lambda K$ decay considered.
- Model: isotropic Ω and Λ distributions.

Results from fast simulations

Setup	ΩΩbar efficiency (%)
Full (12345)	21
No FS (1234)	17

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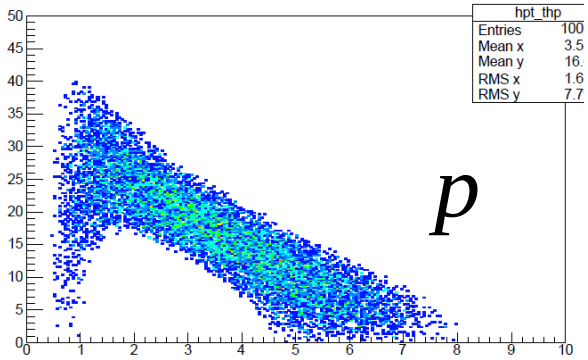
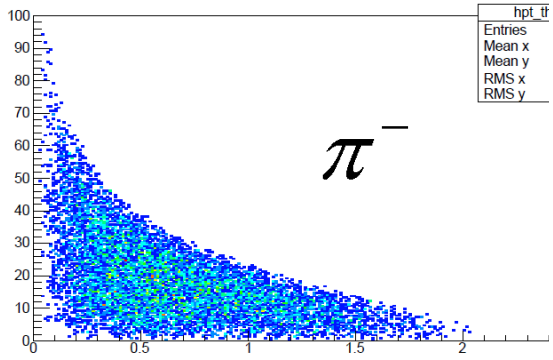
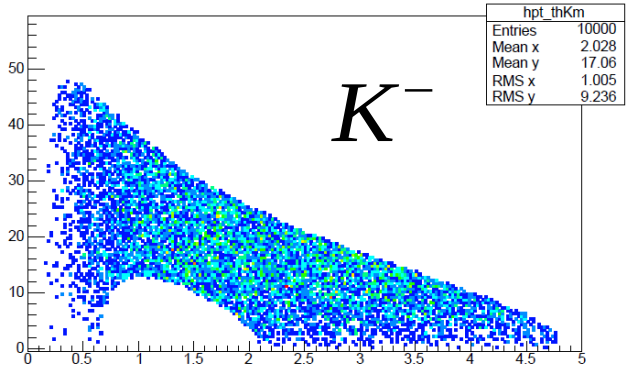
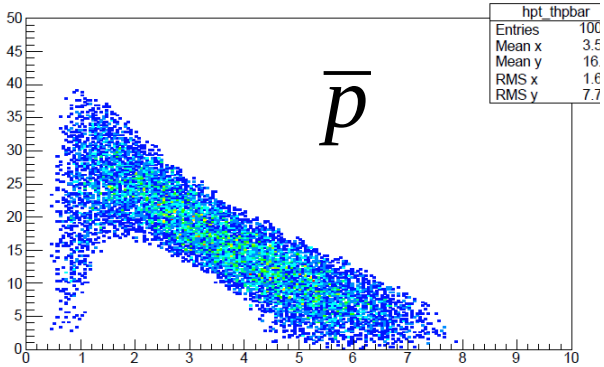
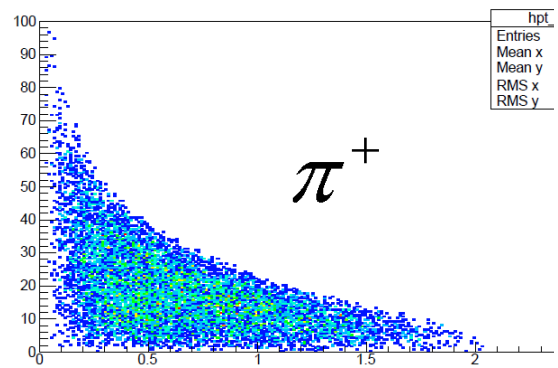
Phase space of $\bar{p}p \to \bar{\Omega}\Omega$ at 12 GeV/c

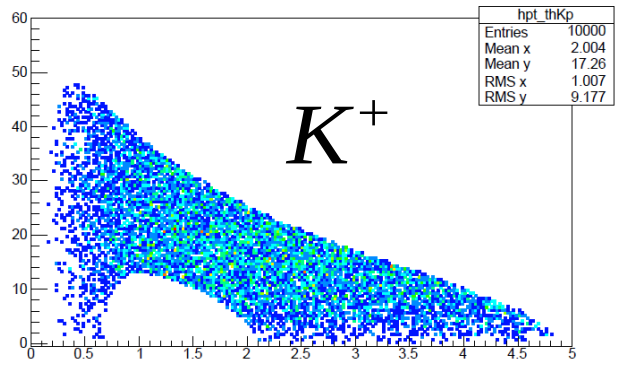












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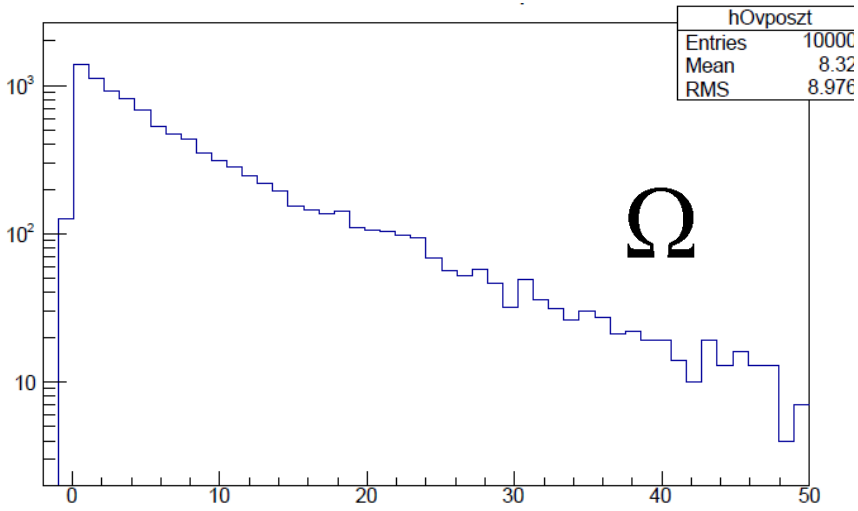
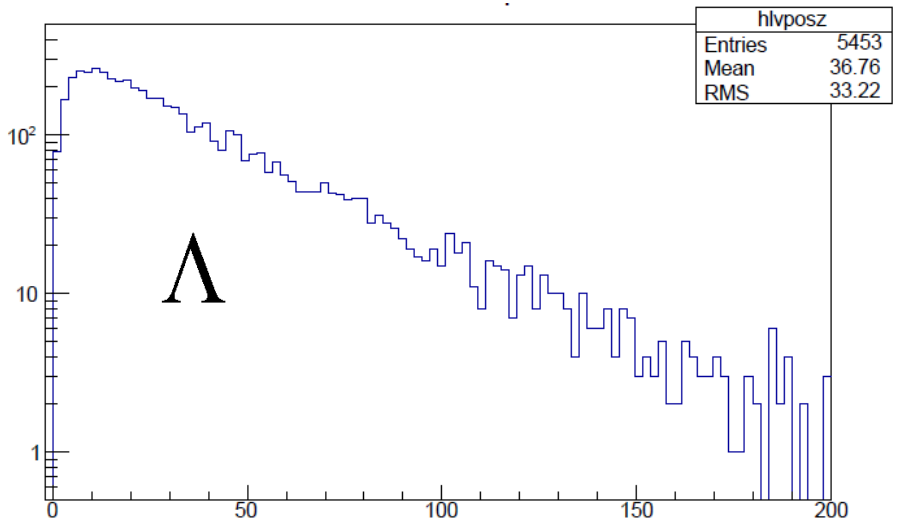
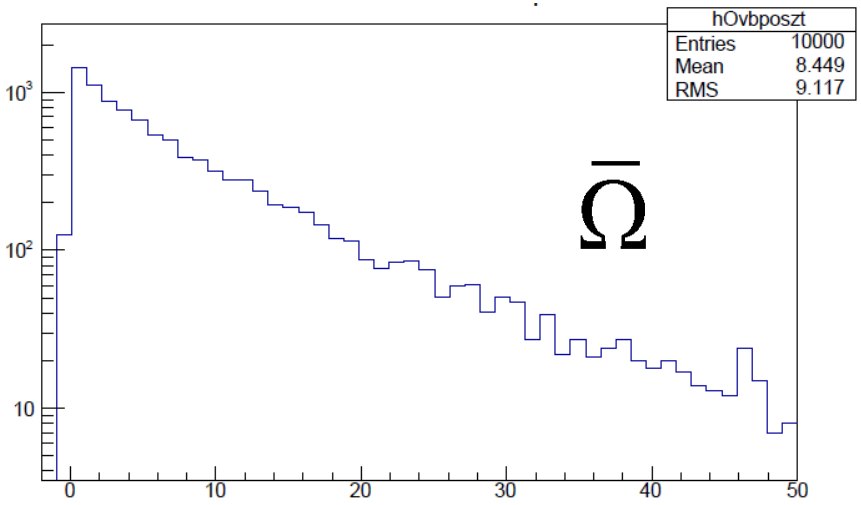
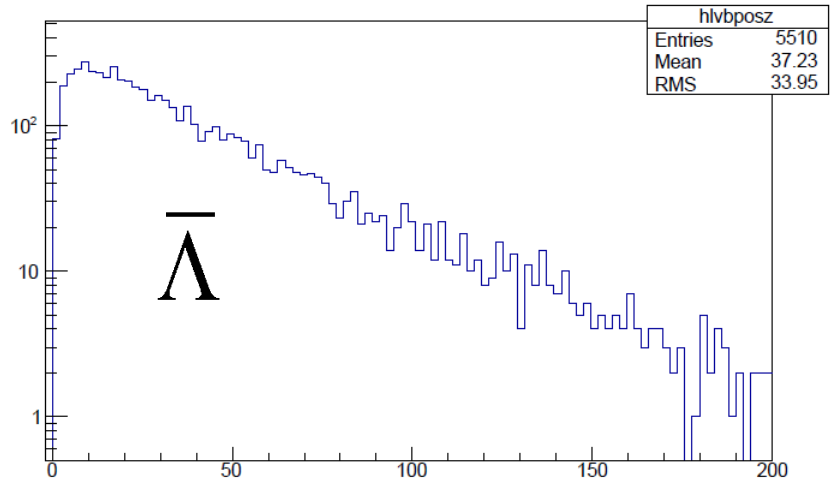
Vertex distributions









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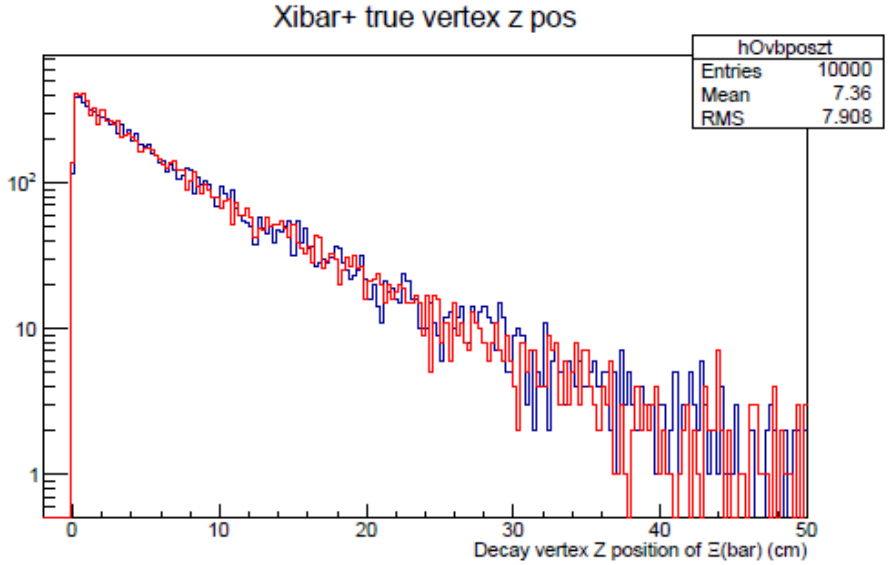
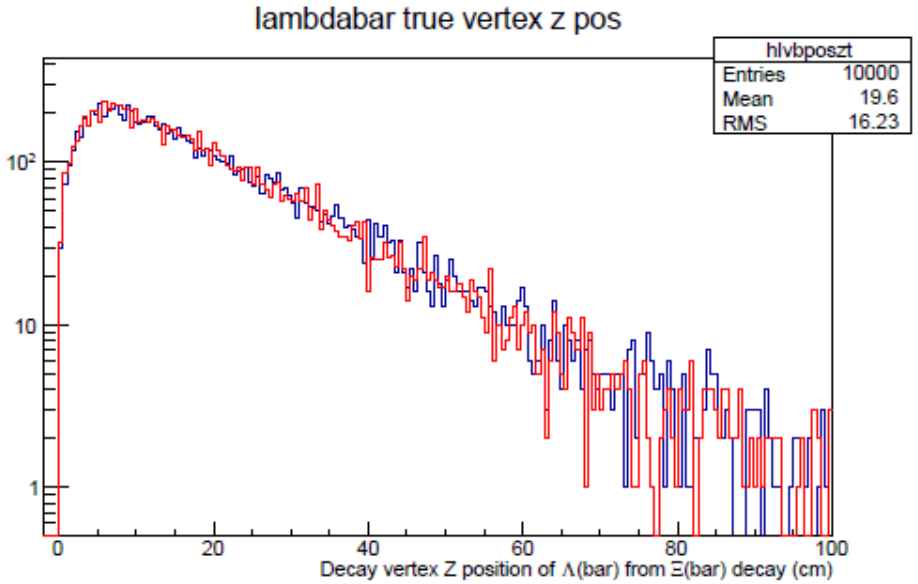
The $\bar{p}p \to \bar{\Xi}^{+}\Xi^{-}$ channel at 4 GeV/c

- $\Xi \to \Lambda\pi$ decay considered.
- Model: isotropic Ξ and Λ distributions.





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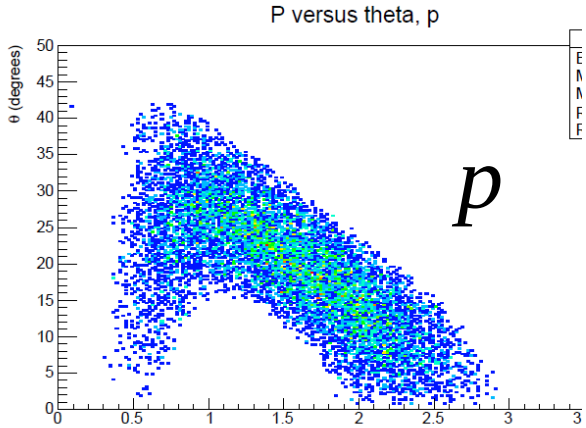
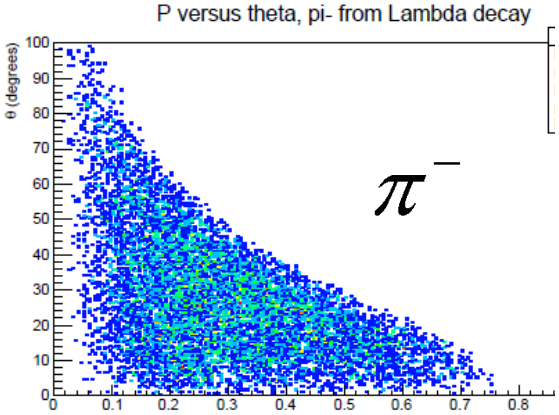
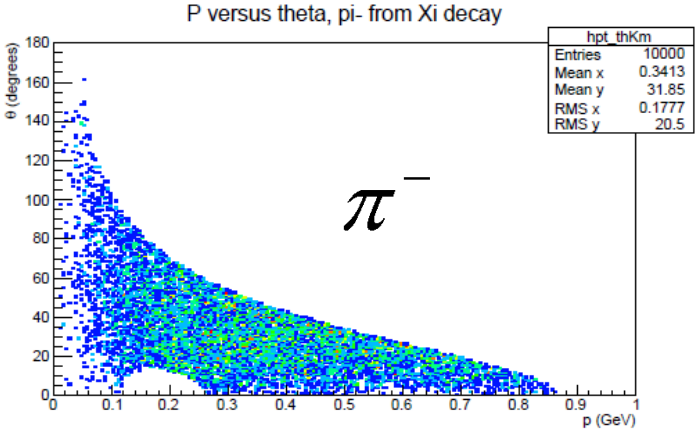
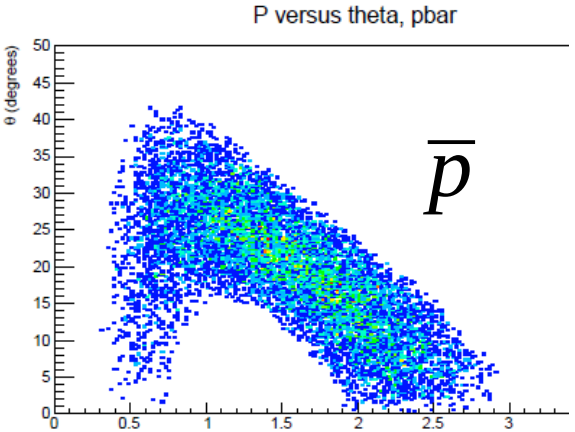
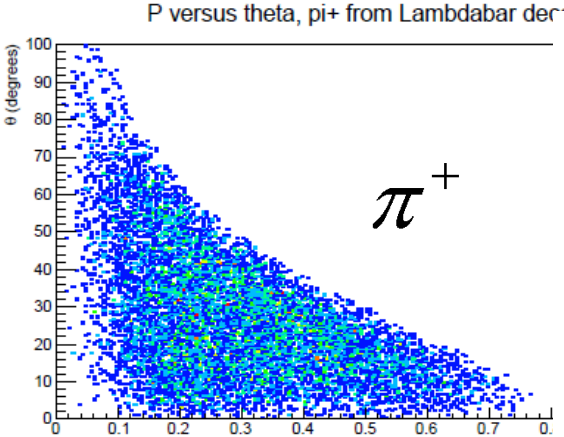
Phase space of $\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{-}$ at 4 GeV/c

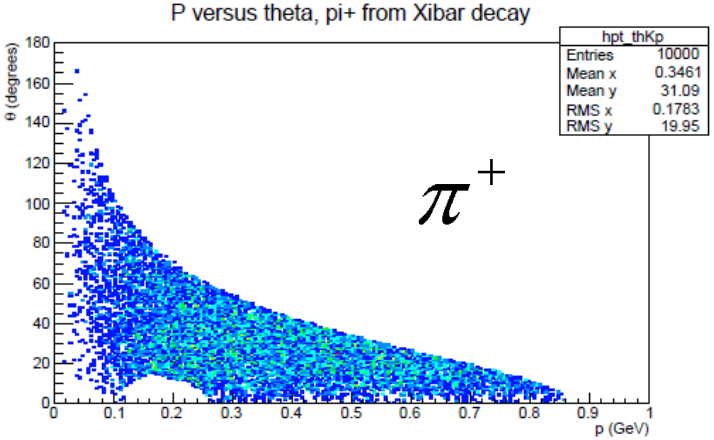






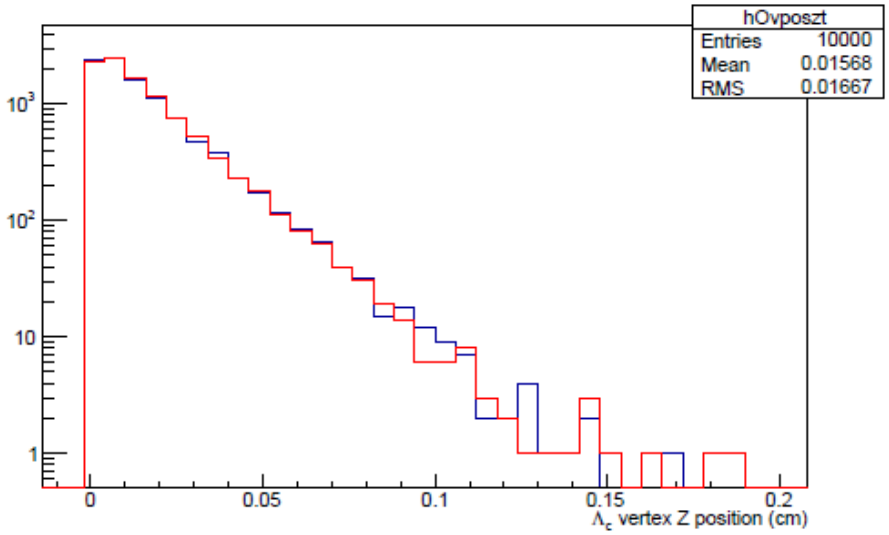


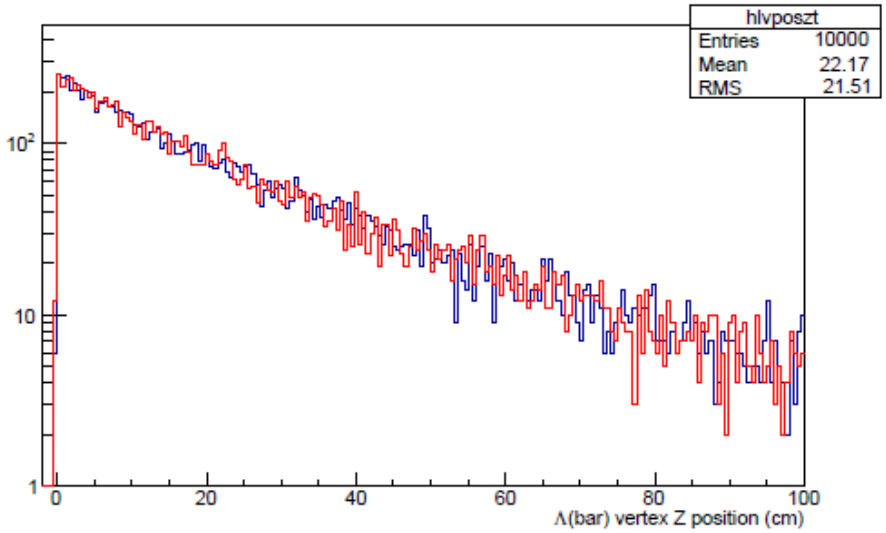




The $\bar{p}p \to \bar{\Lambda}_c \Lambda_c$ channel at 12 GeV/c

- $\Lambda_c \to \Lambda\pi$ decay considered (BR~1%)
- Model: isotropic Λ_c and Λ distributions.





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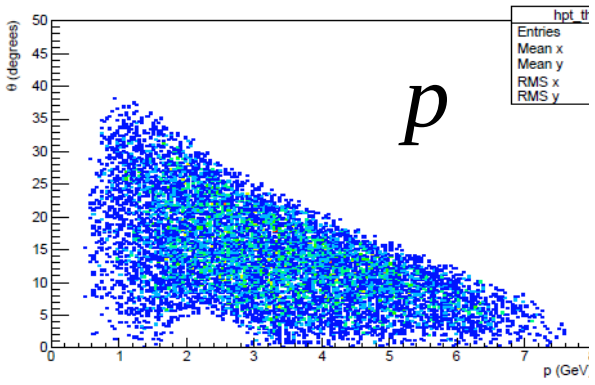
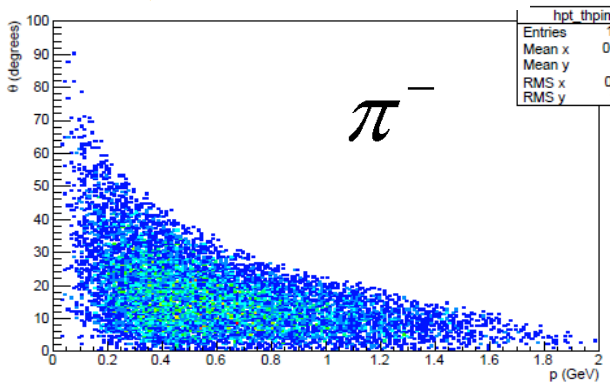
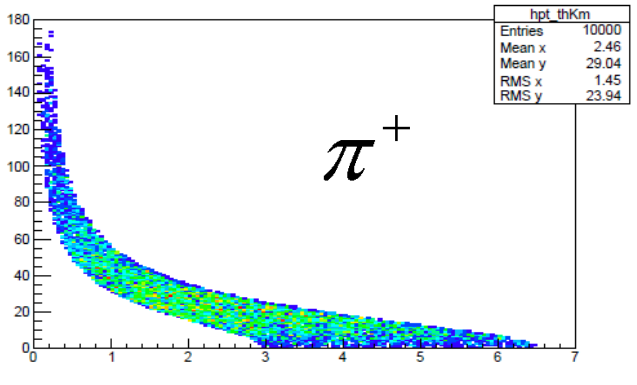
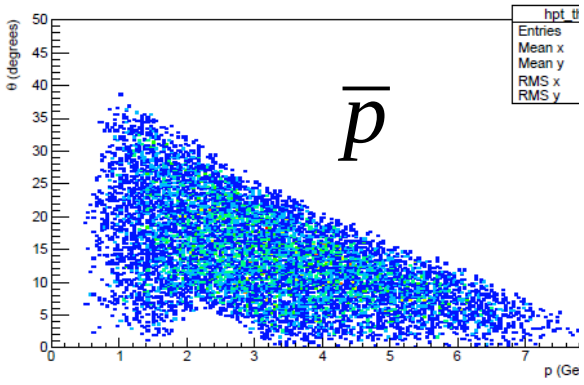
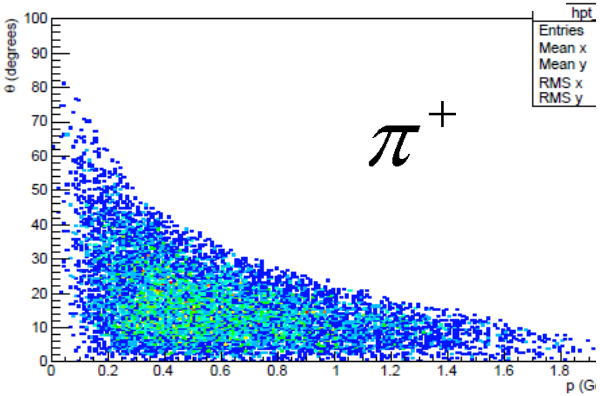
Phase space of $\bar{p}p \to \bar{\Lambda}_c \Lambda_c$ at 12 GeV/c

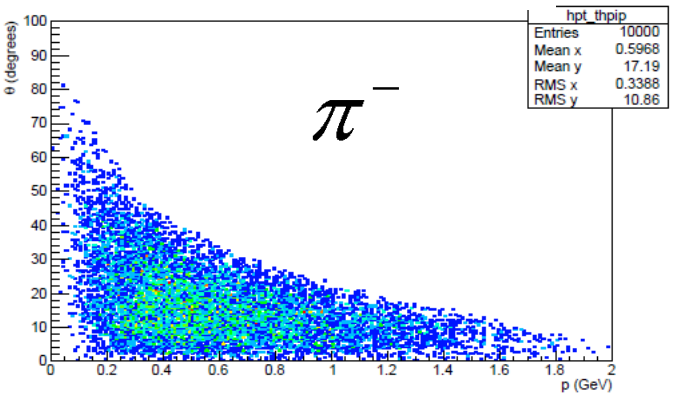












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Summary

- The benchmark channel $\bar{p}p \to \bar{\Lambda}\Lambda$ has been studied with PANDAroot, full simulations.
- The MVD/GEM subdetectors are necessary for spin studies.
- Calorimetry and PID are not necessary.
- At higher energies, the FTS becomes crucial for the $\bar{p}p \to \bar{\Lambda}\Lambda$ channel.
- Study of flagship channels such as $\bar{p}p \to \bar{\Omega}\Omega$, $\bar{p}p \to \bar{\Xi}^{+}\Xi^{-}$ and $\bar{p}p \to \bar{\Lambda}_c\Lambda_c$ follow the same principle as $\bar{p}p \to \bar{\Lambda}\Lambda$.