Study of Excited Ξ Baryons in $\bar{p}p$-Collisions with the $\bar{P}$ANDA Detector

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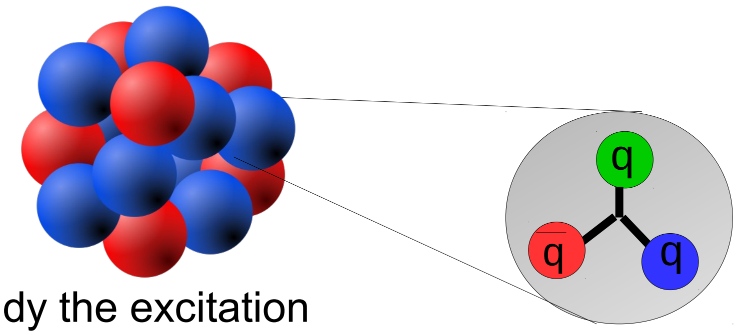
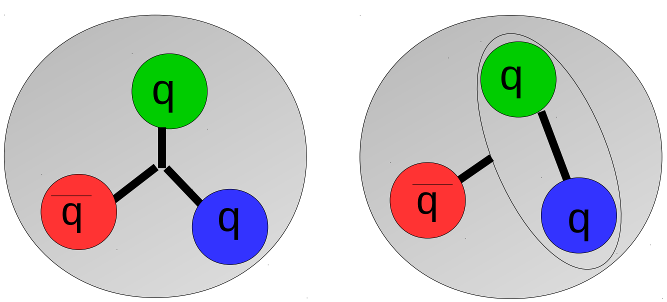
Outline

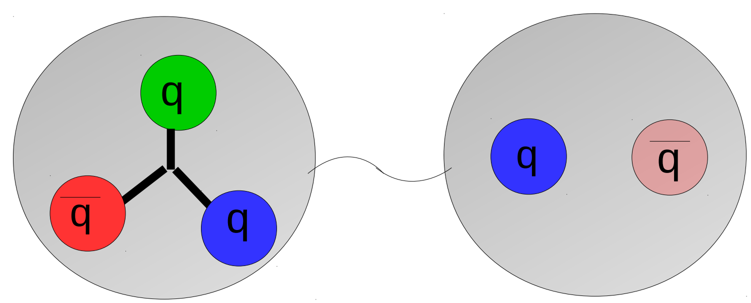
- Motivation
- Event Generation
- The $\overline{\text{P}}$ANDA Detector
- Preliminary reconstruction
- Background
- Summary and Outlook

Why is baryon spectroscopy interesting?

- We want to understand the strong interaction
- Elementary particles of the strong interaction are quarks and gluons
- But observed particles are hadrons = baryons & mesons
- To understand their structure we need to study the excitation pattern
- Open questions: 3-quark or quark-diquark structure? Baryon and meson dynamics?







Baryon Meson

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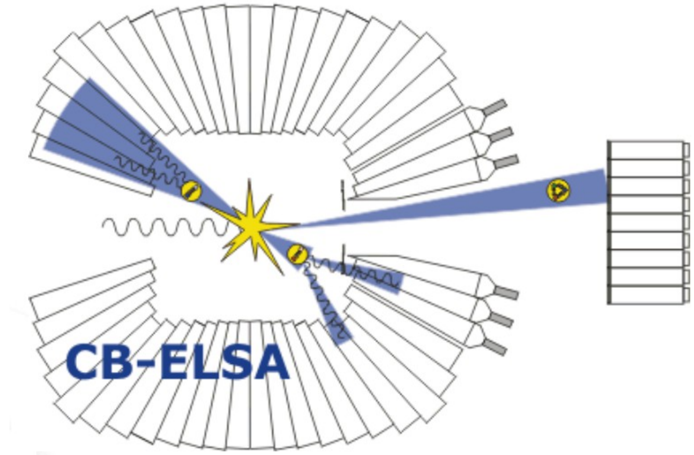
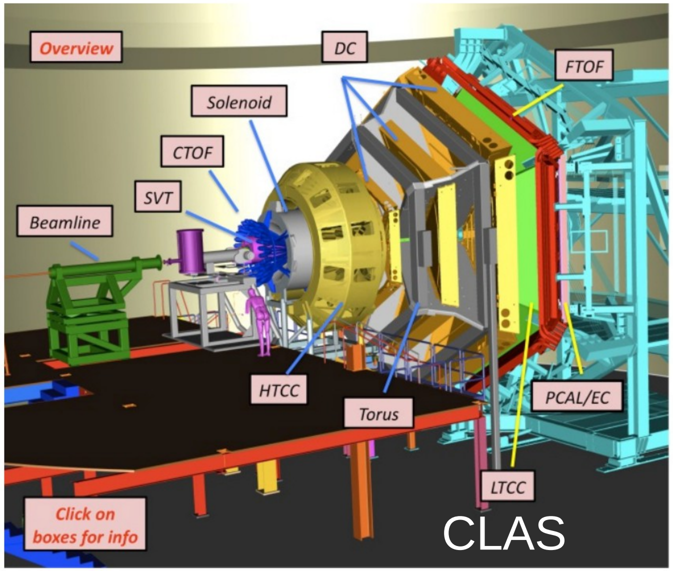
Why is the spectroscopy of double strange baryons interesting?

- Intense worldwide effort to study the nucleon (and Δ) spectrum with photo-induced reactions

N	Δ	Λ	Σ	Ξ	Ω
10	7	8	5	1	0

- Much less information on Λ/Σ, Ξ and Ω baryons
- Study of Ξ spectrum gives independent information
- Allows to verify if the picture deduced from N*, Δ studies is correct





Why with $\bar{p}p$ collisions at $\bar{\text{P}}$ANDA?

- $\bar{\text{P}}$ANDA gives simultaneous access to excited states for baryons and anti-baryons in $\bar{p}p \rightarrow$ baryon + antibaryon + meson(s)
- Large cross sections (e.g. μb cross section for $\Xi\,\bar{\Xi}$) allows collection high-statistics in reasonable time
- Systematic error check

Mitglied der Helmholtz-Gemeinschaft

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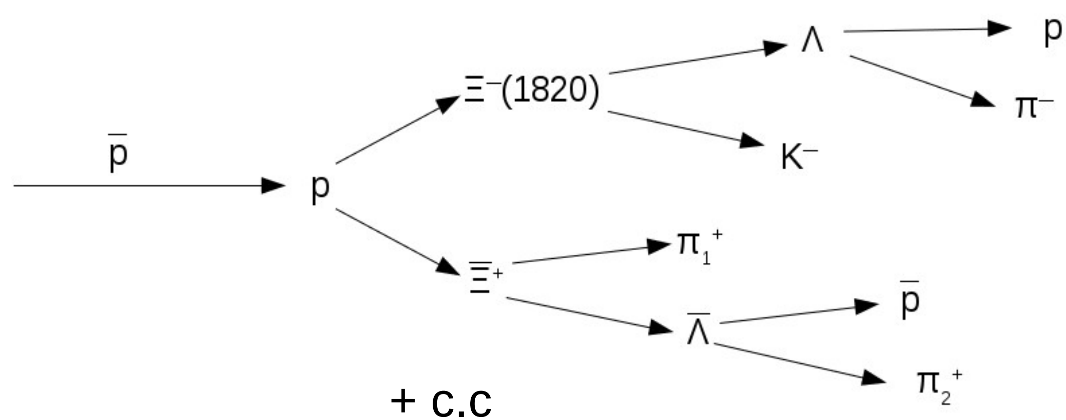
Event Generation

- $\bar{p}p \rightarrow \Xi^{-}(1820)\,\bar{\Xi}^{+}$
  and charge conjugate
- 1.5 million signal events
- $p_{\bar{p}}$ = 4.6 GeV/c
  (approx. 100 MeV above production threshold)
- Assuming a branching ration of 100% for
  $\Xi^{-}(1820) \rightarrow \Lambda + K^{-}$
- Mass of $\Xi^{-}(1820)$:
  $m_{\Xi(1820)}$ = 1.823 GeV/c^2
- Width: Γ = 24 MeV/c^2
- Spin Parity: $3/2^{-}$ (?)



+ c.c

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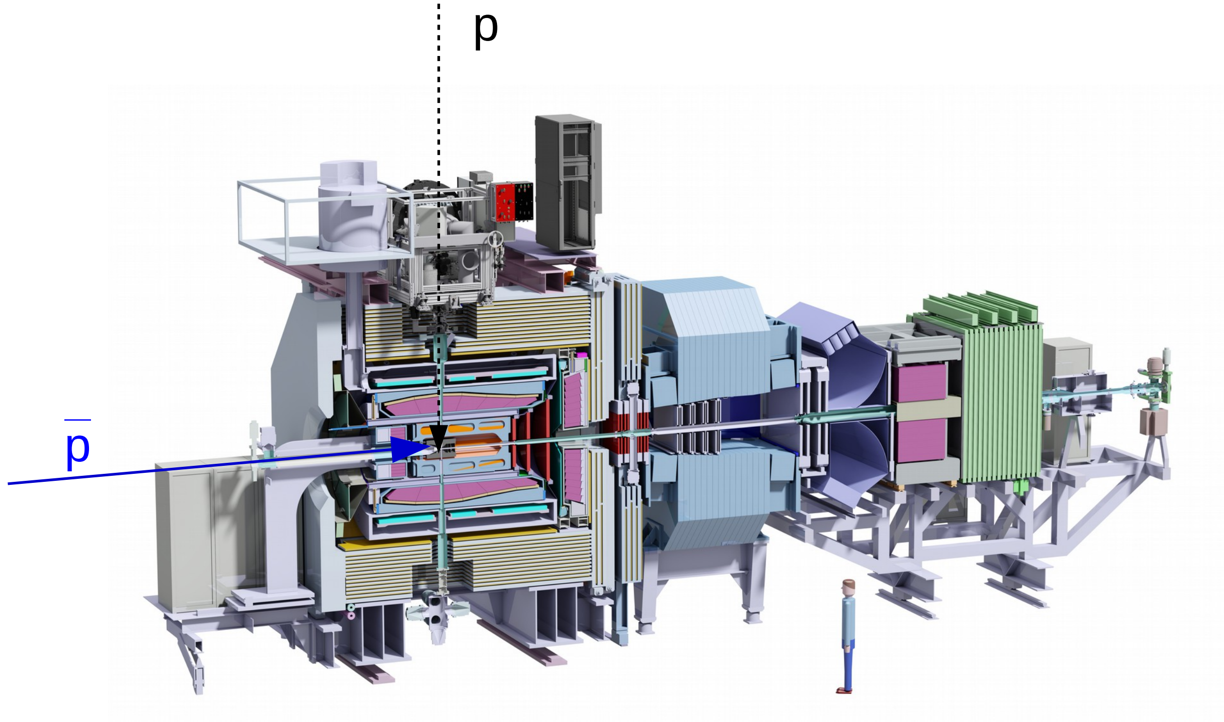
The $\overline{\text{P}}$ANDA Detector

Physics program

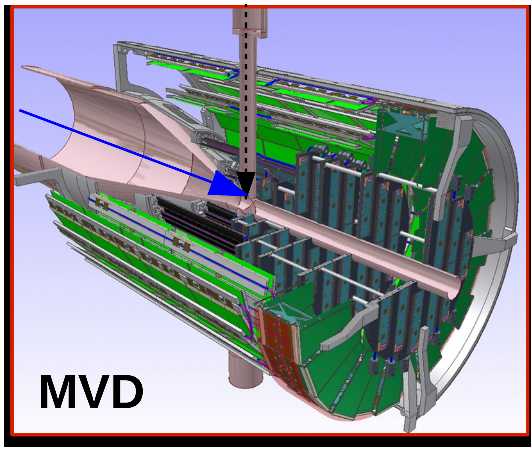
- Baryon spectroscopy
- Meson spectroscopy
- QCD dynamics
- Nucleon structure, em. processes
- Hadrons in nuclei
- Hypernuclear physics

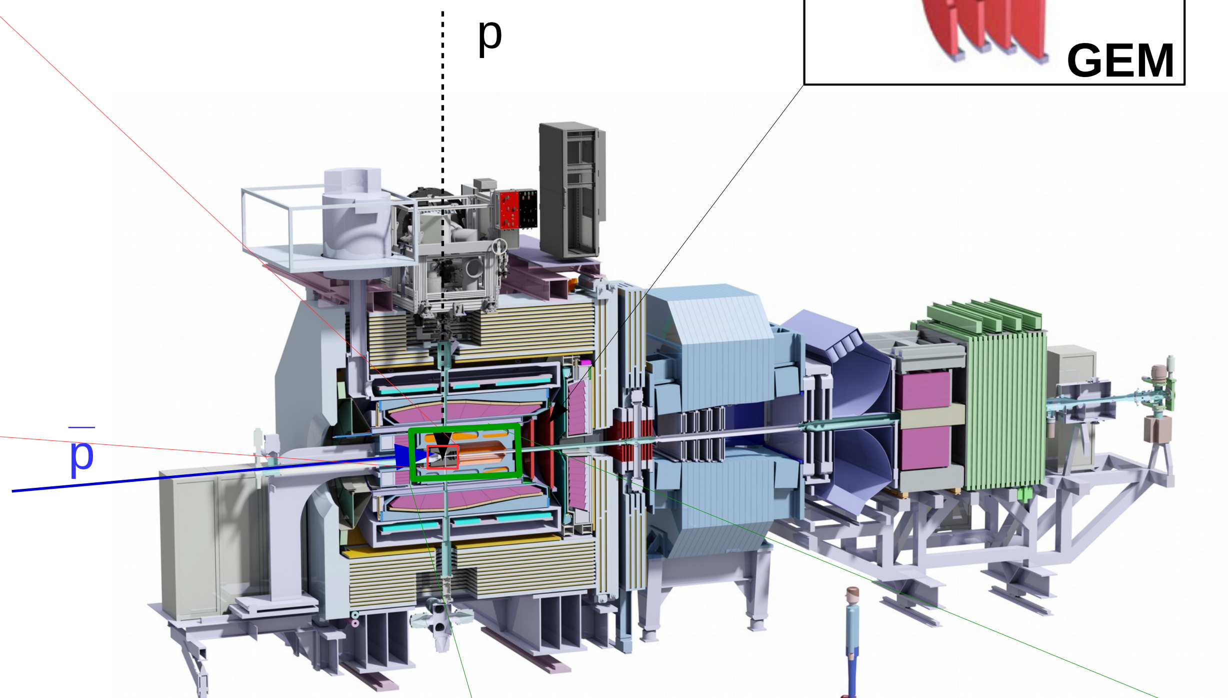


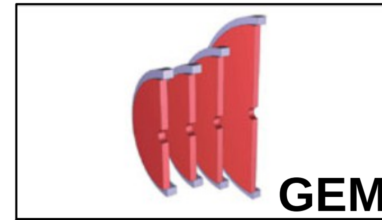
Detector capabilities

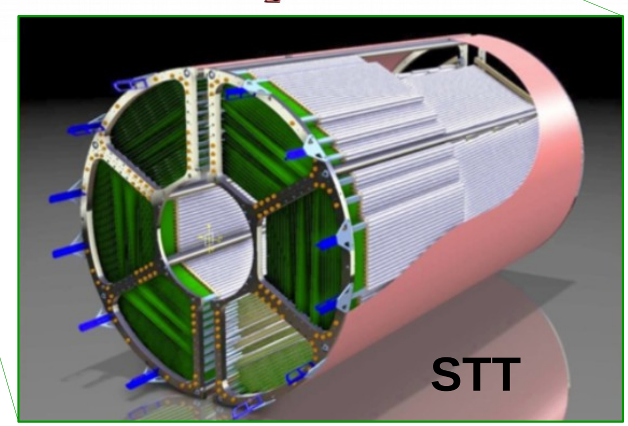
- 4 π acceptance
- High tracking resolution
- Good particle identification

The $\bar{\text{P}}$ANDA Detector









Detector capabilities

- 4 π acceptance
- High tracking resolution
- Good particle identification

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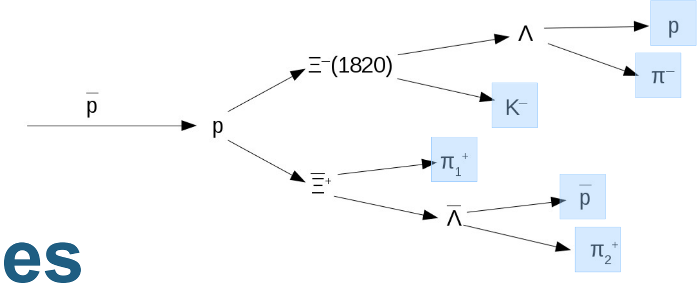
Reconstruction

- Simulation of transport through the detector
- Transport and reconstruction of particles is done with the PandaRoot framework
- Continuous development and improvement of framework
- **This work is at starting point and still under development!**

All following results are preliminary!!!

Reconstruction
Final State Particles



- Used ideal pattern recognition and "best" particle identification (PID)
- Selected only final state particles with $N_{Hits} \geq 4$ in at least one of the inner tracking detector (MVD, STT, GEM)
- Reconstruction efficiency for final state particles:

Reco. eff. $\bar{p}p \rightarrow \Xi^* \bar{\Xi}$

particle	Reco. eff. [%]
π^-	84
π_2^+ ($\bar{\Lambda}^0$)	83
π_1^+ ($\bar{\Xi}$)	81
K^-	79
p	84
$\bar{p}$	78

Reco. eff. $\bar{p}p \rightarrow \Xi \bar{\Xi}^*$

particle	Reco. eff. [%]
π^+	83
π_2^- (Λ^0)	83
π_1^- (Ξ)	80
K^+	83
p	81
$\bar{p}$	81

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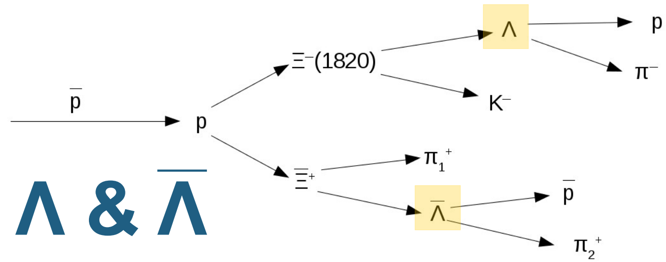
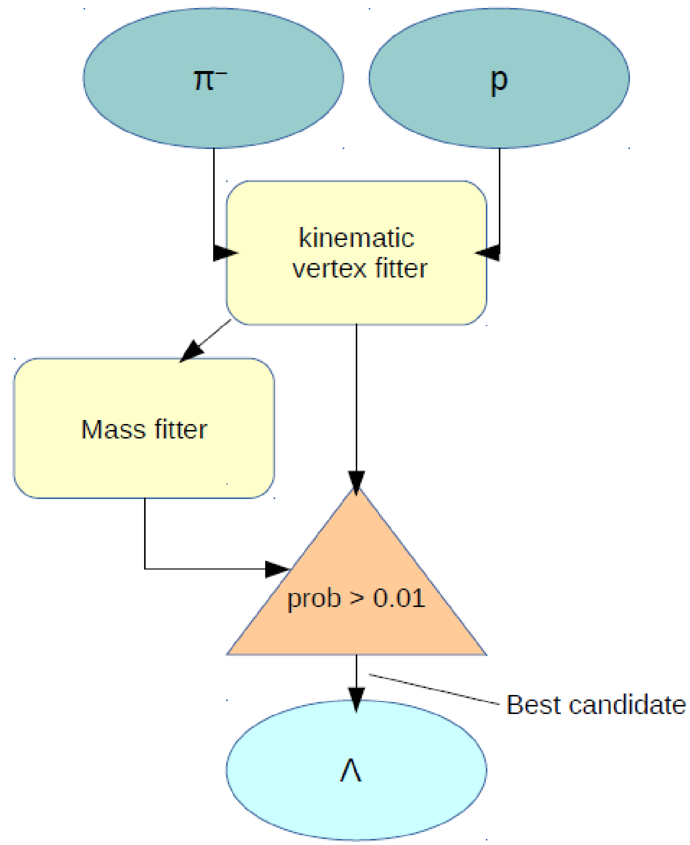
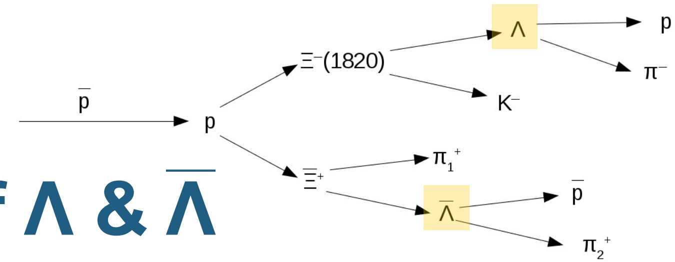
Reconstruction of Λ & $\bar{\Lambda}$



- Select candidates within a mass window of $m = (1.116 \pm 0.15)$ GeV/c^2
- Perform kinematic vertex fit: (Fit tracks of daughter particles to common vertex)
- Kinematic fit with mass constraint is performed on fitted candidate
- Select candidate with vertex fit prob > 0.01 and mass fit prob > 0.01
- More than one candidate: select candidate with smallest χ^2

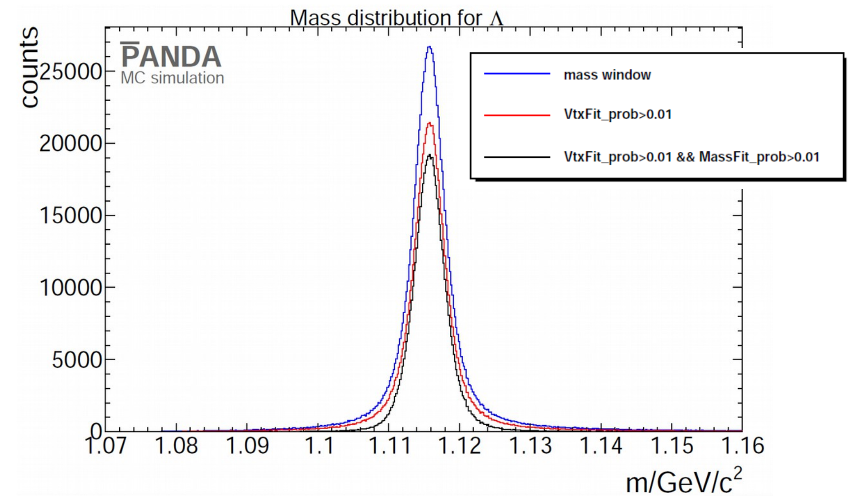


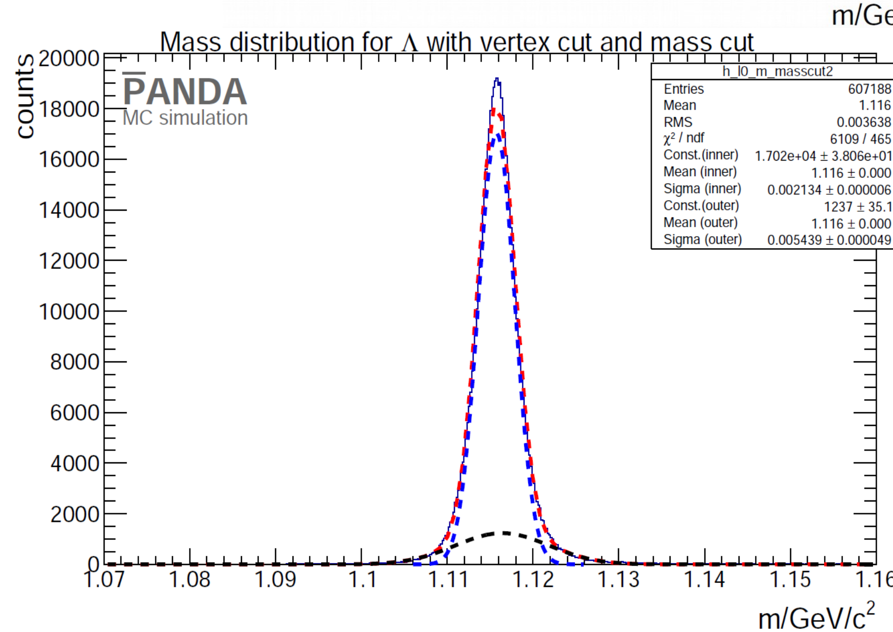
Reconstruction of Λ & $\bar{\Lambda}$

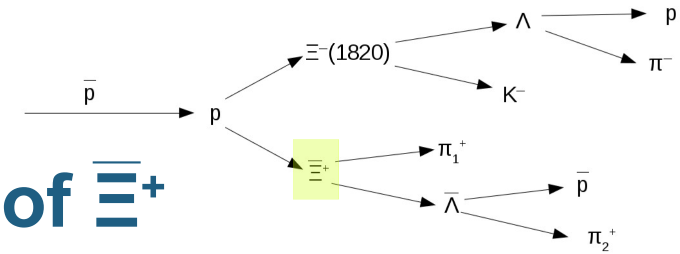


Fitted mass:

- Performed with double Gaussian fit
- "inner" mean is reconstructed mass value
- M_{Λ} = 1.1158 GeV/c² σ = 2.134 MeV/c²
- $M_{\bar{\Lambda}}$ = 1.1159 GeV/c² σ = 2.084 MeV/c²
- Errors are dominated by systematic effects

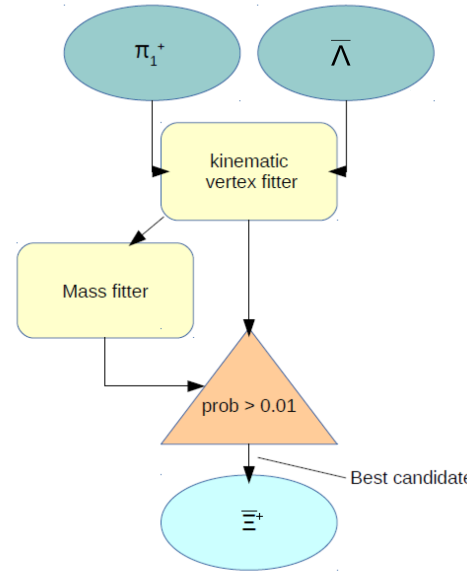


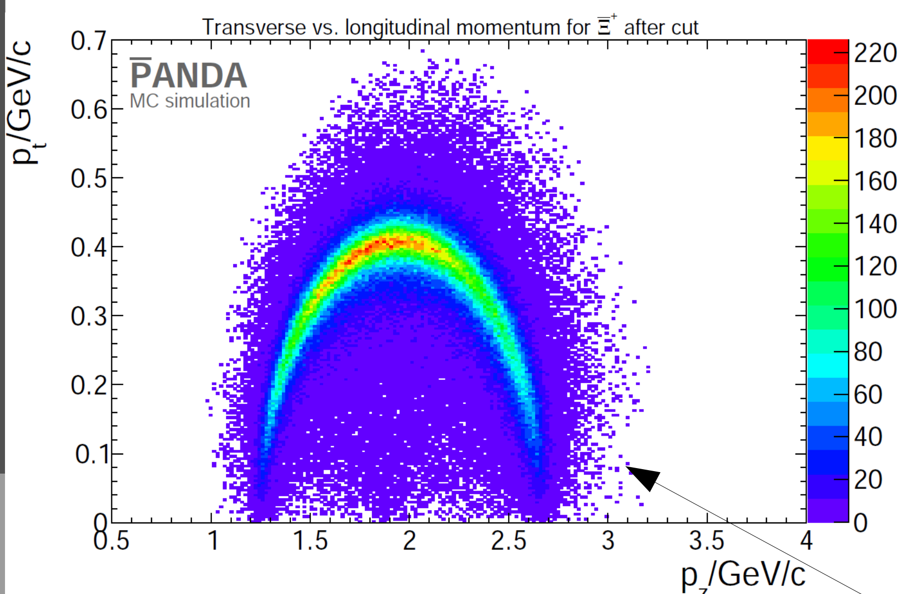




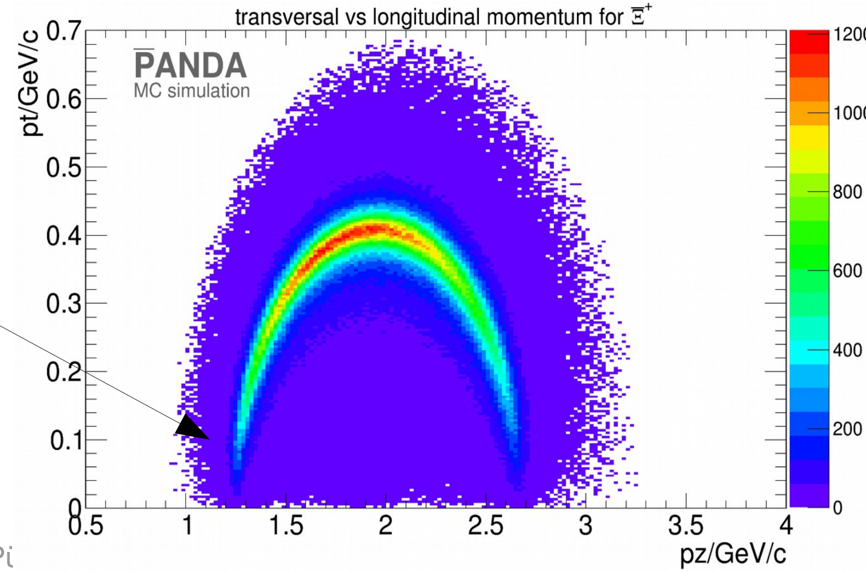
Reconstruction of $\overline{\Xi}^+$

- Combine $\overline{\Lambda}^0$ and π_1^+
- Mass cut with window 1.321 ± 0.15 GeV/c^2

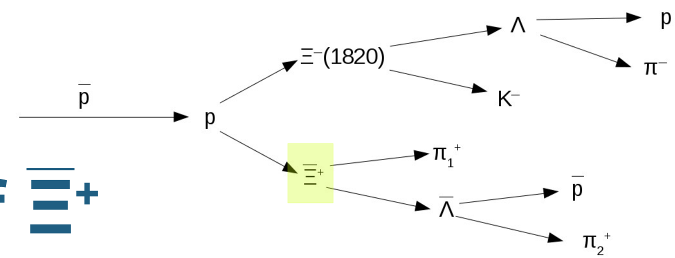


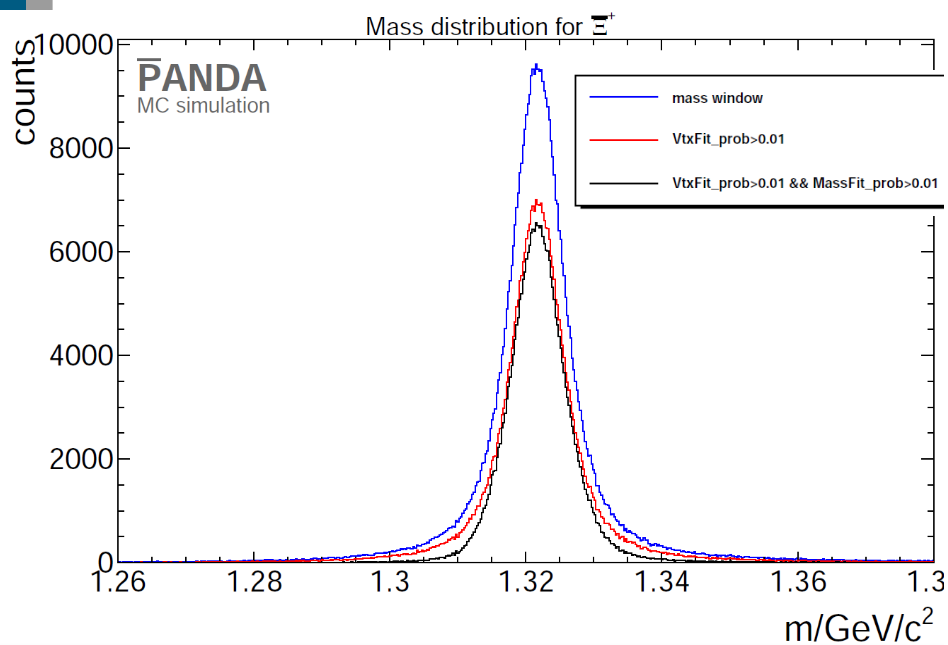


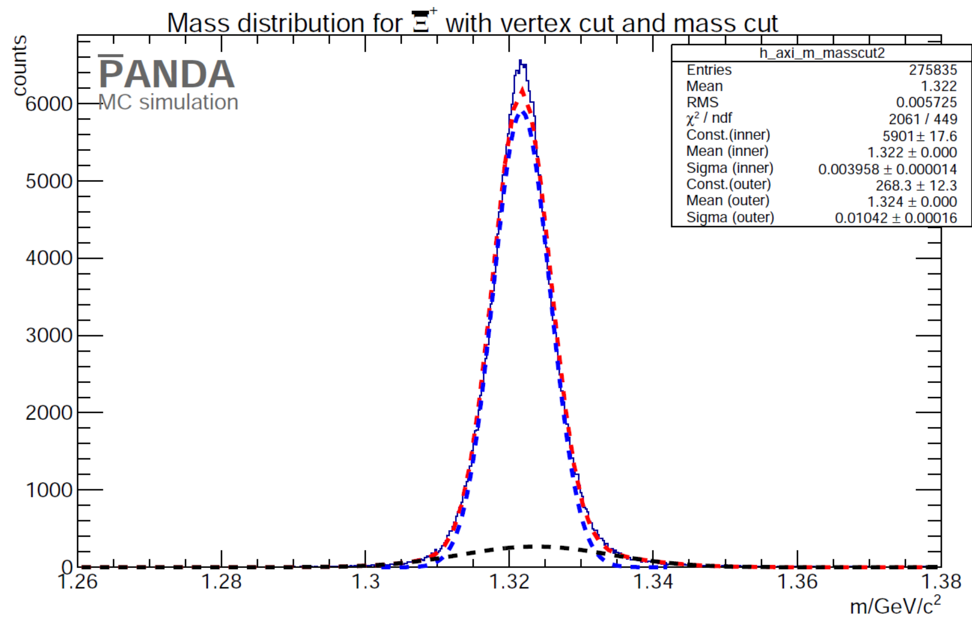
Comparison with generated candidates



Reconstruction of $\overline{\Xi}^+$ mass distribution

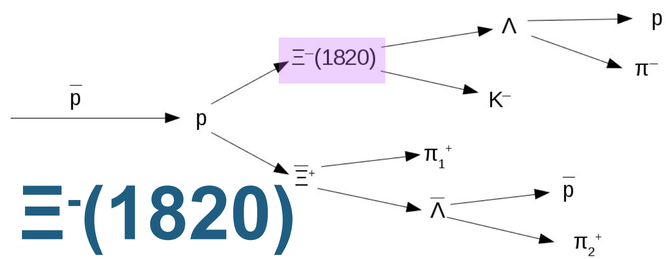




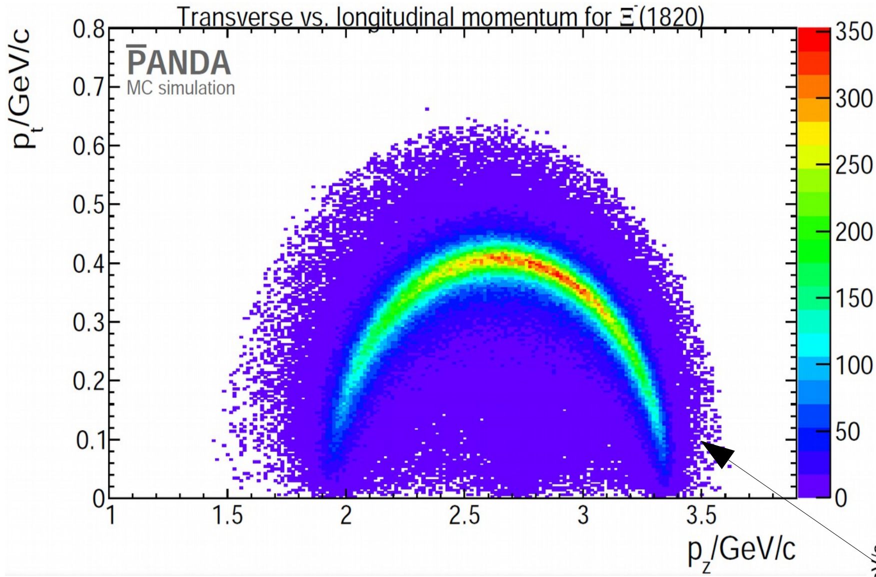


<u>Fitted mass:</u>

- $M_{\overline{\Xi}+}$ = 1.322 GeV/c^2; σ = 3.96 MeV/c^2
- $M_{\Xi-}$ = 1.322 GeV/c^2 ; σ = 4.00 MeV/c^2
- Errors are dominated by systematic effects

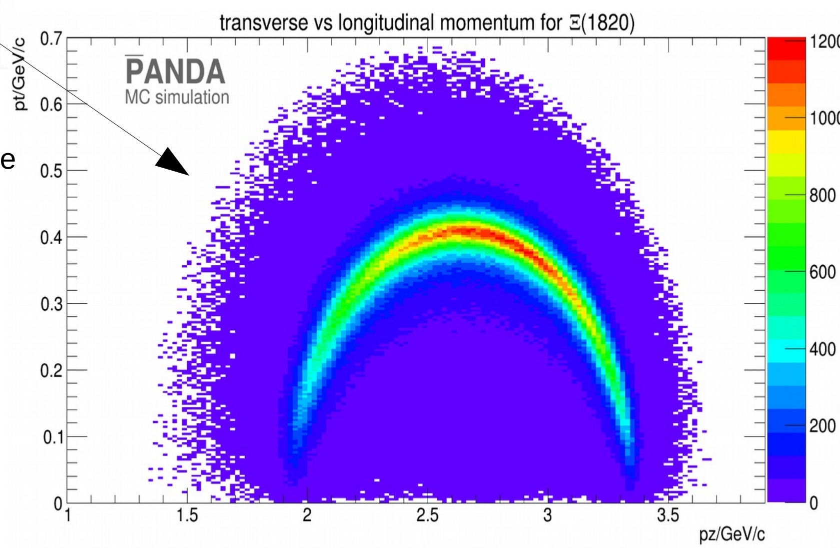


Reconstruction of $\Xi^-(1820)$

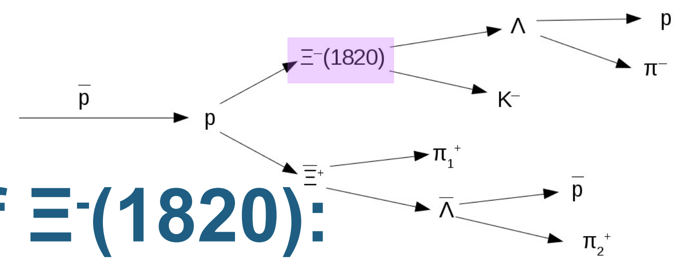


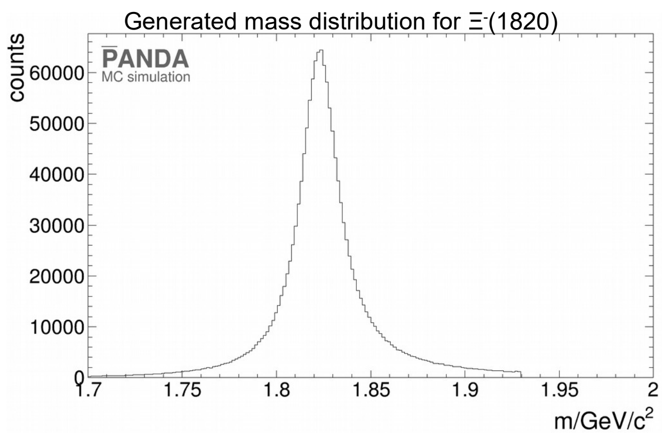
- Combine Λ and K^-
- Mass window 1.823 ± 0.15 GeV/c²
- Select candidate with vertex fit probability > 0.01
- More than one candidate left: candidate with smallest χ^2 is selected

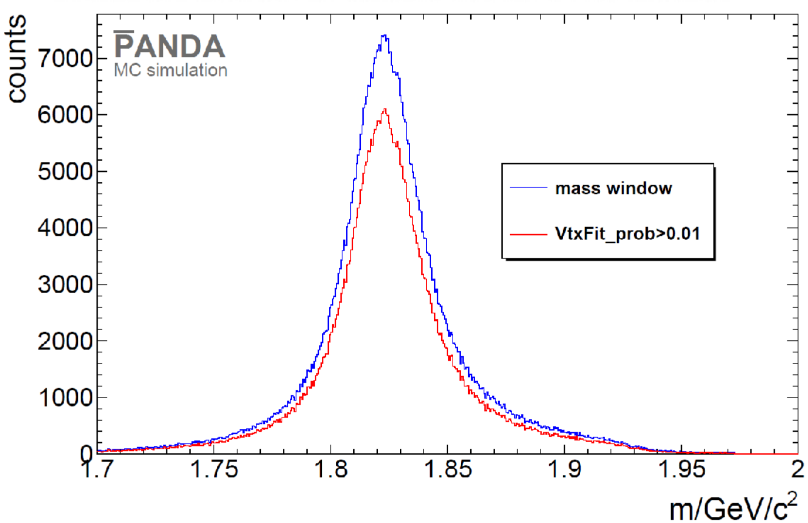
Comparison with generated candidate

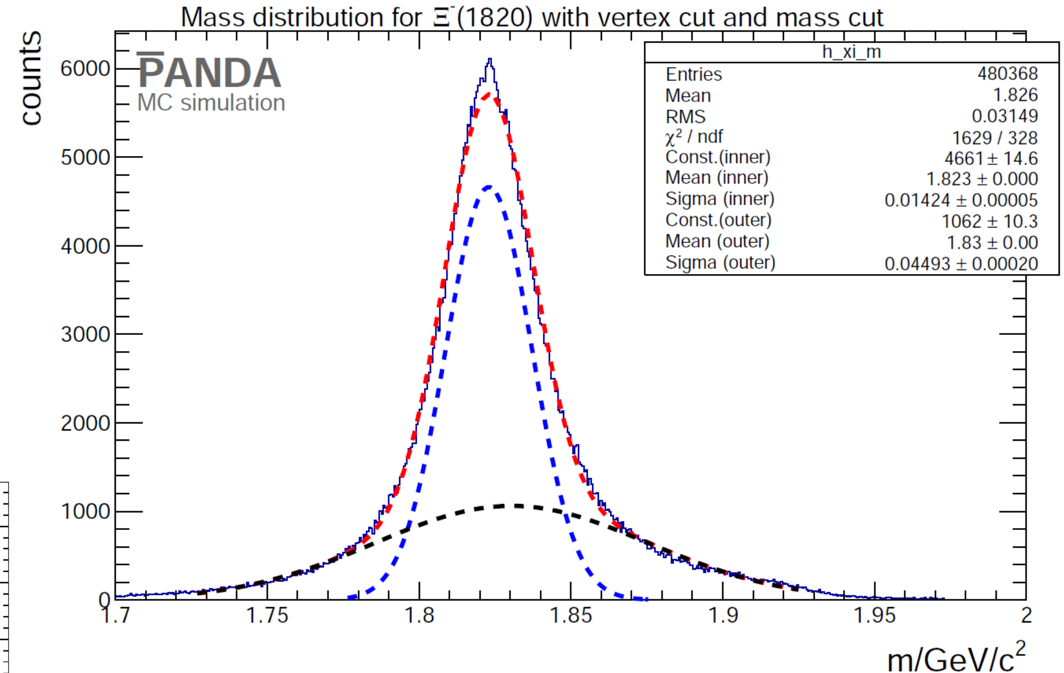


Reconstruction of $\Xi^-(1820)$: reconstructed mass





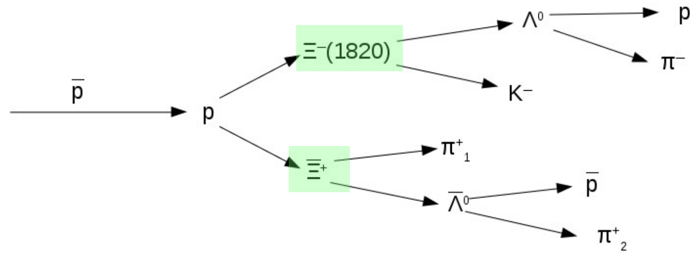




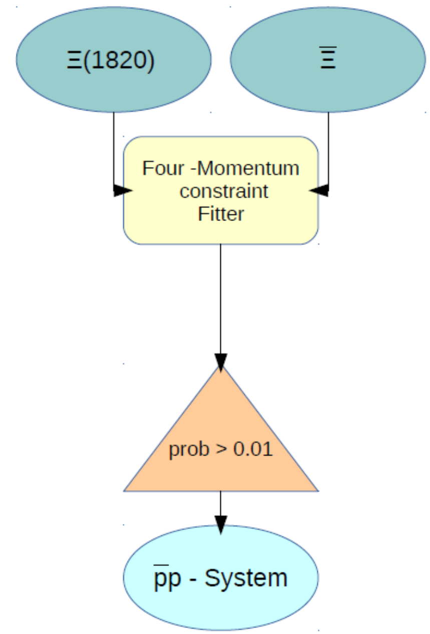
particle	fitted mass	σ
$\Xi^-(1820)$	1.823 GeV/c²*	14 MeV/c²
$\bar{\Xi}^+(1820)$	1.823 GeV/c²*	14 MeV/c²

* Errors are dominated by systematic effects

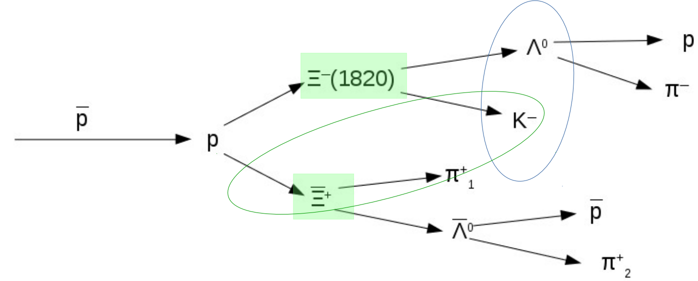
Reconstruction of $\Xi^{-}(1820)\ \bar{\Xi}^{+}$



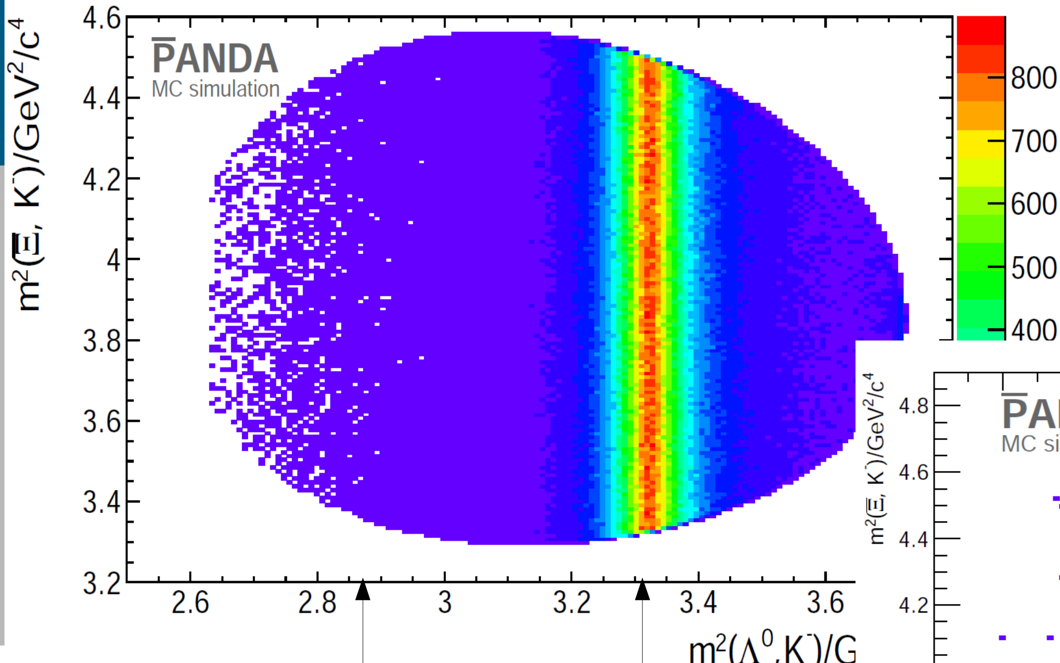
- Combine $\Xi^{-}(1820)$ and $\bar{\Xi}^{+}$
- Perform four momentum constraint fit
- Select candidates with p>0.01



Dalitz plots



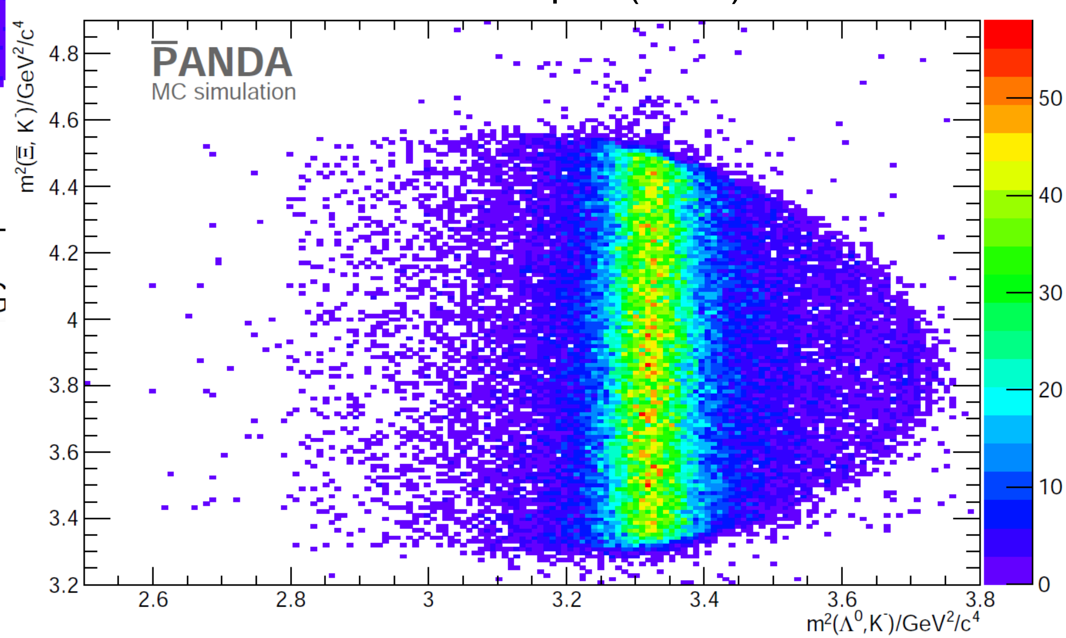
Dalitz plot (MC)



$\overline{\Xi}^{+}$, K^{-} : uncorrelated

Λ, K^{-} : correlated → resonance

Dalitz plot (reco.)



Background

- 15 million events were generated with **D**ual **P**arton **M**odel (DPM)
- For comparison with signal events scaling factor is needed

$$B = \frac{N^{\text{gen}}_{\text{sig}}/\sigma_{\text{sig}}}{N^{\text{gen}}_{\text{bg}}/\sigma_{\text{bg}}} = 6000$$

- Significance is defined as

$$S = \frac{N_{\text{sig}}}{\sqrt{N_{\text{sig}} + N_{\text{bg}} \cdot B}}$$

- Signal-to-background ratio*: 12 : 1
- More background events for higher statistics are needed

σ_{sig} = 1 μb
σ_{bg} = 60 mb

Particle	N_{sig}	N_{bg} * B	S
Λ	786,243	$1.6 \cdot 10^9$	20
$\bar{\Lambda}$	711,820	$744.4 \cdot 10^6$	26
$\bar{\Xi}^+$	302,681	$18.4 \cdot 10^6$	70
$\Xi^-(1820)$	490,672	$1.8 \cdot 10^6$	325
$\Xi^-(1820)\ \bar{\Xi}^+$	74,523	<6000	> 263*

* assuming at least 1 background event

Summary & Outlook

- Simulated 1.5 million signal events for $\bar{p}p \rightarrow \Xi(1820)^{-} \bar{\Xi}^{+}$ and its c.c.
- Reconstructed Mass of $\Xi(1820)$ in agreement with input value
- Number of
  - background events after all cuts: $N_{bg} < 6000$
  - Signal events after all cuts $N_{sig} = 75k$
- Lower limit for significance: $S > 263$
- Intermediate state of analysis looks promising

- More background simulation will be done as next step
- Partial wave analysis of $\Lambda K^{-} \bar{\Xi}$ (& c.c) final state will be explored

Thank you for your attention!

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Backup

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Ideal Tracking and ideal PID

- **Ideal tracking**:
  - hit points caused by a particle track are grouped based on the generated particle information
- **Ideal PID**:
  - true particle gets the probability P = 1, others P = 0.
  - 'best': particle with highest probability is chosen.

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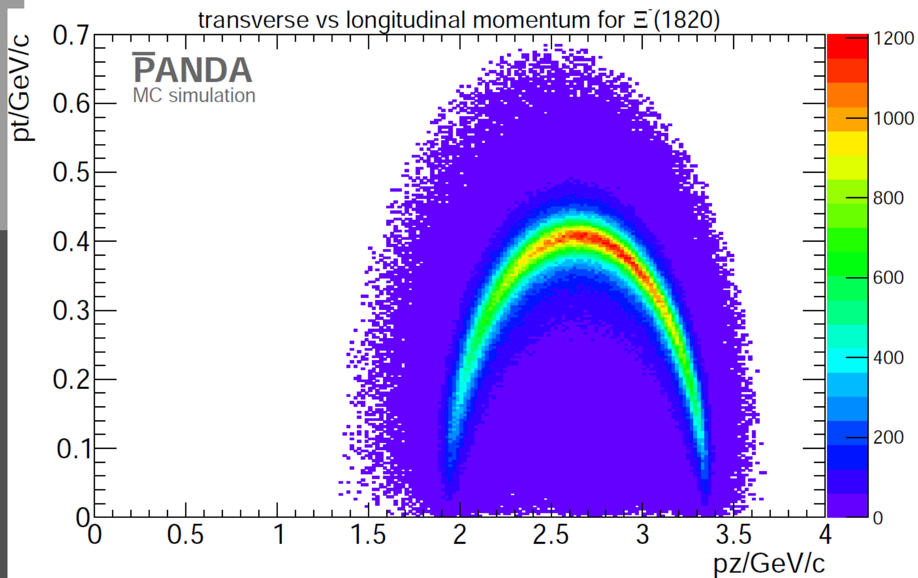
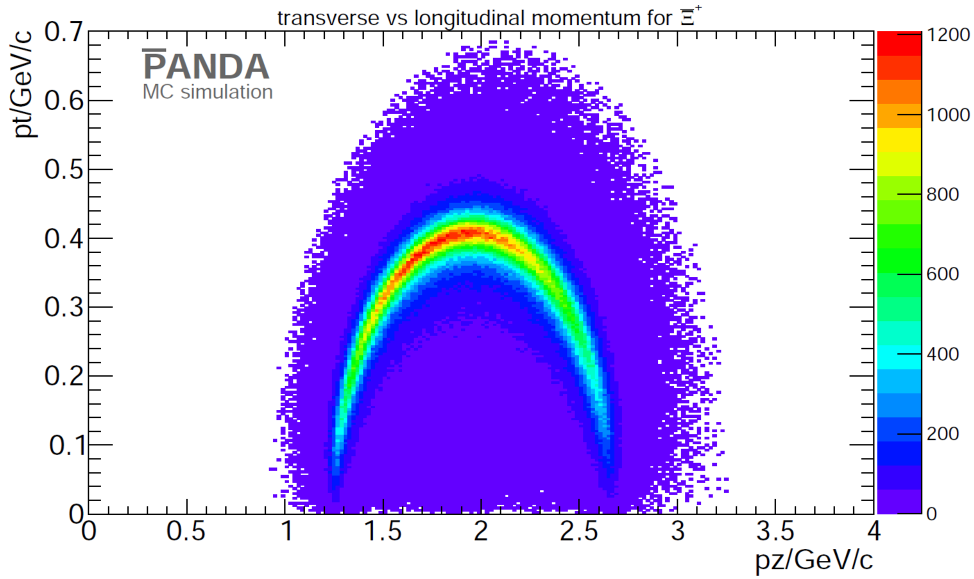
Simulation: Generated Events





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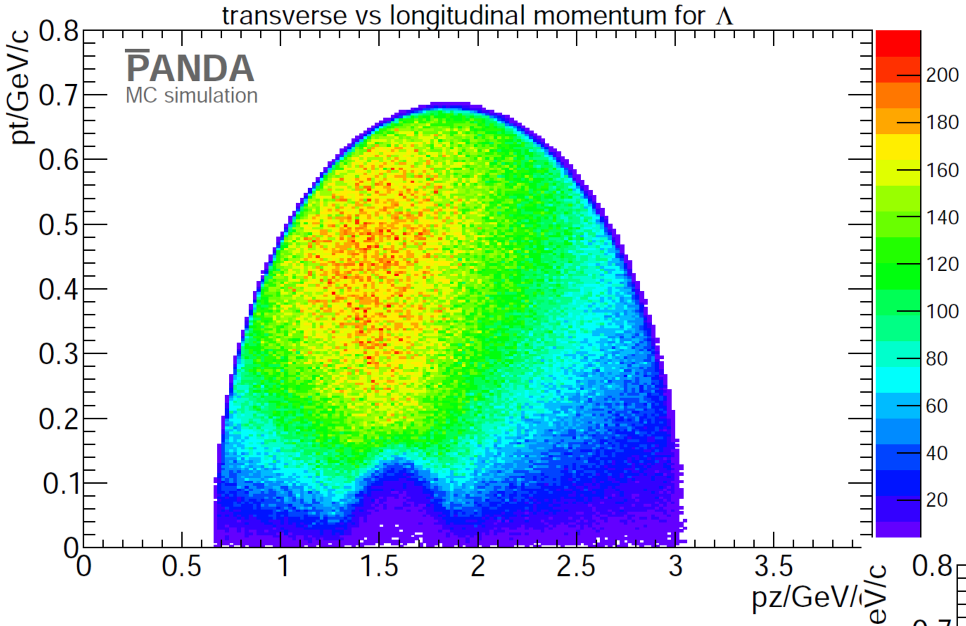
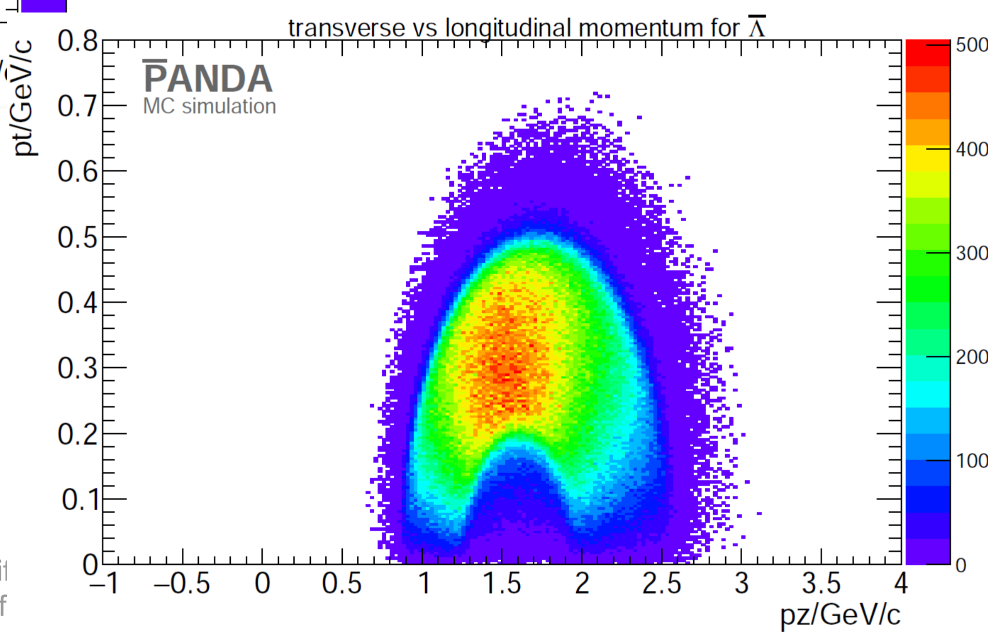
Λ: transverse vs. Longitudinal momentum





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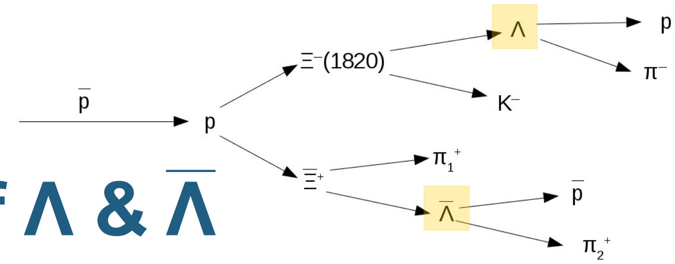
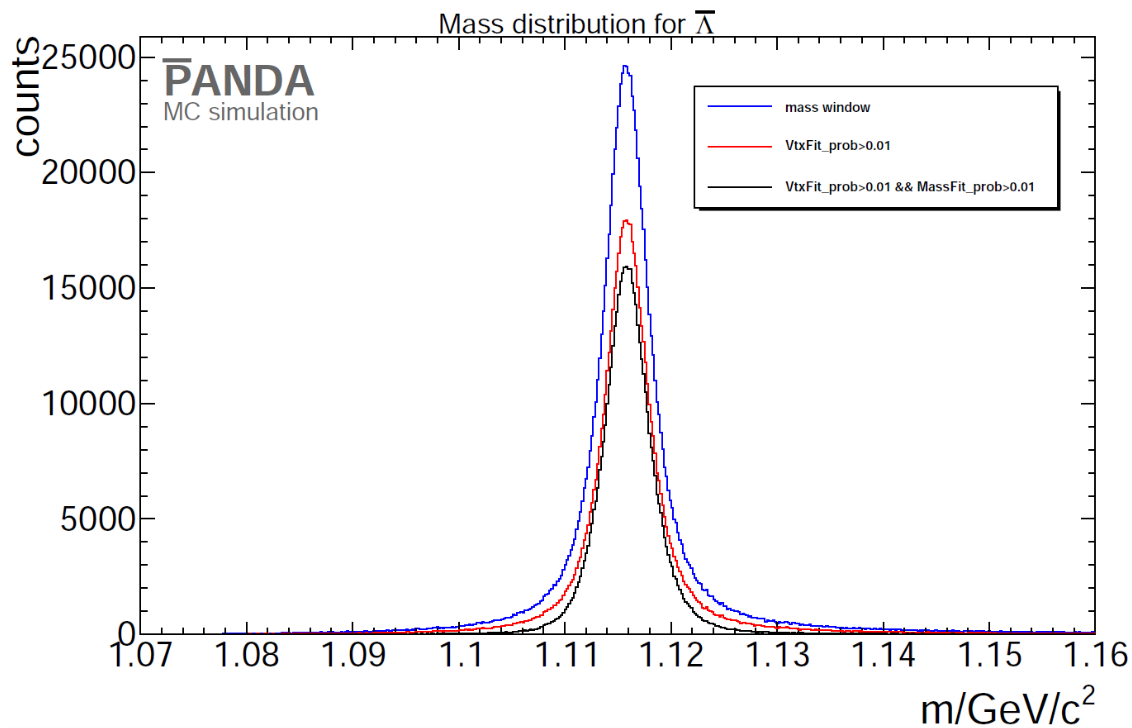
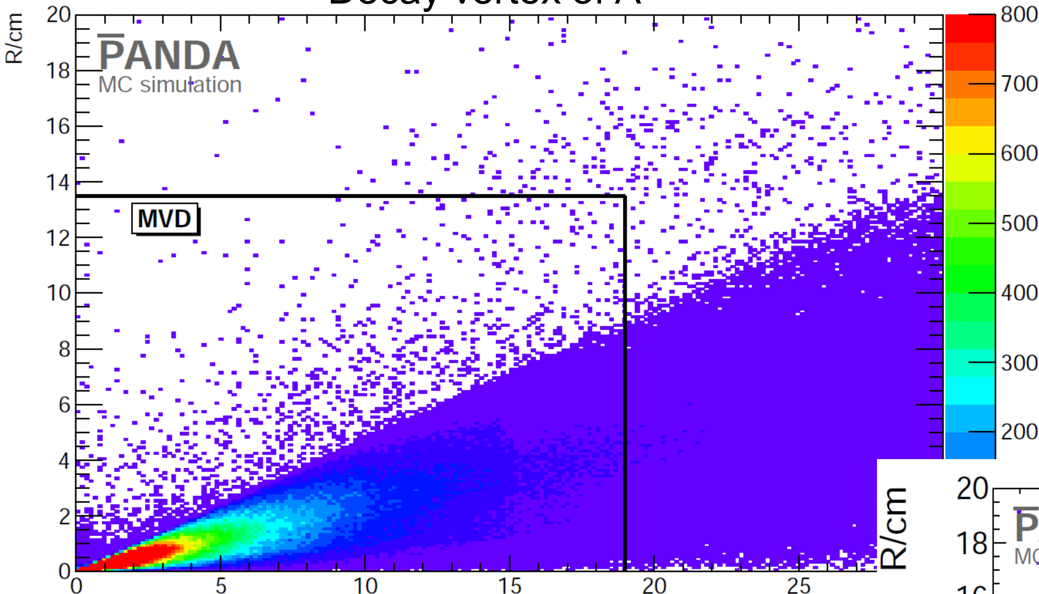
Reconstruction of Λ & $\bar{\Lambda}$





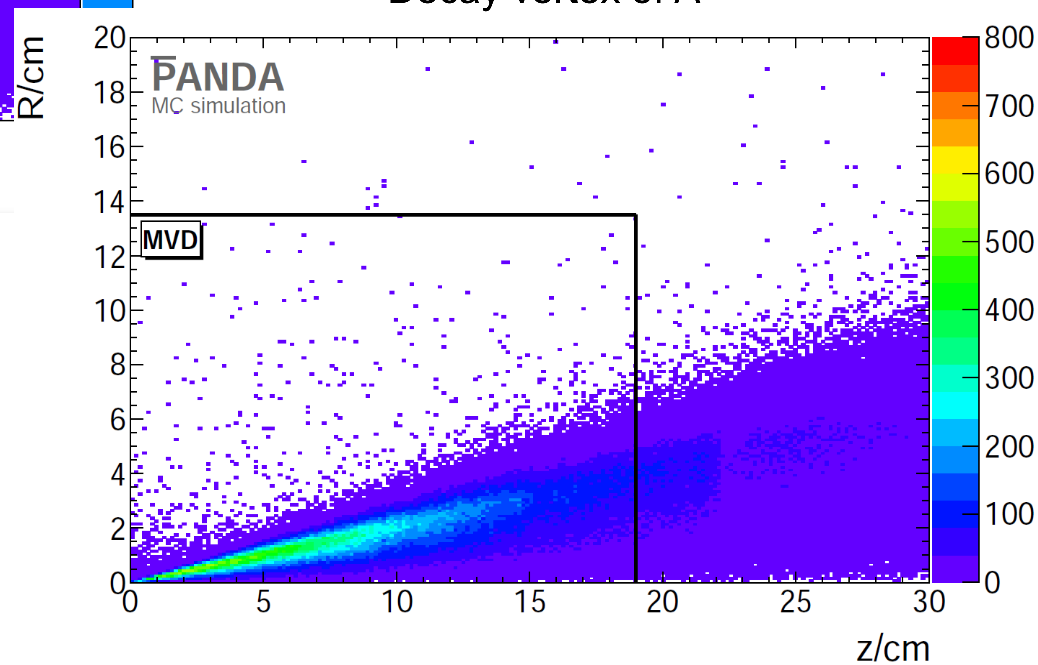
Λ & $\bar{\Lambda}$: decay vertex

Decay vertex of Λ

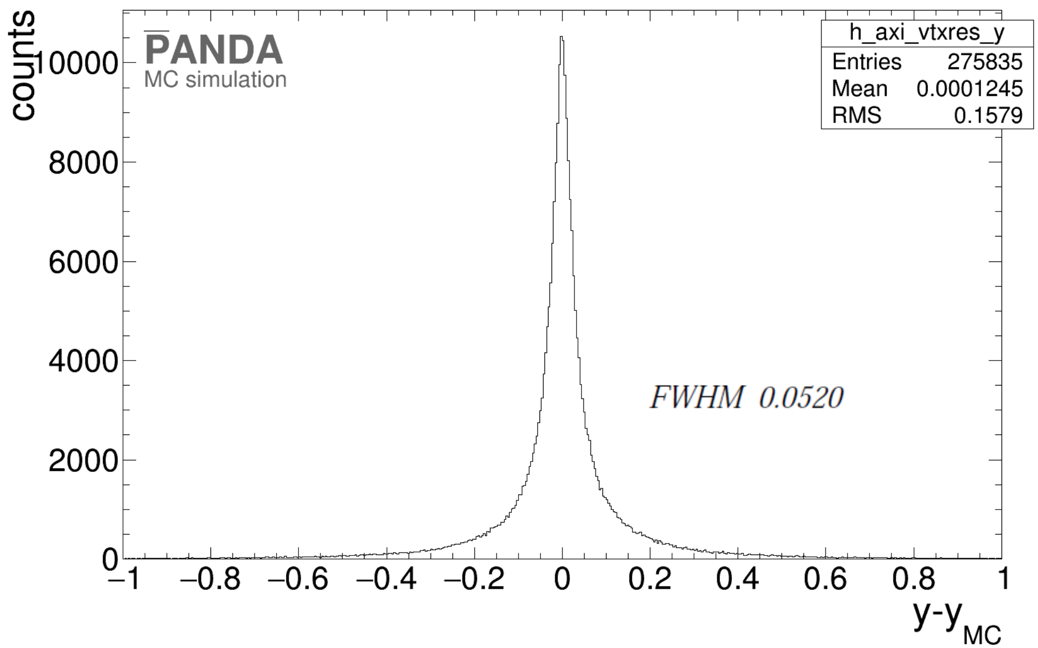


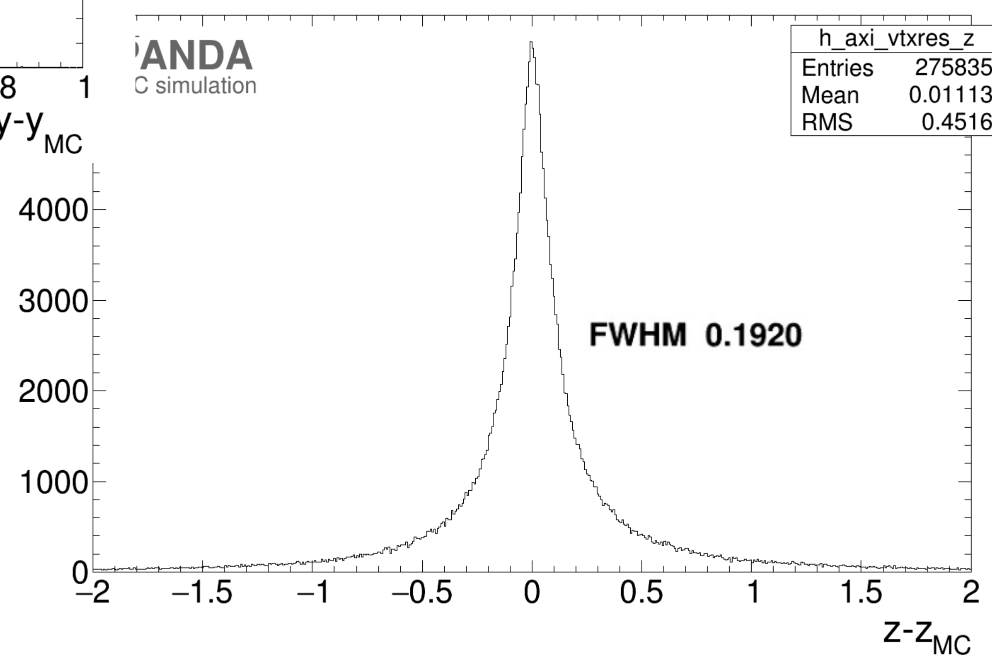
- Black lines mark edges of MVD
- In most cases Λ decays well inside MVD
- Many $\bar{\Lambda}$ decay close to the edge of MVD
- Caused by different lifetime of mother particles $\Xi^-(1820)$ and $\bar{\Xi}^+$

Decay vertex of $\bar{\Lambda}$

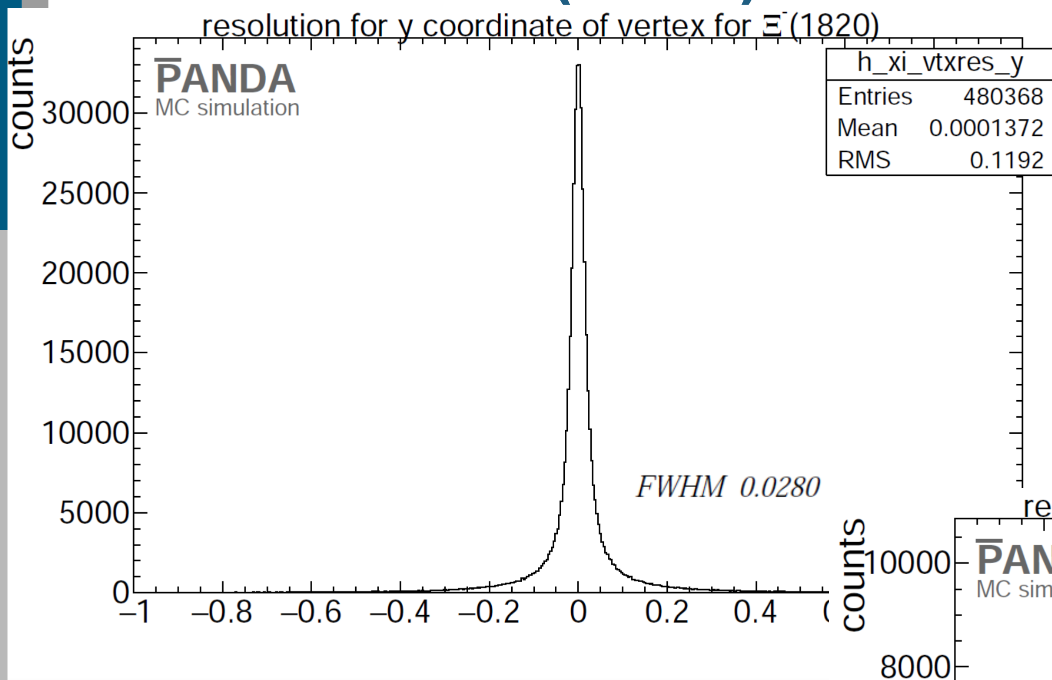


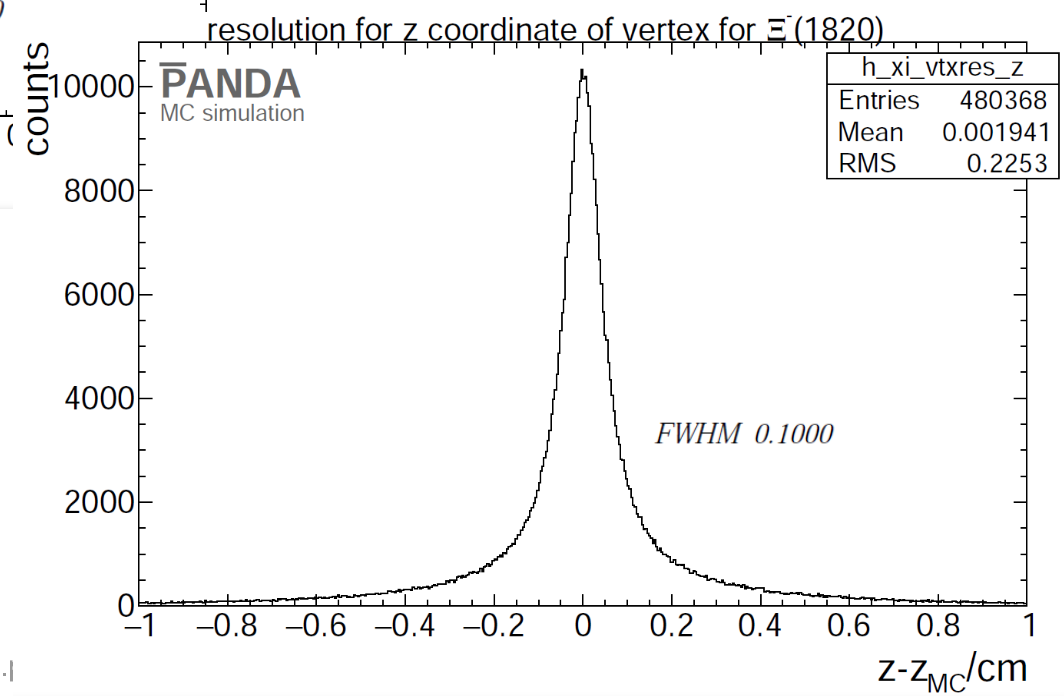
Vertex resolution $\overline{\Xi}^{+}$

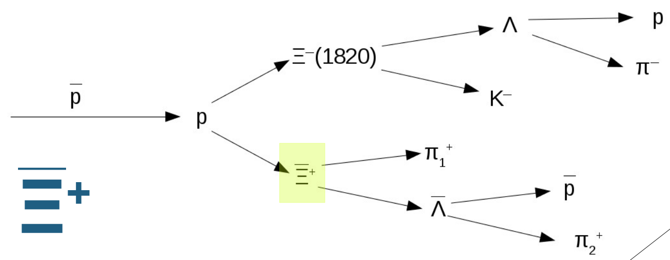




Vertex fit Ξ⁻(1820)

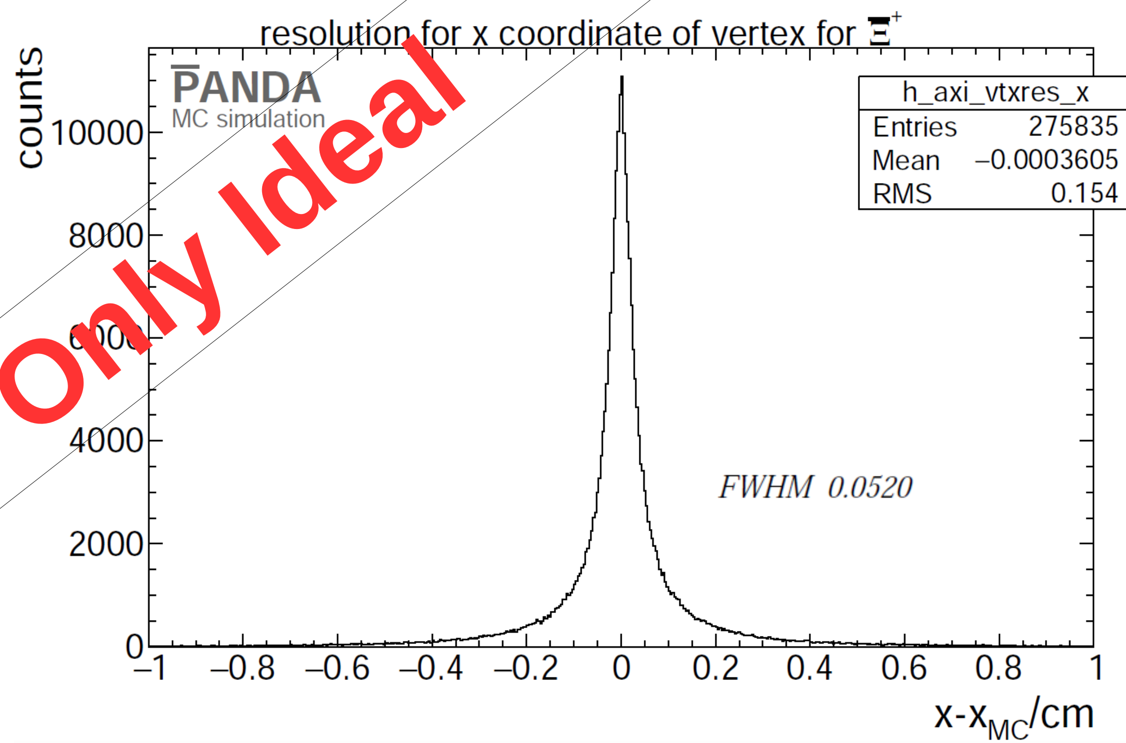






Reconstruction of $\bar{\Xi}^+$ Vertex resolution

- Vertex resolution determined with FWHM
- Advantage: independent of shape of the distribution
- Vertex resolution:
  - transverse: ~ 0.5 ... 0.6 mm
  - longitudinal: ~ 2 mm



Only Ideal

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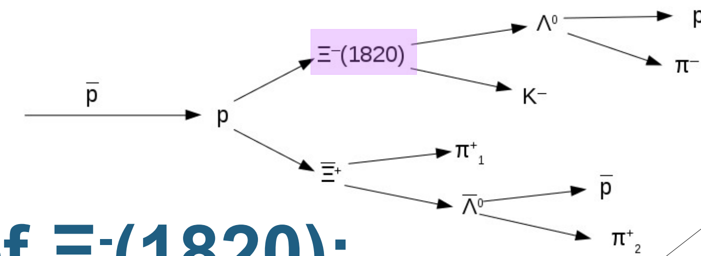
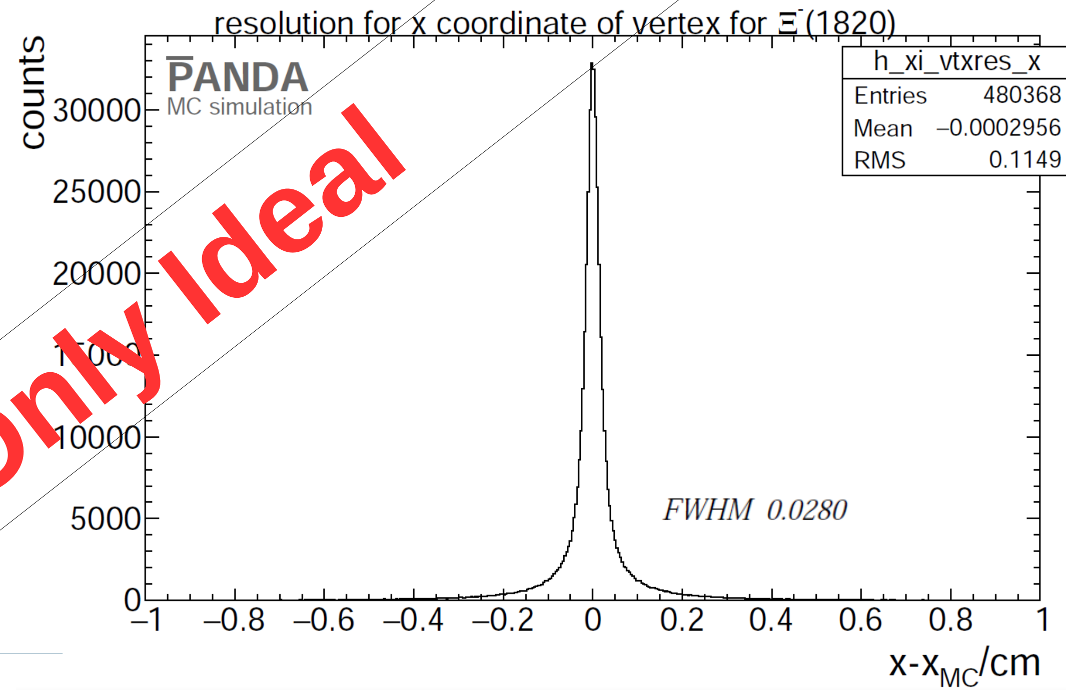


Reconstruction of $\Xi^-(1820)$: Vertex resolution

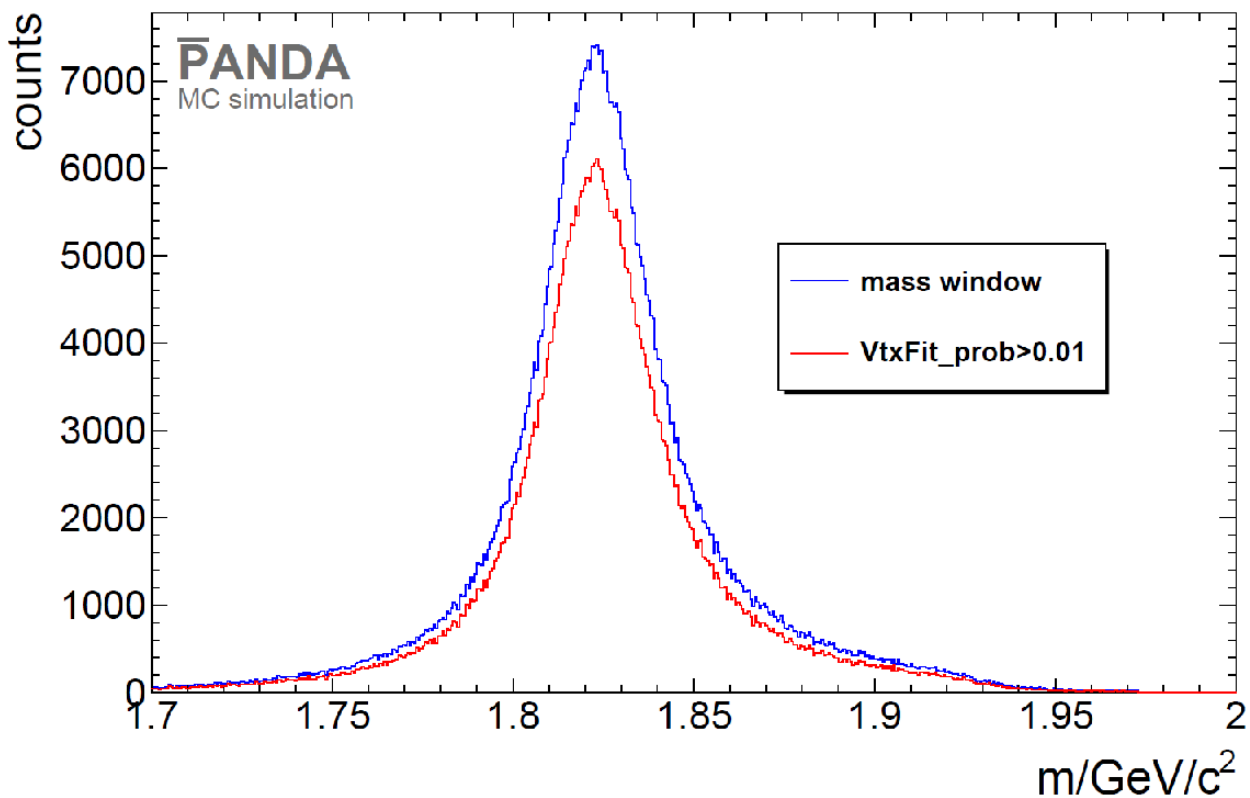
Vertex resolution
determined with FWHM



Only Ideal

position	Vertex resolution	
	$\Xi(1820)$	$\overline{\Xi}(1820)$
x/mm	0.3	0.3
y/mm	0.3	0.3
z/mm	1	1

Mass distribution $\Xi^{-}(1820)$ for different cuts



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