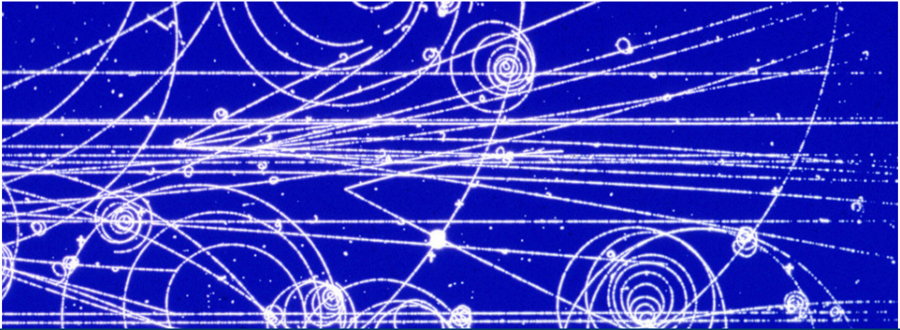
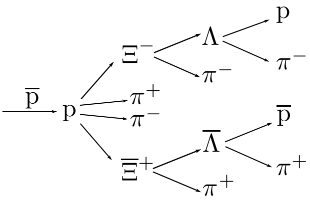


Study of the Reaction $\bar{p}p \rightarrow \Xi^- \bar{\Xi}^+ \pi^+ \pi^-$

8 November 2018 | Alessandra Lai | Forschungszentrum Jülich

Motivation For the Study



- *missing resonances* and lack of unique model to describe baryon spectra
- so far: focus on Δ and nucleons (photo-induced reactions)
- scarce data for baryons with strange content (worse for multi-strange)

Particle	J^P	Overall Status
Ξ (1318)	1/2+	****
Ξ (1530)	3/2+	****
Ξ (1620)		*
Ξ (1690)		***
Ξ (1820)	3/2-	***
Ξ (1950)		***
Ξ (2030)		***
Ξ (2120)		*
Ξ (2250)		**
Ξ (2370)		**
Ξ (2500)		*

Status of Ξ resonances from PDG.
Stars indicate evidence of existence.
Nothing relevant added since 1988.

Technical Details

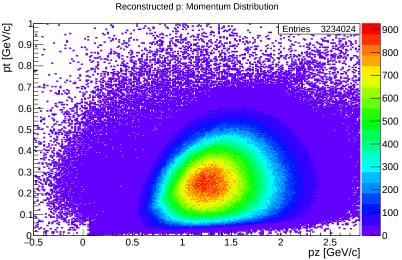
- 3 816 000 events generated
- *fairsoft*: may16p1
- *fairroot*: 17.10b
- *pandaroot*: commit 703b4830f (a.k.a. rev. 30123)
- $p = 4.6\,\mathrm{GeV}/c \rightarrow \sqrt{s} = 3.25\,\mathrm{GeV}$ ($\sim$300 MeV above $\Xi\Xi\pi\pi$ production threshold)

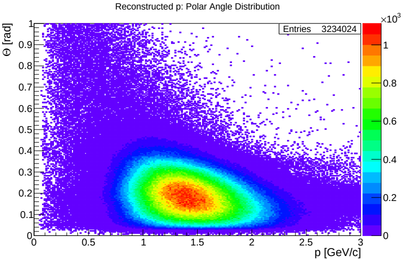
$\bar{p}p \rightarrow$			$\rightarrow \bar{\Xi}^+\Xi^-\pi^+\pi^-$
$\bar{p}p \rightarrow$	$\Xi^-(1690)^*\bar{\Xi}^+$	(+ c.c.)	$\rightarrow \bar{\Xi}^+\Xi^-\pi^+\pi^-$
$\bar{p}p \rightarrow$	$\Xi^-(1820)^*\bar{\Xi}^+$	(+ c.c.)	$\rightarrow \bar{\Xi}^+\Xi^-\pi^+\pi^-$
$\bar{p}p \rightarrow$	$\Xi^0(1530)^*\bar{\Xi}^+\pi^-$	(+ c.c.)	$\rightarrow \bar{\Xi}^+\Xi^-\pi^+\pi^-$
$\bar{p}p \rightarrow$	$\Xi^0(1690)^*\bar{\Xi}^+\pi^-$	(+ c.c.)	$\rightarrow \bar{\Xi}^+\Xi^-\pi^+\pi^-$
$\bar{p}p \rightarrow$	$\bar{\Xi}^0(1530)^*\Xi^0(1530)^*$		$\rightarrow \bar{\Xi}^+\Xi^-\pi^+\pi^-$
$\bar{p}p \rightarrow$	$\bar{\Xi}^0(1530)^*\Xi^0(1690)^*$		$\rightarrow \bar{\Xi}^+\Xi^-\pi^+\pi^-$
$\bar{p}p \rightarrow$	$\bar{\Xi}^0(1690)^*\Xi^0(1530)^*$		$\rightarrow \bar{\Xi}^+\Xi^-\pi^+\pi^-$

- Ξ decay in GEANT4 (account for interaction with detector volume and $\vec{B}$ field)
- $\Lambda, \bar{\Lambda} \rightarrow p\pi$ (100 %)
- uniform phase space distribution for all decays
- ideal tracking (displaced vertices)
- track filtering corrects for non-realistic reco of tracks with low multiplicity (#hits $\geq$ 4 in MVD or STT or GEM)
- ideal PID

Reconstruction of Final State Stable Particles

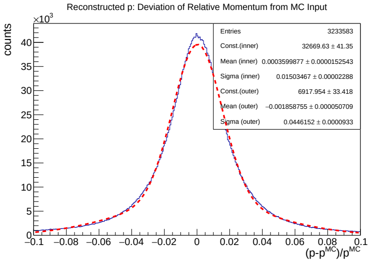
- selection of the *signal* particles $\longrightarrow$ genealogy information (MC)
- transverse VS longitudinal momentum distribution
- polar angle VS total momentum distribution



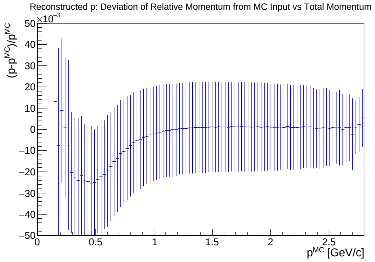


Reconstruction of Final State Stable Particles

- momentum resolution: $\frac{\Delta p}{p} = \frac{p - p^{MC}}{p^{MC}}$



Take inner σ of double Gaussian fit



Drop at low momenta: most likely due to π hypothesis in Kalman filter

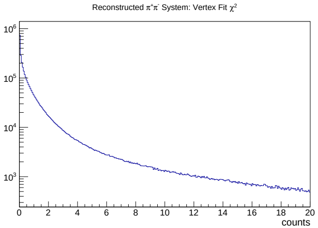
Reconstruction of the Final State Stable Particles

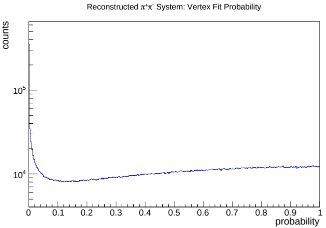
	p	π (Λ)	π (Ξ)	π prompt
ϵ_{reco}	83 %	70 %	75 %	94 %
σ_p/p	1.50 %	1.47 %	1.34 %	1.36 %

- best efficiency for prompt π (primary vertex), worse for π (Λ) (displaced vertices)
- $\prod_{i=1}^{8} \epsilon = 17\,\%$
  14 % of MC events are complete (i.e., all 8 f.s. charged tracks)
  $\rightarrow$ negative correlation
- best momentum resolution for π (Ξ), worse for p
  $\rightarrow$ expected: p_z p $>$ p_z π
- consistent results for particle/antiparticle

Reconstruction of the Prompt Dipion System

- selection of $\pi^+\pi^-$ system coming from the primary vertex
  $\rightarrow$ vertex fit (`RhoKinVtxFitter`)

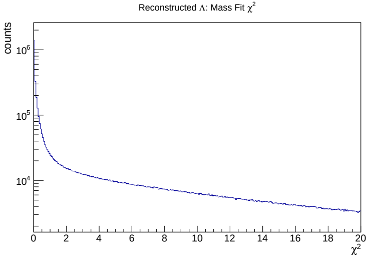


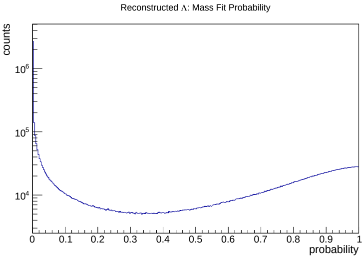


- rising profile towards high probability
- coarse prob. cut (1×10^{-4}) and select candidate with smaller χ^2
- vertex resolution (FWHM): 0.5 mm in *x*, *y*; 1 mm in *z*
- $\epsilon = 65\,\%$; purity $= 96\,\%$

Reconstruction of Λ, $\overline{\Lambda}$

- combination of daughter particles ($\mathrm{p}\pi$)
- mass window cut $m_\Lambda \pm 150\,\mathrm{MeV}/c^2$
- vertex fit `RhoKinVtxFitter` (cut 1×10^{-4})
  similar to observed distributions for the prompt dipion system
- mass fit `RhoKinFitter` (cut 1×10^{-4})
- best cand. passed both probability cuts and has the smallest χ^2





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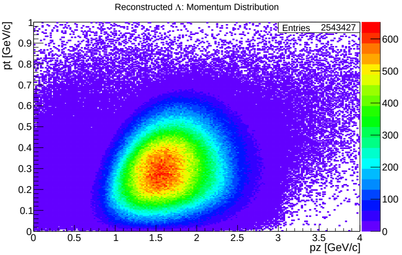
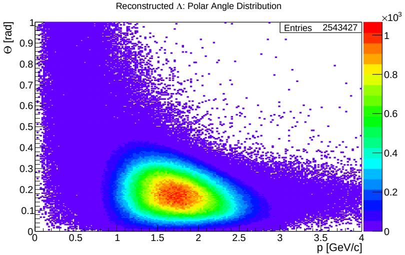
Reconstruction of Λ, $\overline{\Lambda}$





- $\epsilon = 54\,\%$; purity $= 82\,\%$
- decay vertex resolution (FWHM): 0.1 mm in x, y; 0.5 mm in z
- momentum resolution (inner σ of double Gaussian fit): 1.42 %
- invariant mass resolution, after vertex fit (inner σ of double Gaussian fit): $2.0\,\mathrm{MeV}/c^2$
- consistent results for Λ and $\overline{\Lambda}$

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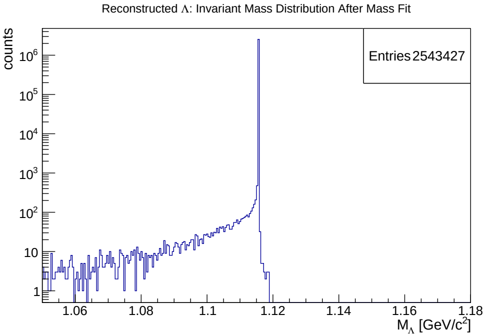
Reconstruction of Λ, $\overline{\Lambda}$

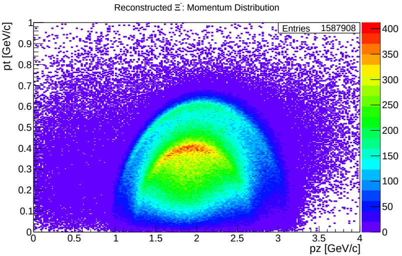
- invariant mass distribution after mass fit

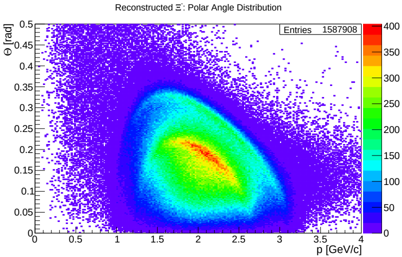


- 0.1 % of total entries populate the unphysical low mass region
  $\rightarrow$ blame mass fitter?
- does not affect analysis
  $\rightarrow$ mass candidate is not propagated

Reconstruction of Ξ^-, $\overline{\Xi}^+$

- same reconstruction and selection criteria as for the Λ
- same critical issues
  $\rightarrow$ rising profile of fit probability, unphysical masses after mass fit

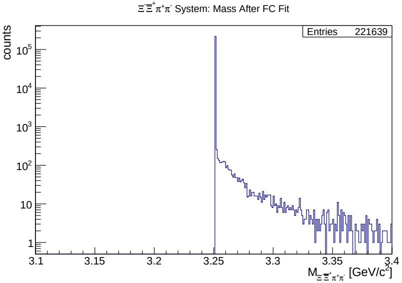




- $\epsilon = 33\,\%$; purity $= 82\,\%$
- decay vertex resolution: 0.3 mm in x, y; 1.3 mm in z
- momentum resolution: 1.30 %
- invariant mass resolution, after vertex fit: 3.8 $\mathrm{MeV}/\mathrm{c}^2$
- consistent results for Ξ^- and $\overline{\Xi}^+$

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

- combine the prompt dipion system with the two cascades
- vertex fit `RhoKinVtxFitter` (cut 1×10^{-4})
- 4-constraint fit `RhoKinFitter` (cut 1×10^{-4})
- best cand. passed both probability cuts and has the smallest χ^2
- decay vertex resolution: 0.3 mm in x, y; 1.2 mm in z
- invariant mass distribution after 4C fit: 0.7 % of total entries populate unphysical high mass region (discarded)
- $\epsilon = 5\,\%$; purity $= 87\,\%$



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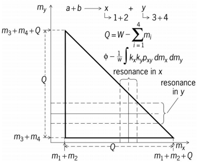
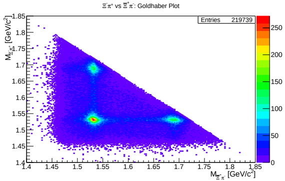
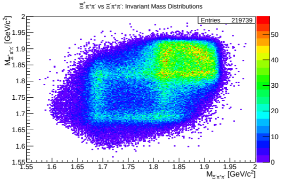
Reconstruction of $\Xi^-\overline{\Xi}^+\pi^+\pi^-$





- neutral Ξ resonances $\rightarrow \Xi\pi$

0.2 % of total entries outside boundaries



- charged Ξ resonances $\rightarrow \Xi\pi\pi$
- $\Xi\pi^+\pi^-$ as two-body system: dipion system is pseudo-particle with variable invariant mass
- superposition of Dalitz plots: one for each $\pi^+\pi^-$ mass (use linear scale)

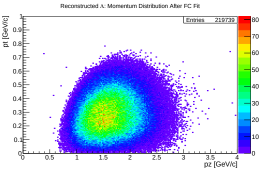
Summary of Reconstruction

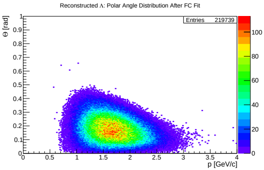
Particle reconstruction stage	ϵ_{reco} [%]	purity [%]
$\pi^+\pi^-$ prompt system	65	96
Λ	54	81
$\overline{\Lambda}$	53	82
Ξ^-	34	81
$\overline{\Xi}^+$	33	82
$\Xi^-\overline{\Xi}^+\pi^+\pi^-$	5	87

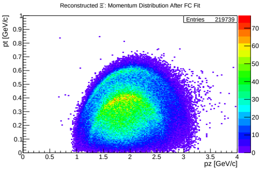
- purity can be increased by tightening the prob. cut after 4C-fit
  e.g., 90 % purity with 5×10^{-1} prob. cut, but $\epsilon = 1$ %

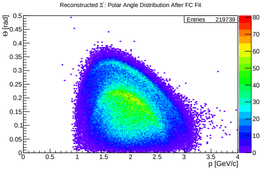
Final Selection

	Reconstructed			Finally selected		
	σ_p/p [%]	σ_M [MeV/c^2]	purity [%]	σ_p/p [%]	σ_M [MeV/c^2]	purity [%]
Λ	1.42	2.0	81	1.33	2.4	96
$\overline{\Lambda}$	1.42	2.0	82	1.33	2.4	96
Ξ^-	1.30	3.8	81	0.83	3.6	93
$\overline{\Xi}^+$	1.31	3.8	82	0.83	3.7	93









Background Studies

- 22×10^6 DPM events
- zero events misidentified as signal
  $\rightarrow$ exclude 2.30 events at 90 % confidence level

- $\eta = \frac{\sigma_{sig} \cdot \epsilon_{sig} \cdot BR}{\sigma_{bkg} \cdot \epsilon_{bkg}} > 3.9$
- $S = \frac{N_{sig}^{reco}}{\sqrt{N_{sig}^{reco} + N_{bkg}^{reco} \cdot F}} > 390$ with $F = \frac{N_{sig}^{gen} / (\sigma_{sig} \times BR)}{N_{bkg}^{gen} / \sigma_{bkg}}$
- $N = \mathcal{L} \cdot \sigma_{sig} \cdot \epsilon_{sig} \cdot BR = 17\,639$
  $\rightarrow$ analyzed sample obtainable in approx. 10 days of data taking

- $\sigma_{sig} = 1\,\mu b$ (estimate based on other strange particle decays)
- $\sigma_{bkg} = \sigma_{inel}^{tot} = 50\,mb$
- $\epsilon_{bkg} = 1.05 \times 10^{-5}\,\%$
- $BR = 0.408$
  (corrects for $\Lambda \rightarrow \pi p$ 100 %)
- $\mathcal{L} = 1 \times 10^{31}\,cm^{-2}\,s^{-1}$
  (PANDA 1st phase)

Summary and Outlook

- first steps towards feasibility study of $\bar{p}p \to \Xi^- \bar{\Xi}^+ \pi^+ \pi^-$
- uniform phase space distribution for the signal (no data available on this process)
- use of ideal tracking and PID algorithms
- backward reconstruction from final state stable particles up to $\bar{p}p$
- $\epsilon = 5\,\%$, purity = 87 %
- decay topology provides good intrinsic background suppression
- limited acceptance for all the 8 charged particles in the final state
- calculated rate indicates that good statistics can be collected in the 1st phase of PANDA

- cuts can be optimized to maximize significance and enhance S/B
  $\to$ more background evts needed
- kinematic fits available in PandaRoot present critical issues
  $\to$ use decay tree fitter
- more realistic studies (e.g., ph.sp. distr, realistic tracking and PID)