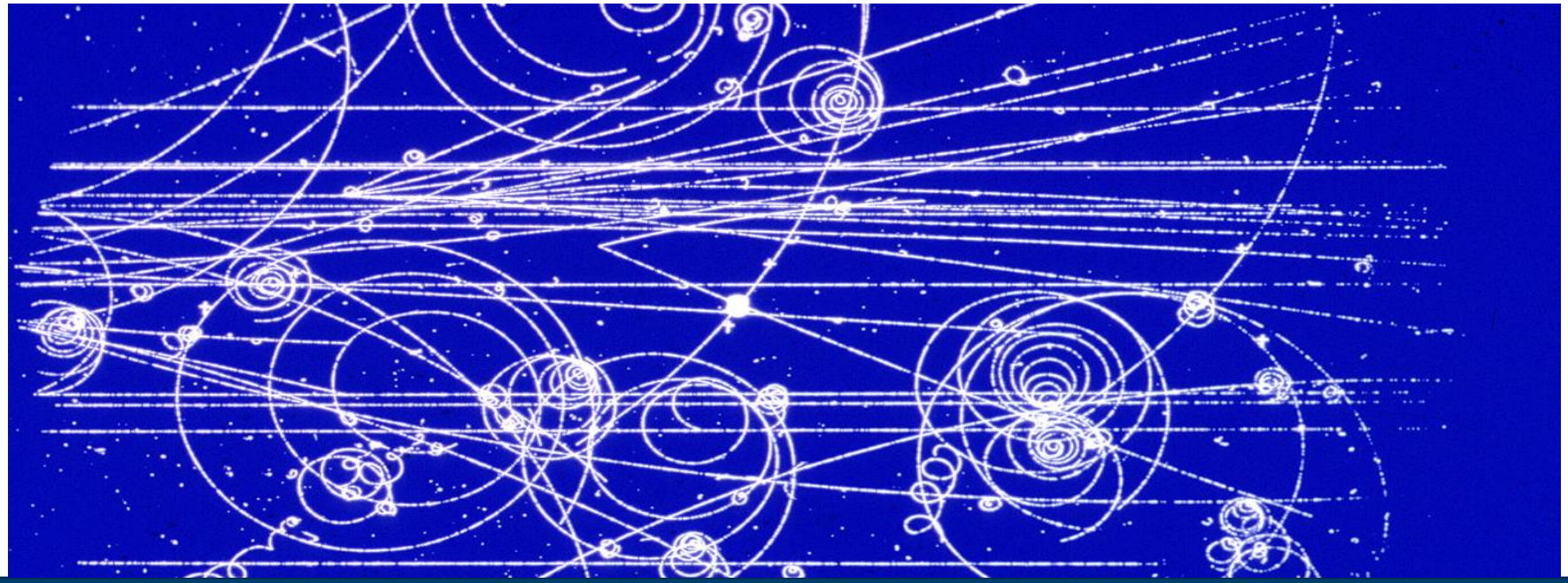


Study of a PWA of the $\bar{\Xi}^+ \Lambda K^-$ Final State with PAWIAN

March 10th 2021| $\bar{\text{P}}$ANDA CM 21/1 Hyperon Session | Jenny Pütz

Mitglied der Helmholtz-Gemeinschaft

p̄anda

JÜLICH Forschungszentrum

Motivation

Partial Wave Analysis

- Up to know: worked on analysis of $\bar{p}p \rightarrow \bar{\Xi}^{+}\Xi^{*-}$ with $\Xi^{*-} \rightarrow \Lambda K^{-}$ (& c.c.) [1)]
- Quantum number of most Ξ resonances unknown or only estimated
- No experimental data and theoretical predictions
- PWA: possibility to determine those quantum numbers

Table 1. The status of the Ξ resonances. Only those with an overall status of *** or **** are included in the Baryon Summary Table.

			Status as seen in —				
Particle	J^P	Overall status	$\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$	Other channels
Ξ(1318)	1/2+	****					Decays weakly
Ξ(1530)	3/2+	****	****				
Ξ(1620)		*	*				
Ξ(1690)		***		***	**		
Ξ(1820)	3/2−	***	**	***	**	**	
Ξ(1950)		***	**	**		*	
Ξ(2030)		***		**	***		
Ξ(2120)		*		*			
Ξ(2250)		**					3-body decays
Ξ(2370)		**					3-body decays
Ξ(2500)		*		*	*		3-body decays

**** Existence is certain, and properties are at least fairly well explored.
*** Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, *etc.* are not well determined.
** Evidence of existence is only fair.
* Evidence of existence is poor.

PDG2014

1) See plenary talk and talk in Hyperon Session at CM 18/3

What is PAWIAN?

- **PA**rtial **W**ave **I**nteractive **AN**alysis software
- Different spin formalisms and dynamics
- Event-based maximum likelihood fit (MINUIT2)
- Generates events based on user-defined decay model or on fit results obtained with real data

For further information: https://panda-wiki.gsi.de/foswiki/bin/view/PWA/PawianPwaSoftware

Work Done In The Past

Until CM 20/3

Investigations on

- Single resonance channel ($\Xi(1690)^-$ & $\Xi(1820)^-$):
  - ➢ $L_{\max} = 2{,}3$; Fit of 30,000 events
  - ➢ Input values were reconstructable

- Data Sample with crossed channel ($\bar{p}p \to \overline{\Lambda}\,(1890)\,\Lambda$):
  - ➢ $L_{\max} = 1$; Fit of 30,000 events
  - ➢ Only 7% of events were Ξ resonances

- First tests for single resonances using PAWIAN and PandaRoot

See talk in hyperon session at CM 20/3 https://indico.gsi.de/event/11482

What is New?

- Crossed channel: 50% contribution for Ξ resonances generated
- Finished investigations of single resonances using PAWIAN and PandaRoot
- Study of a sample with $\Xi(1690)^-$ AND $\Xi(1820)^-$

How are Results Compared?

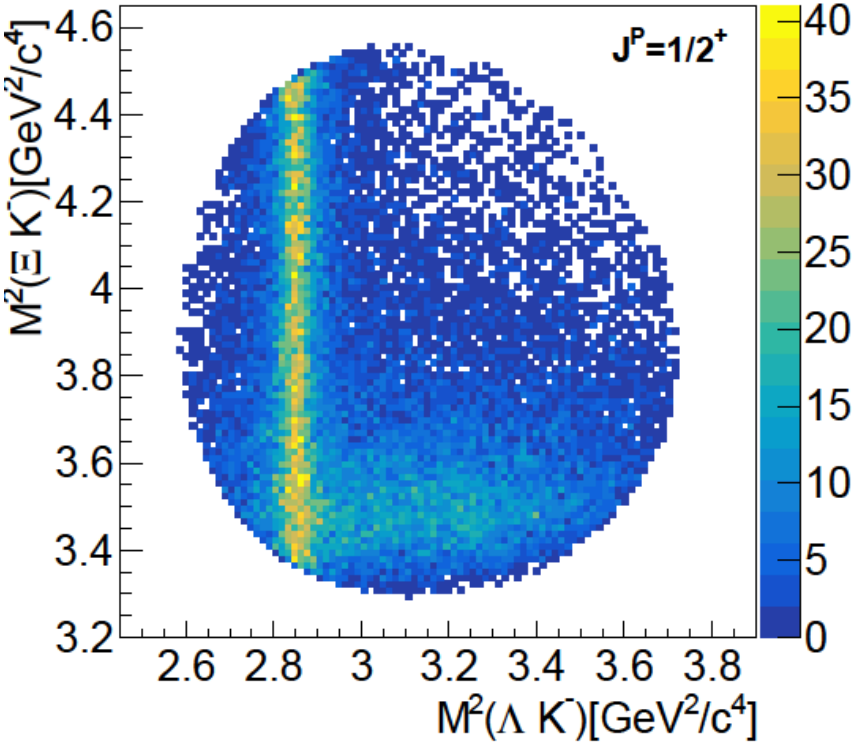
- Different criteria used: BIC and AIC
- BIC: Bayesian information criterion
  - model selection among a finite set of models
- AIC: Akaike information criterion
  - Estimates quality of model relative to set of models
- In both cases, model with lowest value is preferred

- Final selection based on : $\Delta\mathrm{AIC} = \mathrm{AIC}_i - \mathrm{AIC}_{min}$
- $\Delta\mathrm{AIC} < 2$: evidence for the model; $\Delta\mathrm{AIC} > 10$: model unlikely
- Special case: AIC and BIC show different tendencies => AIC+BIC

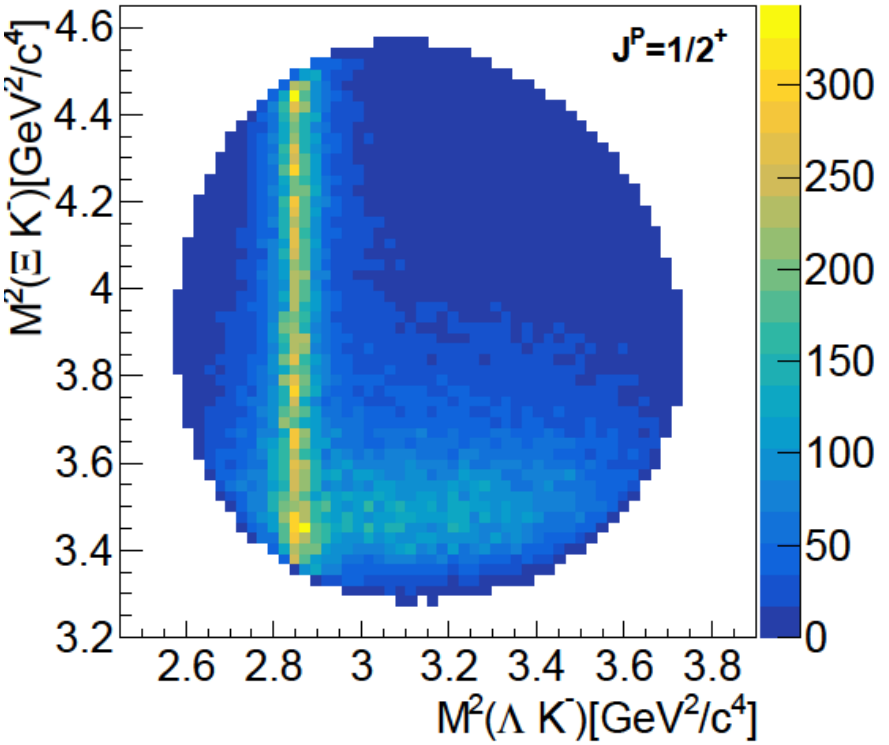
Crossed Channel

Ξ(1690)⁻

Input Data



Fit Results



$$\overline{\Lambda}(1890): \Gamma \approx 120\ \mathrm{MeV/c^2} \quad J^P = 3/2^+$$

Results

$\Xi(1690)^-$ ΔAIC Values 30,000 Events

Gen ↓ \ Fit →	$1/2^+$	$1/2^-$	$3/2^+$	$3/2^-$
$1/2^+$	0.0	42.6	35.6	103.2
$1/2^-$	84.2	0.0	102.8	378.4
$3/2^+$	1,598.6	3,195.4	0.0	175.8
$3/2^-$	1,908.5	2,132.6	840.1	0.0

Results

$\Xi(1820)^-$ ΔAIC Values 30,000 Events

Gen ↓ / Fit →	$1/2^+$	$1/2^-$	$3/2^+$	$3/2^-$
$1/2^+$	0.0	56.5	49.1	48.8
$1/2^-$	24.6	0.0	41.0	11.5
$3/2^+$	1,075.6	1,054.9	0.0	42.5
$3/2^-$	1,417.8	1,443.2	124.8	0.0

PAWIAN & PandaRoot

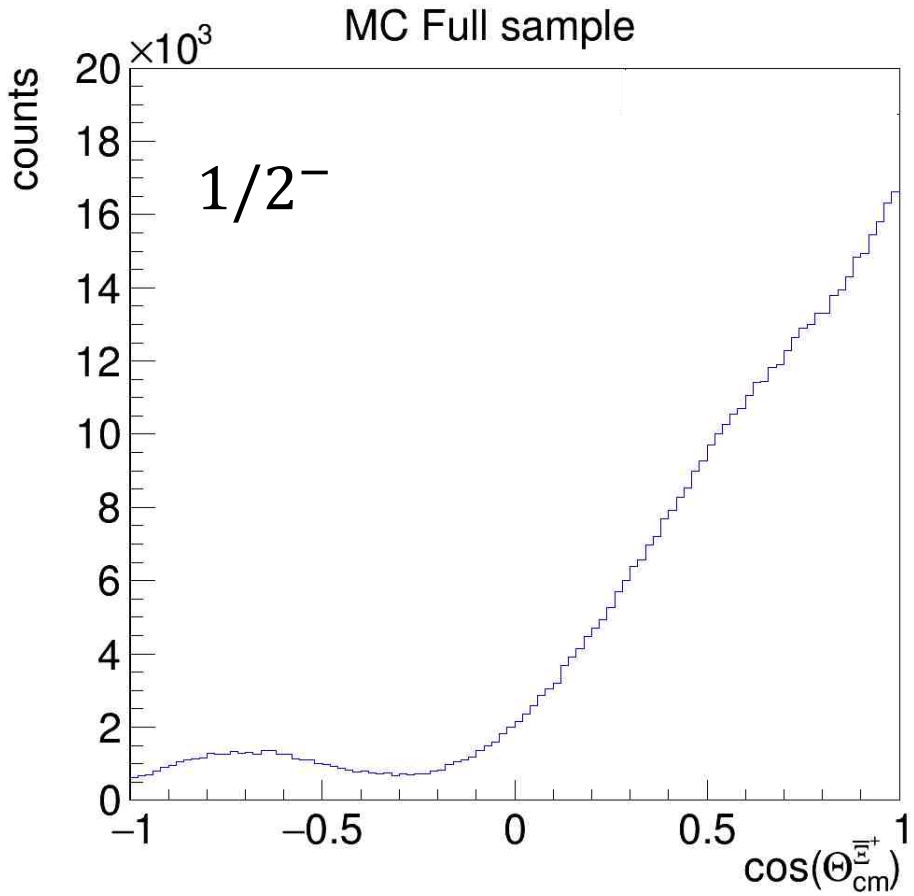
PAWIAN & PandaRoot

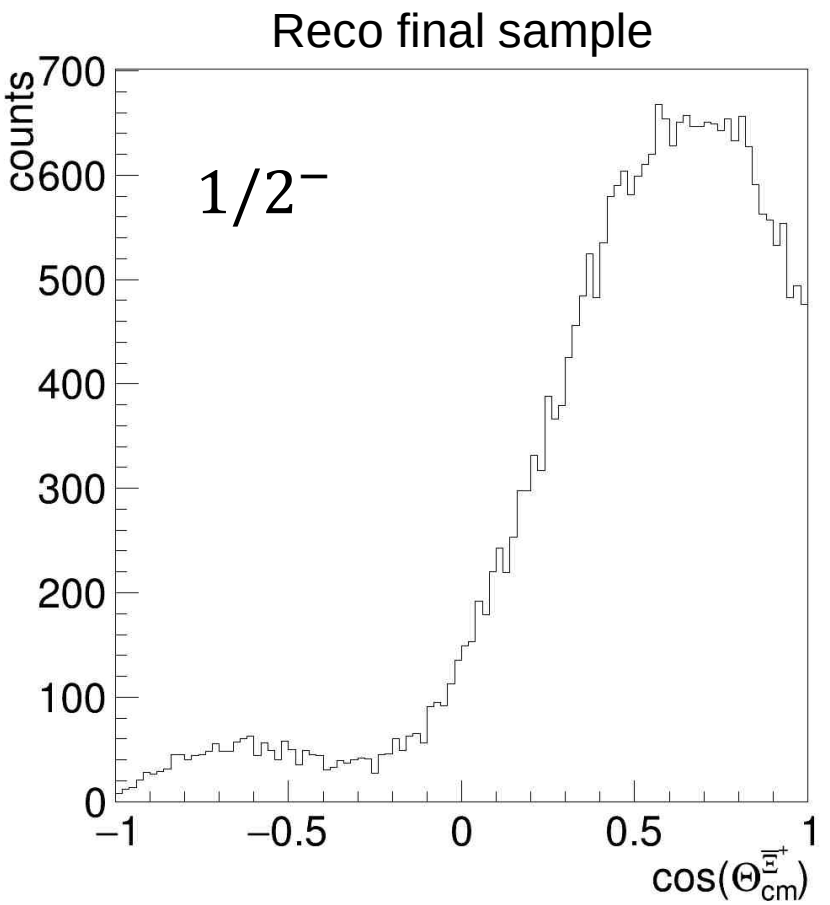
Simulations

- Generated ~600,000 events for both $\Xi(1690)^-$ & $\Xi(1820)^-$ with PAWIAN included event generator
- Used as input for the full sim + reco chain in PandaRoot
- ~26,000 events reconstructed in analysis with DecayTreeFitter
- Reconstructions efficiency: 5%
- Fraction of pure signal events: 94.2%

PAWIAN & PandaRoot

Angular Distribution $\bar{\Xi}^+$ in center-of-mass Frame

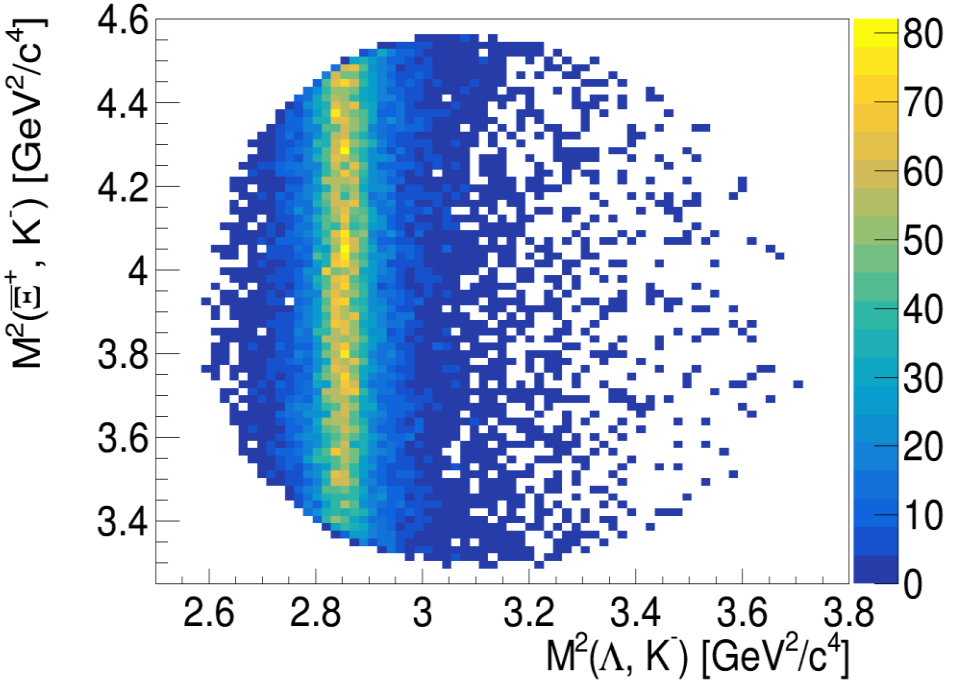




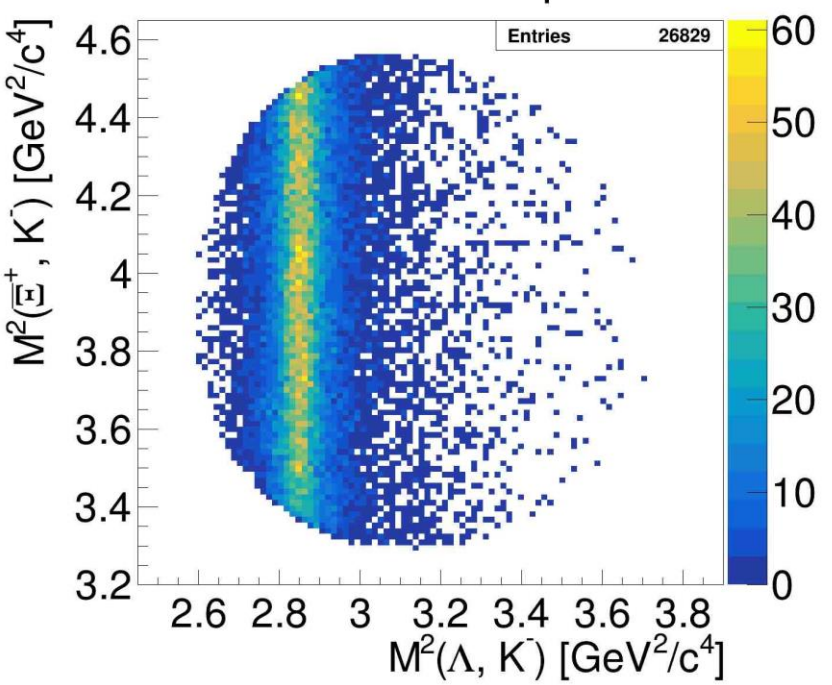
PAWIAN & PandaRoot

Dalitz Plots $\Xi(1690)^-$

MC full sample



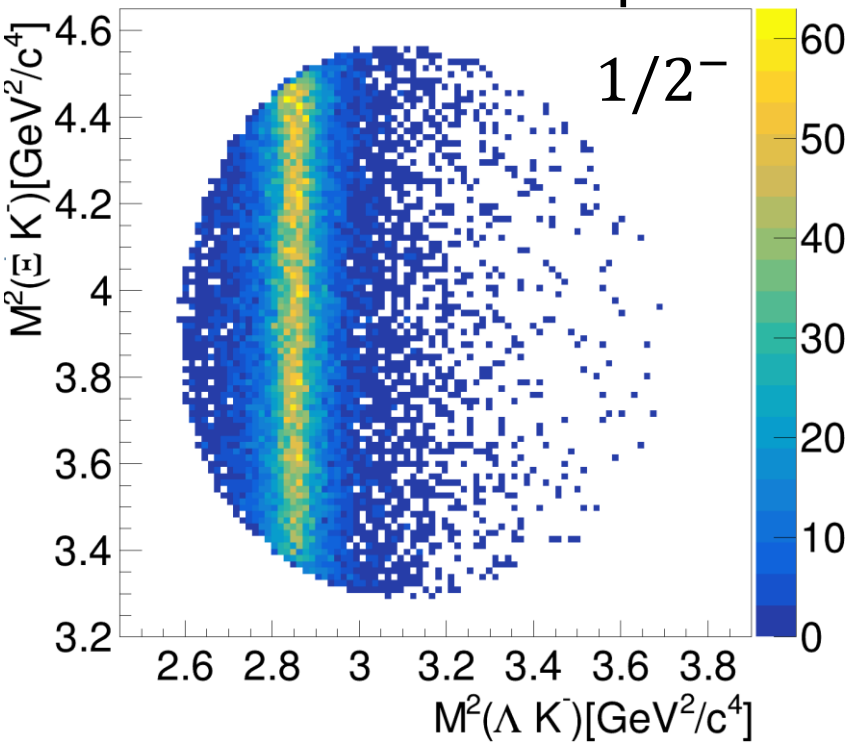
reco final sample



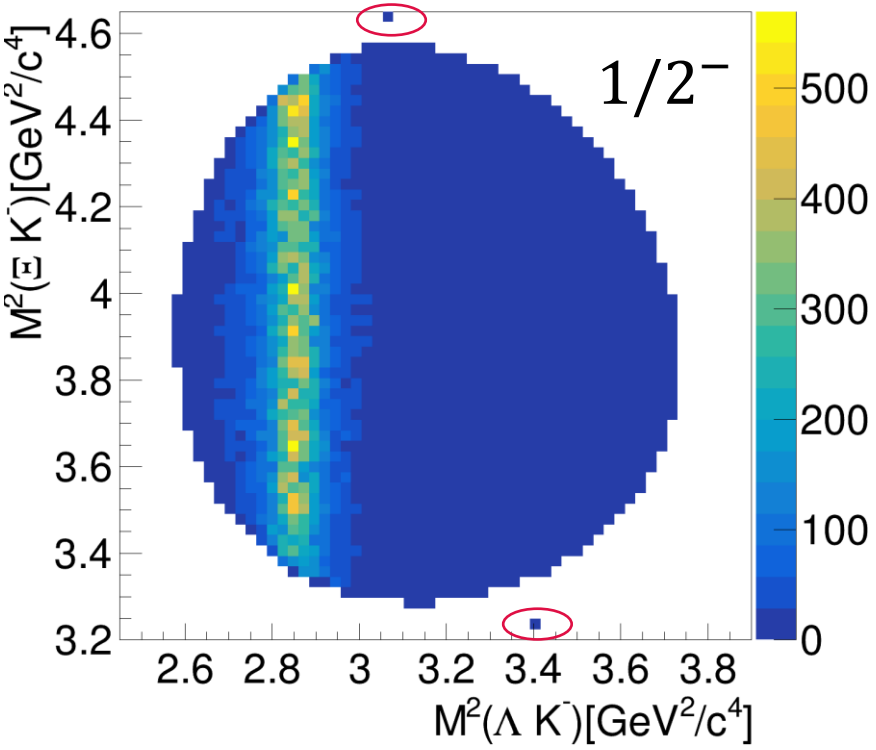
PAWIAN & PandaRoot

Dalitz Plots $\Xi(1690)^-$

Reco final sample



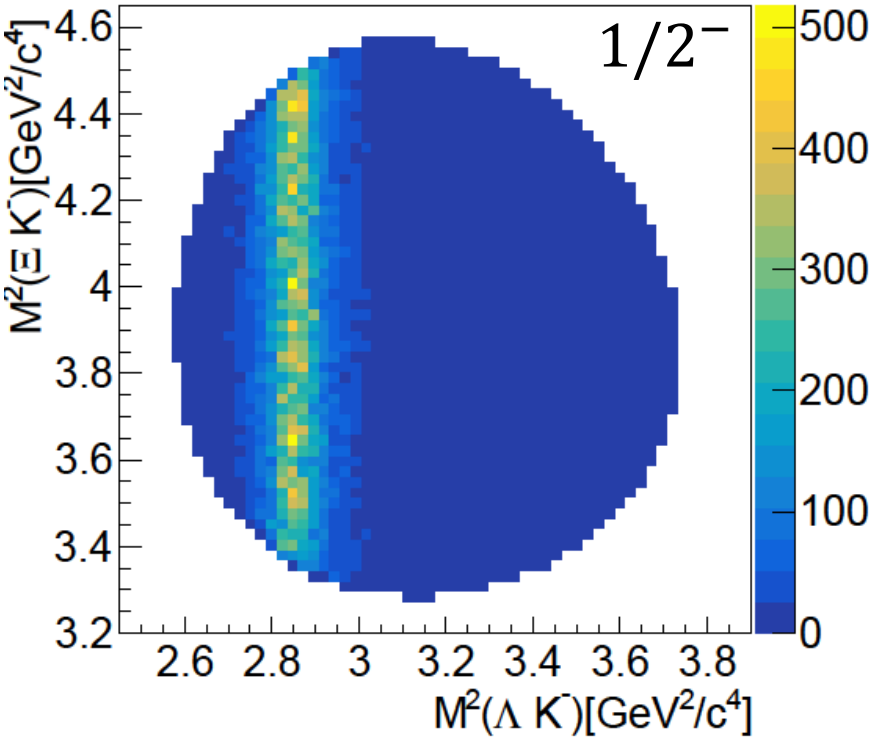
Fit Results



PAWIAN & PandaRoot

Mass Window Selection

- Outliers caused by $\bar{\Xi}^+$ mass far off nominal mass after DTF of continuum sample
- Additional mass window selection:
  $(1.319 < M_{\Xi} < 1.323)\ GeV/c^2$
- Removes all outliers in continuum sample and up to 3 signal events



PAWIAN & PandaRoot

$\Xi(1690)^-$ ΔAIC Values (PandaRoot+ PAWIAN)

Gen ↓ \ Fit →	$1/2^+$	$1/2^-$	$3/2^+$	$3/2^-$
$1/2^+$	0.0	2,550.6	2,310.6	2,706.8
$1/2^-$	316.7	0.0	328.2	2,332.2
$3/2^+$	4,973.9	5,228.0	0.0	584.6
$3/2^-$	5,345.6	3,118.6	833.1	0.0

PAWIAN & PandaRoot

$\Xi(1820)^-$ AIC + BIC Values (PandaRoot+ PAWIAN)

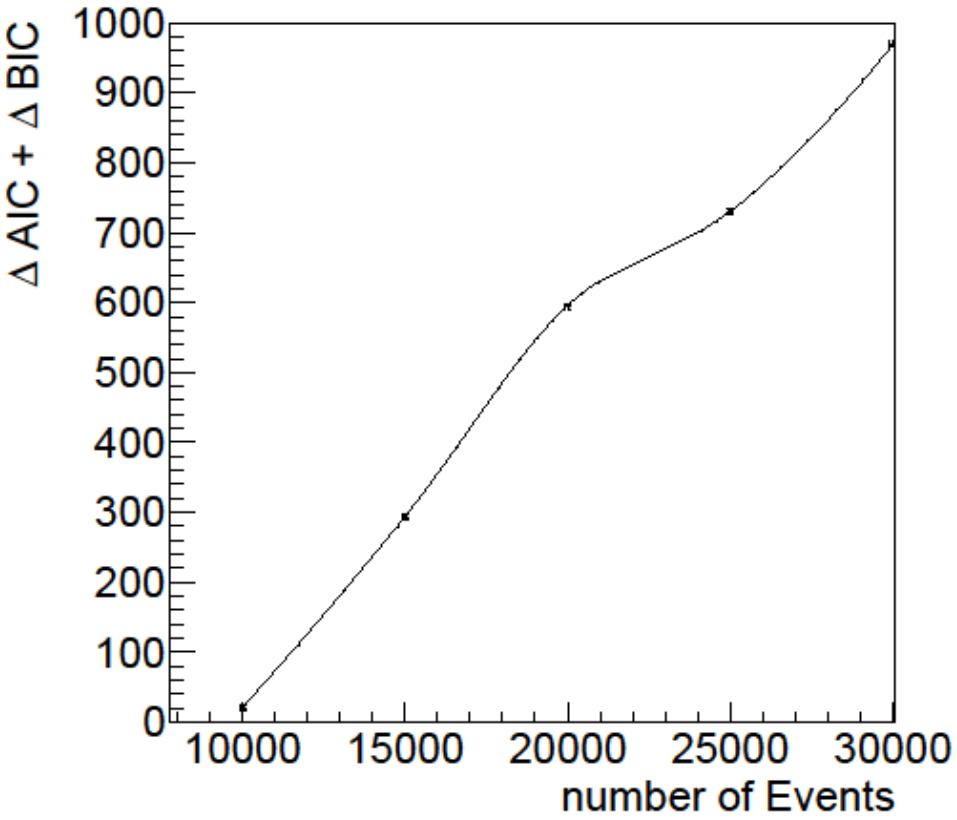
Gen ↓ \ Fit →	$1/2^+$	$1/2^-$	$3/2^+$	$3/2^-$
$1/2^+$	-133,352.4	-133,121.5	-133,193.7	-133,144.3
$1/2^-$	-130,496.3	-130,593.1	-130,382.0	-129,705.7
$3/2^+$	-119,599.4	-119,468.2	-127,072.7	-126,874.3
$3/2^-$	-132,767.8	-133,484.6	-139,895.2	-140,385.4

$\Xi(1690)^-$ and $\Xi(1820)^-$ Sample

Combined Sample

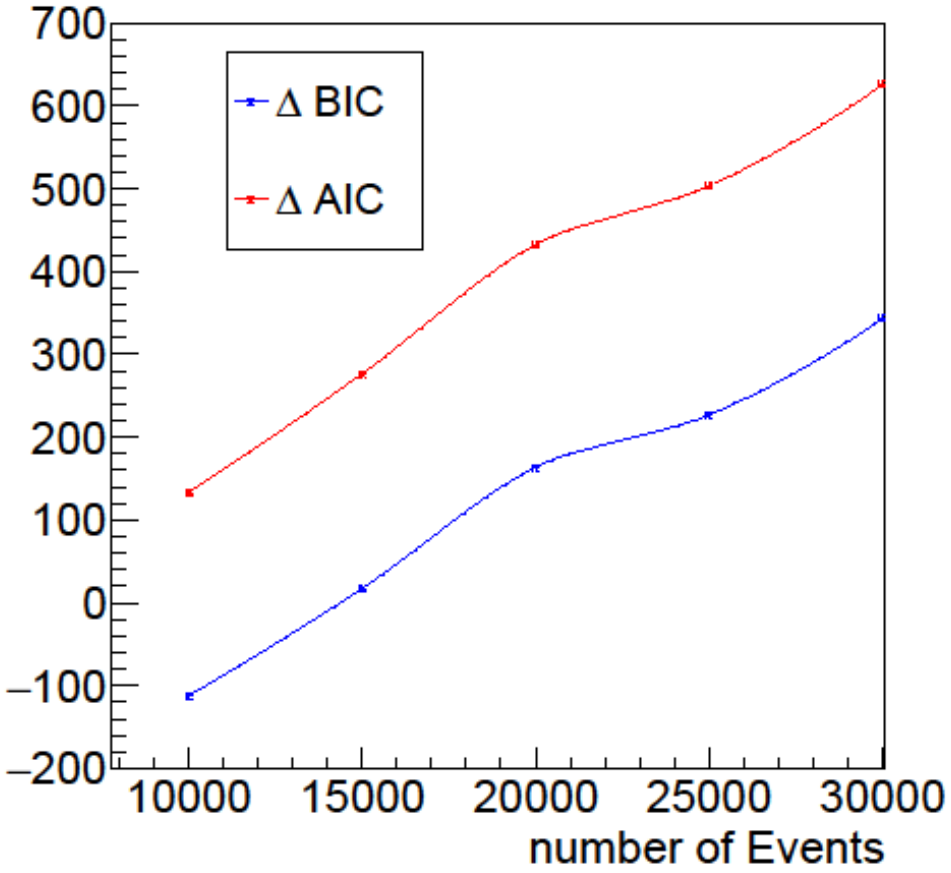
Event Generation and Fit Results Ideal Case

- Generated 10,000 events only $J^P(\Xi(1690)) = 1/2^+$ and $J^P(\Xi(1820)) = 3/2^-$
- Fitted with all possible combinations
- $1/2^+$ $1/2^-$ can not be safely excluded
- How much statistics needed to exclude it?



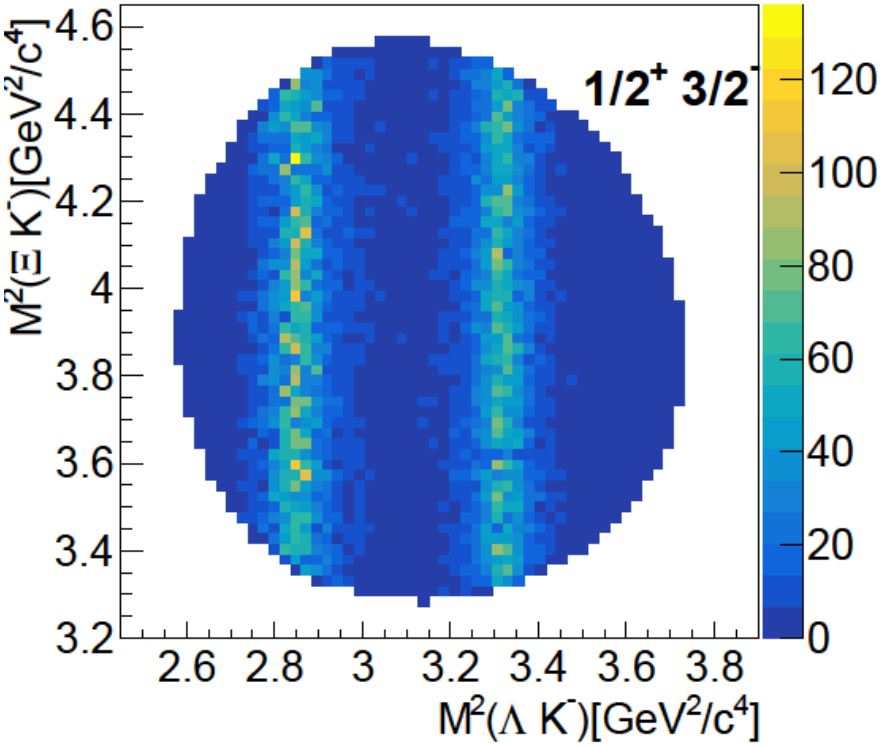
Combined Sample

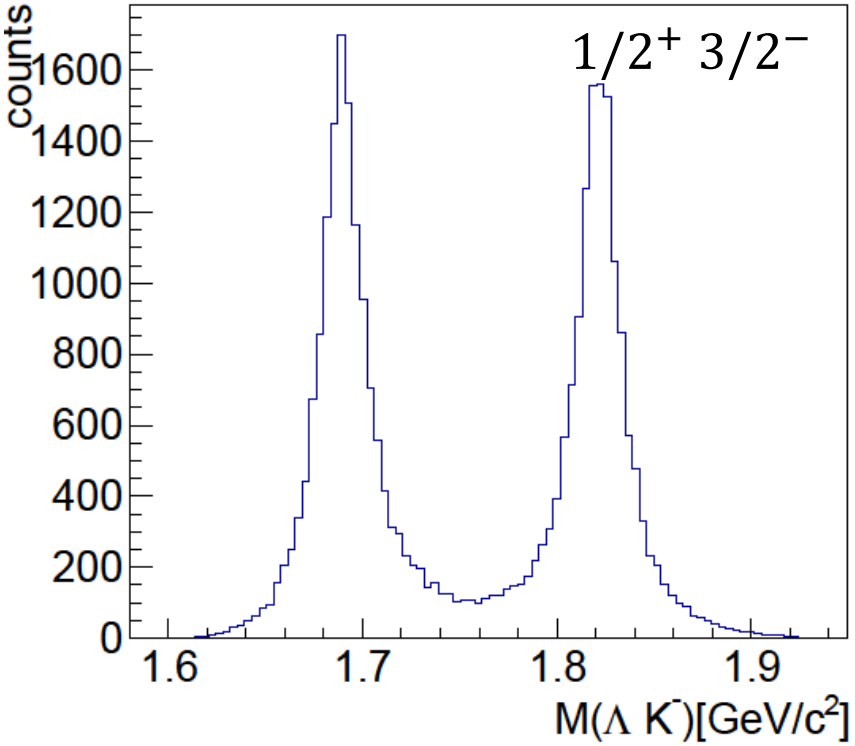
Event Generation and Fit Results Ideal Case



Combined Sample

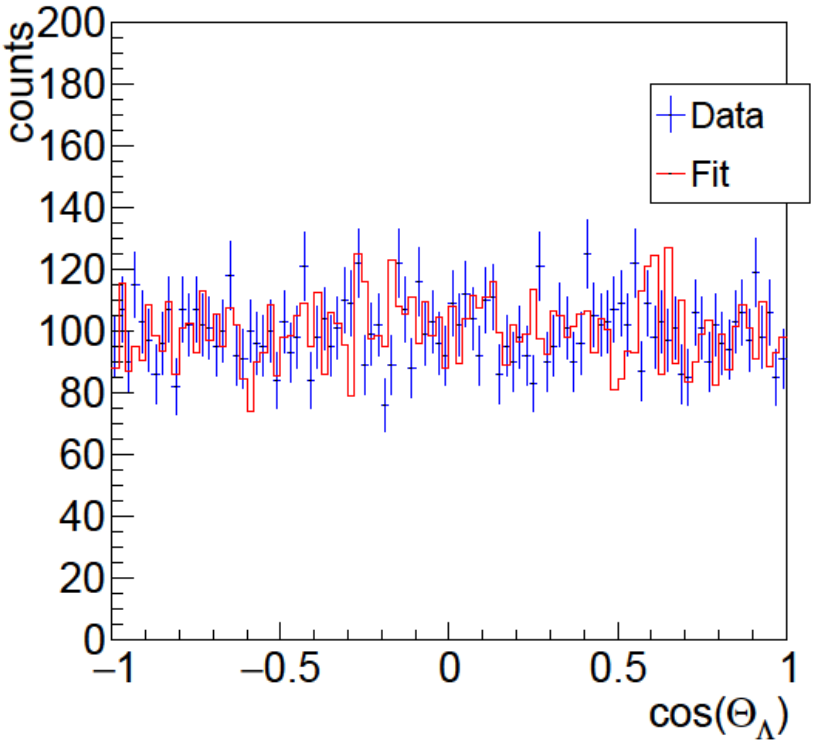
Dalitz Plot and Mass Distribution

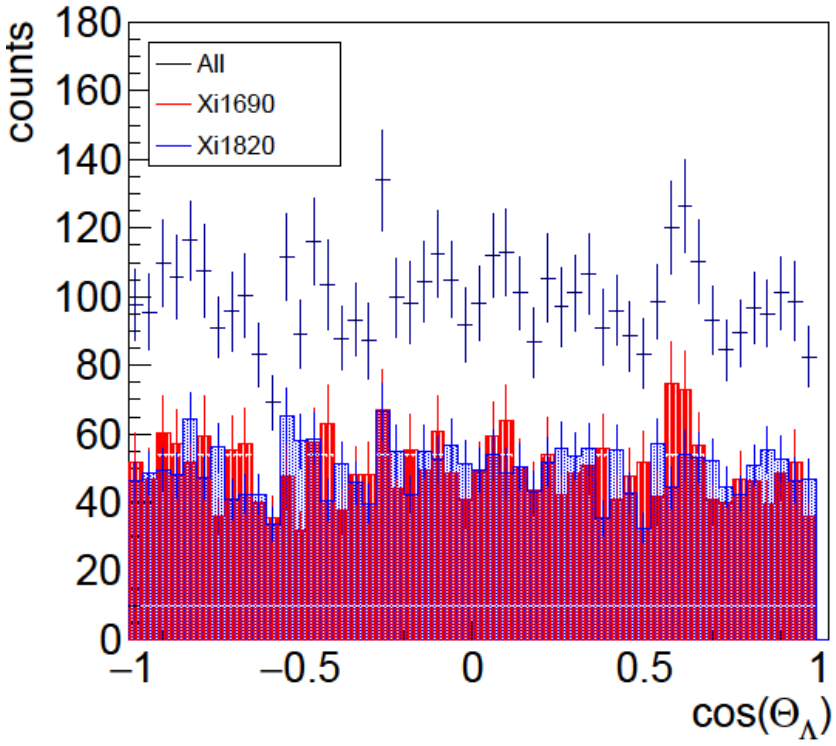




Combined Sample

CosΘ distribution of Λ from ΛK^- System in Helicity Frame





Summary & Outlook

- Performed test to reproduce quantum numbers
- “Single” resonances & crossed channel: promising
- PandaRoot & PAWIAN:
    - in good agreement with feasibility study
    - Input QN can be reproduced
- Combined Sample: first test with 10,000 events leads to promising results -> more statistics needed

- Verify results for combined sample with other QN
- PandaRoot & PAWIAN should be used for combined sample
- Same tests should be done for charge conjugate particles

Summary & Outlook

- Performed test to reproduce quantum numbers
- “Single” resonances & crossed channel: promising
- PandaRoot & PAWIAN:
    - in good agreement with feasibility study
    - Input QN can be reproduced
- Combined Sample: first test with 10,000 events leads to promising results -> more statistics needed

Release note under review and paper in preparation

Thank you for your attention

Backup

Results

$\Xi(1690)^-$ ΔAIC Values

Gen ↓ \ Fit →	$1/2^+$	$1/2^-$	$3/2^+$	$3/2^-$
$1/2^+$	0.0	310.0	23.0	347.0
$1/2^-$	274.0	0.0	281.0	2,256.0
$3/2^+$	60,320.7	4,861.9	0.0	503.9
$3/2^-$	81,128.3	25,893.9	19,541.6	0.0

First fit with fixed mass and width

Results

$\Xi(1820)^-$ ΔAIC Values

Gen ↓ \ Fit →	$1/2^+$	$1/2^-$	$3/2^+$	$3/2^-$
$1/2^+$	0.0	46,427.9	3.9	35,374.6
$1/2^-$	72.9	0.0	40,135.0	446.6
$3/2^+$	3,911.2	3,969.3	0.0	36,377.4
$3/2^-$	3,457.7	3,698.0	201.0	0.0

Strategy

- Is it possible to reconstruct the input values?
- Event Generation:
  - 1 data set for $\bar{\Xi}\Lambda K^-$
  - 1 data set for each resonance
- $p_{\bar{p}}$= 4.6 GeV/c
- Different quantum numbers generated for Ξ(1690)⁻ and Ξ(1820)⁻

$$^1/_2{}^-,\ ^1/_2{}^+,\ ^3/_2{}^-,\ ^3/_2{}^+$$

- Fit all hypotheses to each generated data set
- At later stage: included crossed channel $\bar{\mathrm{p}}\mathrm{p} \rightarrow \bar{\Lambda}(1890)\Lambda$

BIC and AIC

- **Bayesian information criterion (BIC):**

  is a criterion for model selection among a finite set of models; the model with the lowest BIC is preferred.

$$BIC = 2 \cdot (-LHH) + k \cdot \ln(n)$$

  with LHH: maximal loglikelihood value, k: number of free fit parameters and n: number of events in the sample

- **Akaike information criterion (AIC):**

  is a measure of the relative quality of statistical models for a given set of data. Given a collection of models for the data, AIC estimates the quality of each model, relative to each of the other models

$$AIC = 2k + 2 \cdot (-LLH)$$

Event Generation

Maximum Angular Momentum of $\bar{p}p$

- Beam momentum of 4.6 GeV/c² corresponds to a momentum in center-of-mass frame of:
  - $p_{\mathrm{cm}} \approx 600\ \mathrm{MeV/c}$ for $\Xi(1690)^- \rightarrow L_{\mathrm{max}} = 3$
  - $p_{\mathrm{cm}} \approx 410\ \mathrm{MeV/c}$ for $\Xi(1820)^- \rightarrow L_{\mathrm{max}} = 2$

Helicity Frame

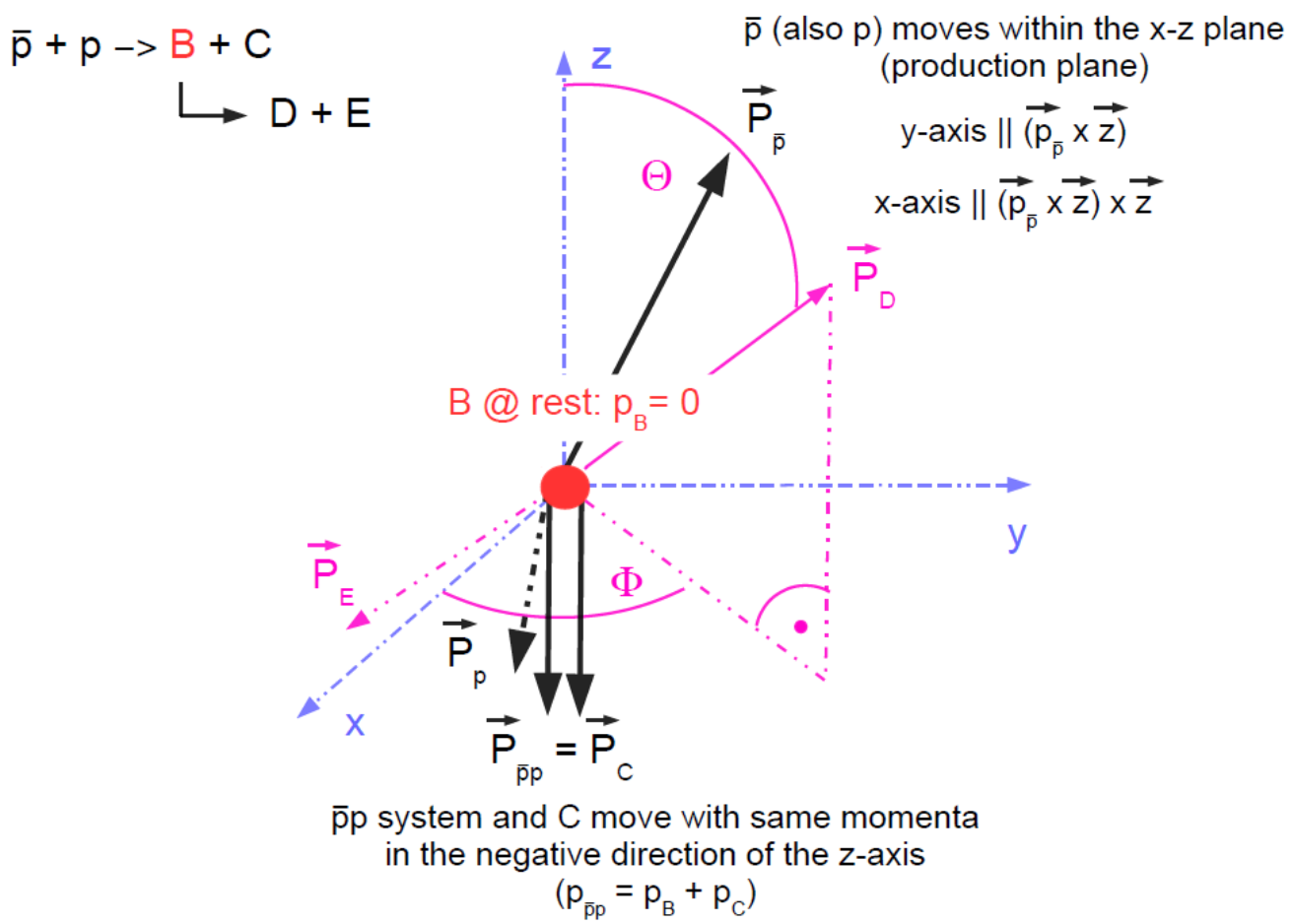


Image from Bertram Kopf

Gottfried-Jackson Frame

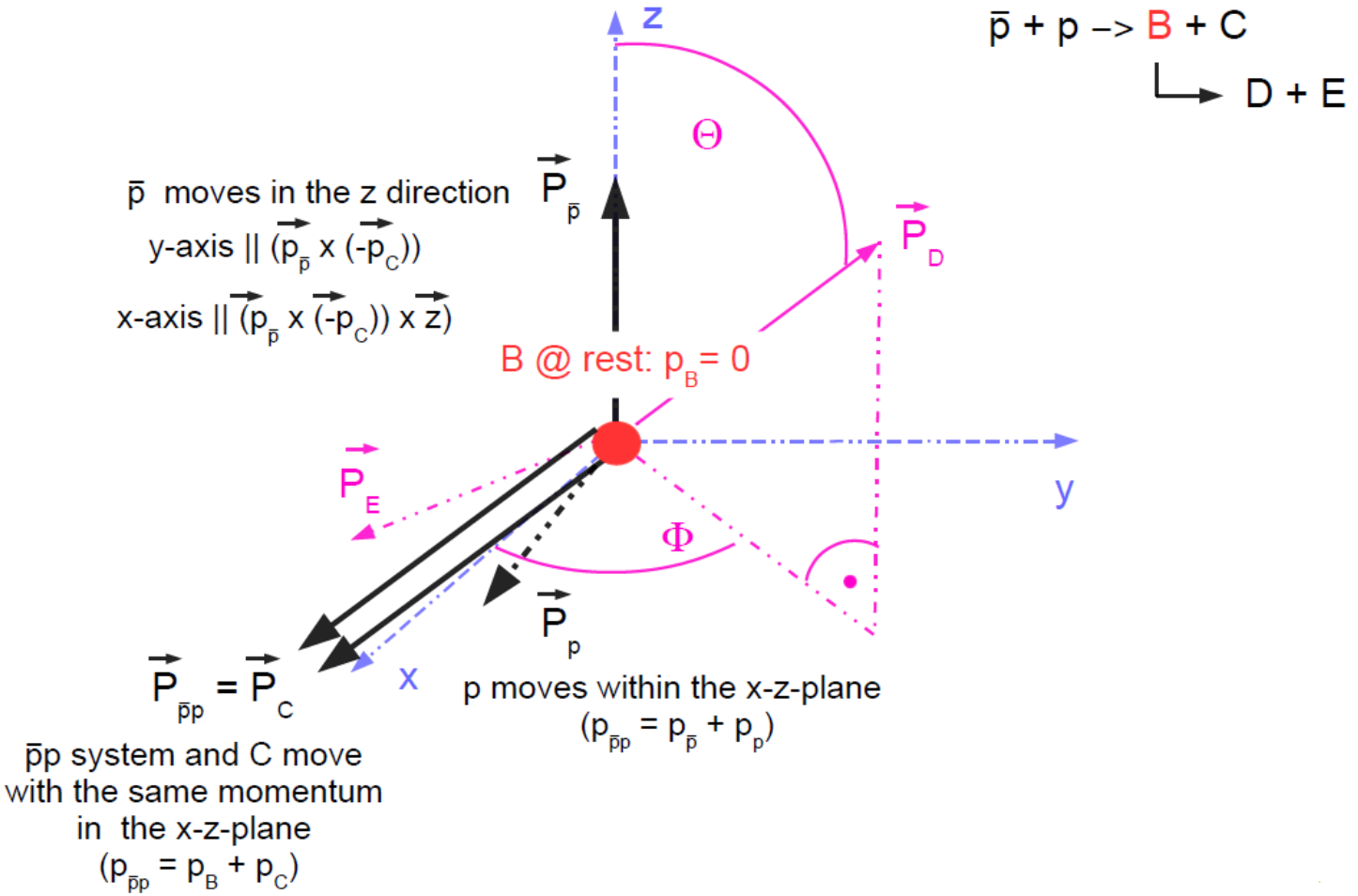


Image from Bertram Kopf