RUHR
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PAWIAN:

Partial Wave Analysis

with Baryons at P̄ANDA

Mainz
PANDA LVIII. Collaboration Meeting
September 12 – 16, 2016

Introduction: Why PWA at $\bar{P}$ANDA

One major $\bar{P}$ANDA topic: QCD-bound states

- Identification of all resonance contribution and determination of their properties
  - accurate measurements of the pole positions (masses, widths)
  - unambiguous determination of the quantum numbers $I^G J^{PC}$
  - . . .

PWA tool is needed for $\bar{P}$ANDA

- Long timescale
  - PWA is mandatory for analyzing real data
- Short timescale
  - PWA is needed for feasibility studies
  - is the performance of the PANDA detector sufficient for the identification of the resonances of interest?

PAWIAN

- Development of a PWA software with the aim
  - to provide a generic software package
  - to support all physics cases to be studied at $\bar{\text{P}}$ANDA
  - to partly support other hadron spectroscopy experiments

Software package PAWIAN (**PA**rtial **W**ave **I**nteractive **An**alysis) already in a good shape, and many analyses have been performed

- Full hypothesis and other input settings defined via configuration files
  - Formalisms (Canonical, Helicity, Rarita-Schwinger)
  - Dynamics (Breit-Wigner, Flatté, K-matrix, ...)
- Event based maximum likelihood fit, minimization by Minuit2
- Multithreading and networking support
- Support for coupled channel analyses
- Event generator, histogramming, analysis tools, ...

New developments

- Coupled channel analysis possible for combining data obtained from measurements based on different production mechanisms
  - so far: $\bar{p}p$, e^+e^- and isolated resonances
- Analysis with any number of final state particles with J>0
- PWA of reactions with any number of baryons in the intermediate and final states are supported

Some relevant Lines in the Configuration File

```
datFile    = ./Lambda1405Sigma1670Rho770Data.dat
mcFile     =  ./evtGenMcLambdac.dat
```
complete path and name of the data and MC files

```
paramFile = ./defaultparams_Lambdac.dat
```
complete path and name of the required input parameter file

```
motherRes = Lambda_c+
```
name of the mother resonance as defined in the pdtTable; needed for res PWA-option

```
finalStateParticle = Sigma+
finalStateParticle = pion-
finalStateParticle = pion+
```
final state particles with the same order as it is listed in the data files

```
production = Lambda(1405)0 pion+ BlattWBarrier 0.66
```
production channels w/ or w/o barrier factors

```
decay = Cano Lambda(1405)0 To Sigma+ pion-
```
decay channels; order important for several decay levels

```
addDynamics = Lambda(1405)0 BreitWignerBlattWRel
```
dynamics for the individual intermediate resonances (optional)

```
#Fixed Parameter
mnParFix = J1/2P1C0Lama1/2Lamb0_Lambda_c+ToLambda(1405)0_pion+Phi
```
fixing of fit parameter

```
noOfThreads = 4
```
number of used threads; working for pwa and also for server-client mode

```
serverPort = 50014
serverAddress = pc14
noOfClients = 100
```
required setup for server-client mode

Documentation on $\bar{P}$ANDA Wiki Page at

https://panda-wiki.gsi.de/foswiki/bin/view/PWA/WebHome

- First step instructions
- Examples and tutorials with toy data
- List and explanation of the individual parser arguments
- Physics Resources

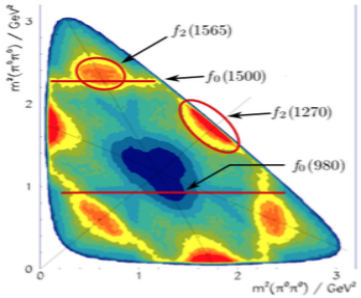
PANDA Wiki > PWA Web > WebHome (08 Jul 2014, JulianPychy)

PANDA PWA

Introduction

In the 90s of the last century high statistics experiments with fully equipped 4π detectors have lead to a better insight in the spectrum of hadrons.

In particular the finding of crypto-exotic and JPC exotic states tremendously improved the experimental situation in meson spectroscopy. All this was possible only with sophisticated analysis methods like the decomposition of measured phase-space distribution into partial waves and to express the partial waves in terms of complicated dynamical functions.



This Wiki page represents the documentation of the PANDA Partial Wave Analysis software project aiming to provide a flexible and experiment independent framework for performing all kinds of amplitude analysis.

Contact

The contact person for the Panda PWA software project is Bertram Kopf, Ruhr-Universität Bochum.

Physics Resources

The PAWIAN PWA Software

Meetings

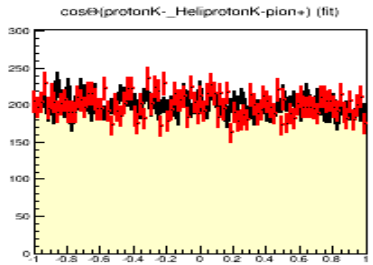
Software Documentation (deprecated)

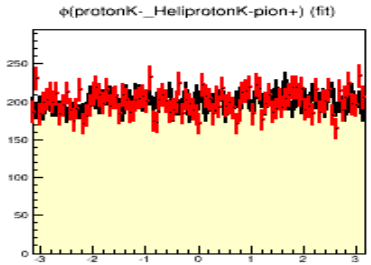
PWA with Baryons

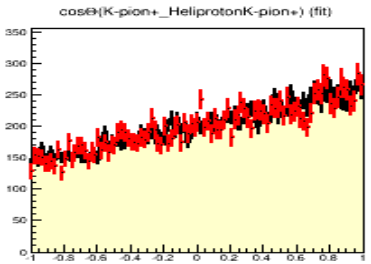
Starting point: Toy data of $\Lambda_c^+ \rightarrow p\, K^-\, \pi^+$

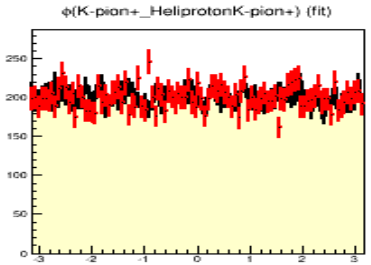
- Λ_c polarized
- Comparison of amplitudes and fit parameter with publication from E791 Collaboration: *Phys. Lett. B471 (2000) 449*
- 3 intermediate resonances
  - $\Lambda_c \rightarrow p\, \bar{K}^{*0}(890)$
  - $\Lambda_c \rightarrow \Delta^{++}(1232)\, K^-$
  - $\Lambda_c \rightarrow \Lambda^0(1520)\, \pi^+$
- D-functions and number of free amplitude parameter consistent with E791 publication
- Good agreement between toy data and fit

Fit result for toy data $\Lambda_c^+ \rightarrow p\, K^-\, \pi^+$

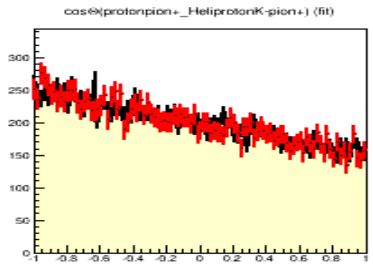


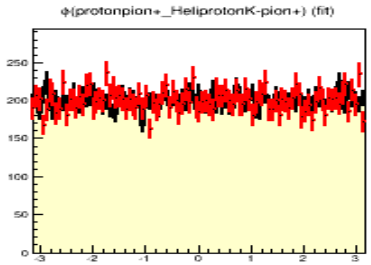


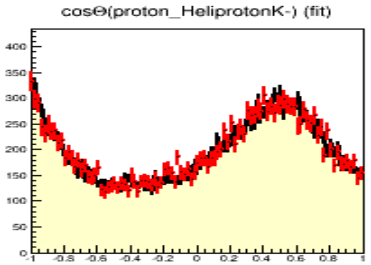


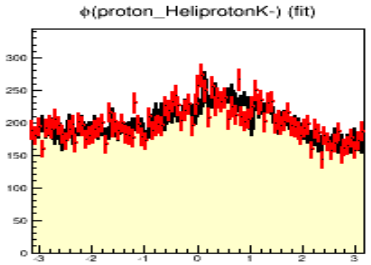


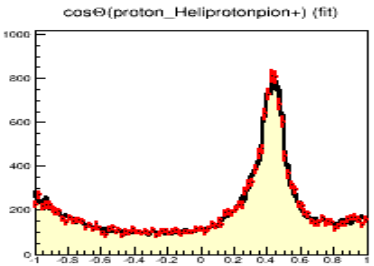
data
fit

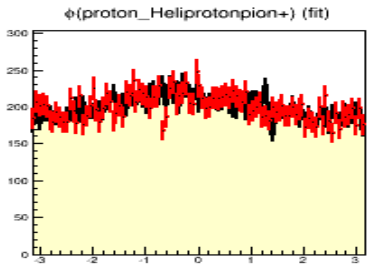


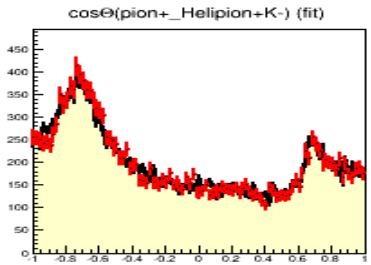


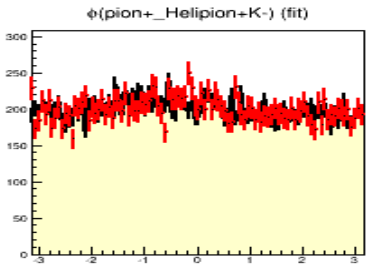


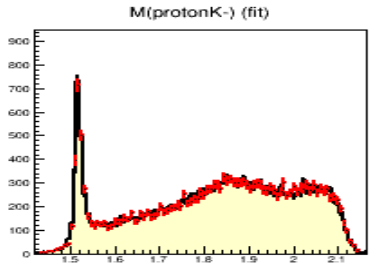


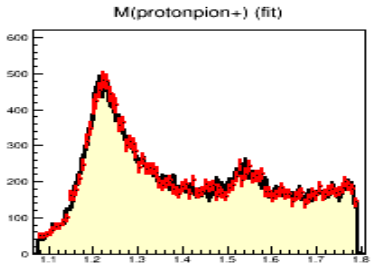


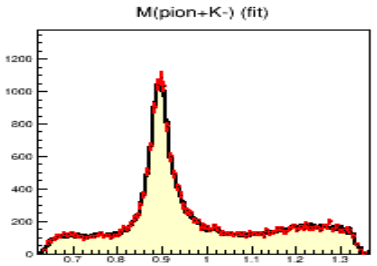






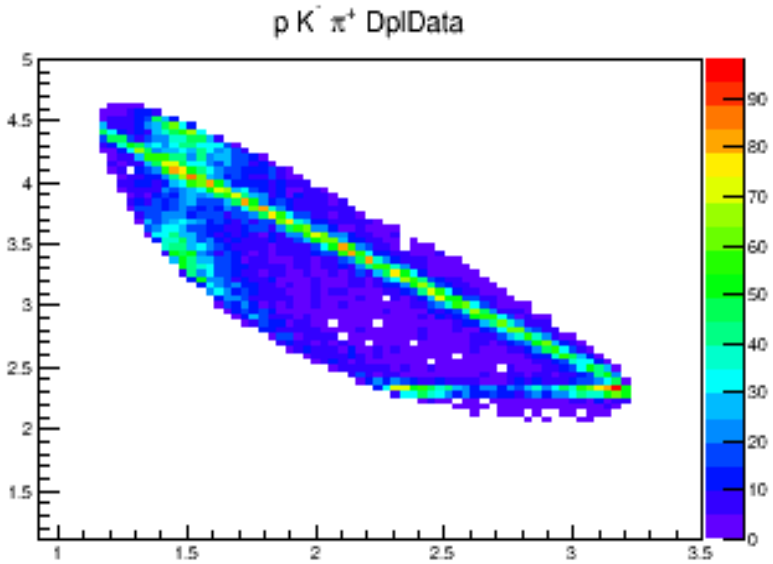


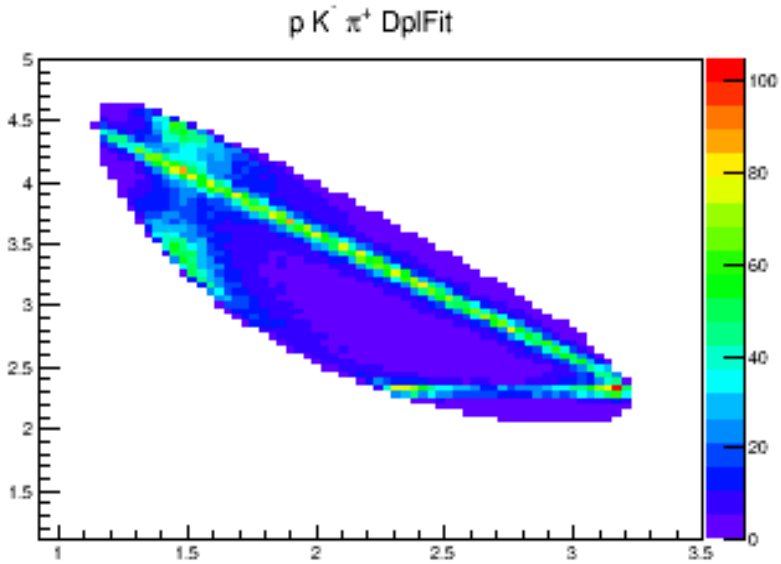


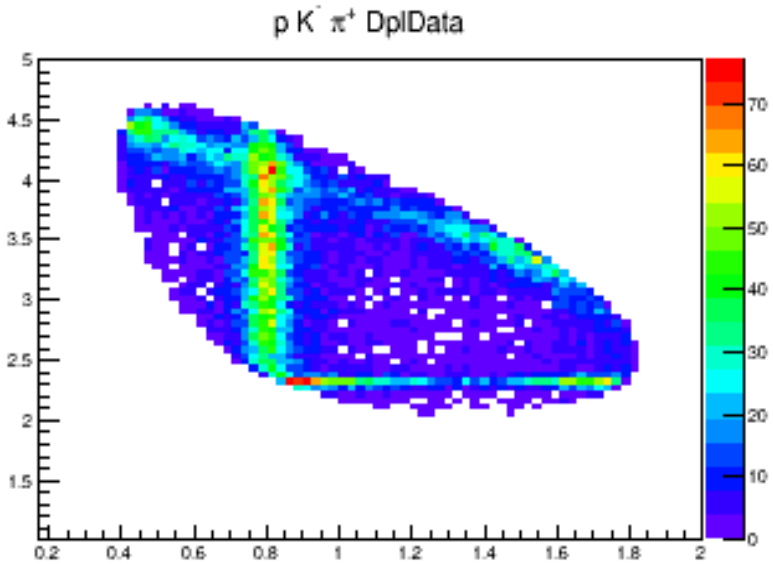


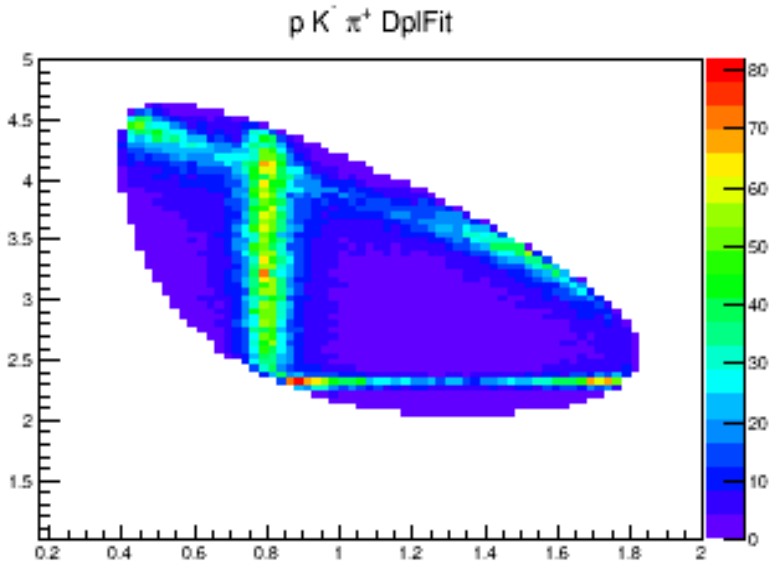
PWA with Baryons: $\Lambda_c^+ \to p\, K^-\, \pi^+$

Fit result for toy data $\Lambda_c^+ \to p\, K^-\, \pi^+$









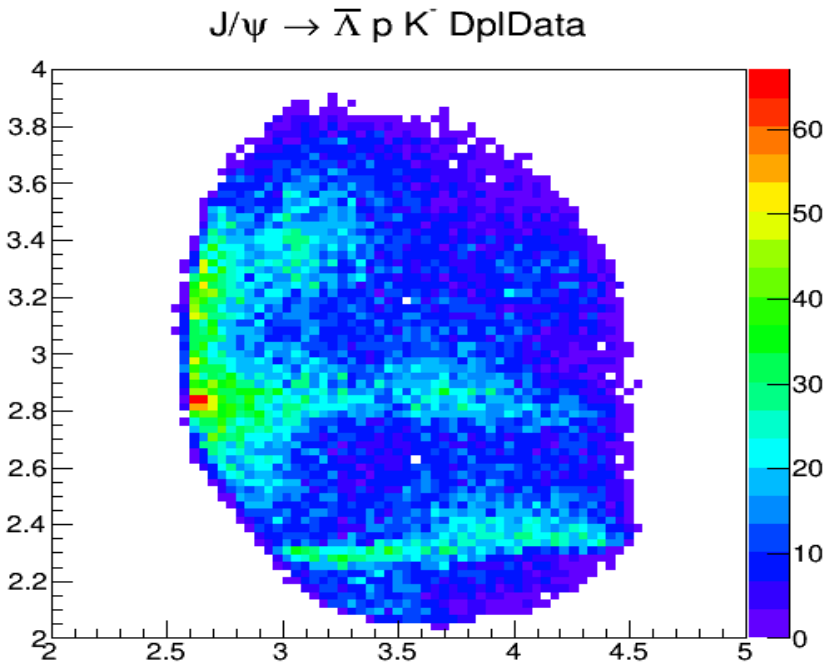
PWA with Baryons

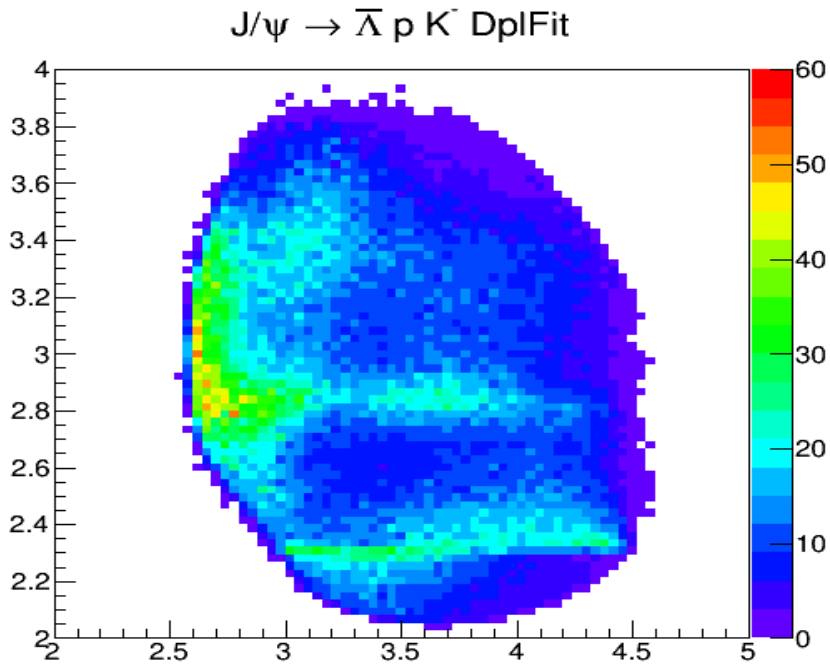
Real data: $J/\psi \rightarrow \bar{\Lambda}\, p\, K^-$

Jan Reher,

bachelor thesis 2016 (RUB)

Reasonable fit results by making use of the helicity formalism and Breit-Wigner parameterizations for the dynamics of a couple of exiting $\bar{\Lambda}$ ($\rightarrow$p K^-) and N* ($\rightarrow$ $\bar{\Lambda}$ K^-) resonances





PWA with Baryons

Real data: $J/\psi \rightarrow \bar{\Lambda}\, p\, K^-$

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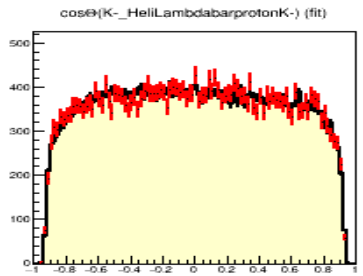
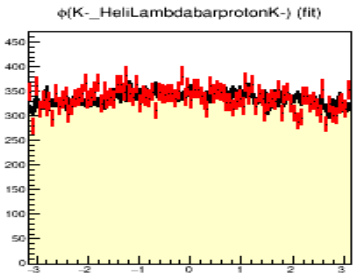
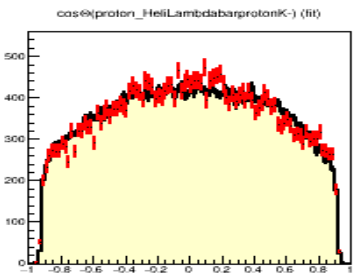
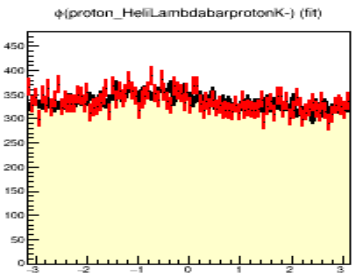
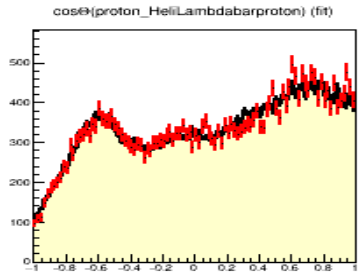
data
fit

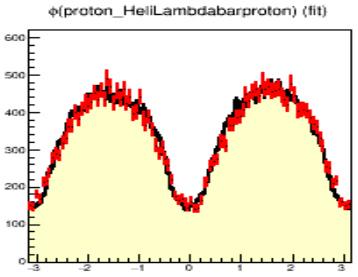


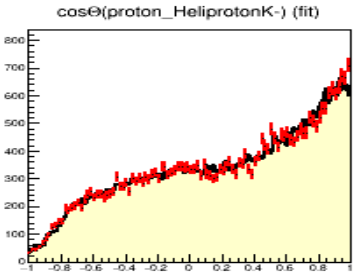


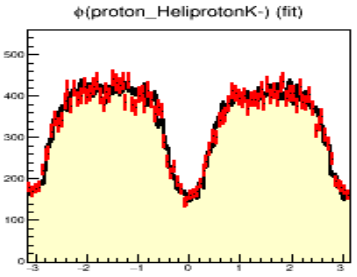


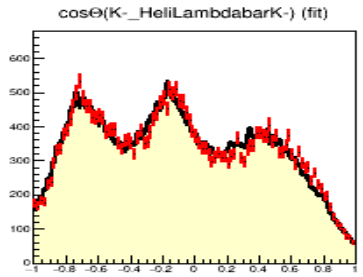


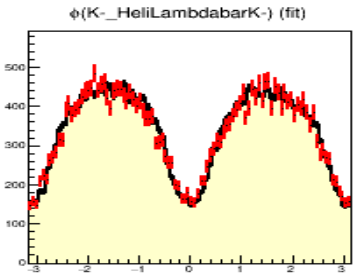


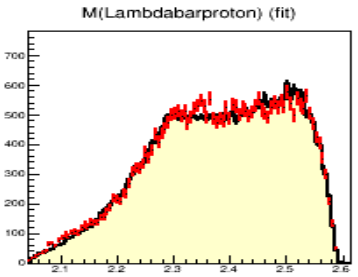


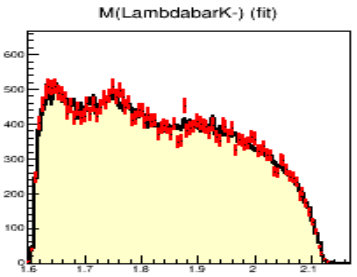


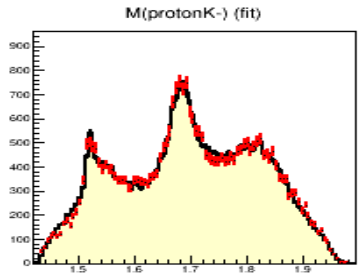








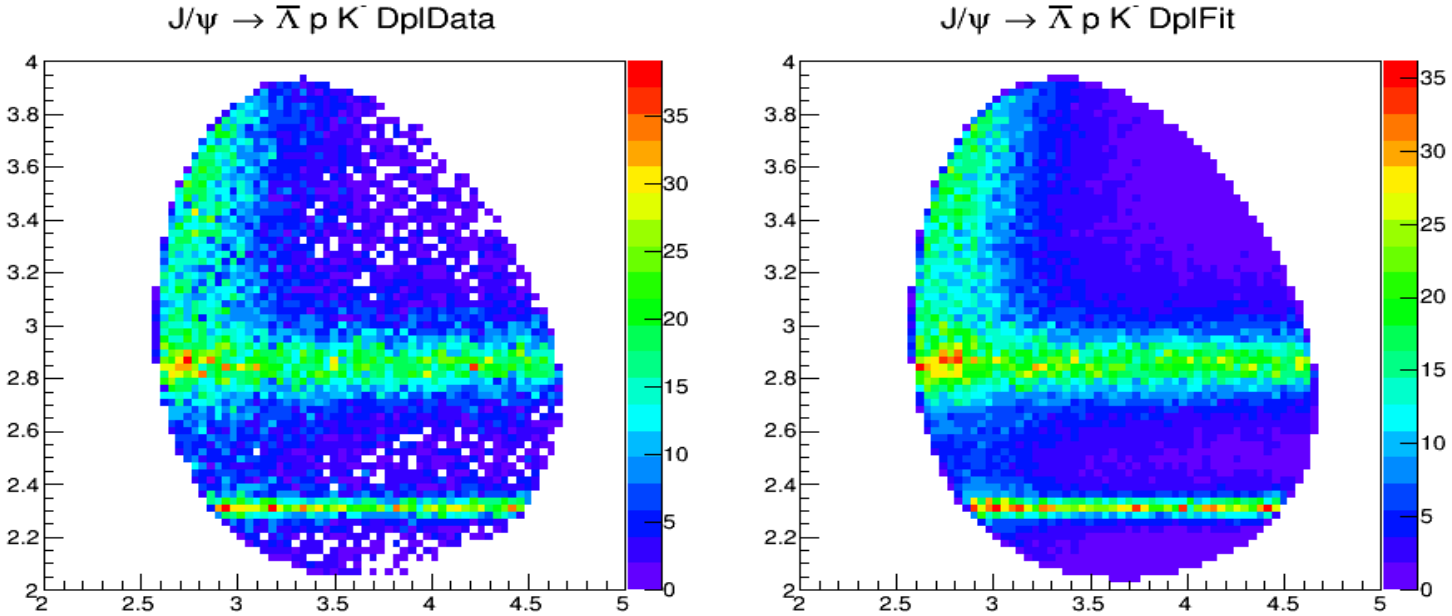




PWA with Baryons in $\bar{p}p$ reactions

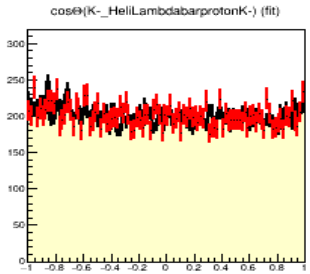
Fit with toy data: $\bar{p}p \rightarrow \bar{\Lambda}\, p\, K^-$

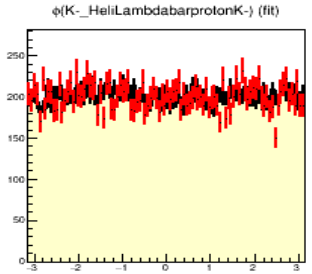
- Event generation at $p_{\bar{p}} = 4.0651$ GeV/c
- Model consists of 4 different intermediate baryon resonances
  - $\bar{p}p \rightarrow \Lambda(1520)\,\bar{\Lambda}$, $\Lambda(1690)\,\bar{\Lambda}$, $N^{*-}(1650)\,p$ and $N^{*-}(1720)\,p$
- $L_{max}(\bar{p}p) = 1$ results in 5 contributing $\bar{p}p$ states
  - 0^{-+}, 0^{++}, 1^{+-}, 1^{++} and 2^{++}
- Reasonable fit result with 102 free parameter

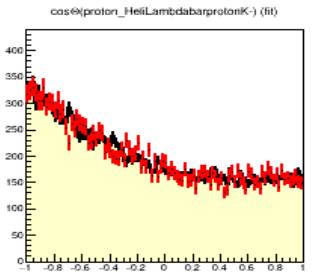


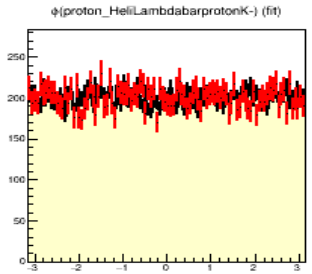
Fit result with toy data: $\bar{p}p \rightarrow \bar{\Lambda}\, p\, K^-$

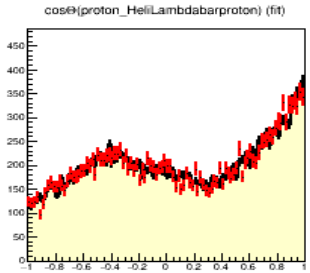
data
fit

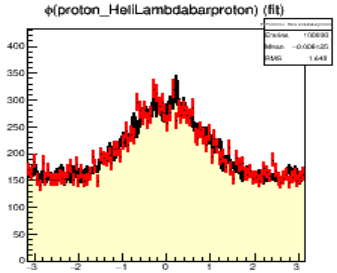


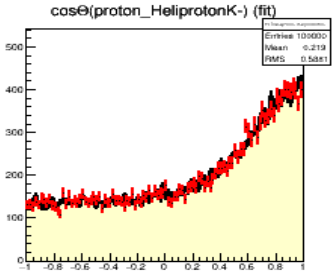


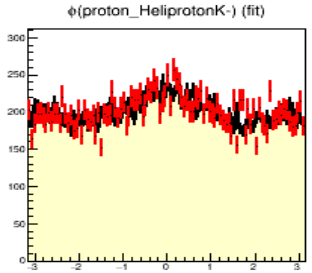


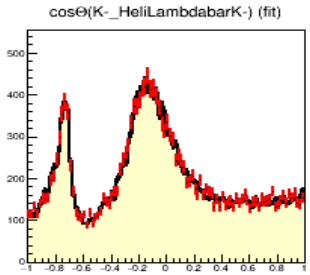


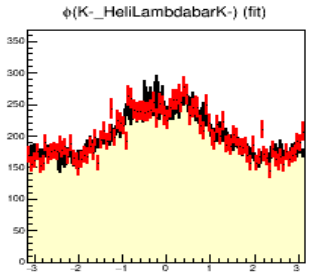


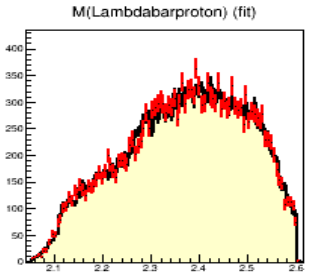


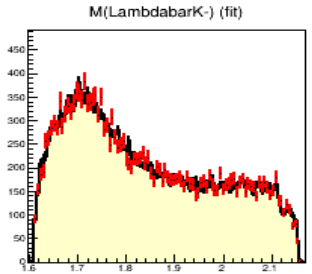


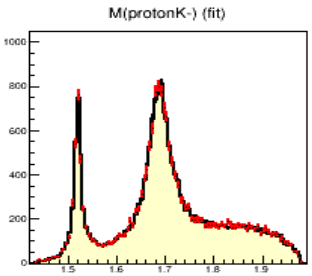












PWA with toy data: $\bar{p}p \rightarrow \bar{\Lambda}\, p\, K^-$

- Masses, widths and contributions of the individual resonances can be well reproduced with less than 3σ

	generated	Fitted result	Startparameter	deviation
contribution $\Lambda(1520)$	14.8%	14.2 ± 0.4%	13.3%	1.5 σ
M($\Lambda(1520)$) / GeV/c^2	1.5207	1.5206 ± 0.0002	1.4800	0.5 σ
$\Gamma(\Lambda(1520))$ / GeV/c^2	0.0151	0.0150 ± 0.0005	0.0270	0.2 σ
contribution $\Lambda(1690)$	41.6%	43.3 ± 0.8%	46.6%	2.1 σ
M($\Lambda(1690)$) / GeV/c^2	1.6899	1.6908 ± 0.0005	1.6400	1.8 σ
$\Gamma(\Lambda(1520))$ / GeV/c^2	0.0536	0.0526 ± 0.0011	0.0900	0.9 σ
contribution N*(1650)	17.6%	17.3 ± 1.2%	18.2%	0.3 σ
M(N*(1650)) / GeV/c^2	1.6837	1.6851 ± 0.0055	1.6700	0.3 σ
Γ(N*(1650)) / GeV/c^2	0.2141	0.2368 ± 0.0246	0.1900	0.9 σ
contribution N*(1720)	23.7%	23.9 ± 1.1%	16.5%	0.2 σ
M(N*(1720)) / GeV/c^2	1.7423	1.7488 ± 0.0032	1.7100	2.0 σ
Γ(N*(1720)) / GeV/c^2	0.1896	0.1913 ± 0.0109	0.1500	0.1 σ

Summary

- Status of PAWIAN
  - generic and user-friendly
  - supports analysis starting from $\bar{p}p$- and e^+e^- annihilation or an isolated resonance with mesons, photons and baryons in the decay tree
  - supports coupled channel analysis with generic K-matrix descriptions
  - event generation with user-defined amplitudes and dynamics possible

- First successful tests with $\bar{p}p$ reactions including baryons

- PAWIAN in principle ready for feasibility studies with the $\bar{P}$ANDA detector
  - event generation
  - single and coupled channel PWA of the complete $\bar{p}p$ reactions from the initial state up to the final states