Λ Production Studies at GSI

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Overview

- Motivation
- Λ Properties
- **HADES** Spectrometer
- pp -> p$K^+\Lambda$ Channel Analysis
- **PANDA** Spectrometer
- $\bar{p}$p -> $\Lambda\bar{\Lambda}$ Benchmark Channel Simulation
- Study of Two Different Detector Options:
  - ➡ Straw Tube Trackers (STT)
  - ➡ Time Projection Chambers (TPC)
- Summary

Motivation

Λ hyperon reconstruction with the HADES and PANDA spectrometers

- Timelike form factors of hyperons:

  $\Sigma^*,\Lambda(1520) \rightarrow \Lambda\gamma$ (BR~1%) $\Sigma^*,\Lambda(1520) \rightarrow \Lambda e^+e^-$ (BR~10^{-2}%)

- Studies on polarization (s_Λ = strange quark spin)
- Search for deeply bound kaonic states
- Spin physics: polarization correlation coefficients (singlet fraction)
- CP violation

Λ properties

Quark content: uds

Mass = 1115.683 ± 0.006 MeV/c^2

Lifetime τ = (2.631 ± 0.020)·10^{-10} s $\rightarrow$ $c\tau$ = 7.89 cm

Decay modes:

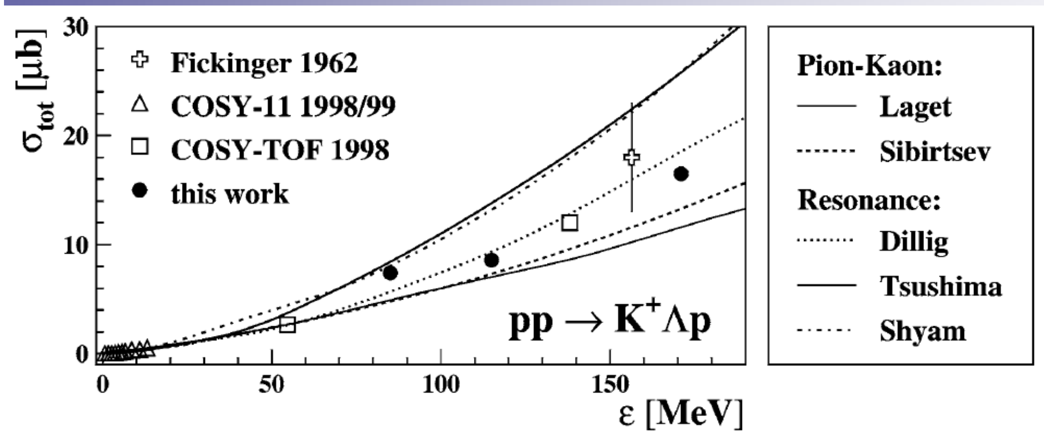
- $p\,\pi^-$ BR 63.9% $\alpha_\Lambda = 0.642$
- $n\,\pi^0$ BR 35.8% $\alpha_\Lambda = 0.650$

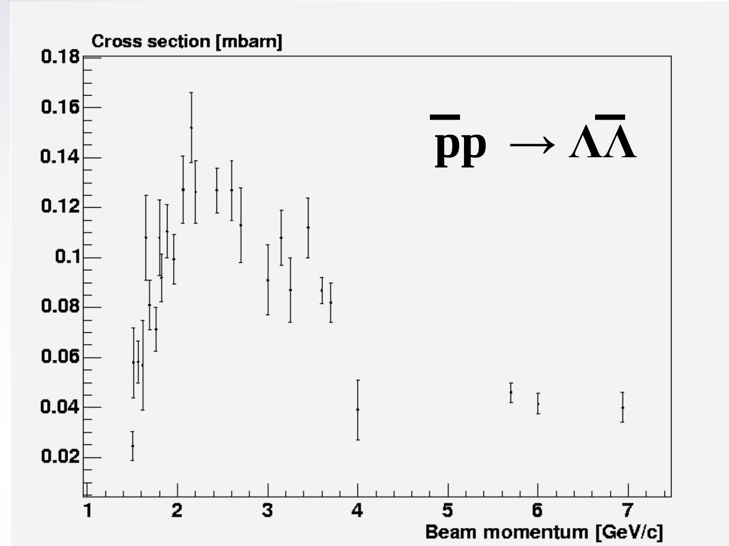
Decay asymmetry $$\frac{dN}{d\Omega} \propto \left(1 + \alpha_\Lambda P_\Lambda \cos\theta^*\right)$$

α_Λ = asymmetry coefficient

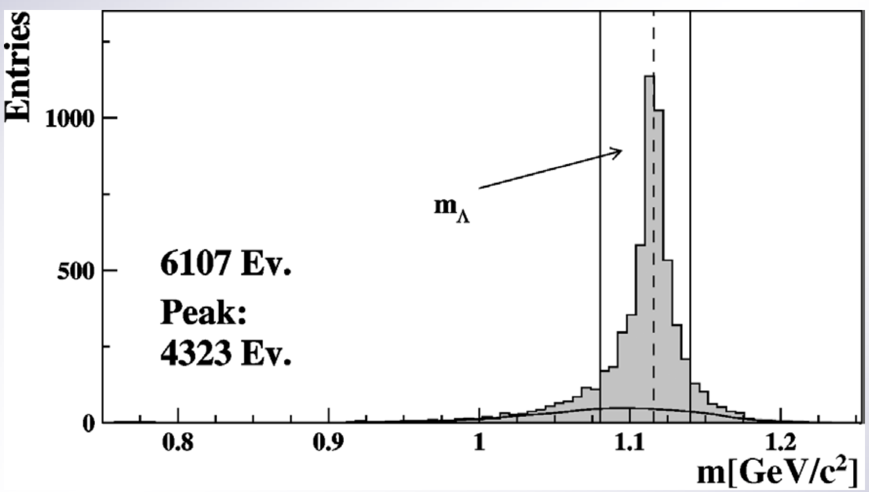
Λ studies

COSY-TOF

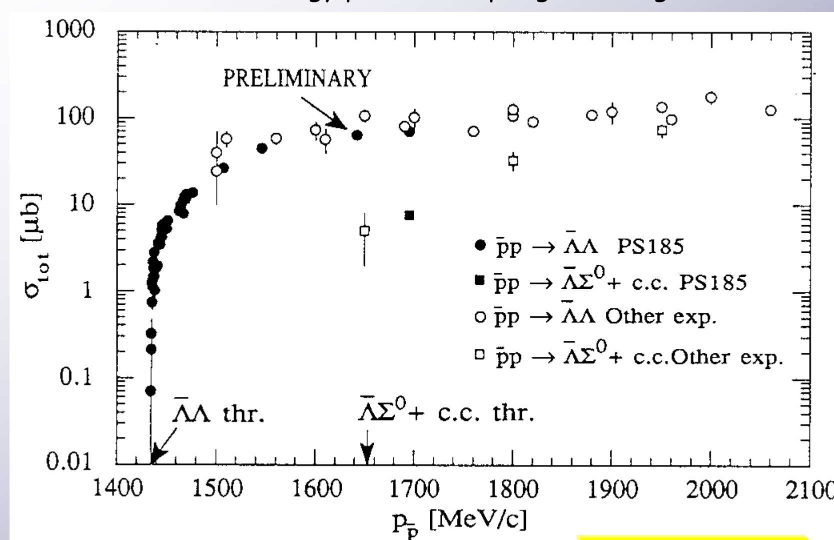




Total cross-section for reactions of high energy particles, Springer-Verlag, 1988



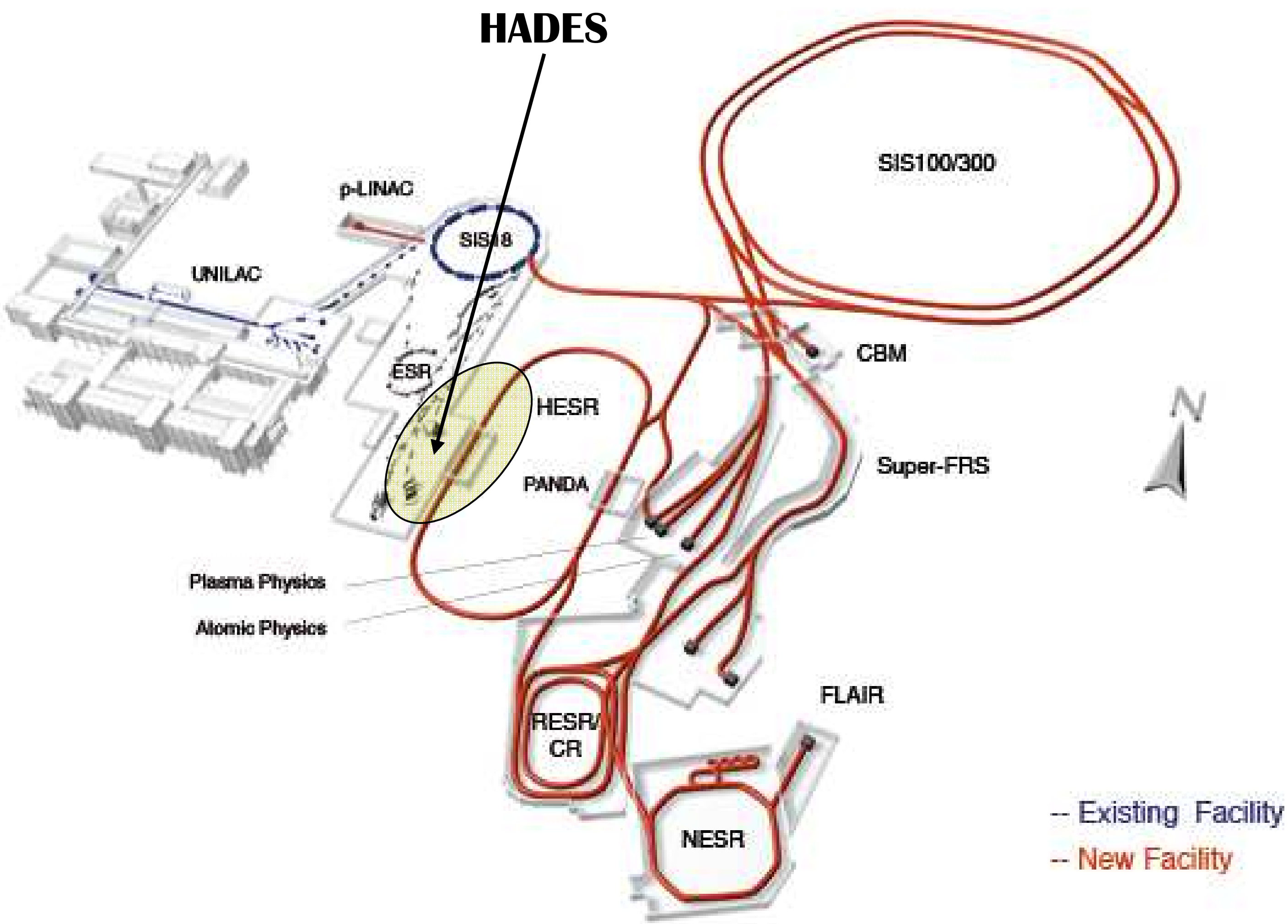
Phys. Lett. B 632, 27-34 (2006)

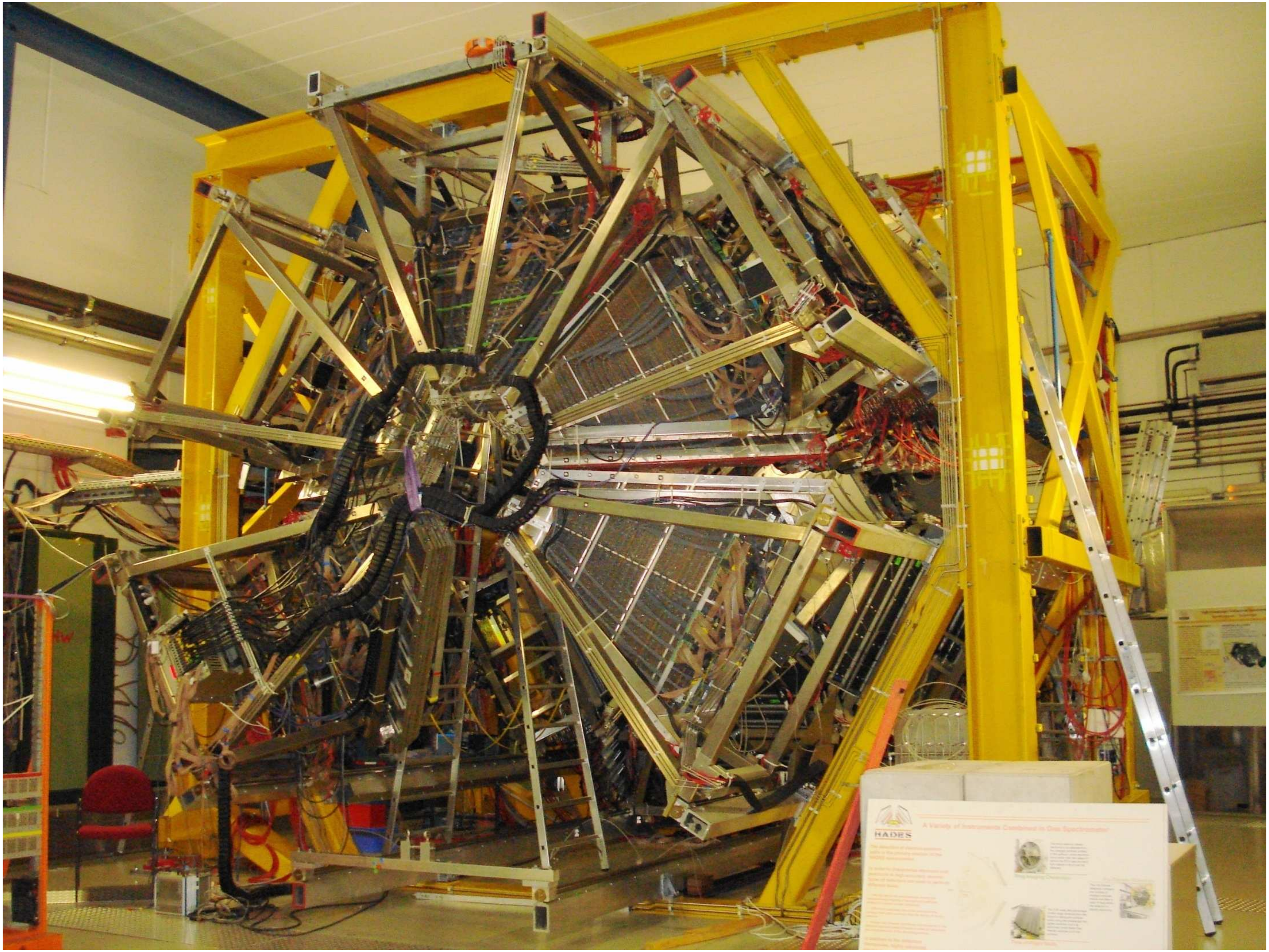


I Biannual Conference on Low Antiproton Physics, Stockholm, Sweden, (1990)

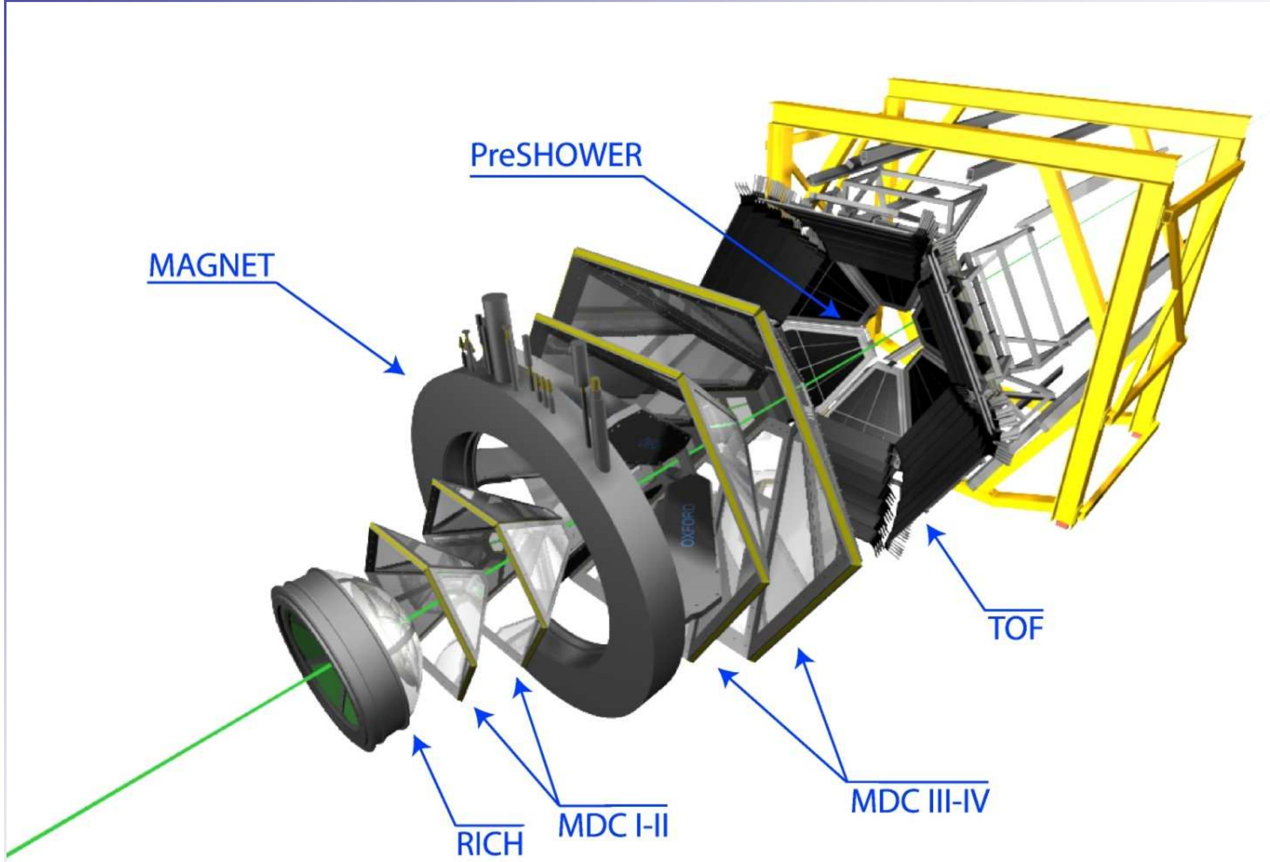
PS185

Actual GSI and Facility for Antiproton and Ion Research




HADES
A Variety of Instruments Combined in One Spectrometer

HADES Spectrometer



Energies

- Heavy Ion: ≤ 2 AGeV
- Proton: ≤ 3.5 GeV

Targets

- Heavy Ions
- Protons

Acceptance

- $18° < \vartheta < 85°$
- $0 < \varphi < 2\pi$

Particle Identification

- TOF
- Pre-Shower
- RICH

Tracking

- MDC $\frac{\Delta p}{p} \approx 2\%$

⇩

Momentum reconstruction

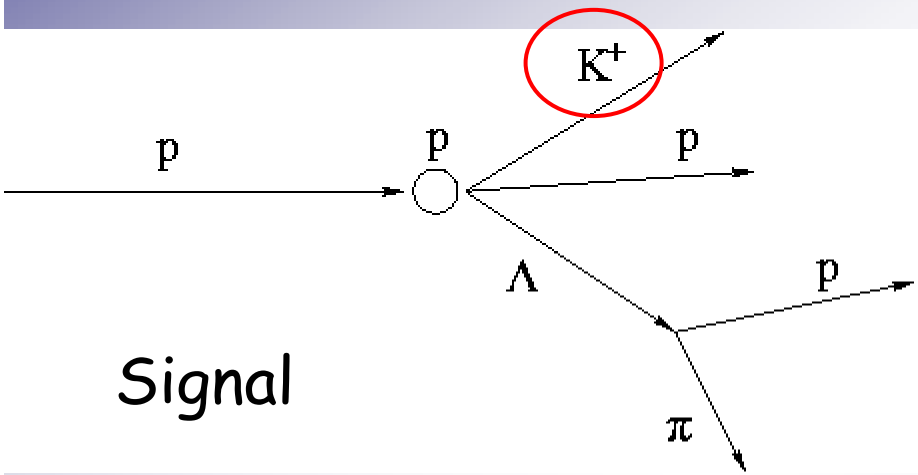
How to Detect Λ

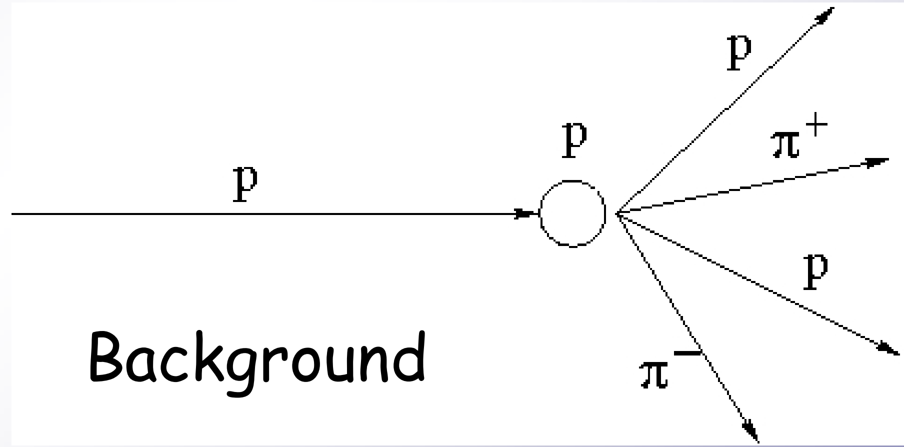
Signal $pp \rightarrow pK^{+}\Lambda$ σ ~ 18 ± 5 μbarn

$\Lambda \rightarrow p\pi^{-}$ (@ 2.0 GeV)

Background $pp \rightarrow pp\pi^{+}\pi^{-}$ σ ~ 2510 ± 140 μbarn

(@ 2.0 GeV)





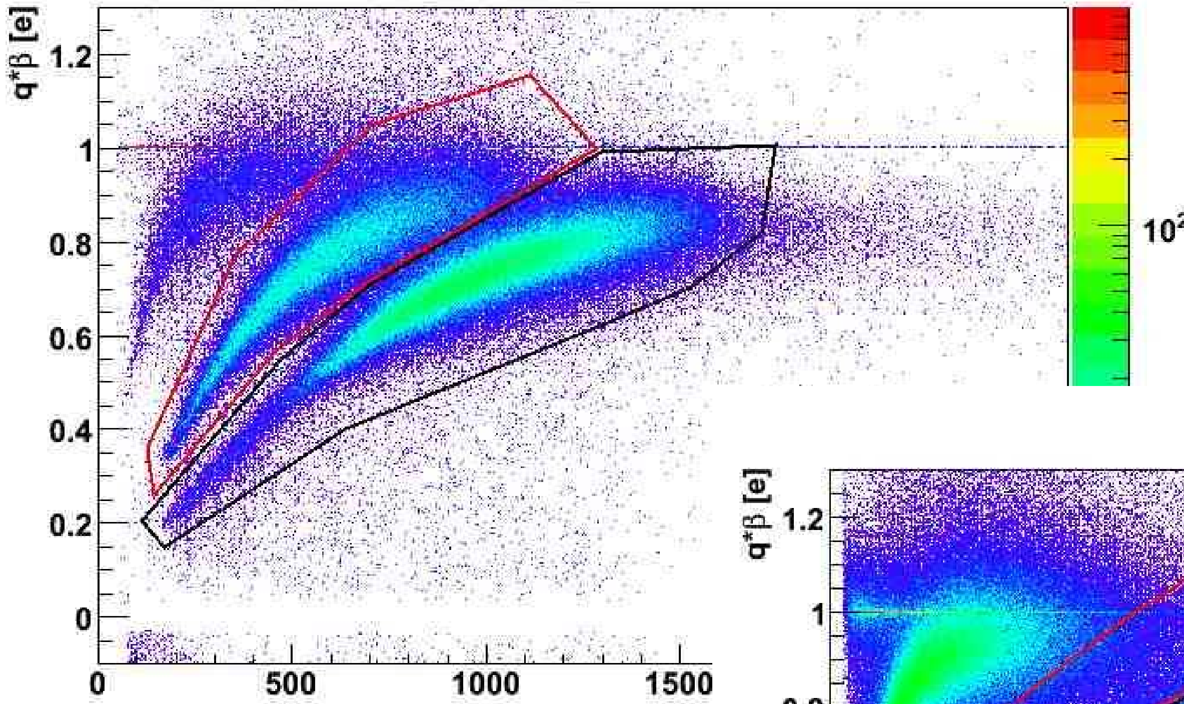
2 particles identified ($p\pi^{-}$) → large background

4 particles identified ($p\pi^{-}pK^{+}$) → acceptance limitations

3 particles identified ($p\pi^{-}X$) → which particle is X?

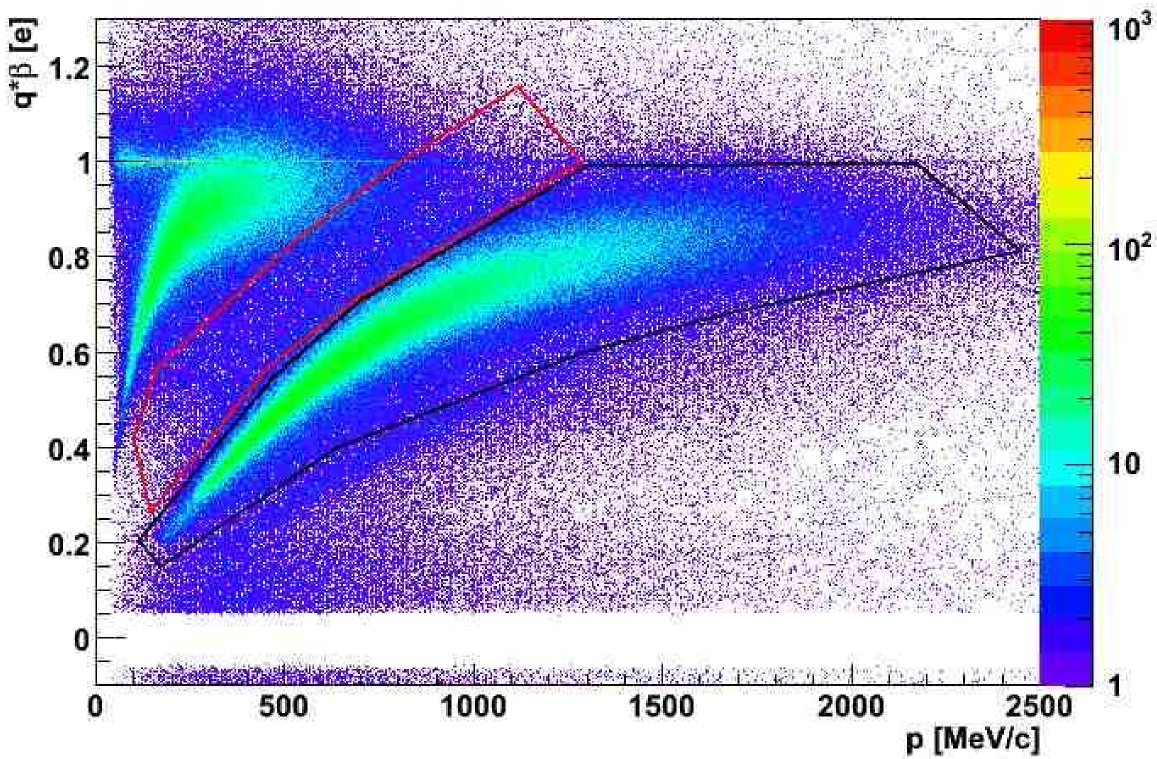
Assumption: isotropic distribution of Λ decay products

Particle Identification



Simulation

Only Λ channel



Real data

signal + background

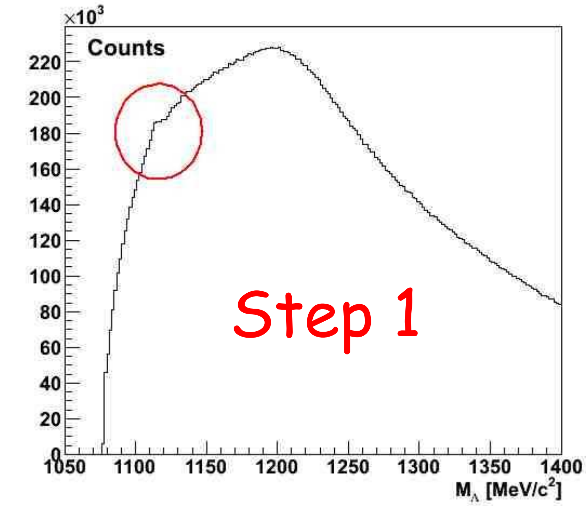
3 particles in the final state

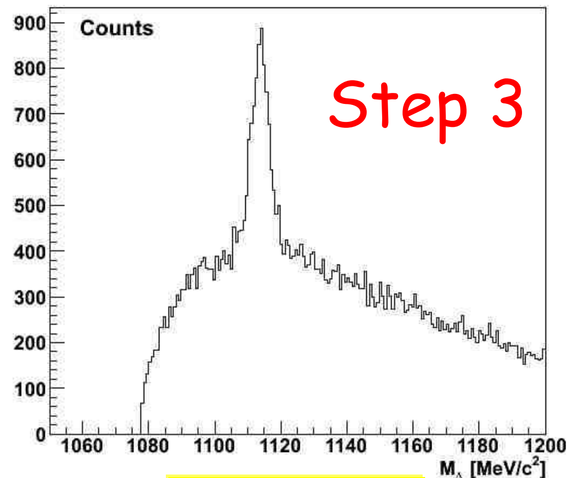
Lambda Identification in Real Data

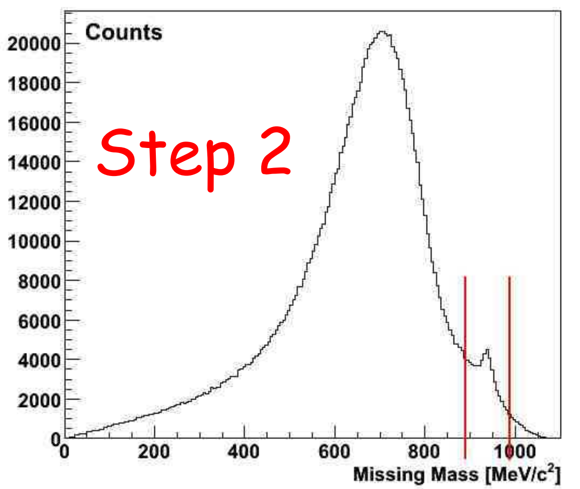
HADES

$pp \rightarrow pK^{+}\Lambda$

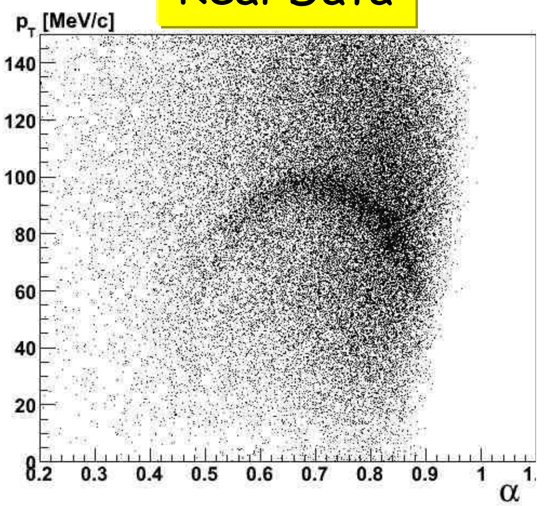
- missing spectator proton



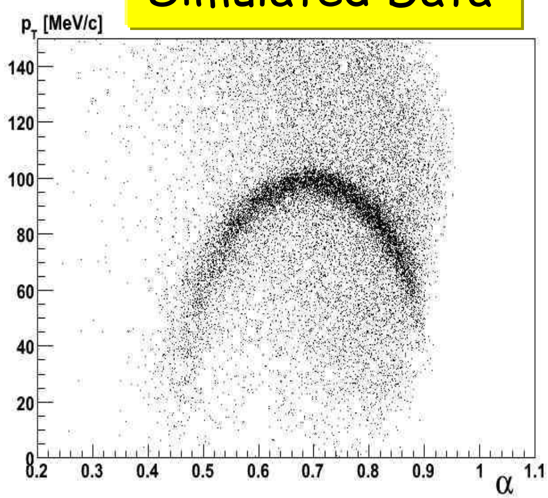




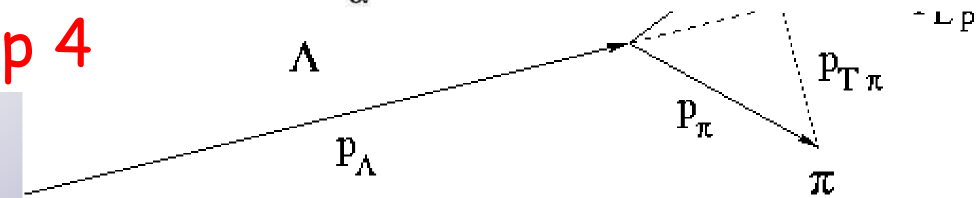
Real Data



Simulated Data



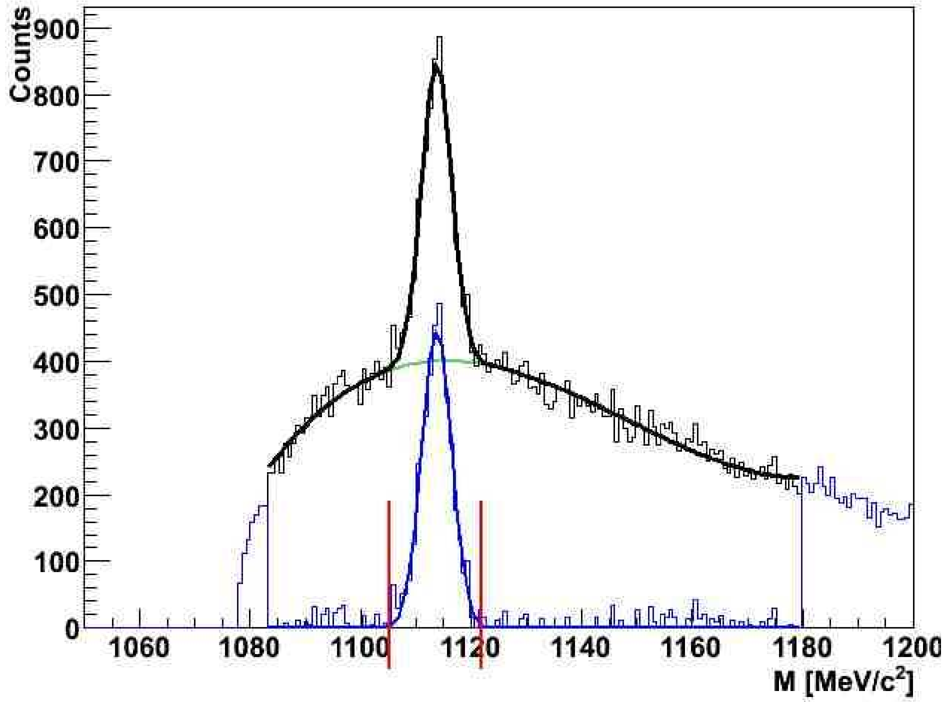
Step 4

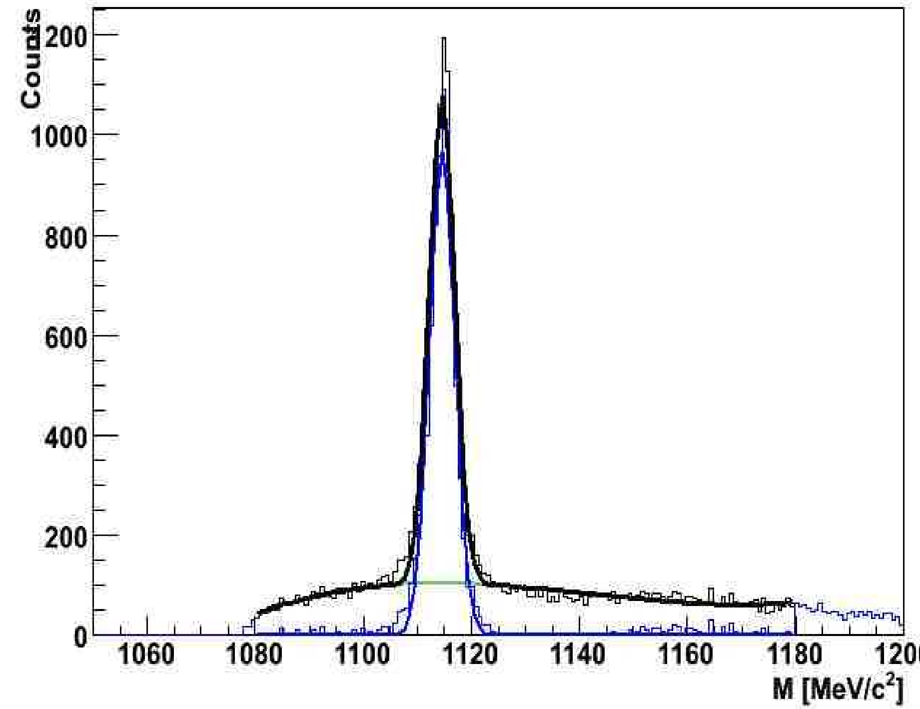


Results: Lambda Invariant Mass

Real Data

Simulated Data





M_Λ = 1113.74 ± 0.11 MeV/c^2

σ = 2.72 ± 0.05 MeV/c^2

n_Λ = 4097 ± 64 ± 115 ± 328 ± 287
(stat) (param) (PID) (miss p)

M_Λ = 1114.55 ± 0.09 MeV/c^2

σ = 2.47 ± 0.04 MeV/c^2

n_Λ = 8303 ± 55
(stat)

Results: Λ Yield

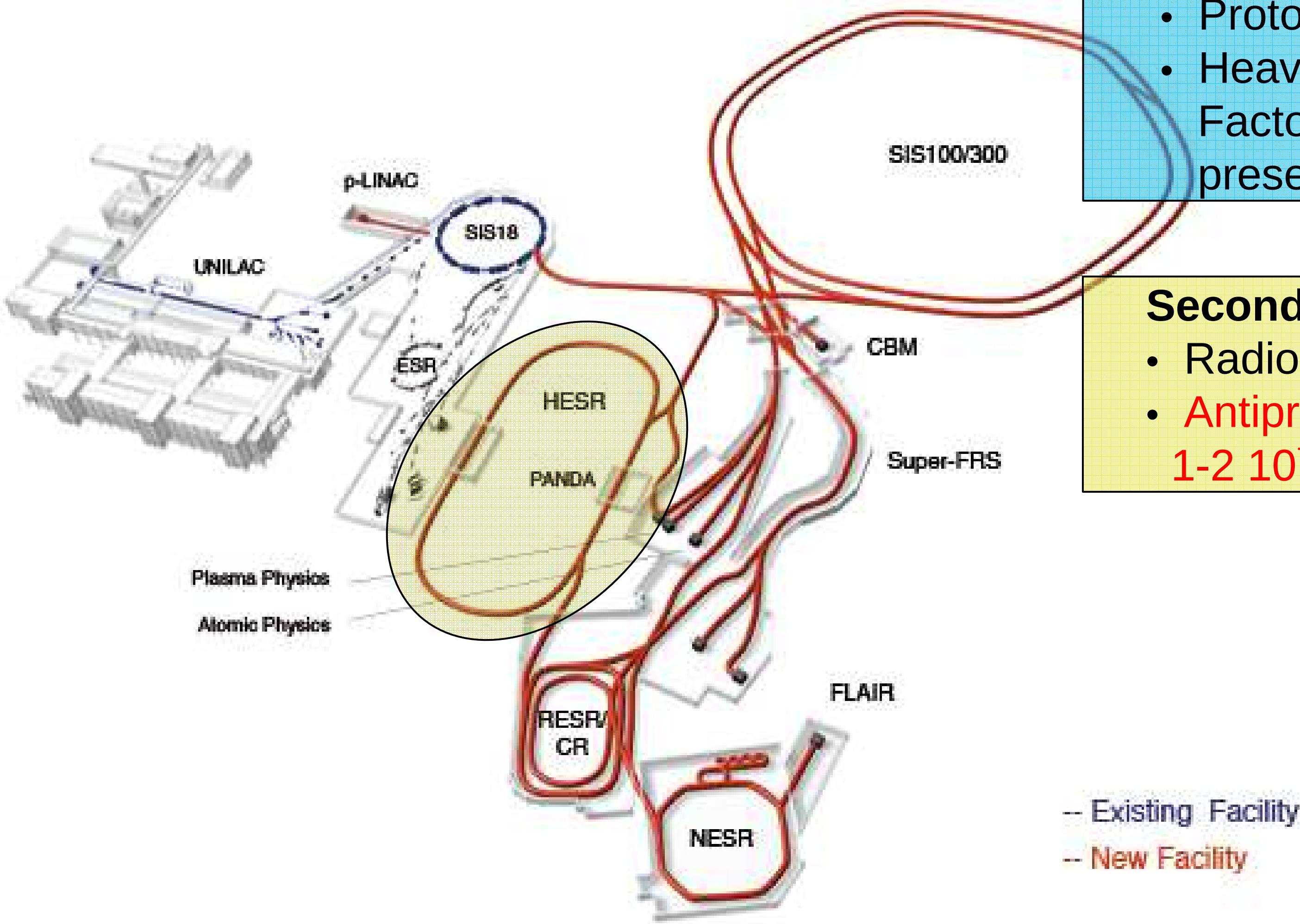
Channel	pp -> $pK^+\Lambda$ Λ -> $p\pi^-$	pp -> $pp\eta$ η -> $\pi^+\pi^-\pi^0$
Cross Section	11.5 μb	16.6 μb
Efficiency + Acceptance	0.28%	0.68%
Yield	~ 4100 this work	~ 22000 T. Perez and S.Spataro PhD Theses

Expected Λ yield: 6300

Observed Λ yield: 4100

Factor 0.35 of discrepancy

Future GSI and Facility for Antiproton and Ion Research



Primary beams:

- Proton
- Heavy Ions

Factor 100-1000 over present in intensity

Secondary Beams:

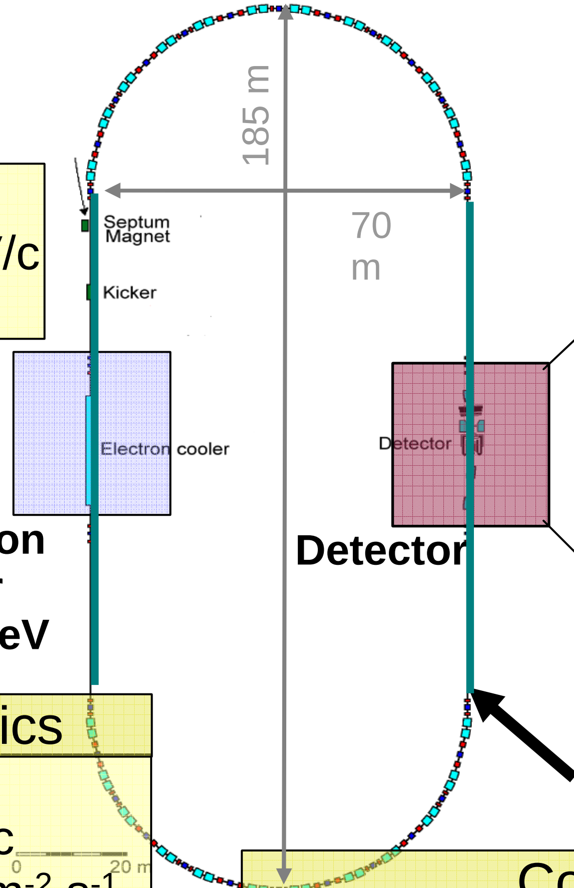
- Radioactive beams
- Antiprotons 3 - 30 GeV

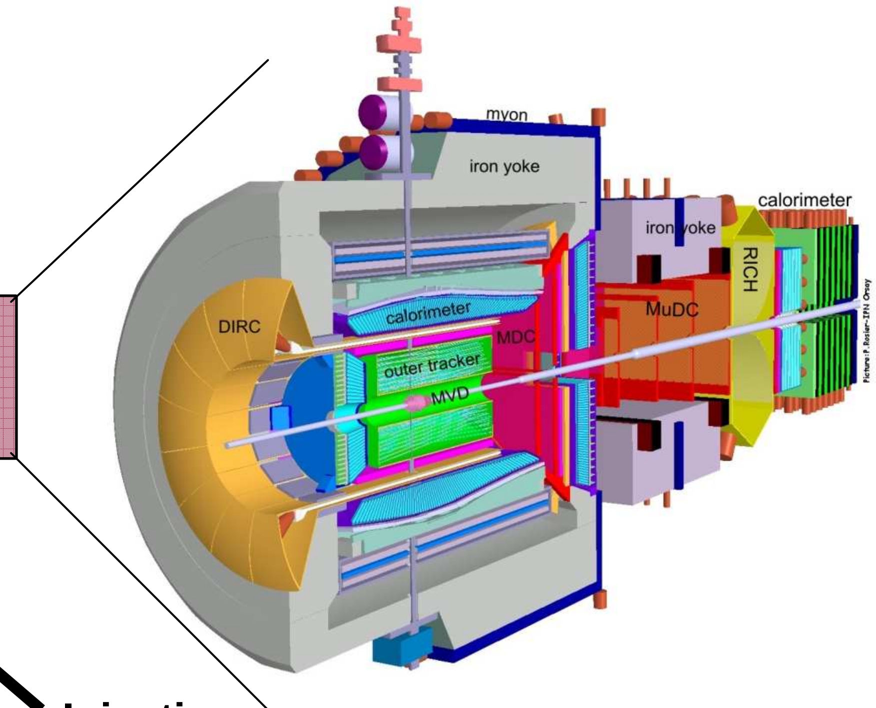
$1\text{-}2\ 10^{7}$ /s

High Energy Storage Ring

HESR

10^{11} stored and cooled 0.8-15 GeV/c antiprotons





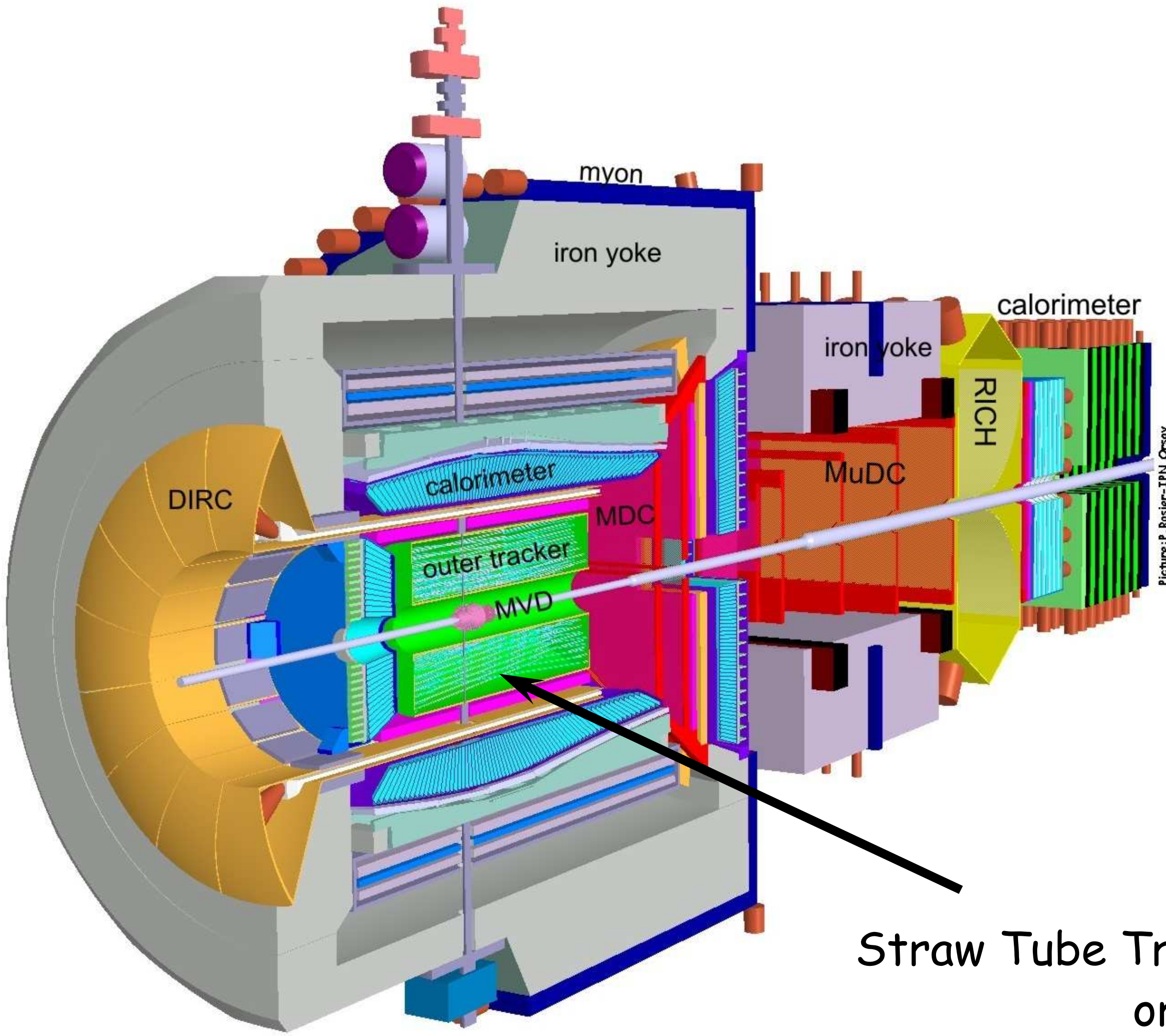
Characteristics

P_{max} = 15 GeV/c
L_{max} = $2\cdot10^{32}$ cm^{-2} s^{-1}
Ø < 100 µm
$\delta p/p$ < 10^{-5}
internal target

Cooling: electron/stochastic

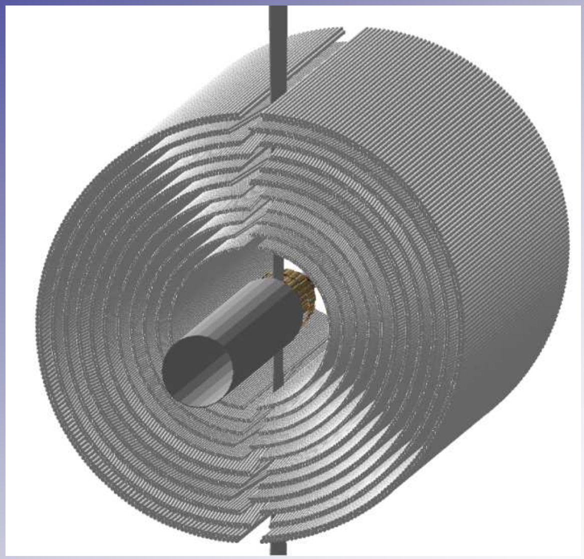
High res. mode:	L =	10^{31} cm^{-2} s^{-1}	$\delta p/p < 10^{-5}$
High lum. mode:	L =	$2\cdot10^{32}$ cm^{-2} s^{-1}	$\delta p/p < 10^{-4}$

PANDA Detector Setup Design



Straw Tube Trackers (STT)
or
Time Projection Chambers (TPC)

Straw Tube Trackers



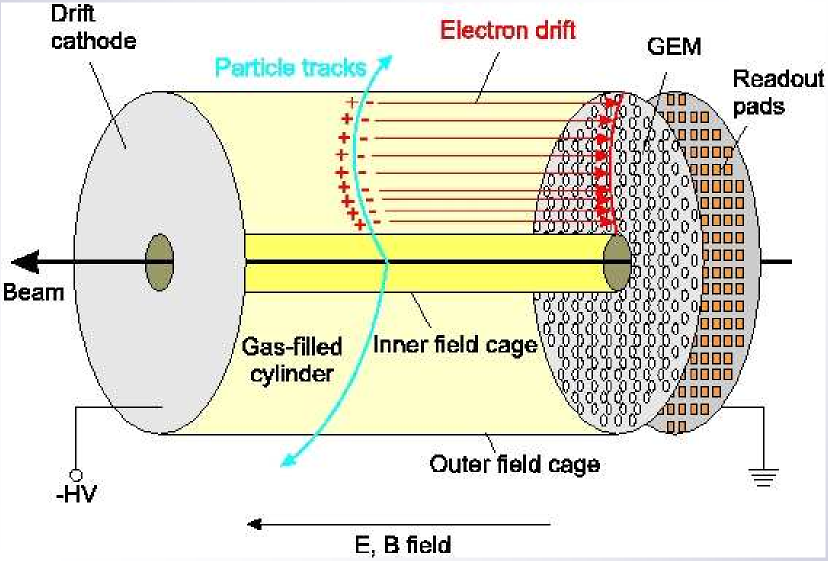
Advantages

- Robust mechanical stability
- High tracking efficiency due to minimal dead zones of the tubes
- High rate capability

Disadvantages

- Dead material causing additional multiple scattering

Time Projection Chamber

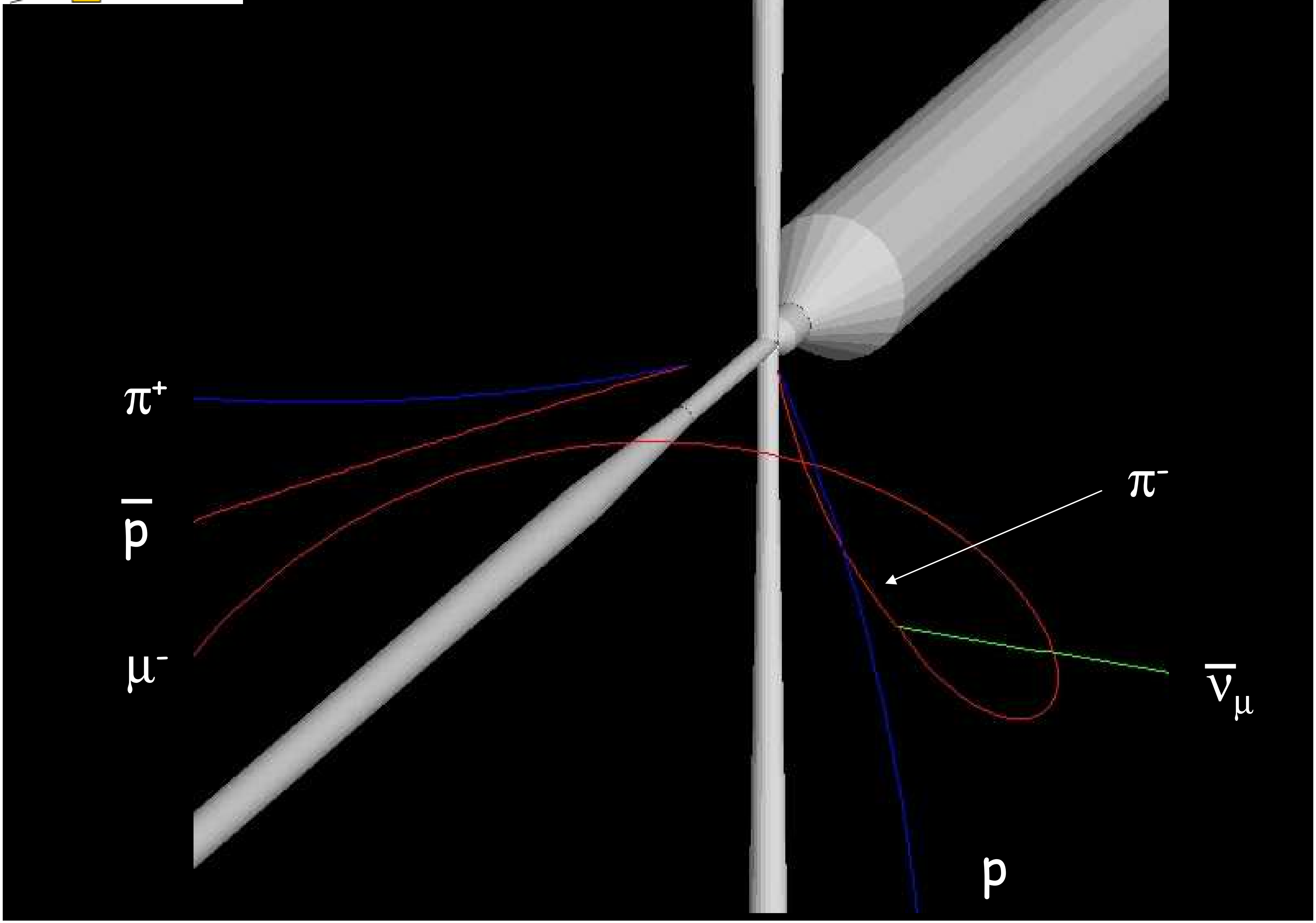


Advantages

- High granularity
- Better particle identification at low momenta

Disadvantages

- Intrinsicly slower detector
  (Long drift time):
  - At high rates, tracks of several events will overlay



π^+
$\bar{p}$
μ^-
π^-
$\bar{\nu}_\mu$
p

Event Generation

10000 events generated

Full simulation and reconstruction of STT and TPC

$\bar{p}p \rightarrow \Lambda\bar{\Lambda}$ p_{beam} = 2.0, 4.0, 6.0, 7.7 GeV/c

Investigation of charged decay channel:

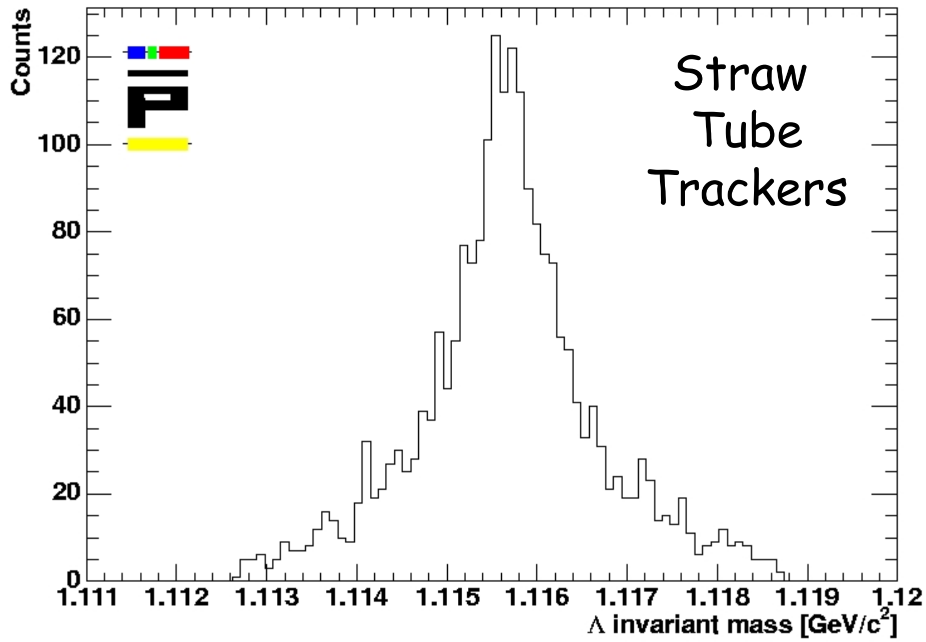
$\Lambda \rightarrow p\pi^-$ $\bar{\Lambda} \rightarrow \bar{p}\pi^+$

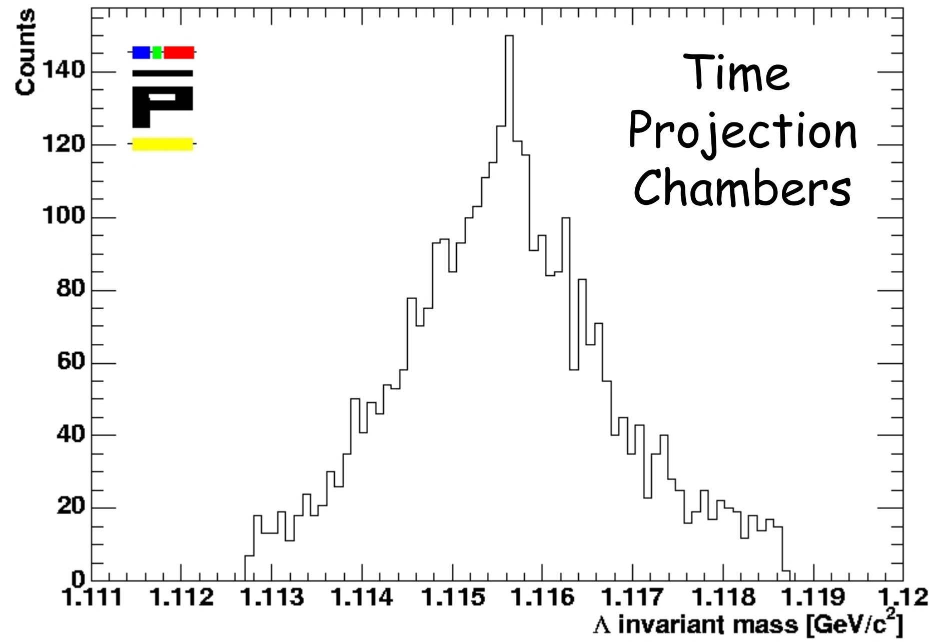
Assumptions:

Isotropic production of Λ-$\bar{\Lambda}$ in the center of mass frame

Isotropic distribution of Λ decay products

Results: Λ Invariant Mass Reconstruction





Mean = 1.116 GeV/c^2

σ = 0.71 ± 0.02 MeV/c^2

Mean = 1.116 GeV/c^2

σ = 1.10 ± 0.02 MeV/c^2

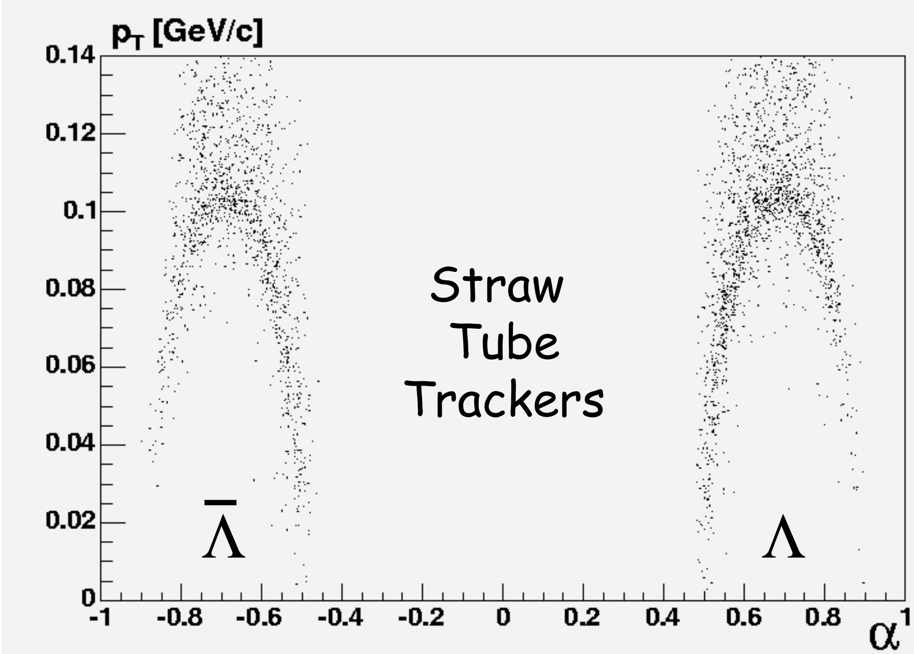
- Forward Spectrometer not used

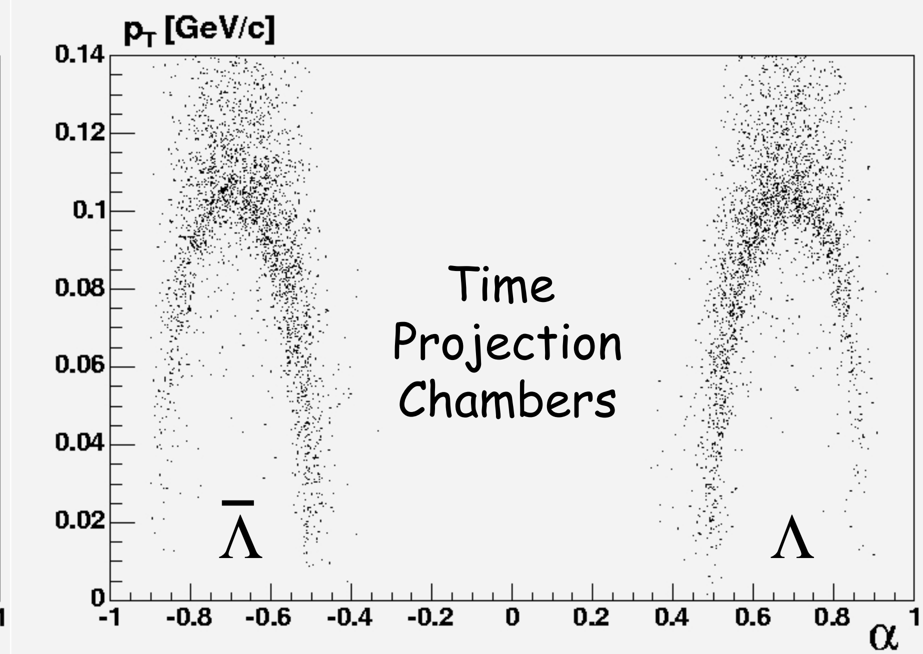
Beam momentum:
4.0 GeV/c

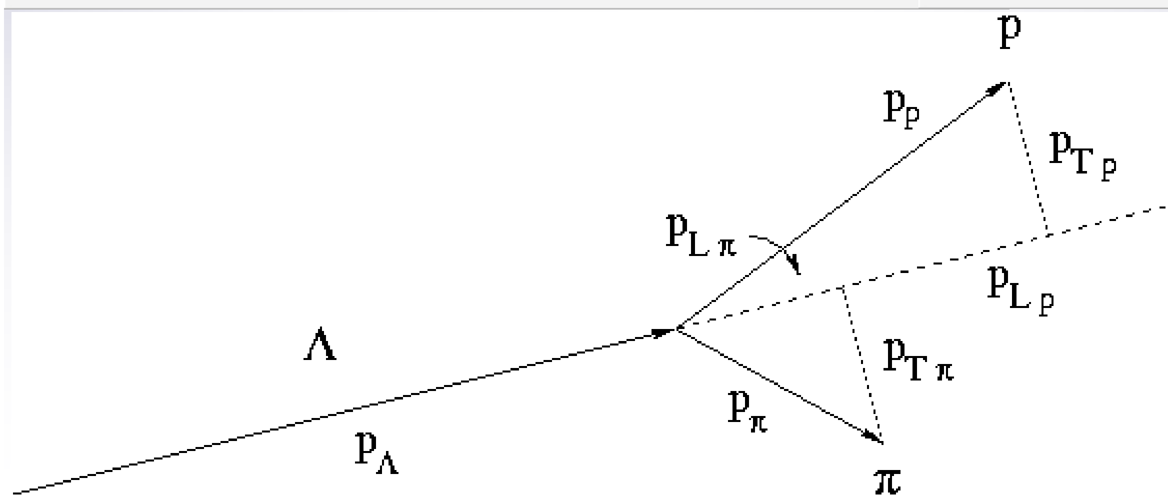
Results: Armenteros Plots

Λ-$\bar{\Lambda}$

p_{beam} = 4 GeV/c

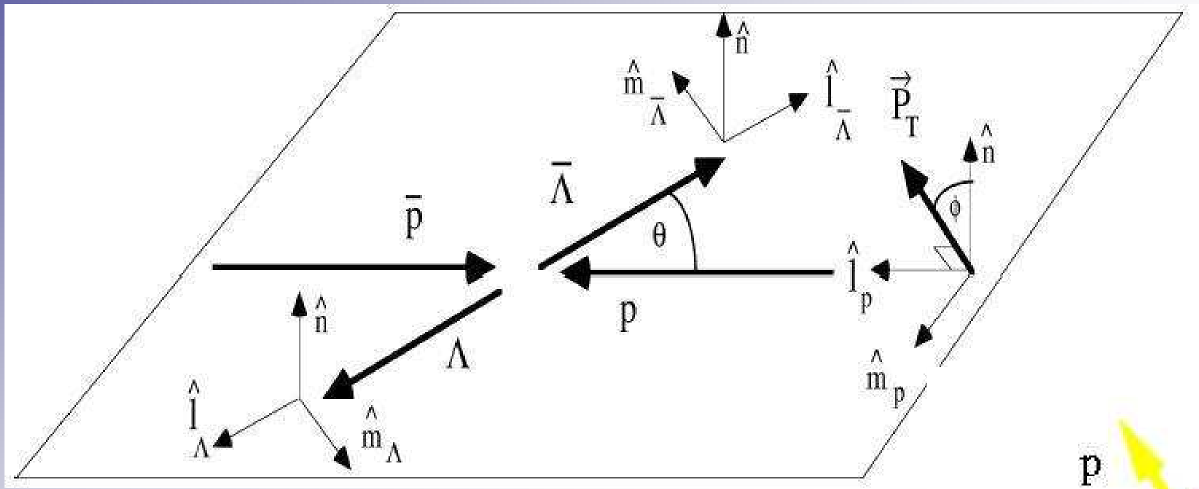






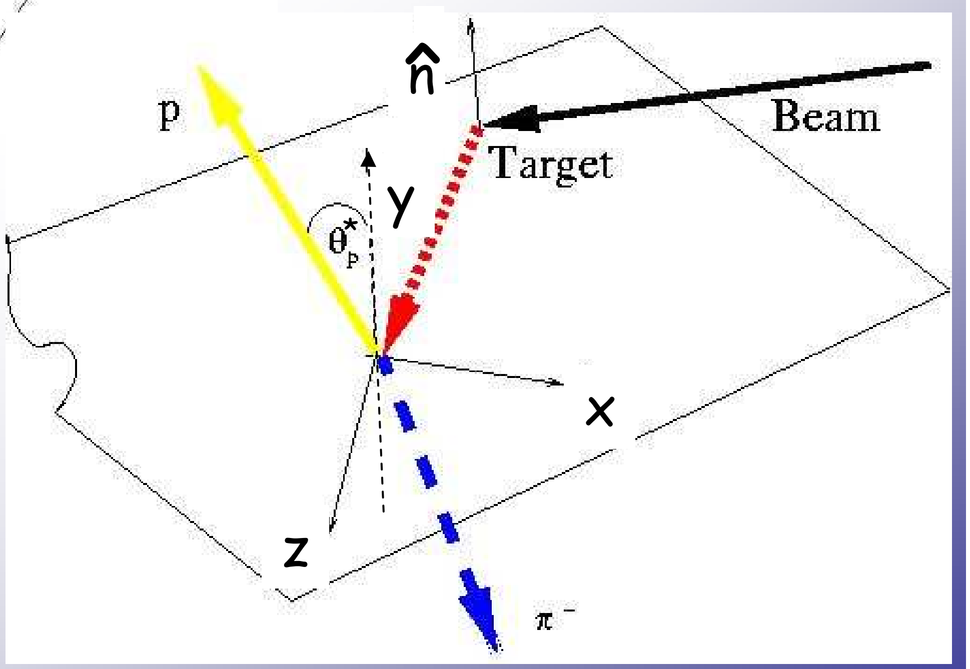
$$\alpha = \frac{p_{L+} - p_{L-}}{p_{L+} + p_{L-}}$$

Λ and $\bar{\Lambda}$ Polarization



Phys. Letter B 495 (2000) 49-54
Spin observables in $\bar{p}p \to \Lambda\bar{\Lambda}$ with a transverse initial state polarization

$$\hat{n} = \frac{p_{beam} \times p_{\Lambda}}{\left| p_{beam} \times p_{\Lambda} \right|}$$



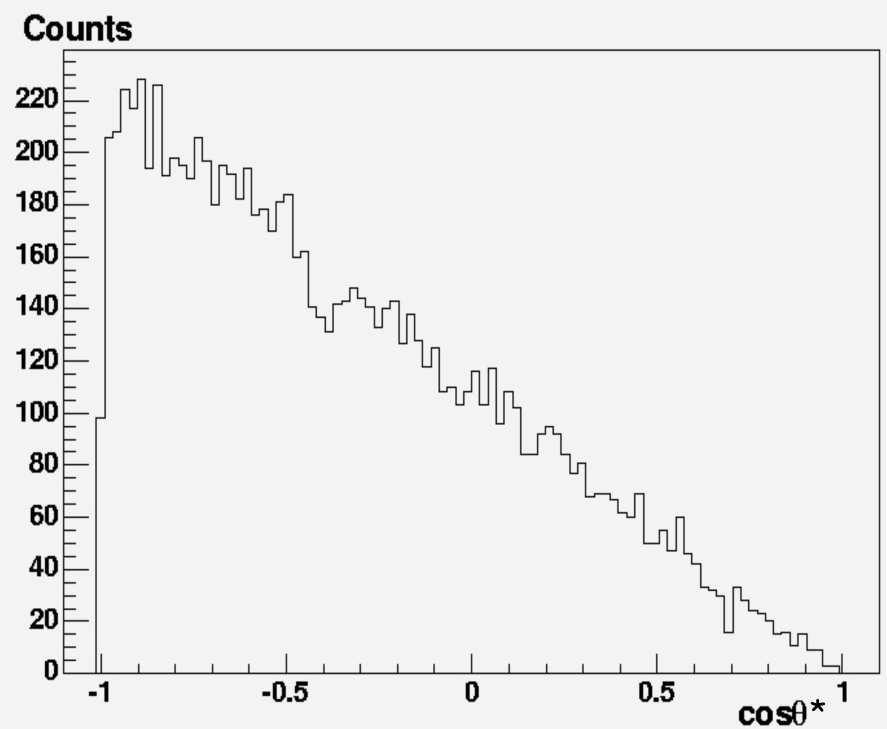
Transverse polarization of Λ and $\bar{\Lambda}$ produced inclusively in 99-00 years at Hermes

$$\frac{dN}{d\Omega} \propto \left(1 + \alpha_{\Lambda} P_{\Lambda} \cos\theta^{*}\right)$$

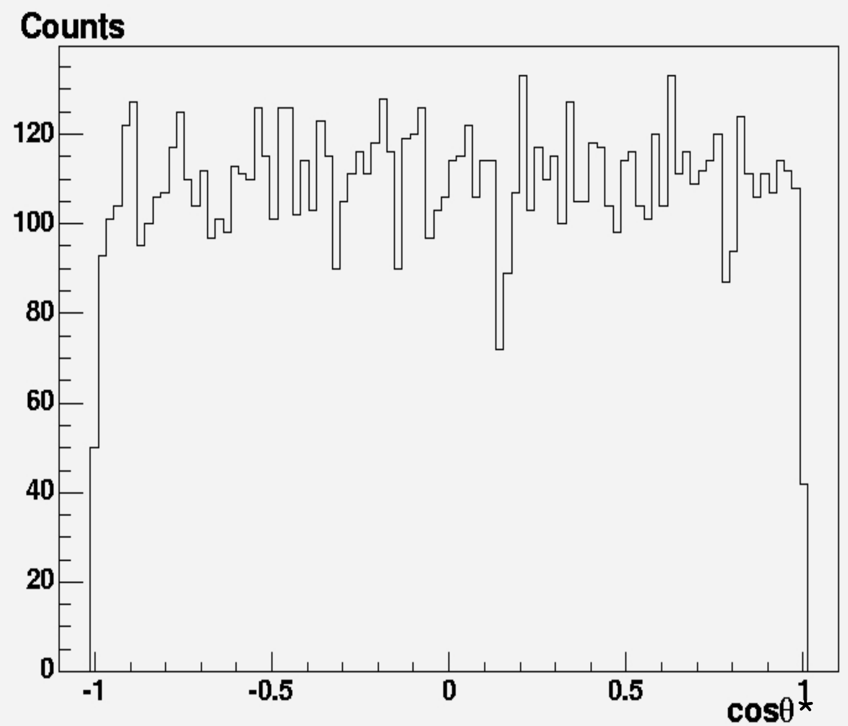
$$\alpha_{\Lambda} = 0.642$$

Generated polarization

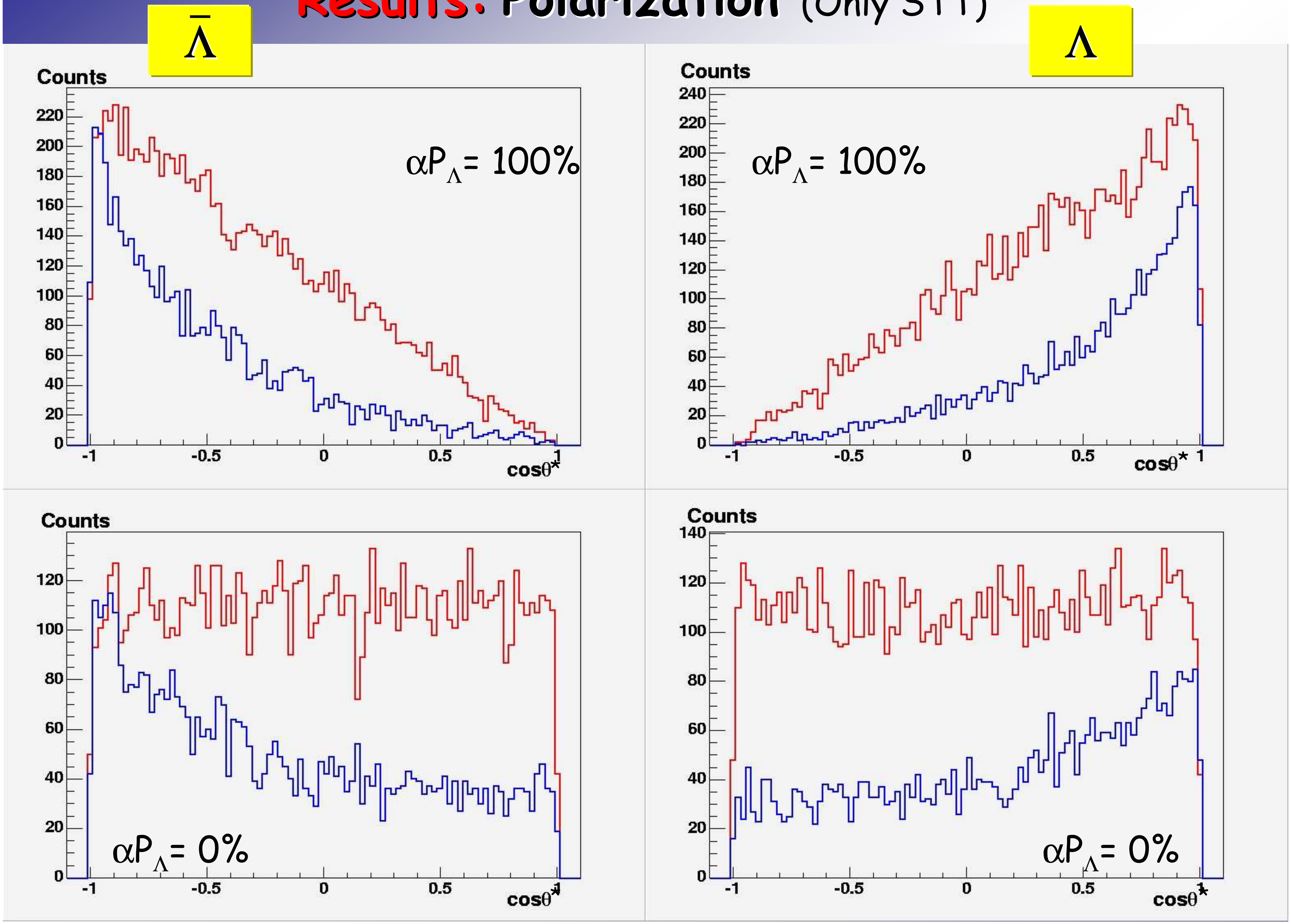
$\alpha_\Lambda P_\Lambda = 100\%$



$\alpha_\Lambda P_\Lambda = 0\%$



Results: Polarization (Only STT)



Summary

- HADES
  - First observation of hyperons at HADES in the channel pp -> $pK^+\Lambda$
  - Observed yield is factor 0.35 lower than expected, based upon extrapolation from η production
  - Comparison between real data and simulation
- PANDA
  - Investigation of PANDA performances for $p\bar{p}$ -> $\Lambda\bar{\Lambda}$ at different beam momentum 2.0, 4.0, 6.0, 7.7 GeV/c
  - Comparison of different tracking options for PANDA: STT and TPC
  - Results for polarization observables