JÜLICH
FORSCHUNGSZENTRUM

Final State Interactions and Polarization Observables in the Process $\vec{p}p \rightarrow pK^+\Lambda$

MESON 2012 | Matthias Röder for the COSY-TOF Collaboration

Motivation

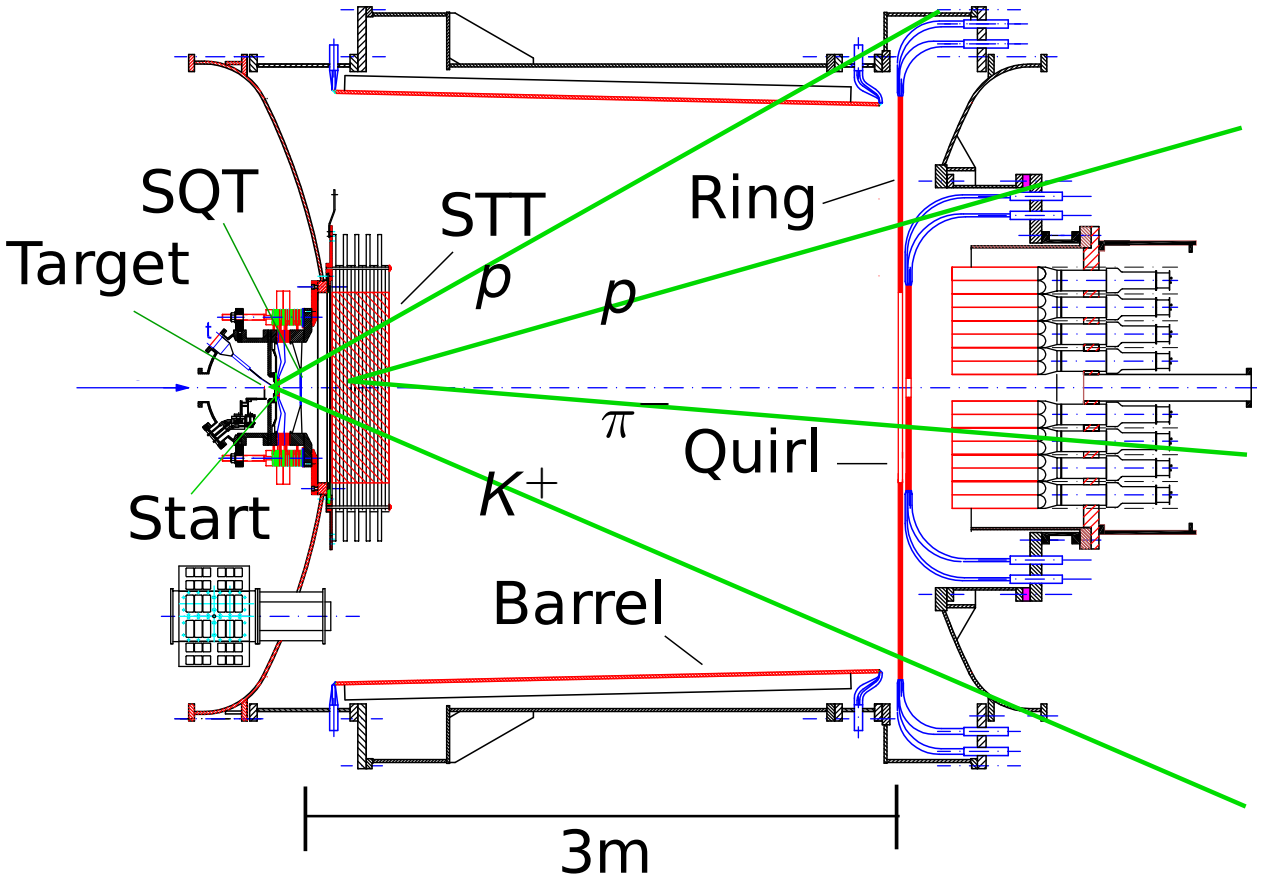
Final State Interactions

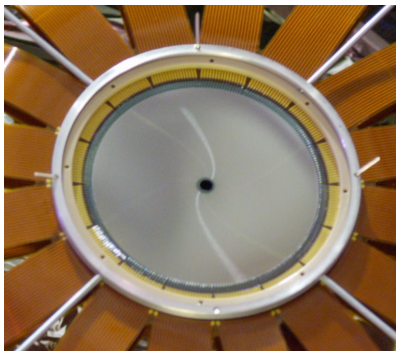
- Goal: Improve the yet scarce data on NY scattering
- Method: Polarized beam should allow for the determination of the spin resolved $p\Lambda$-scattering length Gasparyan et. al. Phys.Rev C69
- Deliver a fundamental parameter of NY interaction

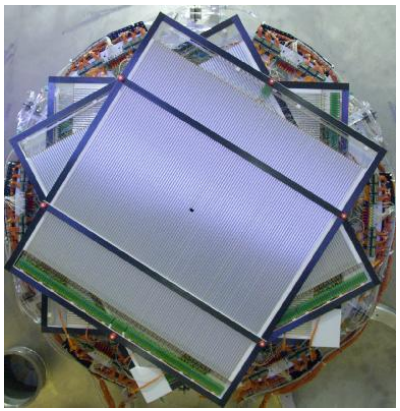
Λ Polarization Observables

- Goal: Study of the $pK^+\Lambda$ production mechanism
- Method: Polarized beam and self analyzing Λ decay allow to determine the Λ-depolarization
- Sensitive to Kaon or Pion exchange

The COSY-TOF Experiment

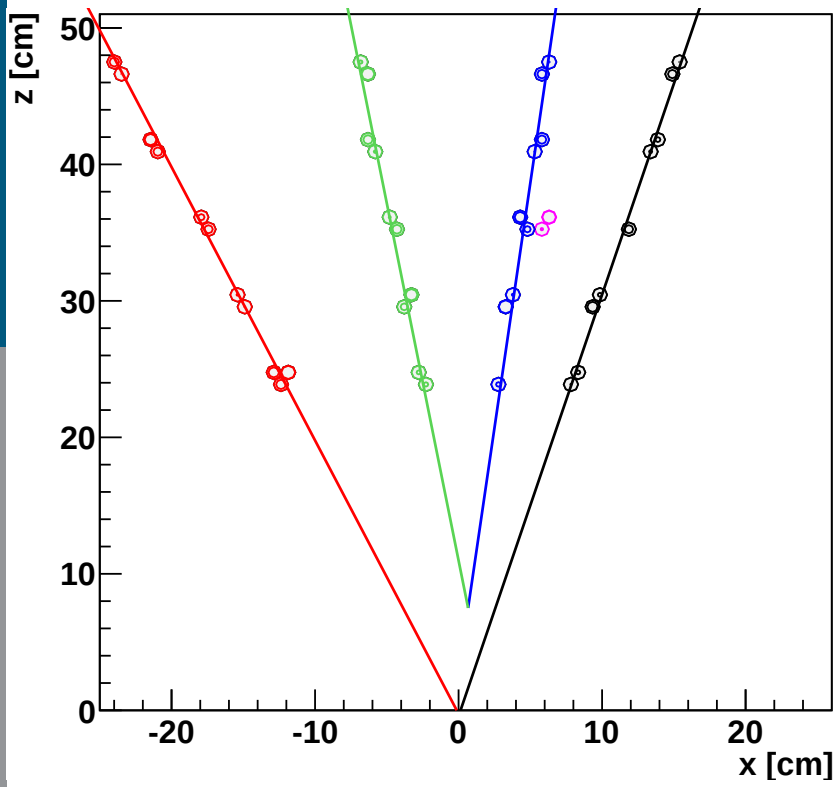


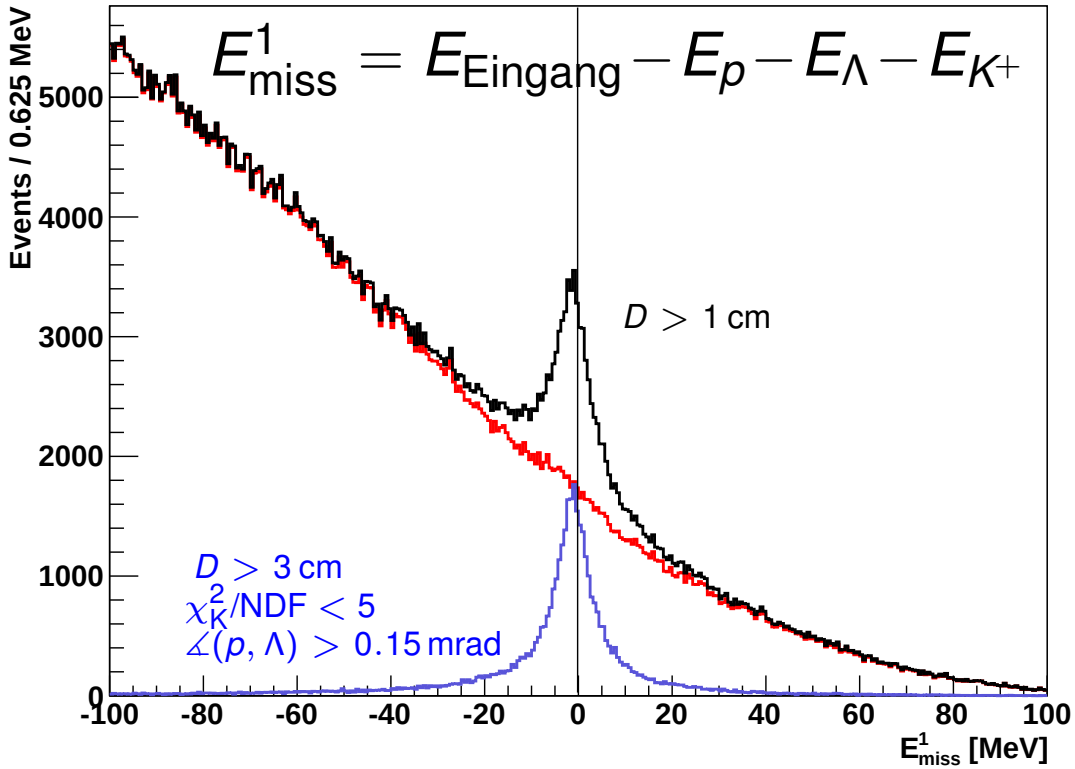




- Scintillators for timing and dE/dx measurement
- Straw Tube Tracker (STT) and Silicon Quirl (SQT) for precise track reconstruction

$pK^+\Lambda$ Event Reconstruction and Selection

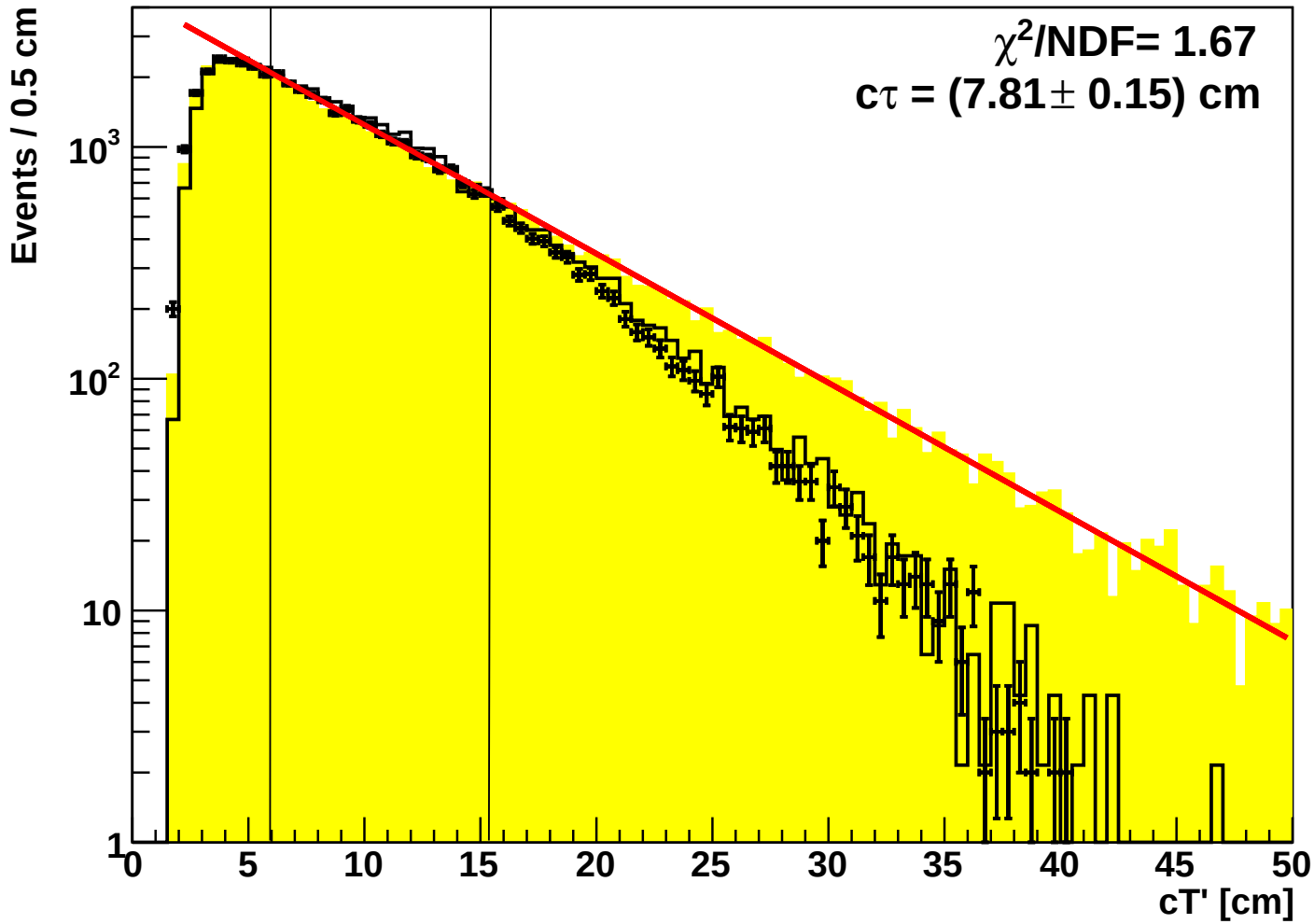




- Straw drift times $\xrightarrow{\textit{calibration}}$ track-wire distances
- Delayed vertex with primary vertex in decay plane
- Complete kinematic fit to track-wire distances

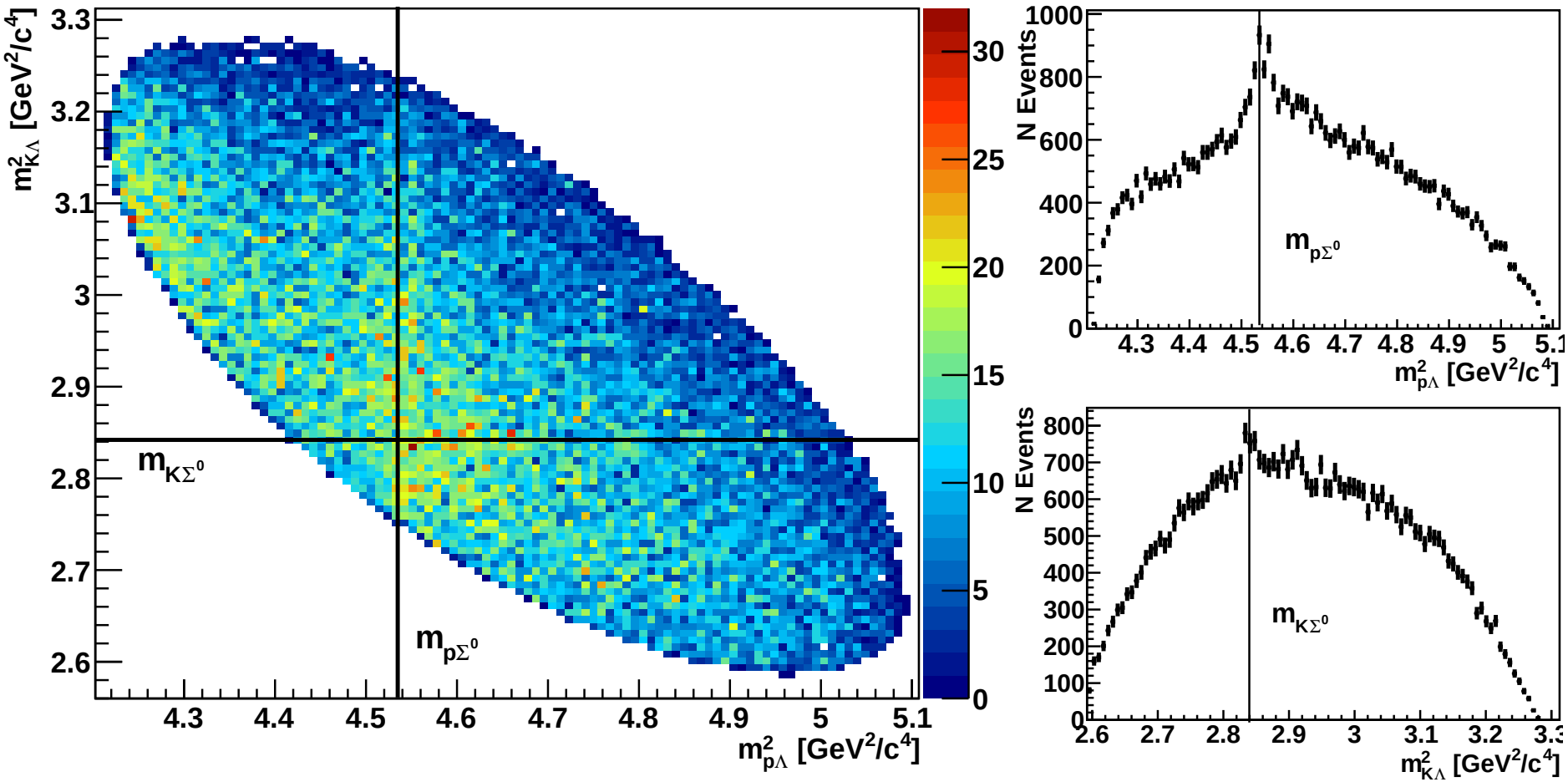
$\Rightarrow$ 42 000 events from 6 days beam time
(MC study: 20% reconstruction efficiency)

Event Sample Check: Λ Decay Length



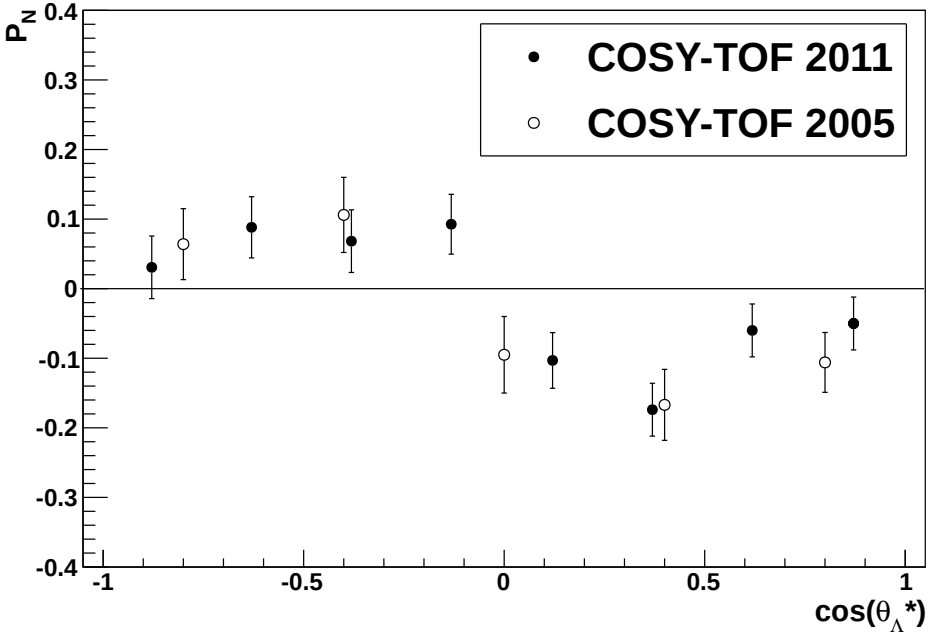
- Data and MC in good agreement
- Correct lambda lifetime ⇒ ”low” background contamination

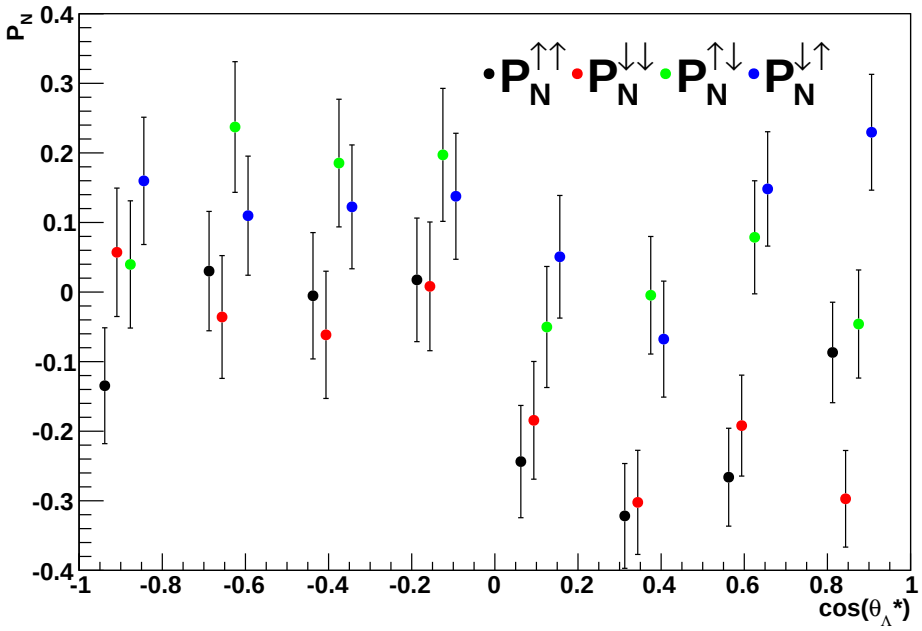
$pK^+\Lambda$ Dalitz Plot $p_{beam} = 2.95\,GeV/c$



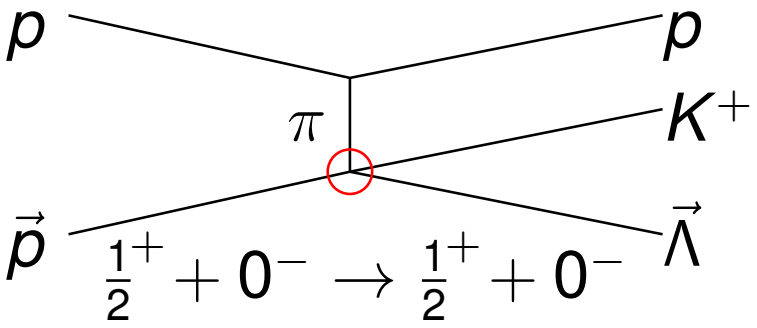
- Full kinematic acceptance
- Cusp structure at $p\Sigma^0$ threshold in $m_{p\Lambda}$!
- Cusp structure at $K\Sigma^0$ threshold in $m_{K\Lambda}$?
- FSI and N^*-resonances can explain structure underneath

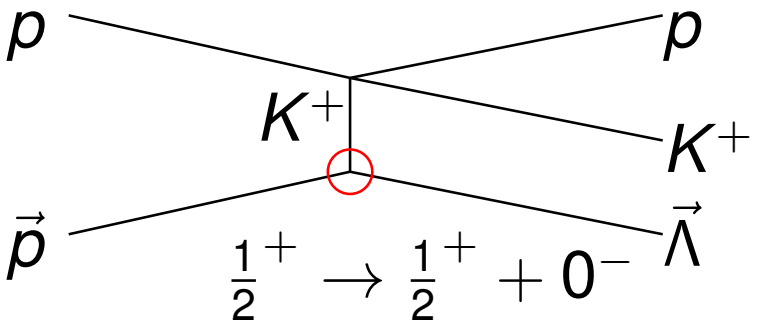
Λ Polarization P_N





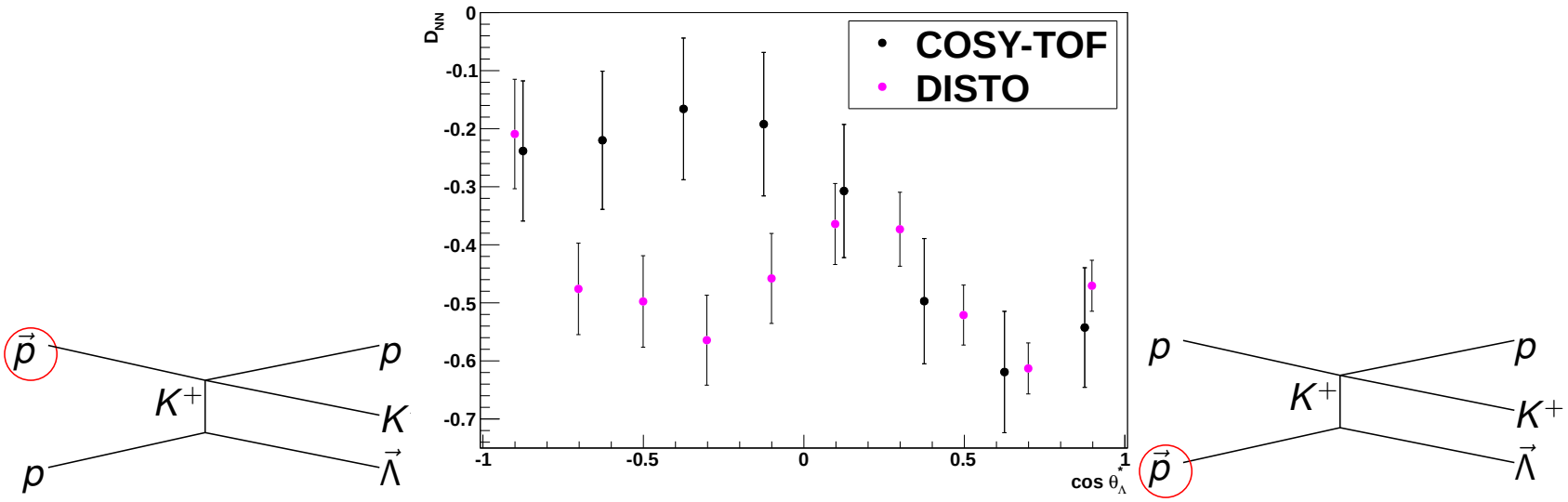
- Self analyzing Λ decay ⇒ Λ polarization (P_N)
- 61% polarized beam ⇒ Λ depolarization (D_{NN}):





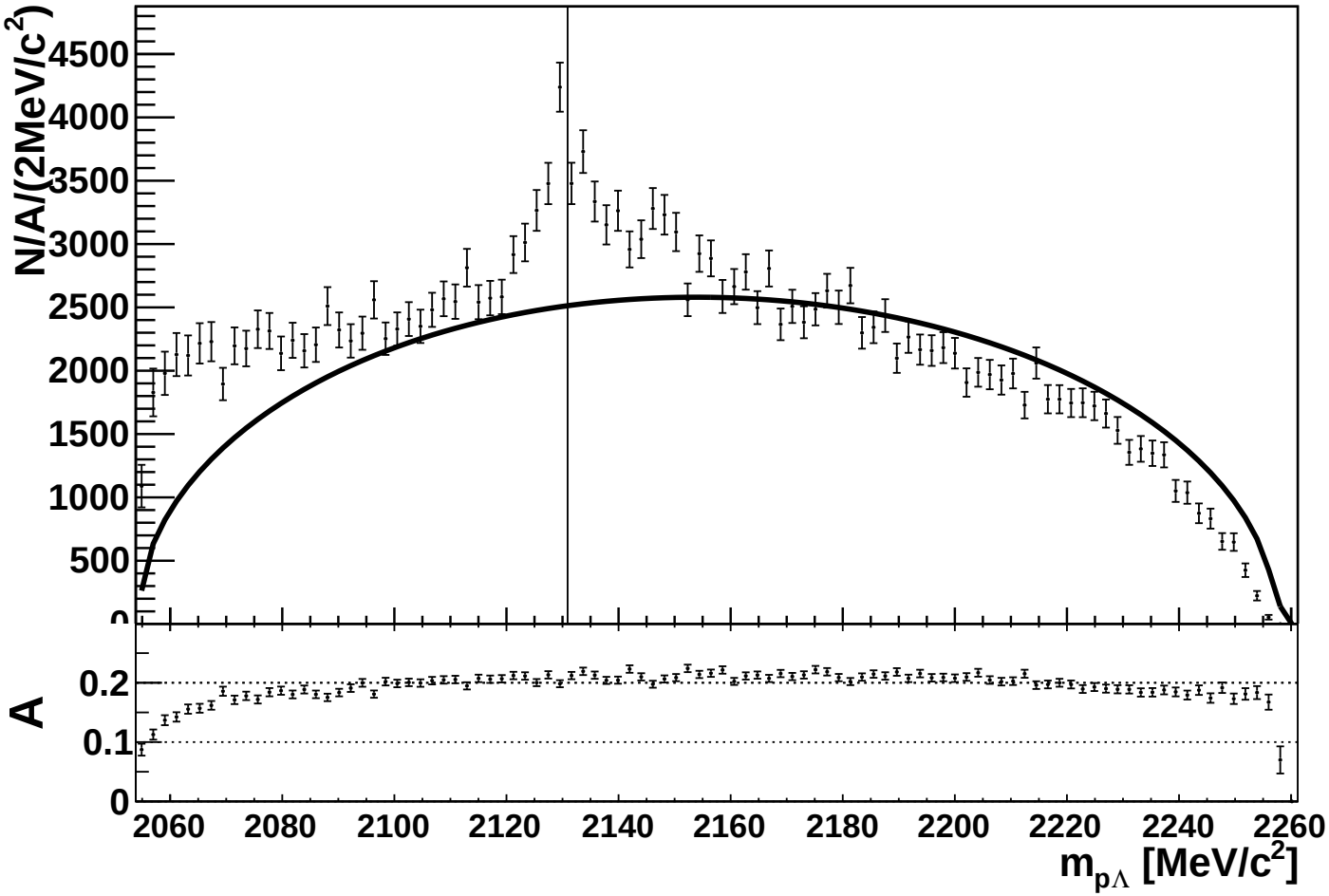
⇒ Spin-Flip

Λ Depolarization



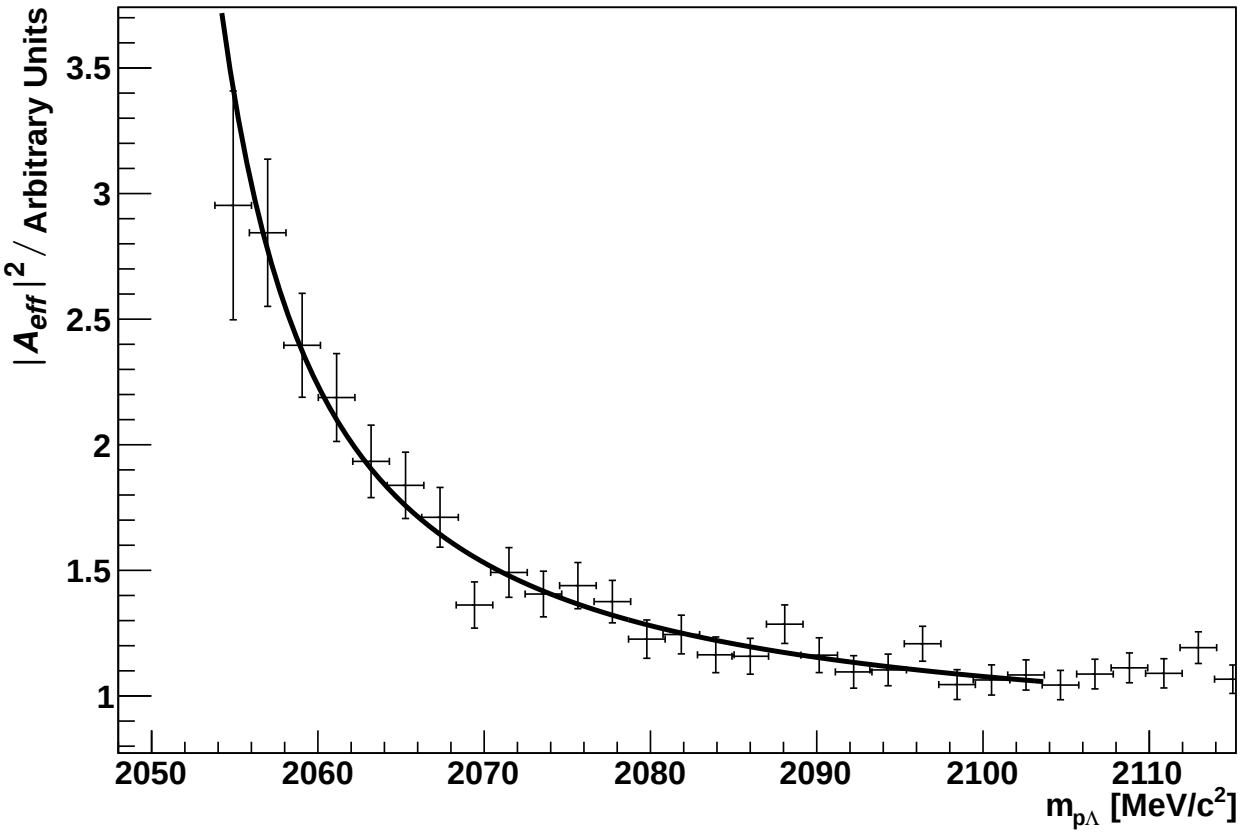
- D_{NN} forward agrees with DISTO M.Maggiora Nucl.Phys. A691
  - ⇒ Kaon exchange dominates production process in the Laget Model (N^*-Resonances neglected)
- Differences for backward Λs
  - Trend to zero expected from gluon-exchange models
- Better statistics needed for competetive results

pΛ Invariant Mass Spectrum



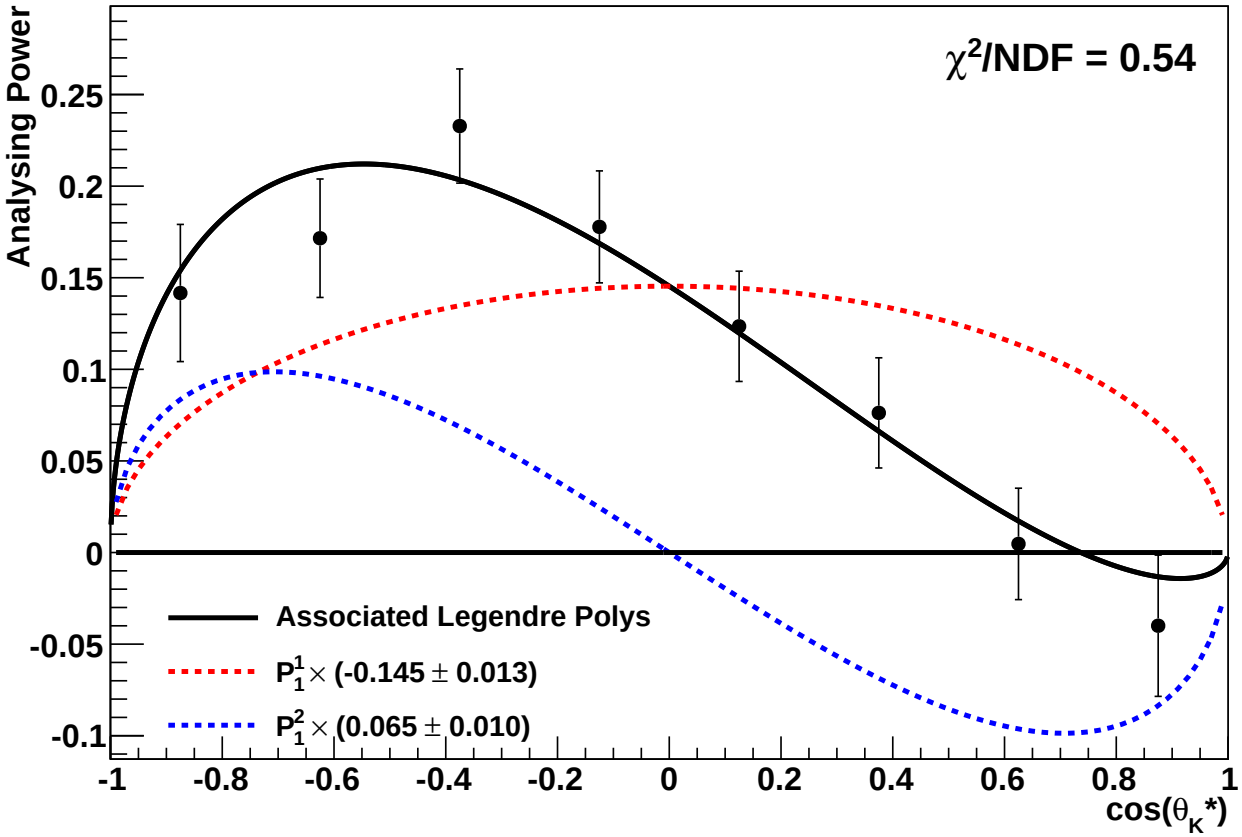
- Resolution $\sigma \approx 1.1\,\mathrm{MeV}/c^2$
- Cusp at $p\Sigma^0$ threshold (shape?, position?, strength?)
- pΛ final state interaction at low $m_{p\Lambda}$

pΛ Final State Interactions



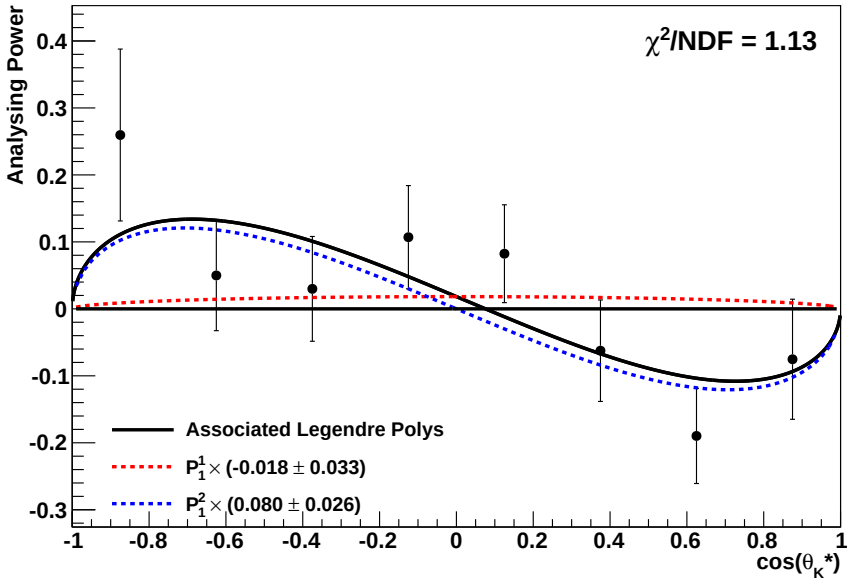
- $\frac{1}{|\vec{p}_p - \vec{p}_\Lambda|} \frac{d\sigma^2}{dm_{p\Lambda} d\Omega} = |A_{eff}(m_{p\Lambda})|^2 \propto$ effective pΛ scattering length
- Fit the shape of the effective scattering amplitude
  $\Rightarrow$ Effective pΛ scattering length $a = -1.28 \pm 0.11 \pm 0.3\ fm$,
- Idea: $|A_t|^2 \propto K^+$ P wave (in FSI region)

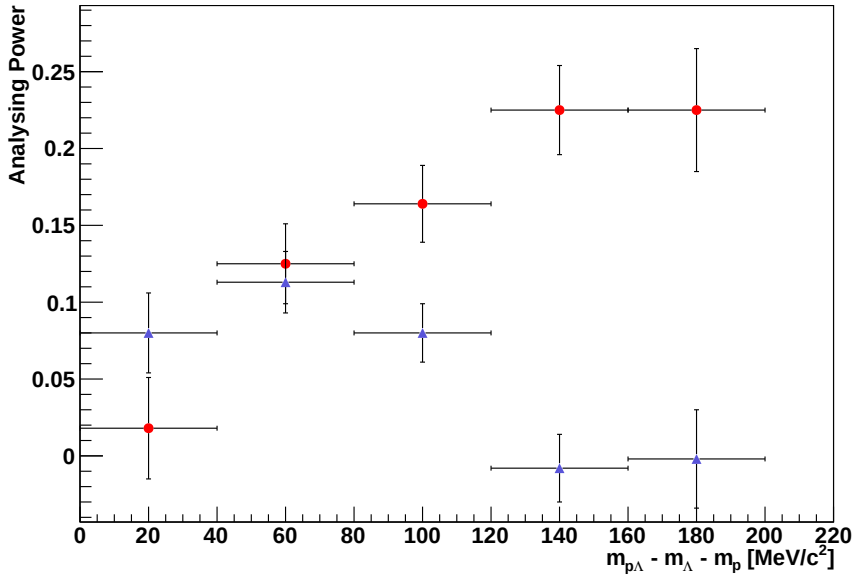
K^+ Analyzing Power



- Kaon analyzing power for full $m_{p\Lambda}$ range
- Partial wave analysis with symmetric (S*P waves) (red) and asymmetric (S*D waves) (blue) contributions
- Symmetric part only from $p\Lambda$ spin triplet scattering
  $\Rightarrow$ Use for extraction of spin triplet scattering length

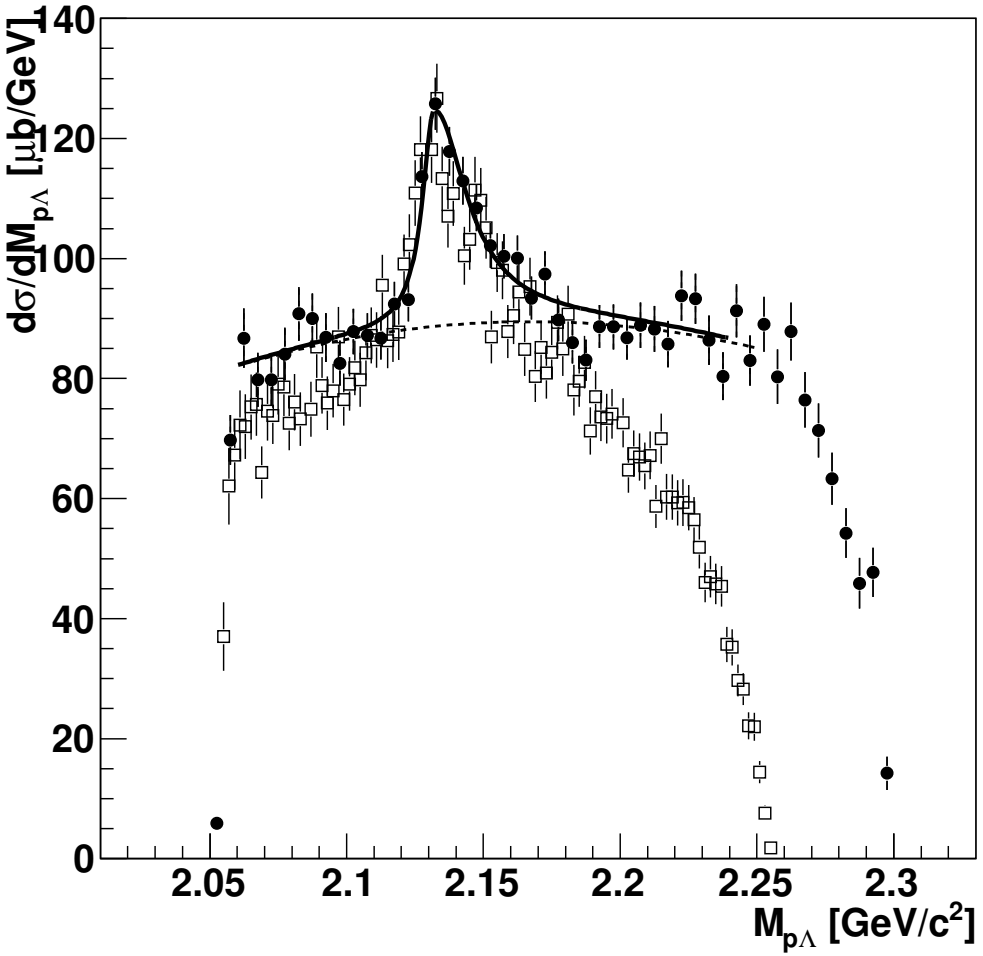
K^+ Analyzing Power: $m_{p\Lambda}$ Dependence





- $m_{p\Lambda} < m_0 + 40\,\mathrm{MeV}/c^2$: Analyzing power $< 11\%$ (3σ)
  $\Rightarrow$ High statistics needed for scattering length determination
- This dependence on $m_{p\Lambda}$ is unexpected
  - Consistent with no spin triplet scattering at all [HIRES]
  - Other explanation: absence/cancellation of P wave
- Measurement with better statistics is important

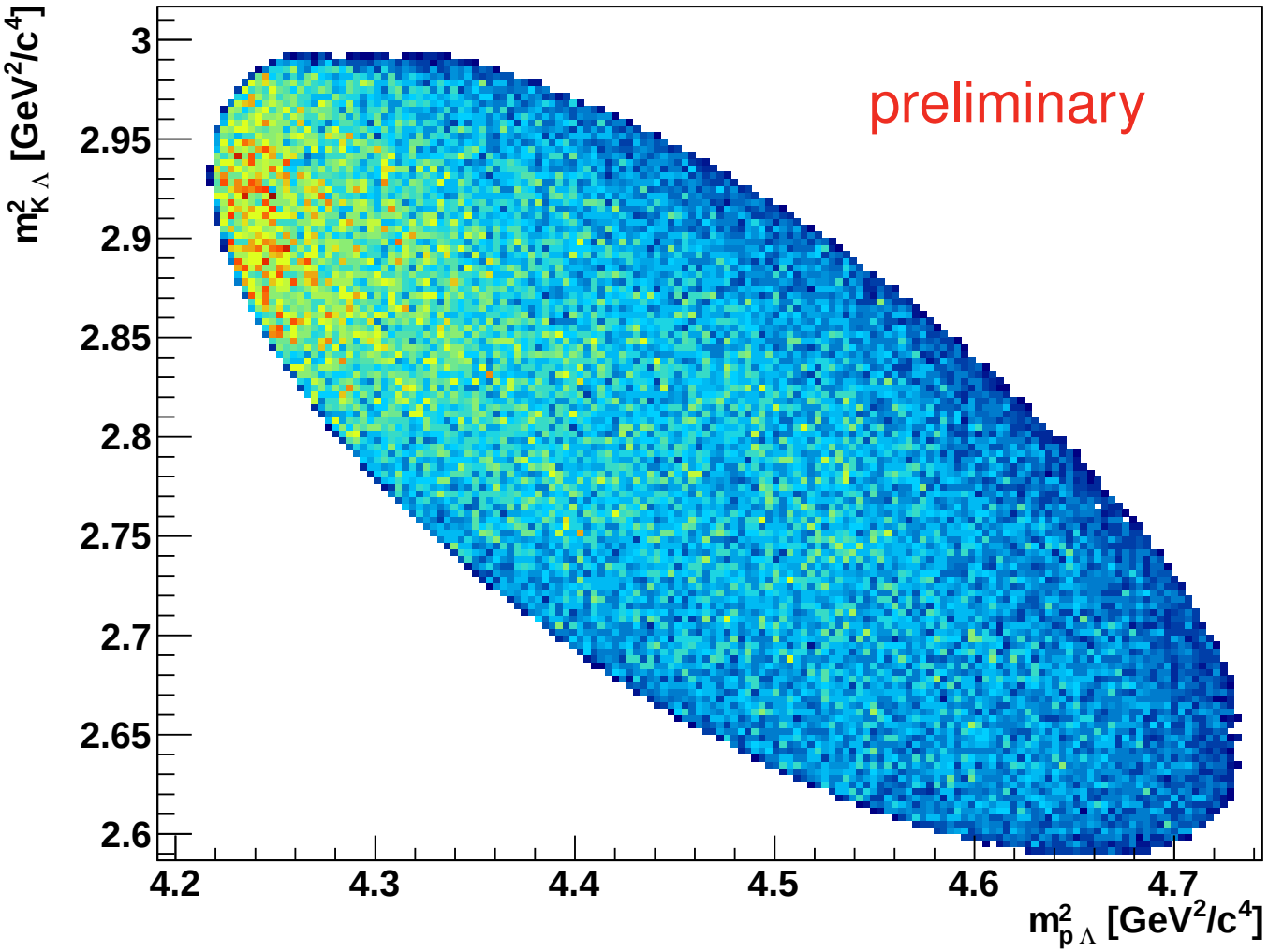
Cusp at $p_{beam} = 3.049 GeV/c$ Old Detector Setup



E. Doroshkevich

- Different detector setup and independent Analysis by K. Ehrhardt (thesis)
- Inferior resolution but clear confirmation of Cusp structure
- Paper with focus on Cusp in preparation

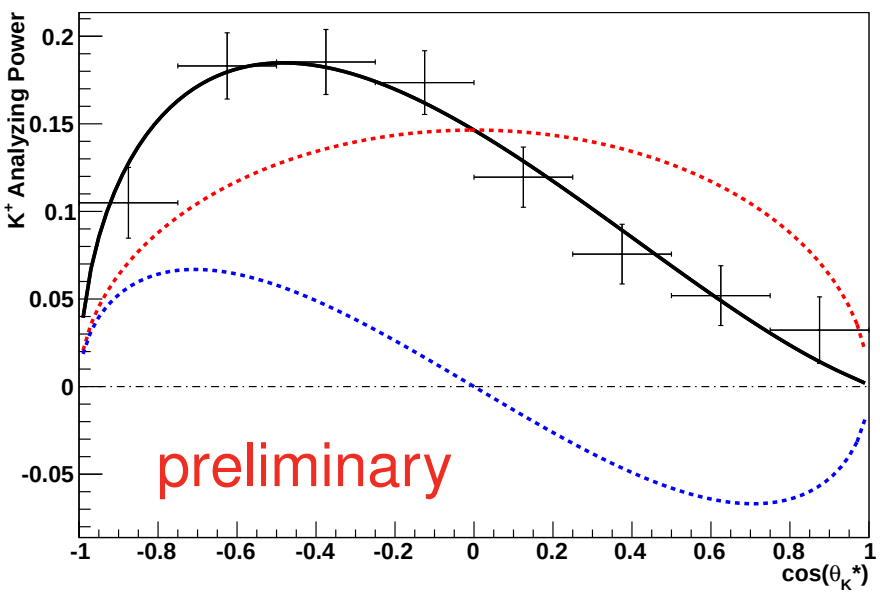
$pK^+\Lambda$ Dalitz Plot $p_{beam} = 2.70\ GeV/c$

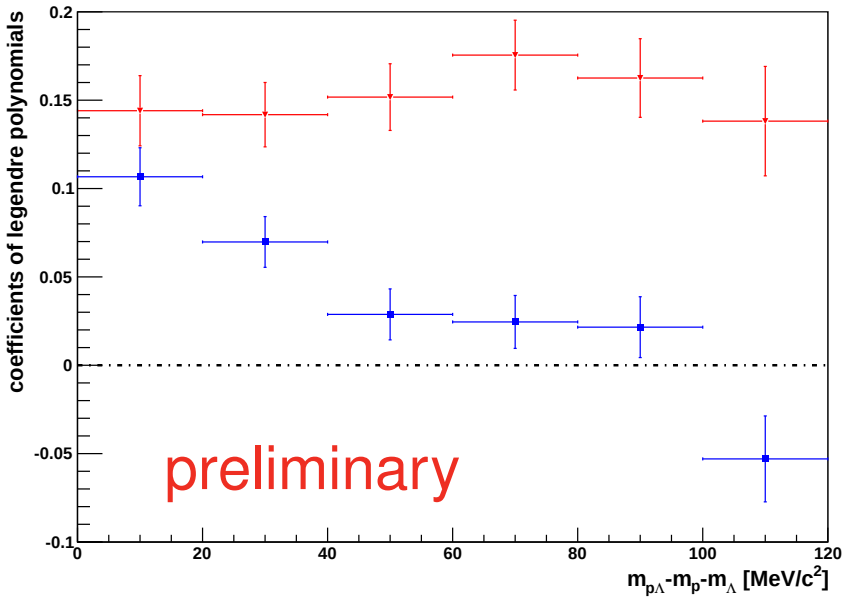


F. Hauenstein

- 100.000 of 200.000 events analyzed
- FSI and phasespace dominate
  - ⇒ Cusp strength energy dependent (Not a phasespace effect)
  - ⇒ Ideal beam momentum for FSI studies

K^+ Analyzing Power: $m_{p\Lambda}$ Dependence





- $m_{p\Lambda} < m_0 + 20\,\mathrm{MeV}/c^2$: Analyzing power $\approx 15\%$

$\Rightarrow$ scattering length determination in progress

- Dependence on $m_{p\Lambda}$ is flat inside statistical limits
  - $\Rightarrow$ Consistent with only spin triplet scattering
- Factor 2 more events available for analysis

Conclusions and Outlook

Conclusions

- Straw Tube Tracker: 20% reconstruction efficiency for the $pK\Lambda$ final state and $\sigma \approx 1\,\mathrm{MeV}/c^2$ resolution in $m_{p\Lambda}$
- Determination of Λ polarization observables especially the Λ depolarization
- Determination of the effective $p\Lambda$ scattering length unexpected behavior of K^+ analyzing power discovered

Outlook

- 6 weeks beam time by the end of the year
  - 1 week with $p_{\mathrm{beam}} = 2.95\,\mathrm{GeV}/c^2$
  - 4 weeks with highest possible p_{beam} ($\approx 3.3\,\mathrm{GeV}/c^2$)
- Advanced studies of the cusp structure
- Determination of the spin-triplet scattering for $2.7\,\mathrm{GeV}/c^2$

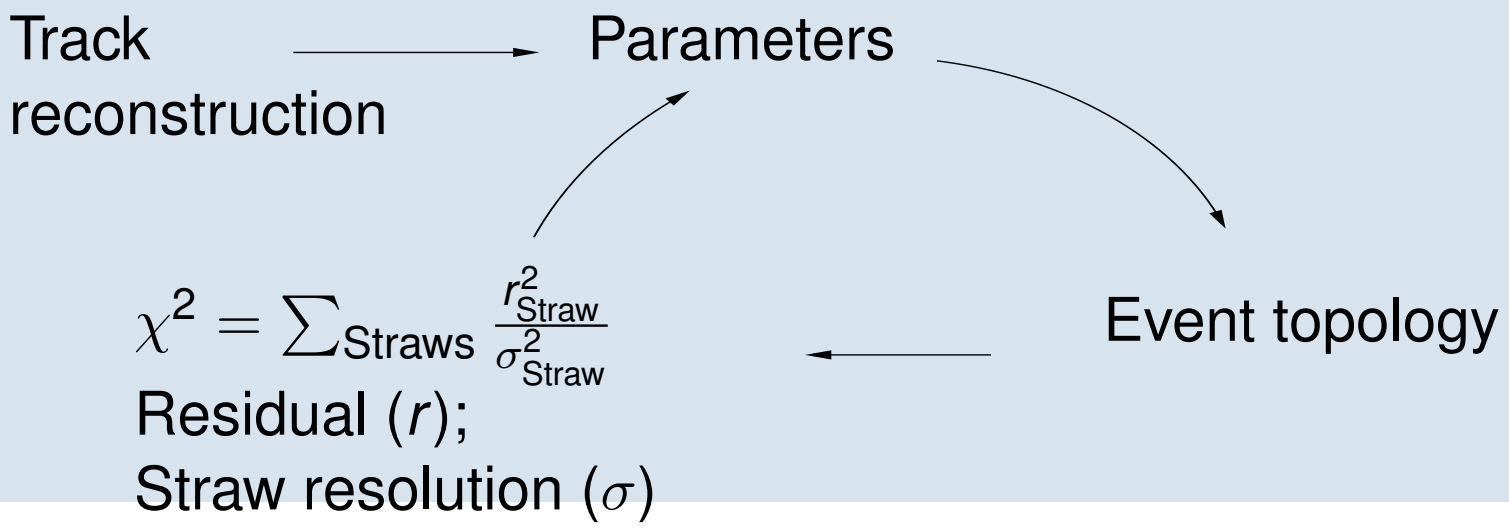
BACKUP

$pK^+\Lambda$ Event Reconstruction

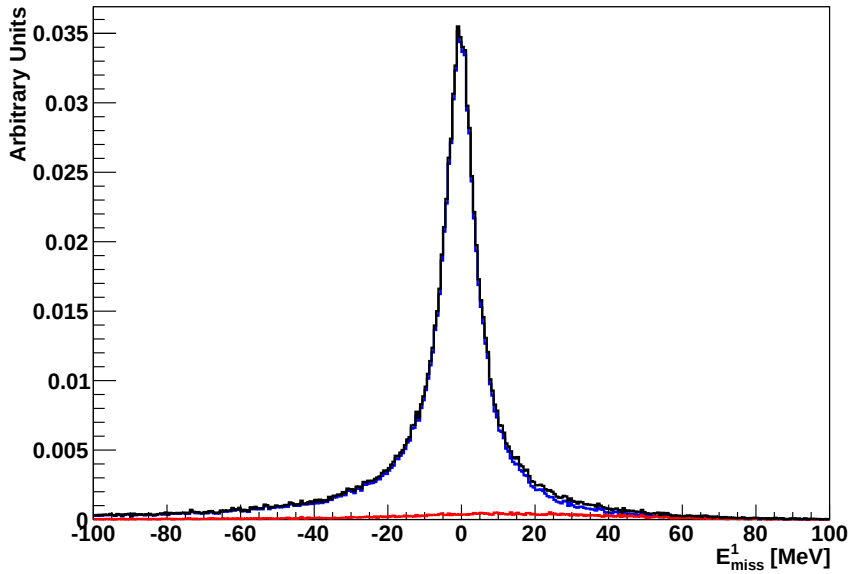
Parametrization $pp \to pK^+\Lambda \to pK^+\pi^- p$ (11 parameter):

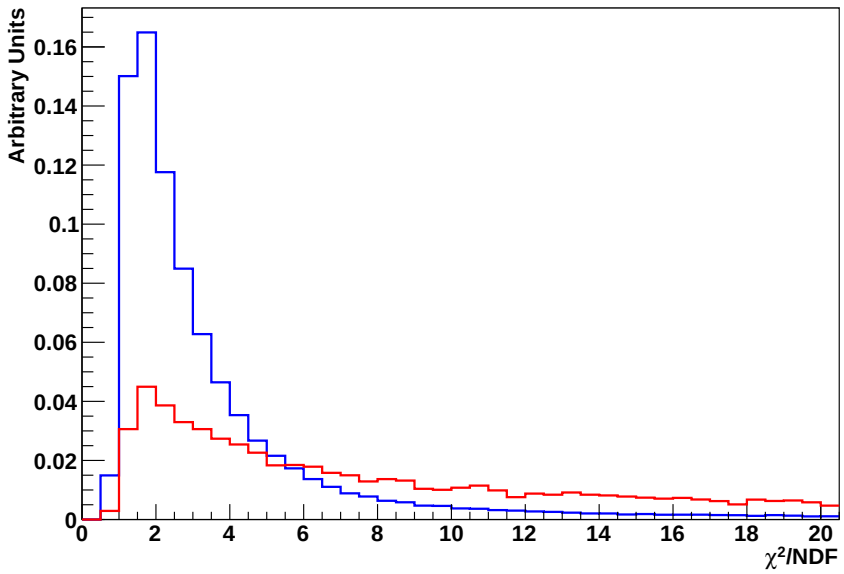
- Primary vertex position v_x, v_y, v_z
- $\{pp\} \to K^+\{p\Lambda\}$: K^+ in CMS $\theta^*_{K^+}, \phi^*_{K^+}$; $m_{p\Lambda}$
- $\{p\Lambda\} \to p\Lambda$: p in the $\{p\Lambda\}$ system $\theta^{**}_p, \phi^{**}_p$
- $\Lambda \to p\pi^-$: Λ decay length s_Λ; Pion in Λ-System $\theta^{***}_\pi, \phi^{***}_\pi$

Kinematic Fit (MINUIT)



$pK^+\Sigma^0$ Background Study





- $pK^+\Sigma^0$ is broadly distributed under the signal peak
- χ^2 of kinematic fit reduces contamination to $< 5\%$