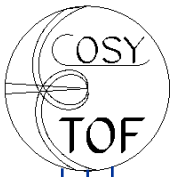


Pentaquark 05

International Workshop, October 20 -22, 2005, Jefferson Lab, U.S.

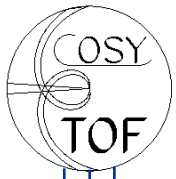
Improved search of COSY-TOF on Θ⁺

Wolfgang Eyrich

Physikalisches Institut, University of Erlangen-Nuremberg, Germany

for the COSY-TOF collaboration

supported by German BMBF and Forschungszentrum Jülich



Content

- Introduction
- The COSY-TOF experiment
- Evidence on Θ^+ from pp → $\Sigma^+ K^0 p$
- Ongoing and new activities
- Outlook

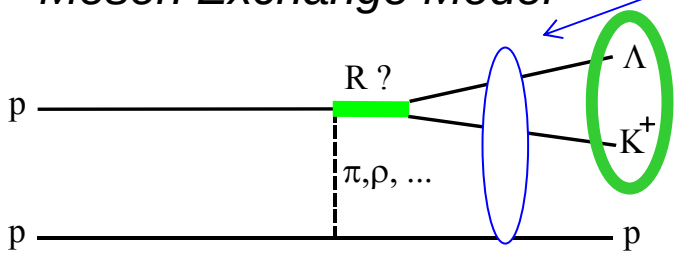
Introduction

Strangeness production at COSY-TOF: pN → KYN

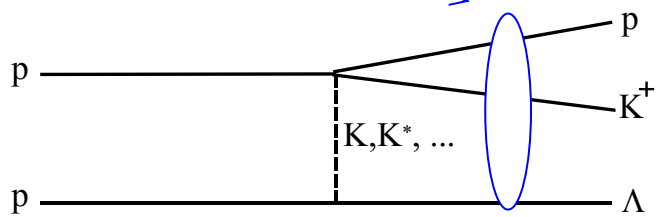
Information: dynamics + structure ⟶ degrees of freedom

different reaction channels : N = p, n Y = Λ, Σ^0, Σ^+, Σ^-

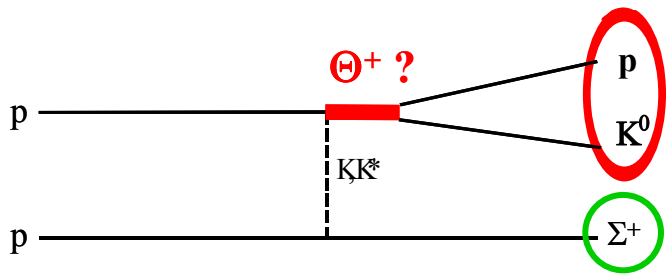
Meson Exchange Model



+ final state interaction



Search for exotic Θ+ ⟷



Introduction

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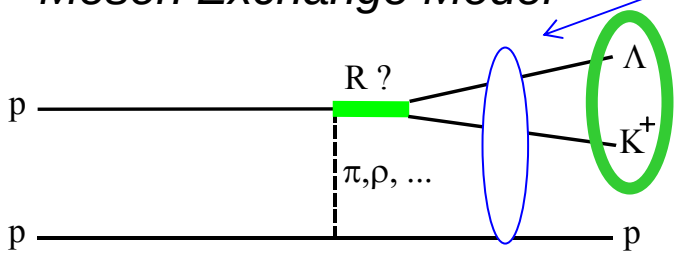
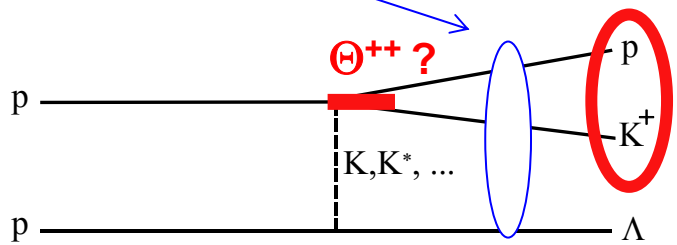
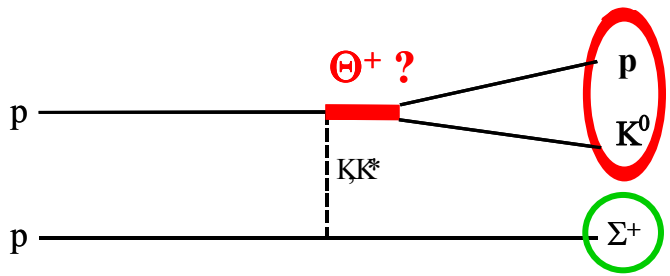
Meson Exchange Model



final state interaction



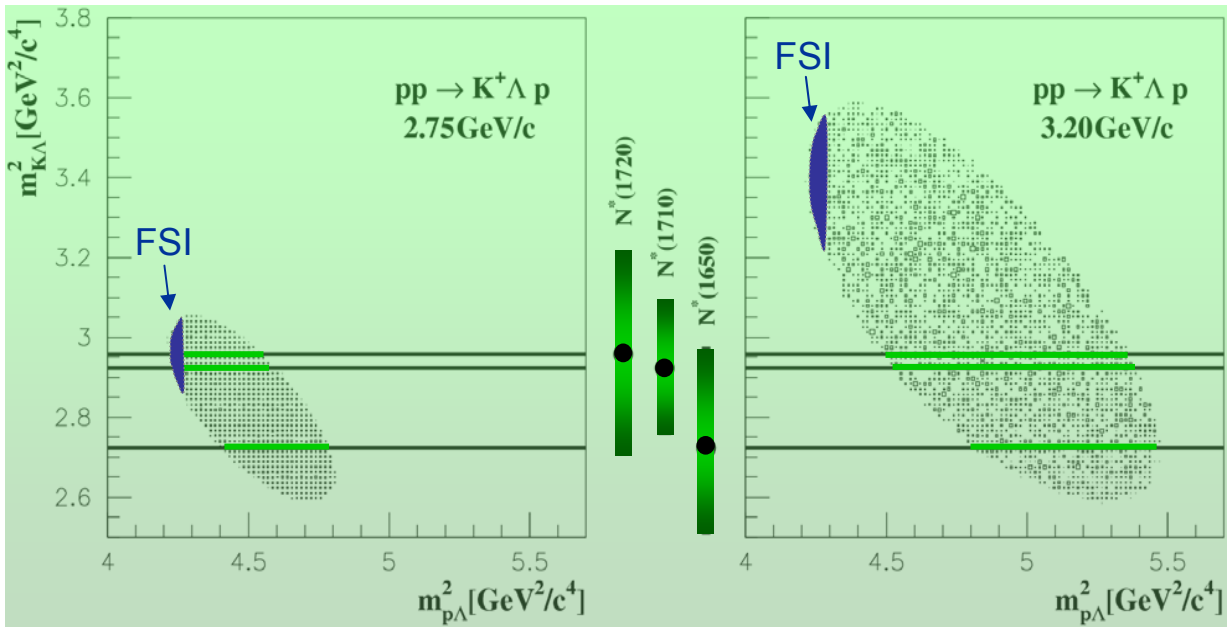
Search for exotic Θ+ ⟷



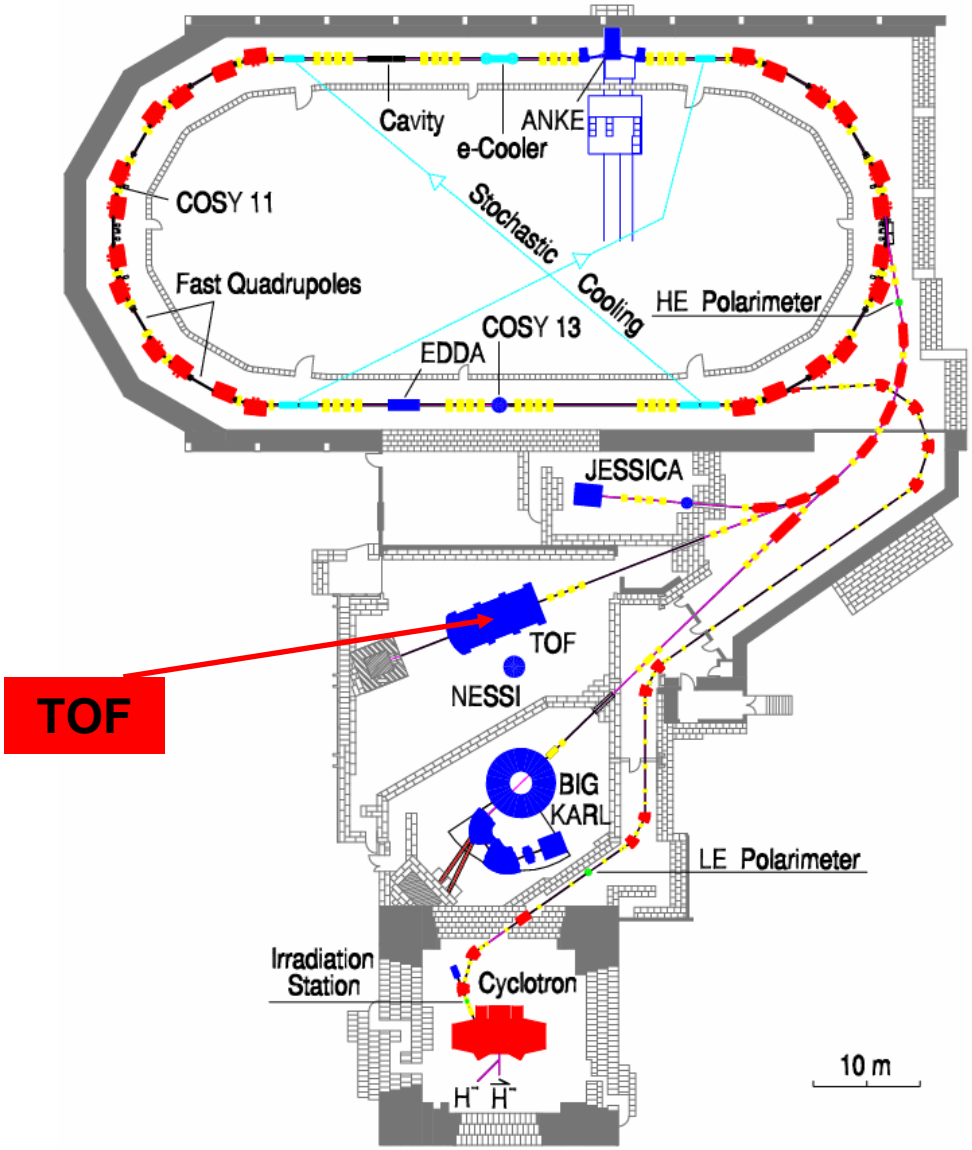
Introduction

Strangeness production at COSY-TOF:

- exclusive observables
- full phase-space → Dalitz Plots
- polarization: Hyperon-polarization, polarized beam, → polarized target
- threshold region → only few partial waves, no Y*, strangeness tagging



COSY - Facility



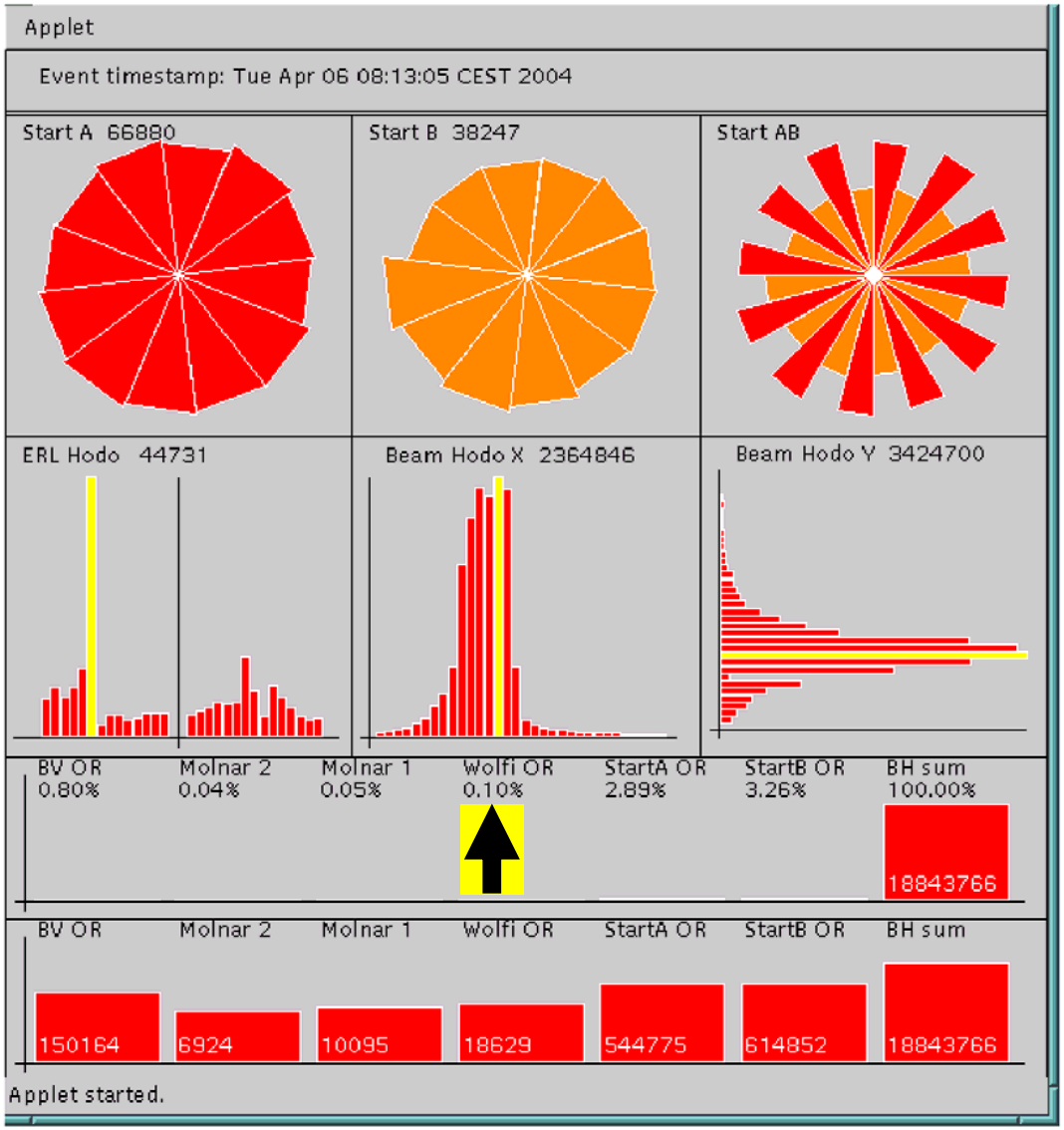
Cooler Synchrotron Jülich

Circumference: 180 m

Phase space cooling: electron and stochastic

Beam momentum: maximum: 3.6 GeV/c

COSY - beam



Beam-Quality

Veto-detector

with 2 mm hole

0.1% intensity

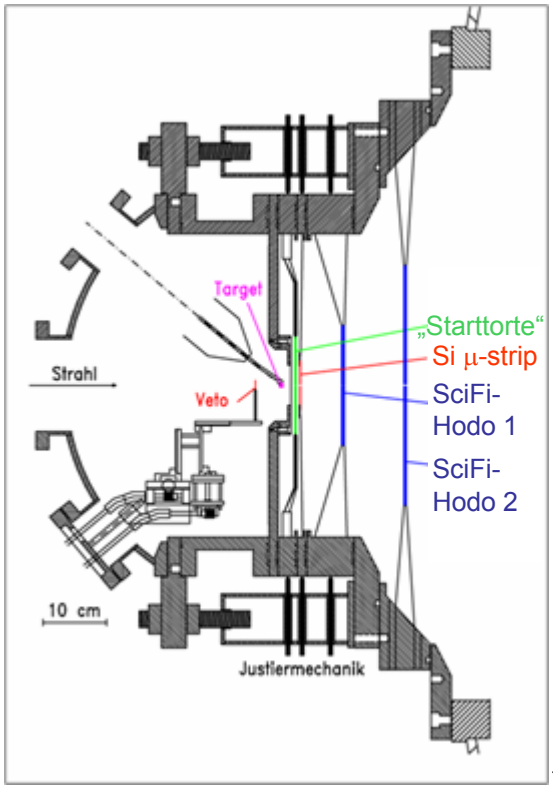
Beam-Intensity

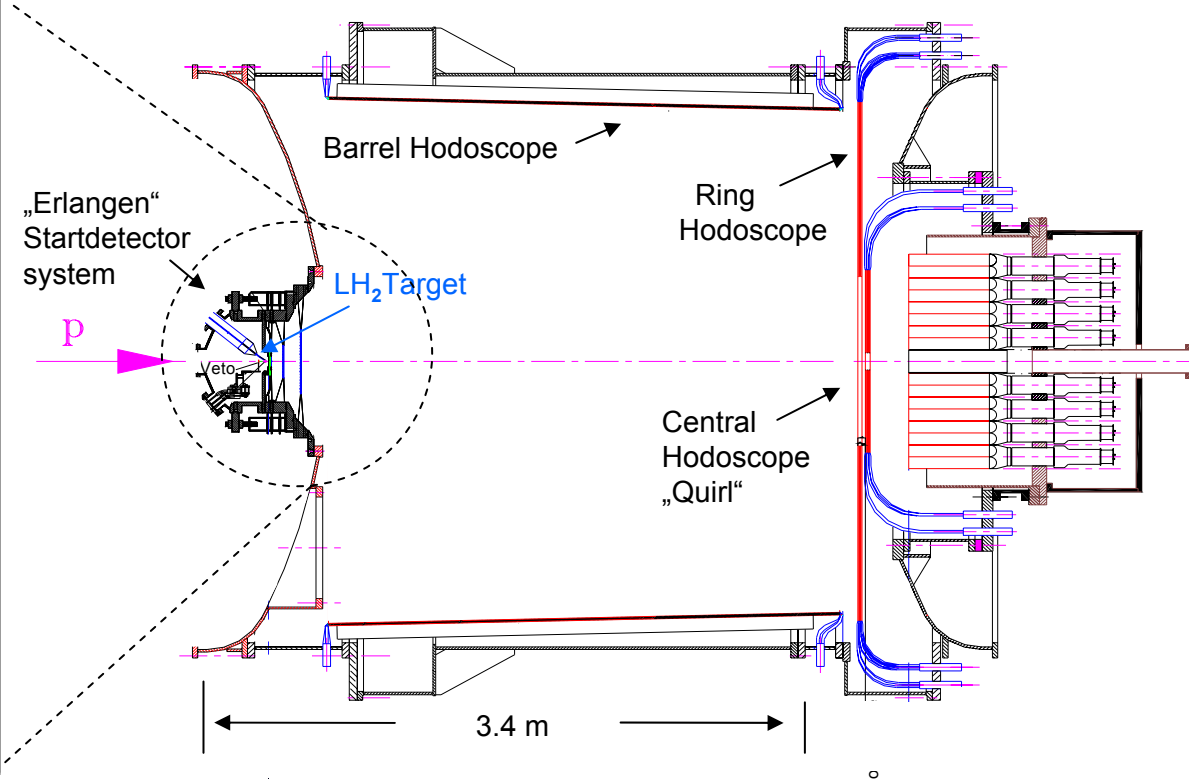
used

1 - 3 x 10^7 p/s

COSY - TOF

Large-angle Time-of-Flight spectrometer (modular vacuum vessel)





Start detector system → vertex reconstruction

designed for strangeness production

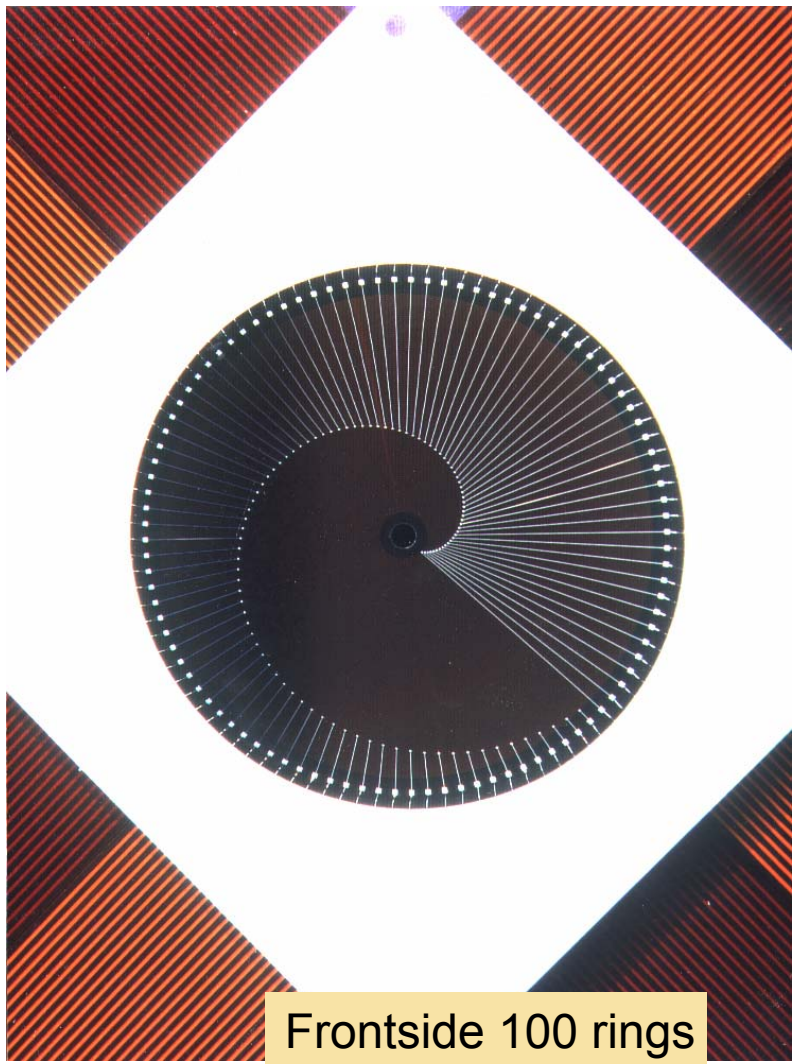
$pp \rightarrow \Lambda K^+p$, Σ^+K^0p, Σ^0K^+p, Σ^+K^+n, $pn \rightarrow \Lambda K^0p$, ...

COSY-TOF - Stop-Detector

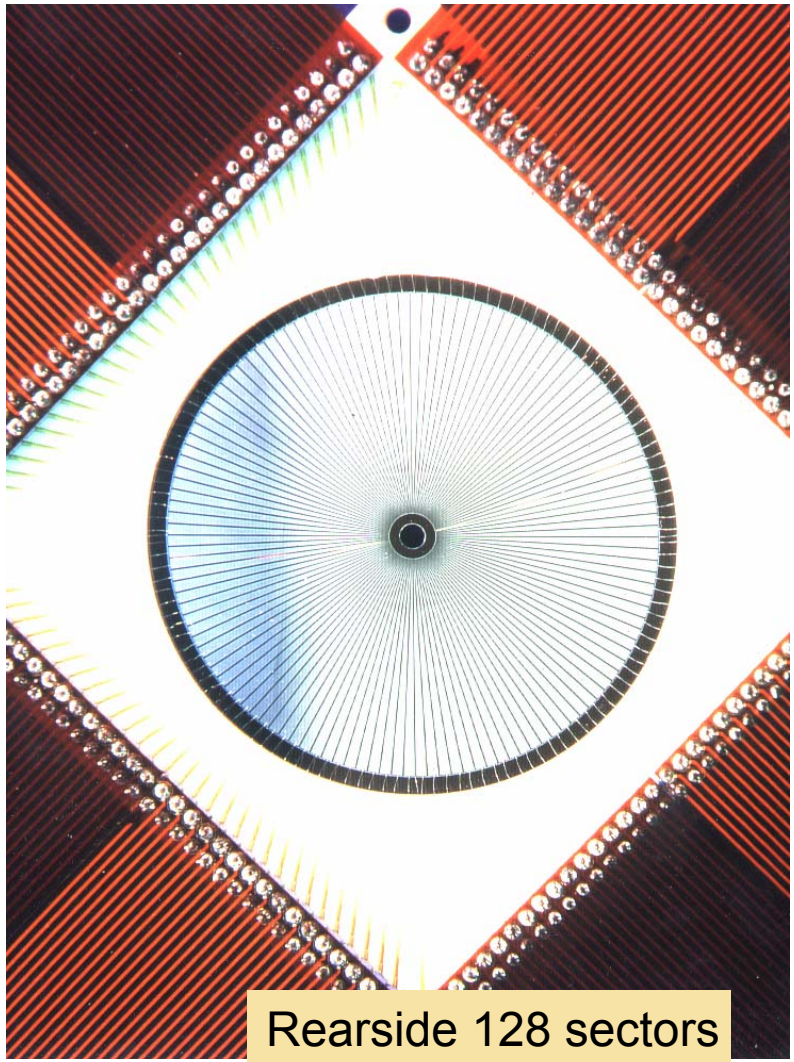
TOF

„Quirl“

„Erlangen Start Detector“: Ring microstrip detector

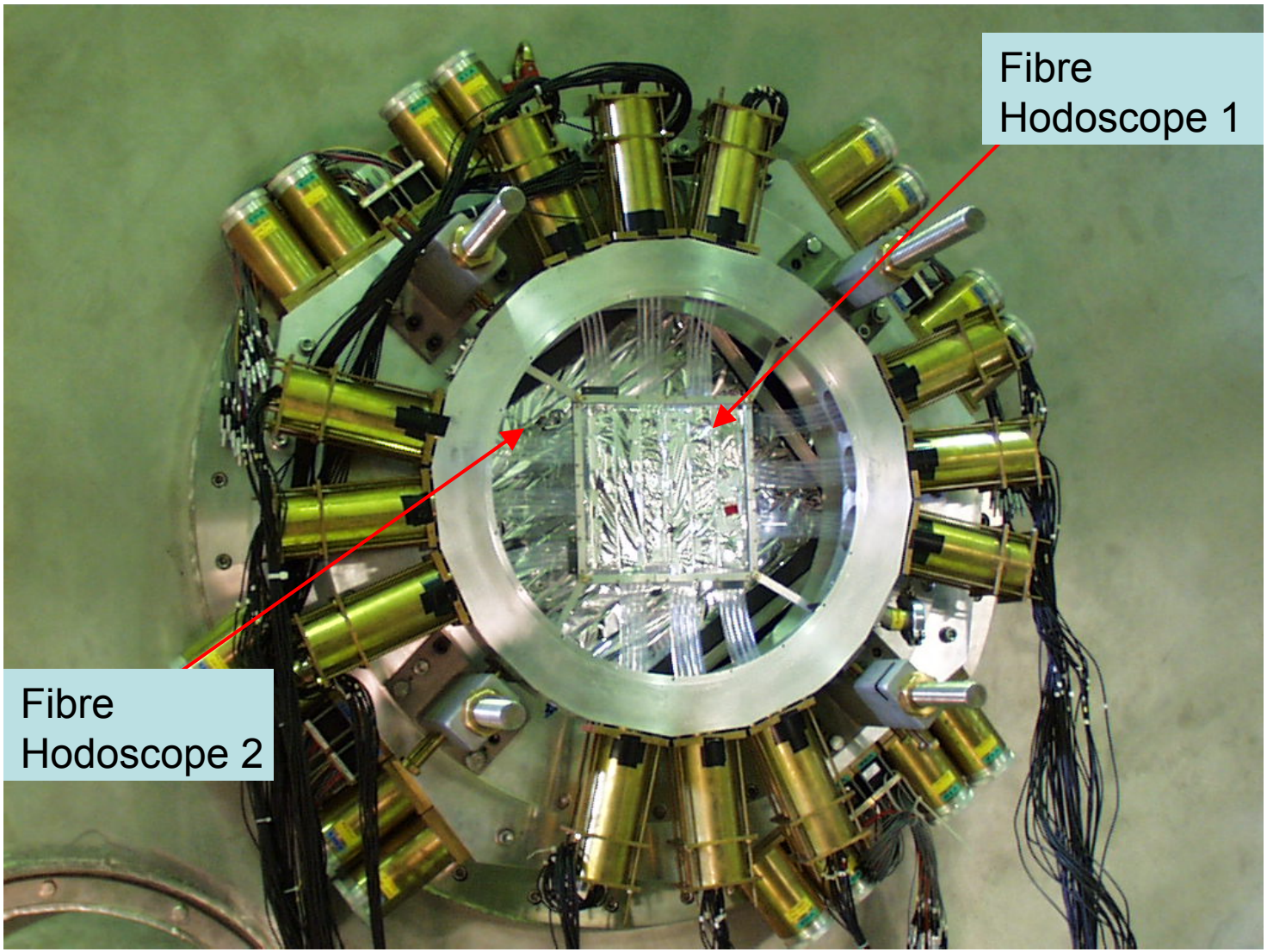


Frontside 100 rings

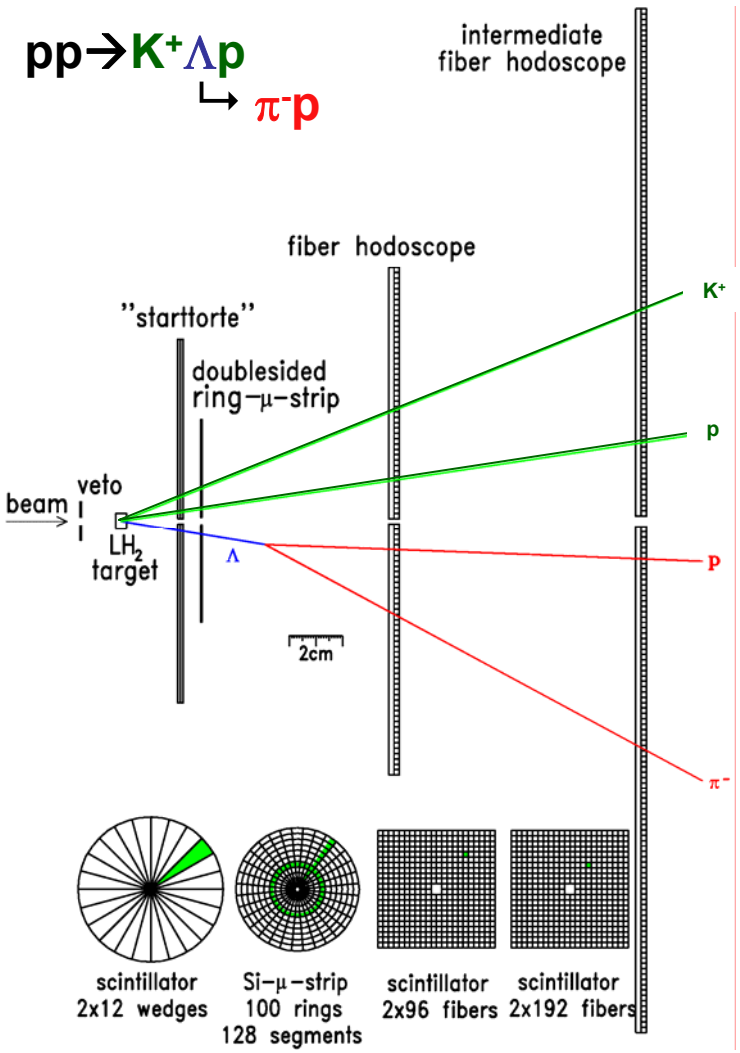


Rearside 128 sectors

„Erlangen Start Detector“: Fibre Hodoscopes



The „Erlangen Start Detector“



delayed decay of **Λ**

→ charged multiplicity 2 → 4

→ trigger

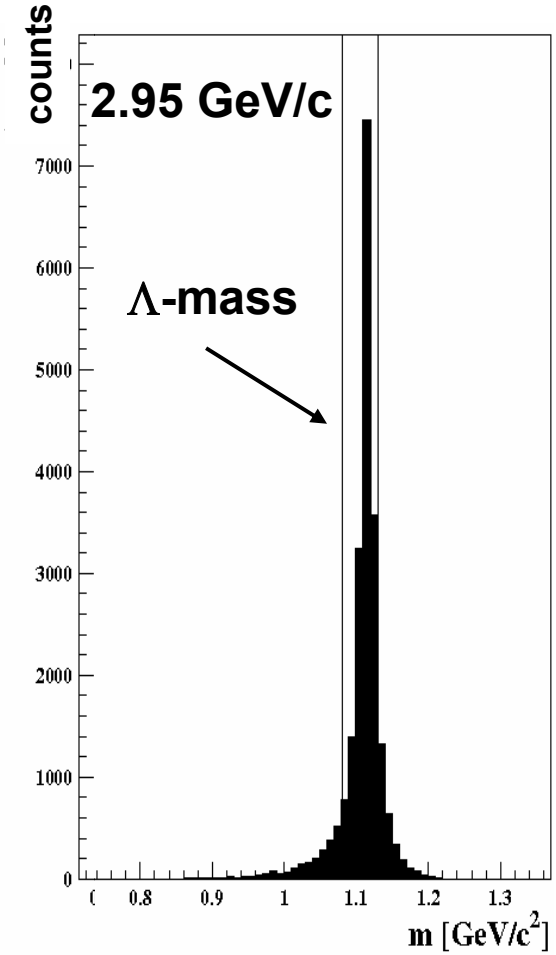
vertex reconstruction

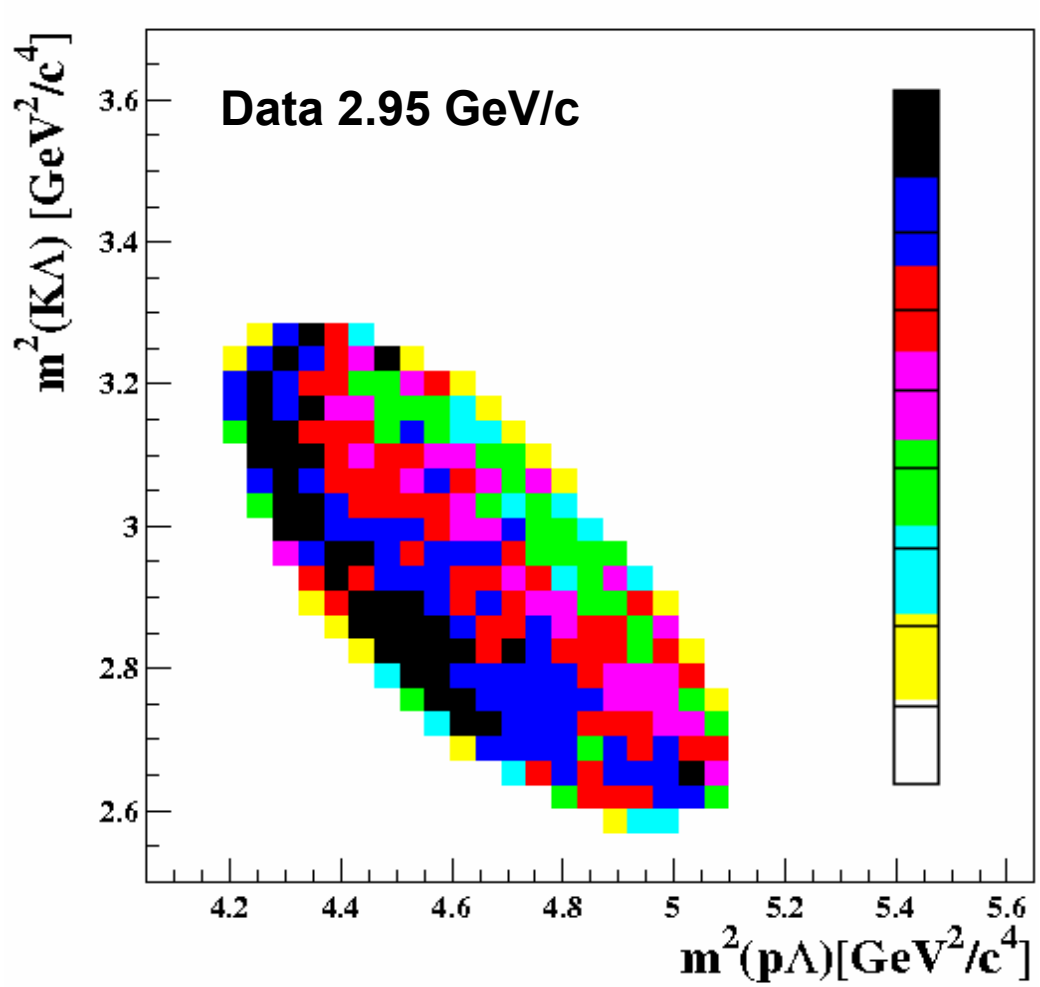
identification of Λ :
decay → „V“

complete geometric reconstruction

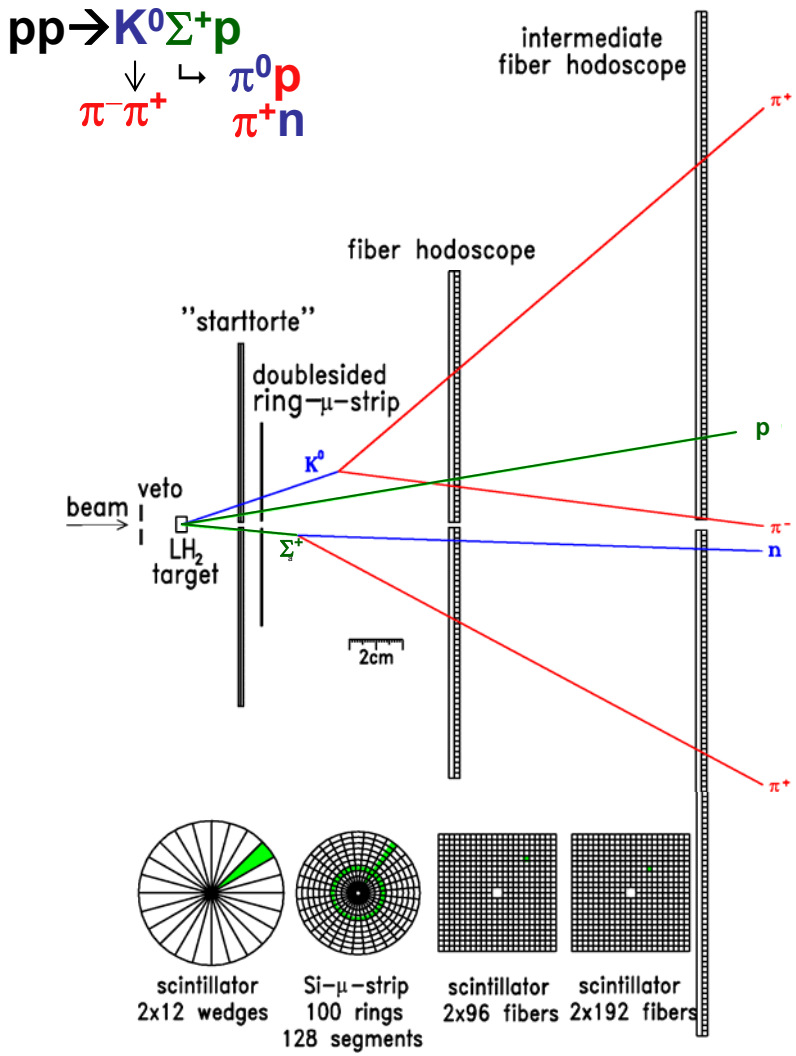
„4π“ coverage

pp → $K^+\Lambda p$: Dalitz plot analysis





The „Erlangen Start Detector“



delayed decay of K^0

→ charged multiplicity 2 → 4

→ trigger

vertex reconstruction

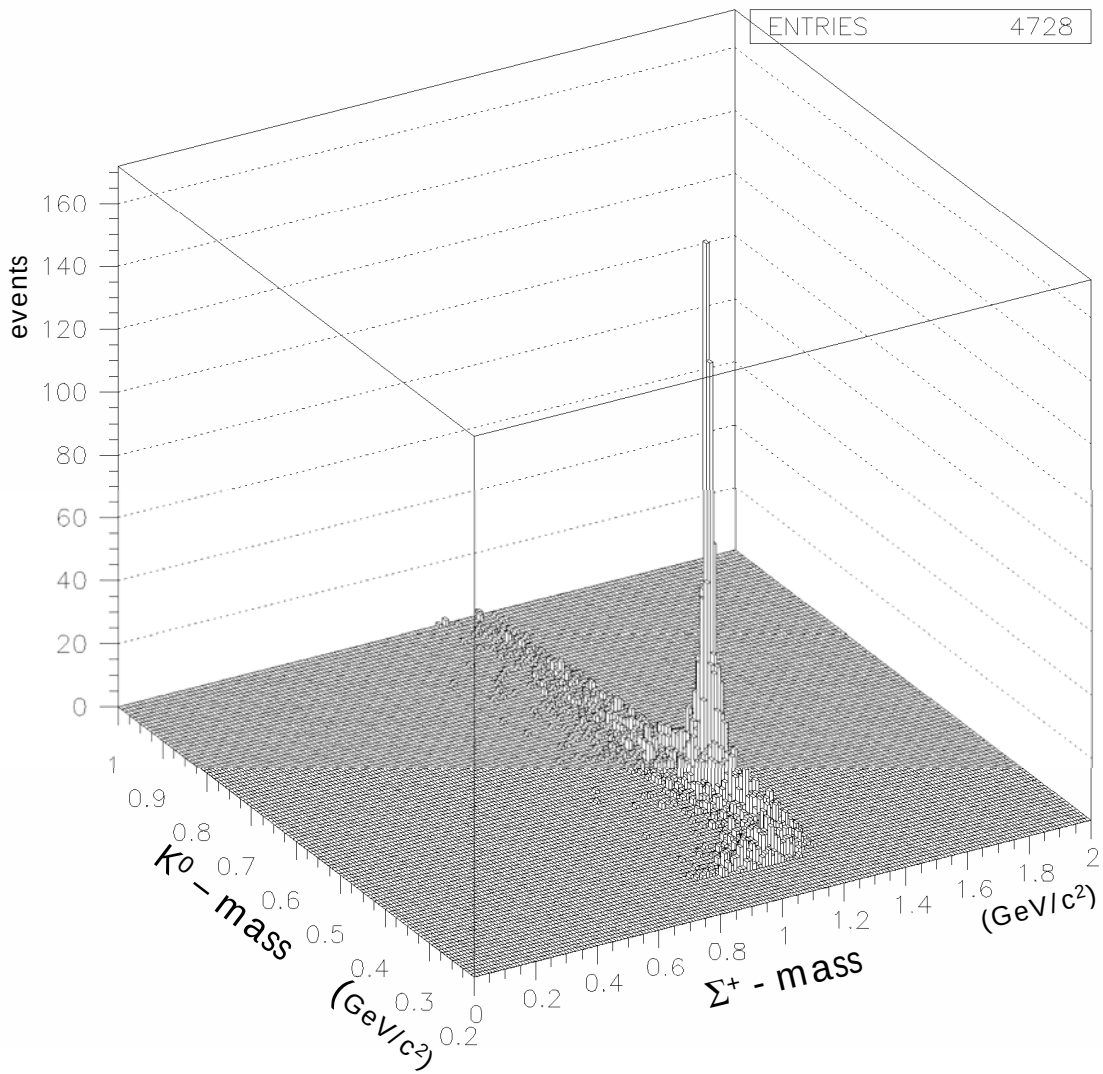
identification of K^0_s:
decay → „V“

identification of Σ^+ :
decay → kink in track

complete geometric reconstruction

„4π“ coverage

pp → $\Sigma^+ K^0 p$: reconstructed masses

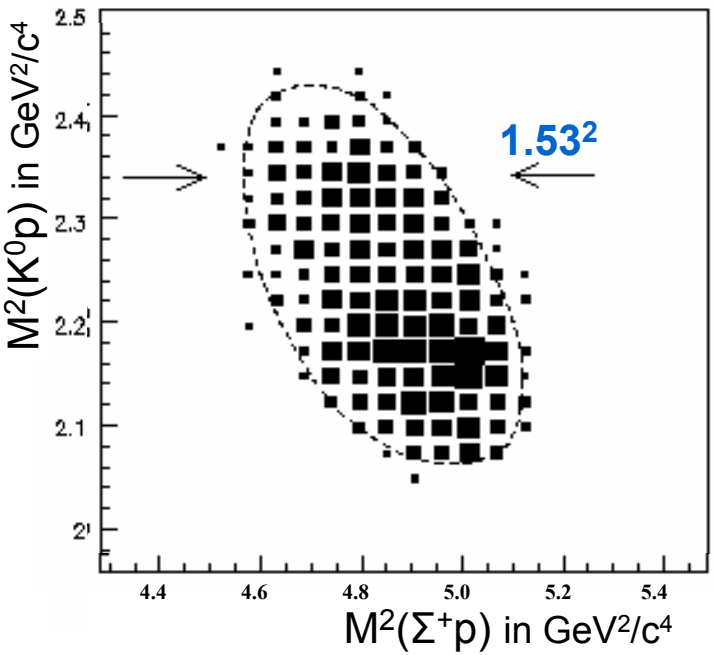


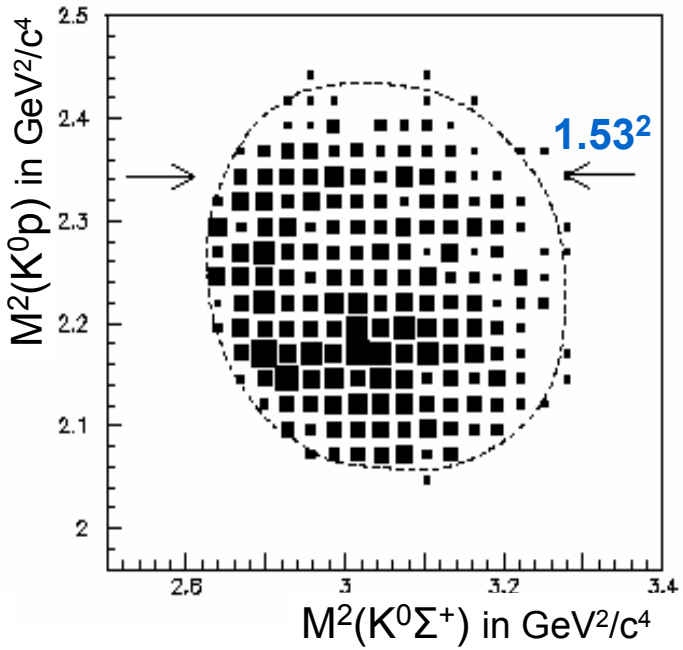
P_{beam} = 2.95 GeV/c

Runs 2000 + 2002

pp → Σ^+K^0p: Dalitz plots

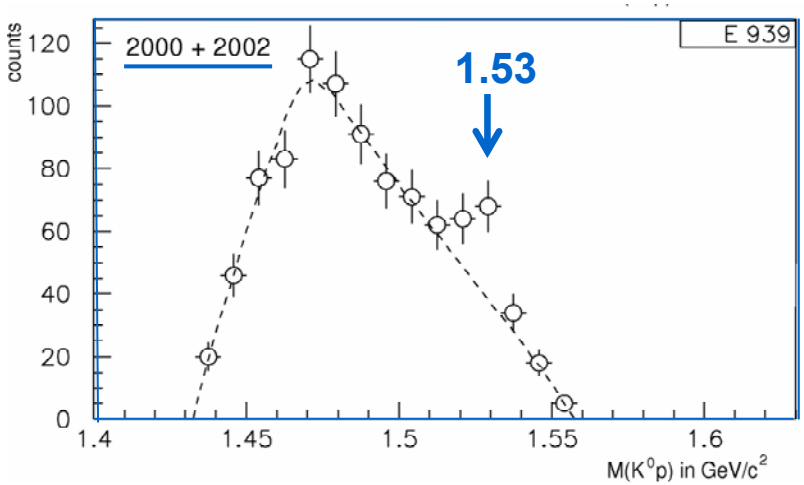
P_{beam} = 2.95 GeV/c



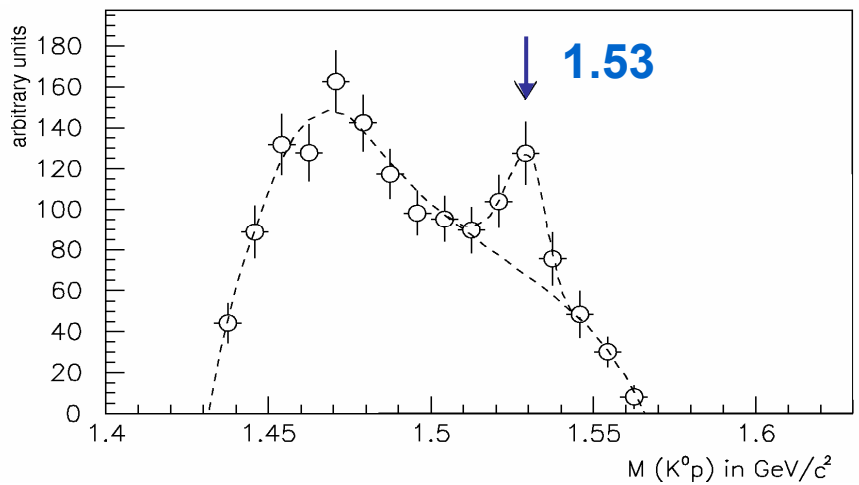


pp → $K^0\Sigma^+p$: K^0p mass spectra

P_{beam} = 2.95 GeV/c



efficiency corrected



significance: 4 – 6 σ

(depending on method)

$NS / \sqrt{NB}$ $5.9\,\sigma$

$NS / \sqrt{NS + NB}$ $4.7\,\sigma$

$NS / \sqrt{(NS + NB) + NB}$ $3.7\,\sigma$

Mass 1530 ± 5 MeV/c²
Width ≤ 18 ± 4 MeV/c² (FWHM)
Strangeness S = + 1
Cross section: 0.4 ± 0.1_{stat} ± 0.1_{sys} μb

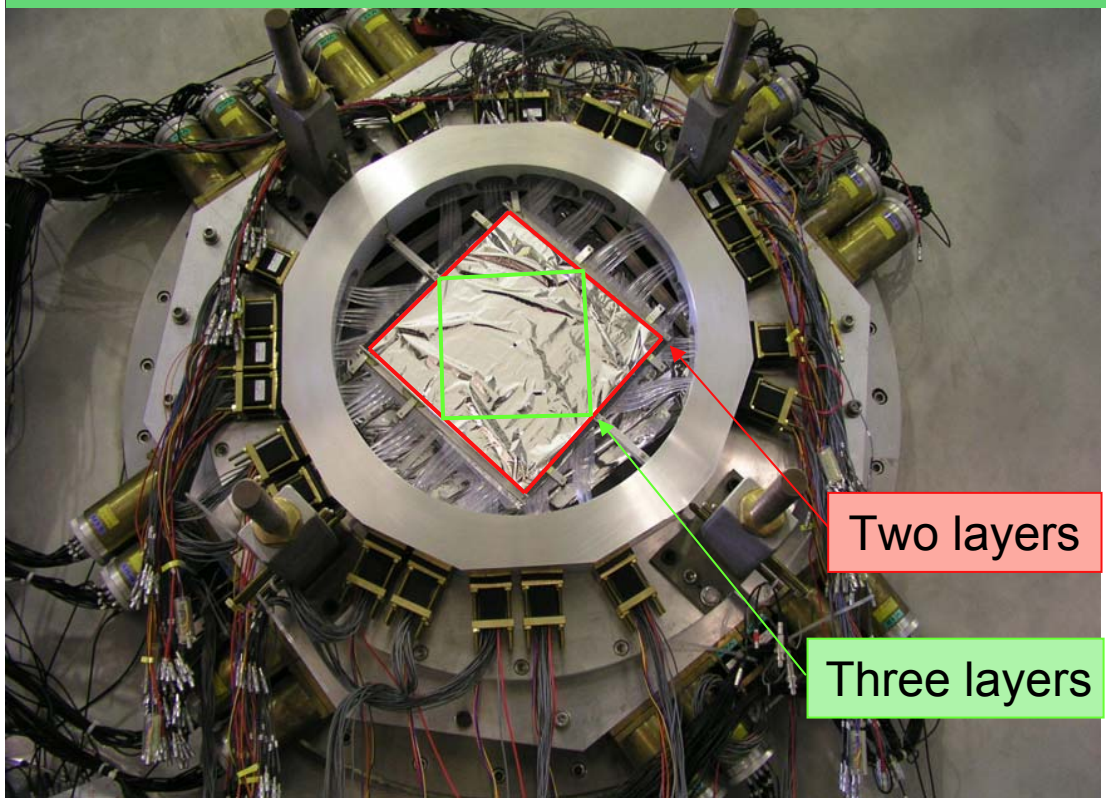
***hep-ex/0403011, Phys. Lett. B* 595 (2004), 127**

2nd Round: COSY-TOF run Oct. / Nov. 2004

Reaction: $pp \rightarrow \Sigma^+ K^0 p$ $\quad p_{beam} = 3.05$ GeV/c

Goal: Decision on the existence of the Θ^+ in the investigated channel

Experimental upgrade: New fibre hodoscope with three layers



→ increase of reconstruction efficiency

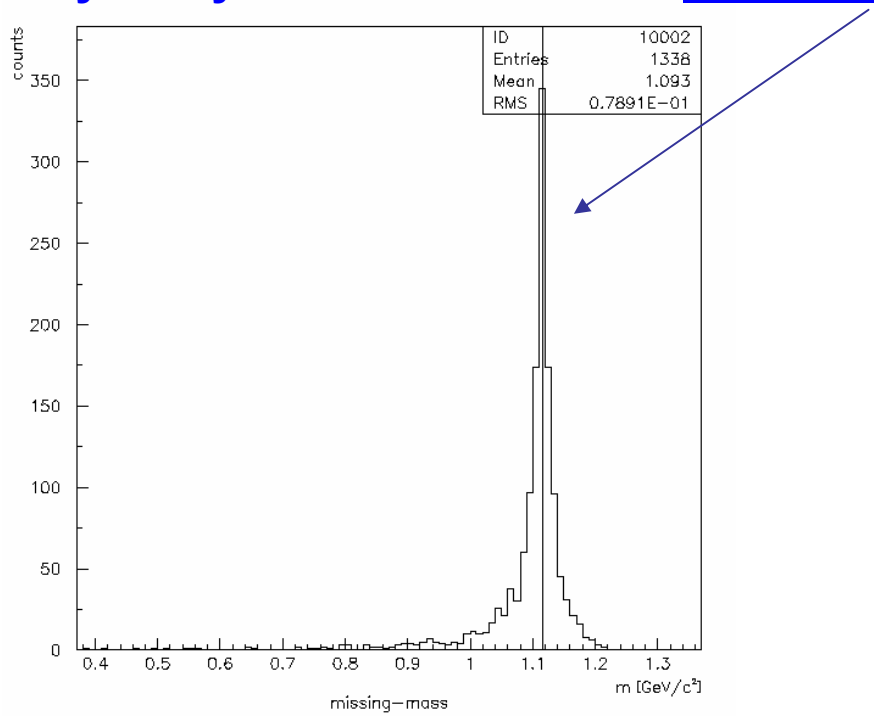
Measurement Oct./Nov. 2004: $pp \rightarrow K^0 \Sigma^+ p$

P_{beam} = 3.05 GeV/c

Estimate of output:

Reference: reaction channel $pp \rightarrow K^+ \Lambda p$ (similar pattern)

Preliminary analyses of 4 hours run: Λ missing mass



Expected overall gain for $pp \rightarrow K^0 \Sigma^+ p$: Factor of ~ 5 more events compared to existing data (in agreement with the proposal)

COSY-TOF run October / November 2004

Ongoing analysis:

Improved Monte Carlo simulations

"Blind" analysis

Independent analyses at several institutes:
- **common calibration database**
- **different codes**
- **emphasising on different detector aspects**
  - **geometric reconstruction**
  - **time-of-flight information**
  - **energy loss information**

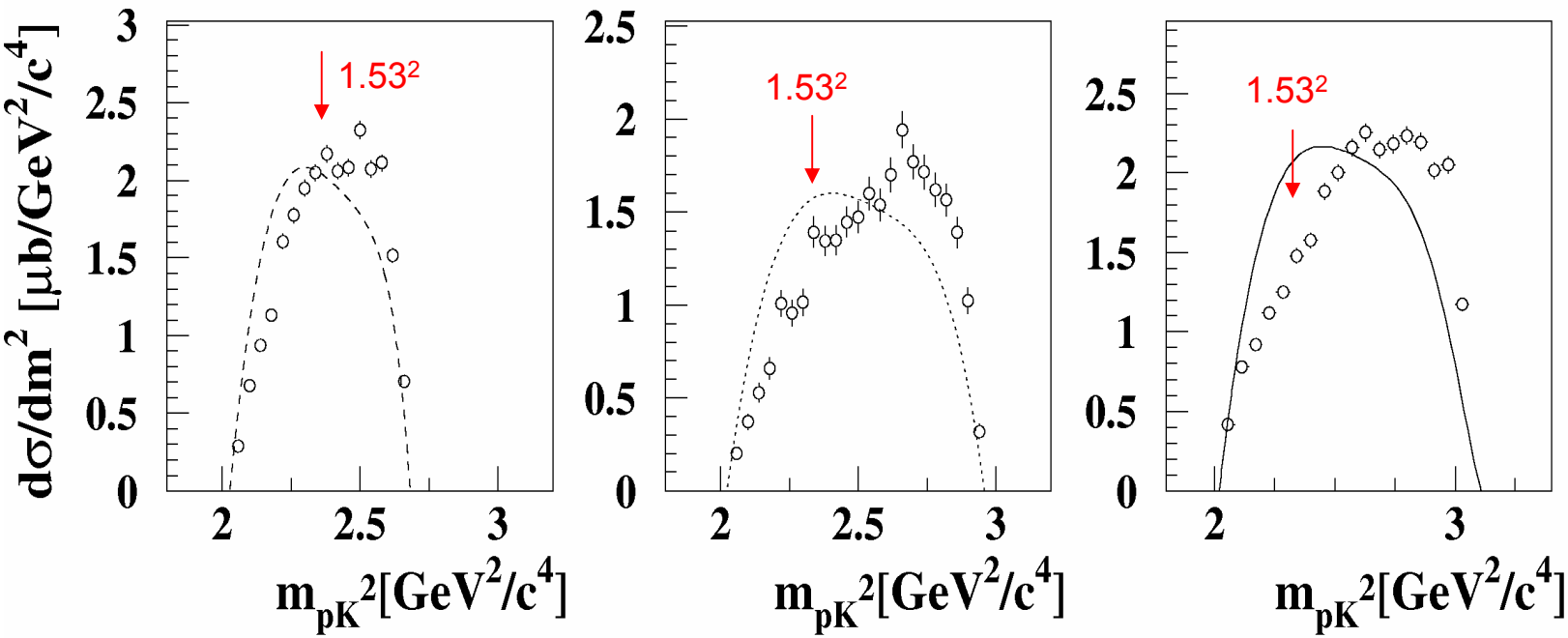
Detailed investigation:

- **$K_s p$ system**
- **Dalitz plot**
- **background (+ modelling)**

Related topic: Search for possible isospin partners

Search for Θ^{++} : $pp \rightarrow \Lambda K^+ p$

P_{beam} : 2.95 GeV/c 3.20 GeV/c 3.30 GeV/c

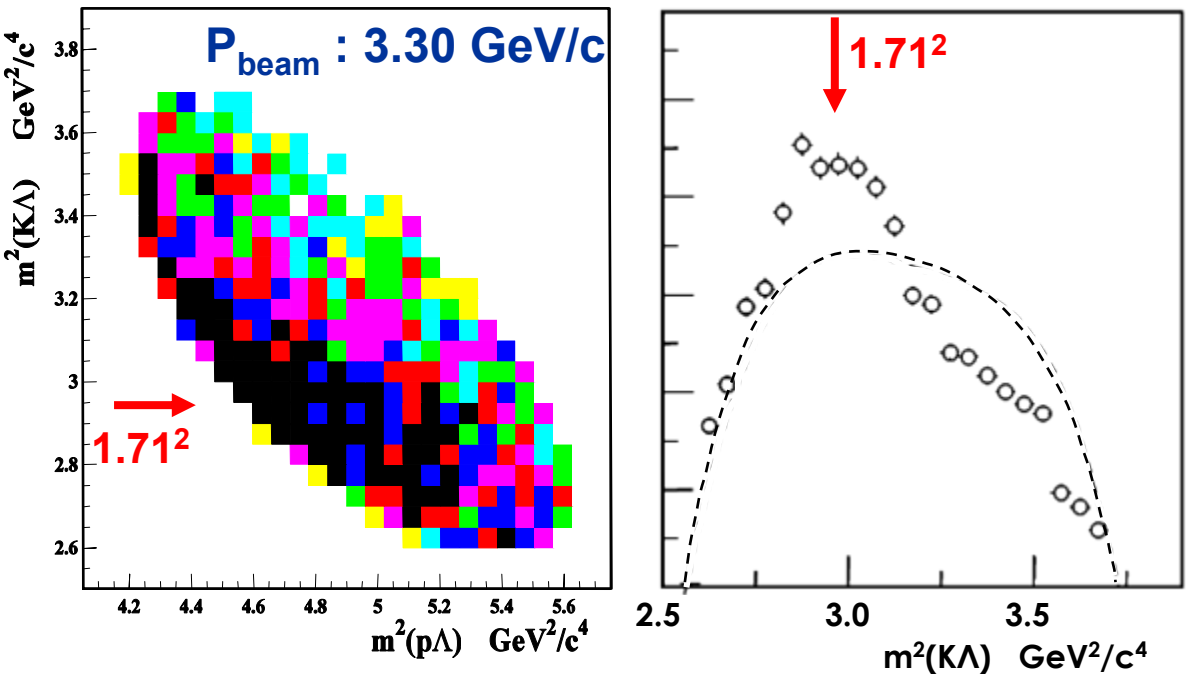


Preliminary: no evidence for Θ^{++} in pK^+ spectra

New data: → ≈ 2x10⁵ $pp \rightarrow \Lambda K^+ p$ events !

Related topic: Width of N*(1710) resonance

$pp \rightarrow \Lambda K^+ p$



N*(1710) contributes strongly

Influence of pΛ-FSI

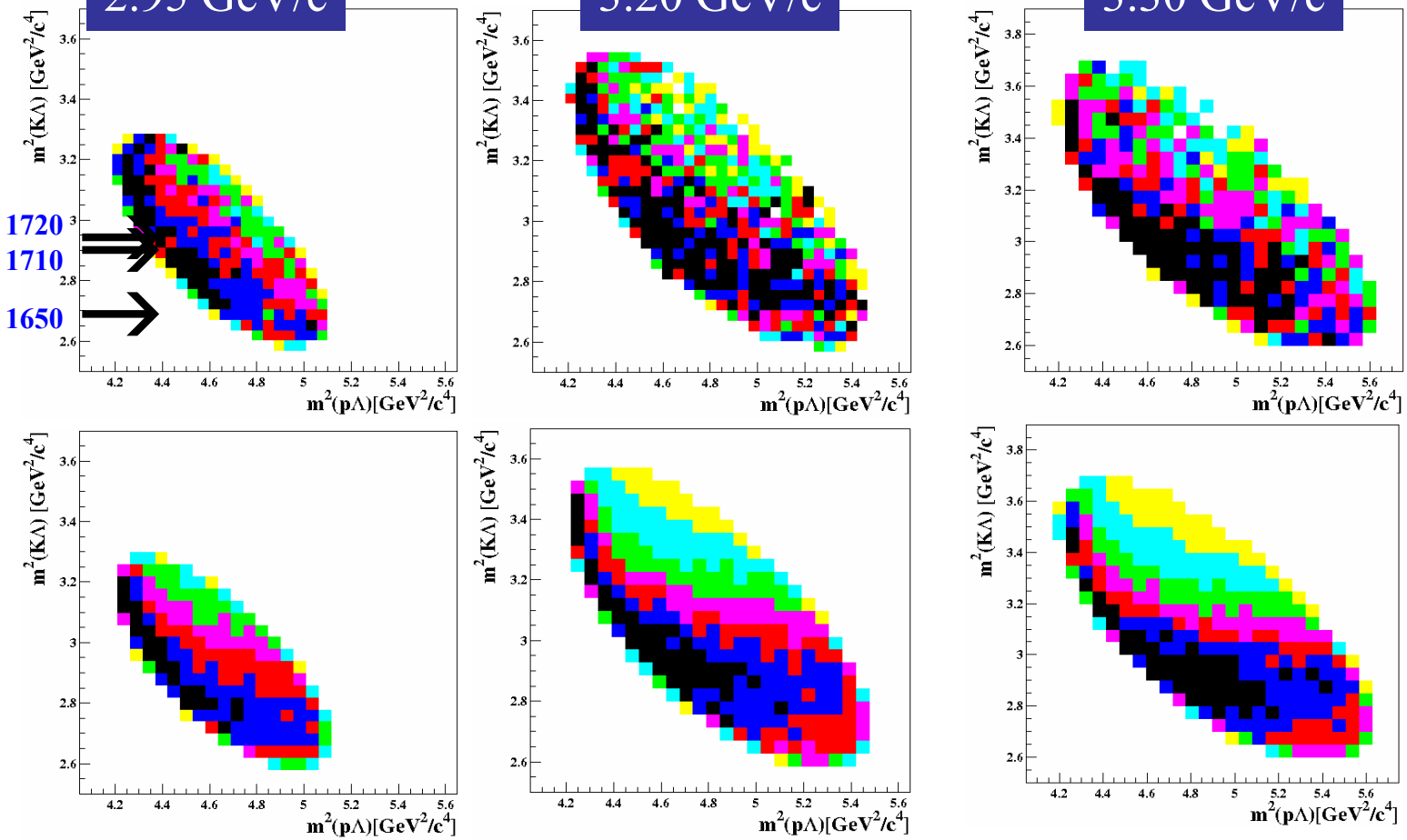
In progress: Investigation of Dalitz plots → **width**

pp → K⁺Λp: Dalitz plots

2.95 GeV/c | 3.20 GeV/c | 3.30 GeV/c

DATA

MODEL



$$\frac{d^2\sigma}{dm^2_{K\Lambda}\, dm^2_{p\Lambda}} = (flux)\cdot\left|\left(\sum_R (C_R\cdot A_R) + C_N\cdot A_N\right)\cdot(1 + C_{FSI}\cdot A_{FSI})\right|^2$$

Sibirtsev

"3rd round": Parity of Θ^+ - proposed measurement

- pp with double polarization

$$\vec{p}\,\vec{p} \rightarrow \Sigma^+ \Theta^+$$

Proposed by W.A. Thomas et al.

Hanhart et al., hep-ph0410293;
PLB590(04)39; PLB606(05)67

Observable:

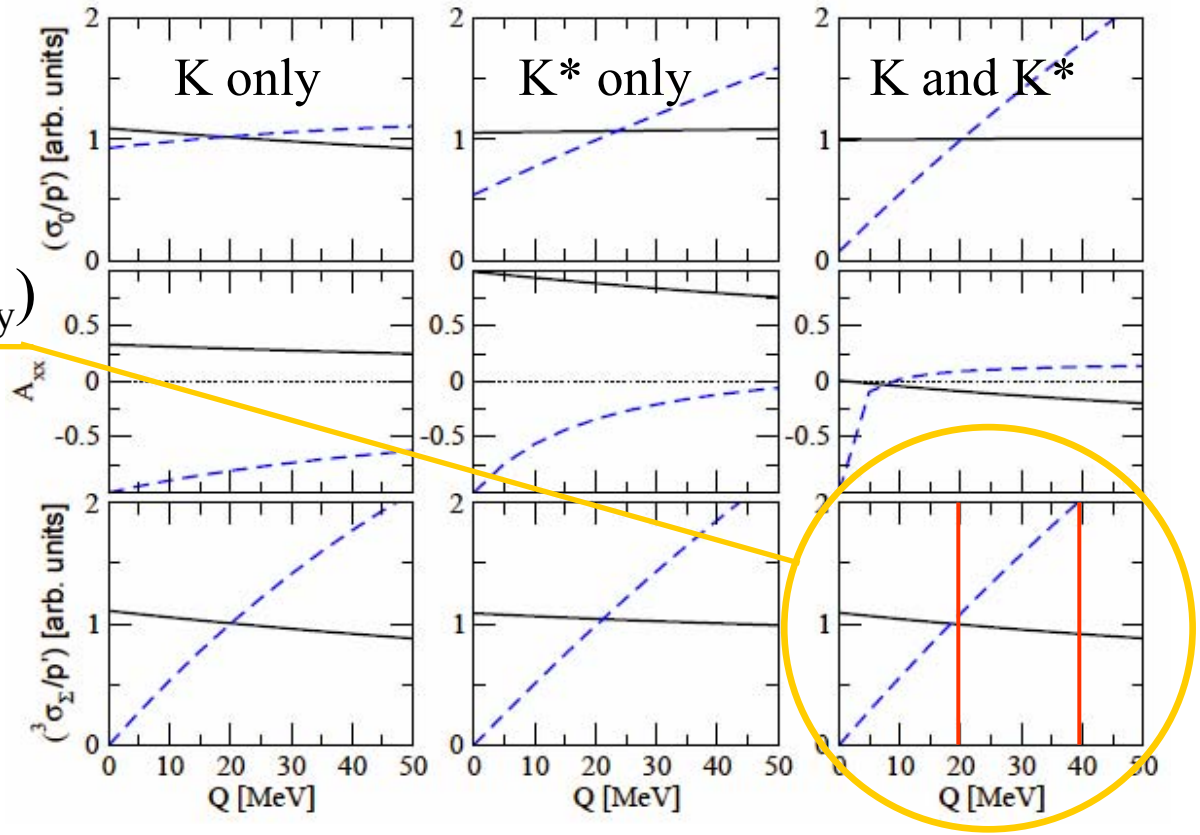
$\uparrow\uparrow$ ($^3P_{0,1}$)

$^3\sigma_\Sigma = \frac{1}{2}\sigma_0(2+A_{xx}+A_{yy})$

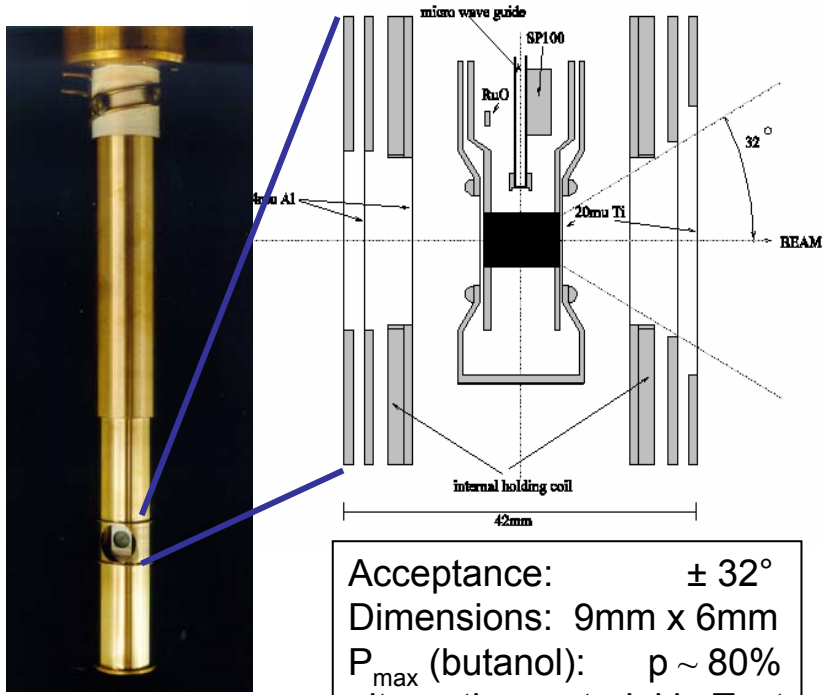
at two energies

(+ $\downarrow\uparrow$ ($^1S_0$)

for reference)



Polarized frozen spin target for COSY-TOF



Acceptance: ± 32°
Dimensions: 9mm x 6mm
P_{max} (butanol): p ~ 80%
alternative material in Test

- Frozen spin technique
  well suited for low intensity external beams
- High polarization
  p_p~90%, p_d~80%
- PS185/3 set up
  will be used
- preparation at
  Bochum and Bonn

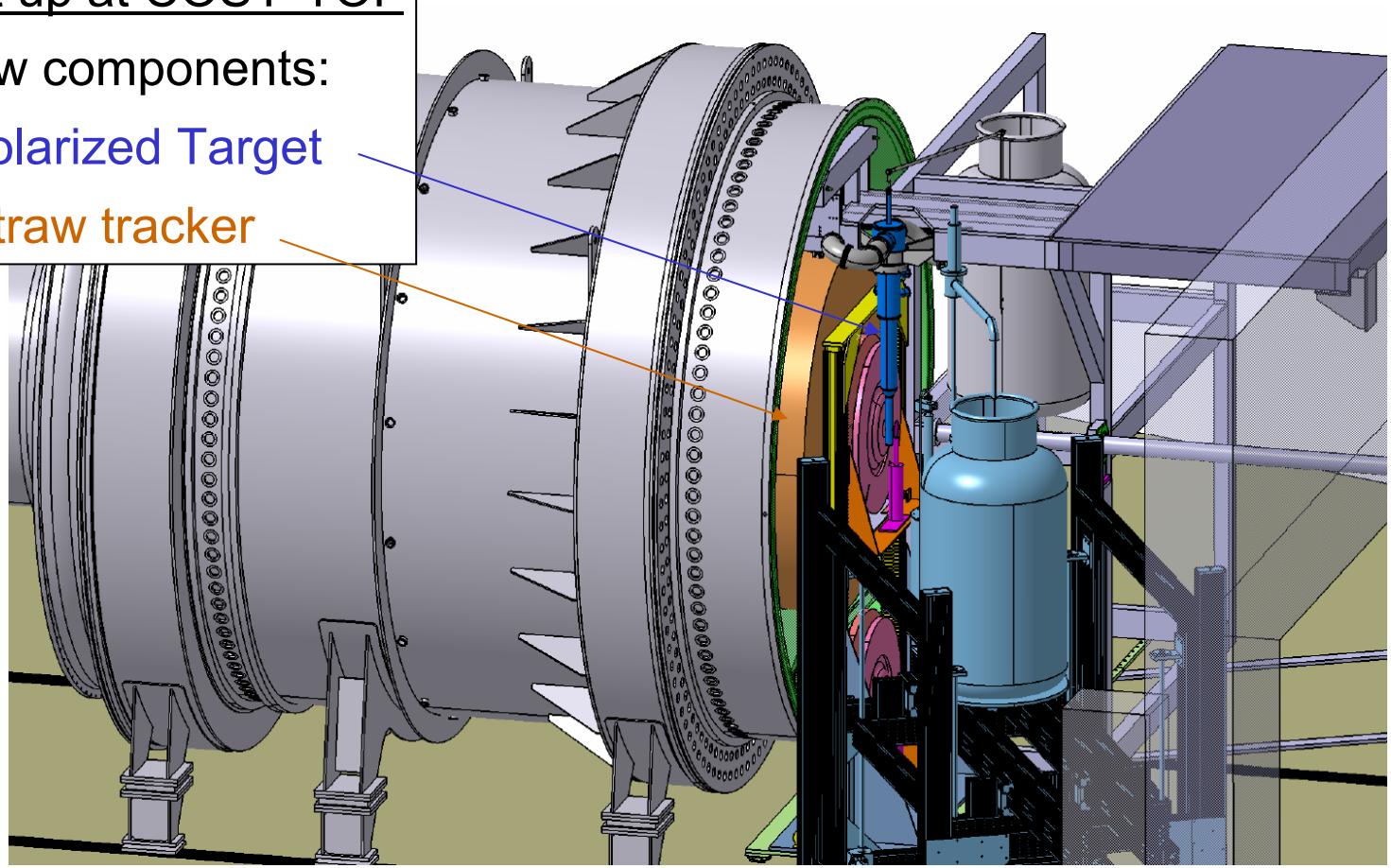
→ Installation
at COSY-TOF

Polarized frozen spin target for COSY-TOF

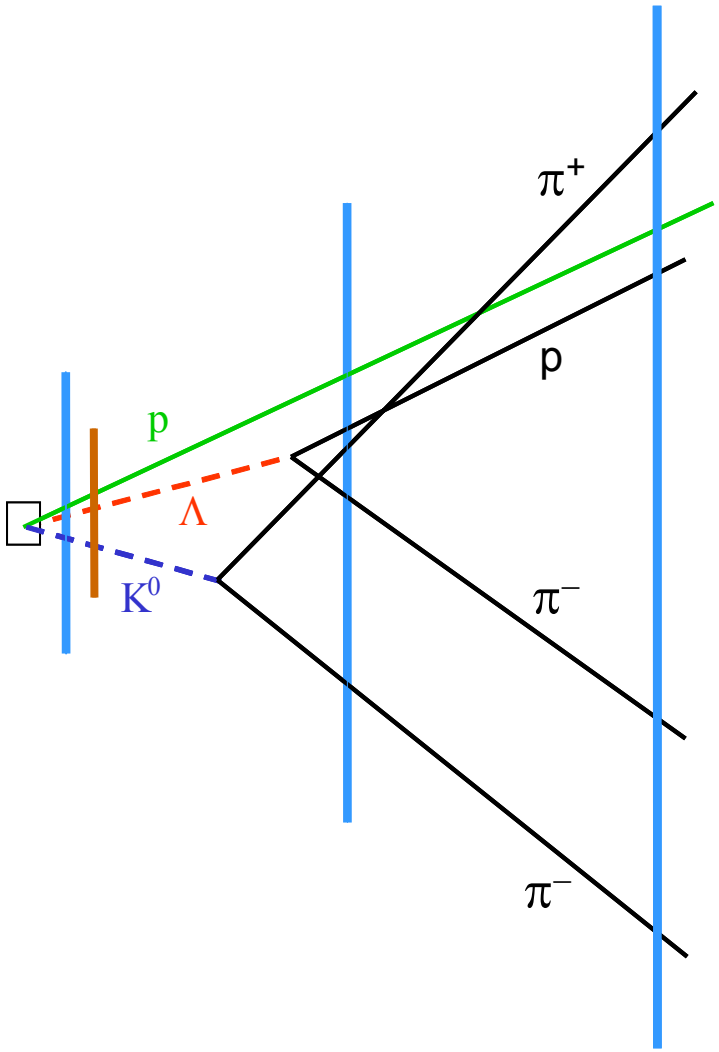
Set up at COSY-TOF

New components:

- polarized Target
- Straw tracker



$pn(p) \rightarrow pK^0\Lambda(p)$ Test 2004



Unique signature:

2 „V's" corresponding to delayed decays of Λ and K^0 into charged particles

Trigger: 1 → 5 v 2 → 6

Successful test:

Trigger o.k.

First events

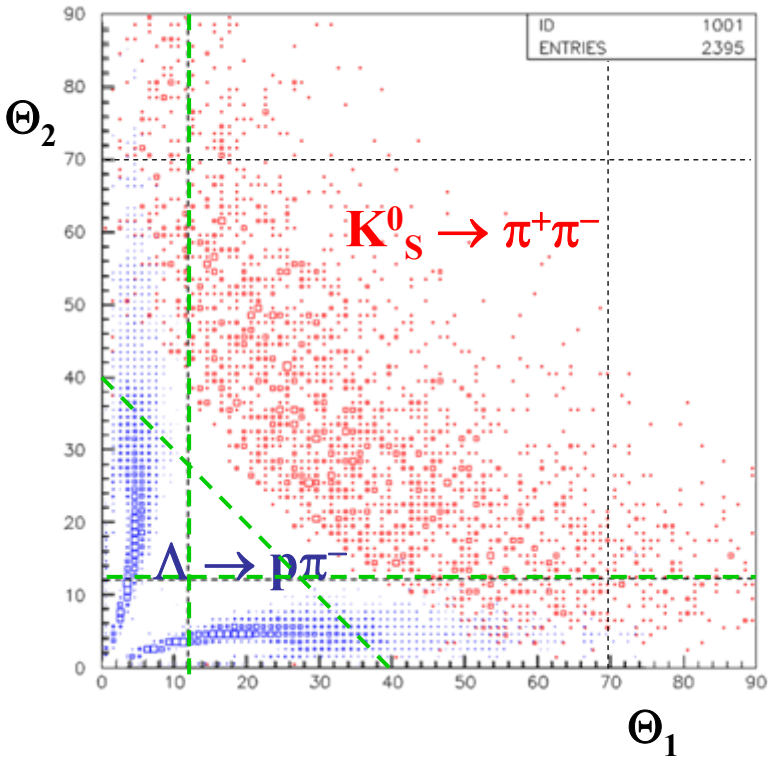
Well suited for COSY-TOF

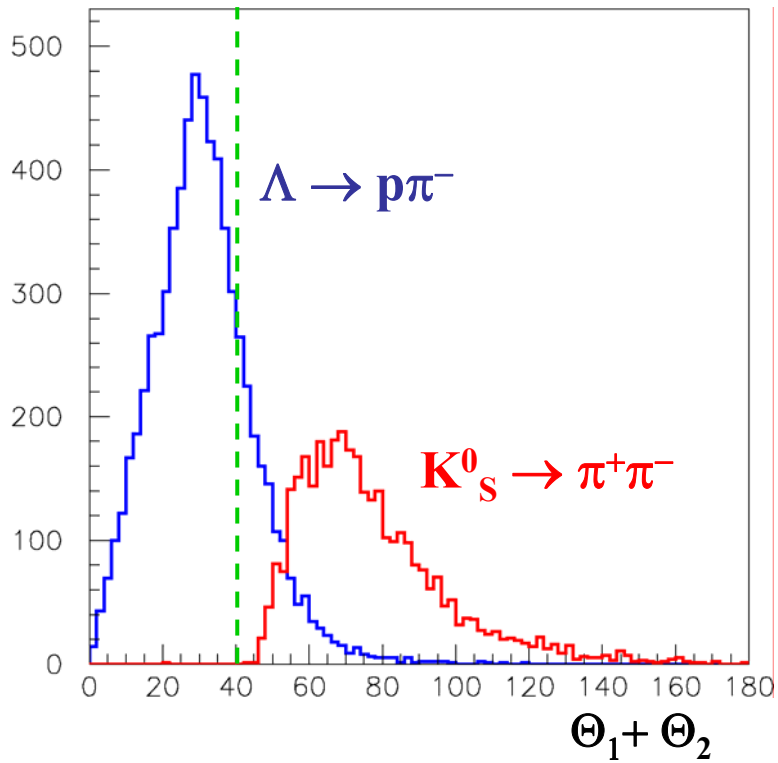
Reserve

pp → Σ^+K^0p: background separation

Separation of pp → $pK^0\Sigma^+$ from pp → $pK^+\Lambda$ and $pK^+\Sigma^0(\to\gamma\Lambda)$

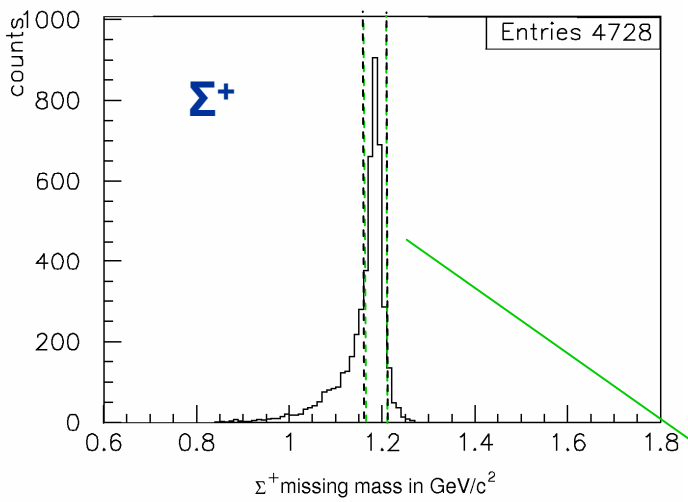
P_{beam} = 2.95 GeV/c Monte Carlo simulations

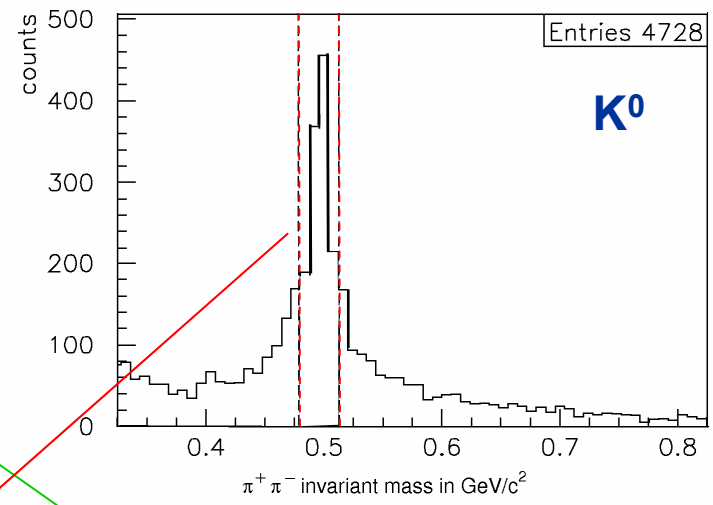


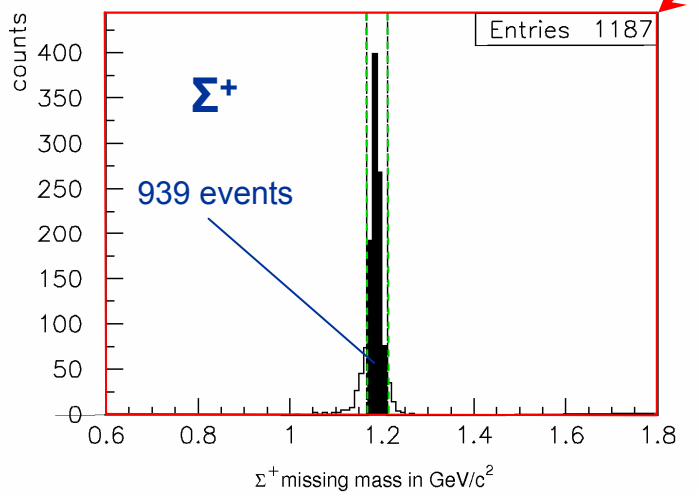


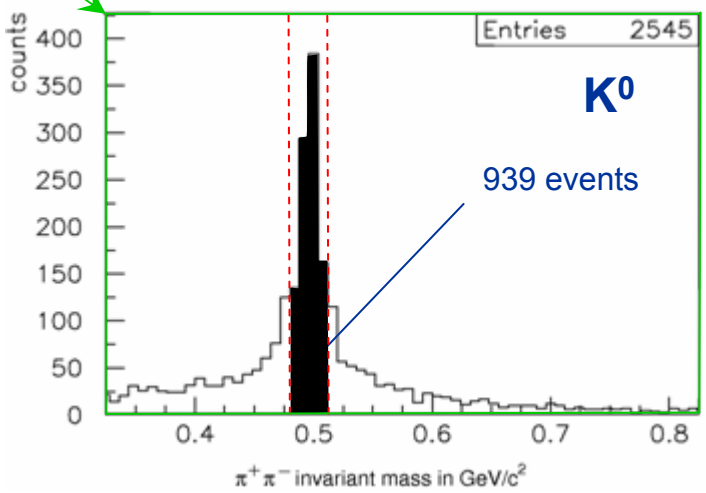
pp → $\Sigma^+ K^0 p$: cuts on masses

P_{beam} = 2.95 GeV/c **Run 2000 + Run 2002**









"3rd round": Parity of Θ^+ - proposed measurement

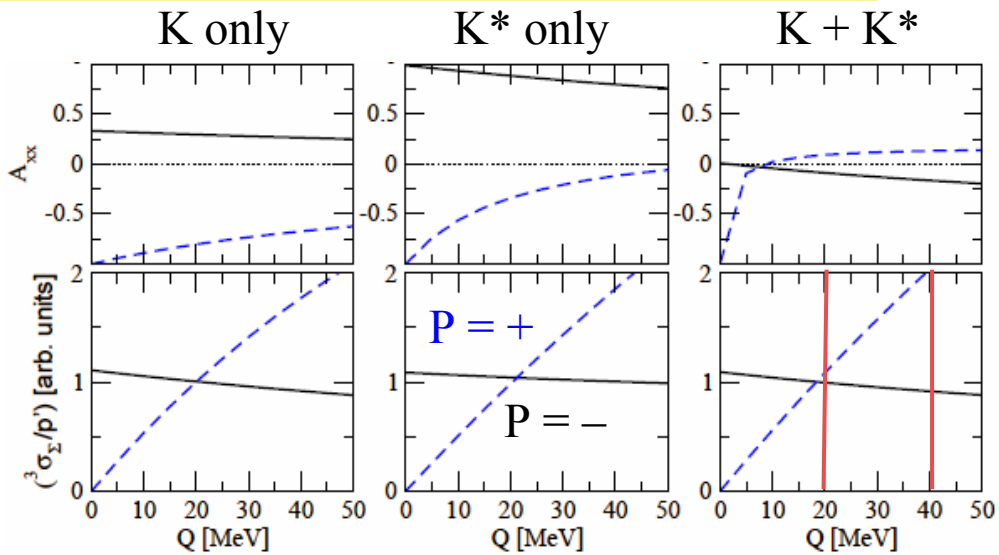
- pp double polarized

$$\vec{p}\,\vec{p} \rightarrow \Sigma^+ \Theta^+$$

Observable:

$$^3\sigma_\Sigma = \tfrac{1}{2}\sigma_0(2+A_{xx}+A_{yy})$$

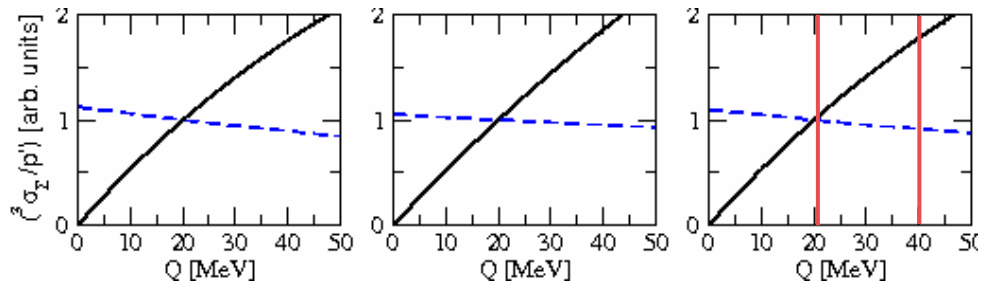
at two excess energies



- pn double polarized

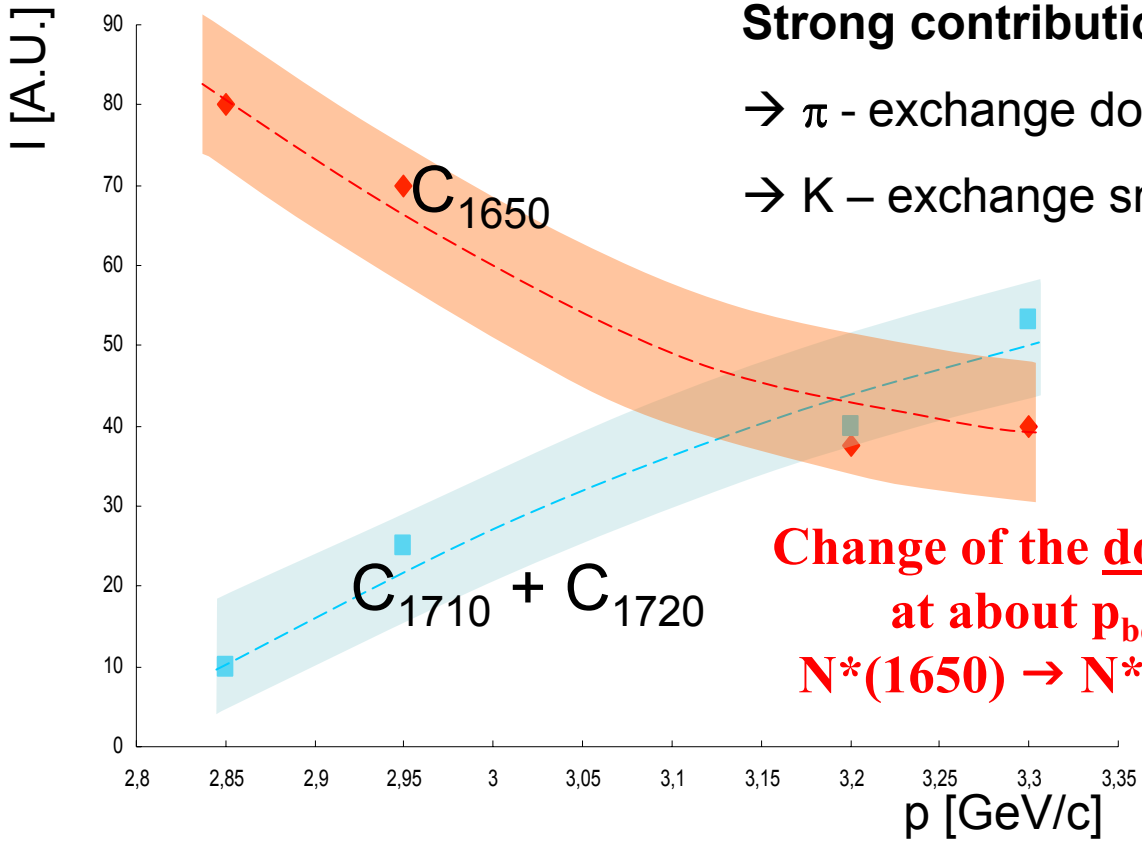
$$\vec{p}\,\vec{n} \rightarrow \Lambda \Theta^+$$

Hanhart et al., hep-ph0410293; PLB590(04)39; PLB606(05)67



$$\vec{p}\,n \rightarrow \vec{\Lambda}\,\Theta^+ \longrightarrow$$ information on parity (model dependent)

pp → $K^+\Lambda p$: Results of analysis



Strong contribution of N*-Resonances:

→ π - exchange dominant

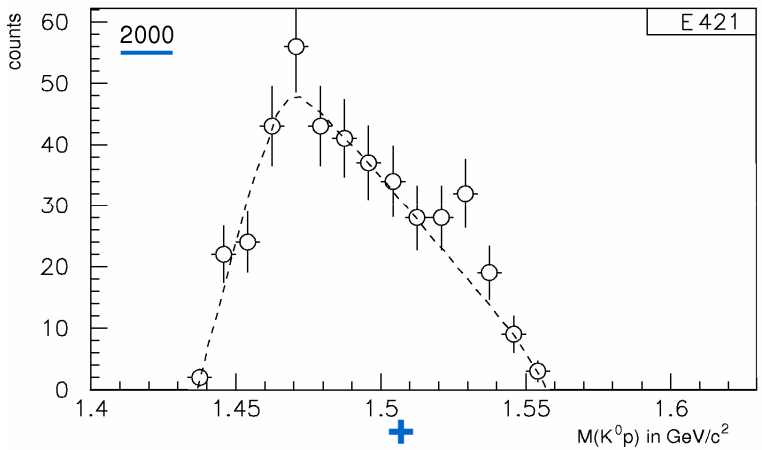
→ K – exchange small contribution

Change of the dominant resonance at about p_{beam}=3 GeV/c : N*(1650) → N*(1710) / N*(1720)

Next step: polarization !

pp → $\Sigma^+ K^0 p$: $K^0 p$ mass spectra

P_{beam} = 2.95 GeV/c



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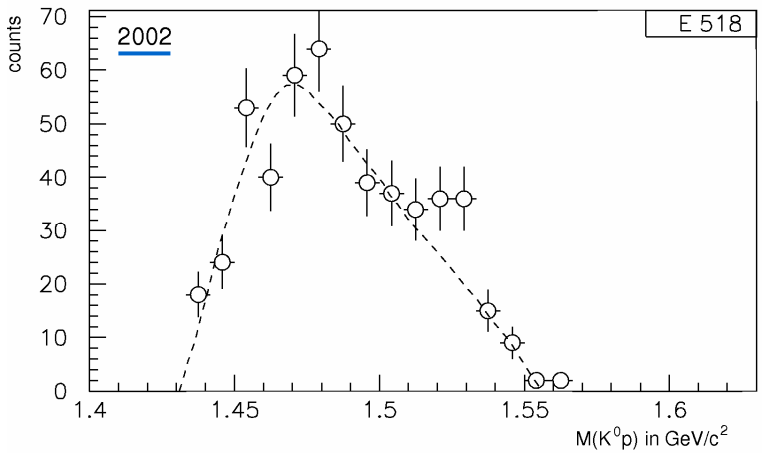

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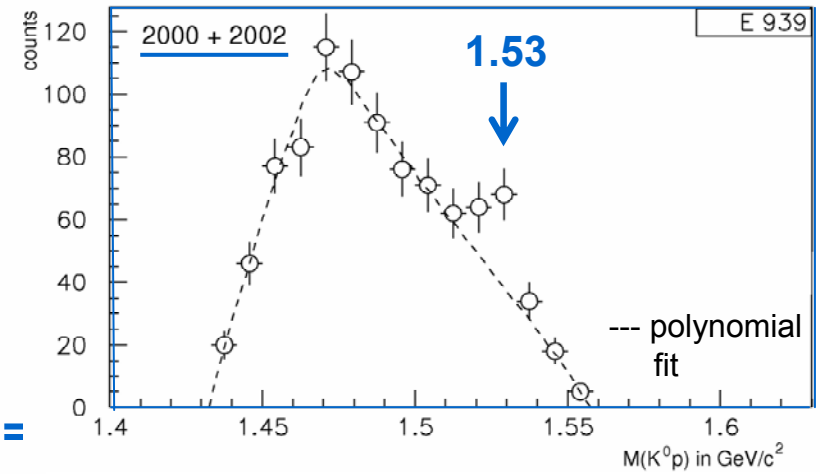
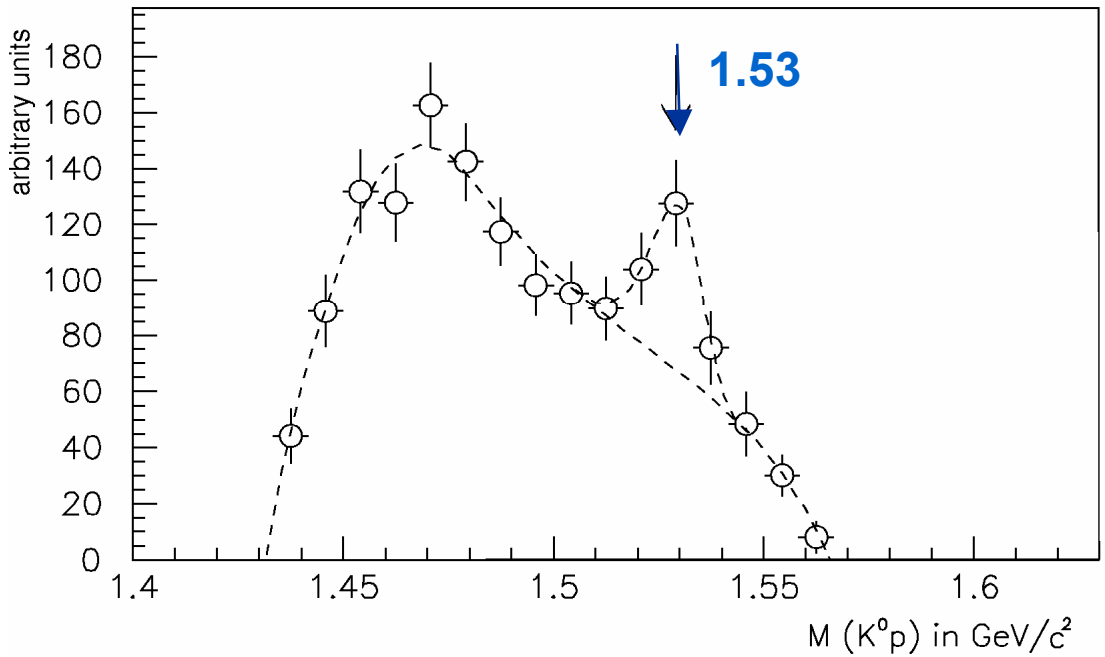


significance: 4 – 6 σ

(depending on method)

$NS / \sqrt{NB}$	$5.9\,\sigma$
$NS / \sqrt{NS + NB}$	$4.7\,\sigma$
$NS / \sqrt{(NS + NB) + NB}$	$3.7\,\sigma$

pp → $\Sigma^+ K^0 p$: efficiency corrected $K^0 p$ spectrum



Background:
Polynomial fit

Peak:
Gaussian fit

Mass 1530 ± 5 MeV/c²
Width ≤ 18 ± 4 MeV/c² (FWHM)
Strangeness S = + 1
Cross section: $0.4 \pm 0.1_{stat} \pm 0.1_{sys}$ μb

***hep-ex/0403011, Phys. Lett. B* 595 (2004), 127**