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JÜLICH
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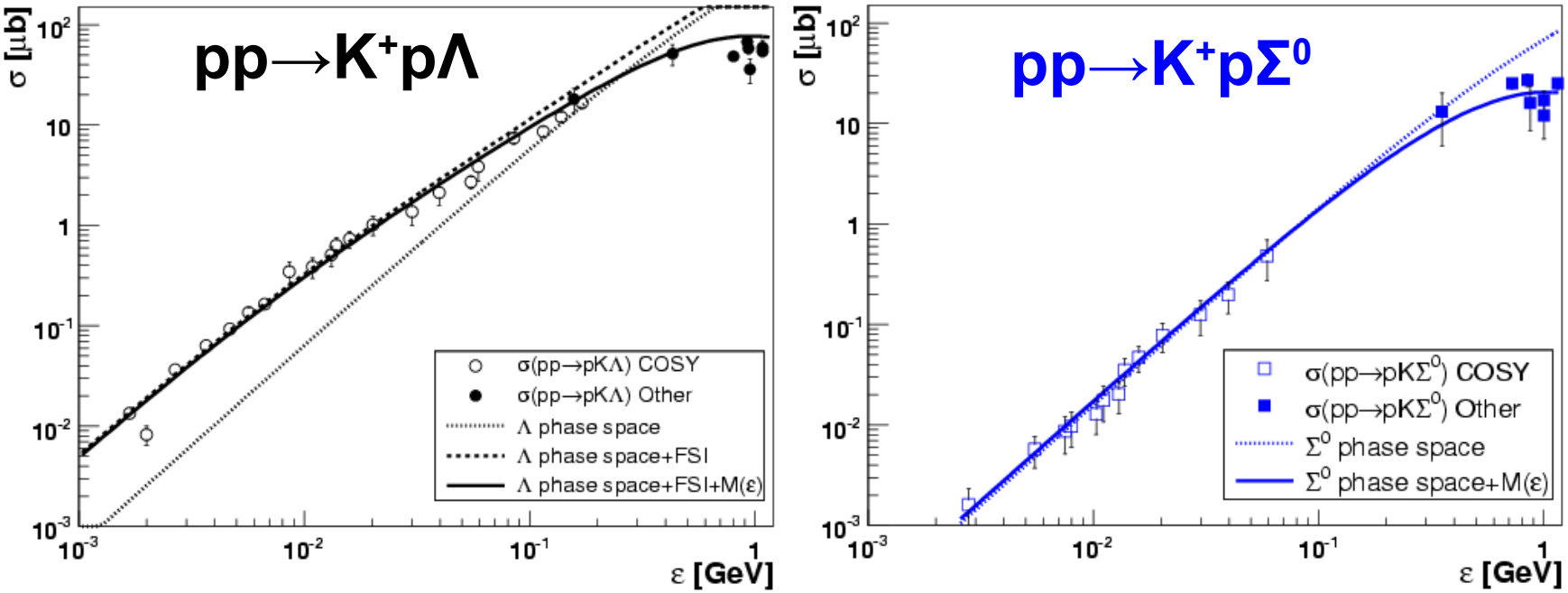
Energy dependence of the $pp \rightarrow K^+ n \Sigma^+$ reaction

Yury Valdau for the ANKE collaboration

31 May 2010 MENU2010

What is known about pp→K⁺NY?

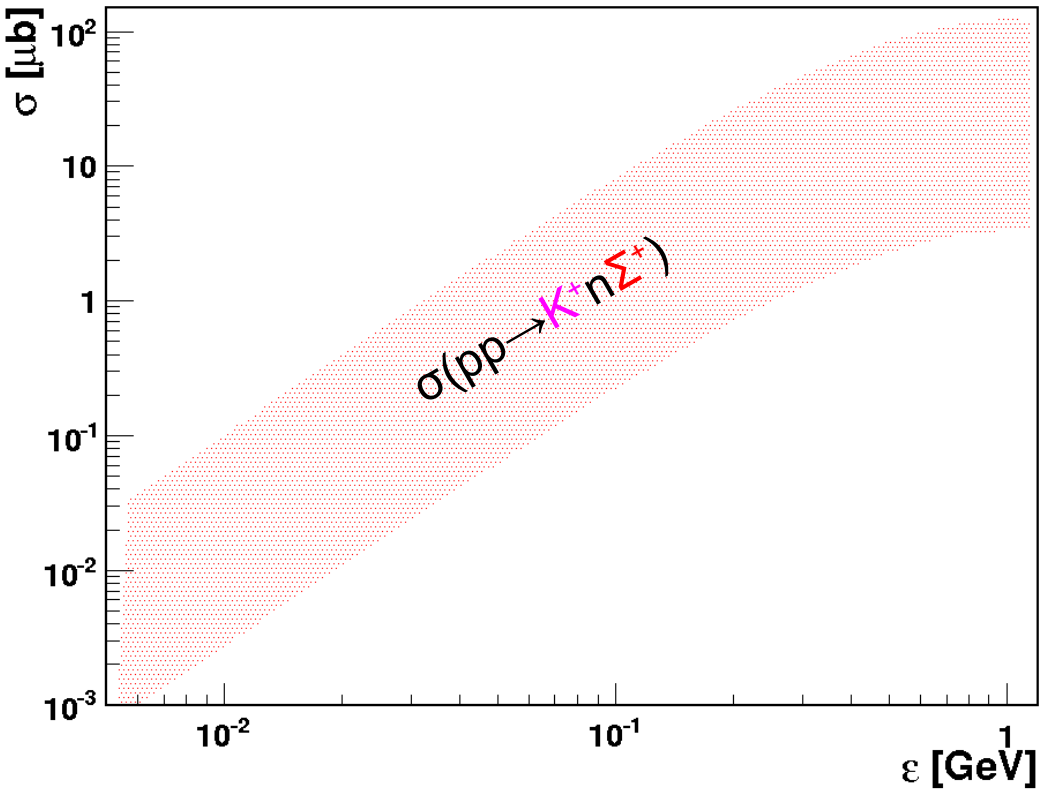


The energy dependence of Λ and Σ^0 total cross sections follows phase space, modified in case of Λ, by the final-state interaction

(*EPJA 29 (2006) 363*)

Triangle inequality for $pp \to K^+ n \Sigma^+$

$$0.16 \cdot \sigma(pp \to K^+ p \Sigma^0) < \sigma(pp \to K^+ n \Sigma^+) < 6 \cdot \sigma(pp \to K^+ p \Sigma^0)$$



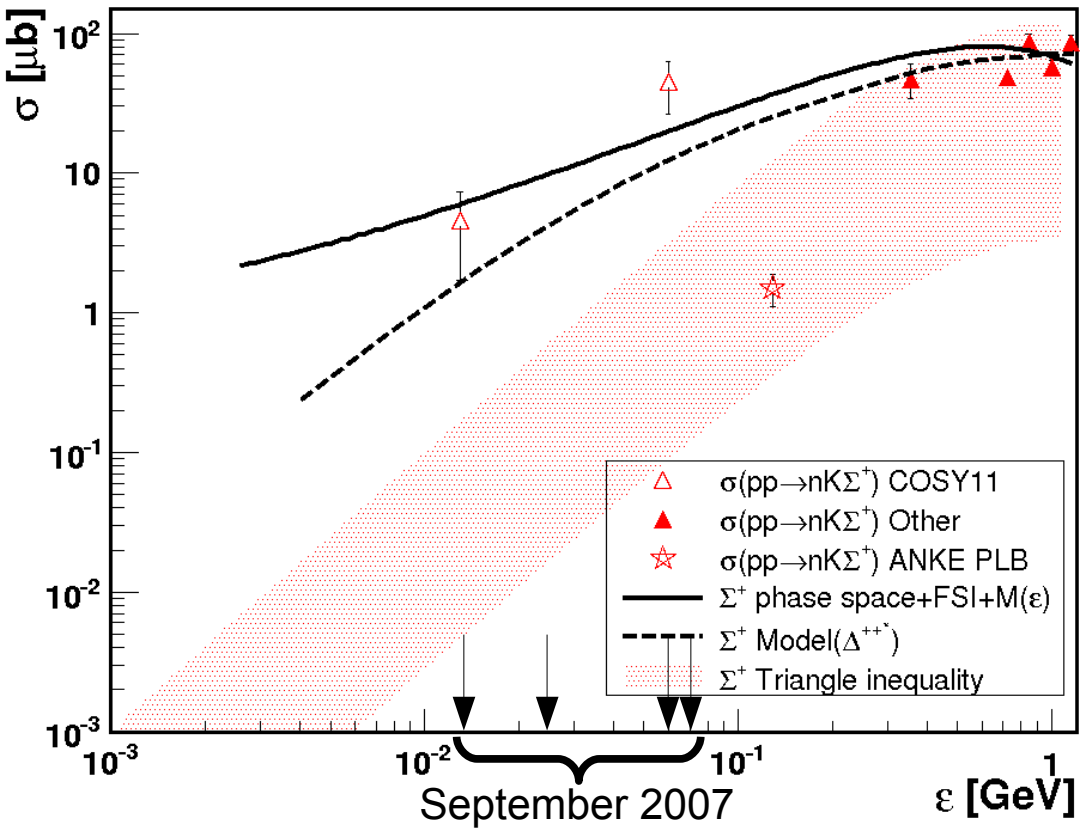
Using:

- **Isospin relations**
- $\sigma(pp \to K^+ p \Sigma^0) \approx \sigma(pp \to K^0 p \Sigma^+)$

Triangle inequality

Cross sections for Σ^0 and Σ^+ production can be linked using isospin relations

What is known about pp→K⁺nΣ⁺?



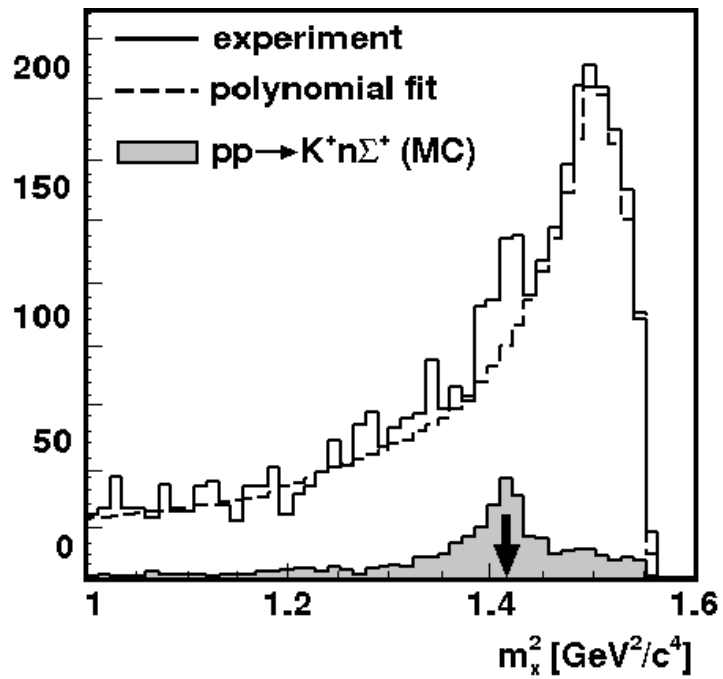
- COSY11 reported surprisingly high production cross section close to threshold
- Available data could be understood if there is a large threshold anomaly
- Possible explanation is influence of $\Delta^{++*}(1620)$ resonance (*PLB 649 (2007) 405*)

New data close to threshold is needed!

Methods to measure pp→K⁺nΣ⁺ reaction

$$pp \rightarrow K^+ n \Sigma^+ \begin{cases} n\pi^+ & (48\%) \\ p\pi^0 & (52\%) \end{cases}$$

Detection of K⁺n in final state:



COSY11 PLB 643 (2006) 251

Simultaneous measurements of three spectra:

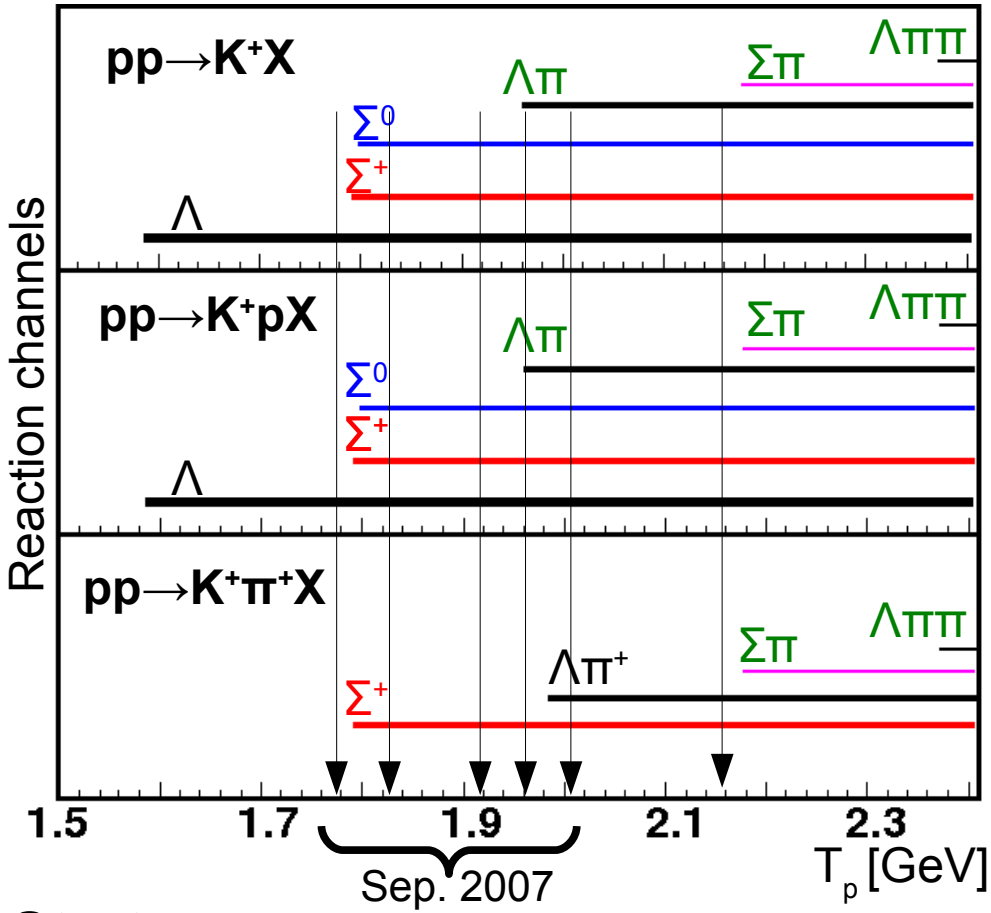
1) K^+ inclusive
2) K^+p correlation

} **cross check**

3) $K^+\pi^+$correlation→ **tagging Σ^+**

ANKE PLB 652 (2007) 245

The principle of methods



Methods:

1) Hard to identify Σ^+.

2) Hard to identify Σ^+ in K^+p correlations.

3) The Σ^+ reaction channel can be identified **unambiguously** using $K^+\pi^+$ correlations.

Strategy:

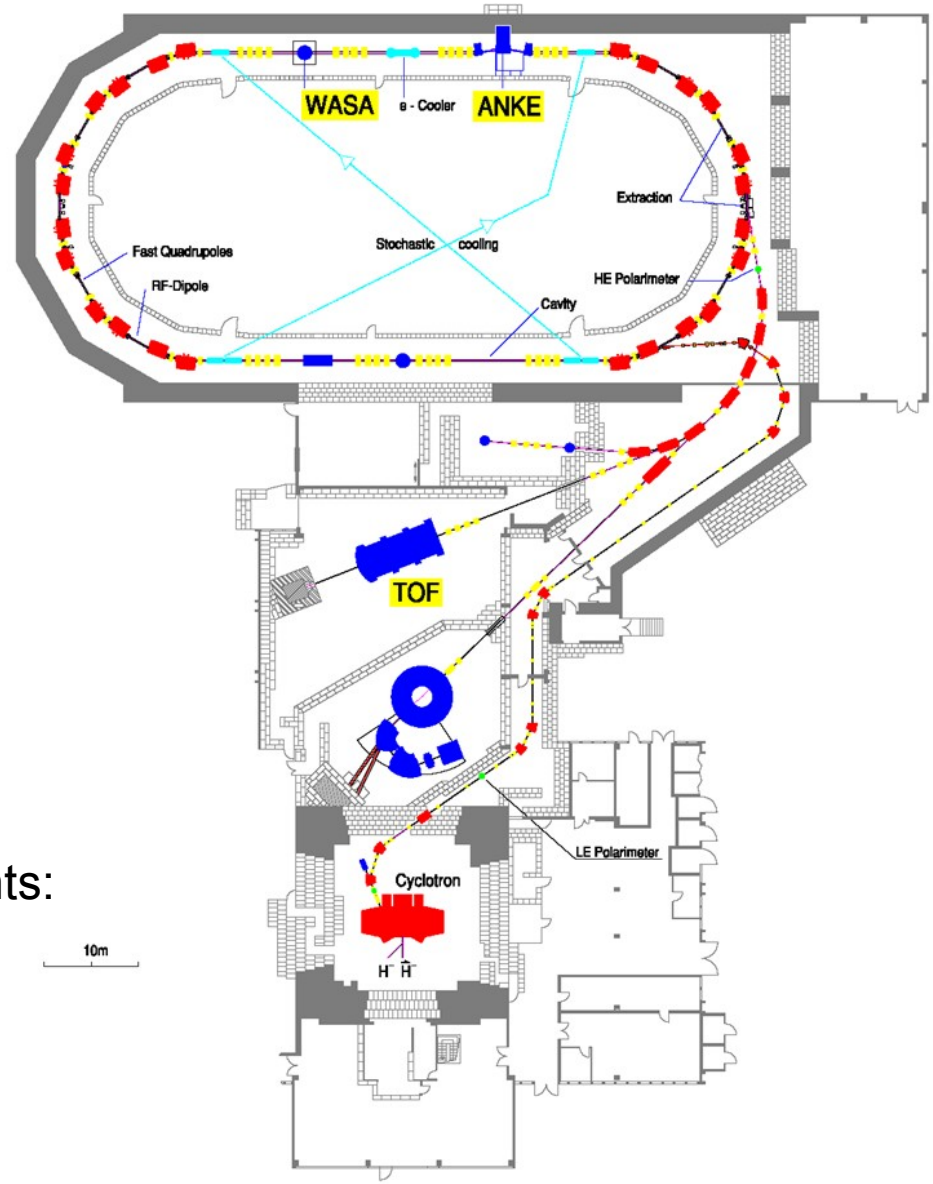
- **Determine Σ^+ total cross section using $K^+\pi^+$ correlations**
- **Cross check obtained values using K^+ inclusive and K^+p correlations**

COSY

Polarised and unpolarised:
p,d

Maximal momentum:
3.7 GeV/c

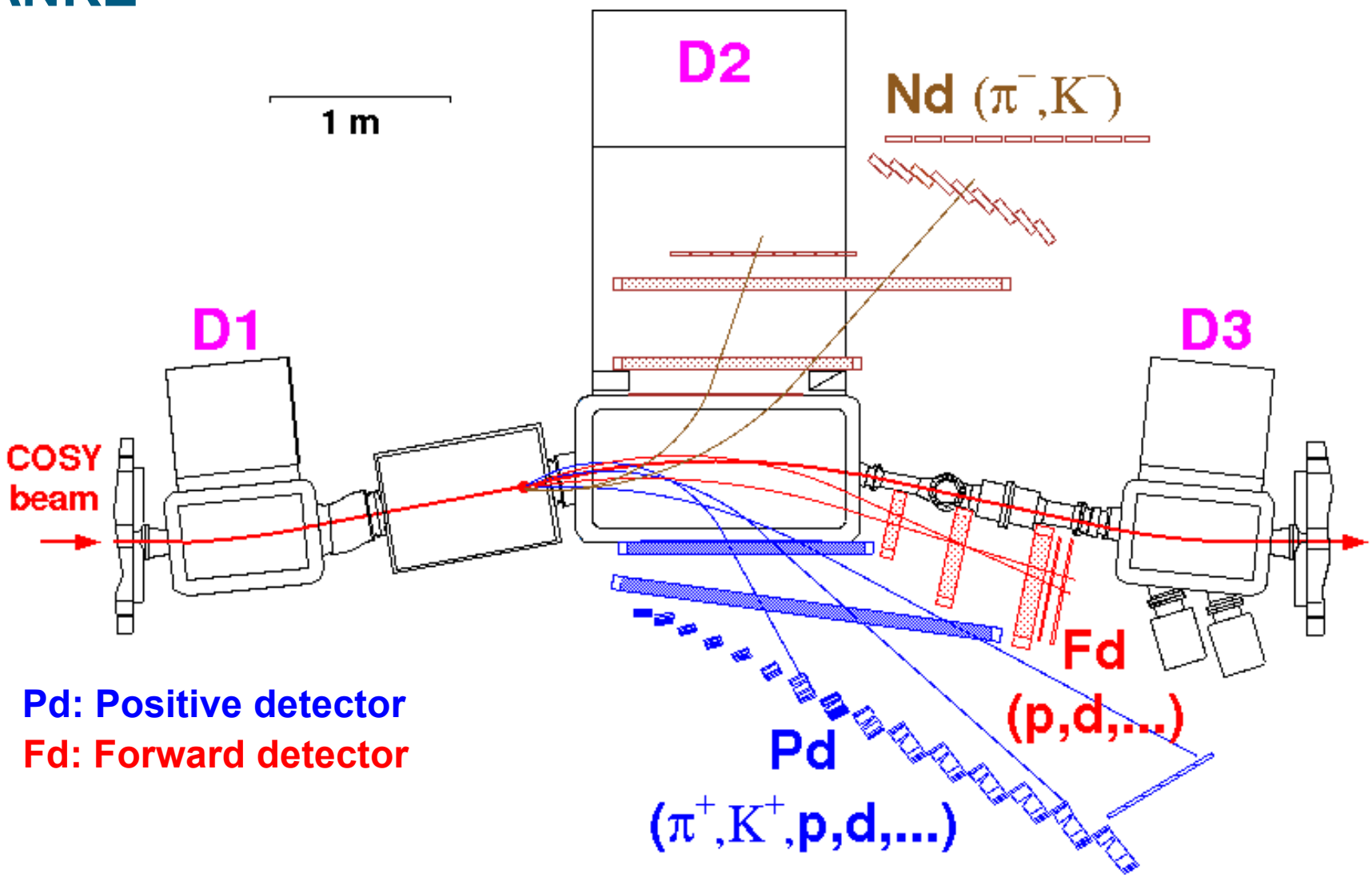
Stochastic and electron cooling



Plenary talks about COSY experiments:

June 3, Thu 11-30 A. Kupsc
June 3, Thu 12-00 F. Hinterberger

ANKE



Pd: Positive detector
Fd: Forward detector

Background suppression ~10^5 times

Simulations

$pp \rightarrow K^+ p \Lambda \rightarrow^{64\%} p\pi^-$

Model for Λ:
1) pΛ FSI
(EPJA 29 (2006) 363)
2) $N^*(1650)$ resonance
(PLB 632 (2006)27)
3) measured p angular spectra
(COSY-TOF theses)

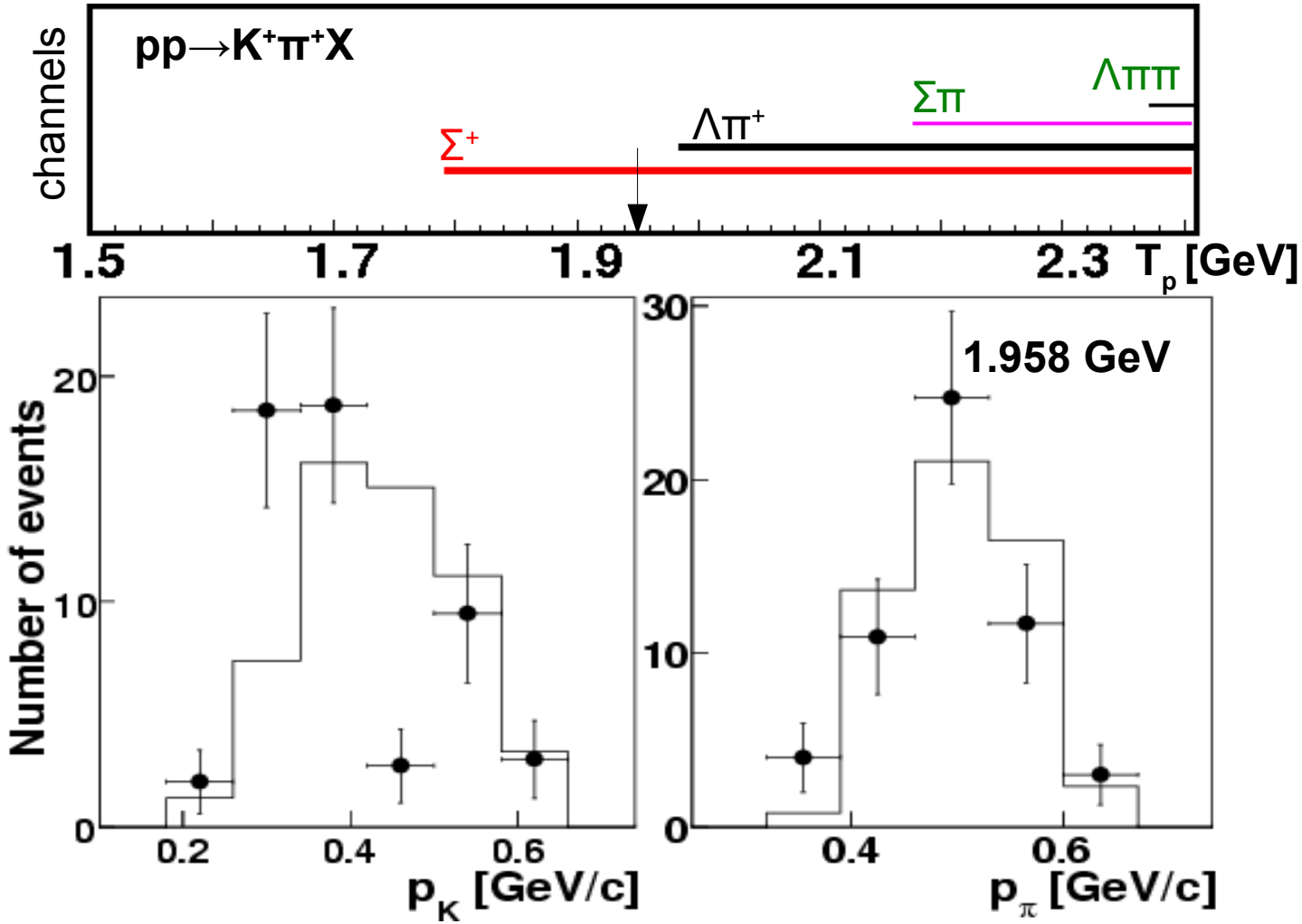
$pp \rightarrow K^+ p \Sigma^0 \rightarrow^{99\%} \Lambda\gamma \rightarrow^{64\%} p\pi^-$

$pp \rightarrow K^+ n \Sigma^+ \rightarrow^{52\%} p\pi^0$

$pp \rightarrow K^+ n \Sigma^+ \rightarrow^{48\%} n\pi^+$

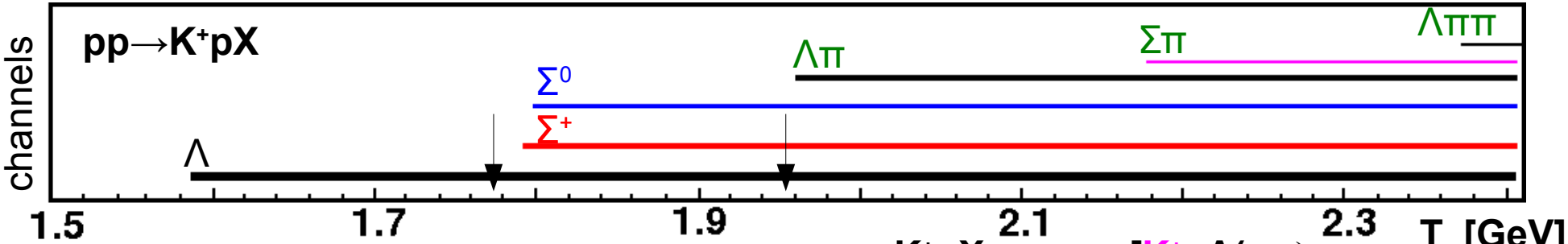
1) K^+ inclusive spectra
2) K^+p correlations
3) $K^+\pi^+$ correlations

Results: $K^+\pi^+$ correlations spectra



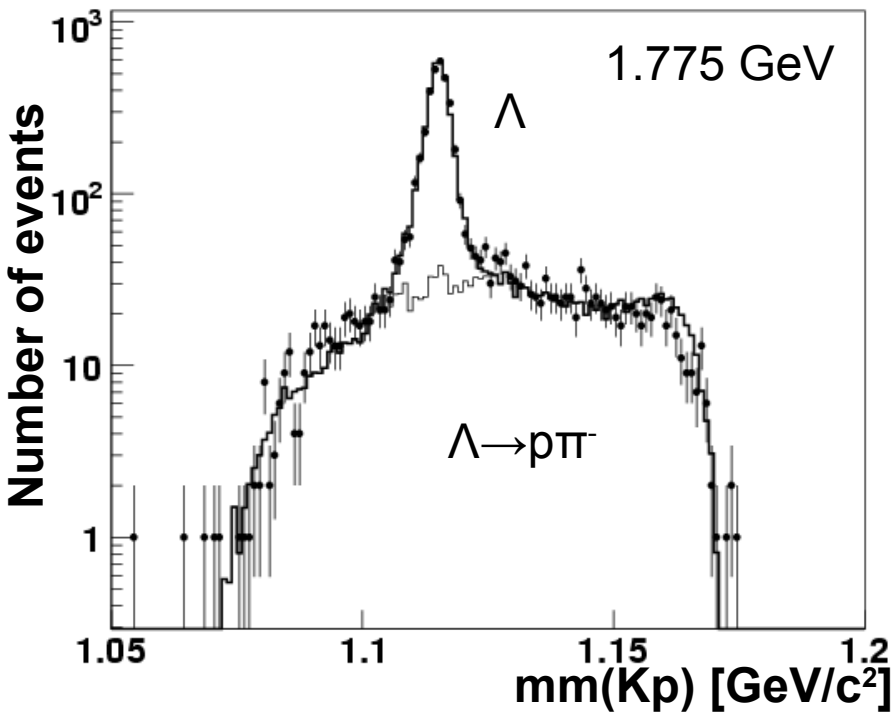
Number of $K^+\pi^+$ correlations identified at four energies used for $\sigma(\Sigma^+)$ determination

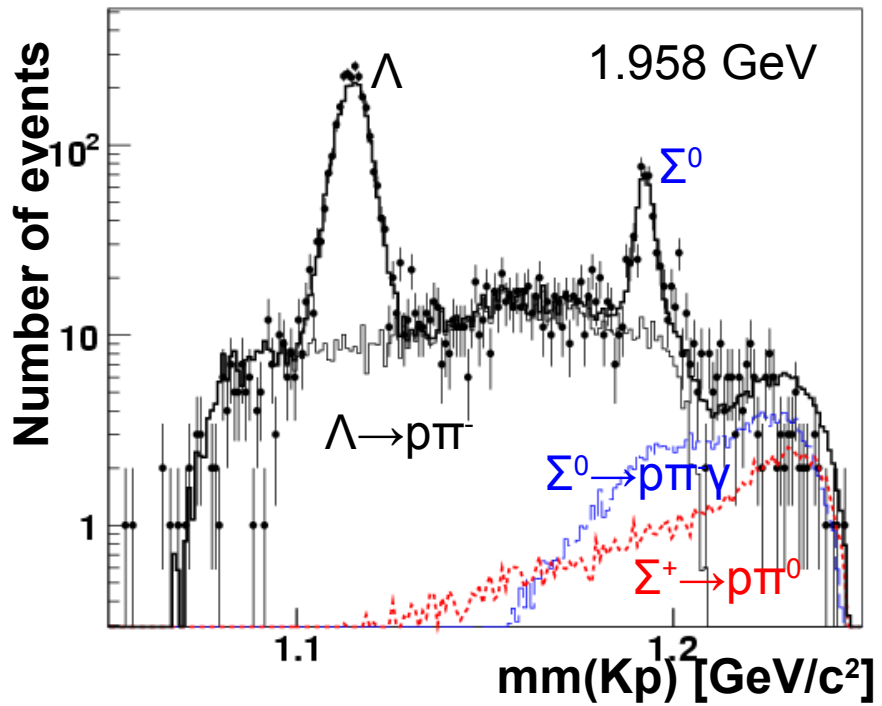
Results: K^+p missing mass spectra



$pp \to K^+pX = \sigma_{anke} \times [K^+p\Lambda(\pi^-p)]$

$pp \to K^+pX = \sigma_{anke} \times [K^+p\Lambda(\pi^-p) + \sigma_{anke} \times K^+p\Sigma^0(\gamma\pi^-p) + \sigma_{anke} \times K^+n\Sigma^+(\pi^0p)]$

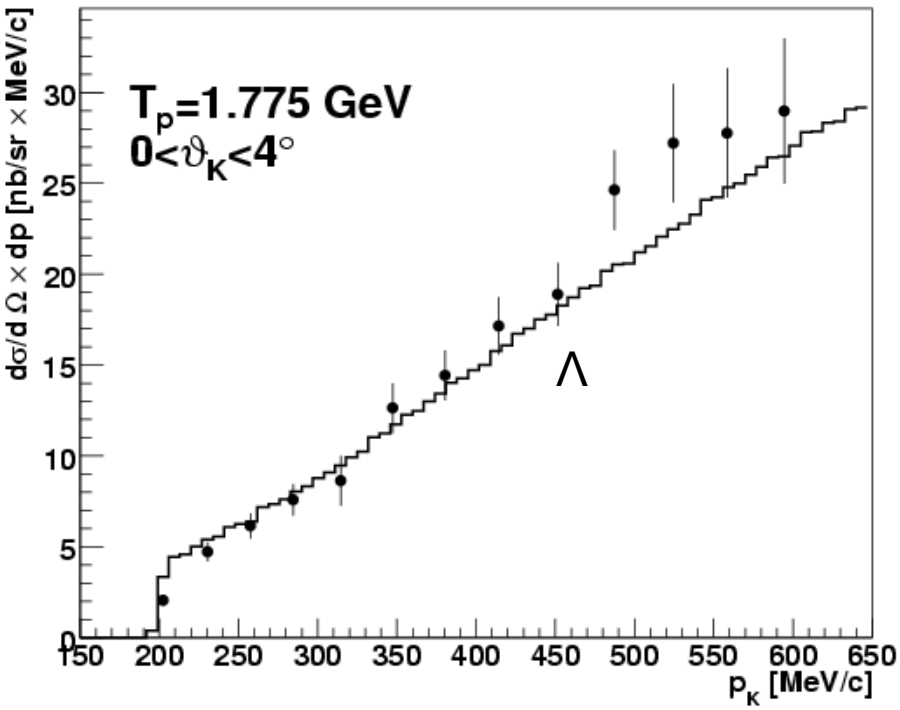


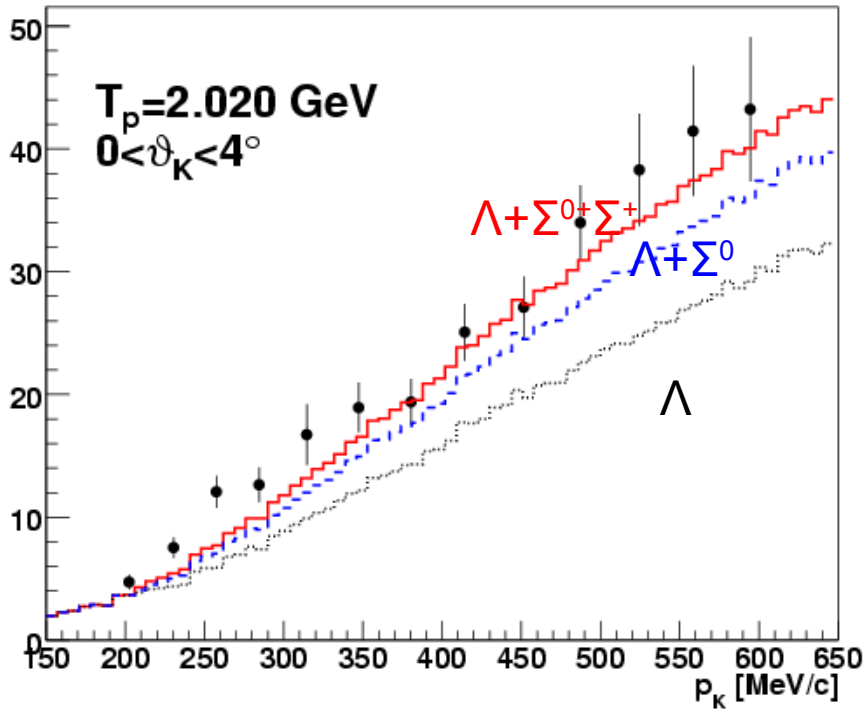


Upper limit on the $\sigma(\Sigma^+)$ can be obtained from K^+p correlations by assuming that there is no contribution from Σ^0

Results: K^+ inclusive spectra

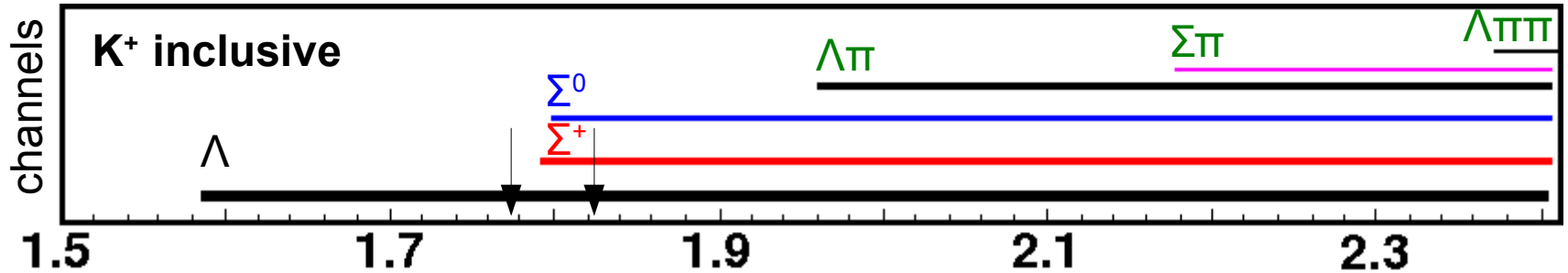
$$pp \rightarrow K^+X = \sigma_{anke} \times [K^+ p \Lambda] + \sigma_{anke} \times [K^+ p \Sigma^0] + \sigma_{anke} \times [K^+ n \Sigma^+]$$



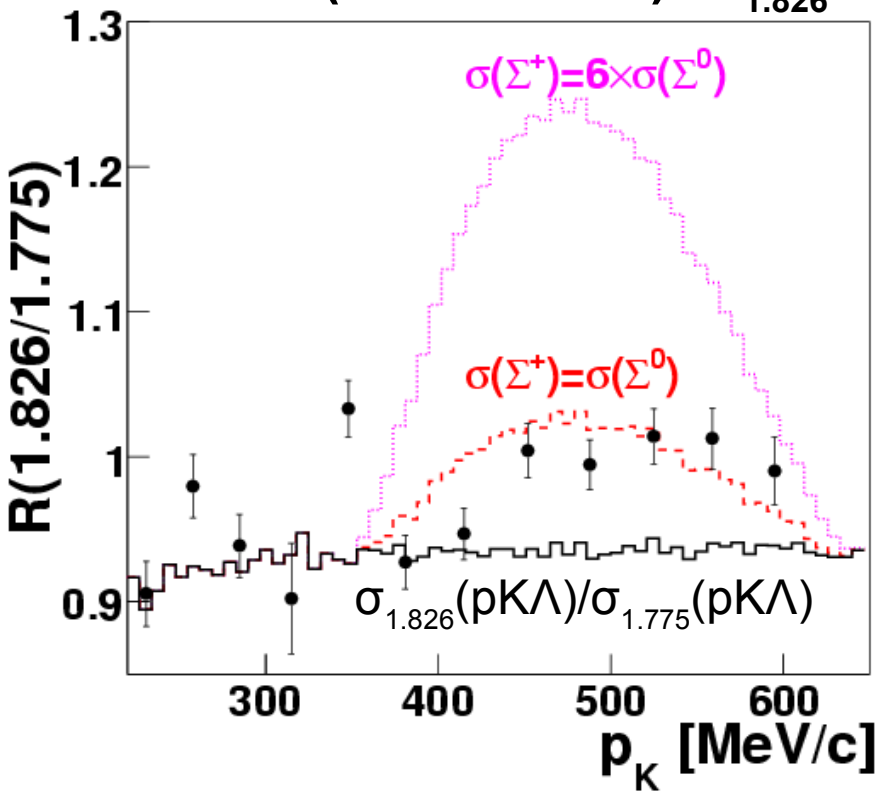


Cross check of extracted $\sigma_{anke}(\Lambda)$,$\sigma_{anke}(\Sigma^0)$ and $\sigma_{anke}(\Sigma^+)$

Results: Ratio of K^+ at 1.826 and 1.775 GeV



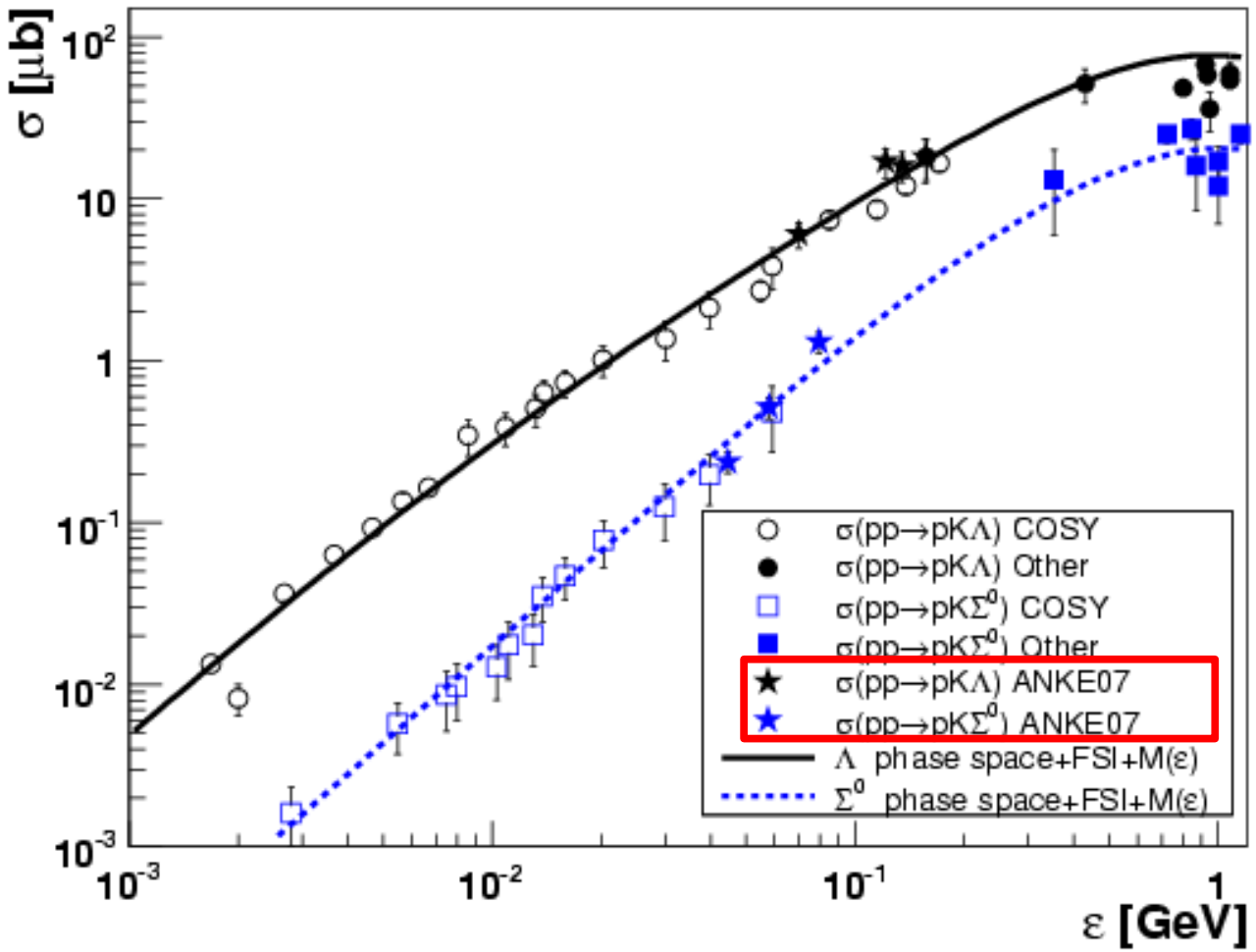
$$R(1.826/1.775)=\Lambda_{1.826}/\Lambda_{1.775}+[\Sigma^0_{1.826}+\Sigma^+_{1.826}]/\Lambda_{1.775}$$



- Ratio R(1.826/1.775) does not depend on acceptance and efficiency
- ANKE acceptance is high 24%

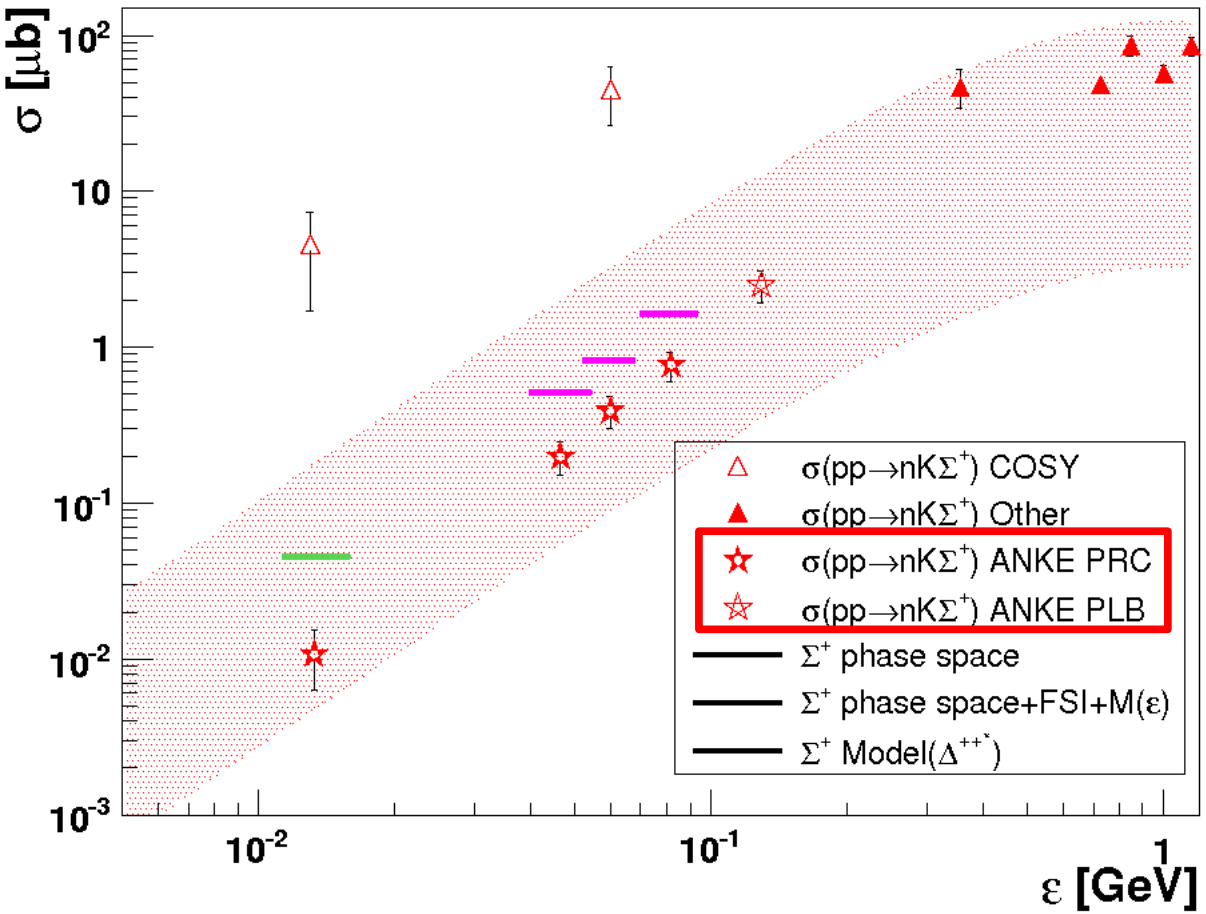
Upper limit on $\sigma_{1.826}(\Sigma^+)$<45 nb

Results: Total cross sections: Λ and Σ^0



Extracted Λ and Σ^0 total cross sections are in agreement with other data

Results: Total cross sections Σ^+



- Measured Σ^+ total cross sections are much smaller then data of other experiment
- Surprising threshold anomaly is excluded by ANKE data
- Extracted total cross sections are in agreement with triangle inequality

PRC 81 (2010) 045208

Conclusions

- ✔ $pp \rightarrow K^+ n \Sigma^+$ total cross section were measured at five energies. ANKE data are in agreement with triangle inequality.
- ✔ Λ and Σ^0 total cross sections, extracted from the same data, agree well with the world data.
- ✔ All three methods (K^+ inclusive, K^+p and $K^+\pi^+$ correlations), using Λ, Σ^0 and Σ^+ total cross sections as input parameters, give consistent answer.
- ✔ Upper limits extracted from K^+ inclusive and K^+p correlation spectra are consistent with $K^+\pi^+$ correlations

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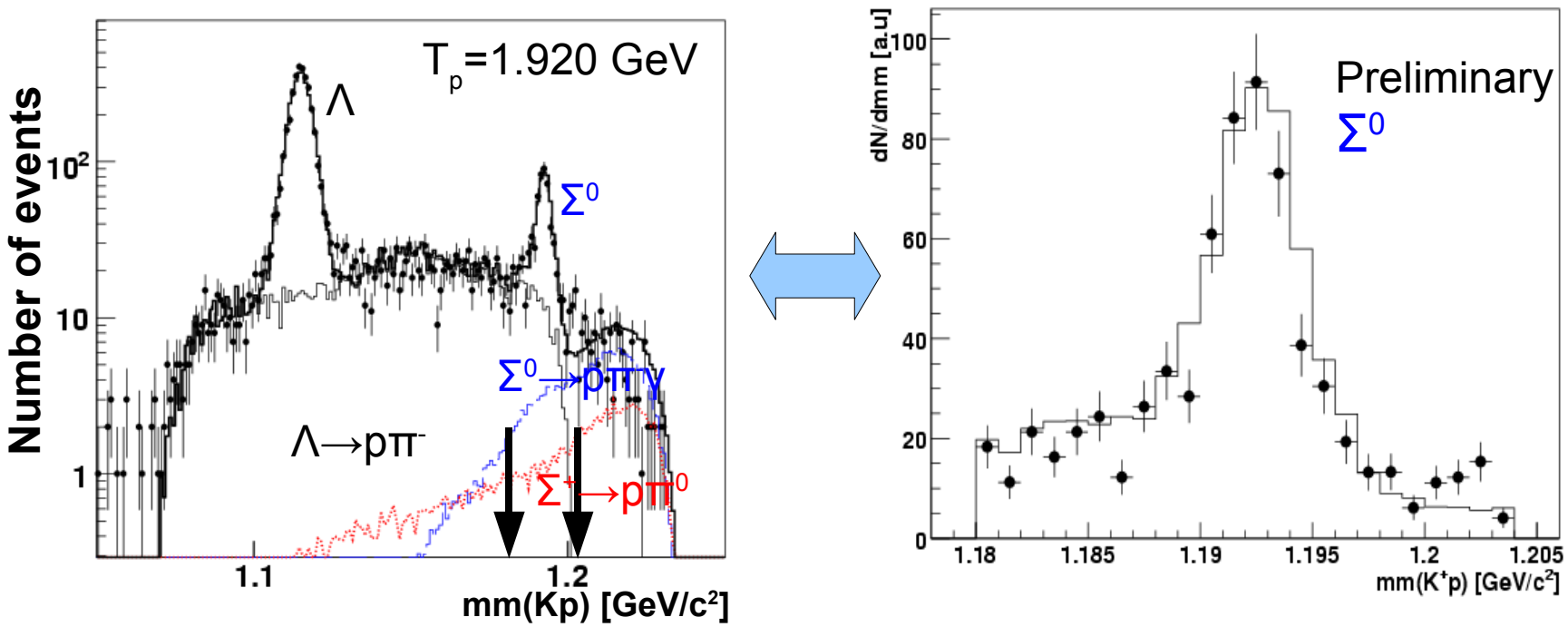
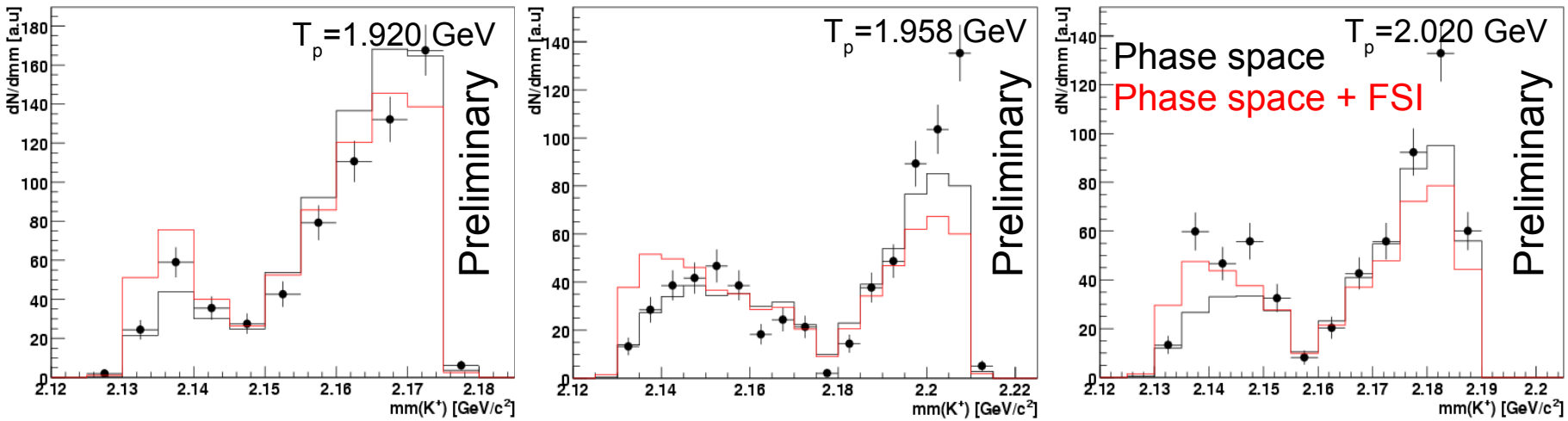
Information about $pp \rightarrow K^+ p \Sigma^0$

- There are no data on differential observables for the $pp \rightarrow K^+ p \Sigma^0$ reaction channel
- There is no indication for attractive $p\Sigma^0$ FSI in energy dependence of the total cross section



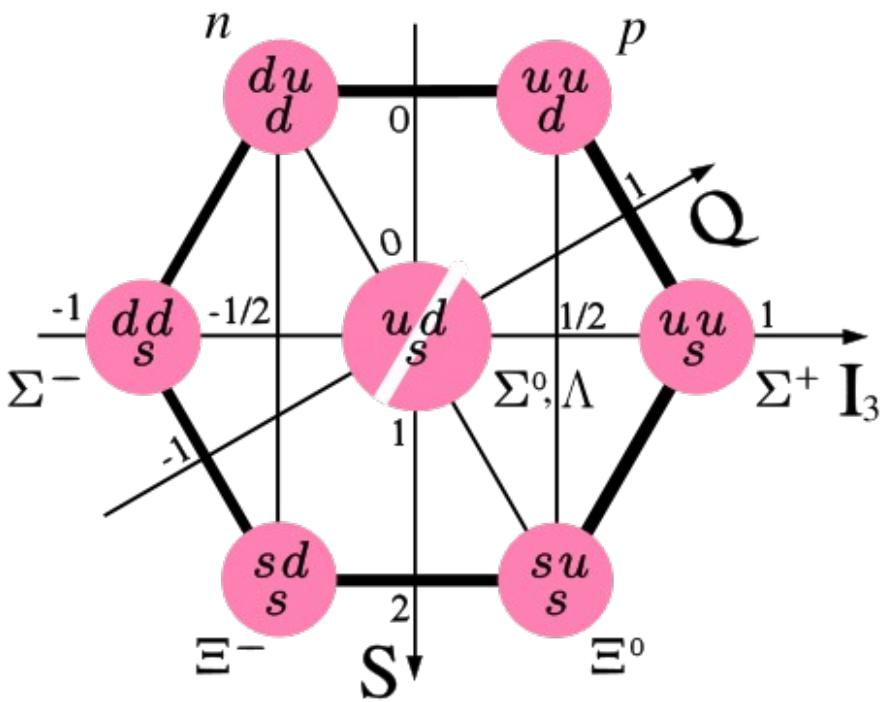
We can select clean Σ^0 events and study differential spectra

Σ^0p FSI



- **If there is a Σ^0p FSI it is small as it is seen from energy dependence of the total cross section**
- **All types of differential observables can be reconstructed**

Outlook



➔ Data on the quasi-free $pn \rightarrow K^+ p \Sigma^-$ reaction are in the progress of being analysed

➔ New proposal for investigation of the quasi-free $pn \rightarrow K^+ n \Lambda$ reaction submitted to COSY-PAC

Thank you!