Strangeness Production @ COSY

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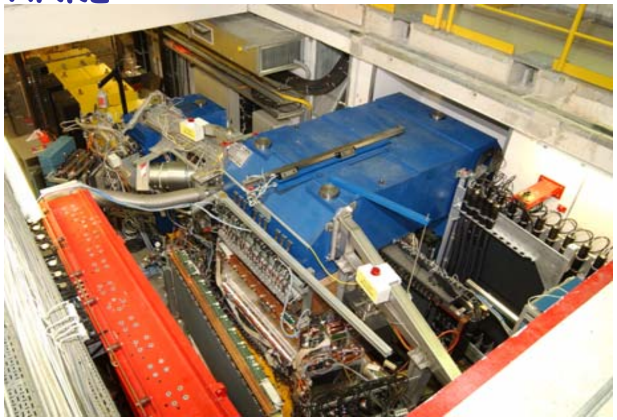
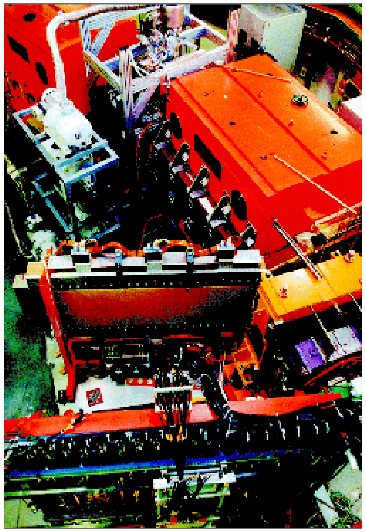
ANKE





COSY-11

COSY-TOF

Proton Induced Strangeness Production on Protons and Nuclei Near Threshold

Markus Büscher
Forschungszentrum Jülich
Germany

The Accelerator: COSY-Jülich

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COSY (Cooler Synchroton)
at FZ-Jülich (Germany):

- (polarized) p & d beams
- phase-space cooling
  - electron & stochasting cooling
- p = 0.30 – 3.65 GeV/c
  - $pp \to pp\ X$ ($m_X \leq 1.1$ GeV/c^2)
  - $dd \to \alpha\ X$ ($m_X \leq 1.0$ GeV/c^2)
  - $pp \to pK^+ Y^*$ ($m_{Y^*} \leq 1.5$ GeV/c^2)
- internal & external beams

COSY vs. Other Accelerators

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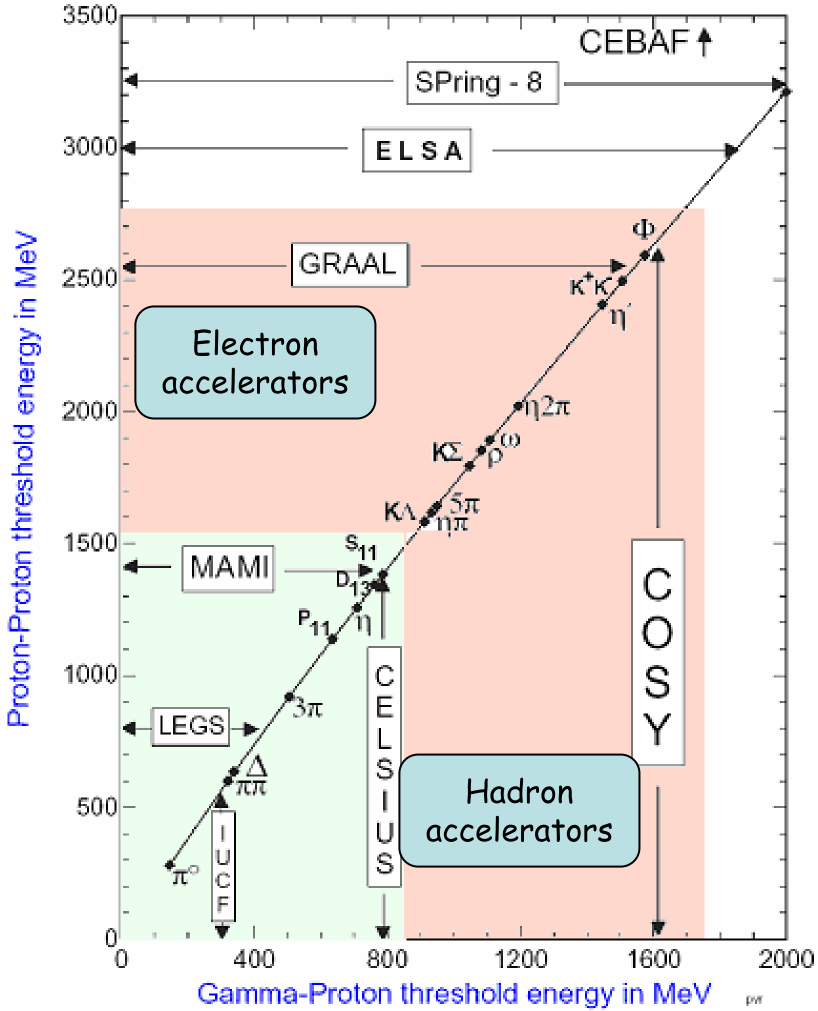


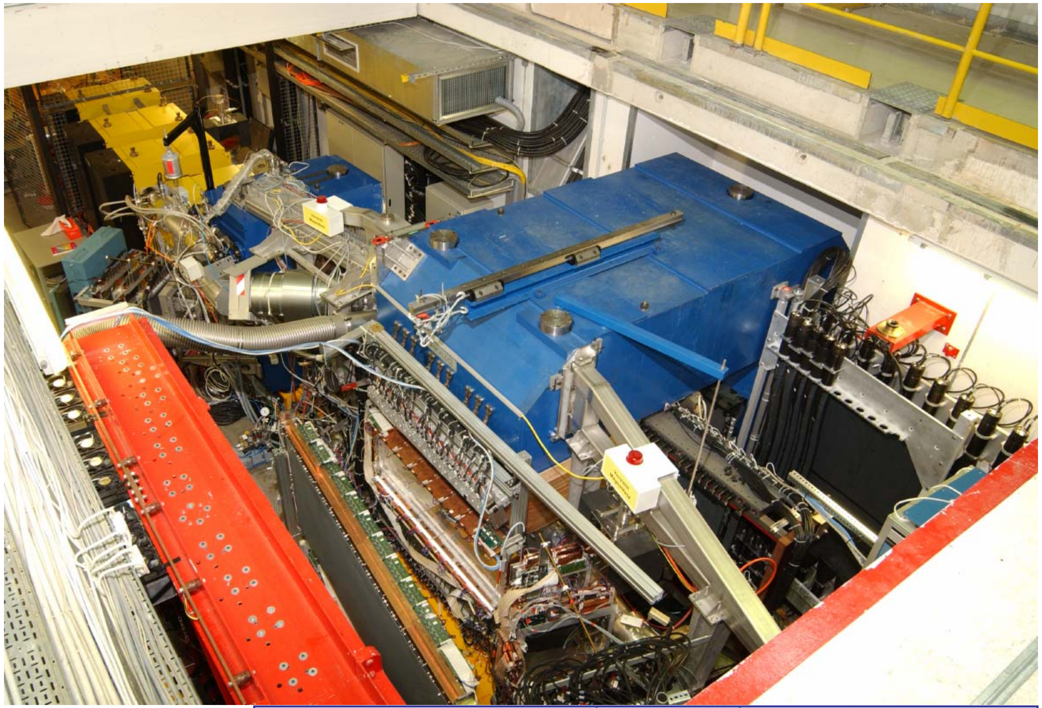
Production Thresholds:

$p\,p \rightarrow p\,K^+\Lambda$ T_p = 1.58 GeV
$p\,p \rightarrow p\,K^+\Sigma^0$ T_p = 1.79 GeV
$p\,p \rightarrow p\,K^0\Sigma^+$ T_p = 1.80 GeV
$p\,p \rightarrow p\,p\,K^+K^-$ T_p = 2.50 GeV

Some interesting reactions:

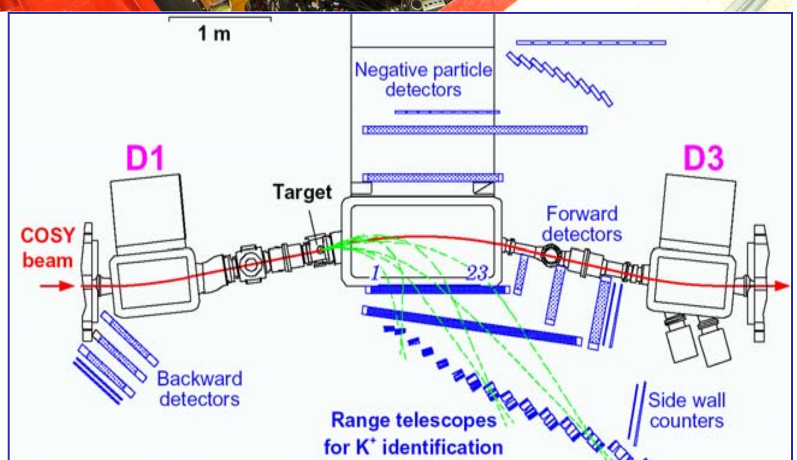
- $pp \rightarrow pK^+Y$ ($m_Y \leq 1.5$ GeV/c^2)
- $pp \rightarrow pp\, a_0/f_0(980)$
- $pA \rightarrow pK^+X$ (T_p = 1.0...2.3 GeV)

Several dedicated detection systems...



ANKE, COSY-11:

- circulating beam
- thin internal targets
- forward spectrometer (small acceptance)
- magnetic spectrometer



COSY-TOF:

- extracted beam
- small target (vertex)
- nearly 4π coverage (no charge id)
- non-magnetic

MOMO (at BIG KARL)

COSY-TOF: Detection Principle

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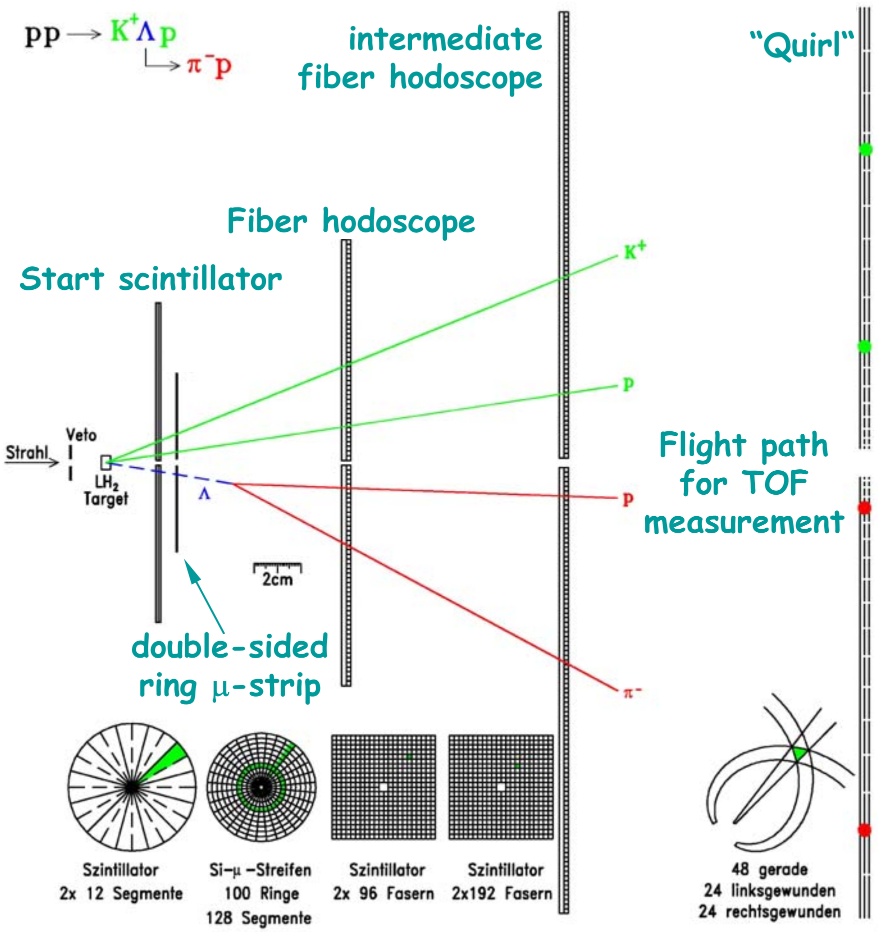

- No magnetic field
- Detection of charged ejectiles
- Complete geometrical reconstruction of each event $\Rightarrow$ kinematical variables
- Start detector optimized for track/vertex reconstruction
- Additionally: TOF & ΔE
- Trigger: charge 2 $\rightarrow$ 4

Strangeness Production …

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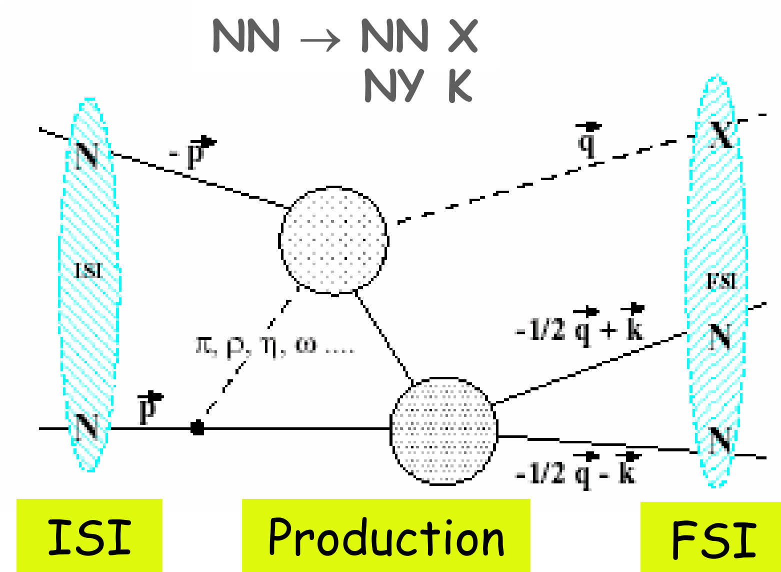

Initial- (ISI) and Final State Interactions (FSI):

If (p,Y), (p,K), or (K,Y) travel along with each other, they interact and „distort" spectra (observables):

→ exploit this to study such interactions !!

→ reactions close to threshold

Example: (pΛ)-FSI

→ (pΛ) scattering length

Λ-Hyperon Production

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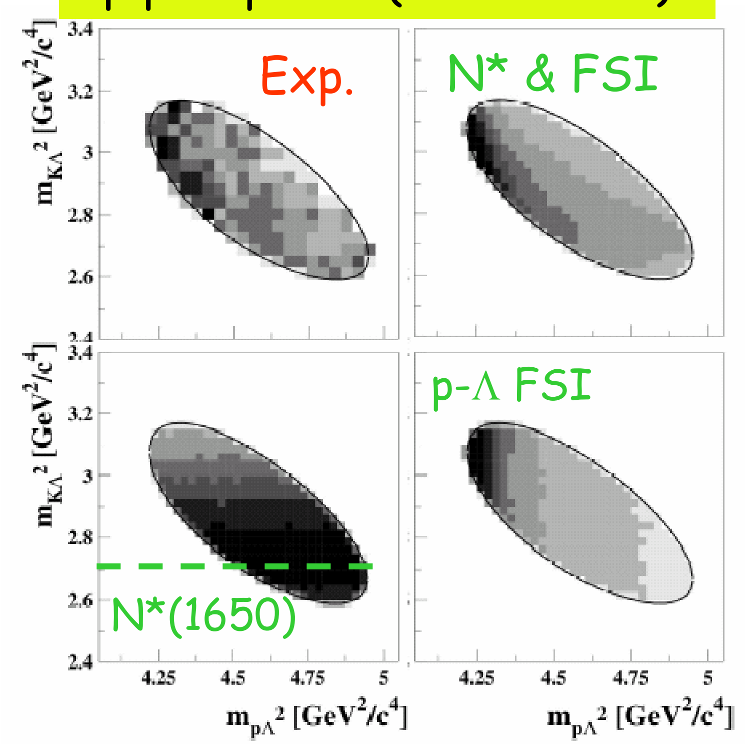
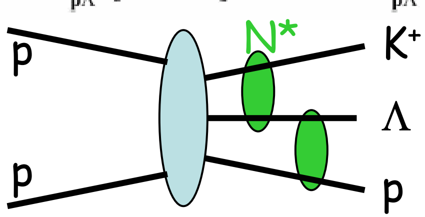
$p\,p \rightarrow p\,K^+\,\Lambda$ (COSY-TOF)





Dalitz-plots:

(analysis w/ theoretical model of A. Sibirtsev)

- at 2.85 GeV/c (see Fig.)

  → in addition to p-Λ FSI, a strong contribution of the N*(1650) nucleon resonance is needed

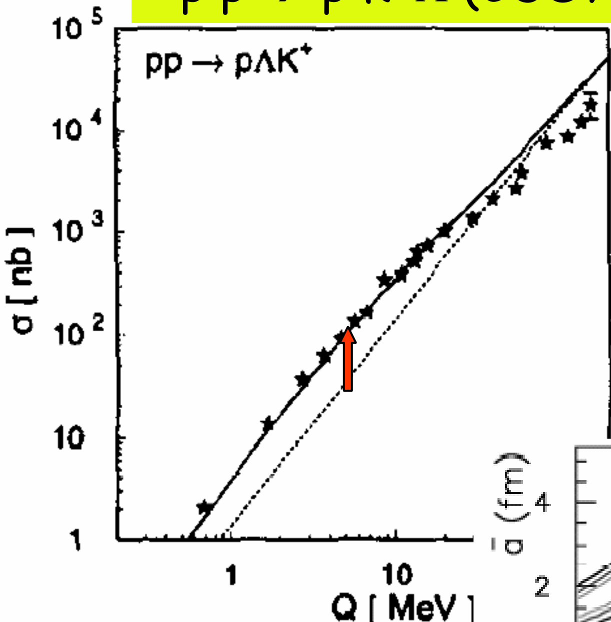
- At higher energies, also the N*(1710) has to be included

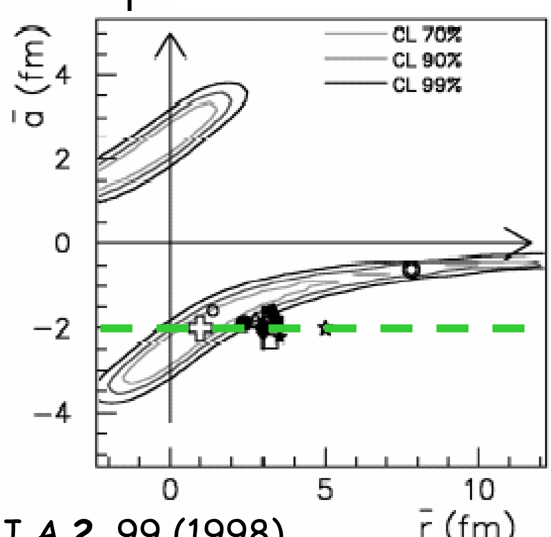
  [FSI+N*(1650)] : N*(1710) ~ 1

W. Schröder, Ph.D. thesis Uni Erlangen, to be published

Λp Interaction

p p → p K^+ Λ (COSY-11)





J.T. Balewski et al., EPJ A **2**, 99 (1998)

Total cross section for pp → p K^+ Λ

a) ········ phase space

b) —— p-K^+ Coulomb repulsion

and

p-Λ strong FSI

Dalitz-pot analysis:

→ spin-averaged Λp-scattering length:

a = - (2.0 ± 0.2) fm

But:

a and r are correlated

Watson formula applicable?

Spin dependence (a_s/a_t)?

Theory can help ... !

Λp Scattering Length

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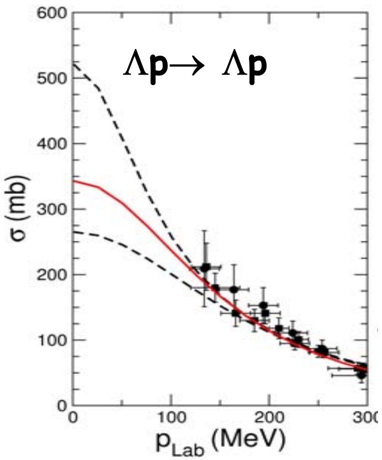
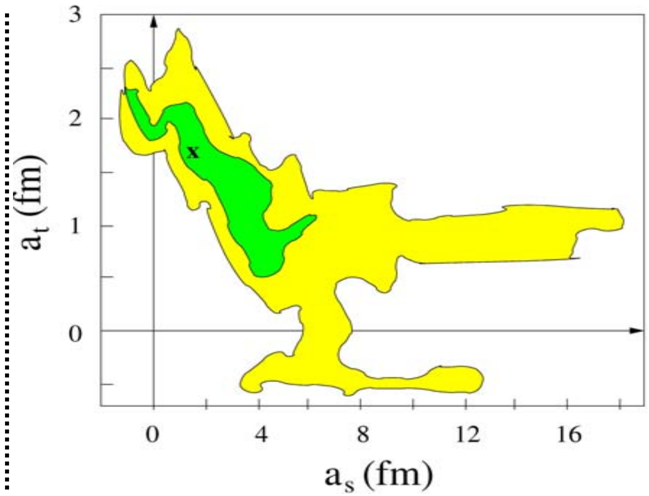
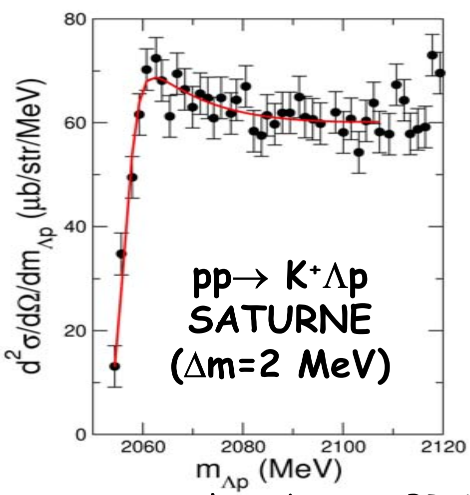


- Data:
  - Λp elastic scattering
    ($\sigma_{el} = \frac{1}{4}\sigma_s + \frac{3}{4}\sigma_t$)
  - Bubble chamber
- Fit:
  - Effective-range expansion



G. Alexander et al., PR **173**, 1452 (1968)



$$a_S = \lim_{M^2\to m_0^2} \frac{1}{2\pi}\left(\frac{m_\Lambda+m_p}{\sqrt{m_\Lambda m_p}}\right) \mathbf{P}\int_{m_0^2}^{m_{max}^2} dm^2 \sqrt{\frac{m_{max}^2-M^2}{m_{max}^2-m^2}} \times \frac{1}{\sqrt{m^2-m_0^2}\,(m^2-M^2)} \log\left\{\frac{1}{p'}\left(\frac{d^2\sigma_S}{dm^2dt}\right)\right\}$$

S = s or t

observable

$\underline{a} = (-1.5 \pm 0.15_{exp} \pm 0.3_{th})$ fm

- Polarisation measurements (COSY) → a_s, a_t
- Formula also applicable for γd → KΛN

A. Gasparian et al., subm. to PRC

Σ-Hyperon Production

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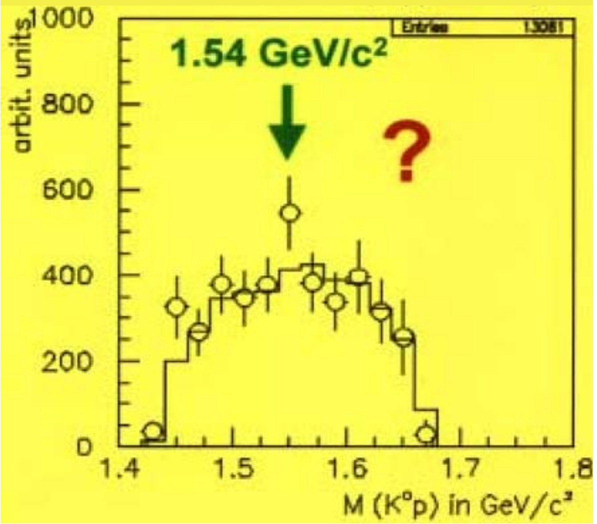
$p\,p \rightarrow p\,K^0\,\Sigma^+$ (COSY-TOF)

$pp \rightarrow pK^0\Sigma^+$, 3.30 GeV/c
preliminary!



Dalitz-plots:

- at 3.20 GeV/c (see Fig.)

  → rather smooth distribution

- "pentaquark" states (θ^+)???
  observed in (nK^+) in photo-nuclear reactions

  → here: $pp \rightarrow \Sigma^+\theta^+$

  ↳ K^0p

  → nothing seen in $pp \rightarrow \Lambda\,(K^+p)$!!

"... we are optimistic to significantly contribute to the topic ..."

The Light Scalar Resonances

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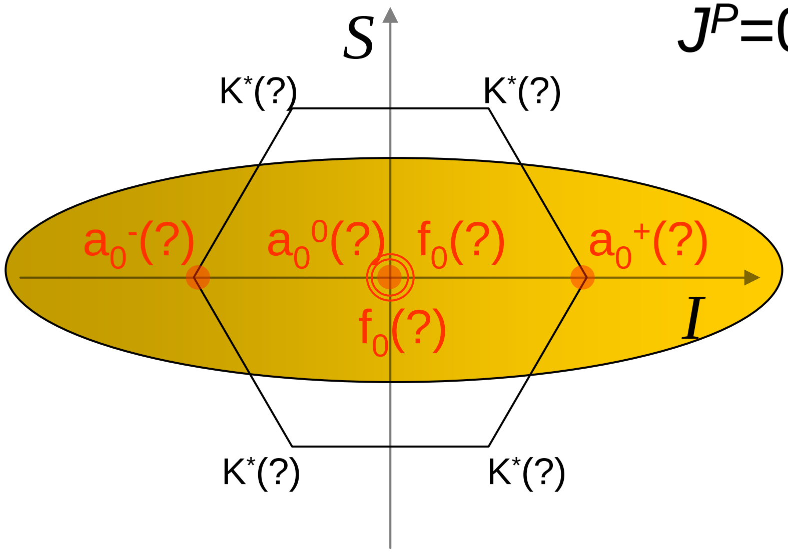
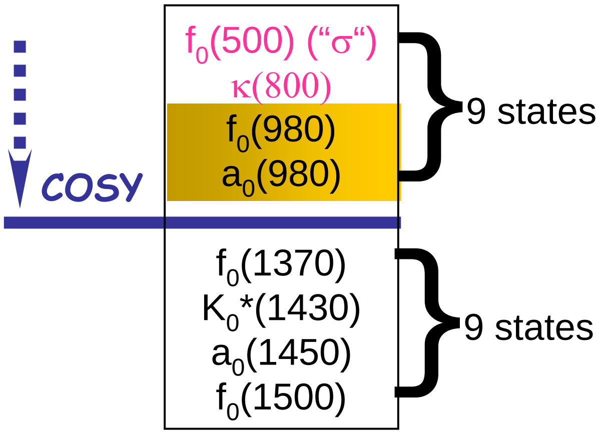
Nonet of light scalar mesons



Possible candidates



The $a_0/f_0(980)$ at ANKE/COSY

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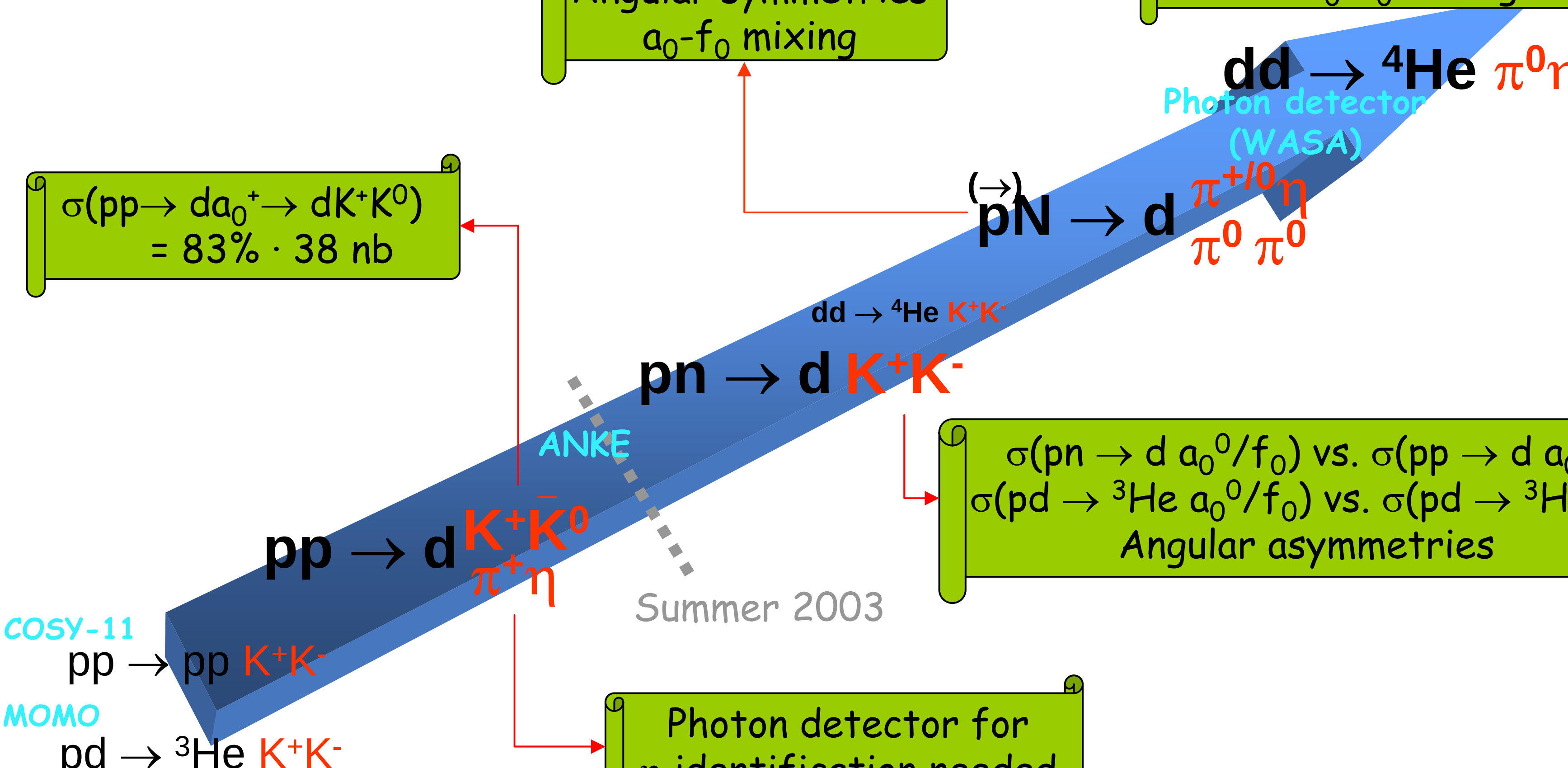
Defined FS isospin
Angular symmetries
a_0-f_0 mixing

Charge-symmetry breaking
a_0-f_0 mixing

$\sigma(pp \to d a_0^+ \to dK^+\bar{K}^0)$
$= 83\% \cdot 38$ nb



$\sigma(pn \to d\ a_0^0/f_0)$ vs. $\sigma(pp \to d\ a_0^+)$
$\sigma(pd \to {}^3He\ a_0^0/f_0)$ vs. $\sigma(pd \to {}^3H\ a_0^+)$
Angular asymmetries

Photon detector for
η identification needed

M. Büscher et al., hep-ph/0301126

K^+ Production from pA Reactions

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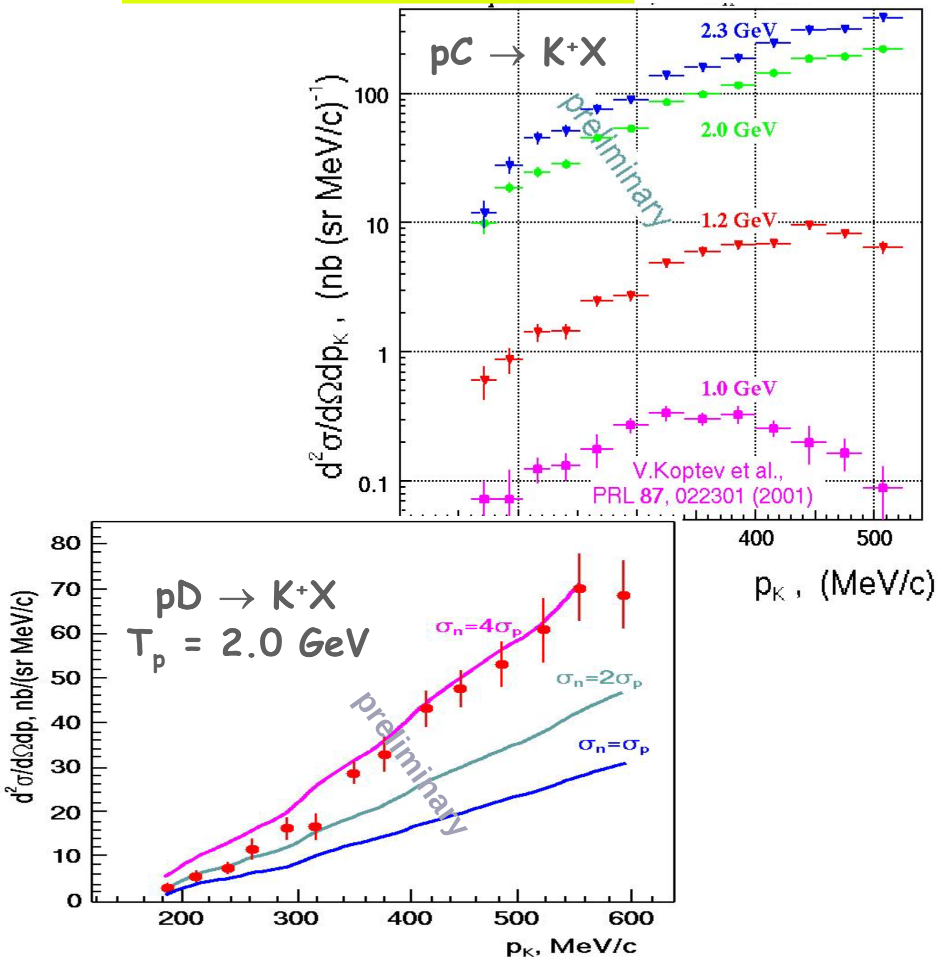
p A → K^+ X (ANKE)



- Inclusive cross sections for
  - D, C, Cu, Ag, Au Targets
  - T = 1.0 ... 2.3 GeV (T_{NN} = 1.58 GeV)

➔ Reaction mechanisms
  - Strong collectivity below threshold
  - Model calculations (CBUU transport, folding model...)
  - Correlation measurements

➔ pD data:
  - $\sigma(pn \to K^+X) \cong 4 \cdot \sigma(pp \to K^+X)$

taken from:
K.Tsushima et al., PRC **59**, 369 (1999)

Publication in preparation

Nuclear Medium Effects

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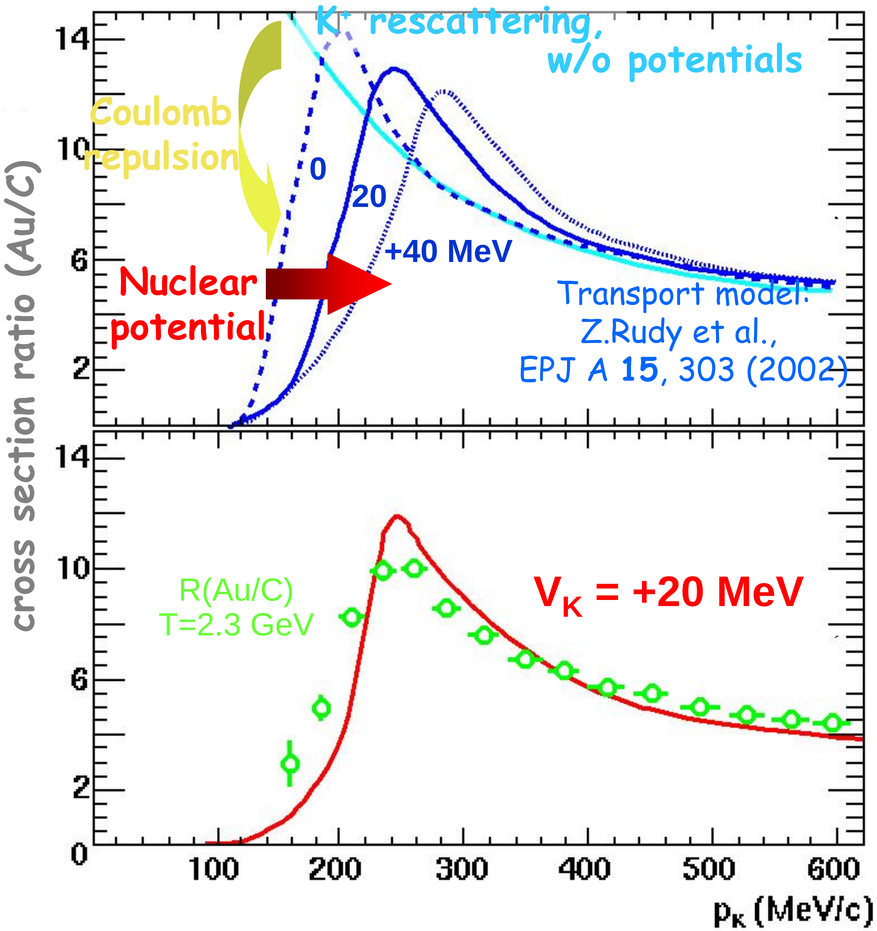
p A → K^+ X (ANKE)



- Cross-section ratios R(A/C) have very small systematic uncertainties
- V_{K+} is sensitive to peak position in R(A/C)
- pA reactions probe nuclear medium at $\rho \leq \rho_0$
- Best agreement with calculations for

$$V_{K+}(\rho \leq \rho_0) = +20 \text{ MeV}$$

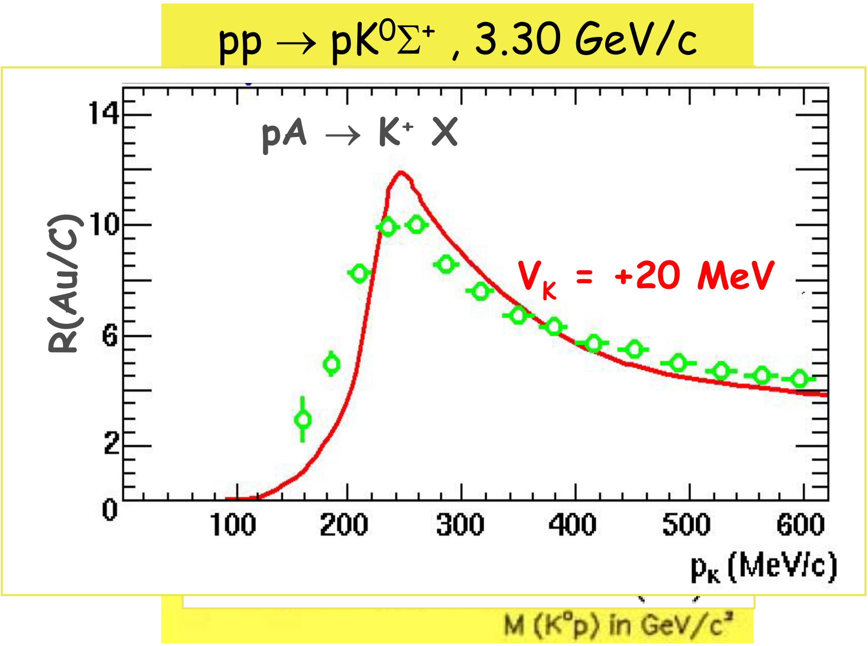
- Expected accuracy <3 MeV

M.Nekipelov et al., PLB **540**, 207 (2002)

Strangeness Production …

… fundamental issues can be addressed …

- "Exotic" states
  - θ^+ in $pp \to pK^0\Sigma^+$???
- Charge-symmetry breaking
  - $dd \to \alpha\ (\pi^0\eta)$ and a_0-f_0 mixing
- $SU(3)_{flavor}$ symmetry breaking
  - NY interaction at low relative energies (compare with NN)
- In-medium masses



… needs to (and will) be vigorously investigated (at COSY)!

I.d. of $pp \to dK^+\bar{K}^0$ events @ ANKE

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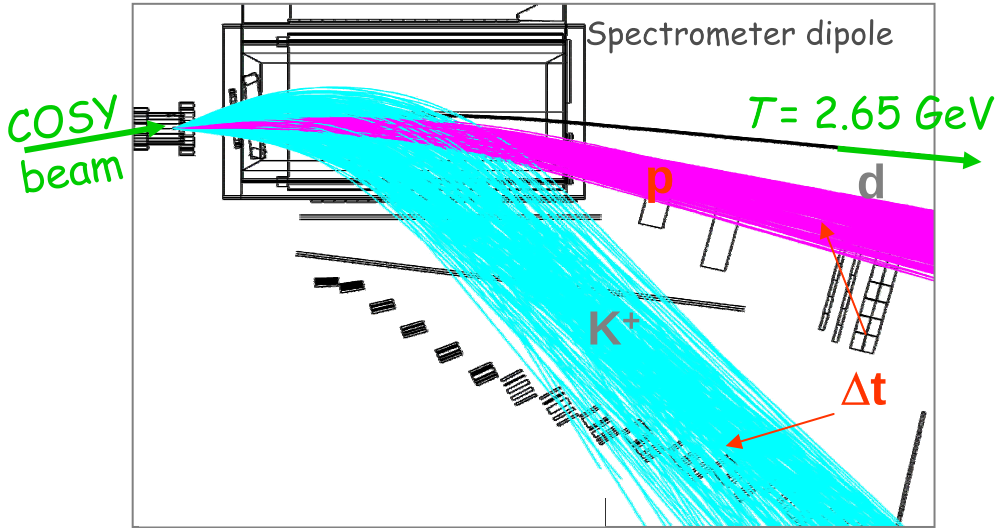
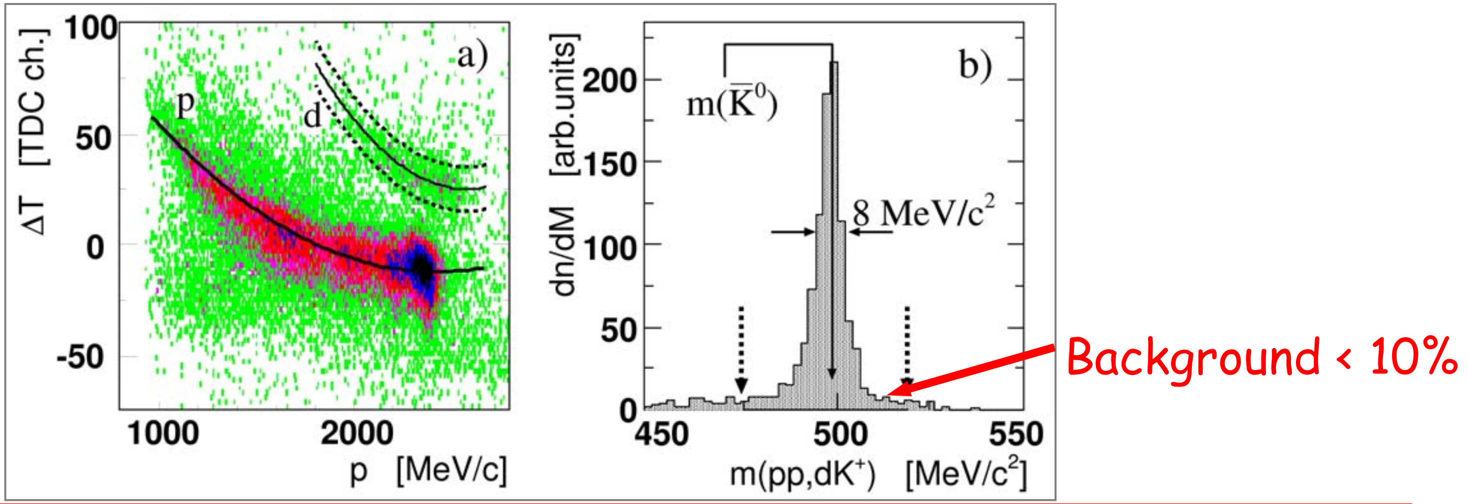


- K^+-d coincidence measurement
- Identification of $pp \to dK^+X$ events via TOF, ΔE and particle momenta
- Identification of $pp \to dK^+\bar{K}^0$ events via dK^+ missing mass



First Results on the a_0^+

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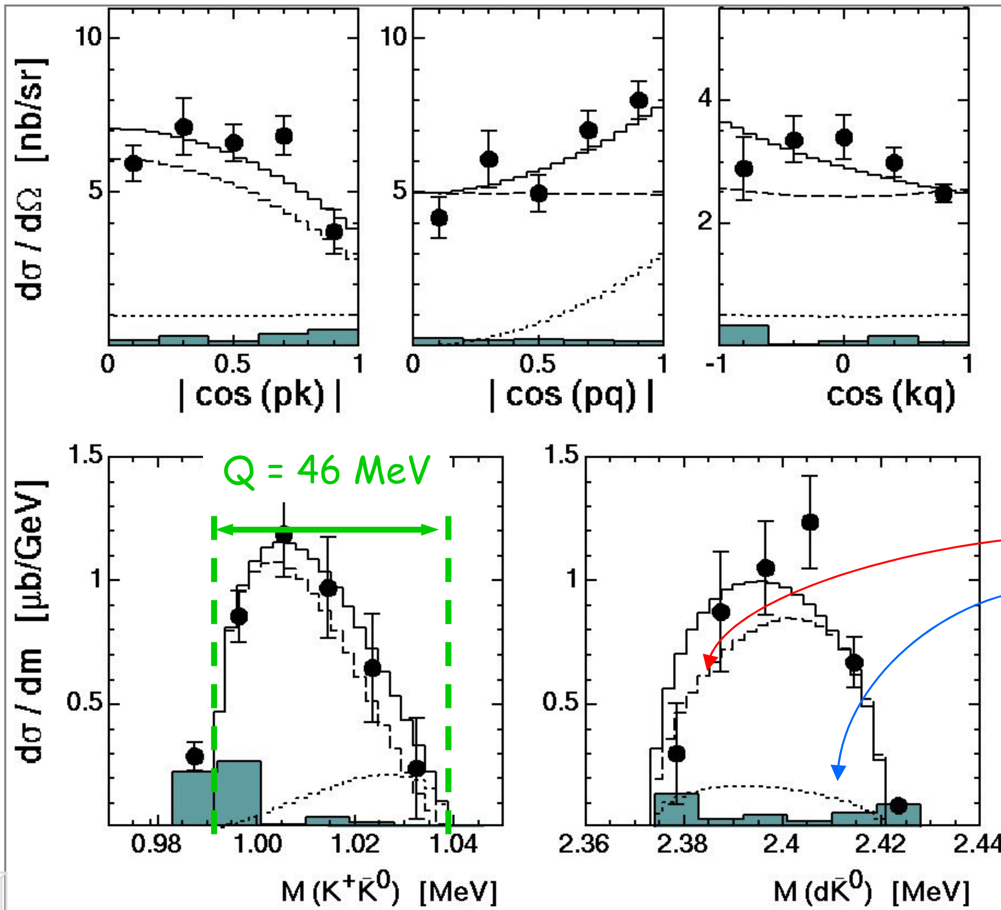
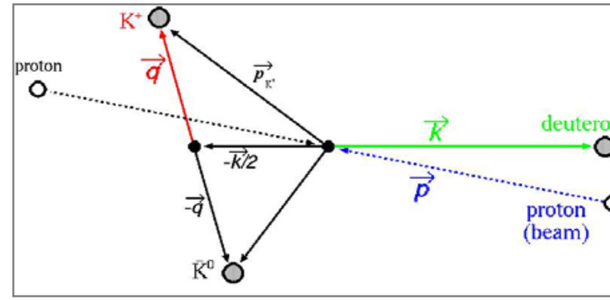
p p → d $K^+\bar{K}^0$ (ANKE)





Fit:
$[(K\bar{K})_P d]_S + [(K\bar{K})_S d]_P$

$\sigma(pp \to d a_0^+ \to dK^+\bar{K}^0) = 83\% \cdot \sigma_{tot}$

$\sigma_{tot}(pp \to dK^+\bar{K}^0) = (38 \pm 2_{stat} \pm 14_{sys})$ nb

V.Kleber et al., PRL in print; nucl-ex/0304020

Λ vs. Σ^0 Production …

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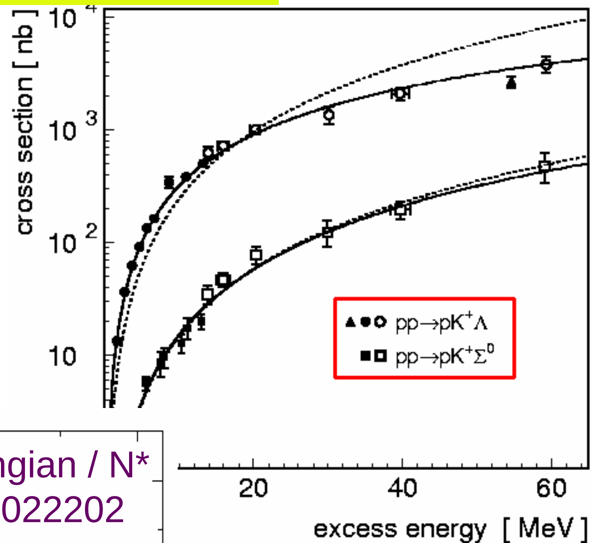
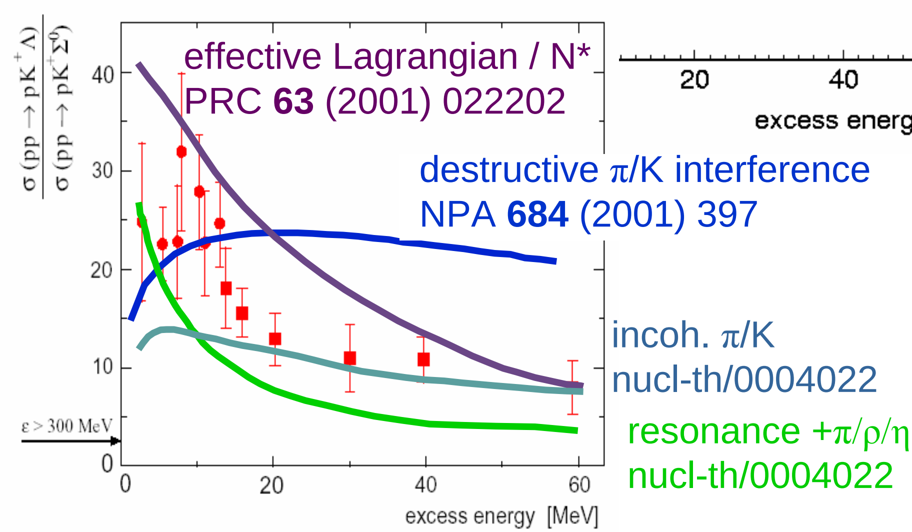
$pp \to pK^+ \Lambda/\Sigma^0$ (COSY-11)





Λ/Σ^0 ratio (same excess energy above threshold):

R ~ 25 at threshold, R(E) → 3

Difference between Λ and Σ^0 ?

$|\Lambda\rangle = |(ud)[I=0,{}^1S_0], s\rangle \quad I=0, \frac{1}{2}^+$

$|\Sigma^0\rangle = |(ud)[I=1,{}^3S_1], s\rangle \quad I=1, \frac{1}{2}^+$

→ R ~ 3

coupling: $g_{N\Lambda K}$, $g_{N\Sigma K}$

→ R ~ 27

$\Sigma N \to \Lambda p$ transition

S. Sewerin et al., PRL 83, 682 (1999)

Experimental challenges …

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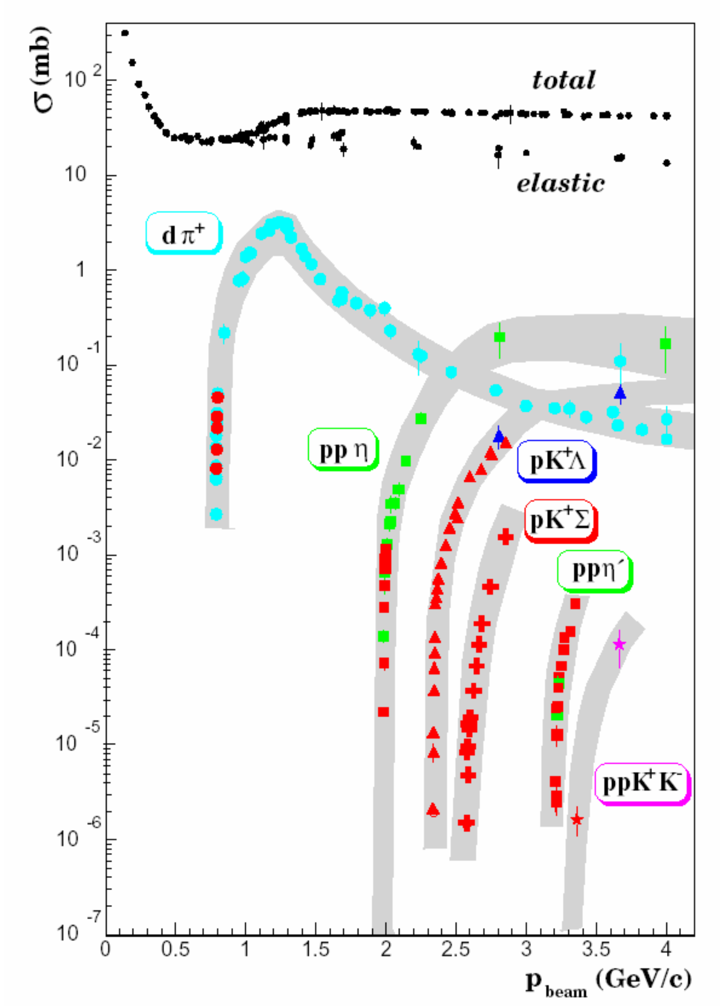

NN Partial Cross Sections:

p p → N Y K

(mostly COSY data)

more specifically:

p p → p Λ K^+

p p → p Σ^0 K^+

p p → p Σ^+ K^0

p p → n Σ^+ K^+

(p p → pp K^+ K^-)