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Hyperon Physics at COSY

Forschungszentrum Jülich

March 14th 2008, Michael Hartmann

Scope of the talk

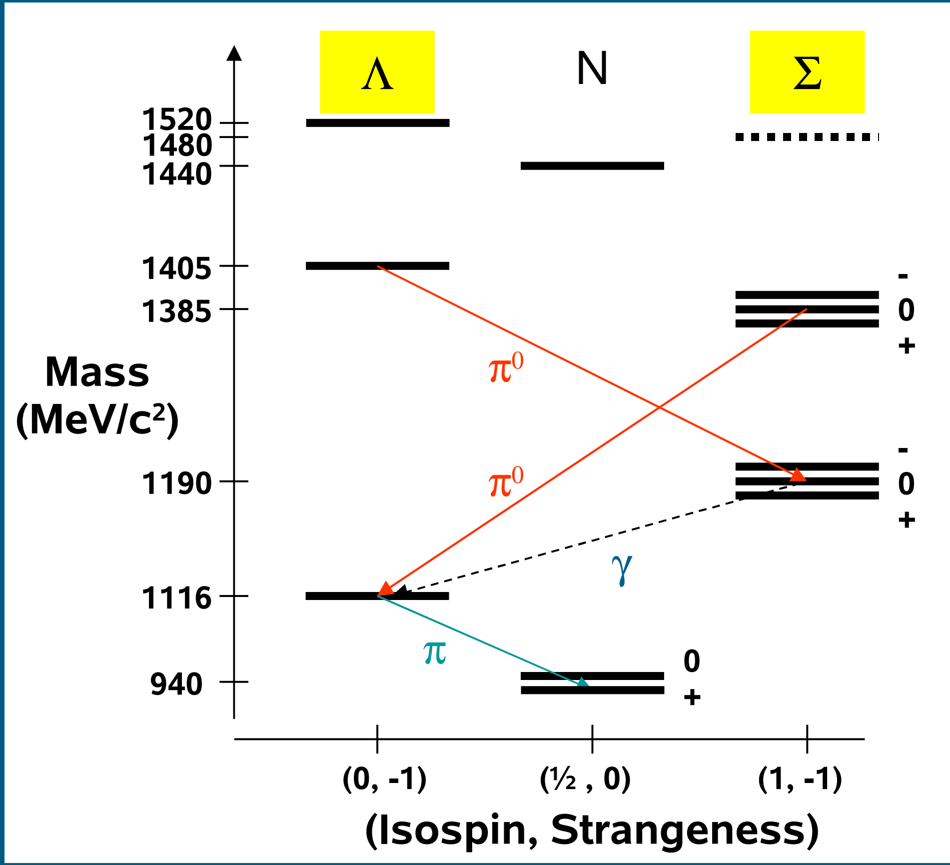
I. Ground state Hyperon production (TOF)
   - $\Lambda(1116)$ (N* resonances)

II. Excited states Hyperon production (ANKE)
   - $\Lambda(1405)/\Sigma^0(1385)$
     - kaon anti-kaon pair production

   - $Y^0(1480)$

all in proton-proton collisions

Starting point: $pp \rightarrow NK^+Y$



COSY: COoler SYnchrotron "high quality beam"

TOF: "large acceptance, Dalitz plot analysis"

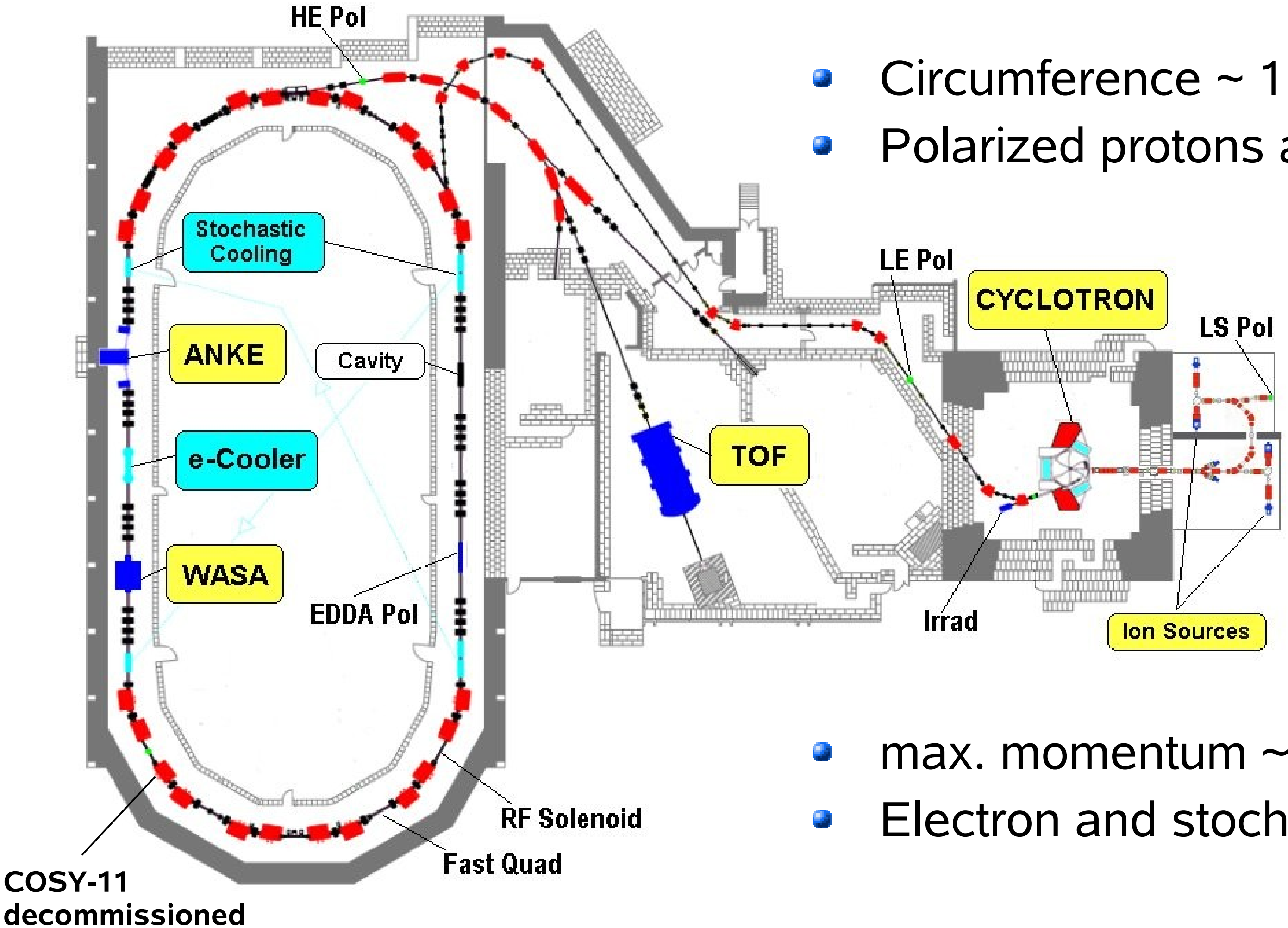
ANKE: "certain reaction channels, charged kaon selectivity"

WASA: "detect both neutral and charged particles"

WASA is now in operation!

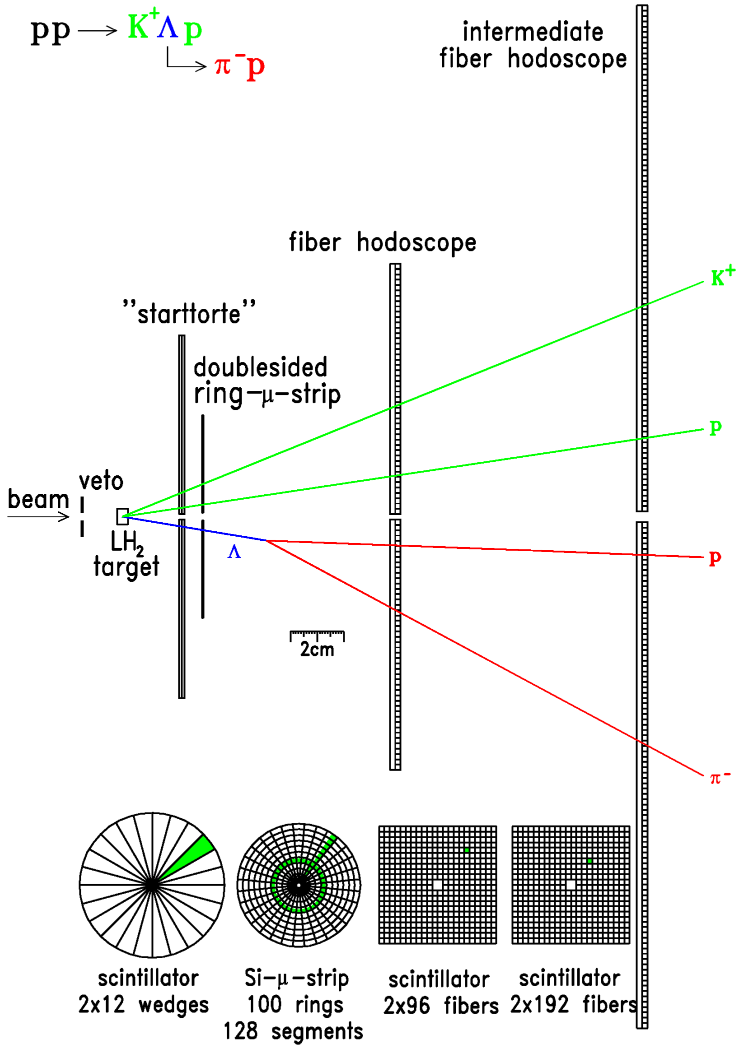
brief look at COSY, TOF and ANKE ⇒

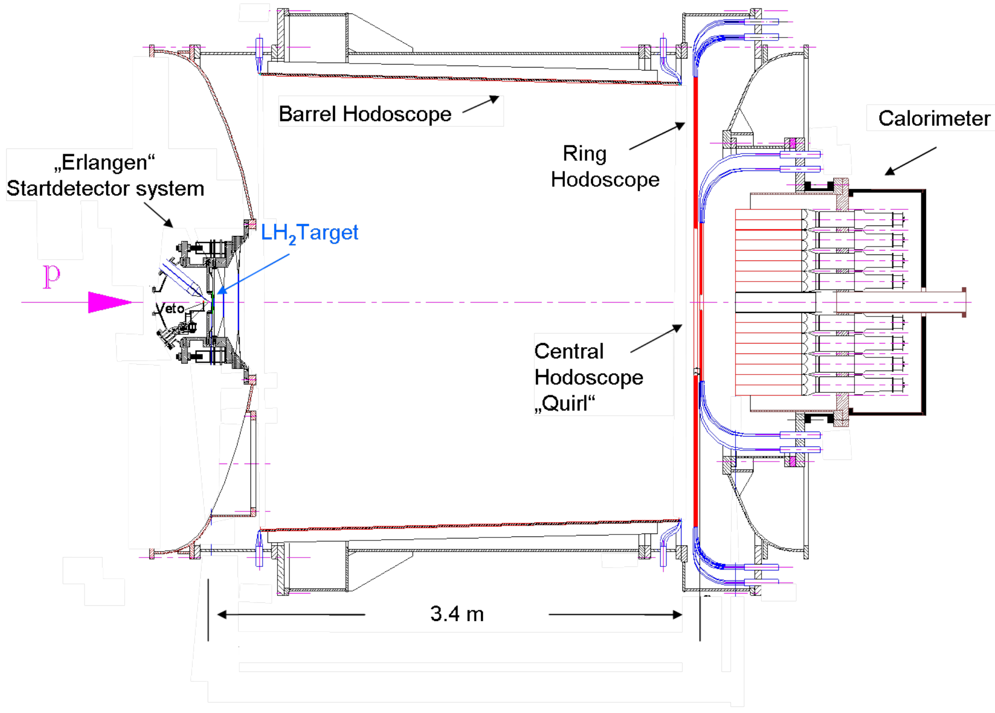
COSY facility, experimental setups



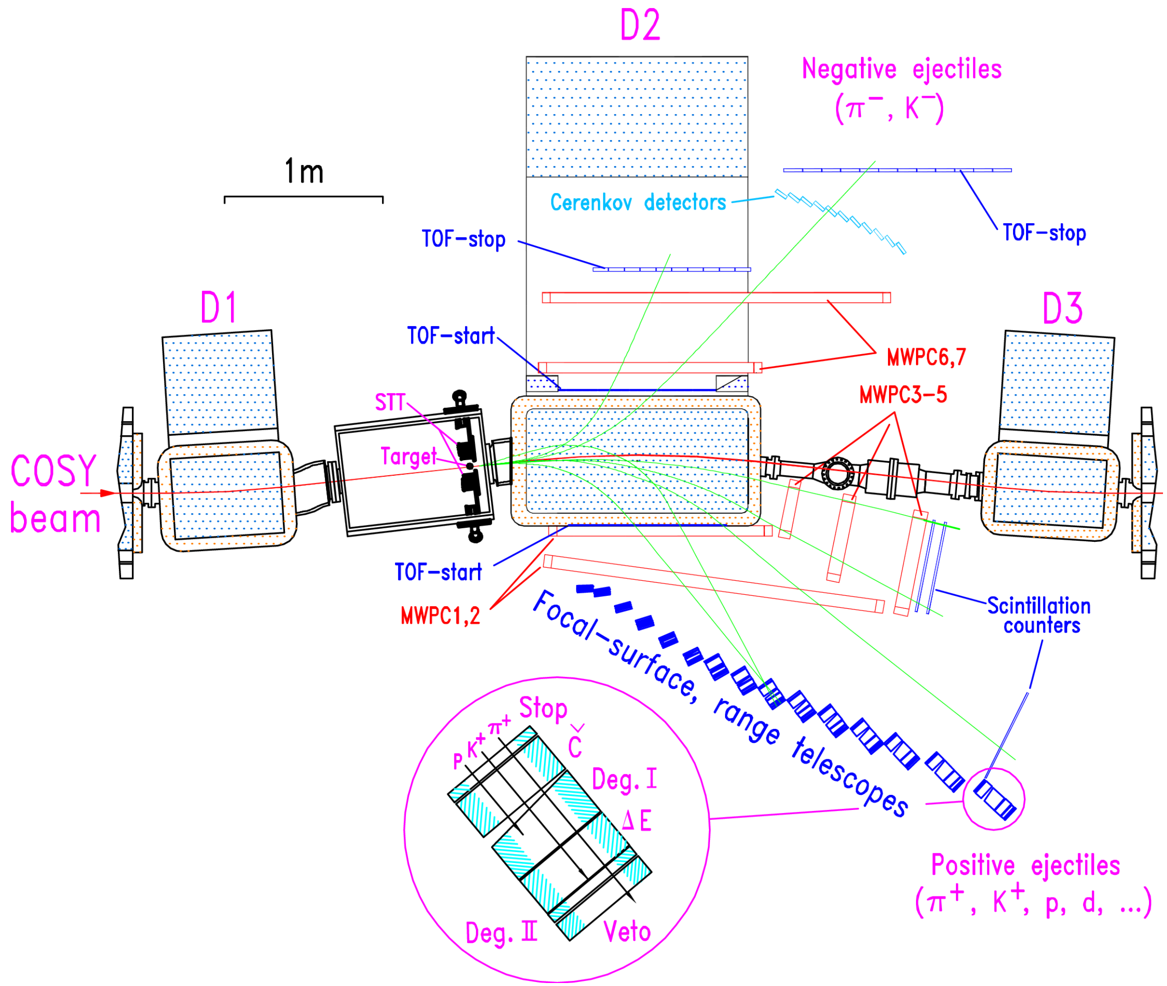
- Circumference ~ 184m
- Polarized protons and deuterons
- max. momentum ~ 3.7 GeV/c
- Electron and stochastic cooling

TOF – large acceptance spectrometer at <u>external</u> target position of COSY





ANKE – forward angle magnetic spectrometer at internal target position of COSY



Investigation of N* resonances via N* → KY
Expt.: pp → $pK^+\Lambda$ (TOF)

Little is known on N* decaying into strange channels

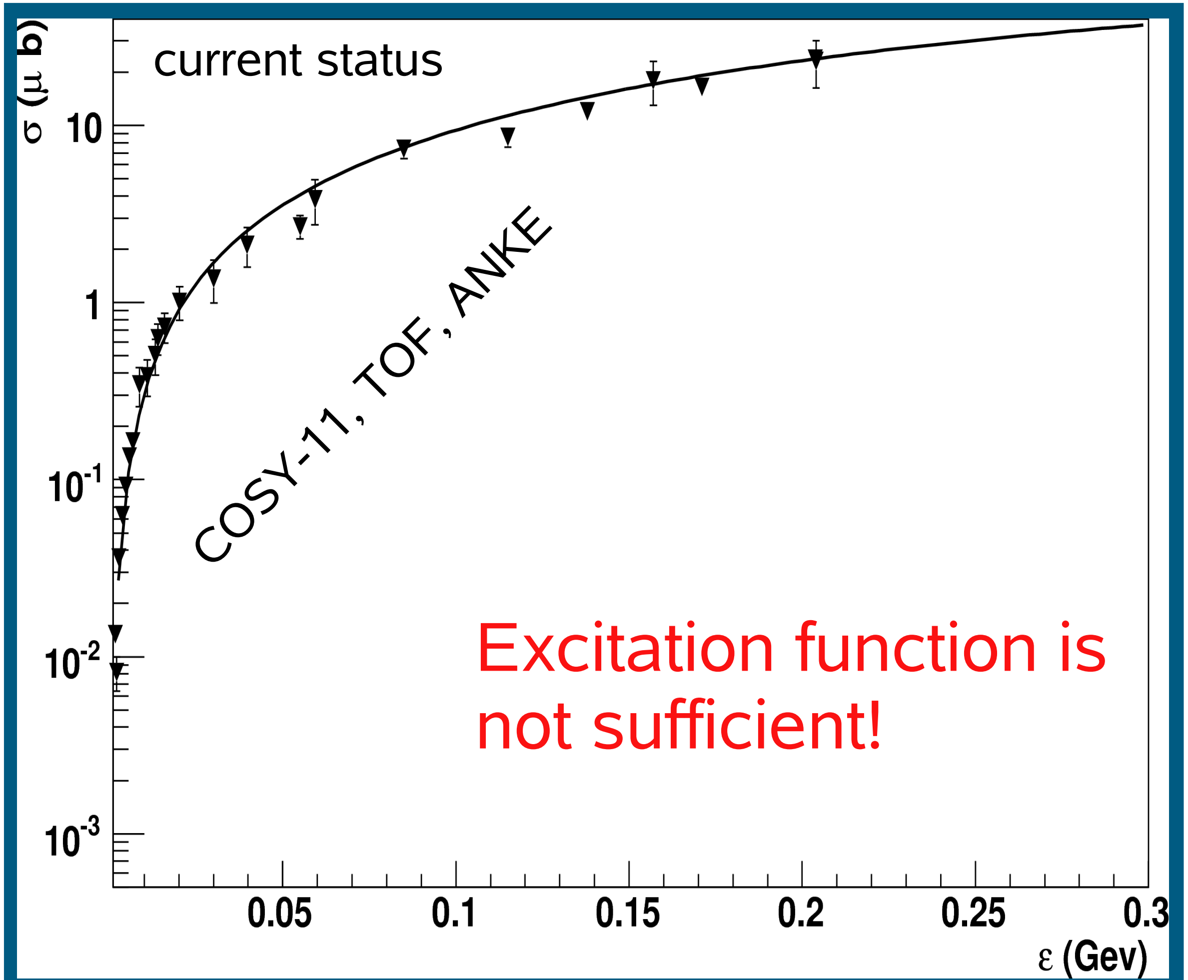
N*	Status	$L_{2I \cdot 2J}$	BR(N*→KΛ)
N(1650)	****	S_{11}	3 - 11%
N(1710)	***	P_{11}	5 - 25 %
N(1720)	****	P_{13}	1- 15 %
N(1900)	**	P_{13}	2.4 ± 0.3 %

No information on N* ⟶ KΛ for L >1

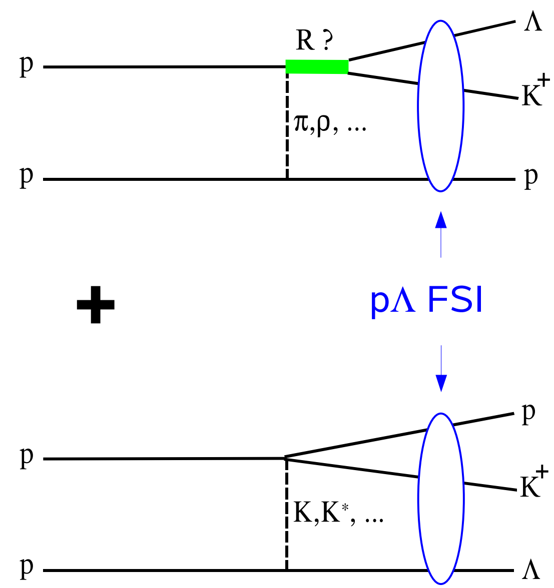
No information on N* ⟶ KΣ at all

first step ⟶ $pK^+\Lambda$ data for momenta: 2.85-3.3 GeV/c

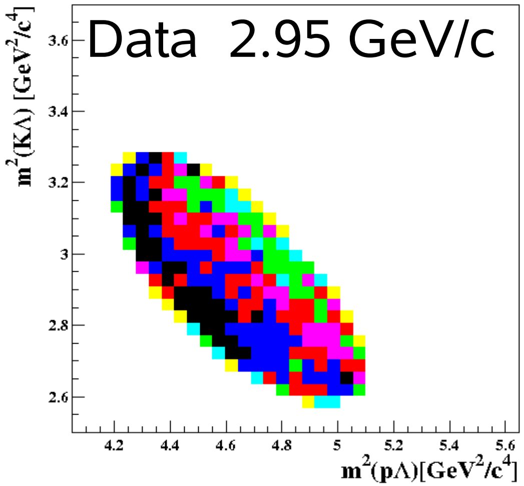
pp → pK⁺Λ, total cross section



Meson Exchange Model



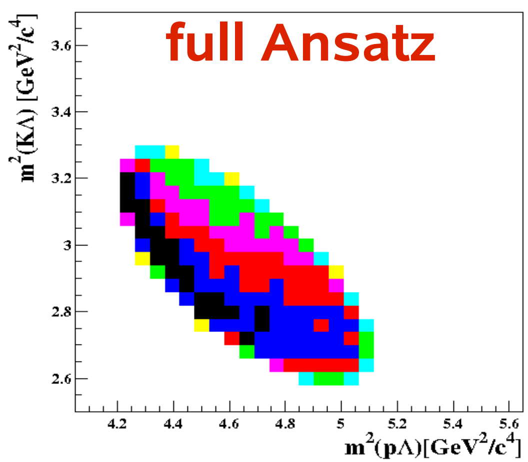
Expt.: $pp \rightarrow pK^{+}\Lambda$, Dalitz plot analysis



A. Sirbirtsev et al., EPJ A27 (2006) 269, personal communication

Ansatz

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



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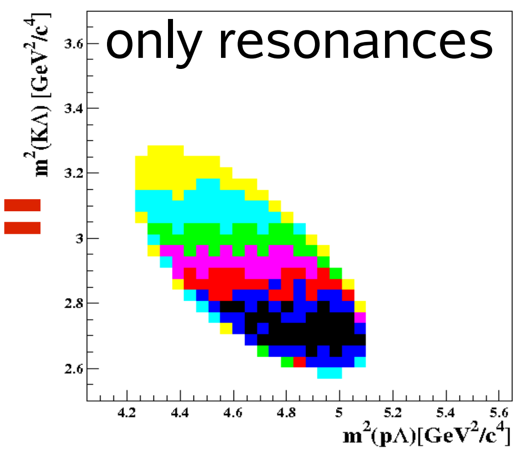

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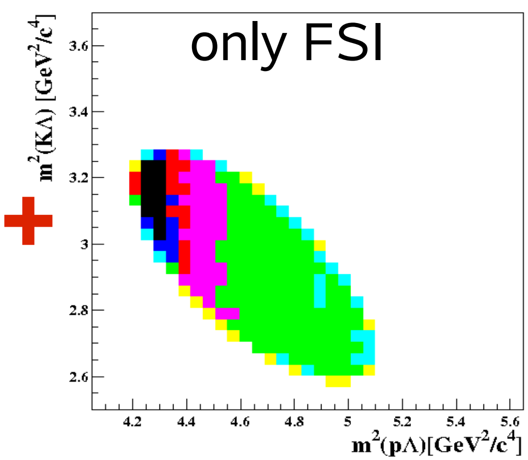
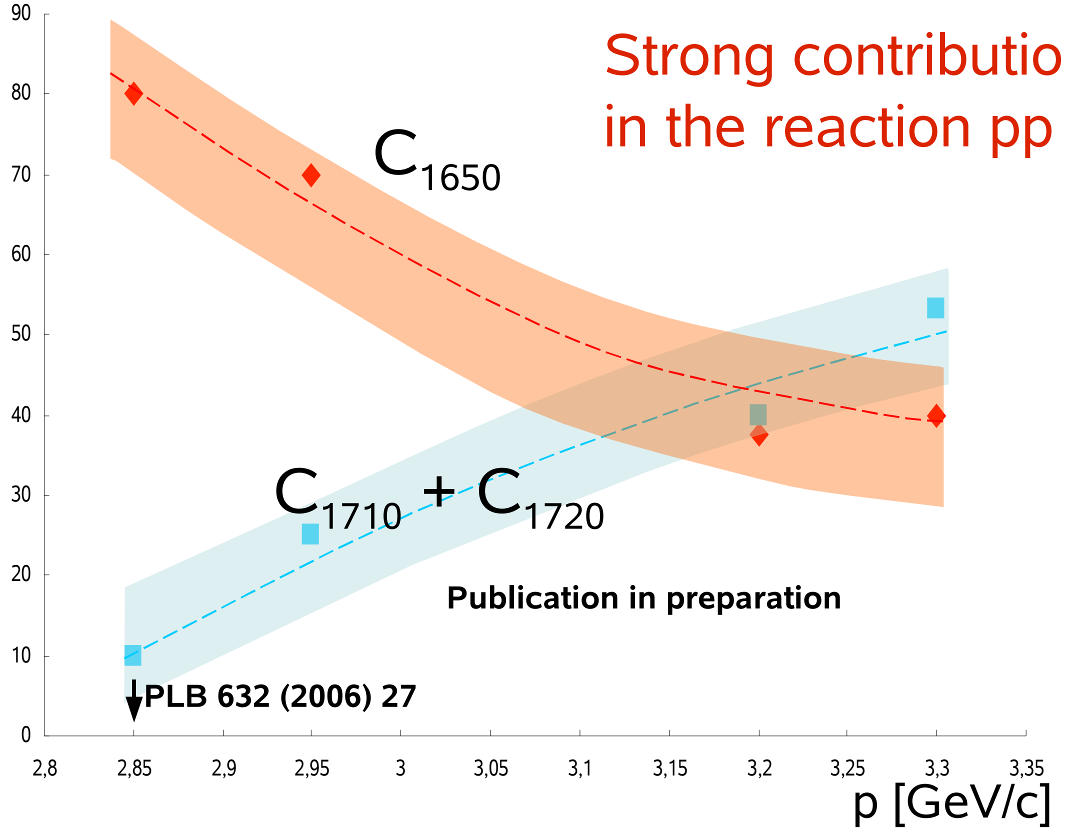


Expt.: $pp \to pK^+\Lambda$, Dalitz plot analysis



Strong contribution of N*-Resonances in the reaction $pp \to pK^+\Lambda$

In good agreement with calculation of R. Shyam

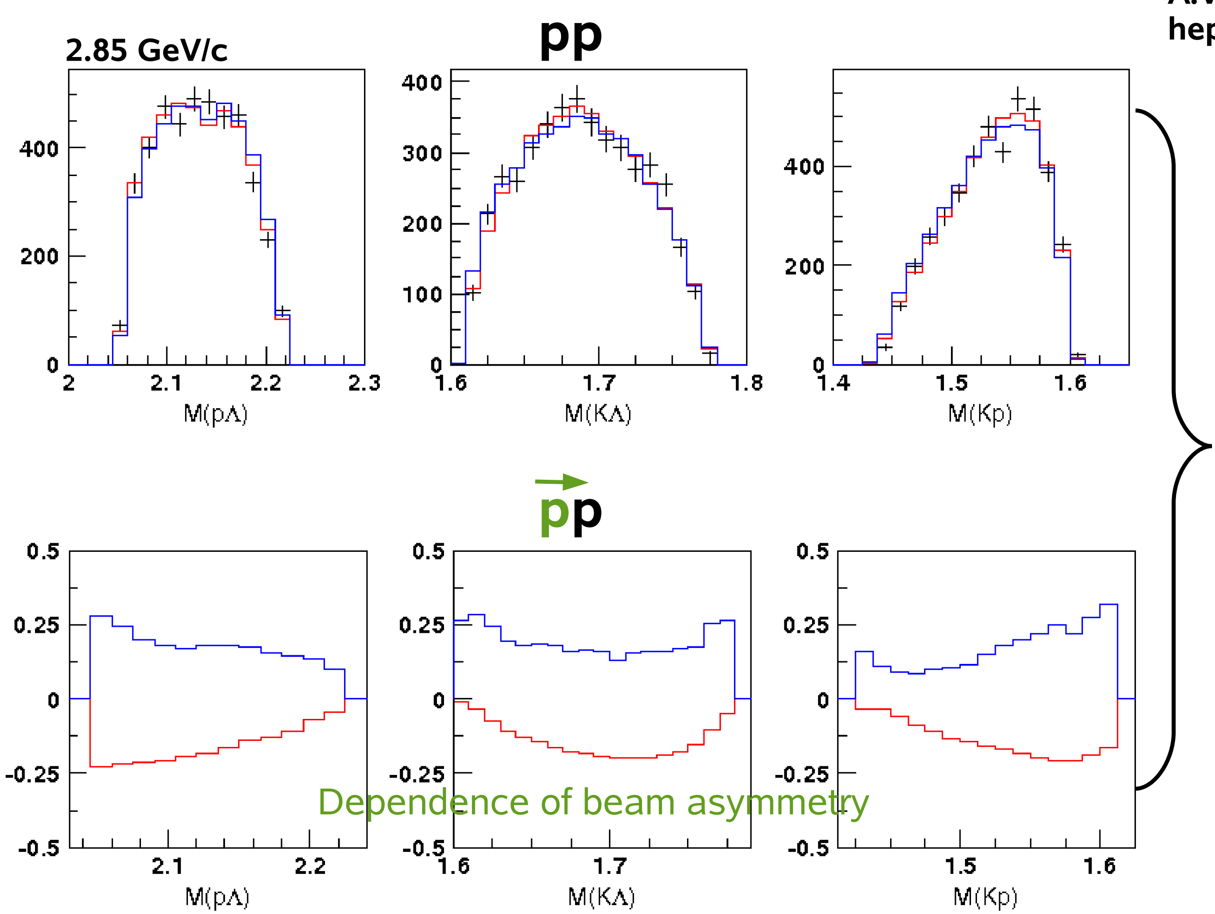
(PRC 60 (1999) 055213)

No discrimination between N*(1710) and N*(1720) →

Separation using polarized beam

Other approach: Full partial wave analysis, $pp/\vec{p}p \rightarrow pK^+\Lambda$

A.V. Anisovitch, PLB 632 (2006) 27, hep-ph/0703216, pers. com.



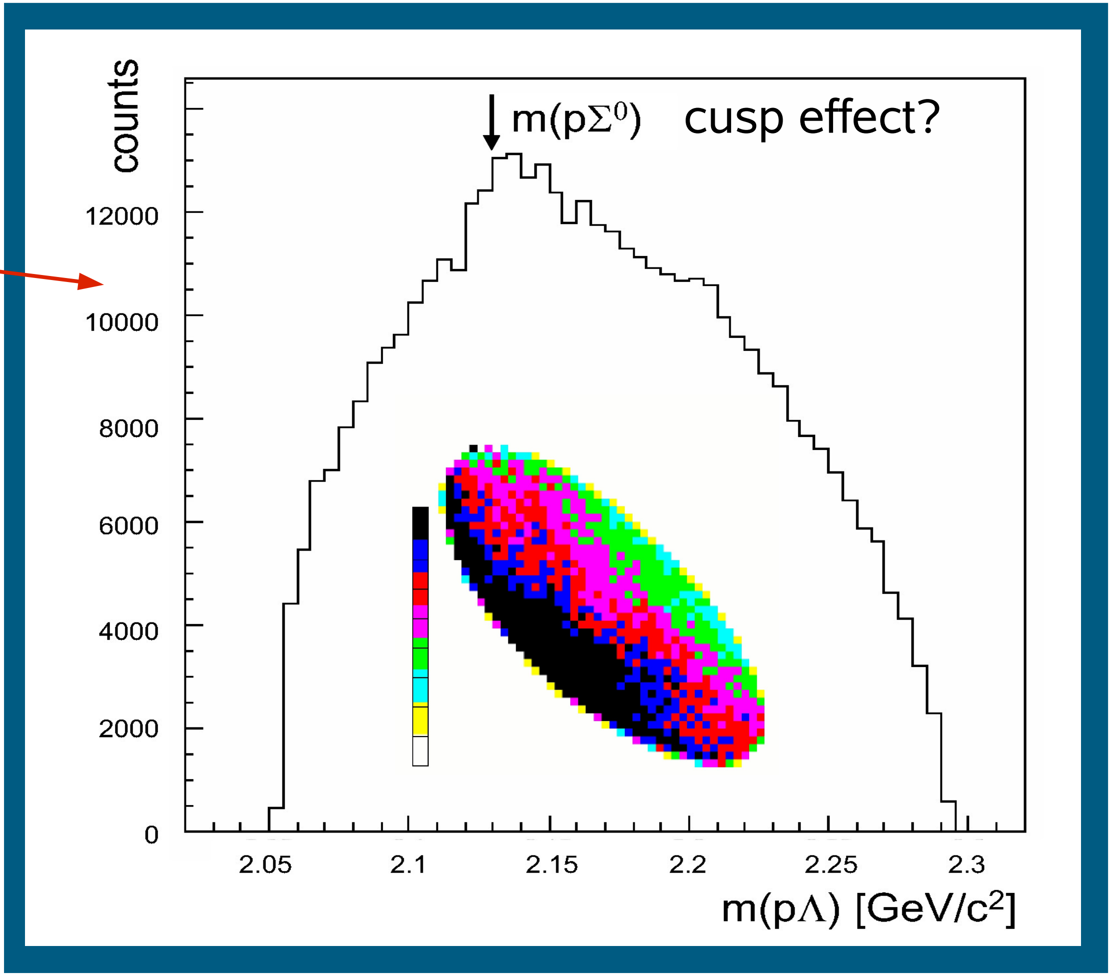
1.Solution (red)
Initial. pp interaction
$^3P_2$, $^3P_0$, $^1S_0$

2. Solution (blue)
Initial. pp interaction
$^3P_2$, $^3P_1$, $^1S_0$

Very different behavior of the two solutions! Discrimination possible!

Expt.: pp → pK$^+\Lambda$, high statistics Dalitz plot analysis

Very new data at
p_{mom} = 3.06 GeV/c
300.000 pK$^+\Lambda$



First data at
p_{mom} = 3.06 GeV/c
15.000 pK$^0\Sigma^+$

$\pi^+\pi^-$

N* → KΣ

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Expt.: $\Lambda(1405)$ (& $\Sigma^0(1385)$) (ANKE)

Nucleon resonances: Nature of $\Lambda(1405)$

$\Lambda(1405)$ S_{01} $I(J^P) = 0(\frac{1}{2}^-)$

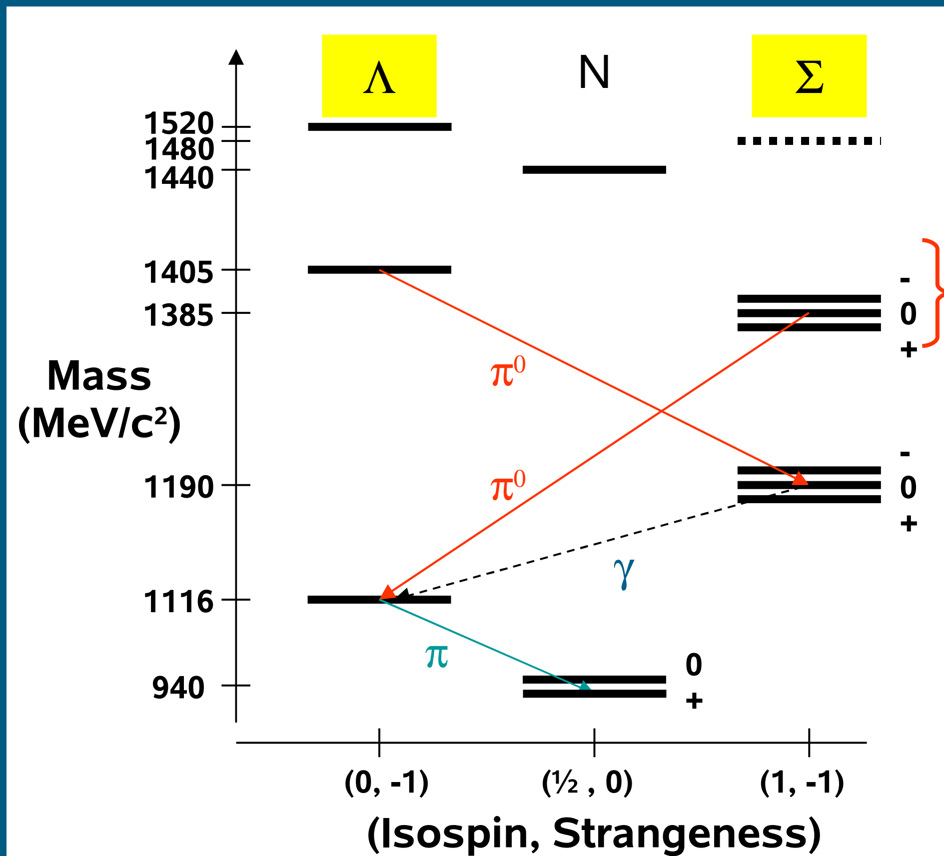
Mass $m = 1406 \pm 4$ MeV
Full width $\Gamma = 50 \pm 2$ MeV
Below $\overline{K}N$ threshold

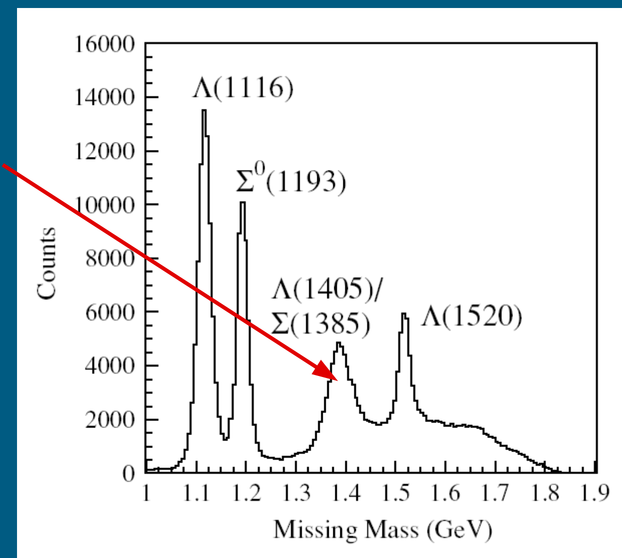
$\Lambda(1405)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Sigma\pi$	100 %	157

PDG: status ****, but ...

Theory: q^3, or $(qqqq\bar{q})$, $\overline{K}N$-molecule, 2 states, ... ?

Starting point: pp → NK⁺Y



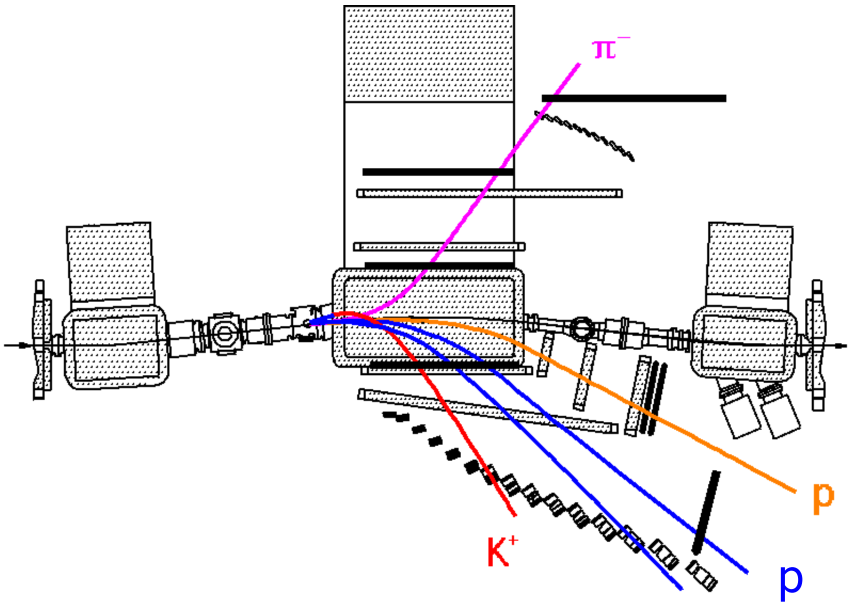


"example from photo-production"

Experimental problem: overlap Σ(1385) and Λ(1405)

Expt: $pp \to pK^+Y^0(1405)$, $Y^0 \to (p\pi^-)X^0$

four-particle coincidences $pK^+p\pi^-$



$\pi^0\Sigma^0$ (cleanest channel)

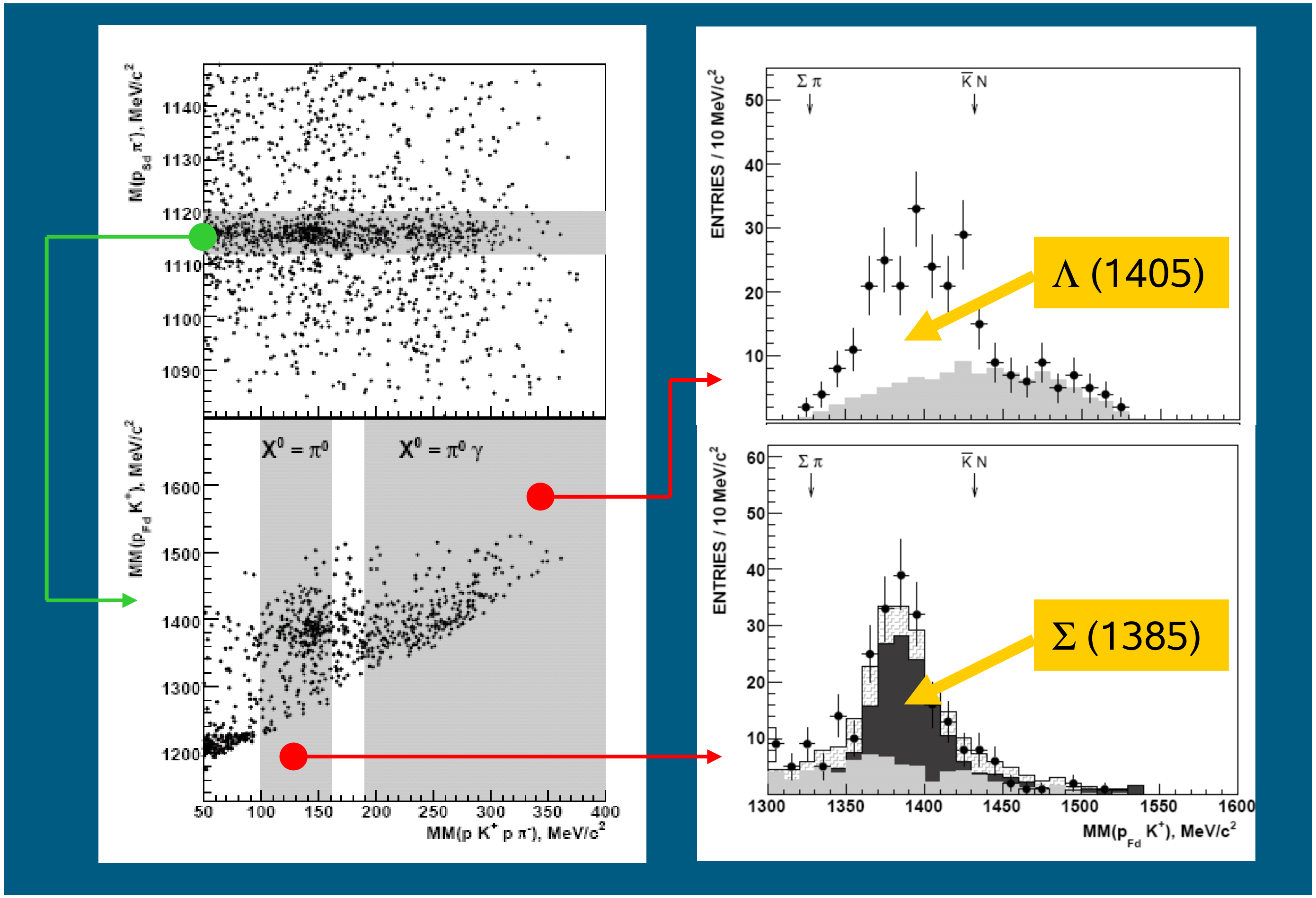
$\gamma\Lambda$

$p\pi^-$

$pp \to pK^+\Sigma^0(1385) \to pK^+(\Lambda\pi^0) \to pK^+(p\pi^-)\,\pi^0$

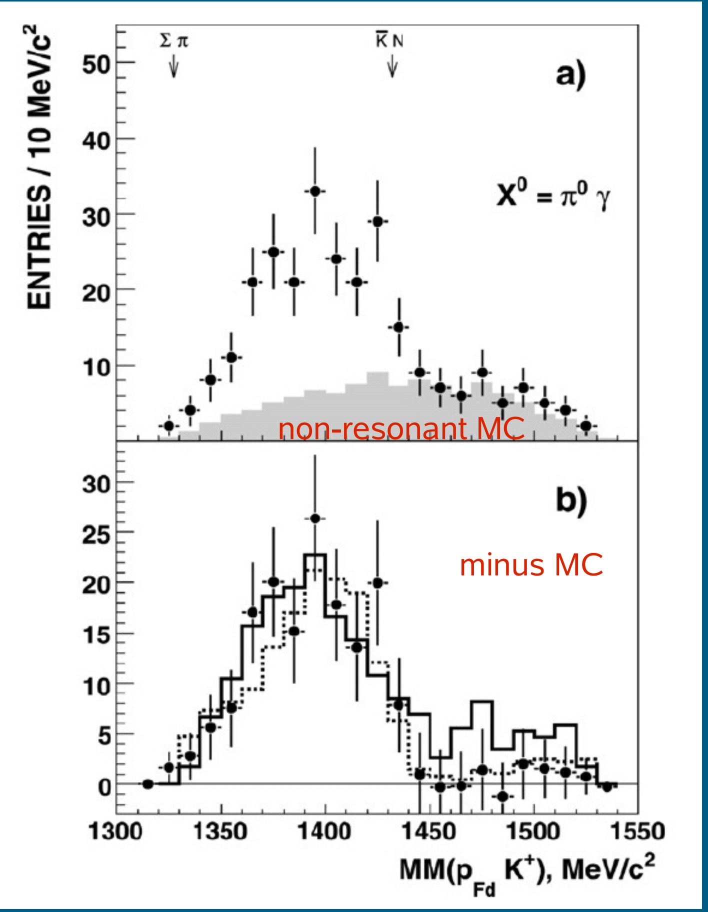
$pp \to pK^+\Lambda(1405) \to pK^+(\Sigma^0\pi^0) \to pK^+(\Lambda\gamma)\pi^0 \to pK^+(p\pi^-)\gamma\pi^0$

Solution: $pp \rightarrow pK^{+}(p\pi^{-})X^{0}$



Clean separation of ∑(1385) and Λ(1405) achieved

Results: $pp \rightarrow pK^{+}(p\pi^{-})X^{0}$



PLB 660 (2008) 167

- Influence of the $\bar{K}N$-threshold ?
- Comparison with results from

  $\pi^{-}p \rightarrow K^{0}(\Sigma N)^{0}$ (solid line)

  "Thomas" NPB 56 (1973) 15

  and

  $K^{-}p \rightarrow \pi^{+}\pi^{-}\Sigma^{+}\pi^{-}$ (dotted line)

  "Hemmingway" NPB 253 (1984) 742

$\Lambda(1405)$: clean separation by ANKE

Theory: L.S. Geng & E. Oset

EPJ A 34 (2008) 405,
hep-ph/0707.3343v3 (2008)

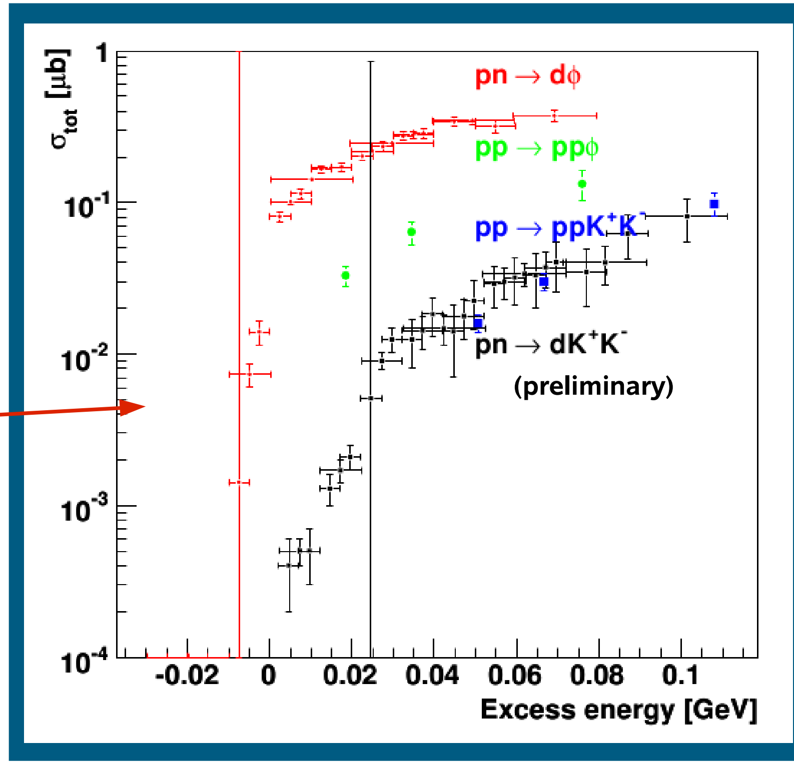
Expt.: $pp \rightarrow ppK^+K^-(\phi)$ (ANKE)

$pp \longrightarrow pK^+(\Sigma^0\pi^0)$

$\Lambda(1405)$

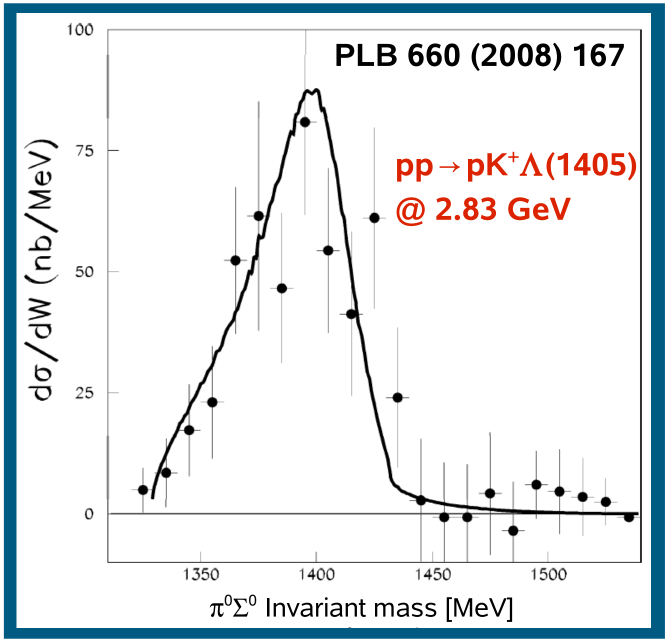
$pp \longrightarrow K^+p(K^-p)$

pp, K^-p & K^-pp, $K\bar{K}$ FSI



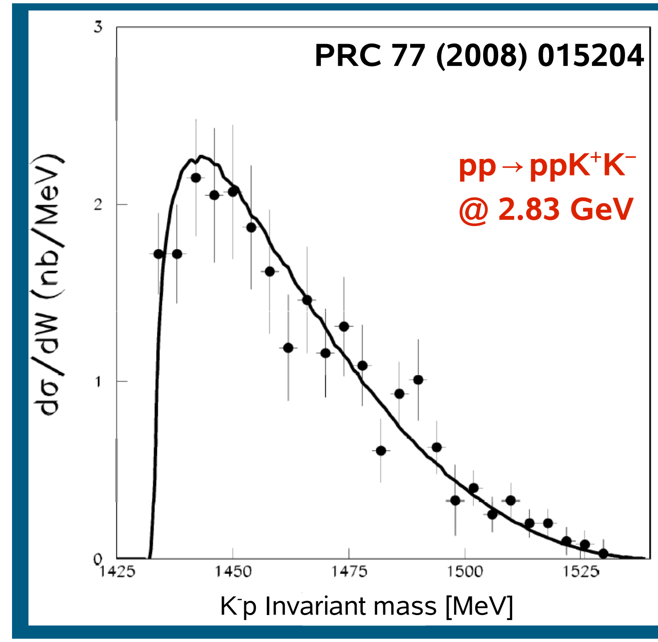
(PRL 96 (2006) 242301, PRL 97 (2006) 142301
PRC 77 (2008) 015204)

Expt.: $pp \to pK^+Y^0$(1405, width 50MeV) $\to K^-p$



$\pi^0\Sigma^0/K^-p$

C. Wilkin, personal cummunication



The simplest description of the I = 0 coupled-channel system is provide by a separable-potential model, e.g. used in Shevshenko *et al.* **[PRC 76 (2007) 055204].**

Suggests that Λ(1405) is the <u>main doorway state</u> also for ppK^+K^-. (If so, kaon pair production is not dominated by a_0/f_0.)

Should analyse $\pi^0\Sigma^0$ and K^-p production at the same time !

Expt.: $pp \rightarrow ppK^+K^-$

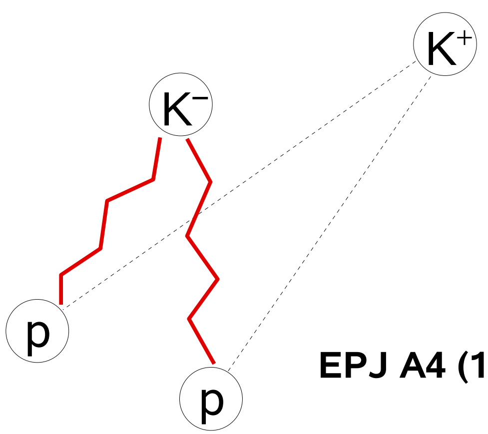
Assumption: K^-p FSI effect

$f(q) = (1-iaq)^{-1}$, q: relative momentum

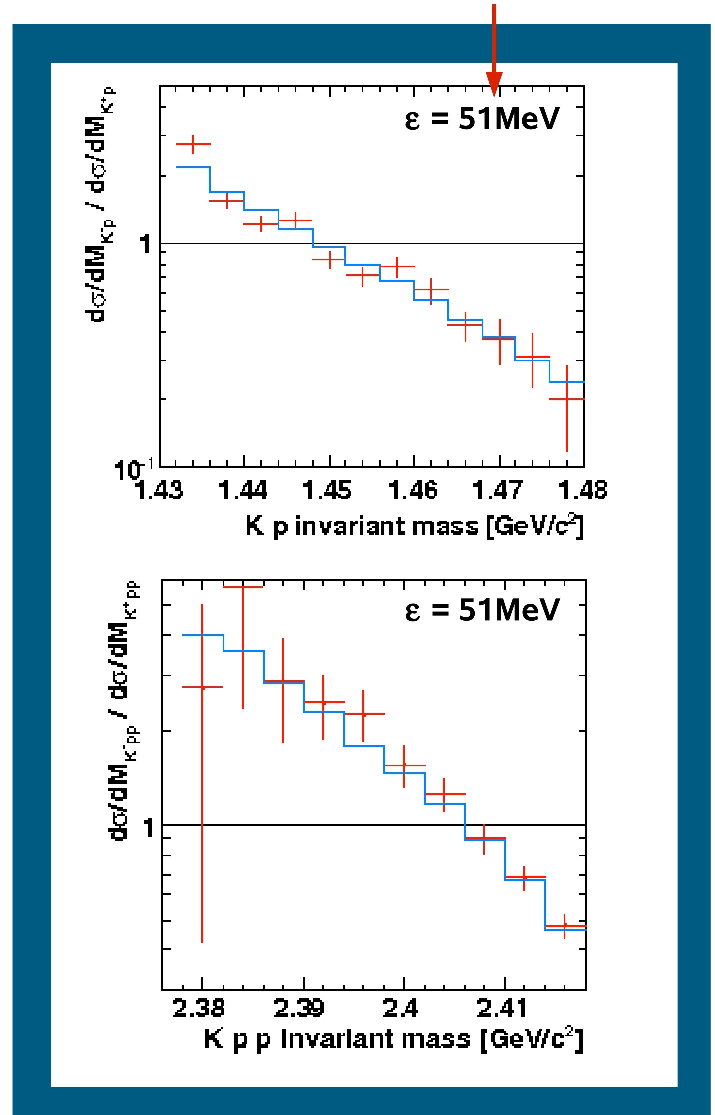
a: scattering length

„3-body-FSI" $\leftrightarrow$ $f(q_1) \times f(q_2)$,

$|a| \approx (1\text{-}2)$ fm



EPJ A4 (1999) 259



PRC 77 (2008) 015204

Expt.: $pp \rightarrow ppK^+K^-$, total cross section

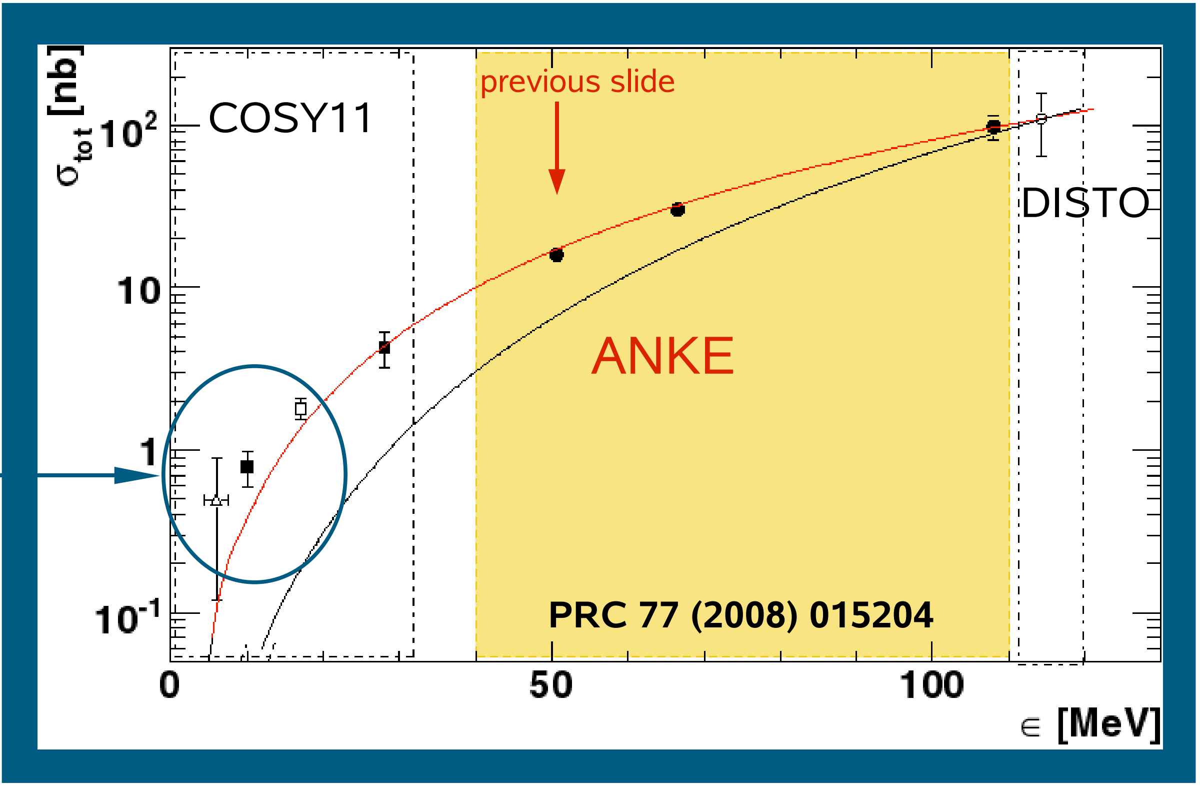
Phase space

+

$f_{pp} \times f(q_1) \times f(q_2)$

$K^+K^- \leftrightarrow K^0\overline{K^0}$

coupled channel effect?



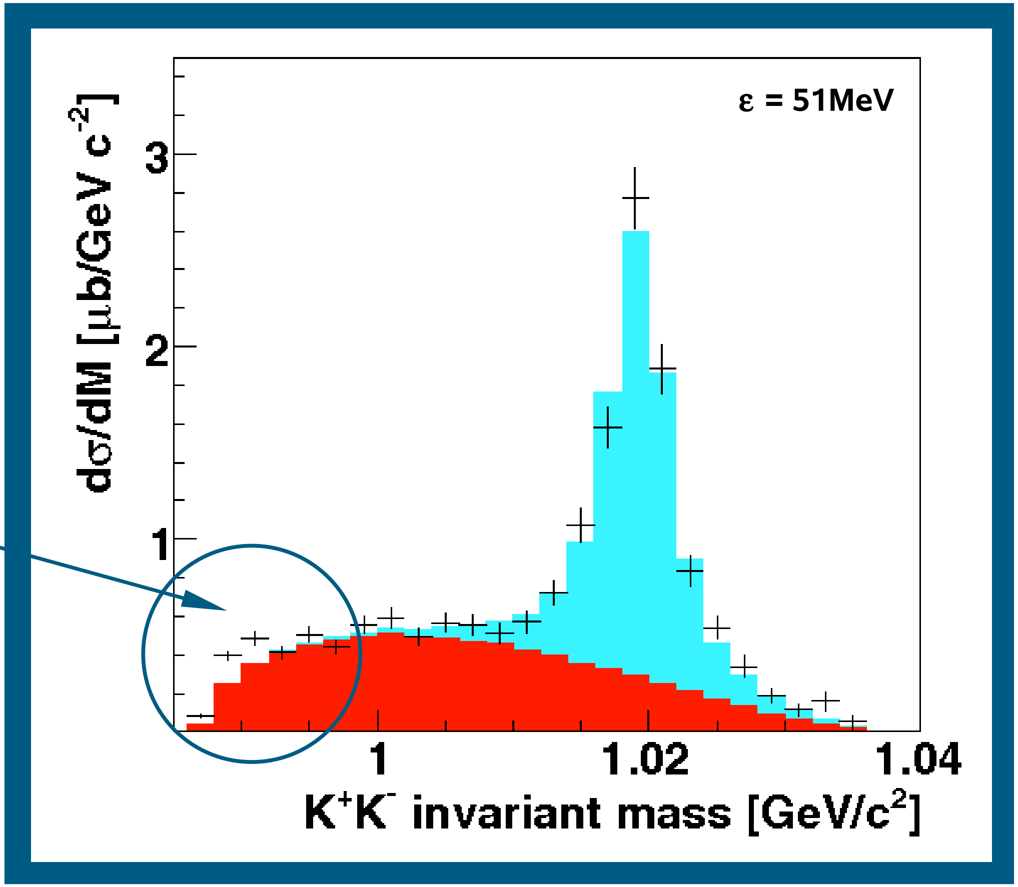
PRC 77 (2008) 015204

Expt.: $pp \to ppK^+K^-(\phi)$

PRC 77 (2008) 015204

$K^+K^- \leftrightarrow K^0\overline{K^0}$

coupled channel effect?



Expt.: $pp \to pK^{+}Y^{0*}(1480)$, $Y^{0*} \to \pi^{-}X^{+}$ or $\pi^{+}X^{-}$ (ANKE)

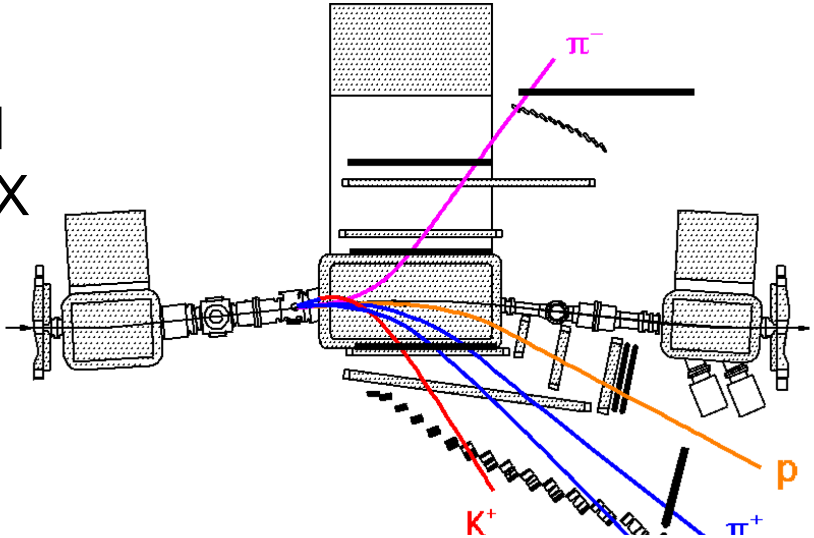
The $\Sigma(1480)$ hyperon is far from being an established resonance.

In PDG, it is described as a "bump", with unknown quantum numbers, one-star rating.

two final states: $Y^{0*} \longrightarrow \pi^{+}X^{-}$ and $\pi^{-}X^{+}$, with unidentified residue X

$X^{-} = \Sigma^{-}$ or $X^{+} = \Sigma^{+}$

three-particle coincidences $pK^{+}\pi^{+} / \pi^{-}$

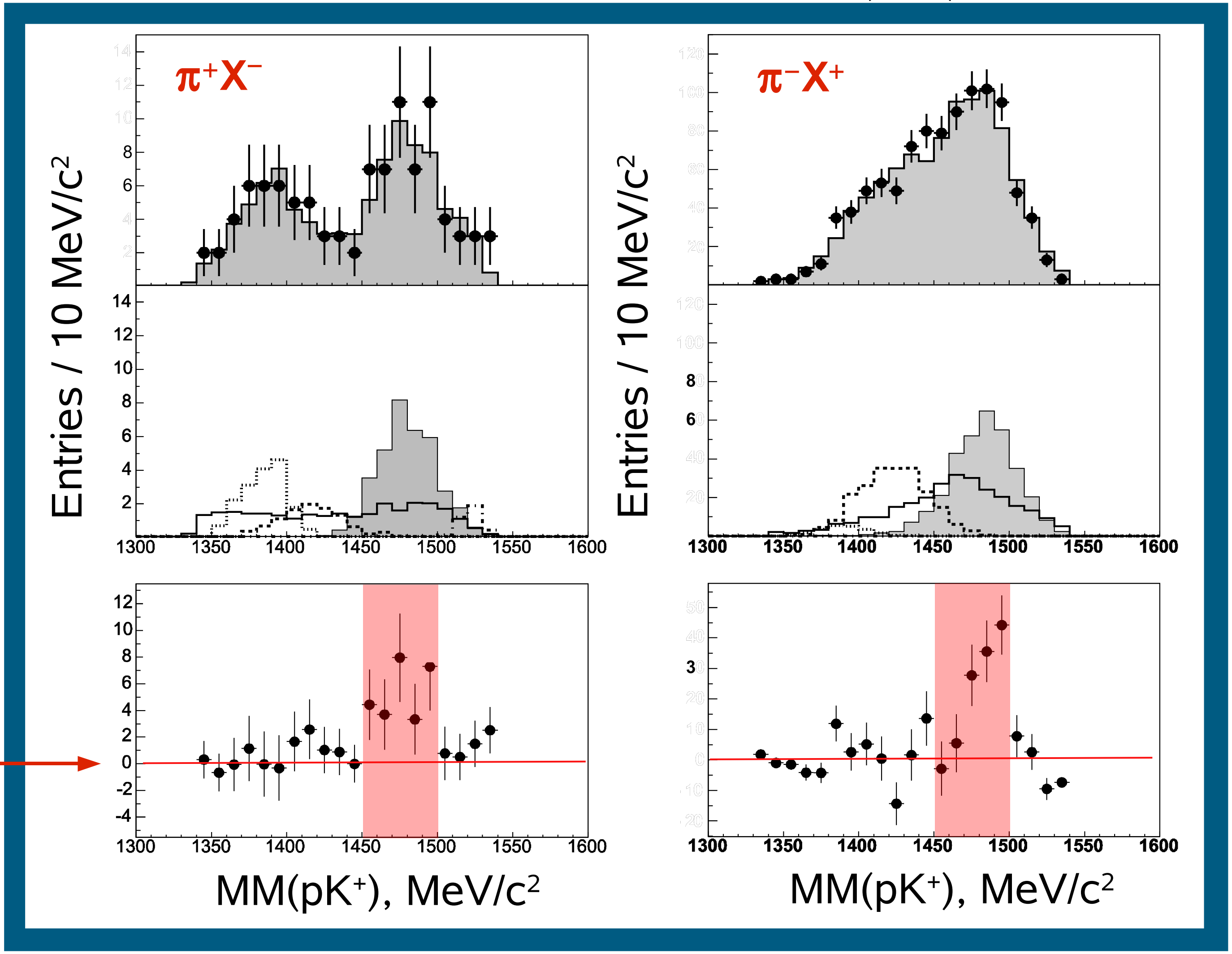


Result: Evidence for $Y^{0*}(1480)$

PRL 96 (2006) 012002

Add in MC a Y^{0*}

$M = 1480$ MeV/c^2,
$\Gamma = 60$ MeV/c^2



experiment —

simulation

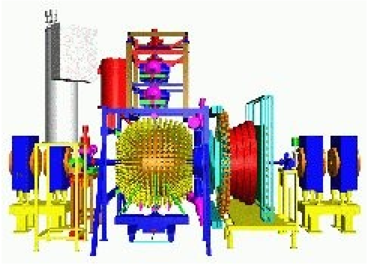
without $Y^{0}(1480)$

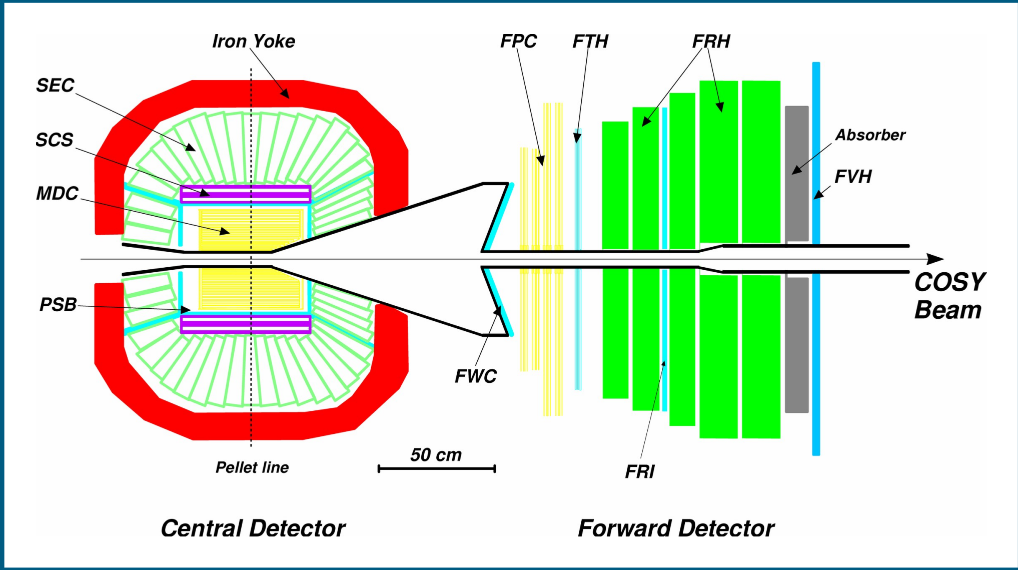
Summary/Outlook

- TOF – the detector for hyperon studies at COSY
  - Detailed investigation of N* resonances
  - Determination of $p\Lambda$ scattering length ($a_{triplet}$)
  - Preliminary results with polarized beam (Λ polarization, spin transfer coefficient: $\vec{p}p \to p\vec{\Lambda}K^+$)
  - Measurements with LD_2 -Target, e.g. $pn \to pK^0\Lambda$ (HK 34.9)

- ANKE – hyperon production close to threshold
  - Results on Y(1405/1480) ↔ significantly more ANKE can't do
  - Preliminary results on $pp \to nK^+\Sigma^+$ (Y. Valdau, HK 35.7)
  - Determination of $n\Lambda$ scattering length ($a_{triplet}$): $\vec{p}\vec{n} \to n\Lambda K^+$

WASA at COSY





WASA is a **internal 4π** detector in COSY

EM calorimeter, SC solenoid, forward det´s, pellet target

WASA is now in operation!

Symmetries and symmetry-breaking

(HK / many talks)

W. Weglorz (HK 35.6)

$pp \to pK^+\Lambda(1405) \to pK^+(p\pi^-)\gamma\pi^0$ ⟵ 3γ

$pp \to pK^+\Sigma(1385) \to pK^+(p\pi^-)\ \pi^0$ ⟵ 2γ

– thank you for your attention –

SFB/Transregio 16

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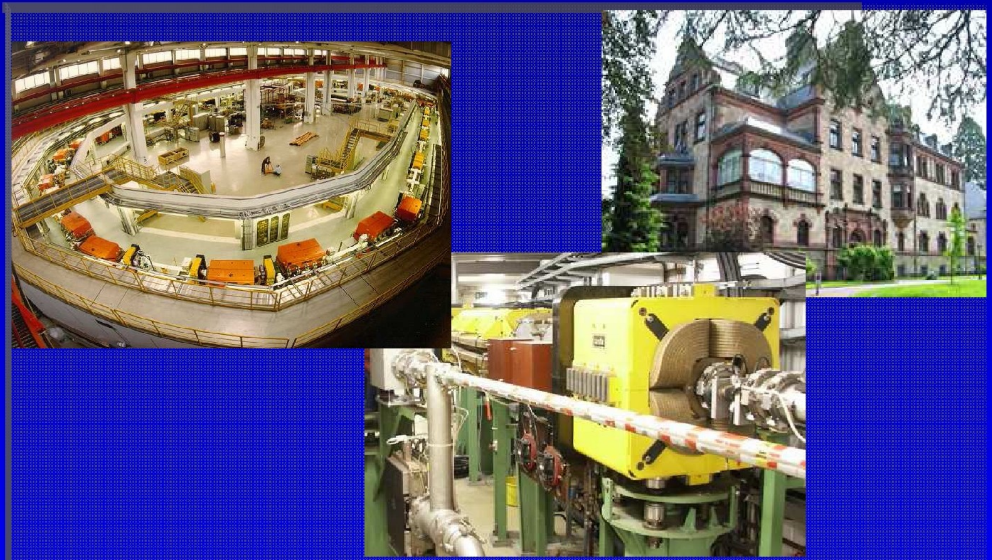
Hadron Physics Summer School 2008

(formerly COSY Summer School)

Physikzentrum Bad Honnef, Germany
August 11 – 15, 2008



Lectures and working groups

- QCD and its Phenomenological Implications
- Symmetries and Symmetry-Breaking
- Hadron Spectroscopy
- New Detector and Target Concepts
- Synchrotrons and Storage Rings
- Polarized and Cooled Beams

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