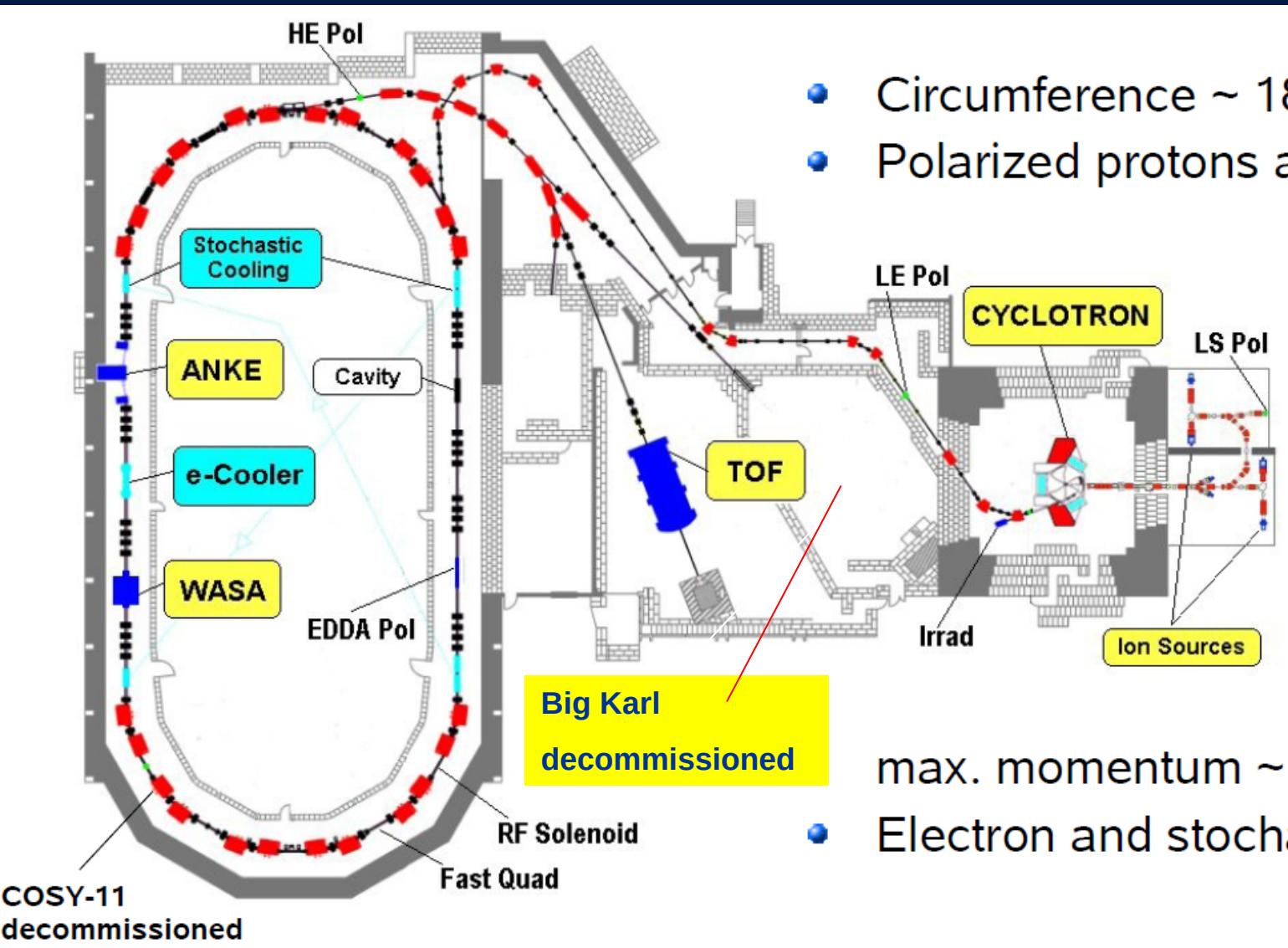
Strangeness production in hadron reactions

1. Experimental Facilities at COSY
2. Kaon Pair Production in pp, pd, dd Collisions
3. Near-Threshold Production of Φ Mesons
4. Hyperon Production in pp and pn Reactions (Λ, Σ^0, Σ^+, Σ^-)
5. Λp Final State Interaction in $pp \longrightarrow K^+(\Lambda p)$
6. Summary

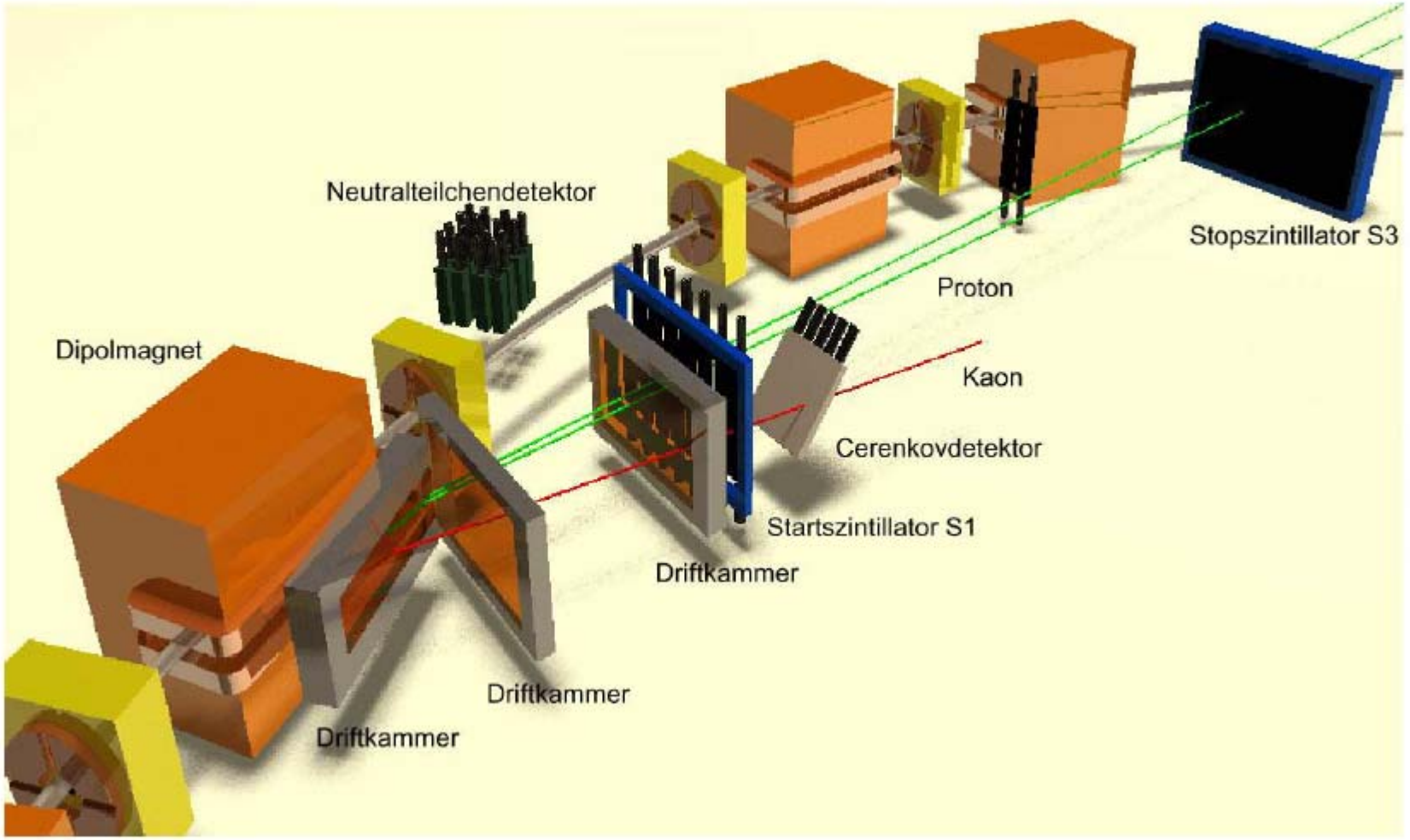


- Circumference ~ 184m
- Polarized protons and deuterons

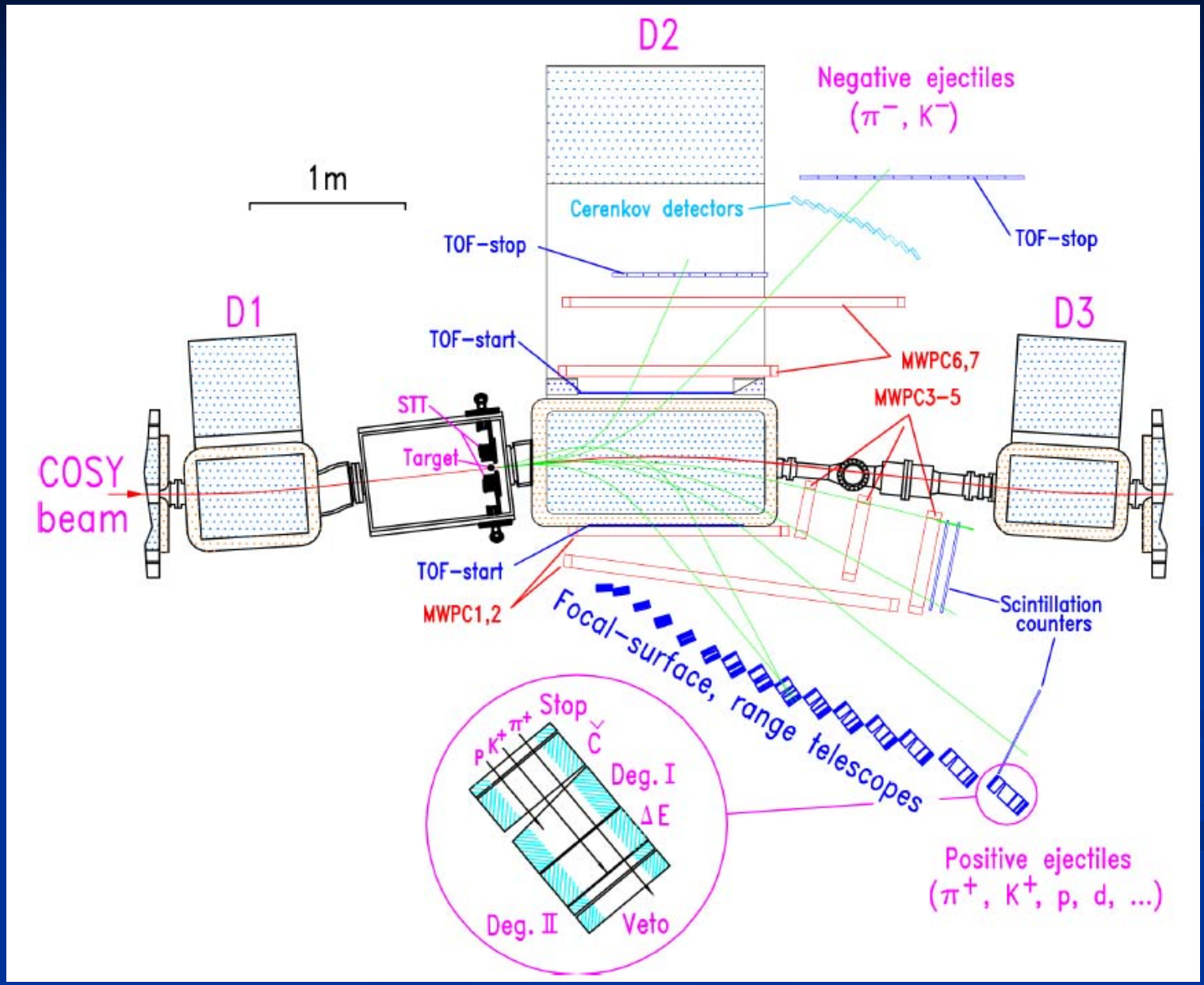
max. momentum ~ 3.7 GeV/c

- Electron and stochastic cooling

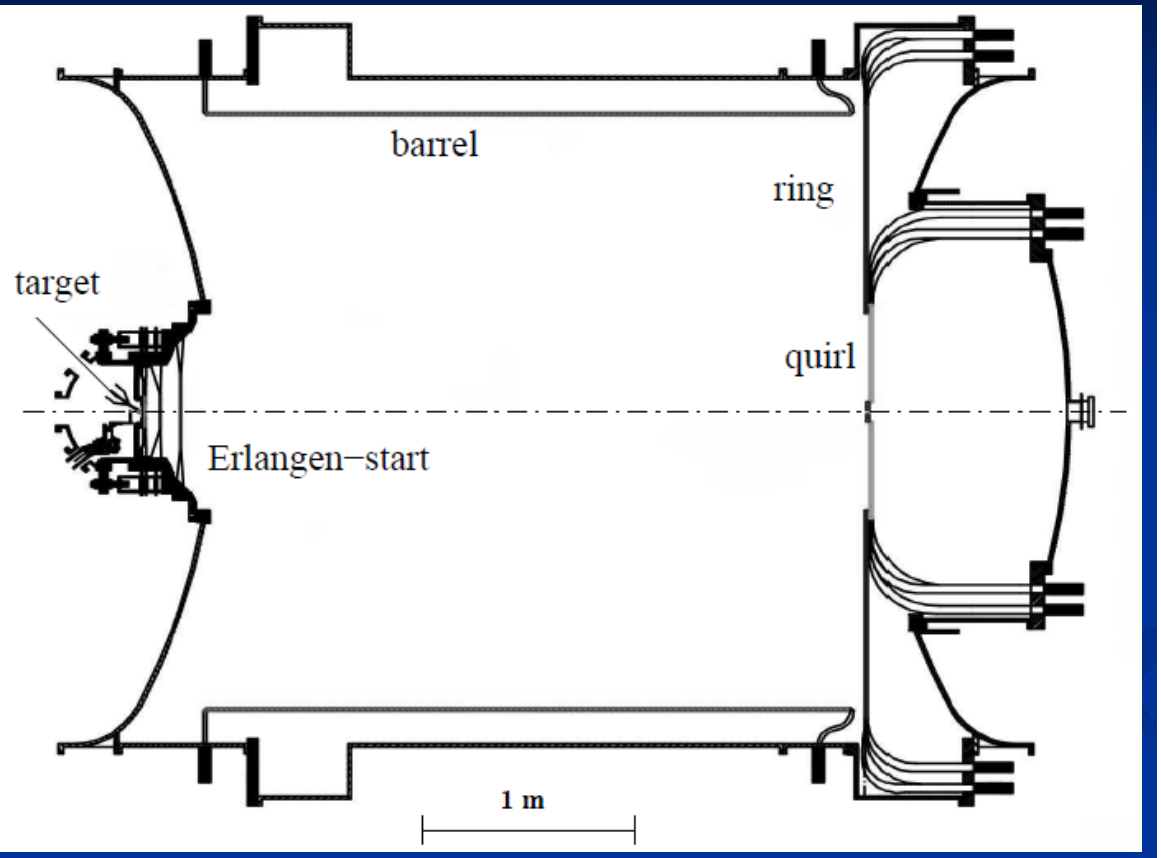
COSY11

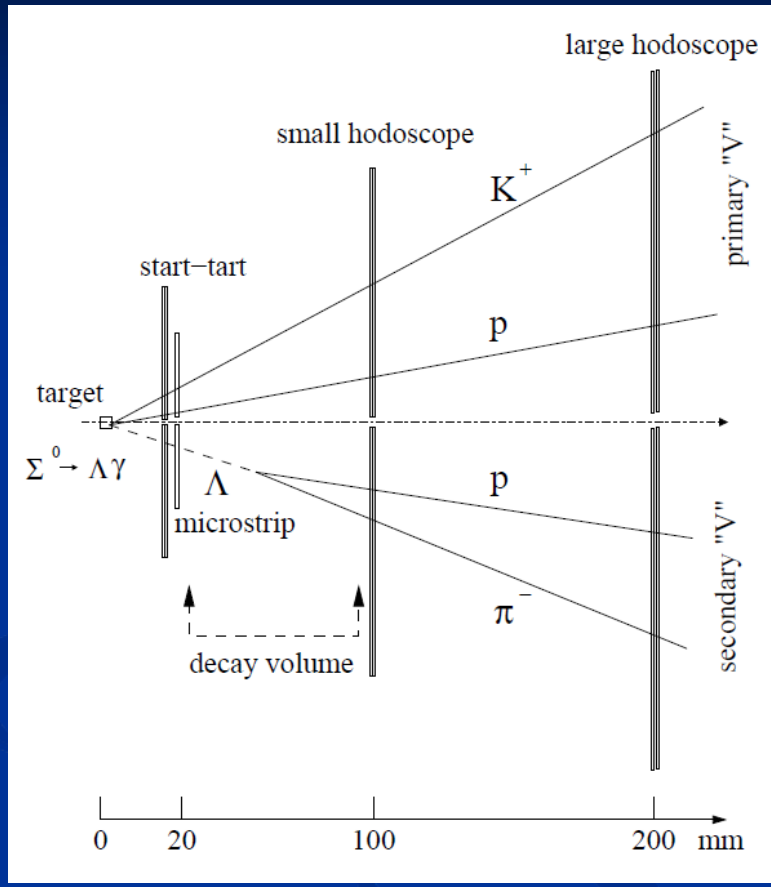

Neutralteilchendetektor
Stopszintillator S3
Proton
Dipolmagnet
Kaon
Cerenkovdetektor
Startszintillator S1
Driftkammer
Driftkammer
Driftkammer

COSY-ANKE Spectrometer



COSY-TOF Detector





$pp \rightarrow pK^+\Lambda$, $pp \rightarrow pK^+\Sigma^0$

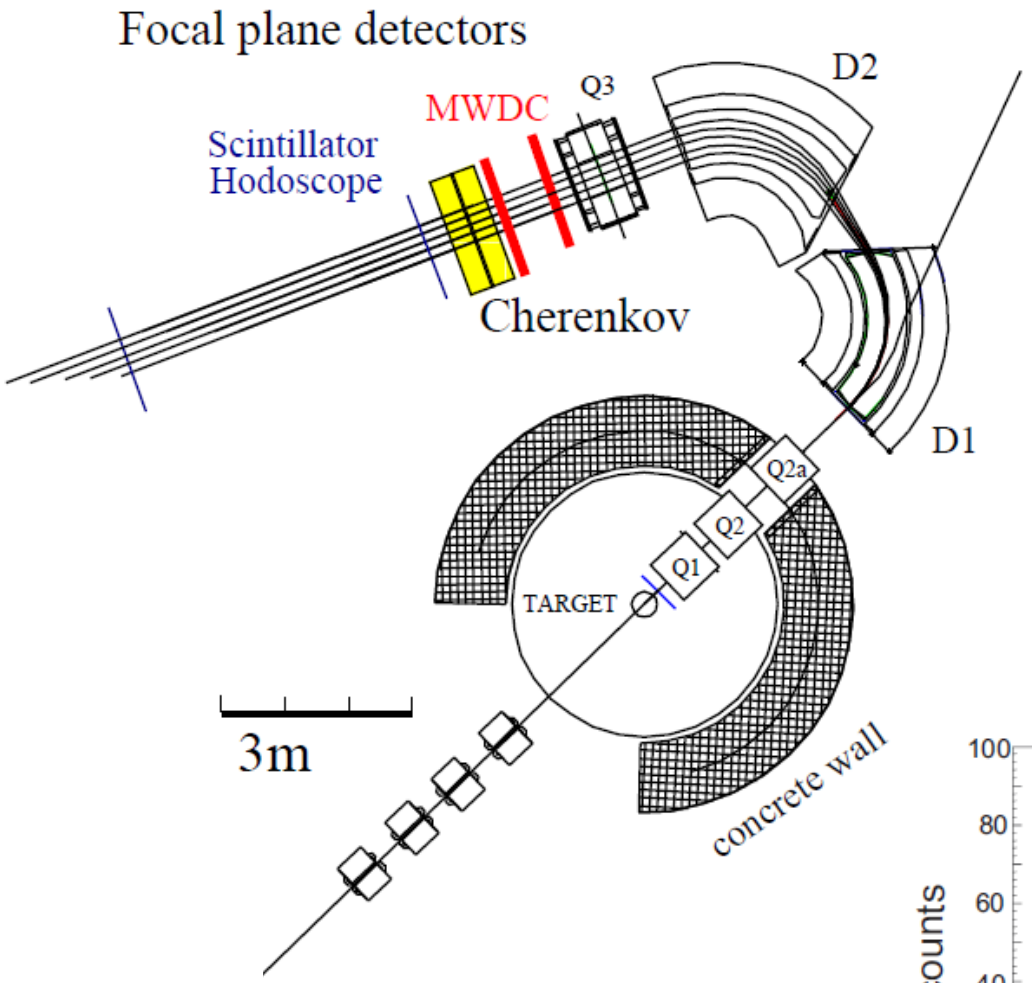
delayed decay of Λ (trigger)

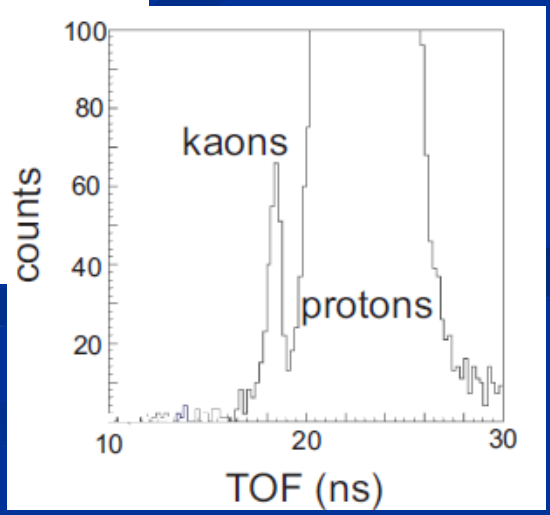
pattern reconstruction + TOF

Track reconstruction with Δmm/mm

$\cong 5*10^{-5}$

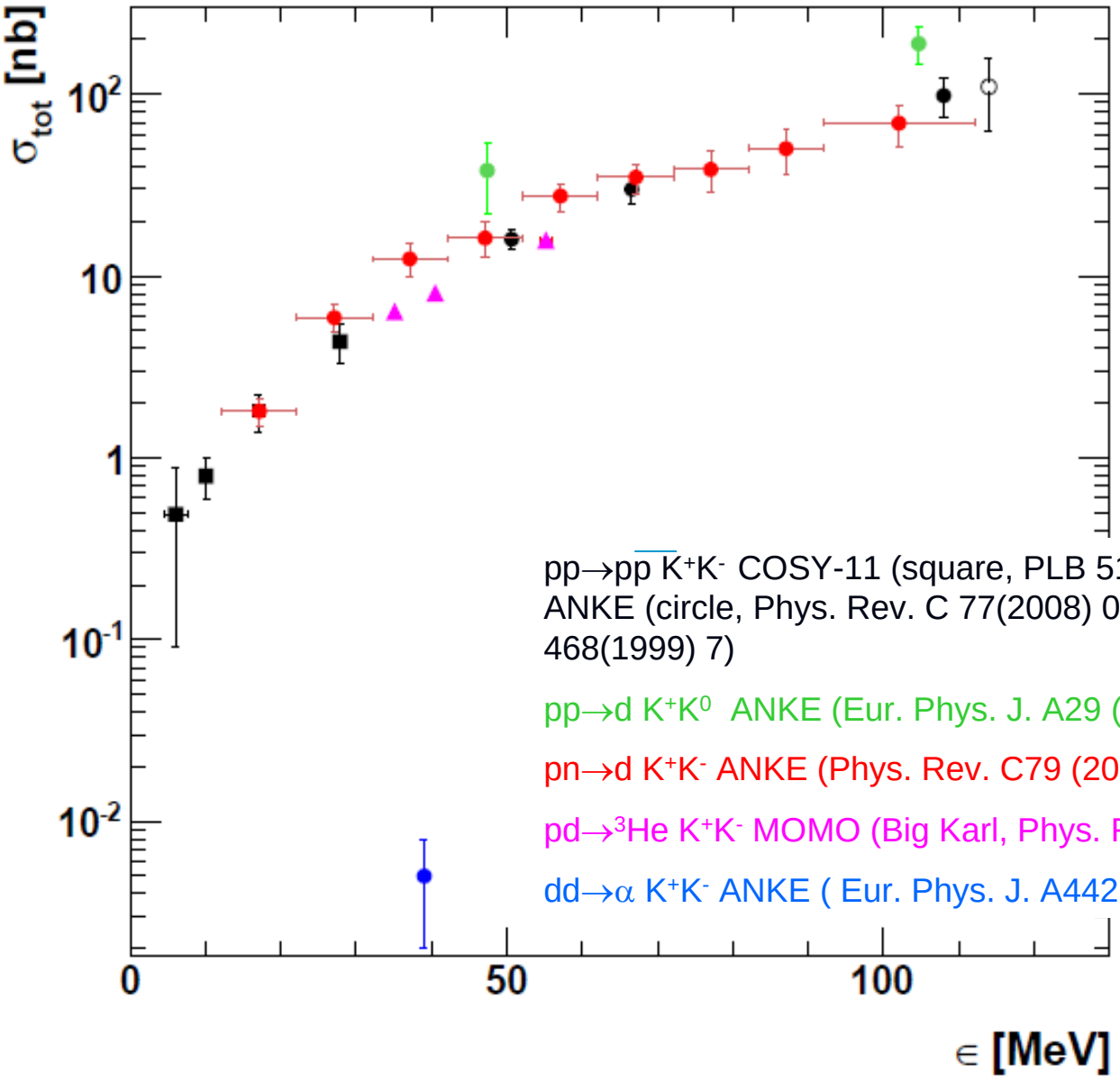
BIG KARL Spectrograph





COSY-HIRES: $pp \rightarrow K^+ (\Lambda p)$

Kaon Pair Production



$pp \rightarrow pp\,\overline{K}^+K^-$ COSY-11 (square, PLB 515 (2001) 276; 635 (2006) 23), ANKE (circle, Phys. Rev. C 77(2008) 015204), Saturne (open, PLB 468(1999) 7)

$pp \rightarrow d\,K^+K^0$ ANKE (Eur. Phys. J. A29 (2006) 245)

$pn \rightarrow d\,K^+K^-$ ANKE (Phys. Rev. C79 (2009) 018201)

$pd \rightarrow {}^3He\,K^+K^-$ MOMO (Big Karl, Phys. Rev. C75(2009)015204)

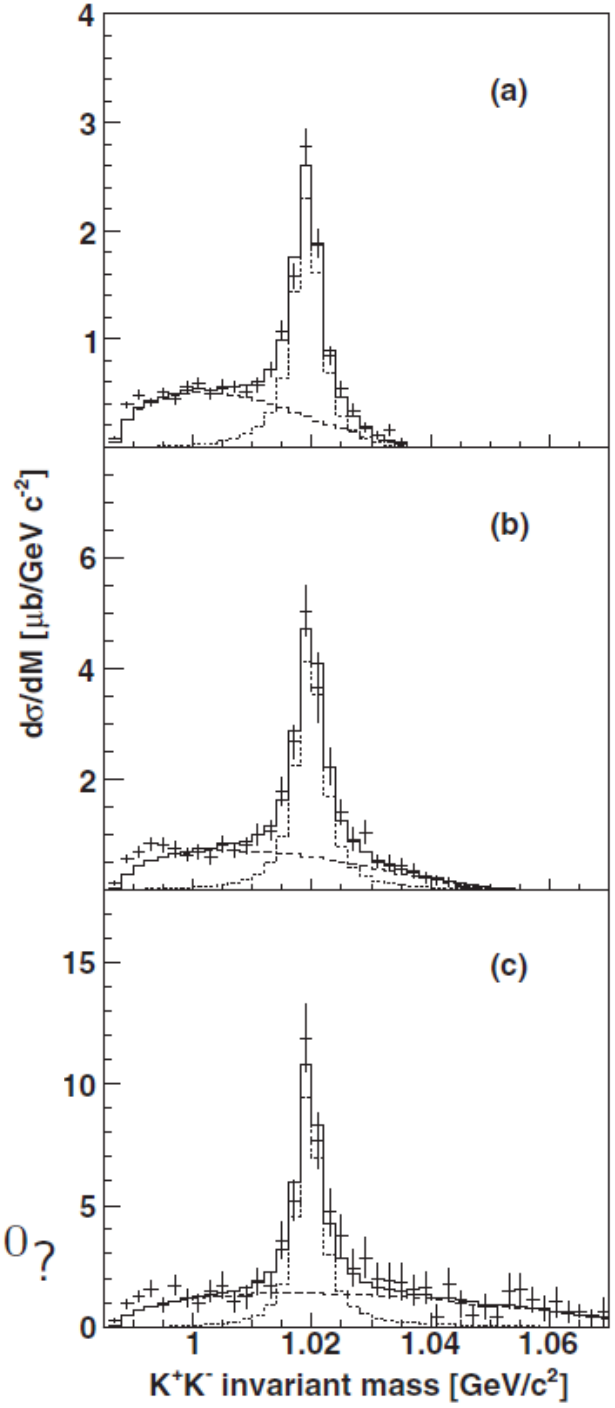
$dd \rightarrow \alpha\,K^+K^-$ ANKE (Eur. Phys. J. A442(09) 1)

$pp \to pp\, K^+K^-$

$pp \to pp\, \phi$

COSY-ANKE

- pp FSI
- K^-p FSI
- K^+K^- FSI
- $K^+K^- \leftrightarrow K^0\bar{K}^0$?



(a) $T_p = 2.65$ GeV, $\epsilon = 51$ MeV

$\epsilon_{KK} = 51$ MeV

$\sigma_{KK} = 16.0 \pm 1.4$ nb

$\sigma_\phi = 33 \pm 5$ nb

(b) $T_p = 2.70$ GeV, $\epsilon = 67$ MeV

$\epsilon_{KK} = 67$ MeV

$\sigma_{KK} = 30 \pm 4$ nb

$\sigma_\phi = 64 \pm 11$ nb

(c) $T_p = 2.83$ GeV, $\epsilon = 108$ MeV

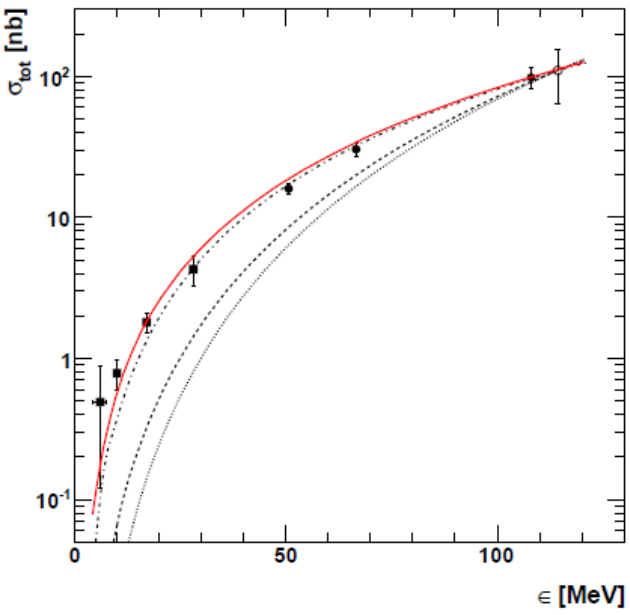
$\epsilon_{KK} = 108$ MeV

$\sigma_{KK} = 98 \pm 17$ nb

$\sigma_\phi = 133 \pm 30$ nb

$\sigma_\phi > \sigma_{KK}$

$pp \to pp\, K^+K^-$



dotted: four-body phase space

dashed: includes pp FSI

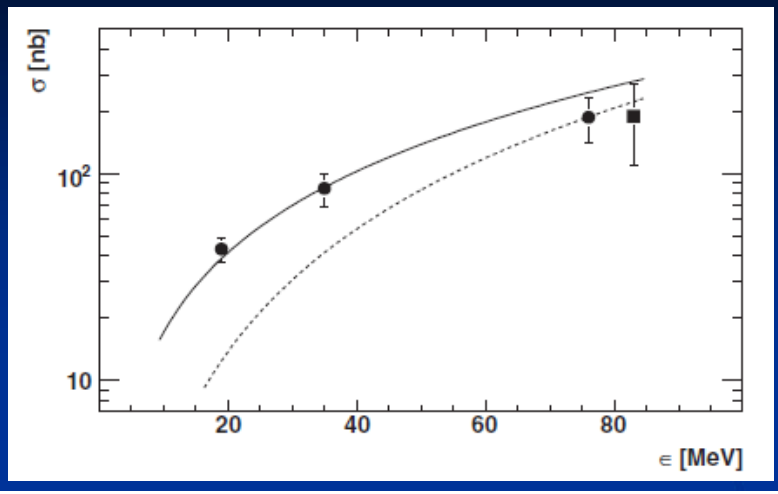
dot-dashed: includes K^-p FSI

solid-red: includes K^+K^- FSI

$a_{K^-p} = (0 + 1.5i)$ fm

$a_{K^-K^+} = \left[0.5^{4}_{-0.5} + (3 \pm 3)i\right]$ fm

$pp \to pp\, \phi$



dotted: three-body phase space

solid: includes pp FSI

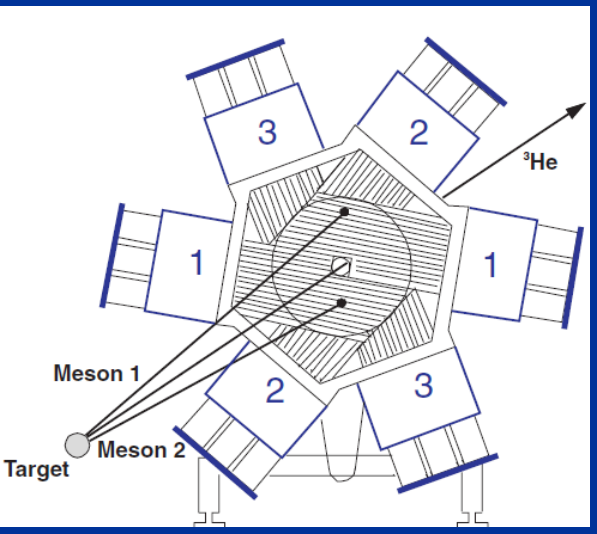
$\phi \to K^+K^- \propto \sin^2\Theta_J$ $(\rho_{00} = 0)$

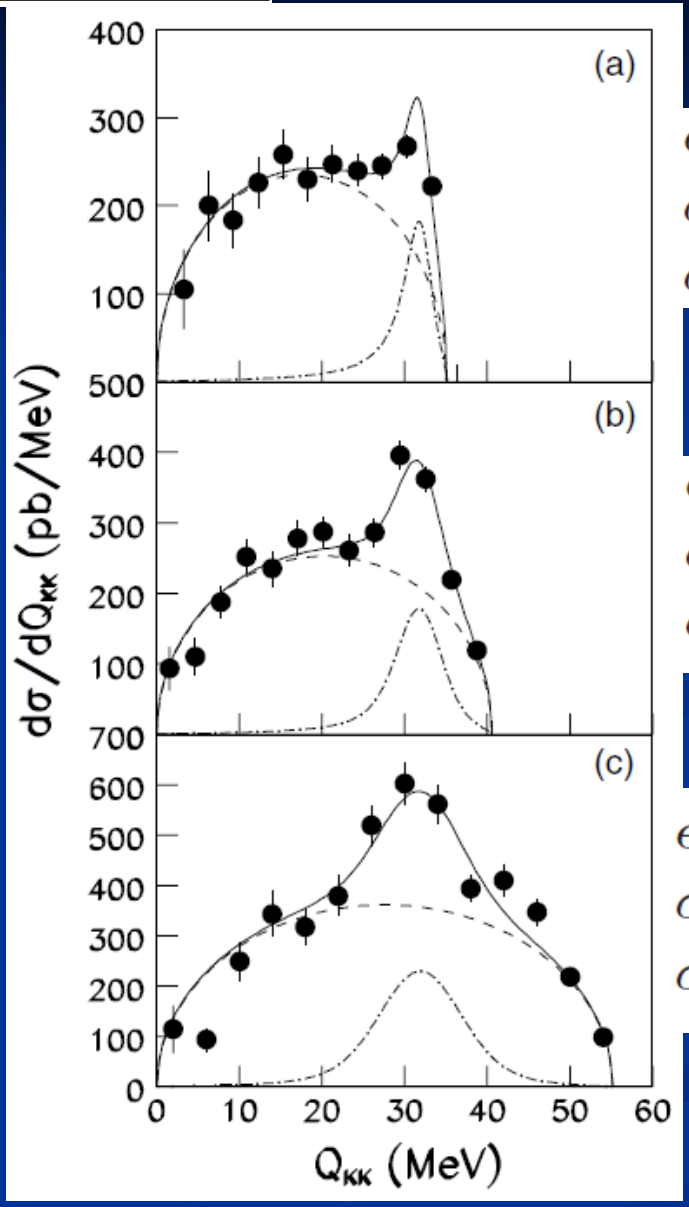
ϕ is tensor polarized $(m = \pm 1)$ along $\vec{p}_{beam}$

$R_{\phi/\omega} \approx 8 \cdot R_{OZI}$

$pd \to {}^3\mathrm{He}\, K^+K^-$ and $pd \to {}^3\mathrm{He}\, \phi(1020)$

COSY-MOMO





$\epsilon_{KK} = 35.1$ MeV
$\sigma_{KK} = 6.4 \pm 0.5$ nb
$\sigma_\phi = 2.0 \pm 0.4$ nb

$\epsilon_{KK} = 40.6$ MeV
$\sigma_{KK} = 8.1 \pm 0.5$ nb
$\sigma_\phi = 3.0 \pm 0.6$ nb

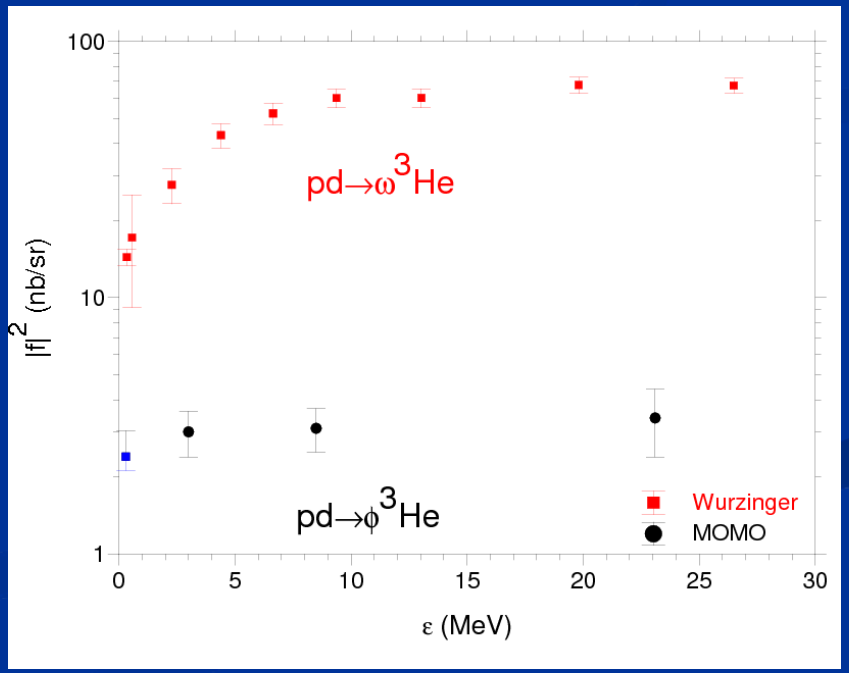
$\epsilon_{KK} = 55.2$ MeV
$\sigma_{KK} = 15.8 \pm 1.0$ nb
$\sigma_\phi = 6.4 \pm 1.8$ nb

$$\sigma_{KK} > \sigma_\phi$$

$pd \to {}^3\mathrm{He}\, K^+K^-$ and $pd \to {}^3\mathrm{He}\, \phi$

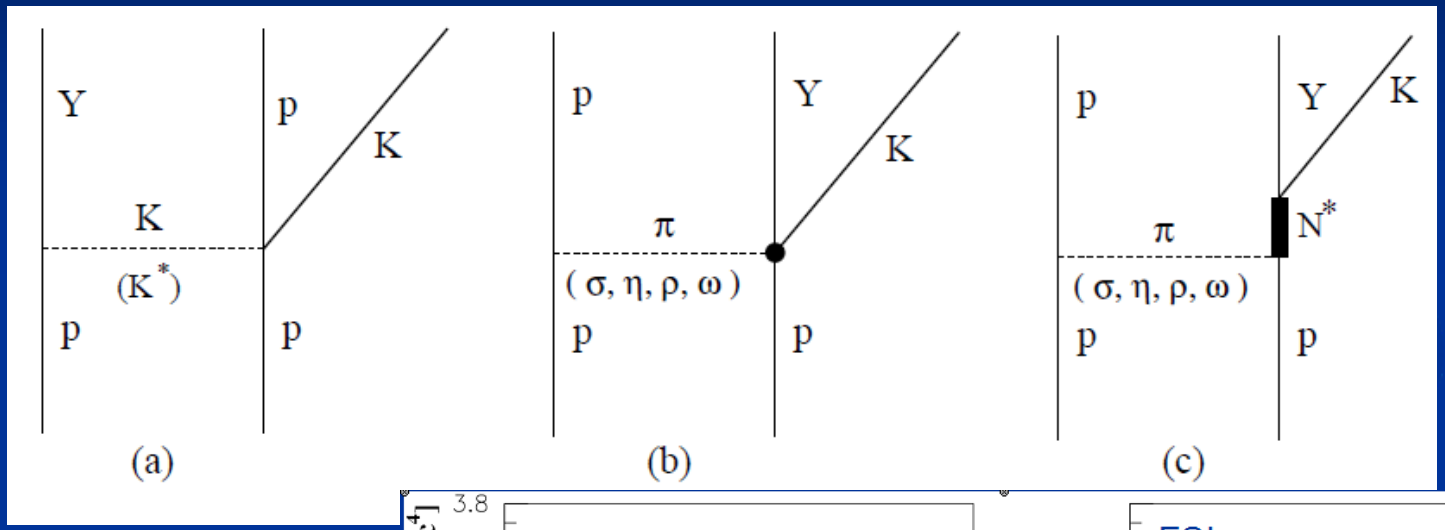
Results:

- $\sigma_\phi < \sigma_{KK}$
- $\sigma_{KK} \propto$ phase space
- $\sigma_\phi \propto$ phase space
- $d\sigma_\phi/d\cos\theta_J \propto \cos^2\theta_J$ (θ_J=Jackson angle)
- ϕ is tensor polarized ($m = 0$) along beam direction
- σ_ω is unpolarized (CELSIUS-WASA)
- $R_{\phi/\omega} = 20 R_{OZI}$

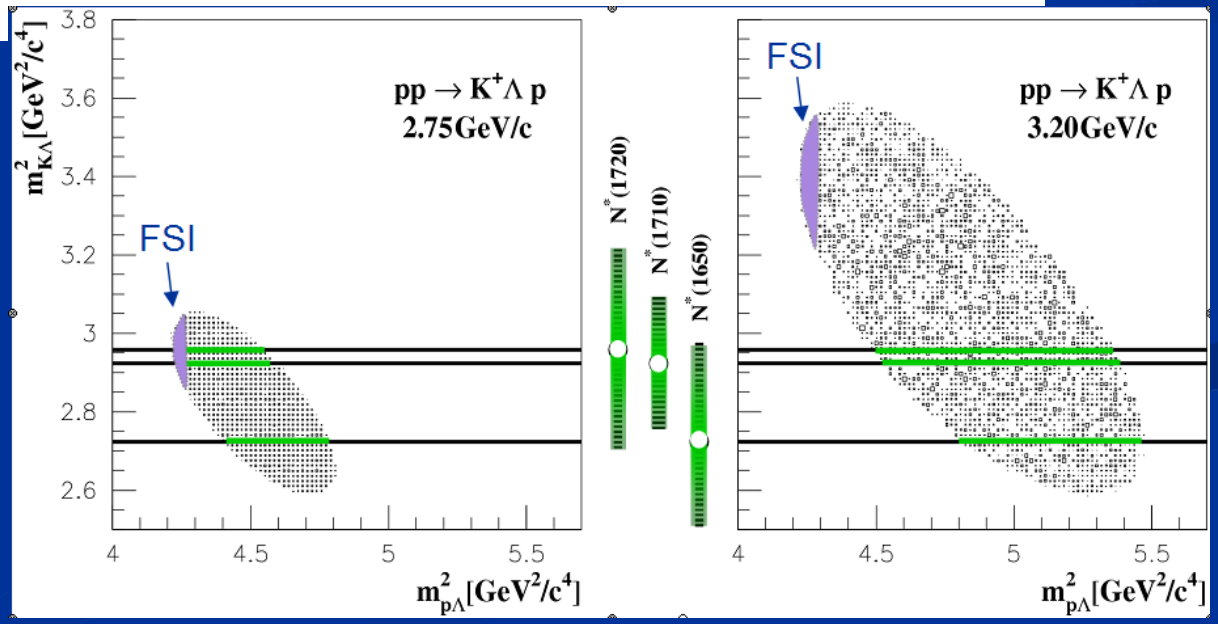


Associated Strangeness Production at COSY-TOF

$$pp \to K^+\Lambda p,\ pp \to K^+\Sigma^0 p,\ pp \to K^0\Sigma^+ p.$$

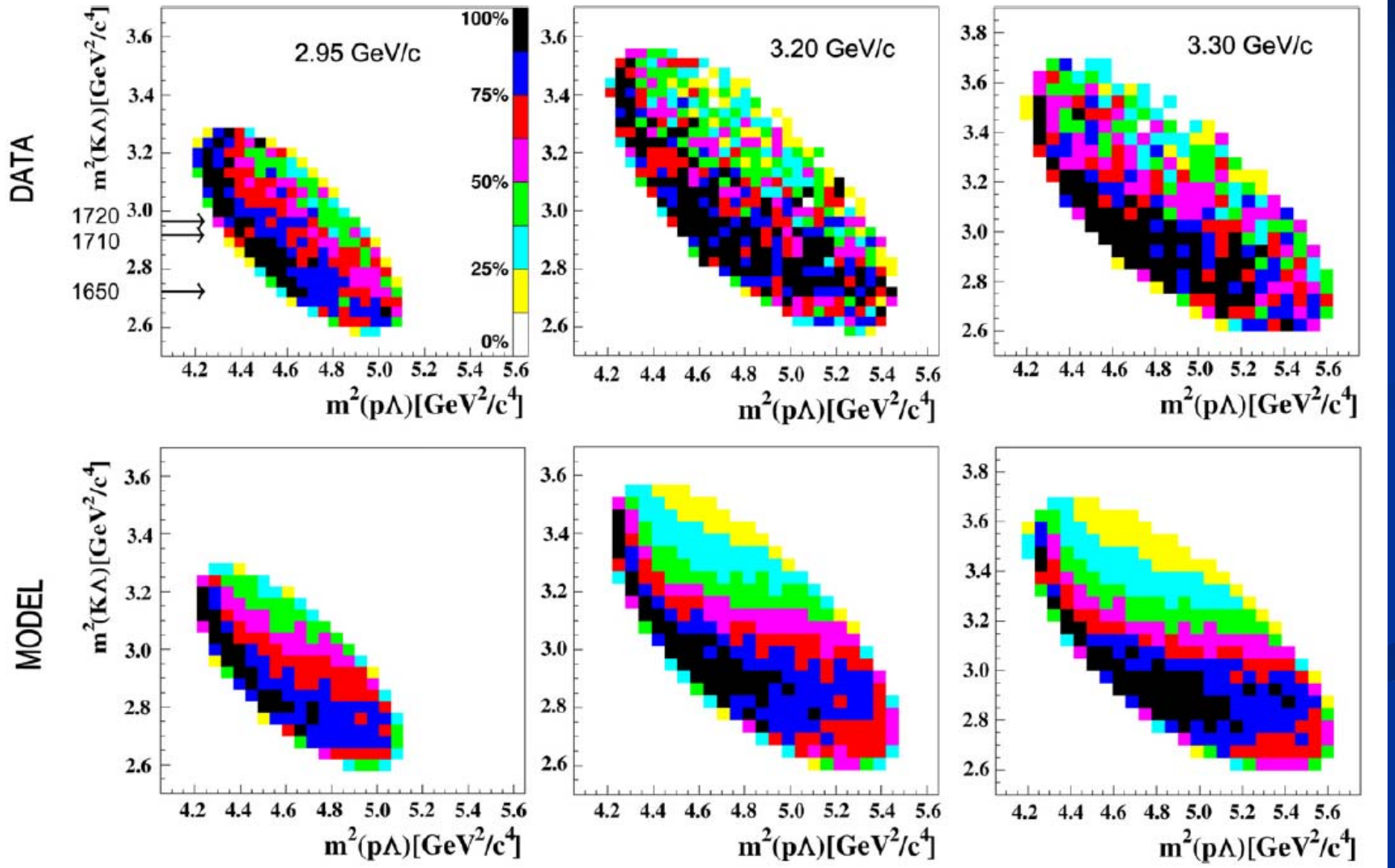


- Meson Exchange
- N^* Resonances
- FSI



$pp \to K^+\Lambda p$, Dalitz Plot

Model: Λp FSI and $N(1650)$, $N(1710)$, $N(1720)$ COSY-TOF, Phys. Lett. B 688, 142 (2010)



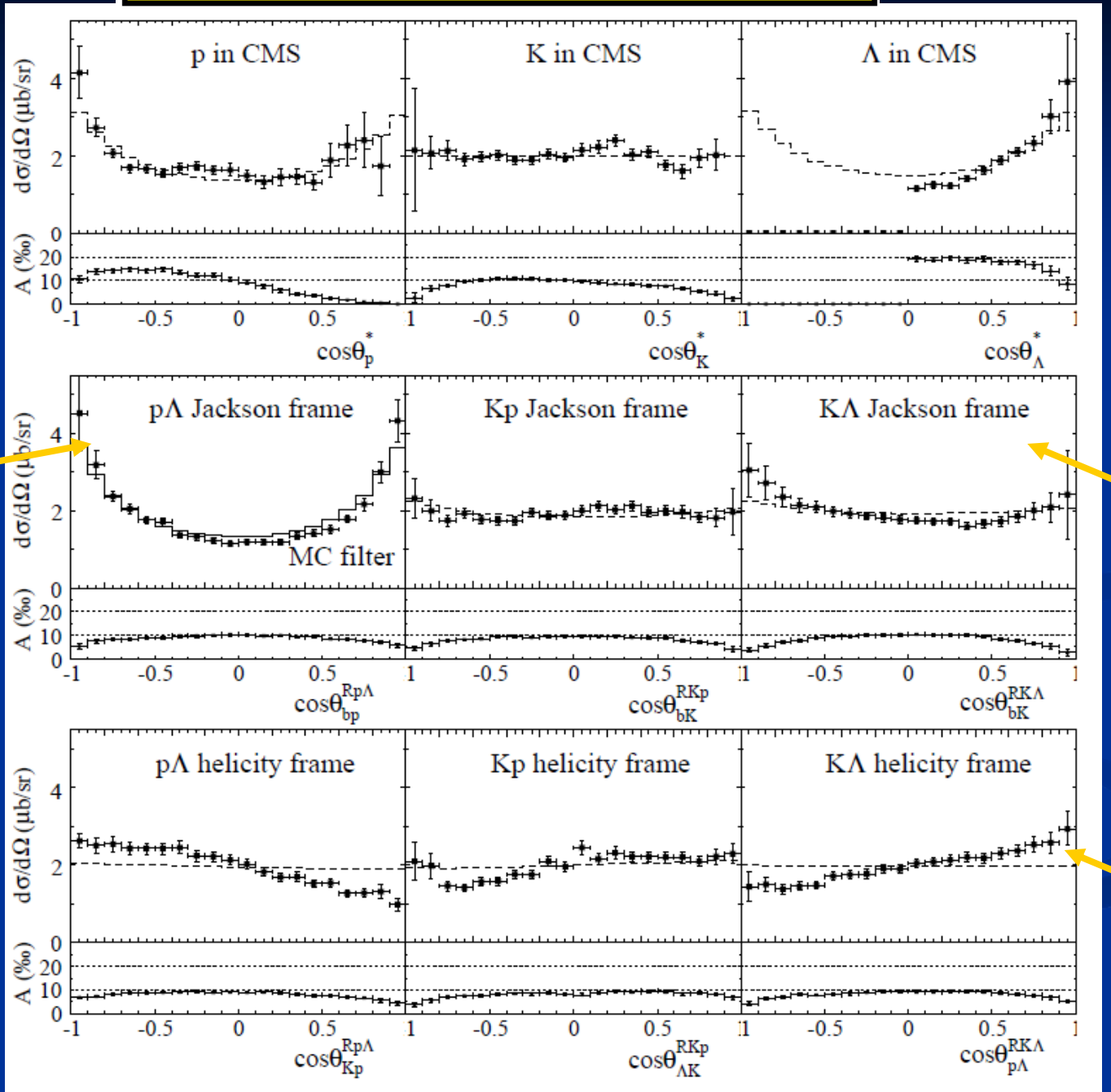
$d\sigma/d\Omega$ in CMS, Jackson- and Helicity-Frame

$pp \rightarrow pK^+\Lambda$

$\epsilon = 239$ MeV

(COSY-TOF)

Eur. Phys. J A46 (2010) 27

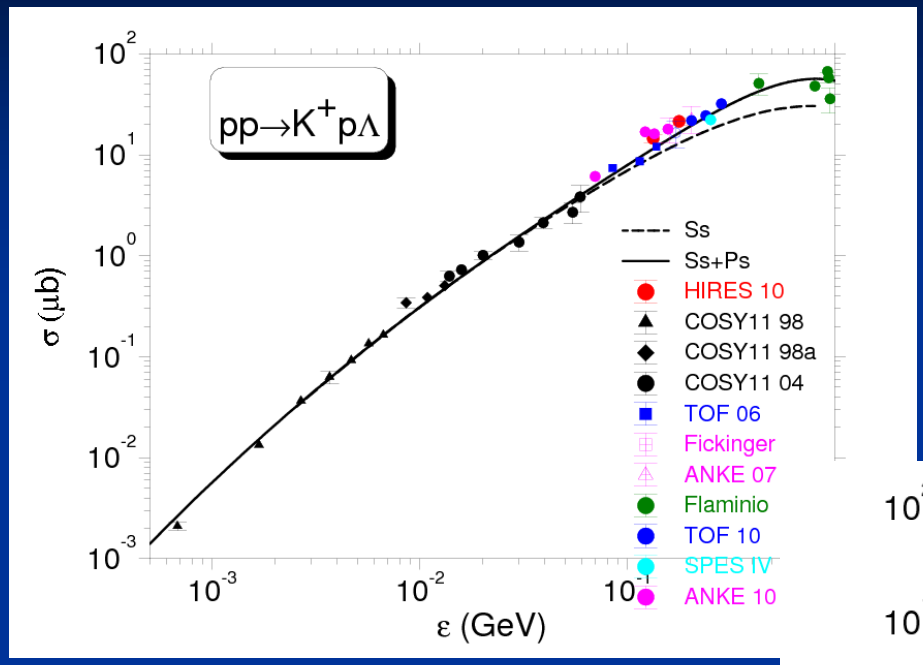


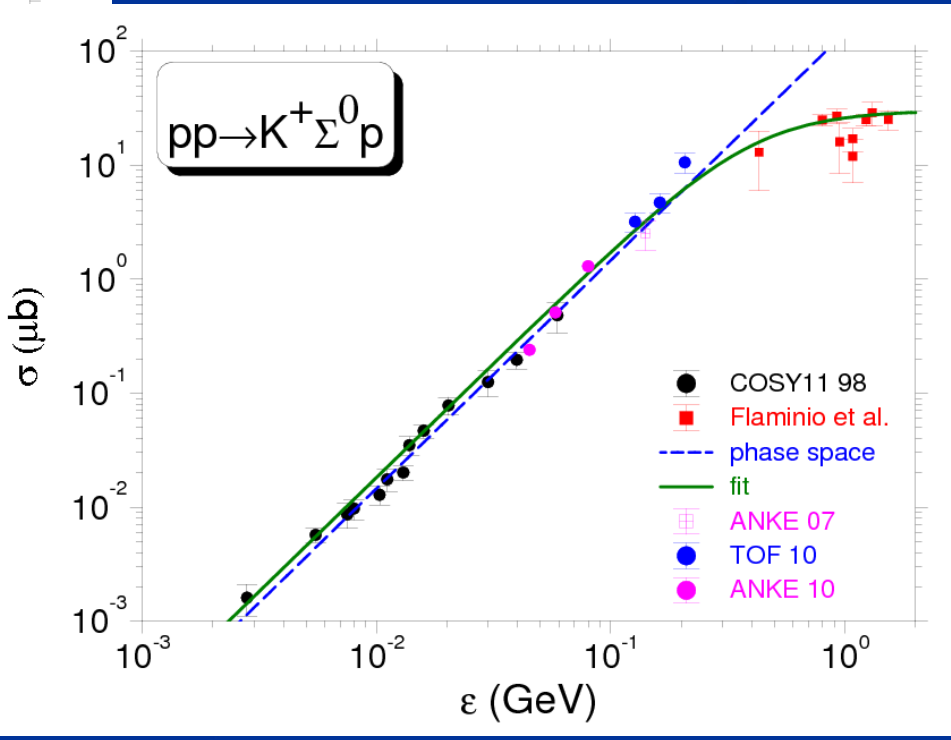
l=1

S_{11}, P_{11}, P_{13}

FSI

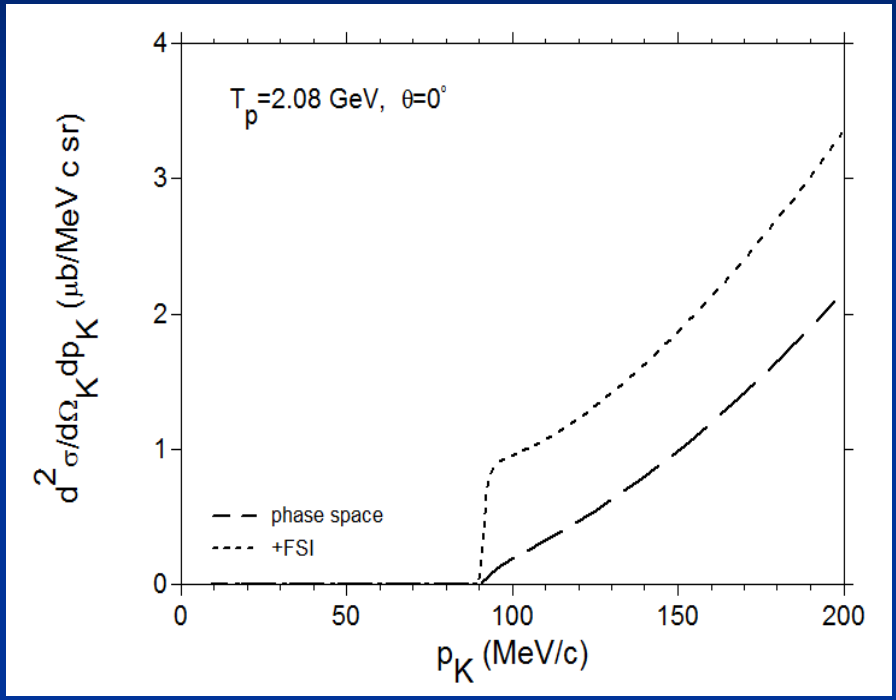
$pp \to K^+\Lambda p$ vs. $pp \to K^+\Sigma^0 p$

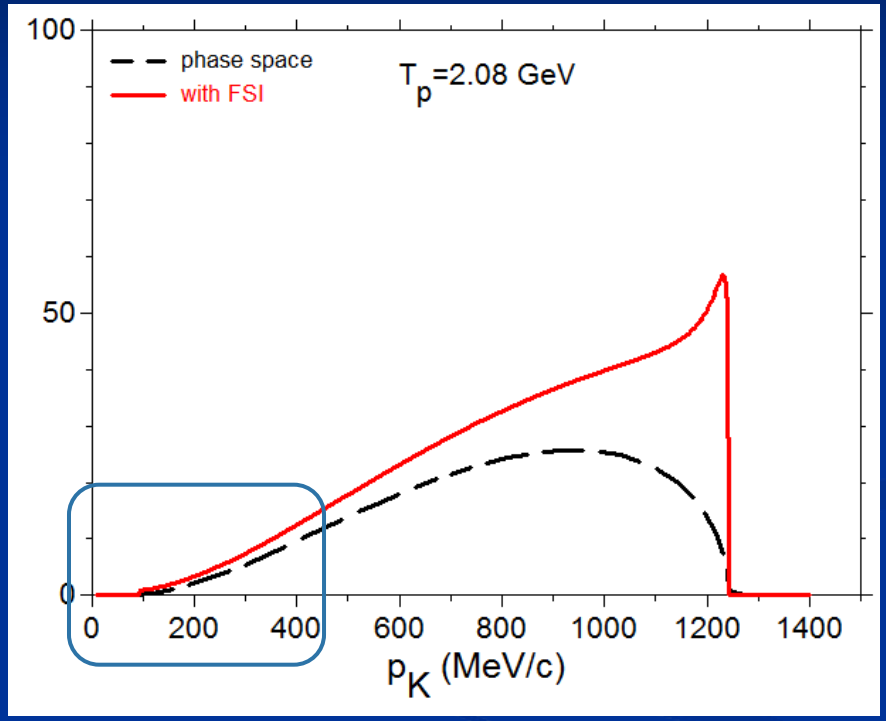




$$\sigma(pp \to K^+\Lambda p, \varepsilon) \approx 3\sigma(pp \to K^+\Sigma^0 p, \varepsilon)$$

Λp: how to study FSI?

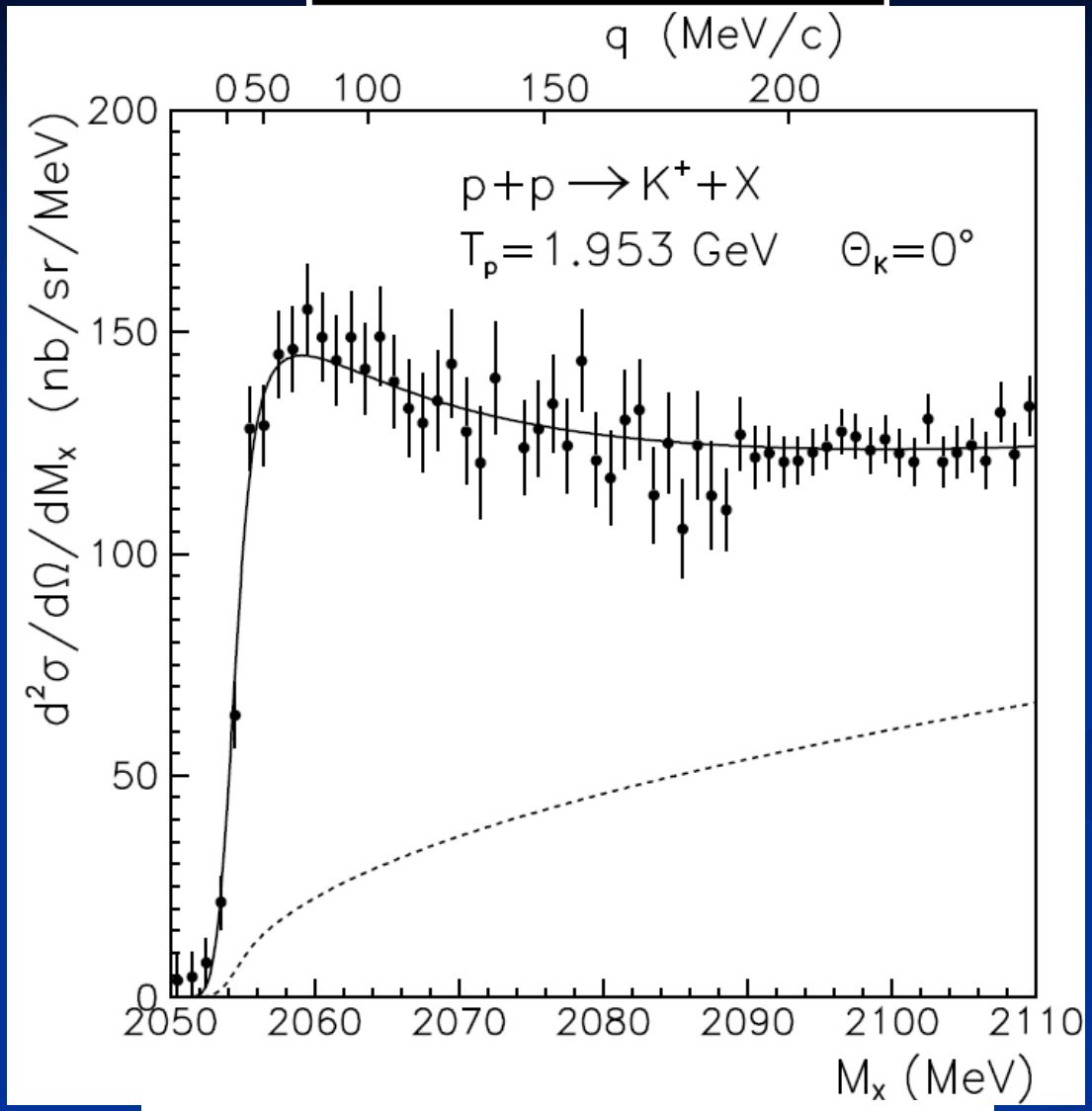


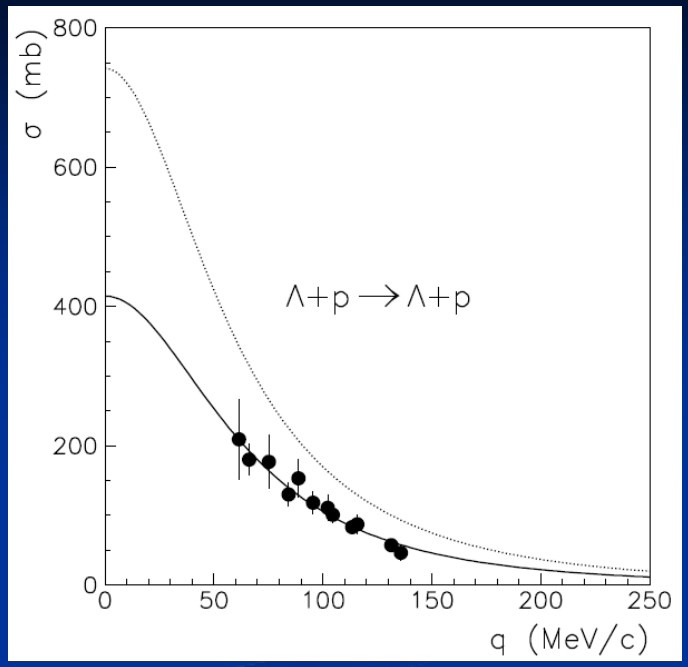


Kaons being forward emitted in the cm system

Kaons being backward emitted in the cm system

Λp FSI in $pp \to K^+ (\Lambda p)$





G. Alexander et al., Phys. Rev. 173 (1968) 1452
B. Sechi-Zorn et al., Phys. Rev. 175 (1968) 1735

FSI enhancement $\propto$ (Jost Function)$^{-2}$

$\bar{a} = -2.43^{+0.16}_{-0.17}$ fm, $\bar{r} = 2.21^{+0.16}_{-0.16}$ fm.

HIRES

Phys. Lett. B 687 (2010) 31

Λp FSI Analysis: Results

	a_s (fm)	r_s (fm)	a_t (fm)	r_t (fm)
COSY-HIRES	$-2.43^{+0.16}_{-0.25}$	$2.21^{+0.16}_{-0.36}$	$-1.56^{+0.19}_{-0.22}$	$3.7^{+0.6}_{-0.6}$
NSC97f	-2.51	3.03	-1.75	3.32
J04	-2.56	2.75	-1.66	2.93
J04c	-2.66	2.67	-1.57	3.08

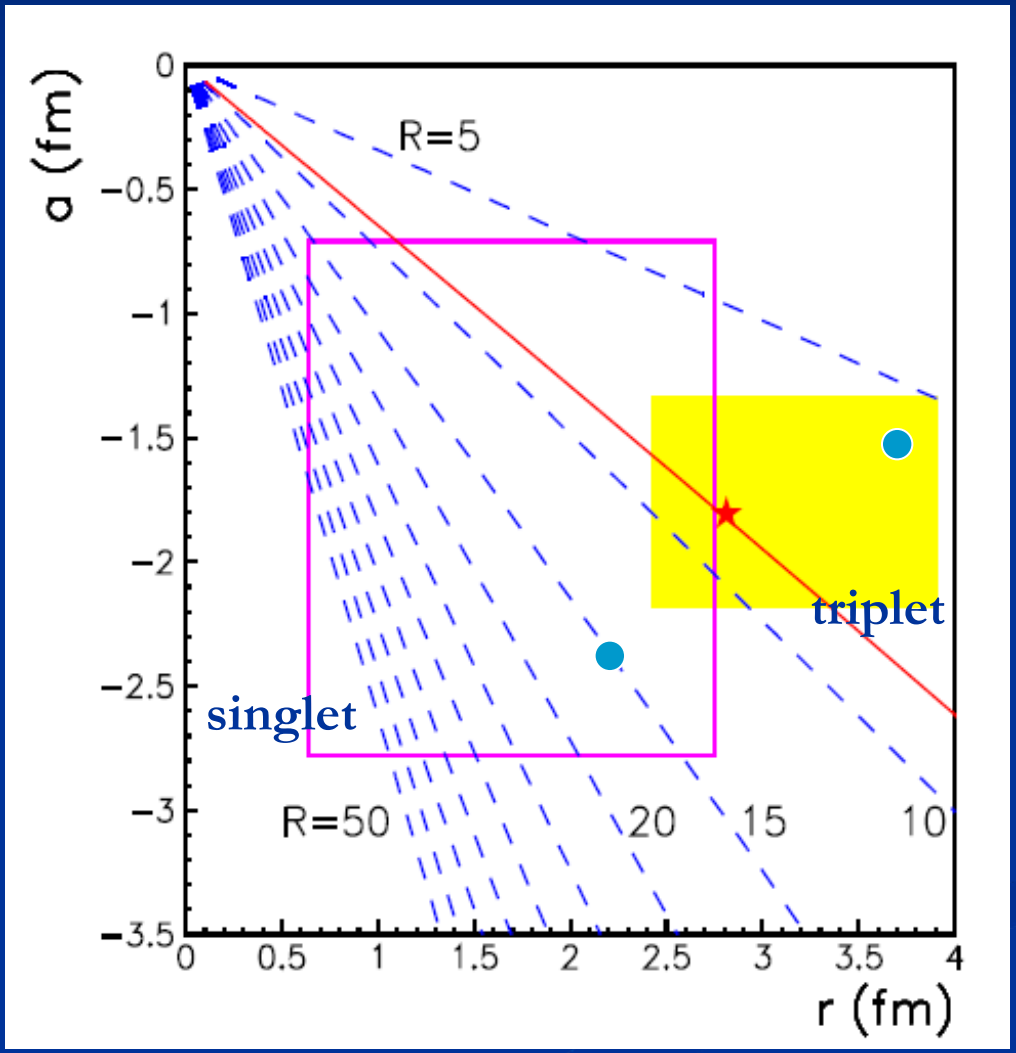
COSY-HIRES, Phys. Lett. B **687**, 31 (2010)

Nijmegen NSC97f: V.G. Stoks, Th.A. Rijken, Phys. Rev. C **59**, 3009 (1999)

Juelich J04: J. Haidenbauer, U.G. Meißner, Phys. Rev. C **72**, 044005 (2005)

Caveat: A possible theoretical uncertainty of the Jost-function approach may be in the order of 0.4 fm for the scattering length and even more for the effective range as suggested by the analysis of pseudodata (A. Gasparyan et al., Phys. Rev. C **72**, 034006 (2005)).

Enhancement

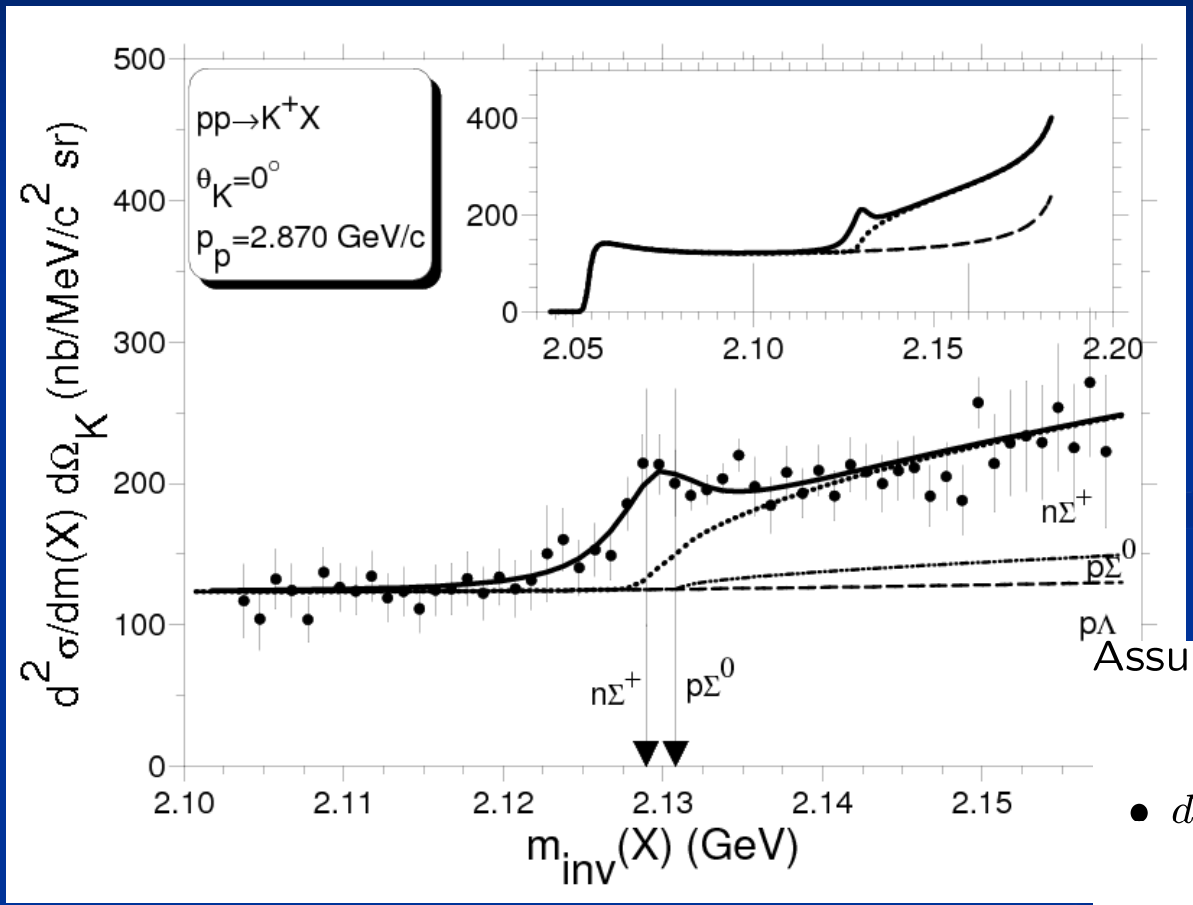


R=enhancement factor

HIRES results

Estimates from Sibirtsev et al. Eur. Phys. J. A27 (2005) 269

$pp \to K^+\Sigma^+n$ cross section (I)



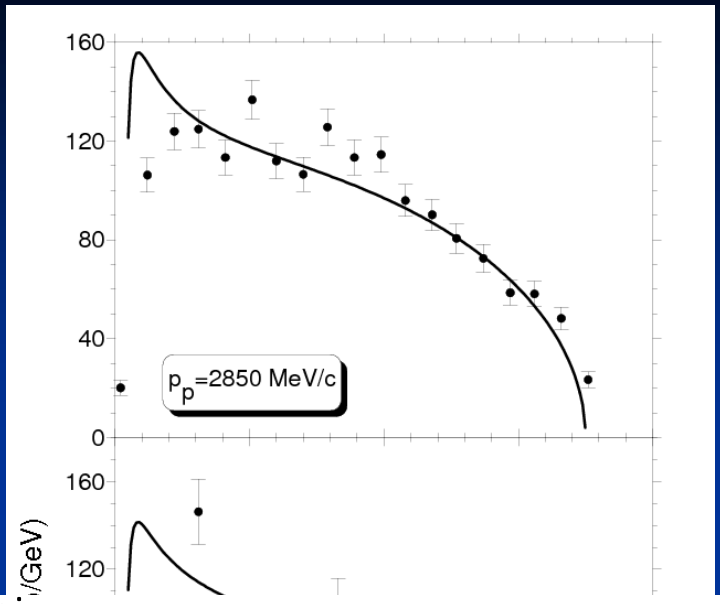
Assumptions:

- $d\sigma_{K+\Lambda p}/d\Omega_K$ isotropic
- $d\sigma_{K+\Sigma^0 p}/d\Omega_K$ isotropic
- fsi according to effective range

$pp \to K^+\Sigma^+n$ cross section (II)

HIRES

Phys. Lett. B 692(2010) 10



Isospin:

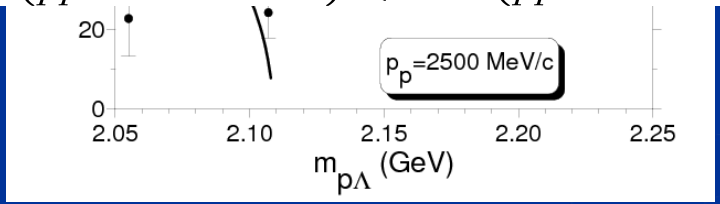
$$M(pp \to K^+\Sigma^+n) + M(pp \to K^0\Sigma^+p) + \sqrt{2}M(pp \to K^+\Sigma^0p) = 0$$

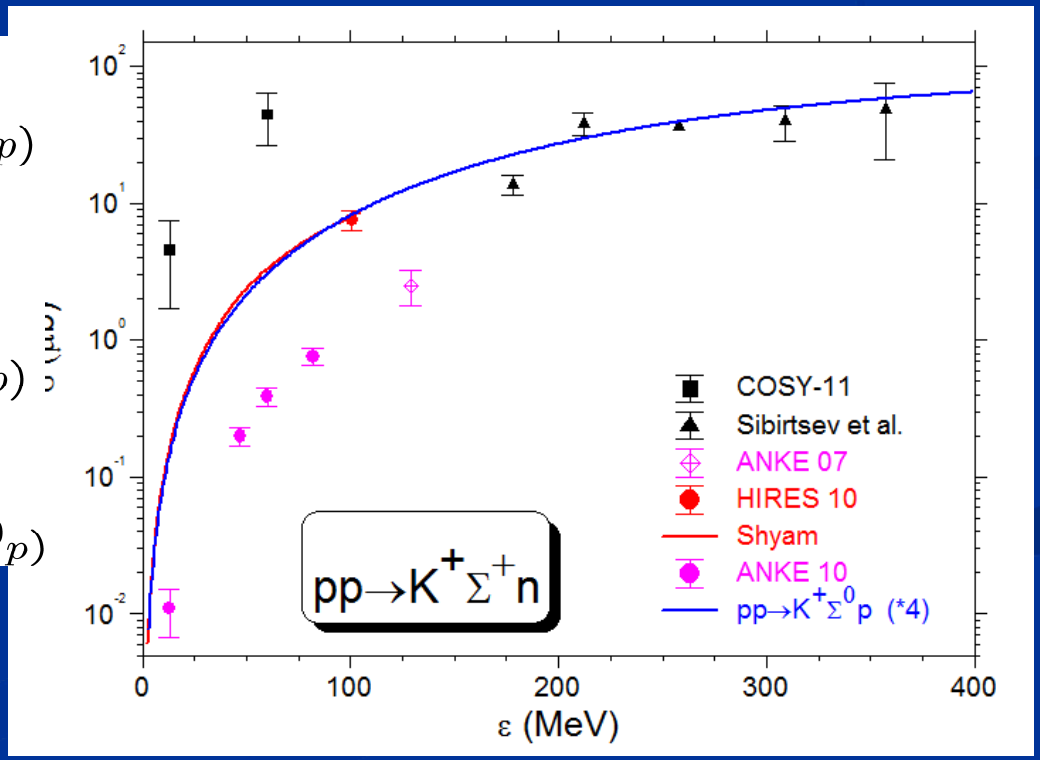
For

$$M(pp \to K^0\Sigma^+p) \approx M(pp \to K^+\Sigma^0p)$$

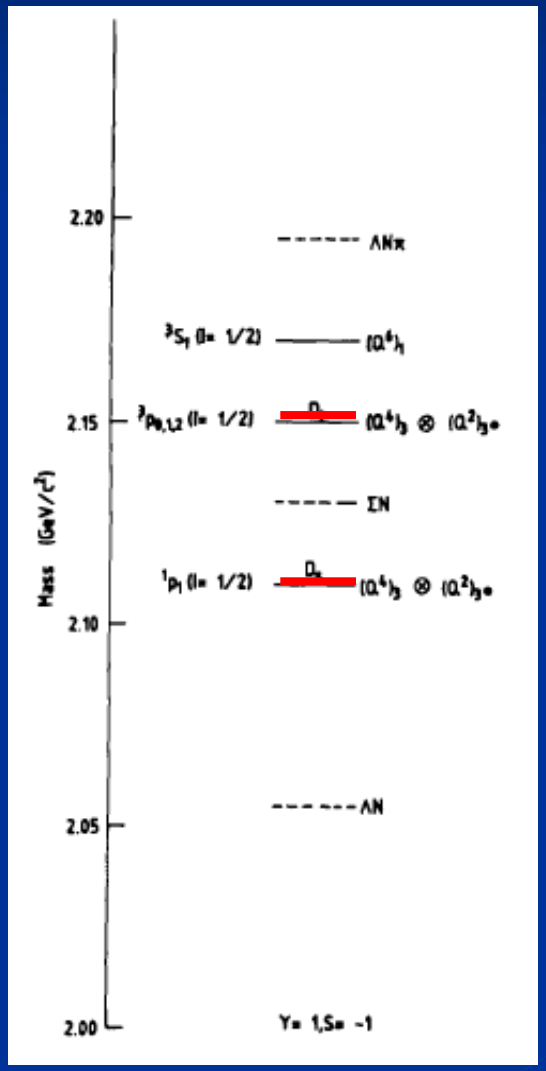
we get

$$\sigma(pp \to K^+\Sigma^+n) < 5.8\sigma(pp \to K^+\Sigma^0p)$$





S=-1 Dibaryons



Aerts and Dover

NPB 253 (1985) 116

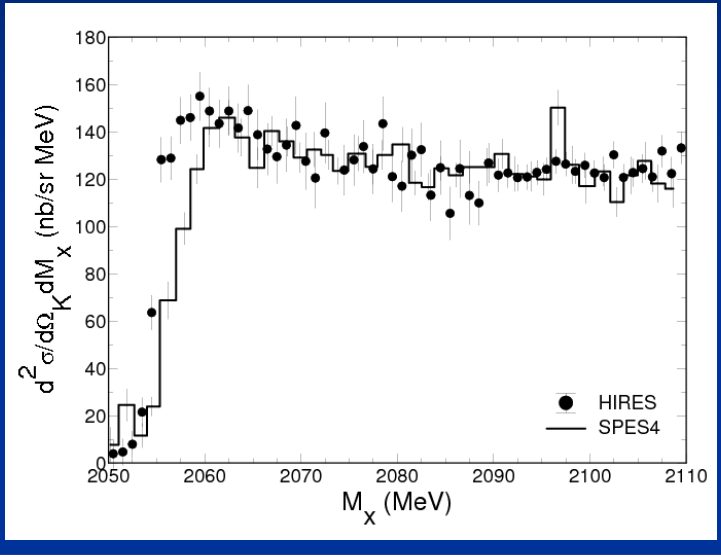
Possible reactions:

$$K^- + d \rightarrow \pi^- + D_t$$

$$K^- + pp + n_{spec} \rightarrow \pi^+ + D_s + n_{spec}$$

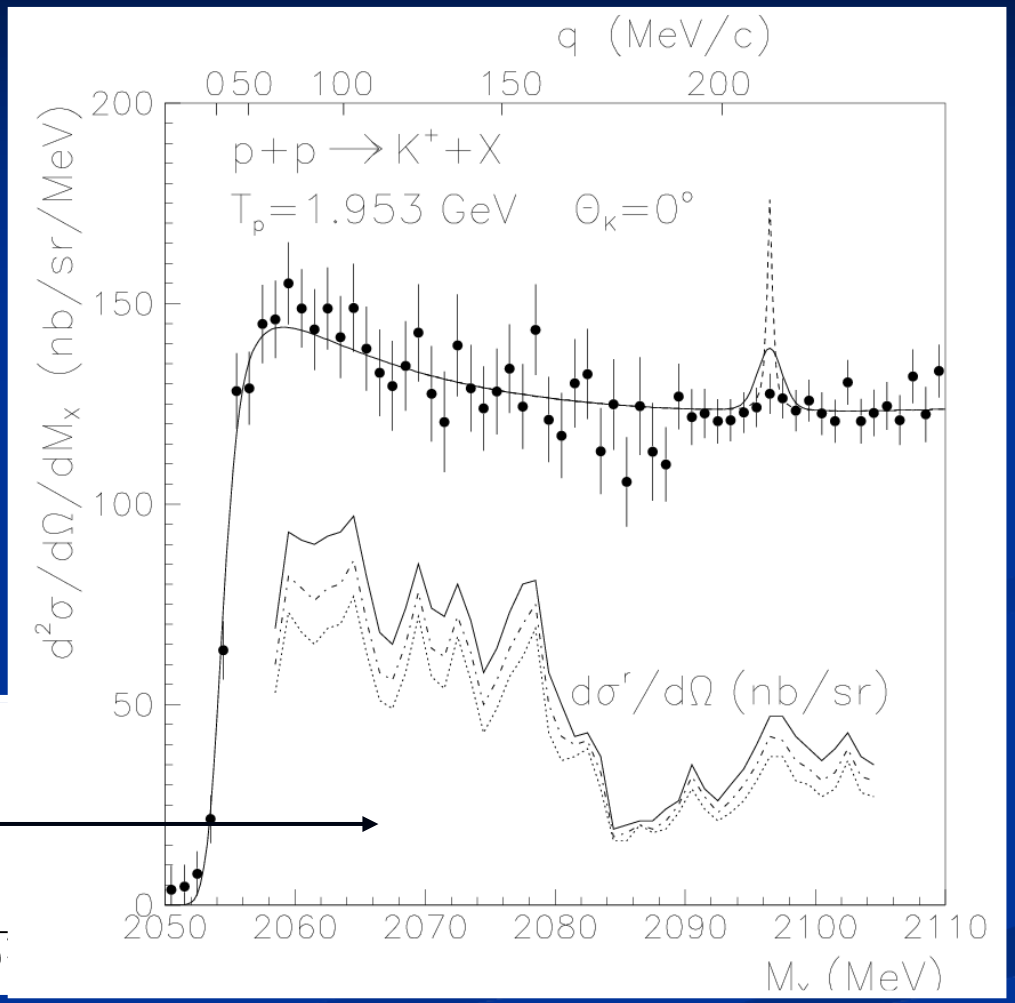
$$p + p \rightarrow K^+ + D_{s,t}$$

Search for a S=-1 Dibaryon



$$\frac{d^2\sigma}{d\Omega_K dM_{\Lambda p}} = \frac{d^2\sigma^{nr}}{d\Omega_K dM_{\Lambda p}} + \frac{d^2\sigma^{r}}{d\Omega_K dM_{\Lambda p}}$$

$$\frac{d^2\sigma^{r}}{d\Omega_K dM_{\Lambda p}} = \frac{d\sigma^{r}}{d\Omega_K}\frac{1}{2\pi}\frac{\Gamma}{(M_{\Lambda p}-M_r)^2+(\Gamma/2)^2}$$



HIRES

Phys. Rev. D 84 (2011) 032002

Γ
1.0 MeV
0.5 MeV
0.1 MeV

99% confidence

Summary

- Experimental Facilities: (COSY-11), COSY-ANKE, (COSY-HIRES), (COSY-MOMO), COSY-TOF, COSY-WASA
- Kaon pair production in pp, pn, pd and dd collisions
- K^-p FSI important in $pp \to ppK^+K^-$
- Tensor polarized ϕ in $pp \to pp\phi$ and $pd \to {}^3He\phi$
- $R_{\phi/\omega} \approx 8R_{OZI}$ and $R_{\phi/\omega} \approx 20R_{OZI}$, respectively
- $pp \to K^+\Lambda p$: Dalitz Plots: Λp FSI, dominant contributions of $N(1650)$, $N(1710)$ and $N(1720)$
- $pp \to K^+\Lambda p$ and $pp \to K^+\Sigma^0 p$: $\mathrm{d}\sigma/\mathrm{d}\Omega$ in CMS-, Jackson- and Helicity-Frame
- Partial Wave Analysis of $pp \to K^+\Lambda p$ and $pp \to K^+\Sigma^0 p$
- FSI enhancement in $pp \to K^+(\Lambda p)$ at $\Theta = 0^\circ$