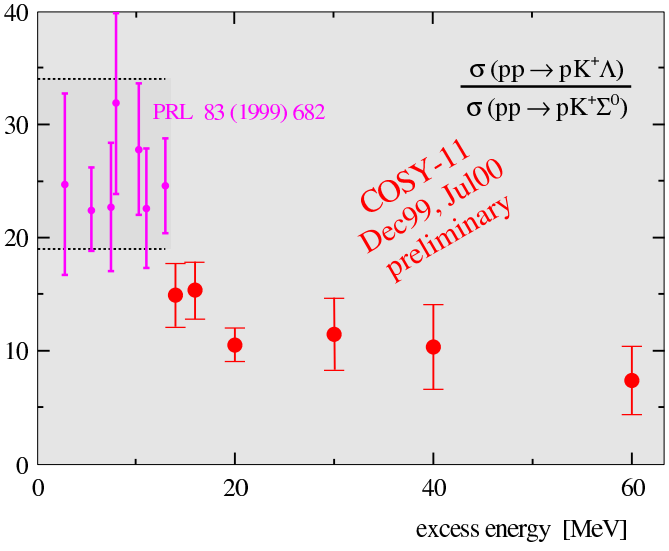
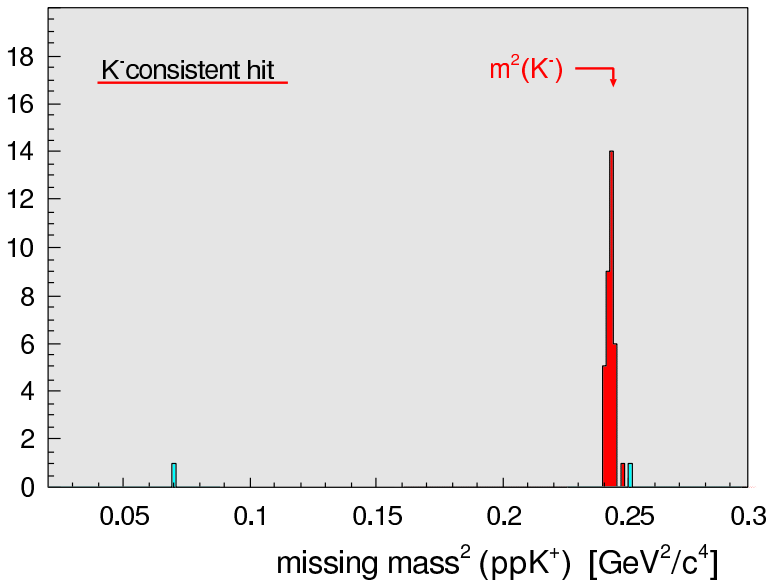
# *Strangeness-Produktion in Schwellennähe an COSY-11*

*Magnus Wolke*
*Institut für Kernphysik I*
*Forschungszentrum Jülich*
*für die*
*COSY-11 Kollaboration*



***Arbeitstreffen "Hadronen und Kerne"***
*Pommersfelden*
*24.-28. September 2001*

# Strangeness-Produktion in Schwellennähe an COSY-11

- **Studien zu $\eta$– und $\eta'$ im Proton-Proton Stoß**

  Energieabhängigkeit des totalen Wirkungsquerschnitts

  Zugang zur Meson-Nukleon Wechselwirkung

  Quasifreie Produktion am Neutron

- **Exklusive Kaon-Hyperon-Produktionsexperimente**

  $\Lambda/\Sigma^0$ Produktionsverhältnis

  Theoretische Studien und physikalische Interpretation

  Gegenwart und Zukunft

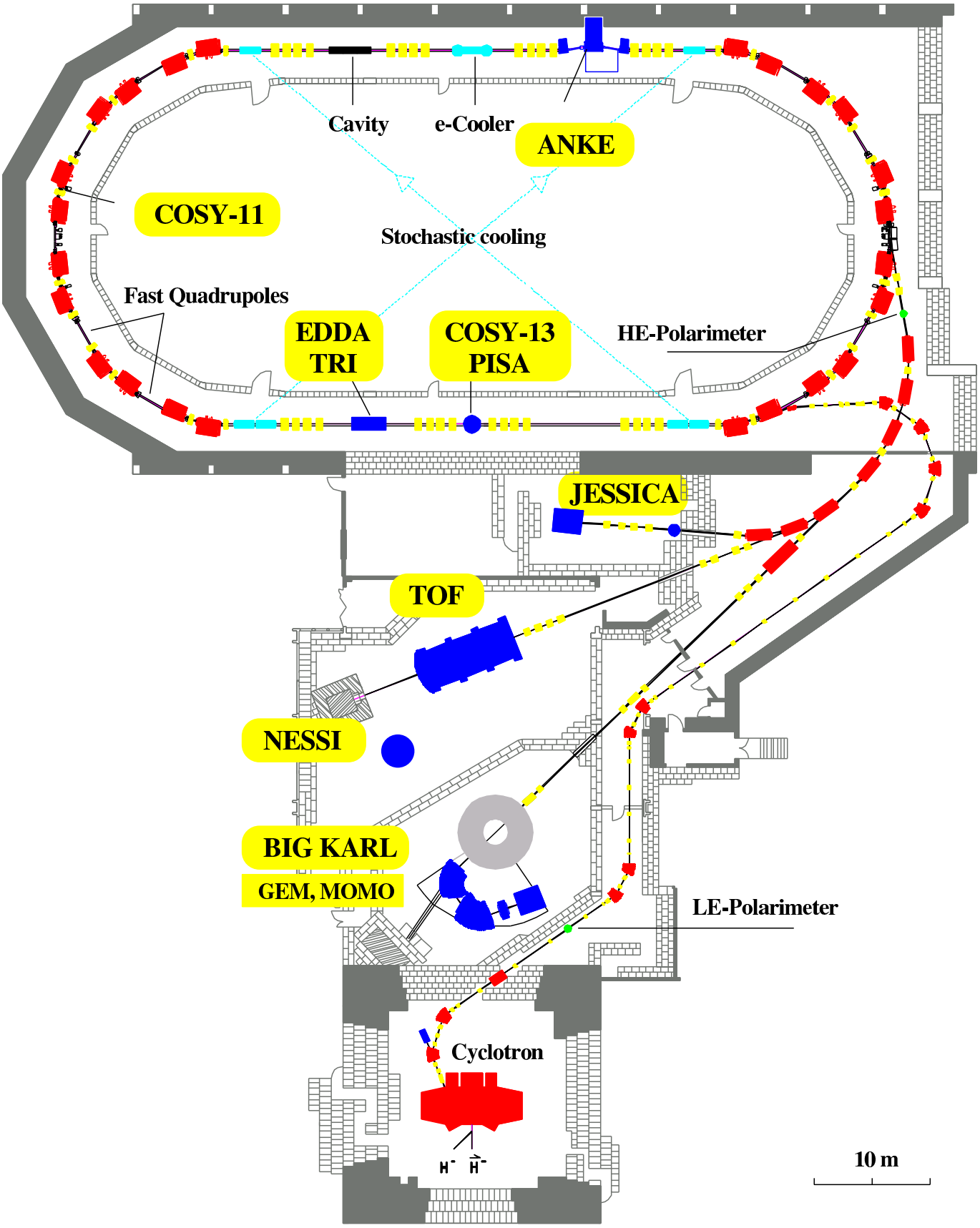
- **Elementare Strangeness-Dissoziation in den $K^+K^-$-Kanal**

  Physikalische Motivation

  Ergebnisse und experimentelles Programm

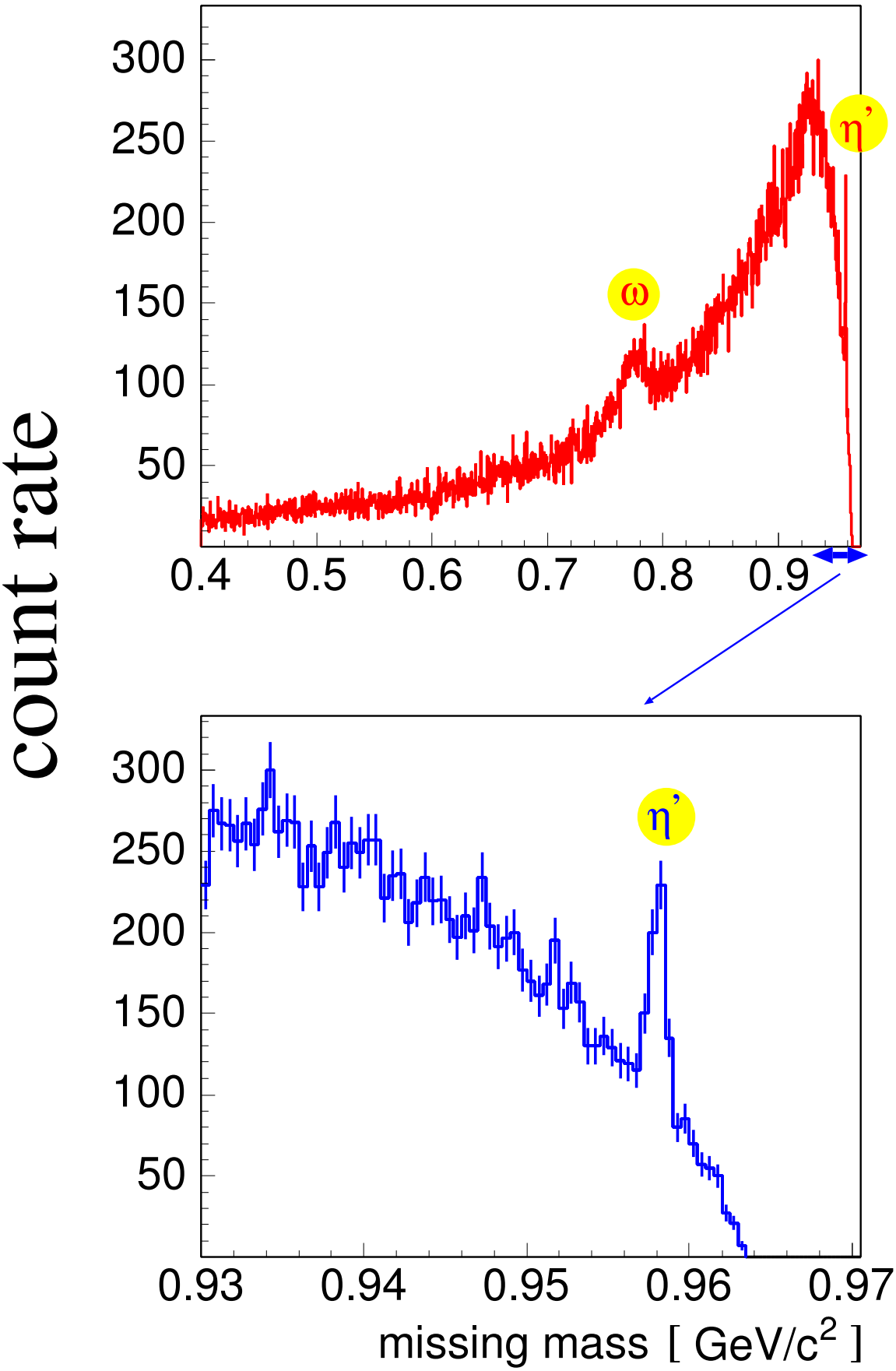
*Arbeitstreffen*
*"Hadronen und Kerne"*
*Pommersfelden, 28. September 2001*

# COoler-SYnchrotron



# $pp \longrightarrow pp\,X$

$Q_{(X=\eta')} = 6$ MeV $\Longleftrightarrow$ $P_{beam} = 3.227$ GeV/c



$$\sigma_T(pp \to ppX) = C \frac{(m_p + m_X)^2}{(2m_p + m_X)^{5/2}} \times \frac{\sqrt{m_X}}{(m_p m_X + m_\pi^2)^2} \times |f(\pi^0 p \to pX)|^2 \times \frac{Q^2}{\varepsilon} \frac{1}{(1+\sqrt{1+Q/\varepsilon})^2}$$

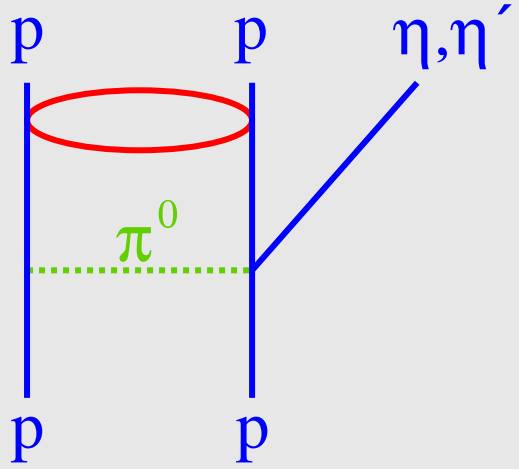
$X = \eta, \eta'$

$\varepsilon = 0.45$ MeV

C = constant, independent of X parameters

$|f(\pi^0 p \to p\eta)|^2 = 365 \pm 30$ μb

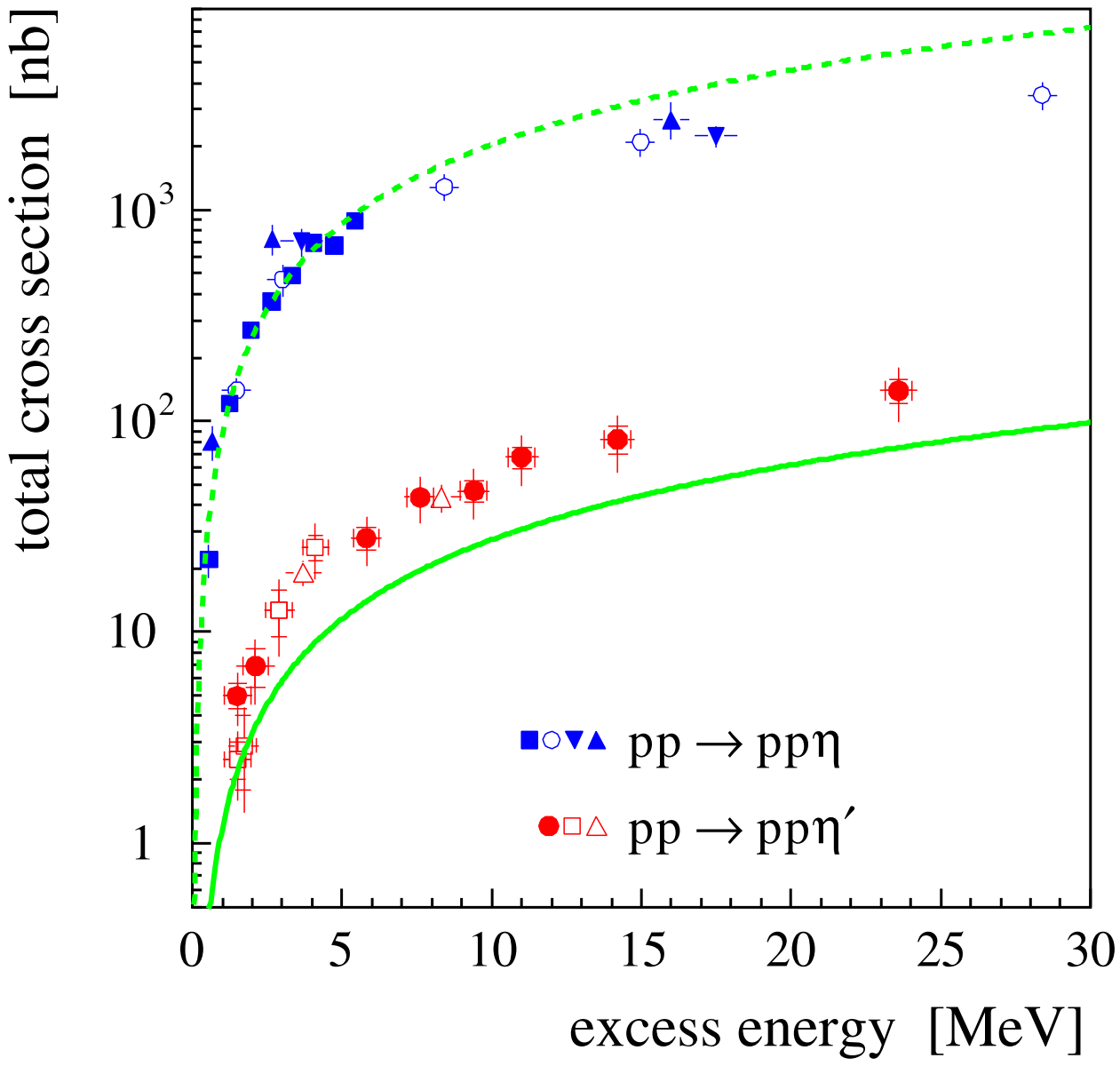
$|f(\pi^0 p \to p\eta')|^2 = 10 \pm 1$ μb

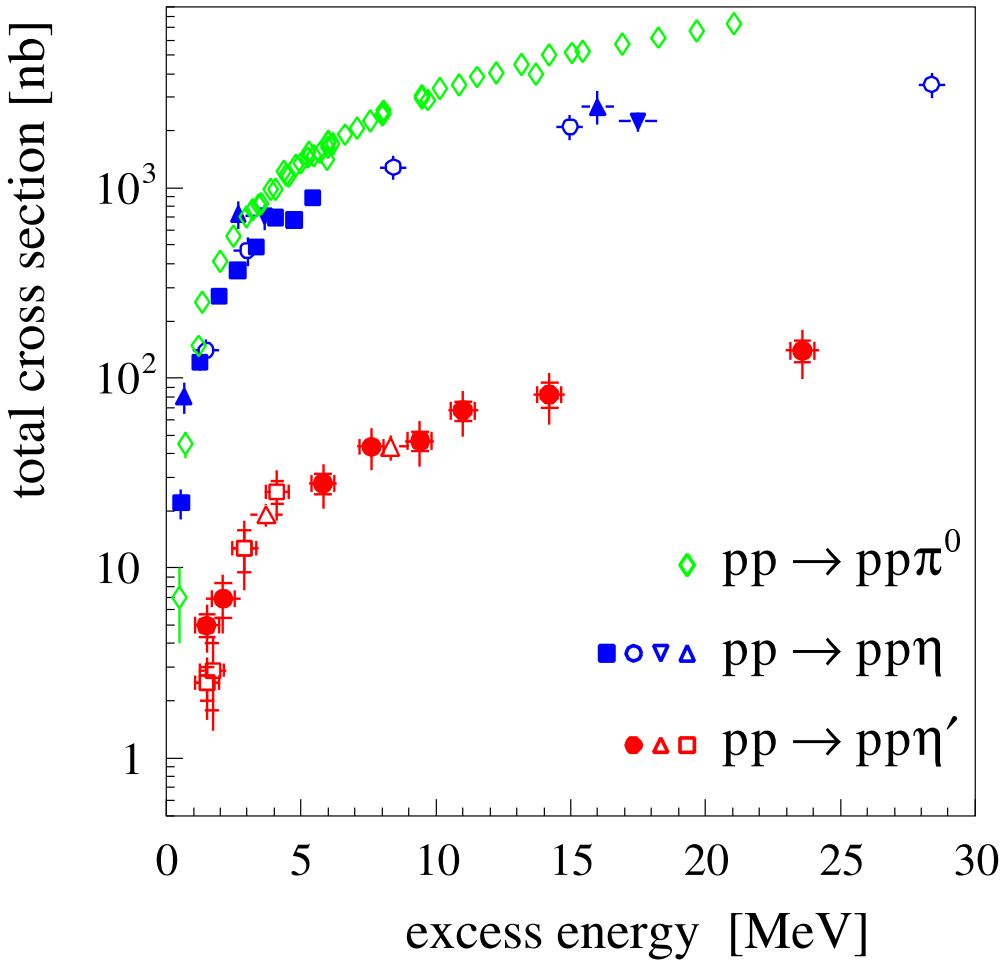


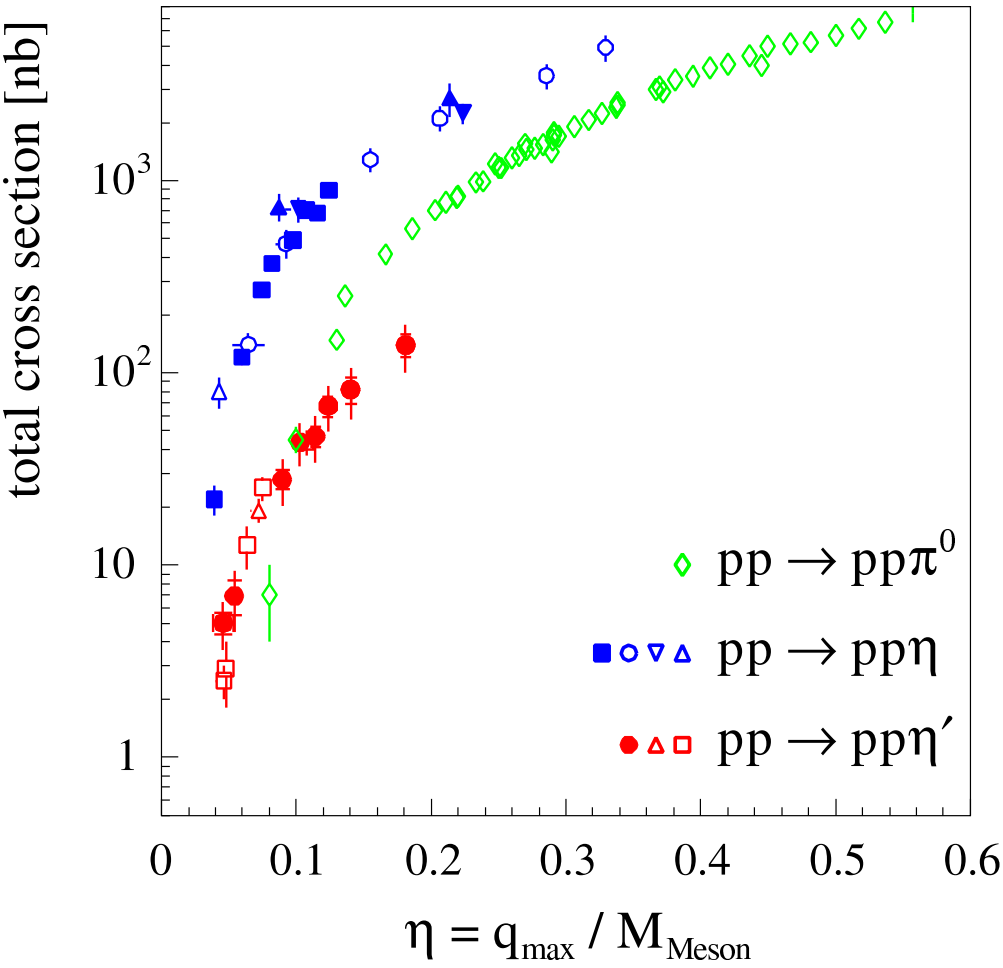

J.-F. Germond, C. Wilkin,
Nucl. Phys. A518 (1990) 308

G. Fäldt, C. Wilkin,
Phys. Lett. B382 (1996) 209

F. Hibou et al.,
Phys. Lett. B438 (1998) 41


total cross section [nb]
$10^3$
$10^2$
10
1
0
5
10
15
20
25
30
excess energy [MeV]
pp → ppη
pp → ppη′


total cross section [nb]
$10^3$
$10^2$
10
1
0
5
10
15
20
25
30
excess energy [MeV]
$pp \rightarrow pp\pi^0$
$pp \rightarrow pp\eta$
$pp \rightarrow pp\eta'$


total cross section [nb]
$10^3$
$10^2$
10
1
0
0.1
0.2
0.3
0.4
0.5
0.6
$\eta = q_{max} / M_{Meson}$
$pp \rightarrow pp\pi^0$
$pp \rightarrow pp\eta$
$pp \rightarrow pp\eta'$

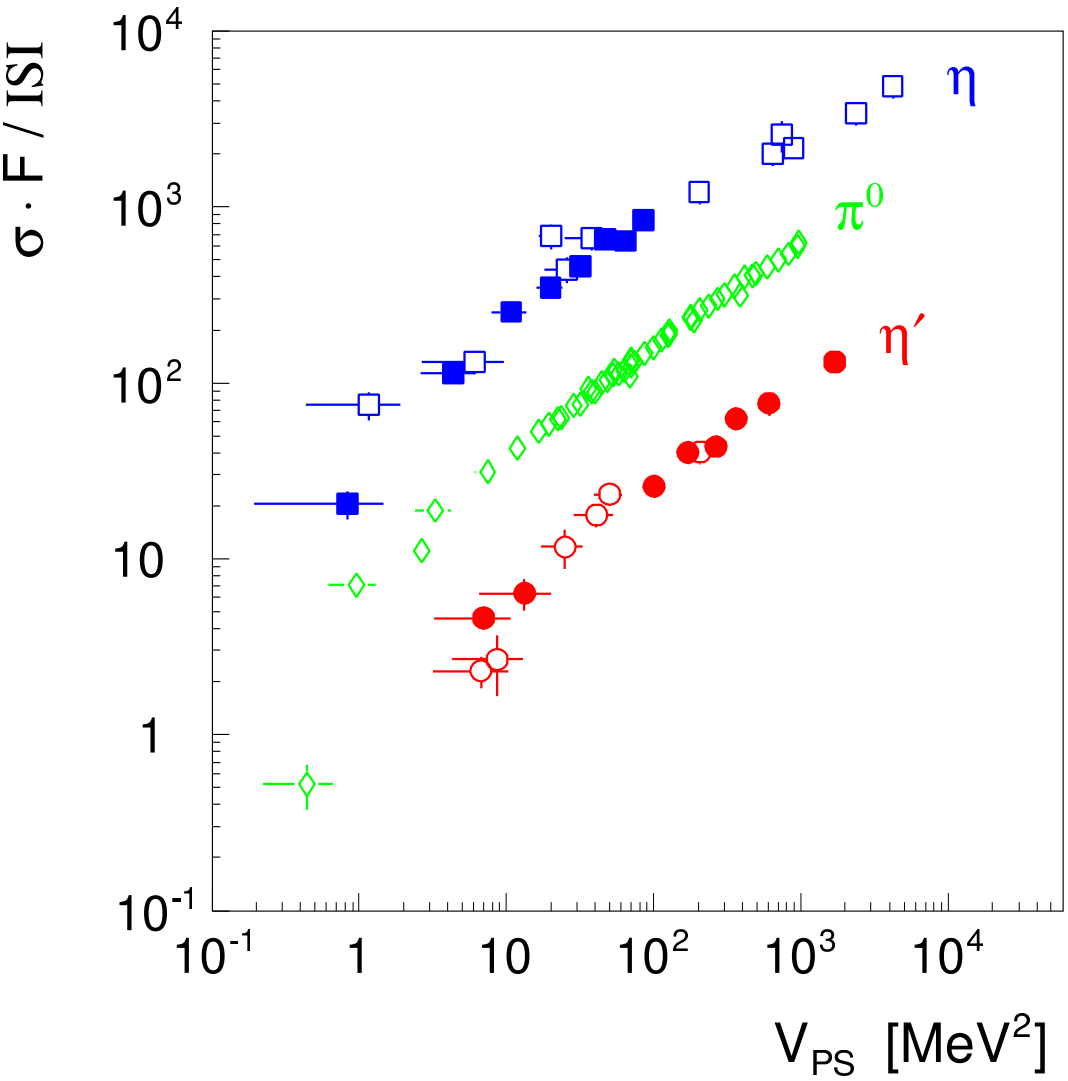
# $pp \rightarrow ppX$ Close to Threshold

## Phase Space Dependence

$$\sigma_{pp \rightarrow ppX} = \frac{1}{F} \int dV_{PS} \; |M_{pp \rightarrow ppX}|^2$$

$$|M_{pp \rightarrow ppX}| \approx |M_0| \cdot |M_{FSI}| \cdot ISI$$

$$F = 2(2\pi)^5 \sqrt{s(s - 4m_p^2)}$$

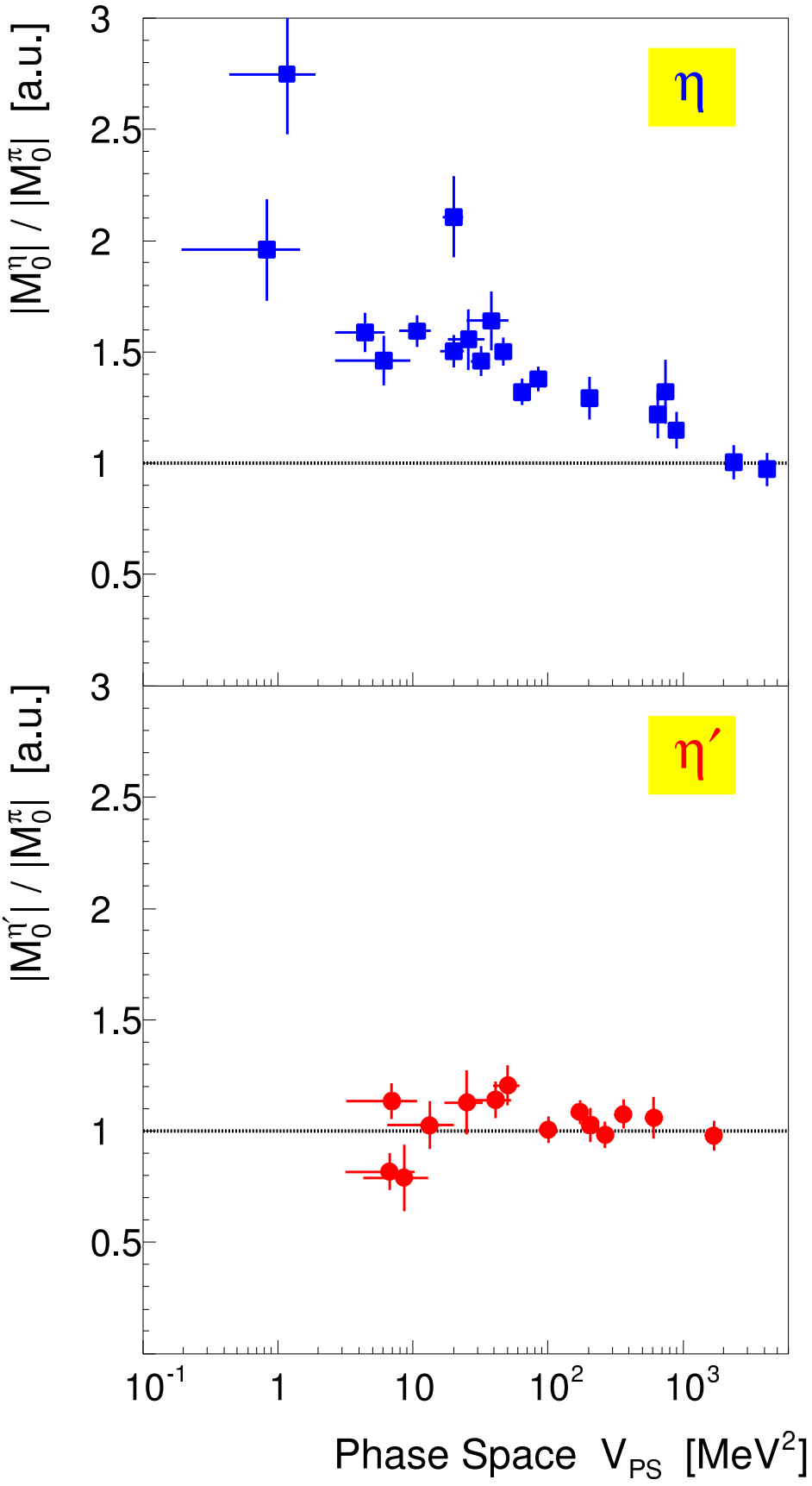



| | | | | | |
|---|---|---|---|---|---|
| ■ | COSY-11 | Phys. Lett. B474 (2000) 182 | ◊ | IUCF | Phys. Rev. Lett. 65 (1990) 2846 |
| □ | SPES3 | Phys. Lett. B 438 (1998) 41 | | CE-01, CE-23 | Nucl. Phys. A 539 (1992) 633 |
| | | Phys. Rev. D 48 (1993) R2969 | | CELSIUS | Phys. Lett. B 356 (1995) 8 |
| | CELSIUS | Phys. Lett. B 366 (1996) 39 | ● | COSY-11 | Phys. Lett. B 474 (2000) 416 |
| | PINOT | Phys. Lett. B 322 (1994) 270 | | | Phys. Rev. Lett. 80 (1998) 41 |
| | | | ○ | SPES3 | Phys. Lett. B 438 (1998) 41 |

# η and η′ Production Amplitude

P.Moskal et al.,
Phys. Lett. B 482 (2000) 356

Normalization to $\pi^0$ Production



**Kurzreichweitige Wechselwirkung (~ 0.2 fm)**
**der Nukleon-Nukleon Streuung**
**produziert Glue,**
**das sich zu dem Endzustand η' entwickelt.**

Glue "flavour-blind"
→ bei Dominanz im Reaktionsmechanismus...
...wird der Verlauf der Reaktionen

$pp \to pp\eta'$ und $pn \to pn\eta'$ nach gleichem Muster geschehen

$$\text{CELSIUS: } R(\eta) = \frac{\sigma(pn \to pn\eta)}{\sigma(pp \to pp\eta)} \approx 6.5$$

energie-unabhängig

→ starke Isovektor-Austauschkomponenten

$$\text{COSY: } R(\eta') = \frac{\sigma(pn \to pn\eta')}{\sigma(pp \to pp\eta')} = \frac{?}{\text{gemessen}}$$

## Szenario:

a) {Struktur η'} = {Struktur η} bezogen auf gluonischen Anteil:

→ $R(\eta') = R(\eta)$

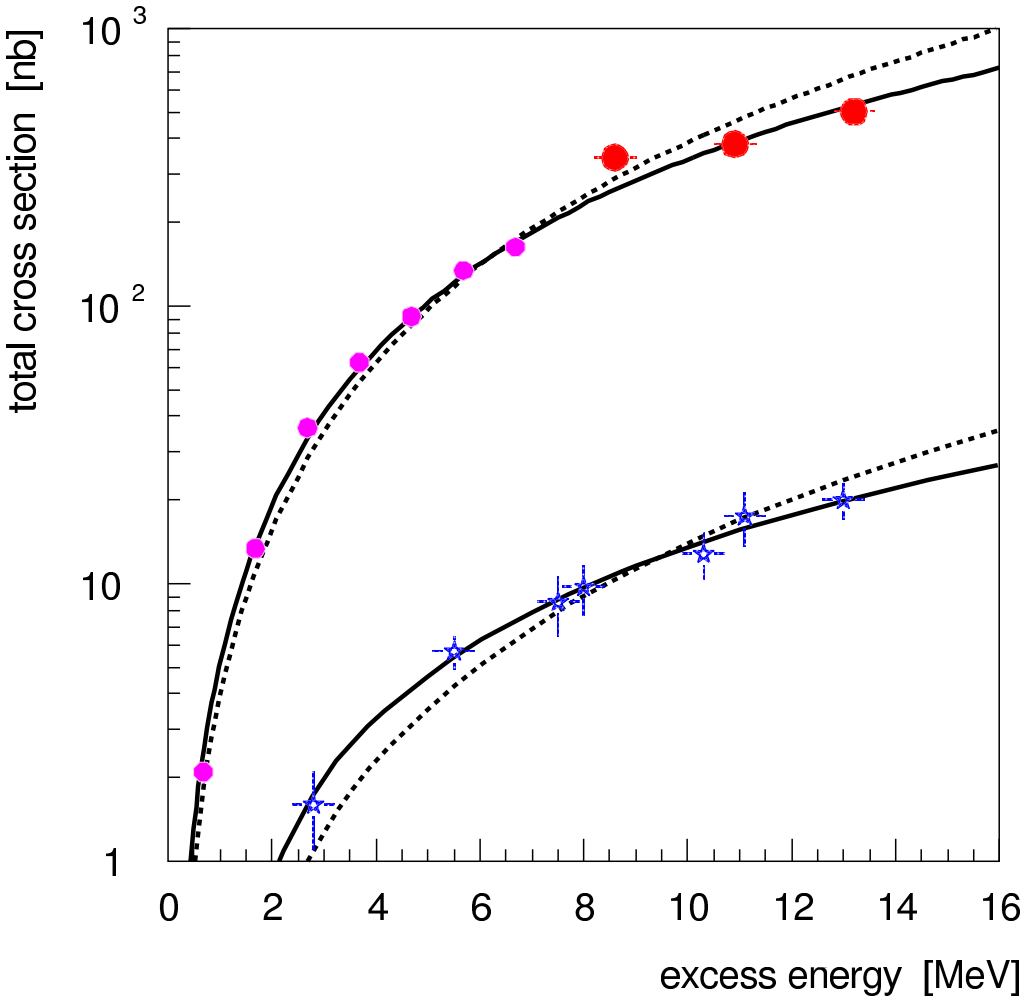
b) η' über gluon-induzierten Prozess erzeugt:

→ $R(\eta') \to$ Eins an der Schwelle

S.D. Bass,
PL B 463 (99) 286, hep-ph/0006348

COSY-11 plant Messungen hierzu

# Hyperon Production close to Threshold at COSY-11




p p → p K⁺Λ

p p → p K⁺Σ⁰

3-body phase space

phase space + (pΛ)-FSI

[G.Fäldt and C.Wilkin Z. Phys. A 357 (1997) 241]

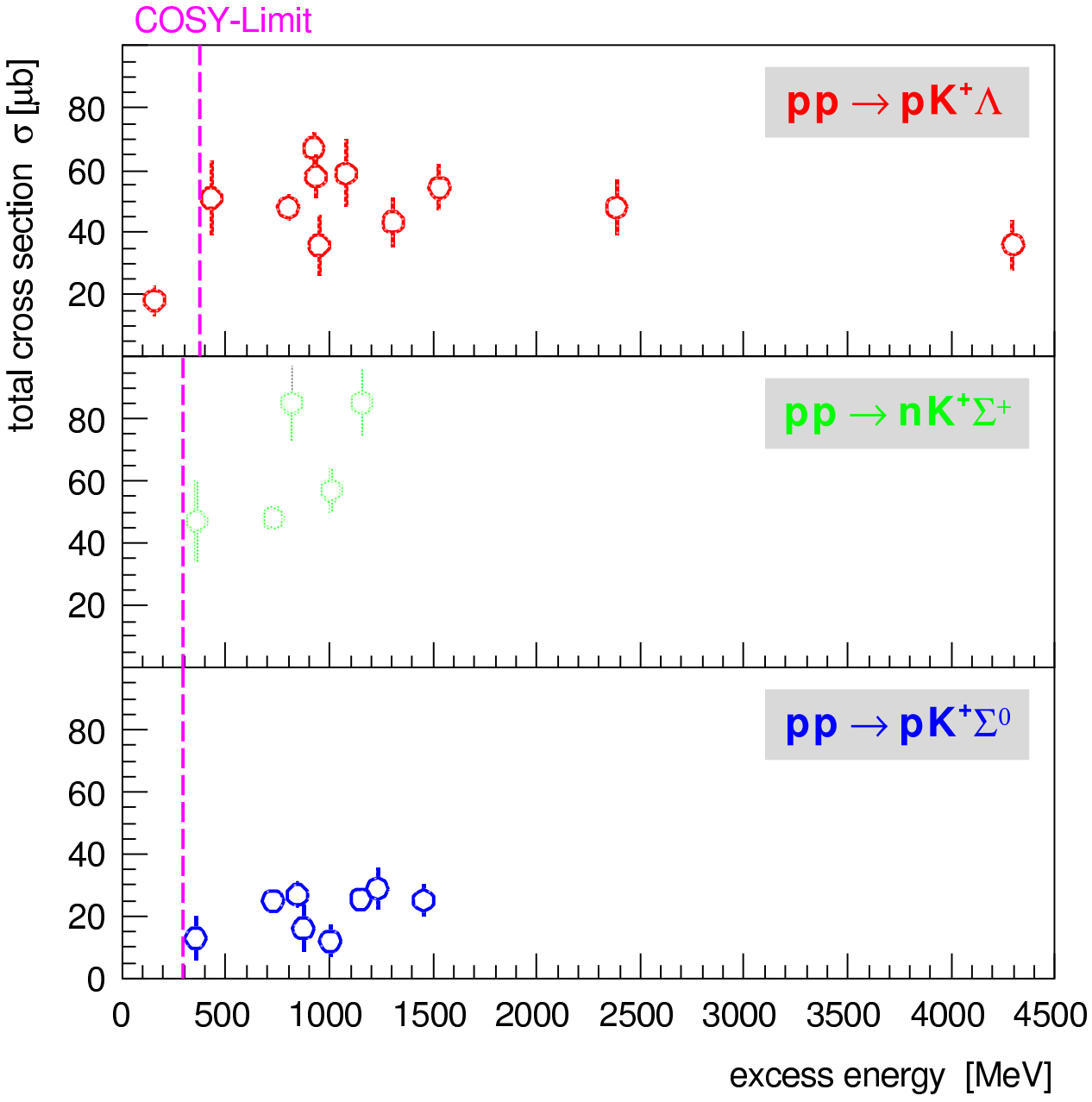
$$\frac{\sigma_T\ (\mathrm{p\,p} \rightarrow \mathrm{p\,K^+\Lambda})}{\sigma_T\ (\mathrm{p\,p} \rightarrow \mathrm{p\,K^+\Sigma^0})} = 28^{+6}_{-9}$$

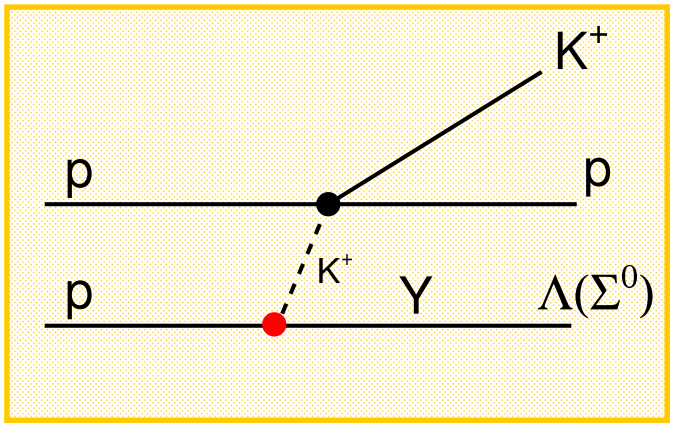
S.Sewerin et al., Phys. Rev. Lett. 83 (1999) 682

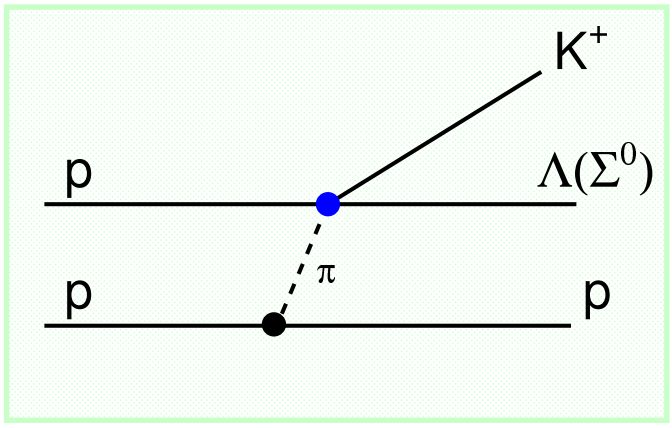
# Hyperon Production in Proton-Proton Scattering

V.Flaminio, W.G.Moorhead,
D.R.O.Morrison, N.Rivoire,
*Compilation of Cross Sections,*
CERN-HERA 84-01 (1984)

**High Energy Data**






SU(6)

$\pi^- p \rightarrow K^0 \Lambda(\Sigma^0)$

**27** $\Longleftarrow$ $\dfrac{pp \rightarrow pK^+\Lambda}{pp \rightarrow pK^+\Sigma^0}$ $\Longrightarrow$ **0.4**

$\dfrac{\Lambda}{\Sigma^0}$ **ratio of production can not be explained by a dominant $\pi^0$-exchange**

- **inclusive $K^+$ data in pp collisions (SPES4)**

**possible explanation: $\Sigma N \rightarrow \Lambda N$ conversion**

**$\Sigma$ yield must be larger than from $K^+$-exchange with SU(6) coupling**

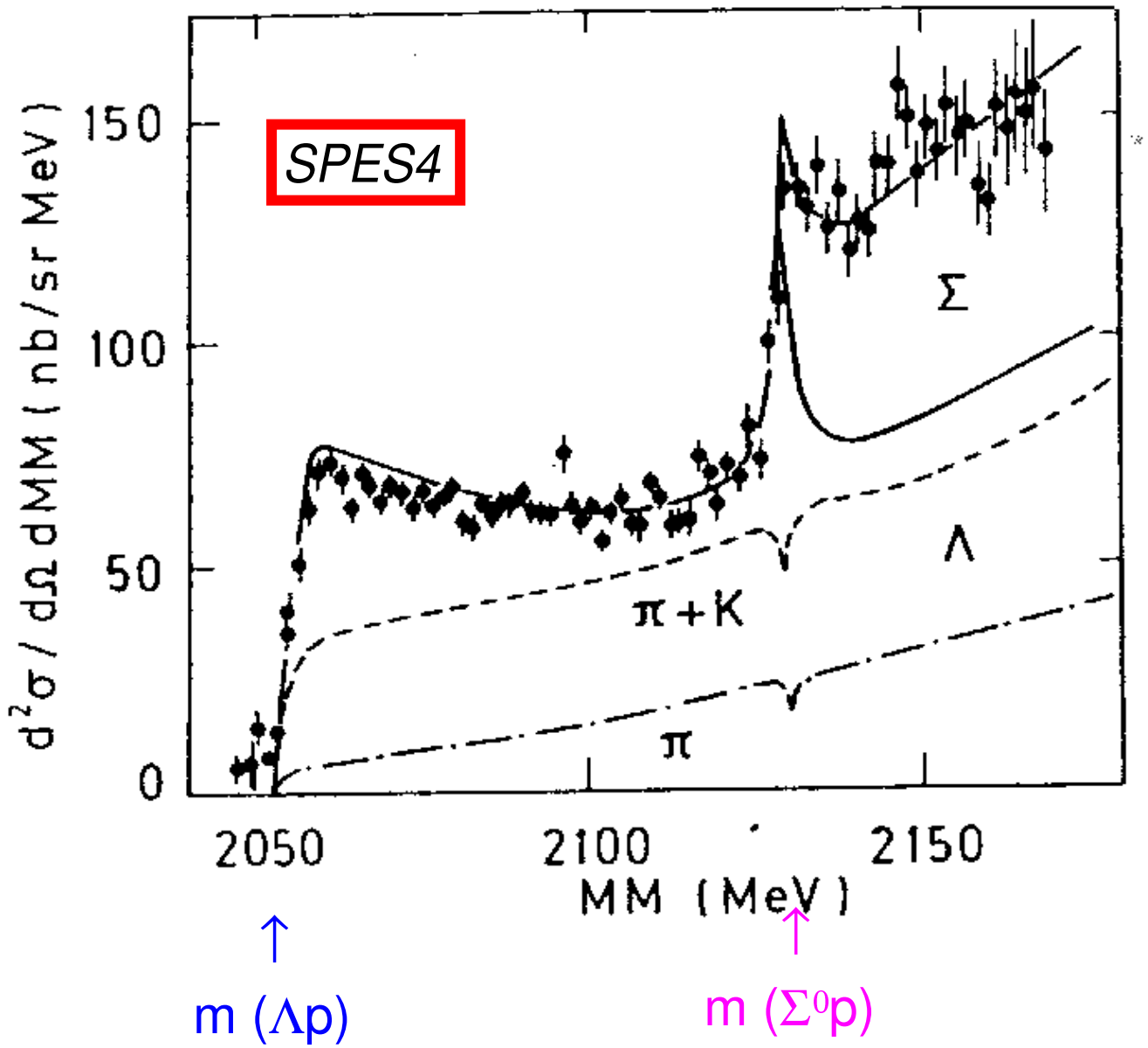
**...in qualitative agreement with**

- **$K^-$absorption on deuterium (BNL 1969)**
- **"cusp"-effect observed at COSY-TOF**

# p p → $K^+$ Y N

inclusive cross sections

R. Siebert et al.,
Nucl. Phys. A567 (1994) 819



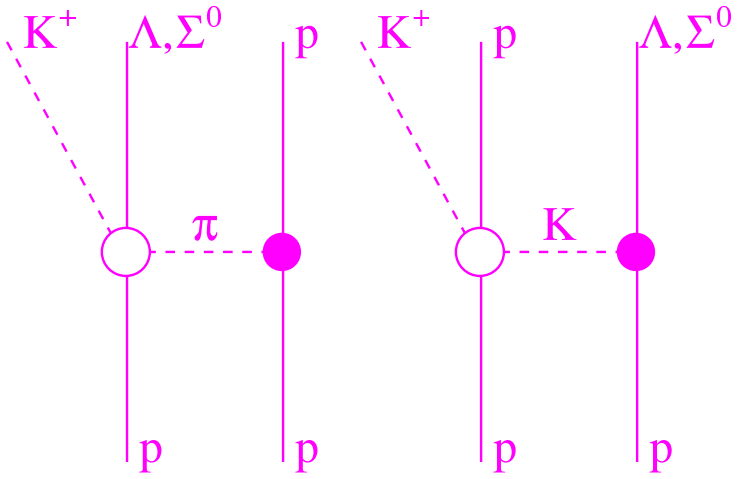

J. M. Laget,
Phys. Lett. B259 (1991) 24

($\pi + K$)-exchange
YN-final state interaction

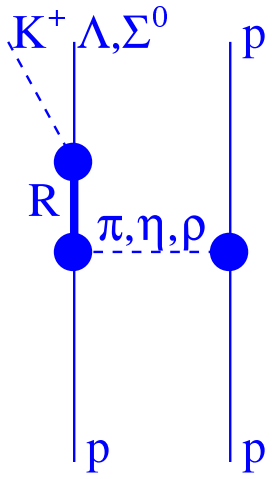
# The $pp \to pK^+\Lambda/\Sigma^0$ Ratio: Energy Dependence

A.Sibirtsev, K.Tsushima, W.Cassing, A.W.Thomas
e-Print Archive nucl-th/0004022

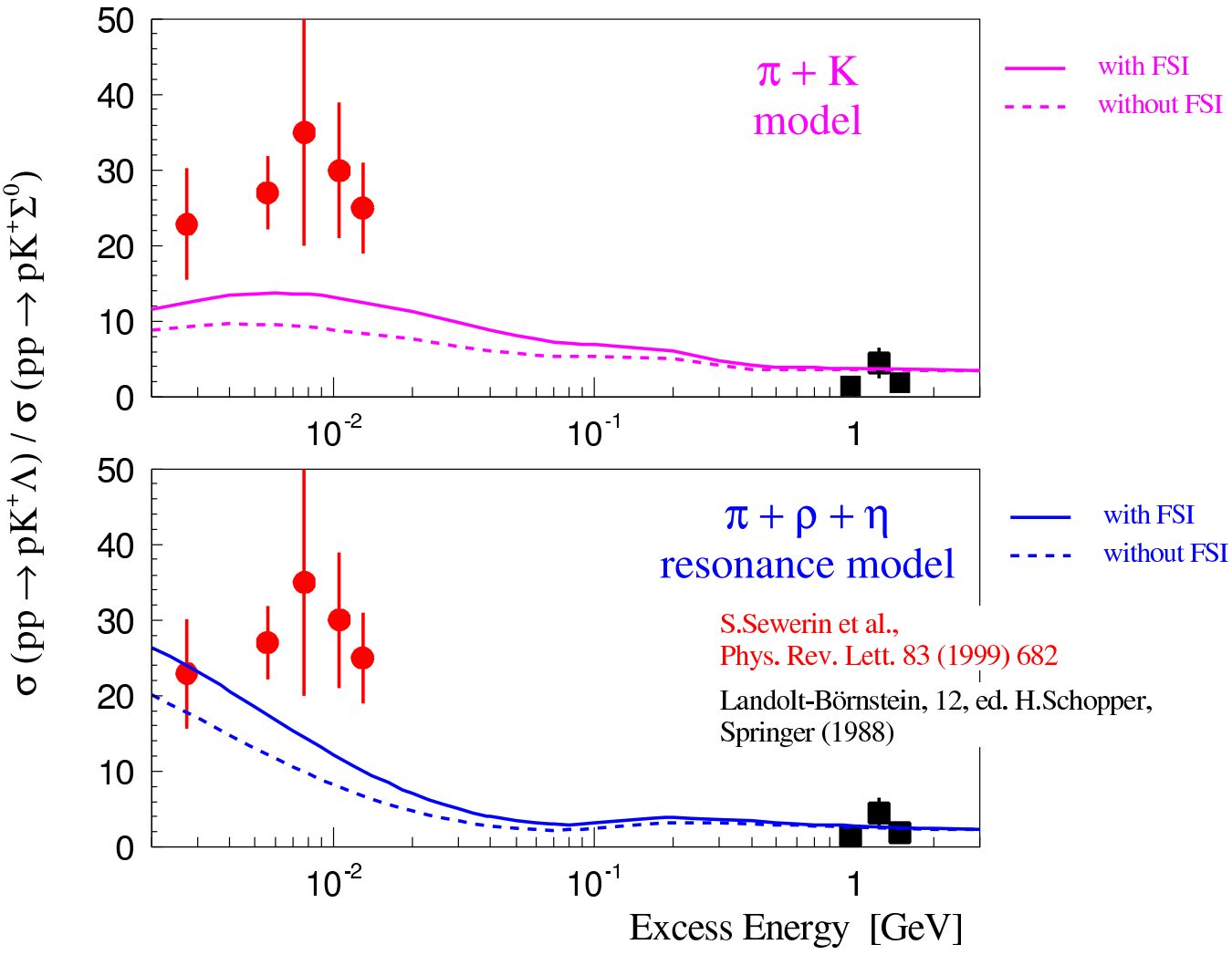
## Boson Exchange Model and Resonance Model Predictions




A.Sibirtsev, W.Cassing,
e-Print Archive nucl-th/9802019




K.Tsushima, A.Sibirtsev, A.W.Thomas, G.Q.Li,
Phys. Rev. C59 (1999) 369

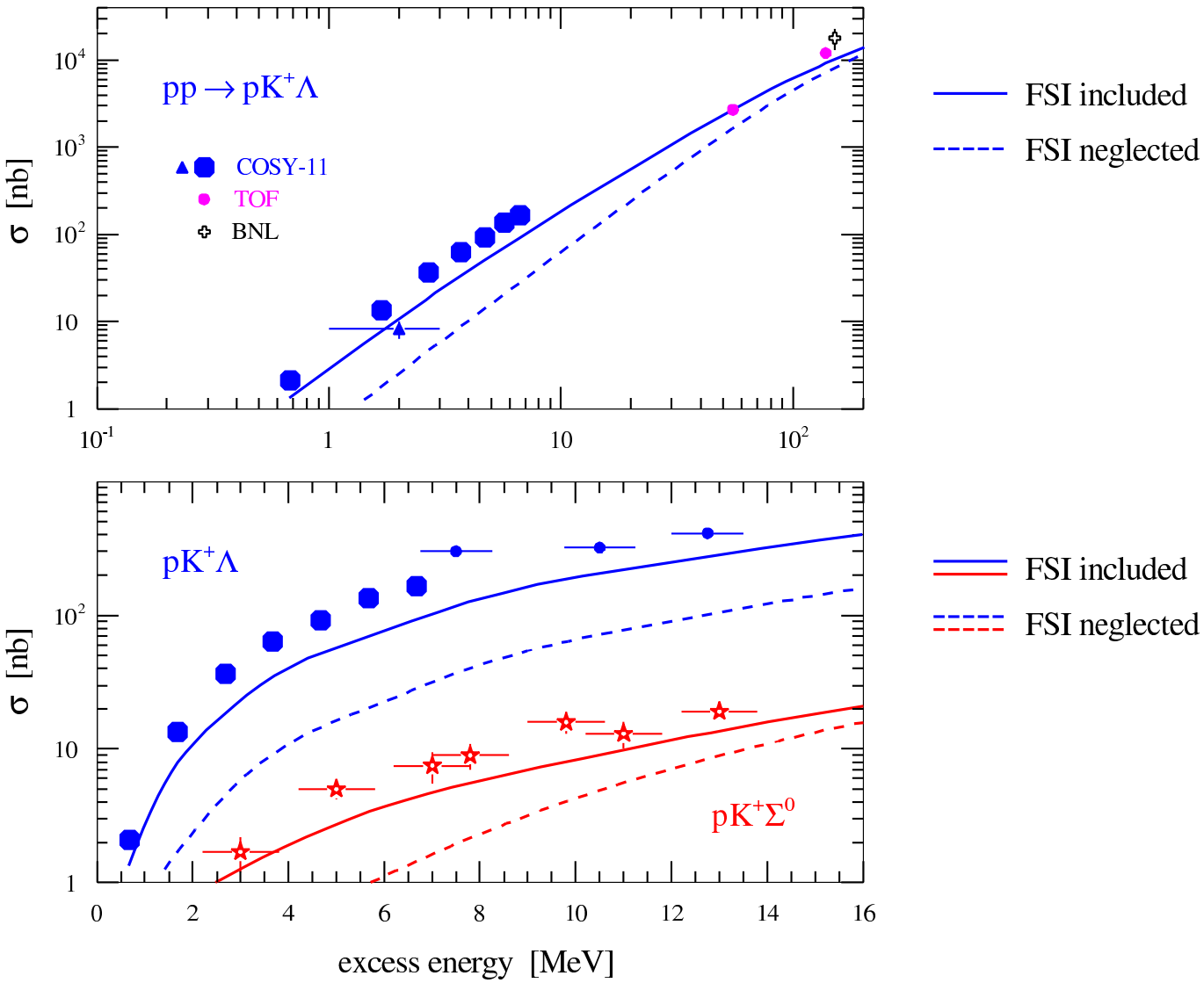


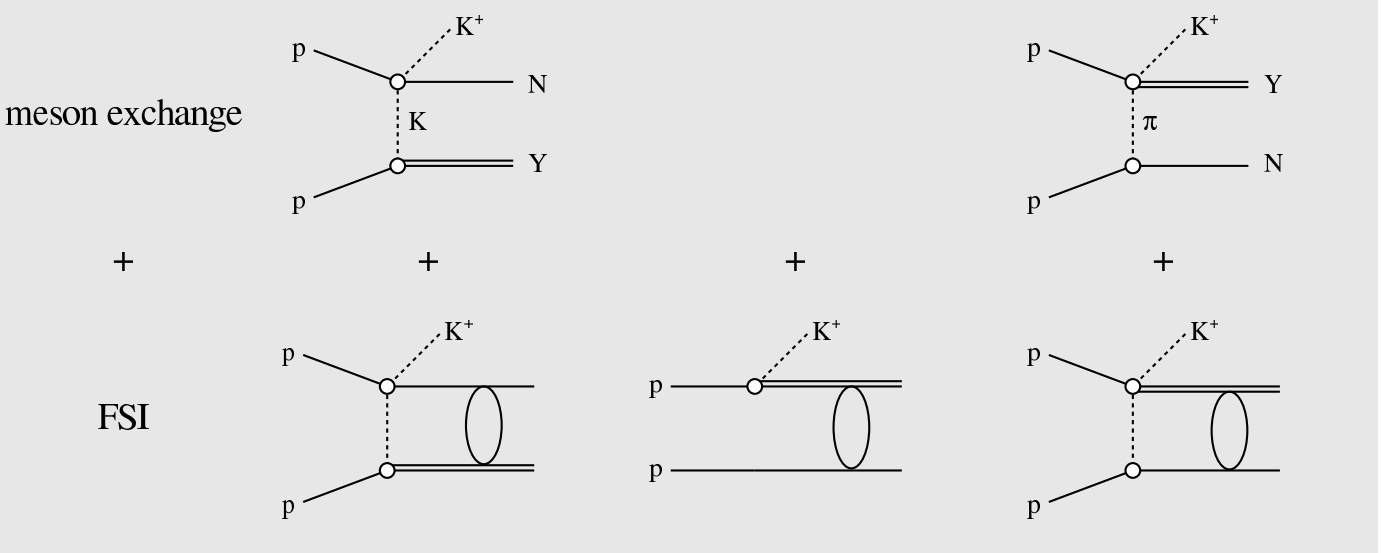

S.Sewerin et al.,
Phys. Rev. Lett. 83 (1999) 682

Landolt-Börnstein, 12, ed. H.Schopper,
Springer (1988)

# Pion and Kaon Exchange Model

J.-M. Laget,
HYP2000,
Torino, 23-27 October, 2000
ArXiv: hep-ph/0101047

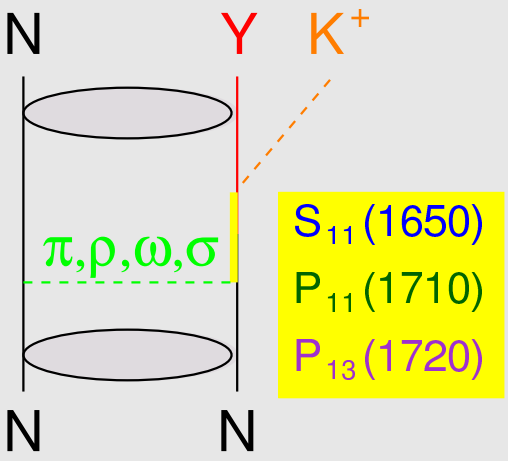


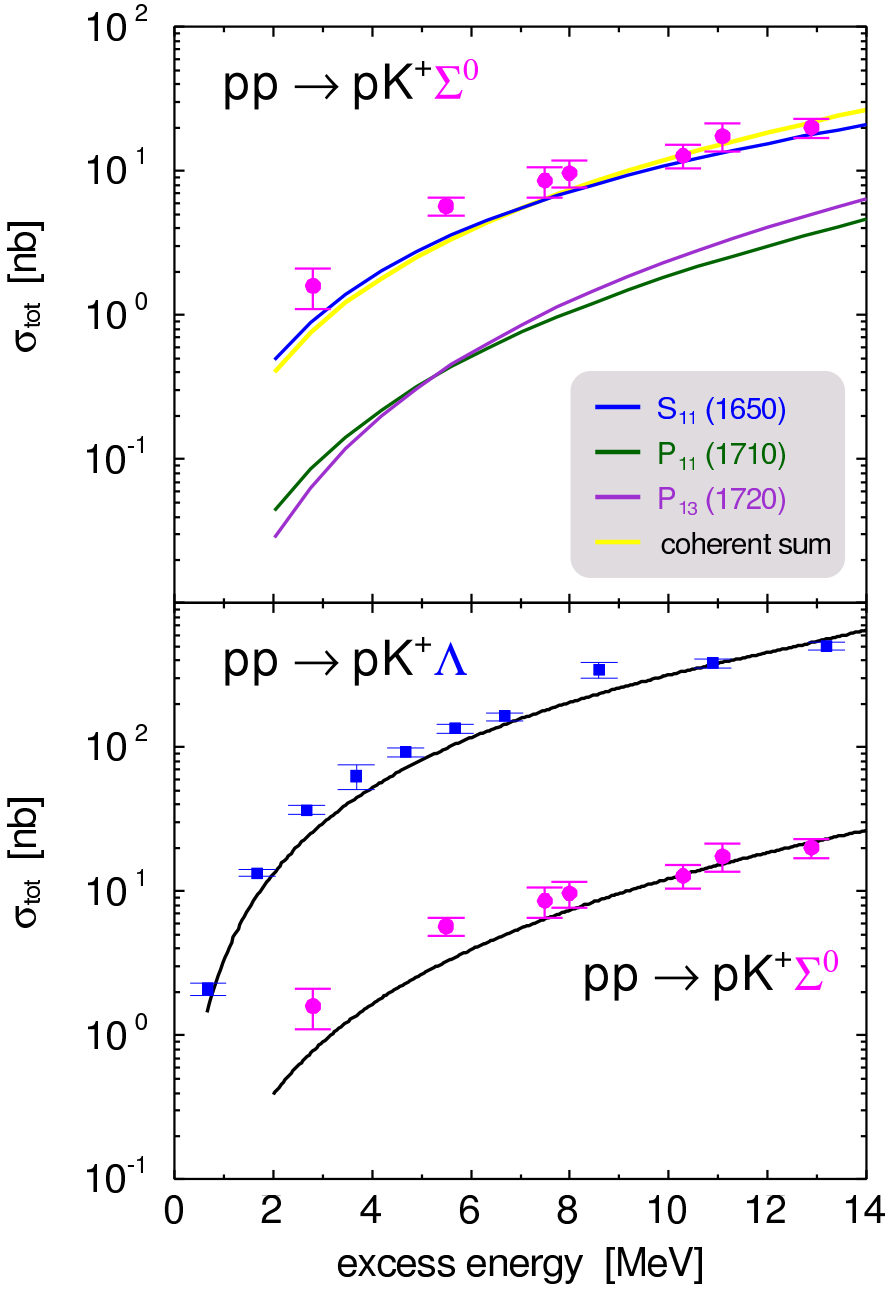



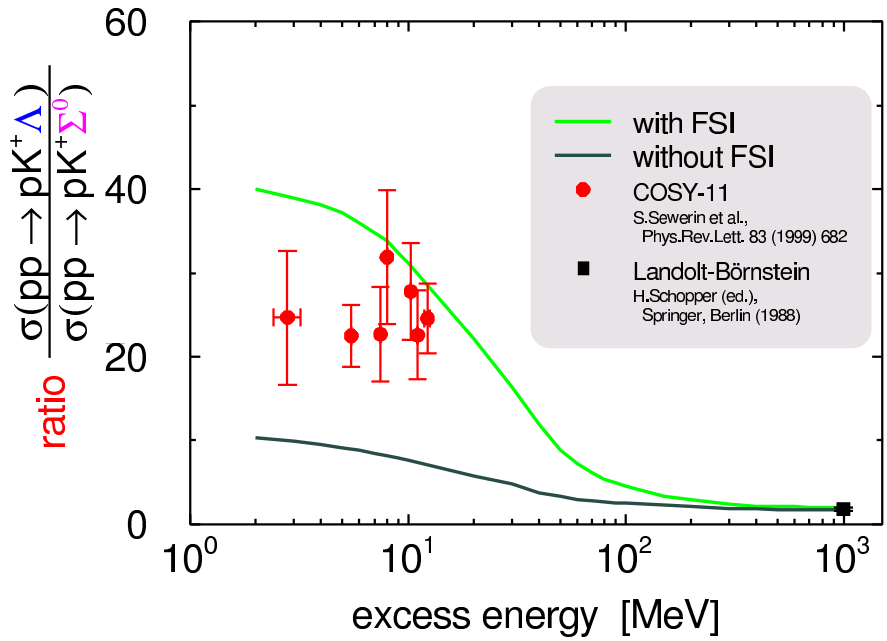
## Effective Lagrangian Approach

R.Shyam, G.Penner, U.Mosel
Phys.Rev. C 63 (2001) 022202

$pp \to pK^+Y$



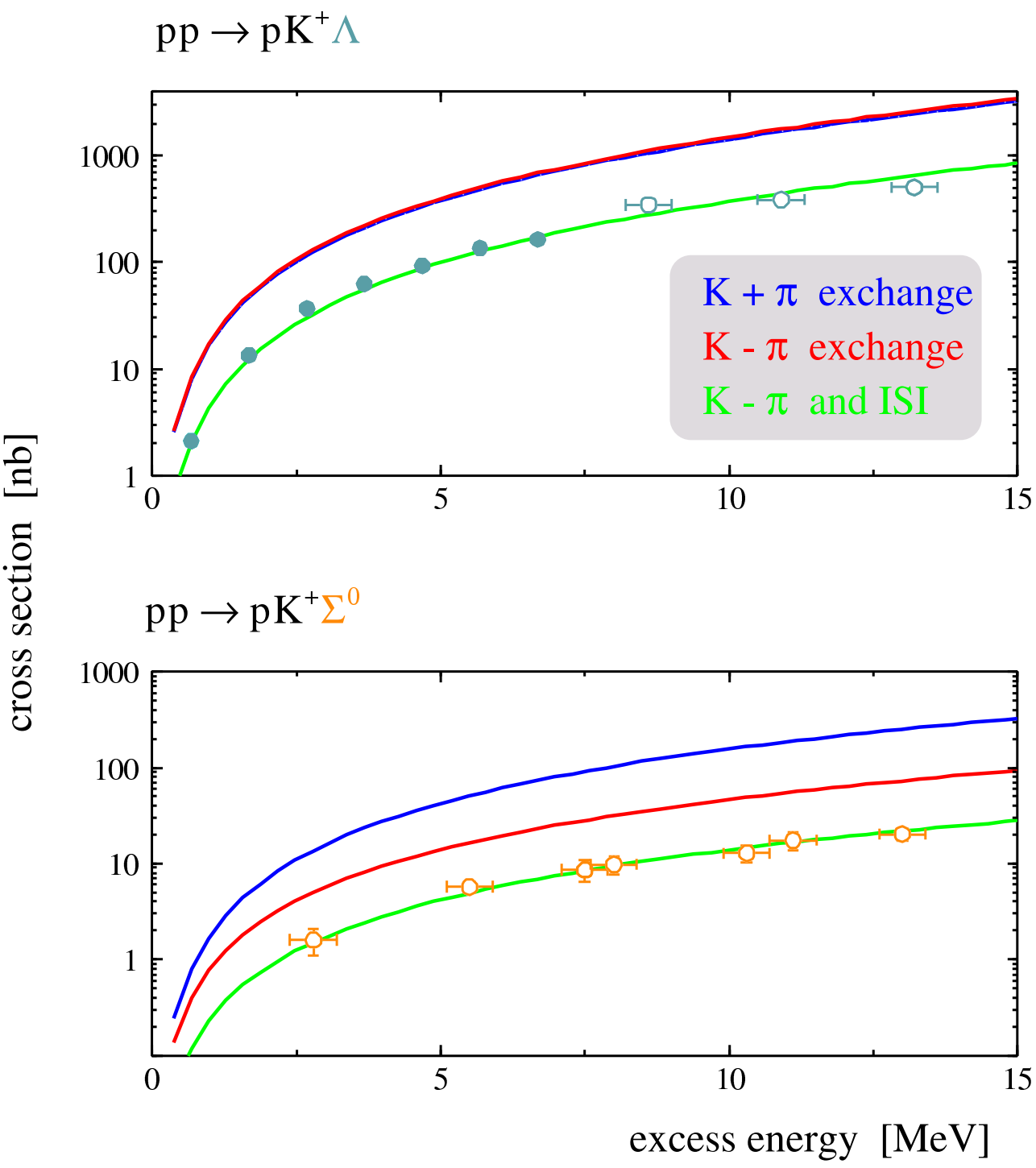



# $pp \to pK^+\Lambda/\Sigma^0$

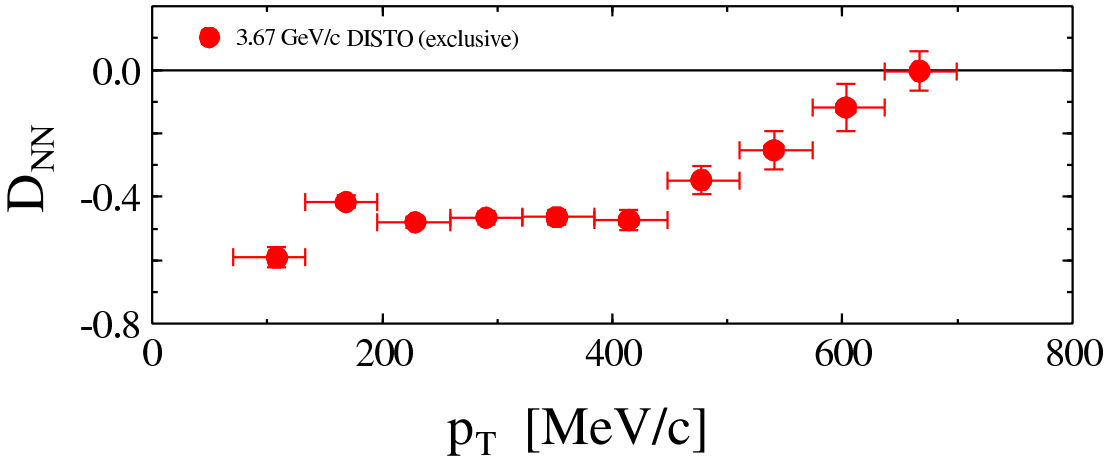
Jülich Meson Exchange Model

A.M.Gasparian, J.Haidenbauer, C.Hanhart, L.Kondratyuk, J.Speth, Phys.Lett.B 480 (2000) 273

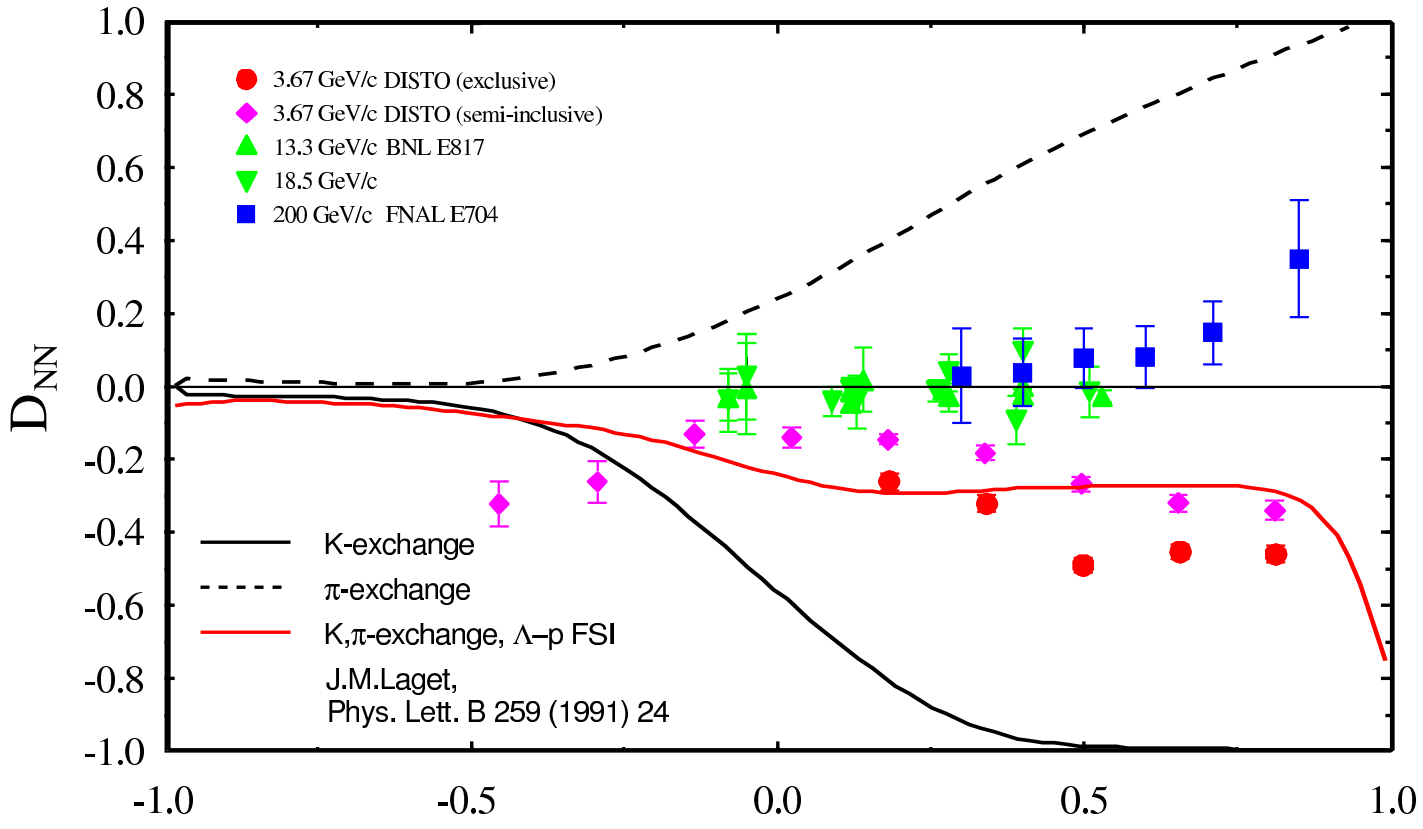


# Spin Transfer $\vec{p}p \rightarrow pK^+\vec{\Lambda}$

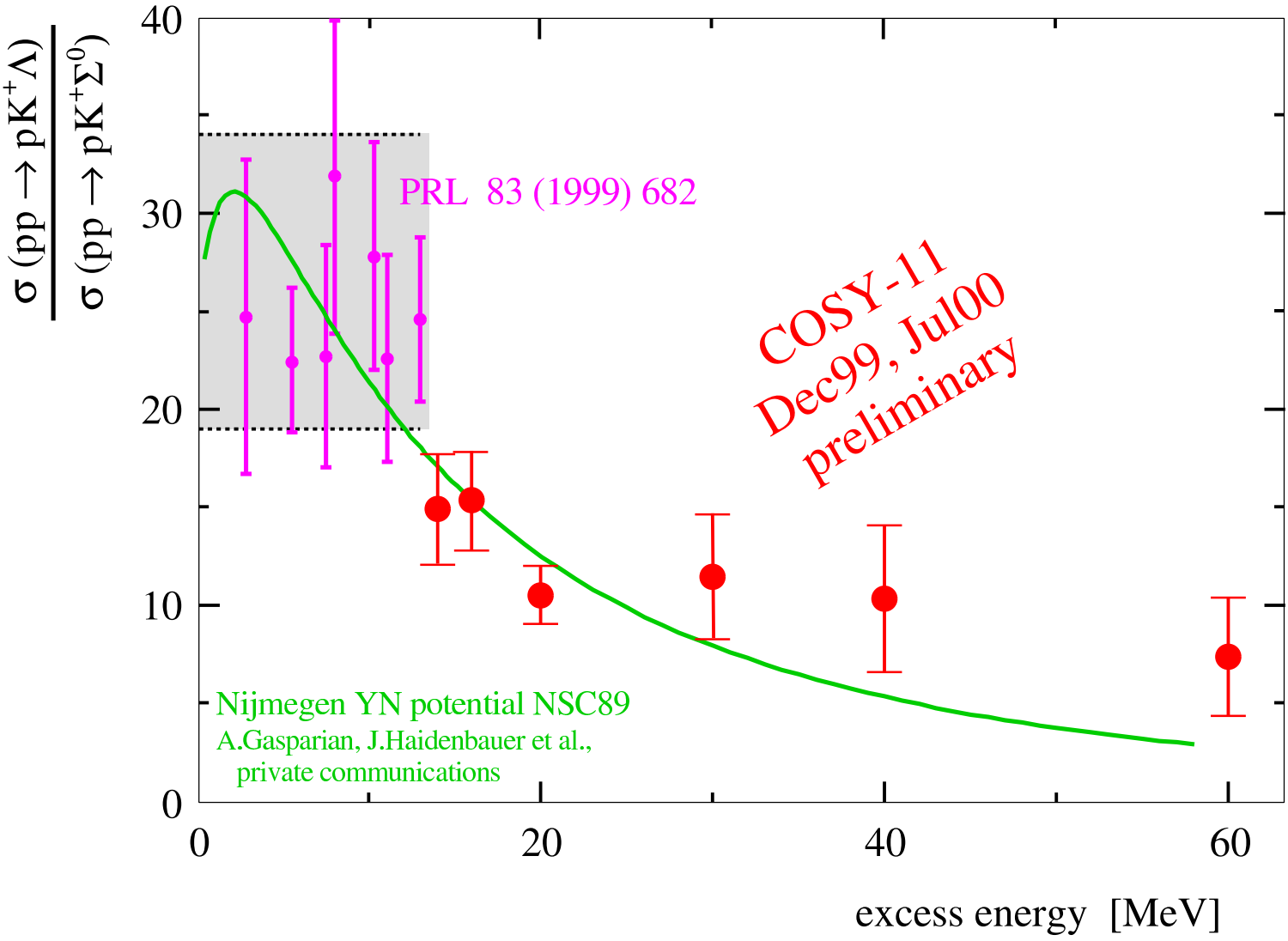
DISTO



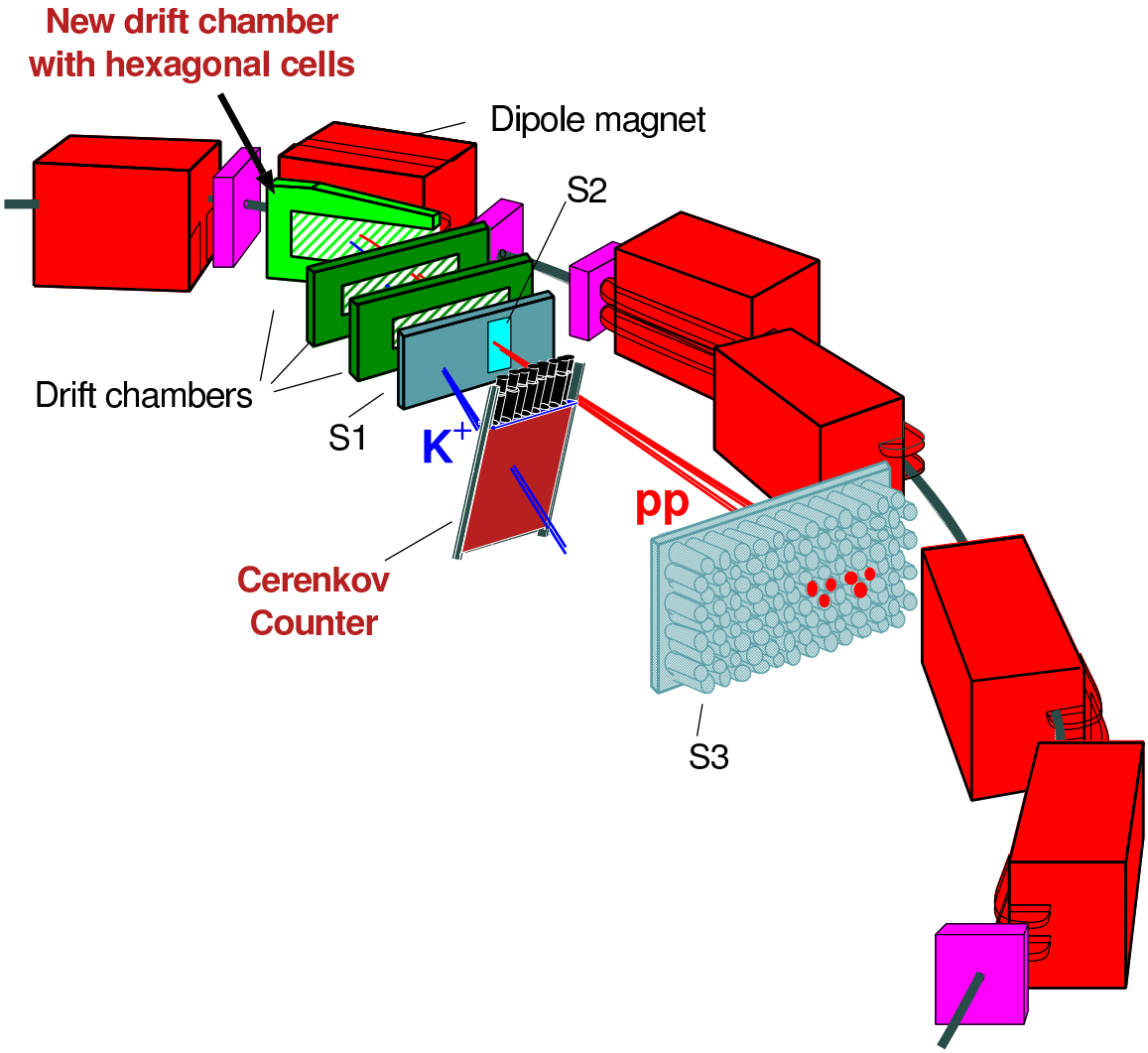

F.Balestra et al.,
Phys. Rev. Lett. 83 (1999) 1534

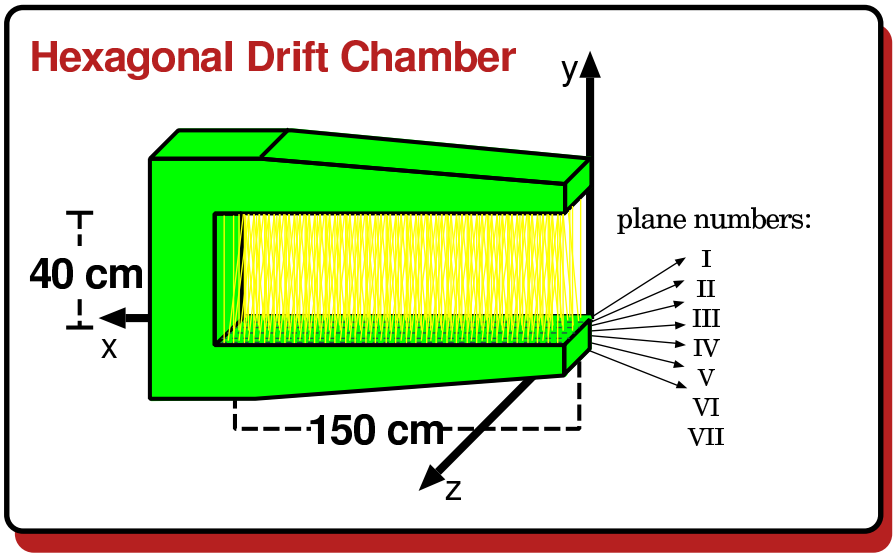


# $\Lambda/\Sigma^0$ Ratio - Energy Dependence



# COSY-11: The Kaon Identification System

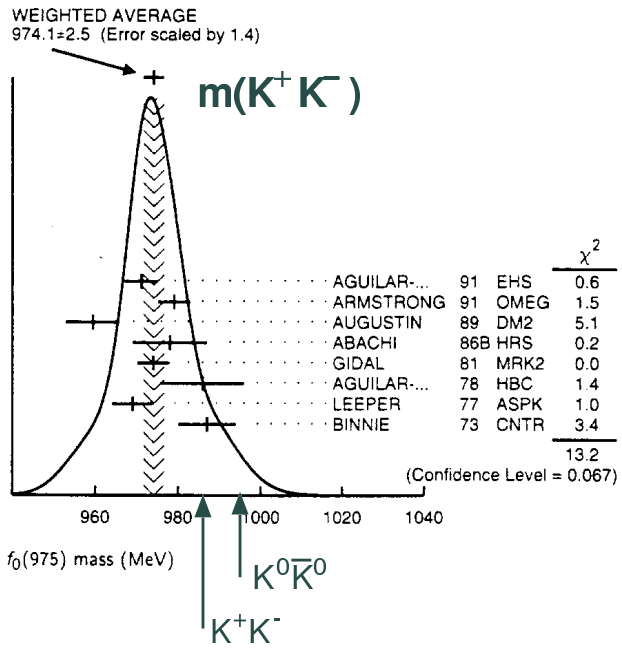


VII.20

Meson Full Listings

$f_0(975)$




## $qq\bar{q}\bar{q}$

R.L.Jaffe

PR D15 (1977) 267

## $q\bar{q}$

D.Morgan, M.R.Pennington

PR D48 (1993) 1185

## $K\bar{K}$-molecule

J.Weinstein, N.Isgur

PR D41 (1990) 2236

D.Lohse, J.W.Durso, K.Holinde and J.Speth

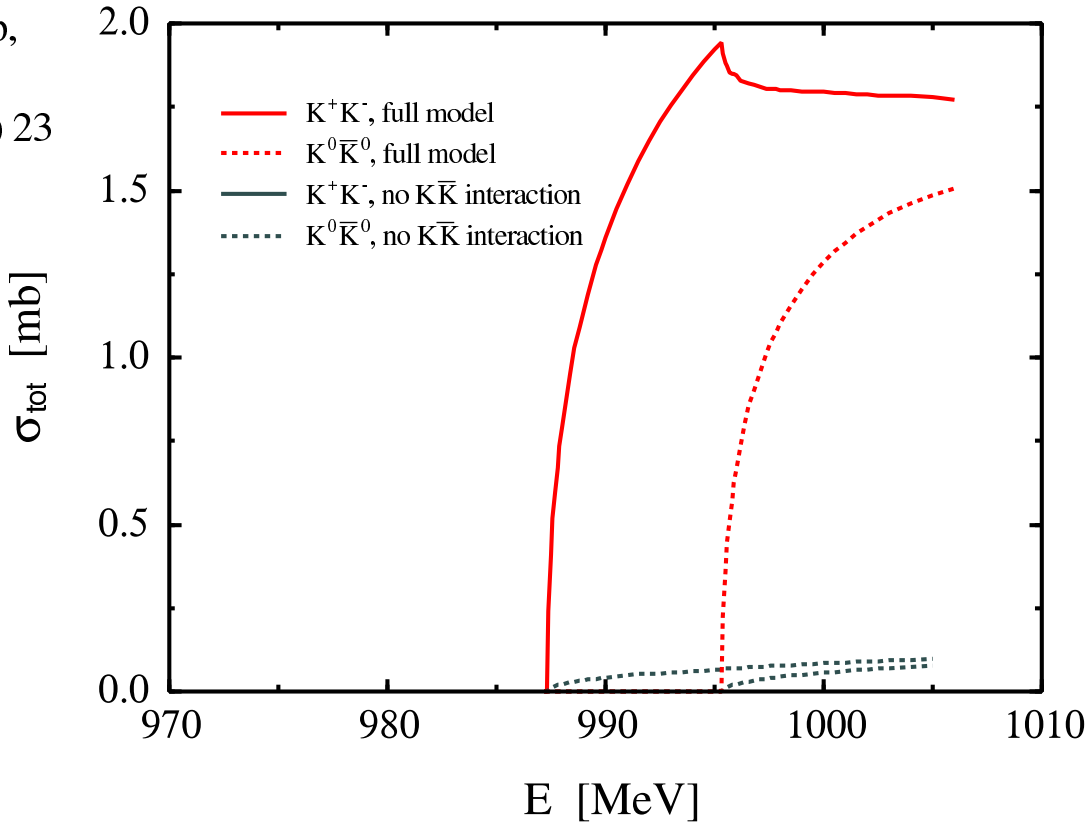
NP A 516 (1990) 513

**Jülich meson exchange model for $\pi\pi$ and $\pi\eta$ scattering**

O.Krehl, R.Rapp, J.Speth

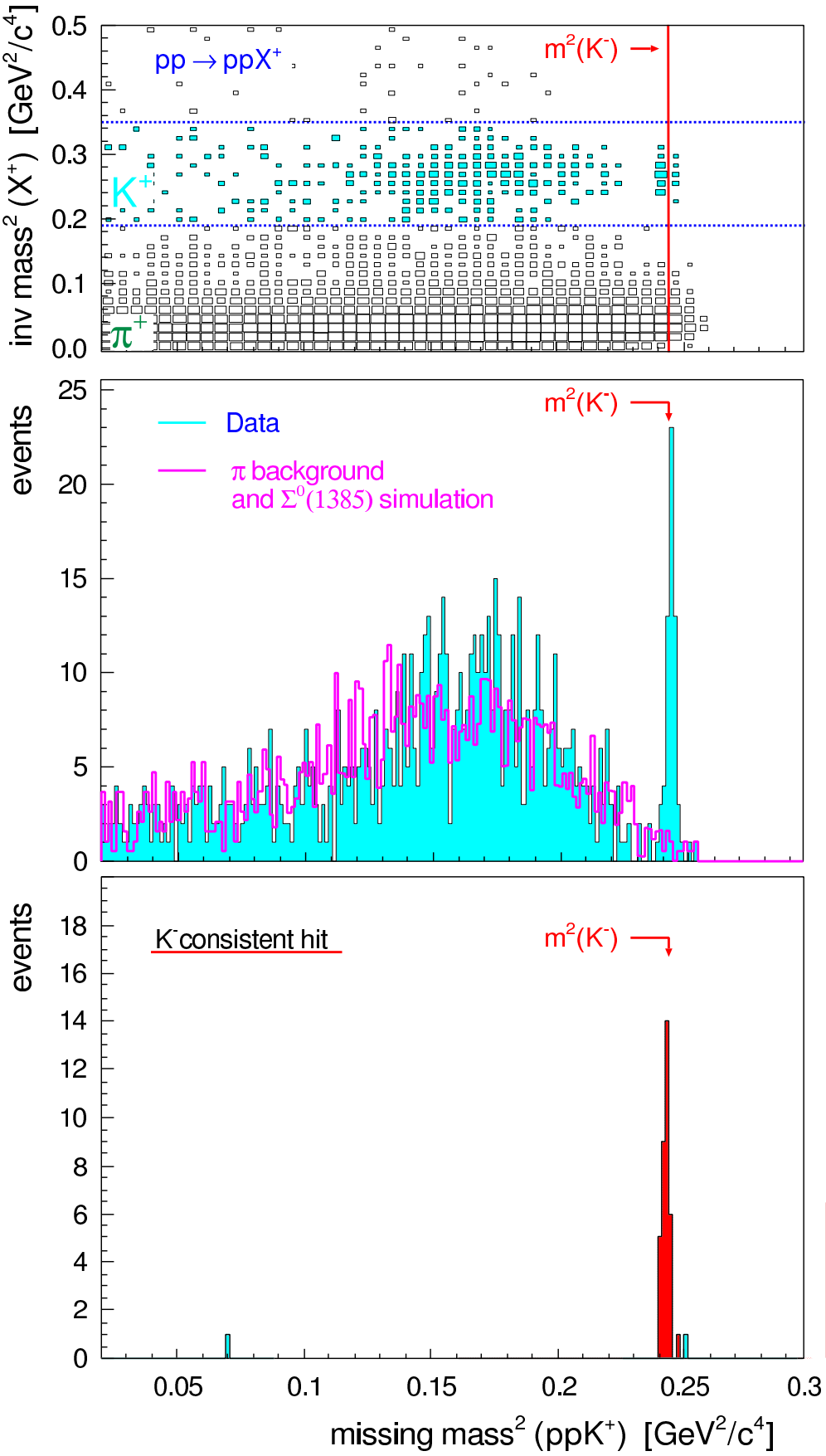
PL B390 (1997) 23

$\pi^+\pi^- \to K\bar{K}$



# $pp \rightarrow ppK^+K^-$

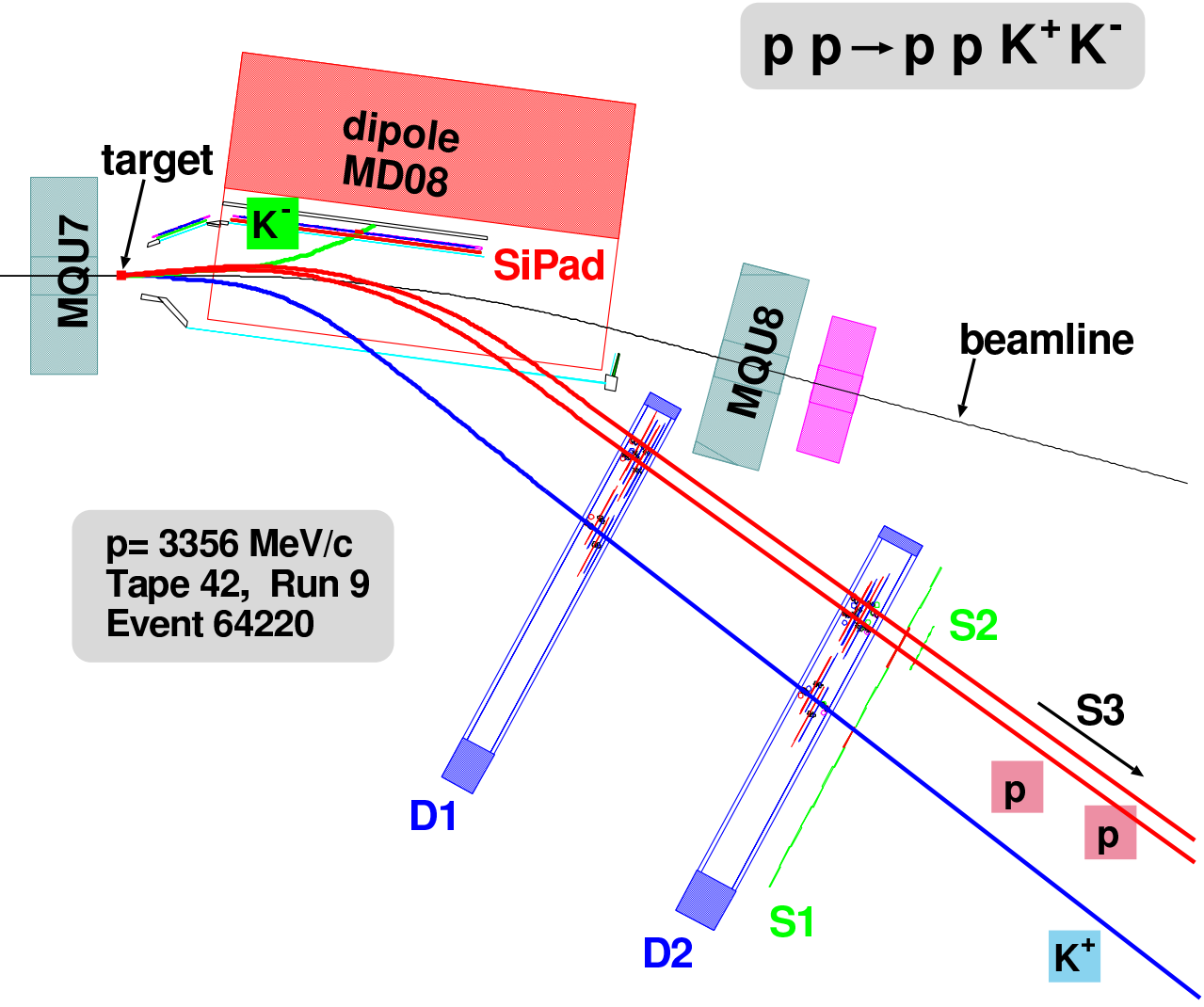
# $Q = 17MeV$



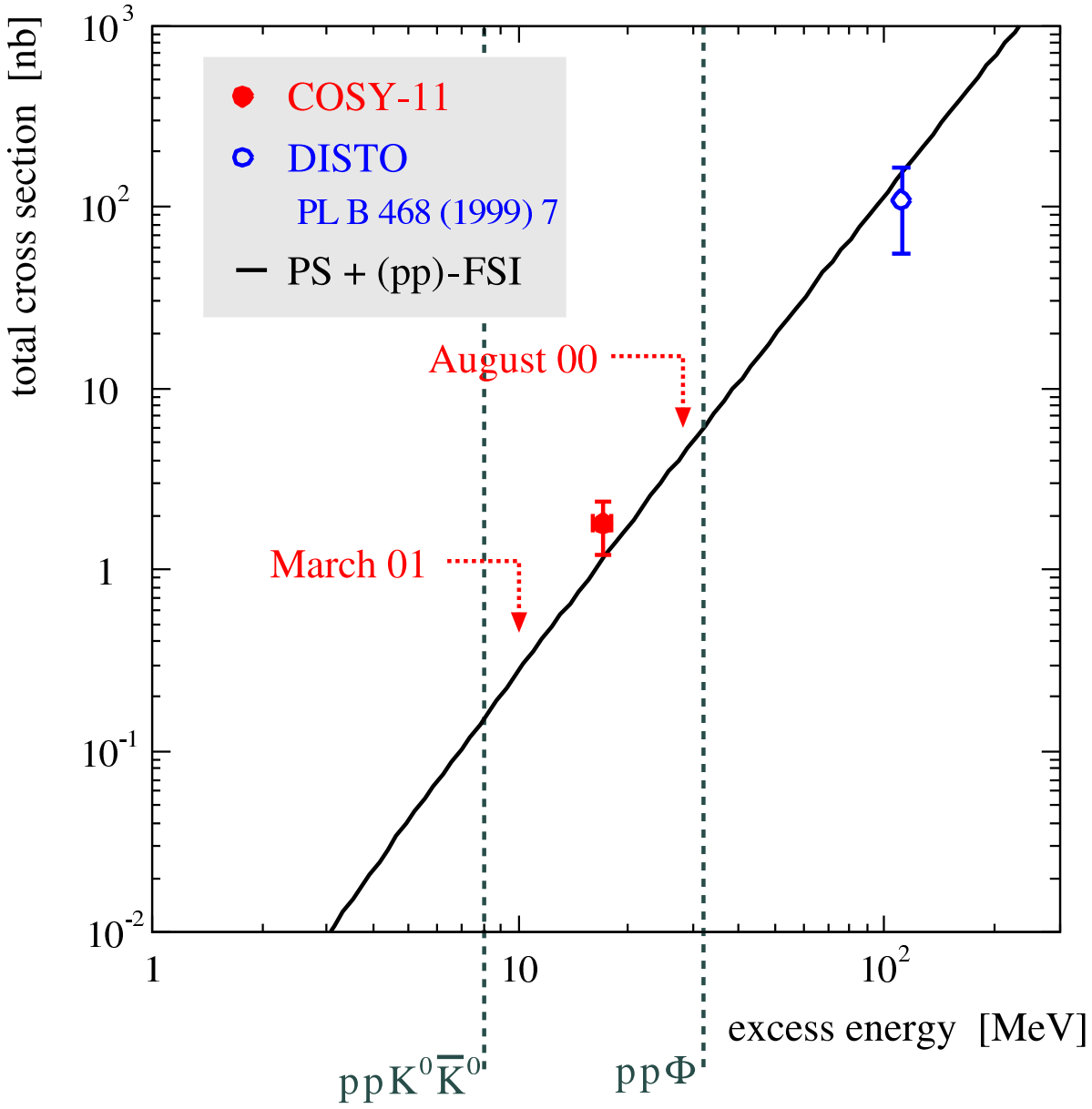

$$\sigma(pp \rightarrow ppK^+K^-) = 1.80 \pm 0.27^{+0.28}_{-0.35}\ nb$$

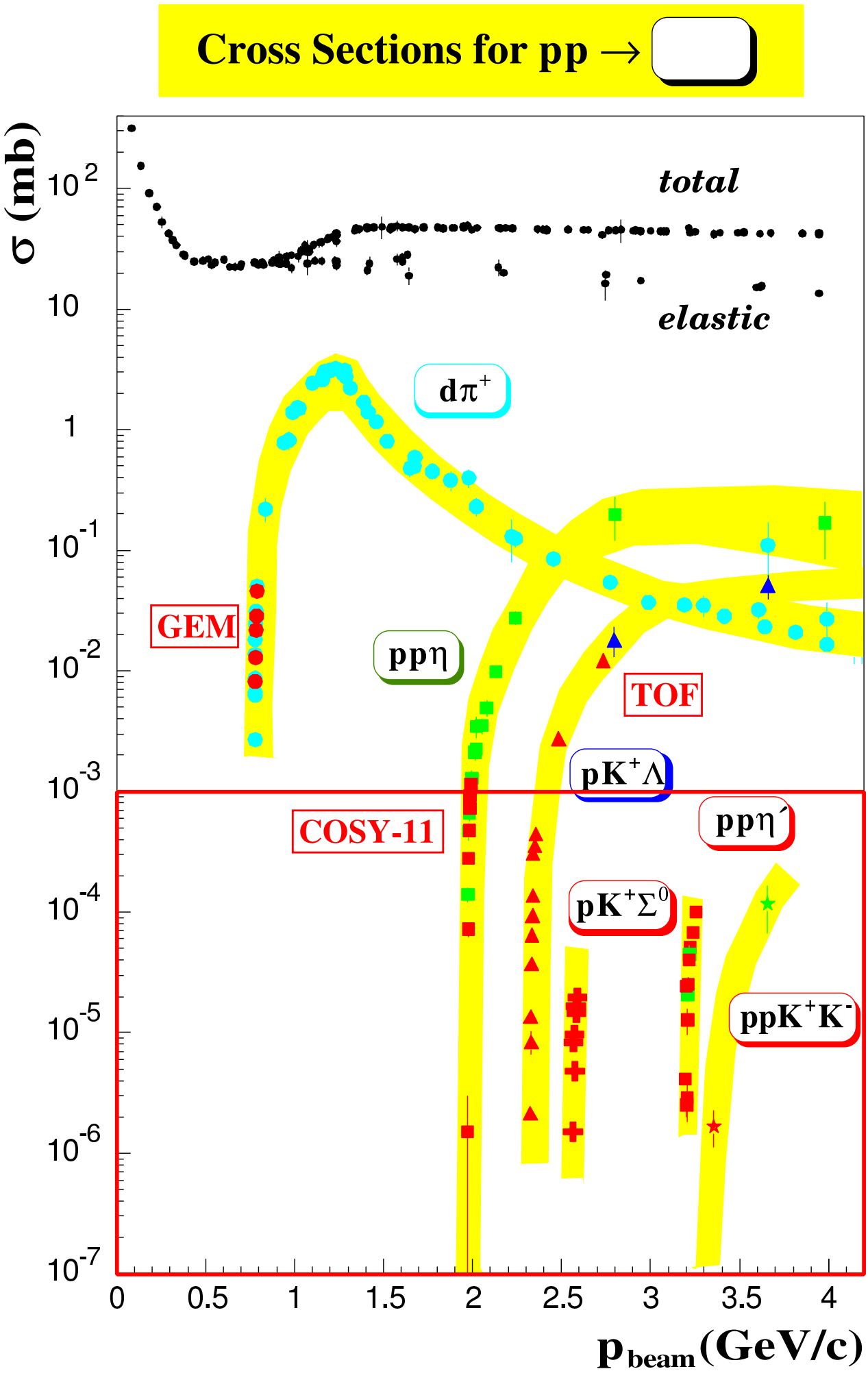
C.Quentmeier,
Westf. Wilhelms-Univ. Münster,
PhD Thesis (2001)
Phys. Lett. B 515 (2001) 276

# COSY-11: Experimental Setup



# $pp \rightarrow ppK^+K^-$ close to threshold




Cross Sections for pp →
σ (mb)
total
elastic
dπ+
GEM
ppη
TOF
pK+Λ
COSY-11
ppη´
pK+Σ0
ppK+K-
10 2
10
1
10-1
10-2
10-3
10-4
10-5
10-6
10-7
0
0.5
1
1.5
2
2.5
3
3.5
4
p beam (GeV/c)

# COSY-11 Collaboration

September 2001


D. Grzonka, K. Kilian, C. Kolf, W. Oelert,
G. Schepers, T. Sefzick, P. Winter, M. Wolke

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P. Wüstner

ZEL, Forschungszentrum Jülich, Germany

R. Czyzykiewicz, M. Janusz, L. Jarczyk,
P. Moskal, J. Smyrski, A. Strzalkowski

IP, Jagellonian University Cracow, Poland

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INP, Cracow, Poland

H.-H. Adam, I. Geck, A. Khoukaz, N. Lang,
T. Lister, C. Quentmeier, R. Santo, S. Steltenkamp

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P. Kowina, M. Siemaszko, W. Zipper

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