

SFB-TR 16

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JUSTUS-LIEBIG-
UNIVERSITÄT
GIESSEN



Photoproduction of neutral Mesons at ELSA

Hartmut Schmieden

Physikalisches Institut der Universität Bonn

Crystal Barrel - TAPS Collaboration

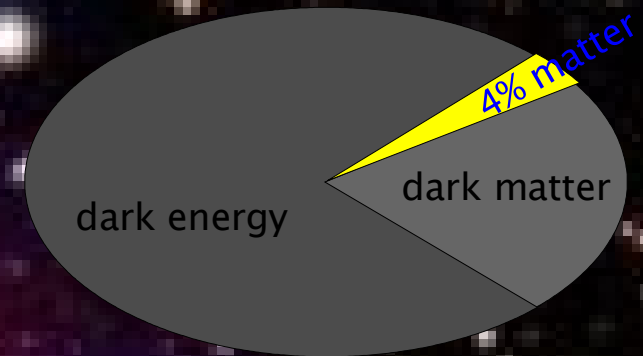
GWU/CNS seminar - March 4, 2008



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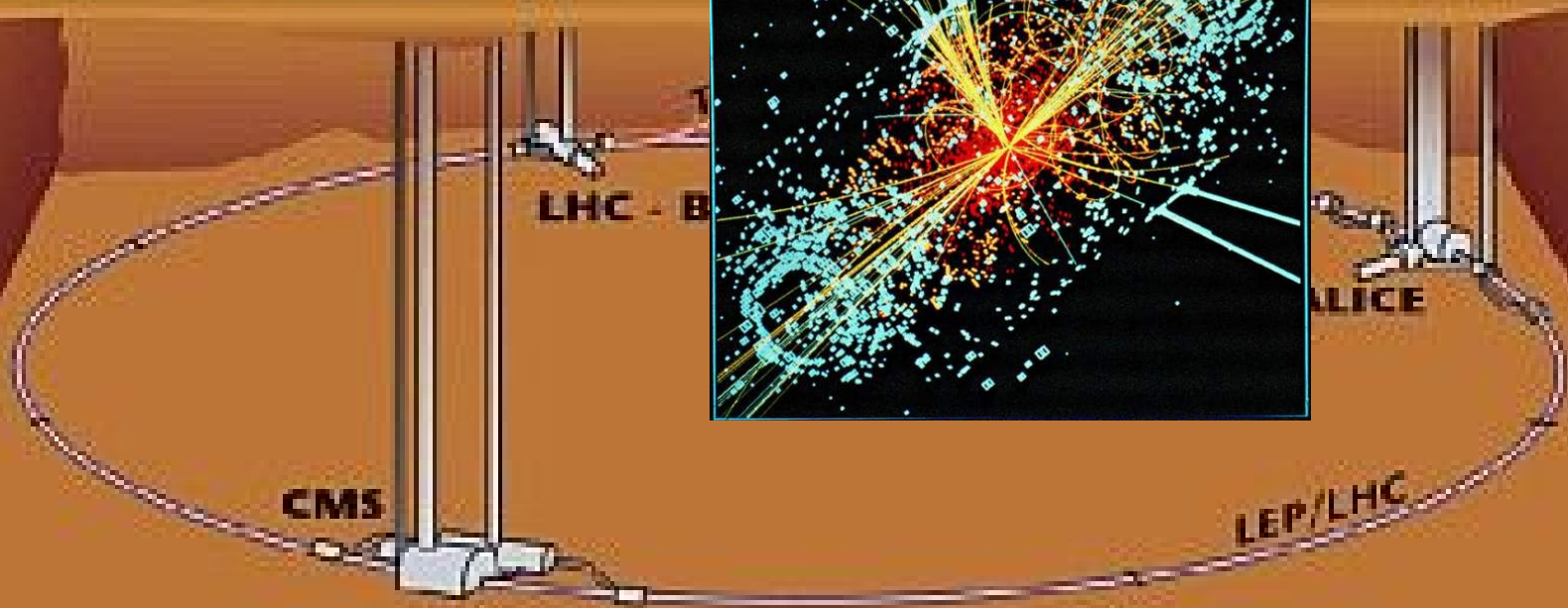
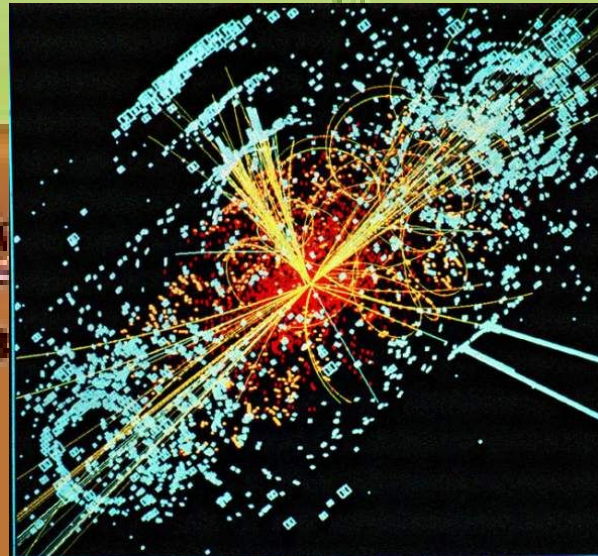
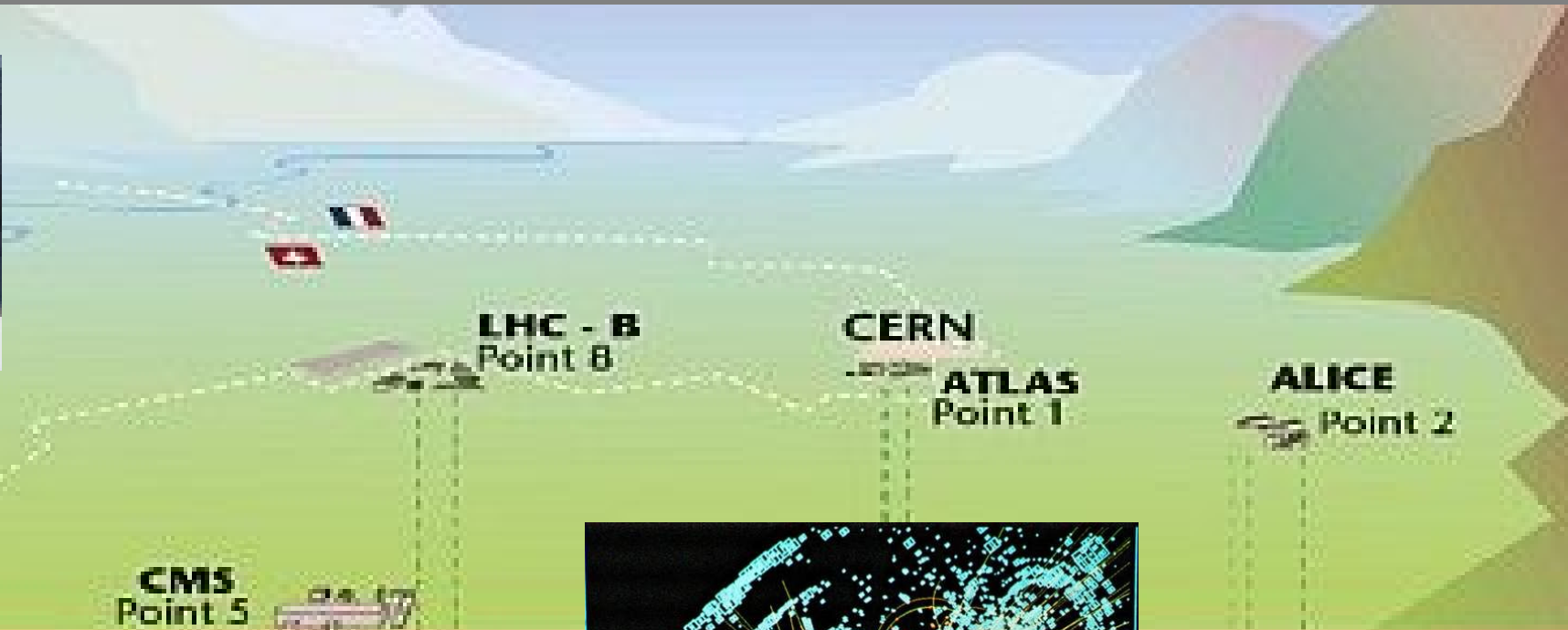
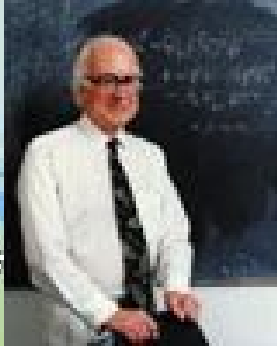
Outline

- ◆ Motivation
- ◆ ELSA accelerator
- ◆ Experimental setup
 - polarised photon beams
 - CB-TAPS detector
- ◆ selected recent results
 - $\eta p/n$ photoproduction
 - $K_s^0 \Sigma^+$ photoproduction
 - ω photoproduction
- ◆ Summary & Outlook
 - double polarisation
 - $\Phi p/n$ & $\Lambda(1405)$



D. Clowe et al., APJ 648 (2006) L109
“A direct empirical proof of the existence of dark matter“

Bullet Cluster
(Chandra X-ray telescope)
red: ordinary matter
blue: “dark“ matter



$$G_{\mu\nu}^a G_a^{\mu\nu} \neq 0$$

trace anomaly

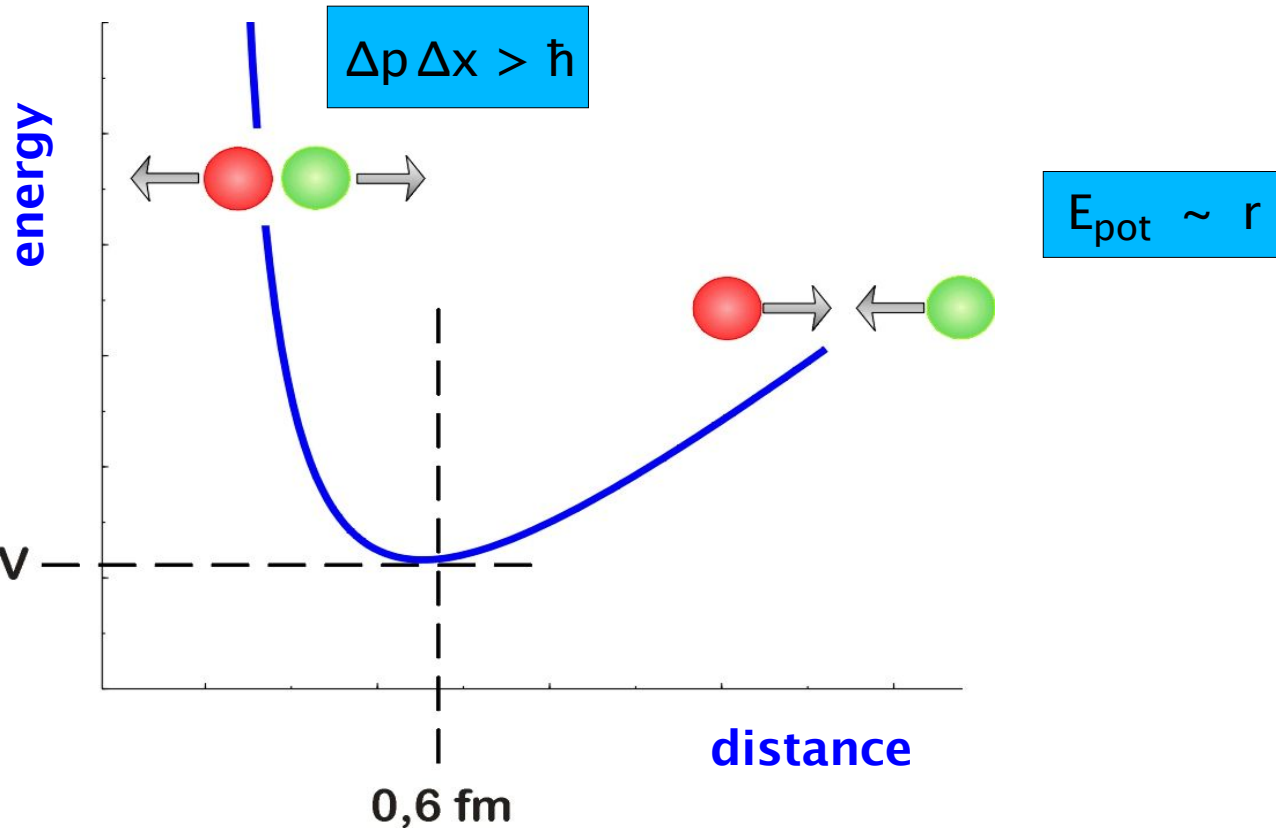


$$m = E/c^2$$

300 MeV

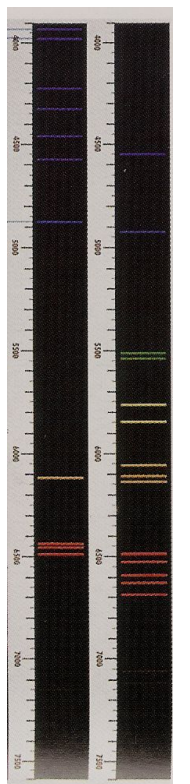
“mass without mass“

J. Wheeler
F. Wilczek



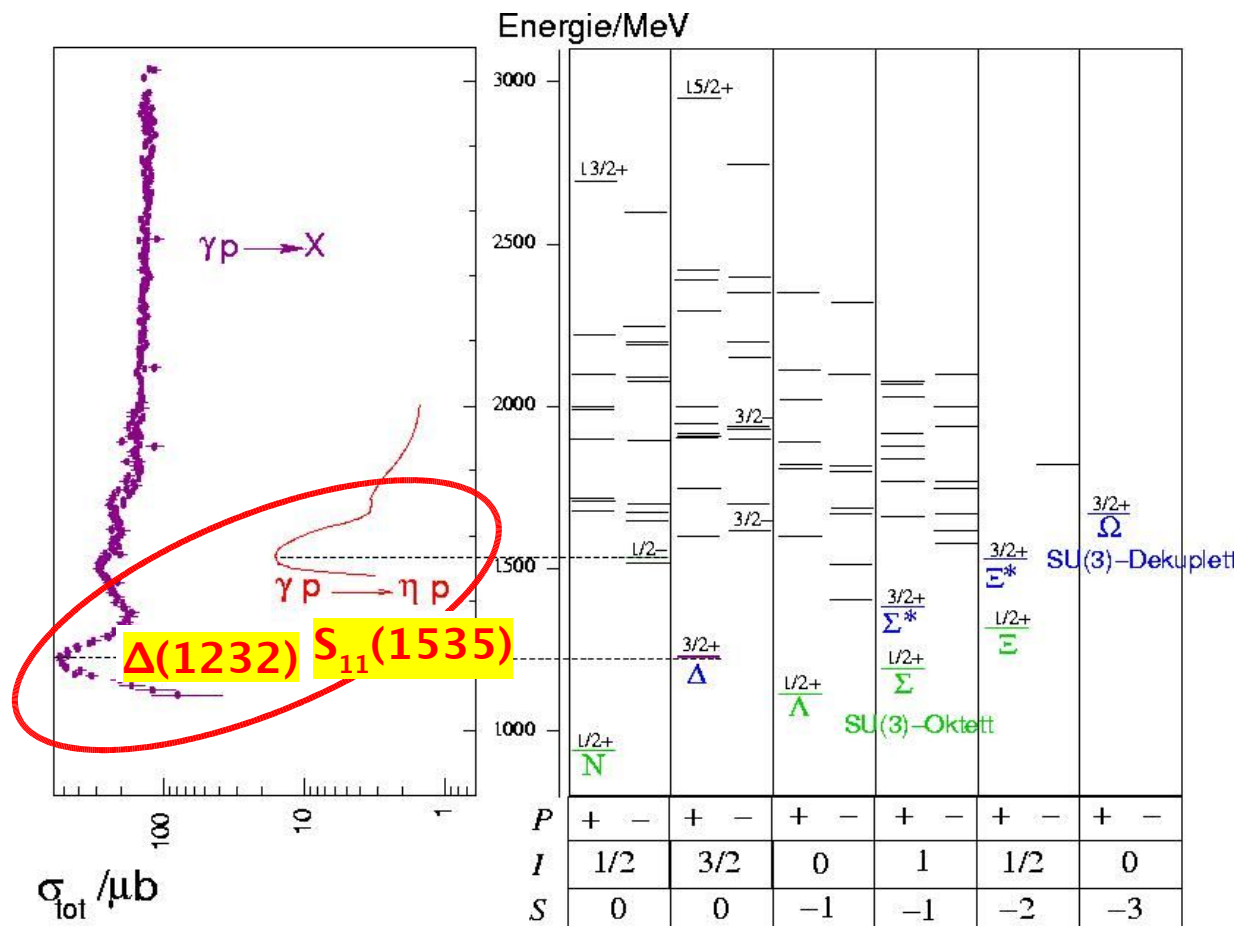
size ↔ excitation spectrum

Ericson & Hufner
NP B57 ('73) 604



Ba Ca

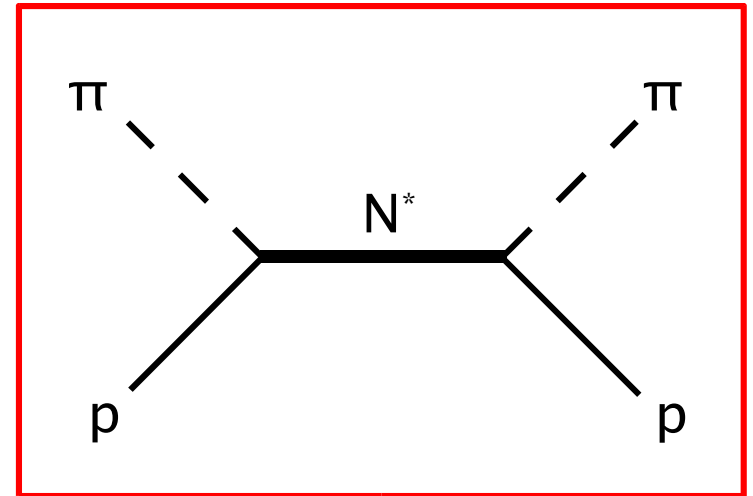
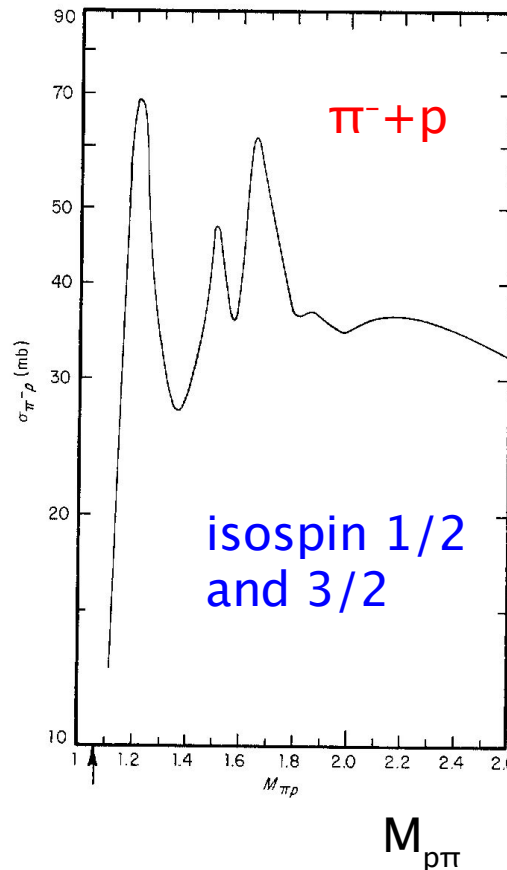
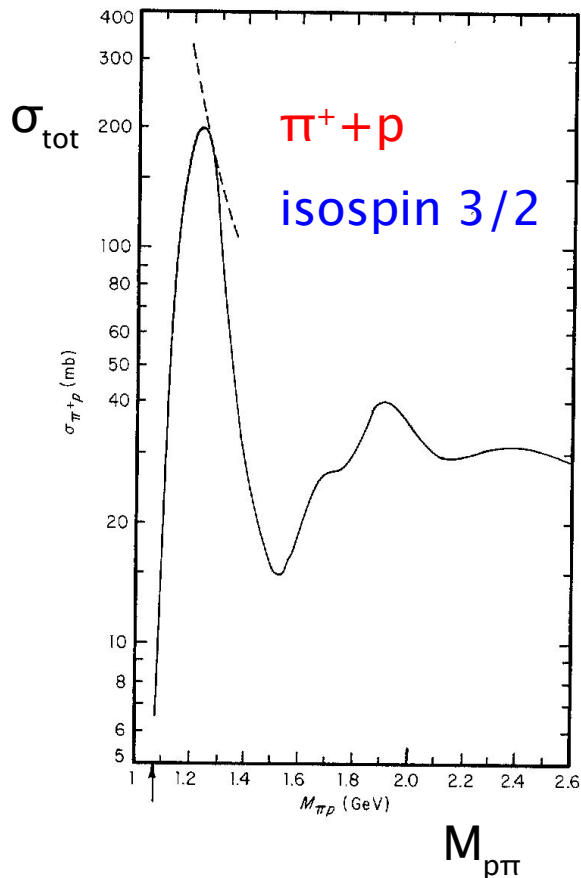
atom



nucleon

Flavour

1952 Long & Nagle (Chicago Cyclotron)
 π^+/π^-+p ($E_{\pi}^{\text{kin}} \sim 180 \text{ MeV}$)



decay angular distribution

$$N^* \rightarrow p \pi$$

spin 3/2



$$P_{33}(1232)$$

isospin 3/2

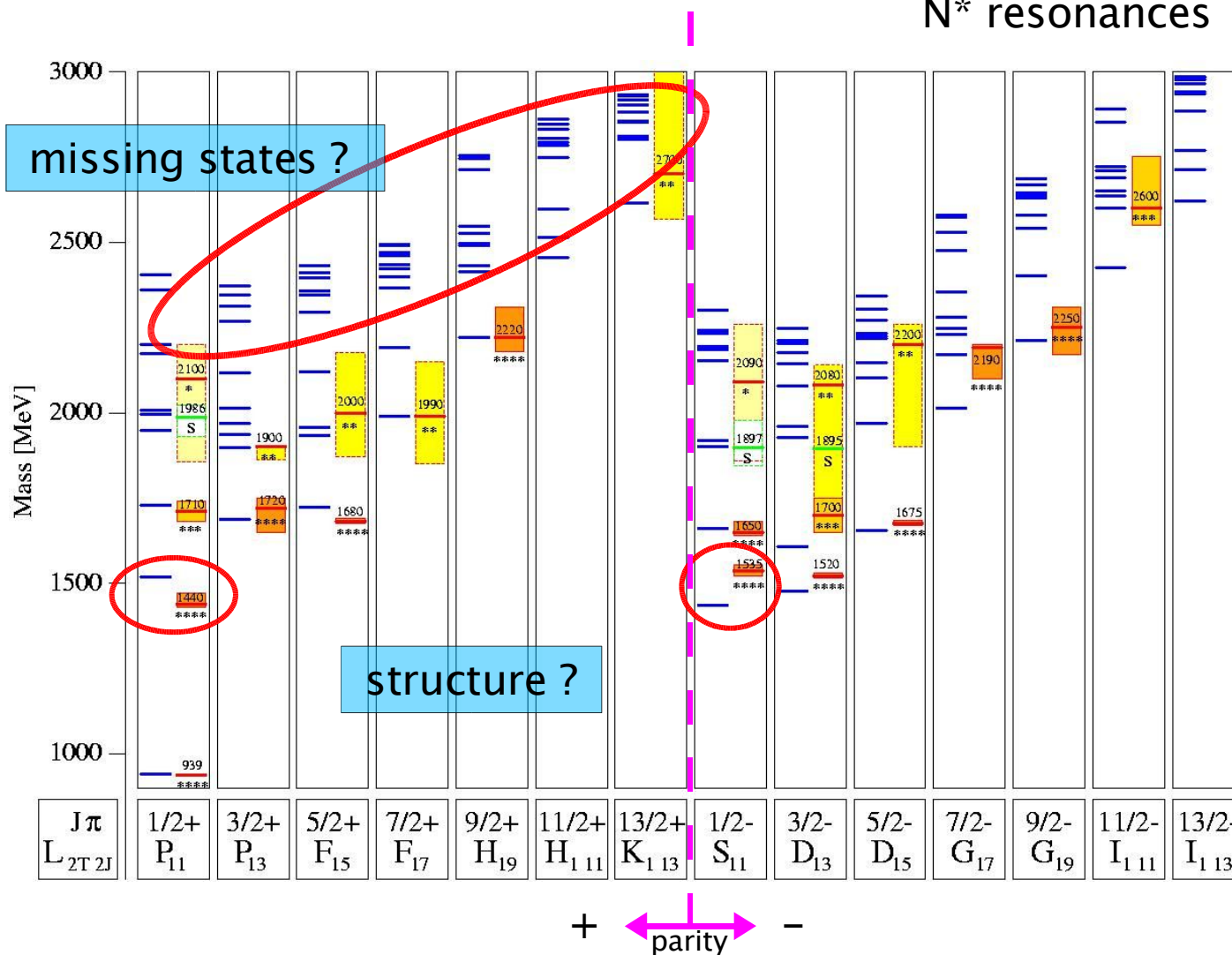
spin 3/2

from Gottfried-Weisskopf,
 Vol II, Figs. III.5 & 6

Nucleon spectroscopy

Löhring, Metsch, Petry, EPJ A10, 395(2001)

N^* resonances

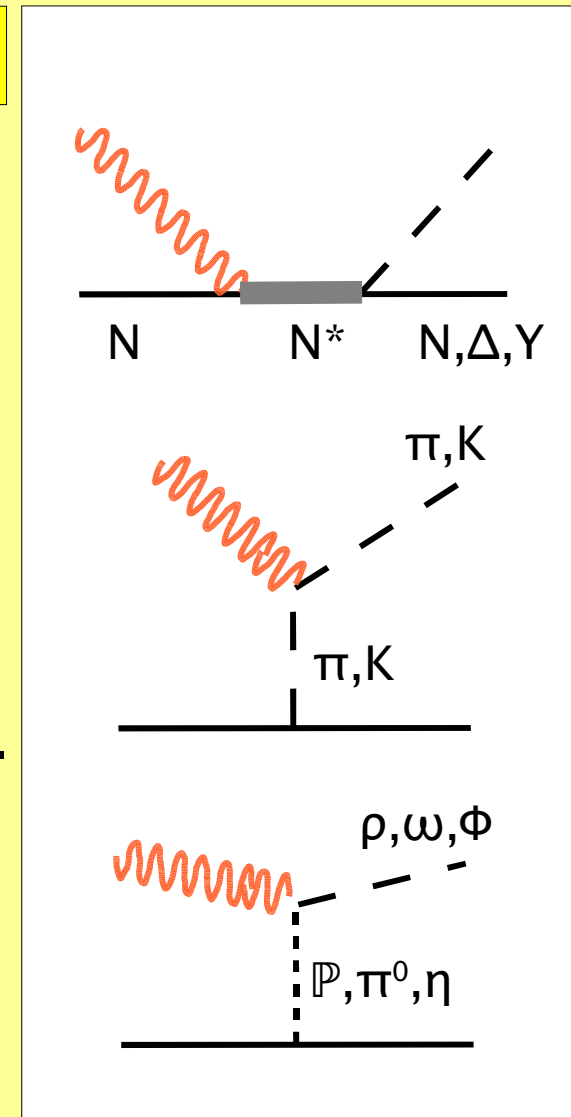


- ▶ *pattern* of states $\Rightarrow \gamma + N \rightarrow (\mathbf{non-\pi}) + N$
- ▶ *structure* of specific states
- ▶ *internal* degrees of freedom ?
 - 3q
 - 3q-g hybrids
 - q-2q quark-diquark correlations
 - qq-q-qbar baryon-meson molecules
 - chiral meson-baryon dynamics

$$|N\rangle = |qqq\rangle + |qqq q\bar{q}\rangle + |qqq g\rangle + \dots$$

- ▶ *mechanism* of meson photoproduction ?
 - role of *t-channel* processes ?

\Rightarrow **polarization**



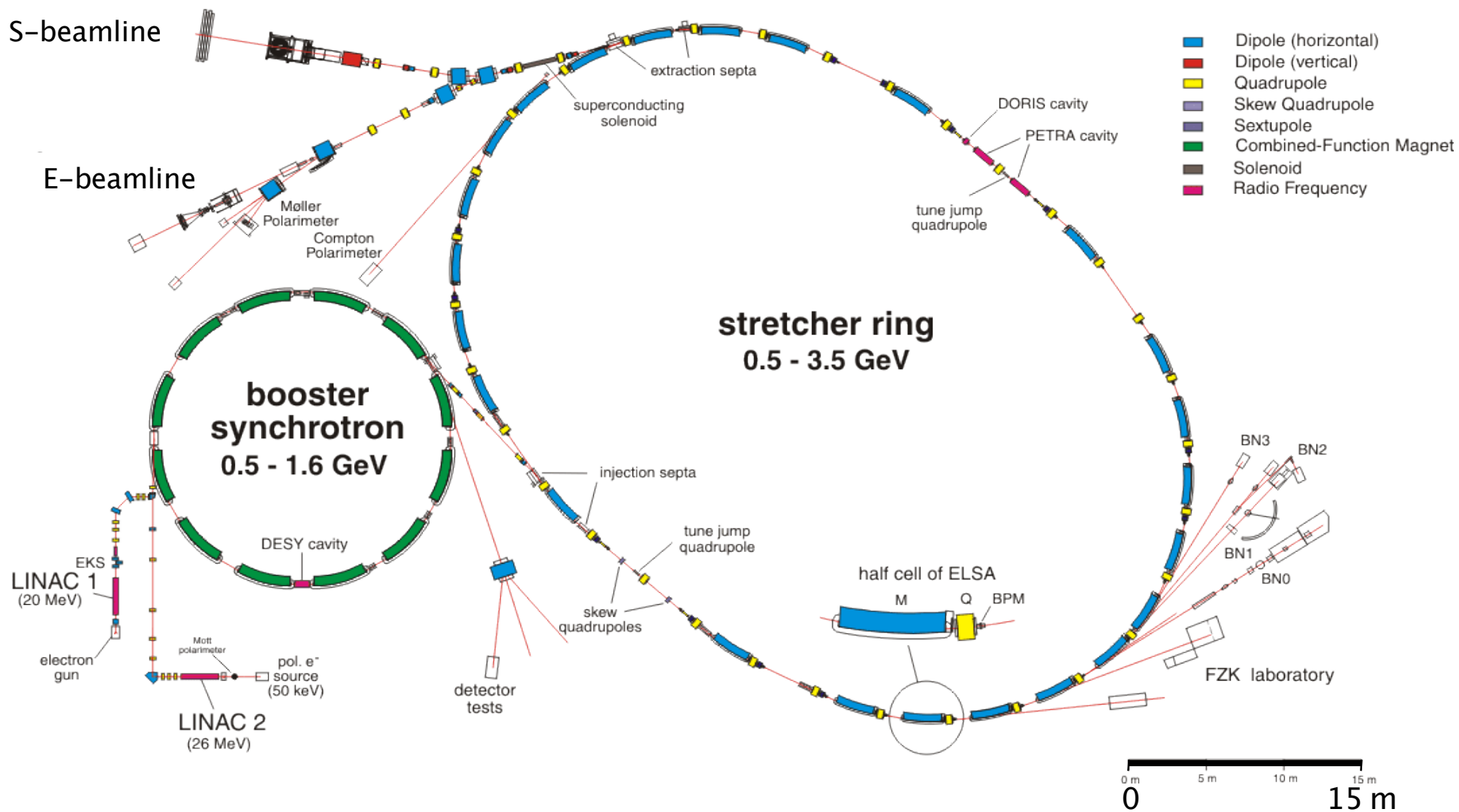
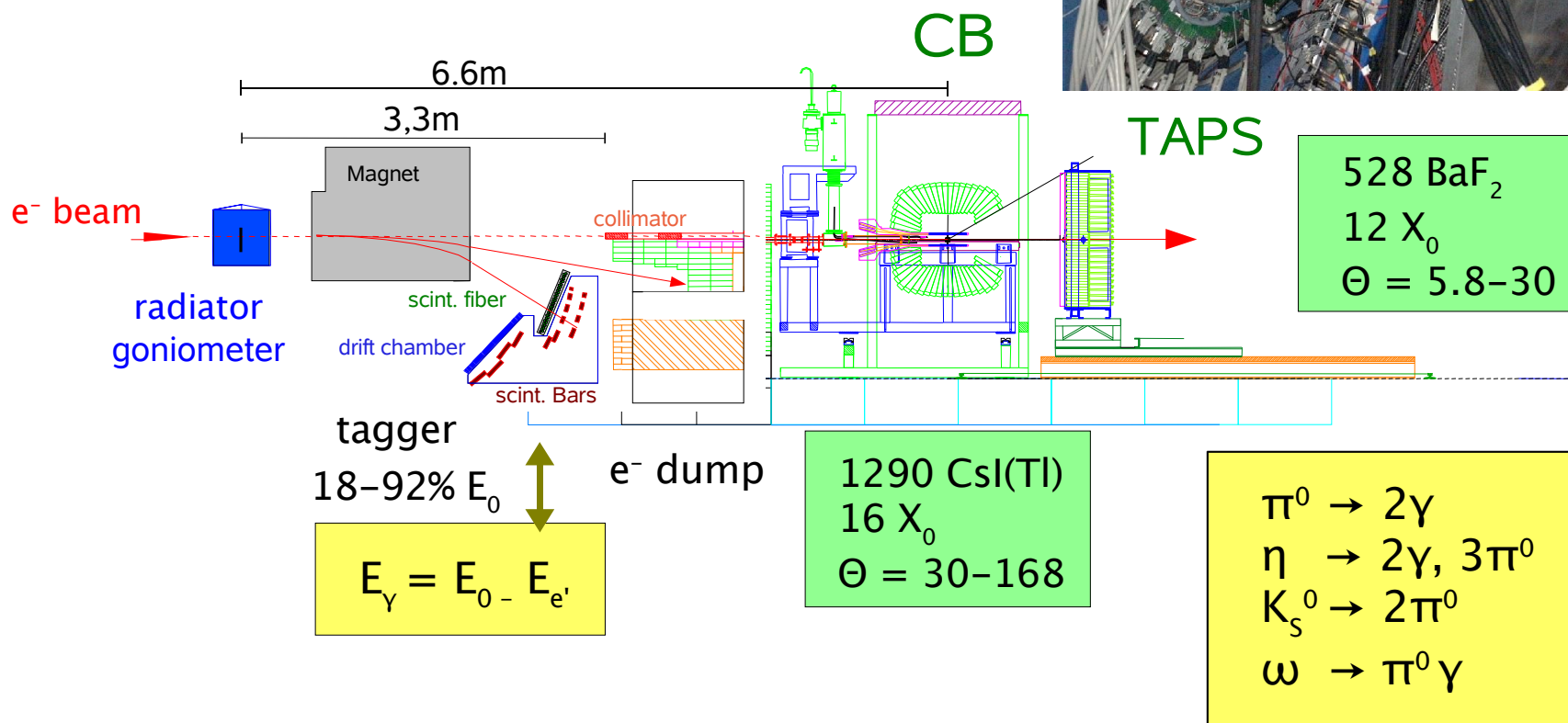
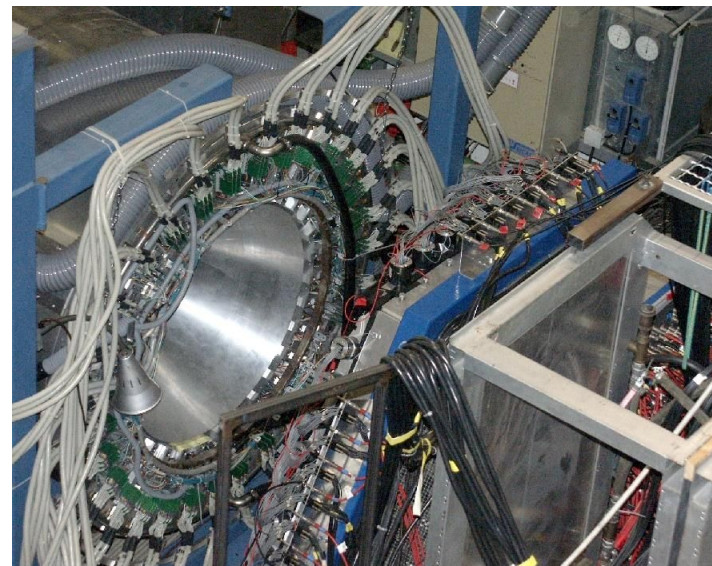
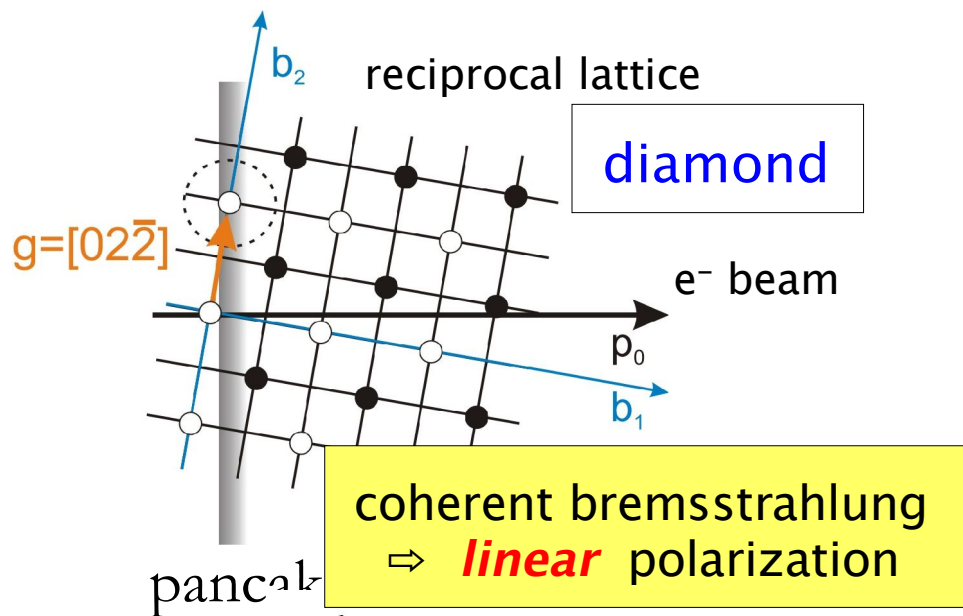




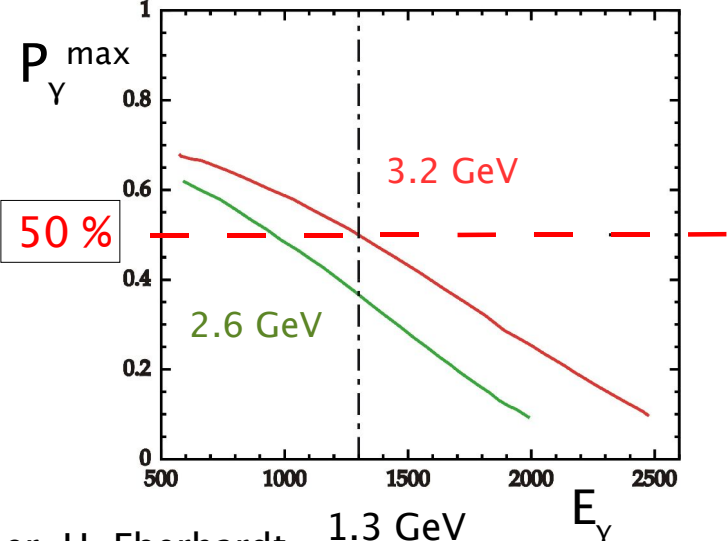
Photo: D.Elsner

CB/TAPS @ beamline S

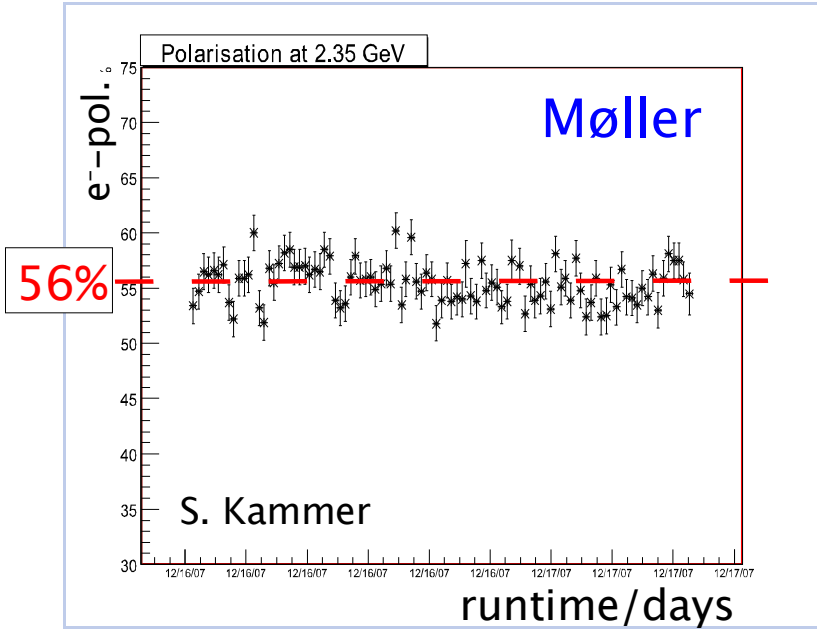




coherent bremsstrahlung
⇒ **linear** polarization



longit. polarized electrons
⇒ **circular** polarization



$$\frac{P_{Y,circ}}{P_e} = \frac{E_Y}{E_0} \frac{1 + \frac{1}{3}(1 - E_Y/E_0)}{1 - \frac{2}{3}(1 - E_Y/E_0) + (1 - E_Y/E_0)^2}$$

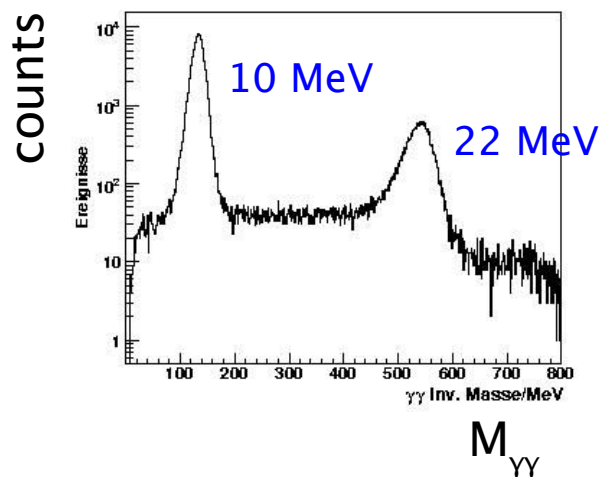
H. Olsen & L.C. Maximon, PR 114 (1959) 887

p (γ, η) p

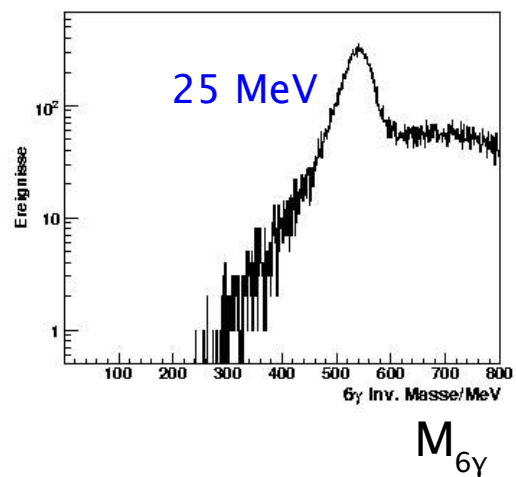
neutral meson ID

V. Crede, A. Süle, D. Elsner, ...

$\eta \rightarrow \gamma\gamma$



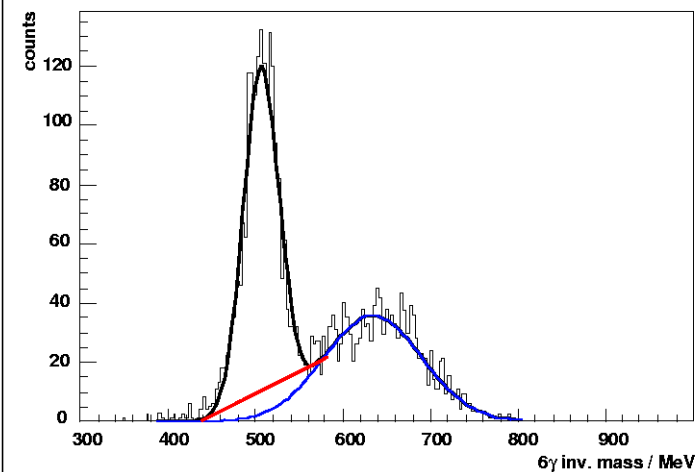
$\eta \rightarrow 3\pi^0$



$\eta \rightarrow 3\pi^0$

$E_\gamma = 1100 - 1200$

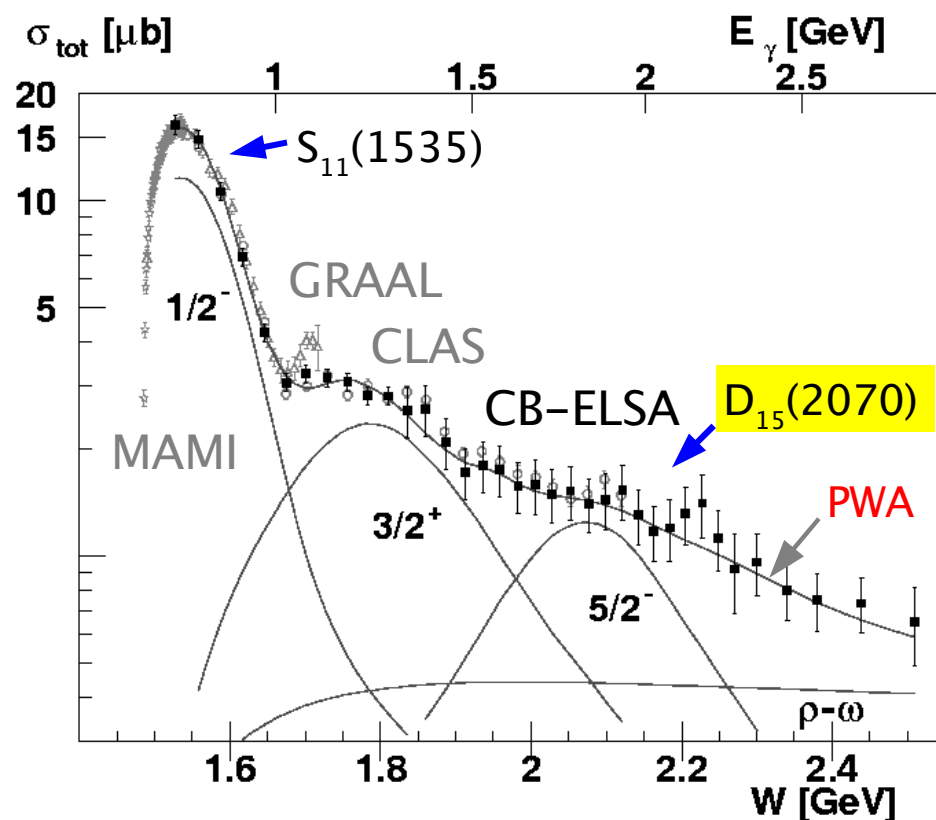
$\theta_{cm} = 80 - 100$



p (γ, η) p

unpol. data set

O. Bartholomy, V. Crede, ...



“complete“ experiment

- ◆ 8 independent observables
- ◆ $d\sigma/d\Omega$
- ◆ P, T
- ◆ Σ
- ◆ 4 'well chosen' double spin asymmetries
- ◆ more observables for 2ps & vectormesons

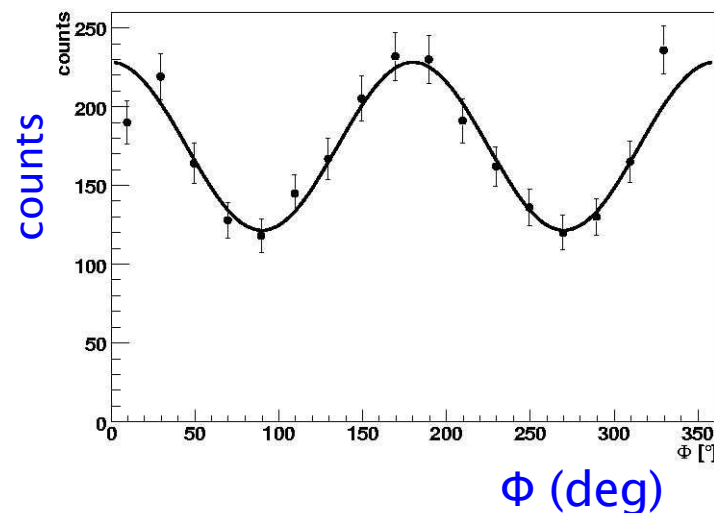
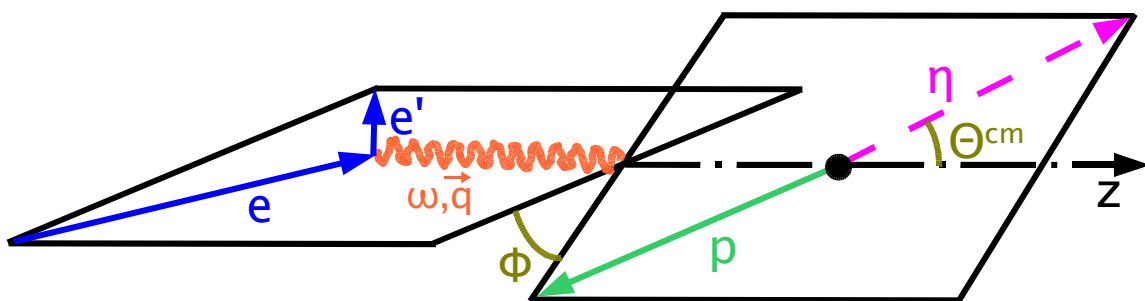
Chiang & Tabakin, PRC55 (97) 2054

V. Crede, O. Bartolomy et al.,
 PRL 94 (2005) 012004,
 EPJ A33 (2007) 133

$p(\gamma, \eta) p$

linear polarisation

D. Elsner et al., EPJ A33 (2007) 147

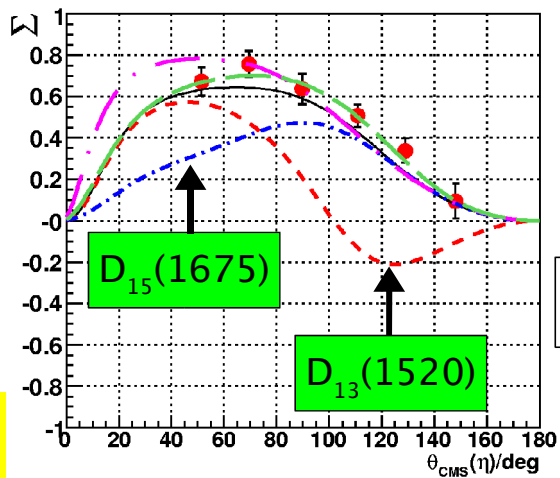


$$d\sigma = d\sigma_0 [1 + P_Y \Sigma \cos 2\Phi]$$

$p(\vec{\gamma}, \eta)p$

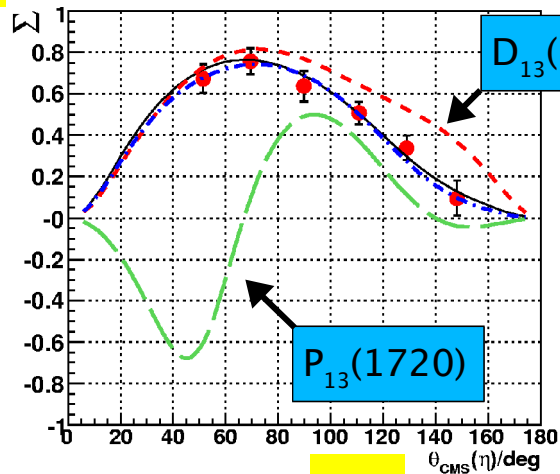
linear polarisation

D. Elsner et al., EPJ A33 (2007) 147



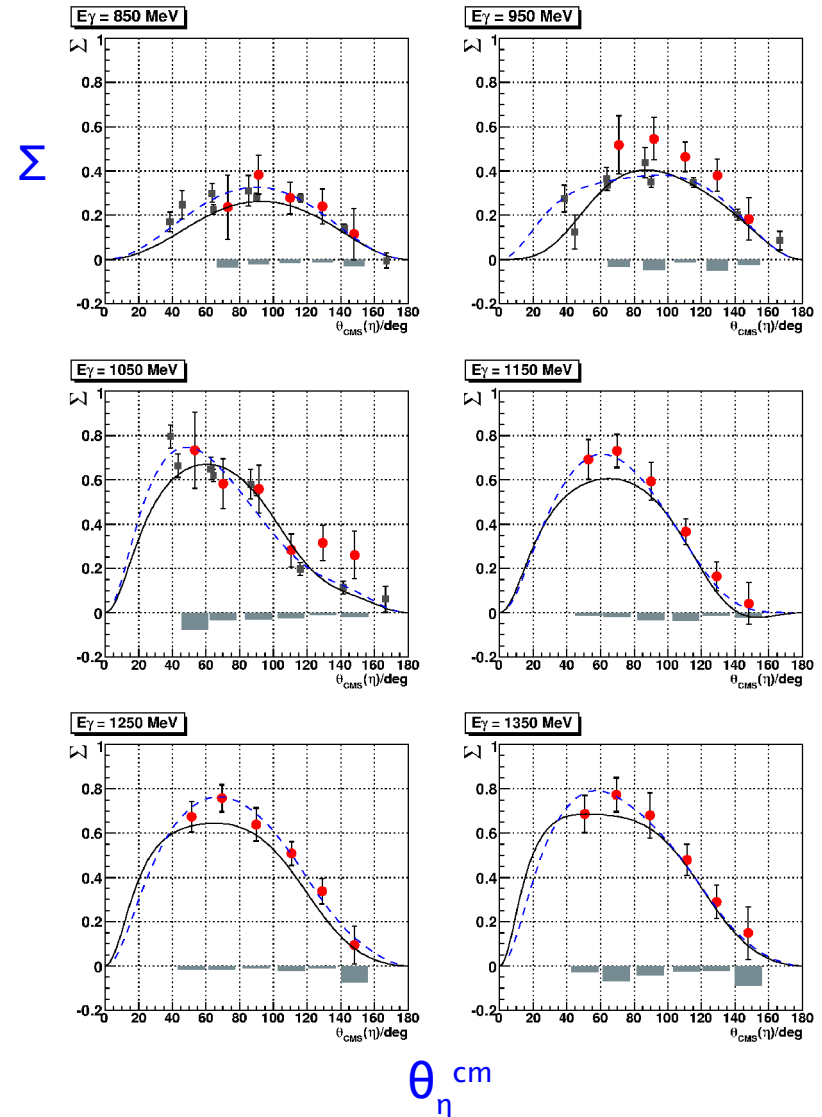
η -MAID

$E_\gamma = 1250$ MeV



BoGa PWA

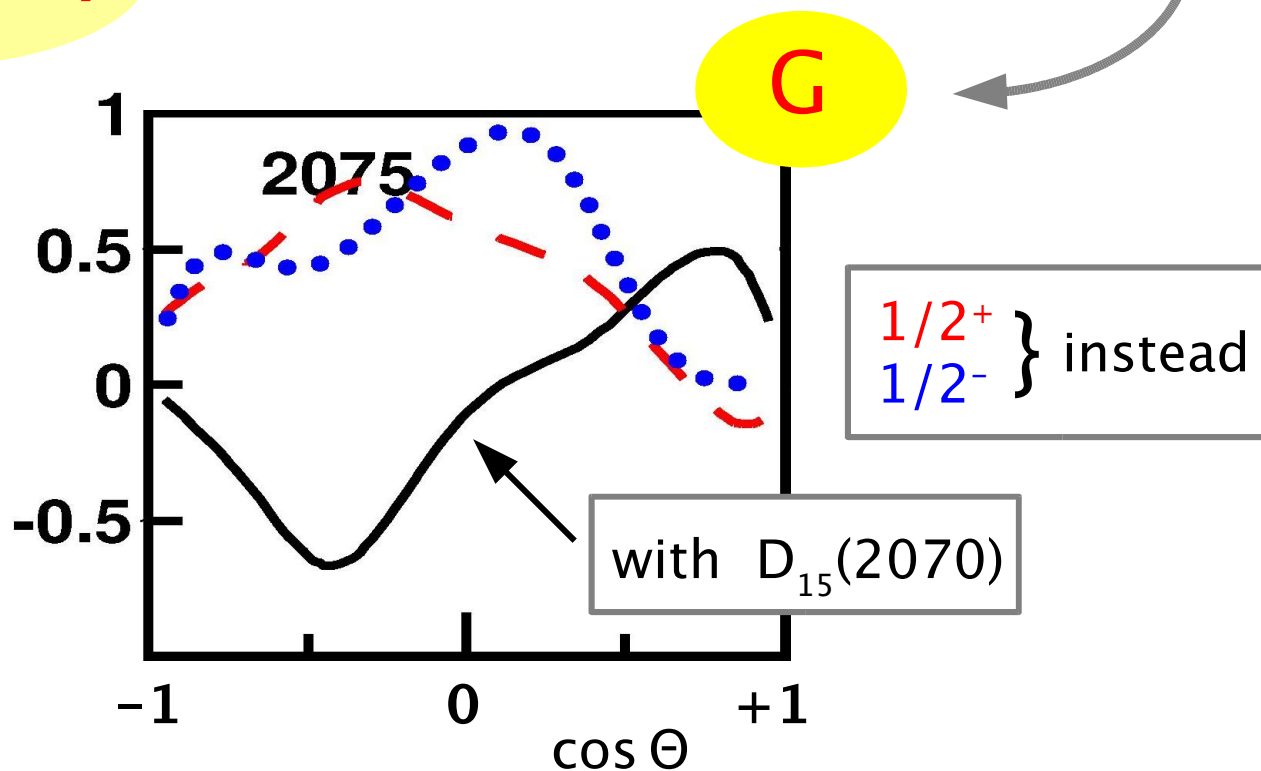
Θ_{cm}



GRAAL: J. Ajaka et al., PRL 81
 new: O. Bartalini et al., arXiv:0707.1385

double polarisation:
long. pol. target & lin. pol. beam

? $D_{15}(2070)$?

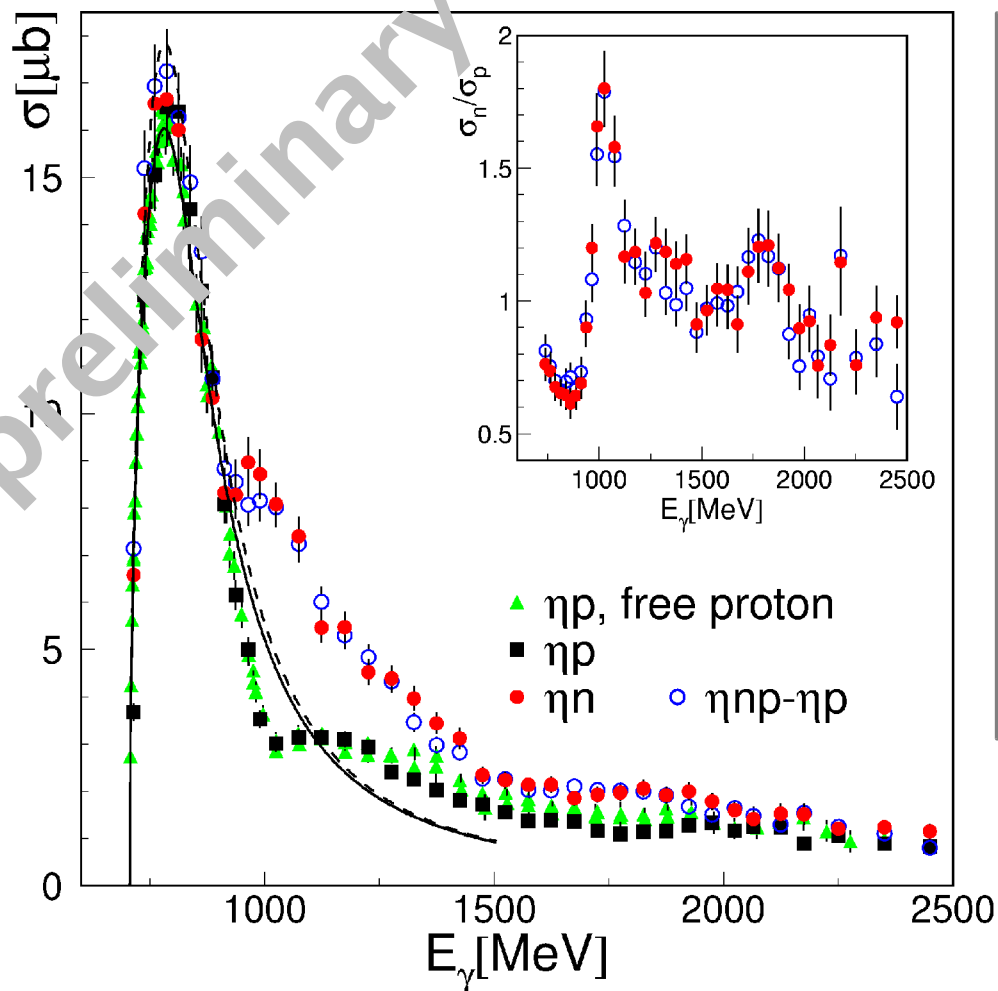


A. Sarantsev, priv. comm.

d (γ, η)

neutron target

B. Krusche, I. Jäggle (Basel)



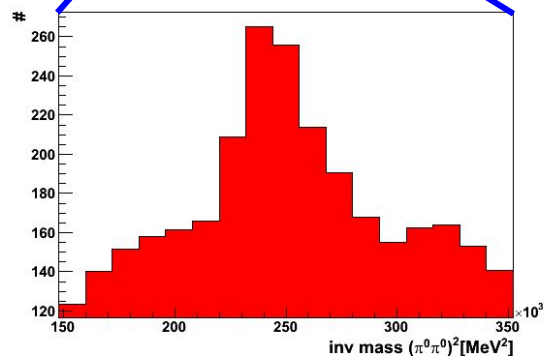
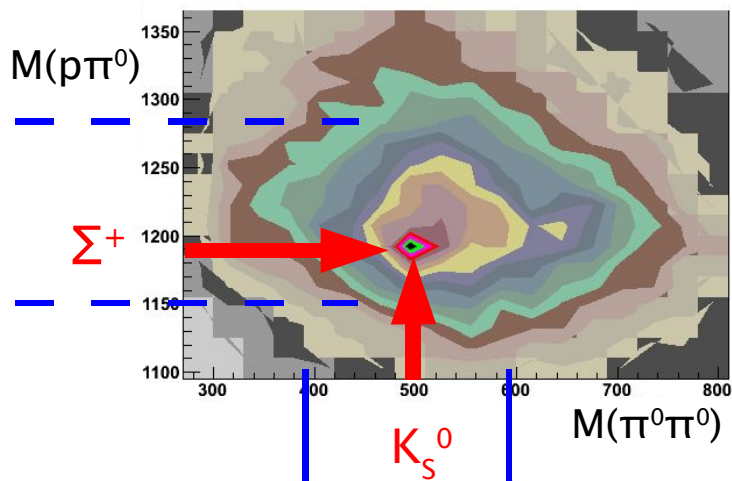
- ◆ Fermi smearing unfolded
- ◆ bump in $n\eta$ channel
 - ⇒ also GRAAL data
 - ⇒ peak in $M(\eta n) \leftrightarrow$ narrow
 - ⇒ interference $S_{11}(1535)/S_{11}(1650)$
 - ⇒ interference $S_{11}(1535)/D_{13}(1520)$
 - ⇒ role of $D_{15}(1675)$?
 - ⇒ “exotic state” ?
 - $P_{11}(1670)$?? \leftrightarrow Σ in $p\eta$ (GRAAL)
 - ⇒ NSTAR07 proceedings

need $\vec{n}(\vec{\gamma}, \eta)$ double pol.

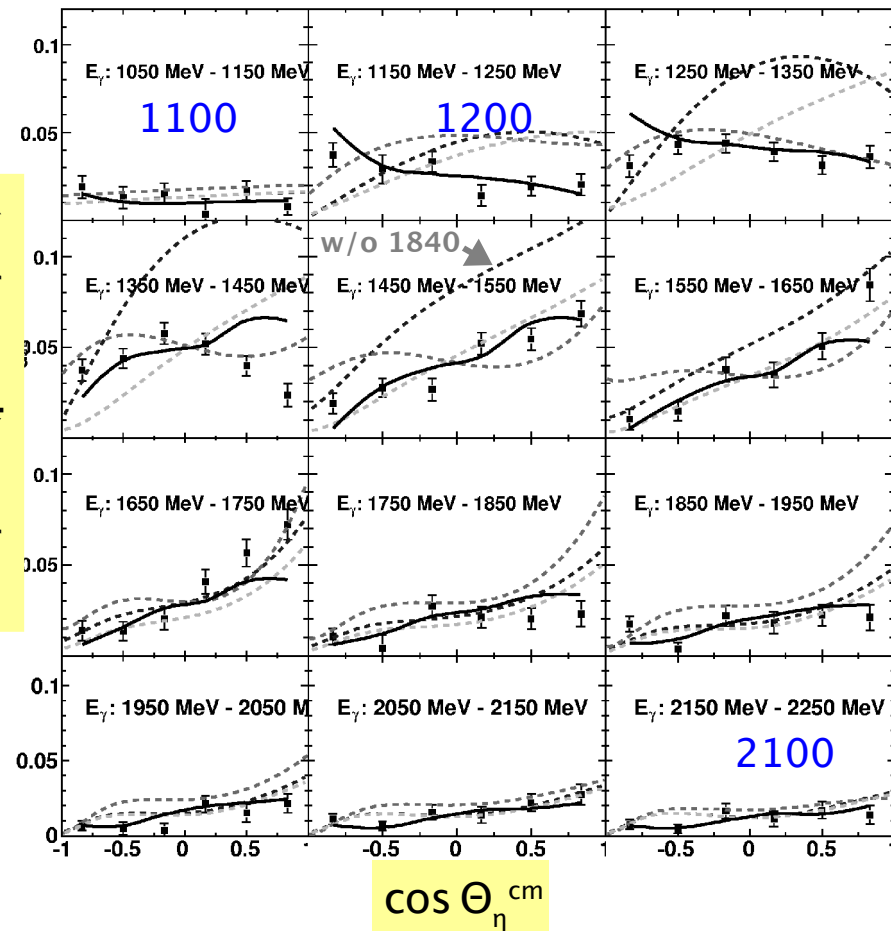
$p(\gamma, K^0)\Sigma^+$ **ass. strangeness**

R. Castelijns (Groningen), R. Ewald (Bonn)

kinematic fit $\gamma p \rightarrow p 3\pi^0$



$d\sigma/d\Omega$ ($\mu\text{barn/sr}$)

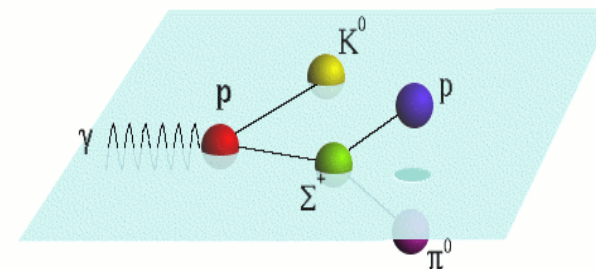


- ◆ BoGa PWA $\leftrightarrow P_{11}(1840)$ [solid]
- ◆ Usov-Scholten $\leftrightarrow P_{13} P_{33}$??? [broken]

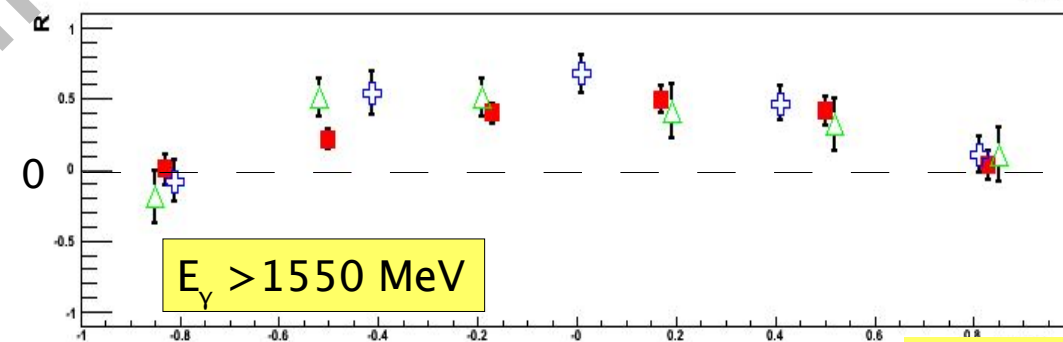
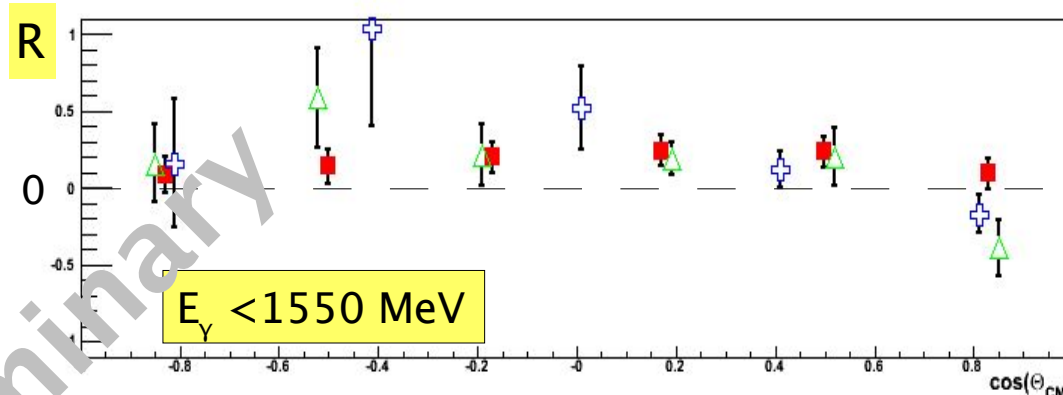
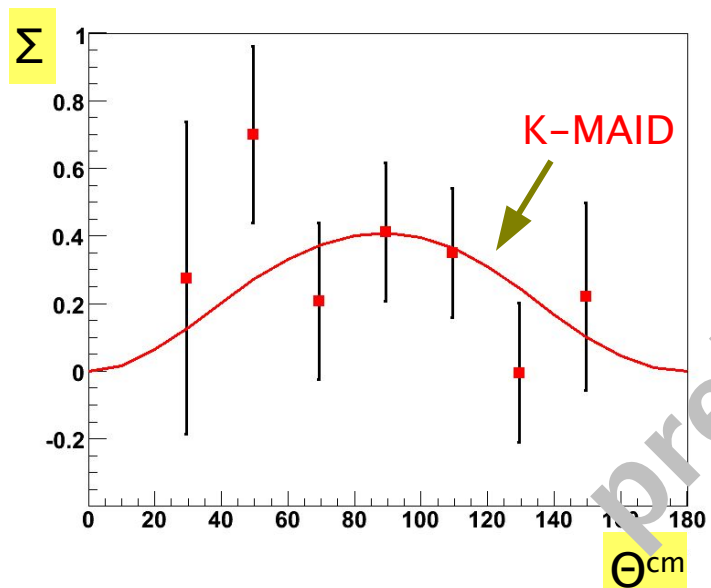
$p(\vec{\gamma}, K^0)\Sigma^+$

R. Ewald (Bonn)

ass. strangeness



1550 ± 100 MeV

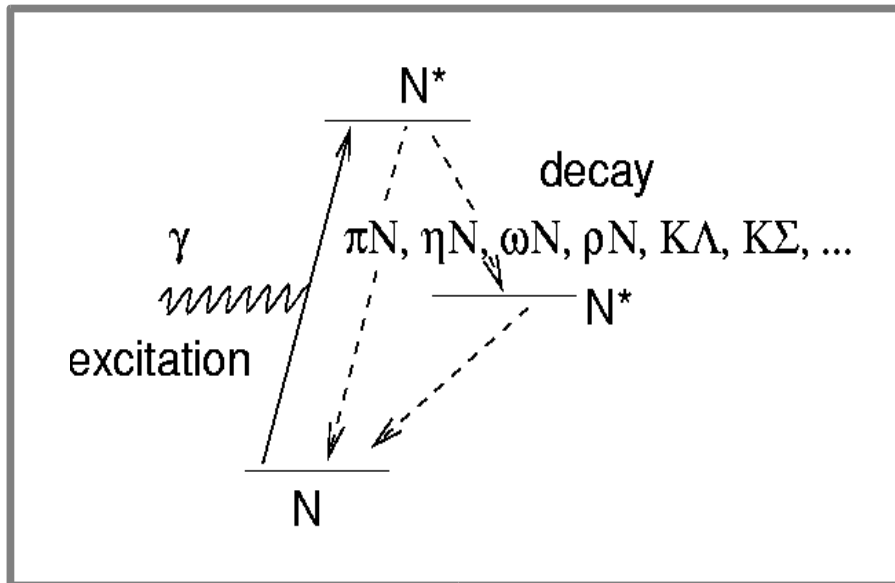


- CBELSA-TAPS
- △ Castelijns et al (nucl-ex/0702033)
- ⊕ Lawall et al (Eur. Phys. J. A24, 275(2005))

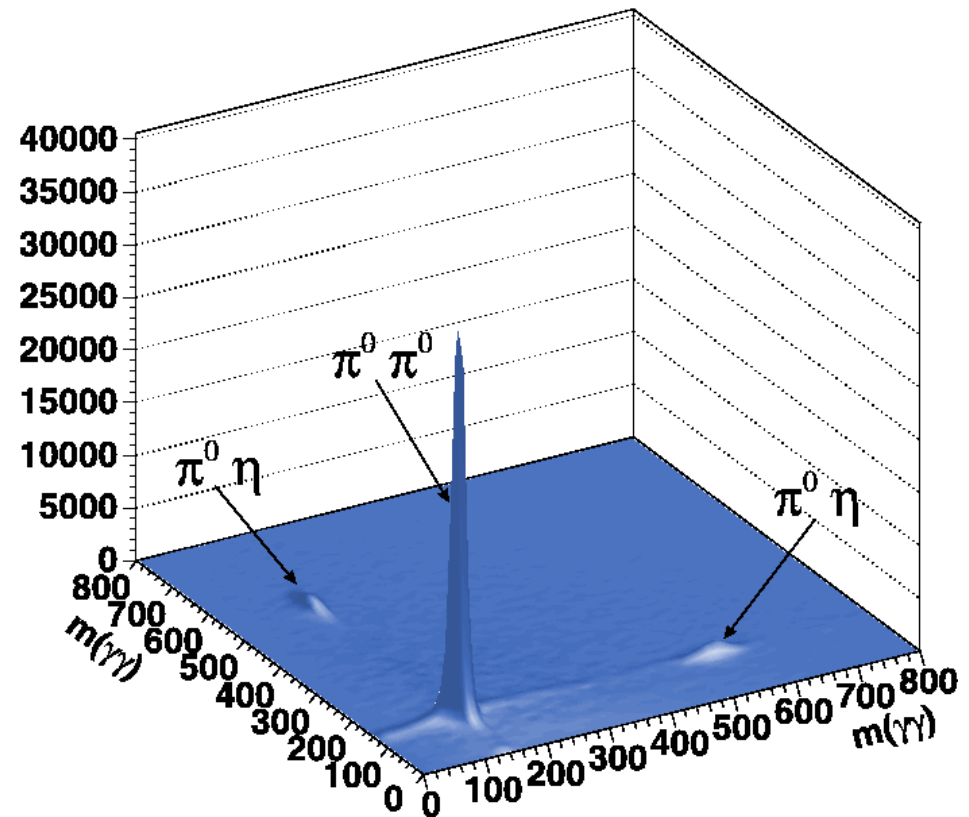
$\cos \Theta_{cm}$

$p(\gamma, 2\pi^0/\pi^0\eta)p$ **2 ps mesons**

M. Fuchs, E. Gutz, I. Horn, V. Sokhoyan, U. Thoma, E. Klempt (Bonn)



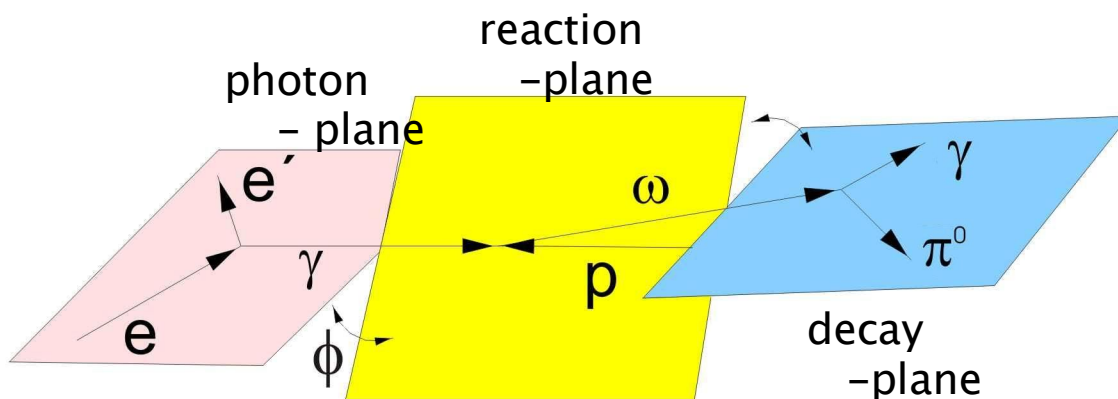
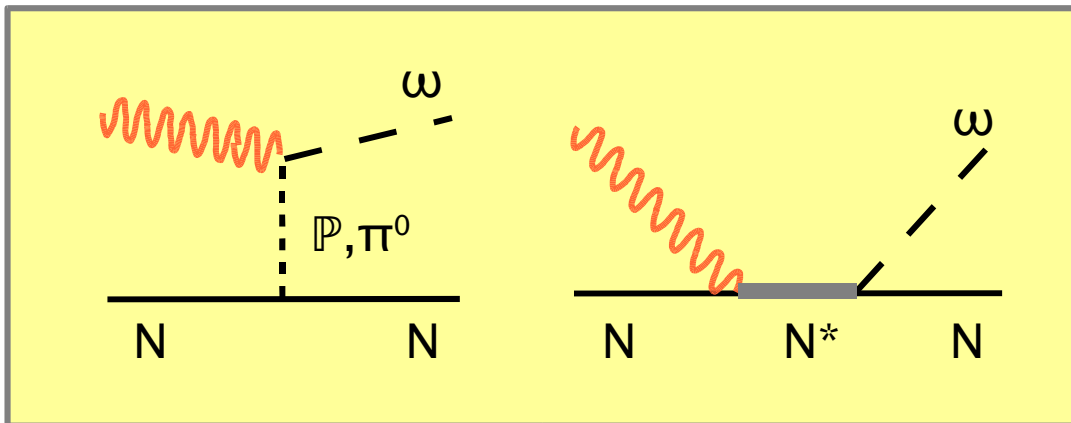
- ◆ ρ suppressed
- ◆ t-channel suppressed
- ◆ $\Rightarrow \pi^0\pi^0 / \pi^0\eta$ “clean“ channels



$p(\vec{\gamma}, \omega)p$

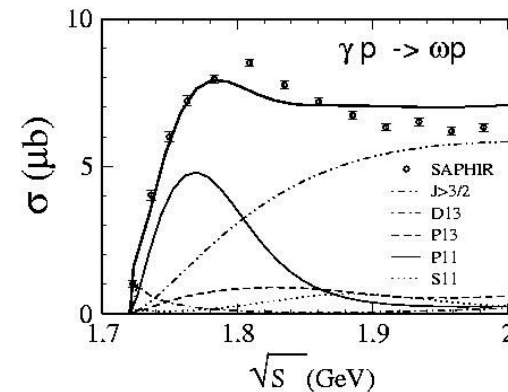
ω mesons

Frank Klein (thesis, Bonn)



$$d\sigma = d\sigma_0 [1 + P_\gamma \sum_{(\pi)} \cos 2\Phi]$$

Penner et al., PR C66 (2002) 055212



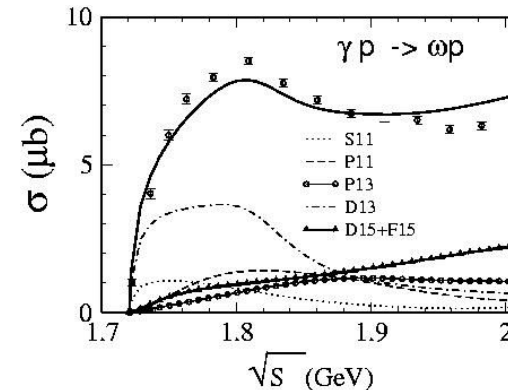
$J_{res} \leq 3/2$

$P_{11}(1710)$

Shklyar et al. (Giessen group)

PR C71 (2005) 055206

PR C72 (2005) 019903



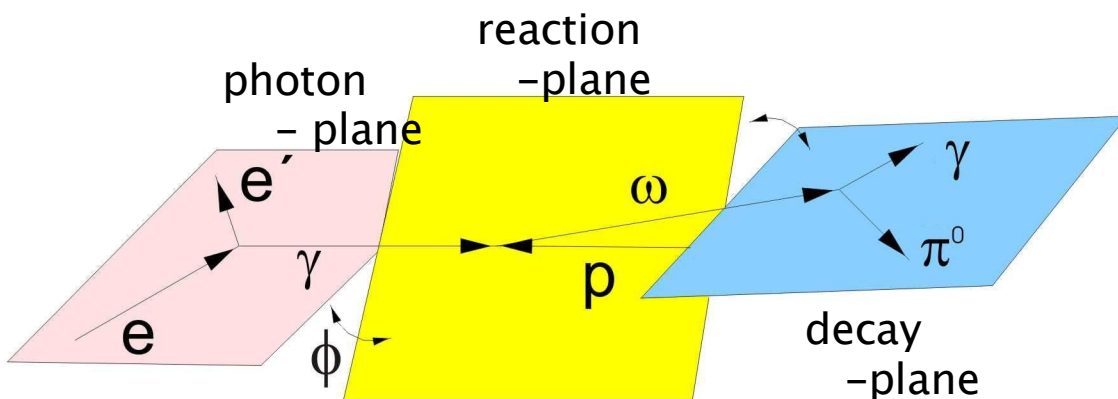
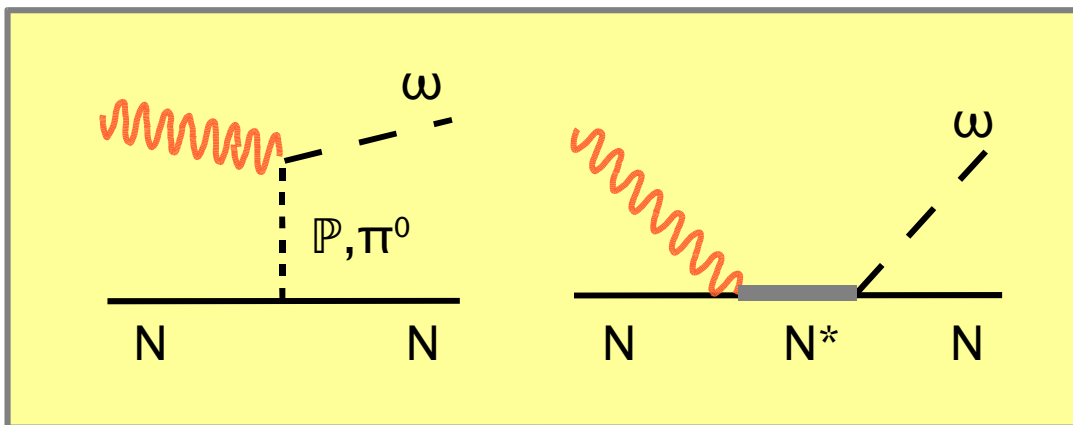
$J_{res} \leq 5/2$

~~$P_{11}(1710)$~~

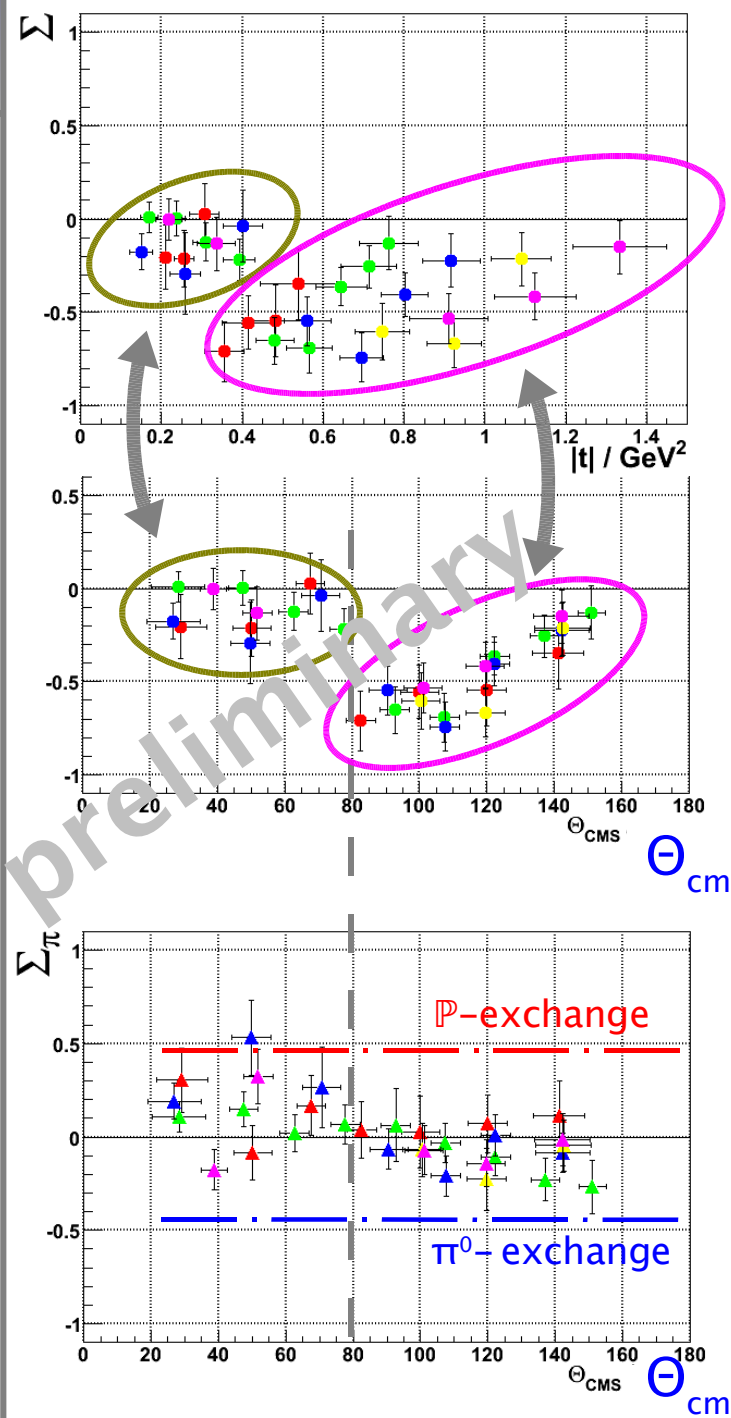
$p(\vec{\gamma}, \omega)p$

ω mesons

Frank Klein (thesis, Bonn)



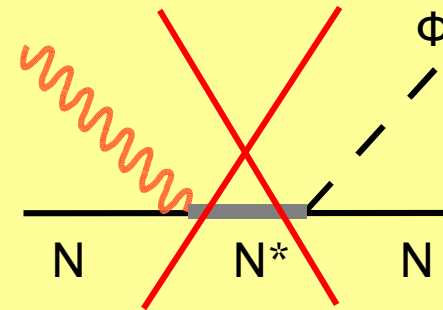
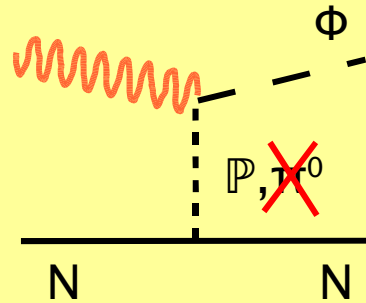
$$d\sigma = d\sigma_0 [1 + P_\gamma \Sigma_{(\pi)} \cos 2\Phi]$$



ω and ϕ !!

reaction dynamics ?

- ◆ pomeron exch.
- ◆ role of π/η exch.
- ◆ exotics



p/n/d targets
B-T asymm's

$\phi \rightarrow K^+K^-$

requires
 K^+K^- detection
in forward direction

- ◆ nucleon resonances ↔ neutral meson photoproduction @ ELSA
- ◆ Crystal Barrel / TAPS detector
- ◆ ηp
 - new $D_{15}(2070)$?
 - $\Sigma \rightarrow$ resonance decomposition
 - need beam-target polarisation
- ◆ ηn
 - “sharp“ structure in exct.-function
 - conventional ↔ “exotic“ ??
 - need beam-target polarisation
- ◆ $K_S^0 \Sigma^+$
 - x-sec $\rightarrow P_{11}/P_{13}/P_{33}(1840)$
 - Σ & P to include into PWA
 - need beam-target polarisation
- ◆ ωp
 - x-sec \rightarrow resonance decomposition
 - Σ & Σ_π favour resonances
 - need beam-target polarisation
- ◆ $\Phi p/n$ - need beam-target polarisation

TAPS

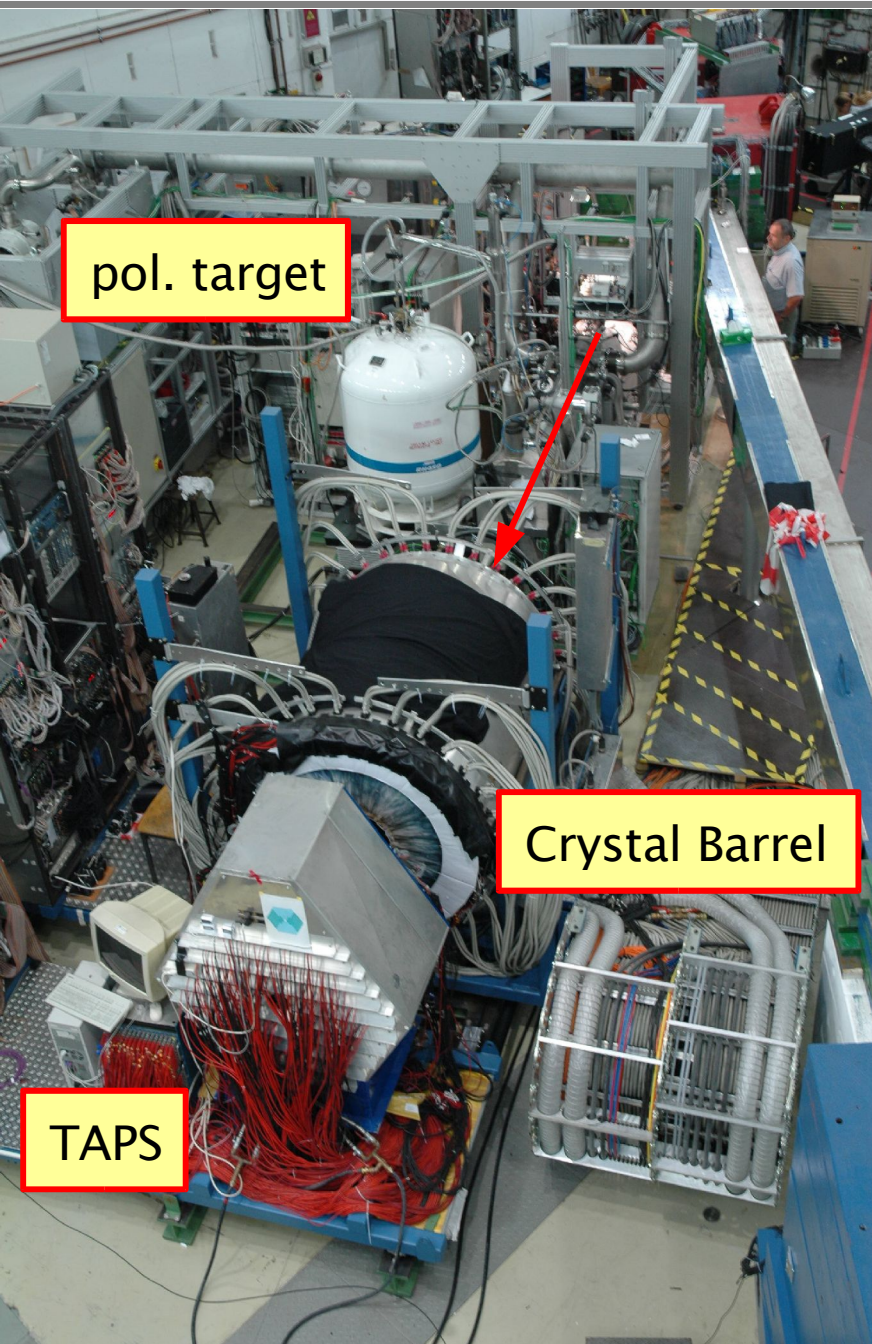
Crystal Barrel

pol. target

tagger

double polarisation setup
at beamline E

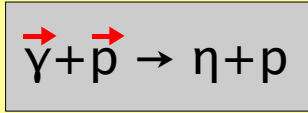
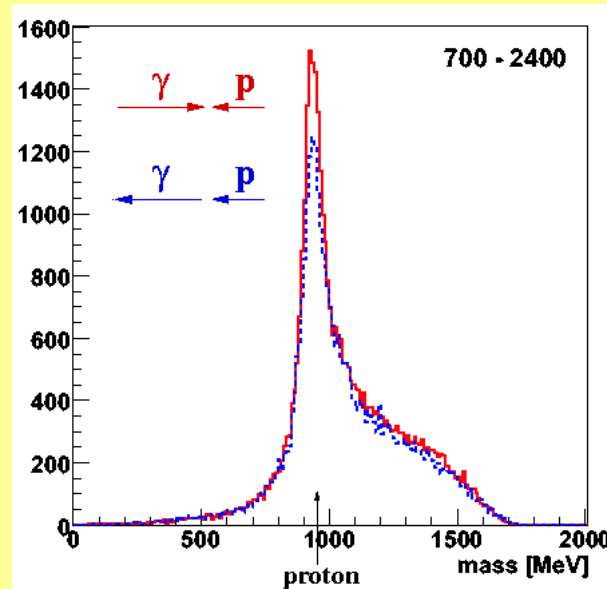
- ◆ longitudinally polarised butanol target
- ◆ circularly polarised photon beam (polarised electrons)
- ◆ linearly polarised photon beam (coherent bremsstrahlung)



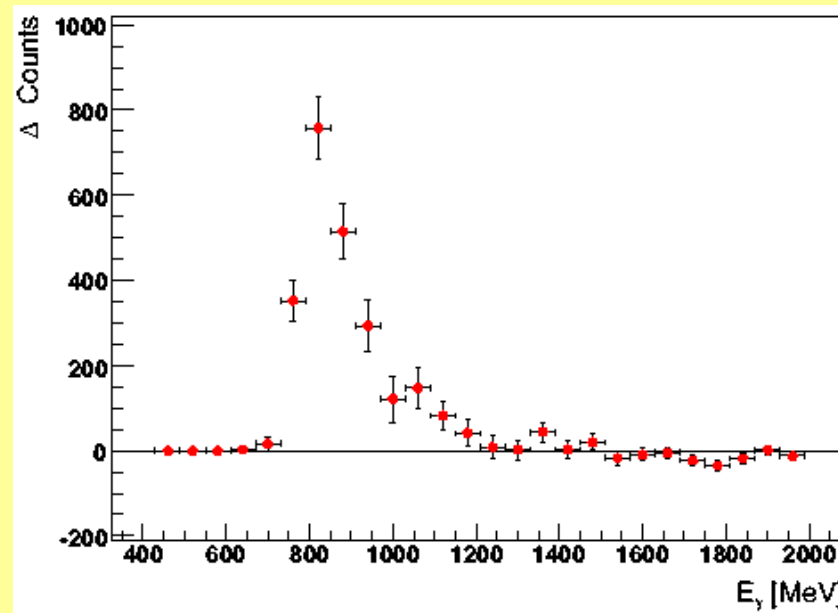
pol. target

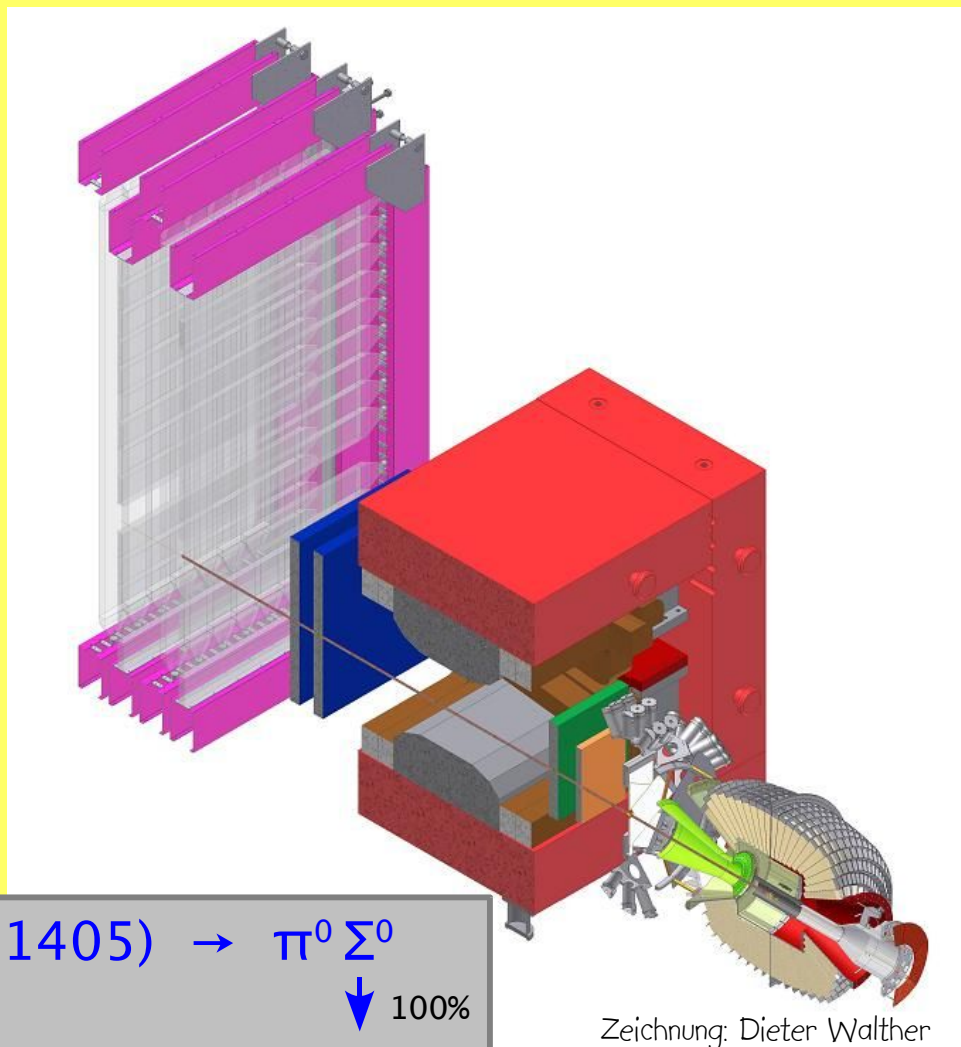
Crystal Barrel

TAPS



Ch. Schmidt

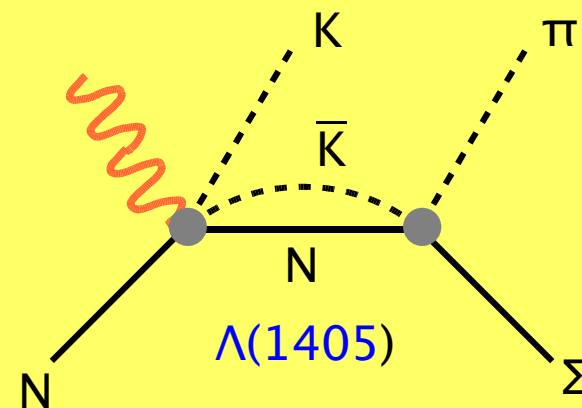




Zeichnung: Dieter Walther

$\Lambda(1405) \rightarrow \pi^0 \Sigma^0$
 \downarrow 100%
 $\Lambda \gamma$
 \downarrow 36%
 $n \pi^0$

- ◆ $K^+ id$
- ◆ $\Phi \rightarrow K^+ K^-$
- ◆ $\omega \rightarrow \pi^+ \pi^- \pi^0$
- ◆ $K^+ \Lambda(1405)$



- ◆ $L=1$ uds singlet state ??
- ◆ \leftrightarrow $\Lambda(1520)$ splitting ?
- ◆ $\bar{K}N$ "molecule" ??
- ◆ \leftrightarrow where is singlet ?
- ◆ \rightarrow scattering length ?