ELSA

the upcoming polarisation programme

Hartmut Schmieden

Physikalisches Institut
Rheinische Friedrich–Wilhelms–Universität

Bonn

FSU Tallahassee, Oct 2005

NSTAR'05

SFB–TR 16

Outline

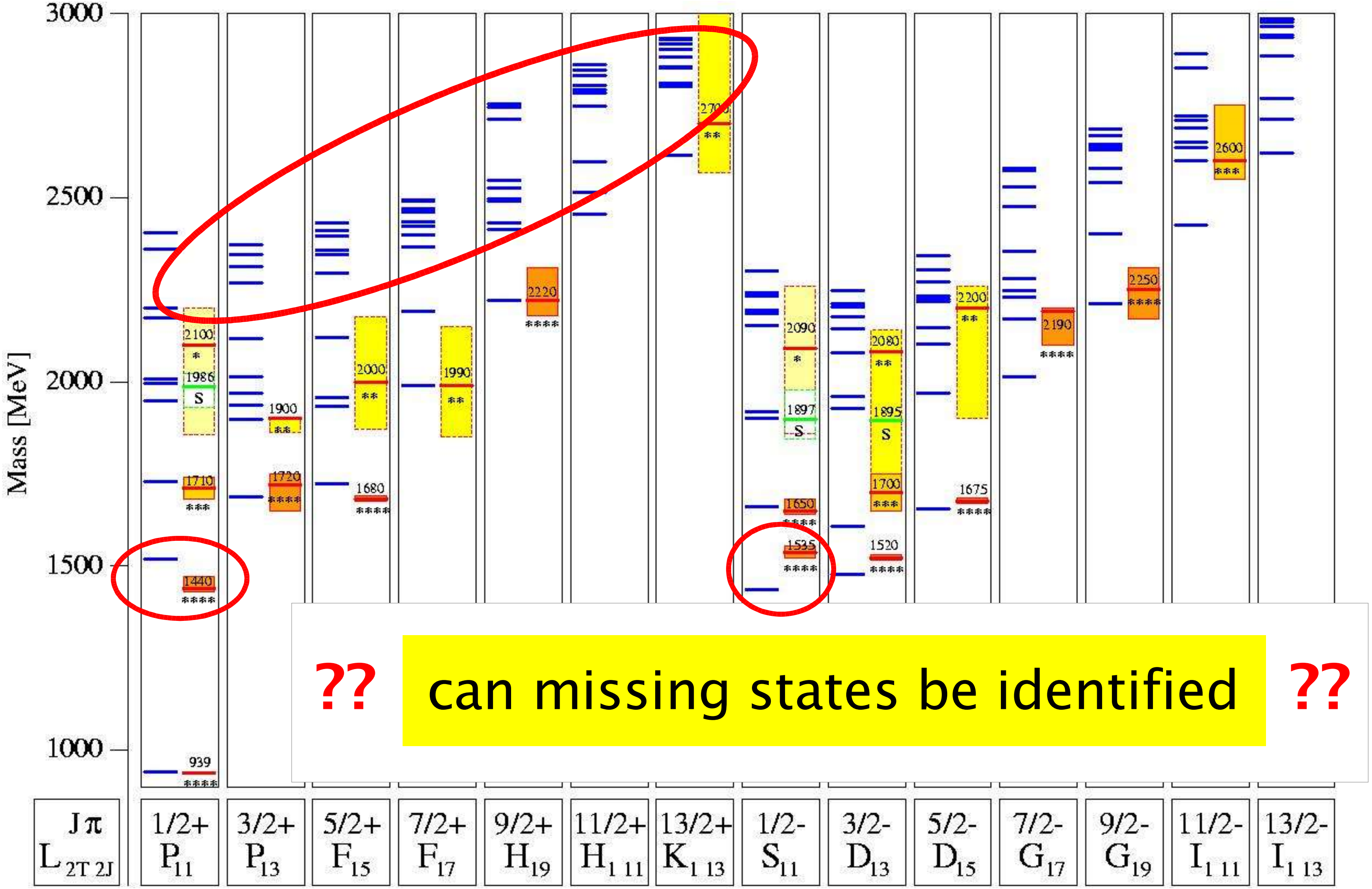
- Baryon spectrum & spectroscopy
- Role of polarisation observables
- Selected cases for CrystalBarrel@ELSA
  - η
  - $\pi^0 \pi^0$ / $\pi^0 \eta$
  - ω

beam & target polarisation

- Future extension: forward spectrometer
  - $K^+ \Lambda(1405)$
  - $\Phi(\eta)$

Quark model

N* resonances

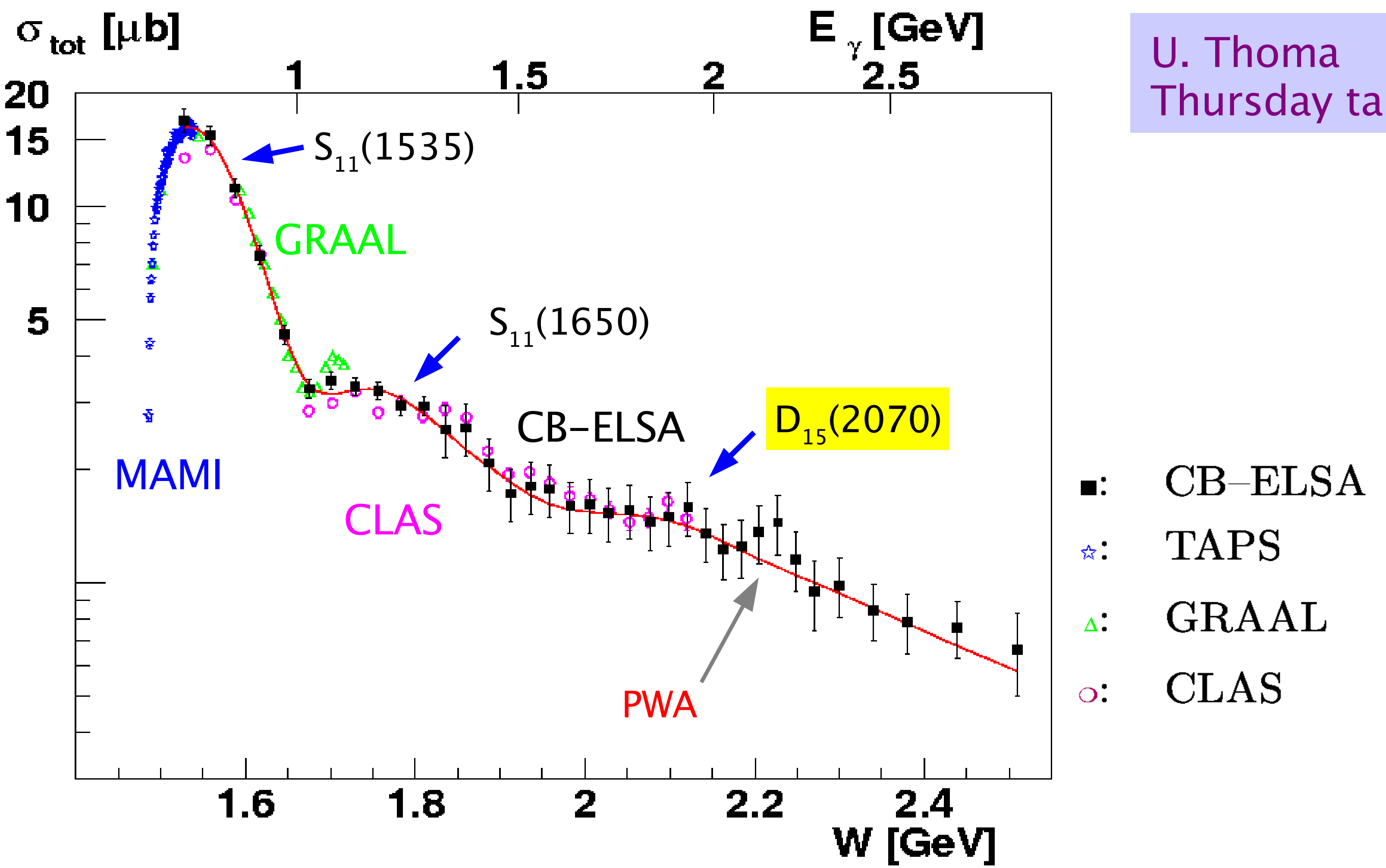


?? can missing states be identified ??

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

$\gamma p \rightarrow p \eta$

U. Thoma
Thursday talk

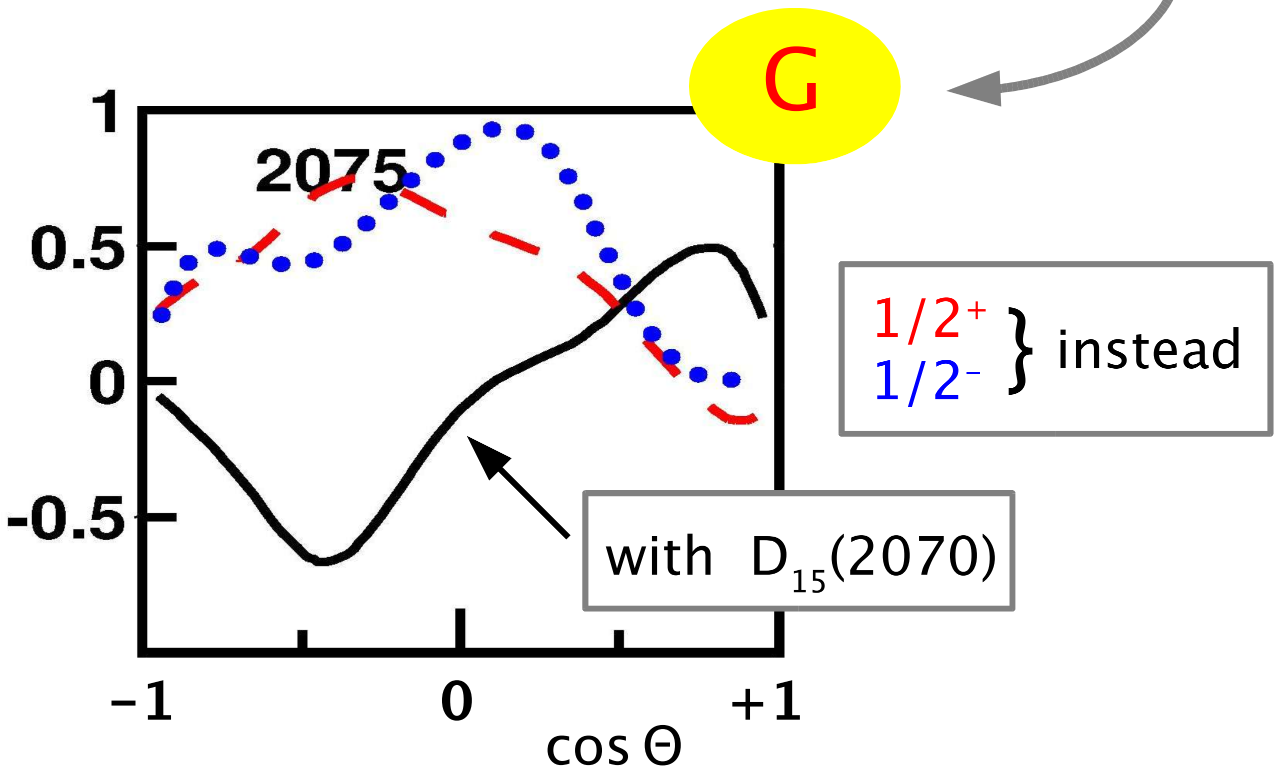


V. Crede, O. Bartolomy et al., PRL 94 (2005) 012004

$\gamma p \rightarrow p \eta$

? $D_{15}(2070)$?

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



A. Sarantsev, priv. comm.
Bonn-Gatchina PWA

complete experiment

Chiang & Tabakin, PRC55 (97) 2054

isoscalar

$\gamma + p \rightarrow p + \eta$

λ ±1 ±½ ±½ 0

4 x 2 —parity consv.→ 4 complex amplitudes

4 complex amplitudes → 8 ↔ no discrete ambiguities ← 4 BT/TR

4 complex amplitudes → ≥7 independent quantities

$\gamma + p \rightarrow p + \omega$

λ ±1 ±½ ±½ 0,±1

4 x 6 —parity consv.→ 12 complex amplitudes

12 complex amplitudes → ≥23 independent quantities

polarisation observables

$\gamma + p \to p + \pi$

$$\frac{d\sigma}{d\Omega} = \left.\frac{d\sigma}{d\Omega}\right|_0 \Big[1 - P_\gamma^{lin} \Sigma \cos 2\Phi + P_T^x(-P_\gamma^{lin} H \sin 2\Phi + P_\gamma^{circ} F) - P_T^y(-T + P_\gamma^{lin} P \cos 2\Phi) - P_T^z(-P_\gamma^{lin} G \sin 2\Phi + P_\gamma^{circ} E) \Big]$$

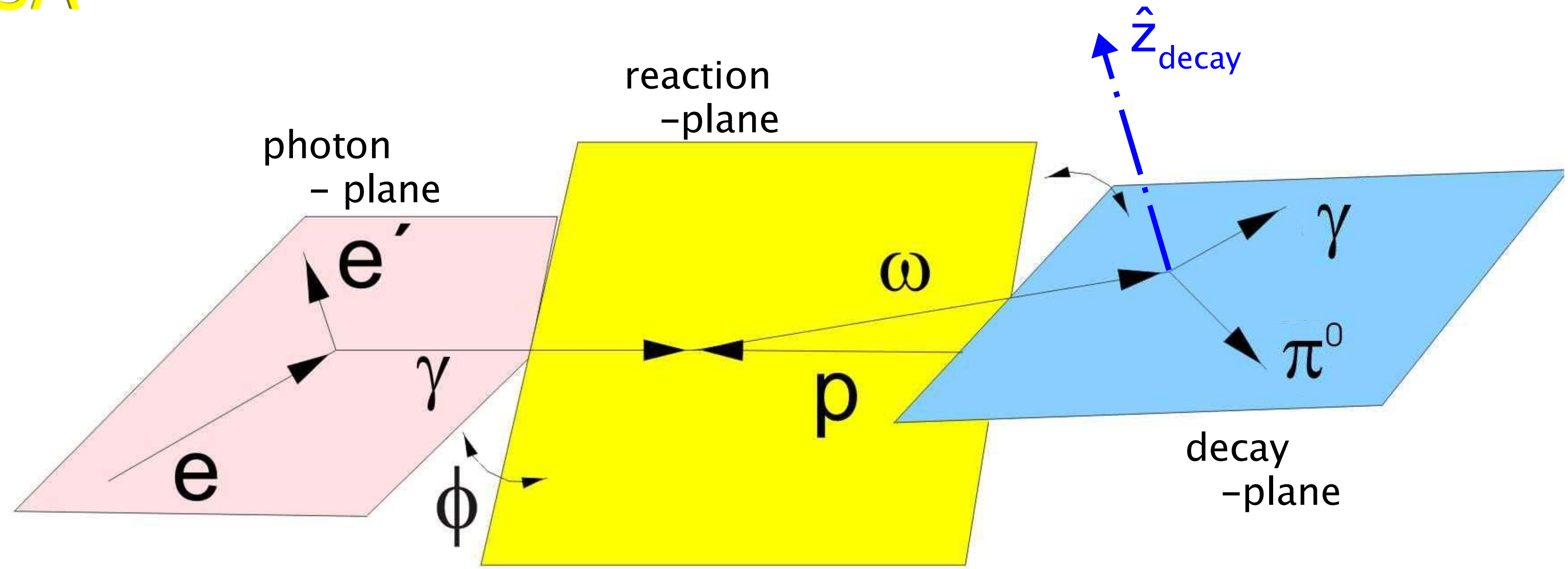
photon		target			recoil			target-recoil			
					x'	y'	z'	x'	x'	z'	z'
		x	y	z				x	z	x	z
unpol.	σ_0	0	T	0	0	P	0	$T_{x'}$	$-L_{x'}$	$T_{z'}$	$L_{z'}$
lin. pol.	$-\Sigma$	H	$-P$	$-G$	$O_{x'}$	$-T$	$O_{z'}$	$-L_{z'}$	$T_{z'}$	$-L_{x'}$	$-T_{x'}$
circ. pol.	0	F	0	$-E$	$-C_{x'}$	0	$-C_{z'}$	0	0	0	0

7

14

more observables: 2-meson & vector meson final states

polarisation observables & kinematics



$$\Sigma_x = \frac{\sigma_{||} - \sigma_{\perp}}{\sigma_{||} + \sigma_{\perp}} \sim \cos 2\Phi$$

$$\Sigma_{dec} = \frac{\sigma_{||} - \sigma_{\perp}}{\sigma_{||} + \sigma_{\perp}}\Bigg|_{\hat{z}_{decay}}$$

single-polaris.

double-polarisation

$$G_{x,dec} \leftrightarrow P_{\gamma,lin} P_{T,z} \Sigma_{x,dec} \sin 2\Phi$$

$$E = \frac{\sigma_{3/2} - \sigma_{1/2}}{\sigma_{3/2} + \sigma_{1/2}} \leftrightarrow P_{\gamma,circ} P_{T,z}$$

overview ELSA (double-polarisation) proposals

PAC-05 / Sep'05

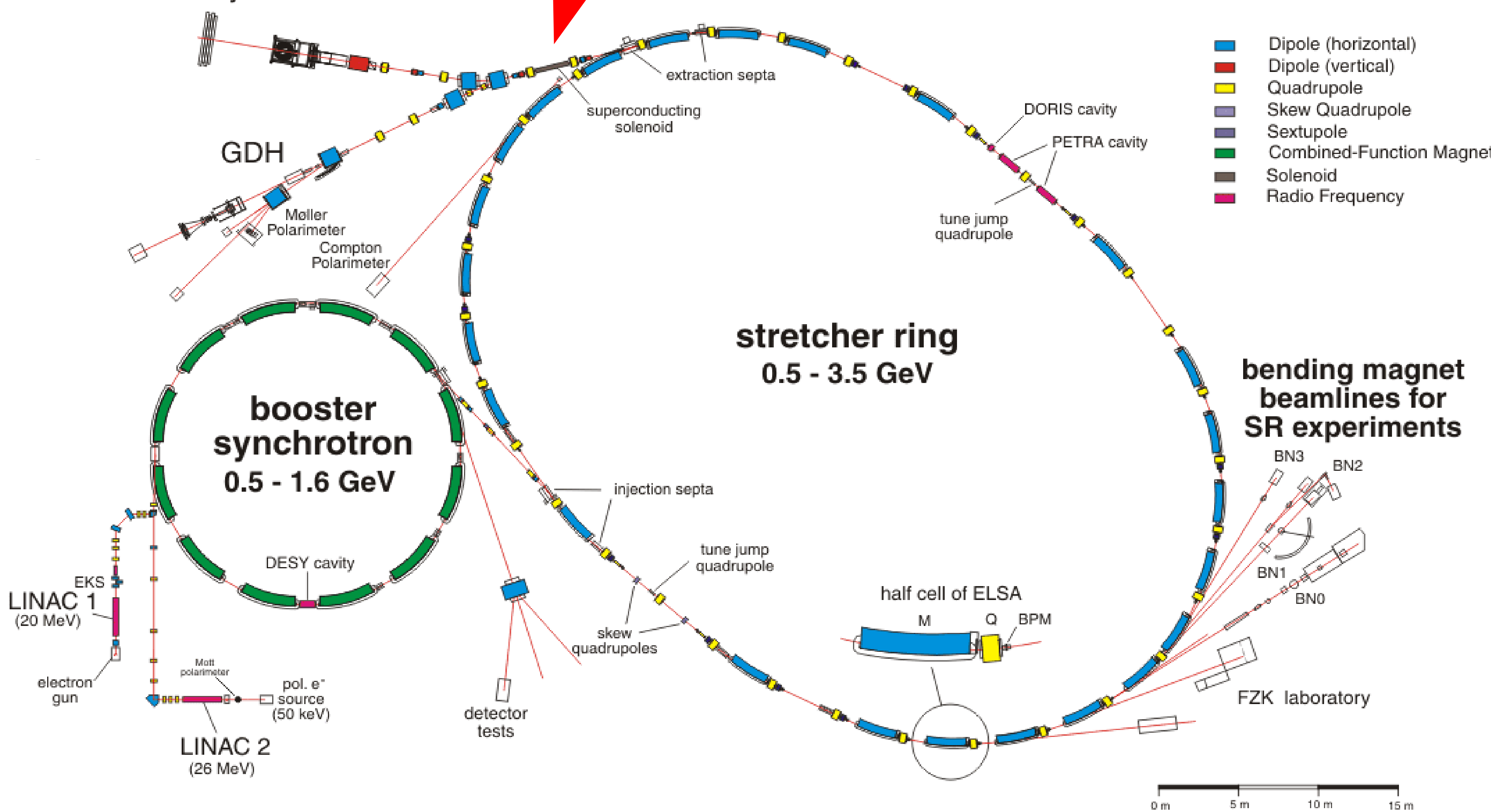
- * 1. ELSA/1-2005 — G in single π^0 and η production
- 2. ELSA/2-2005 — Helicity dependence in single π^0 and η production
- * 3. ELSA/3-2005 — Σ and G in η-photoproduction off neutron
- * 4. ELSA/4-2005 — Beam-target asymmetries in ω-photoproduction
- 5. ELSA/5-2005 — Meson-nucleus bound states
- * 6. ELSA/6-2005 — Double polarisation in $2\pi^0$-photoproduction
- 7. ELSA/7-2005 — Helicity difference in $\pi^0\eta$-photoproduction

experimental requirements

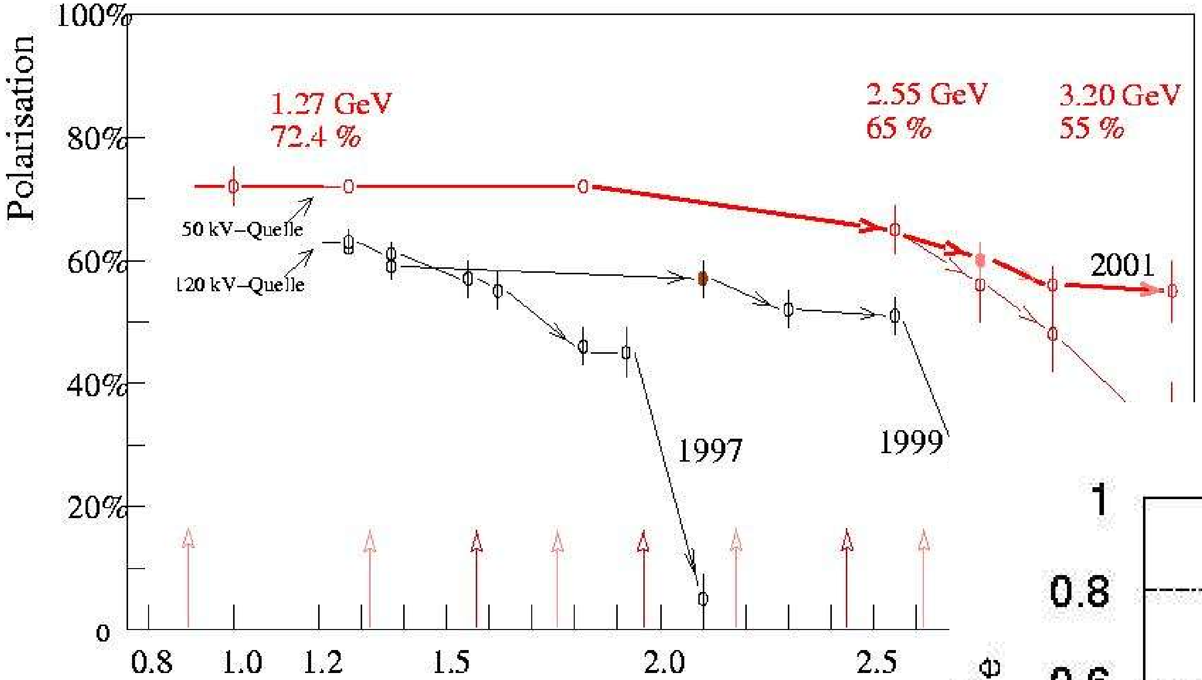
- accelerator of sufficient energy
- longitudinal electron-beam polarisation
- photon tagging
- circular & linear photon-beam polarisation
- beam polarimetry
- polarised target
- (recoil polarimetry)
- 4π detector

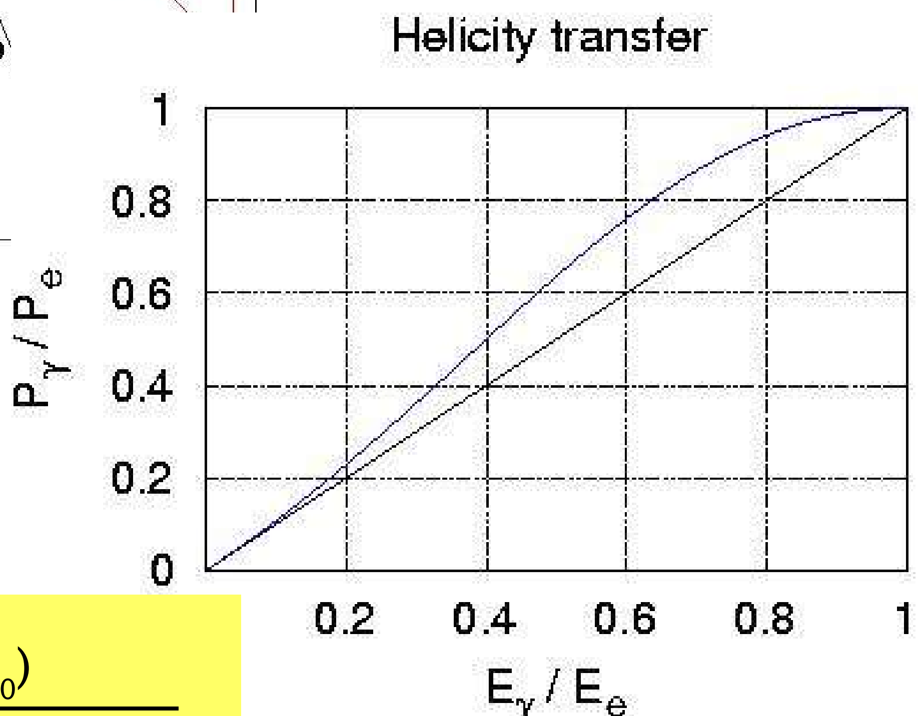
ELSA facility

solenoid ↔ $E_0^{max} = 2.46$ GeV



photon beam circular polarisation



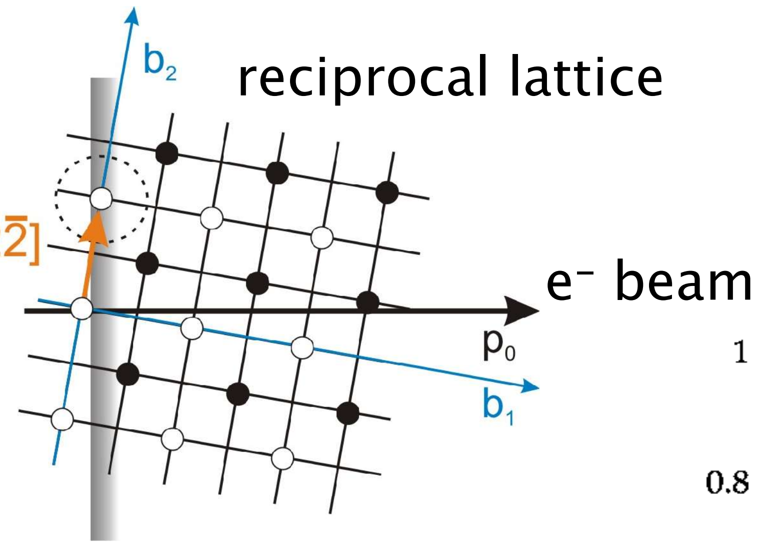


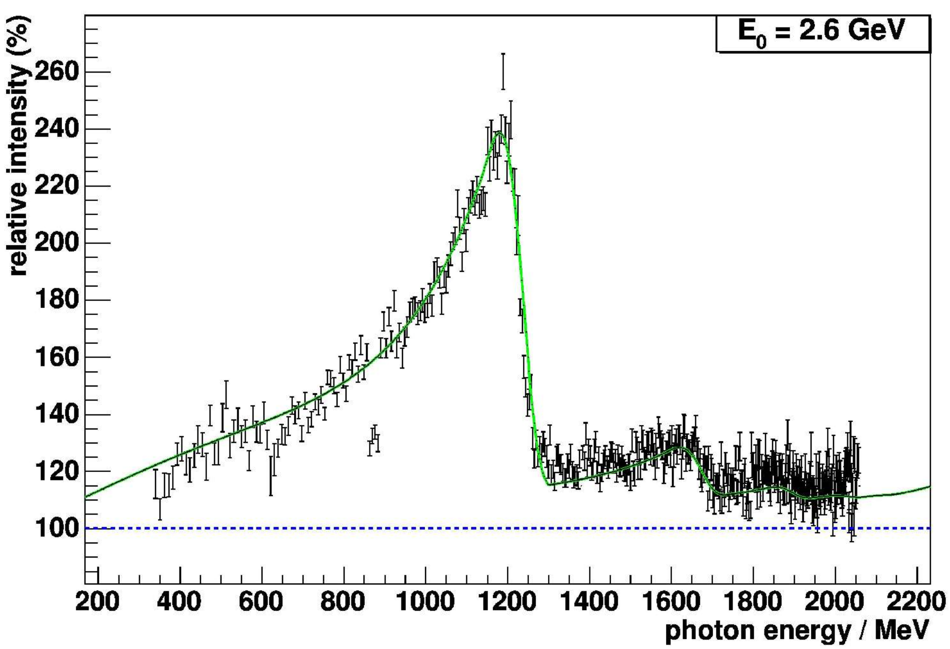
$$\frac{P_{\gamma,circ}}{P_e} = \frac{E_\gamma}{E_0}\,\frac{1 + \frac{1}{3}(1-E_\gamma/E_0)}{1 - \frac{2}{3}(1-E_\gamma/E_0) + (1-E_\gamma/E_0)^2}$$

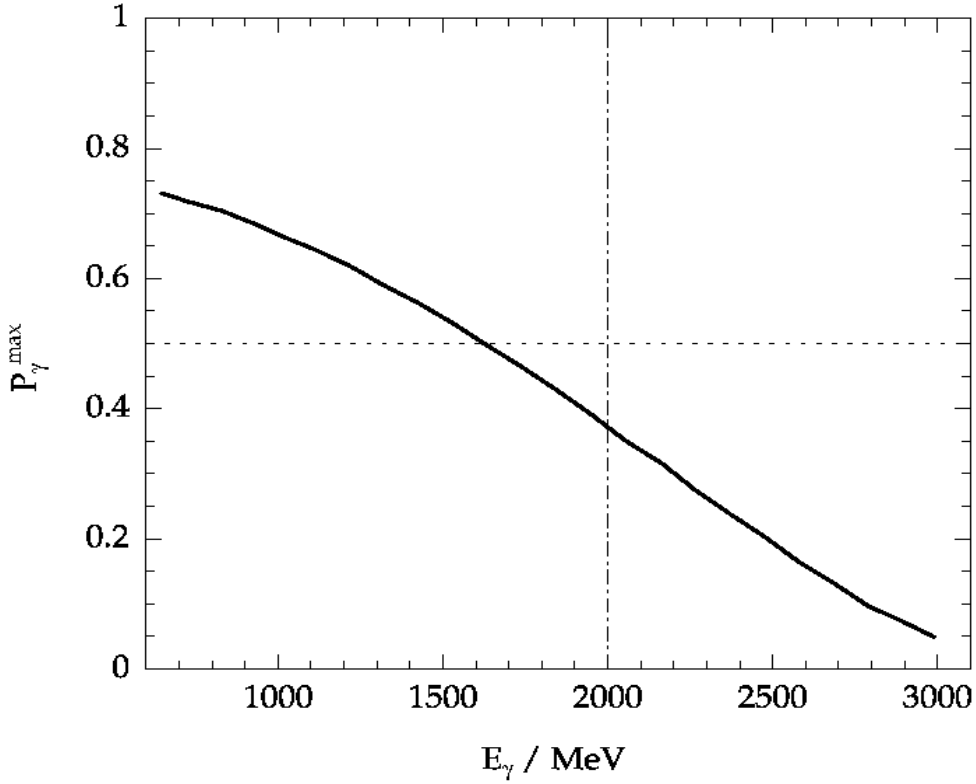
H. Olsen & L.C. Maximon, PR 114 (1959) 887

linear polarisation: Coherent Bremsstrahlung

D. Elsner

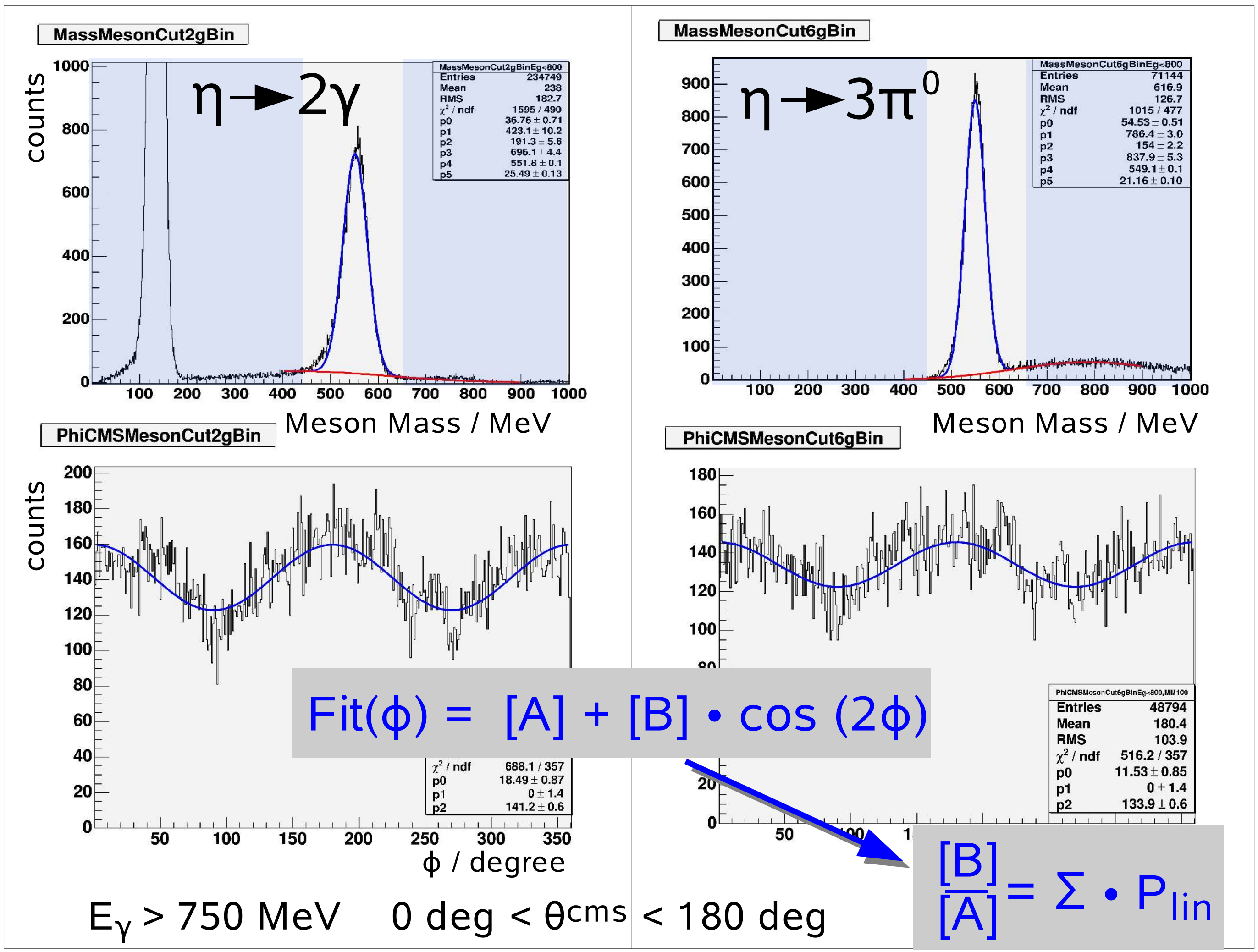






η-photoproduction: beam asymmetry

D. Elsner



$$Fit(\phi) = [A] + [B] \cdot \cos(2\phi)$$

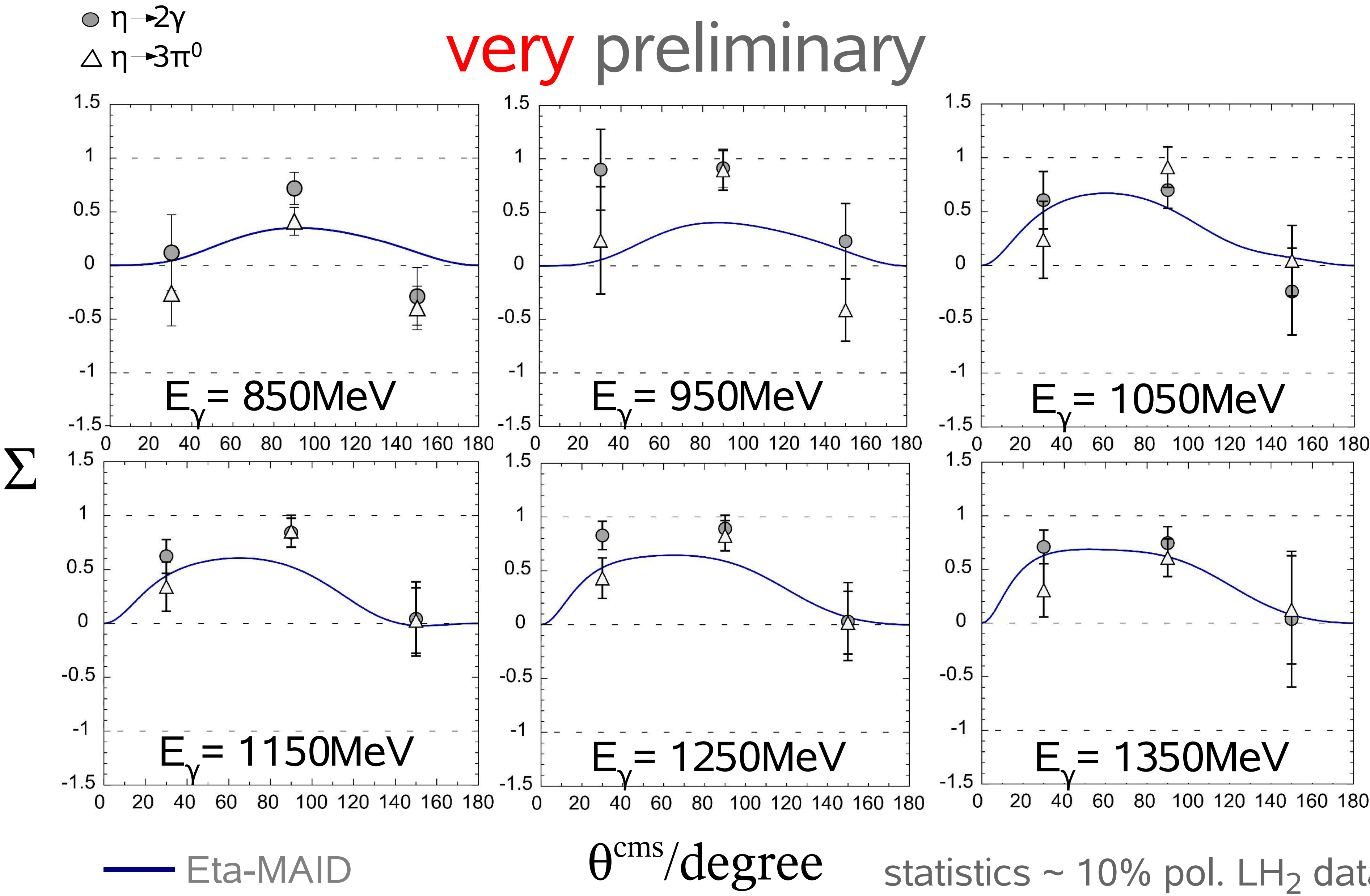
$$\frac{[B]}{[A]} = \Sigma \cdot P_{lin}$$

$E_\gamma > 750$ MeV   0 deg $< \theta^{cms} <$ 180 deg

η-photoproduction: beam asymmetry

D. Elsner

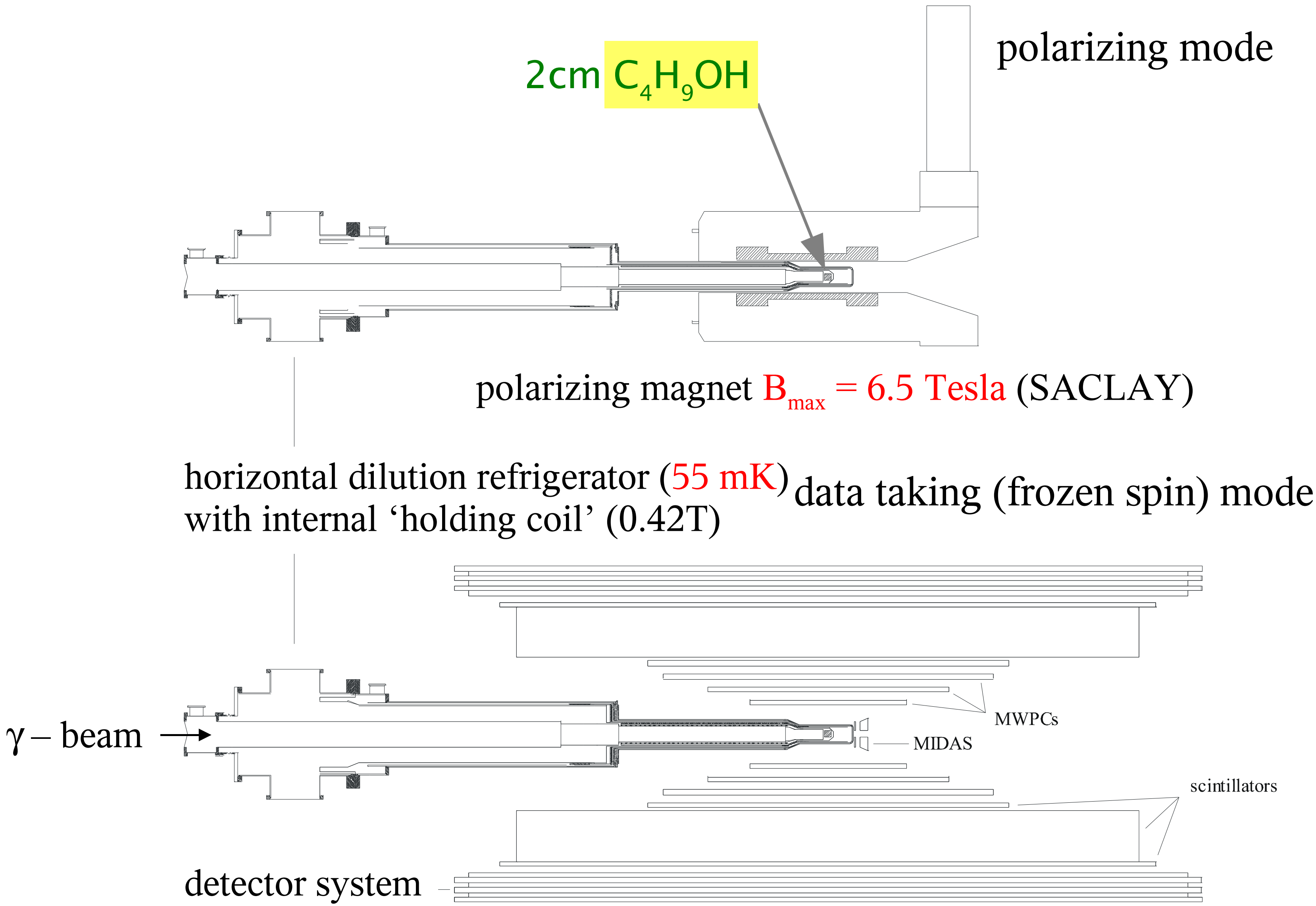
very preliminary



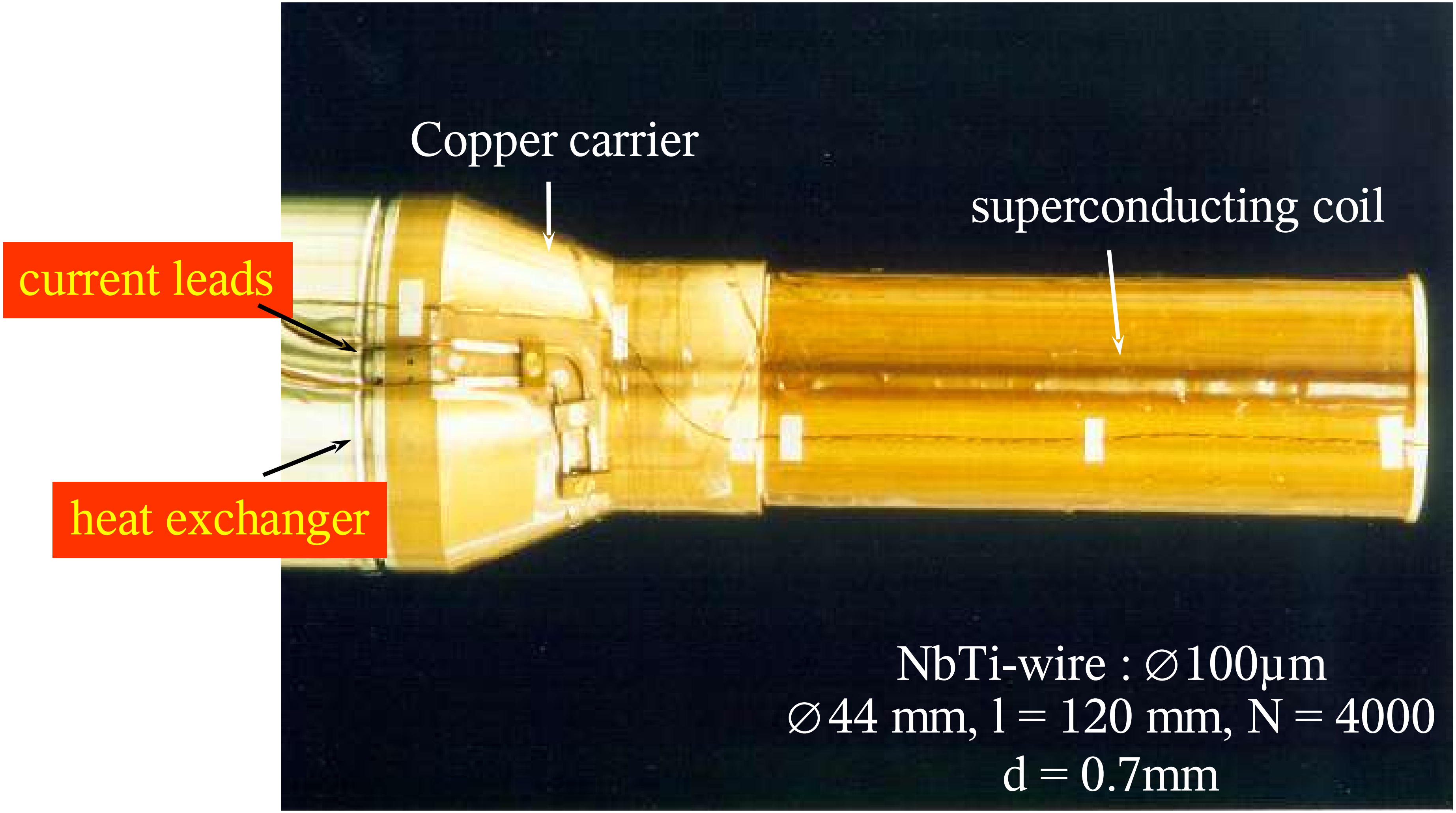
statistics ~ 10% pol. LH_2 data

Bonn polarised frozen spin target

H. Dutz et al.



Bonn polarised frozen spin target

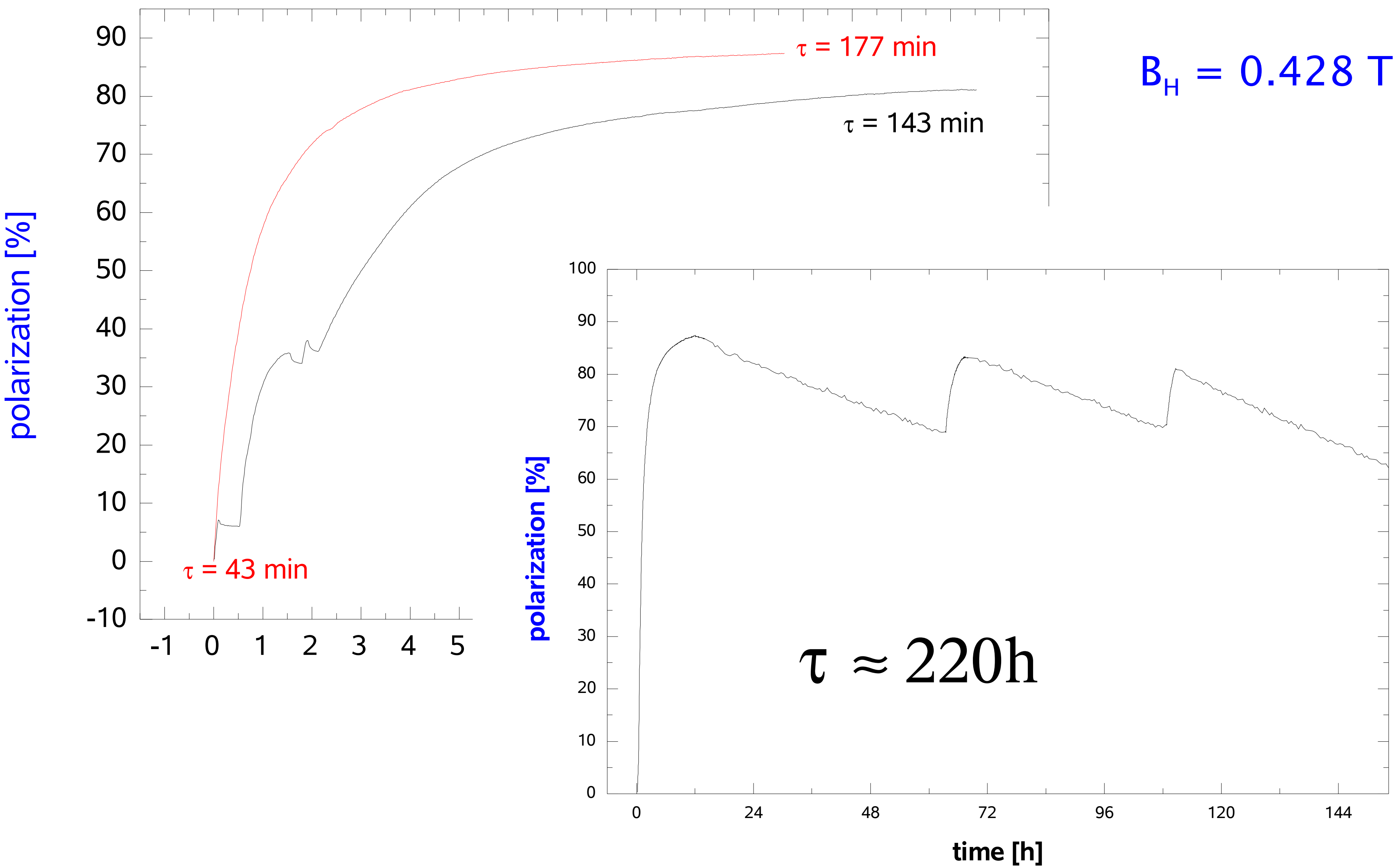


reliable operation at B_h = 0.44 T @ 11.5 A, T < 1.2 K

NIM A 356 (1995) 111, NIM A 418 (1998) 233

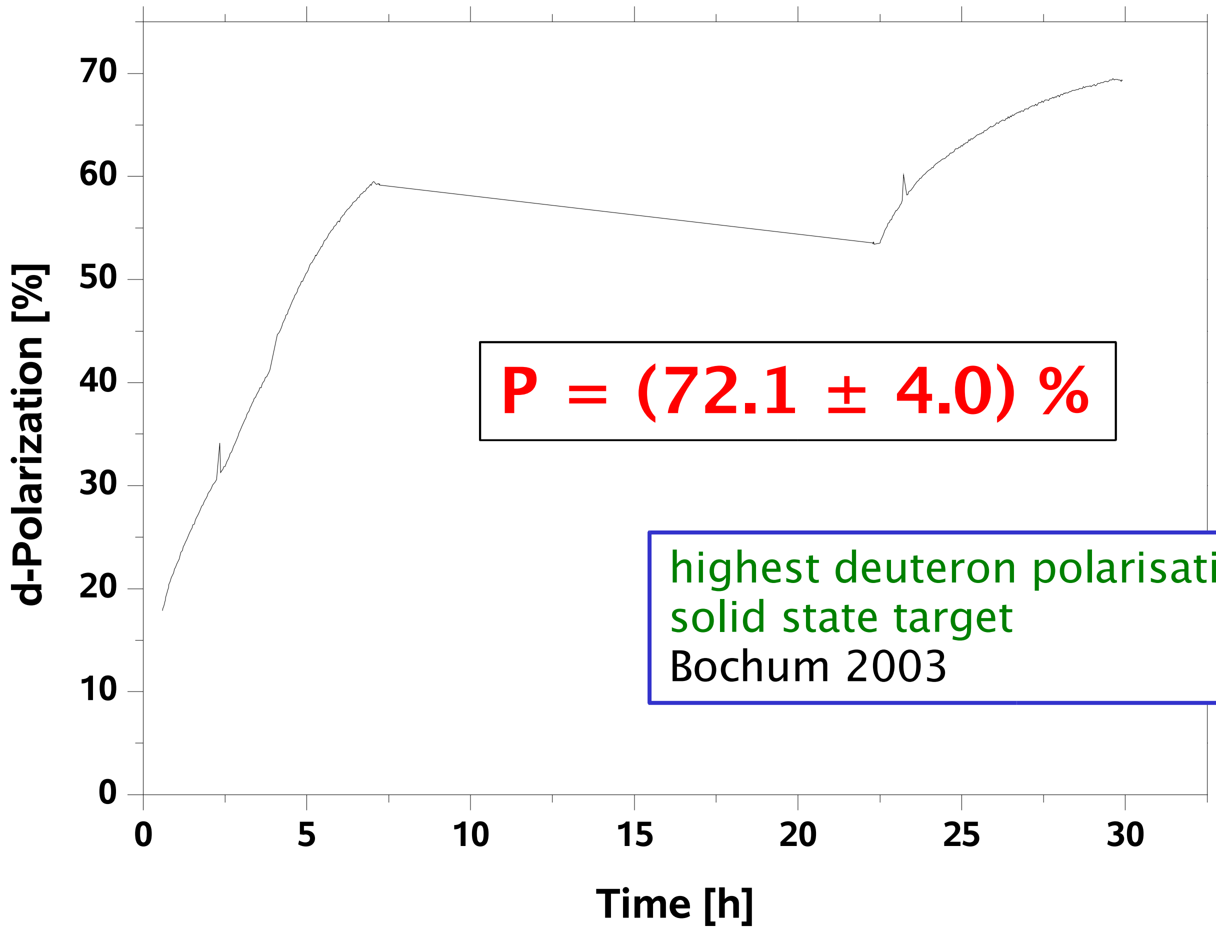
Bonn polarised frozen spin target

$B_H = 0.428$ T



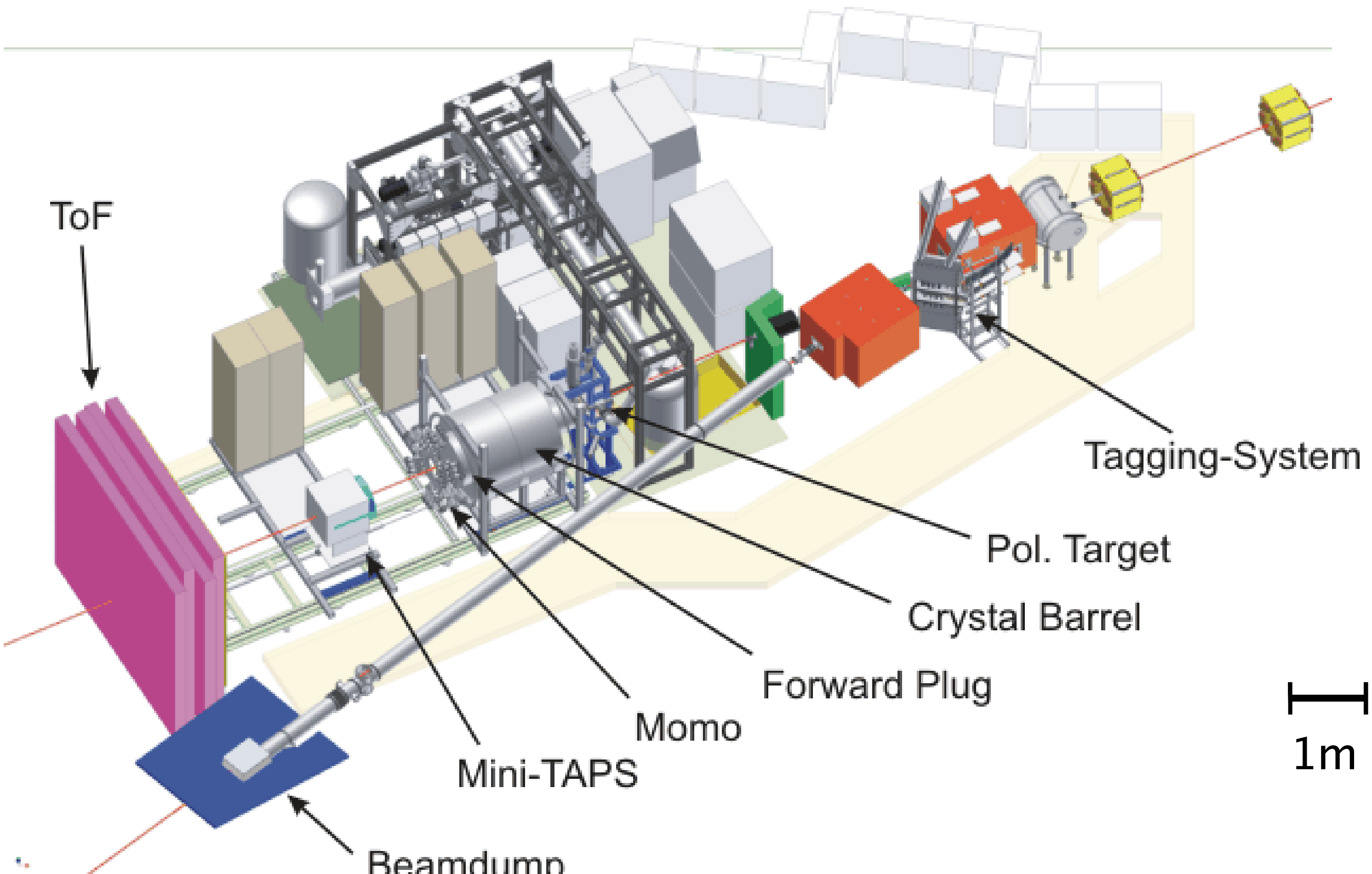
Bonn polarised frozen spin target

deuteron

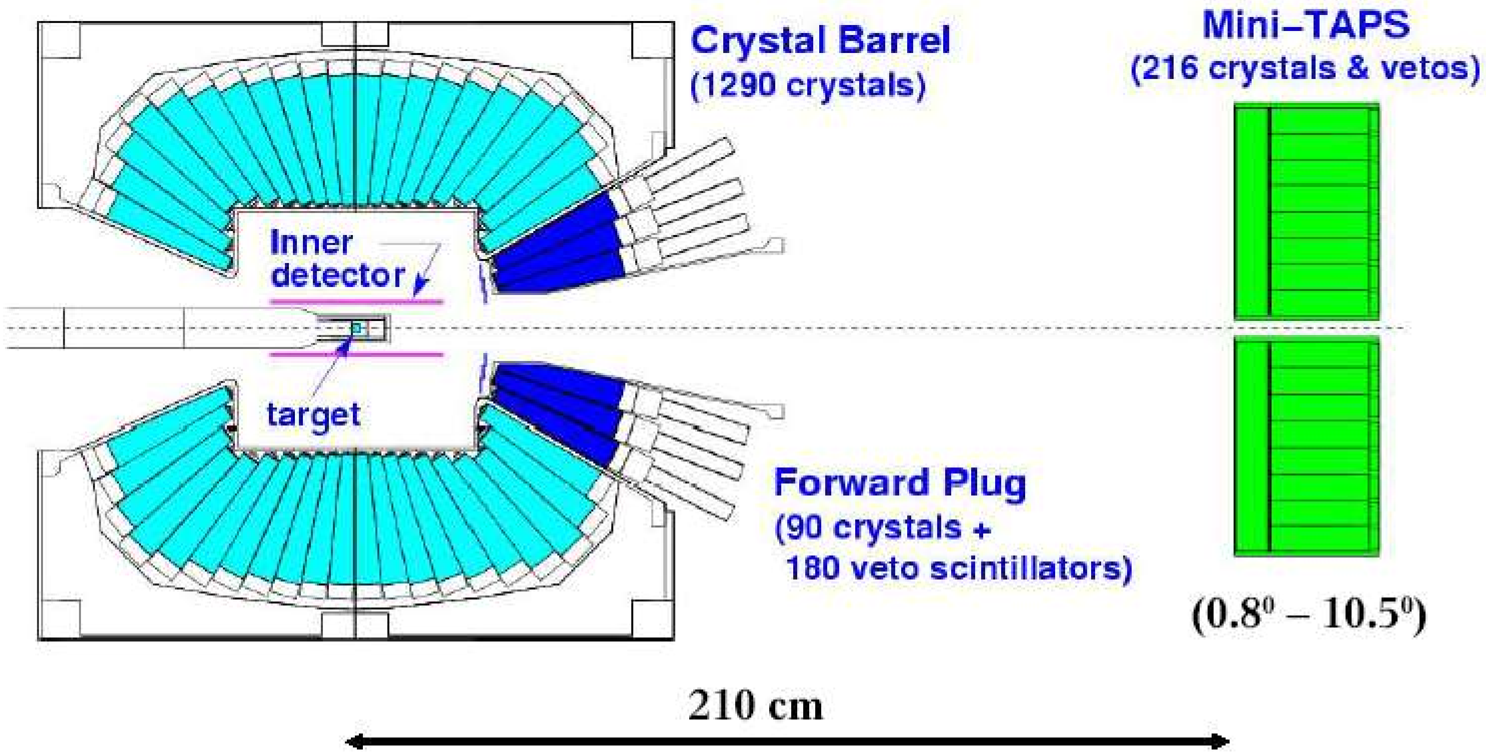


highest deuteron polarisation in a solid state target
Bochum 2003

Setup


ToF
Tagging-System
Pol. Target
Crystal Barrel
Forward Plug
Momo
Mini-TAPS
Beamdump
1m

Setup

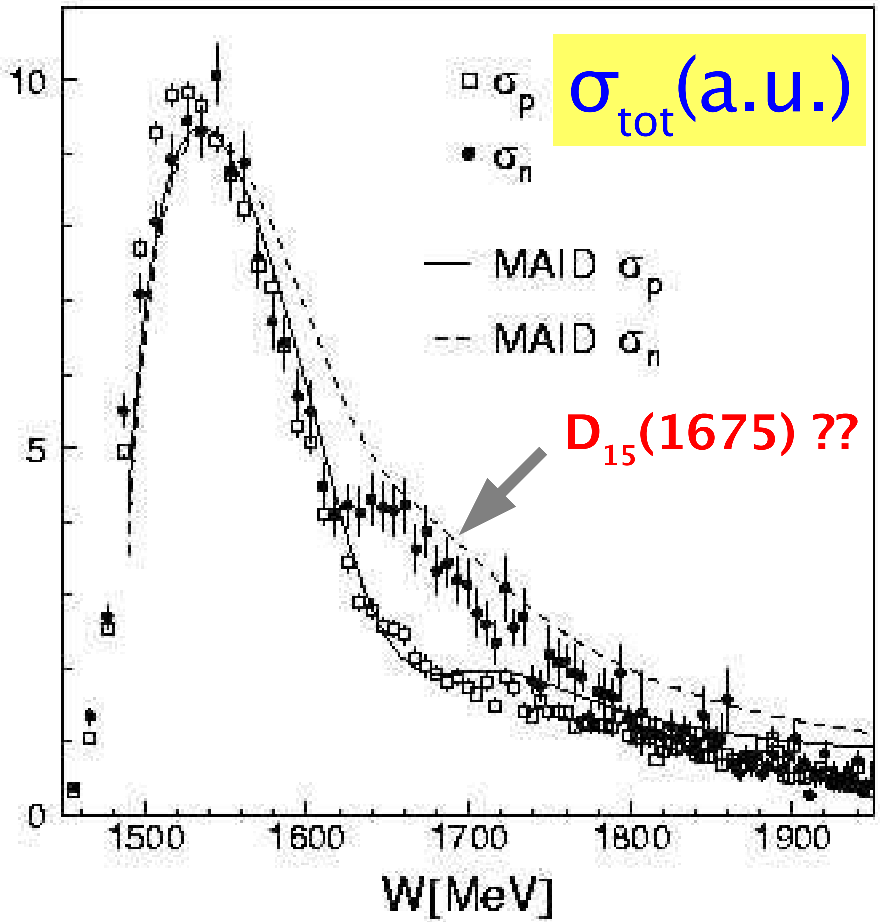


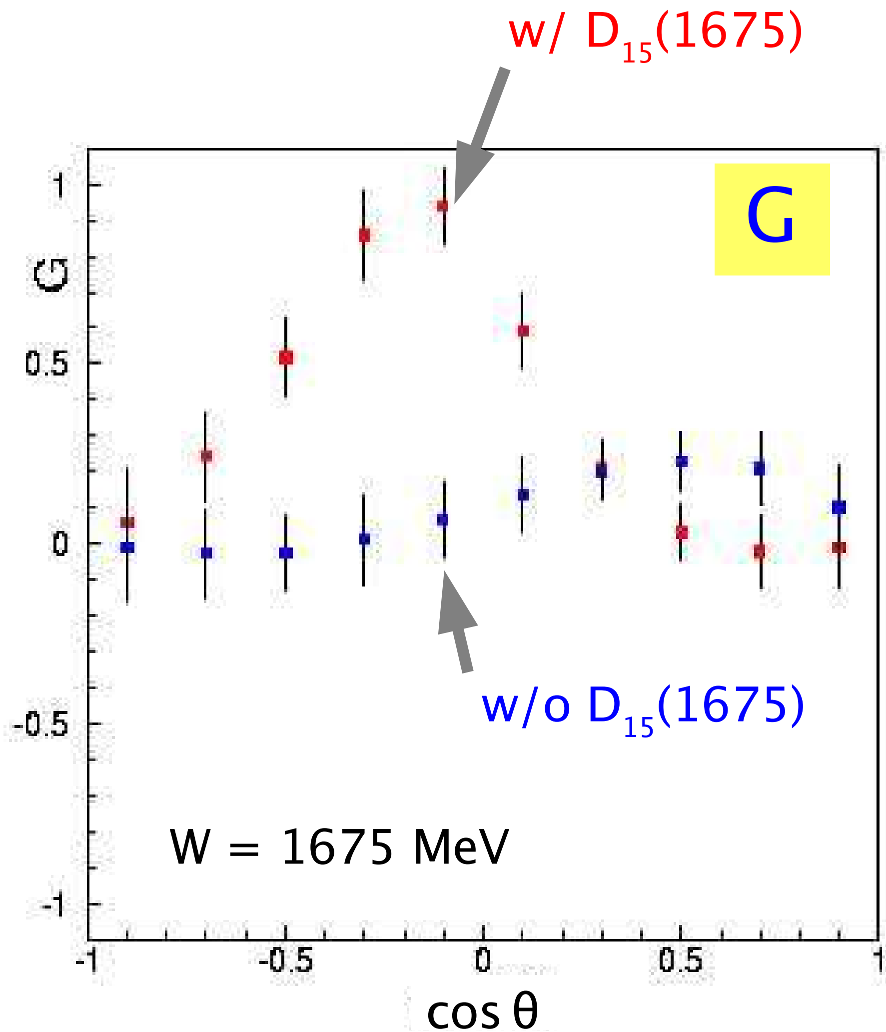
Crystal Barrel
(1290 crystals)
Mini–TAPS
(216 crystals & vetos)
Inner
detector
target
Forward Plug
(90 crystals +
180 veto scintillators)
(0.8° – 10.5°)
210 cm

γ n → n η quasifree off d

B. Krusche et al.

CrystalBarrel/TAPS prel.



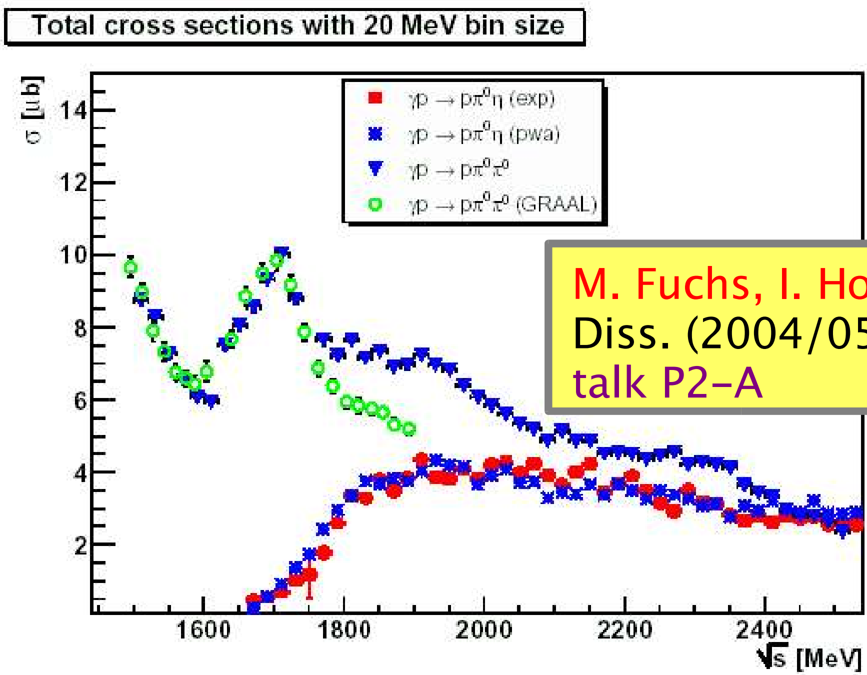


simulation based on η–MAID

L. Tiator
Wednesday talk

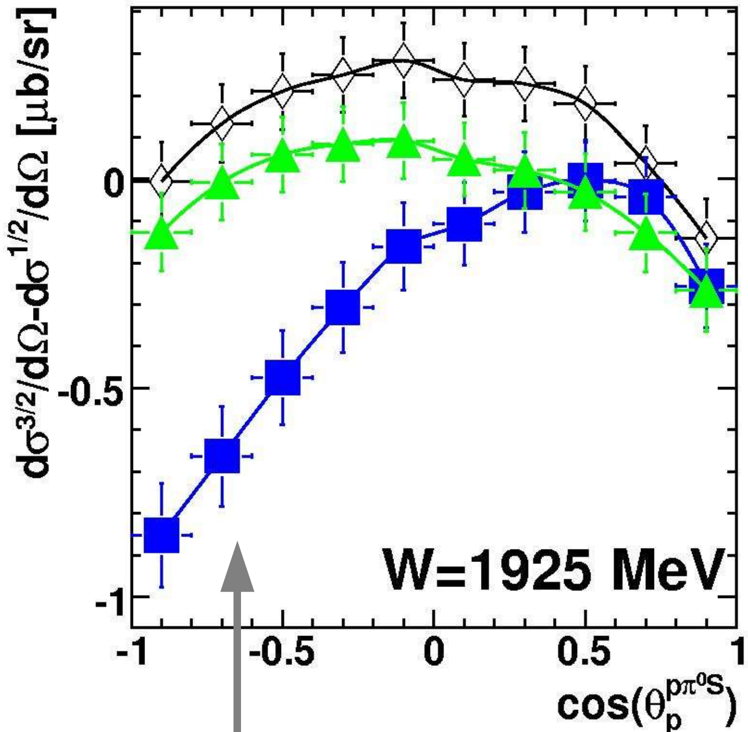
$\gamma p \rightarrow p\, \pi^0 \pi^0$

U. Thoma et al.



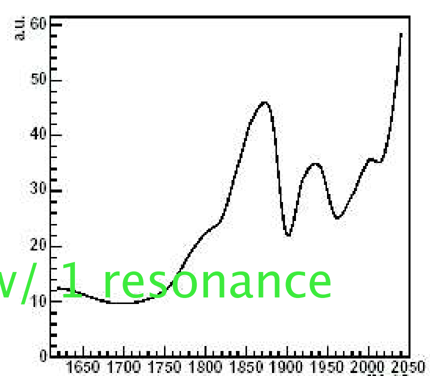
M. Fuchs, I. Horn
Diss. (2004/05)
talk P2-A

$\sigma_{3/2} - \sigma_{1/2}$

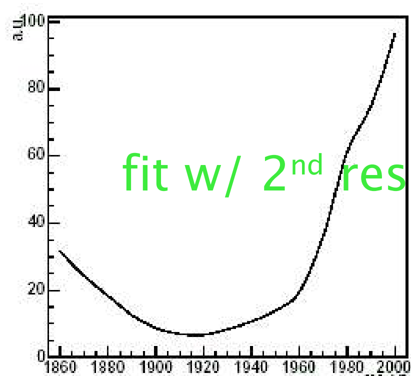


strength:
~ 60-70 % from $\Delta^+(1232)\,\eta$ with L=0:
$\Delta(1700)D_{33}$ and $\Delta(1940)D_{33}$

χ^2



fit w/ 1 resonance



fit w/ 2nd resonance

without $D_{33}(1940)$
without $P_{33}(1920)$

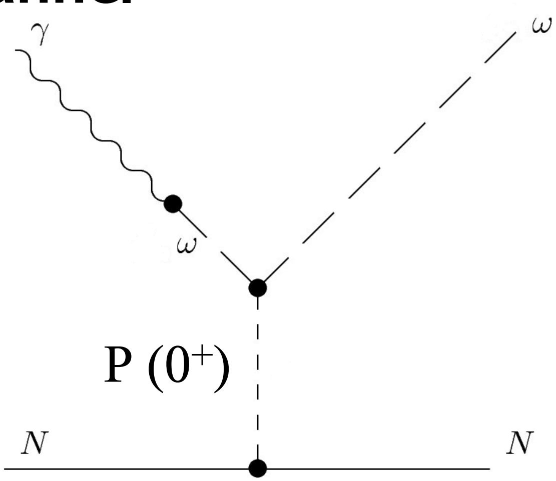
800 hs @ 3.2 GeV
(ELSA/6-2005)

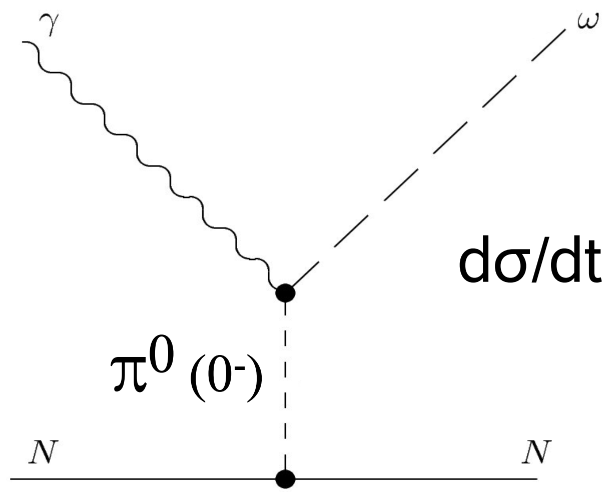
$\gamma p \to p \omega$ ↔ resonances ?

N* SU(6)xO(3)	exp. status	Isgur-Karl assignment	J^P	coupling πN	ωN	tot. width
$S_{11}(1535)$	****	N(1535)	$1/2^-$	85	0	164
$P_{11}(1710)$	***	N(1710)	$1/2^+$	42	32	242
$P_{13}(1870)$	*	N(1870)	$3/2^+$	10	98	149
$P_{13}(1950)$	missing	N(1955)	$3/2^+$	1.2	90	236
$P_{13}(2030)$	missing	N(2060)	$3/2^+$	0.3	98	145
$D_{15}(1675)$	****	N(1670)	$5/2^-$	30	0	130
$F_{15}(1680)$	****	N(1715)	$5/2^+$	50	1.4	77
$F_{15}(1995)$	missing	N(1955)	$5/2^+$	0.2	184	324
$F_{15}(2000)$	*	N(2025)	$5/2^+$	1.7	180	316

$\gamma\, p \rightarrow p\, \omega$

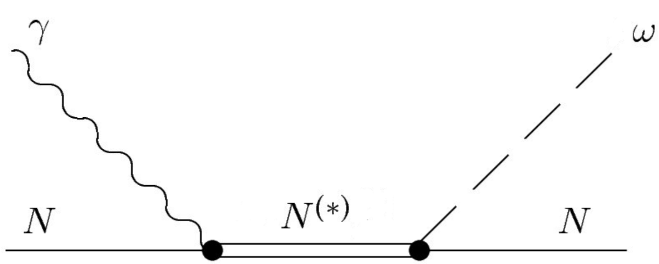
t-channel

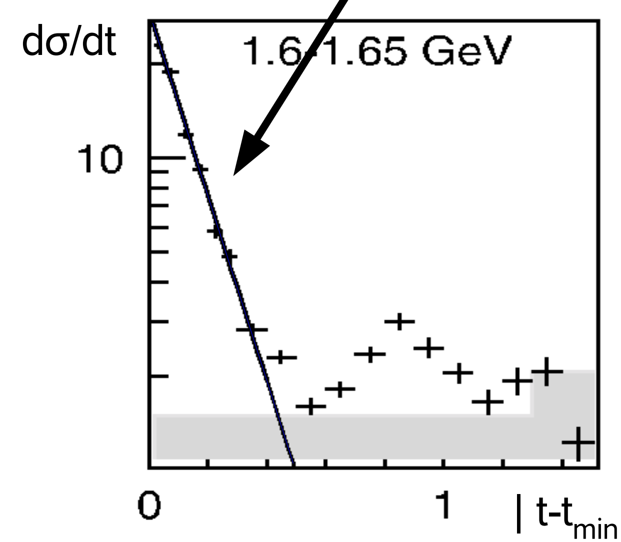




$$d\sigma/dt \approx d\sigma/dt\,\big|_{t=t_{min}} \bullet e^{-b\,|t|}$$

s-channel



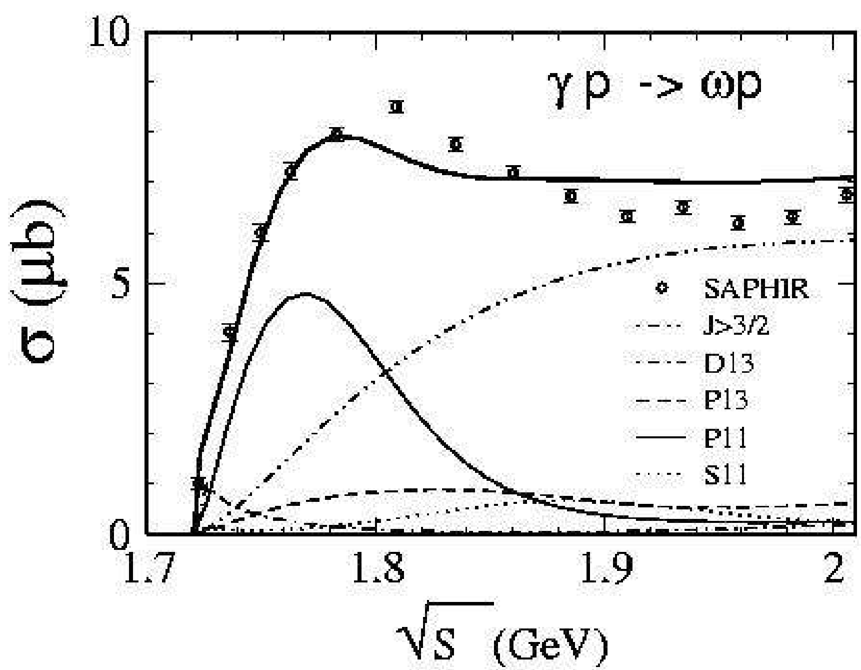


J. Barth *et al*. EPJ **A18**, 117 (2003)

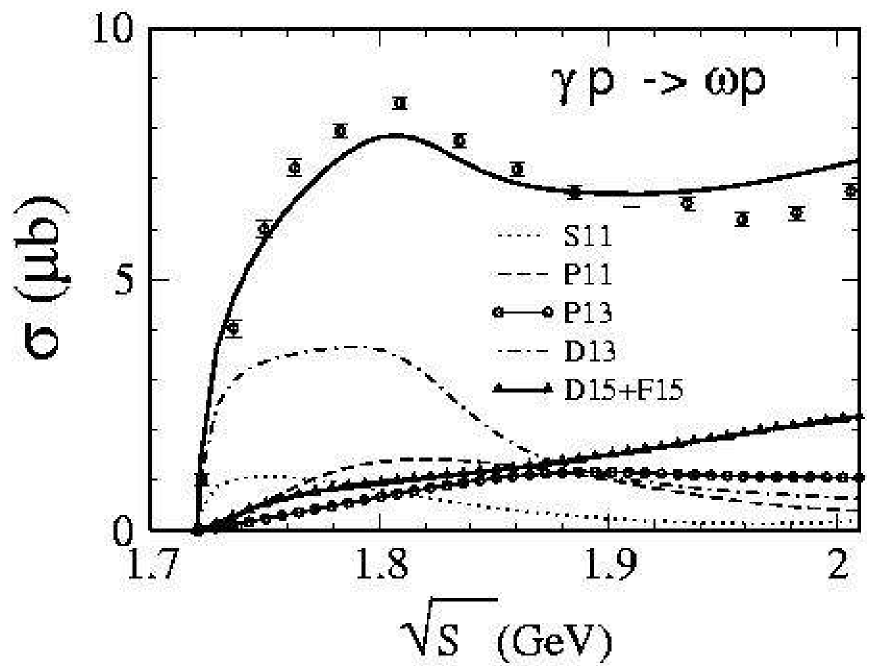
$\gamma p \rightarrow p \omega \quad \leftrightarrow \quad$ resonances ?

talk H. Lenske

Shklyar et al. (Giessen group)   nucl-th/0412029v2



Penner et al., PR C66 (2002) 055212



$J_{res} \leq 3/2$

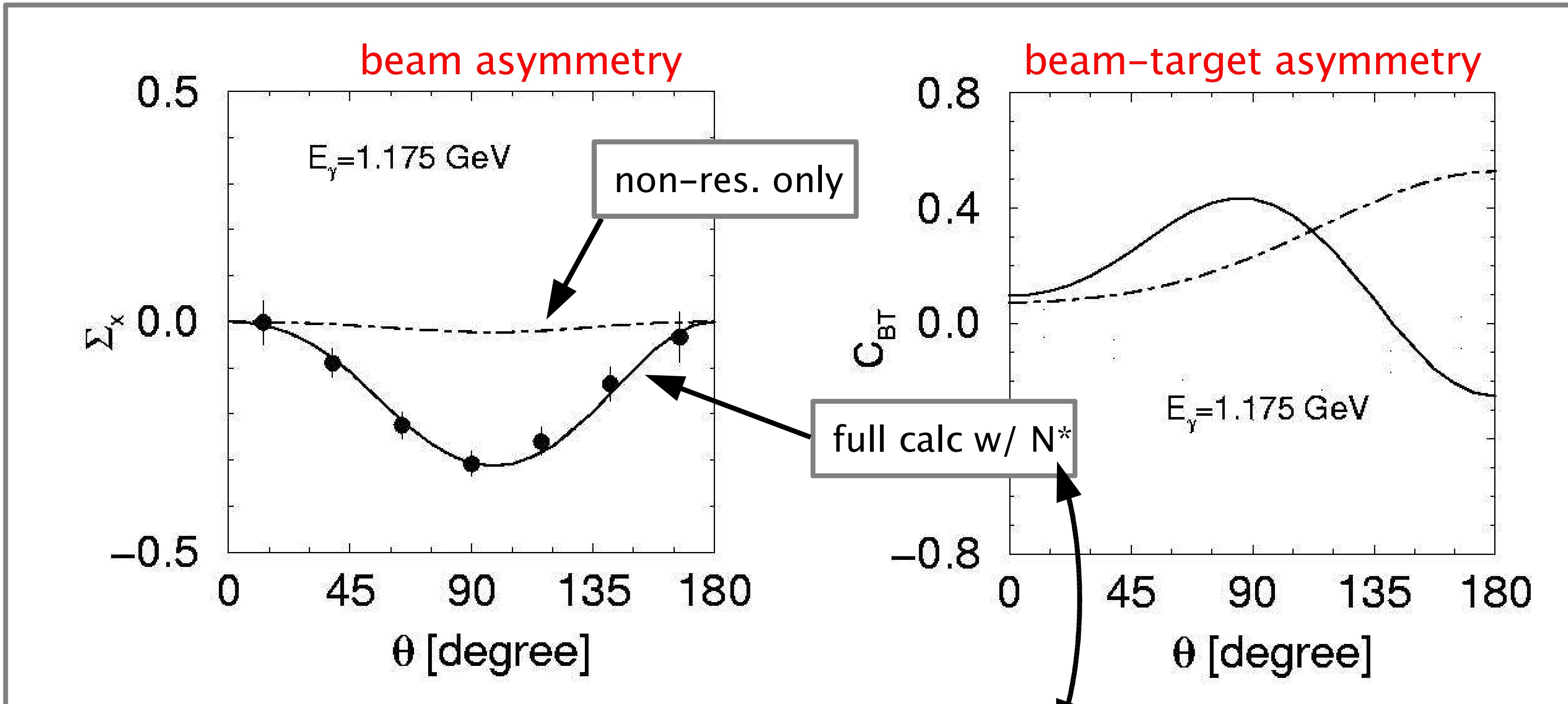
P_{11}(1710) main contrib. @ thresh.

$J_{res} \leq 5/2$

P_{11}(1710) negligible

$\gamma\, p \rightarrow p\, \omega$

polarisation observables



preliminary data from GRAAL
J. Ajaka et al.,
AIP conf. proc. 570 (2001) 198

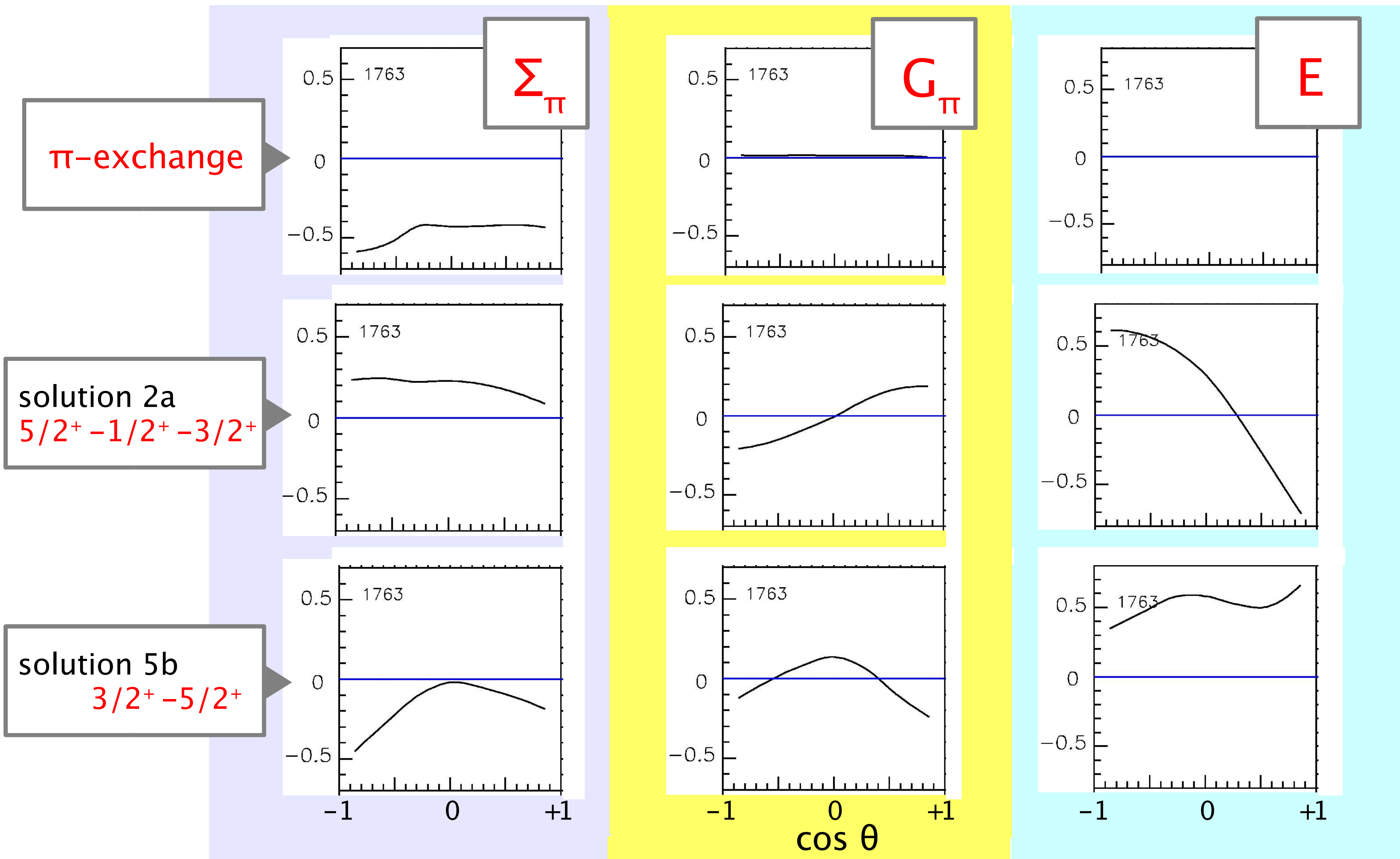
F_{15}(1680) dominating contrib.

A. I. Titov and T.-S.H. Lee
PR C66 (2002) 015204

$\gamma\, p \rightarrow p\, \omega$

polarisation observables

Bonn PWA
A. Sarantsev, priv. comm.



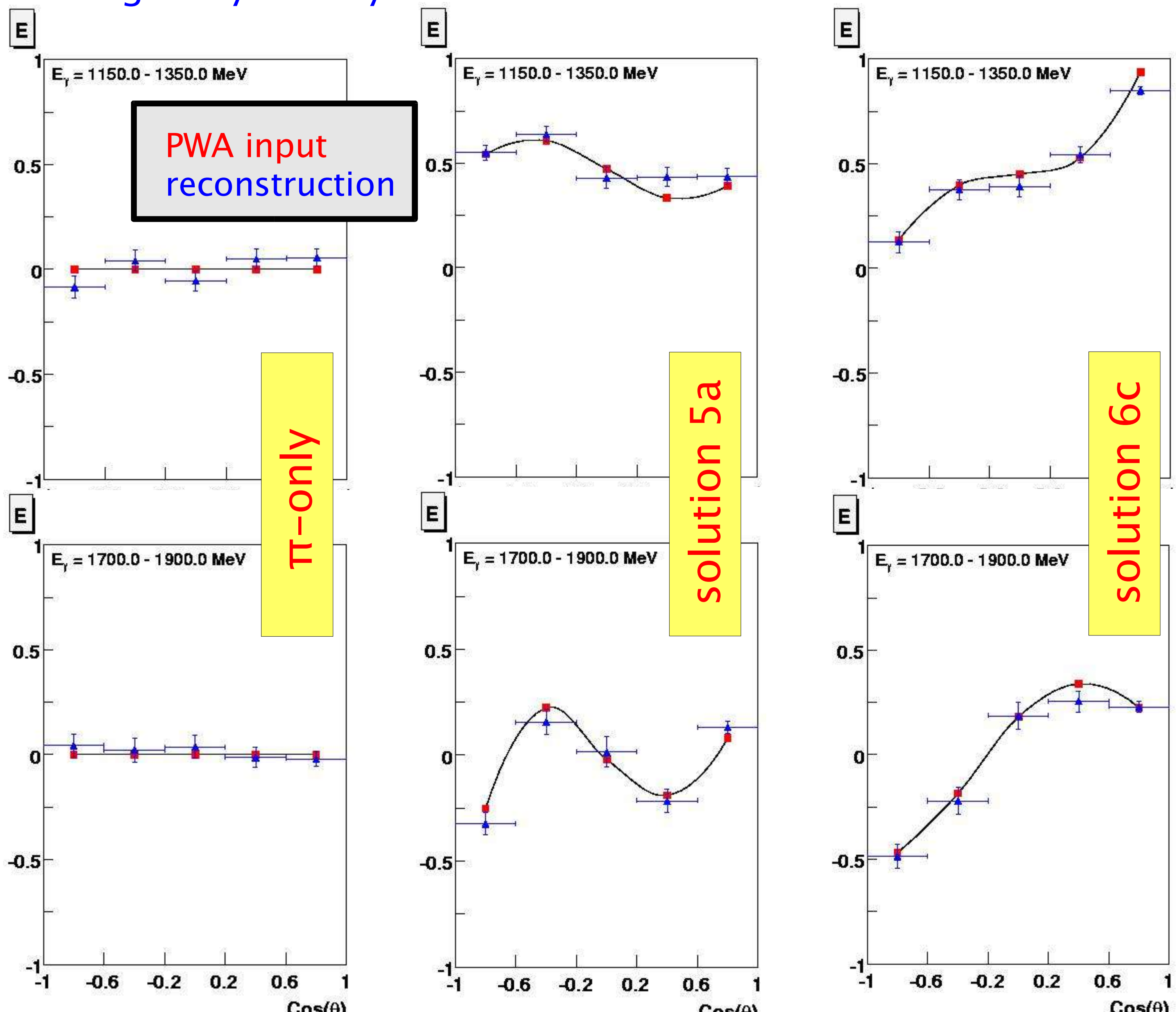
$\gamma\, p \rightarrow p\, \omega$ Monte-Carlo

beam-target asymmetry

E_γ/MeV =

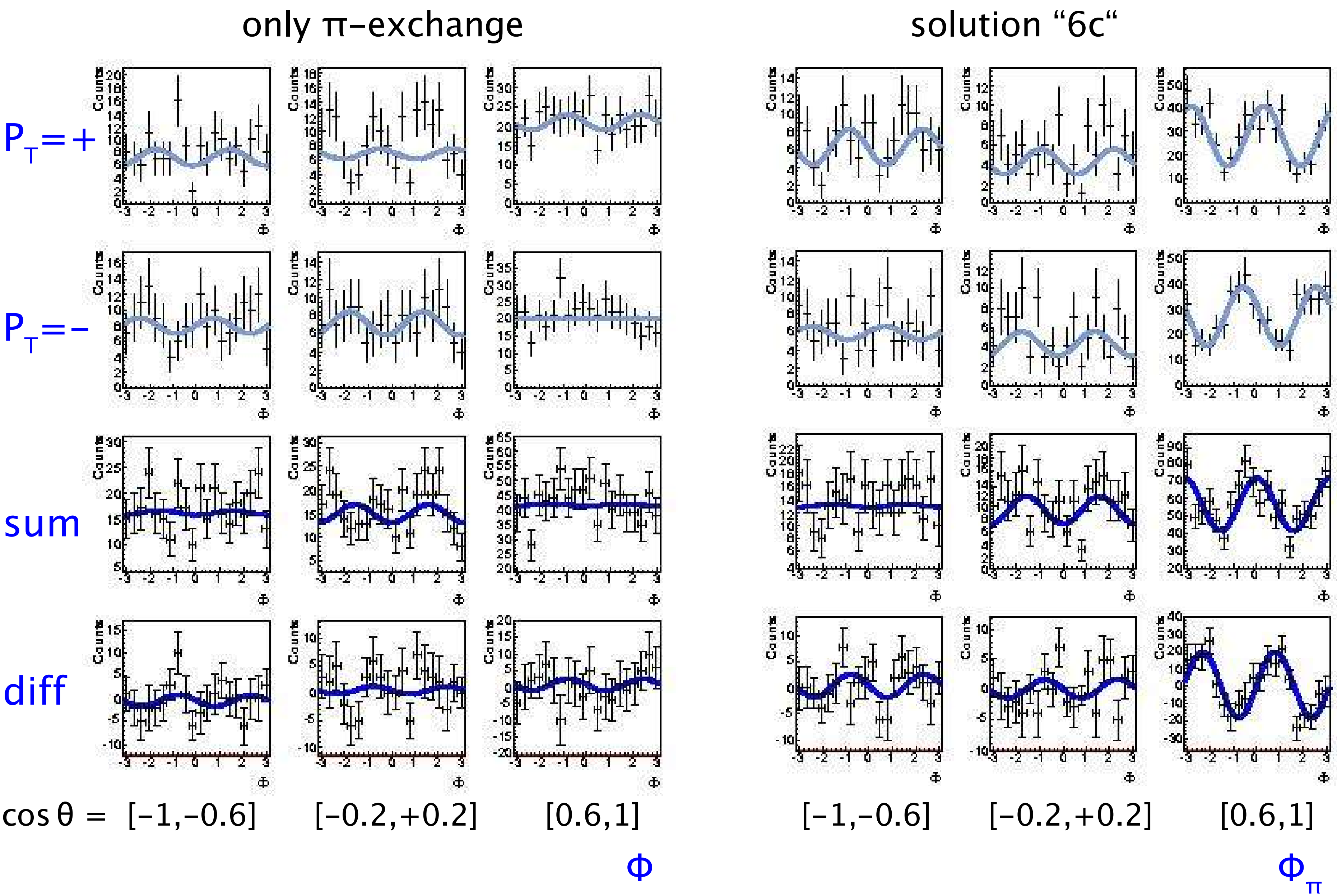
1150 – 1350

1700 – 1900



γ p → p ω Monte-Carlo

azimuthal angular distributions @ 1700-1900 MeV



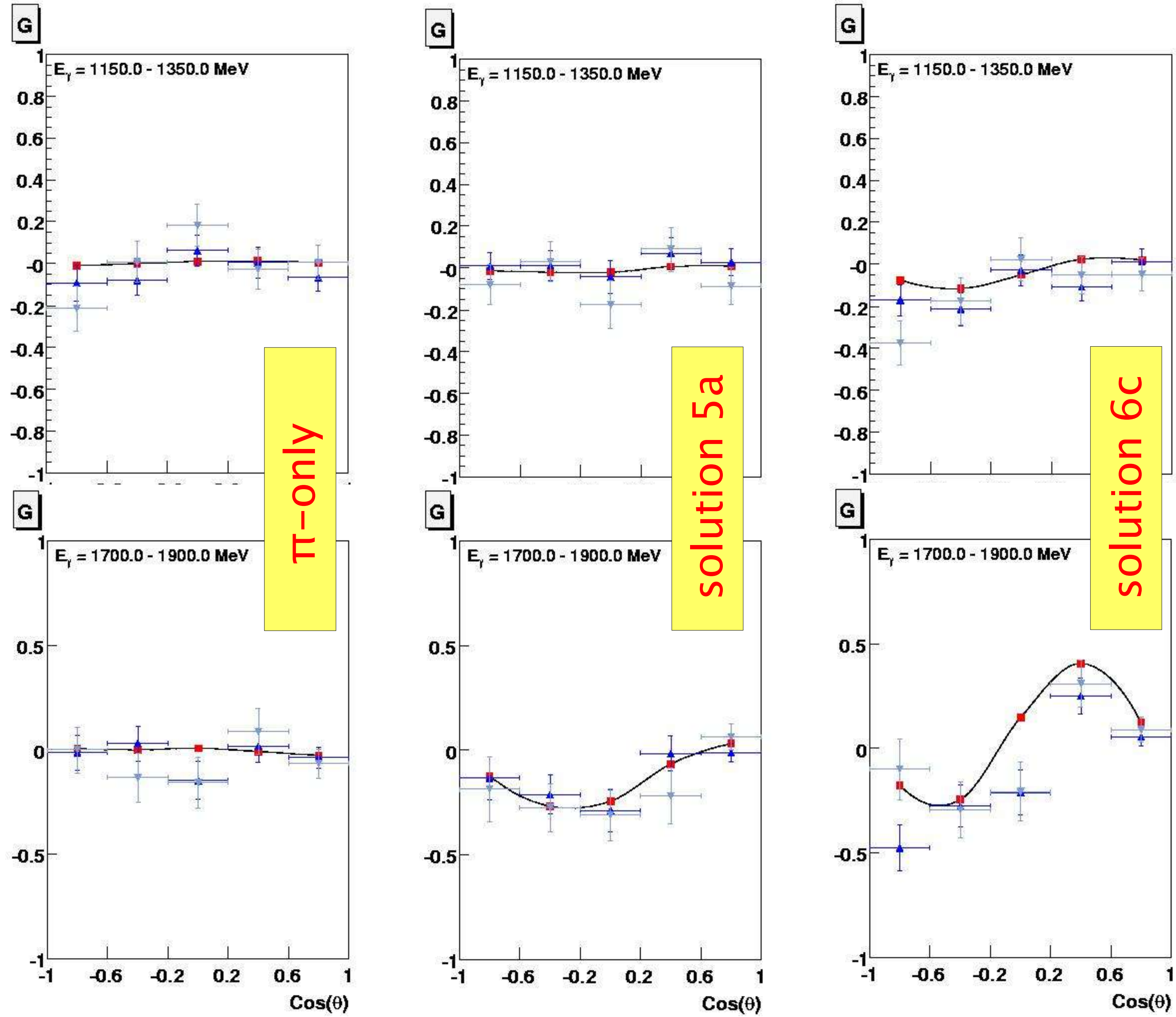
γ p → p ω Monte-Carlo

G-asymmetry

E_γ/MeV =

1150 – 1350

1700 – 1900



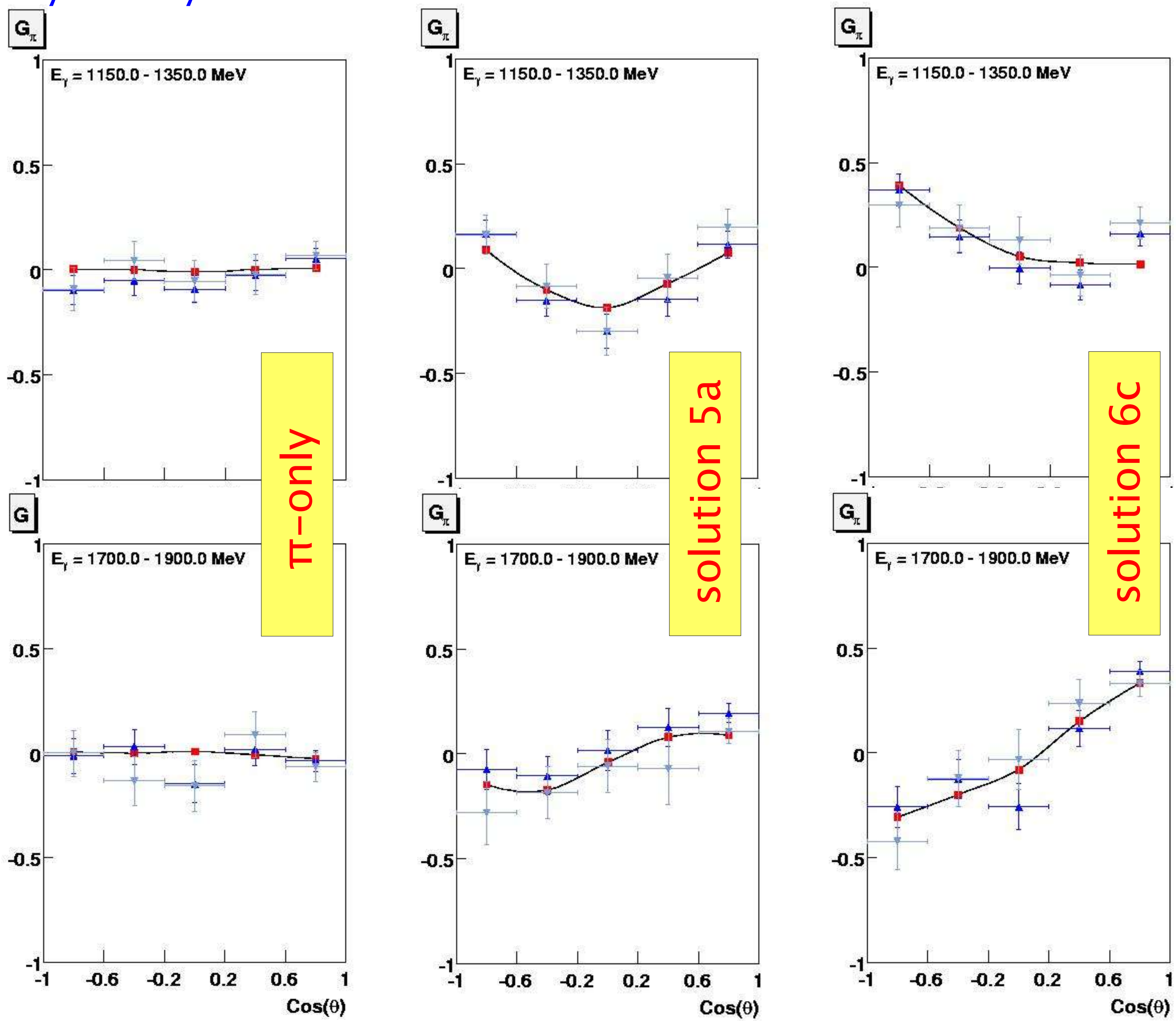
γ p → p ω Monte-Carlo

G_π-asymmetry

E_γ/MeV =

1150 – 1350

1700 – 1900



polarisation programme @ ELSA

Summary

supported by DFG
& fed. state NRW

SFB–TR 16

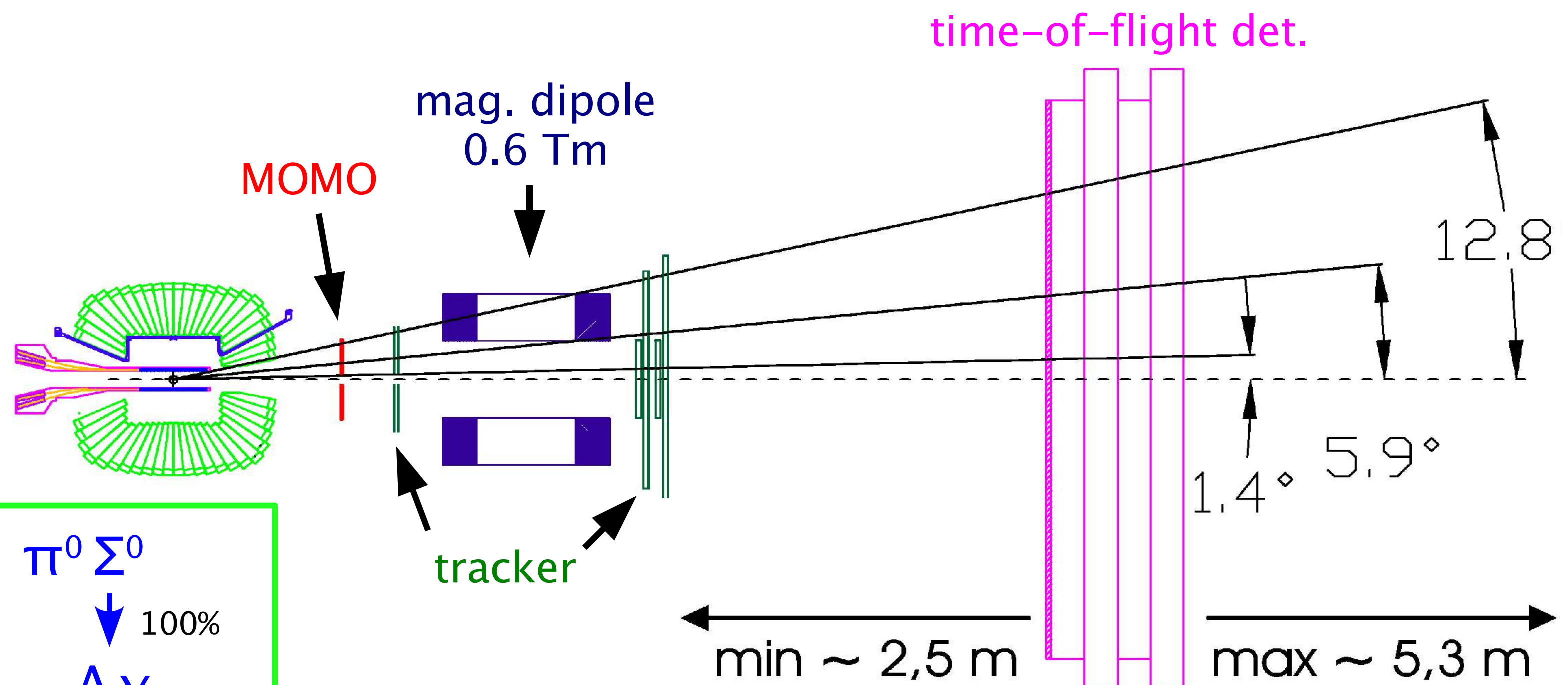
- Crystal Barrel @ ELSA
  - → **4π multi-photon detector & forward extensions**
- first results
  - → single π^0/η production — $N(2070)D_{15}$
  - sequential decays $\pi^0\pi^0$/ $\pi^0\eta$ — $\Delta(1940)D_{33}$
- PWA
  - “incomplete“ experiments
- linear & circular beam polarisation
- target & recoil polarisation
- next
  - $\gamma + N \rightarrow N^* \rightarrow \omega/\eta/\pi^0 + N$ — **double polarisation beam / long. pol. target**
- future plans
  - → forward spectrometer
  - $K^+K^- \leftrightarrow \Phi$
  - $K^+ \Lambda(1405) \rightarrow \pi^0 \Sigma^0$

EXTRA PAGES

$\gamma\, p \rightarrow K^+\, \Lambda(1405)$

planned experiment @ ELSA

- SFB/Transregio 16
- double polarization beam/target
- reaction specific forward extensions → K^+ id



$\Lambda(1405) \rightarrow \pi^0\, \Sigma^0$

↓ 100%

$\Lambda\, \gamma$

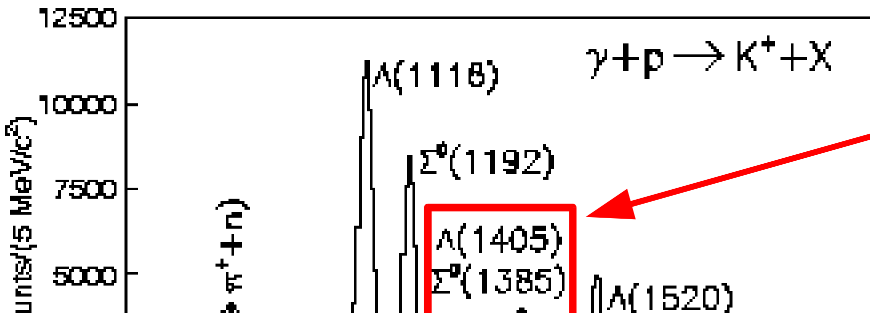
36% ↓

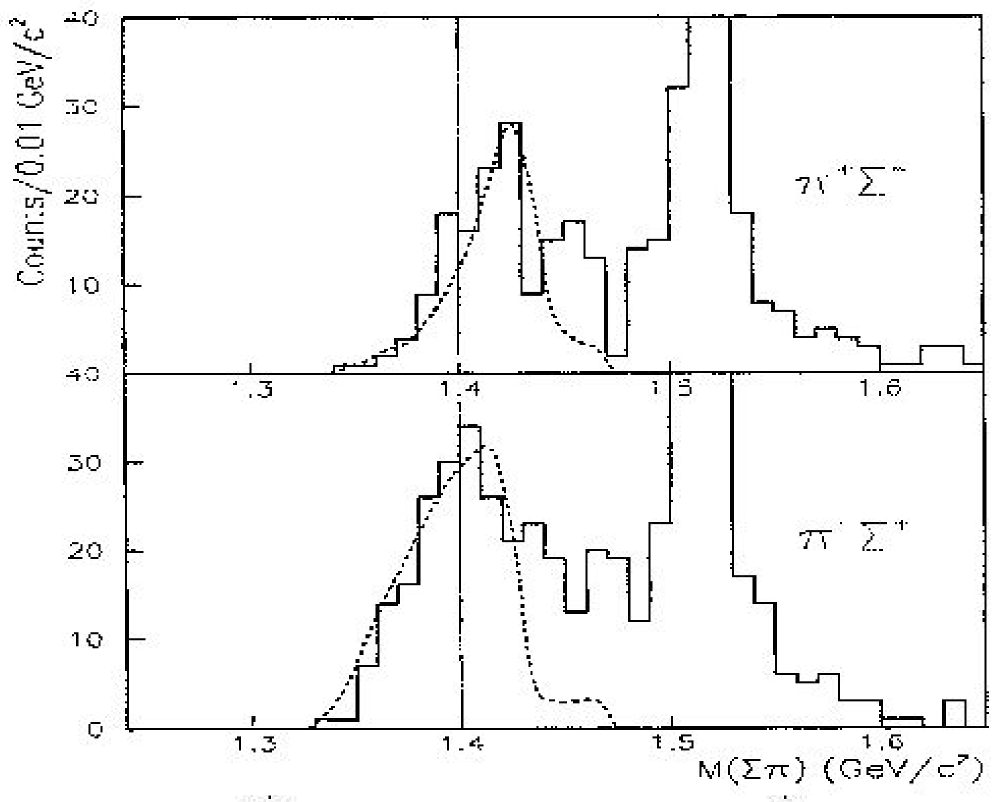
$n\, \pi^0$

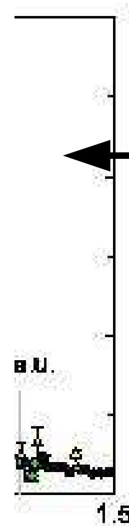
ideal for Crystal Barrel

$\gamma\, p \rightarrow K^+\, \Lambda(1405)$

LEPS collab., PRL 91 (2003) 092001







separation

$\Sigma(1385)$

$\sqrt{2}\ [\sigma(\pi^+\Sigma^-) - \sigma(\pi^-\Sigma^+)]$

$\sqrt{(4/3}\ [\sigma(\pi^+\Sigma^-) + \sigma(\pi^-\Sigma^+)]$

$\Lambda(1405)$

$\pi^0\,\Sigma^0$ — unique

assumption:

$\pi^\pm\Sigma^\mp$ ← (6%) $\sigma(\Sigma_{1385}) = \sigma(\Lambda_{1405})$ → (33%) $\pi^\pm\Sigma^\mp$

Jido, Oller, Oset , Ramos, Meißner
NP A725 (2004) 181

M. Lutz & M. Soyeur
NP A748 (2005) 499

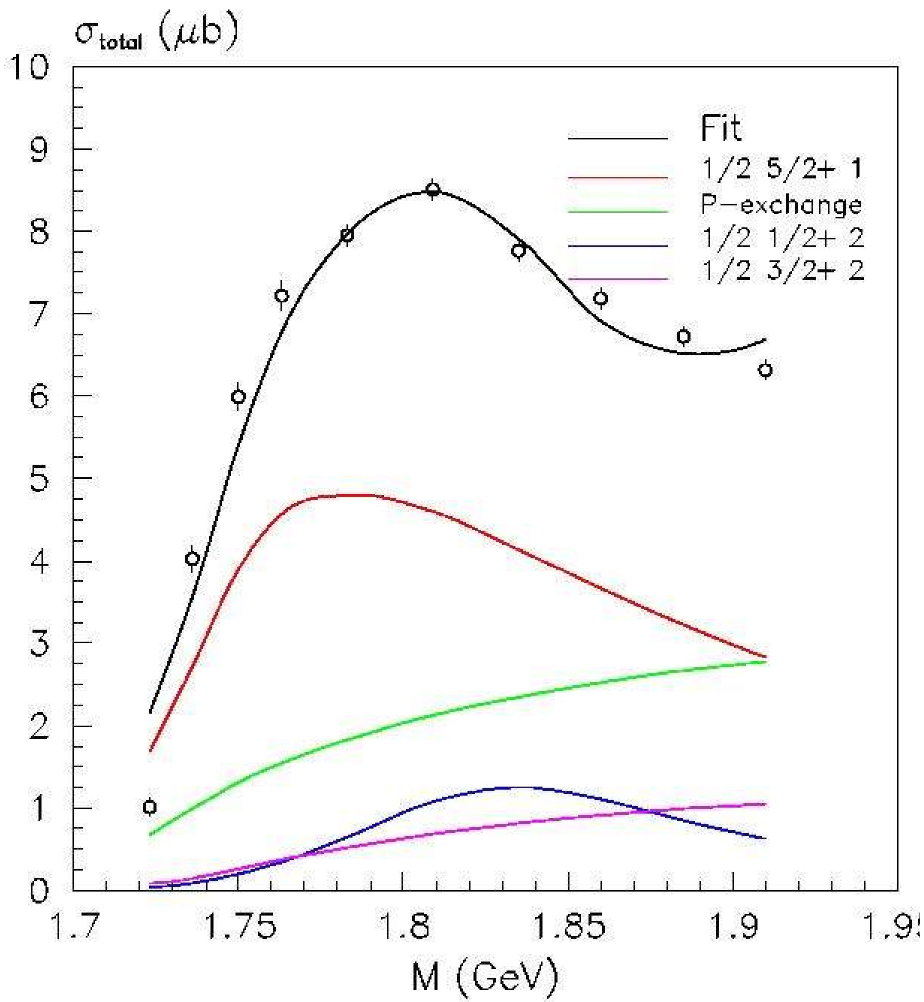
Data from J.K. Ahn et al., NP A721 (2003) 715c

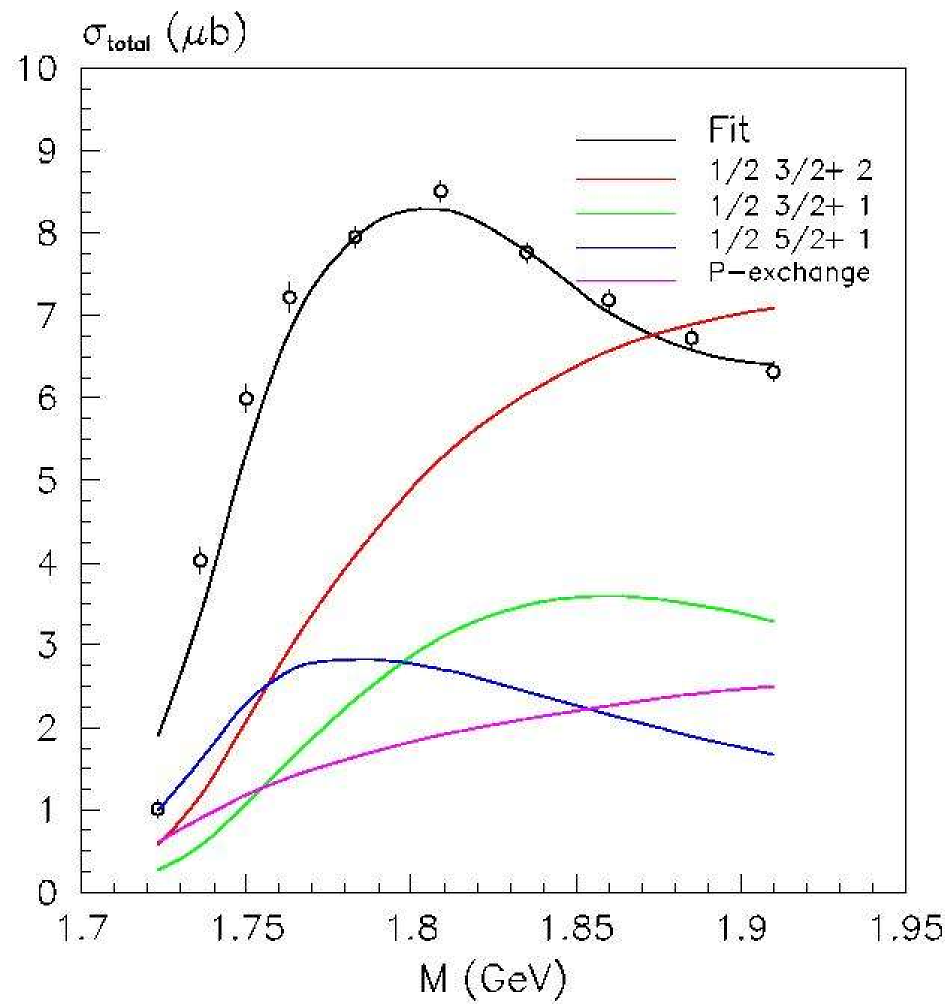
γ p → p ω

total cross section

Bonn PWA
A. Sarantsev, priv. comm.

sol_05a	sol_06c





$\gamma\, p \rightarrow p\, \omega$

target dilution factor & measurement of asymmetries

polarised target comp.

$$N_{pol} = N_0^{pol} \{ 1 + P_C P_T E + P_L (\Sigma_{pol} \cos 2\Phi + P_T G \sin 2\Phi) \}$$

$$N_{unpol} = N_0^{unpol} \{ 1 + 0 + P_L (\Sigma_{unpol} \cos 2\Phi + 0) \}$$

unpolarised target comp.

$$N_{exp} = N_0^{pol} \{ 1/f + P_C P_T E + P_L [(\Sigma_{pol} + (1/f - 1) \Sigma_{unpol}) \cos 2\Phi + P_T G \sin 2\Phi] \}$$

dilution factor

$$N_0 = (1/f)\, N_0^{pol}$$

$$P_T^{eff} = f\, P_T$$

free proton polarisation

$\gamma\, p \rightarrow p\, \omega$

target dilution factor & measurement of asymmetries

beam helicity

target polarisation

$$N(\uparrow) - N(\downarrow) = \pm\, 2\, N_0^{pol}\, P_C\, P_T\, E$$

$$N(\uparrow) + N(\downarrow) = 2\, N_0^{pol} \{\, 1/f + P_L\, [\, (\, \Sigma_{pol} + (1/f - 1)\, \Sigma_{unpol}\,)\cos 2\Phi \pm P_T\, G \sin 2\Phi\,]\, \}$$

fit

$$c + c_{cos} \cos 2\Phi + c_{sin} \sin 2\Phi$$

effective target polarisation

$$A_{exp}(E) = \frac{N(\uparrow) - N(\downarrow)}{c} = P_C\, P_T^{eff}\, E$$

fixed target spin-direction

$$A_{exp}(G) = \frac{c_{sin}}{c} = P_L\, P_T^{eff}\, G$$

sum/difference of reversed target spin-directions

$$A_{exp}(\Sigma) = \frac{c_{cos}}{c} = P_L\, \Sigma$$

assumption: free = quasifree