ELECTROMAGNETIC TESTS OF CHIRAL SYMMETRY

9th International Conference on the Structure of Baryons
BARYONS
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Harald Merkel

A1 COLLABORATION

- Introduction
  - Chiral Perturbation Theory
- Threshold π^0 production off the Proton
  - Photo production (MAMI, SAL)
  - Electro production (NIKHEF, MAMI)
  - Low 4-momentum transfer $Q^2 = 0.05\,GeV^2/c^2$
  - Polarization structure functions
- Coherent π^0 production off the Deuteron
  - Photo production (SAL)
  - Electro production (MAMI)
- Summary

Symmetries of QCD

Starting point: QCD Lagrangian

$$\mathcal{L}_{QCD} = \sum_f \bar{q}_f (iD_\mu \gamma^\mu - m_f) q_f - \frac{1}{4} \sum_{\alpha=1}^{8} G^\alpha_{\mu\nu} G^{\mu\nu,\alpha}$$

- Strong interaction (completely?) determined
- No analytic solution in confinement range $E < 1\,\mathrm{GeV}$
- Hadrons as $q\bar{q}$ or qqq states
  - Quark masses 1% of proton mass
  - Hadron spectrum from $\mathbb{SU}(3)_{flavour}$
  - Resonance structure of nucleons

Access at $E < 1\,\mathrm{GeV}$: Symmetries

- Local Gauge Symmetry, C, P, T, etc.
- Chiral Symmetry $\mathbb{SU}(3)_L \times \mathbb{SU}(3)_R$
  - Chiral limit $m_u, m_d, m_s \rightarrow 0$:

$$\mathcal{L}^0_{QCD} = \sum_{u,d,s} (\bar{q}_{R,f} iD_\mu \gamma^\mu q_{R,f} + \bar{q}_{L,f} iD_\mu \gamma^\mu q_{L,f}) - \frac{1}{4} \sum_{\alpha=1}^{8} G^\alpha_{\mu\nu} G^{\mu\nu,\alpha}$$

  - Not visible $\Rightarrow$ spontaneous broken symmetry
  - Goldstone theorem: 8 massless bosons
  - Identified as 8 pseudo scalar mesons

Chiral Perturbation Theory

Recipe for an "Effective Field Theory":

- Choose effective degrees of freedom:

  Nucleons, Pions

- Most general Lagrangian
- Symmetries of $\mathcal{L}^0_{QCD}$
- Expansion in masses:

  Symmetry broken by $-\overline{q}_f M q_f$

- Simultaneous expansion in p, q^2
- "Power counting"

Problems:

- Degrees of freedom: Resonances?
- Limited range in p, q^2
- Regularization $\Rightarrow$ Low Energy Constants (LEC)

  Determined by experiment

- Convergence

Pion photo and electro production

$$\gamma^{(*)} + p \rightarrow \pi^0 + p$$

- Test of Chiral Perturbation Theory
  - Direct production of Goldstone Bosons
  - QED: photon coupling well known
  - π^+ production dominated by charge $\Rightarrow$ π^0
- Threshold production
  - Expansion in small momenta
  - Only s- and p wave multipoles contribute

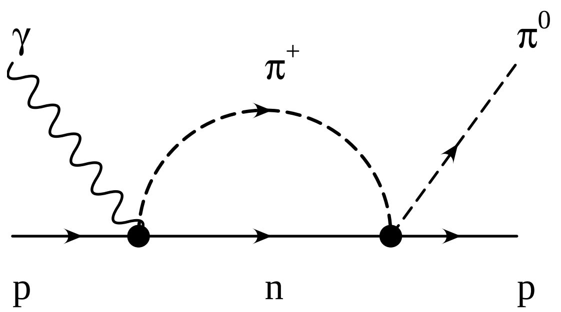
$$\frac{d\sigma}{d\Omega} = \frac{q}{k}\left(A + B\cdot\cos\theta + C\cdot cos^2\theta\right)$$

$$\begin{aligned} A &= E_{0+}^2 + {P_{23}}^2 \\ B &= 2\cdot Re(E_{0+}{P_1}^*) \\ C &= {P_1}^2 - {P_{23}}^2 \end{aligned} \qquad \begin{aligned} P_1 &= 3E_{1+} + M_{1+} - M_{1-} \\ P_2 &= 3E_{1+} - M_{1+} + M_{1-} \\ P_3 &= 2M_{1+} + M_{1-} \\ P_{23} &= \frac{1}{2}(P_2^2 + P_3^2) \end{aligned}$$

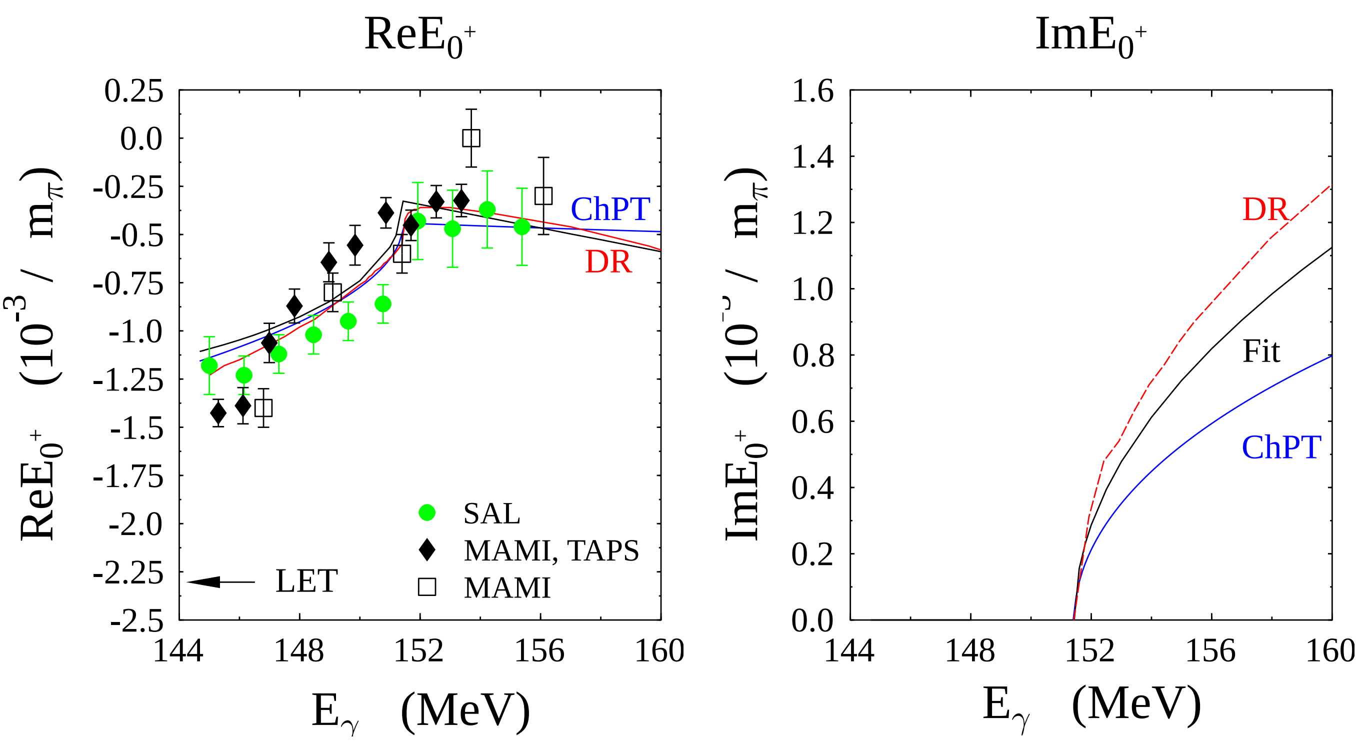
  - Known energy dependence $P_i(q) \sim q\cdot k$
- Theory
  - E_{0+} slow convergence
  - P_1, P_2 “new Low Energy Theorems”
  - P_3 fit to data

Unitary Cusp

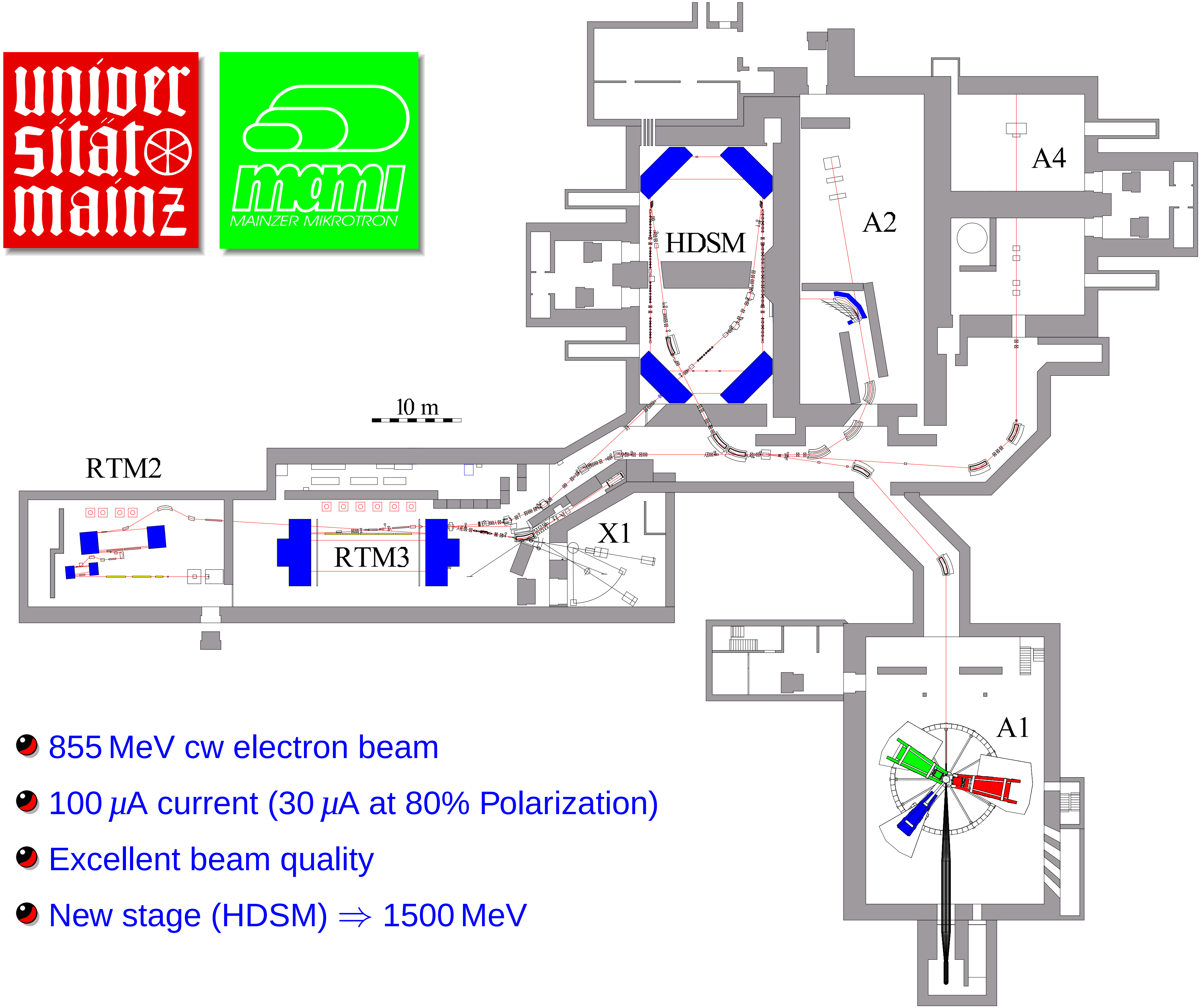
- Pion pole dominance $\Rightarrow$ strong $\gamma + p \longrightarrow n + \pi^+$
- Charge exchange amplitude



- Unitarity: $E_{0+}^{p\pi^0} = A^{p\pi^0} + i \cdot q_\pi \cdot E_{0+}^{n\pi^+} \cdot a_{\pi^+\pi^0}$

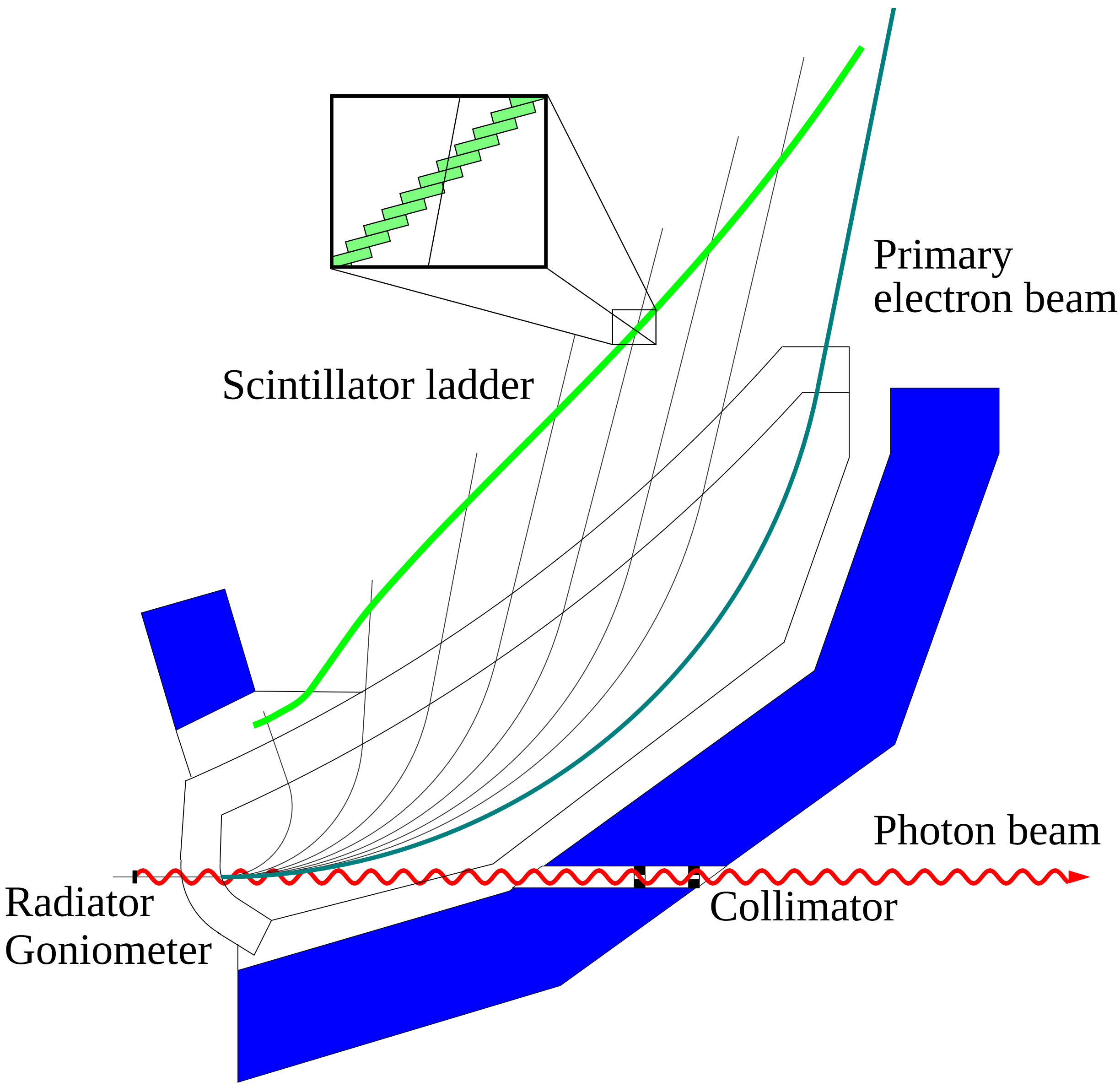


ChPT: Chiral Perturbation theory: V. Bernard *et al.*, Nucl. Phys. **B 383** (1992) 442
DR: Dispersion Relations: O. Hanstein *et al.*, Phys. Lett. **B 399** (1997) 13



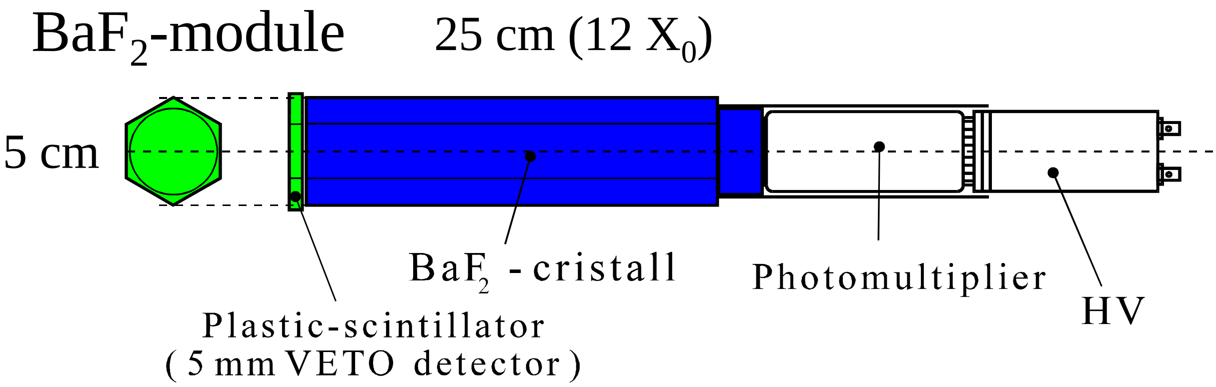
- 855 MeV cw electron beam
- 100 μA current (30 μA at 80% Polarization)
- Excellent beam quality
- New stage (HDSM) $\Rightarrow$ 1500 MeV

Tagged Photon Facility

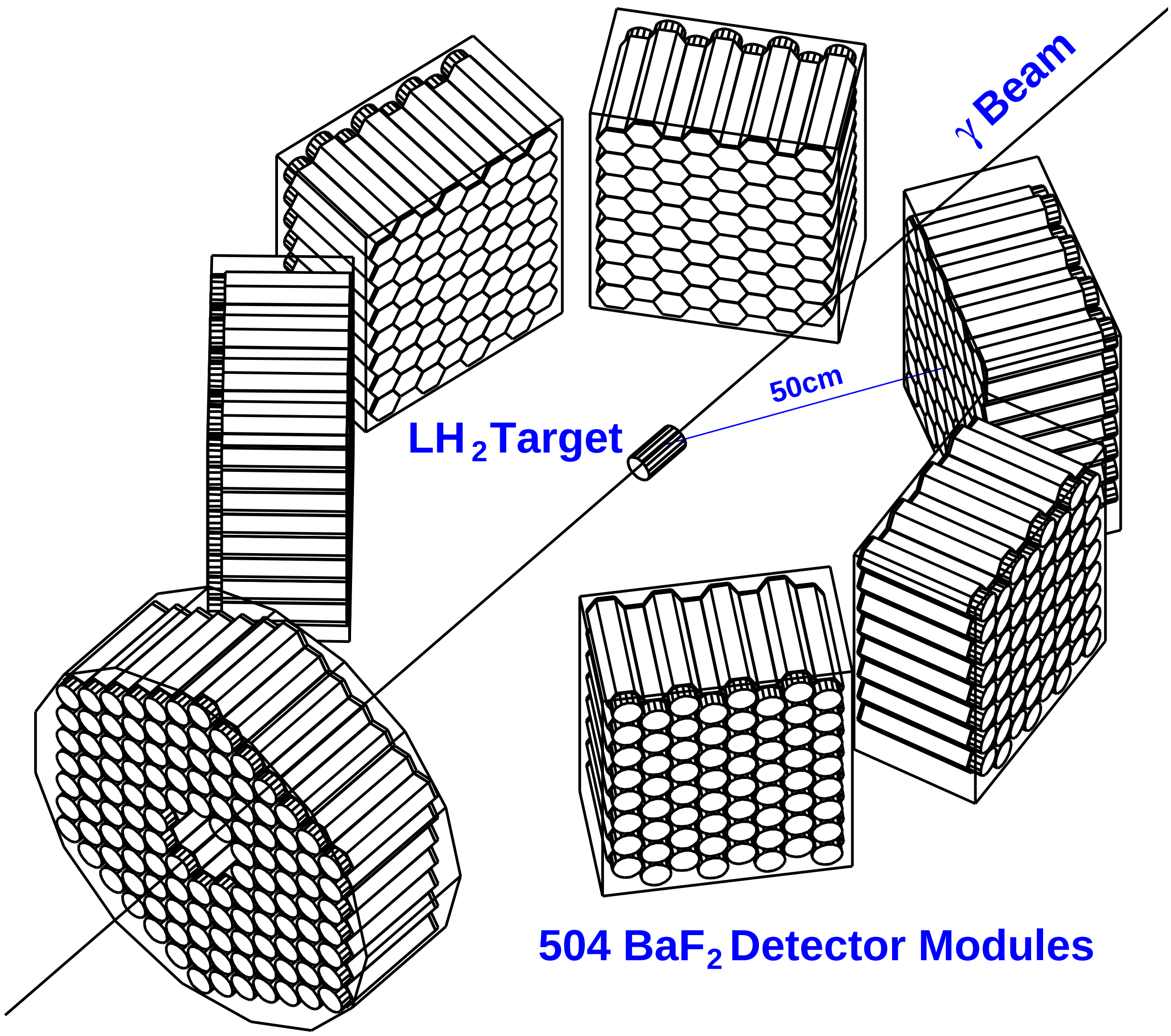


- Energy range: 5%–94% of electron energy
- Energy resolution: $\Delta E_\gamma = 2\,\text{MeV}$ at $E_0 = 855\,\text{MeV}$
- Timing resolution: 1 ns
- Maximum count rate: 10^8 photons/s
- Luminosity (Target: 10cm H_2) $L > 40\frac{\text{Hz}}{\mu\text{barn}}$

TAPS at MAMI

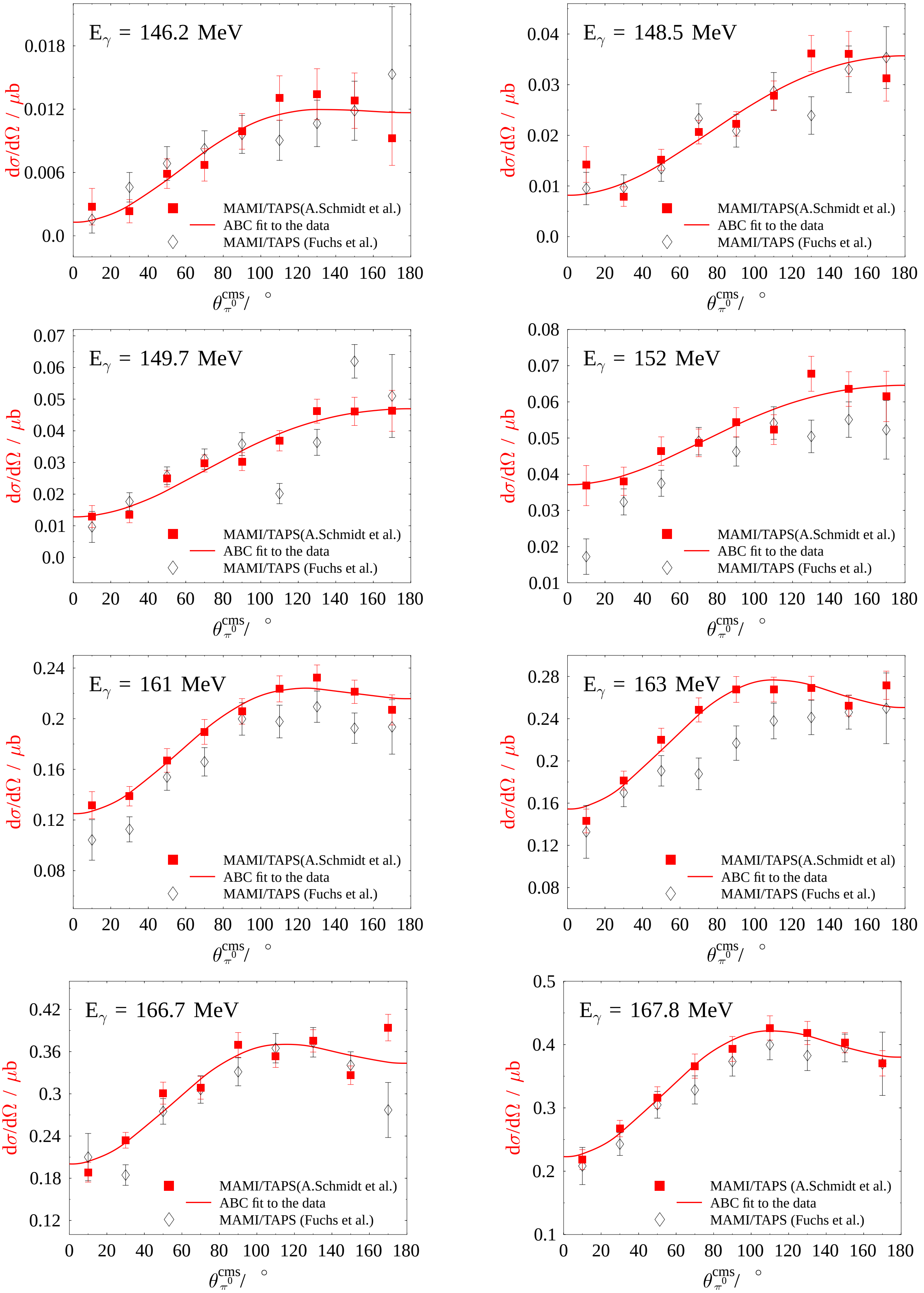


BaF$_2$-module
25 cm (12 X_0)
5 cm
BaF$_2$ - cristall
Photomultiplier
HV
Plastic-scintillator
(5 mm VETO detector)



γ Beam
50cm
LH$_2$ Target
504 BaF$_2$ Detector Modules

Differential Cross Section



Fit of A,B,C to Differential Cross Section

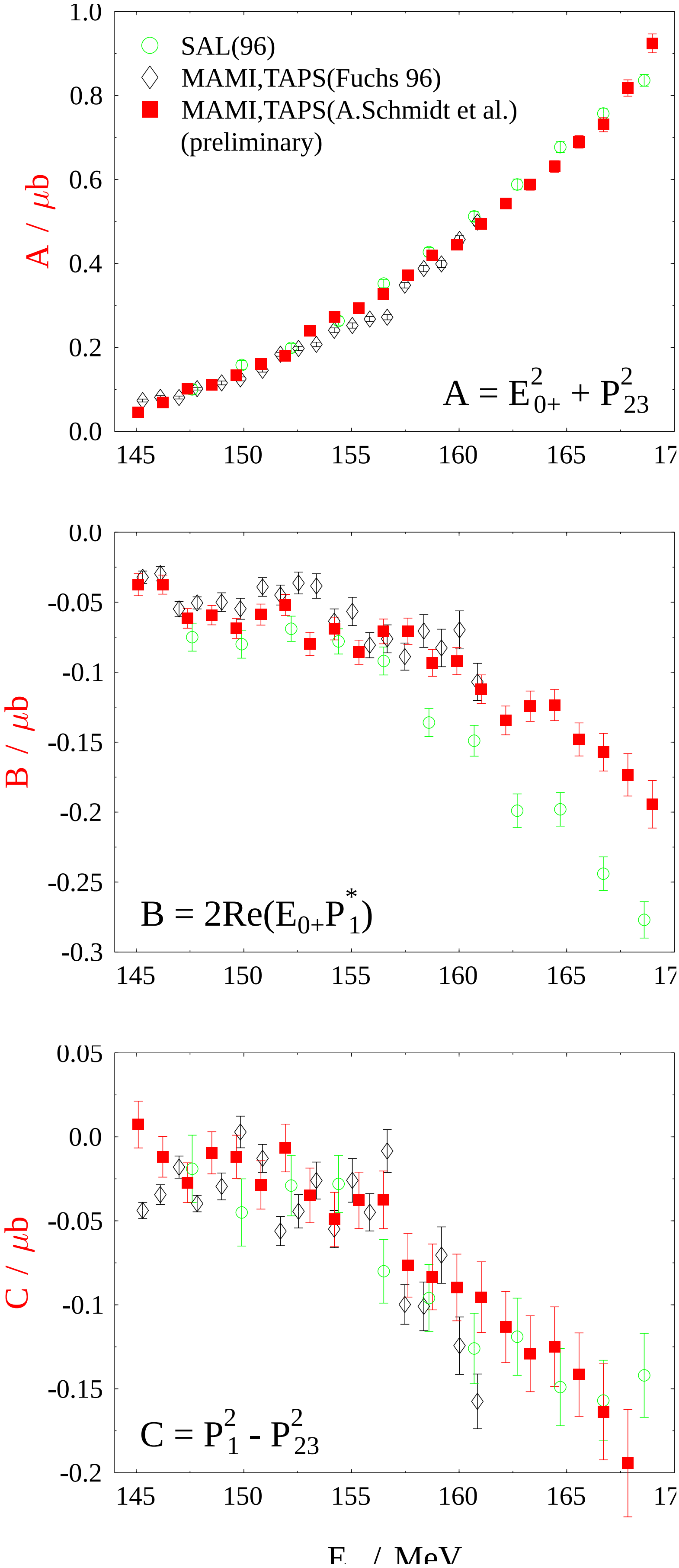
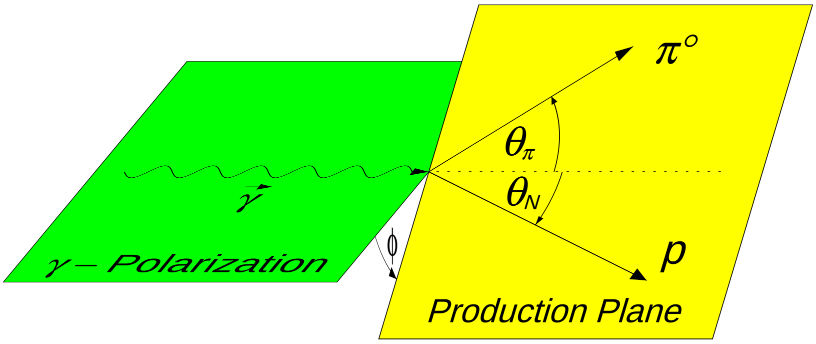


Photo production



$$\sigma(\theta) = \frac{q}{k}\left(A + B\cdot\cos\theta + C\cdot\cos^2\theta\right) \qquad (1)$$

$$A = E_{0+}^2 + \frac{1}{2}({P_2}^2 + {P_3}^2)$$
$$B = 2\cdot Re(E_{0+}{P_1}^*)$$
$$C = {P_1}^2 - \frac{1}{2}({P_2}^2 + {P_3}^2)$$

$$P_1 = 3E_{1+} + M_{1+} - M_{1-}$$
$$P_2 = 3E_{1+} - M_{1+} + M_{1-}$$
$$P_3 = 2M_{1+} + M_{1-}$$

$$\sigma(\theta) \Rightarrow ReE_{0+},\ P_1,\ (P_2^2 + P_3^2)/2$$

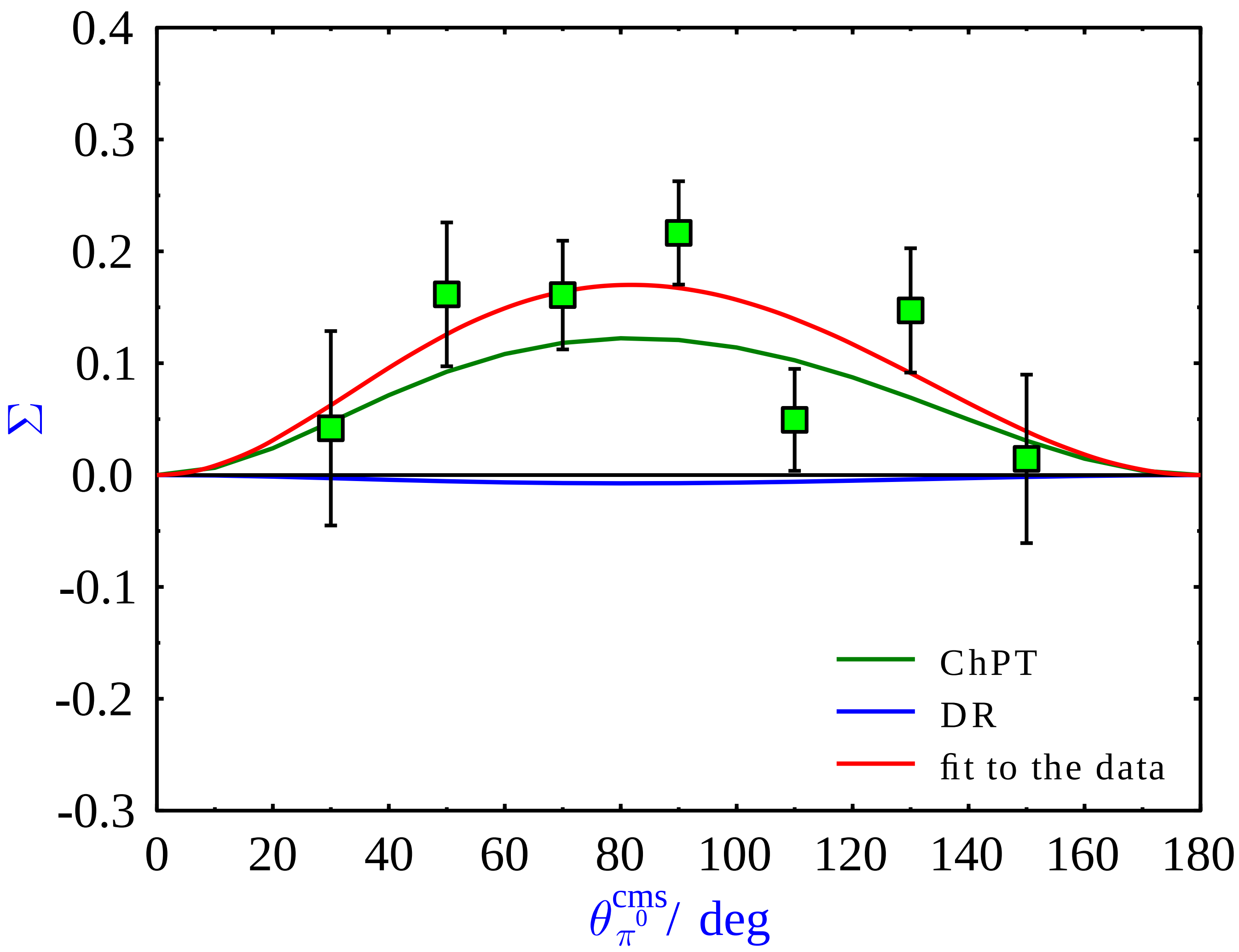
$$\sigma(\theta,\phi) = \sigma(\theta)\left[1 - P_\gamma\cdot\Sigma(\theta)\cdot\cos 2\phi\right] \qquad (2)$$
$$\Sigma(\theta) \sim \frac{1}{2}(P_3^2 - P_2^2)$$

$$\Sigma \Rightarrow (P_3^2 - P_2^2)/2$$

	E_{0+} $[10^{-3}/m_\pi]$	P_1 $[q\cdot k\cdot 10^{-3}/m_\pi^3]$	P_2 $[q\cdot k\cdot 10^{-3}/m_\pi^3]$	P_3 $[q\cdot k\cdot 10^{-3}/m_\pi^3]$
MAMI	-1.31±0.08	10.02±0.2	-10.5±0.2	13.1±0.1
SAL	-1.32±0.05	10.26±0.1		
ChPT	-1.16	10.33±0.6	-11.0±0.6	11.7±0.6
DR	-1.22	10.54	-11.4	10.2

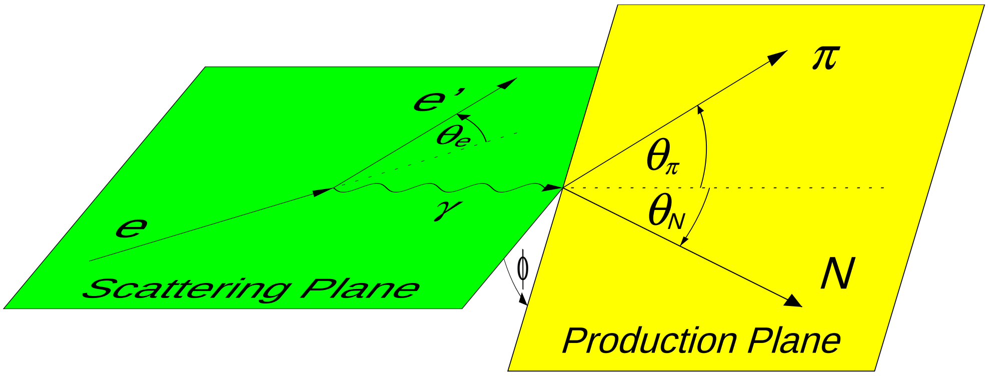
Polarized Photon Asymmetry

A. Schmidt *et al.*, Phys. Rev. Lett. **87**, 232501 (2001)



$$\sigma(\theta,\phi) = \sigma(\theta)\left(1 - P_\gamma \cdot \Sigma(\theta) \cdot cos2\phi\right)$$

Pion Electro Production



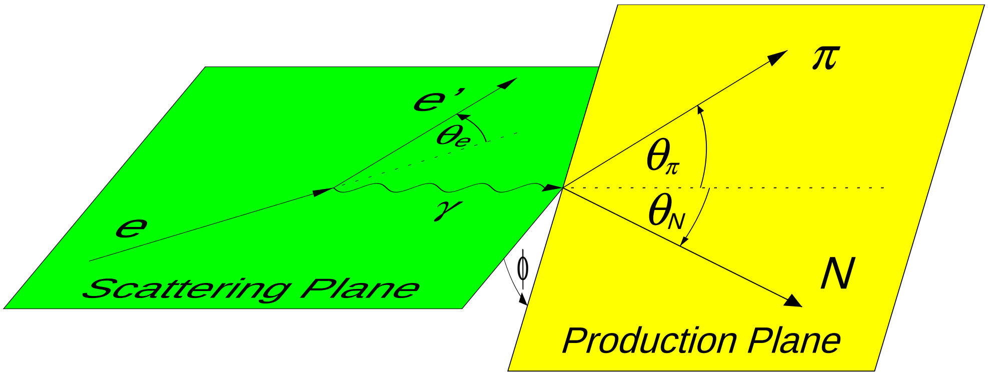
$$\frac{d^5\sigma}{d\Omega_e dE' d\Omega_\pi^*} = \Gamma_t \big(\sigma_T(\theta) + \epsilon \cdot \sigma_L(\theta) + \epsilon \cdot \sigma_{TT}(\theta) \cdot \cos 2\phi + \sqrt{2\epsilon(1+\epsilon)} \cdot \sigma_{TL}(\theta) \cdot \cos\phi + h \cdot \sqrt{2\epsilon(1-\epsilon)} \cdot \sigma_{TL'}(\theta) \cdot \sin\phi \big)$$

- Additional longitudinal s and p waves
- Interference structure functions
- Multipoles depend on four-momentum transfer Q^2

Experiment: $H(\vec{e}, e'p)\pi^0$

- Detection of recoil proton
- Lorenz boost $\Rightarrow$ 4π in spectrometer acceptance
- Small cross section $\Rightarrow$ high luminosity

Kinematics



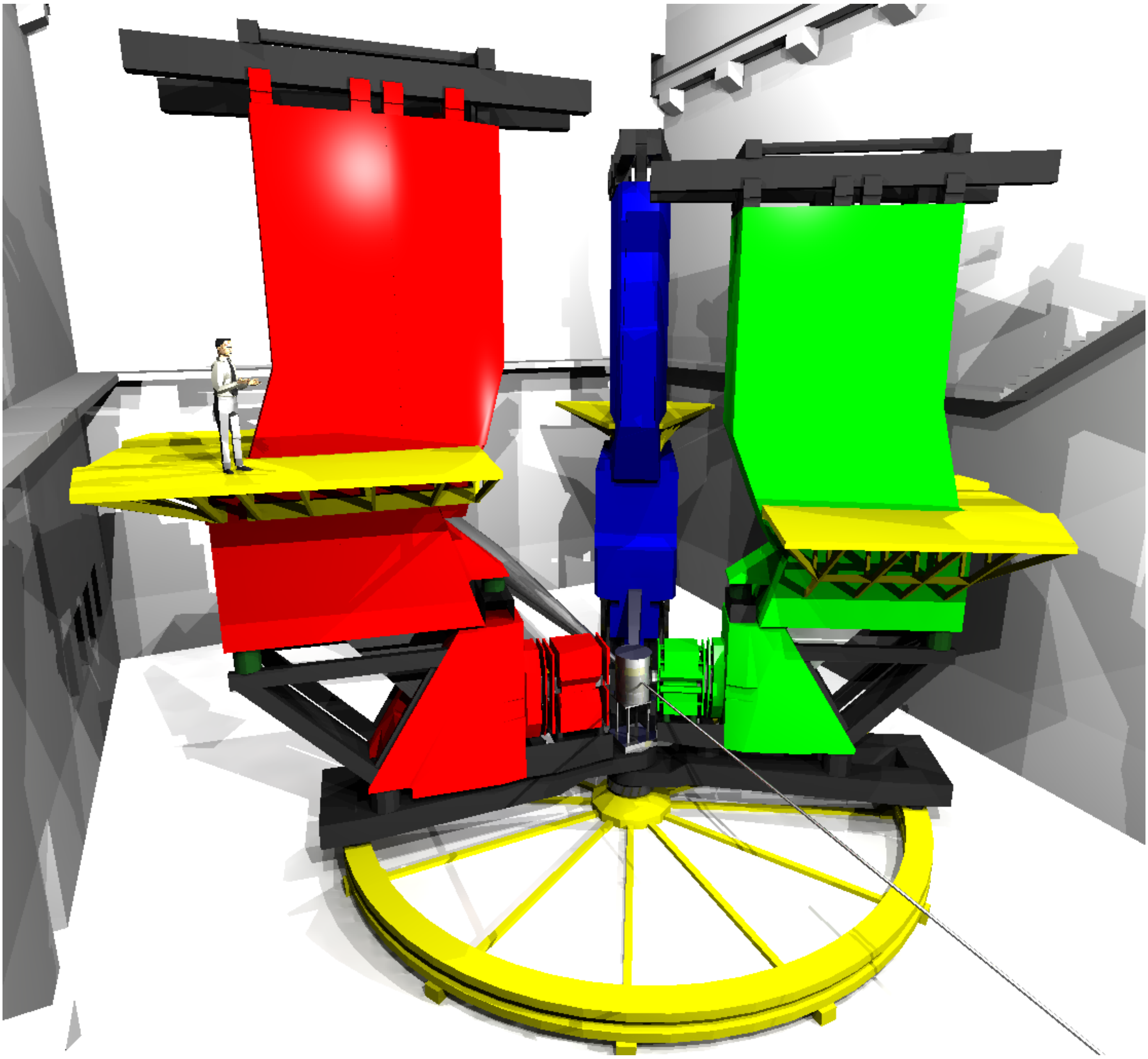
$$\frac{d^3\sigma}{d\Omega_e dE' d\Omega^*_\pi} = \Gamma_t(\sigma_T(\theta) + \varepsilon_L \cdot \sigma_L(\theta) + \varepsilon \cdot \sigma_{TT}(\theta) \cdot \cos 2\phi$$
$$+ \sqrt{2\varepsilon_L(1+\varepsilon)} \cdot \sigma_{TL}(\theta) \cdot \cos\phi + h\sqrt{2\varepsilon_L(1-\varepsilon)} \cdot \sigma_{TL'}(\theta) \cdot \sin\phi)$$

$$\sigma_T(\theta) = \frac{p^*}{k^*}(A + B \cdot \cos\theta + C \cdot \cos^2\theta)$$
$$\sigma_L(\theta) = \frac{p^*}{k^*}(A' + B' \cdot \cos\theta + C' \cdot \cos^2\theta)$$
$$\sigma_{TL}(\theta) = \frac{p^*}{k^*}(D \cdot \sin\theta + E \cdot \sin\theta\cos\theta)$$
$$\sigma_{TT}(\theta) = \frac{p^*}{k^*} F \cdot \sin^2\theta$$
$$\sigma_{TL'}(\theta) = \frac{p^*}{k^*}(G \cdot \sin\theta + H \cdot \sin\theta\cos\theta)$$

$$A = |E_{0+}|^2 + \frac{1}{2}(|P_2|^2 + |P_3|^2)$$
$$B = 2 \cdot Re E_{0+}{}^* \cdot P_1$$
$$C = |P_1|^2 - \frac{1}{2}(|P_2|^2 + |P_3|^2)$$
$$A' = |L_{0+}|^2 + |P_5|^2$$
$$B' = 2 \cdot Re L_{0+}{}^* \cdot P_4$$
$$C' = |P_4|^2 - |P_5|^2$$
$$D = -Re(E_{0+} \cdot P_5{}^* + L_{0+} \cdot P_2{}^*)$$
$$E = -Re(P_1 \cdot P_5{}^* + P_4 \cdot P_2{}^*)$$
$$F = \frac{1}{2}(|P_2|^2 - |P_3|^2)$$
$$G = -Im(E_{0+} \cdot P_5{}^* + L_{0+} \cdot P_2{}^*)$$
$$H = Im(P_1 \cdot P_5{}^* + P_4 \cdot P_2{}^*)$$

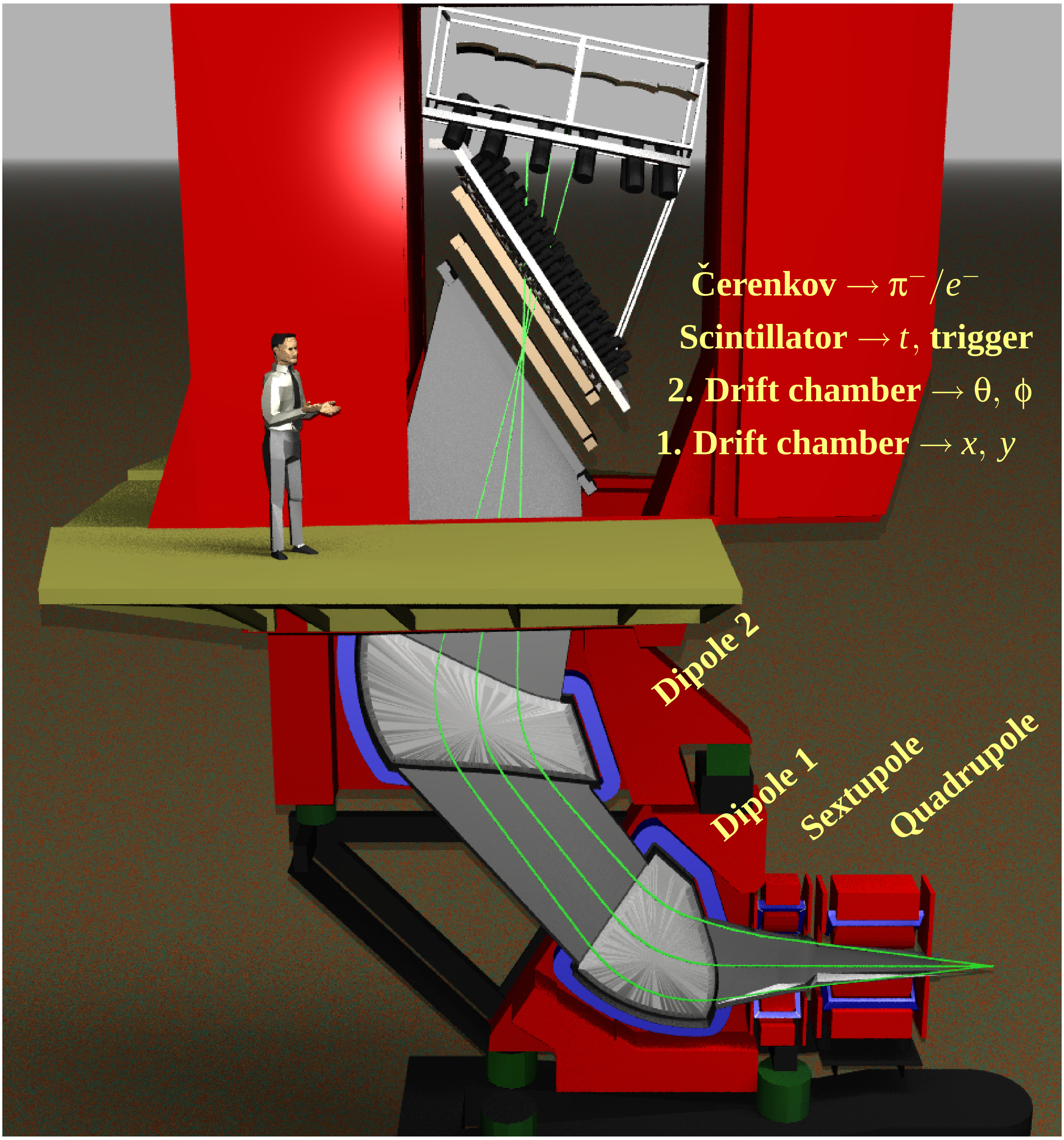
$$P_1 = 3E_{1+} + M_{1+} - M_{1-}$$
$$P_2 = 3E_{1+} - M_{1+} + M_{1-}$$
$$P_3 = 2M_{1+} + M_{1-}$$
$$P_4 = 4L_{1+} + L_{1-}$$
$$P_5 = L_{1-} - 2L_{1+}$$

A1: 3-Spectrometer Setup



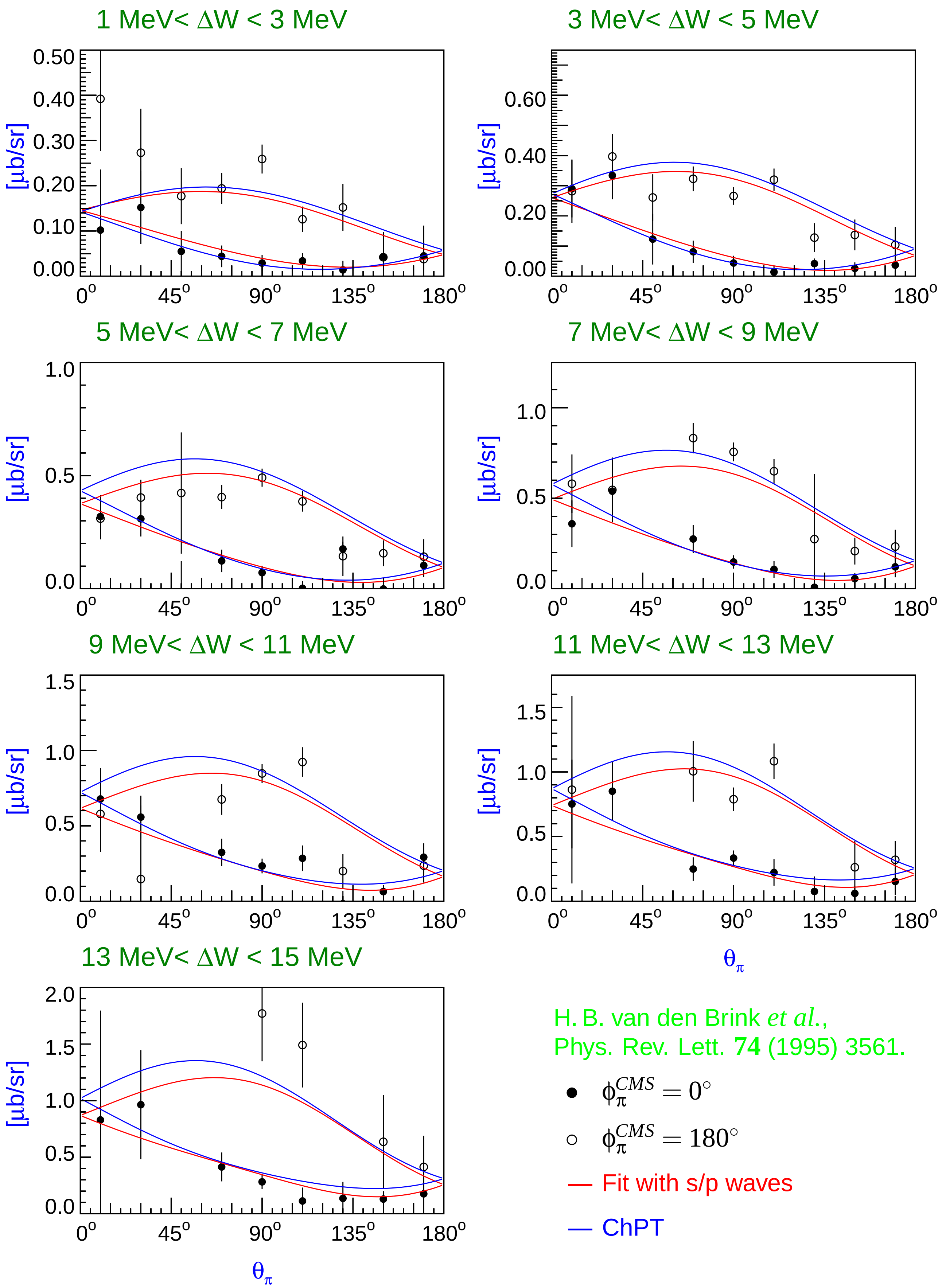
Spectrometer A:	Spectrometer B:	Spectrometer C:
$\alpha > 20^\circ$	$\alpha > 8^\circ$	$\alpha > 55^\circ$
$p < 735\,\mathrm{MeV/c}$	$p < 870\,\mathrm{MeV/c}$	$p < 655\,\mathrm{MeV/c}$
$\Delta\Omega = 28\,\mathrm{msr}$	$\Delta\Omega = 5.6\,\mathrm{msr}$	$\Delta\Omega = 28\,\mathrm{msr}$
$\Delta p/p = 20\%$	$\Delta p/p = 15\%$	$\Delta p/p = 25\%$

A1: Spectrometer A



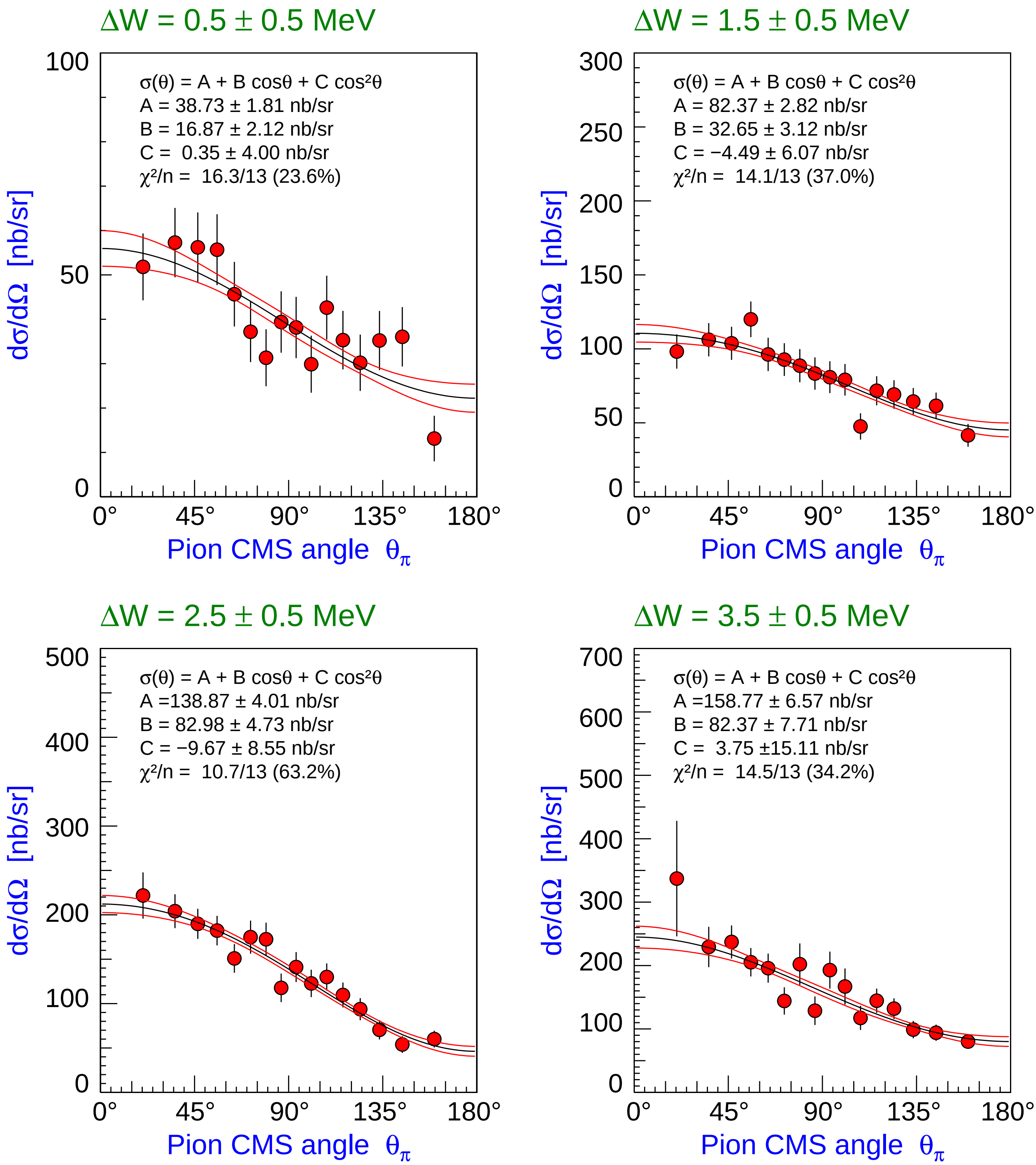
- Momentum resolution: $\delta p/p < 10^{-4}$
- Momentum acceptance: $\Delta p/p = 20\%$
- Angular acceptance: $\Delta\Omega = 11.5^\circ \times 8.0^\circ = 28\,\mathrm{msr}$

NIKHEF $H(e,e'p)\pi^0$ $Q^2 = 0.1\,\mathrm{GeV}^2/c^2$



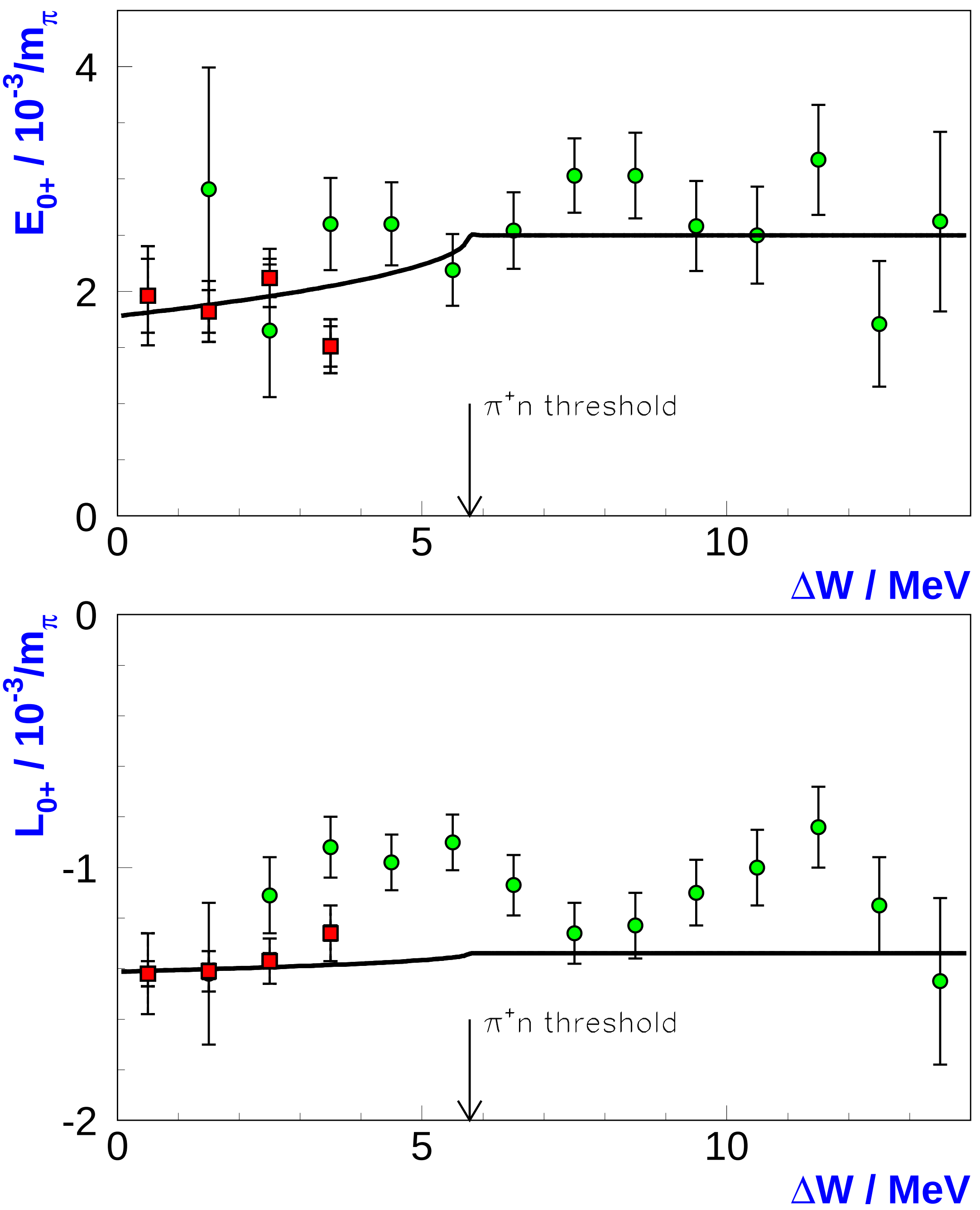
MAMI $H(e,e'p)\pi^0$ $Q^2 = 0.1\,\mathrm{GeV}^2/c^2$

$q^2 = -0.10\ \mathrm{GeV}^2/c^2$ $\varepsilon = 0.529$



M. O. Distler *et al.*, Phys. Rev. Lett. **80** (1998) 2294.

Results $H(e,e'p)\pi^0$ at $Q^2 = 0.1\,\mathrm{GeV}^2/\mathrm{c}^2$

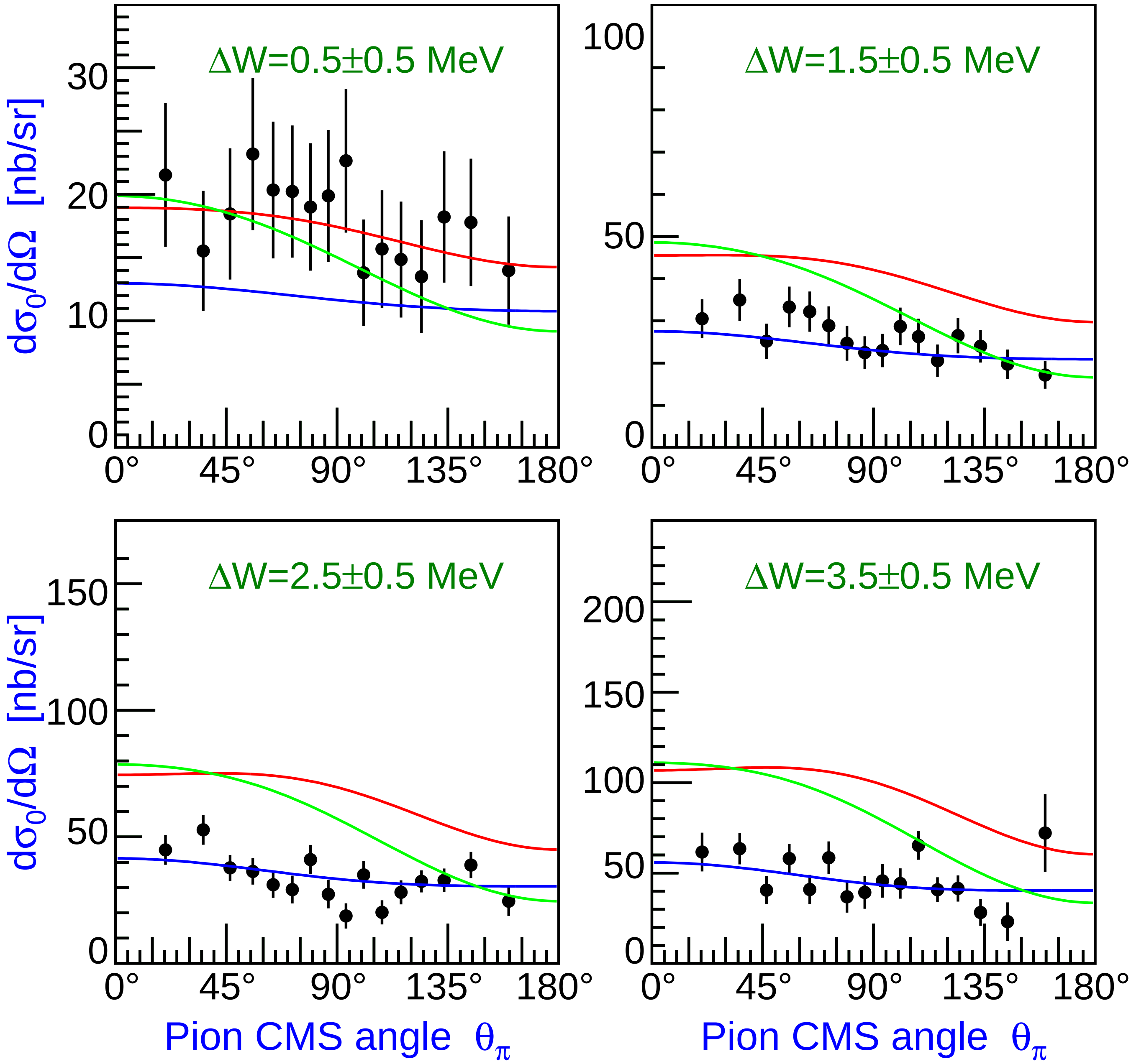


AmPS: H. B. van den Brink *et al.*, Phys. Rev. Lett. **74** (1995) 3561.

MAMI: M. O. Distler *et al.*, Phys. Rev. Lett. **80** (1998) 2294.

– ChPT: V. Bernard *et al.*, Nucl. Phys. **A 607** (1996) 379.

Differential Cross Section $Q^2 = 0.05\,\mathrm{GeV}^2/c^2$



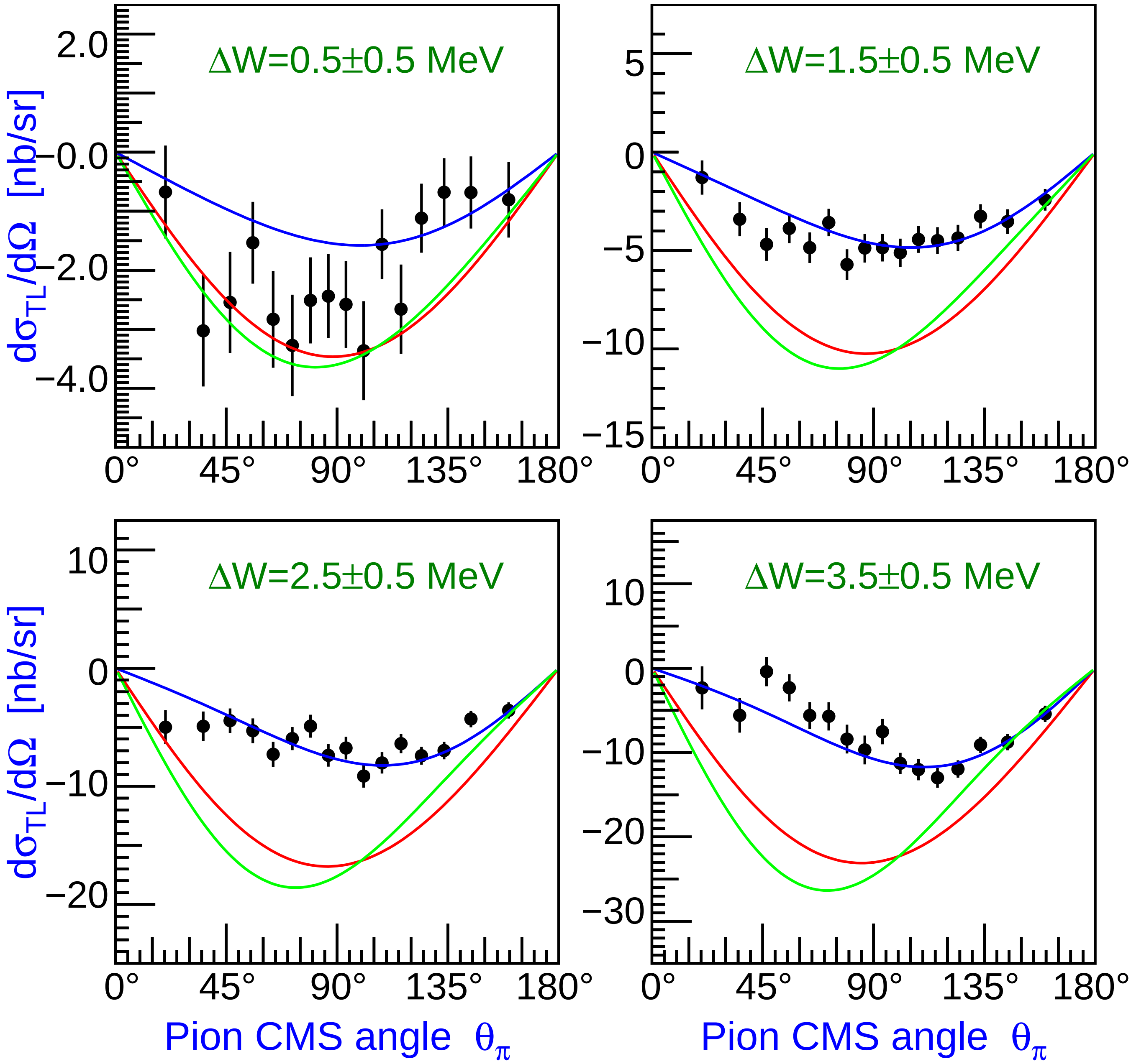
● H. Merkel *et al.*, Phys. Rev. Lett. **88**, 012301 (2002)

— Fit with s-waves = const., p-waves $\sim p_\pi^{cms}$

— ChPT, V. Bernard *et al.*, Nucl. Phys. **A 607** (1996) 379-401

— MAID, D. Drechsel *et al.*, Nucl. Phys. **A 645** (1999) 145-174
and S. S. Kamalov *et al.*, Phys. Lett. **B 522** (2001) 27-36

LT Interference Structure $Q^2 = 0.05\,\mathrm{GeV}^2/c^2$



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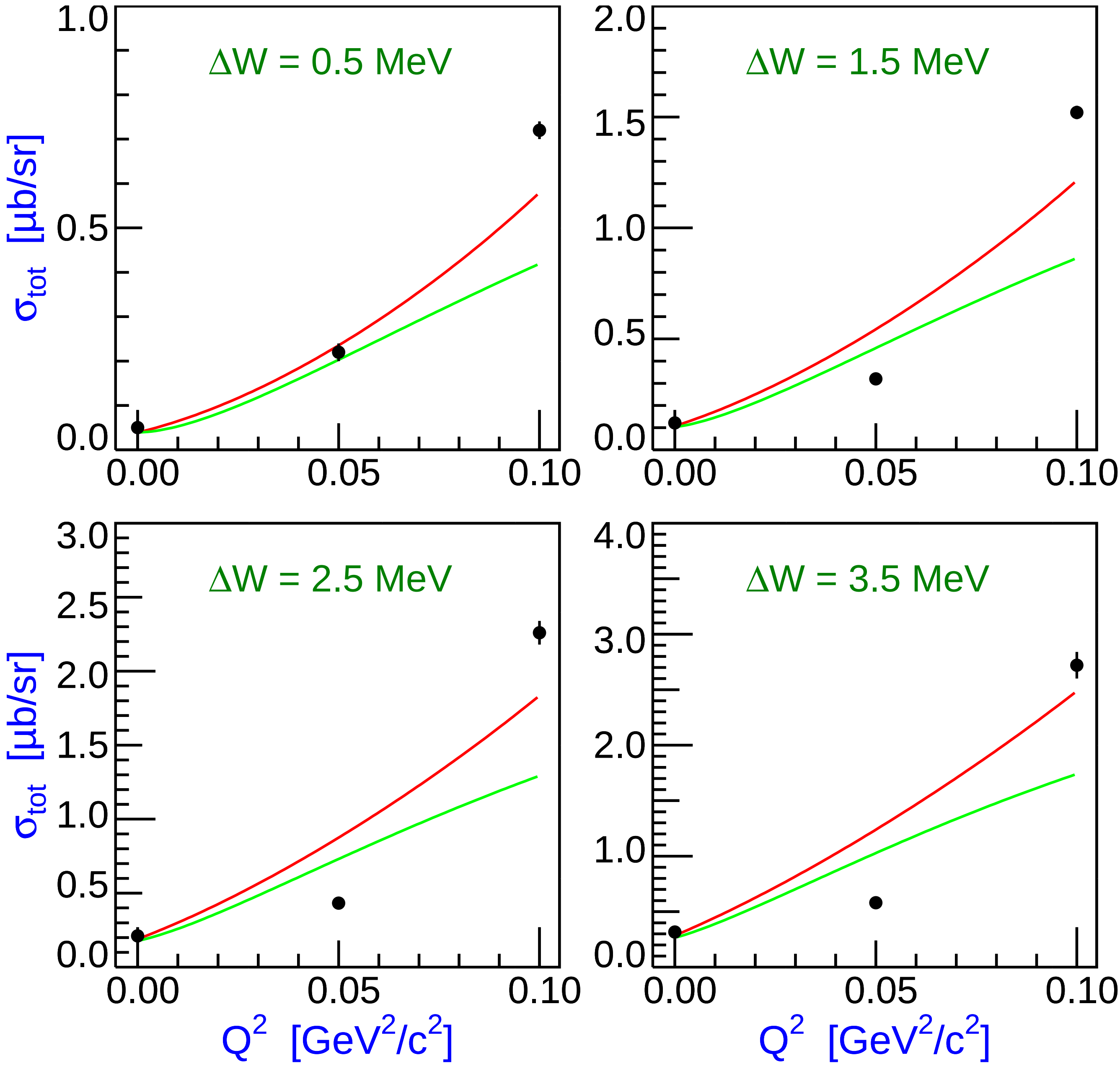
and S. S. Kamalov *et al.*, Phys. Lett. **B 522** (2001) 27-36

$\gamma^* + p \rightarrow p + \pi^0$ Total Cross Section vs. Q^2



— ChPT, V. Bernard *et al.*, Nucl. Phys. **A607** (1996) 379-401.

— MAID, D. Drechsel *et al.*, Nucl. Phys. **A645** (1999) 145-174.
and S. S. Kamalov *et al.*, Phys. Lett. **B 522** (2001) 27-36

● $Q^2 = 0$	A. Schmidt *et al.*, Phys. Rev. Lett. **87**, 232501 (2001).
$Q^2 = 0.05\,\mathrm{GeV}^2/\mathrm{c}^2$	H. Merkel *et al.*, Phys. Rev. Lett. **88**, 012301 (2002).
$Q^2 = 0.1\ \ \mathrm{GeV}^2/\mathrm{c}^2$	M. O. Distler *et al.*, Phys. Rev. Lett. **80** 2294 (1998).

Multipole amplitudes at threshold

	E_{0+}	L_{0+}	$\hat{P}_{23}^{2}$	$\hat{P}_{1}$	$\hat{P}_{4}$	$\hat{P}_{5}$
	$(10^{-3} m_{\pi}^{-1})$		$(10^{-6} m_{\pi}^{-4})$		$(10^{-3} m_{\pi}^{-2})$	
Photon point $Q^2 = 0\,\mathrm{GeV}^2/\mathrm{c}^2$						
MAMI	-1.33		111	9.5		
ChPT	-1.14	-1.70	105	9.3	-0.6	-0.2
MAID	-1.16	-1.29	95	9.3	-3.0	2.2
$Q^2 = 0.05\,\mathrm{GeV}^2/\mathrm{c}^2$						
MAMI	0.57	-1.29	100	12.0	0.29	-1.9
	± 0.11	± 0.02	± 3	± 0.3	± 0.33	± 0.3
AmPS		$(-)1.57$				
		± 0.96				
ChPT	0.27	-1.55	353	16.5	-0.72	-0.2
MAID	0.76	-1.4	250	15.0	-1.75	1.9
$Q^2 = 0.1\,\mathrm{GeV}^2/\mathrm{c}^2$						
MAMI	0.58	-1.38	573	15.1	-2.3	0.1
	± 0.18	± 0.01	± 11	± 0.8	± 0.2	± 0.3
AmPS	1.99	-1.33	526	16.4	-1.0	-1.0
	± 0.3	fixed	± 7	± 0.6	± 0.4	± 0.4
ChPT	1.42	-1.33	571	20.1	-0.6	-0.1
MAID	2.2	-1.12	315	17.1	-1.1	1.4

Interference Structure-Functions

$$\frac{d^5\sigma}{d\Omega_e dE' d\Omega^*_\pi} = \Gamma_t(\sigma_T(\theta) + \varepsilon \cdot \sigma_L(\theta)$$
$$+ \varepsilon \cdot \sigma_{TT}(\theta) \cdot \cos 2\phi$$
$$+ \sqrt{2\varepsilon(1+\varepsilon)} \cdot \sigma_{TL}(\theta) \cdot \cos\phi$$
$$+ h \cdot \sqrt{2\varepsilon(1-\varepsilon)} \cdot \sigma_{TL'}(\theta) \cdot \sin\phi)$$

Motivation:

- σ_{TT} Separation of transverse p waves
- σ_{TL} Separation of longitudinal p waves
- $\sigma_{TL'}$ Unitary cusp at π^+ threshold

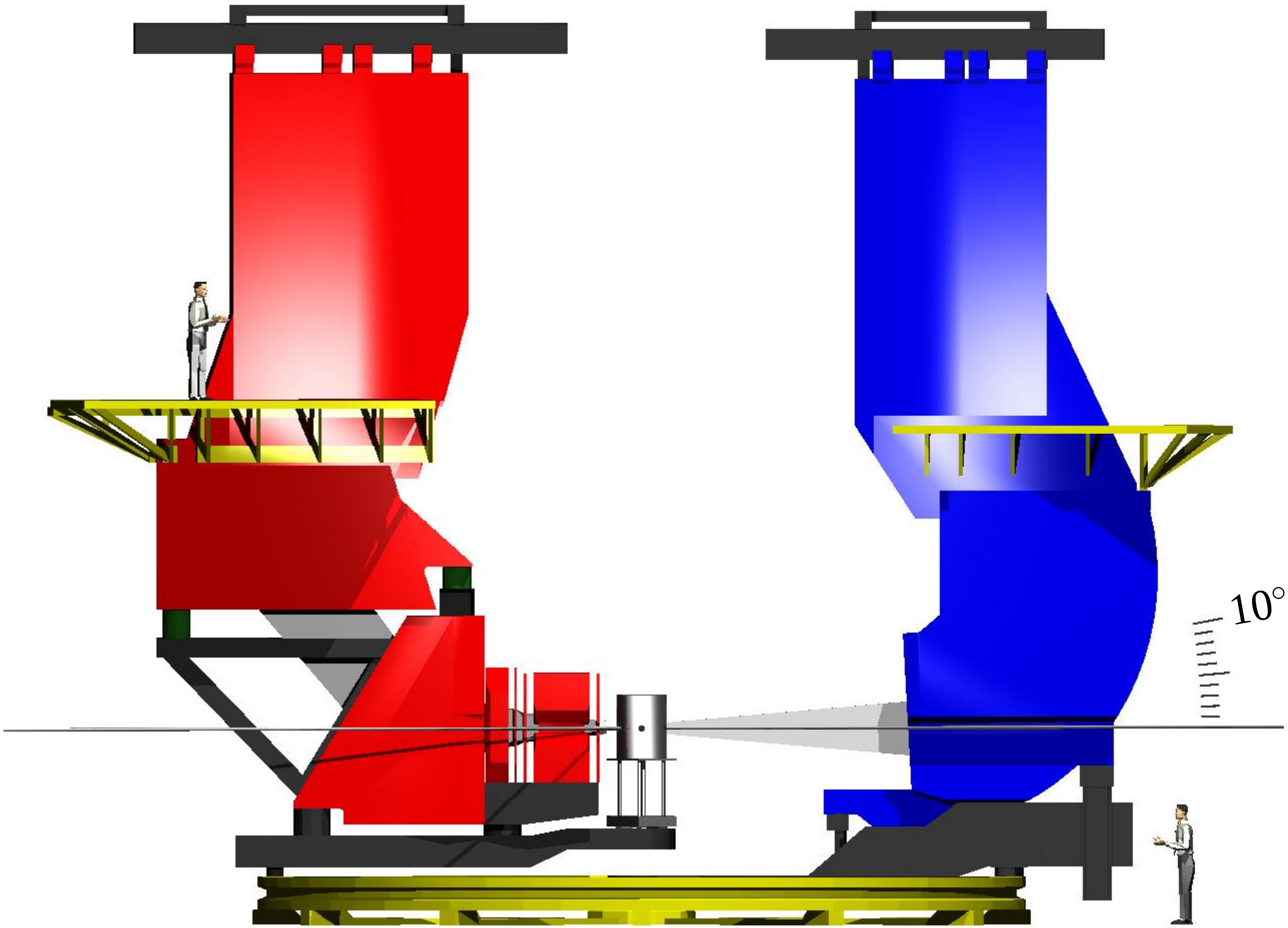
  $\Rightarrow$ ImL_{0+}

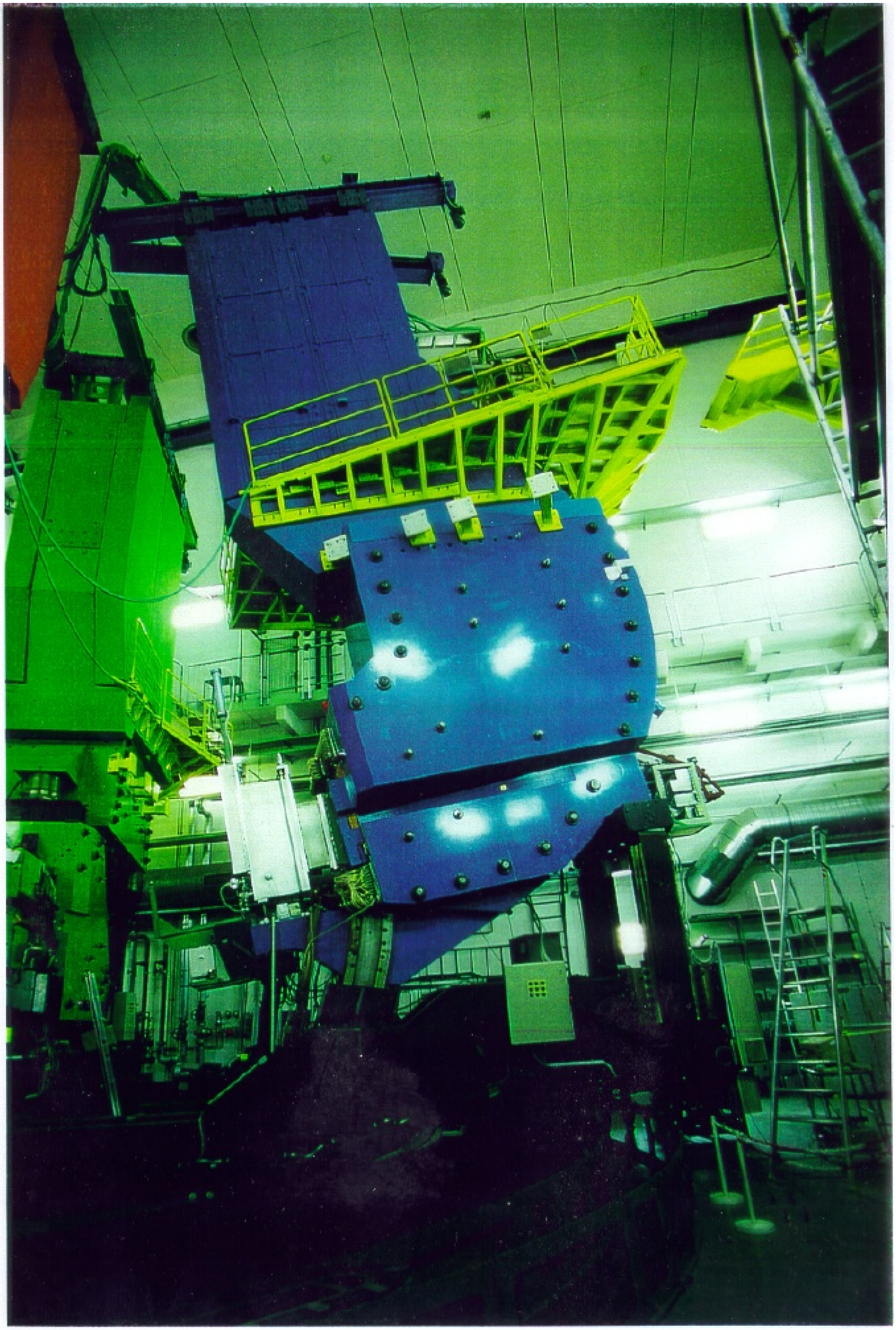
Experiment:

- Polarized beam $h = 75\%$
- Out of Plane $\phi_{LAB} = 8^\circ \quad \Rightarrow \quad \phi_{CMS} = 90^\circ$
- Extended kinematical range

$$0\, MeV/c < p^*_\pi < 100\, MeV/c$$
$$\phi_{CMS} = 0^\circ,\ 90^\circ,\ -90^\circ$$

$\Rightarrow$ 14 kinematical setups


10°

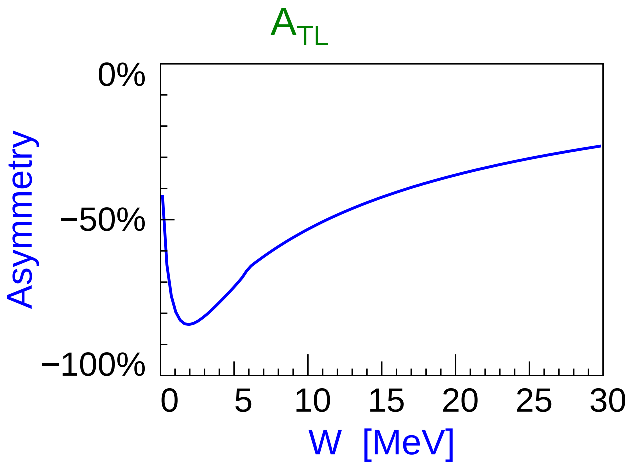


Interference Asymmetries

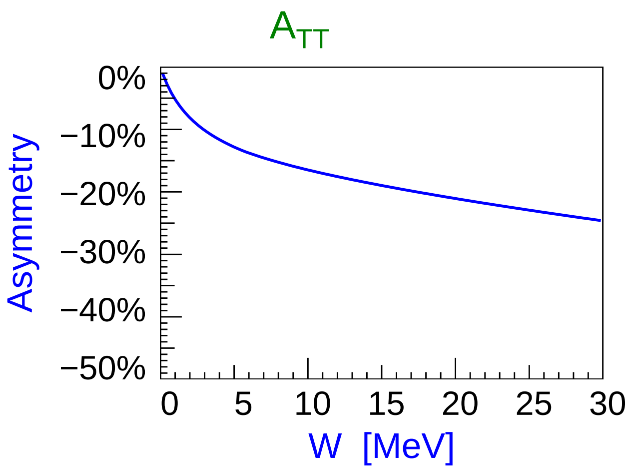
$$\frac{d^5\sigma}{d\Omega_e dE' d\Omega^*_\pi} = \Gamma_t\Big(\sigma_T(\theta)+\varepsilon\cdot\sigma_L(\theta)+\sqrt{2\varepsilon(1+\varepsilon)}\cdot\sigma_{TL}(\theta)\cdot\cos\phi$$

$$+\ \varepsilon\cdot\sigma_{TT}(\theta)\cdot\cos 2\phi + h\cdot\sqrt{2\varepsilon(1-\varepsilon)}\cdot\sigma_{TL'}(\theta)\cdot\sin\phi\Big)$$

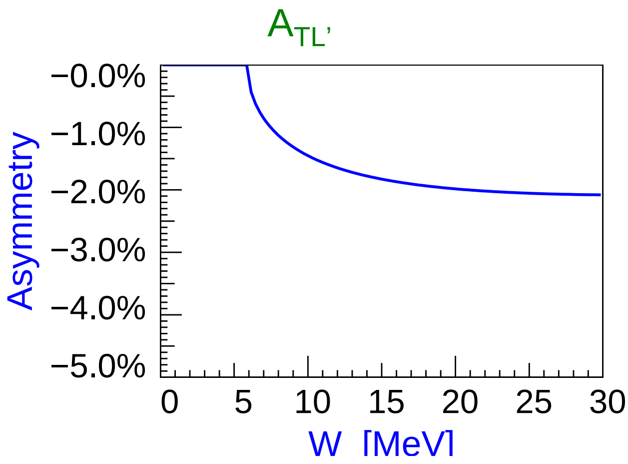
$$A_{TL} = \frac{\sqrt{2\varepsilon(1+\varepsilon)}\cdot\sigma_{TL}(\theta)}{\sigma_T(\theta)+\varepsilon\cdot\sigma_L(\theta)} = \frac{\sigma(\phi=0)-\sigma(\phi=\pi)}{\sigma(\phi=0)+\sigma(\phi=\pi)}$$



$$A_{TT} = \frac{\varepsilon\cdot\sigma_{TT}(\theta)}{\sigma_T(\theta)+\varepsilon\cdot\sigma_L(\theta)} = \frac{\sigma(0)+\sigma(\pi)-2\sigma(\pi/2)}{\sigma(0)+\sigma(\pi)+2\sigma(\pi/2)}$$

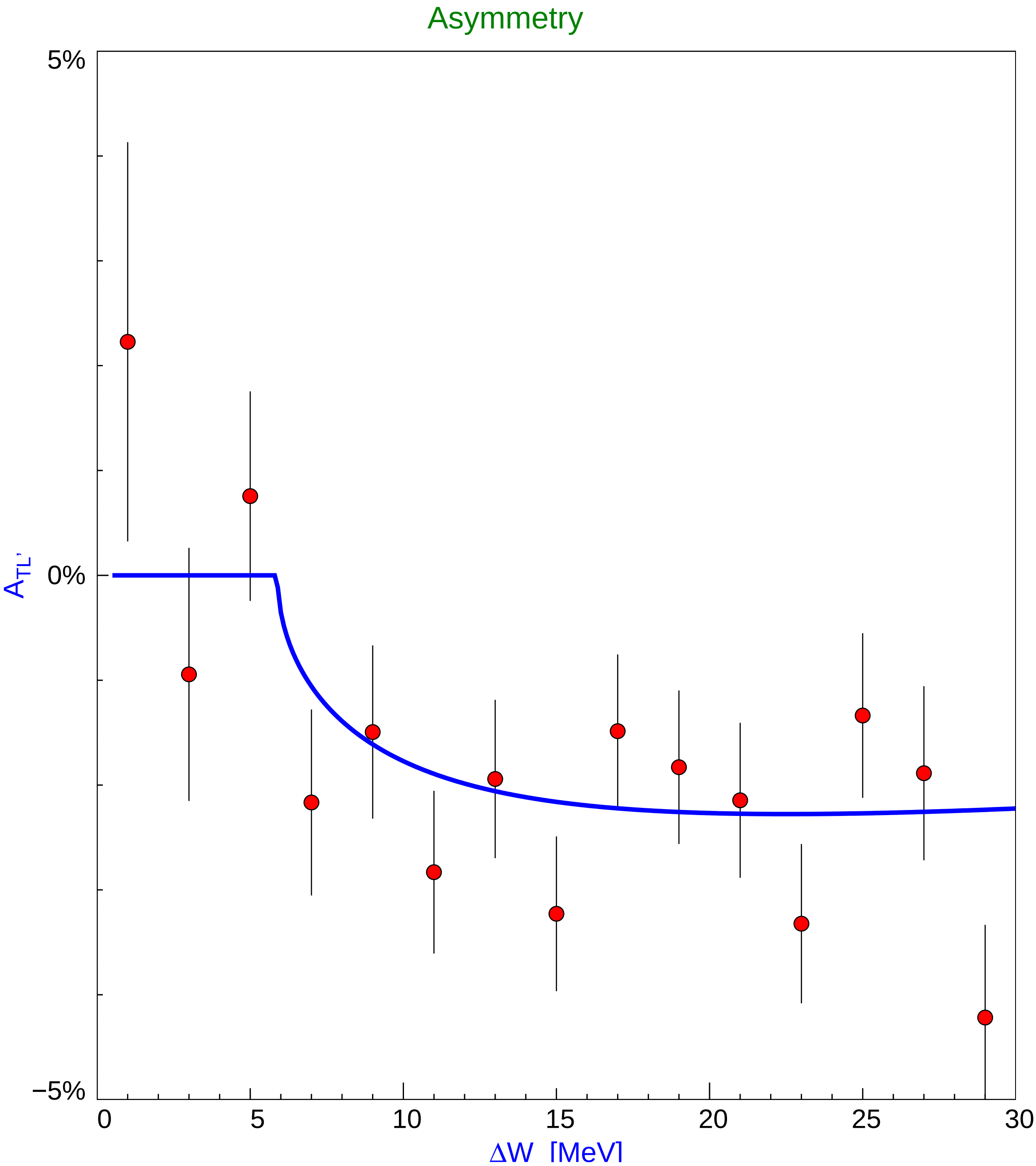


$$A_{TL'} = \frac{\sqrt{2\varepsilon(1-\varepsilon)}\cdot\sigma_{TL'}(\theta)}{\sigma_T(\theta)+\varepsilon\cdot\sigma_L(\theta)} = \frac{\sigma(h=1)-\sigma(h=-1)}{\sigma(h=1)+\sigma(h=-1)}$$



Asymmetrie $A_{TL'}$

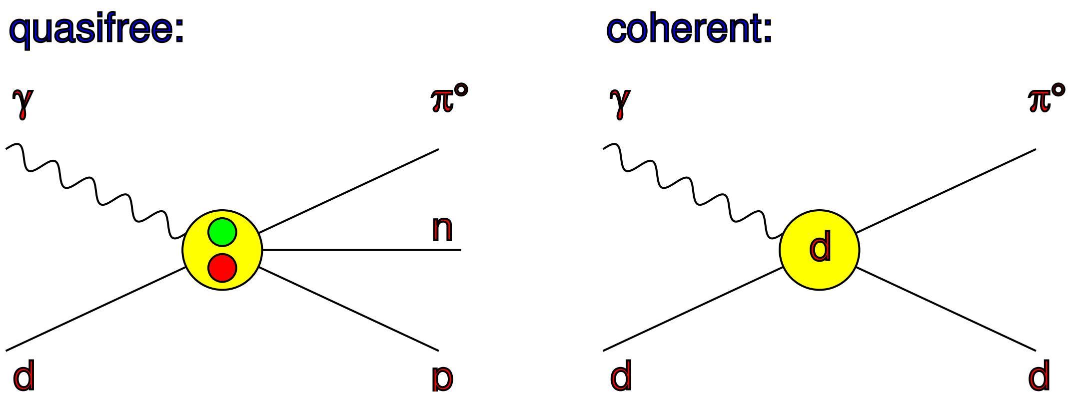
$q^2 = -0.05$ GeV²/c² $\varepsilon = 0.933$



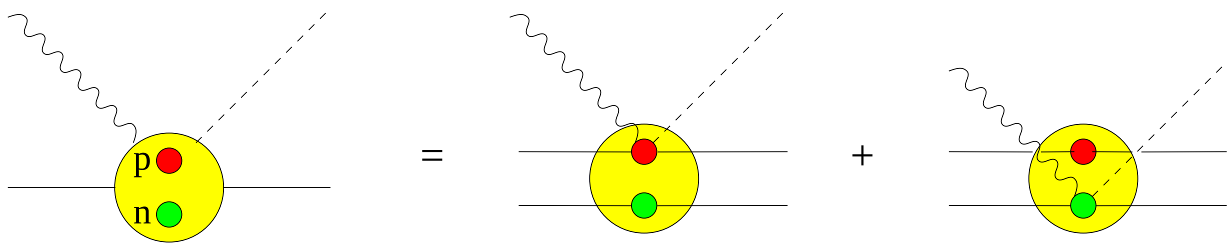
- Asymmetry $\approx (2 \pm 0.3)\%$
- $R_{TL'}$ to small!
- $A_{TL'}$ consistent with Chiral Perturbation Theory

Neutron Amplitude

- Pion production off the proton
  - Low Energy Constants fixed by experiment
- Pion production off the neutron
  - No further Low Energy Constants
  - Strong prediction of ChPT
  - Additional isospin breaking effects
- Access: Deuteron as neutron target



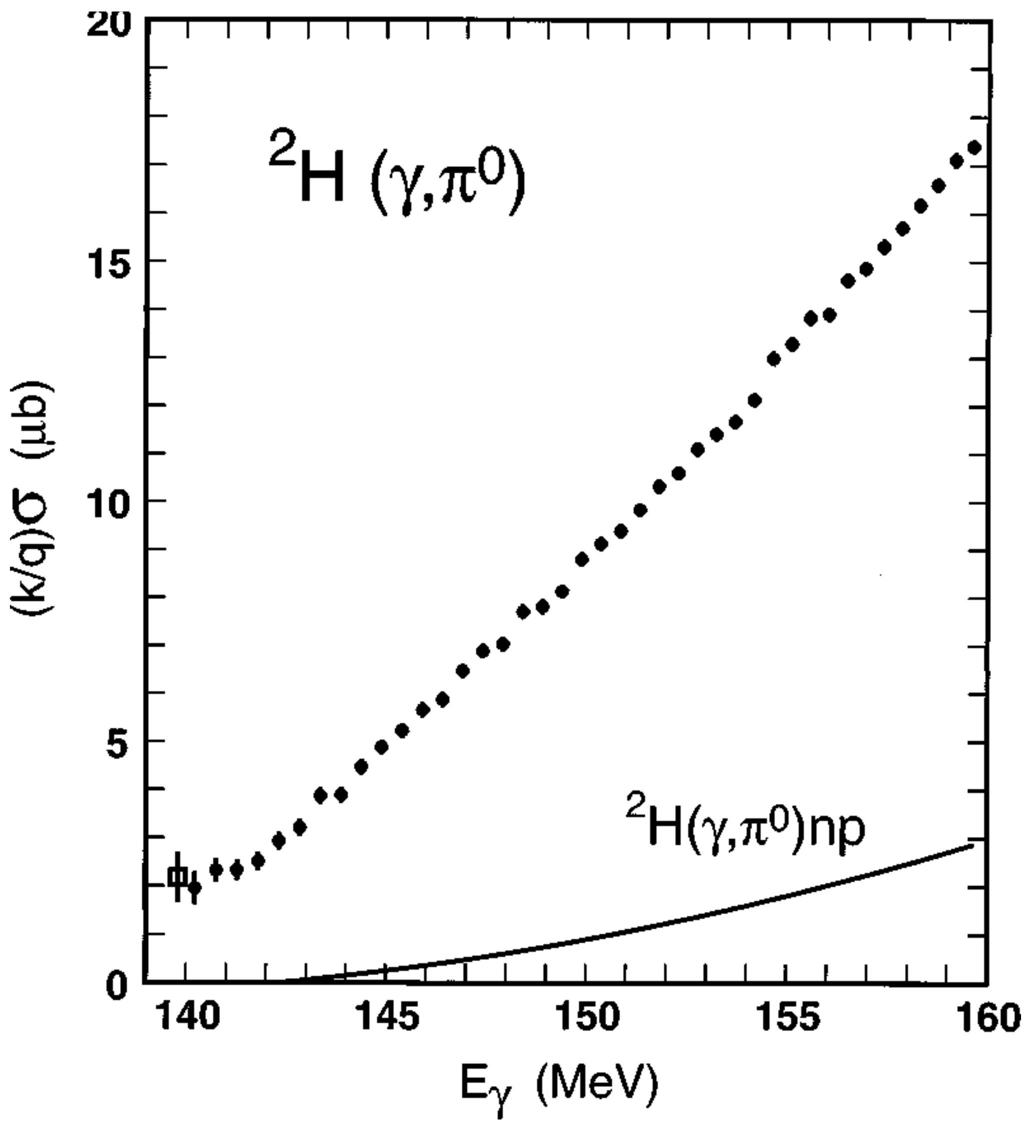
  - Fermi momentum ≈ reaction momentum
- Coherent production



  - Deuteron structure has to be unfolded
  - Measure E_d, try to extract $E_{0+}^{n\pi^0}$

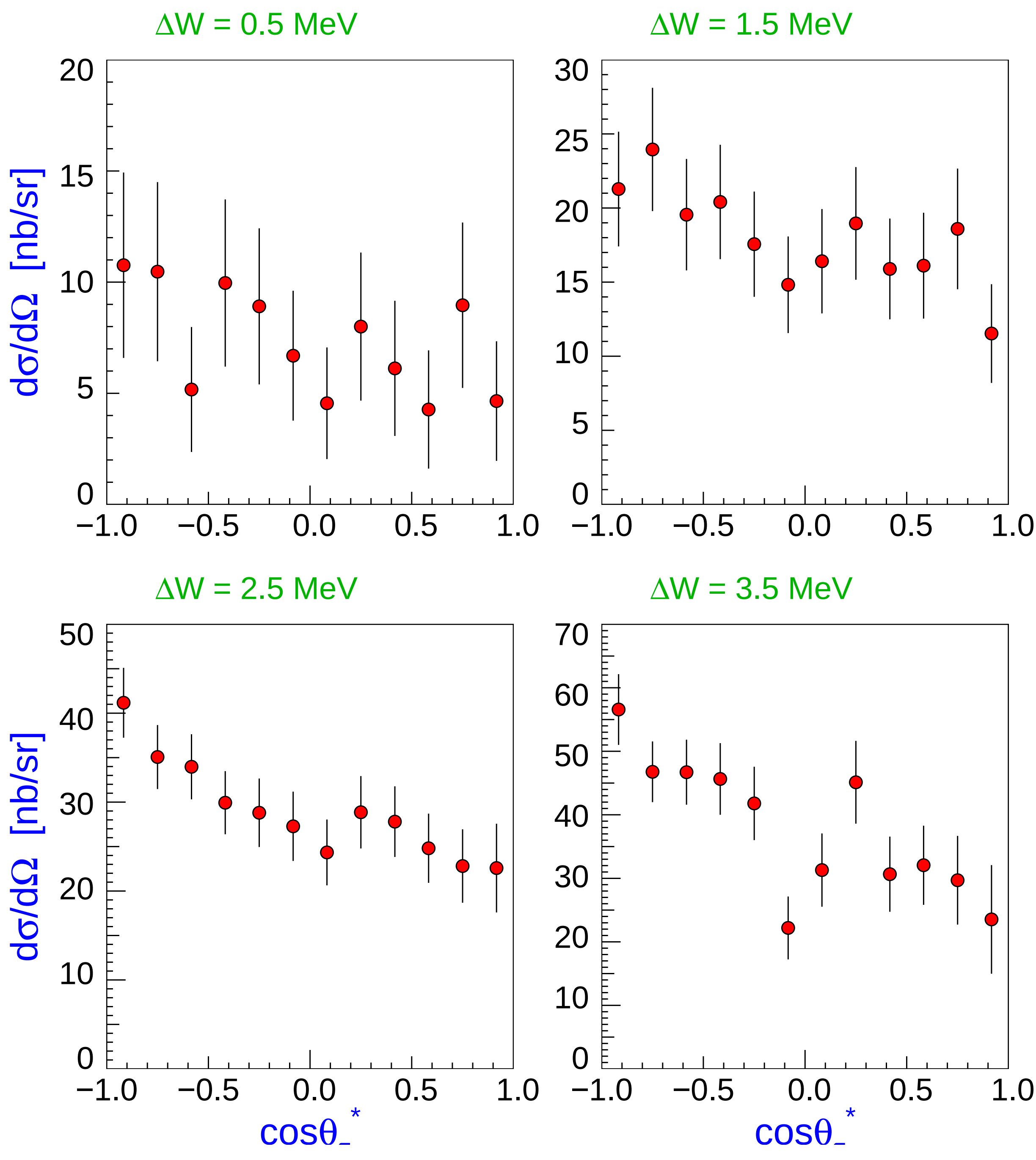
Coherent Photo Production: SAL

- Detection of $\pi^o \to \gamma\gamma$ with IGLOO Detektor
- Deuteron breakup calculated
- Extrapolation of s wave cross section $\longrightarrow$ threshold
- E_d 20% less than Chiral Perturbation Theory



- SAL J. C. Bergstrom *et al.*, Phys. Rev. **C57,6** (1998) 3203
- ChPT S. R. Beane *et al.*, Nucl, Phys. **A618** (1997) 381

Differential Cross Section ($\varepsilon = 0.59$)

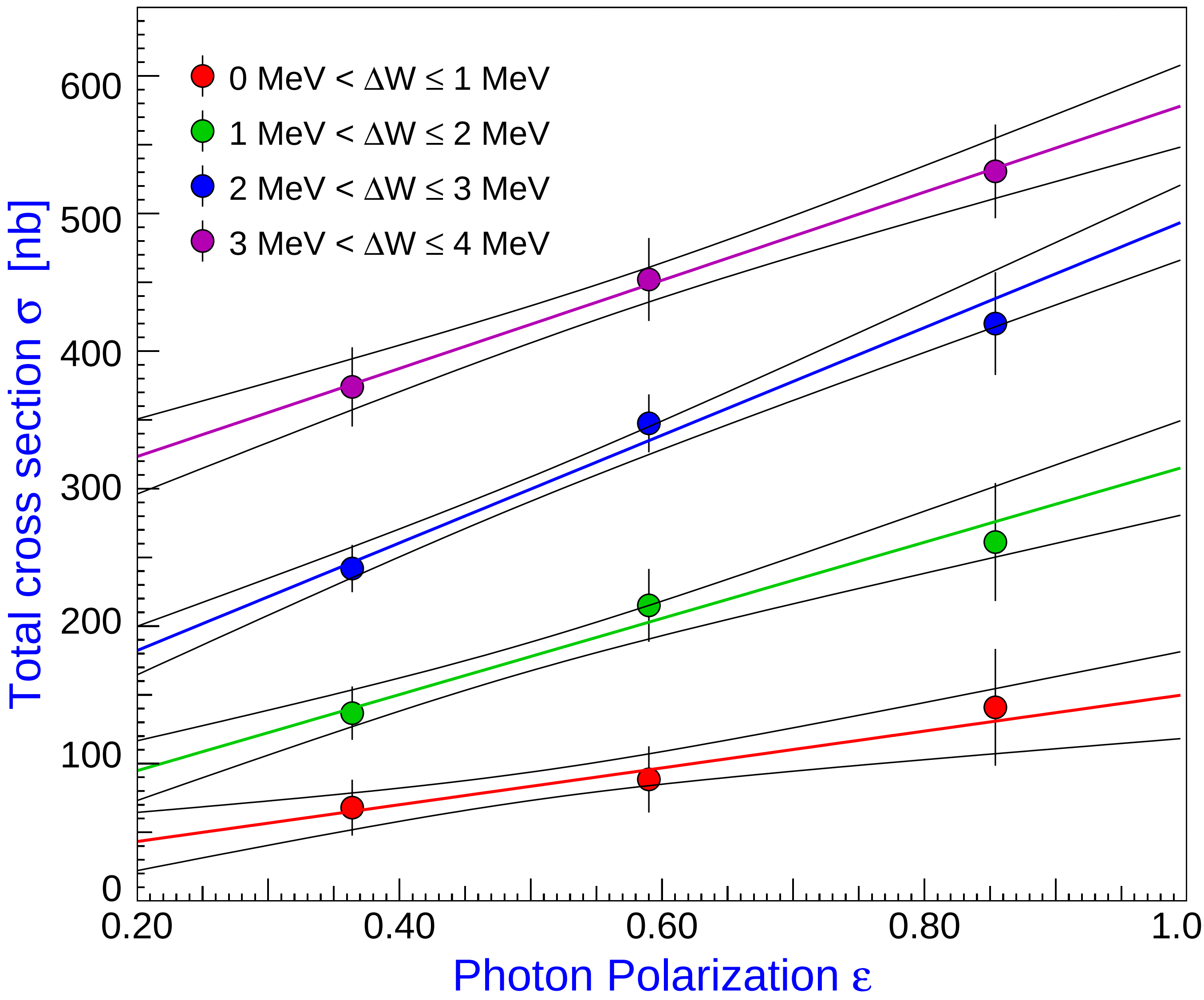


I. Ewald *et al.*, Phys. Lett. **B 499** (2001) 238-244

- Three values of photon polarization ε
  $\Rightarrow$ transverse-longitudinal separation
- Full coverage in azimuthal angle ϕ

L-T Separation

$$\sigma(W,q^2) = \sigma_T(W,q^2) + \varepsilon_L \sigma_L(W,q^2)$$

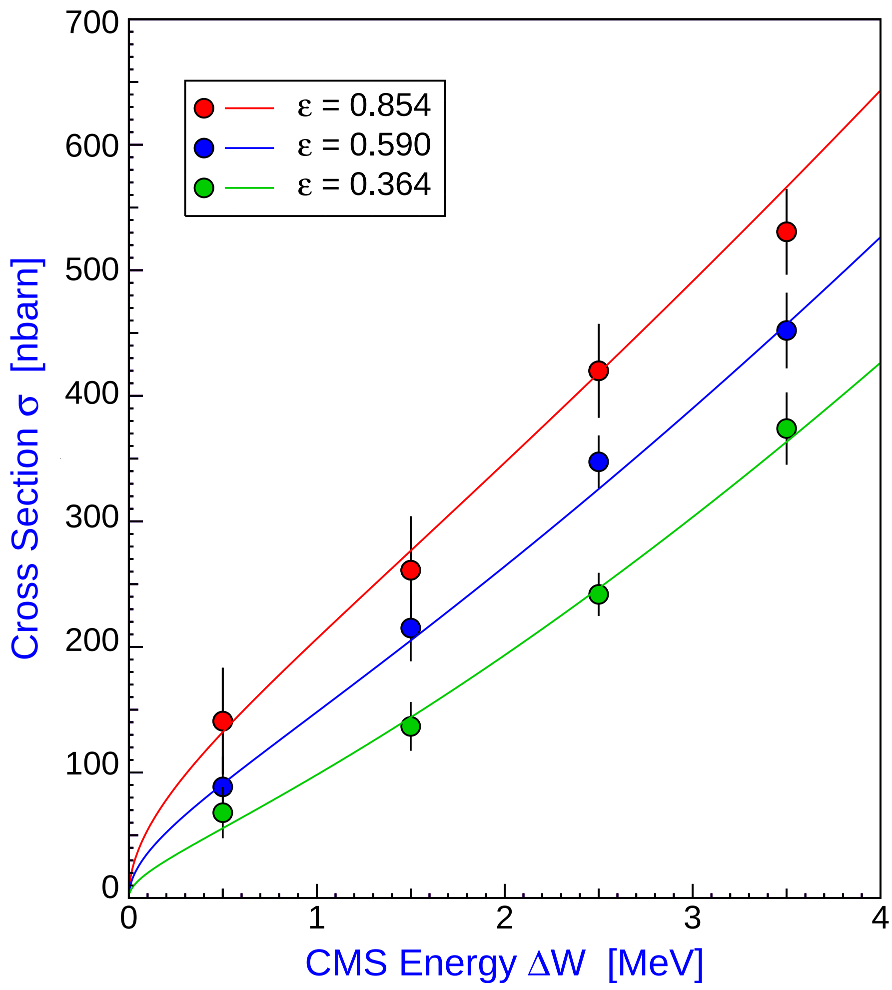


- Extrapolation to threshold
- $\varepsilon_L = \frac{Q^2}{\omega^{*2}}\varepsilon \approx 9 \times \varepsilon \Rightarrow$ upper limit for $|E_d|$
- $|L_d| = (0.47 \pm 0.18)10^{-3}/m_\pi$ at threshold

Separation of s and p waves

- only s and p waves at threshold
- p waves $\sim$ pion CMS momentum p_π^*

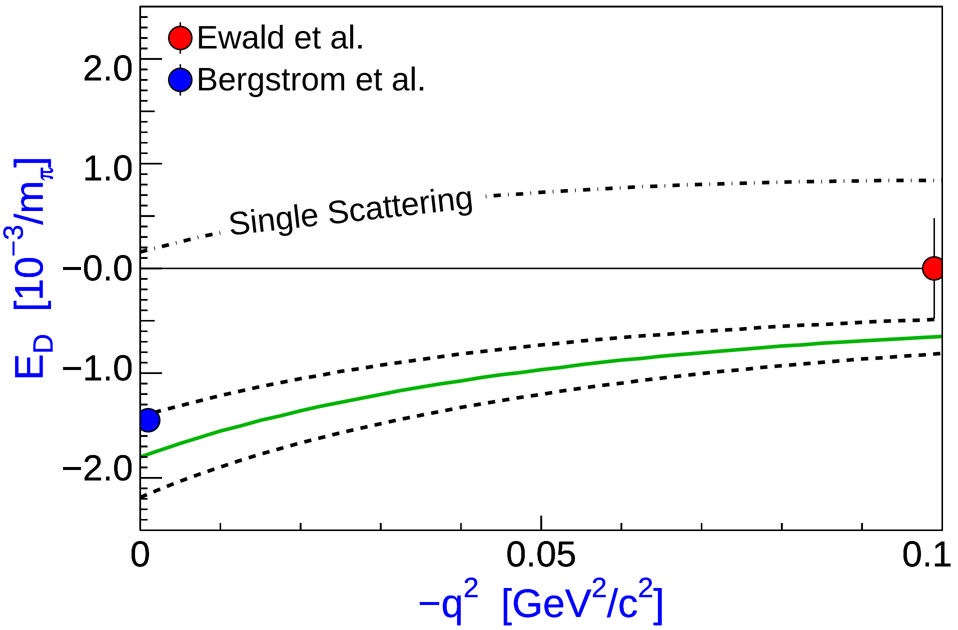
$$\frac{d\sigma}{d\Omega} = \frac{p_\pi^*}{k_\gamma^*}\{A + Bp_\pi^{*2} + Cp_\pi^*\cos\theta + Dp_\pi^{*2}\cos^2\theta$$
$$+ \ \varepsilon_L \cdot (E + F p_\pi^{*2} + G p_\pi^* \cos\theta + H p_\pi^{*2}\cos^2\theta)\}$$

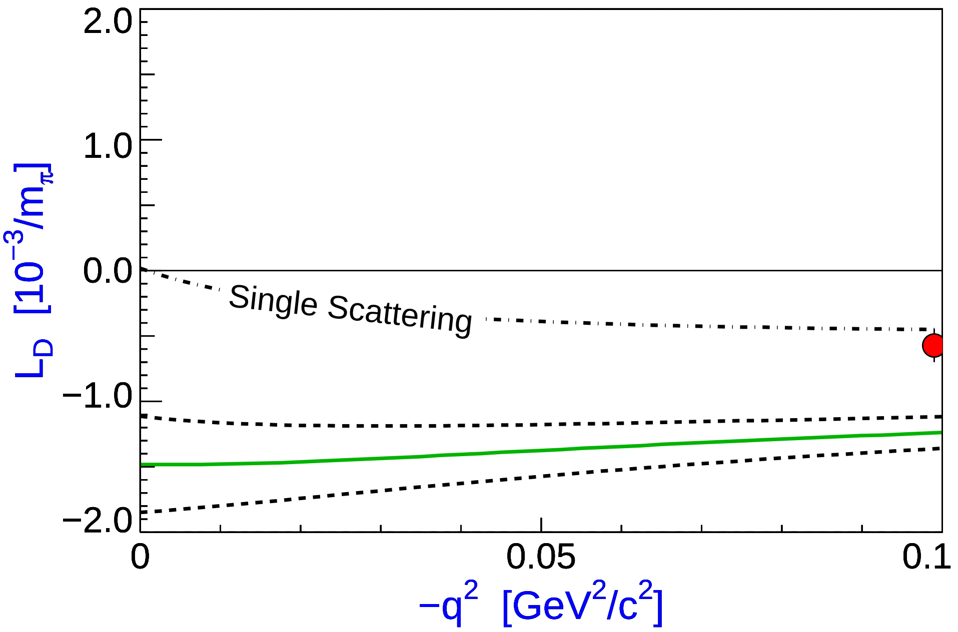


$$A \Rightarrow |E_d| \leq 0.42 \quad \cdot 10^{-3}/m_\pi$$
$$E \Rightarrow |L_d| = (0.50 \pm 0.11) \quad \cdot 10^{-3}/m_\pi$$

Comparison with ChPT

V. Bernard, H. Krebs, U.-G. Meißner, Phys. Rev. **C 61** (2000) 58201





- $|E_d|$ to small, consistent with photo production
- $|L_d|$ clear disagreement
- threshold cross section

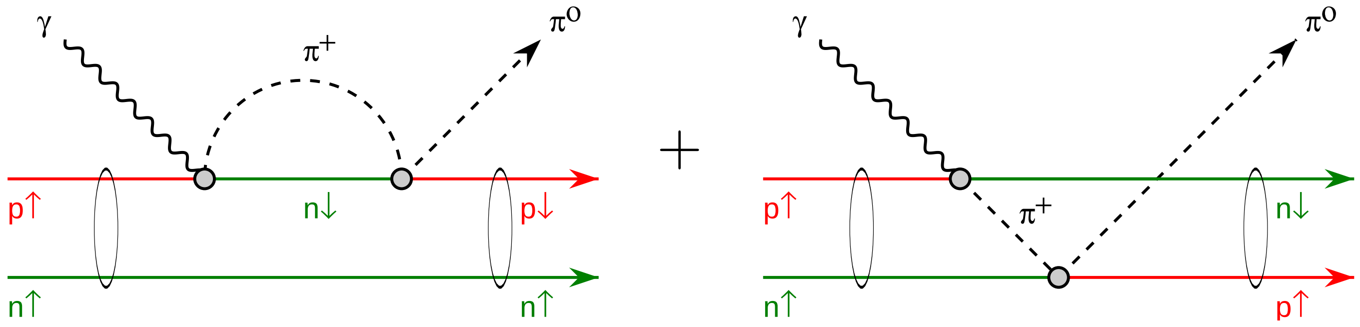
$$a_0 = |E_d|^2 + \varepsilon_L |L_d|^2$$

$\Rightarrow$ 1/10 of prediction

Explanation for Discrepancy

M. Rekalo and E. Tomasi-Gustafsson, nucl-th/0112063

Rescattering:



- Final $d\pi^0$ state:

$$J^P = 1^- \quad \Rightarrow \quad |pn\rangle = \frac{1}{\sqrt{2}}(|p\uparrow\ n\downarrow\rangle + |p\downarrow\ n\uparrow\rangle)$$

- Intermediate state for $l_{nn} = l_\pi = 0$:
  Pauli principle:

$$|nn\rangle = \frac{1}{\sqrt{2}}(|n\uparrow\ n\downarrow\rangle - |n\downarrow\ n\uparrow\rangle) \quad \Rightarrow \quad J^P = 0^-$$

- Coherent sum $\Rightarrow$ exact cancellation

$\Rightarrow$ No rescattering AND no s-wave cusp!

Summary

- Existing data
  - Photo production ✓
  - NIKHEF $Q^2 = 0.05\,\mathrm{GeV}^2/\mathrm{c}^2$
  - NIKHEF $Q^2 = 0.1\ \ \mathrm{GeV}^2/\mathrm{c}^2$ (✓)
  - MAMI $Q^2 = 0.1\ \ \mathrm{GeV}^2/\mathrm{c}^2$ (✓)

- New data set
  - MAMI $Q^2 = 0.05\,\mathrm{GeV}^2/\mathrm{c}^2$
  - Fifth structure function
  - σ_{TT} interference $\Rightarrow$ Separation of p waves

- Data sets inconsistent?
  - No discrepancy between data sets!
  - Strong Q^2 dependence unlikely?
  - JLab proposal E-01-014
  - MAMI experiment: $\Rightarrow$ Q^2 dependence

- Coherent production from the deuteron
  - Photo production ✓?????
  - Elektro production $1/10$ of prediction
  - Pauli $\Rightarrow$ no rescattering
  - Neutron amplitude in impulse approximation