MEASUREMENT OF THE PROTON SCALAR POLARIZABILITIES @ MAMI

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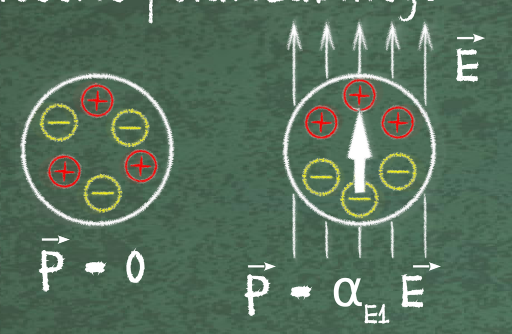
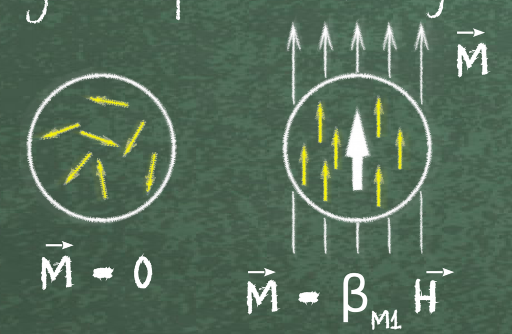
The scalar dipole polarizabilities α_{E1} and β_{M1} are fundamental properties related to the internal structure of the nucleon. They are important in hadronic physics, astrophysics, atomic physics, and other fields.

Electric polarizability:



Response of a proton to an applied electric field: "stretchability"

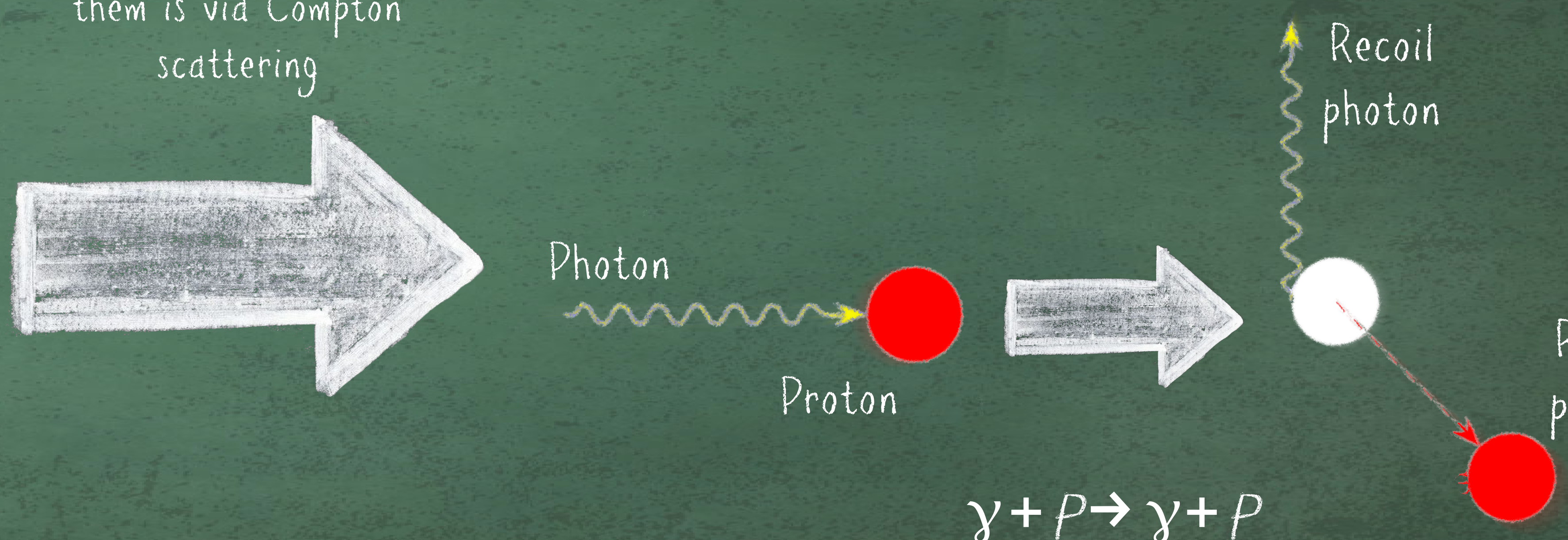
Magnetic polarizability:



Response of a proton to an applied magnetic field: "alignability"

The best way to measure them is via Compton scattering

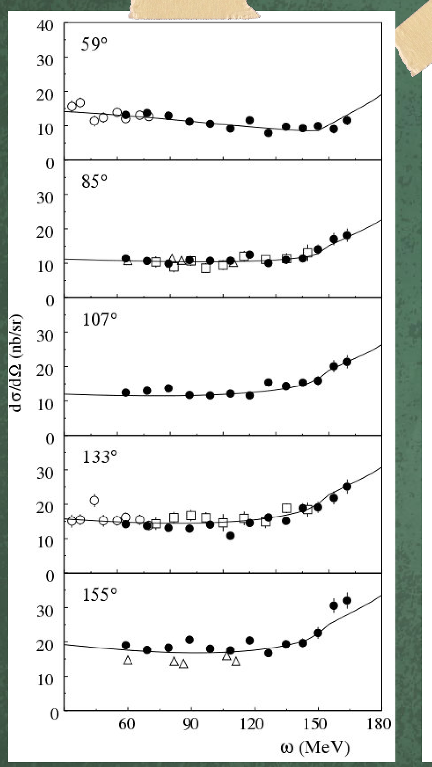
They contribute at the second order to the Hamiltonian for Compton scattering on the proton



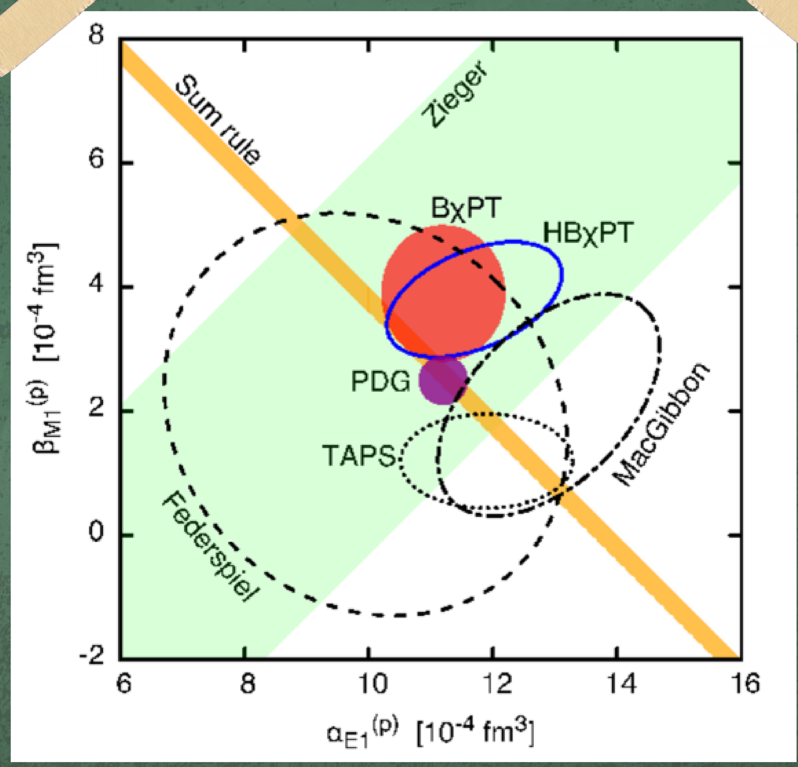
$\gamma + p \rightarrow \gamma + p$

EXISTING DATA

All on the unpolarized differential cross-section of Compton scattering



Olmos de Leon, V., EPJA 10, 207 (2001)



PDG (2012) values:
$\alpha_{E1}=(12.0\pm0.6)\times10^{-4}\ fm^3$
$\beta_{M1}=(1.9\pm0.5)\times10^{-4}\ fm^3$

Current PDG values:
$\alpha_{E1}=(11.2\pm0.4)\times10^{-4}\ fm^3$
$\beta_{M1}=(2.5\pm0.4)\times10^{-4}\ fm^3$

Significant change between reviews without new experimental data?
⇒ New high quality dataset needed!

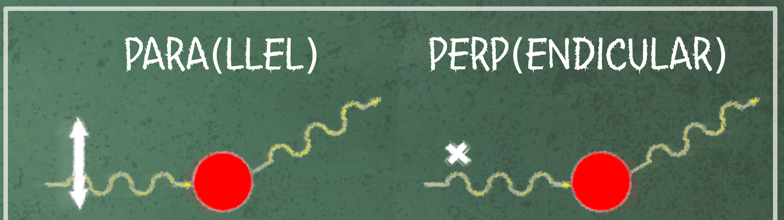
METHOD

At low energy, β_{M1} can be extracted from the beam asymmetry Σ_3 using a linearly polarized photon beam and an unpolarized proton target:

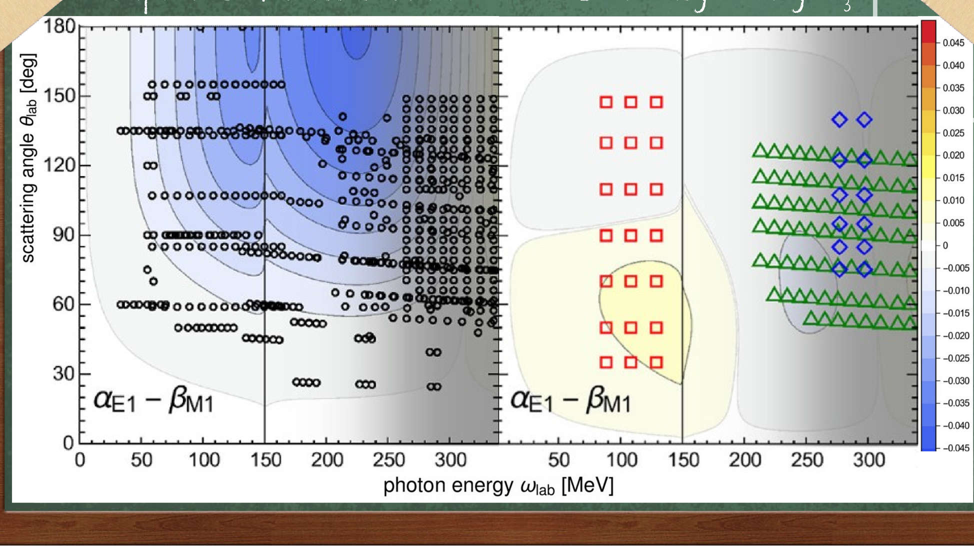
$$\frac{d\sigma}{d\Omega}(\theta,\phi)=\frac{d\sigma}{d\Omega}(\theta)\left[1+p_\gamma\Sigma_3\cos(2\phi)\right]$$

$$\Sigma_3=\frac{d\sigma_\perp-d\sigma_\parallel}{d\sigma_\perp+d\sigma_\parallel}$$

Unpolarized cross-section — Beam asymmetry Σ_3



Linearly polarized beam and unpolarized target

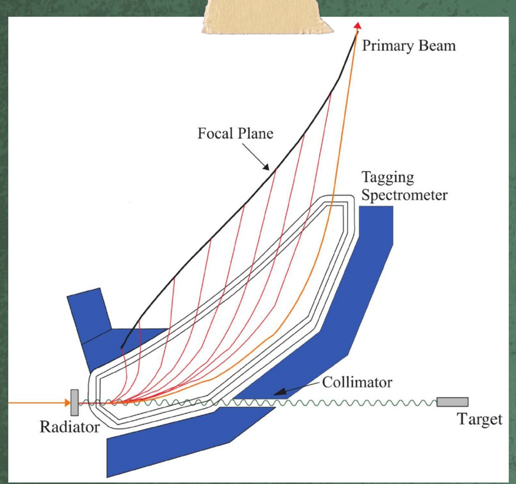


Grießhammer, H.W., McGovern, J.A. & Phillips, D.R. EPJA (2018) 54: 37

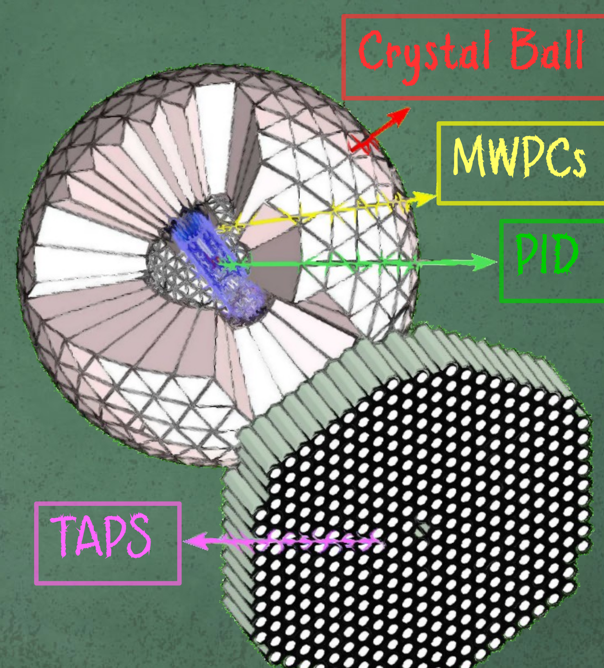
Simultaneous measurement of unpolarized cross-section and beam asymmetry Σ_3

CRYSTAL BALL/TAPS APPARATUS @ MAMI (MAINZ)

High intensity beam of linearly polarized tagged photons



Upgrade of the Focal Plane Detector (FPD)!
⇒ 3 times higher rate!



Target: LH_2

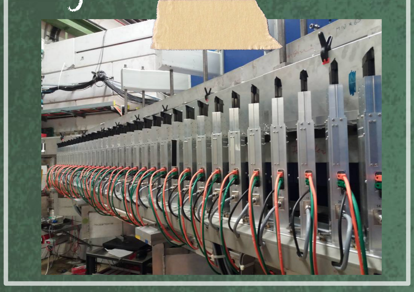
Crystal Ball
672 NaI(Tl) crystals
Particle Identification Detector (PID):
24 scintillator paddles
2 Multiwire Proportional Chambers (MWPCs)

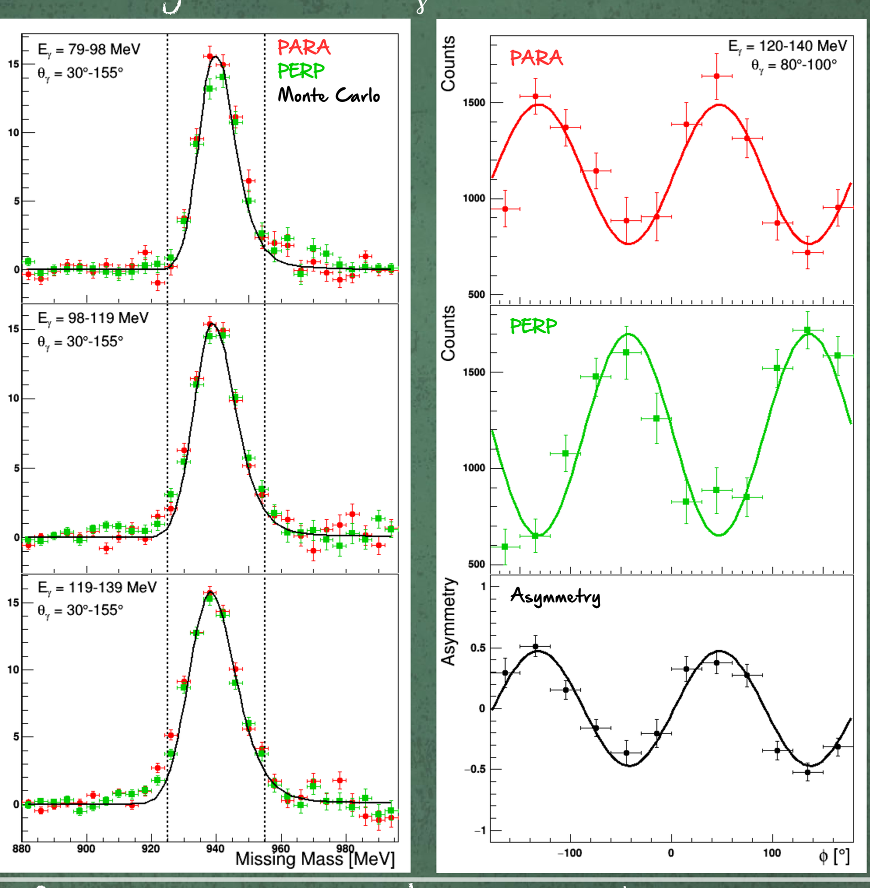
TAPS calorimeter
366 BaF_2 and
72 $PbWO_4$ crystals
384 veto paddles

HIGH PRECISION EXPERIMENT

~ 600k good Compton scattering events in E_γ = 80-140 MeV

New FPD is here:
- higher photon flux
- higher efficiency
- better control of systematics





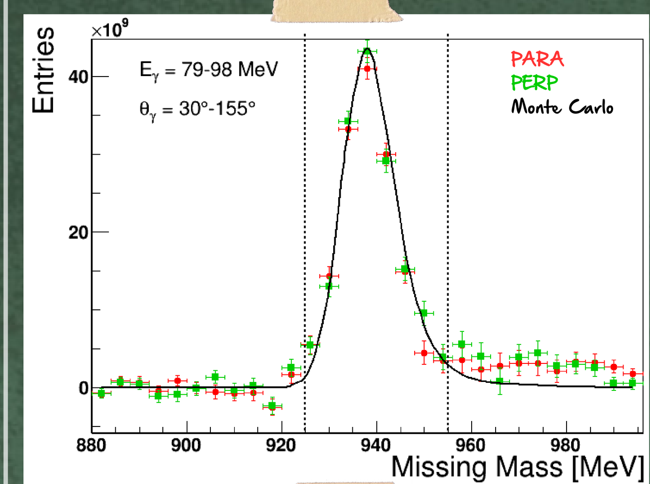
The biggest Compton scattering dataset in this energy range!
(and even more data will come soon...)

I acknowledge the contributions and suggestions of N. Krupina, V. Lensky, J. McGovern, V. Pascalutsa and B. Pasquini to this work, as well as support from the Collaborative Research Center (CRC) 1044.

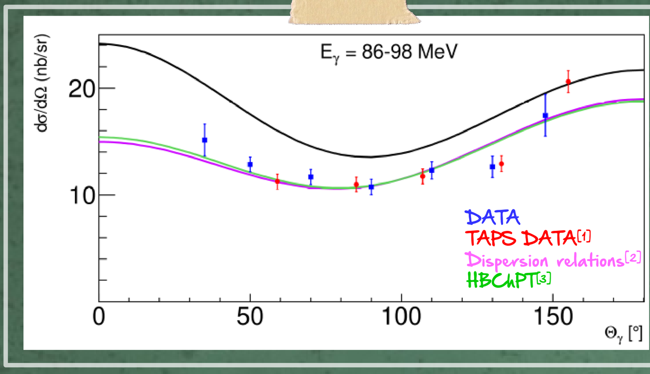
ONGOING

PILOT EXPERIMENT

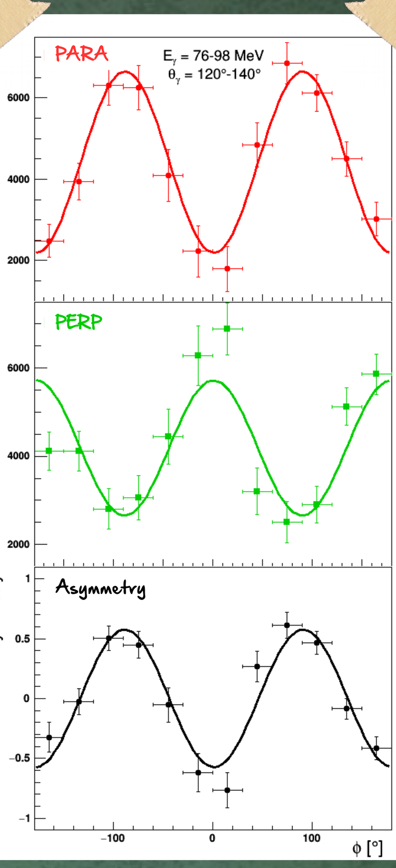
~ 200k good Compton scattering events in E_γ = 80-140 MeV



Good agreement between PARA, PERP and Monte Carlo simulation!



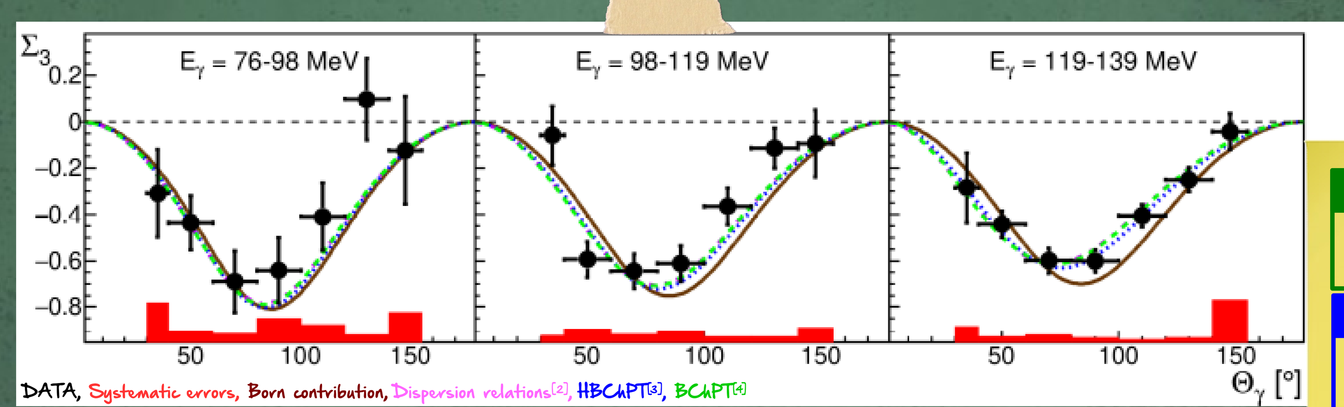
Good agreement in unpolarized cross section with old data and DR prediction!



RESULTS

Sokhoyan, V., Downie, E.J., Mornacchi, E., McGovern, J.A., Krupina, N., et al. Eur. Phys. J. A (2017) 53: 14

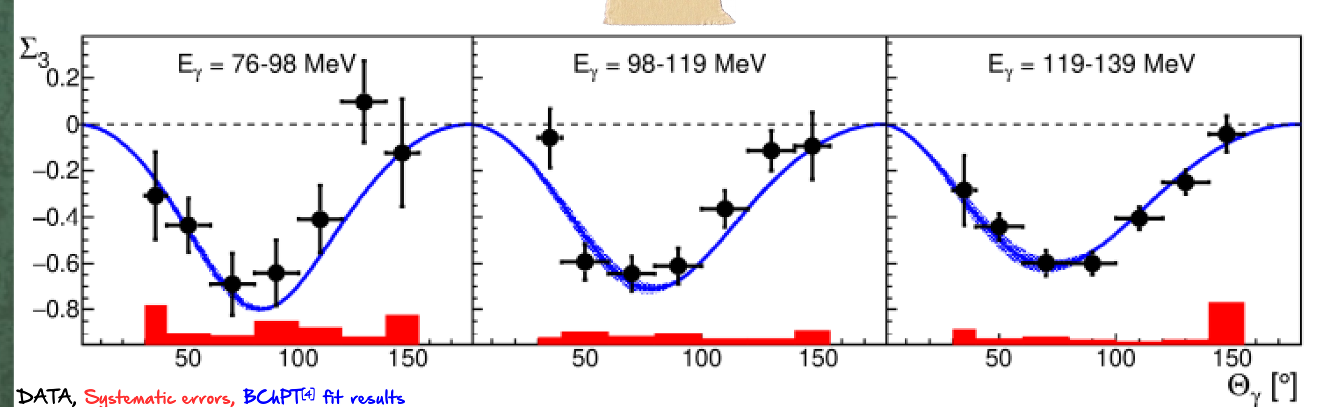
Theoretical predictions for fixed α_{E1} = 10.65x10^{-4} fm^3 and β_{M1} = 3.15x10^{-4} fm^3:



BChPT framework[4]:
$\beta_{M1}= 2.8^{+2.3}_{-2.1}\times10^{-4}\ fm^3$
χ^2/ndf = 19.2/20

HBChPT framework[3]:
$\beta_{M1}= 3.7^{+2.5}_{-2.3}\times10^{-4}\ fm^3$
χ^2/ndf = 17.1/20

Fit results using only new Σ_3 data within ChPT[4] framework:



[1] Olmos de Leon, V., EPJA 10, 207 (2001)
[2] B. Pasquini, D. Drechsel, and M. Vanderhaeghen, Phys. Rev. C 76 (2007)
[3] J. A. McGovern, D. Phillips, H. Grießhammer, EPJA 49, 12 (2013)
[4] N. Krupina and V. Pascalutsa, PRL 110, 262001 (2013)

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