Modifications of the $D_{33}(1700)$ resonance in the nuclear medium

Vahe Sokhoyan

A2 Collaboration Meeting
Basel, 07.09.2016

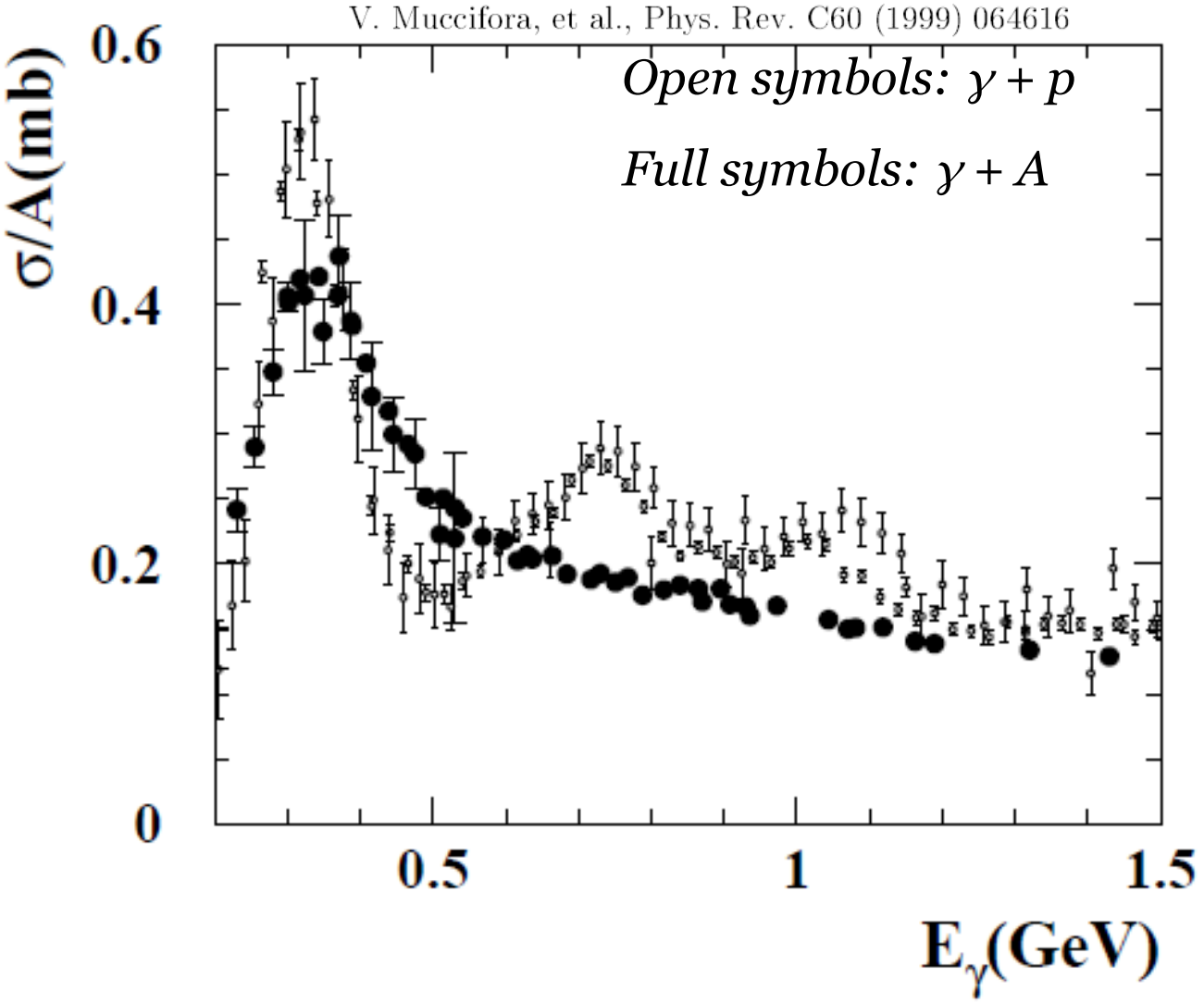
Supported by the Carl-Zeiss-Stiftung

Motivation

- Goal: Search for in-medium modifications of baryon resonances

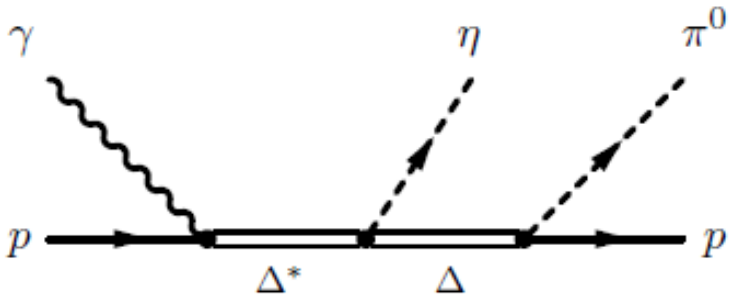
  Pronounced in-medium effect: No bump structure in the photoabsorption cross-section measured for $\gamma + A$

  → not fully explained in a model-independent way

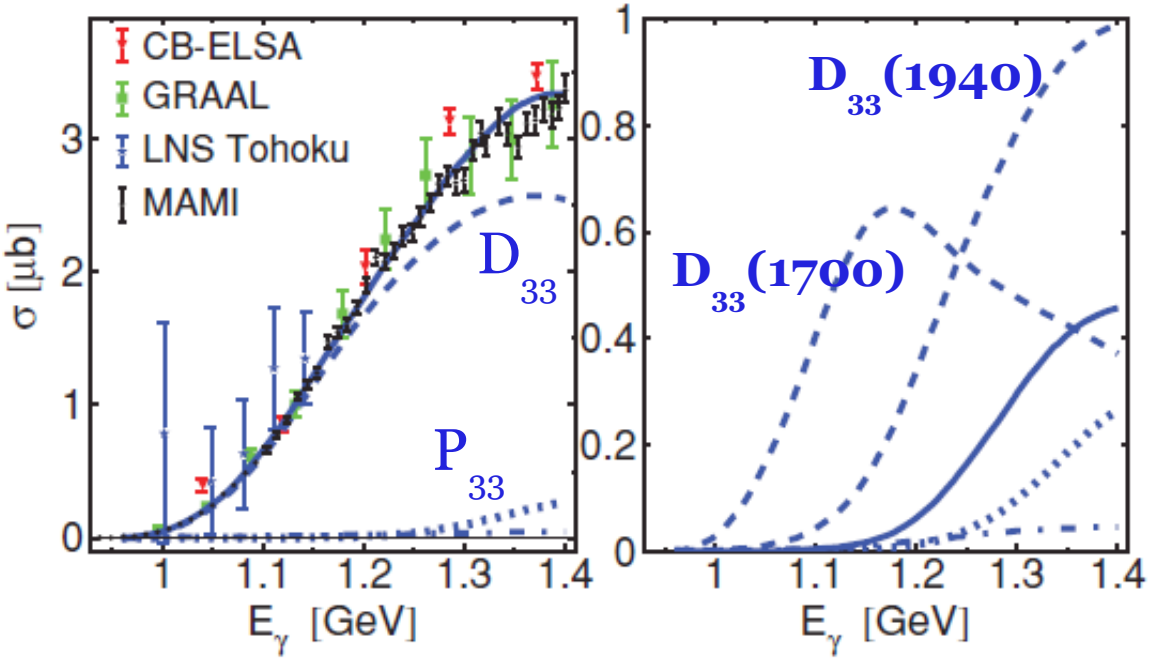


$\pi^0\eta$ photoproduction (proton target)

- The production of $\pi^0\eta$ pairs best suited to study the $D_{33}(1700)$ resonance
- η acts as an isospin filter: Access to $\gamma p \rightarrow D_{33}(1700) \rightarrow \Delta(1232)\eta \rightarrow p\pi^0\eta$

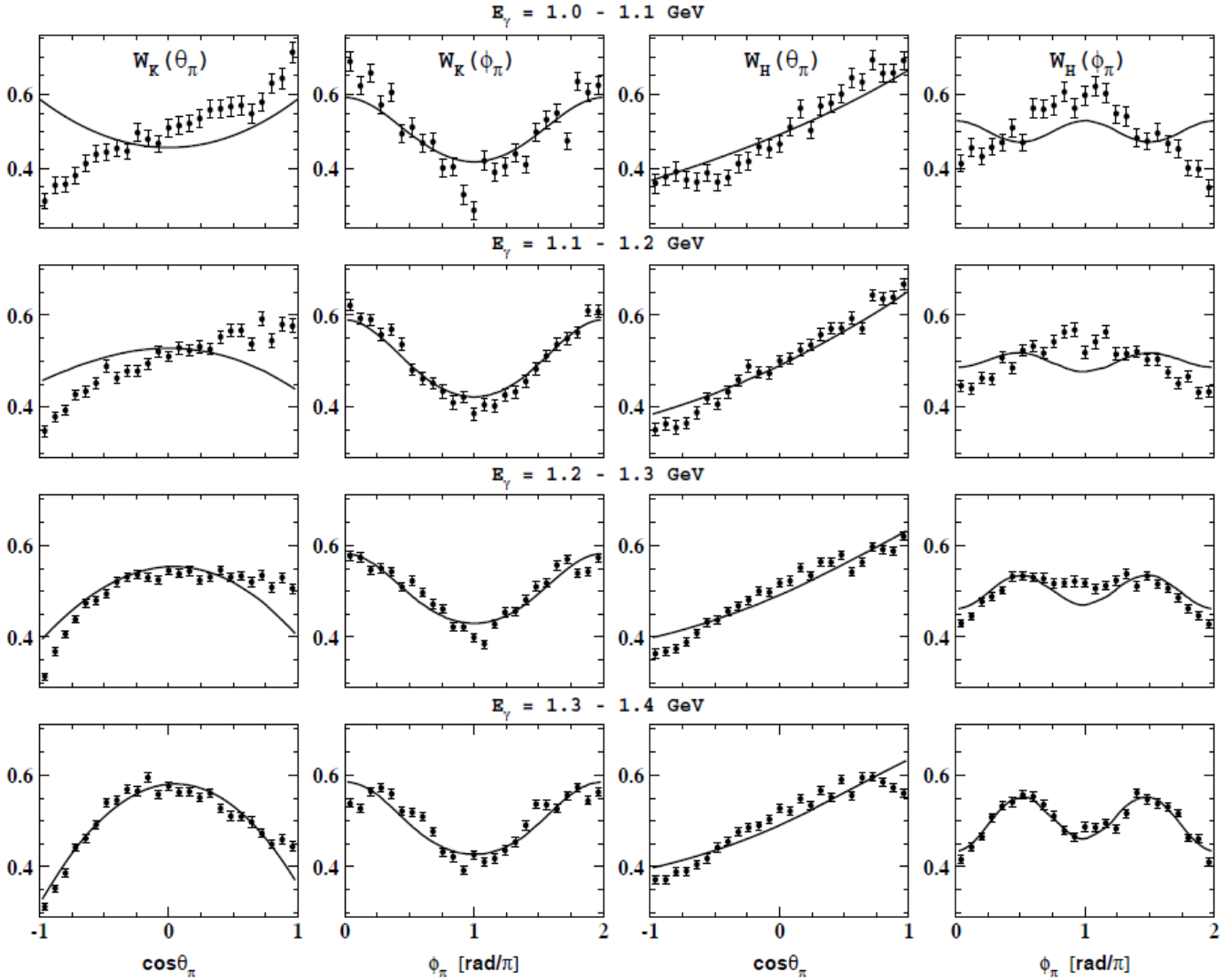


- $D_{33}(1700)$ dominates close to the production threshold



V. L. Kashevarov, A. Fix et al., Eur. Phys., J. A 42, 141 (2009) [A2 Collaboration]

Angular distributions (proton target)



Angular distributions: Reasonable agreement with a model including only the D_{33} amplitude

V. L. Kashevarov, A. Fix et al., Eur. Phys., J. A 42, 141 (2009)
[A2 Collaboration]

Polarization observables

Double meson final states:
For a complete experiment, 15 observables are needed!
W. Roberts and T. Oed, Phys. Rev. C 71, 055201 (2005)

Polarized cross-section (only polarized beam):

$$\frac{d\sigma}{dx_i} = \left(\frac{d\sigma}{dx_i}\right)_0 (1 + P_\gamma\, I^{\odot} + \delta_l\,(\, I^c cos\,2\varphi + \, I^s sin\,2\varphi))$$

Pγ: degree of circular polarization, δ_l: degree of linear polarization

Linear polarization: high sensitivity to resonances

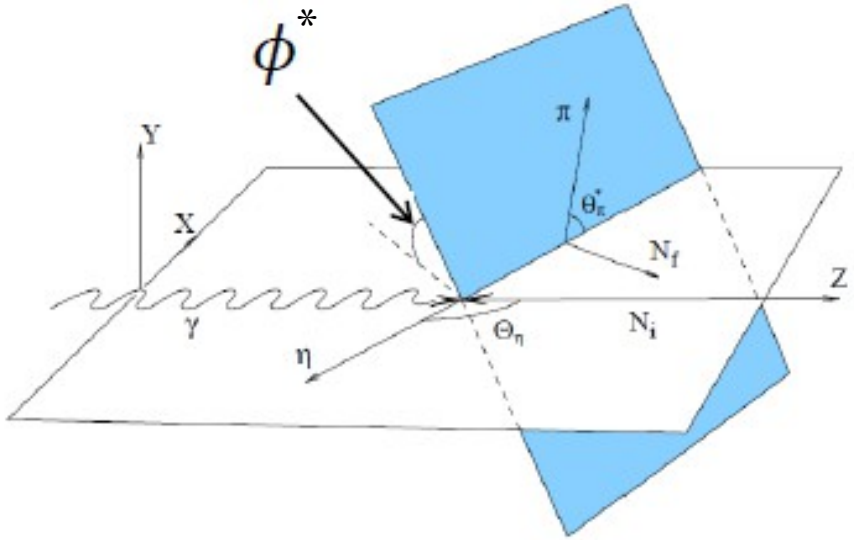
V. S., E. Gutz, V. Crede, H. van Pee, et al., Eur. Phys. J. A51, 2015 *[CBELSA/TAPS Collaboration]*
V. S., E. Gutz, H. van Pee et al., Phys.Lett. B746, 2015 *[CBELSA/TAPS Collaboration]*
E. Gutz, V.S., H. van Pee et al., *Phys. Lett. B687, 2010 [CBELSA/TAPS Collaboration]*
E. Gutz, V. Crede, V.S., H. van Pee et al., *Eur. Phys. J. A50 74, 2014 [CBELSA/TAPS Collaboration]*

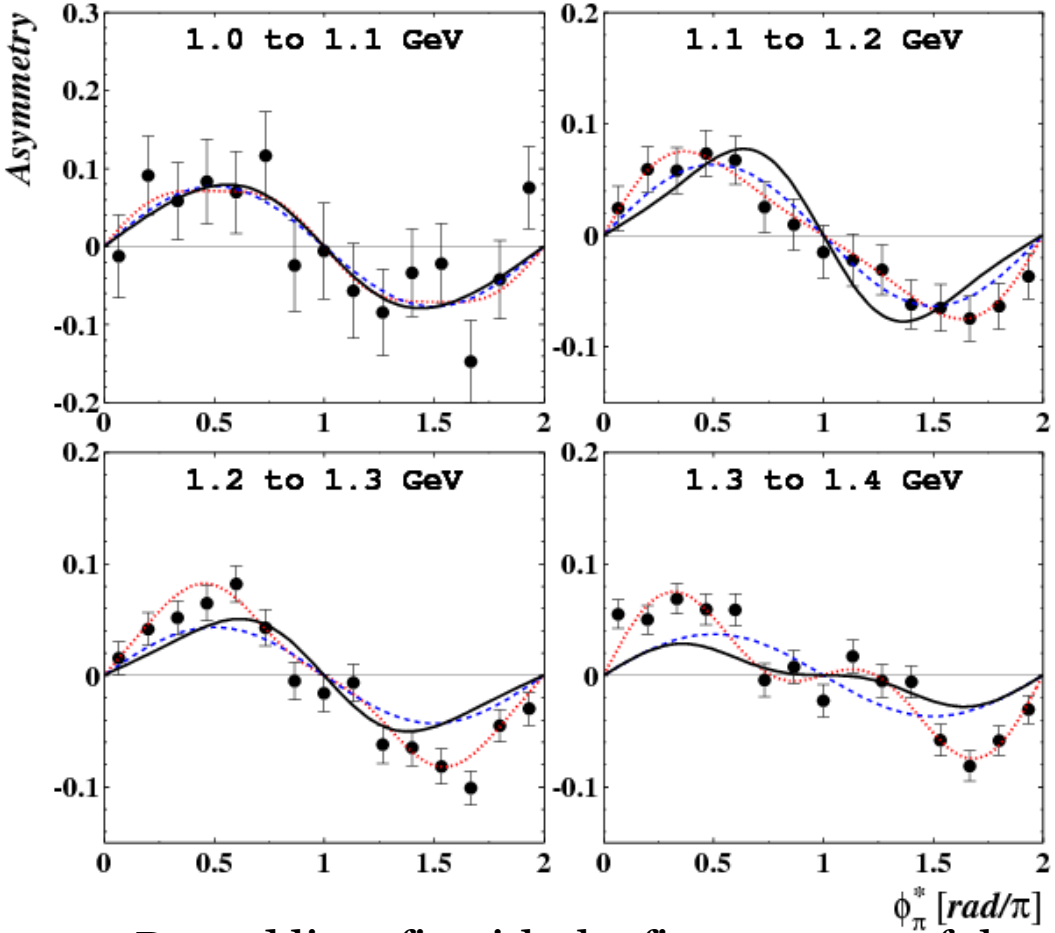
- Relatively low polarization at energies ~1 GeV
- Difficulties in extraction of unpolarized cross-sections

Circular polarization: high sensitivity to $D_{33}(1700)$

V. L. Kashevarov, A.Fix et al., *Phys. Lett. B 693, 551, 2010 [A2 Collaboration]*
High values of polarization achievable at ~1 GeV
No modification of the incoming photon energy spectrum

Beam helicity asymmetry (proton target)





Beam helicity asymmetry:

$$W^c(\phi) \sim \sigma^+(\phi) - \sigma^-(\phi)$$

$W^c(\phi)$ can be expanded as:

$$W^c(\phi) = \sum_{n=1}^{n_{max}} A_n \sin n\phi$$

Dotted line: fit with the first 3 terms of the sine expansion (A1, A2, A3)
Solid line: isobar model with 6 resonances
Dashed line: only D33 wave

V. L. Kashevarov, et al., Phys. Lett. B 693, 551 (2010)

[A2 Collaboration]

Both unpolarized and polarized data indicate the dominance of the D_{33} wave at energies $E_\gamma < 1.2$ GeV

Existing data and next steps

Existing data sets:

- The structure in these observables is reasonably described by the $D_{33}(1700)$ resonance within the isobar model for the proton target at $E_\gamma < 1.2$ GeV (A. Fix, et al.)
- Any changes of these observables beyond FSI will allow access to the in-medium properties of the $D_{33}(1700)$
- Measurements performed by the A2 Collaboration with proton and deuteron targets will be used as a reference

We are extracting:

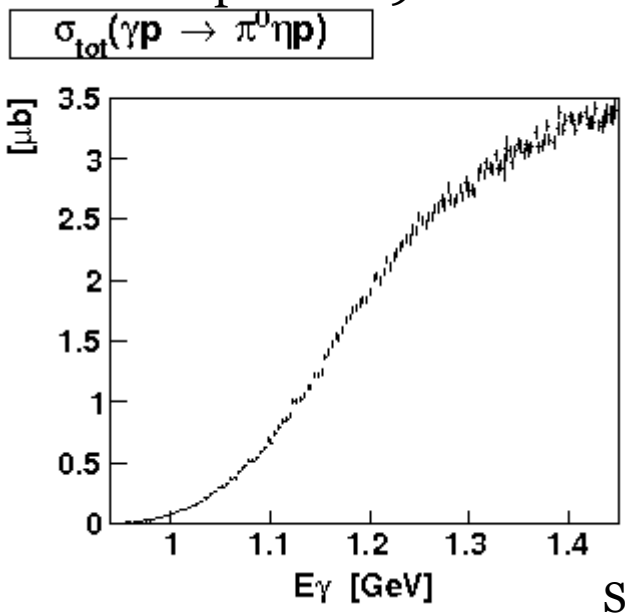
- **Differential cross-sections and beam helicity asymmetry close to the $\pi^0\eta$ production threshold with C, Al and Pb targets**

- Data on ^{4}He will be acquired in the near future

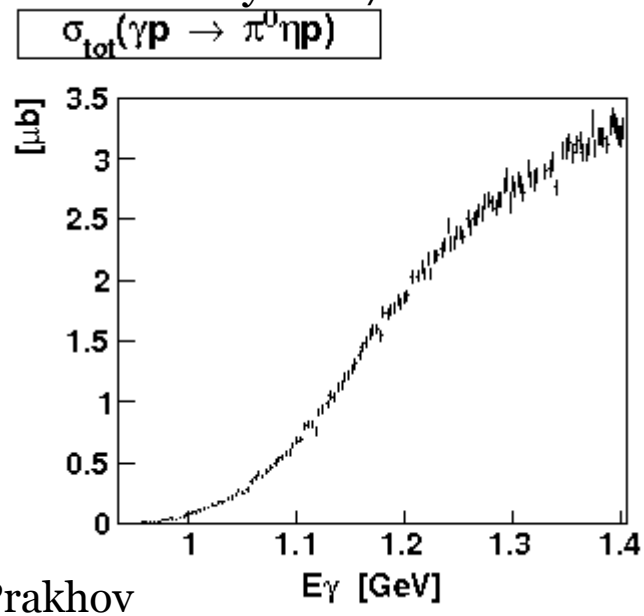
Reanalysis of the LH2 data

- LH2 data were reanalyzed to obtained reference spectra for solid targets
- Kinematic fit applied (S. Prakhov) and event-based data sample obtained
- Reasonable agreement between April 2009 data (> 77,000 events), July 2007 (> 22,000 events) and previously published (2009) data observed
- Total cross-section, angular distributions, Dalitz plots and beam helicity asymmetry extracted
- Besides serving as a reference for the solid targets, the LH2 data (4-vectors) can be used as input for the PWA

April 2009 data

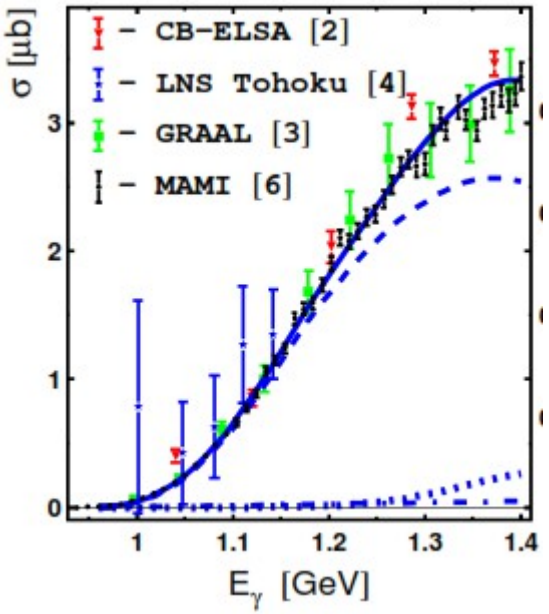


July 2007 data



S. Prakhov

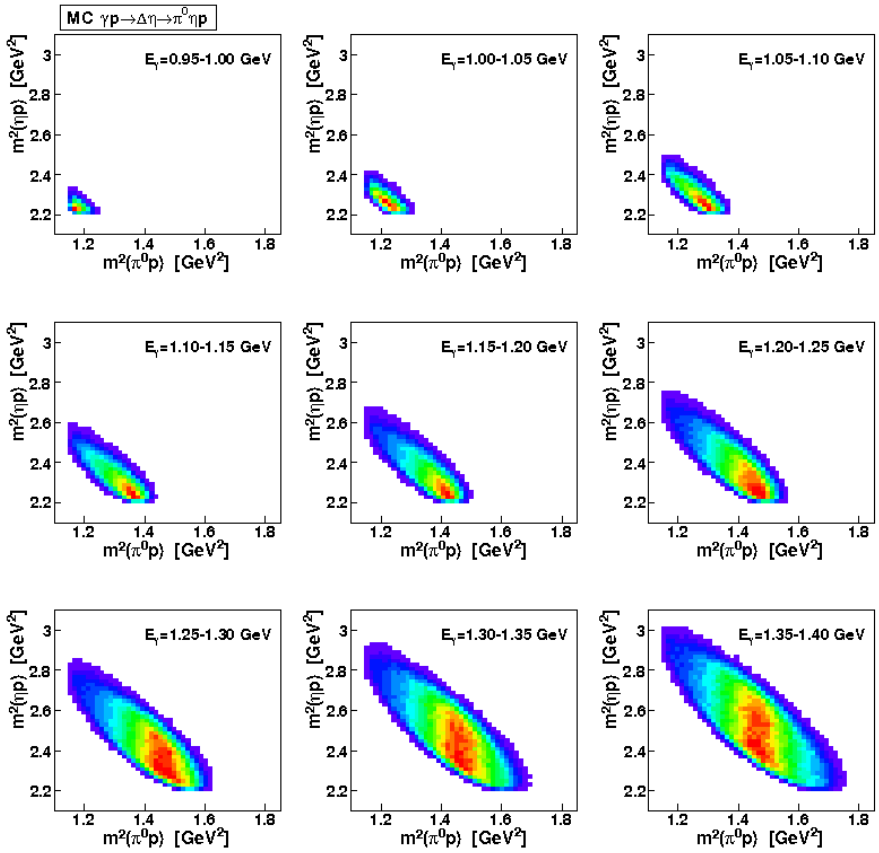
V. L. Kashevarov, A. Fix et al., Eur. Phys., J. A 42, 141 (2009)



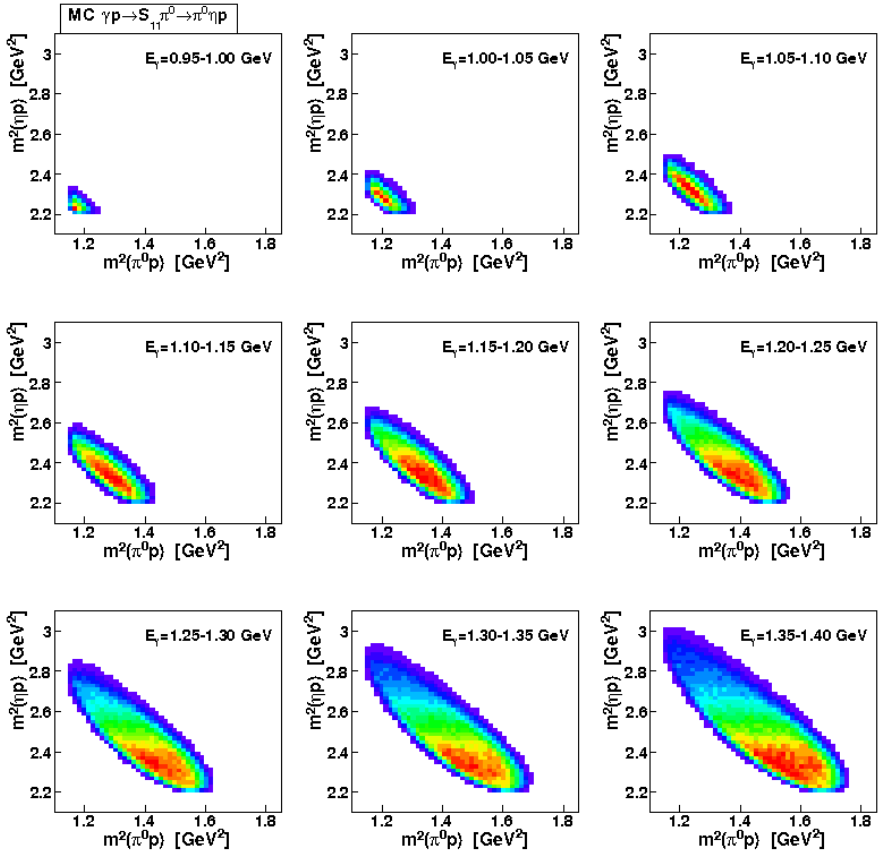
Reanalysis of the LH2 data, Dalitz plots

Monte Carlo simulation

$\gamma p \to \Delta(1232)\eta \to p\pi^0\eta$



$\gamma p \to S_{11}\pi^0 \to p\pi^0\eta$

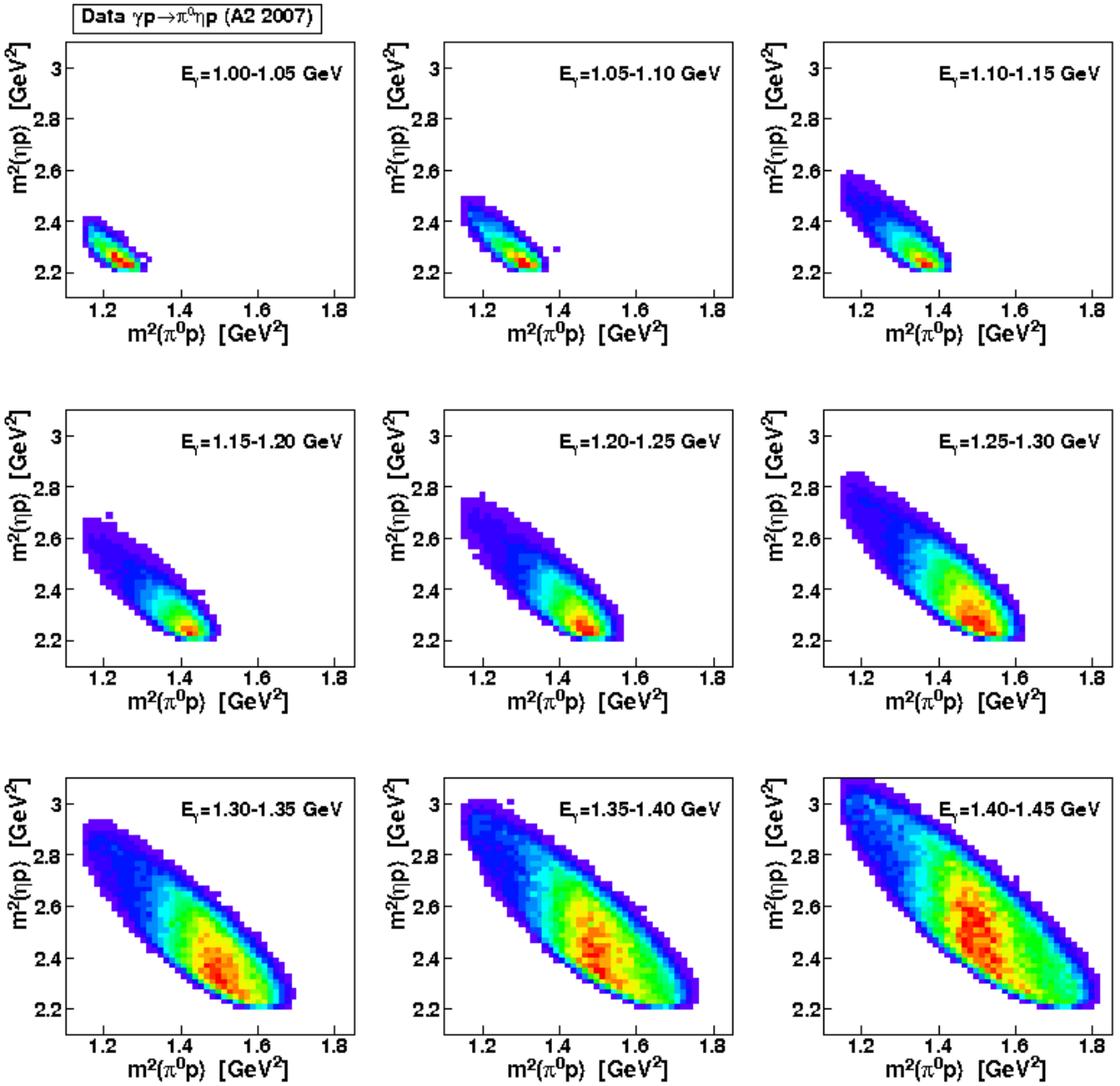


S. Prakhov

Reanalysis of the LH2 data, Dalit plots

Data

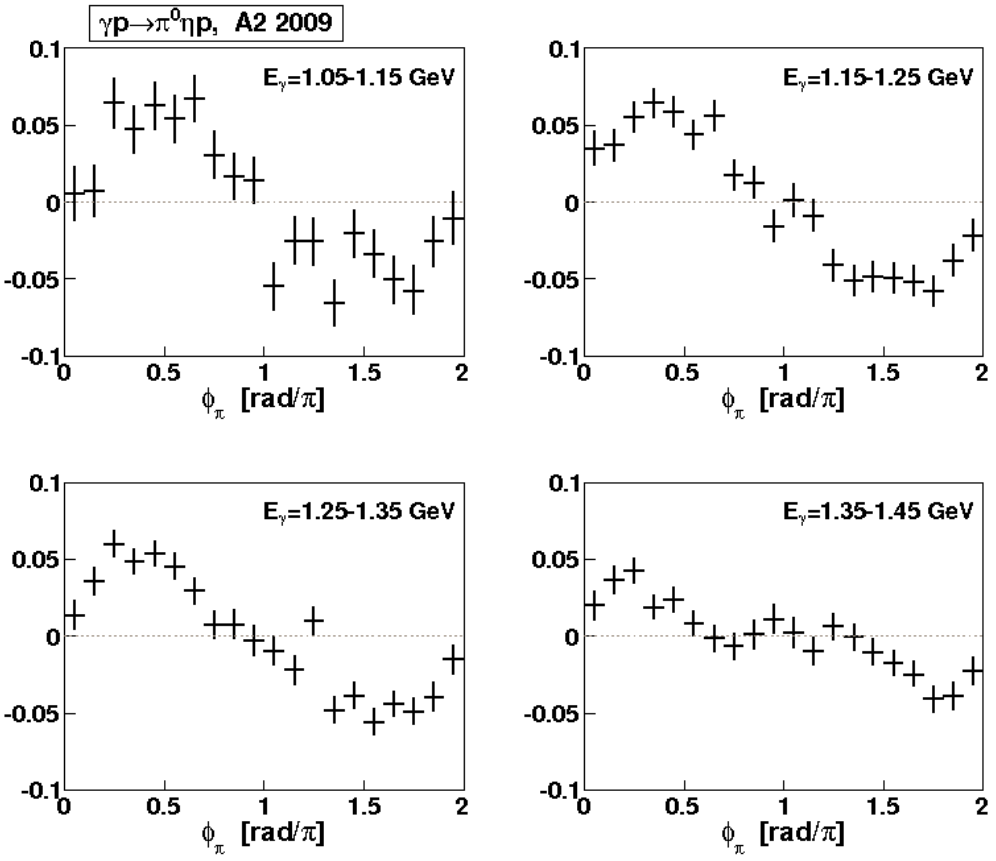
S. Prakhov



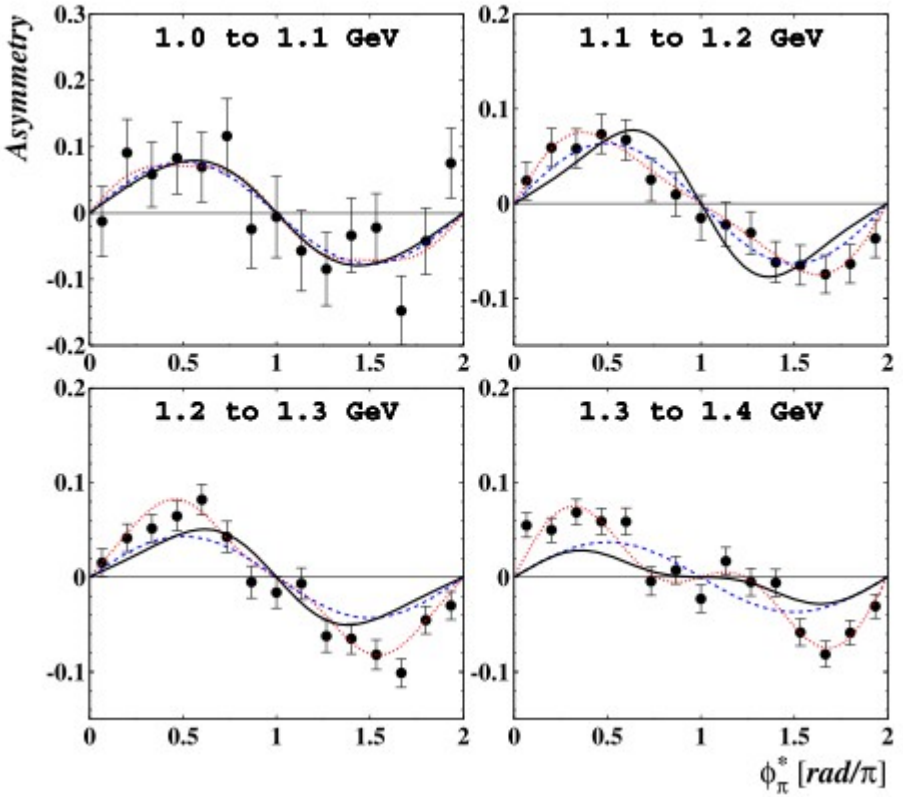
Compatible with $\gamma p \to (D_{33}(1700)) \to \Delta(1232)\eta \to p\pi^0\eta$

Reanalysis of the LH2 data

April 2009



Beam helicity asymmetry (polarization included)
S. Prakhov



V. L. Kashevarov, et al., Phys. Lett. B 693, 551 (2010)

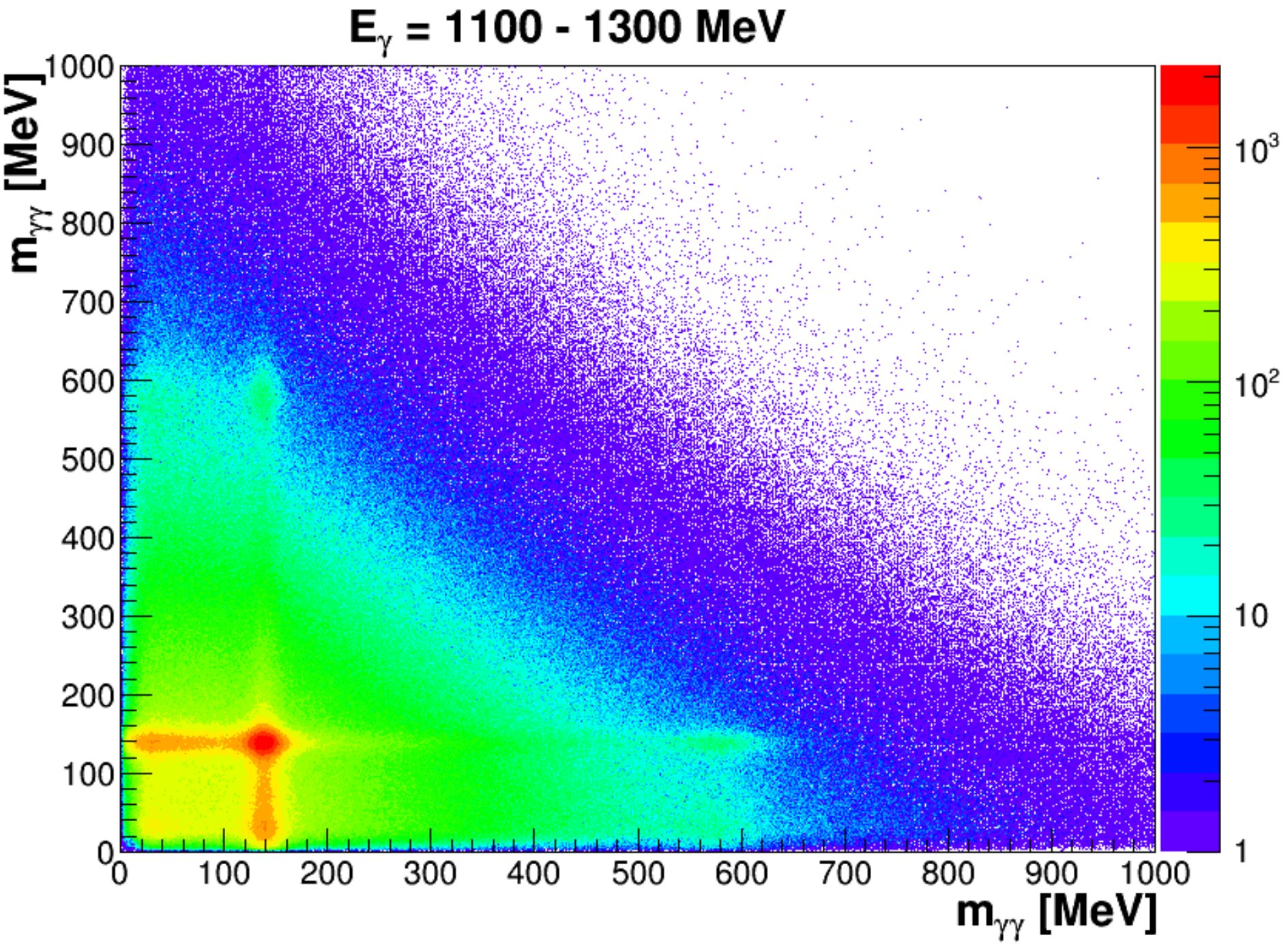
Run conditions

- Targets C (2 cm), Al (8 mm), Pb (0.5 mm), empty target
- E_{beam} = 1557 MeV (+ 8 hours with 883 MeV with the Pb target)
- Circularly polarized photons (electron polarization 70-74%)
- Tagged photon energy E_γ > 500 MeV for C and Al, E_γ > 780 MeV for Pb
- Currents: 4.5 nA (C), 7.5 nA (Al), 16.5 nA (Pb)
- Collimator: 2.5 mm
- Trigger: M2+ and

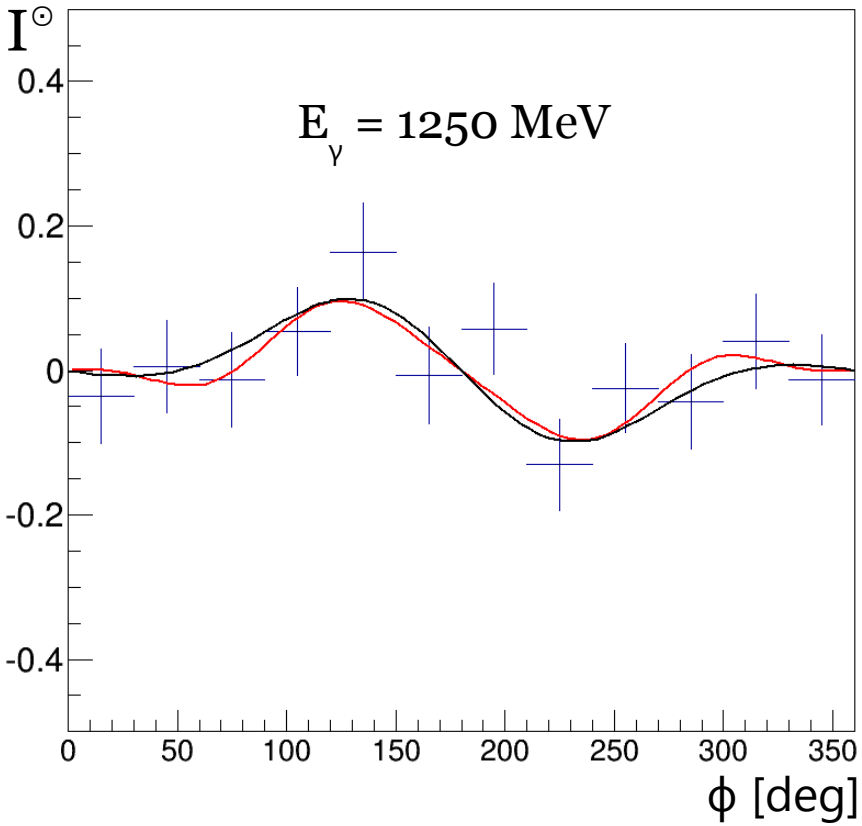
  CB_{Esum} > 320 MeV for Al and Pb targets

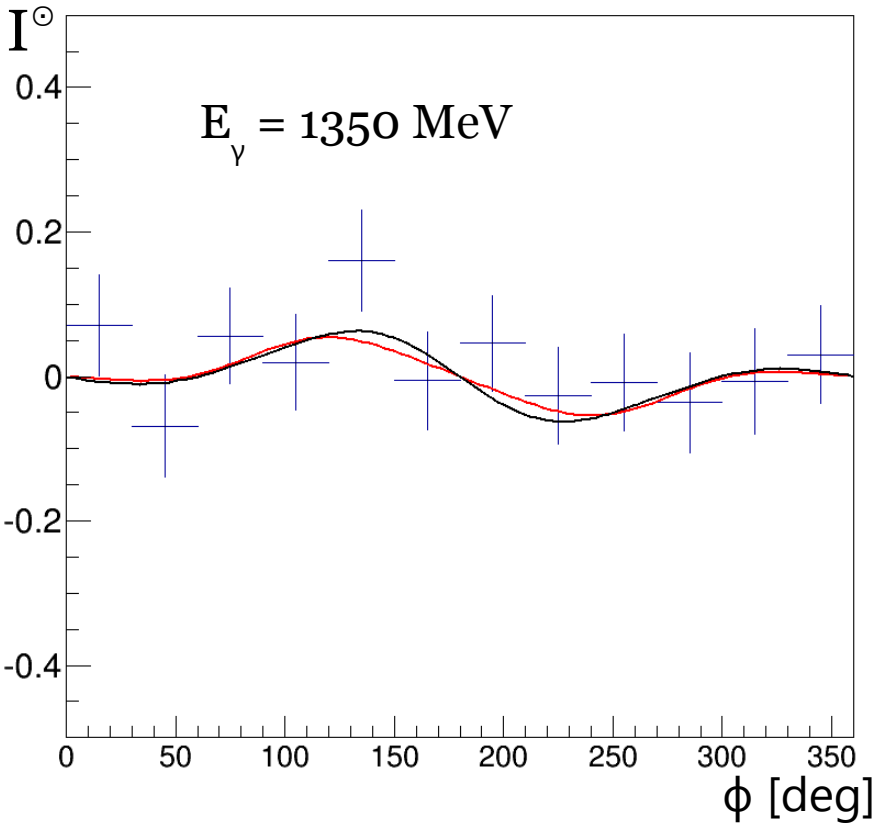
  CB_{Esum} > 350 MeV for C target
- Preliminary analysis shows compatible resolution between LH2 (April 2009) and Carbon 2015 data (Sergey Prakhov)

Example Spectra (Carbon target)



Example Spectra (Al target)





- Very preliminary asymmetries seen in the data for ~35% of Aluminium data (4 photons + X) events considered
- Curves: red fit to the data, black calculation within isobar model
- Small asymmetry in energy binning → differential distributions

Outlook: Next steps

- LH2 data reanalyzed, cross-sections, Dalitz plots, beam helicity asymmetry extracted
- Dominance of $\gamma p \rightarrow (D_{33}(1700)) \rightarrow \Delta(1232)\eta \rightarrow p\pi^0\eta$ confirmed directly by the Dalitz plots
- LH2 event-based data alone can be used as input for the PWA (to be discussed)
- The new calibration of Carbon 2015 close to be final
- Adjustments for solid target analysis in progress
- Differential cross-sections for $\pi^0\eta$ photoproduction and beam helicity asymmetry will be extracted

Thank you for your attention!

Backup

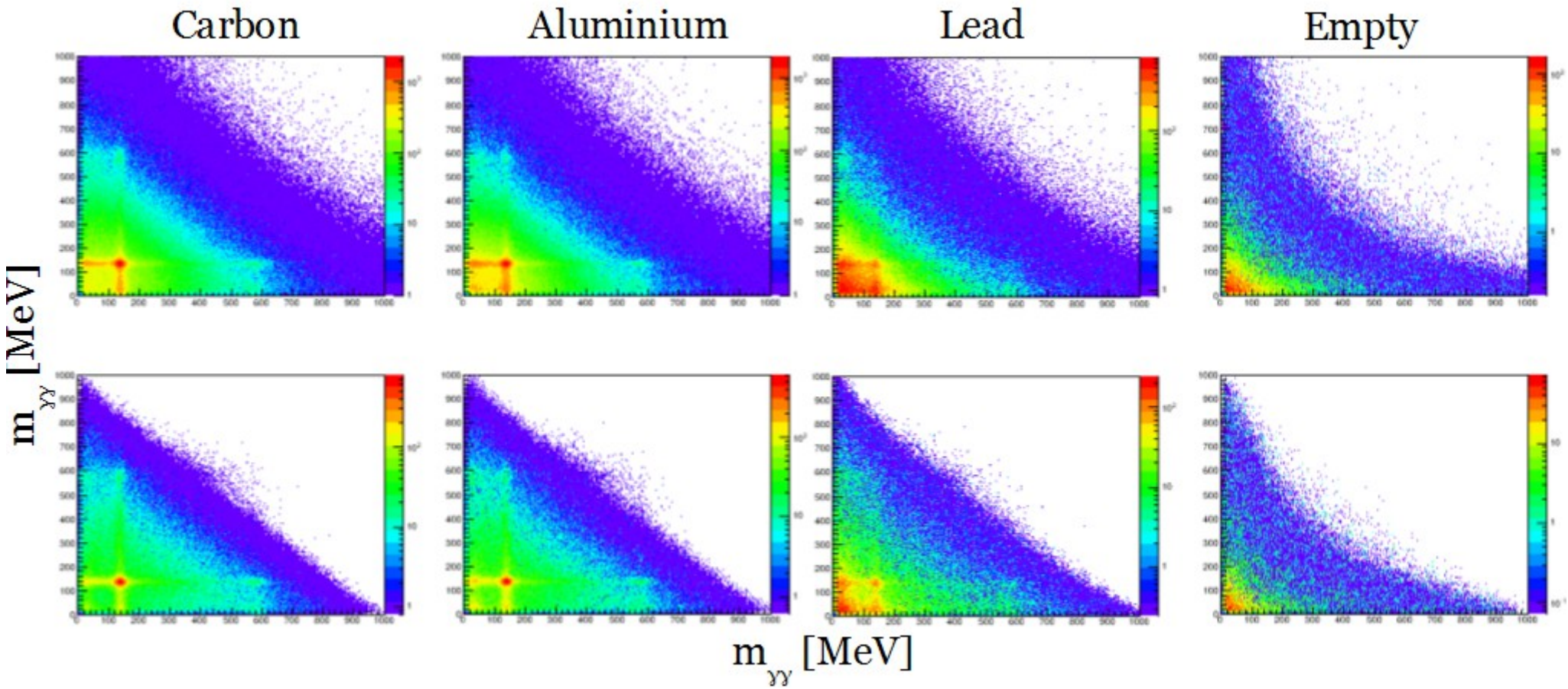
Acquired data

- C target ~90 h with 1557 MeV beam
- Al target ~120 h with 1557 MeV beam
- Pb target ~100 h (1557 MeV beam), ~8 h with 883 MeV beam
- Empty ~20 h with 1557 MeV beam

Preliminary selection of events with $\pi^0\eta$ and $\pi^0\pi^0$ production

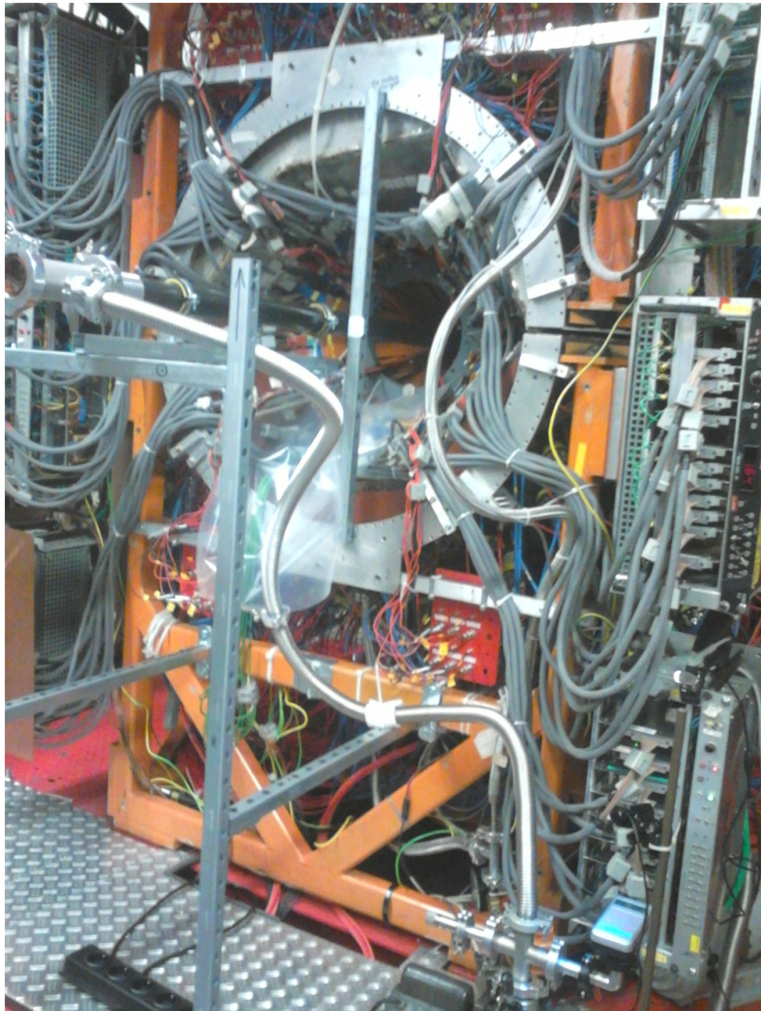
- $E\gamma_{(beam)}$ = 1000 – 1450 MeV
- Selecting events with 4 γ (+ 1 charged hit or + X hits)
- Invariant mass cut
- Missing mass cut (?)
- Subtraction of random timing background
- Negligible empty target contribution

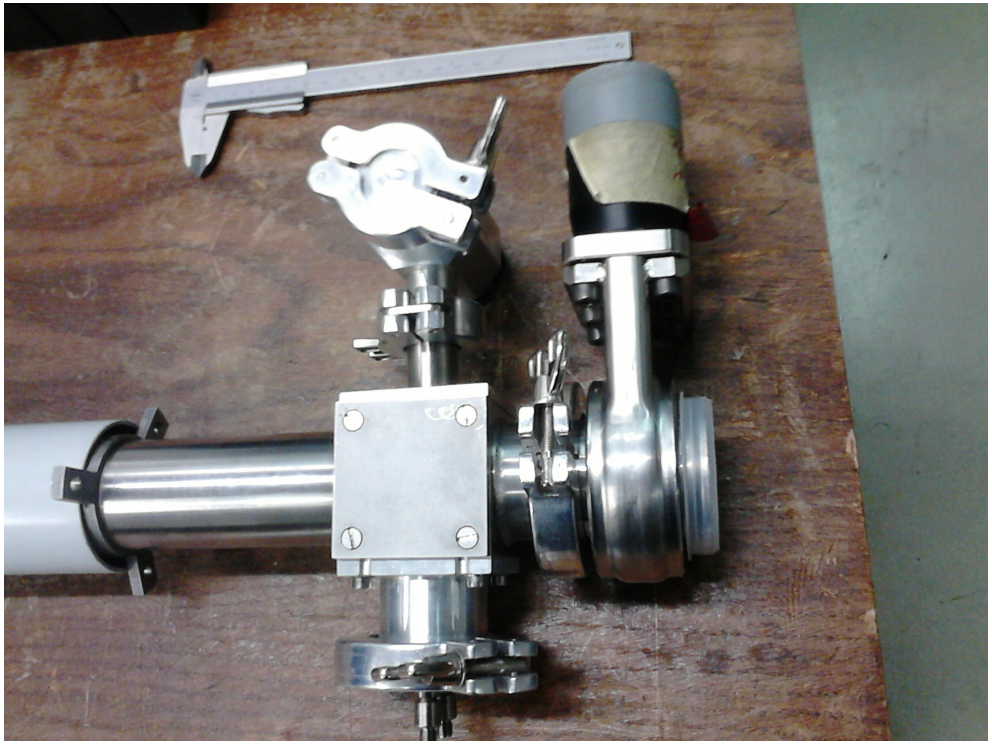
Example Spectra (Carbon target)

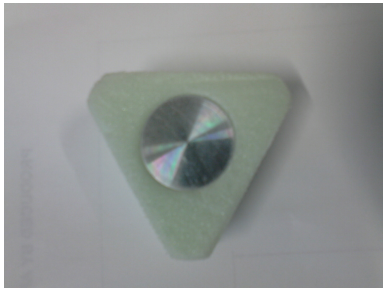


Experimental Setup

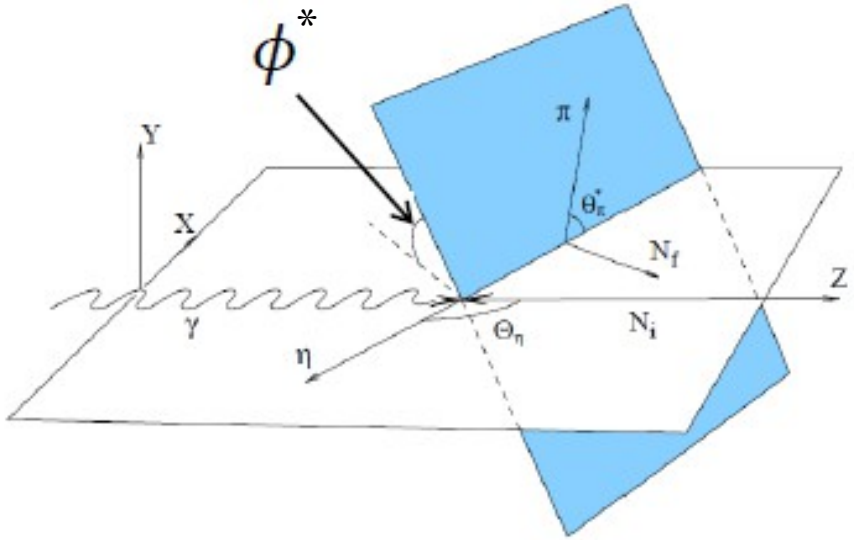
- Carbon pipe for positioning targets in the Crystal Ball
- Targets: C, Al, Pb and other parts such as an inserter prepared
- Empty insert for the cryostat built in the KPH Mechanical and Vacuum Workhops

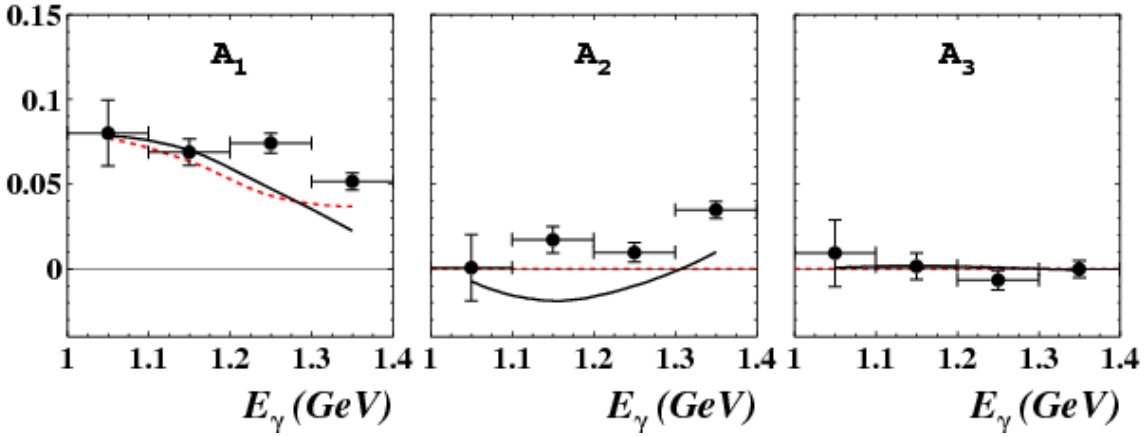






Beam helicity asymmetry (proton target)





Coefficients of the sine expansion
Solid line : full model prediction
Dashed line: only the *D*33 amplitude.

V. L. Kashevarov, et al., Phys. Lett. B 693, 551 (2010)

$W^c(\phi)$ can be expanded as:

$$W^c(\phi) = \sum_{n=1}^{n_{max}} A_n \sin n\phi$$

A_1 represents purely the contribution of the D_{33} wave

A_2 is sensitive to interference terms

A_3 is negligible

Both unpolarized and polarized data indicate the dominance of the D_{33} wave at energies E_γ < 1.2 GeV

Existing data and next steps

Existing data sets:

- The structure in these observables is reasonably described by the $D_{33}(1700)$ resonance within the isobar model for the proton target at $E_\gamma < 1.2$ GeV (A. Fix, et al.)
- Any changes of these observables beyond FSI will allow access to the in-medium properties of the $D_{33}(1700)$
- Measurements performed by the A2 Collaboration with proton and deuteron targets will be used as a reference

This program is aiming for:

- Study modifications of the $D_{33}(1700)$ resonance
- Measurement and interpretation of polarization observables for the investigation of in-medium modifications (and unpolarized cross-sections)
- Better understanding of the Final State Interaction (FSI)
- Understanding of the nature of the $D_{33}(1700)$: Is it dynamically generated?