New Measurement of Beam Asymmetry from Pion Photoproduction on a Neutron at CLAS

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On behalf of the CLAS collaboration and Jefferson Laboratory:

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Nucleon resonance spectrum

- Predictions limited primarily to calculations on the **lattice** and **phenomenological models** (constituent quark model, di-quark…).

- Resonances extracted from data using **PWA** (Partial Wave Analyses).

- Too many ambiguities as insufficient experimental observables measured –> **missing resonances** in baryon spectroscopy: not there, or not observed?

- Many wide, overlapping **resonances** – expected to couple to the **pion channel**.

Pion Photoproduction

- **Pion photoproduction** – large cross-section, low threshold energy, easy detection.

- **Polarised real photons** a powerful probe – well understood interaction (EM).

- Full analysis requires proton and **neutron** data – needed to separate isoscalar and isovector components of amplitude.

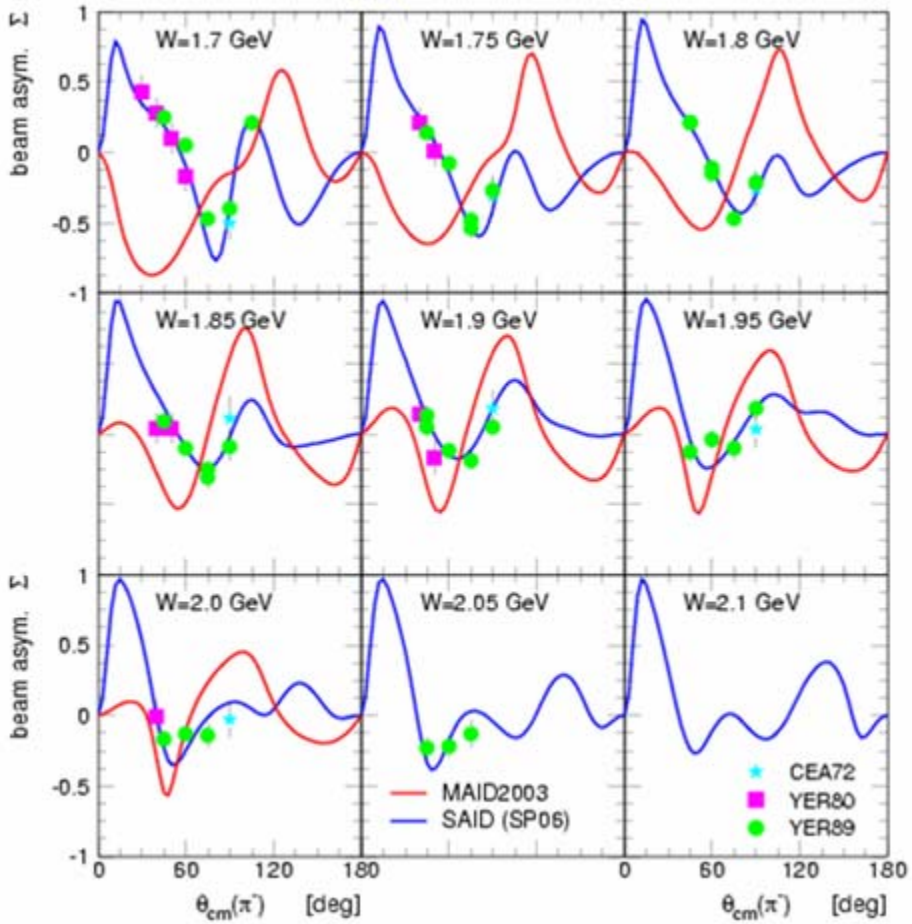
$$\gamma + n \rightarrow \pi^- + p$$

- **Beam asymmetry, Σ**, from **linearly polarised** photons **–** crucial observable to constrain PWA.

$$\frac{d\sigma}{d\Omega} = \sigma_0 (1 - P_{lin} \Sigma \cos 2\varphi)$$

Data to date…

World **neutron** data set:



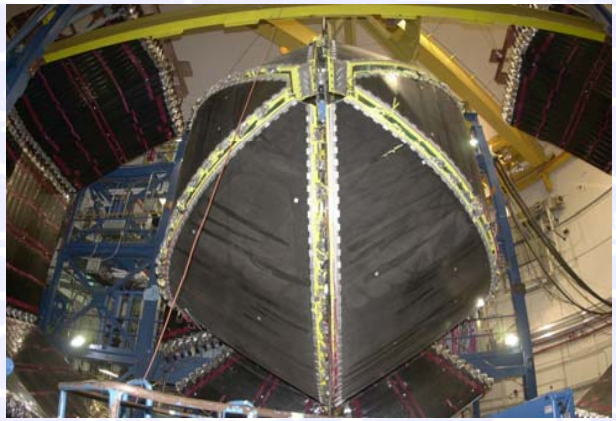
- … has very **few points** from the neutron (most data is from proton).
- … is in a **limited polar-angle** and energy range.

The Jefferson Laboratory

CLAS:

- **Multi-layer** onion of detectors for charged and neutral particles.

- Very **large angular coverage**: **Near full coverage** in azimuthal angle and from **8° to 140°** in polar angle.



- 1.4 km racetrack accelerator with two LinAc sections.

- Operation at up to **6 GeV**.

- Linearly polarised photon beam via **Coherent Bremsstrahlung.**

The g13b Experiment

- Experimental run: **March – June 2007**

- Linearly polarised beam produced by **Coherent Bremsstrahlung** off a diamond lattice, then "tagged" in the **Tagger** so specific photon causing reaction can be identified and its energy measured.

- **Electron energies**: 3.3 – 5.2 GeV

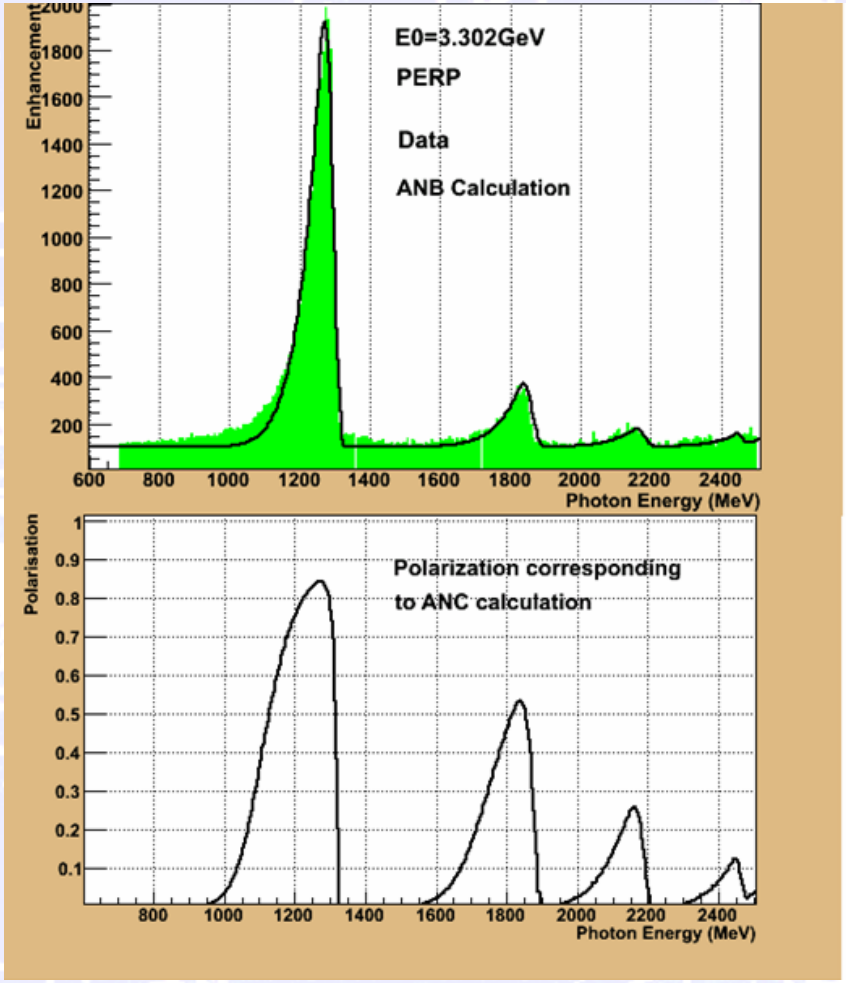
- Six photon energy settings in range: **1.1 - 2.3 GeV,** with **two orthogonal orientations**.

- **Target**: liquid Deuterium.

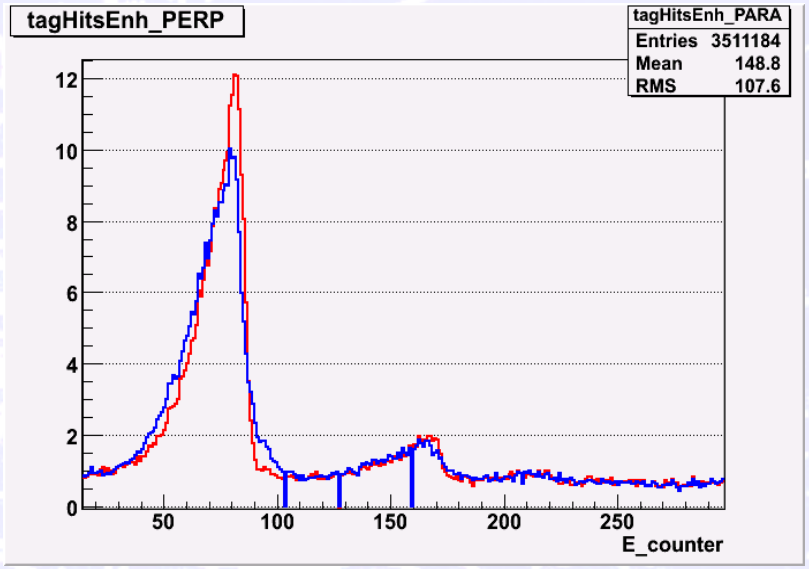
- Single charged particle **trigger**. Total of $3 \cdot 10^{10}$ events.

Photon polarisation spectrum

Analytic calculation:



Data from tagger (1.7 – 1.9 GeV):



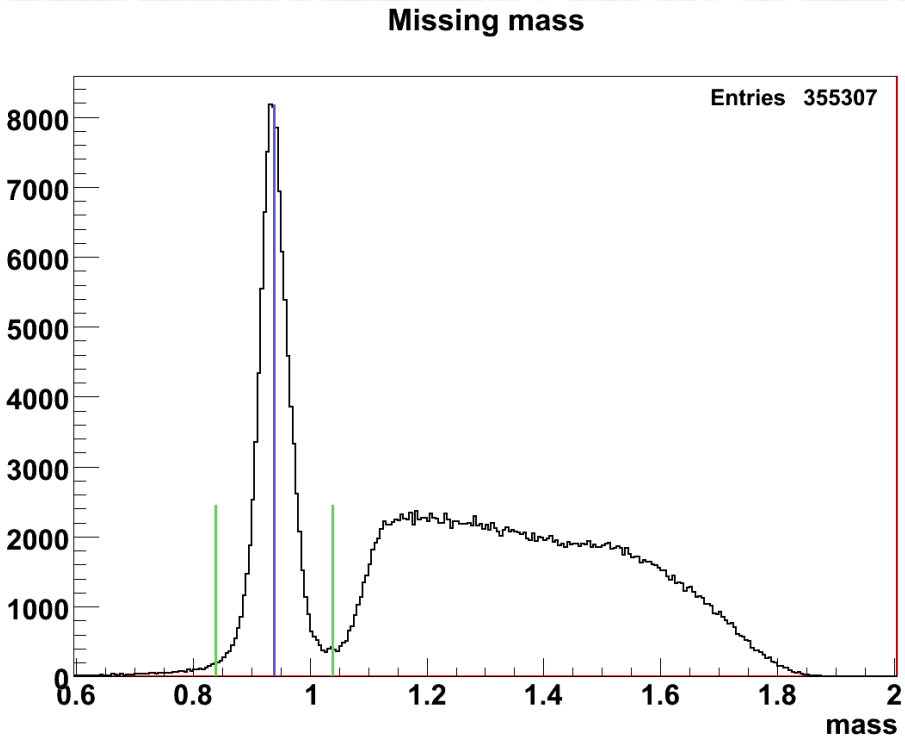
Blue and Red: Orthogonal beam polarisation planes

Reaction Identification

- **Deuterium** target – quasi-free reaction with spectator proton:

$$\gamma + d \rightarrow \pi^- + p + (p_{spectator})$$

- Identify the $n(\gamma,\pi^-)p$ channel:



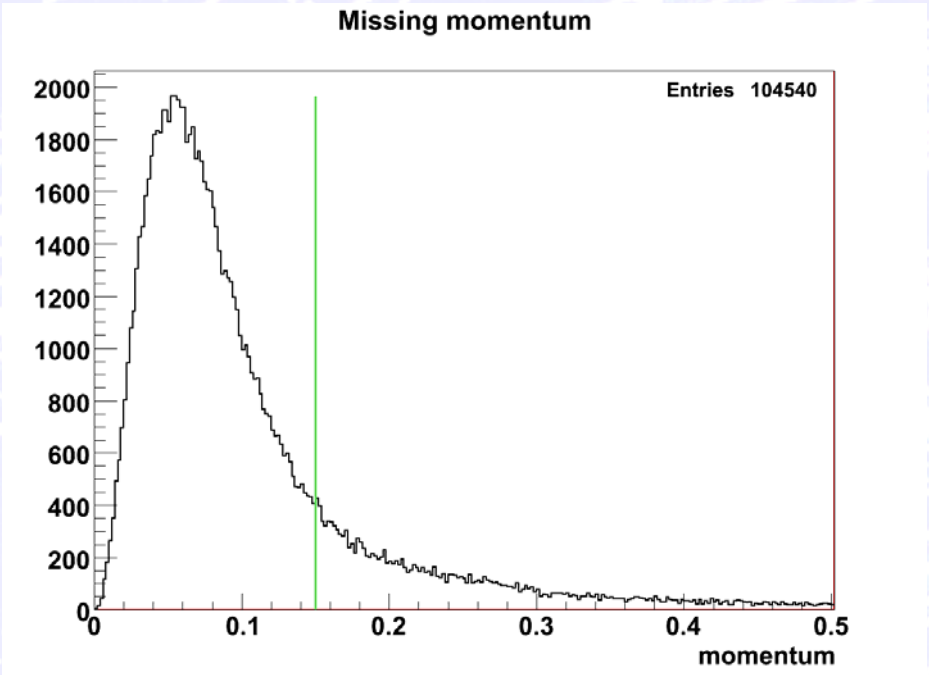
- Cut on events with **two particles**, loose mass cut on proton and pion.

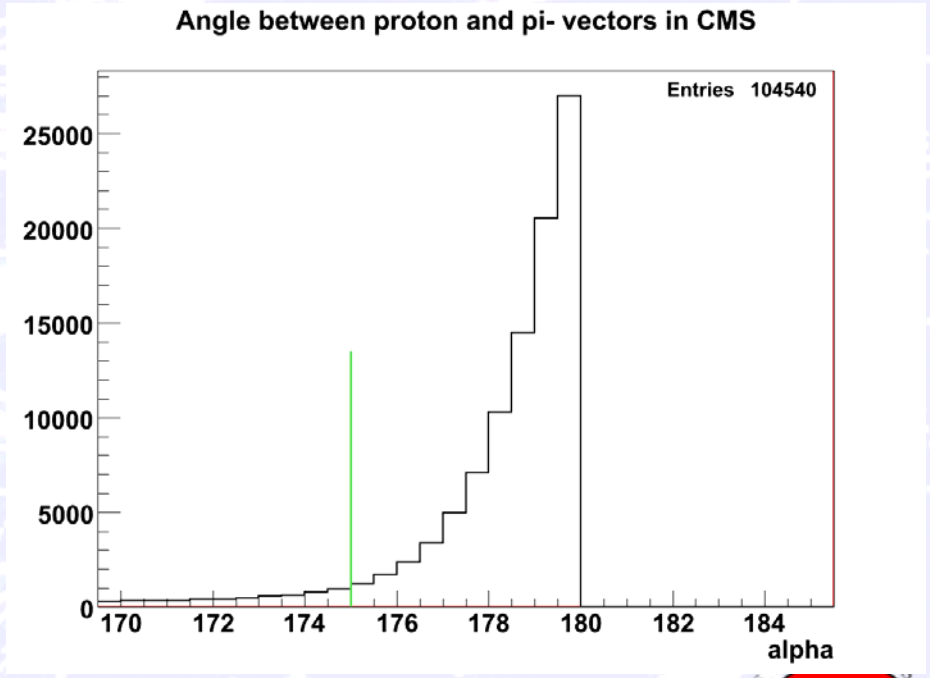
- Cut on "**missing mass" –** for the spectator proton.

❖ Cut on low **“missing momentum”** below 0.15 GeV where quasi-free contribution dominates.

$$\underline{P}_{\gamma} + \underline{P}_{deuterium} = \underline{P}_{\pi^-} + \underline{P}_{p} + \underline{P}_{spectator}$$

❖ Cut on proton and pion back-to-back in CMS: **coplanarity.**

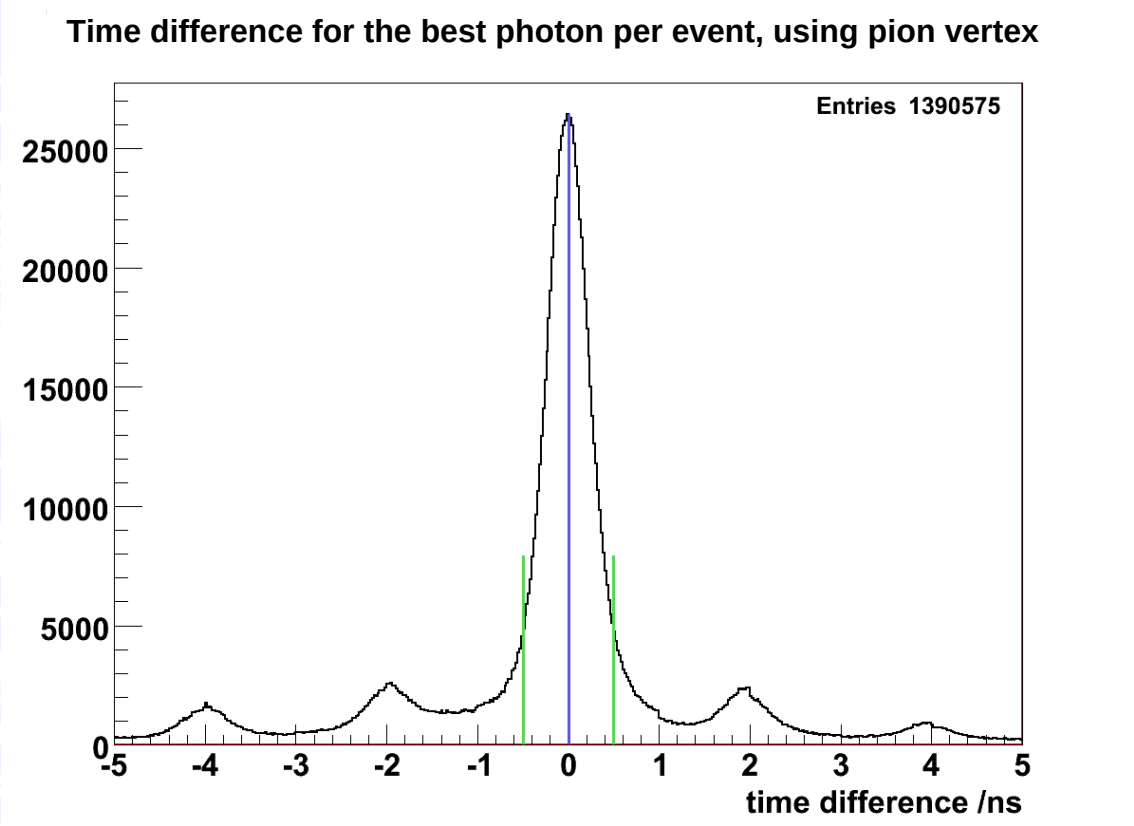




Photon-spotting

- Energy of each photon measured by the **tagger**.

- Identify **exact photon** from timing coincidence – beam in 2ns bunches.



Extracting the Asymmetry

- Reaction **axes**:

$$z = \underline{p}_{\gamma} \Big/ p_{\gamma} \qquad y = \underline{p}_{\gamma} \times \underline{p}_{\pi^-} \Big/ \left| \underline{p}_{\gamma} \times \underline{p}_{\pi^-} \right|$$

*in the **Centre of Momentum System** (CMS)*

- ***φ***: angle of beam polarisation plane in CMS w.r.t. reaction plane.

- **Asymmetry** from *cos(2φ)* fit to the *φ*-distribution of pions:

$$\frac{d\sigma}{d\Omega} = \sigma_0 (1 - P_{lin} \Sigma \cos 2\varphi)$$

Status of Analysis

- **Calibrations** are still underway.

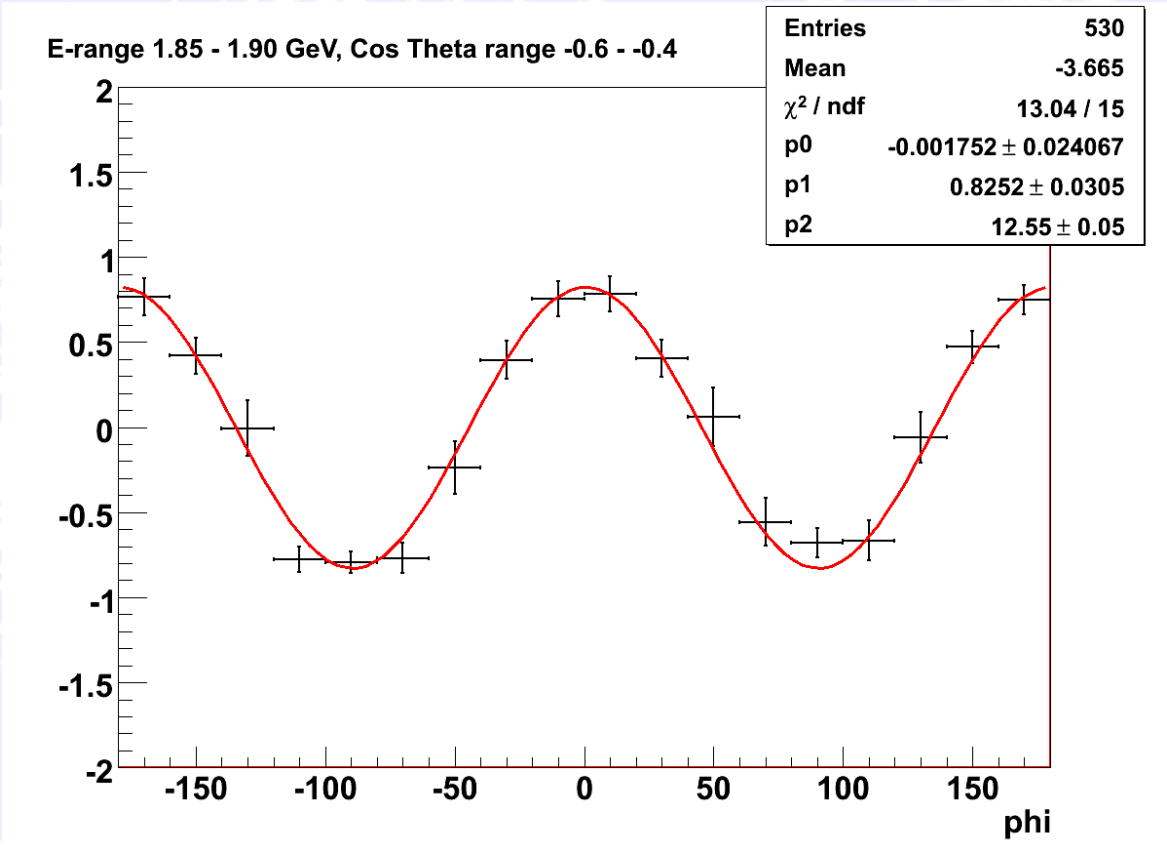
- **Polarisation** has not yet been calculated. Assumed ~ 70% with uncertainty on the order of 10%.

- In final analysis, statistical uncertainty expected be tiny – goal is to reduce **systematics** to ~ 5%.

- As an illustration of **current analysis**, first look at the data on following slide...

Preliminary!

- To reduce systematics, beam polarisation plane rotated between two orthogonal directions during experiment.



$$N_{\parallel} = N_{\theta}(1 - P\Sigma\cos 2\varphi)$$

$$N_{\perp} = N_{\theta}(1 + P\Sigma\cos 2\varphi)$$

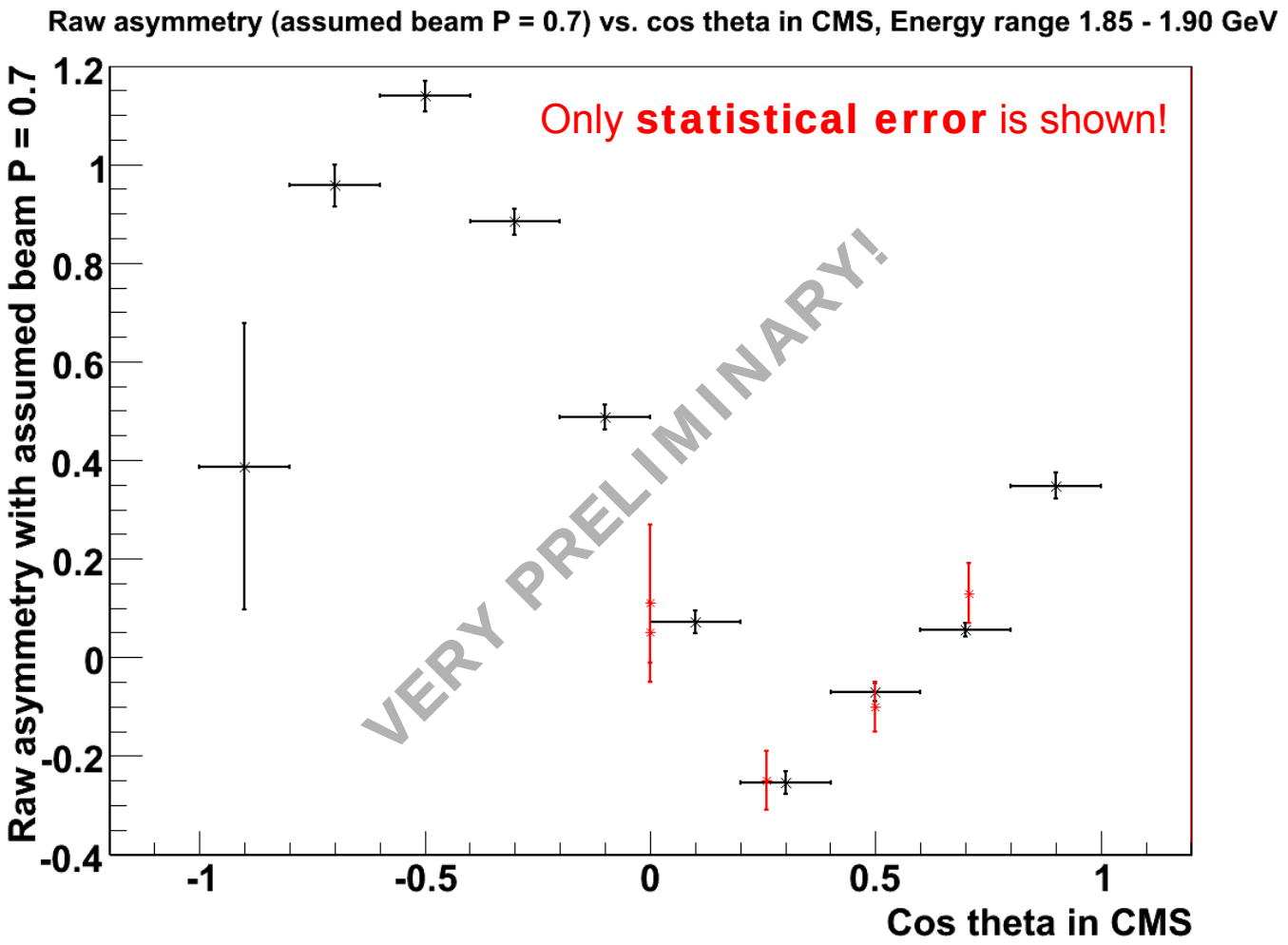
$$\Sigma P\cos 2\varphi = \frac{N_{\parallel} - N_{\perp}}{N_{\parallel} + N_{\perp}}$$

Fit with:

$$A + B\cos(2\phi + C)$$

Where B = PΣ, **P ~ 0.7**

1.85 < W < 1.9 GeV



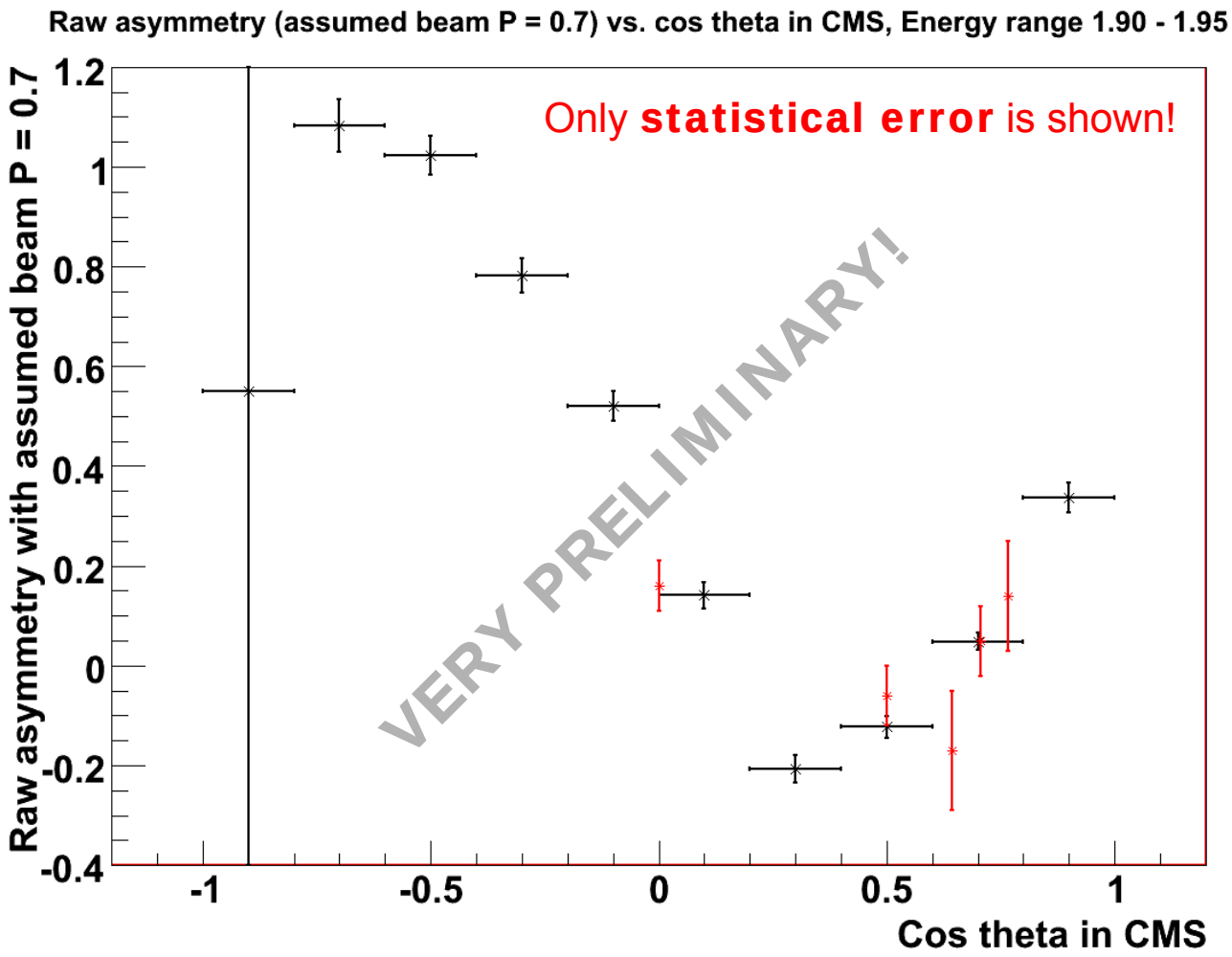
~ **0.4%** *of all data*

Black: current experiment

Red: previous experiments:

Adamyan, JPG **15** 1797 ('89).
Alspector, PRL **28**, 1403 ('72).

1.9 < W < 1.95 GeV



*~ **0.4%** of all data*

Black: current experiment

Red: previous experiments:

Adamyan, JPG **15** 1797 ('89).
Abrahamian, SJNP **32** 69 ('80)

Epilogue

- An early analysis shows that the data quality is good and a **sizeable asymmetry** can be seen at backward angles.

- Indication of **probable overall shape** of the final result.

- Illustration of **statistics** – low statistical uncertainty on a tiny sample of the data.

- **Calibrations are currently under way** – full analysis to follow soon in:
  - full polar angle from **20° to 145°** (in CMS)
  - entire photon energy range, **1.1 to 2.3 GeV**

- Will greatly expand the **sparse world data** set on neutron and aid in constraining amplitudes of PWA's, shedding light on the **nucleon excitation spectrum**.

Thank you!