Photoproduction of the d*(2380) Dibaryon

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Overview

- Motivation
- Experimental Setup
- Σ Results
- $C_{x'}$ Preliminary Results

Motivation - Exotic Hadrons

- Hadrons are colour neutral particles formed of quarks

- This includes the well known mesons ($q\overline{q}$) and baryons (qqq)

- Our model of the strong force, **Q**uantum **C**hromo**D**ynamics (QCD) does not forbid other hadronic states

- Recent experiments have seen evidence of potential tetraquark ($qq\overline{q}\overline{q}$), pentaquark ($qqqq\overline{q}$) and hexaquark ($qqqqqq$) states

- A hexaquark state of the form above would have a baryon number of 2, a *dibaryon*

Motivation - d*(2380) Dibaryon

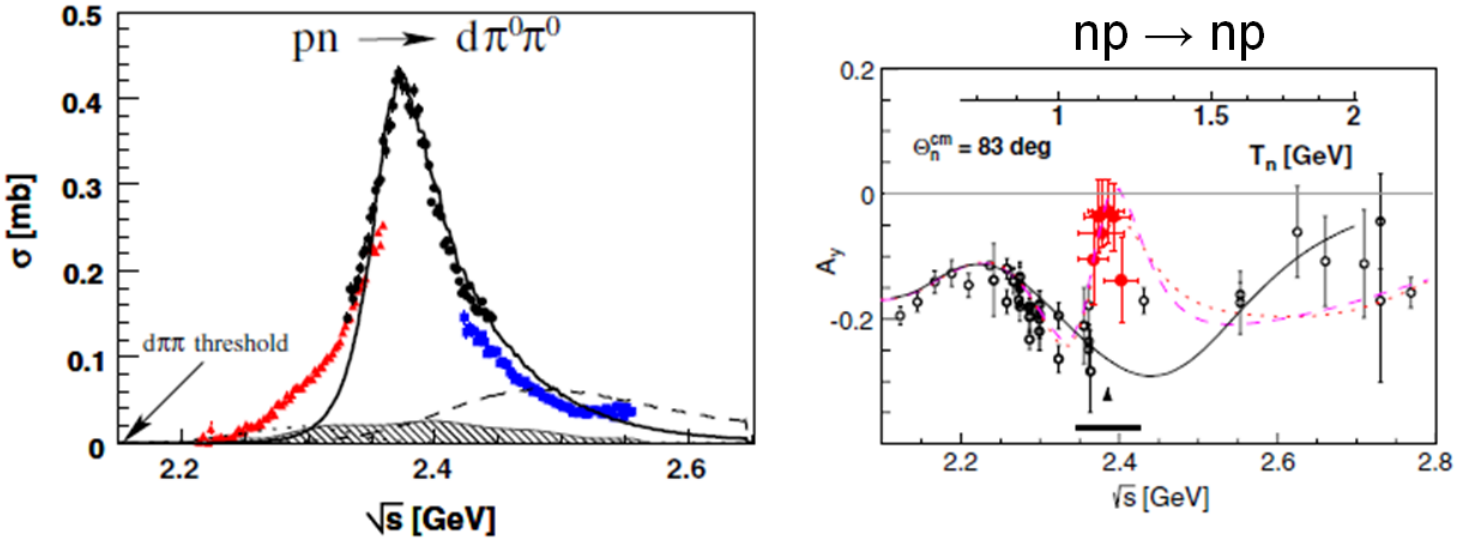


Figure: [1,2] - Results from WASA-at-COSY showing structure at $\sqrt{s} = 2380$ MeV

- d* has $J^\pi = 3^+$, $m = 2380$ MeV and $\Gamma = 70$ MeV

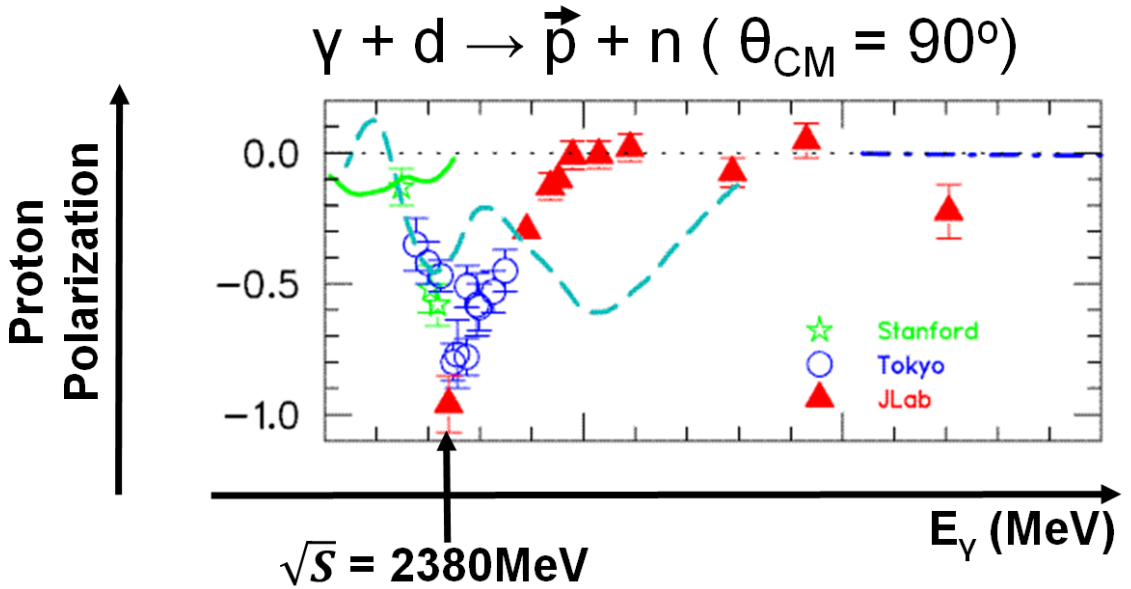
- d* predominantly (90%) decays via $d^* \to \Delta\Delta$

[1] - PRL 106, 242302 (2011), [2] - PRL 112, 202301 (2014)

Motivation - d*(2380) Photoproduction

- One potential photoproduction channel is $\gamma + d \rightarrow d^* \rightarrow p + n$

- Anomalous proton polarisation in d* region?



R. Gilman and F. Gross nucl-th/0111015 (2001) , H. Ikeda et al., PRL 42, May 1979, 1321 , T. Kamae, T. Fujita, PRL 38, Feb 1977, 471

Motivation - d*(2380) Dibaryon

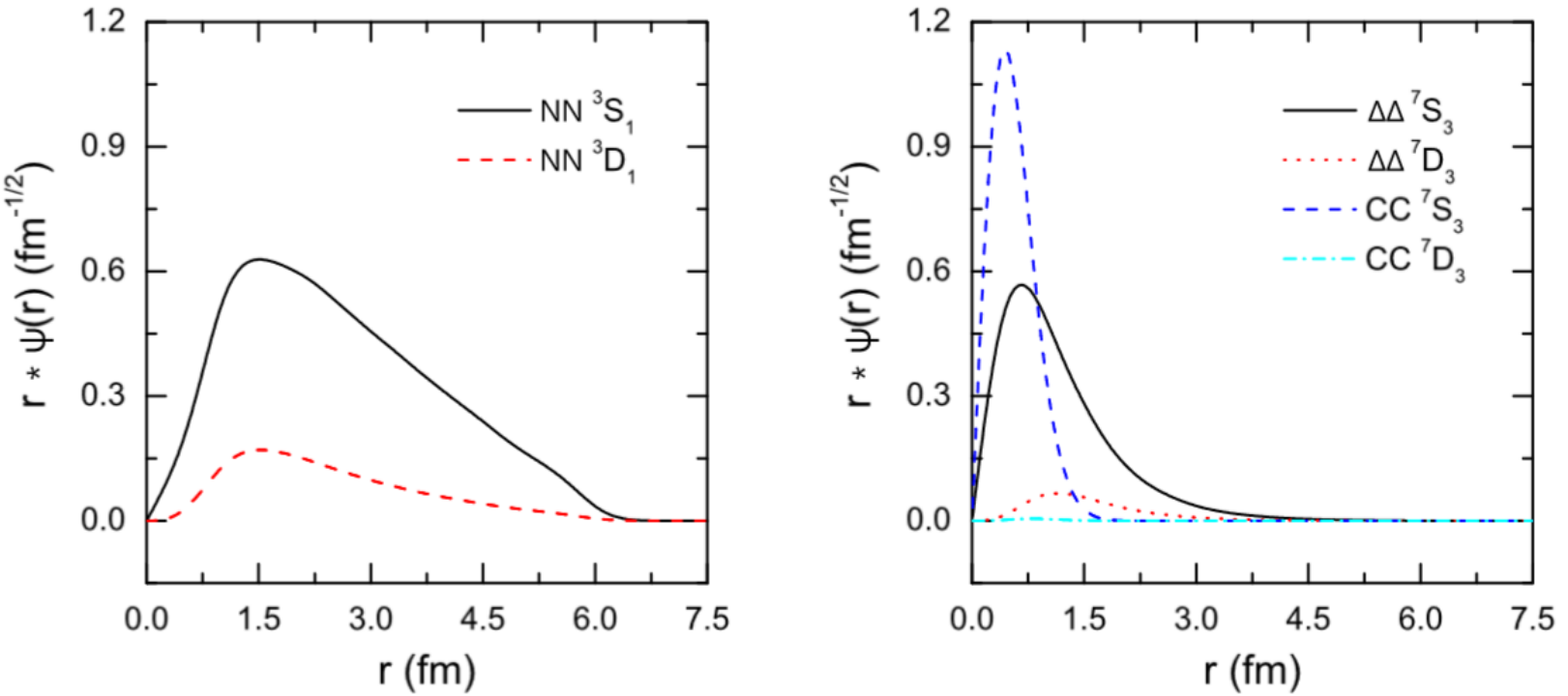


Figure: [1] - Model predictions of the "size" of the d* (right) compared to deuteron (left)

[1] - Chin. Phys. C 39, 7, 071001 (2015)

Motivation - Polarisation Observables

- Can gain information about the state by measuring polarisation observables in the reaction

Observable	Helicity Amplitude Combination
P_y	$2\Im\sum_{i=1}^{3}[F^*_{i+}F_{(i+3)-} + F_{i-}F^*_{(i+3)+}]$
T	$2\Im\sum_{i=1}^{2}\sum_{j=0}^{1}[F^*_{(i+3j)+}F^*_{(i+3j+1)+} + F_{(i+3j)-}F^*_{(i+3j+1)-}]$
Σ	$2\Re\sum_{i=1}^{3}(-)^i[-F_{i+}F^*_{(4-i)-} + F_{(3+i)+}F^*_{(7-i)-}]$
T_1	$2\Im\sum_{i=1}^{3}(-)^i[-F_{i+}F^*_{(7-i)+} + F_{i-}F^*_{(7-i)-}]$
$\mathrm{C}_{x'}$	$2\Re\sum_{i=1}^{3}[F^*_{i+}F_{(i+3)-} + F_{i-}F^*_{(i+3)+}]$
$\mathrm{C}_{z'}$	$\sum_{i=1}^{6}\{\lvert F_{i+}\rvert^2 - \lvert F_{i-}\rvert^2\}$
$\mathrm{O}_{x'}$	$2\Im\sum_{i=1}^{3}(-)^{i+1}[F_{i+}F^*_{(7-i)+} + F_{i-}F^*_{(7-i)-}]$
$\mathrm{O}_{z'}$	$2\Im\sum_{i=1}^{3}(-)^{i+1}[F_{i+}F^*_{(4-i)-} + F_{(3+i)+}F^*_{(7-i)-}]$

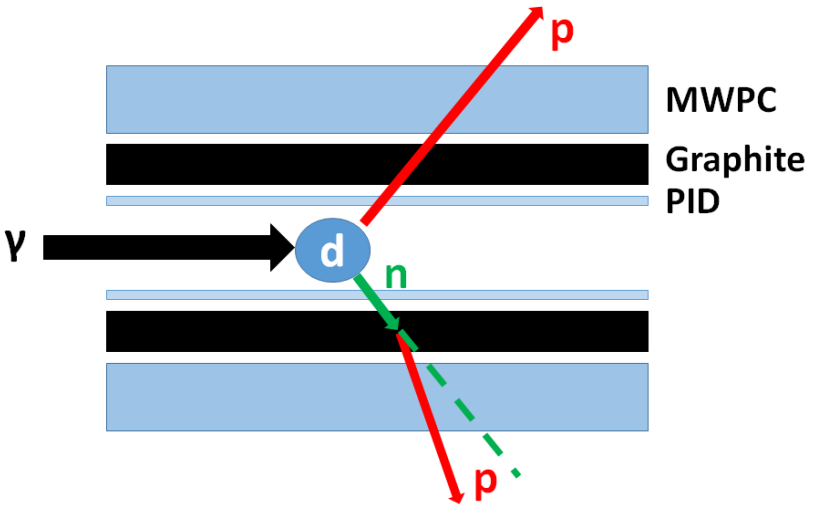
- F terms relate to helicity amplitudes

Motivation - New Polarimeter

- $\vec{n}$ previously unmeasured

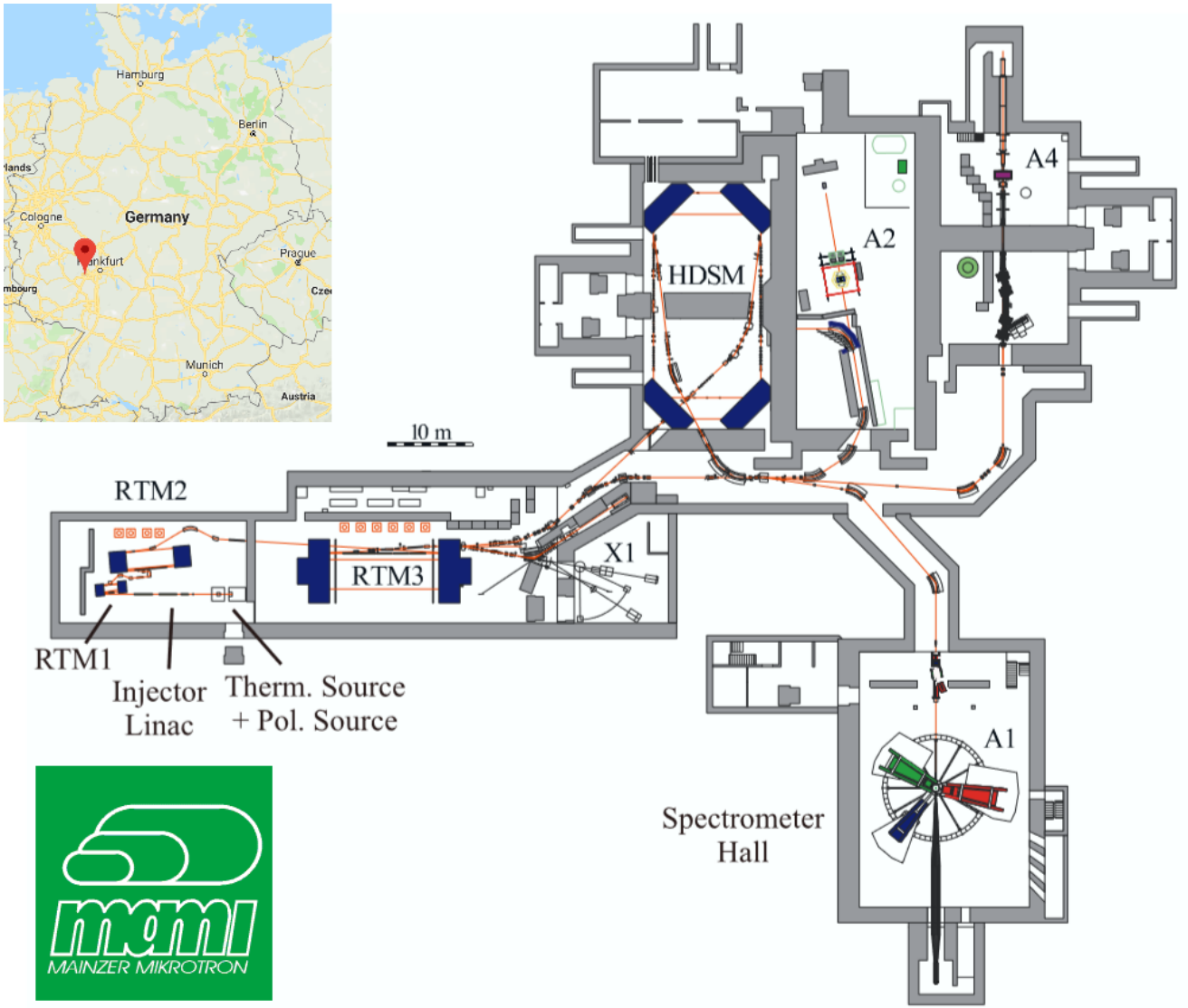
- Polarimeter can measure $\vec{n}$ and $\vec{p}$ simultaneously

- Measure neutron via charge exchange interactions in polarimeter

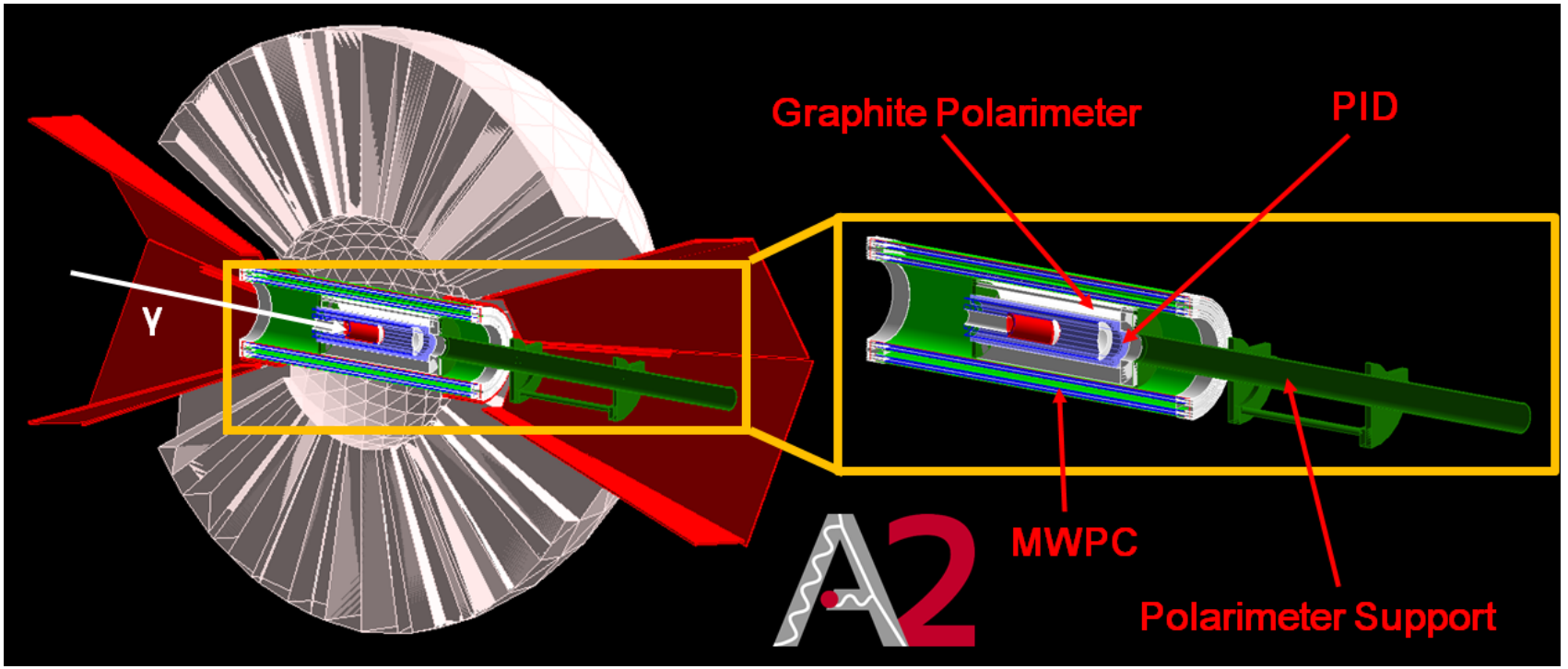


- Establish if d*(2380) dibaryon has Electromagnetic Coupling
  $\rightarrow$ Tests of size and internal structure

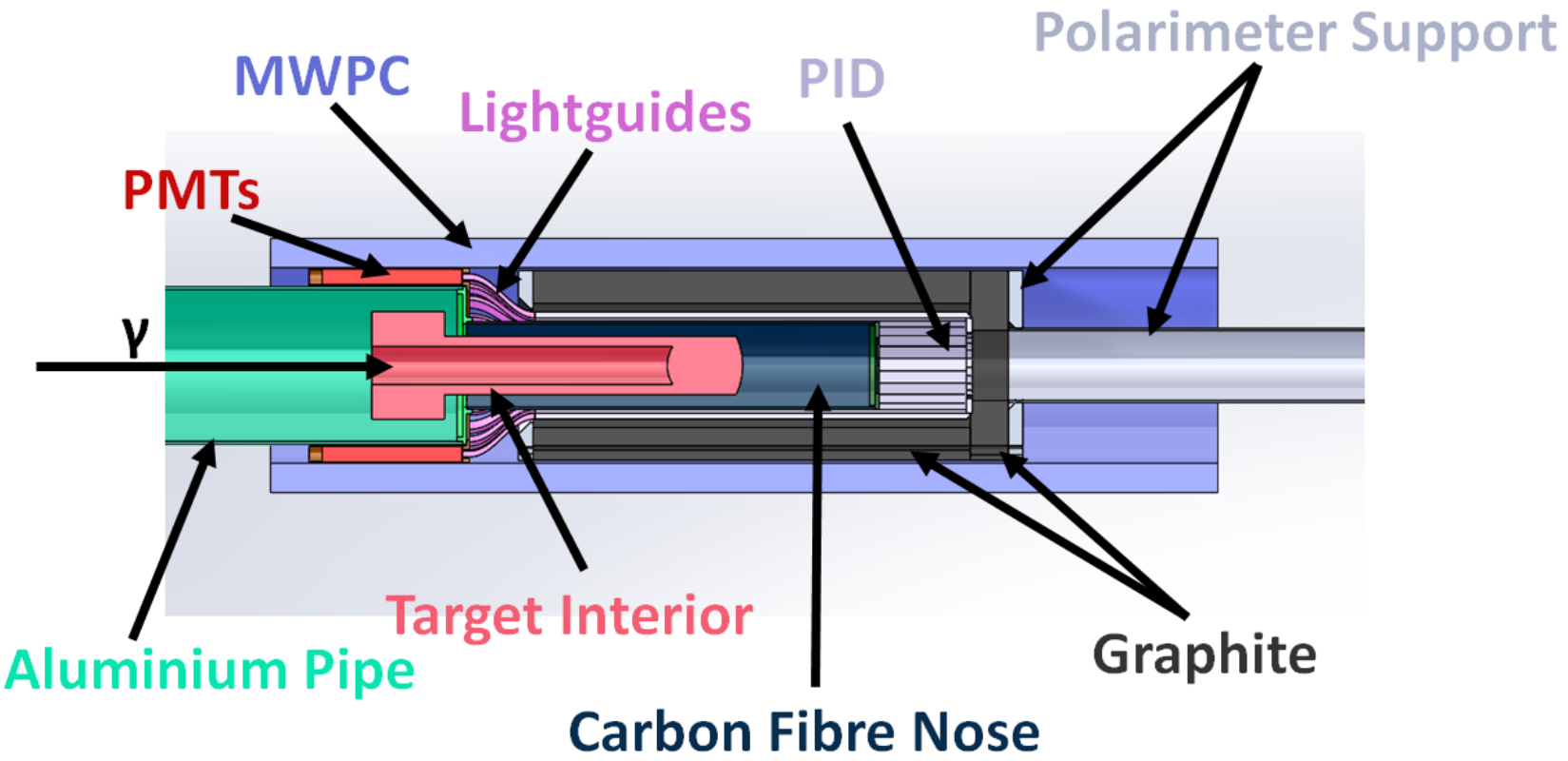
MAMI Layout


Hamburg
Berlin
Germany
Cologne
Prague
Munich
Austria
10 m
RTM2
RTM3
RTM1
Injector
Linac
Therm. Source
+ Pol. Source
X1
HDSM
A2
A4
A1
Spectrometer
Hall
MAINZER MIKROTRON

A2 Hall Setup



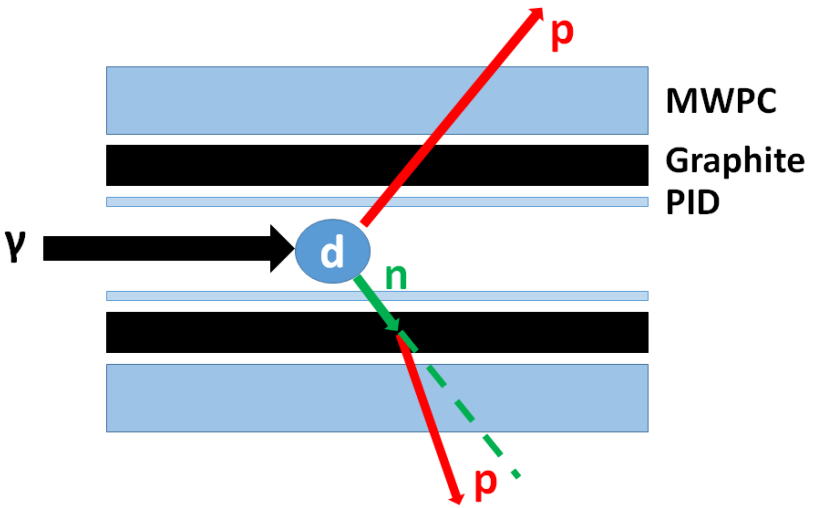
Overview of Polarimeter Setup



Event Selection - Particle Assignment

- Particle assignment is based upon detector hit combinations

	Proton	Charge Exchange Proton	Neutron
PID	✓	✗	✗
MWPC	✓	✓	✗
CB	✓	✓	✓



Event Selection

- Energy loss correction applied to the proton track

- Reconstruct the "neutron" track from proton track information via - $\underline{n}_{rec} = (\underline{d} + \underline{\gamma}) - \underline{p}$

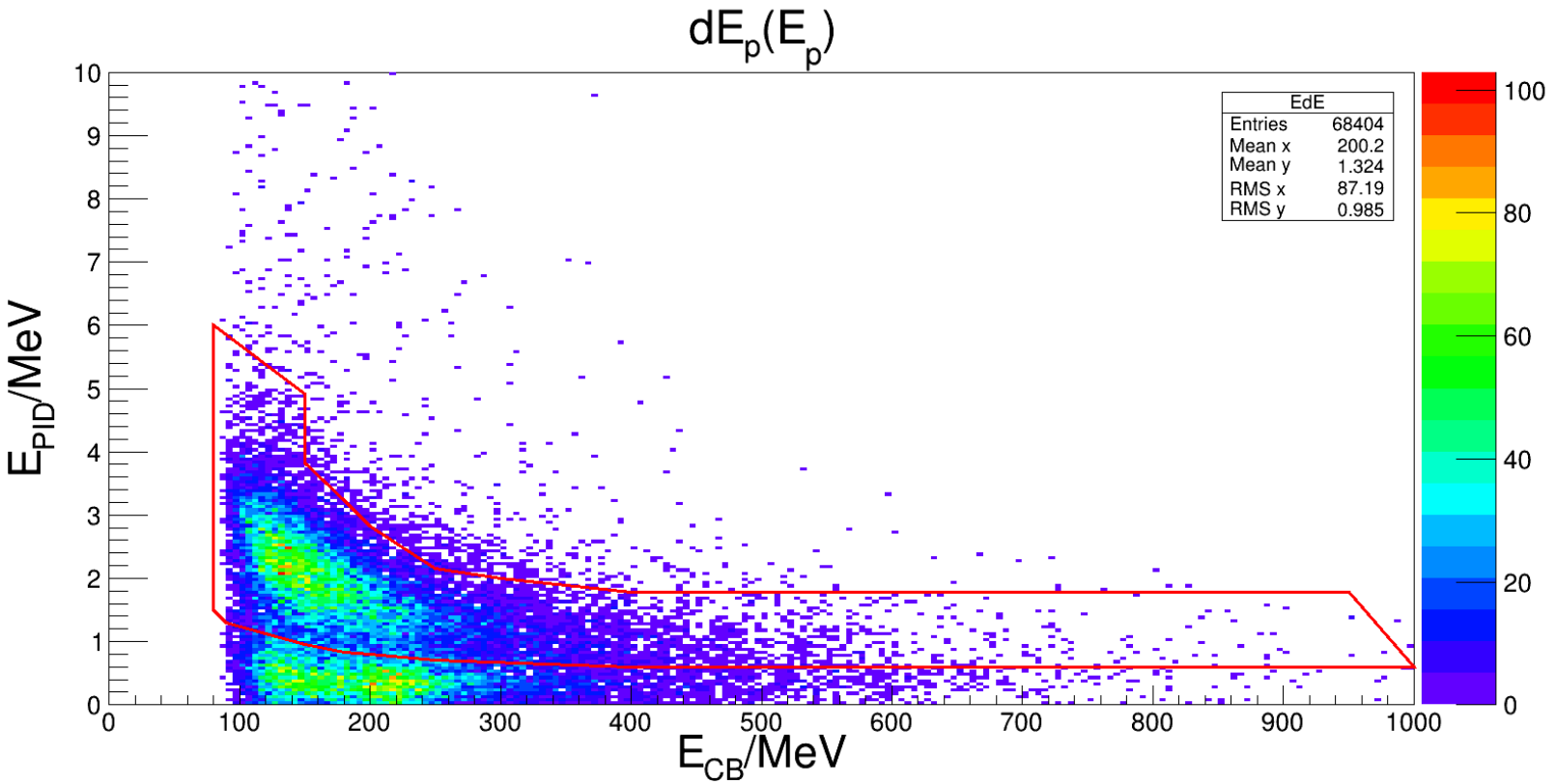
- Cuts:

  - Proton vertex
  - Missing mass of reconstructed track -

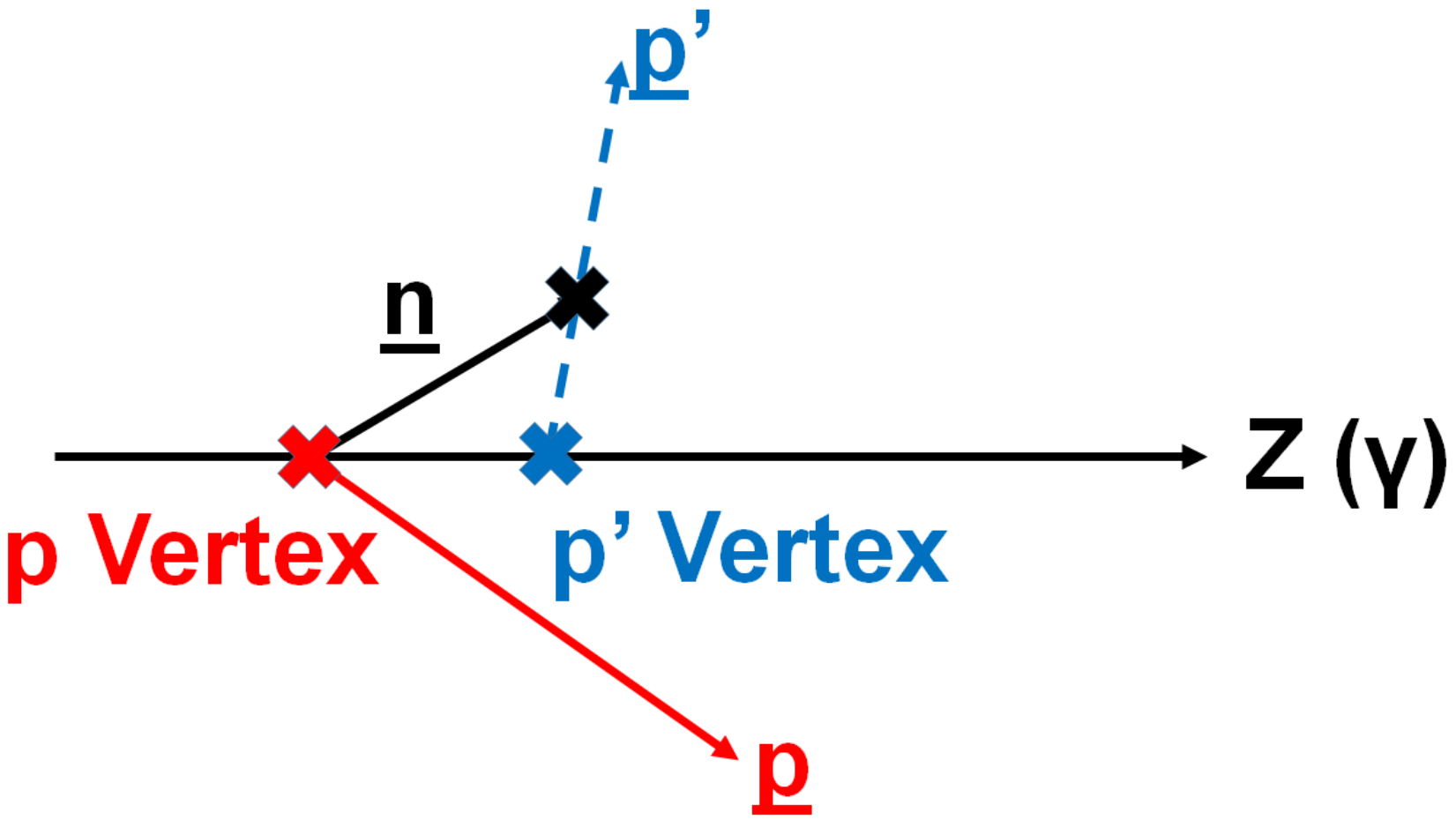
$$M_n = \sqrt{E_n^2 - p_n^2}$$

  - dE_{PID} vs E_{CB} cut on proton track (banana cut)
  - **D**istance **O**f Closest **A**pproach cut (DOCA)

Event Selection - EdE Cut



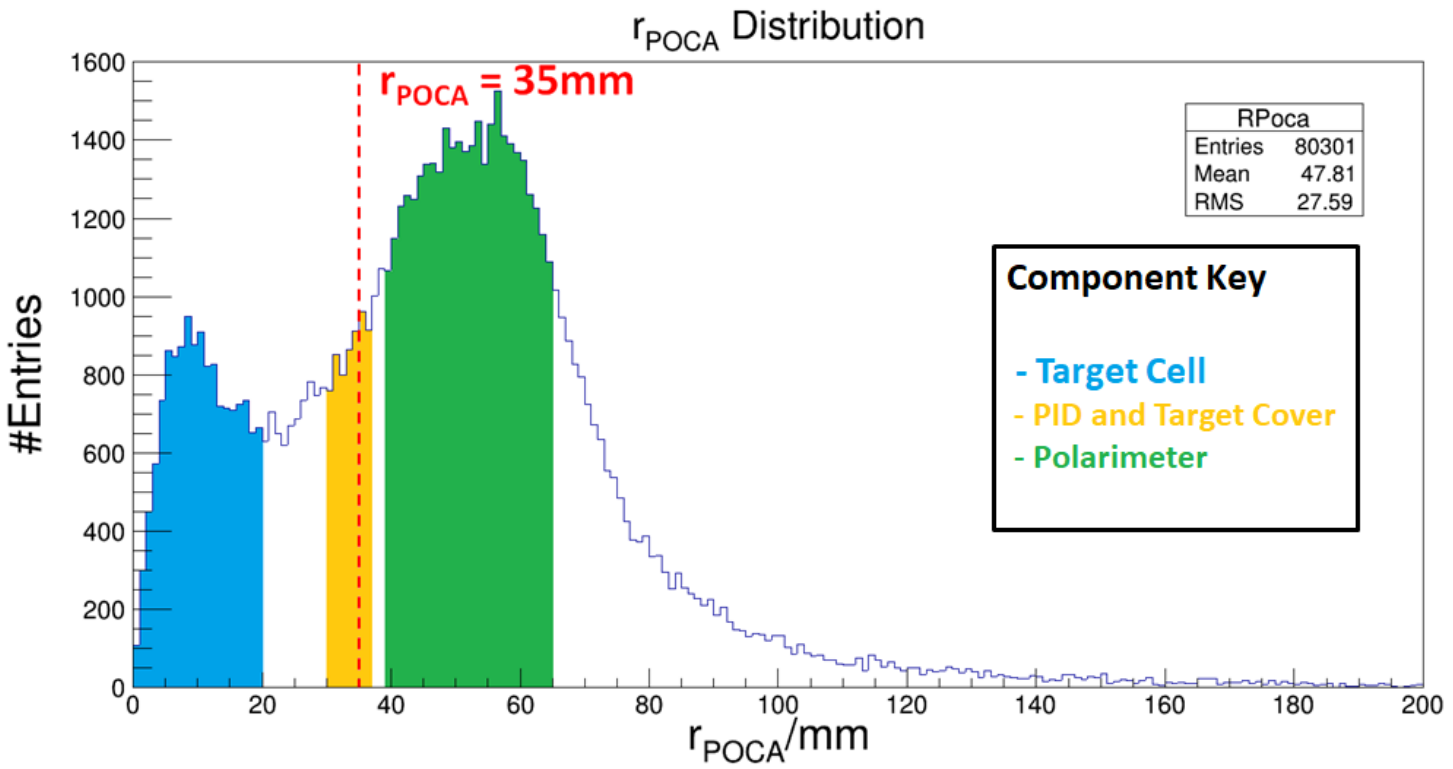
Event Selection - DOCA Method



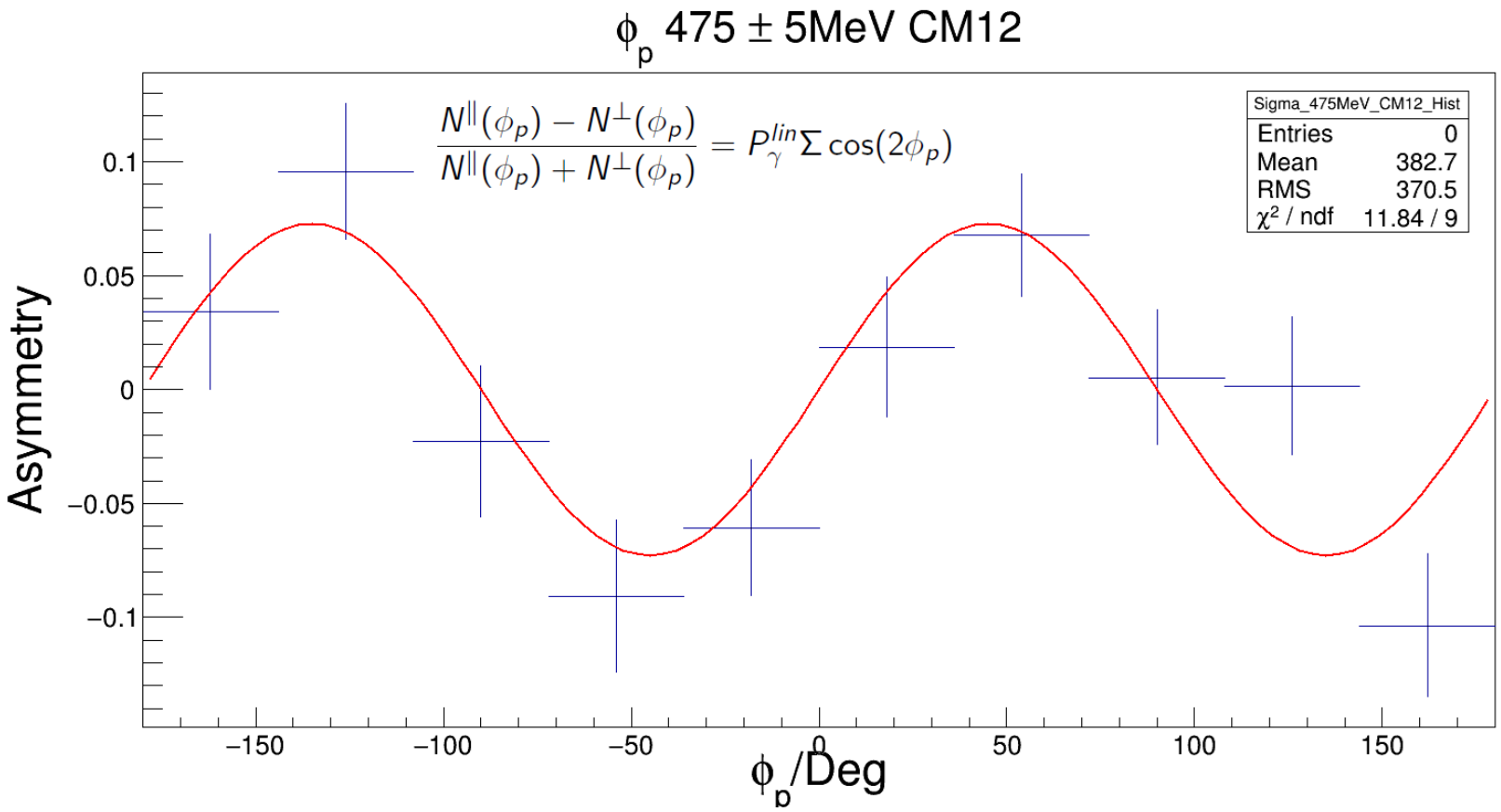
Event Selection - DOCA

- DOCA occurs at the **P**oint **O**f **C**losest **A**pproach (POCA)

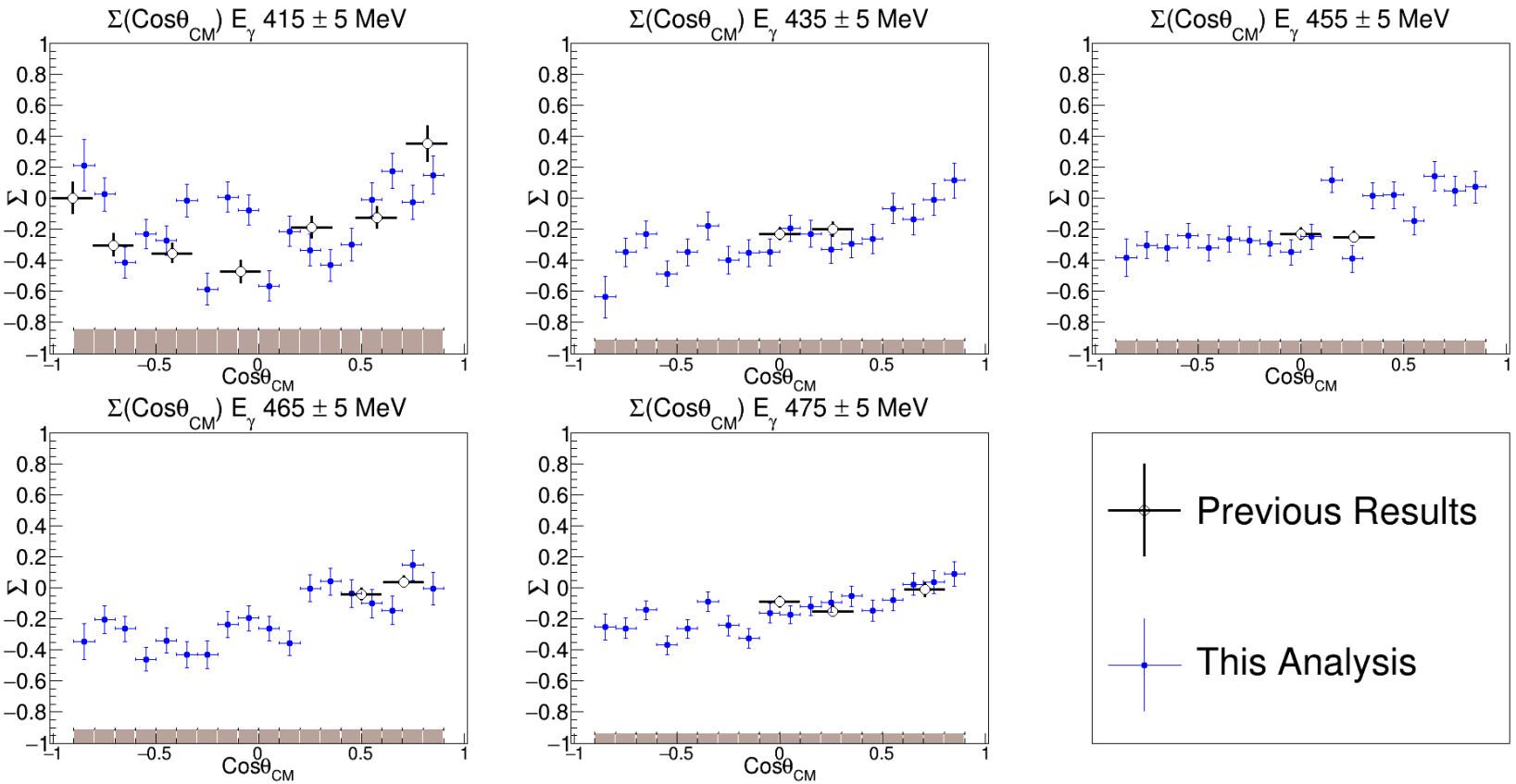
$$r_{POCA} = \sqrt{x_{POCA}^2 + y_{POCA}^2}$$



Σ - Asymmetry Fitting

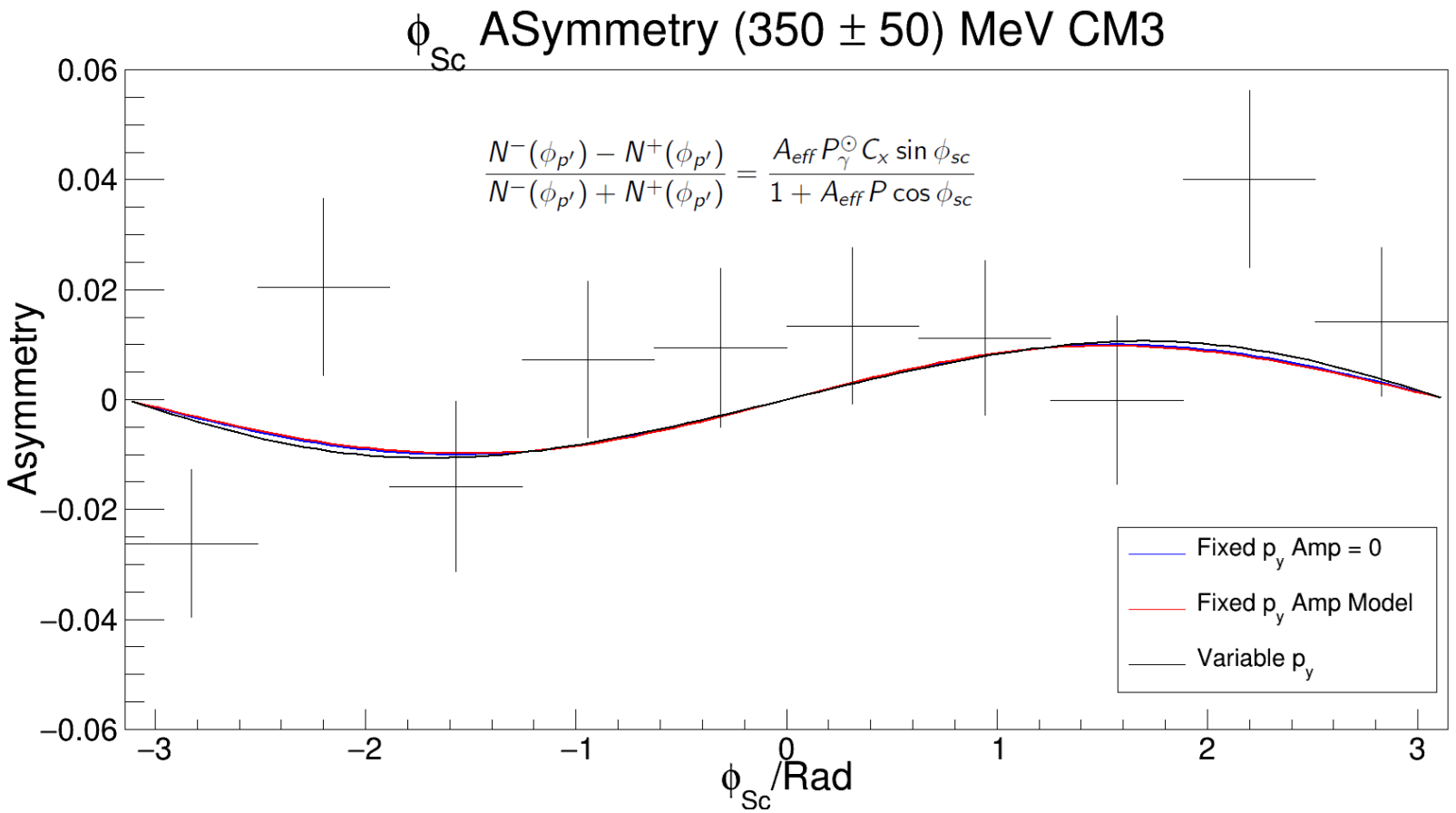


Σ Results

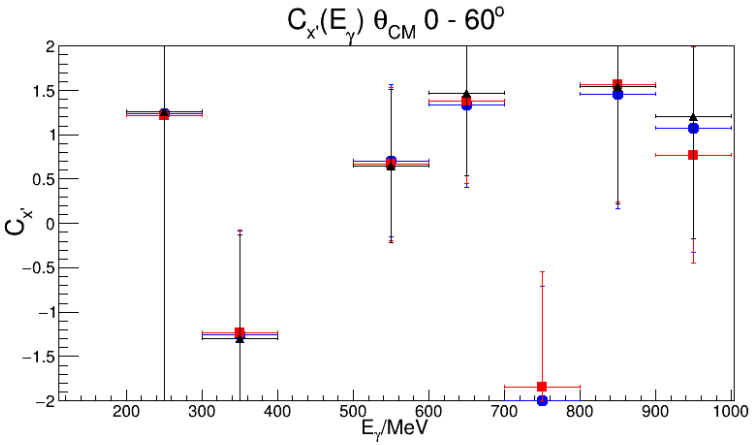


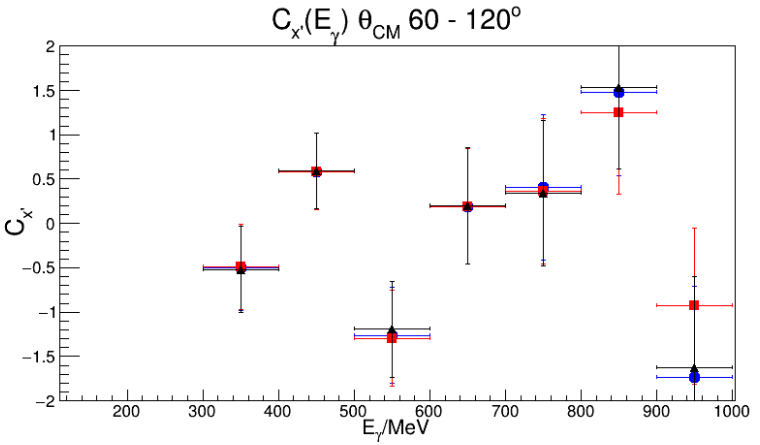
Black Data Points from - J.PhysG, 17, 8, 1189, F. V. Adamian et. al.
Results published in - PLB, 789, 7-12, M. Bashkanov, S.Kay, D.P. Watts, C. Mullen et. al.

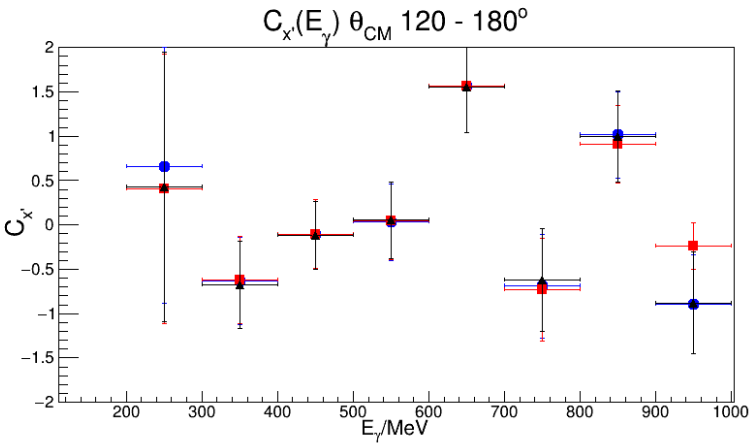
$C_{x'}$ - Asymmetry

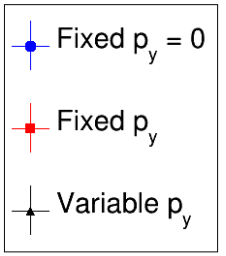


$C_{x'}$ - Results


$C_{x'}(E_\gamma)$ θ_{CM} 0 - 60°
$C_{x'}$
E_γ/MeV


$C_{x'}(E_\gamma)$ θ_{CM} 60 - 120°
$C_{x'}$
E_γ/MeV


$C_{x'}(E_\gamma)$ θ_{CM} 120 - 180°
$C_{x'}$
E_γ/MeV


Fixed p_y = 0
Fixed p_y
Variable p_y

Outlook and Summary

- Event selection identifies clean sample of scattered events

- Σ results extracted, consistent with existing data

- Σ results published in PLB, PLB 789 pp7-12, https://doi.org/10.1016/j.physletb.2018.12.026

- Initial interpretation of Σ results suggests hints of the influence of the d*(2380)

- Preliminary analysis of $C_{x'}$ carried out

- Refinement of analysis ongoing

Thanks for listening, any questions?

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