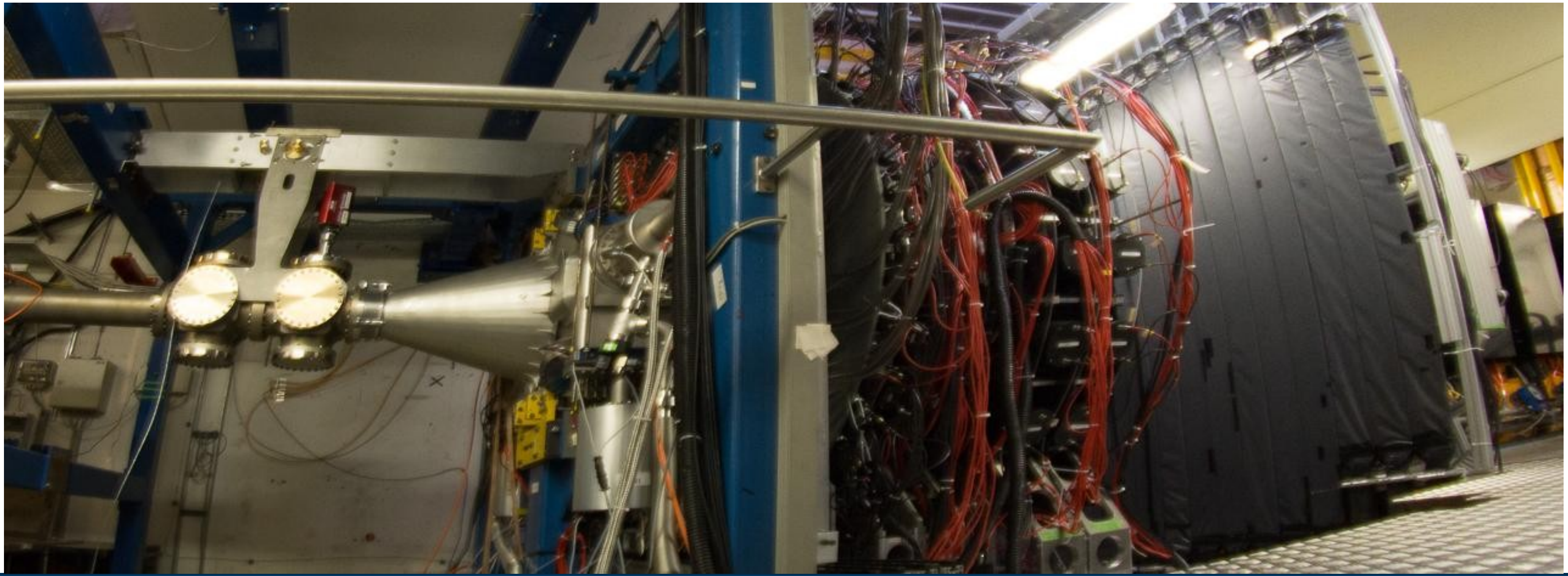


Measurement of dC Vector Analyzing Power and Cross Section at COSY for srEDM Polarimetry

12. 09. 2018 I FABIAN MÜLLER | IKP-2 | ON BEHALF OF JEDI

RWTH AACHEN UNIVERSITY

JEDI

JÜLICH Forschungszentrum

OUTLINE

- Short EDM Introduction / Motivation
- WASA Forward Detector
- dC Vector Analyzing Power
- Elastic dC Cross Section
- Summary / Conclusion

EDM

Introduction / Motivation

Electric **D**ipole **M**oment (EDM): $\vec{d} = d\vec{S}$

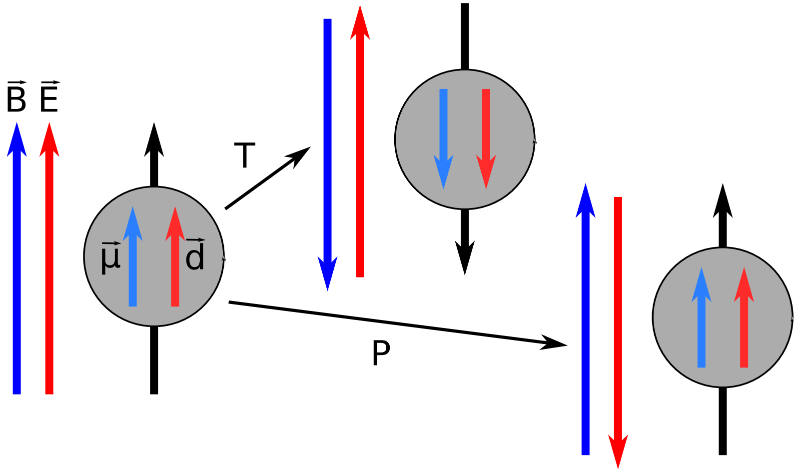
Magnetic **D**ipole **M**oment (MDM): $\vec{\mu} = \mu\vec{S}$

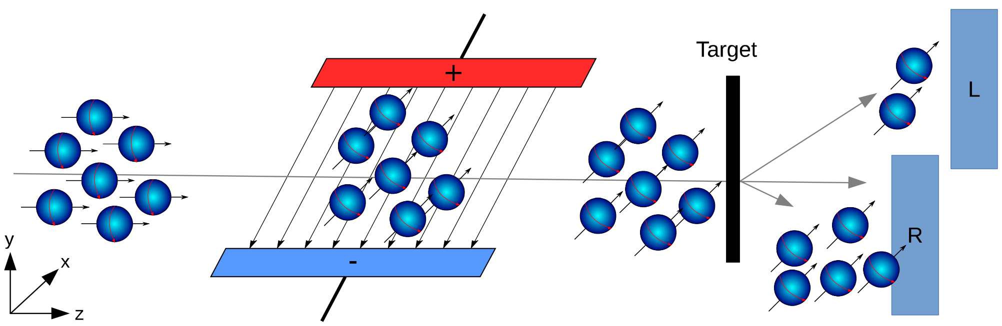
$$H = -d\vec{S}\cdot\vec{E} - \mu\vec{S}\cdot\vec{B}$$

$$T: H = +d\vec{S}\cdot\vec{E} - \mu\vec{S}\cdot\vec{B}$$

$$P: H = +d\vec{S}\cdot\vec{E} - \mu\vec{S}\cdot\vec{B}$$

→ EDM violates both CP and P symmetry!



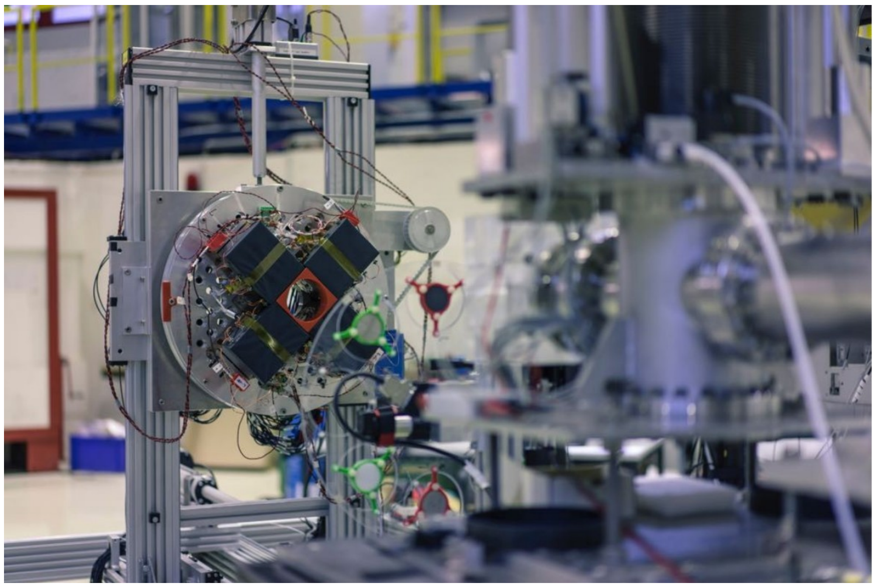


Simplified EDM measurement procedure

- Use horizontally polarize deuterons
- Horizontal E-field creates spin build-up along y
- Elastic scattering creates asymmetry proportional to polarization along y
- EDM is proportional to polarization build-up

MOTIVATION

Research and development towards a first proof-of-principle EDM experiment within the JEDI (**J**ülich **E**lectric **D**ipole **I**nvestigation) Collaboration http://collaborations.fz-juelich.de/ikp/jedi/

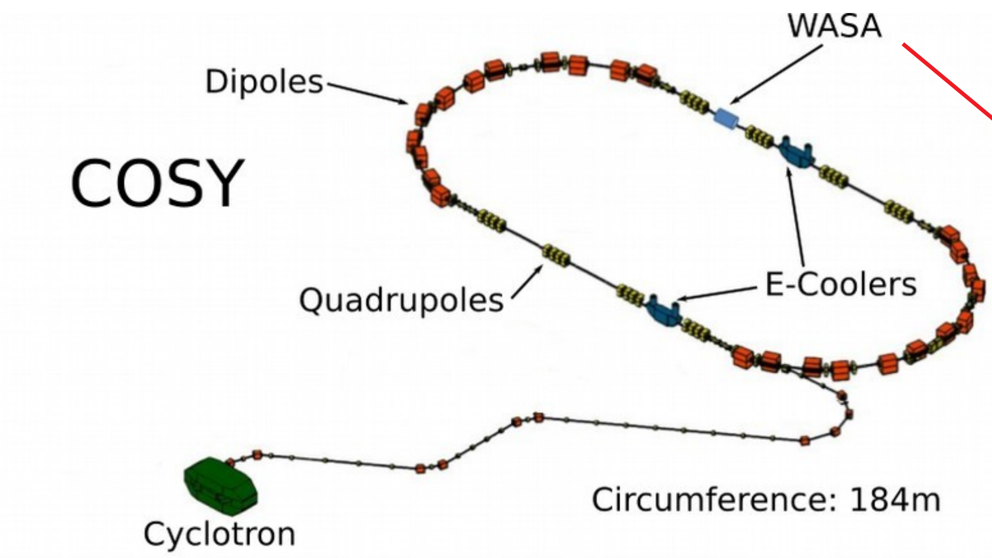


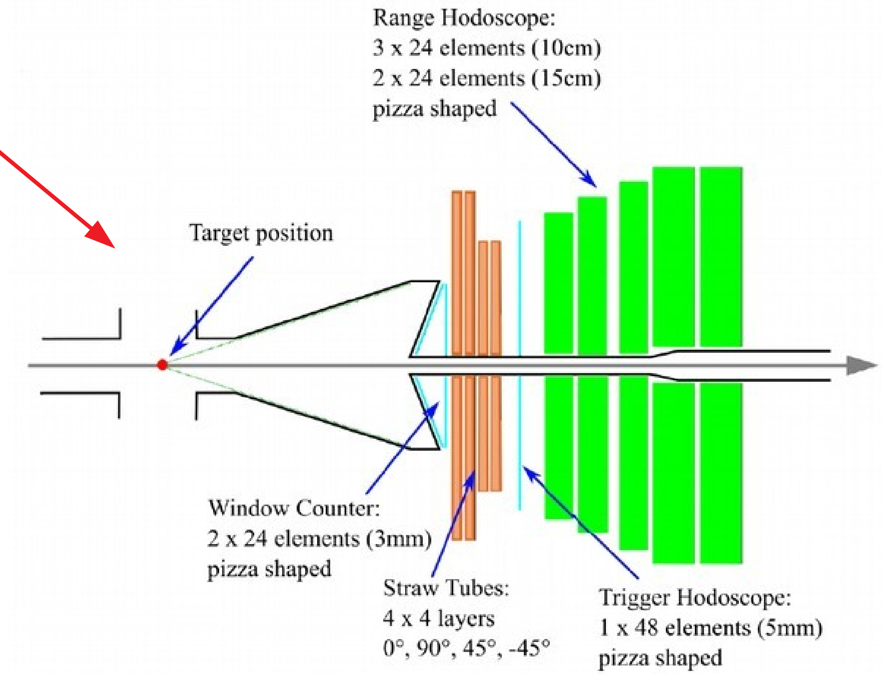
- Plans for first storage ring based EDM measurements on protons and deuterons
  → Overview talk given by Dr. Frank Rathmann: *Electric dipole moment searches using storage rings*

- Development of a dedicated polarimeter based on LYSO crystals
  → Detailed talk given by Dito Shergelashvili: *Development of LYSO detector modules for a charge-particle EDM polarimeter*

→ Measurement of deuteron analyzing power and elastic cross section will be used to find optimal polarimeter configuration

DETECTOR SETUP





- Installed in the COSY (**CO**oler **SY**ncrotron) accelerator at the research center in Jülich
- Detector is remnant of former WASA
- Multi layer design
- Large acceptance: 2° - 17° in Θ, full coverage in Φ
- Two strip targets installed: Carbon (Diamond) and Polyethylene (CH2)

VECTOR ANALYZING POWER

Elastic Scattering of Polarized Deuterons - Overview

Asymmetry ε
→ first topic of the talk

Deuteron spin-1 factor

$$\sigma_{dC}^{pol}(\Theta,\Phi) = \sigma_{dC}^{unpol}(\Theta)[1 + \frac{3}{2}P_y A_y(\Theta)\cos(\Phi)]$$

Polarized elastic cross section

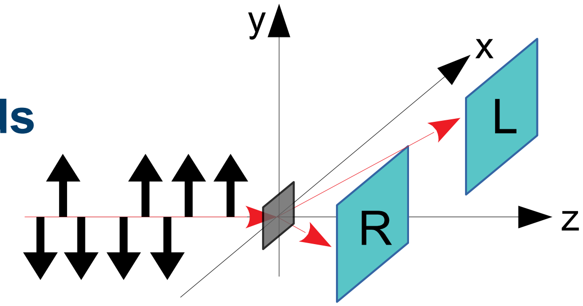
Unpolarized elastic cross section
→ second topic of the talk

Vector polarization

Vector analyzing power

VECTOR ANALYZING POWER

Measurement Principle – One Asymmetry, Two Methods



Asymmetry
→ can be extracted from data

$$\epsilon = \frac{3}{2} P_y A_y = \begin{cases} \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow} = \frac{N_L - N_R}{N_L + N_R} \\ \frac{\sqrt{N_\downarrow^L N_\uparrow^R} - \sqrt{N_\uparrow^L N_\downarrow^R}}{\sqrt{N_\downarrow^L N_\uparrow^R} + \sqrt{N_\uparrow^L N_\downarrow^R}} \end{cases}$$

Asymmetry Method:
- Either, one detector and two polarization states
- Or, two detectors and one polarization state
- Left/right detector acceptance must be equal

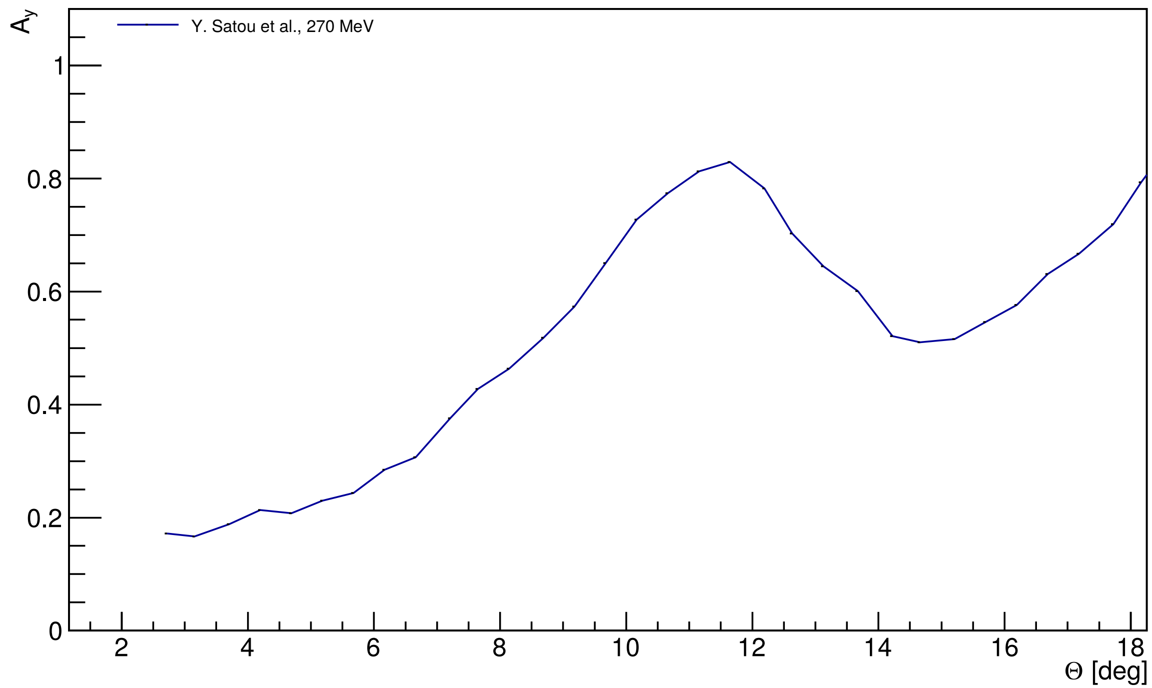
Cross Ratio Method:
- Uses both polarization states and detector sides simultaneously
- Different acceptances in left/right detector cancels

→ This method was used in this work

→ Important for polarimetry:
Polarization can be calculated from asymmetry if the analyzing power is known!

VECTOR ANALYZING POWER

Results

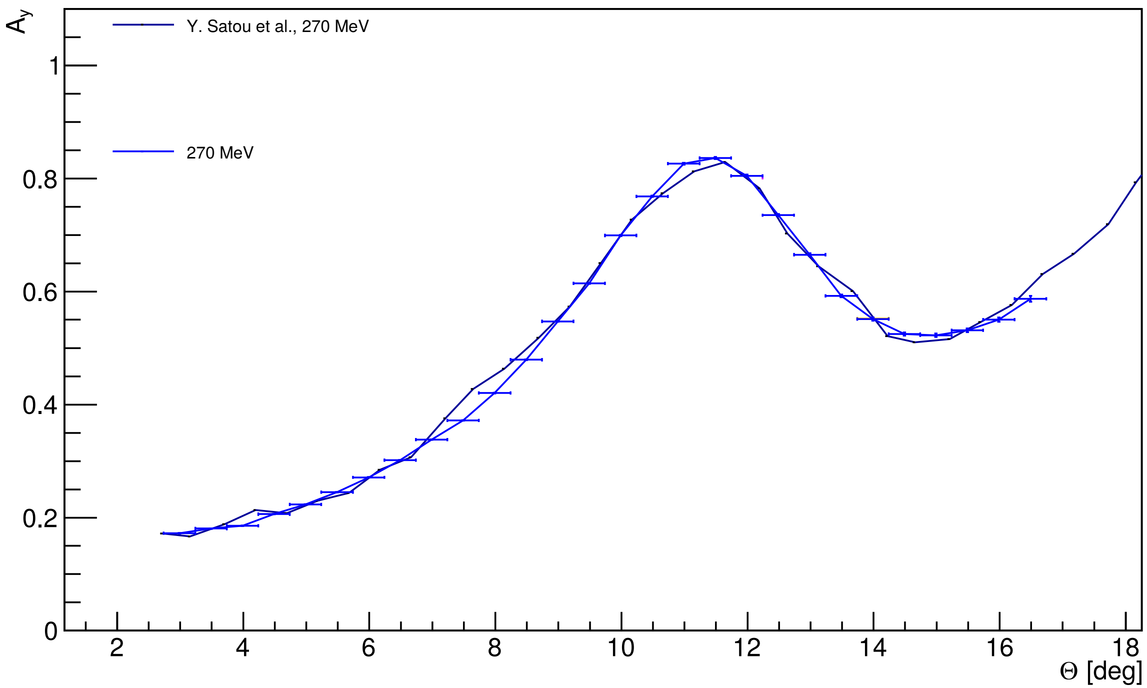


Extracting the analyzing power from the asymmetries:

1. Absolute beam polarization was not known → using reference A_y from Satou et al

VECTOR ANALYZING POWER

Results

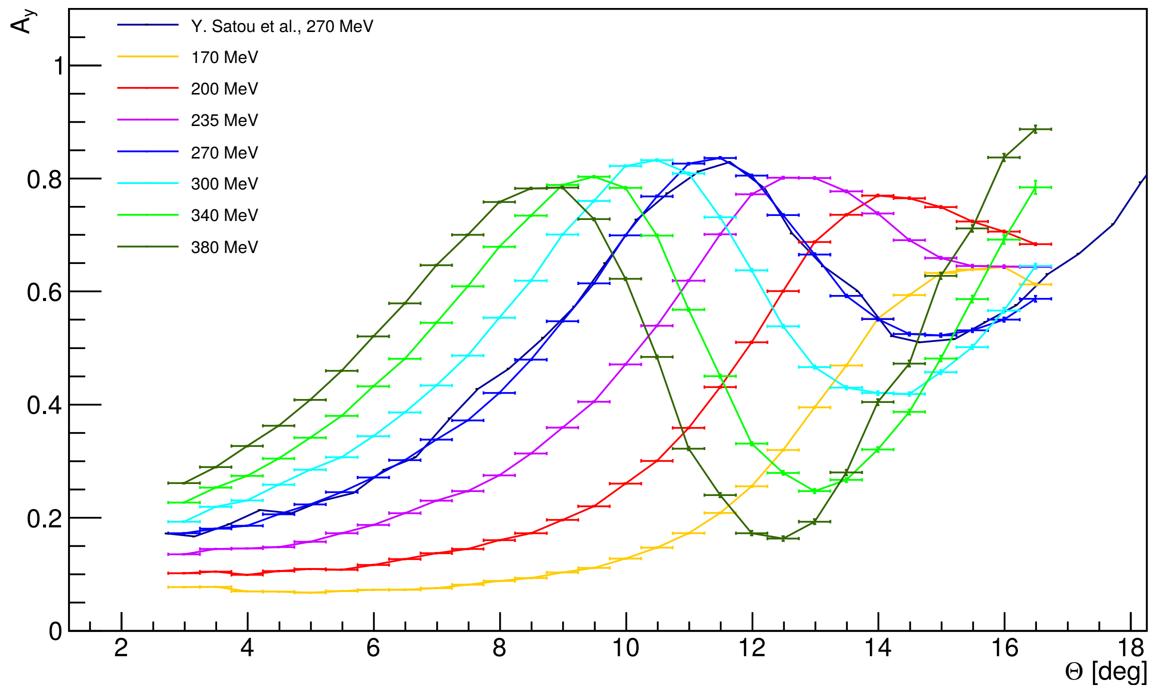


Extracting the analyzing power from the asymmetries:

1. Absolute beam polarization was not known → using reference A_y from Satou et al
2. Fitting asymmetry for 270 MeV to reference → got polarization value of 0.434

VECTOR ANALYZING POWER

Results



← Statistical errors shown

← Results will be used for an optimal EDM polarimeter development

Extracting the analyzing power from the asymmetries:

1. Absolute beam polarization was not known → using reference A_y from Satou et al
2. Fitting asymmetry for 270 MeV to reference → got polarization value of 0.434
3. Using this polarization to scale asymmetries for other energies (assuming same polarization)

ELASTIC DC CROSS SECTION

Approach for Cross Section Extraction

Elastic dC Cross Section

Number of elastically scattered deuterons
→ extracted from measured data

$$\sigma_{dC} = \frac{N_d^{el}}{\epsilon_{dC}\mathcal{L}_{dC}^{int}}$$

Detector acceptance for dC scattering
→ from Monte-Carlo simulation

Integrated luminosity for dC scattering
→ proportional to the beam current
→ no direct measurement in storage ring experiment

→ Luminosity cannot be extracted from dC scattering only

ELASTIC DC CROSS SECTION

Approach for Cross Section Extraction

Solution:

- Measure dp elastic scattering off CH_2
- Extract luminosity by comparison to dp reference data
- Scale luminosity for CH_2 to C target

Number of elastically scattered protons
→ extracted from data

Integrated luminosity for pd scattering

$$\mathcal{L}_{pd}^{int} = \frac{N_p^{el}}{\epsilon_{pd}\sigma_{pd}}$$

Detector acceptance for pd scattering
→ from Monte-Carlo simulation

Elastic pd cross section
→ from reference data

$$\mathcal{L}_{dC}^{int} = \frac{1}{2}\frac{\mathcal{L}_{dp}^{int}}{\eta_{CH_2\to C}}$$

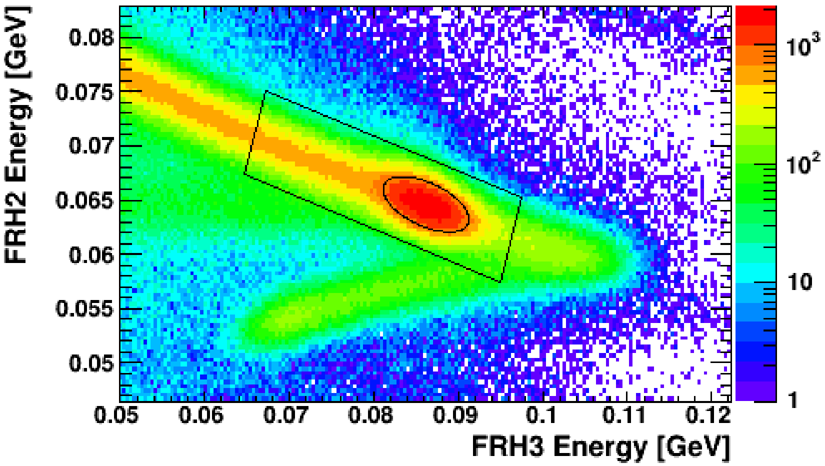
Scaling factor H_2 to C in CH_2 target

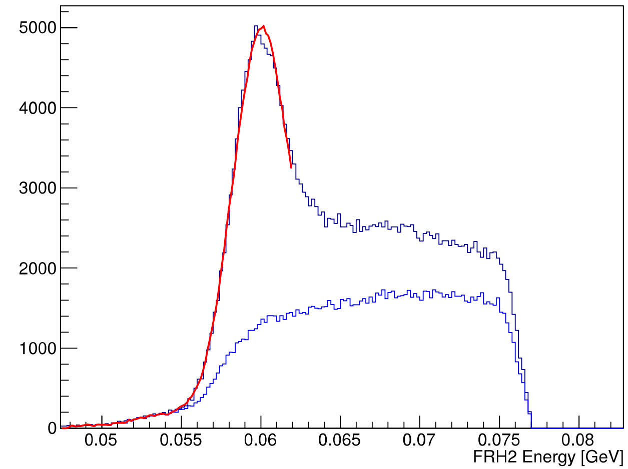
Scaling factor CH_2 to C target
→ Fitting CH_2 to C spectra

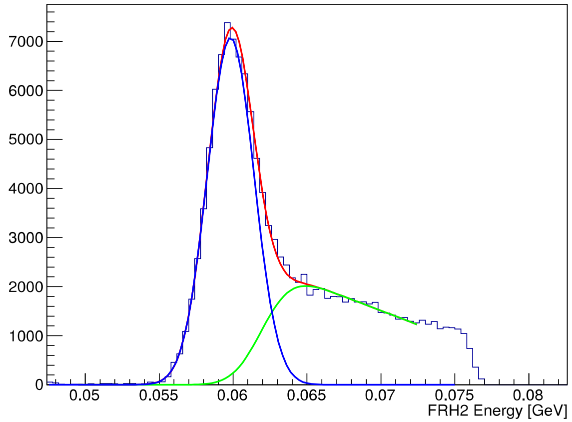
$$\Rightarrow \sigma_{dC} = 2\sigma_{pd}\frac{N_d^{el}}{N_p^{el}}\frac{\epsilon_{pd}}{\epsilon_{dC}}\eta_{CH_2\to C}$$

ELASTIC DC CROSS SECTION

Proton Extraction from CH_2 Data







Steps done for each energy and each Θ-bin:

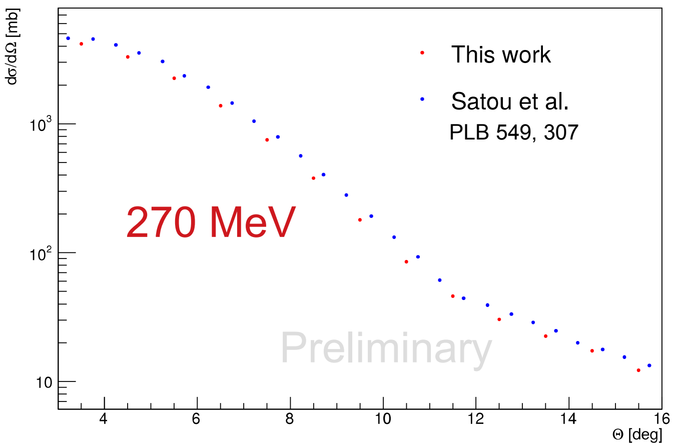
1. Graphical cut around the elastic proton peak
2. Subtracted C contribution from CH_2 data
3. Fitted elastic peak and background

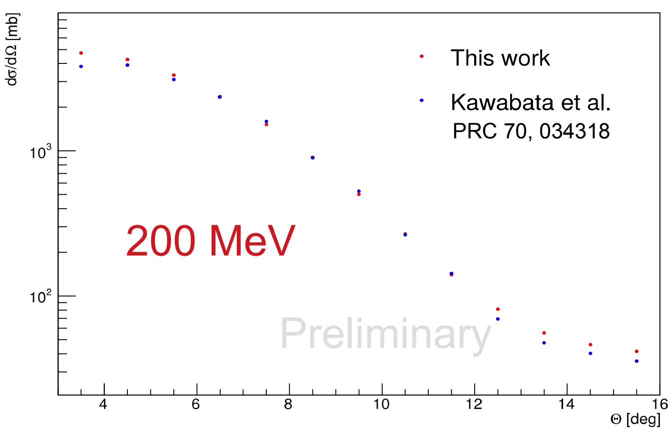
→ Number of elastically scattered protons from peak integral

ELASTIC DC CROSS SECTION

Elastic dC Cross Sections & Reference pd Cross Sections

dC Cross Sections:



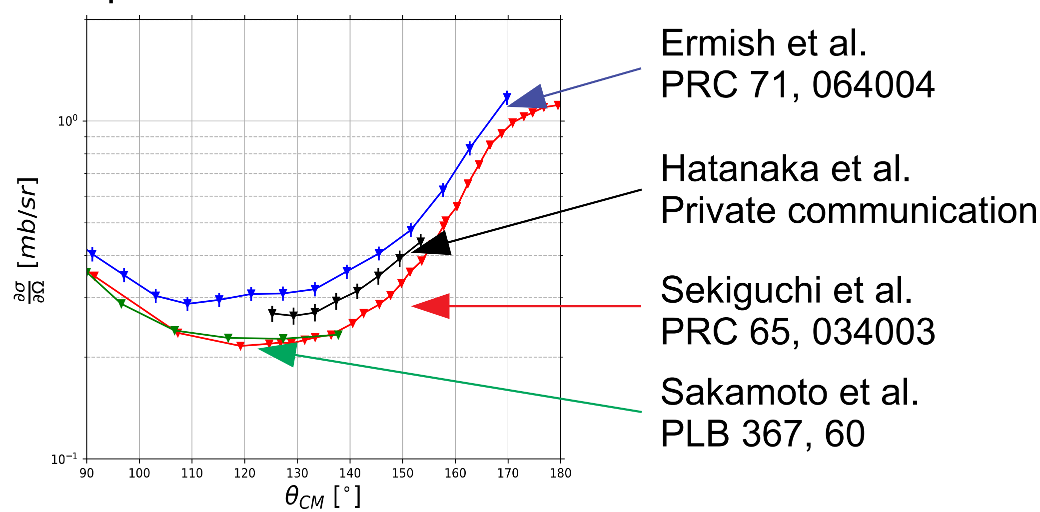


Elastic dC cross section:

- Calculated using experimental data and MC
- Scaled using reference data for elastic pd scattering
- Statistic error bars are shown
- Available reference data for elastic pd scattering shows some deviations among different publications

→ Careful ponder on the choice of reference is needed

dp Cross Sections for 270 MeV:



SUMMARY / CONCLUSION

Summary:

- Non-zero EDM violates both, P and CP symmetry
- High precision asymmetry measurements are needed to access EDMs
- The WASA Database Experiment aims to provide the necessary tools for an optimal polarimeter development
- First results of the vector analyzing are very promising and show good agreement with published references
- Preliminary results for the elastic cross section extraction are compatible with experiments done by Satou et al. and Kawabata et al.

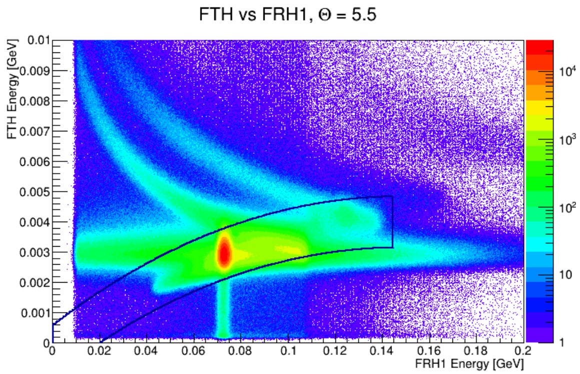
Outlook:

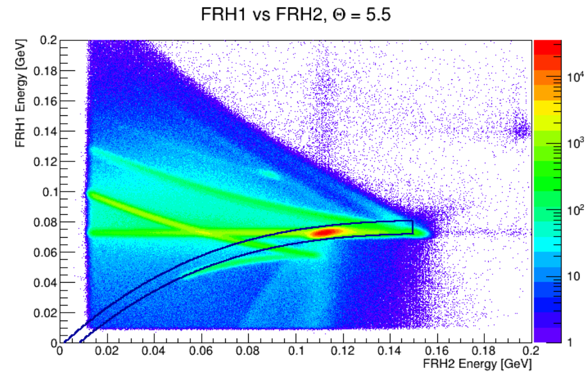
- Extraction of the cross section for the energies between 170 MeV and 380 MeV
  → Work in progress but not ready to be presented yet
- Investigation on the polarization stability during the beam time
- Estimation of the systematic errors of the experiment

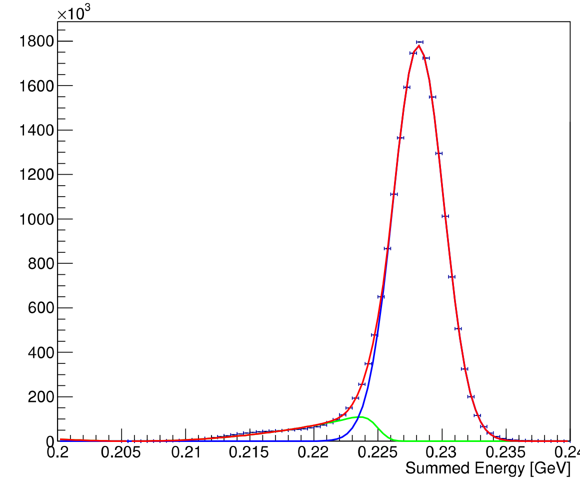
BACKUP

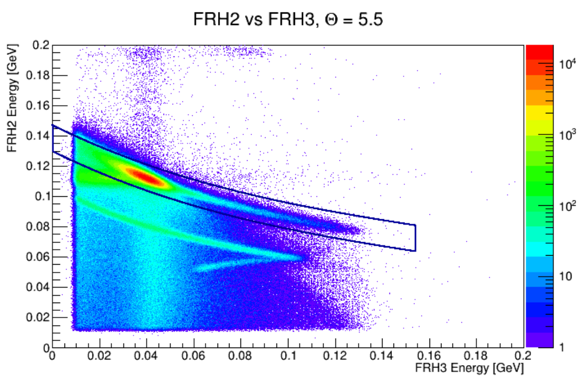
ELASTIC DC CROSS SECTION

Deuteron Extraction from Carbon Data









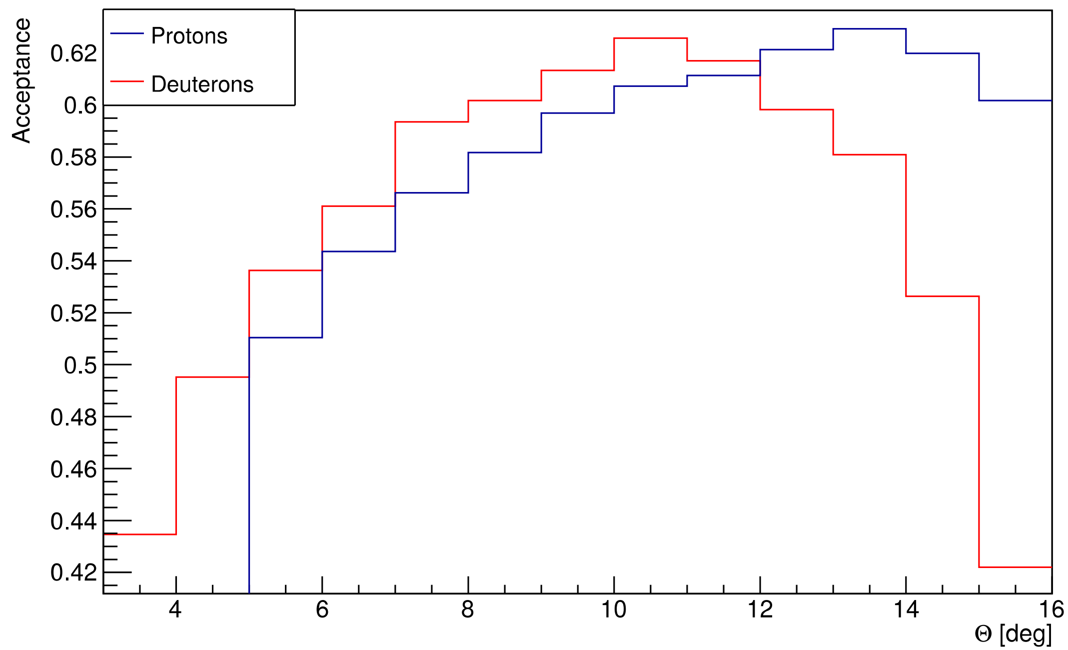
Steps done for each energy and each Θ-bin:

1. Graphical cuts around the deuteron band for all layers
2. Spectra for summed for all layers
3. Fit the elastic peak and the backgound

→ Number of elastically scattered deuterons from peak integral

ELASTIC DC CROSS SECTION

Acceptance from Monte-Carlo Simulation



Generated elastic events
→ Isotropically distributed:

$$\Phi \in [0^\circ, 360^\circ], \quad \Theta \in [3^\circ, 16^\circ]$$

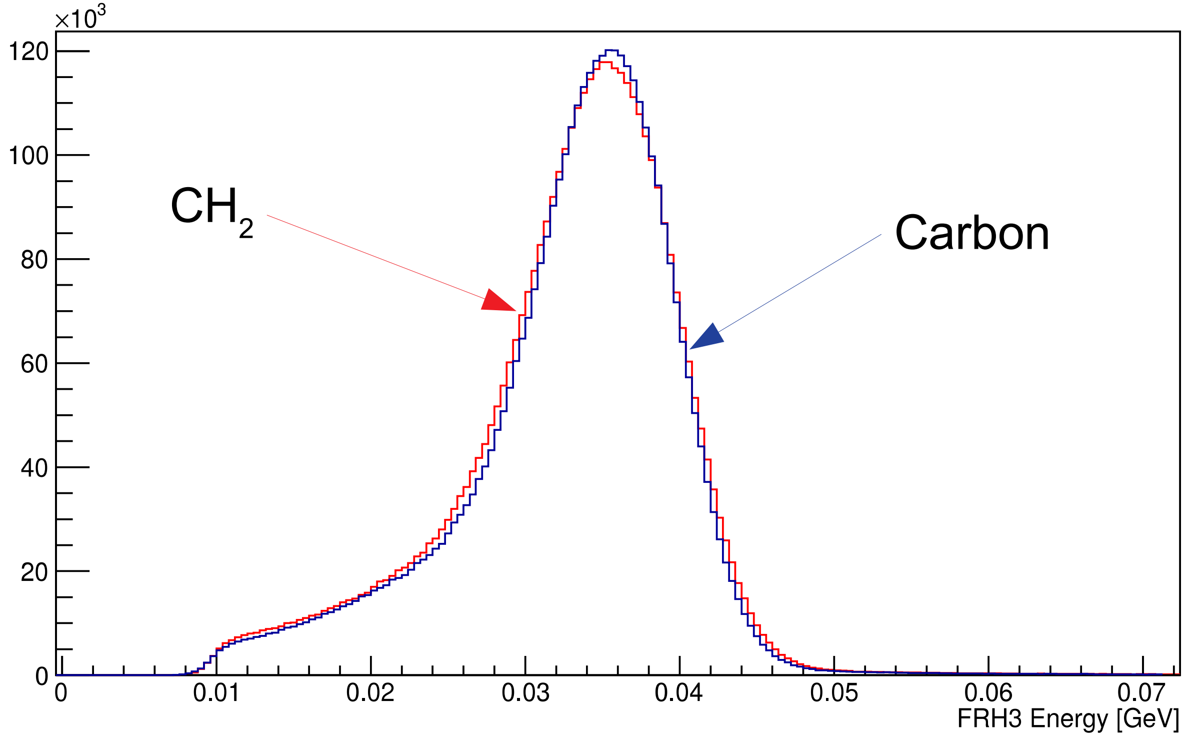
Detector acceptance

$$\epsilon = \frac{N_{gen}}{N_{det}}$$

Detected events from Geant3 MC
→ includes detector geometry
→ includes nuclear reactions in the scintillators
→ cut on particle bands

ELASTIC DC CROSS SECTION

C to CH_2 Scaling



- Apply same band cuts on C and CH_2 data
- Simultaneous fitting histogram on histogram in all Θ-bins