Beam normal single spin asymmetry measurement at MAMI

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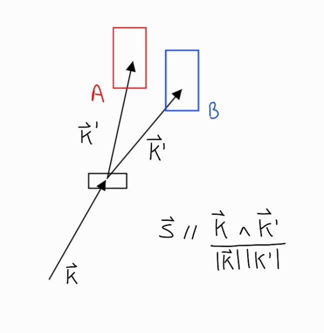
During the last beam-time, several mesurements were performed at Mainz Mikrotron MAMI. The last data acquisition campaign had the following goals:

- Test the new data acquisition system, developed for the new setup with a low rate signals ($\simeq 1\,\mathrm{MHz}$).
- Measure the trasverse asymmetry A_n of ^{12}C.
- Measure the expected rates on ^{208}Pb target, in anticipation of the future mesurement of A_n for lead.
- Long term goal: acquire more knowledge on the systematic effects that the transverse asymmetry has on the measurement of the Parity-violating asymmetry.

A first look the physics of the problem

Before moving on to the experimental details, we identify the kinematics of the experiment. For the beam normal single spin asymmetry, the electrons are polarized in the normal plane identified by the $\frac{\vec{k'} \wedge \vec{k}}{|\vec{k}||\vec{k'}|}$



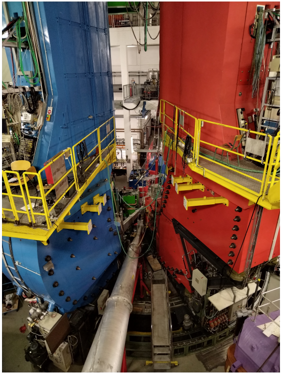


Figure: (very) schematic figure of the experiment on the left, Spektrometers B (blue) and A on right, view is from the beam dump

The position of the two dectector is fixed at $\simeq 23^\circ$, that correspond to a $Q^2 = 0{,}04\,\mathrm{GeV}$

The trasverse asymmetry is defined as the ratio between the sum and the difference of the elastic cross section for the two different polarized electrons:

$$A_{transverse} = \frac{\sigma_{\uparrow} - \sigma_{\downarrow}}{\sigma_{\uparrow} + \sigma_{\downarrow}}$$

straightforward this quantity can be measured with the asymmetry in the counts of a detector. With the following convention, the beam is polarized (using a de bruijn sequence) in one of the two possible configuration of the spin. So an event corresponds to the integration of all particles scattered during 80 ms window.

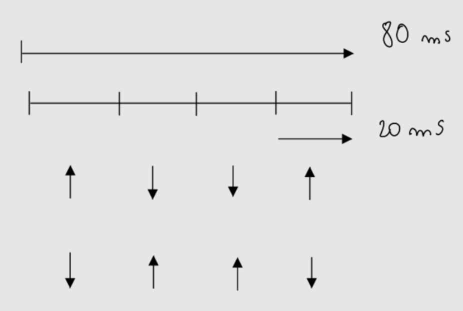
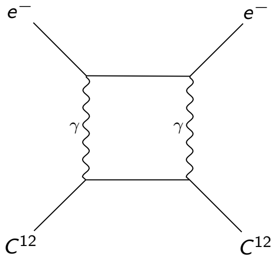
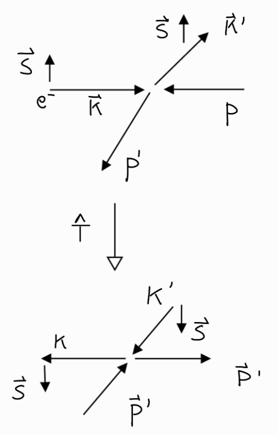


Figure: Event sequence: all the particle

Scattering process

The following one is the diagram we are interest to calculate, the one loop correction to the electron-nucleus elastic scattering. This diagram give rise to a non-zero imaginary part of the elastic amplitude, that is related to the transverse asymmetry.





If we consider the same scattering process, but after applying $\hat{T}$ operator, the spin of the electron is reversed. This means that the asymmetry is directly correlated to Time-reversal simmetry.

Scattering Process

The incident beam is made by 570 MeV electrons, that are polarized along the trasverse axes ($\uparrow$ and $\downarrow$). The physical quantity to measure is the asymmetry between the number of scattered electrons, due to the change of the polarity:

$$asym = \frac{N_+ - N_-}{N_+ + N_-} (\text{expected} \sim +/\text{- } 20 \text{ ppm, Q} = 0{,}2\,\text{GeVc}^{-1}) \tag{1}$$

It's possible to obtain a final formula for the trasverse Asymmetry, writing the Amplitude of the 1-loop diagram, considering the elastic intermediate state and the inelastic intermediate state (whose contribution is higher):

$$A_n \simeq C_0 \log \frac{Q^2}{m_e^2 c^2} \frac{F_{Compton}(Q^2)}{F_{ch}(Q^2)} \tag{2}$$

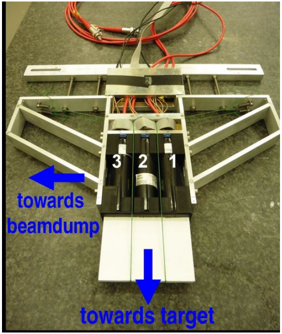
It's possible to perform analytical calculation for the inelastic intermediate state, however for the inelastic term, some parametrizations are needed.

The counts of the pmts can be slightly different due to the variation of the position of the beam on the target, the variations of the incident angles, the uncertain associated with the energy and the current of the beam. All this quantity can influence the asymmetry measured by the pmts, considering also that the expected asymmetry is in the order of ten part per million, and small asymmetry introduced by fluctuations of the beam parameters are not negligible:

$$Asym = A_{physical} \cdot P + \delta_I + A_x \delta x + A_y \delta y + A_{\theta_x} \delta\theta_x + A_{\theta_y} \delta\theta_y + A_E \delta E \tag{3}$$

The Detectors

The detectors are made by 9 and 3 pmts coupled to a fused-silica material, exploiting the Cherenkov light produced when a particle travel inside the material.



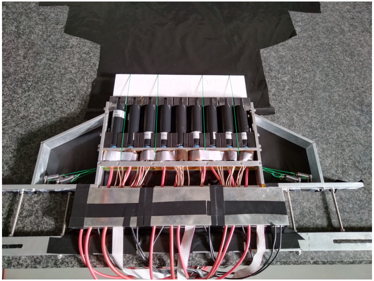
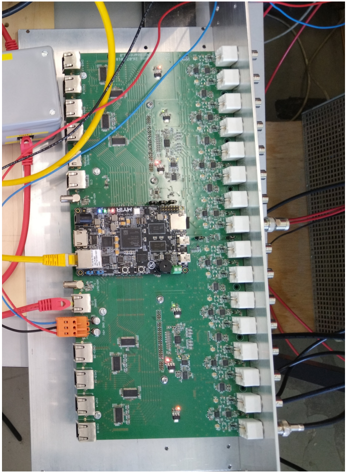


Figure: Detector B on the left, detector A on the right.

Read-out

The pmt signals are read-out by a Nino-board, shown in figure: This device collects the number of pulses directly from the pmts. It's made by discriminators which compare the input signals (on the left side) to a signal that can be adjusted manually with the pvDaq.py scripts. Three parameters are important for the DAQ and calibration of the pmt: the Voltage supply of the pmts, the threshold (always fixed) and the Attenuation.

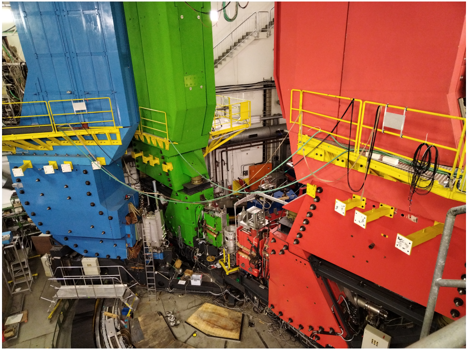


Here we present a picture of the MasterBoard, the core of the electronics system, which controls and supervises the following functions:

- it controls the X and Y signals to the Wobbler, to avoid melting the target.
- it sends the signals to the Source, to change the polarity of the beam ($\simeq 0.79$).
- it Manages the data from all the beam monitors: X21/25/26, Y21/25/26, I21, I13, ENMO.

The Detectors

The detectors are placed inside the two spektrometers, which were used only to align the two detectors to the elastic scattering line (changing the magnetic field).



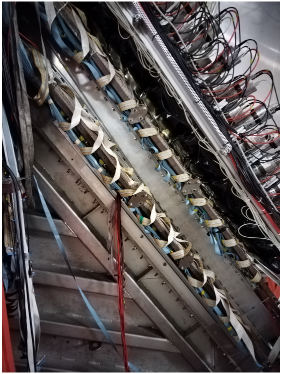


Figure: Spektrometers B and A on the left, view of the inside with the detector A in position.

Vfc I21 calibration

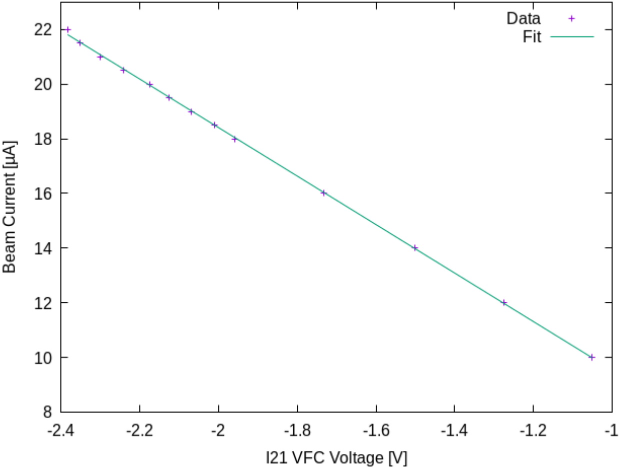
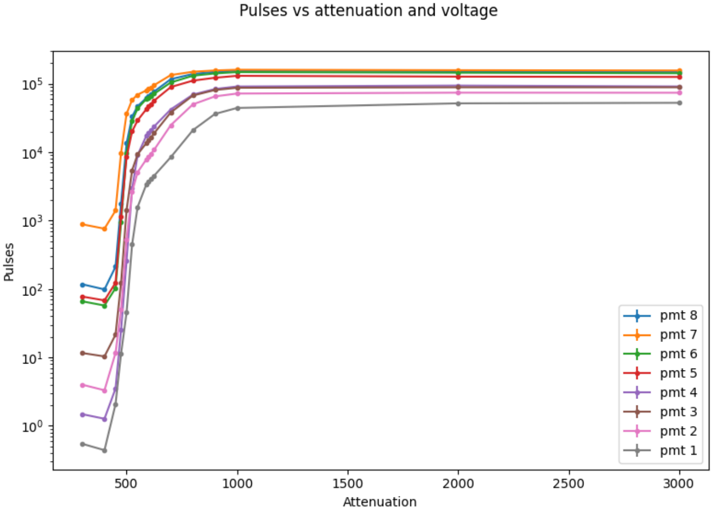


Figure: Calibration of the VFC I21 monitor, for me measurement of the beam current.

Calibration of the pmt

Figure: pmt Count spekA, the threshold was selected at the edge of the knee for each pmt.



Calibration of the pmt

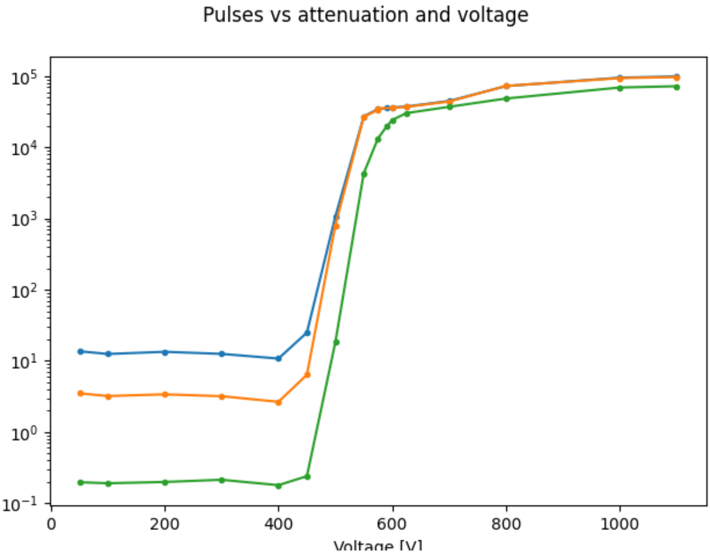


Figure: Calibration of the pmt of detectorB, the threshold was selected at the edge of the knee for each pmt.

XY calibration

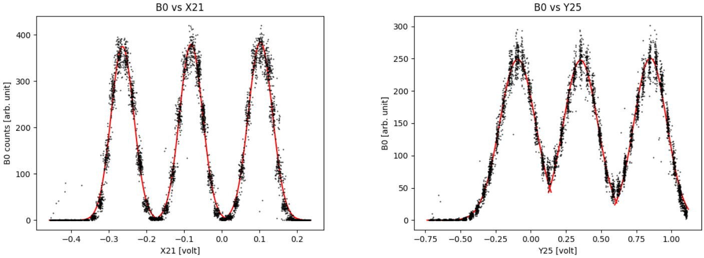
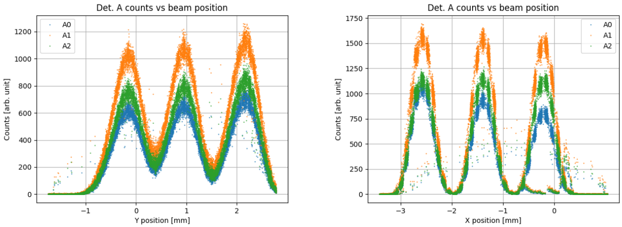


Figure: Vertical and horizontal calibration. Knowing the distance between the center of the first wire and the last one, it is possible to obtain the scaling factor for X and Y position on the target.



Expected error

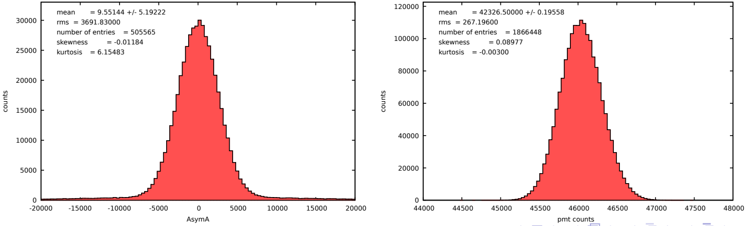
The expected error is recostruncting the asymmetry is now computed:

$$Var[A_{asym}] = Var[\frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow}] \simeq \frac{Var[N_\uparrow - N_\downarrow]}{(N_\uparrow + N_\downarrow)^2}$$

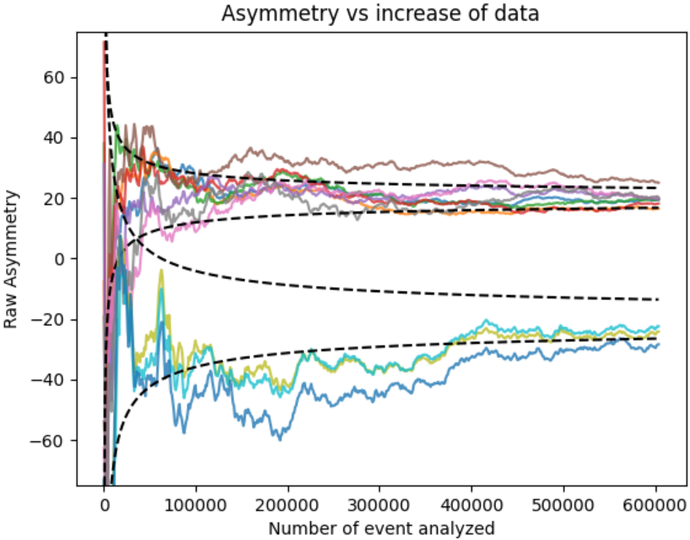
$$\frac{2Var[N]}{4N^2} = \frac{1}{2N} \qquad \sigma = \frac{1}{\sqrt{2N}}$$

This is the σ supposing that the pmt's Counts are gaussian distributed, with μ equal to σ^2. The rms associated to the sample mean decrease as the $\sqrt{N_{measure}}$.
Considering a $\mu = 10000$ and $3 \cdot 10^6$ data (often used during the simulation) the error is about $4ppm$. Therefore, considering $5 \cdot 10^5$ data, but $\mu = 40000$, a factor of 4 more scattered electron (as we observed in the real data), we obtain an error of $\simeq 5ppm$.

Figure: Pmt 4, asymmetry on the left, pmt counts on the right



Here a plot about the trend of the asymmetry as the data increases. The band is the error computed as showed in the previous slide, centered around the values of $+20ppm$ for detector A and $-20ppm$ for detector B.



Preliminary results

For each pmt, we present the raw values of the asymmetry, obtained by subtracting the Raw current asymmetry, that is roughly -1.11 ppm , then we compute the averaged values:

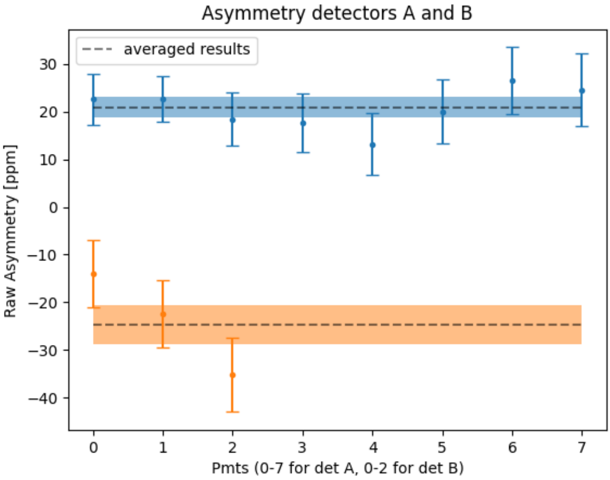


Figure: Asymmetries obtained for each pmt. The asymmetries are corrected subtracting the current asymmetries, without any further fit procedure.

Preliminary results

Combining the result of each pmt, assuming all the asymmetries measured are indipendent of each other, we obtain the following quantities for Beam normal single spin asymetries:

$$\hat{Asym} = \frac{\Sigma_i Asym_i \frac{1}{w_i}}{\frac{1}{w_i}} \qquad w_i = \frac{1}{\sigma_i^2}$$

We obtain the following:

$$A_{detA} = (20.45 \pm 1.6)ppm \qquad A_{detB} = (-23.19 \pm 4.18)ppm \tag{4}$$

Reversing the sign of the asymmetry for detB we notice that the two measurement are consistent, and this show the good behaviour of the electronic setup used for the experiment.

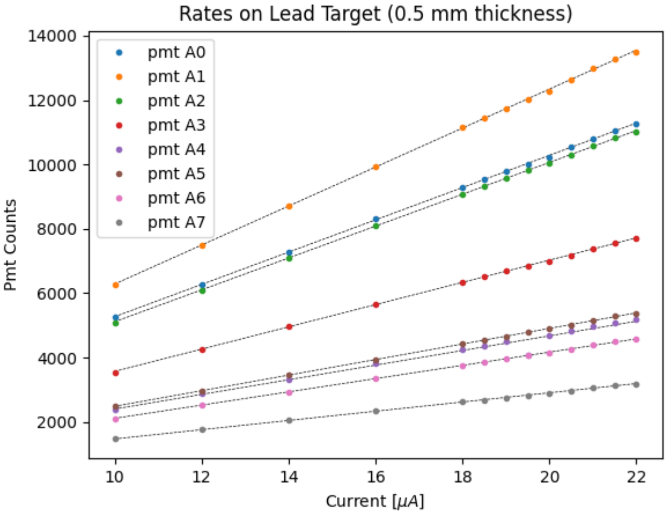


Figure: Rate for Lead target, pmts of detector A