The Low Energy Polarimeter at COSY

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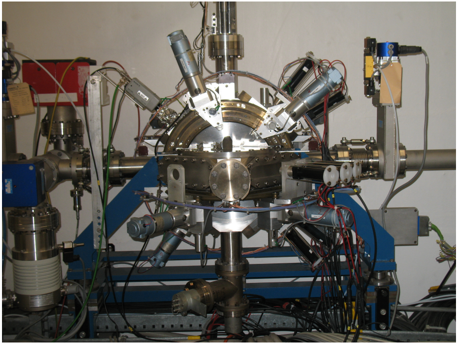
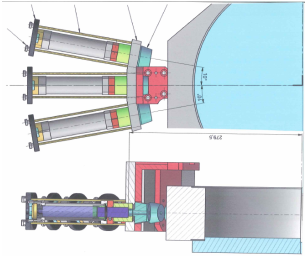
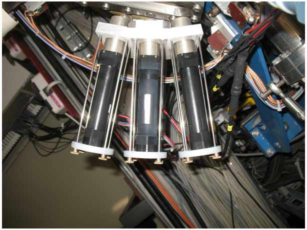
Low Energy Polarimeter



- 8 flanges to attach detectors
- Target selectable: carbon, polyethylene, deuterated polyethylene
- 75 MeV deuterons or 45 MeV protons

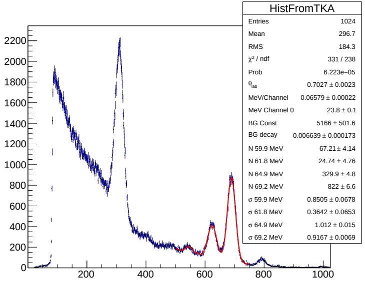
Detectors



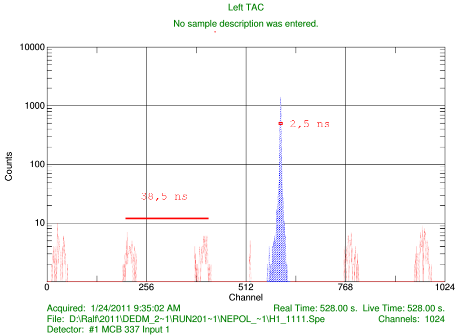


- Three detectors each for particles scattered left, right, up and down
- Plastic scintillators + PMTs spaced 10° apart
- Changeable collimators

Event Selection

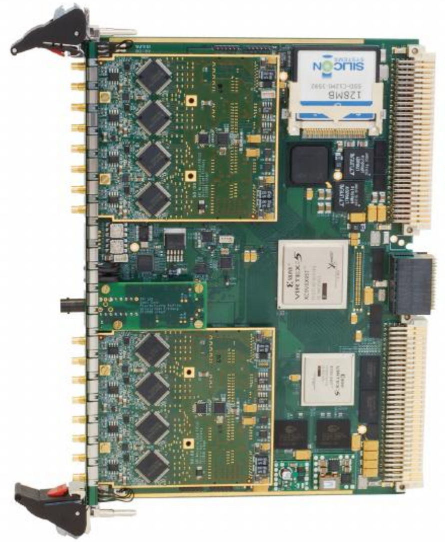


- Pulse height spectrum
  - Proton peak, two carbon peaks
  - Roughly exponential background
  - Scintillator resolution $\sim 5\%$



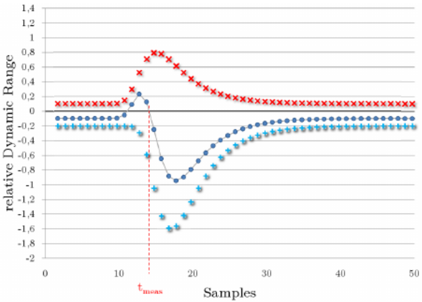
- Time spectrum
  - Ejectile recoil coincidence
  - Smaller peaks from cyclotron frequency

GANDALF



- 8 analog input channels for ADC in interleaved mode (1 GSample/s), need two modules
- FPGA for readout, time resolution $\mathcal{O}(50\,\mathrm{ps})$
- USB connection: $20\,\mathrm{MB/s}$
- One borrowed from Freiburg
- Aim: online determination of beam polarization, increase rate $\sim 1\,\mathrm{MHz}$

Firmware

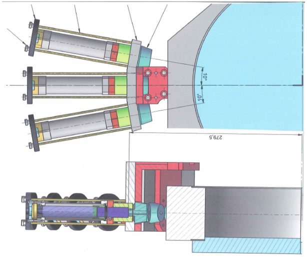


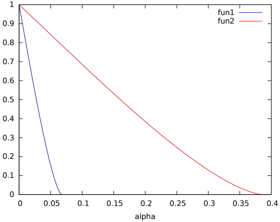
- Mostly finished
- Constant fraction discriminator to measure amplitude and time (from Freiburg)
- Single channel analyzer + counter module to select events based on amplitude
- Coincidence unit to select events based on time between ejectile and recoil + amplitudes
- Readout: numbers of events, prescaled amplitudes and times

Systematic Errors

- Angular dependence of σ and A: discussed in Brantjes et. al. paper
- Solid angle of detectors: dominated by collimator
- Pile-up

Collimators

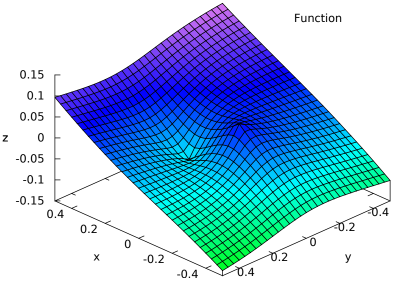




- Effective solid angle dominated by geometrical shadow of front opening
- Correction factor

$$\eta_0 \cos\alpha \left(1 - \frac{\tan\alpha l}{2\pi r^2}\sqrt{4r^2 - \tan^2\alpha l^2} + \frac{2}{\pi}\arcsin\left(\frac{\tan\alpha l}{2r}\right)\right) \approx \eta_0\left(1 - \frac{2l\alpha}{\pi r}\right)$$

Beam Alignment



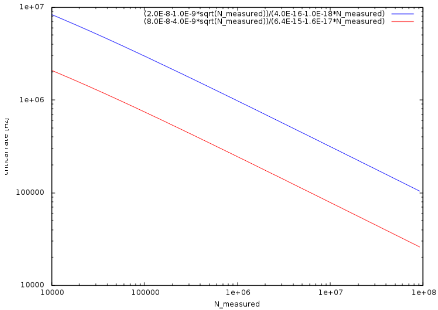
$x_{0,L} = 1\,\mathrm{mm}$, $y_{0,L} = 1\,\mathrm{mm}$, $x_{0,R} = -1\,\mathrm{mm}$ and $y_{0,R} = 0$ for a collimator radius of $1\,\mathrm{mm}$

- First order dependence from σ, A
- Bumps from collimator, non-differentiable

Pile-Up

- Pile-up leads to underestimation of event rate. Correction: $N_{\mathrm{corrected}} = \frac{N_{\mathrm{measured}}}{1 - f_{\mathrm{tot}} \cdot t_{\mathrm{pile\text{-}up}}}$
- Systematic error $\sigma_{\mathrm{pile\text{-}up}} = \frac{N_{\mathrm{measured}}}{\left(1 - f_{\mathrm{tot}} \cdot t_{\mathrm{pile\text{-}up}}\right)^2} \cdot f_{\mathrm{tot}} \cdot \sigma_{t_{\mathrm{pile\text{-}up}}}$
- Is Struck-ADC with shaper an alternative to GANDALF? What rate can be achieved?

Pile-Up Error on Count Rate

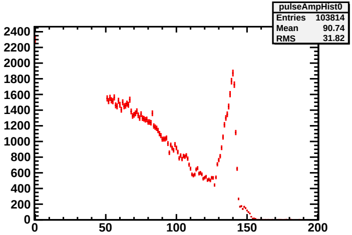


- Above curve: error dominated by pile-up, below curve: dominated by statistics
- Blue: estimated GANDALF pile-up $20 \pm 1\,\mathrm{ns}$, red: estimate for Struck-ADC $80 \pm 4\,\mathrm{ns}$
- Not including cyclotron duty factor

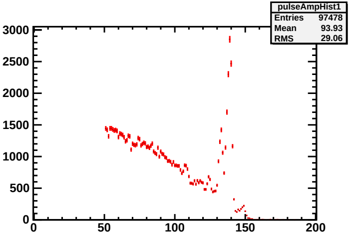
Beam Time

- Test and optimize GANDALF for use with actual detector
- Measure and understand pulse height and time spectrum
- Asymmetry as function of beam position and angle
- Variation of detector angle
- Rate as function of collimator diameter

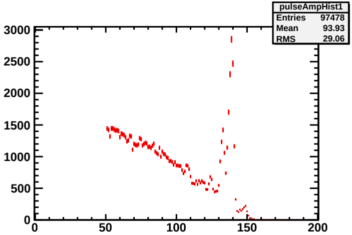
First Results



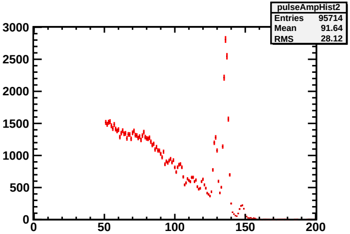
Left



Up



Right

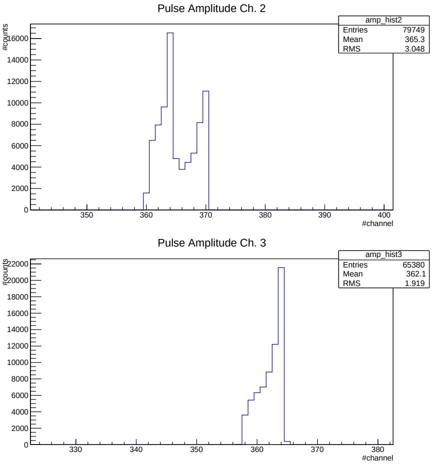


Down

Outlook

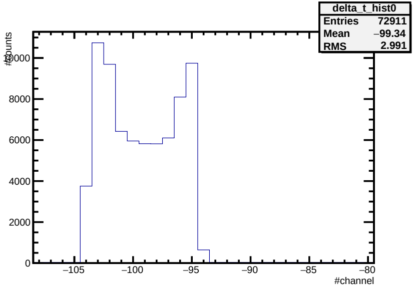
- Final aim: measure tensor and vector analyzing power for deuteron scattering at 75 MeV
- Can the pulse shape be used to distinguish signal from background?
- Time of flight?

Pulse Height



- RMS 2 to 3 channels, 8 to 12 mV
- Double peak structure in 3/8 channels
  - Probably not a significant problem

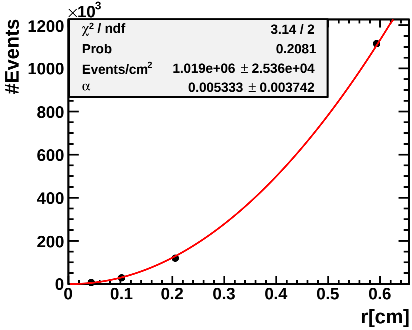
Coincidence Measurement



17 ps per channel

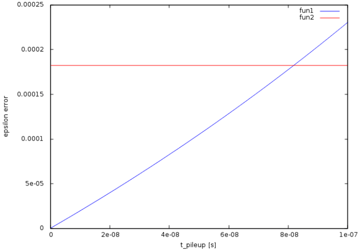
- Counts events
- Both pulse heights within adjustable window
- Time difference within adjustable window
- Start and stop interchangeable
- Resolution close to 50 ps mentioned in GANDALF article

Rate and Collimator Diameter



- Measure rate for different collimator diameters
- Extract incident angle and detector efficiency
- Precision 3 to 6 mrad
- Information on background

Pile-Up Error for Asymmetry



- Statistical error (red), systematic error (blue)
- Measurement over 10000 s at $\sigma_{t_{\text{pile-up}}}/t_{\text{pile-up}} = 0.05$, $f_0 = 800\,\text{kHz}$, $f_{sig} = 200\,\text{kHz}$, $\epsilon = 1/\sqrt{3}$