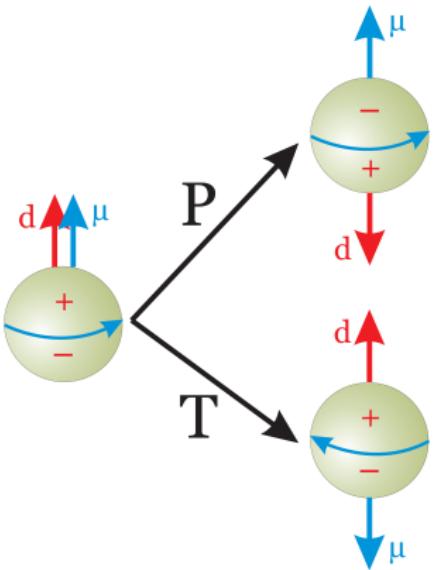


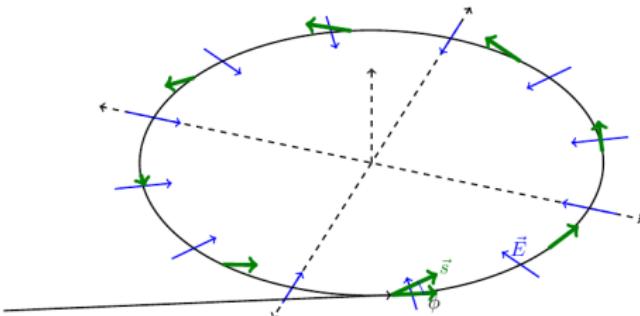
FPGA-Based Upgrade of the Read-Out Electronics for the Low Energy Polarimeter at COSY/Jülich

Electric Dipoles and Fundamental Symmetries



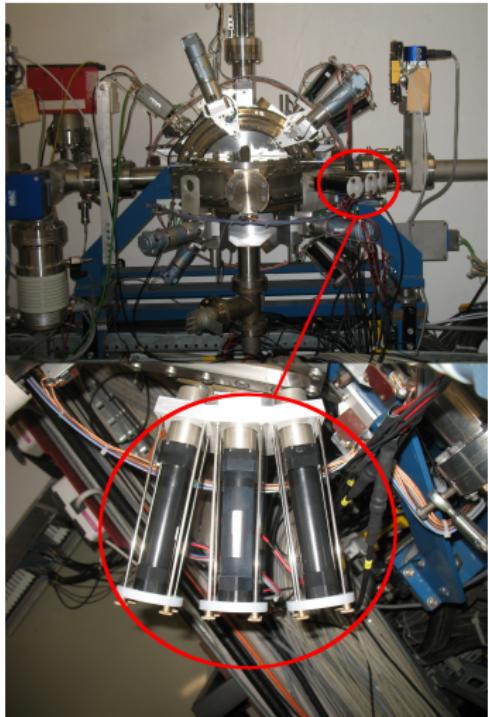
- Nonzero electric dipole moment of elementary particles violates CP-Symmetry
$$H = -\mu \sigma \cdot \mathbf{B} - d \sigma \cdot \mathbf{E}$$
$$\mathcal{T} : H = -\mu \sigma \cdot \mathbf{B} + d \sigma \cdot \mathbf{E}$$
$$\mathcal{P} : H = -\mu \sigma \cdot \mathbf{B} + d \sigma \cdot \mathbf{E}$$
- Standard Model prediction: 10^{-32} to 10^{-31} e cm
- New physics?

Measurement of Charged Hadron EDM at Storage Rings

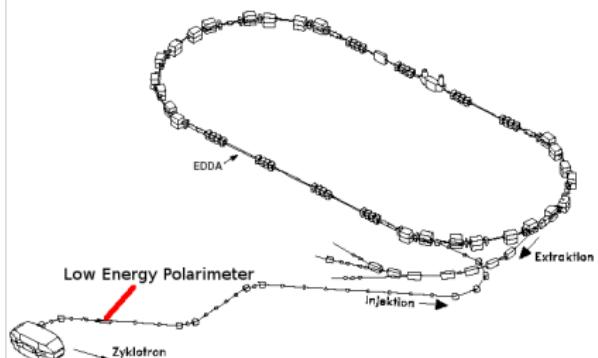


- Various Methods
 - E-Field (Pictured)
 - B-Field
 - Combination
- Measure left-right-asymmetries in cross section
- Precursor experiment at COSY, Forschungszentrum Jülich

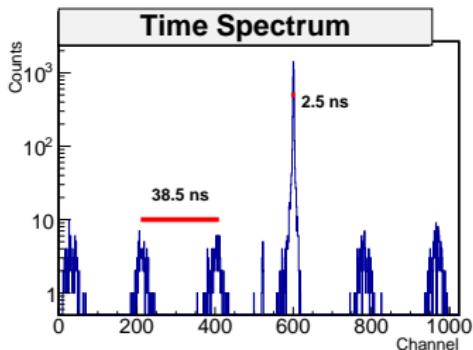
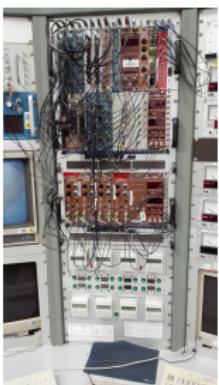
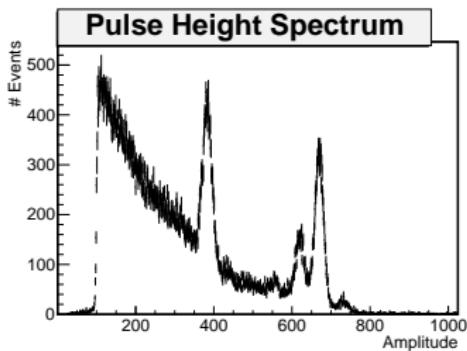
Low Energy Polarimeter



- Located in injection beam line of the Cooler Synchrotron (COSY)
- Particle detection using plastic scintillators
- Kinetic energy 45 MeV for protons, 75 MeV for deuterons



Old Event Selection



- Pulse height spectrum
- Proton peak, two carbon peaks
- Scintillator resolution $\approx 5\%$

- Measure ejectile recoil coincidence
- Smaller peaks at cyclotron frequency from random coincidences

New Electronics



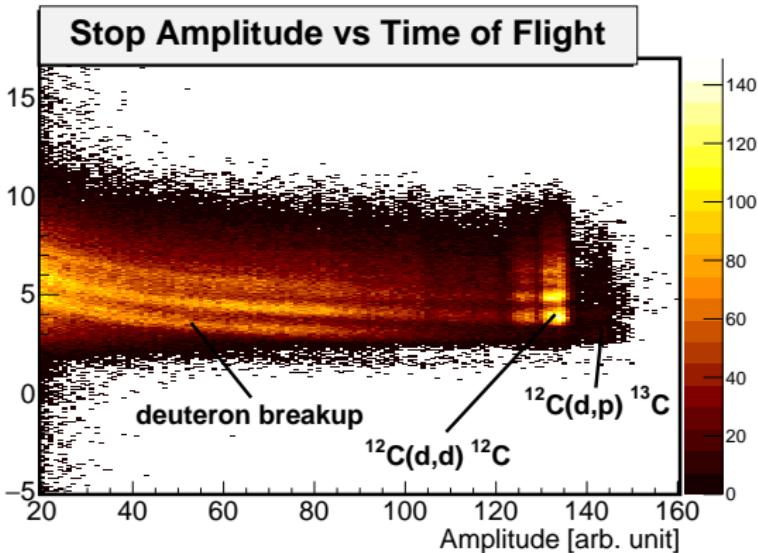
- GANDALF module, developed at University of Freiburg
- 8 ADC channels
- FPGA for readout, sampling rate 1 GHz
- USB for readout 20 MB s^{-1}
- Aim: online polarization measurement, rate $\approx 1 \text{ MHz}$

Firmware

- I Constant fraction discriminator
 - Measures time and amplitude of each pulse
 - New: Measure time of flight using cyclotron HF-signal as reference
- II Counters
 - Count events in adjustable amplitude and time range
- III Transfer to computer
 - Counts of signal events
 - Full event information for a fraction of events

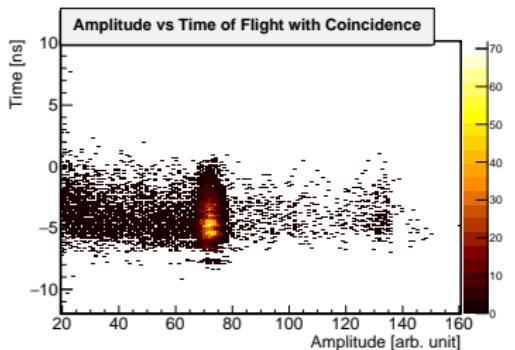
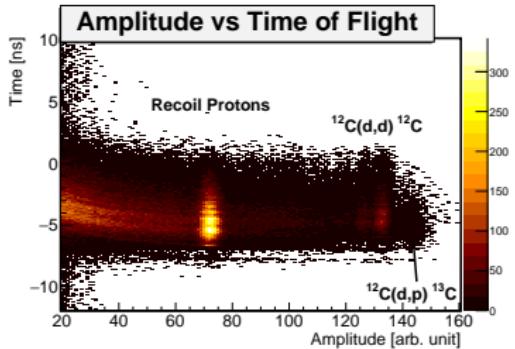
Deuteron Carbon Scattering

Time [ns]



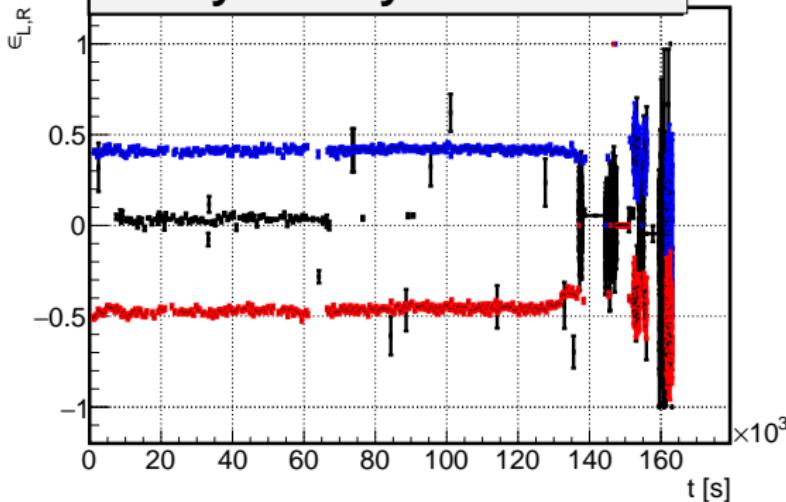
- Deuterons scattered off carbon target, $\theta = 40^\circ$
- Broad multimodal distribution in time, changed during measurement

Deuteron CH₂ Scattering



- Recoil and ejectile can be measured in coincidence
- Coincidence measurements only at a few angles because of fixed detector positions
- Recoil protons measured at 45.9° , deuterons were at 25.9°

Asymmetry over Time



- Asymmetry over time:
$$\frac{N_L - N_R}{N_L + N_R}$$
- **Black:** unpolarized beam, **blue:** positive polarization, **red:** negative polarization

Conclusion and Outlook

- New electronics were installed
- Successful tests with deuteron-carbon and deuteron-proton scattering
- Time of flight measurements implemented
- Aim: Measure tensor polarization in addition to vector polarization