# Experimental Normal Spin Asymmetry across the Nuclear Chart

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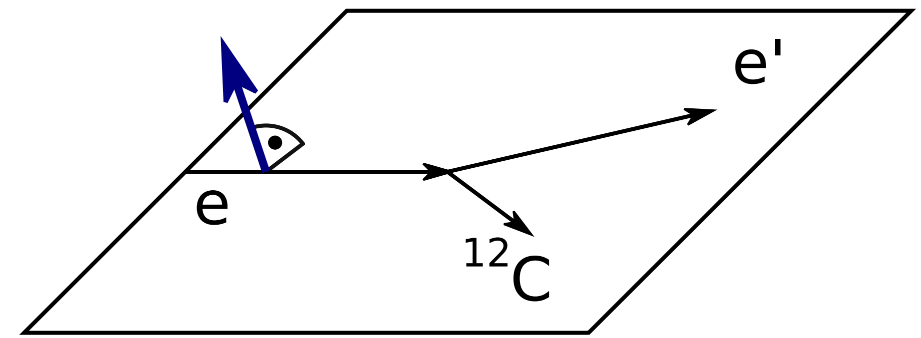
# Transverse Asymmetry in Short

Beam-Normal Single-Spin Asymmetry, Transverse Asymmetry, $A_n$, $A_\perp$, $A_T$

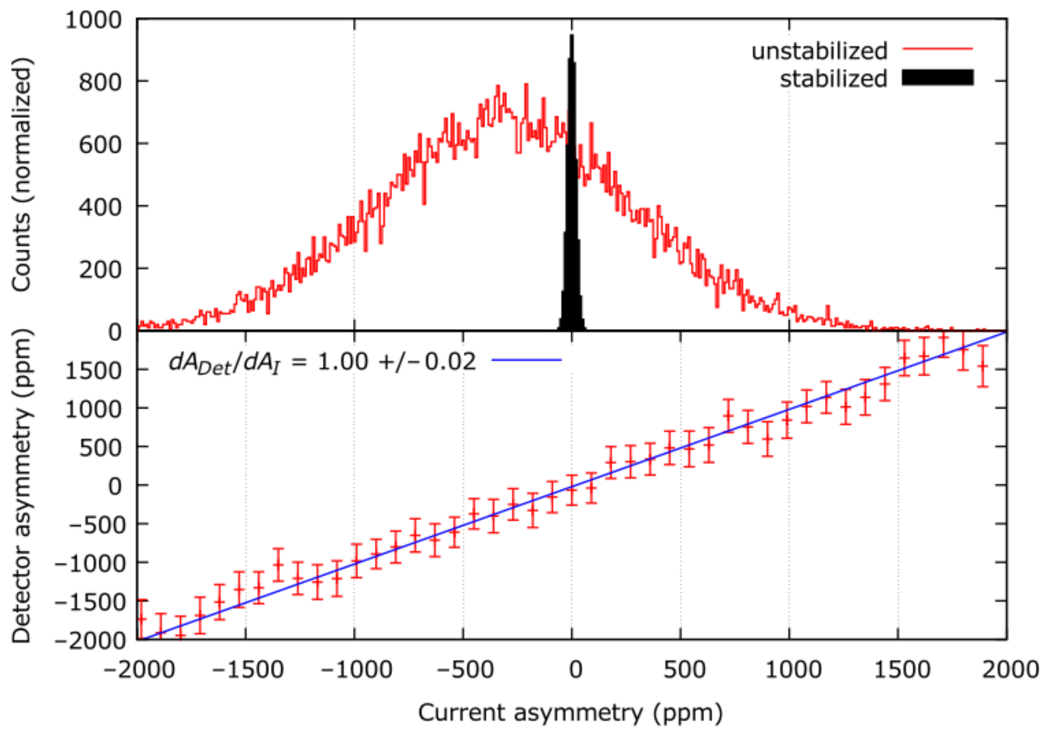



Background in PV Measurements

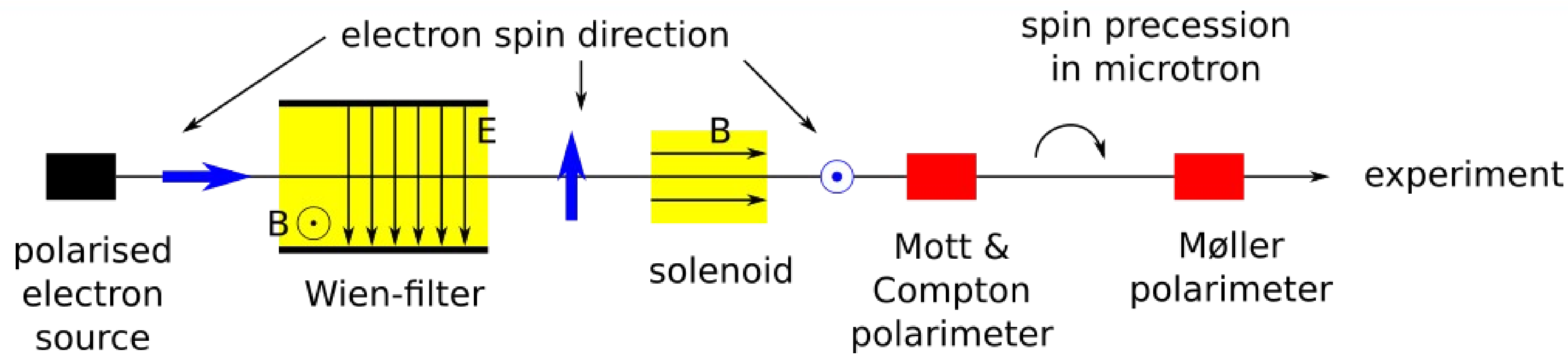
Probe for Multi-Photon-Exchange

# Measurements in Mainz - Accelerator

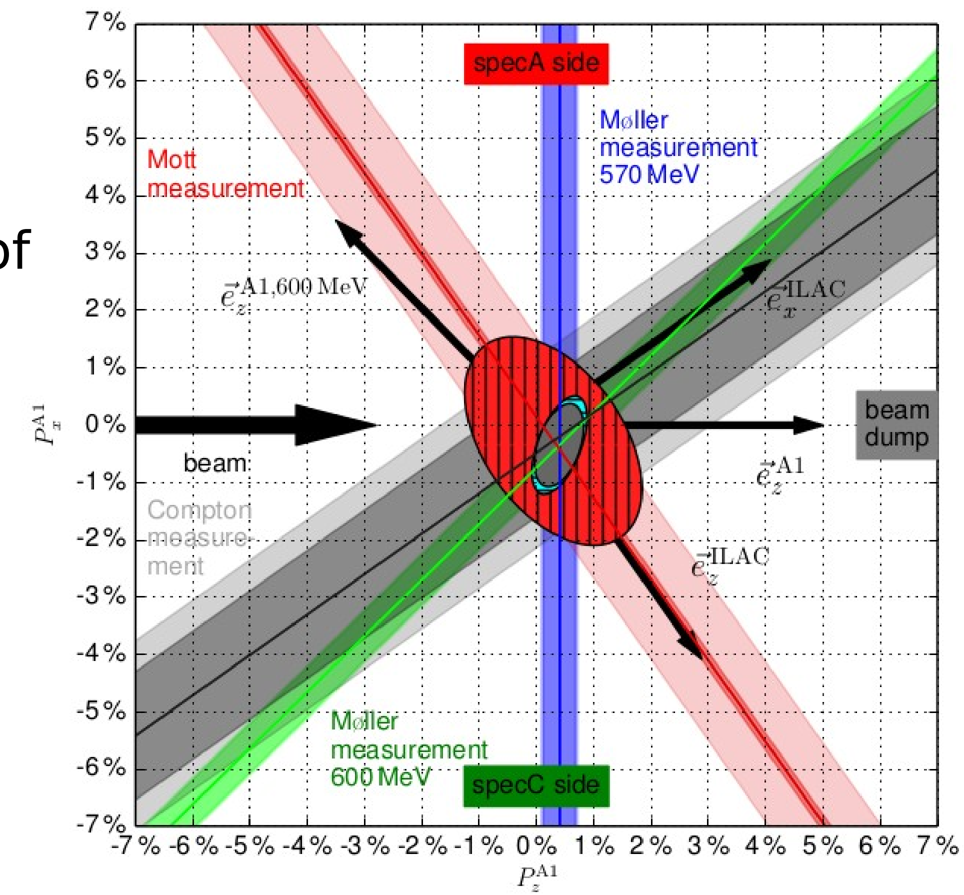
- MAMI: Continuous wave electron beam
  - Beam energy: 185 - 1600 MeV (energy used: 570 MeV)
  - 20 µA polarized beam ~ 80 % polarization
  - Available polarimeters: Møller, Mott, Compton
- Previous A4 Experiment
  - Experience with polarized & highly stabilized beams
  - Active stabilization of:
    - Current
    - Energy
    - Position & angle



# Polarimetry

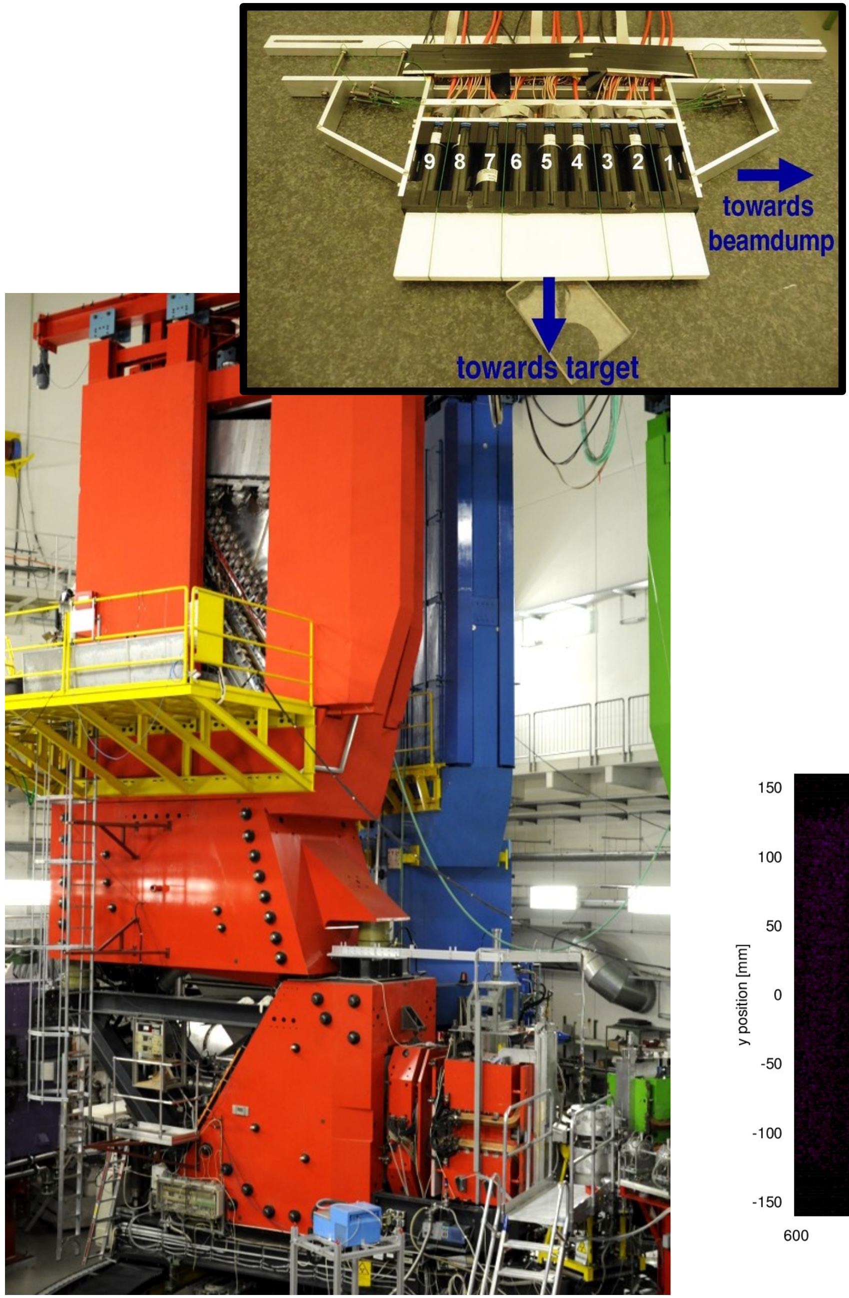



- No direct measurement of vertical polarization
- Wien-filter setting:
  - Maximization and measurement of absolute degree of polarization in longitudinal direction using Mott and Møller
  - Maximization of horizontal transverse polarization at Mott polarimeter
- Solenoid setting & fine tuning
  - Minimization of horizontal components in all polarimeters
  - Variation of spin precession by changing beam Energy

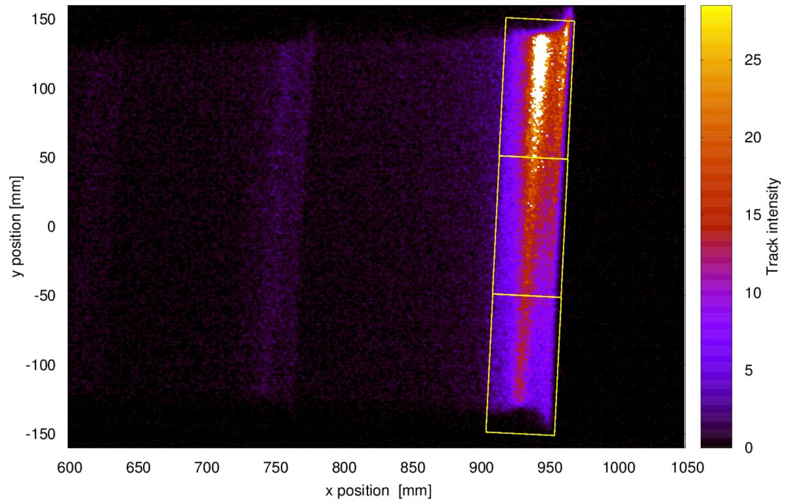


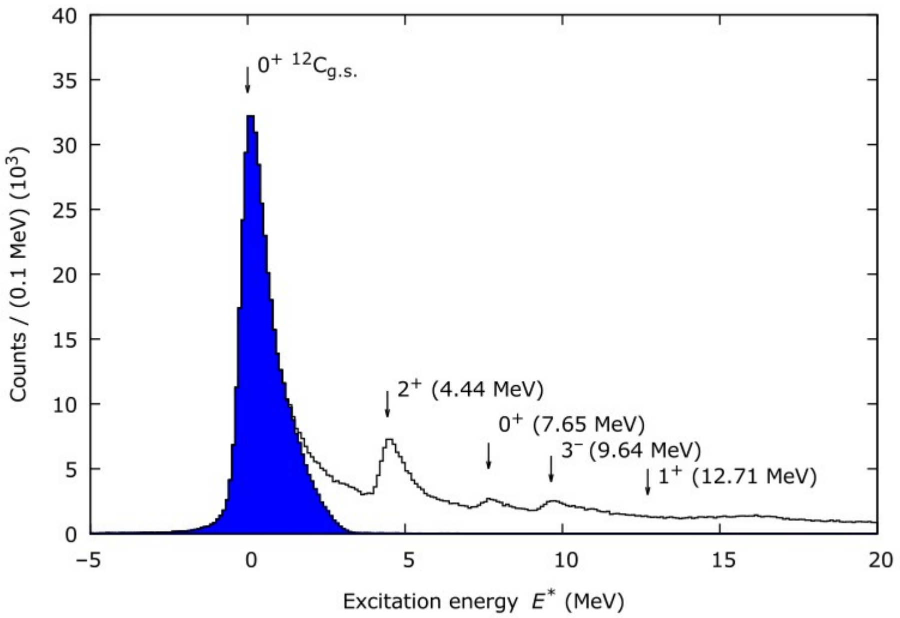

https://doi.org/10.1016/j.nima.2017.01.024

# Spectrometer Facility




- High resolution magnetic spectrometers
- Fused silica Čerenkov detectors
  - Selection of elastic Events
- A4 luminosity monitor electronics
  - Integration of PMT current
  - Control of beam polarity



# Systematic Uncertainties

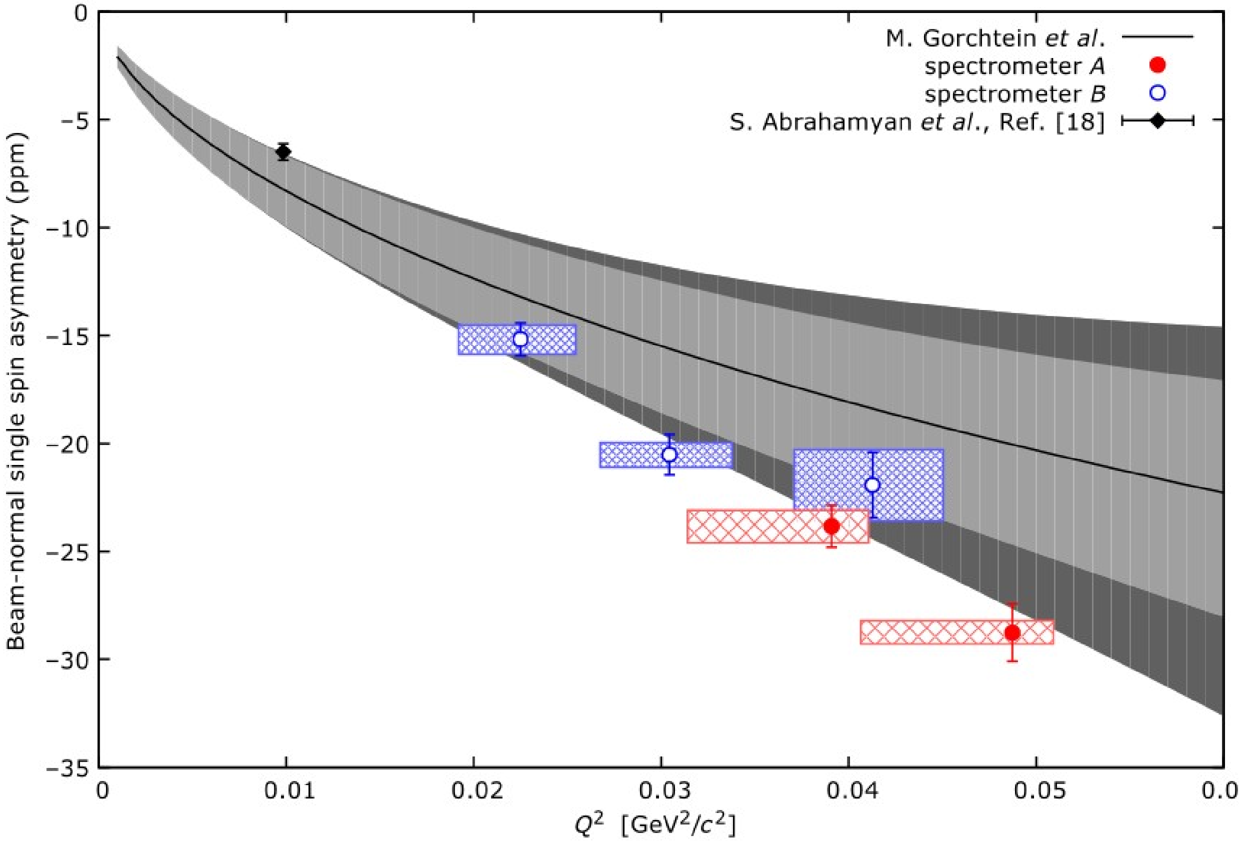
| Source of Error | Typical Value [%] | Typical Value [ppb] | Maximum Value [ppb] |
|---|---|---|---|
| Beam polarization | 1.862 | 384 | 523 |
| $\partial\sigma/\partial x$ | 0.023 | 5 | 23 |
| $\partial\sigma/\partial y$ | 0.023 | 5 | 136 |
| $\partial\sigma/\partial x'$ | 0.013 | 3 | 120 |
| $\partial\sigma/\partial y'$ | 0.064 | 14 | 343 |
| $\partial\sigma/\partial E$ | 0.044 | 9 | 321 |
| PMT gain | 0.288 | 62 | 1100 |
| Current asymmetry | 0.050 | 11 | 13 |
| Gate length asymmetry | 0.044 | 8 | 13 |
| Inversion | 0.395 | 92 | 500 |
| Beam profile | 0 *) | 0 *) | 28 |
| Current dips | 0.111 | 17 | 31 |
| Signal tails | 0.751 | 149 | 405 |

*) Typically no error contribution

# Previous Measurements

Q²-dependence

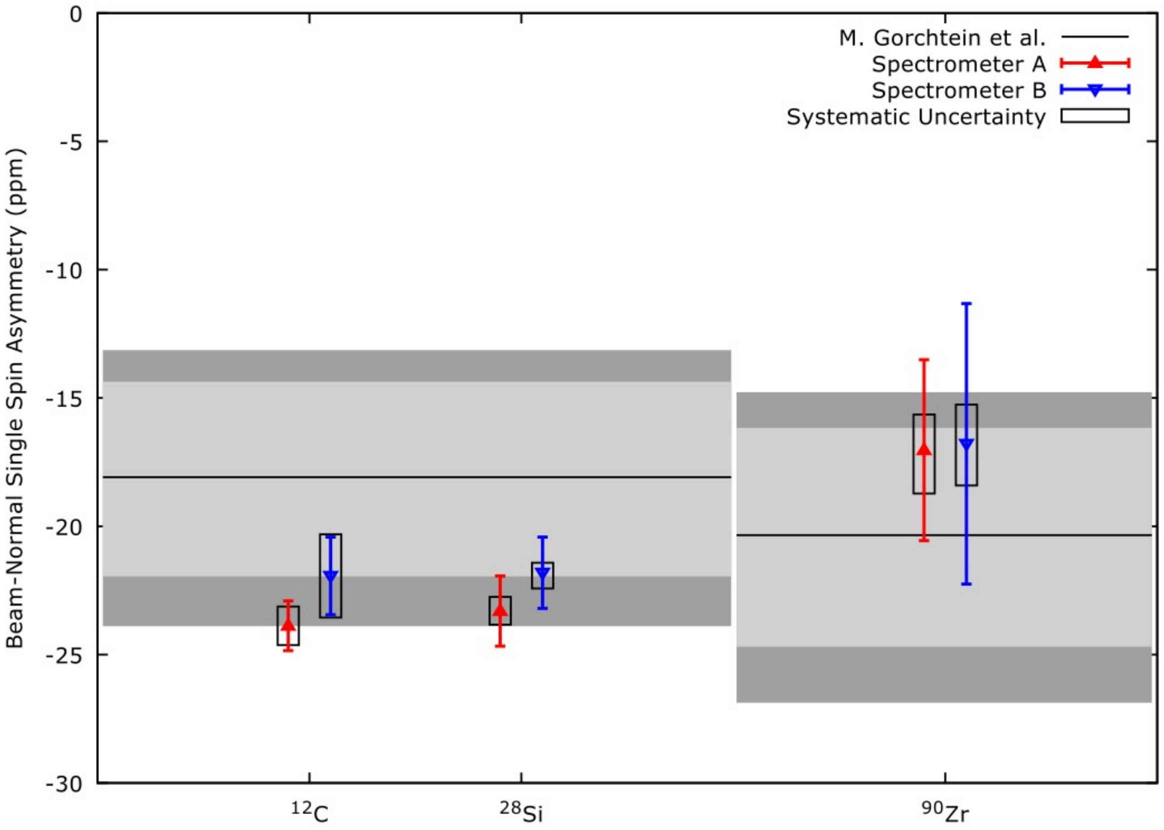
$^{12}C$ @ 570 MeV




https://doi.org/10.1103/PhysRevLett.121.022503

A - dependence

$^{12}C$, $^{28}Si$, $^{90}Zr$ @ E = 570 MeV, $Q^2 = 0.04$ GeV²/c²




https://doi.org/10.1016/j.physletb.2020.135664

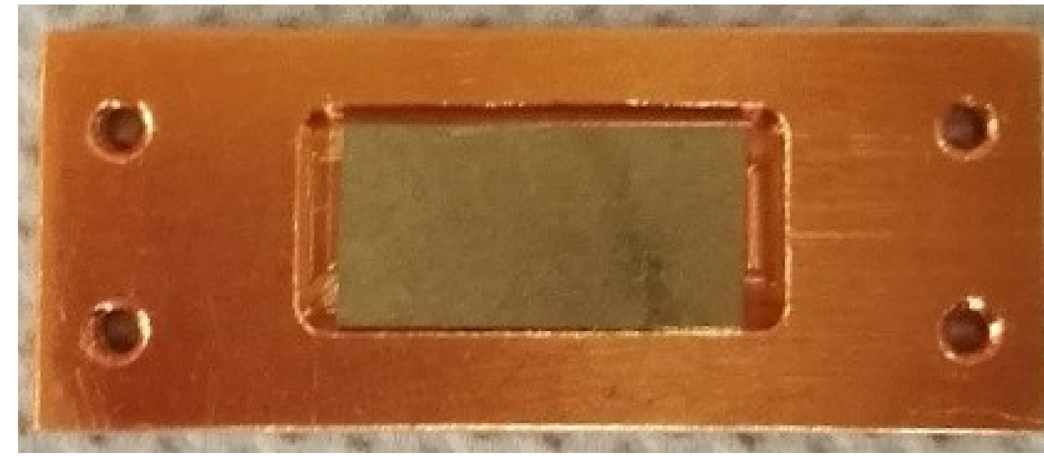
# Our Experiences with $^{90}$Zr

## $^{90}$Zr target

- High background radiation
  - → Leaks in vacuum seals
- Brittle oxide
  - → Contamination of scattering chamber
- Direct Production of $^{88}$Y ($T_{1/2}$=107d)

  $^{90}Zr \rightarrow {}^{88}Y + n + p$
  - → 17 mSv/h residual radiation after several weeks of decaying

Before



After

| | | | | | |
|---|---|---|---|---|---|
| 88Nb 14.55 M ε: 100.00% | 89Nb 2.03 H ε: 100.00% | 90Nb 14.60 H ε: 100.00% | 91Nb 6.8E+2 Y ε: 100.00% | 92Nb 3.47E+7 Y ε: 100.00% β- < 0.05% | 93Nb STABLE 100% |
| 87Zr 1.68 H ε: 100.00% | 88Zr 83.4 D ε: 100.00% | 89Zr 78.41 H ε: 100.00% | 90Zr STABLE 51.45% | 91Zr STABLE 11.22% | 92Zr STABLE 17.15% |
| 86Y 14.74 H ε: 100.00% | 87Y 79.8 H ε: 100.00% | 88Y 106.626 D ε: 100.00% | 89Y STABLE 100% | 90Y 64.053 H β-: 100.00% | 91Y 58.51 D β-: 100.00% |
| 85Sr 64.84 D ε: 100.00% | 86Sr STABLE 9.86% | 87Sr STABLE 7.00% | 88Sr STABLE 82.58% | 89Sr 50.57 D β-: 100.00% | 90Sr 28.90 Y β-: 100.00% |

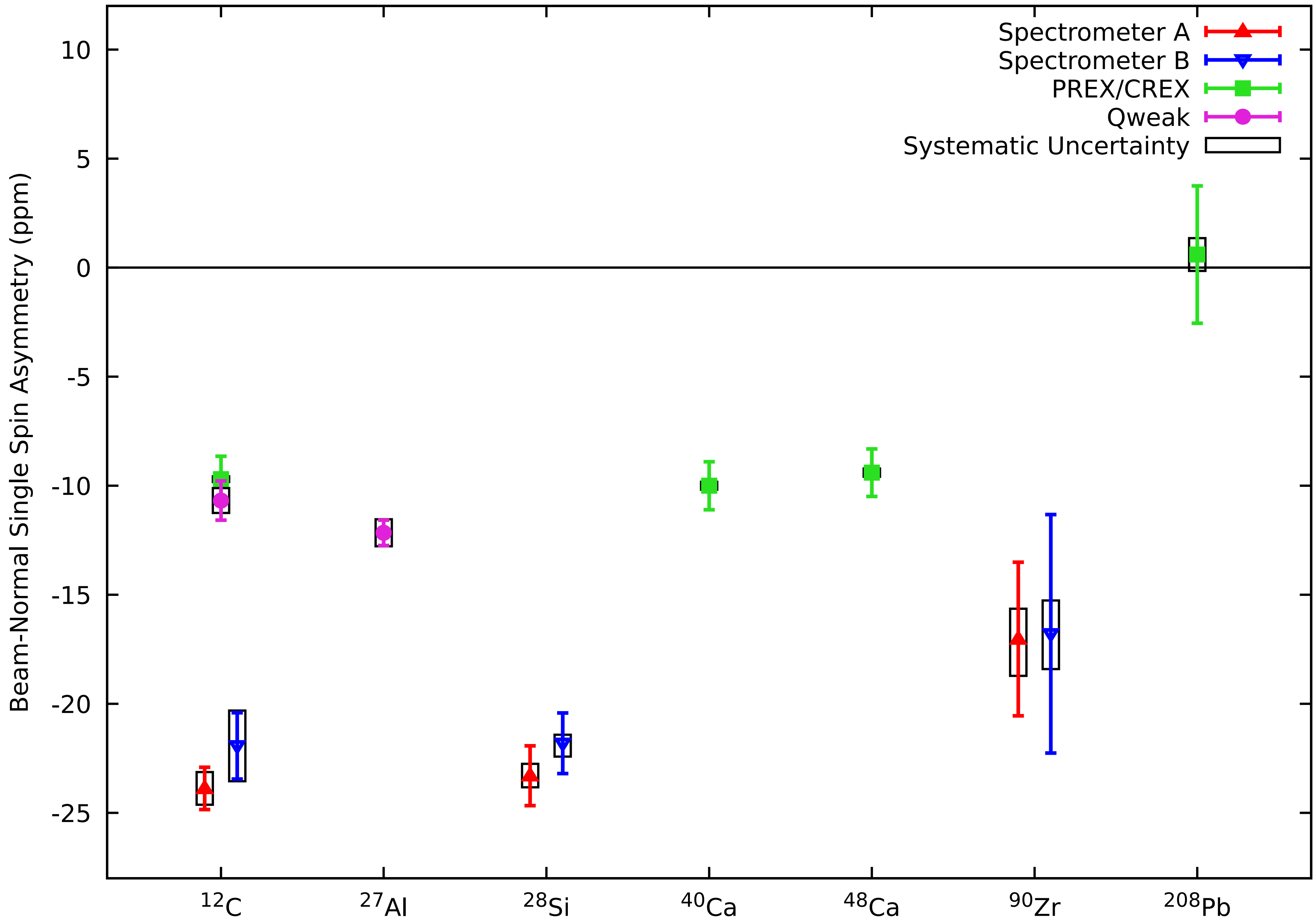
# Nickel 58 as Target

- $^{58}$Ni
  - Brittle oxide (probably)
  - Direct production possible:
    - $^{58}\text{Ni} \rightarrow {}^{56}\text{Co} + n + p$ $(T_{1/2}=77\text{d})$
    - $^{58}\text{Ni} \rightarrow {}^{57}\text{Co} + p$ $(T_{1/2}=272\text{d})$
    - $^{58}\text{Ni} + n \rightarrow {}^{58}\text{Co} + p$ $(T_{1/2}=71\text{d})$
- Improvements in vacuum seals
  - Radiation resistant metal seals
  - Require more compacting pressure
  - New scattering chamber constructed

Nickel oxide

| | | | | | |
|---|---|---|---|---|---|
| $^{56}$Cu 94 MS ε | $^{57}$Cu 196.3 MS ε: 100.00% | $^{58}$Cu 3.204 S ε: 100.00% | $^{59}$Cu 81.5 S ε: 100.00% | $^{60}$Cu 23.7 M ε: 100.00% | $^{61}$Cu 3.333 H ε: 100.00% |
| $^{55}$Ni 202 MS ε: 100.00% | $^{56}$Ni 6.075 D ε: 100.00% | $^{57}$Ni 35.60 H ε: 100.00% | $^{58}$Ni STABLE 68.077% | $^{59}$Ni 7.6E+4 Y ε: 100.00% | $^{60}$Ni STABLE 26.223% |
| $^{54}$Co 193.28 MS ε: 100.00% | $^{55}$Co 17.53 H ε: 100.00% | $^{56}$Co 77.233 D ε: 100.00% | $^{57}$Co 271.74 D ε: 100.00% | $^{58}$Co 70.86 D ε: 100.00% | $^{59}$Co STABLE 100% |
| $^{53}$Fe 8.51 M ε: 100.00% | $^{54}$Fe STABLE 5.845% | $^{55}$Fe 2.737 Y ε: 100.00% | $^{56}$Fe STABLE 91.754% | $^{57}$Fe STABLE 2.119% | $^{58}$Fe STABLE 0.282% |

# Comparison to other Experiments



# Comparison to other Experiments

| | MAMI | PREX / CREX | QWeak |
|---|---|---|---|
| Beam Energy | 570 MeV | 950 – 2180 MeV | 1158 MeV |
| Scattering Angle | 15 – 30 ° | 4 – 5 ° | 7.7 ° |
| $Q^2$ | 0.02 – 0.05 $GeV^2/c^2$ | 0.006 – 0.033 $GeV^2/c^2$ | 0.02437 $GeV^2/c^2$ |
| Targets | $^{12}C$, $^{28}Si$, $^{90}Zr$ | $^{12}C$, $^{40}Ca$, $^{48}Ca$, $^{208}Pb$ | $^{12}C$, $^{27}Al$ |

# New DAQ - Features to Maintain

- Fused silica Čerenkov detectors
- Integration window synchronized to power grid frequency
- Polarity patterns:
  - + - - + or - + + -
  - Pseudo-random sequence
- Monitoring of:
  - PIMO (current)
  - ENMO (energy)
  - XYMO (position)
- Inversion of general sign ~ once per day

# Improved DAQ Approach

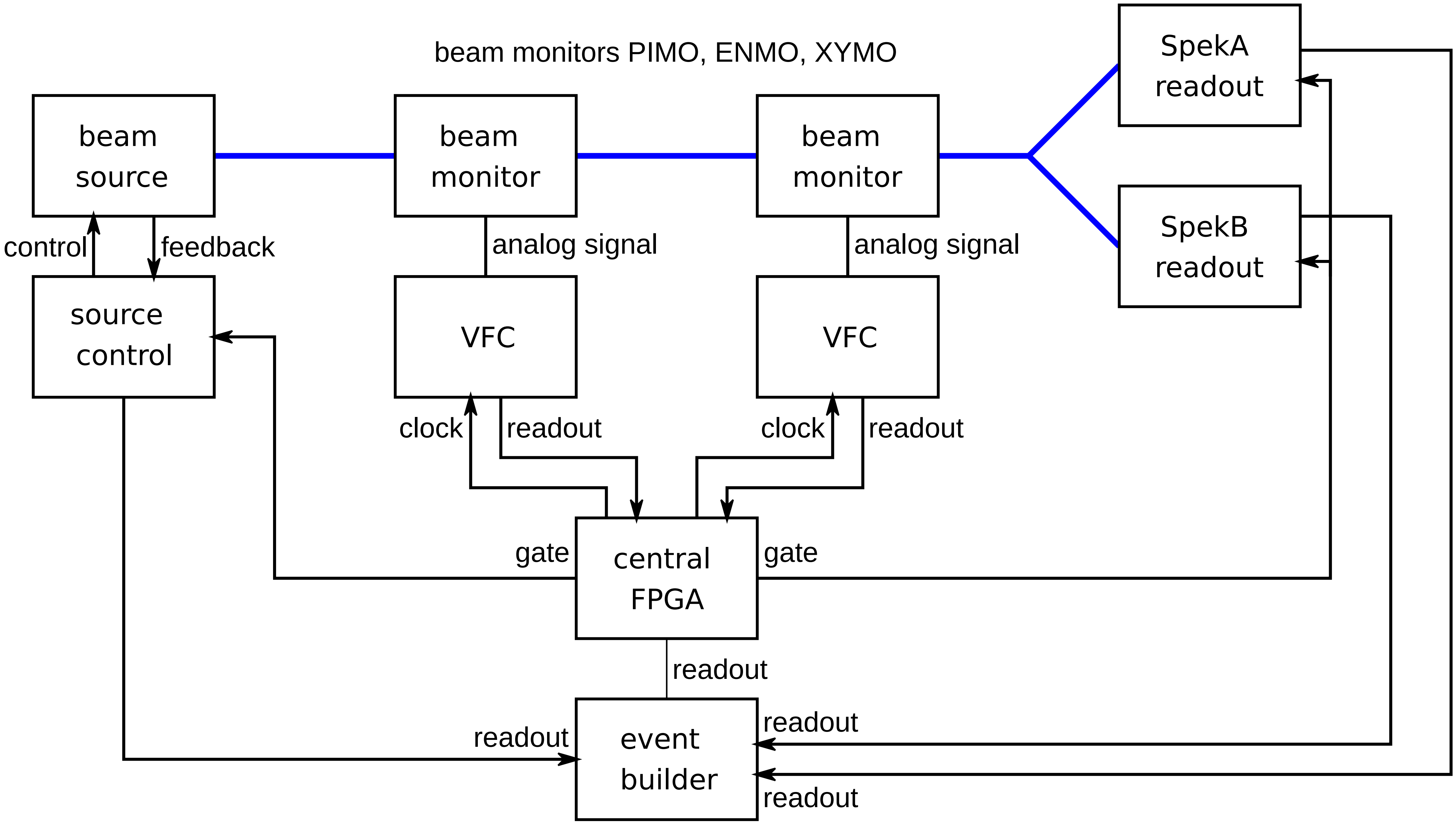
## Weak points of previous set-up

- Limited resolution at low counting rates
- Polarity bit generation in close proximity to analog integrators
- Variation of integration window length within event

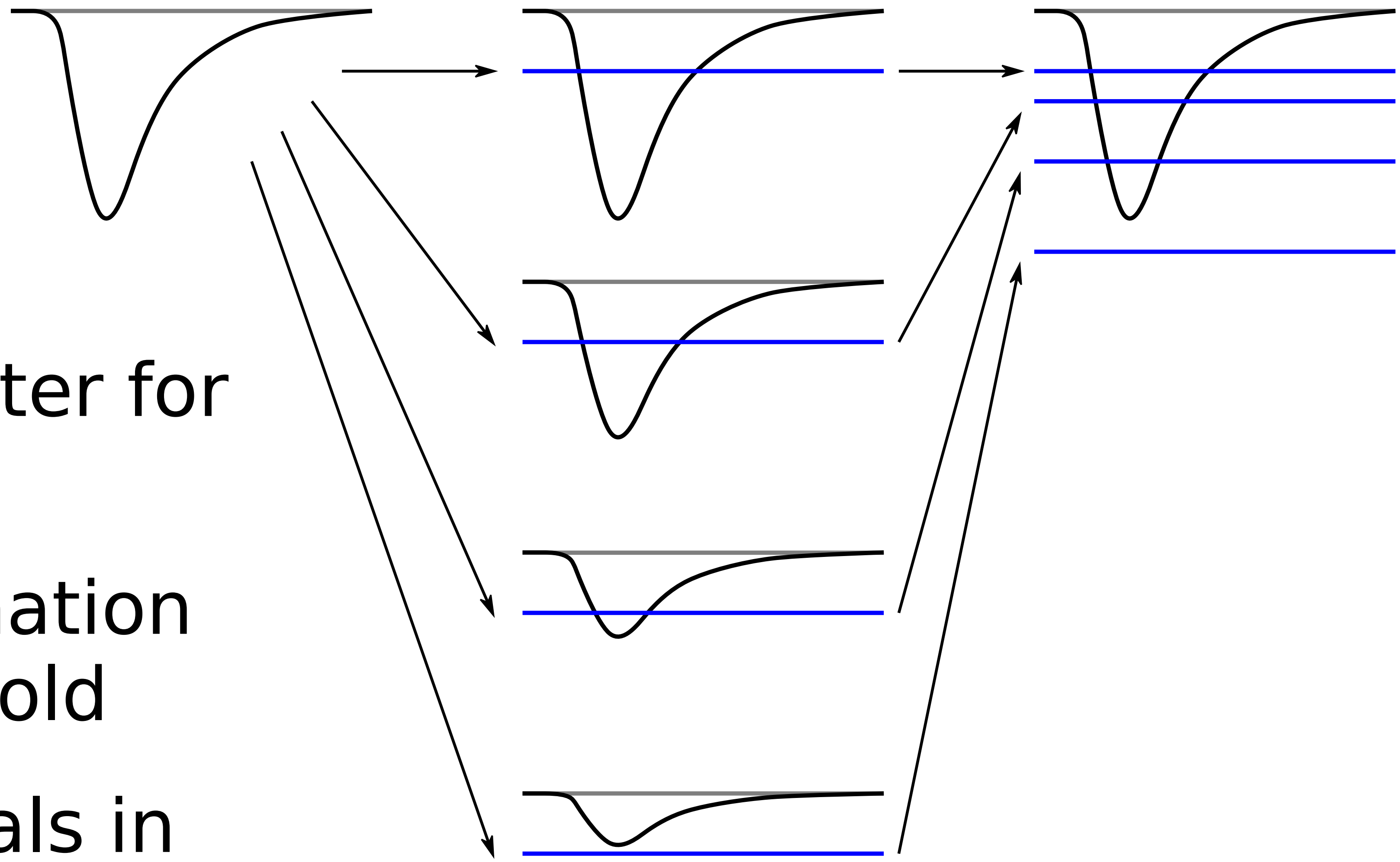
## Improvements in new set-up

- Counting of PMT Pulses
- Voltage Frequency converters for beam monitors
- Pseudo-random generation of sets of patterns with identical amount of + - - + & - + + -
- Equal length of “integration gates” in one quadruplett

# DAQ Scheme (very simplified)



# PMT Readout



- Asymmetric splitter for analog signal
- Parallel discrimination with fixed threshold
- Counting of signals in integration gate using FPGA

# Current Status & Future Plans

- Status:
  - Electronics for beam diagnostics in final development phase
  - PMT readout under investigation
  - Beam polarization control electronics under development
- Planned experiments
  - July 2022: Parasitic tests of beam diagnostics
  - Late 2022: Commissioning run for new electronics
  - 2023: Measurement of $A_n$ on $^{208}$Pb
  - Later:
    - Measurement of $A_{PV}$ on $^{208}$Pb
    - Other targets?

# Thank you
# for your attention!