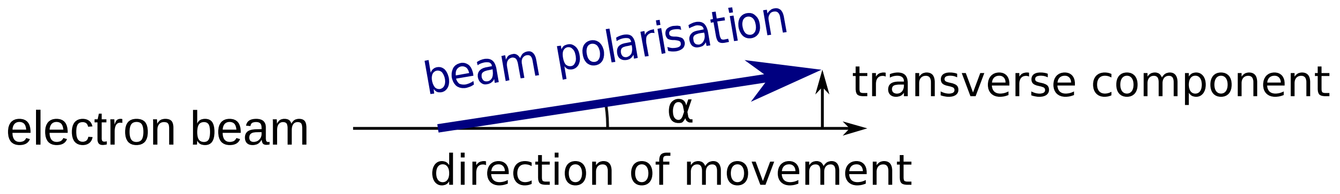
Measurement of the Transverse Asymmetry of ^{12}C

Beam Normal Asymmetry

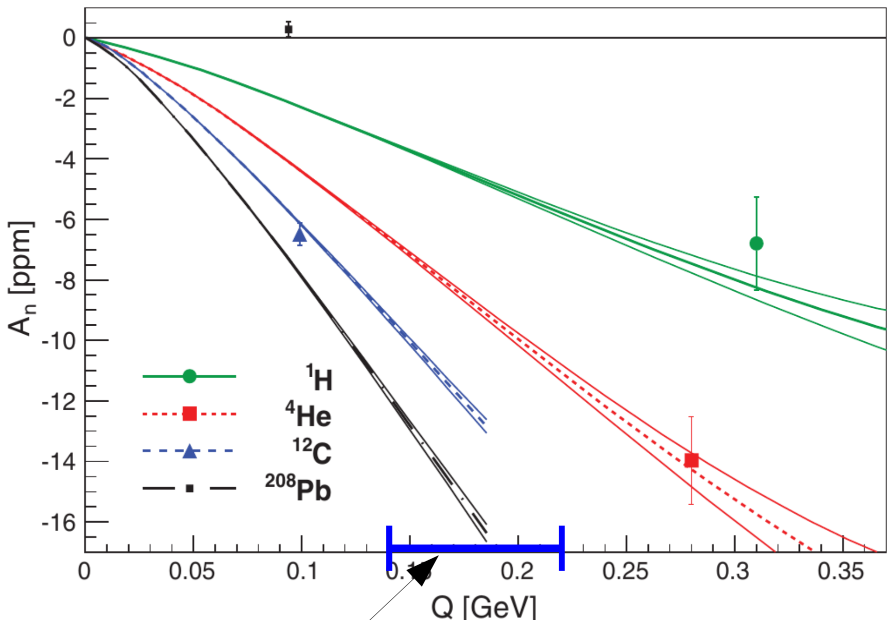
- Beam normal (single spin) asymmetry:
  - Count rate asymmetry in elastic e^- scattering for transverse polarisation (normal to scattering plane)
  - No Parity Violation effect, but:
  - Helicity-correlated background contribution in PV experiments
    - Caused by transversal polarisation component
    - Necessary to measure for all targets used in PV experiment



  - Interference Term amongst one- and multi-photon exchange

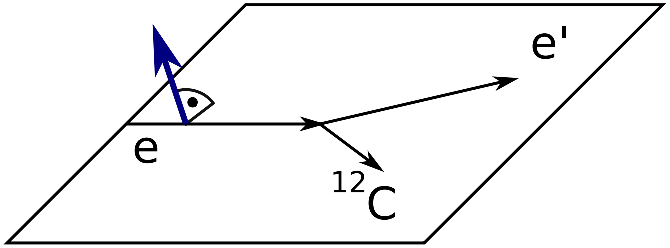
Mainz Measurement

Measurement at PREX



kinematic range of the measurement in Mainz

- Measurement in Mainz
  - Target: ^{12}C
  - E_{Beam} = 570 MeV
  - Scattering angle = 15° - 26°
  - $Q^2 = 0.02 – 0.05\ GeV^2/c^2$
  - ($Q = 0.14 – 0.22$ GeV/c)



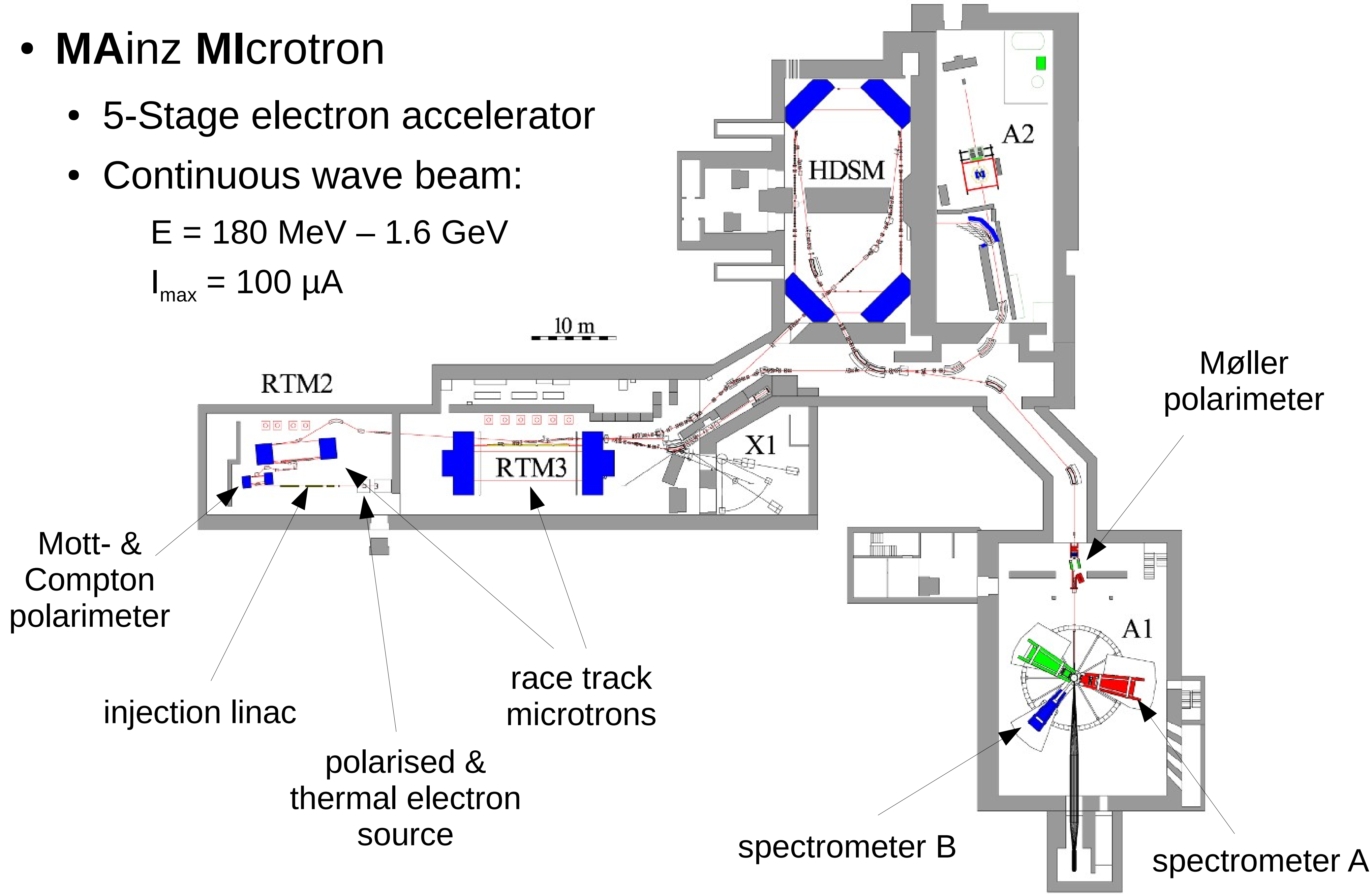
- Requirements:
  - High quality transversely polarised electron beam of known polarisation
  - High rate capable detector system

MAMI Accelerator

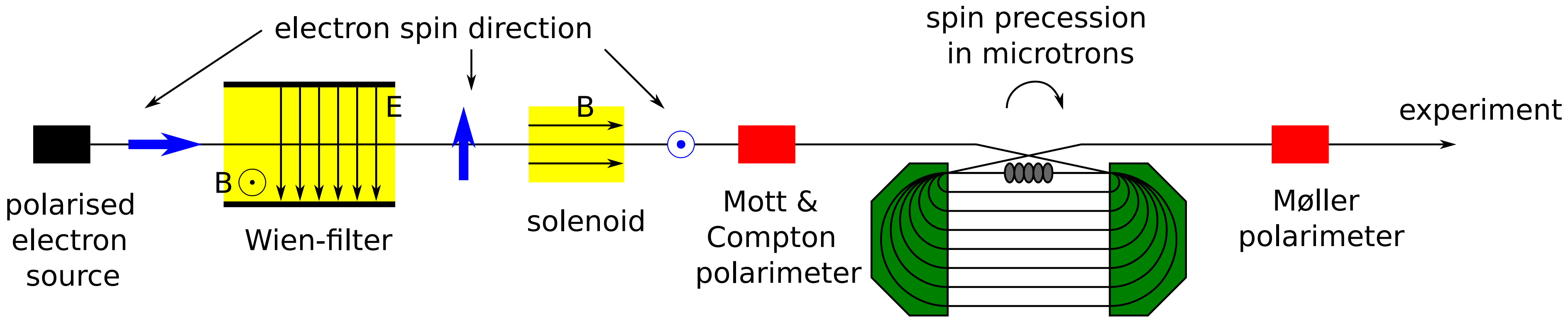
- **MA**inz **MI**crotron
  - 5-Stage electron accelerator
  - Continuous wave beam:

    E = 180 MeV – 1.6 GeV

    I_{max} = 100 µA



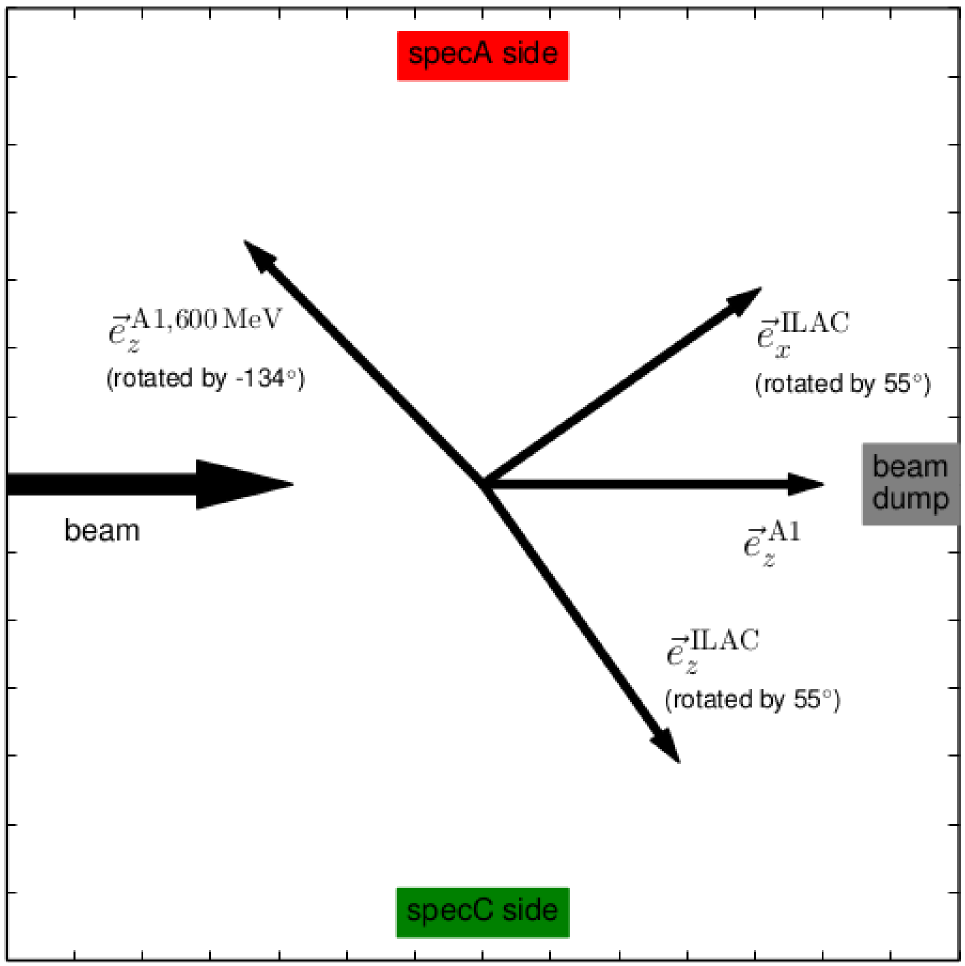
Polarised Electron Beam



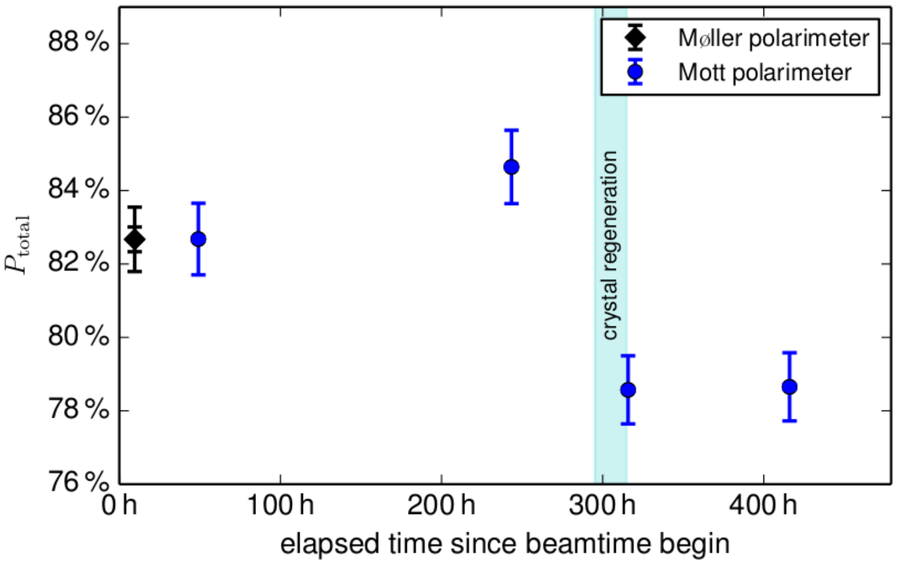
- No polarimeter for direct vertical transversal polarisation measurement available
  - Mott: horizontal transversal @ source
  - Compton: longitudinal @ source
  - Møller: longitudinal @ target
- Polarimetry:
  - Maximise and measure longitudinal polarisation at target
  - Maximise transversal horizontal component at source
  - Minimise longitudinal and horizontal component at source and target

Absolute Degree of Polarisation

Spin Rotation

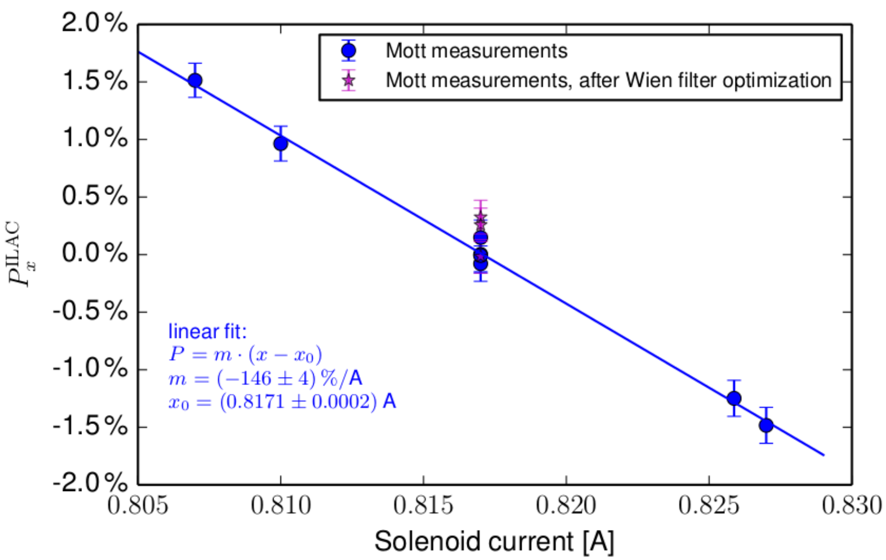


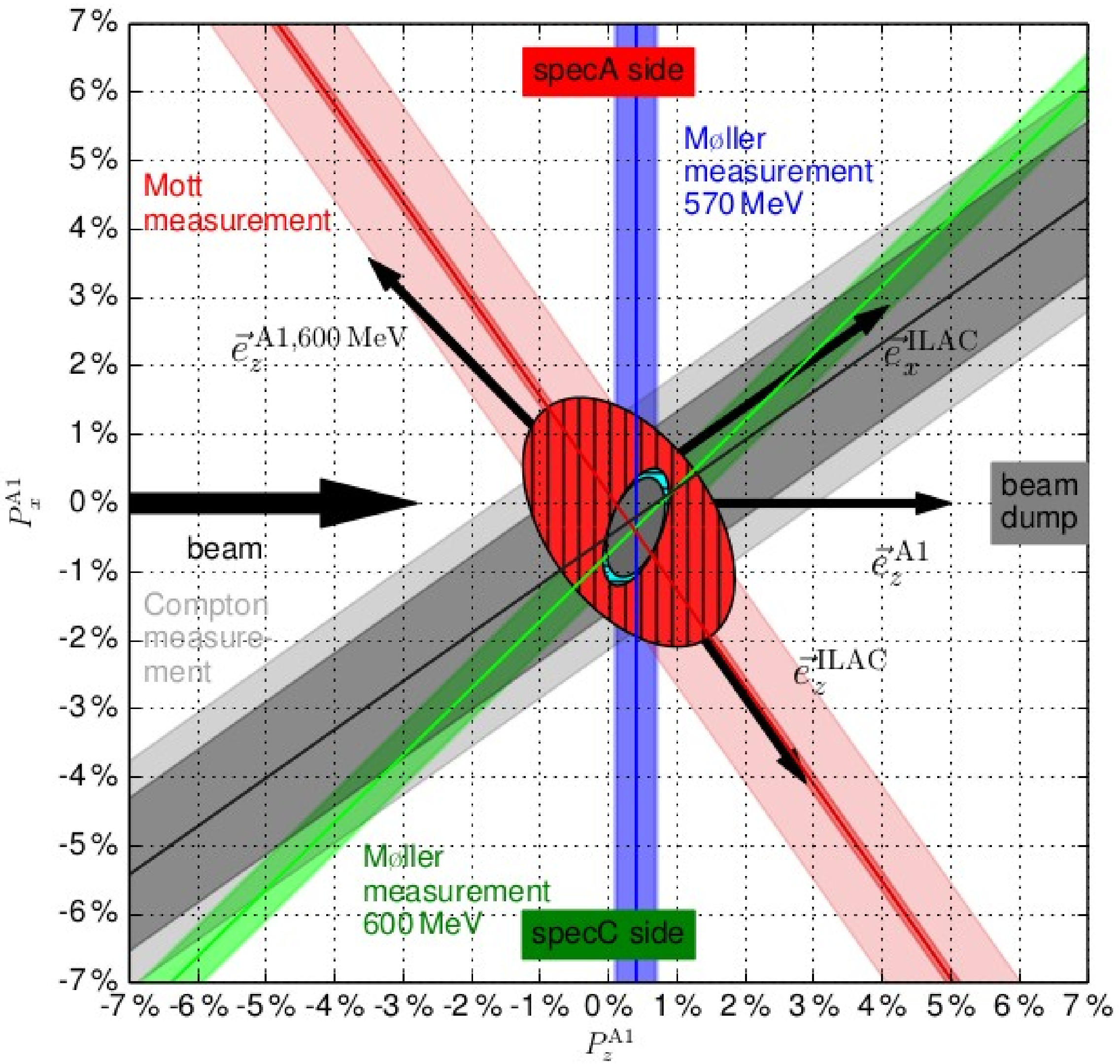
- Spin Rotation due to anomalous magnetic Moment
  - 55° at 570 MeV
  - -134° at 600 MeV
- Premise: Spin rotation does not change degree of polarisation
  - Horizontal depolarisation ~ 10^{-4}
- Measurement of total polarisation:
  - Wien-filter angle scan
  - Mott & Møller polarimeter



Vertical Transverse Polarisation

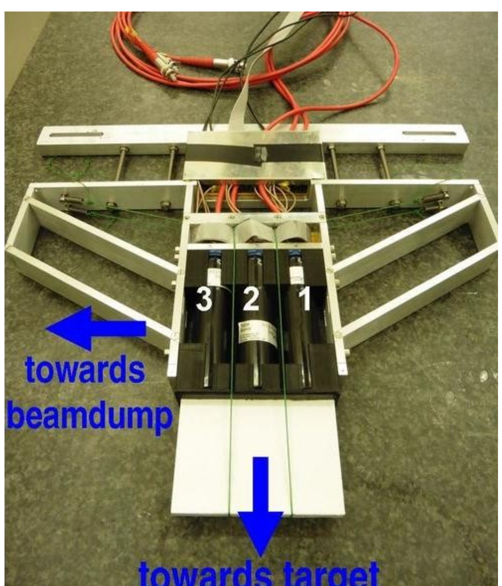
- Maximising horizontal transverse component at source
  - Wien-filter scan & Mott measurement
- Minimising remaining horizontal components:
  - Solenoid current scan
  - Mott, Compton & Møller measurement
  - Møller measurement at different energy
  - → Combination of results

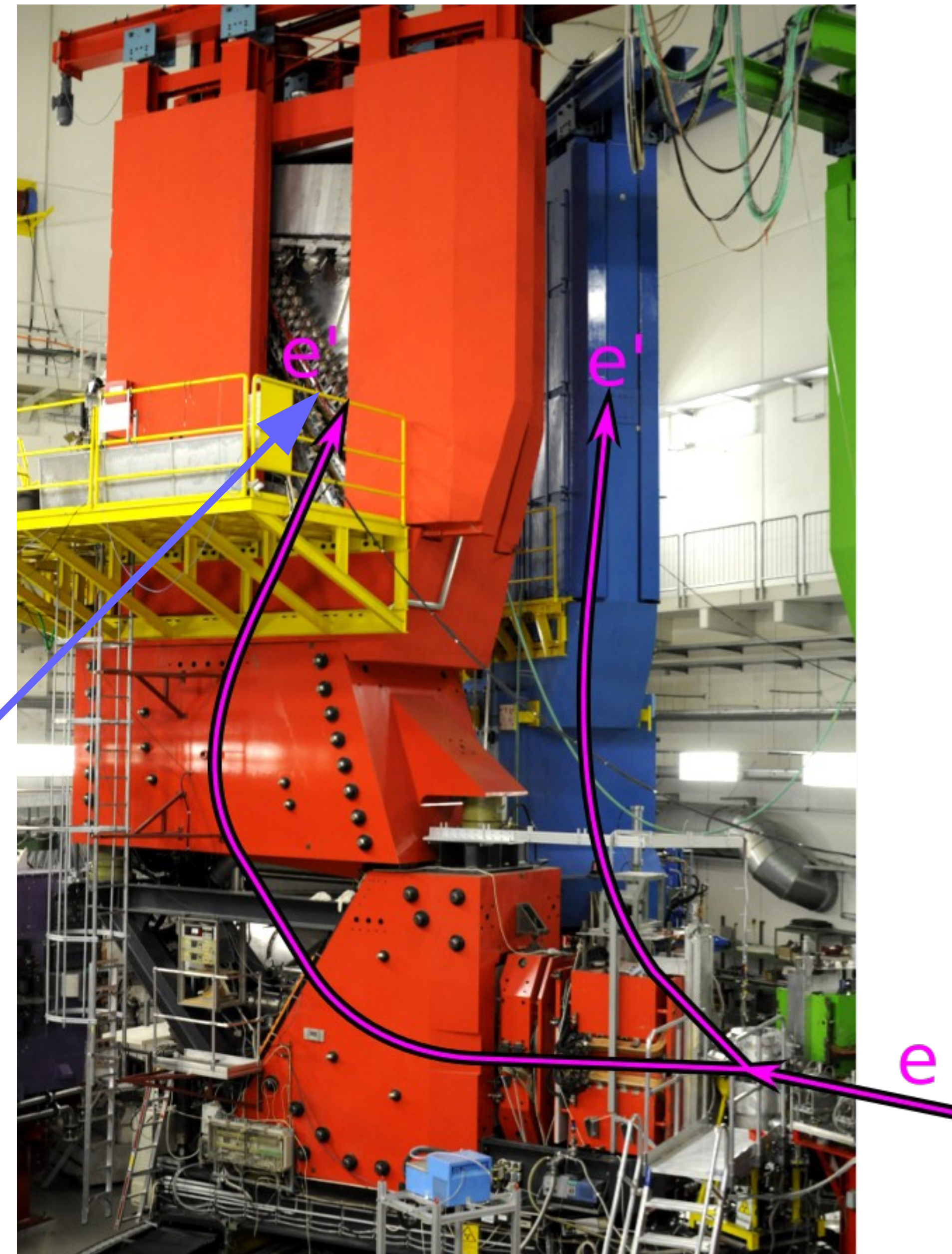




Experimental Set-up

- Electron Beam:
  - E = 570 MeV
  - I = 20 µA
- Target:
  - 10 mm ^{12}C
- Magnetic Spectrometers:
  - Define angular acceptance (angles 15.11° - 25.9°)
  - Select elastic events
- Detectors:
  - Quartz-Cherenkov radiator
  - PMTs with reduced amplification → High rate capability

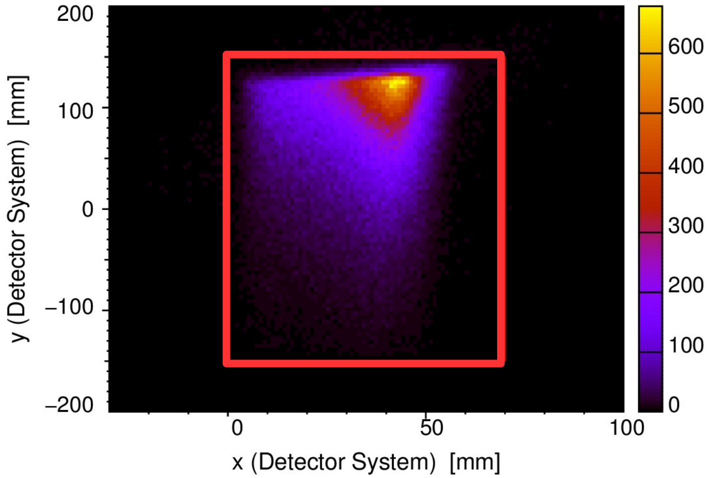


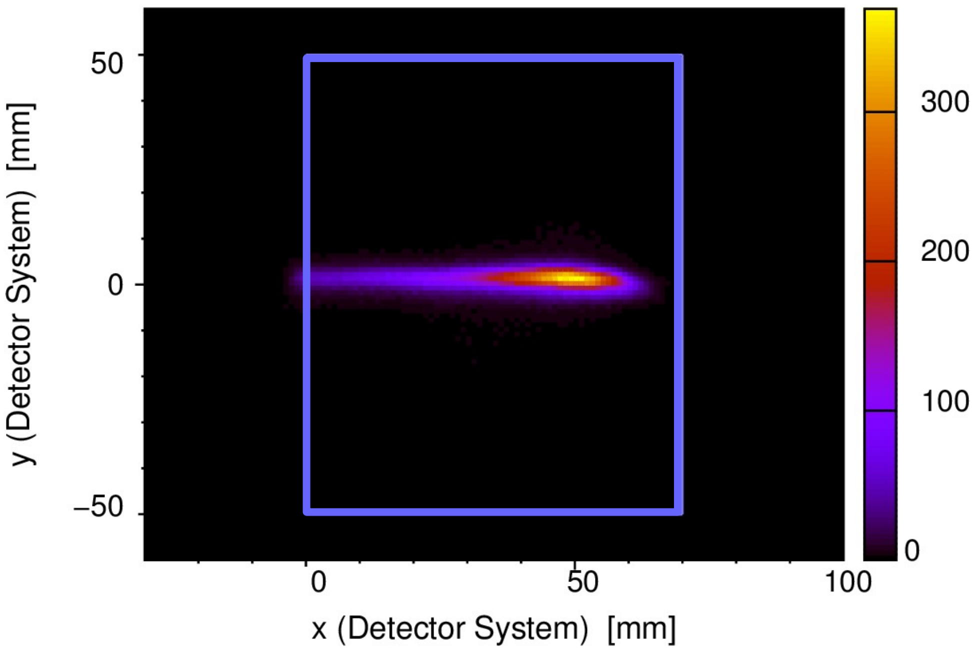


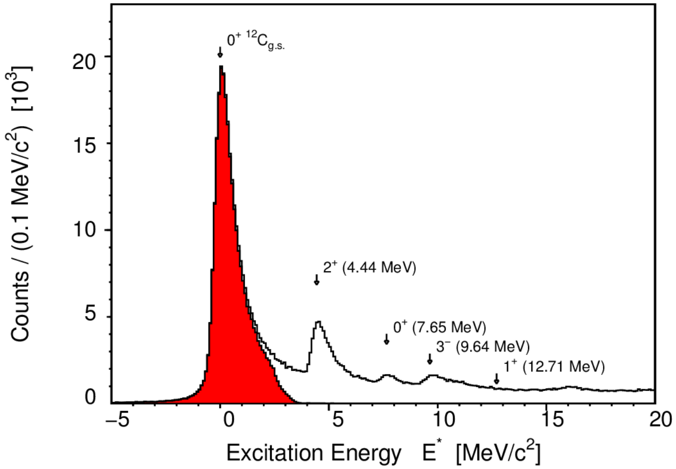
Benefits of the Spectrometers

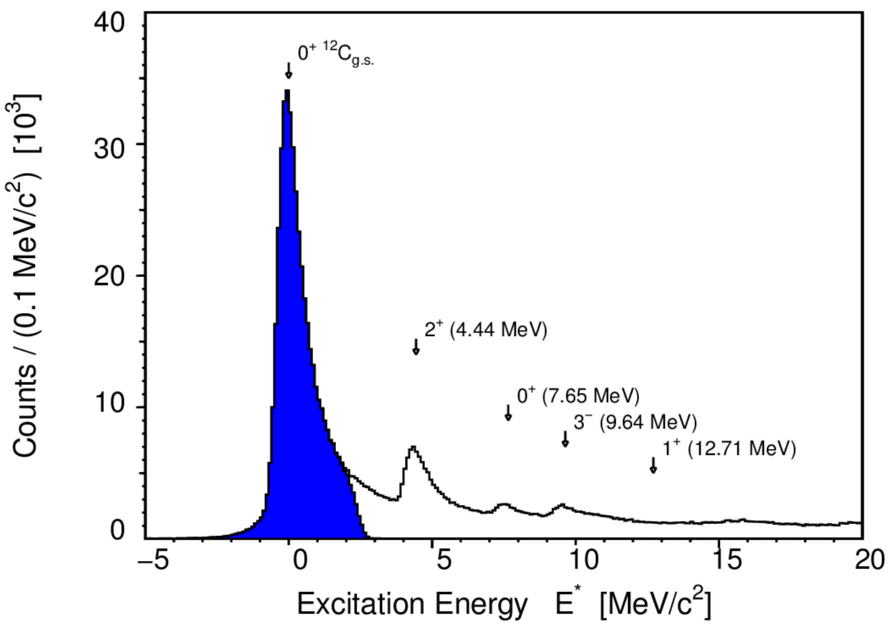
Low rate particle tracking mode:

Precise positioning of detectors & magnetic field setting
→ Only elastic line in detector acceptance









Measurement Principle

- Data Acquisition:
  - Usage of established electronics from A4 PV experiment
  - 50 Hz spin flip at source
    - Synchronised with Power grid frequency
      → Intrinsic suppression of ground noise
  - Integrating detector signals over 20 ms gates
  - Acquisition of beam parameters in the same way
    → Current, energy, position, angle
  - Various stages of absolute sign inversion on different time scales
    - Identification & elimination of most sources of false asymmetries

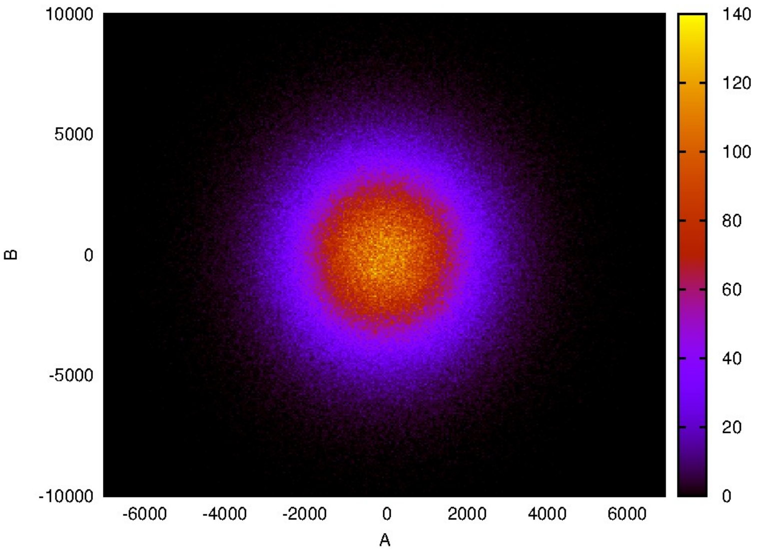
- Data analysis:
  - Cut out events with large variations of beam parameters
  - Corrections for polarity correlated variations
    - Gate length fluctuations (power grid frequency)
    - Beam variations
  - Calculation of asymmetry in detectors

Beam Stability

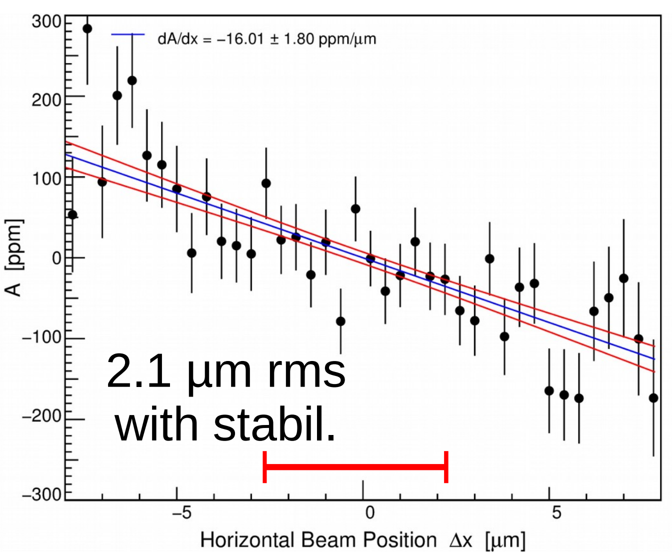
Active beam stabilisations:

- Current (AC / DC)
- Position (AC / DC)
- Energy

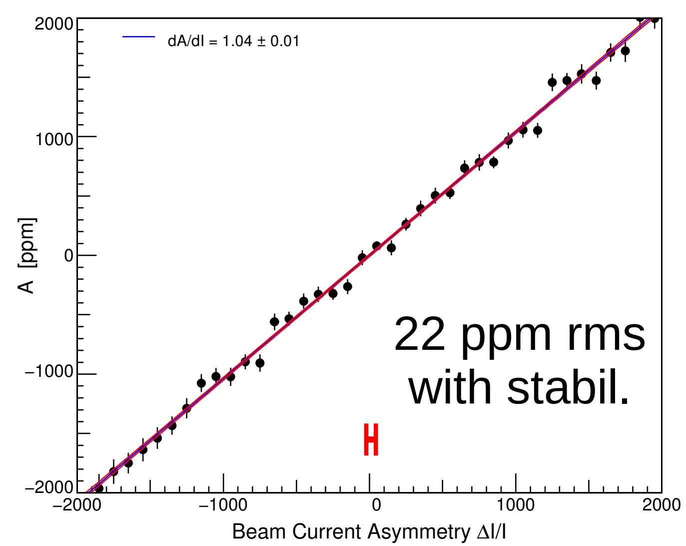
Correlation of asymmetries in both spectrometers



Position stabilisation disabled



Current stabilisation disabled



Asymmetry Correction

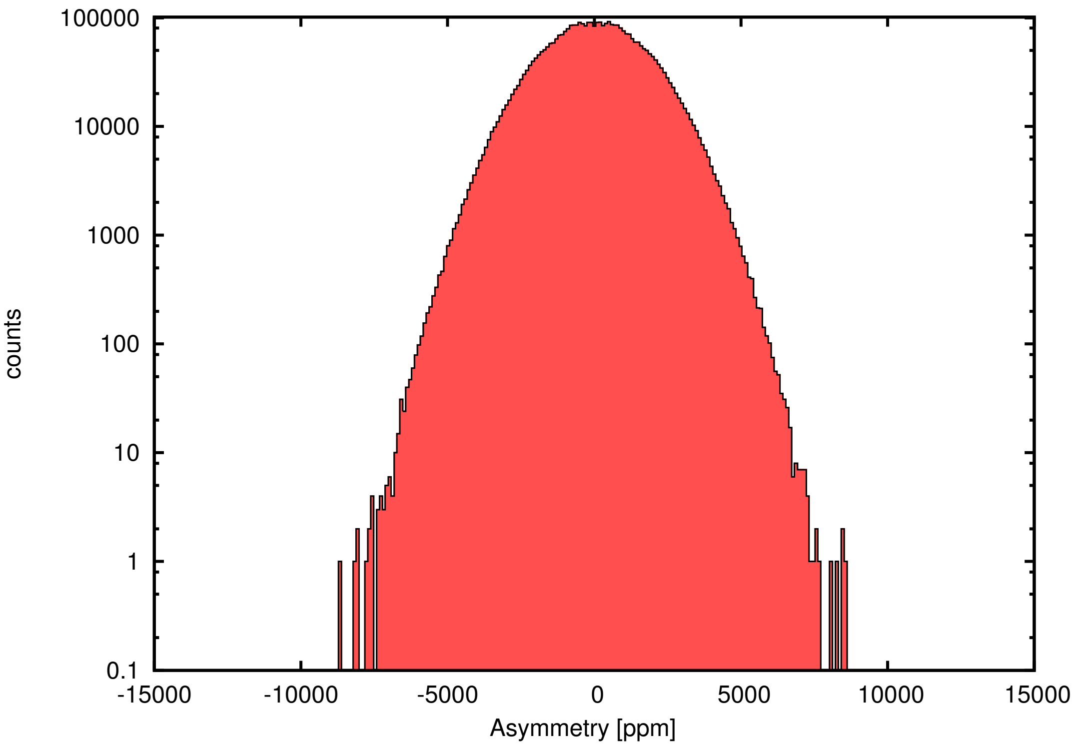
- Correction of raw asymmetries by beam parameters:

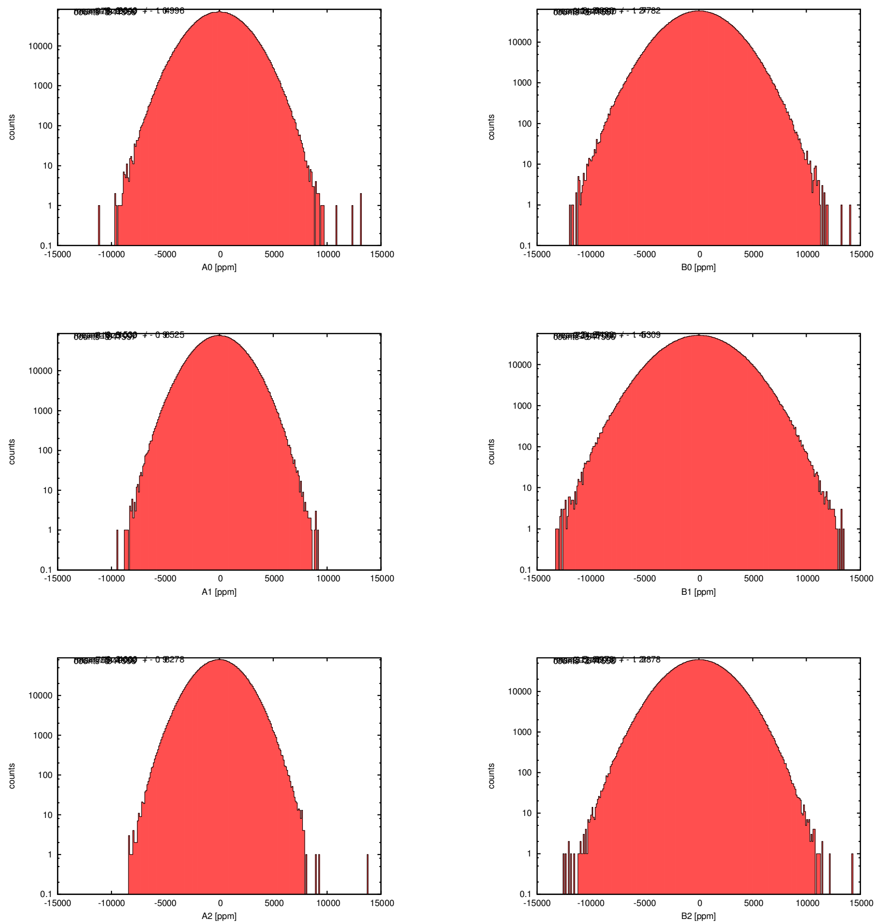
$$A=\frac{N^{+}-N^{-}}{N^{+}+N^{-}}-\frac{I^{+}-I^{-}}{I^{+}+I^{-}}$$
$$-(\Delta x\cdot\frac{dA}{dx})-(\Delta y\cdot\frac{dA}{dy})-(\Delta\varphi\cdot\frac{dA}{d\varphi})-(\Delta\theta\cdot\frac{dA}{d\theta})-(\Delta E\cdot\frac{dA}{dE})$$

- Determination of Parameters:
  - High beam stability $\rightarrow$ Multidimensional linear regression is impossible
  - Determination by Calculation:
    - Energy, Angle: Deviation of cross-section parametrisation
  - Determination by Simulation:
    - Beam Positions: Usage of Spectrometer simulation
  - Comparison of calculated parameters with data acquired with unstabilised beam

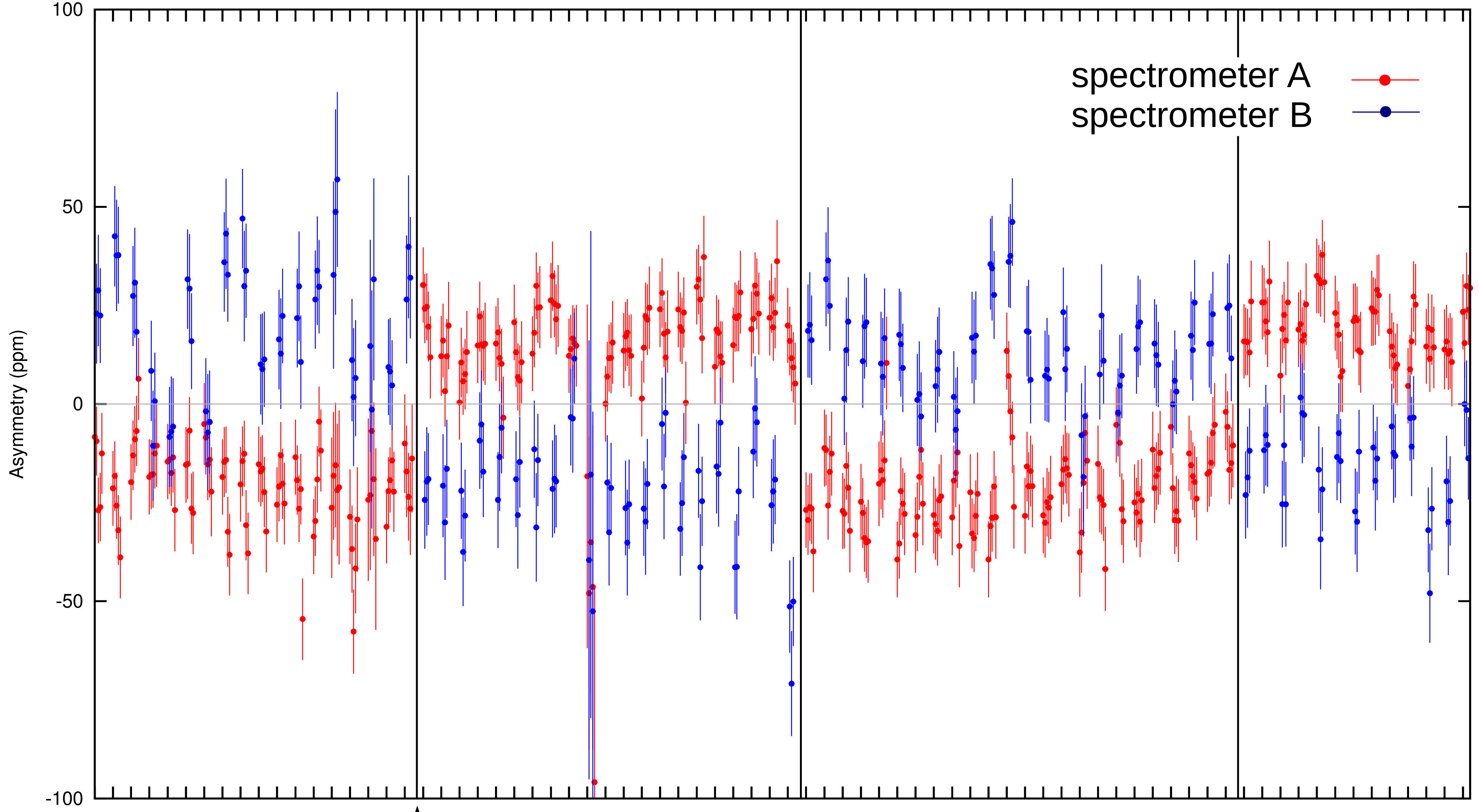
Raw Asymmetries

- No significant deviation from gaussian shape in any channel
- Width 800 – 4000 ppm rms (depending on Spectrometer angle)
- 6 hours – 6 days of data taking to obtain statistical uncertainty of < 1 ppm





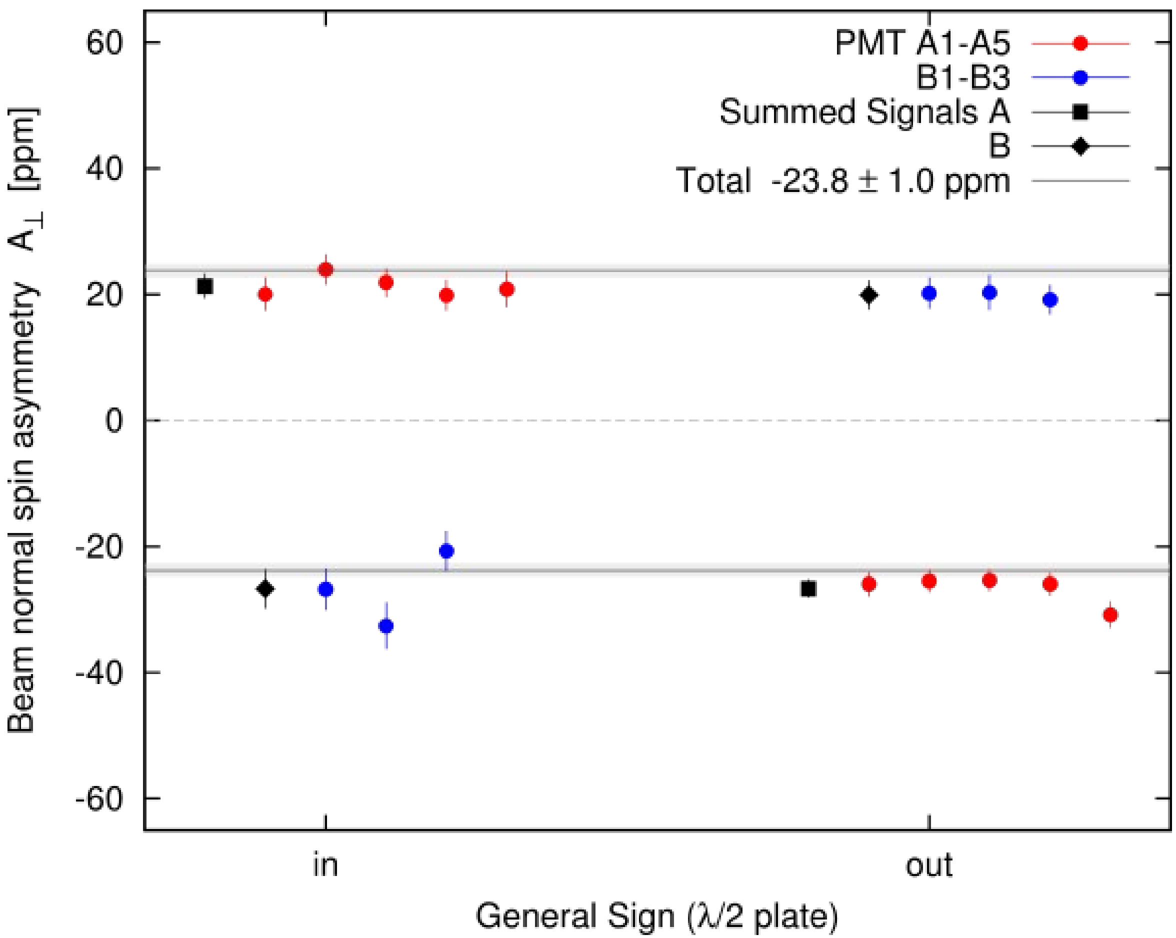
Results



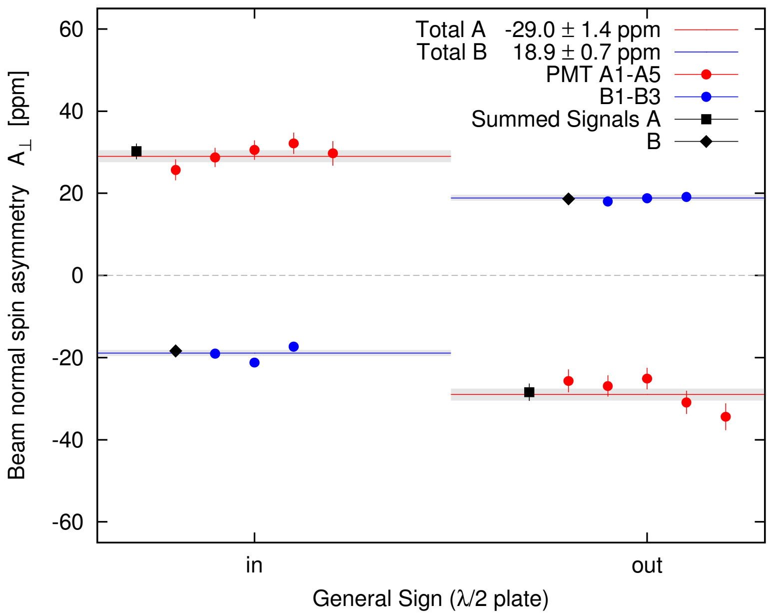
Inversion of general sign

Runs with equal Q² In both spectrometers

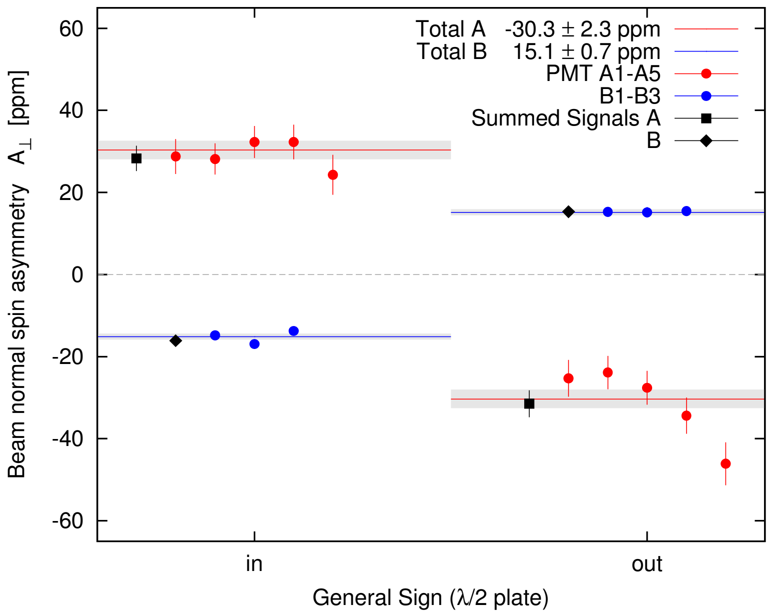
Results



PMT A1-A5
B1-B3
Summed Signals A
B
Total -23.8 ± 1.0 ppm
Beam normal spin asymmetry A⊥ [ppm]
General Sign (λ/2 plate)
in
out



Total A -29.0 ± 1.4 ppm
Total B 18.9 ± 0.7 ppm
PMT A1-A5
B1-B3
Summed Signals A
B
Beam normal spin asymmetry A⊥ [ppm]
General Sign (λ/2 plate)
in
out



Total A -30.3 ± 2.3 ppm
Total B 15.1 ± 0.7 ppm
PMT A1-A5
B1-B3
Summed Signals A
B
Beam normal spin asymmetry A⊥ [ppm]
General Sign (λ/2 plate)
in
out

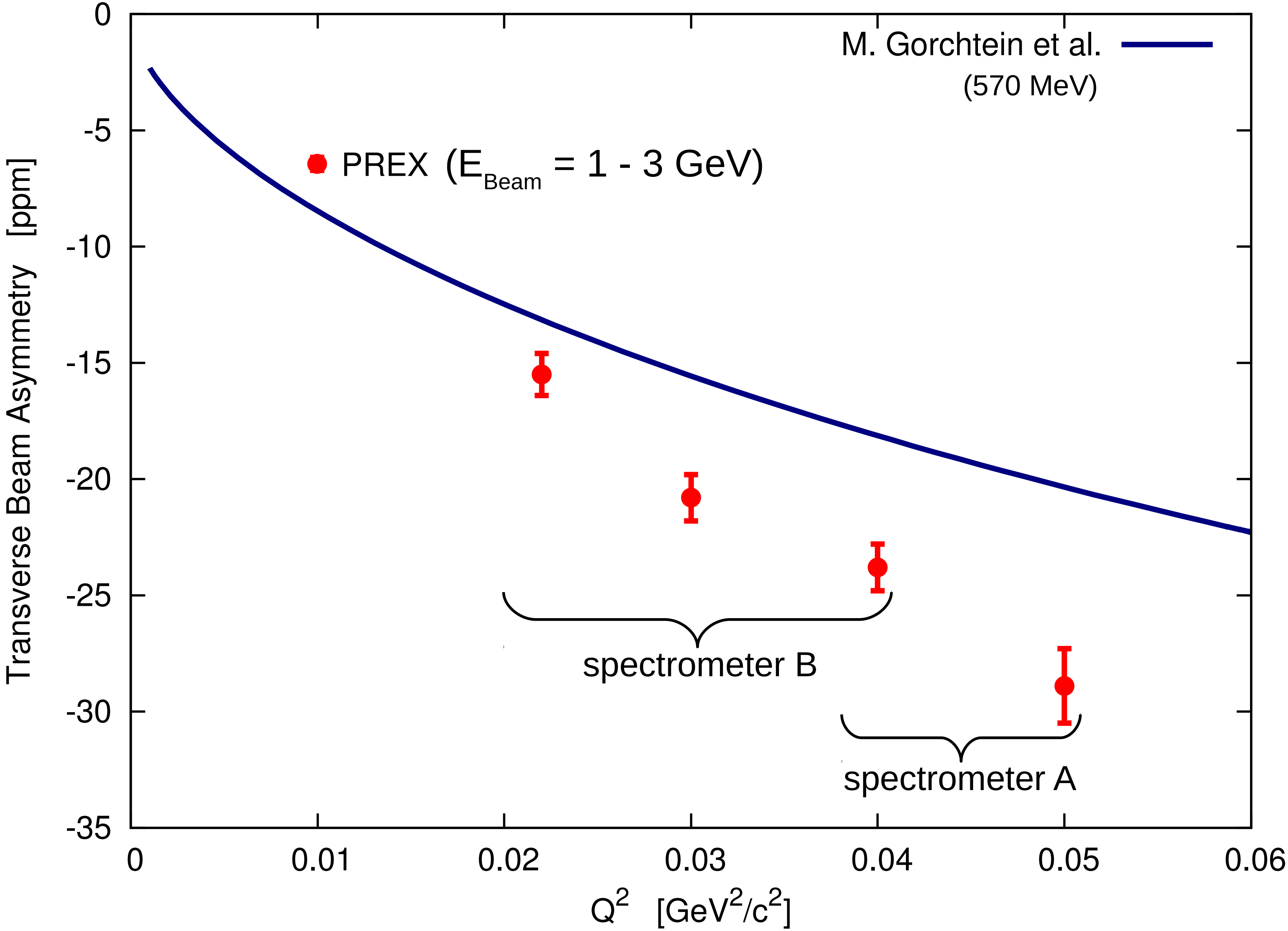
Systematic Uncertainties

Statistical Uncertainty of the order of 1 ppm

		Correction [ppm] *)	Error of correction [ppm]
Beam Current	A_I	-0.83	0.01
Beam Energy	ΔE	-0.0090	0.0004
Horizontal position	Δx	0.10	0.02
Vertical position	Δy	-0.00082	0.00004
Horizontal angle	ΔΘ	0.010	0.003
Vertical angle	ΔΦ	0.00	0.00
Linearity		Work in progress	
Polarisation related:			
Degree of polarisation	P	-4.18	0.04
Longitudinal polaristaion	P_l	0.03	0.03
Sum		-5.11	0.10

*) The Set-up with the highest correction respectively was chosen

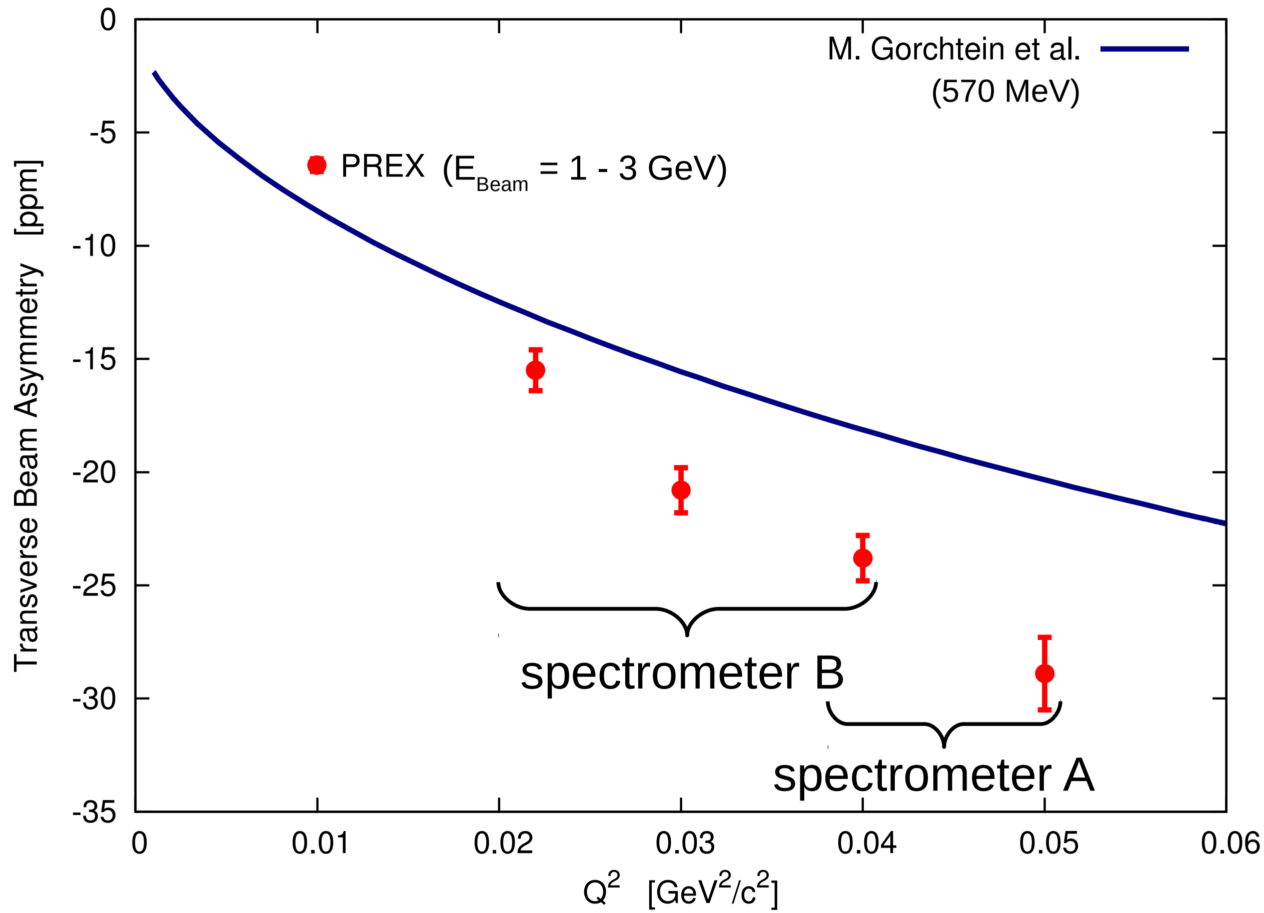
Results



M. Gorchtein et al.
(570 MeV)
PREX (E_Beam = 1 - 3 GeV)
spectrometer B
spectrometer A
Transverse Beam Asymmetry [ppm]
0
-5
-10
-15
-20
-25
-30
-35
0
0.01
0.02
0.03
0.04
0.05
0.06
Q2 [GeV2/c2]

Implications

- Observations
  - Data points don't agree with theory
  - Data shows different slope
- Theory limitations
  - Only 2 photon exchange
  - No coulomb distortion effects included
  - Nuclear structure for heavy nuclei similar to hydrogen
  - Scattering angle: Θ ≈ 0



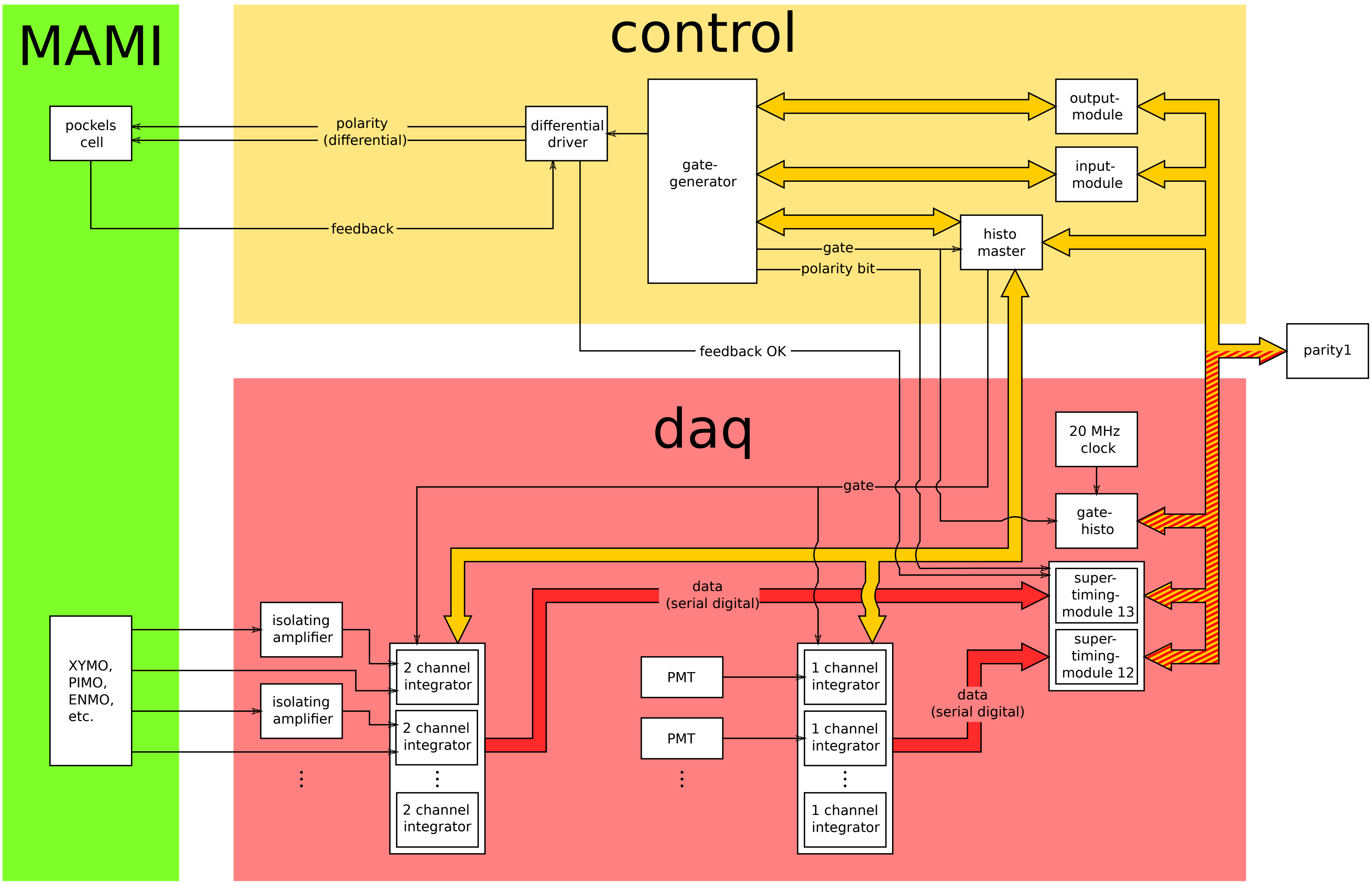
=> Theory present in many physical measurements
Room for improvement, feedback welcome

Summary & Outlook

- Beam-normal asymmetry:
  - Important background of PV electron scattering
  - Direct probe for two-photon exchange
- Experiment:
  - Vertically polarised electron beam &
    Elaborate polarisation measurement
  - Spectrometers to select elastic events &
  - Quartz-Cherenkov detectors
  - Suppression & Correction for false asymmetries
- Disagreement between theoretical prediction and measurement
- Continuation of program:
  - Energy dependence:
    - Similar Q^2 values accessable for ^{12}C at 210 & 855 MeV
  - Z-depencence
    - Possible targets with intermediate masses: ^{28}Si, ^{40}Ca

Backup

DAQ Electronics



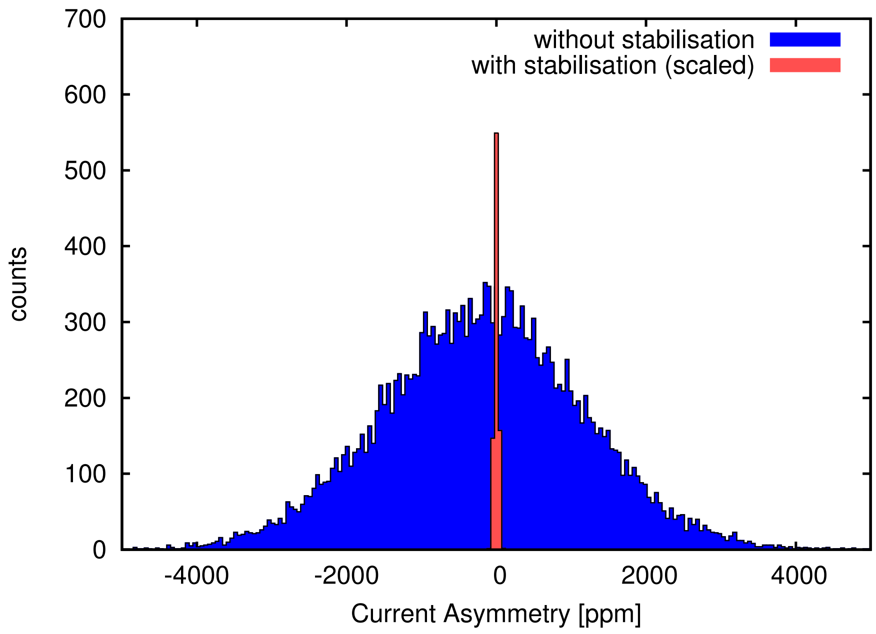
Time Line

- Commissioning beam-times, longitudinally polarised beam:
  - July 2014:
    Detector commissioning (1 week)
  - September 2014:
    Test and improvement of beam stabilisation (1 week)
- Production beam-times, transversely polarised beam:
  - September 2015:
    Measurement of transverse polarisation (1 week)
  - November 2015:
    Measurement of transverse asymmetry (3 weeks)
  - April 2016:
    Continuation of Program
    (1 week, shortened due to spectrometer failure)

Minimising False Asymmetries

Beam related sources:
- beam current, energy, position, angle

=> beam stabilisation

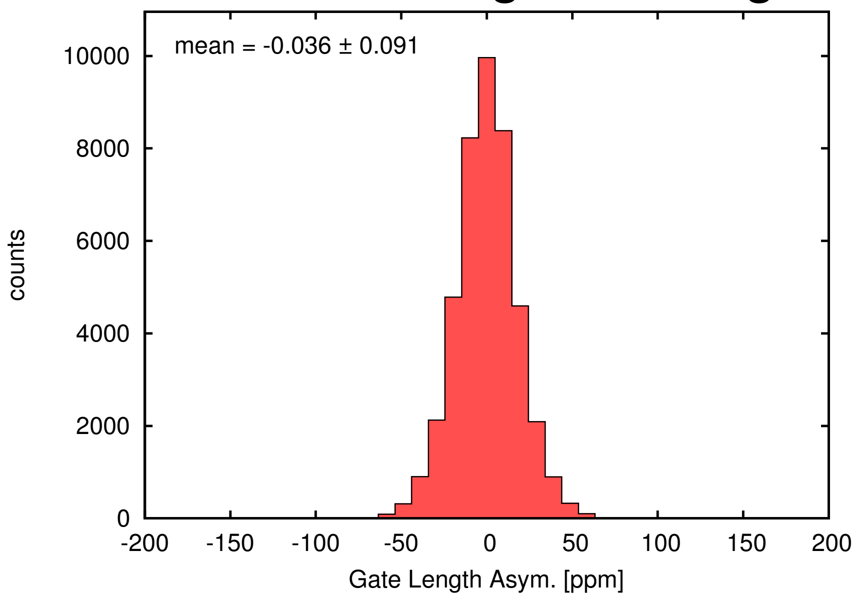


- Remaining asymmetry:
  beam current: ~ 1 ppm
  other parameters: < 0.1 ppm

=> Correction in offline analysis

Non beam related sources:
- Ground noise,
- Gate length fluctuations,
- Electrical cross talk

- Hardware suppression
  - Synchronised with power grid
  - Random polarity sequence
  - Inversions of general sign



=> Offline corrections

Polarity Correlated Beam Variations