Status of the *a*SPECT experiment

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Introduction

- The physics
- The experimental set-up

Systematic uncertainties

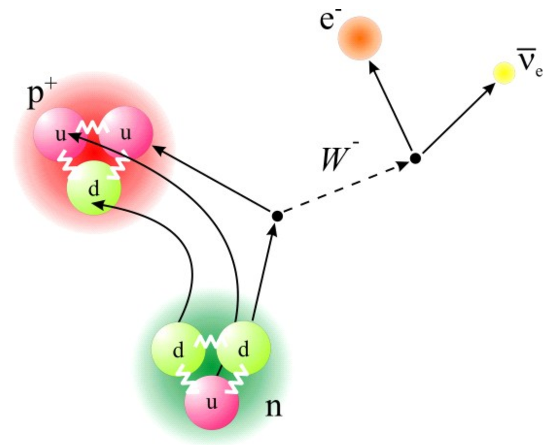
- Major systematic effects
- Improvements since 2008

The beamtime 2013

Next steps

Decay of the free neutron

β–ν correlation in neutron decay $n \rightarrow p + e^- + \overline{\nu}$



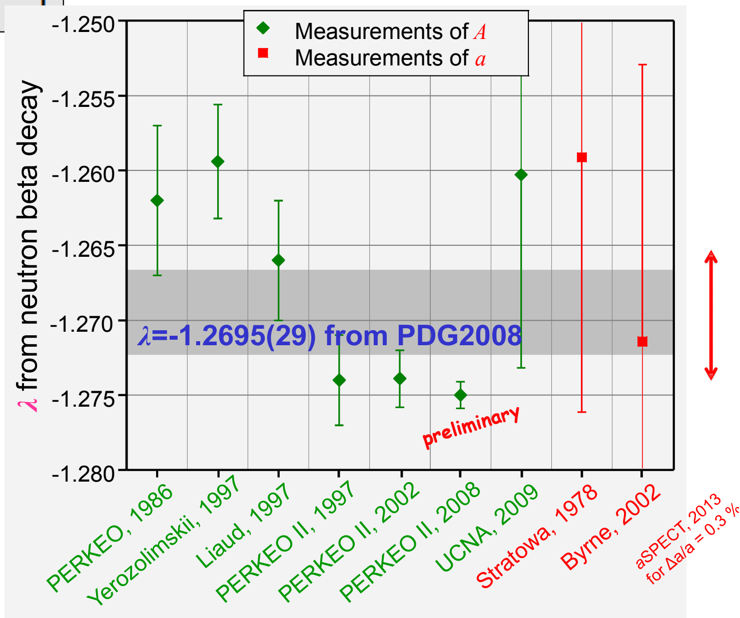
Mixed Fermi and Gamow Teller decay.
Differential neutron decay probability:

$$dW \propto \rho(E_e)\cdot\left\{1 + a\frac{\vec{p}_e\cdot\vec{p}_\nu}{E_eE_\nu} + b\frac{m_e}{E_e} + \left(A\frac{\vec{p}_e}{E_e} + B\frac{\vec{p}_\nu}{E_\nu} + D\frac{\vec{p}_e\times\vec{p}_\nu}{E_eE_\nu} + \ldots + R\frac{\vec{p}_e\times\vec{\sigma}_e}{E_e}\right)\cdot\vec{\sigma}_n\right\}$$

$$\boxed{a = \frac{1-|\lambda|^2}{1+3|\lambda|^2}} \qquad A = -2\frac{|\lambda|^2 + |\lambda|\cos\phi}{1+3|\lambda|^2}$$

$$\lambda = |g_A/g_V|\,e^{i\phi}$$

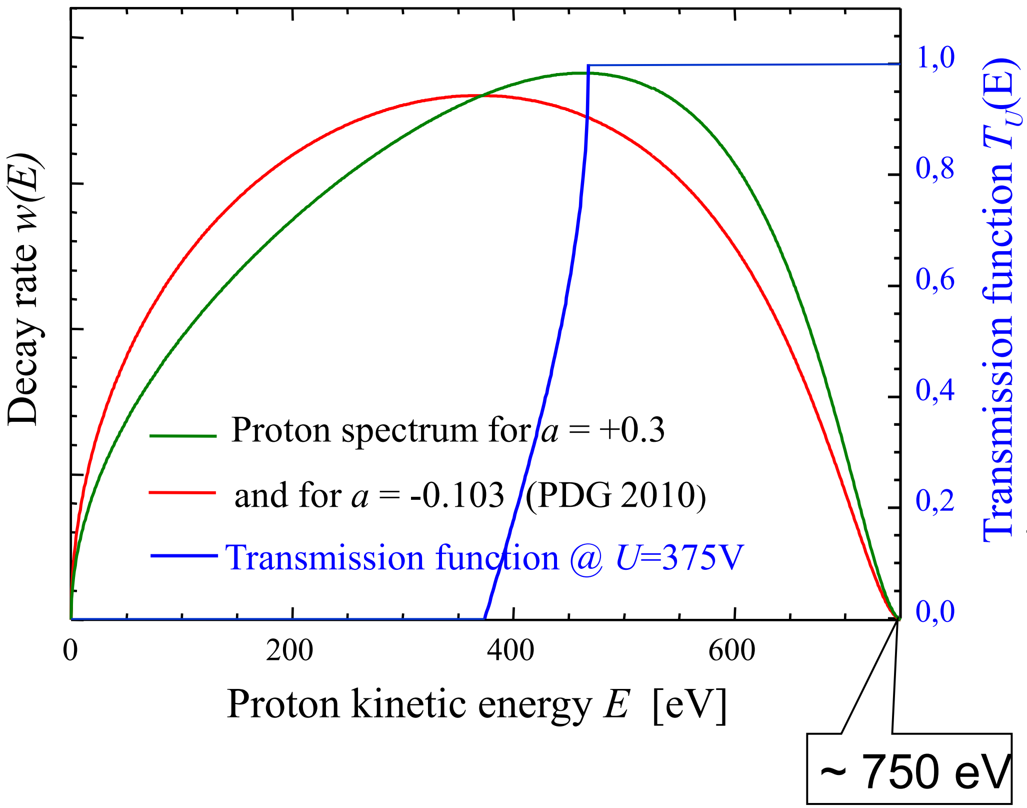
Accuracy of best previous experiments: $\Delta a/a \sim 5\%$
Our final aim: $\Delta a/a \sim 0.3\%$



For the physics see e.g. H. Abele, Prog. Part. Nucl. Phys. 60 (2008) 1

Experimental principle

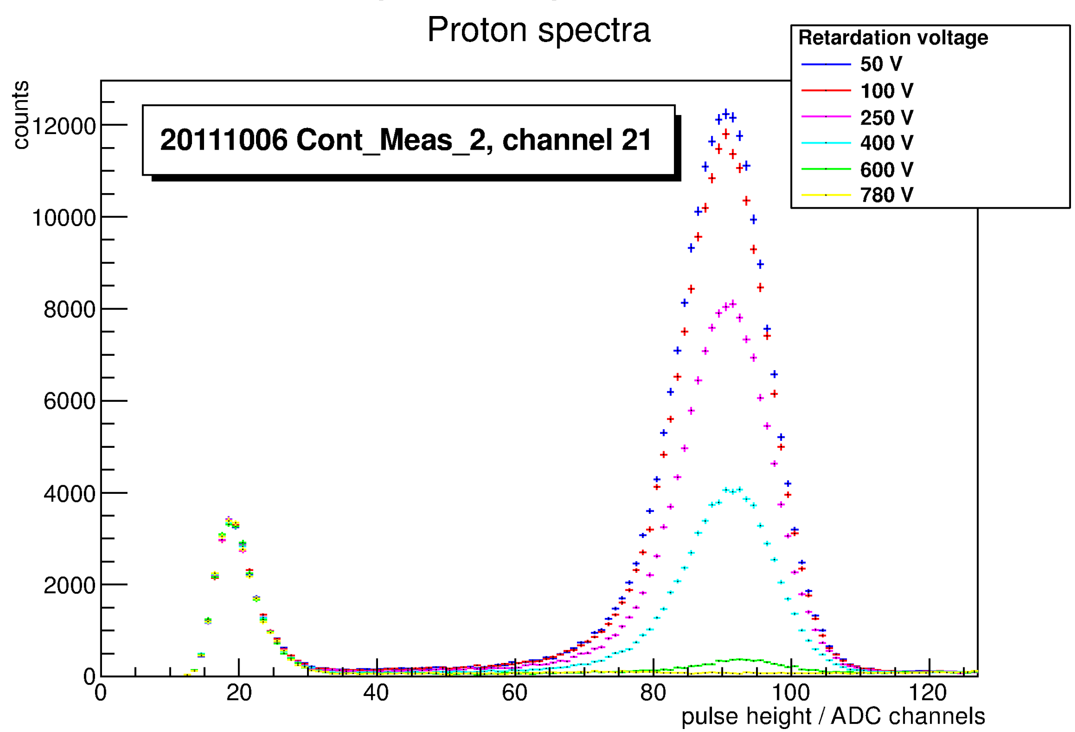
Measurement of the β–ν angular correlation
via the energy spectrum of the decay protons



Energy determination using
a retardation spectrometer (MAC-E filter).

Proton detection using
a silicon drift detector (SDD).

Measured proton spectra:

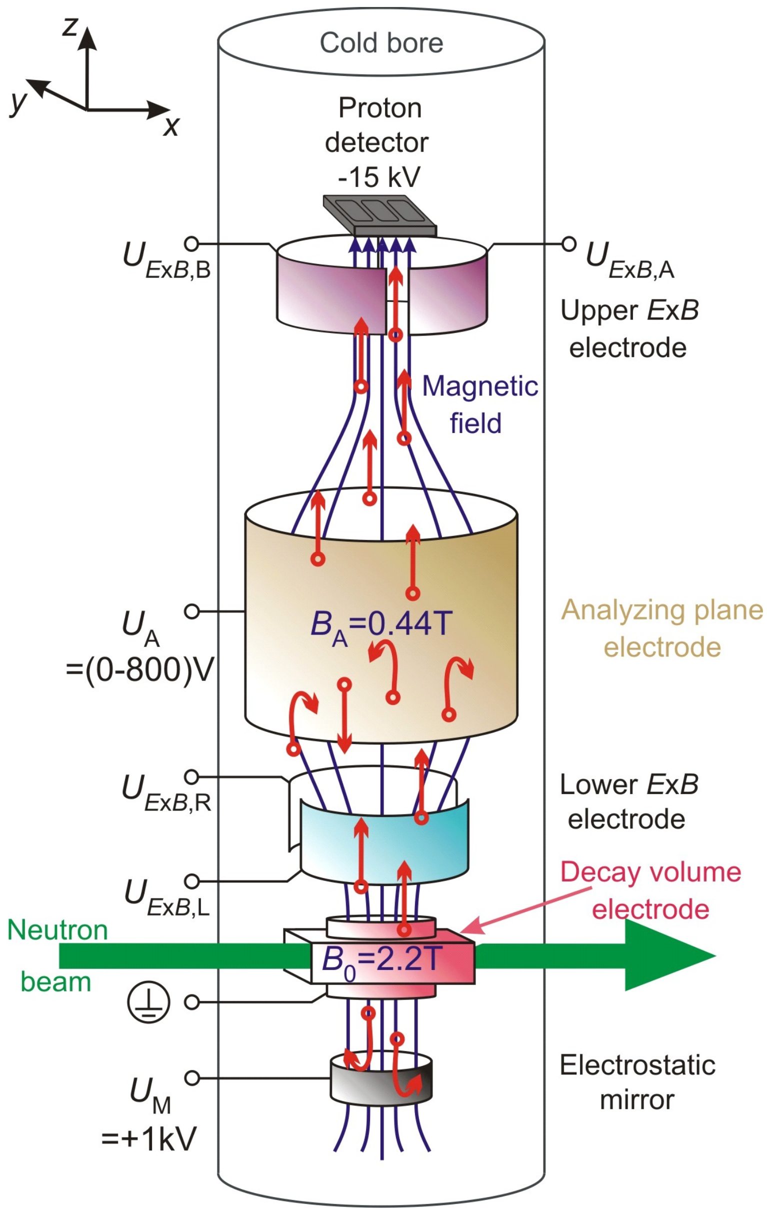


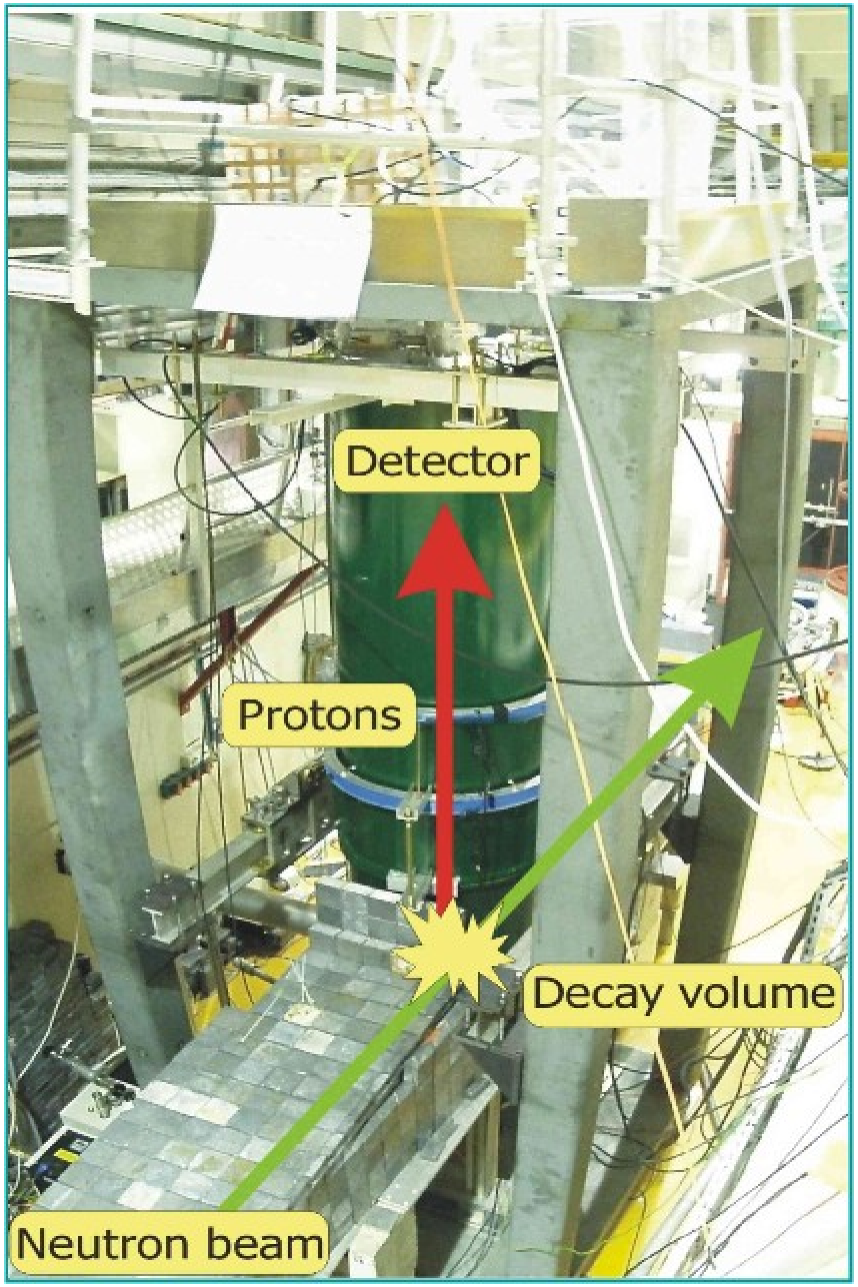
For details on *a*SPECT see

O. Zimmer et al., NIM A 440 (2000) 440
F. Glück et al., EPJ A 23 (2005) 135
S. Baeßler et al., EPJ A 38 (2008) 17
M. Simson et al., NIM A 611 (2009) 203
G. Konrad et al., Nucl. Phys. A 827 (2009) 529c

Overview aSPECT

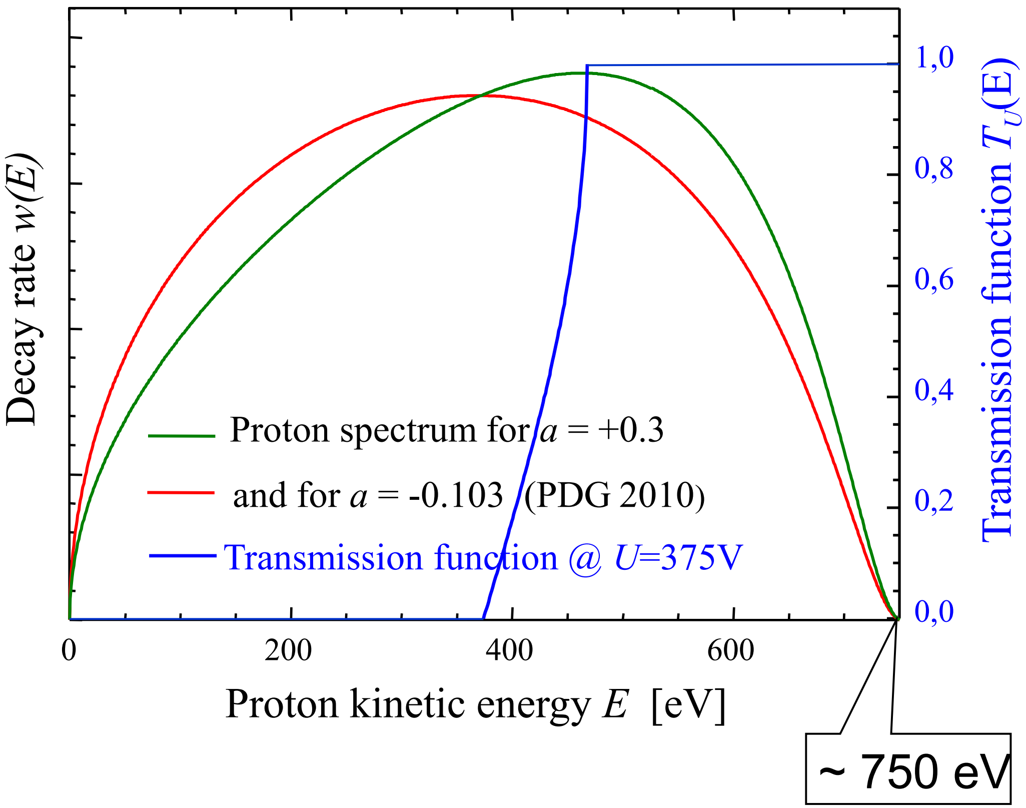
Schematic and set-up at ILL

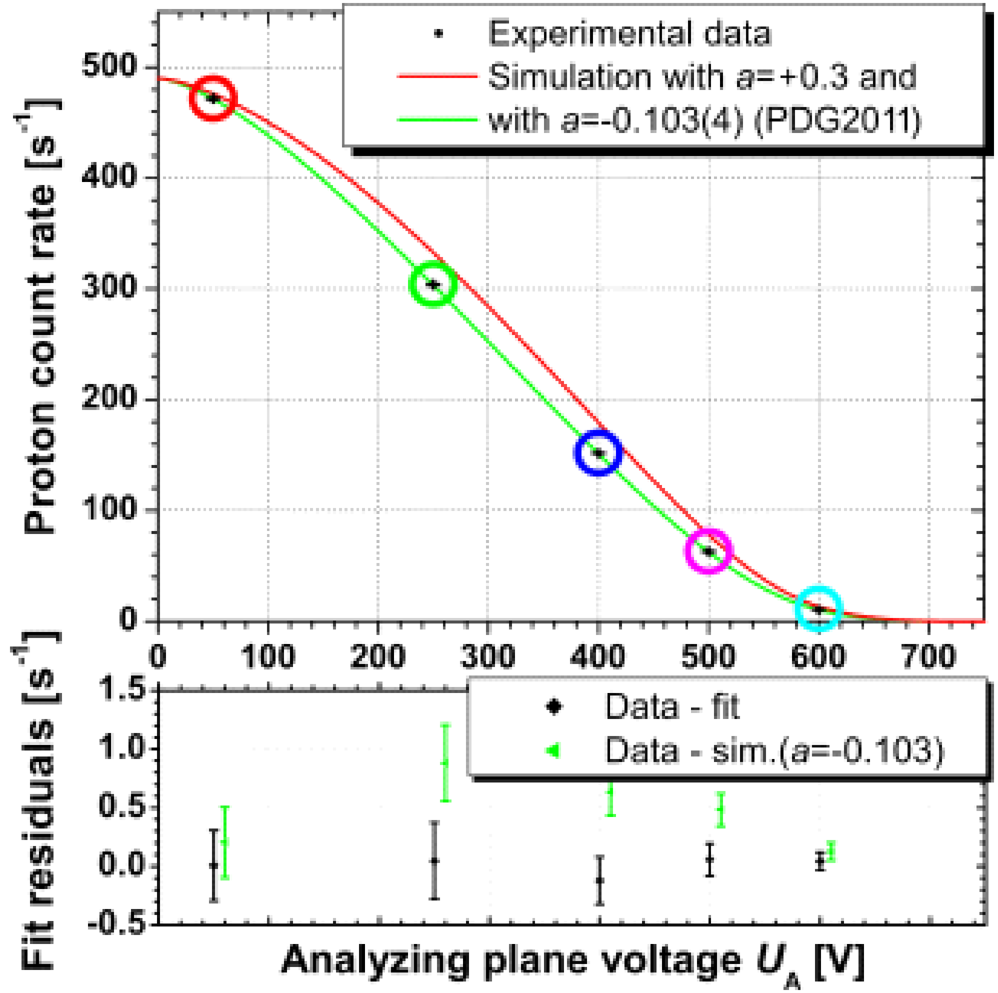




Recoil energy spectrum 2008

Measurement of the β–ν angular correlation via the energy spectrum of the decay protons





The systematic errors have to be understood.

A new beamtime of ~100 days has just been completed successfully at the cold neutron beam line PF1B at ILL!

Systematic uncertainties

Major systematic uncertainties at *a*SPECT are:

The stability and homogeneity of the retardation potential

Required for $\Delta a/a = 0.3\%$: 10 mV

The field ratio r_B of the magnetic fields in the DV and AP

Required for $\Delta a/a = 0.3\%$: $\Delta r_B/r_B = 1e\text{-}4$ (absolute, stability)

Retardation voltage dependent background

Should be < 0.1 1/s

A saturation effect of the detector electronics observed in 2008

Increased the error on small a to $\Delta a/a > 10\%$

Discharges due to trapped particles observed in 2011

Have to be absent

→ All of these have to be checked experimentally!

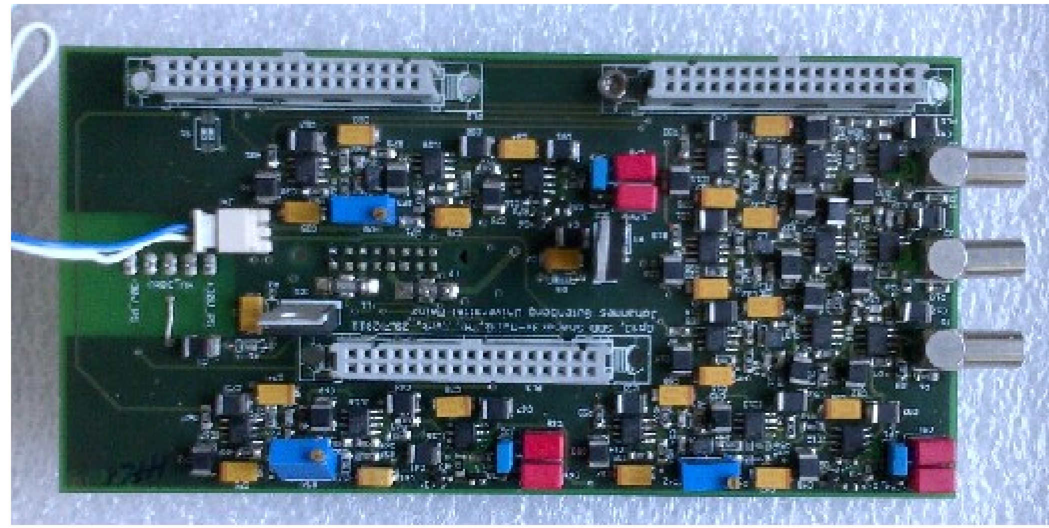
For details and other systematics based on the analysis of a beam time in 2008 see

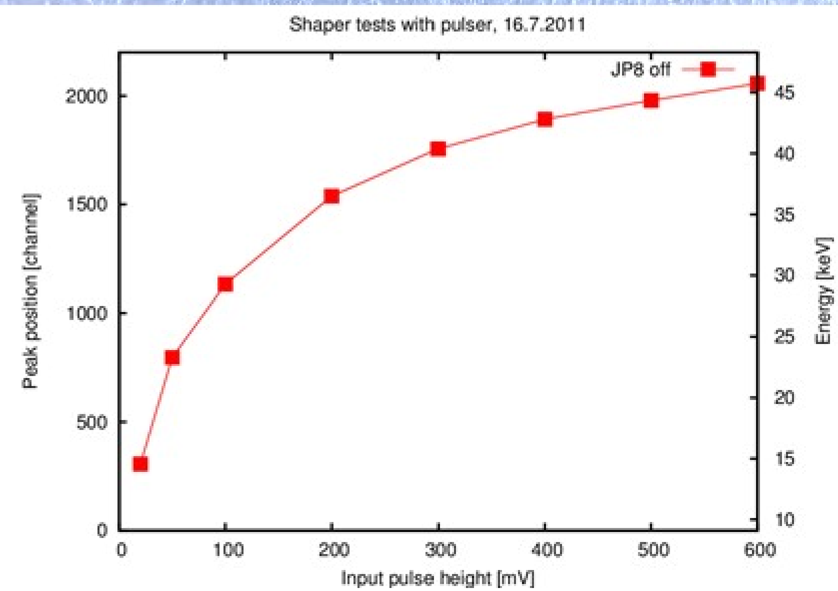
- M. Simson, PhD thesis, ILL 2009
- M. Borg, PhD thesis, Mainz 2010
- G. Konrad, PhD thesis, Mainz 2011
- F. Ayala Guardia, PhD thesis, Mainz 2011

Essential Improvements

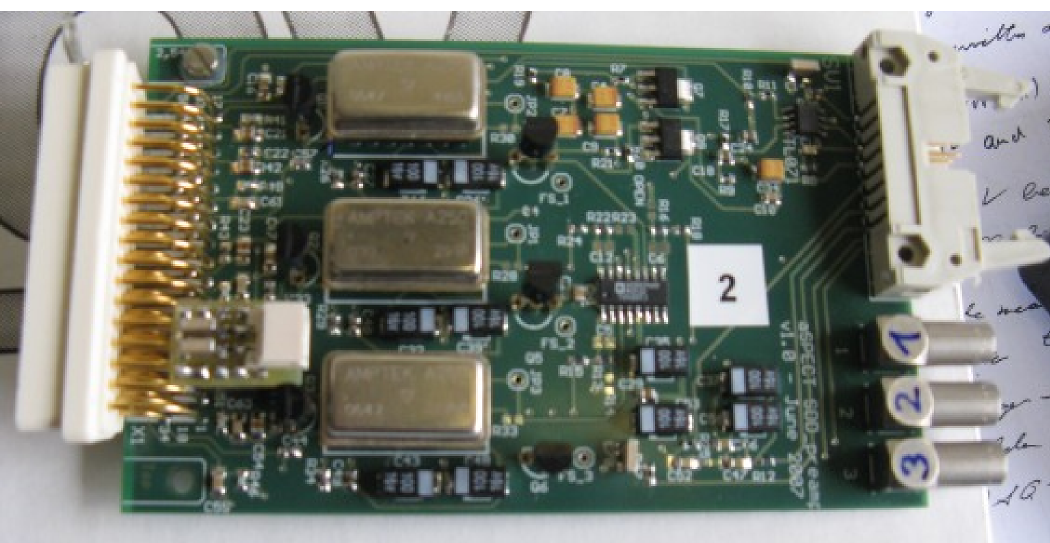
Modified detector electronics

New shaper with
- proton-electron separation
- log amplification for large signals





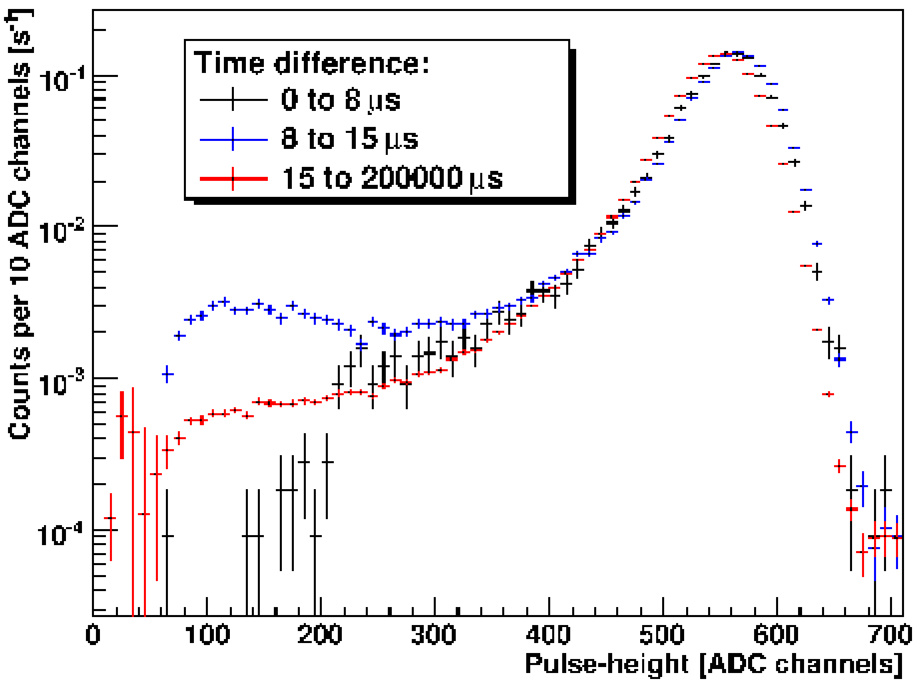
Preamplifier with reduced amplification



Modified detector electronics

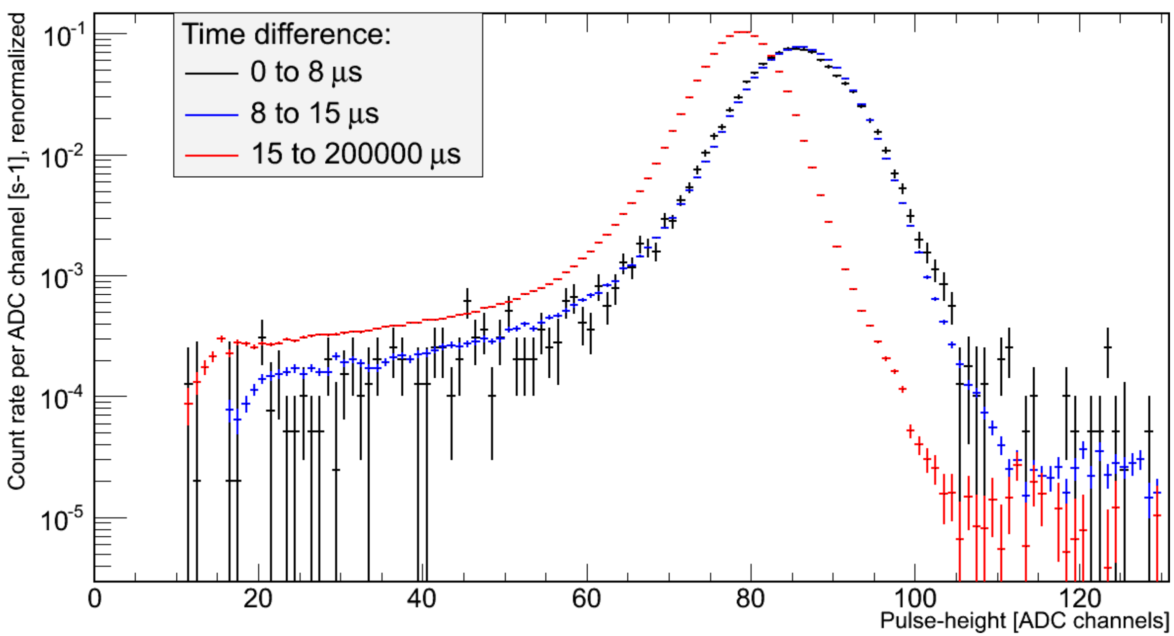
Saturation effect visible in the pulseheight spectrum of the detector
for short time differences between correlated electron and proton events

2008



2013

Ch. 20, AP=50V, background subtracted



2008: Protons shortly after electron events are lost (black) or show reduced pulse heights (blue)
2013: The same protons show normal pulse height distribution

→ Saturation problem of the detector electronics solved.

Essential Improvements

Electrode system

Goal: Well-defined potentials

→ New DV and AP electrodes

Goal Eliminate/reduce discharges

Reduce the background due to field emission/trapped particles

→ Improved vacuum

→ Remove edges/any sharp points/rough surfaces

Several electrodes made newly

All electrodes checked for edges, etc.

New Au-coating for many electrodes (DV and all AP electrodes)

Has to be redone before every beam time! (degrades within one year, costly)

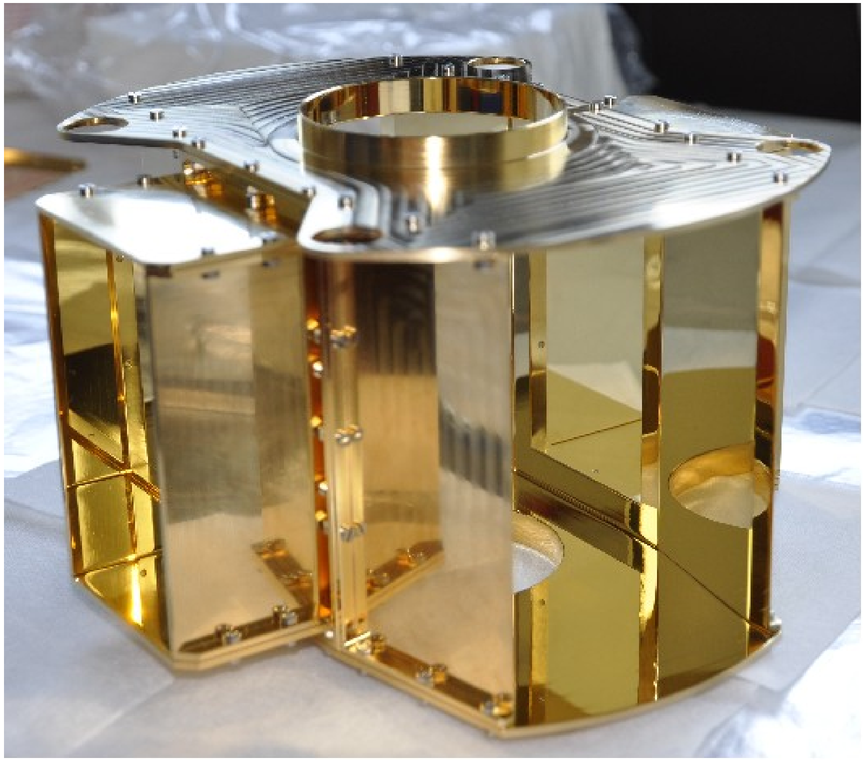
→ Electrode above AP electrode changed to a dipole electrode

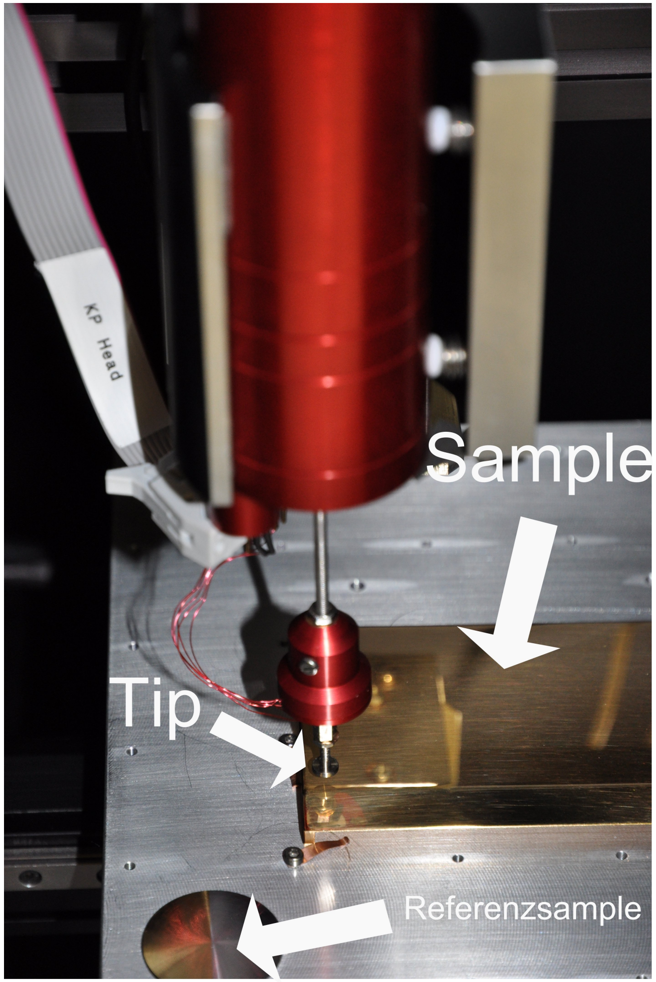
To remove trapped particles by the ExB drift

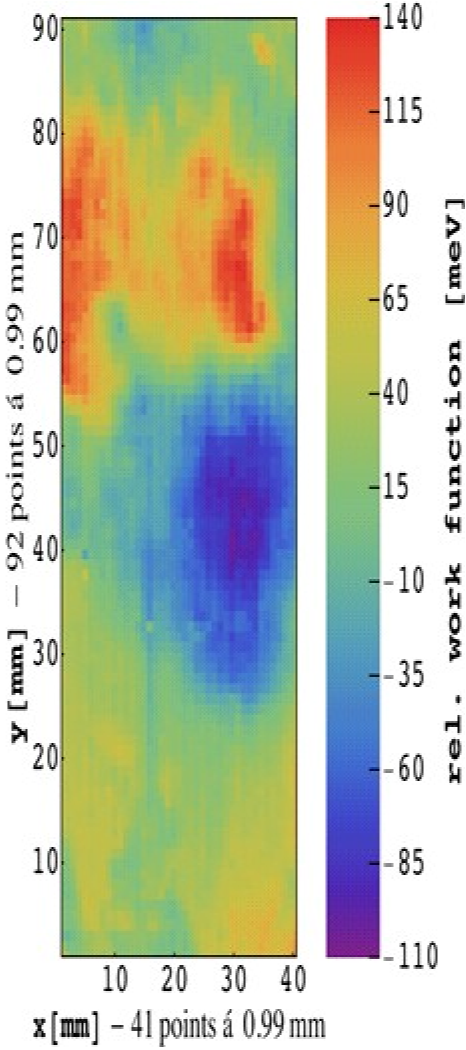
Essential Improvements

New decay volume and analyzing plane electrode

Flat surfaces
→ well defined surface properties
→ work function can be measured easily
See poster by Ch. Schmidt







Essential Improvements

New decay volume and analyzing plane electrode

1 μm Au on 10 μm Ag on a smoothly polished Cu-surface

Essential Improvements

Electrode system

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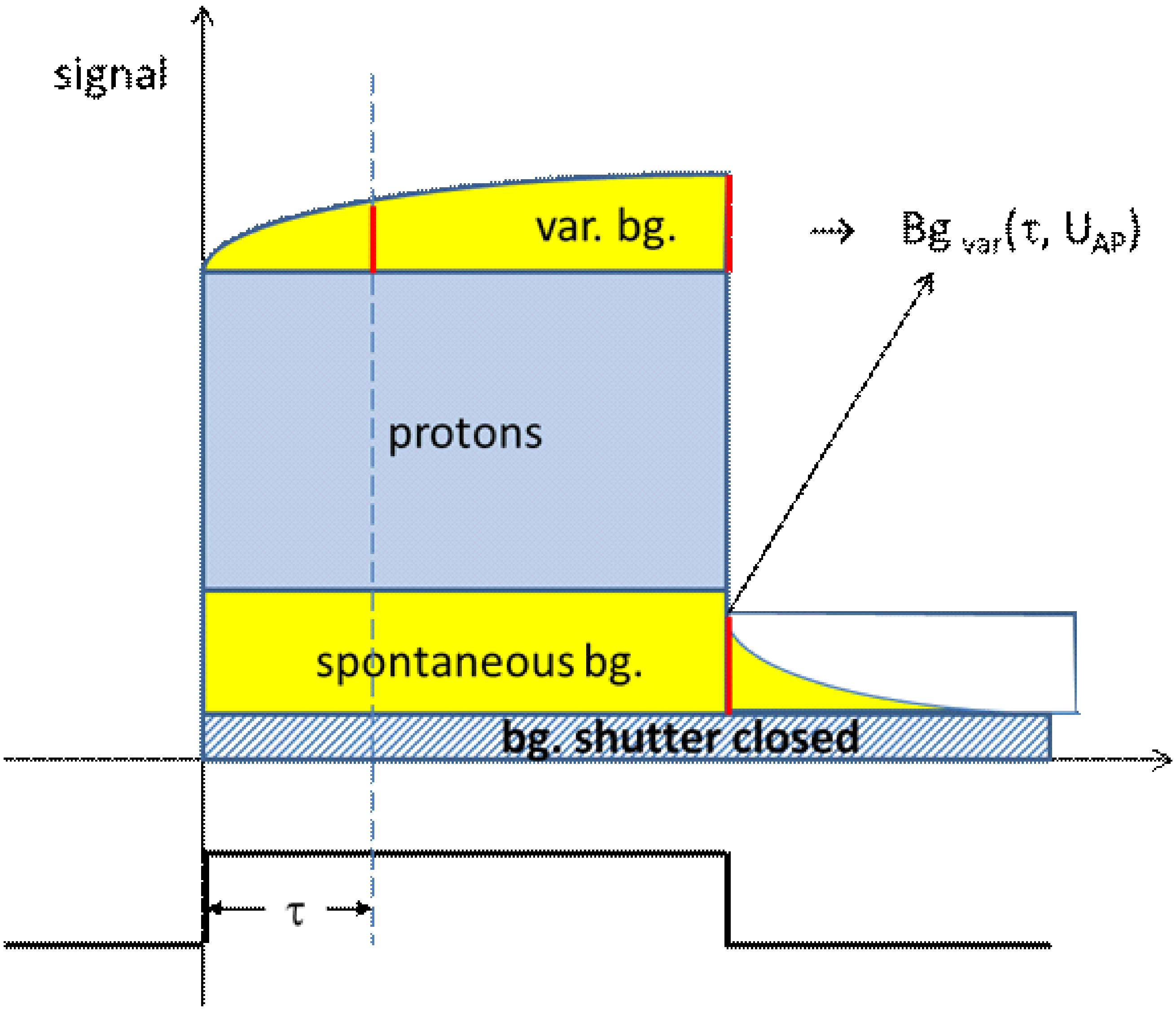
The beamtime

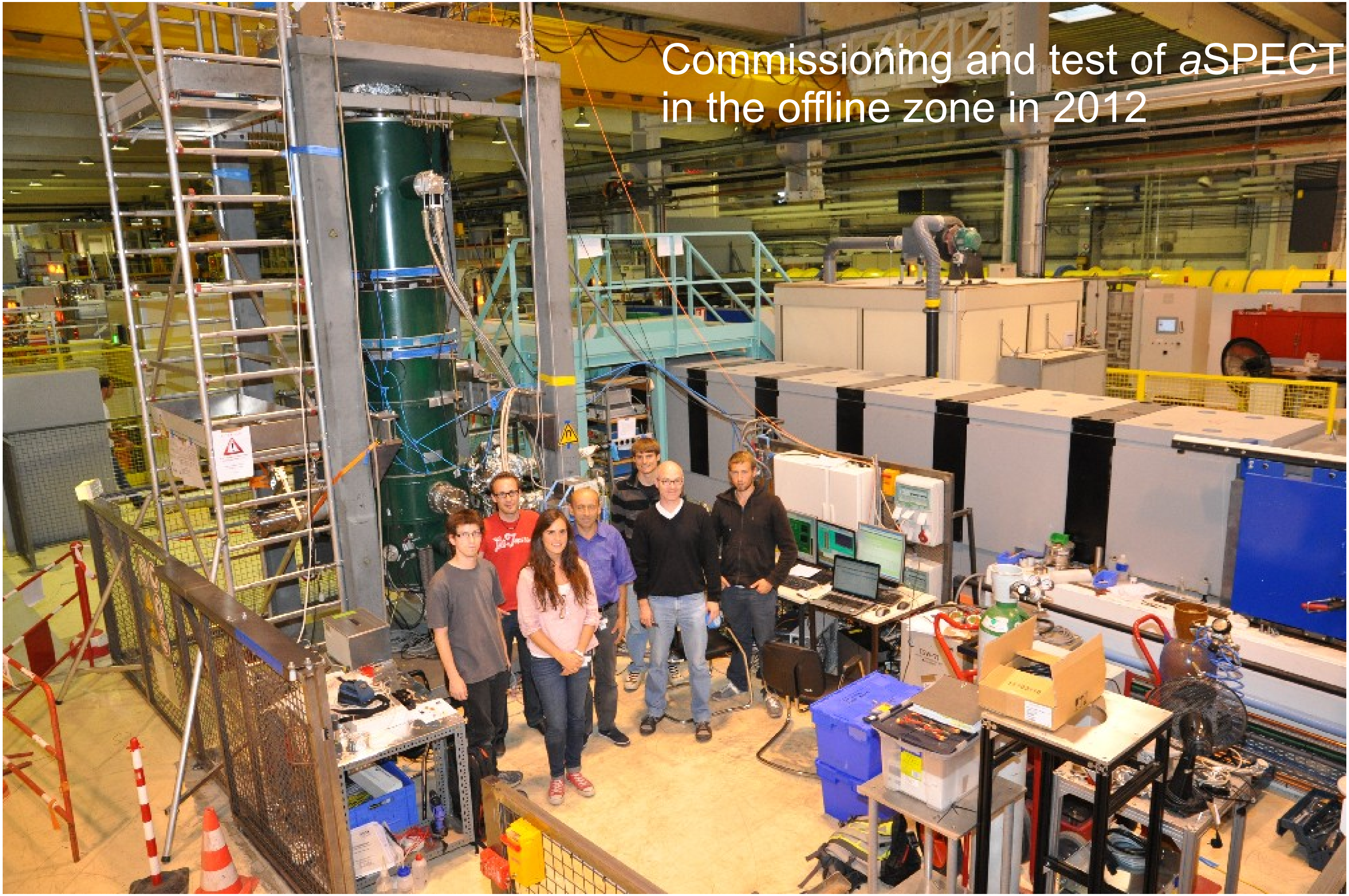
The background at *a*SPECT consists of several components with potentially different dependence on the AP potential.



- beam off ↔ beam on
- variable ↔ constant
- spontaneous
- retardation voltage dependence

→ See poster R. Maisonobe

Essential Improvements



Other improvements

There were many other improvements, e.g.

Improved **vacuum**

Cascaded turbopumps, additional NEG pump, improved cleaning procedures

New **beam collimation** inside *a*SPECT

Conductive to avoid field leakage into the decay volume

Monitoring of the **B-field** of *a*SPECT on the outside using Hall probes

Check of the field stability

New **NMR**

Determination of the absolute B-field and the field ration of AP and DV at the level of 10^{-5}

Measurement of the **work function** of the electrodes using a Kelvin probe

Important for the determination of the retardation potential and several other syst. effects

Measurement of the **beam profile** directly inside the DV

And more ...

The beam time 2013

Beam time successfully completed

After initial checks and tuning:
Data taking for small a and for systematic investigations:

1 day of data ↔ $\Delta a/a \sim 2\%$, typical length of one data set 2-3 days

→ Systematic investigations for different conditions with the full statistics

- 2 different detector electronics → See poster R. Virot
- Different background conditions → See poster R. Maisonobe
  (E15 dipole on/off,different focussing on the detector)
- 2 different beam profiles
- Check of field leakage into the DV

Emphasis on the understanding of the background.
(variable component and retardation voltage dependence).

No catastrophic systematic effect observed. The data look good!

Next steps

Several support measurements are ongoing

- Measurement of the **work function** of the DV and AP electrodes used.
- Measurement of the **magnetic field** with an NMR system (absolute values, ratio, stability).
- Detailed test measurements with the **preamplifier and shaper** used.
- Check of the **calibration** of the Hall probe and Agilent DVM.

Detailed analsyis with quantitative determination of the systematic uncertainties, including simulations.

See poster A. Wunderle

We expect a total systematic uncertainty of $\Delta a/a \sim 1\text{-}2\%$

The collaboration

From left to right

M. Simson, ILL
T. Soldner, ILL
O. Zimmer, ILL
R. Virot, ILL
R. Maisonobe, ILL
A. Wunderle, Mainz
W. Heil, Mainz
G. Konrad, Wien,
S. Baessler, U of Virginia
M. Beck, Mainz
Ch. Schmidt, Mainz

plus

F. Glück, KIT