

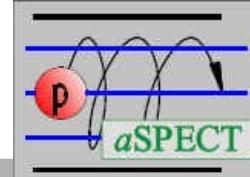
M. Beck

*Institut für Physik, Johannes Gutenberg-Universität Mainz*  
for the aSPECT collaboration

The aSPECT experiment  
Systematic uncertainties  
Examples and solutions  
B-field ratio  
Backscattering  
Edge effect  
Conclusion



# Decay of the free neutron



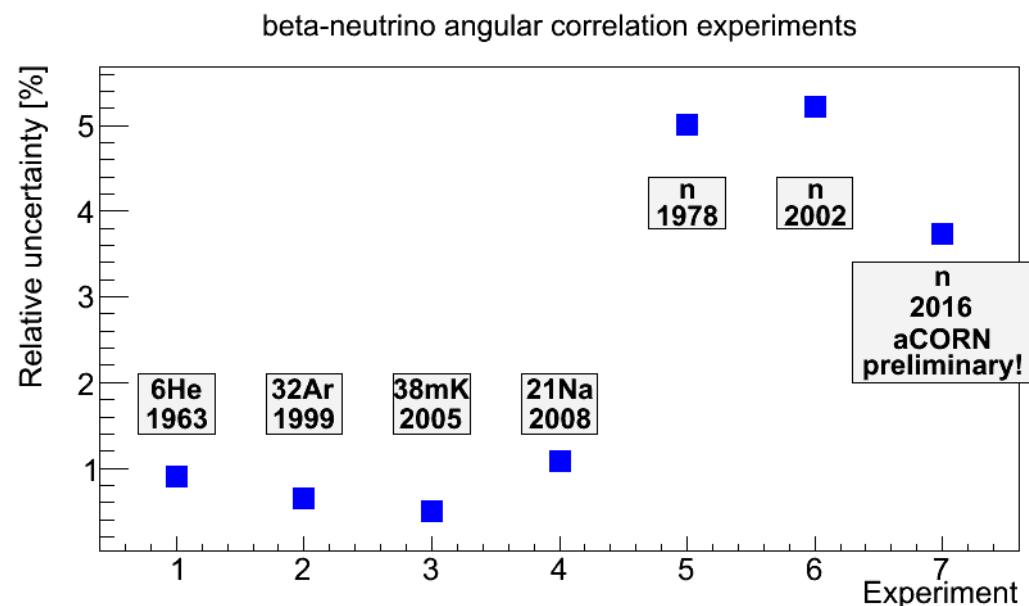
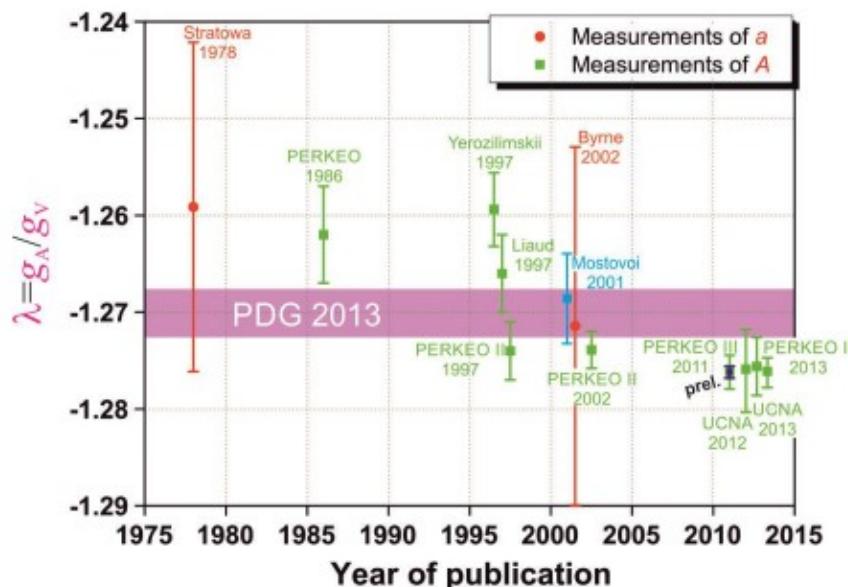
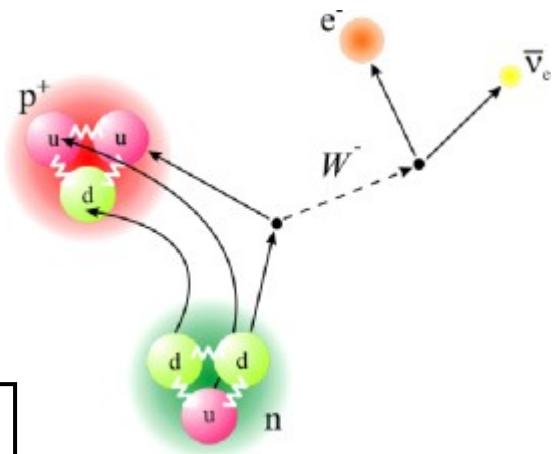
$\beta-\nu$  correlation in neutron decay  $n \rightarrow p^+ + e^- + \bar{\nu}$

Mixed Fermi and Gamow Teller decay.

$$a = \frac{1 - |\lambda|^2}{1 + 3|\lambda|^2} \quad A = -2 \frac{|\lambda|^2 + |\lambda| \cos \phi}{1 + 3|\lambda|^2} \quad \tau_n^{-1} \propto G_F^2 V_{ud}^2 (1 + 3|\lambda|^2)$$

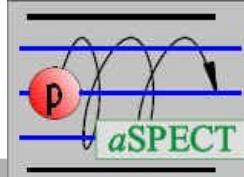
$$\lambda = |g_A/g_V| e^{i\phi}$$

Previous experiments:  $\Delta a/a \sim 5\%$   
 Present goal:  $\Delta a/a \sim 1\%$

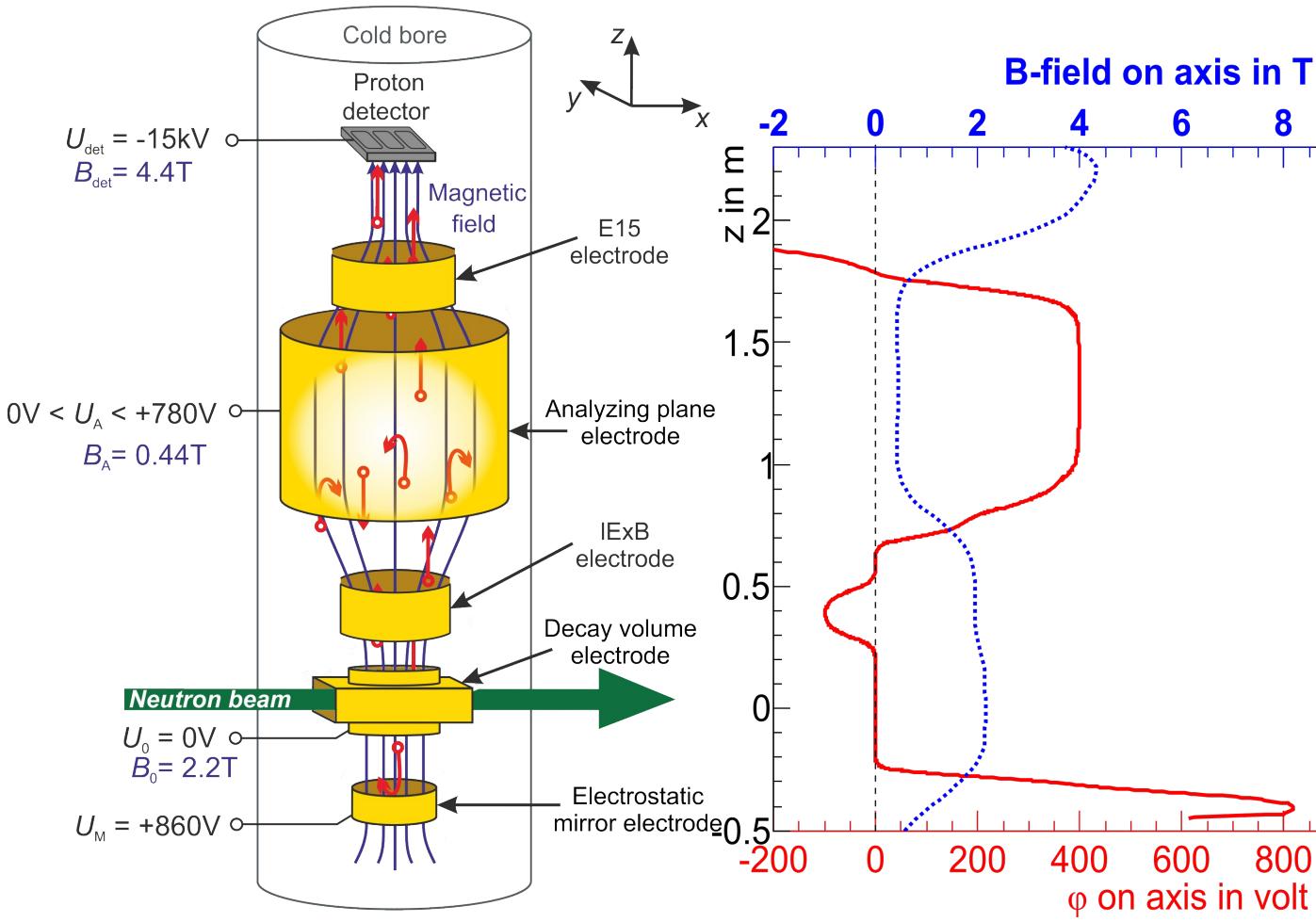




# Overview aSPECT

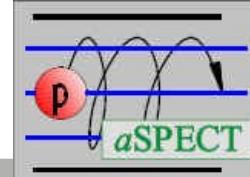


## Schematic and set-up at PF1b at the Institut Laue Langevin

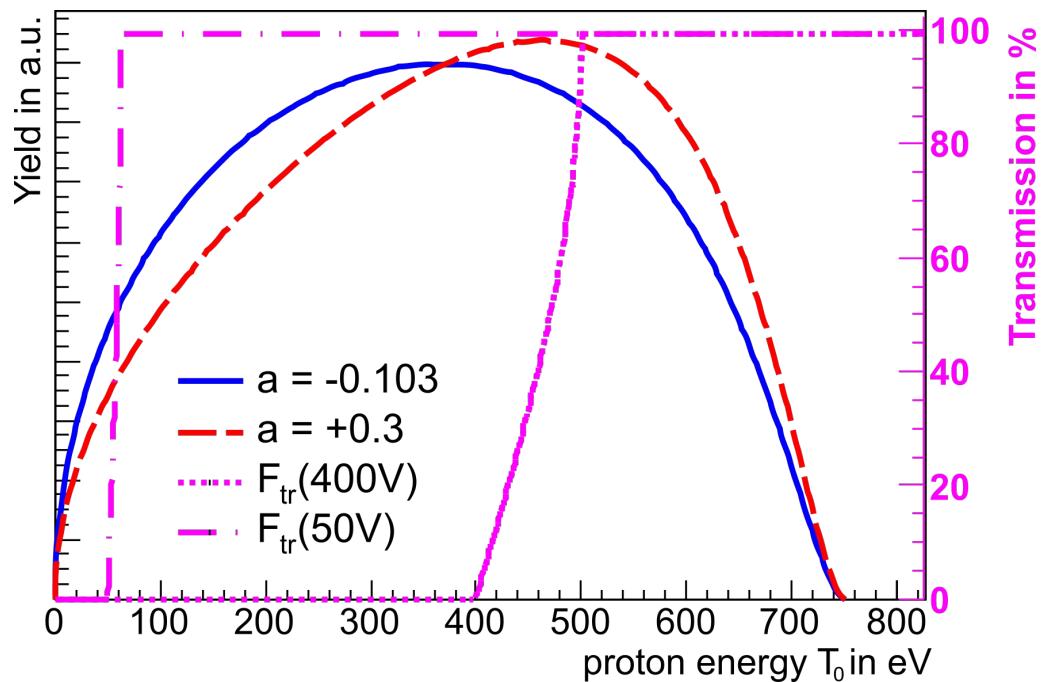




# Experimental principle

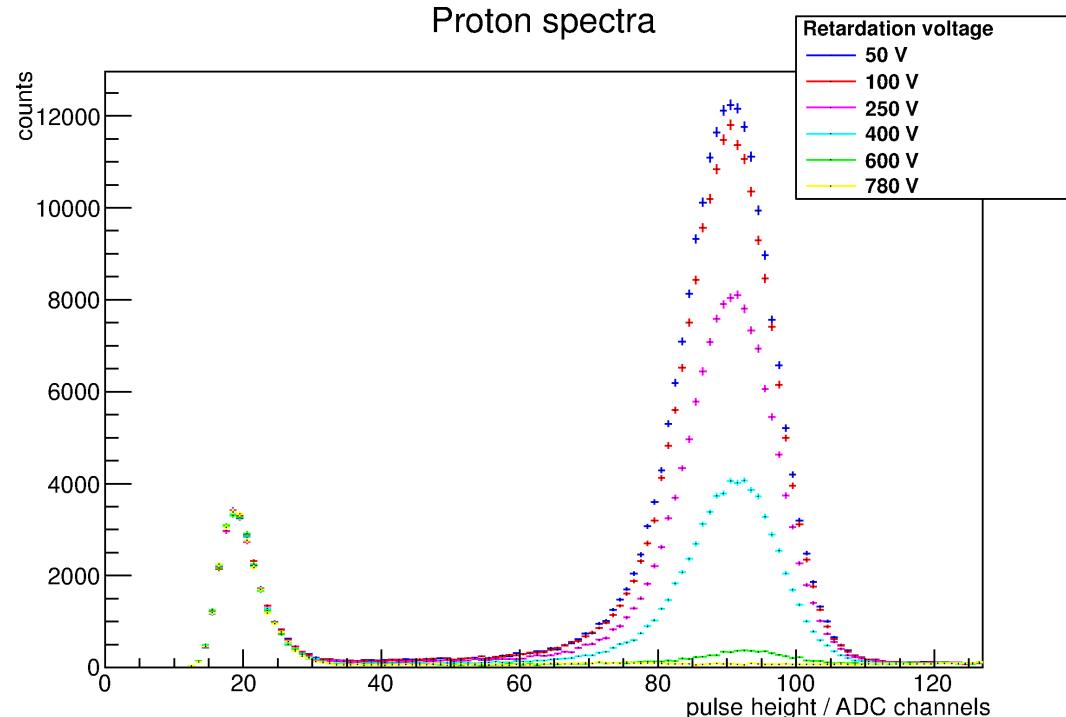


Measurement of the  $\beta-\nu$  angular correlation via the energy spectrum of the decay protons



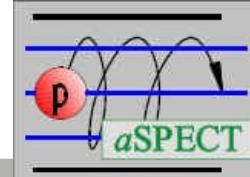
- 1.) Energy determination using a retardation spectrometer (MAC-E filter).
- 2.) Proton detection using a silicon drift detector (SDD).

Measured protons (pulse height distr.):

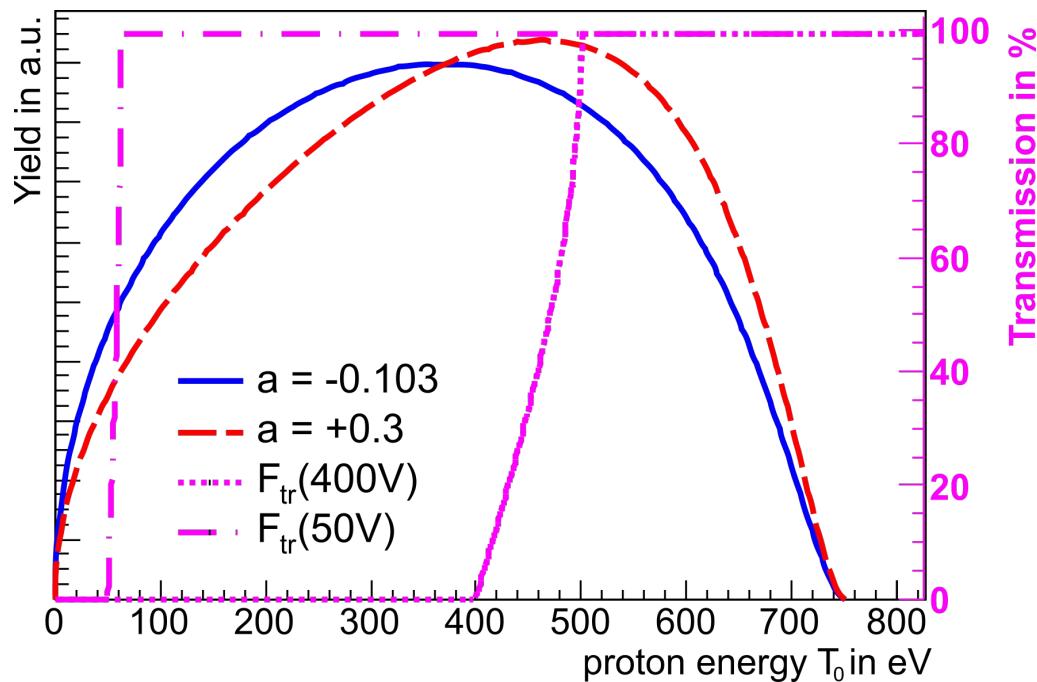




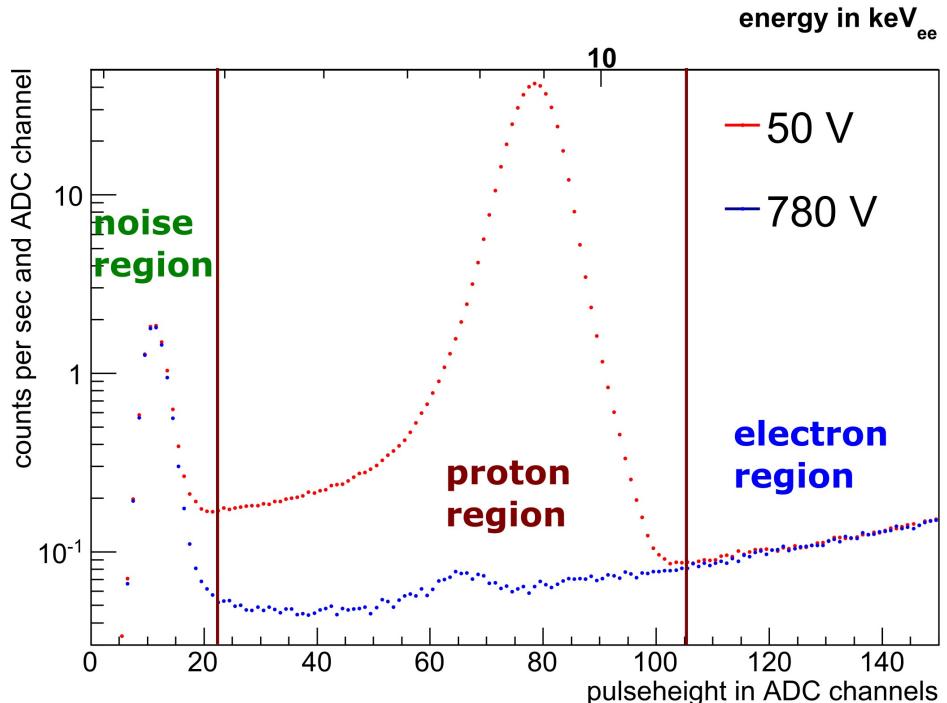
# Experimental principle



Measurement of the  $\beta-\nu$  angular correlation via the energy spectrum of the decay protons

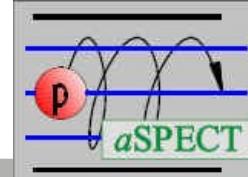


- 1.) Energy determination using a retardation spectrometer (MAC-E filter).
- 2.) Proton detection using a silicon drift detector (SDD).
- 3.) Integrate counts in the proton region:

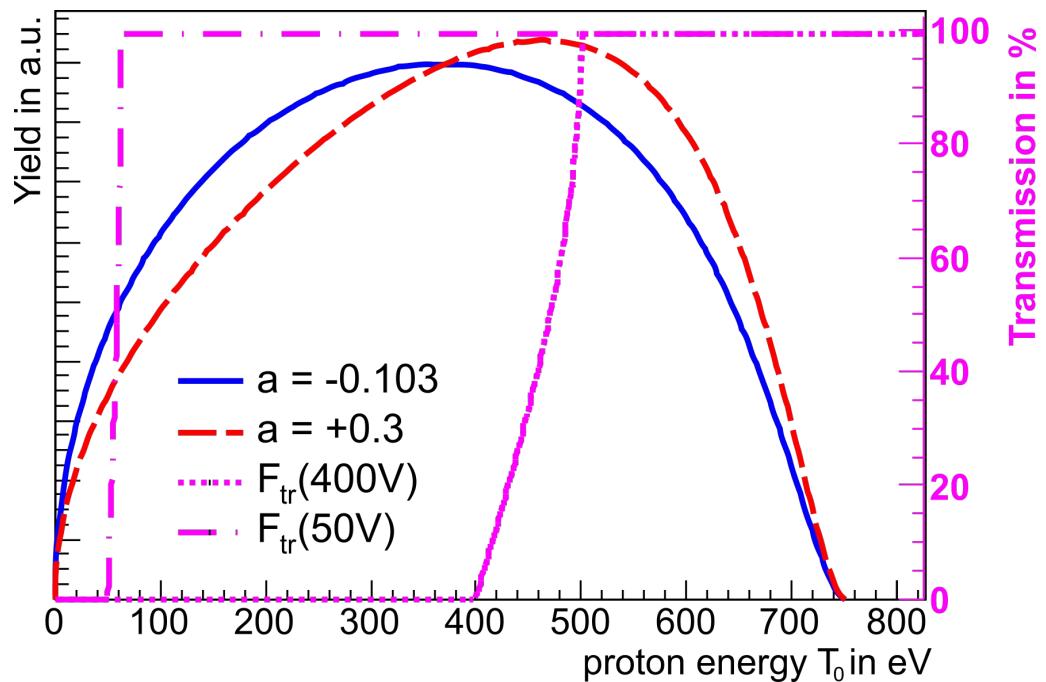




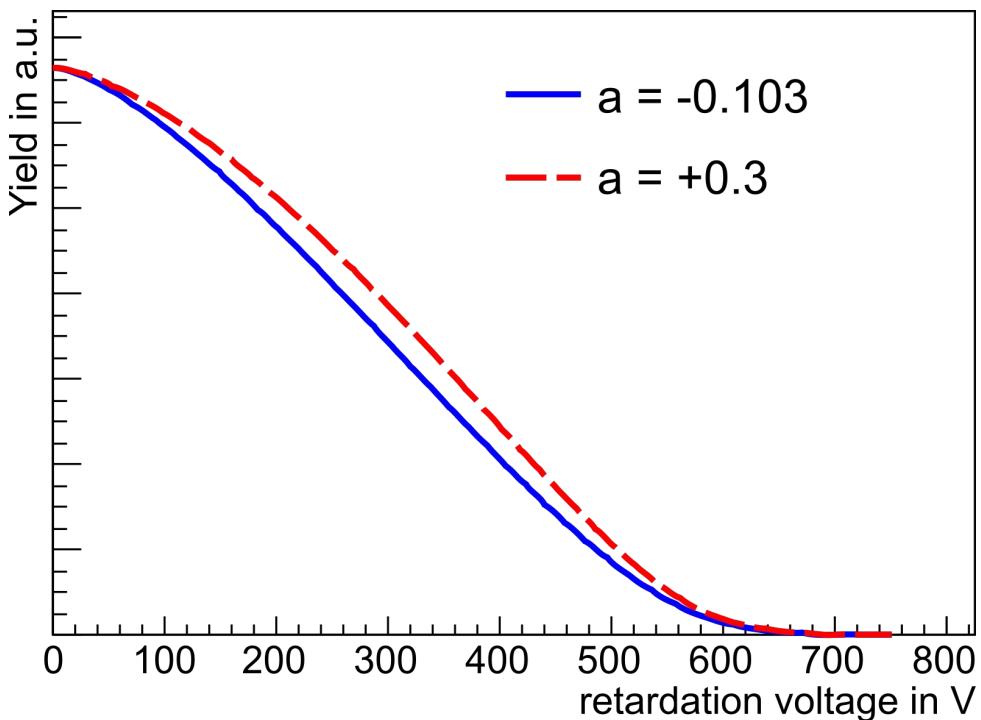
# Recoil energy spectrum



Measurement of the  $\beta-\nu$  angular correlation  
via the energy spectrum of the decay protons

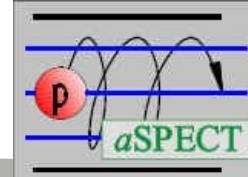


Integral proton spectra

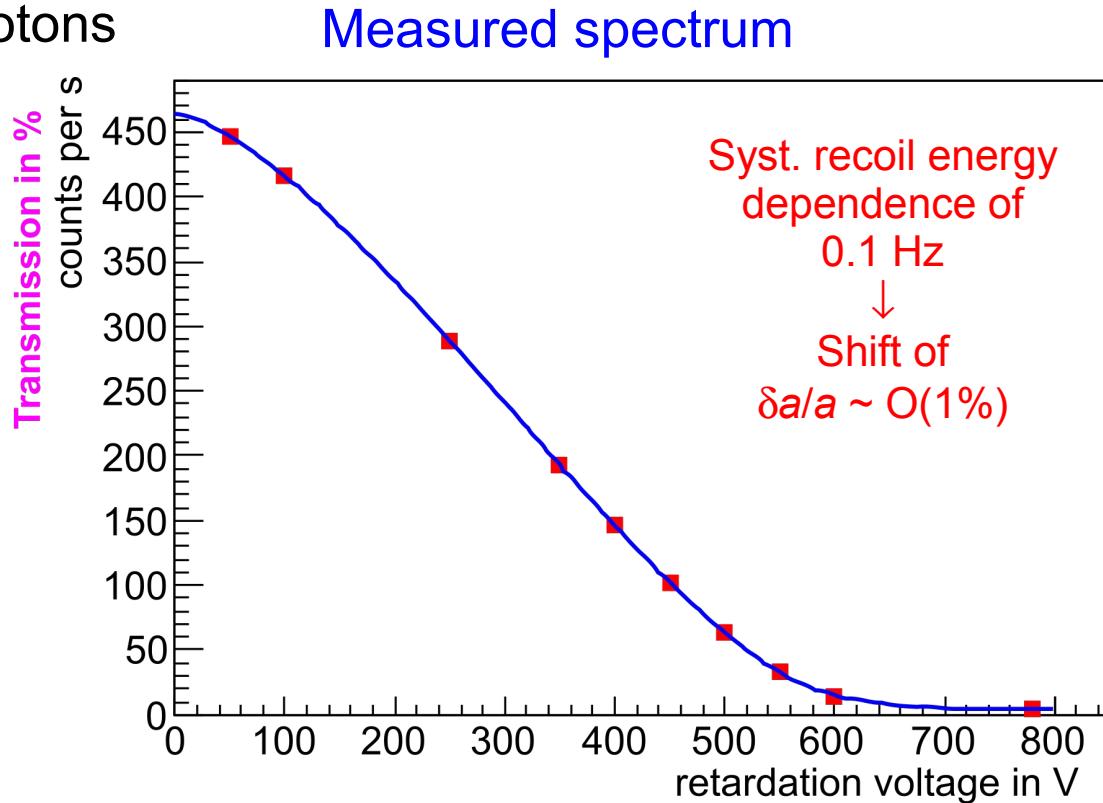
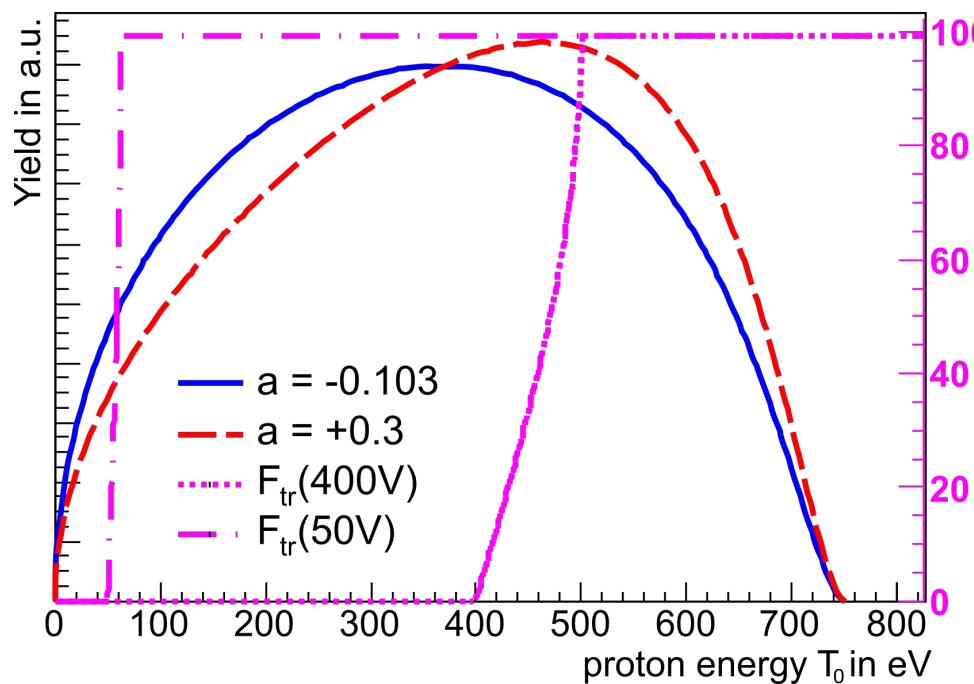




# Recoil energy spectrum



Measurement of the  $\beta-\nu$  angular correlation via the energy spectrum of the decay protons

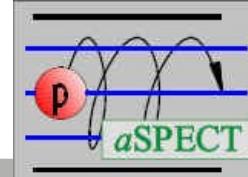


Successfull beam time at the cold neutron beam line PF1B at ILL in 2013!

Understand and determine the systematic effects!



# Systematic uncertainties



Procedure:

- Measure the effect
- Determine its energy dependence (recoil energy or ret. voltage)
- Include the energy dependence as a correction in the fit

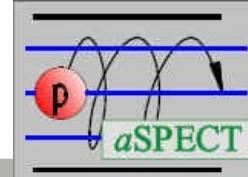
✓ DAQ effects	from data & offline measurements
✓ magnetic field ratio $r_B$	NMR & Hall probe measurements
✓ background	from data & dedicated measurements
✓ pile-up/upper integration limit	from pulse FADC data
✓ backscattering/lower integration limit	from data & simulations
✓ retardation voltage $U_A$	high precision DVM, KP data, simulations
✓ edge effect	semi-analytical calculations, simulations, data
✓ fields in DV	from data & simulations

Multidimensional fit including  
the systematic corrections and their uncertainties  
To give the fully correlated uncertainty of a

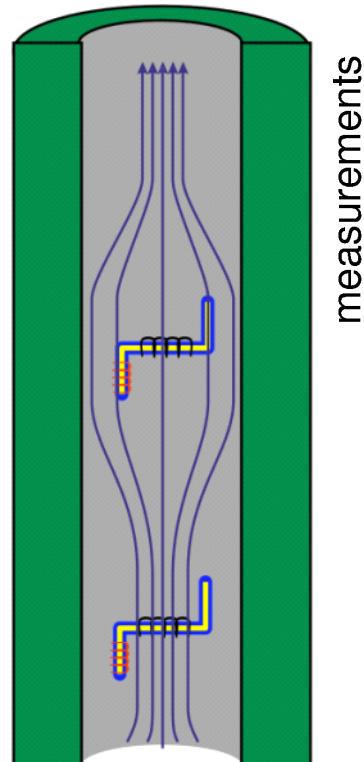
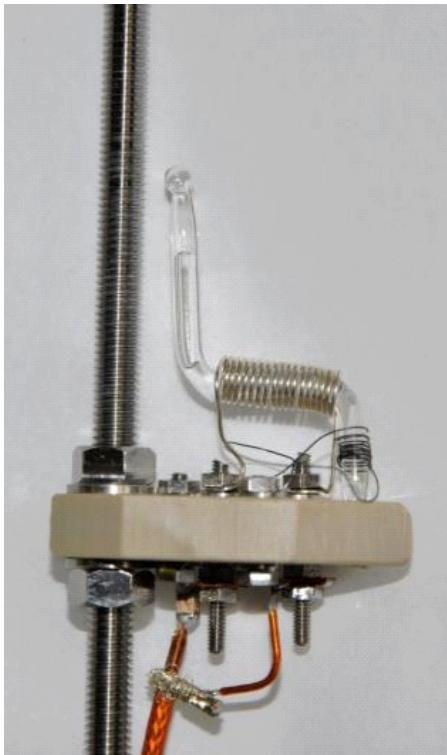
For details of the fit see  
the poster by A. Wunderle



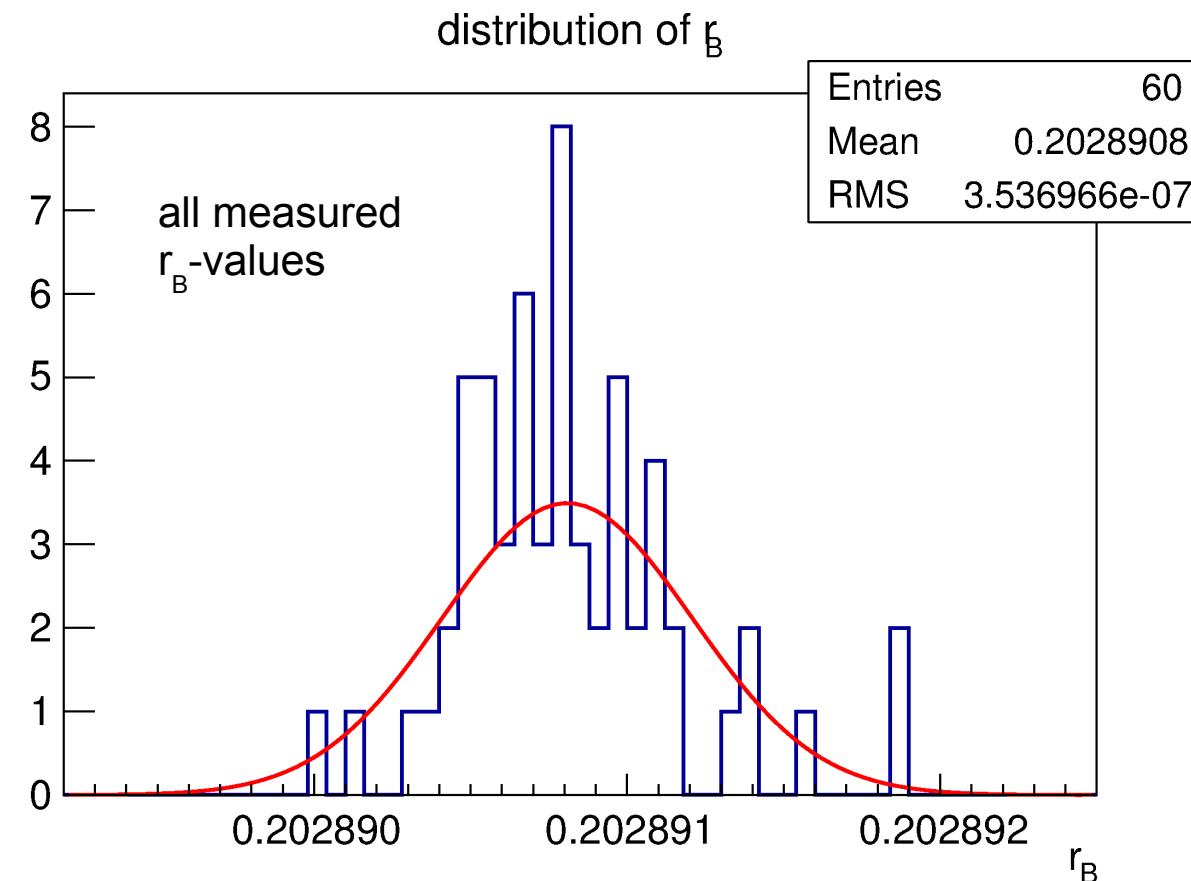
# B-field ration $r_B$



## Nuclear Magnetic Resonance measurement



measurements



$$\Delta a/a \approx 10 \Delta r_B / r_B$$

$$\Delta a/a \approx 1\% \Leftrightarrow \Delta r_B / r_B \approx 1 \cdot 10^{-3}$$

$\Rightarrow \Delta r_B / r_B \leq 10^{-4}$  to be neglegible

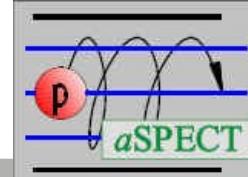
$$\text{rms-fluctuation of } r_B$$

$$\Delta r_B / r_B \approx 2 \cdot 10^{-6}$$

field inhomogeneity suitable by design  
 → All right!

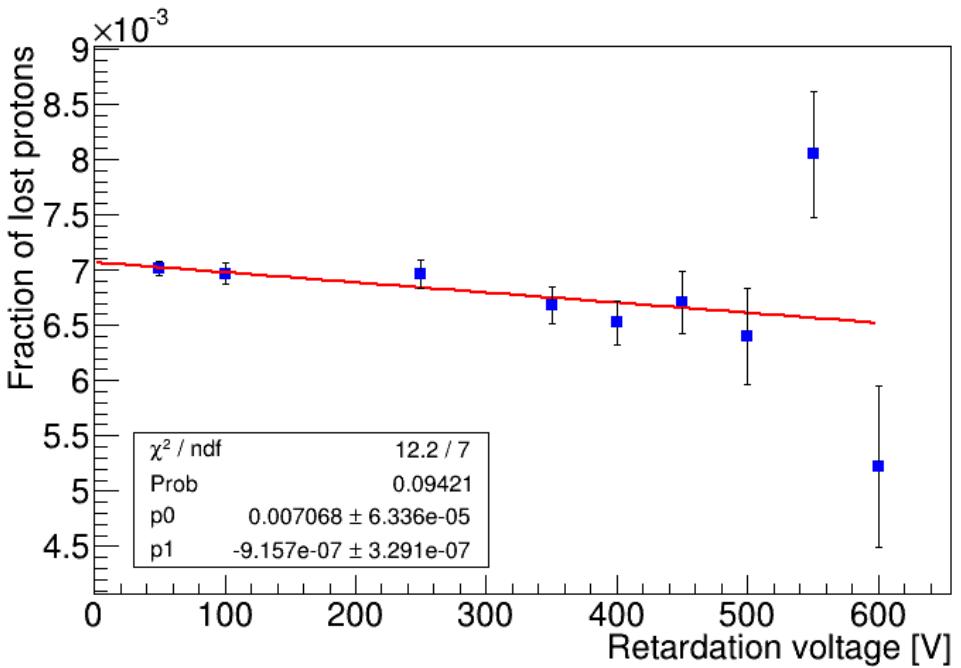
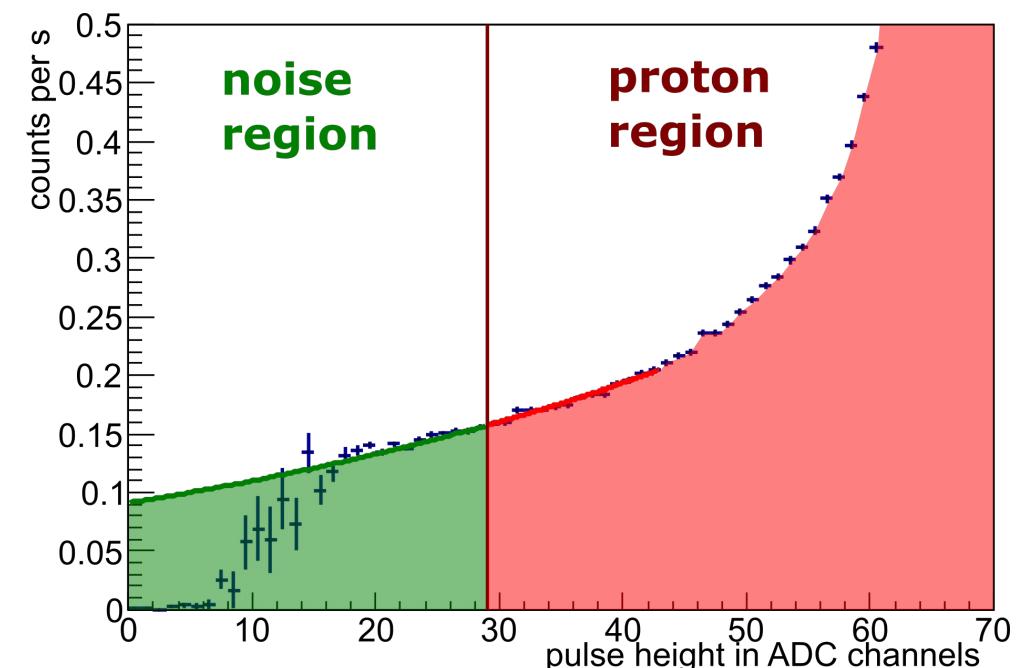


# Backscattering and lower integration limit



Problem: Lower integration limit cuts off backscatter tail  $\Rightarrow$  proton losses

Solution: Use extrapolation of measured pulse height spectrum

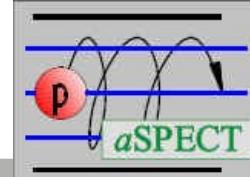


Retardation voltage dependent  
correction  
to the recoil proton spectrum

Size of the shift:  
 $\sim 0.5\text{e-}3 \leftrightarrow 0.2 \text{ Hz}$   
 $\delta a/a = O(2\%)$

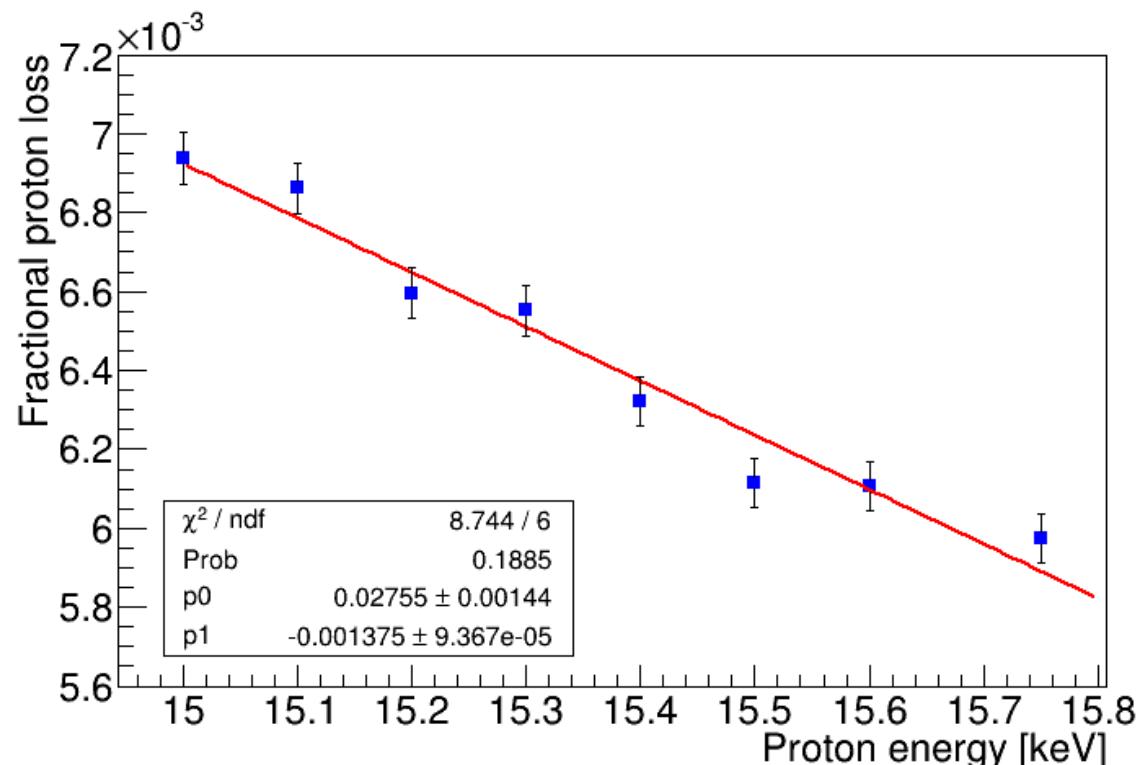


# Backscattering in the deadlayer



Problem: Backscattering in the deadlayer  $\Rightarrow$  proton losses

Solution: Tracking simulation using SRIM

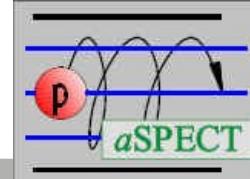


Recoil energy dependent  
correction  
to the recoil proton spectrum

Size of the effect:  
 $\sim 1\text{e-}3 \leftrightarrow 0.4 \text{ Hz}$   
 $\delta a/a = O(4\%)$



# Edge effect



Problem: p-detector covers just a part of the beam profile

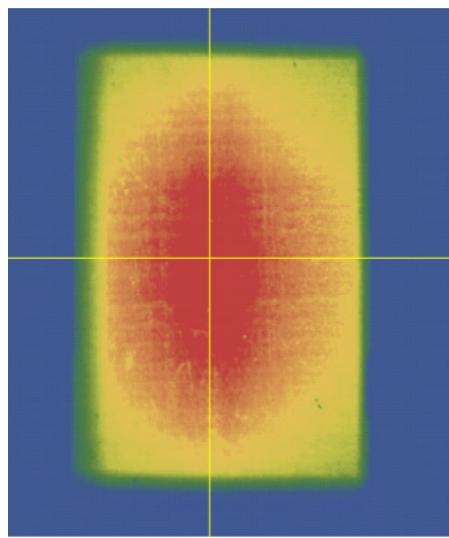


beam profile is inhomogeneous

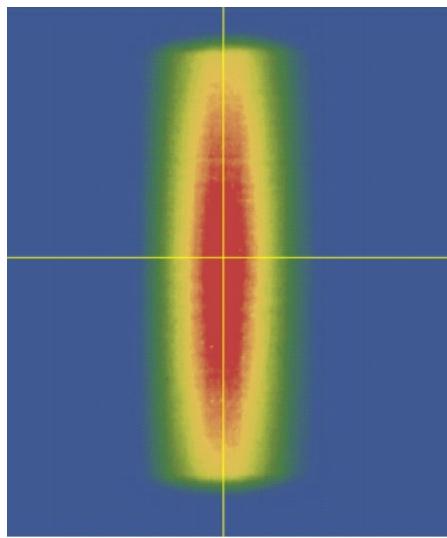


recoil energy dependent proton loss

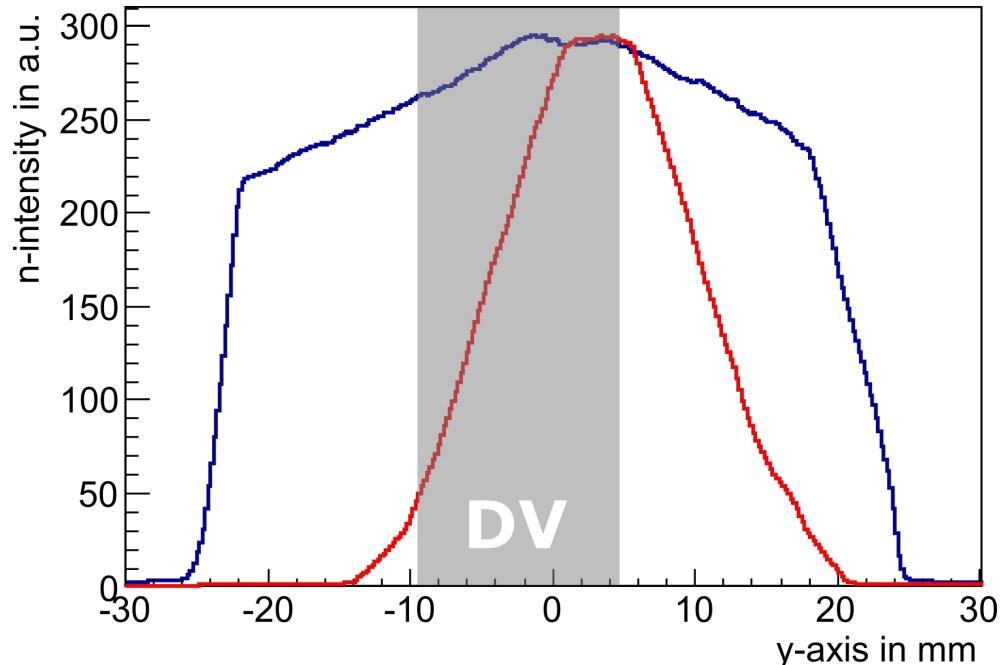
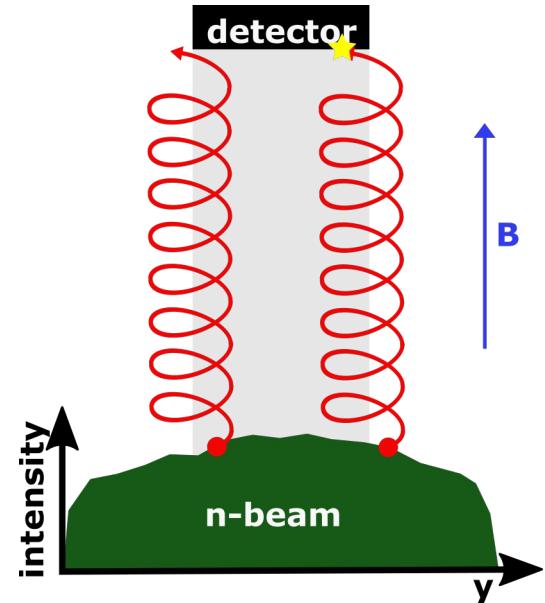
Solution: Effect measured using two different beam profiles  
Particle tracking simulations through aSPECT



standard

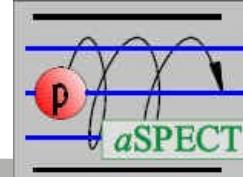


reduced  
(for enhanced edge effect)

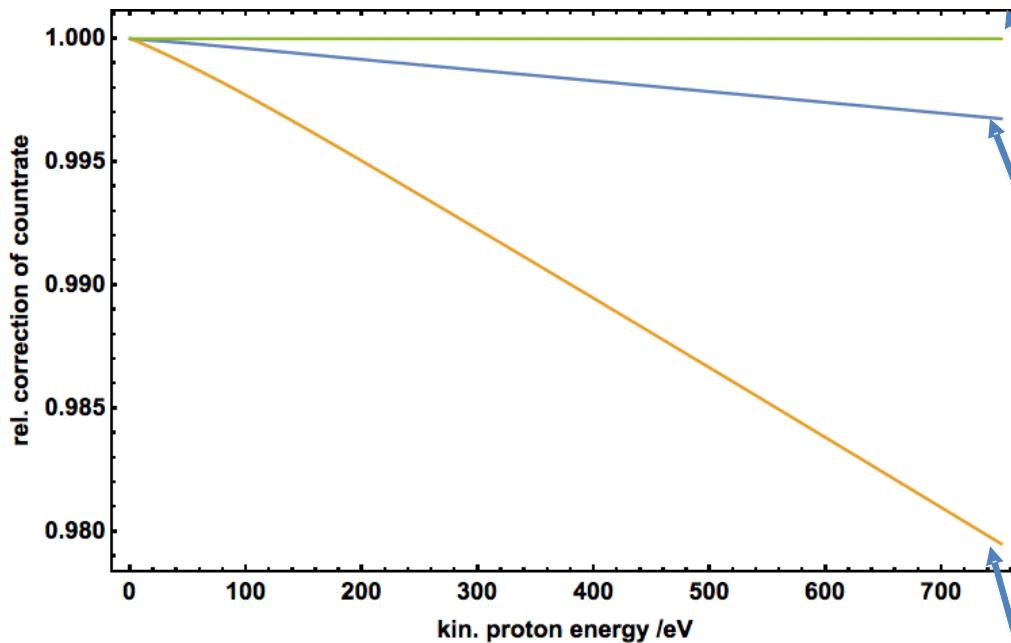




# Edge effect



## First order correction



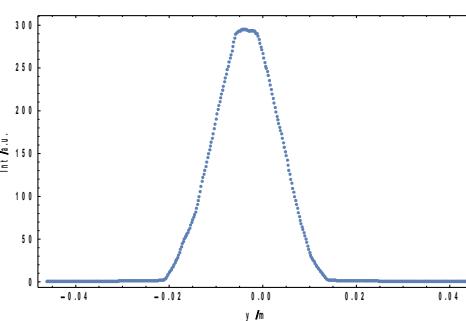
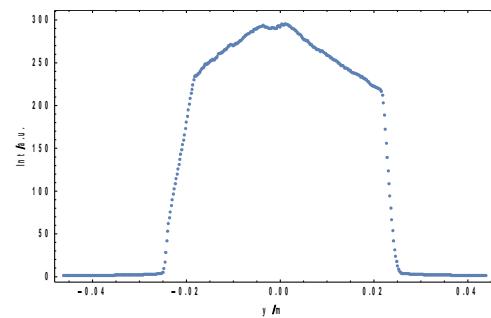
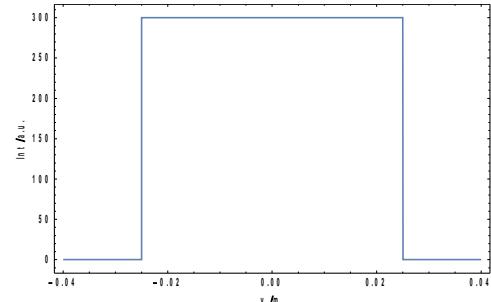
**uniform beamprofile**  
- *no edge effect*

**standard beamprofile**  
- “normal” edge effect

Size of the shift  
 $\sim 1e-3 \leftrightarrow 0.4 \text{ Hz}$   
 $\delta a/a = O(4\%)$

Recoil energy dependent  
correction  
to the recoil proton spectrum

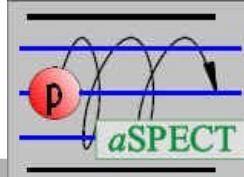
**reduced beamprofile**  
- *enhanced edge effect*



Detailed correction from particle tracking simulations

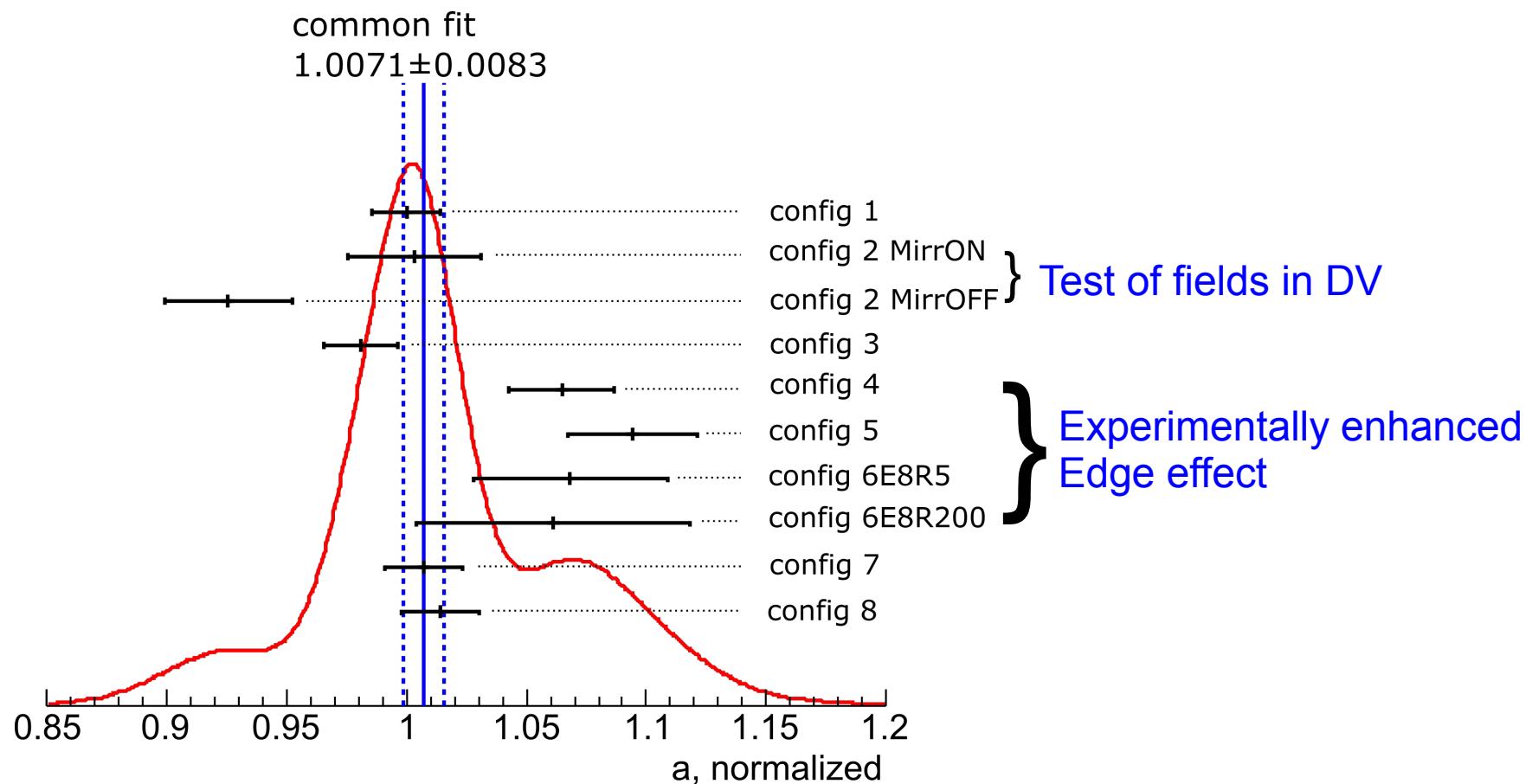


# Distribution of $a$ -values



## Measurements:

- Config 1, 3, 7: Normal data taking  
Config 2, 4, 5, 6: Dedicated tests with enhanced systematics





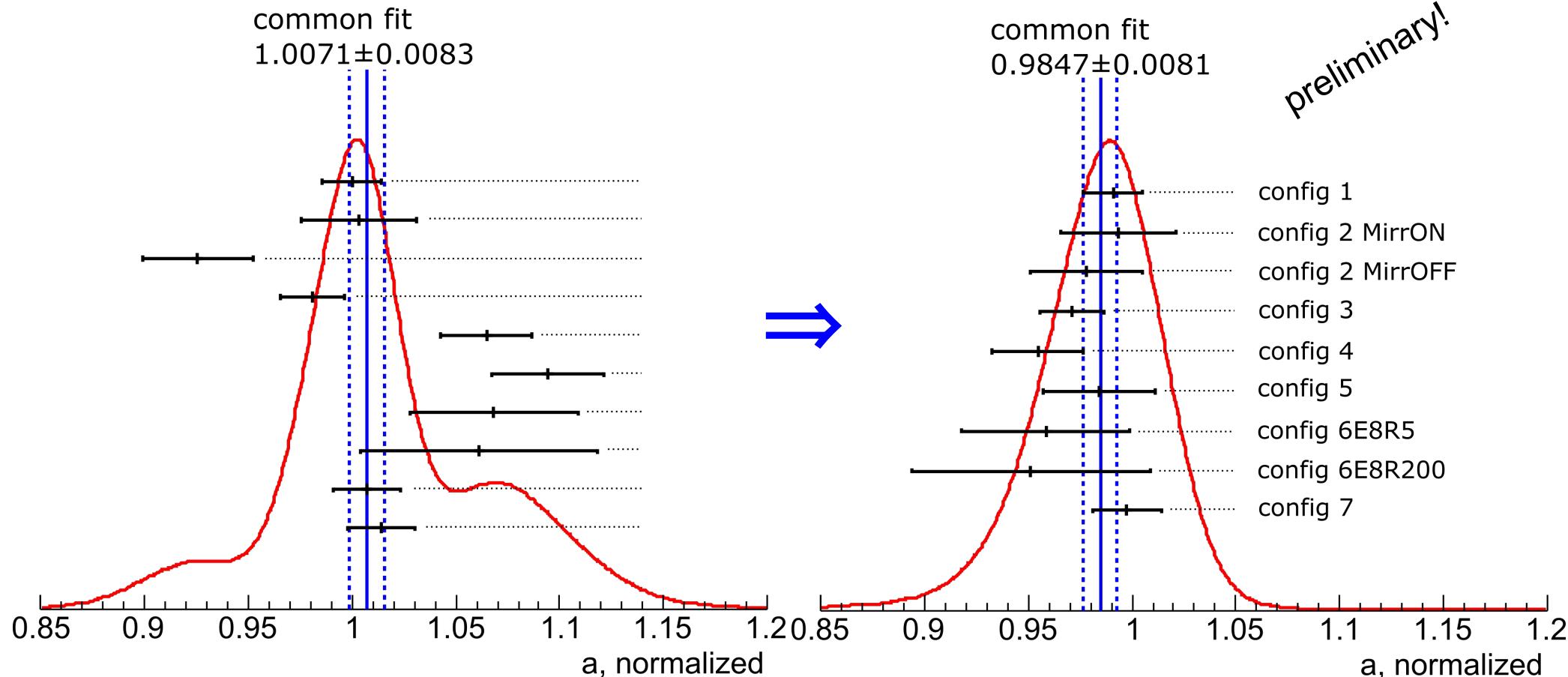
# Distribution of a-values

## Measurements:

Config 1, 3, 7: Normal data taking

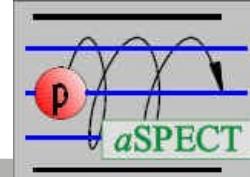
Config 2, 4, 5, 6: Dedicated tests with enhanced systematics

Include first order corrections for edge effect, field corrections in DV





# Distribution of a-values

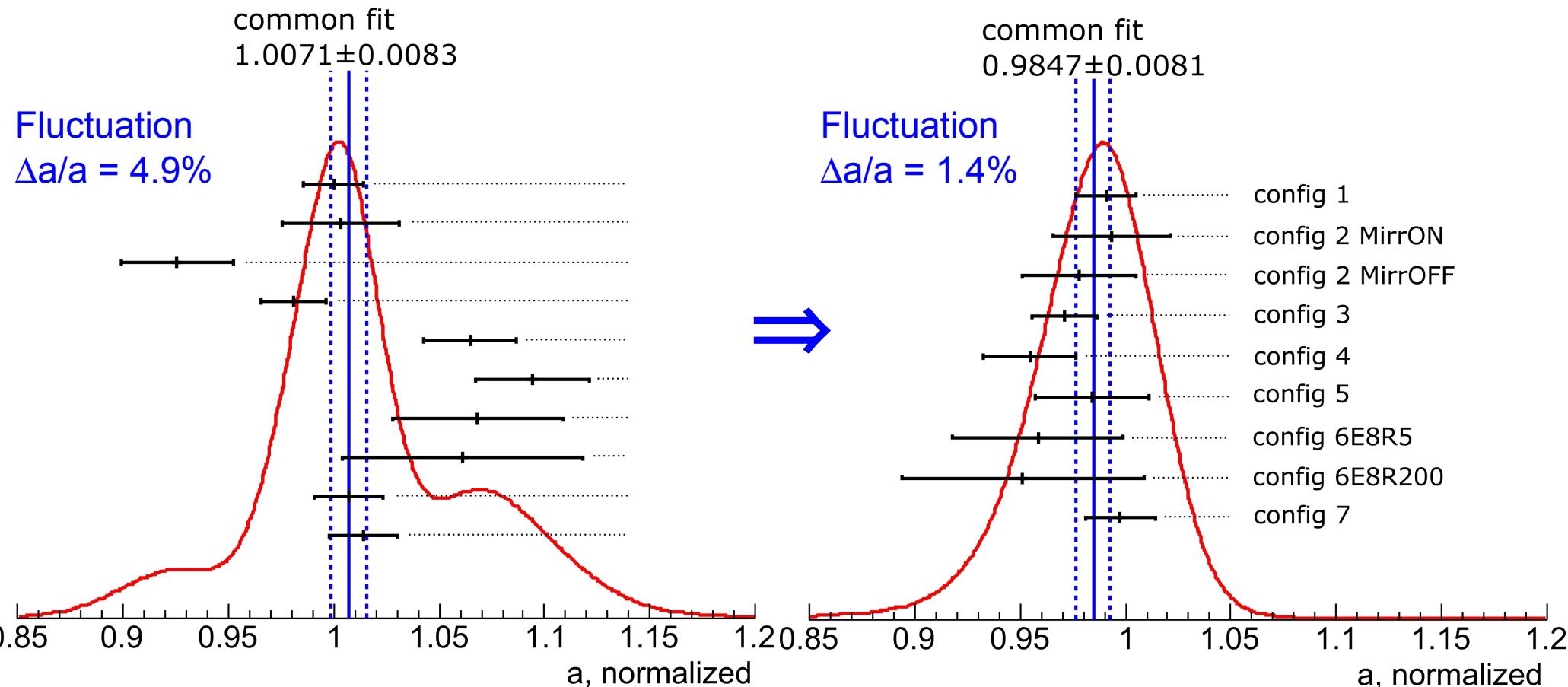


## Measurements:

Config 1, 3, 7: Normal data taking

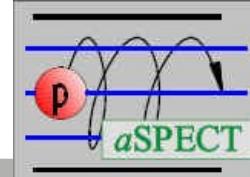
Config 2, 4, 5, 6: Dedicated tests with enhanced systematics

Include first order corrections for edge effect, field corrections in DV





# Distribution of a-values



## Measurements:

Config 1, 3, 7: Normal data taking

Config 2, 4, 5, 6: Dedicated tests with enhanced systematics

Include first order corrections for edge effect, field corrections in DV

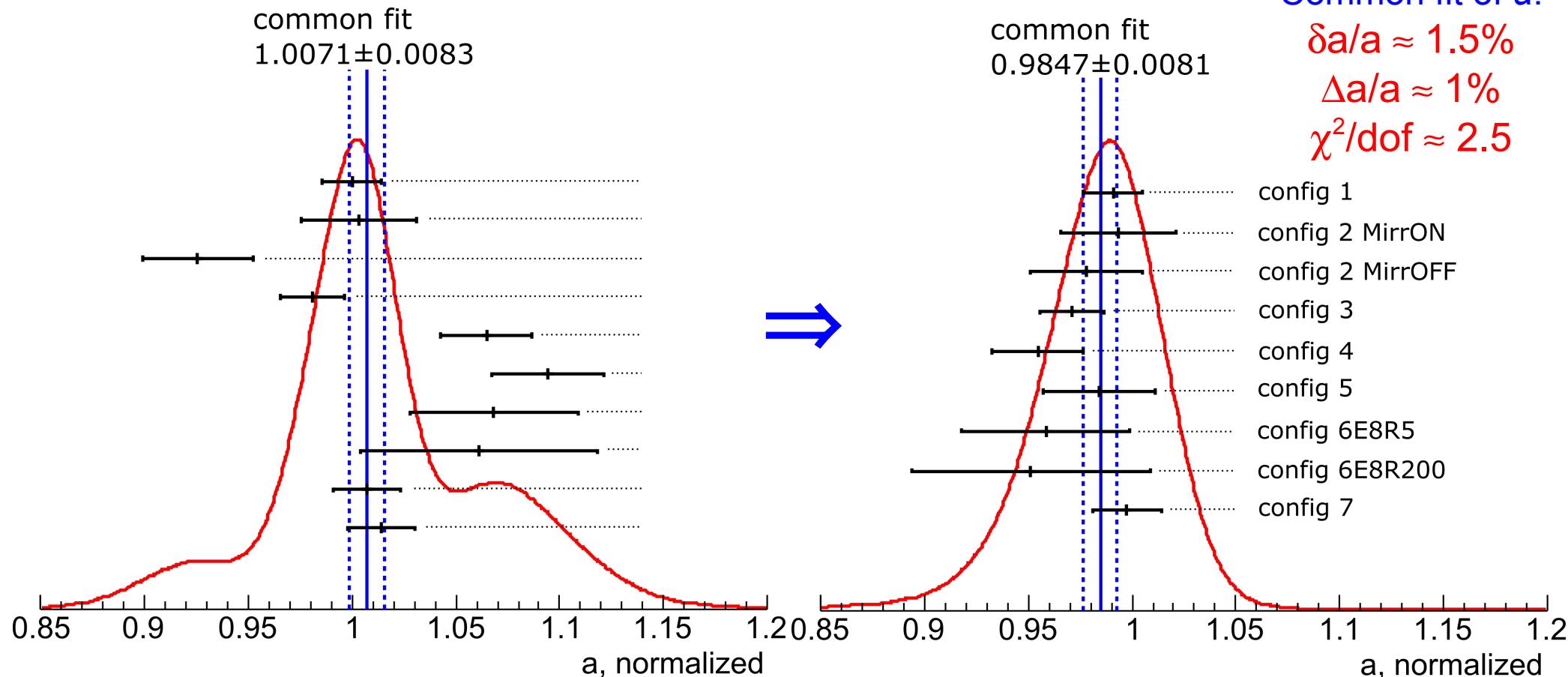
preliminary!

Common fit of  $a$ :

$$\delta a/a \approx 1.5\%$$

$$\Delta a/a \approx 1\%$$

$$\chi^2/\text{dof} \approx 2.5$$





## Finalize the investigation of the systematic effects

- ✓ DAQ effects
- ✓ magnetic field ratio  $r_B$
- ✓ background
- ✓ pile-up/upper integration limit
- ✓ backscattering/lower integration limit
- ✓ retardation voltage  $U_A$  → field simulations have started
- ✓ edge effect → tracking simulations to be started
- ✓ fields in DV → consistency tests
- ✓ misc. stuff

And include all in the final fit (including their uncertainties)  
to get the correlated uncertainty on the  $\beta$ - $v$  angular correlation coefficient  $a$ .

Present status:  $\Delta a/a < 2\%$  is feasible

Further details available at the aSPECT posters



# 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  
J. Haack, Mainz  
R. Horn, Mainz  
K. U. Ross, Mainz  
D. Stipp, Mainz  
J. Kahlenberg, Mainz  
E. Bickmann, Mainz  
M. Klopf, Wien



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