# The WITCH Experiment

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# Outline

- Introduction & motivation
- Overview of the WITCH setup
- Online experiments
- Results
- Outlook

# Motivation: New Physics

Search for physics beyond the standard model

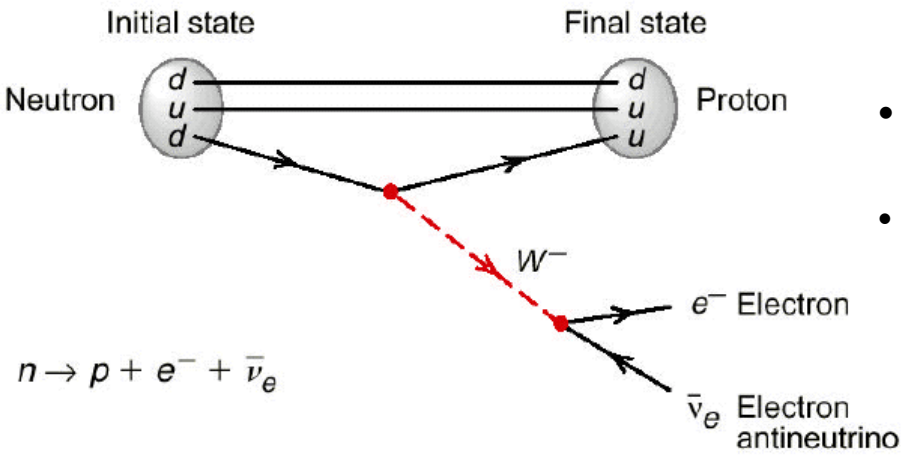
## High energy

*Direct production - LHC*

## High precision

*Low energy – β-decay*

Beta decay:

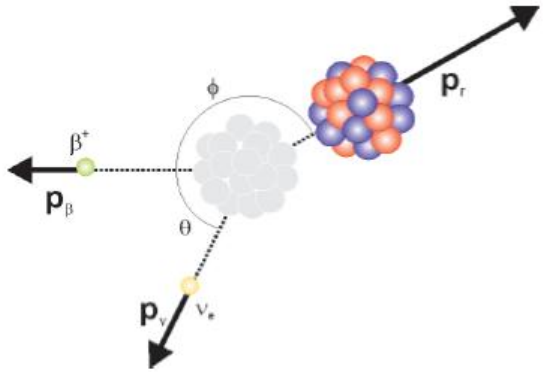



- Observables: Energy, angular correlations
- Historical: Parity violation on Co

# Introduction

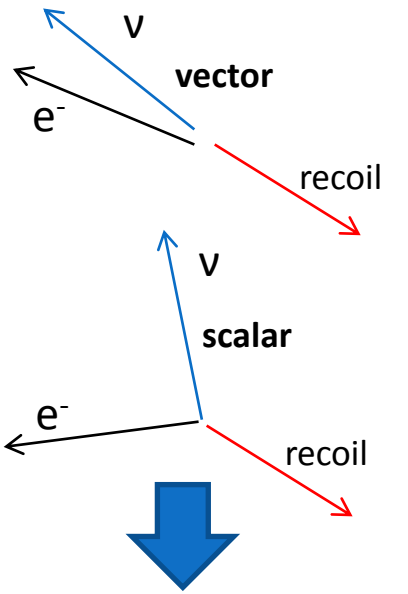
$$\mathcal{H} = g \sum_{j=S,V,A,T,P} (\overline{\psi}_p \mathcal{O}^j \psi_n)(\overline{\psi}_\beta \mathcal{O}_j (C_j + C_j' \gamma_5)\psi_\nu) + h.c.$$

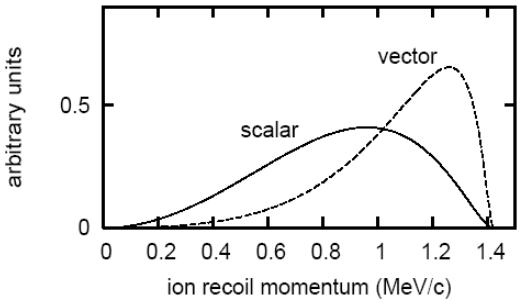
$$W(E,\theta) = W(E)\,[1 + a\,\frac{v_e}{c}\cos(\theta) + b\,\frac{m}{E}\,]$$



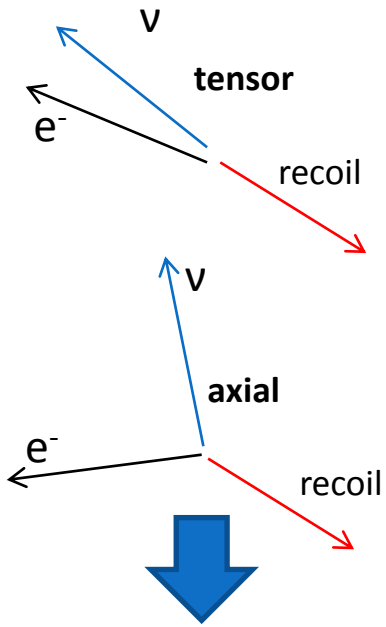

Current experimental limits:
(from nuclear & neutron $\beta$ decay)
$\frac{C_S}{C_V} < 7\%,\ \frac{C_T}{C_A} < 9\%$

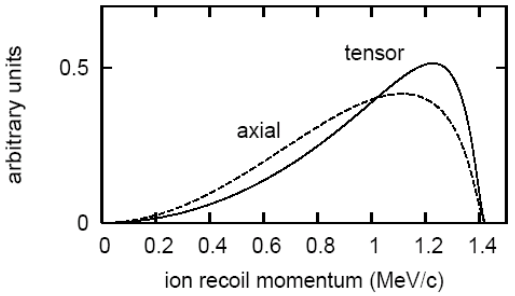
**Fermi transitions**



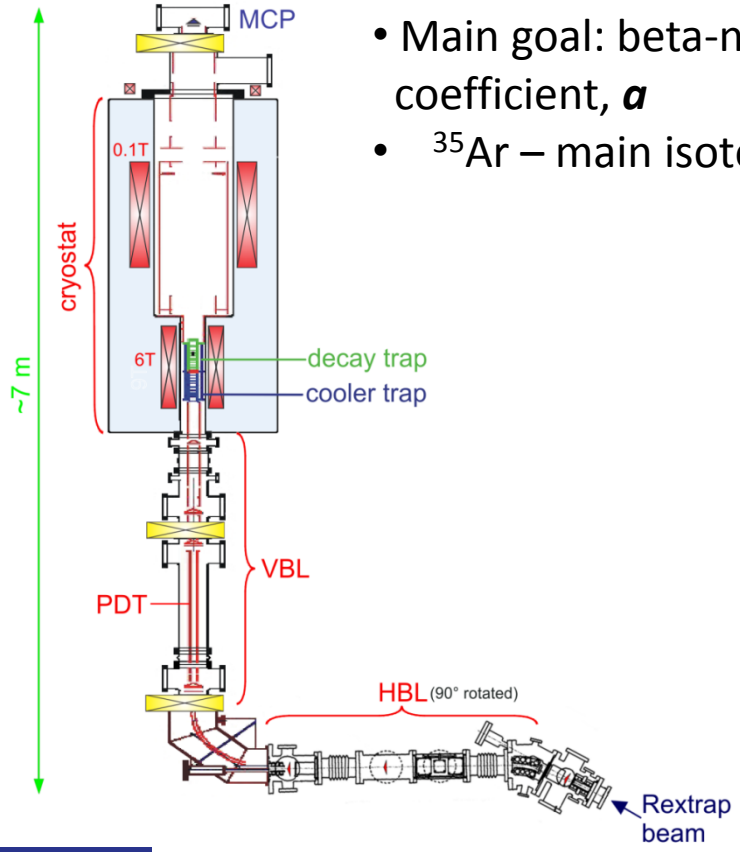

**Gamow-Teller transitions**

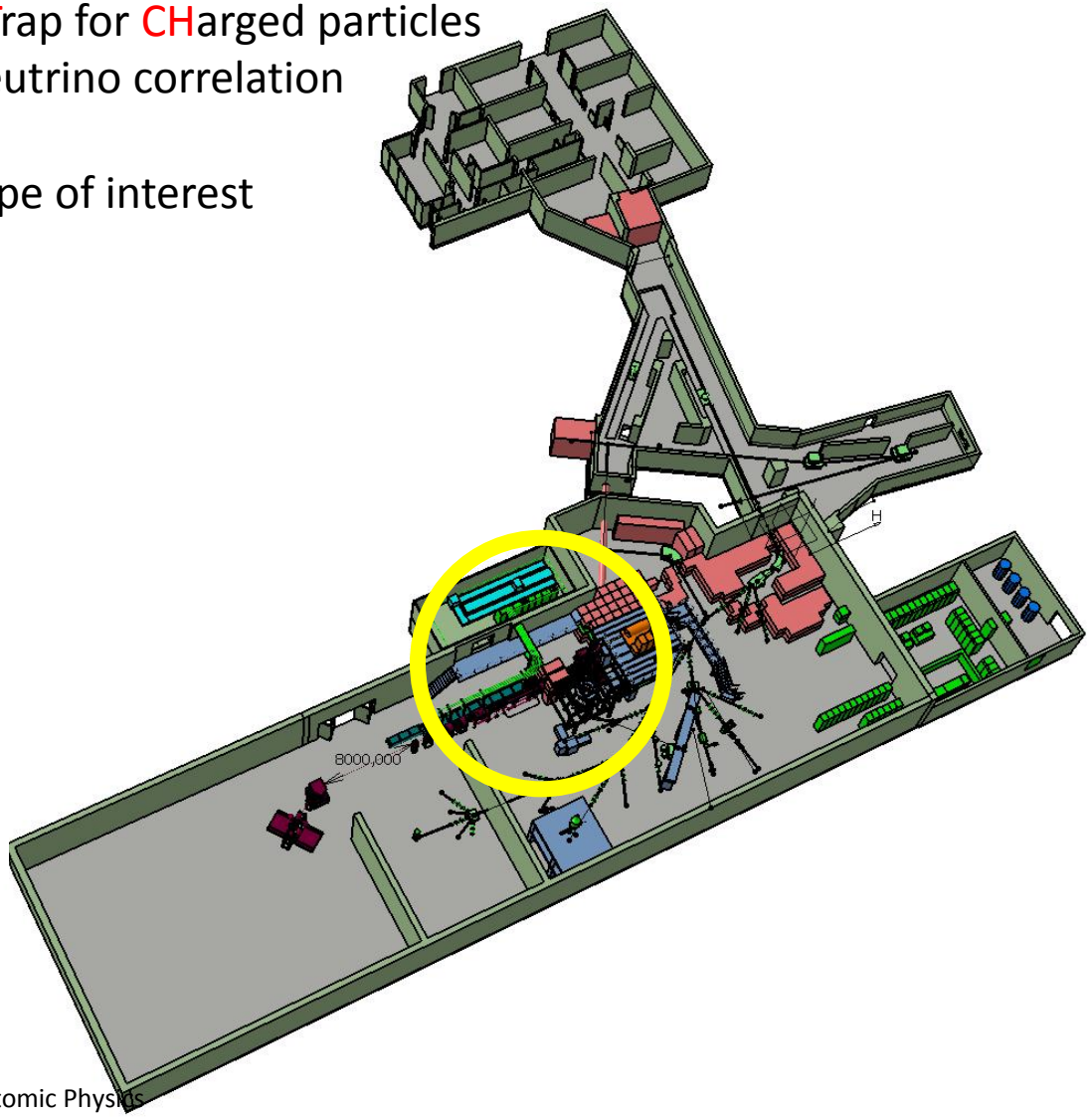


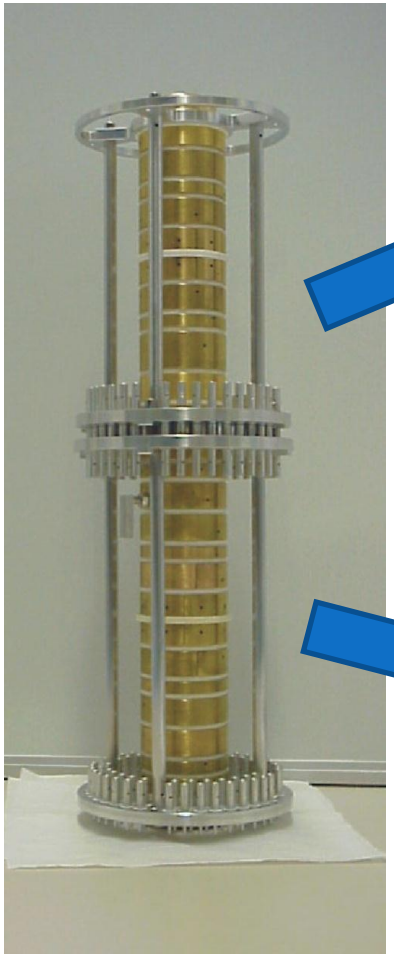
# WITCH experiment (CERN/ISOLDE)

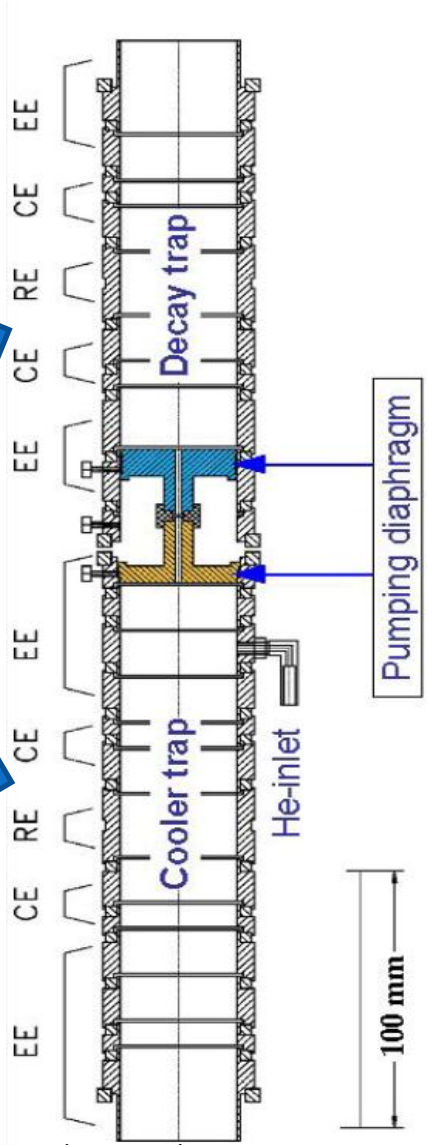
- Weak Interaction Trap for CHarged particles
- Main goal: beta-neutrino correlation coefficient, ***a***
- $^{35}$Ar – main isotope of interest



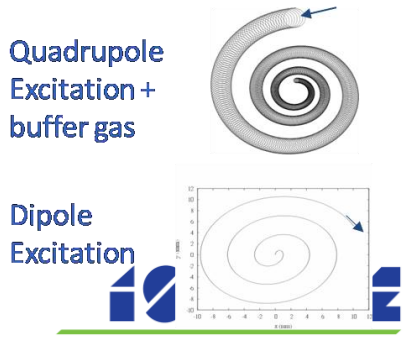



# Penning traps at WITCH

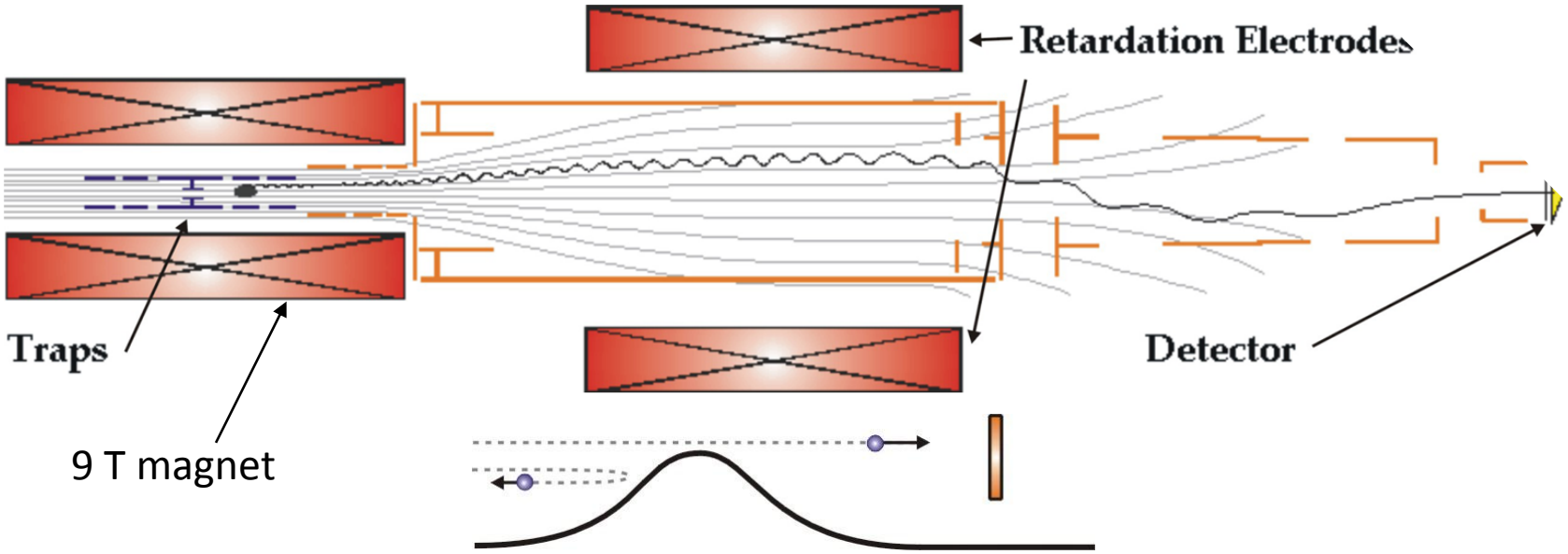





- **Scattering-free sources**
- **He buffer gas** in the cooler trap
- **Dipole excitation** at magnetron $\omega_-$ frequency – mass independent removal from trap center
- **Quadrupole excitation** at cyclotron frequency $\omega_c$ – mass selective centering & buffer gas --> cooling of the ion cloud

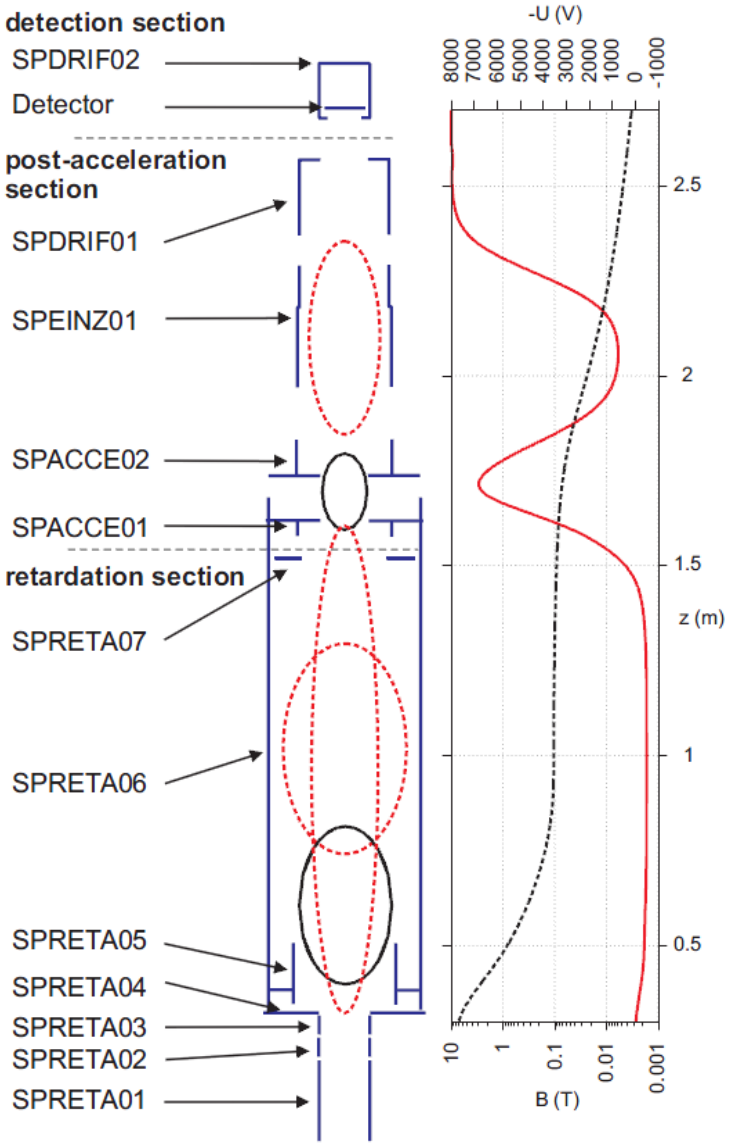


# WITCH: MAC-E filter




- High field (9 T) at the traps, low (0.1 T) in the analyzing plane
- Adiabatic approximation: field gradient in a single cyclotron gyration radius is small
- $E_{cycl}$ /B is an adiabatic invariant -> if $B_{source} >> B_{plane}$ , then $E_{cycl,plane} << E_{cycl,source}$
- Combination of electrostatic filter and inhomogenous mag. field => high energy resolution + high statistics

# Unwanted Penning-like traps in the spectrometer



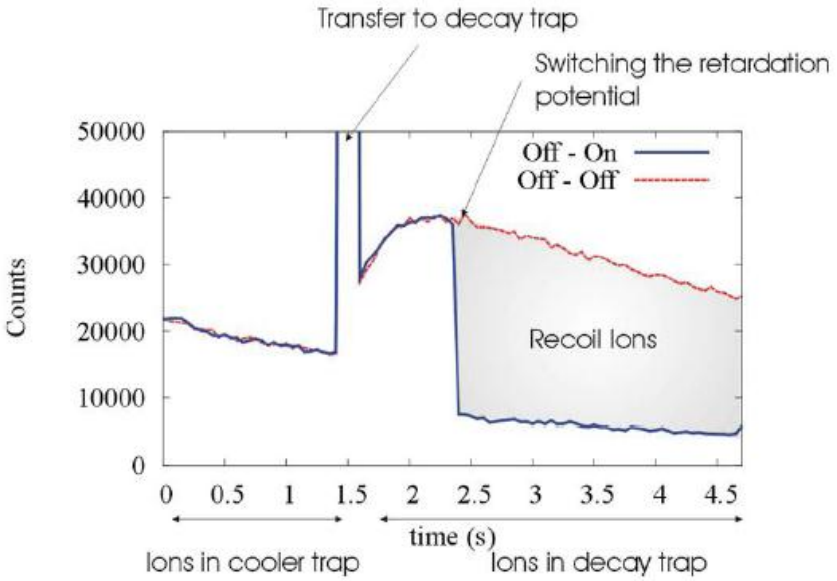

spectrometer

- Formed at undesirable locations due to the combination of magnetic and electric fields
- Two electrodes connected by a magnetic field line
- Primary electron emission: by particle collisions (electron and ion sputtering, Compton scattering, photoelectric effect) and by field emission
- Typical mechanism of a Penning discharge: electrons from the cathode enter the Penning-like trap and gain kinetic energy -> causing ionisation of the rest gas -> secondary electrons create more ionisation and positive ions travel to the cathode and create more secondary electrons
- Solutions: compensating magnet and a wire in the spectrometer

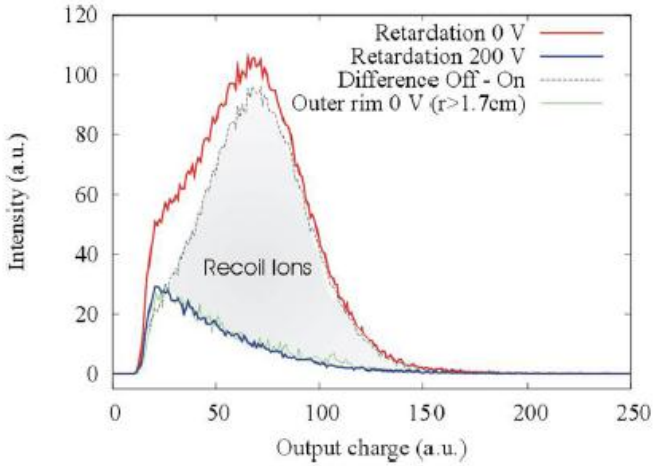
# WITCH Results: Proof of principle in 2006[1]

- Test case: $^{124}$In

Recoil spectrum




Charge state distribution

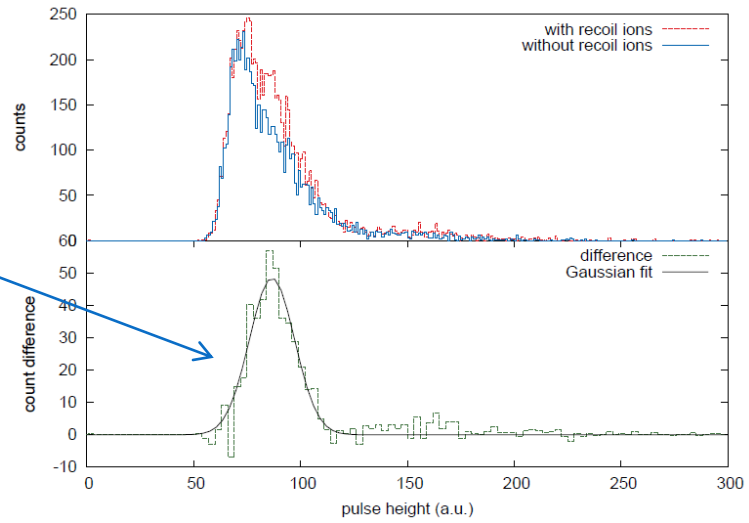



- showing that ions can be trapped and retarded
- but taken with the einzel lens as retardation electrode

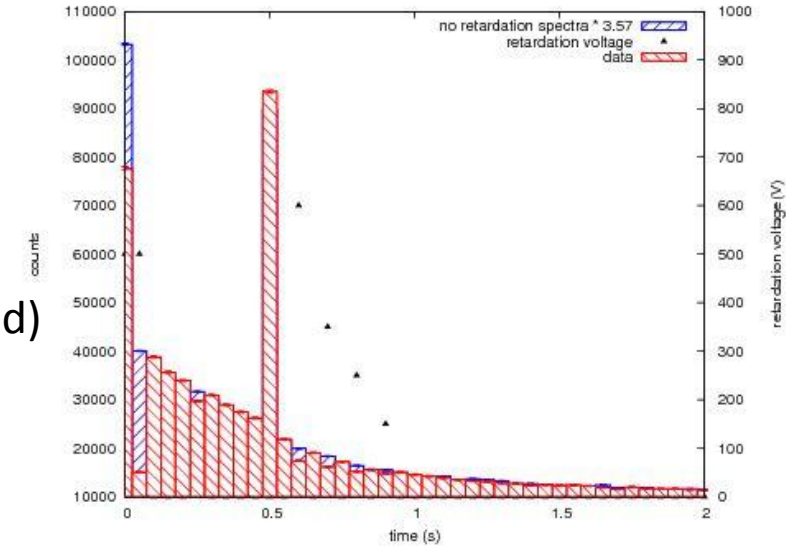
[1]**M. Beck et al., The European Physical Journal A 47, 9 (2010).**

# WITCH results: June 2011

- **Recoil ions observation**
  - Gaussian shape of the pulse-height distribution difference indicates recoil ions

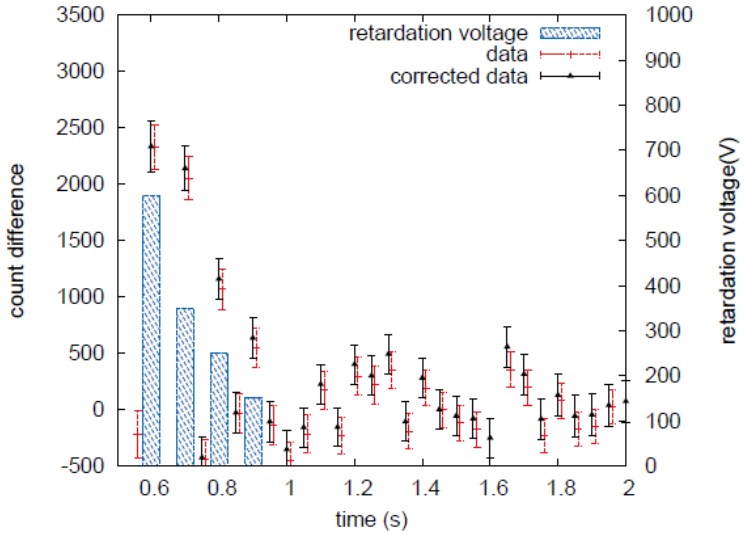



- Recoil ion time spectra
- 500 ms cooling in the cooler trap
- Afterwards capture in the decay trap
- No retardation (blue) & retardation (red)



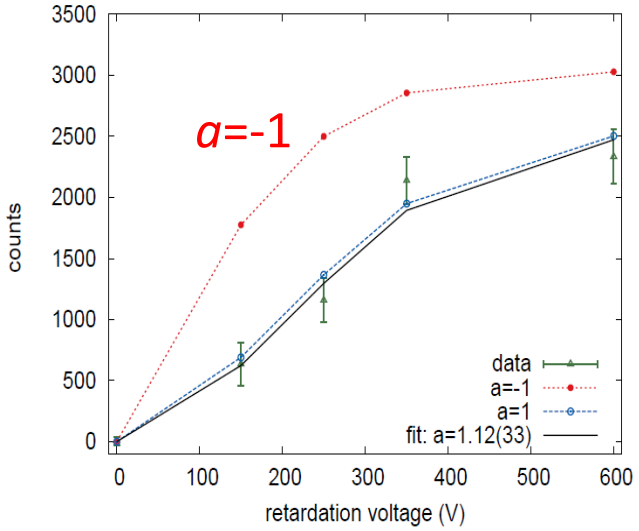
# WITCH results: June 2011[2]

Difference in retardation spectra and non-retarded spectra




(a) Data set 1.

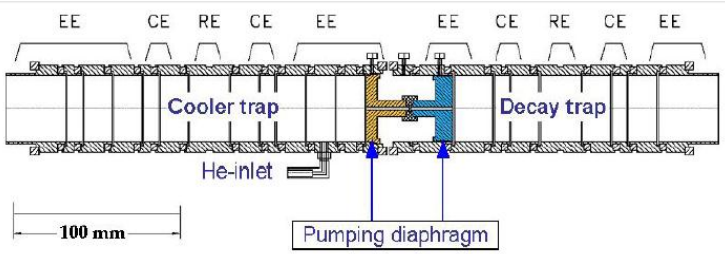
Fit of ***a*** to simulated values



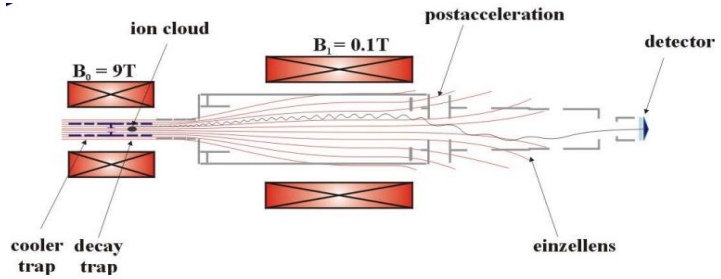

- Result: $a$ = 1.12(33)
- SM: a=0.9004(16)
- First determination of ***a*** with the WITCH setup

**[2]Van Gorp et al, Determination of the Beta-neutrino angular correlation coefficient, a, on $^{35}$Ar with the WITCH setup** (submitted to PRL)

# WITCH results: Simulations



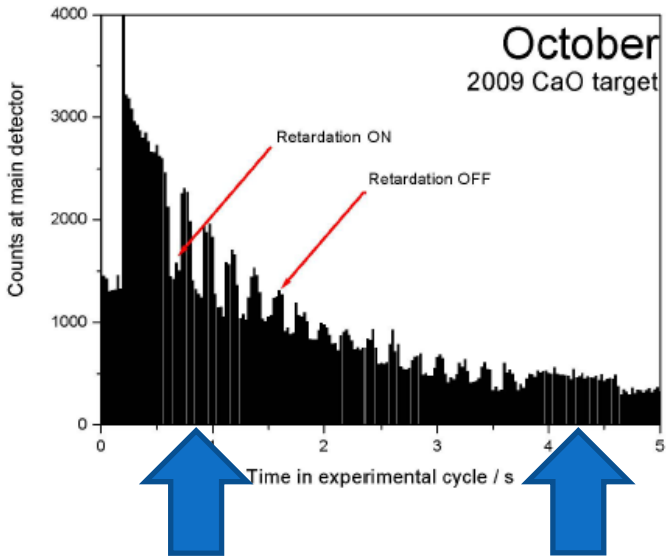

- **Ion cloud in the traps simulations:** Simbuca[1]
- Electric field map calculated with COMSOL
- Magnetic field map provided by manufacturer



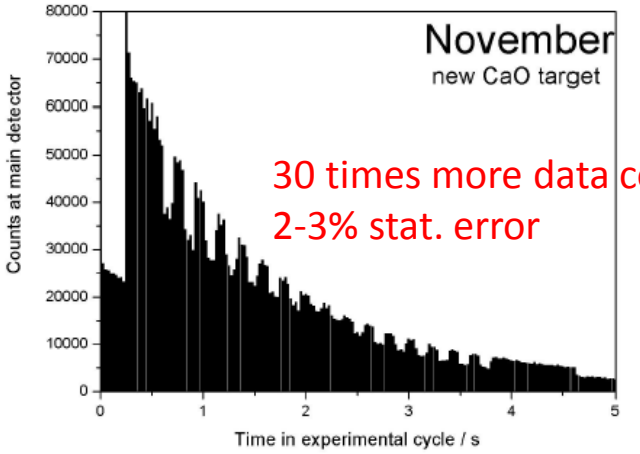

- **Ion tracking in the spectrometer:** SimWITCH
- Ion transport simulated for various retardation voltages (0 V – 450 V)
- Also for all $^{35}Ar$ charge states ($1^+$, $2^+$, $3^+$, $4^+$, $5^+$) (*charge state measurement by LPC trap@GANIL*)

[1]S. Van Gorp et al. Nucl. Instr. and Meth. A 638 (2011) 192-200.

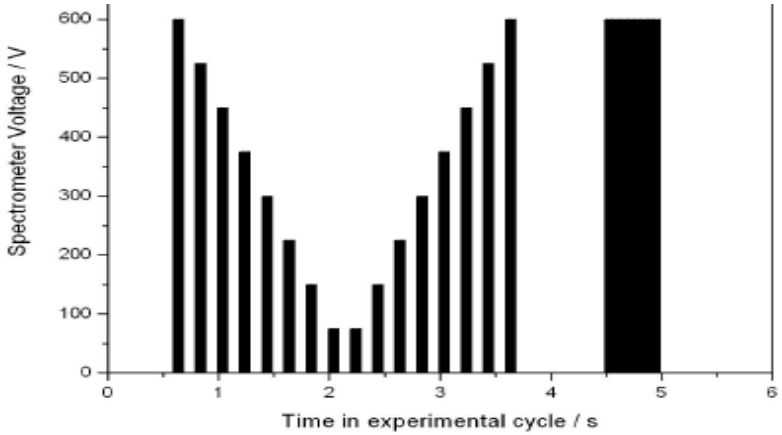
# WITCH results: October/November 2011

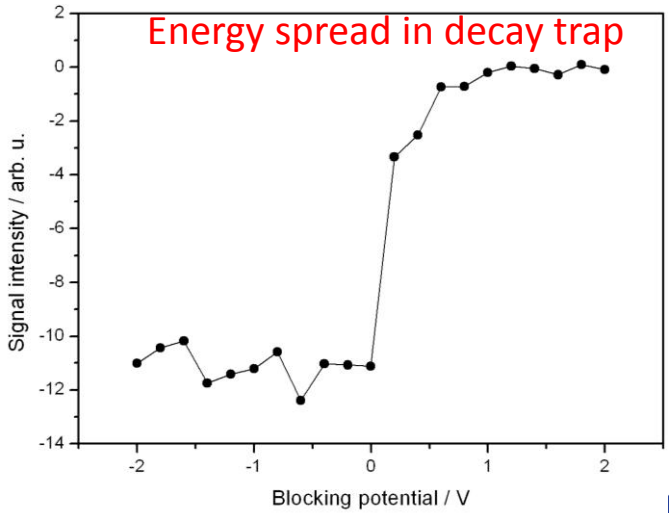



V-shaped retardation voltage pattern




30 times more data counts,
2-3% stat. error



# WITCH: Outlook

- Analysis of October/November data
- Systematic effects (misalignment of the traps due to baking)
- Misc. upgrades of the system
- Next run in Autumn 2012