Instituut voor Kern- en Stralingsfysica

KATHOLIEKE UNIVERSITEIT LEUVEN

Recent developments and results of WITCH

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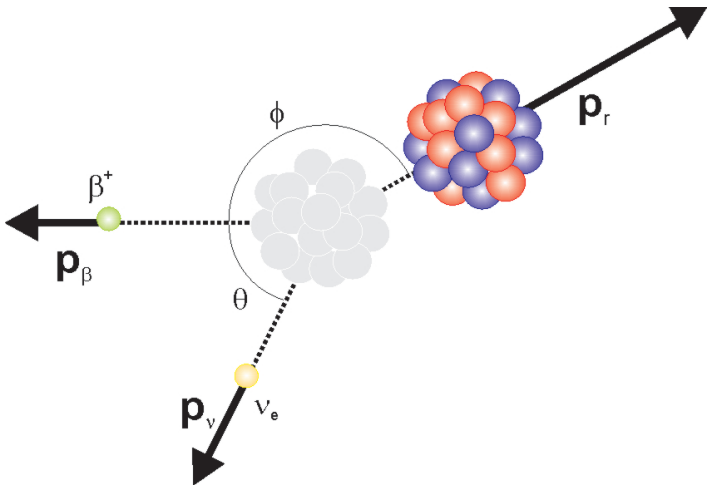
Outline

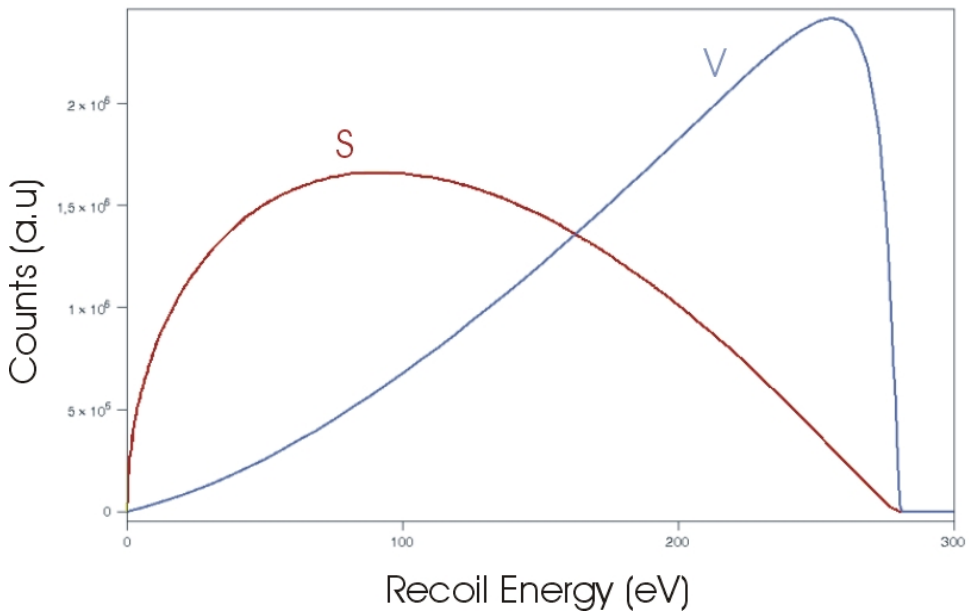
Physics motivation: β-ν angular correlation

$$\mathcal{H}_\beta = \mathcal{H}_S + \mathcal{H}_V + \mathcal{H}_T + \mathcal{H}_A + \mathcal{H}_P$$

e.g: Fermi β decay ($0^+ \rightarrow 0^+$)

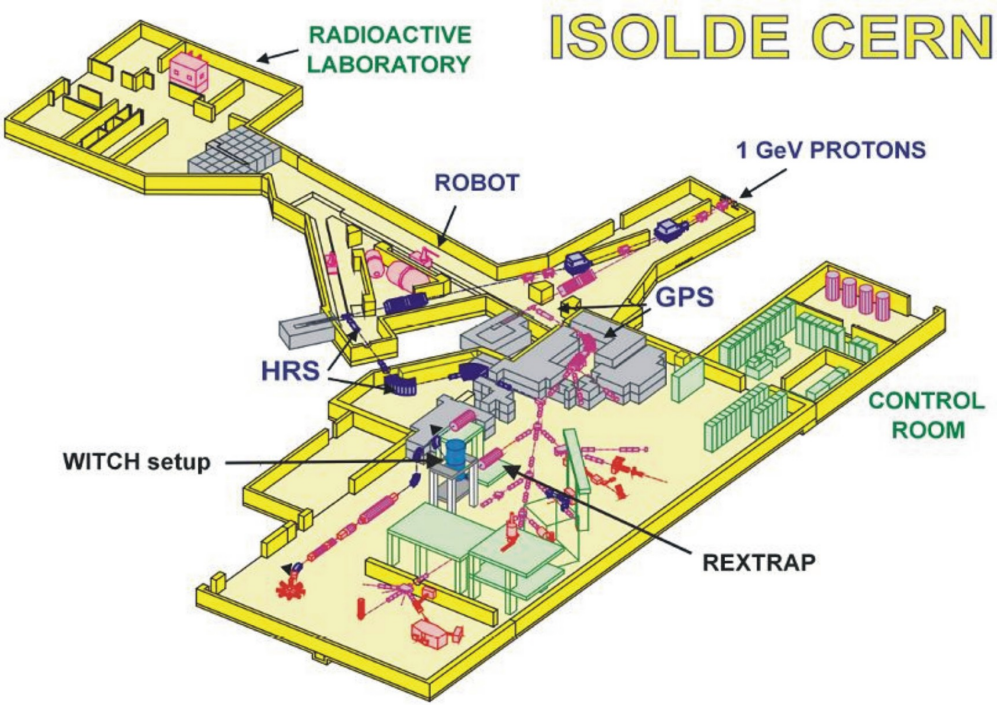
$$W(\theta) \approx 1 + a\frac{v}{c}cos\theta \qquad a \approx 1 - \frac{|C_S|^2 + |C_S'|^2}{|C_V|^2}$$

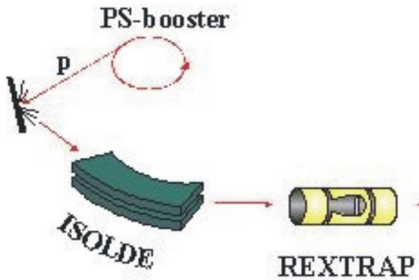


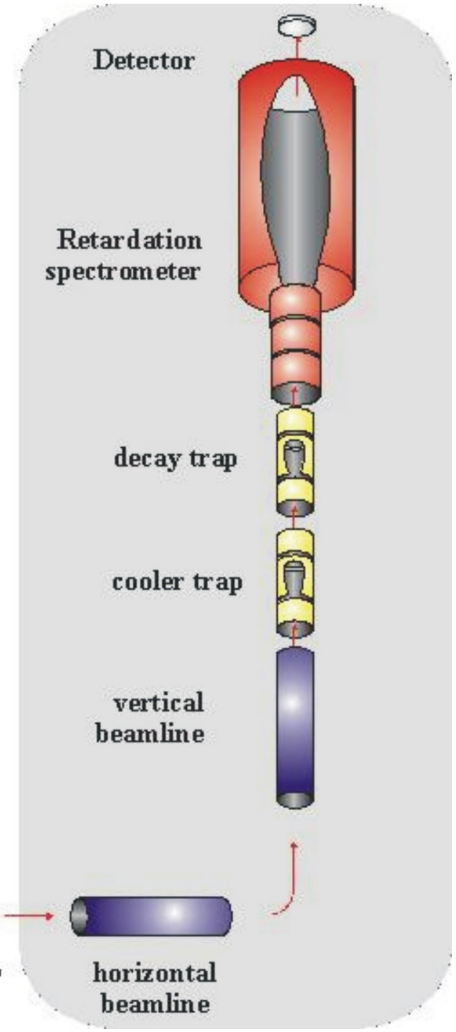


Current experimental limits:
(from nuclear & neutron β decay)
$\frac{C_S}{C_V} < 7\%$, $\frac{C_T}{C_A} < 9\%$

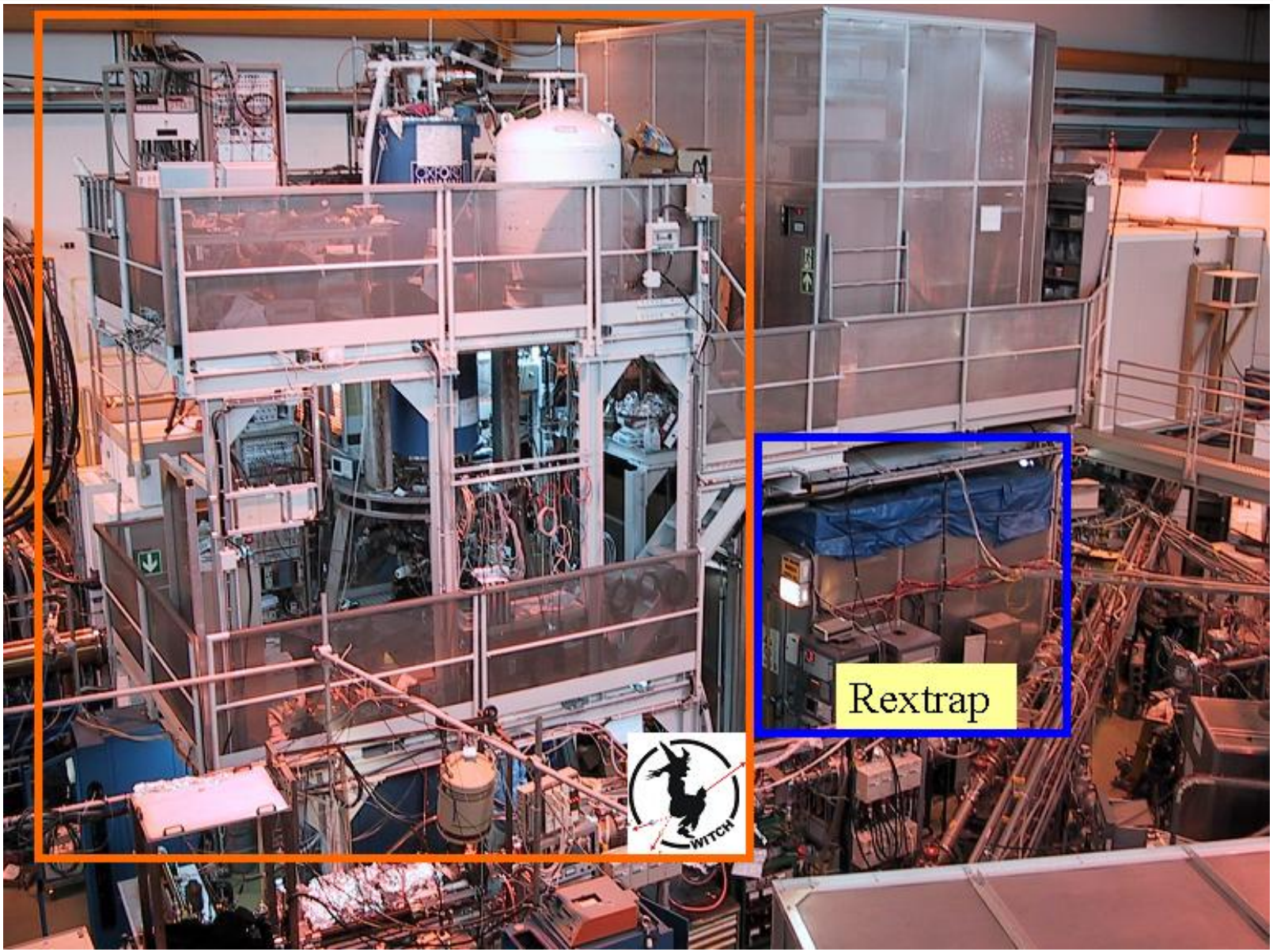
WITCH:
Weak **I**nteraction **T**rap for **Ch**arged Particles



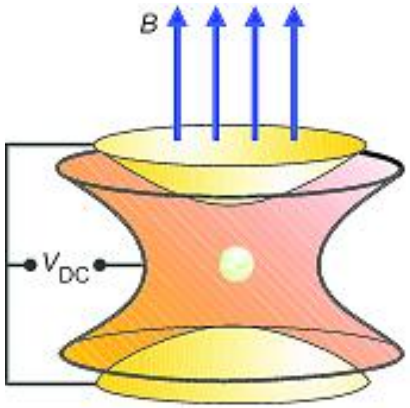




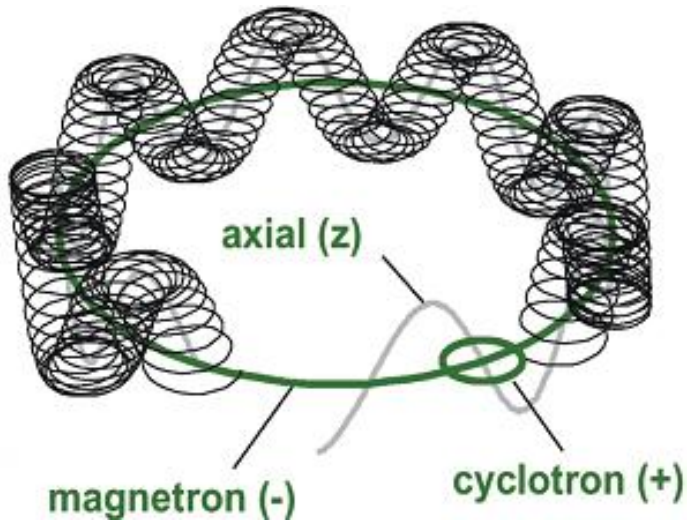
Picture of WITCH in ISOLDE



Basics of Penning Traps



$$\omega_c = \frac{qB}{m}$$
$$\omega_\pm = \frac{1}{2}(\omega_c \pm \sqrt{\omega_c^2 - 2\omega_z^2})$$
$$\omega_c \approx \omega_+ \gg \omega_z \gg \omega_-$$

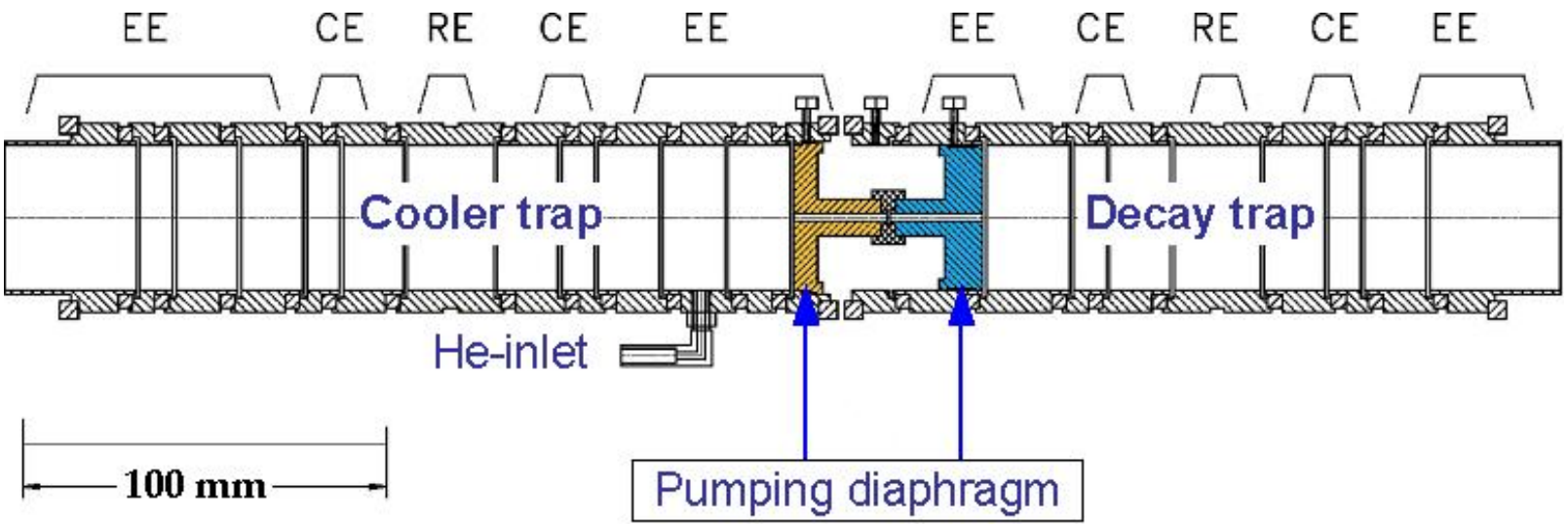


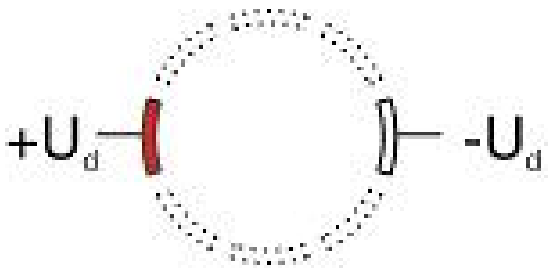
- An axial B field for radial confinement
- A quadrupole E field for axial confinement

Three eigenmotions:

- Cyclotron motion with frequency, ω_+
- Harmonic oscillation in electric potential, ω_z
- Interplay between B and E field (magnetron motion), ω_-

Ion Cloud Manipulation



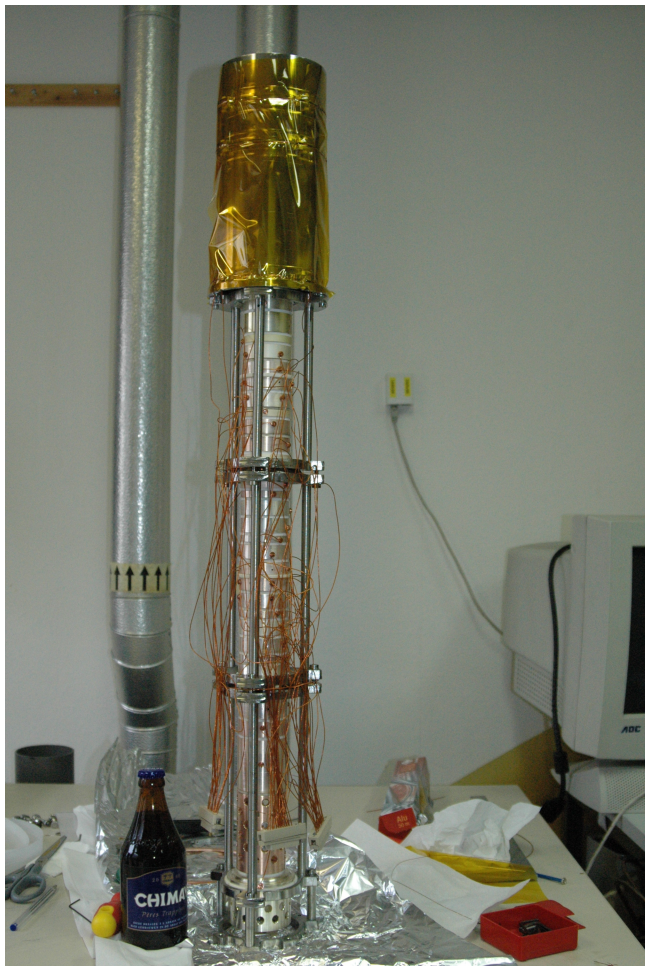


Segmented central electrode (RE)

In cooler trap

- Dipole Excitation (ω_-): Mass independent removal from trap center
- Quadrupole Excitation (ω_c): Mass dependent centering + buffer gas = cooling of ion cloud

The trap structure



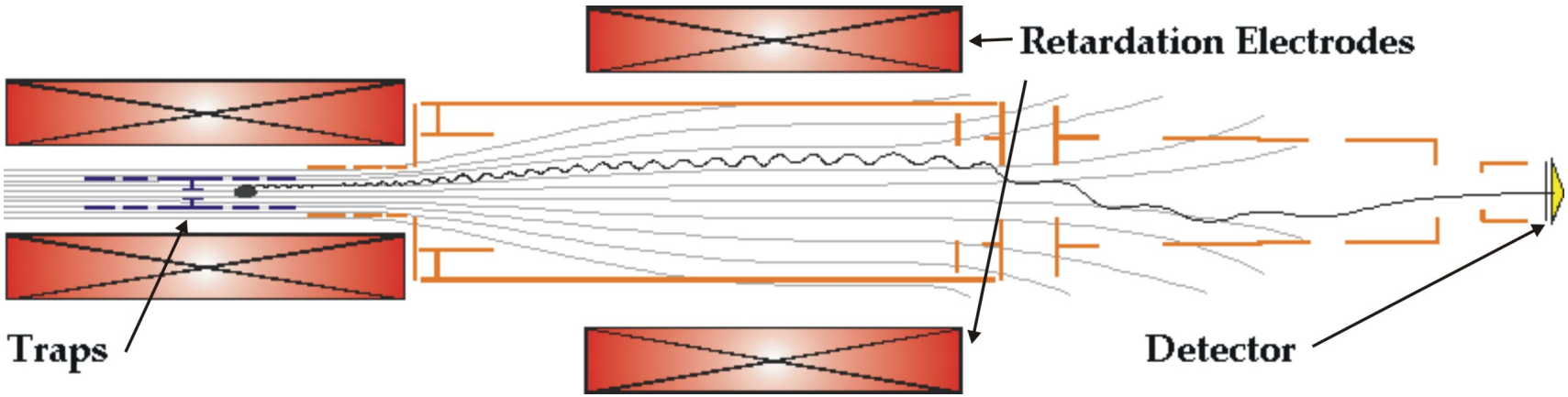
Colors

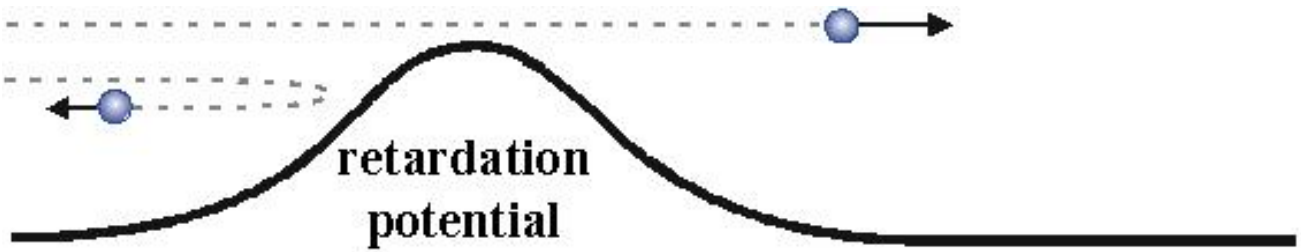
- different colors due to baking to 220 degrees for NEG activation

Bake out problem

- failure of feed-back loop → reached 400 degrees
- traps: re-machining and coating
- back in operation beginning of February

Retardation Spectrometer

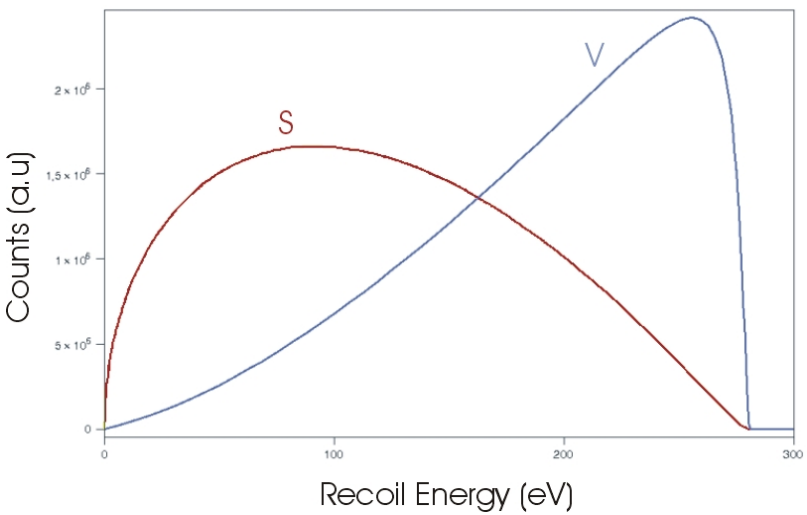


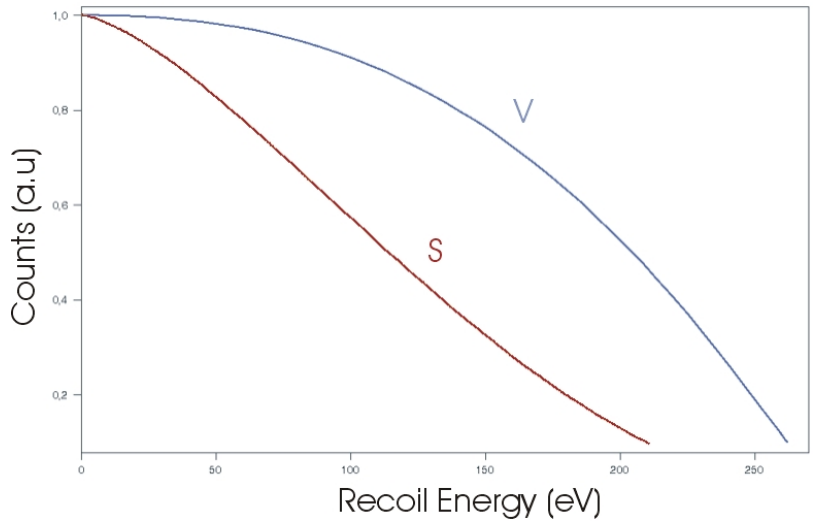


Energy conversion

$$\frac{p_\perp^2}{B} = \text{constant} \Rightarrow \frac{E^{\text{kin}}_{\perp \text{high field}}}{E^{\text{kin}}_{\perp \text{low field}}} = \frac{B_{\text{high}}}{B_{\text{low}}} = \frac{9\text{T}}{0.1\text{T}} = 98.8\%$$

Retardation spectrometer

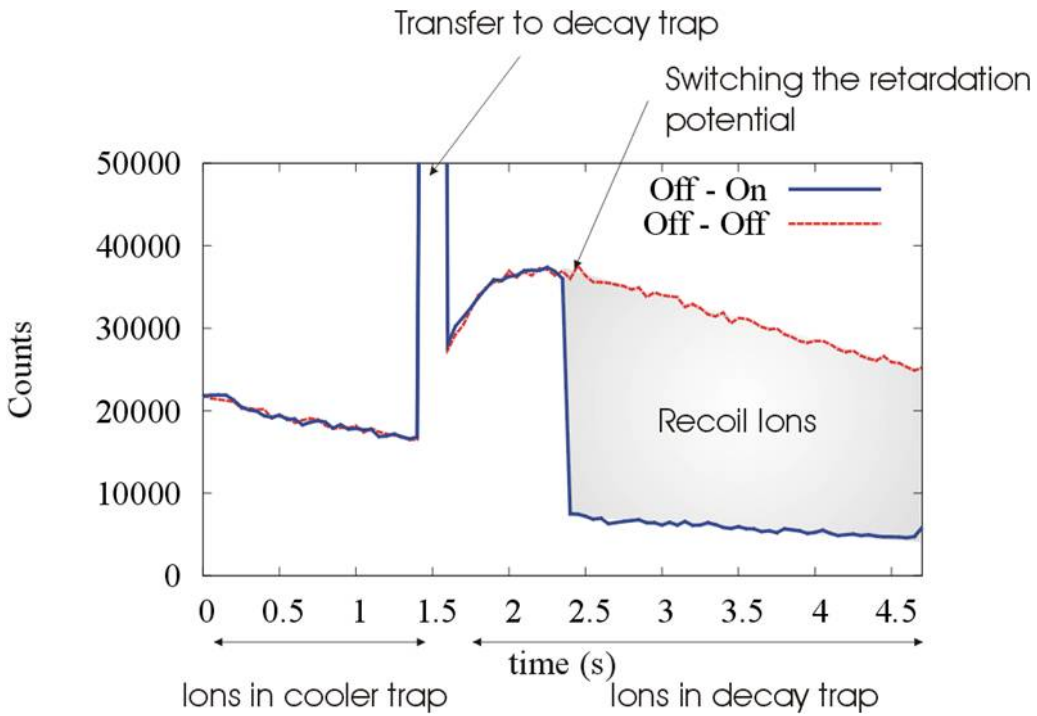




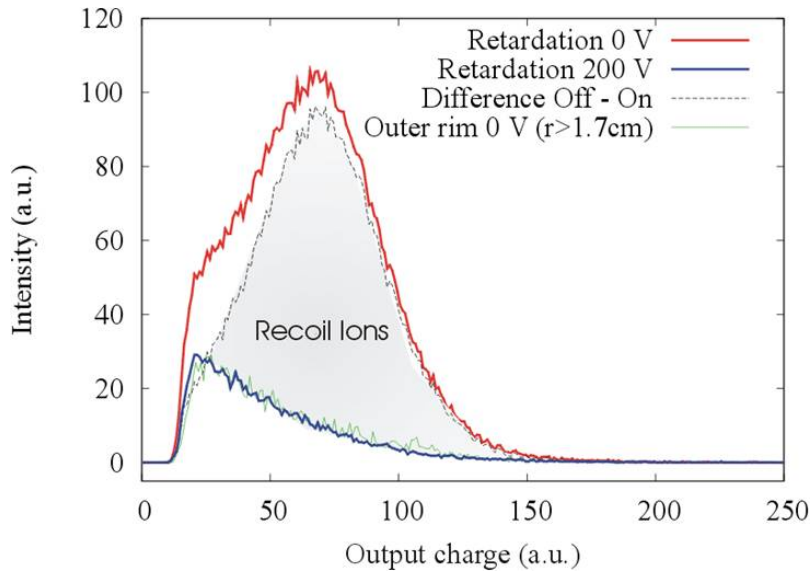
Due to the measurement method integral spectra are measured at WITCH instead of differential spectra.

Proof of Principle with ^{124}In

Recoil spectrum



Charge state distribution



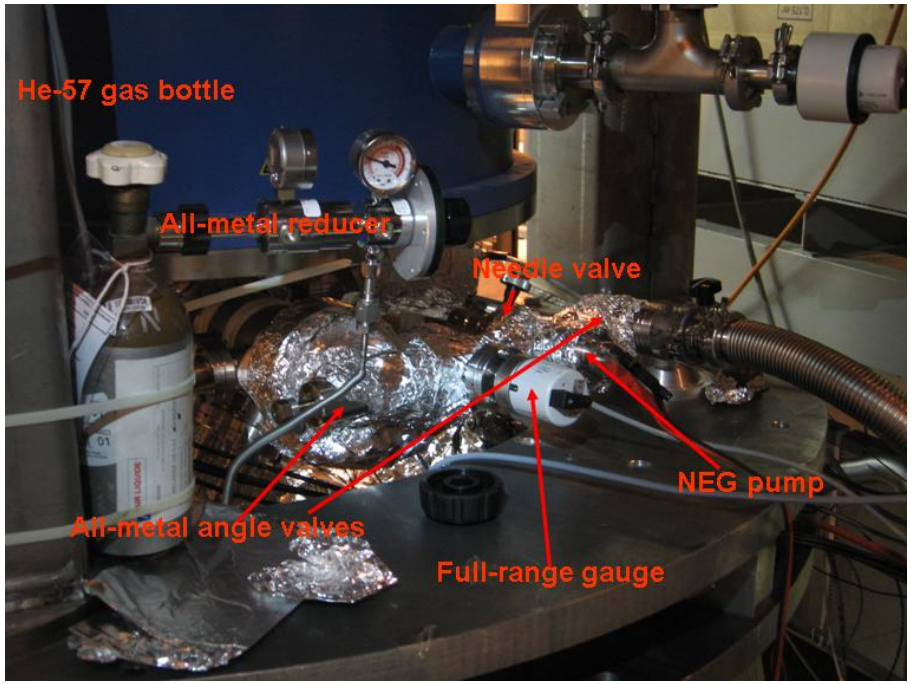
- showing that ions can be trapped and retarded
- but taken with the einzel lens as retardation electrode

M. Beck *et al.* submitted

Charge exchange and improved $^{35}Ar/^{35}Cl$ ratio

Development and improvement of a VADIS (Versatile Arc Discharge Ion Source) at ISOLDE

- 13/11/09: 70 pA ^{35}Cl
  $\Rightarrow 6 \cdot 10^6$ $^{35}Ar/\mu C$, with gating; ratio 10/1
- 16/11/09: 10 pA ^{35}Cl
- Tape station measurement before run:
  $^{35}Cl/^{35}Ar = 1/5$

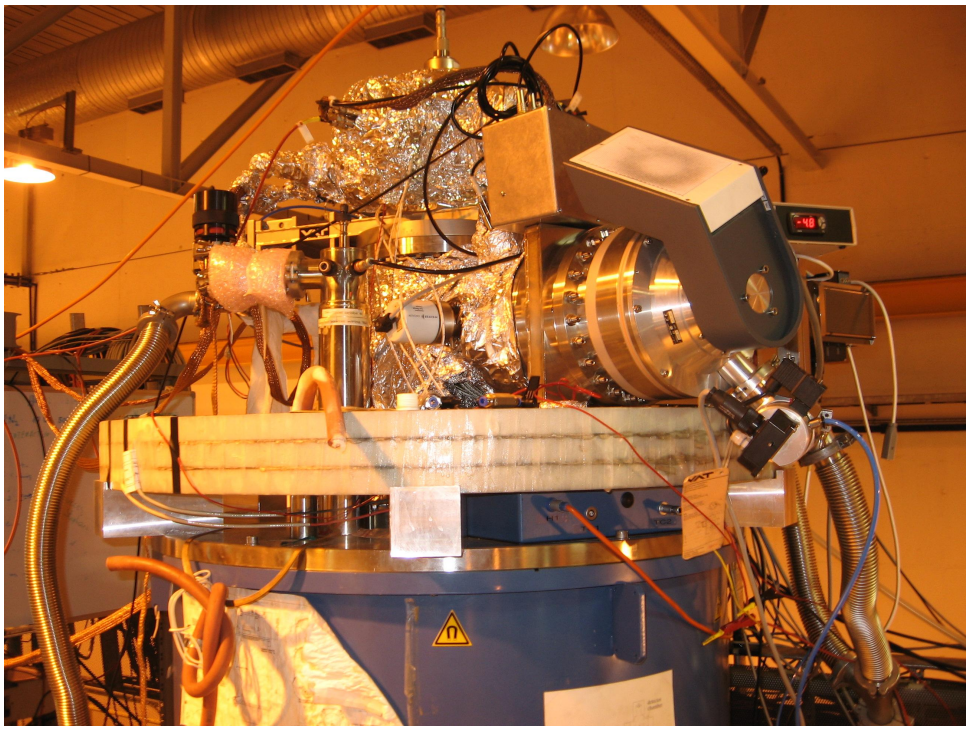


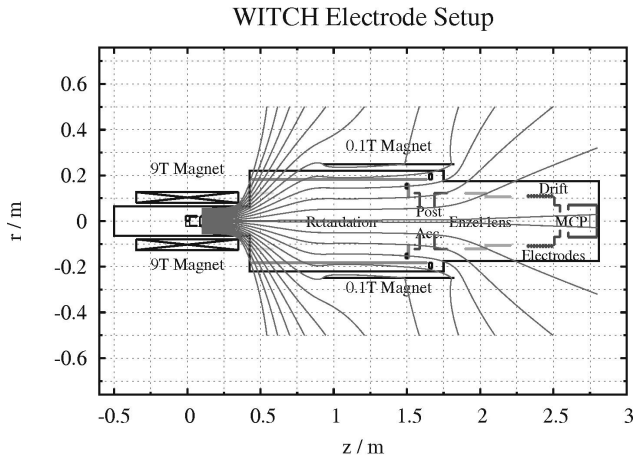
vacuum improved by about 2 orders of magnitude to 10^{-10} mbar region
$\rightarrow$ only 10% loss of ^{35}Ar after about 1 s

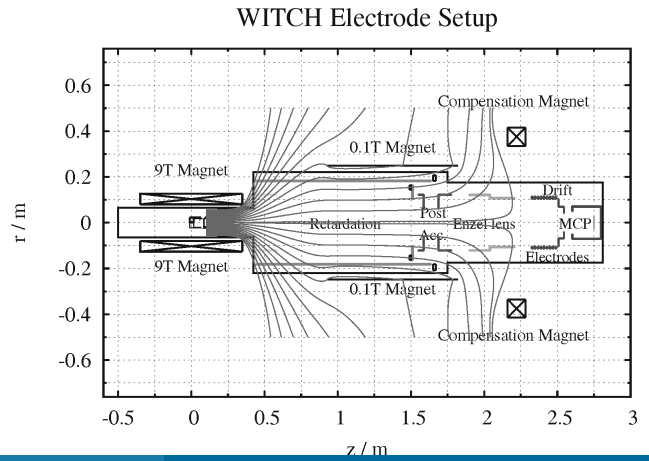
Unwanted Penning Traps

Installation of additional magnet at the top of the setup

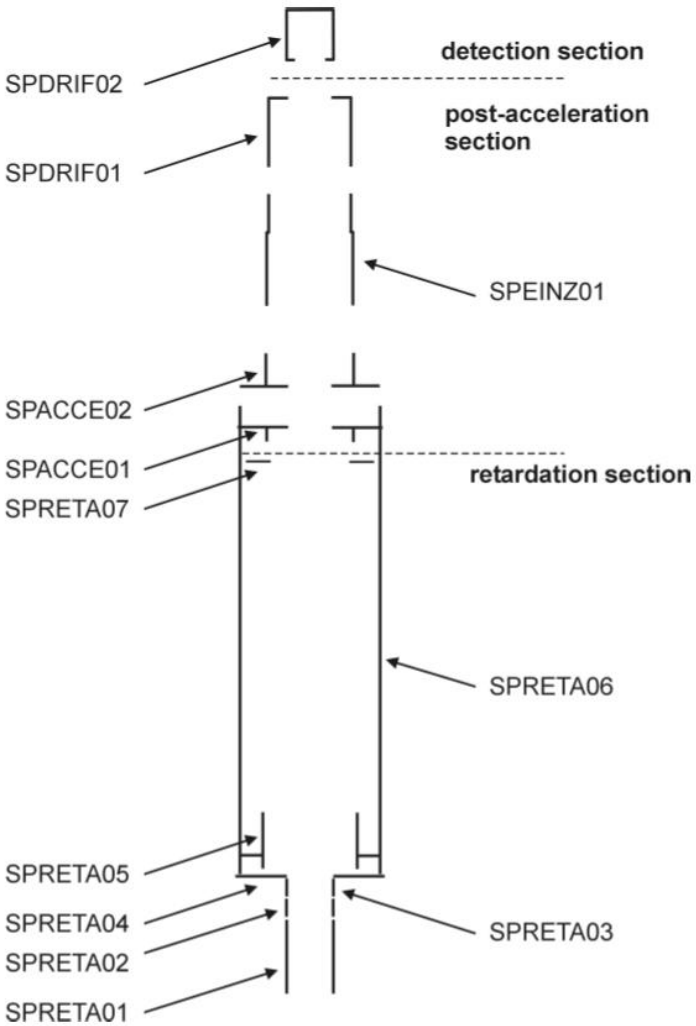
An unwanted Penning trap prevented ramping up the re-acceleration electrodes to their nominal values



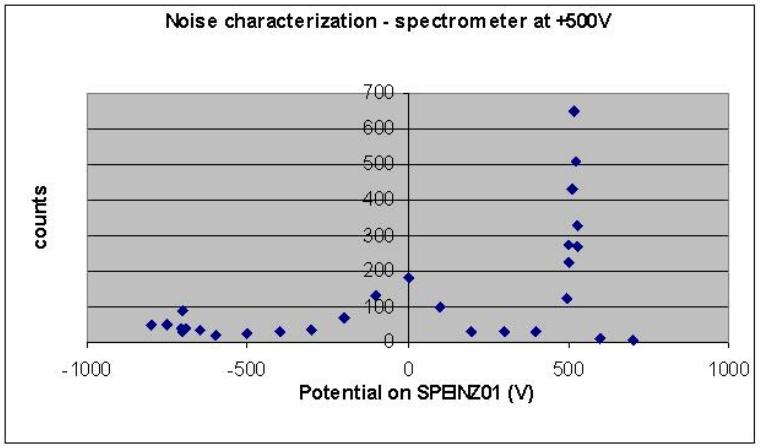




^{35}Ar, November 2009: low-level ionization



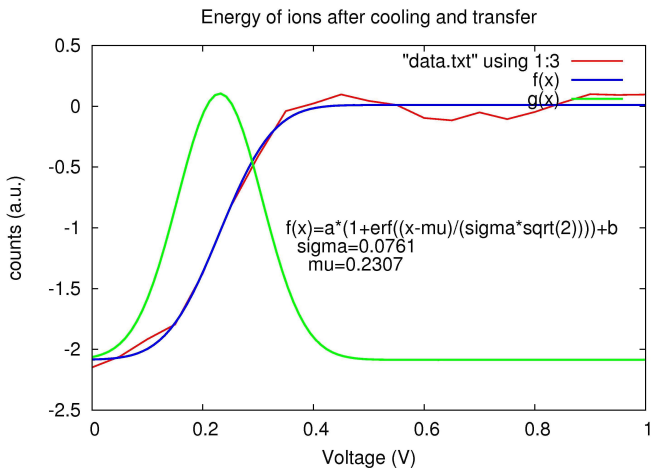
Ionization is heavily dependent on the exact voltages of the spectrometer and einzel lens electrodes



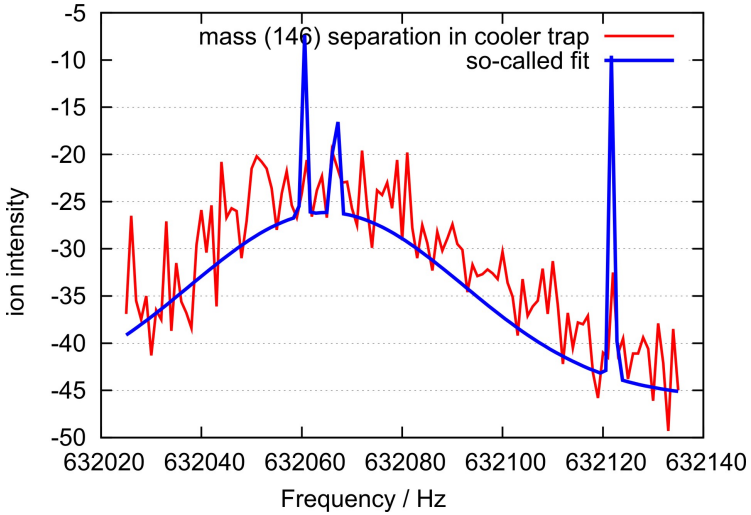
Solution: a wire as charge collector in the analysis plane

Operation of Traps

energy straggling of ions now only about 1 eV



Problems with mass resolution for rare earth beam time



In addition: Computer Controls

→ much more smooth and faster optimization and operation

new electronics & control system (based on the CS framework by GSI) lead to a tremendous improvement of the entire experiment

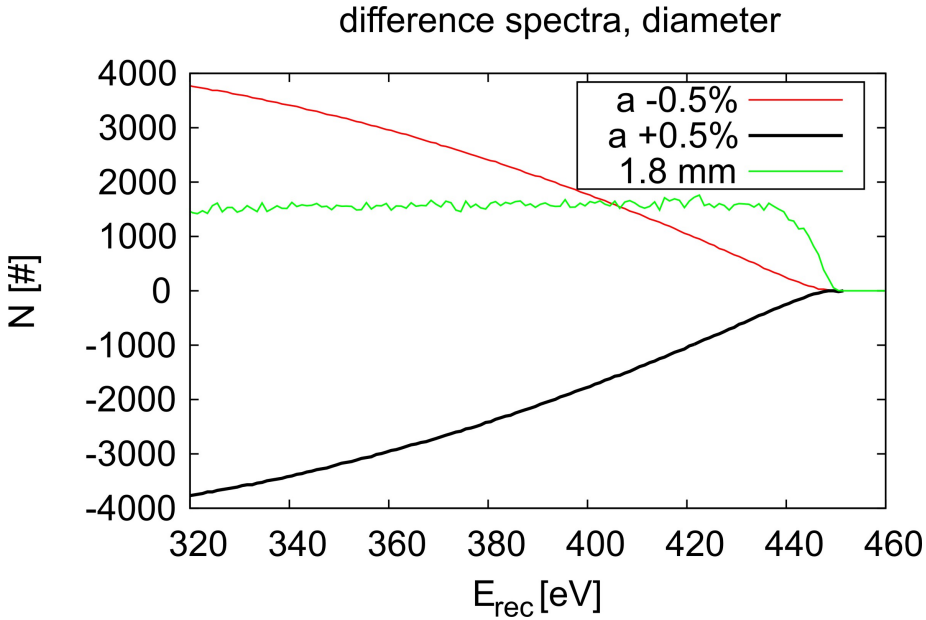
M. Tandecki *et al.* DOI: 10.1016/j.nima.2010.10.111

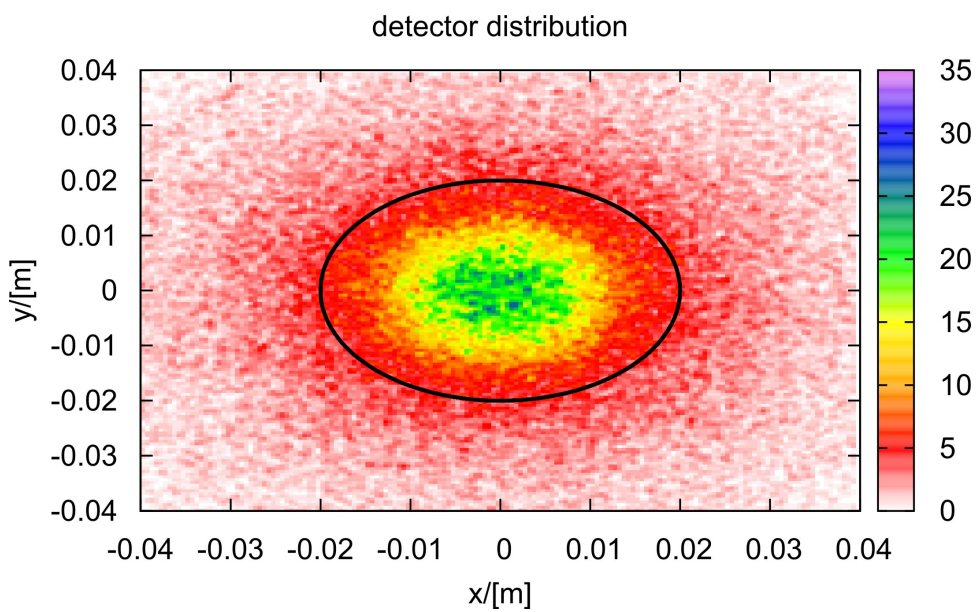
Simulation Codes: SIMWITCH

for investigations of ion trajectories from the trap to the main detector

estimating the influence of the wire on the extracted value of the beta neutrino angular correlation coefficient *a*

determine the distribution of events on the detector

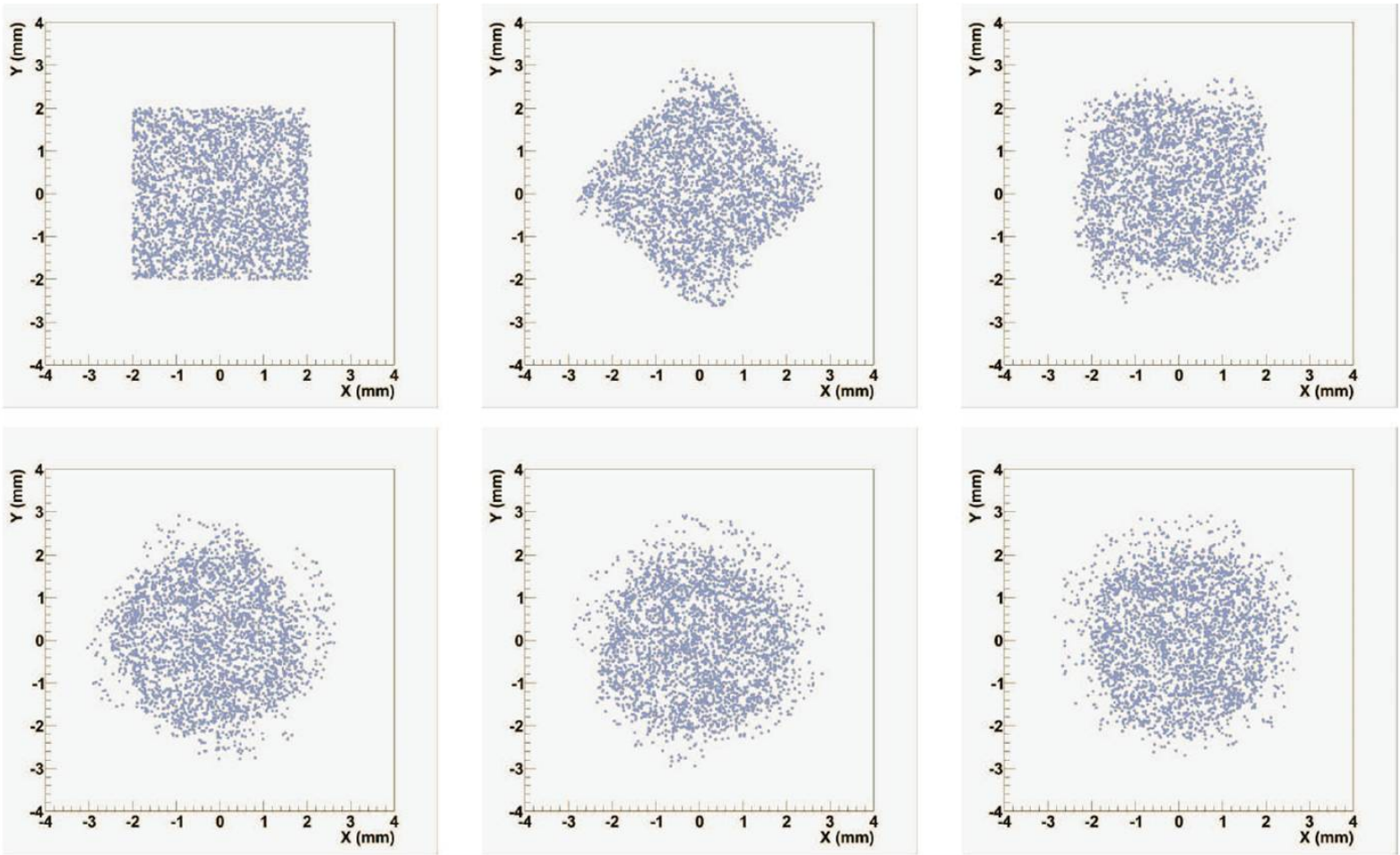




- influence of the wire can be unfolded
- the old detector is too small → installation of a bigger one

Simulation Codes: SIMBUCA

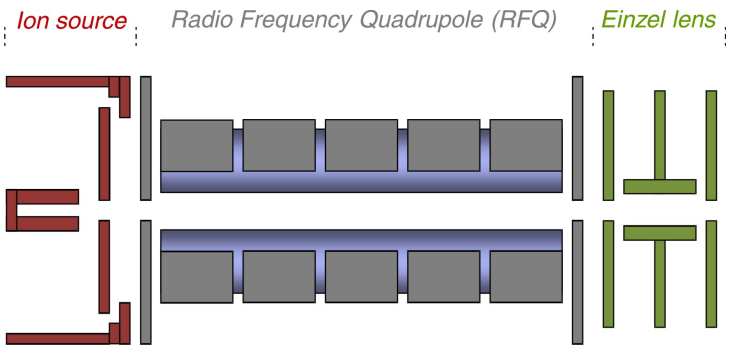
for behavior of large ion clouds in Penning traps
Eg. evolution of a rectangular ion cloud due to Coulomb interaction



S. Van Gorp *et al.* DOI: 10.1016/j.nima.2010.11.032

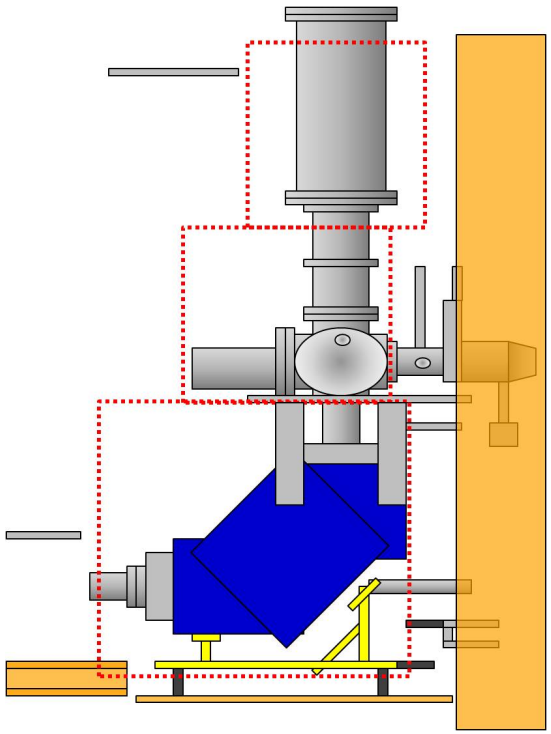
Independence of WITCH from REX operation

Off-line source for alkali ions
Surface ion source with small RFQ



delivering bunches of 2 μs length and 10^7 ions
ion source at 30 kV
E. Traykov *et al.* paper submitted

For full independence of REX-ISOLDE magnetic shielding working at 3 T



Magnetic shielding

Summary & Outlook

Summary

- it has been shown that WITCH is working
- discharge and charge exchange problems solved
- investigations of traps and spectrometer by simulations
- operation independent of REX-ISOLDE

Outlook

- traps back in operation beginning of February 2011
- detailed characterization of systematics effects
- physics run next year on ^{35}Ar