Instituut voor Kern- en Stralingsfysica

KATHOLIEKE UNIVERSITEIT LEUVEN

The WITCH Experiment

status and perspectives

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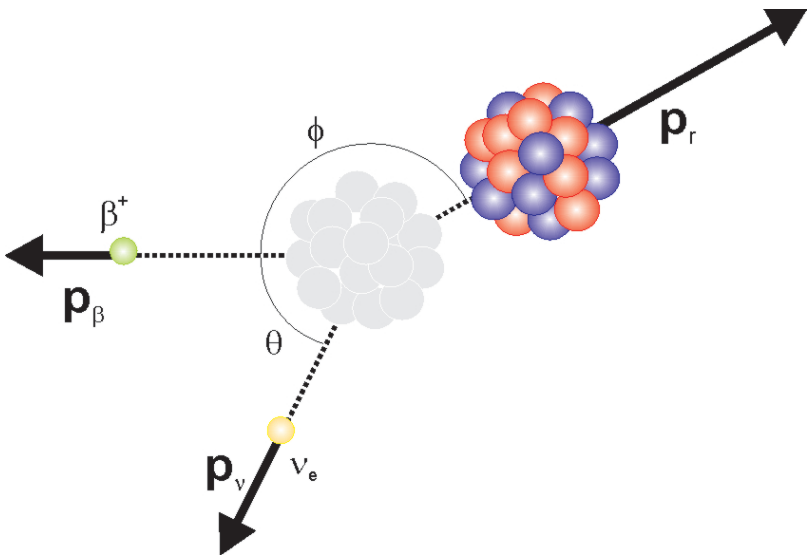
Outline

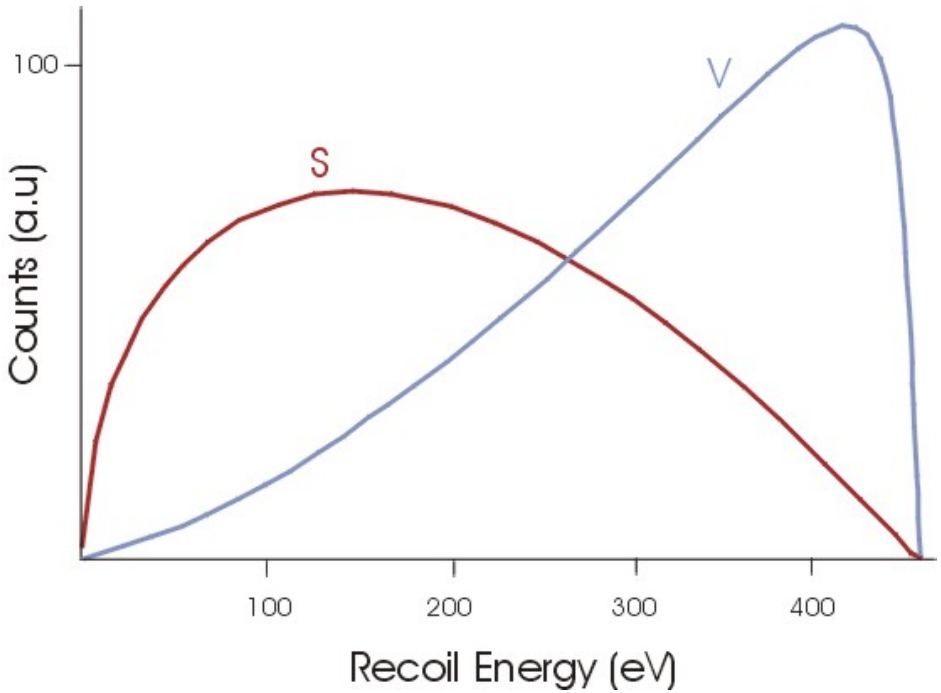
Physics motivation

$\mathcal{H}_\beta = f(C_S, C_V, C_T, C_A, C_P)$
e.g: Fermi β decay $(0^+ \rightarrow 0^+)$

$$W(\theta) \approx 1 + a\frac{v}{c}cos\theta$$

$$a \approx 1 - \frac{|C_S|^2 + |C'_S|^2}{|C_V|^2}$$

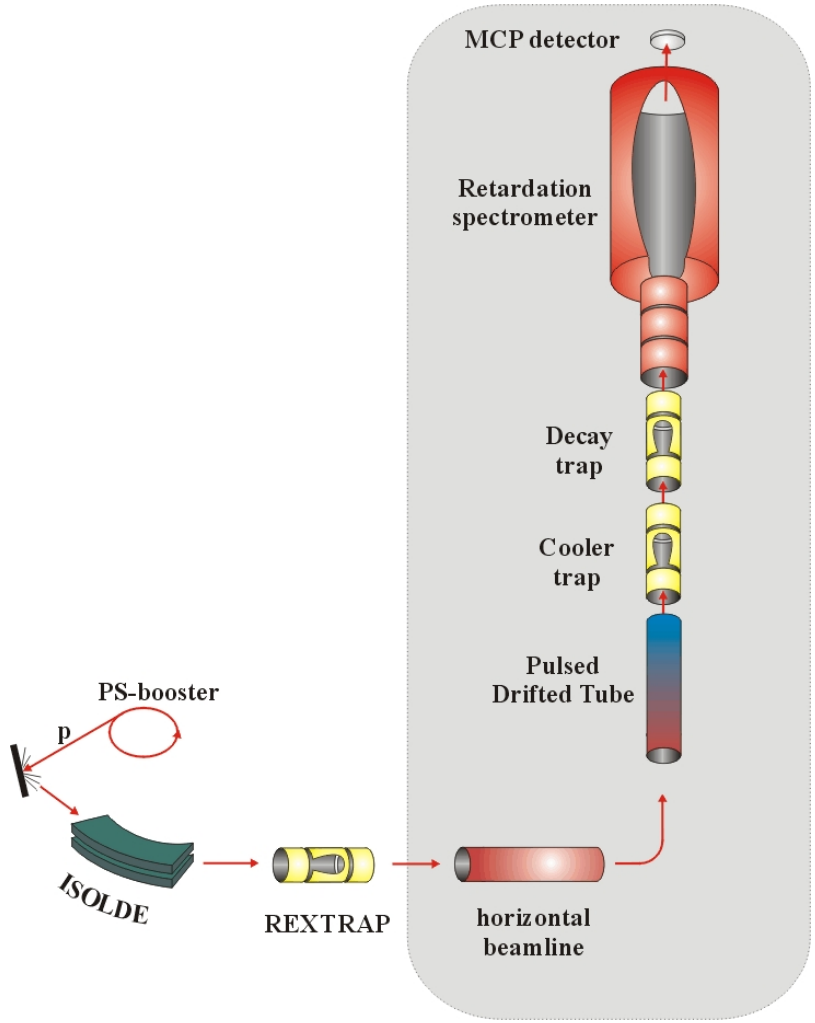




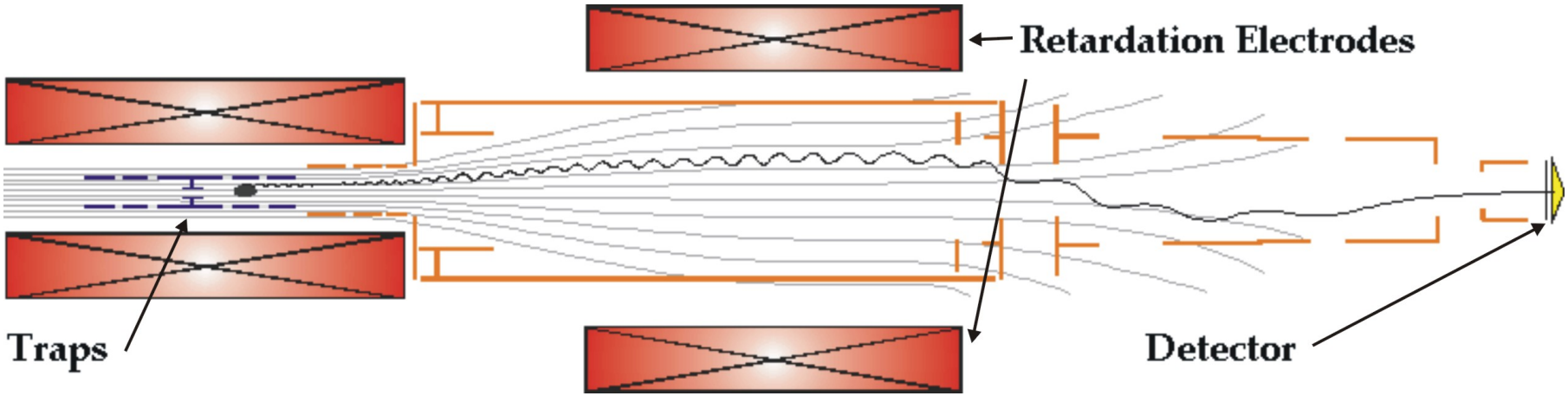
Current experimental limits:
$\frac{C_S}{C_V} < 7\%$

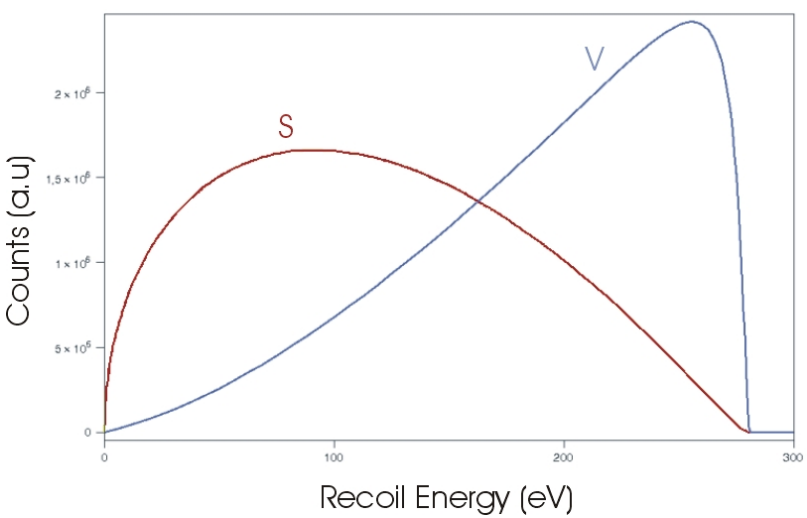
Weak Interaction Trap for Charged Particles

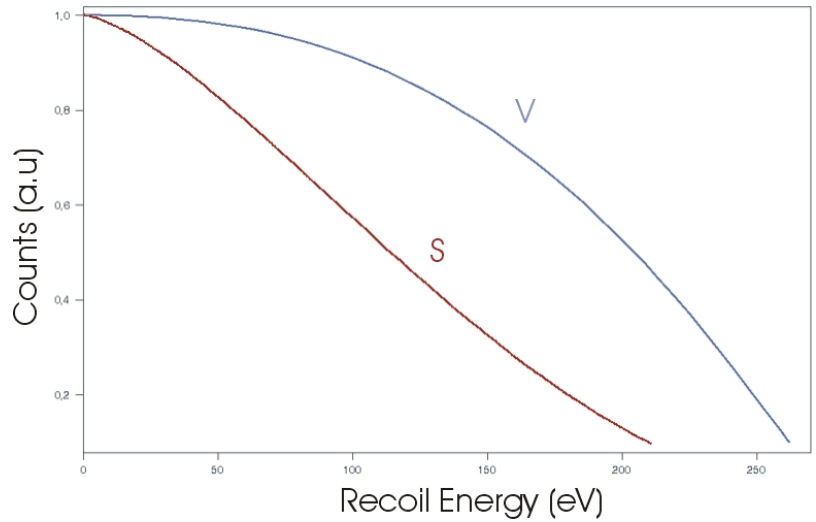
- A Double Penning trap system to prepare the ions acts as a scattering-free source
- Retardation spectrometer to probe the energy of the recoiling ions



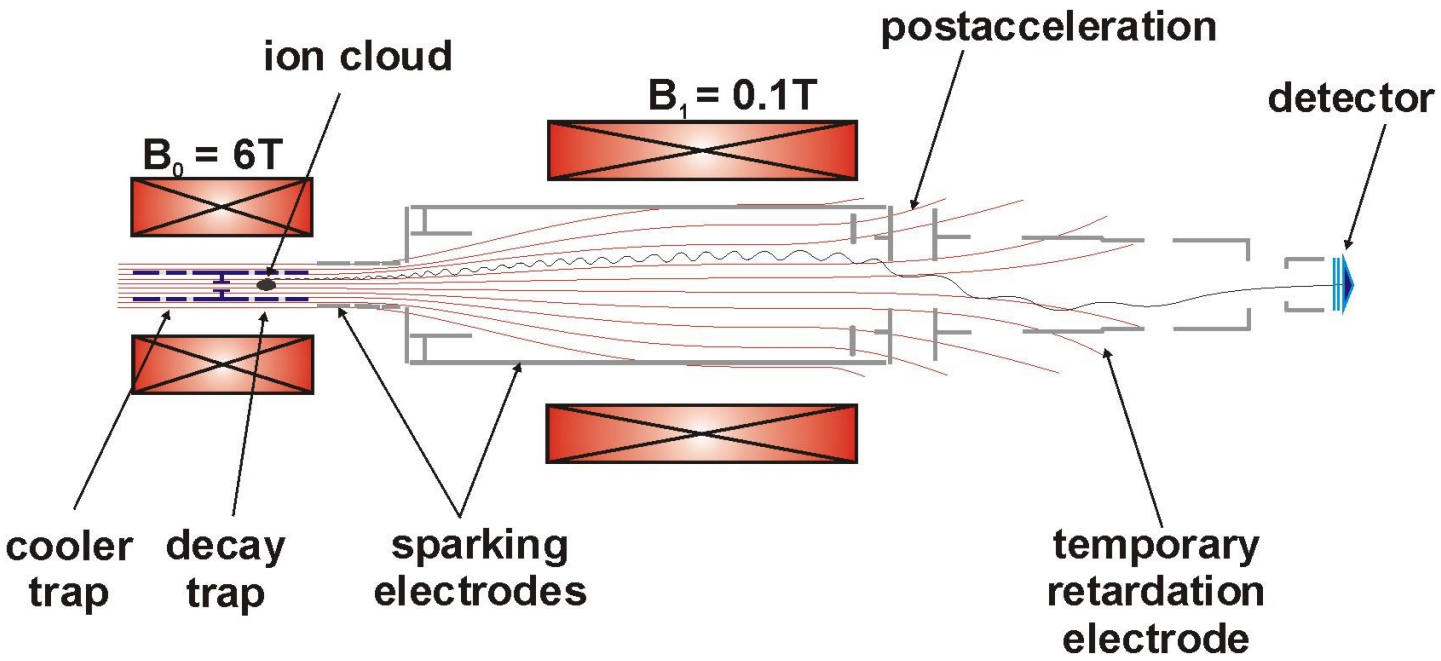
Retardation spectrometer





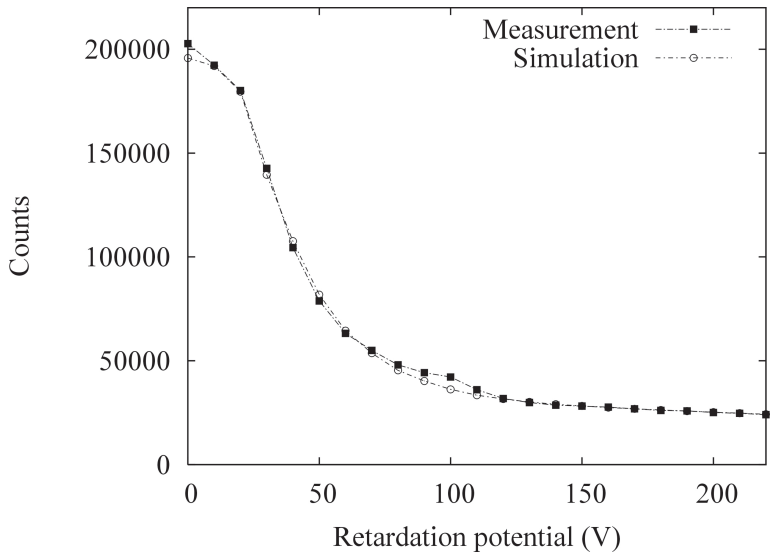


^{124}In run - Nov 2006



- First time we encountered the secondary ionisation problem
- This prevented us from using the spectrometer as it was intended
- With a trick the first recoil ion energy spectrum could be measured

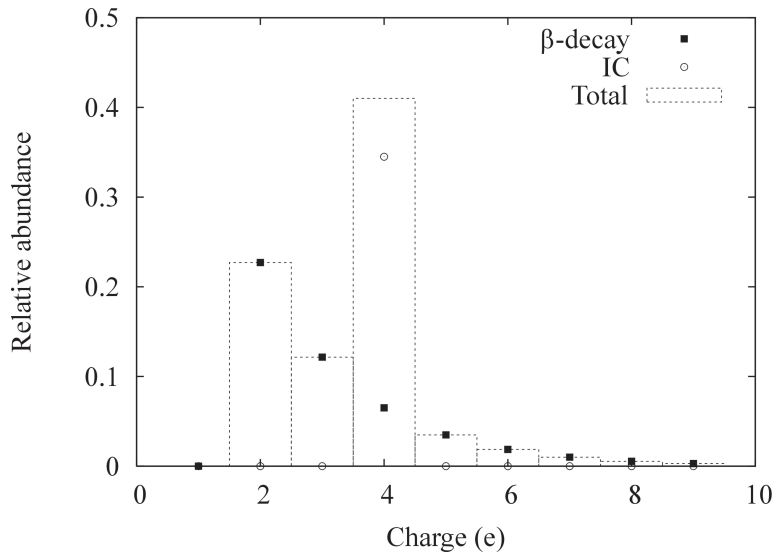
^{124}In Recoil Spectrum - Charge state distribution



Fit parameters

- Potential offset
- Isomer contribution
- Overall scaling
- Background scaling

- β charge state scaling
- Gaussian charge state position
- Gaussian charge state width



offline tests - Dec 2006 / June 2007

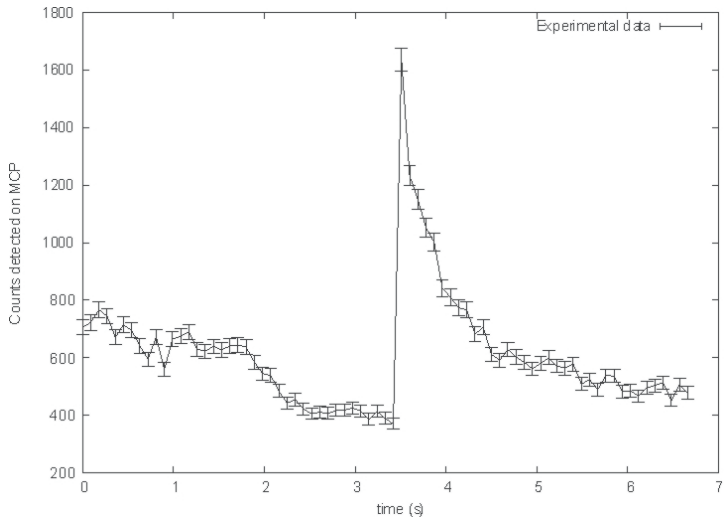


Figure: Example of the problem

- β-particles do not seem to cause anything, γ's are the culprit
- Later tests (June 2007) did not show an uncontrollable effect anymore. Possible reasons: modified electronics + better vacuum + *luck*

^{35}Ar run - Oct 2007

The run did not go as hoped..

- ^{35}Cl contamination
  At first: The Cl:Ar was 400:1
  Optimized: 25:1 ratio, but greatly reduced yield
  This issue is solved by the target group
- Charge exchange
  REXTRAP: trap-halflife of 63 ms
  WITCH: Even worse trap-halflife; this prevented us from preparing the ion cloud
  $\Rightarrow$ contaminations arising from Teflon buffergastube in the system.
  $\Rightarrow$ We are improving *the buffergassystem* to ensure a *pure buffer gas*
- The secondary ionisation returned with a vengeance
  $\Rightarrow$ We are improving *the vacuum, electropolishing the electrodes* and *investigating this problem throughly*

vacuum improvements

Vacuum improvements:

- More careful choice of materials with a low outgassing rate (but also non-magnetic and bakable at 200°C): no teflon (or other plastics), Sn, Zn, etc.
  $\longrightarrow$ Especially true for the buffer gas sytem!
- More careful treatment of all the parts
- Installation of NEG (Non-evaporative getter) material in the trap and spectrometer region
- Decent bake-out procedure; also needed to activate the getters

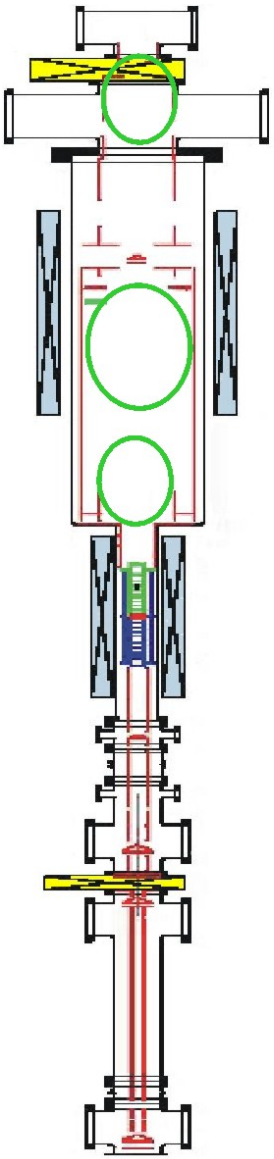
Definition of a Penning Trap

Definition

Penning traps are devices for the storage of charged particles using a constant **static magnetic field** and a spatially inhomogeneous **static electric field**

- Any potential well along a magnetic field line can trap particles
- Electrode walls also count as potential barriers
- Common to all retardation spectrometers (e.g. aSPECT and KATRIN)
- Big topic of investigation in KATRIN

Unwanted Penning Traps in WITCH



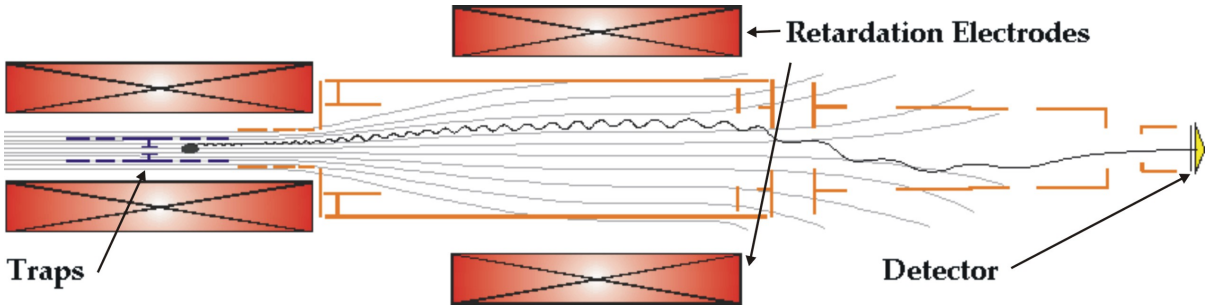
Obstacles:

- We cannot power the re-acceleration electrodes to their nominal values
- Huge discharges when combining radioactivity and switching of the spectrometer

Possible unwanted traps

- An electron trap (vacuum-to-vacuum and vacuum-to-cathode) between the 9T field and SPACCE01 (-2 kV)
- A trap for positive particles between the analysis plane (+500V) and the 9T field
- A (vacuum-to-vacuum) electron trap in the Einzel lens

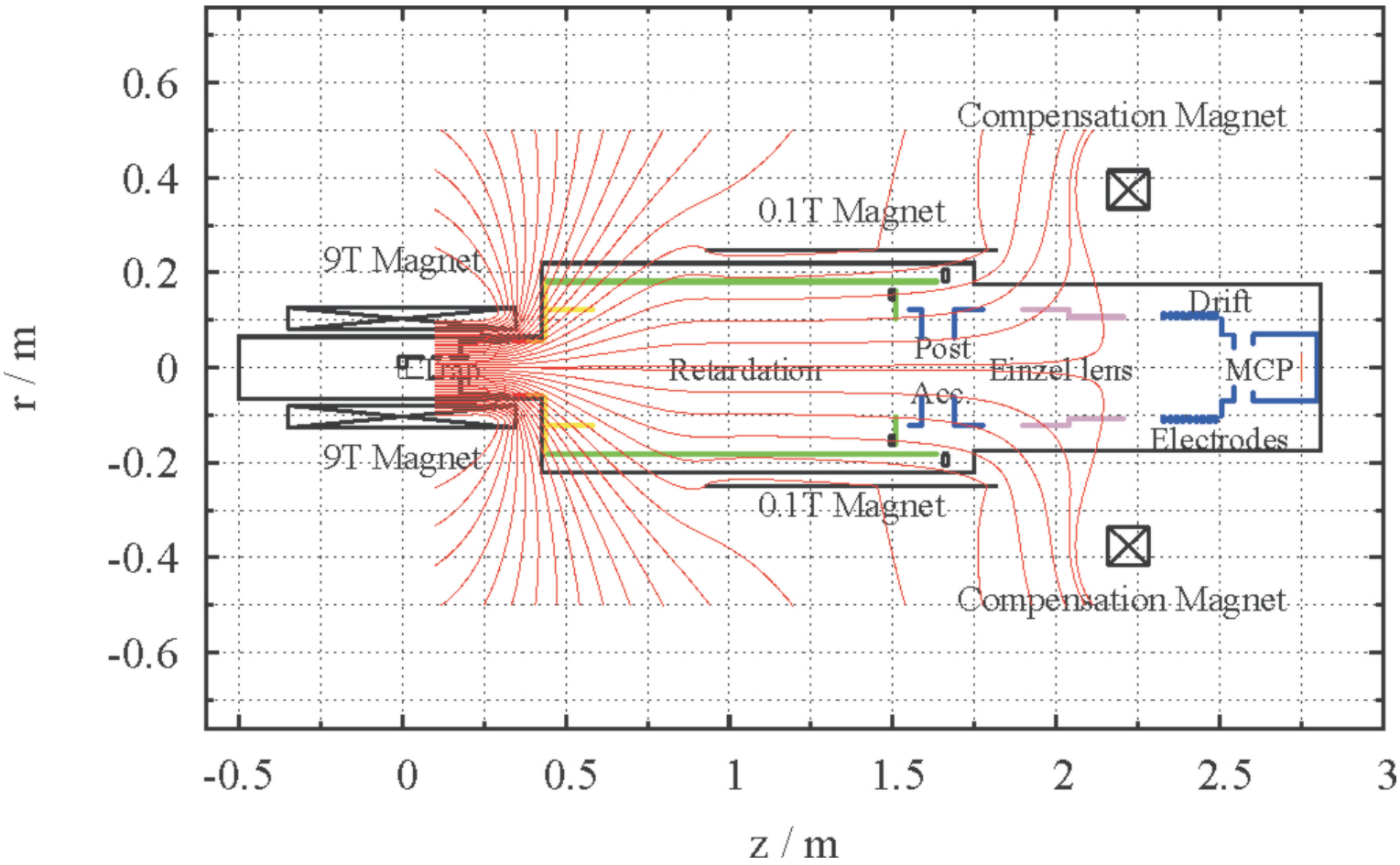
Possible solutions (a)



- Electropolishing of re-acceleration electrodes
  $\Longrightarrow$ This might remove the field emission and loading of electron traps
- Periodically empty the particle traps
  At KATRIN tests were done with a wire periodically crossing the trap volume

Possible solutions (b)

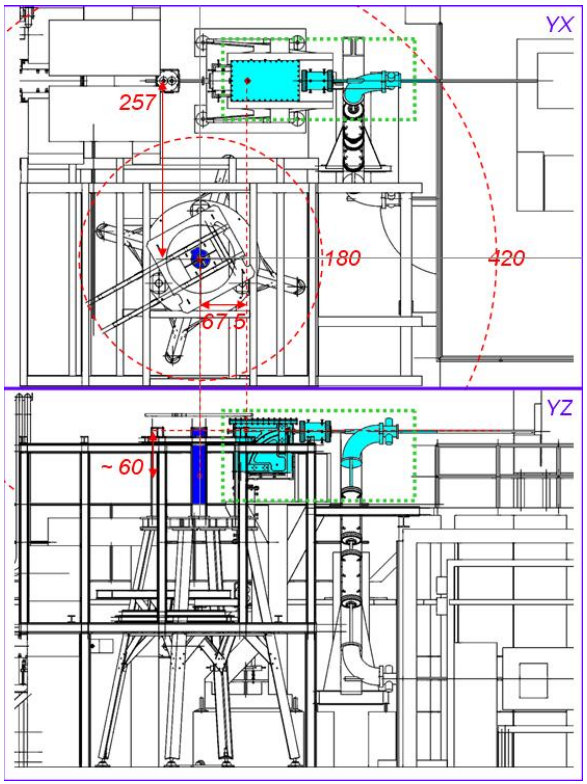
Removal of the electron trap in the Einzel lens by using a compenstation magnet

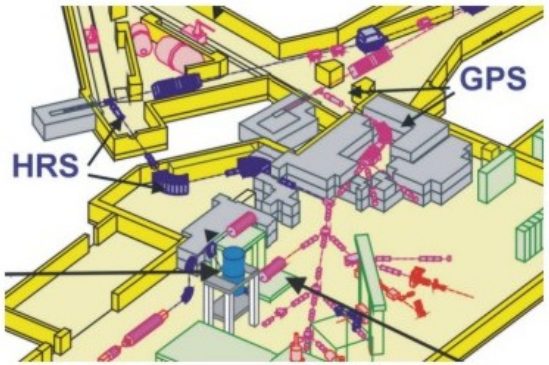


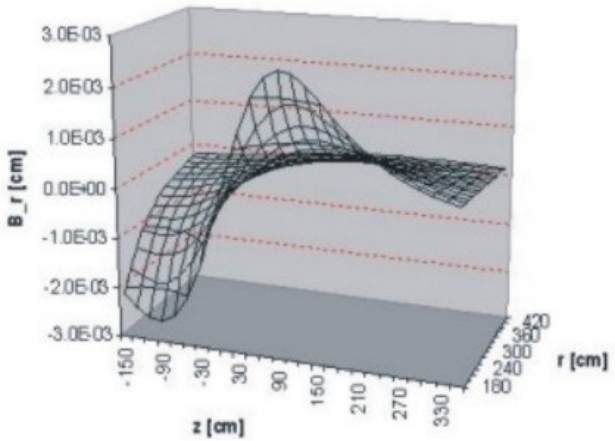
Bonus: lower β background on MCP detector

Magnetic Shielding of REX-EBIS

- If the WITCH-magnet is at 9T. The field at REX-EBIS is still 3mT. → Unable to do offline tests when REX needs a beam (...)
  → *Magnetic shielding* and a high intensity well *bunched ion source* are needed.
- When powering up the WITCH magnet to 9T, the REX-postacceleration beam is lost at 0.2 T.

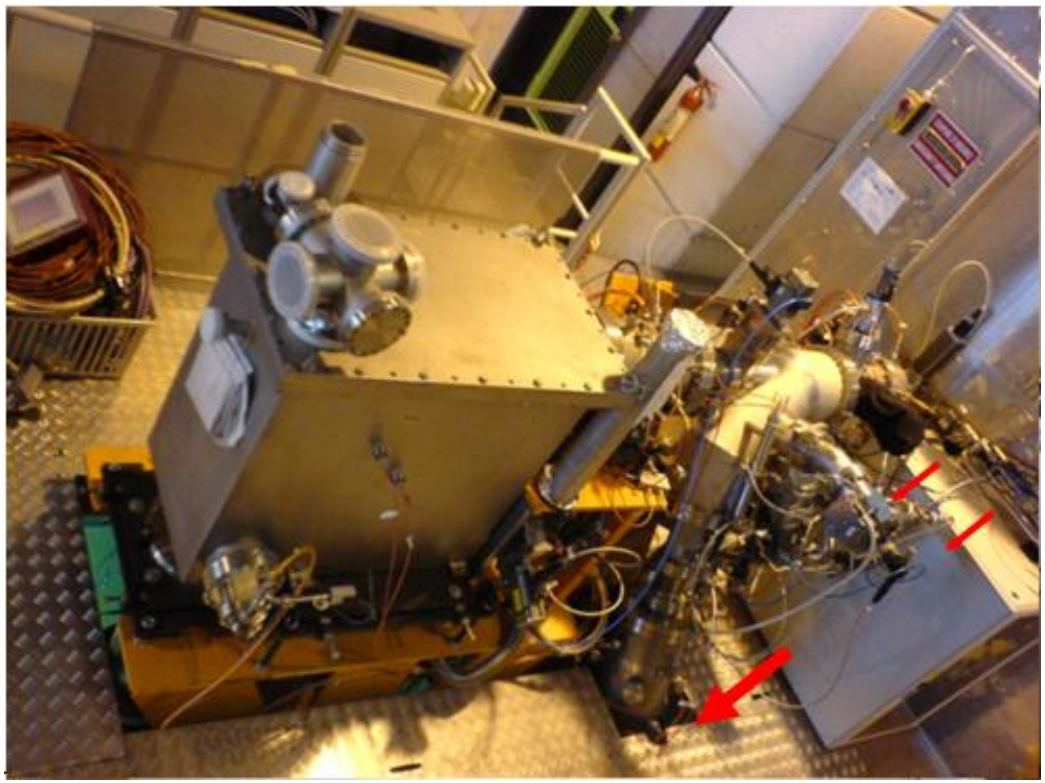


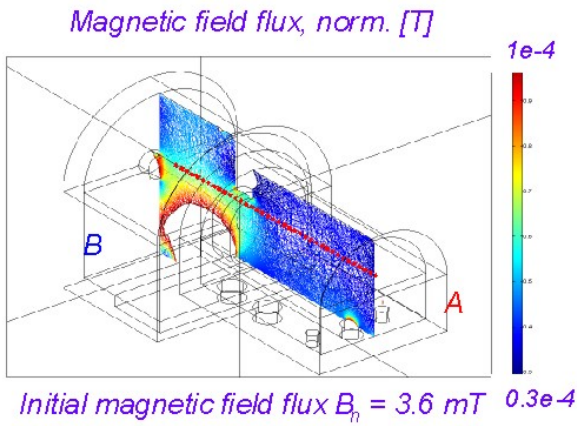


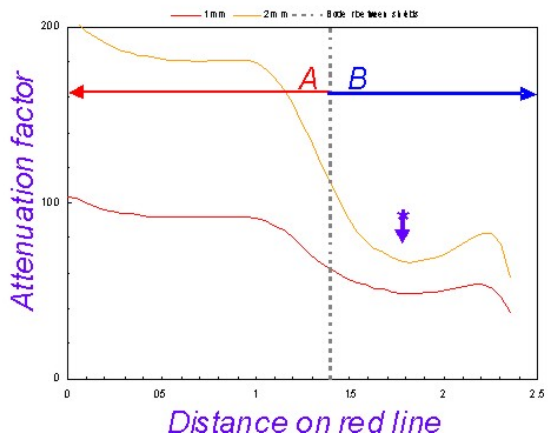


Magnetic Shielding Design

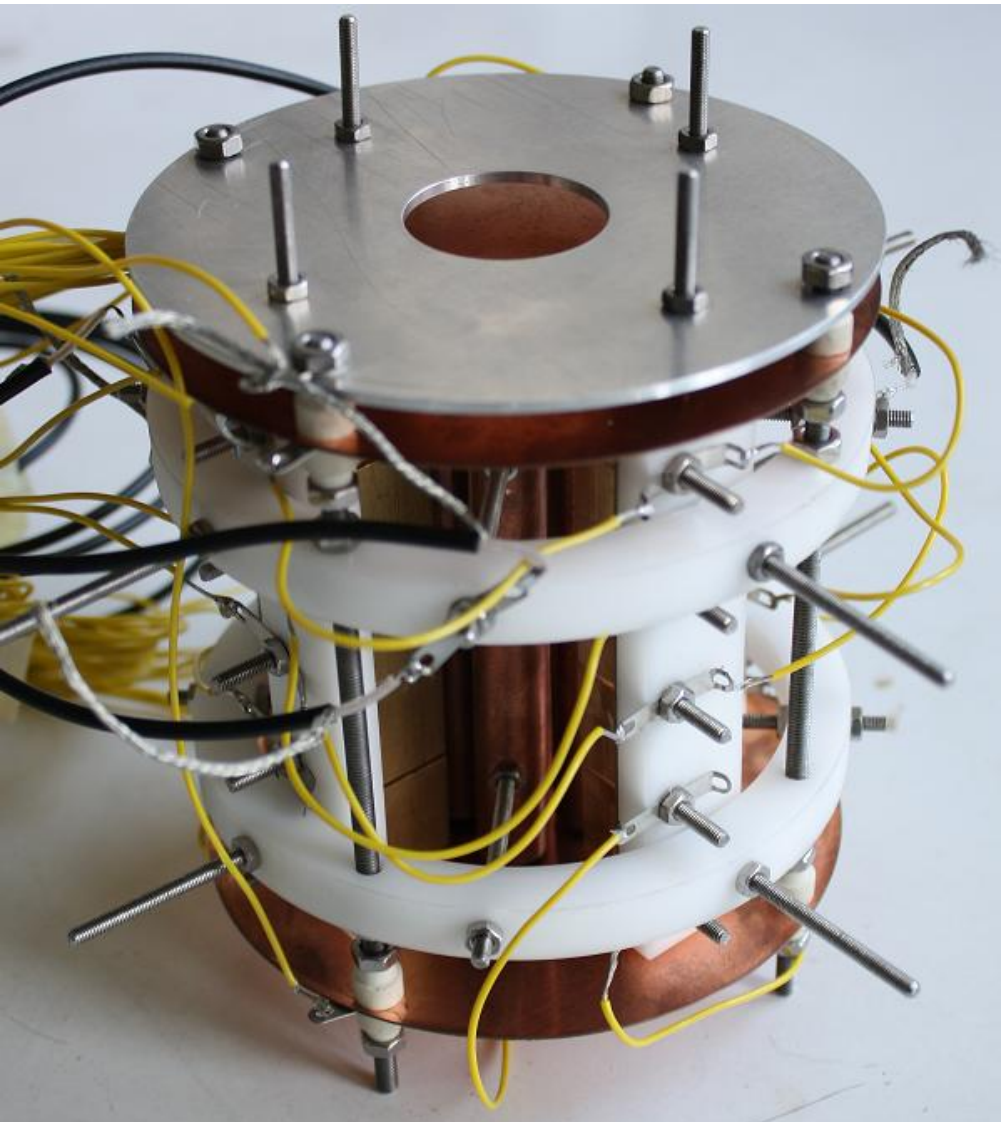
- 2 Seperate boxes made of 1mm mu-metal
- Final construction will be rectangular
- This gives an attenuation factor >50







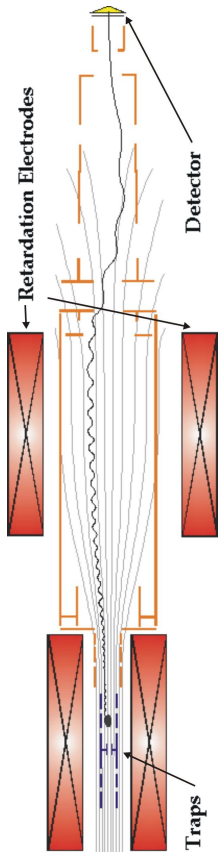
A bunched ion source

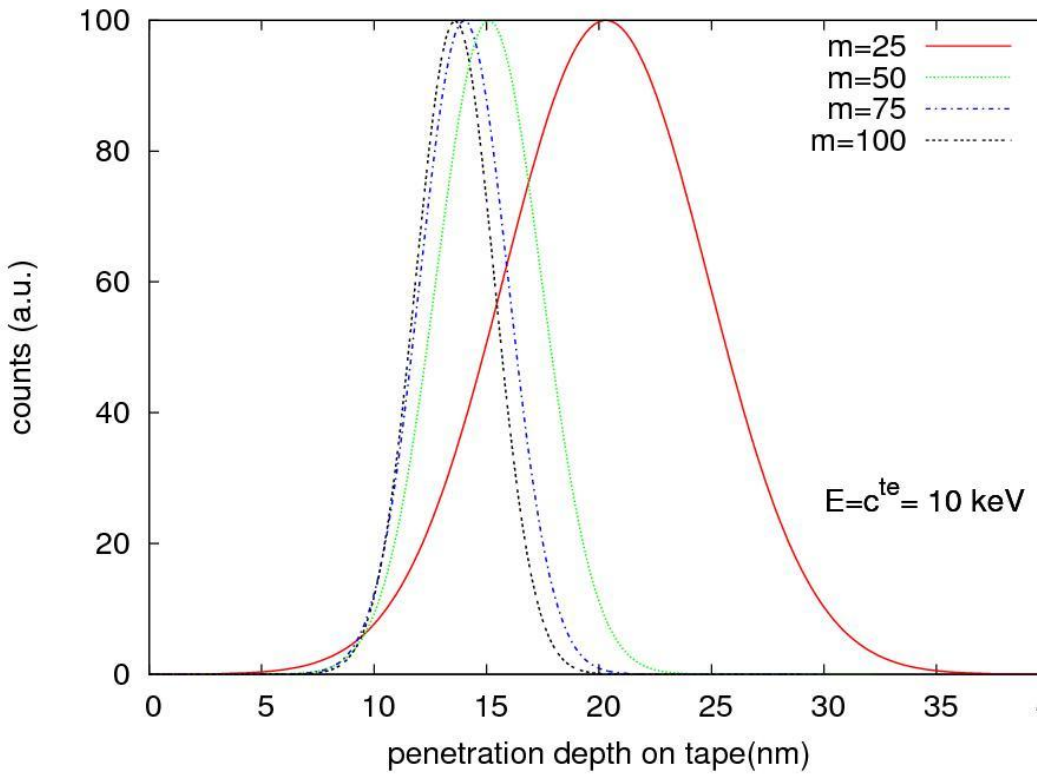


- WITCH's surface ionisation source has at most 1 nA Intensity, BUT only 2 μs are used
- Using the ion source in combination with a small RFQ one can get bunched beams up to 10(100)picoAmp ($\sim 10^7$ particles)

Tapestation Investigation

- The WITCH PenningTraps currently have a mass resolution 300.000
- Simulations prove that it is possible to accelerate the beam up to 30 kV and still have a beamspot of maximum 2mm
- The acceleration is done by switching a 1 m large electrode





Conclusion & Outlook

Conclusion

- This year WITCH choses to improve the set-up (new buffergas-system, vacuum-improvements, electro-polished electrodes) rather than taking beamtime
- At the same time a magnetic shielding and a high intensity well bunched ion-source are being developed as well

Outlook

- When all the testing has been done and the proposed solutions work a run will be next year
- The use of a tapestation (in combination with the good mass resolving power of the traps) is being investigated as well