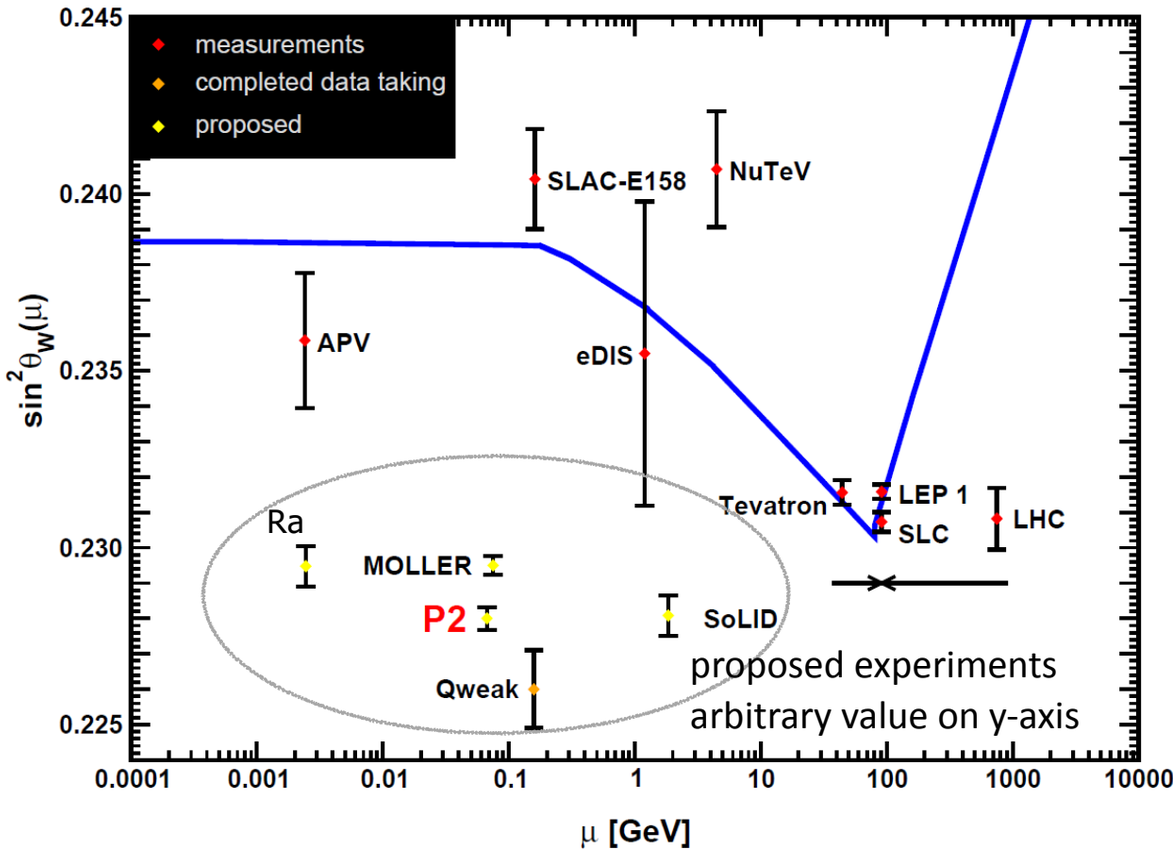
muX Beamtime 2018

Atomic parity violation in radium

- Weak interaction leads to parity violating effects in atomic transitions
  → enhanced in heavy atoms ($\propto Z^3$)
  due to large overlap with nucleus

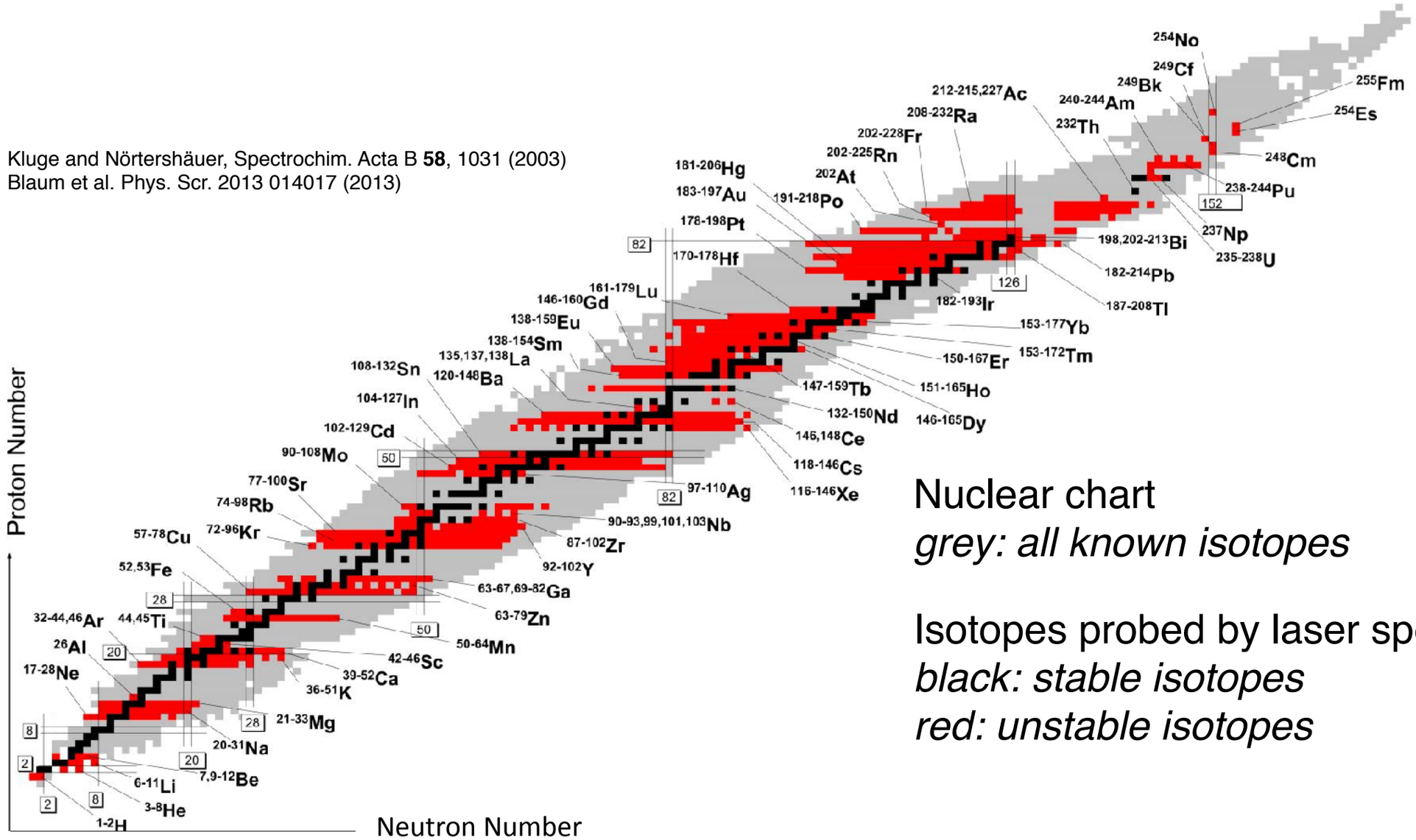
- Extract Weinberg angle using precision atomic calculations
  → Needs knowledge of the radium charge radius with 0.2% accuracy

- Weinberg angle comparable to α and m_e in electromagnetism



⇨ Atomic parity violation fixes weak interaction properties at low momentum

Charge radii in nuclear physics

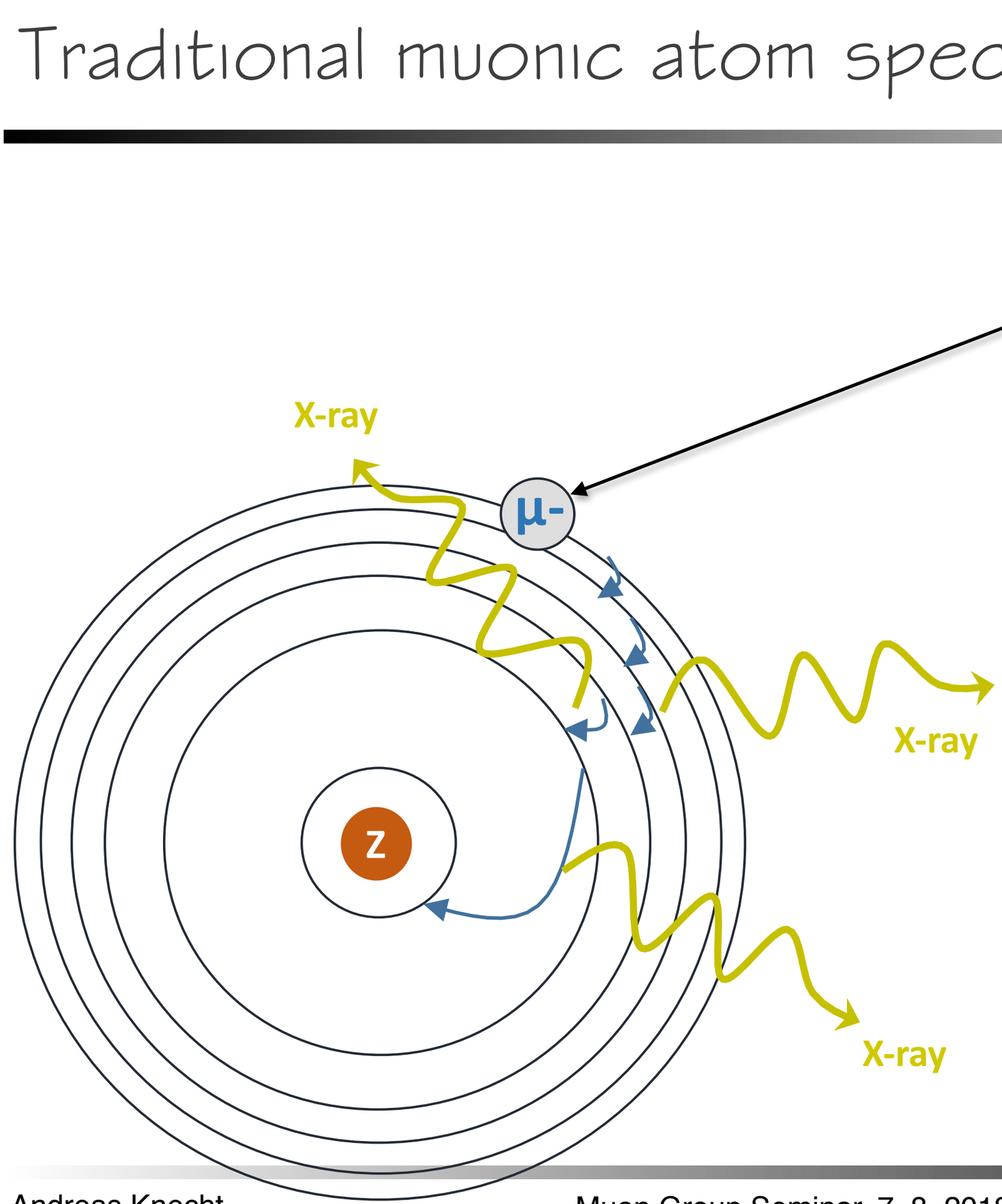


Nuclear chart
grey: all known isotopes

Isotopes probed by laser spectroscopy
black: stable isotopes
red: unstable isotopes

- Large efforts at ion beam facilities to determine charge radii
- Wealth of information on nuclear properties from laser spectroscopy
- Need electron scattering or muonic atom spectroscopy for absolute radii

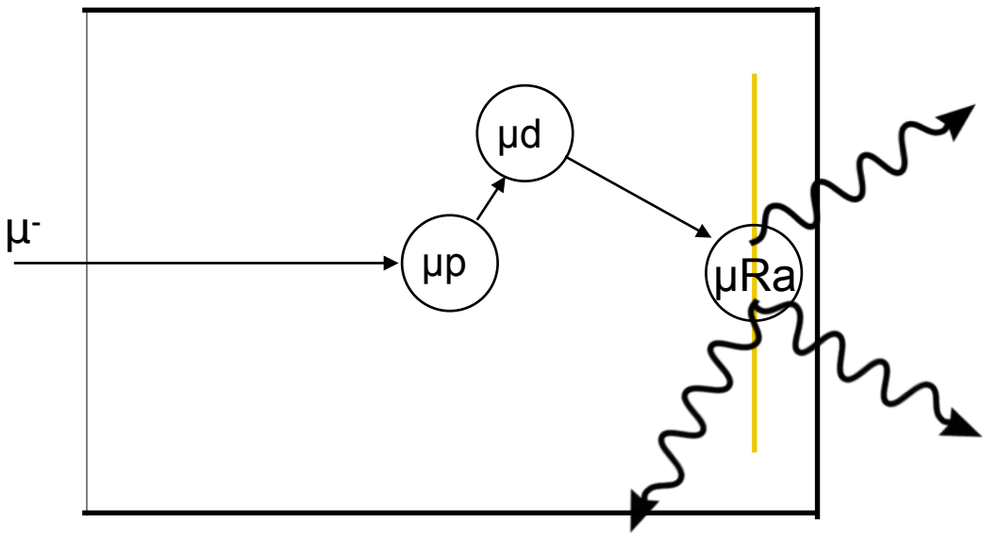
Traditional muonic atom spectroscopy



- Negative muons at rest quickly get captured by surrounding atoms
- Cascade down into 1s state emitting characteristic X-rays
- For heavy muonic atoms: X-rays have MeV energies
- Comparison to precision calculations allows to extract charge radius

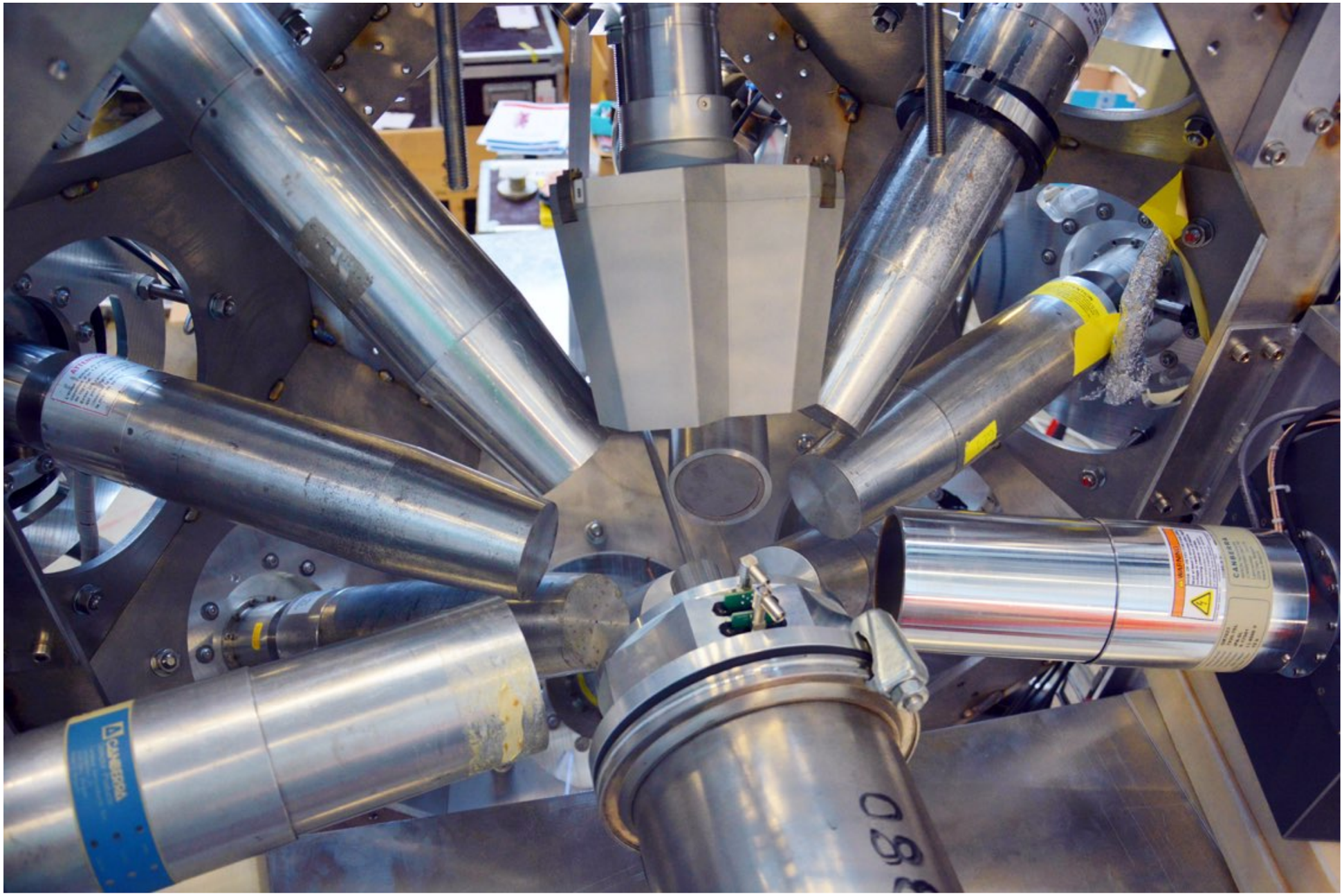
Using transfer reactions for microgram targets

- Stop in 100 bar hydrogen target with 0.25% deuterium admixture
- Form muonic hydrogen μp
- Transfer to deuterium forming μd, gain kinetic energy of 45 eV
- Hydrogen gas quasi transparent for μd at ~5 eV (Ramsauer-Townsend effect)
- μd reaches target and transfers to μRa
- Measure emitted X-rays from cascade



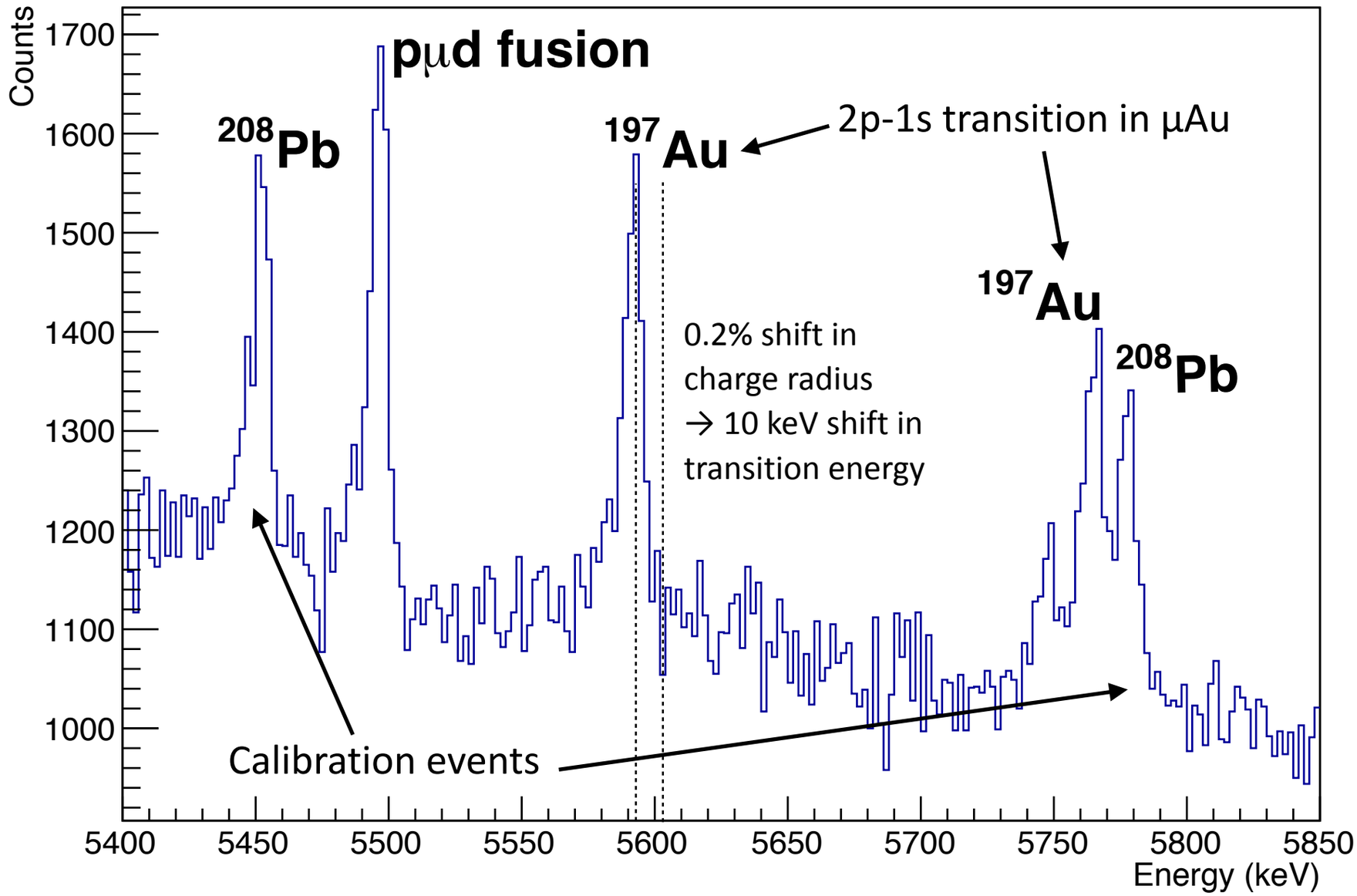
Inspired by work of Strasser et al. and Kraiman et al.

Experimental setup 2017



- 11 germanium detectors in an array from French/UK loan pool, Leuven, PSI
- First time a large array is used for muonic atom spectroscopy

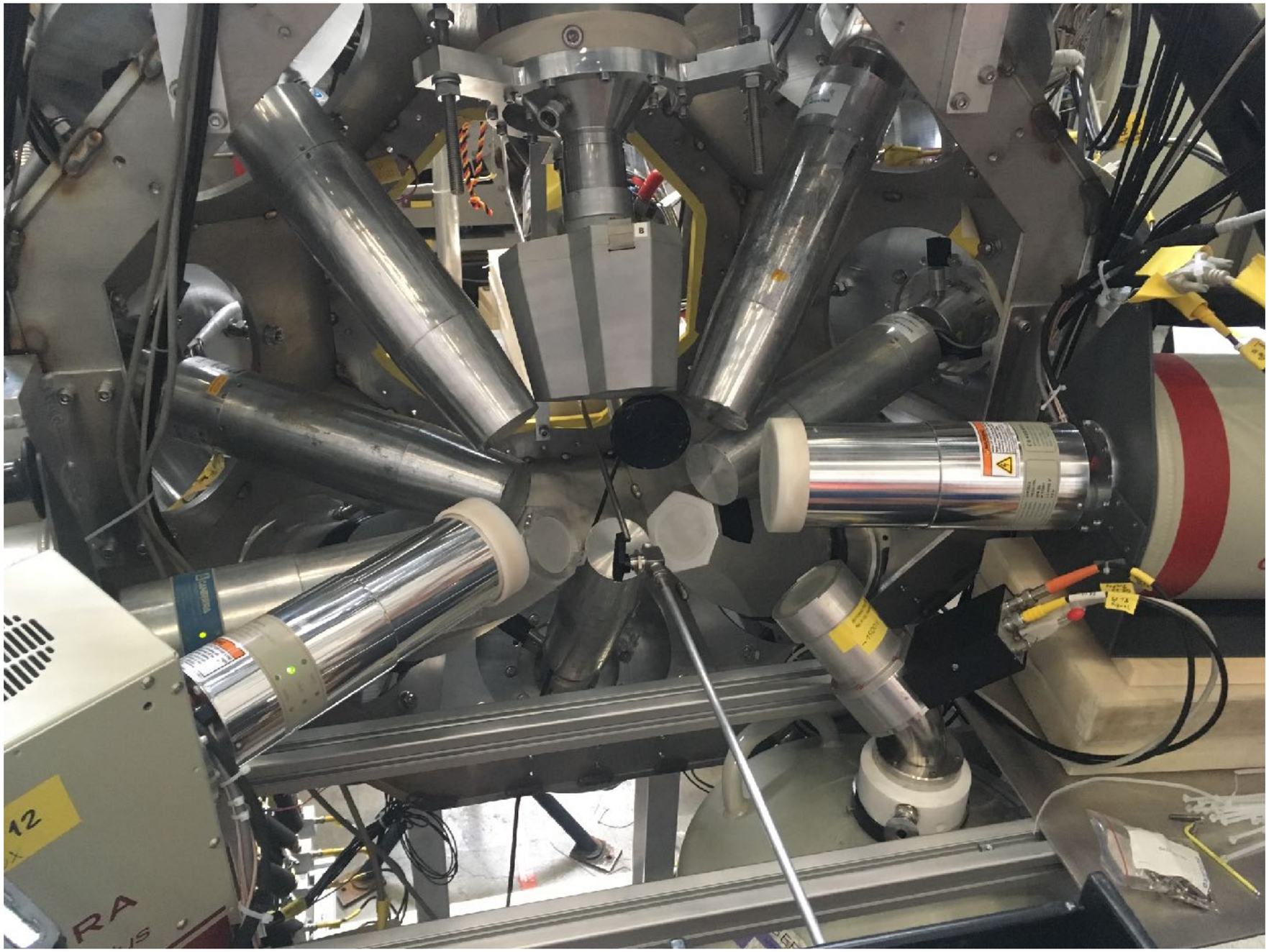
Measurement with microgram gold target



- Measurement with 5 µg gold target as proof-of-principle
- Tests with high-activity gamma source successful

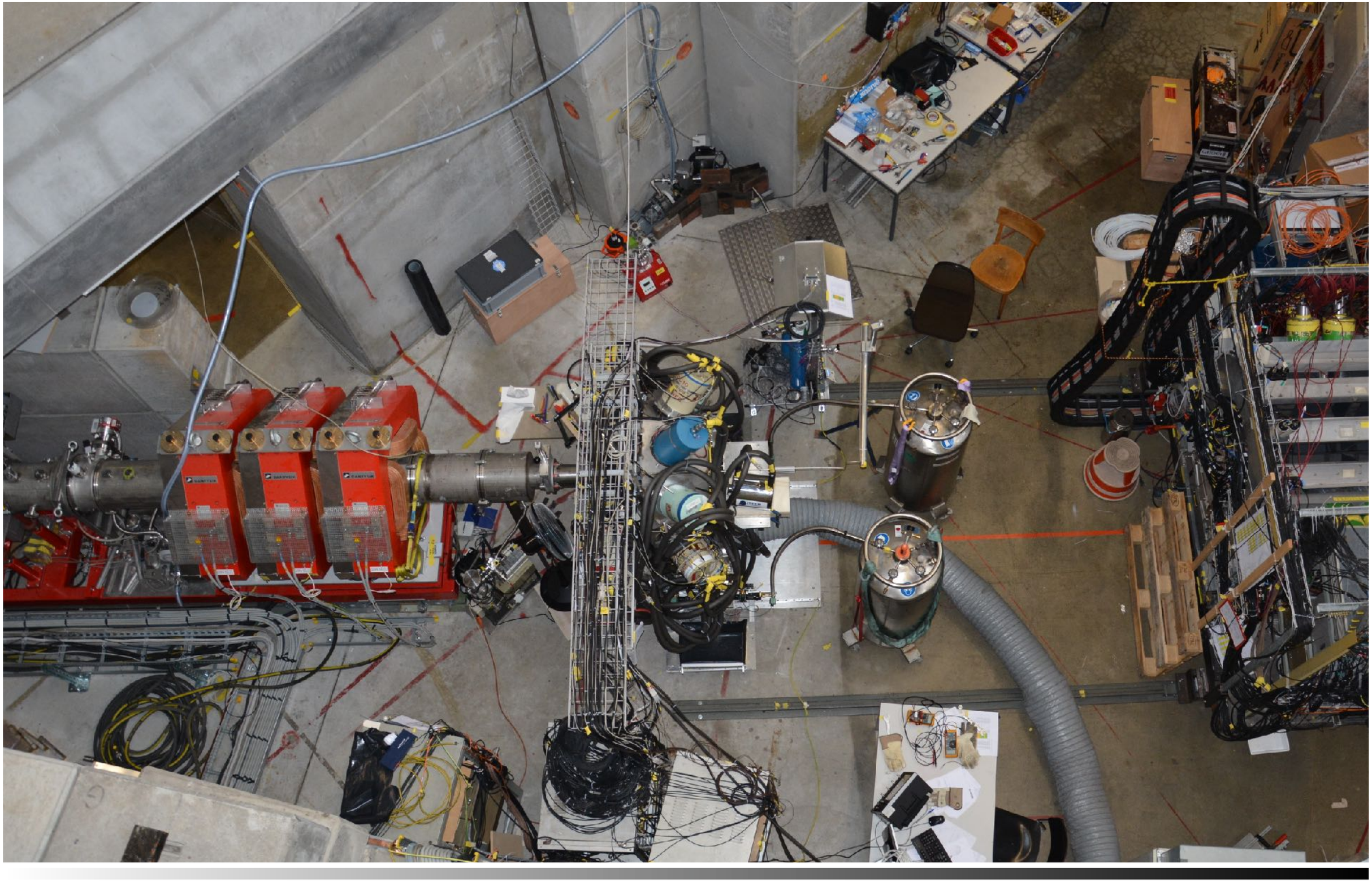
⇨ Experiment is ready for measurements with radioactive target this summer

Setup 2018

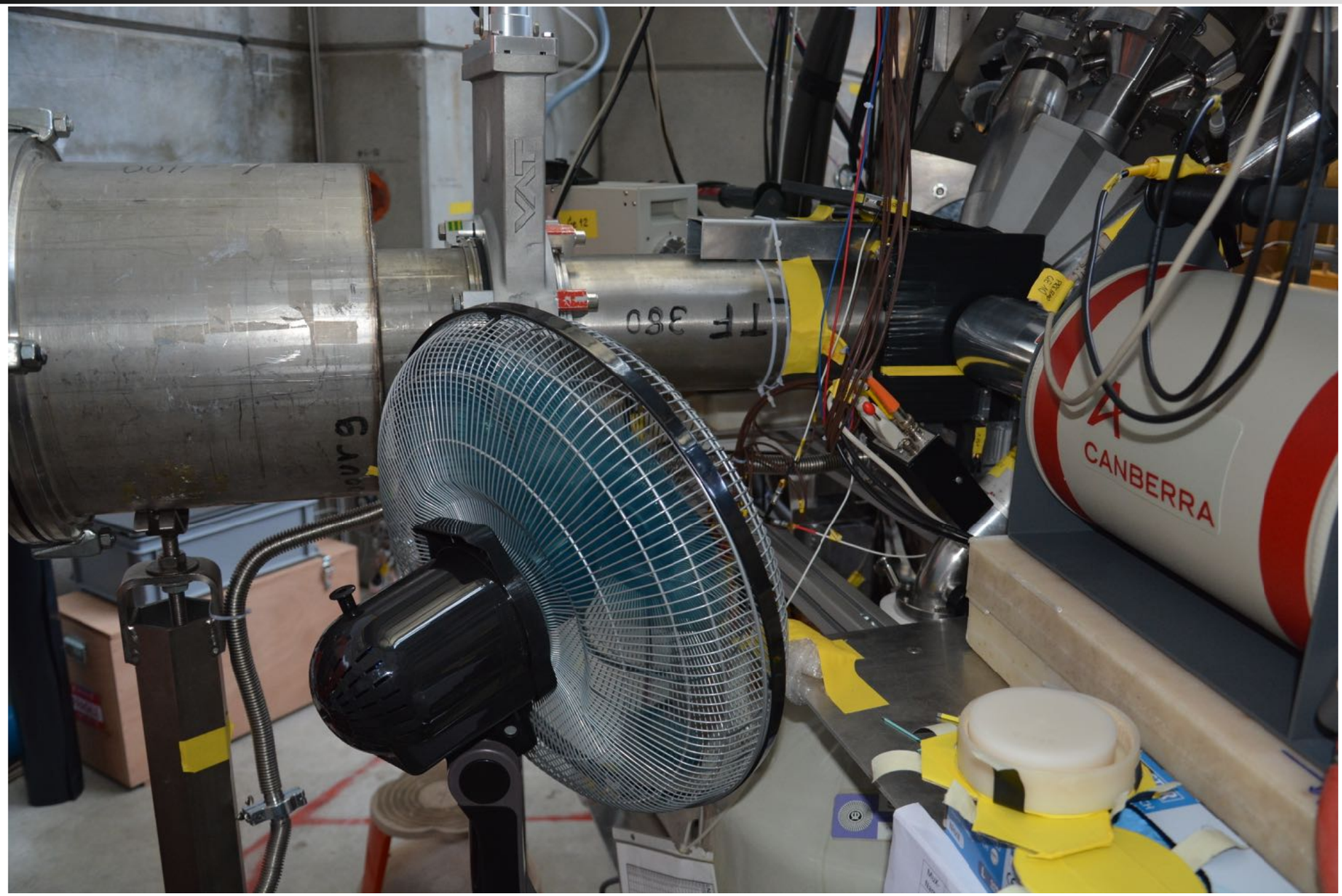


- 2 additional detectors, but 1 not really very good….

Setup 2018

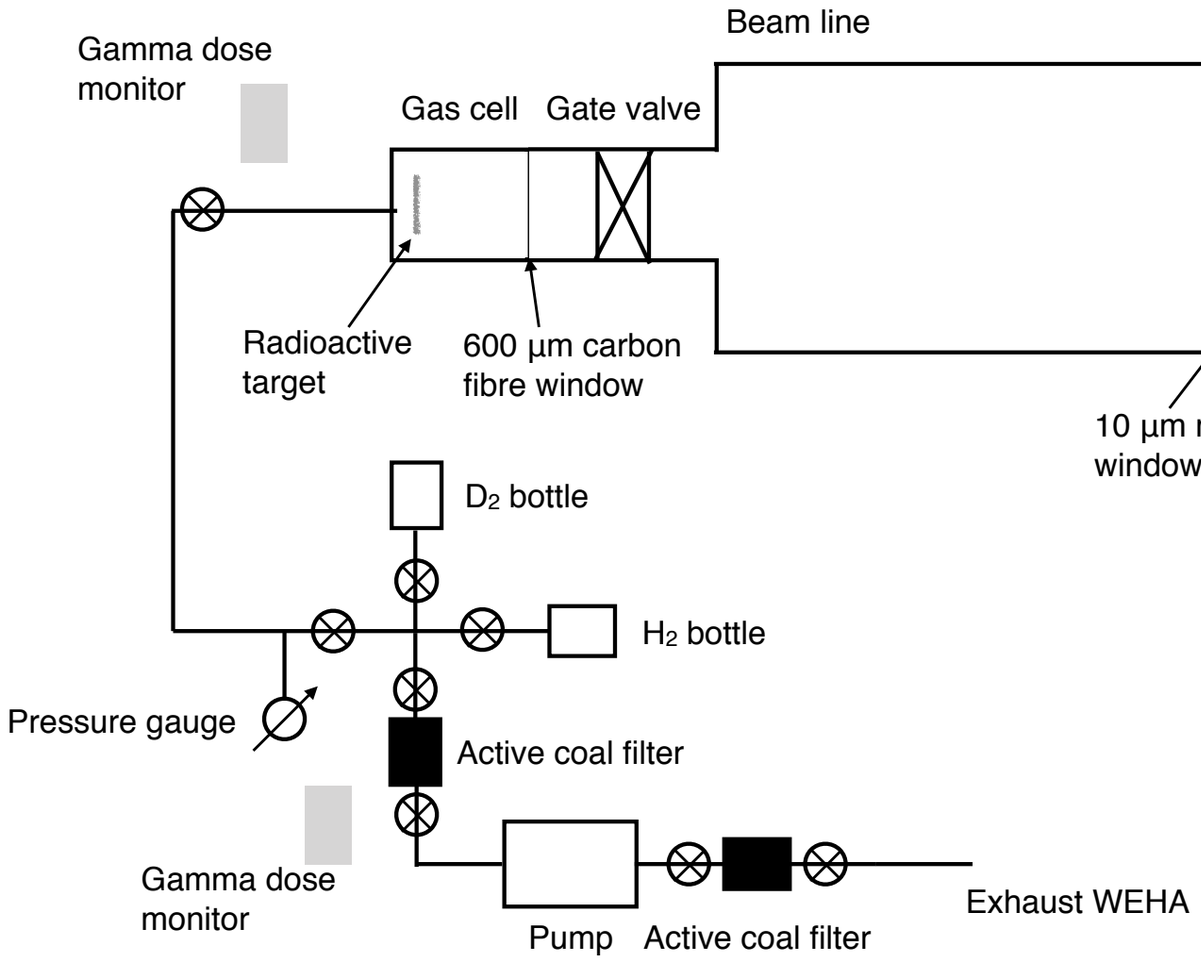


Issues with humidity



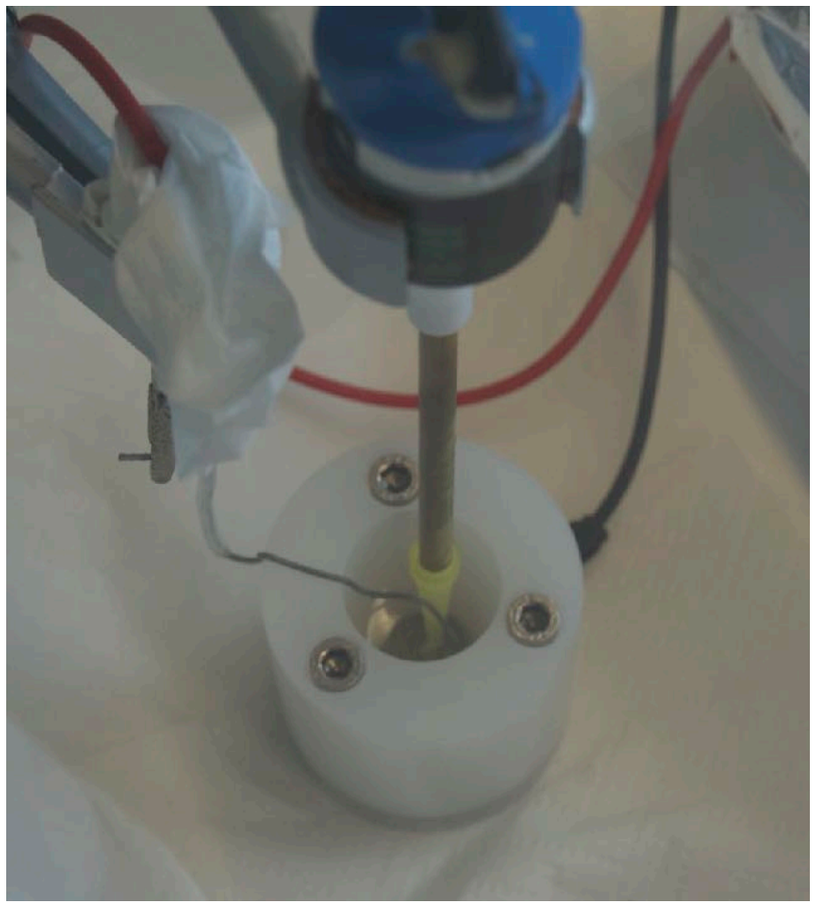
- As last year some issues with humidity -> tripping Ge detectors
- Fan + lower voltages helped

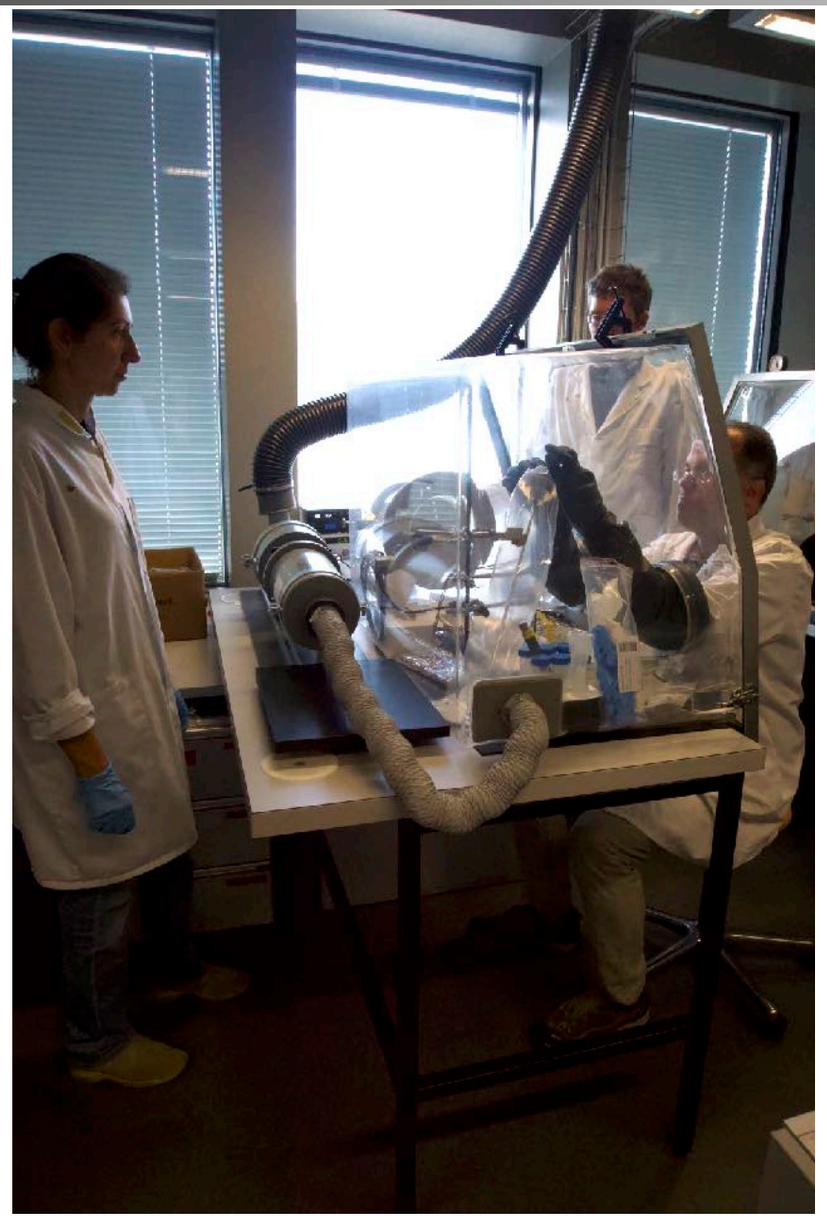
Safety

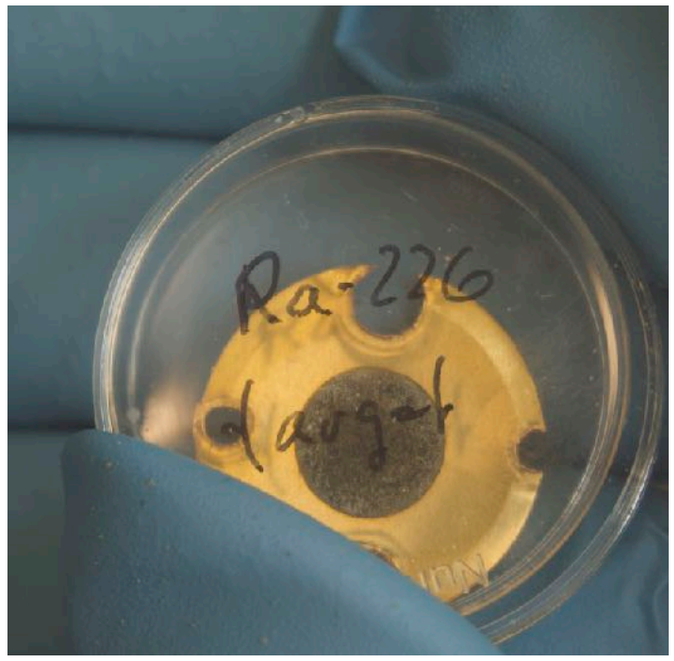


- Implemented full safety features for handling radioactive targets

Making radium target







- Electroplating the Ra-226 out of the isopropanol solution onto the gold plated copper foil

Making radium target

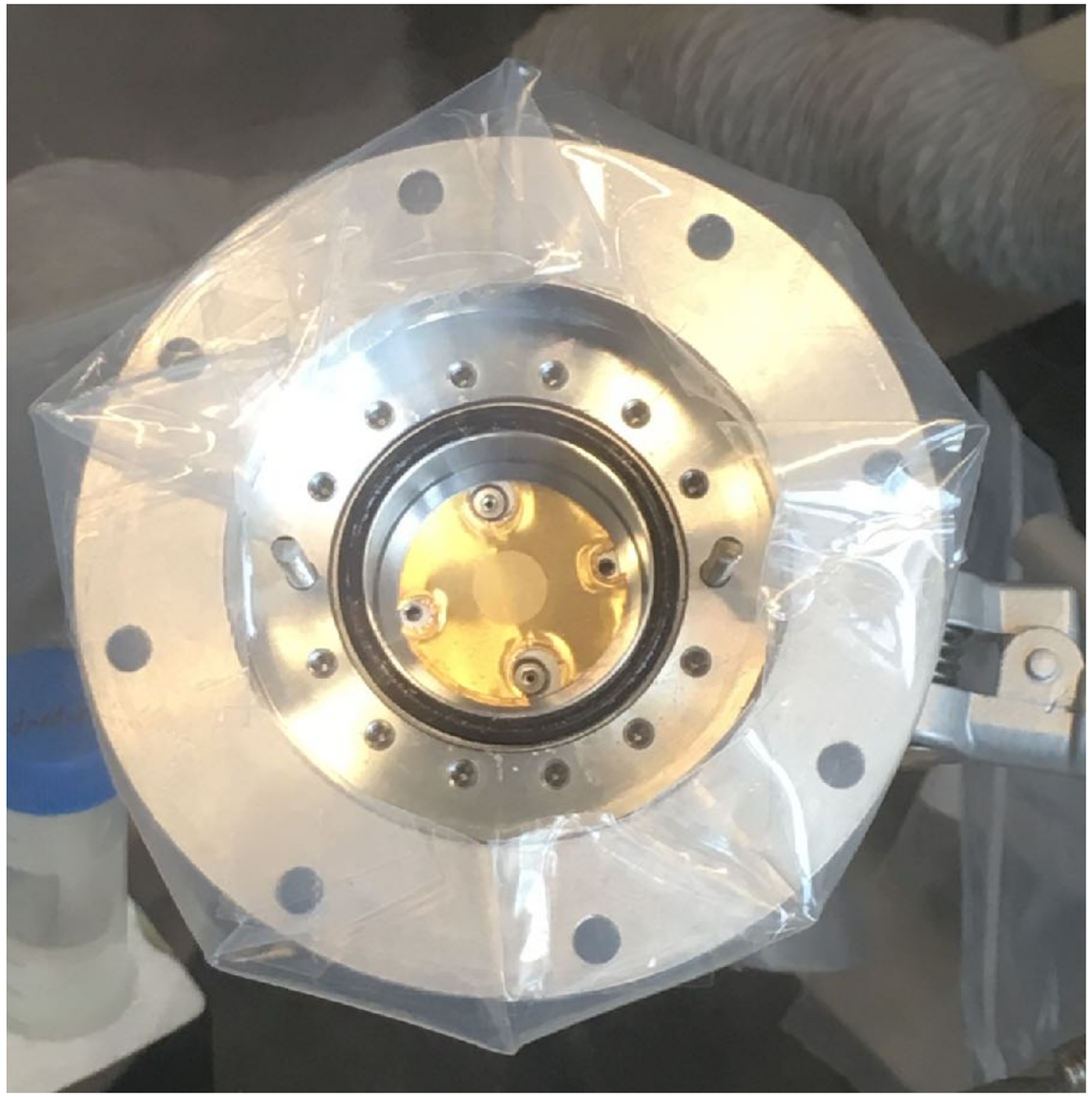
- Lots of problems during electroplating!
- Not really clear what happened

- Solution + electrolysis attacked copper, which got replated
- Trying to separate radium from copper, chromium, gold. Additionally contamination from iron.

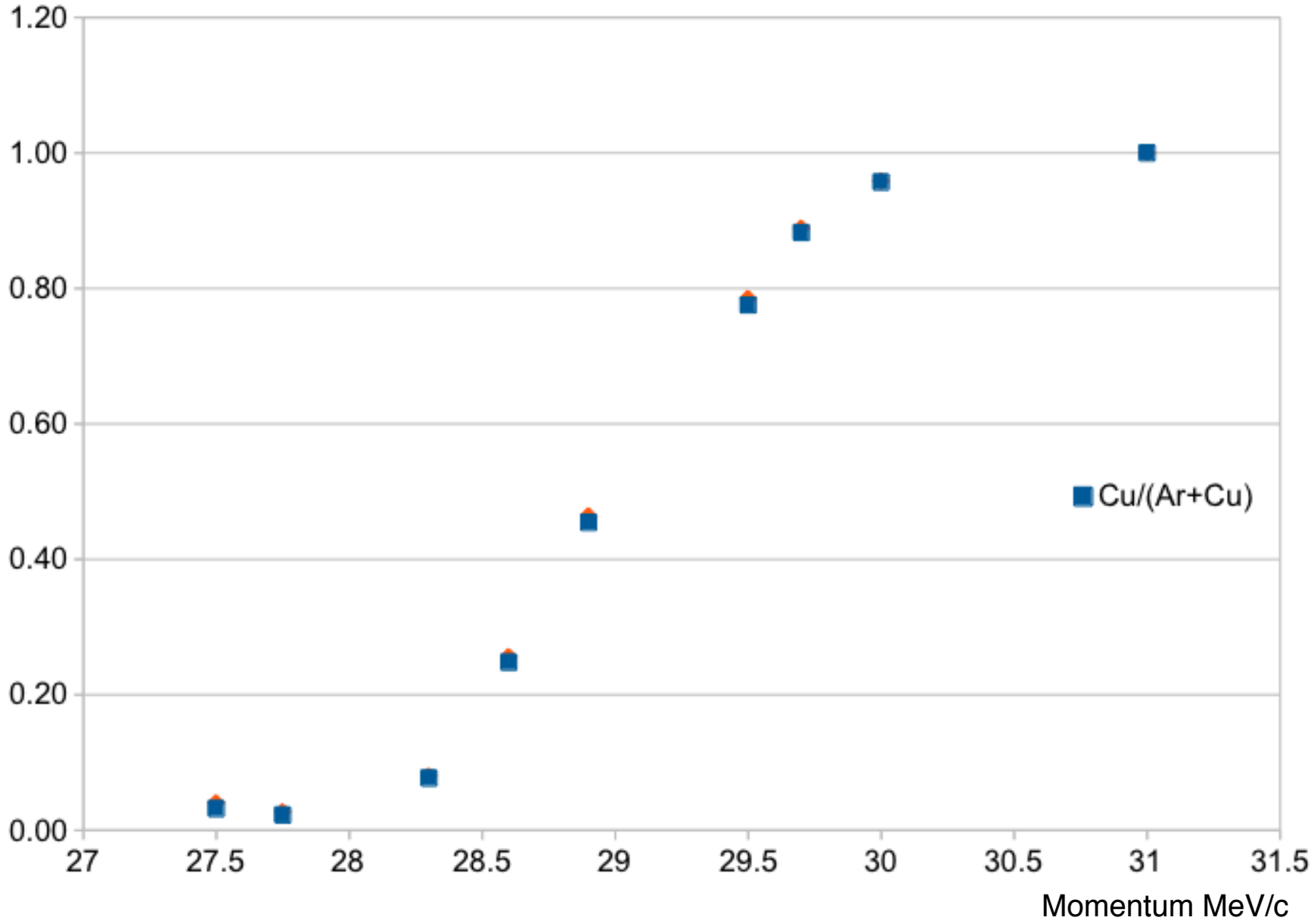
- Accident -> spill of radium -> radium in tissues and contamination with aluminium
- Finally all separated by use of ion exchangers
- First target on aluminium produced, but lots of organic material plated in addition
- Tried second target -> electroplating solution completely dissolved aluminium backing

Making curium target

- Curium-248 target was made in Mainz
- Some issues with plating too much activity & contamination of Cm-246
- Due to the contamination could not plate as much Cm-248 as planned

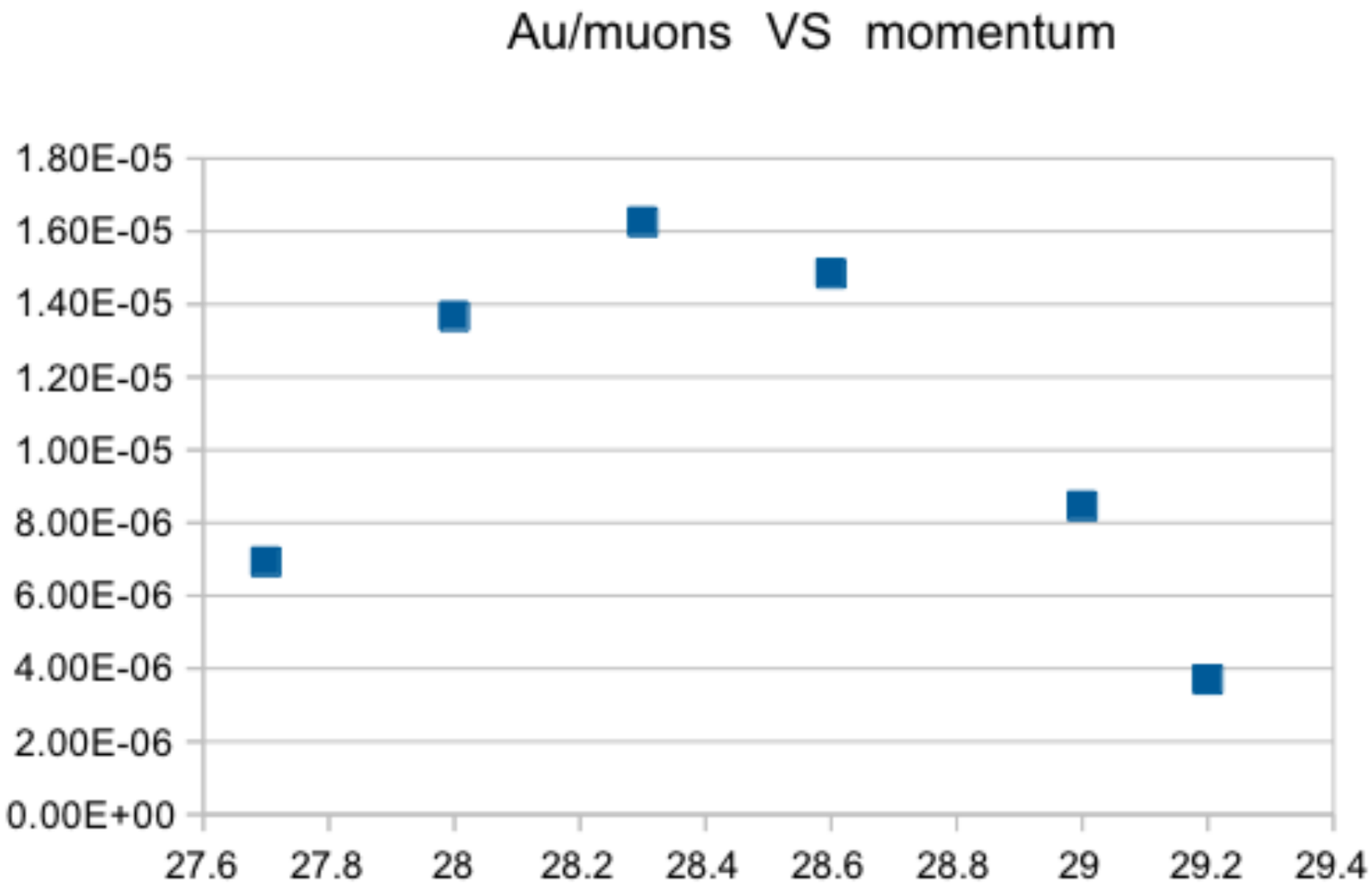


Optimising target conditions



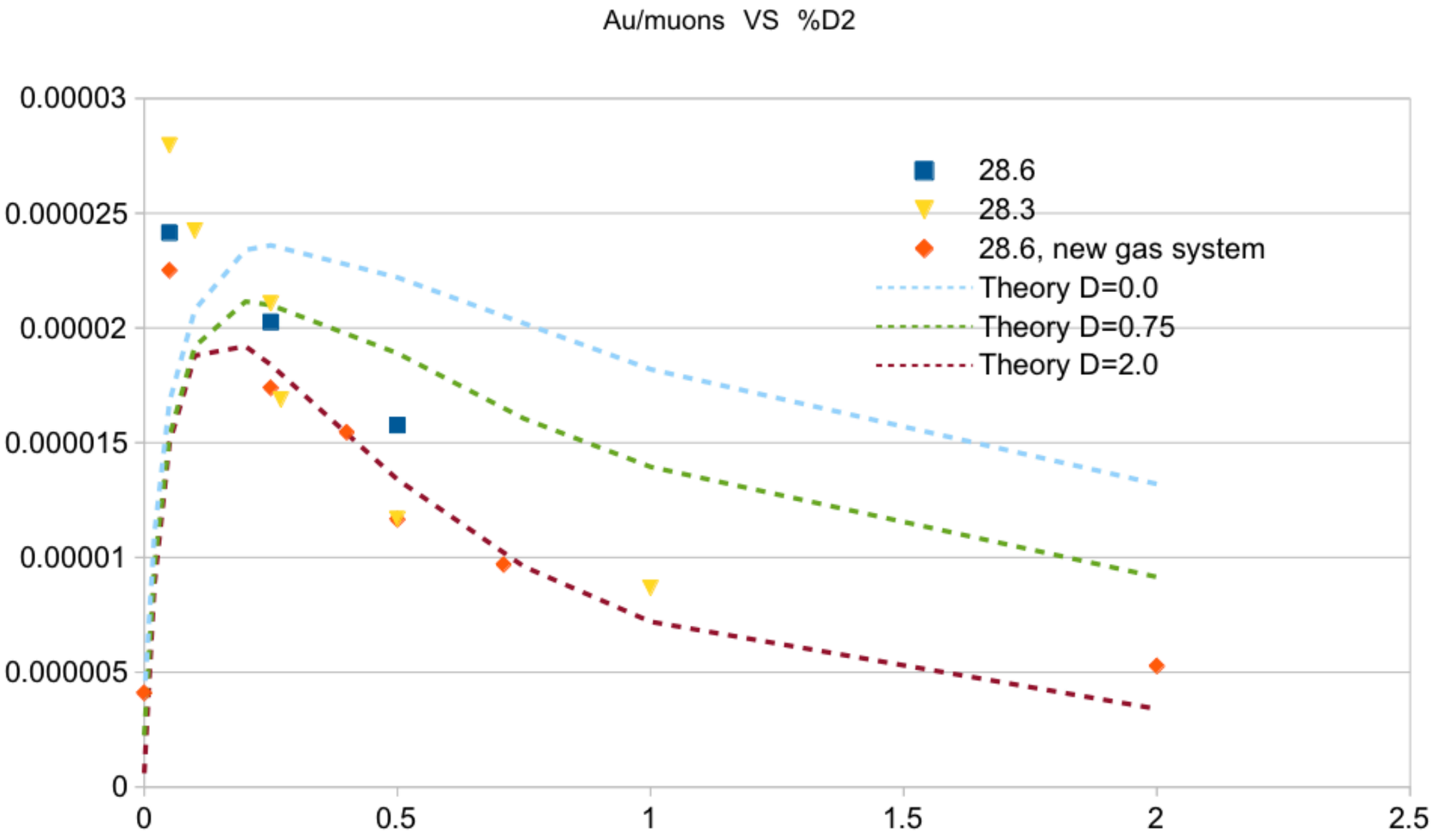
- Measured stopping distribution
- Ar/H_2 mixture plus copper foil at the end

Optimising target conditions



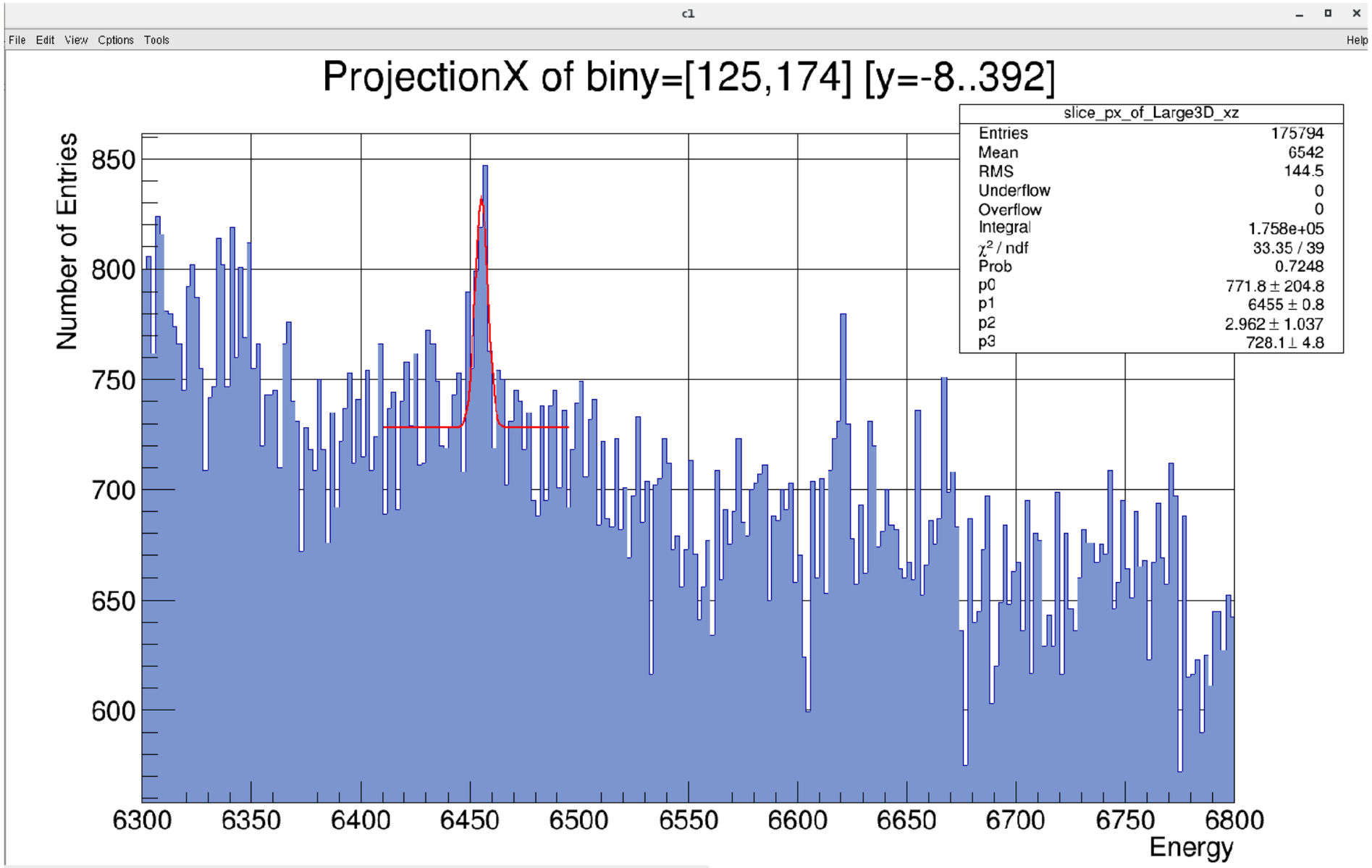
- Measured transfer to 50 nm gold coating
- Optimizing momentum

Optimising target conditions



- Measured transfer to 50 nm gold coating
- Optimizing deuterium concentration
- Somewhat different than last year…

Going for curium target

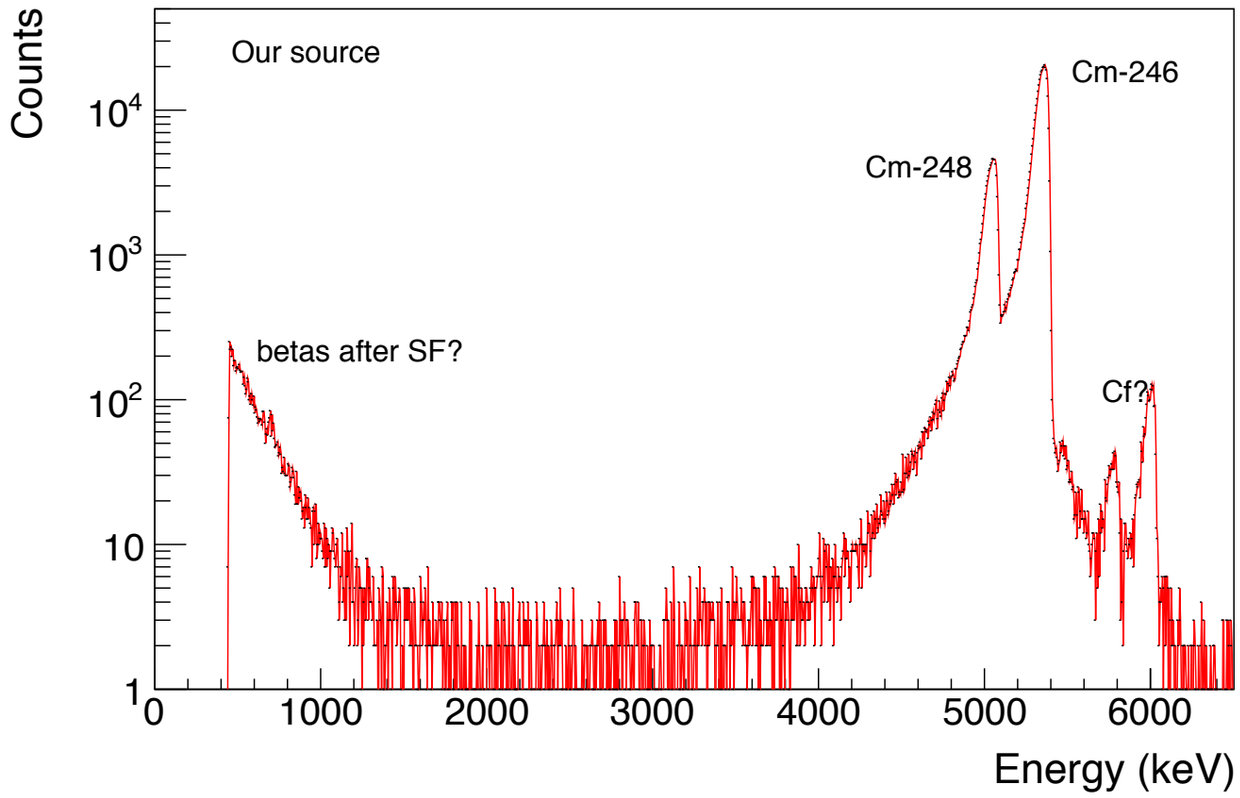


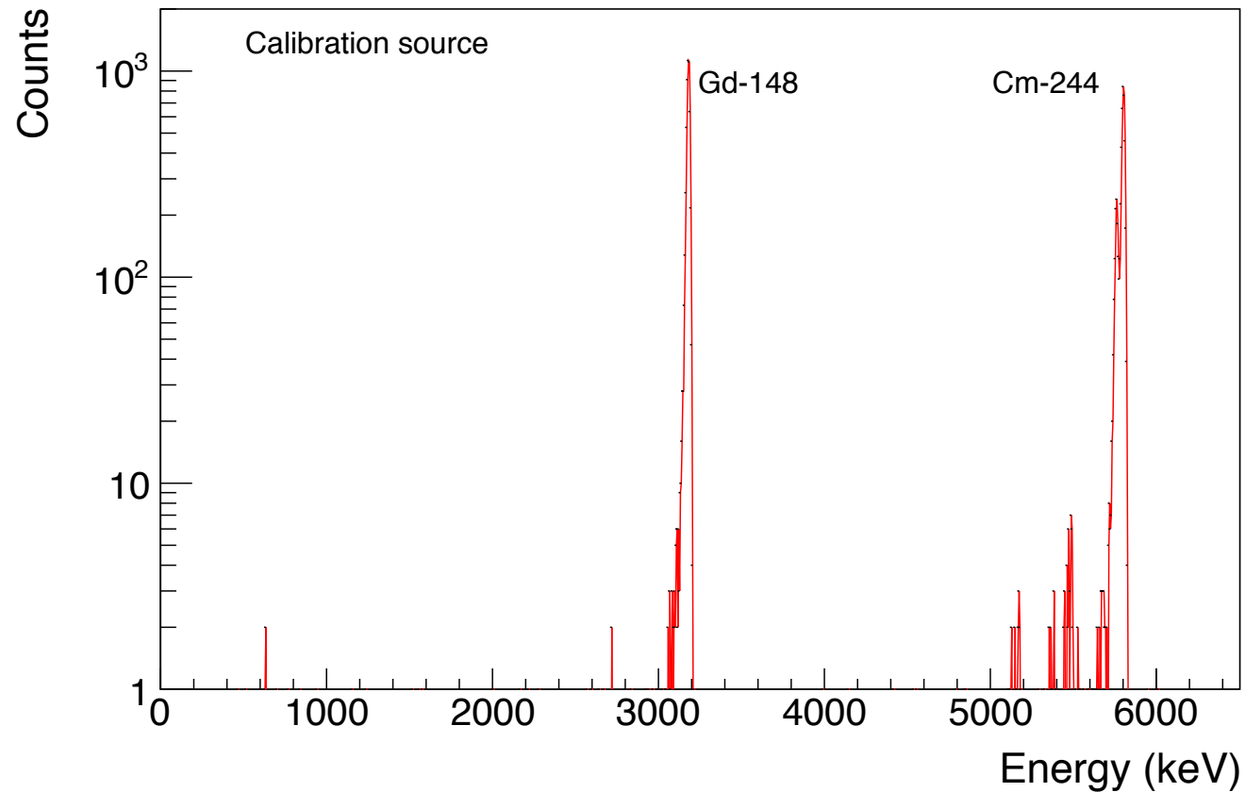
- Were very excited about this peak at 6450 keV for quite some time
- Turned out, that it's also there without curium
- Probably a nuclear capture line but unsure where it's from

Going for curium target

- In the end we did not see any sign of curium x-rays
- Electroplating inherently leads to organic layers on the target
- Tried several times to burn away organic layer on curium target

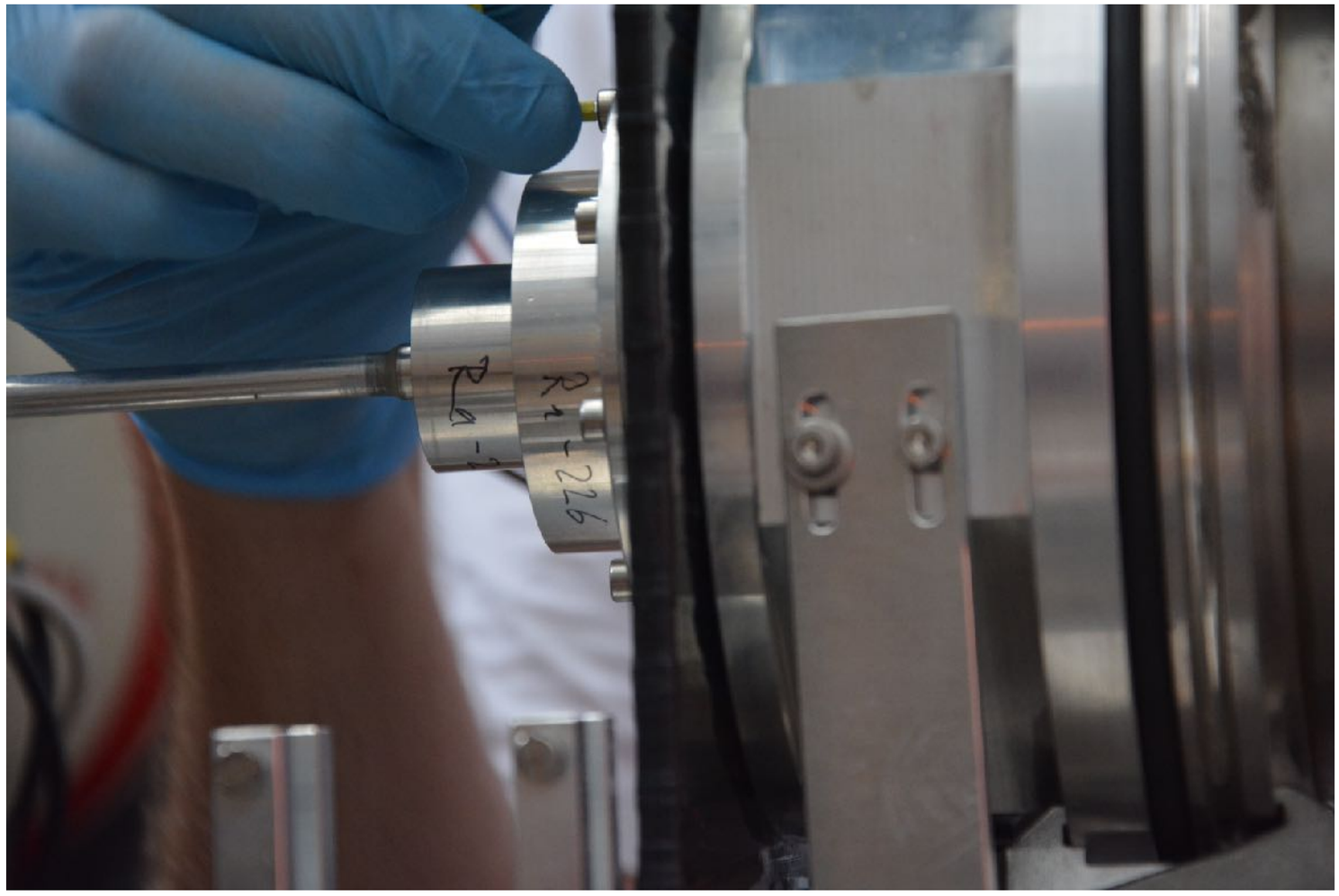
Alpha Spectrum





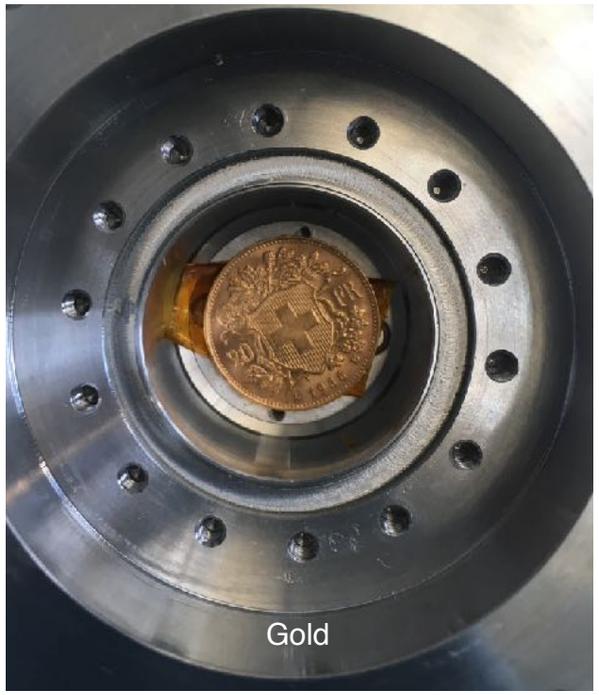
- Alpha spectrum measurements can reveal some hints on source thickness
- Tails and unresolved double peak clearly show that we have a “thick” source
- Doing some simulations with organic layer as free parameter trying to match the measured spectra

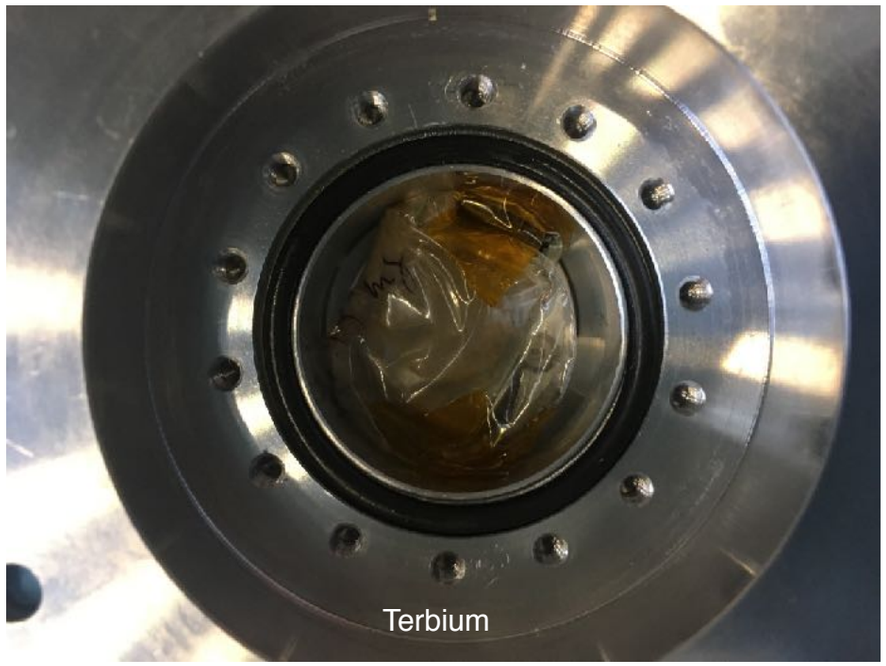
Going for radium target



- We knew that we had lost a lot of radium in the target making process plus target had a large organic contamination
- Mounted target anyway but immediately saw that we had only 1% of the required target mass…
- Measured for a while, but clearly saw nothing

Measuring some other targets


Gold


Terbium


Hafnium

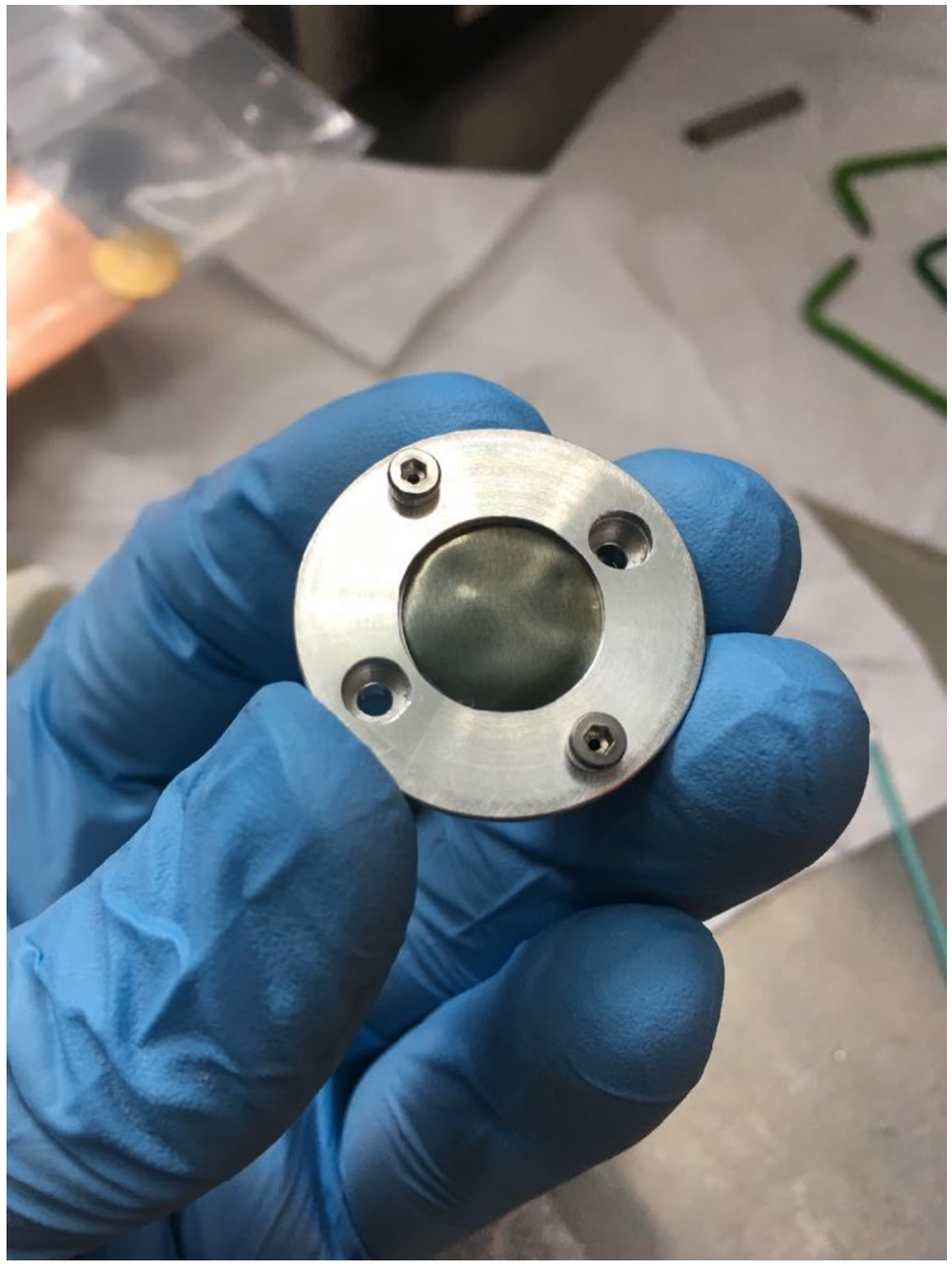
- Decided to measure some samples that are useful:
  - Gold: Has never been properly measured & published
  - Terbium/hafnium: Ideal test cases to extract quadrupole moments from 5-4 transitions
- Gold coin was a present to Finn ;-), Klaus brought terbium and hafnium from Cologne

Carbon coatings on gold

- In order to understand the influence of the organic layer on our measurements prepared gold coatings with 100 and 500 nm carbon coating on top.

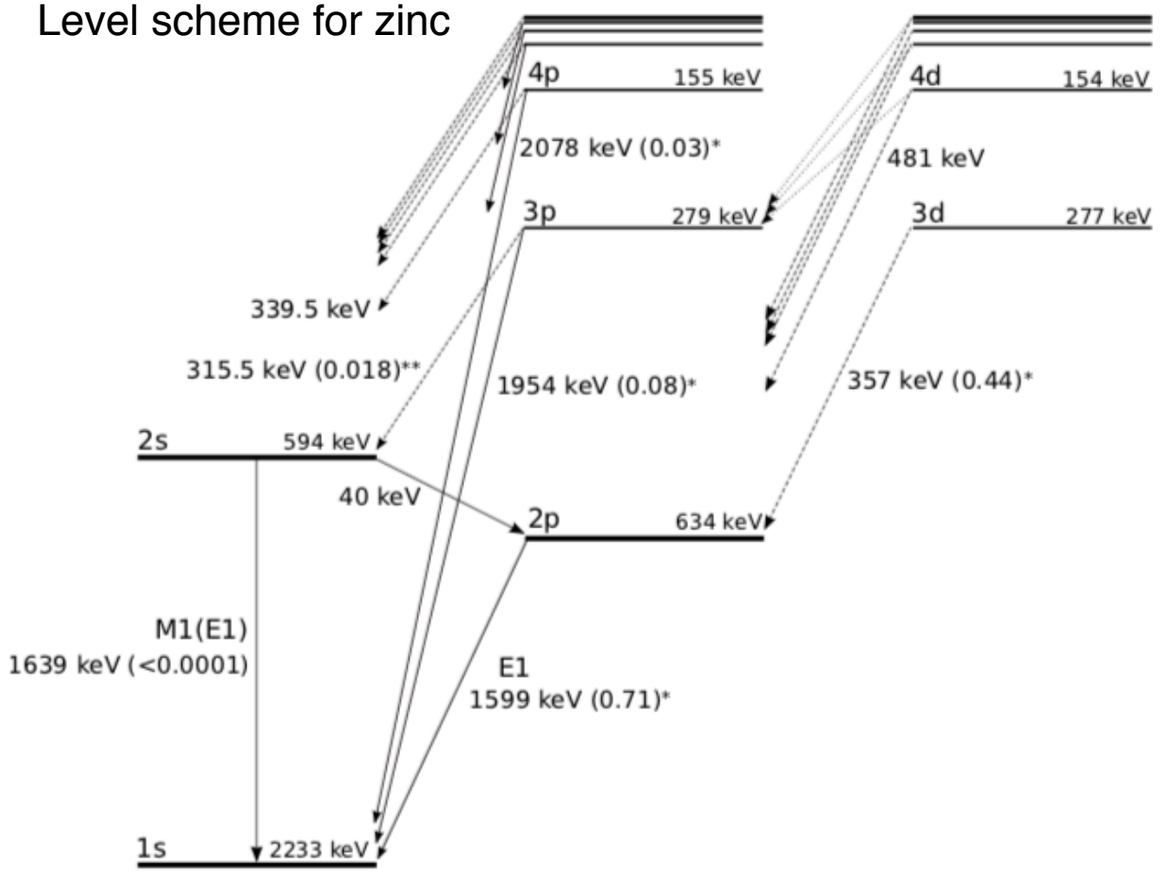
- Results:
  - 100 nm: 27% of gold x-rays left
  - 500 nm: no gold x-rays seen

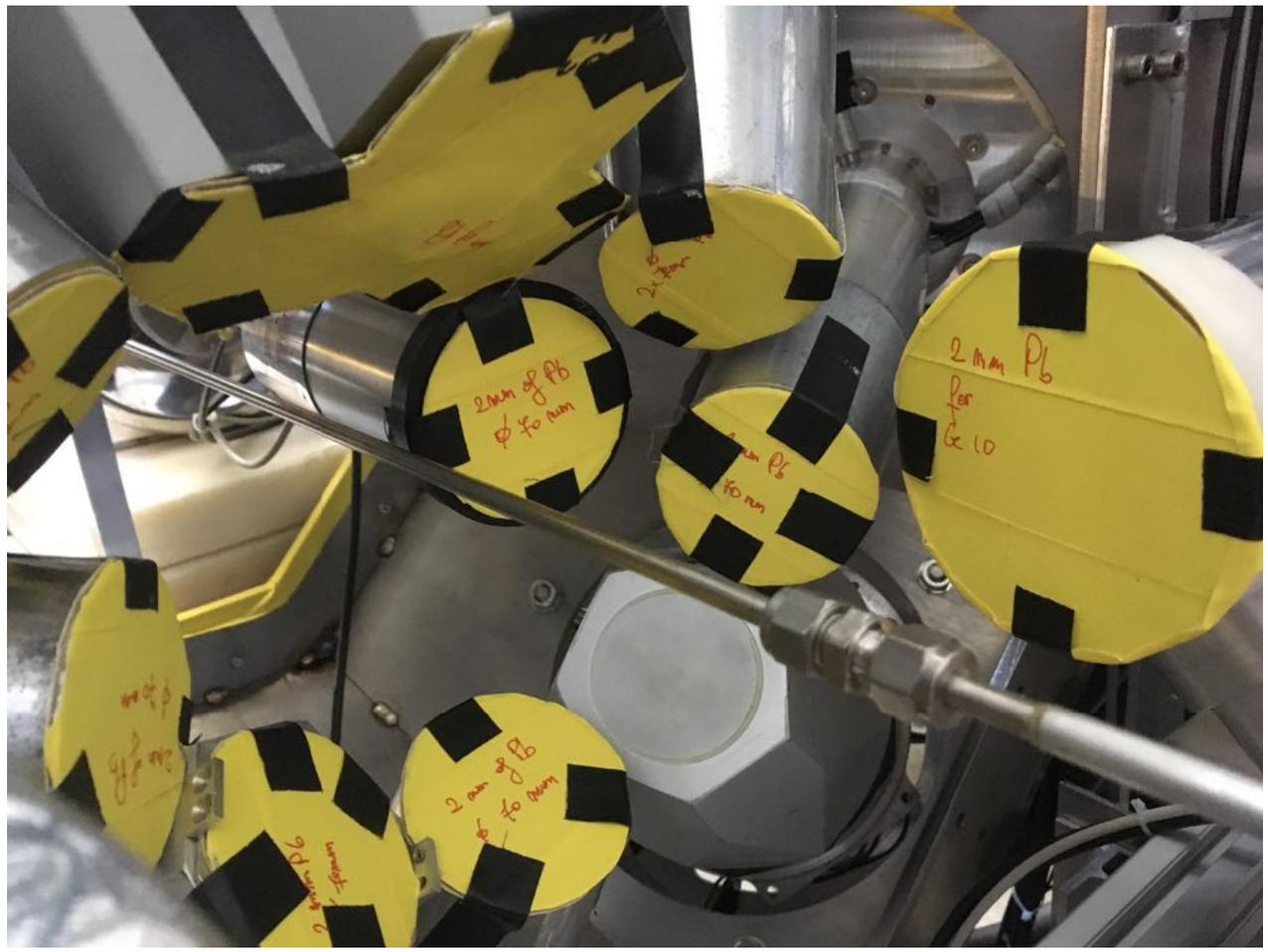
- We are super sensitive to organic layers!



2s-1s measurement in krypton

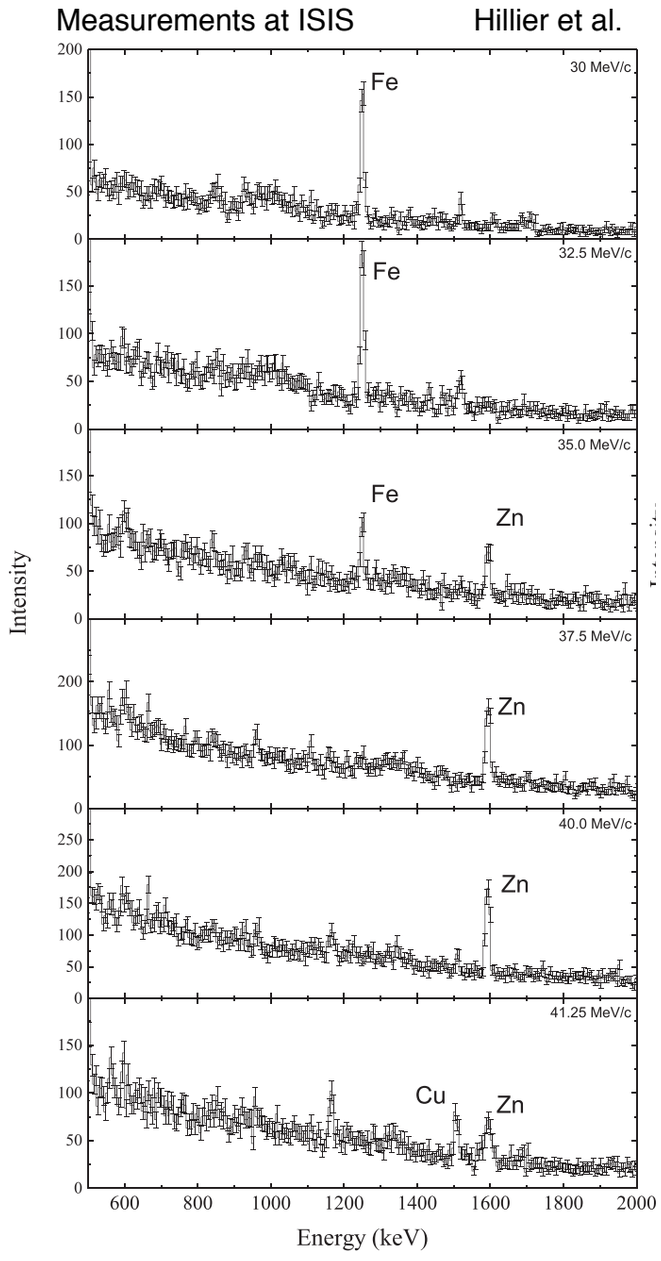
Level scheme for zinc

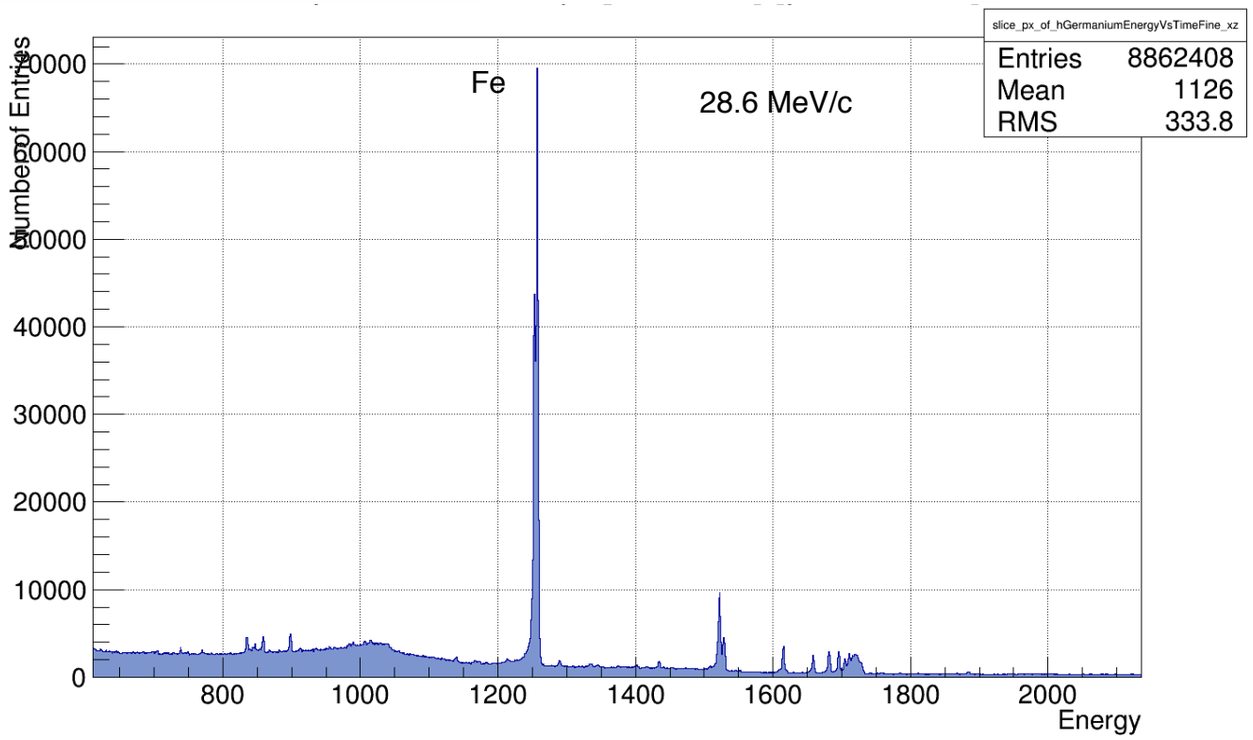


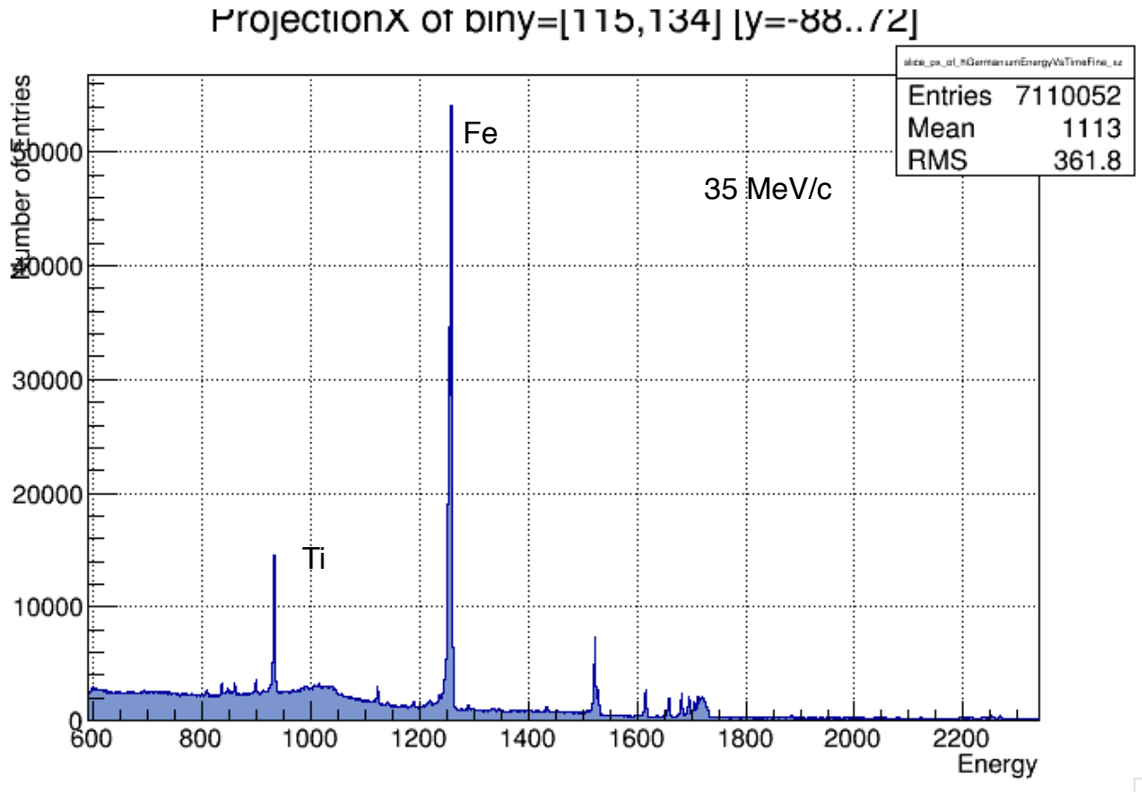


- Last year measured 2s-1s transition in zinc and tried to measure also in krypton/hydrogen mixture
- Krypton/hydrogen mixture increases population of 2s by factor 3-4
- Realised only late (after Badenfahrt) that we did not have enough shielding against 2s-2p (80 keV instead of 40 keV)
- Repeated measurement with thick 2 mm lead shielding and nicely saw 2s-1s (probably)

muSR people getting to know muX

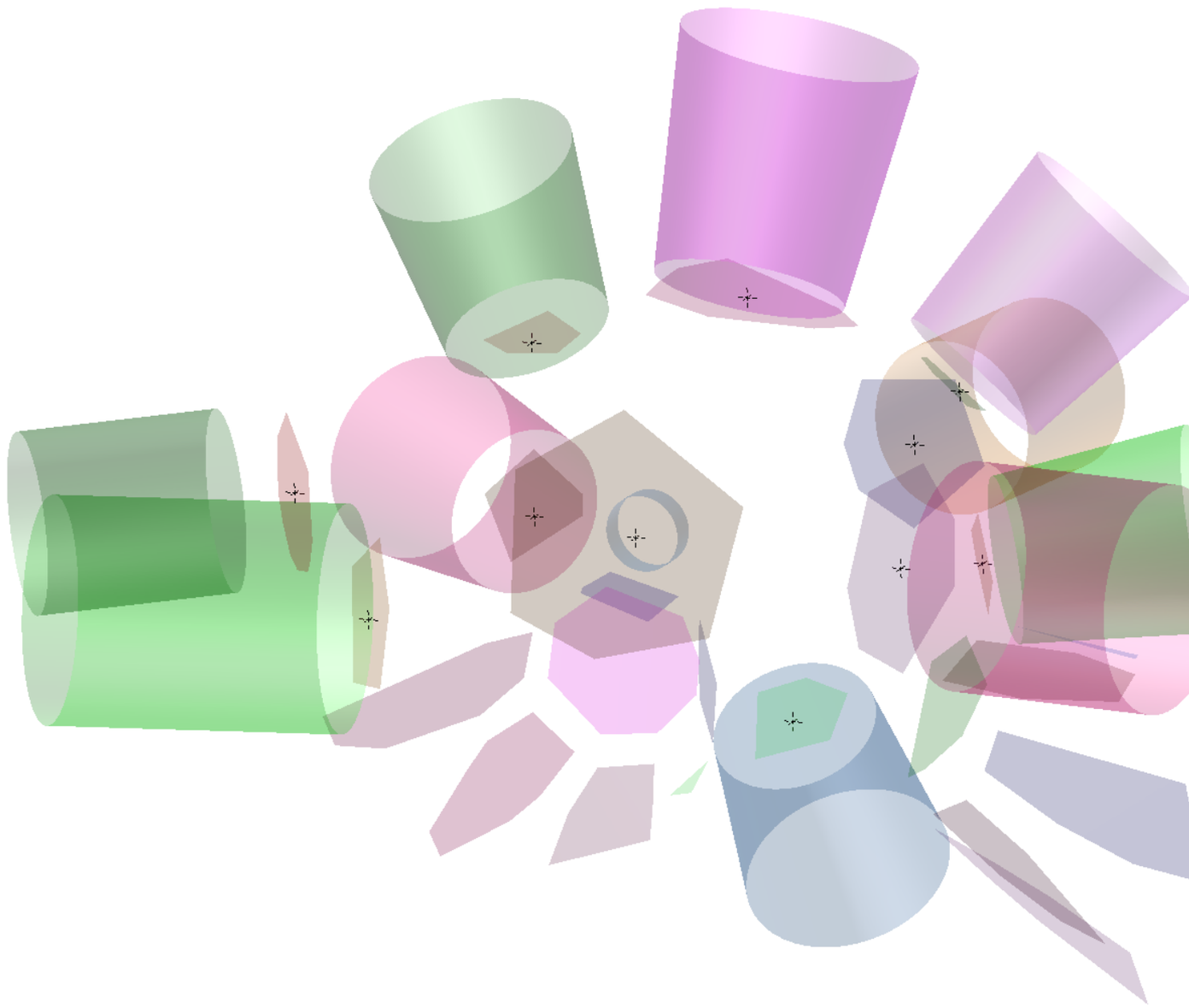






- Elemental analysis with muonic x-rays
- Depth profiling as a function of momentum
- Proof-of-principle with stacks of foils

By the way: Optical survey



- PSI survey team has an absolute tracking system from Leica
- Allows for easy measurement of all the germanium positions

Conclusions

- Apparatus worked very well
- Targets did not work very well ;-)
- Some interesting alternative measurements performed
- Need target development for next year!