Systematic studies for E1066

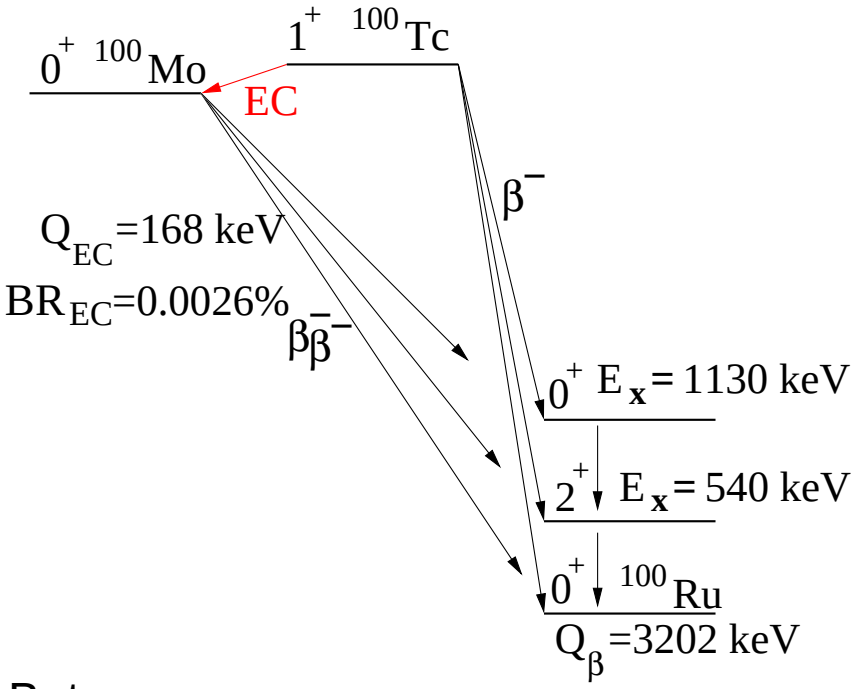
Towards the measurement of Electron Capture Branching Ratios related to $2\nu\beta\beta$ decays

This novel in-trap concept will be used for $2\nu2\beta$ decay BR measurements (E1066) at ISAC

M. Brodeur, T. Brunner, S. Ettenauer, S. Foubister, A. Gallant, A. Lapierre, D, Lunney, R. Ringle, P. Delheij, J.Dilling, R. Krücken, D. Frekers, I. Tanihata

UBC, TRIUMF, TU Munich, U Münster, RCNP Osaka, Université de Paris

Electron Capture BR measurement



Knowledge of ECBR can be used to benchmark the theoretical framework of ββ decays

S.K.L. Sjue et al., Phys. Rev. C78(2008)064317

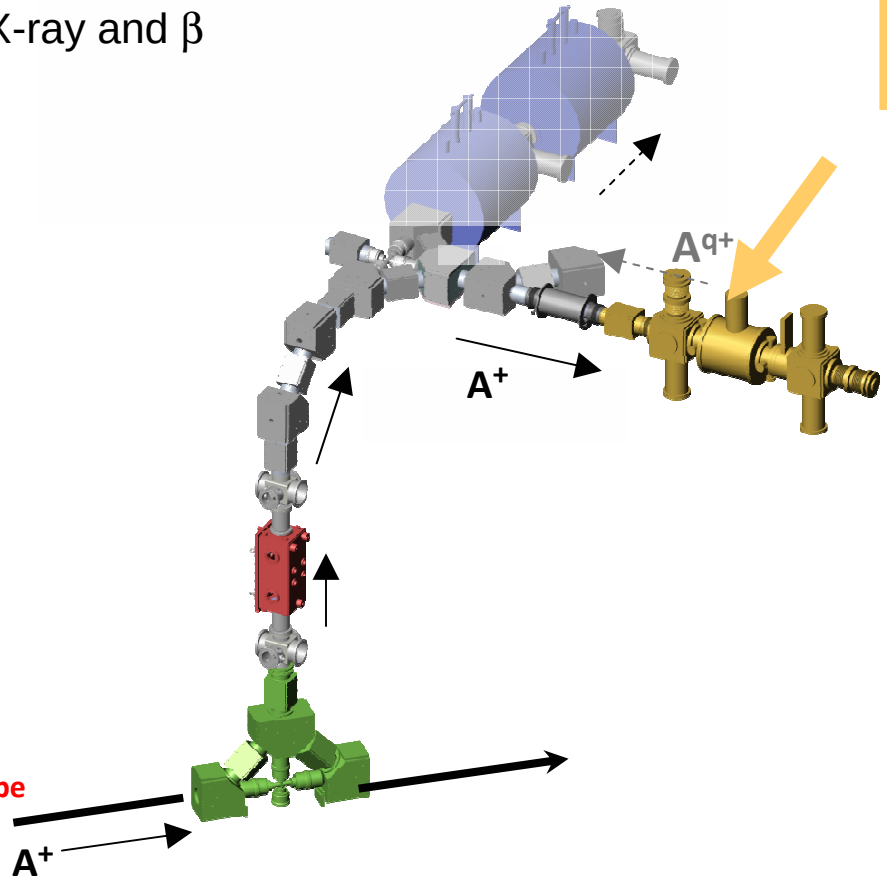
But:

- Difficult measurement due to a small EC branch and difficult X-ray signatures
- High background due to dominating beta decay and possible bremsstrahlung
- Isobaric contamination

Novel technique

- Use TITAN facility at ISAC
- make use of the open access Penning trap EBIT (no e-beam)
- Spatially separate X-ray and β detection

Electron Beam Ion Trap (EBIT) in Penning trap mode for EC-BR measurement



Short-lived isotopes from an Isotope Separator and Accelerator (ISAC)

Novel technique

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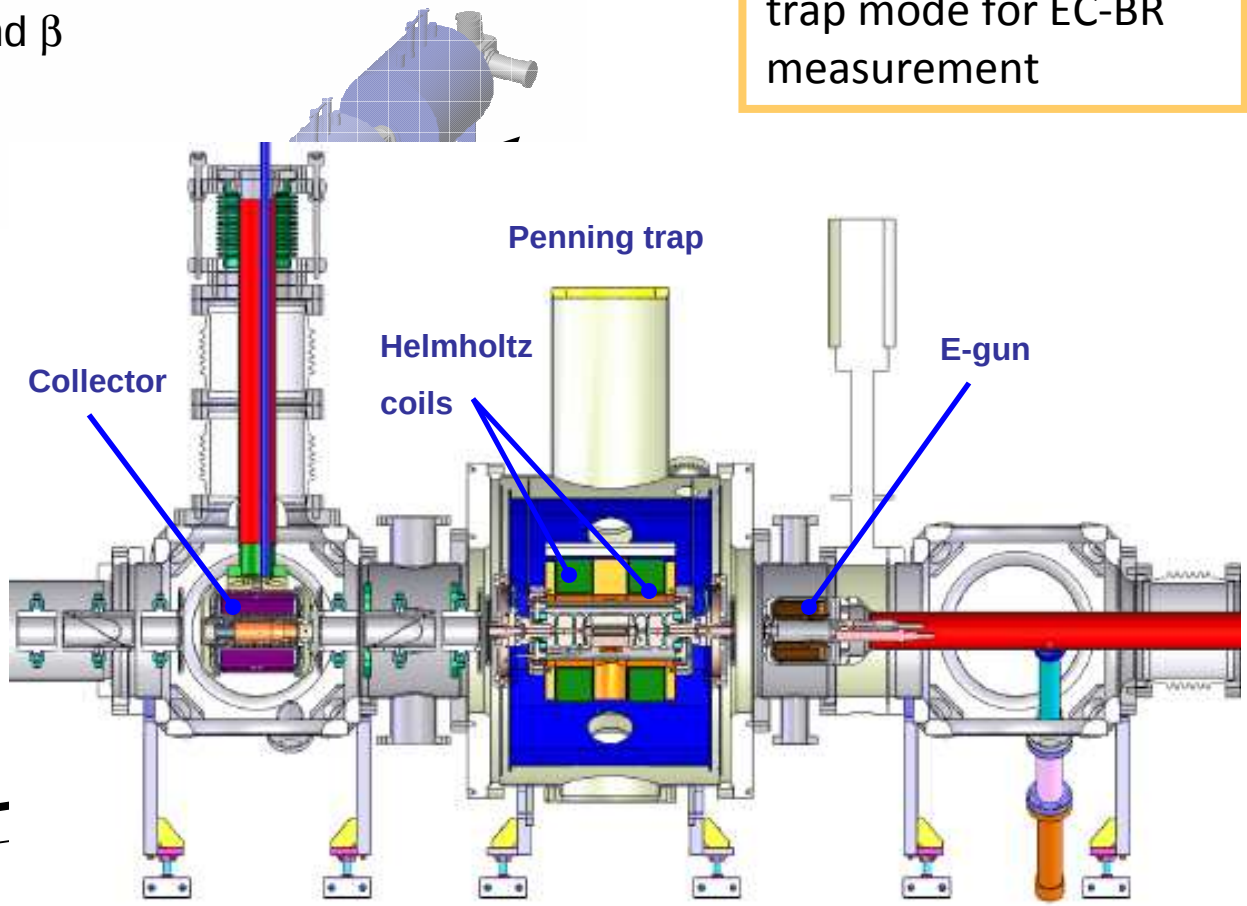


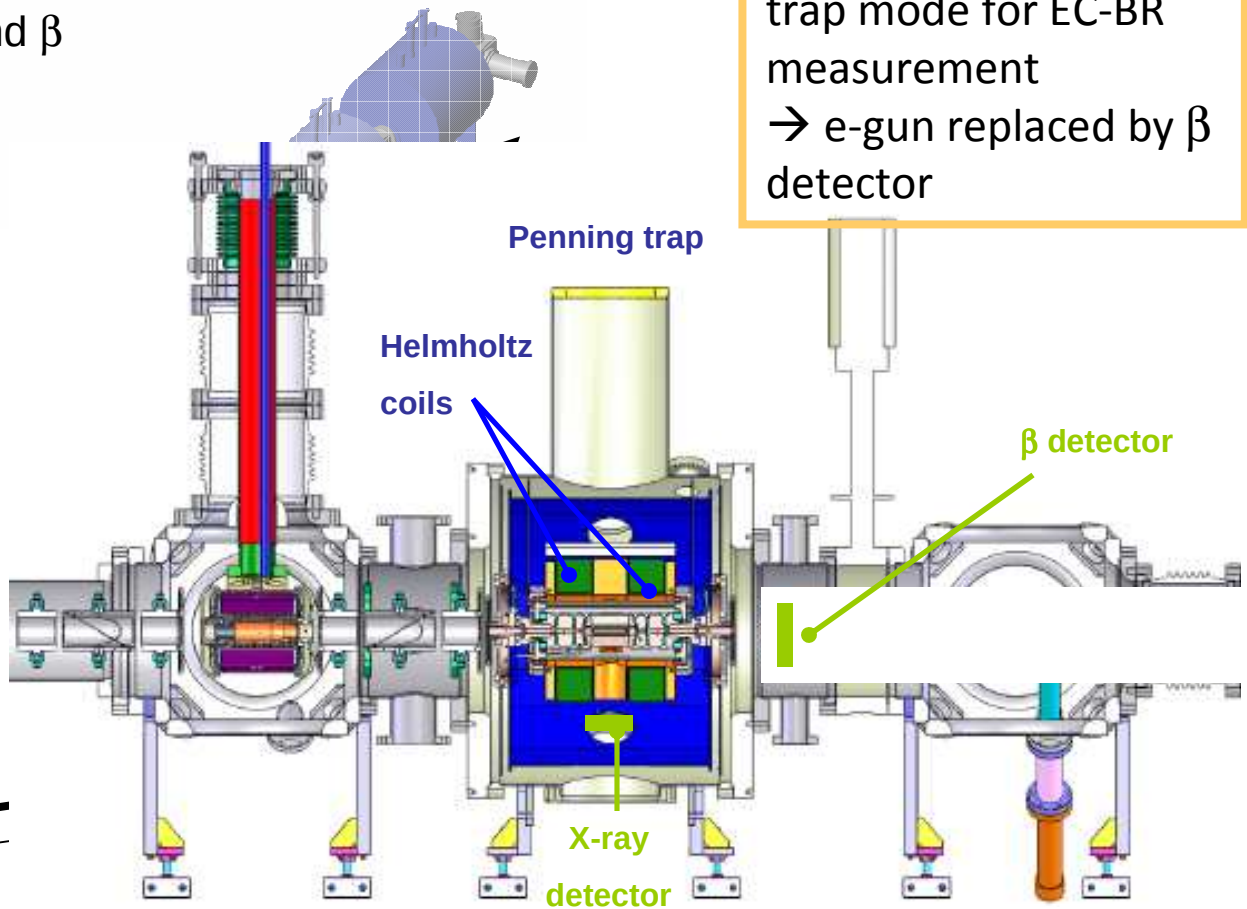
Short-lived isotopes from an Isotope Separator and Accelerator (ISAC)

A^+

Novel technique

- Use TITAN facility at ISAC
- make use of the open access Penning trap EBIT (no e-beam)
- Spatially separate X-ray and β detection

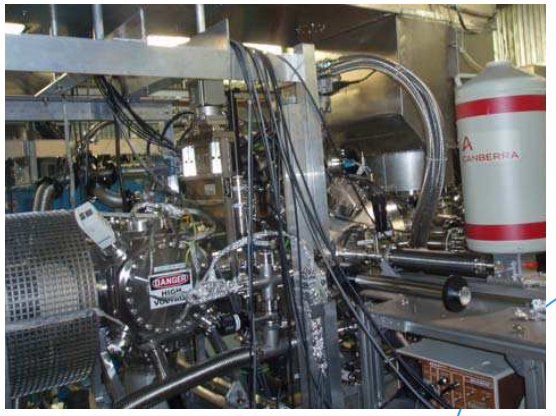
Electron Beam Ion Trap (EBIT) in Penning trap mode for EC-BR measurement
→ e-gun replaced by β detector



Short-lived isotopes from an Isotope Separator and Accelerator (ISAC)

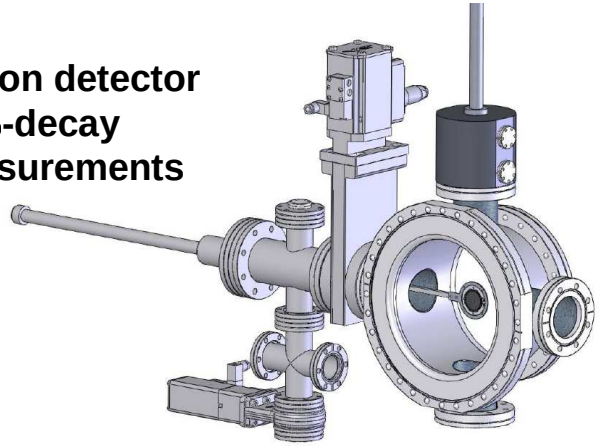
A^+

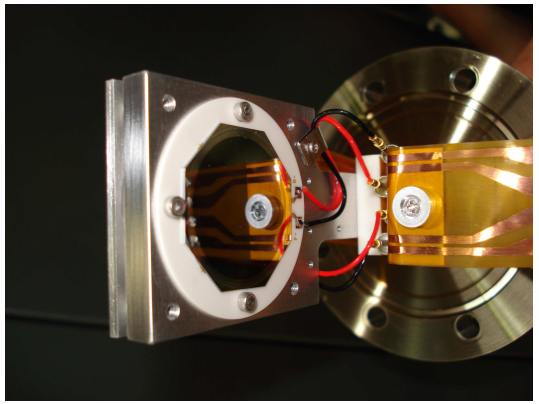
Novel technique

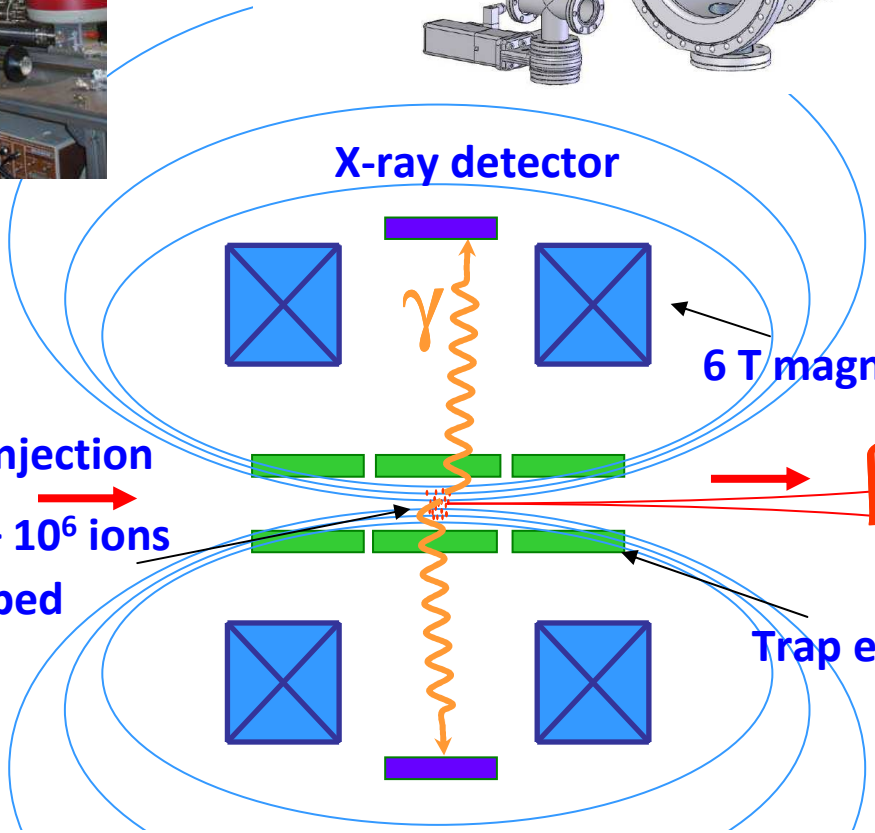


X-ray detector

Silicon detector for β-decay measurements

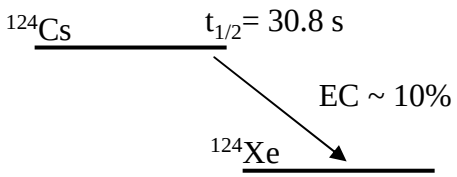


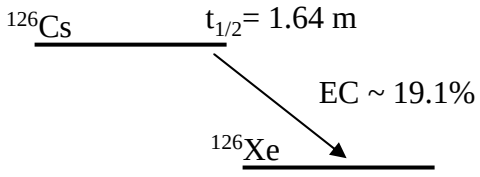




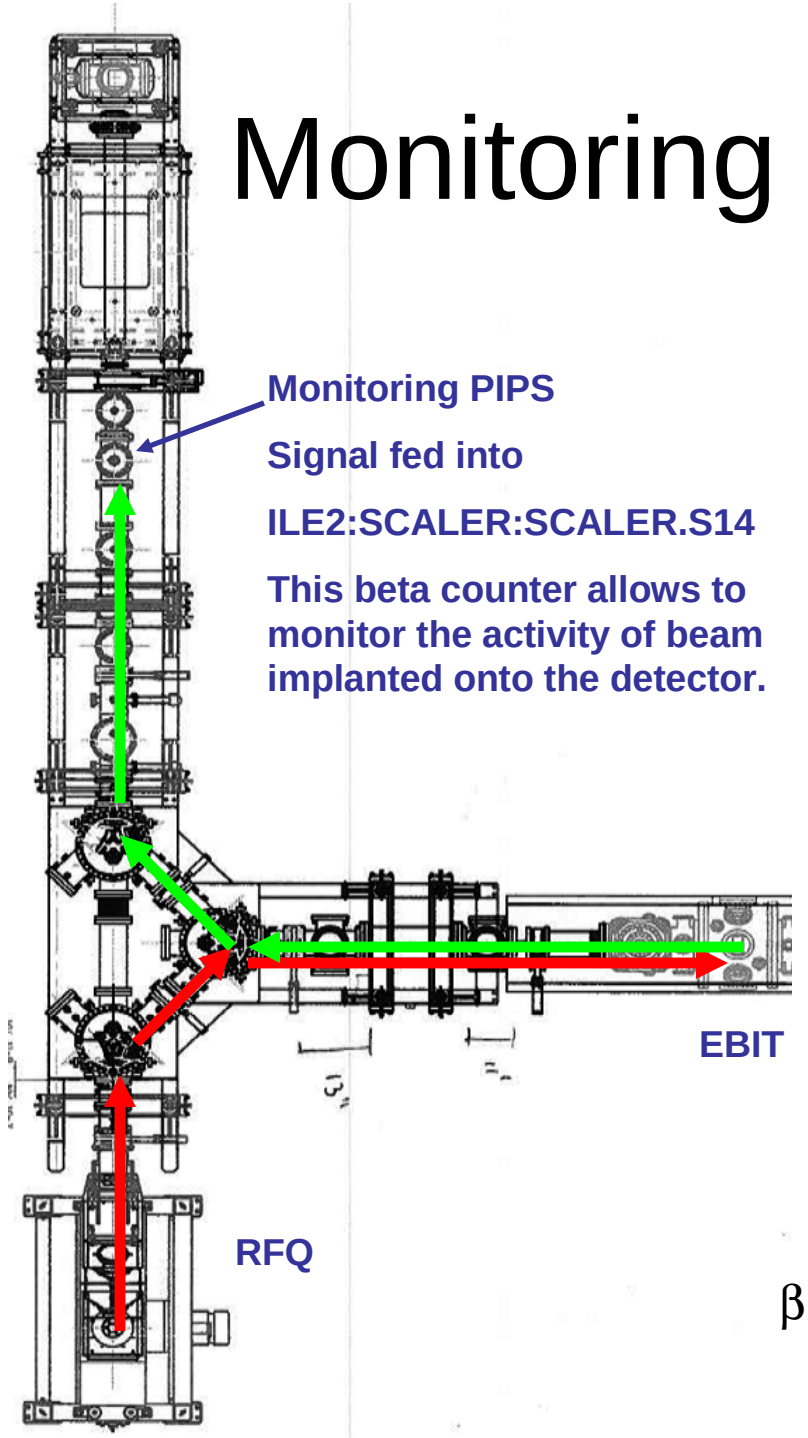
Goals for the ^{126}Cs beam time

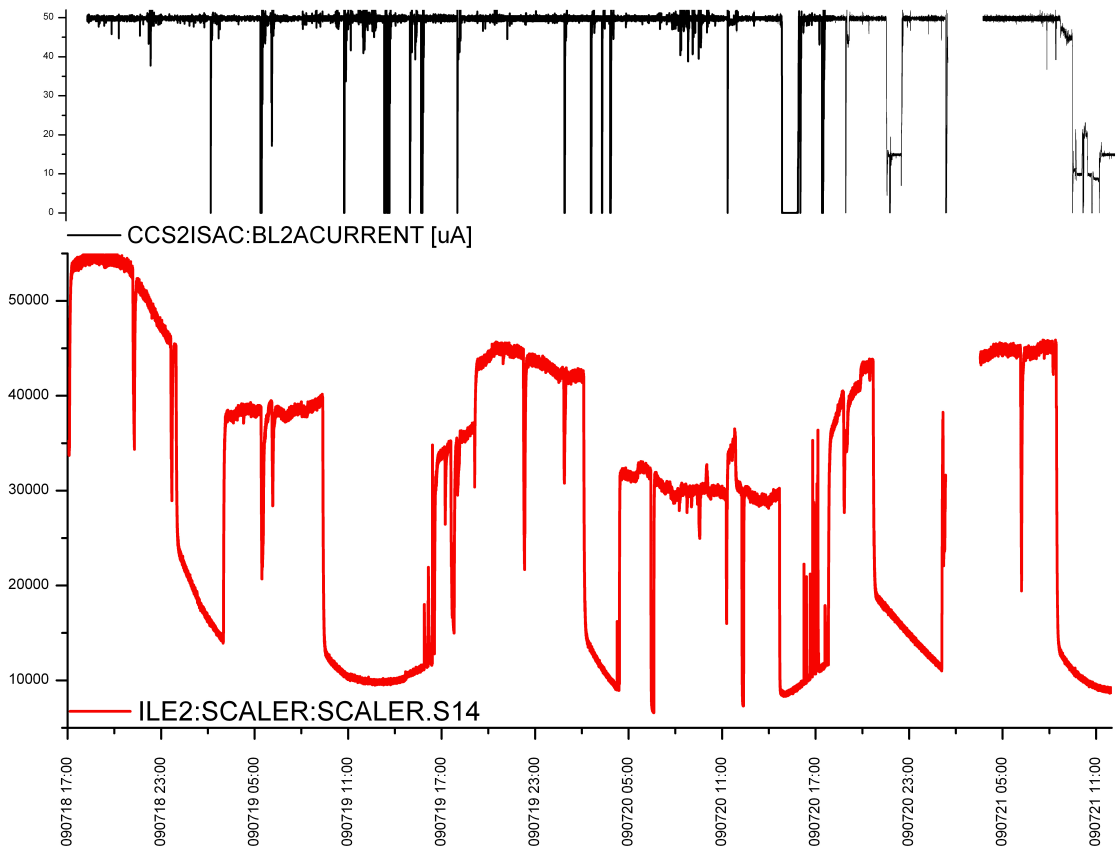
- Monitor the ISAC beam intensity during the experiment
- Determine #ions/shot of the TITAN-RFQ
- Identify the isotope by its half life
- Store ^{126}Cs inside the Penning trap and observe EC X-rays
- Store ^{126}Cs inside the Penning trap and observe β^+ with PIPS detector outside the trap
- Observe correlations in time between γ/X-ray and β detector
- Use ^{124}Cs as reference to calibrate X-ray detector efficiency





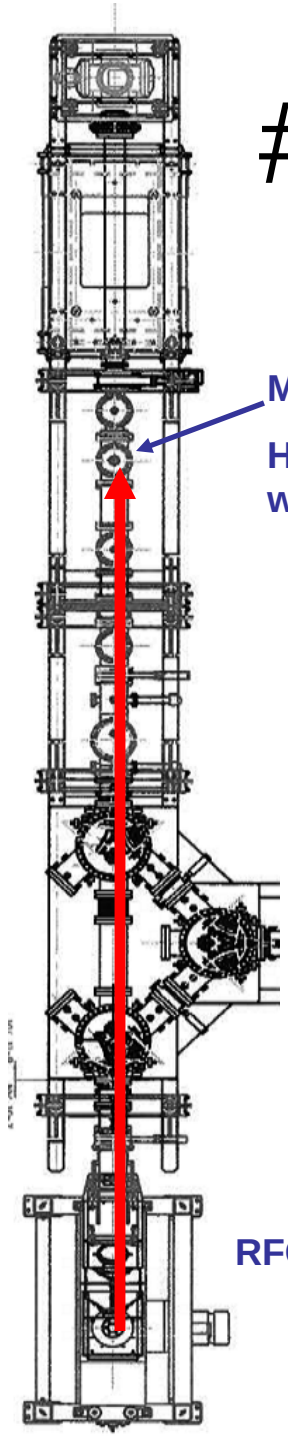
Monitoring the radioactive beam



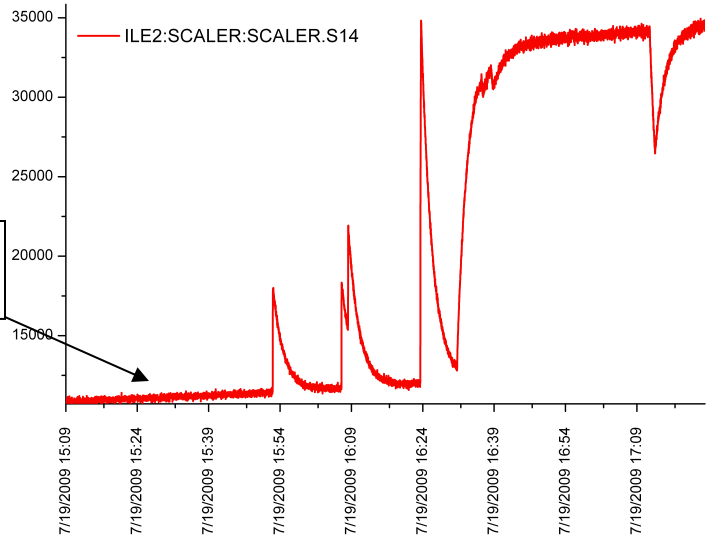


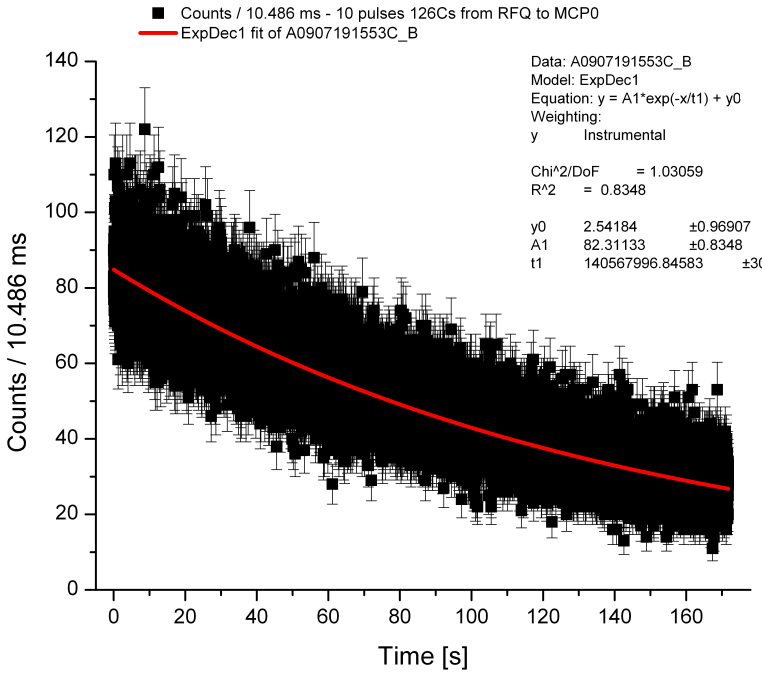
β counter and proton beam current during experiment

ions/shot & Half Life of ^{126}Cs



6 hrs beam off before first 10 pulses ^{126}Cs





$t_{½}$ = 97.4 ± 2.1 s (fit) (lit: 98.4 ± 1.2s) for first 10 shots (1st spike)

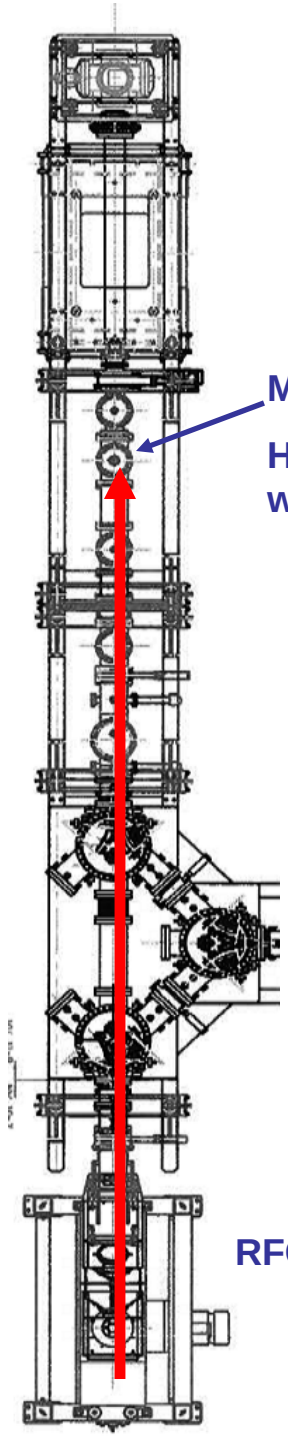
Beam intensity ≈ **3 * 10^5** ions/RFQ extraction pulse @ 10 Hz

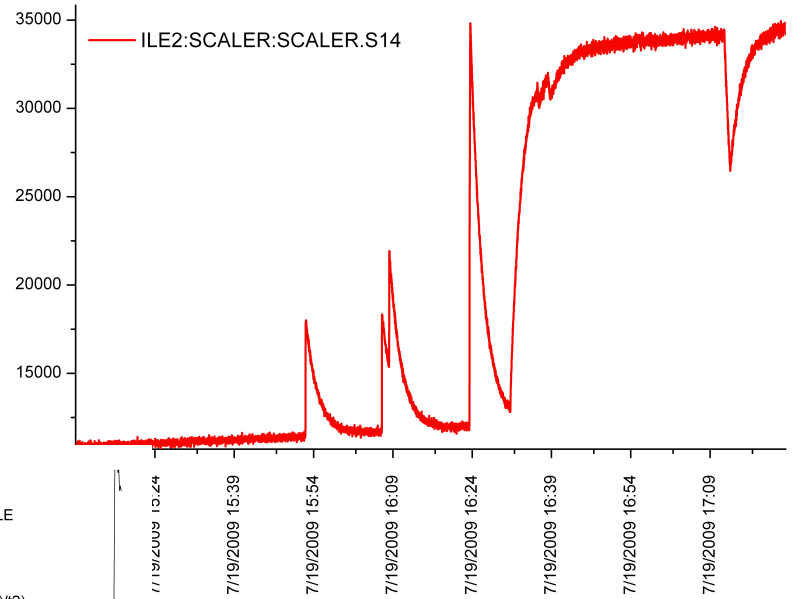
BUT:

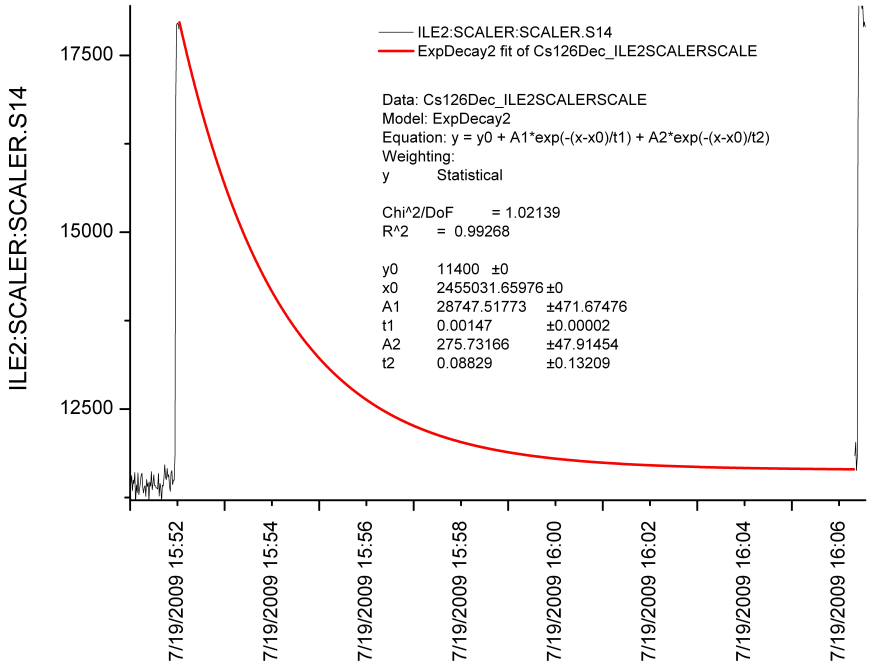
Half life increases for the following $t_{½}$ measurements

→ Contamination built up on PIPS detector

Contamination of ^{126}Cs beam







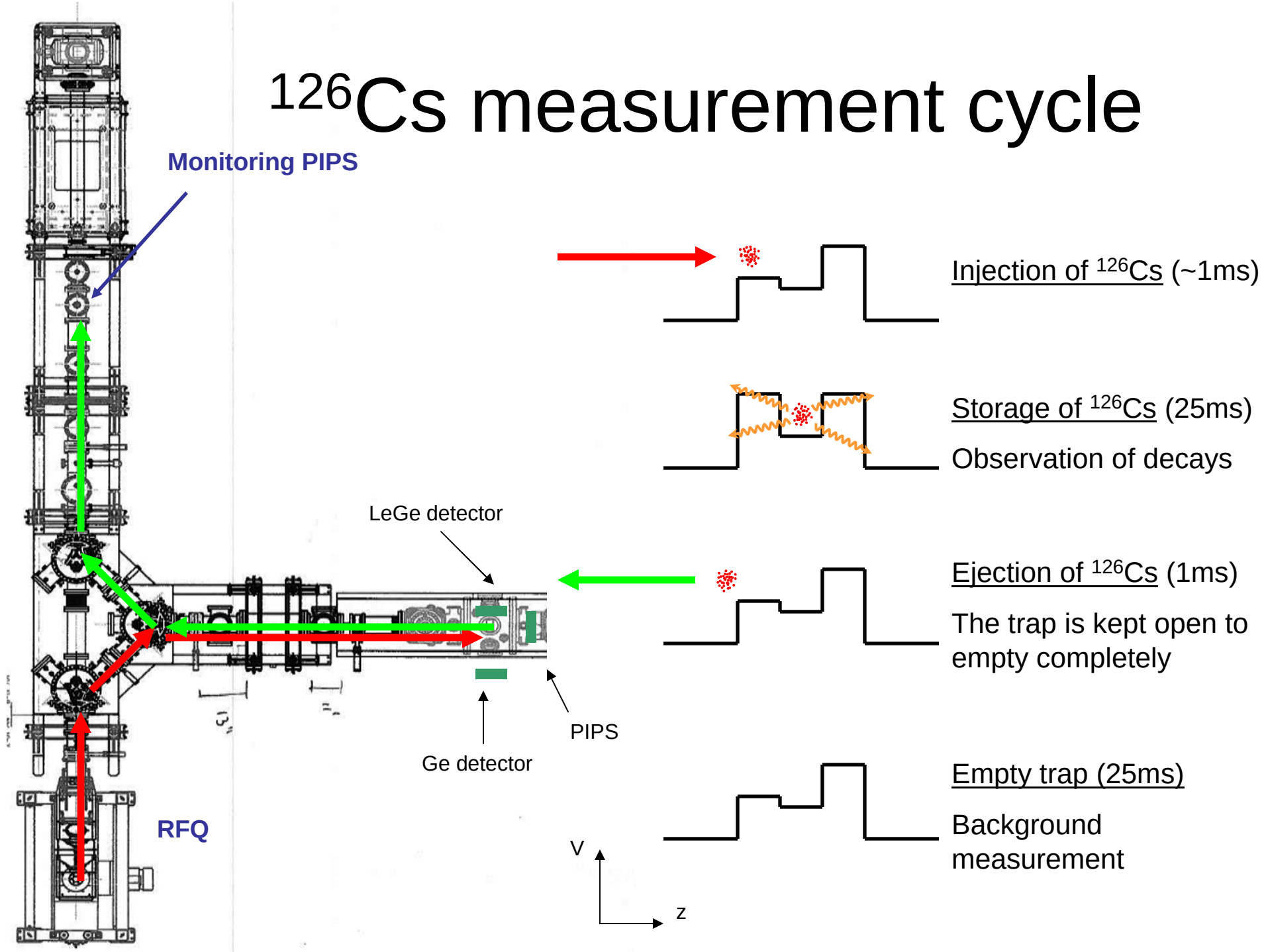
Fit of strip tool data under the assumption of ^{126}Ba contamination:

$t_{½}$ is fixed to the literature values

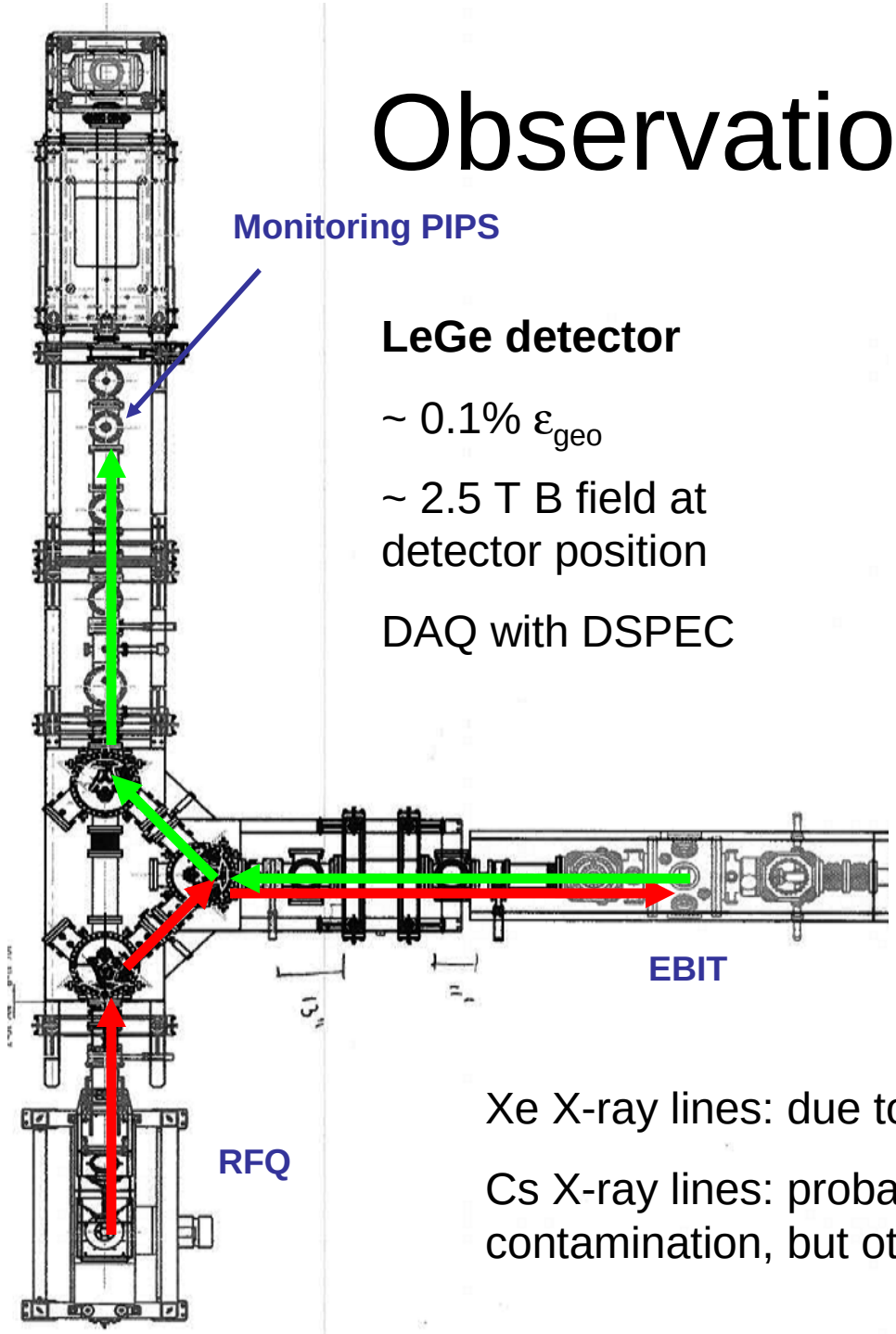
Intensities are the only free parameter

→ ~ 35% ^{126}Ba contamination ???

^{126}Cs measurement cycle



Observation of EC X-rays

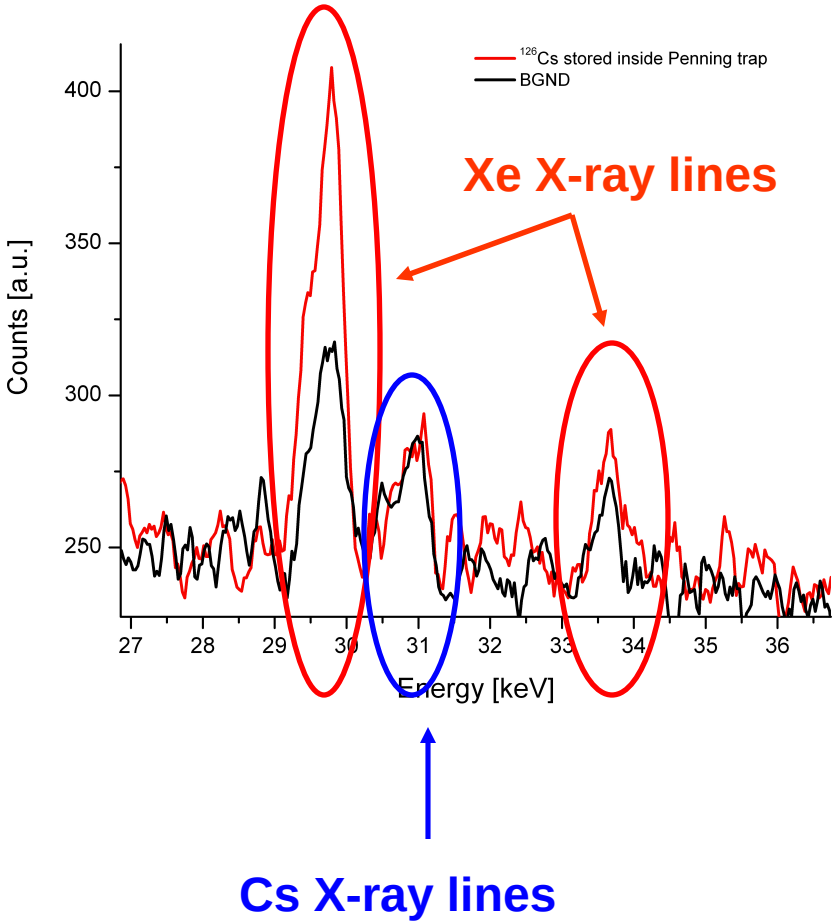


LeGe detector

~ 0.1% ε_{geo}

~ 2.5 T B field at detector position

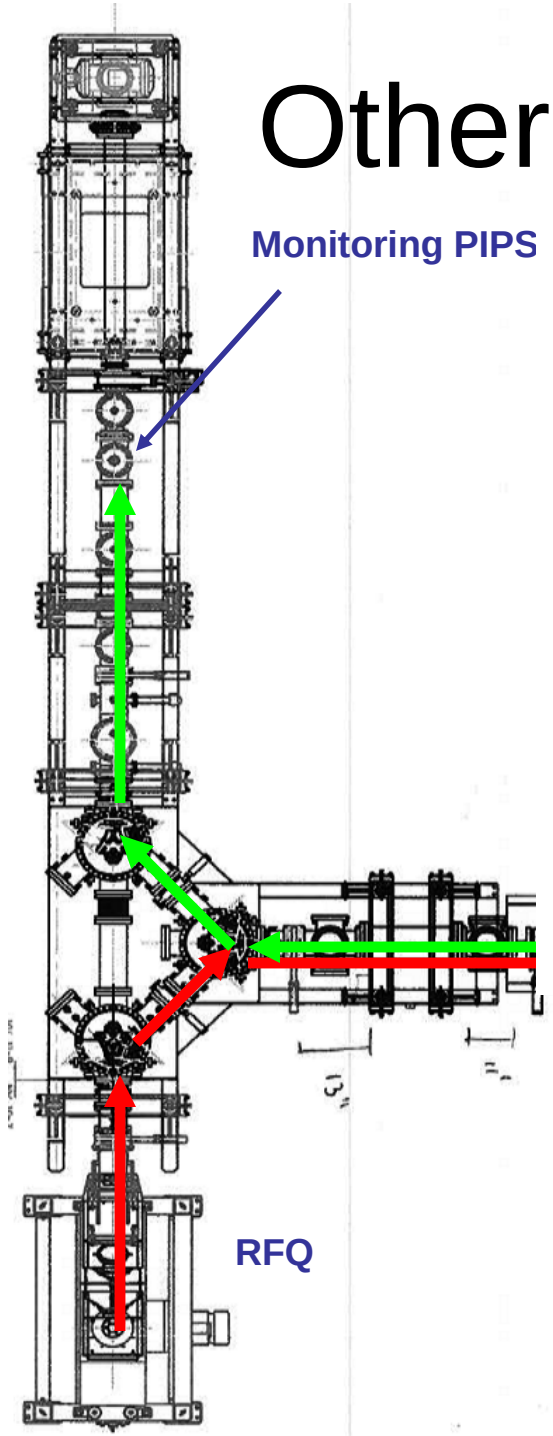
DAQ with DSPEC

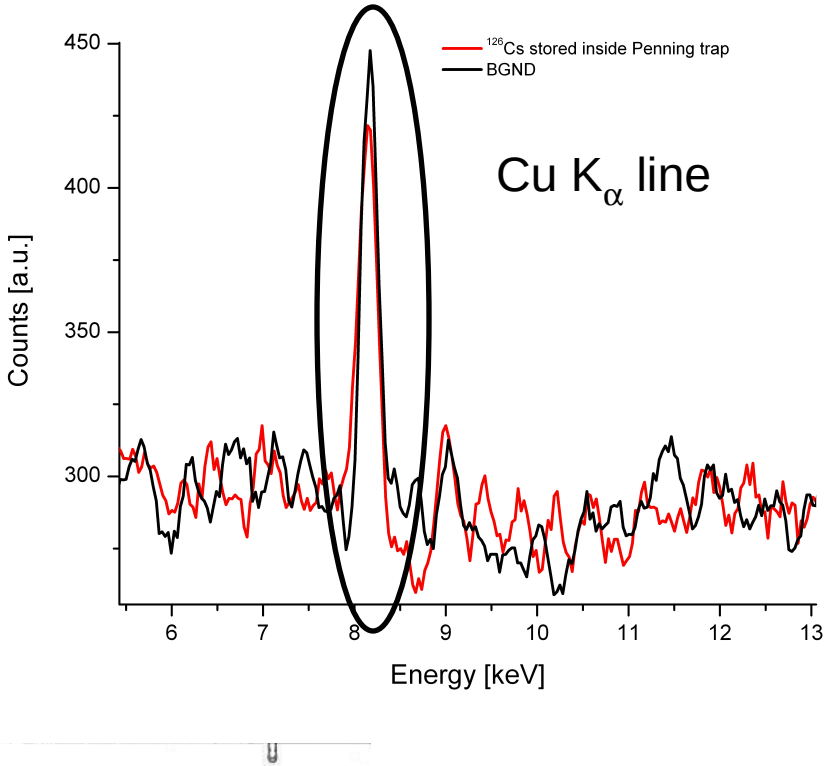


Xe X-ray lines: due to ^{126}Cs EC

Cs X-ray lines: probably dominant due to ^{126}Ba contamination, but other channels also possible

Other interesting lines @ LeGe





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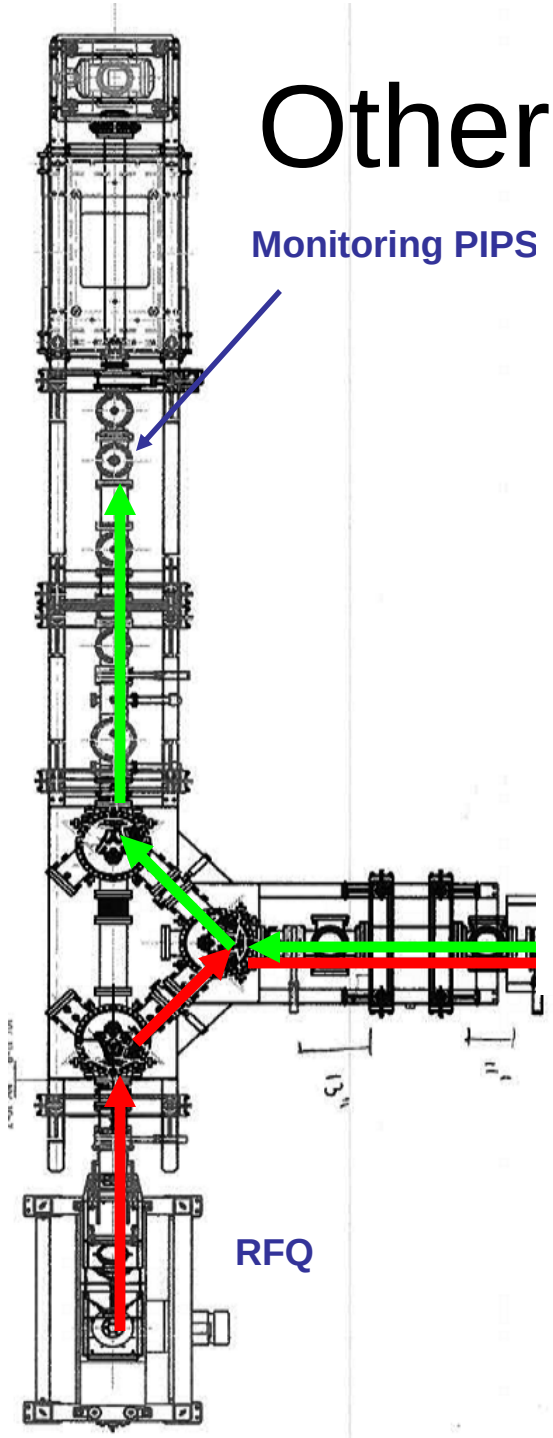
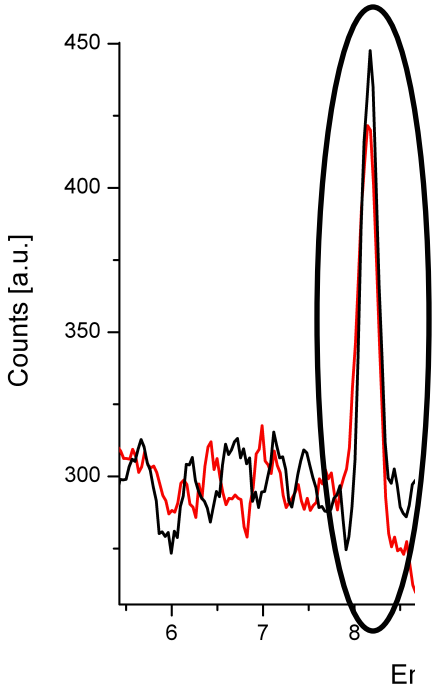
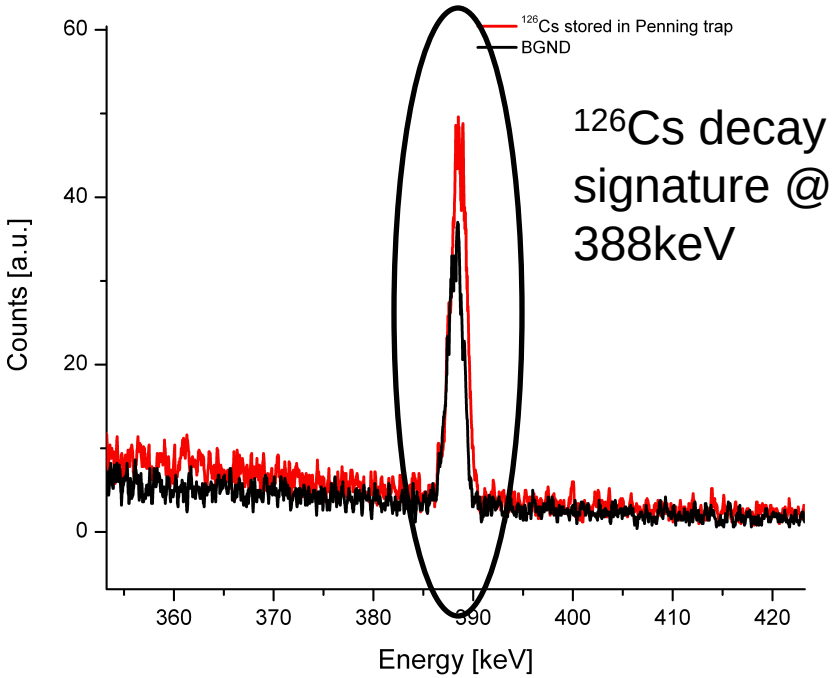


EBIT

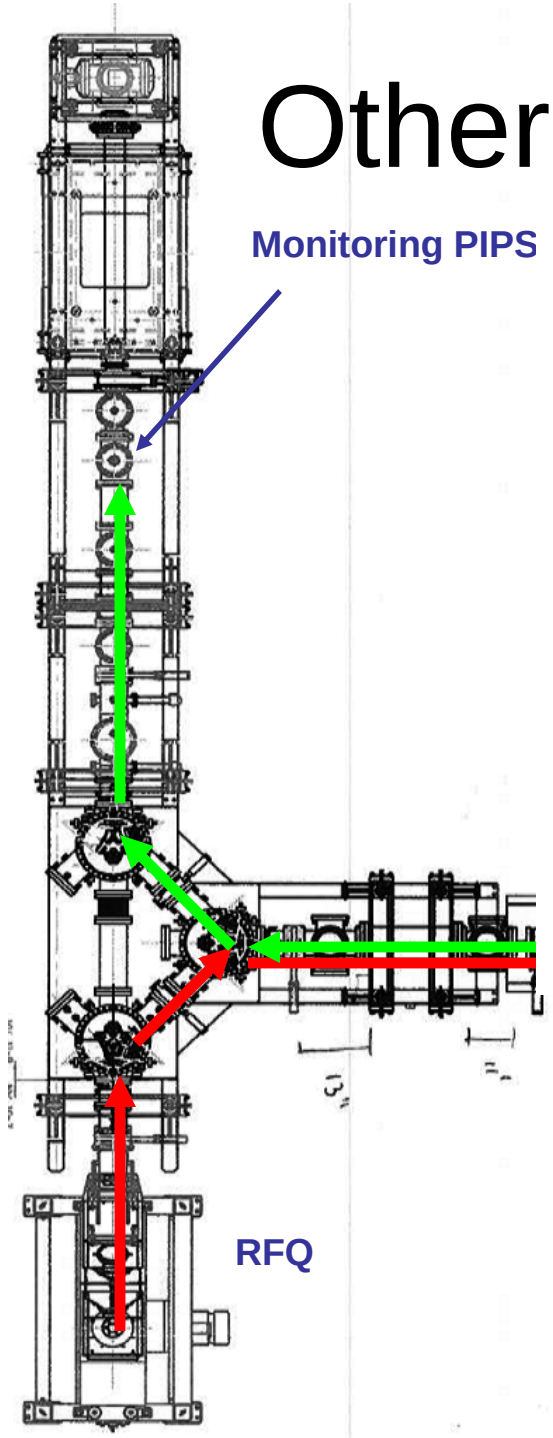


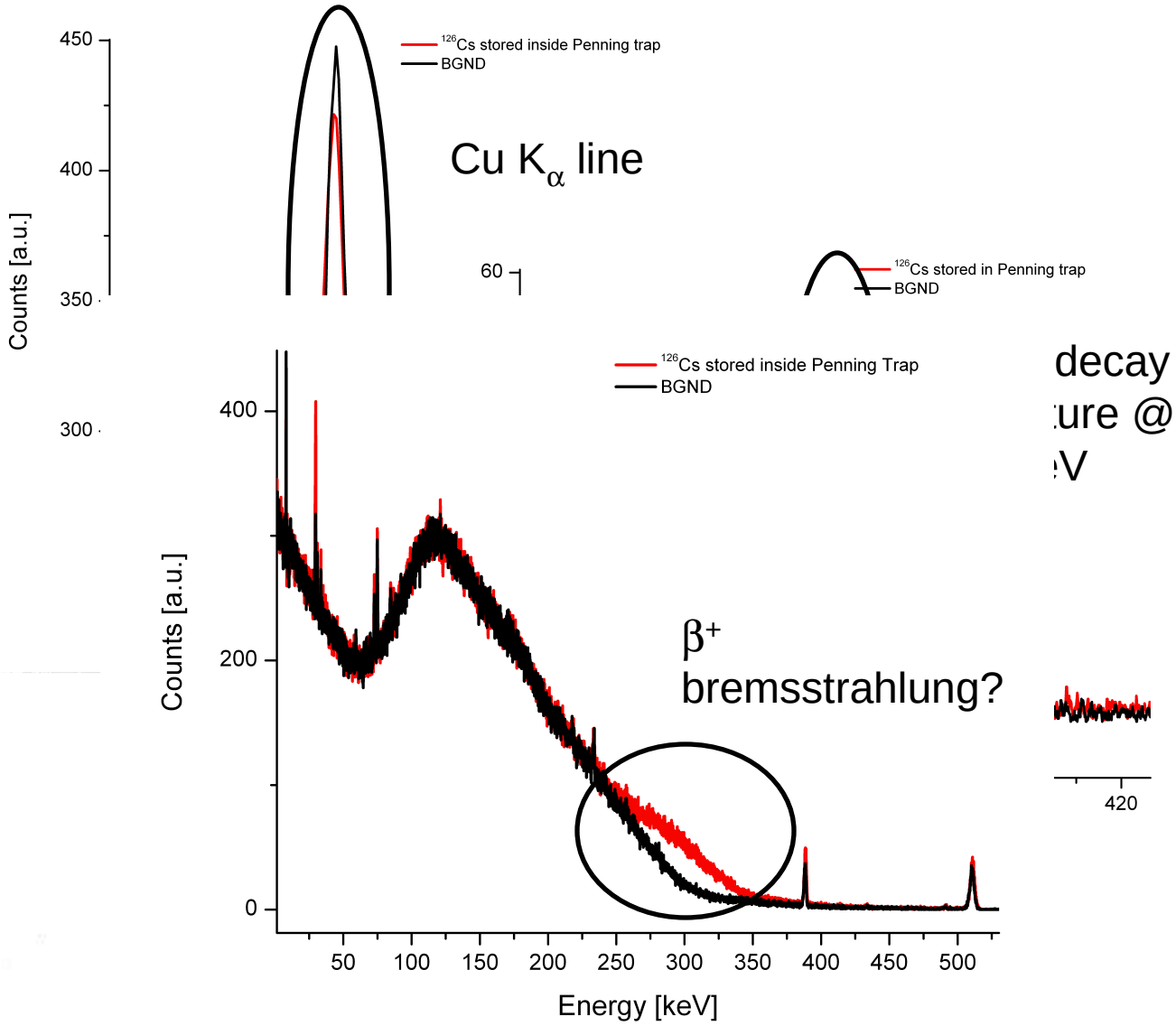
Cu K_α line



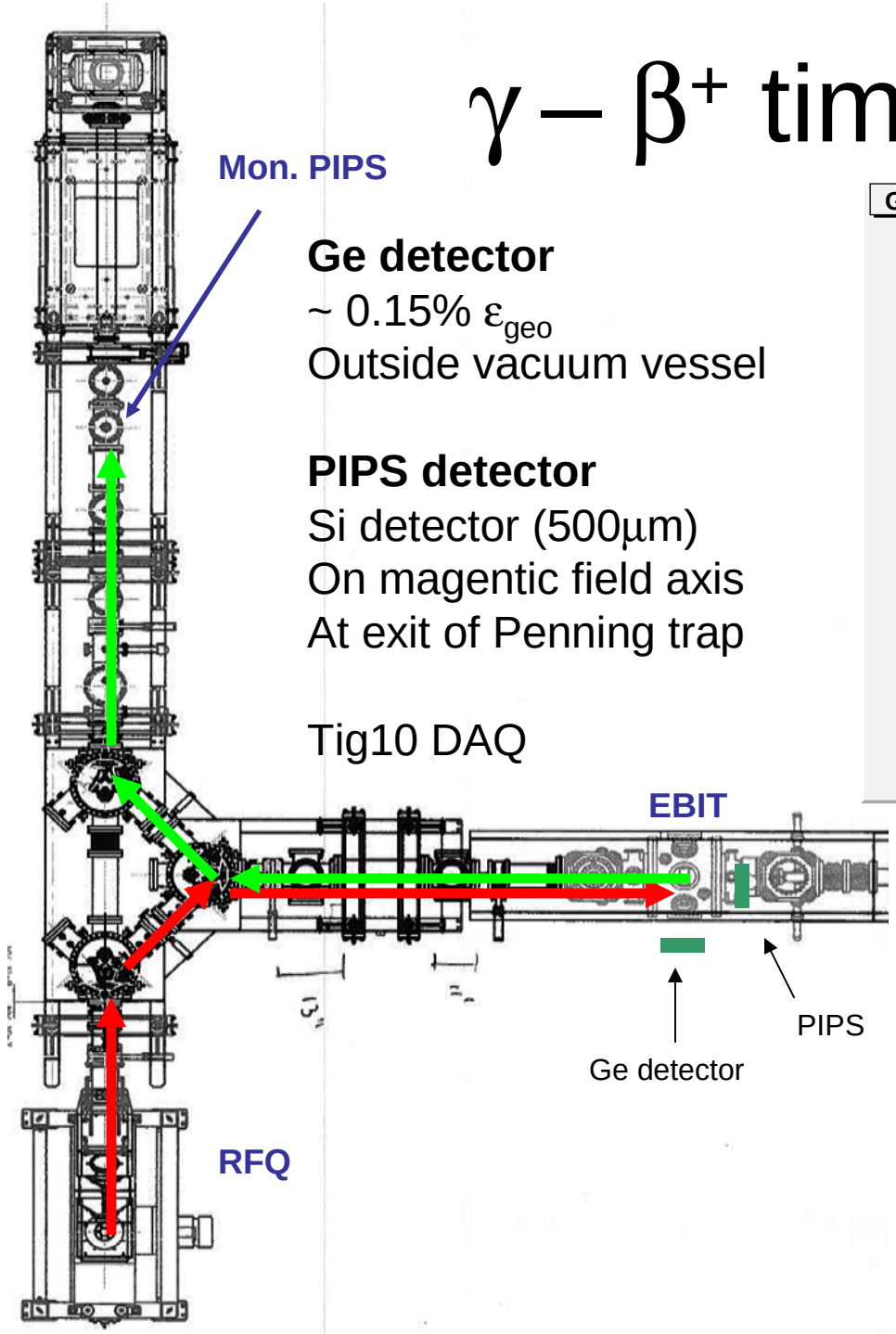
126Cs decay signature @ 388keV

Other interesting lines @ LeGe





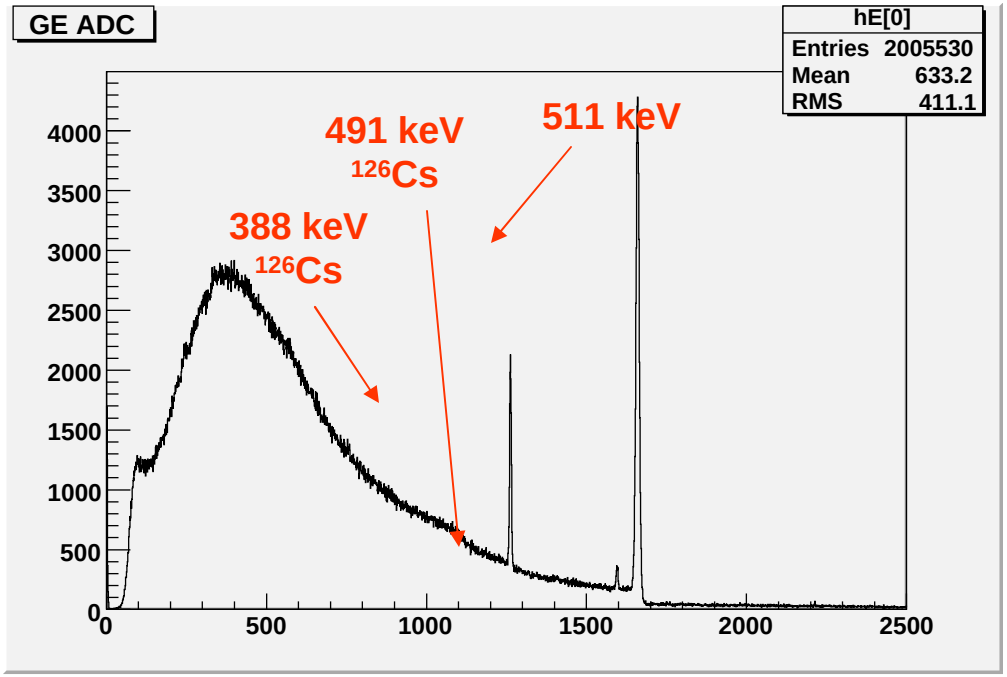
$\gamma - \beta^+$ time correlation



Ge detector
~ 0.15% ε_{geo}
Outside vacuum vessel

PIPS detector
Si detector (500µm)
On magentic field axis
At exit of Penning trap

Tig10 DAQ



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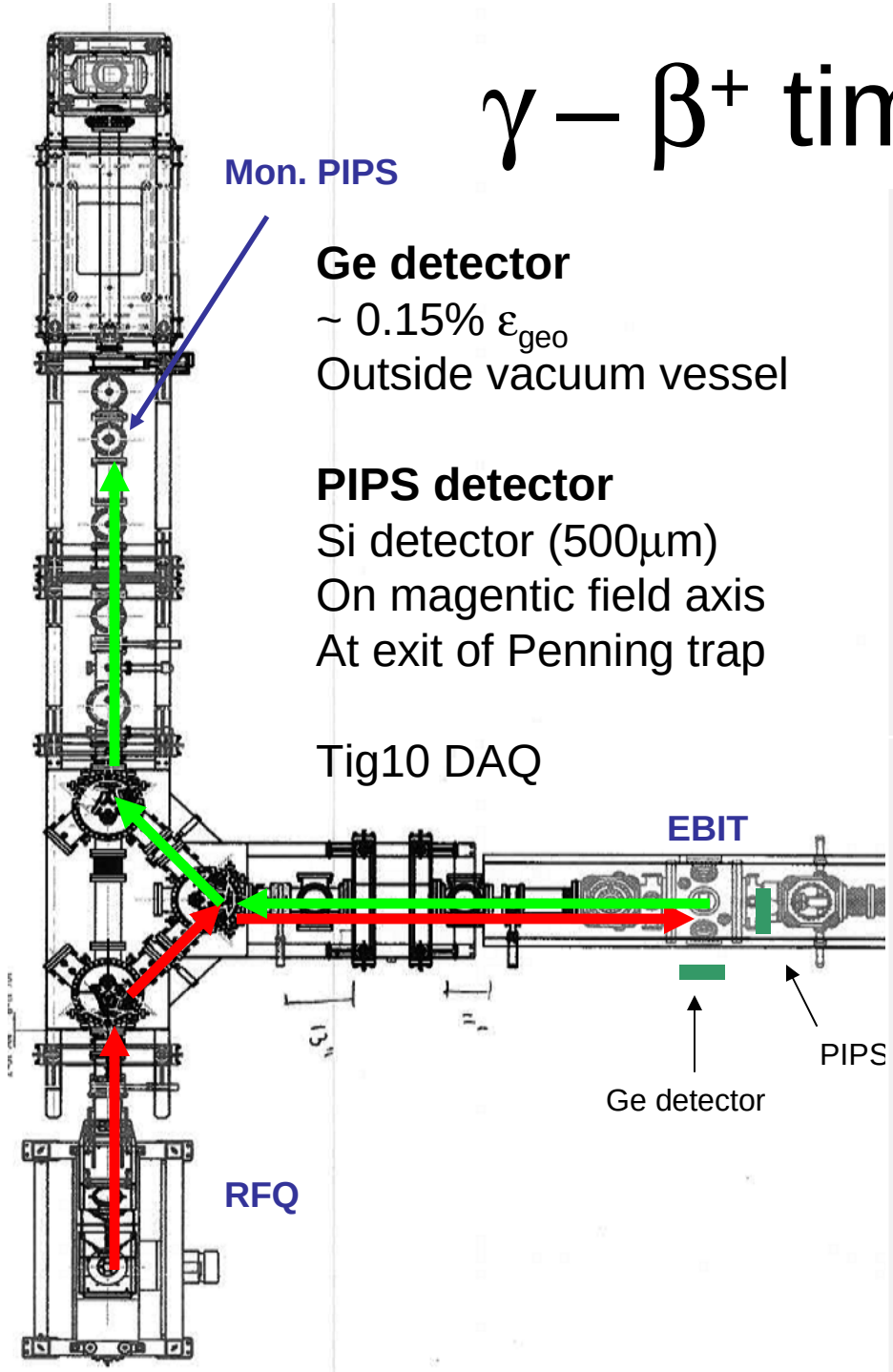

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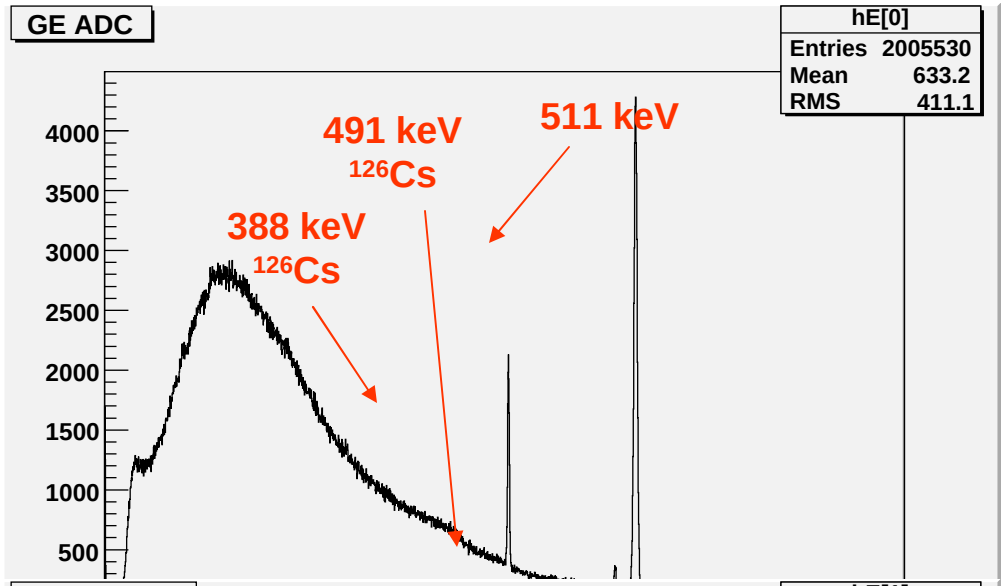

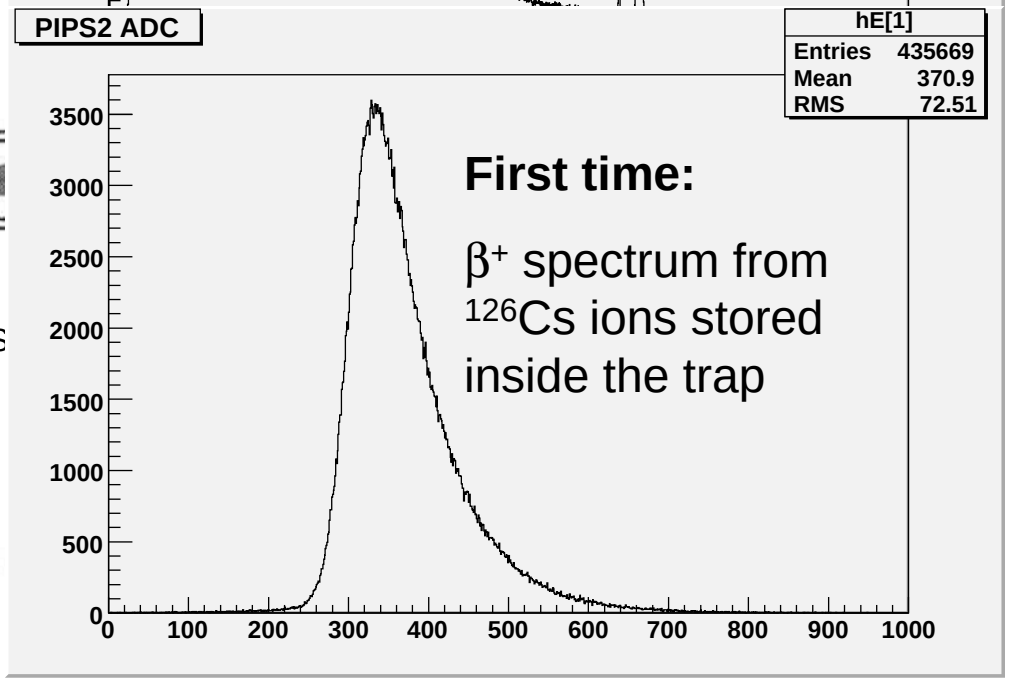

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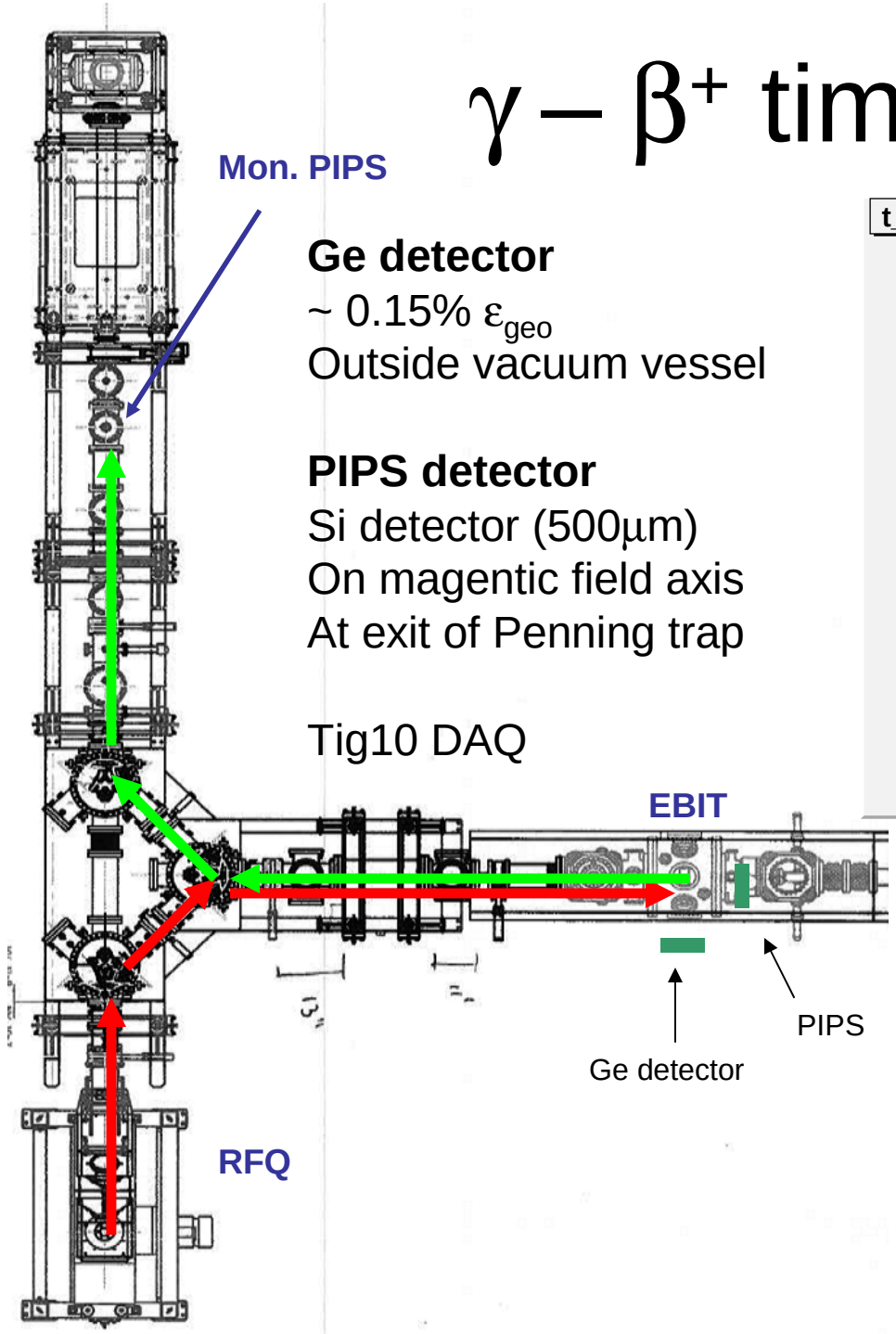

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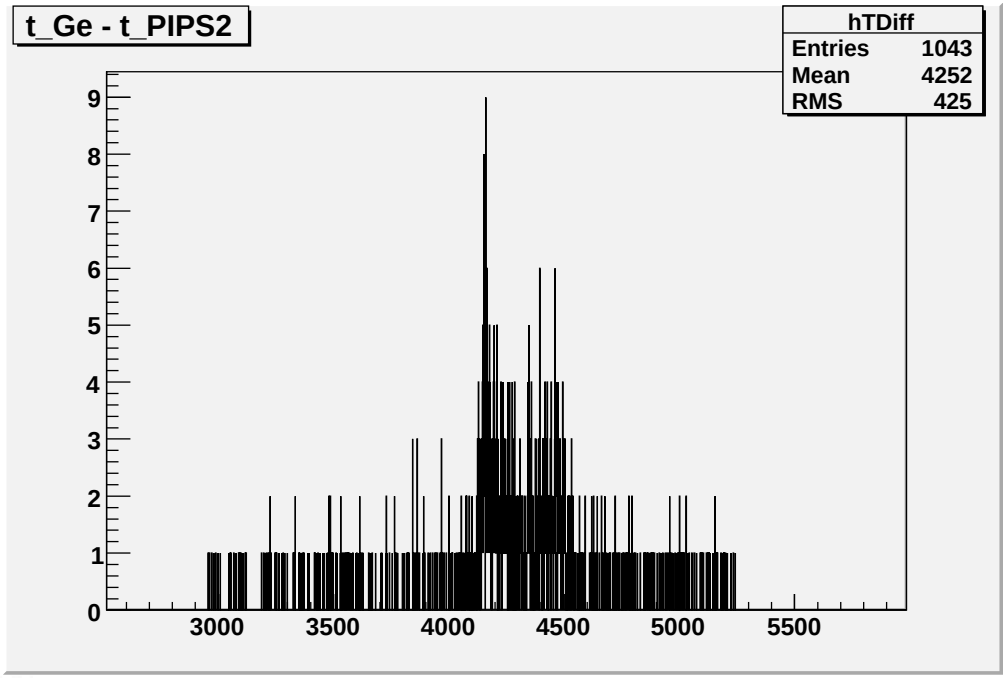
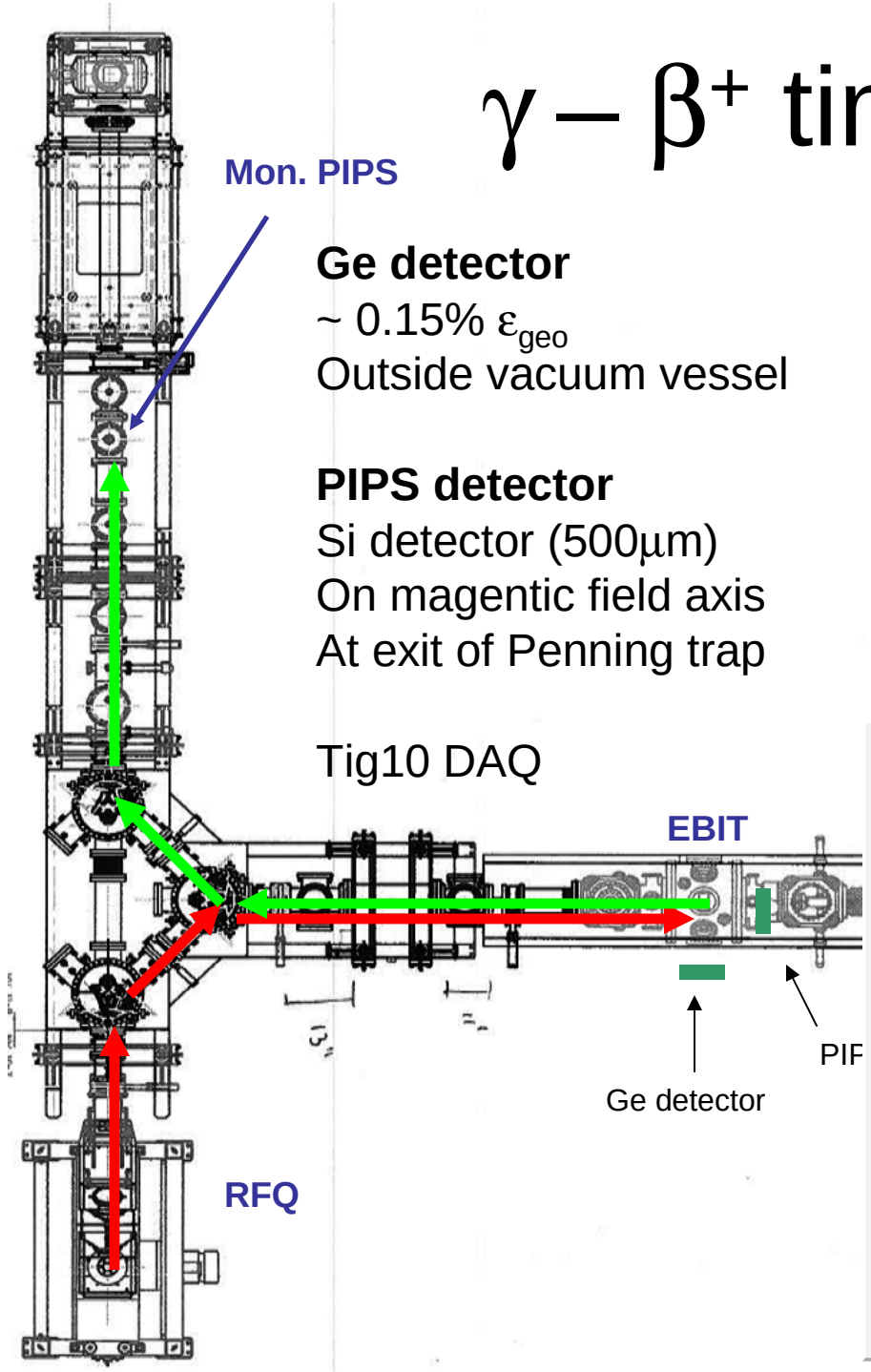


Time correlation between γ and β^+

$\gamma - \beta^+$ time correlation



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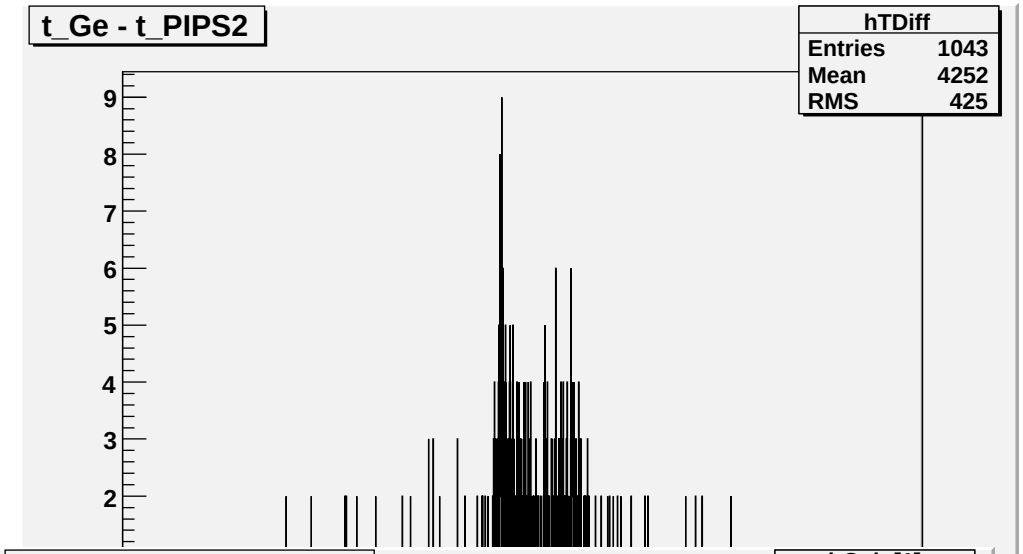

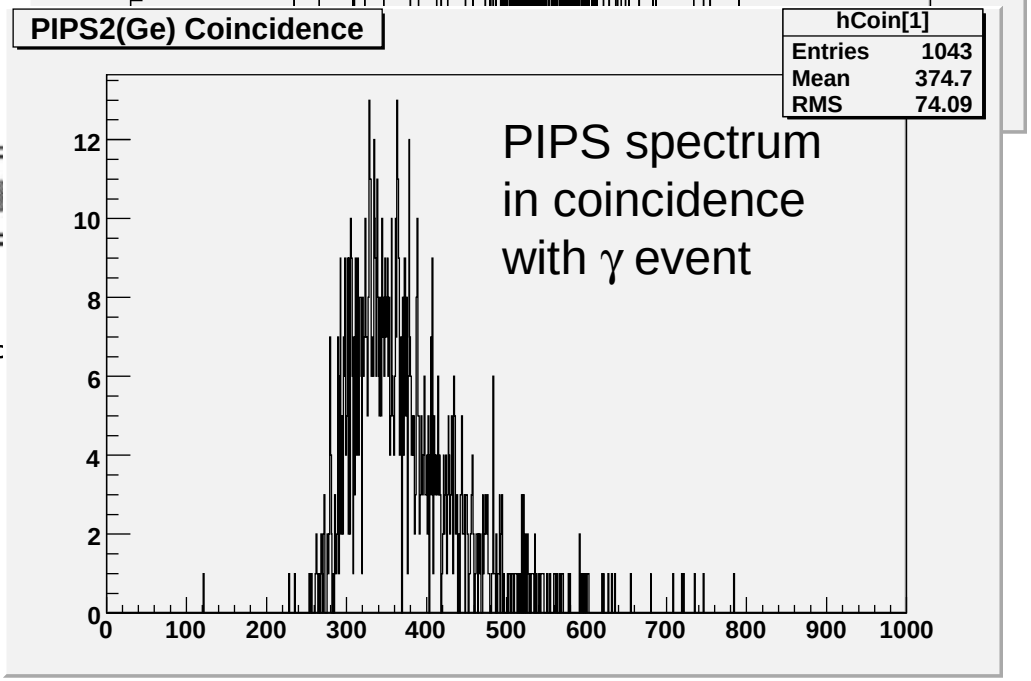

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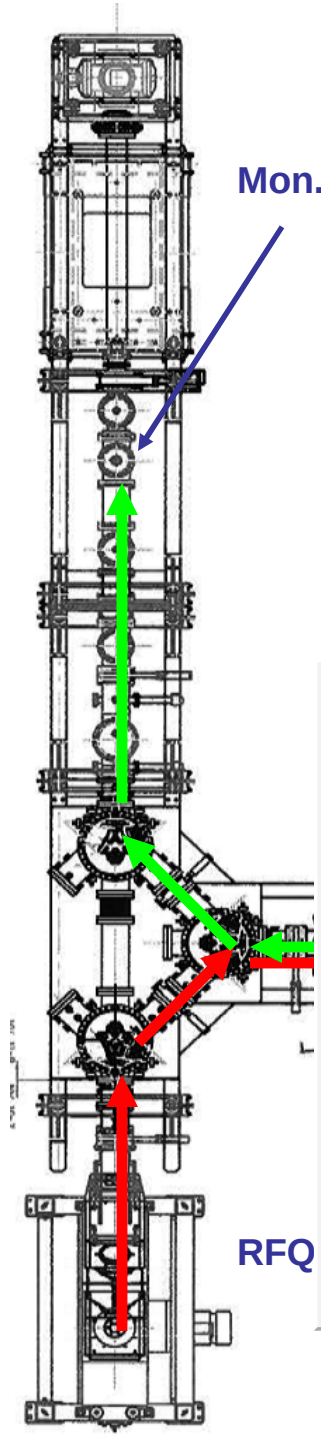

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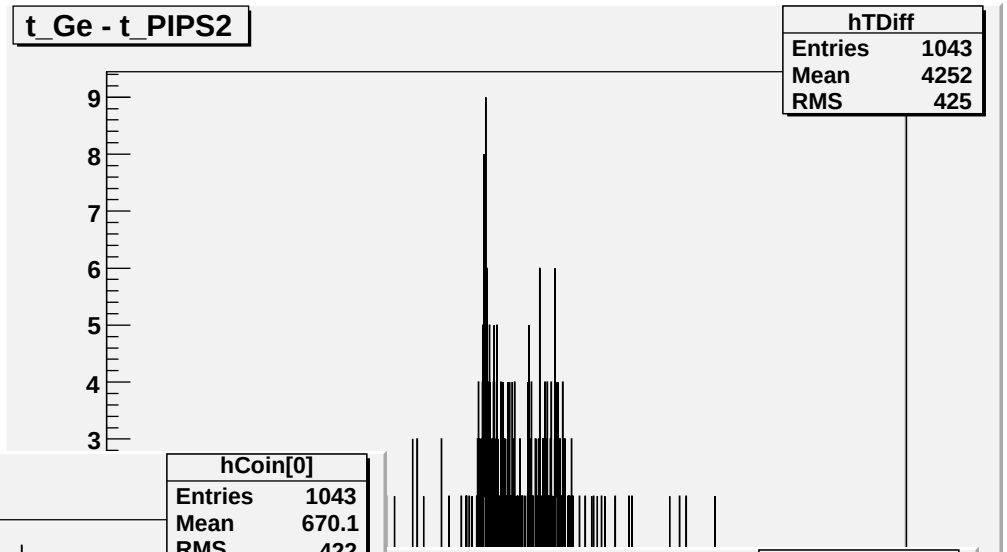
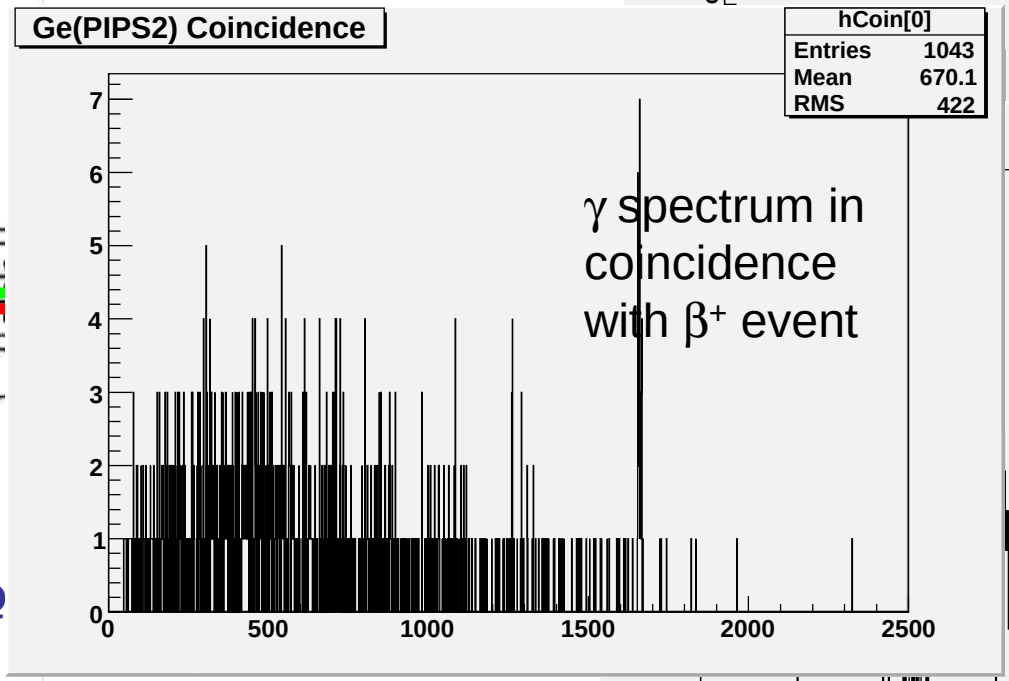
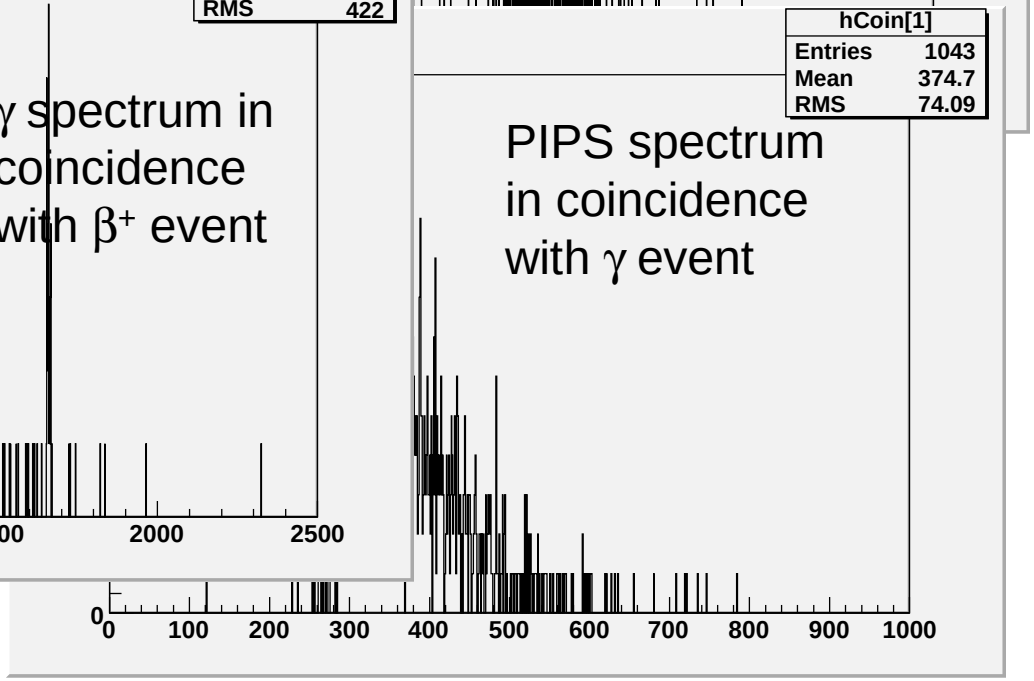
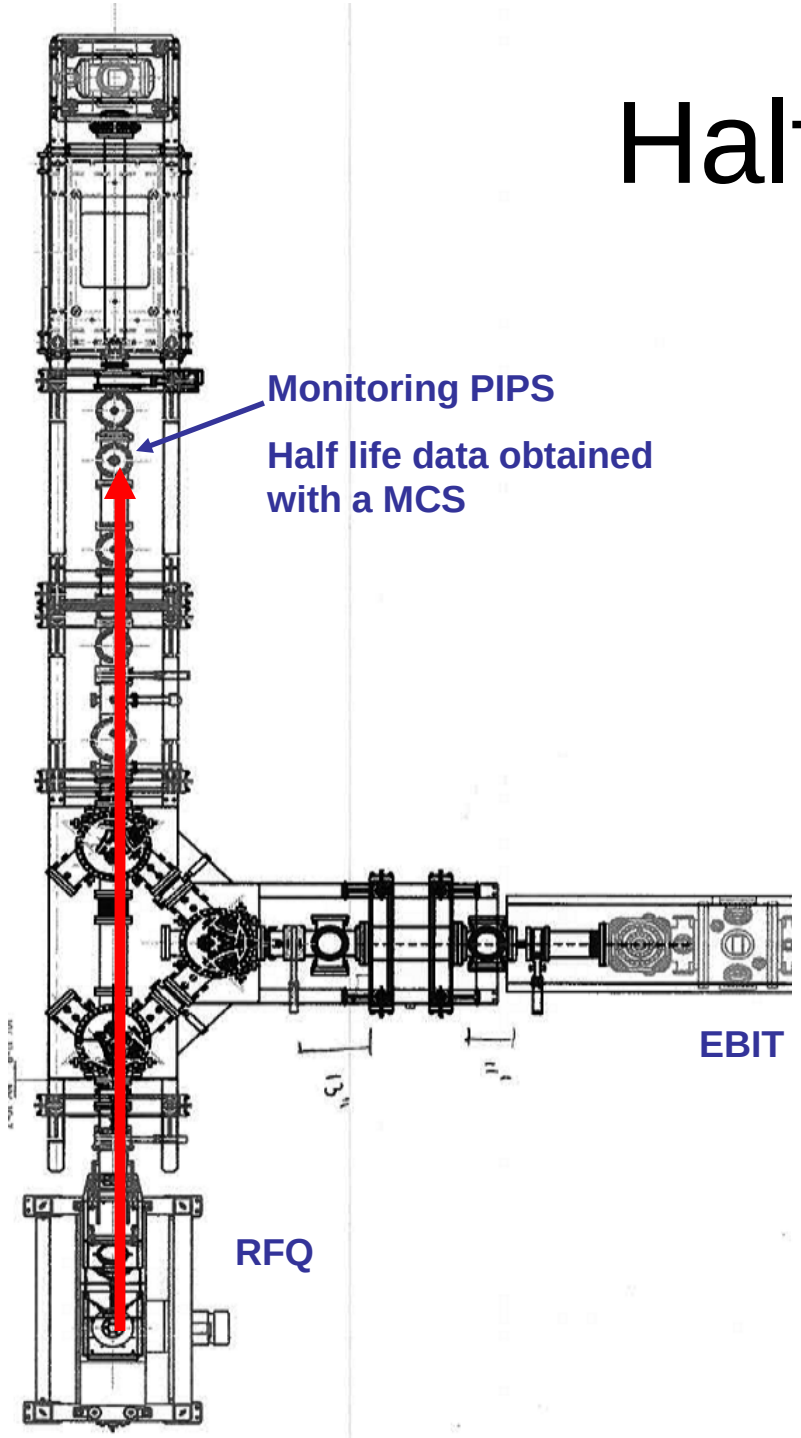
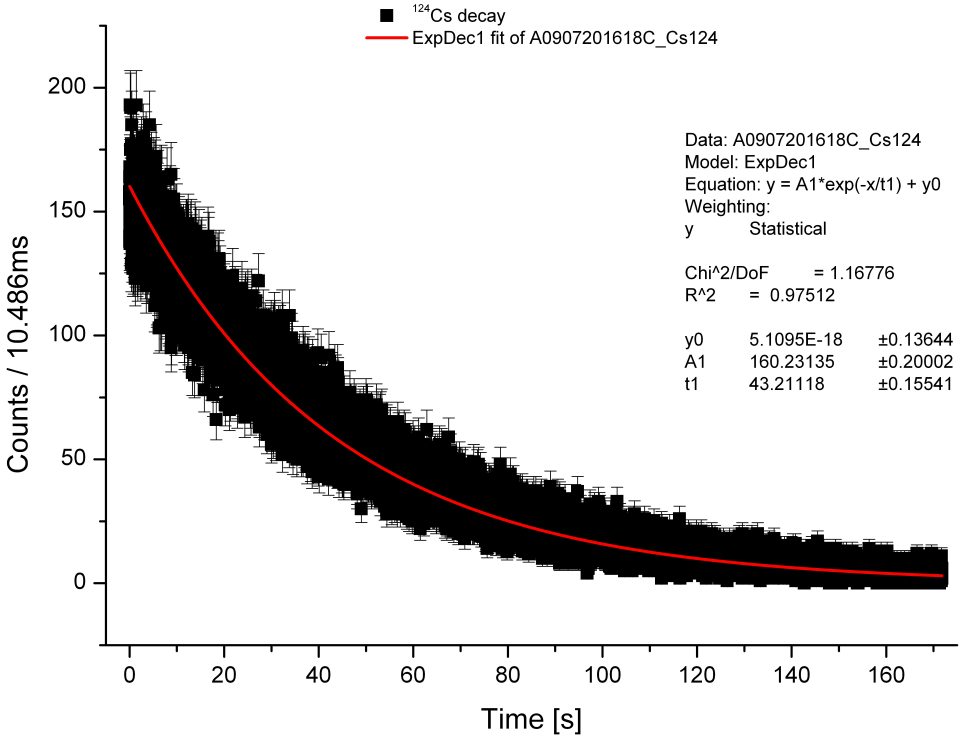






Half Life of ^{124}Cs

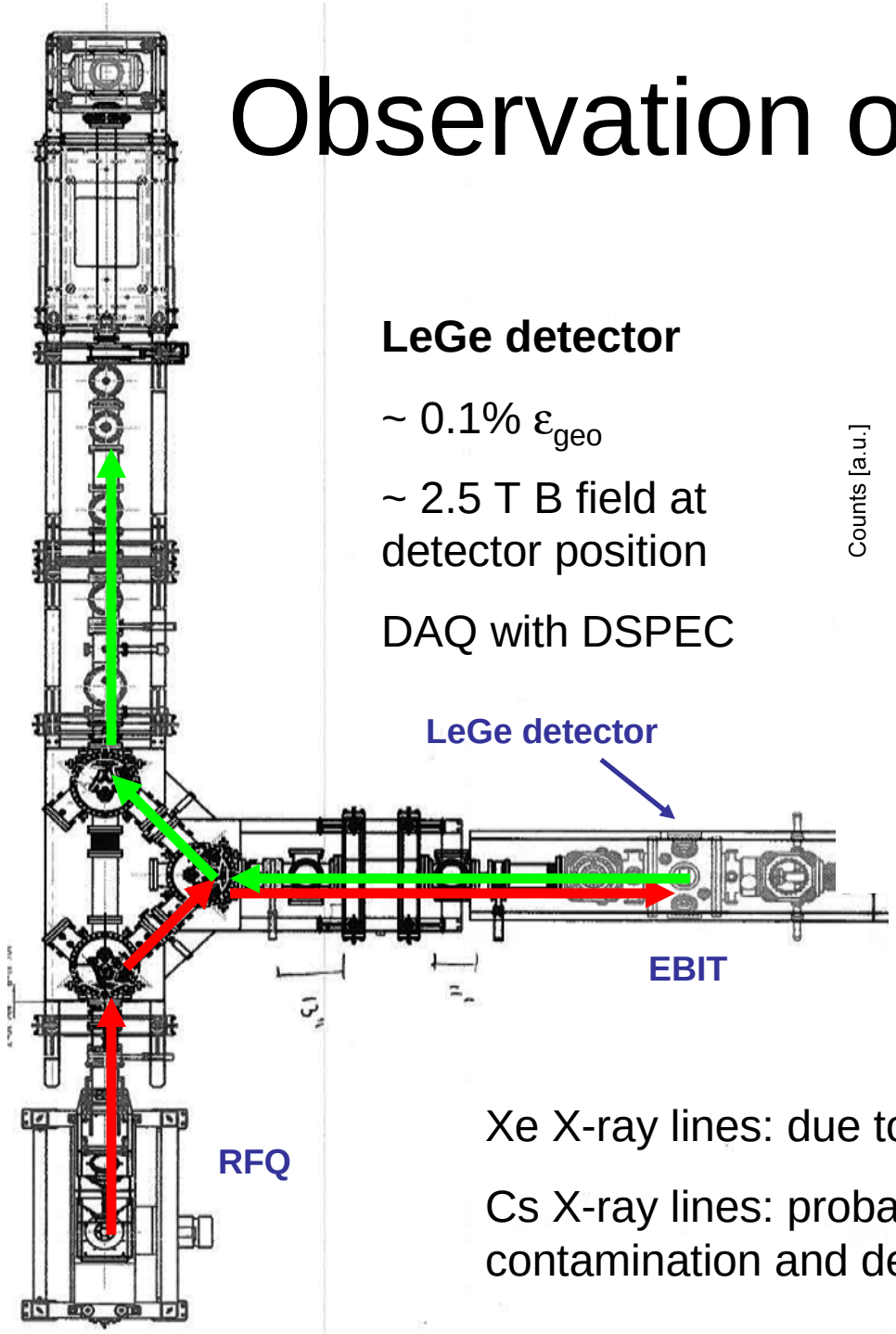




$t_{½}$ = 30.0 ± 0.1 s (fit) (lit: 30.8 ± 0.5s) for first 10 shots (1st spike)

Beam intensity ≈ **3 * 10^4** ions/RFQ extraction pulse @ 10 Hz

Observation of ^{124}Cs EC X-rays

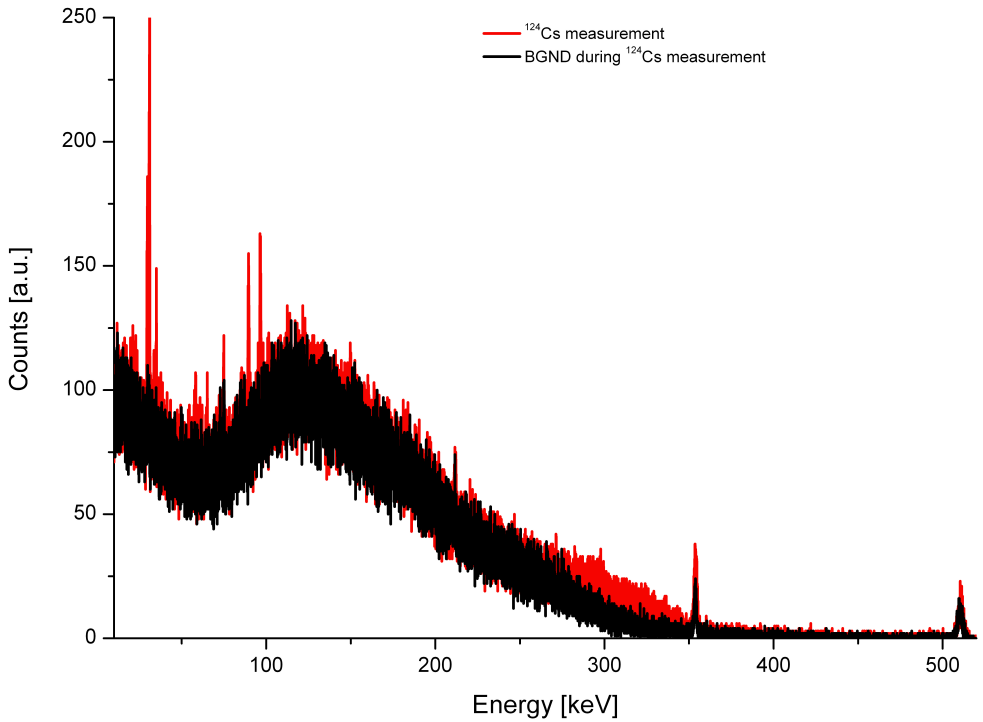


LeGe detector

~ 0.1% ε_{geo}

~ 2.5 T B field at detector position

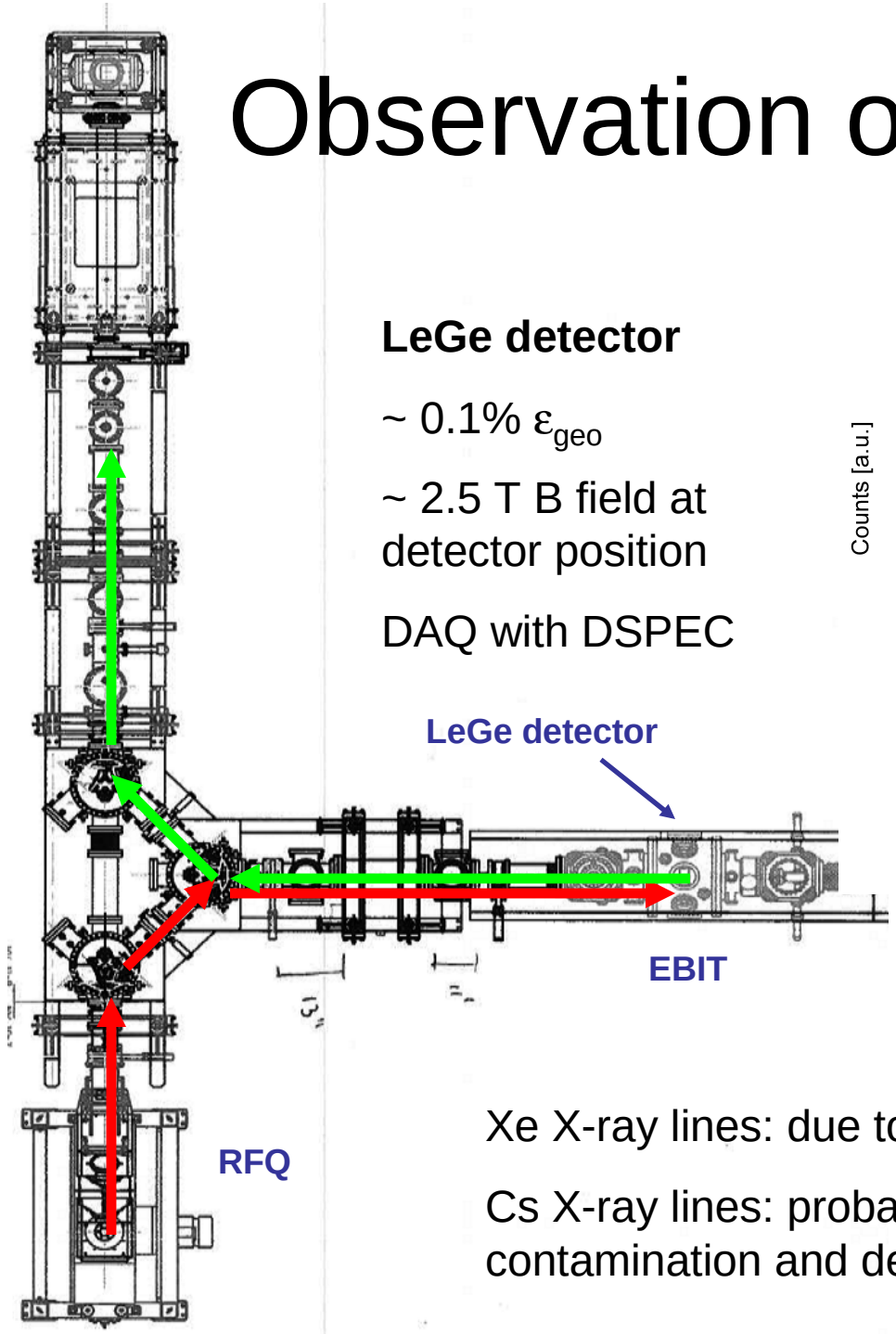
DAQ with DSPEC



Xe X-ray lines: due to ^{124}Cs EC

Cs X-ray lines: probably dominant due to ^{124}Ba contamination and decay of ^{124m}Cs

Observation of ^{124}Cs EC X-rays



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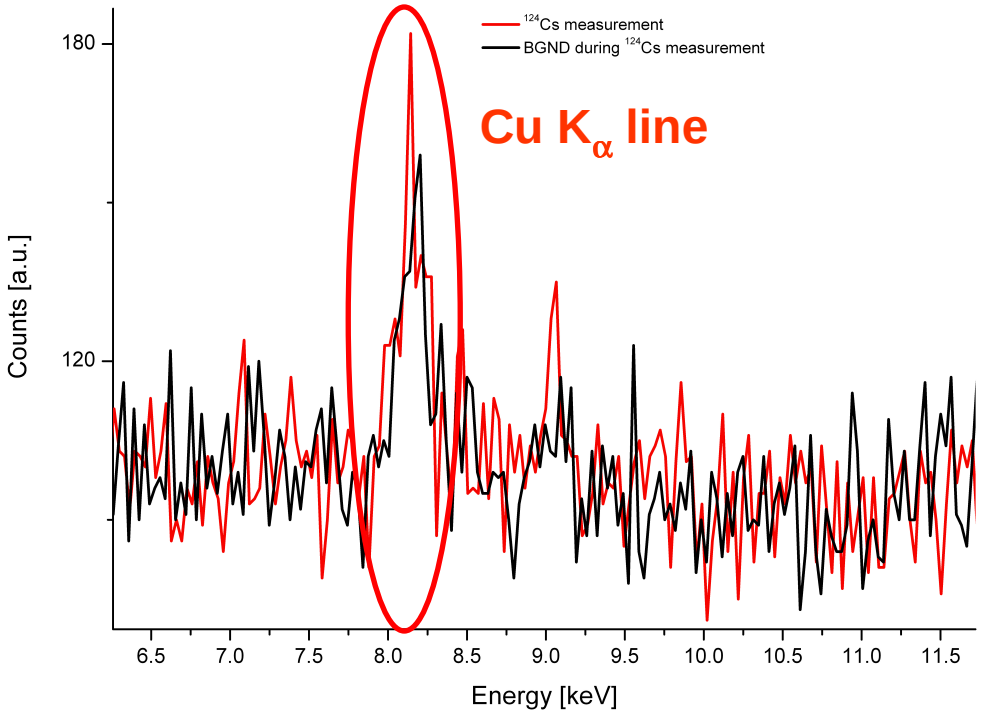

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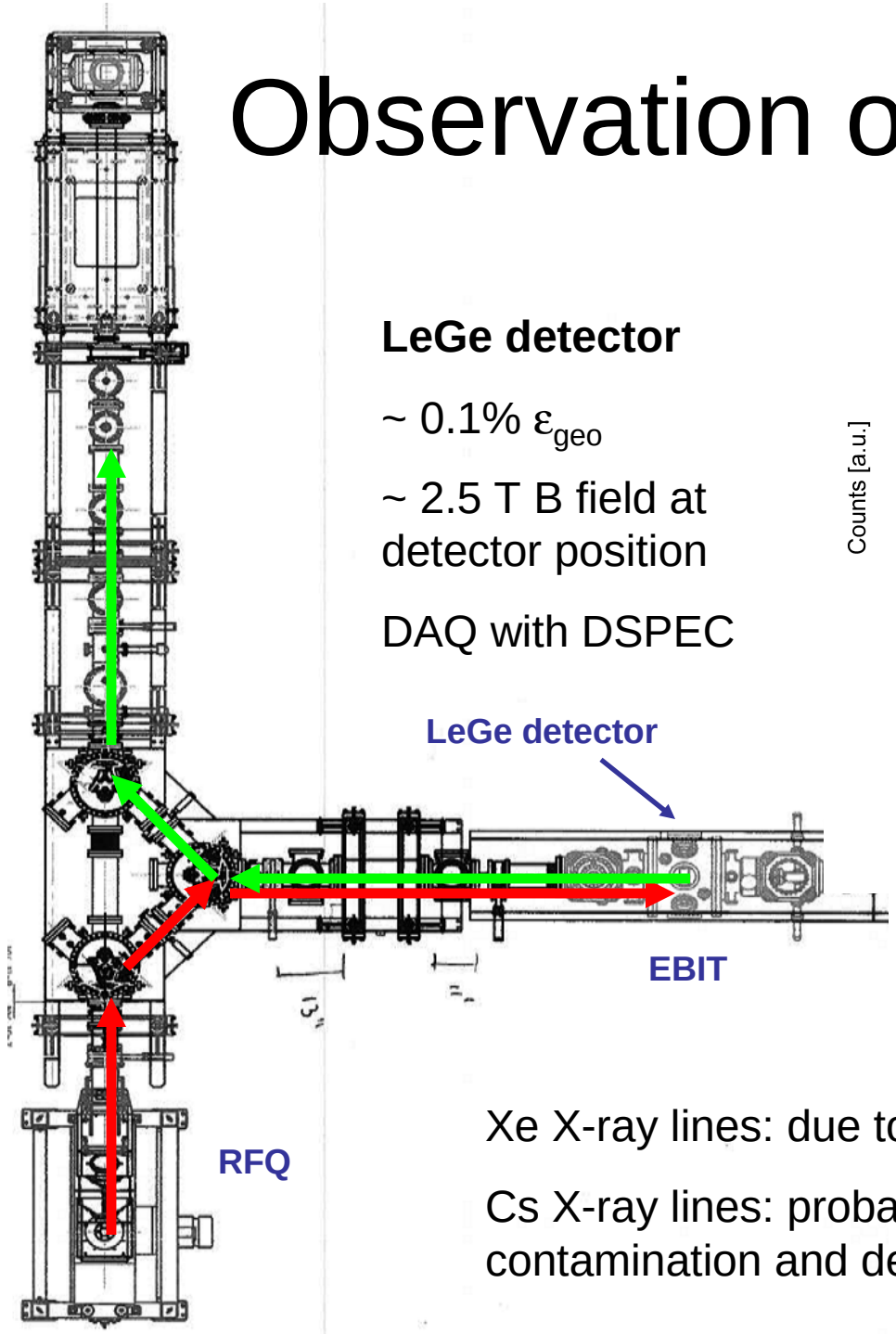

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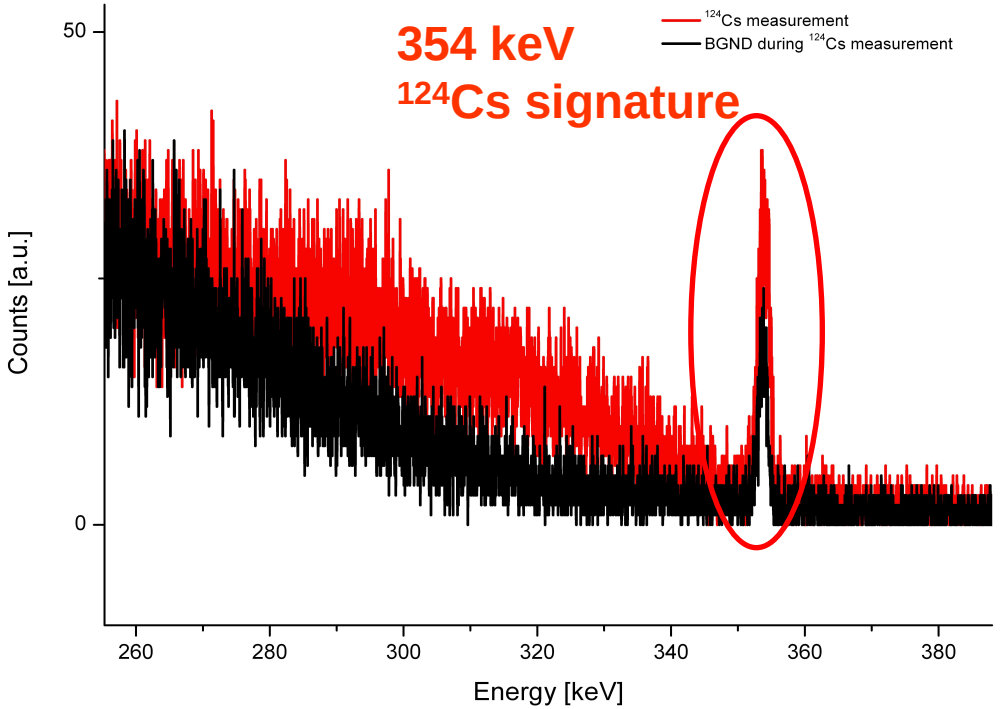

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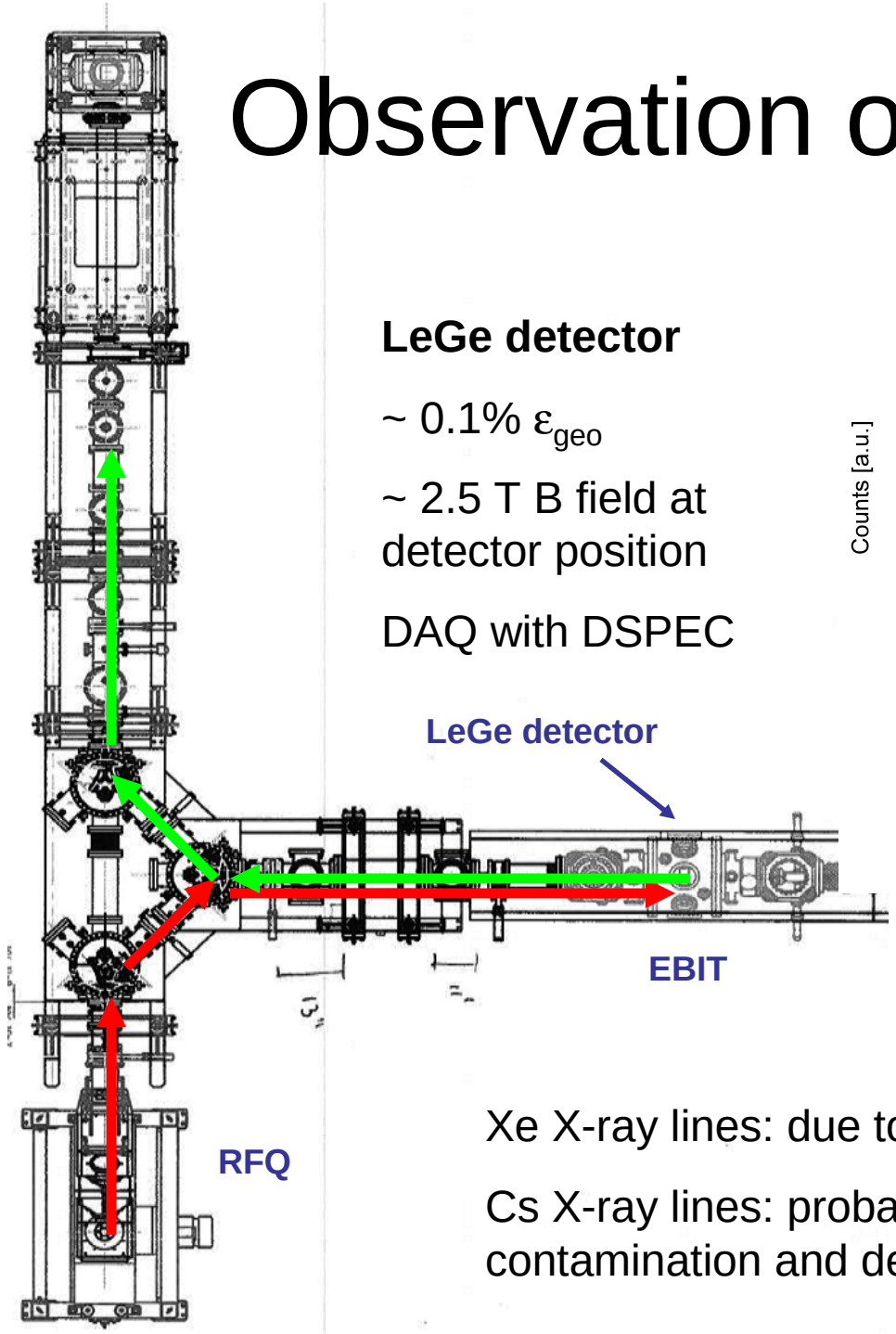
Observation of ^{124}Cs EC X-rays

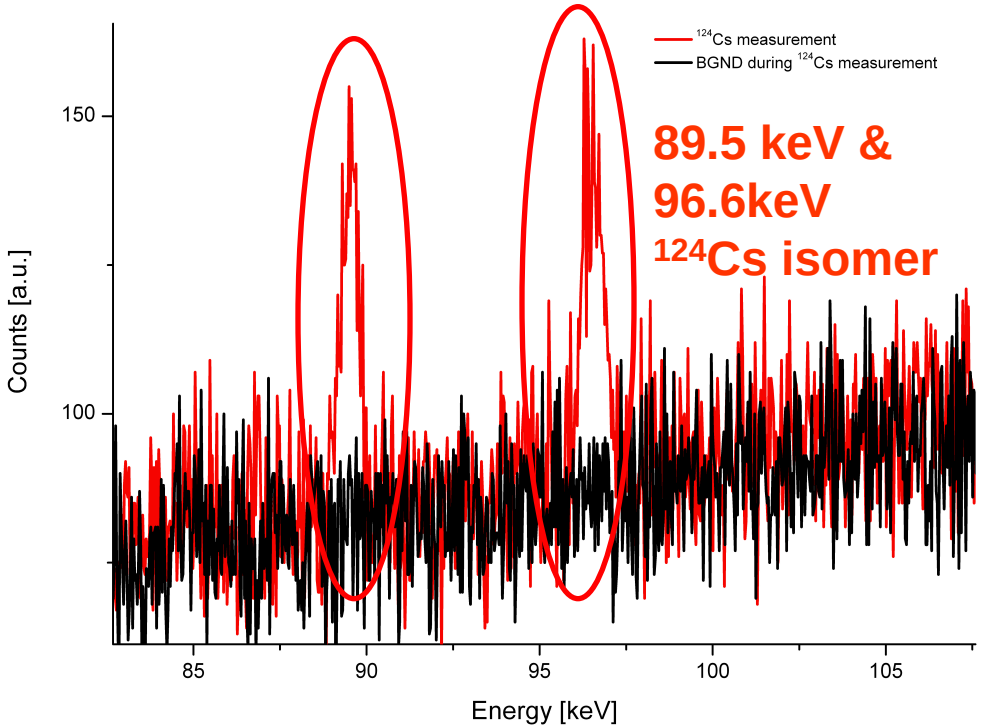


LeGe detector

~ 0.1% ε_{geo}

~ 2.5 T B field at detector position

DAQ with DSPEC



Xe X-ray lines: due to ^{124}Cs EC

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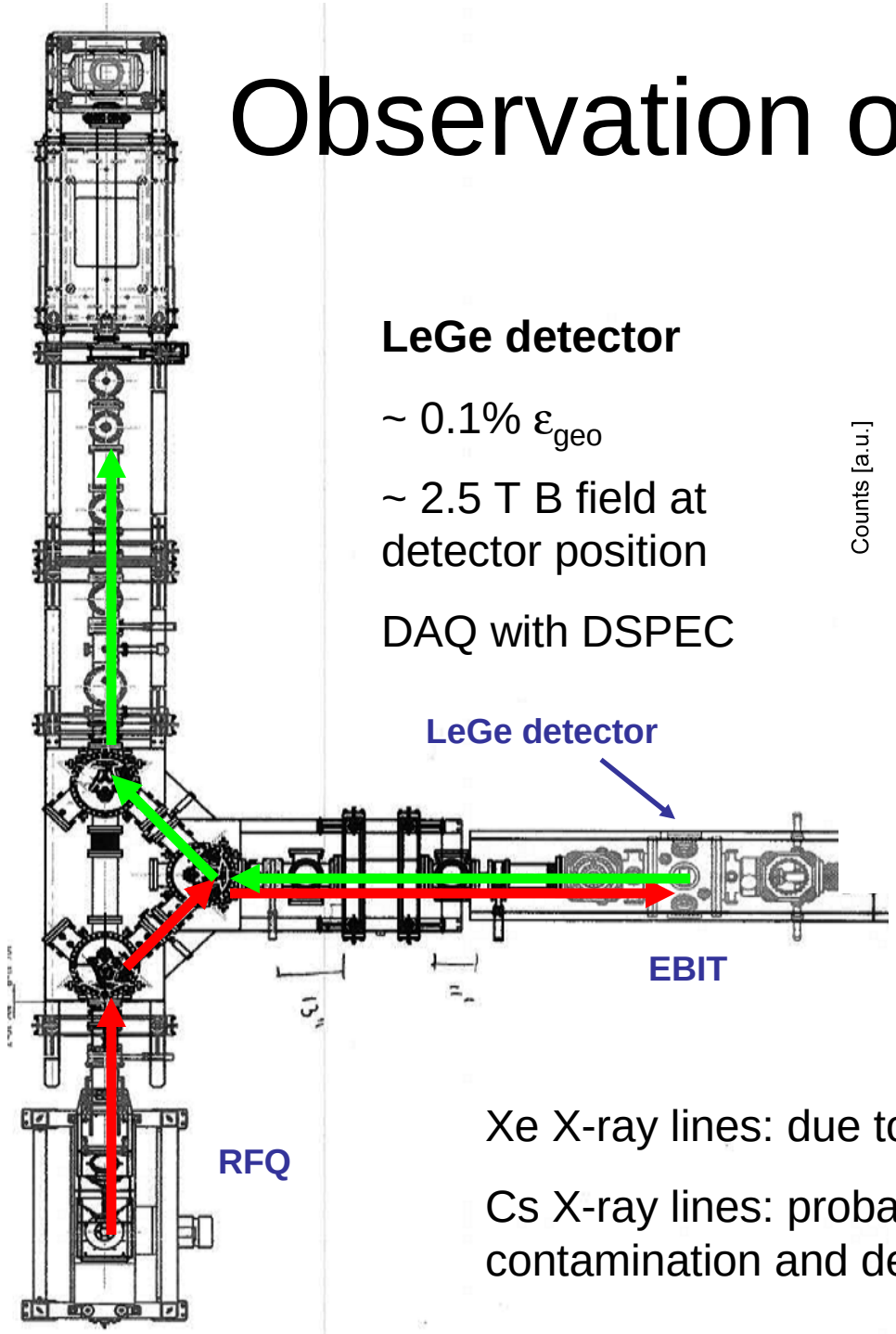

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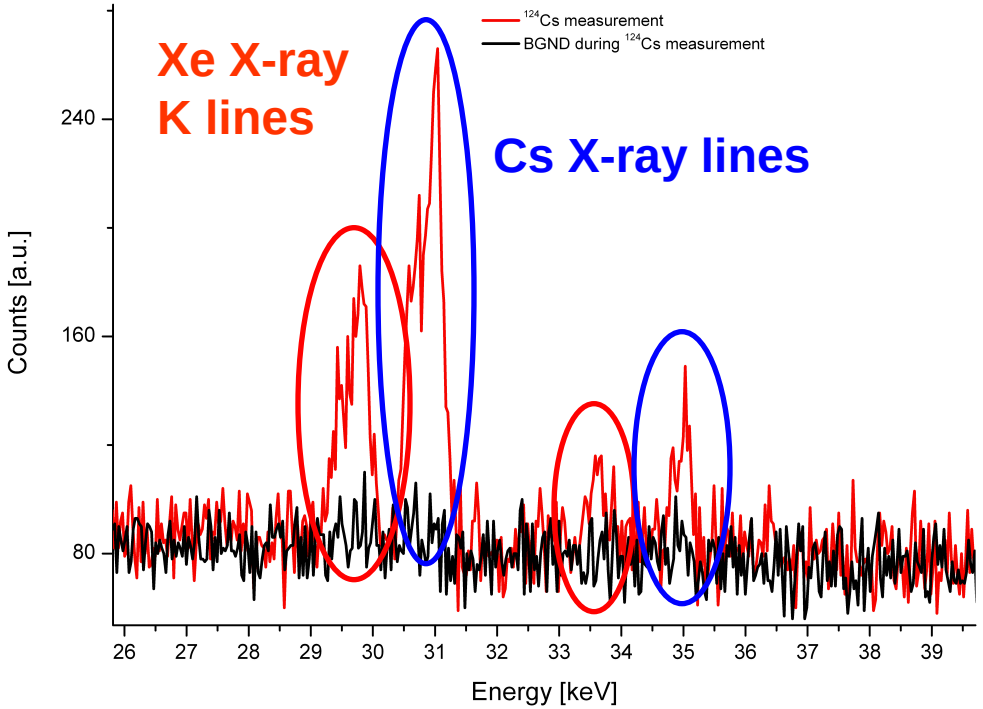

Better distinction between ^{124}Cs stored and BGND measurement than ^{126}Cs
→ reached space charge limit with ^{126}Cs

Xe X-ray lines: due to ^{124}Cs EC

Cs X-ray lines: probably dominant due to ^{124}Ba contamination and decay of ^{124m}Cs

Goals for the ^{126}Cs beam time

- Monitor the ISAC beam √
- Determine #ions/shot out of the TITAN-RFQ √
- Identify radioactive isotopes √
- Observe EC X-rays of stored ions √
- Observe β^+ of stored ions with PIPS detector √
- Time correlations between γ/X-ray and β detector √
- Use ^{124}Cs as reference to calibrate X-ray detector efficiency √

The ^{126}Cs run was a very successful experiment where we performed a lot of systematic studies. Lots of data is awaiting its analysis.

For the future we further need to understand the background and minimize losses inside the Penning trap.

We are on the right way towards the measurement of ECBR with ^{100}Tc…

Thanks a lot….

to ISAC delivery and operation and everyone
who helped to make this experiment a success.