# Trap-assisted spectroscopy $^{53}$Co$^{m}$ with JYFLTRAP

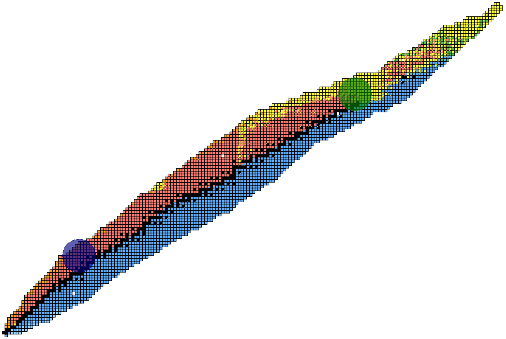
L.G. Sarmiento, Lund University, Sweden

on behalf of the
TRAPSPEC and JYFLSPEC Collaborations

NUSTAR Annual Meeting 2016
Darmstadt, Germany
March 2016

# Overview

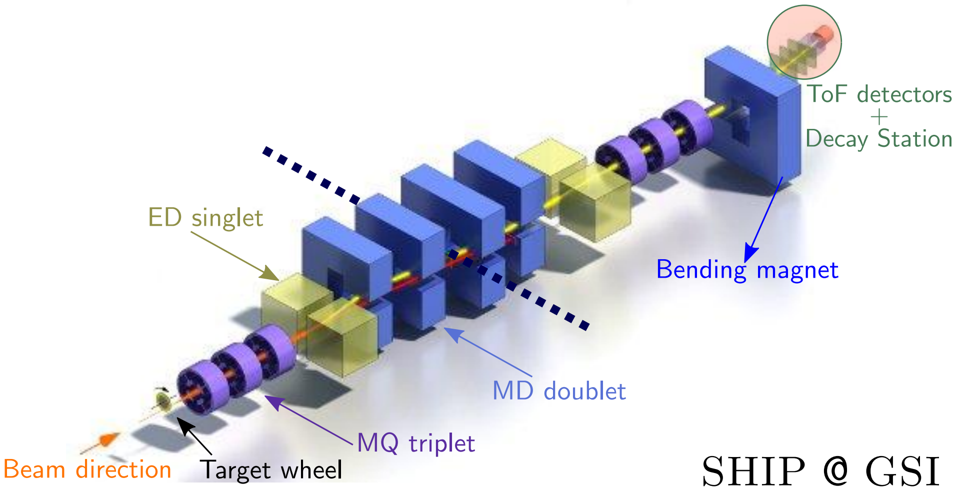
1. Quantum-selective spectroscopy
2. The TASISPEC setup
3. The $^{213}\mathrm{Ra}^{g}$ and $^{53}\mathrm{Co}^{m}$ case
4. Final remarks



JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

GSI

# Typical separation of isotopes



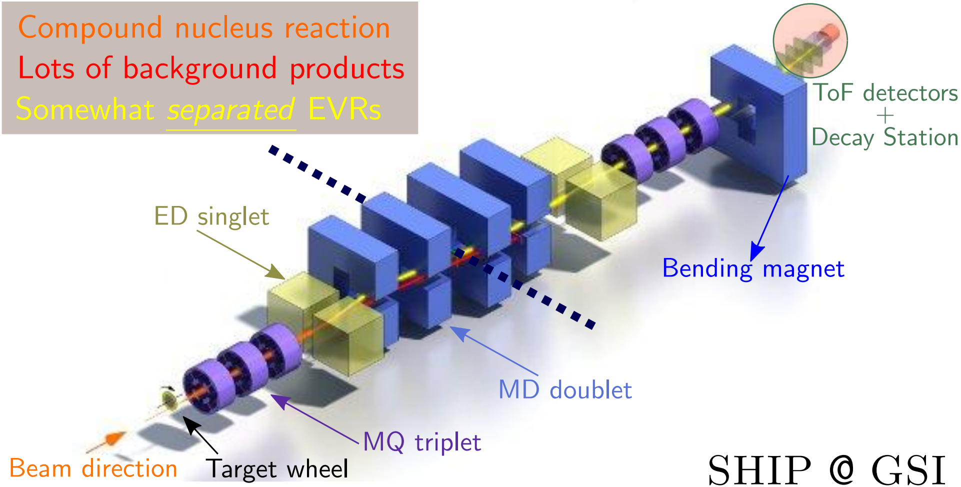

SHIP @ GSI

# Typical separation of isotopes

Compound nucleus reaction

Lots of background products

Somewhat *separated* EVRs

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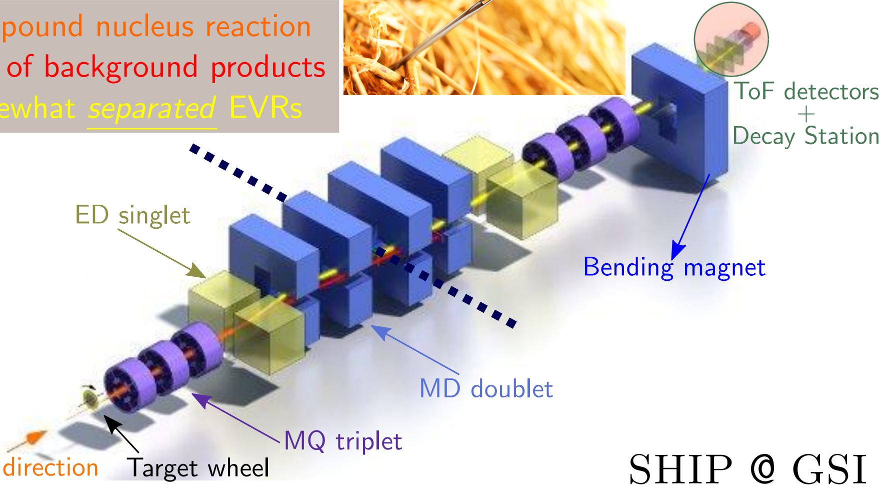
We want to find those
needles in the haystack

Compound nucleus reaction
Lots of background products
Somewhat *separated* EVRs

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# Typical separation of isotopes

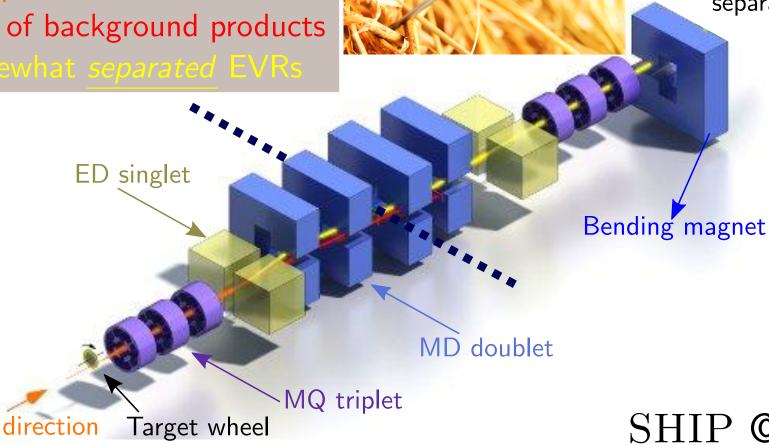
We want to find those needles in the haystack

Compound nucleus reaction

Lots of background products

Somewhat *separated* EVRs

... we need further separation

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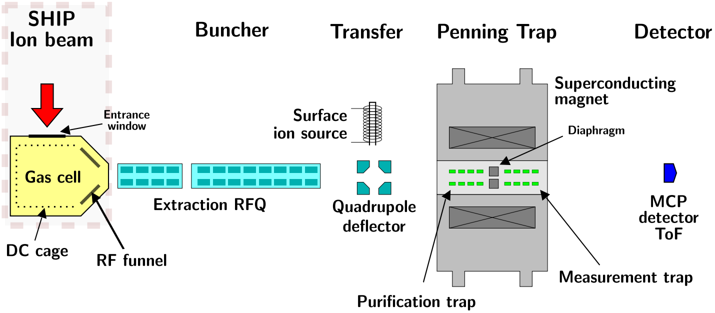
# ... further separation



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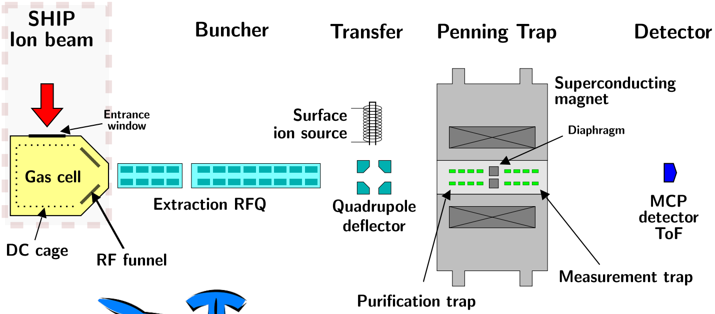
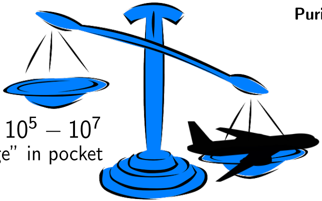
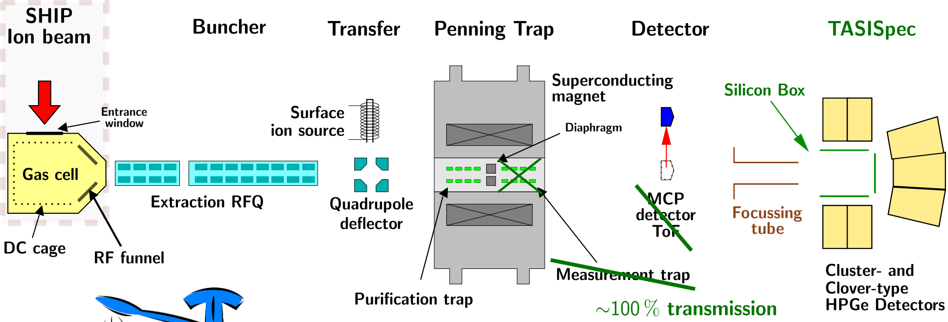


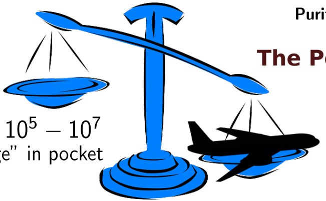
$R \sim 10^5 - 10^7$
"change" in pocket

"$\mathbf{E = mc^2}$"

# … further separation




**The Penning trap acts like a tunable quantum sieve!**



$R \sim 10^5 - 10^7$
"change" in pocket

$$\text{“}\mathbf{E = mc^2}\text{”}$$

# TASiSpec

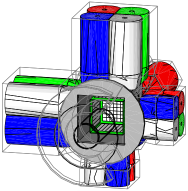
Highly efficient multi-coincidence spectroscopy set-up
for TASCA's very compact focal plane image

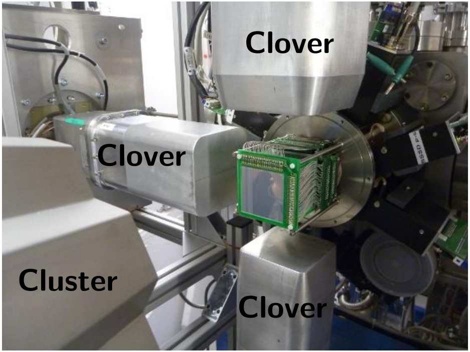
1 Imp. DSSSD (1024 pixels)
\+ 4 Box DSSSDs (1024 pixels)

$\sim$ 80% $\alpha$-detection efficiency

4 Ge Clover (4 crystals each)
\+ 1 Ge Cluster (7 crystals each)

$\sim$ 40% $\gamma$-detection effi. @ 150 keV






L.-L. Andersson et al., NIM A 622, 164 (2010).

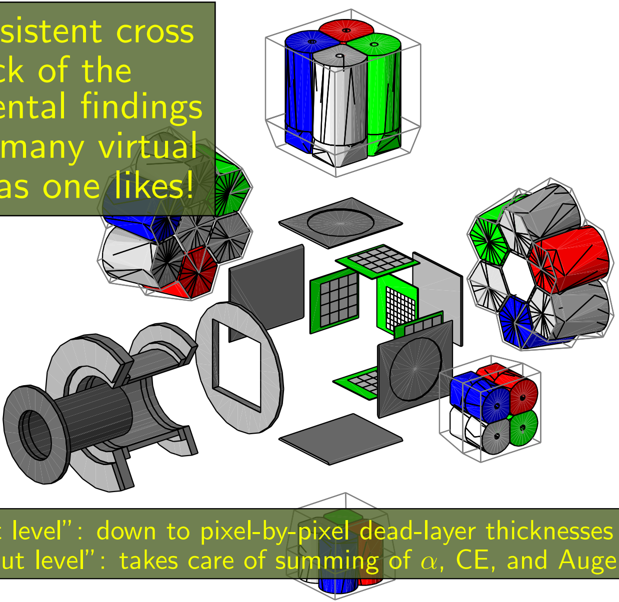
L.G. Sarmiento et al., NIM A 667, 26 (2012).

Fully simulated with Geant4

JOHANNES GUTENBERG UNIVERSITÄT MAINZ · LUND UNIVERSITY · UNIVERSITY OF LIVERPOOL · GSI · HELMHOLTZ GEMEINSCHAFT Helmholtz-Institut Mainz · UNIVERSIDAD NACIONAL DE COLOMBIA

# TASISPEC

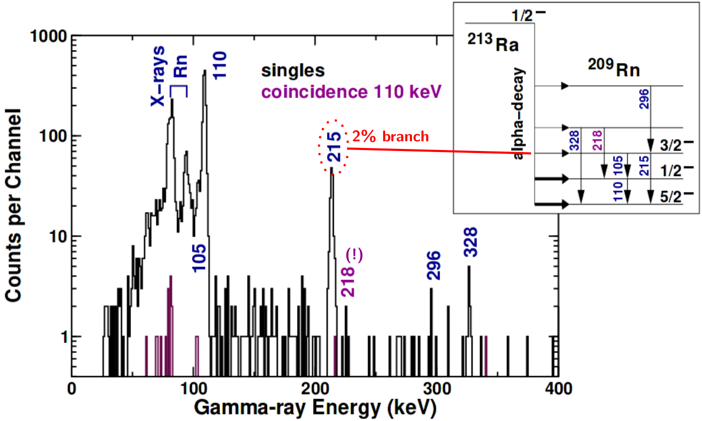
Self-consistent cross check of the experimental findings with as many virtual decays as one likes!



"Input level": down to pixel-by-pixel dead-layer thicknesses . . .
"Output level": takes care of summing of $\alpha$, CE, and Auger energies . . .

# Proof-of-principle

$^{170}\mathbf{Er}(^{48}\mathbf{Ca}, 5n)^{213}\mathbf{Ra}$




**~15h parasitic**

P. Kuusiniemi et al., Eur.Phys. J. A 30, 551 (2006)

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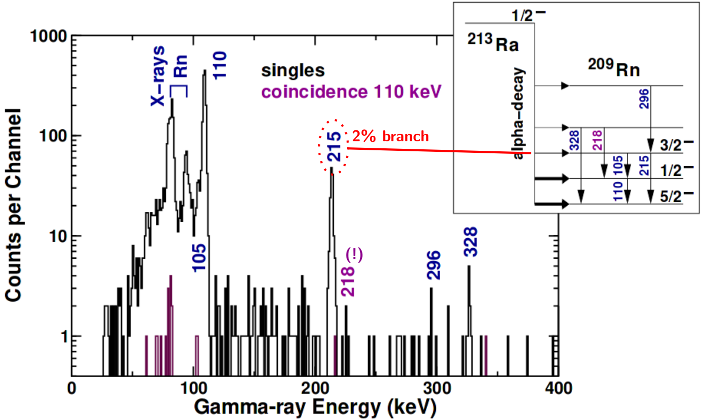
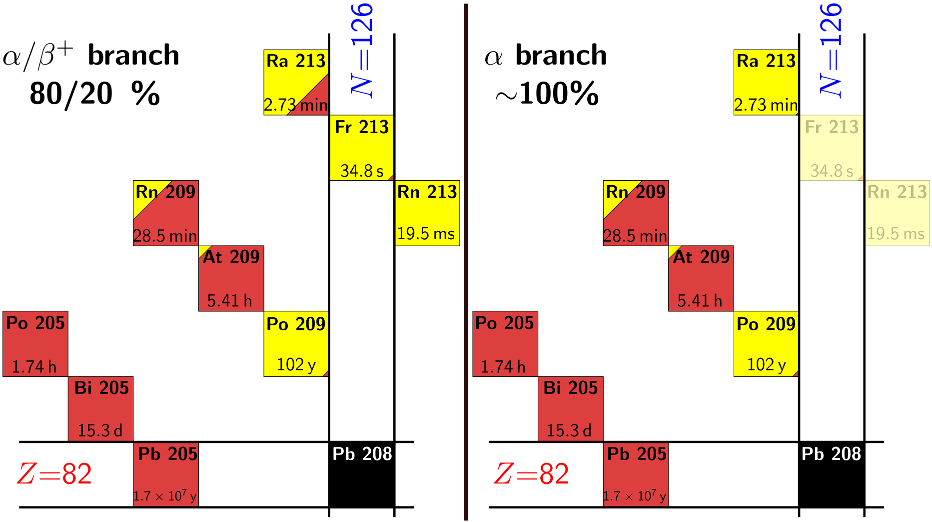



**nice results... but something doesn't add up...**

**∼15h parasitic**

P. Kuusiniemi et al., Eur.Phys. J. A 30, 551 (2006)

# Proof-of-principle



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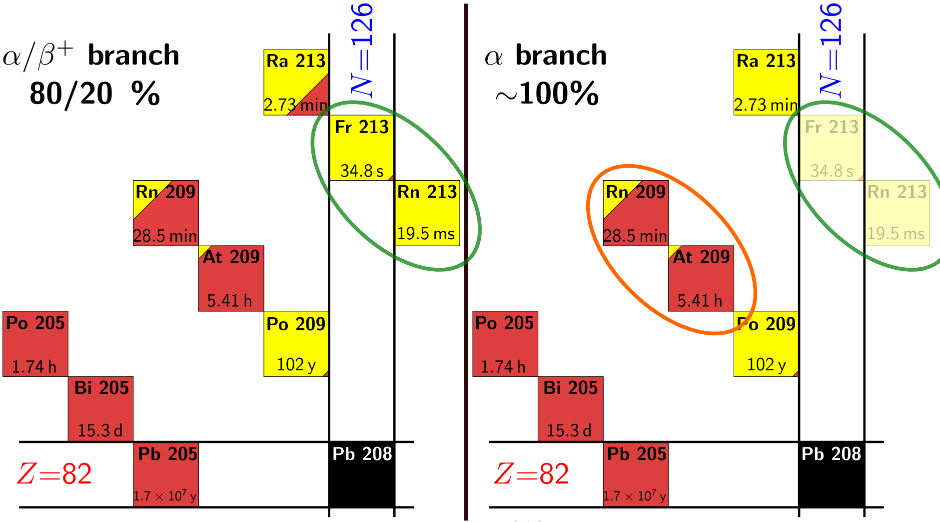
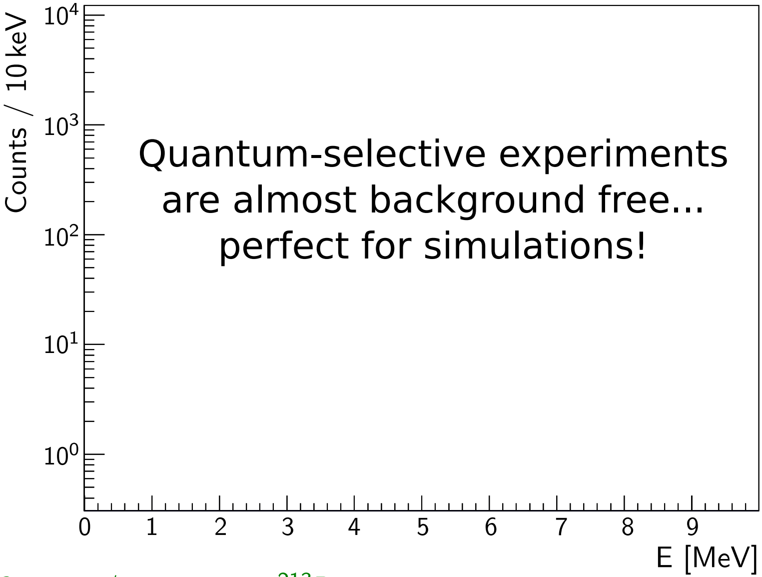



Distinguishable by the *absence* of $^{213}$Fr decay
and the enhanced $^{209}$Rn EC/$\beta^+$ decay

# Proof-of-principle




$15\,\mathrm{h}$ @ $\sim 2\,\mathrm{ev/s} \rightarrow 108000\ {}^{213}\mathrm{Ra}$

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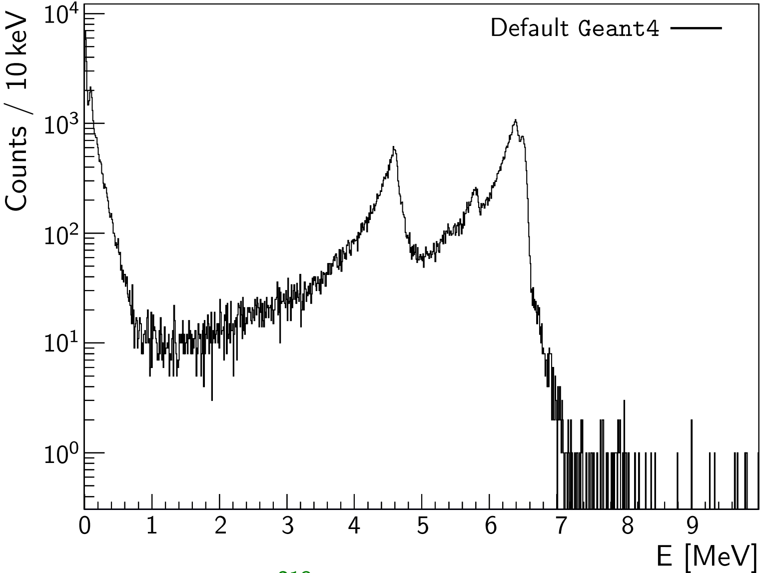


15 h @ $\sim 2$ ev/s $\rightarrow$ 108000 $^{213}$Ra

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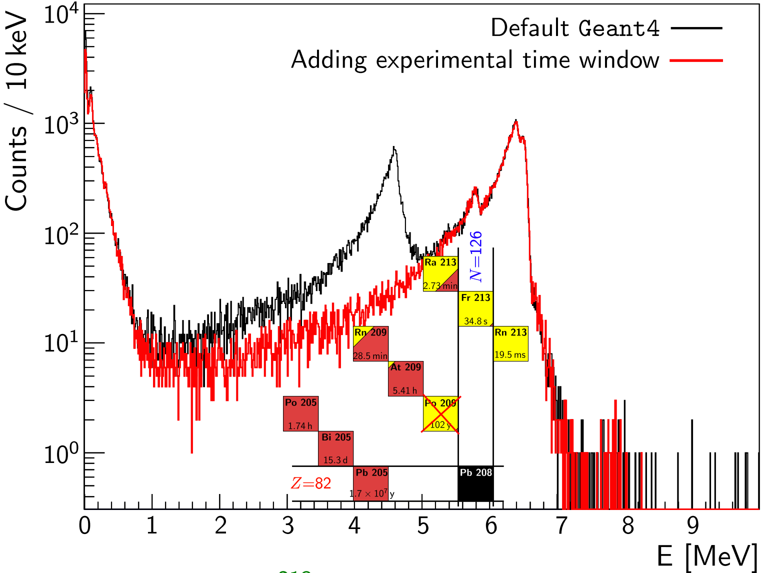


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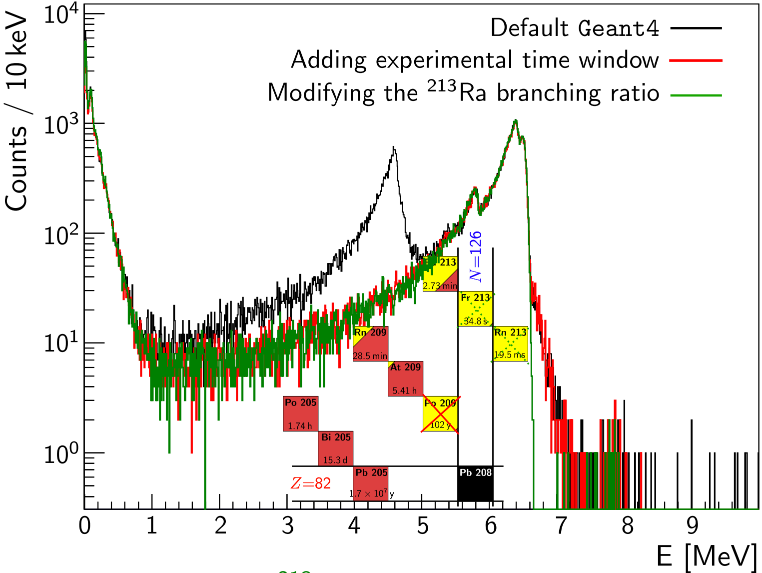


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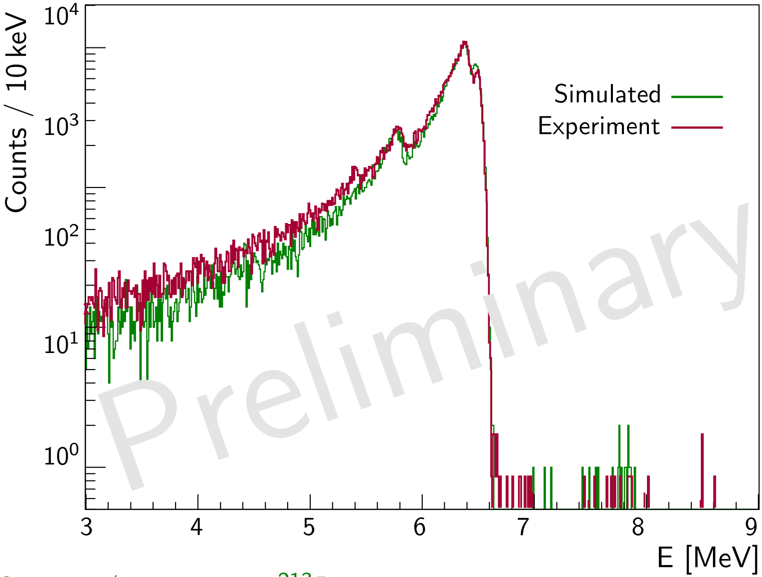


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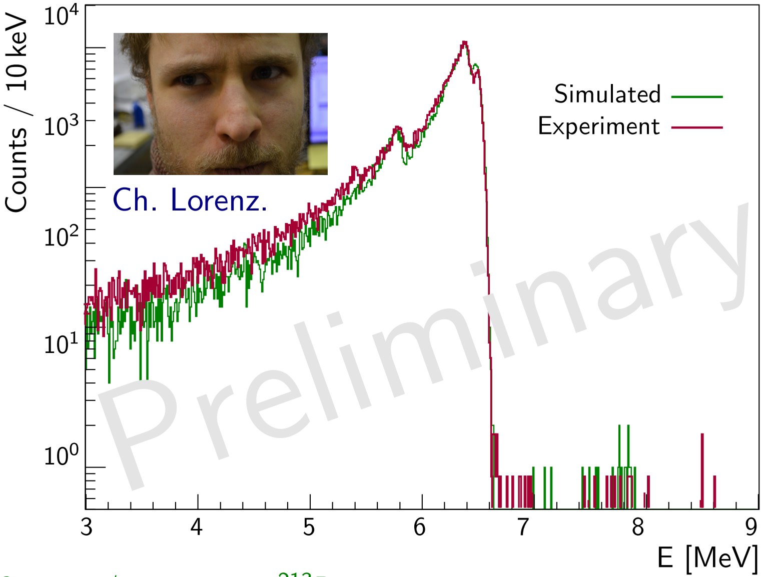


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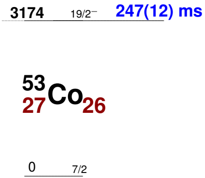
# Proton *radioactivity*



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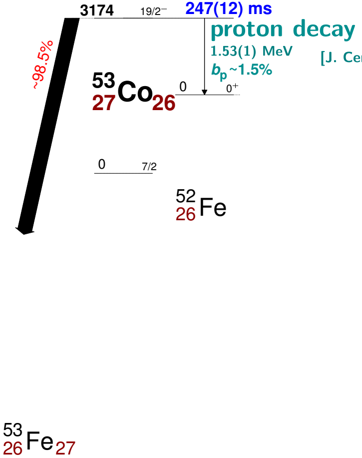


$\ell = 9(!)$

[J. Cerny, K.P. Jackson (circa 1970)]

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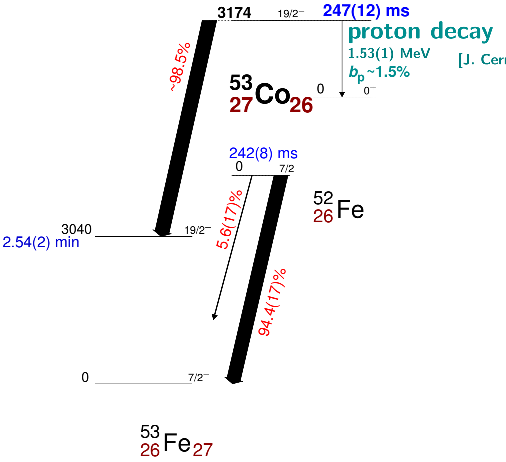


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**IAS** = Isobaric Analog States

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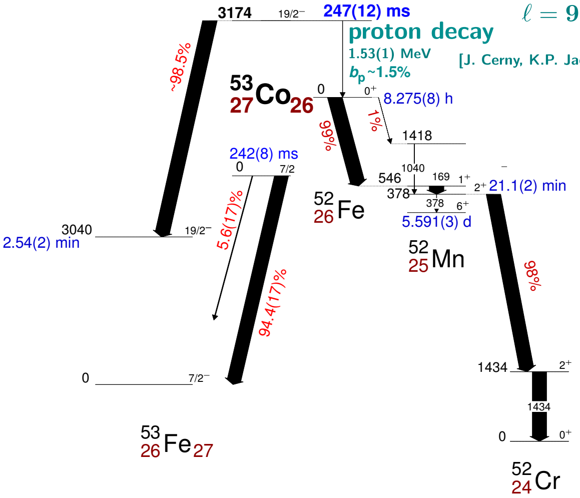


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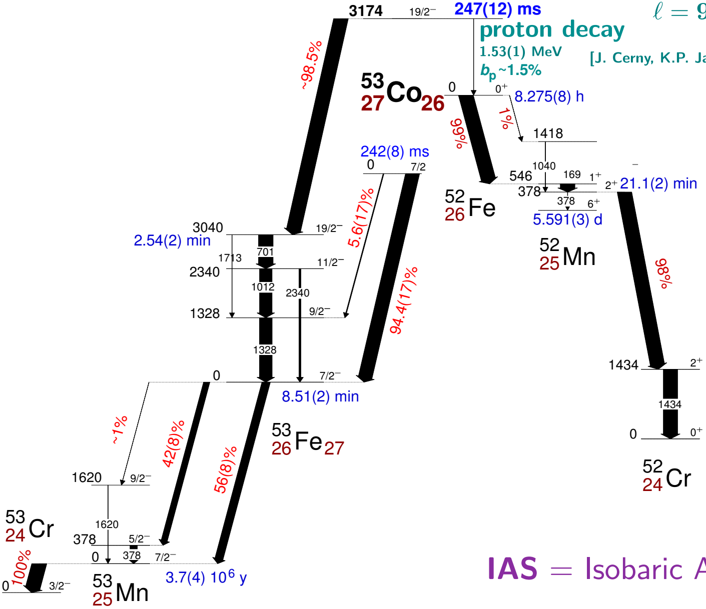


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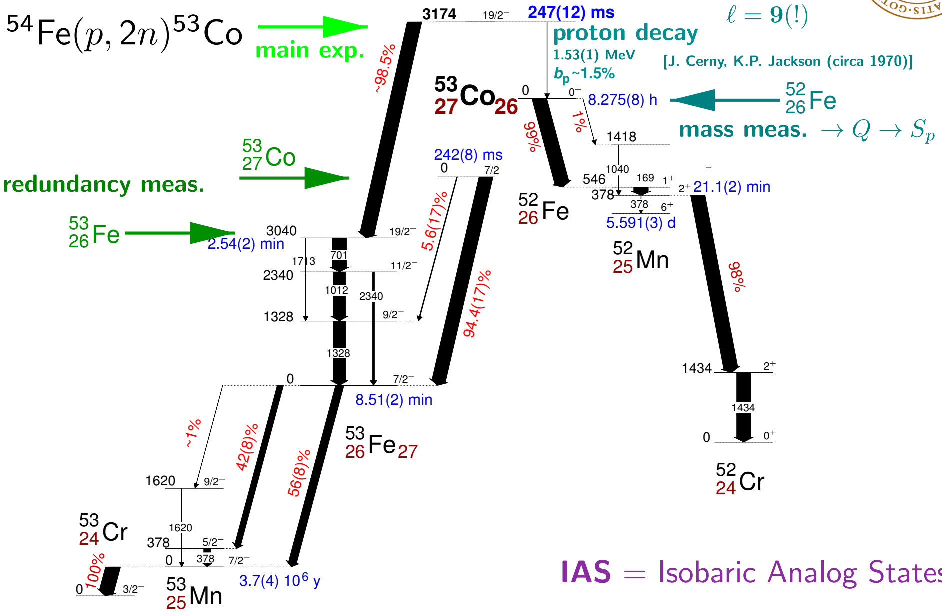


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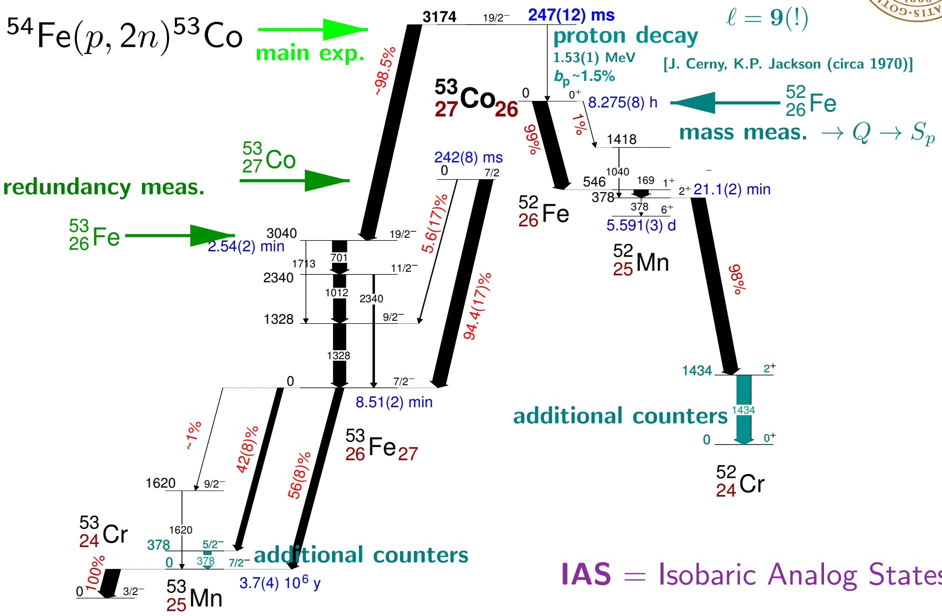


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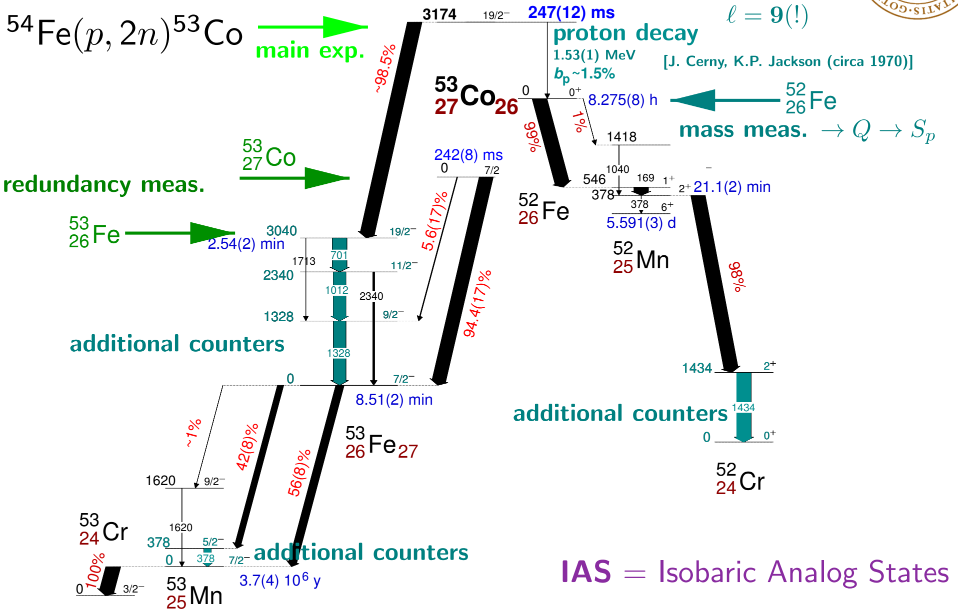

| | |
|---|---|
| Virtual TASISPEC coded? | ... checked |
| Radioactive decay enabled? | ... checked |
| $^{53}$Co ions ready? | ... checked |
| Analysis set? | ... checked |

OK, let's run some simulations

Virtual TASISPEC coded? ... checked
Radioactive decay enabled? ... checked
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OK, let's run some simulations
**... wait! no proton emission?**

# Proton *radioactivity*

**Simple solution:** Modify the Geant4 source code

**Nov. 2013:** Appointed by the TASCA collaboration to include the SHE decay into `Geant4`

**Apr. 2014:** Contact with the `Geant4` collaborators

**Jul. 2014:** Accepted as a `Geant4` developer

**Aug. 2014:** ‘Prompt’ proton emission included in `Geant4-RDM`

**Apr. 2015:** Various improvements SHE- and not SHE-related

**Oct. 2015:** ‘Prompt’ neutron emission included `Geant4-RDM`

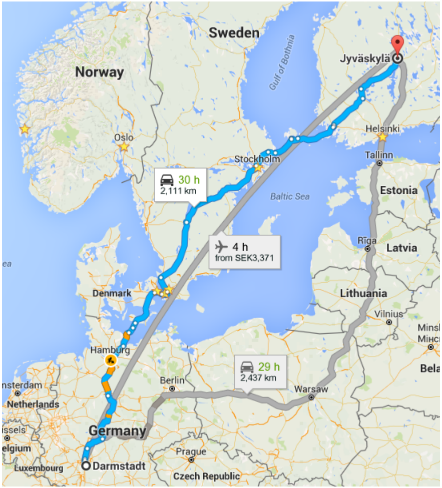
**Nov. 2015:** First steps towards SHE-extension, Reverted!.

**Feb. 2016:** Green light for SHE-extension, WIP.

$p-$ and $n-$ emission available on Dec. 4 (v 10.2 release)

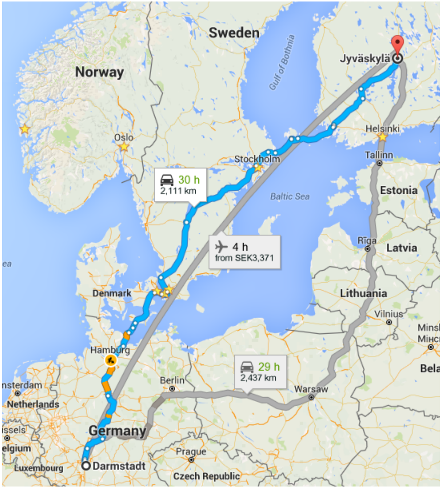
... more "*nuclear physics*" to come

# Let's do it...



Sweden
Norway
Gulf of Bothnia
Jyväskylä
Helsinki
Oslo
Tallinn
Stockholm
30 h
2,111 km
Estonia
Baltic Sea
4 h
from SEK3,371
Riga
Latvia
Denmark
Lithuania
Vilnius
Minsk
Hamburg
Bela
29 h
2,437 km
Berlin
Warsaw
nsterdam
Netherlands
Germany
ssels
elgium
Prague
Luxembourg
Darmstadt
Czech Republic

# Let's do it...



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# *Let's do it...*

# Let’s do it...

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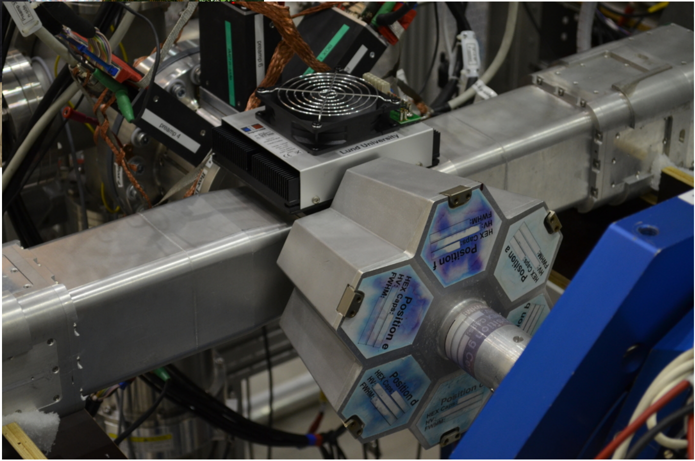
preamp 4
Lund University
Position f
Position a
Position e
Position d

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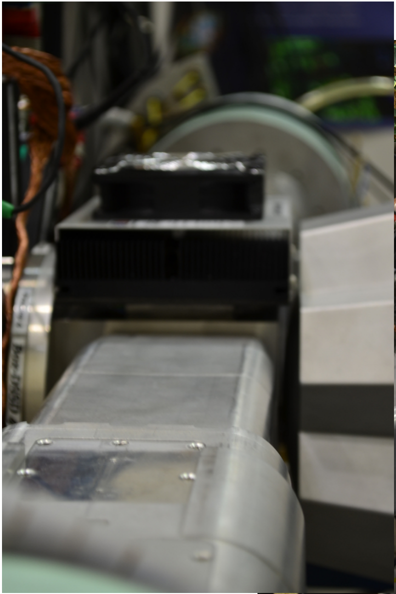

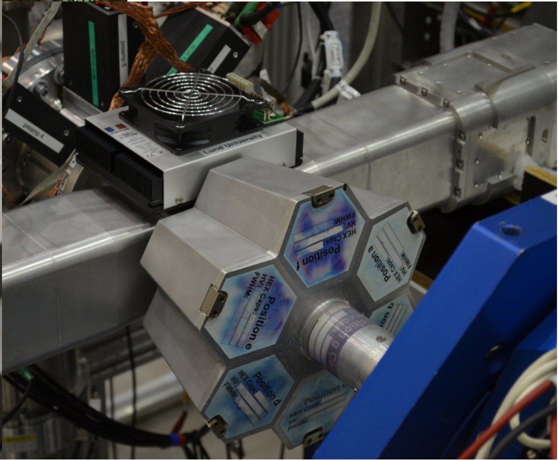
Lund University
Position f
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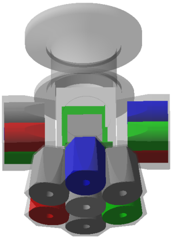
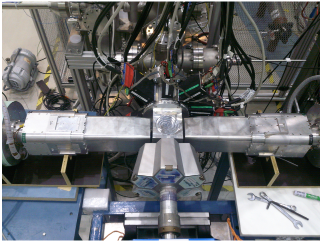
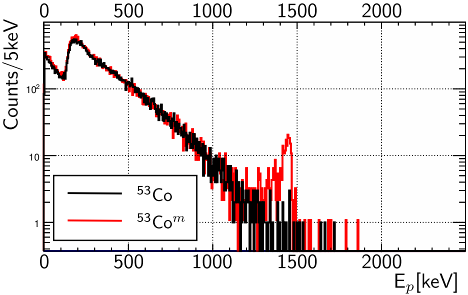
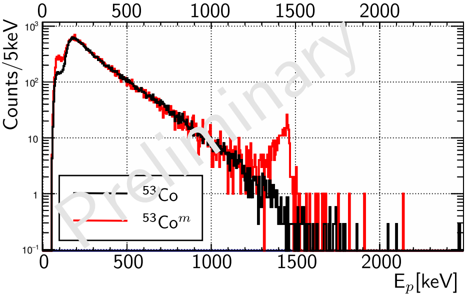
Position a

# Proton radioactivity







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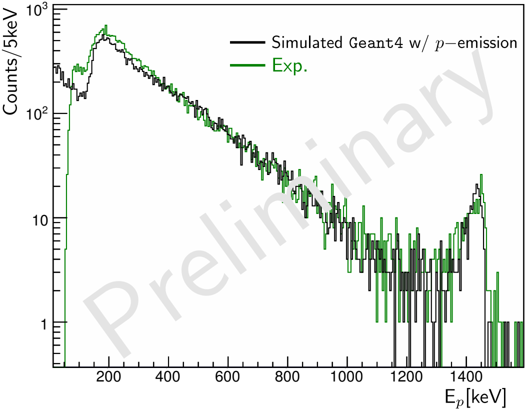


The match is fantastic[ly boring]

The branching ratio $b_p \lesssim 1.5$

Improved $^{52}$Fe mass measurement $\rightarrow Q_p$

... it was measured for the very first time(!)
with the help of the quantum-state selectivity of the JYFLTRAP

# Final remarks

**Experiment** Penning traps present an excellent opportunity to perform state selective decay spectroscopy. This is the first in hopefully a series of trap-assisted experiments

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- Before the experiment
- During the data analysis
- Proposing new physics or re-interpreting physical cases

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- Before the experiment
- During the data analysis
- Proposing new physics or re-interpreting physical cases

**coming soon...** The final numbers and subsequent analysis are being finalized at Lund.

- With the branching ratio, half-life, and $Q$-value we can proceed with the theoretical description.

# The collaborations

## JYFLSpec


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*GSI Helmholzzentrum für Schwerionenforschung GmbH, D-64291 Darmstadt, Germany*

# The collaborations

## TRAPSpec

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# THANK YOU
for your attention