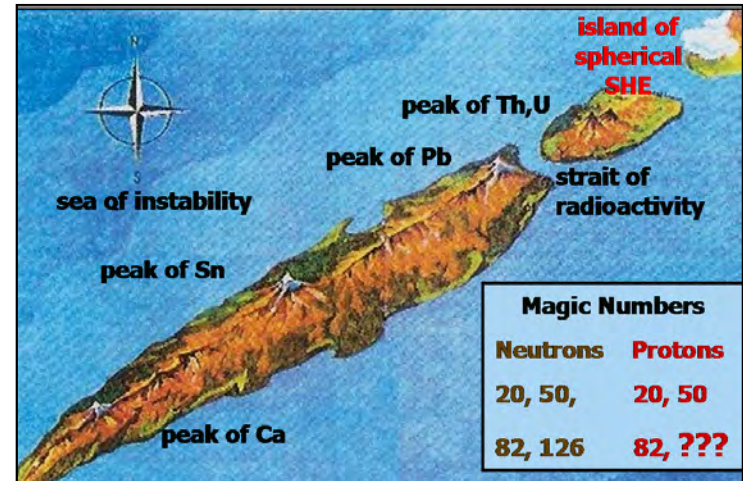
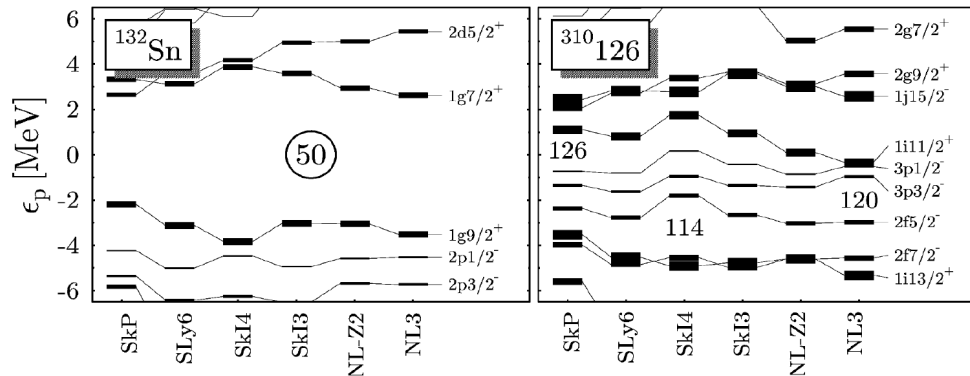
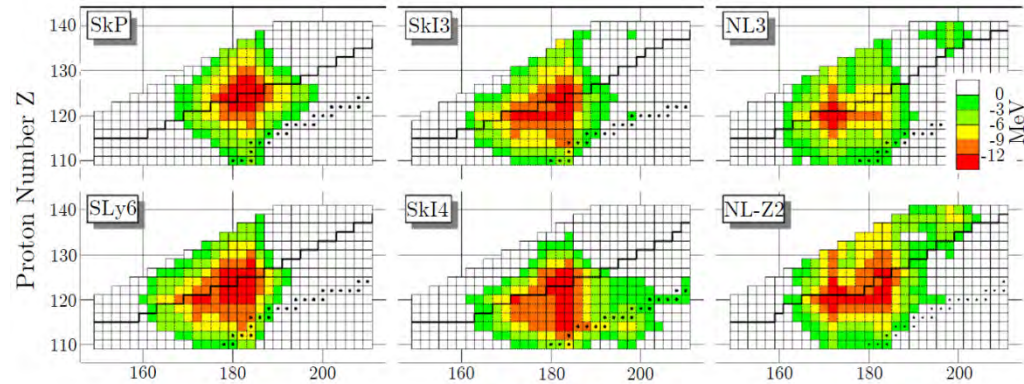


# Decay Spectroscopy Measurements at SHIP 2016

**Andrew Mistry**  
**HIM**

# Motivation: Heavy and Superheavy Elements

- **Nuclear structure features of superheavy nuclei**  
(decay spectroscopy)
  - Quasi-particle excitations → deformation/K-isomers
  - Single particle levels – trends towards the next closed p- and n-shell
  - Head towards the heavy shell stabilised region



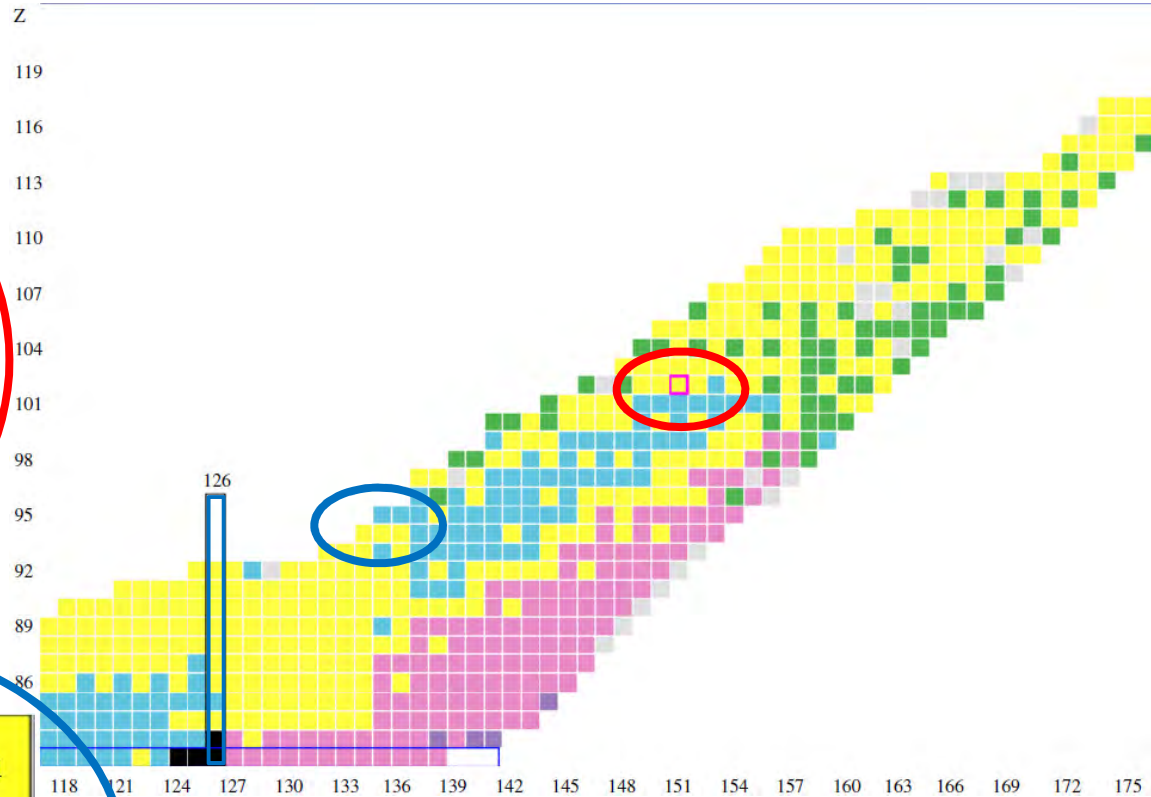
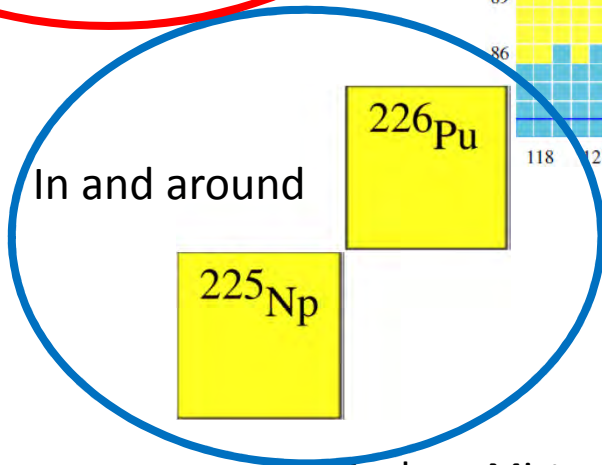
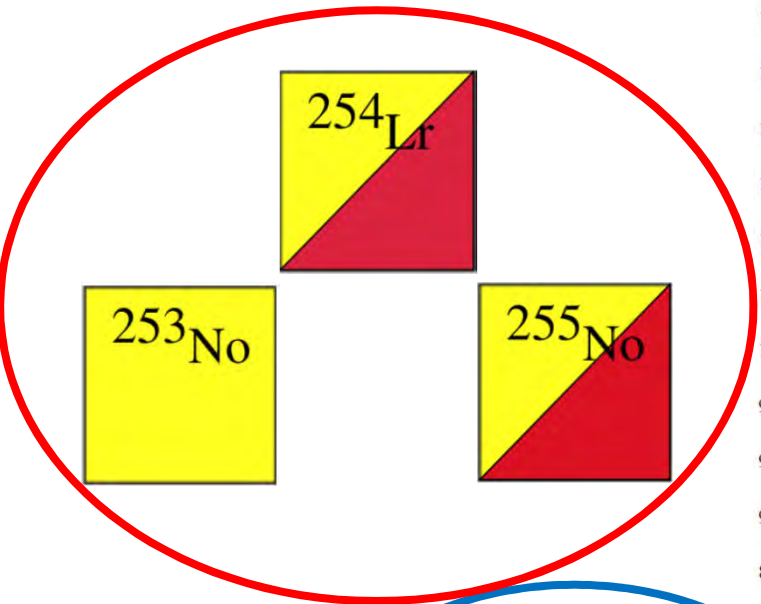
# Motivation: Heavy and Superheavy Elements

## *Measure:*

- Alpha decay energies/decay times/intensities
- EM transitions in the nucleus (Gamma-rays, Conversion electrons)
- X-rays

- *Low cross sections Maximum  $\sim nb$  cross-sections for SHEs*
- *Deformed mid-shell region favourable. Max  $\sim \mu b$  cross-sections*

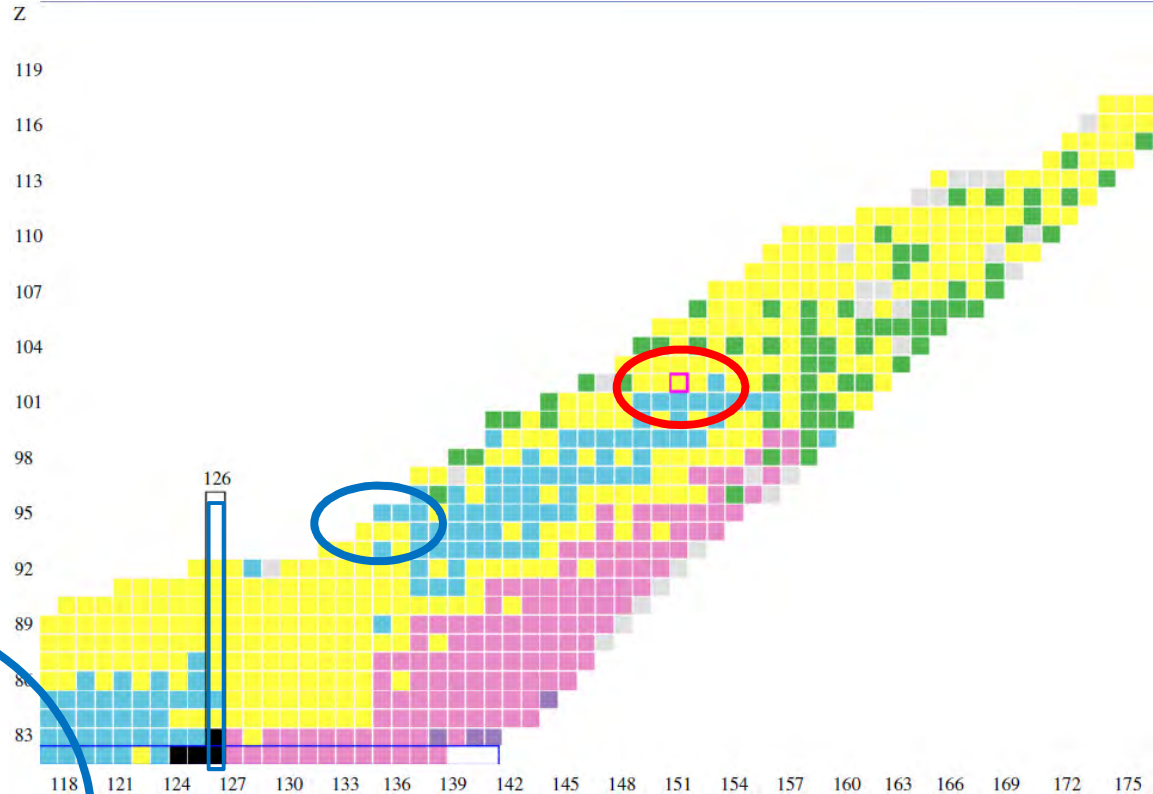
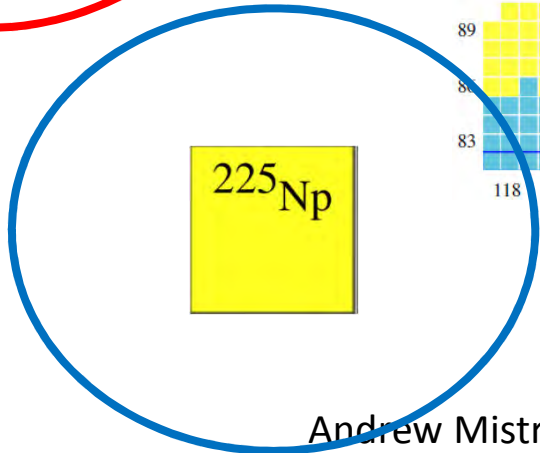
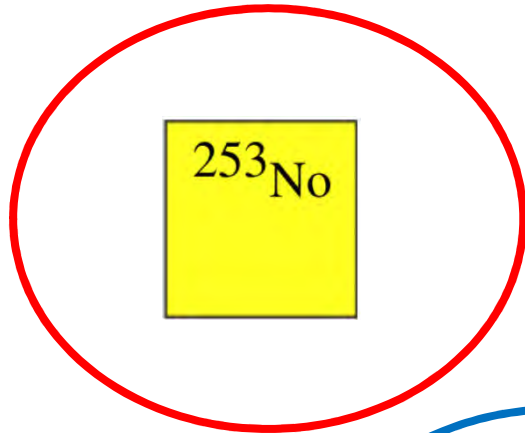
# Previously areas of exploration during 2015



# Areas of exploration during 2016

## Goals of the 2016 parasitic beamtime:

- Reduce thresholds  $^{253}\text{No}$  ✓ -> **1MeV to 100keV**
- Synthesis of  $^{225}\text{Np}$

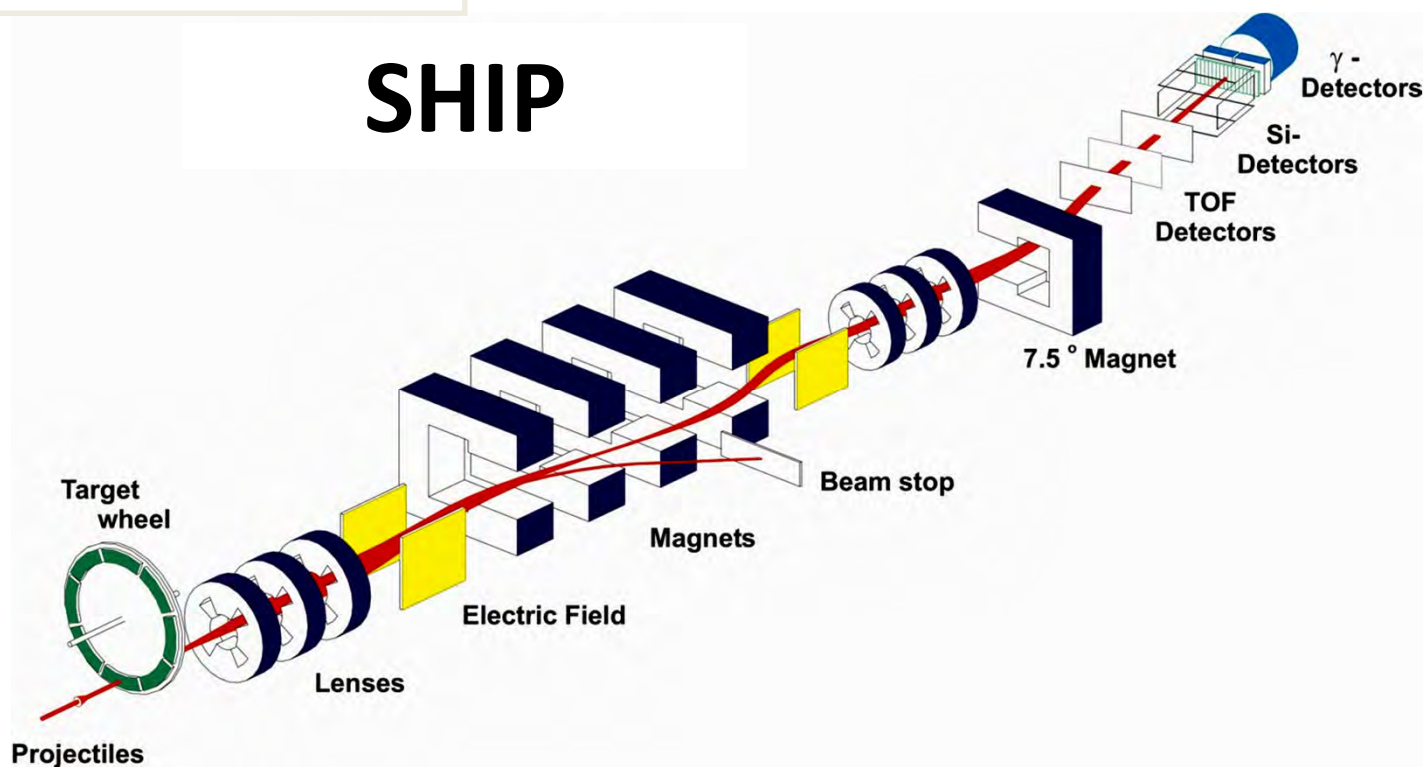


All measurements preliminarily

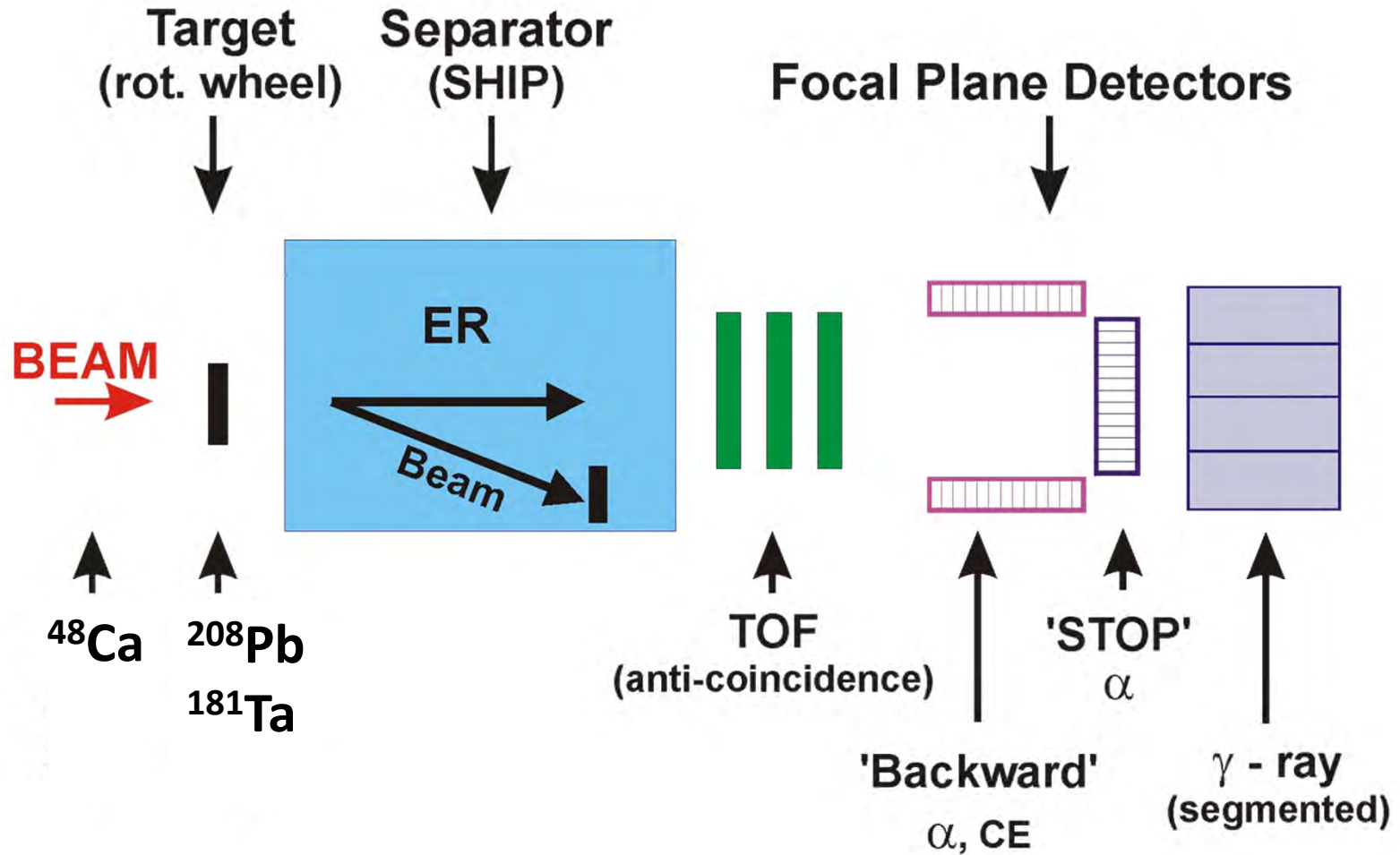
# SHIP velocity separator at GSI

## SHIP

Separation time: 1 – 2  $\mu$ s  
Transmission: 20 – 50 %  
Background: 10 – 50 Hz  
Det. E. resolution: 30 – 40 keV



# SHIP velocity separator at GSI



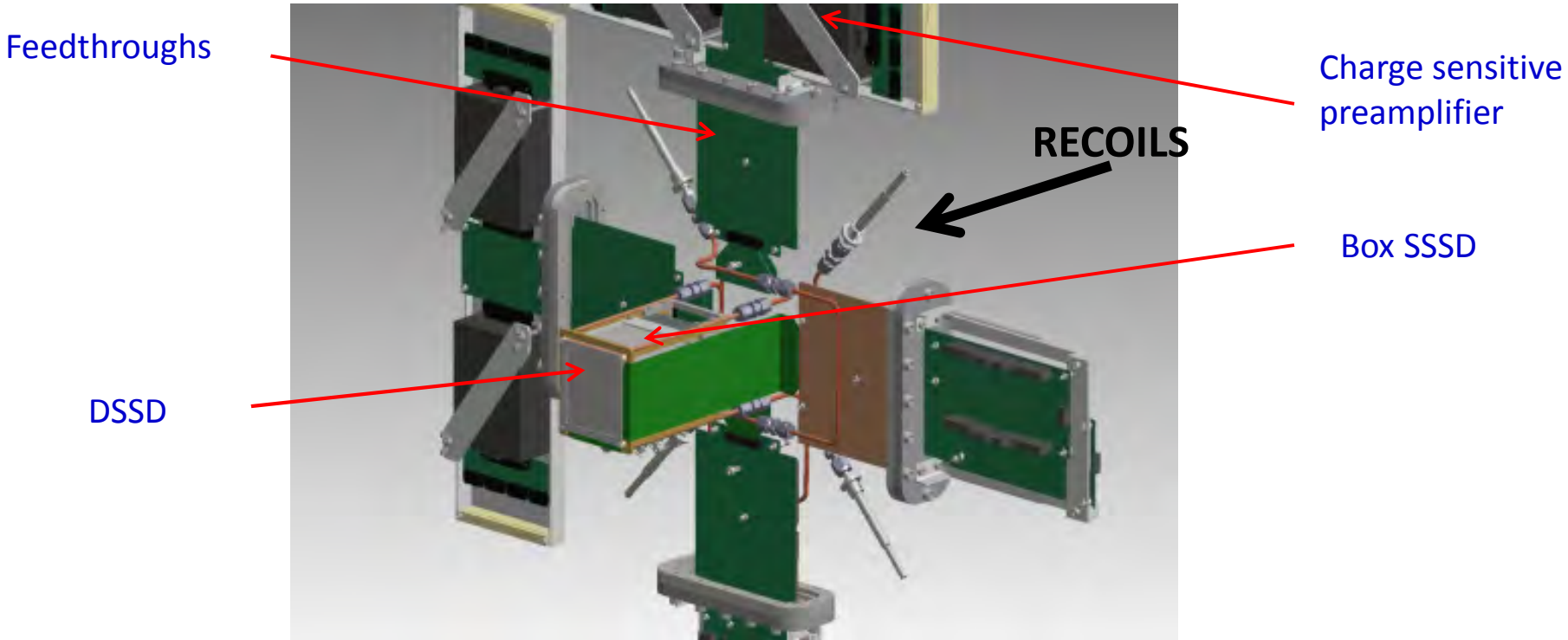
# Focal Plane Detection System

## Configuration

- Stop detector: 1 × DSSD (60×60 strips pitch 1mm, 300 μm)
- Box detectors: 4 × SSSD (32 strips)
- 5 EXOGAM clover Ge detectors surrounding the box

## Chamber

- Compact (overall length 35 cm)
- Al-cap with thin  $\gamma$  window (1.5 mm)





# Electronics and read-out

2 read out options:



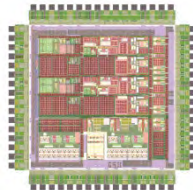
## 1. Classic PA

- PCB vacuum feed through
- 2×32 channels
- differential output signal

## 2. APFEL ASIC

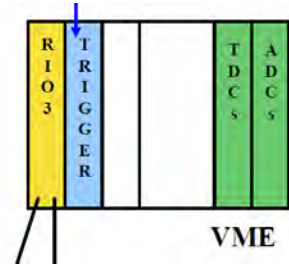
- Cooled
- 64 input channels (8 piggybacks)
- 2 amplification factors
  - 1
  - 16/32 switchable
- Differential output signal

In total max. 256 channels



## MBS architecture

- Local server + mass storage
- 2 MBS branches



## 1. RIO power PC/VME

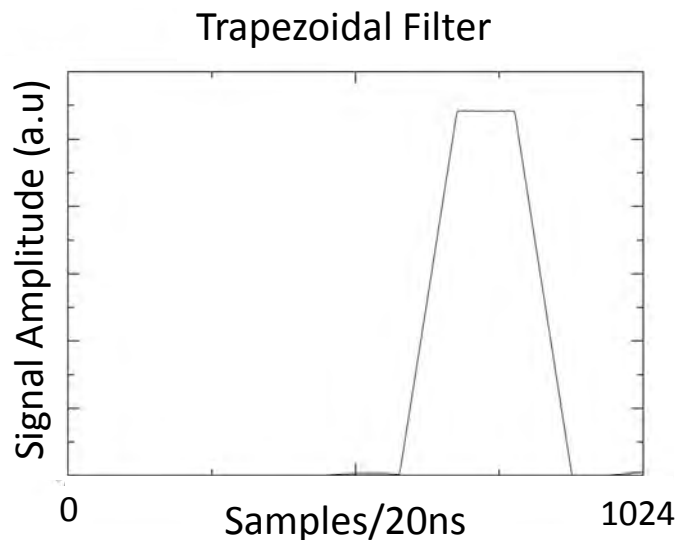
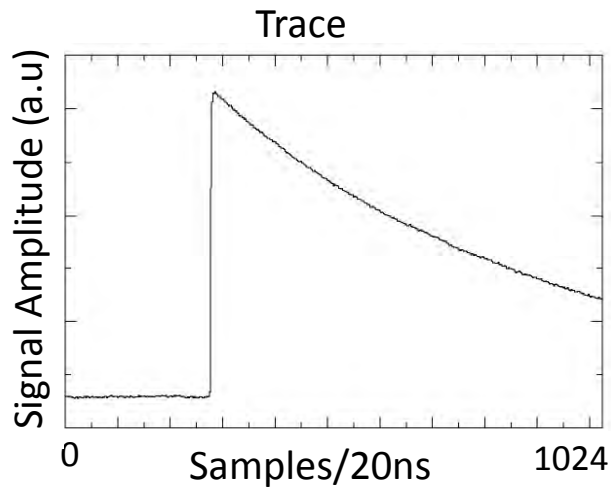
- Analog shaping and amplification 32-fold 12bit ADCS

## 2. FEBEX + MBS-Linux PC

- 1 FEBEX frame – 198 channels

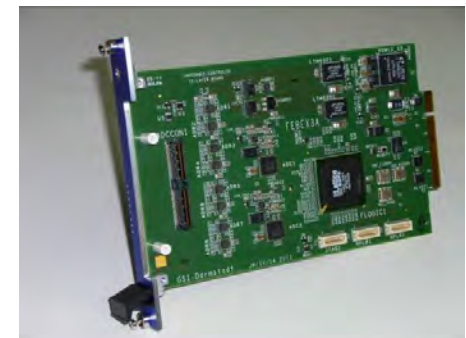


# FEBEX Readout



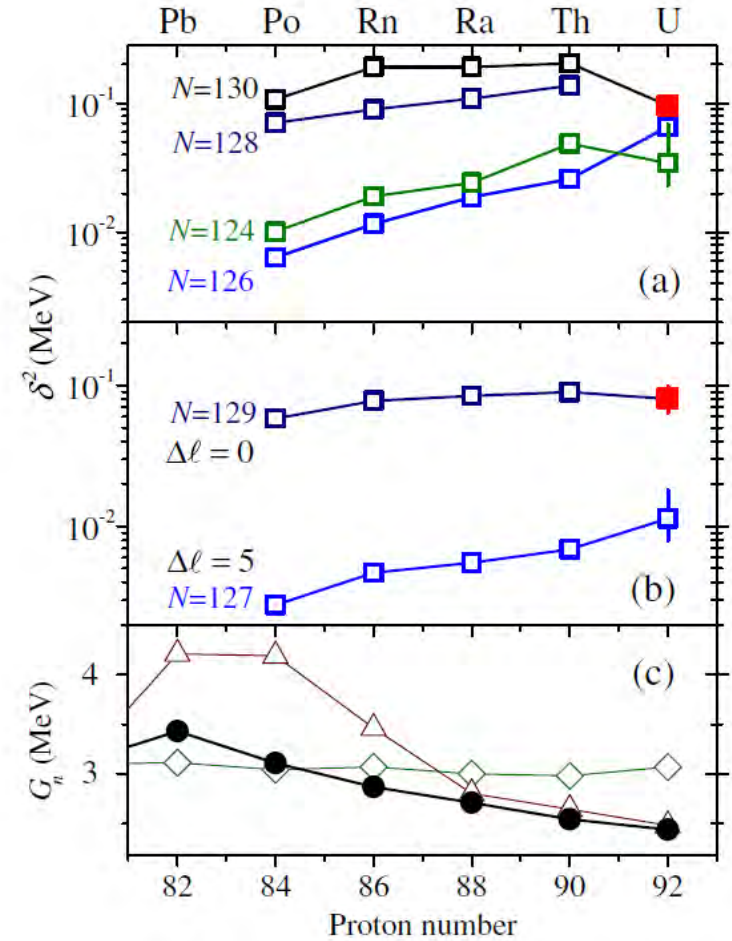
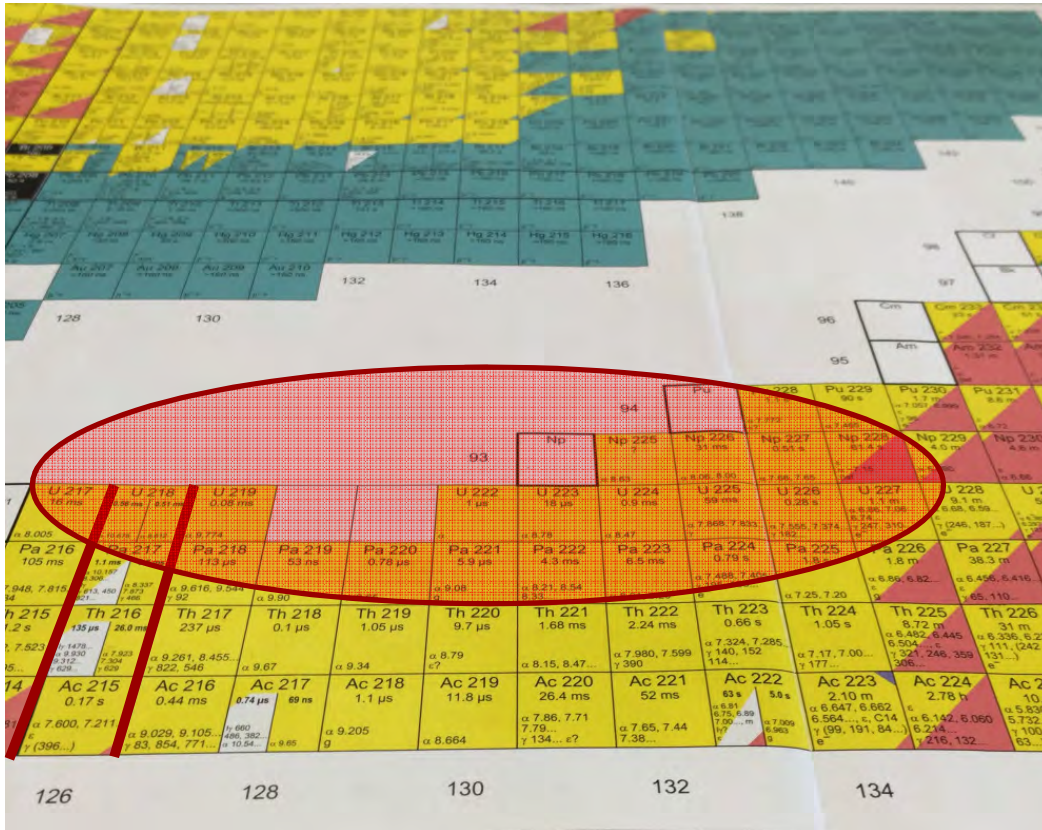
## *This Experiment*

- ***Front End Board with optical link Extension version: FEBEX 3A/B***
  - 16 channels
  - 60 MHz (20ns time resolution)
  - 14 bit flash ADC
  - On-board FPGA trapezoid filter
- ***FEBEX + conventional PA***
  - Fast timing
  - (Almost) deadtime free
  - Pulse shape analysis options



# $^{225}\text{Np}$ motivation

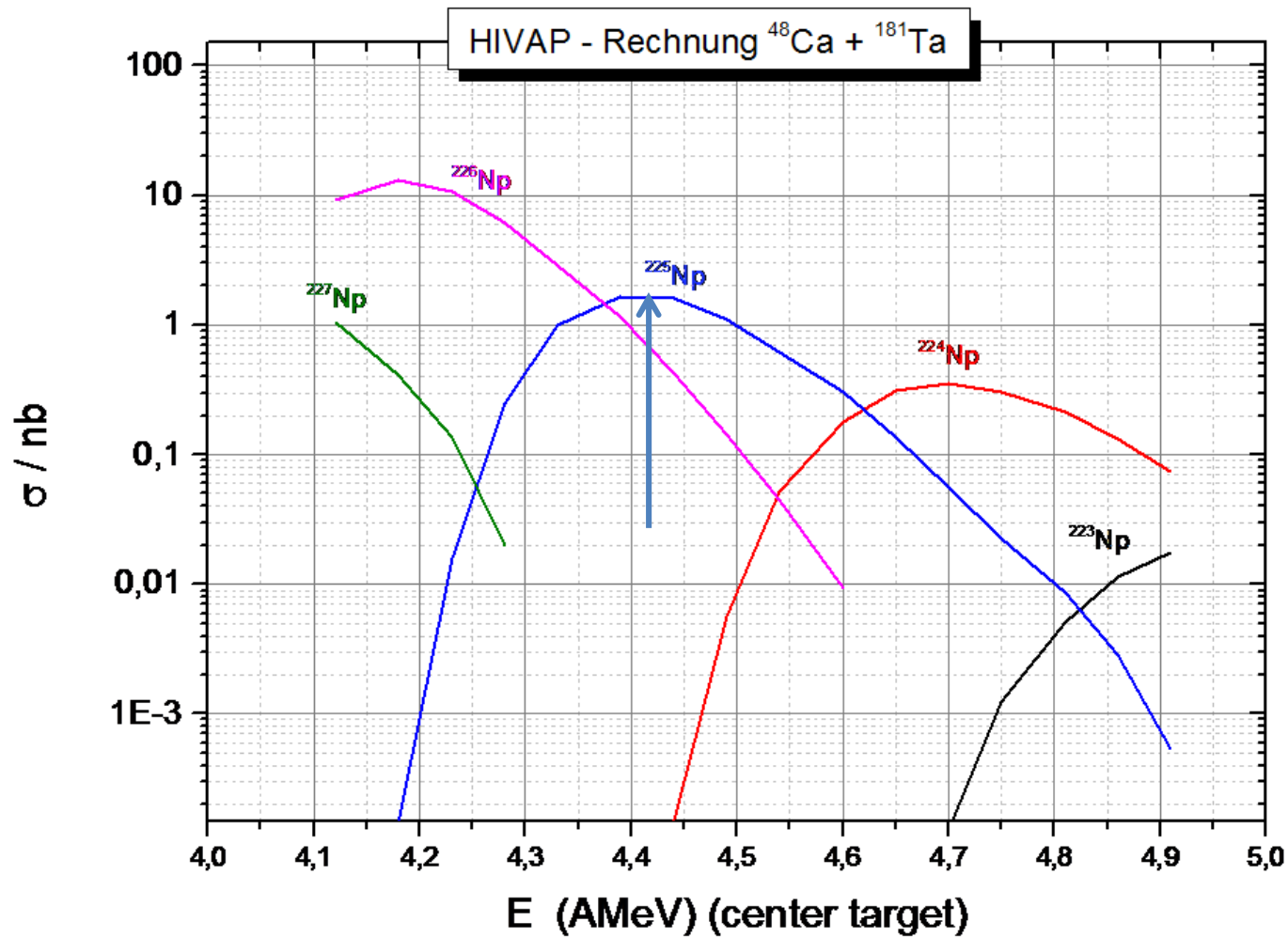
- Weakening of the N=126 neutron shell closure



*J. Khuyagbaatar PRL 115, 242505, 2015*

# $^{225}\text{Np}$ experimental conditions

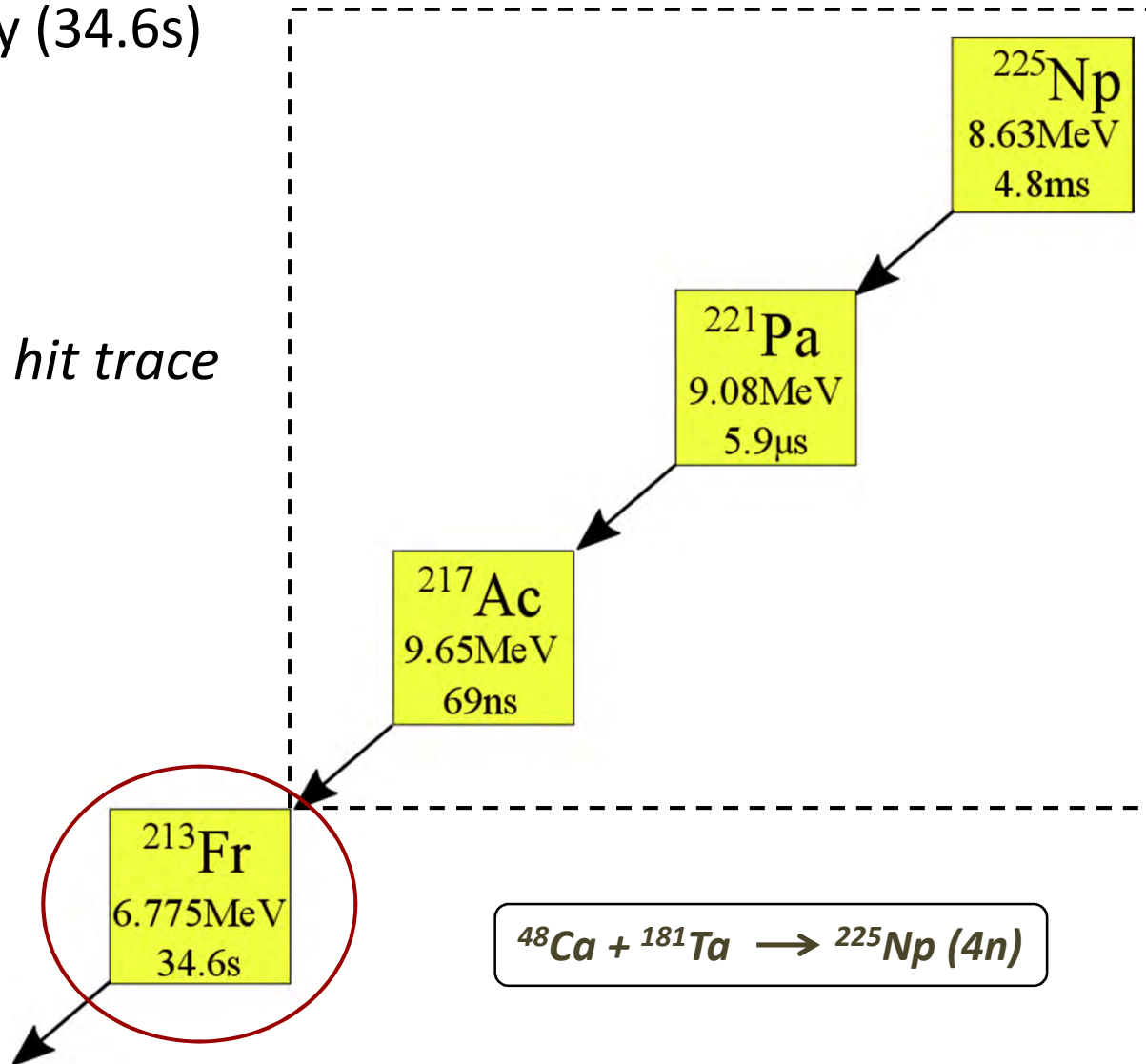
- New target, different energy



# Signatures for decay chains

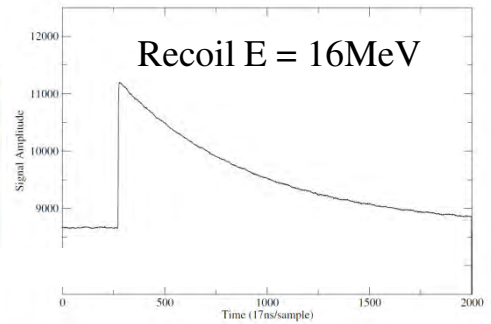
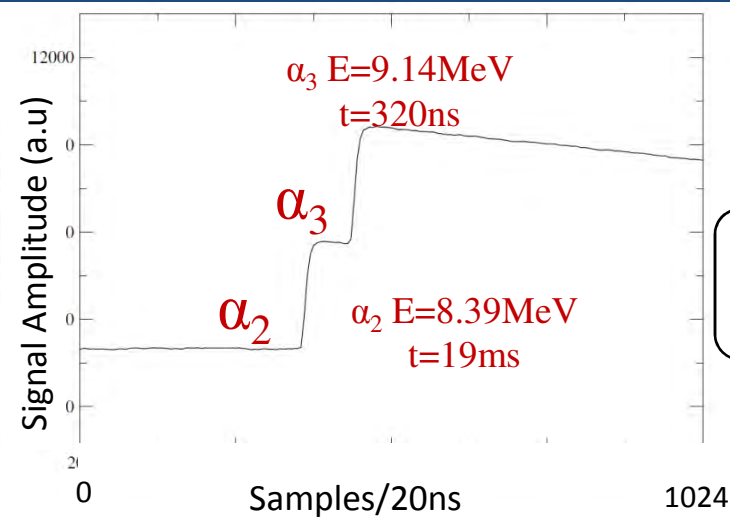
- $^{225}\text{Np}$  Recoil implantation  $\rightarrow$  3 triple hit trace  $\rightarrow$   $^{213}\text{Fr}$  alpha decay (34.6s)

Triple hit trace



# $^{226}\text{Np}$ fast-decay chain (2015)

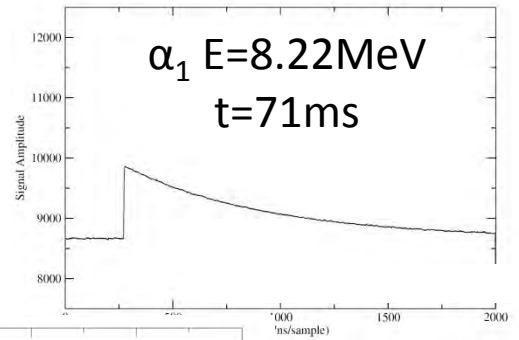
$^{48}\text{Ca} + ^{181}\text{Ta} \rightarrow ^{226}\text{Np} (2n)$   
 ~86 hours parasitic beam



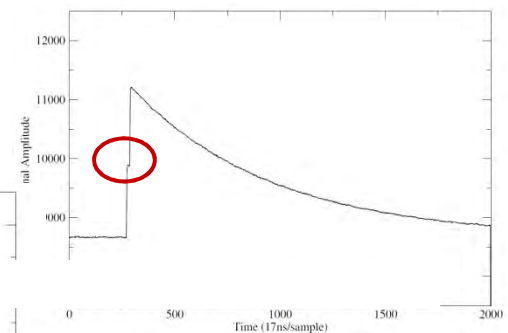
$^{226}\text{Np}$   
 8.0 MeV  
 31ms

Double hit trace

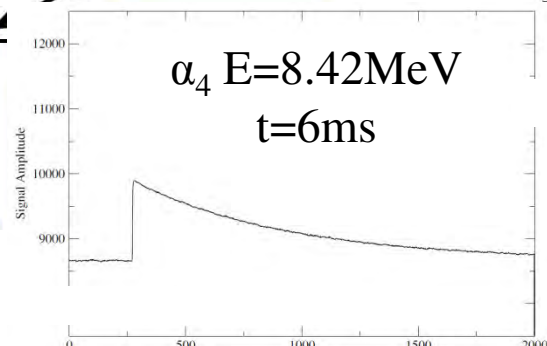
$^{222}\text{Pa}$   
 8.21 MeV  
 4.3ms



$^{218}\text{At}$   
 9.205 MeV  
 1.1 $\mu\text{s}$



$^{214}\text{Fr}$   
 8.4/8.5 MeV  
 3.35/5ms



$^{226}\text{Np}$  Recoil implantation  $\rightarrow$  alpha decay (31ms)  $\rightarrow$  double trace hit (4.3ms)  $\rightarrow$   $^{214}\text{Fr}$  alpha decay (3.5ms)

# Signatures for decay chains

**$^{226}\text{U}$** : Recoil implantation  
→  $^{226}\text{U}$  alpha decay → 3 hit trace

**$^{225}\text{Np}$**  Recoil implantation → 3 triple hit trace →  $^{213}\text{Fr}$  alpha decay (34.6s)



$^{226}\text{U}$   
7.55MeV  
0.28s

$^{225}\text{Np}$   
8.63MeV  
4.8ms

$^{222}\text{Th}$   
7.98MeV  
2.24ms

$^{221}\text{Pa}$   
9.08MeV  
5.9μs

$^{218}\text{Ra}$   
8.39MeV  
25.6μs

$^{217}\text{Ac}$   
9.65MeV  
69ns

$^{215}\text{Fr}$   
9.36MeV  
90ns

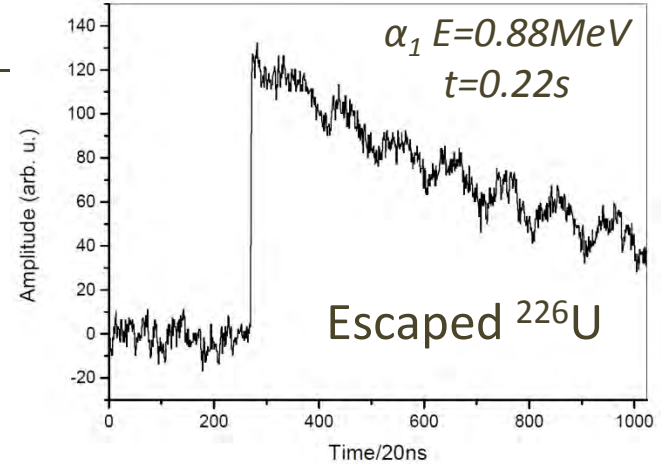
$^{213}\text{Fr}$   
6.775MeV  
34.6s



# $^{226}\text{U}$ Chain (2016)

$^{226}\text{U}$ : Recoil implantation

→  $^{226}\text{U}$  alpha decay → 3 hit trace



Triple hit trace

$\alpha_1$

$^{226}\text{U}$   
7.55MeV  
0.28s

$^{222}\text{Th}$   
7.98MeV  
2.24ms

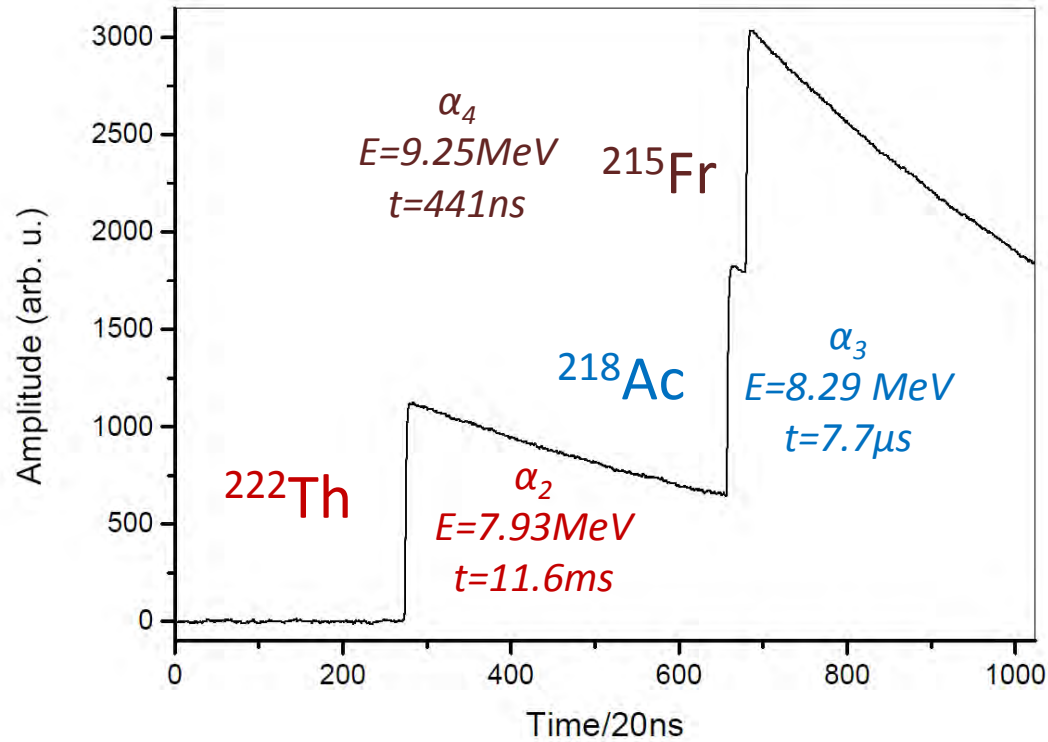
$\alpha_2$

$^{218}\text{Ra}$   
8.39MeV  
25.6 $\mu\text{s}$

$\alpha_3$

$^{215}\text{Fr}$   
9.36MeV  
90ns

$\alpha_4$





## *Continuation of detector development*

- *Development work on the box detectors*
- *Currently read out 32 strips combined into 8 readouts – ideally read out all channels*
- *Future groundwork to producing a GEANT4 simulation*
- *FEBEX 4/5*

# Conclusion

- *SHIP focal plane detector system employed – Advanced commissioning completed*
- *Nuclear near dripline studied – N=126 shell closure evolution*
- *Observation of multi pile-up events ( $^{226}\text{U}$ ), search for  $^{225}\text{Np}$  in a similar fashion*

# Collaborators

## GSI, Darmstadt:

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UNIVERSITÄT MAINZ

