

# A Cryogenic Stopping Cell used as an Ion Trap: Measuring Half-Lives and Decay Branching Ratios of Exotic Nuclei with the FRS Ion Catcher

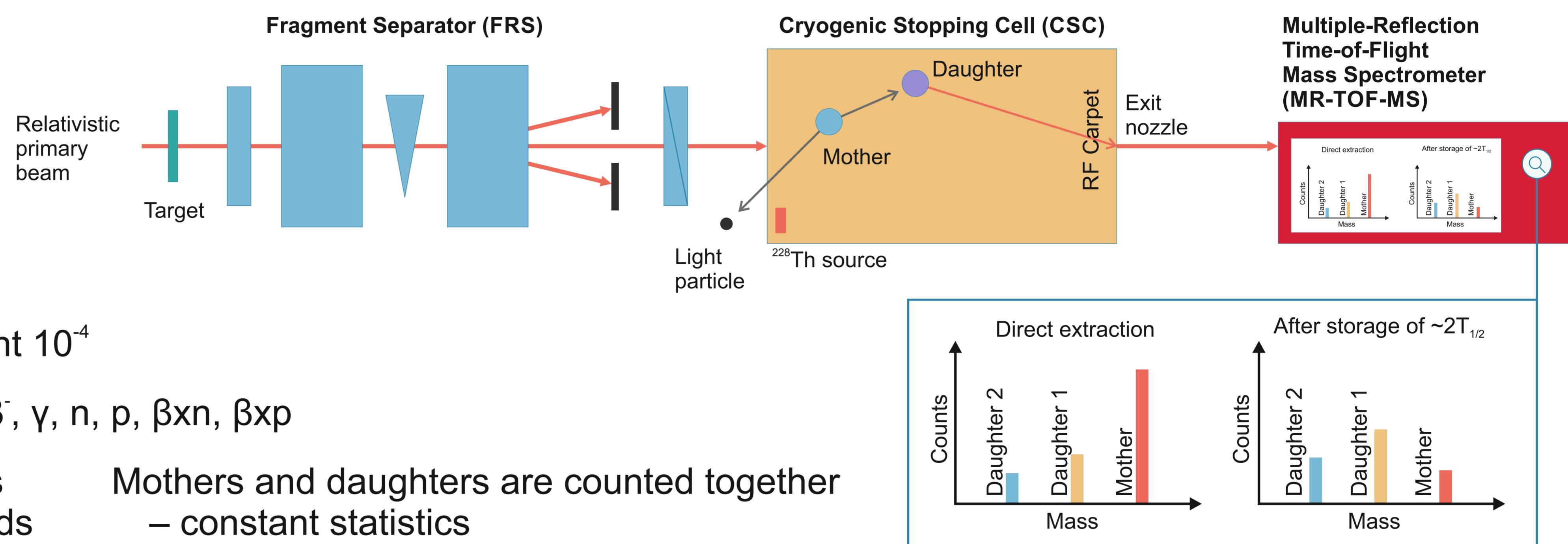


## Outline of the Method – the FRS Ion Catcher at GSI [1]

Exotic nuclides of interest (mothers) are produced and separated in-flight at the Fragment separator FRS [2] at GSI. They are stopped and stored for a controllable duration decaying in a gas-filled Cryogenic Stopping Cell (CSC) [3-5]. Due to the high CSC density, the daughter nuclides are stopped as well [6]. The decay branching-ratios are determined from the ratios between the number of daughter nuclides that are identified and counted by a Multiple-Reflection Time-of-Flight Mass Spectrometer (MR-TOF-MS) [7,8].

Simultaneous and direct measurements:

- Branching Ratios
- Masses
- Half-lives
- Q-values
- Excitation Energies



Containment time — up to 10 seconds

Lower limit for branching ratio measurement  $10^{-4}$

Suitable for various decay modes –  $\alpha$ ,  $\beta^+$ ,  $\beta^-$ ,  $\gamma$ ,  $n$ ,  $p$ ,  $\beta\text{xn}$ ,  $\beta\text{xp}$

No need to detect light particles or photons  
– complementary to conventional methods

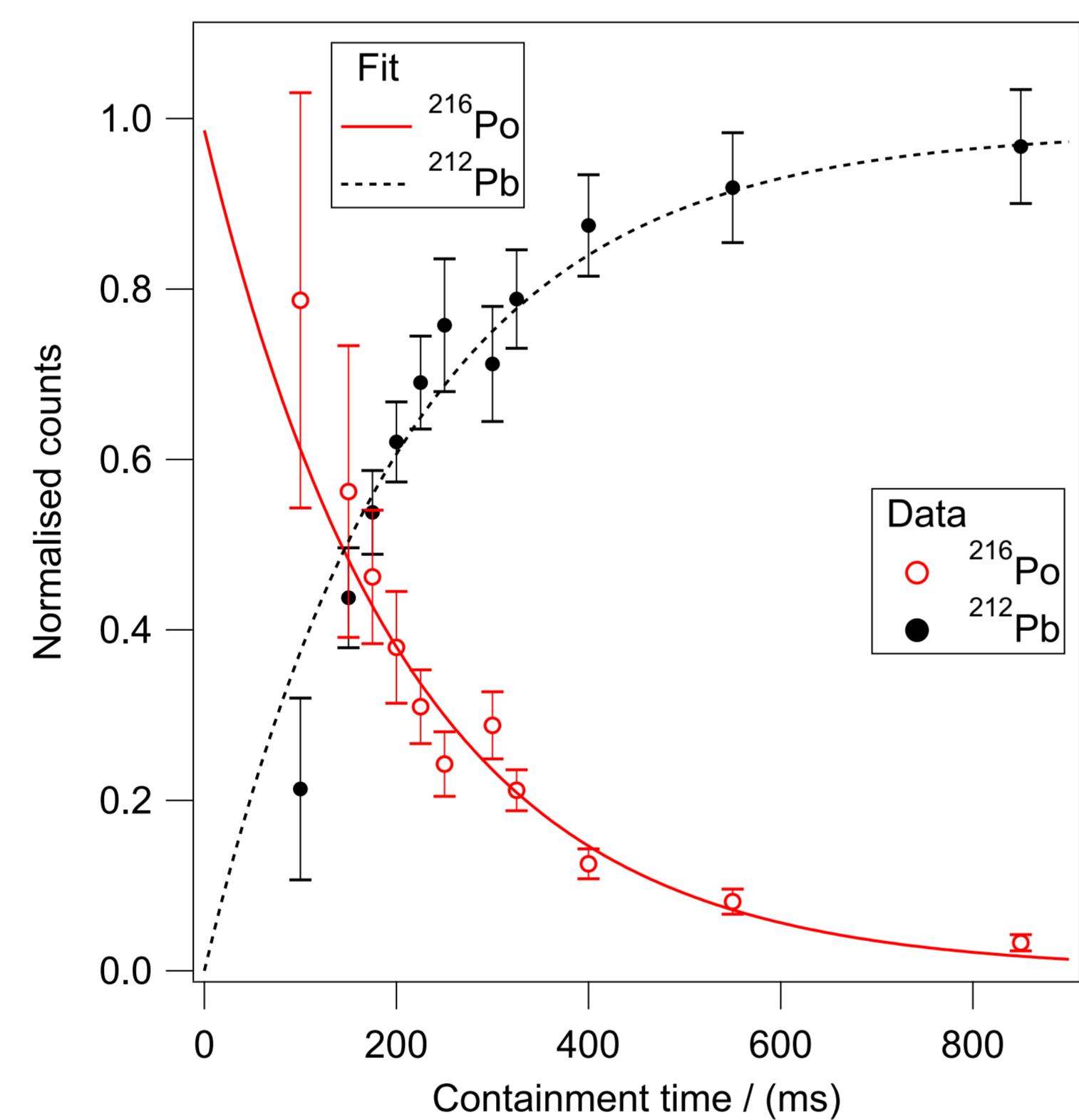
Mothers and daughters are counted together  
– constant statistics

## Results

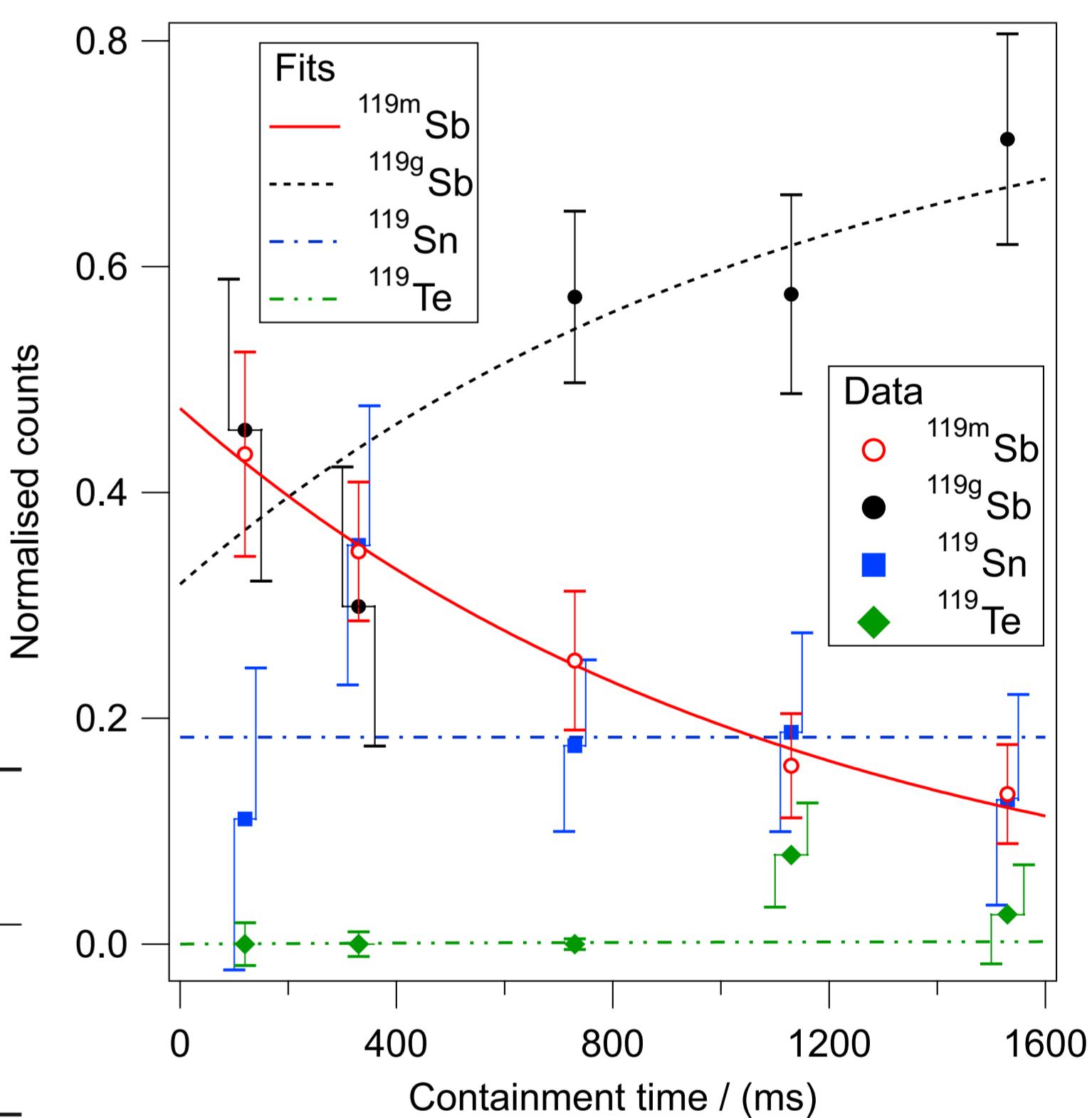
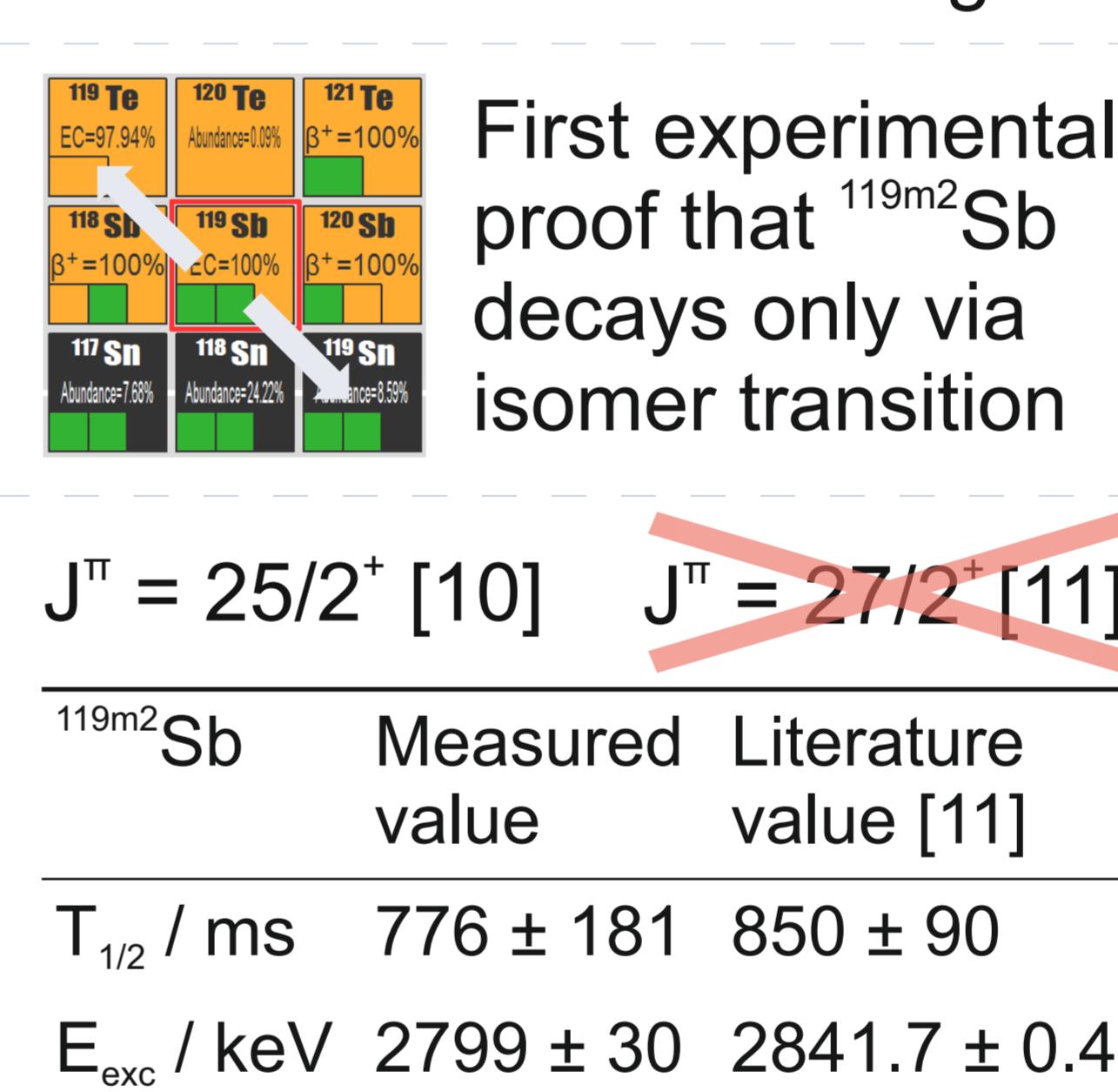
Offline-test:  
Alpha decay of  $^{216}\text{Po}$  to  $^{212}\text{Pb}$ .  
 $^{228}\text{Th}$  source in CSC

Decay of  $^{216}\text{Po}$  is consistent  
with the increase of  $^{212}\text{Pb}$

$^{216}\text{Po}$	Measured value	Literature value
$T_{1/2} / \text{ms}$	$145 \pm 11$	$145 \pm 2 [9]$



Proof of Principle:  
Projectile fragmentation of  $^{238}\text{U}$  at 300 MeV/u on a Be target.



## Outlook – short-term

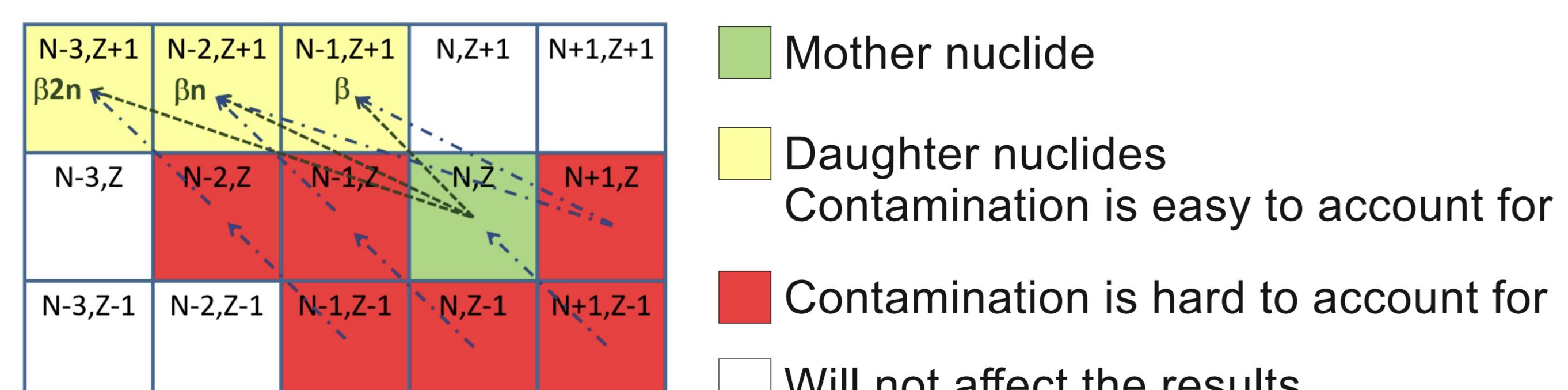
Pxn:  $\beta$ -delayed Neutron Emission Probability [12]  
(approved proposal for FAIR Phase-0 Experiment)

P<sub>xn</sub> provide valuable information to:

- Nuclear astrophysics models of the r-process
- Nuclear models of neutron-rich nuclides
- Nuclear reactor control operation

No need to detect neutrons!

Sources of contamination for the branching ratio measurement:

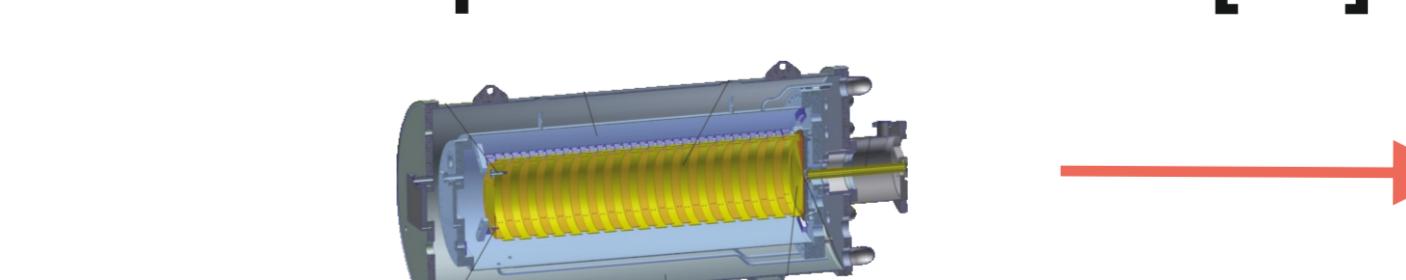


## Outlook – long-term

$^{94\text{m}2}\text{Ag}$  (N=Z) [13] decays by:

- p, 2p,  $\beta$ p,  $\beta$ 2p,  $\beta$ <sup>+</sup>
- direct two-proton emission is still under investigation

Next-generation Cryogenic Stopping Cell for the Low-Energy Branch of the Super-FRS at FAIR [14]



- Access to more short-lived exotic nuclei
- x5 faster extraction
- x2-4 higher stopping efficiency
- x10<sup>3</sup> rate capability

