r-Process Nuclear Physics Experiments: Plans at the FRS@GSI and recent results from TITAN@TRIUMF

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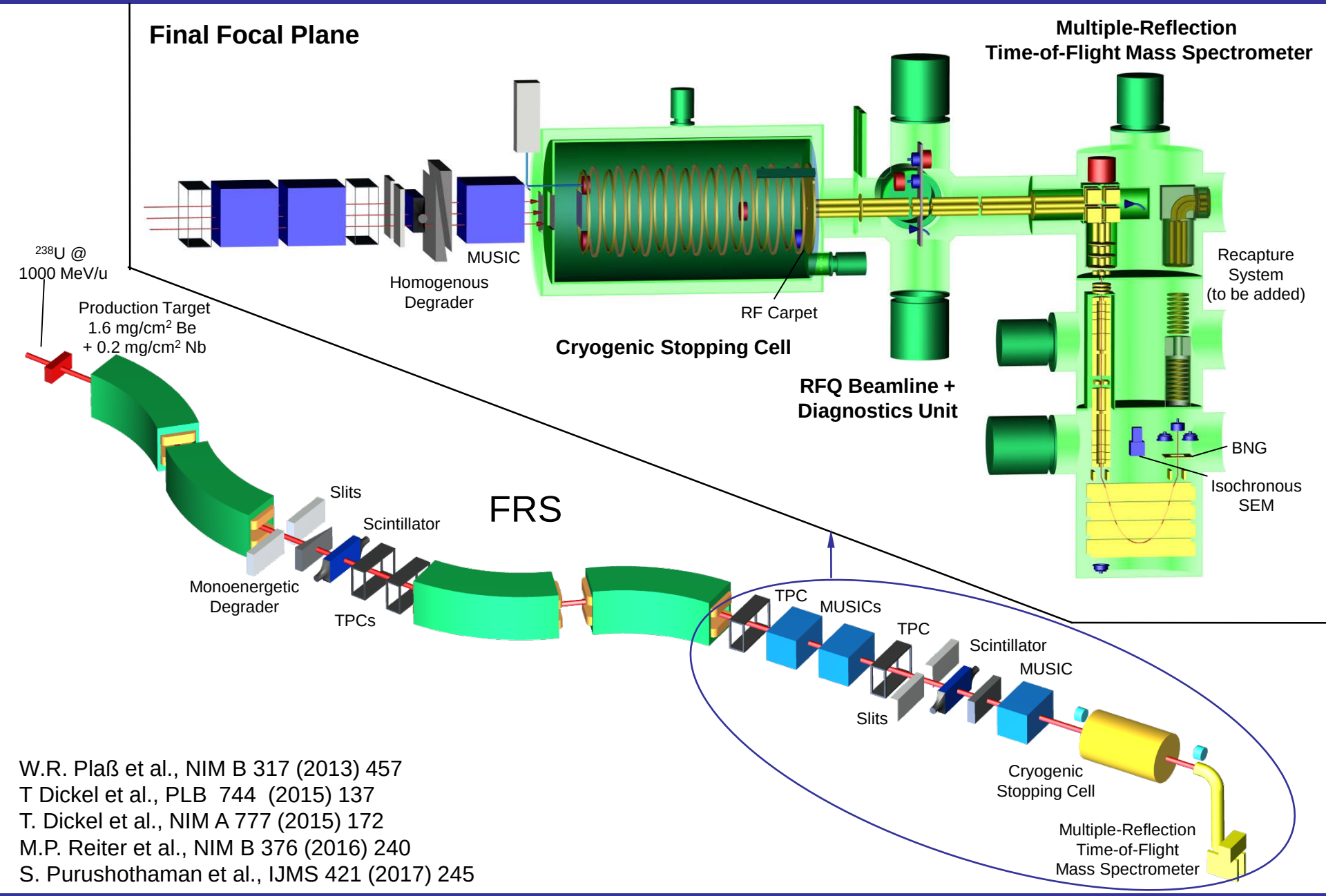
Overview

- The FRS Ion Catcher
  - Approved Proposals to measure: masses, half-lives and PXN
- The MR-TOF-MS at TITAN

FRS Ion Catcher a Test Facility for the LEB



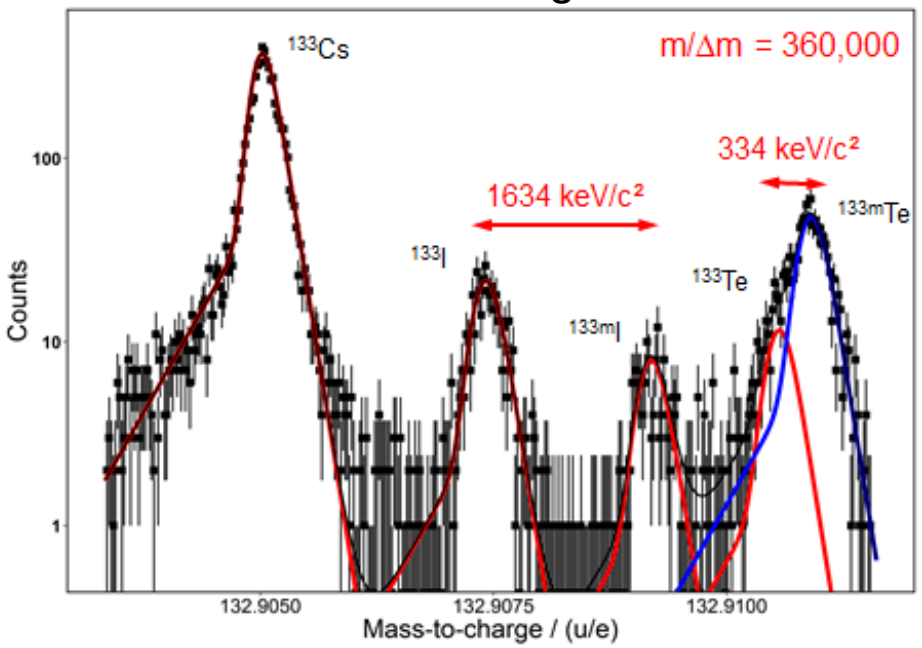
W.R. Plaß et al., NIM B 317 (2013) 457
T Dickel et al., PLB 744 (2015) 137
T. Dickel et al., NIM A 777 (2015) 172
M.P. Reiter et al., NIM B 376 (2016) 240
S. Purushothaman et al., IJMS 421 (2017) 245

Mass Measurements with the FRS Ion Catcher

Mass measurements with an accuracy >= $6 \cdot 10^{-8}$ (→ 6keV/c² @ 100u)

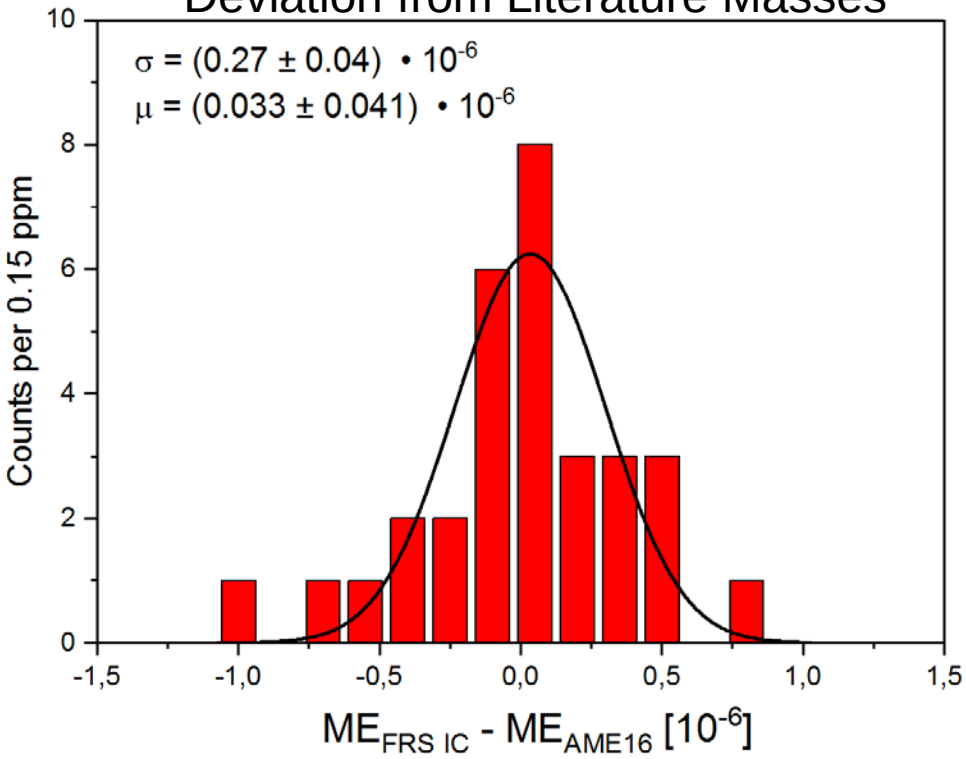
- > 40 short-lived ground states (as short lived as 18 ms)
- 15 isomers
- down to 10 events only

^{238}U fission fragments



Low-lying isomers resolved
mass accuracy = $1 \cdot 10^{-7}$

Deviation from Literature Masses

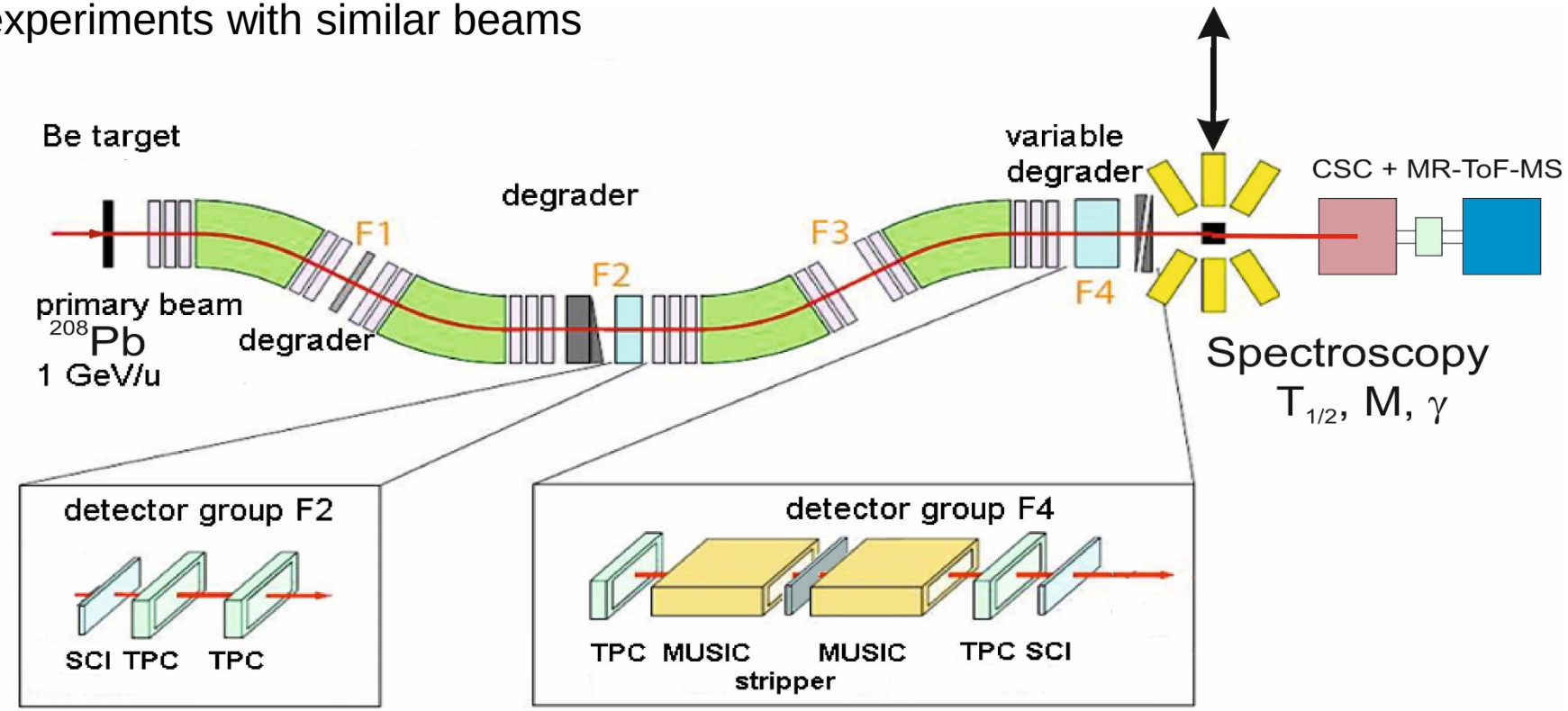


S. Ayet, PhD thesis, JLU Giessen 2018
C. Hornung, PhD thesis, JLU Giessen 2018

Proposal: New Isotope Search (S468) - Method

^{208}Pb+^{9}Be@ 1 A.GeV at the entrance of the FRS (2.5 g/cm^2 target with Nb backing)

^{208}Pb intensity up to 10^9 per spill (2 second ramping, 0.5 extraction)
➔ assures a duty cycle of 10 to 50 times higher than previous isotope search experiments with similar beams



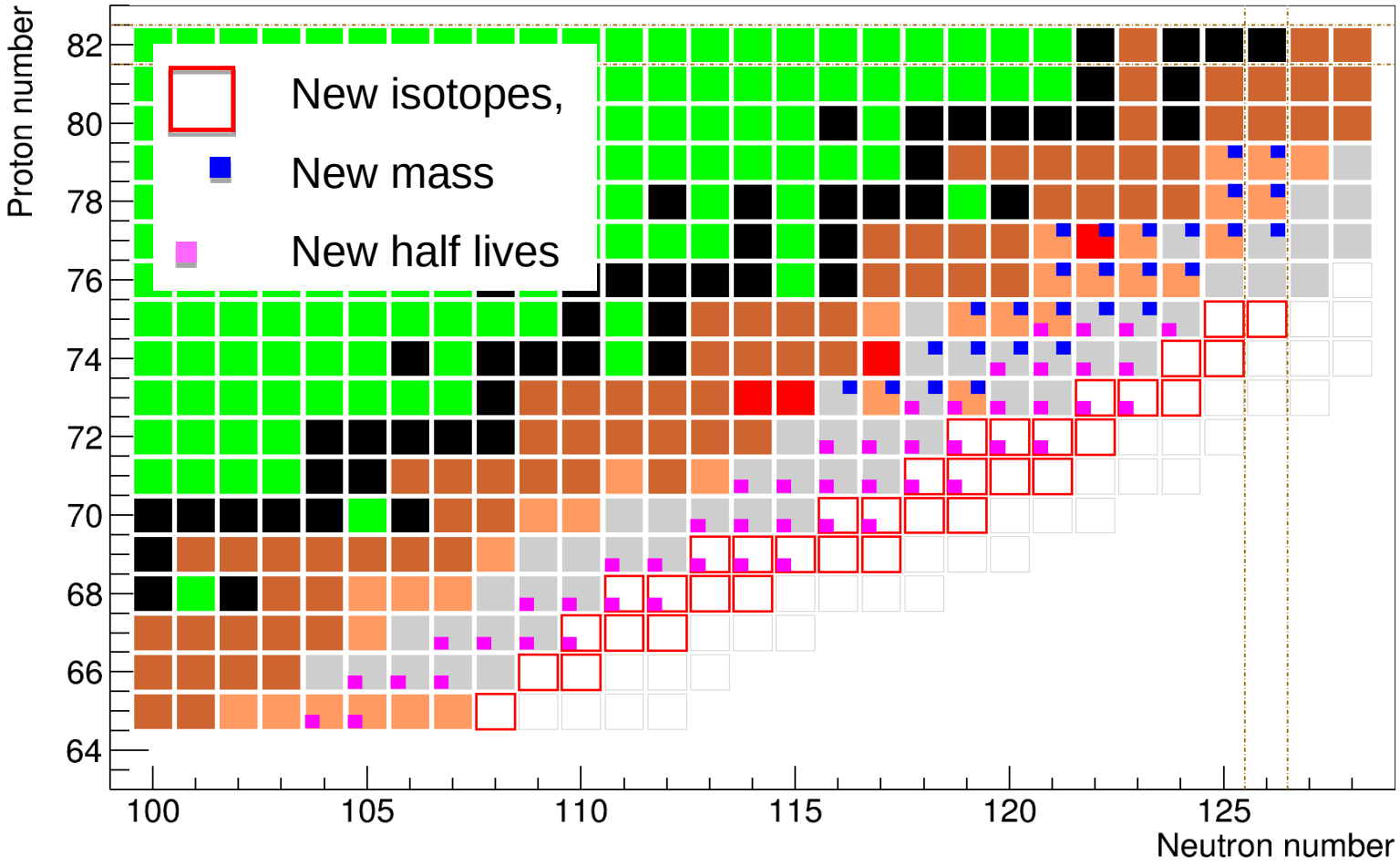
At final focal plane:

- FRS Ion Catcher for mass measurements
- Active Stopper for life time measurements

S. Pietri et al.

Proposal: New Isotope Search (S468)

- Identification of new neutrons rich isotopes
- Measurement of production cross sections and momentum distribution
- Mass, half-life and decay spectroscopy measurement after implantation

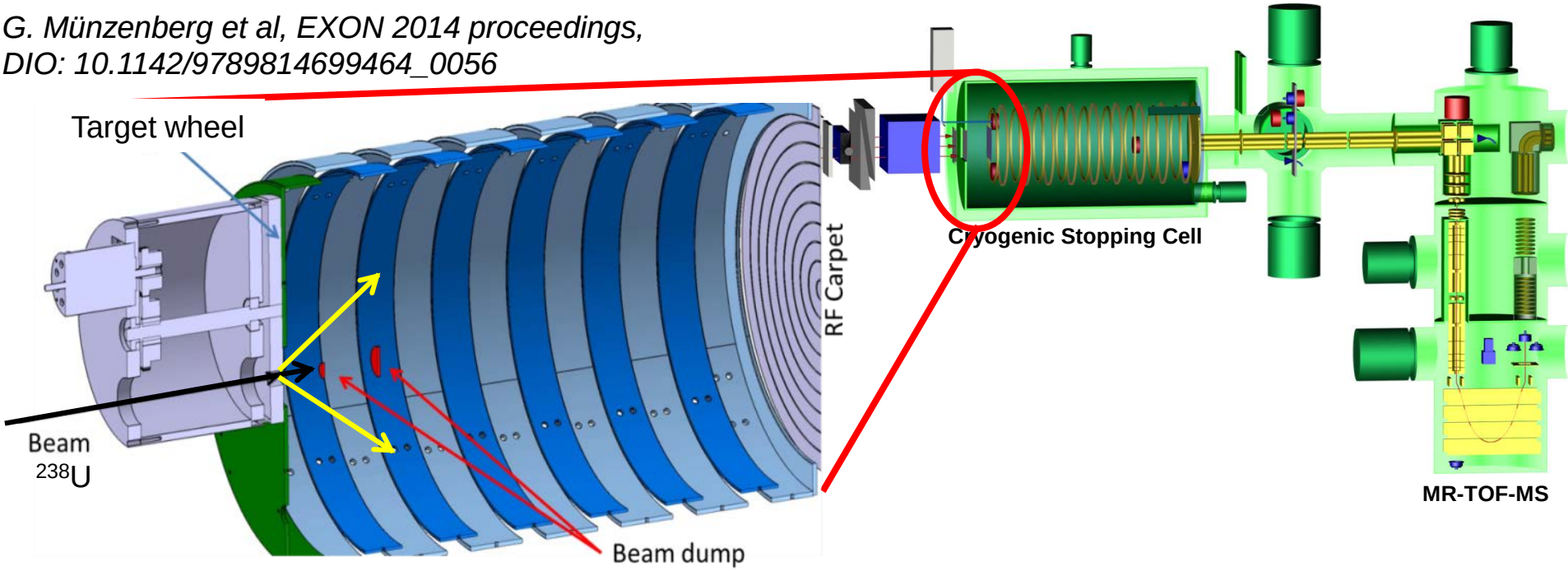


➔ **47 new half lives, 26 new masses and 27 new isotopes**

S. Pietri et al.

Proposal: Reaction studies / MNT (S475) - Method

G. Münzenberg et al, EXON 2014 proceedings,
DIO: 10.1142/9789814699464_0056



Universal, efficient, sensitive and broadband method:

- Different beams (primary and secondary) from the (Super-)FRS
- CSC: universal, fast, efficient, clean extraction of all reaction products
    - Target (TLF) and projectile-like fragments (PLF) in one experiment
- MR-TOF-MS: Tens of different products measured simultaneously

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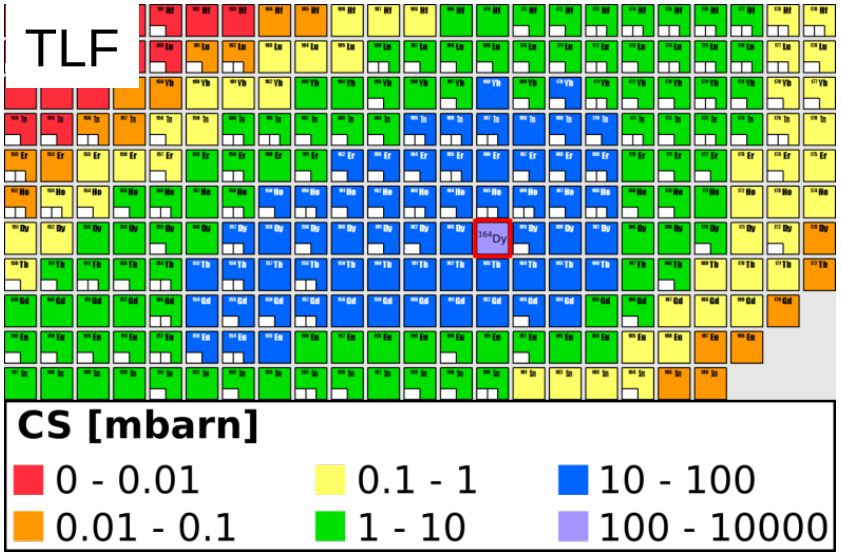
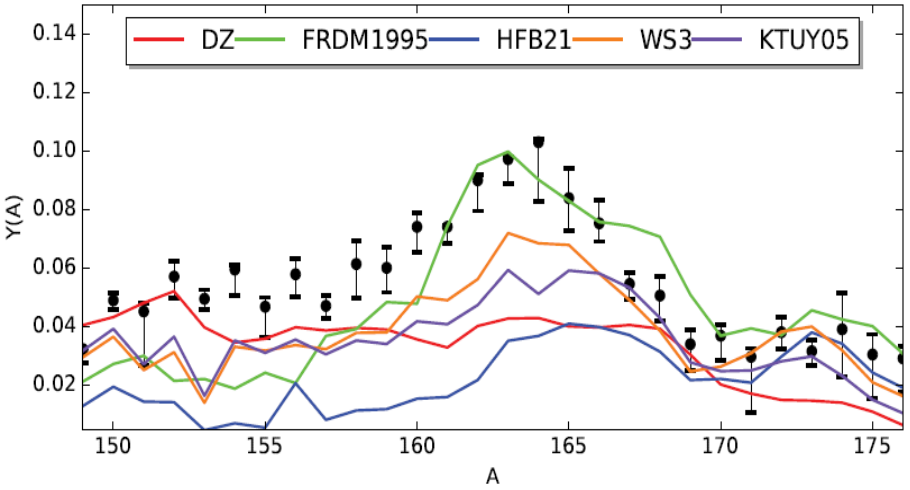
Proposal: Reaction studies / MNT (S475)

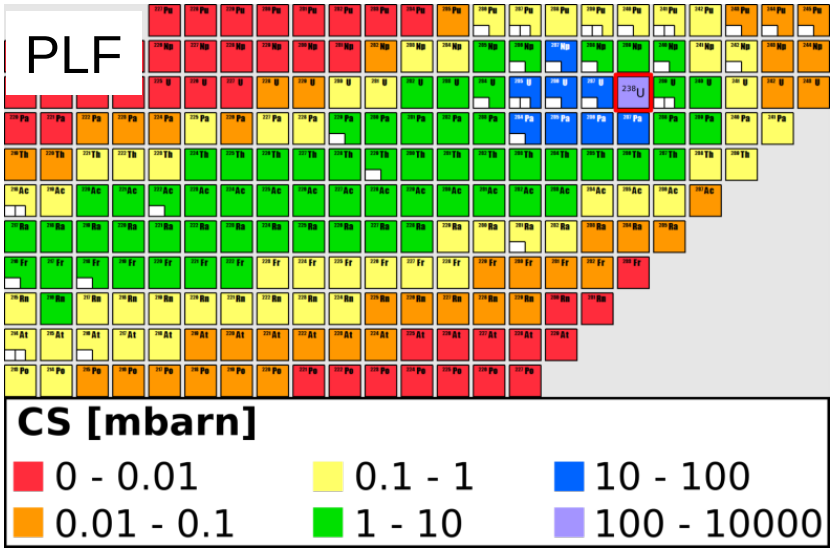
Rare-earth peak (r-process)





M. Mumpower et al., J. Phys. G, 44 (2017) 3
SA Guiliani et al., https://arxiv.org/abs/1704.00554
M. Eichler at al., Astrophys. J 808 (2015) 30

„East“ of ^{238}U



A.V. Karpov, et al PRC 96 (2017) 024618

Results for ^{238}U on ^{164}Dy & ^{64}Ni:

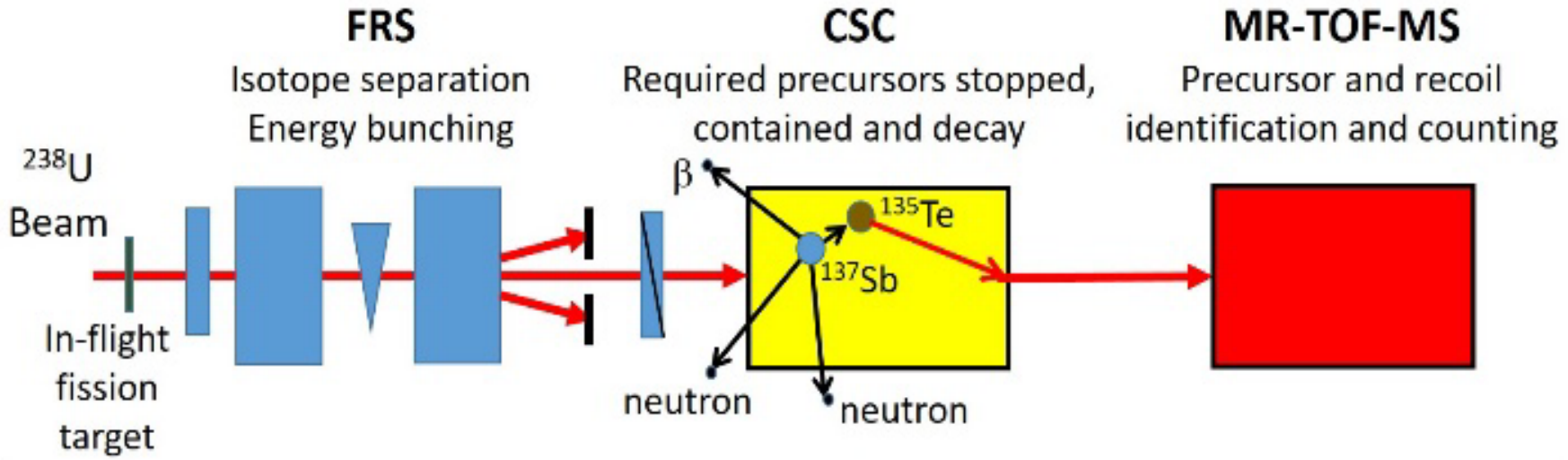
- **Cross Sections: >150**
- **New masses: ~20**
- **Discovery of long-lived isomers**

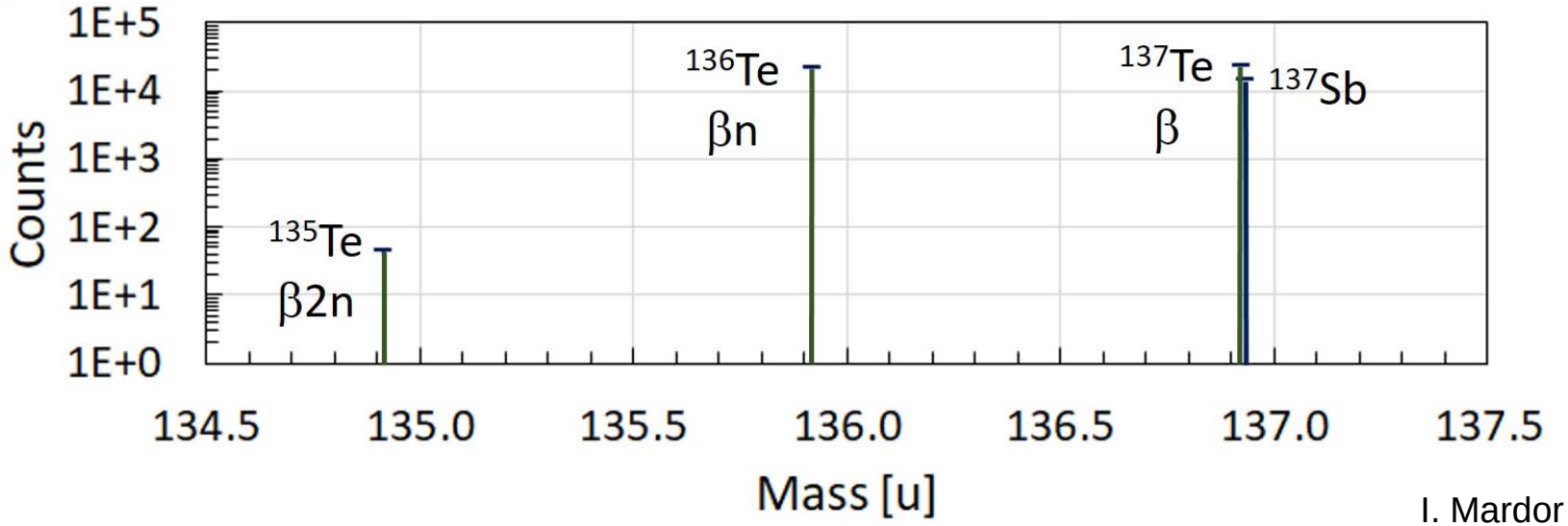
G.D. Dracoulis et al.,
Phys. Scr. T152 (2013) 014015

T. Dickel et al.

Proposal: beta-delayed neutrons (S472) – Method

- We propose to demonstrate and use a novel method for measuring β-delayed single- and multi-neutron emission probabilities (P_{xn}) (and also mass, Q-values and $T_{1/2}$), in the following way:





I. Mardor et al.

Proposal: beta-delayed neutrons - first experiments

- Method is direct, essentially background free, model independent and complementary to worldwide programs, which mostly use n, β, γ coincidence
- Especially suited for multi-neutron emission probabilities
- Quick and “easy” analysis (“ion counting”)

Objective
Implement and demonstrate a **novel** P_{xn} **measurement method**
3 improved accuracy $\mathbf{P_{1n}}$ for $^{135\text{-}137}$**Sb**
3 new $\mathbf{P_{2n}}$ for $^{136\text{-}137}$**Sb,** ^{142}**I** and **1 new** $\mathbf{P_{1n}}$ for ^{142}**I**
1 improved mass and $\mathbf{Q_{bxn}}$ values for ^{137}**Sb** **1 new mass** and $\mathbf{Q_{bxn}}$ values for ^{142}**I** **Simultaneous** with $\mathbf{P_{xn}}$ measurements

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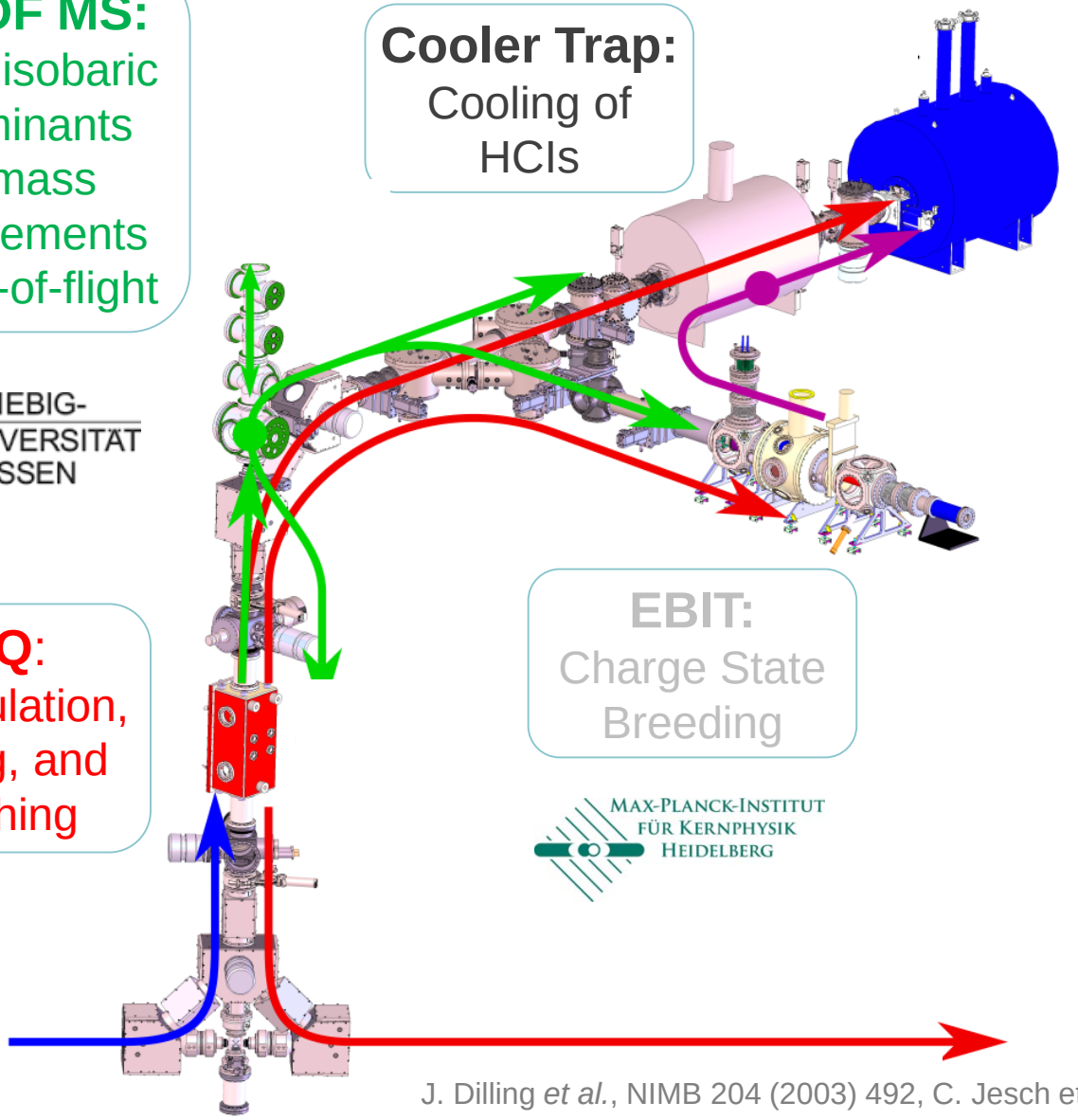
TITAN Experiment at TRIUMF

University of Manitoba

MR-TOF MS: remove isobaric contaminants and mass measurements via time-of-flight

Cooler Trap: Cooling of HCIs

MPET: mass measurement via determination of cyclotron frequency



Justus-Liebig-Universität Giessen

RFQ: Accumulation, cooling, and bunching

EBIT: Charge State Breeding

Max-Planck-Institut für Kernphysik Heidelberg

J. Dilling *et al.*, NIMB 204 (2003) 492, C. Jesch et al., Hyperfine Interact. 235 (2015) 97

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FRS Ion Catcher Collaboration

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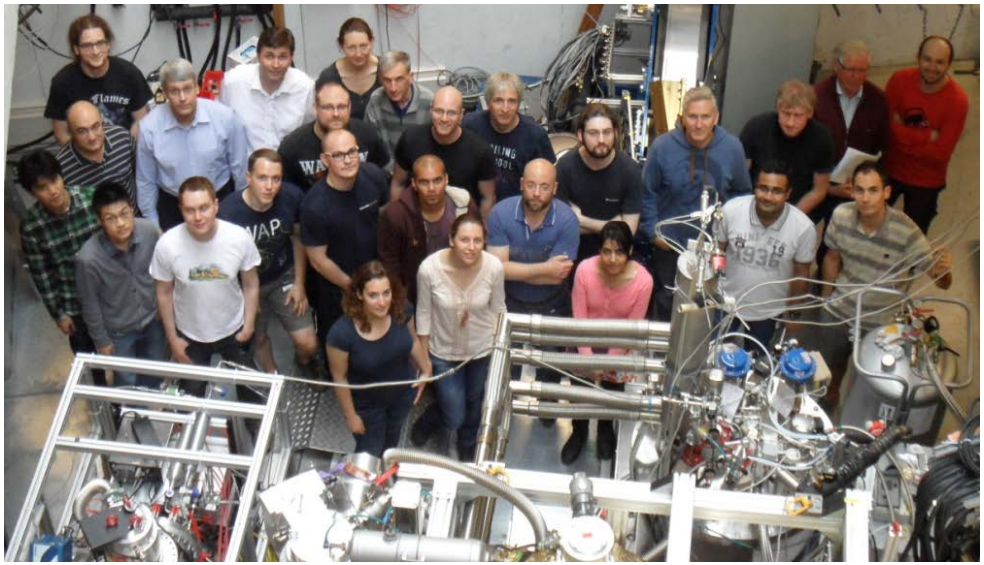

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