Slowing down exotic beams from the FRS: the FRS Ion Catcher experience

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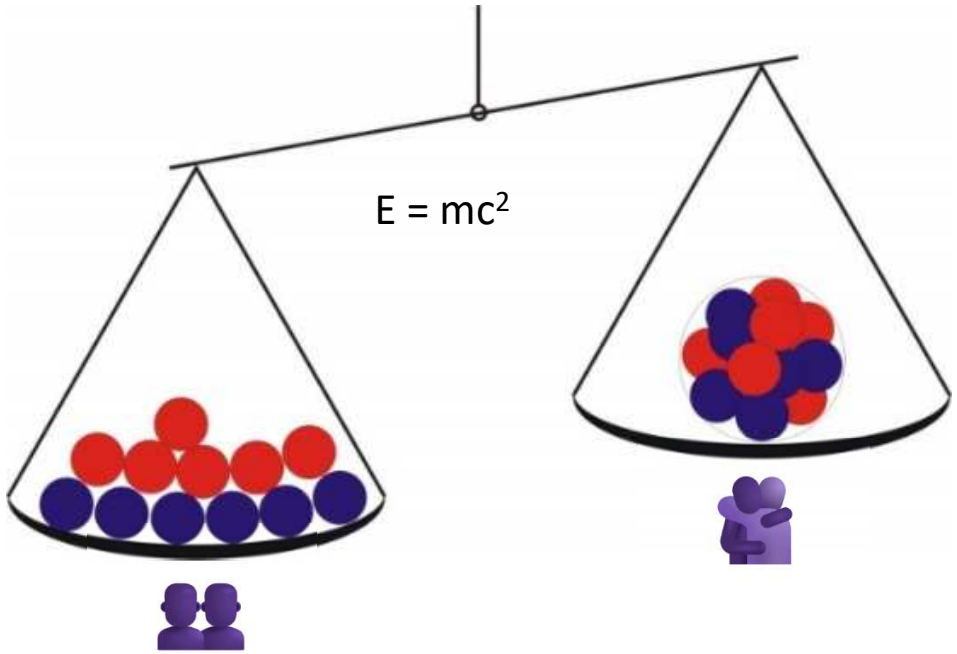
for the FRS Ion Catcher Collaboration

- Nuclear Masses
- Fragment Separator (FRS) and FRS Ion Catcher
- Tagging with the FRS Ion Catcher: Mass Tagging
- Experiences

Information Behind Mass Measurement



Z Protons (Proton number)

N Neutrons (Neutron number)

A = N + Z (Mass number)

B = Binding energy

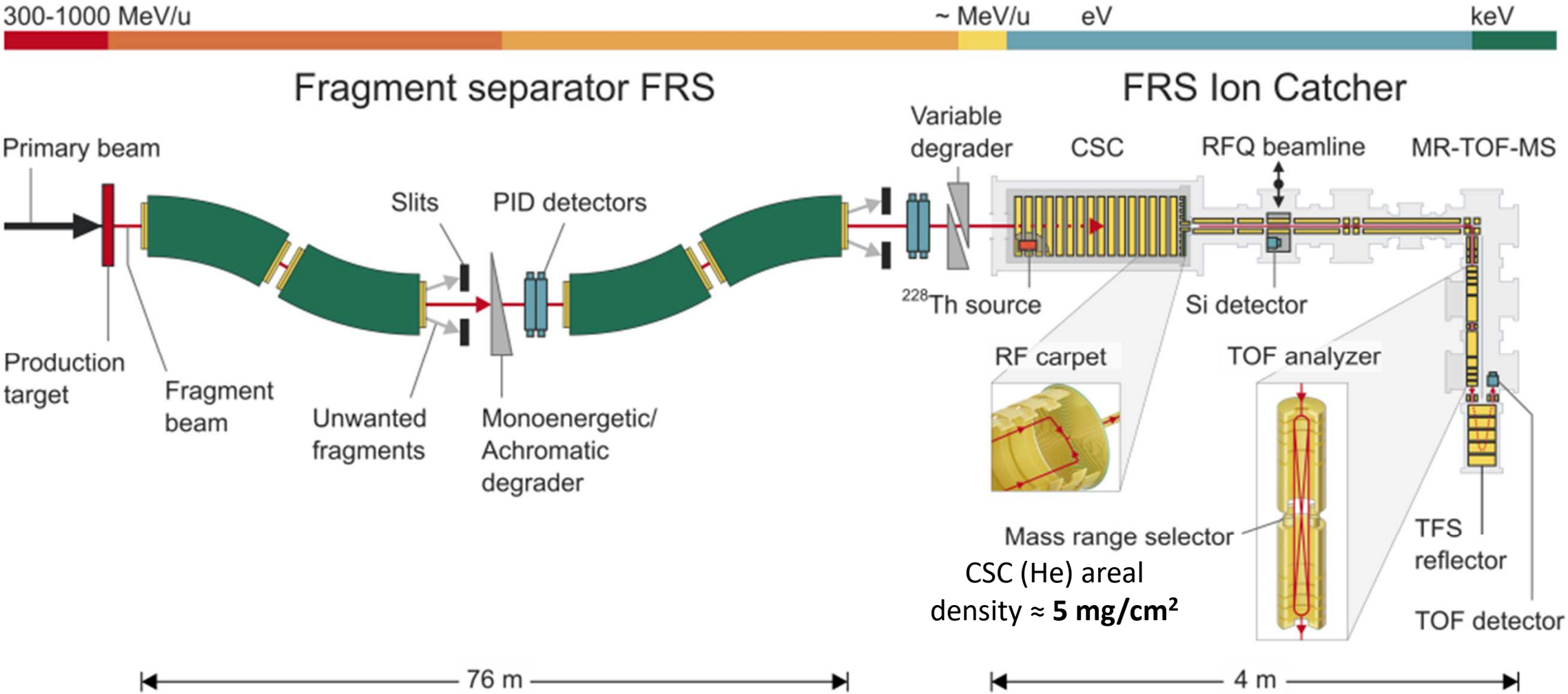
Nuclear mass ↔ nuclear binding energy:

$$M(N,Z) = Z \cdot m_p + N \cdot m_n - B(N,Z)/c^2$$

Several masses ↔ Binding energy derivatives, such as $S_n \mid \delta V_{pn} \mid \delta_{np}$ ….

Also serves as identification for known masses!

The FRS and the FRS Ion Catcher at GSI



W.R. Plaß *et al.*, *Nucl. Intr. Meth.* B **317** (2013) 457
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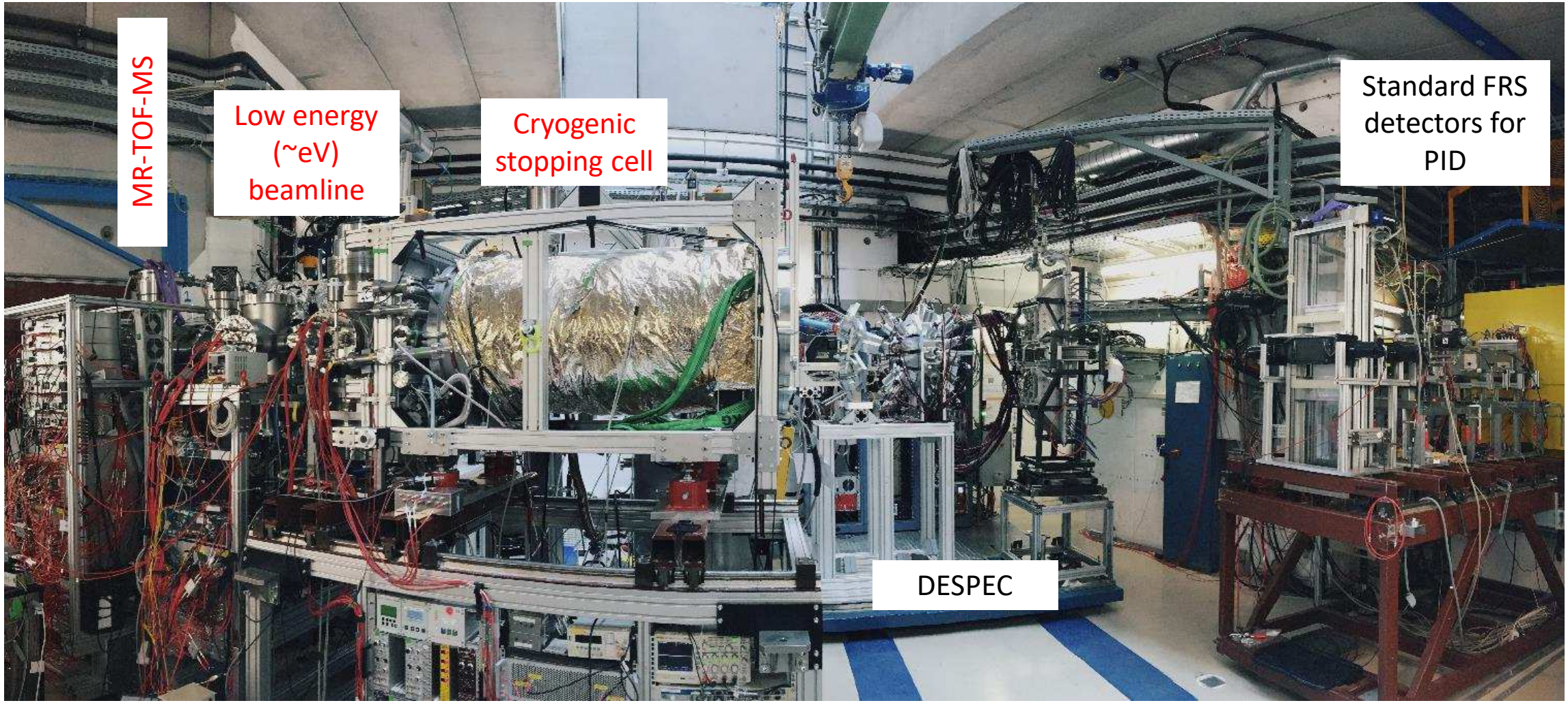
The FRS Ion Catcher at GSI – Setup at S4



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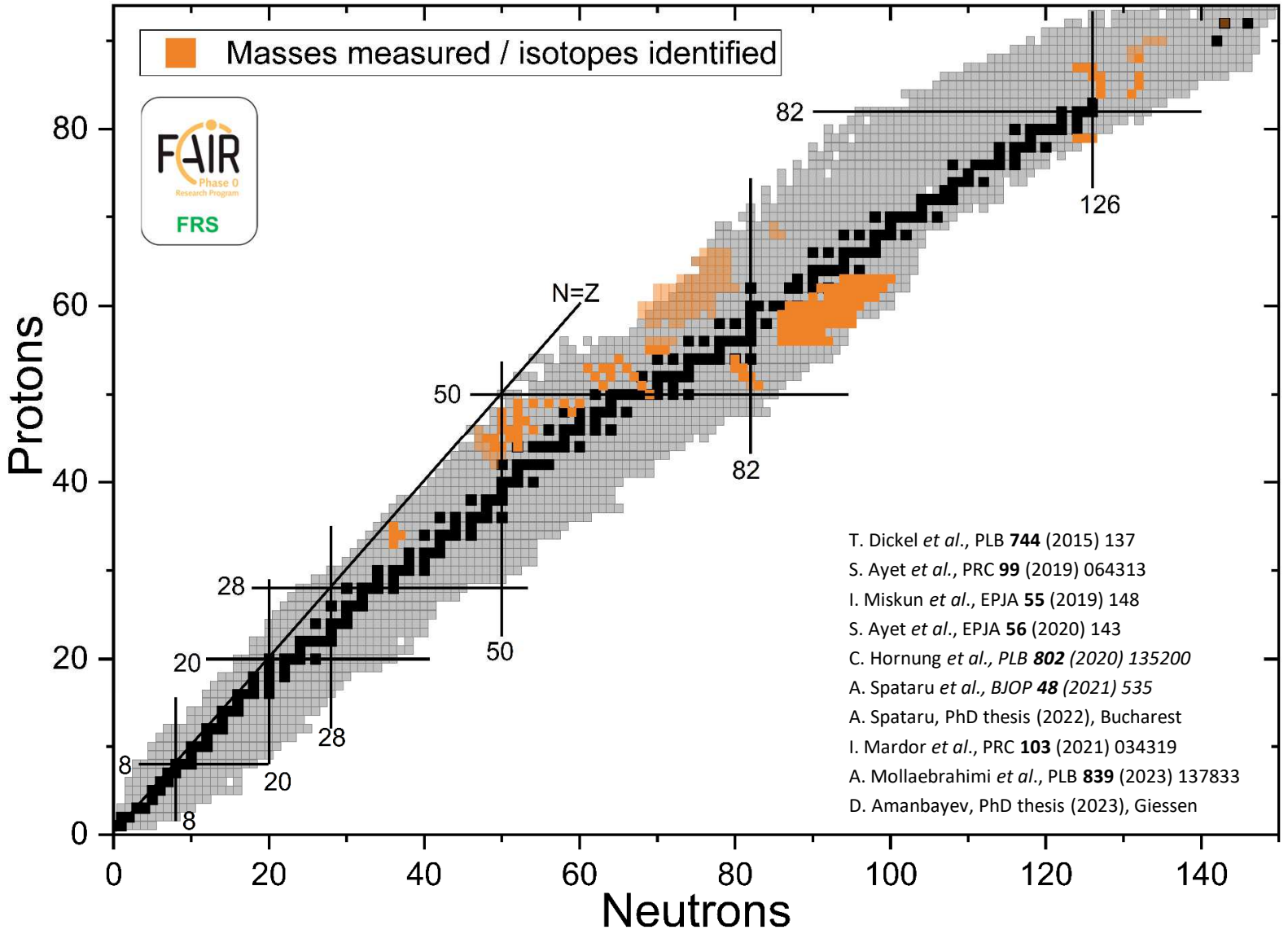
Measurements with the FRS Ion Catcher



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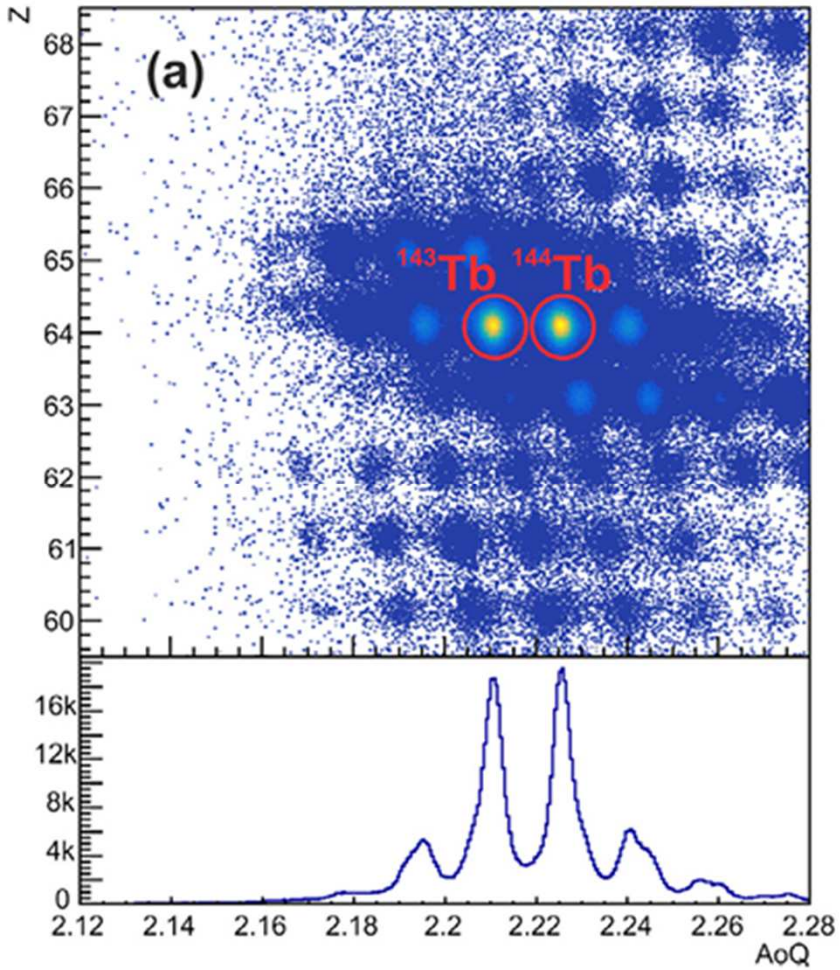
S. Ayet *et al.*, EPJA **56** (2020) 143
C. Hornung *et al., PLB **802** (2020) 135200*
A. Spataru *et al., BJOP **48** (2021) 535*
A. Spataru, PhD thesis (2022), Bucharest
I. Mardor *et al.*, PRC **103** (2021) 034319
A. Mollaebrahimi *et al.*, PLB **839** (2023) 137833
D. Amanbayev, PhD thesis (2023), Giessen

G. Kripko-Koncz

FRS Particle Identification (PID) Tagging?



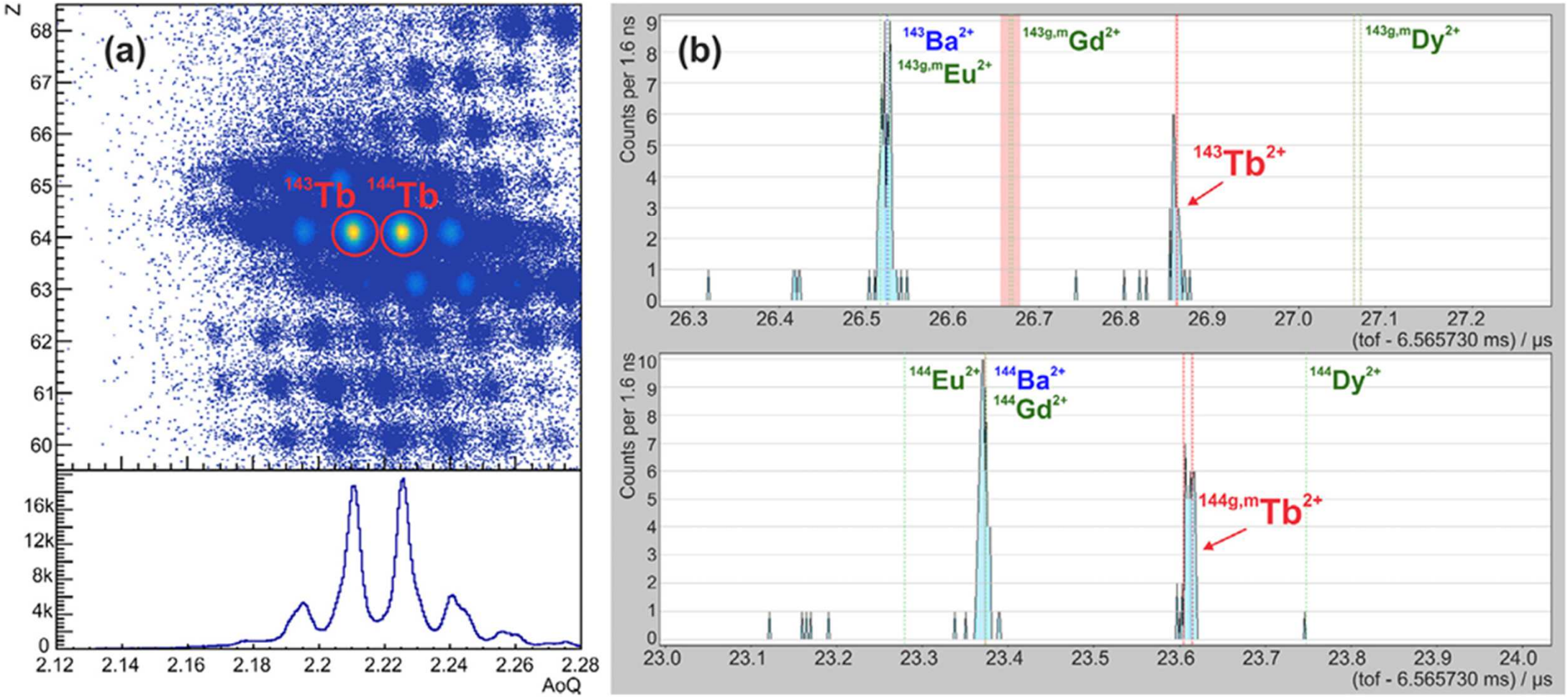
- **Counting**: one step at a time from primary beam.
- **Beta**: tagging by beta decay lifetime or endpoint energy.
- **Alpha**: tagging by alpha decay lifetime and energy.
- **Mass**: tagging by mass.
- **Isomer**: tagging by gamma rays.

Mass Tagging – FRS + FRS Ion Catcher

- Mass Tagging: mass measurement of stopped fragments as PID calibration.

FRS PID

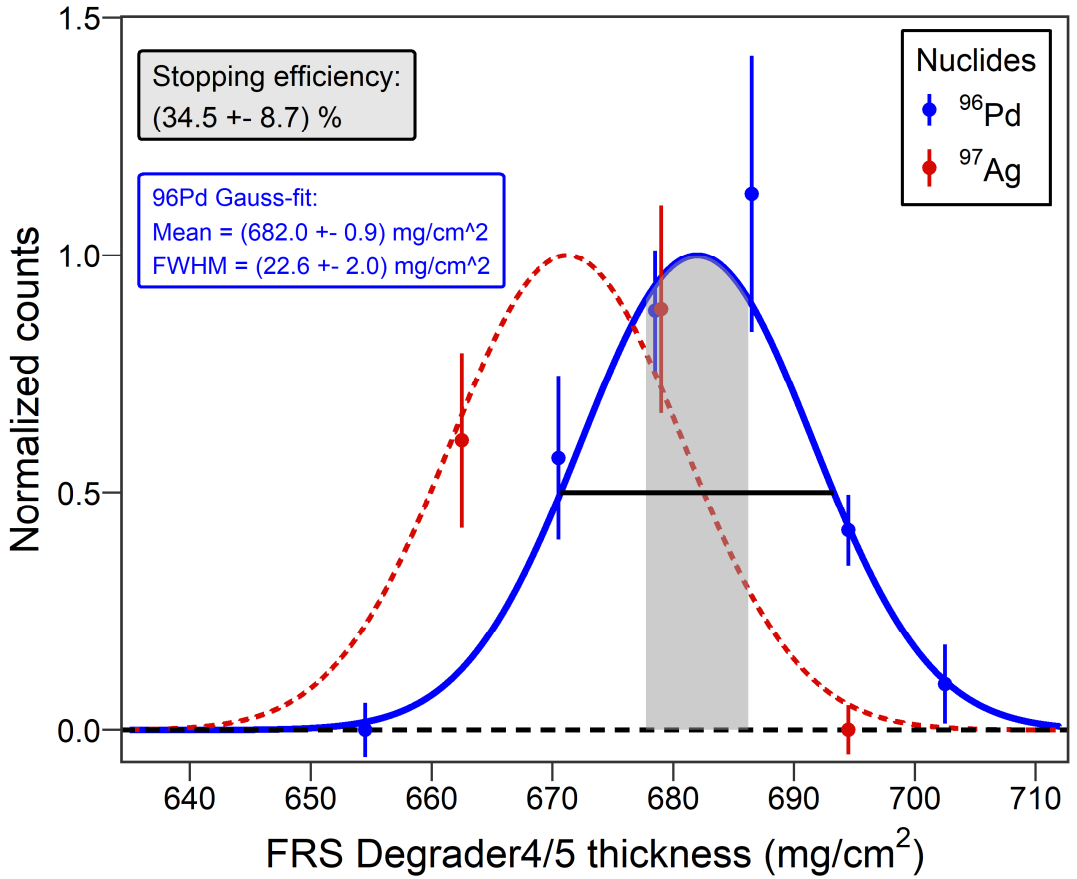
MR-TOF-MS Mass Tagging for FRS PID Calibration



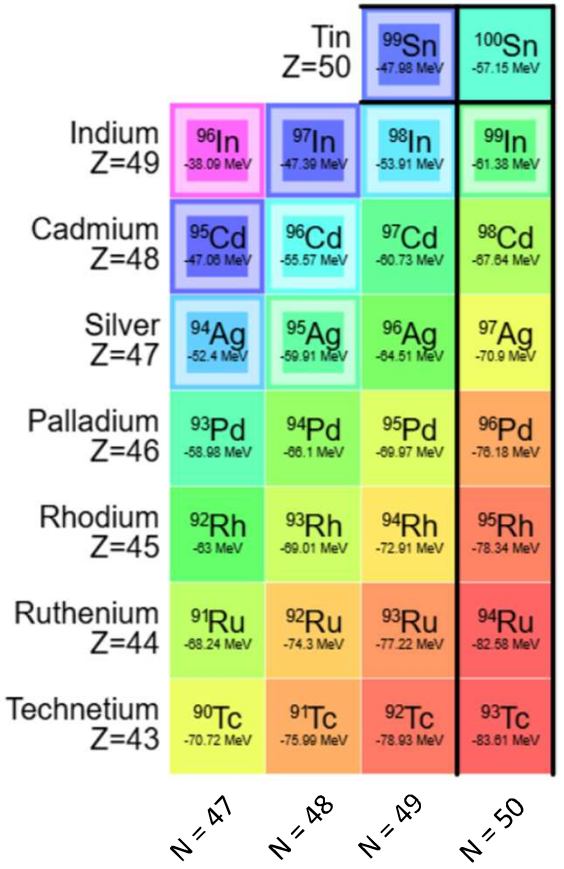
C. Hornung – NIM B (2023) 541 – 257 - https://doi.org/10.1016/j.nimb.2023.04.045

Range Determination: Mass Identification of Sevaral Fragments

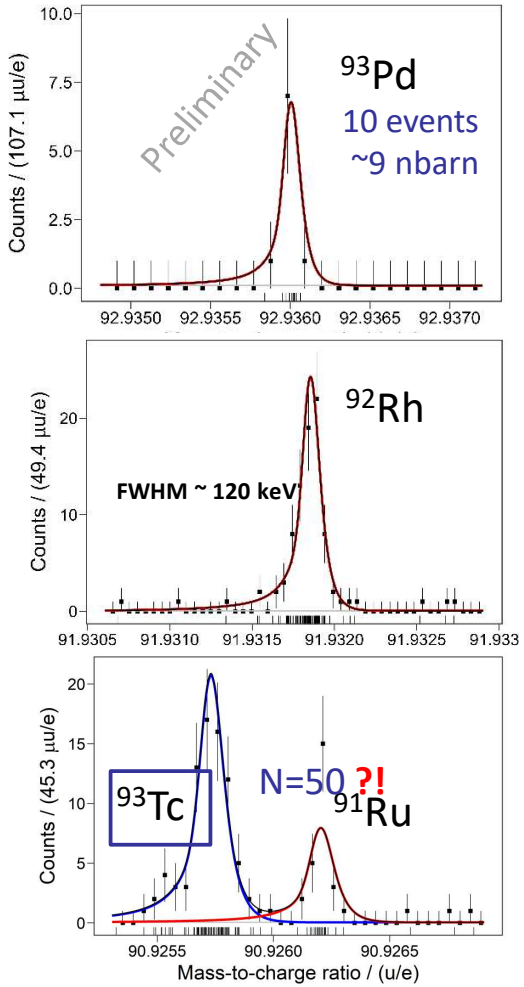
- Primary beam range: ionization or mass measurement.
- Range Scan @ CSC + MR-TOF-MS @ **N=50 isotones**:
  - High (enough) rate.
  - Close (as much as possible) to target nuclei.
  - Fast scan (about 5 min per point).



…FRS scaling…



- Measurement @ N = 47 isotones



„Unexpected“ isotopes!

G Kripko-Koncz – JLU Giessen PhD Thesis (2025), *In preparation.*

Explanation for „unexpected“ isotopes?

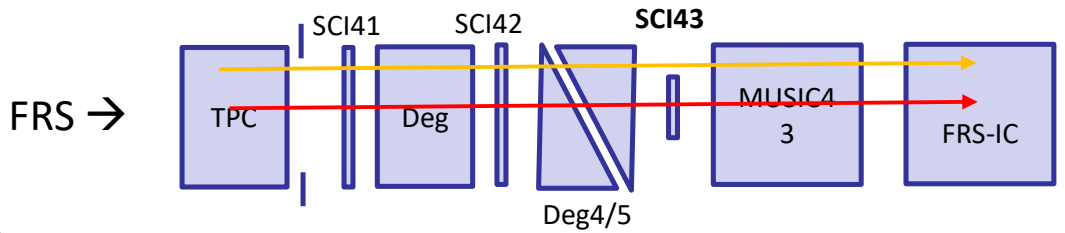
LISE++ simulations

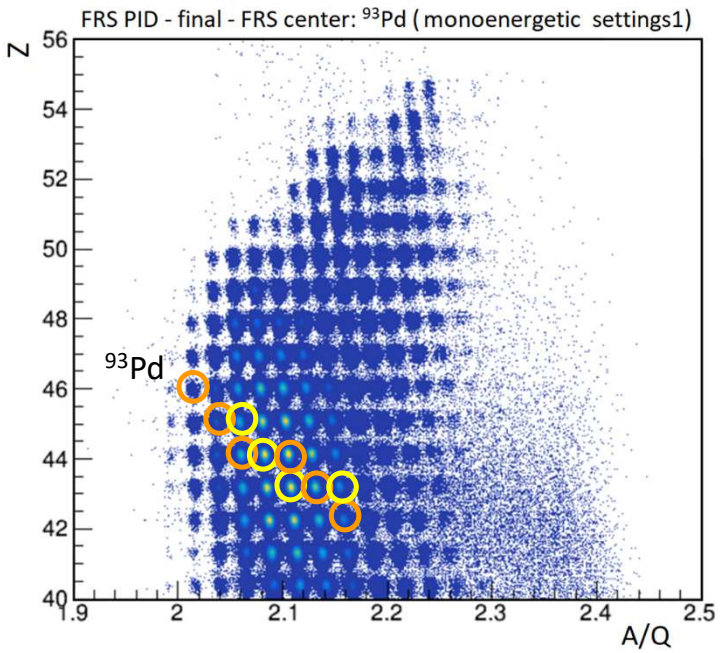
Yields from FRS PID detectors

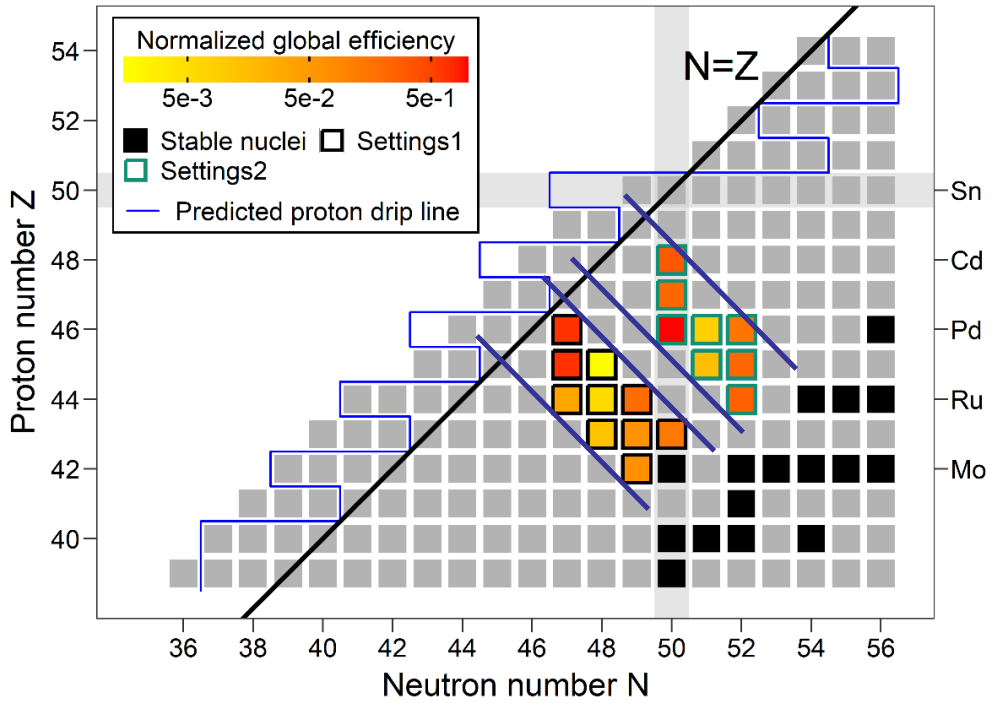
Consistent picture

Yields from FRS Ion Catcher

- Height of SCI43 at Final Focal plane in S4







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Super-FRS Experiment Collaboration

FRS Ion Catcher Collaboration

D. Amanbayev, B. Ashrafkhani, O. Aviv, S. Ayet San Andrés, J. Äystö, S. Bagchi, D.L. Balabanski, S. Beck, O. Beliuskina, J. Bergmann, A. Blazhev, Z. Brencic, S. Cannarozzo, O. Charviakova, P. Constantin, D. Curien, I. Dedes, M. Dehghan, T. Dickel, F. Didierjean, G. Duchene, J. Dudek, T. Eronen, T. Fowler-Davis, M. Friedman, Z. Gao, Z. Ge, H. Geissel, S. Glöckner, M. Górska, T. Grahn, F. Greiner, L. Gröf, M. Gupta, E. Haettner, M. Harakeh, C. Hornung, Y. Ito, A. Jaries, A. Jokinen, B. Kaizer, N. Kalantar-Nayestanaki, A. Kankainen, D. Kar, A. Karpov, Y. Kehat, D. Kostyleva, G. Kripkó-Koncz, D. Kumar, K. Mahajan, I. Mardor, A.A. Mehmandoost-Khajeh-Dad, N. Minkov, A. Mollaebrahimi, I. Moore, D. Morrissey, I. Mukha, M. Narang, D. Nichita, Z. Patyk, H. Penttilä, A. Perry, S. Pietri, A. Pikhtelev, W.R. Plaß, I. Pohjalainen, S. Pomp, R.K. Prajapat, S. Purushothaman, M.P. Reiter, M. Reponen, S. Rinta-Antila, H. Rösch, A. Rotaru, J. Ruotsalainen, N. Saadon, C. Scheidenberger, P. Schury, A. Shrayer, M. Simonov, S.K. Singh, A. Solders, A. Spataru, A. State, Y. Tanaka, P. Thirolf, N. Tortorelli, E. Vardaci, L. Varga, M. Vencelj, V. Virtanen, M. Wada, H. Weick, L. Welde, M. Wieser, M. Will, H. Wilsenach, M.I. Yavor, J. Yu, A. Zadvornaya, J. Zhao

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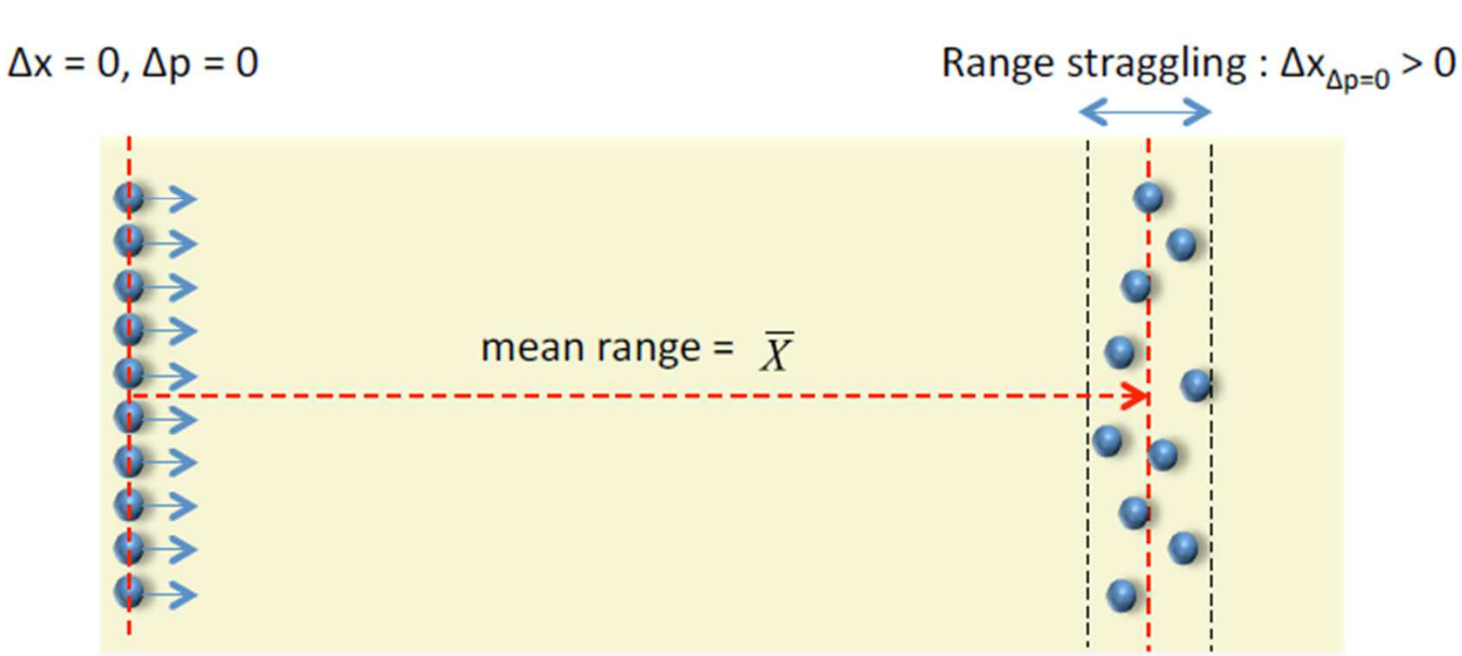
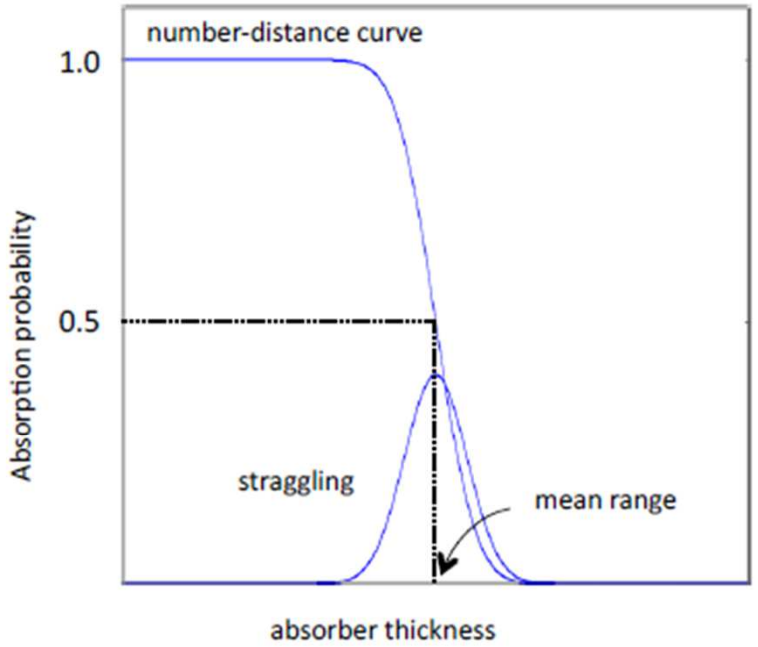
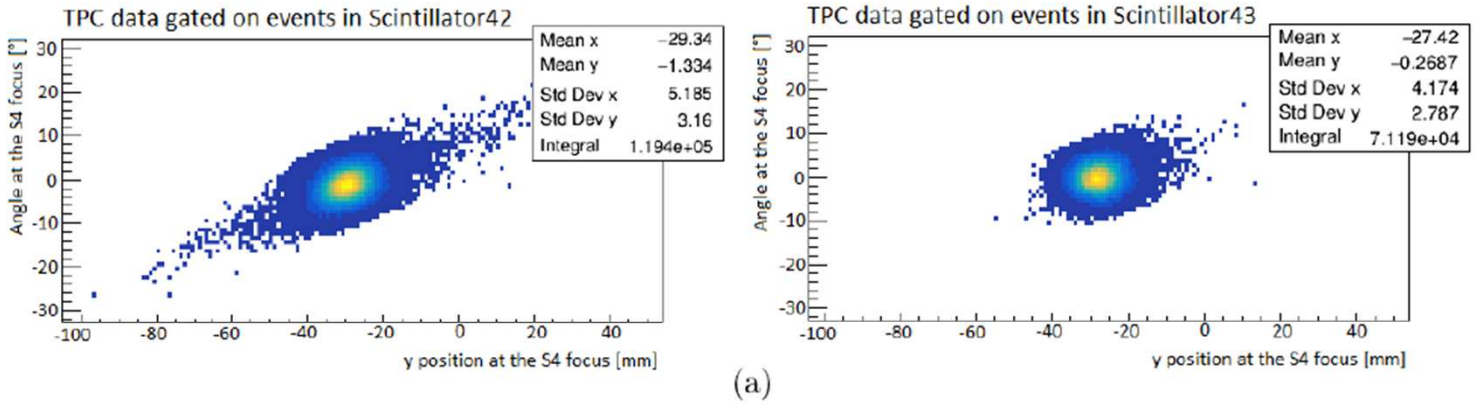
Backup

Mean Range and Range Straggling

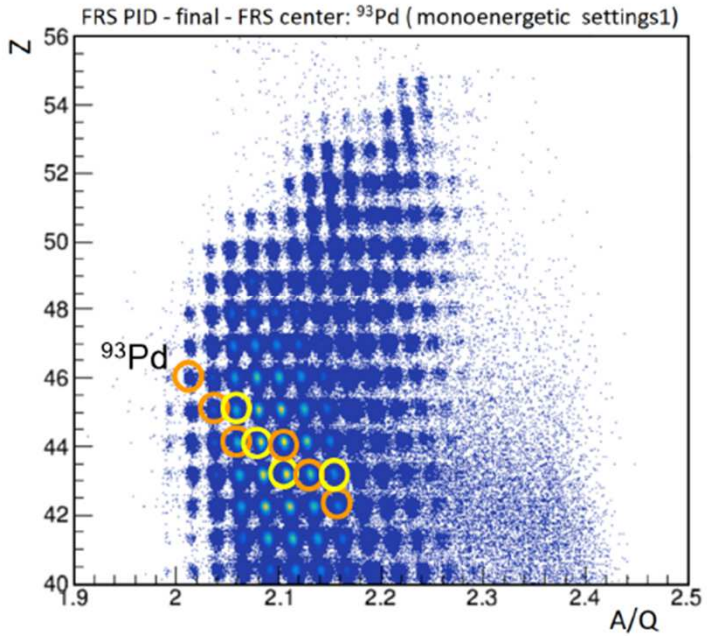




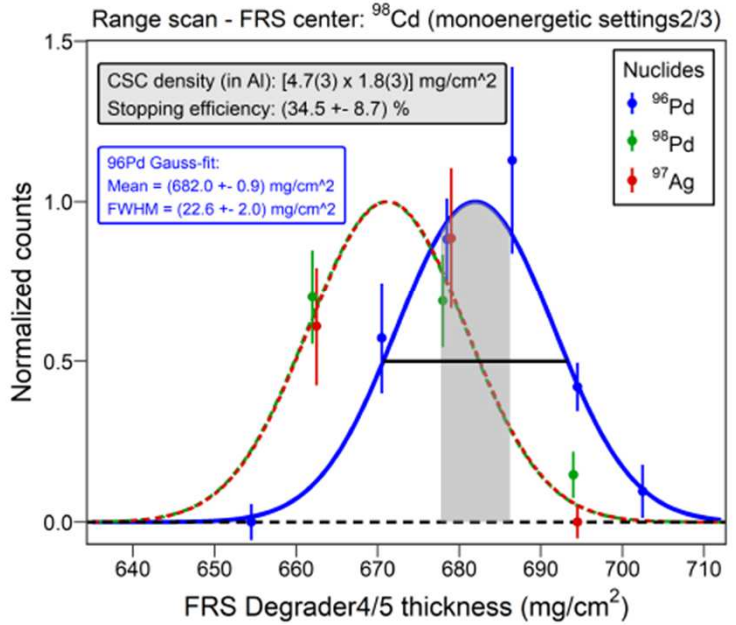
Unexpected Isotopes



(a)



(b)



(c)