Investigation of heavy neutron-rich nuclides with Schottky mass spectrometry at the ESR

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Introduction

Motivation for research

Experiment

Experimental facilities

Data Analysis

ROOT-based software

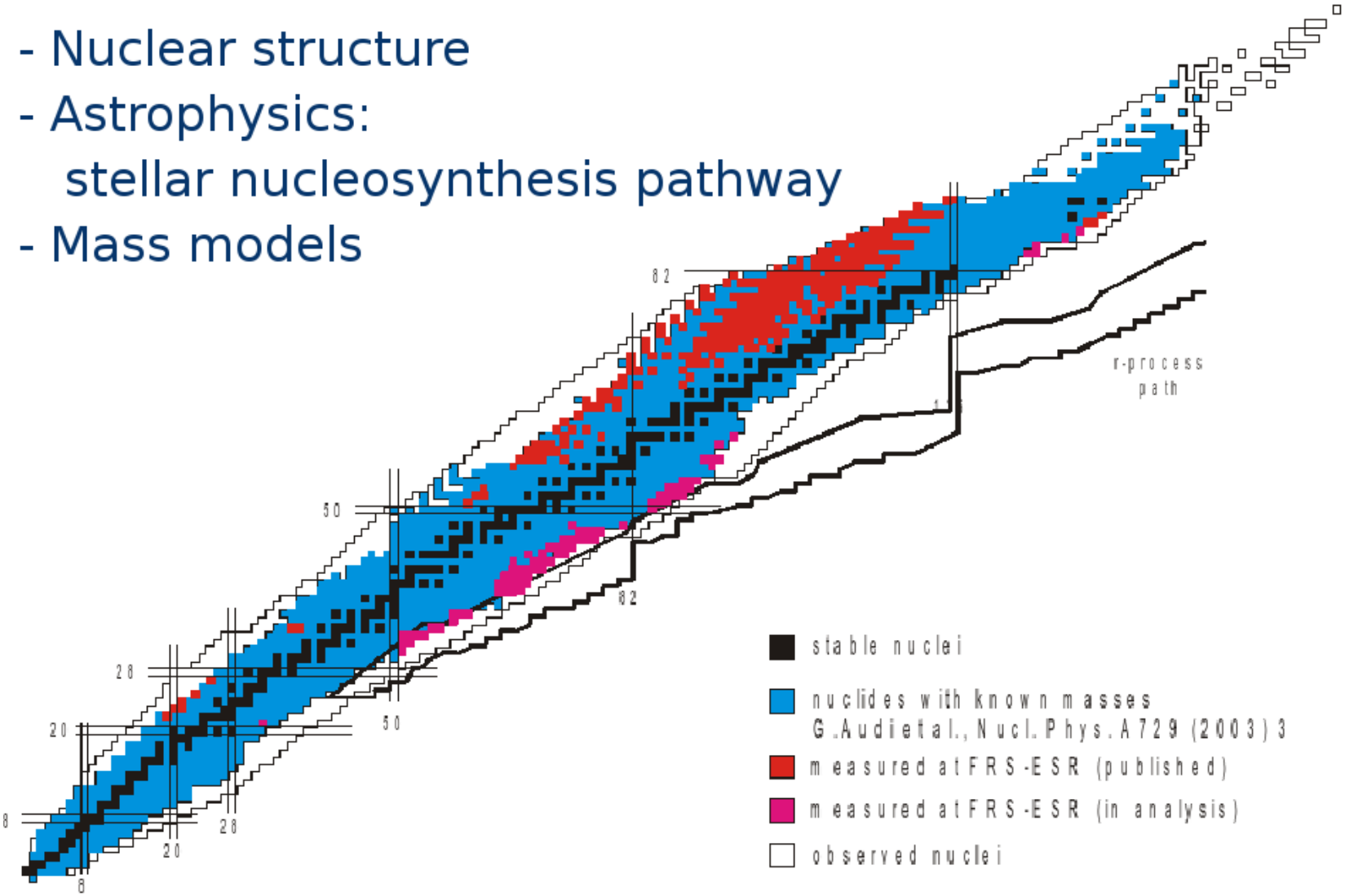
Results

Masses measured for the first time and discovered isomers

Discussion

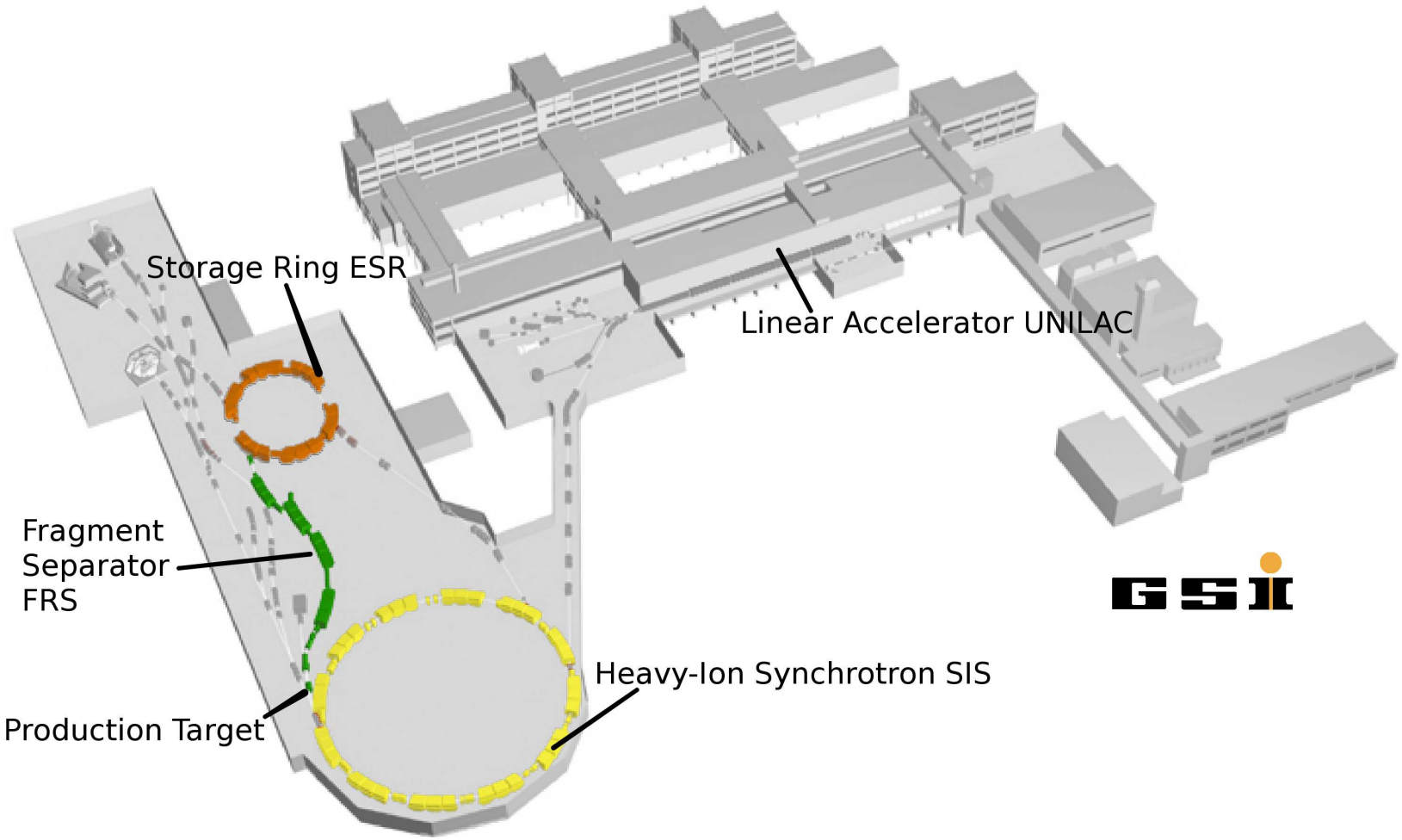
Separation energies and pairing-gap energies

- Nuclear structure
- Astrophysics:
  stellar nucleosynthesis pathway
- Mass models

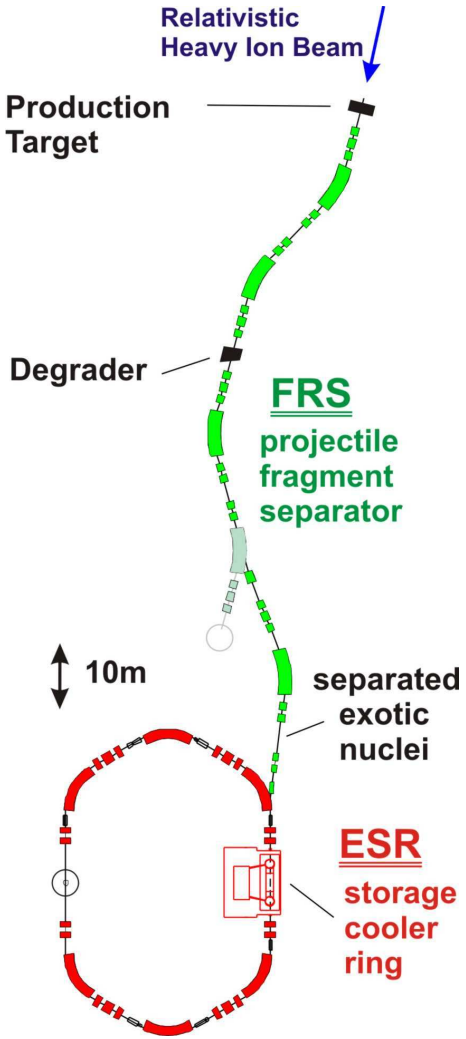


B.Franzke et al., Mass Spectrometry Reviews, 27, 428 (2008)

GSI Helmholtzzentrum



Separation and Storage



FRS

- Highly-charged ions
- In-Flight separated
- Cocktail or monoisotopic beams

H. Geissel et al., Nucl. Instr. and Meth. B70, 286 (1992)

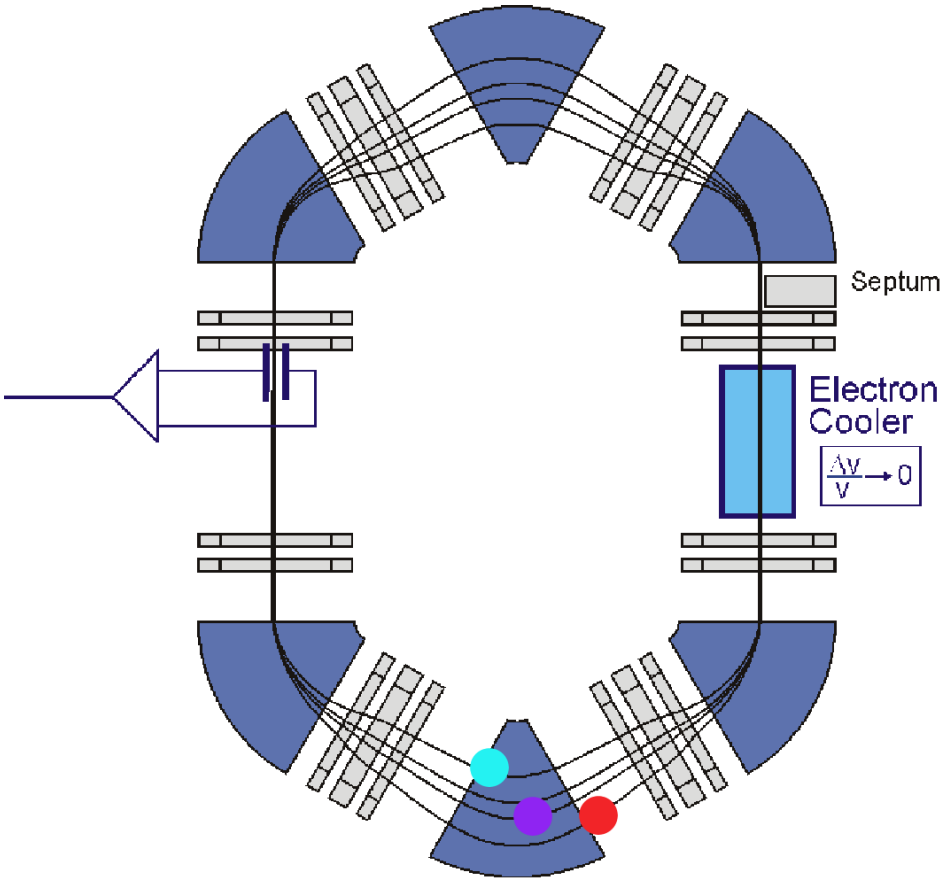
ESR

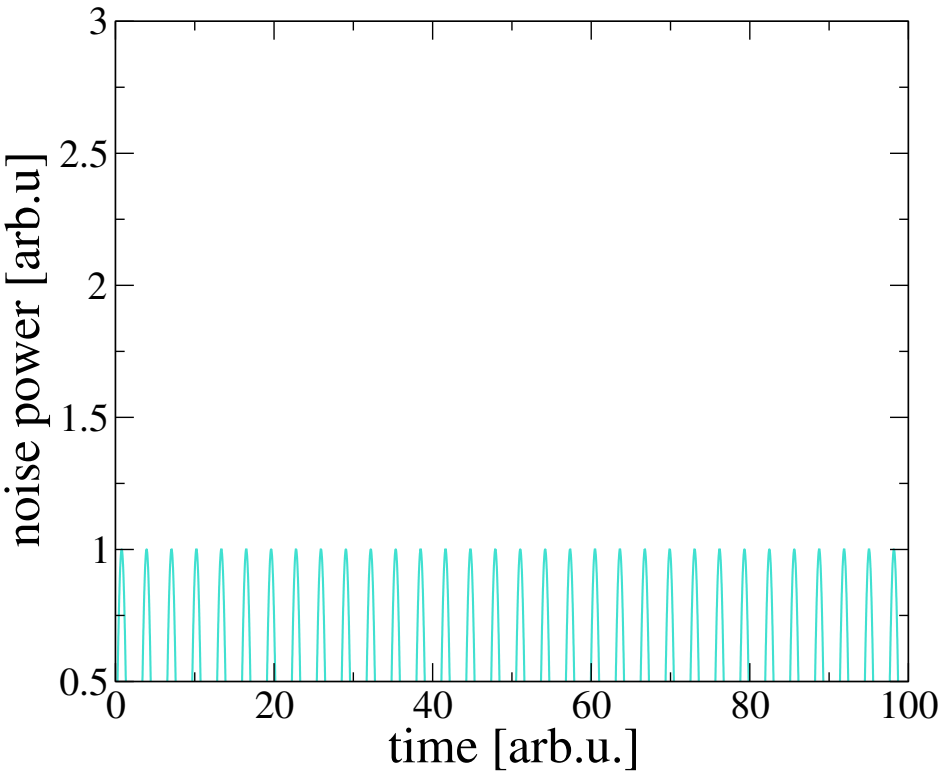
- Circumference: 108 m
- Vacuum: 10^{-11} mbar
- Revolution frequency: 2 MHz @ E = 400 MeV/u
- Stochastic[1] and electron[2] cooling

B.Franzke et al., Nucl. Instr. and Meth. B24/25, 18 (1987)
[1] F.Nolden et al., Nucl. Instr. and Meth. A532, 329 (2004)
[2] M.Steck et al., Nucl. Instr. and Meth. A532, 357 (2004)

H. Geissel et al., Phys. Rev. Lett. 68, 3412 (1992)

Schottky Mass Spectrometry(SMS)





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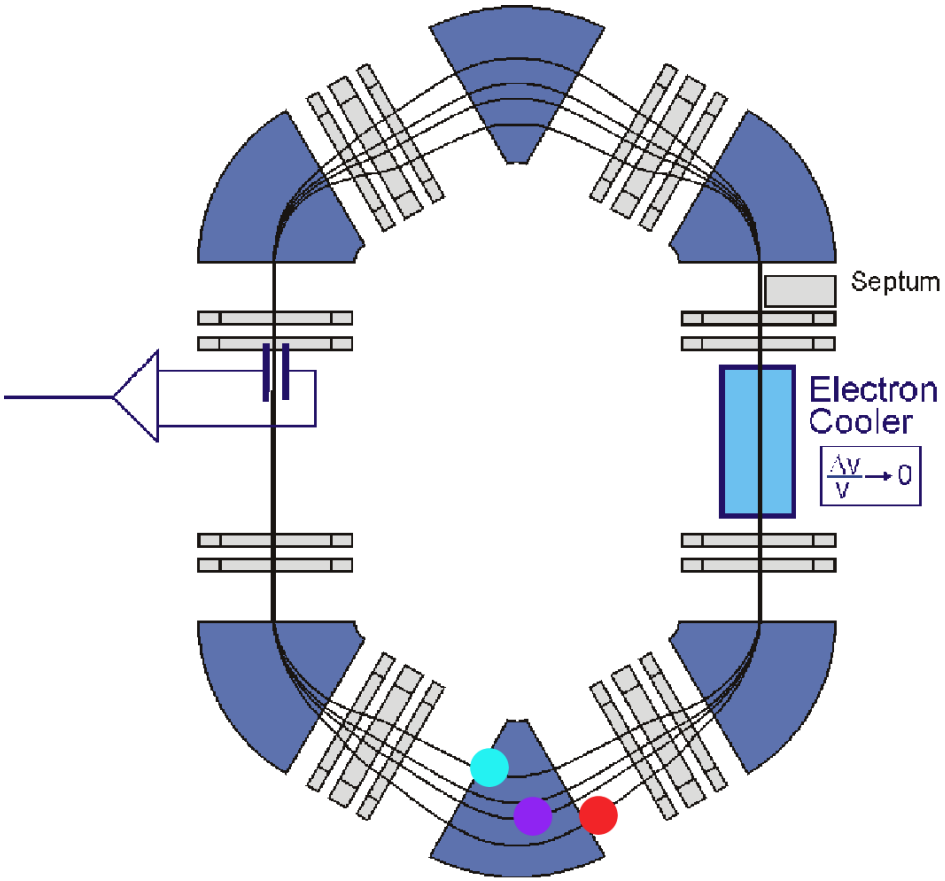

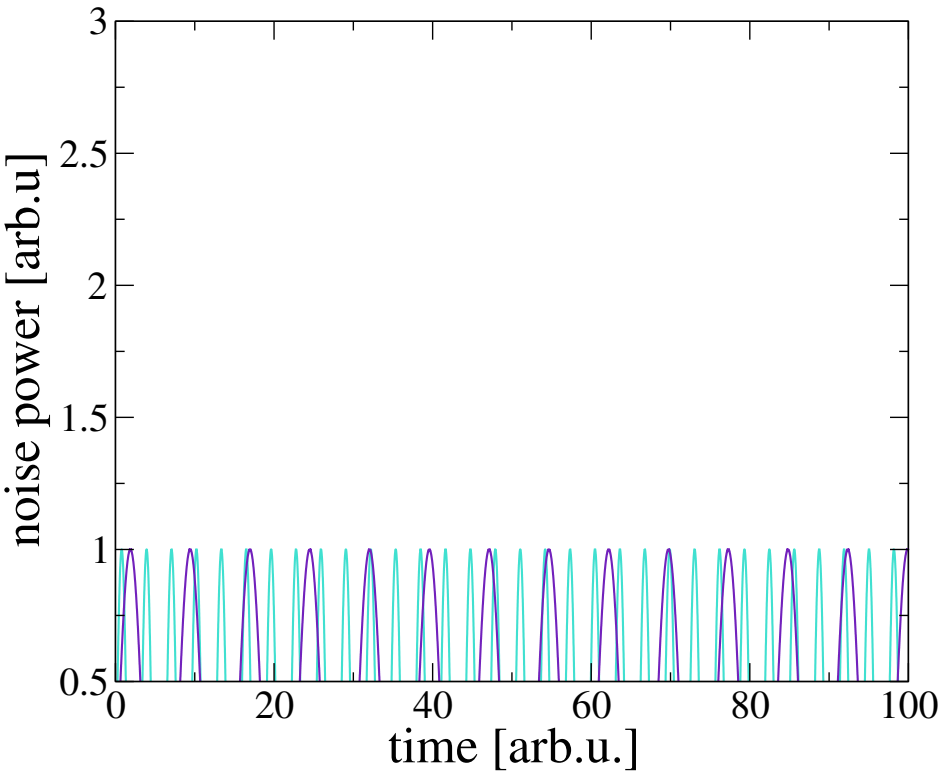

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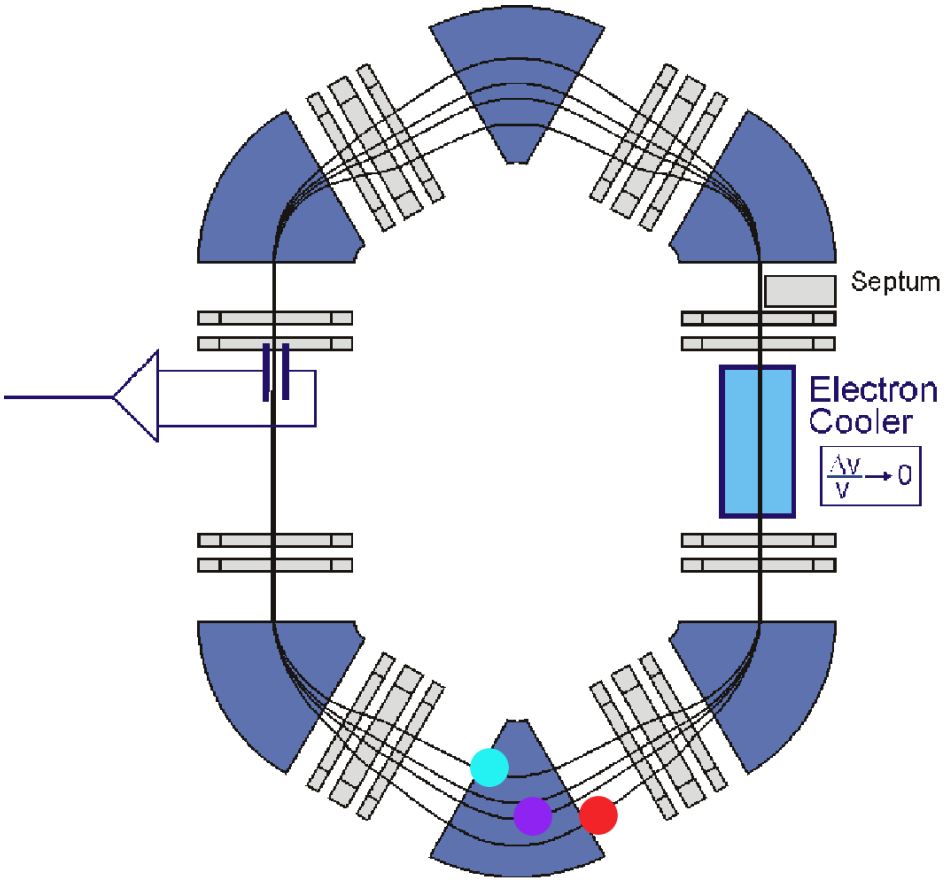

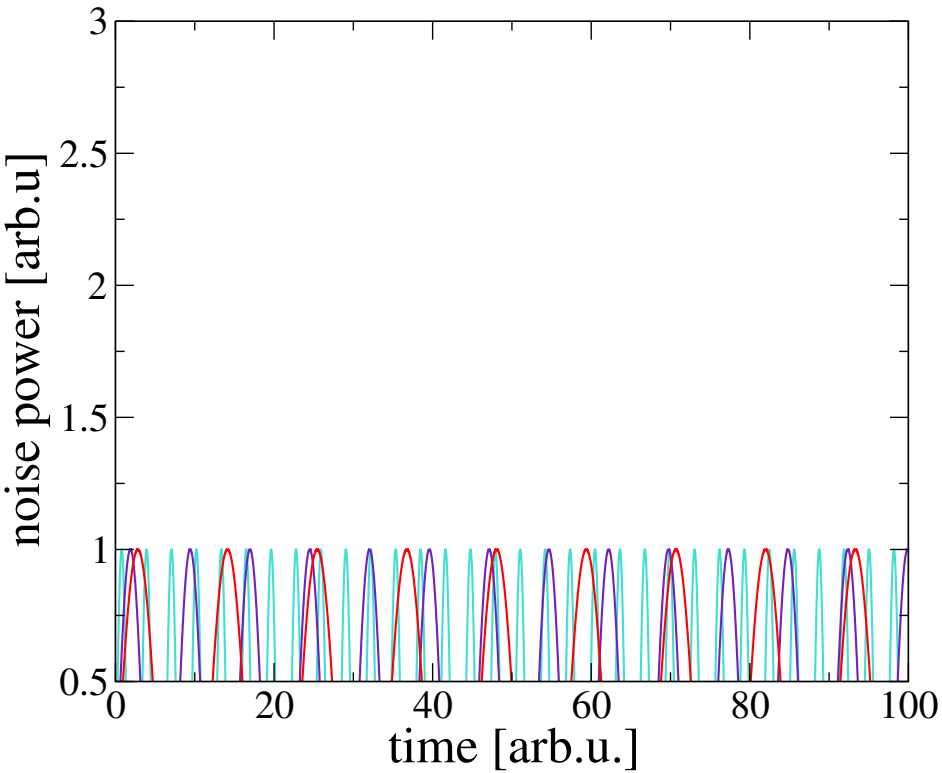

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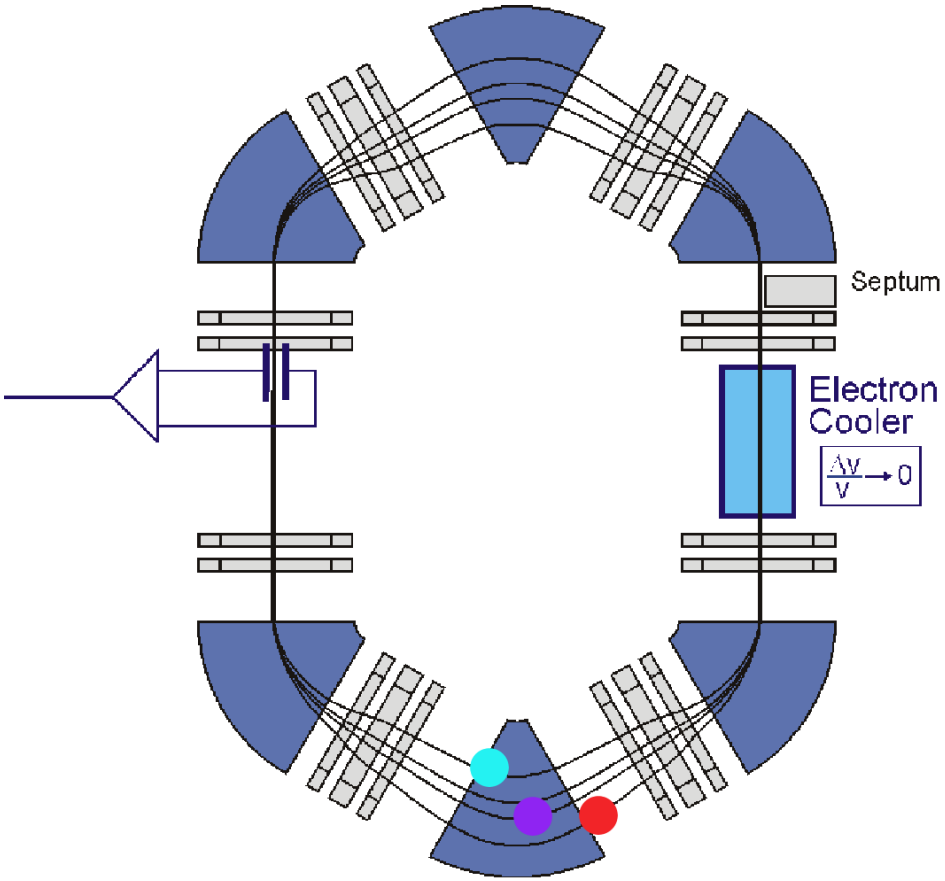

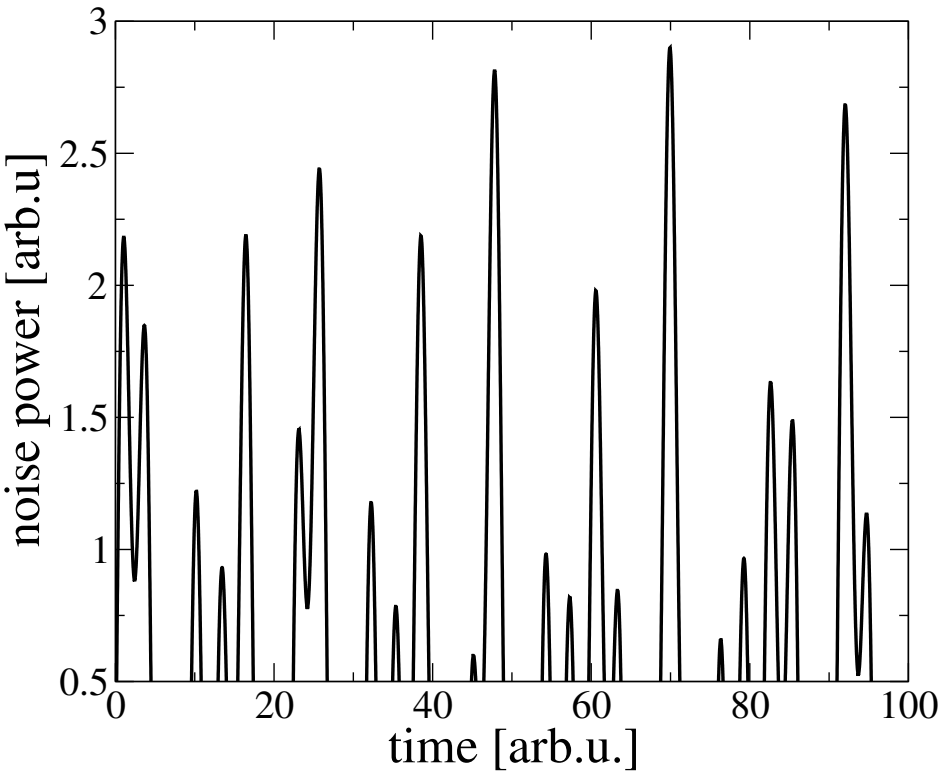

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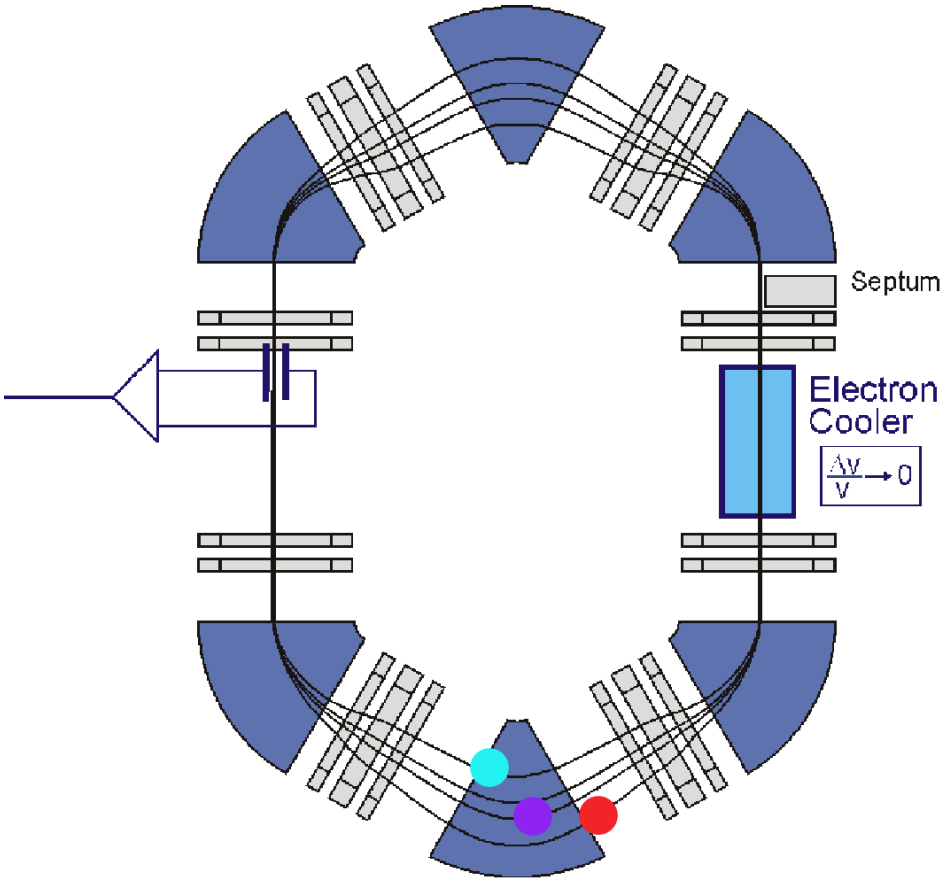
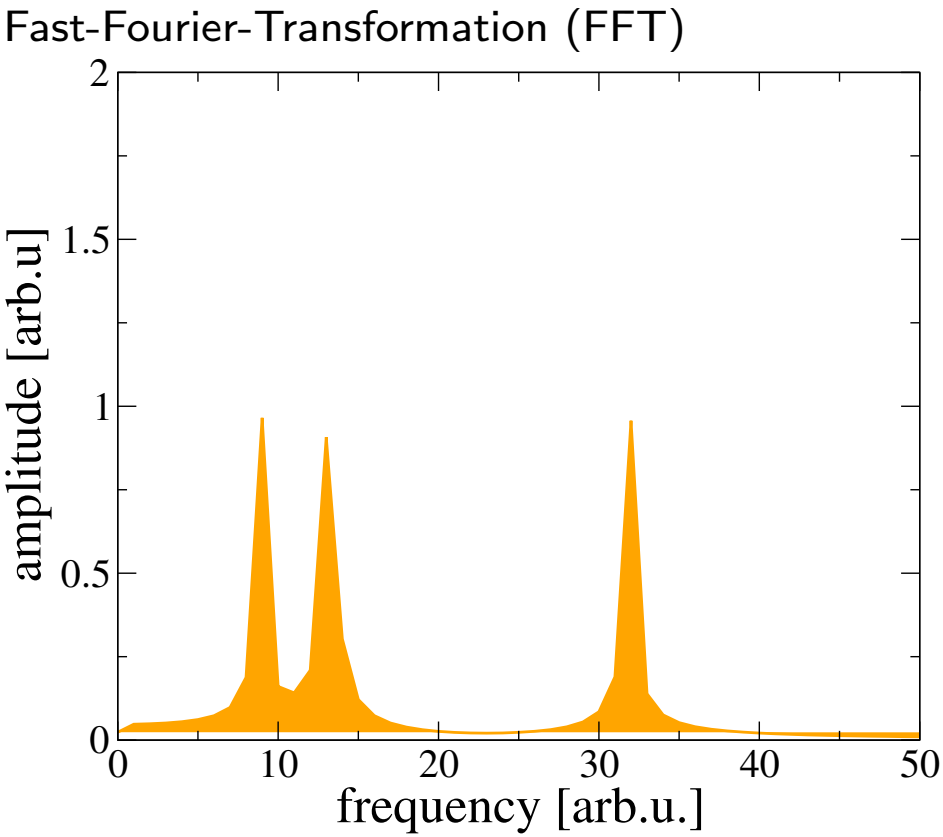
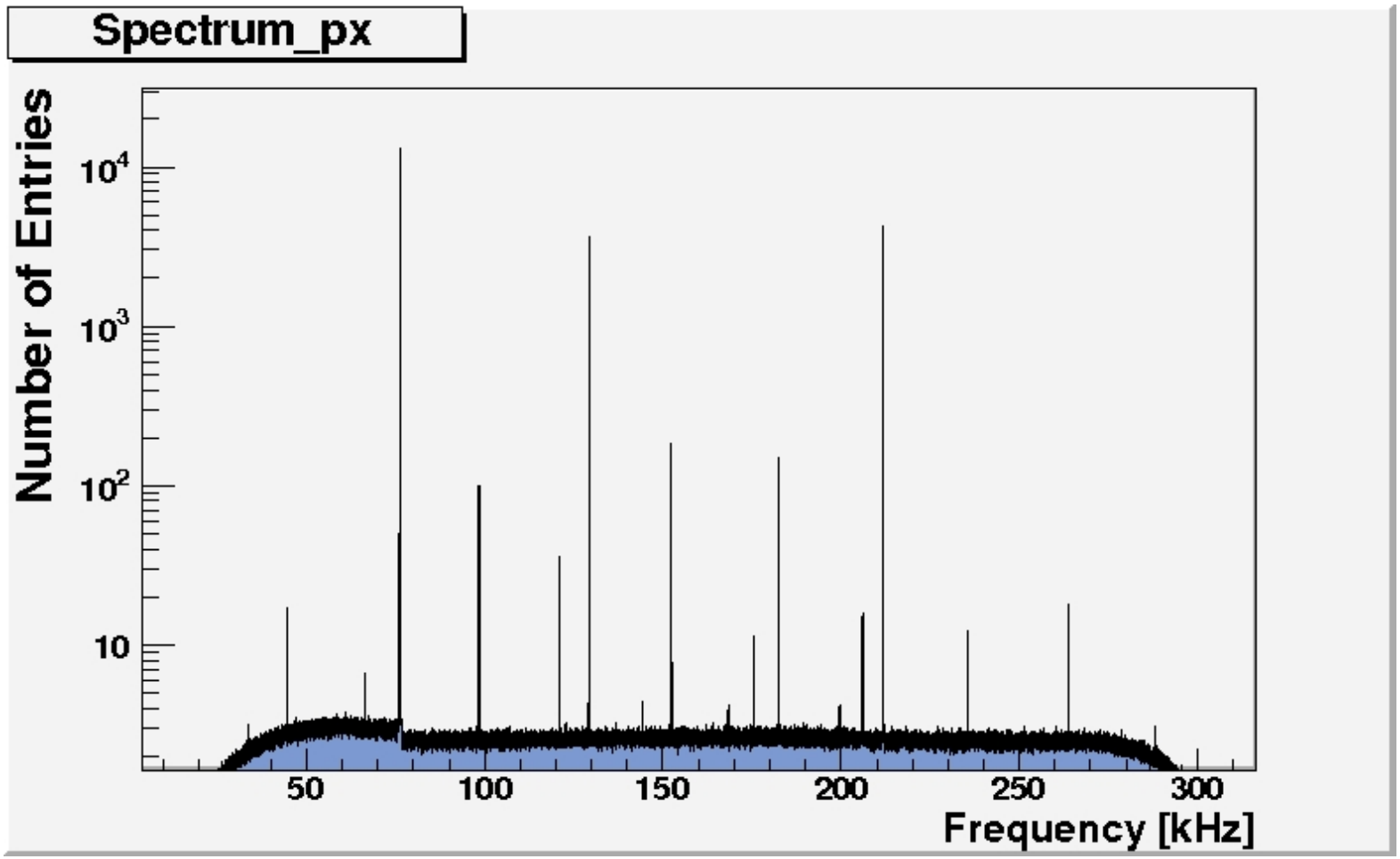




Broad-band spectrum



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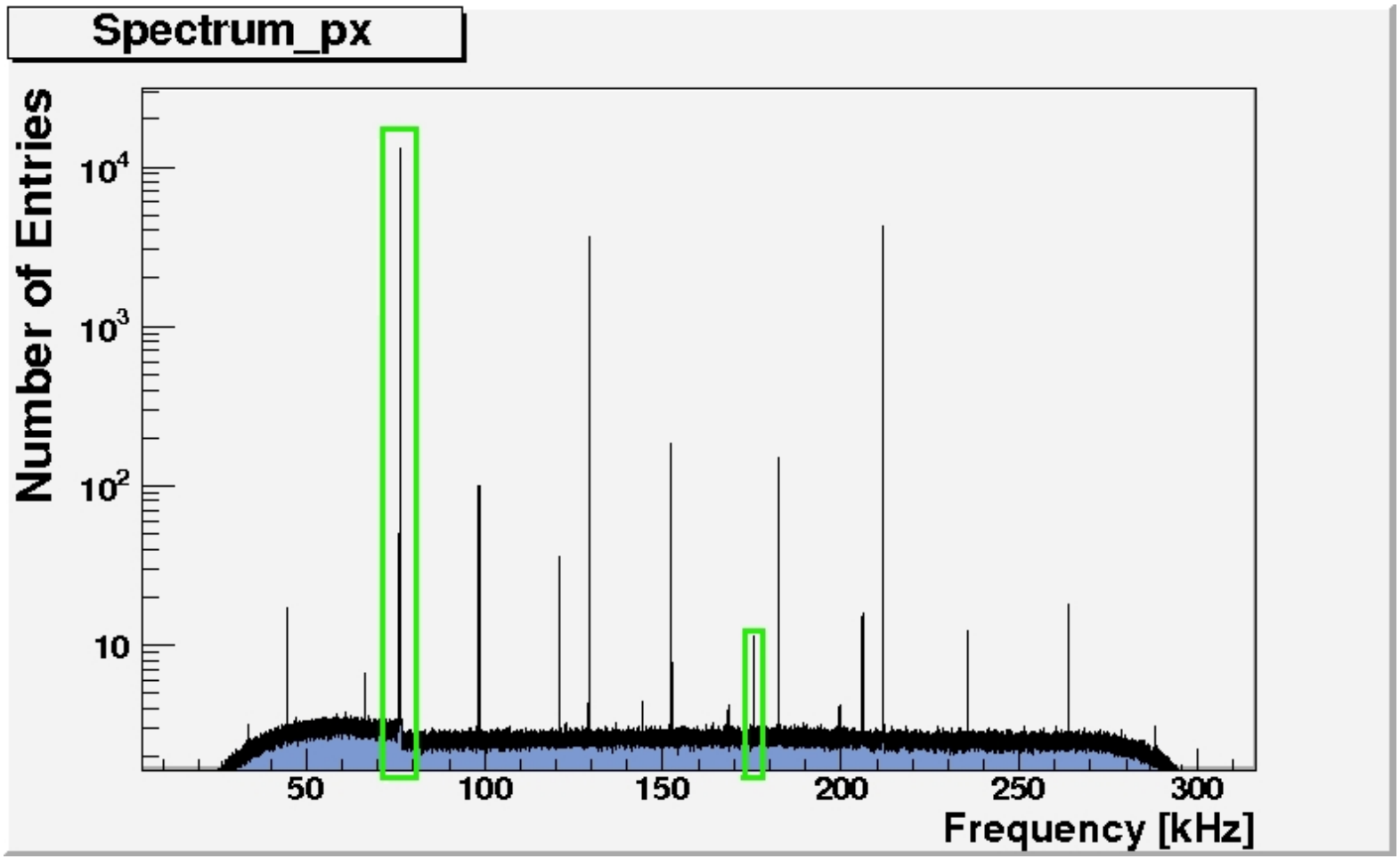
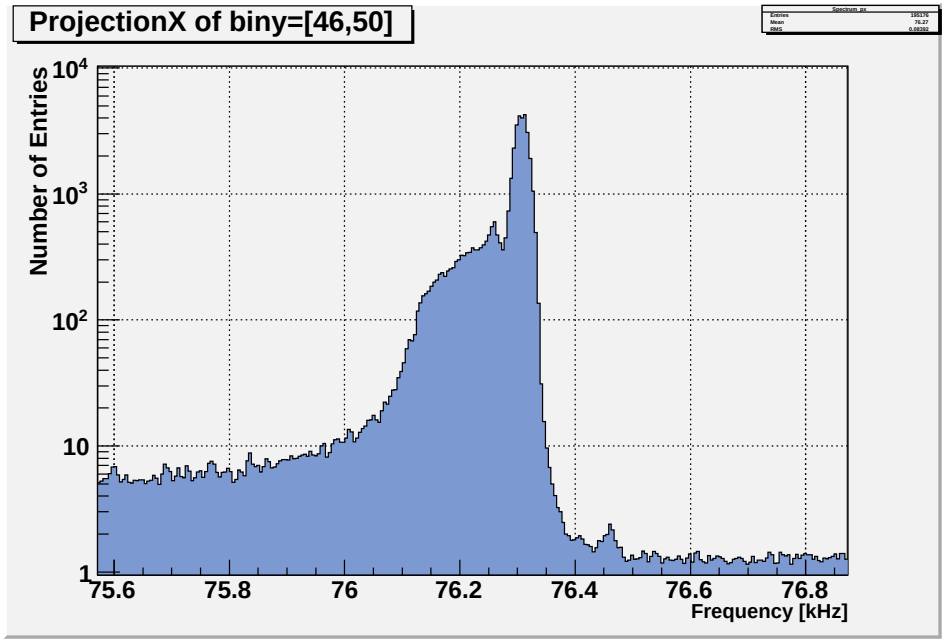
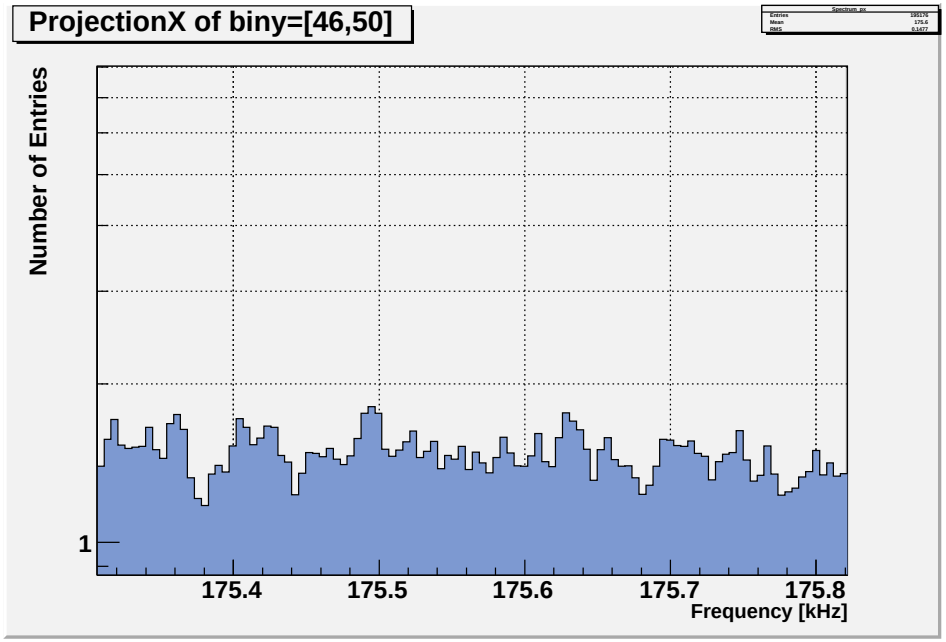


Evolution of frequency peaks in time





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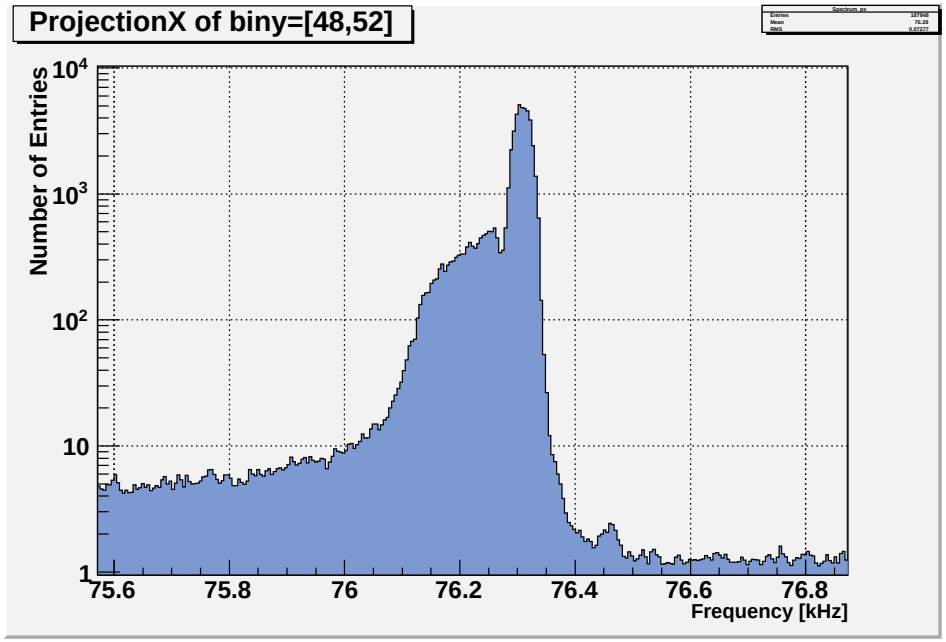

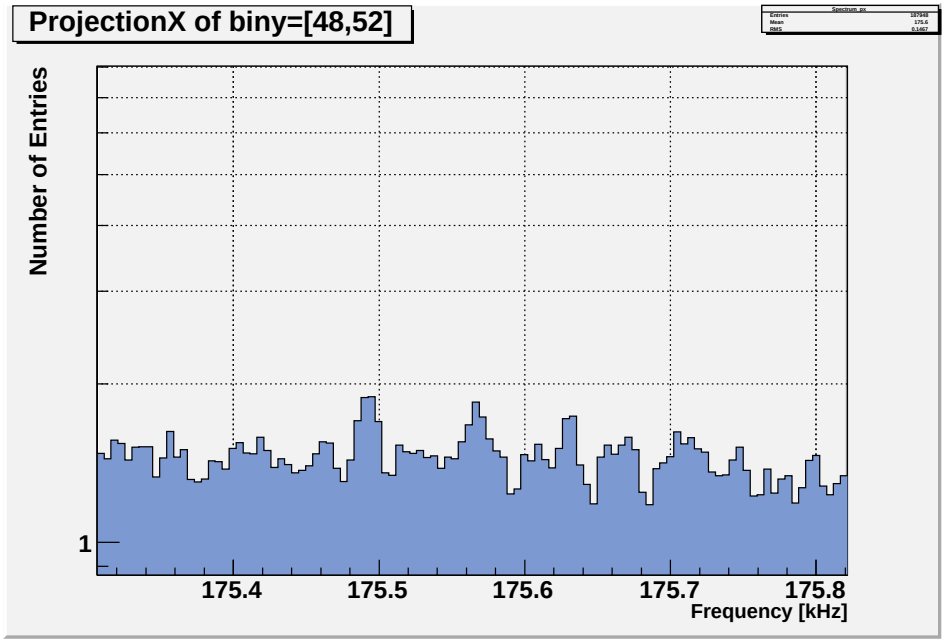

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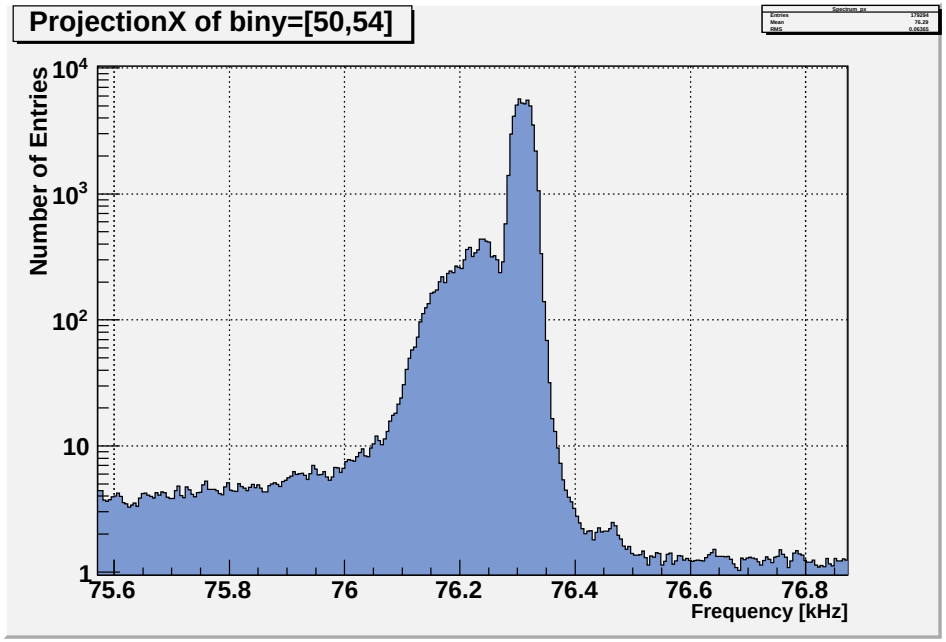

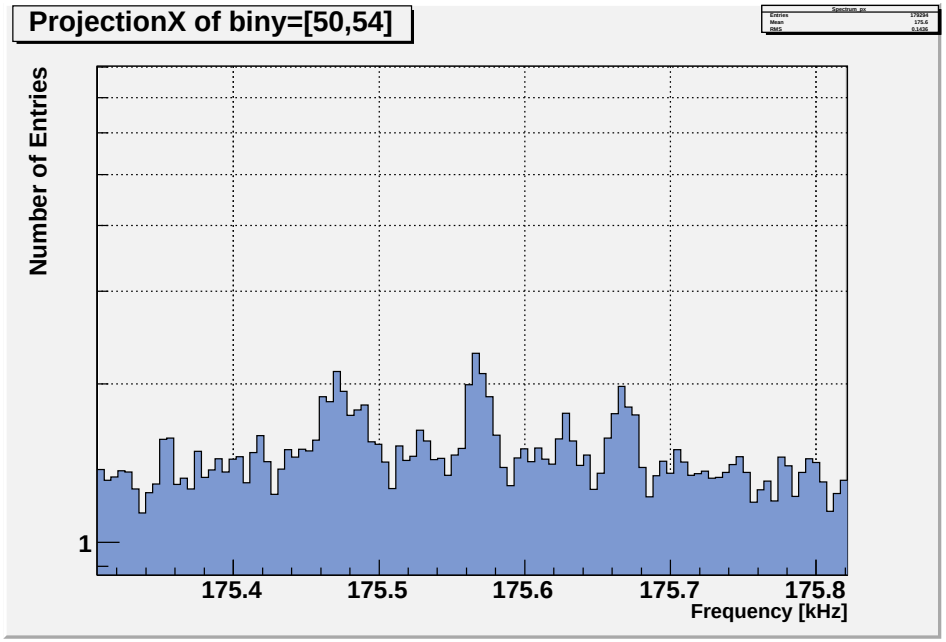

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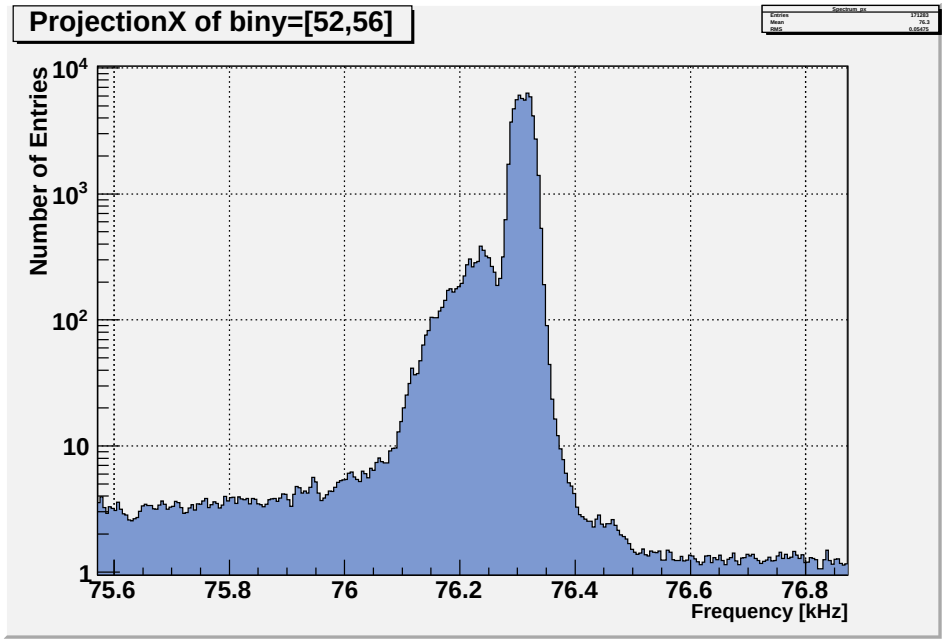

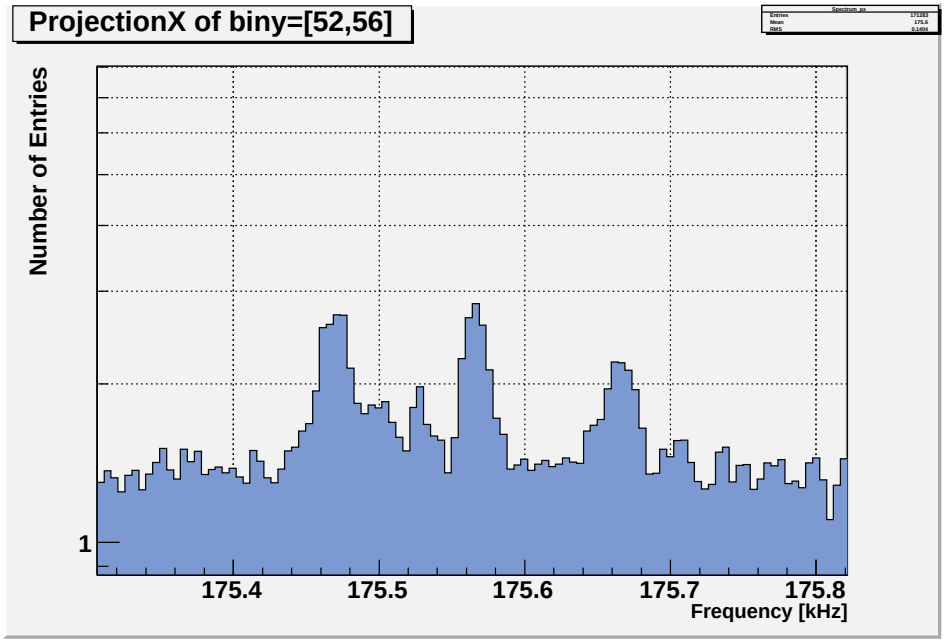

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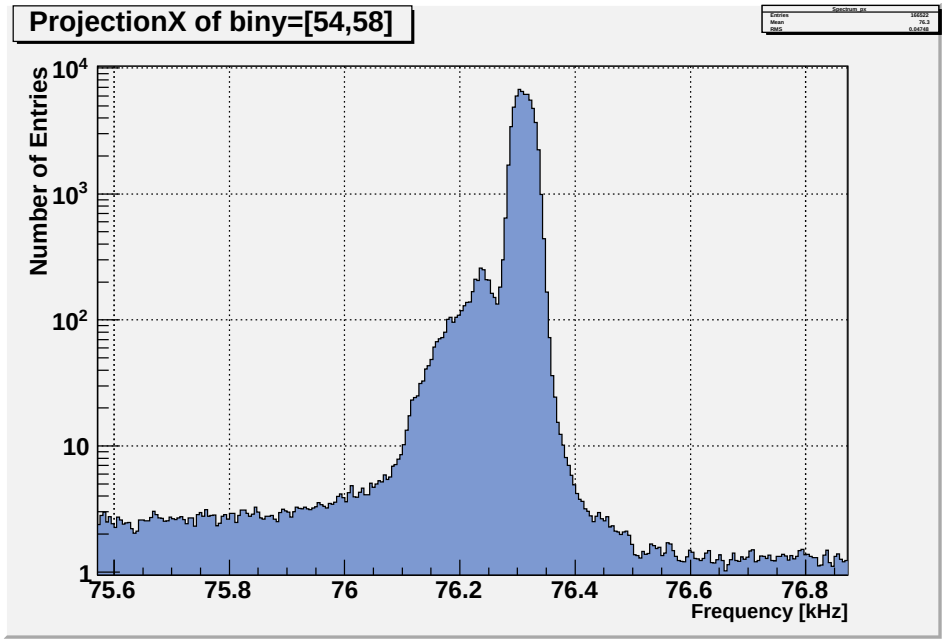

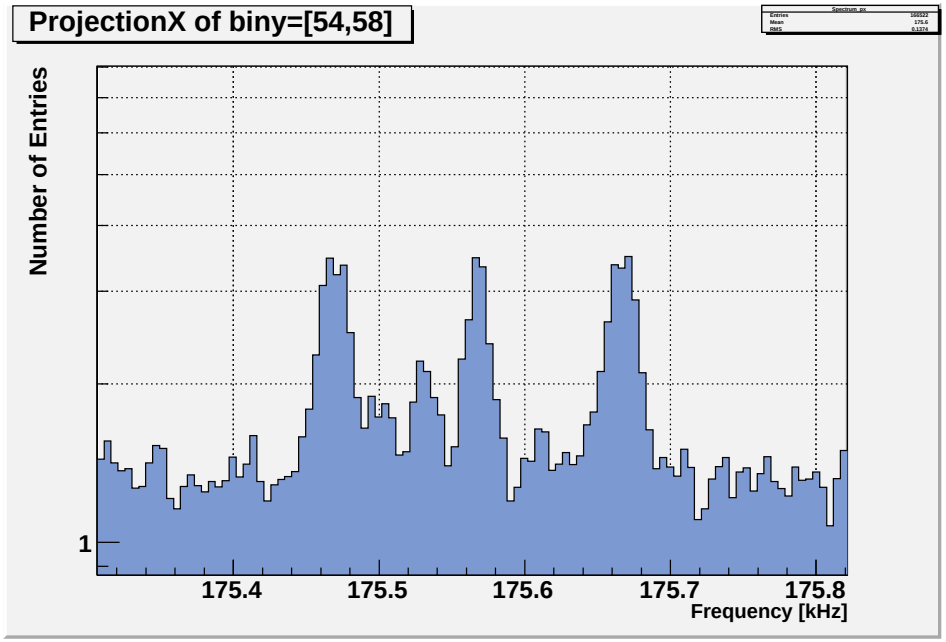

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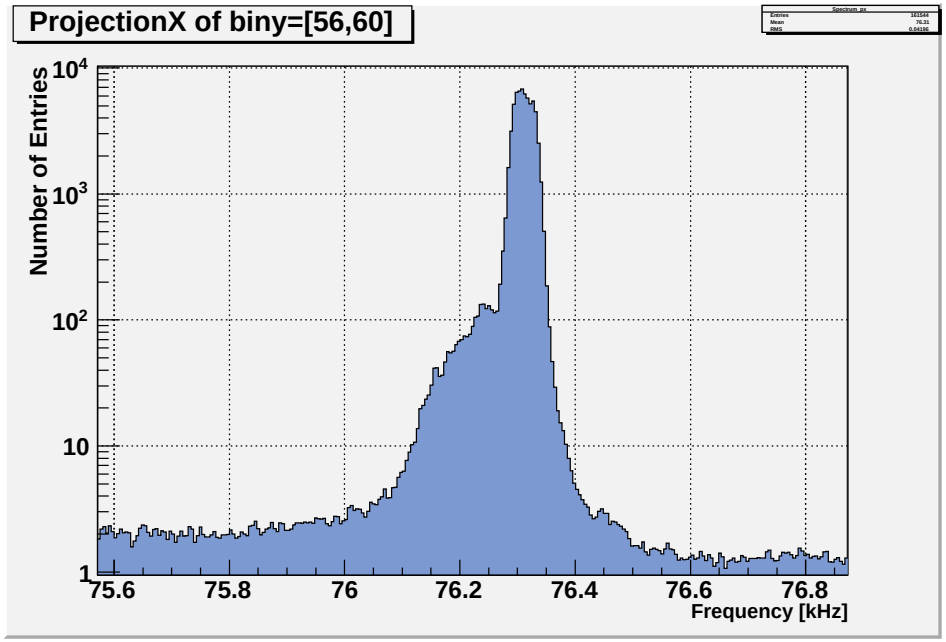

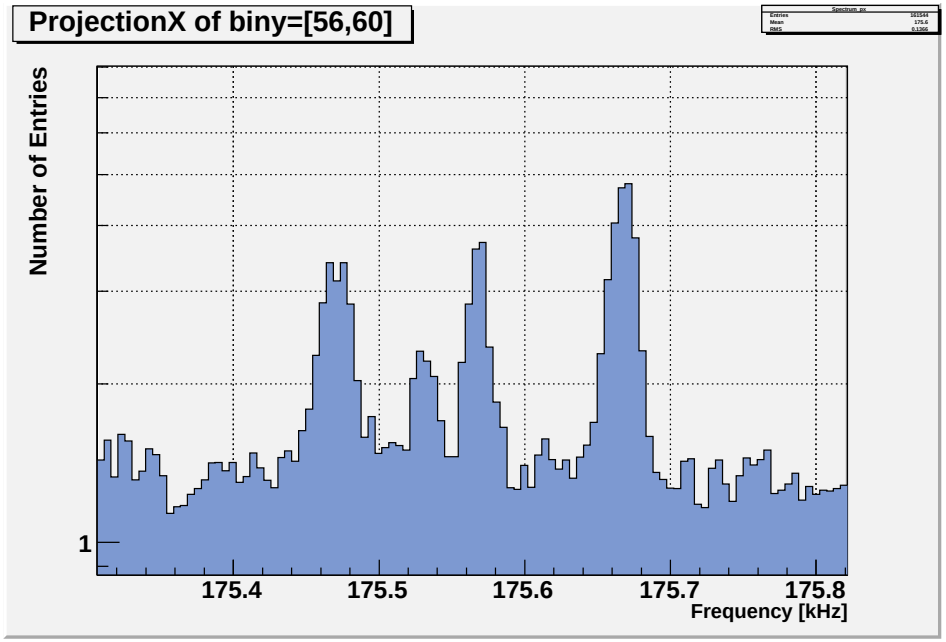

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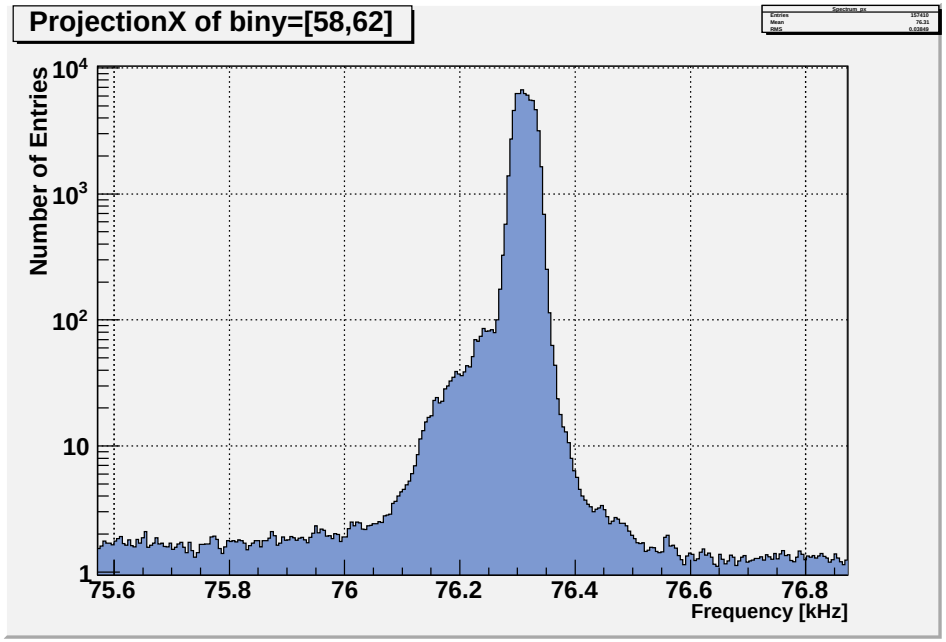

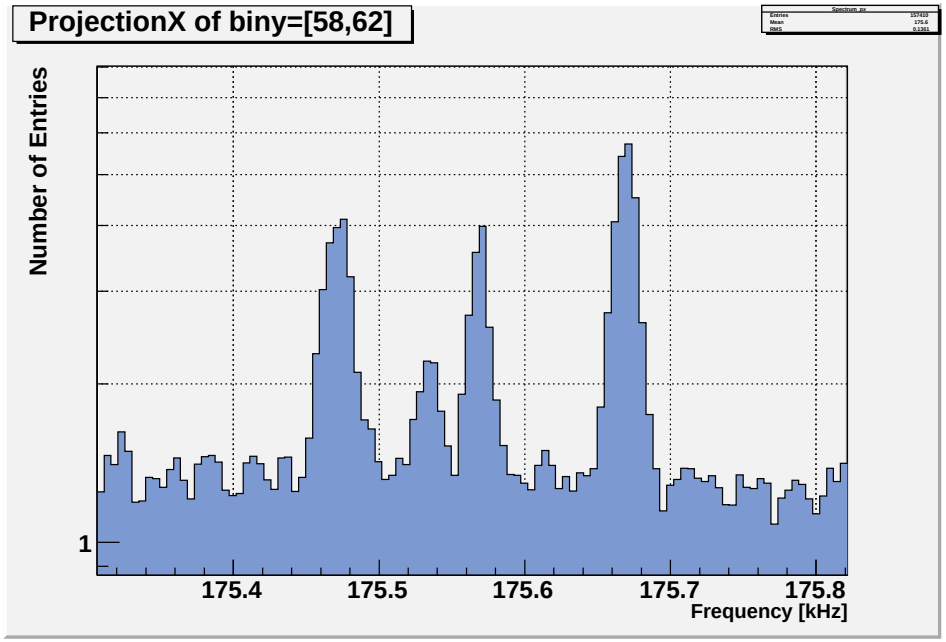

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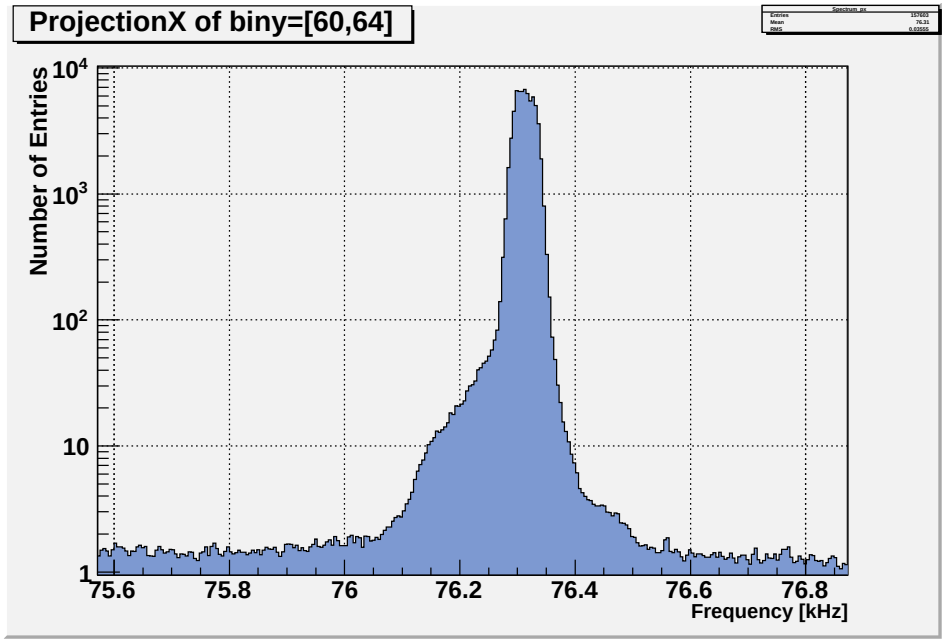

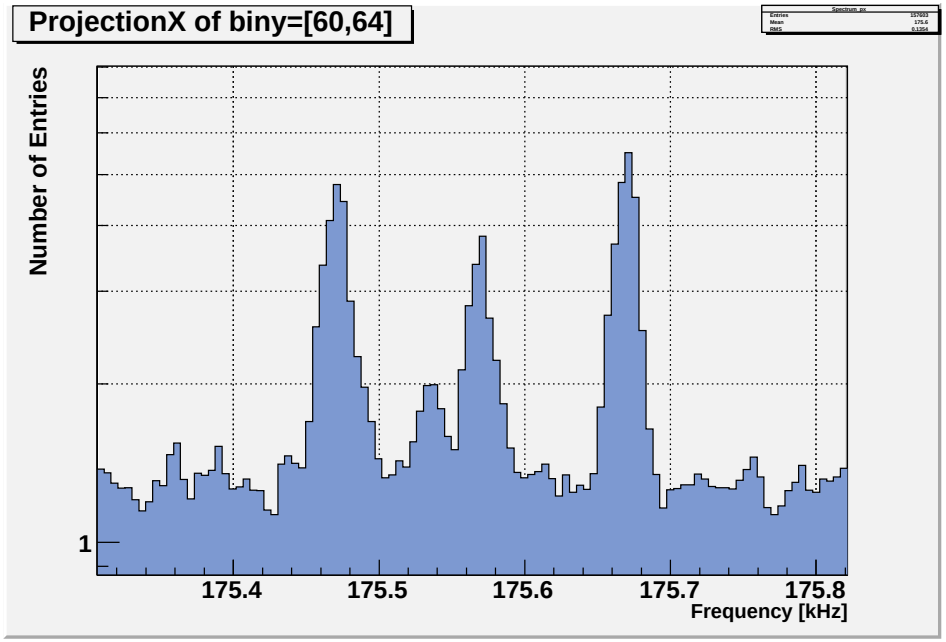

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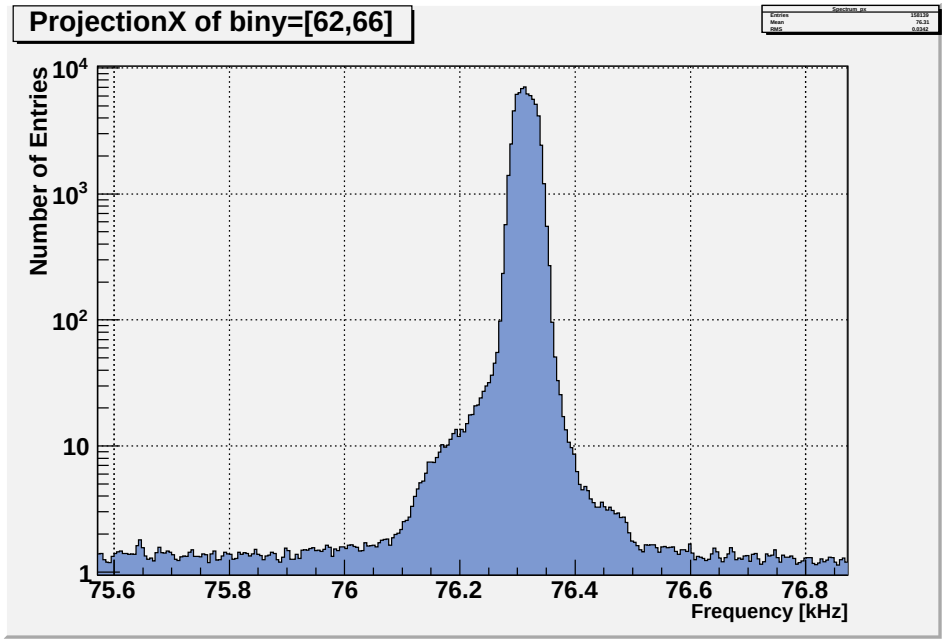

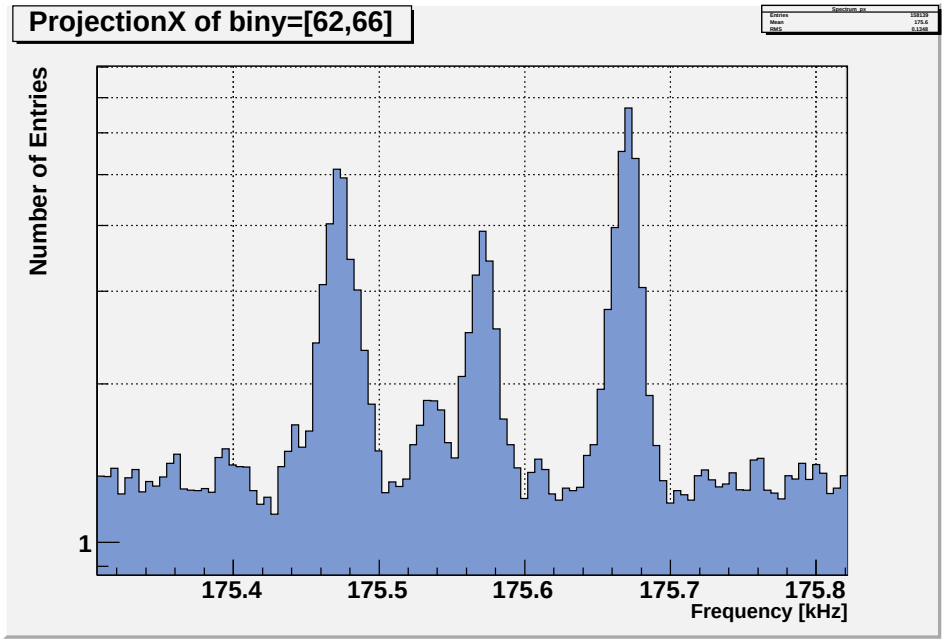

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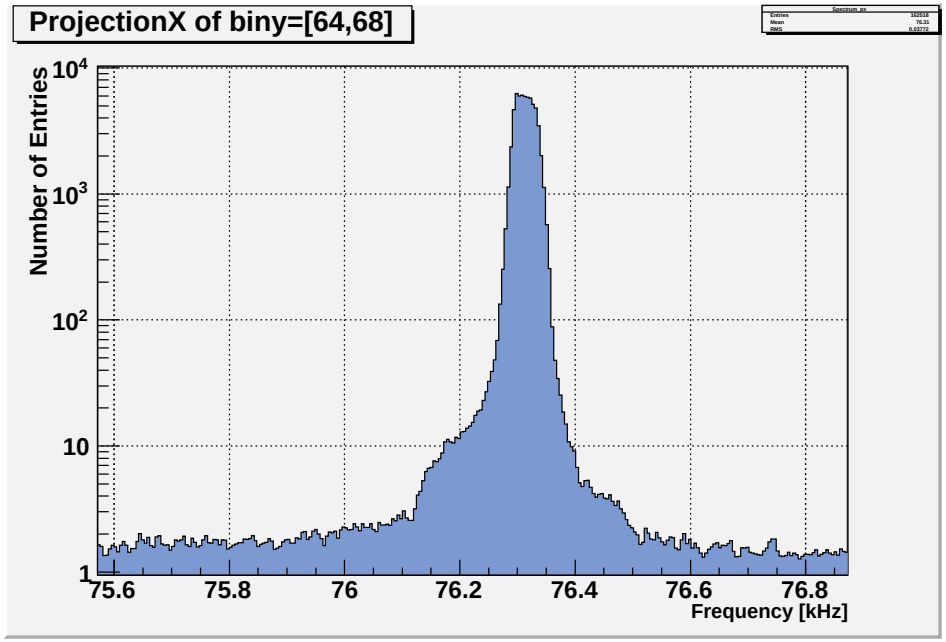
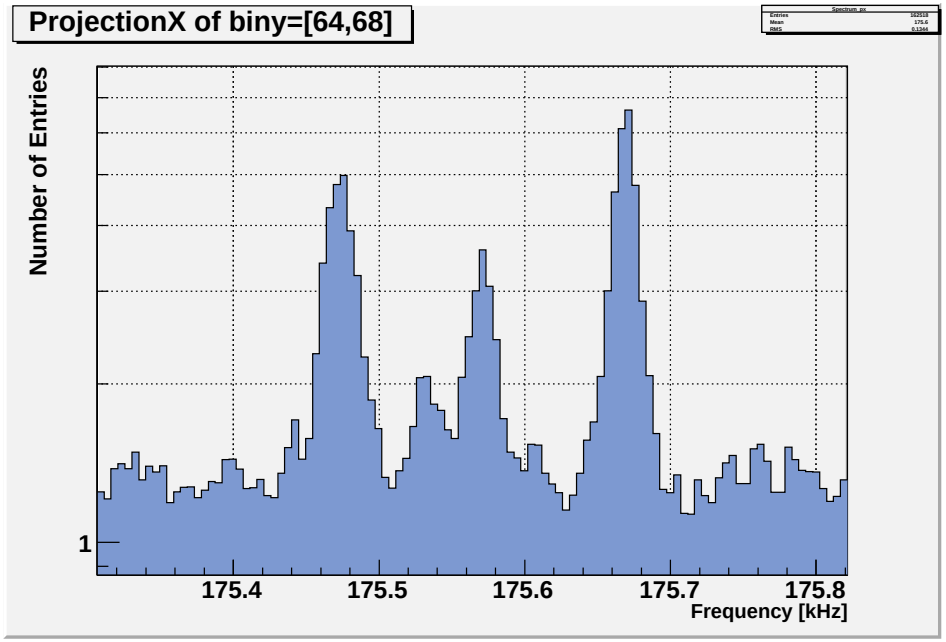
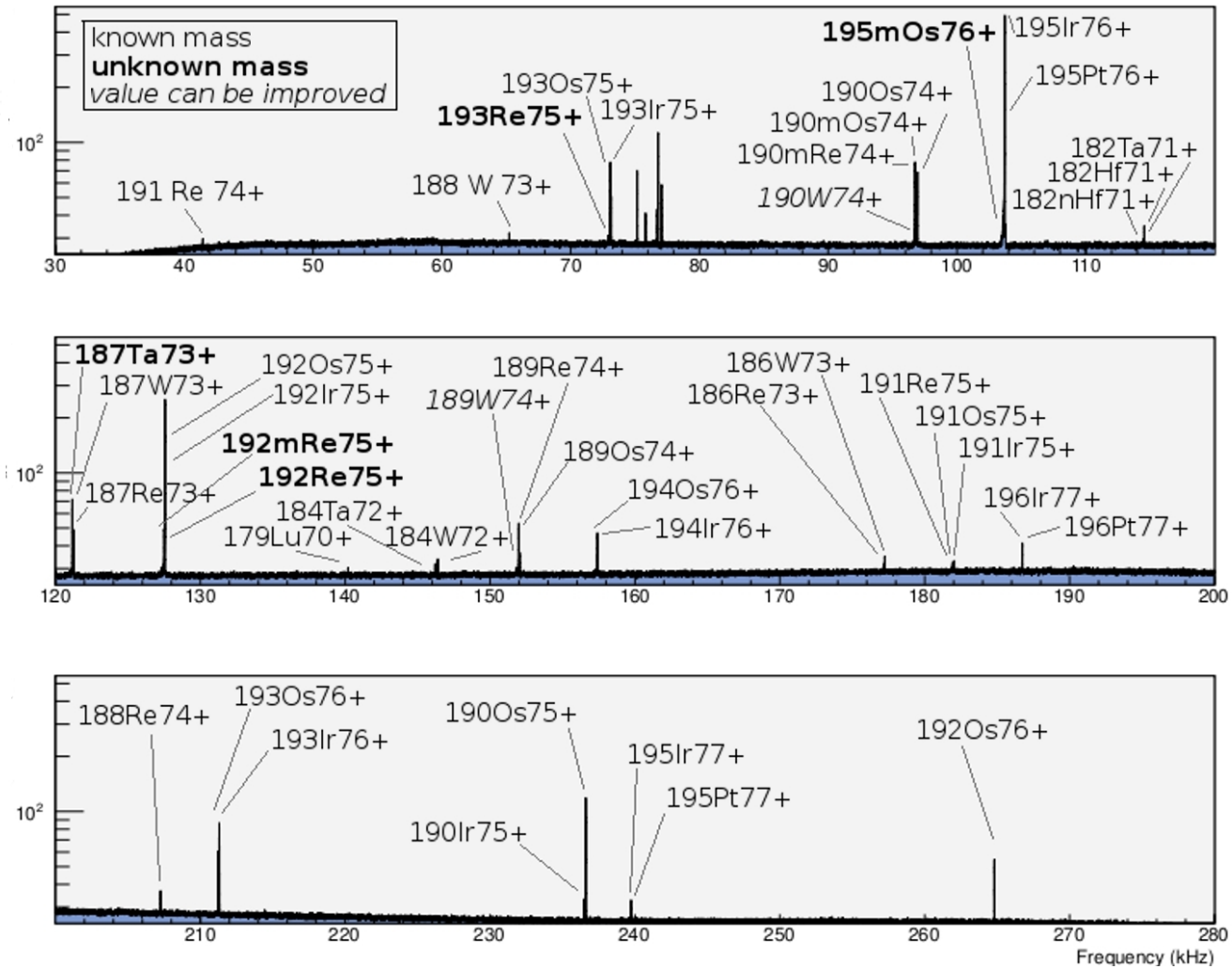




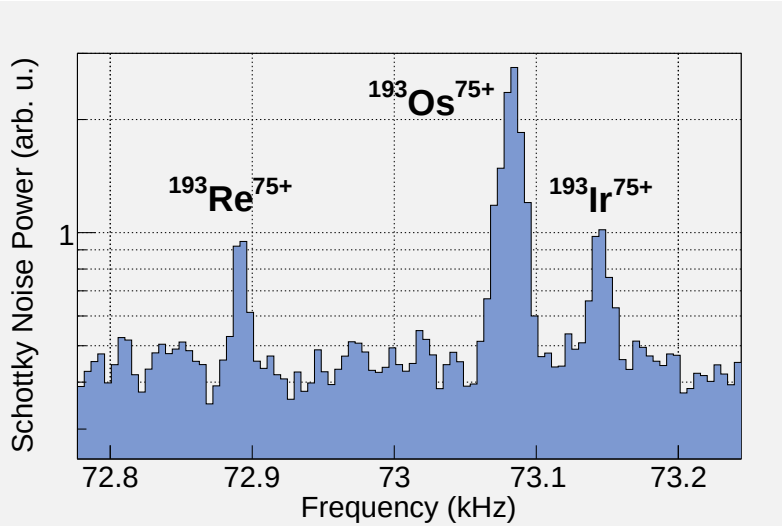
Identification



Mass Evaluation

Relationship between frequency, mass-to-charge ratio and velocity:

$$\frac{\Delta f}{f} = -\frac{1}{\gamma_t^2}\frac{\Delta \frac{m}{q}}{\frac{m}{q}} + \frac{\Delta v}{v}\left(1 - \frac{\gamma^2}{\gamma_t^2}\right)$$



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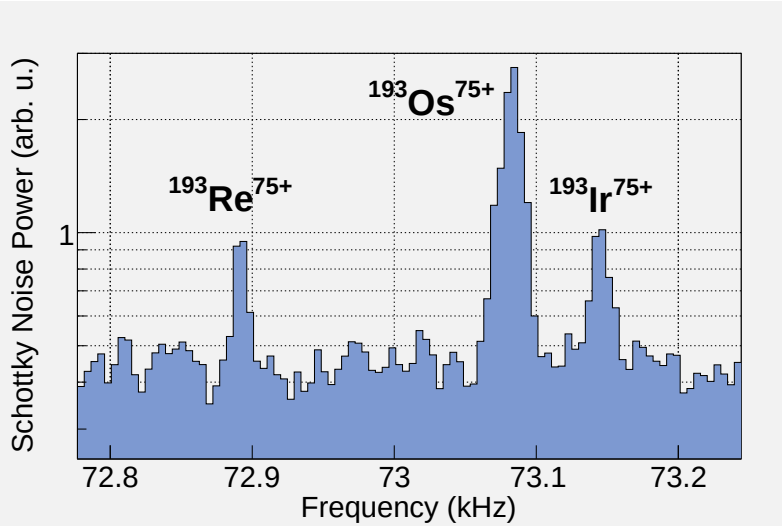

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The mean velocity of cooled ions is identical:

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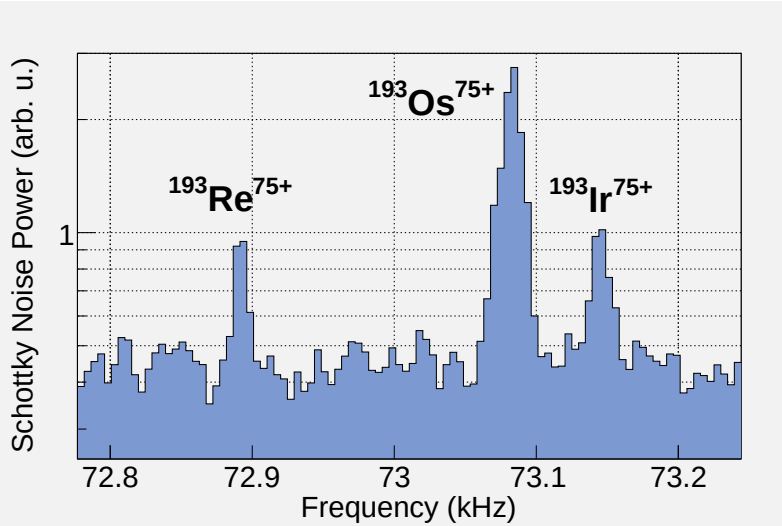

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Revolution frequency depends on the mass-to-charge ratio of the ions as:

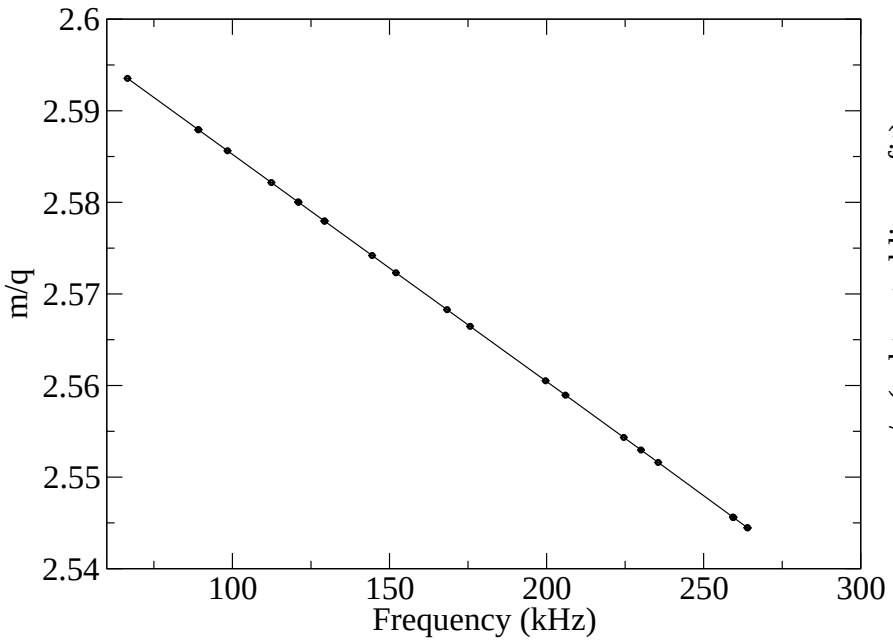
$$\frac{\Delta f}{f} \sim \frac{\Delta \frac{m}{q}}{\frac{m}{q}}$$

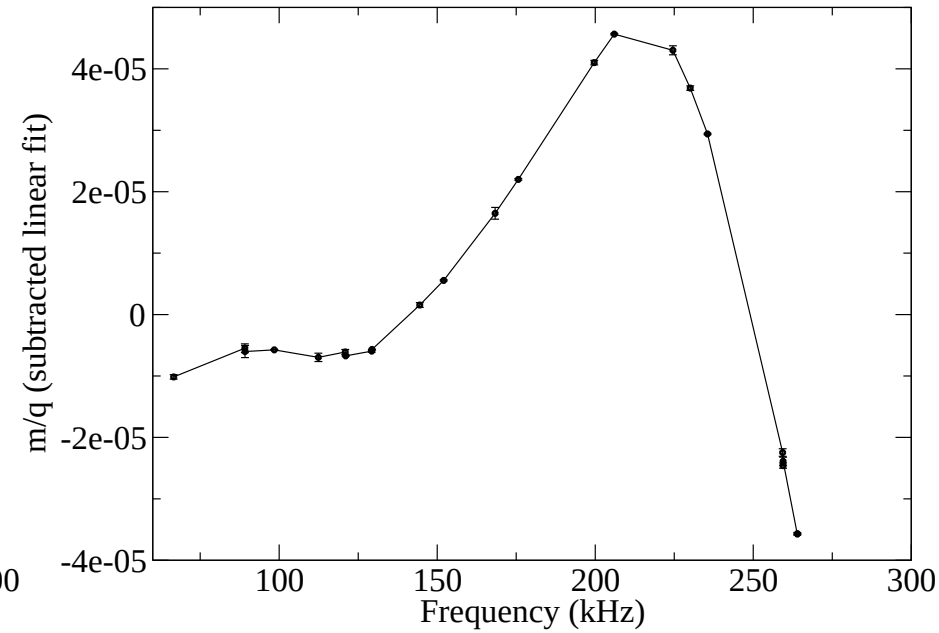
Spline method

$\frac{m}{q} = \frac{m}{q}(f)$

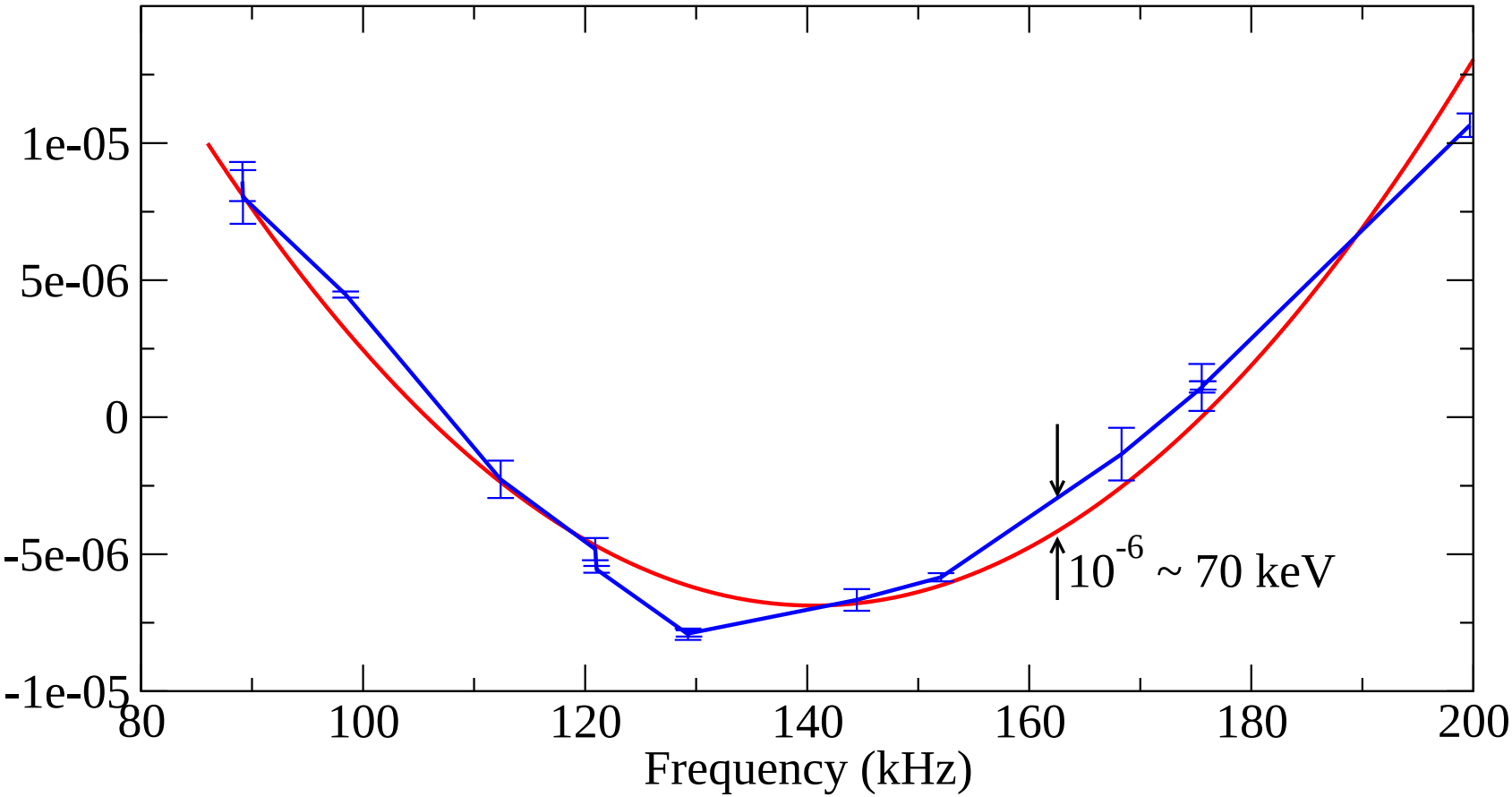
What is this function $\frac{m}{q}(f)$?

In the first order approximation it looks linear. But not in the second.



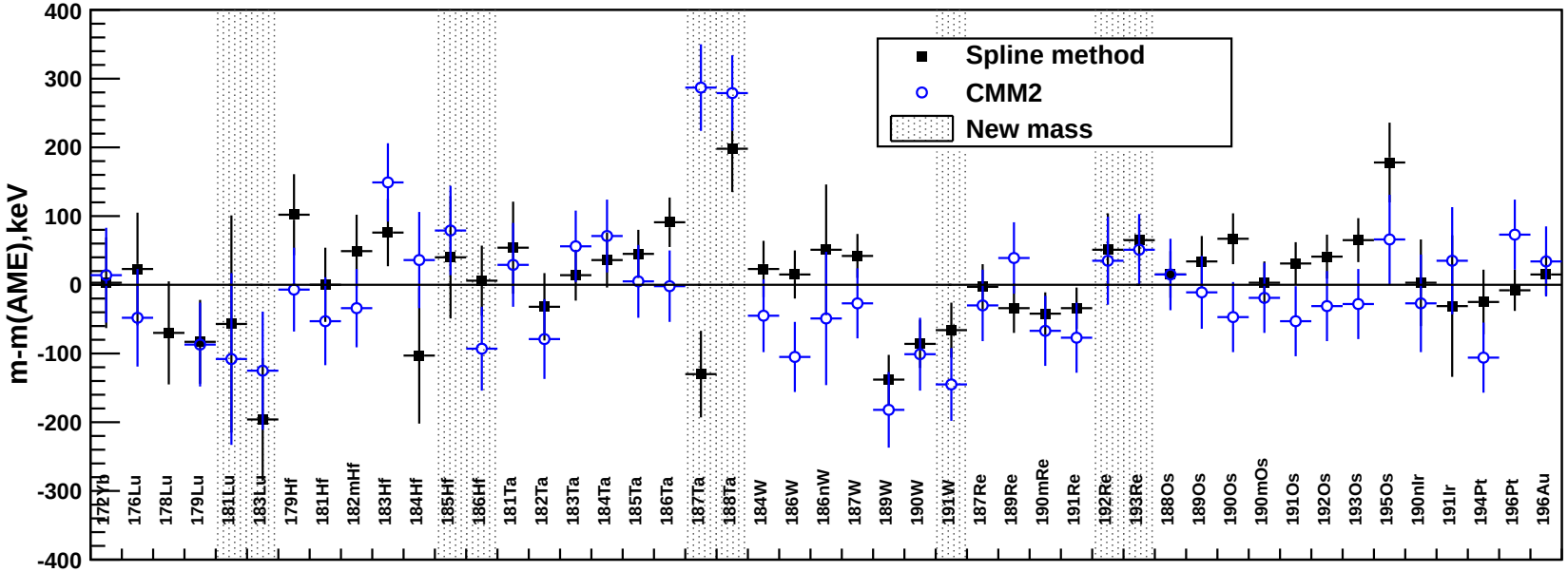


Linear spline vs quadratic polynomial

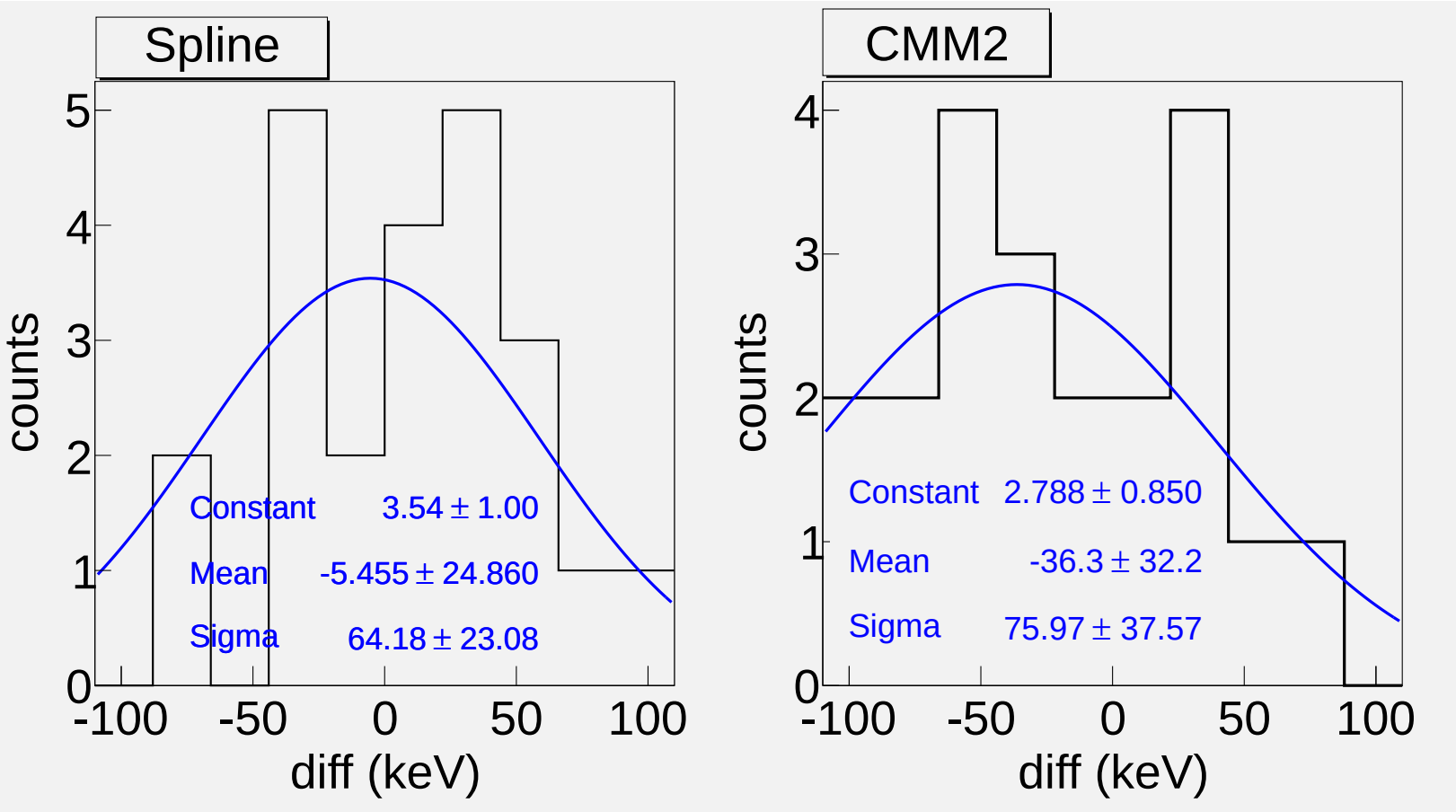


Mass values

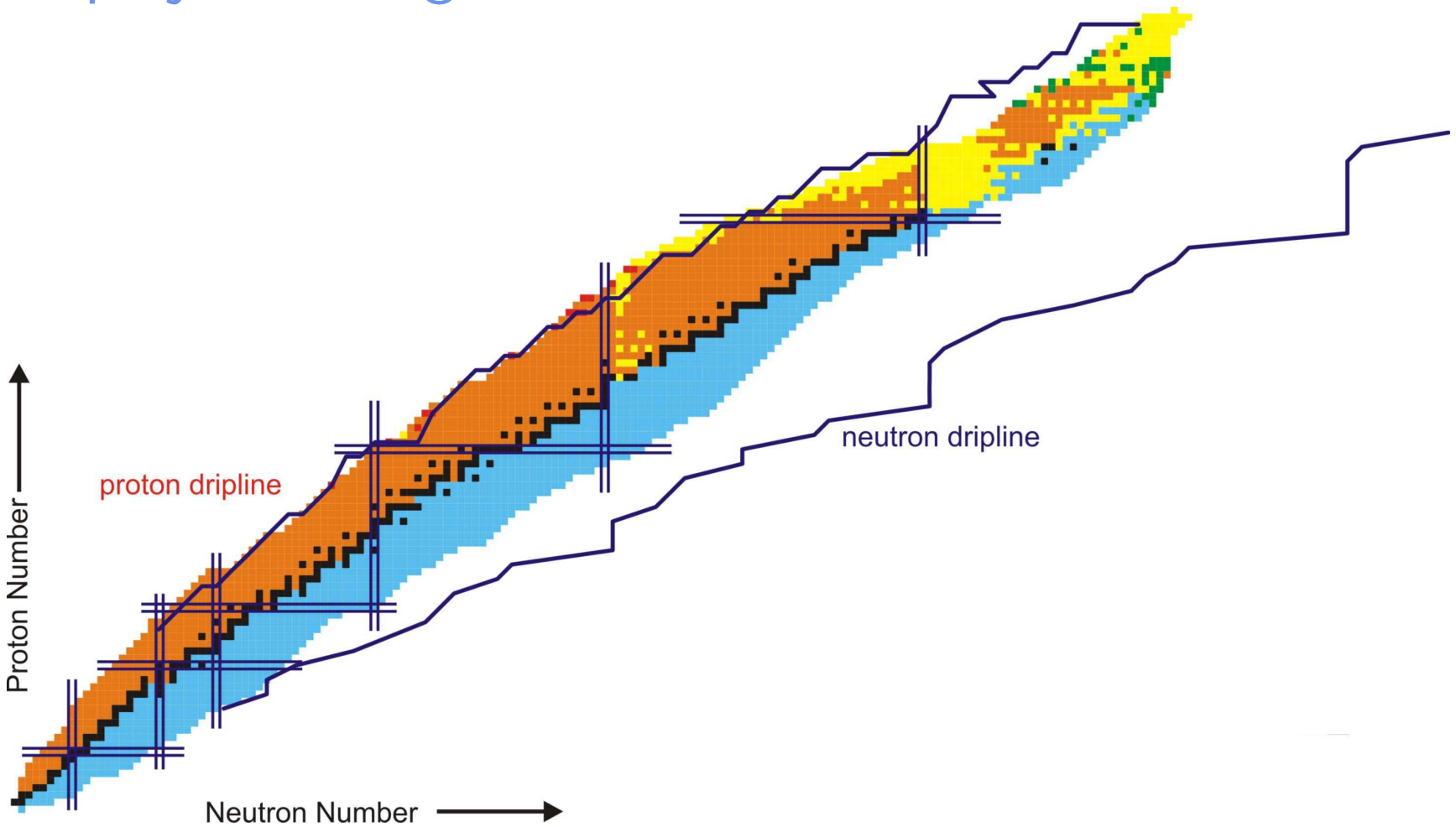
Comparison with the AME-03 table:



Distribution of deviation from AME-03 (only reference masses)



^{197}Au projectile fragments



New discovered isomers: M.W. Reed et al., PRL 105 (2010) 172501

Mass measurements at the ESR: B.Franzke et al., Mass Spectrometry Reviews, 27, 428 (2008)

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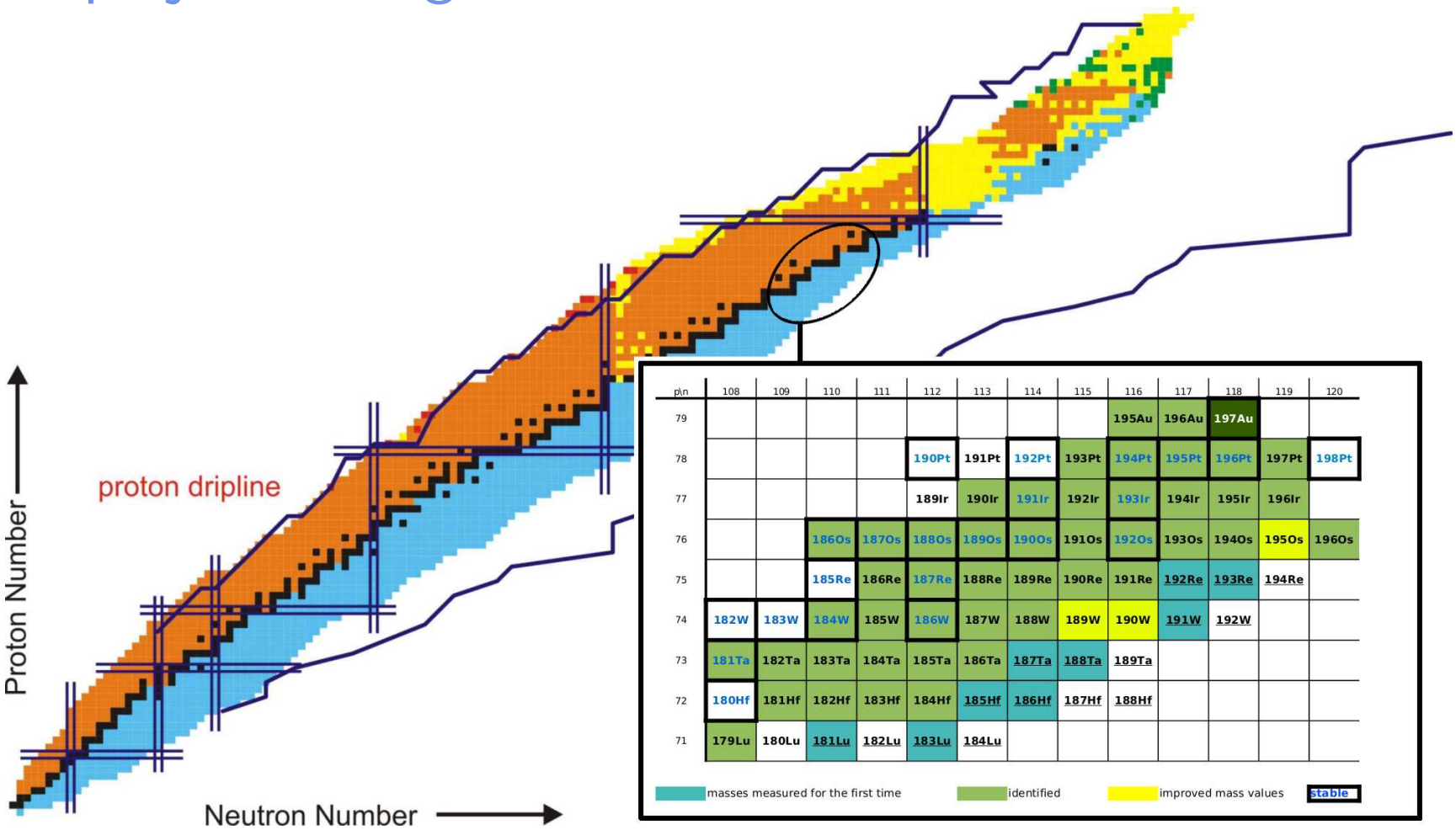

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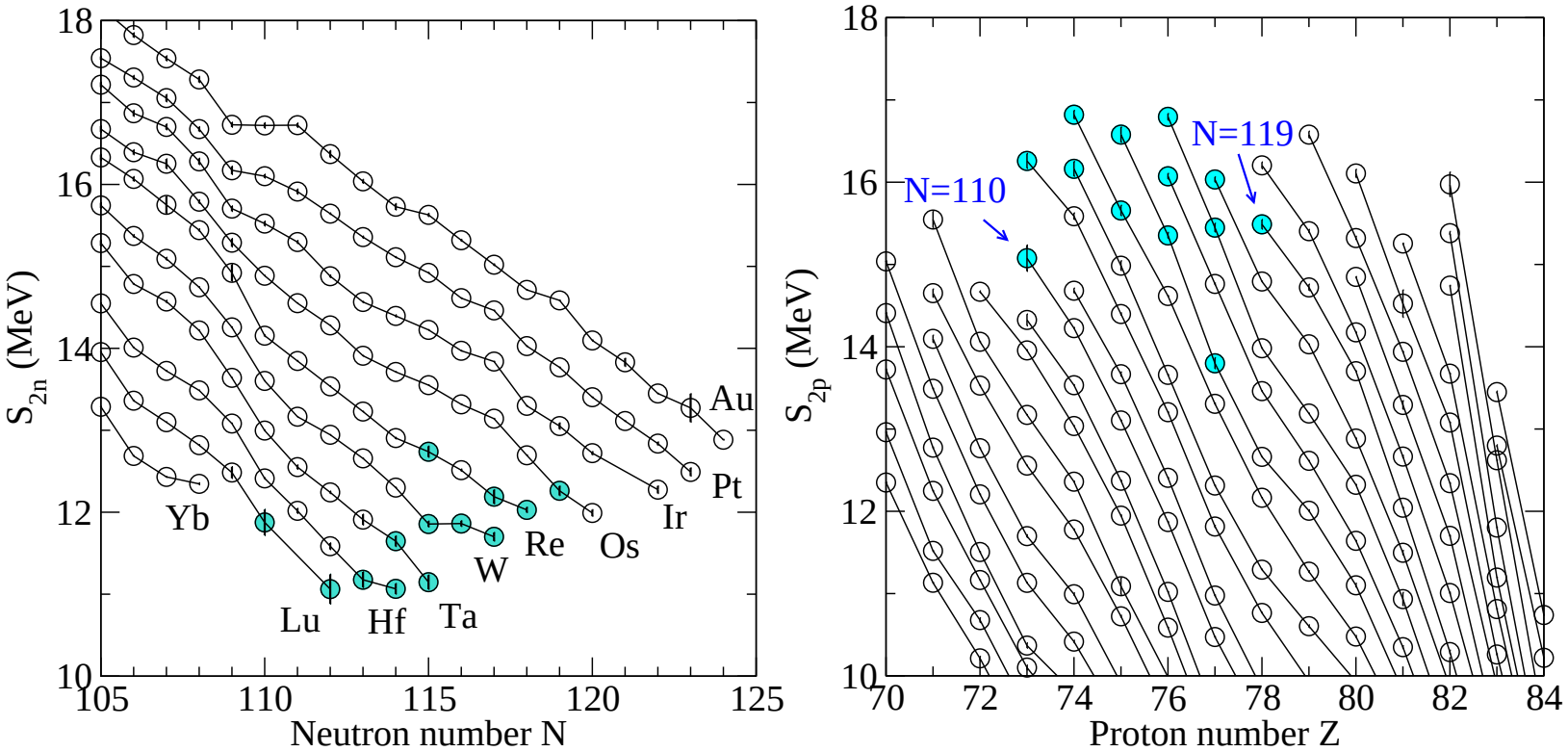
Two-neutron and two-proton separation energies

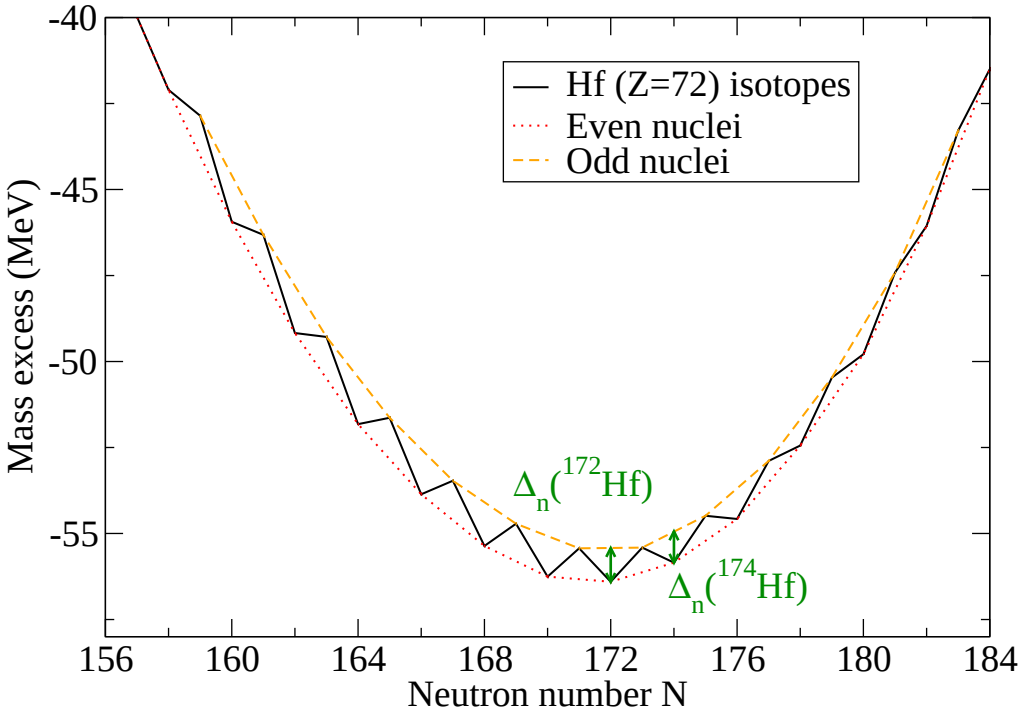
$$S_{2n} = m(Z, N-2) + 2m_n - m(Z, N)$$

$$S_{2p} = m(Z-2, N) + 2m_H - m(Z, N)$$



Pairing-gap energy

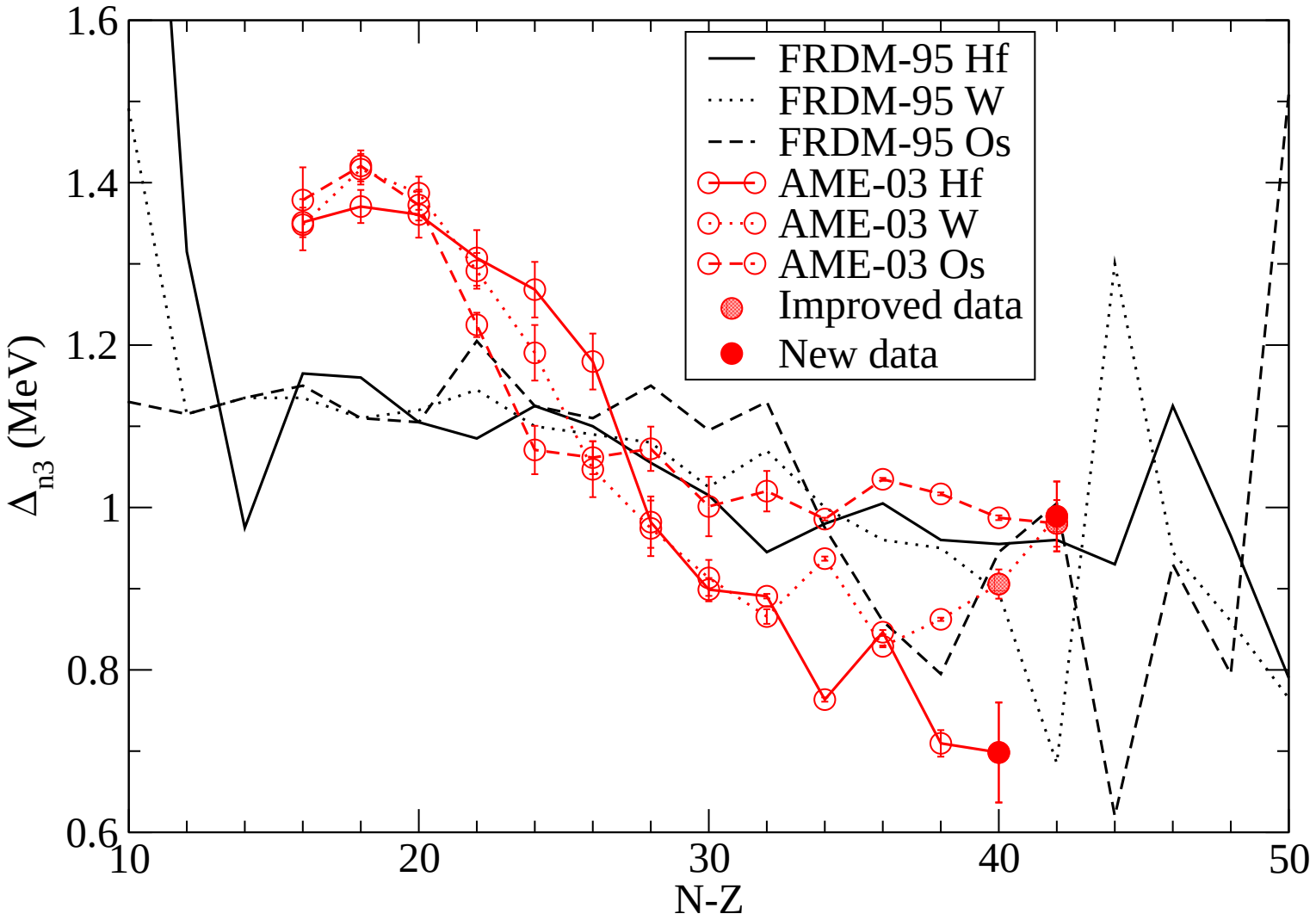
Mass excess: $ME = m(Z, N) - A \cdot u$



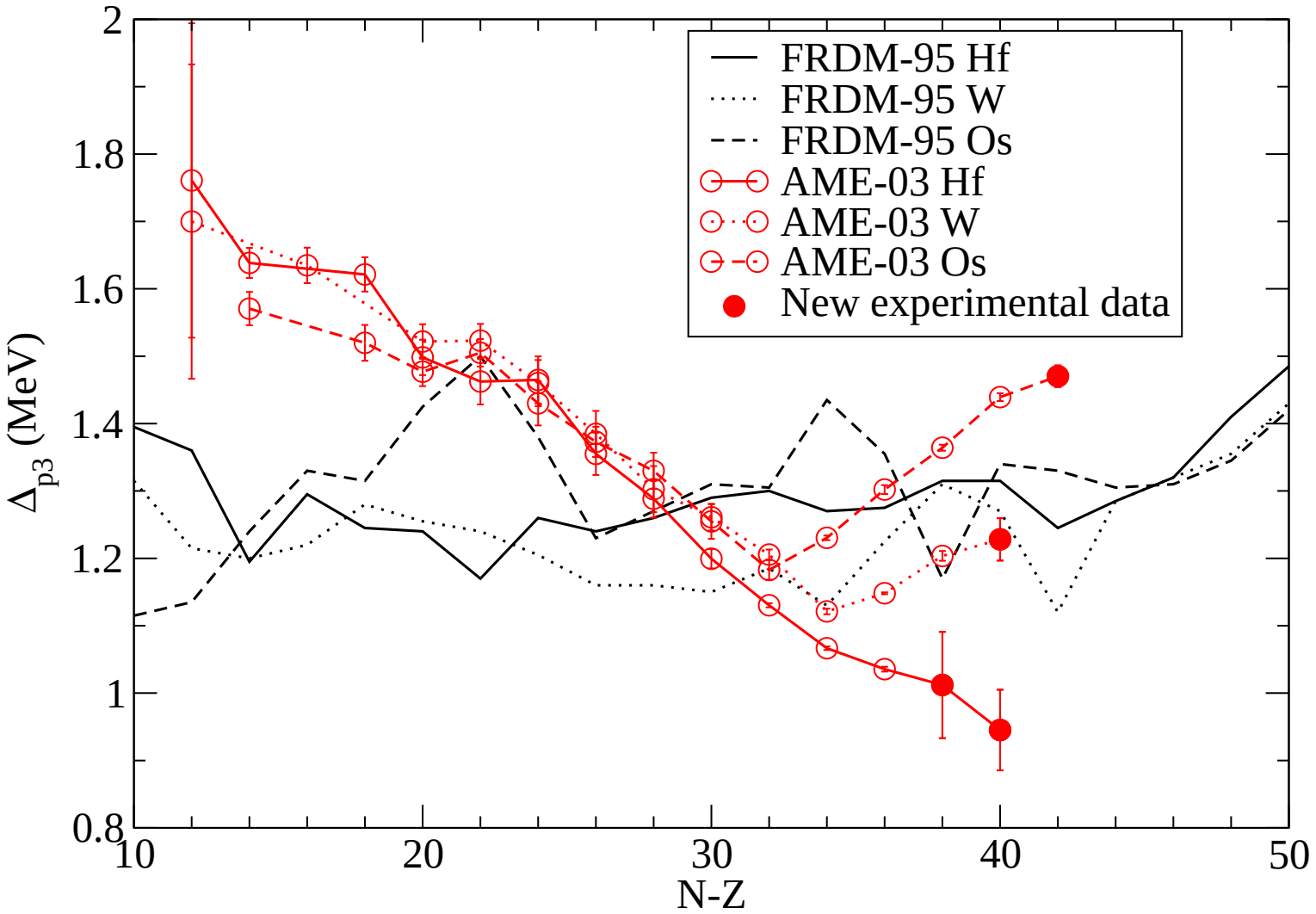
$$\Delta_{n3} = \frac{1}{2}(m(Z, N-1) - 2m(Z, N) + m(Z, N+1))$$

$$\Delta_{p3} = \frac{1}{2}(m(Z-1, N) - 2m(Z, N) + m(Z+1, N))$$

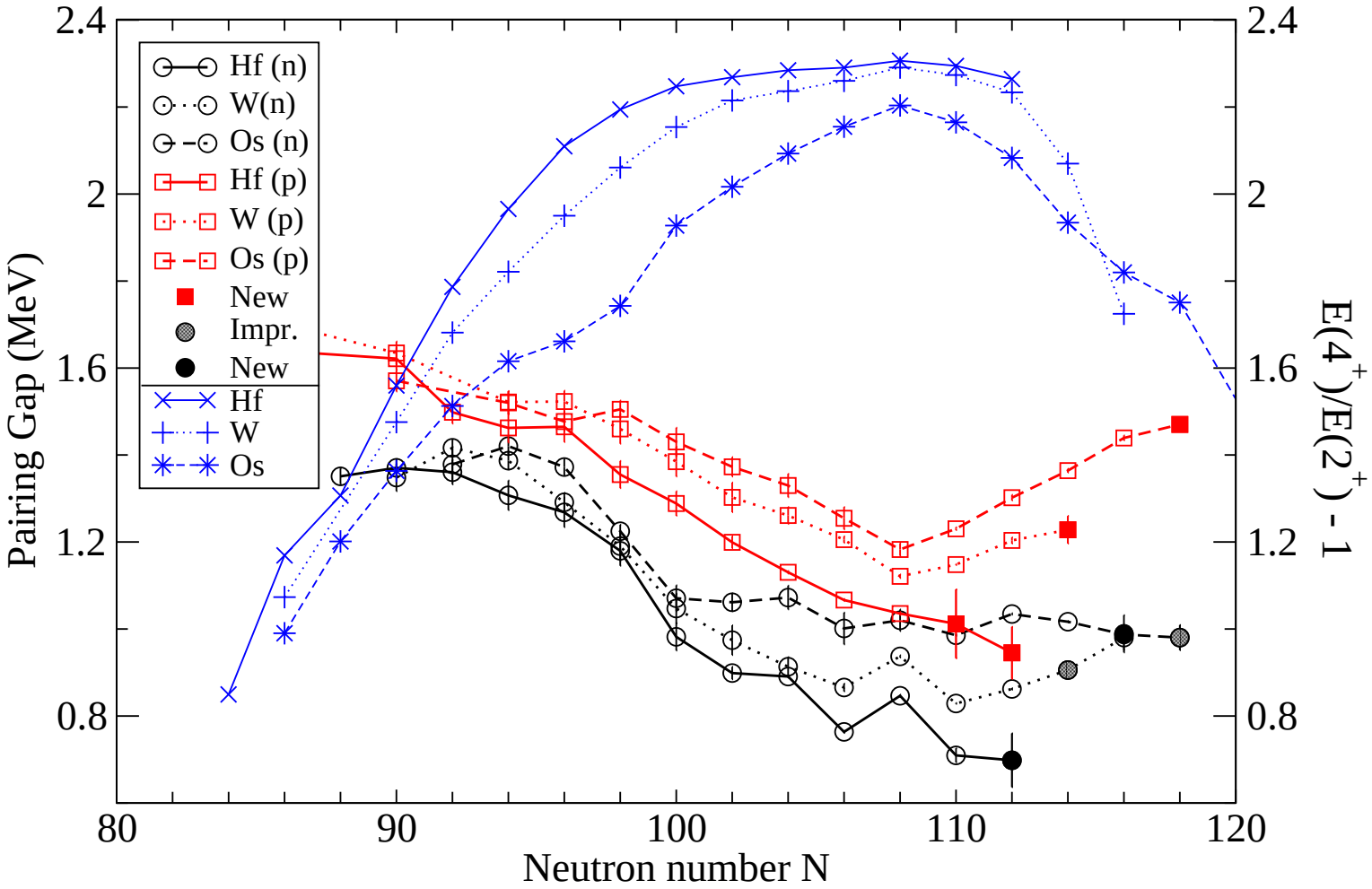
Neutron pairing-gap energies



Proton pairing-gap energies



Comparison with spectroscopic data



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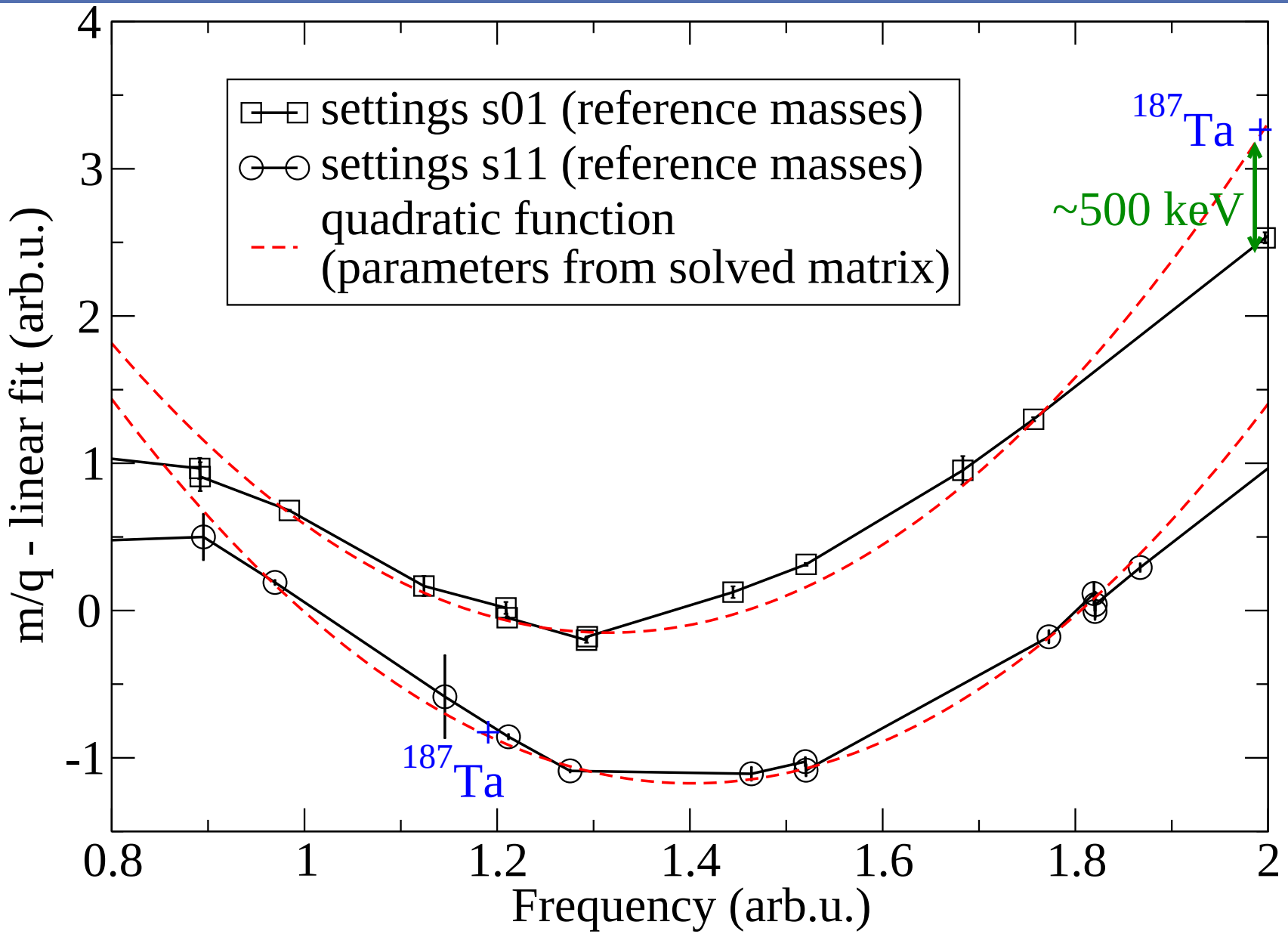
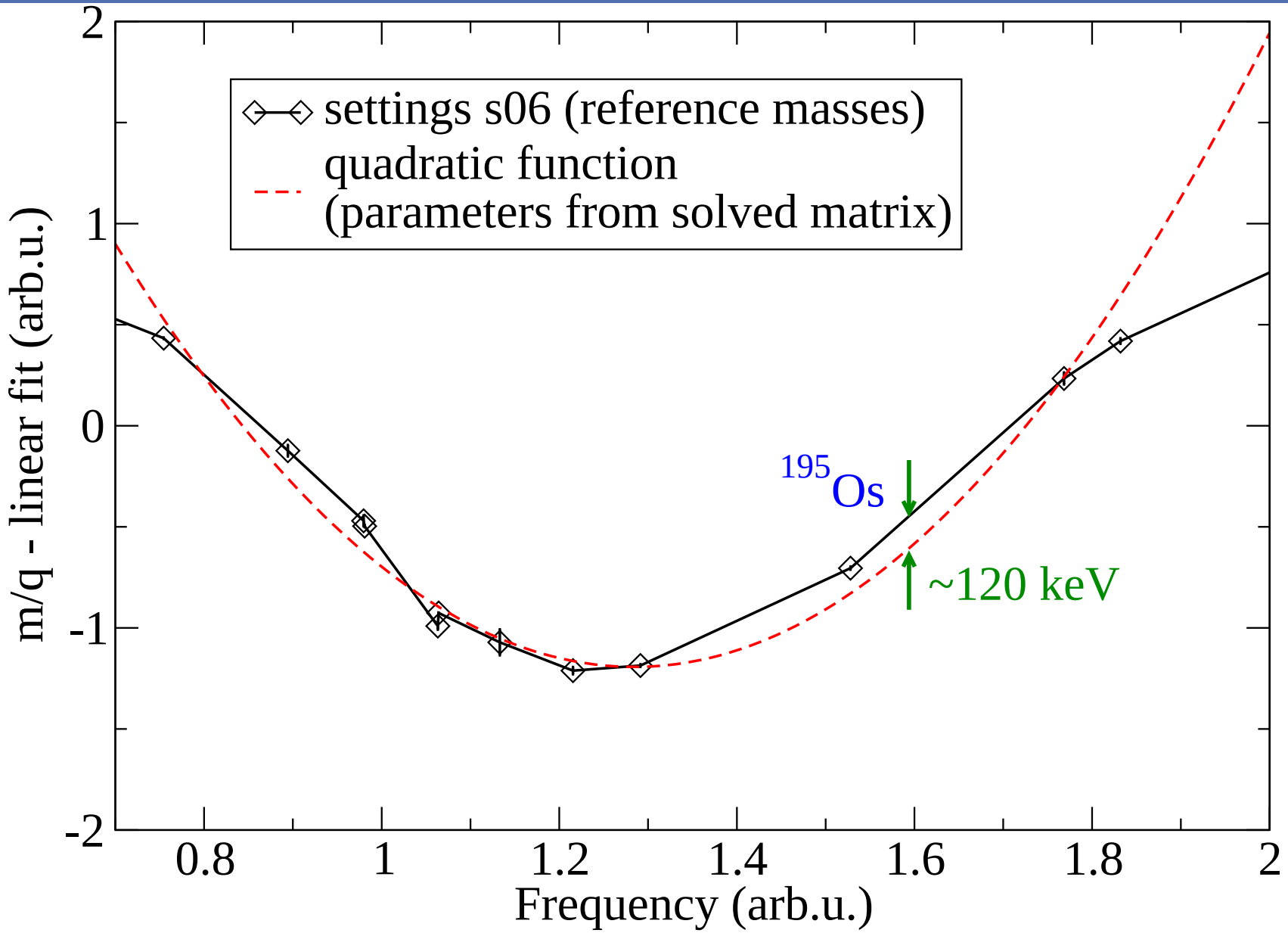
- Masses for 9 nuclides have been measured for the first time
- Masses for 3 nuclides have been improved
- Investigation of deformations in nuclei confirms spectoscopical results: **Hf** isotopes with N=110 and N=112 are still well-deformed, in contrast with **W** and **Os** isotopes, which "turn back" to sphericity at N=108

Thank you for your attention!

K. Blaum, F. Bosch, C. Brandau, R.B. Cakirli, J.J. Carroll, R.F. Casten, D.M. Cullen, I.J. Cullen, A.Y. Deo, B. Detwiler, C. Dimopoulou, F. Farinon, H. Geissel, E. Haettner, M. Heil, R.S. Kempley, R. Knöbel, C. Kozhuharov, J. Kurcewicz, N. Kuzminchuk, S.A. Litvinov, Yu.A. Litvinov, Z. Liu, R. Mao, C. Nociforo, F. Nolden, Z. Patyk, W.R. Plass, A. Prochazka, M.W. Reed, M.S. Sanjari, C. Scheidenberger, M. Steck, Th. Stöhlker, B. Sun, T.P.D. Swan, G. Trees, P.M. Walker, H. Weick, N. Winckler, M. Winkler, P.J. Woods, T. Yamaguchi


settings s01 (reference masses)
settings s11 (reference masses)
quadratic function
(parameters from solved matrix)
187Ta +
~500 keV
187Ta +
m/q - linear fit (arb.u.)
Frequency (arb.u.)
4
3
2
1
0
-1
0.8
1
1.2
1.4
1.6
1.8
2


settings s06 (reference masses)
quadratic function
(parameters from solved matrix)
m/q - linear fit (arb.u.)
Frequency (arb.u.)
195Os
~120 keV
2
1
0
-1
-2
0.8
1
1.2
1.4
1.6
1.8
2