

Masses and beta-decay studies with fast beams

A. Estradé¹

University of Edinburgh¹

2nd workshop on β delayed neutron emission measurements at RIKEN

Nuclear data for the r-process

- BRIKEN:

- β -decay half lives.
- β -decay delayed neutron emission probabilities.

- MBRIKEN:

- BRIKEN + Nuclear masses.

- Fission properties, (n,γ) reaction rates.

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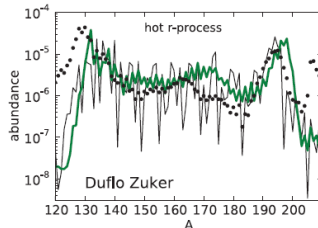
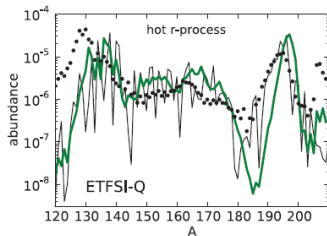
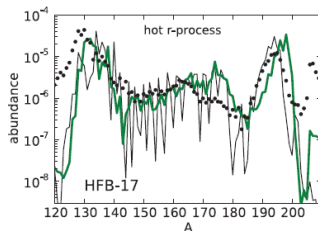
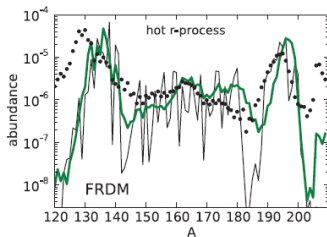
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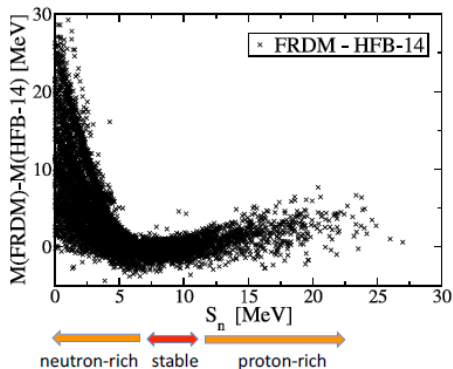
Sensitivity of r-process calculations to nuclear masses



A. Arcones and G. Martinez, PRC , 2011.

see also: S. Brett et al., EPJ A 2012 for sensitivity to single mass values.

Extrapolations of nuclear mass models



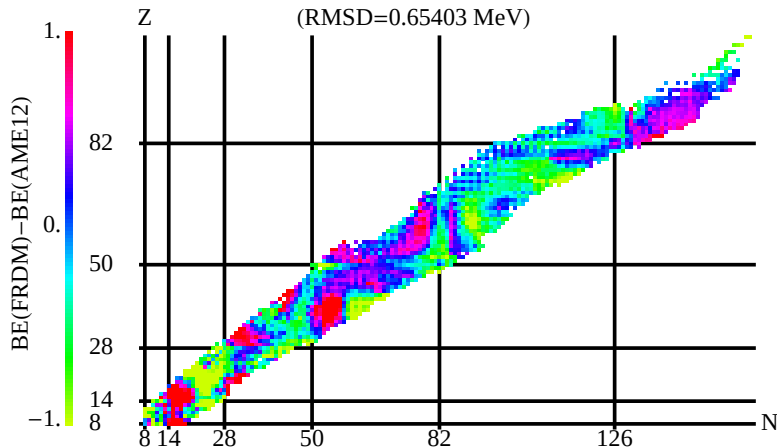
Comparison with experimental data

	FRDM	HFB14
$\sigma(M)$ [keV]	656	729
$\sigma_{nr}(M)$ [keV]	910	833

nr: Exp. masses with $S_n < 5$ MeV

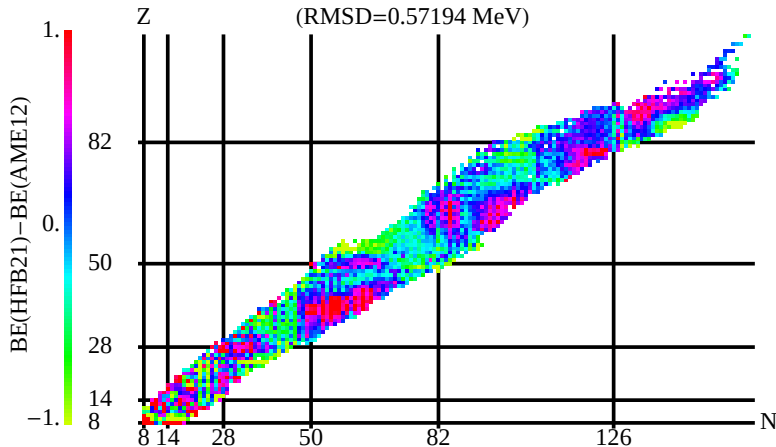
D. Lunney et al, Rev. Mod. Phys., 2003

FRDM vs AME2012



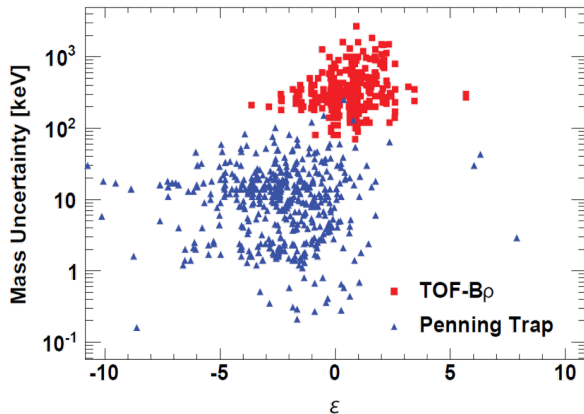
Courtesy: J. Mendoza Temis

HFB21 vs AME2012



Courtesy: J. Mendoza Temis

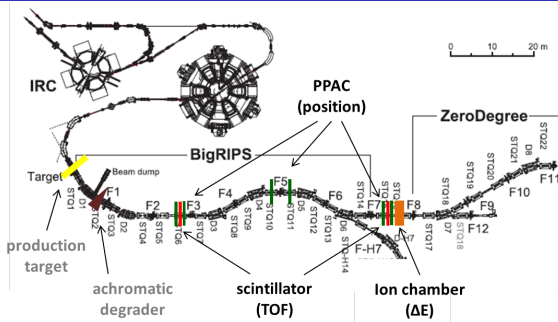
Comparison of mass measurement techniques



$$\text{Exoticity: } \epsilon = \log_{10} \left(\frac{\delta N_{\text{stab.}}}{\tau_{1/2} \cdot \delta N_{\text{drip}}} \right)$$

Courtesy: Z. Meisel and S. George.

Time-of-flight mass measurements with BigRIPS



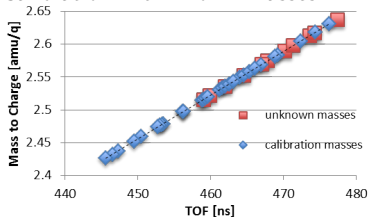
CCSD stack
(β -decay)

$$B\rho = \gamma v \left(\frac{m}{q} \right) = \gamma \left(\frac{TOF}{L} \right) \left(\frac{m}{q} \right)$$

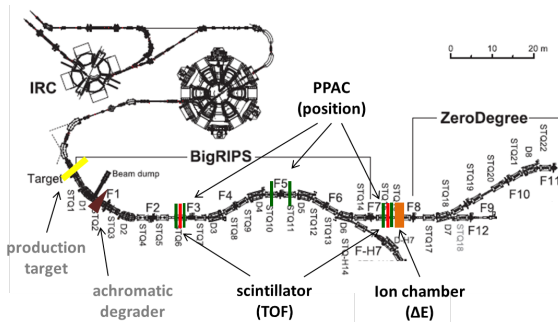
In practice need calibration function:

$$\frac{m}{q} = f(TOF, B\rho, Z, A)$$

Calibration with known masses:

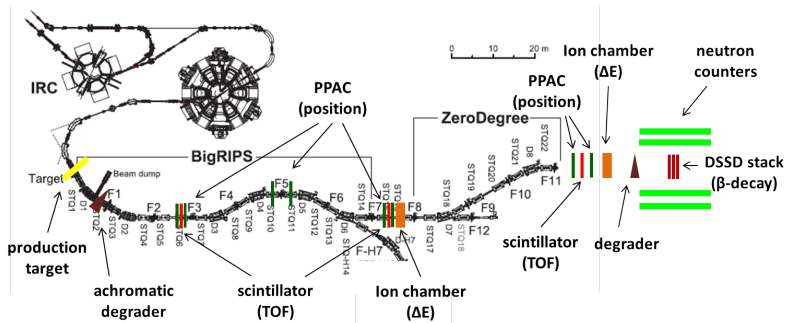


Time-of-flight mass measurements with BigRIPS



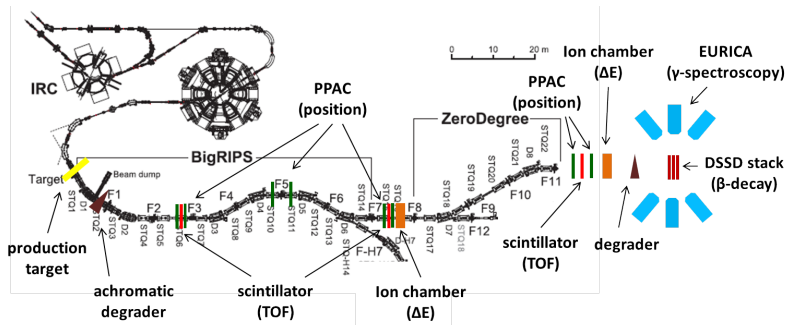
- **Mass resolution:** $\frac{\delta m}{m} \leq 3.5 \times 10^{-4}$ (beam test Dec. 2012; N. Fukuda, T. Kubo et al.)
- **Mass accuracy:** need few $\times 10^{-6}$.
 - BigRIPS test under analysis.
 - Setup at NSCL (M.Matos et al., NIMA 2012):
 $\sigma_{\text{sys.}} = 5.3 \text{ keV}/q$ (i. e. 180 keV for $Z=35$)

MBRIKEN: Masses + β -decay studies at RIKEN



- Reference isotopes: $\approx 20\%$ of run time less neutron-rich setting (thin target; Nuclear Technologies? D. Cano Ott).
- Big RIPS setting with wide acceptance in Z , A/Z .
- Minimize systematic effects on TOF.

MBRIKEN: Masses + β -decay studies at RIKEN



Proposal combining TOF masses with β -decay spectroscopy (EURICA) accepted in latest PAC meeting (June 2013).

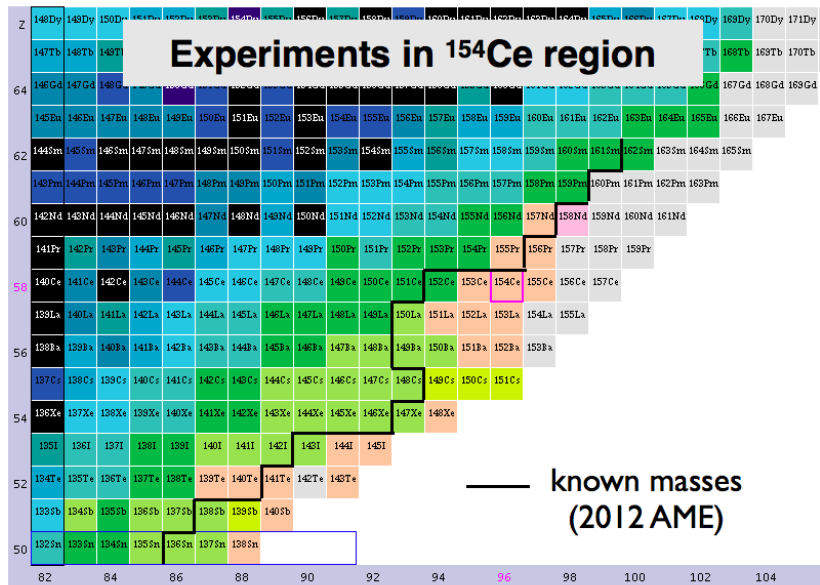
Masses and β -decay properties of r-process nuclei around N=56

89 Zr	90 Zr	91 Zr	92 Zr	93 Zr	94 Zr	95 Zr	96 Zr	97 Zr	98 Zr	99 Zr	100 Zr	101 Zr	102 Zr	103 Zr	104 Zr	105 Zr	106 Zr	107 Zr	108 Zr	109 Zr	110 Zr
88 Y	89 Y	90 Y	91 Y	92 Y	93 Y	94 Y	95 Y	96 Y	97 Y	98 Y	99 Y	100 Y	101 Y	102 Y	103 Y	104 Y	105 Y	106 Y	107 Y	108 Y	109 Y
87 Sr	88 Sr	89 Sr	90 Sr	91 Sr	92 Sr	93 Sr	94 Sr	95 Sr	96 Sr	97 Sr	98 Sr	99 Sr	100 Sr	101 Sr	102 Sr	103 Sr	104 Sr	105 Sr	106 Sr		108 Sr
86 Rb	87 Rb	88 Rb	89 Rb	90 Rb	91 Rb	92 Rb	93 Rb	94 Rb	95 Rb	96 Rb	97 Rb	98 Rb	99 Rb	100 Rb	101 Rb	102 Rb	103 Rb		105 Rb		107 Rb
85 Kr	86 Kr	87 Kr	88 Kr	89 Kr	90 Kr	91 Kr	92 Kr	93 Kr	94 Kr	95 Kr	96 Kr	97 Kr	98 Kr	99 Kr	100 Kr		102 Kr	103 Kr	104 Kr	105 Kr	106 Kr
84 Br	85 Br	86 Br	87 Br	88 Br	89 Br	90 Br	91 Br	92 Br	93 Br	94 Br	95 Br	96 Br	97 Br		99 Br	100 Br	101 Br	102 Br	103 Br		
83 Se	84 Se	85 Se	86 Se	87 Se	88 Se	89 Se	90 Se	91 Se	92 Se	93 Se	94 Se	95 Se		97 Se	98 Se		100 Se				
82 As	83 As	84 As	85 As	86 As	87 As	88 As	89 As	90 As	91 As	92 As	93 As	94 As	95 As								
81 Ge	82 Ge	83 Ge	84 Ge	85 Ge	86 Ge	87 Ge	88 Ge	89 Ge	90 Ge		92 Ge	93 Ge	94 Ge								
80 Ga	81 Ga	82 Ga	83 Ga	84 Ga	85 Ga	86 Ga	87 Ga		89 Ga	90 Ga											
79 Zn	80 Zn	81 Zn	82 Zn	83 Zn	84 Zn		86 Zn														
78 Cu	79 Cu	80 Cu																			
77 Ni	78 Ni																				

A. Estrade, G. Lorusso, V. Werner, et al. (12th NP-PAC at RIBF)

- 22 new nuclear masses (red+yellow).
- 13 new β -decay half-lives (yellow+green).
- γ -ray spectroscopy for N=56 Ge/Se isotopes (NP1112-RIBF81).

Towards the rare earth peak (C. Domingo's talk)

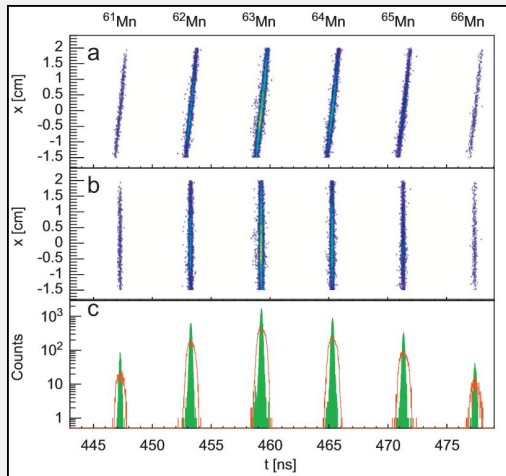
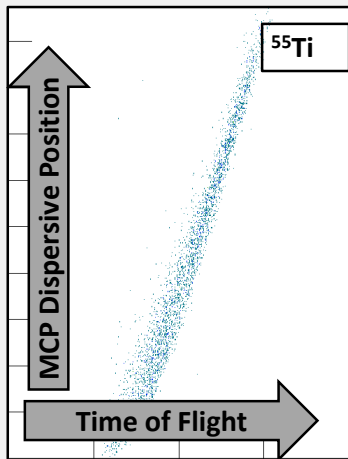


Concluding remarks

- Nuclear data for the r-process! Nuclear data for the r-process!
- TOF mass measurements under development at RIBF (T. Kubo, M. Famiano, et al.).
- First experiment combining β -decay and TOF mass measurements approved by latest NP-PAC.
- Interesting opportunities for symbiosis with BRIKEN (timeline?).

Thank you for your time

Rigidity Correction



M. Matoš et al. NIMA 696, 171 (2012)

Z. Meisel & NSCL TOF Collaboration

Recent Results in Time-of-Flight Mass Measurement

7/31/2013, Slide 10



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