Beginning precision mass measurements at CARIBU with the CPT

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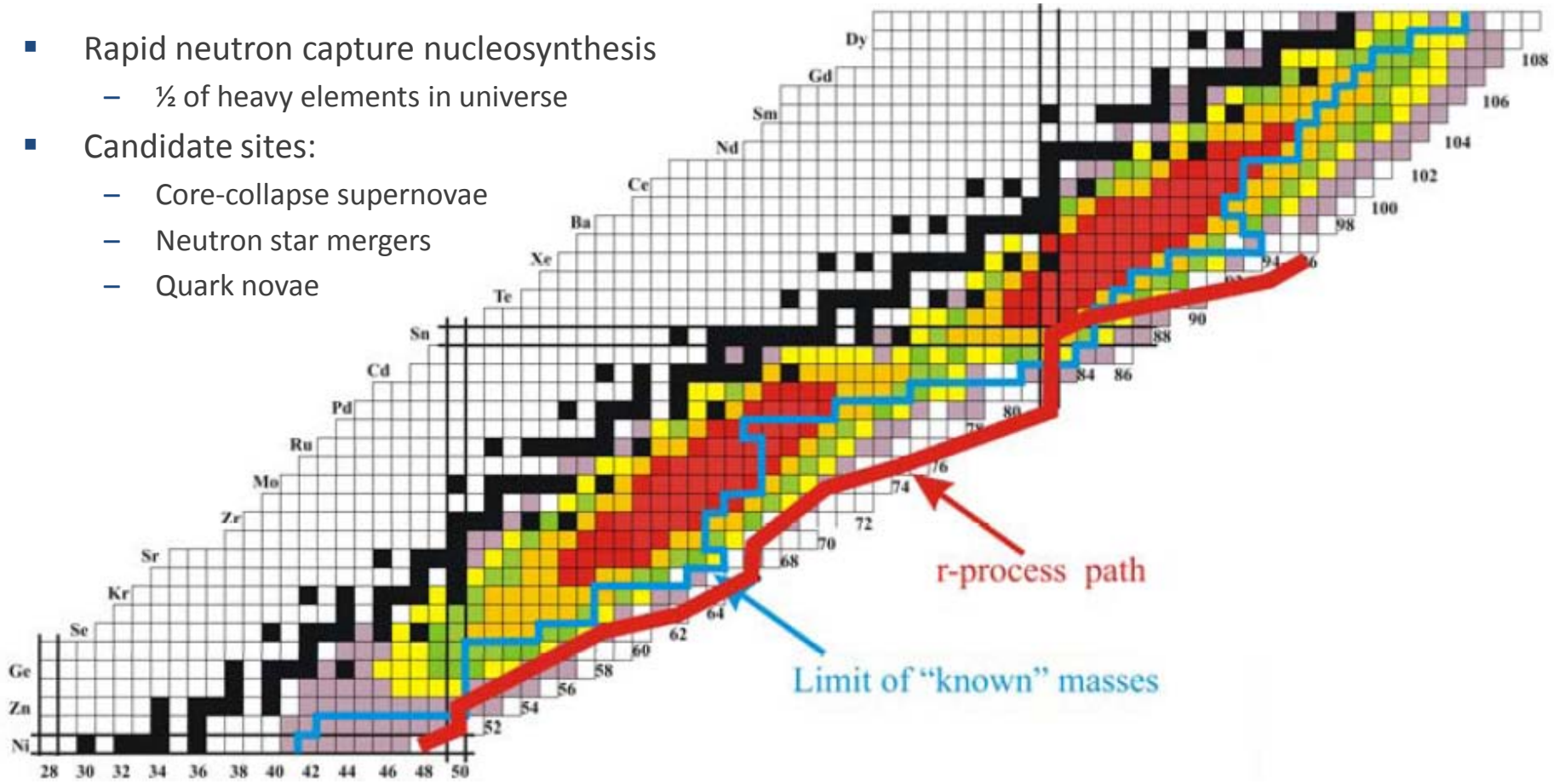
Outline

- Astrophysical r-Process
  - Importance of mass measurements
- Past mass measurements at CPT
  - Differences from mass models
- CARIBU and future mass measurements
  - Data coming soon!

The Astrophysical r-Process

- Rapid neutron capture nucleosynthesis
  - ½ of heavy elements in universe
- Candidate sites:
  - Core-collapse supernovae
  - Neutron star mergers
  - Quark novae



$$\frac{Y(Z,A+1)}{Y(Z,A)} = n_n \left(\frac{2\pi\hbar^2}{m_u kT}\right)^{3/2} \left(\frac{A+1}{A}\right)^{3/2} \frac{G(Z,A+1)}{2G(Z,A)} \exp\left[\frac{S_n(Z,A+1)}{kT}\right]$$

Mass measurements needed to find *r*-process path

$$\overline{S_n} = kT \ln\left[\frac{2}{n_n}\left(\frac{m_u kT}{2\pi\hbar^2}\right)^{3/2}\right]$$

Independent of neutron capture cross-section

For T=1.5 GK, $n_n = 10^{24}$ / cm^3, $S_n \sim 3$ MeV

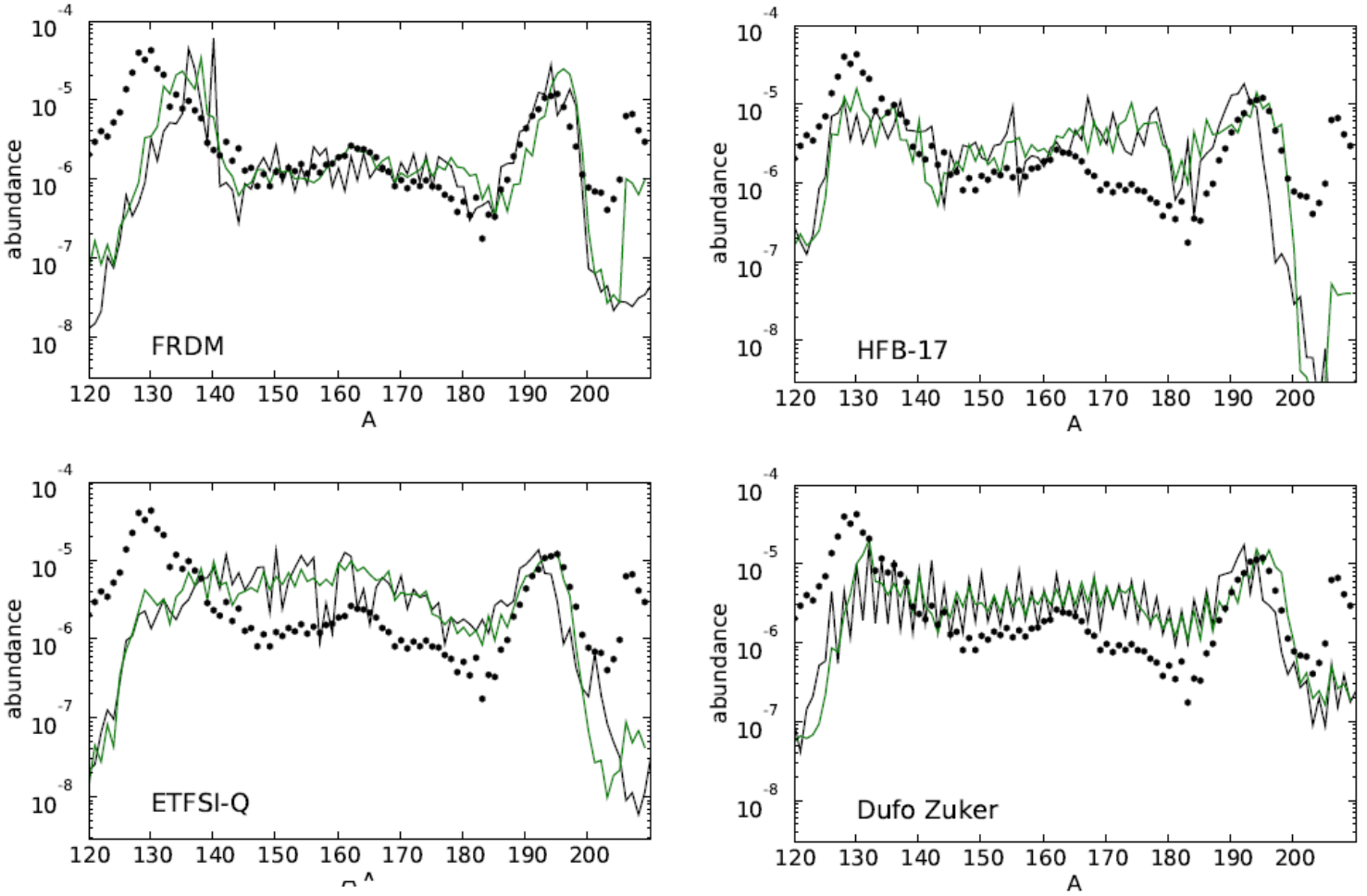
- S_n is the critical parameter that determines the r-process path
- The path determines final elemental abundances
- Mass models have been used due to lack of measurements

- Therefore, we need to measure S_n as far out as possible

Mass measurements!

$$S_n = M(Z,A-1) + M_n - M(Z,A)$$

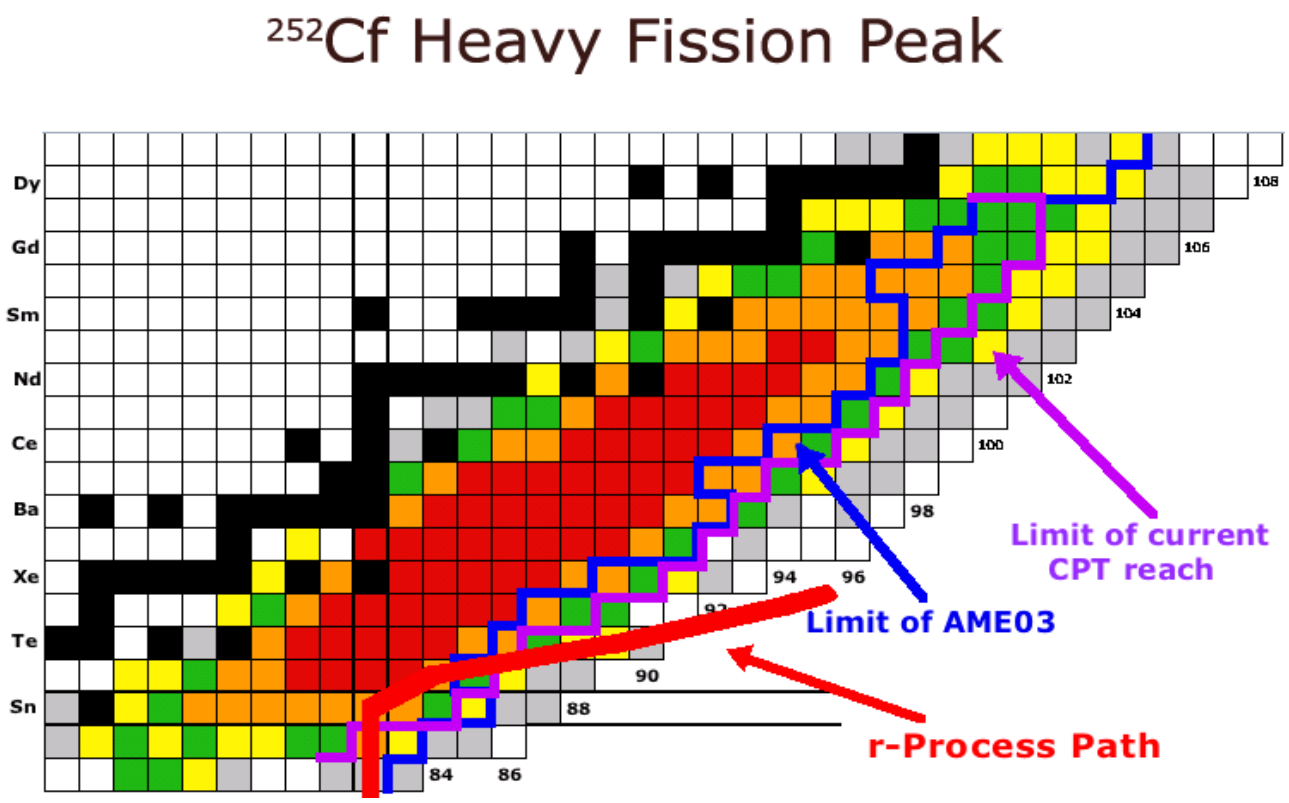
Mass Model Dependence



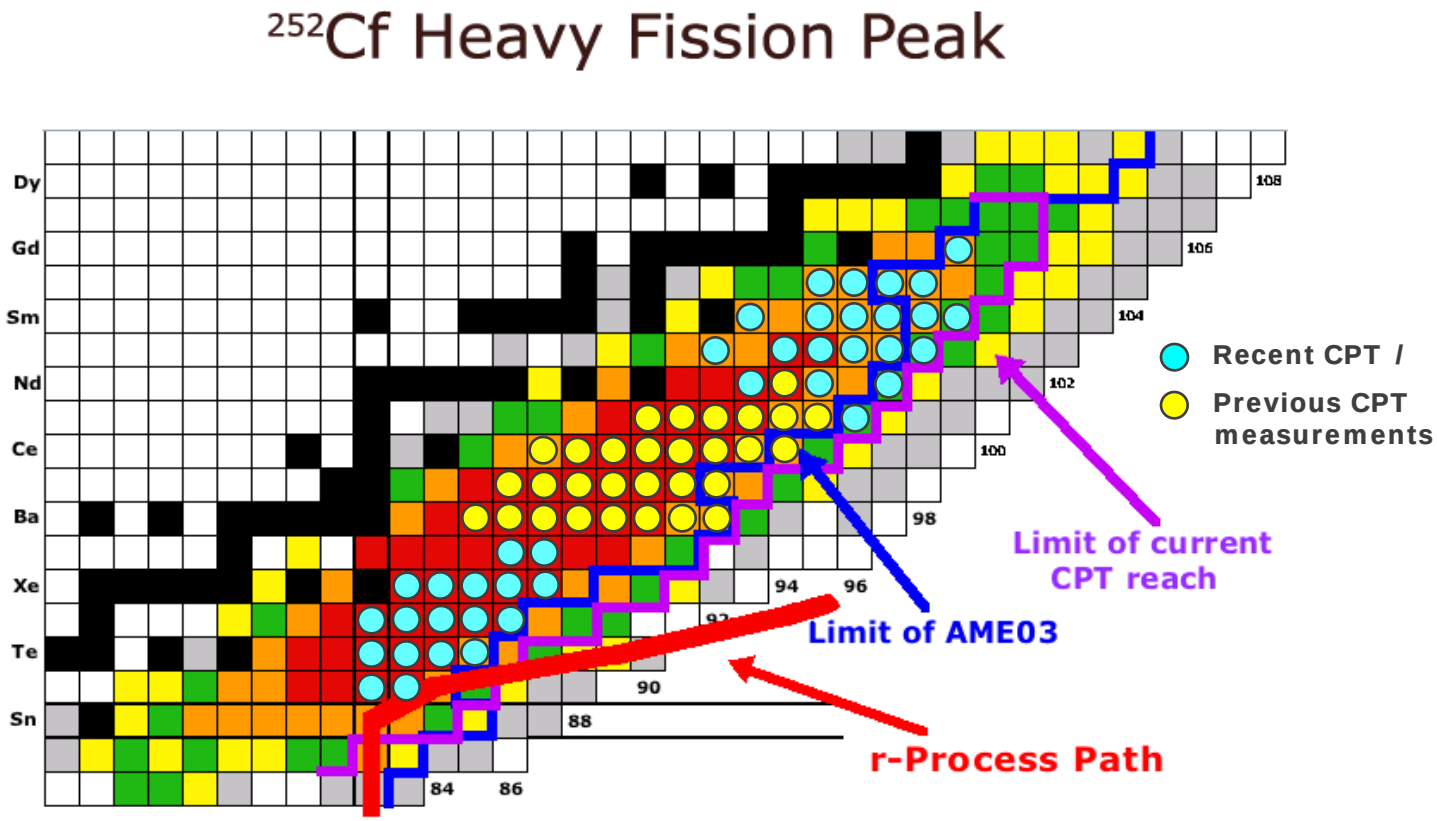
Taken from A. Arcones and G. Martínez-Pinedo, arXiv:1008.3890v1 [astro-ph.SR]

Get real S_n values with the Canadian Penning Trap.

- Target precision ~ 15 keV
  - $\delta m/m \sim 10^{-7}$
- Get nuclei near the r-process path from ^{252}Cf fission fragments.
- CPT system designed to harvest short-lived nuclei (≥100 ms)

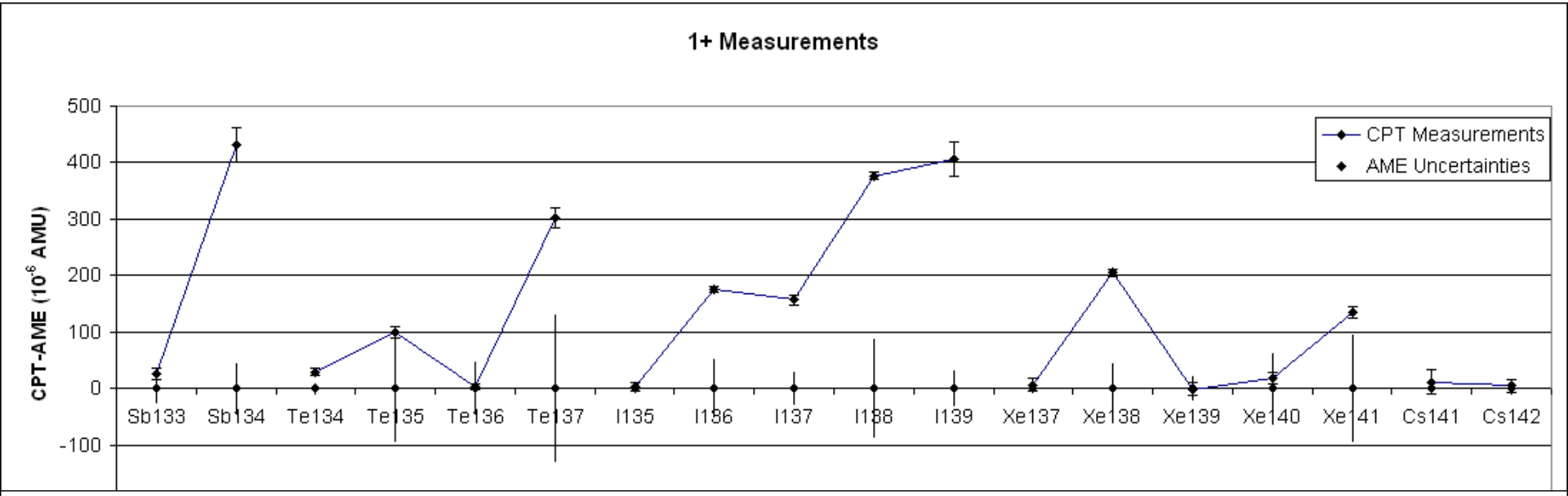


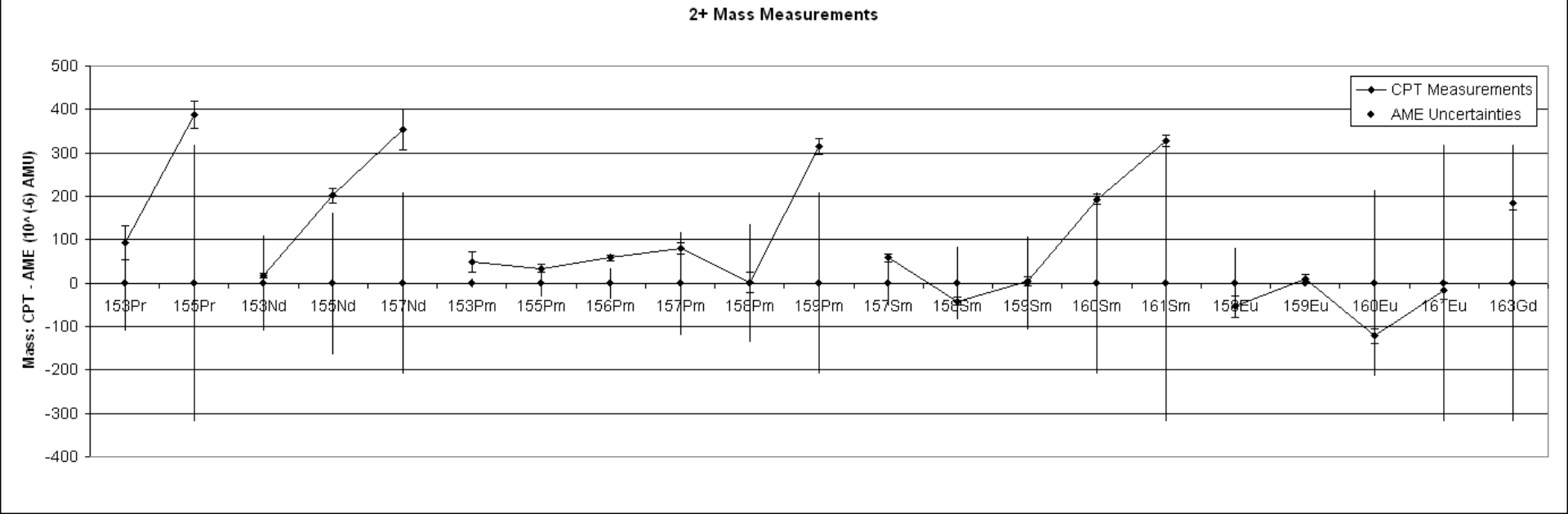
Past CPT Fission Fragment Measurements



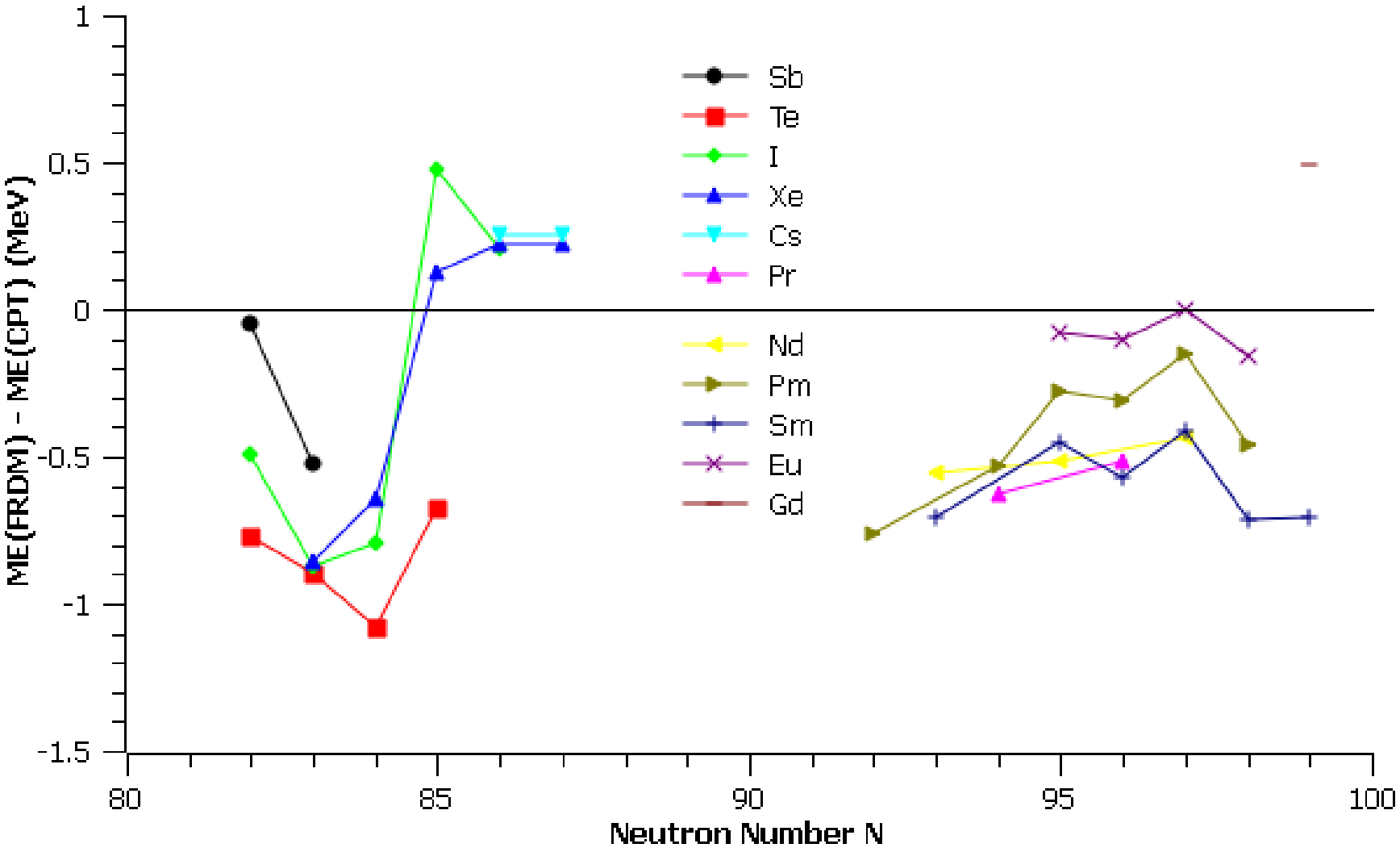
- Ongoing program of measurements since March 2008, using 100 µCi fission source
- Target 15 keV uncertainty ($\delta m/m \sim 10^{-7}$)
- 40 recent species, 20 have never been measured by method other than β-endpoint
- Typically improved precision by factor of 5-10
- Adds to 30 measurements taken at CPT in past years with small gas catcher and source

Comparison of past results to the AME03

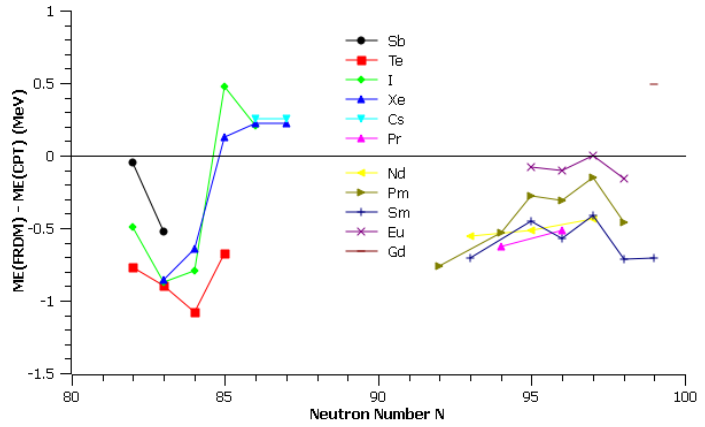


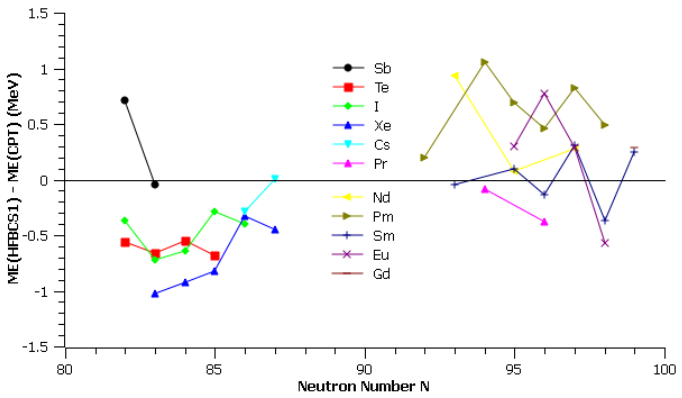


Mass model example: FRDM mass – CPT mass

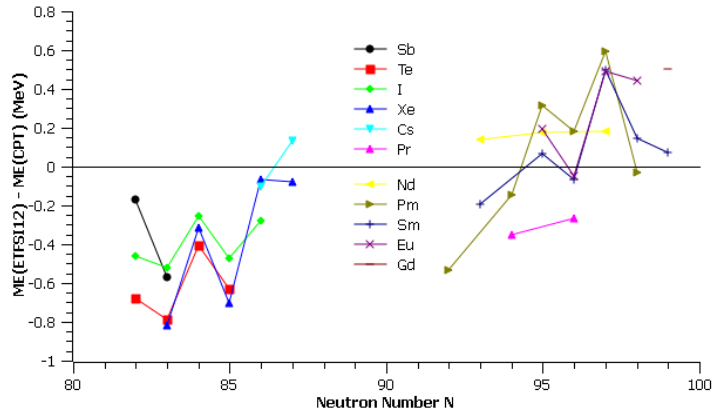


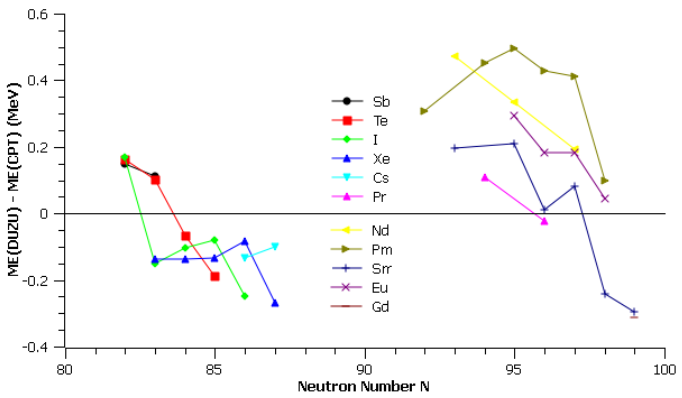
Mass model variance: Mass models - CPT

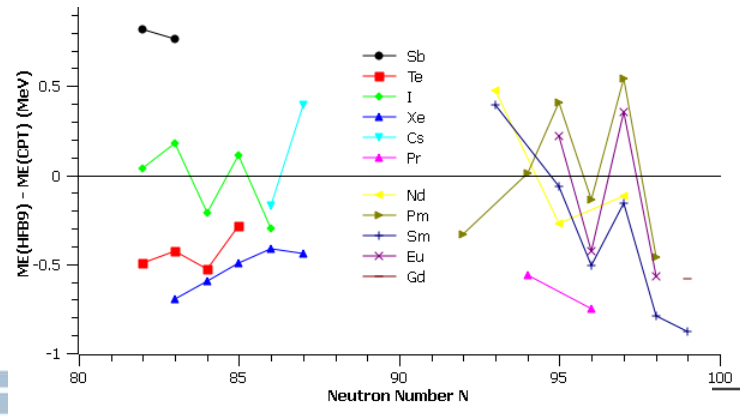


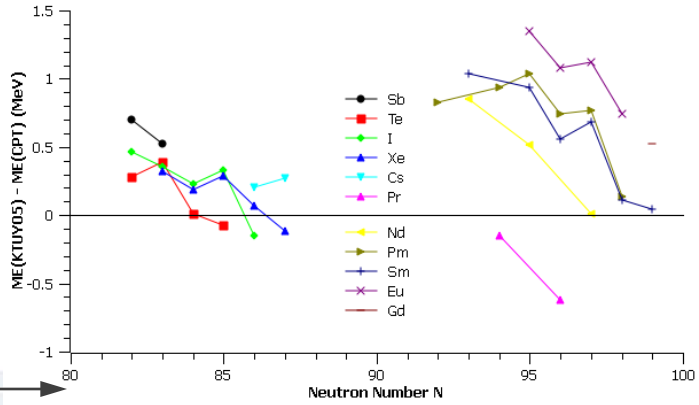


Model – CPT (MeV)



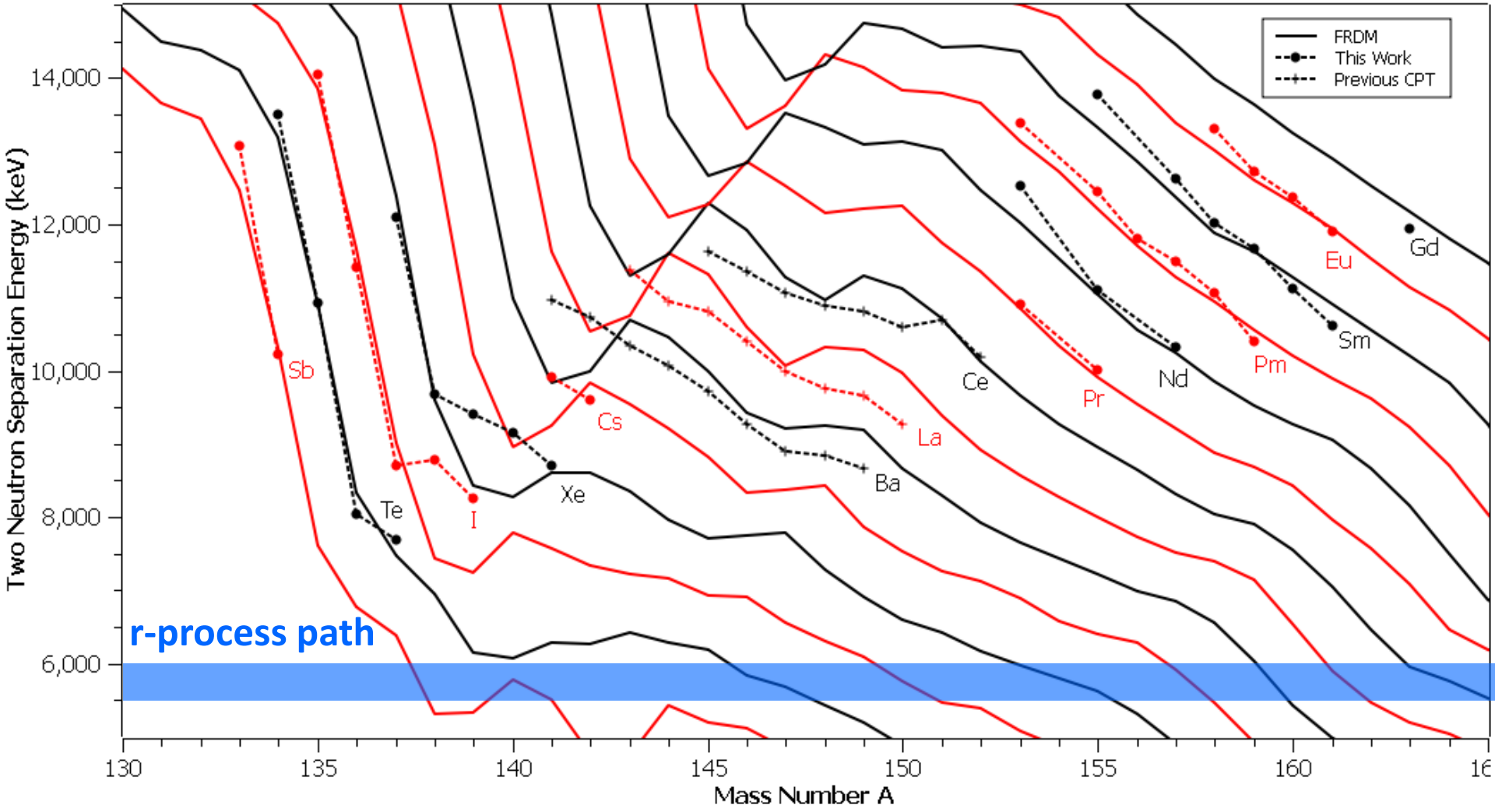






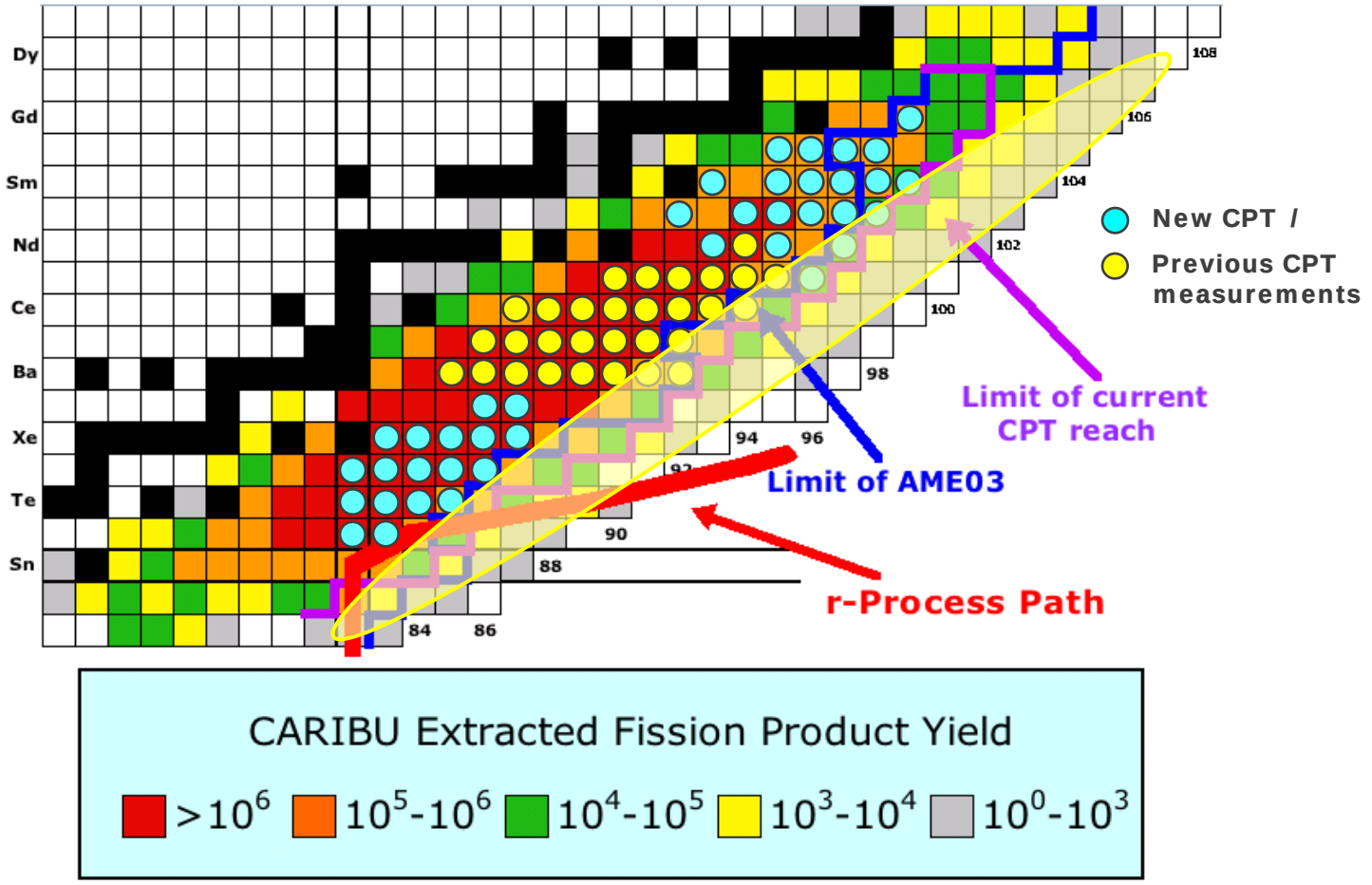
N

Mass model example: CPT S_{2N} vs FRDM S_{2N}



Future work: CPT at CARIBU

- CARIBU at ANL has larger gas catcher and 10,000 x larger fission source.
- Extend measurements 3-5 neutrons out near r-process path (Cd, In, Sn, Sb, Te)
- CARIBU is commissioning successfully - start data collection in days-weeks



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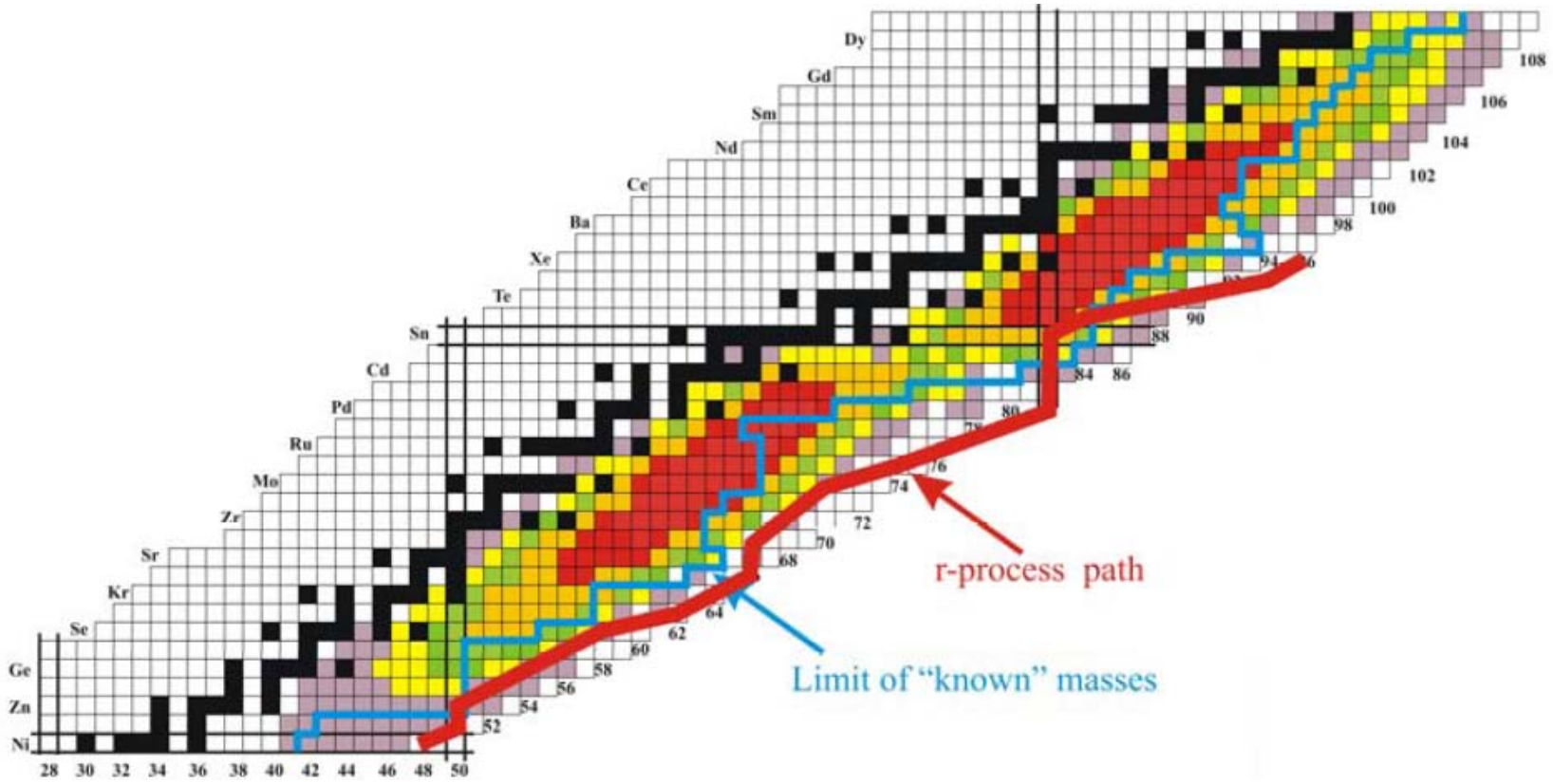

CPT Collaboration

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