Mass measurements of proton-rich nuclides in the region of A=85 and their impact on the rp process

SHIPTRAP, GSI

- Experiment + results
- rp process calculations
- Summary

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11th Symposium on Nuclei in the Cosmos
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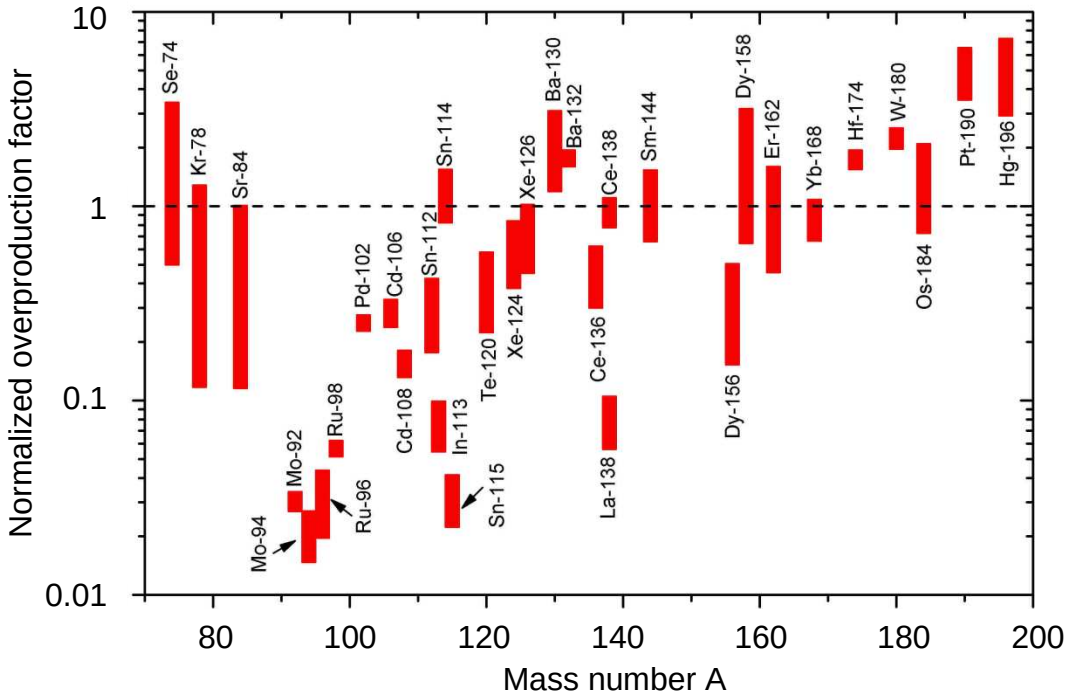
Motivation – why measure masses?

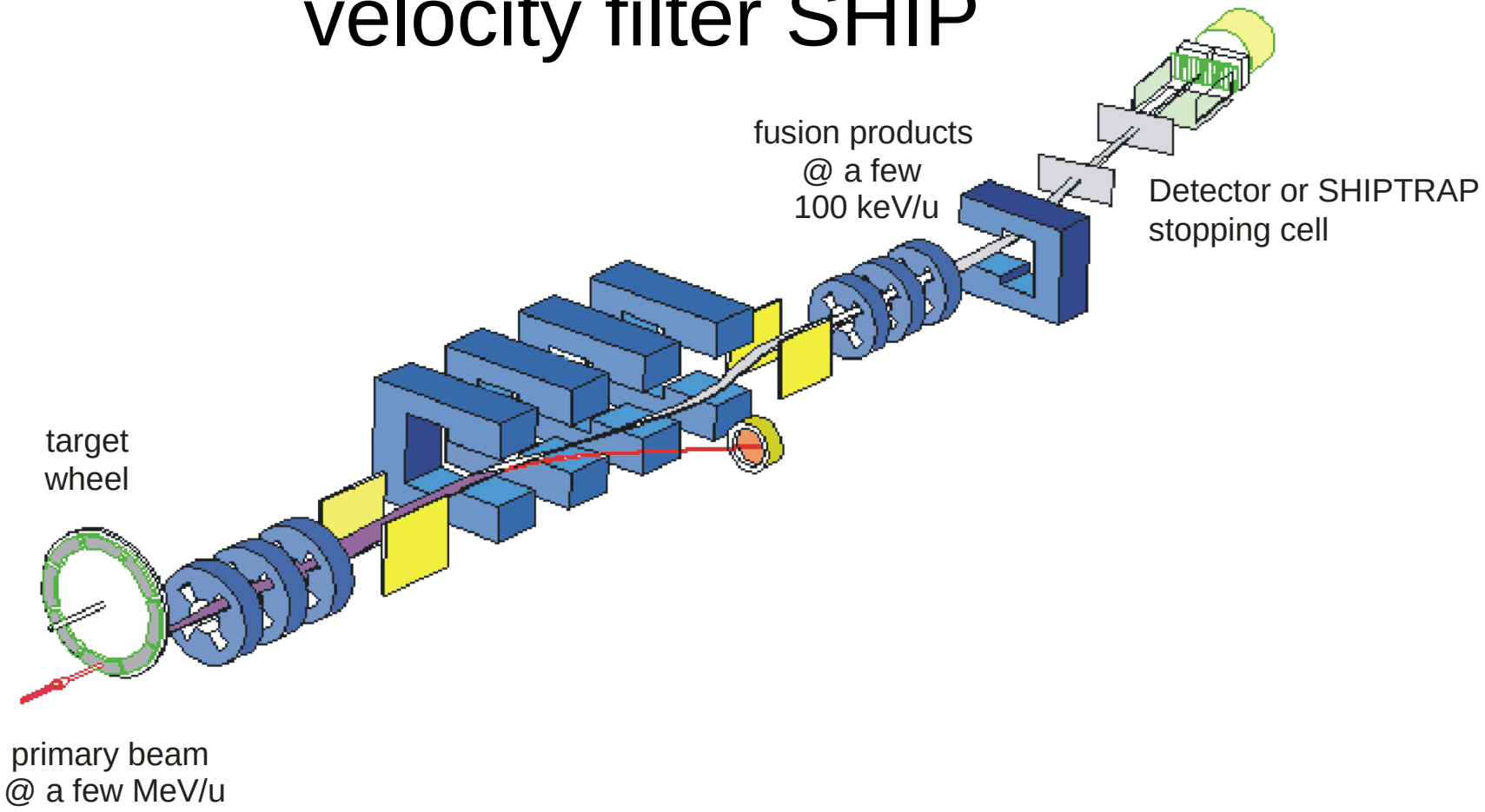
- Nucleosynthesis
  - νp-, rp-process path
  - Abundance of p-nuclei ^{92,94}Mo and ^{96,98}Ru
  - Stellar observations (x-ray bursts)
- Nuclear structure
  - Proton drip-line
  - Wigner-energy
  - Mirror nuclei
  - Theoretical mass models



Plot: I Dillmann, Data: M. Rayet et al., Astron. Astrophys. 298, 517 (1995)

Exotic ion production and separation

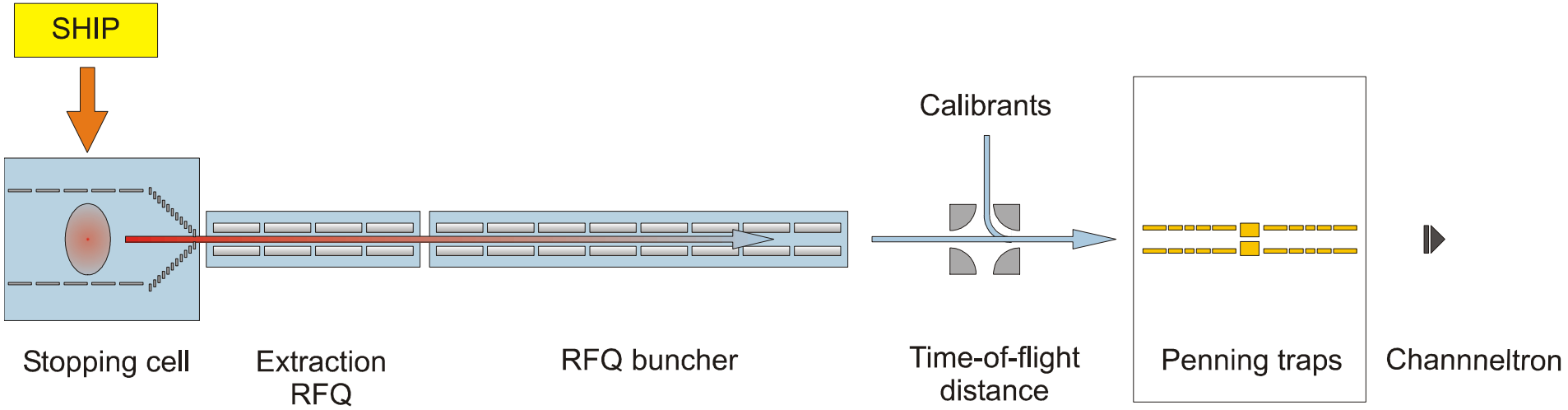
velocity filter SHIP



S. Hofmann and G. Münzenberg, Rev. Mod. Phys. **72**, 733 (2000).

Mass measurement at SHIPTRAP

SHIPTRAP



Stopping Cooling Accumulation

Isobar Selection,
Mass measurement

M. Block *et al.*, Eur. Phys. J. D **45**, 39 (2007)

The experiment

Reaction:

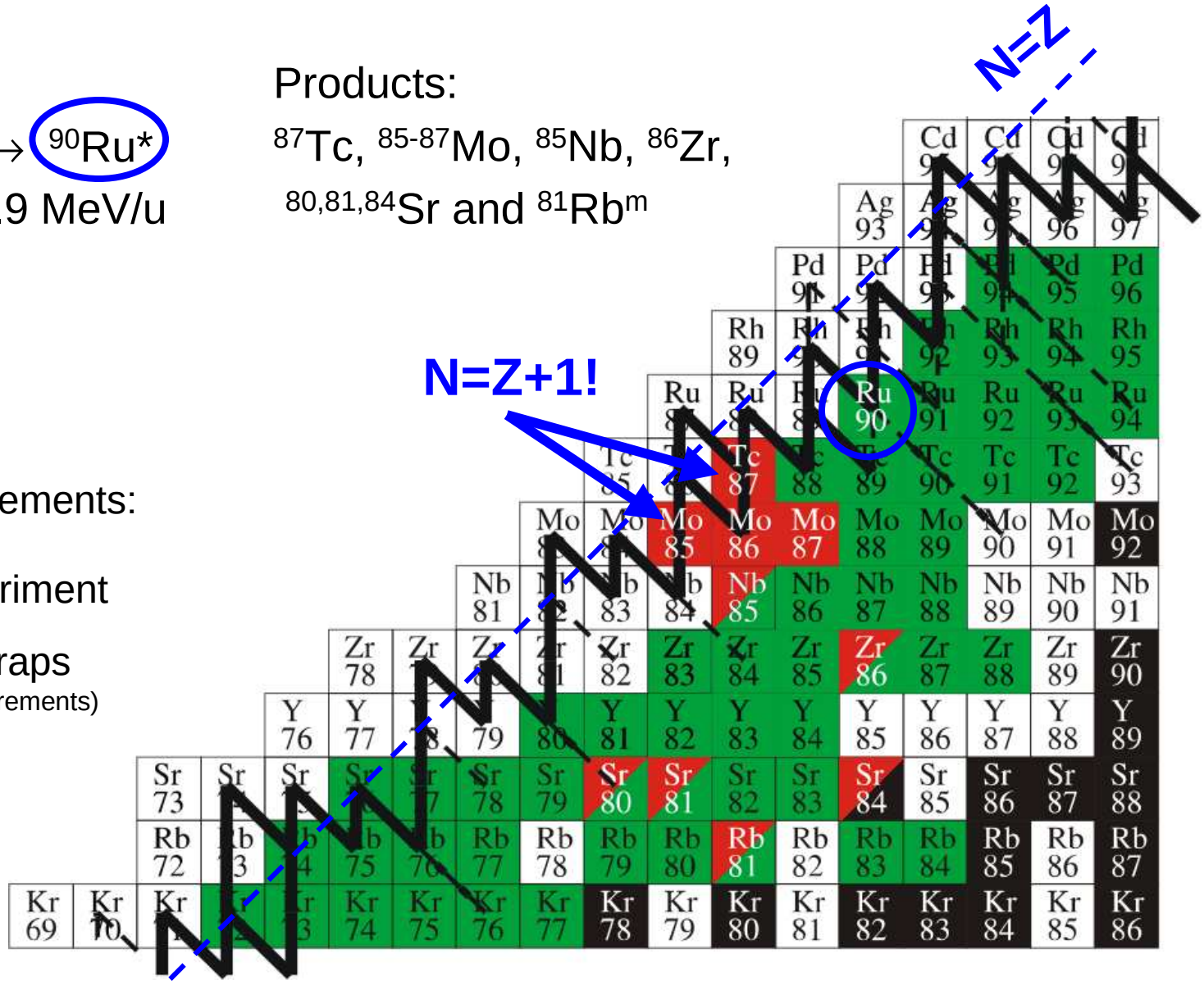
$^{36}Ar + {}^{54}Fe \rightarrow {}^{90}Ru^*$

at 5.0 and 5.9 MeV/u

Products:

^{87}Tc, $^{85\text{-}87}Mo$, ^{85}Nb, ^{86}Zr,

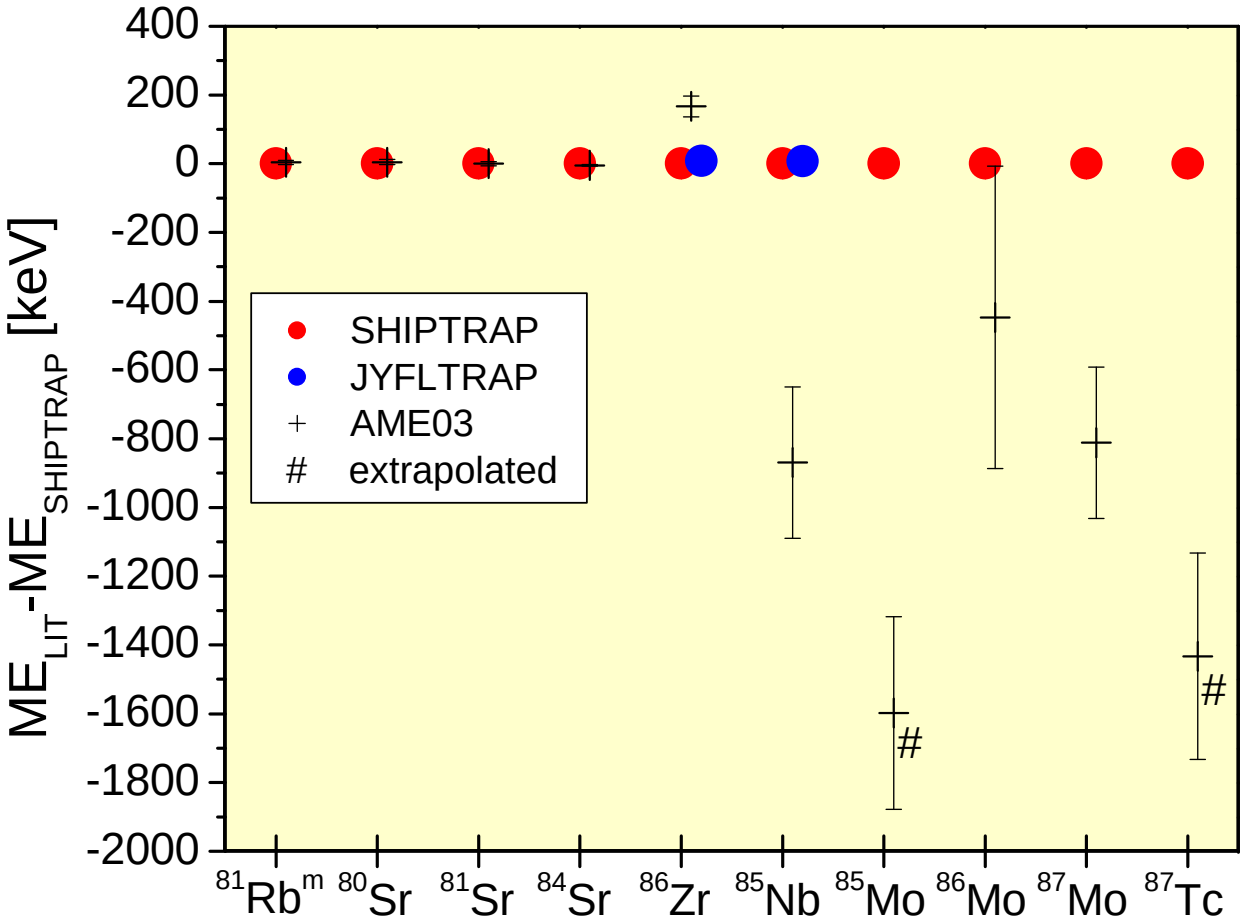
$^{80,81,84}Sr$ and $^{81}Rb^m$

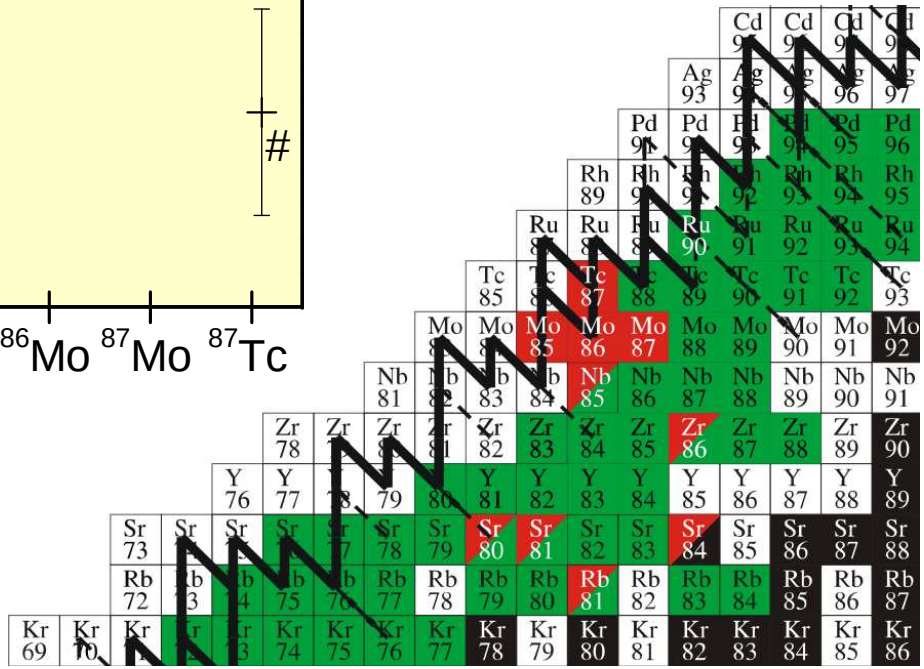


Mass measurements:

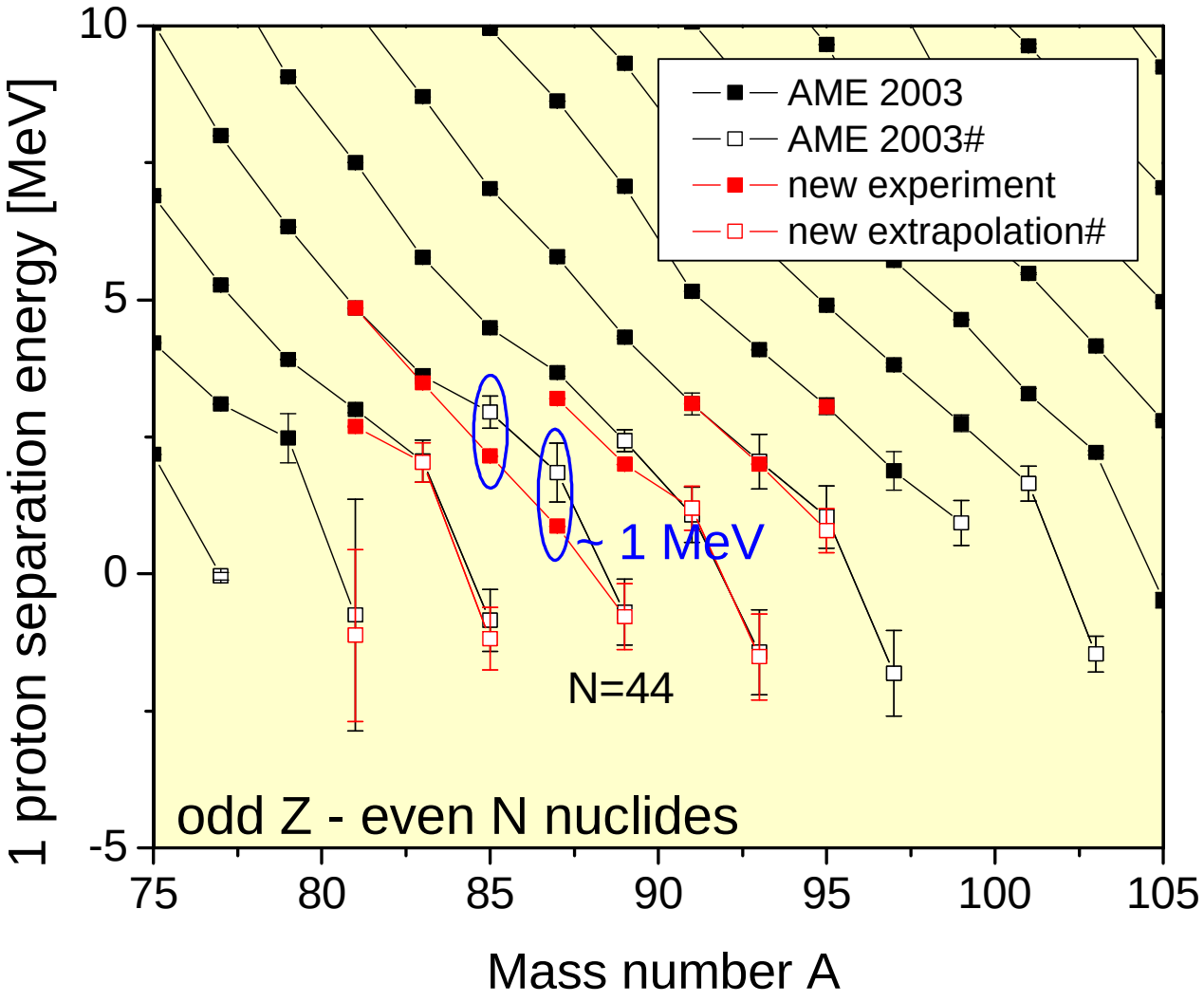
- This experiment
- Penning traps (recent measurements)
- Stable

Mass excess


400
200
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-2000
ME_LIT-ME_SHIPTRAP [keV]
SHIPTRAP
JYFLTRAP
AME03
extrapolated
#
#
#
81Rb m
80Sr
81Sr
84Sr
86Zr
85Nb
85Mo
86Mo
87Mo
87Tc



Proton separation energies

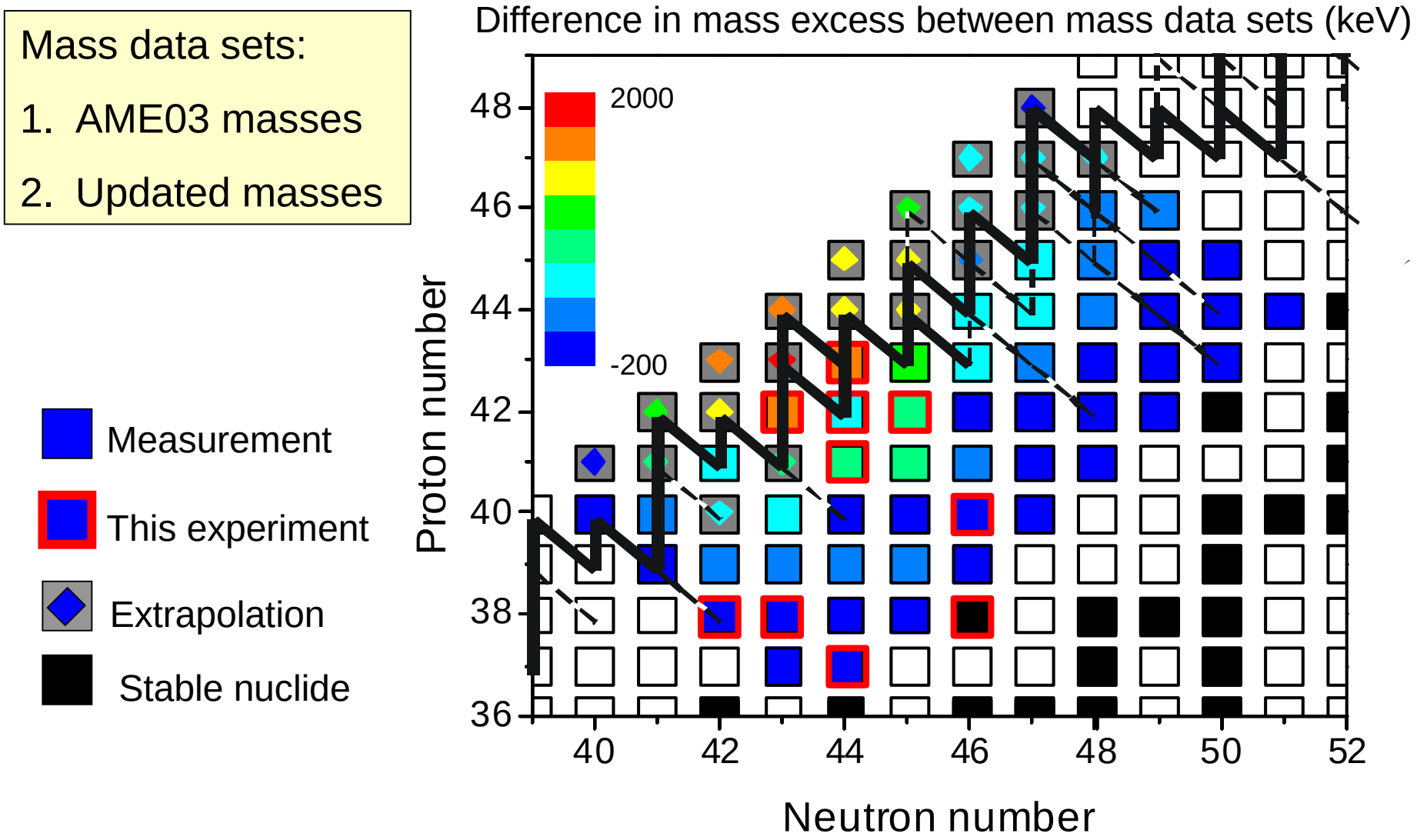


- S_p of ^{87}Tc decreased by ~1 MeV

New mass surface

Mass data sets:

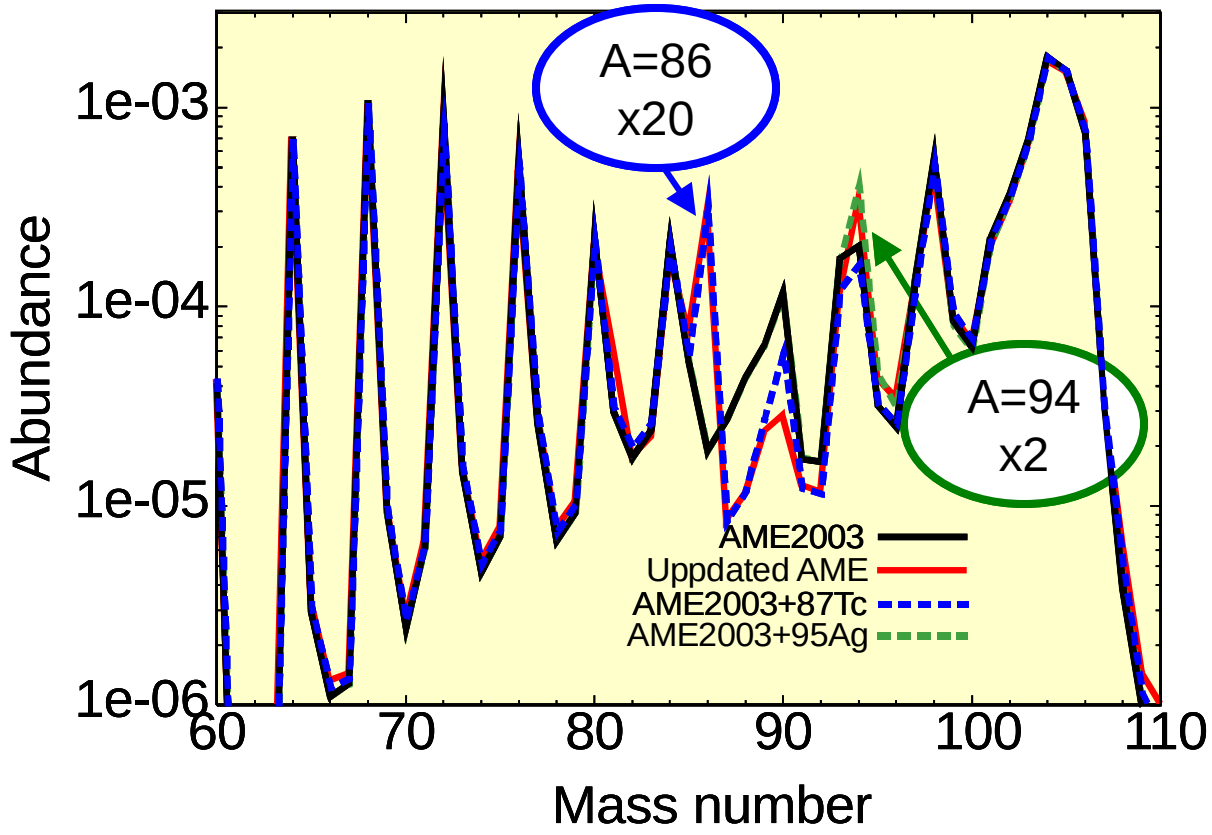
1. AME03 masses
2. Updated masses



G. Audi, M. Wang, E. Haettner

Network calculations: abundances

Final abundances after x-ray burst



S_p of ^{87}Tc
1.8 MeV → 0.8 MeV
→ increase of A=86

S_p of ^{95}Ag
1.0 MeV → 0.8 MeV
→ increase of A=94

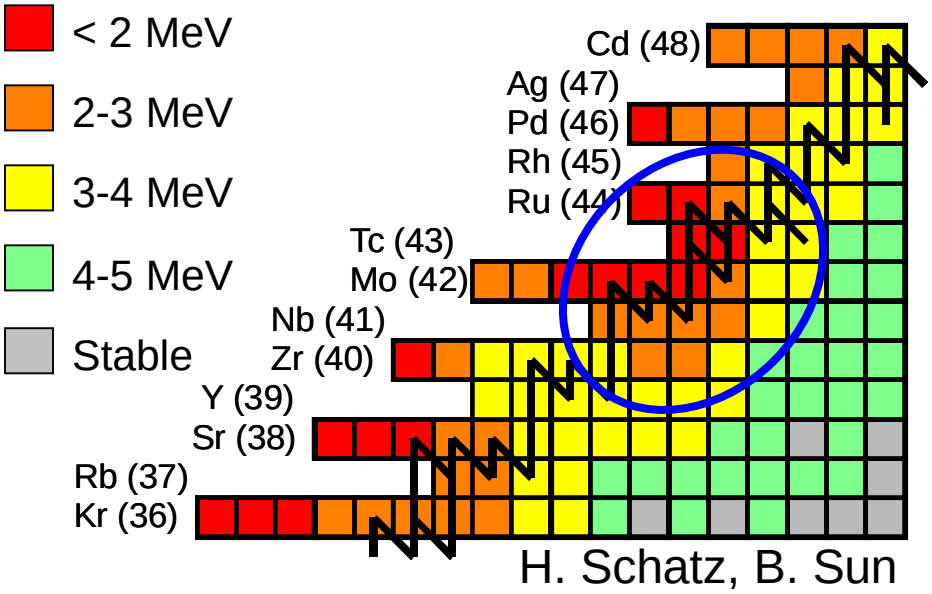
H. Schatz, B. Sun

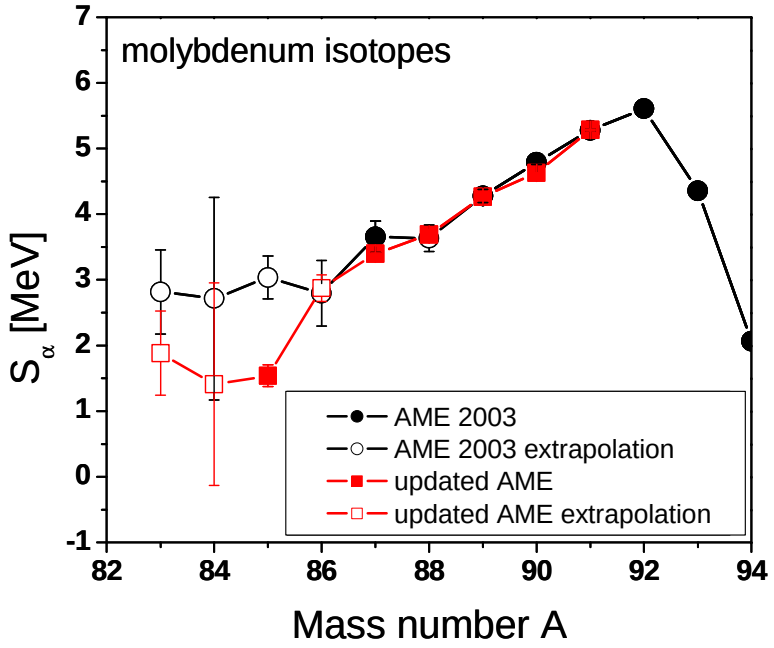
Model: H. Schatz, PRL 86, 3471 (2001), (x-ray burst)

Alpha separation energies

•Early termination of rp process in a Nb-Zr cycle?
(H. Schatz, Physics Report 294 (1998) 167.)

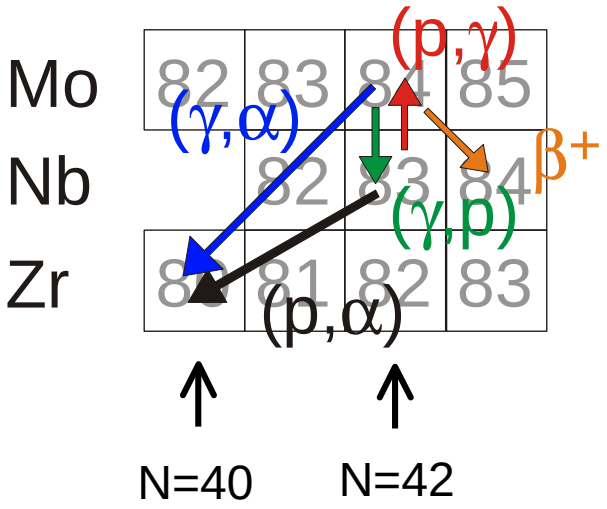
S_α from updated masses

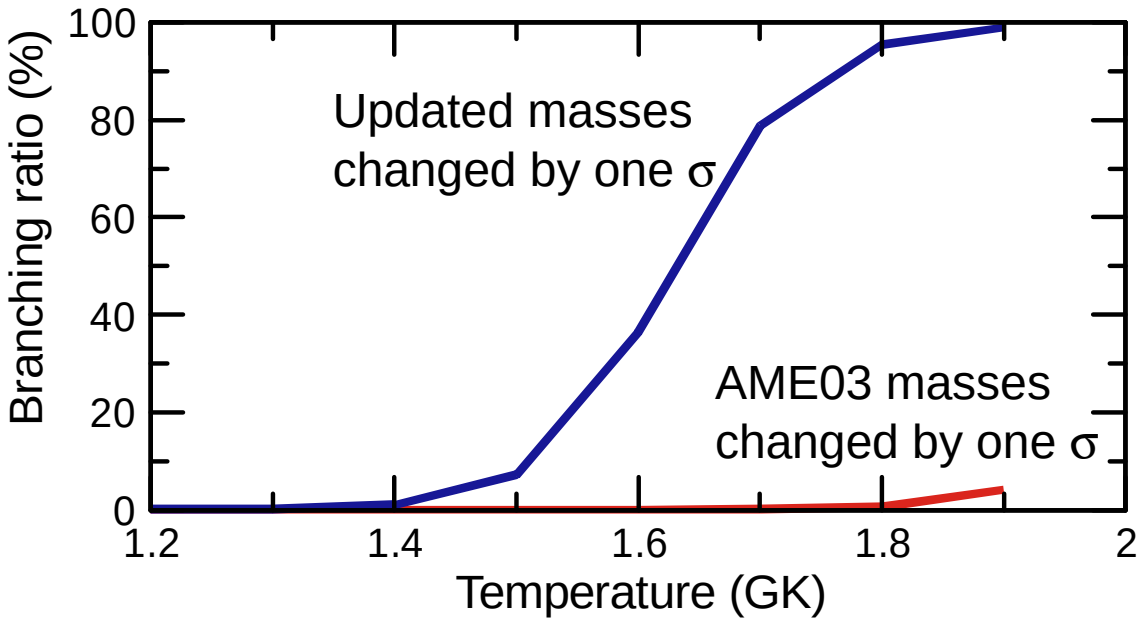




- Experiment revealed small S_α small for A≈85
- S_α smallest for ^{84}Mo → can a Nb-Zr cycle appear?

Nb-Zr cycle?





T. Rauscher, H. Schatz

Calculation starting at ^{82}Zr (N=42):

→ Cycle possible within uncertainties at realistic temperatures and densities

Full calculation of x-ray burst:

→ No cycle (A~85 nuclides only reached in the cooling phase)

Summary

- Experiment
  - Penning trap mass measurements in the vicinity of the proton dripline
  - First mass measurement of ^{85}Mo and ^{87}Tc
  - Separation energies
    - S_p of ^{87}Tc decreased by a factor of two
    - S_α of ^{84}Mo could be negative
- Calculations
  - Large changes in abundance pattern
    - Small S_p for ^{87}Tc causes enhanced production of A=86 by a factor of 20
    - Production of A=94 sensitive to mass of ^{95}Ag
  - A Nb-Zr cycle
    - Possible within present uncertainties
    - Does not appear in full X-ray burst calculations

Collaboration

Experiment

D. Ackermann, K. Blaum, M. Block, S. Eliseev, T. Fleckenstein, E. Haettner, F. Herfurth, F.-P. Heßberger, S. Hofmann, J. Ketelaer, J. Ketter, H.-J. Kluge, G. Marx, M. Mazzocco, Y. Novikov, W. R. Plaß, S. Rahaman, D. Rodriguez, C. Scheidenberger, L. Schweikhard, P. Thirolf, G. Vorobyev and C. Weber

Mass extrapolations

G. Audi and M. Wang

Network calculations

T. Rauscher, H. Schatz and B. Sun