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INTC-P-475

Penning-trap mass measurements of Zn and Cu isotopes relevant for the astrophysical *rp*-process

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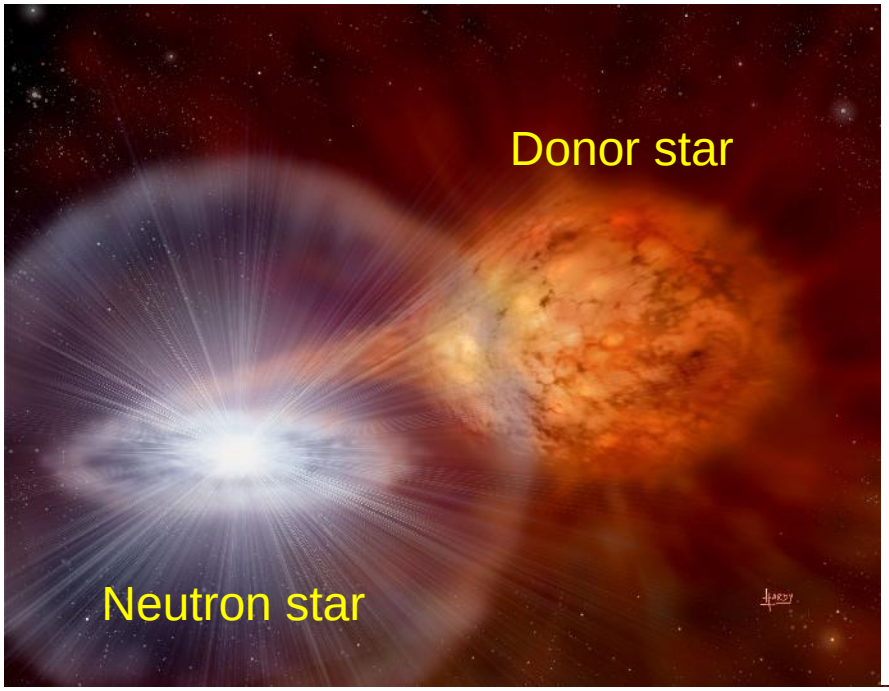
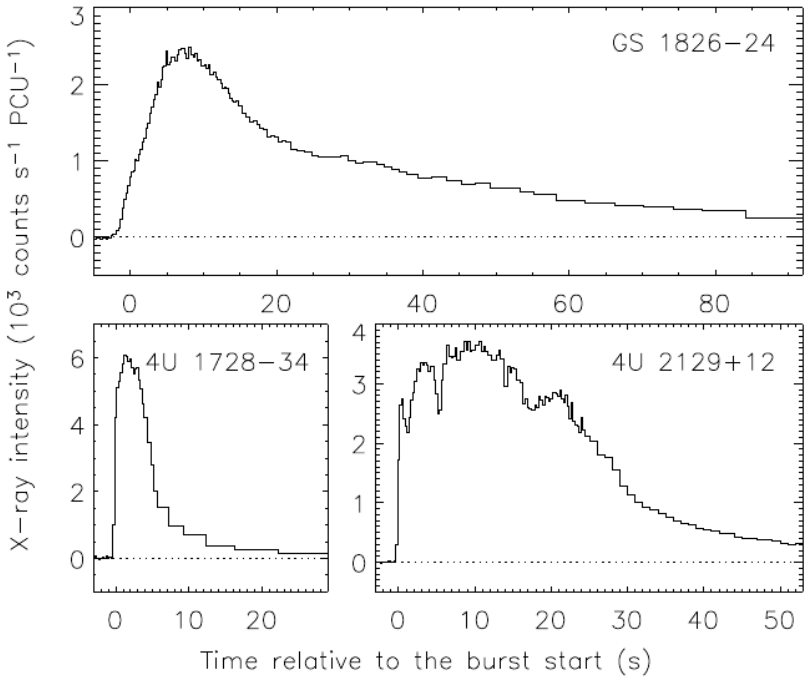
Physics Motivation
Measurement techniques
Beam time request

Type I X-ray burst

- Very frequent & bright phenomena
- Burst output - typically 10^{39} ergs/s. (duration 10s – 200s)
- H/He-rich acceting material
- Thermonuclear runaway leads to nucleosynthesis (*rp*-process)



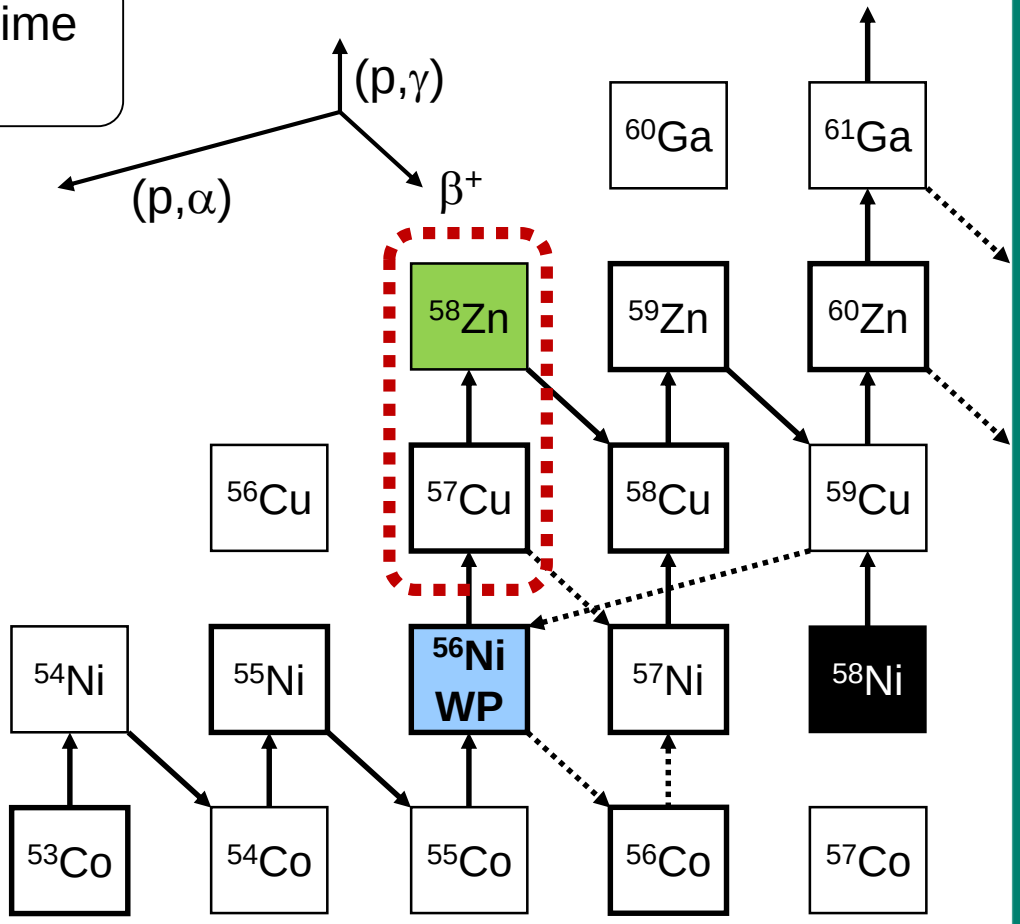


rp-process path

^{56}Ni - Long electron capture lifetime (~10^4s) blocks exit channel

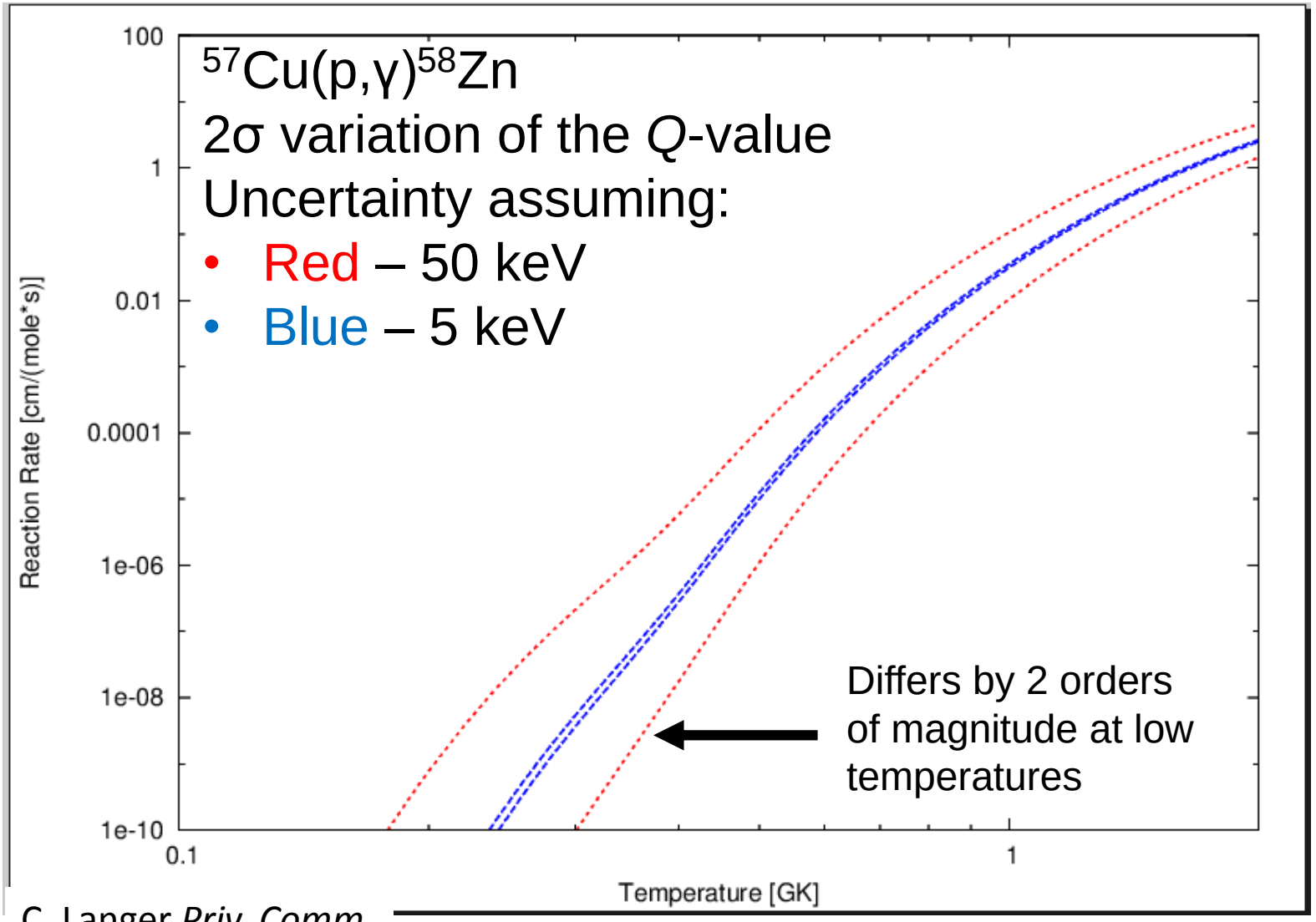
^{56}Ni(p,γ)-(γ,p)^{57}Cu equilibrium

^{57}Cu(p,γ)^{58}Zn rate has been experimentally constrained



H. Schatz et al., Phys. Rev. Lett. **86**, 3471 (2001).
A. Kankainen *et al.*, Phys. Rev. C **82**, 052501(R) (2010)
C. Langer and Montes et al. (2014) PhRvL 113 032502

Reaction rate - calculations



C. Langer *Priv. Comm.*

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rp-process path

Alternative flow through the reaction rate ^{55}Ni(p,γ)^{56}Cu **~40% branching**

Resonance energy: $E_r = E_x - Q$

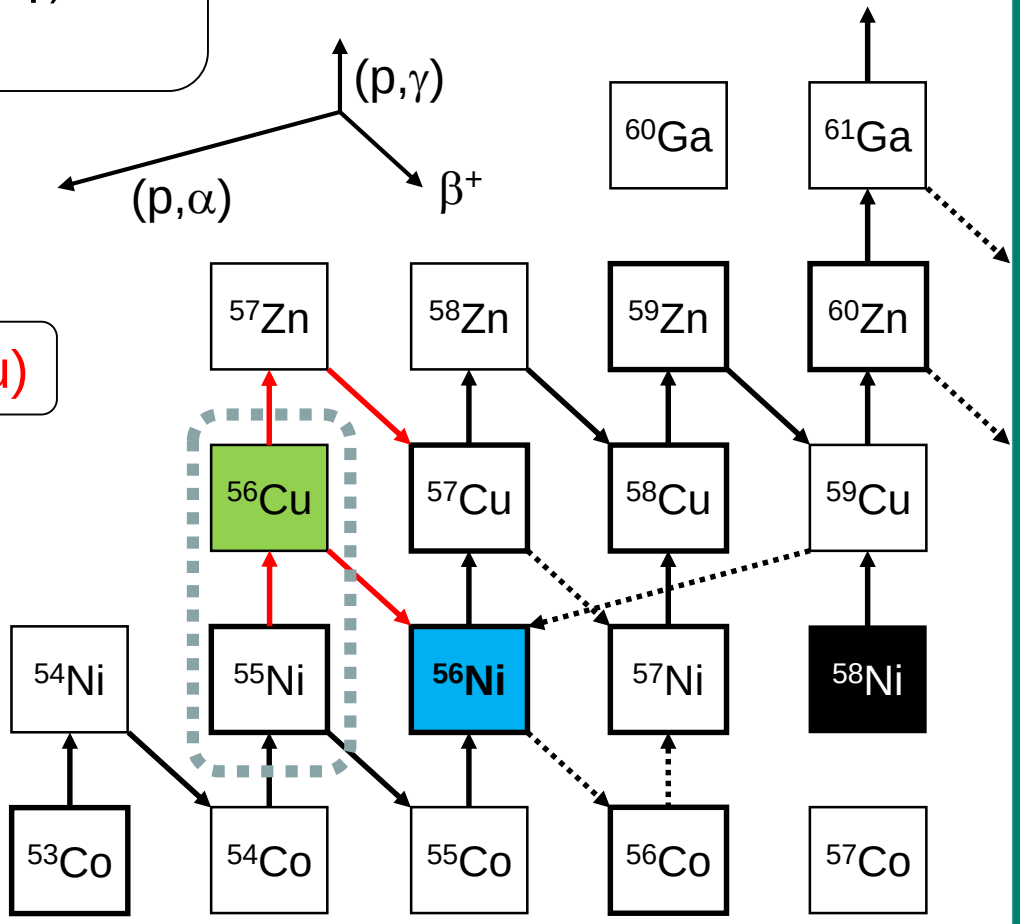
$Q = m(\mathrm{H}) + m(^{55}\mathrm{Ni}) - m(^{56}\mathrm{Cu})$

AME2012

ME(^{56}Cu) = -38 238(196) keV

Indirect Estimation:

ME(^{56}Cu) = −38 697(88) keV



X. L. Tu *et al.* Nuclear Physics A **945** 89–94 (2016)
W. Ong and C. Langer Priv. Comm.

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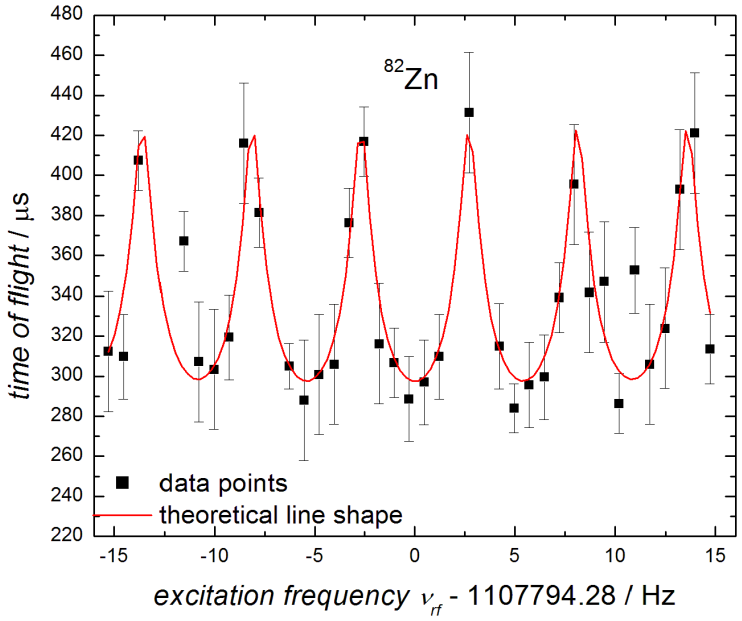
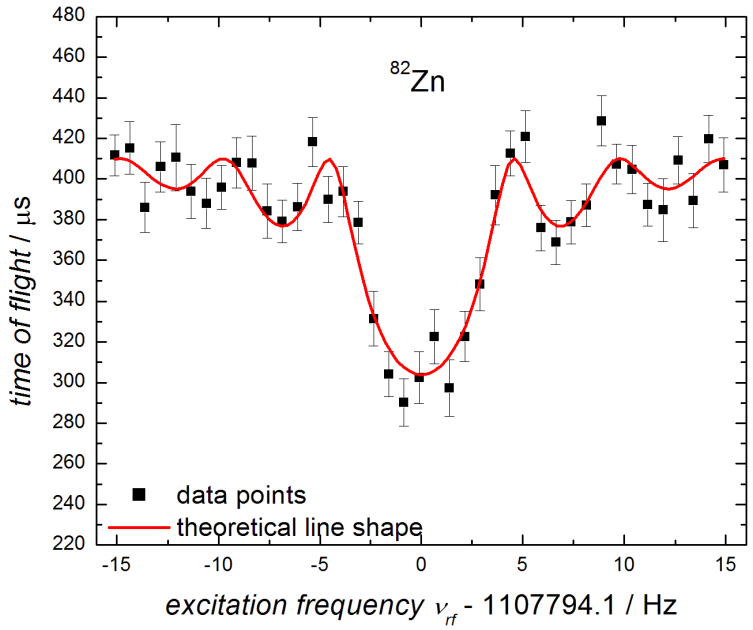
Measurement Technique

Time-Of-Flight Ion-Cyclotron Resonance





$$\nu_c = \frac{1}{2\pi}\frac{q}{m}B$$

TOF-ICR 200ms	Excitation	Ramsey 20-160-20ms
195 minutes	**Duration**	35 minutes
580	**Ion count**	75
$1*10^{-7}$	**Rel. Uncertainty**	$8*10^{-8}$

R.N. Wolf et al., PRL 100, 041101 (2013), S. Baruah *et al.*, PRL.**101**, 262501 (2008)

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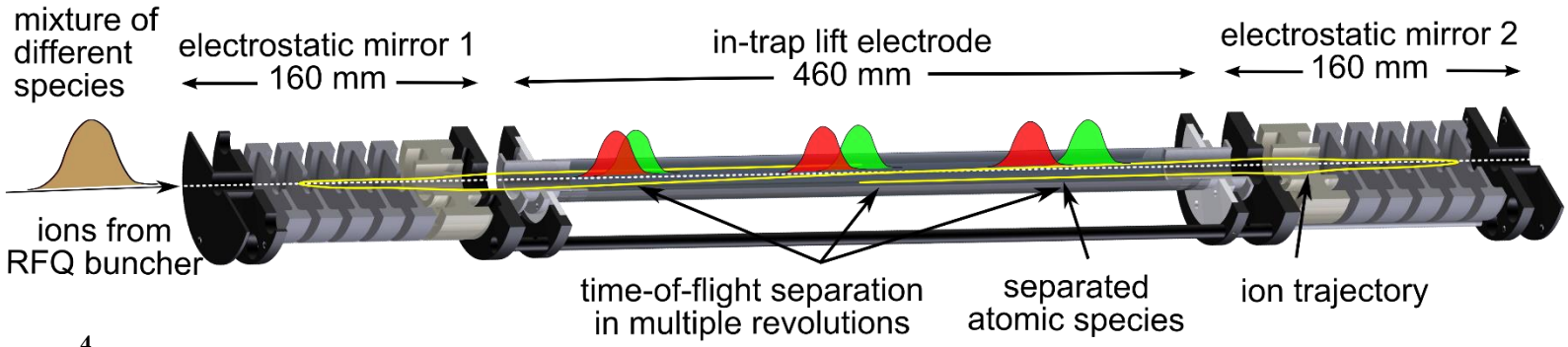
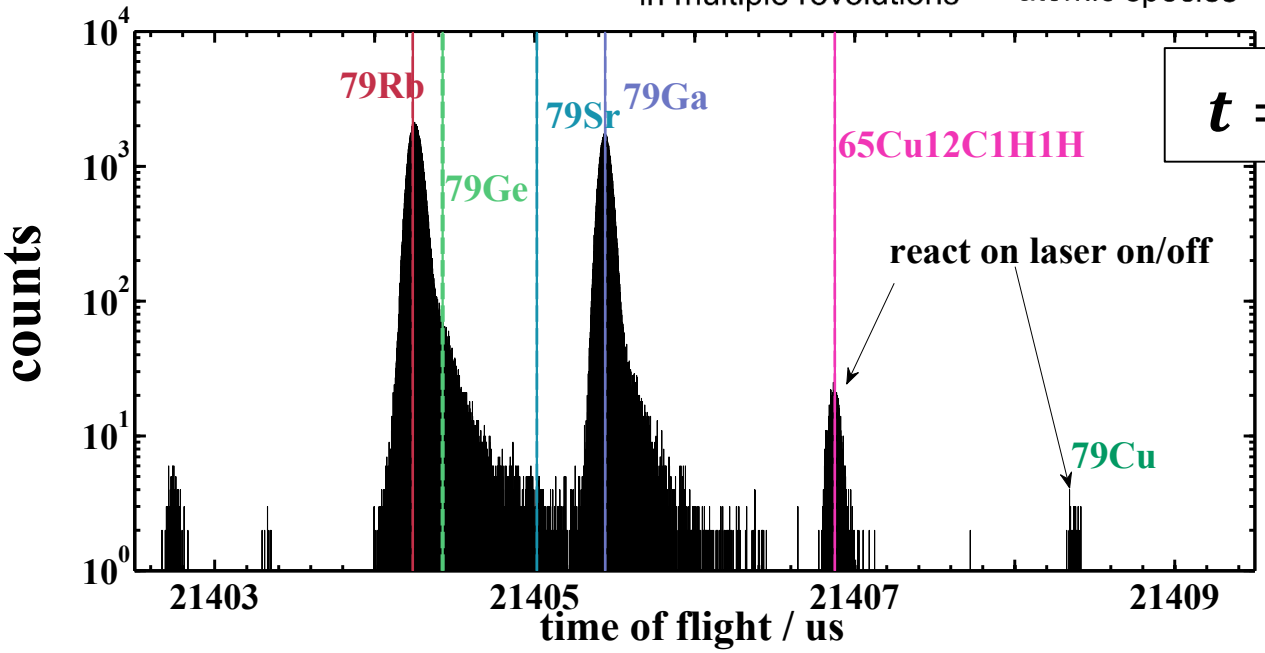
Measurement Technique

Multi-Reflection Time-of-Flight Mass Spectrometry





$$t = a.\sqrt{m/q} + \mathrm{b}$$

Wolf *et al.*, IJMS **313**, 8 (2012); Wolf *et al.*, IJMS 349-350, 123 (2013);

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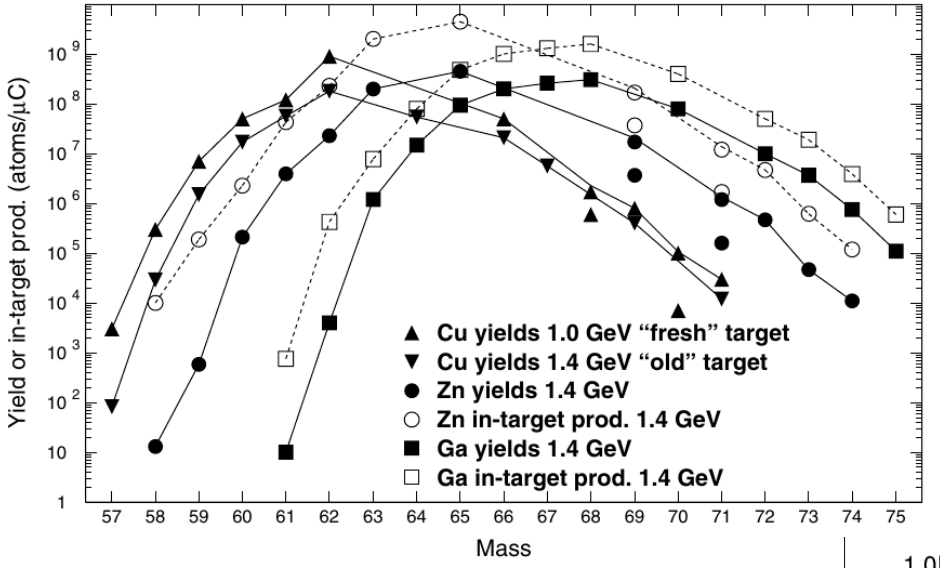
Yield expectations



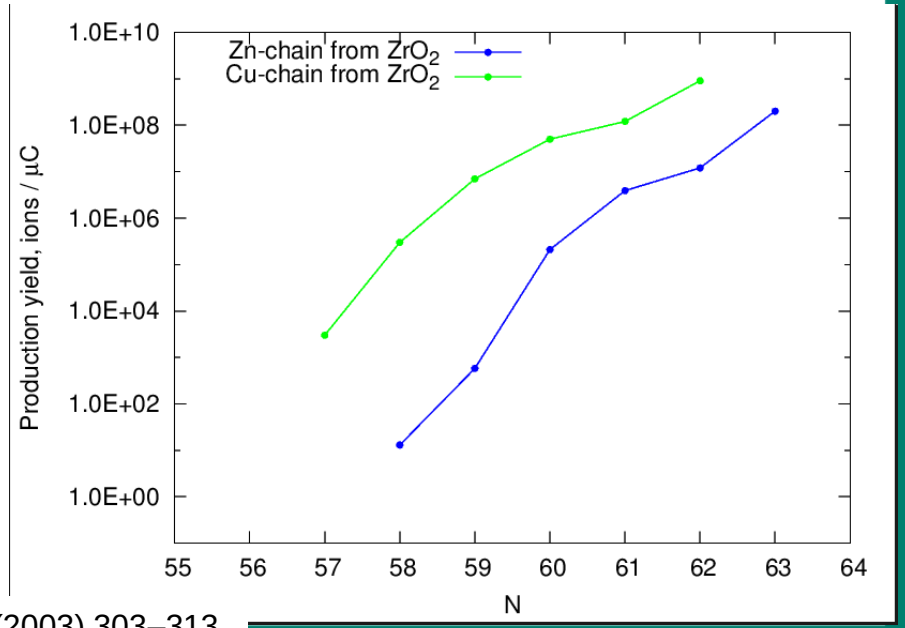
- ZrO_2 felt target
- Release of Cu is about 1s
- Surface-ionized Fe, Ga from ion-source

Yield of ^{56}Cu

Estimates are based on ^{57}Cu (3×10^3 ions/μC)

Yield of ^{58}Zn

10 ions/μC



U. Koster et al. Nucl. Instr. and Meth. in Phys. Res. B 204 (2003) 303–313

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Beam time Request

Isotope	Half-life (ms)	Mass uncertainty (keV)	Target	Yield (ions/μC)	Ion source	Shifts
^{56}Cu	93(6)	extrapolated	ZrO_2	10^0 - 10^1	RILIS	**2+4**
^{58}Zn	86.7(24)	50		10		**2+4**

- **Low resolving power:** required for separating Fe, Ni ($m/\Delta m \approx 3000$)
- **MR-TOF separator:** up to 10^4 contamination suppression with 10^5 resolving power in 30 ms.
- **Precision Penning trap:** Resolving contamination (CaO) require about $2x10^5$ mass resolving power

Thank you for your attention

D. Atanasov , K. Blaum, S. George , F. Herfurth , A. Herlert, D. Lunney, Yu. A. Litvinov, A. Kankainen, V. Manea, M. Mougeot, D. Neidherr, C. Langer, M. Rosenbusch, L. Schweikhard, F. Wienholtz, R. N. Wolf, A. Welker, and K. Zuber

ISOL TRAP

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