Constraining the $^{95}Zr(n,\gamma)$ cross section using SONIC at Horus

Tom Sittig, Dennis Mücher (IKP Cologne)

- **Neutron Capture cross sections in exotic nuclei in the vicinity of N=82**

Nucleosynthesis in the Zr & Mo chain

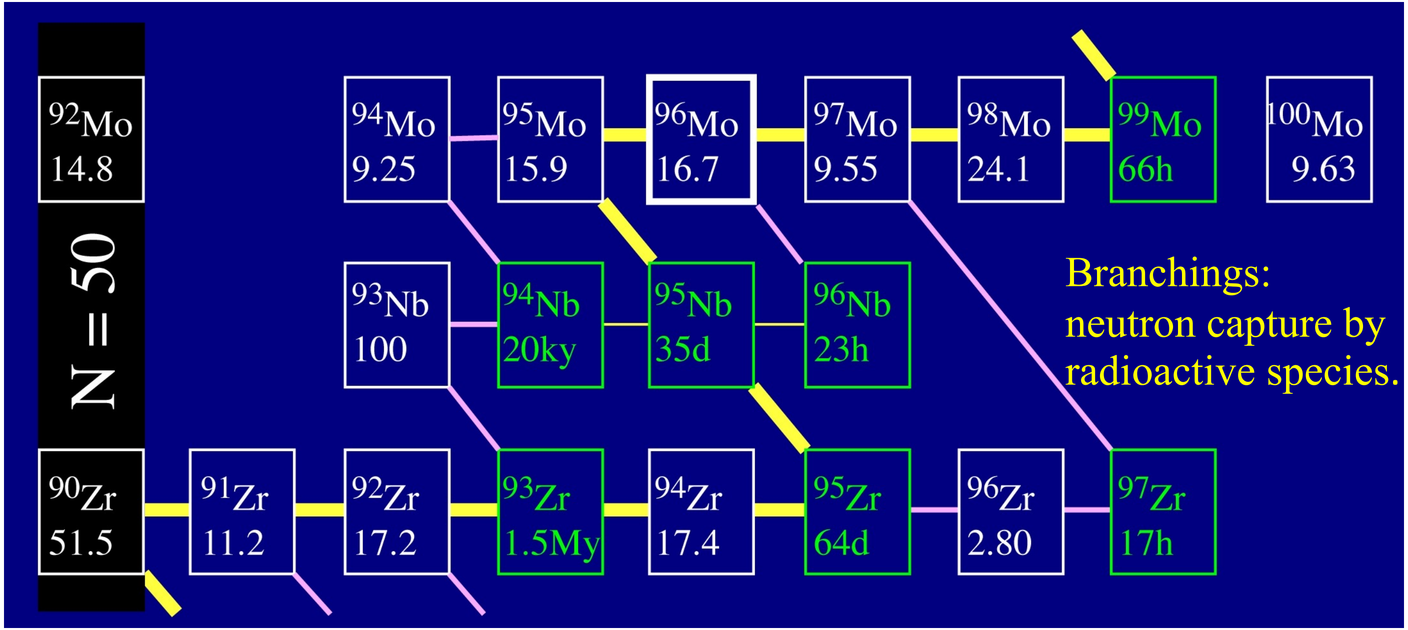

image by Falk Herwig & Rene Reifarth

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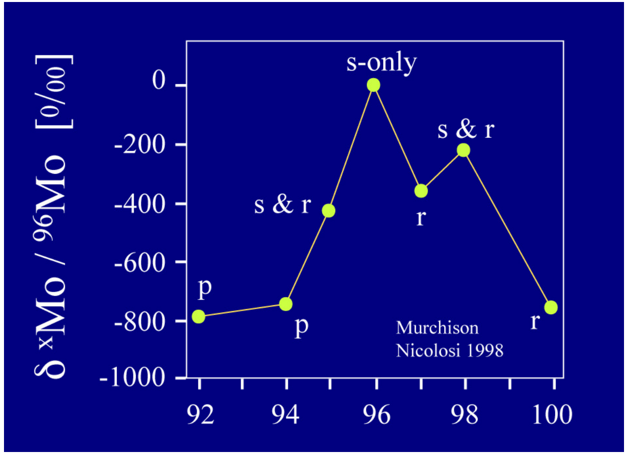
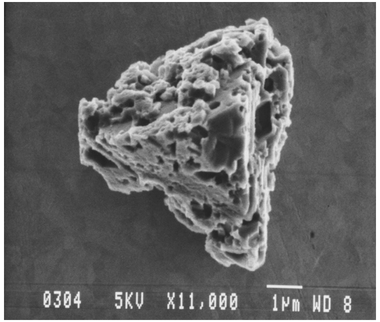
slide adapted from F. Herwig & R. Reifarth

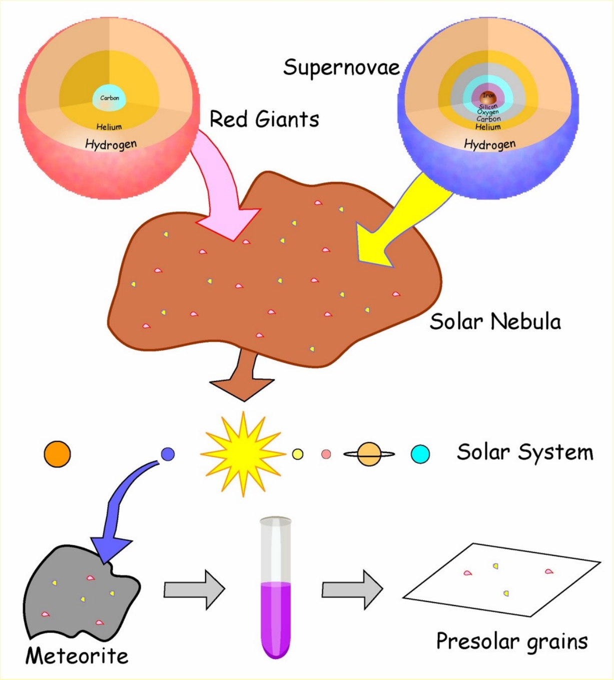
Presolar grains

Pre-solar meteoritic grains provide a powerful diagnostic tool.

- Trace signatures of individual stellar sources
- High-precision isotopic abundances
- Multiple elements now from individual grains







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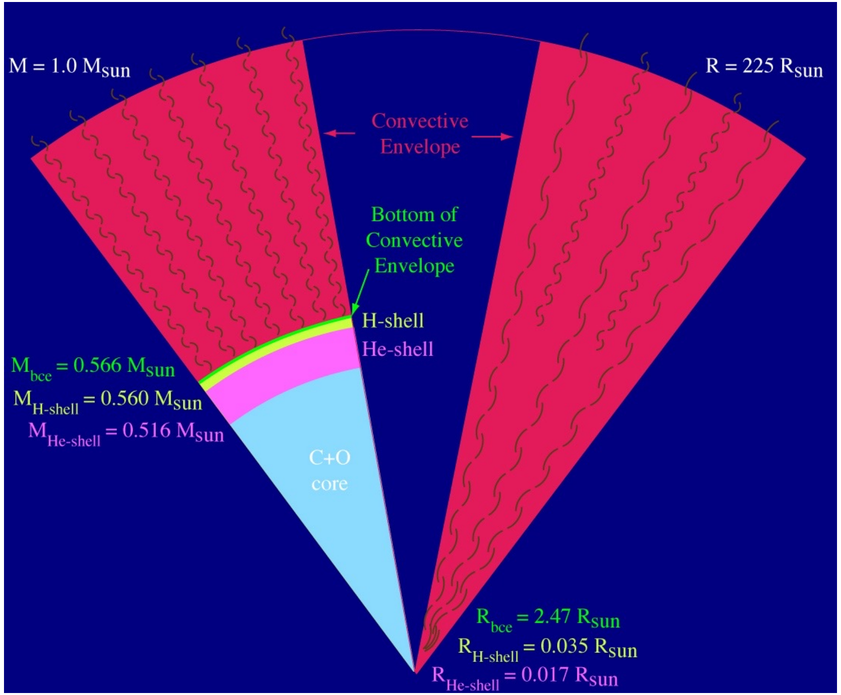
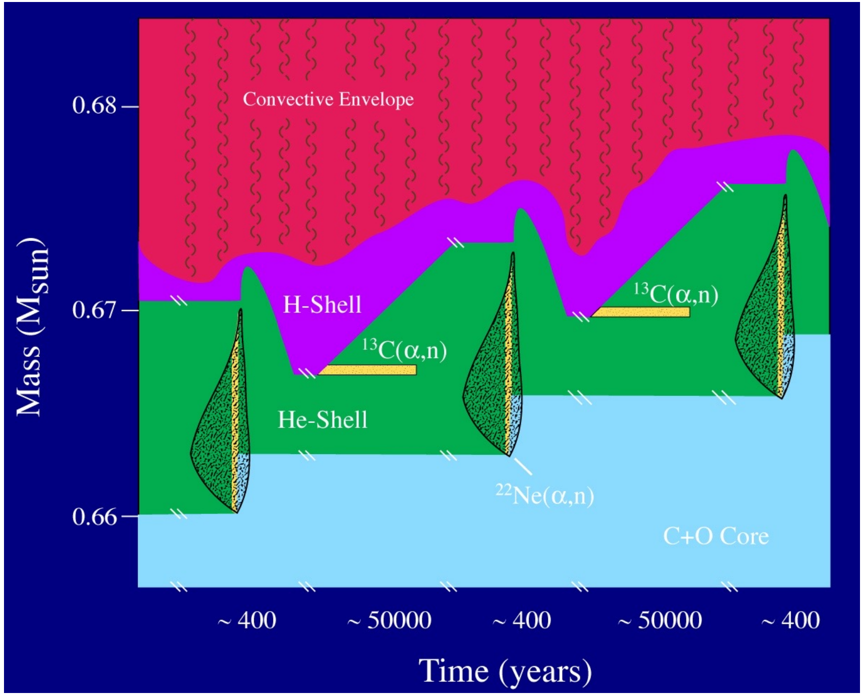
slide adapted from F. Herwig & R. Reifarth

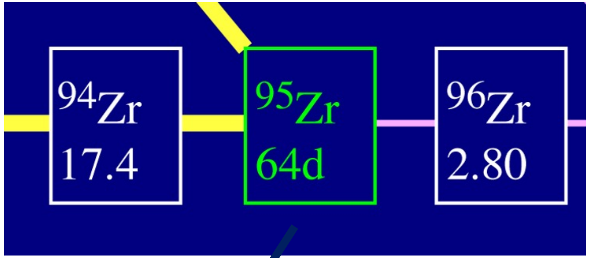
He shell thermal pulses in AGB stars

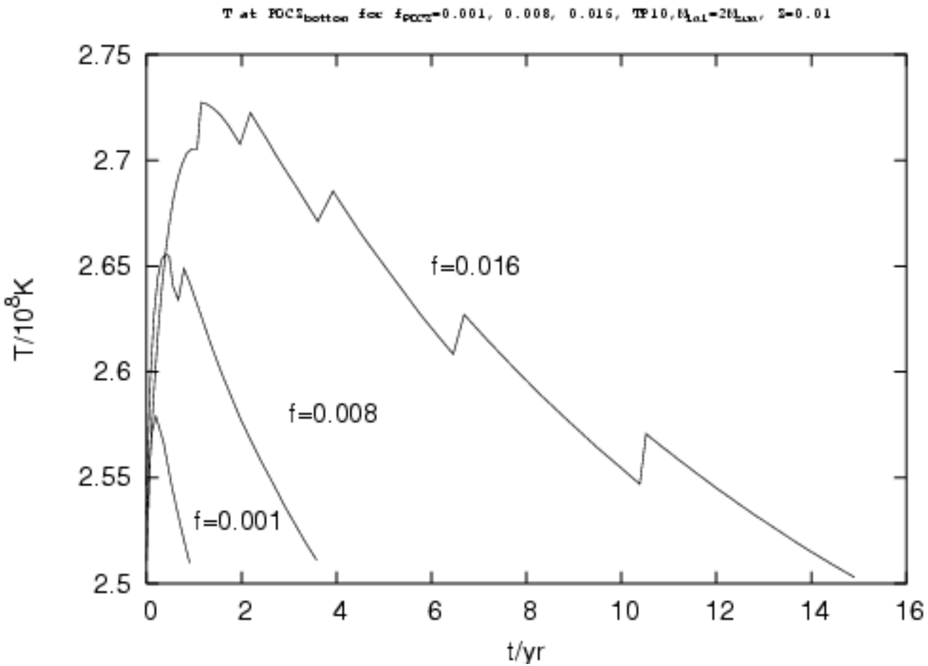


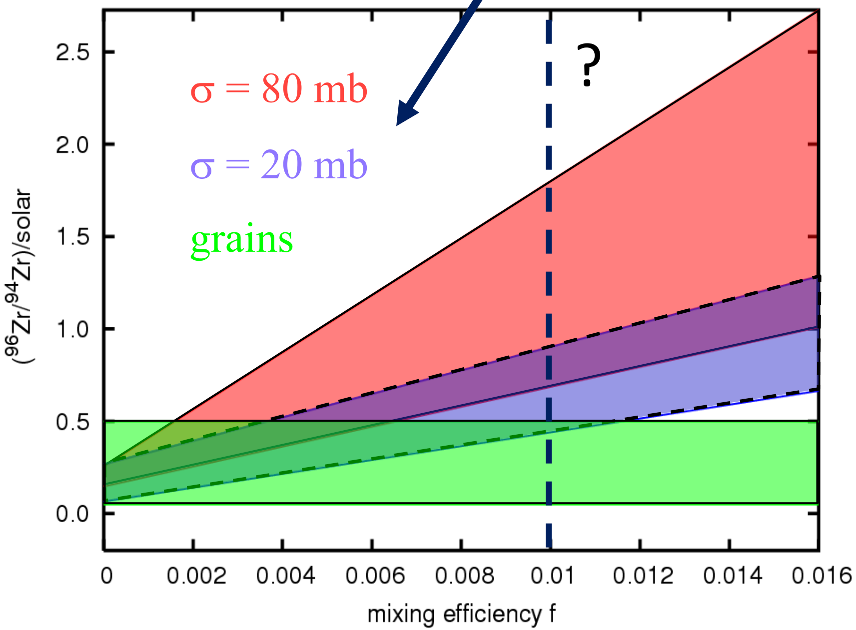


Convective boundary mixing parameter

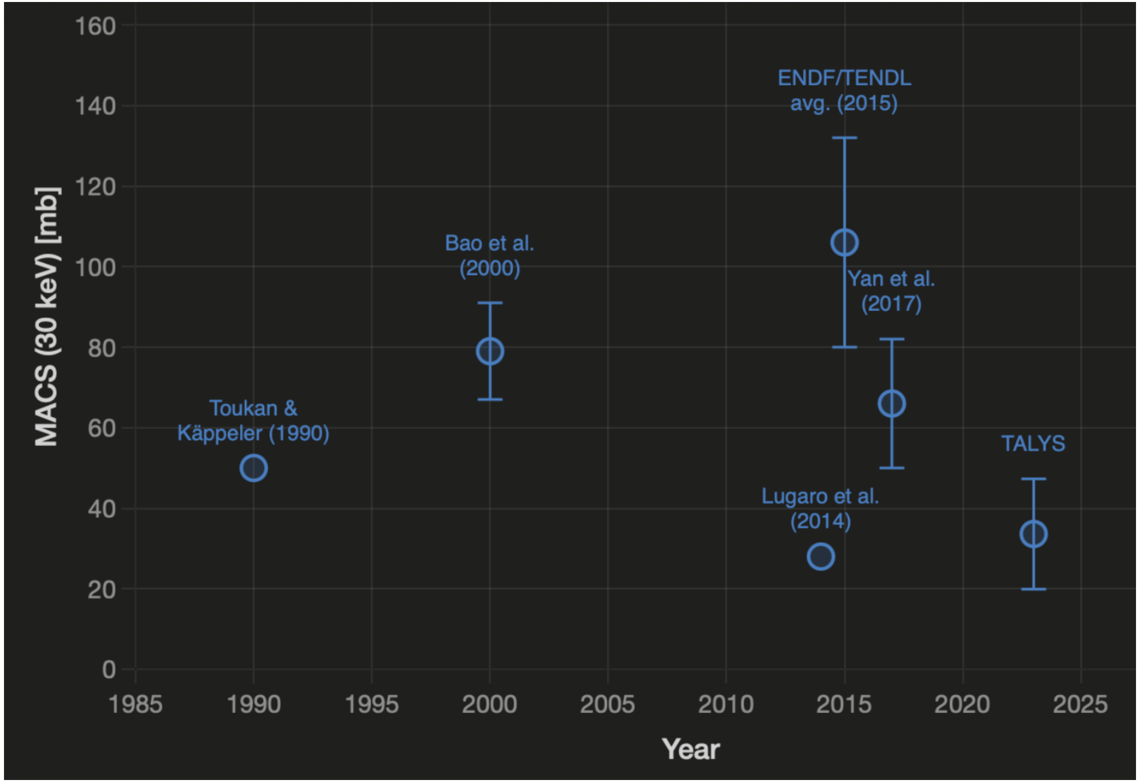
slide adapted from F. Herwig & R. Reifarth







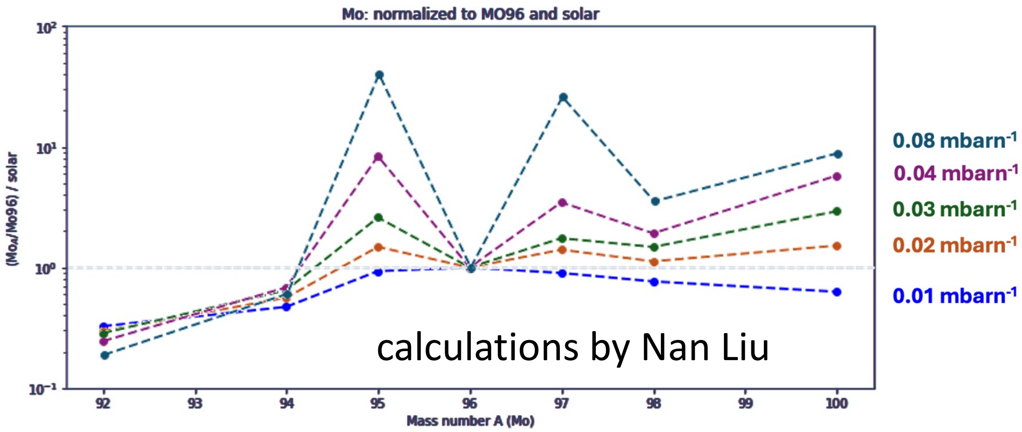
Literature values for $^{95}Zr(n,\gamma)$ MACS at 30 keV

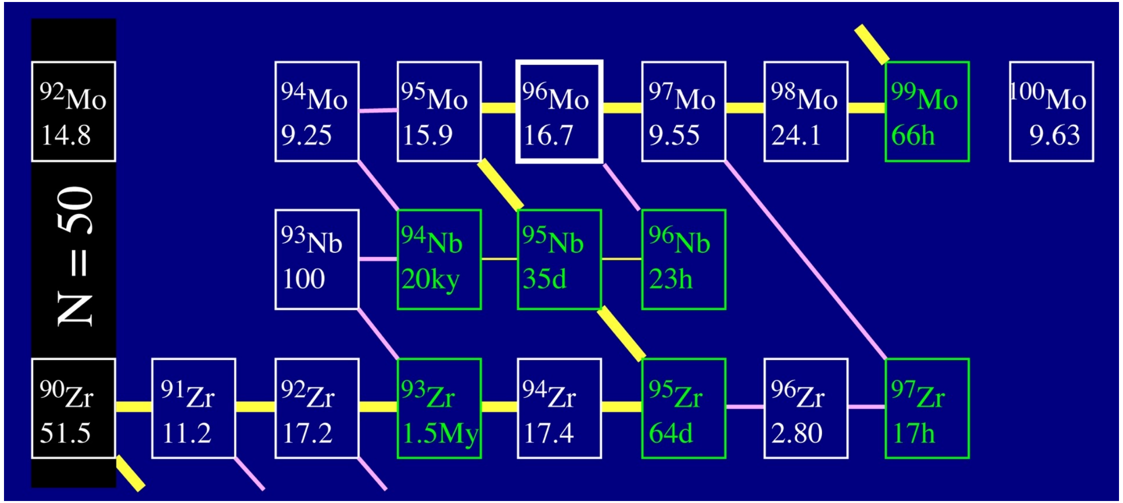


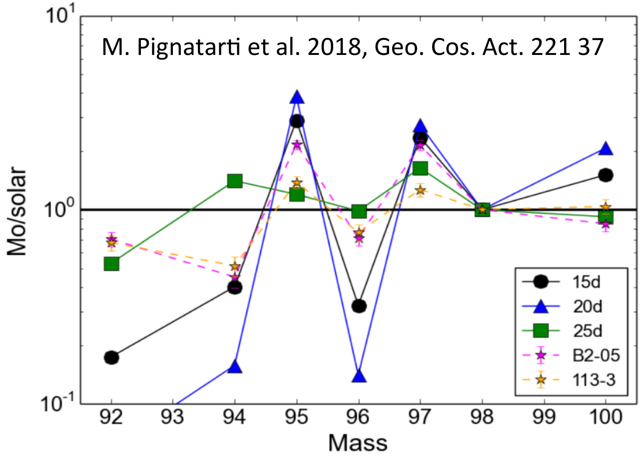
plot created with Claude Sonnet 4.6

Overabundance of Mo isotopes in presolar grains

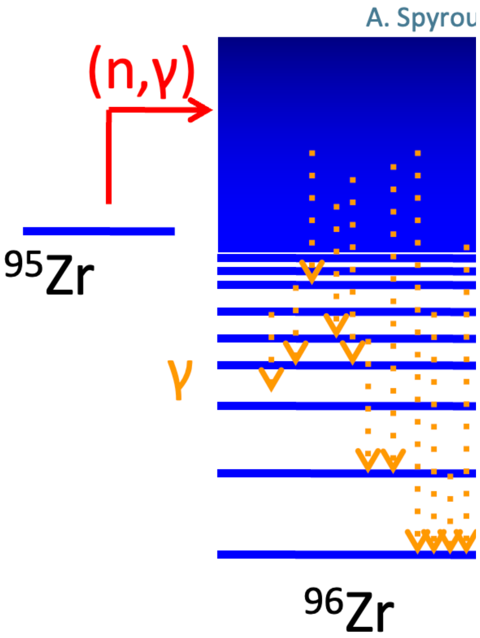
^{95}Zr branch: thermometer for neutron exposure!

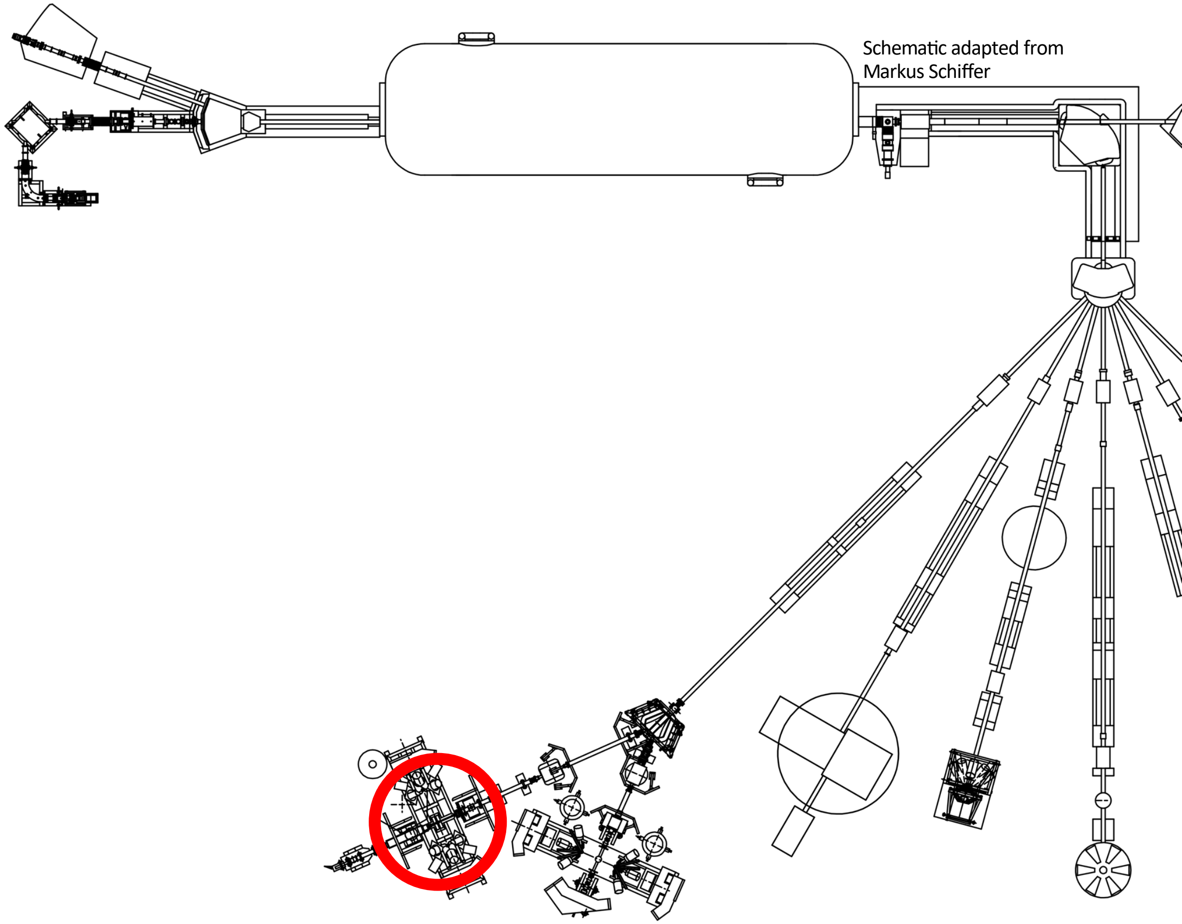






10MV FN Tandem at IKP Cologne





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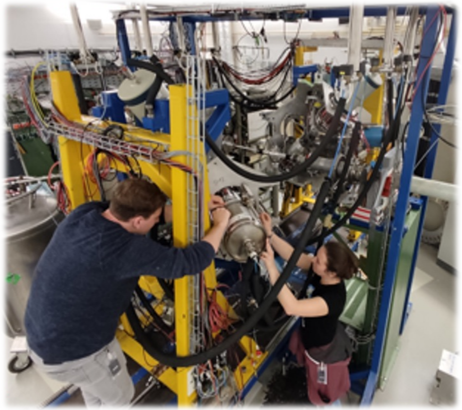

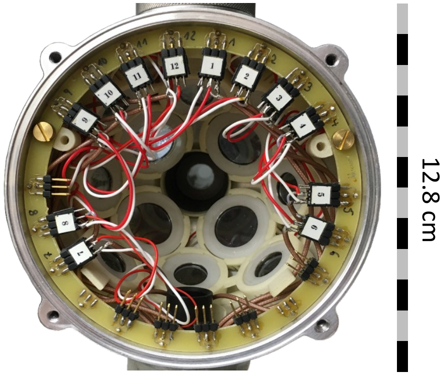

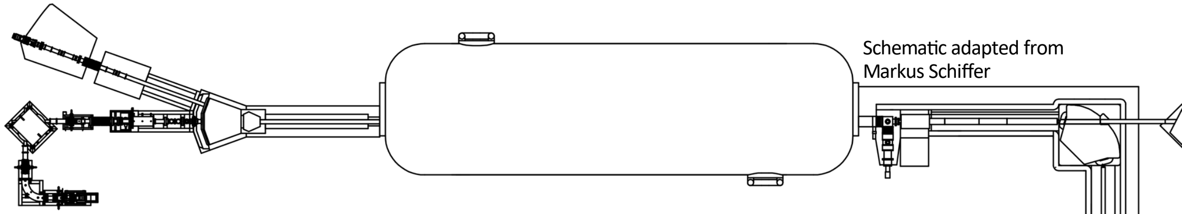

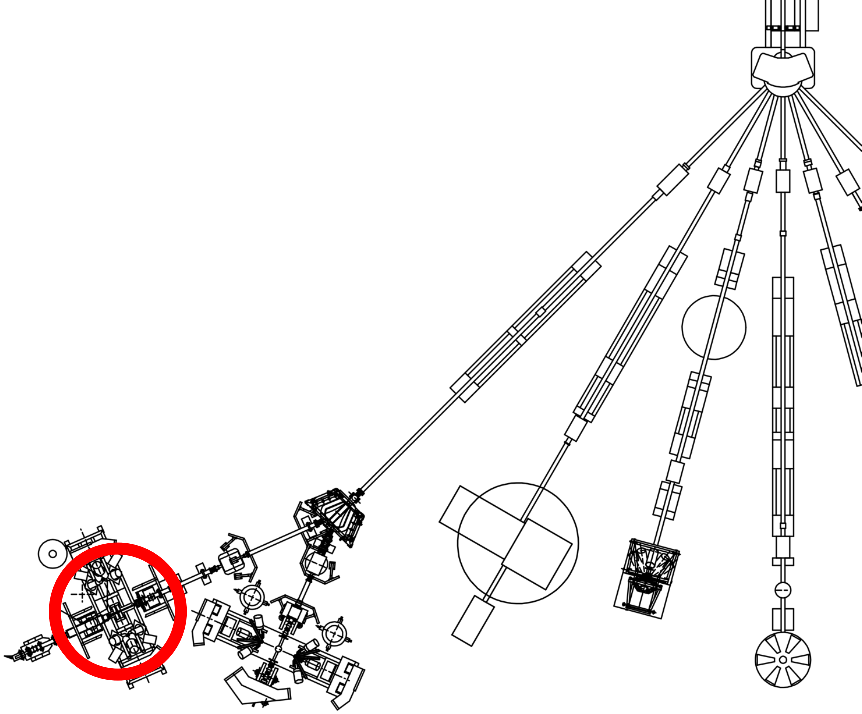

HORUS + **SONIC**

- Up to 14 HPGe detectors
- Up to 12 Si-telescopes

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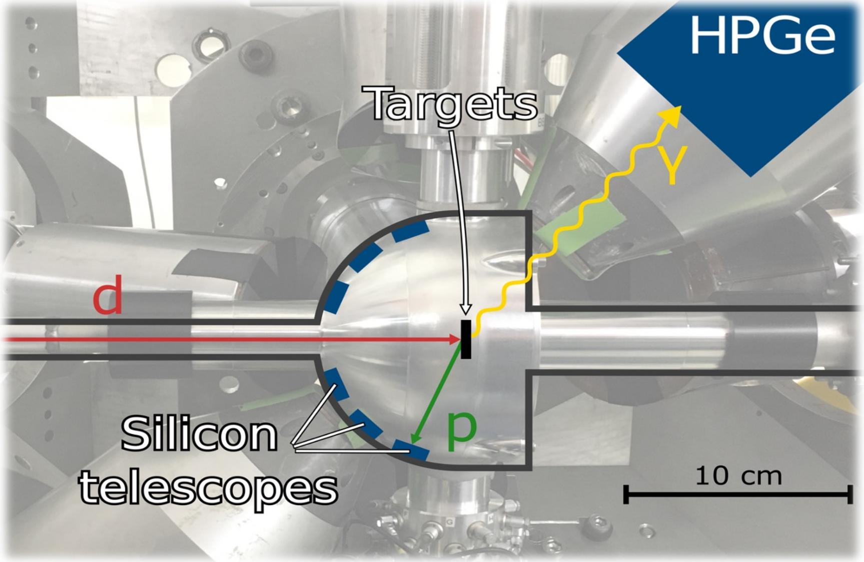
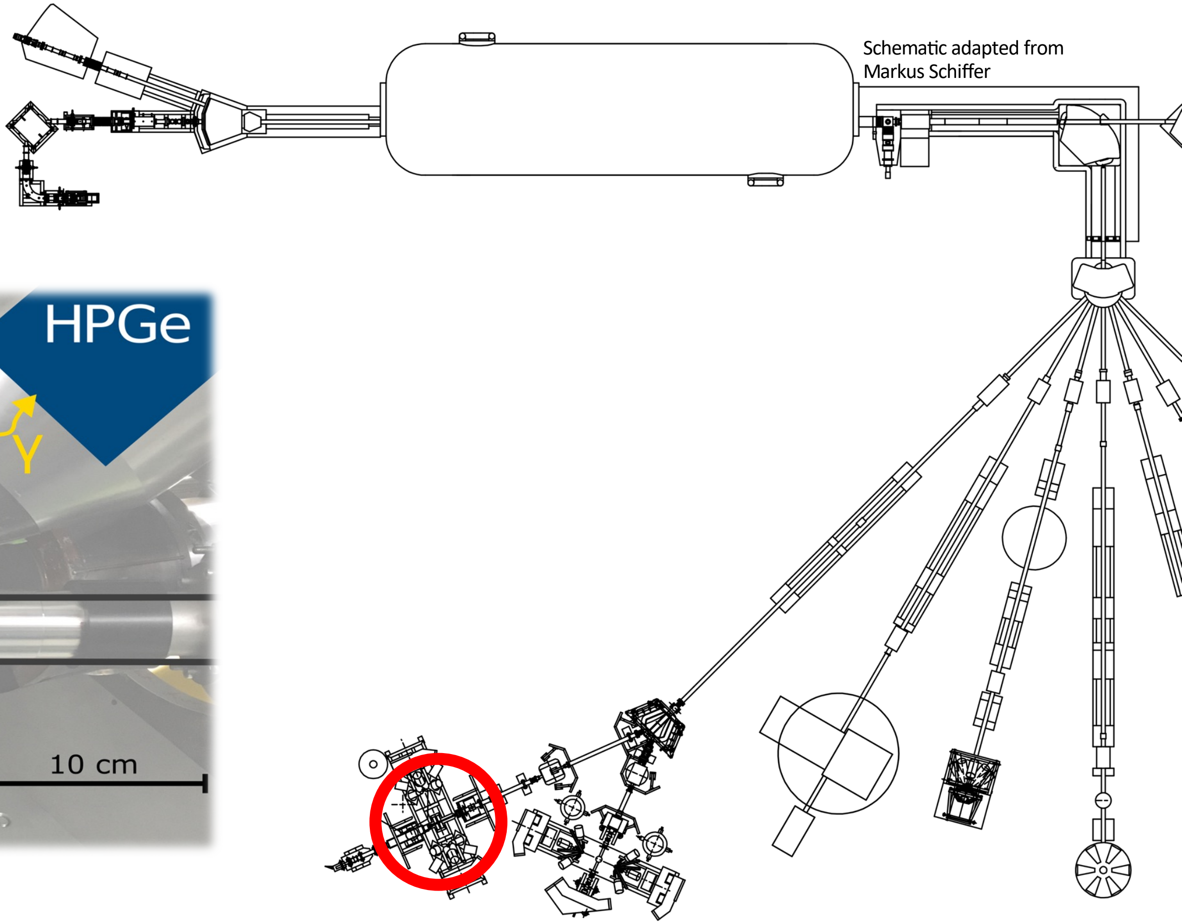
group Andreas Zilges

Schematic adapted from Markus Schiffer





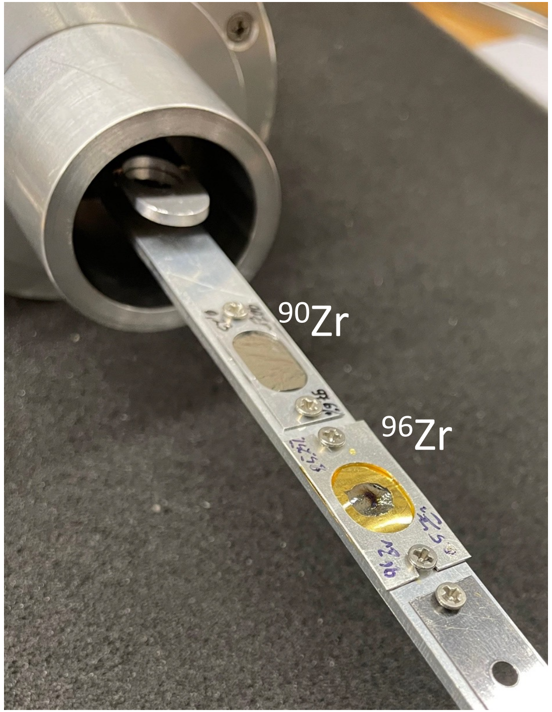
First Measurement

- Measurement of (p,p') reaction at 15 MeV

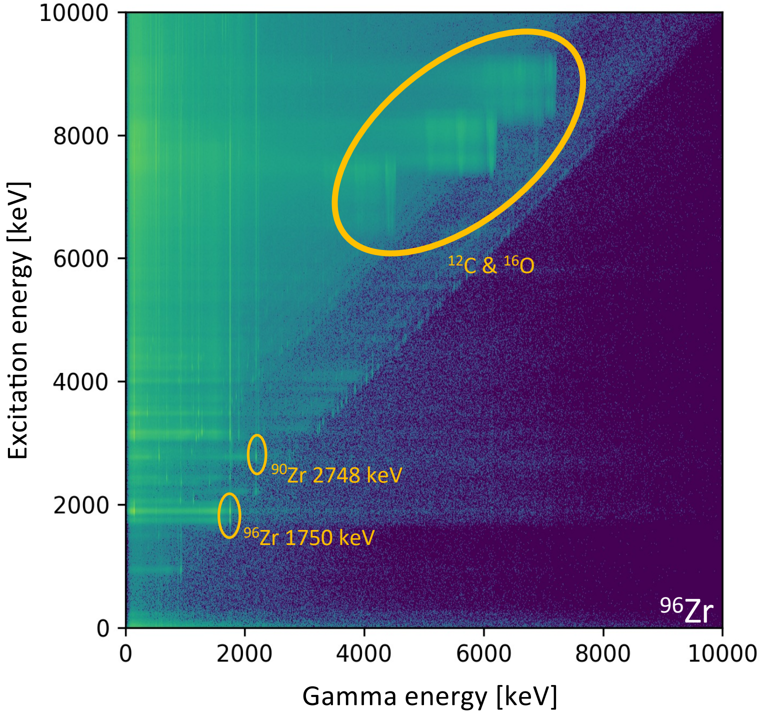
Target	Purity	Thickness	Beamtime	Target Current
^{12}C	~99%	100 µg/cm^2	5 h	745 - 820 pA
^{28}Si	~92%	950 µg/cm^2	10 h	3000 - 3800 pA
^{90}Zr	97.6%	230 µg/cm^2	8 h	560 - 630 pA
^{96}Zr	85.2%	500 µg/cm^2	23 h	450 - 670 pA

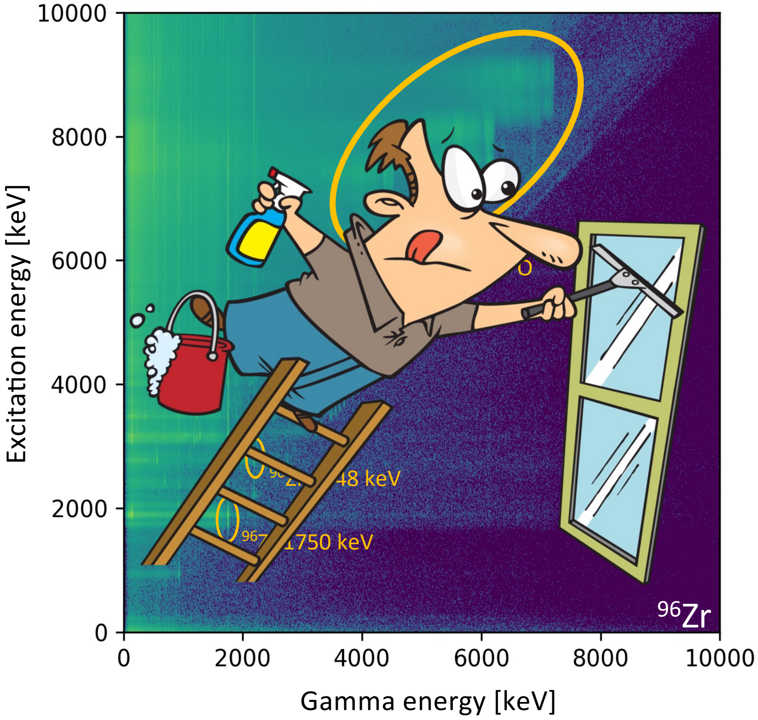
- ^{12}C & ^{90}Zr measurements to reduce contaminations in ^{96}Zr

➢ Produce ExG spectra for each target



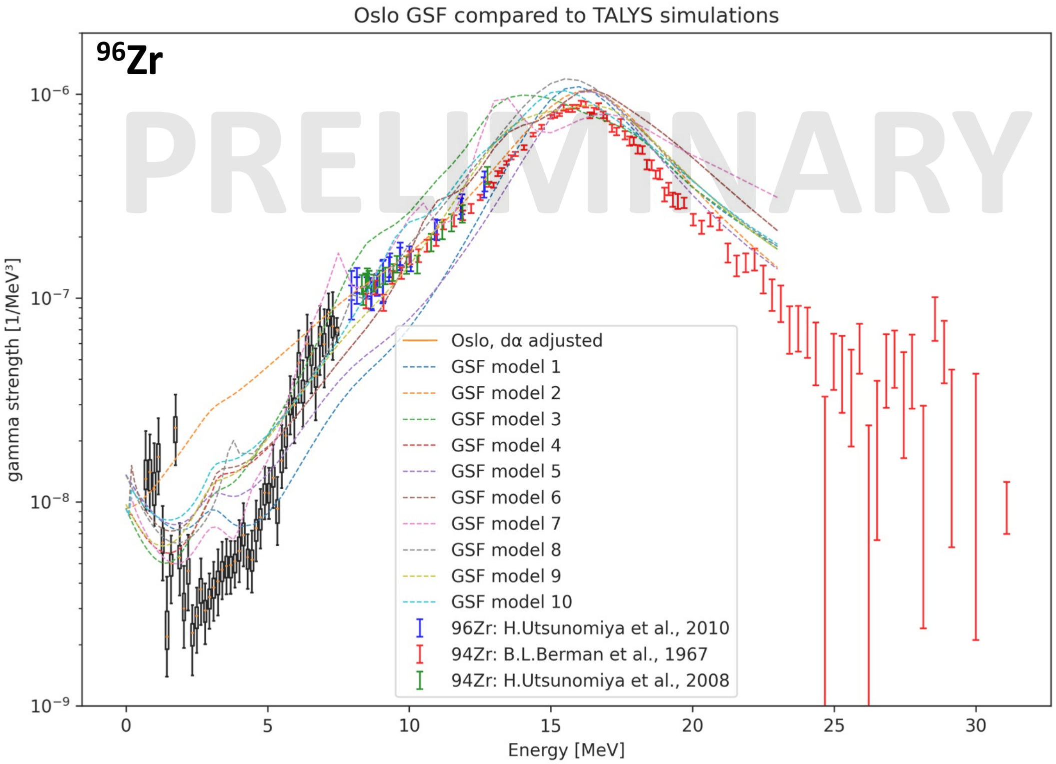
Excitation energy vs γ ray energy matrices





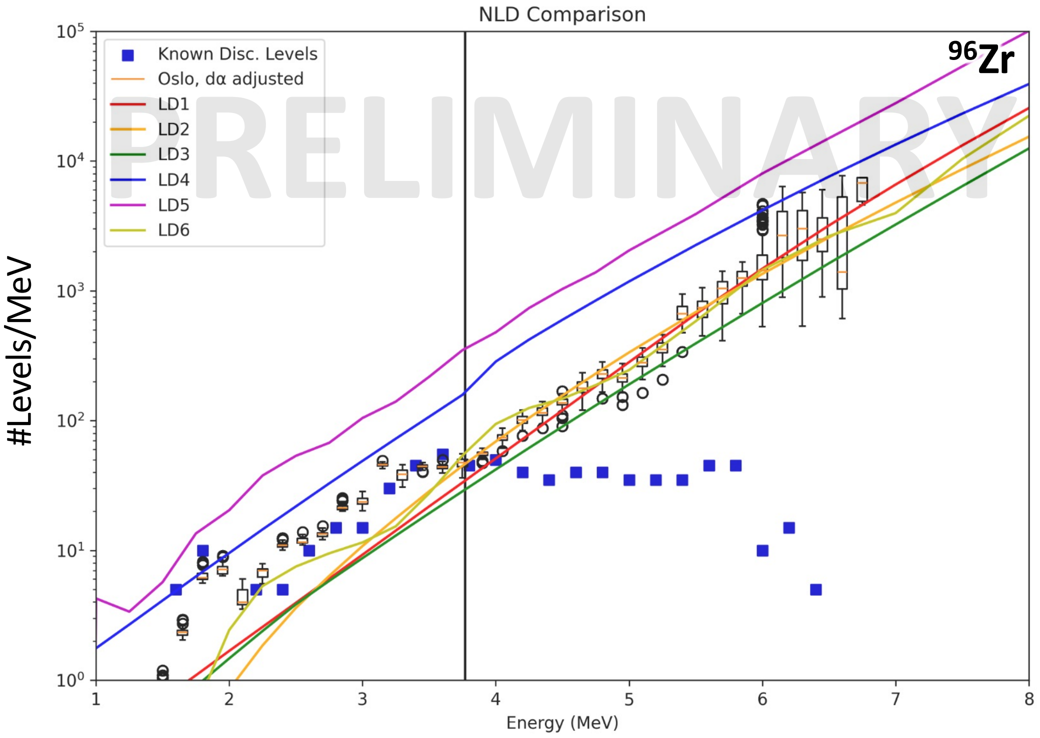
Tom Sitting
MSc. Student

^{96}Zr Gamma Strength Function

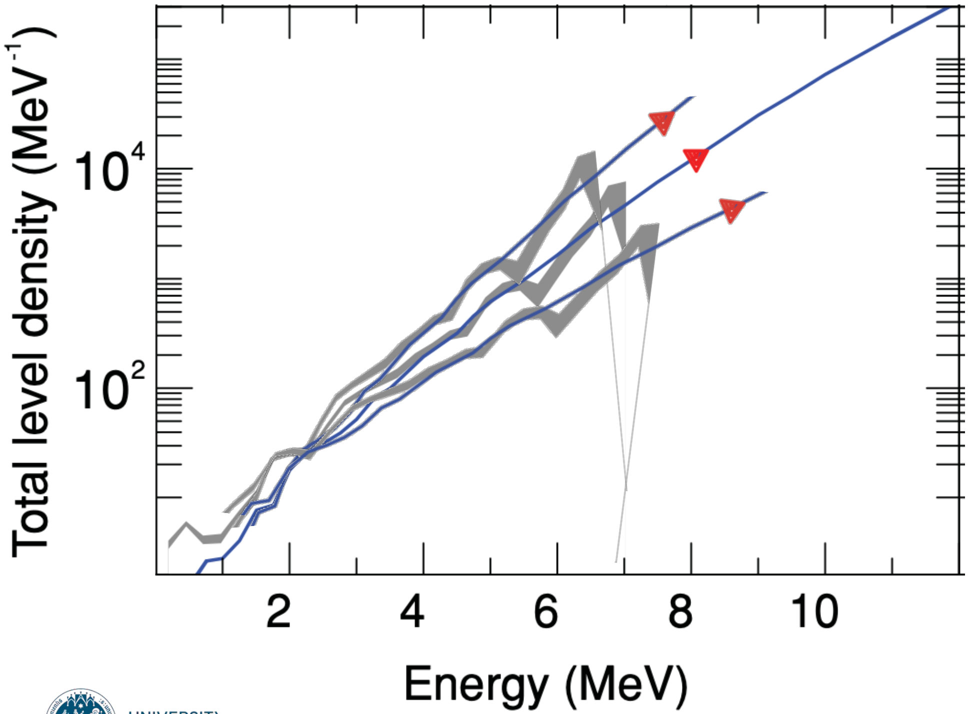


Nuclear Level Density

$$\tilde{\varrho}(E_\mathrm{i} - E_\gamma) = \varrho(E_\mathrm{i} - E_\gamma) A \exp(\alpha(E_\mathrm{i} - E_\gamma))$$



Normalizations and the Oslo Method



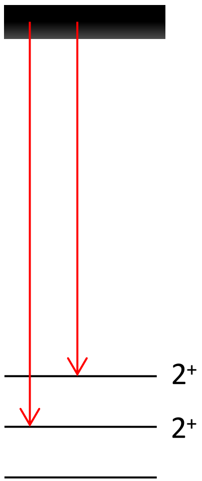
$$\tilde{\varrho}(E_i - E_\gamma) = \varrho(E_i - E_\gamma) A \exp(\alpha (E_i - E_\gamma))$$

$$\tilde{F}(E_\gamma) = F(E_\gamma) B \exp(\alpha E_\gamma).$$

In exotic nuclei: we don't know D_0

→ We can't determine the "slope" α
→ use level density model to calculate $\rho(Sn)$ which defeats the purpose

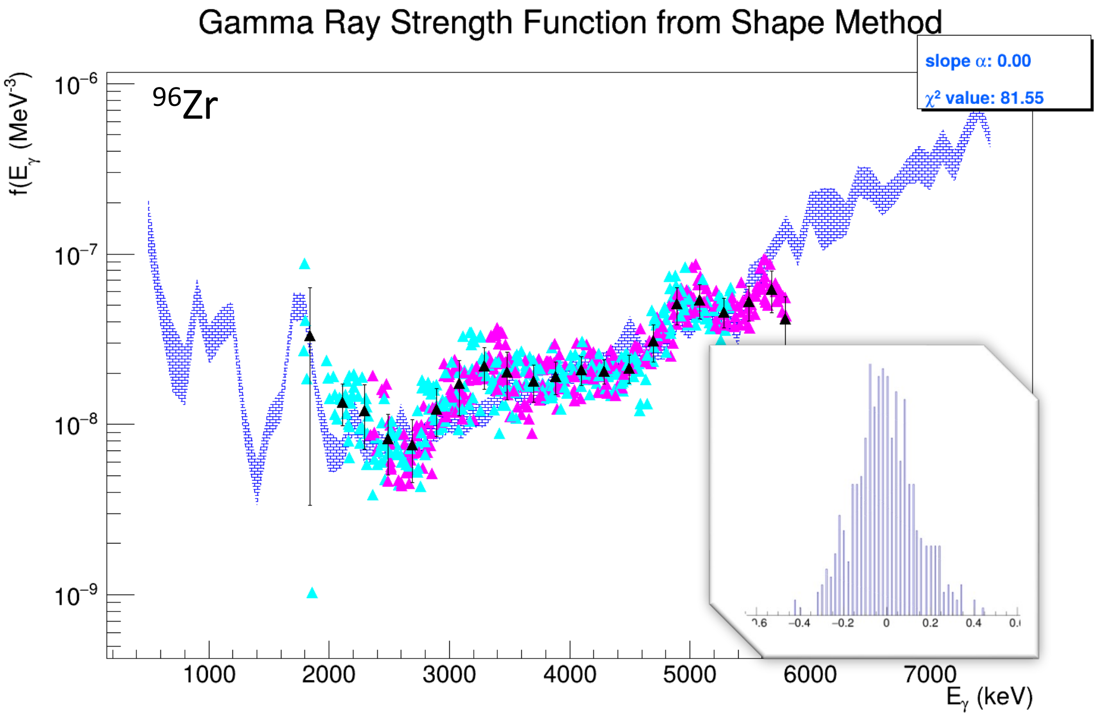
The Shape method for ^{96}Zr



Integration bin with sufficient number of states

$$R = \frac{f(E_{x,i} - E_{L_1})}{f(E_{x,i} - E_{L_2})} = \frac{N_{L_1}(E_{x,i})(E_{x,i} - E_{L_2})^3}{N_{L_2}(E_{x,i})(E_{x,i} - E_{L_1})^3}$$

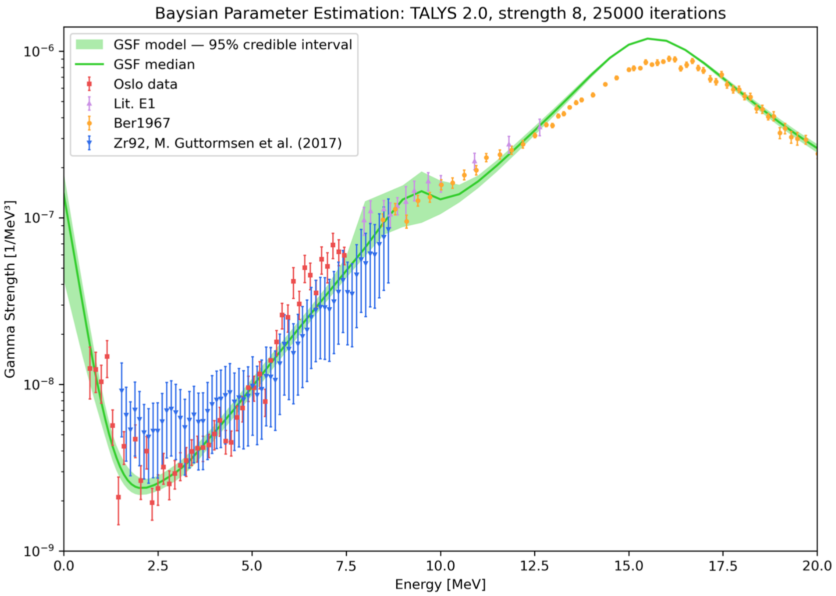
DM et al, Phys. Rev. C 107 (2023)



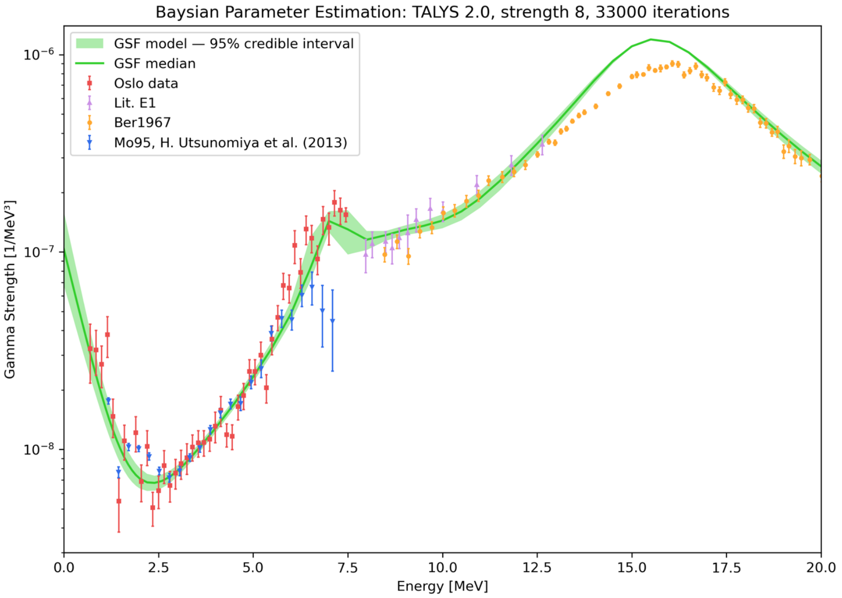
M. Wiedeking, M. Guttormsen, A. C. Larsen, F. Zeiser, A. Görgen, S. N. Liddick, D. Mücher, S. Siem, and A. Spyrou
Phys. Rev. C **104**, 014311 – Published 12 July 2021

Normalization of the gamma ray strength function

92Zr

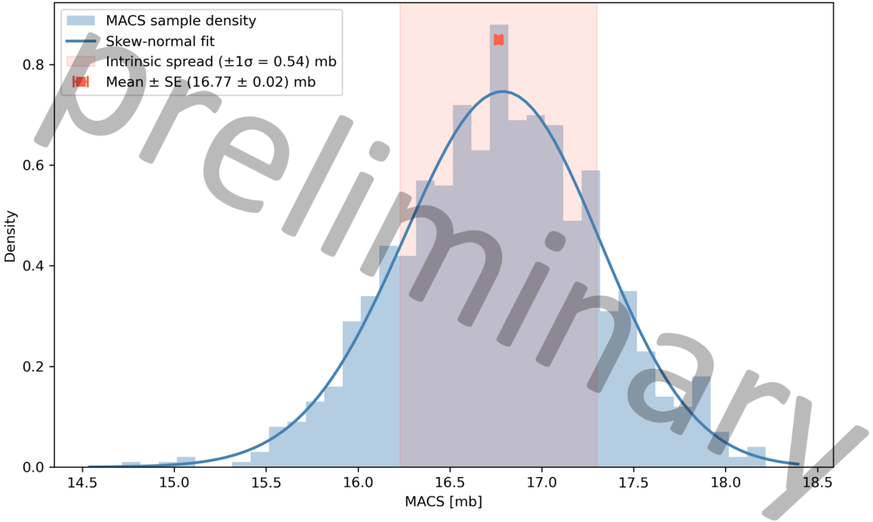


95Mo

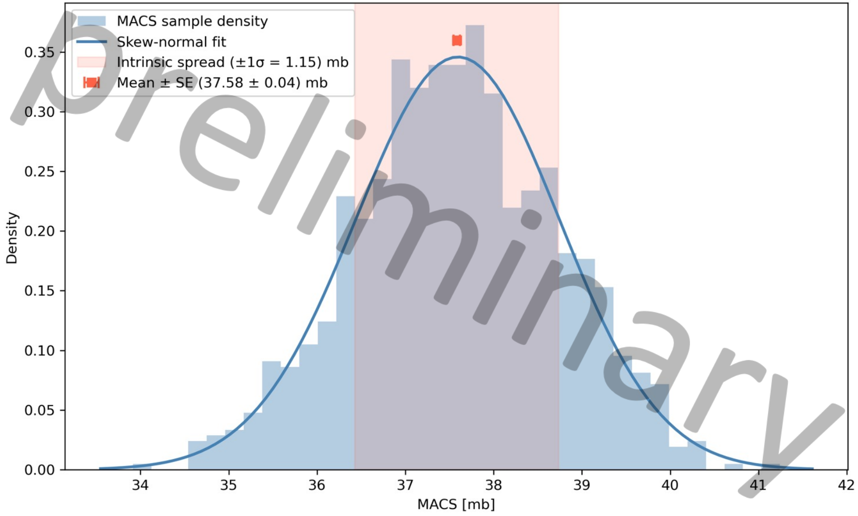


Results for $^{95}Zr(n,\gamma)$ MACS @30keV

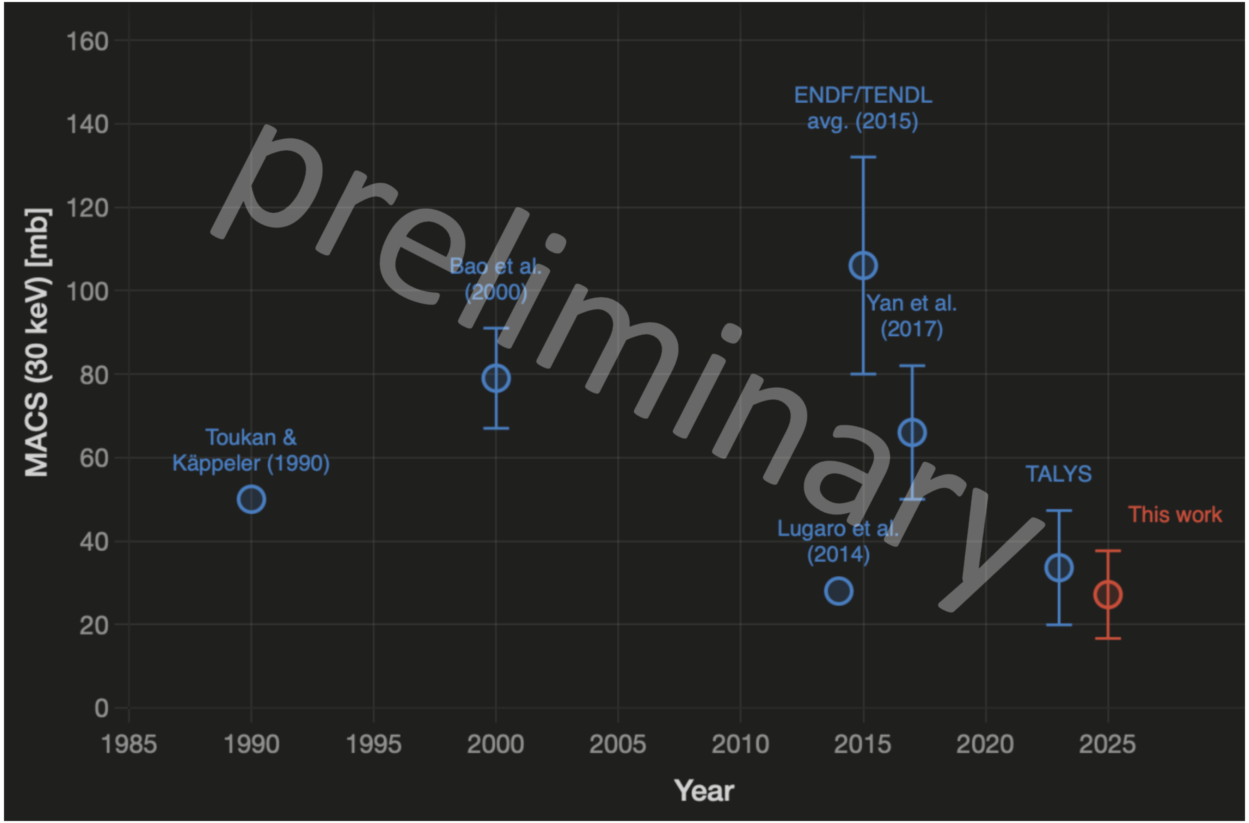
gSF normalized to ^{92}Zr



gSF normalized to ^{95}Mo



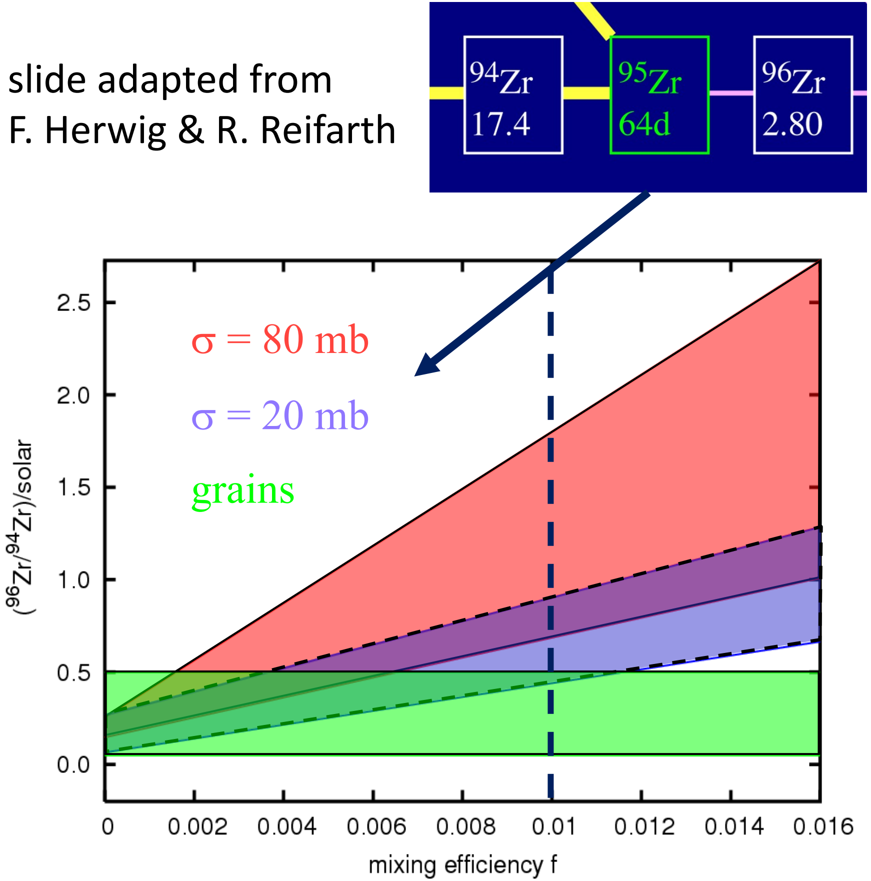
Result for $^{95}Zr(n,\gamma)$ MACS at 30 keV



plot created with Claude Sonnet 4.6

Impact on Convective boundary mixing parameter

slide adapted from
F. Herwig & R. Reifarth



Preliminary conclusions:

- ^{95}Zr(n,γ) thermometer for neutron exposure &
- ^{95}Zr(n,γ) helps constraining mixing efficiency during He shell flashes in AGB stars
- Oslo-data suggest a smaller value for the MACS@30keV of 27+-11 mbarn
- this is in line with expectations for a mixing efficiency of f=0.01

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Thank you to everyone involved!

Tom Sittig[1], Anna Bohn[1], C. Fransen[1], Magne Guttormsen[3], Devin Hymers[1], Abdallah Karaka[1], Ann-Cecilie Larsen[3], Markus Müllenmeister[1], Sarah Prill[1], Sebastian Schröder[1], Amal Sebastian[2], Artemis Spyrou[2], Michael Weinert[1], Gereon Weingarten[1], A. Zilges[1], Dennis Mücher[1]

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[3]Universitetet I Oslo, Fysisk Institutt, Oslo, Norway

Thank you for your attention!