In-beam studies of the astrophysical p-process

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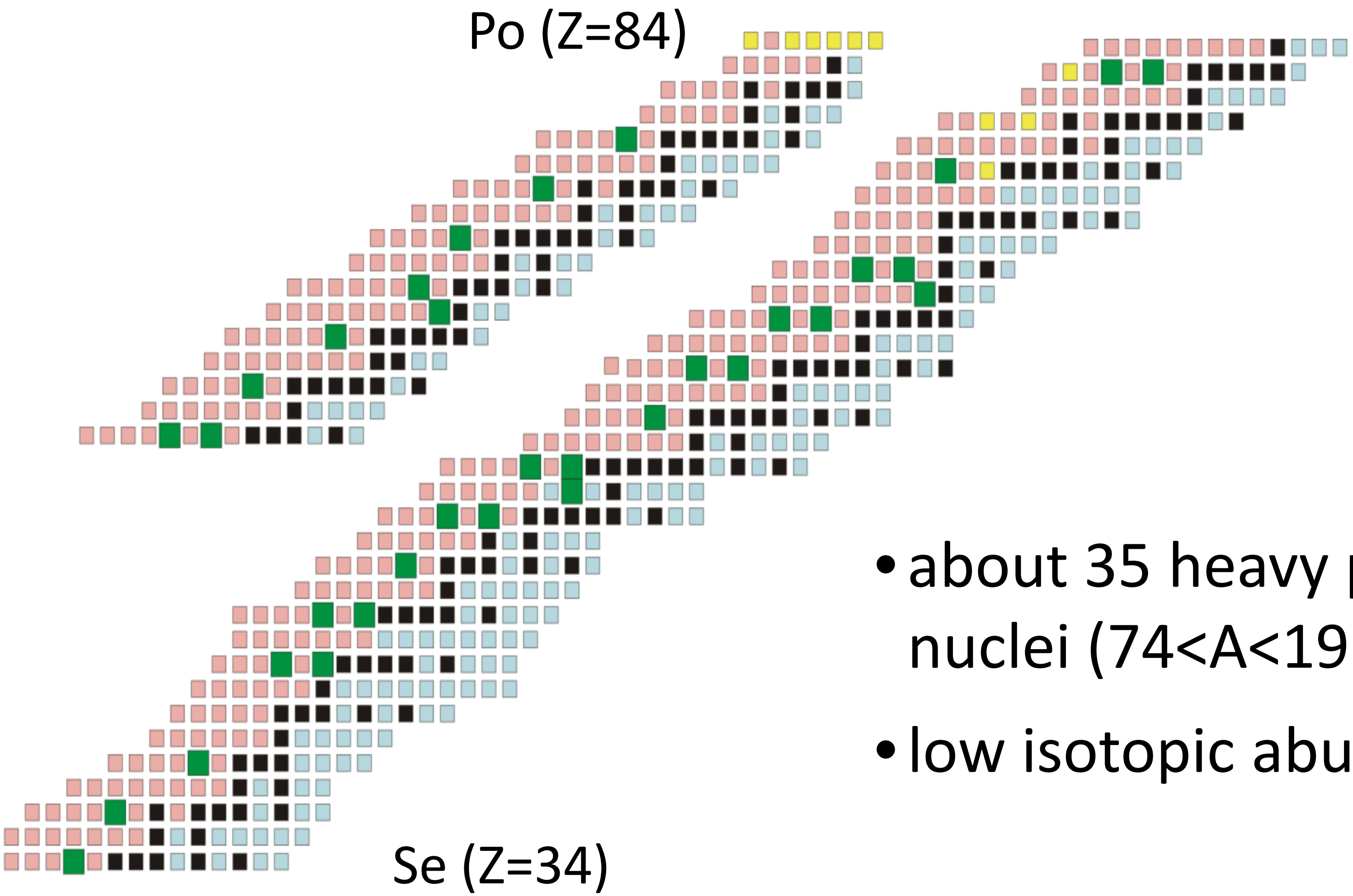
supported by DFG (ZI 510/5-1 and INST 216/544-1)

The *p* nuclei

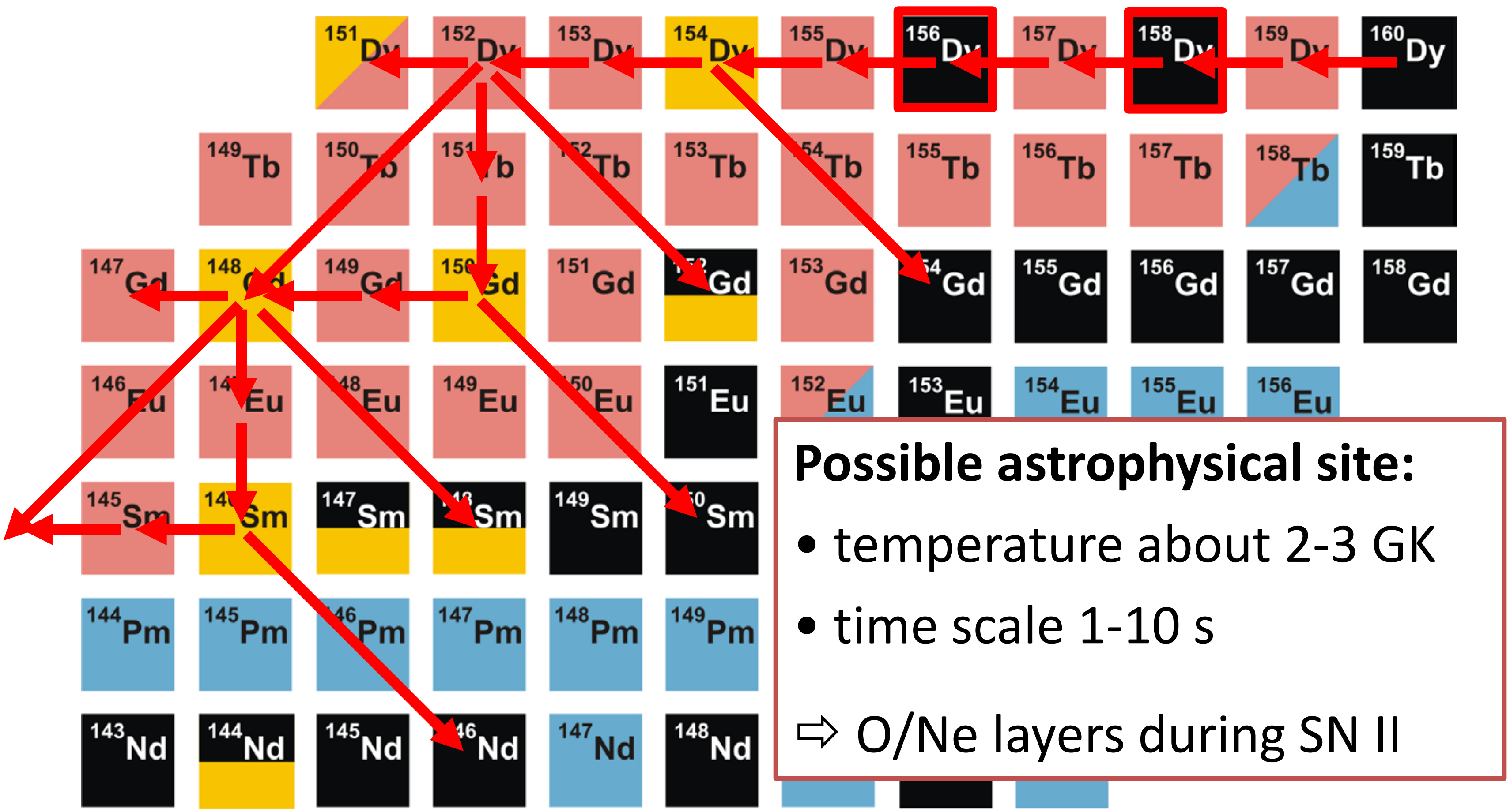


- about 35 heavy p-rich nuclei (74<A<196)
- low isotopic abundance

The *p*-process network

Reaction network:

- mainly (γ,n), (γ,p), and (γ,α) reactions
- about 2000 nuclei and 20000 reactions

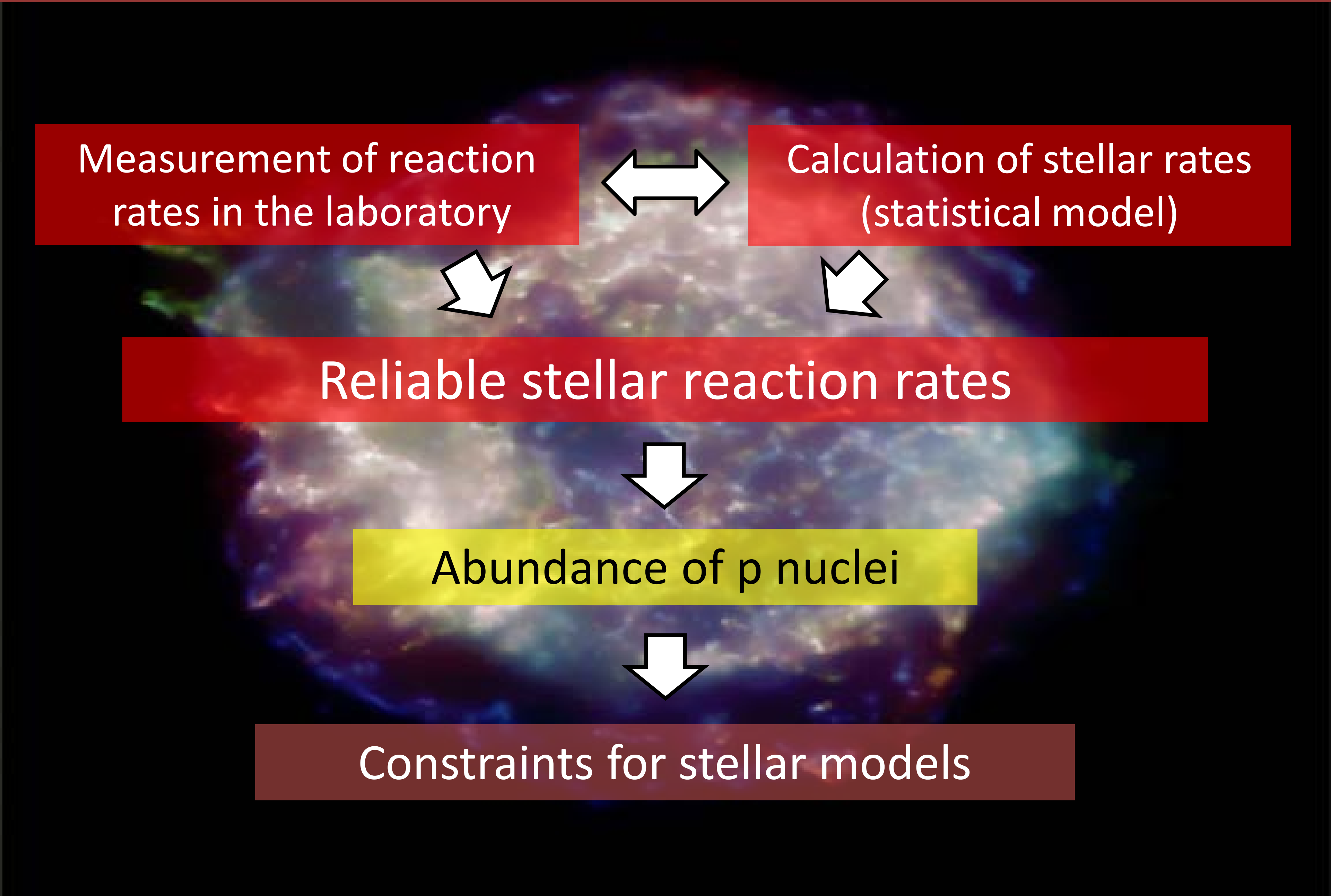


Possible astrophysical site:

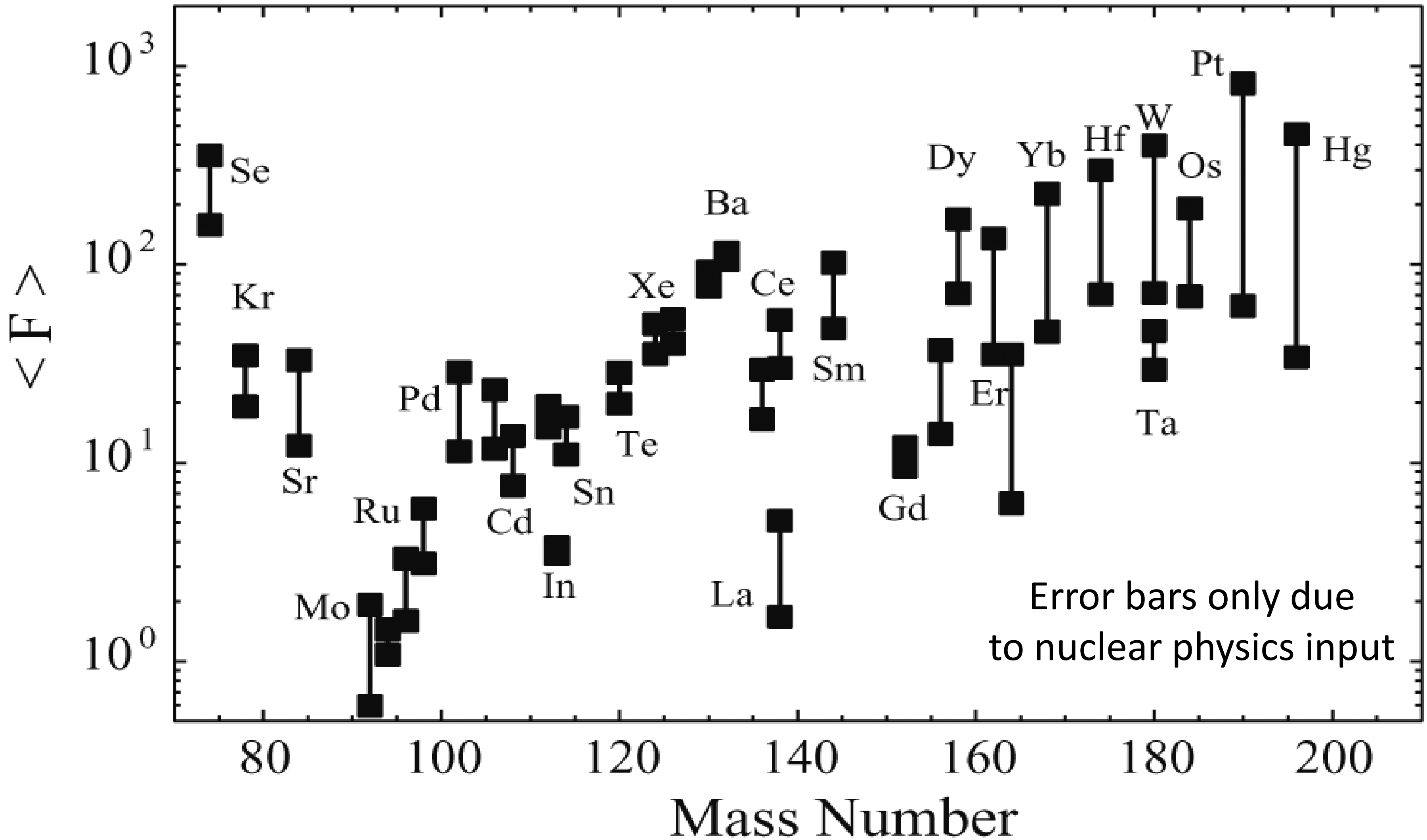
- temperature about 2-3 GK
- time scale 1-10 s

⇨ O/Ne layers during SN II

Impact of reaction rate measurements



Abundance of *p* nuclei: prediction vs. observation



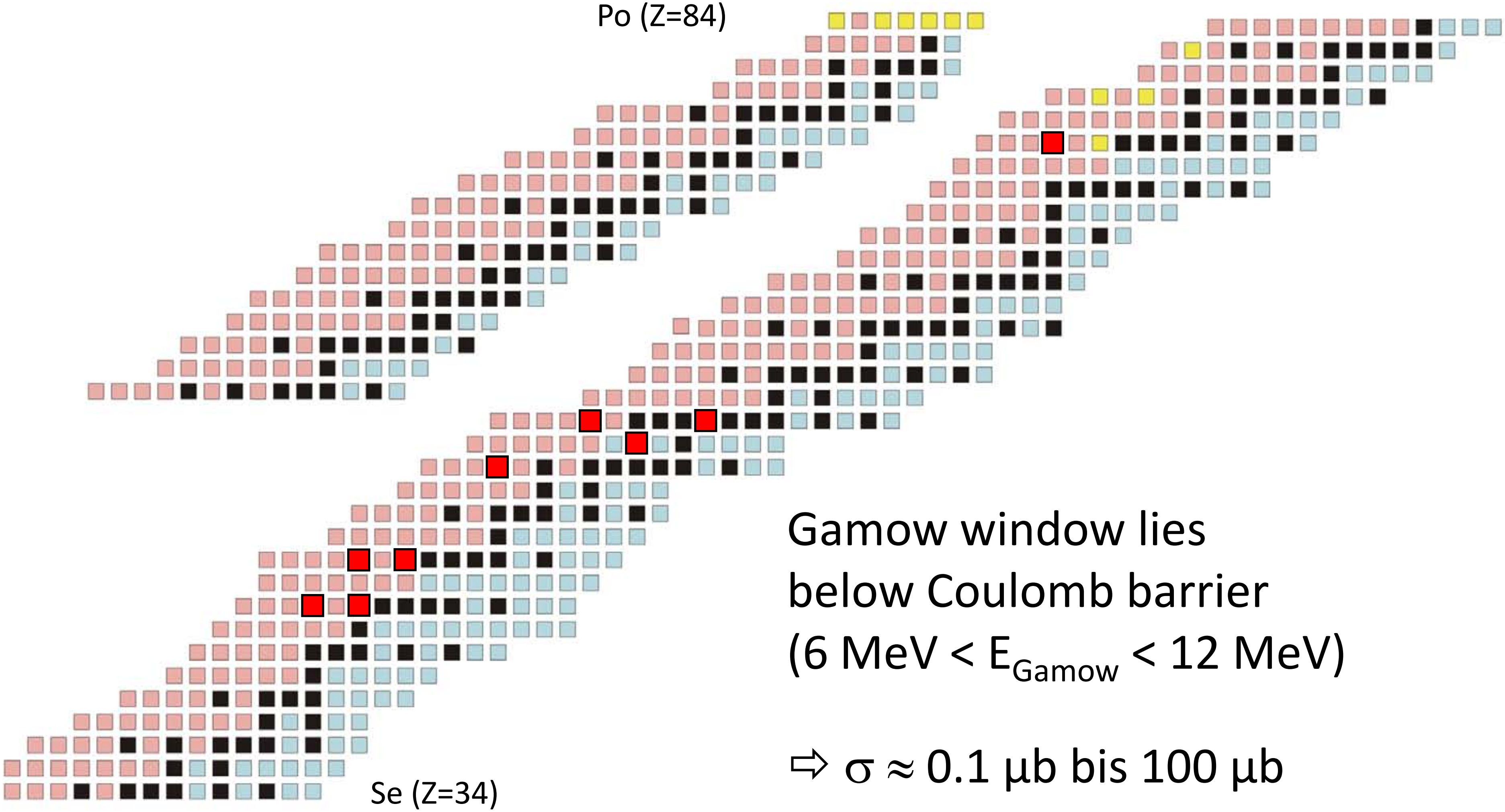
M. Arnould and S. Goriely, Phys. Rep. 384 (2003) 1

S. Goriely et al., Astronomy & Astrophysics 444 (2005) L1

Nuclear Physics input for the network calculations

- Ground state masses
- Properties of excited states
- Level densities
- Photoresponse (γ,γ‘), (γ,*n*), (γ,α), (γ,*p*)
- Optical potentials (p,n,α – nucleus)

Measurement of α-nucleus optical potentials

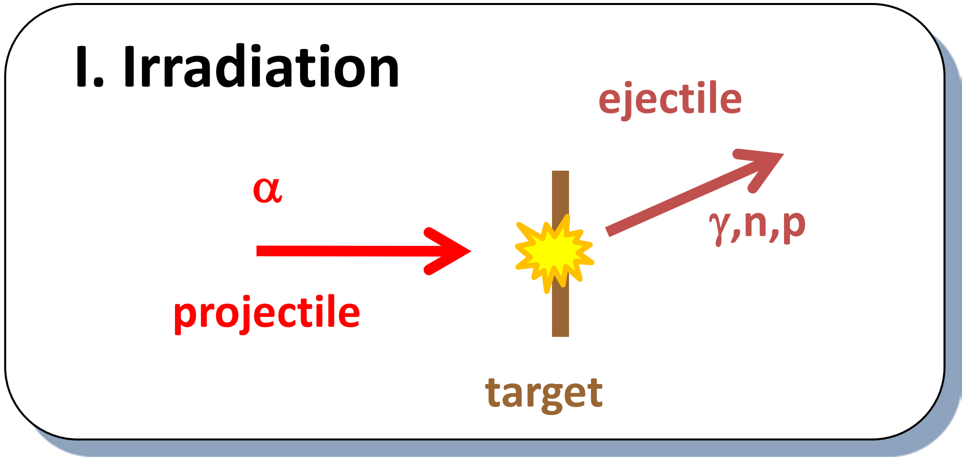


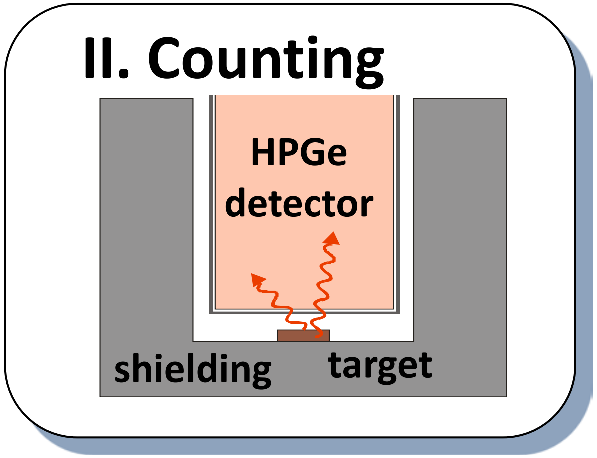
Gamow window lies below Coulomb barrier ($6\ \mathrm{MeV} < E_{Gamow} < 12\ \mathrm{MeV}$)

⇨ $\sigma \approx 0.1\ \mu b$ bis $100\ \mu b$

Only nine α– induced reactions have been published within the Gamow window!

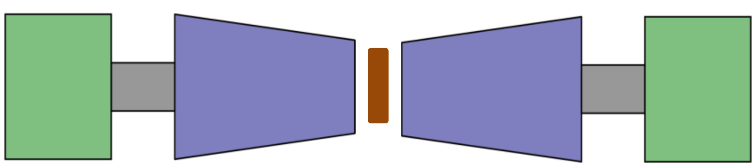
A very sensitive tool: Activation analysis





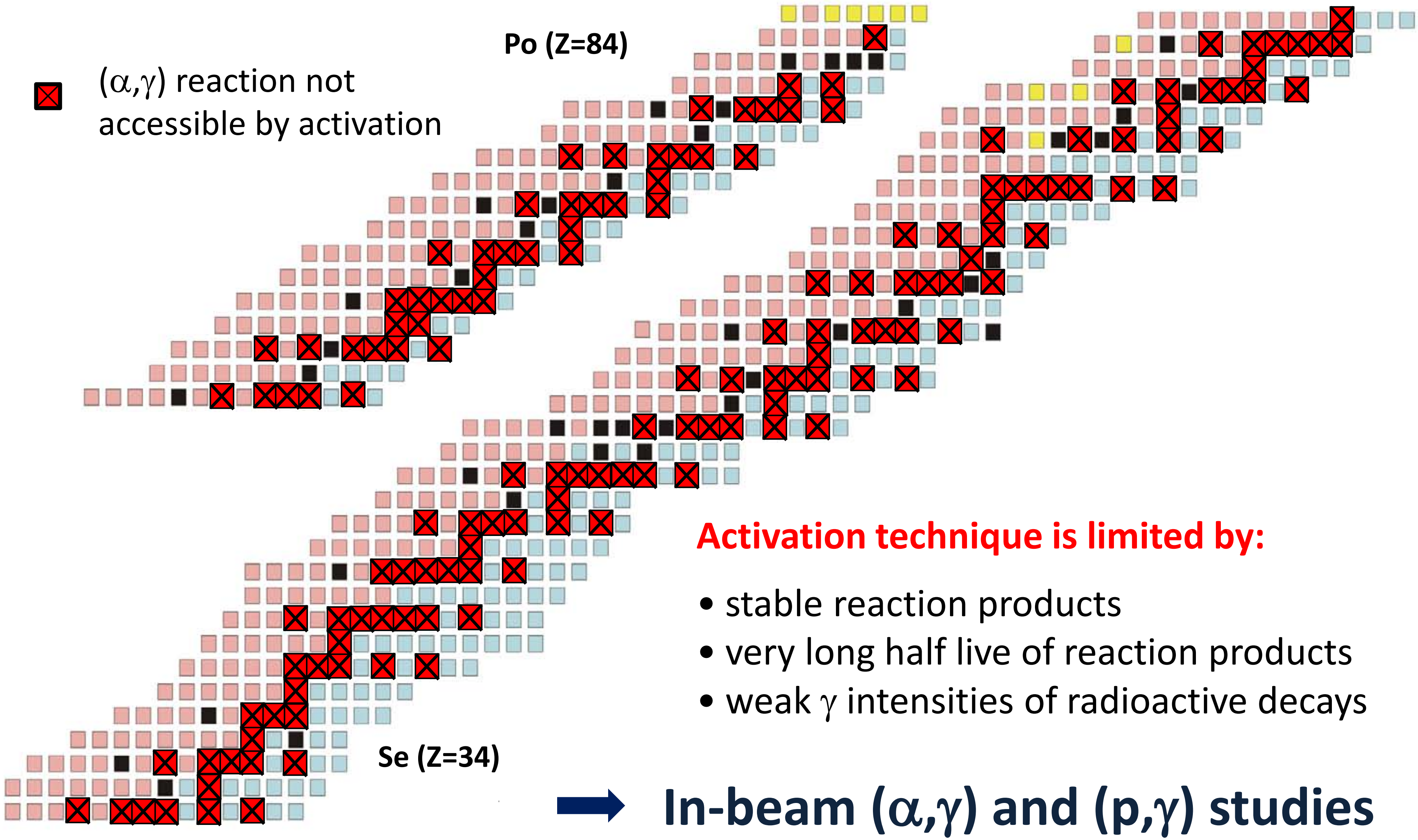
➡ György's talk

At IKP Cologne:



Two 120% Clover plus addback,
shielded by BGO and passive shielding

Limitations of the activation technique



Activation technique is limited by:

- stable reaction products
- very long half live of reaction products
- weak γ intensities of radioactive decays

➡ **In-beam (α,γ) and (p,γ) studies**

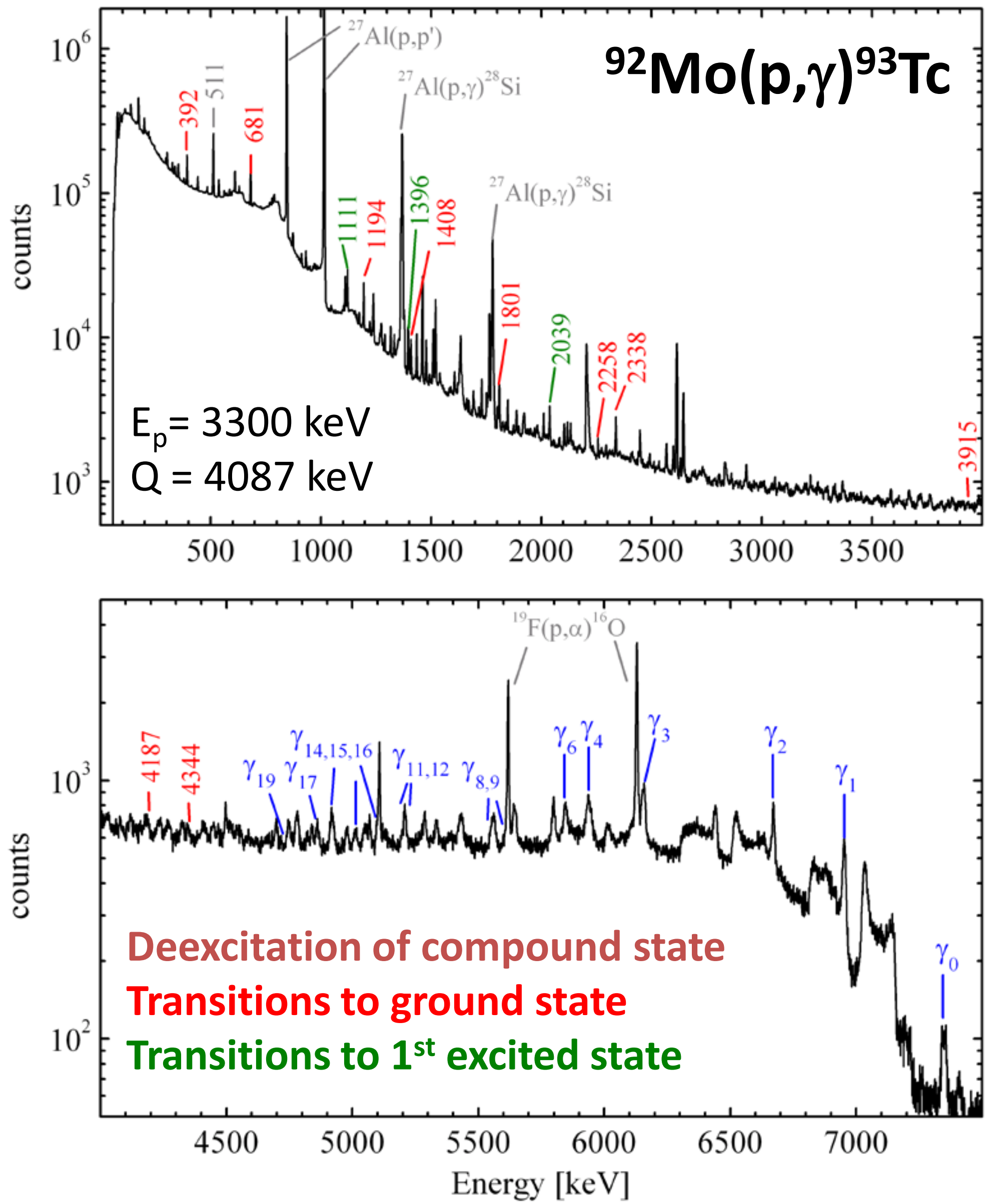
In-beam experiments using HPGe detectors

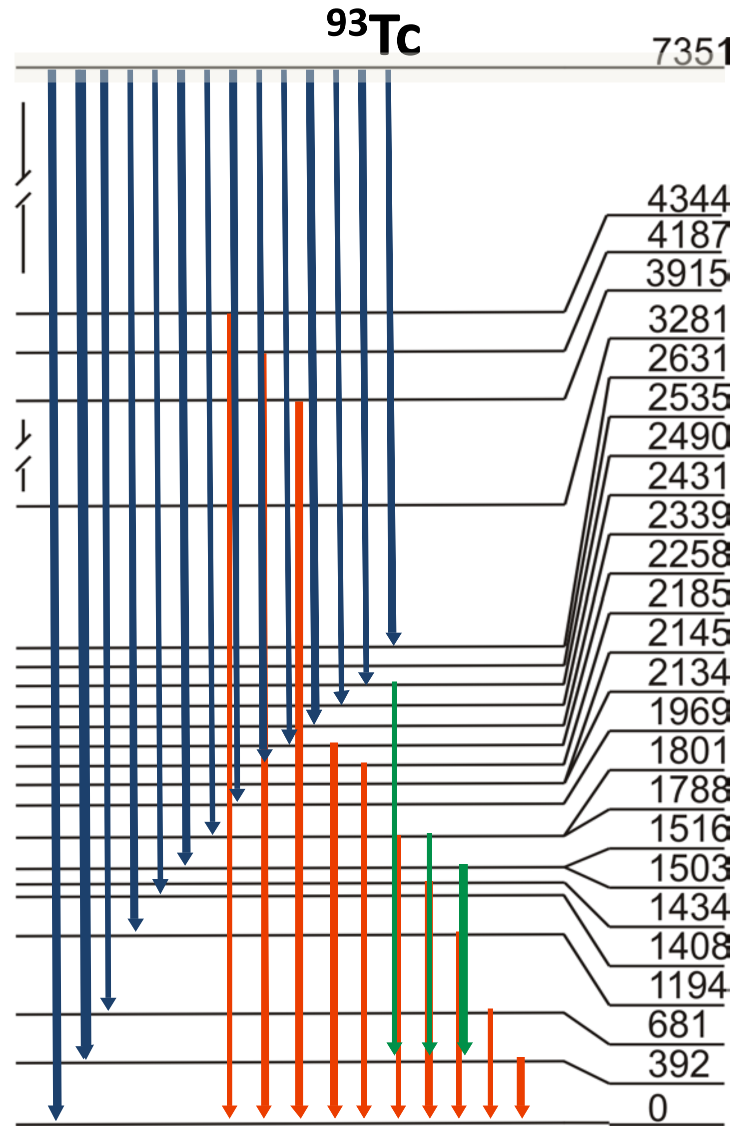
HORUS @ IKP Köln:

- **14 HPGe detectors** in close geometry
- Photopeak efficiency at 1332 keV: up to 5%

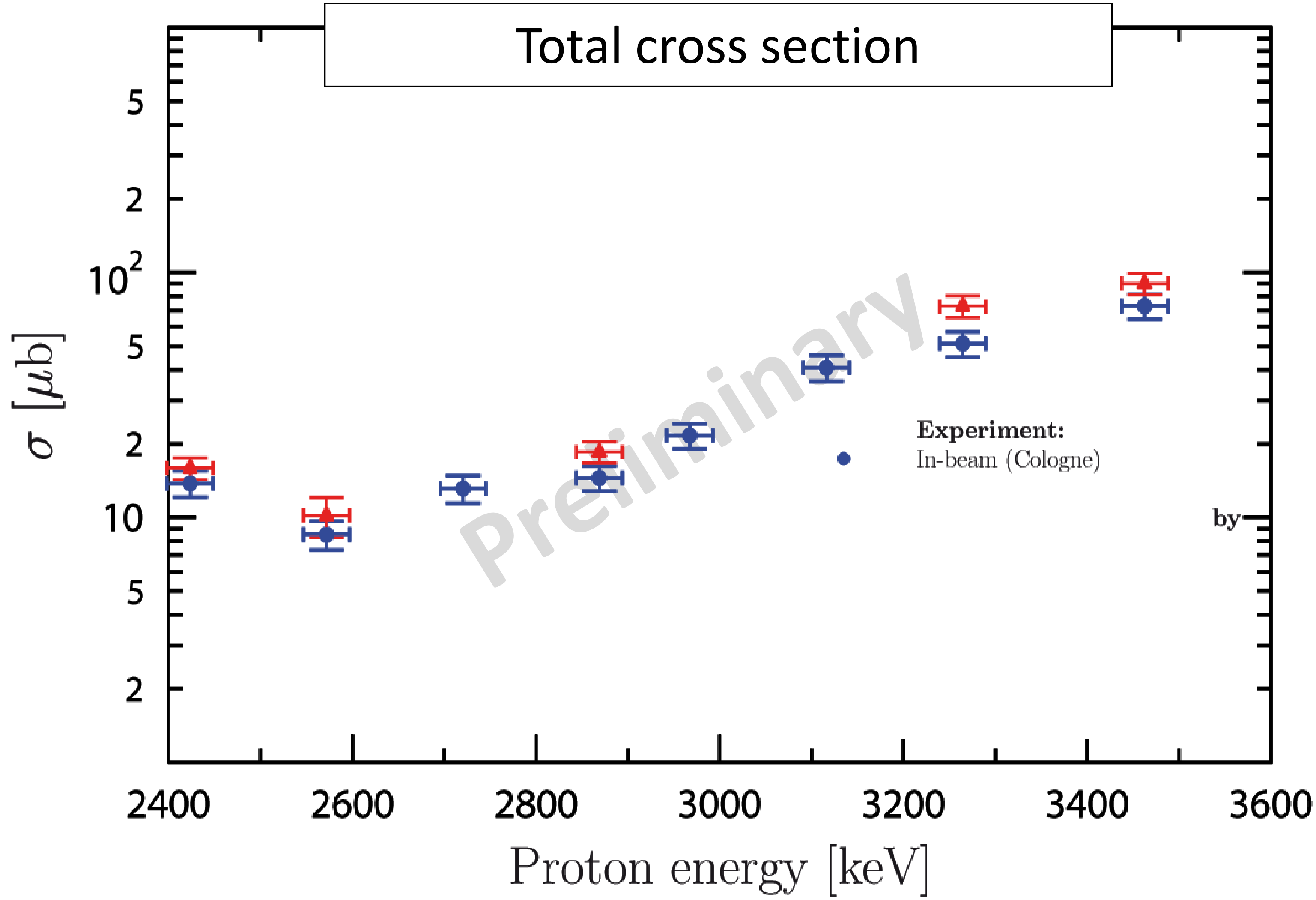
- **High energy resolution to observe single transitions**
- **Adequate efficiency to study low cross sections**
- **Determination of angular distributions possible**
- **Coincidence technique to suppress background**

Radiative proton capture on ^{92}Mo

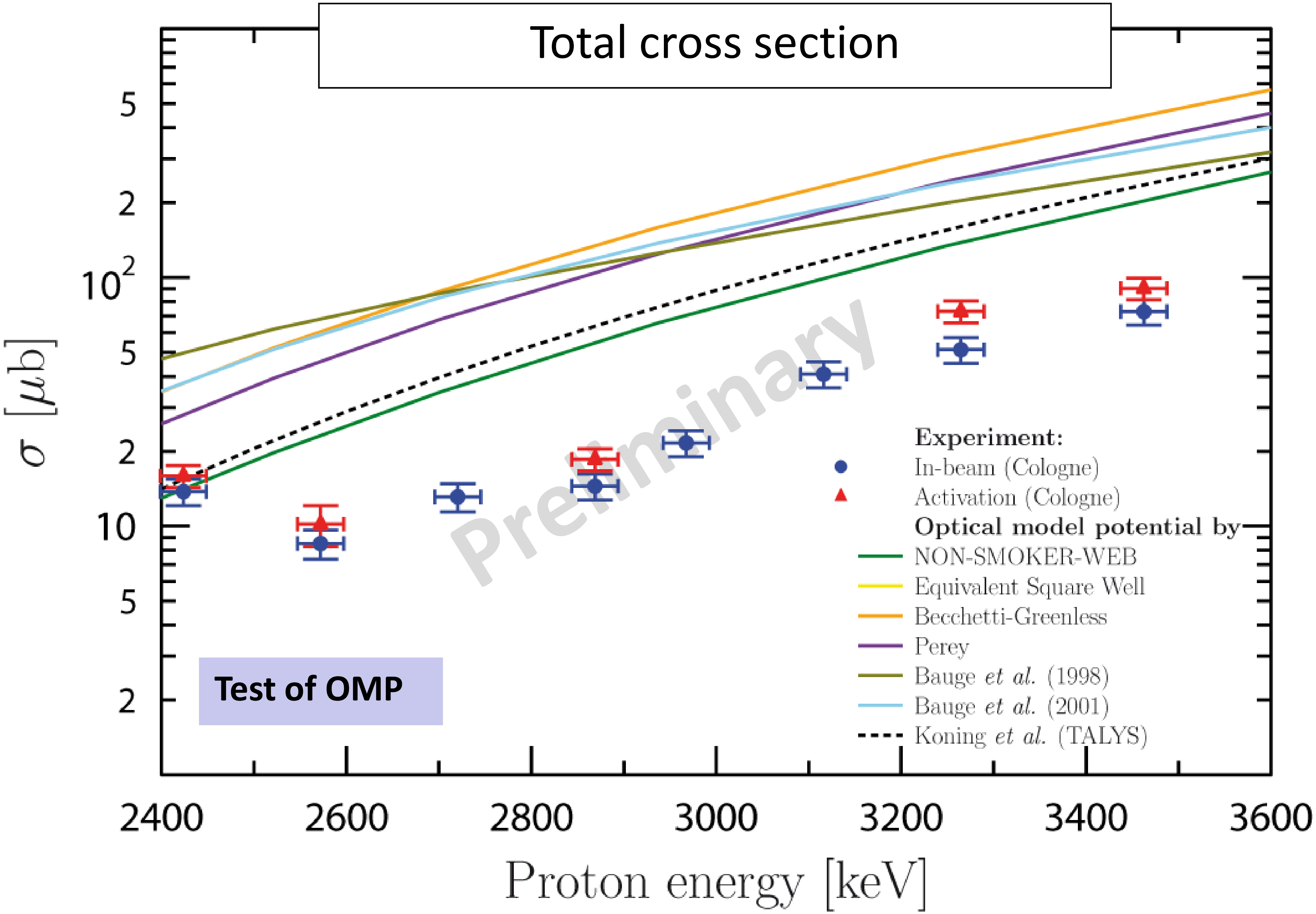




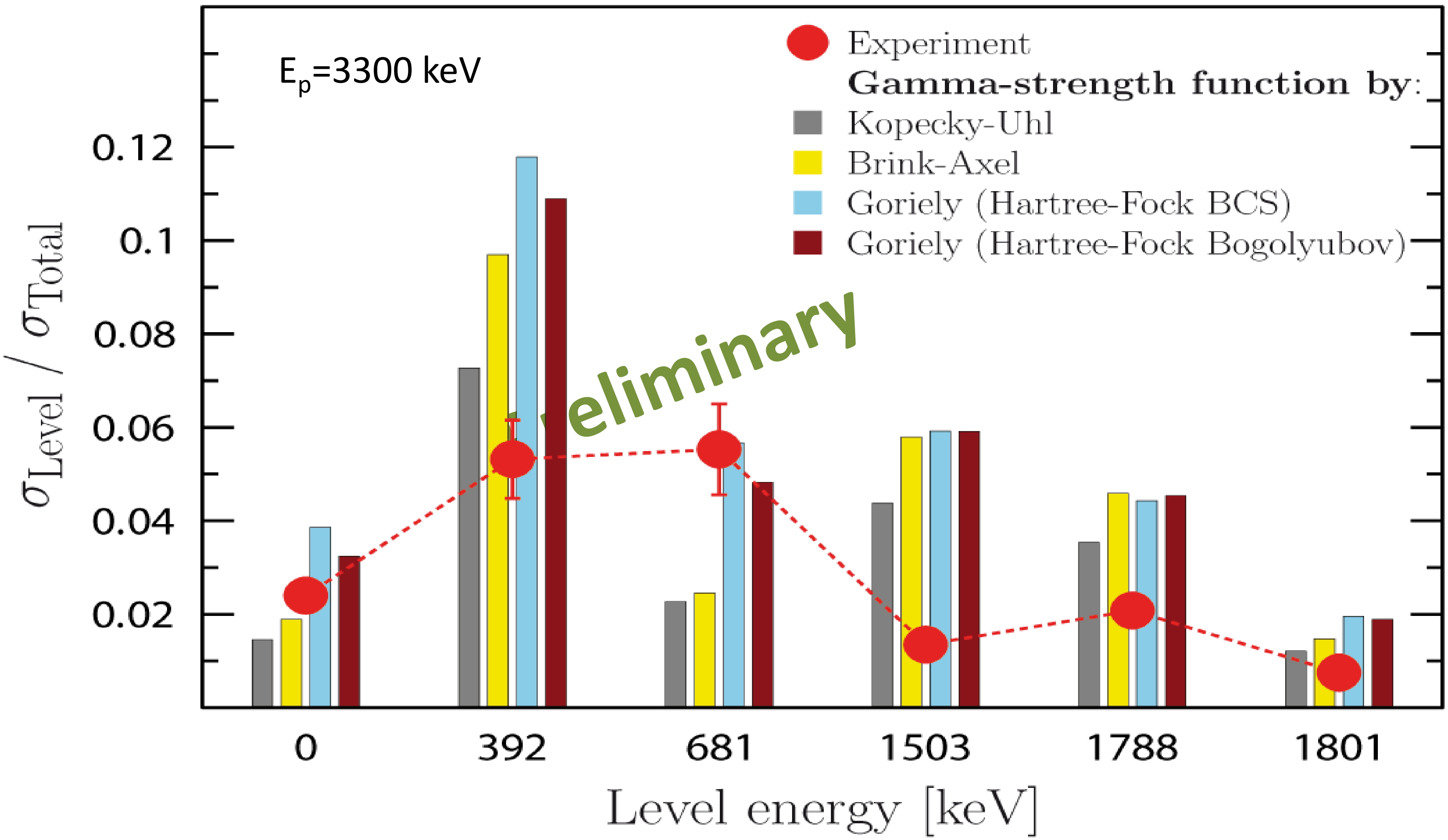
Radiative proton capture on ^{92}Mo



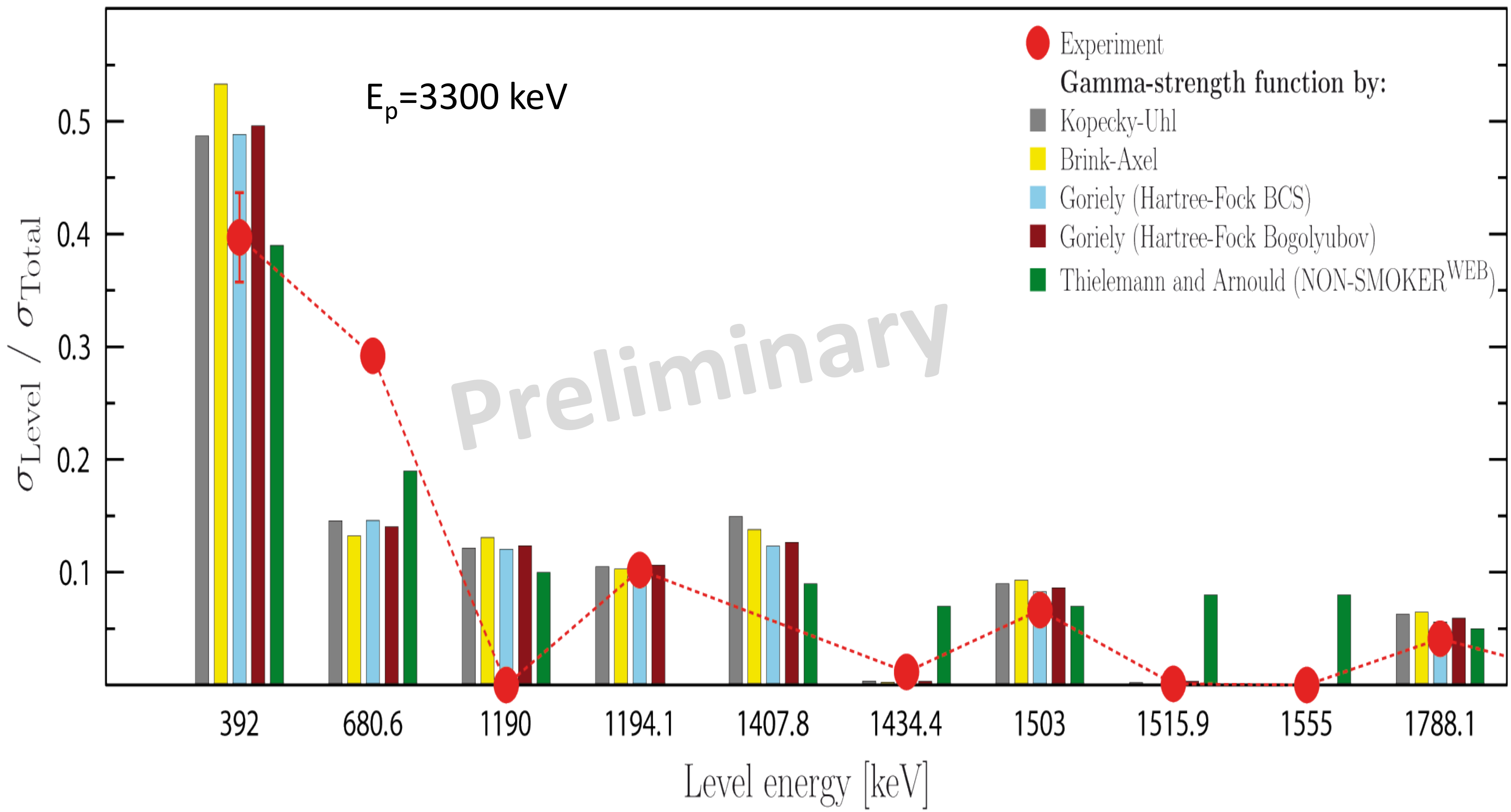
Radiative proton capture on ^{92}Mo



$^{92}Mo(p,\gamma)$: Partial cross sections

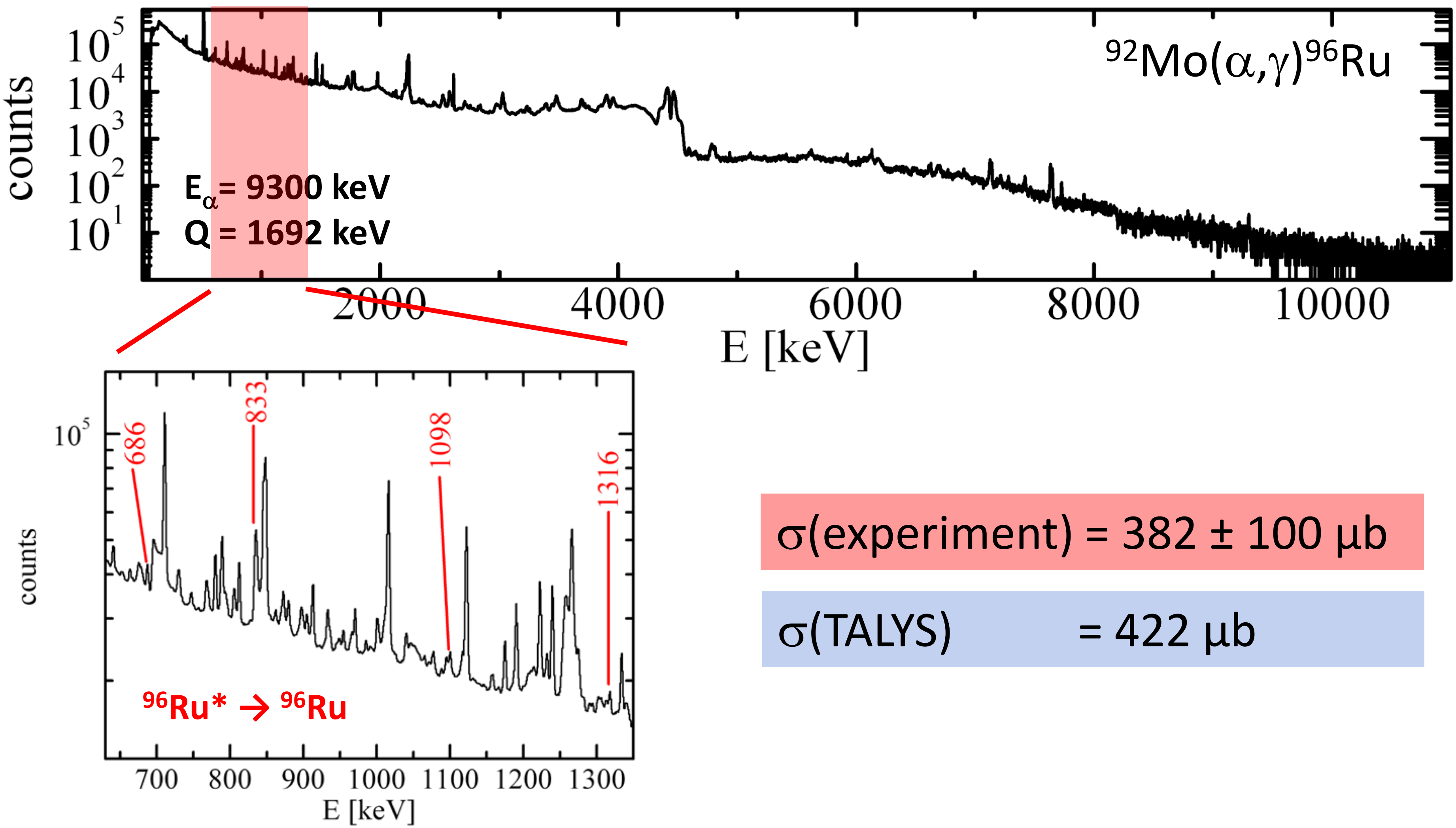


$^{92}Mo(p,\gamma)$: Production of excited states



➡ Information about γ-ray strength function

Radiative α capture: $^{92}Mo(\alpha,\gamma)$

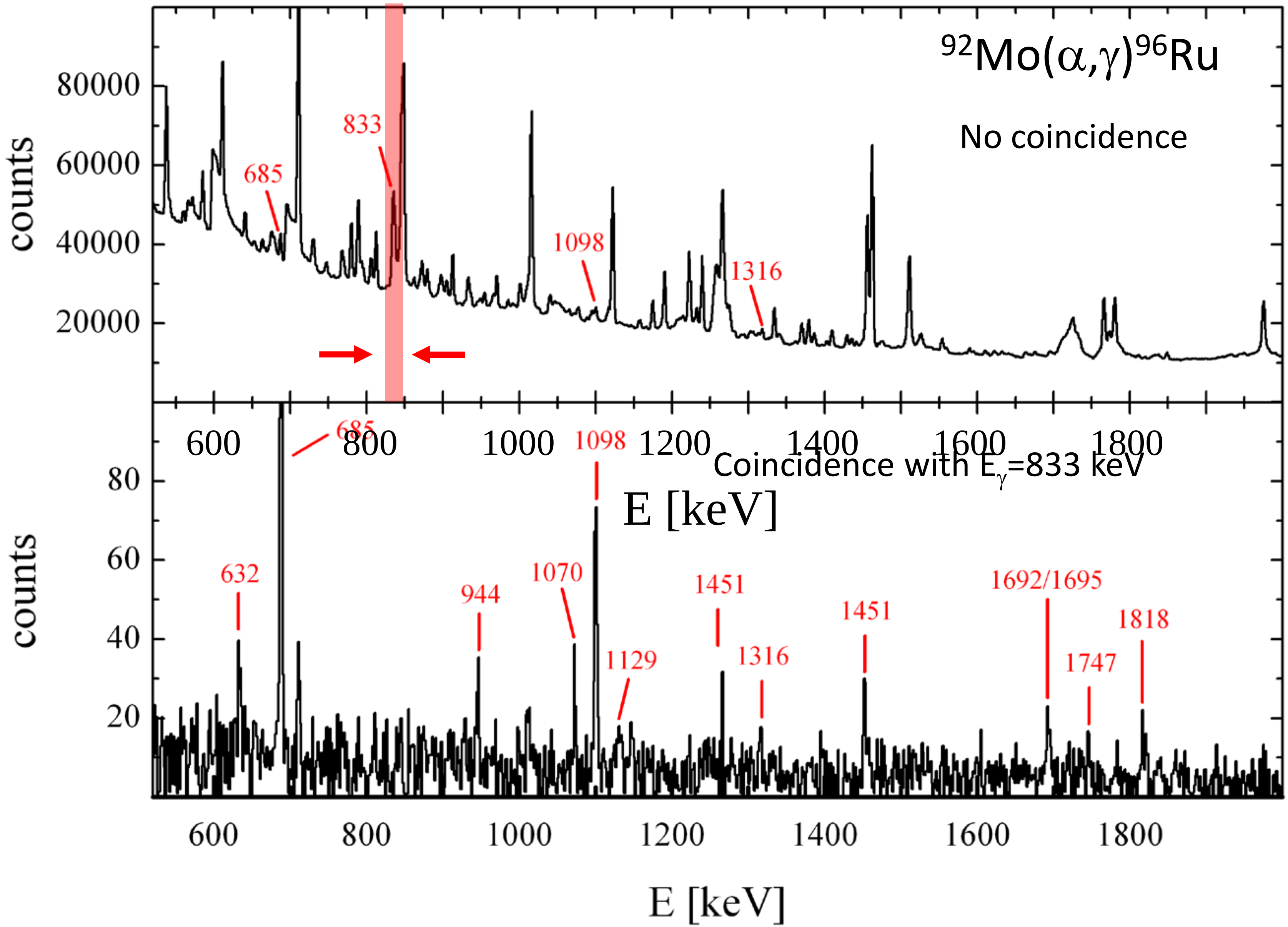


σ(experiment) = 382 ± 100 μb

σ(TALYS) = 422 μb

Background reduction necessary for smaller cross sections!

Background reduction using γ-γ coincidence techniques



Accelerator Mass Spectrometry – an option to measure small reaction cross sections

CologneAMS

- Tandetron with 6 MV terminal voltage
- standard isotopes: ^{10}Be, ^{14}C, ^{26}Al, ^{36}Cl, ^{129}I (geosciences, prehistory, protohistory)
- ample beam time for development

DFG

Universität zu Köln

GFZ Helmholtz-Zentrum POTSDAM

CologneAMS – a new option to measure small reaction cross sections

- Main shipment: May 18th, 2010
- Ready to go: July 10th, 2010

In-beam studies of the astrophysical p-process

In-beam studies using multi detector γ arrays can allow the determination of many astrophysically relevant observables

<u>Fall 2010</u>: Restart of HORUS@IKP
(after 3M€ Tandem renovation)

<u>Spring 2011</u>: Start of CologneAMS

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