Nuclear physics experiments for the astrophysical *p* process

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INTERNATIONAL SCHOOL OF NUCLEAR PHYSICS

32nd Course

Particle and Nuclear Astrophysics

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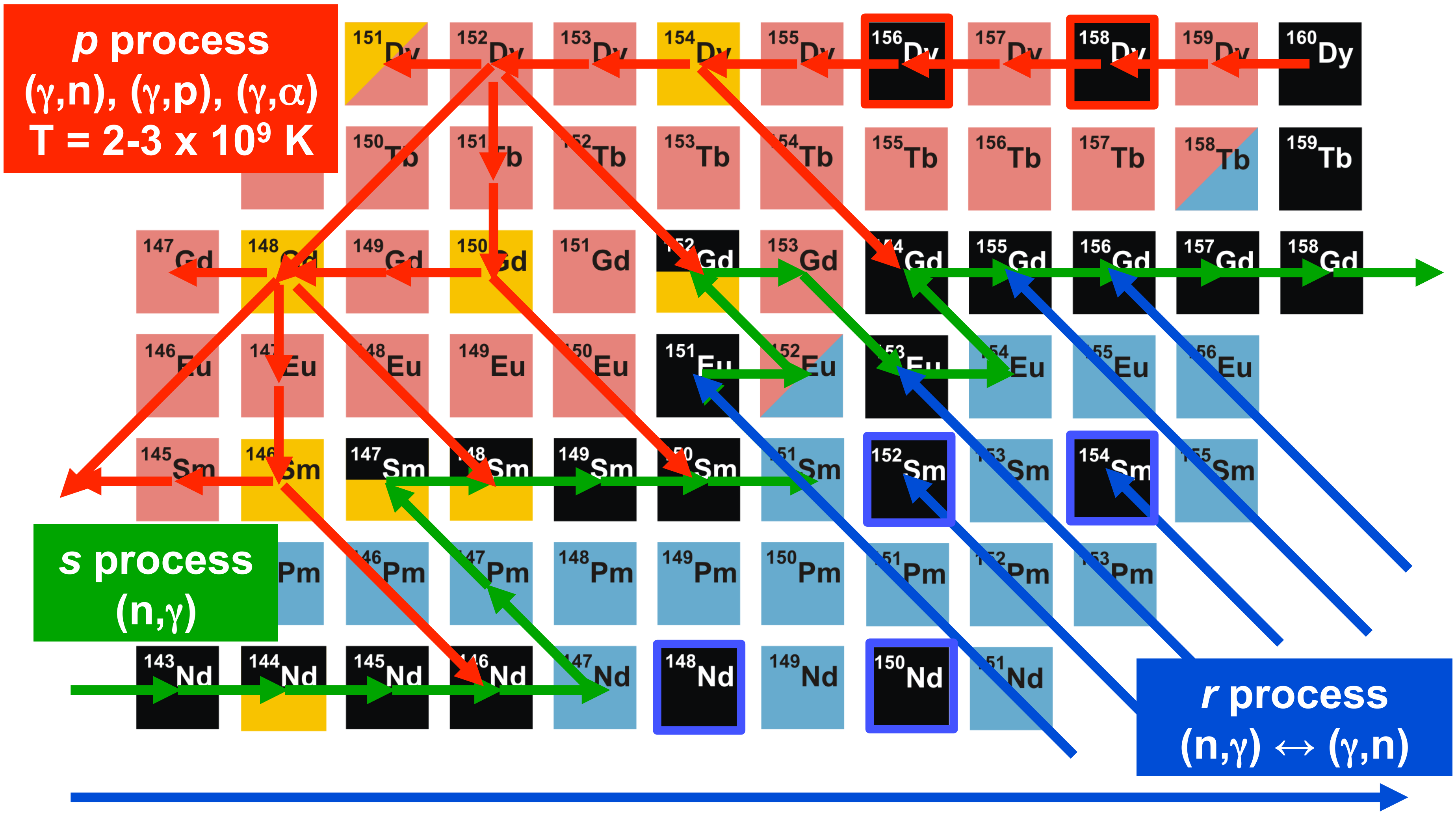
Content

- Nucleosynthesis above iron
  ⇨ *p* process

- ^{141}Pr(α,n)^{144}Pm at PTB Braunschweig
  ⇨ Activation experiment

- ^{92}Mo(p,γ)^{93}Tc at IKP Cologne
  ⇨ In-beam experiment

Nucleosynthesis above iron



Nuclear physics data for the *p* process

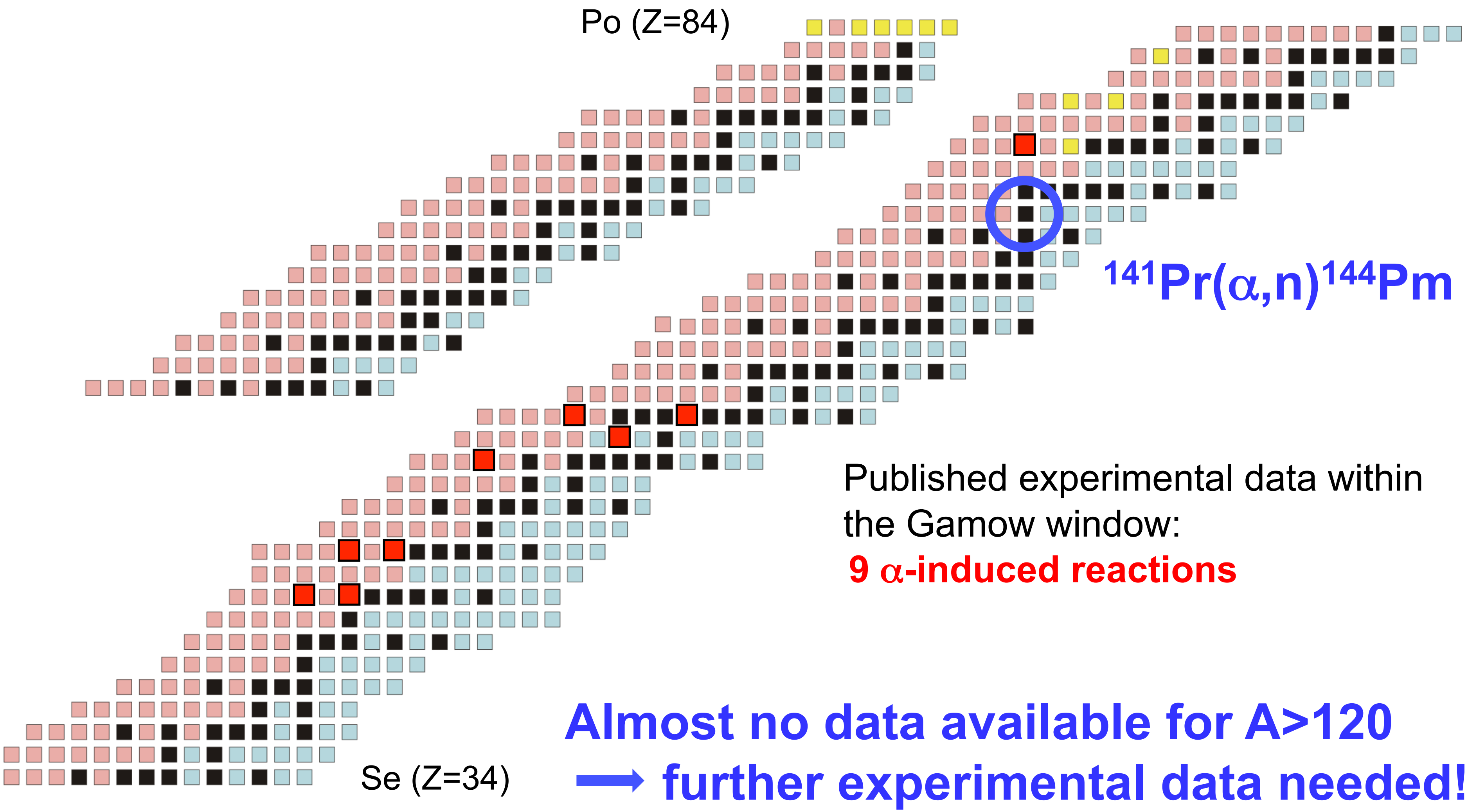
Option 1:
Measure astrophysical reaction rates directly

Only possible for a few number of reactions within the network

Option 2:
Improve nuclear models to calculate reaction rates

- Nuclear masses
- Properties of excited states
- Nuclear level densities
- Photon strength function
- Nucleon-nucleus OMP
- α-particle-nucleus OMP

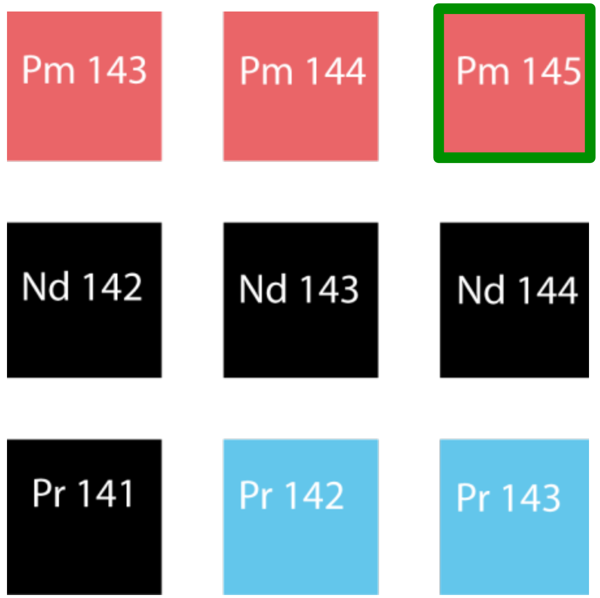
Experimental situation for reactions relevant for the *p* process



Published experimental data within the Gamow window:
9 α-induced reactions

Almost no data available for A>120
⟶ further experimental data needed!

Impact of ^{145}Pm(γ,α) on the *p* process reaction flow



Strong branching at ^{145}Pm

$$f = \frac{\lambda_{(\gamma,\alpha)}}{\lambda_{(\gamma,n)}} \sim 1$$

- direct impact of ^{145}Pm(γ,α) on final abundance pattern

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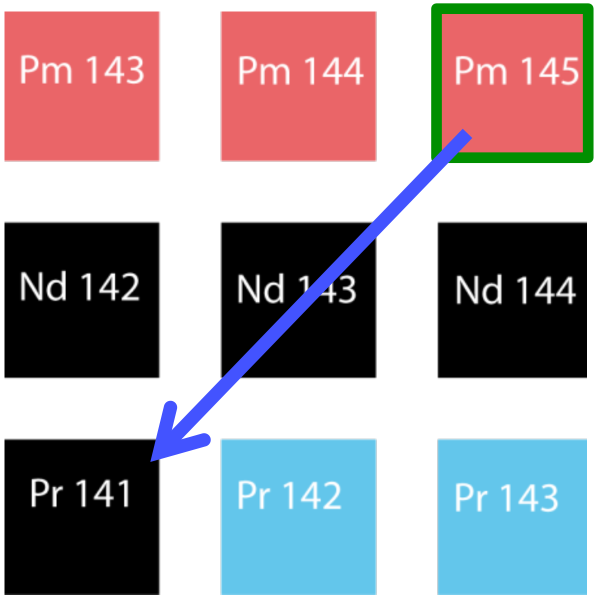

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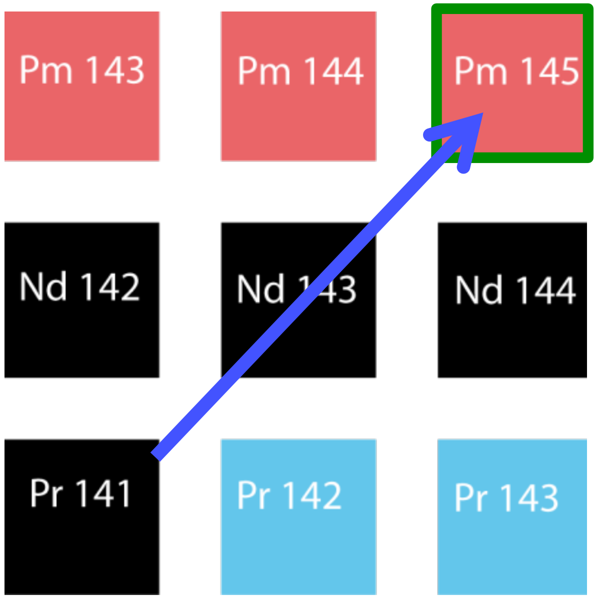

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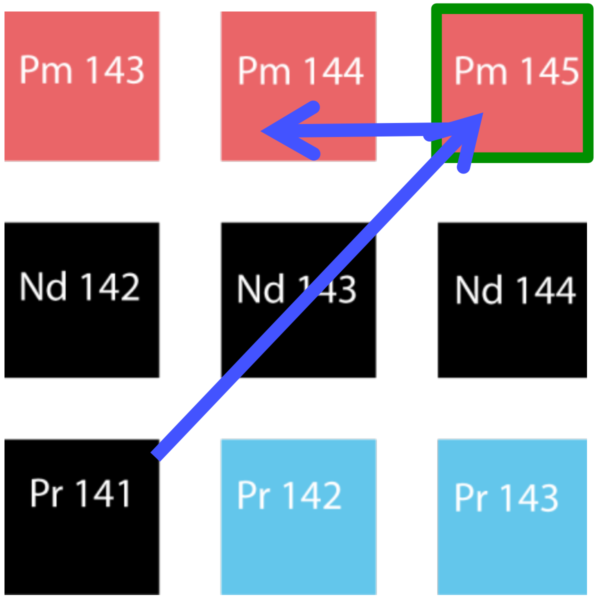

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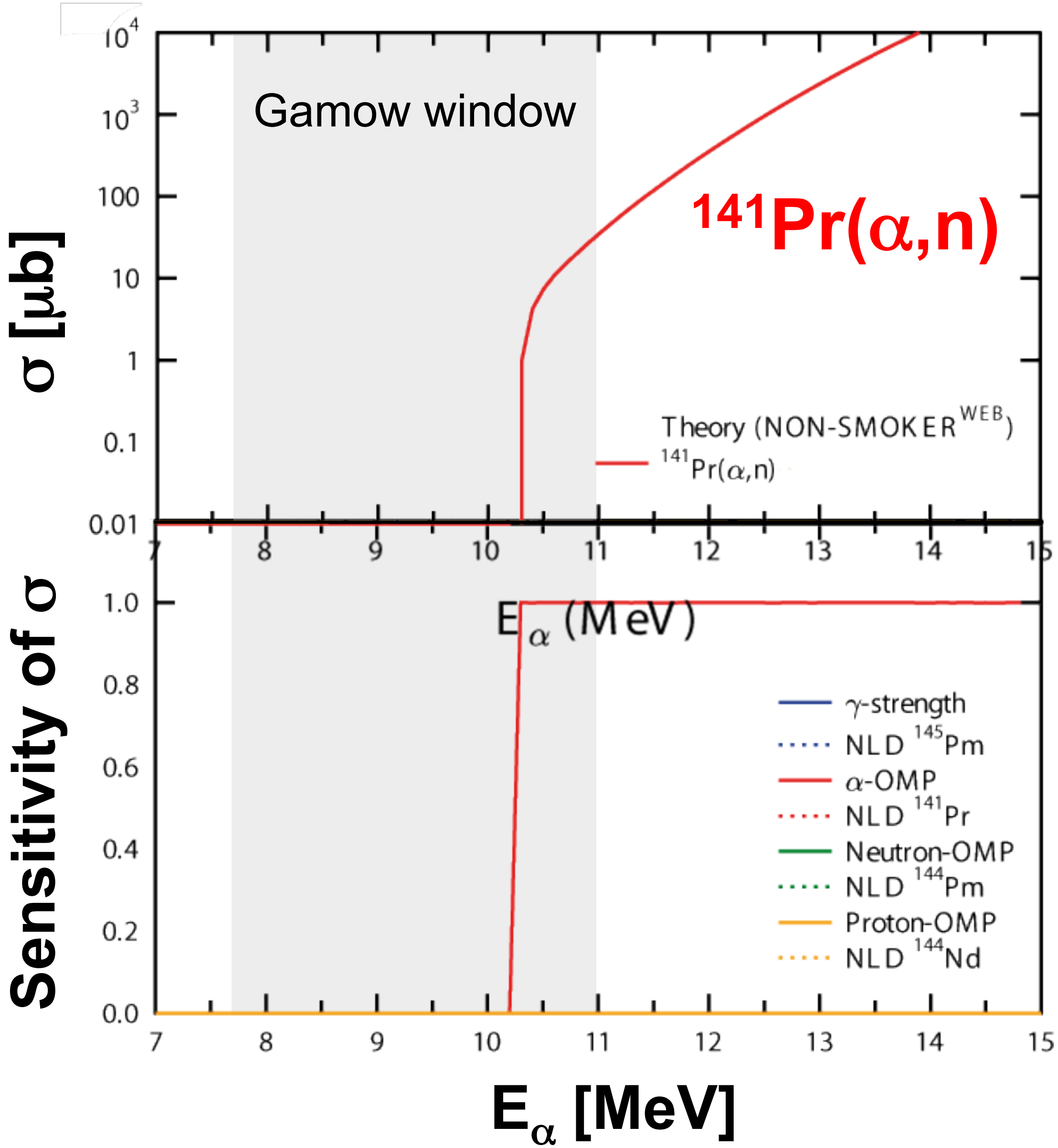
Idea: improve α-nucleus OMP for ^{145}Pm by measuring ^{141}Pr(α,n)

Relevance of nuclear physics input of different reaction channels



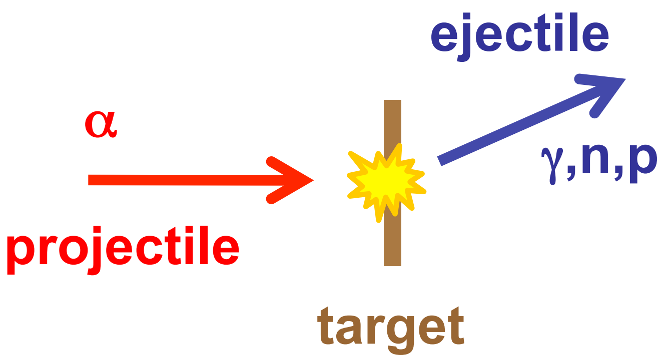
At measurable energies:
^{141}Pr(α,n)-rate is only sensitive to the α-particle nucleus OMP

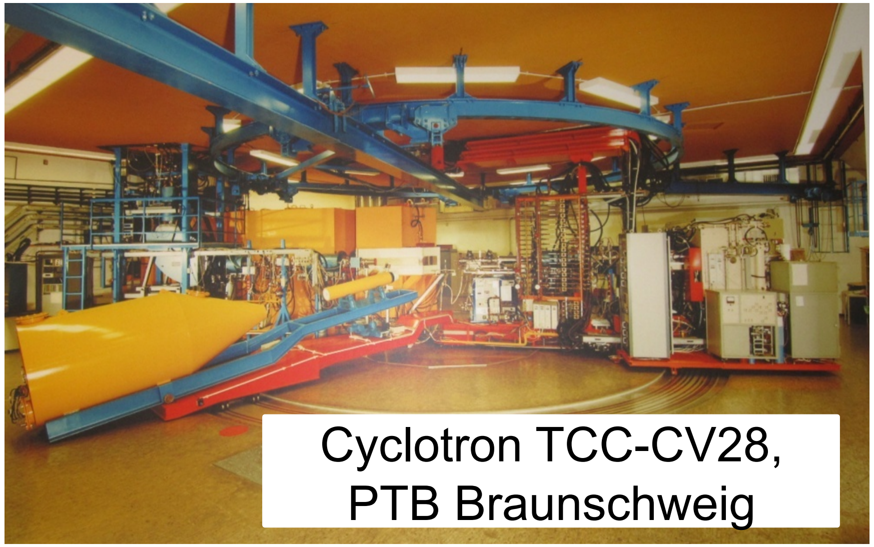
Experimental data improves the α-particle nucleus OMP

Improvement of predictions of stellar ^{145}Pm(γ,α)-rate

Activation experiments

I. Activation





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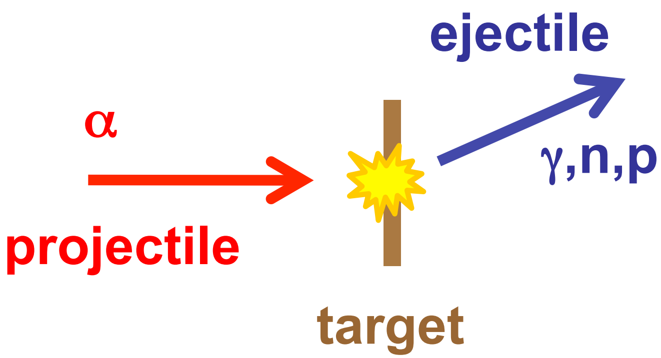
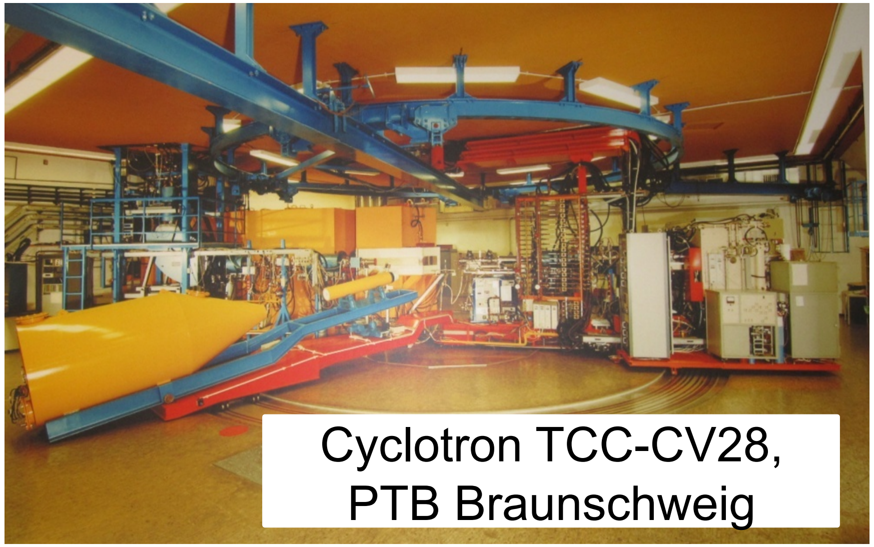
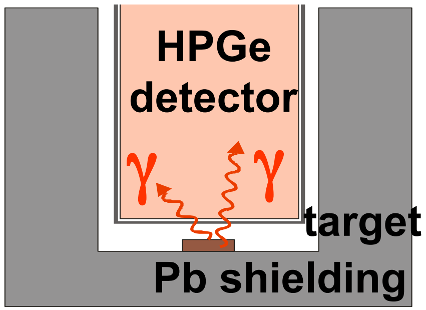




Cyclotron TCC-CV28,
PTB Braunschweig

II. Counting



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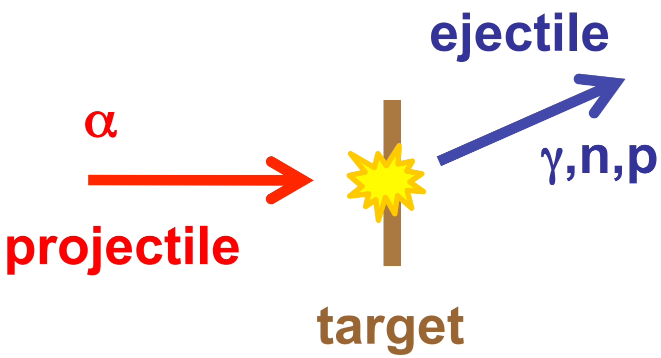

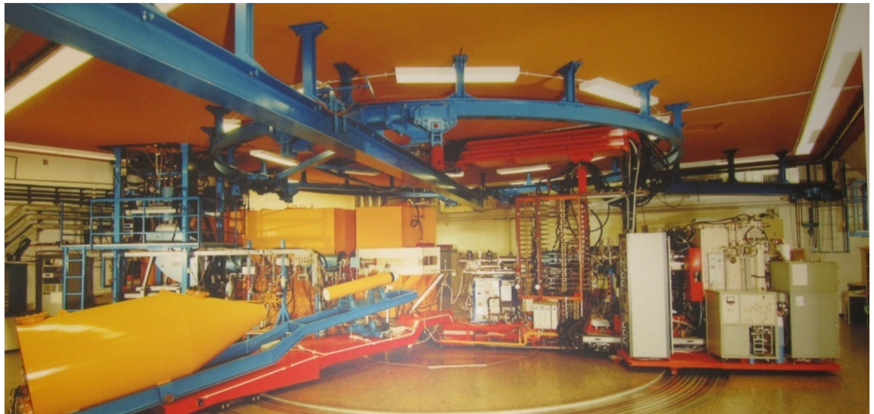

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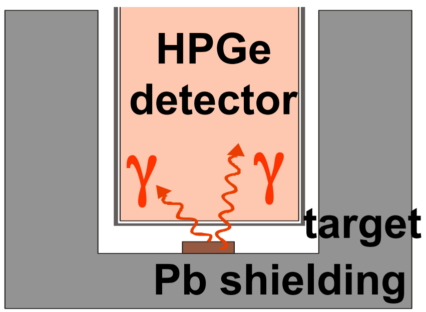
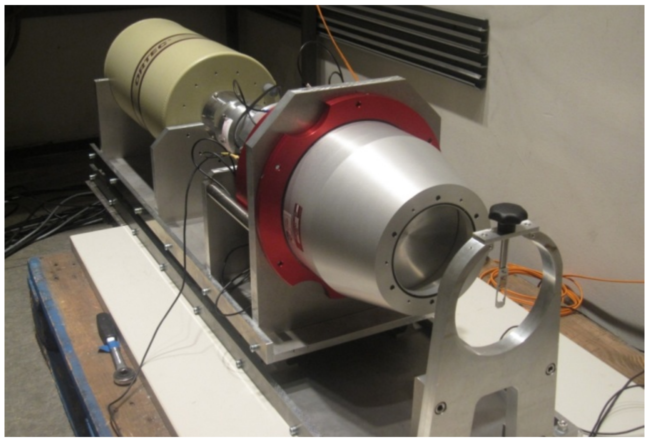


Counting setup in Cologne:



- *2 HPGe Clover detectors* (relative efficiency of 120%, respectively)
- *Passive lead shielding*
- *Active BGO shields*

Activation experiments

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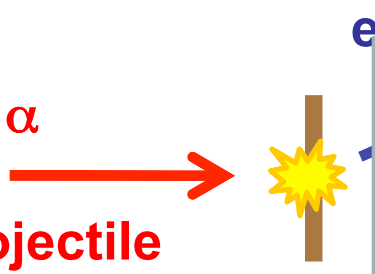

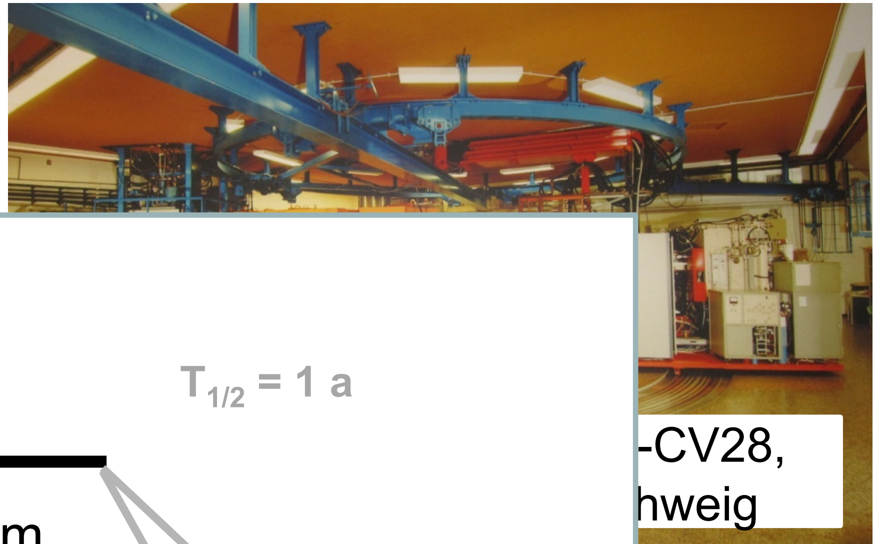

-CV28,
hweig

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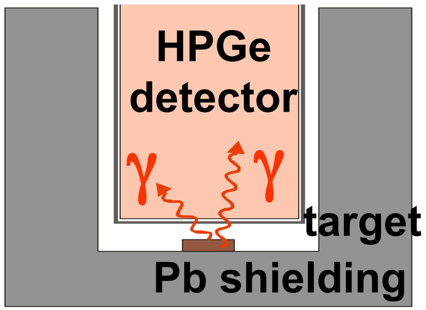

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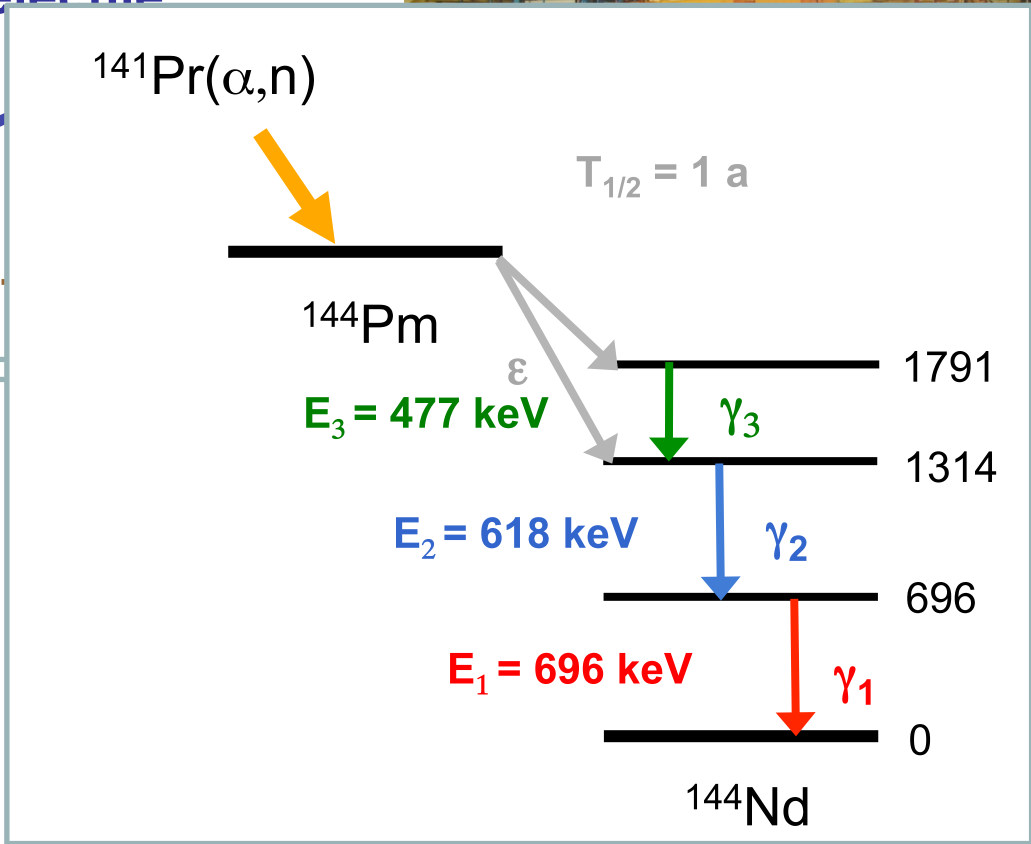
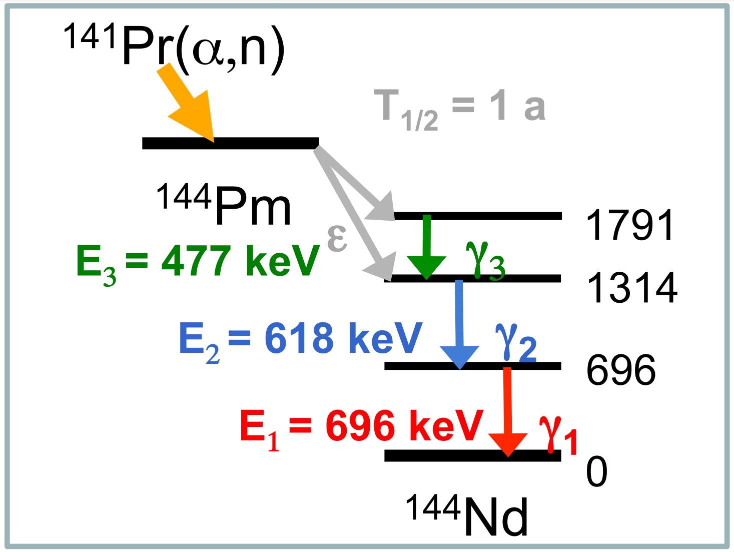
ative
0%,
shielding
Active BGO shields



Experimental parameters and first spectra

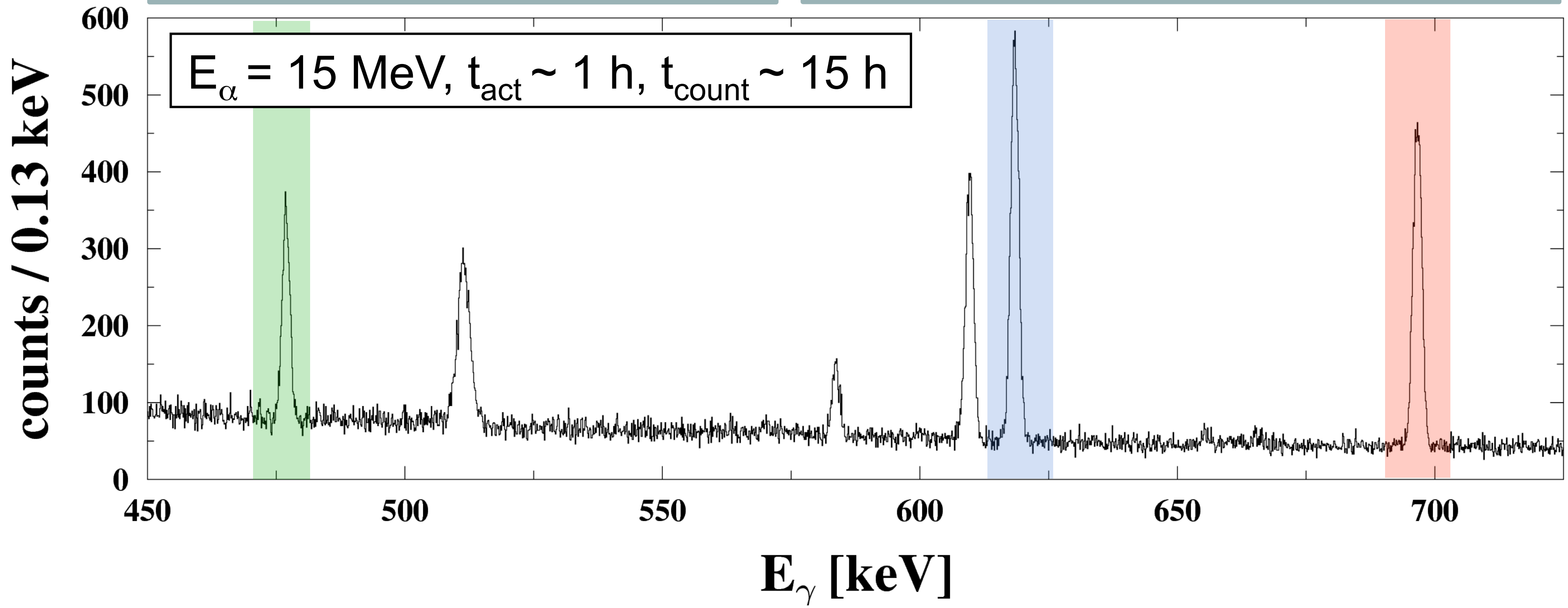


Beam intensities up to 3.5 μA (1.75 pμA)

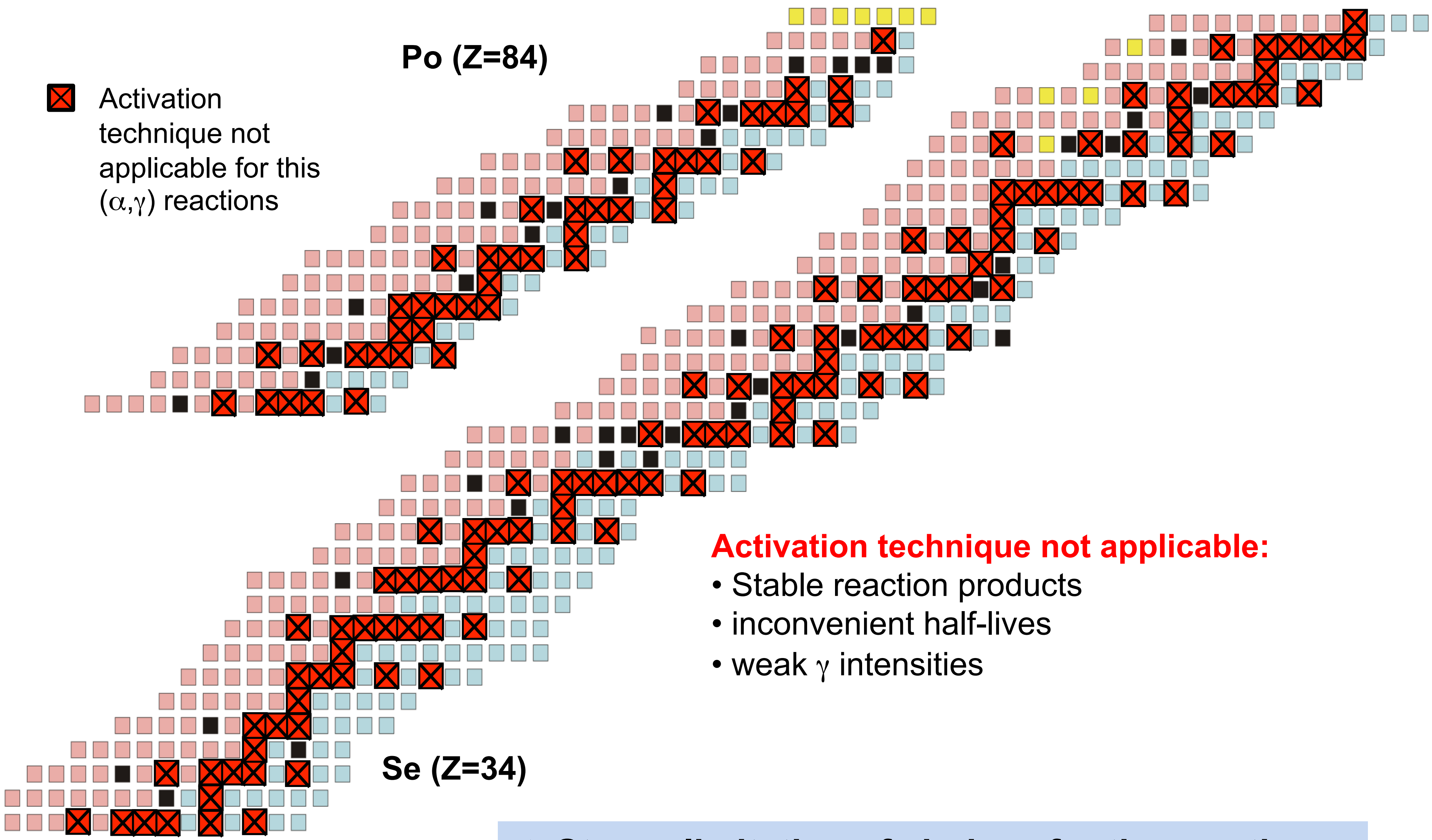
α energies: 11, 11.4, 12, 12.6, 13.2, 13.8, 14.4, and 15 MeV

t_{act} : 1-17 h

t_{count} : 15 h - 40 d



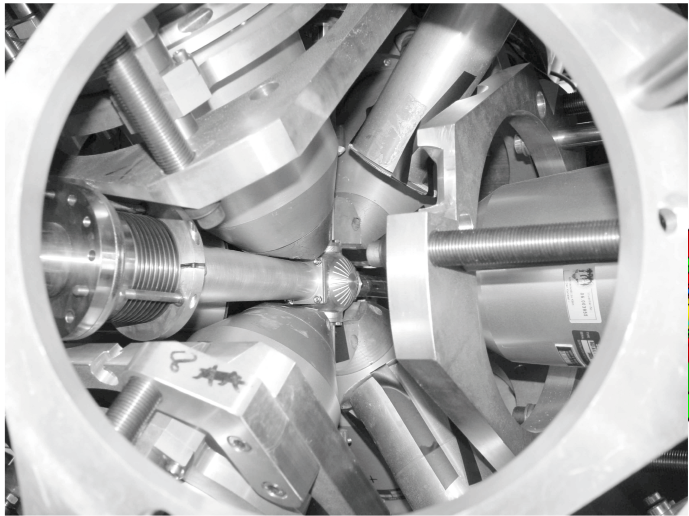
Limitations of the method of activation

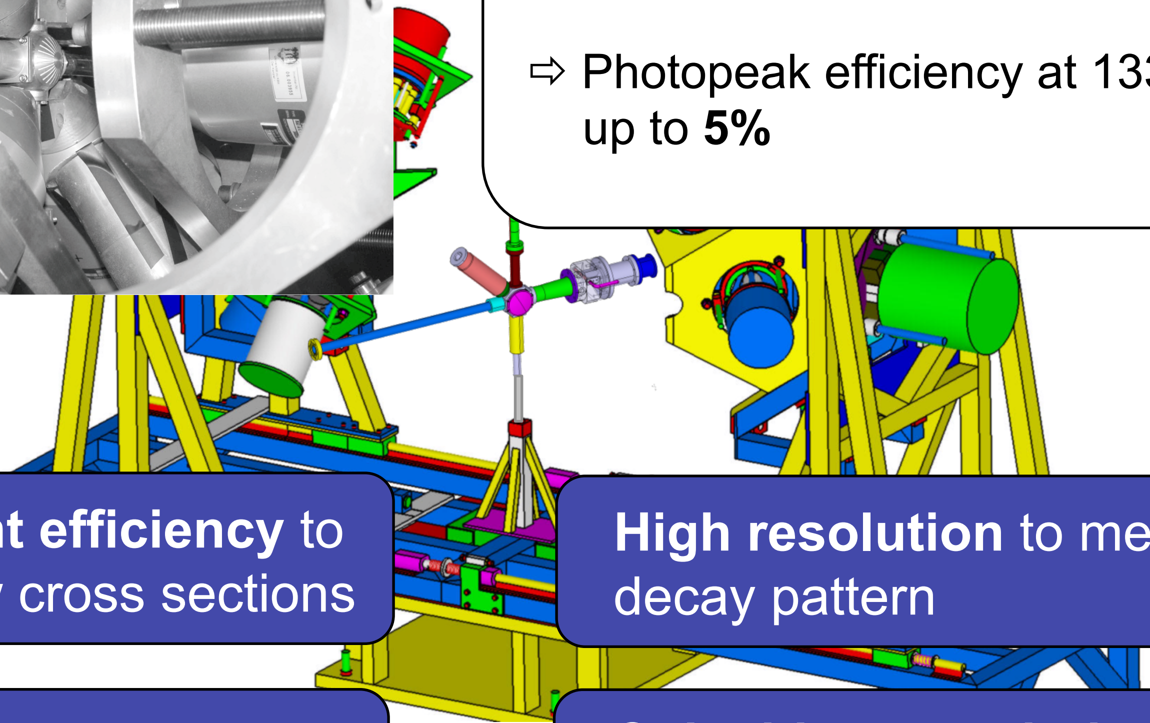


Activation technique not applicable:
- Stable reaction products
- inconvenient half-lives
- weak γ intensities

⇨ **Strong limitation of choices for the reactions**

In-beam measurements with HPGe detectors @ HORUS





14 HPGe detectors in close geometry (6 of them equipped with BGO shields)

⇨ Photopeak efficiency at 1332 keV: up to **5%**

Sufficient efficiency to study low cross sections

High resolution to measure decay pattern

Determination of **angular distributions**

Coincidence techniques to suppress background

Test experiment for ^{92}Mo(p,γ)^{93}Tc

$T_{1/2}(^{93}Tc^g) = 2.75$ h

- Activation measurement can be performed simultaneously
- Comparison with existing data from an activation experiment possible (*T. Sauter et al., PRC 55 (1997) 3127*)

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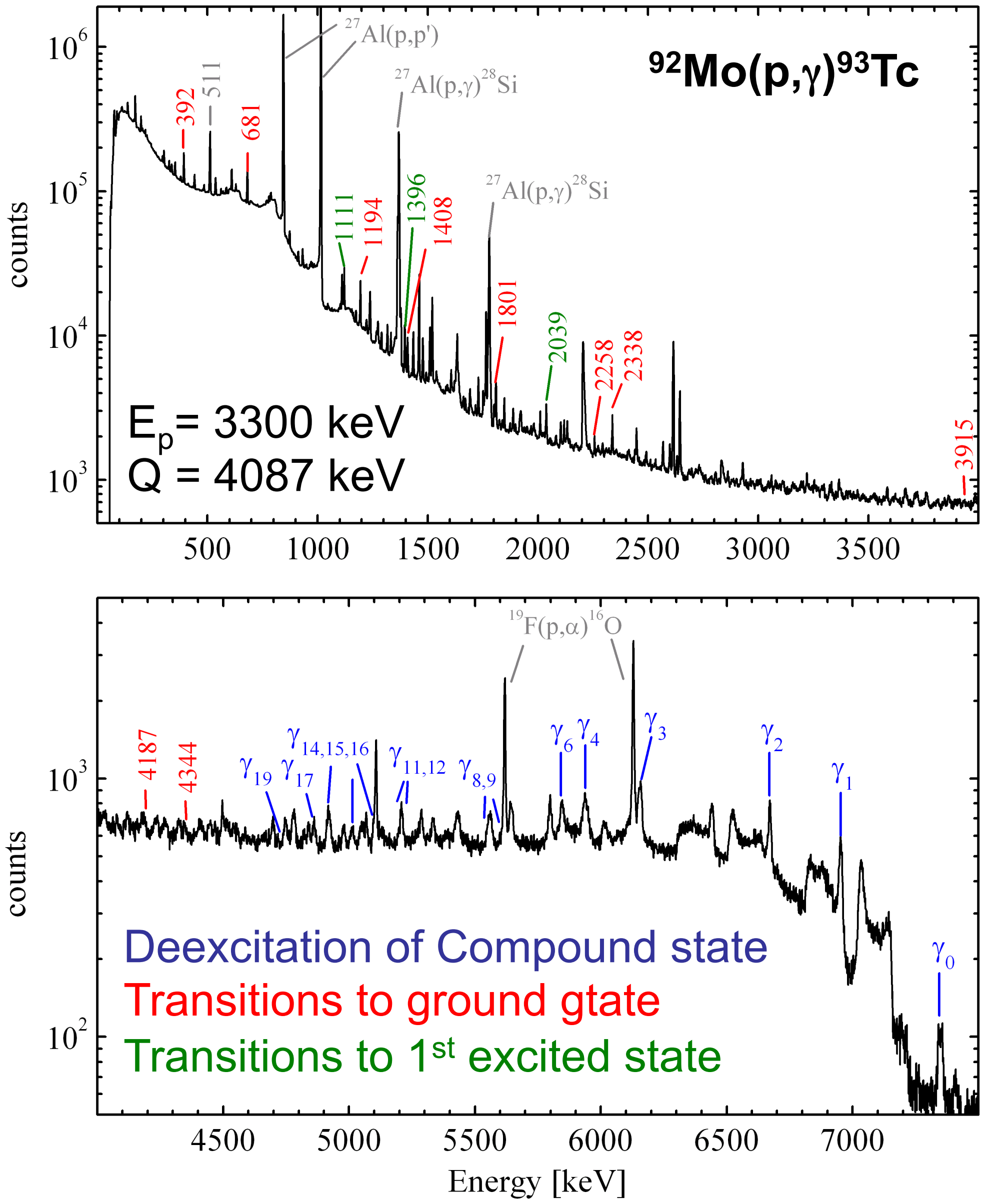
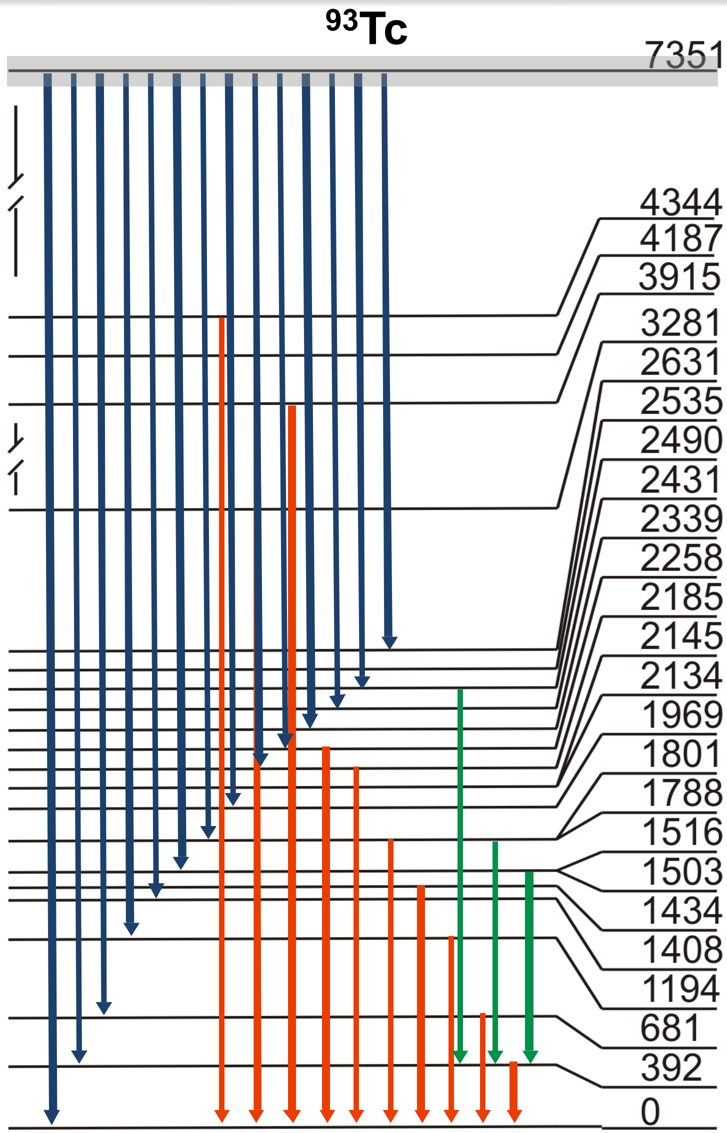
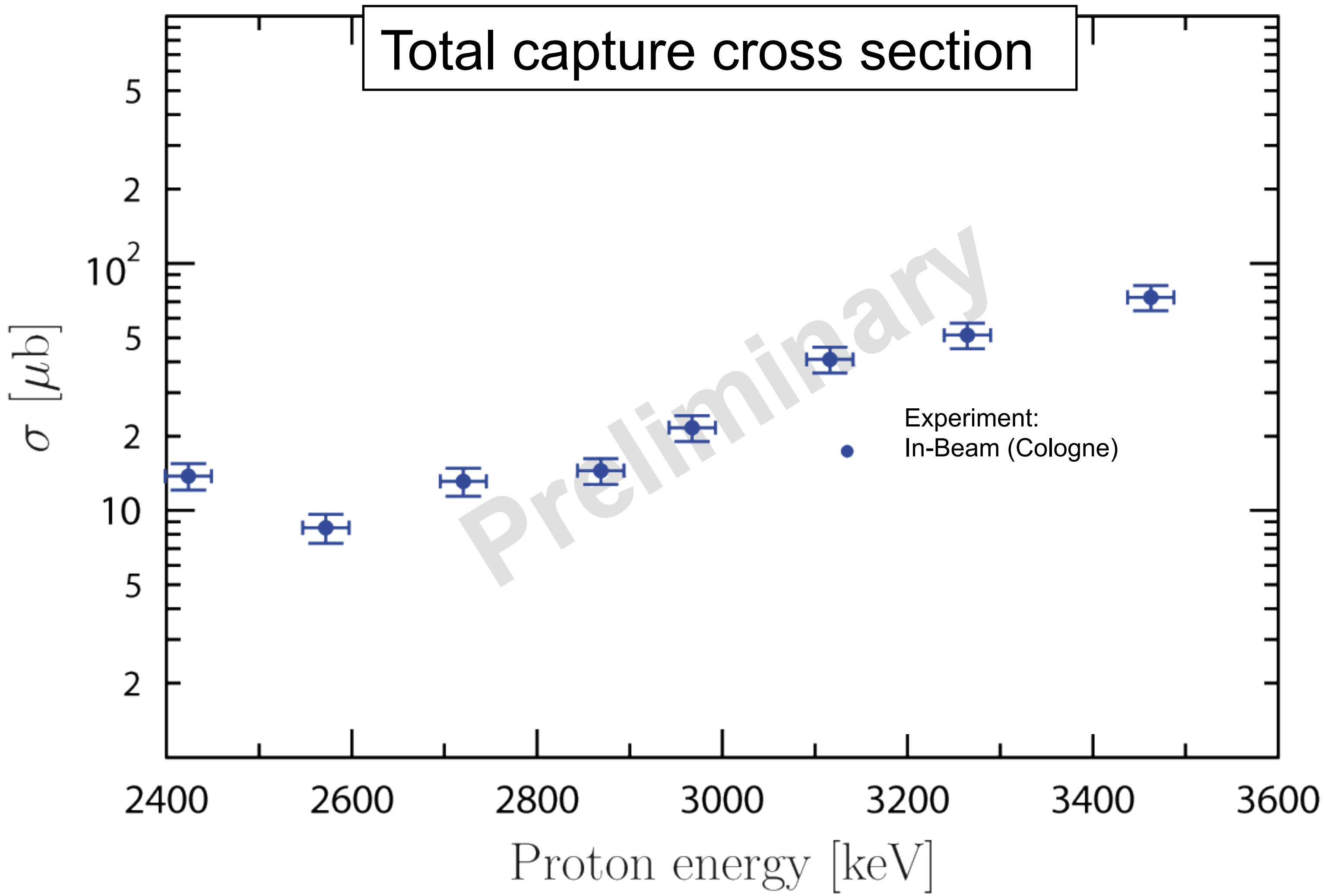




Production of 1st excited state

Preliminary results for $^{92}Mo(p,\gamma)$



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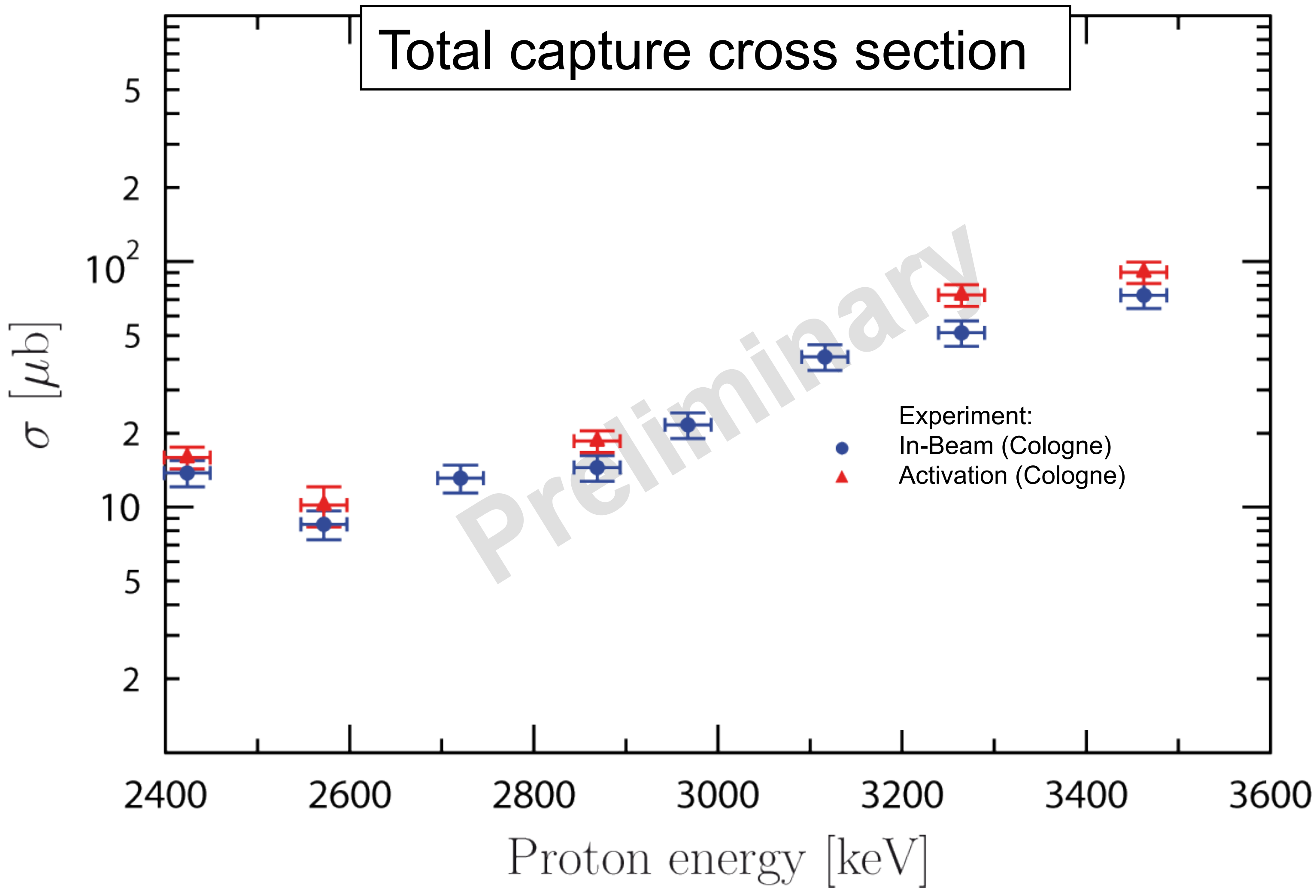

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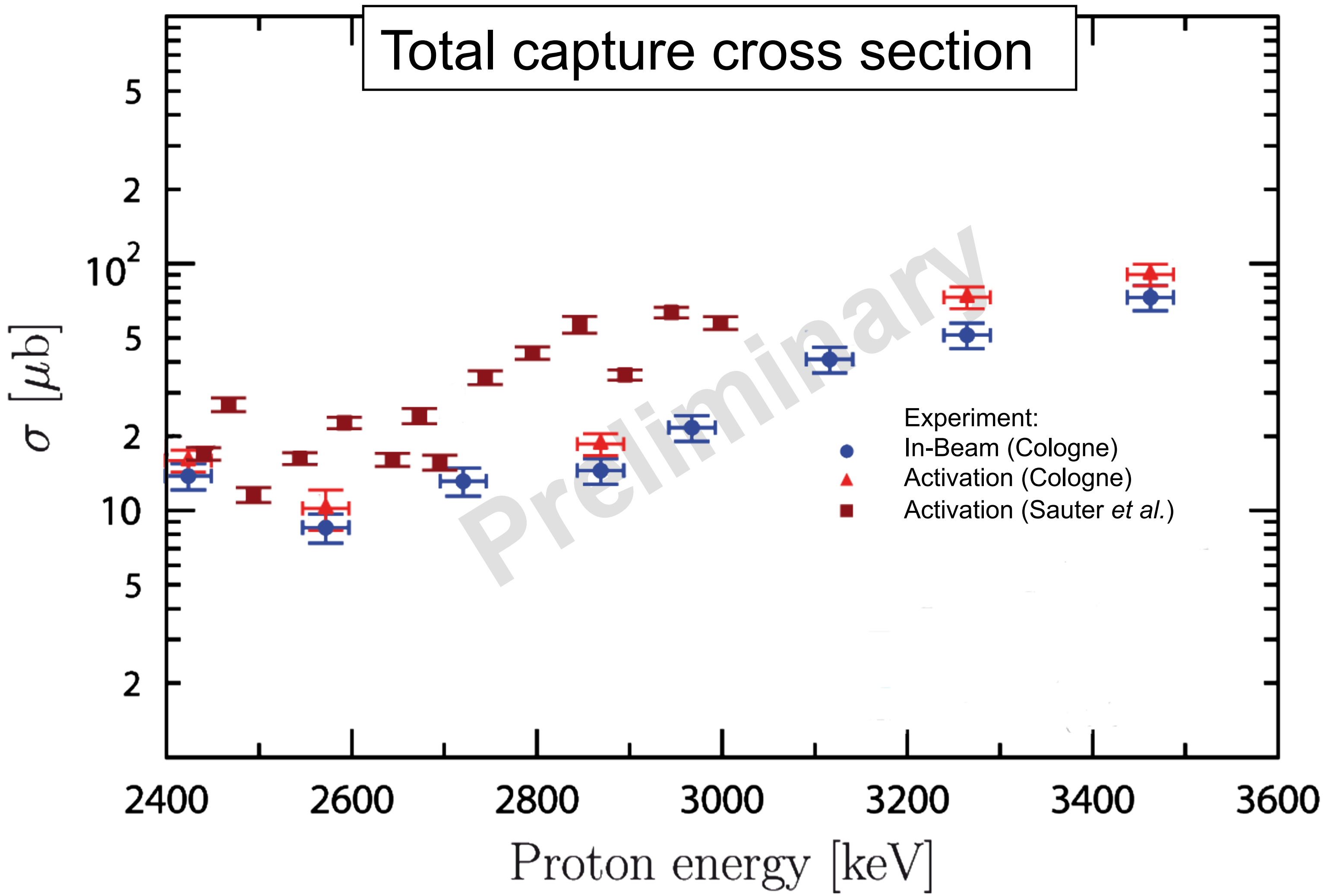

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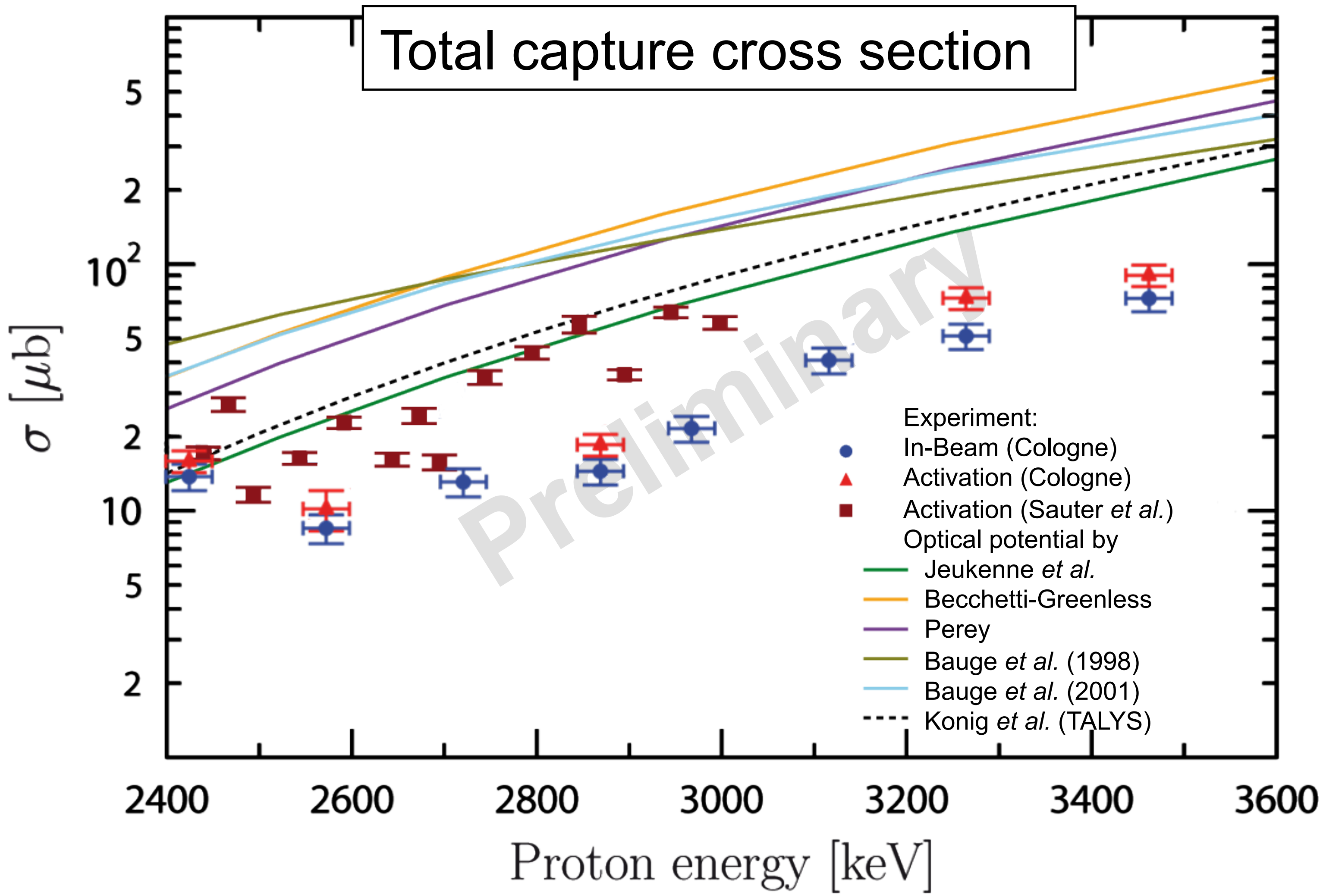

Conclusions

- Several experimental possibilities to measure reactions of particular interest for the *p* process in Cologne
  - Access to many reactions with in-beam measurements
  - Complementary counting setup for activation measurements
- But our TANDEM underwent complete renovation (no beam until spring 2011)
  - New tandetron accelerator available for AMS

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and thank you very much for your attention!

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