Nuclear Astrophysics Experiments in Cologne

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for the group of Prof. Dr. Andreas Zilges

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Nuclear Astrophysics in Germany,
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Supported by the Bonn-Cologne Graduate School of Physics and Astronomy.

Nuclear Astrophysics Motivation

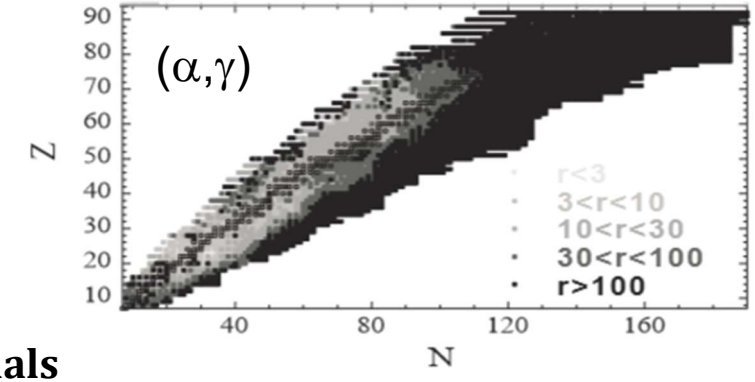
Nucleosynthesis of p-nuclei

- mostly produced via photodisintegration reactions (γ process)
- measurements of inverse reactions, *e.g.*, (p,γ),(α,γ)
- contributions of other processes?
  - neutrino-driven wind
  - rapid proton-capture process

T. Rauscher *et al.*, Phys. Rep. Prog. **76** (2013) 066201.

Hauser-Feshbach statistical model

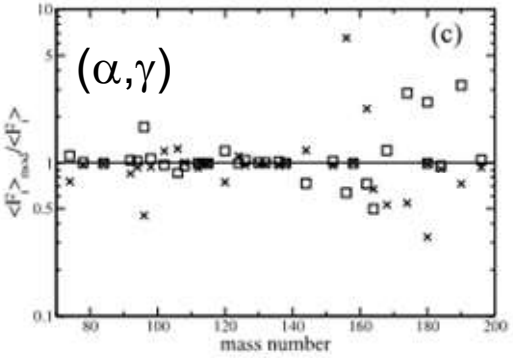
- sufficiently high level density
- transition probabilities from **γ-strength function**
- transmission coefficients from **optical-model potentials**



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

Sensitivity on reaction rates

- 25 solar mass supernova model
- varying reaction rates by a factor of 3
- ➢ improving nuclear physics input



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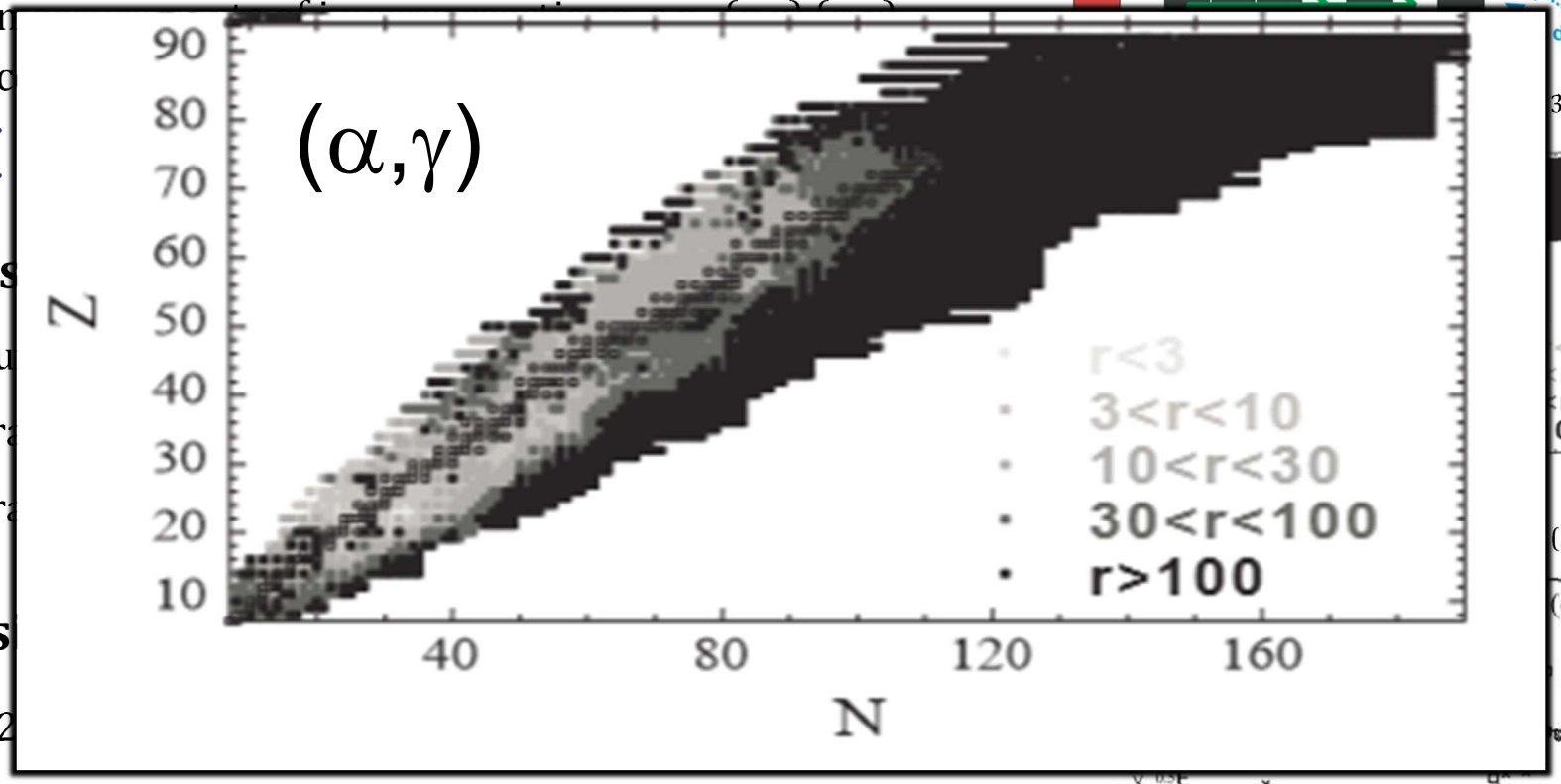

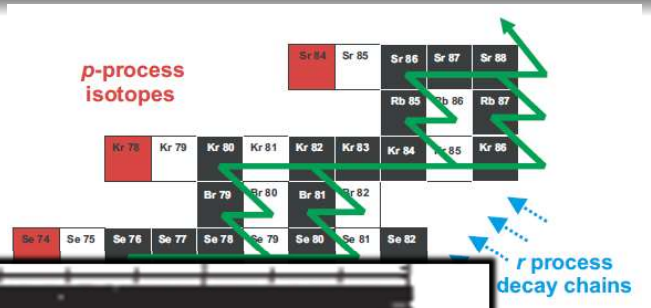

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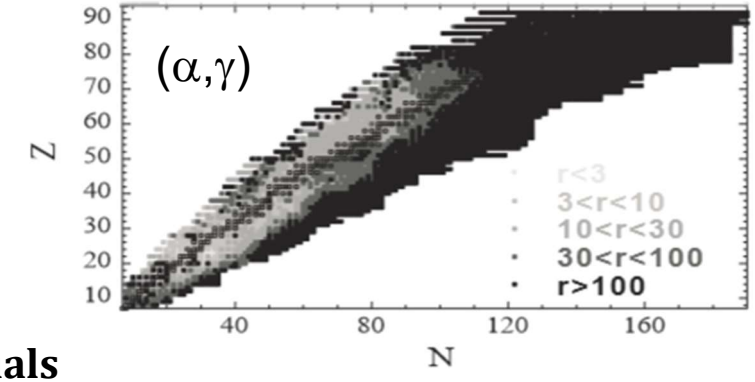

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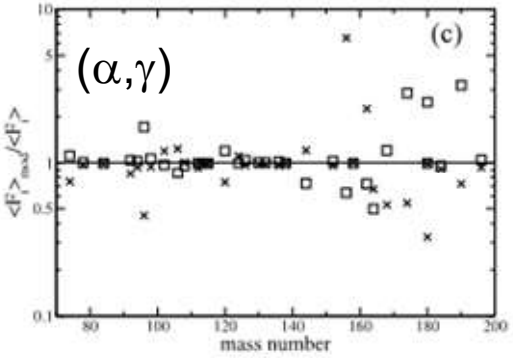

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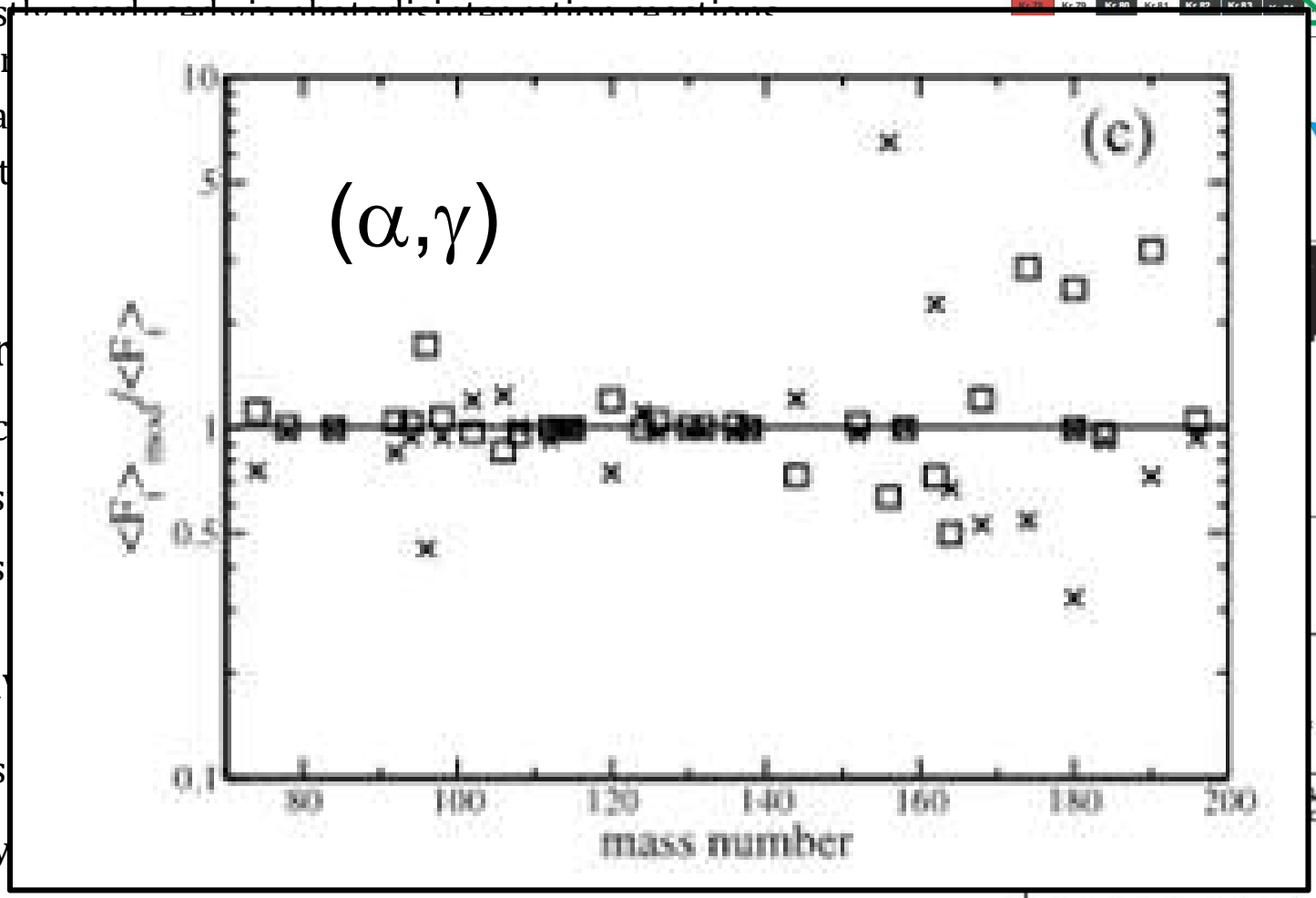

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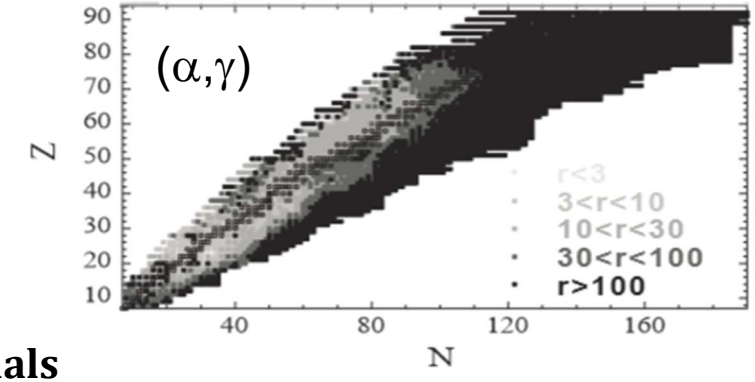

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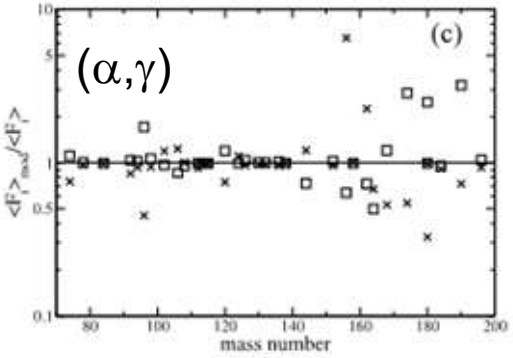

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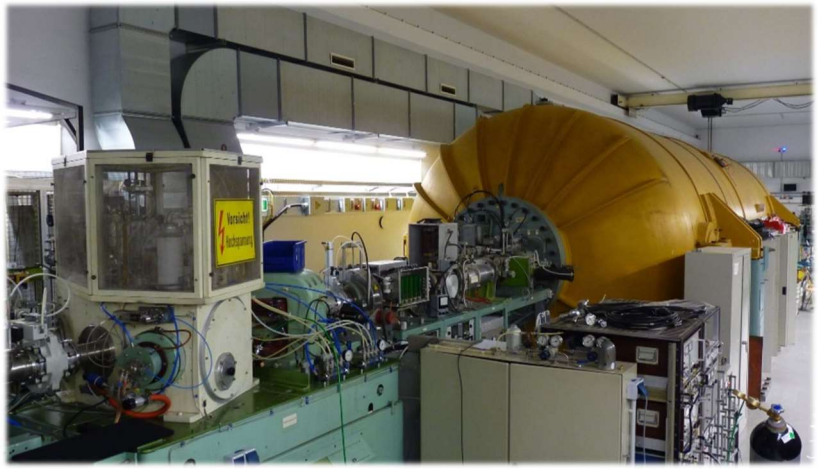
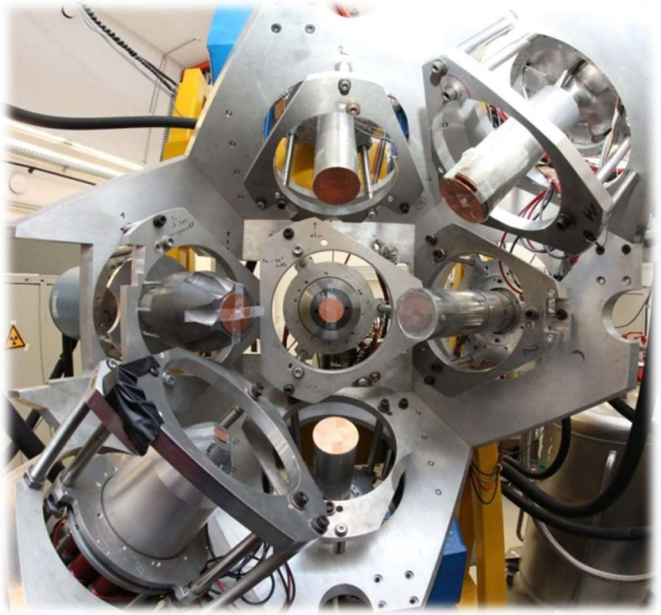
γ-ray spectrometer HORUS

- 10 MV FN-Tandem ion accelerator



HORUS γ-ray spectrometer

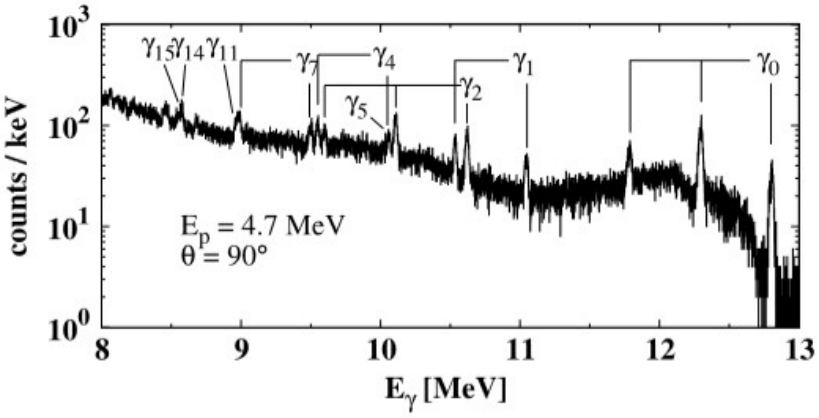
- 14 HPGe detectors
  - High resolution
    ≈ 2 keV @ 1332 keV
  - High total efficiency
    ≈ 2% @ 1332 keV
- 5 different angles with respect to beam axis
  - determination of angular distributions
- BGO shields



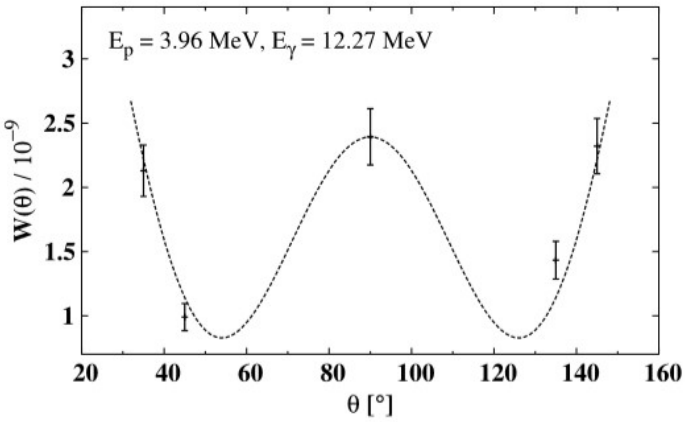
L. Netterdon *et al.*, NIM A **754** (2014) 94

In-beam measurement of cross sections

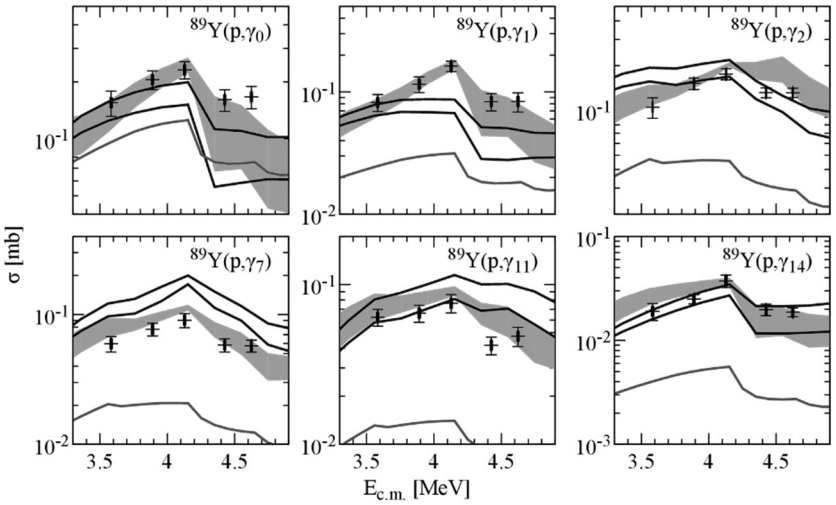
High-resolution γ-ray spectrum



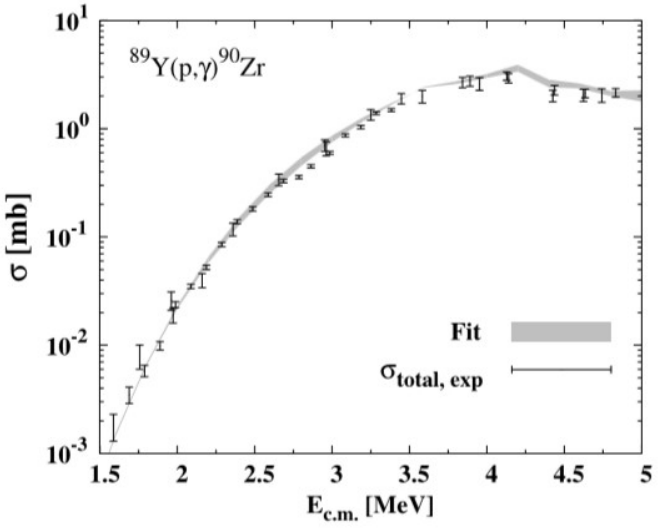
Angular distribution of γ-rays



Partial cross sections

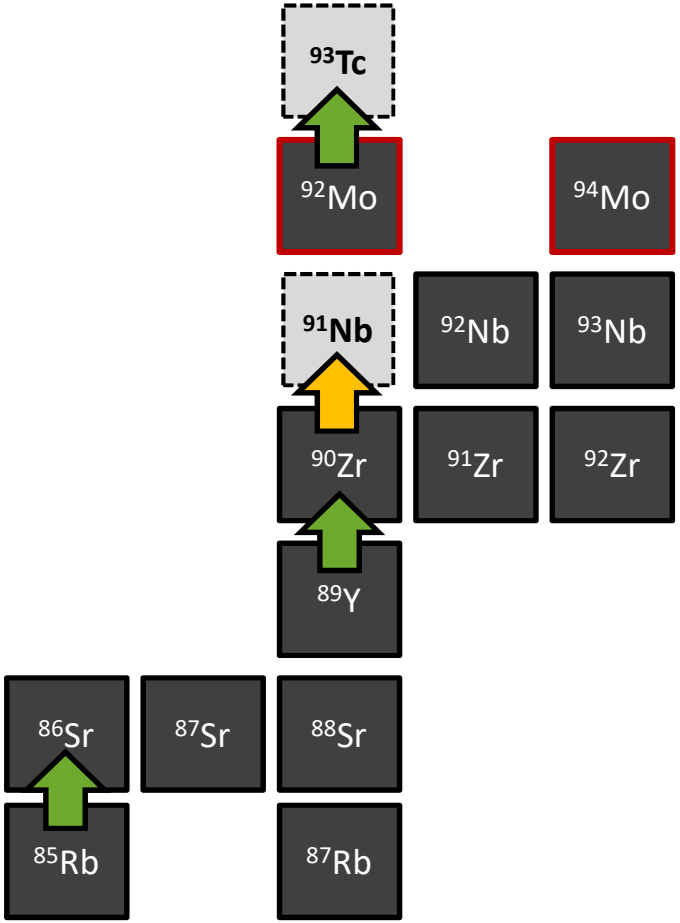


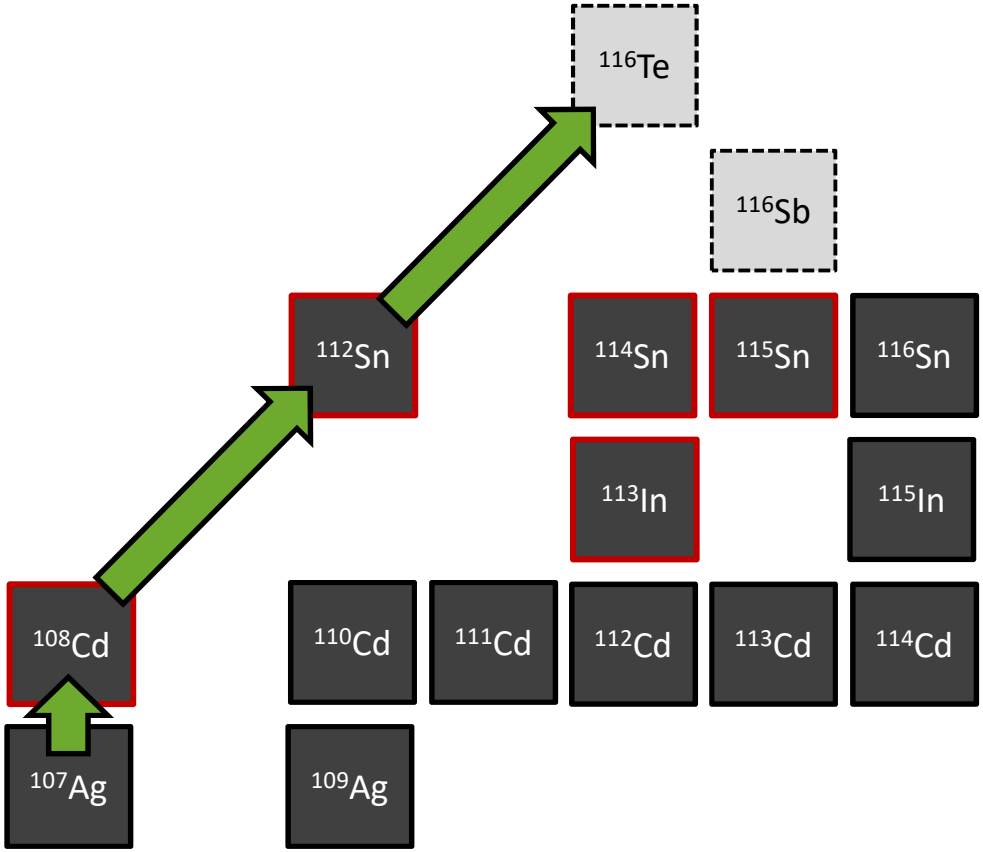
Total cross sections



L. Netterdon *et al.*, PLB **744** (2015) 358

In-beam measurements at HORUS





L. Netterdon *et al.*, PLB **744** (2015) 358

L. Netterdon *et al.*, Phys. Rev. C **91** (2015) 035801

J. Mayer *et al.*, Phys. Rev. C **93** (2016) 045809

P. Scholz *et al.*, PLB **761** (2016) 247

In-beam measurements at HORUS

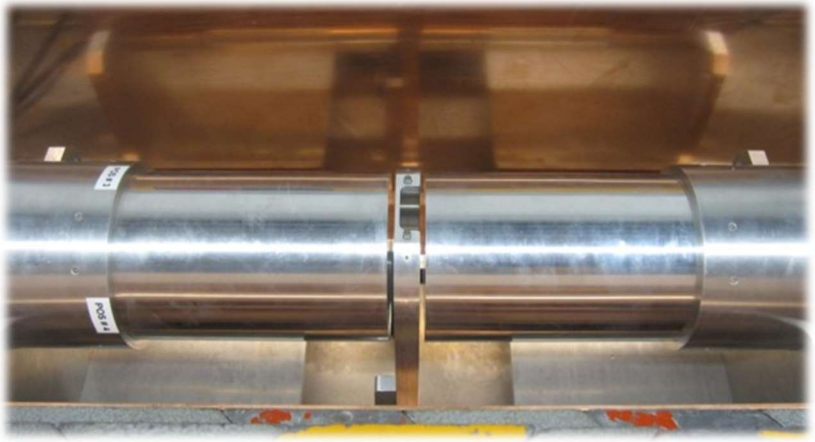
Advantages

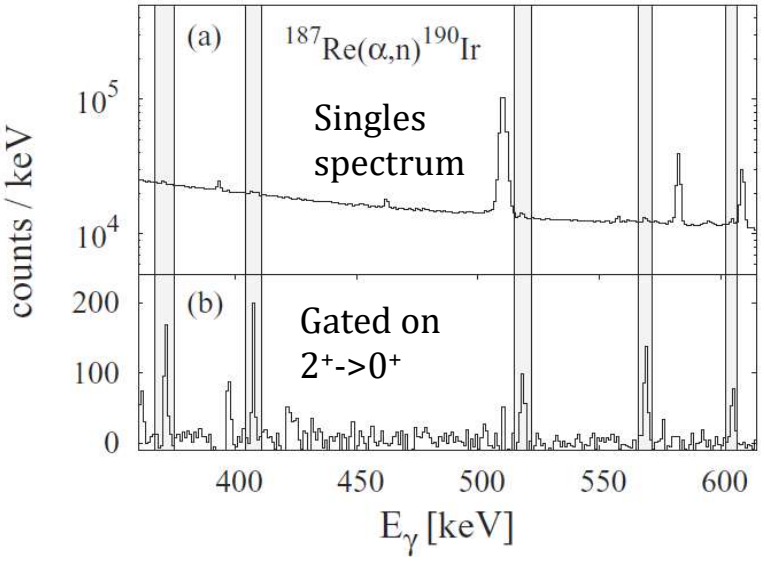
- highly resolved γ-decay information
- partial cross sections accessible
- wide choice of reaction products
- selection of reaction channel via angular distributions

Disadvantages

- relatively time consuming measurements
- limitations due to beam current/contaminants
- ➢ new α-particle source in 2017/18

Cologne Clover Counting Setup

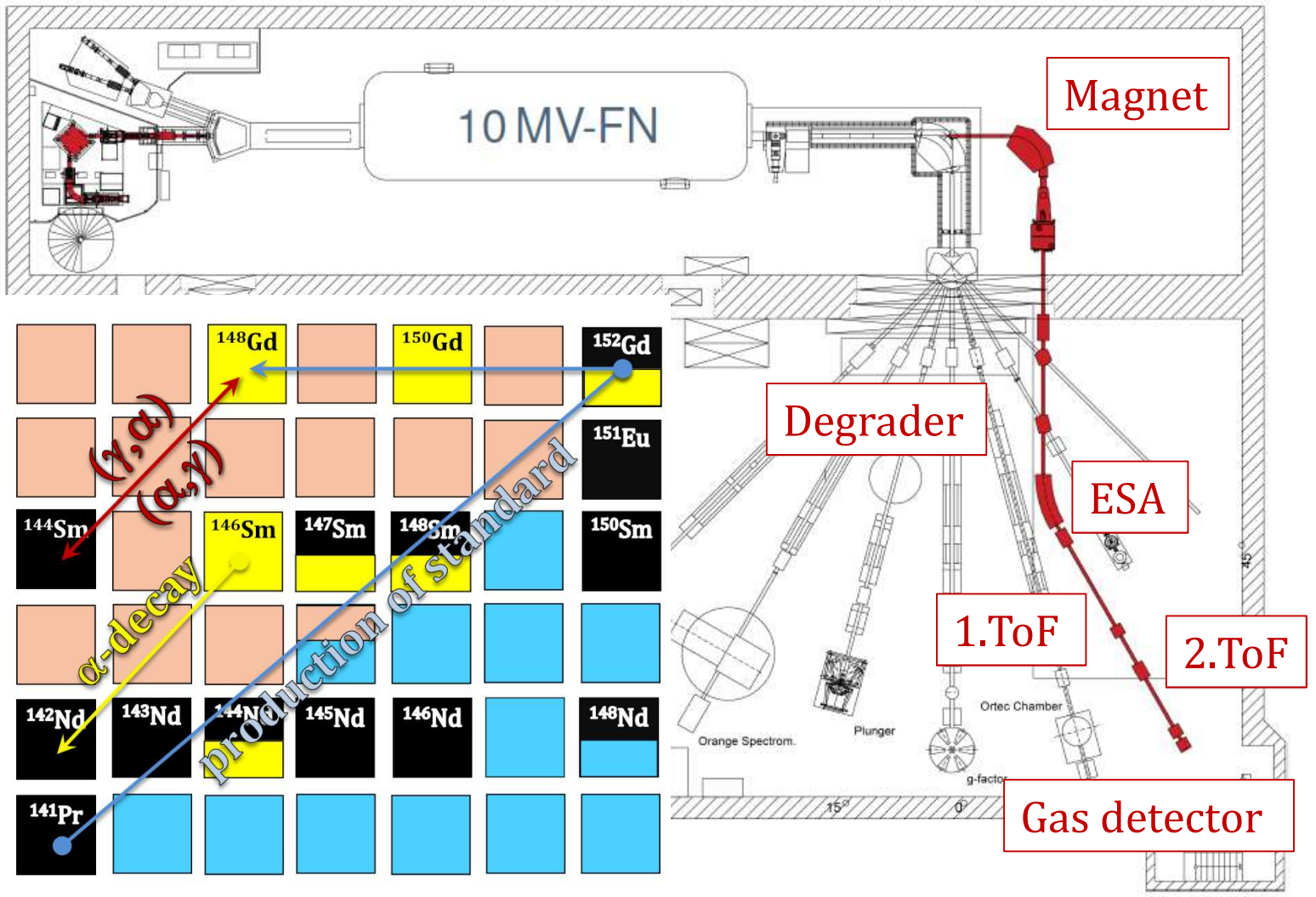




P. Scholz *et al.*, Phys. Rev. C **90** (2014) 065807

- complementary measurement of (α,n) cross sections
- sensitive to the α-OMP
- half-lives down to several minutes possible
- even higher mass α-induced reactions possible
- using γγ coincidence method

AMS cross-section measurements



Summary

Nuclear Astrophysics experiments in Cologne

- measuring radiative charged-particle induced cross-sections
- sensitive to particle+nucleus optical-model potentials and γ-strength function
- experimental methods:
  - In-beam technique with HPGe detectors
  - Activation and Accelerator Mass Spectrometry
  - Two Step γ-cascade technique

Systematic studies of nuclear physics input-parameters

- constraining global models means systematic investigation
- need for a larger experimental database
- using complementary methods, *e.g.,* in-beam, activation, 4π summing, etc.
- see own results in the context of other measurements