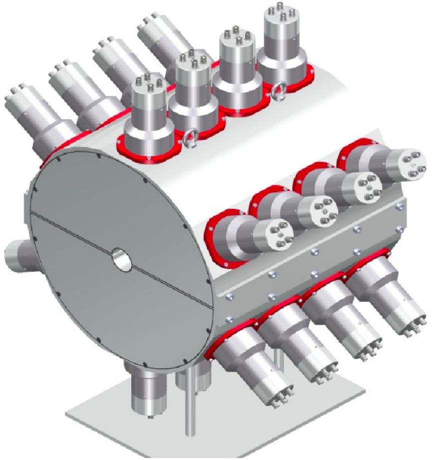
Nd: will it make a difference in the *i* process?



Hannah C. Berg

18th Russbach School on Nuclear Astrophysics

A.Simon et. *al*. NIMA **703,** 0168-9002 (2013)

The well known picture

On neutron side:

s and r process

On proton side:

rp and p process

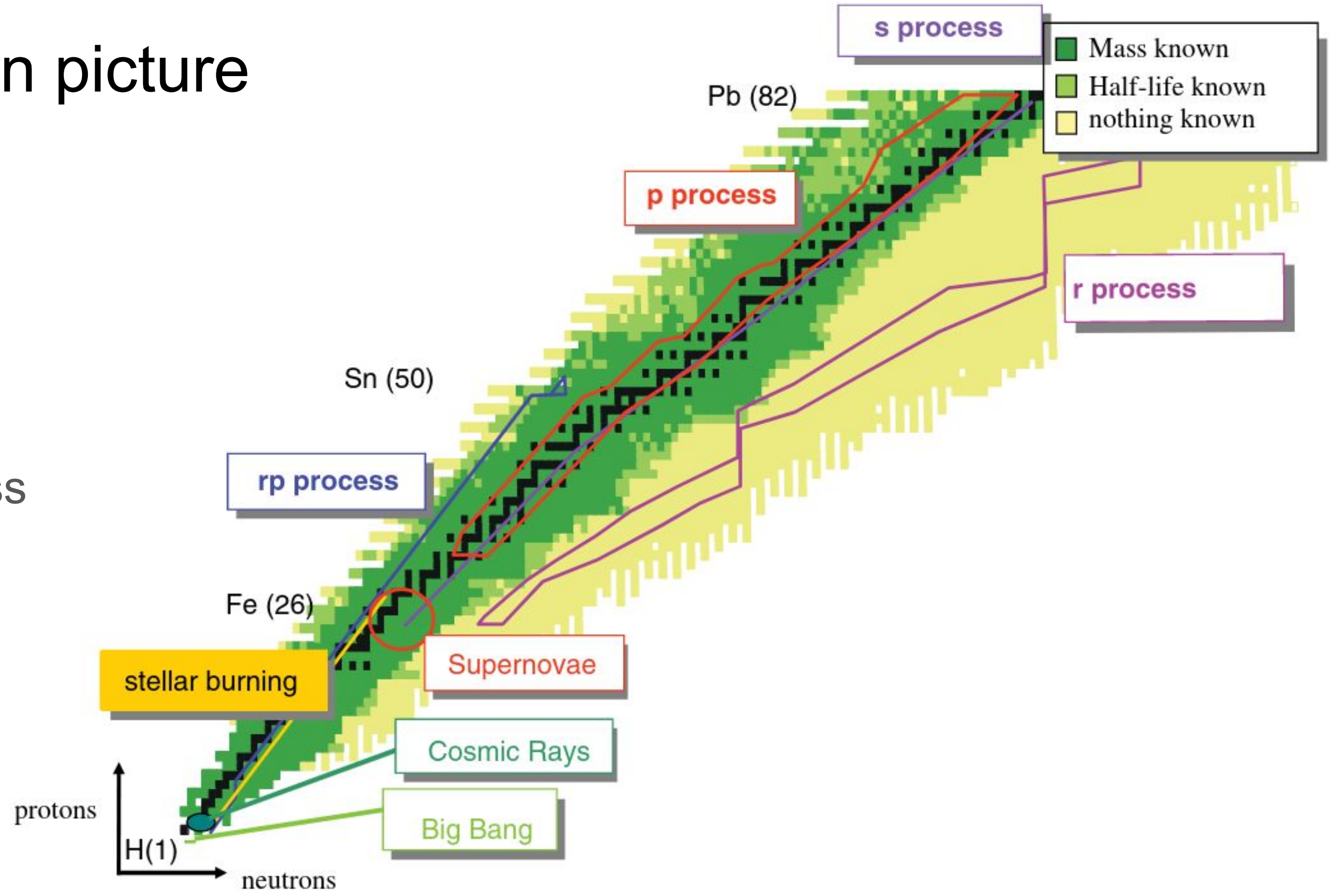


Chart: K. Blaum / Physics Reports 425 (2006), p.1-78

So you’ve heard about the s- and r-process

In between these more well known processes, we have the *intermediate* process, hence the i-process.

- Abundances
- Eu, Ba, Sm

Neutron capture rates only unknown

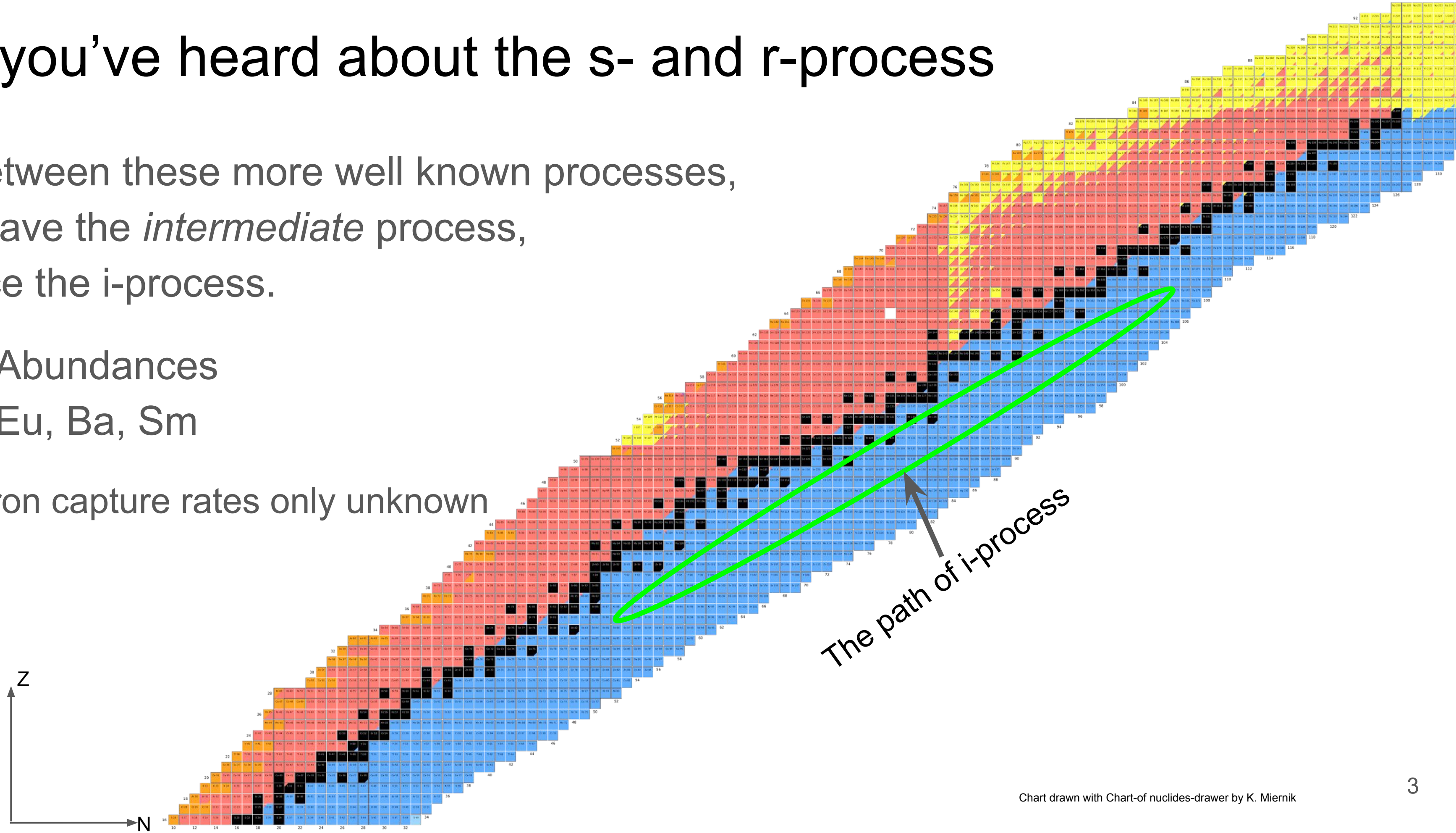
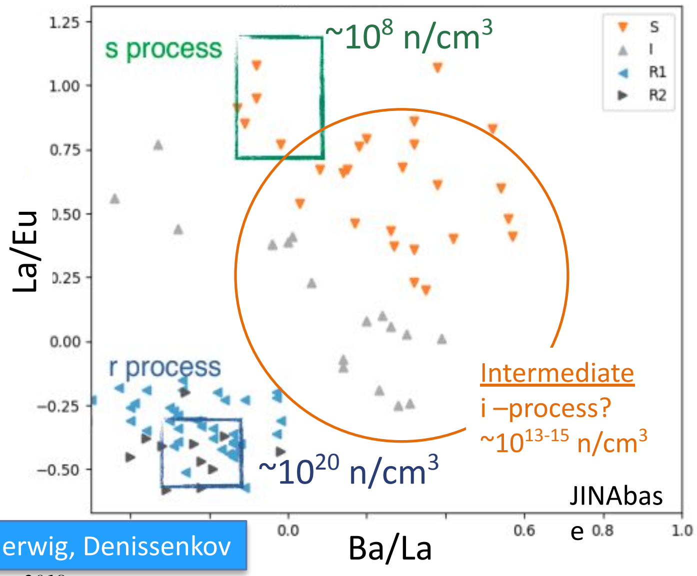


Chart drawn with Chart-of nuclides-drawer by K. Miernik

Abundances and the neutron-capture processes



Herwig, Denissenkov

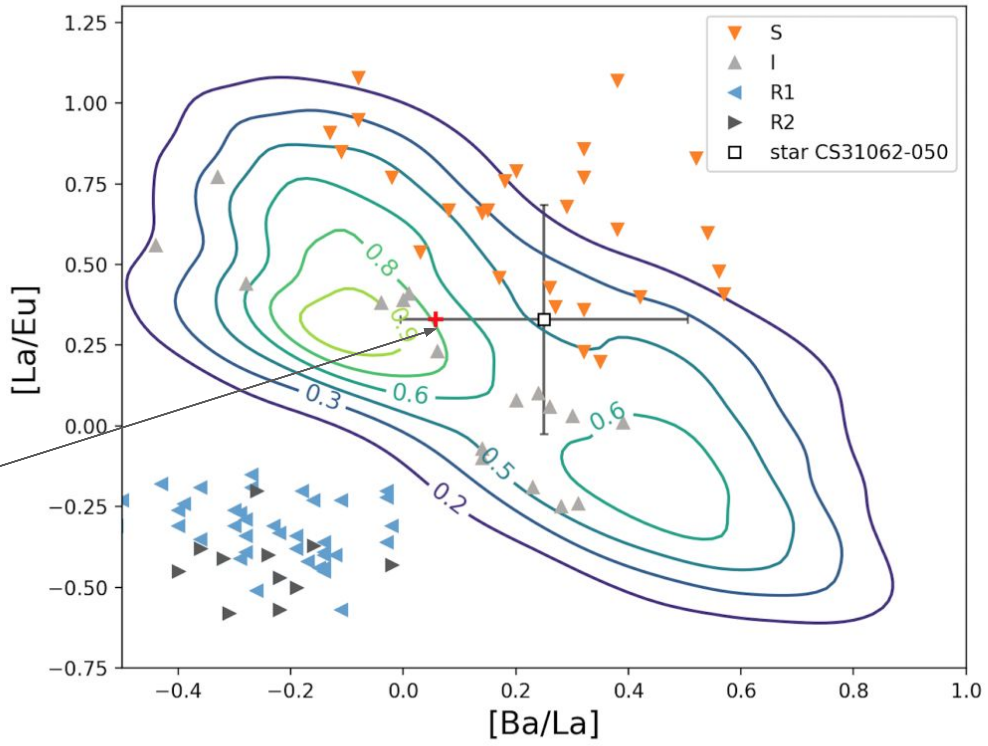
2018

Abundances that are not explained by r/s process

Sneak peak on Nds importance

A. Spyrou, D. Mücher et al. (submitted) on $^{139}Ba(n,g)^{140}Ba$ rate shows effect on heavy element abundance [Ba/La]

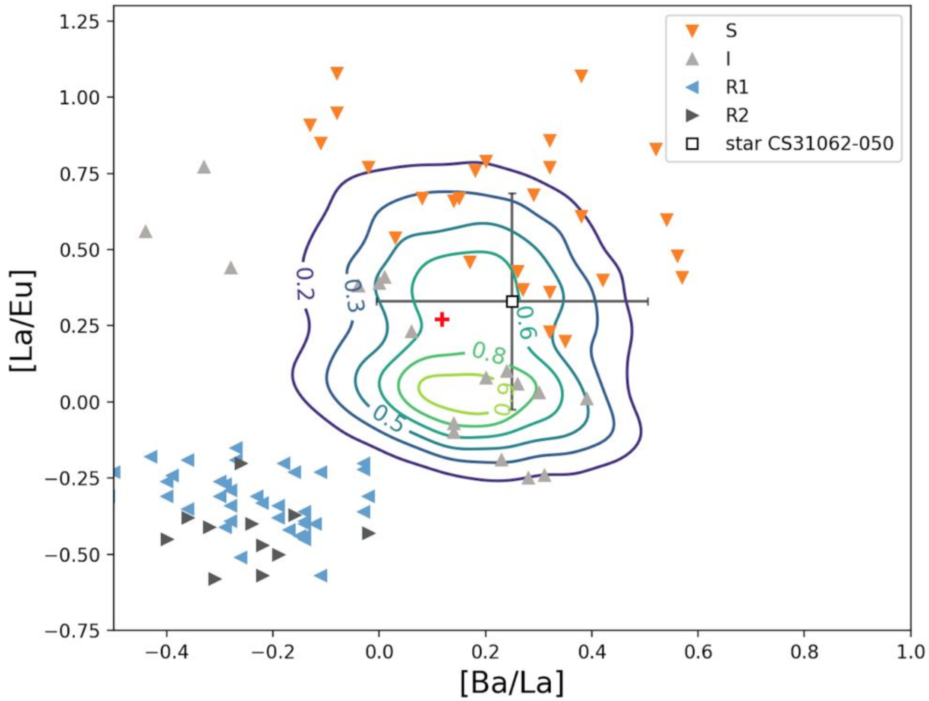
Calculations for one set of astronomical parameters, huge error due to nuclear uncertainty



Sneak peak on Nd's importance

A. Spyrou, D. Mücher et al. (submitted) on $^{139}Ba(n,g)^{140}Ba$ rate shows effect on heavy element abundance [Ba/La]

Now need more nuclear data for Eu abundance



Sensitivity study

How much does the neutron-capture cross section uncertainty affect the **Eu** abundance?

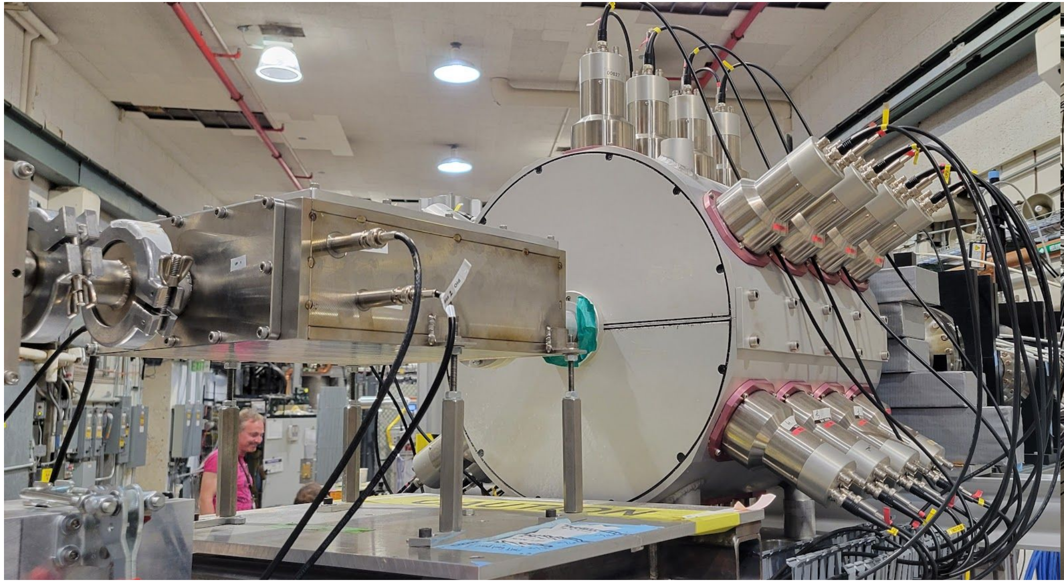
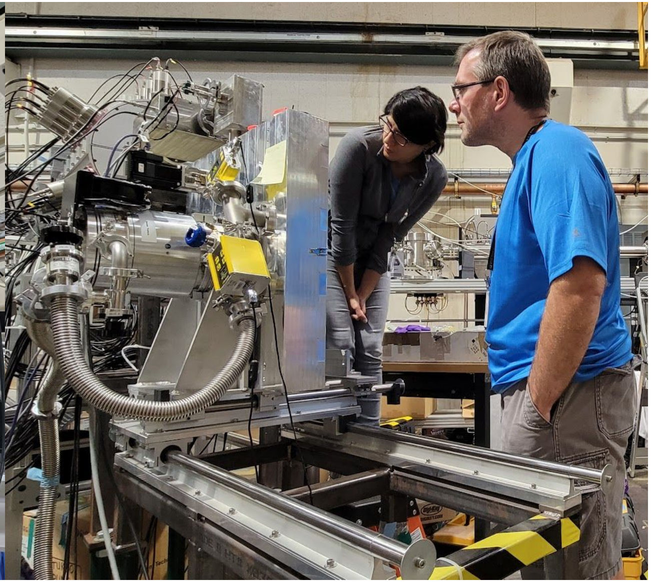
$\mathbf{r_p}$ close to +/- 1, dictates that (n, γ) reaction is more important for final abundance

My experiment

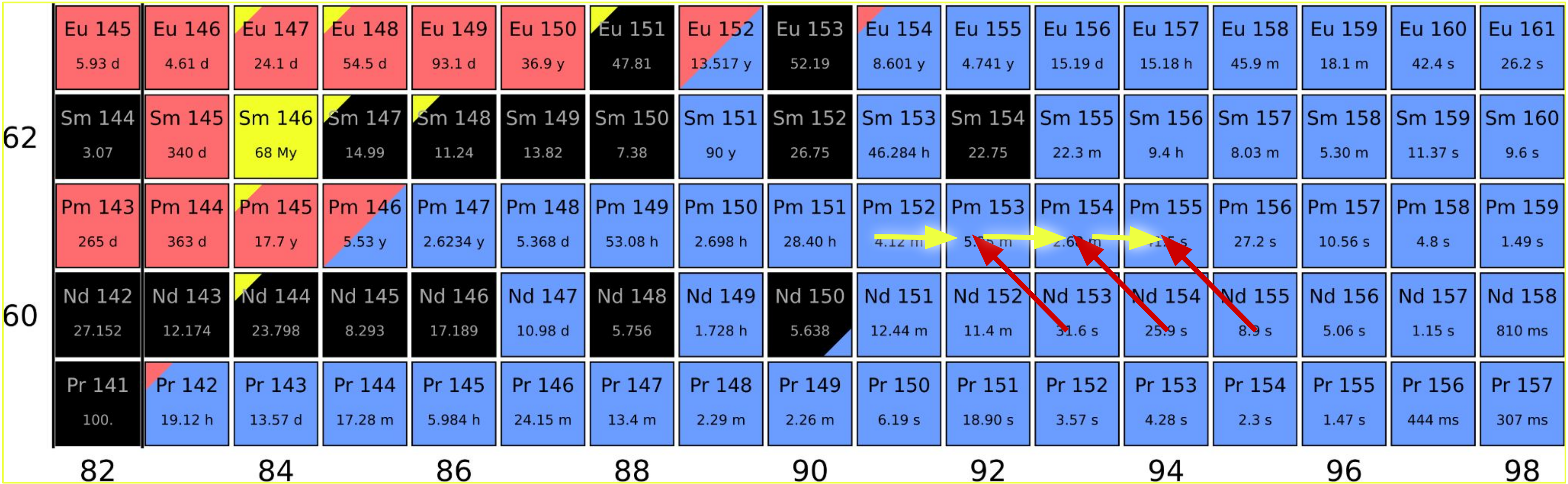
Element	Reaction	r_P	r_S
Ba	^{135}I	-0.9325	-0.9348
La	^{139}Cs	-0.6862	-0.8500
	^{139}Ba	-0.4407	-0.4811
Ce	^{140}Cs	-0.2134	-0.1977
	^{140}Ba	-0.8051	-0.9084
Pr	^{141}Ba	-0.8670	-0.9834
Nd	^{144}Ce	-0.4964	-0.5267
	^{146}Ce	-0.4886	-0.5395
Sm	^{147}Pr	-0.3284	-0.3848
	^{152}Nd	-0.7763	-0.8493
Eu	^{151}Nd	-0.7427	-0.8767
	^{153}Nd	-0.2122	-0.2627
Gd	^{156}Sm	-0.5144	-0.6305
	^{158}Sm	-0.4616	-0.5361
Tb	^{159}Sm	-0.3931	-0.4134
	^{159}Eu	-0.7555	-0.8639

Ref. P. Denissenkov et al *MNRAS*, **503**, 3, (2021), 3913–3925

From idea to proposal to data

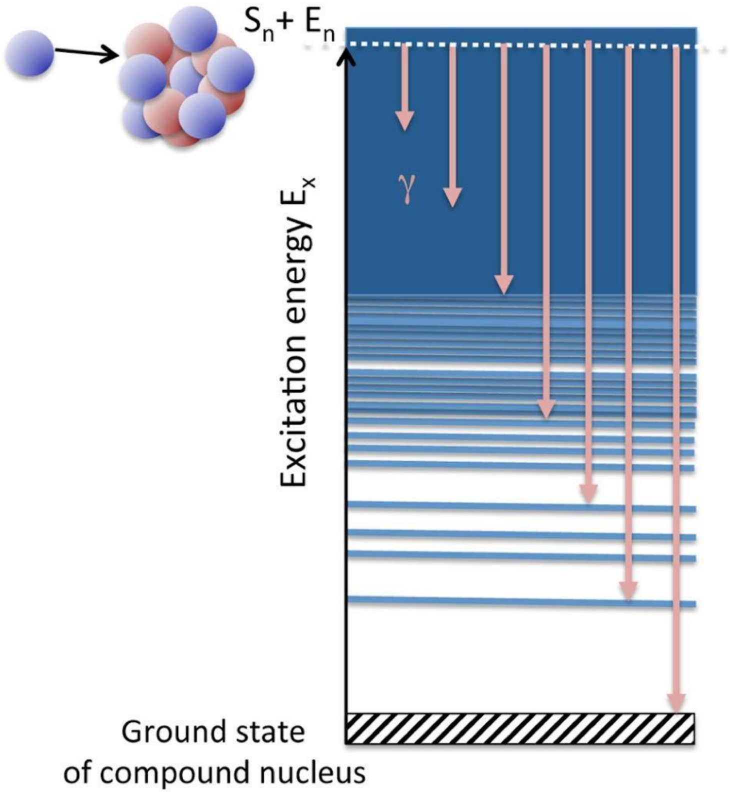



Let’s take a closer look at our area of interest



Green - (n,γ) reaction
Red - beta decay

Chart drawn with Chart-of nuclides-drawer by K. Miernik



Indirect constraints on neutron-capture reactions

Excited nucleus, decays by ɣ-rays

Look at statistical properties when there are many levels

Nuclear level density (NLD)
- *Levels per energy bin*

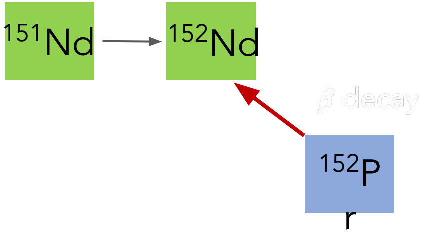
γ-strength function (γSF)
- Probability of γ emission

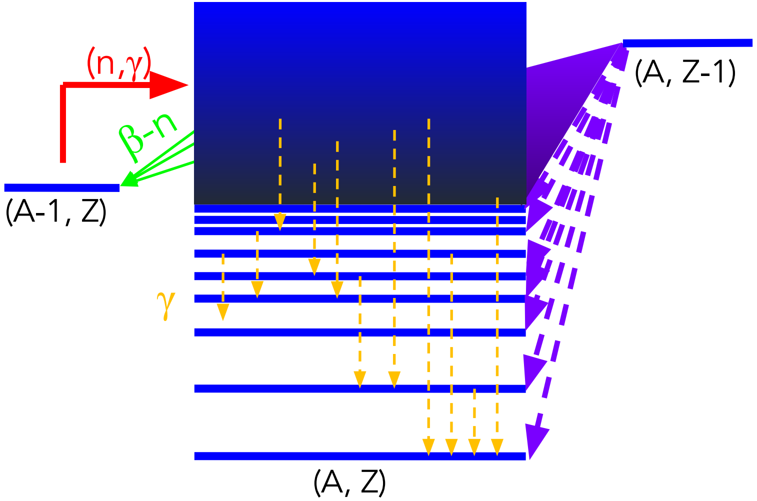
Need to know excitation energy and individual γ-ray energies

A. C. Larsen et al. Progress in Particle and Nuclear Physics 107 (2019)

What is the β-Oslo method[1]?

- Find the excitation energy based on the β decay
- Assume only allowed decays
- Can study more neutron rich nuclei - but here there may be challenges
- Nuclear properties





Figs modified from C. M. Harris

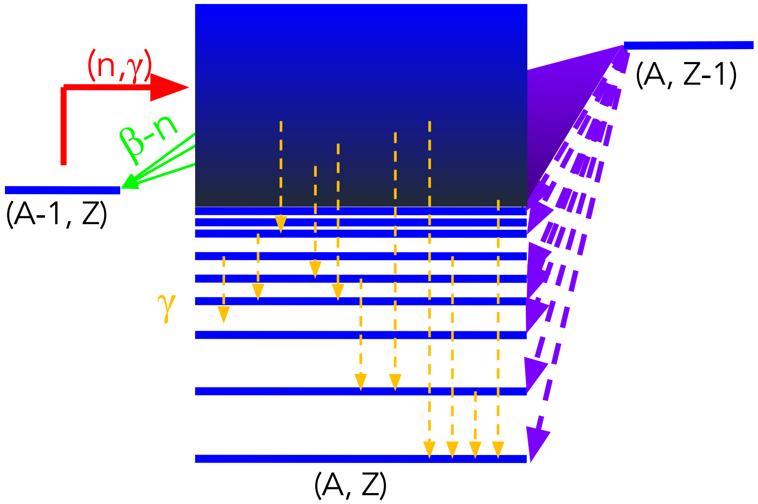
[1] A. Spyrou, S.N. Liddick, et al. PRL **117** 142701

After Ex-Eg

After excitation energy is found, same procedure as Oslo method:

1. Unfold with detector response
2. Extract primary γ-ray matrix
3. Global minimization to find level density and γ-ray strength function
4. Normalize to known parameters

Use NLD and γSF to find cross section

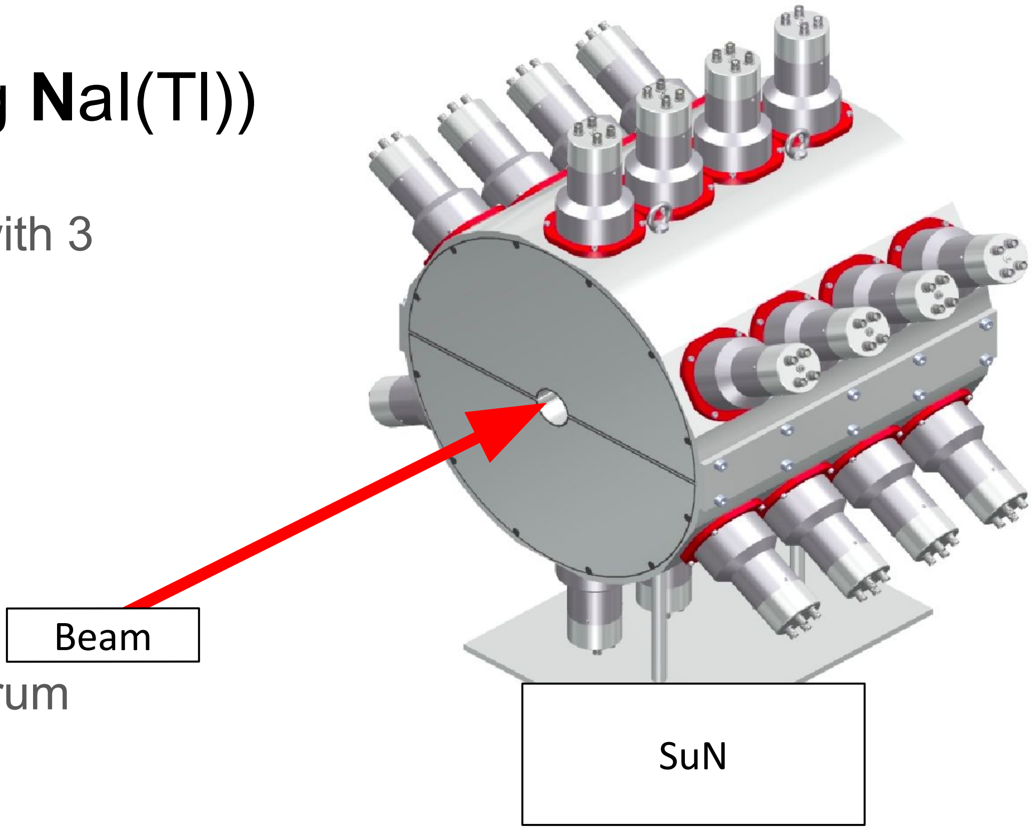


SuN - (**Su**mming **N**aI(Tl))

Split into 8 segments with 3 PMTs (16” x 16”)

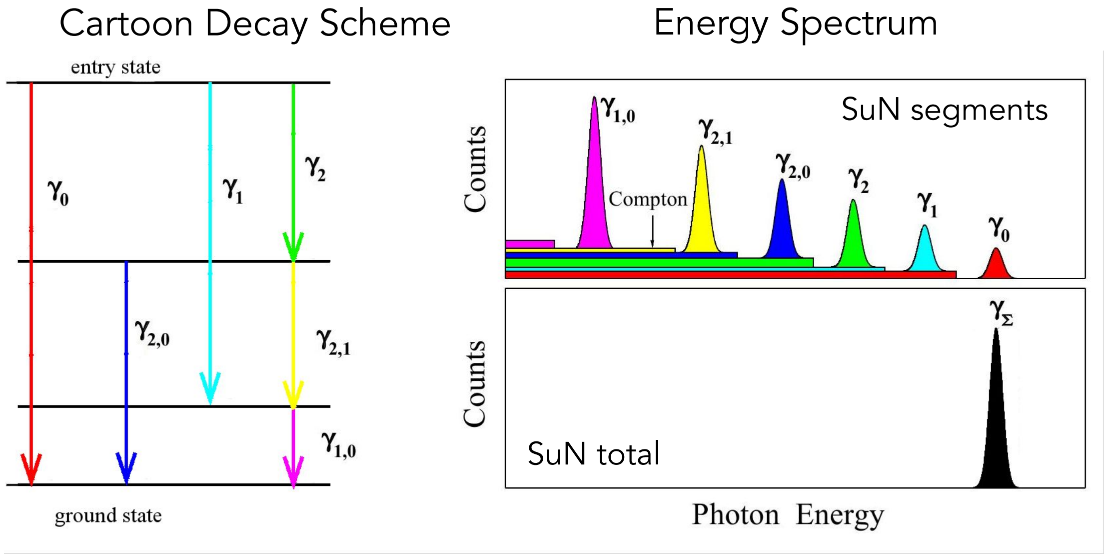
High efficiency

Total Absorption Spectrum possible



A.Simon et. *al*. NIMA **703,** 0168-9002 (2013)

Summing Technique



Sensitive to initial excited energies + individual gamma rays!

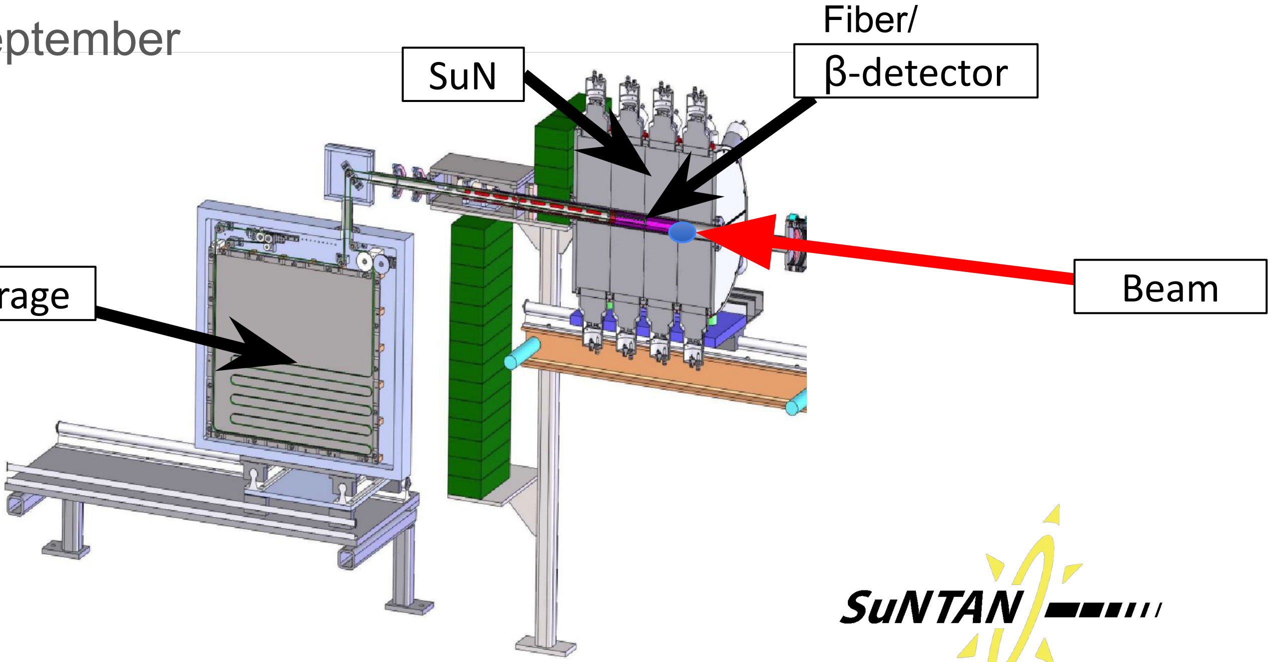
TAS = initial excited energies
Segments = individual gamma rays

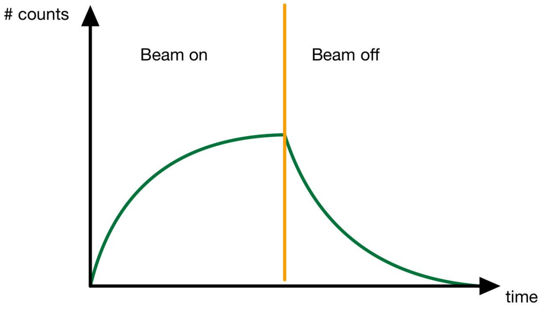
Fig. modified from C. M. Harris

Experiment setup

Tape system for Active Nuclei: SuNTAN

Ran experiment in September

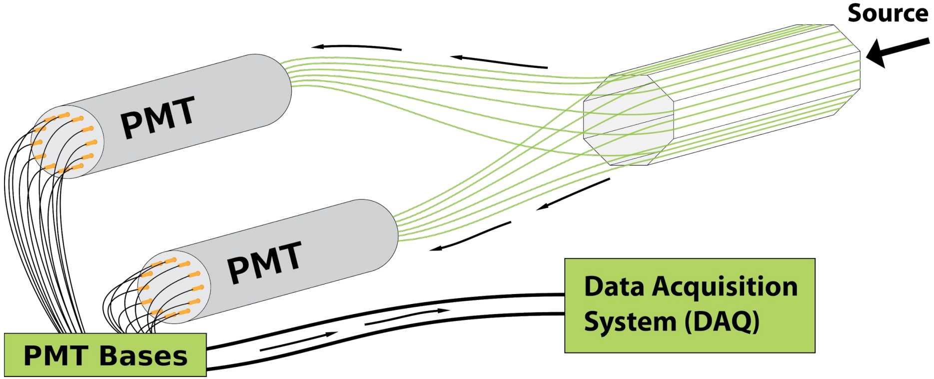


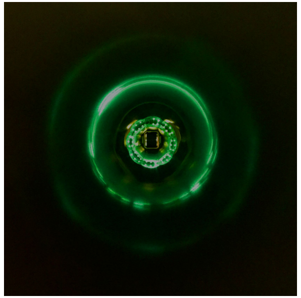


Slide modified from A. Richards and C. M. Harris

Scintillating detector for β-decay

Scintillating Plastic Optical Transport Detector - SPOT



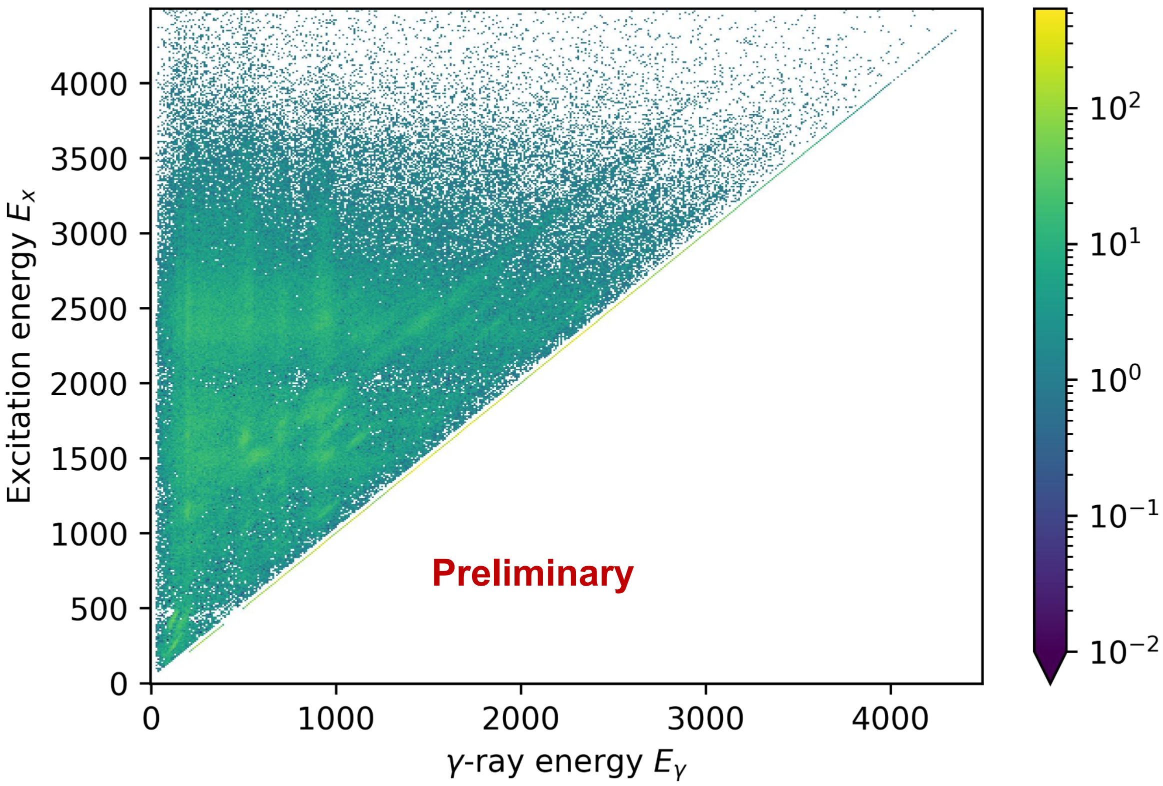


^{153}Nd preliminary results

RAN SUCCESSFUL EXPERIMENT LAST SEPTEMBER!

^{152,153,154}Nd from the ANL experiment

Thanks for listening!



Thanks for listening!

H. C. Berg[1], A. Spyrou[1], D. L. Bleuel[2], K. Bosmpotinis[1], J. Clark[3], P. DeYoung[4], A. Doetsch[1], E. C. Good[1], B. Greaves[5], S. Grimes[6], C. Harris[1], V. W. Ingeberg[7], A.-C. Larsen[7], S. N. Liddick[1], J. E. L. Larsson[7], S. Lyons[8], K. Malatji[9], M. Mogannam[1], T. Ogunbeku[10], J. Owens-Fryar[1], A. L. Richard[2], E. Ronning[1], D. Santiago[3], G. Savard[3], M. K. Smith[1], A. Sweet[2], A. Tsantiri[1], A. V. Voinov[6]

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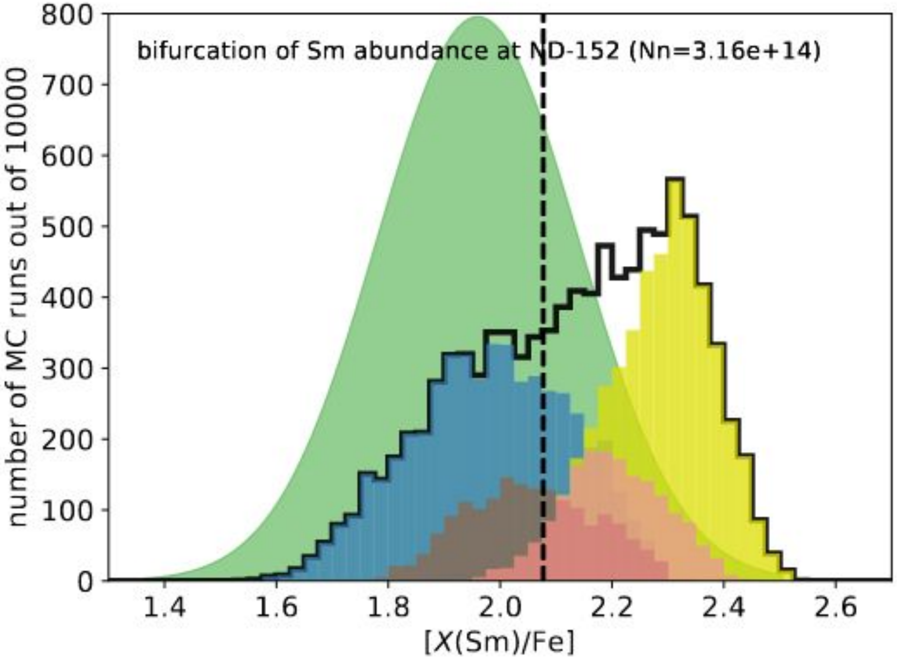
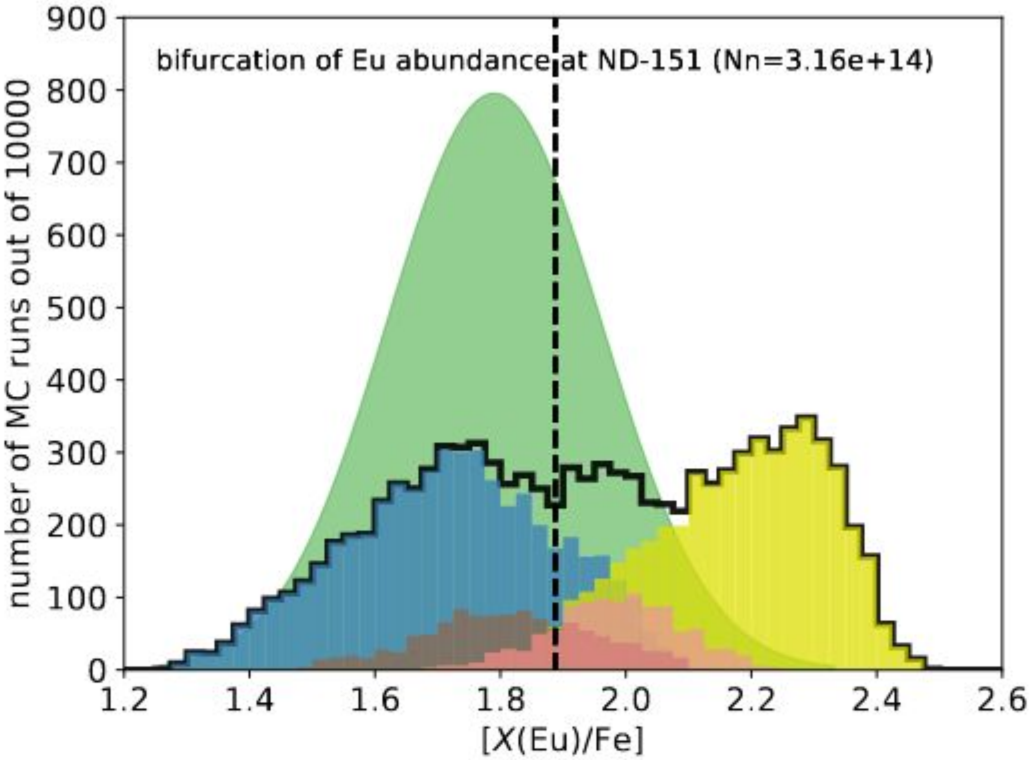


From P. Denissenkov



From P. Denissenkov