^{80}Se(n,γ) measurement

and

Commissioning of the i-TED Demonstrator (i-TED2)

V. Babiano Suarez, L. Caballero Ontanaya, D. Calvo, C. Domingo-Pardo, I. Ladarescu, JL Tain (IFIC), A. Casanovas, A. Tarifeño (UPC), C. Guerrero, J. Lerendegui (US), C. Lederer-Woods (U.Edinburgh), R. Reifarth (U. Frankfurt), …

the n_TOF local team (CERN)

and the n_TOF Collaboration

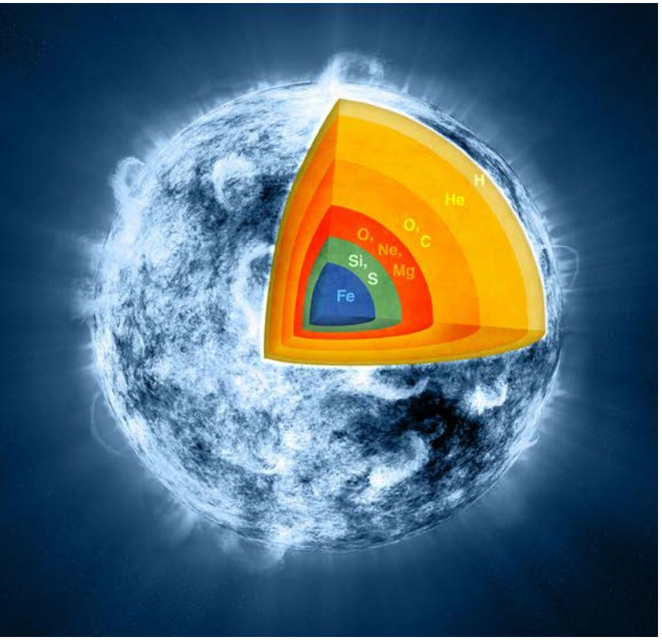
PROPOSAL TO BE SUBMITTED TO THE NEXT INTC-PAC, by January 10th, 2018

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 681740).

Outline

- Motivation & Introduction: The branching around ^{79}Se(n,γ)
- Need for a new ^{80}Se(n,γ) measurement
- Need to develop high-selectivity (n,g) techniques: i-TED
- i-TED Commissioning
- Summary & Outlook

Motivation and Introduction: MSs & Temperature evolution



REVIEWS OF MODERN PHYSICS, VOLUME 84, JANUARY–MARCH 2012

Rotating massive stars: From first stars to gamma ray bursts

André Maeder* and Georges Meynet†

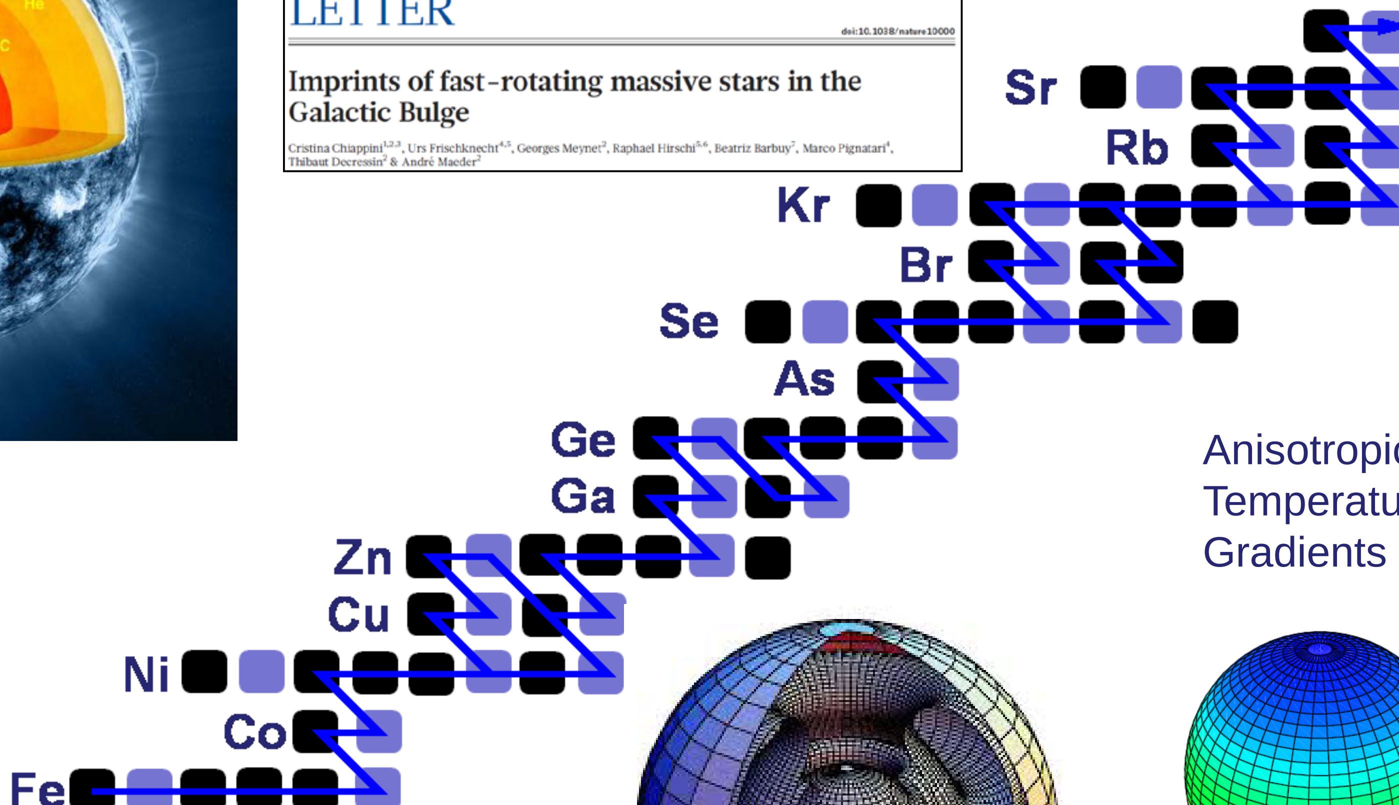
Geneva Observatory, University of Geneva, 51 chemin des Maillettes, CH-1290 Versoix, Switzerland

LETTER

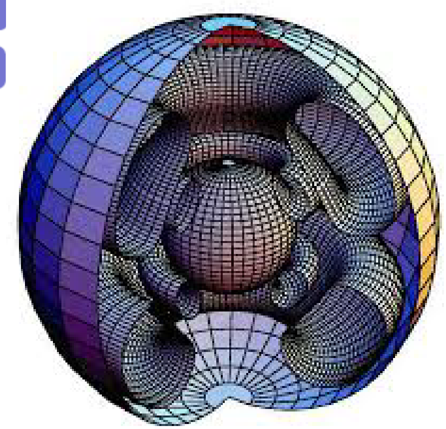
doi:10.1038/nature10000

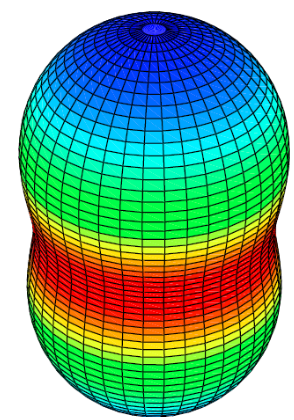
Imprints of fast-rotating massive stars in the Galactic Bulge

Cristina Chiappini[1,2,3], Urs Frischknecht[4,5], Georges Meynet[2], Raphael Hirschi[5,6], Beatriz Barbuy[7], Marco Pignatari[4], Thibaut Decressin[2] & André Maeder[2]



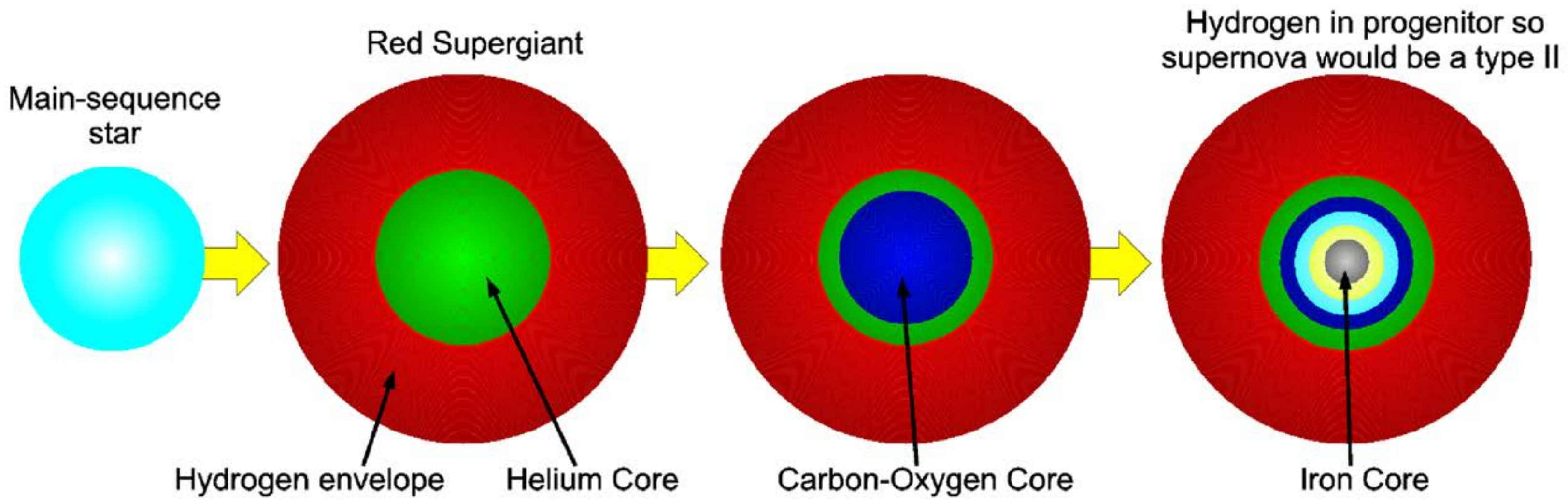
Anisotropic Temperature Gradients

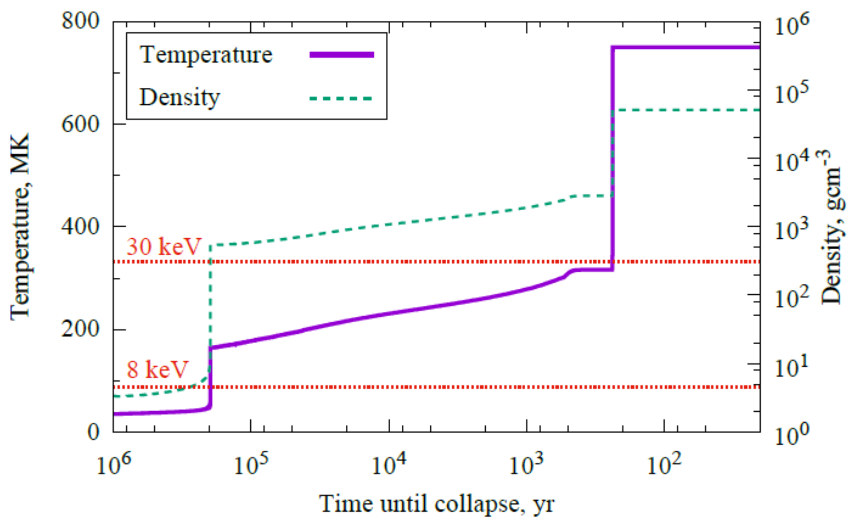


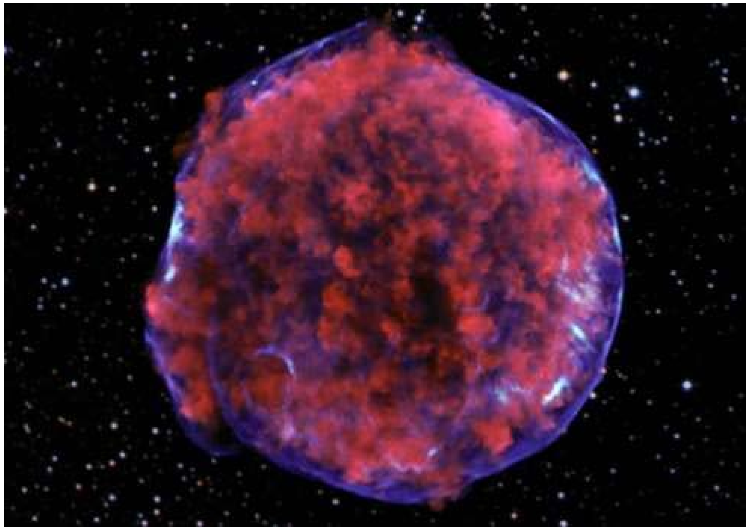


Currents, rotation, mixing

Temperature: a key ingredient in stellar structure and evolution

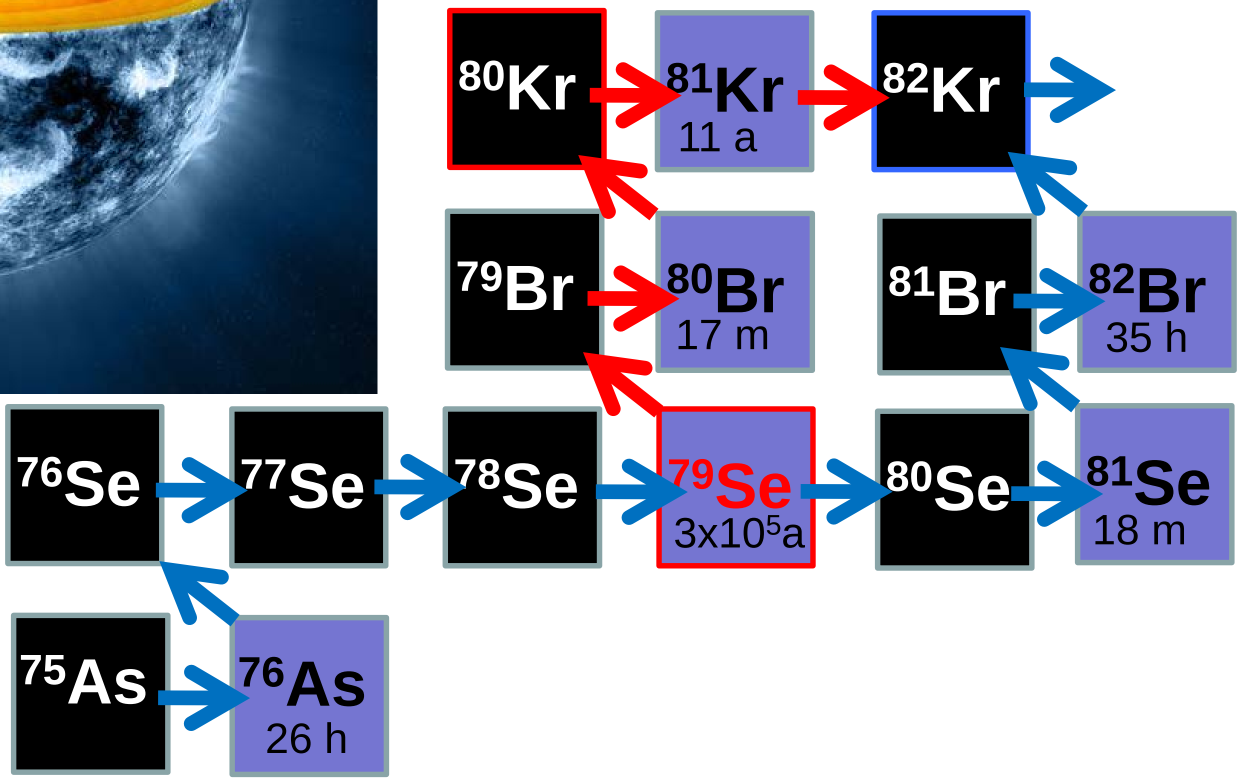


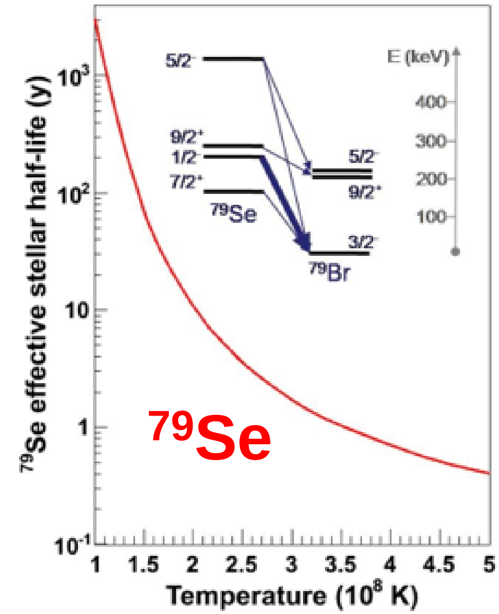




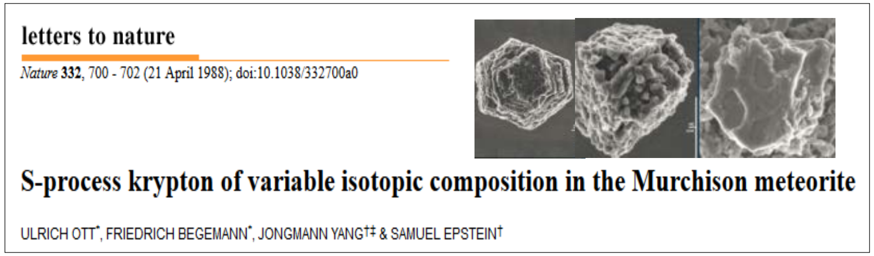
N.Nishimura, et al. 2017 MNRAS

The massive-star nuclear-thermometer





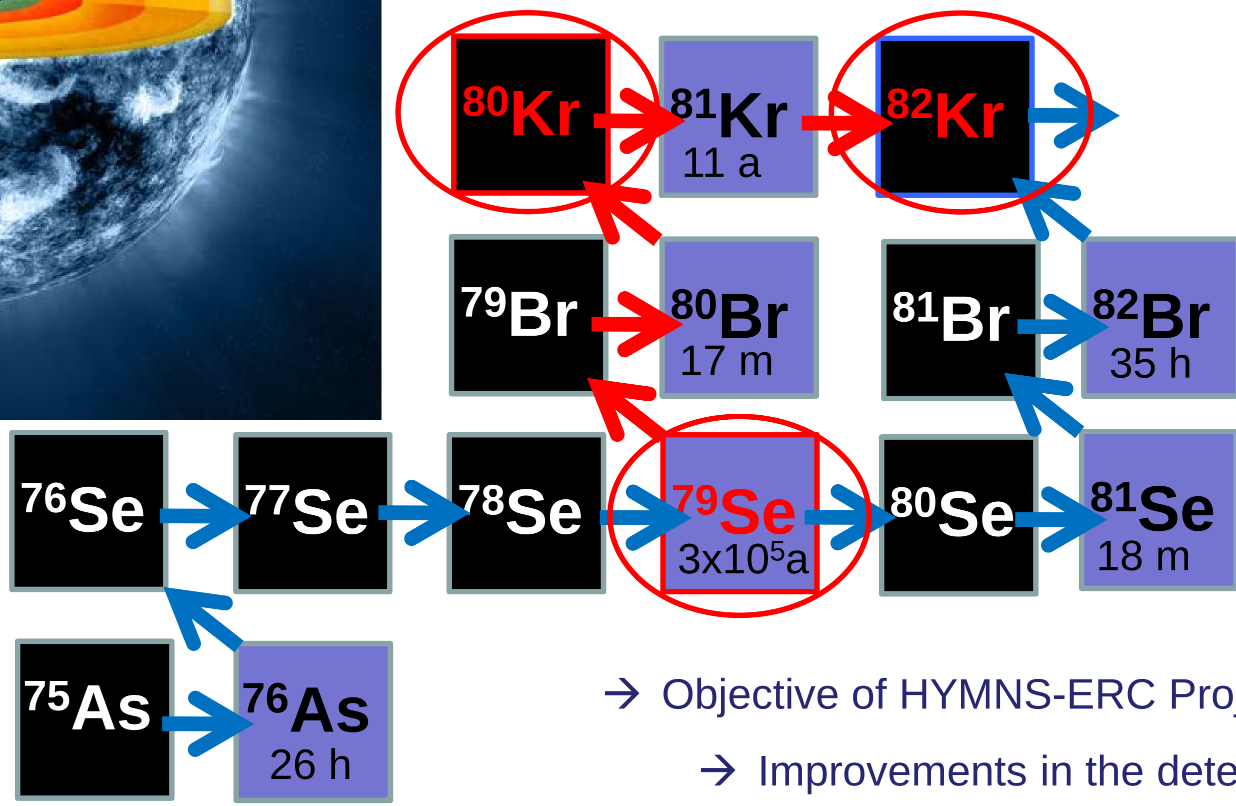
The massive-star nuclear-thermometer

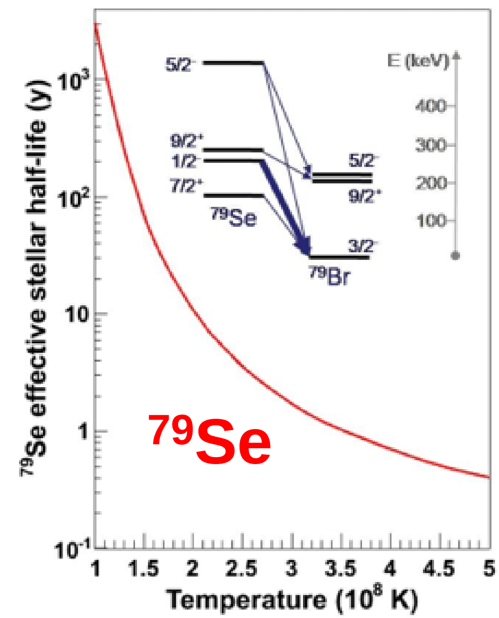

letters to nature

Nature 332, 700 - 702 (21 April 1988); doi:10.1038/332700a0

S-process krypton of variable isotopic composition in the Murchison meteorite

ULRICH OTT*, FRIEDRICH BEGEMANN*, JONGMANN YANG†‡ & SAMUEL EPSTEIN†



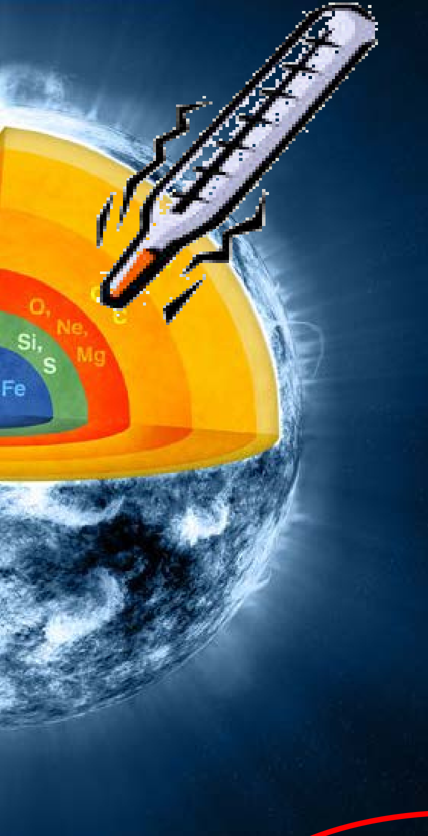


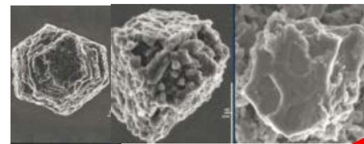
→ Objective of HYMNS-ERC Project (LoI, CERN INTC 2014)

→ Improvements in the detection system: i-TED

→ Accurate (n,g) CSs of neighbouring nuclei

The massive-star nuclear-thermometer




letters to nature

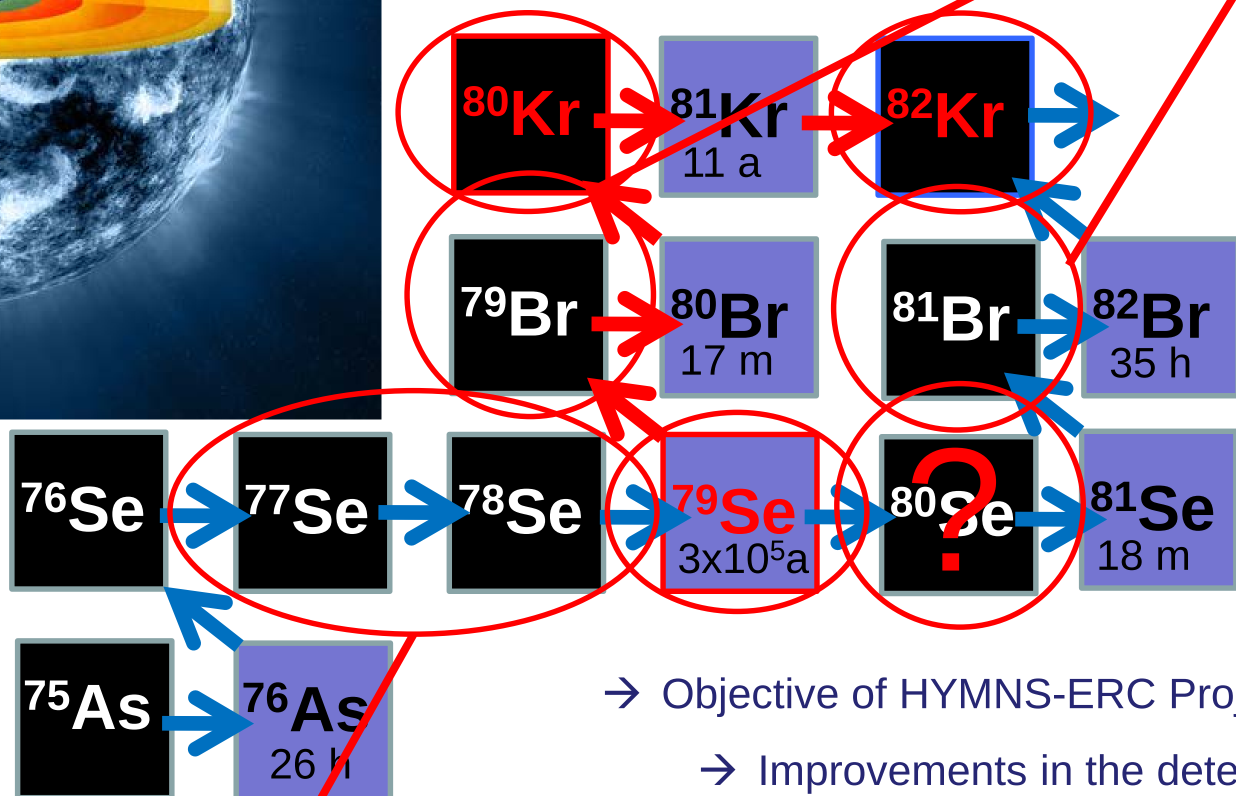
Nature 332, 700 - 702 (21 April 1988); doi:10.1038/332700a0

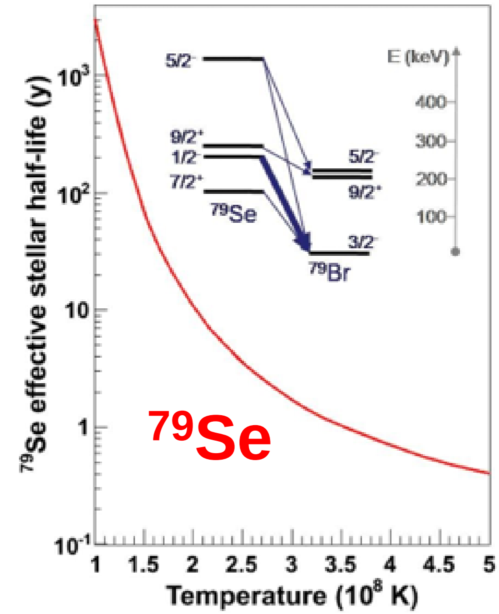
S-process krypton of variable isotopic composition in the Murchison meteorite

ULRICH OTT*, FRIEDRICH BEGEMANN*, JONGMANN YANG†‡ & SAMUEL EPSTEIN†

M.Heil et al. PRC2008→ Unc.(79Br)= 5.5%

Unc.(81Br)=3%





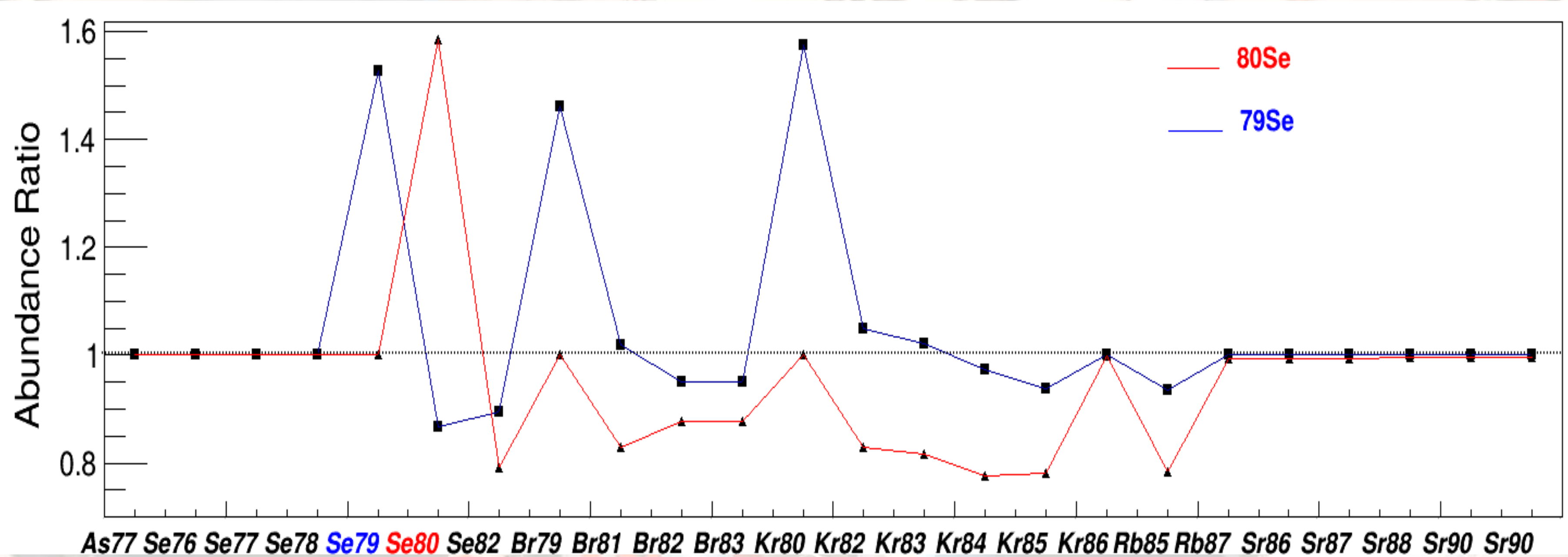
→ Objective of HYMNS-ERC Project (LoI, CERN INTC 2014)

→ Improvements in the detection system: i-TED

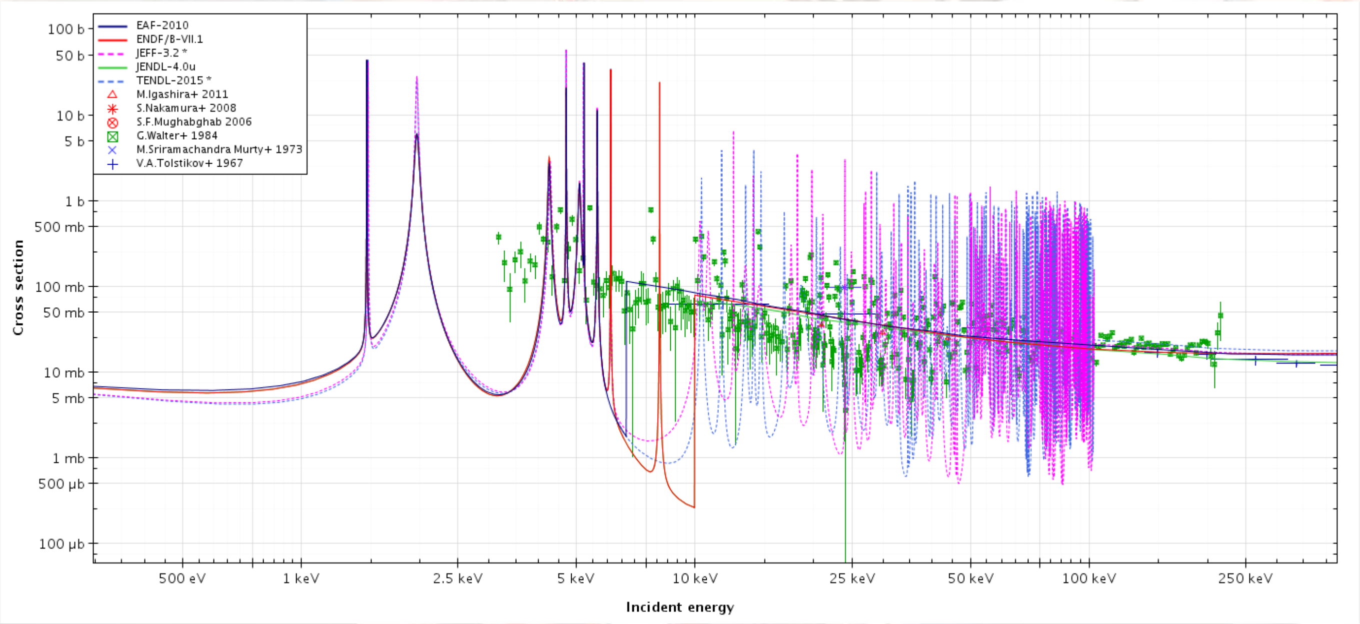
→ Accurate (n,g) CSs of neighbouring nuclei

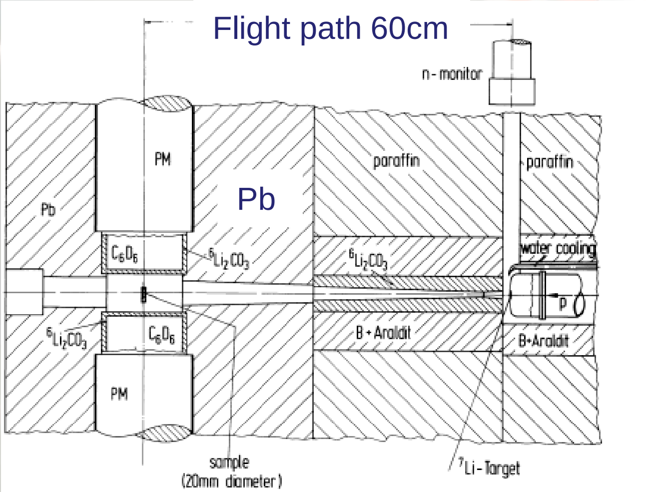
C.Lederer, A. Murphy et al. (n_TOF Col.), 2017 → CS Uncertainty 4-5%

$^{80}Se(n,\gamma)$ Status of the data



^{80}Se(n,γ) Status of the data

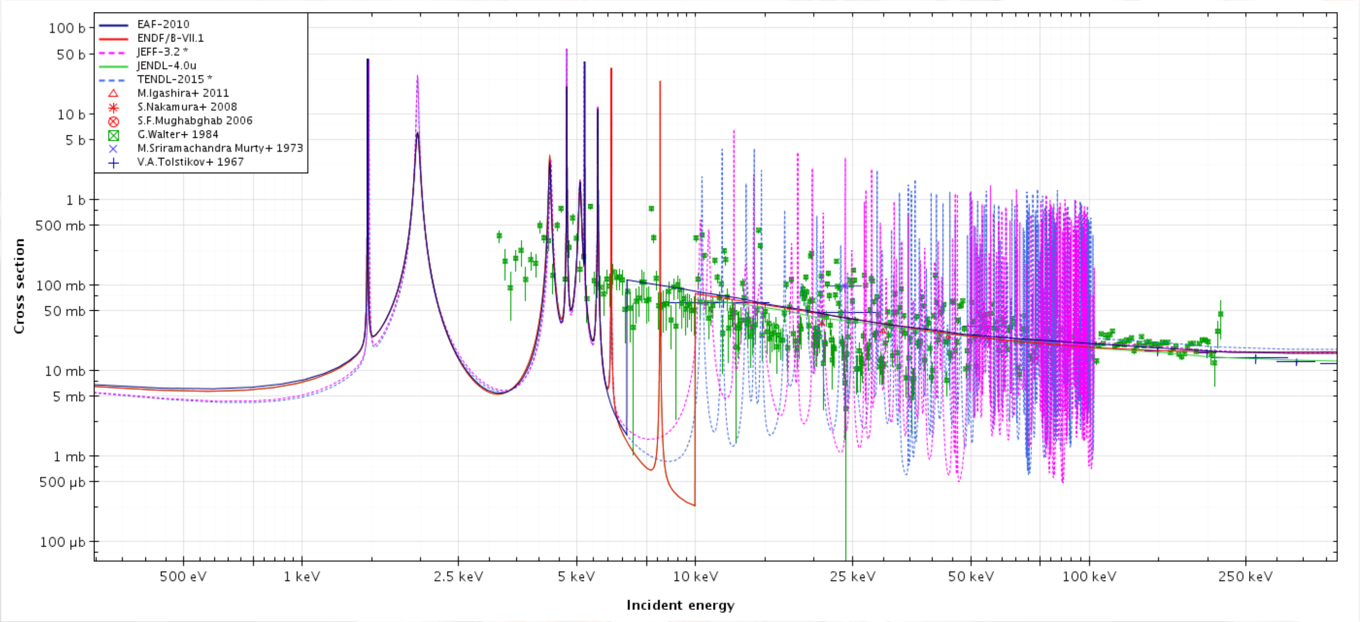




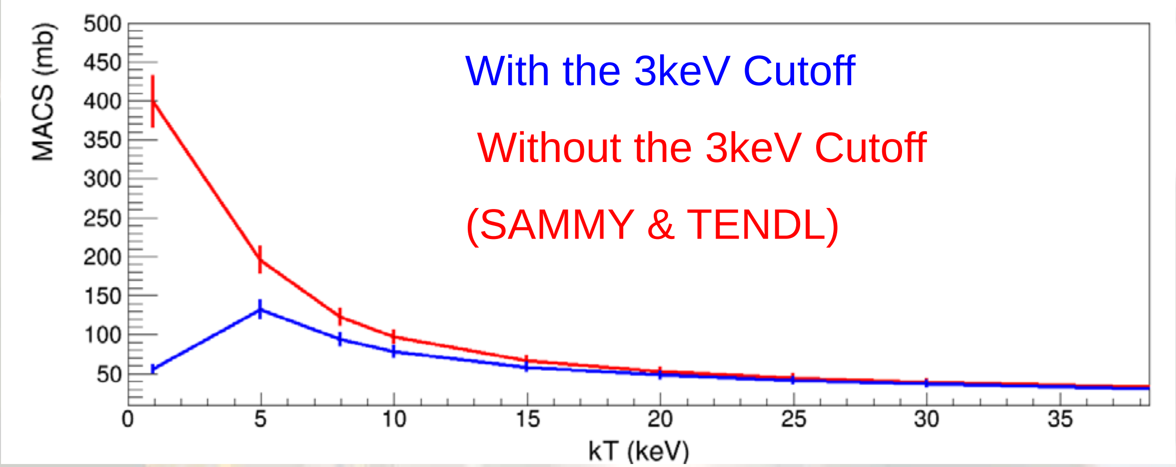
G. Walter *et al.*, Astron. Astrophys. **167**, 186 (1986)

- → Low energy cut-off at 3 keV
- → Limited En-resolution
- → (Probably with strong n-sensitivity bias)

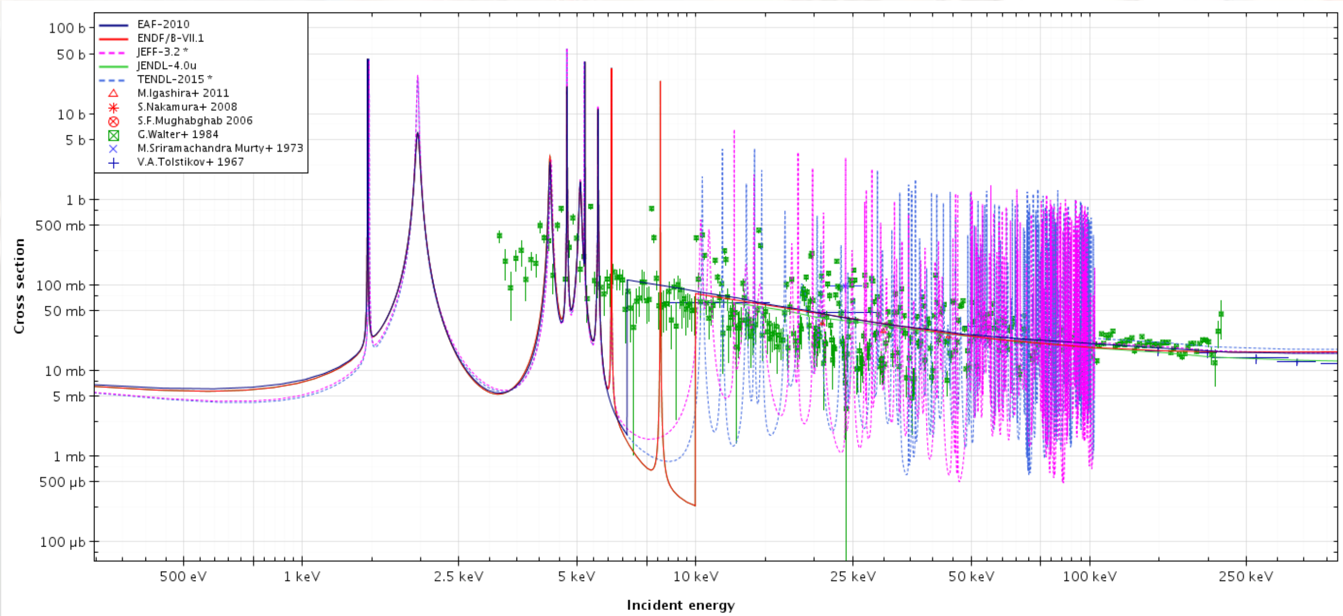
^{80}Se(n,γ) Status of the data

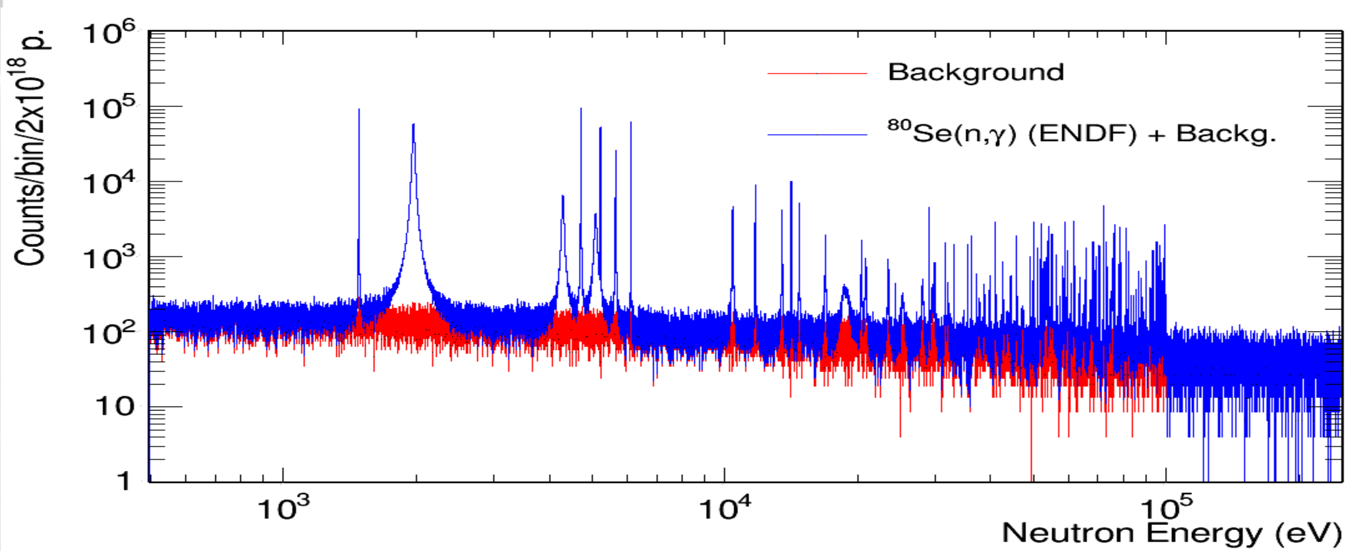


G. Walter *et al.*, Astron. Astrophys. **167**, 186 (1986)



$^{80}Se(n,\gamma)$ at n_TOF EAR1





Simulation for n_TOF EAR1

185 m

$4xC_6D_6$

2x10^18p

^{80}Se(n,γ) Status of the data

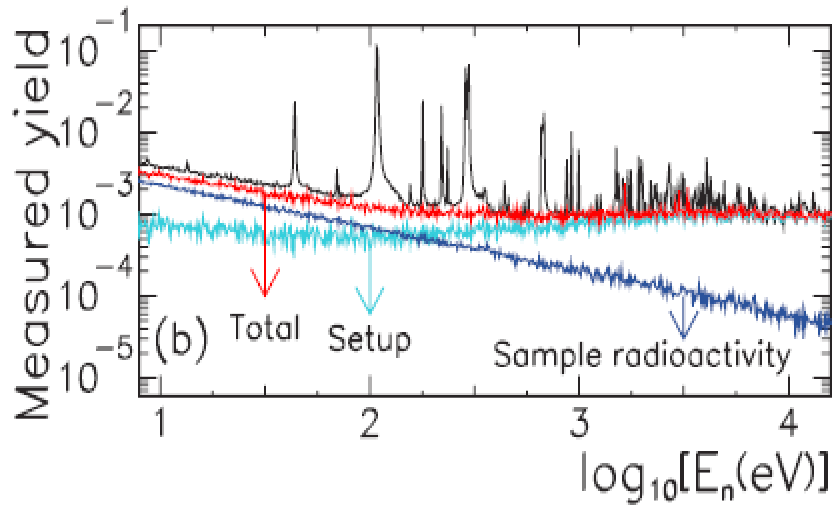
Sample	Objective(s)	Protons	Area	Set-up
^{80}Se	^{80}Se(n,g) via C6D6 Benchmark i-TED2 performance	$2{\cdot}10^{18}$	EAR1	$4xC_6D_6$ i-TED2
Dummy	Background for ^{80}Se(n,g)	$5{\cdot}10^{17}$	EAR1	$4xC_6D_6$ i-TED2
Au, Pb, C	Normalization ^{80}Se(n,g), Beam-induced background in (n,g) Data to develop i-TED bkg. rejection algorithms.	$1{\cdot}10^{18}$	EAR1	$4xC_6D_6$ i-TED2
Au,Pb,C	i-TED Detector response function.	$5{\cdot}10^{17}$	EAR2	i-TED2
^{80}Se	S-wave at 2keV in ^{80}Se, 1 g sample n-sensitivity (no i-TED)		EAR1	$4xC_6D_6$
Total protons requested:		**4.5x1018**		

Need of new developments: illustrated @ $^{93}Zr(n,\gamma)$

PHYSICAL REVIEW C 87, 014622 (2013)

The $^{93}Zr(n,\gamma)$ reaction up to 8 keV neutron energy

G. Tagliente,[1,*] P. M. Milazzo,[2] K. Fujii,[2] U. Abbondanno,[2] G. Aerts,[3] H. Álvarez,[4] F. Alvarez-Velarde,[5] S. Andriamonje,[3] J. Andrzejewski,[6] L. Audouin,[7] G. Badurek,[8] P. Baumann,[9] F. Bečvář,[10] F. Belloni,[2] E. Berthoumieux,[3] F. Calviño,[11] M. Calviani,[12] D. Cano-Ott,[5] R. Capote,[13,14] C. Carrapiço,[15] P. Cennini,[16] V. Chepel,[17] E. Chiaveri,[16] N. Colonna,[1] G. Cortes,[11] A. Couture,[18] M. Dahlfors,[16] S. David,[9] I. Dillmann,[7,19] C. Domingo-Pardo,[20,19] W. Dridi,[3] I. Duran,[4] C. Eleftheriadis,[21] M. Embid-Segura,[5] A. Ferrari,[16] R. Ferreira-Marques,[17] W. Furman,[22] I. Goncalves,[15] E. Gonzalez-Romero,[5] F. Gramegna,[12] C. Guerrero,[5] F. Gunsing,[3] B. Haas,[23] R. Haight,[24] M. Heil,[7,19] A. Herrera-Martinez,[16] E. Jericha,[8] F. Käppeler,[7] Y. Kadi,[16] D. Karadimos,[25] D. Karamanis,[25] M. Kerveno,[9] E. Kossionides,[26] M. Krtička,[10] C. Lamboudis,[21] H. Leeb,[8] A. Lindote,[17] I. Lopes,[17] S. Lukic,[9] J. Marganiec,[6,19] S. Marrone,[1] T. Martínez,[5] C. Massimi,[27] P. Mastinu,[12] A. Mengoni,[13] C. Moreau,[2] M. Mosconi,[7,28] F. Neves,[17] H. Oberhummer,[8] S. O'Brien,[18] C. Papachristodoulou,[25] C. Papadopoulos,[29] C. Paradela,[4] N. Patronis,[25] A. Pavlik,[30] P. Pavlopoulos,[31] L. Perrot,[3] M. T. Pigni,[8] R. Plag,[7,19] A. Plompen,[32] A. Plukis,[3] A. Poch,[11] J. Praena,[12] C. Pretel,[11] J. Quesada,[14] R. Reifarth,[24,19] M. Rosetti,[33] C. Rubbia,[34] G. Rudolf,[9] P. Rullhusen,[32] J. Salgado,[15] C. Santos,[15] L. Sarchiapone,[16] I. Savvidis,[21] C. Stephan,[35] J. L. Tain,[20] L. Tassan-Got,[35] L. Tavora,[15] R. Terlizzi,[1] G. Vannini,[27] P. Vaz,[15] A. Ventura,[33] D. Villamarin,[5] M. C. Vincente,[5] V. Vlachoudis,[16] R. Vlastou,[29] F. Voss,[7] S. Walter,[7] M. Wiescher,[18] and K. Wisshak[7]
(n_TOF Collaboration[†])



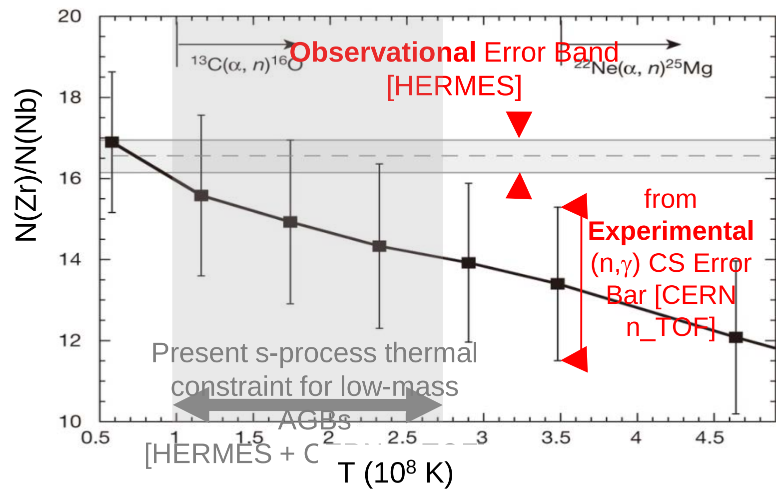
- HERMES observations of Nb and Zr in S-type stars
- Determination of the s-process temperature directly in evolved low-mass GSs, using Zr and Nb abundances, independent of stellar evolution models.
- 93Zr/93Nb provides chronometric information on the time elapsed since the start of the s-process (one-three million years).

LETTER **nature**

The temperature and chronology of heavy-element synthesis in low-mass stars

P. Neyskens[1], S. Van Eck[1], A. Jorissen[1], S. Goriely[1], L. Siess[1] & B. Plez[2]

The present determination of the s-process temperature relies on a single assumption, namely that the equilibrium approximation is valid along the Zr isotopic chain, which is known to be true locally[1]. For this reason, the uncertainties in the method are mainly those in the derived abundances and in the experimental Zr cross-section[14,15], that is, about 5% for the stable Zr isotopes and 11% for ^{93}Zr. Reducing the ^{93}Zr error would constrain the s-process operation temperature even more.

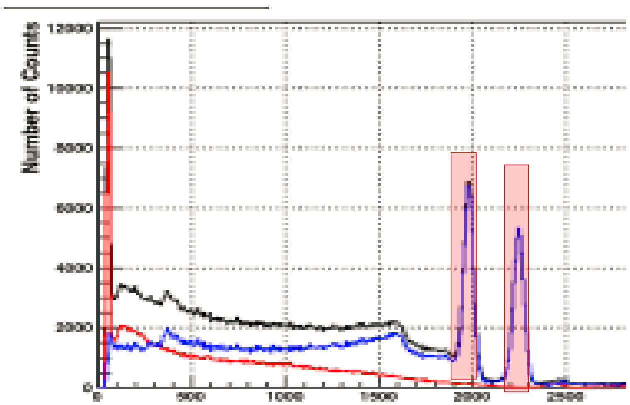


Adapted from P. Neyskens et al., *Nature* **517**, 174-176 (2015)

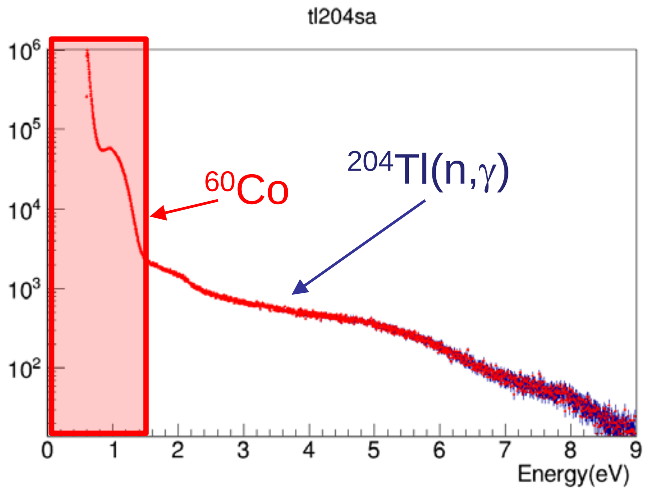
The i-TED project

High E-resolution → Better selectivity

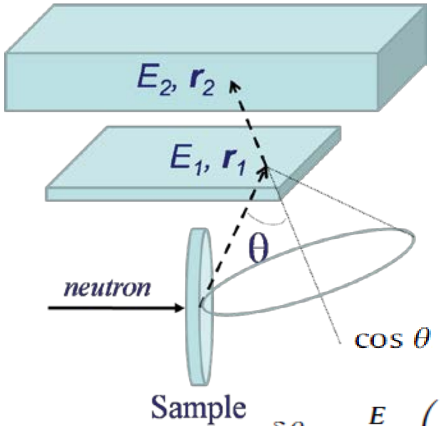
60Co measurement with **LaCl3 (i-TED)**



204Tl(60Co) measurement with **C6D6**

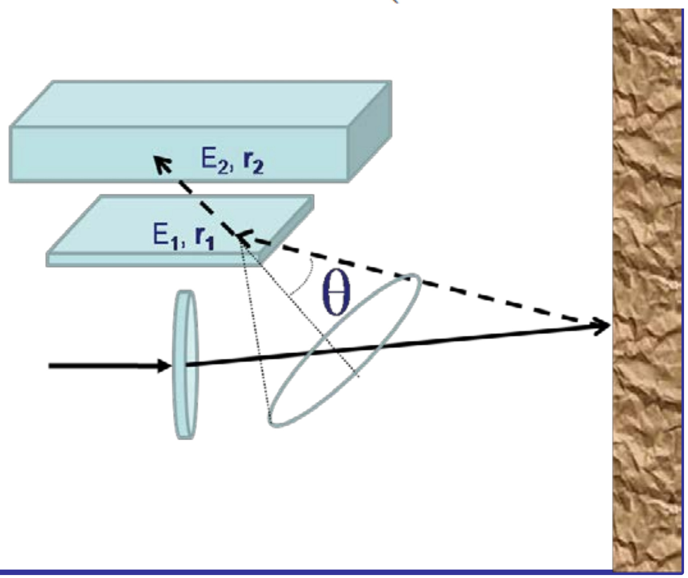


γ-Imaging → Better sensitivity



$$\cos\theta = 1 + \frac{511}{E} - \frac{511}{E'}$$

$$\delta\theta = \frac{E}{\sin\theta}\left(\frac{1}{E'^2}\left(\frac{\delta E'}{E'}\right)^2 + 2\sin^2\theta\left(\frac{\delta r}{r}\right)^2\right)^{1/2}$$



i-TED Commissioning: Motivation $^{79}Se(n,\gamma)$

Radioactive sample

Small (n,g) vs. (n,n)

erc European Research Council

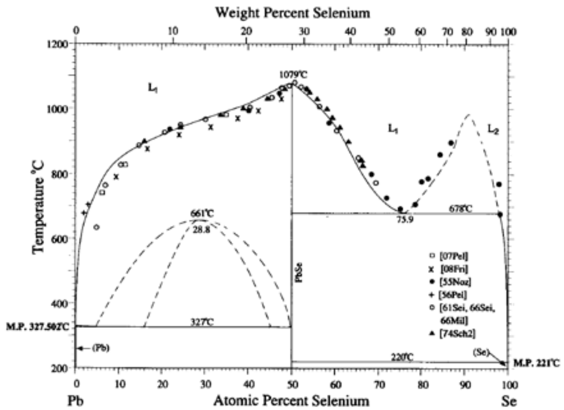
CSIC

99.3% ^{78}Se [Cortecnet]

99.1% ^{208}Pb [ORNL]

6g ^{208}Pb

2.5g ^{78}Se



0.01% ^{74}Se → GBq of ^{75}Se

0.01% of ^{60}Co → 2.6 MBq ^{60}Co
(10 months after EOI)

D. Schumann, S. Heinitz

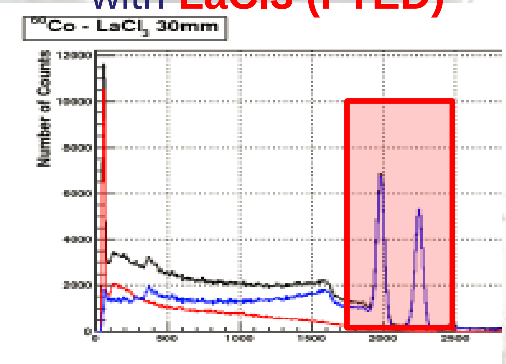
U. Koster

i-TED Commissioning: Motivation

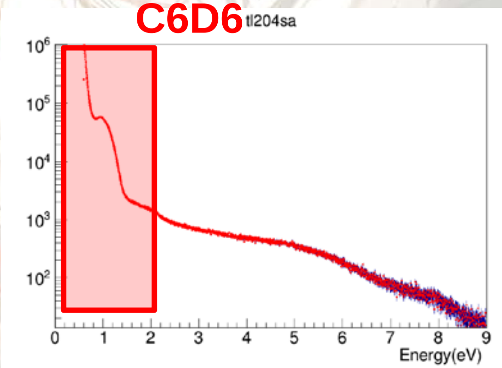
Radioactive sample → Enhance selectivity via high Eg-resolution

Small (n,g) vs. (n,n)

60Co measurement with **LaCl3 (i-TED)**



204Tl(60Co) measurement with **C6D6**

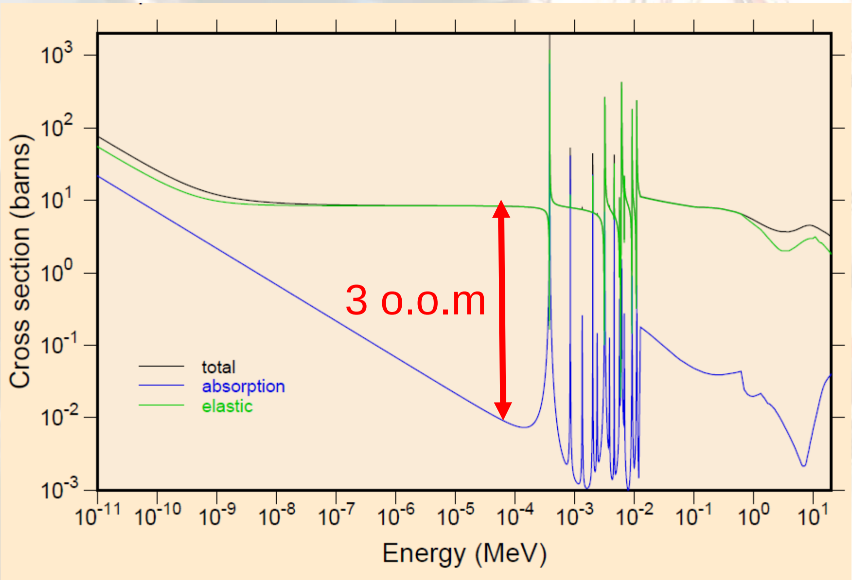


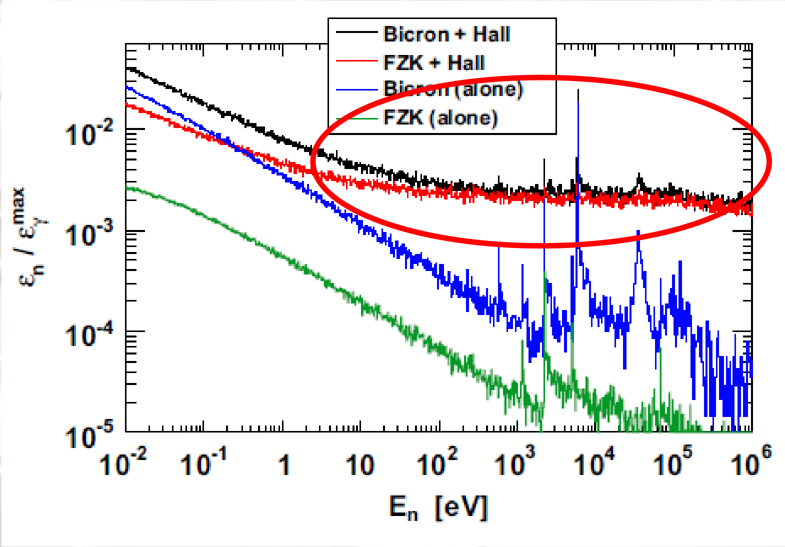
Energy resolution (spectroscopy resol.) means higher selectivity

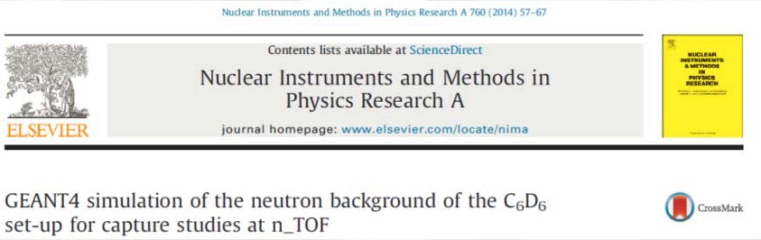
i-TED Commissioning: Motivation

Radioactive sample → Enhance selectivity via high Eg-resolution

Small (n,g) vs. (n,n) → Enhance (n,γ) sensitivity via imaging techniques






Nuclear Instruments and Methods in Physics Research A 760 (2014) 57–67

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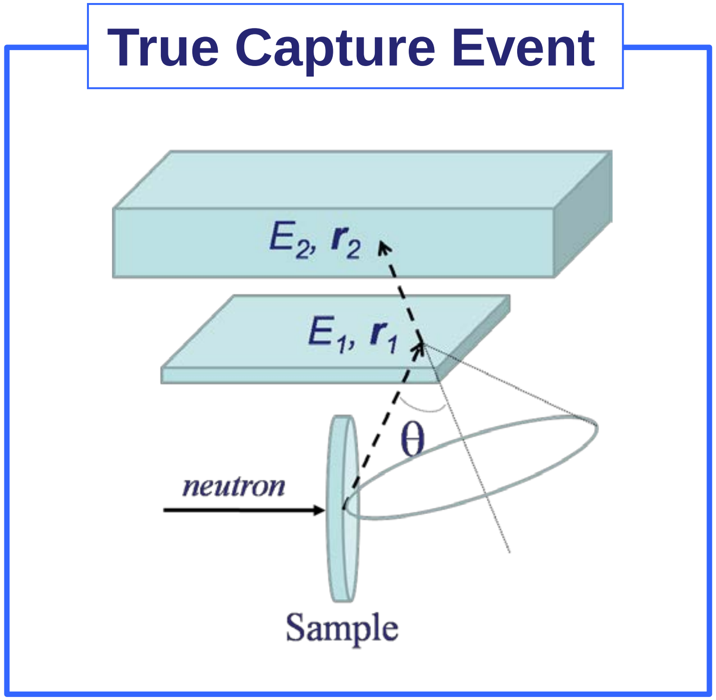
Nuclear Instruments and Methods in Physics Research A

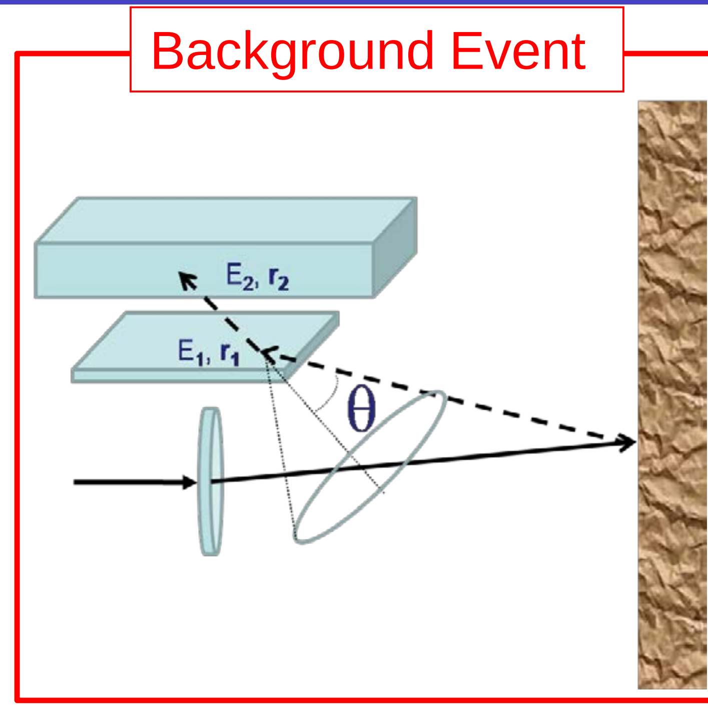
journal homepage: www.elsevier.com/locate/nima

ELSEVIER

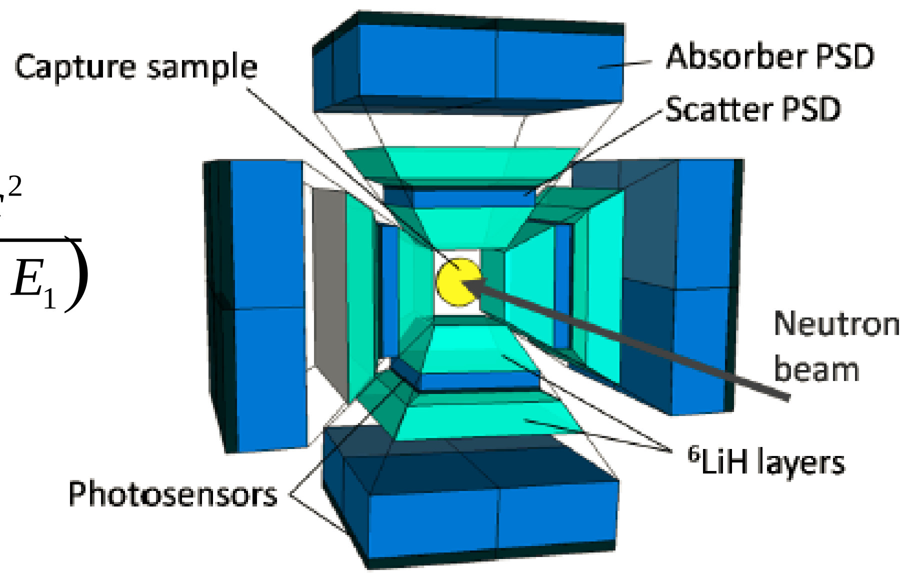
GEANT4 simulation of the neutron background of the C_6D_6 set-up for capture studies at n_TOF

i-TED: imaging-Total Energy Detector



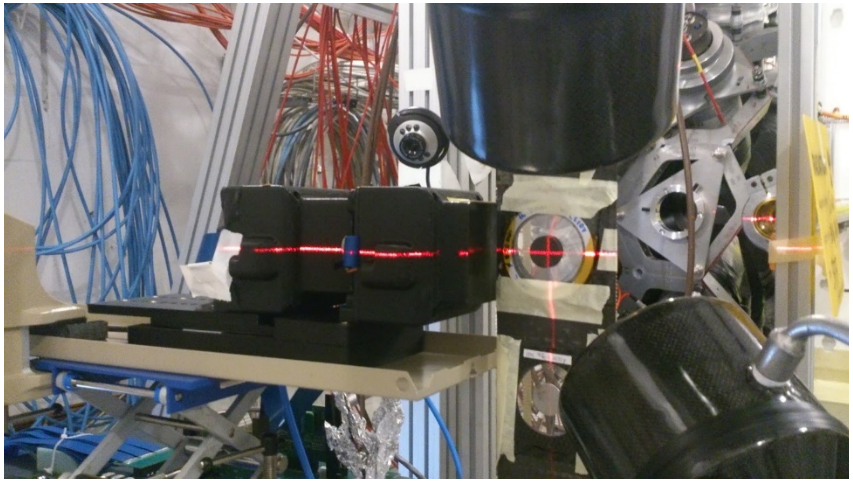


$$\cos\theta = 1 - \frac{E_1 m_0 c^2}{E_\gamma (E_\gamma - E_1)}$$

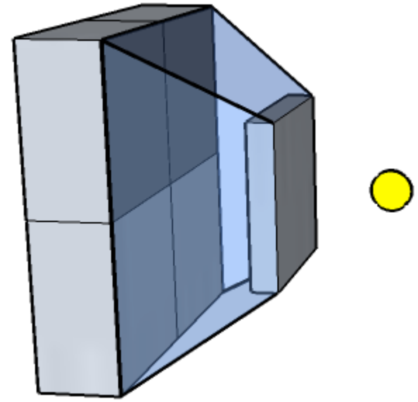


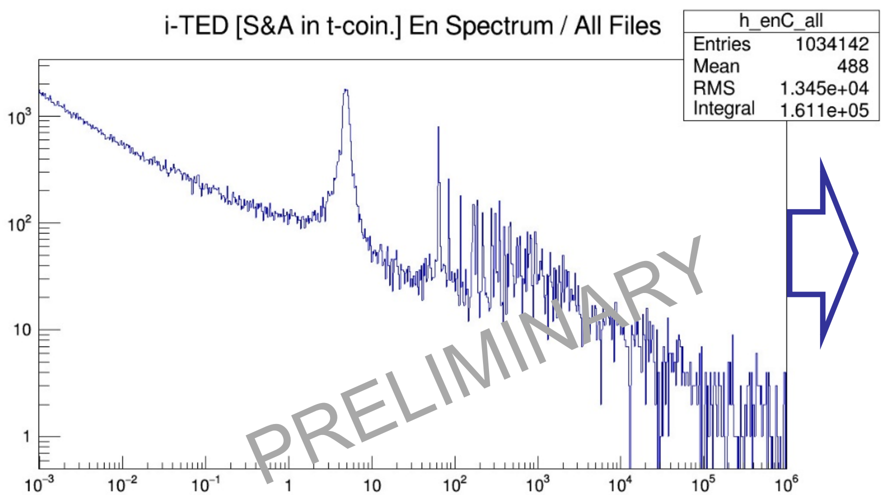
i-TED: imaging-Total Energy Detector

Technical commissioning i-TED Prototype (OK)



i-TED Demonstrator (i-TED2)





Performance commissioning needed → i-TED2

- Technical validation of the detectors
- Technical validation of readout electronics
- PS-Trigger signal correctly implemented
- Efficiency
    - Estimate from tech. Comm.
    - Enhancement due to improved detector design and larger A

Objectives for the i-TED Commissioning

- Proof-of-concept demonstration via a true / realistic (n,g) measurement (in the low energy range where CS is larger)
- Check for the long-term stability of the full i-TED2
- Evaluate the intrinsic neutron sensitivity of i-TED, via the C-sample measurement
- Explore the i-TED performance in EAR2

^{80}Se(n,γ) Status of the data

Sample	Objective(s)	Protons	Area	Set-up
^{80}Se	^{80}Se(n,g) via C6D6 Benchmark i-TED2 (n,g) performance	$2\cdot10^{18}$	EAR1	$4xC_6D_6$ i-TED2
Dummy	Background for ^{80}Se(n,g)	$5\cdot10^{17}$	EAR1	$4xC_6D_6$ i-TED2
Au, Pb, C	Normalization ^{80}Se(n,g), Beam-induced background in (n,g) Data to develop i-TED bkg. rejection algorithms.	$1\cdot10^{18}$	EAR1	$4xC_6D_6$ i-TED2
Au,Pb,C	Detector response function.	$5\cdot10^{17}$	EAR2	i-TED2
^{80}Se	S-wave at 2keV in ^{80}Se, 1 g sample n-sensitivity		EAR1	$4xC_6D_6$
Total protons requested:		**4.5x1018**		

Remaining technical i-TED tests / 2018 (with parasitic neutron beam/n_TOF detector test):

6-7 days of **test-beam** requested for:

- Effect of **sample-detector distance**, how close we can come with i-TED (its S-detector) to the sample → Efficiency / high En
- Possibility to use a **veto time-gate** in our readout electronics to go higher in neutron energy, for the case that the detector is affected by the gamma-flash
- Combined **capture & gamma-source measurement** to develop sample-activity rejection algorithms
- Effect of the **LiH moderator** for reducing intrinsic neutron sensitivity
- i-TED response **tests at EAR2**