Nuclear aspects of the s process

Claudia Lederer

University of Edinburgh

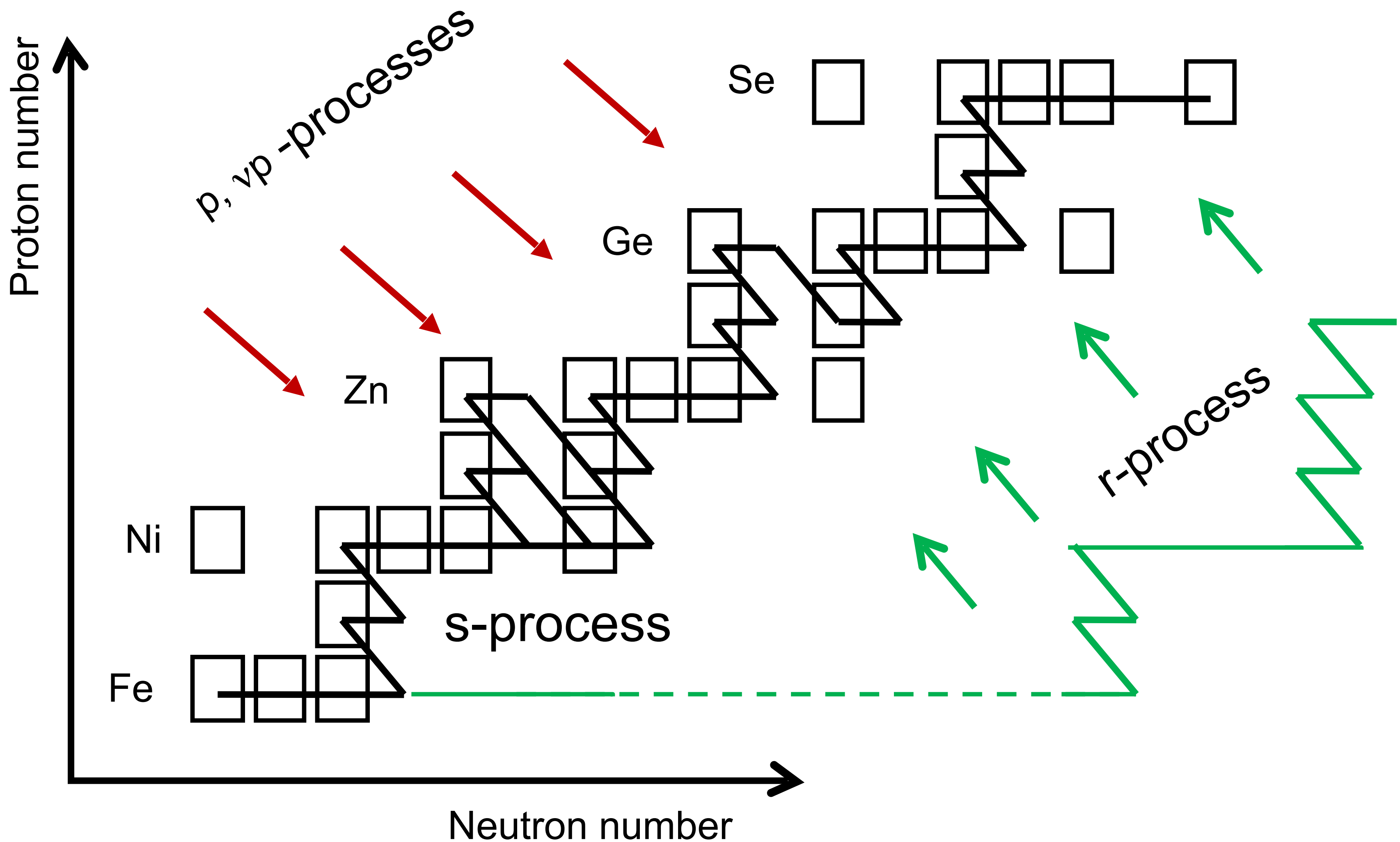
Hirschegg 2015

Der Wissenschaftsfonds.

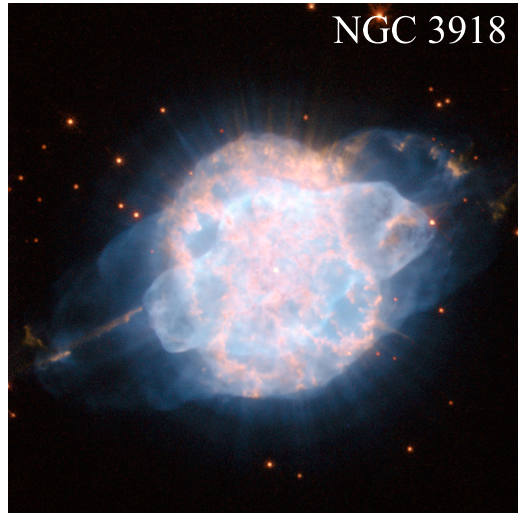
European Commission

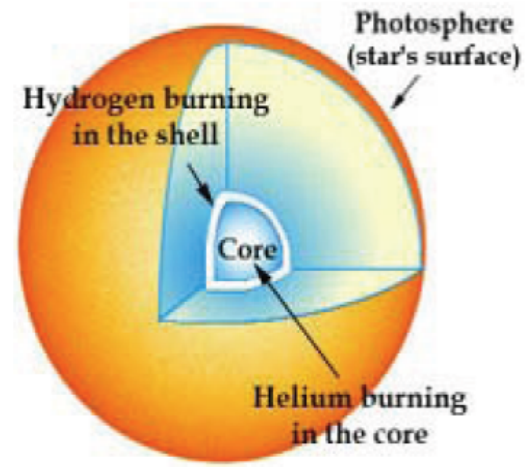
THE UNIVERSITY OF EDINBURGH

Heavy element nucleosynthesis



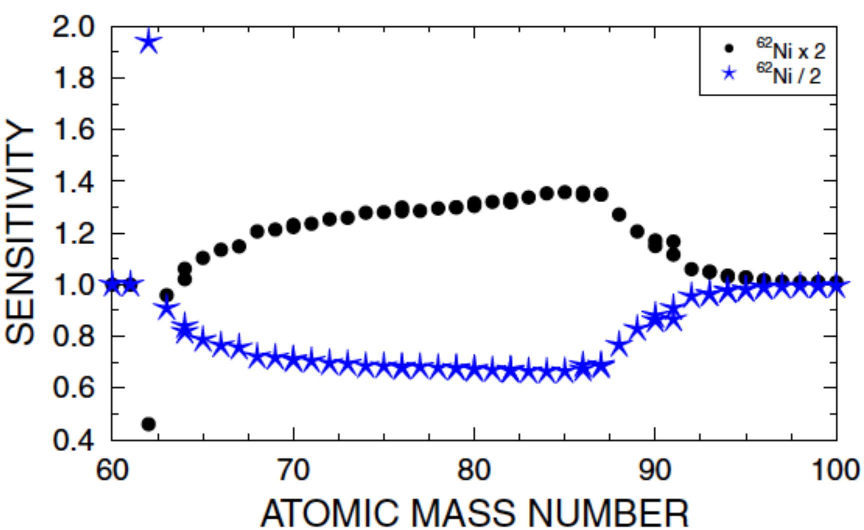
Slow neutron capture process process





Astrophysical Sites

- AGB stars
- Massive stars



J. Phys G **41**, 053101 (2014)

Nuclear Physics Input:

- β decay half lives
- $<\sigma>$…. Maxwellian Averaged Cross Section MACS

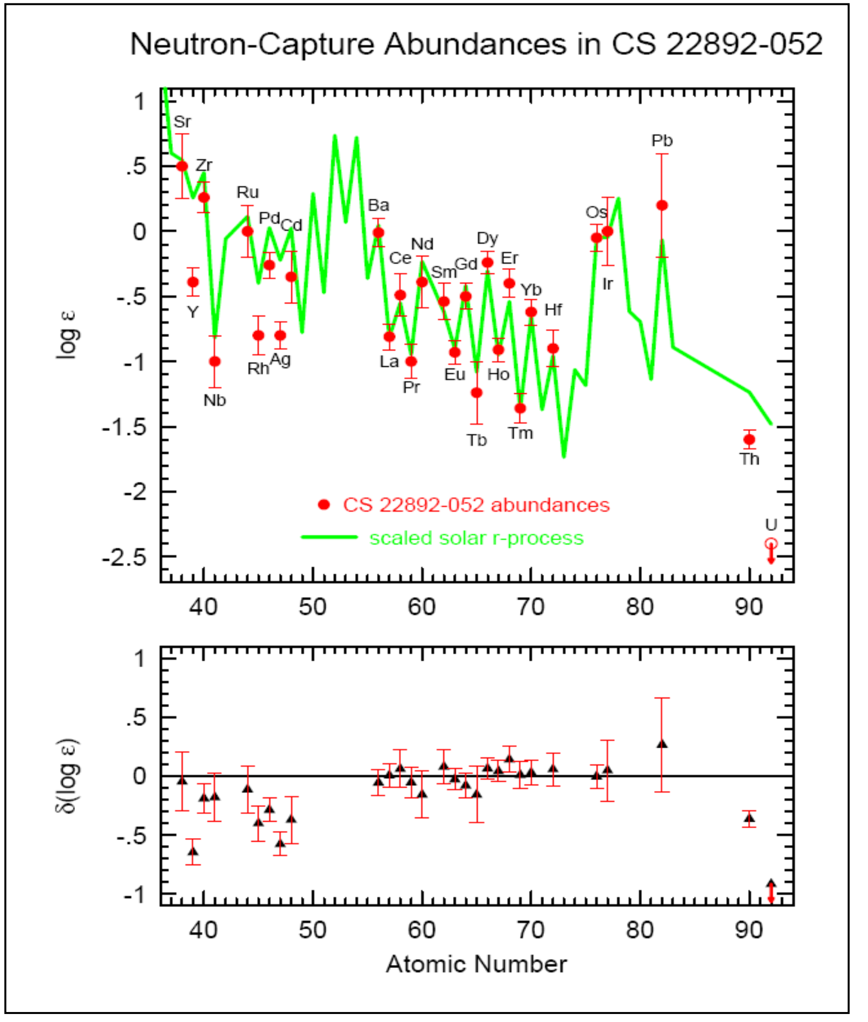
$$<\sigma>_{kT} = \frac{2}{\sqrt{\pi}} \frac{\int \sigma(E_n) E_n \exp(-E_n/kT) dE_n}{\int E_n \exp(-E_n/kT) dE_n}$$

Ultra Metal Poor Star Abundances

solar r-component:

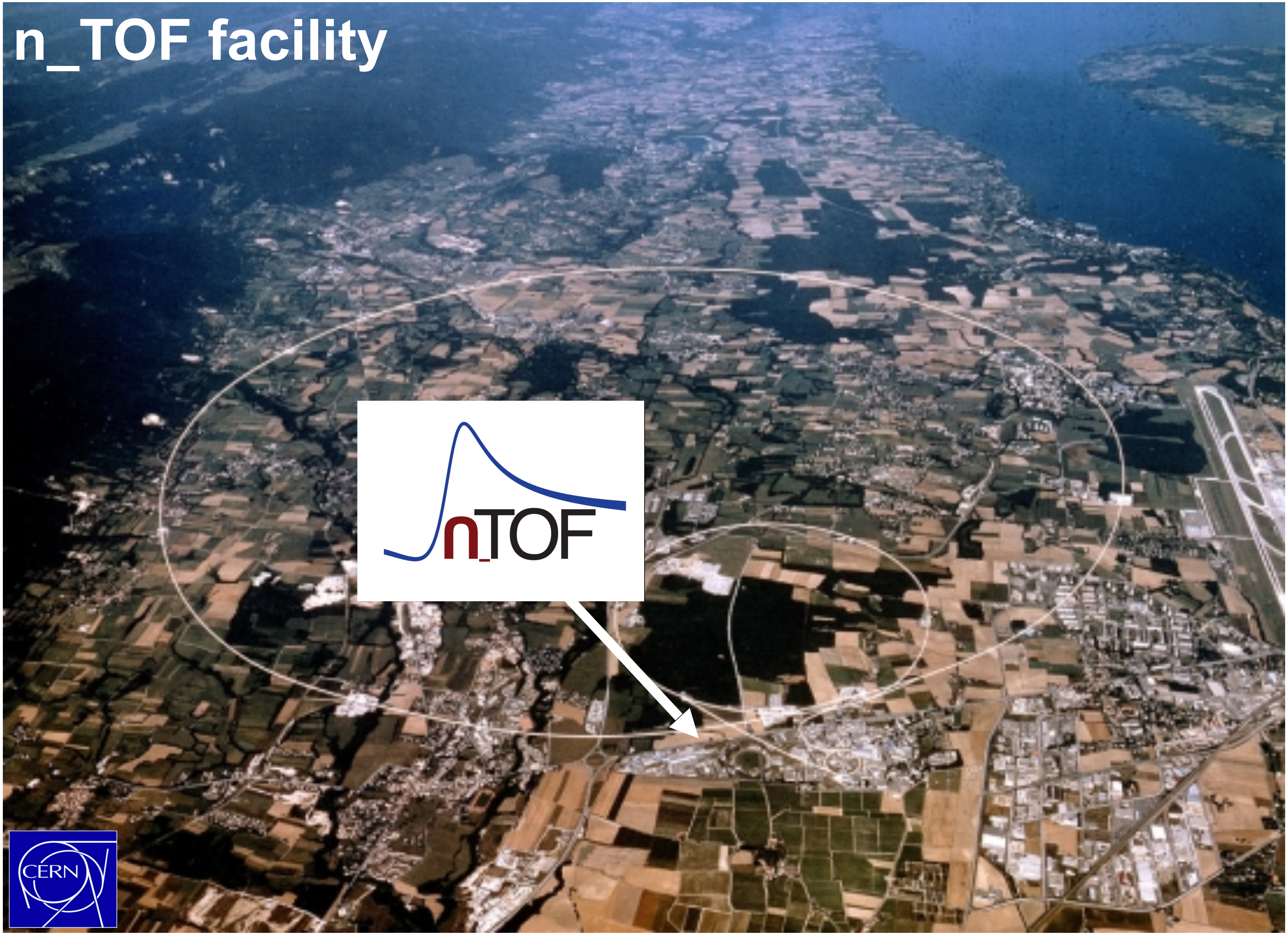
$$N_r = N_{sun} - N_s$$

- abundances scale with solar r process component
- indication for robust primary r process
- offset for A<130 → indication for two r process components

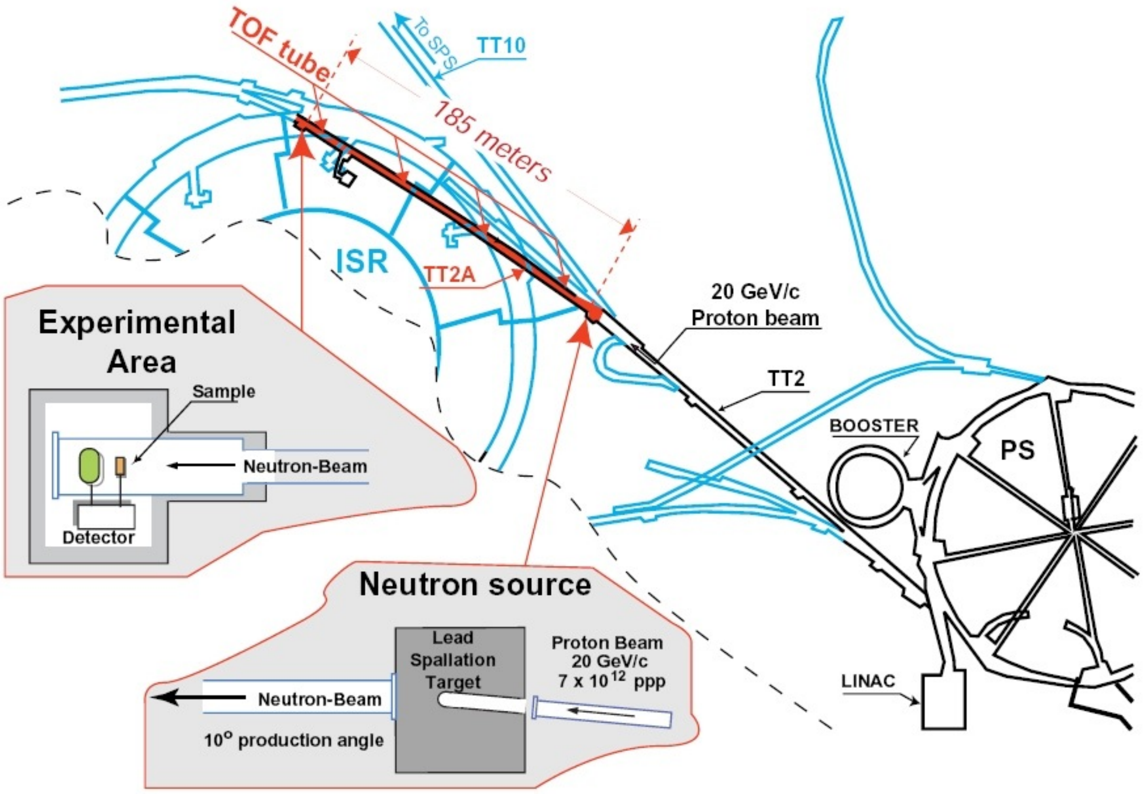


Sneden at al. APJ533 (2000)

n_TOF facility

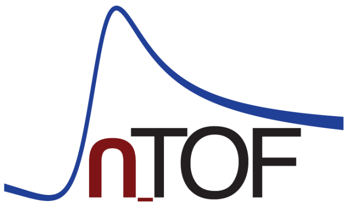


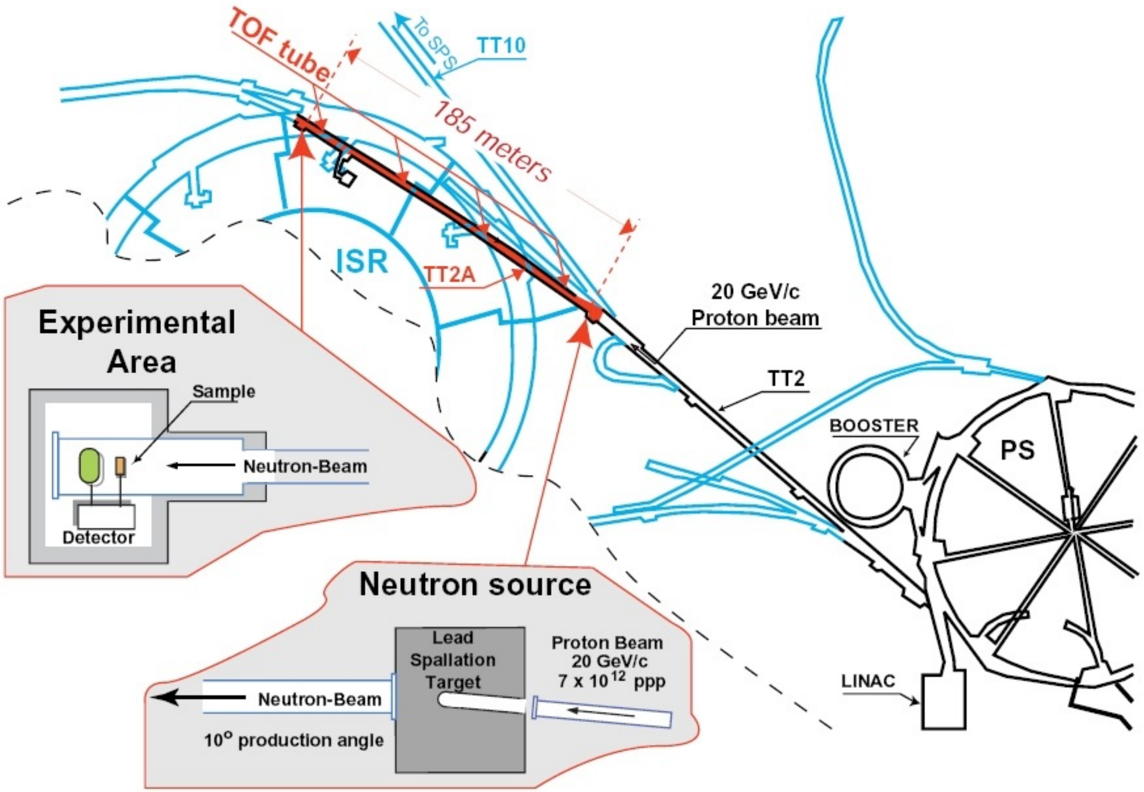
The n_TOF facility at CERN

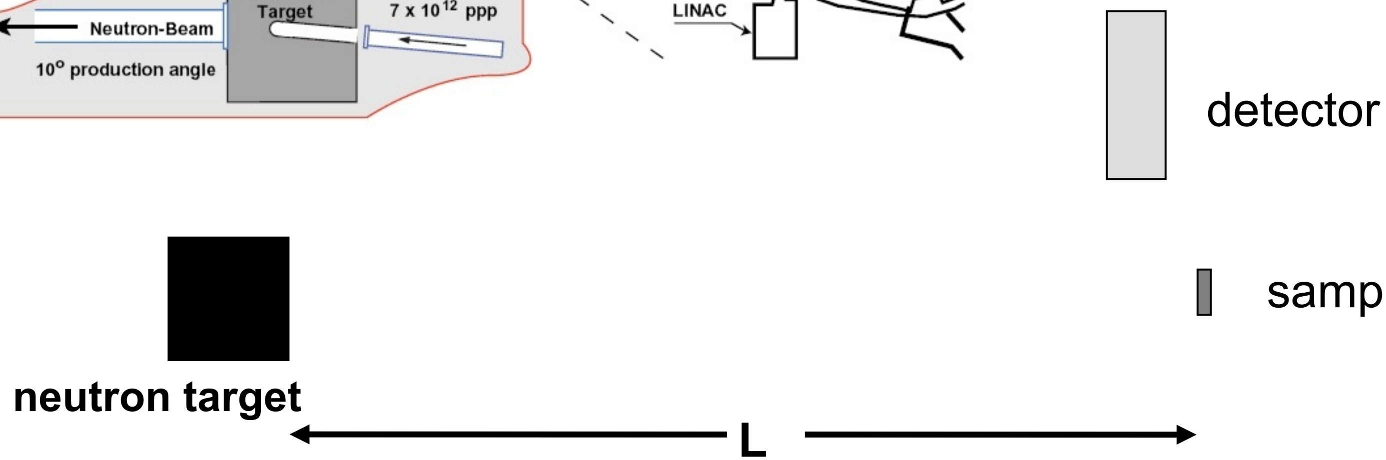


www.cern.ch/ntof

The n_TOF facility at CERN







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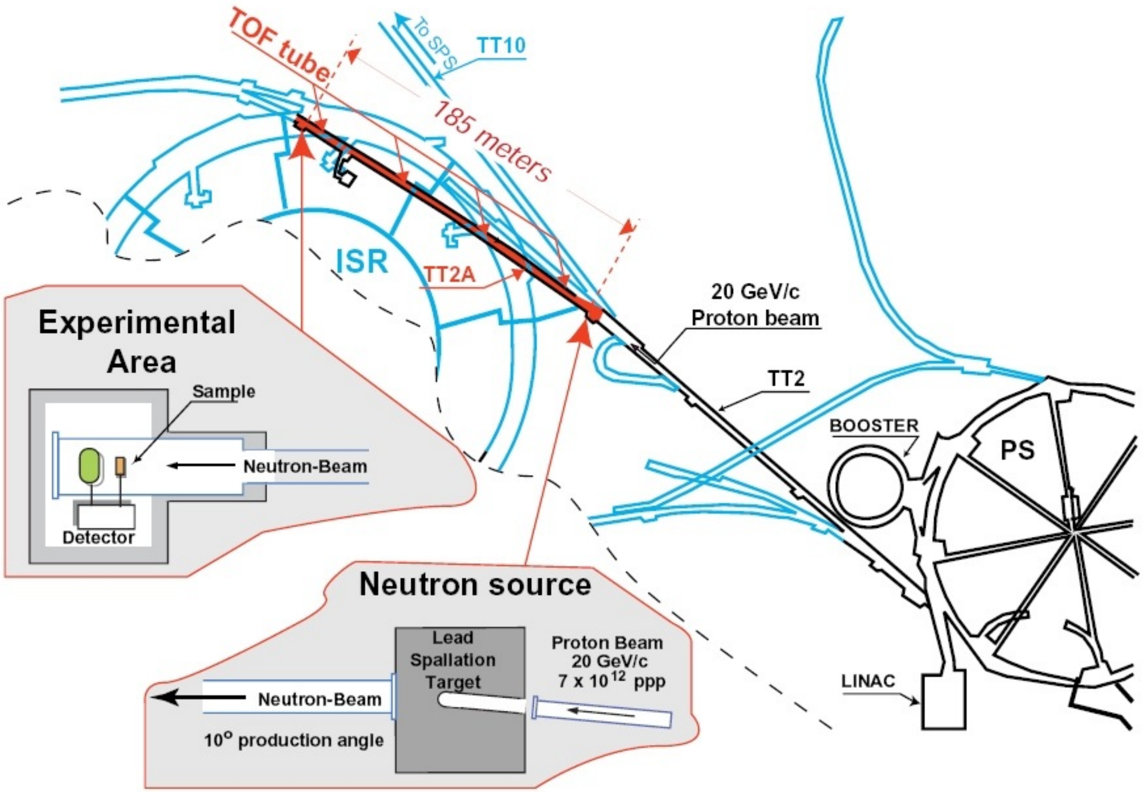

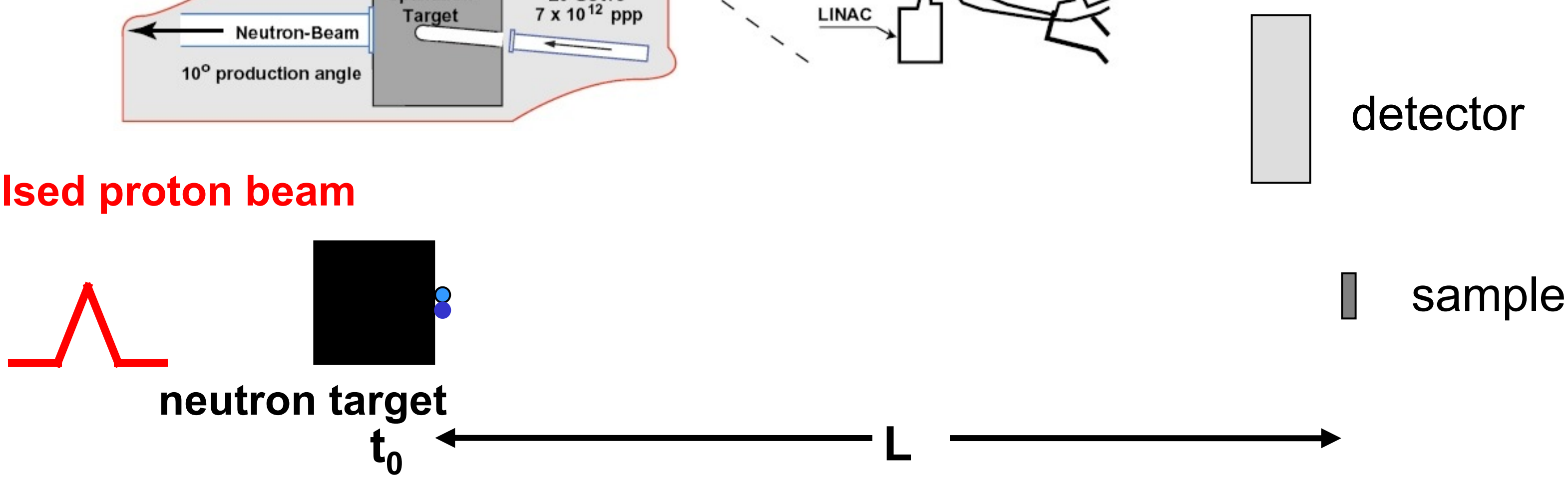

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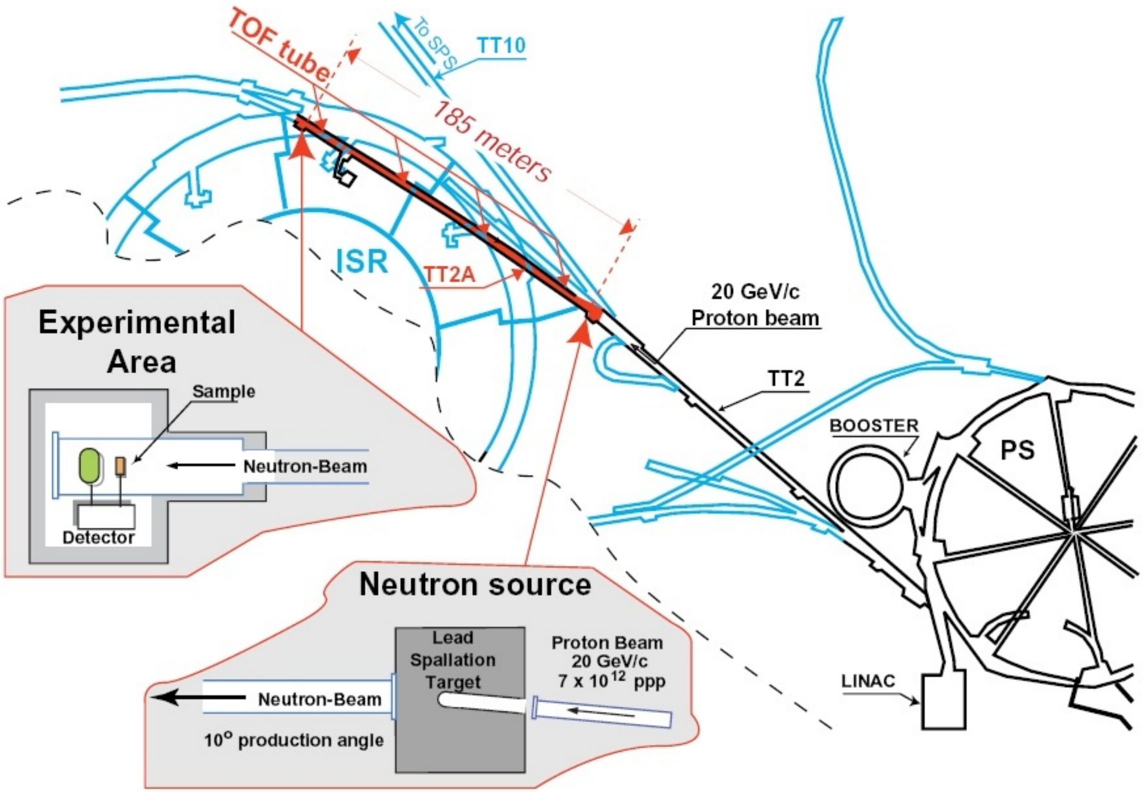

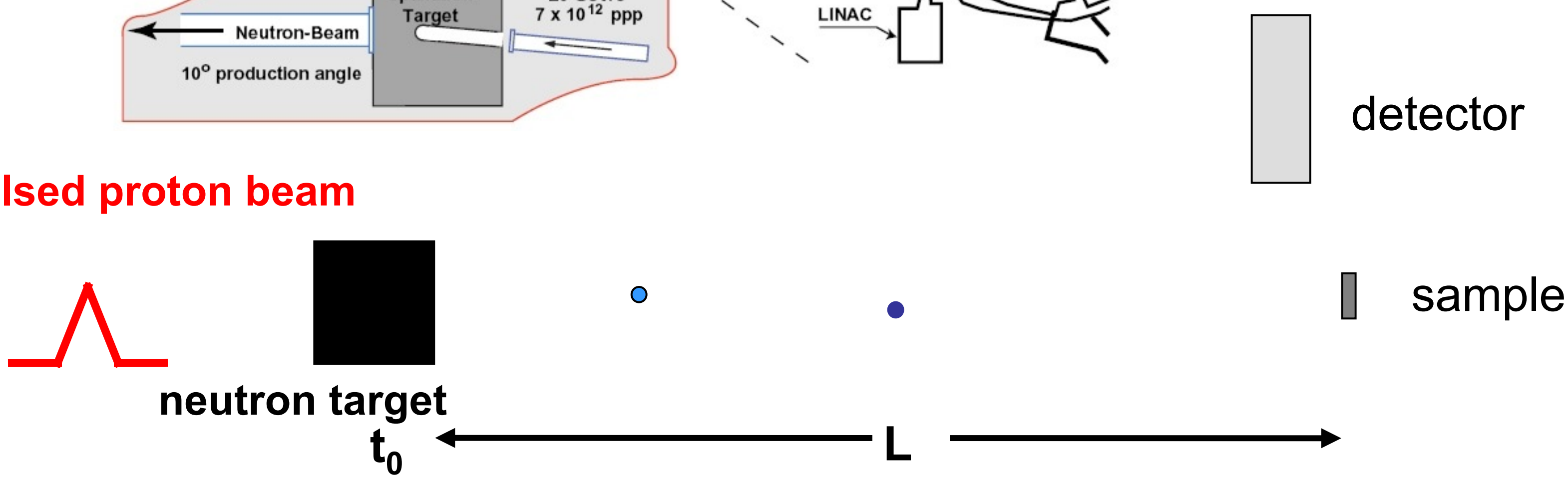

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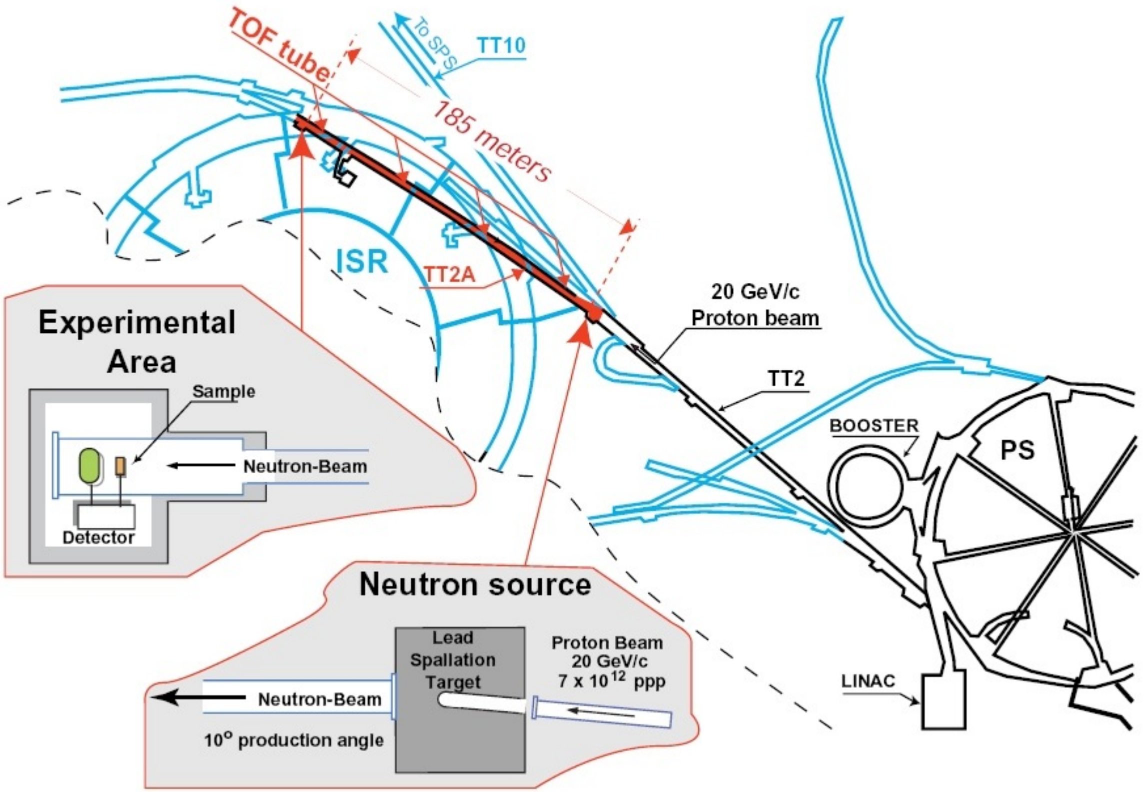
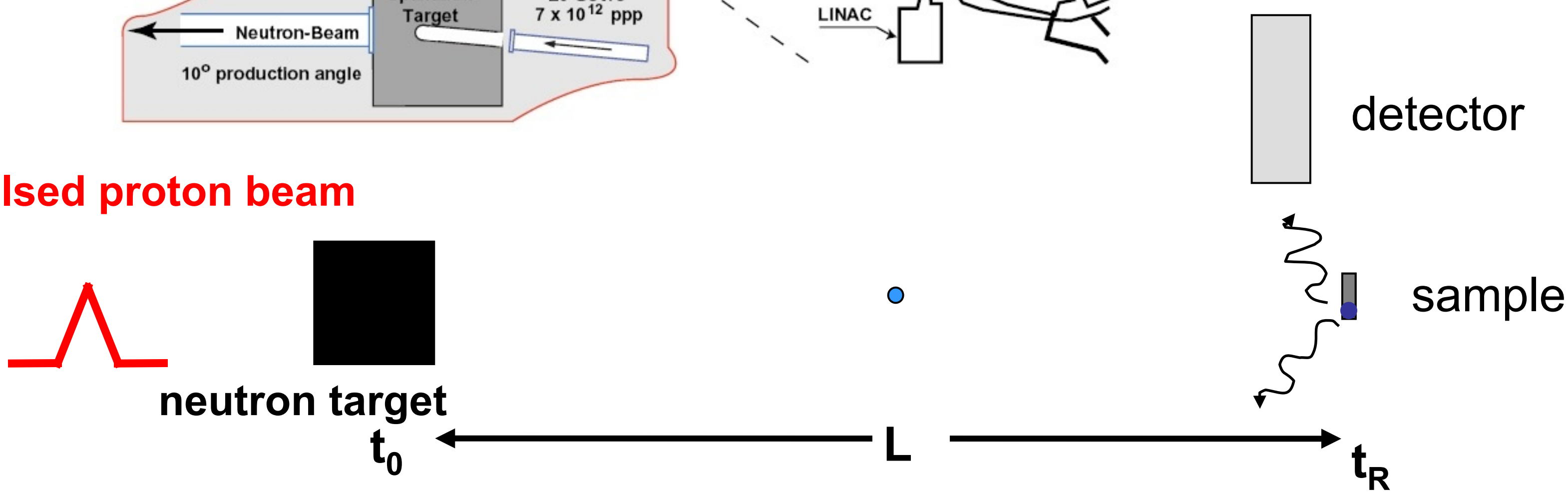
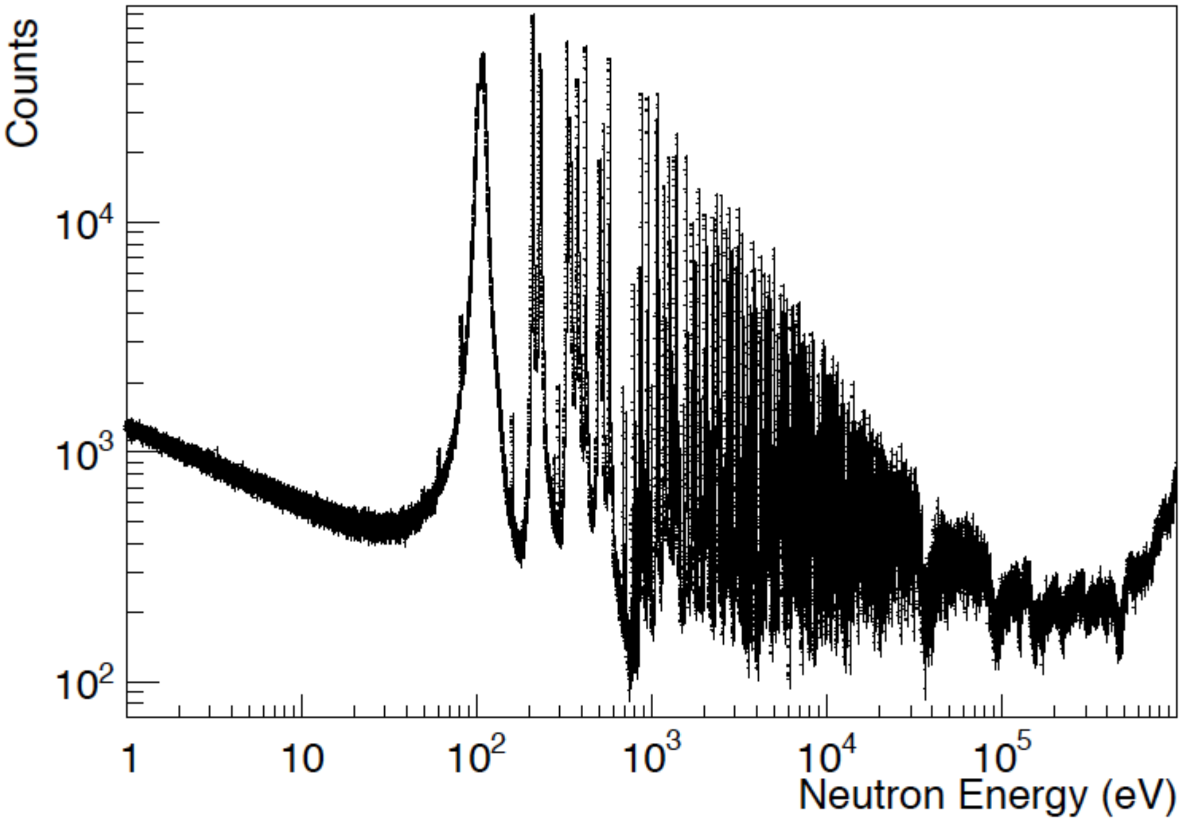


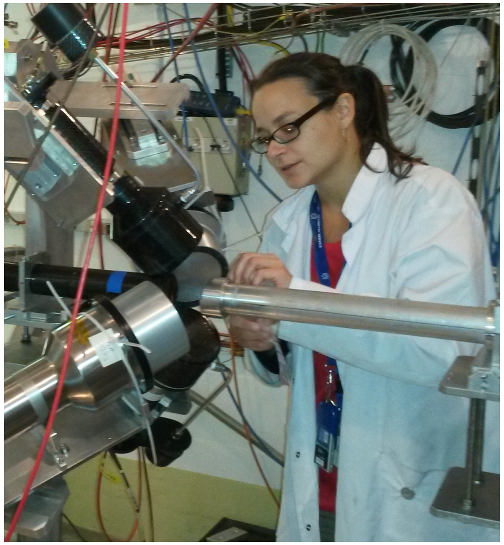
Pulsed proton beam



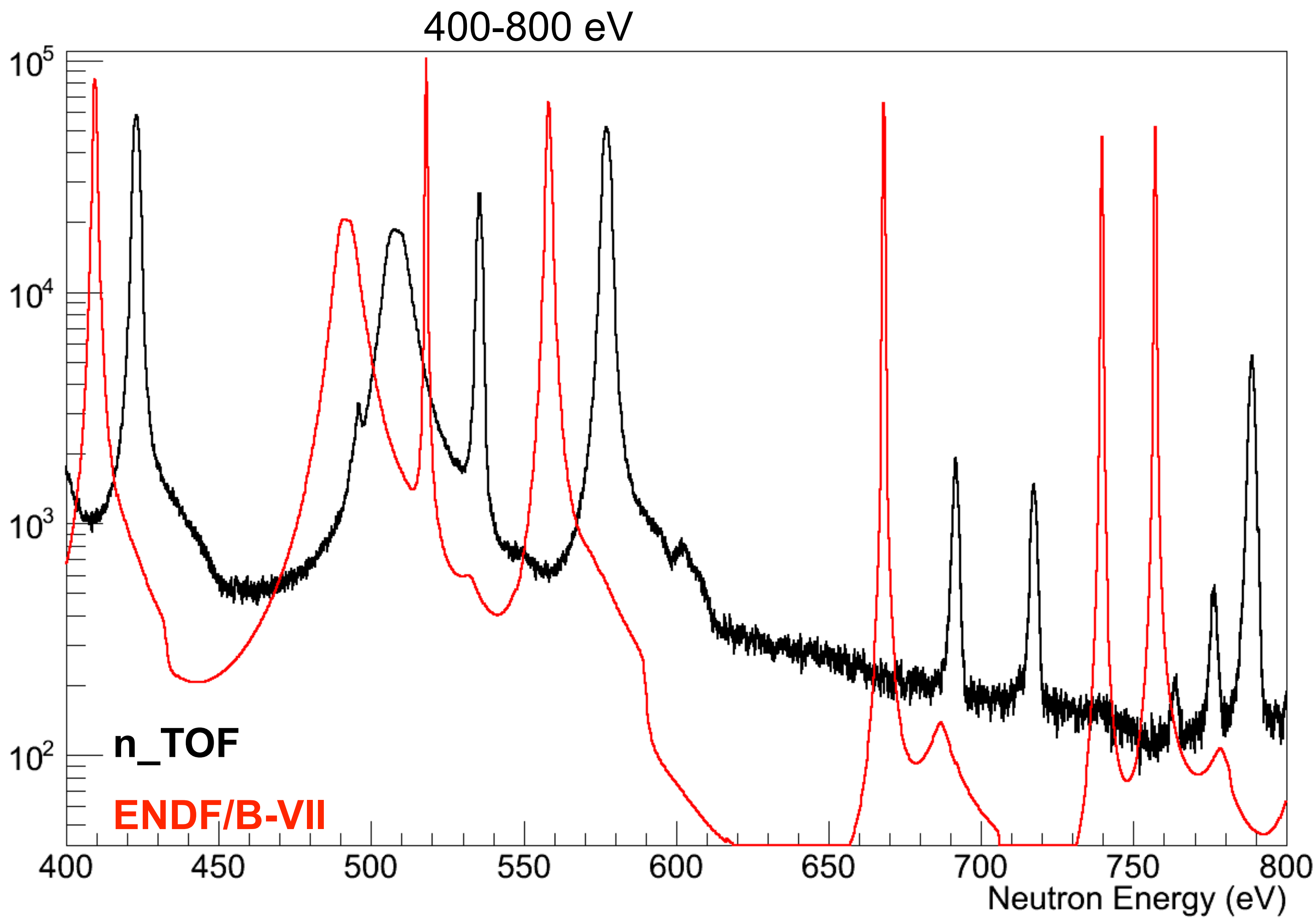
First n_TOF data $^{73}Ge(n,\gamma)$ - 2014

Measurement of all stable germanium isotopes



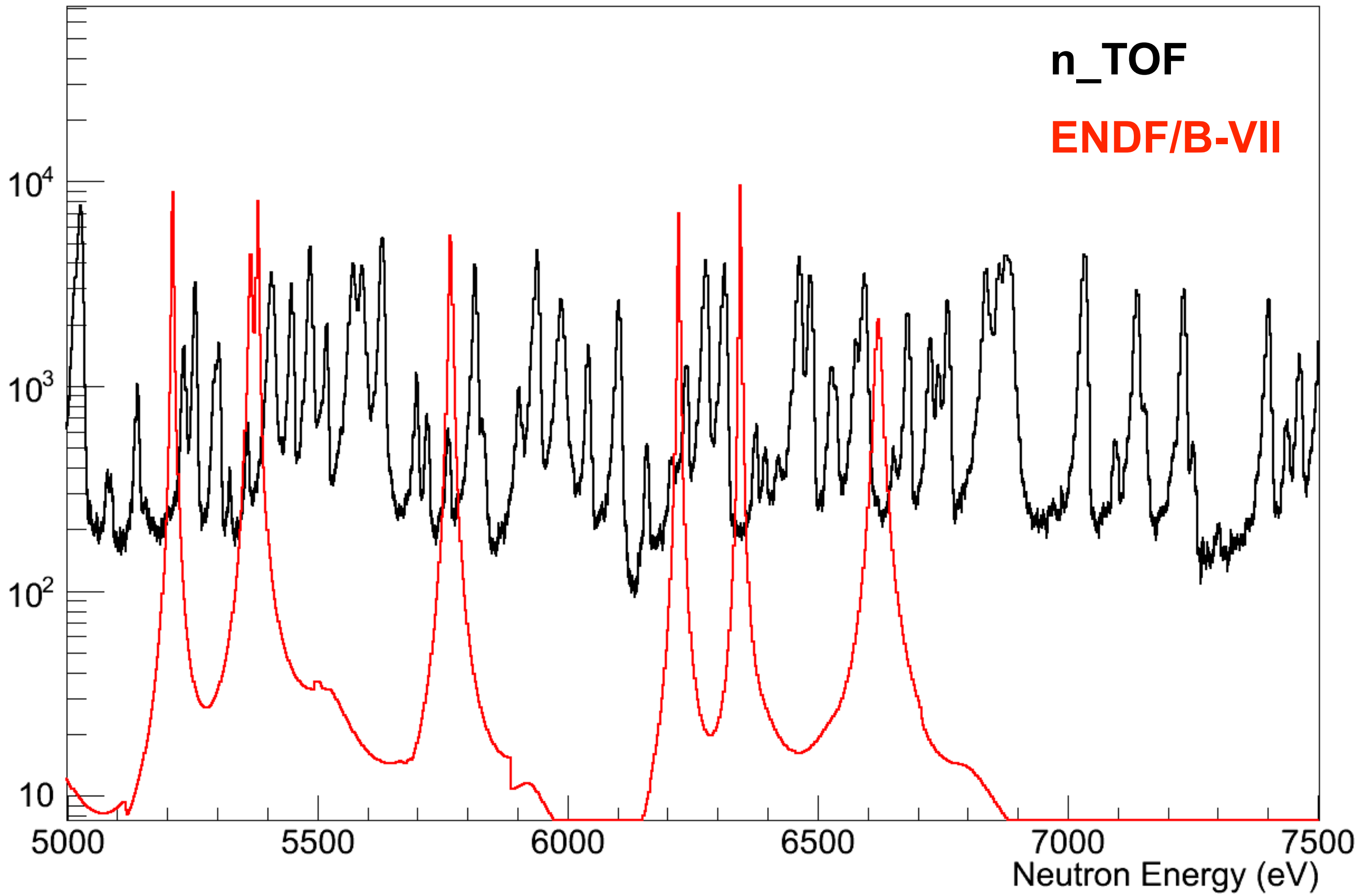


First n_TOF data $^{73}Ge(n,\gamma)$ - 2014



First n_TOF data $^{73}Ge(n,\gamma)$ - 2014

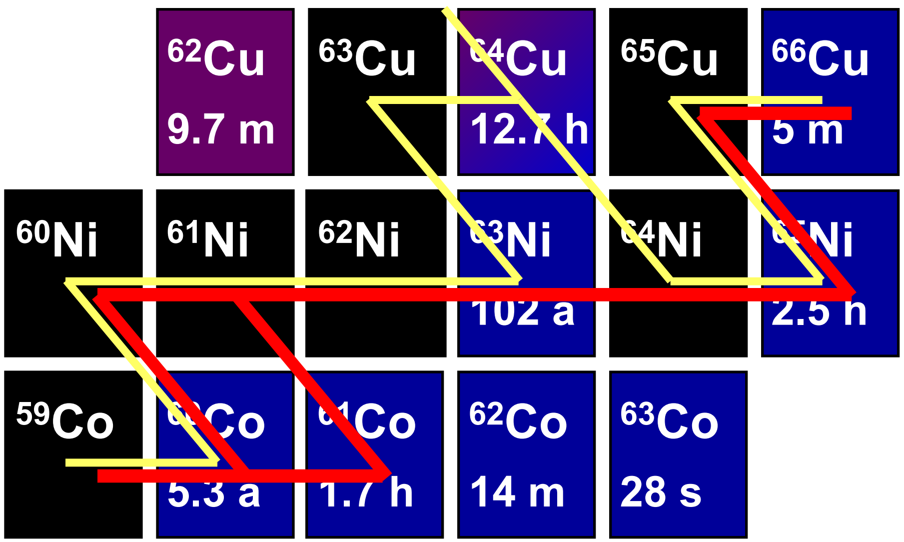
5-7 keV neutron energy

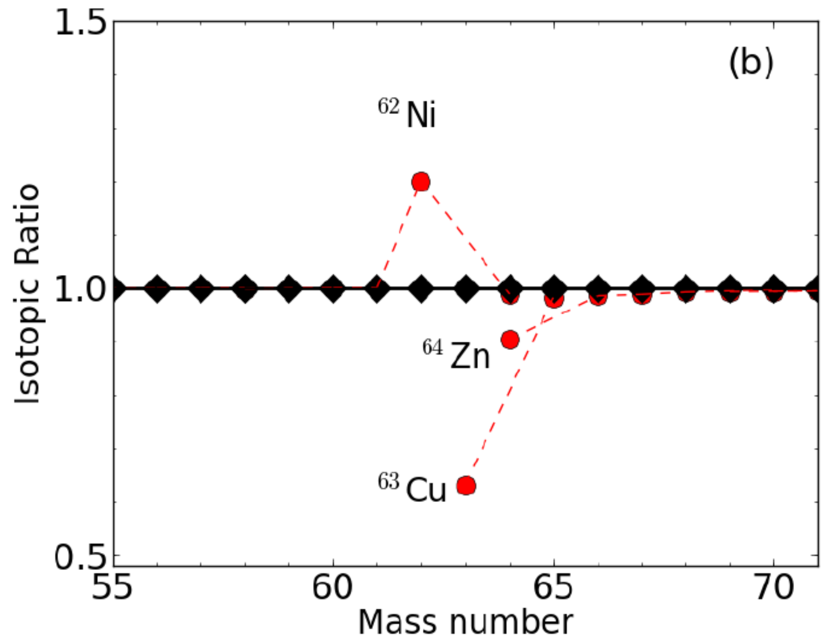


New ^{62}Ni and ^{63}Ni data: Implications for the s process

Two burning stages in massive stars:

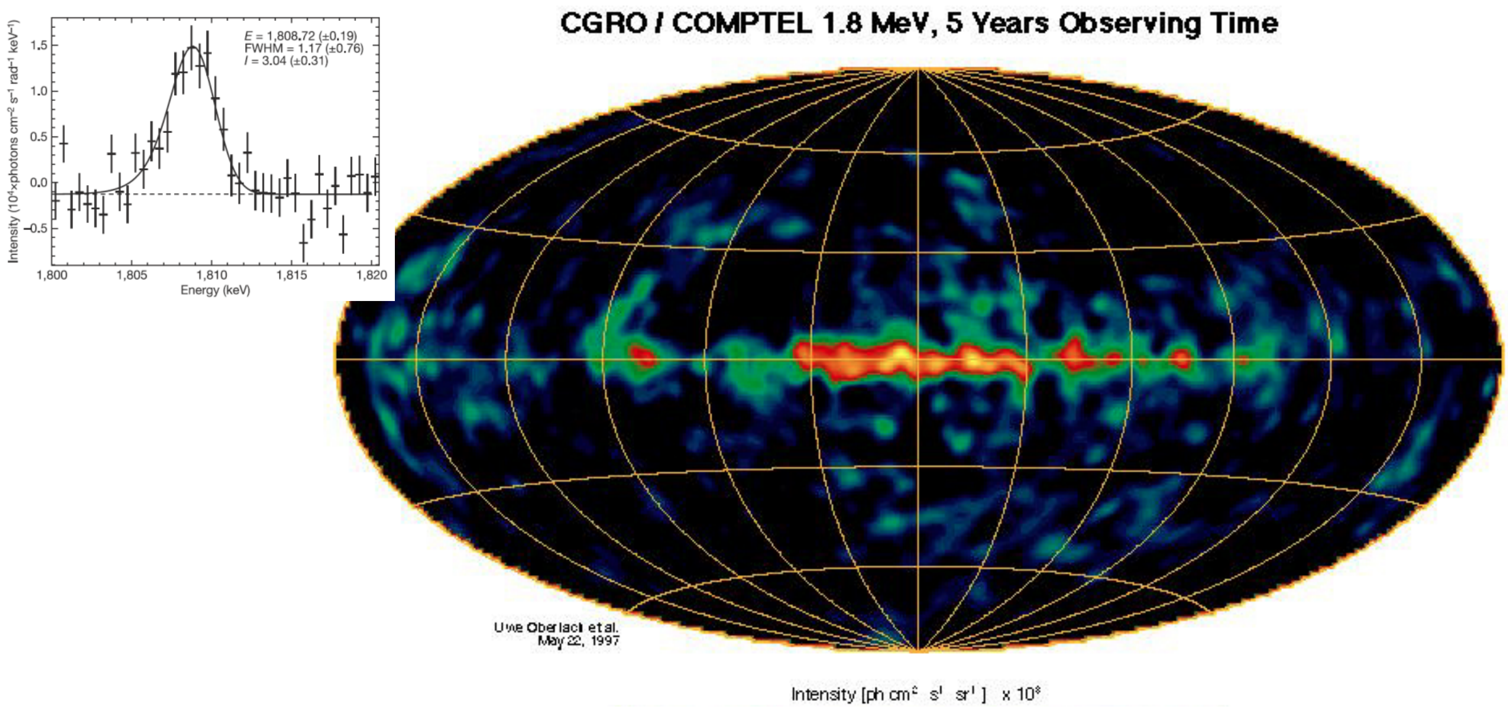
- **He Core burning: kT~26 keV, N_n~10^6 cm^{-3}**
- **Carbon shell burning: kT~90 keV, N_n~10^{11} cm^{-3}**





C. Lederer et al., PRL 110, 022501 (2013)
C. Lederer et al., PRC 89, 025810 (2014)

Cosmic γ ray emitter ^{26}Al



Main Origin of ^{26}Al in massive stars (Diehl et al, Nature 439 (2006))

- convective hydrogen burning in Wolf-Rayet stars followed by ejection by stellar wind
- convective Carbon shell burning followed by ejection from core collapse supernova
- explosive Ne/C burning in core collapse phase of supernova

Sensitivity study of ^{26}Al abundance in Massive stars

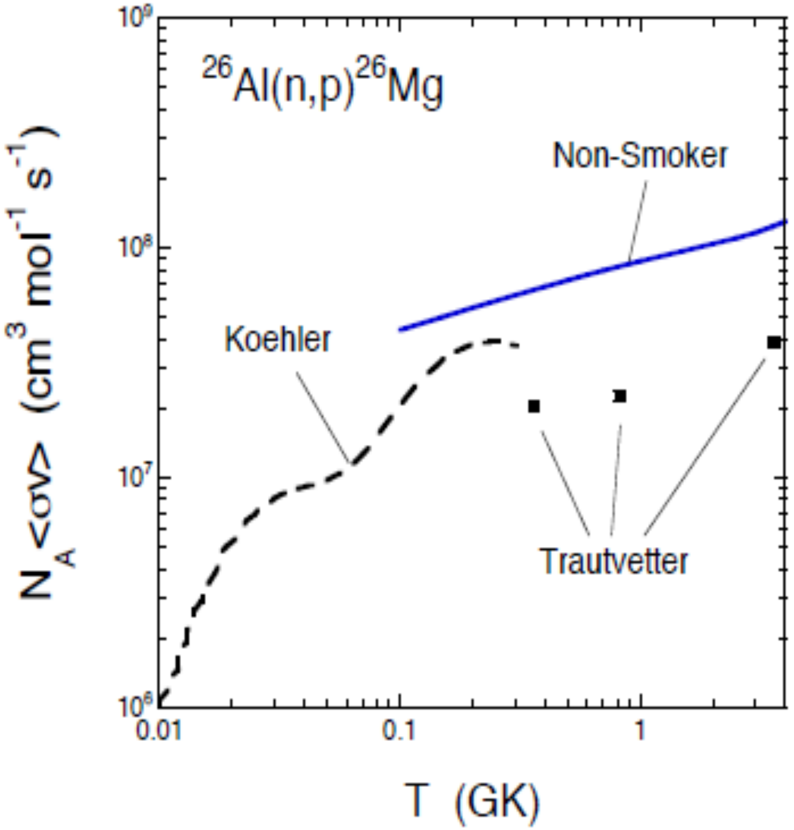
FACTOR CHANGES OF FINAL $^{26}Al^{g}$ ABUNDANCE RESULTING FROM REACTION RATE VARIATIONS FOR CONVECTIVE SHELL C/NE BURNING[a], ASSUMING FIVE SPECIES OF ^{26}AL

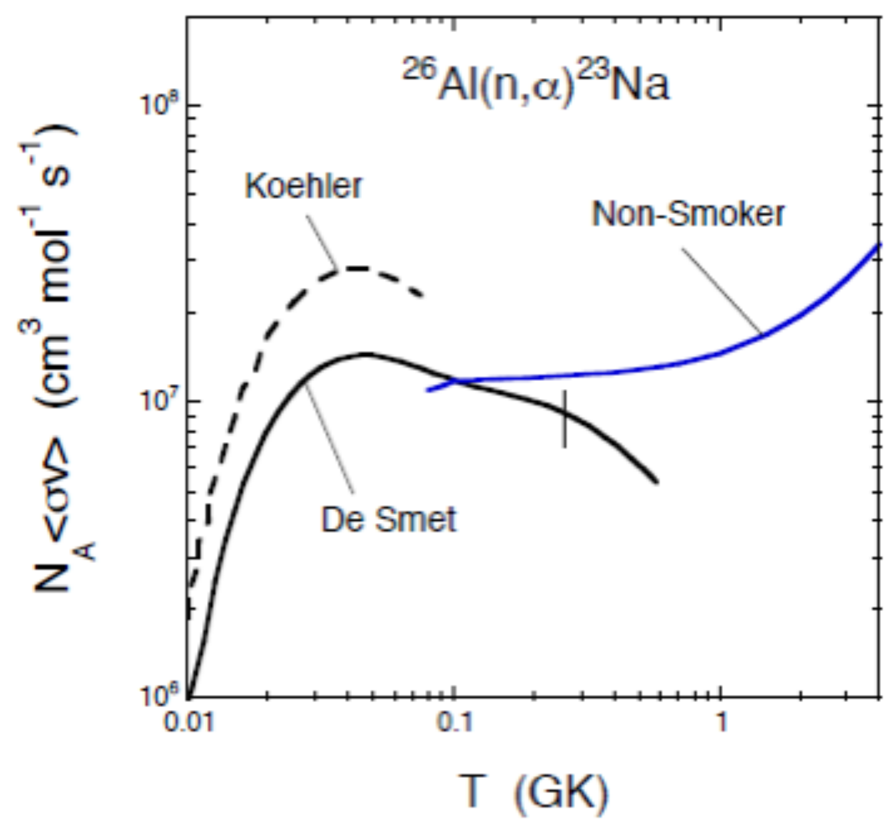
Reaction[b]	Rate multiplied by 100	10	2	0.5	0.1	0.01	Source[c]	Uncertainty[d]
$^{26}Al^{g}(n,p)^{26}Mg$	0.017	0.16	0.63	1.3	1.9	2.0	present	
$^{25}Mg(p,\gamma)^{26}Al^{g}$	2.9	5.4	1.5	0.63	0.35	0.29	il10	5%
$^{25}Mg(p,\gamma)^{26}Al^{m}$	6.7	3.0	···	···	0.75	0.71	il10	6%
$^{26}Al^{g}(n,\alpha)^{23}Na$	0.12	0.54	···	···	···	···	present	
$^{26}Al^{m}(n,p)^{26}Mg$	0.58	···	···	···	···	···	present	

→ ^{26}Al(n,p) and ^{26}Al(n,α) reaction rates represent critical uncertainties for ^{26}Al material processed by explosive and convective burning in massive stars and ejected into the ISM by core collapse supernovae

C Iliadis et al., Ast. J. Supp. 193, 16 (2011)

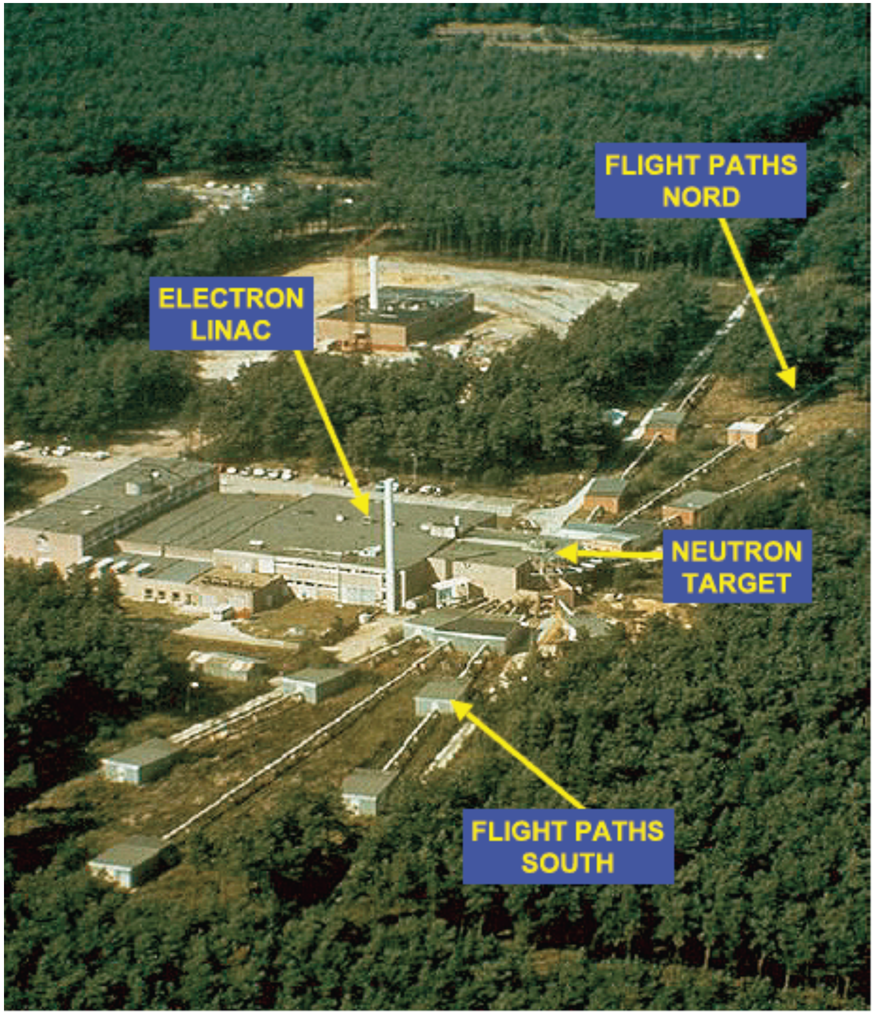
^{26}Al +n reaction rates from previous measurements





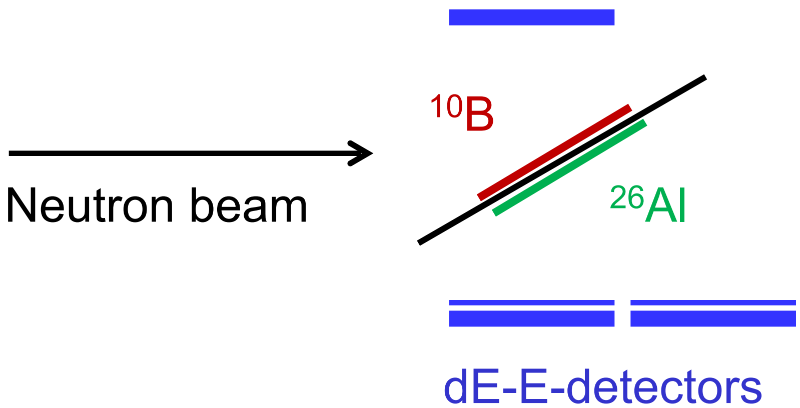
C Iliadis et al., Ast. J. Supp. 193, 16 (2011)

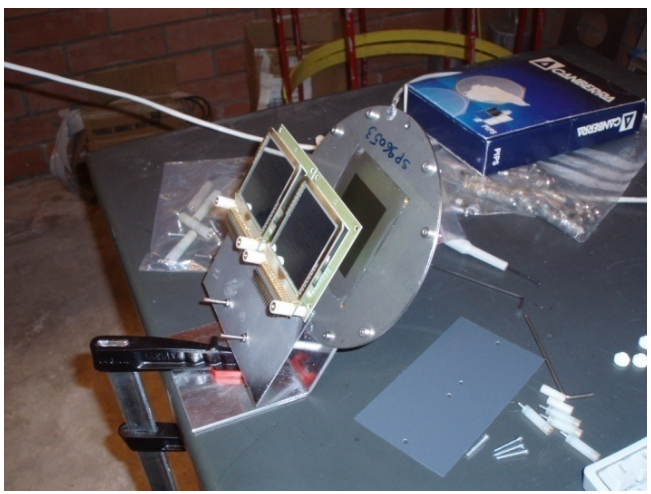
^{26}Al +n measurement at GELINA



Edinburgh DSSD setup at GELINA (IRMM)

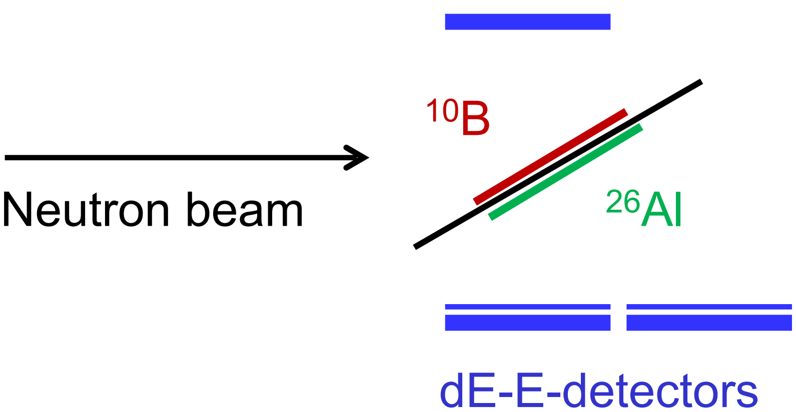
Institute for Reference Materials and Measurements

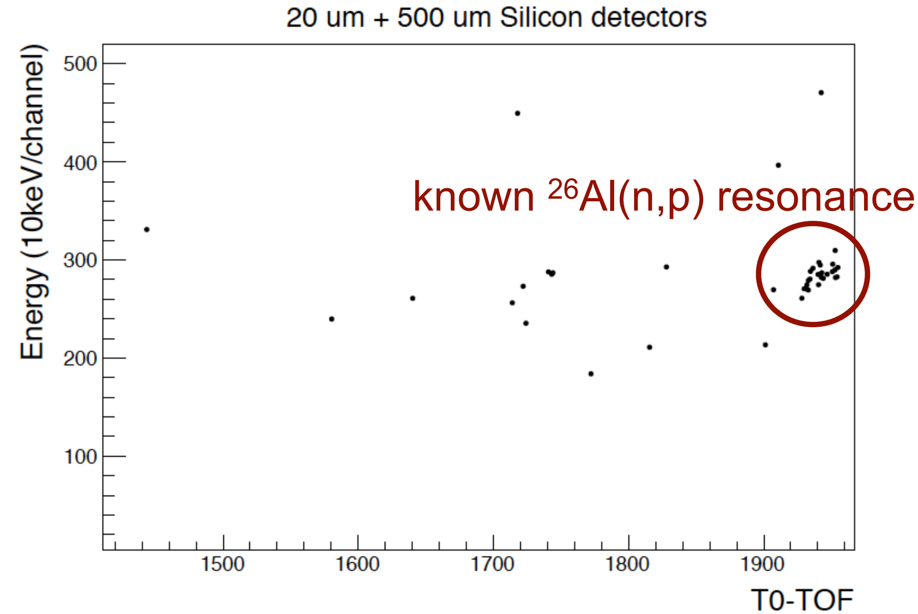


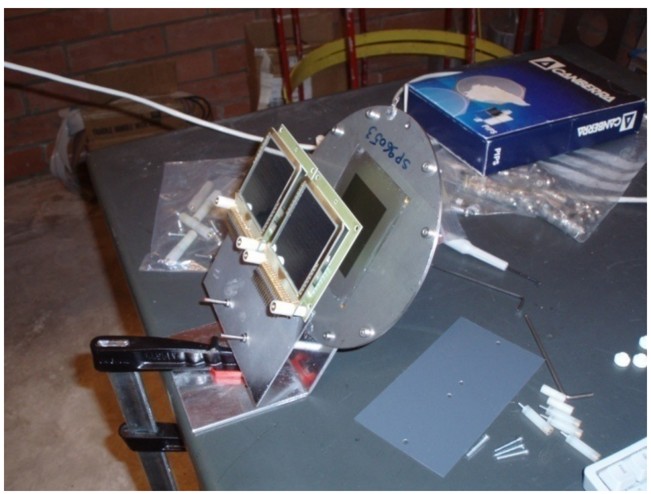


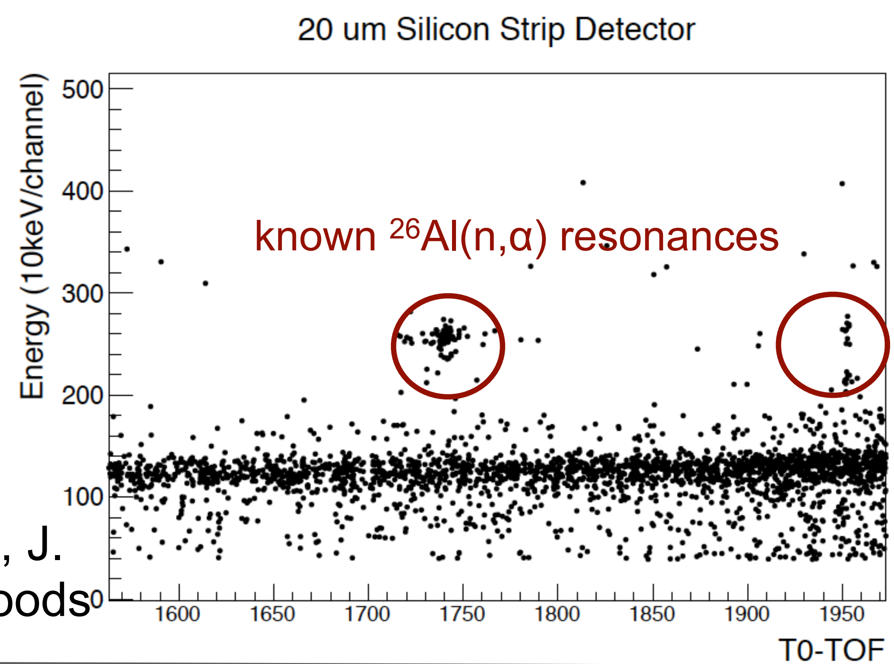
In collaboration with: T. Davinson, A. Estrade, J. Heyse, C. Paradela, P. Schillebeeckxs, P. Woods

^{26}Al(n,p)/(n,α) spectra









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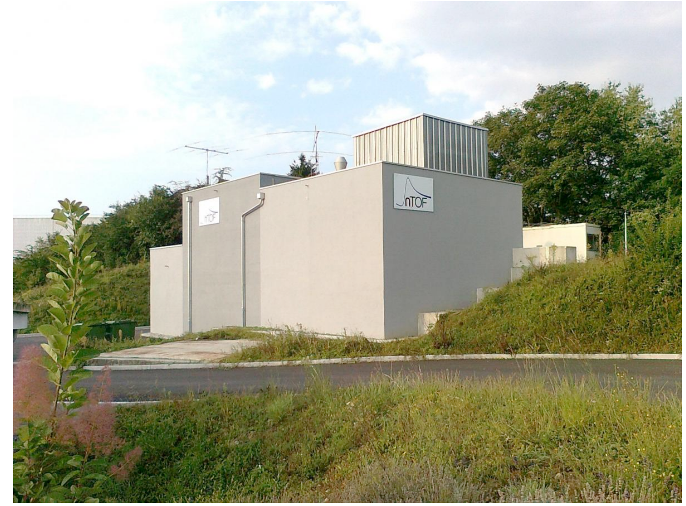
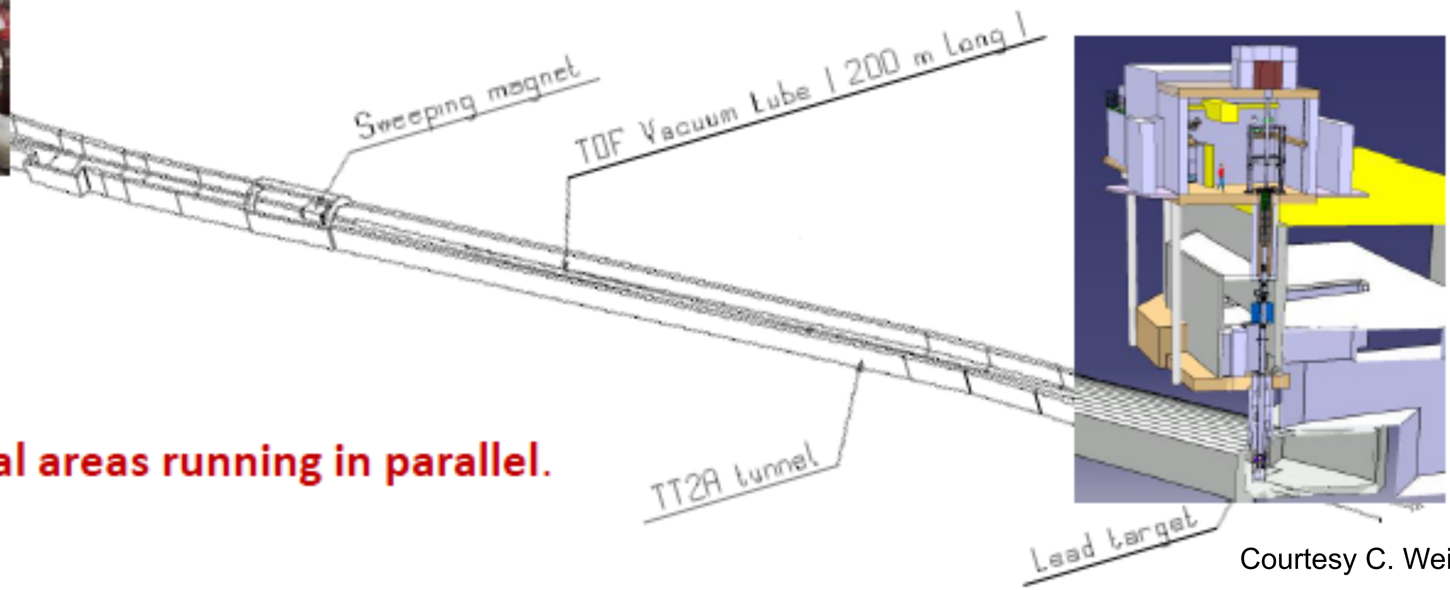
n_TOF EAR-2

New beam line at CERN **n_TOF EAR-2** (first measurement autumn 2014) provides ~30 times higher neutron flux than at present



EAR1

EAR2



Courtesy C. Weiß

Two experimental areas running in parallel.