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Measurement of the neutron capture cross-sections of ^{53}Mn at EAR2

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Outline

- Introduction
- STIP-samples
- Simulations $^{53}Mn(n, \gamma)$ at EAR-2
- Mass separation at CERN ISOLDE
- Beam time requirements

Cosmogenic Radio-Nuclides (CoRN)

- Produced
  - *via neutron capture reaction*
  - *during explosive phases of star evolution*
  - *in spallation reactions with high energetic particles*
- Present in the Universe
  - *as constitute of molecular cloud formed our Sun e.g. found in meteorites*
  - *injected from nearby super novae to our Solar System e.g.* ^{26}Al, ^{44}Ti, ^{60}Fe
  - *continuously produced at Earth from cosmic rays e.g.* ^{7}Be, ^{14}C, ^{53}Mn

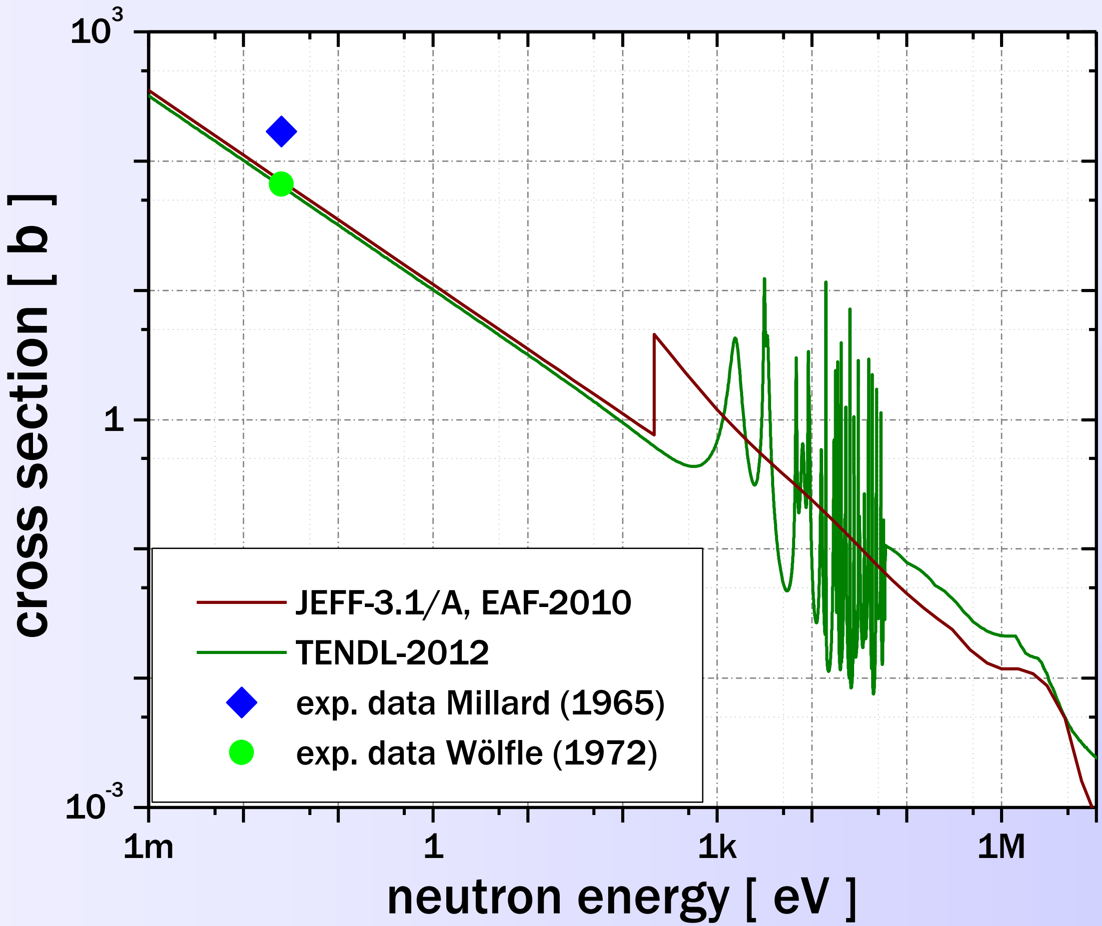
Short Lived Cosmogenic Radio-Nuclides

$t_{1/2}$ < 100 Ma

parent nuclide	half-life (Ma)	daughter nuclide	estim. init. abundance	Reference	at PSI
^{53}Mn	3.74	^{53}Cr	^{53}Mn / ^{55}Mn = $6.28 \cdot 10^{-6}$	Birck & Allègre 1985, Shukolyukov & Lugmair 2006, Trinquier et al. 2008	☑
^{10}Be	1.387	^{10}B	^{10}Be / ^{9}Be = $7.5 \cdot 10^{-4}$	McKeegan et al. 2000, Chaussidon & Gounelle 2006, 2007	☑
^{26}Al	0.717	^{26}Mg	^{26}Al / ^{27}Al = $5.23 \cdot 10^{-5}$	Jacobsen et al. 2008, Lee et al. 1976	☑
^{60}Fe	2.62	^{60}Ni	^{60}Fe / ^{56}Fe = $5.8 \cdot 10^{-9}$	Quitt´e et al. 2010, Shukolyukov & Lugmair 1993, Tang & Dauphas 2011	☑
^{36}Cl	0.301	^{36}S (~2%) ^{36}Ar (~98%)	^{36}Cl / ^{35}Cl > $17.2 \cdot 10^{-6}$	Jacobsen et al. 2009, Lin et al. 2005	☑
^{41}Ca	0.102	^{41}K	^{41}Ca / ^{40}Ca = $1.41 \cdot 10^{-8}$	Srinivasan et al. 1994, 1996	☑
^{7}Be	$1.46 \cdot 10^{-7}$	^{7}Li	^{7}Be / ^{9}Be = $6.1 \cdot 10^{-3}$	Chaussidon et al. 2006	☑

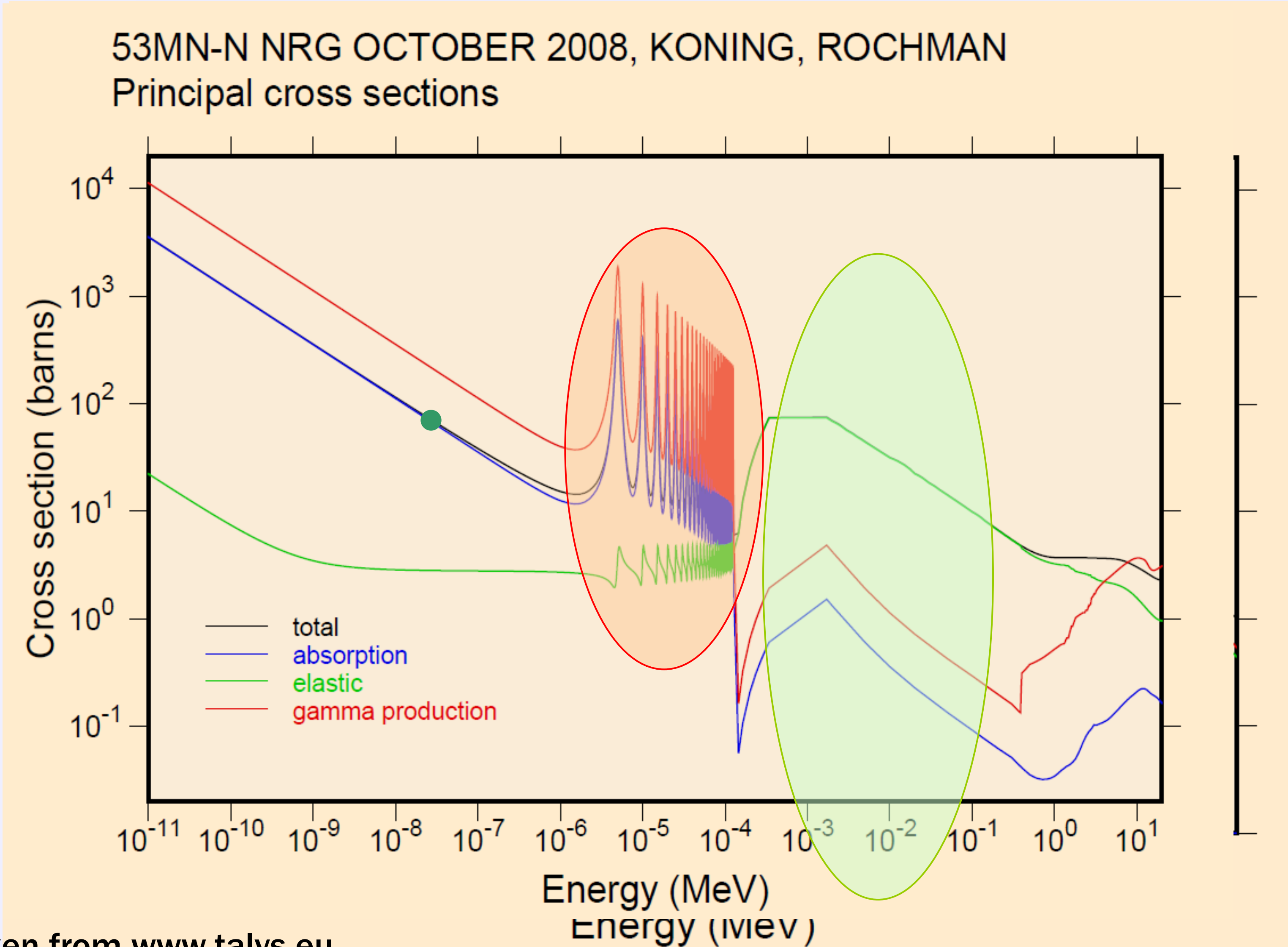
adapted from N. Dauphas, M.Chaussidon: Annu. Rev. Earth Planet. Sci. **39** (2011) 351

Neutron capture cross-section ^{53}Mn



JEFF-3.1/A = R. A. Forrest, J. Kopecky, J.-Ch. Sublet (2003) UKAEA FUS 486
EAF-2010 = J.-Ch. Sublet, et al. (2010) CCFE-R (10) 05
TENDL-2012 = A.J. Koning, D. Rochman (2012) Nucl. Data Sheets 113, 2841

Changes in TALYS predictions



taken from www.talys.eu

SINQ Target-Irradiation Program

STIP sample

- diff. structure materials investigated
- placed at diff. positions in SINQ targets
- irradiated with up to 570 MeV protons
- average current 1.5 mA for up to 2 years
- mechanically tested after cool down period
- radioactive waste afterwards

STIP analytics

- total available material ~ 60 g bulk material Fe, additional 9.5% Cr, 1% W, 0.5% Mn, 0.25% V
- radio nuclides available

^{26}Al 350 Bq ≈ 9.8 × 10^{15} atoms
^{44}Ti 280 MBq ≈ 1.1 × 10^{18} atoms
^{54}Mn 72 MBq
(^{53}Mn ~ 3 × 10^{19} atoms)

^{60}Co 72 MBq

R. Dressler et al.: J. Phys. G **39** (2012) 105201

Chemical separation

- content of STIP-samples $3 \cdot 10^{19}$ atoms ^{53}Mn

  $1.8 \cdot 10^{21}$ atoms V $6.8 \cdot 10^{22}$ atoms Cr
  $3.2 \cdot 10^{21}$ atoms Mn $5.7 \cdot 10^{23}$ atoms Fe

- chemical yield: 70%
  sup. of other elements 10^{-4}

- stock solution: $2 \cdot 10^{19}$ atoms ^{53}Mn

  $1.8 \cdot 10^{19}$ atoms V $6.6 \cdot 10^{18}$ atoms Cr
  $2.3 \cdot 10^{21}$ atoms Mn $5.7 \cdot 10^{19}$ atoms Fe

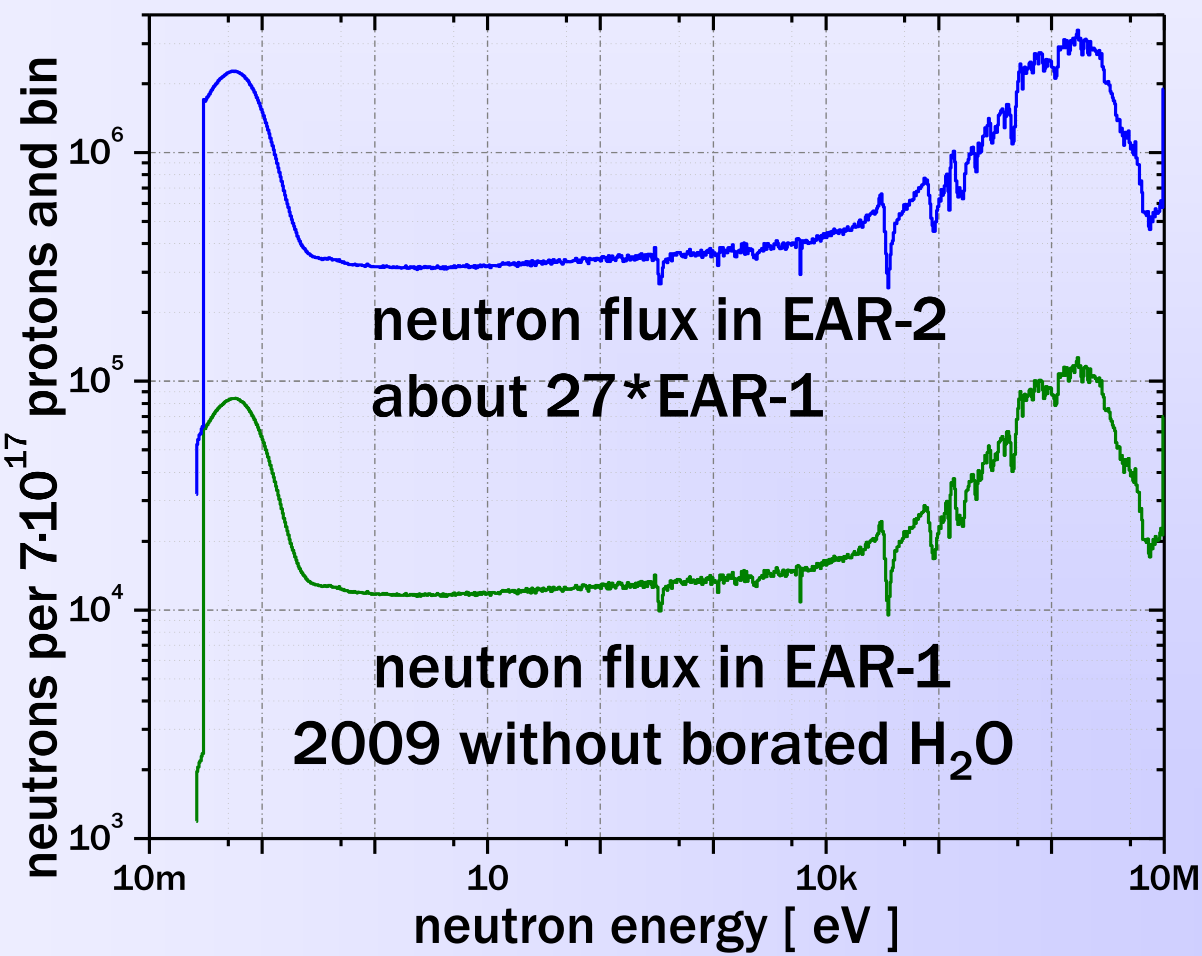
- backing material: 0.2 mm pyrolytic graphite
  2.0 µm Mylar foile

^{53}Mn(n, γ) at EAR-2

Estimation of total event numbers:

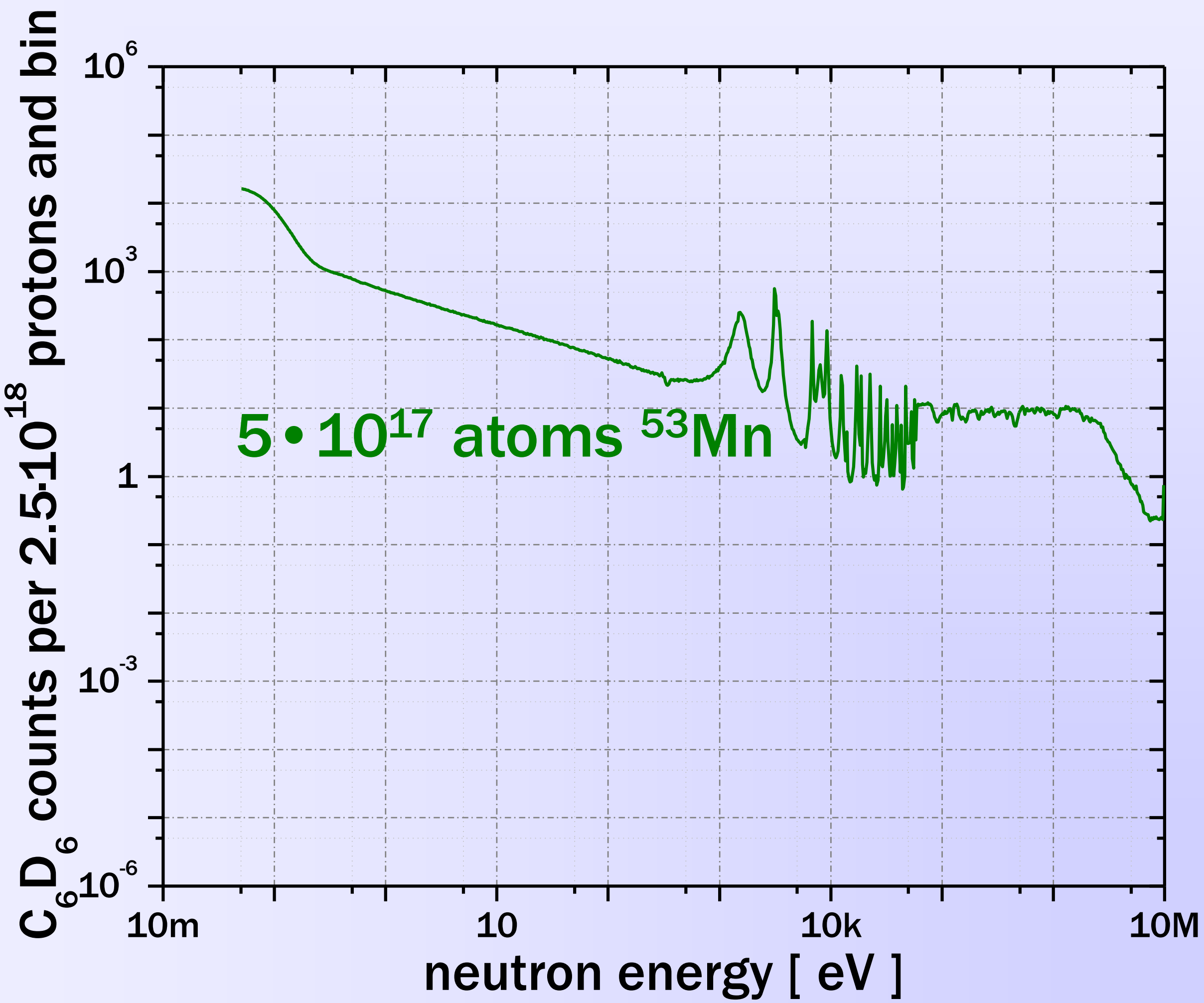
- $2.5 \cdot 10^{18}$ protons on target
- 100 bin per energy decade
- 27 × neutron flux of EAR-1 without borated H_2O
- $5 \cdot 10^{17}$ atoms = 44 µg ^{53}Mn in sample
- sample diameter 2.0 cm
- two C_6D_6 detectors total detection efficiency 14%
- capture cross section of stable elements ENDF-B/VII.1
- capture cross section of ^{53}Mn from TENDL-2012
- scatter to capture cross section ratio < 100
- no ambient background from installation considered

Expected Neutron flux in EAR-2



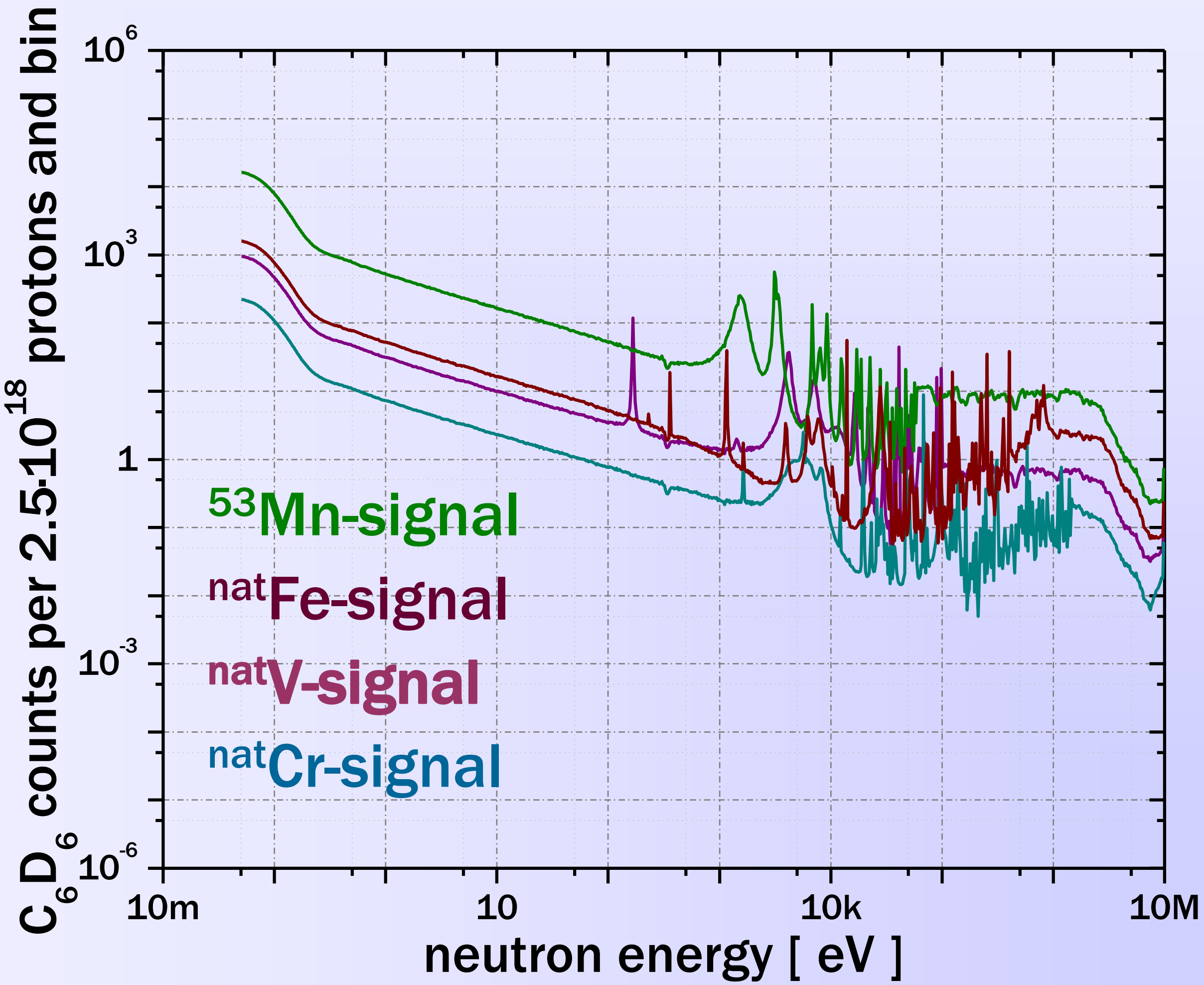
M. Barbagallo, et n_TOF: to be published

^{53}Mn signal



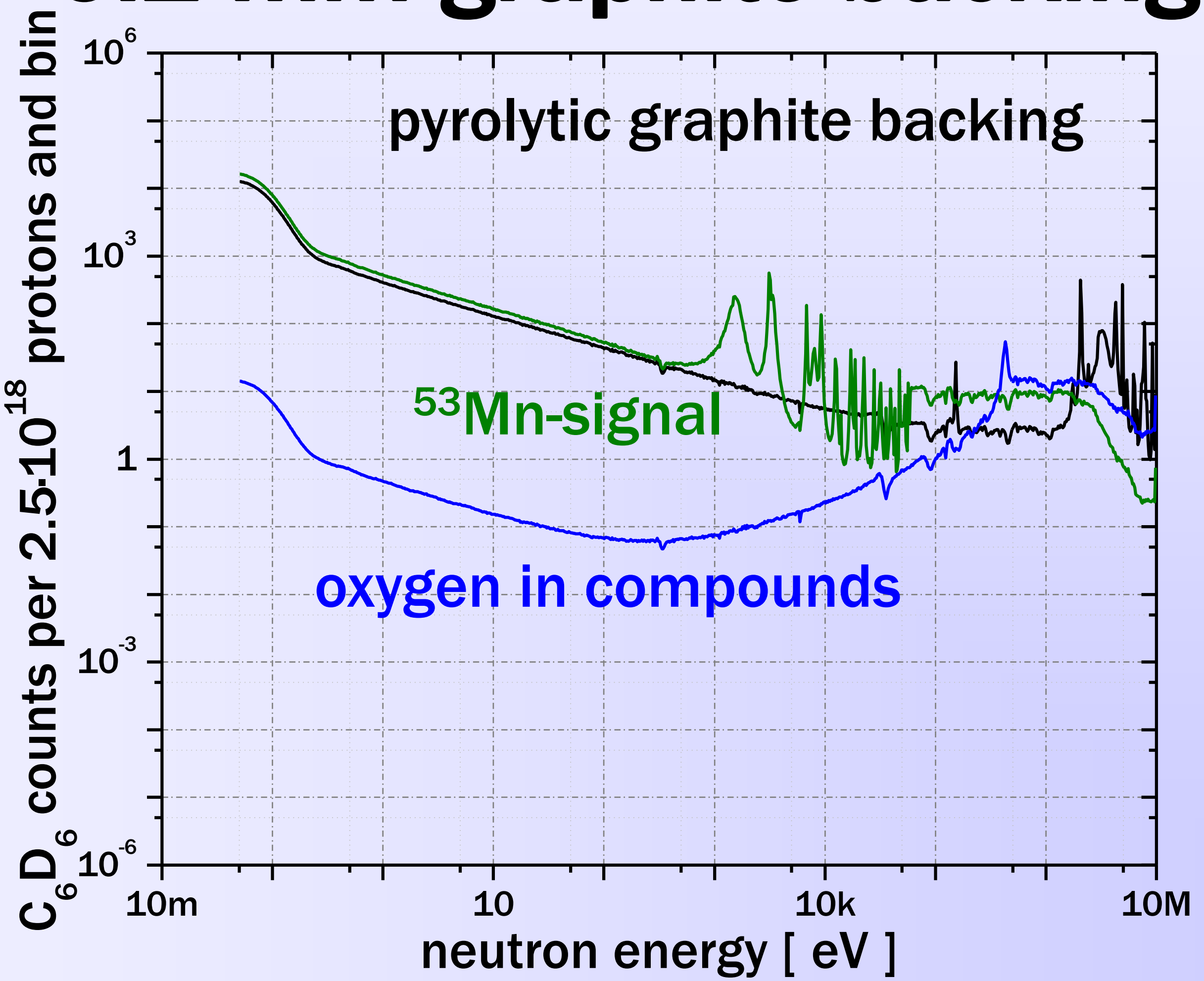
TENDL-2012 = A.J. Koning, D. Rochman (2012) Nucl. Data Sheets 113, 2841

Contribution of other elements



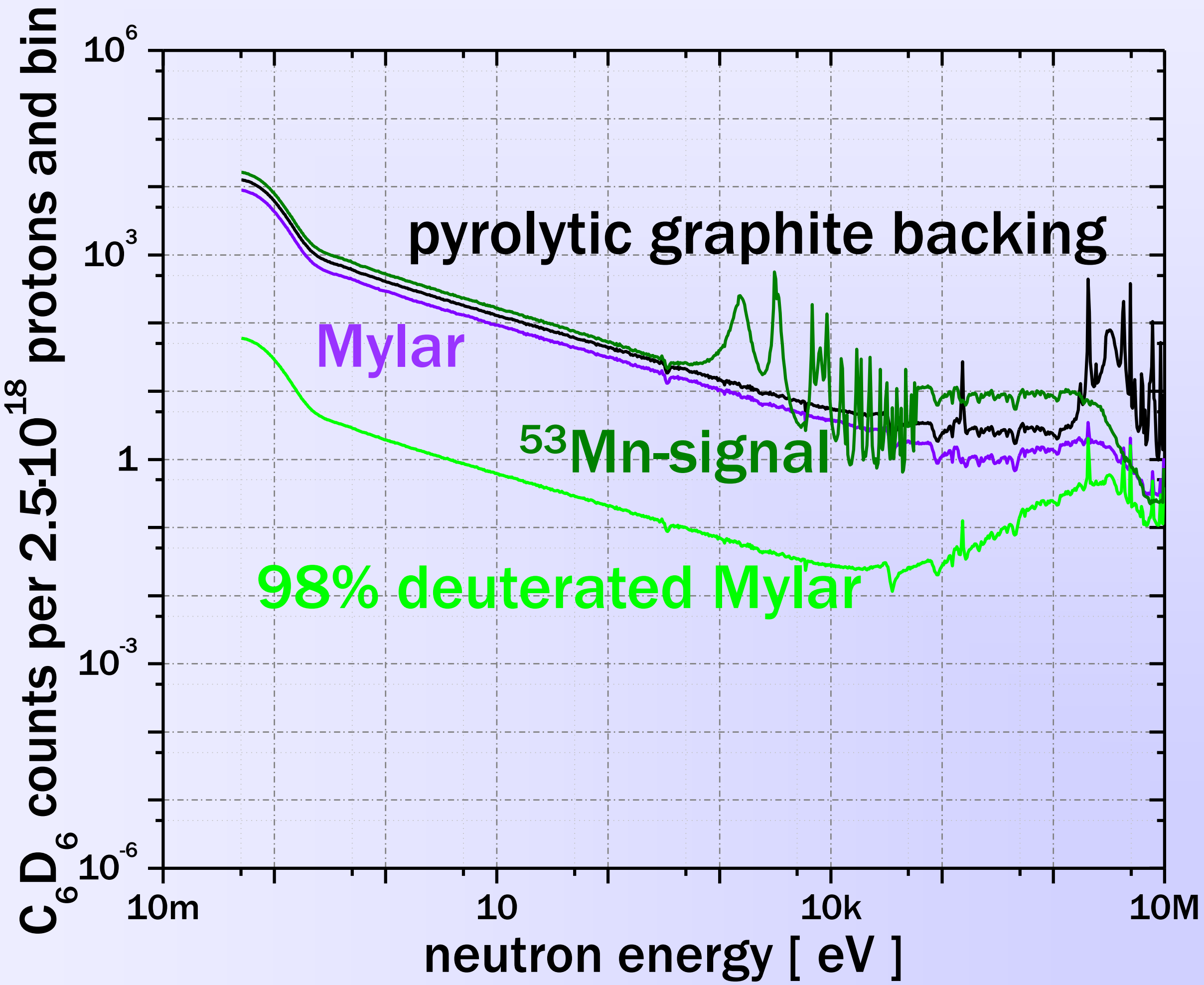
ENDF-B/VII.1 = M.B. Chadwick, et al. *Nuclear Data Sheets* **112** (2011) 2887

Contribution of oxygen and 0.2 mm graphite backing



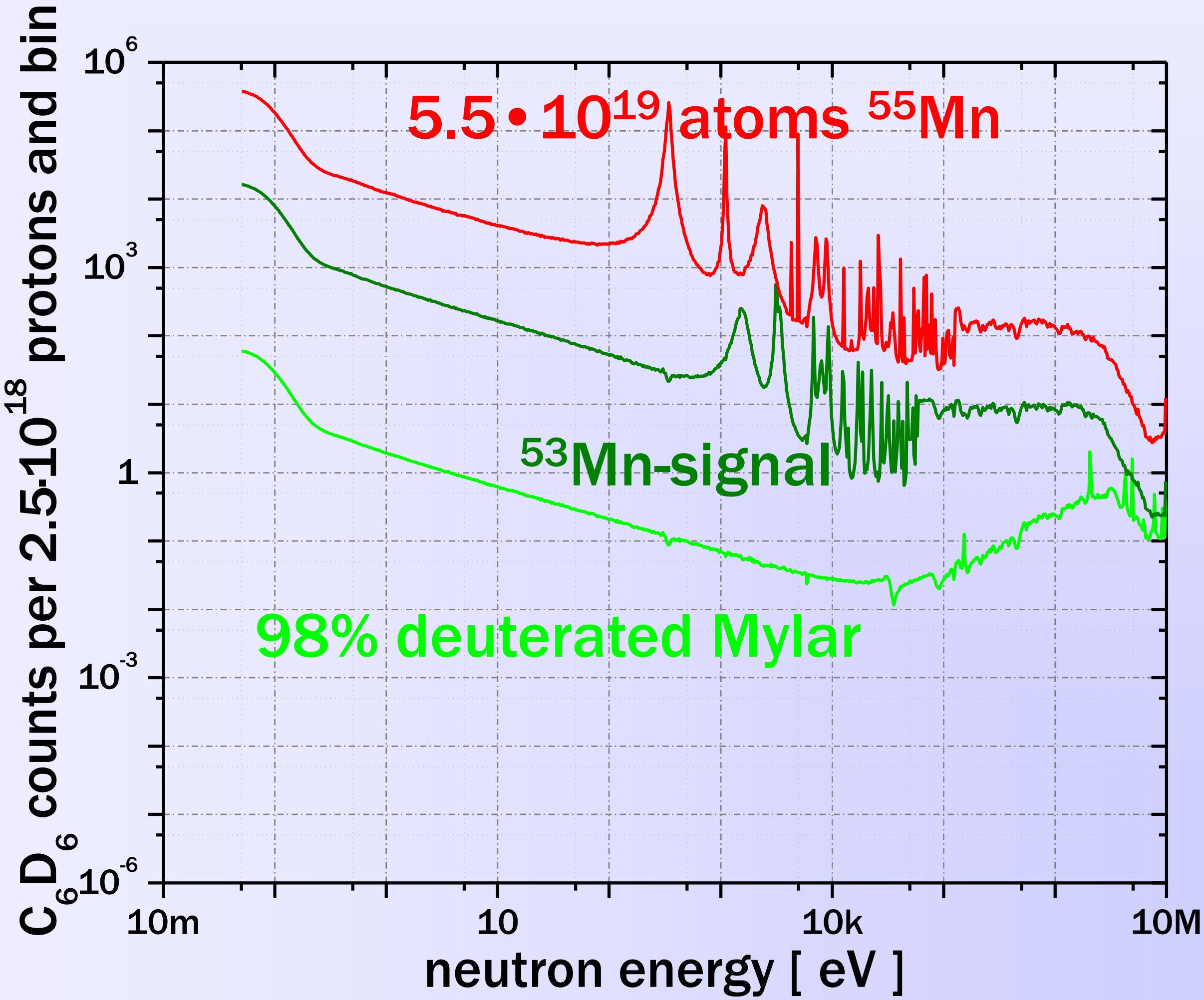
ENDF-B/VII.1 = M.B. Chadwick, et al. *Nuclear Data Sheets* **112** (2011) 2887

Contribution of 2 µm Mylar backing



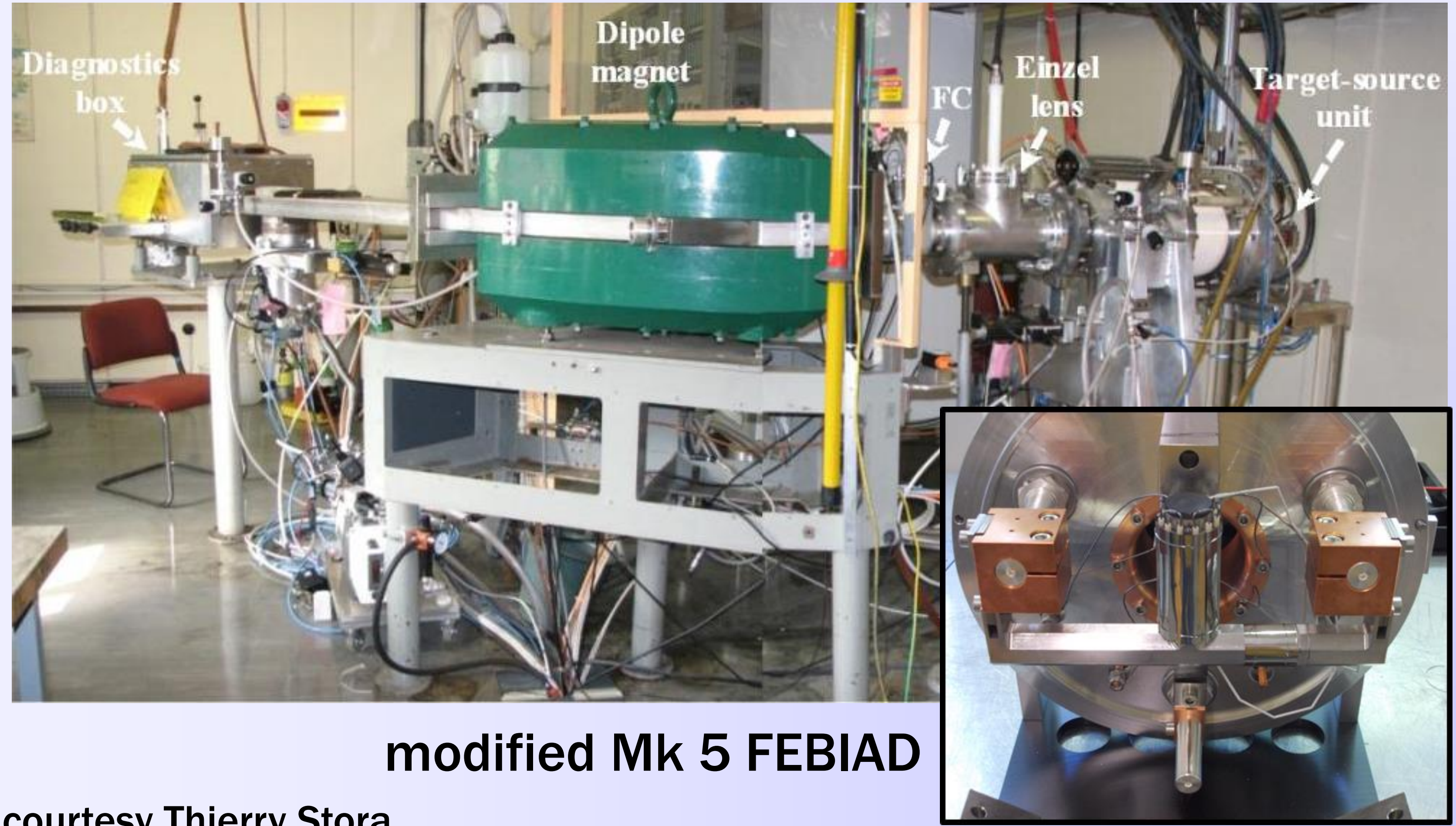
ENDF-B/VII.1 = M.B. Chadwick, et al. *Nuclear Data Sheets* **112** (2011) 2887

Contribution of ^{55}Mn



ENDF-B/VII.1 = M.B. Chadwick, et al. *Nuclear Data Sheets* **112** (2011) 2887

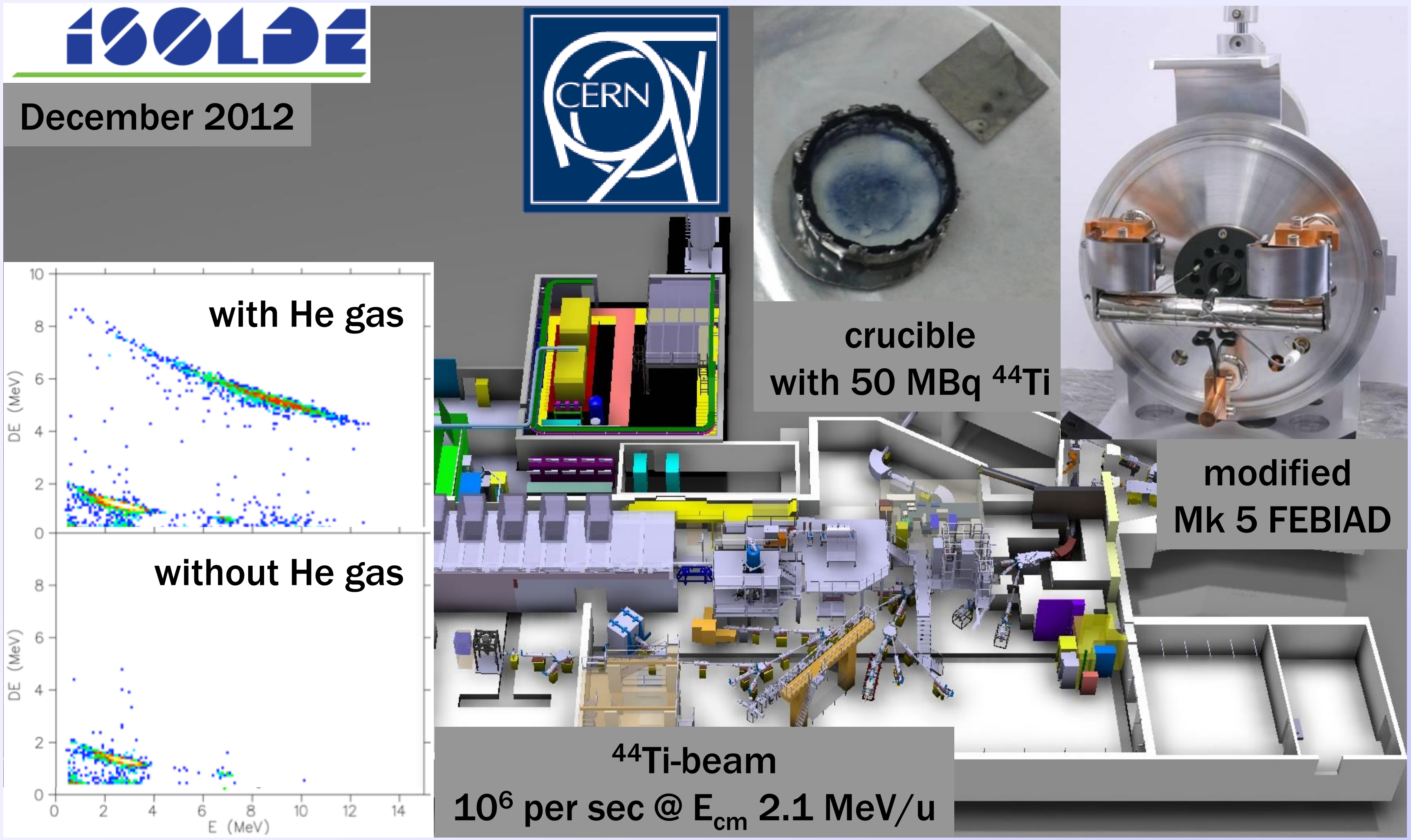
Off-line ISOLDE setup as a mass separator



modified Mk 5 FEBIAD

courtesy Thierry Stora

Inverse kinematics of $^{44}Ti(\alpha,p)^{47}V$



FEBIAD ion source parameters

operation temperature:	1000°C – 2300°C
operation pressure:	10^{-6} mbar – 10^{-2} mbar
extraction hole:	0.5 mm – 3.0 mm
ohmic cathode Heating: (e$^-$ bombardment)	100 W – 1000 W
plasma density :	10^7 cm^{-3} – 10^{10} cm^{-3}
electron energy:	10 eV – 300 eV
total beam current:	1 µA – 300 µA

G.D.Alton, NIM A382 (1996) 207

L.Penescu et al, NIM B **266**, 4415 (2008)

Mass separation

- FEBIAD output: 100 µA
  (single charged Mn) $6.2 \cdot 10^{14}$ part. per sec

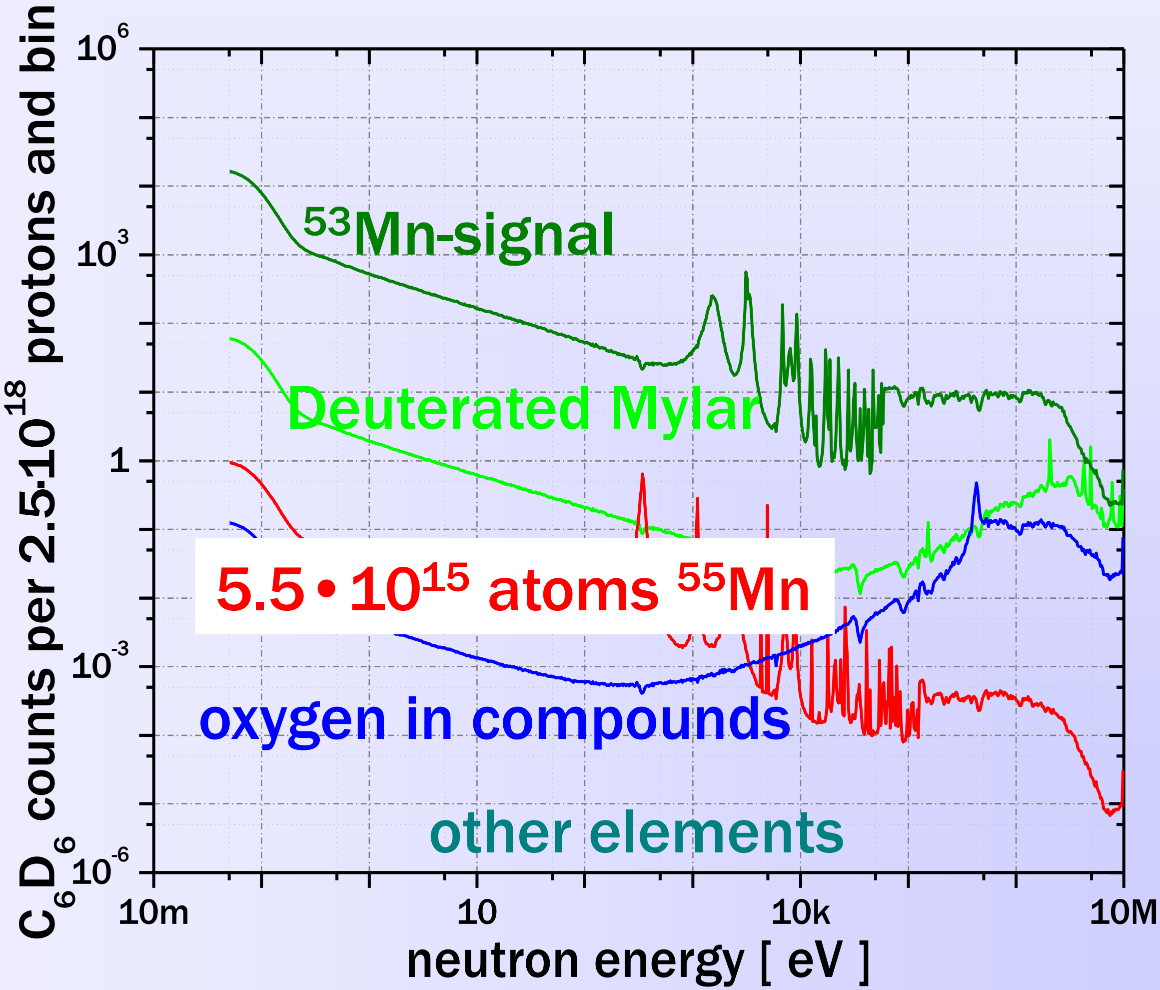
- suppression Δmass = 1: $> 10^3$
- suppression Δmass > 1 : $> 10^4$

- mass separation ISOLDE: 2.5% Mn yield
- process time: 240 h per 10^{17} atoms ^{53}Mn

- final sample: $5 \cdot 10^{17}$ atoms ^{53}Mn

  $8.7 \cdot 10^{04}$ atoms V $2.4 \cdot 10^{12}$ atoms Cr
  $5.8 \cdot 10^{15}$ atoms Mn $4.9 \cdot 10^{09}$ atoms Fe

Final sample



Proton budget
total $3.5 \cdot 10^{18}$

sample	purpose	protons
5×10^{17} atoms ^{53}Mn (on 0.1 mm graphite foil)	$^{53}Mn(n, \gamma)$	$2.5 \cdot 10^{18}$
1×10^{20} atoms ^{197}Au (1 µm Au foil or on 0.1 mm graphite foil)	$^{197}Au\ (n, \gamma)$	$2.0 \cdot 10^{17}$
7.4×10^{21} atoms ^{197}Au (0.1 mm Au foil)	saturated resonance analysis $^{197}Au\ (n, \gamma)$	$2.0 \cdot 10^{17}$
1×10^{21} atoms ^{55}Mn (on 0.1 mm graphite foil)	background $^{55}Mn(n, \gamma)$	$2.0 \cdot 10^{17}$
2.3×10^{22} atoms ^{12}C (2×1 mm graphite foil)	Background graphite backing	$4.0 \cdot 10^{17}$
none	background w/o beam	
	total dose	$3.5 \cdot 10^{18}$

Summary of proposal

Proposal:

- stock solution $3 \cdot 10^{19}$ atoms ^{53}Mn from STIP
- depletion of ^{55}Mn using off-line mass separator
- target with $5 \cdot 10^{17}$ atoms = 44 µg ^{53}Mn
- experiment at EAR-2 using $2.5 \cdot 10^{18}$ protons

Goal:

- cross section measurement from 25 meV to 250 keV
- date to perform 2015/2016

Thank you for attention

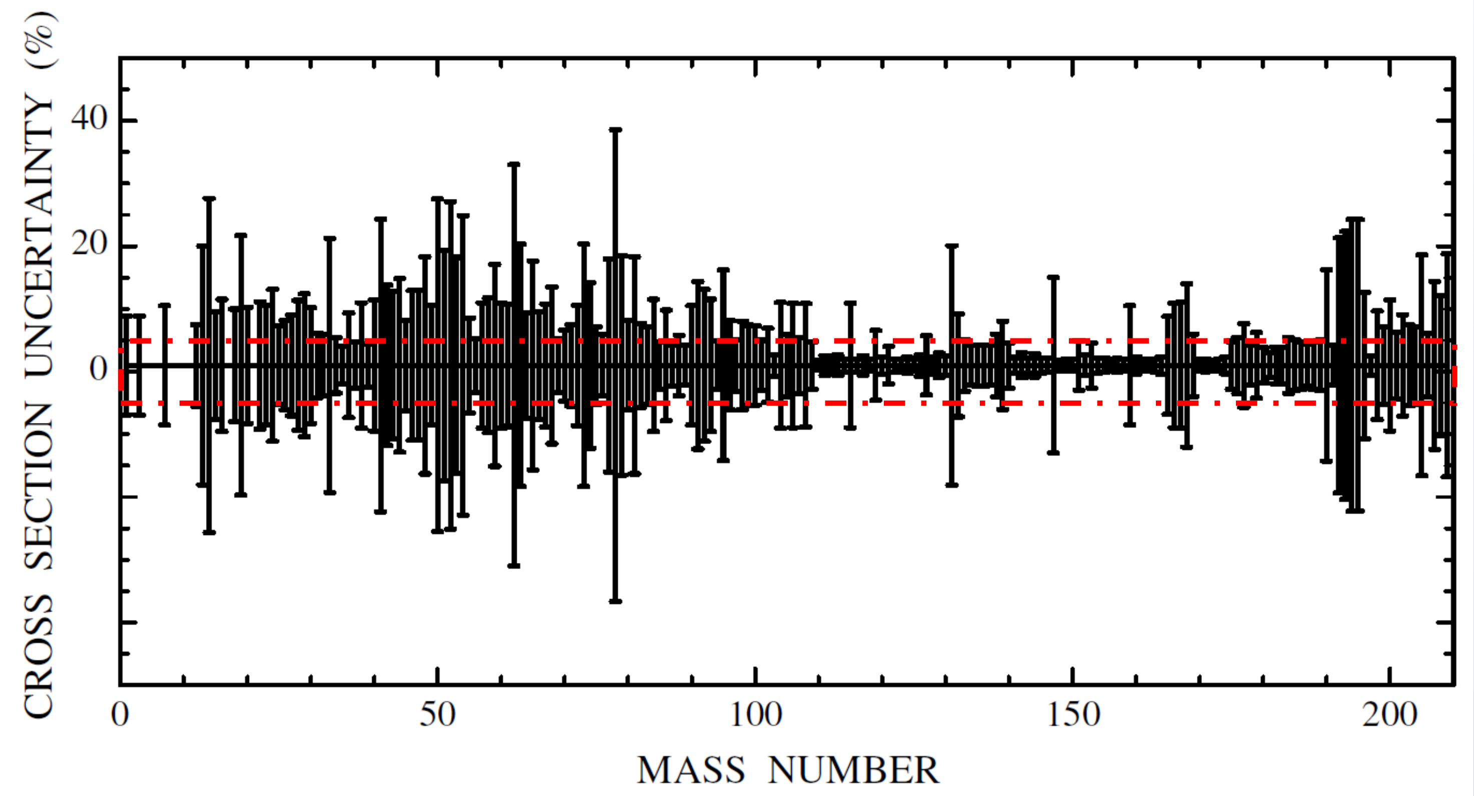
combined visible and near infrared pictures

star-forming pillar with a jet (HH 901)

Carina nebula: birthplace of stars

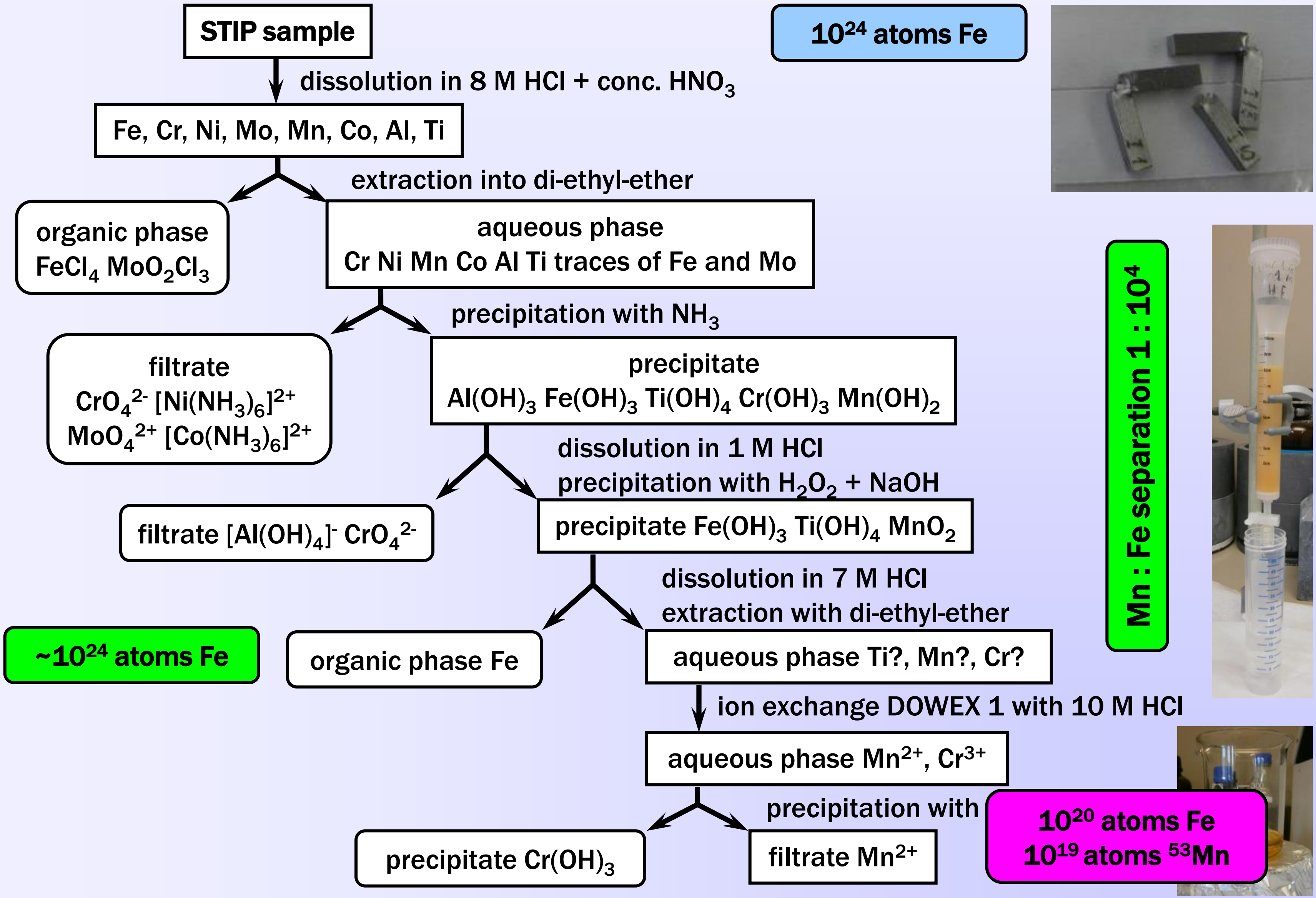
Hubble Space Telescope: http://hubblesite.org

Neutron capture cross-sections at stellar neutron energies

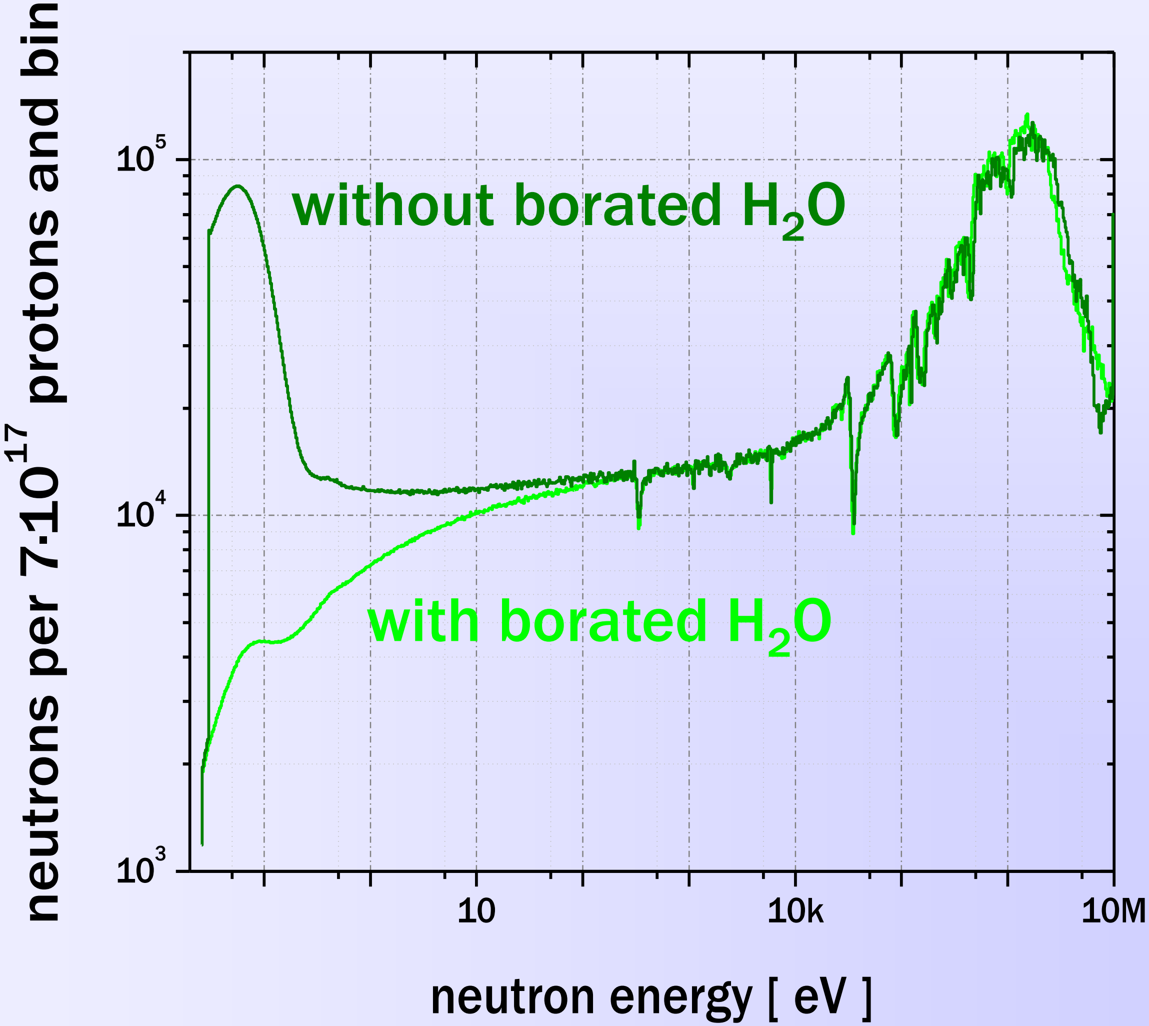


F. Käppeler: Nucl. Instr. and Methods **B 259** (2007) 663

Separation scheme of STIP samples



Neutron spectrum EAR-1



M. Barbagallo, et n_TOF: to be published