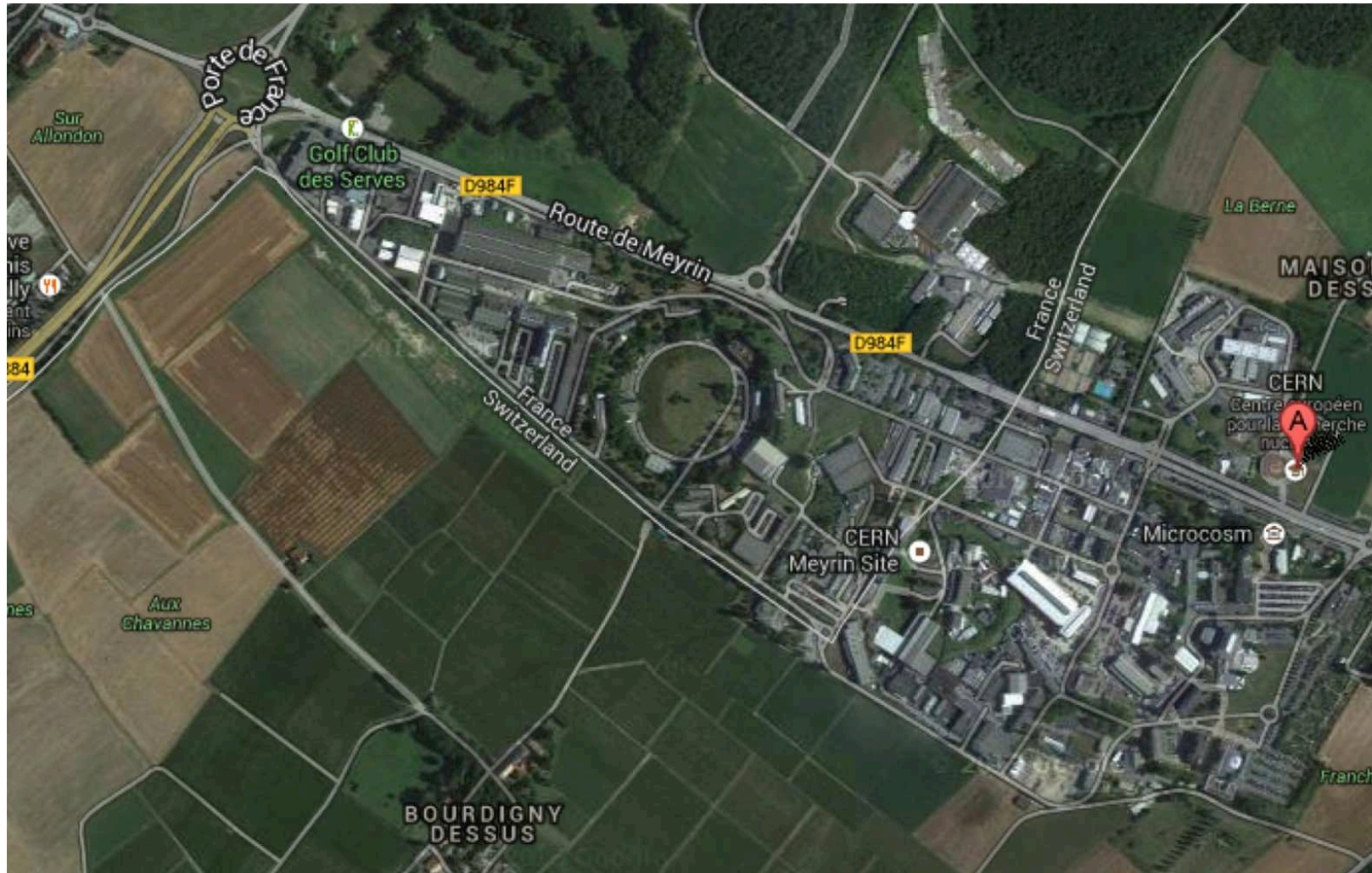


The measurement programme of the n_TOF facility at CERN

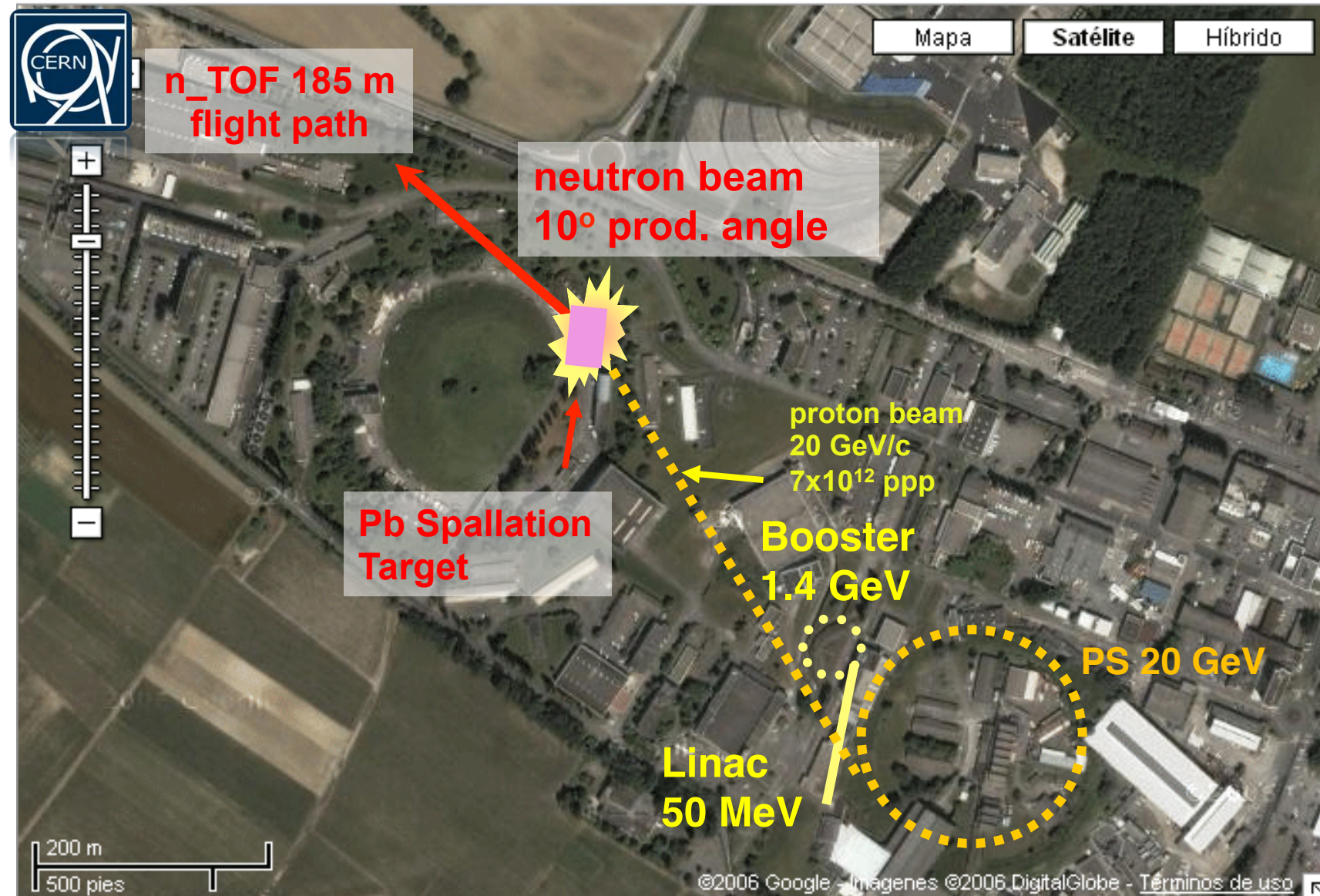
Frank Gunsing
CEA Saclay, Irfu
F-91191 Gif-sur-Yvette

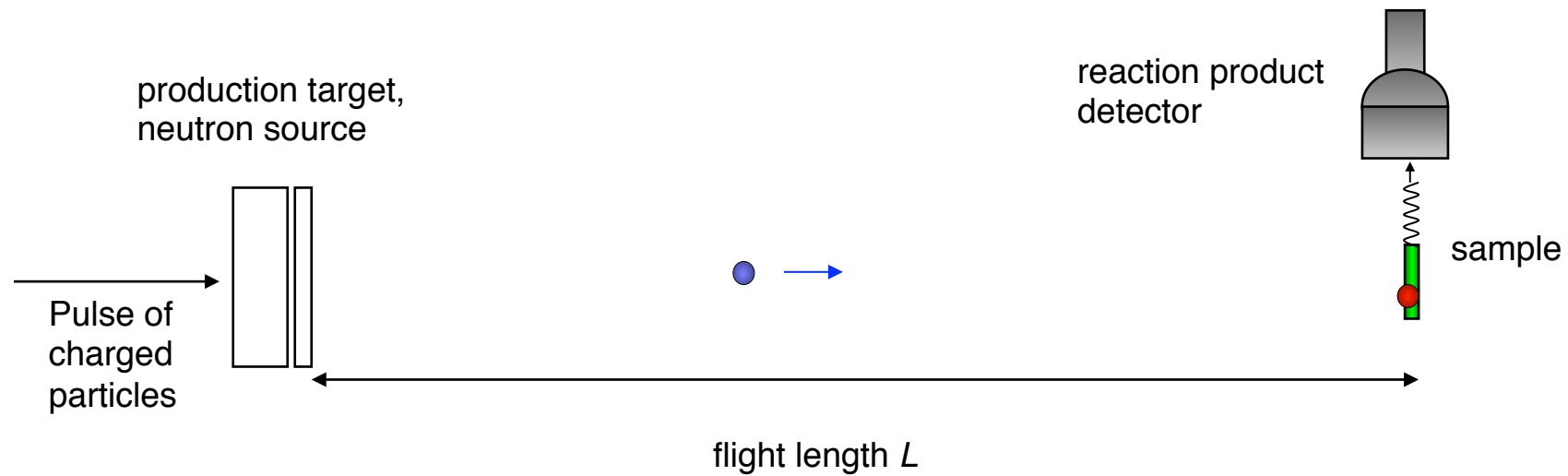
on behalf of the n_TOF Collaboration

The n_TOF facility at CERN



The n_TOF facility at CERN





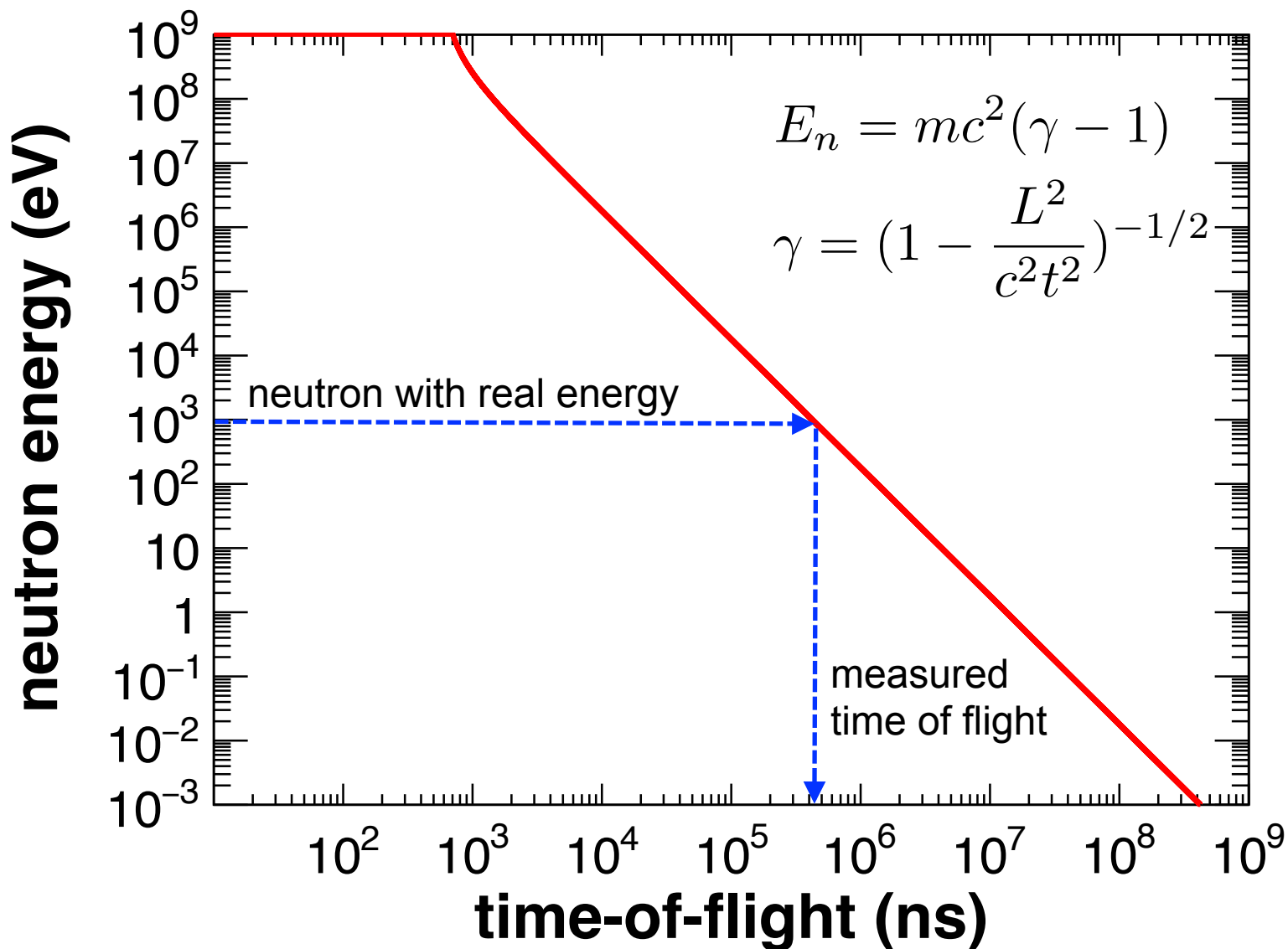
time of flight t

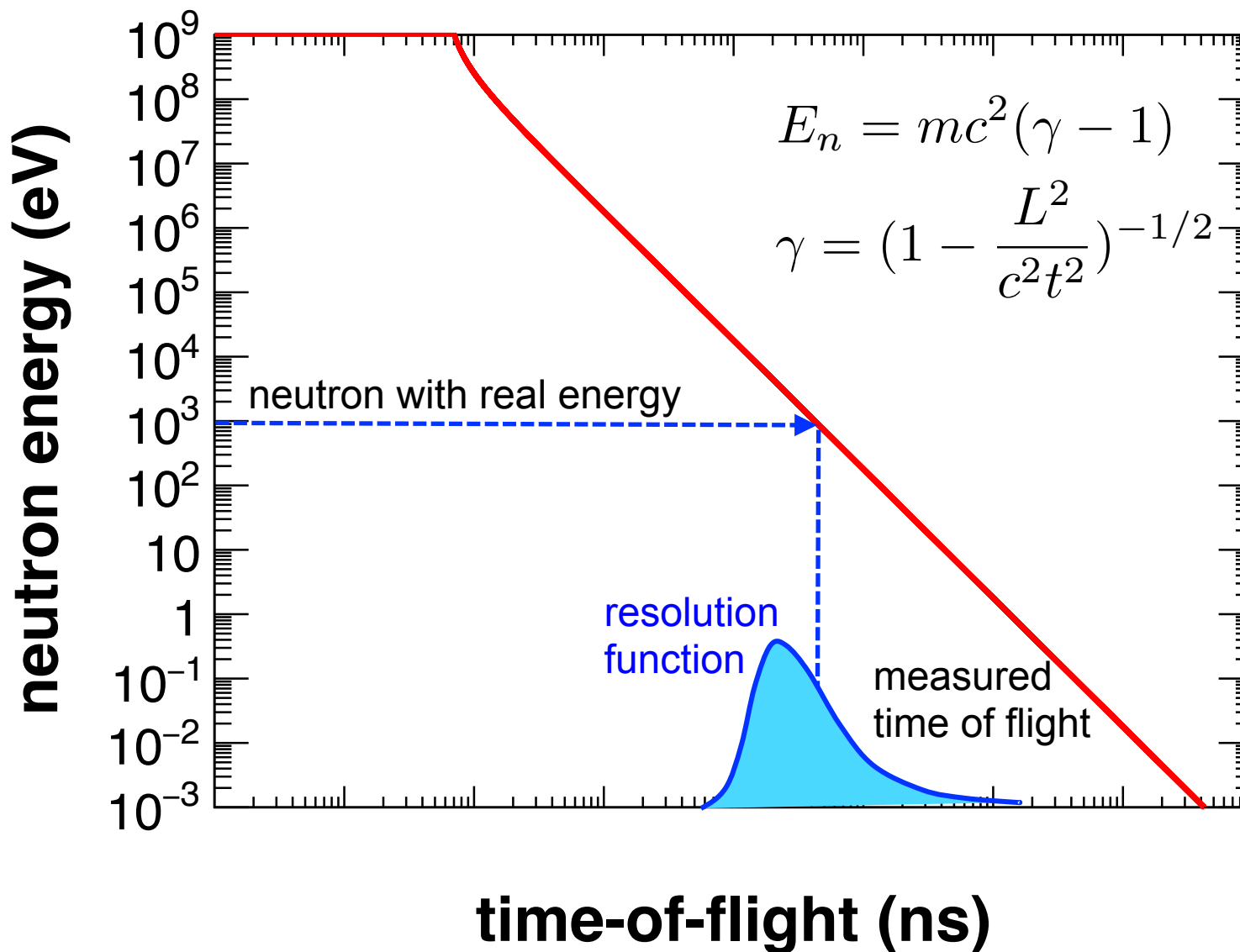
**Deduce kinetic energy from
neutron by time-of-flight:**

$$E_n = mc^2(\gamma - 1)$$

$$\gamma = \left(1 - \frac{L^2}{c^2 t^2}\right)^{-1/2}$$

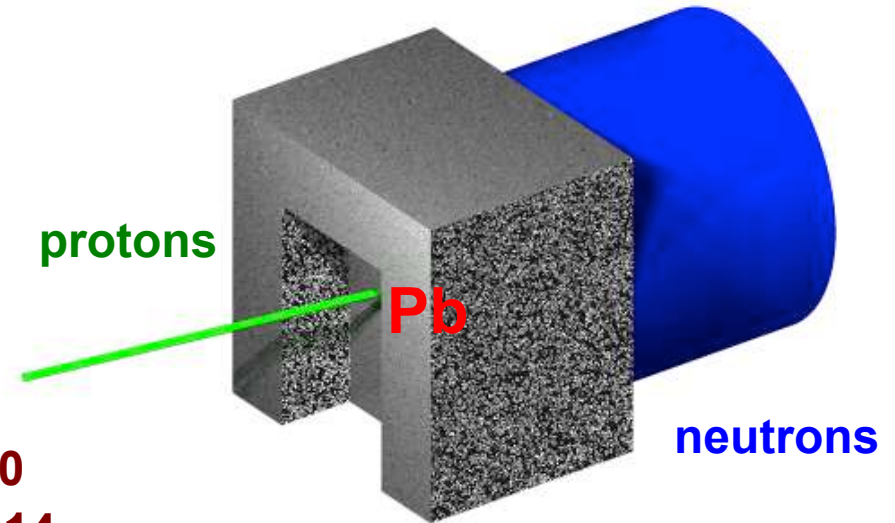
Neutron time-of-flight





Pulsed white neutron source:

- 20 GeV/c protons
- neutrons from spallation
- 6 ns rms pulse width
- frequency 1 pulse/2.4 seconds
- separate cooling and moderation
- flight path length EAR1: 185 m, **since 2000**
- **flight path length EAR2: 20 m, since 2014**
- @source: 7×10^{12} protons/pulse
- @source: 2×10^{15} neutrons/pulse
- @EAR1: $5 \cdot 10^5$ (capture) – $5 \cdot 10^7$ (fission) neutrons/pulse



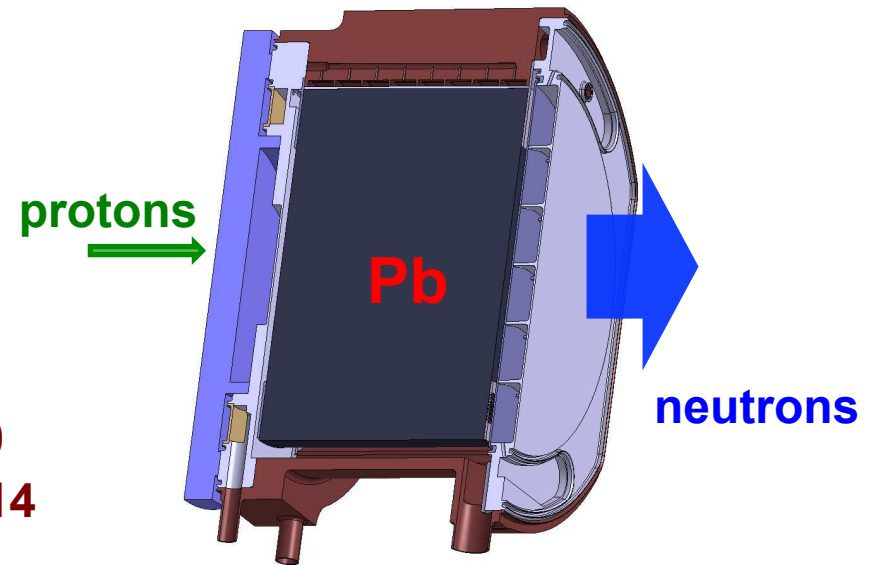
**phase I target
2001-2004**

Main features:

- Large energy range in one experiment (0.1 eV - 250 MeV)
- Favorable signal to noise ratio for capture on radioactive isotopes (actinides, fission products)

Pulsed white neutron source:

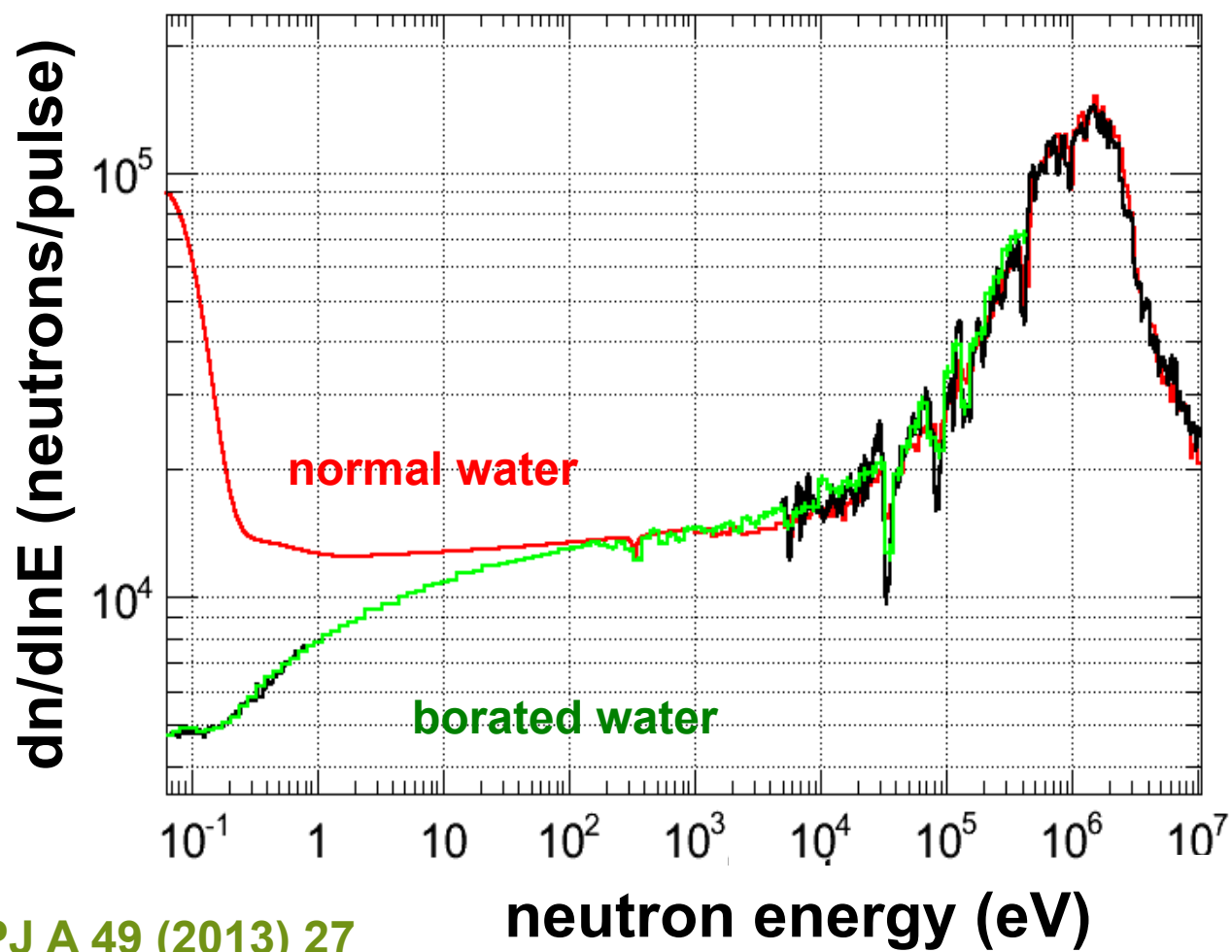
- 20 GeV/c protons
- neutrons from spallation
- 6 ns rms pulse width
- frequency 1 pulse/2.4 seconds
- separate cooling and moderation
- flight path length EAR1: 185 m, **since 2000**
- **flight path length EAR2: 20 m, since 2014**
- @source: 7×10^{12} protons/pulse
- @source: 2×10^{15} neutrons/pulse
- @EAR1: $5 \cdot 10^5$ (capture) – $5 \cdot 10^7$ (fission) neutrons/pulse



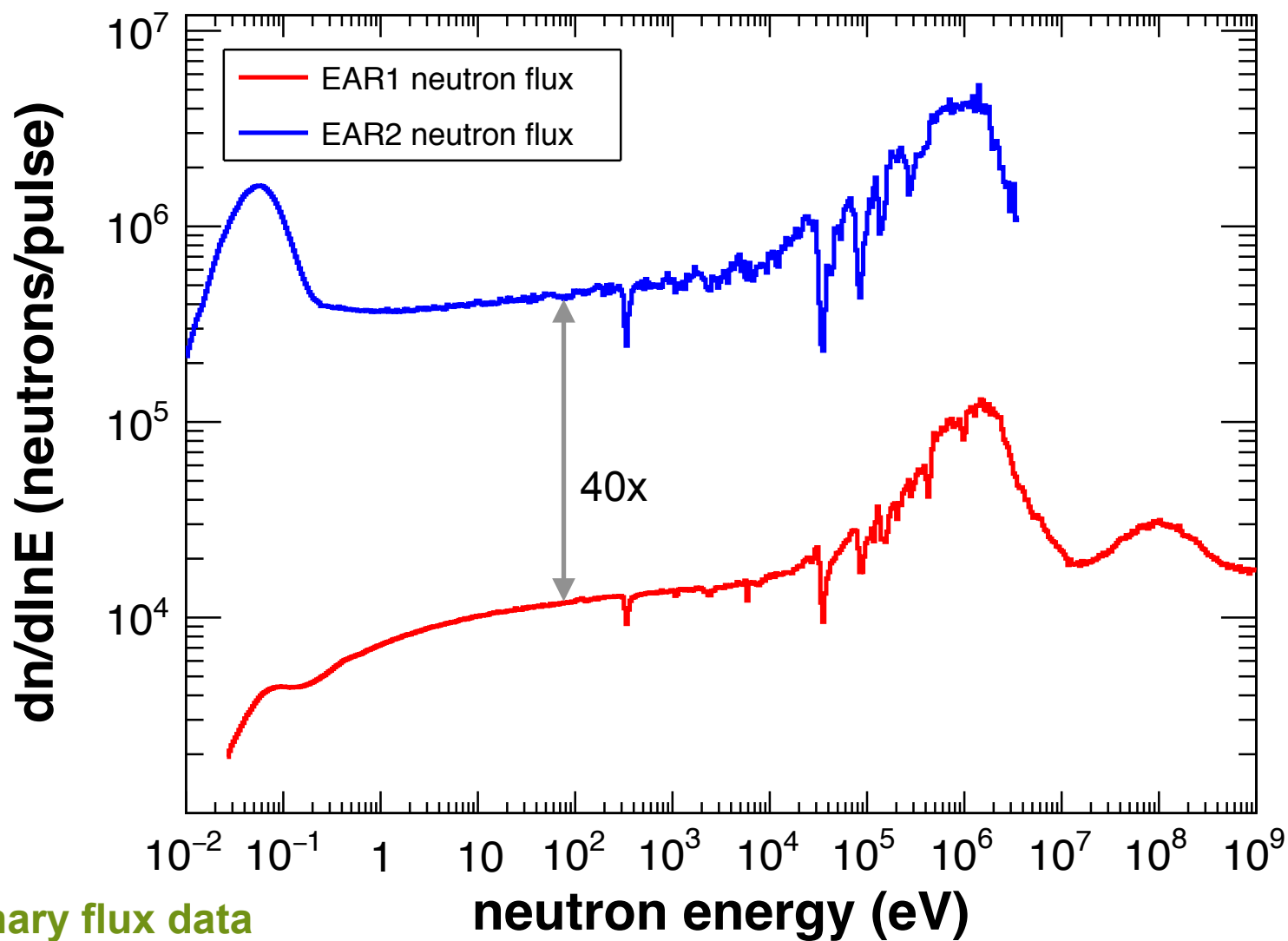
**phase II-III target
2009-present**

Main features:

- Large energy range in one experiment (0.1 eV - 250 MeV)
- Favorable signal to noise ratio for capture on radioactive isotopes (actinides, fission products)

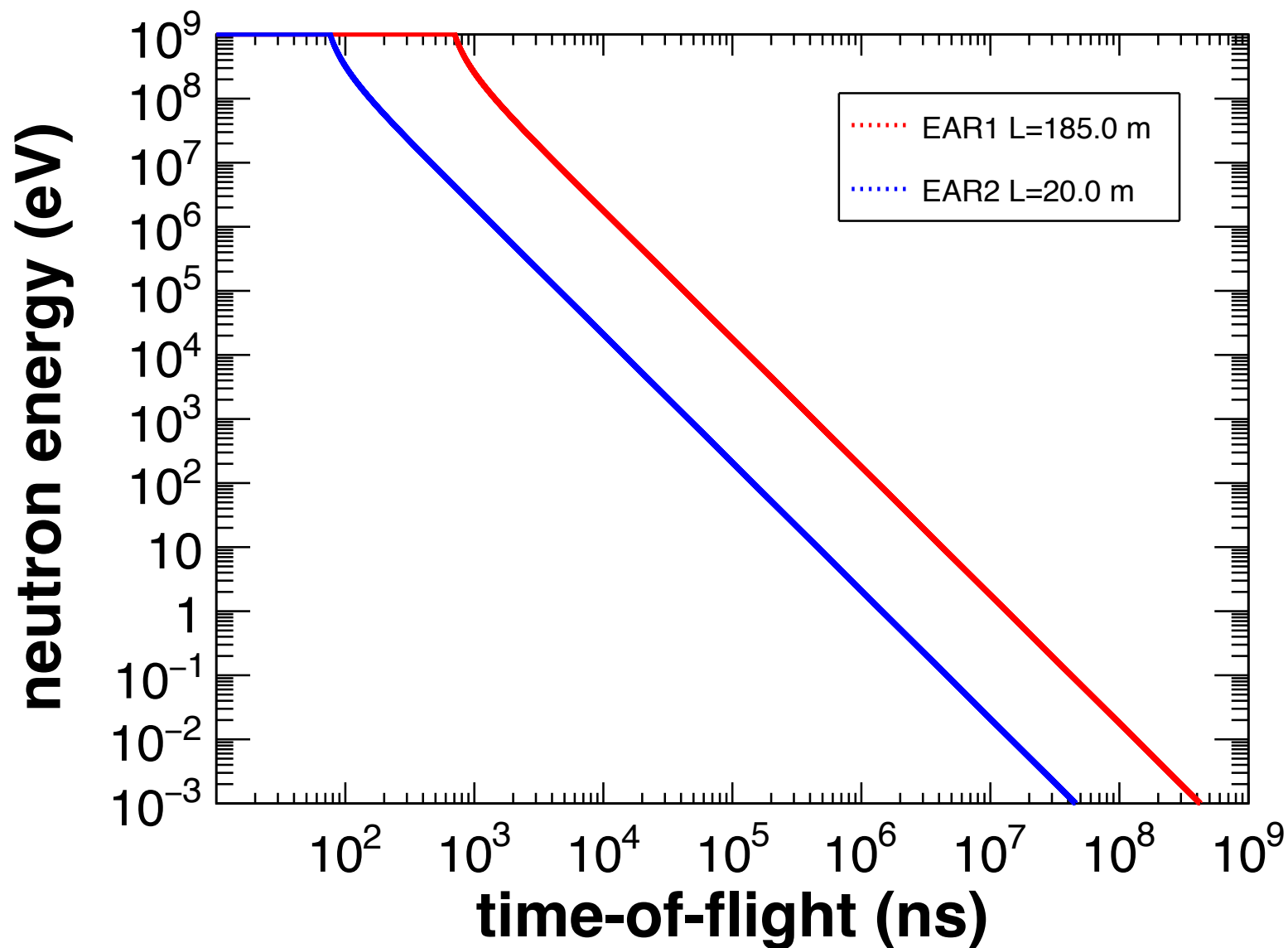


from: EPJ A 49 (2013) 27

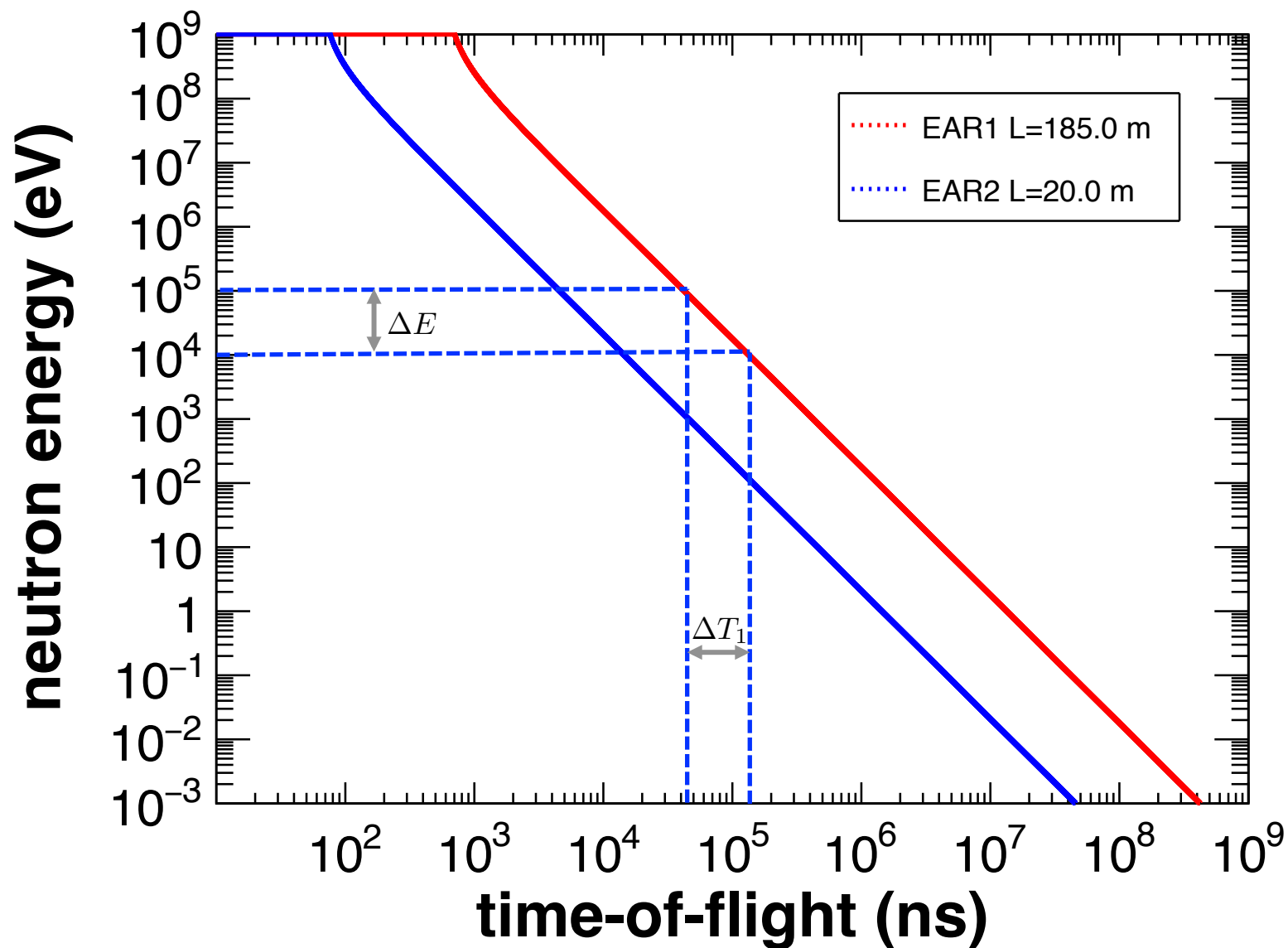


preliminary flux data

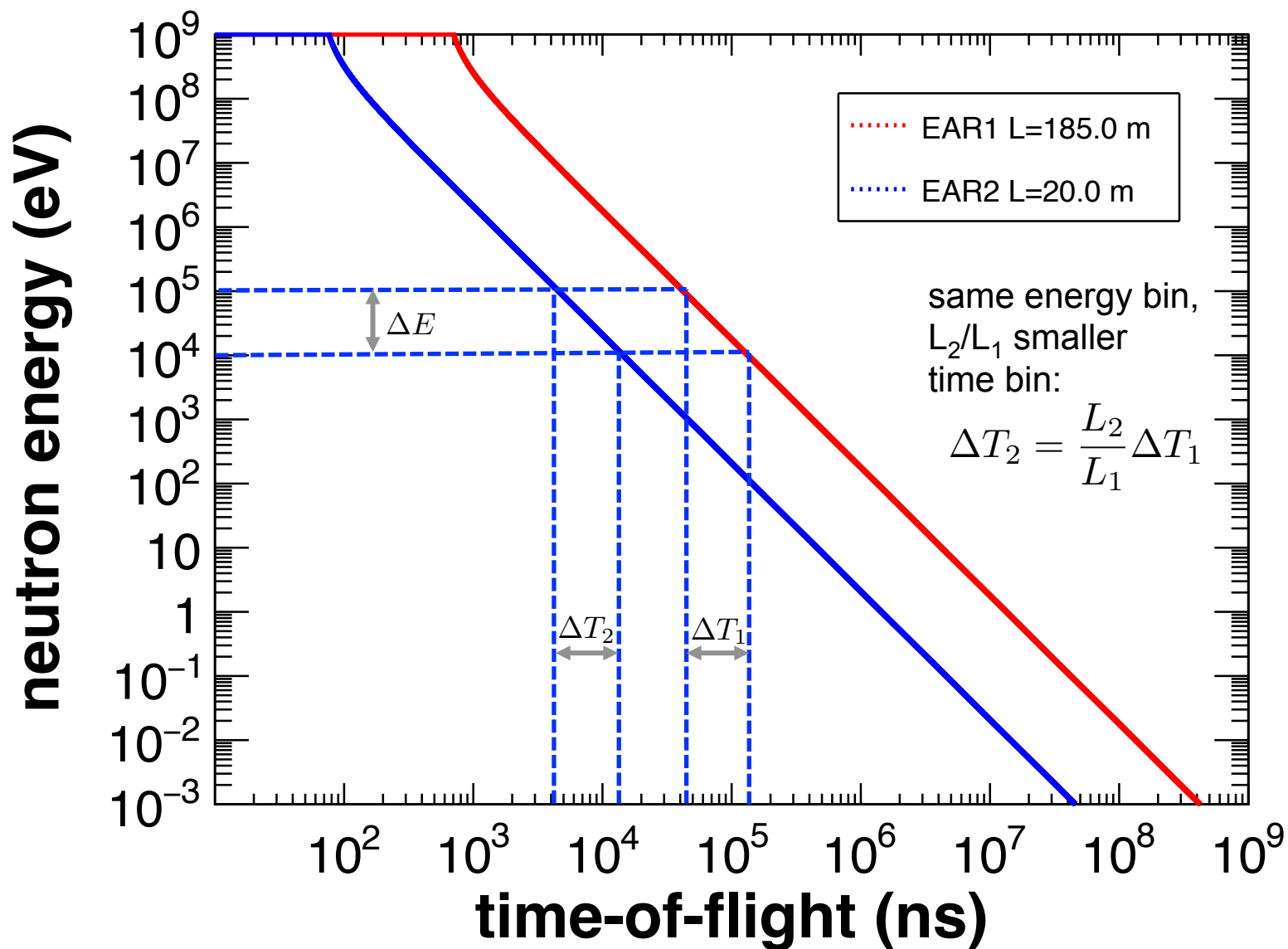
TOF-energy relation at n_TOF



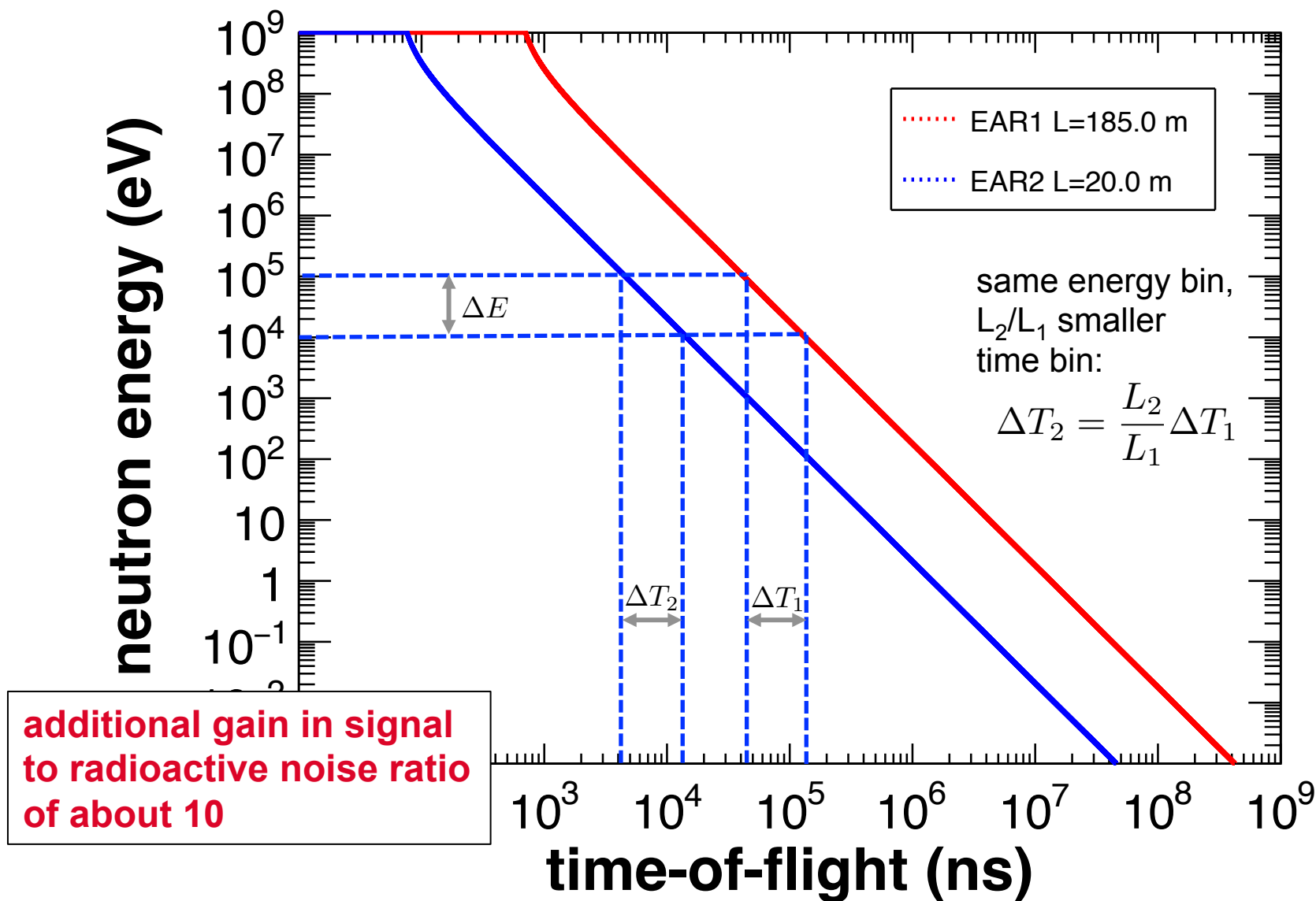
TOF-energy relation at n_TOF

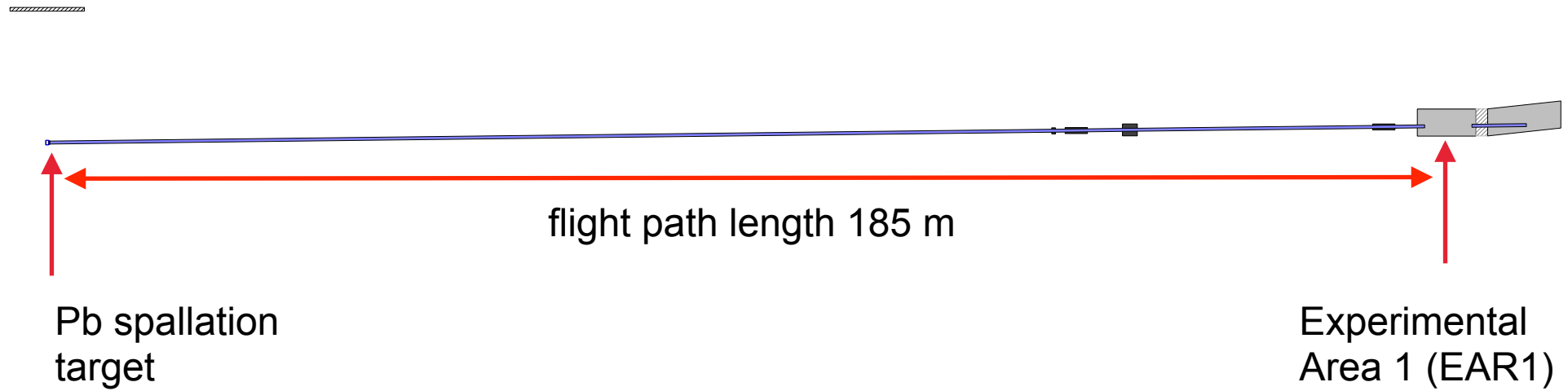


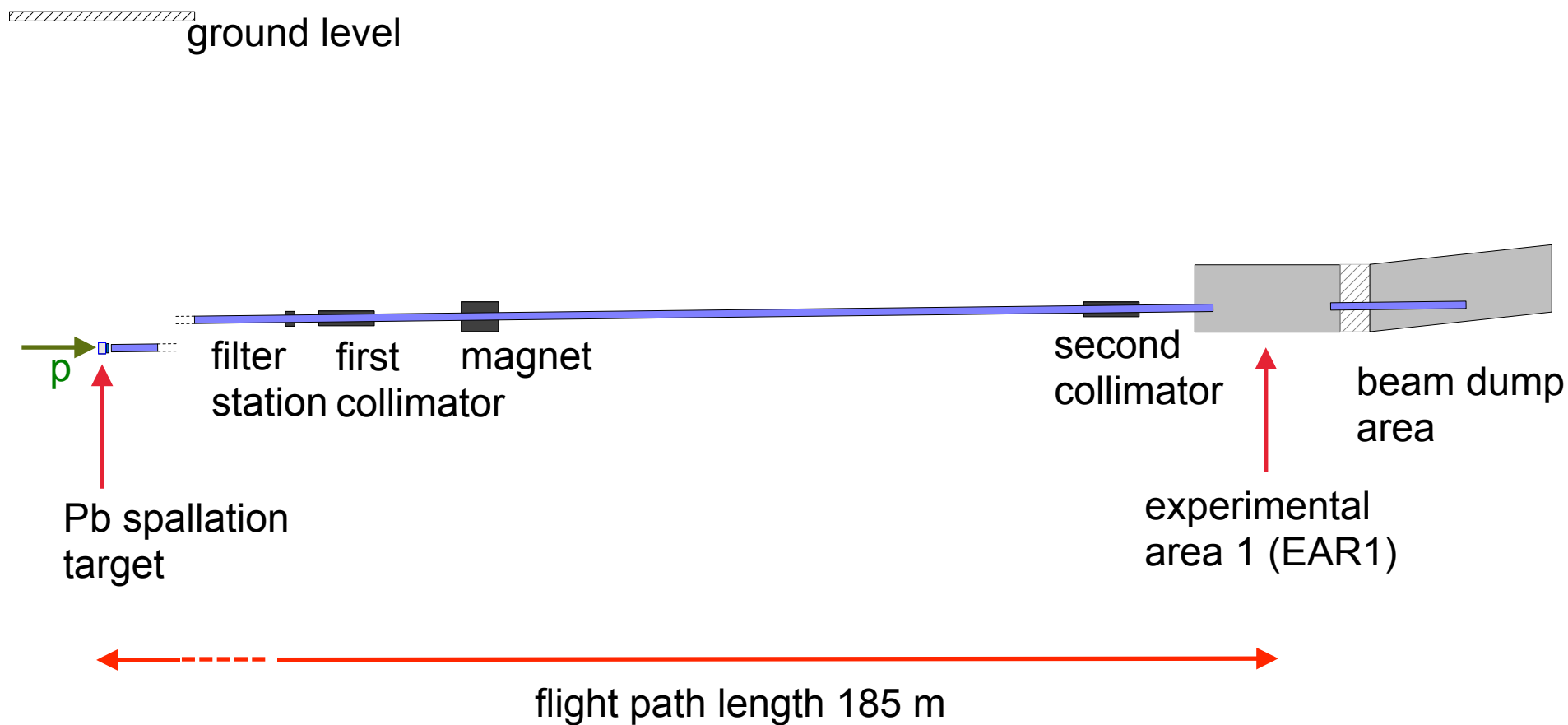
TOF-energy relation at n_TOF

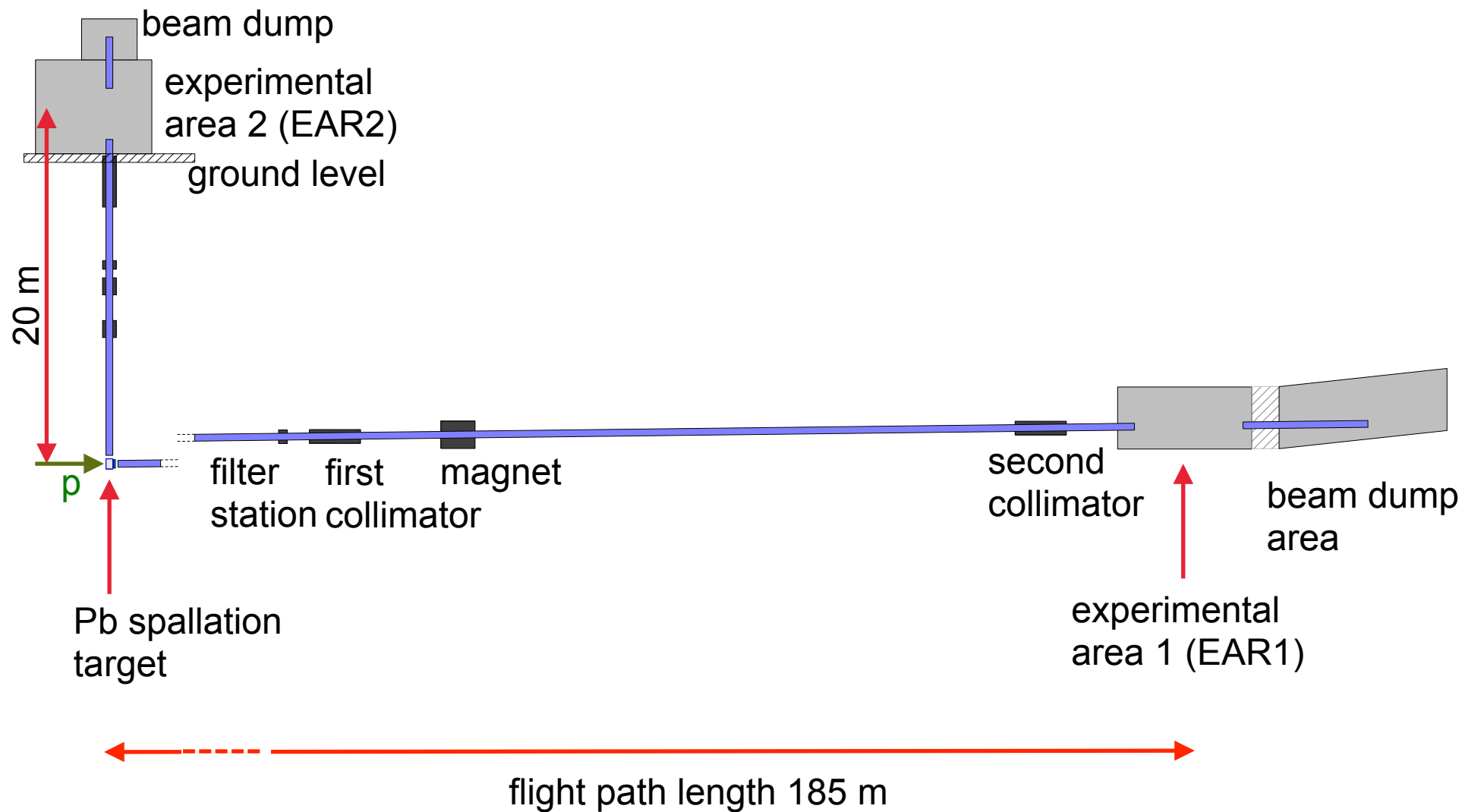


TOF-energy relation at n_TOF





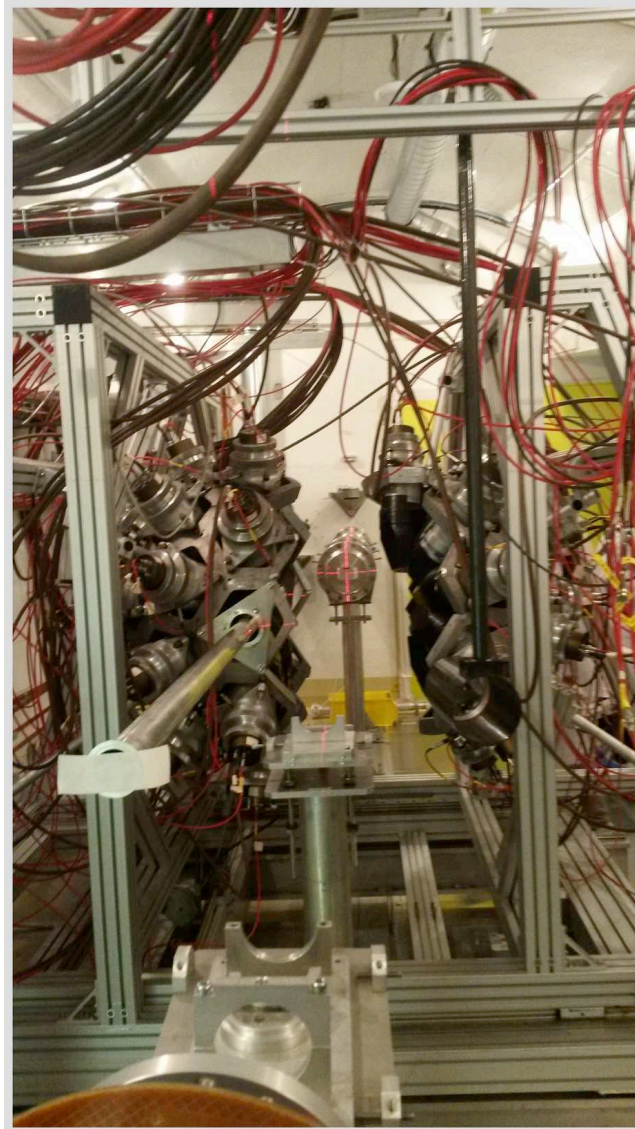




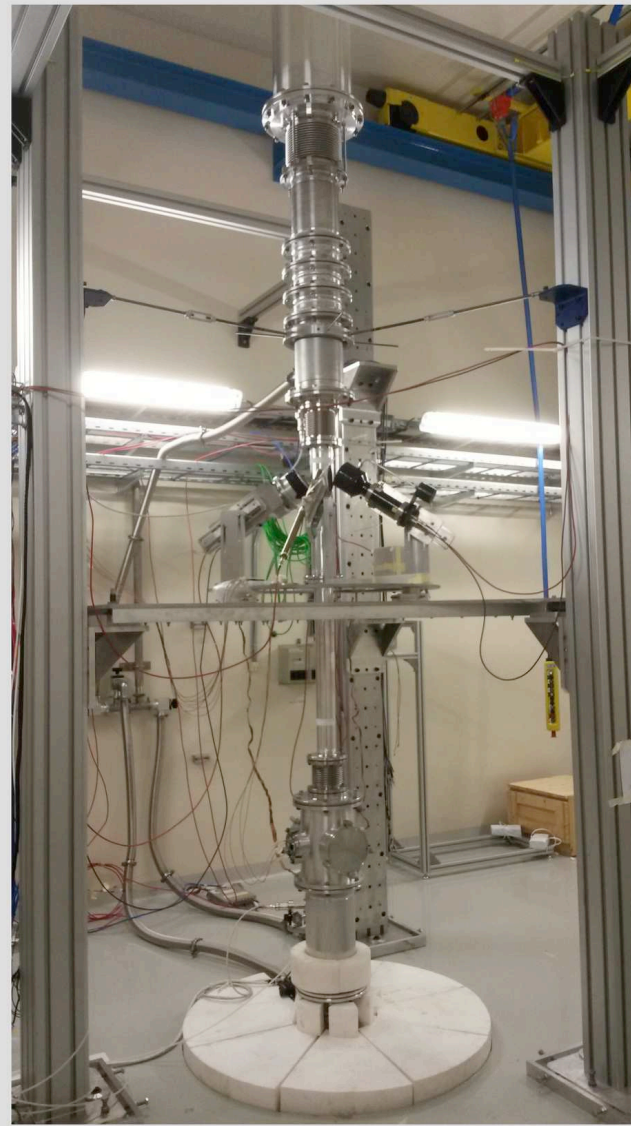


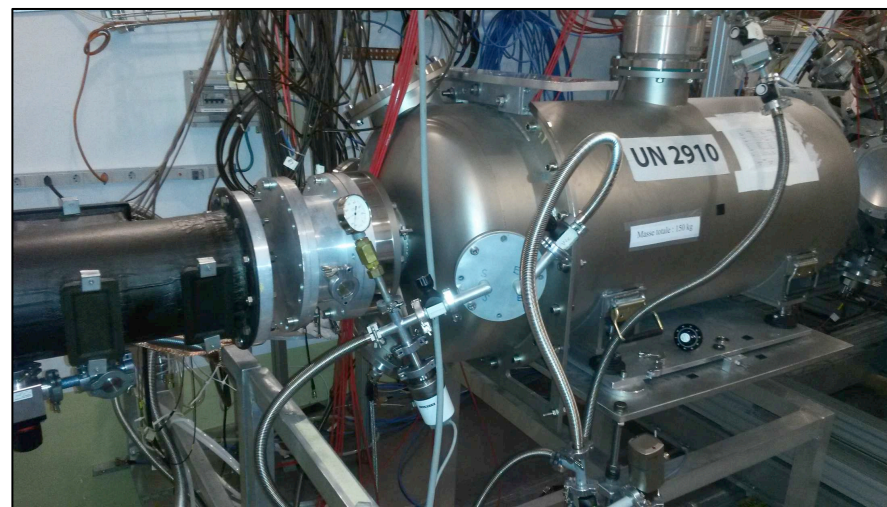
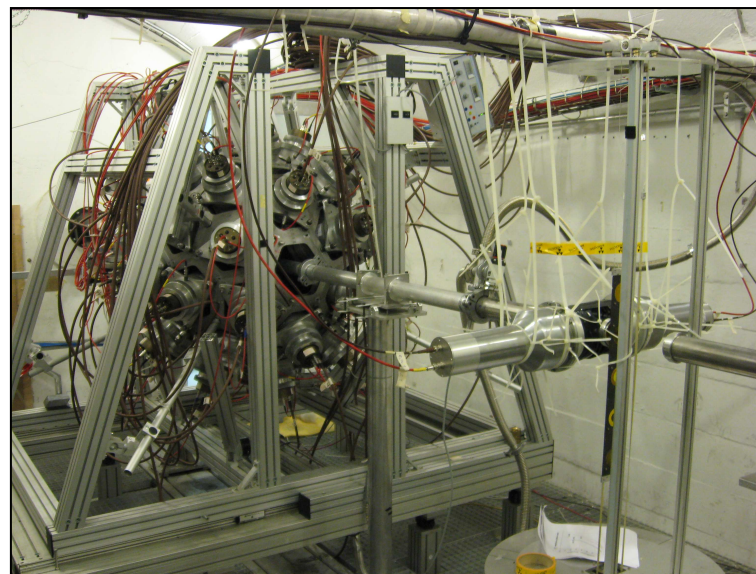
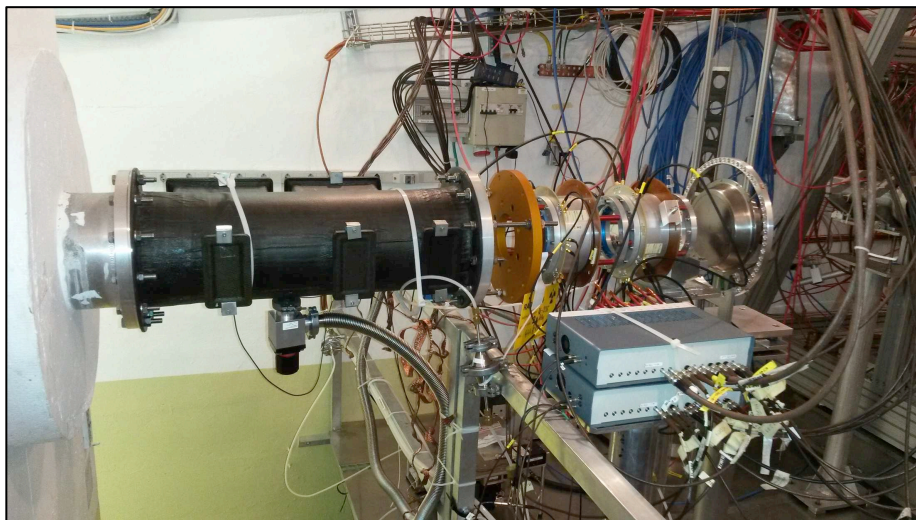
EAR1 – EAR2

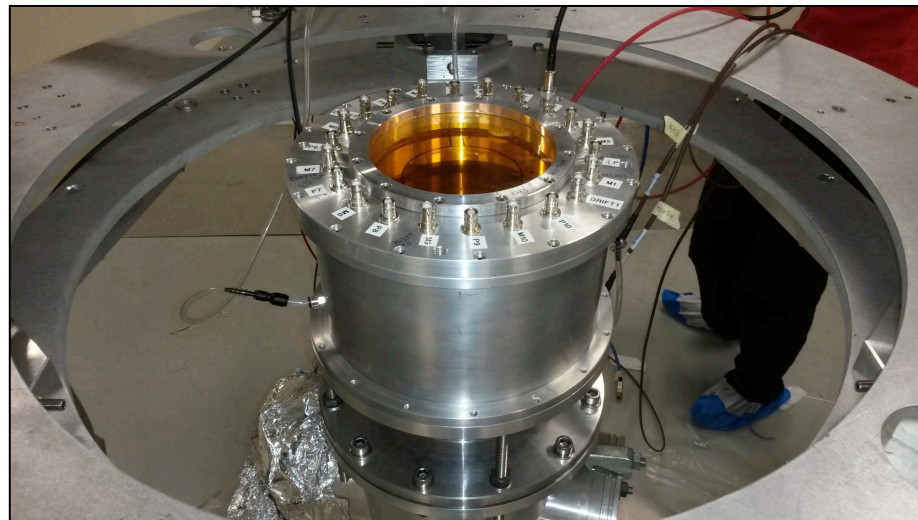
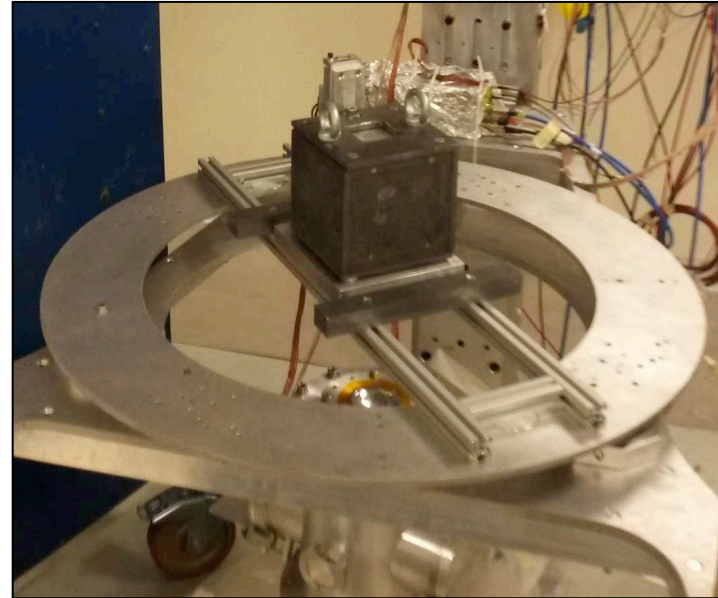
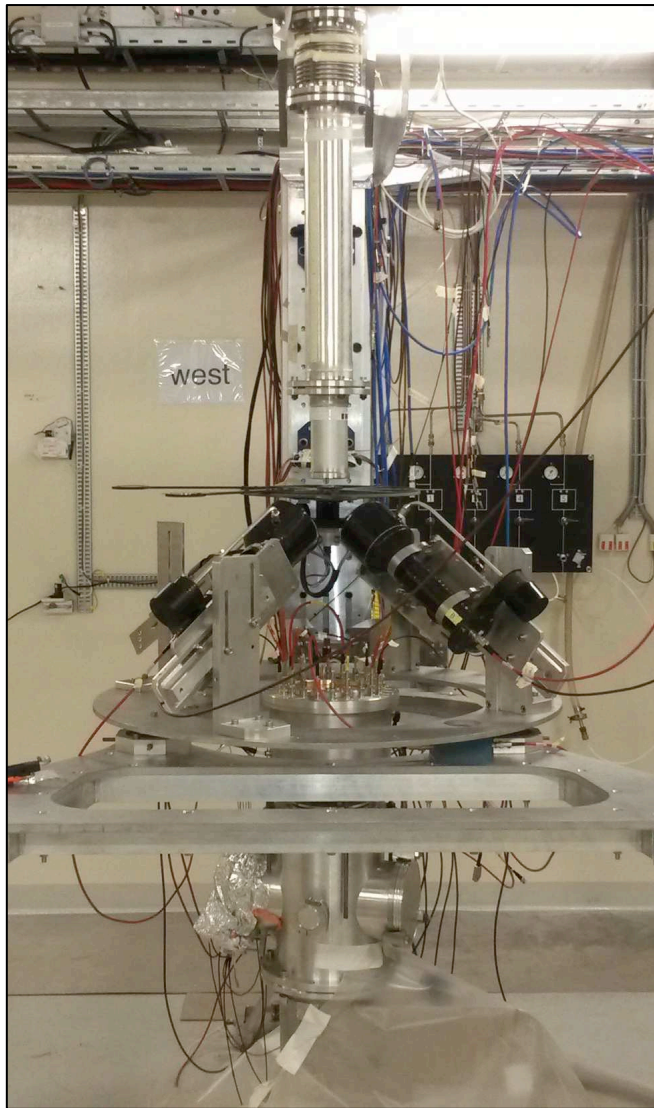
EAR1

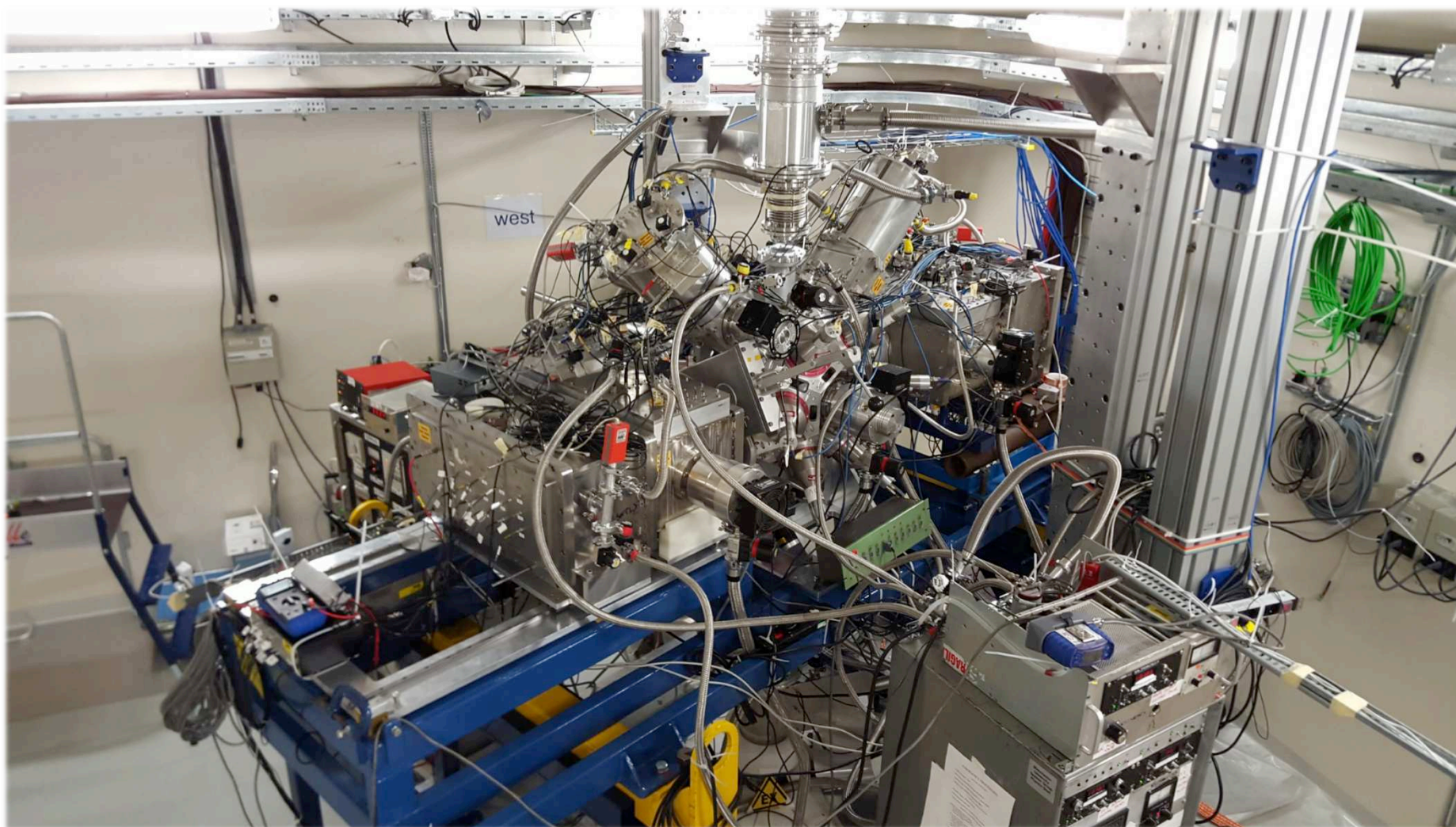


EAR2









FIC0	^{234}U
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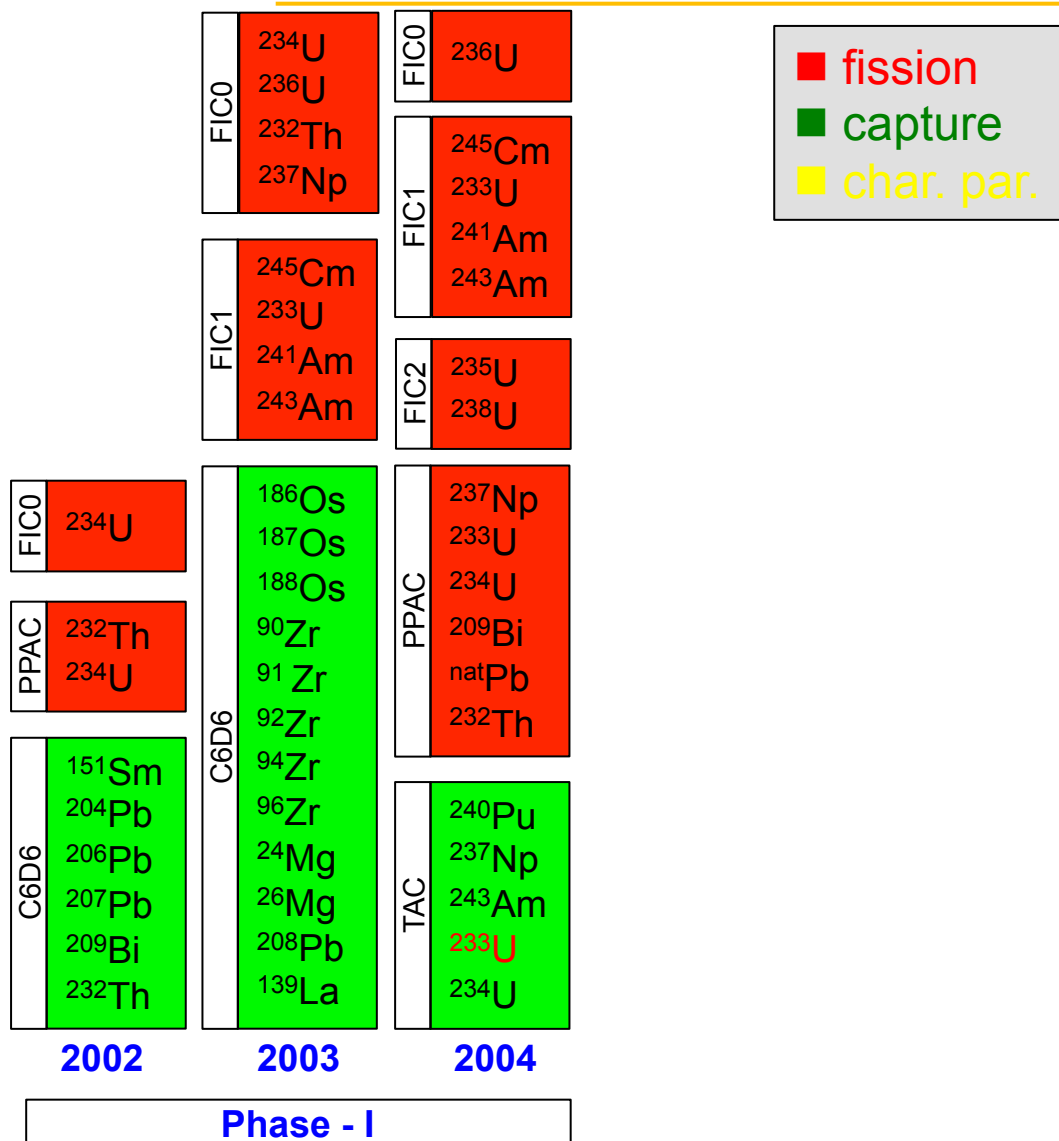
PPAC	^{232}Th ^{234}U
------	---------------------------------------

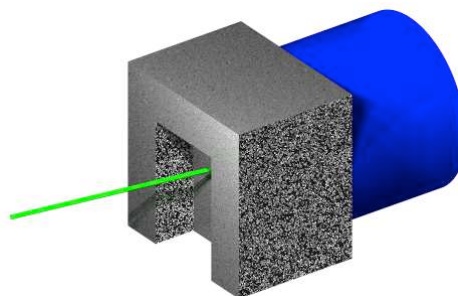
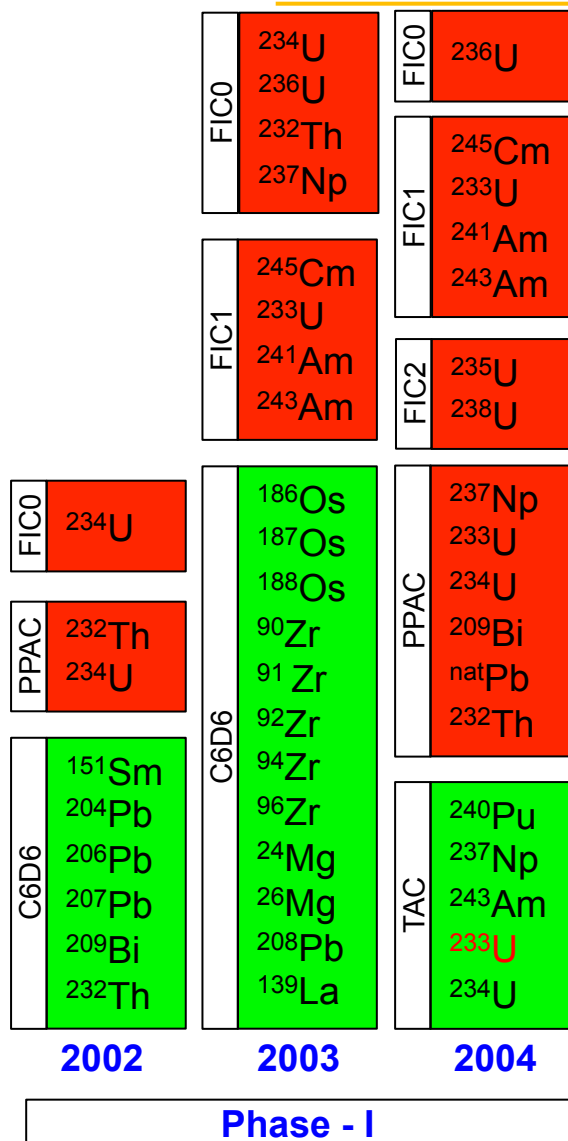
C6D6	^{151}Sm ^{204}Pb ^{206}Pb ^{207}Pb ^{209}Bi ^{232}Th
------	--

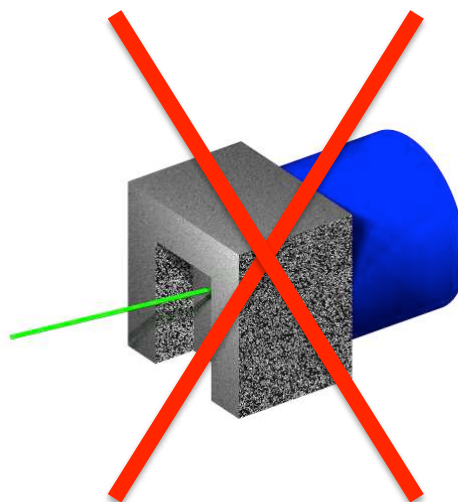
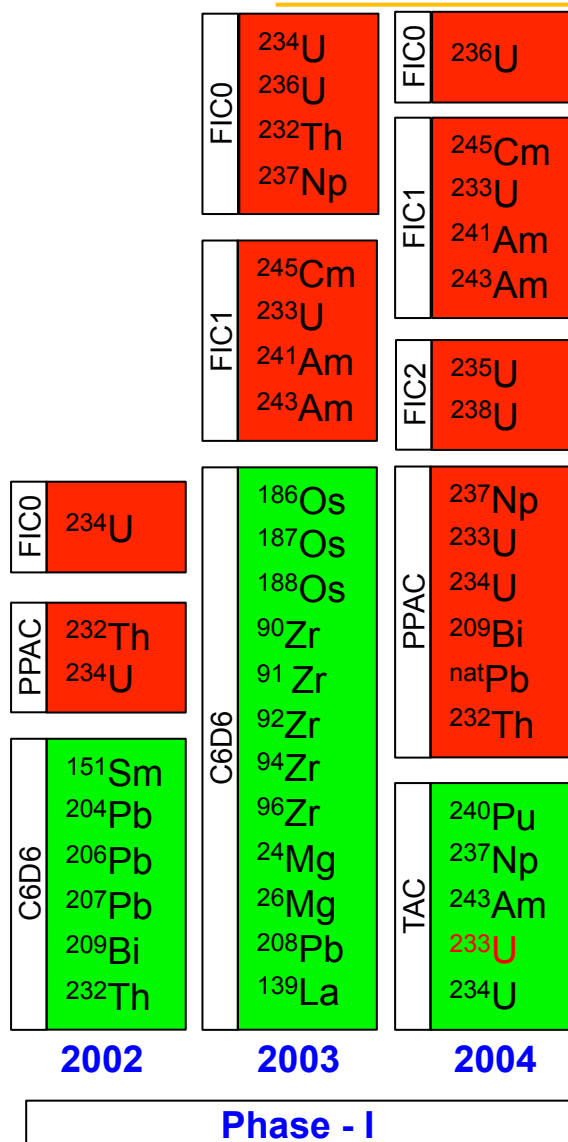
2002

Phase - I

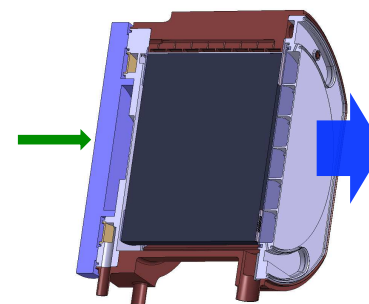
	FIC0 ^{234}U ^{236}U ^{232}Th ^{237}Np	FIC0 ^{236}U
	FIC1 ^{245}Cm ^{233}U ^{241}Am ^{243}Am	FIC1 ^{245}Cm ^{233}U ^{241}Am ^{243}Am
		FIC2 ^{235}U ^{238}U
FIC0 ^{234}U	C6D6 ^{186}Os ^{187}Os ^{188}Os ^{90}Zr ^{91}Zr ^{92}Zr ^{94}Zr ^{96}Zr ^{24}Mg ^{26}Mg ^{208}Pb ^{139}La	PPAC ^{237}Np ^{233}U ^{234}U ^{209}Bi natPb ^{232}Th
PPAC ^{232}Th ^{234}U		
C6D6 ^{151}Sm ^{204}Pb ^{206}Pb ^{207}Pb ^{209}Bi ^{232}Th		TAC ^{240}Pu ^{237}Np ^{243}Am ^{233}U ^{234}U
2002	2003	2004
Phase - I		





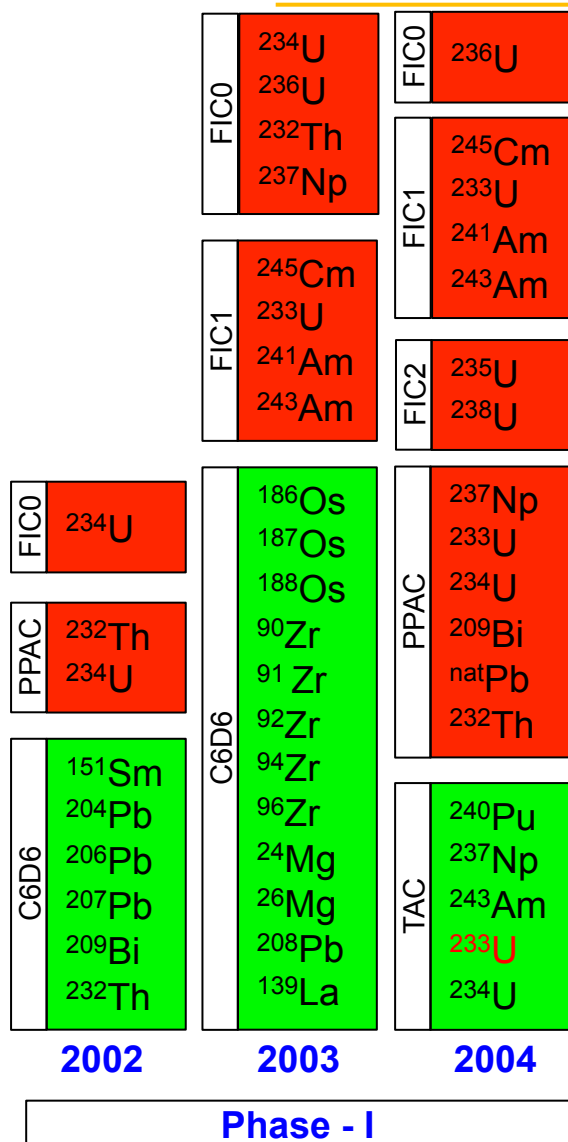


phase I target
2001 – 2004

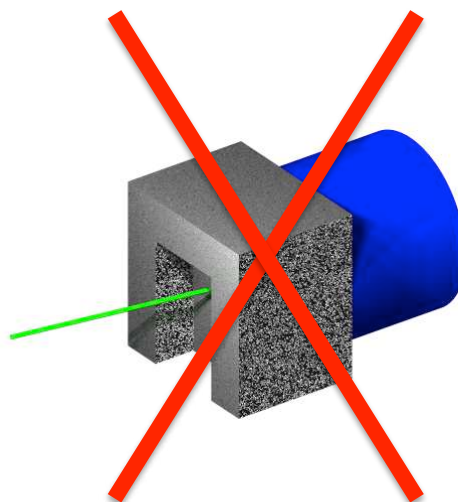


phase II target
2009 – today

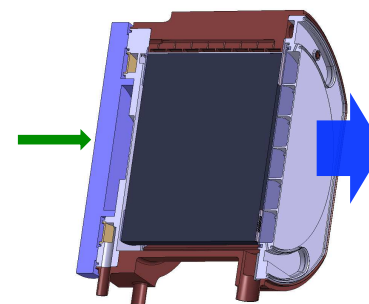
Measurements performed at n_TOF



■ fission
■ capture
■ char. par.

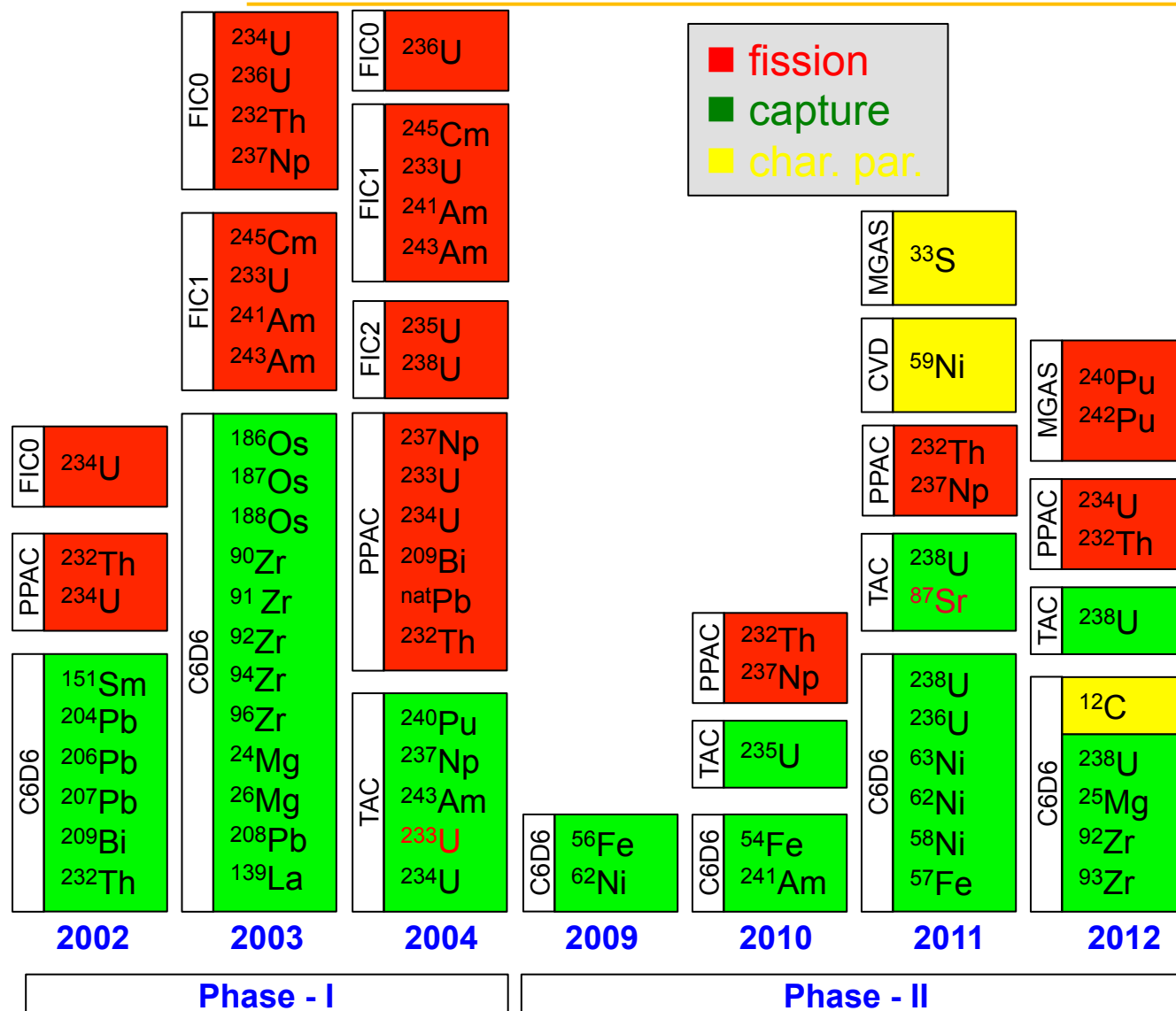


phase I target
2001 – 2004

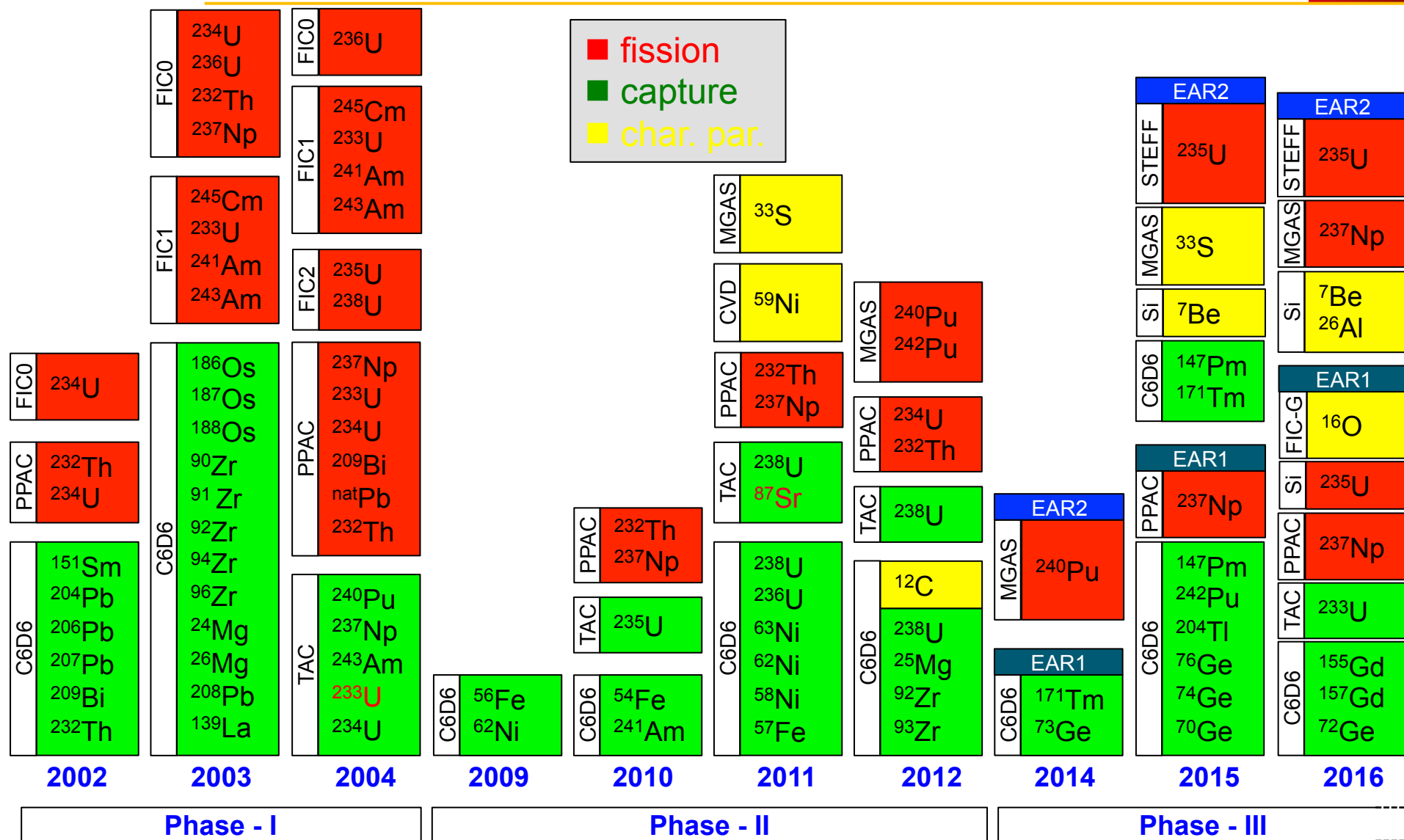


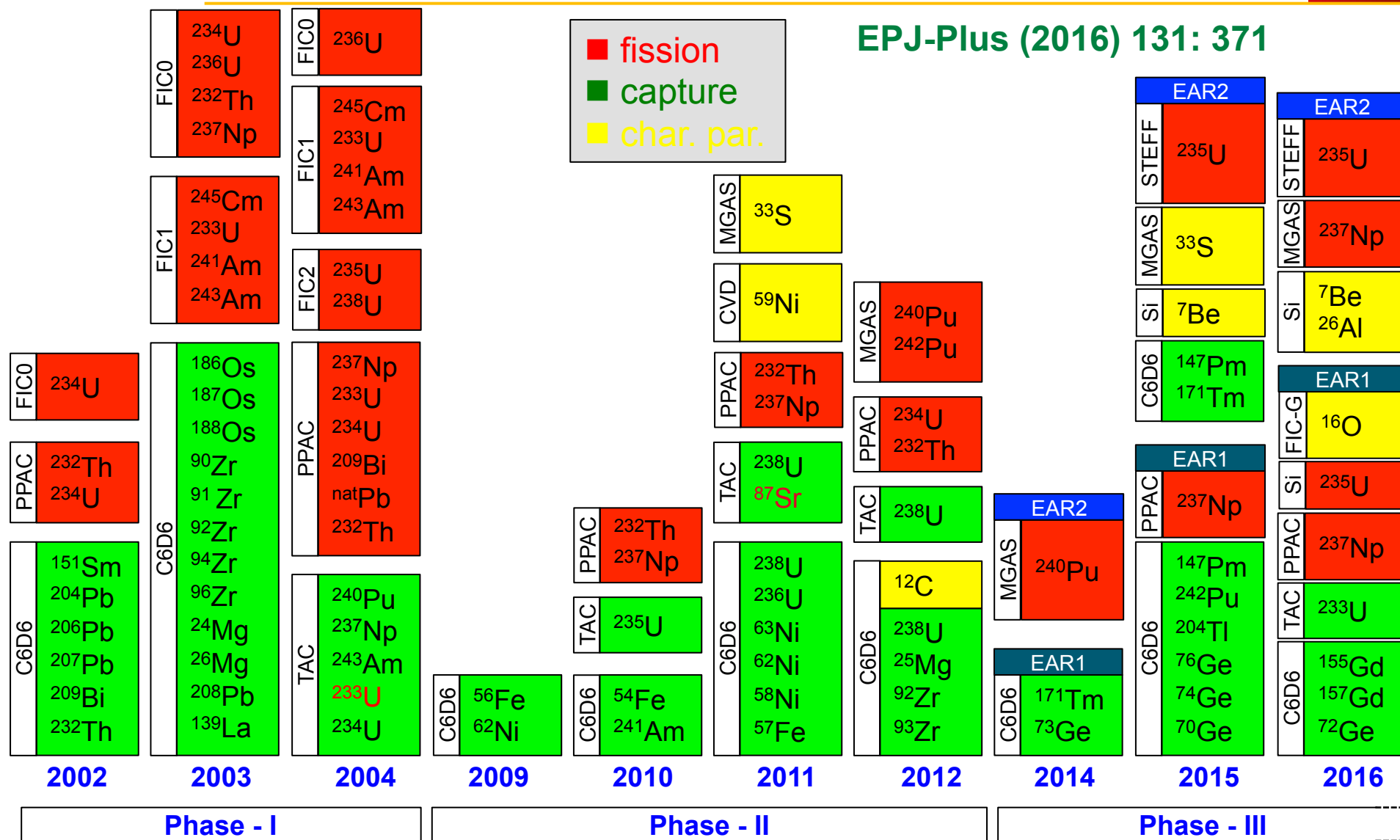
phase II target
2009 – today

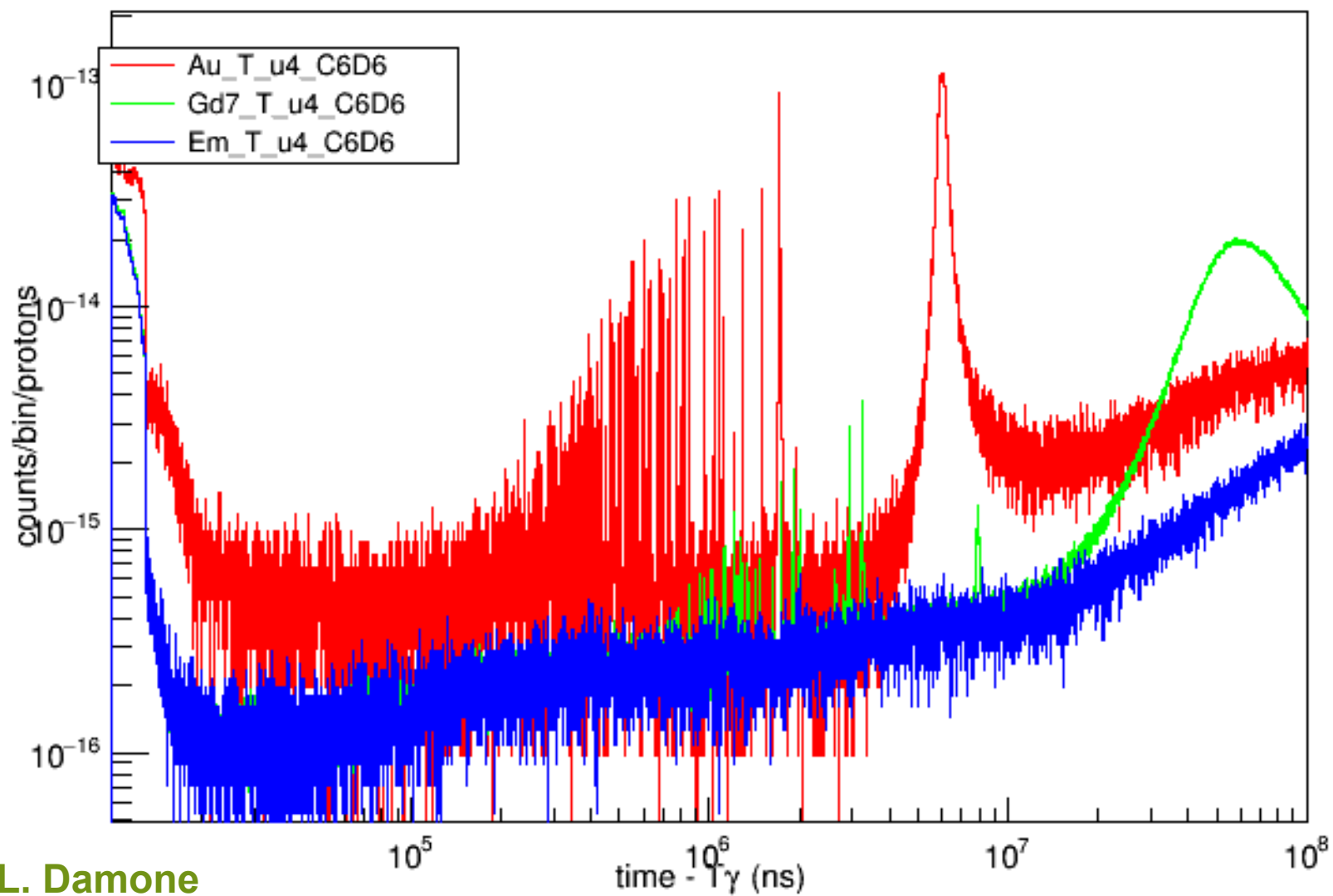
+ borated water
+ class A lab



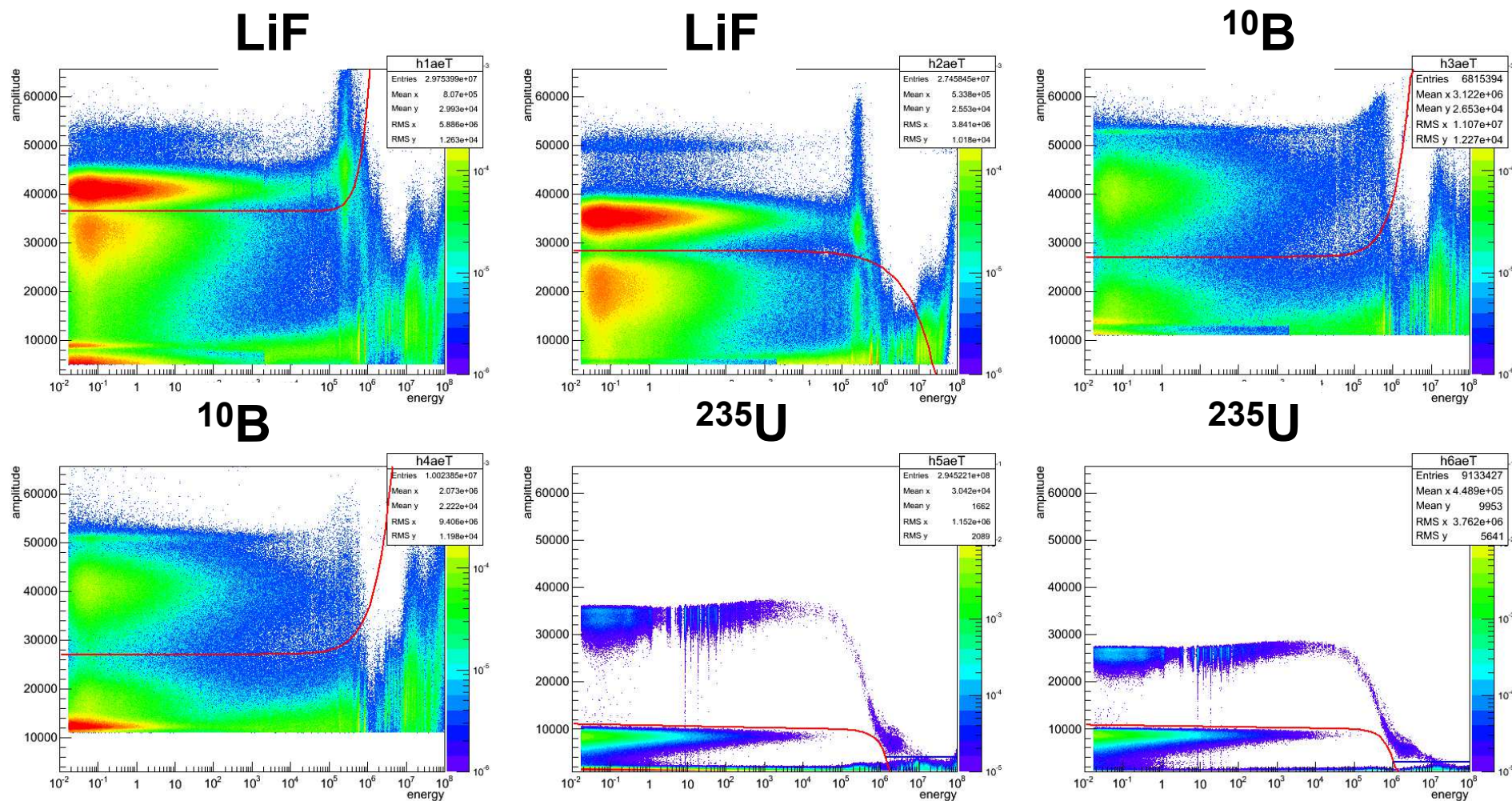
Measurements performed at n_TOF



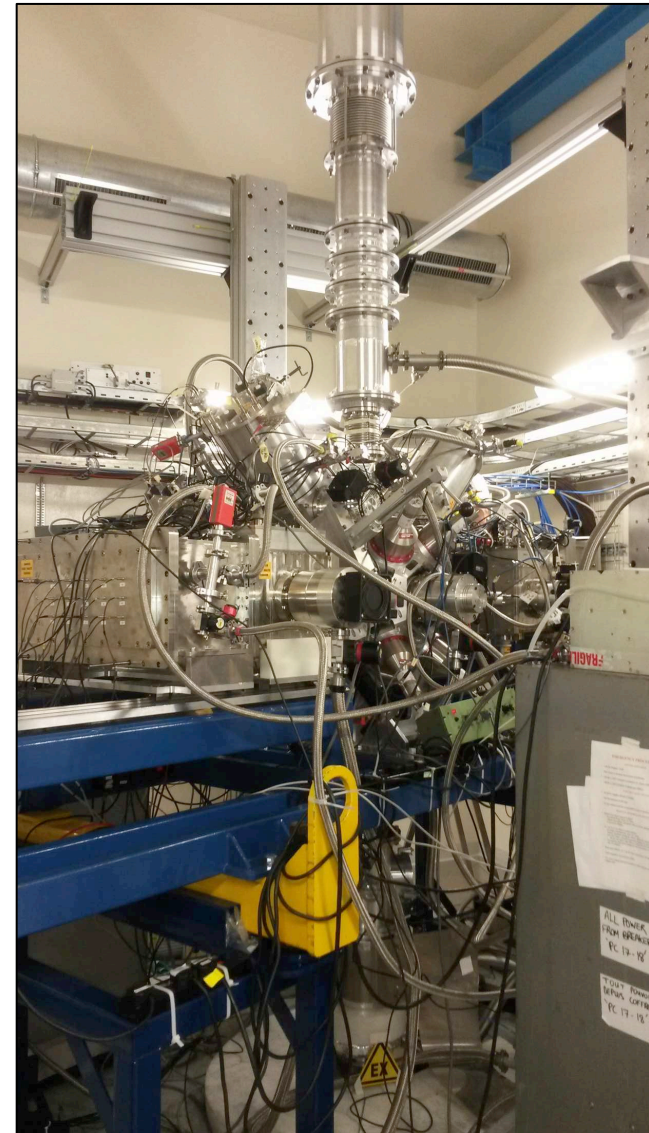
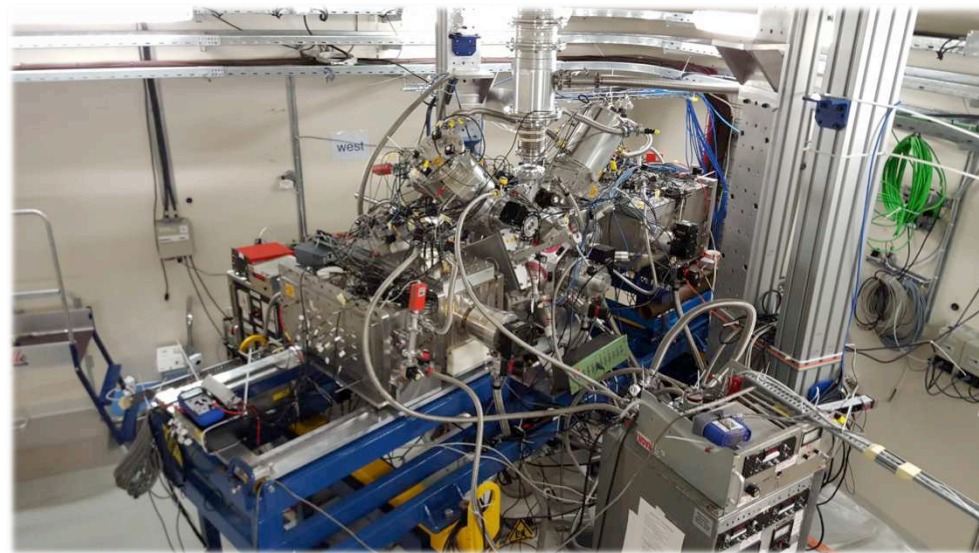
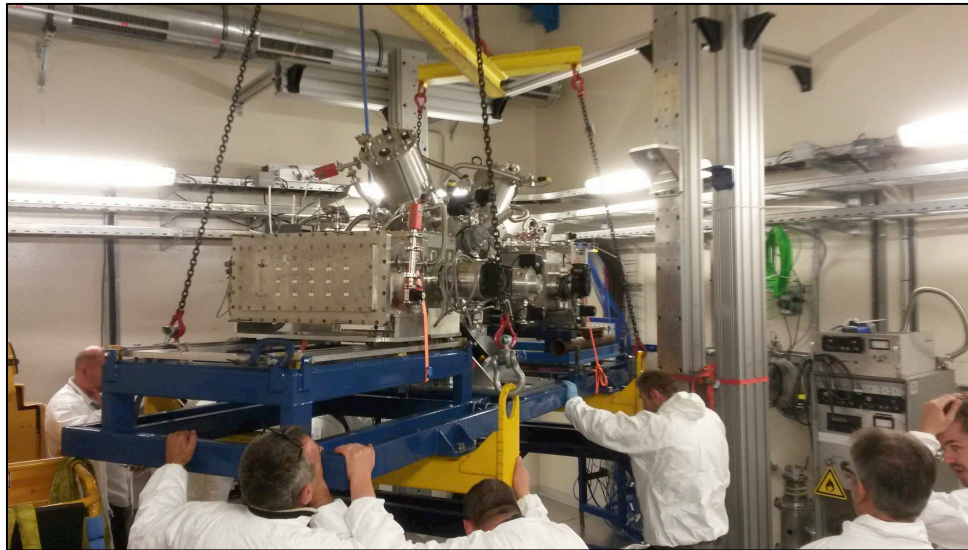


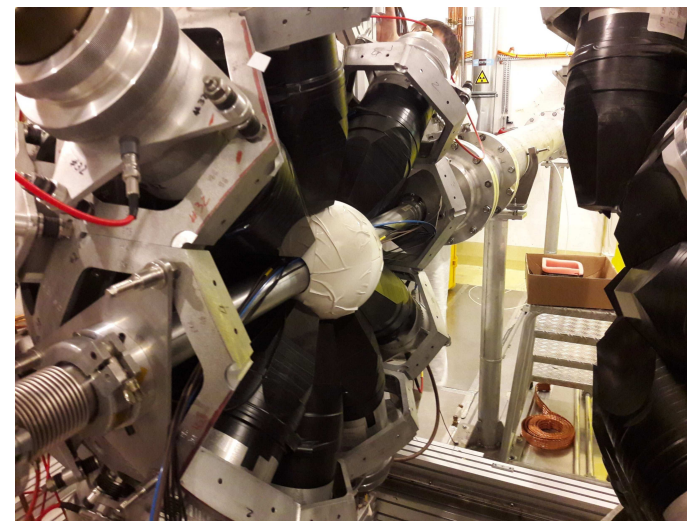
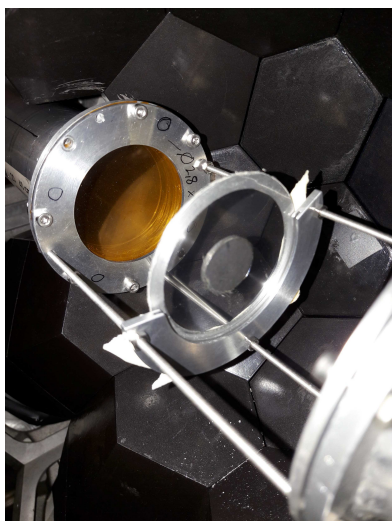
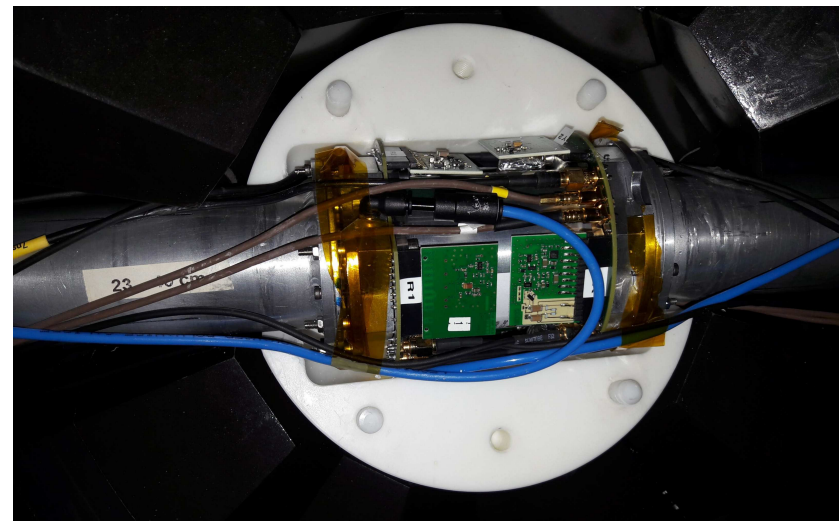
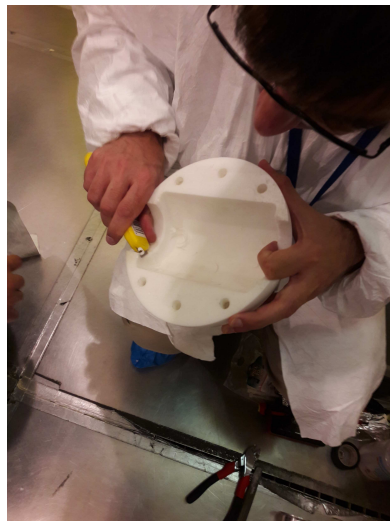


PhD L. Damone

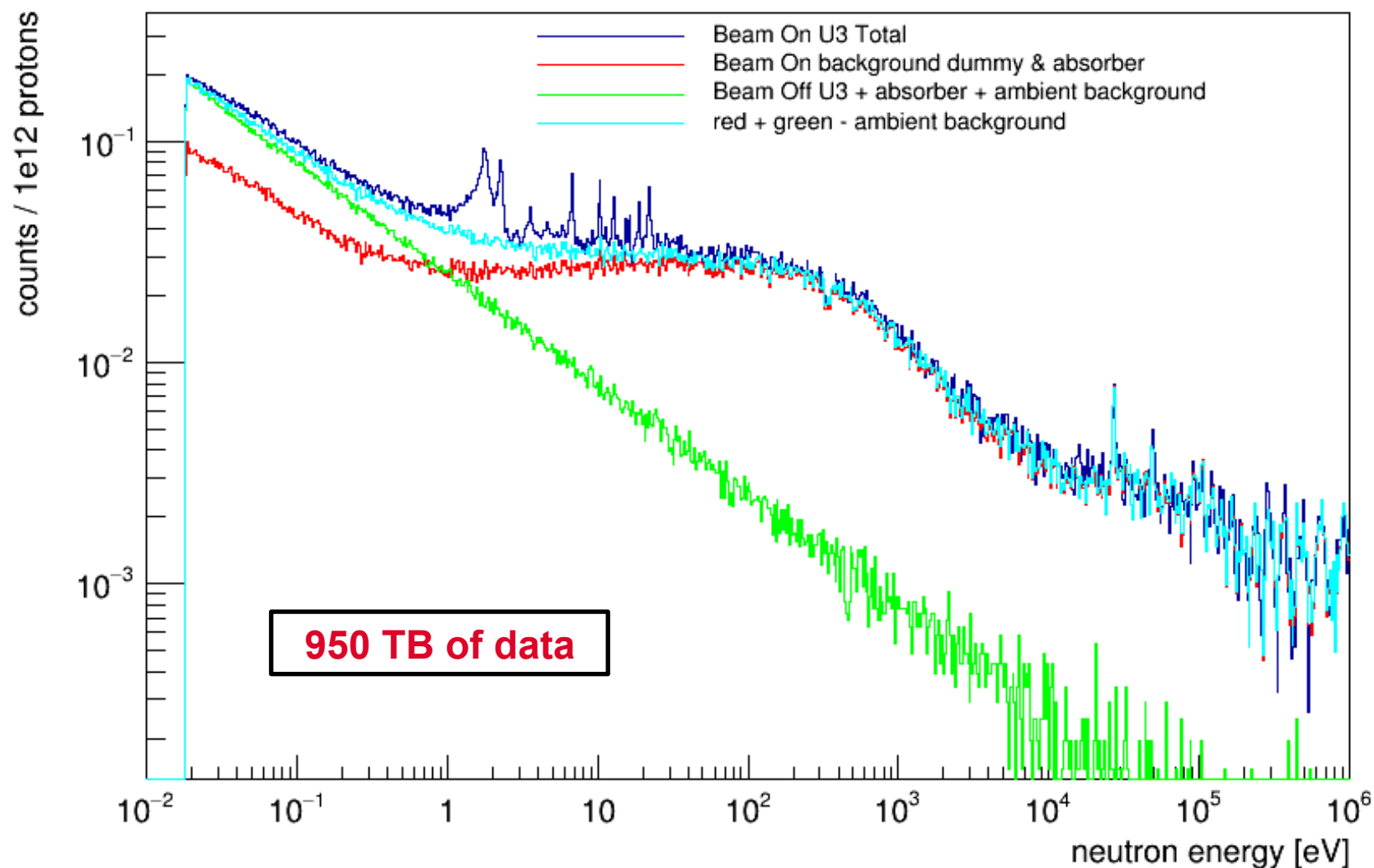


M. Barbagallo

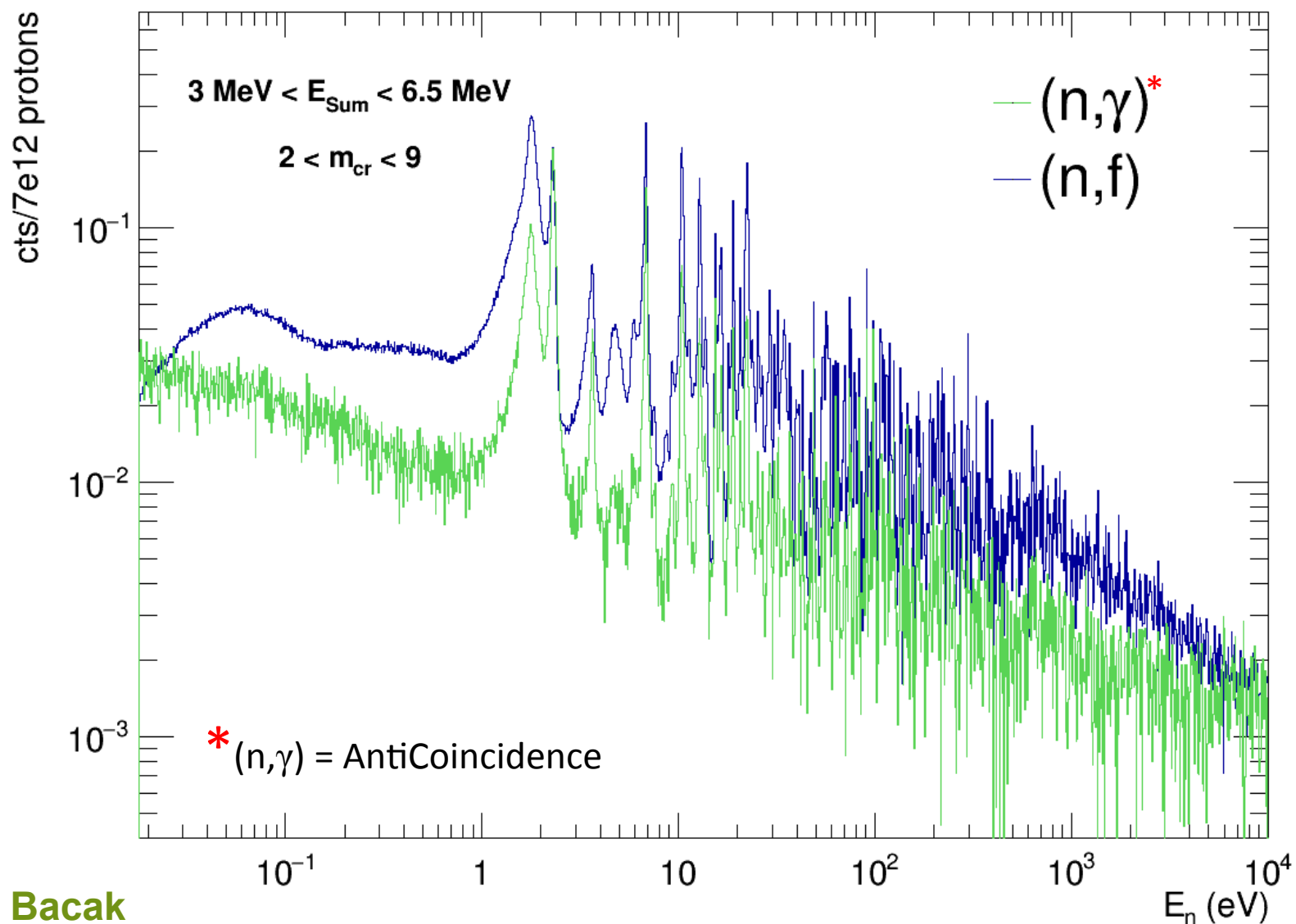




Collaboration: CEA-Saclay, JRC-Geel, CEA-DIF, CEN-Bordeaux, TU-Wien



PhD M. Bacak



PhD M. Bacak

EAR1

- $^{69,71}\text{Ga}(n,\gamma)$
- $^{88}\text{Sr}(n,\gamma)$
- $^{89}\text{Y}(n,\gamma)$
- $^{154,\text{nat}}\text{Gd}(n,\gamma)$
- $^{12}\text{C}(n,p)$
- $^{45}\text{Sc}(n,p)$
- $^{16}\text{O}(n,\alpha)$
- $^{235}\text{U}(n,f)/(n,p)$
- $^{231}\text{Pa}(n,f)$
- $^{77,78}\text{Se}(n,\gamma)$
- $^{79}\text{Zn}(n,\gamma)$
- $^{\text{even}}\text{Gd}(n,\gamma)$
- detector tests

EAR2

- $^{244,246}\text{Cm}(n,\gamma)$
- $^{14}\text{N}(n,p)$
- $^{35}\text{Cl}(n,p)$
- $^{241}\text{Am}(n,\gamma)$
- $^{163}\text{Ho}(n,\gamma)$
- $^{241}\text{Am}(n,f)$
- $^{230}\text{Th}(n,f)$
- $^{239}\text{Pu}(n,f)$
- $^{228,239,241}\text{Pu}(n,f)$
- $^{53}\text{Mn}(n,\gamma)$
- detector tests

No beam at CERN in 2019 and 2020 Long Shutdown 2 (LS2)

■ Status as of April 2017

n_TOF Phase	Reaction	Data Status = Final (datasets with a final publication)	EXFOR Status = Not OK (digitized or incomplete datasets)	EXFOR Status = ongoing (compilation work in progress)	EXFOR Status = OK (mandatory data available)	Data Dissemination Status (OK + ongoing)
I (2001-2004)	(n, γ)	26	11	4	11	58%
	(n,f)	14	0	0	14	100%
	All	40	11	4	25	73%
II (2009-2012)	(n, γ)	7	2	2	3	71%
	(n,f)	2	0	0	2	100%
	(n,cp)	2	0	0	2	100%
	All	11	2	2	7	82%
III (2014-...)	(n,cp)	1	0	0	1	100%

■ (n, γ): 6 datasets under compilation

Phase-I: Zr-90,94,96, Bi-209, and Phase-II: Mg-25
+ U-235 TAC-FT test experiment (on hold, pending green light)

More information: <https://twiki.cern.ch/NTOFPublic>

■ Status as of April 2017

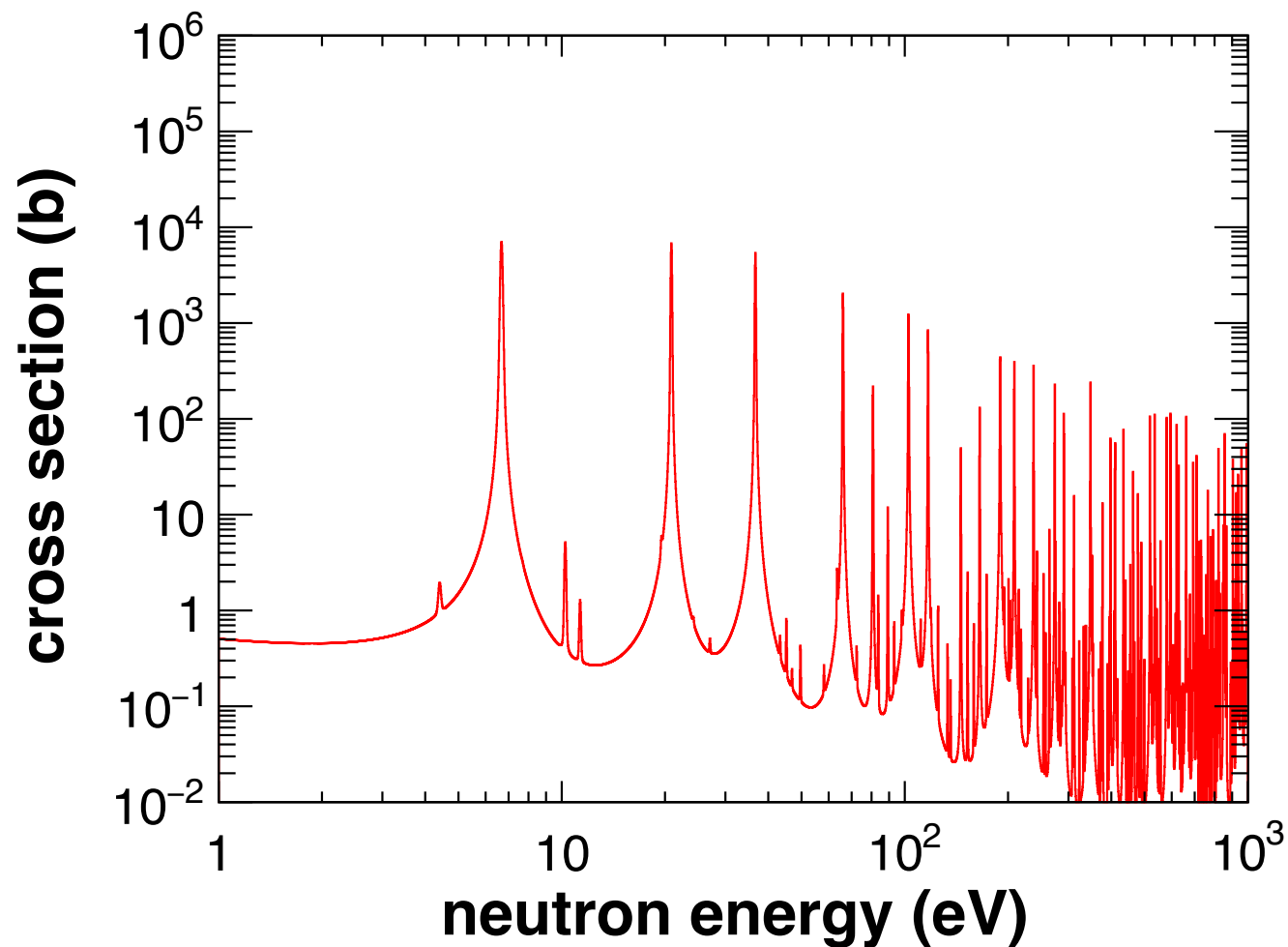
n_TOF Phase	Reaction	Data Status = Final (datasets with a final publication)	EXFOR Status = Not OK (digitized or incomplete datasets)	EXFOR Status = ongoing (compilation work in progress)	EXFOR Status = OK (mandatory data available)	Data Dissemination Status (OK + ongoing)
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	All	11	2	2	7	82%
III (2014-...)	(n,cp)	1	0	0	1	100%

■ (n,f) and (n,cp)

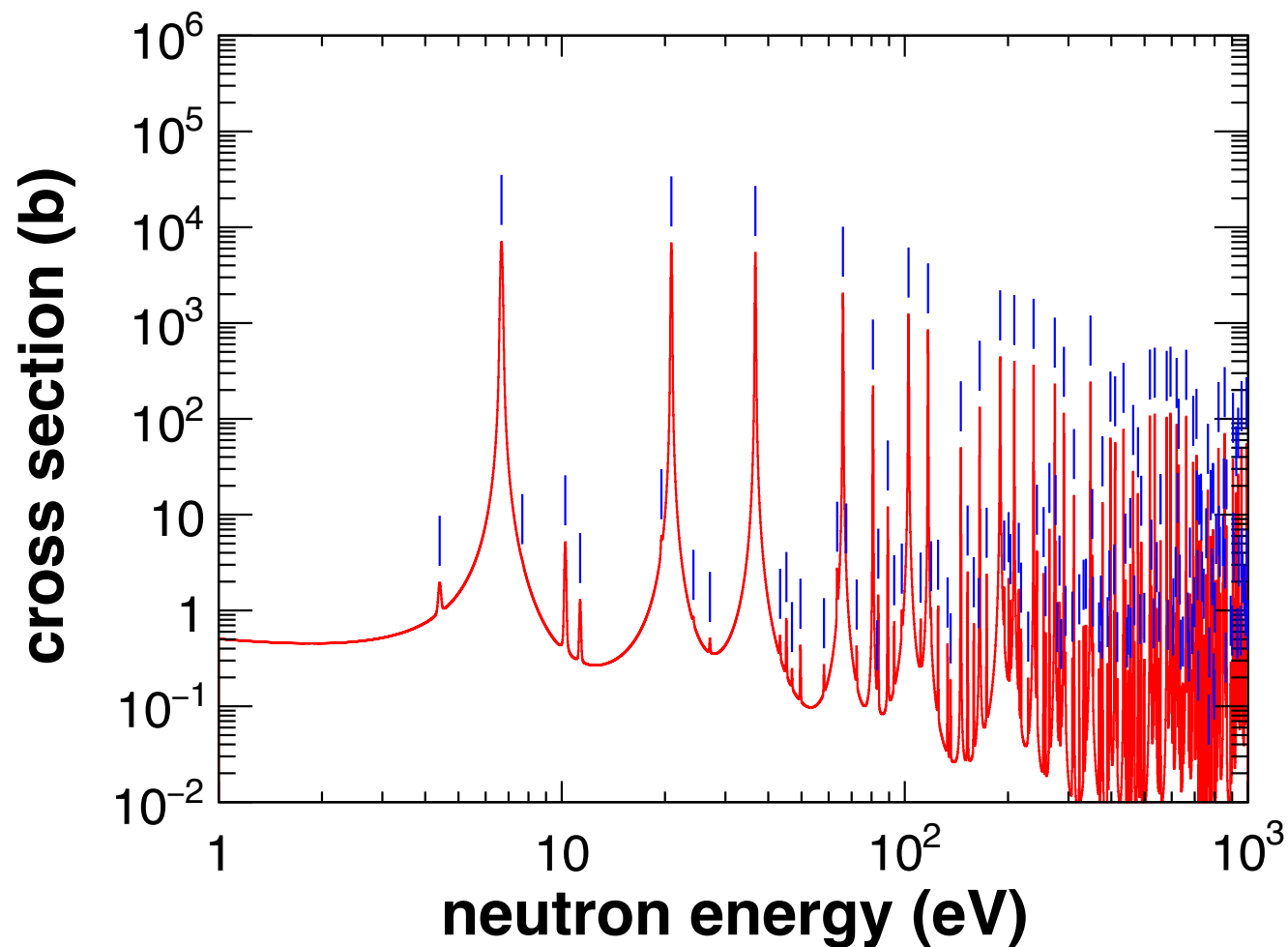
All final/published data are publicly available in EXFOR

More information: <https://twiki.cern.ch/NTOFPublic>

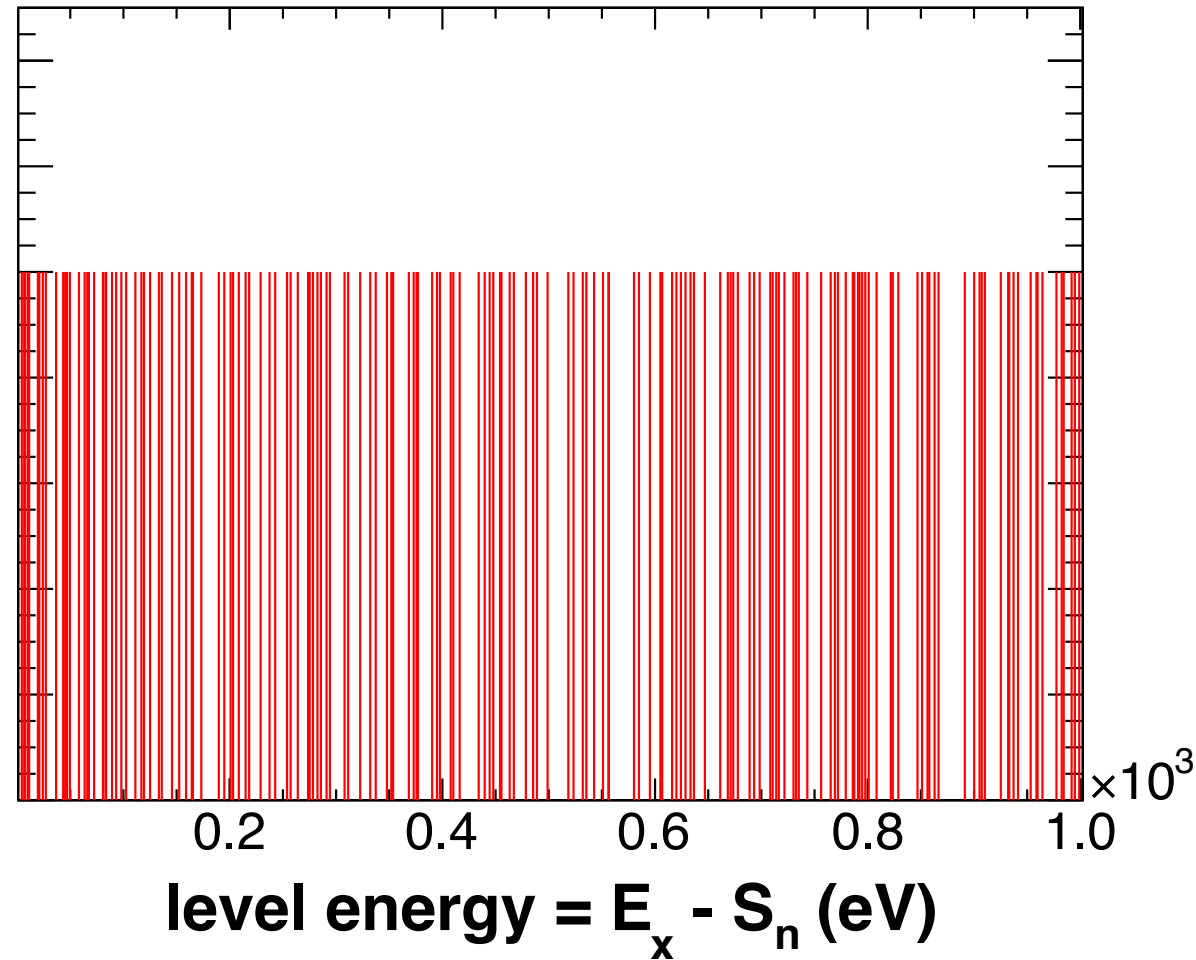
What about LD and PSF?



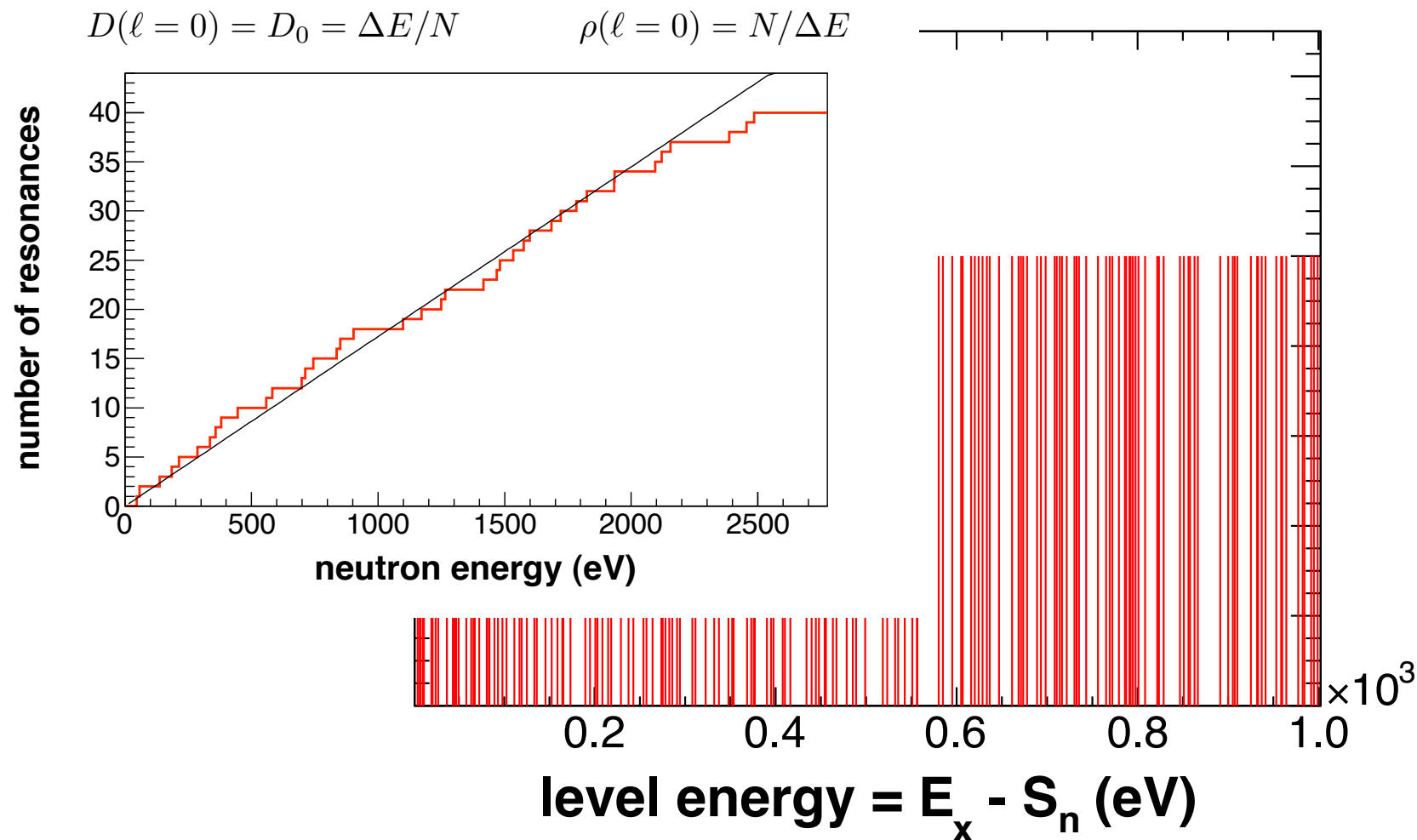
Use level positions to estimate D_0



positions of levels



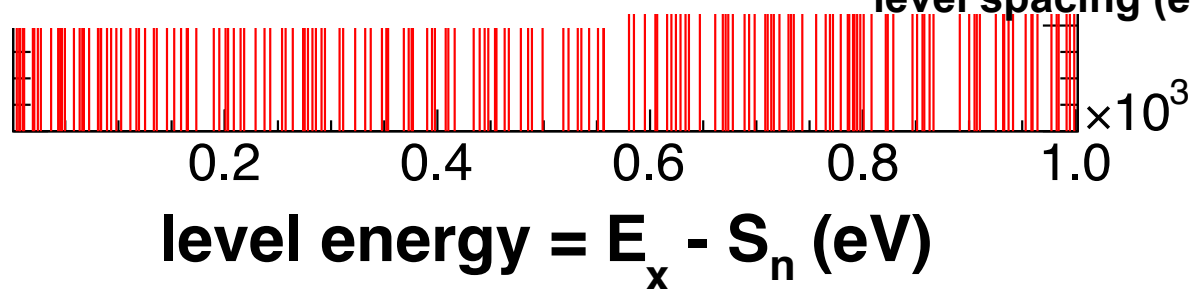
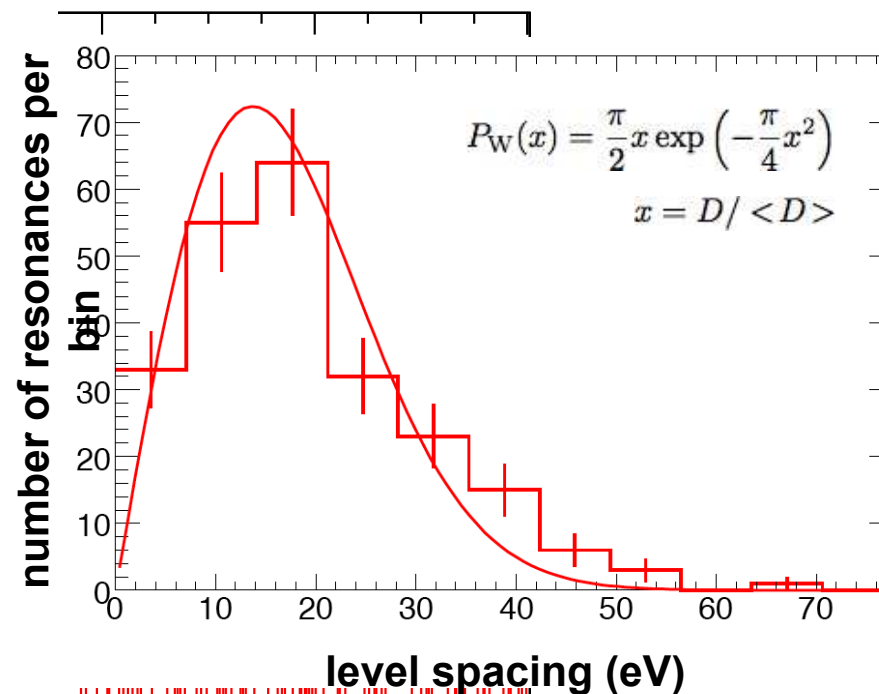
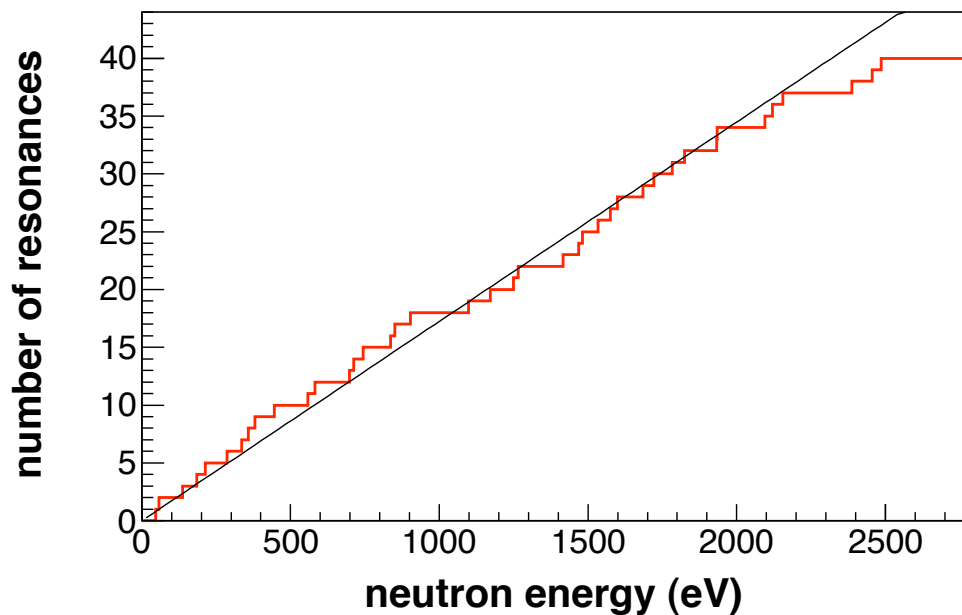
Use level positions to estimate D_0

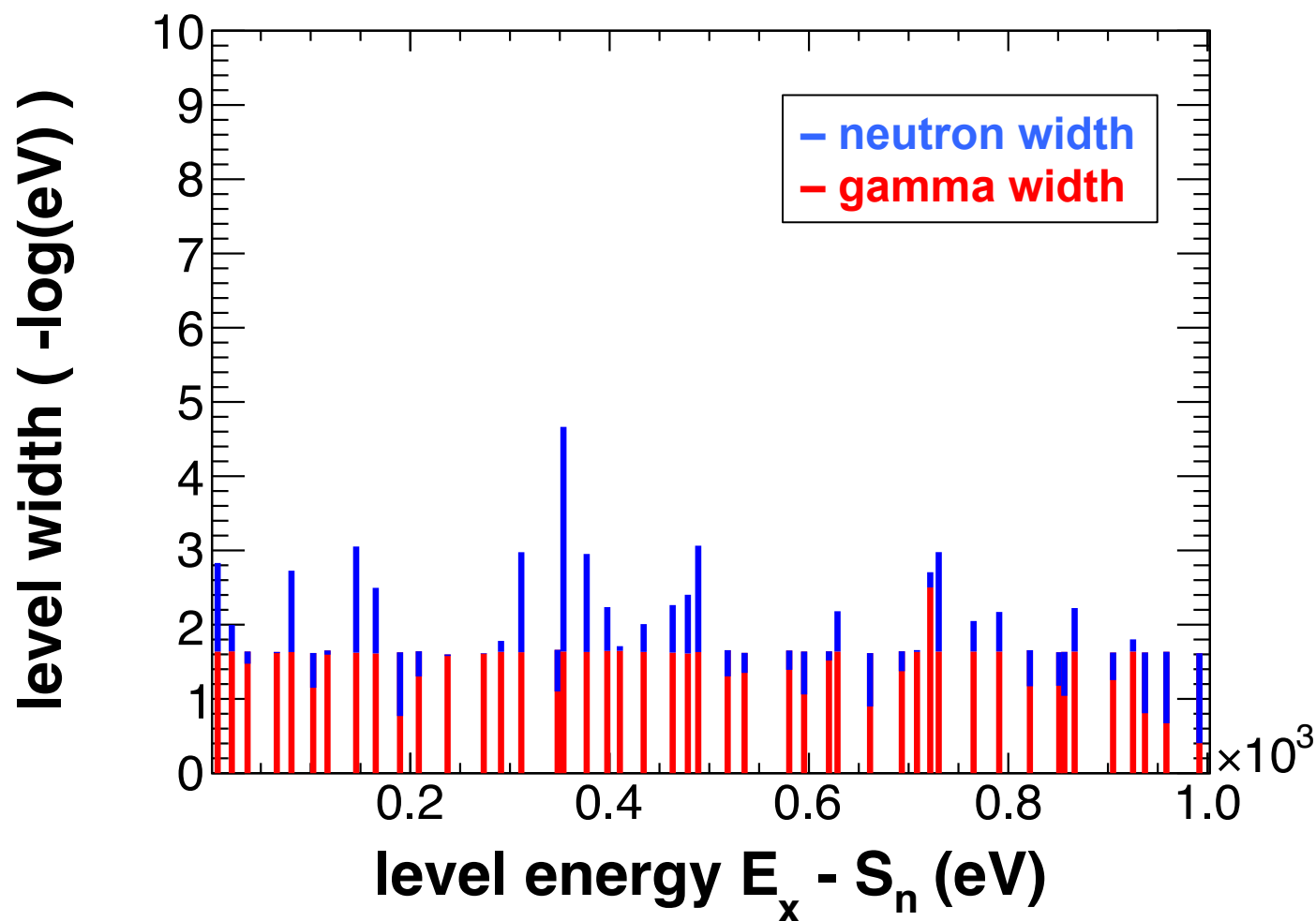


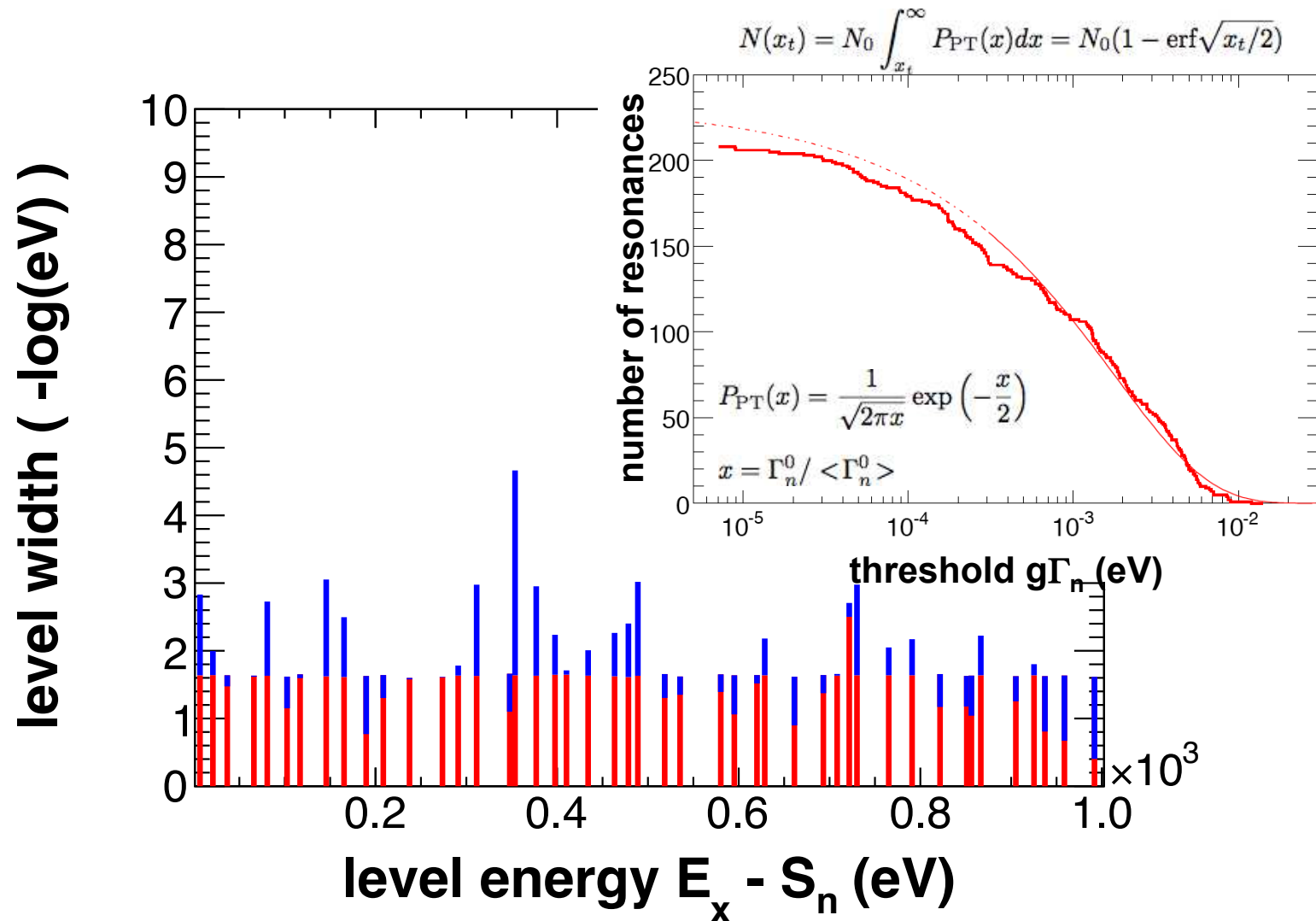
Use level positions to estimate D_0

$$D(\ell = 0) = D_0 = \Delta E / N$$

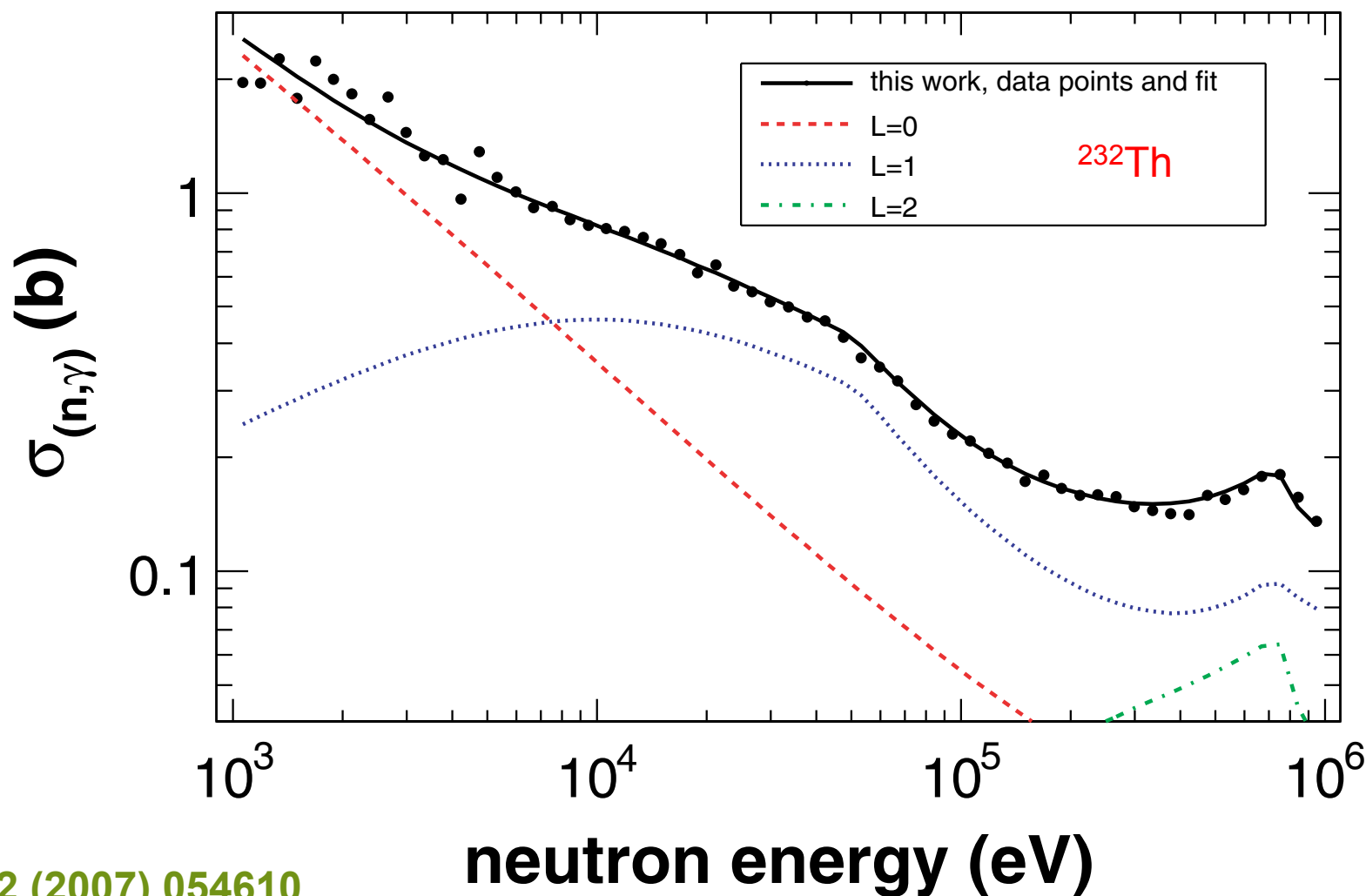
$$\rho(\ell = 0) = N / \Delta E$$





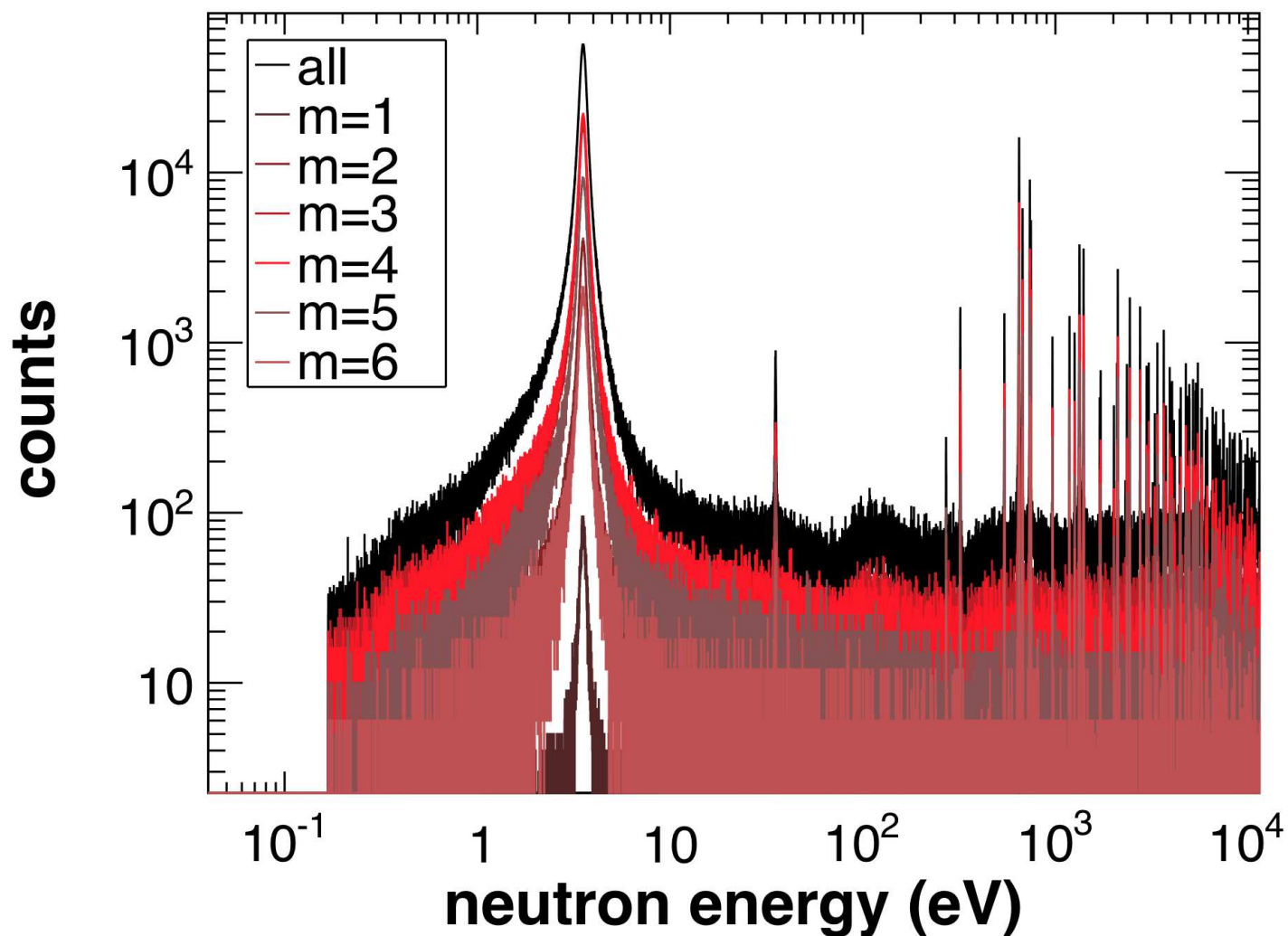


fit: $S_L, D_L \langle \Gamma \gamma \rangle_L$



PRC 72 (2007) 054610

(n,γ) spectra for different multiplicities



- Many neutron-induced reaction datasets taken, submission to EXFOR for dissemination.
- Level densities
 - improved estimates for $D_0 = 1/\rho_0$
- Photon strength functions
 - $\langle \Gamma_\gamma \rangle / D$ and $\langle \Gamma_n \rangle / D$ from resonance-averaged data
 - shapes of multistep cascades to be used

O. Aberle, J. Andrzejewski, L. Audouin, V. Bécaries, M. Bacak, J. Balibrea, M. Barbagallo, S. Barros, F. Bečvář, C. Beinrucker, F. Belloni, E. Berthoumieux, J. Billowes, V. Boccone, D. Bosnar, A. Brown, M. Brugger, M. Caamaño, F. Calviño, M. Calviani, D. Cano-Ott, R. Cardella, A. Casanovas, D. M. Castelluccio, F. Cerutti, Y. H. Chen, E. Chiaveri, N. Colonna, G. Cortés, M. A. Cortés-Giraldo, L. Cosentino, L. A. Damone, K. Deo, M. Diakaki, C. Domingo-Pardo, R. Dressler, E. Dupont, I. Durán, B. Fernández-Domínguez, A. Ferrari, P. Ferreira, P. Finocchiaro, R. J. W. Frost, V. Furman, K. Göbel, M. B. Gómez-Hornillos, A. R. García, A. Gawlik, I. Gheorghe, S. Gilardoni, T. Glodariu, I. F. Gonçalves, E. González, A. Goverdovski, E. Griesmayer, C. Guerrero, F. Gunsing, H. Harada, T. Heftrich, S. Heinitz, A. Hernández-Prieto, J. Heyse, D. G. Jenkins, E. Jericha, F. Käppeler, Y. Kadi, A. Kalamara, T. Katabuchi, P. Kavargin, V. Ketlerov, V. Khryachkov, A. Kimura, N. Kivel, M. Kokkoris, M. Krtička, D. Kurtulgil, E. Leal-Cidoncha, C. Lederer, H. Leeb, J. Lerendegui-Marco, M. Licata, S. Lo Meo, S. J. Lonsdale, R. Losito, D. Macina, J. Marganec, T. Martínez, A. Masi, C. Massimi, P. Mastinu, M. Mastromarco, F. Matteucci, E. A. Maugeri, A. Mazzone, E. Mendoza, A. Mengoni, P. M. Milazzo, F. Mingrone, M. Mirea, S. Montesano, A. Musumarra, A. Negret, R. Nolte, A. Oprea, F. R. Palomo-Pinto, C. Paradela, N. Patronis, A. Pavlik, J. Perkowski, I. Porras, J. I. Porras, J. Praena, J. M. Quesada, D. Radeck, K. Rajeev, T. Rauscher, R. Reifarth, A. Riego-Perez, M. Robles, P. C. Rout, C. Rubbia, J. A. Ryan, M. Sabaté-Gilarte, A. Saxena, P. Schillebeeckx, S. Schmidt, D. Schumann, P. Sedyshev, A. G. Smith, N. V. Sosnin, A. Stamatopoulos, S. V. Suryanarayana, G. Tagliente, J. L. Tain, A. Tarifeño-Saldivia, L. Tassan-Got, A. Tsinganis, S. Valenta, G. Vannini, V. Variale, P. Vaz, A. Ventura, V. Vlachoudis, R. Vlastou, A. Wallner, S. Warren, M. Weigand, C. Weiss, C. Wolf, P. J. Woods, T. Wright, and P. Žugec



<https://www.youtube.com/watch?v=atJNBaDUmIU>