An activation database for materials used at high-intensity laser acceleration facilities

A. Fasso',[1] Anna Ferrari,[2,1]
V. Olšovcova,[1] R. Versaci [1]

(1) Eli- Beamlines, Prague, Czech Republic
(2) Helmholtz-Zentrum Dresden-Rossendorf

Outline

- A fast look at the ELI Project and at the ELI-Beamlines Facility
- Motivation of our work: why to build an activation database
- Structure of the database:
  type and energy of incident particles,
  irradiation and cooling time pattern, considered materials
- Selected results for activation analysis

A look at the ELI Project

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ELI (Extreme Light Infrastructure) is a new scientific infrastructure devoted to the fundamental study of laser-matter interaction **in a new regime of laser intensity,** the ultra-relativistic regime ($I_L > 10^{23}$ W/cm^2)

ELI will attain his extreme power from the shortness of its pulses, from *femtoseconds* (10^{-15} s) to *attoseconds* (10^{-18} s)

➡ A **new generation of compact accelerators**, delivering high energy particles and radiation beams, can be then investigated

Potential applications and technology transfer ➡

- **Accelerator science (new and compact approaches)**
- **Plasma physics** (diagnostics of fusion plasmas, compressed warm dense matter, laboratory astrophysics)
- Development of new methods of nuclear waste processing
- Ageing studies of nuclear reactor materials
- Material science
- Medicine (cancer therapy)

ELI is a collaboration of 13 european countries

A look at the ELI-Beamlines Project

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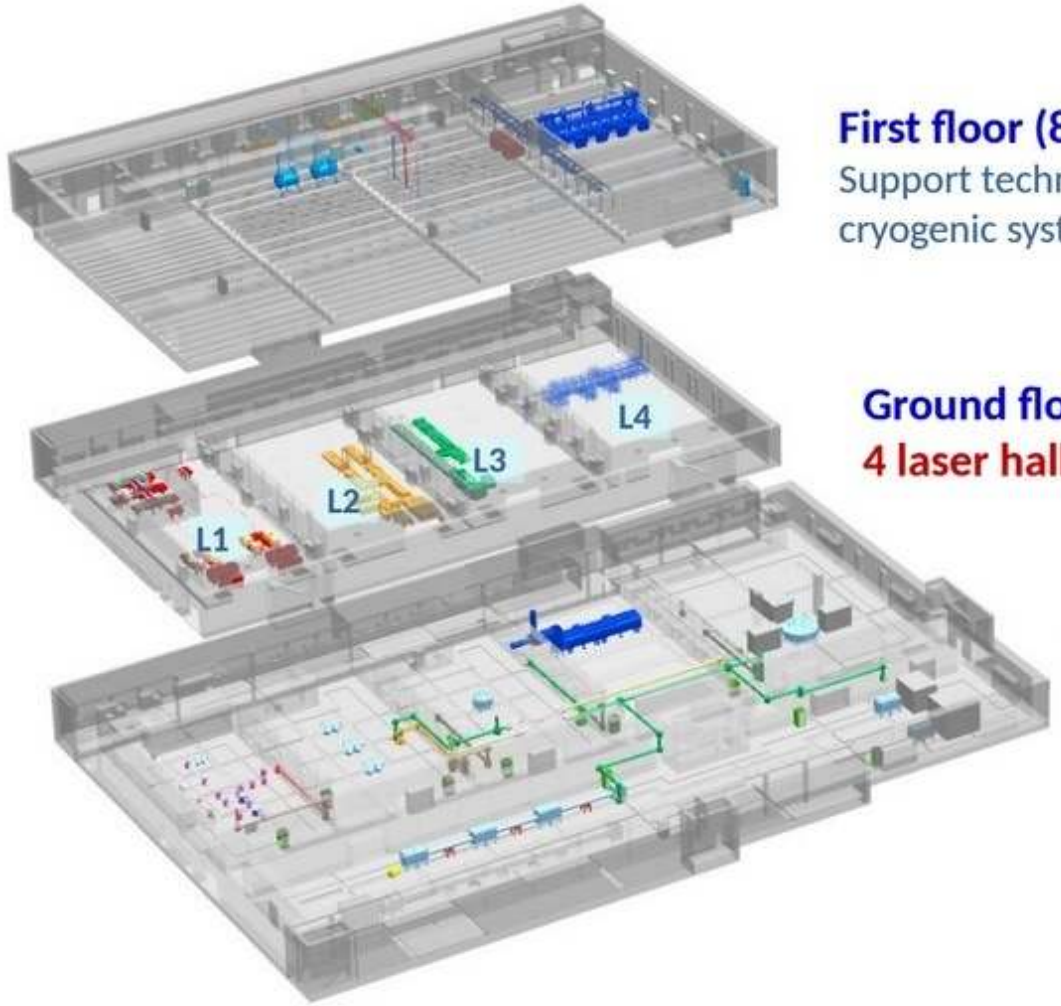
One of the designed 4 pillars:

ELI- Beamlines facility in Czech Republic should complete the construction in Summer 2015

(July 14)

A look at the ELI-Beamlines Project



First floor (80 x 40 m)
Support technologies, cooling systems, cryogenic systems

Ground floor (80 x 40 m)
4 laser halls (L1 to L4)

Basement (110 x 60 m)
6 dedicated experimental halls (E1 to E6)

A look at the ELI-Beamlines Project

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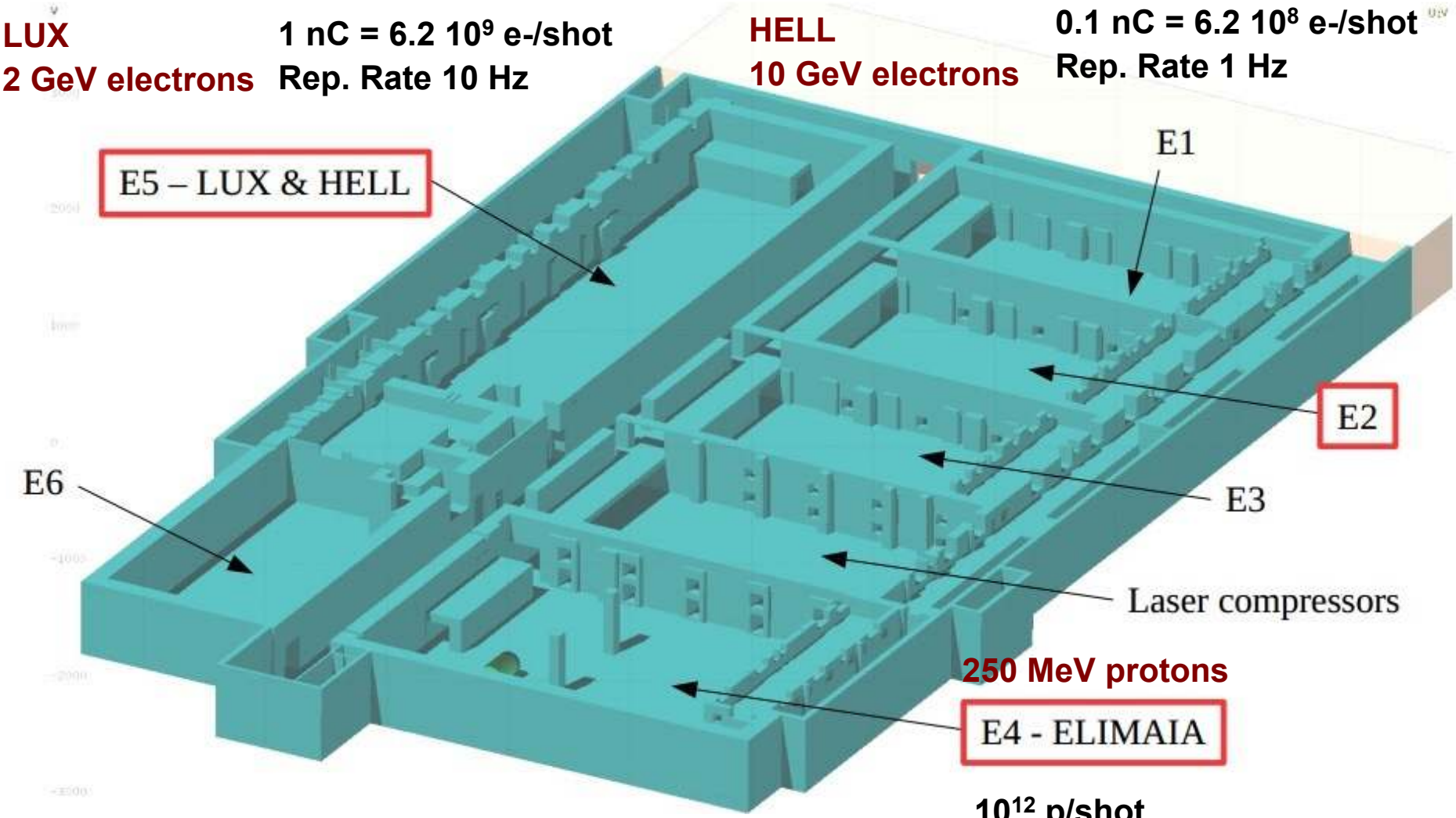
LUX
2 GeV electrons

1 nC = 6.2 10^9 e-/shot
Rep. Rate 10 Hz

HELL
10 GeV electrons

0.1 nC = 6.2 10^8 e-/shot
Rep. Rate 1 Hz



10^{12} p/shot
Rep. Rate 1 Hz

Motivation of this work

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The goal of this study is to perform an evaluation of the possible activation problems in the ELI experimental halls, in order to give **a guide in the choice of the most typical materials** used in the vacuum chambers where the experiments will be carried out (**targets, diagnostic elements, chamber itself**) and around

➡ **A systematic analysis with the FLUKA Monte Carlo code in on-going, even if activation problems in ELI are not expected to be an issue**

Radiation protection problems considered:

- **Ambient dose equivalent rates**
  at the typical position of somebody working close to the activated item

- **Activity and specific activity of the activated item**
  (this affects the possible removal of the item , storage conditions, and eventually decommissioning)

Structure of the Database

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✓ **Particles considered: protons, electrons**

✓ **Energies: 100 MeV** for both protons and electrons are adequate for the initial ELI running time

✓ **Irradiation and cooling time patterns:**

- **Short (1 d)** **EOI + cooling 1 h, 3 h, 8 h**
- **Intermediate (1 month)** **EOI + cooling 8 h, 24 h, 1 w**
- **Long (1 y)** **EOI + cooling 1 w, 4 w, 6 months**

✓ **Size and shape of the irradiated object, characterization of irradiation:**

- pencil beam of monoenergetic p, e-
- slabs of 60 x 60 cm^2 section, **30 cm** tickness

This arbitrary choice has been made to simplify the comparison between different materials

Materials

Materials considered: structural materials, materials possibly used for viewports, plastics, special materials (tungsten alloys)

Table 1: H*(10) rate in μSv/h at 30 cm from slabs of different materials, irradiated by 100 MeV protons

Material	One-day irradiation: decay times					One-month irradiation: decay times				One-year irradiation: decay times			
	EOI	10 min	1 h	3 h	8 h	EOI	8 h	24 h	1 wk	EOI	1 wk	4 wk	26 wk
Aluminium alloys													
Al 2090	4250	554	357	251	156	4750	497	241	16.5	4890	155	144	110
Al 2219	3650	626	398	283	178	4220	572	281	23.7	4400	194	172	117
Al 3003	4160	509	350	249	158	4680	512	253	20.0	4820	157	140	118
Al 5083	4540	497	352	252	158	5050	509	248	17.2	5200	163	152	132
Al 6082	4240	483	337	238	148	4720	472	229	14.8	4850	143	134	115
Al 7005	5570	648	412	288	184	6150	581	280	19.5	6300	167	151	118
Copper alloys													
Glidcop	4970	3280	1210	646	289	5650	679	288	126	6490	905	733	202
Brass	5260	3490	1440	757	360	6170	913	401	130	6930	835	661	203
Bronze	4990	3240	1280	677	305	5730	750	331	135	6550	884	699	194
Copper	4560	3020	1140	609	276	5220	660	283	122	6050	896	729	199
Window materials													
Glass plate	6720	789	199	53.5	17.6	6770	54.3	28.2	7.15	6850	78.5	75.1	63.2
Pyrex	6190	690	152	40.0	16.9	6240	52.7	26.5	5.45	6300	58.7	55.1	42.4
Quartz	6420	663	145	40.8	20.6	6480	64.6	31.7	4.01	6520	44.1	41.8	33.1
Plastics													
Polyethylene	5490	1710	312	5.53	0.247	5500	6.72	6.66	6.16	5540	41.5	31.6	4.26
Plexiglas	7130	1690	299	5.20	0.159	7130	4.32	4.28	3.96	7160	26.7	20.3	2.74
Iron alloys													
Cast iron	2930	1420	438	192	134	4340	1430	1250	652	6200	2130	1230	376
Wrought iron	3030	1520	499	228	155	4620	1620	1400	730	6720	2410	1400	427
Stainless steel													
304L	2710	1480	539	250	174	4410	1740	1490	762	6730	2620	1520	402
CrNi	3040	1510	561	263	178	4810	1800	1540	798	7190	2710	1560	409
AISI	2850	1580	624	309	204	4700	1880	1580	784	6990	2620	1500	399
Tungsten alloys													
HD18D	4090	2230	1210	889	595	5950	1860	927	144	6400	521	334	88.5
LBL Heavimet	3800	2230	1260	933	631	5790	1990	999	162	6340	633	421	107
Rochester Heav.	3820	2140	1150	832	551	5620	1800	935	159	6180	644	437	111

Results I: Aluminum (intermediate irradiation)

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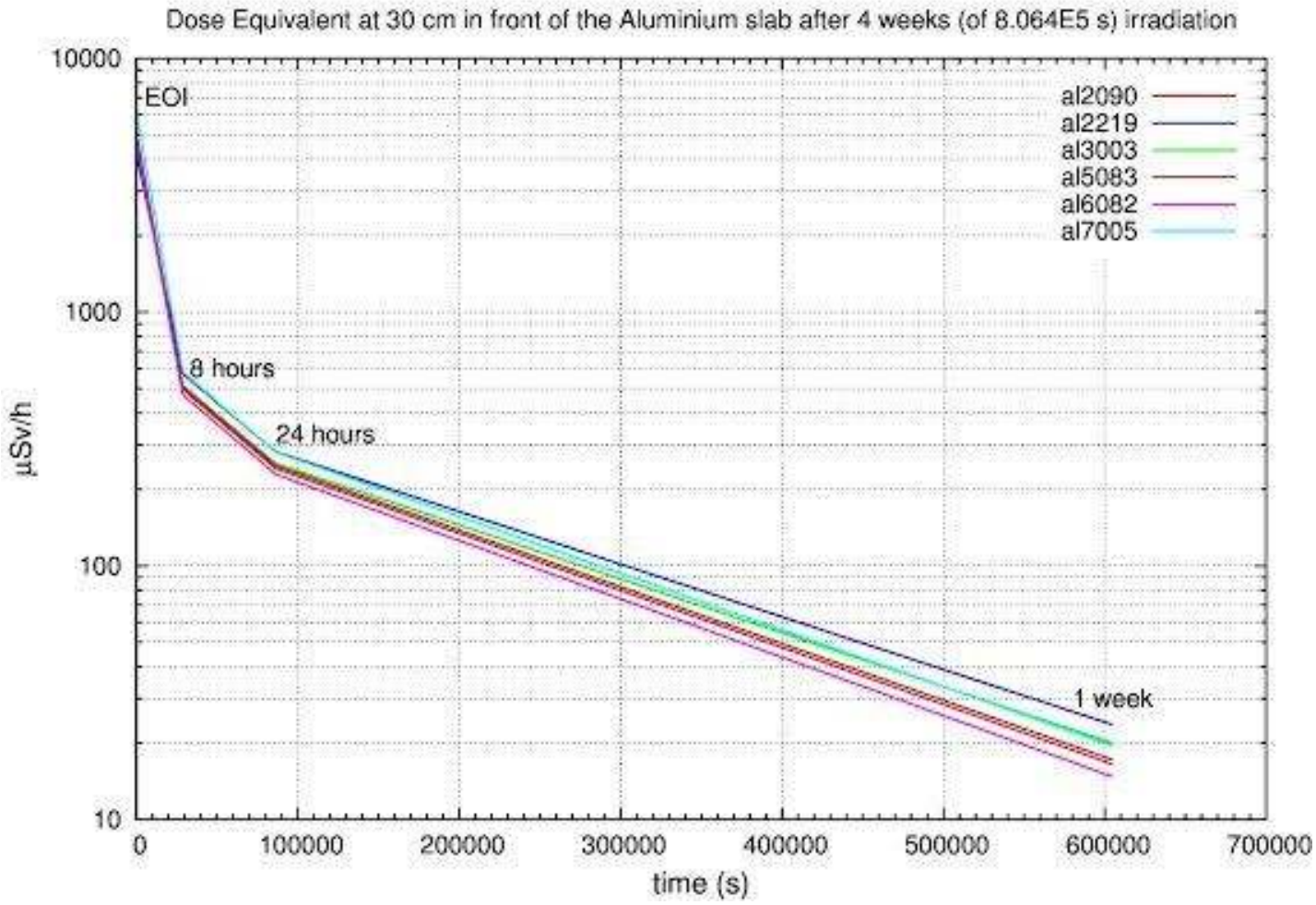
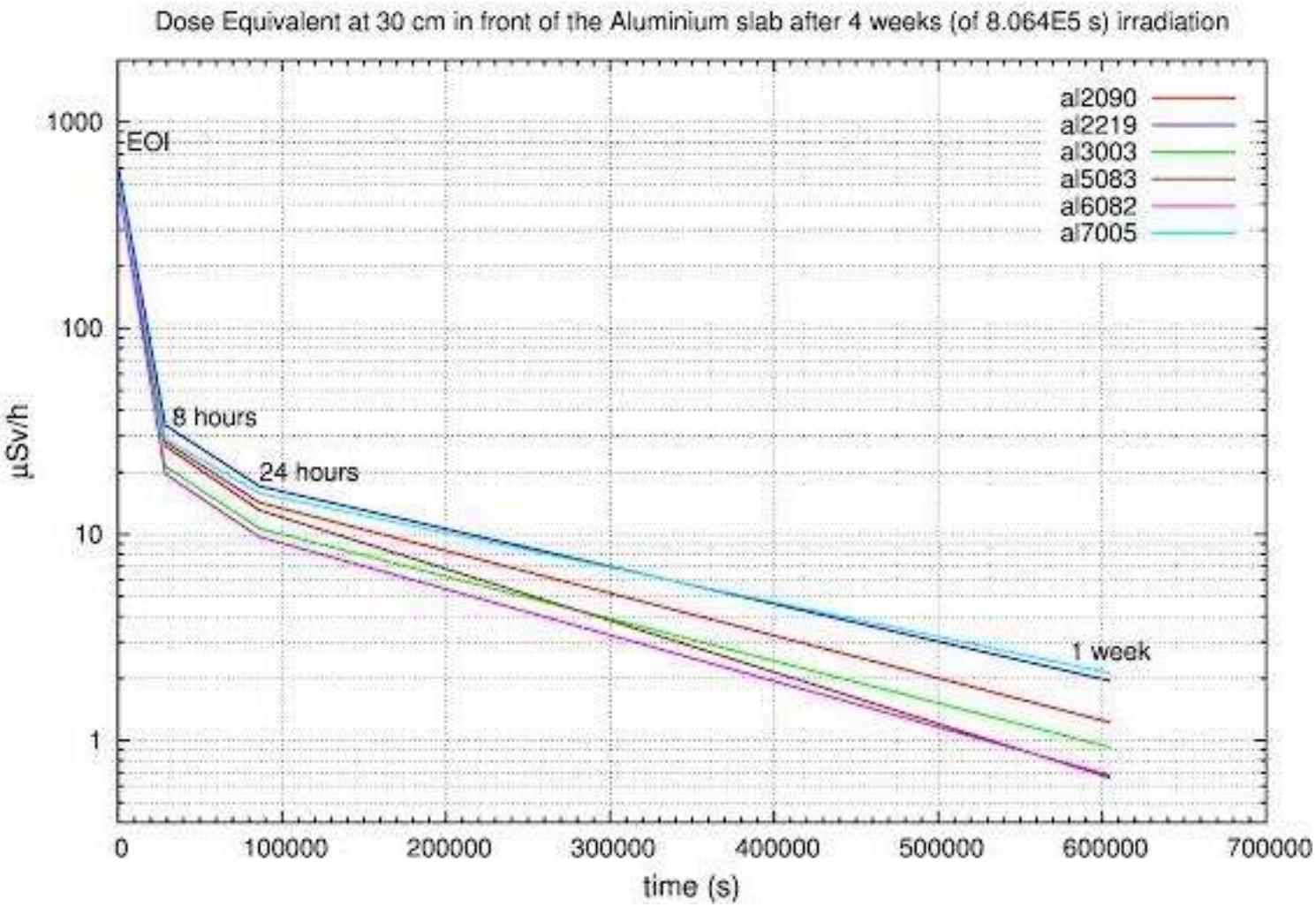
Proton irradiation

H*(10) at 30 cm



Electron irradiation

H*(10) at 30 cm



Results I: Aluminum (intermediate irradiation)

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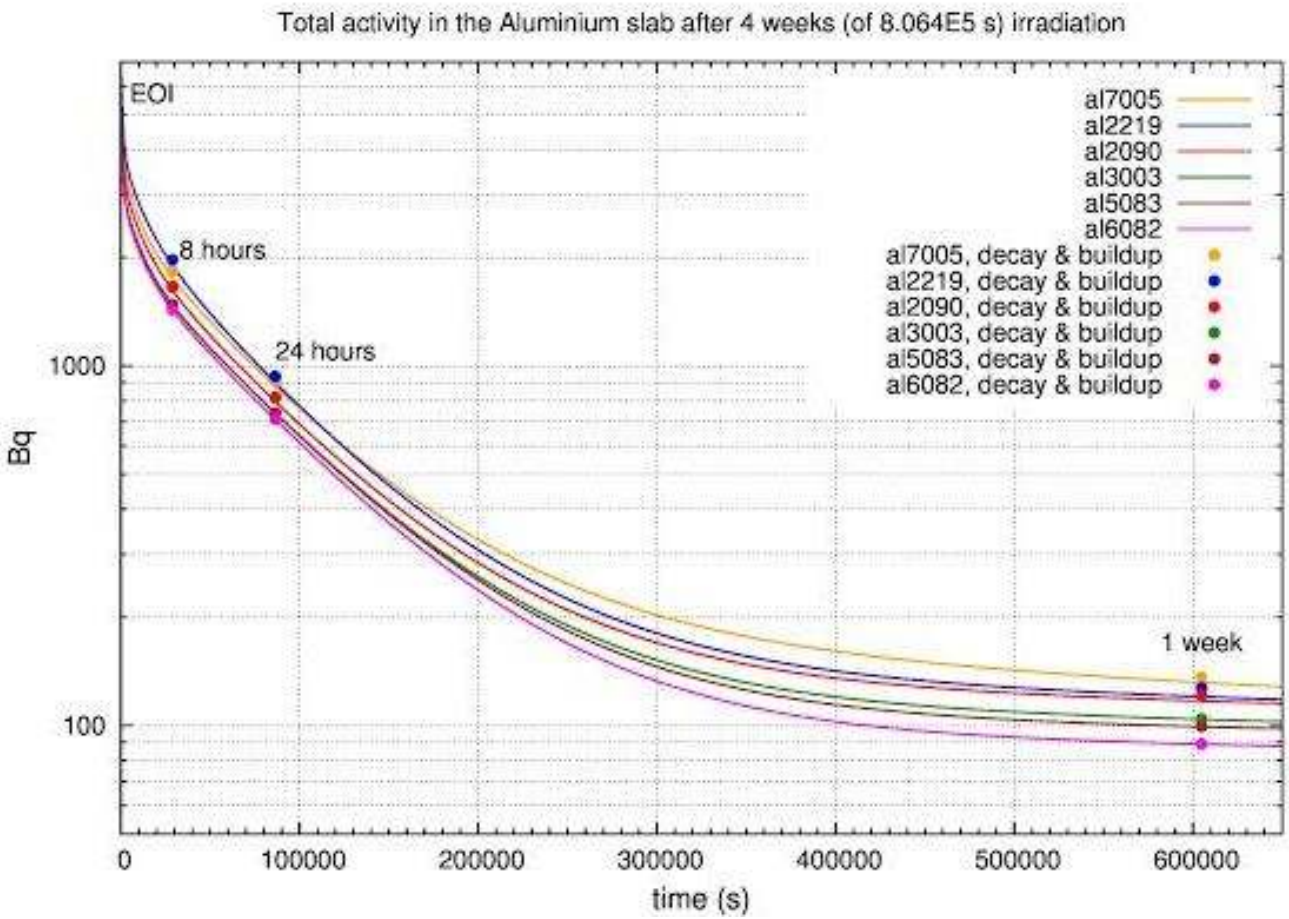
Proton irradiation

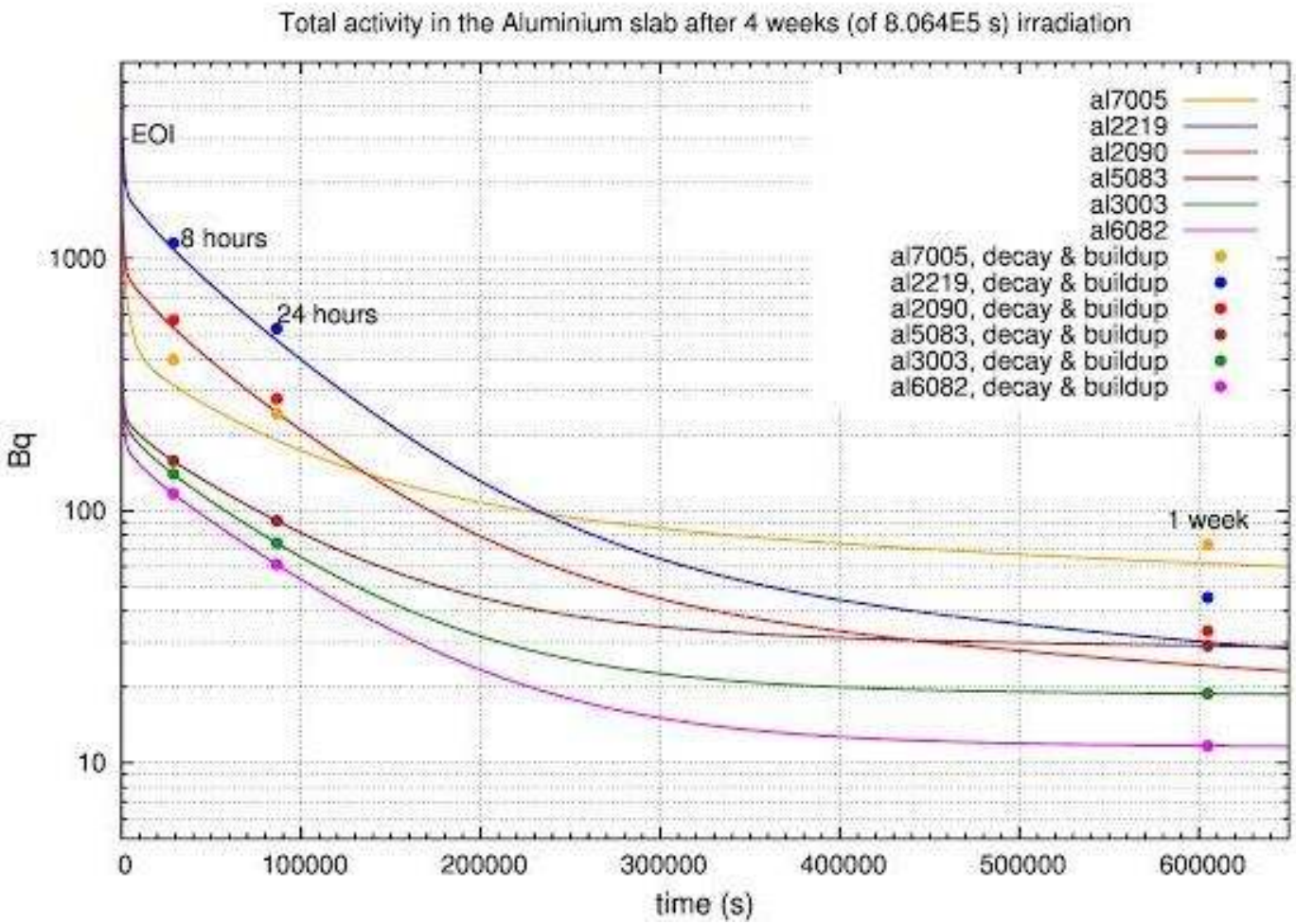
Activity



Al 2219 and **Al 7005** show the highest activities due to their higher content of **Cu** and **Zn** from which Cu, Zn and Co isotopes (especially ^{58}Co, $t_{1/2}$ 70.9 d and ^{60}Co, $t_{1/2}$ 5.3 y) are formed

Electron irradiation

Activity



Results II: W (intermediate irradiation)

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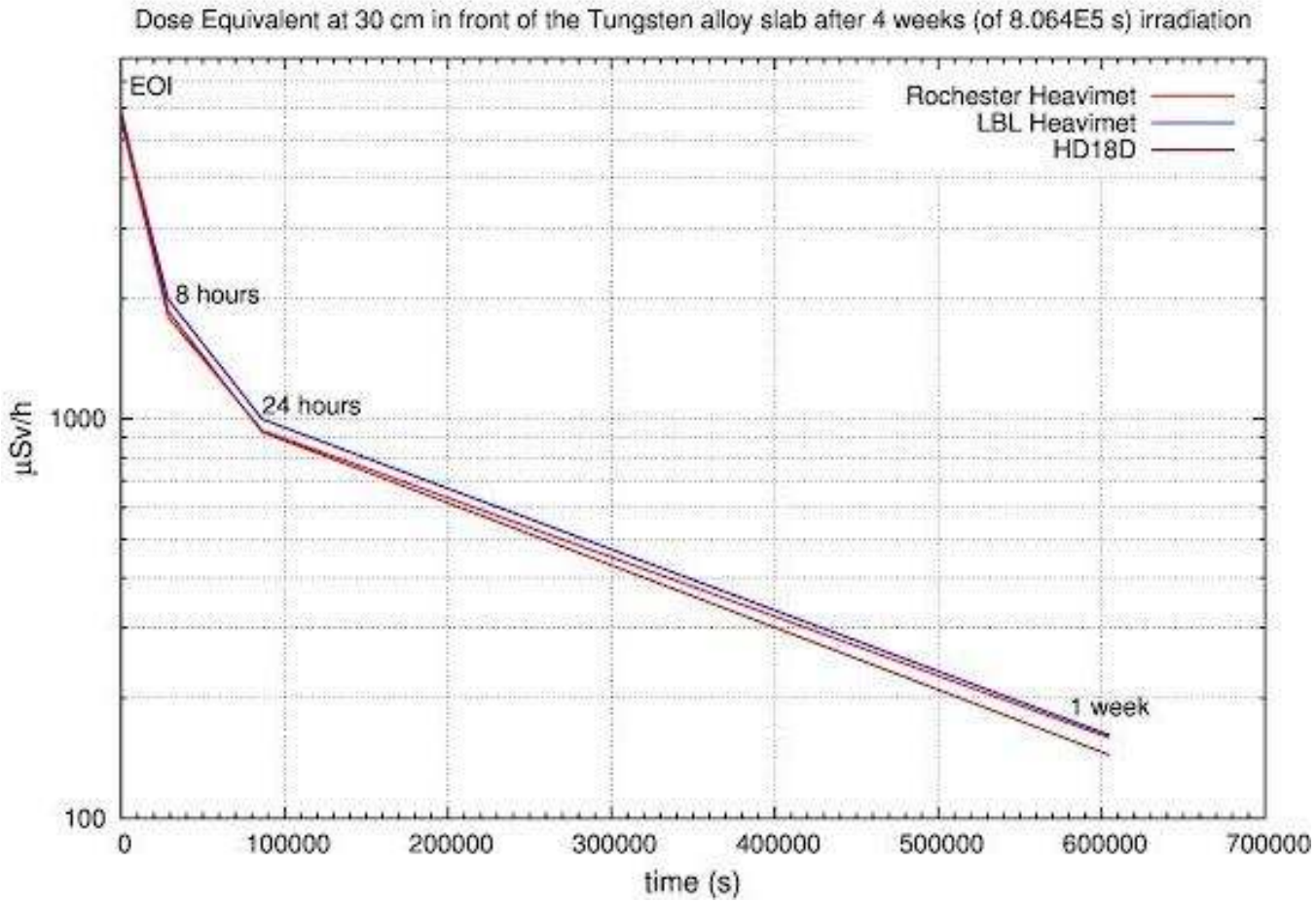
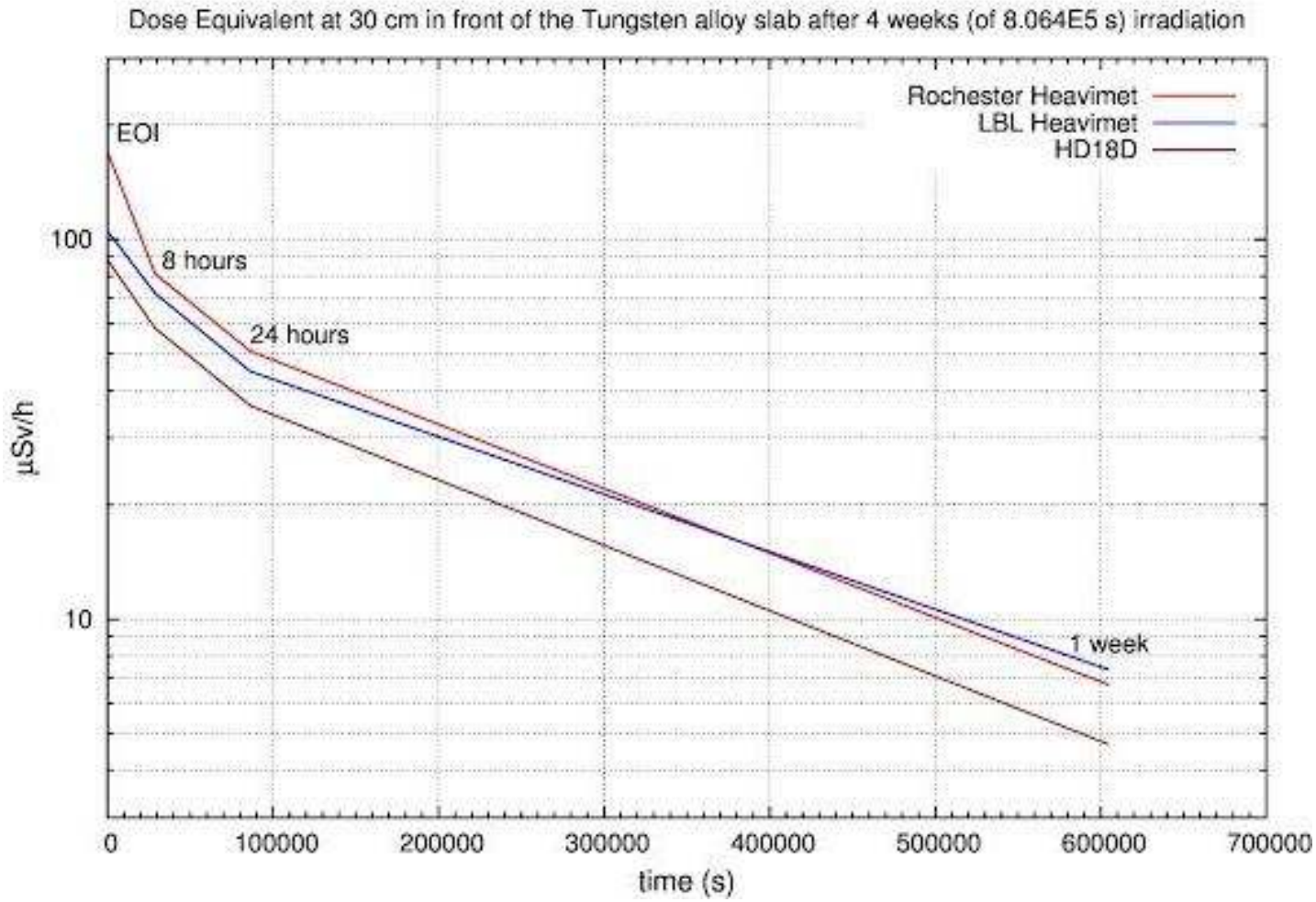
Proton irradiation

H*(10) at 30 cm



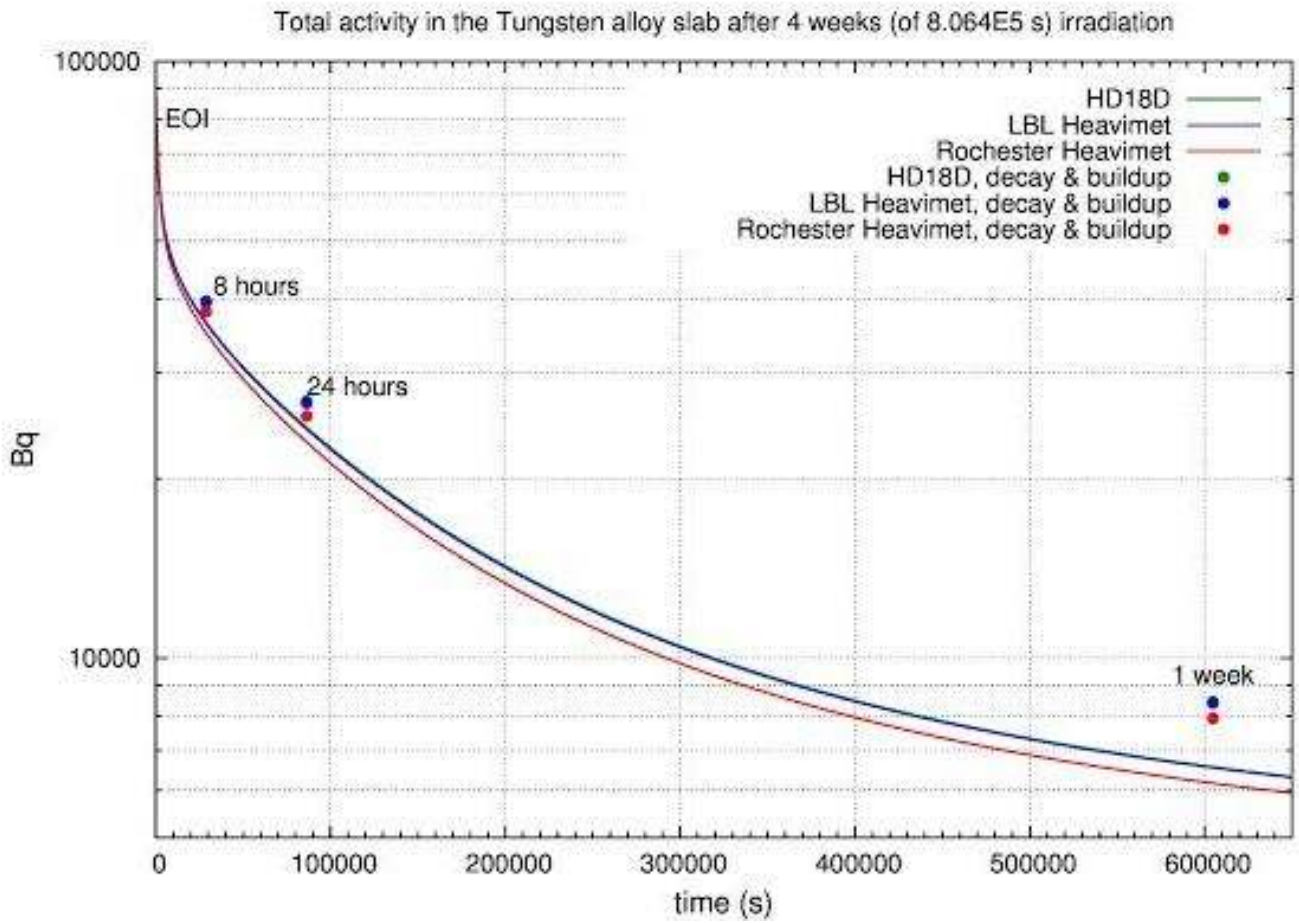
Electron irradiation

H*(10) at 30 cm



Proton irradiation

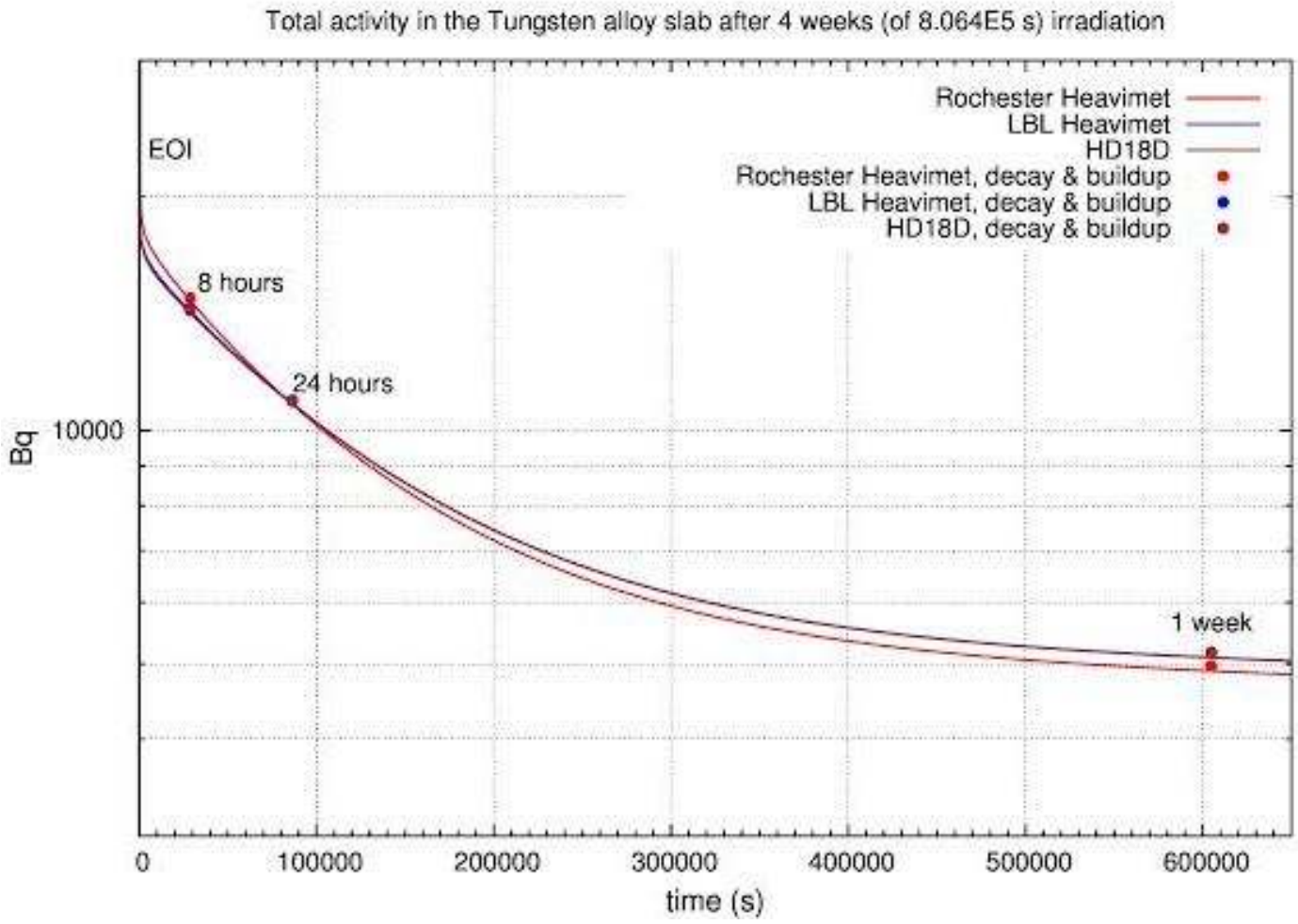
Activity



The important build-up during the decay is due to many **W** and **Ta** isotopes + ^{173}**Hf** and ^{175}**Hf**
For Rochester Heavimet, wich contain more Copper, also ^{63}**Zn** ($t_{1/2}$ 38 min) is important

Electron irradiation

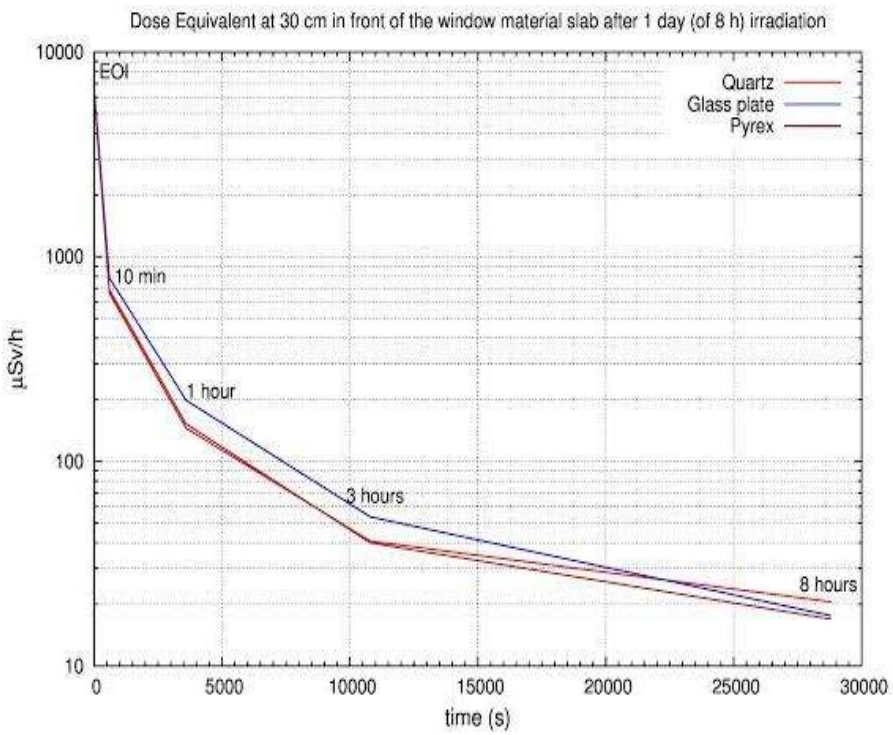
Activity



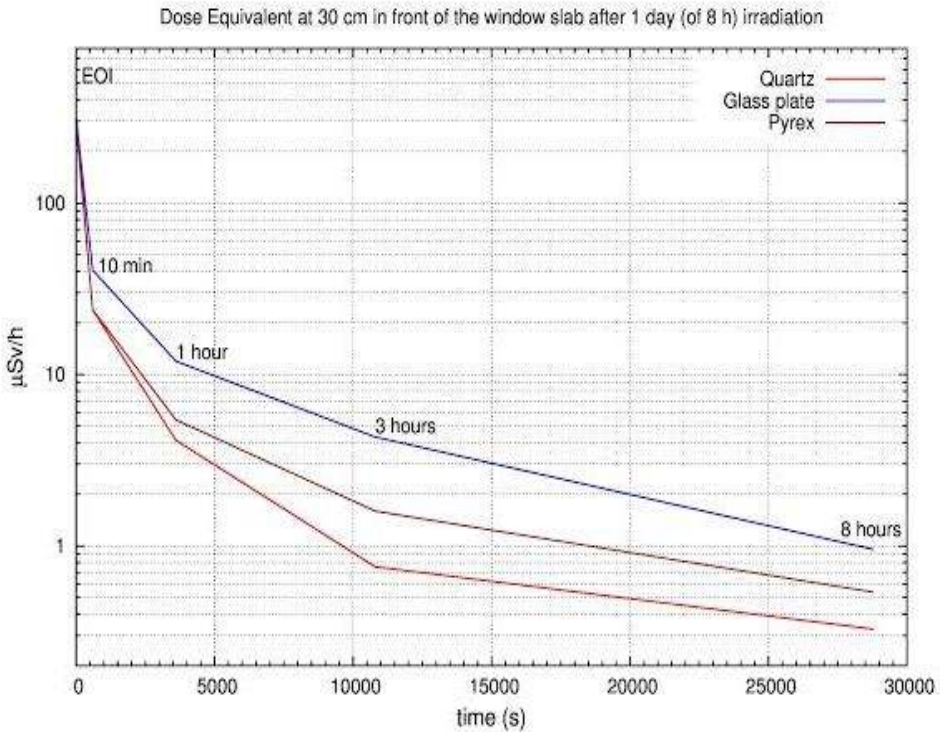
Results III: Glass plates, Pyrex, Quartz

H*(10)

Proton irradiation

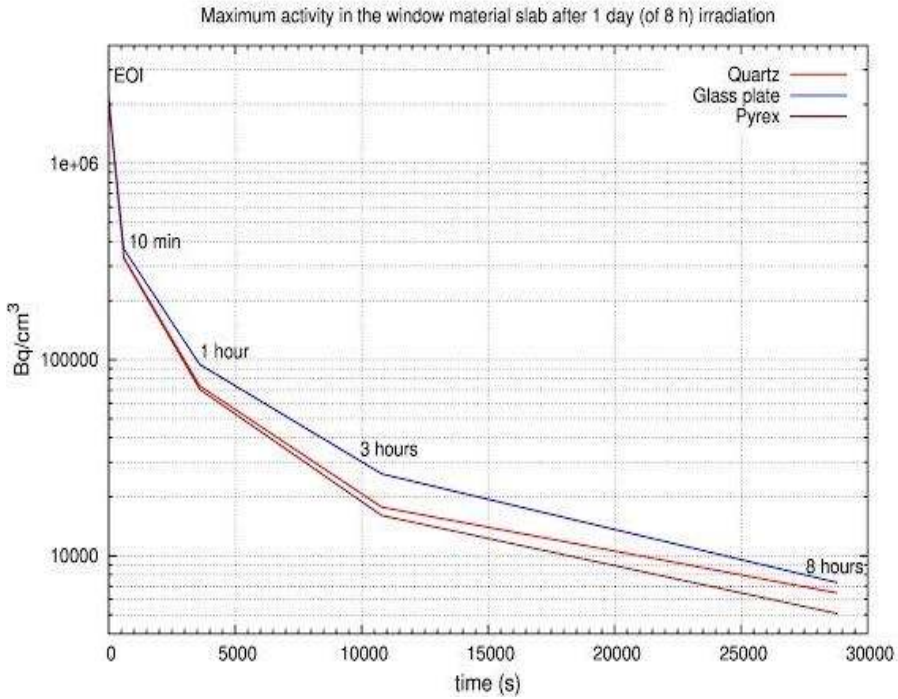


Electron irradiation

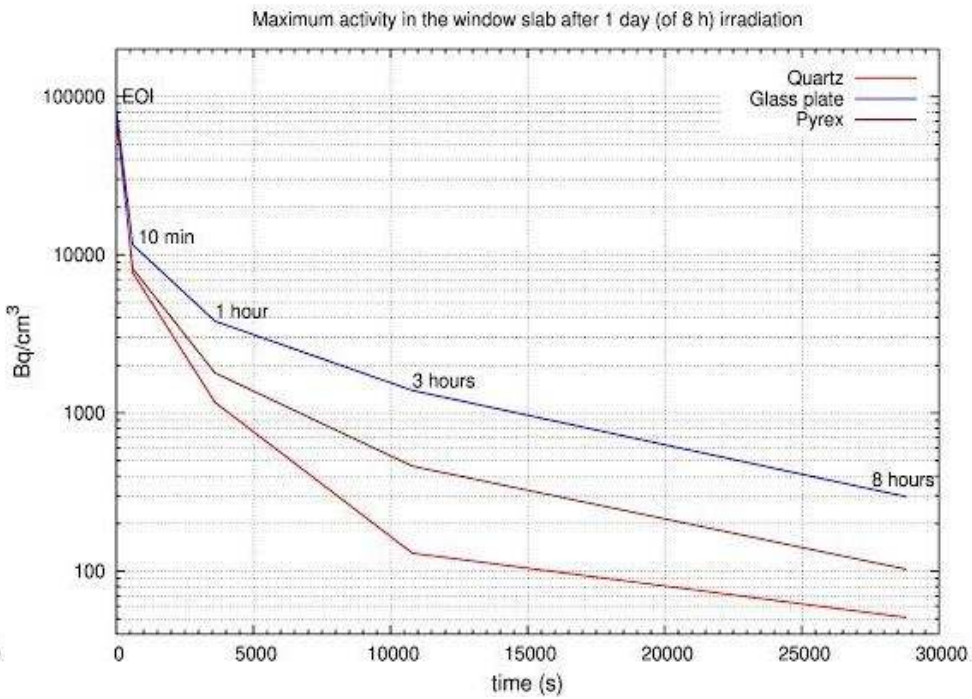


Activity

Proton irradiation



Electron irradiation

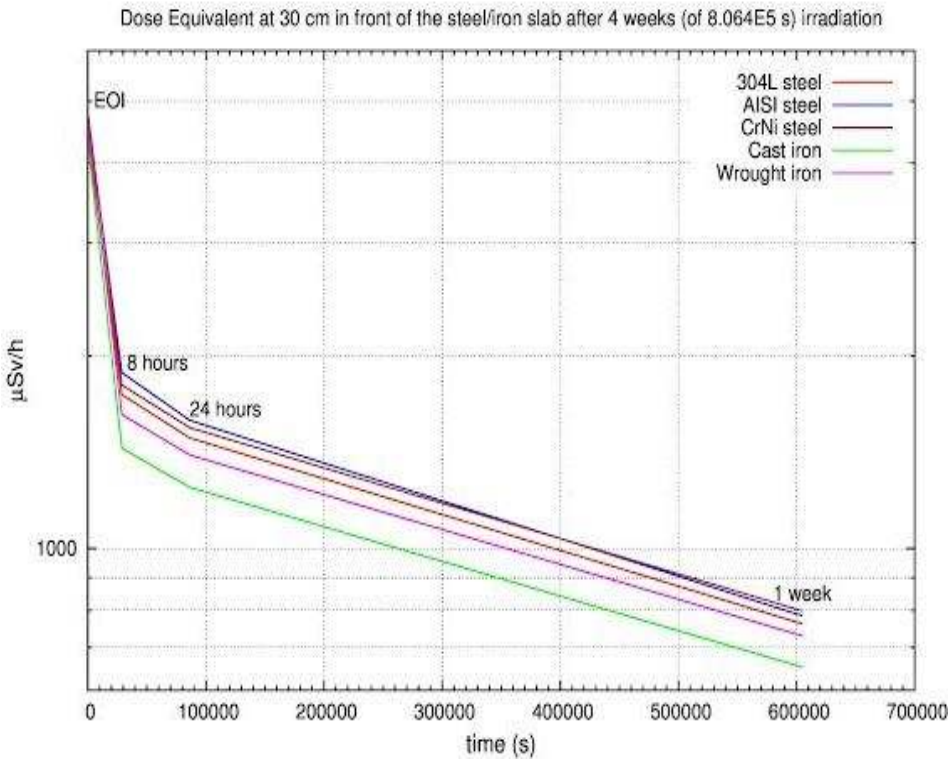


The only notable radioisotope is ^{18}**F** (110 min) in glass plates, only in limited amount in quartz

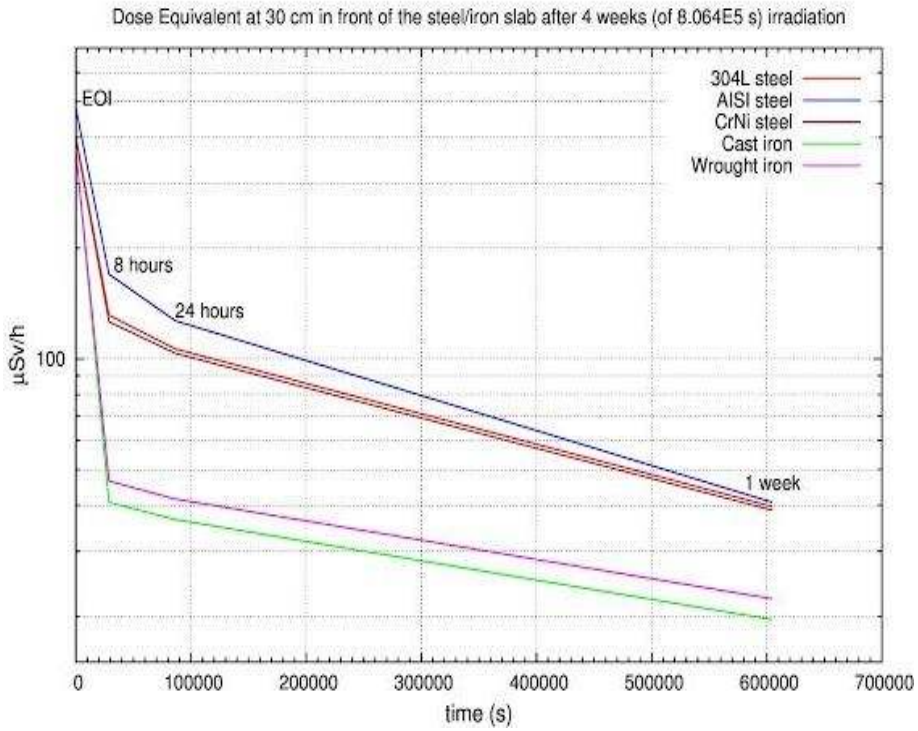
Results IV: Steel

H*(10)

Proton irradiation

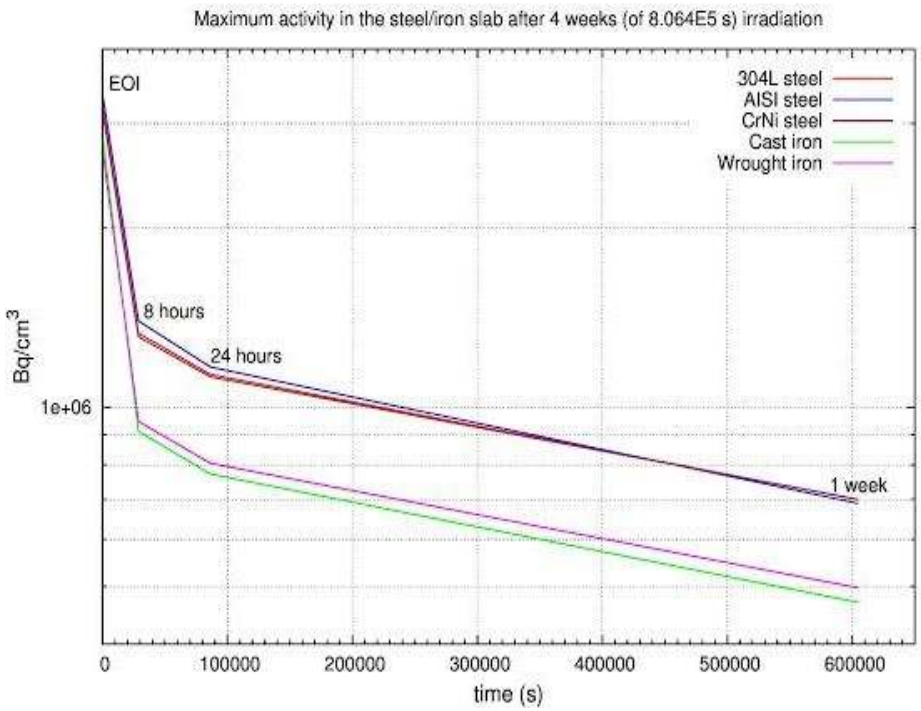


Electron irradiation

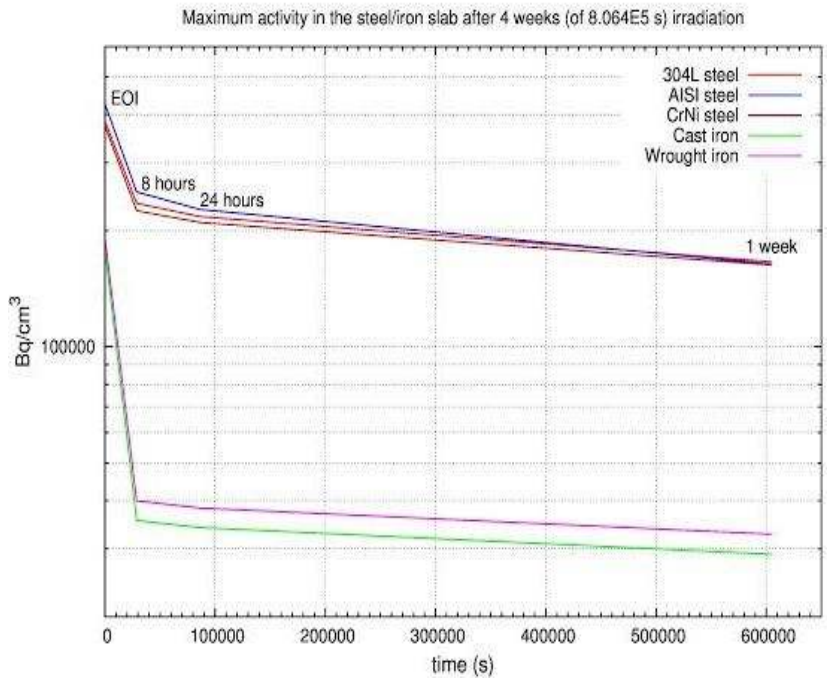


Activity

Proton irradiation

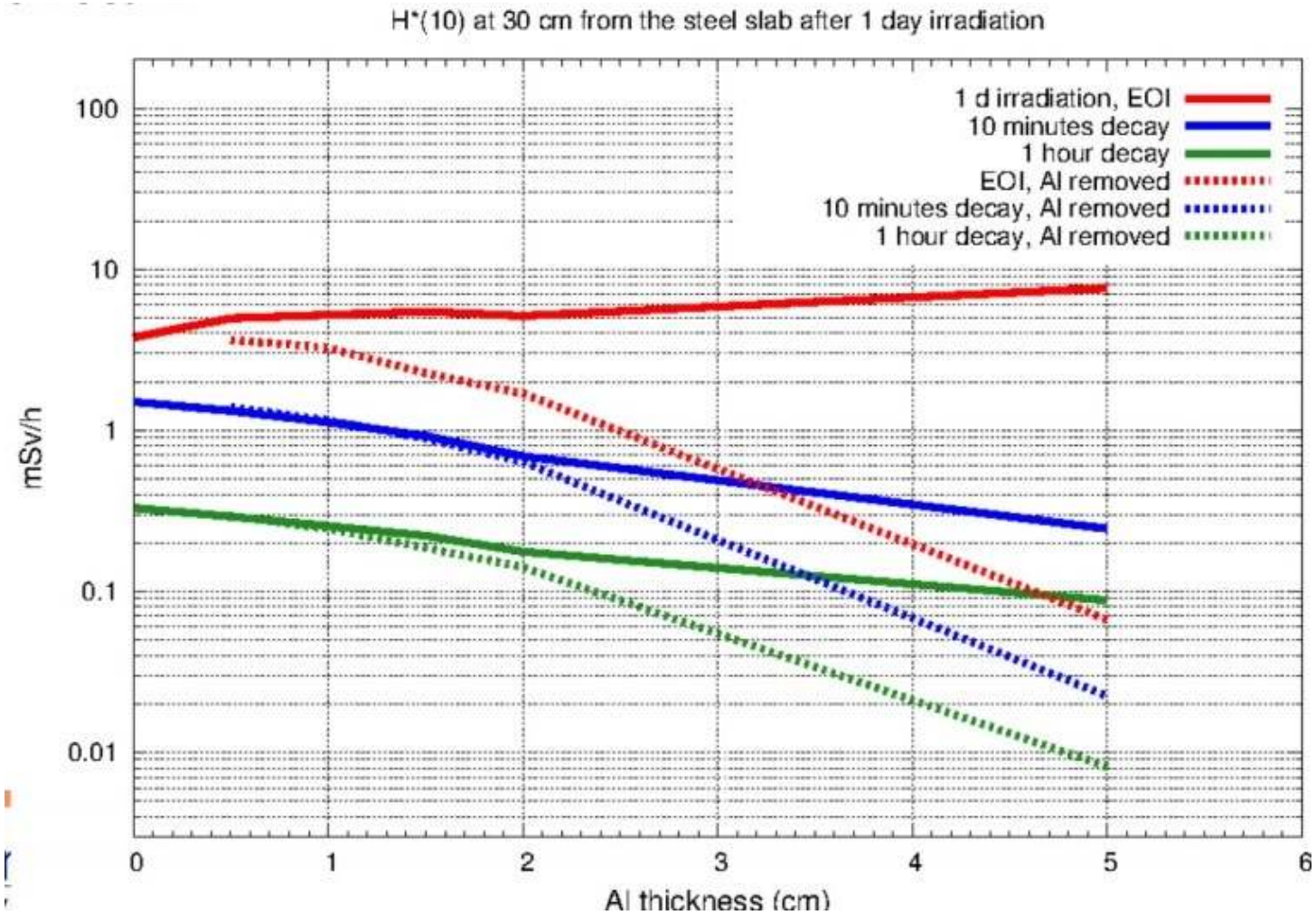


Electron irradiation



Most radioactive produced isotopes: **^{45}Ti** ($t_{1/2}$ 185 min) in all steel considered and in cast iron.
In iron (only in iron): **^{49}Cr** ($t_{1/2}$ 42 min) and **^{51}Cr** ($t_{1/2}$ 27.7 d)

Results V:
looking for an optimal material for the chambers

AISI 316L slab + Al slab as protection (thickness from 1 to 5 cm)

Proton irradiation