Wrocław University of Technology

Irradiation test of electrical insulation materials performed at NCBJ, Poland

Jaroslaw Polinski, Maciej Chorowski, Piotr Bogdan

Faculty of Mechanical and Power Engineering

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Outlet

- EuCARD insulators certification irradiation requirements
- Selection of the irradiation source for the sample irradiation purpose
- Irradiation cryostat and set-up at NCBJ, Swierk, POLAND
- Tests of irradiation set-up and irradiation procedure
- First mechanical tests results

EuCARD insulators certification irradiation requirements

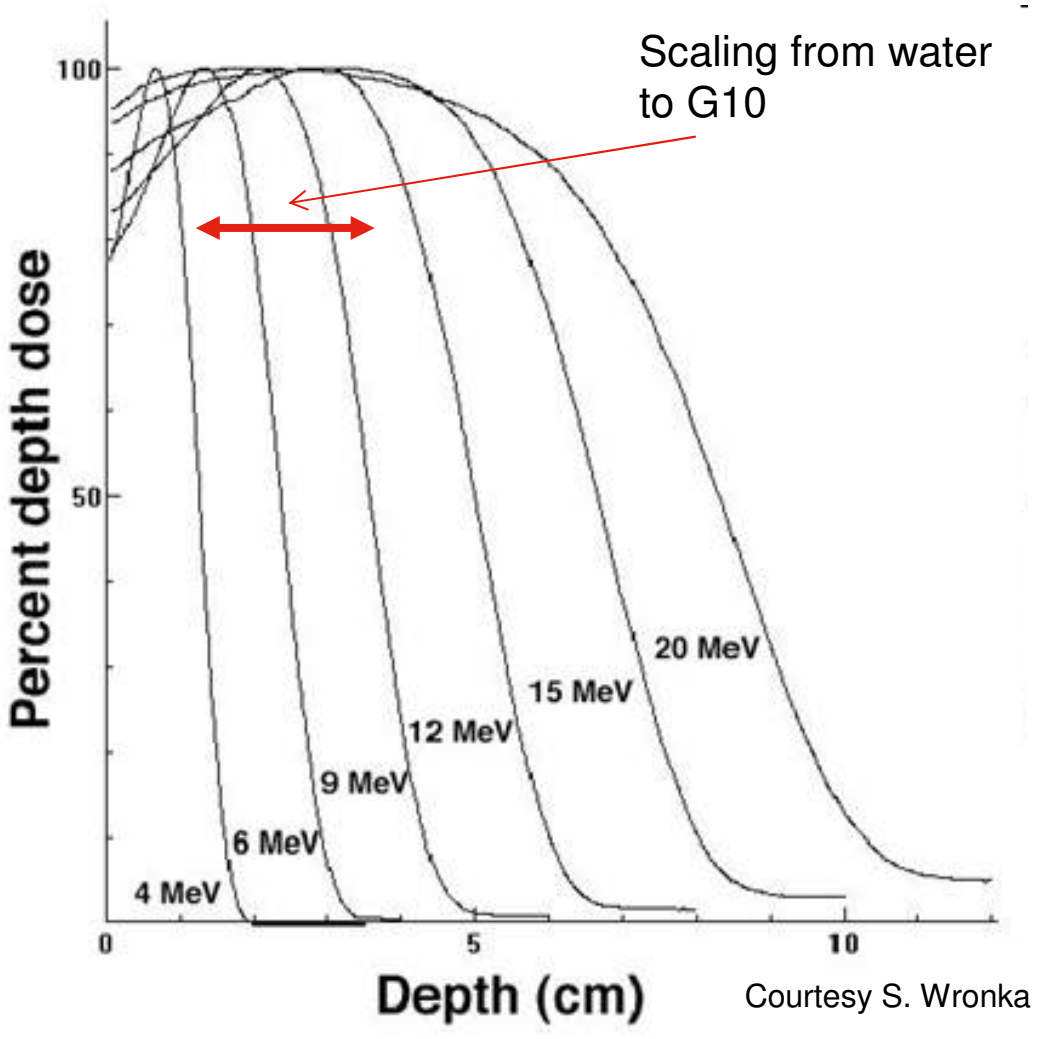
- Radiation type: electron beam, E>1MeV
- Integrated radiation dose – 50 MGy
- Irradiation temperature – 77 K
- The electrons beam should have as large diameter as possible
- The insulation material penetration by the beam should be as large as possible

Beam energy required for the sample irradiation

Depth of bean penetration in water for various beam energy value

ρ_{H20} = 1.0 g/cm^3
ρ_{PMMA} = 1.2 g/cm^3
ρ_{G10} = 1.8 g/cm^3

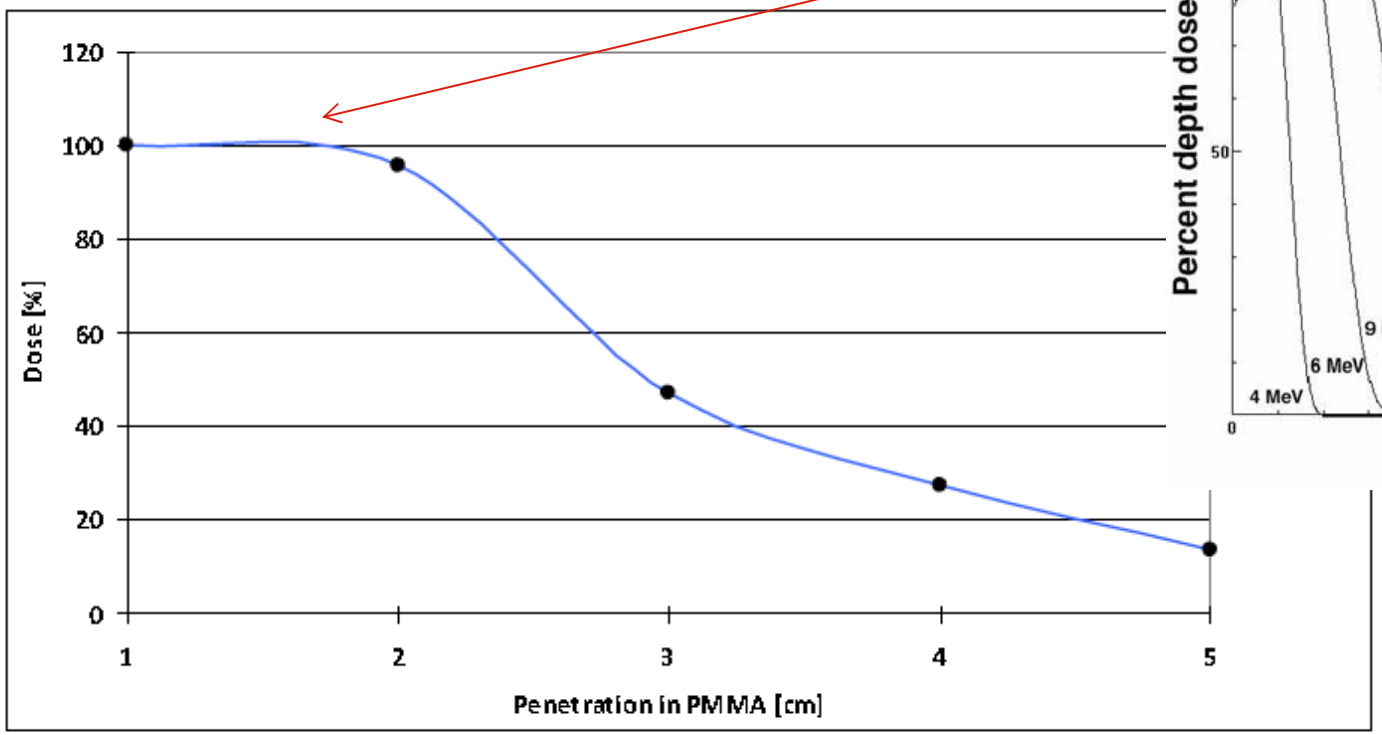
For 2 cm long mechanical sample irradiation the beam energy as 10 – 11 MeV is necessary



Courtesy S. Wronka

Experimental confirmation of the beam energy for 12 MeV structure

„12 MeV" Accelerator Structure: PMMA irradiation



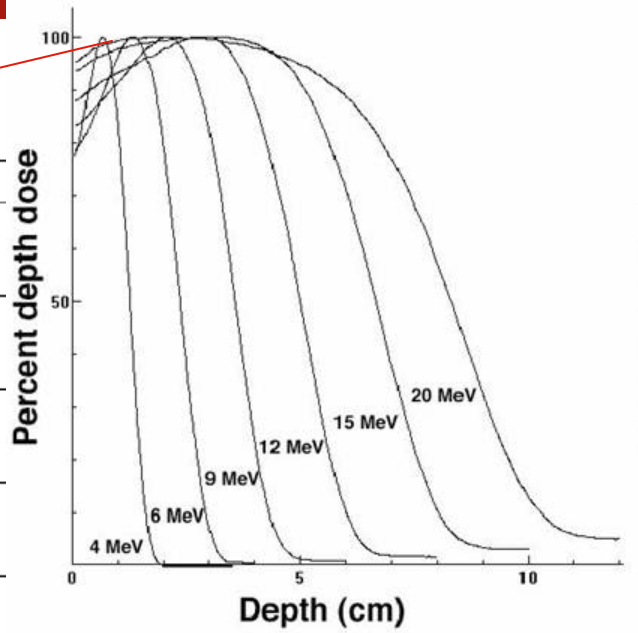


Fig. 3 Measured depth-dose curve of "12 MeV" structure.

Confirmed energy - 7÷8 MeV

S. Wronka, Soltan Inst.

Experimental confirmation of the beam energy for 15 MeV structure

„15 MeV" Accelerator Structure: PMMA irradiation

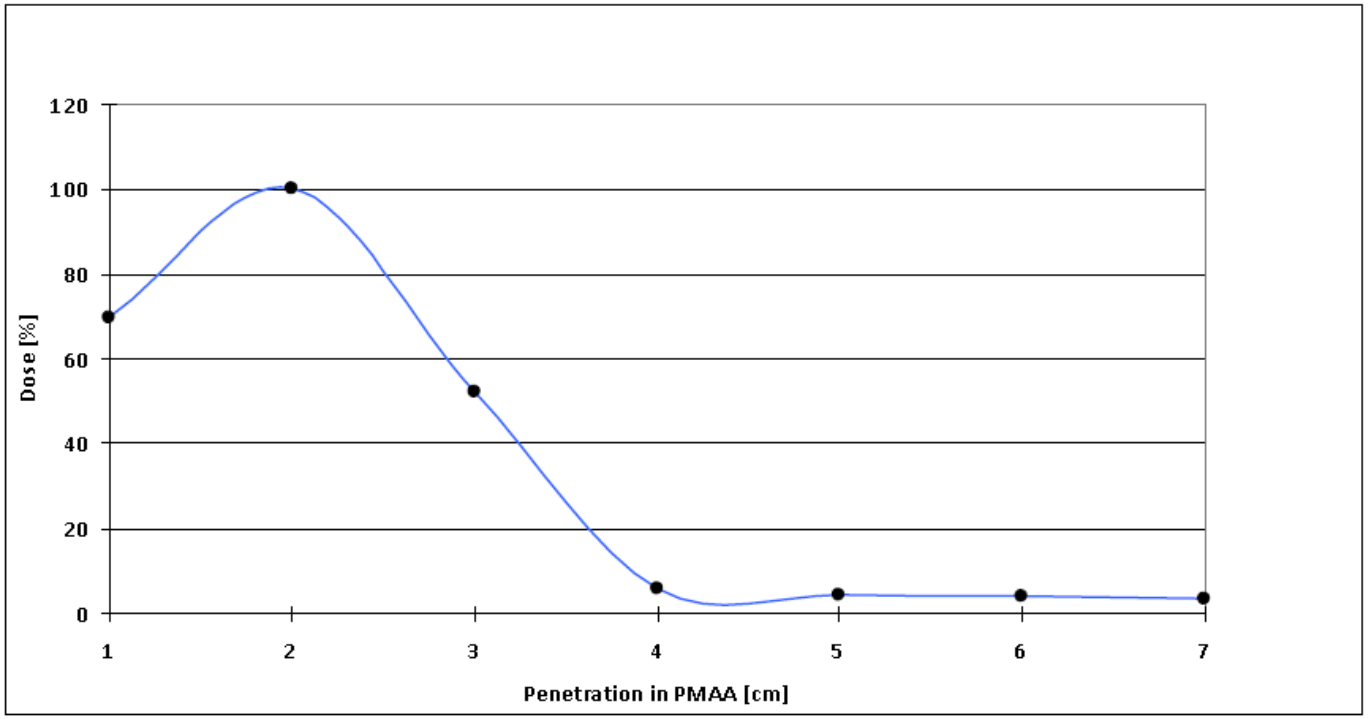
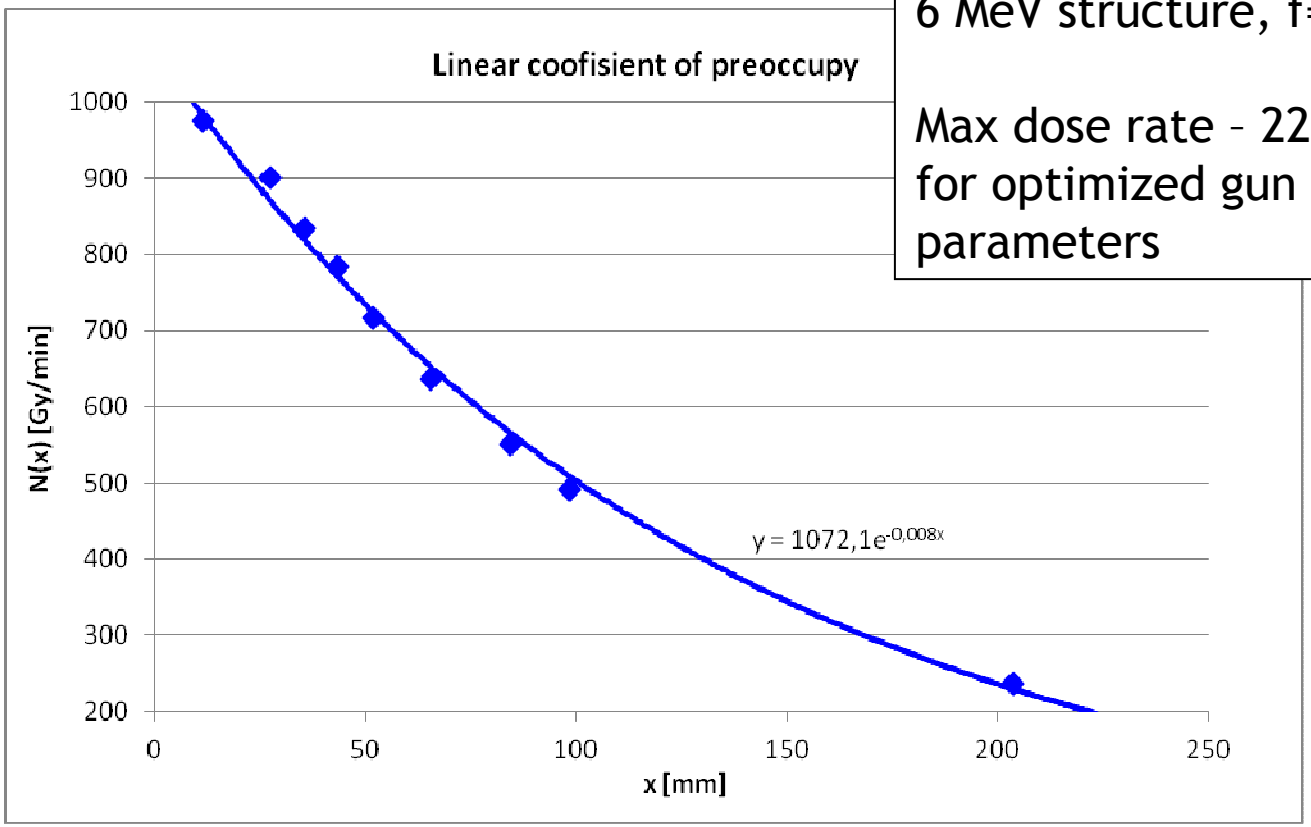


Fig. 4 Measured depth-dose curve of „15 MeV" structure.

Confirmed energy - 10÷11 MeV

S. Wronka, Soltan Inst.

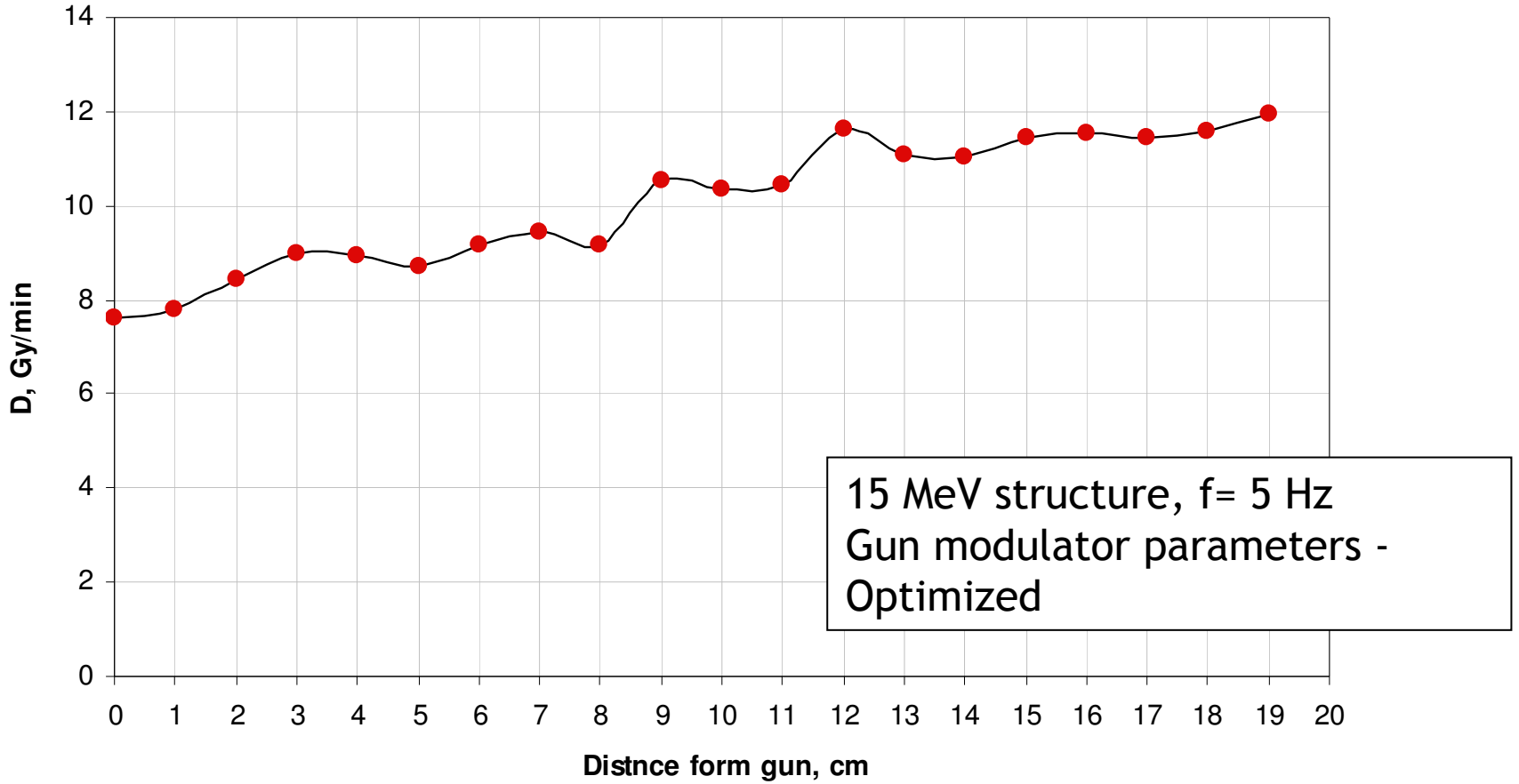
Dose rate in function of distance form the accelerator gun for 6 MeV structure



6 MeV structure, f= 76,4 Hz

Max dose rate – 2200 Gy/min for optimized gun modulator parameters

Dose rate in function of distance form the accelerator gun – much lower than for 6 MeV !



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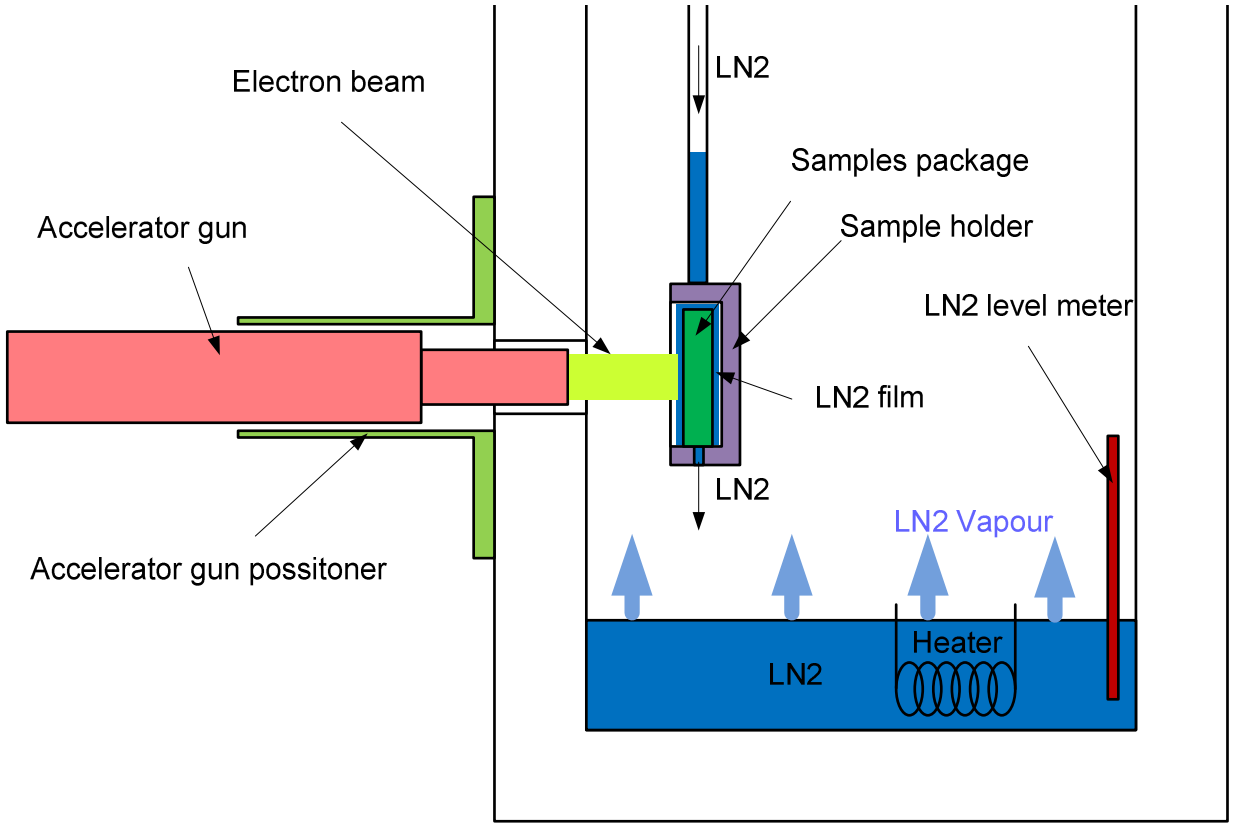
Selection of the electron source available at NCBJ, Świerk, Poland

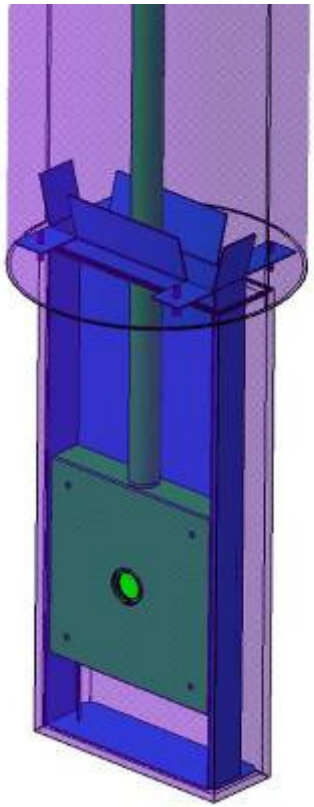
Structure		6 MeV	12 MeV	15 MeV
Real electron energy	MeV	4	8	11
Depth of water penetration (range 80-100% of dose)	mm	10	26	38
Beam diameter (90-100% of intensity)	mm	**8**	2	2
Depth of insulation penetration	mm	5,6	14,4	21,1
Nbrs of samples radiated at once*		11,1	28,9	42,2
Max recorded dose rate	Gy/min	2200	12	12
Repetition frequency	Hz	76,4	5	5
Expected dose @f=300Hz	Gy/min	**8639**	720	720
Irradiation time for 50 MGy	Working days	12,1	144,7	144,7
Irradiated samples	Work. days/sample	1,1	5,0	3,4

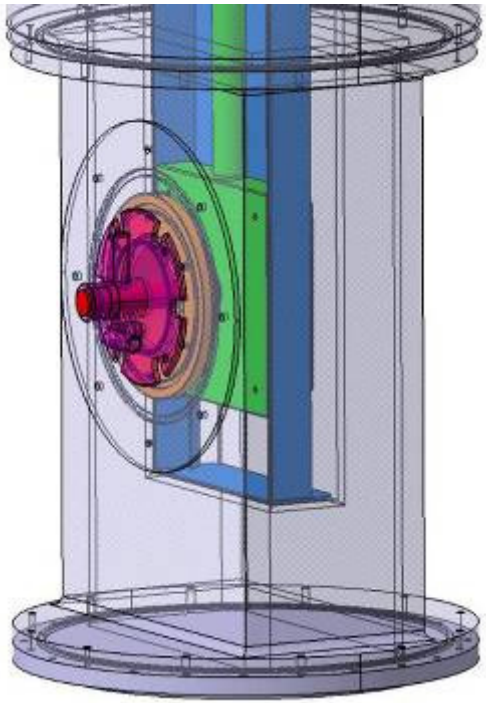
* For 0.5 mm thick sample

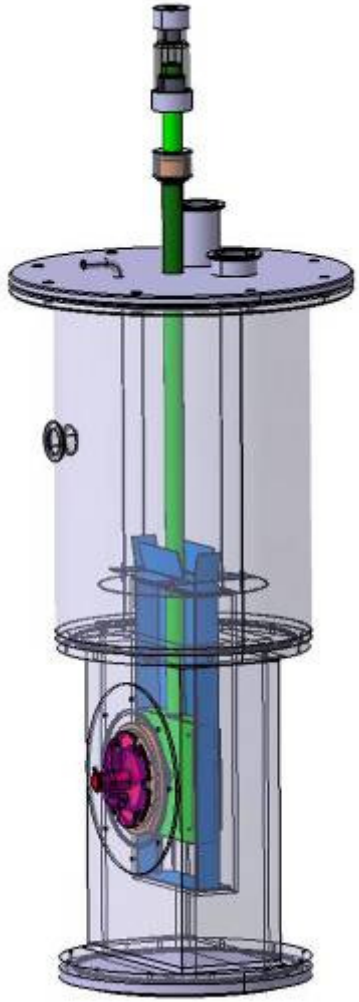
Irradiation cryostat - principle of irradiation process



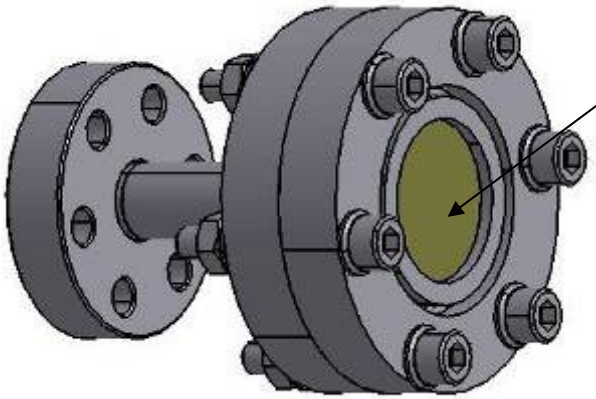
Conceptual design of the irradiation cryostat







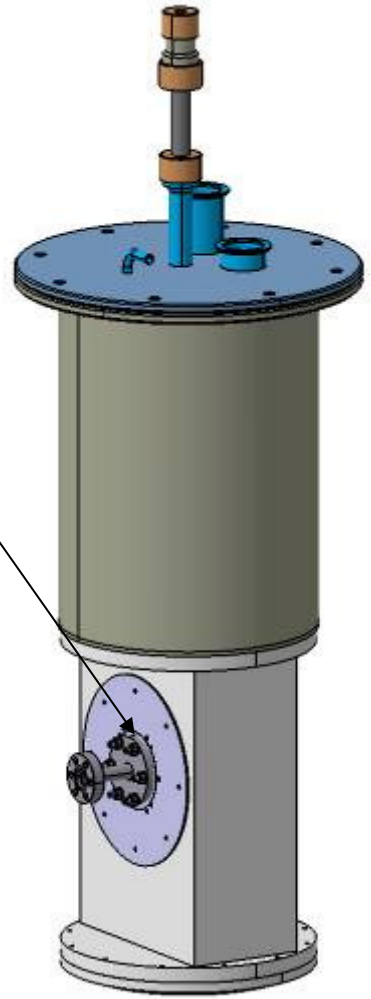
Conceptual design of the irradiation cryostat



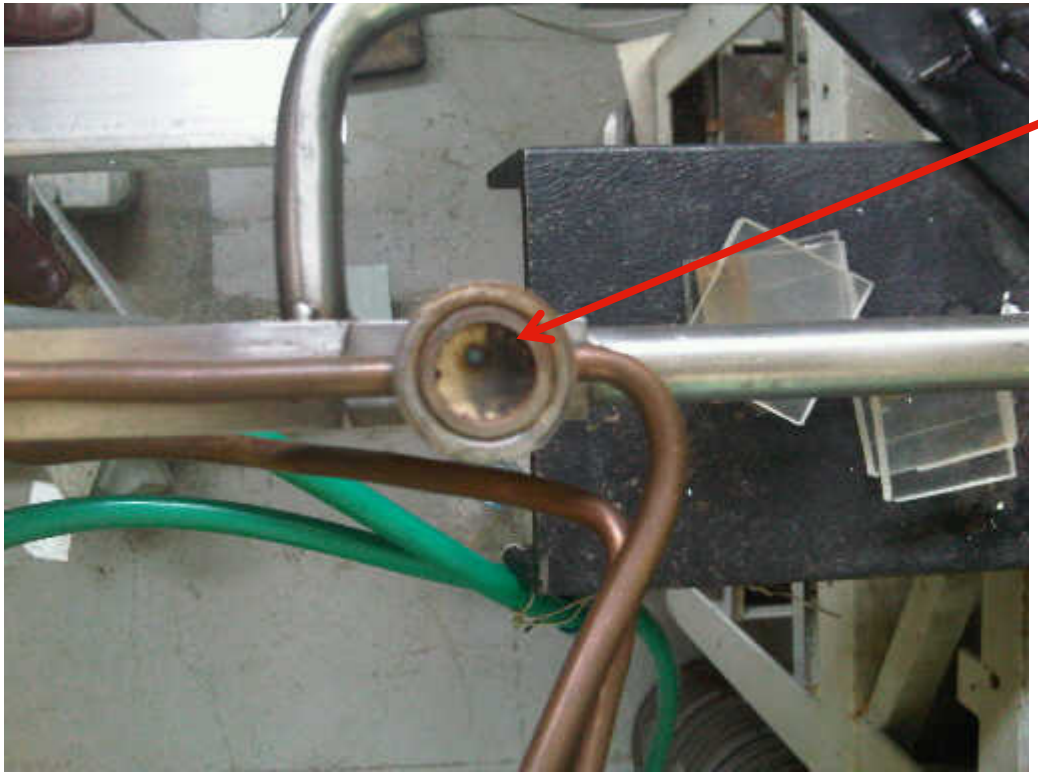
0.02 mm thick Ti window

Previous, stainless steel window

Change of accelerator windows and update of accelerator electronics have increased the dose rate form 8 to over 30 kGy/min (measured at sample package location)



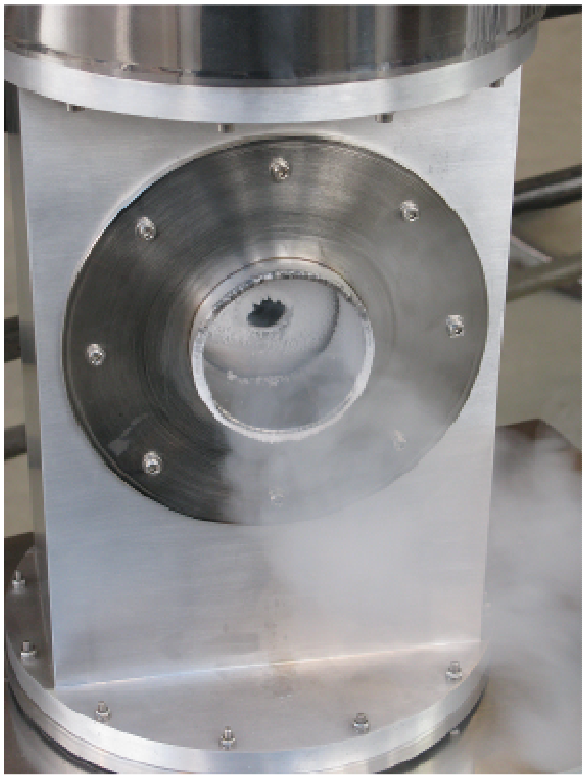
Titanium window degradation



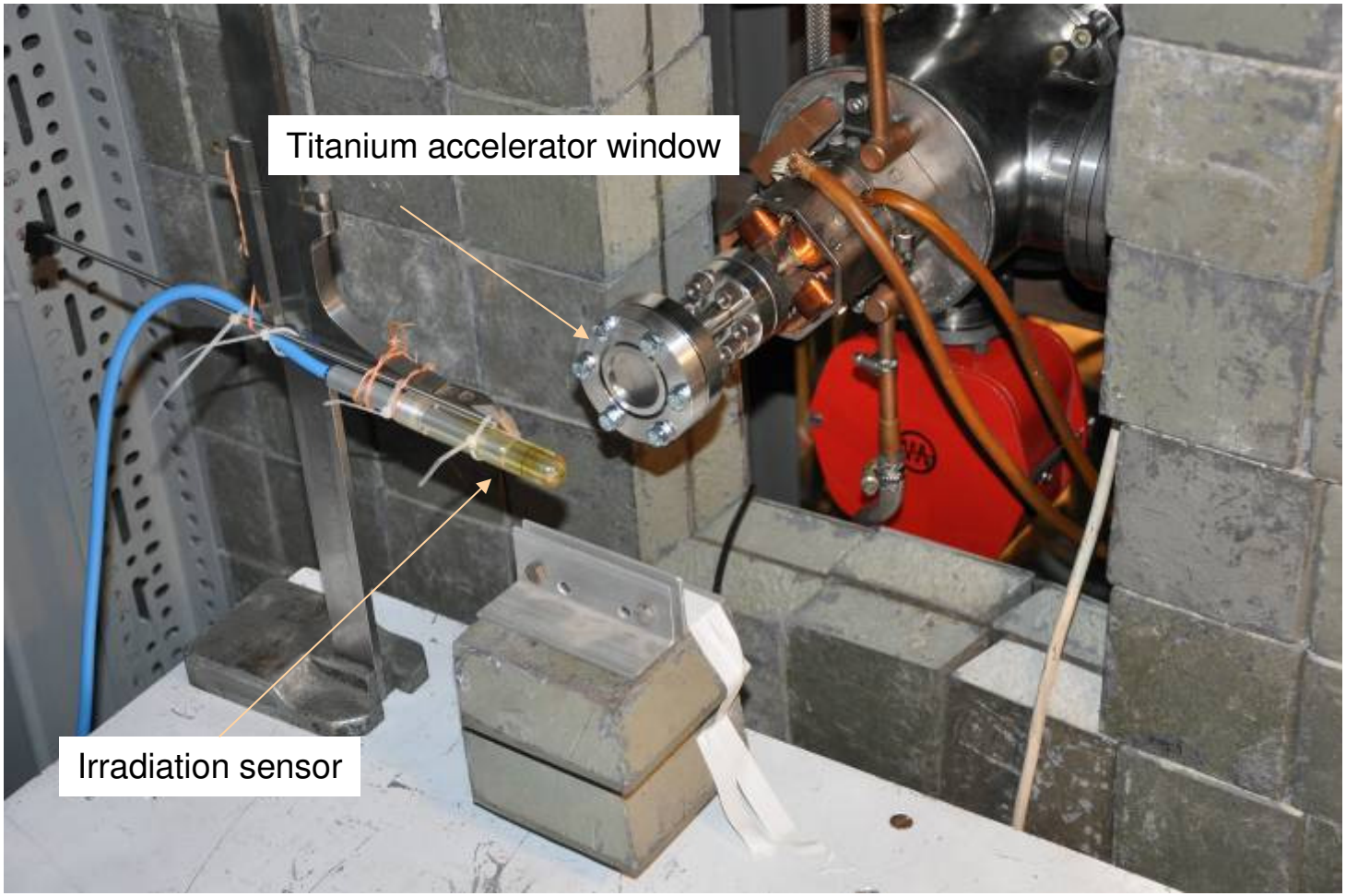
Titanium heating effect: 700 °C

Open issue – will the titanium oxidation destroy the leak-tightness of the window?

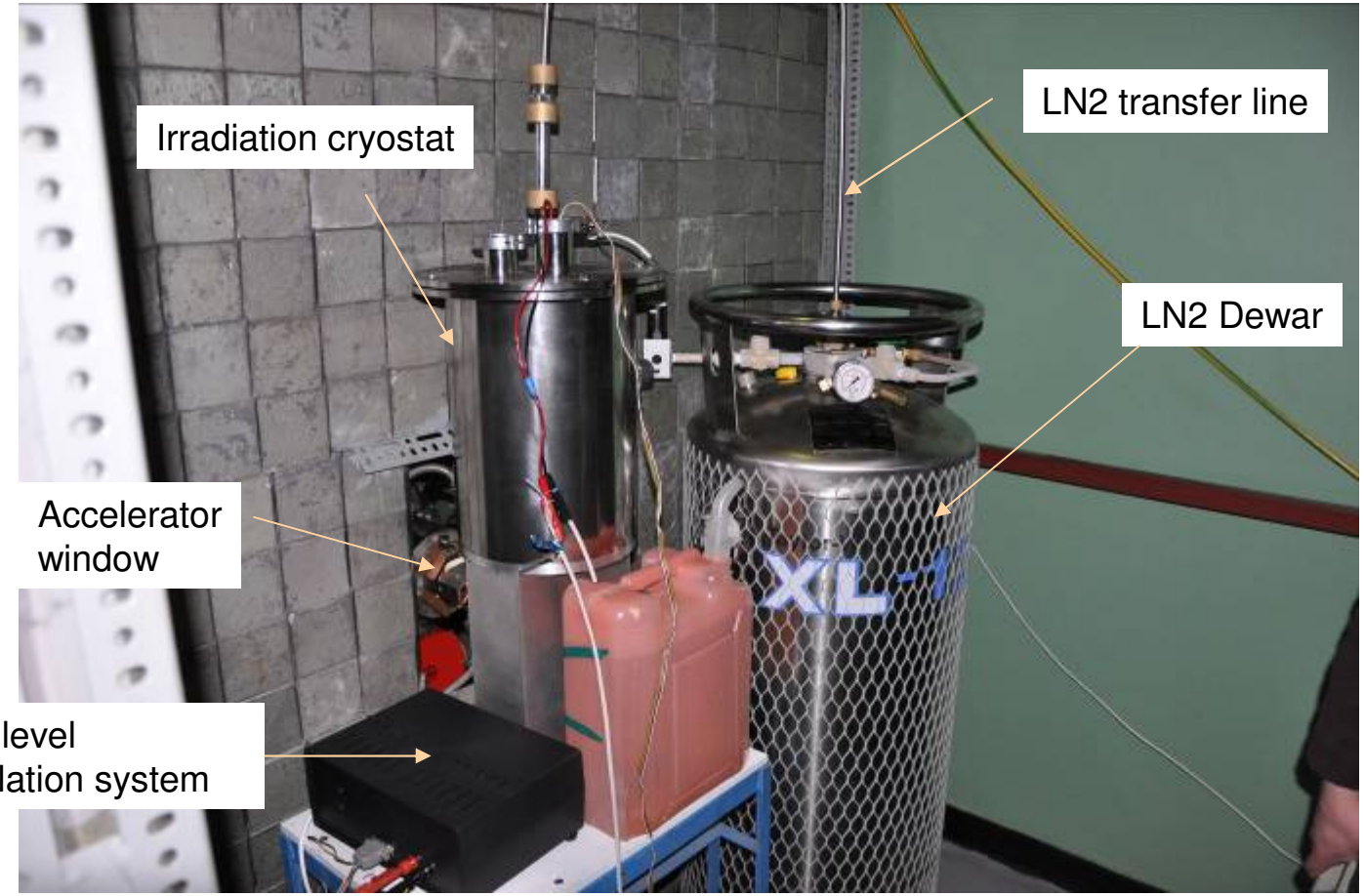
Irradiation cryostat – commissioning test at manufacturer site



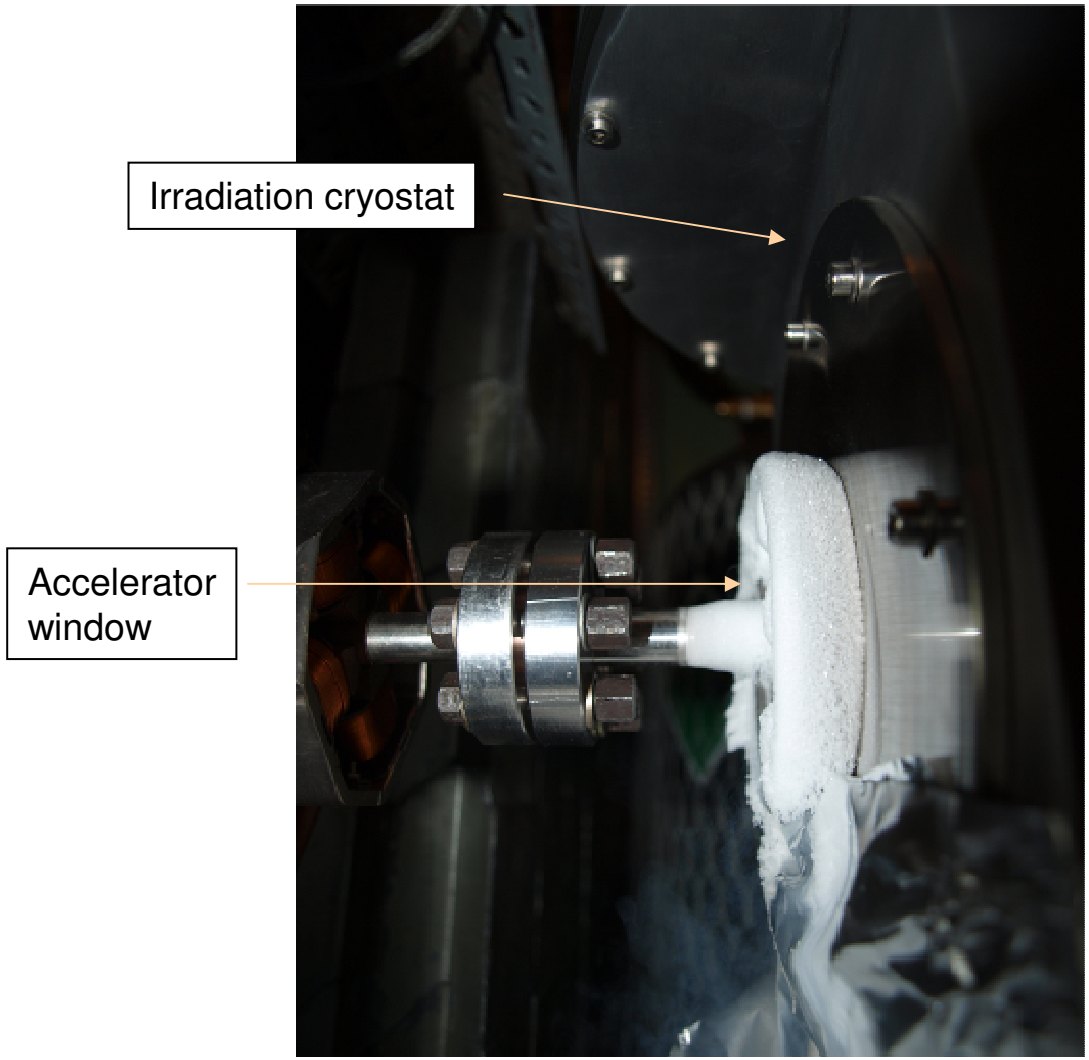
Accelerator window at National Centre for Nuclear Research (NCBJ), Swierk, POLAND



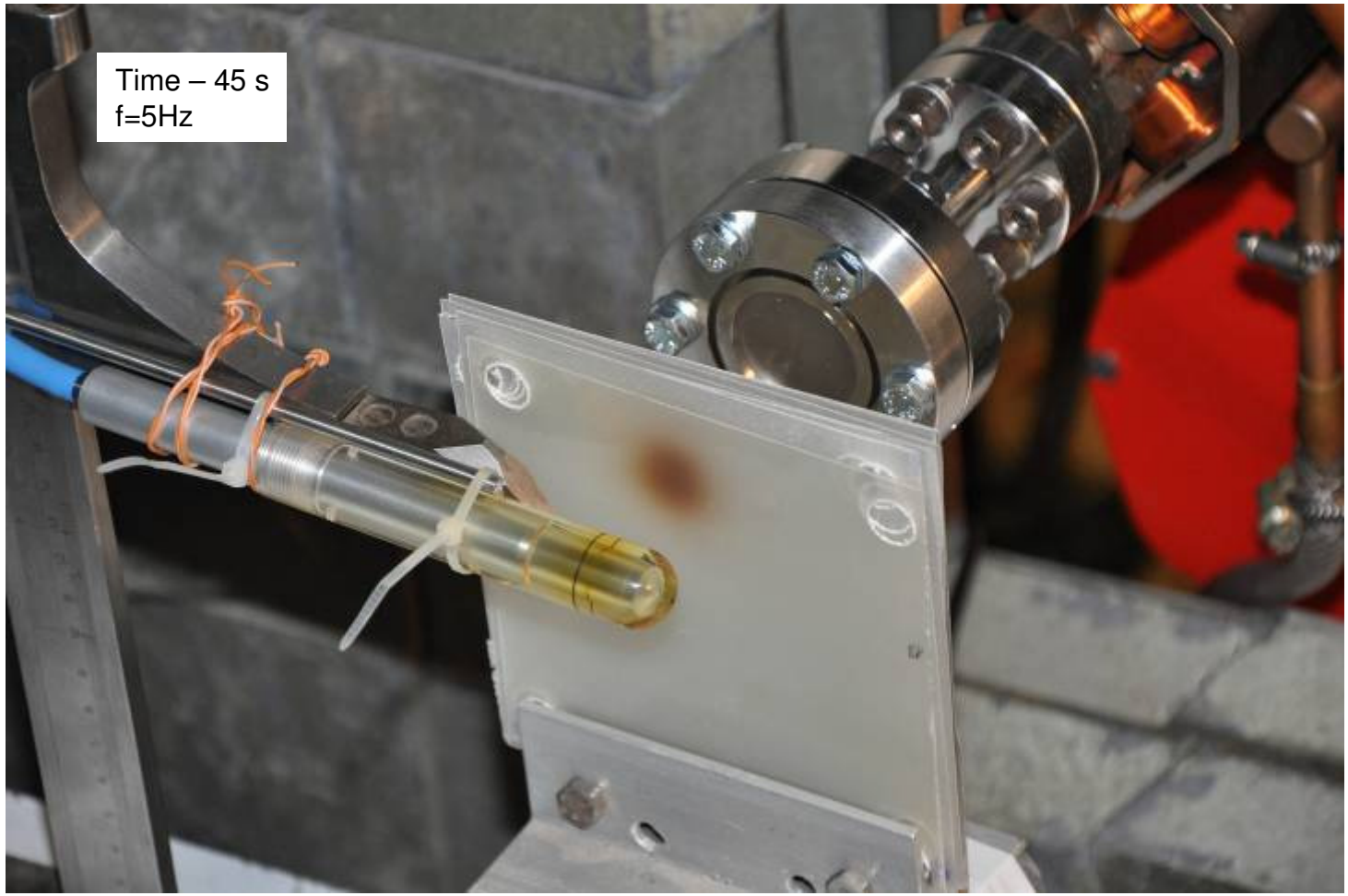
Irradiation at cryogenic temperature



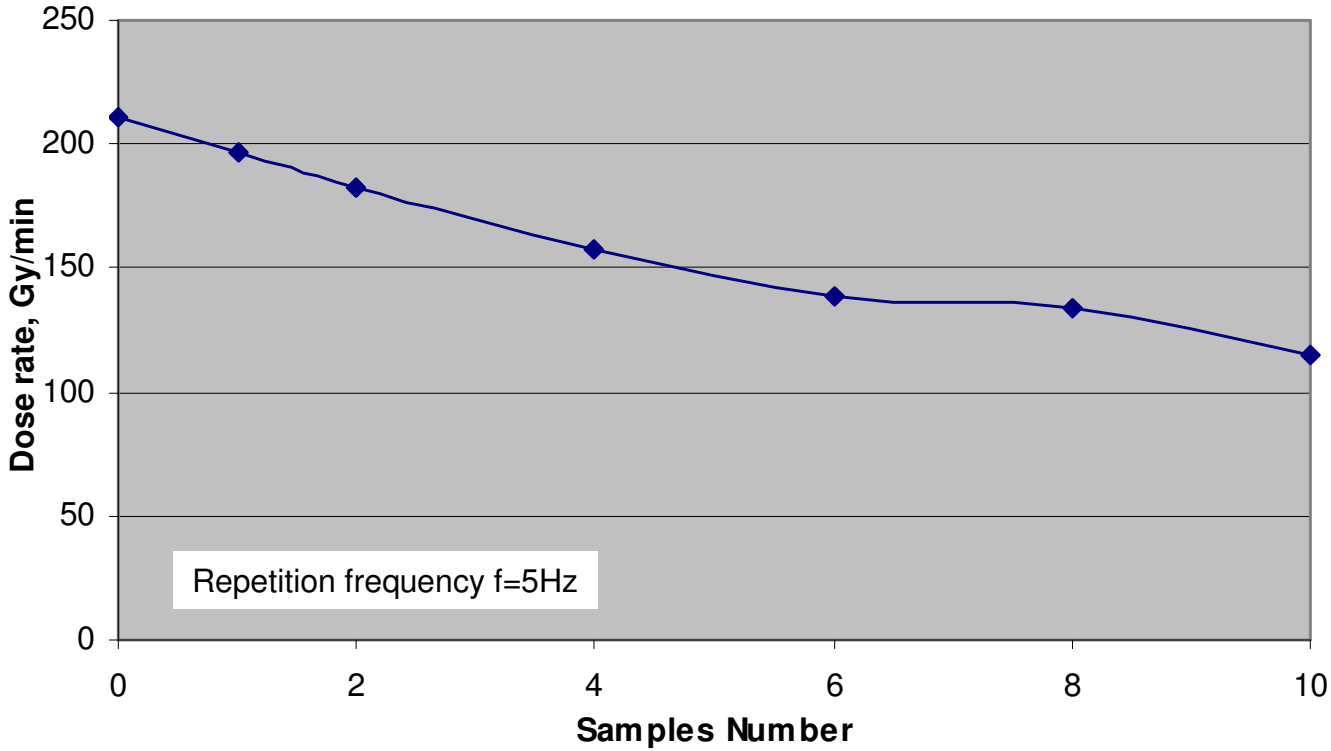
Accelerator window cooling with N2 vapors



Determination of irradiation deposition in the samples package

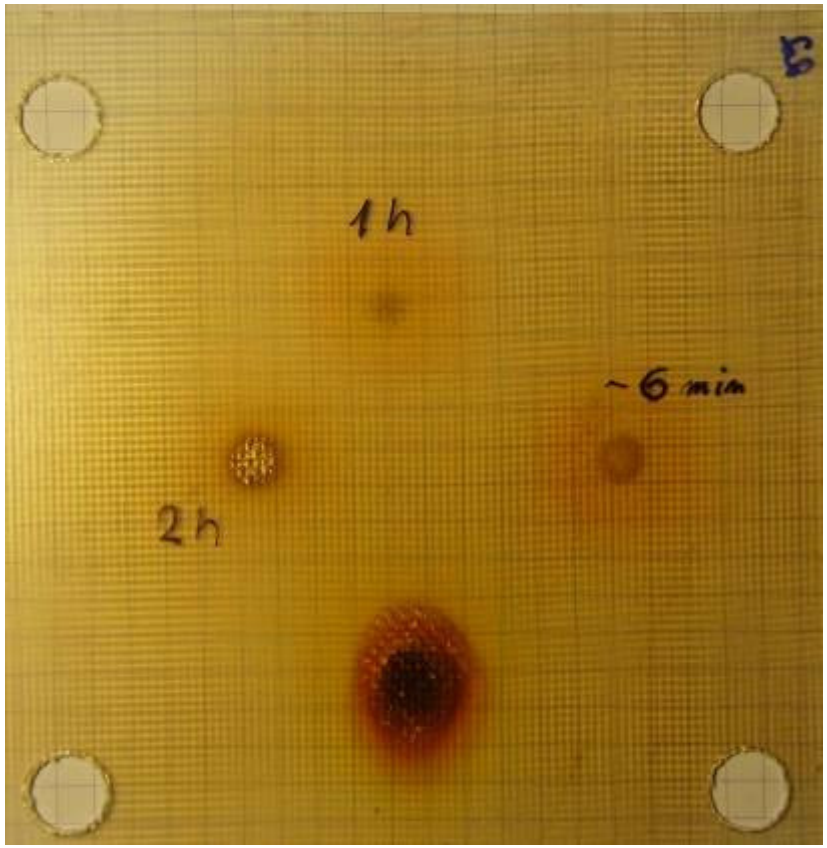


Determination of irradiation deposition in the samples package



Cold irradiation test – integrated dose 0.5 – 0.7 MGy

Second spot
75 Hz, 1h

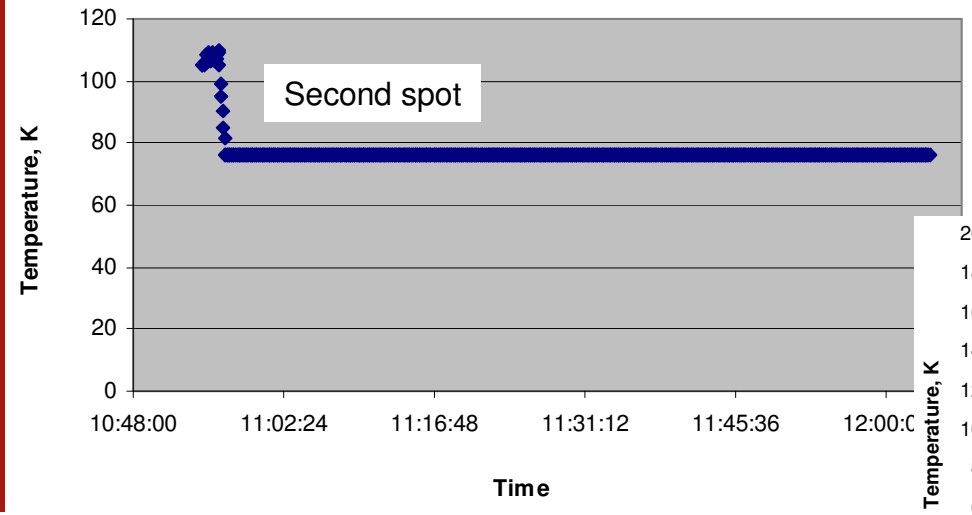


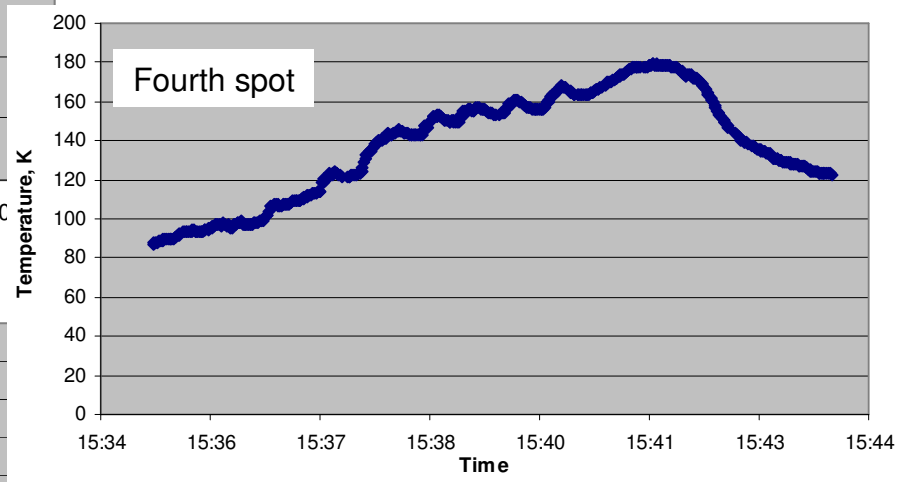
Third spot
37.5 Hz, 2h

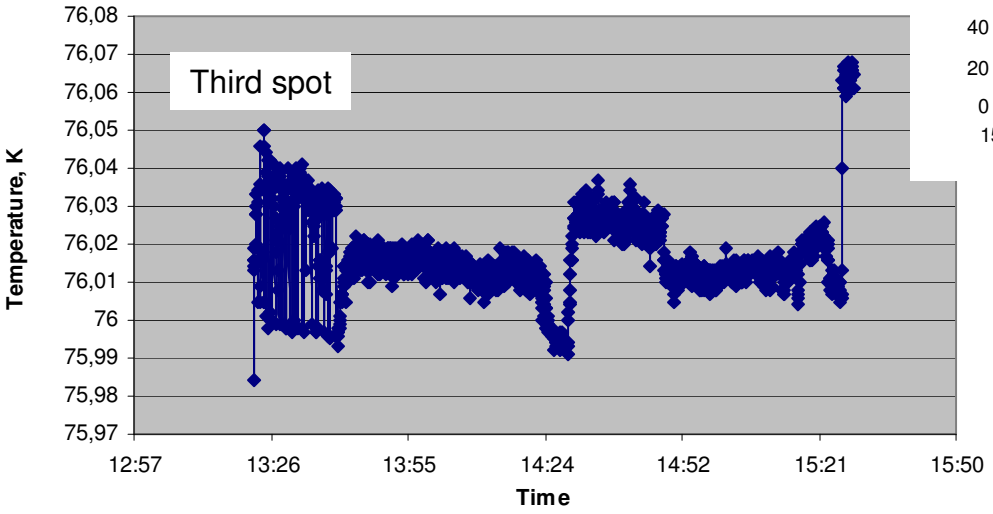
Fourth spot
150 Hz, 6 min
Dose – very small

First spot
150 Hz, 30 min

Coold irradiation - temperature near the spot during irradiation



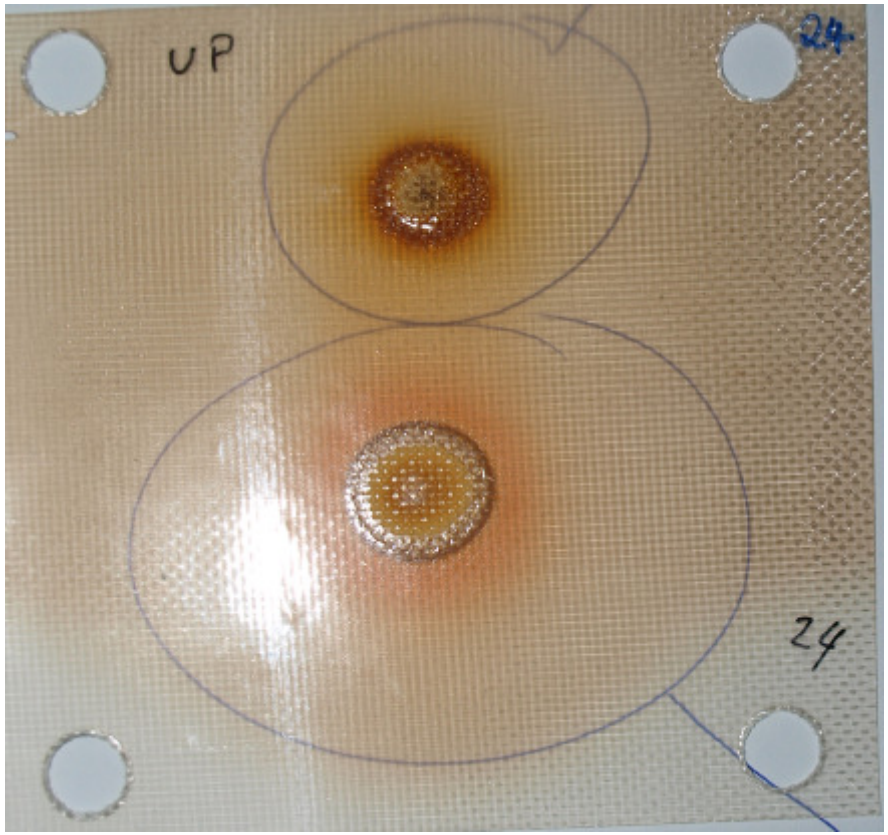


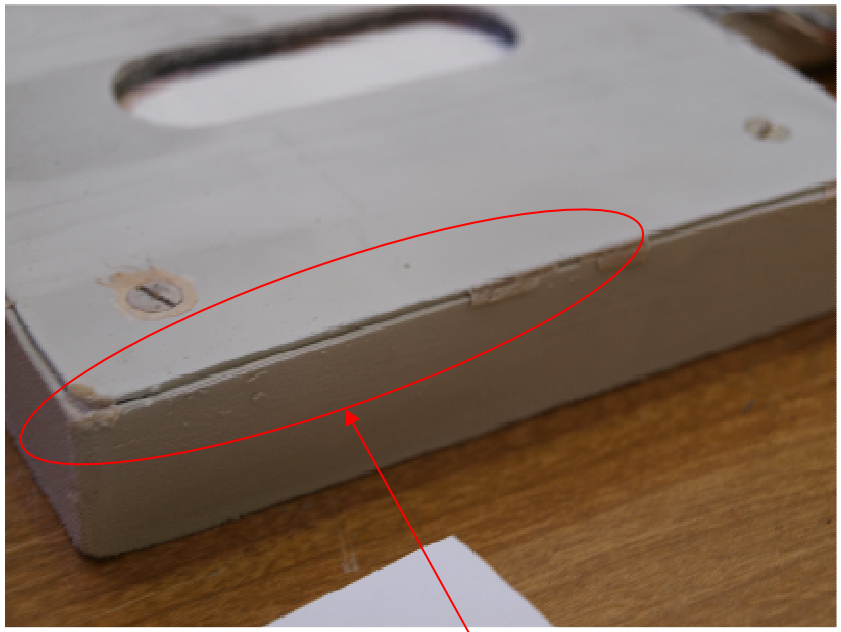


Determination of the dose absorbed by LN2

20-30% lower dose rate was measured for cooling with LN2 compare with N2 vapor cooling

Long term irradiation test - dose ~5MGy



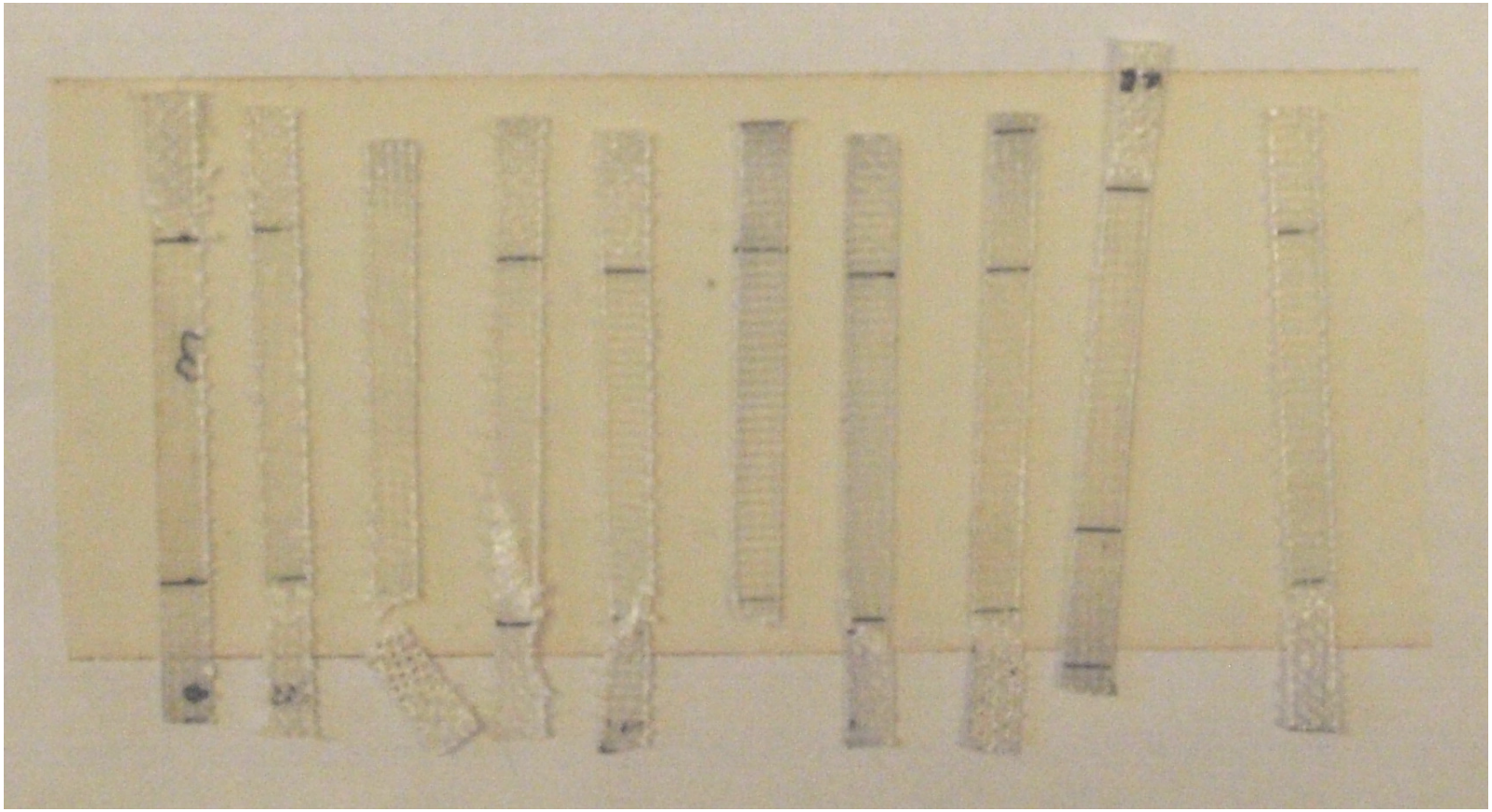


Destruction of sealing glue

Mech. tests – unirradiated samples

- Purpose
  - determination of basic mechanical properties of material
  - determination of material anisotropy
- Samples
  - material: RAL Mix71 (DGEBA epoxy + D400 hardener)
  - dimensions: 0.5x4,0x50 (thickness, width, length), 30 mm of testes length

Mech. tests – unirradiated samples



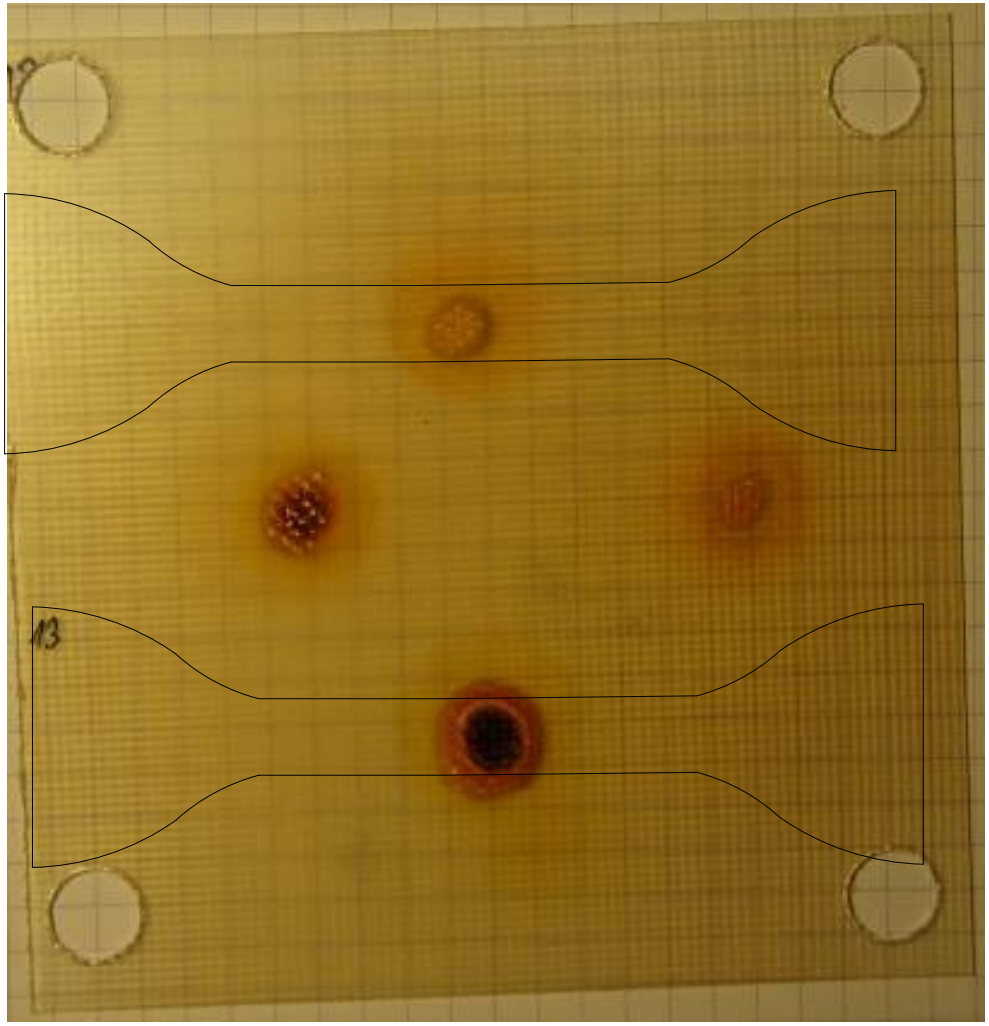
Mech. tests – unirradiated samples

- Observations:
  - Samples break next to the sample holder
- Results:
  - normal direction:
    - UTS=264 ±38MPa
    - Elastic module =26.7 ±1.7GPa
    - Elongation = 1.8 ±0.5%
  - perpendicular direction:
    - UTS=380 ±57MPa
    - Elastic module =31.2 ±1.2GPa
    - Elongation = 1.8 ±0.3%

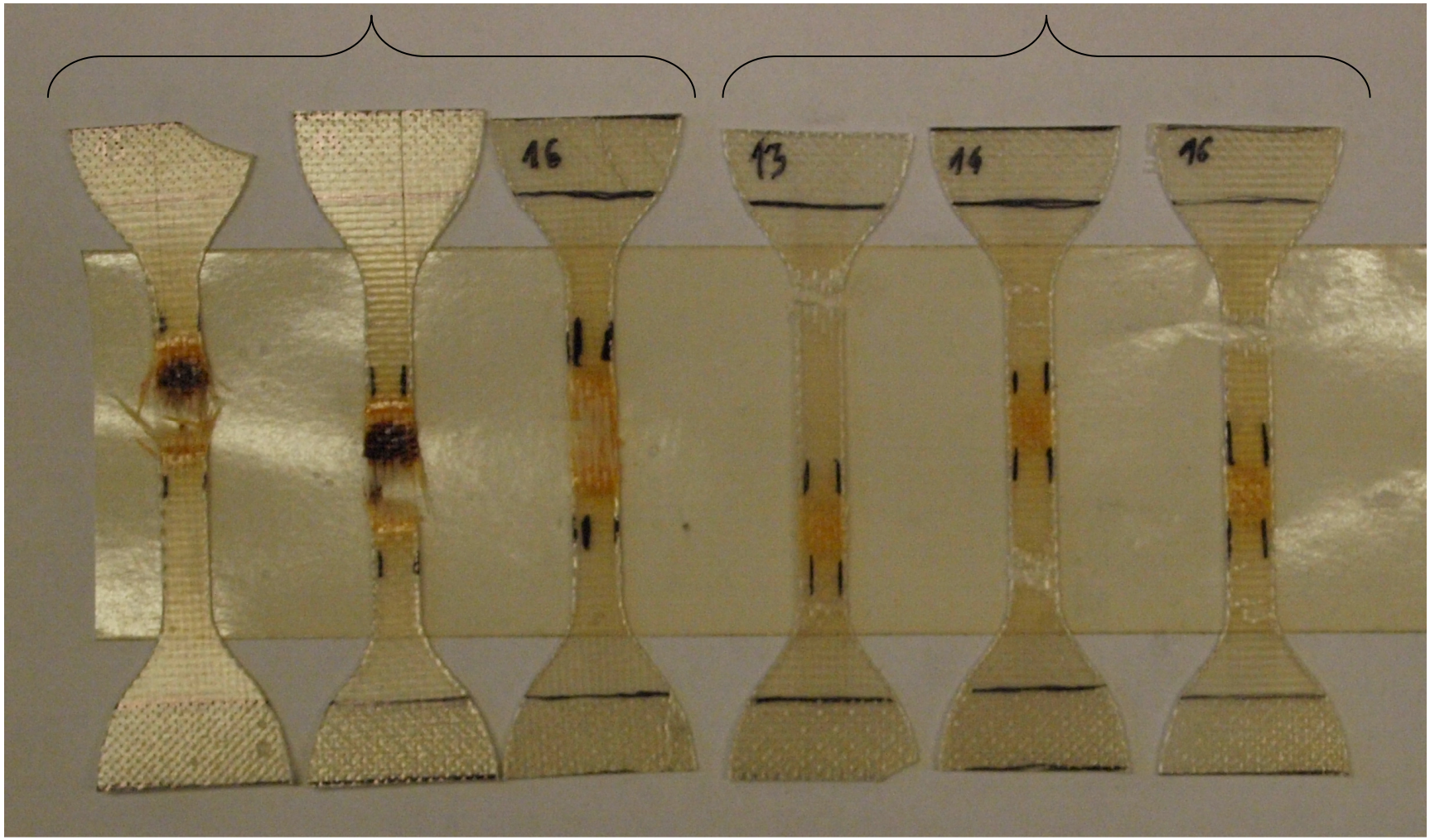
Mech. tests – irradiated samples

- Purpose
  - determination of material properties at irradiation point
- Samples
  - material: RAL Mix71 (DGEBA epoxy + D400 hardener)
  - sample shape – in accordance with ISO 37:2007 standard
  - dimensions of the tested part: 0.5x6.0x60 mm (thickness, width, length)
  - 3 sheets where tested: no. 13, 14 and 16
  - from each sheet a 2 test samples where cut of: with burned spot and with „normal” (not burned) spot – see next slide

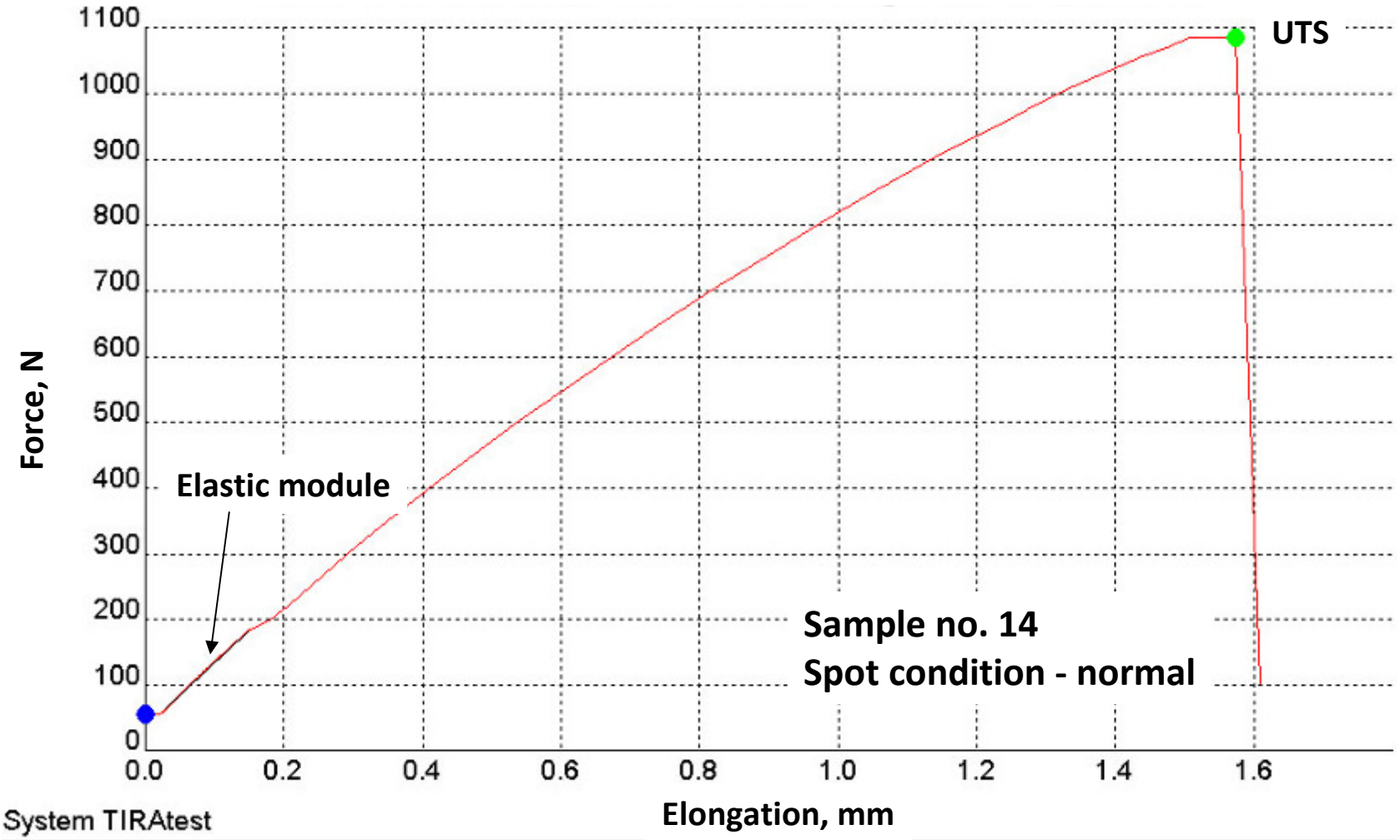
Mech. sample preparation



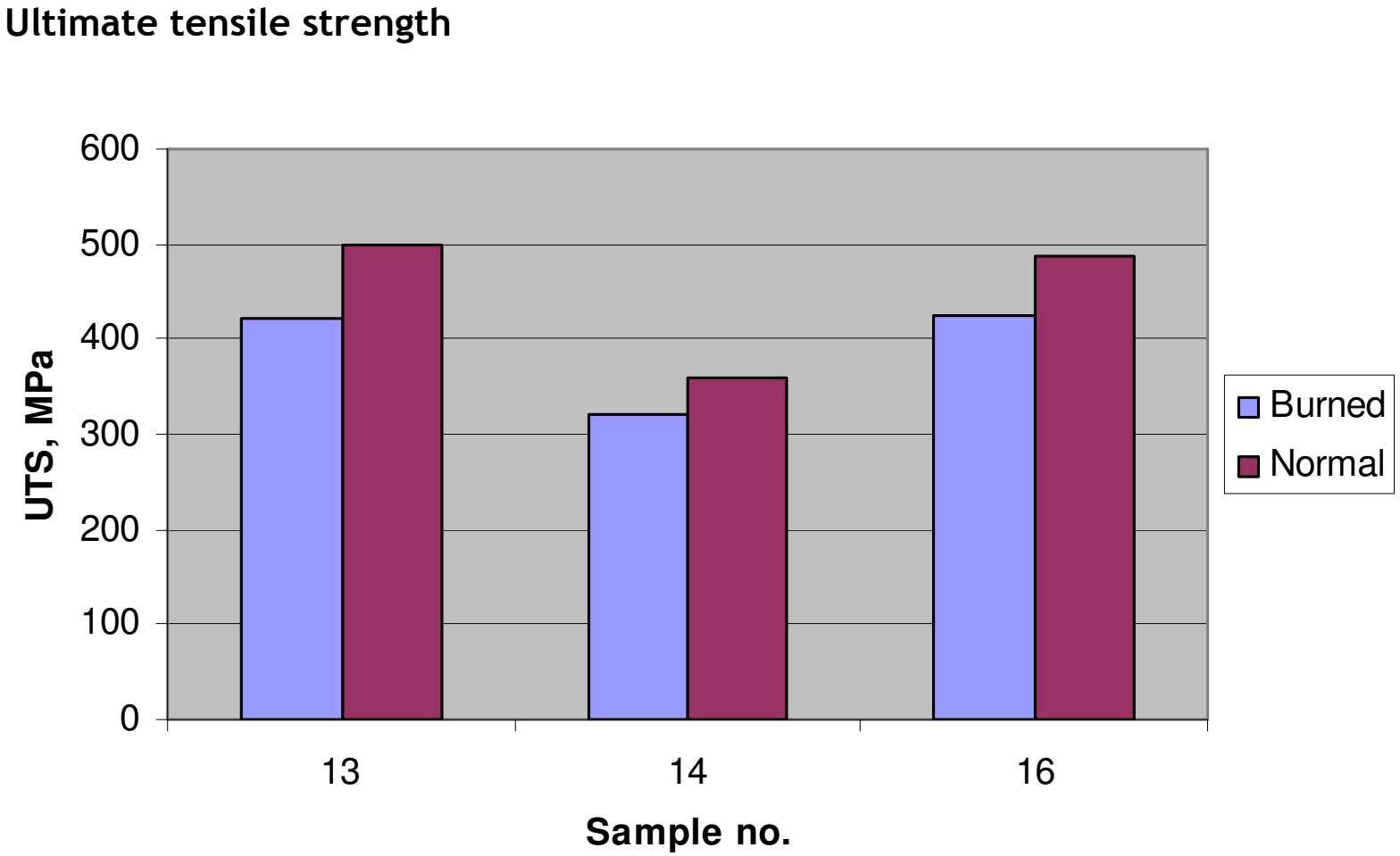
Mech. tests – irradiated samples



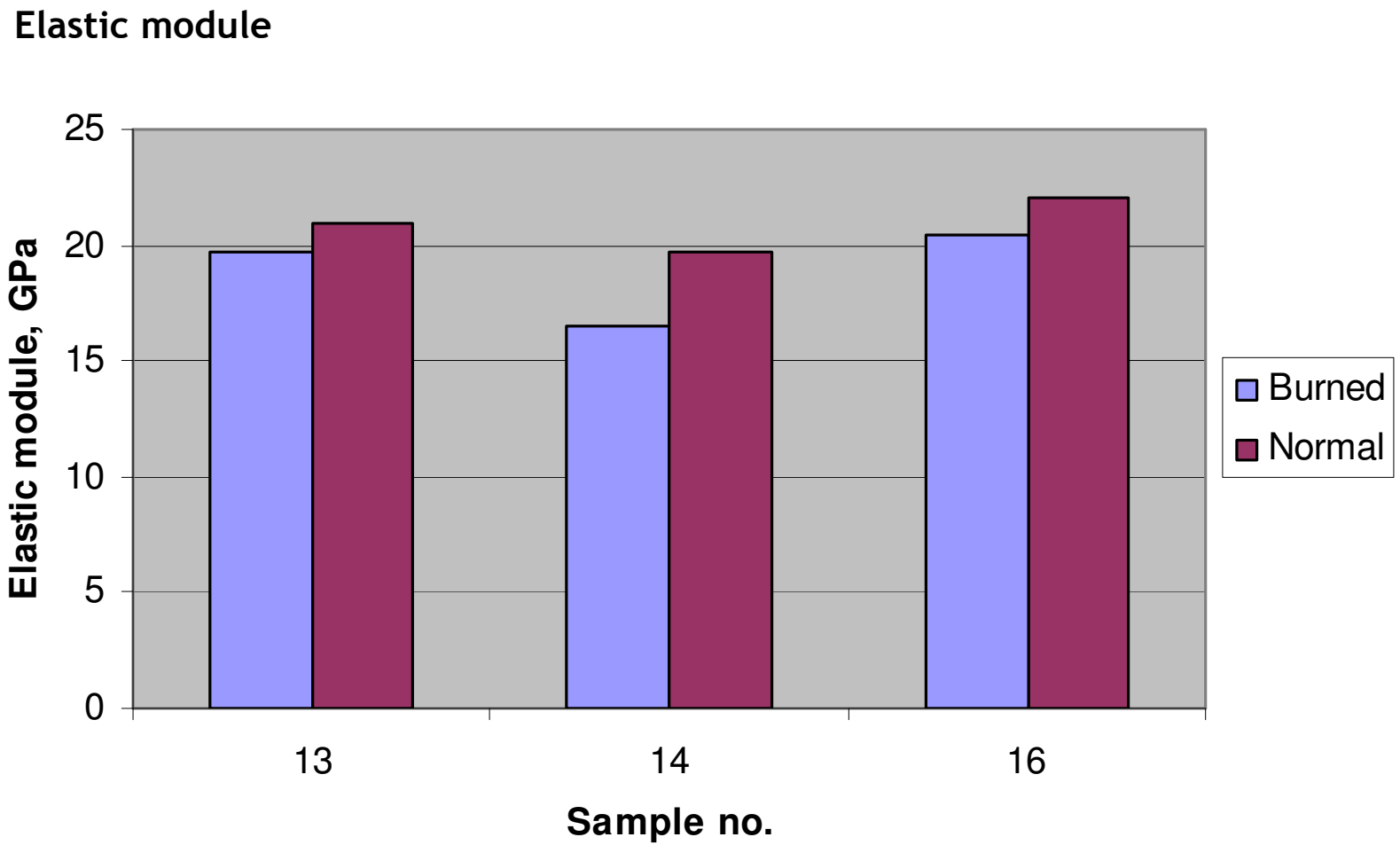
Mech. tests – irradiated samples



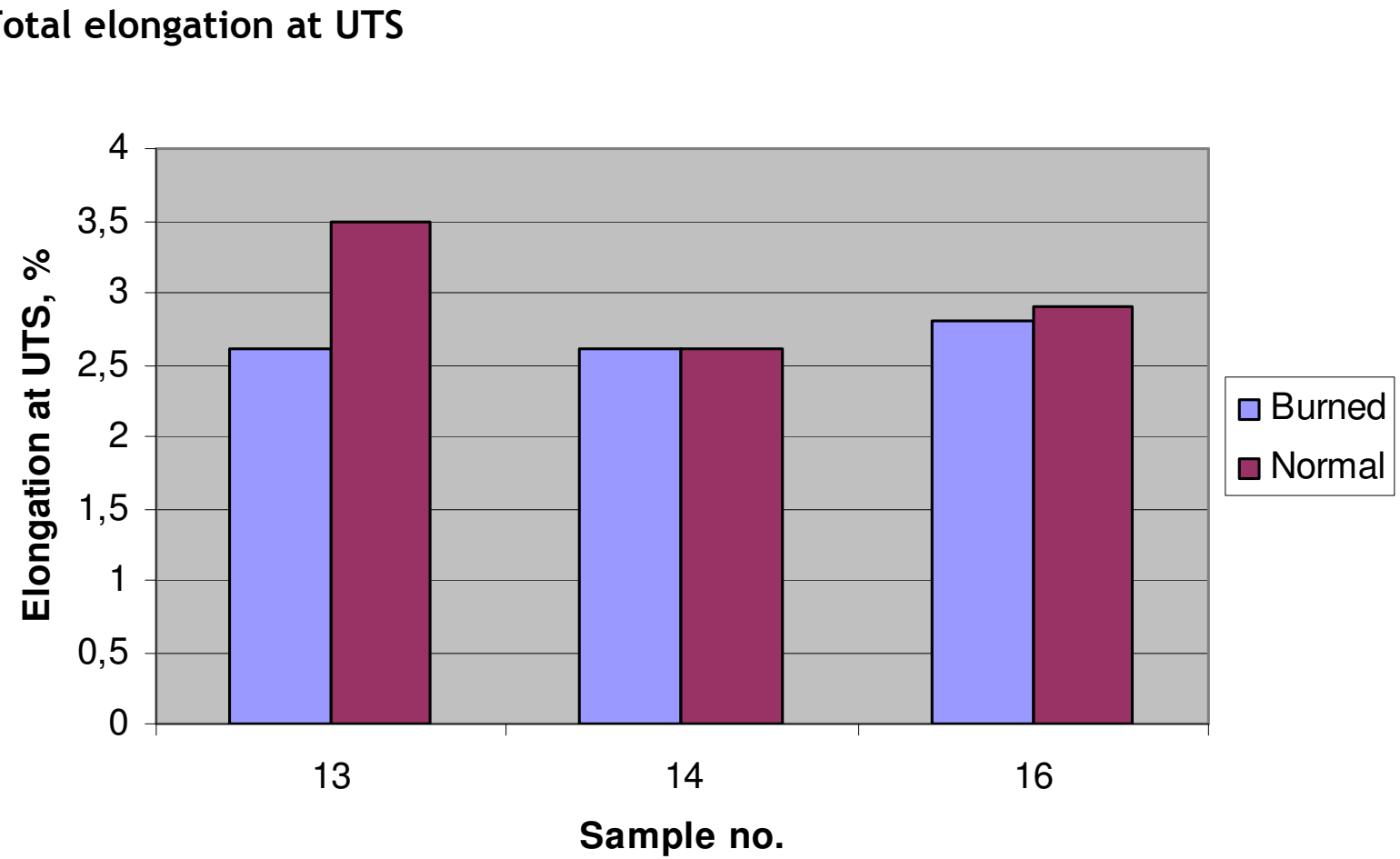
Mech. tests – irradiated samples



Mech. tests – irradiated samples



Mech. tests – irradiated samples



Mech. tests – plan for next weeks

- UTS test of irradiated and unirradiated sheets in direction 45 deg. to the fibers
  - in 45 deg. direction the strength of material should be more determine by resin than by the fibers
  - determination of material anisotropy for this case

Conclusions

- The electron beam source for irradiation of the Nb3Sn coils insulation material samples has been selected,
- Technical up-date of electron accelerator infrastructure allows to achieve the dose rate as 30kGy/min at sample package location,
- The irradiation cryostat has been designed, fabricated and integrated with electron accelerator window at NCBJ, Swierk, Poland. Tests of irradiation set-up and procedure have been done.
- The first mechanical tests of the RAL Mix71 insulation material show strong anisotropy in normal and perpendicular directions of the sheet. The UTS test in 45 deg. direction to the fibers should be free of the anisotropy effect or this effect should be negligible.