"Experimental study of the plastic scintillator damage caused by radiation on IREN at JINR".

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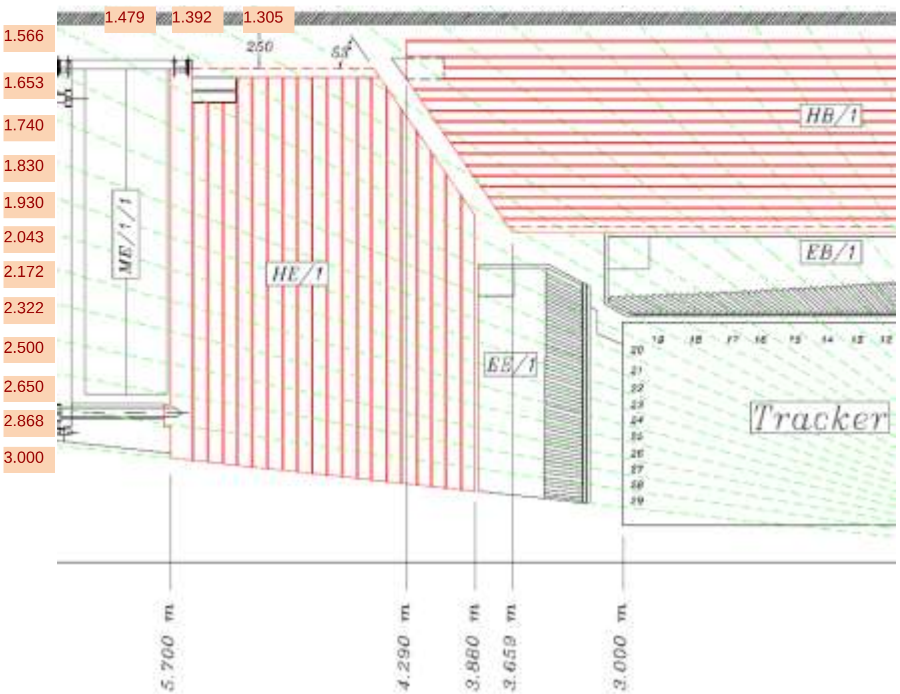
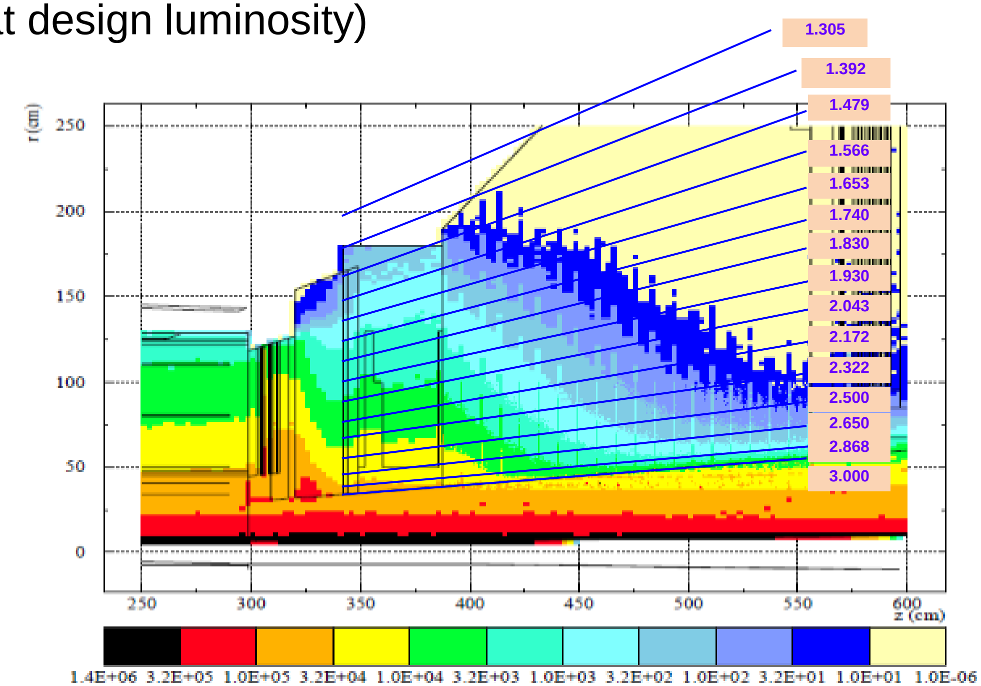
Radiactive exposure of HE detector.

Simulation of a dose map (Gy per 500 fb-1) in the HE

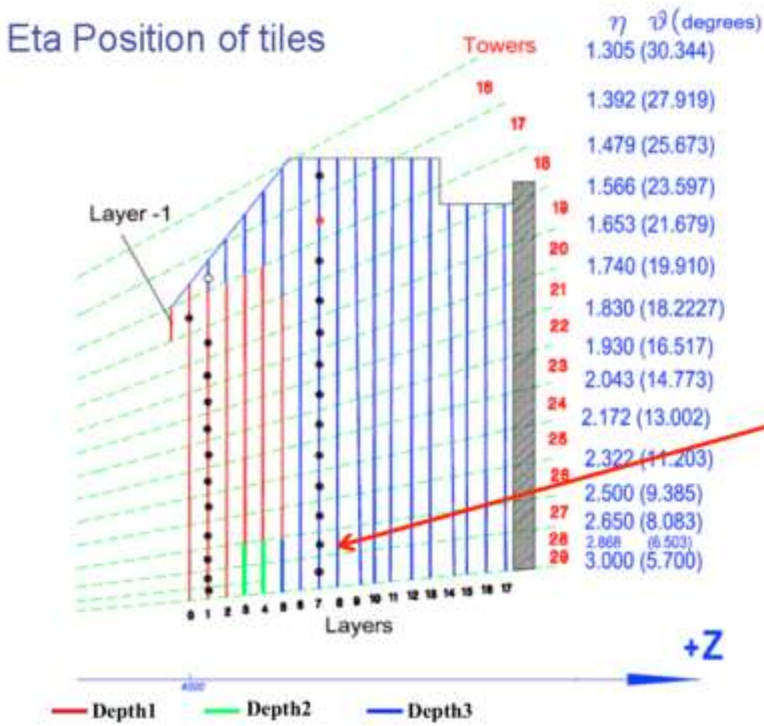
(10 year of LHC operation at design luminosity)

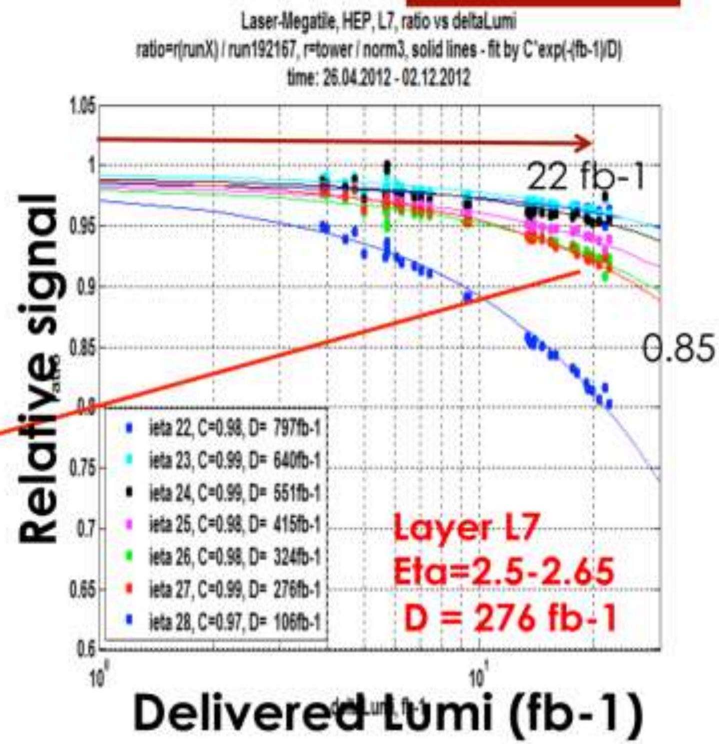




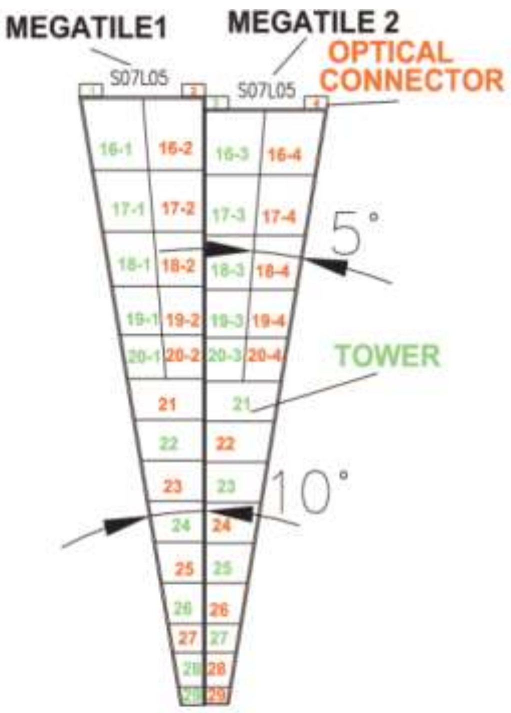
- **Normal operation of HE tiles up to integral radiation level at 5 Mrad.**
- **Scintillator tiles of HE, which are closer to the beam, absorb the greater radioactive dose.**
- **Radiation doses for the period of time, which should provide an accumulation of experimental data for integrated luminosity of 500 fb^{-1}. It means ~10 years of LHC operation**
- **Main aspect is to provide a work of HE calorimeters after a upgrade phase II.**

Laser->Megatile data, 2012
RadDam = exp(-x/D[fb-1])



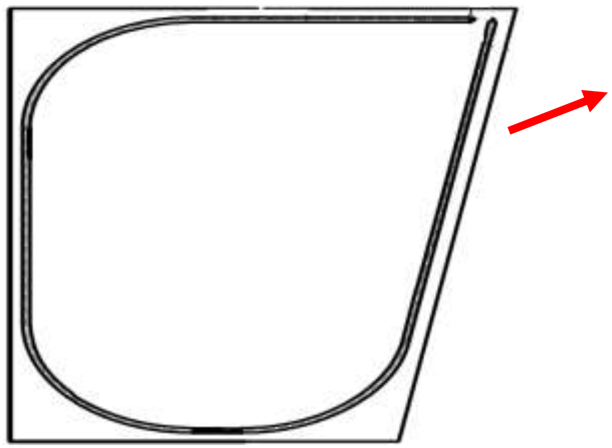


Main factor of light loss



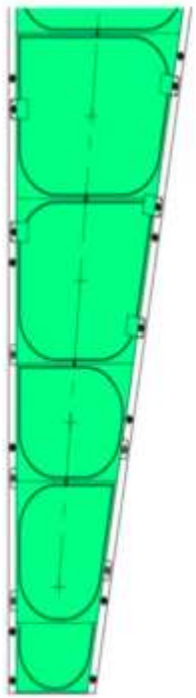
Main factors of light loss with dose increase.

1. Transmittance loss of scintillator (becomes yellow).
2. Transmittance loss of WLS fiber.
3. Degradation of scintillating ability.
4. Reducing of conversion efficiency of WLS fiber.
5. Unknown effects

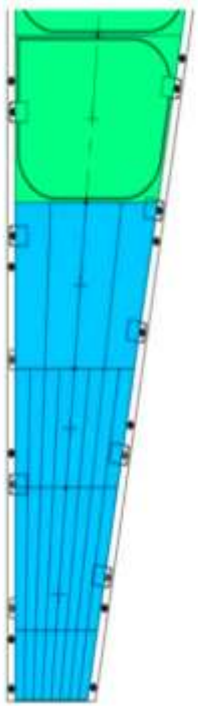


WLS fiber Kuraray Y-11.

"Finger" scintillator concept



Existing tiles granulation



New "fingers" granulation option

A proposal to upgrade of HE calorimeter will provide a solution for survivability at future LHC higher luminosity. A finger-strip plastic scintillator option has many advantages and is a lower cost alternative to keep the excellent HE performance at high luminosity.

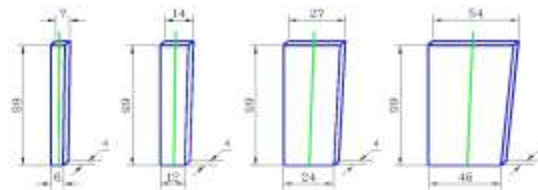
Main concept

How to improve the radiation hardness of HE scintillators?

We decided to improve a light collection from more irradiated tiles.

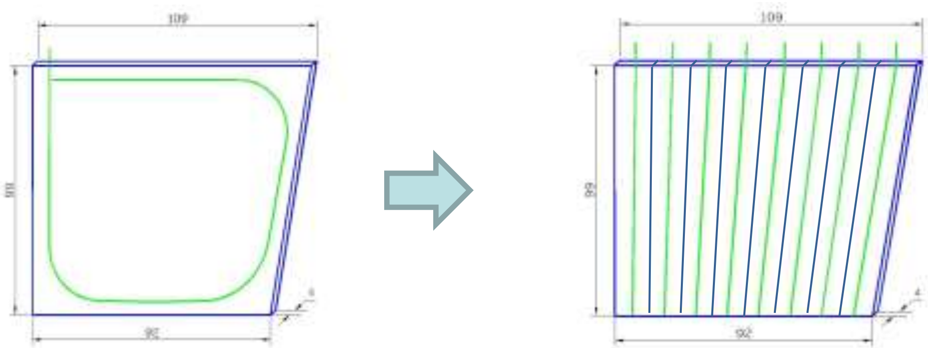
Proposed solution:

Divide tile to several strips. Each strip (width *W*) has own WLS fiber in the middle .



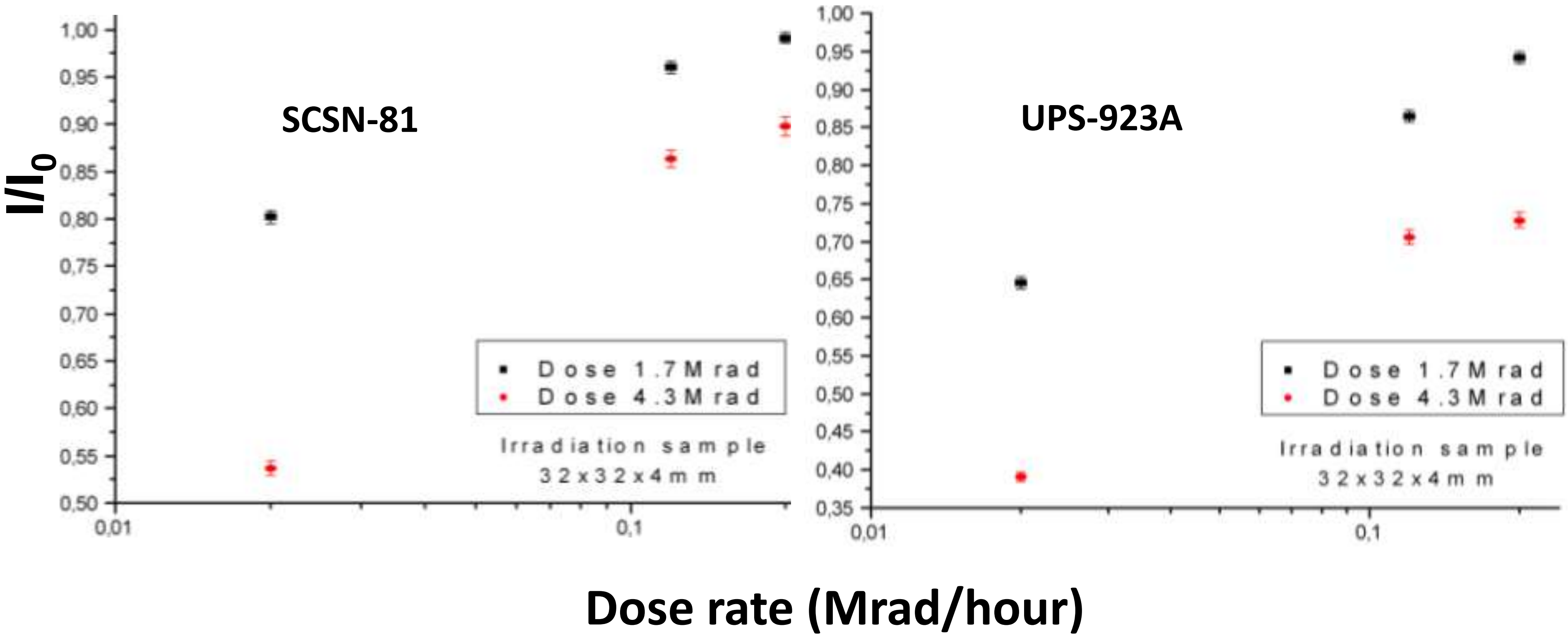
Advantages:

An average path of light inside a strip becomes shorter.
The length of each WLS fiber becomes shorter.
The losses of light are decreased.



KIPT results
(32x32 mm^2 "squares", 1.7 and 4.3 Mrad)

Light output (10 days after irradiation)



At smallest dose rate of 20 krad/hour, light output for 4.3 Mrad is ~1.5 times smaller than that for 1.7 Mrad (both for SCSN-81 and UPS-923A)

Materials under study by now

Scantillators: SCSN-81
UPS-923A
BC-408,
LHE

Samples for study

We study:

- sigma tiles close to tile #27 in the layer #1 with WLS Y11 d=0.85mm;

for understanding of SCSI-81/Y11 radiation damage for 30 fb^{-1} integrated luminosity and for predicting of the properties existing tiles up to 500-700 fb^{-1}

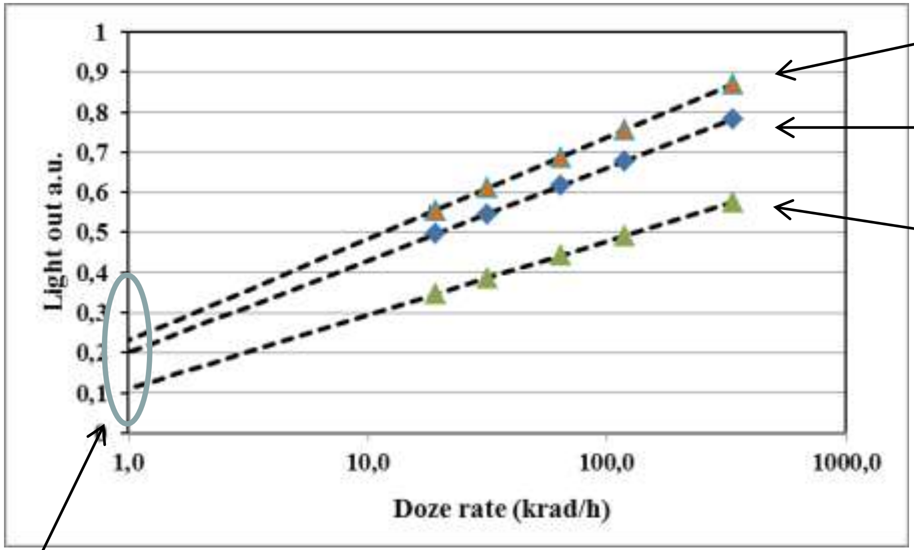
- finger type scintillators: length 60÷148mm, width 12÷20mm, thickness 4mm SCSN-81 and UPS-923A

for predicting of the radiation damage new tiles up to 2500-3000 fb^{-1} integrated luminosity

- “squares” samples 25x25mm^2 of SCSN-81, UPS-923A, BC-408 and LHE. The thickness is uniform (4mm);

Main idea of irradiation study

After measuring the parameter of samples for available dose rates to extrapolate data to real condition of CMS setup.



Dose 5Mrad

Dose 10Mrad

Dose 25Mrad

Extrapolation region

Research program at IREN (JINR)

A number of samples were irradiated with dose rates
from 0.00025 up to 0.338 Mrad/hr. Measurement time 60 days.

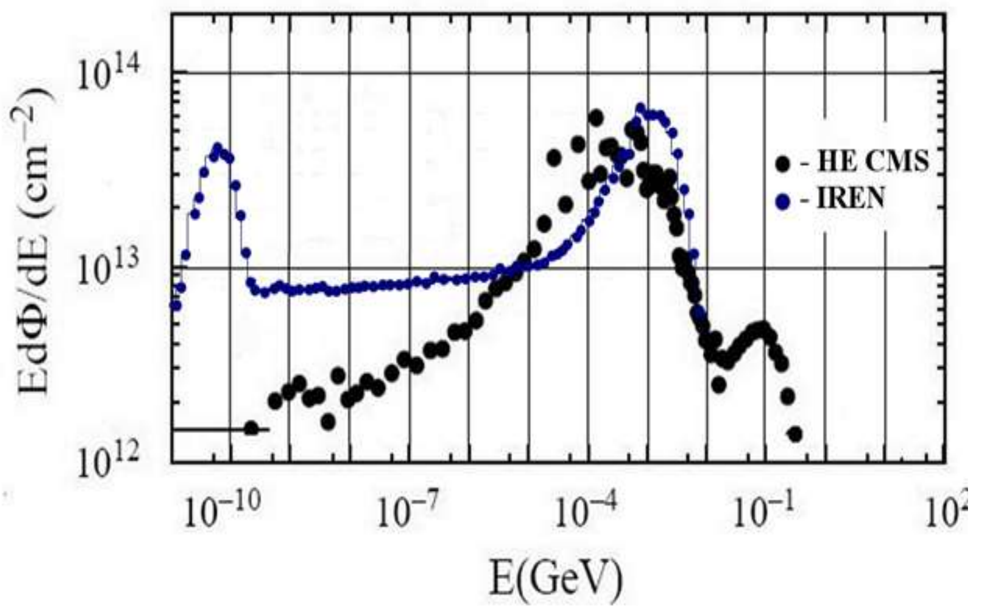
- **"sigma" tiles up to dose 0.3 Mrad** - ***for understanding of SCSN-81/Y11 radiation damage for 30 fb^{-1} integrated luminosity***

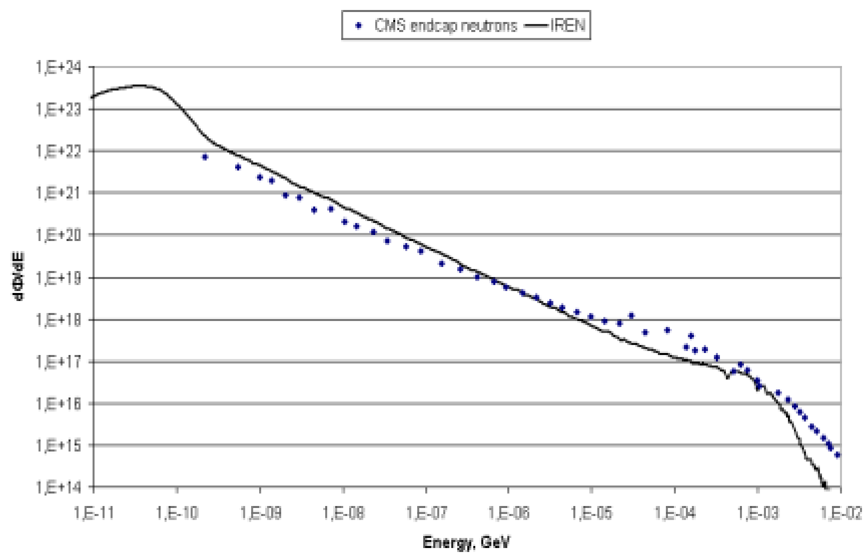
- **"sigma" tiles up to dose 5.0 Mrad** - ***for predicting of the properties existing tiles up to 500-700 fb^{-1}***

- **"finger" type tiles up to dose 25 Mrad** - ***for predicting of the radiation damage new tiles up to 2500-3000 fb^{-1} integrated luminosity***

- **"squares" samples up to dose 10 Mrad** - ***for testing properties of scintillators as function of dose rate and integrated dose***

Neutron spectrum IRENE close to the calculated neutron spectrum in the hadronic calorimeter HE CMS. In the range of neutron energies less than 10MeV.

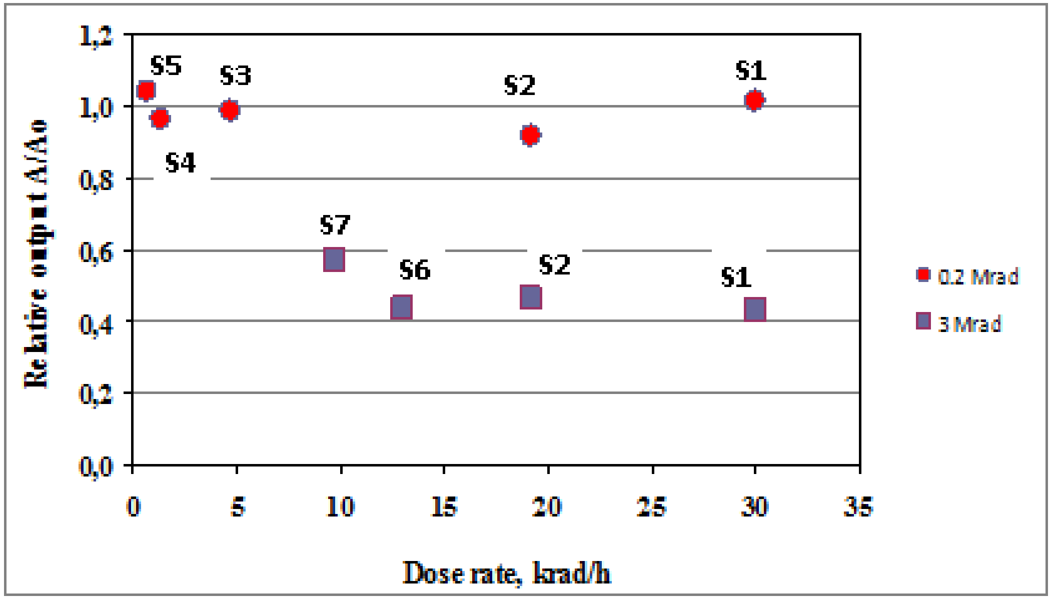




Prepared samples for irradiation

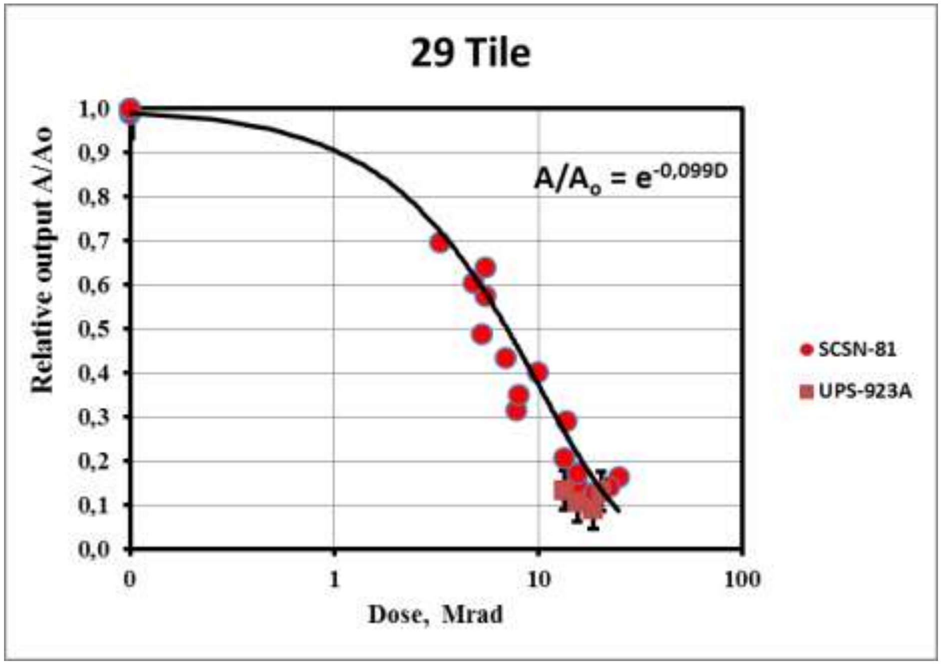
Using this expression was made for calculation of distances L samples were installed.

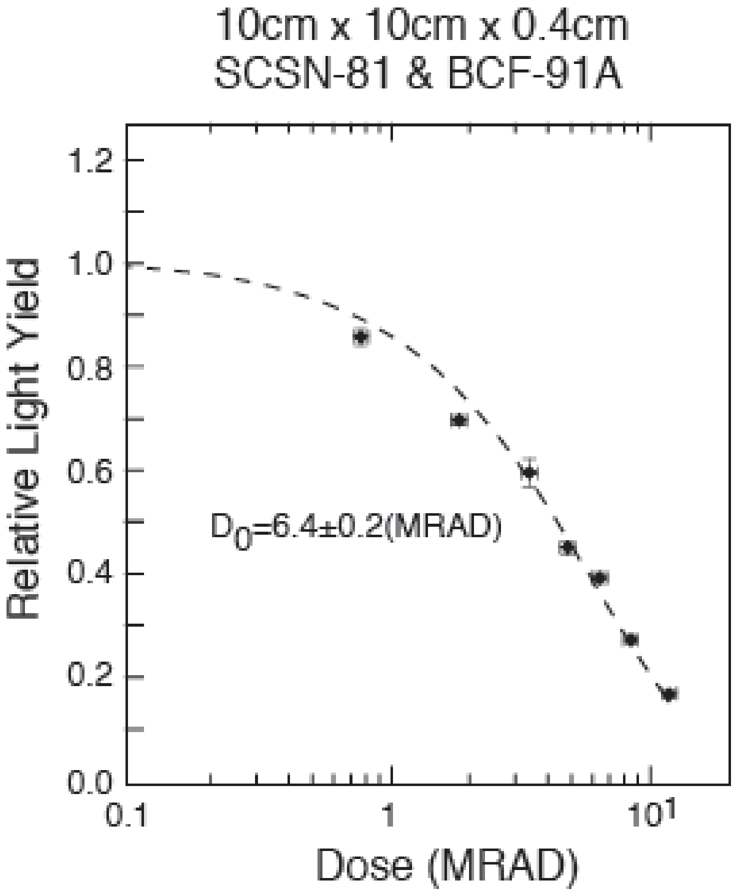
“sigma” tile studies



Dependence of light yield for Sigma type samples.

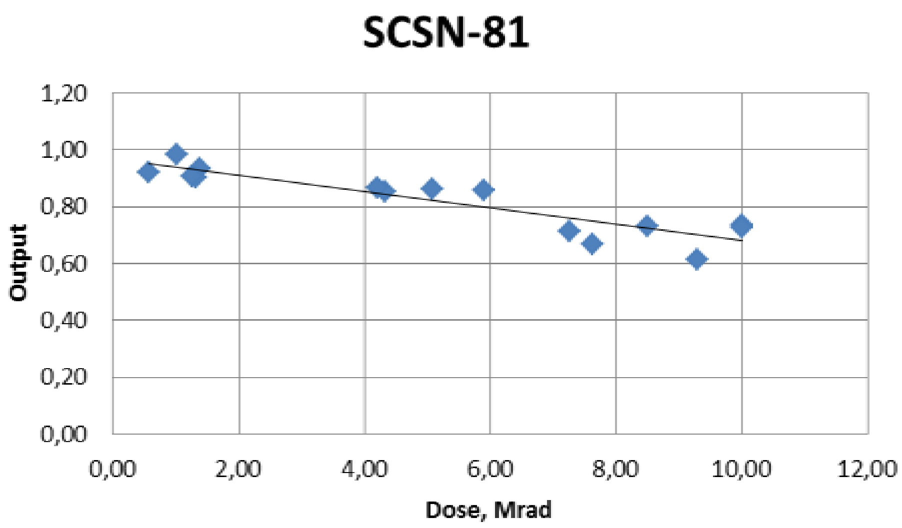
. Figure represented amplitude of the detected signal from the test sample, which is proportional to light yield, vs. the absorbed dose. This amplitude is normalized to the amplitude of signal from the non-irradiated sample. Data for SCSN-81 were fitted by an exponential function.

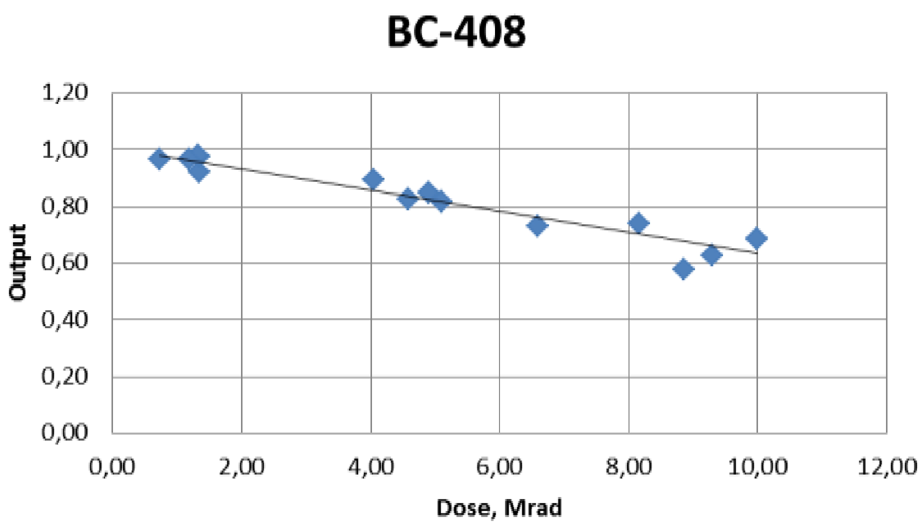


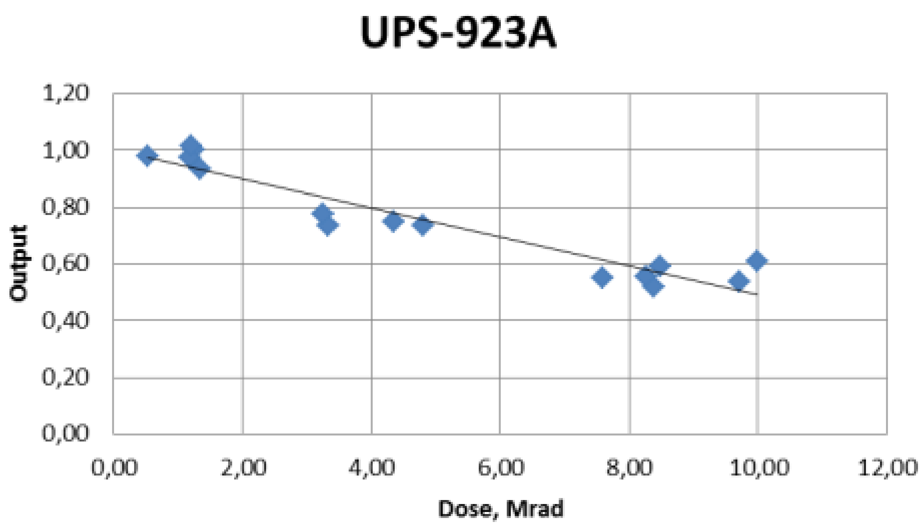


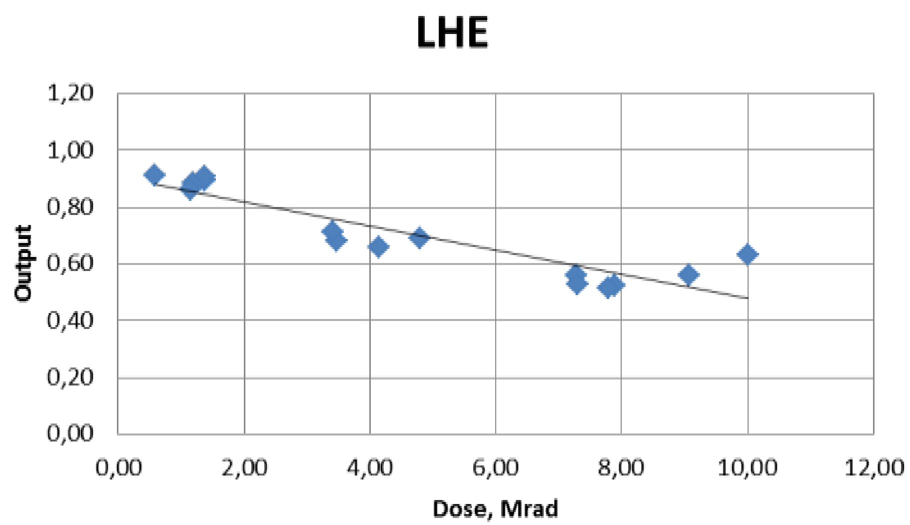
1997 TDR:
Scintillator/WLS fiber light yield degradation as a function of ionization radiation dose

The amplitude of the signal from the absorbed dose for the different samples.



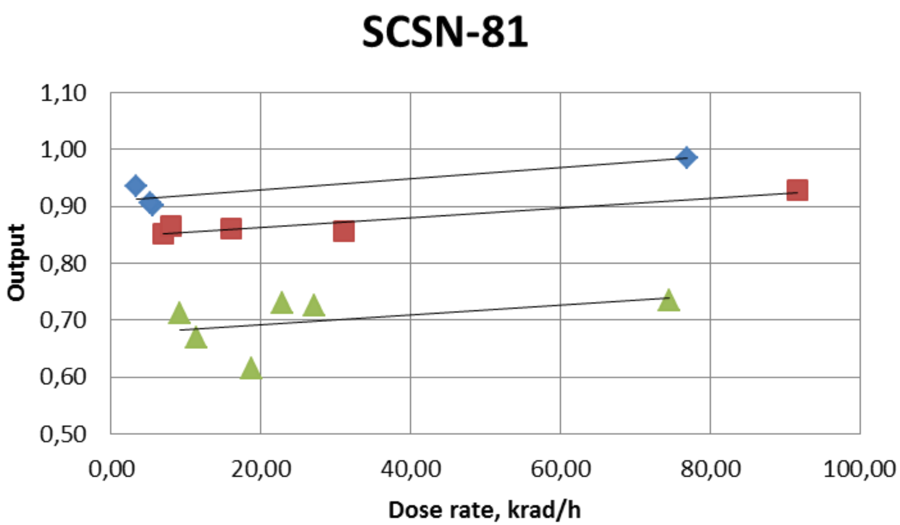


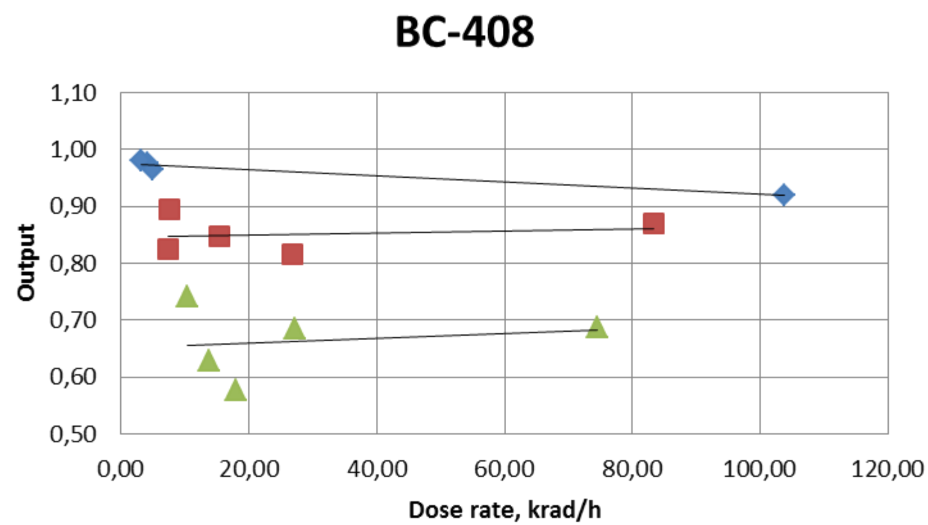


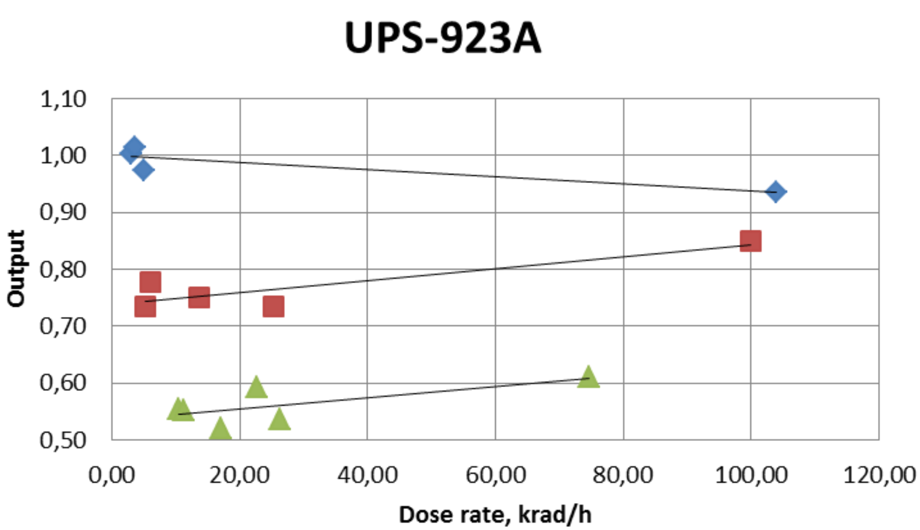


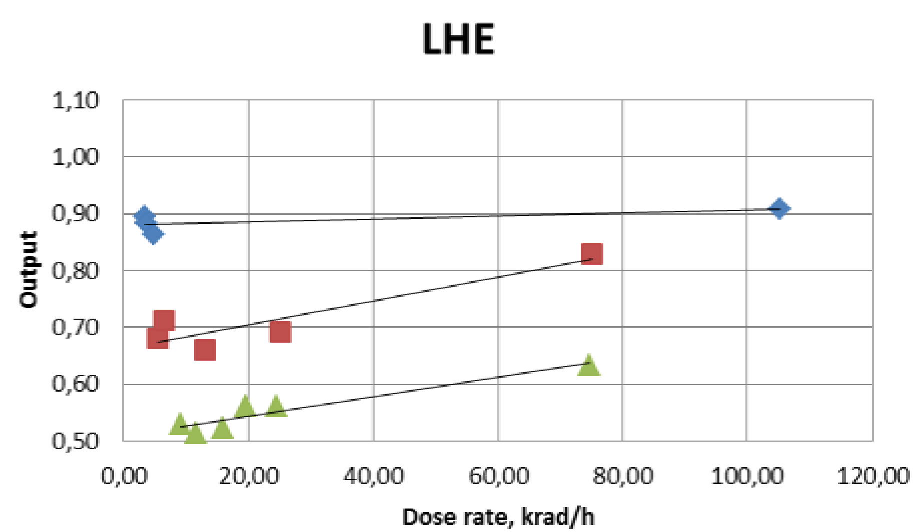
The amplitude of the signal from the absorbed dose rate for the different samples.

Dose range 1÷1.4, 3.6÷4.8, 7.3÷10 Mrad

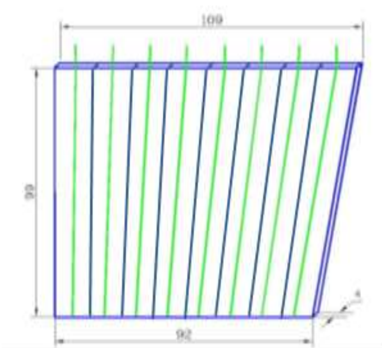


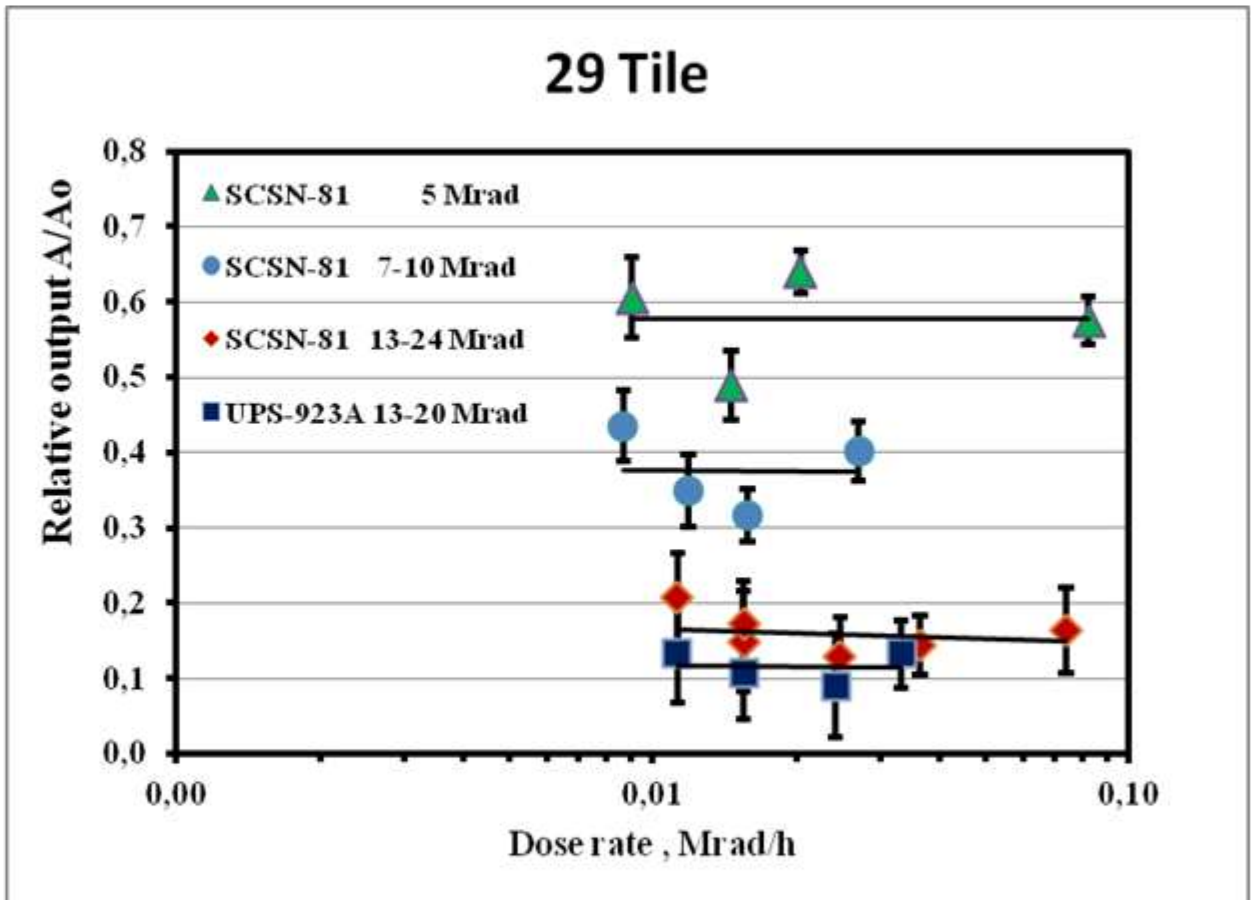




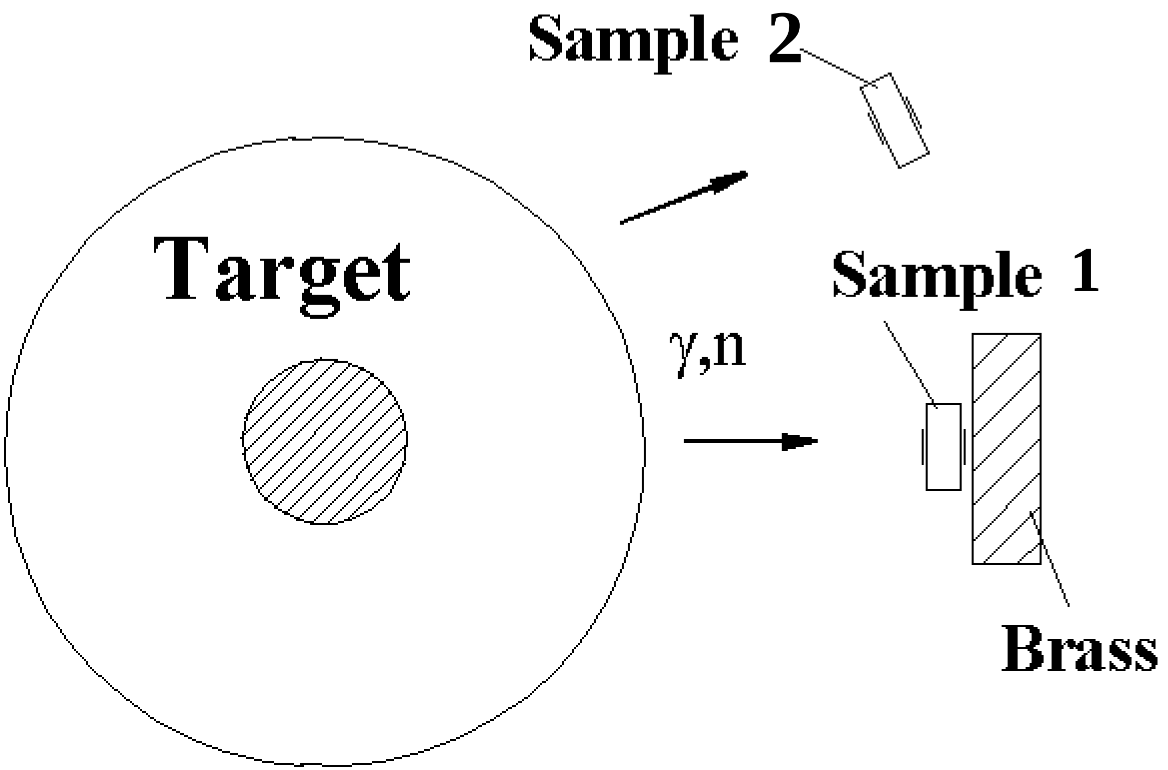


Dependencies of normalized amplitude vs. a dose rate separately for each type of finger type scintillator and for each group of the closely adjacent absorbed dose intervals.





Effect of induced radioactivity on the measured signal from the sample.



Samples = UPS-923A

Brass dimension
D=59mm, h=9.6mm

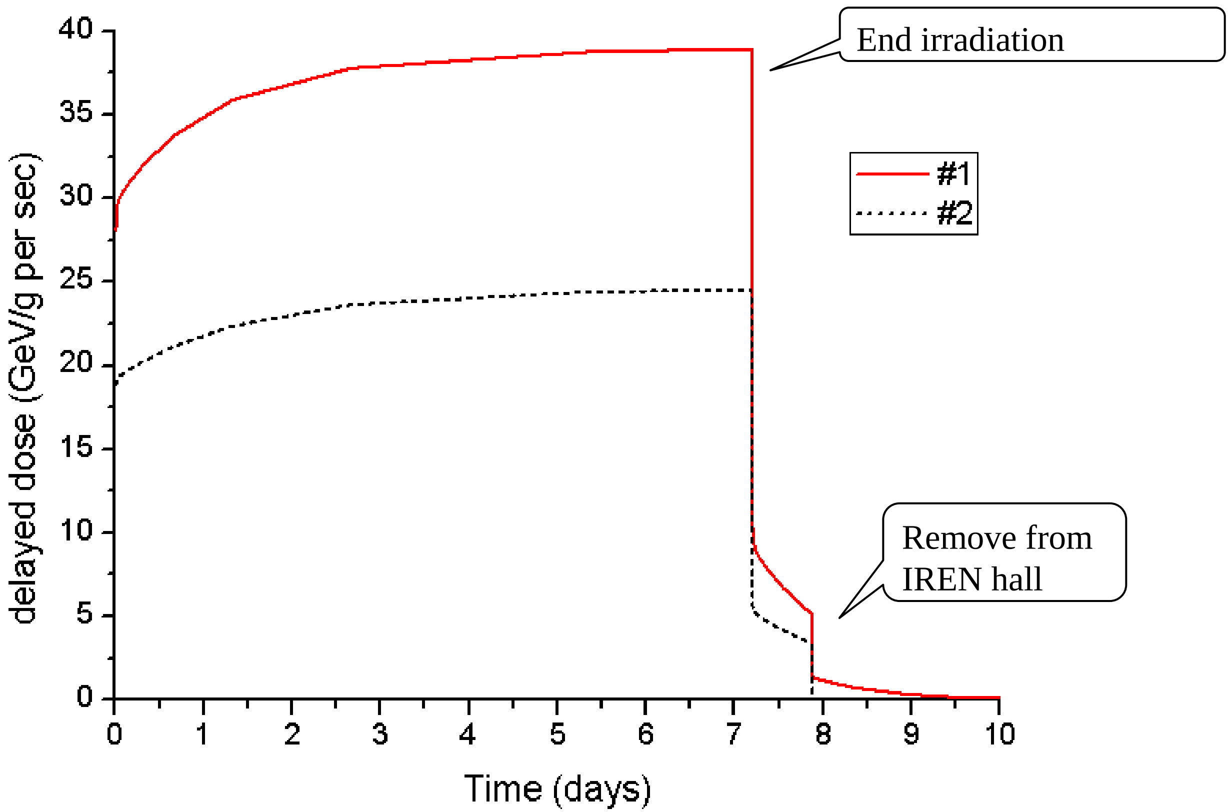
Neutron flax $5{,}5\cdot10^{7}c^{-1}$
Time 7,2 dais
Total flax =***3,4·10^13^***

	Dose		Amplitude A/Ao	
	front side	end side	front side	end side
Sample 1	9,0 Mrad	19,5 Mrad	**0,82**	**0,79**
Sample 2	6,7 Mrad	6,0 Mrad	**0,85**	**0,86**

Simulation of the absorbed dose

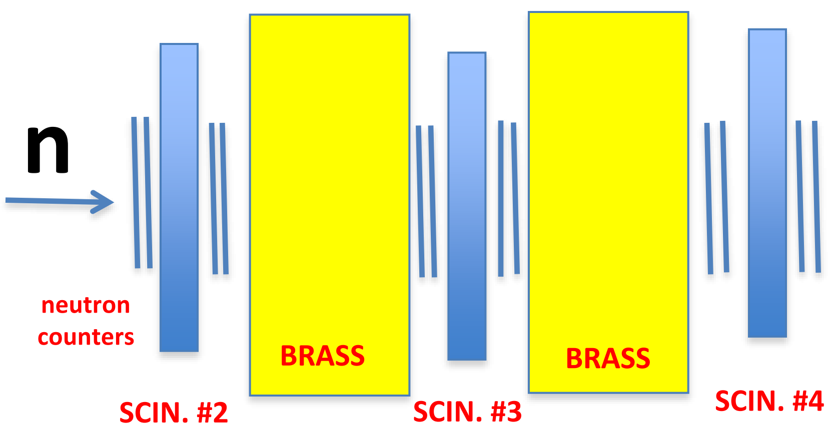
Total dose “prompt” irradiation time [0-7,2 сут]
Sample №1 + Brass: 4,693E+11 GeV/g +/-0,53% **D = 7,518 Mrad**
Sample №2: 4,065E+11 GeV/g +/-0,57% **D = 6,512 Mrad**

Total dose “delayed” all time [0-13,2 лет]
Sample №1: 2,414E+07 GeV/g +/-6,20% D = 387 Рад
Sample №2: 1,480E+07 GeV/g +/-8,76% D = 237 Рад



Bicron squares irradiation with induced radioactivity from neutrons in IBR-2M ($1.5x10^{15}n/cm^2$). 1^{st} attempt

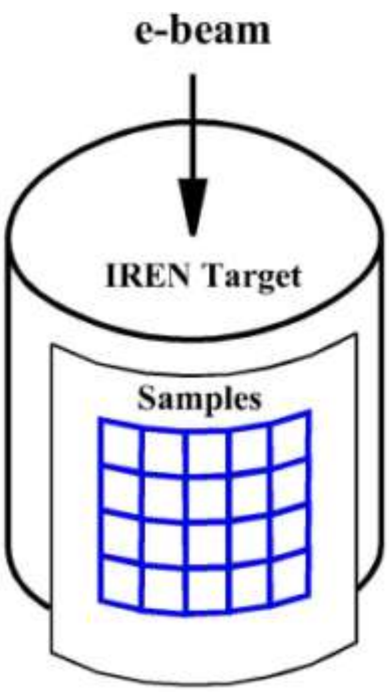
Bicron with brass absorber



	RLY front side	RLY back side
SCIN. N2	.73	.74
SCIN. N3	.78	.78
SCIN. N4	.80	.81

For neutron fluence *($1.5x10^{15}n/cm^2$) relative light yield (RLY) is not less than .73*

Irradiation at IREN target



Max. electron energy – 30 MeV

Pulse current – 2 A

Pulse width – 100 ns

Repetition rate – 25 Hz

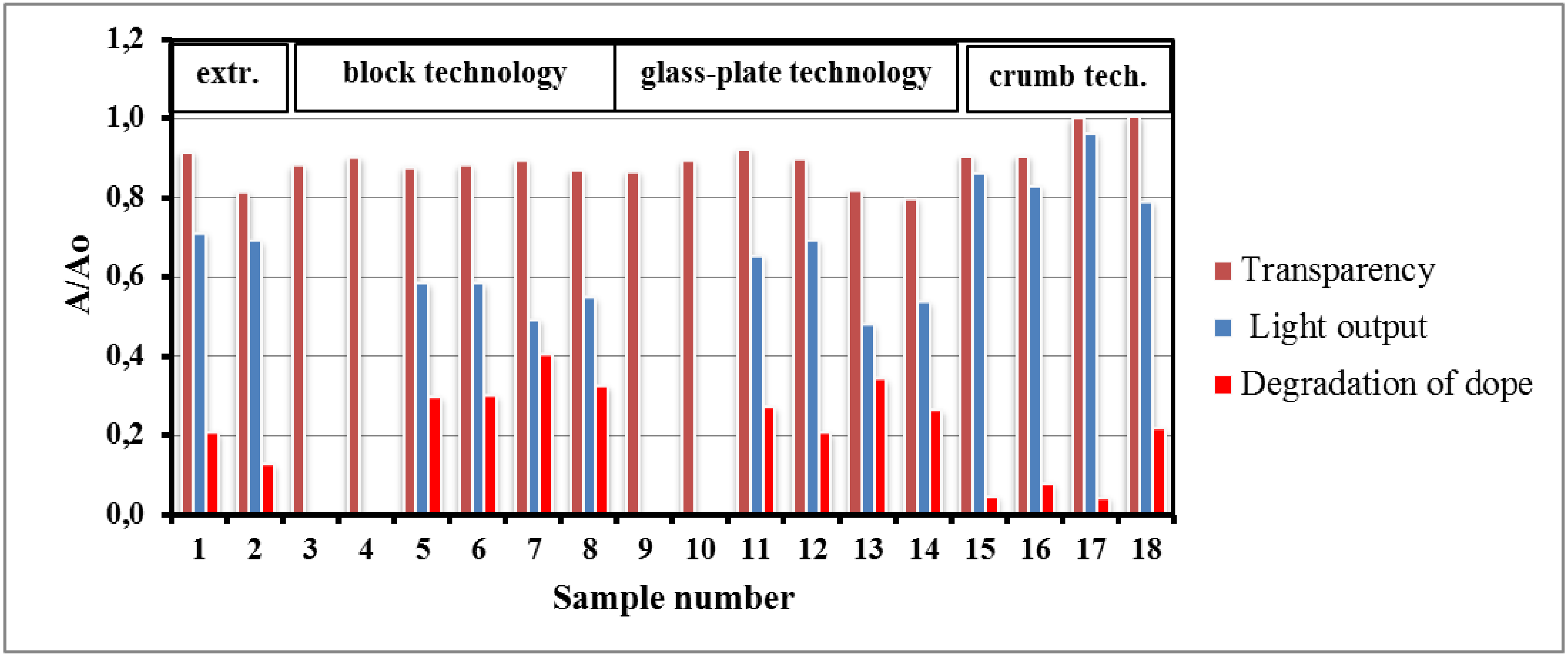
Beam power – ~1kW

Neutron intensity – ~10^{11} n/s

Gamma intensity -- ~$3 \cdot 10^{13}$ γ/s

Irradiation time from 31.03.2014 to 4.04.2014. Total time is 100 hours.
Doze 8-9Mrad

Summary results of IREN study



Degradation of dope is result of subtraction Light output from transparency.

Conclusions

1. The studies of four types of plastic scintillator SCSN-81, UPS-923A, BC-408, LHE were carried out on IREN.
2. The results have not shown the confident evidences of some considerable changes in light outputs for different dose rates for all four types of the scintillator
3. No confident evidences of changes in the light outputs for different dose rates were found for Sigma type samples.
4. The influence of the additional radioactivity emitted by radioisotopes induced in the brass was also studied. The results of the relative light outputs from the samples have shown the presence of additional radiation coming from the brass disc.
5. A study of the radiation stability of scintillators from their production technologies.
6. The degradation of the plastic surface due to the presence of ionized air was also investigated.

Thank you for attention!

And special thanks to the staff of Intense Resonance Neutron source (IREN) for active participation in the measurements.

Effect of ionized air on the signal amplitude.

Sample = UPS-923A