Measurements of doped BaF_2 crystals

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Outline

- Crystal samples
- Neutron irradiation facility
- Results
- Conclusion

Crystal samples

We have samples from both SICCAS and BGRI (China):

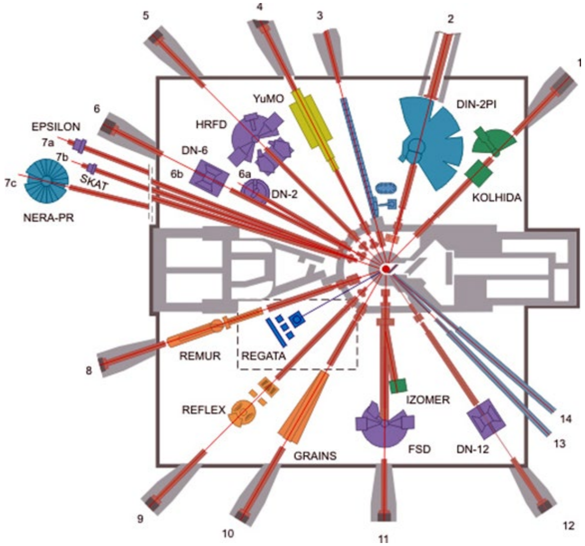
BaF_2 pure crystal,	10x10x10 mm
BaF_2 crystal doped with Y (1at.%),	10x10x10 mm
BaF_2 crystal doped with Y (3at.%),	10x10x10 mm
BaF_2 crystal doped with Y (5at.%),	10x10x10 mm

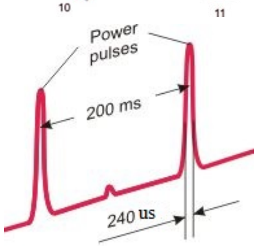
and

BaF_2 pure crystal,	30x30x200 mm
BaF_2 crystal doped with Y (3at.%),	30x30x200 mm

We also expect to receive more samples from Incrom (Russia)

Irradiation facility at IBR-2M

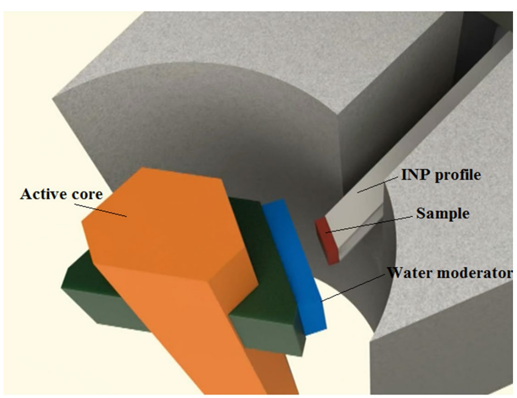


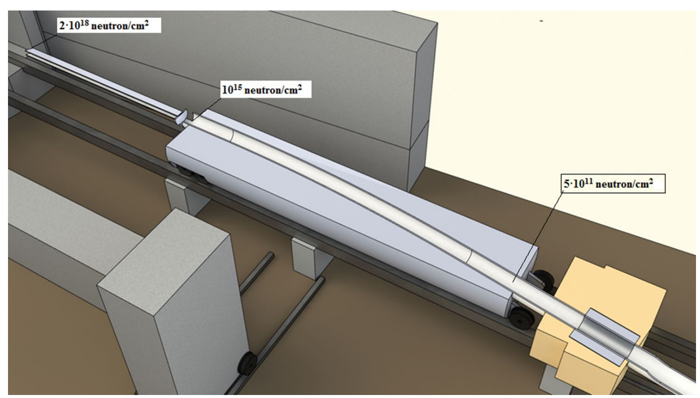


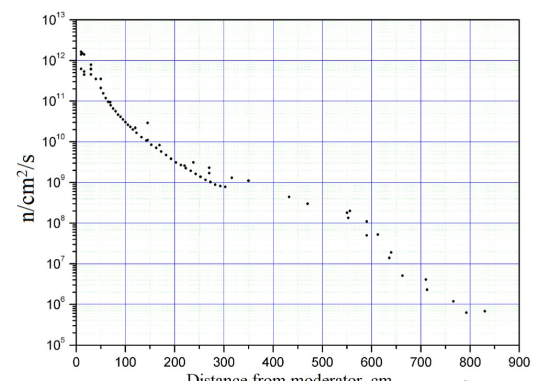
- Crystal samples were irradiated on channel 3 of the IBR-2M pulsed reactor at the Frank Laboratory of Neutron Physics, JINR (Dubna, Russia)
- Typical reactor run continues 12-14 days. The reactor operates with a pulse frequency of 5 or 10 Hz
- Thermal neutron flux density immediately after the water moderator is $\sim 10^{16}$ n/cm^2 per pulse or $\sim 10^{13}$ n/cm$^2\cdot$s on average over time. For 2 weeks of operation, it is possible to obtain a neutron fluence from $\sim 10^{11}$ n/cm^2 on the end of channel #3 up to $\sim 10^{18}$ n/cm^2 next to the water moderator.

For the first irradiation run, only 4 samples from SICCAS of 10x10x10mm were taken: pure BaF_2, BaF_2:Y(1 at.%), BaF_2:Y (3 at.%) and BaF_2:Y (5 at.%)
The samples were placed in channel #3, about 5 m from the water moderator. A nickel wire placed along with the samples was used to measure the neutron fluence.

During the irradiation run, ~**2.3×10^{14} n/cm^2** were passed through the samples







Measurement of samples

- Light outputs were measured by a Hamamatsu R2059 PMT with ^{22}Na gamma source with a coincidence trigger (E=511 keV)
- Samples were wrapped with Teflon film (2x0.1mm)
- No optical grease was used between samples and PMT
- No light output adjustments have been made due to QE differences for fast and slow components (QE is around 16-17% and 23-24% for fast and slow components, respectively)
- The total signal was integrated within 2 microseconds, while the fast component was taken within first 20 ns and the slow component – after 20 ns

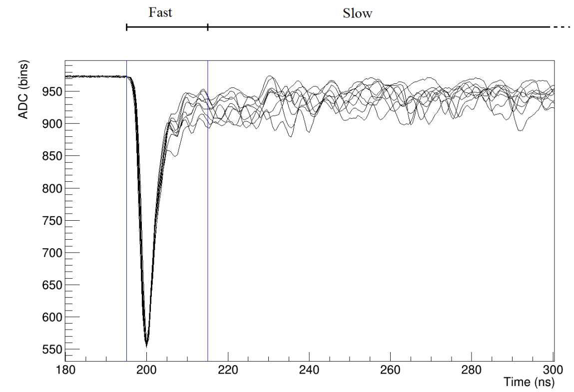
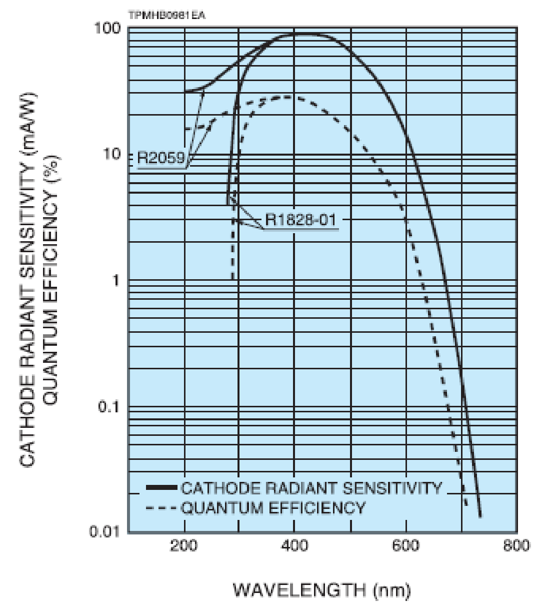
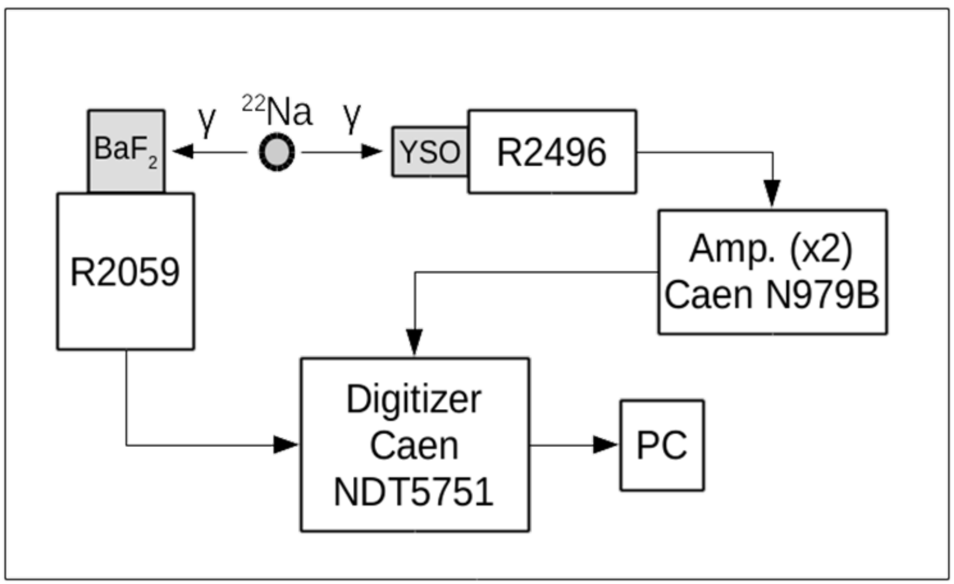


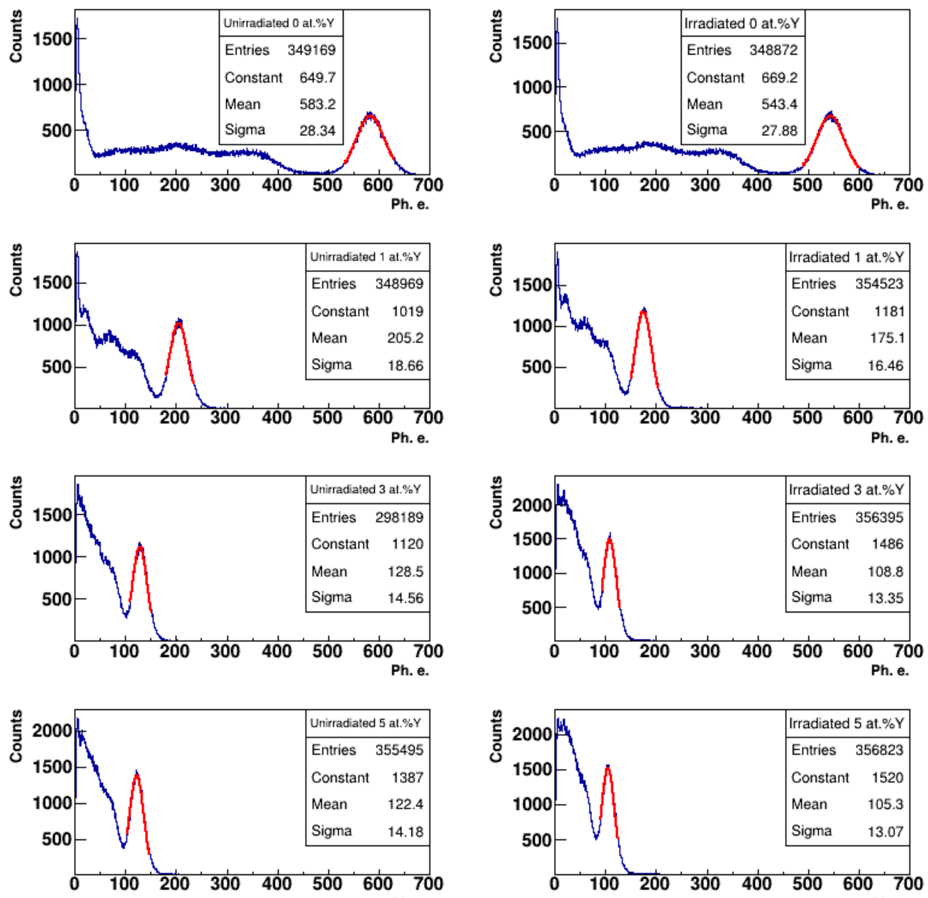
Figure 1: Typical spectral response

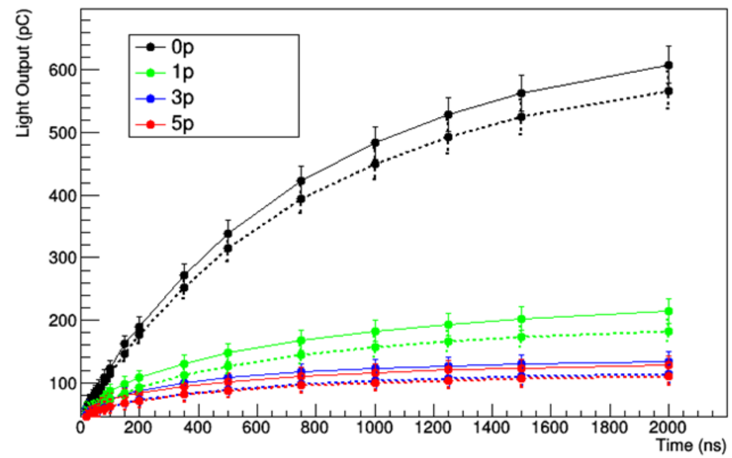




Total signals

Spectra of total signals (2 μs) from unirradiated (left column) and irradiated (right column) crystal samples (pure and Y doped) due to E=511 keV gammas from a ^{22}Na source





In unirradiated samples, the total signal drops 2.8 times in the 1at.% doped sample, 4.5 times in the 3at.% doped sample and ~4.8 times in the 5at.% doped sample compared to the pure BaF_2 sample

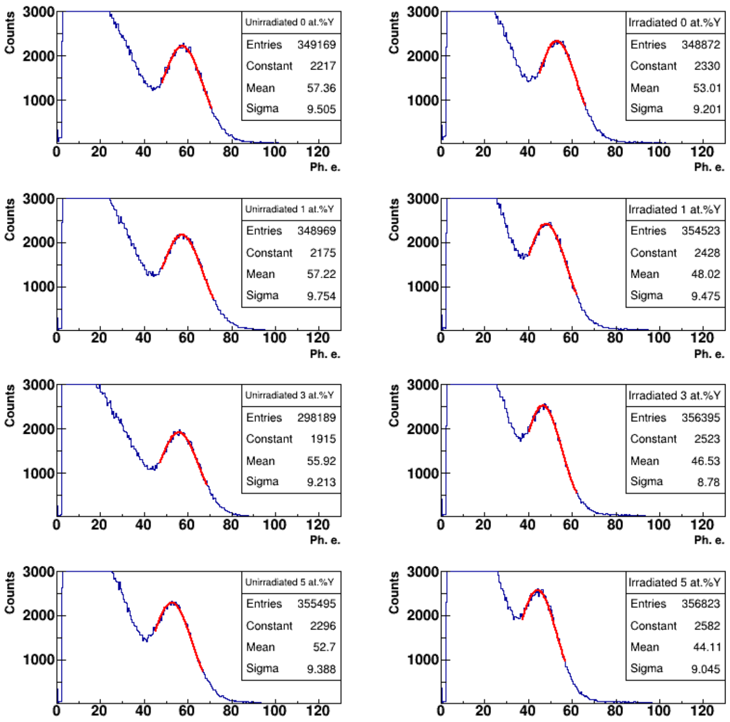
Irradiation of the crystals resulted in a greater loss of light yield in the yttrium-doped samples

Total LO, ph.e.

Y doping	0%	1at.%	3at.%	5at.%
Unirradiated	**583**	205	128.5	122.4
Irradiated	543	175	109	105.3
LO_{Irr}/LO_{Unirr}	0.93	0.85	0.85	0.86

Fast and slow components

Spectra of fast signals (20 ns) from unirradiated (left column) and irradiated (right column) crystal samples (pure and Y doped) due to E=511 keV gammas from a ^{22}Na source



In unirradiated samples, **the slow signal is suppressed** 3.6 times in the 1at.% doped sample, 7.2 times in the 3at.% doped sample and ~7.5 times in the 5at.% doped sample compared to the slow component of a pure BaF_2 sample

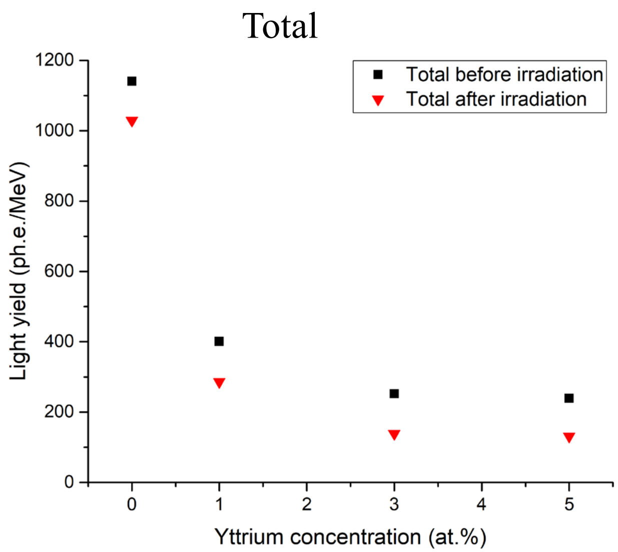
Fast emission LO, ph.e.

Y doping	0%	1at.%	3at.%	5at.%
Unirradiated	**57.4**	57.2	55.9	52.7
Irradiated	53.0	48.0	46.5	44.1
LO_{Irr}/LO_{Unirr}	0.923	0.84	0.83	0.84

Slow emission LO, ph.e.

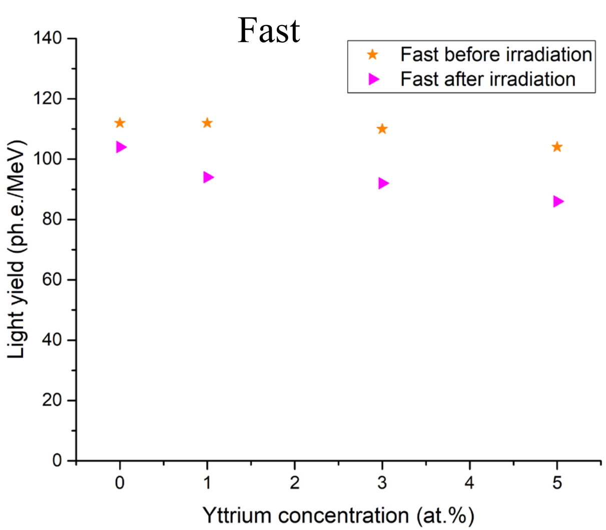
Y doping	0%	1at.%	3at.%	5at.%
Unirradiated	**526**	146	71	67
Irradiated	490	125	60	58
LO_{Irr}/LO_{Unirr}	0.93	0.856	0.845	0.866

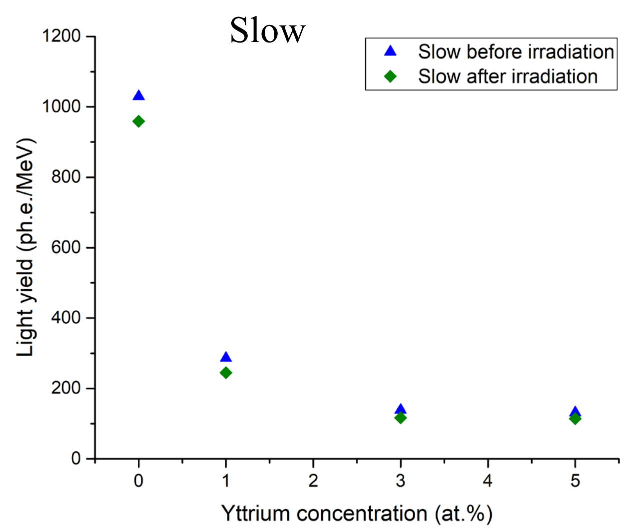
Light yields of all samples



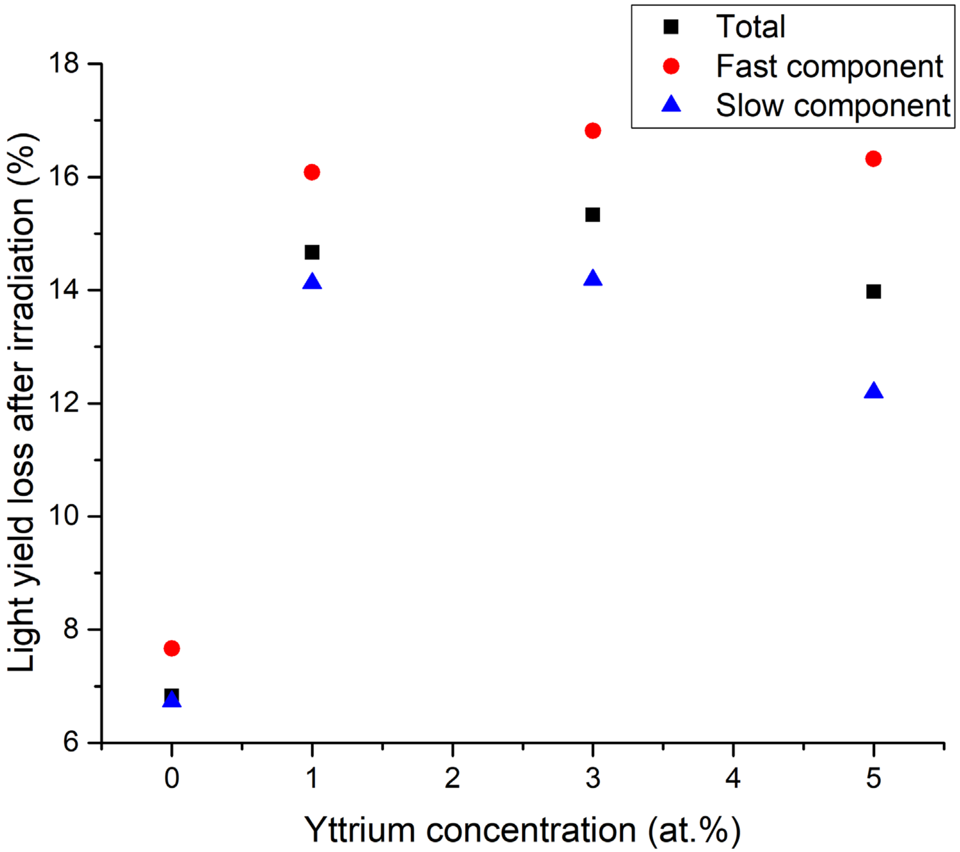
The light yield is shown in ph.e./MeV

It is clearly seen that the irradiated samples doped with yttrium lose the light yield more as compared to the pure BaF_2 crystal





Light output loss after irradiation



The light output loss after neutron irradiation is more than twice as high for yttrium doped samples as compared to the pure BaF_2 sample

Y doping	0% (pure)	1at.%	3at.%	5at.%
Fast	7.6%	16.1%	16.8%	16.3%
Slow	6.8%	14.4	15.5	13.4
Total	6.9%	14.7%	15.3%	14.0%

Conclusion

- The light yield losses after neutron irradiation are almost two times higher for the yttrium doped samples compared to the losses in the pure BaF_2 sample

- The light yield loss of the fast component after neutron irradiation is higher compared with the slow component on all samples

Obviously, more study is required in a wider range of radiation doses…

Acknowledgments

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