Suppression of a slow component of a BaF_2 crystal luminescence with a thin multilayer filter

A.M. Artikov[1], V. Baranov[1], J.A. Budagov[1], A.N. Chivanov[2], **Yu.I. Davydov**[1], E.N. Eliseev[3]
E.A. Garibin[4], V.V. Glagolev[1], A.V. Mihailov[3], V.V. Terechschenko[1], I.I.Vasilyev[1]

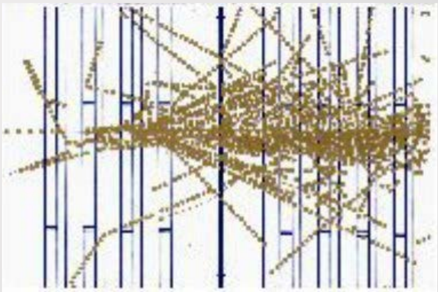
[1] *JINR, Dubna, Russia*

[2] *"Ural-GOI", Branch of JSC «PA «UOMP», St. Petersburg, Russia*

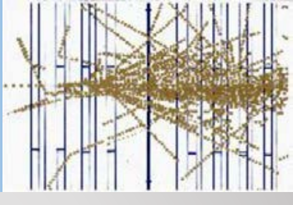
[3] *LLC "Optech", St. Petersburg, Russia*

[4] *INCROM ltd, St. Petersburg, Russia*

CALOR 2018
Eugene OREGON
May 21-25, 2018



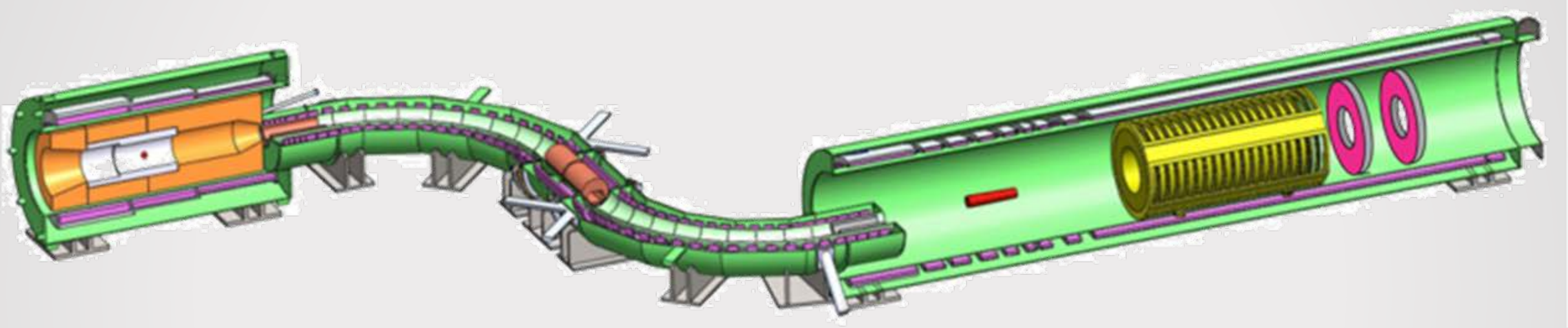
Outline



1. Introduction
2. Motivation
3. Suppression of a slow component
4. Thin multilayer filter
5. Tests results
6. Conclusion

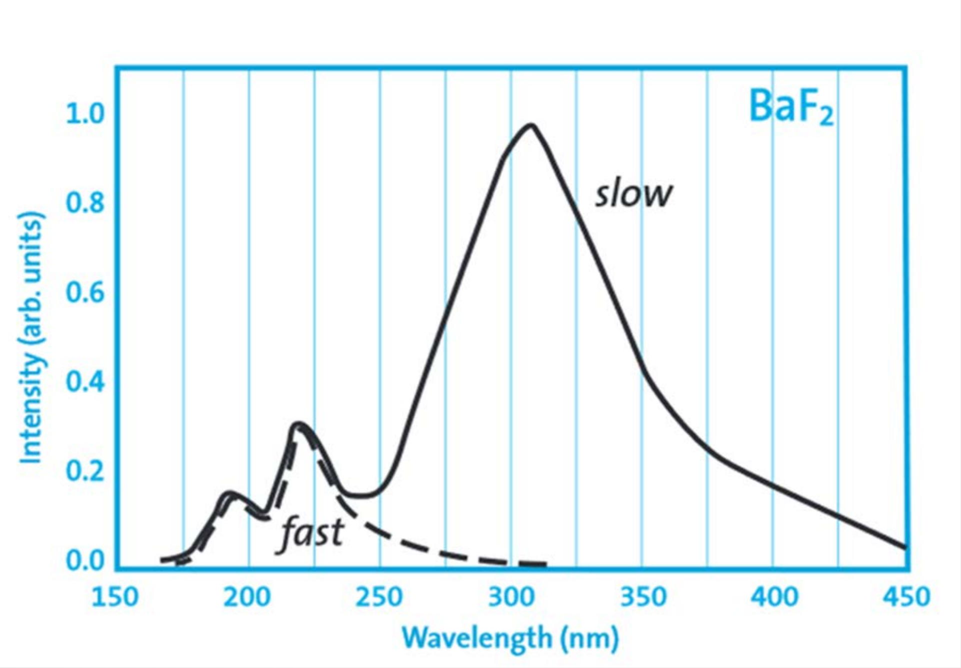
Introduction

The Mu2e calorimeter is composed by two disks of pure CsI crystals of 34 x 34 x 200 mm^3 dimension (see talks by Mu2e group members)



- An Expression of Interest for the evolution of the Mu2e experiment (Mu2e-II) has been submitted to the Fermilab Physics Advisory Committee
- The upgraded experiment Mu2e-II will extend sensitivity to the muon-to-electron conversion process by an order of magnitude
- The radiation environment and average event rate will increase by factor ~10 as well
- BaF_2 is an excellent candidate to use in the Mu2e-II calorimeter

Motivation



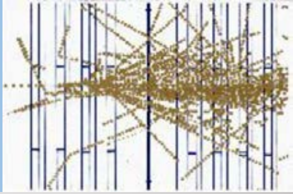
Fast components (195, 220 nm)
- Decay time <1 ns

Slow component (310 nm)
- Decay time ~620 ns

BaF_2 crystals are natural choice for the Mu2e-II calorimeter to use at the intensity frontier (see talk by Ren-Yuan Zhu).

However, a slow component of the BaF_2 luminescence could cause a problems at high rate and needs to be suppressed

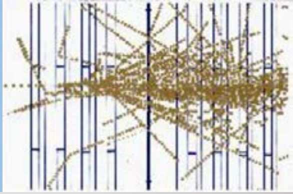
Suppression of a BaF_2 slow component



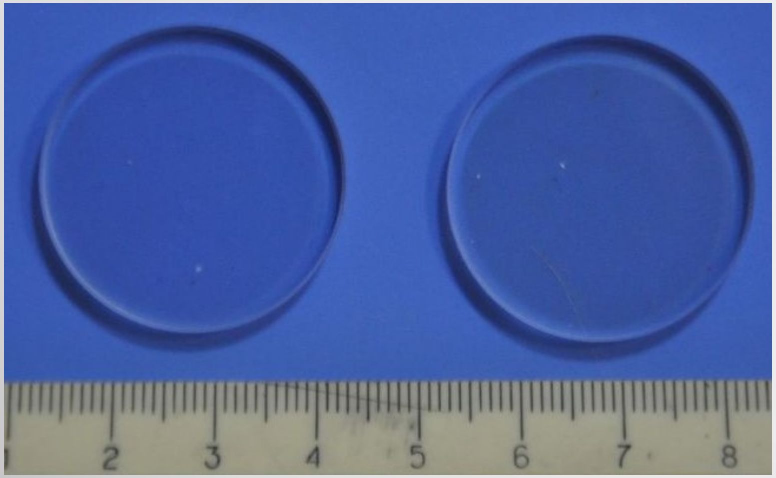
Suppression of a slow component by means of:

- BaF_2 with doping (see Ren-Yuan Zhu talk)
- ALD interference to get solar blind windows on the sensors
- Nanoparticle coatings on sensors
- External interference optical filters

Thin multilayer filter for a BaF_2 slow component suppression

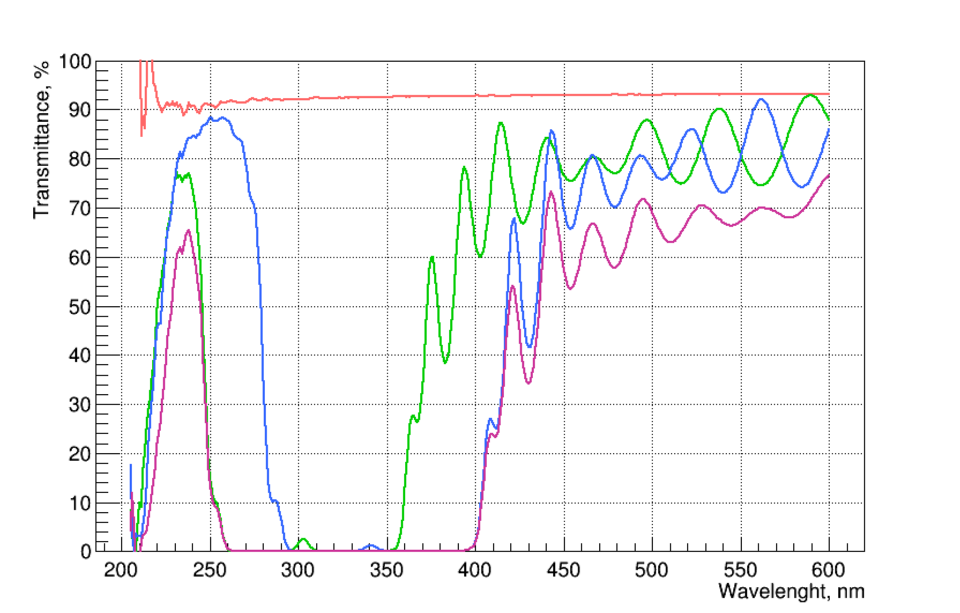


- Thin multilayer filters made of rare earth oxides can suppress luminescence in the range about from 250 nm to 400 nm
- Calculation of the filter design, selection of film-forming materials and complex analysis of a sprayed filter was carried out by the special developed program
- Filters are made by spraying thin layers of rare earth oxides on the substrate
- Thin layers are made by electron-beam evaporation of materials
- Typically filters comprise up to 200-220 layers depending of optical range and suppression level
- Patent pending technology



We got a few samples of a multilayer filters sprayed on the quartz glass substrate (KU-2 type)
Quartz glass substrates are 30 mm in diameter and 3 mm thick
Quartz glass is optimal material for the multilayer filter evaporation

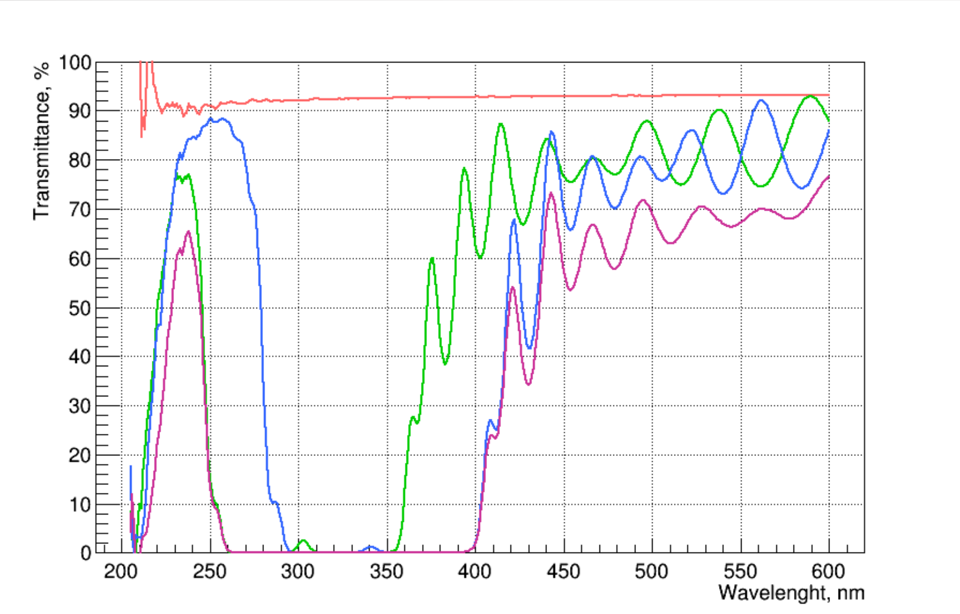
Transmittance of filters



Transmittances of filters were measured with Shimadzu SolidSpec-3700 DUV photo spectrometer

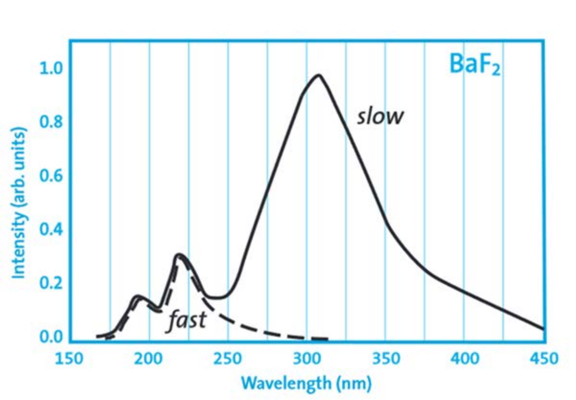
Red line – quartz glass, no filter
Green line – filter “type 1”
Blue line – filter “type 2”
Burgundy line – filer “type1”+filter “type2”

Transmittance of filters



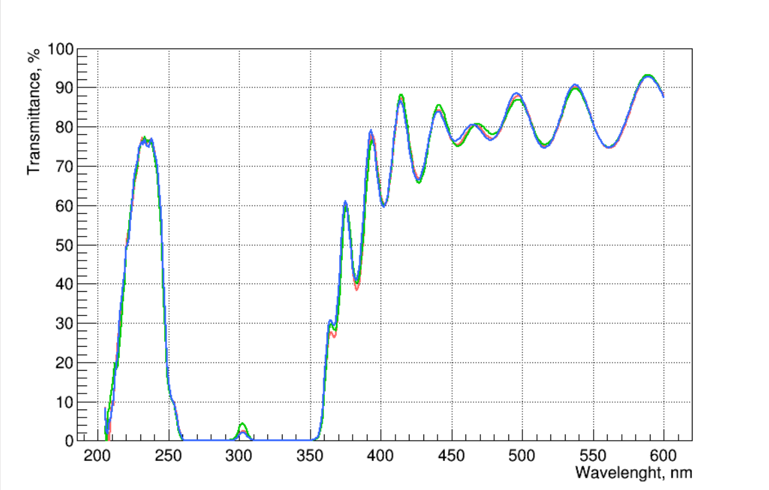
Transmittances of filters were measured with Shimadzu SolidSpec-3700 DUV photo spectrometer

Red line – quartz glass, no filter
Green line – filter “type 1”
Blue line – filter “type 2”
Burgundy line – filer “type1”+filter “type2”

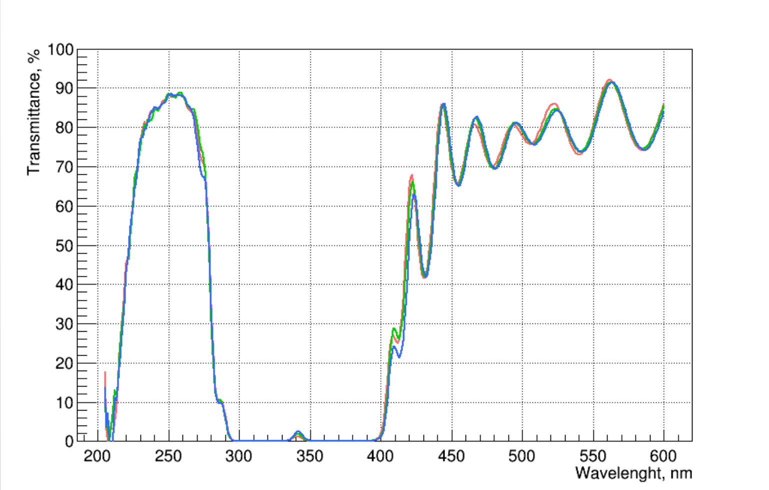


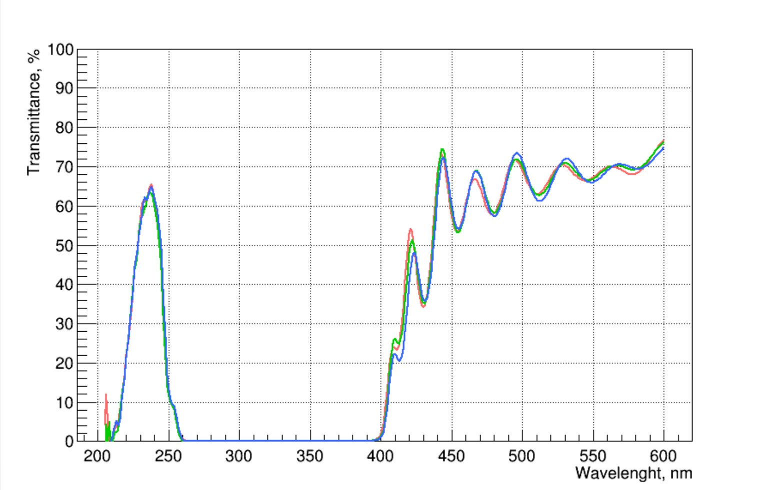
One can see that single filter type1 or type2 is not enough to significantly suppress the slow component. Two filters together should provide essential suppression of the slow component. However, fast component will be suppressed as well

Reproducibility of samples

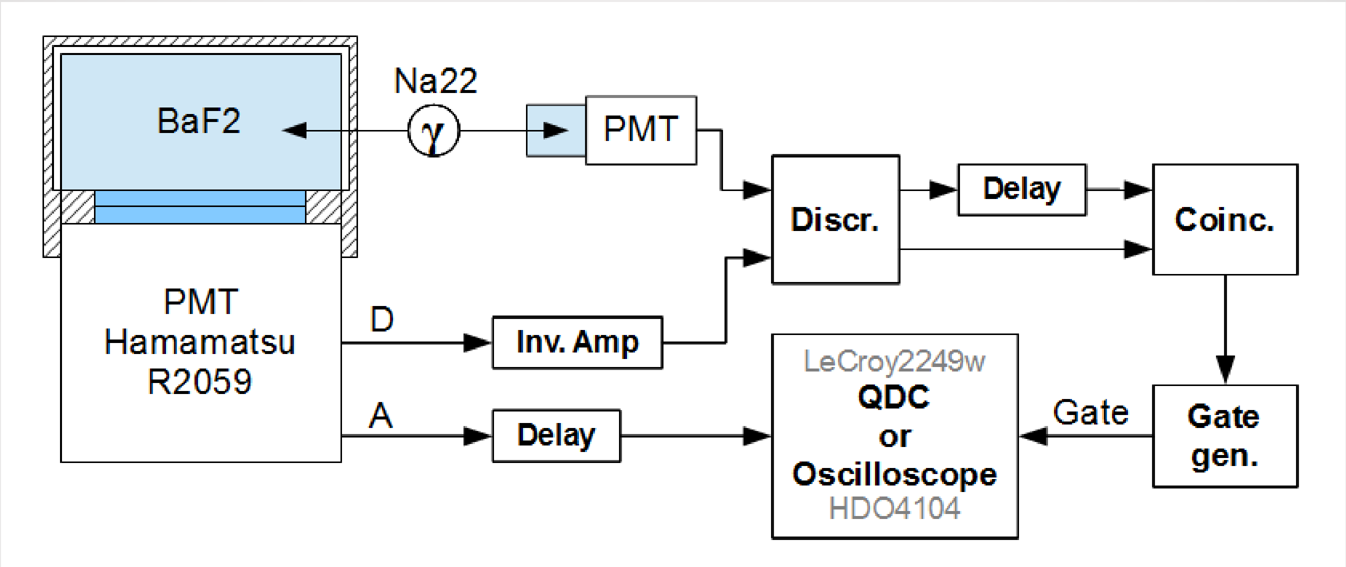


Three filters of “type 1” (top frame) as well as three filters of “type 2” (bottom left frame) were evaporated in different runs
Three pairs of filters (“type1”+”type2”) provide suppression of a slow component in the range 250-400 nm (bottom right frame)



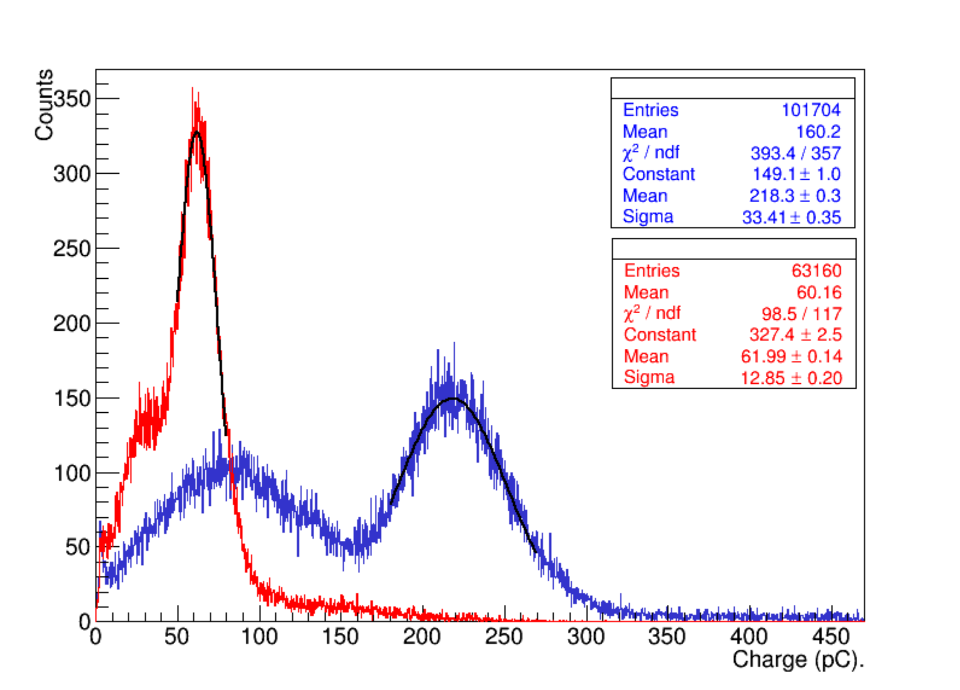


The block diagram of setup



- We tested BaF_2 crystal with pair of filters (type1+type2)
- Crystal has dia. 38 mm and height 18 mm
- Hamamatsu R2059 PMT was employed for measurements
- Data were taken with LeCroy 2249W QDC (2 μs gate) or digitized with HDO4104 scope (6 μs range)
- Triggers were provided by two back-to-back emitted 511 keV gammas
- No optical grease was used between PMT-filters-crystal

ADC data



Data taken with LeCroy 2249W ADC:

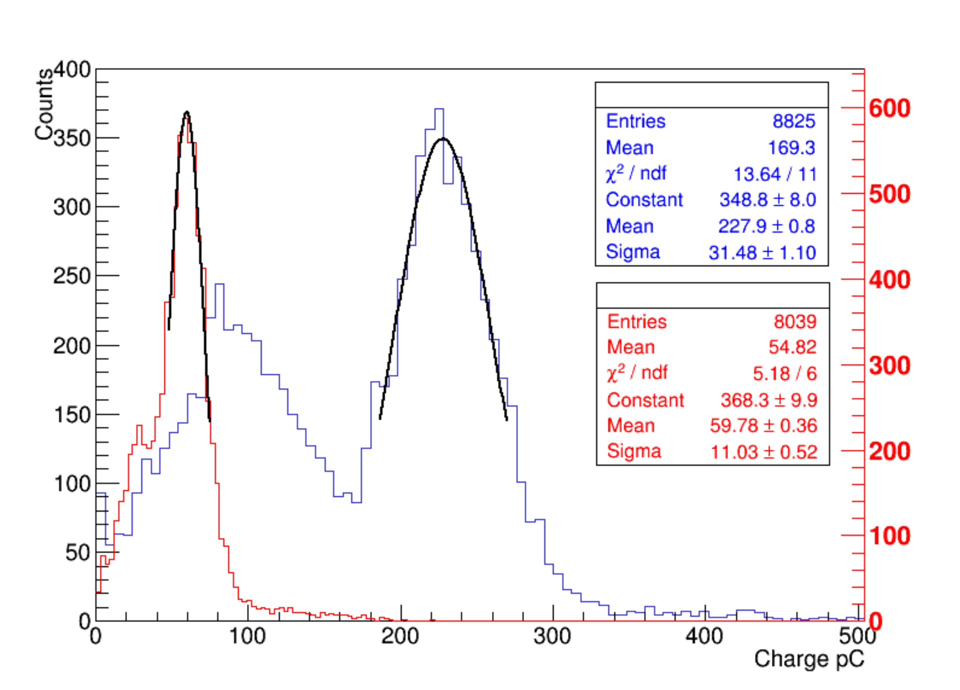
- 2 µs gate
- Trigger: two back-to-back emitted 511 keV gammas

Blue - BaF_2 with no filter
Red - BaF2 with a filter

The total signal is suppressed approximately 3.5 times.

Unfortunately, the fast component is also suppressed

Scope data



Data taken with HDO4104 scope :

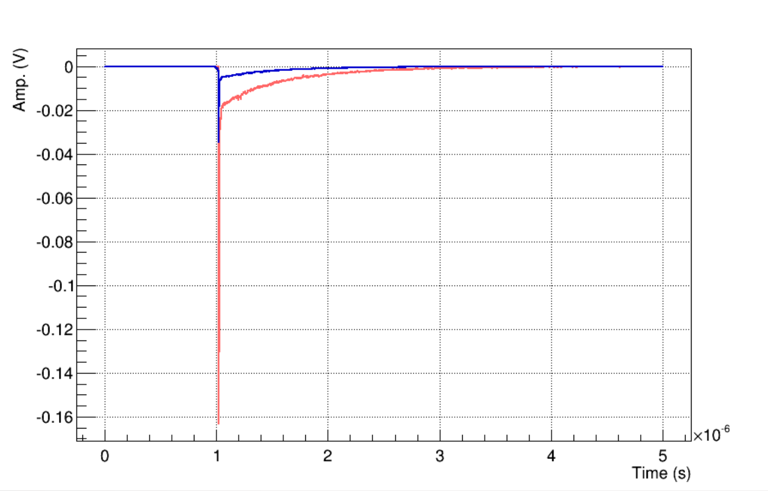
- 6 μs digitizing range
- Trigger: two back-to-back emitted 511 keV gammas

Blue - BaF_2 with no filter
Red - BaF2 with a filter

Suppression of total signal is about of 4 times.

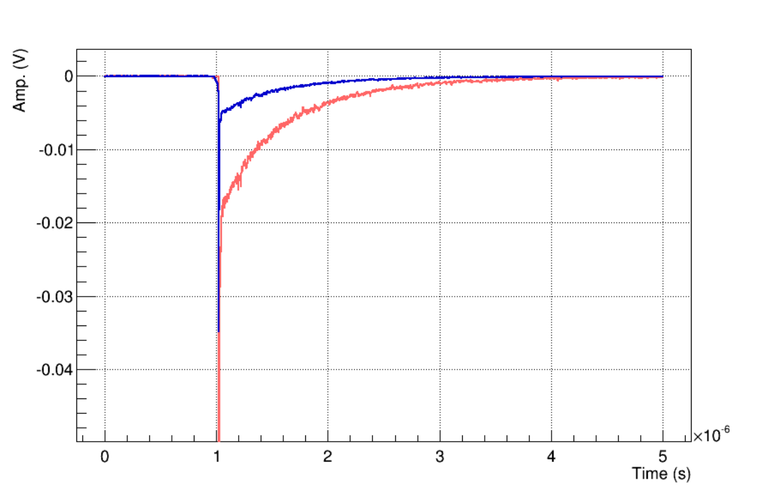
To estimate the suppression of signals we selected 1100 events in the centers of full absorption peaks from the spectra with and with no filter and averaged them

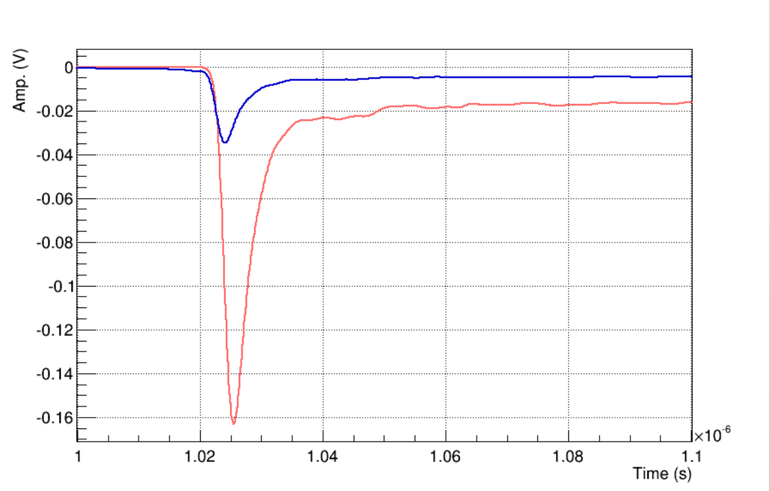
BaF_2 signals



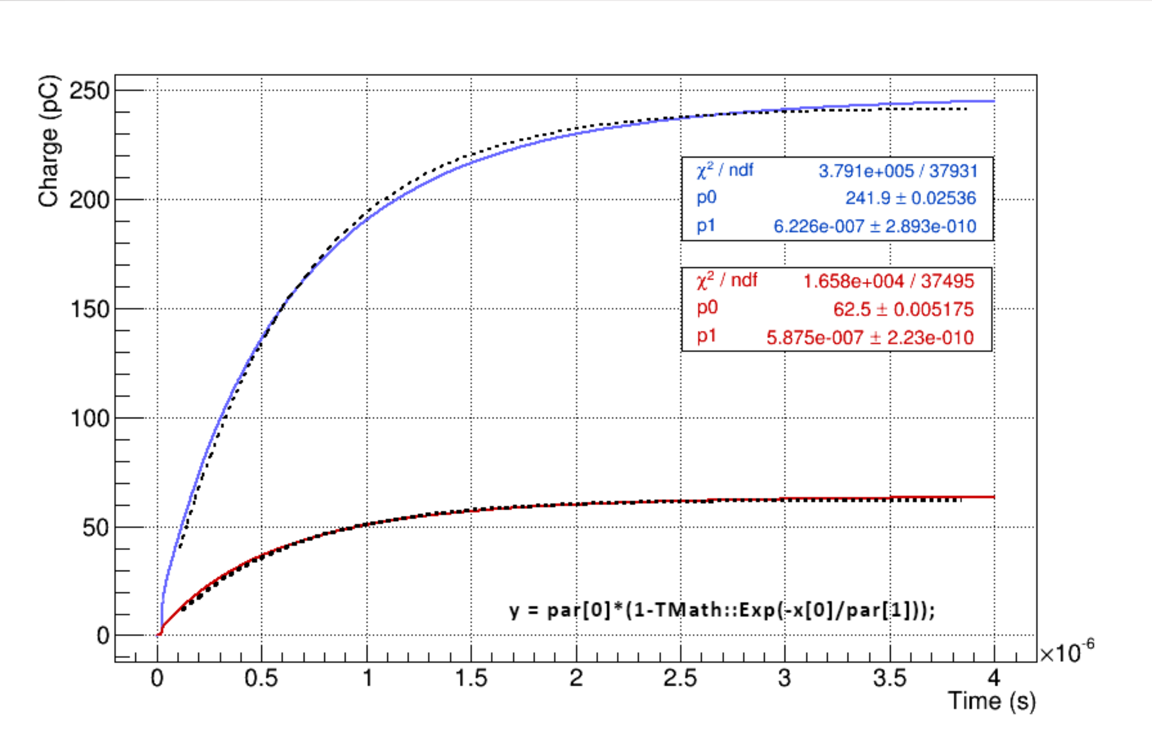
Averaged signals from the crystal with and with no filter:
Left, top – full scale
Left, bottom – with details in amplitudes
Right, bottom – with fast component details

Two bottom frames demonstrate that both slow and fast components are suppresses about 4 times





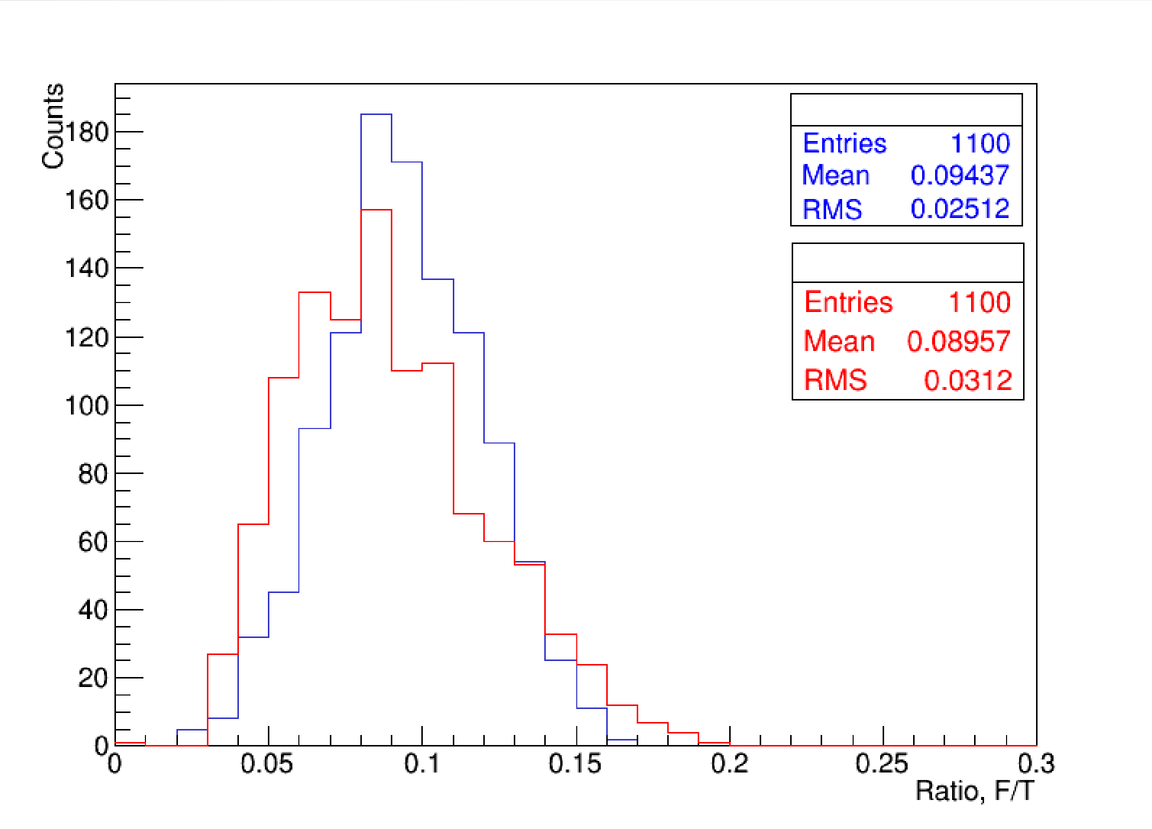
Charge integral



The averaged signal charges were calculated for the full range of digitization for a crystal with no and with a filter

The total charge indicates the suppression of the signal from the crystal with the filter about 4 times

Ratio Fast/Total

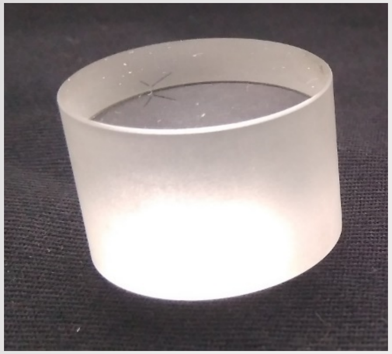


Fast/Total ratio was estimated by calculating charge due to fast component within 20 ns from the signal start and total signal within 2 µs

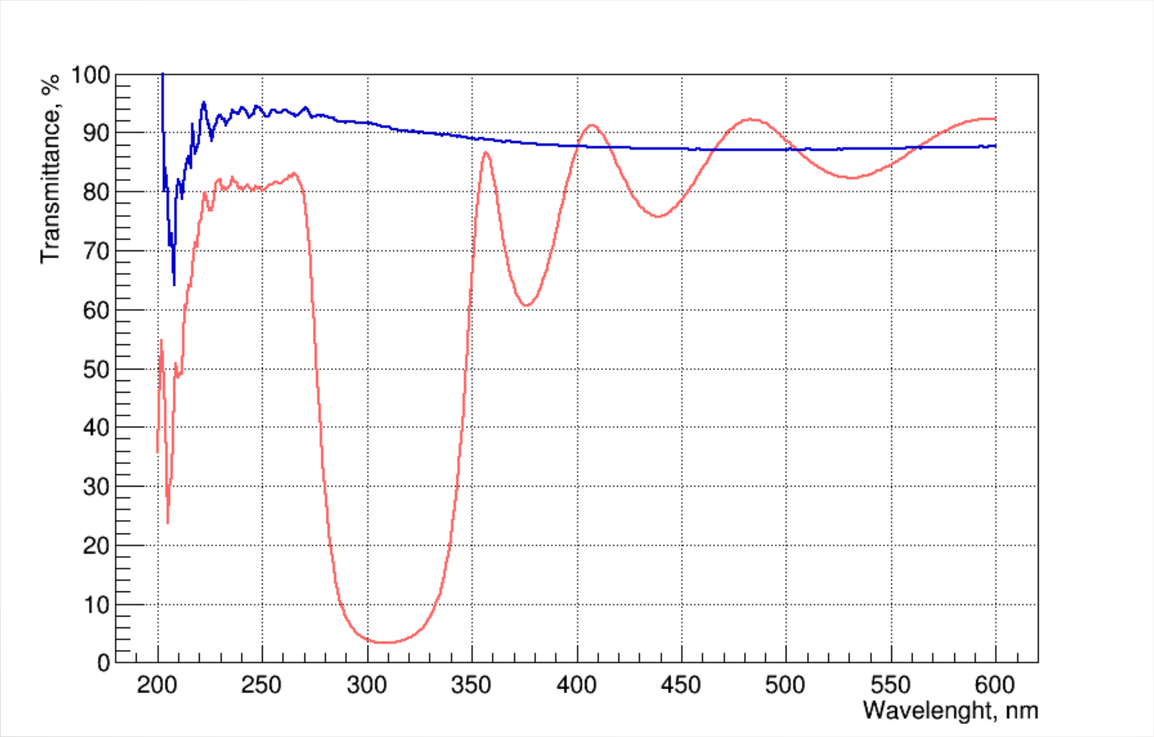
Results demonstrate that crystal with no filter (blue) and with filter (red) has almost the same F/T ratio.
This confirms that the fast component has approximately the same suppression as the slow component has

Filters need to be improved to reduce the suppression of a fast component

Filter sprayed on the BaF_2 crystal



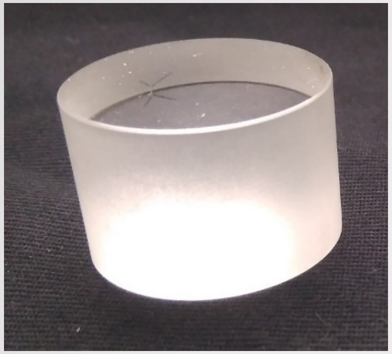
Crystal is 30 mm in diameter and 20 mm in height
Two ends are polished, side is unpolished
It was first attempt to spray a filter on the crystal:
multilayer filter was sprayed on one BaF2 crystal end



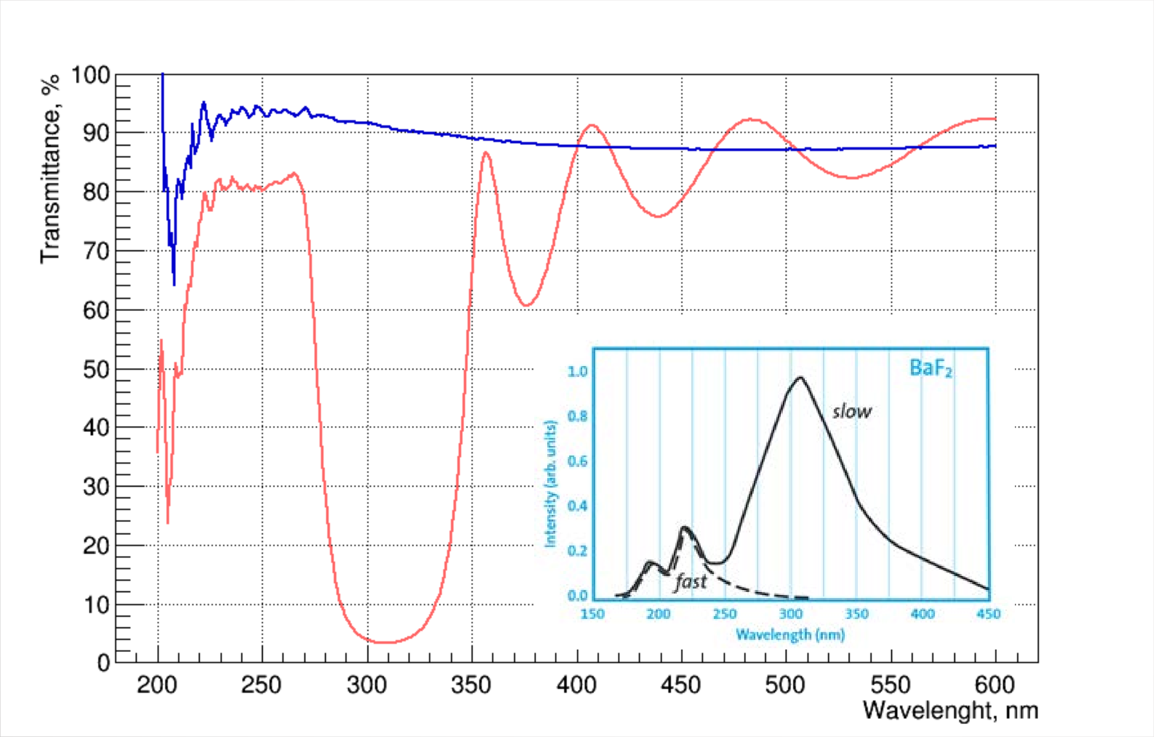
Transmittances:
blue – dia. 38mm x 18 mm
red - dia. 30mm x 20 mm

The filter quality is much worse than that one sprayed on the quartz window

Filter sprayed on the BaF_2 crystal



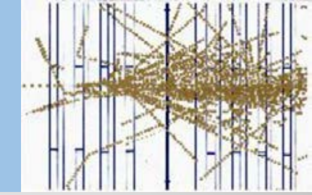
Crystal is 30 mm in diameter and 20 mm in height
Two ends are polished, side is unpolished
It was first attempt to spray a filter on the crystal:
multilayer filter was sprayed on one BaF2 crystal end



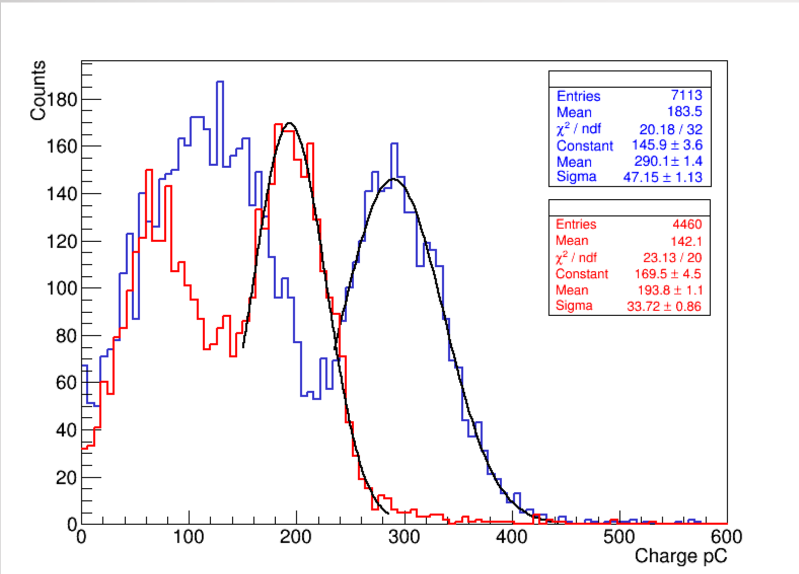
Transparencies:
blue – dia. 38mm x 18 mm
red - dia. 30mm x 20 mm

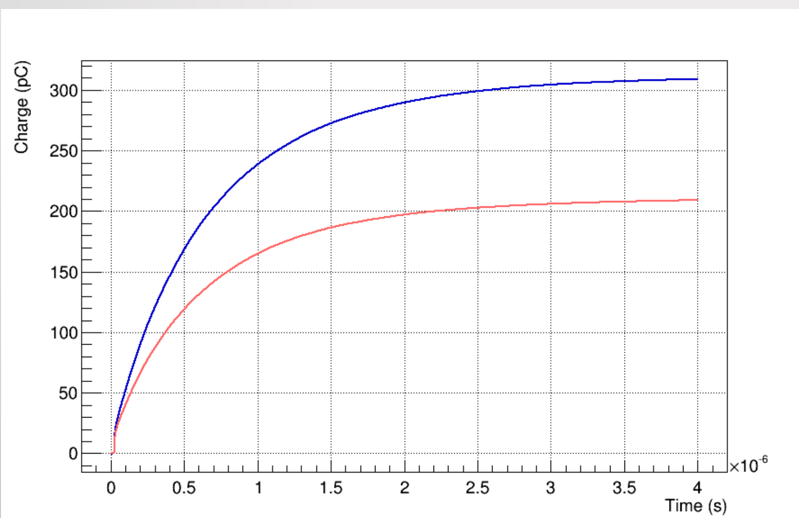
The filter quality is much worse than that one sprayed on the quartz window

One can see that filter will suppress only a fraction of a slow component luminescence



Signals from BaF_2 crystal with a sprayed filter





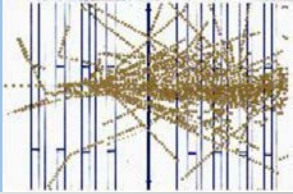
Data taken with HDO4104 scope :

- 6 μs digitizing range
- Trigger: two back-to-back emitted 511 keV gammas from ^{22}Na

Top frame – ^{22}Na spectra from the BaF_2 with no and with filter
Bottom frame – integral charge of averaged signals from the full absorption peaks

Blue - BaF_2 with no filter
Red - BaF2 with a filter

Data shows that suppression of a total signal is about 1.5 times



Conclusion

- Thin multilayer filters made of up to 200 layers of rare earth oxides can suppress a luminescence in the range about from 250 nm to 400 nm and could be used for suppression of a slow component in the BaF_2 crystals

- Filters made by spraying thin layers of rare earth oxides on a quartz glass substrate suppress the total signals from the BaF_2 4 times

- Filter sprayed directly on the BaF_2 surface allowed to suppress the total signal about 1.5 times

- Certainly, it is necessary to continue research to improve the quality of multilayer filters