CALORIMETER SESSION: Summary

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Calorimeter Session

We had 8 talks:

- Introduction to Mu2e-II in term of requirements.
- Baseline solution is to use BaF2 crystals
  → efforts to reduce the slow component working on

  Crystals | Photo-sensors

- Useful techniques can help to find the optimal solution.

Calorimeter Requirements (1/2)

Maintain the Mu2e-I requirement:

- We aim to same energy (< 10%) and time (< 500 ps) resolutions as in Mu2e.
- Aiming to provide standalone trigger, track seeding and PID as before.
- Work in vacuum @ 10^{-4} Torr, keep a low level of outgassing.

Stefano's talk

Face up to the higher rate, neutron fux and dose **on Disks**:

X 10 Factor →

Disk1:
Inner:(60x 5 x 3 → 900 krad
Outer:((15x5x3) → 180 krad

Disk2:
Inner: (10x 5 x 3) → 150krad
Outer:(5x5x3) → 75 krad

→ With respect to dose, disk 2 could be almost left as it is with CsI + SiPM readout
Speeding up the amplification stage.
→The innermost area of first disk will need a drastic change

Calorimeter Requirements (2/2)

Face up to the higher rate, neutron fux and dose **on Photo-sensors**:

X 10 Factor →

Disk1: Inner:
(10x2x 5 x 3) → 300 krad
Outer: (10x0.5x5x3) → 75 krad

Disk2:
Inner: (10x1x 5 x 3) → 150 krad
Outer = (10x0.5x5x3) → 75 krad

Latest SiPM Dose test indicated no hints of deterioration up to 80 krad

X 10 Factor

Disk 1 = 10 x 6 x 10^{10} x 5 x 3 = 900 x 10^{10} = 9 x 10^{12}

Neutron fluence up to 10^{13} n_1MeV/cm^2 → -40 C

A BaF2 crystals calorimeter

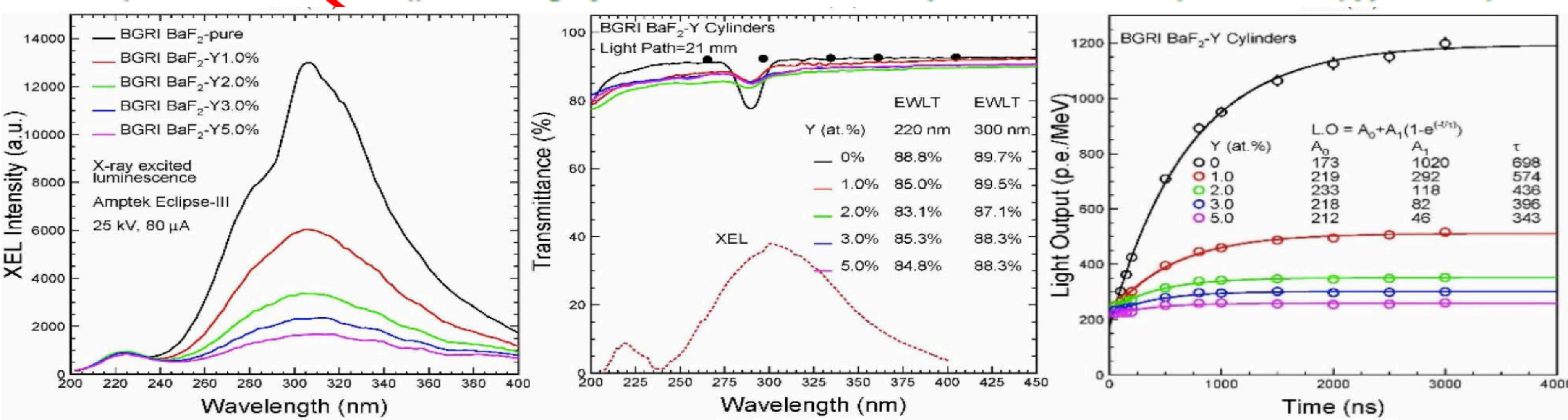
Ren-Yuan's talk

The use of BaF2 crystals is a baseline solution for Mu2e-II.
Rad Hard. → OK
Light Yield → OK
Fast → yes, but we have to handle with the slow component.

There are two effective approaches to handle the 600 ns slow scintillation in BaF2: solar blind photodetector and/or selective doping.

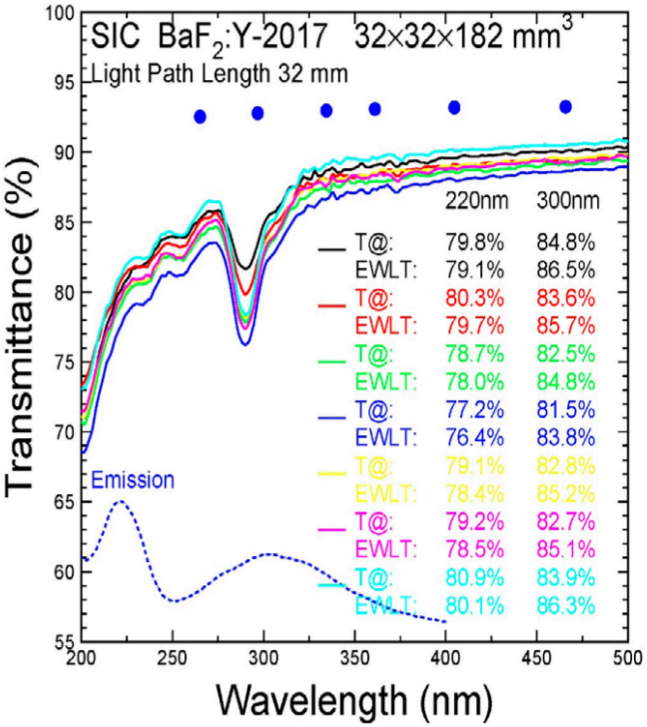
Slow component may be suppressed by RE doping: Y, La and Ce

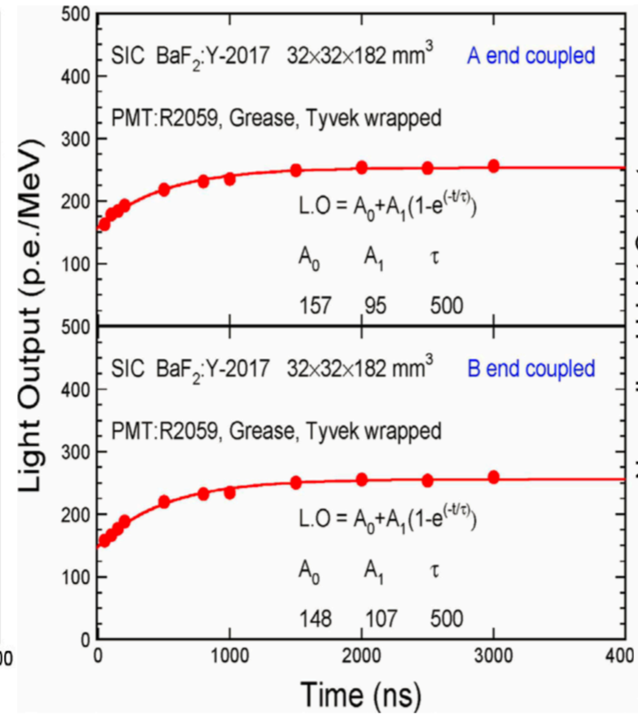
B.P. SOBOLEV et al., "SUPPRESSION OF BaF2 SLOW COMPONENT OF X-RAY LUMINESCENCE IN NON-STOICHIOMETRIC Ba0.9R0.1F2 CRYSTALS (R=RARE EARTH ELEMENT)," *Proceedings of The Material Research Society: Scintillator and Phosphor Materials*, pp. 277-283, 1994.

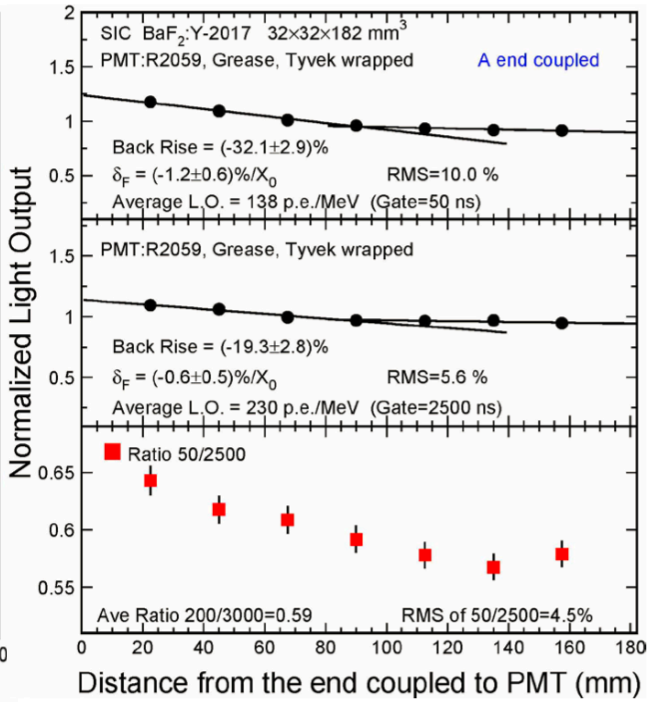


Performance of SIC 18 cm BaF2:Y

F/S increased up to 1.6; LRU: 10% and 5.6% for fast and total



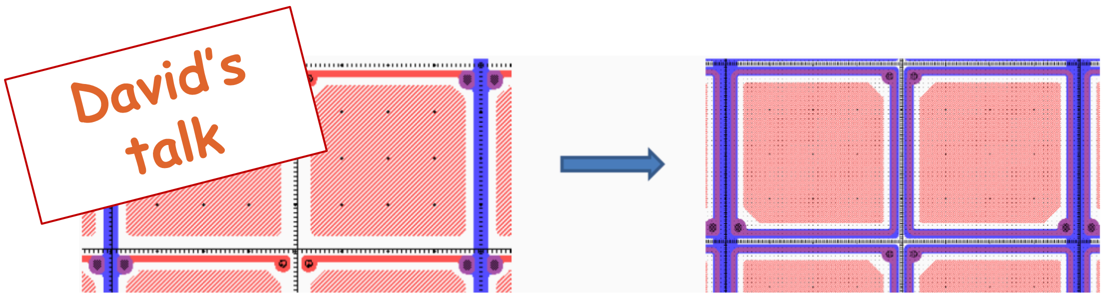


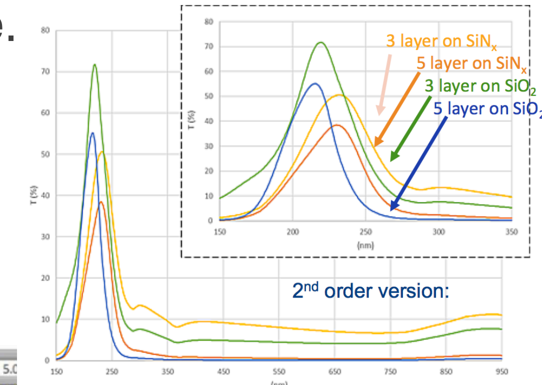


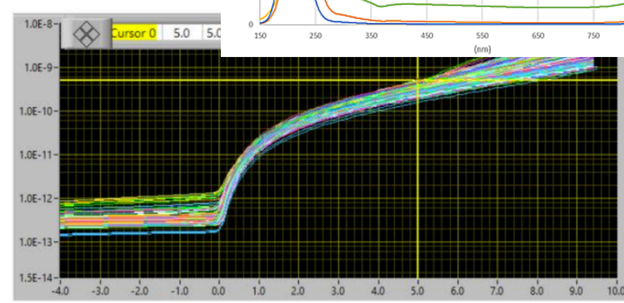
- ***Very promising… optical properties to be improved.***
- ***Rad Hard must be investigated, but should be ok.***

Photo-detectors (1/3)

- A **large area SiPM**, with **delta-doping** (a super-lattice) for improved speed and QE, and an integrated ALD-applied **interference filter**
  → Caltech and JPL are working with FBK to incorporate a 220nm filter on a large area SiPM and to also incorporate a superlattice.







Six wafers are currently at JPL for processing

- SiN_x passivation - apply filter
- SiO_2 passivation – apply filter
- SiO_2 passivation, no filter – delta-doped to improve QE and rise time

- ***Initial results will be available within a few months***
- ***Rad Hard is the real issue…***

Photo-detectors (2/3)

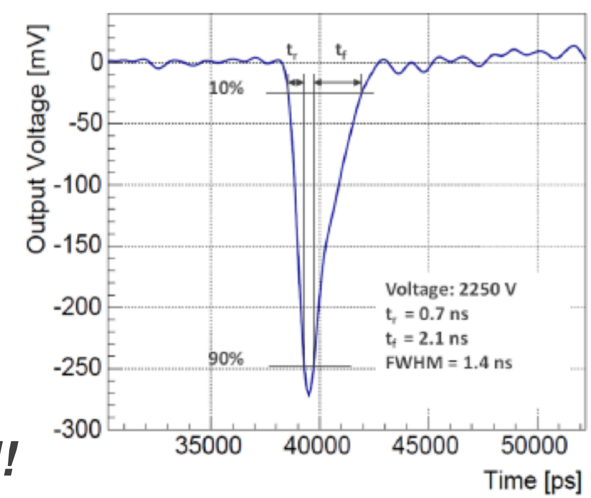
❑ MCP @ Argonne are a very promising development.

MCP-PMT	HPK6 R3809U-50-11X	BINP8 N4428	HPK10 R3809U-50-25X	Burle25 85011-501	ANL 6cm tube
PMT size(mm)	45	30.5	52	71x71	85×76
Effective size(mm)	11	18	25	50x50	60×60
Channel diameter(μm)	**6**	**8**	**10**	**25**	**20**
Length-diameter ratio	40	40	43	40	60
Max. H.V. (V)	3600	3200	3600	2500	2900
photo-cathode	multi-alkali	multi-alkali	multi-alkali	bi-alkali	Bi-alkali
Q.E.(%) (λ=408nm)	26	18	26	24	13

Lei's talk

→ Needs to be improved

- Excellent time resolution ~ 40 ps,
- High gain ~10^7,
- Radiation Hardness OK.
- B field tolerance should be OK.



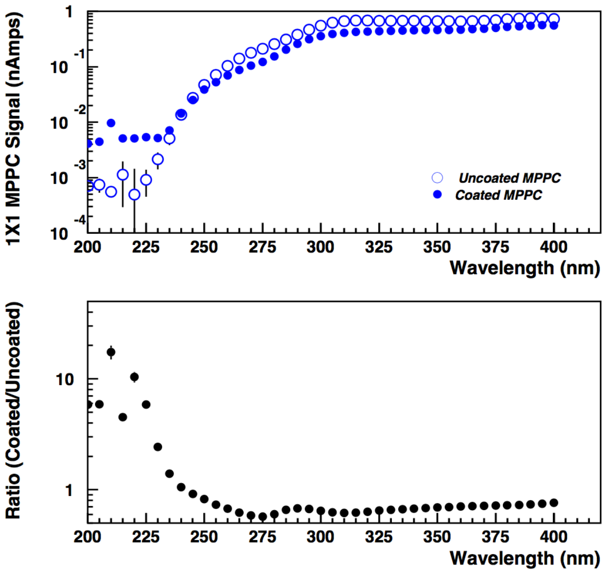
- ***Cost at large scale production must be evaluated!***

R&D to match with the BaF2 fast component should start asap…

Photo-detectors (3/3)

- Nano-enhanced BaF2 Readout
  - Detection of 220 nm (UV) fast component of BaF2 scintillation
  - Nanoparticle type that absorbs 220 nm emission
  - Preferably little absorption >250 nm
  - Large Stokes shift to visible wavelength range for detection

Steve's talk



UTA nanoparticles *deposited directly on the resin (face) of the SiPM*

Enhanced response of coated SiPM seen in the wavelength range from 200 nm – 240 nm compared to uncoated sensor

Without any optimization, ratio of coated to uncoated in the 200 – 240 nm range is ~factor of 10 greater than in the region > 250 nm!

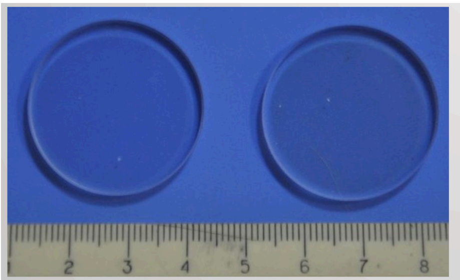
To do:

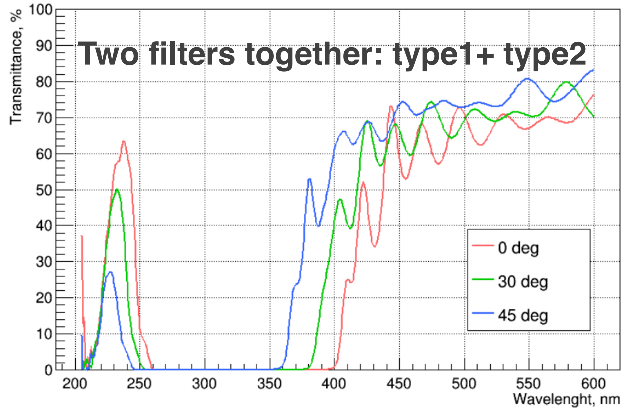
- Optimize thickness
- Test this on a BaF2 crystal with muons
- ***QE of the process need to be evaluated…***

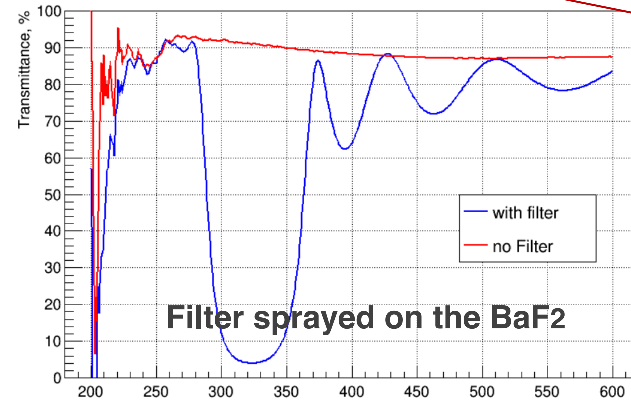
Promising Techniques

- Thin multilayer filters made of rare earth oxides can suppress luminescence in the range about from 250 nm to 400 nm

Yuri's talk

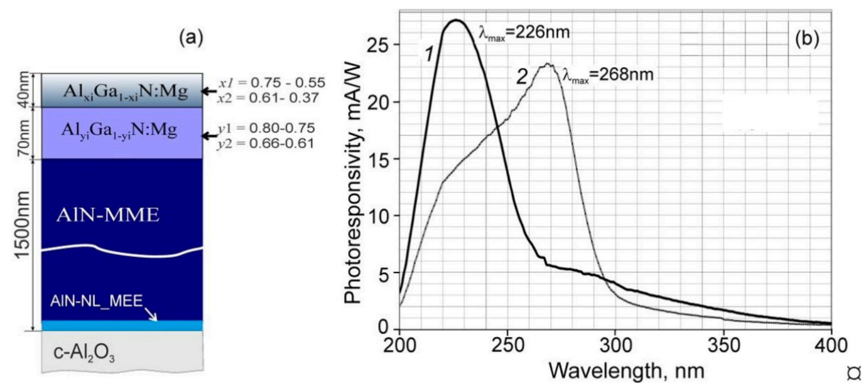






- AlGaN photocathodes to extend the MCP response in deep UV region of BaF2

Nicolay's talk



Good spectral range, but high dark noise at level 1 uA

R&D considerations ... and infrastructures ..

List of R&D tests for whatever proposed solution

→ Measure resistance to doses

→ Measure resistance to neutrons up to 10^{13} n_1MeV/cm^2

→ Control behavior at low temperatures

→ Measure resistance for large integrated charge

List of engineering details:

- Qualify MTTF
- Work on improving Cooling system and cooling distribution
- Improve/change the electronics:

  (1) FEE → Move to ASIC?

  (2) FEE → Move it to Mezzanine boards

  (3) DIRAC → new proposals ..of picoTDC