Studies of the response of a BaF2 calorimeter

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- Geant4 simulation
- Optical photons generation
- Timing
- Electronics response

Motivation

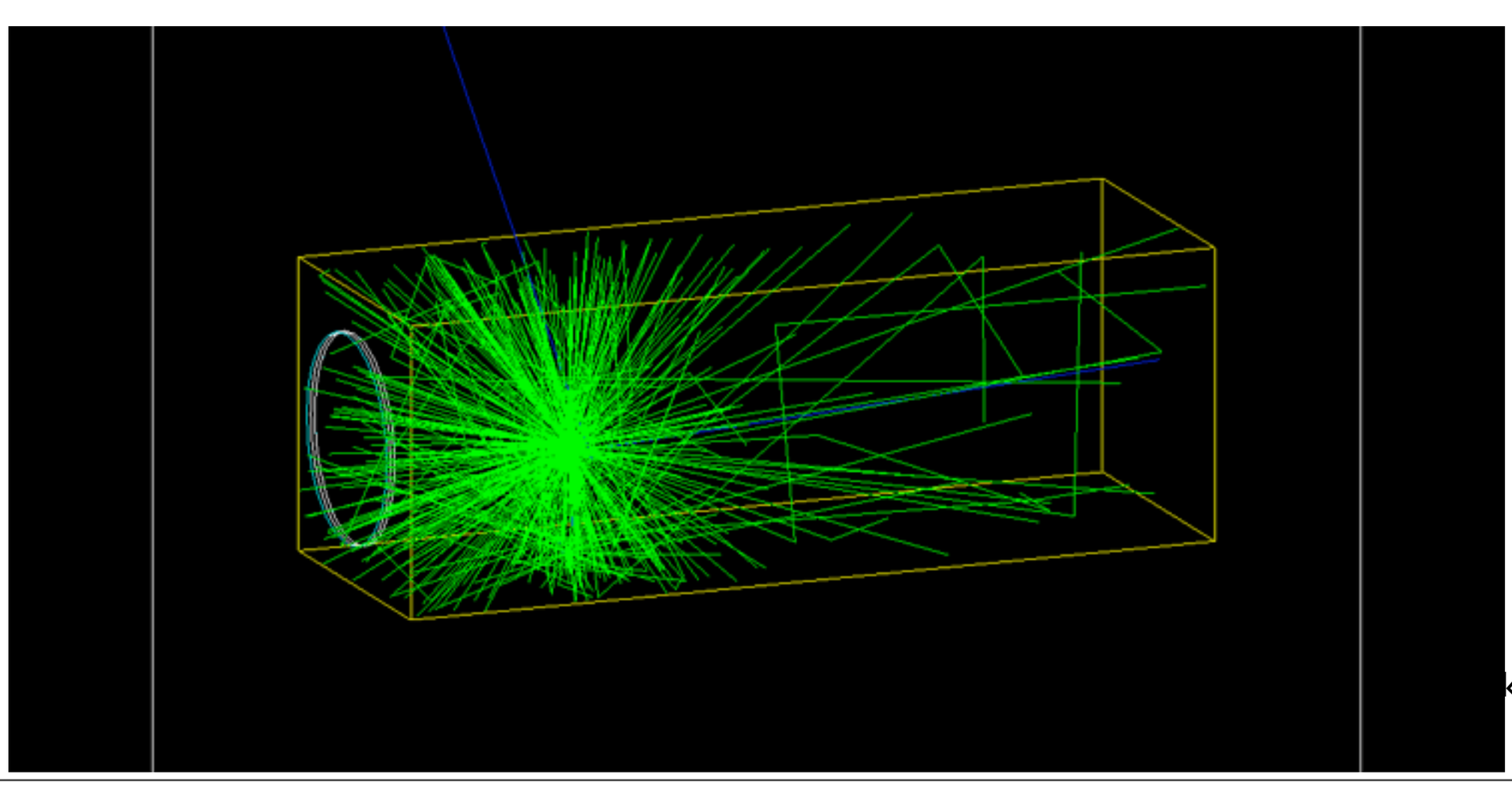
- to understand the physics inside the calorimeter
- to have an idea about timing of optical photons in the scintillator
- to estimate the time and energy resolution of the scintillator
- ....

To do this we use Geant4 toolkit
(v4.9.4.b01)

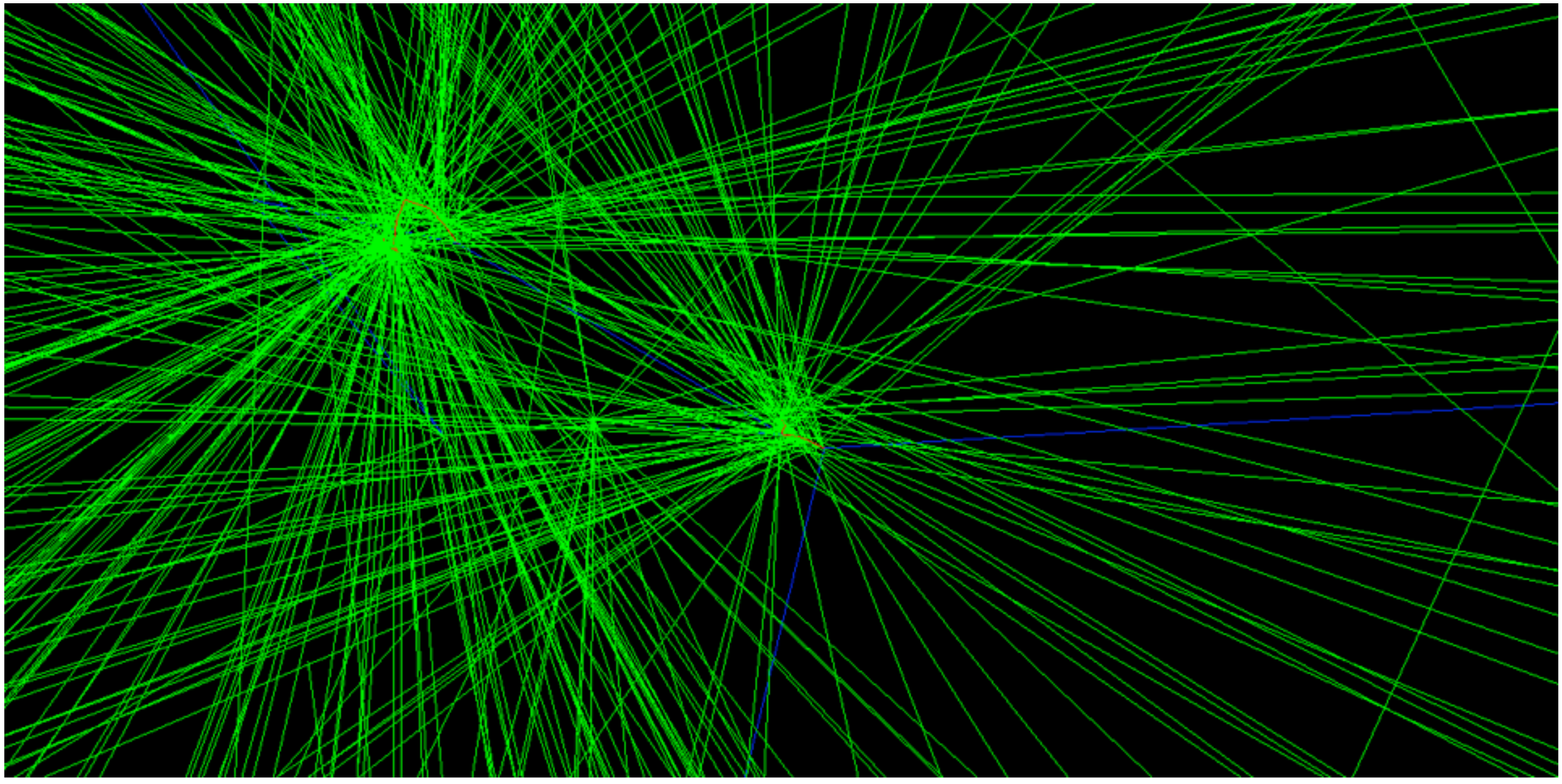
Detector model

Geometry:

- One piece of 200mm x 70mm x 70 mm (the optical surface between two pieces should be added)
- All surfaces are polished;
- Wrapping: absorbing teflon;
- UV - filter (should be implemented soon) ;



Vertices of the gamma interaction inside the scintillator



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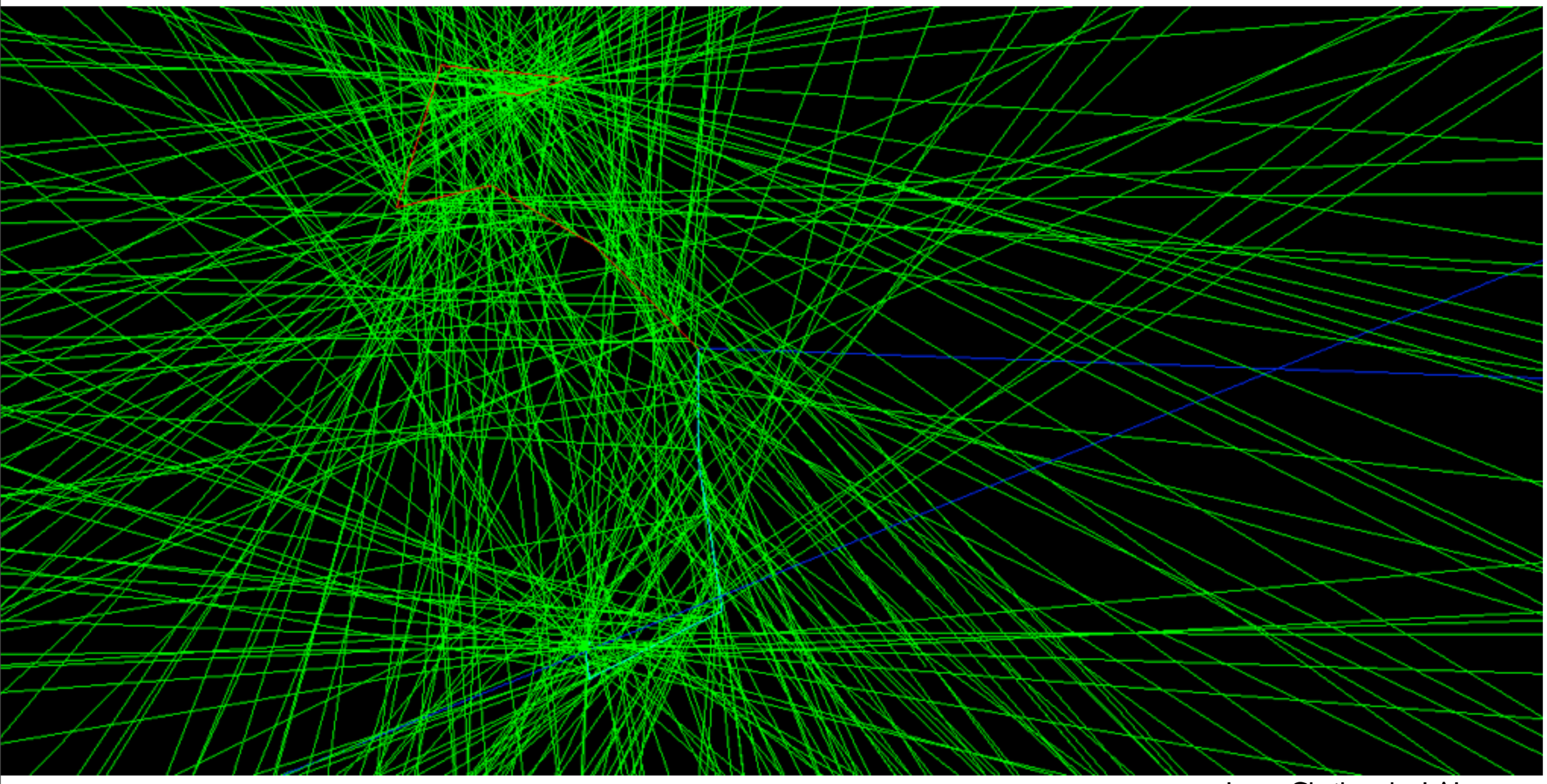
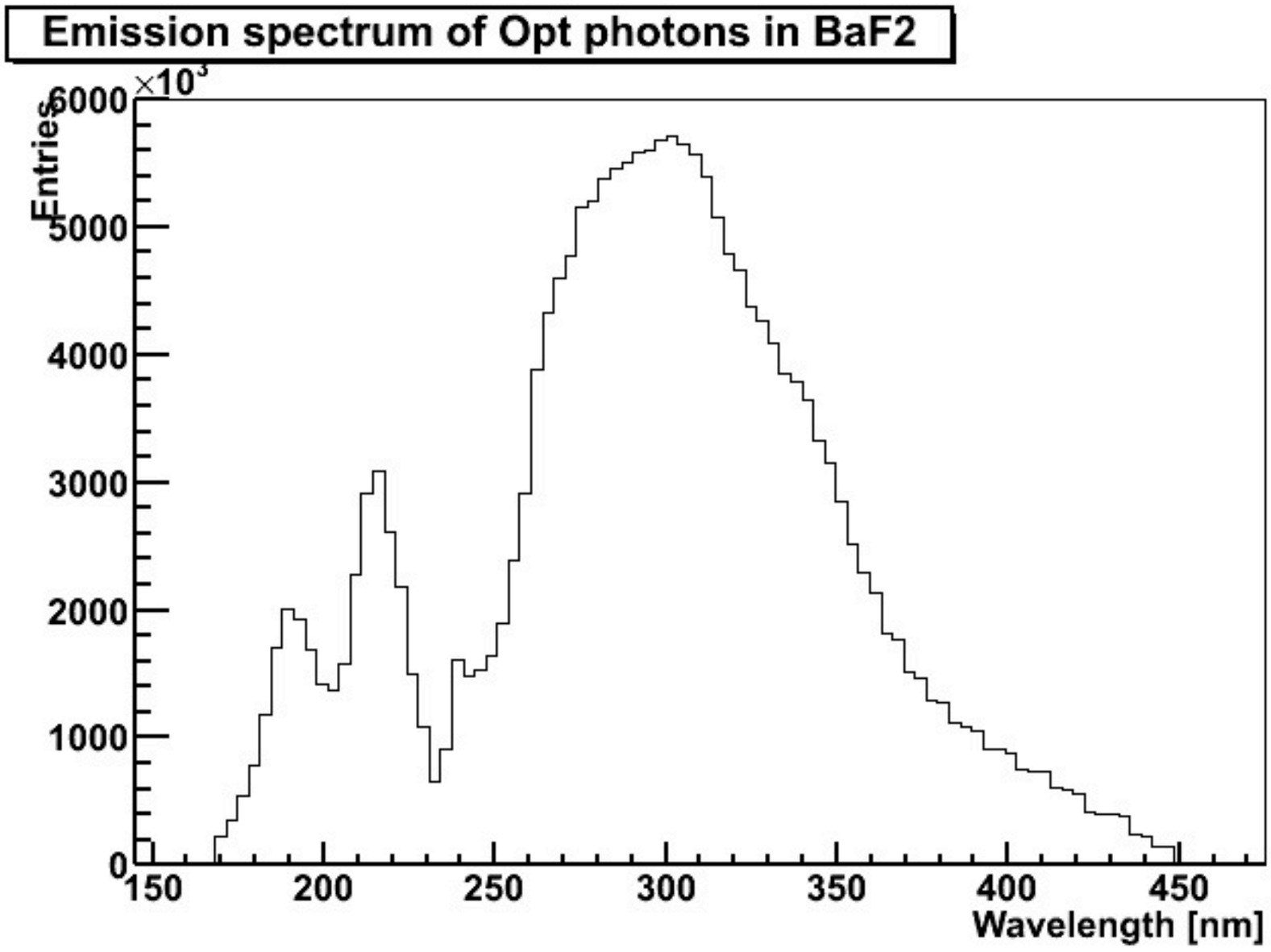


Emission spectrum of optical photons produced in BaF_2

E_{gamma}=20 MeV

Statistics 1000 events



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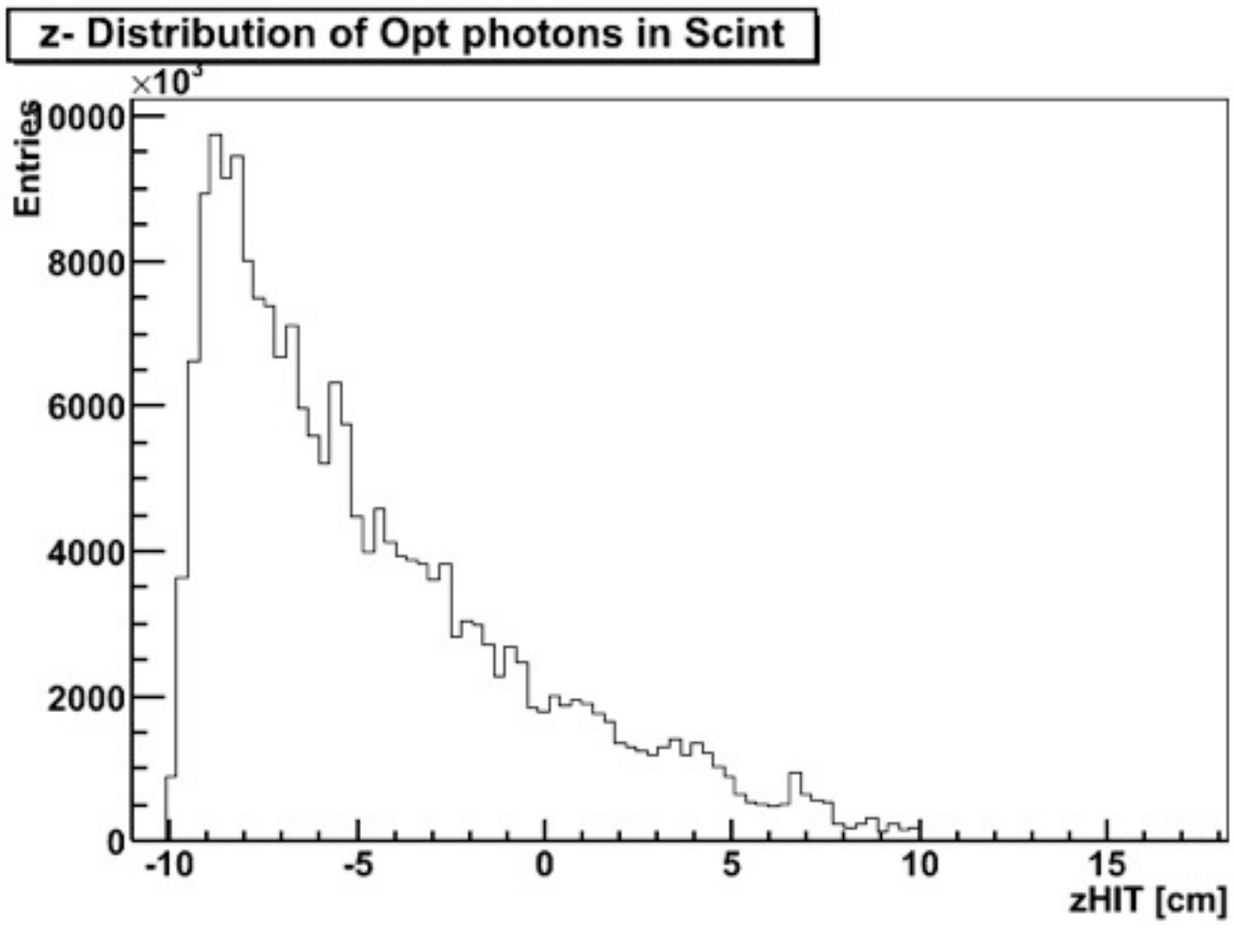
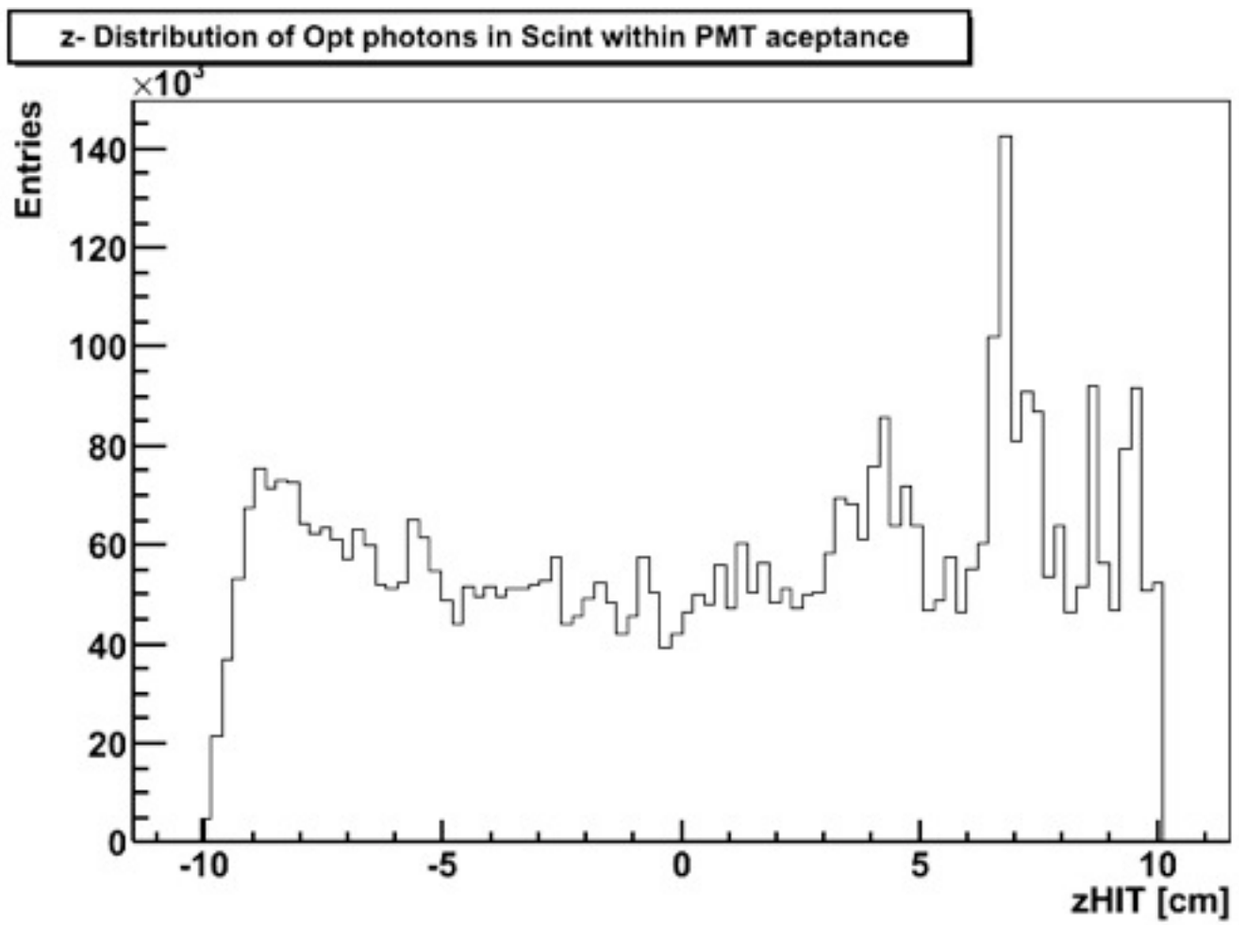
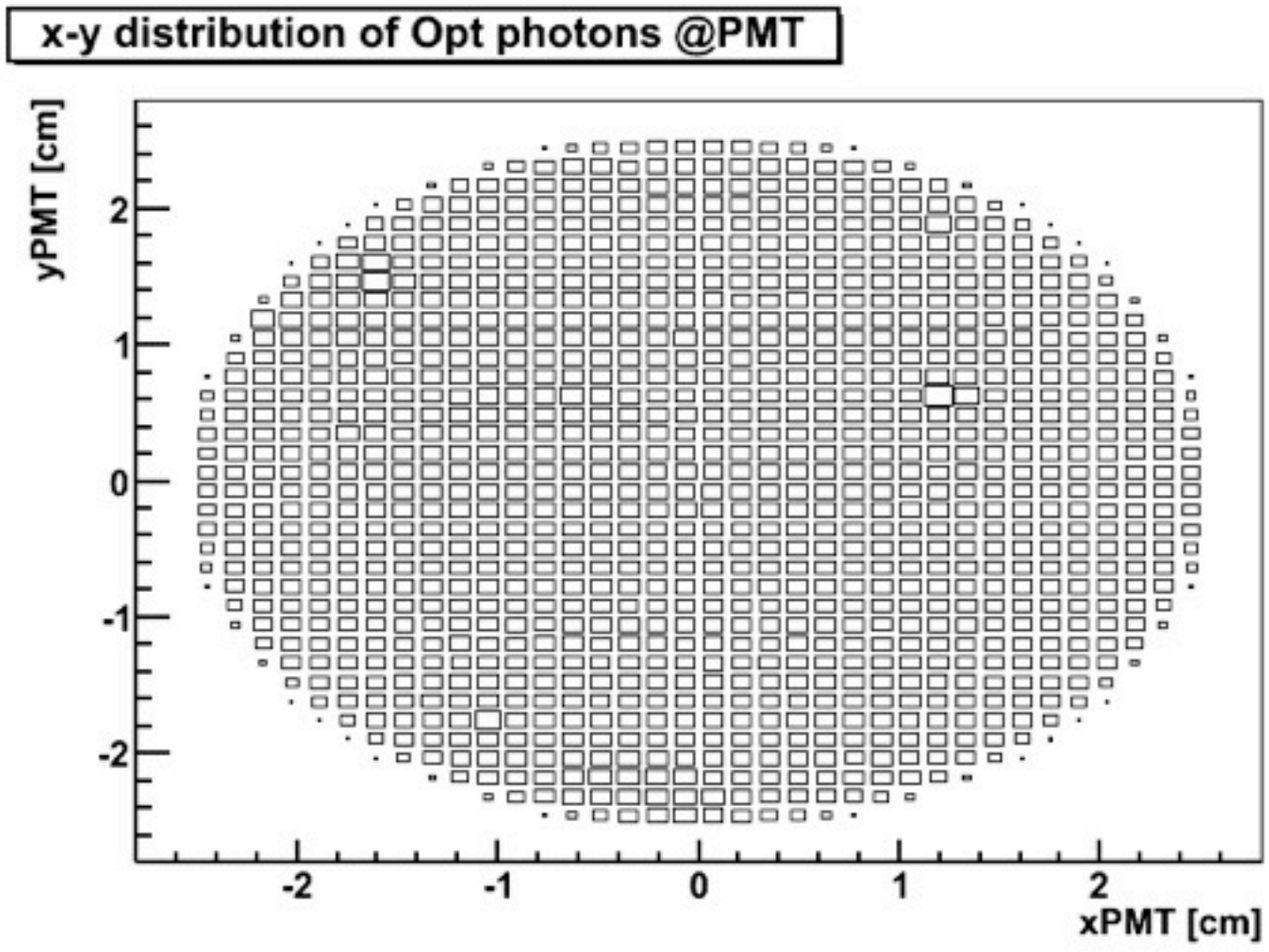
Location where the optical photons are produced inside the scintillator

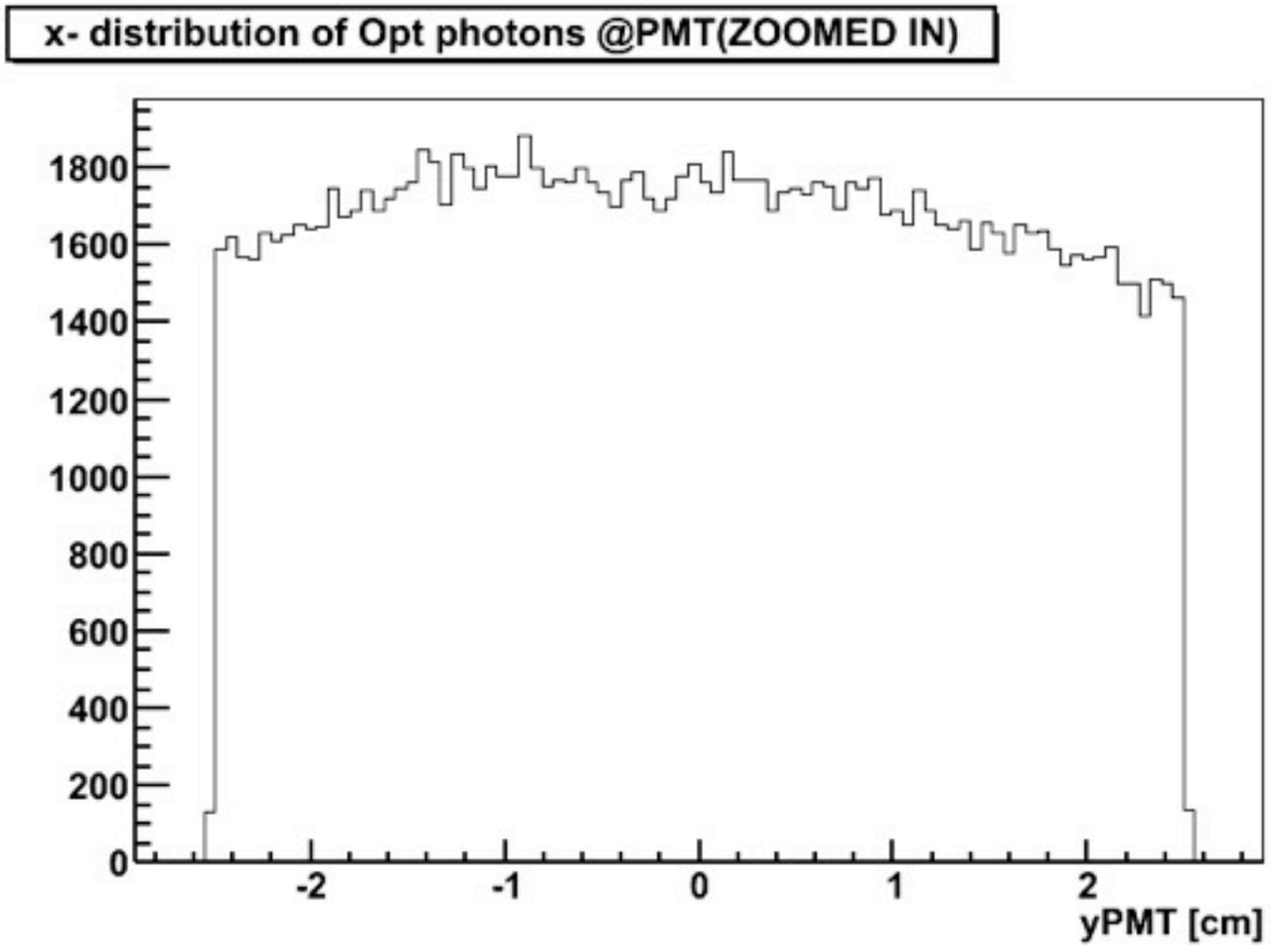




The optical photons contribution to the signal at the PMT is uniform in z (along the crystal)

Optical photons at the PMT





The optical photons hit the PMT uniformly.

Calorimeter's time response

Detection process

- Gammas absorption and light emission
- Light collection at the photocathode
- Production of photoelectrons
- Collection of photoelectrons
- Multiplication by PMT dynodes
- Electronics

Time resolution

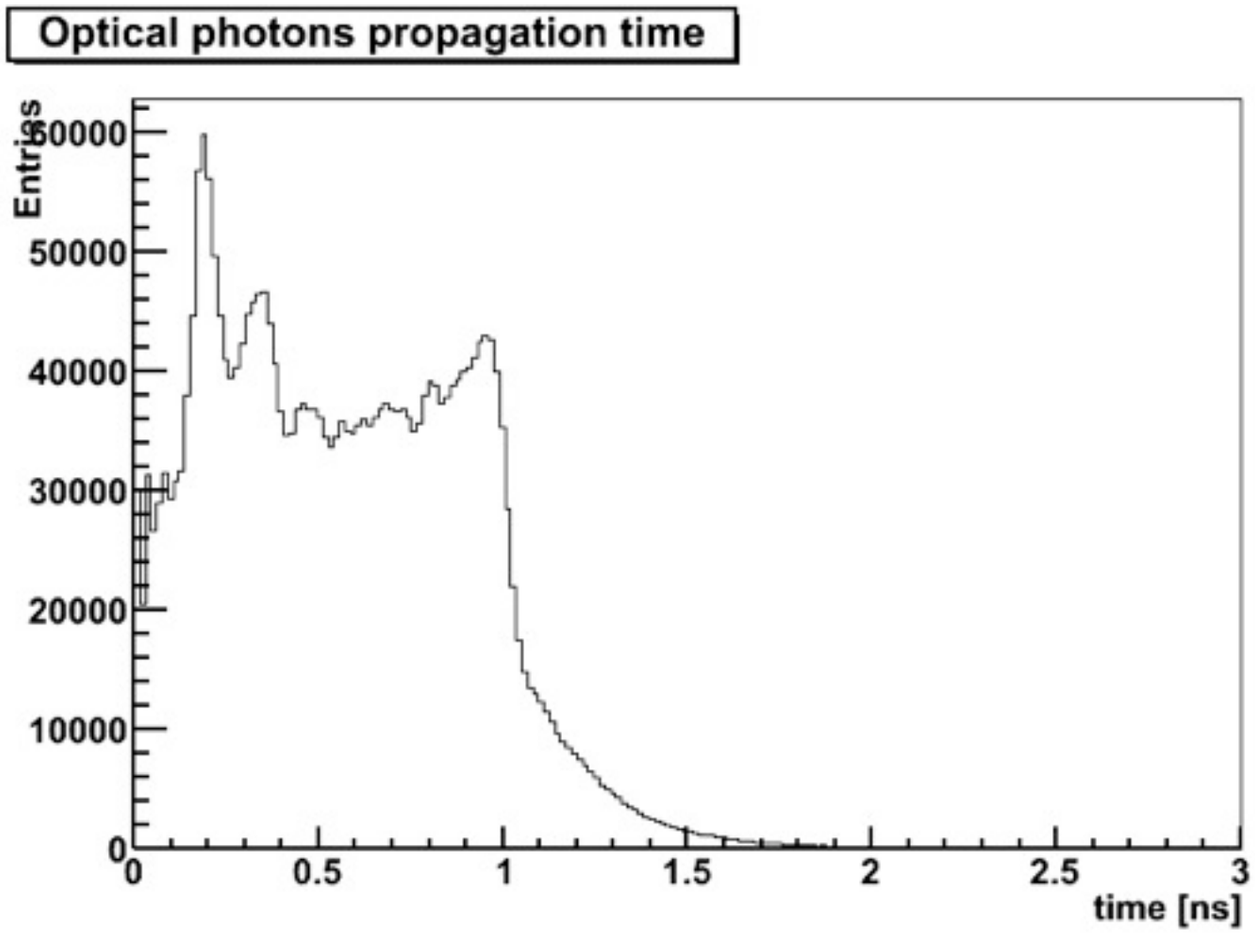
- Intrinsic resolution of the crystal (scintillation emission time)
- Transfer resolution (light propagation time in scintillator)
- PMT contribution (transit time of single photoelectron)
- ....

PMT simulation is still to be done

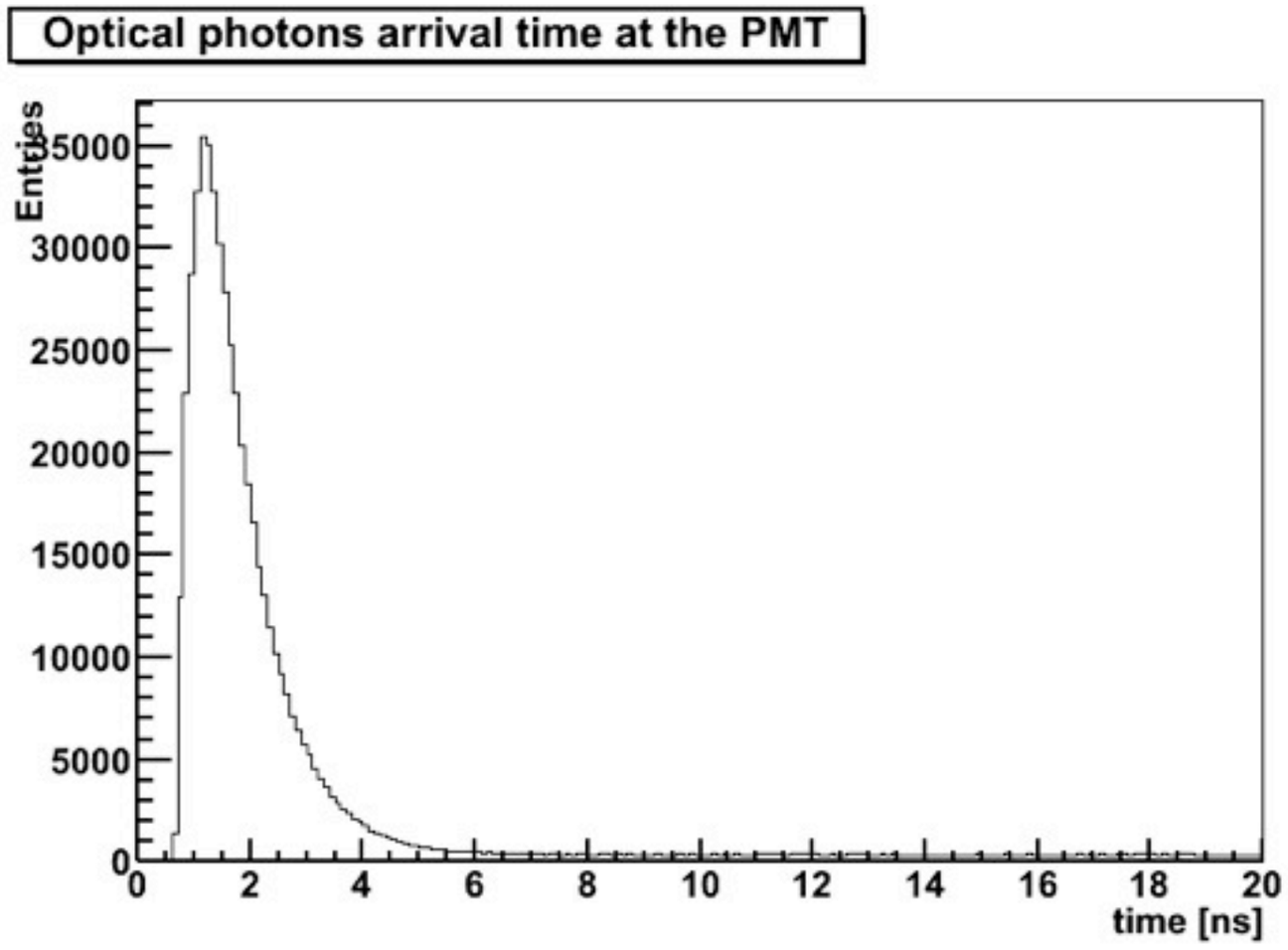
$$t_{pe} = t_{emit} + t_{pro} + t_{PMT}$$

Timing of optical photons

Propagation time



Time of arrival at the PMT



The contribution of the propagation time to the signal duration is about 1 ns. The total signal duration (including t_{prop} and t_{emit}) at the exit of the crystal is approximately 2 ns.

Simulation for DAQ system

We develop a matlab simulation to understand

- effect of the optical filter
- PMT response (rough)
  Voltage divider - to be done!
- limited ADC resolution
- time sampling
- bandwidth

Signal Model

$$S_s(t) = \frac{A_s}{2\tau_s} e^{\frac{\sigma^2}{2\tau_s^2} - \frac{t-t_0}{\tau_s}} \operatorname{erfc}\left(\frac{\sigma}{\sqrt{2}\tau_s} - \frac{t-t_0}{\sqrt{2}\sigma}\right)$$

$$S_f(t) = \frac{A_f}{2\tau_f} e^{\frac{\sigma^2}{2\tau_f^2} - \frac{t-t_0}{\tau_f}} \operatorname{erfc}\left(\frac{\sigma}{\sqrt{2}\tau_f} - \frac{t-t_0}{\sqrt{2}\sigma}\right)$$

$$S(t) = S_f(t) + S_s(t)$$

A_f	0.18
A_s	0.82
τ_f	0.8 ns
τ_s	630 ns
σ	0.4 ns
t_0	5 ns

$A_f, A_s,$ - relative light yields ;

τ_s, τ_f - the decay constants of the light;

σ - variance of the Gaussian response of the PMT to a light pulse;

t_0 - starting point of the time interval;

$$S_{RC} = \frac{A_r}{\theta} e^{-\frac{t-\mathrm{t0}}{\theta}} \operatorname{erfc}\left(\frac{\sigma}{\sqrt{2}\theta} - \frac{t-\mathrm{t0}}{\sqrt{2}\sigma}\right) \rightarrow$$

response of RC (voltage divider) circuit should be understood

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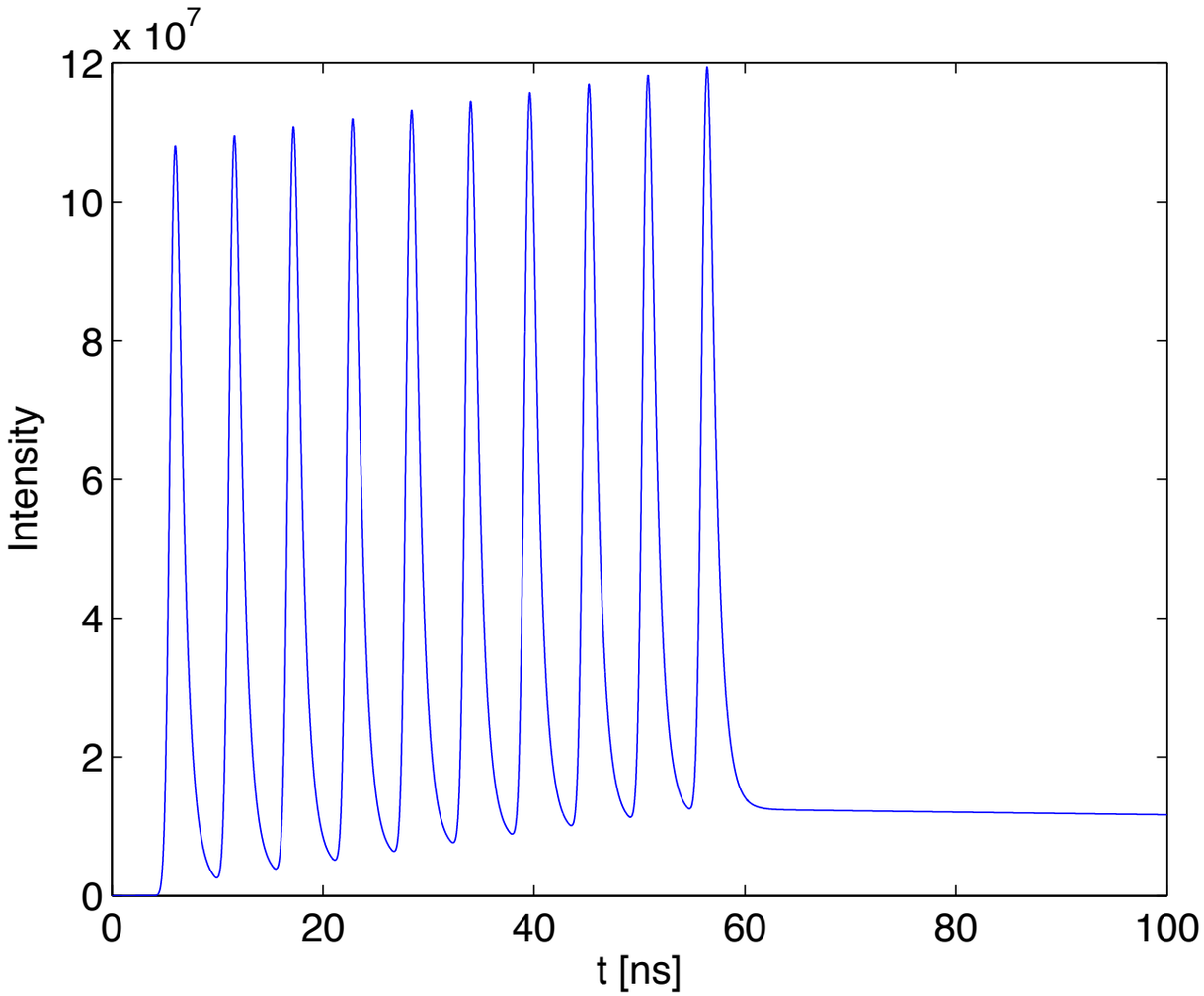
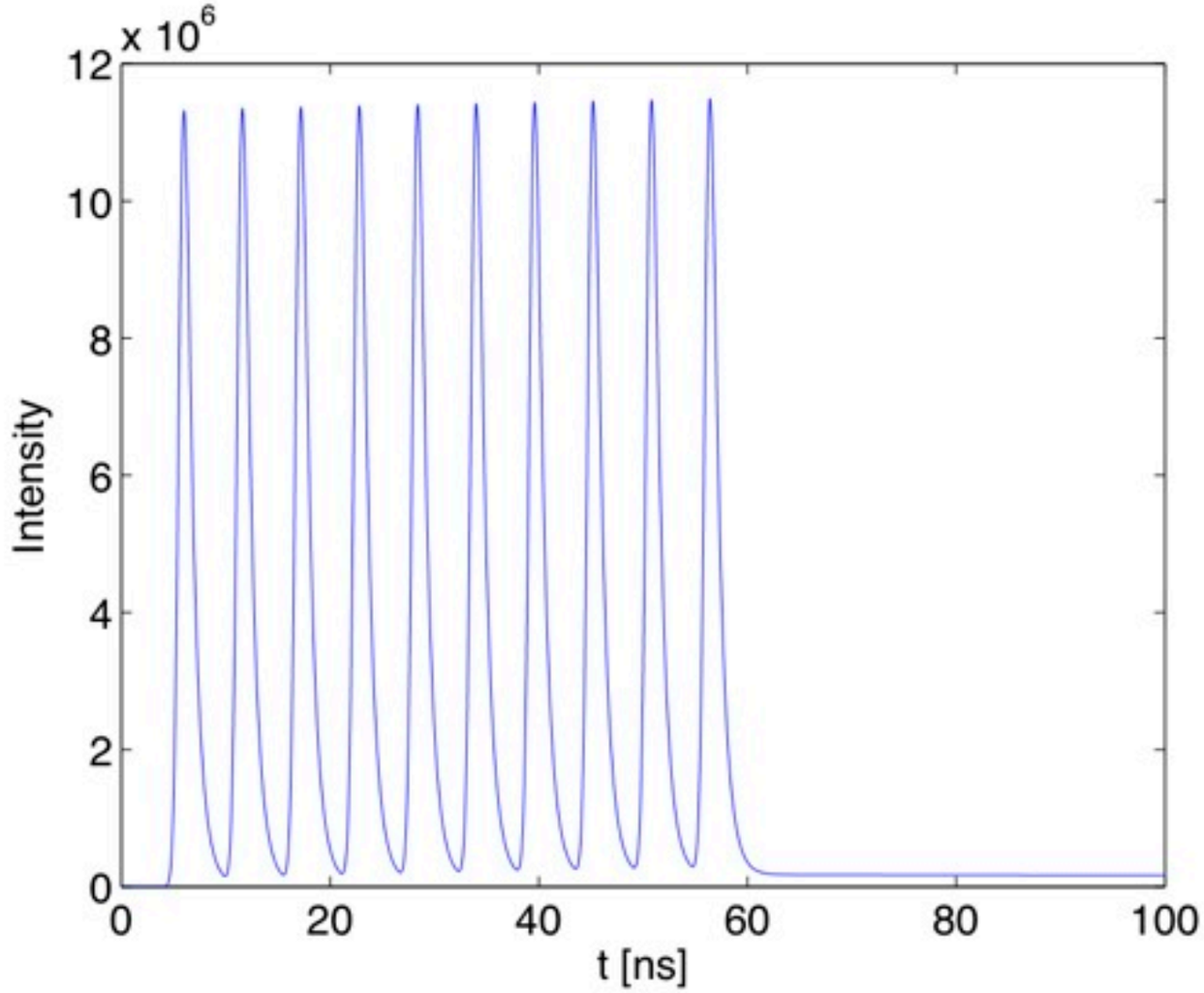
One train of 10 bunches

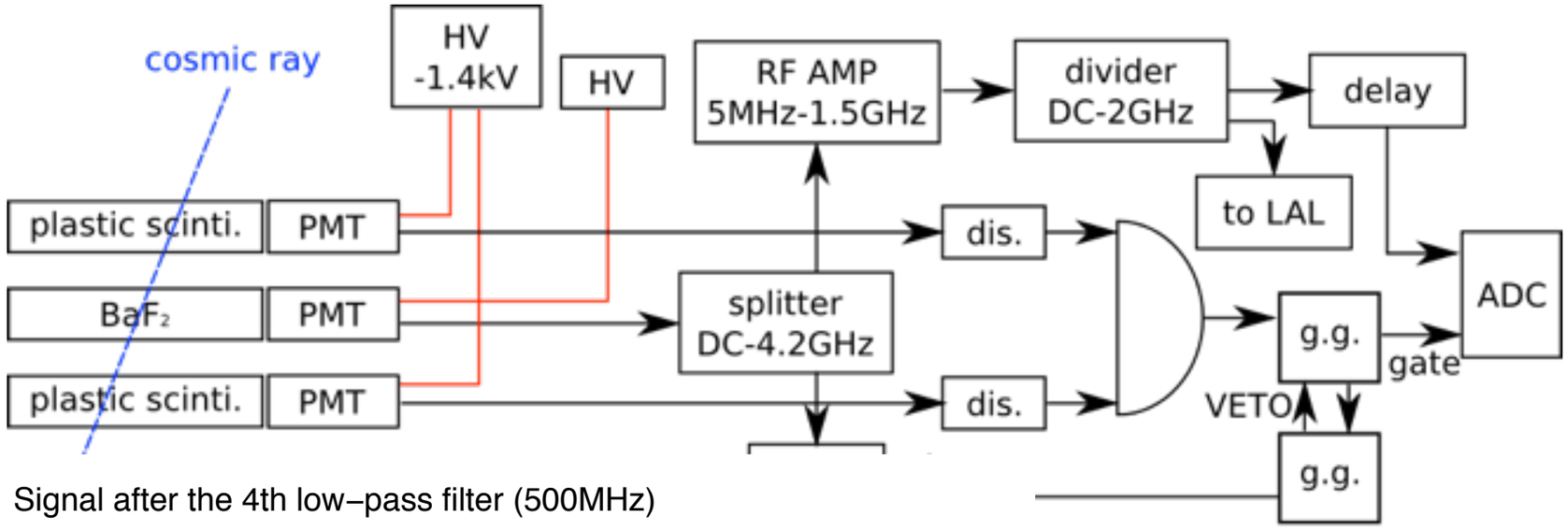
w/o UV-filter

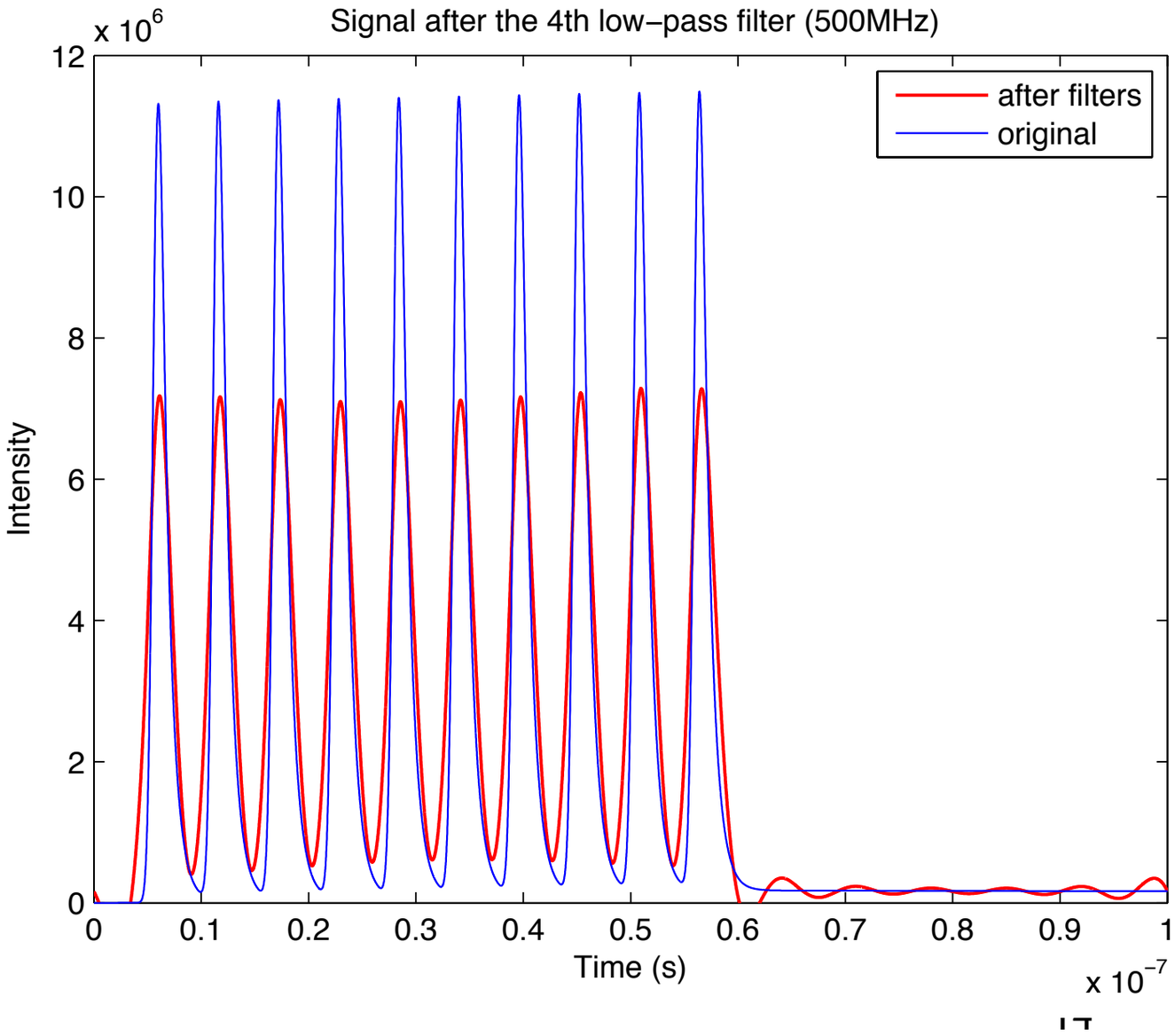


with UV-filter



Effect of bandwidth limitation





Scope: 500 MHz
RF Amp: DC-150 MHz

Cables specifications???

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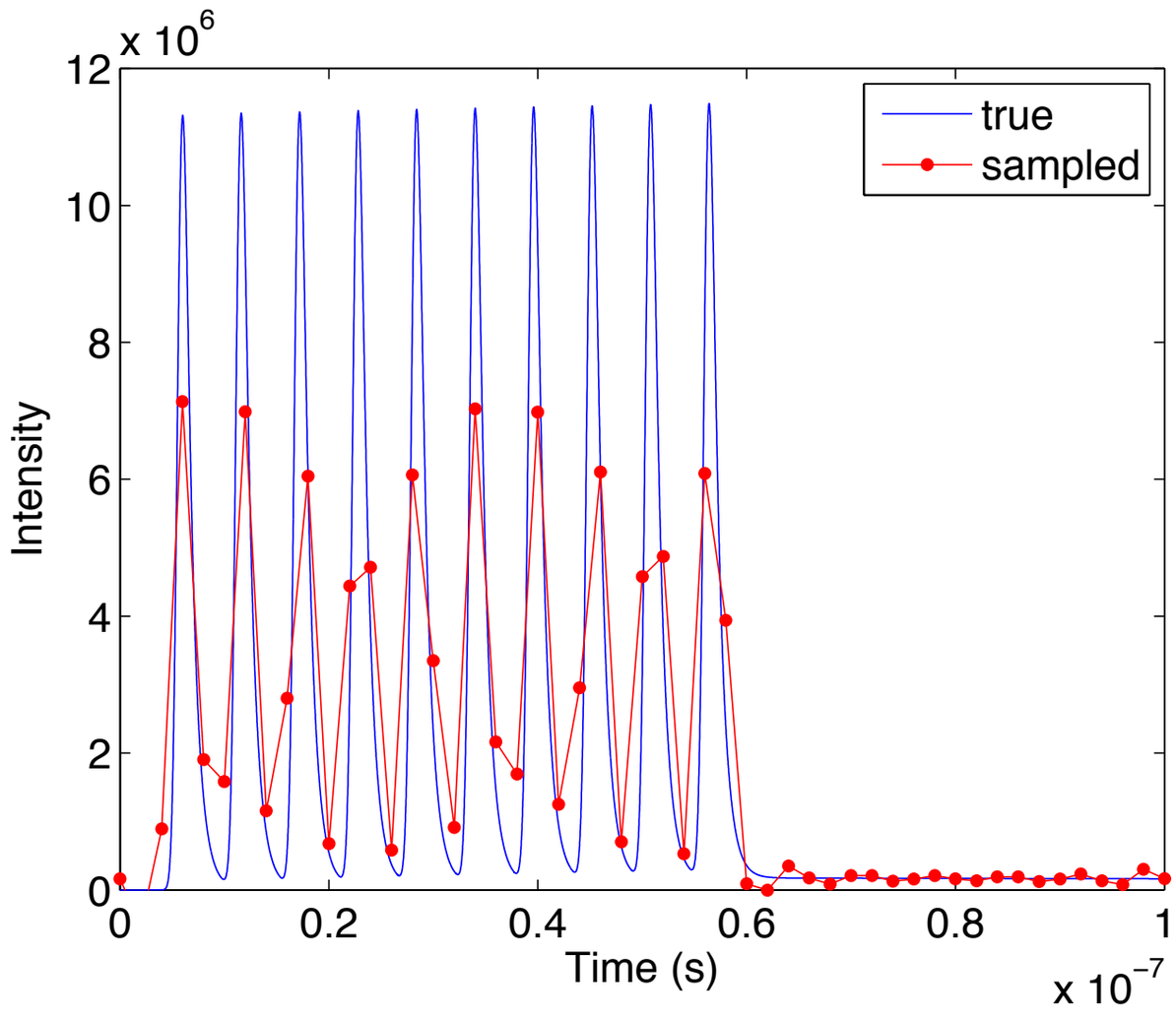
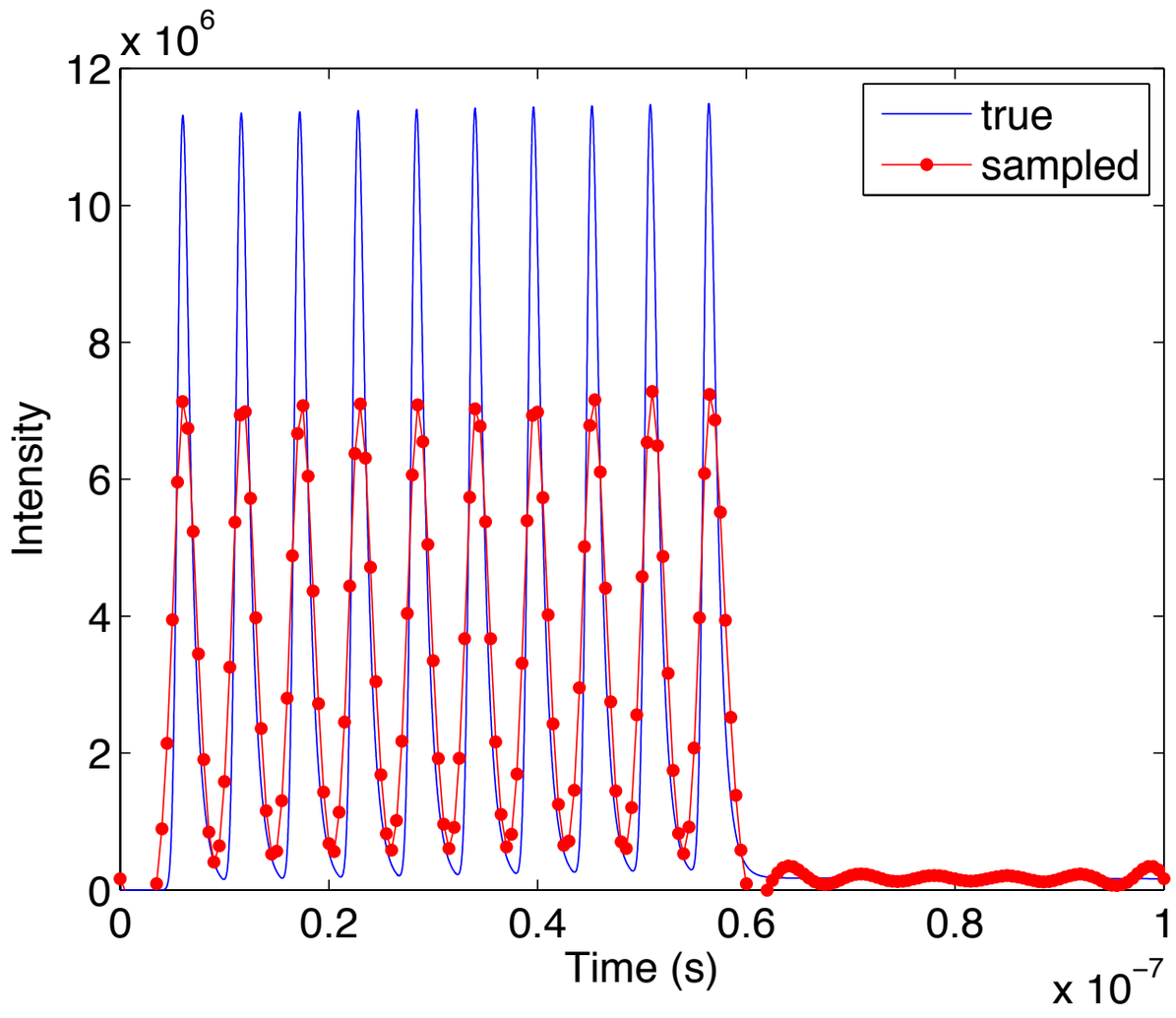
Effect of sampling rate

0.5 Gs/s

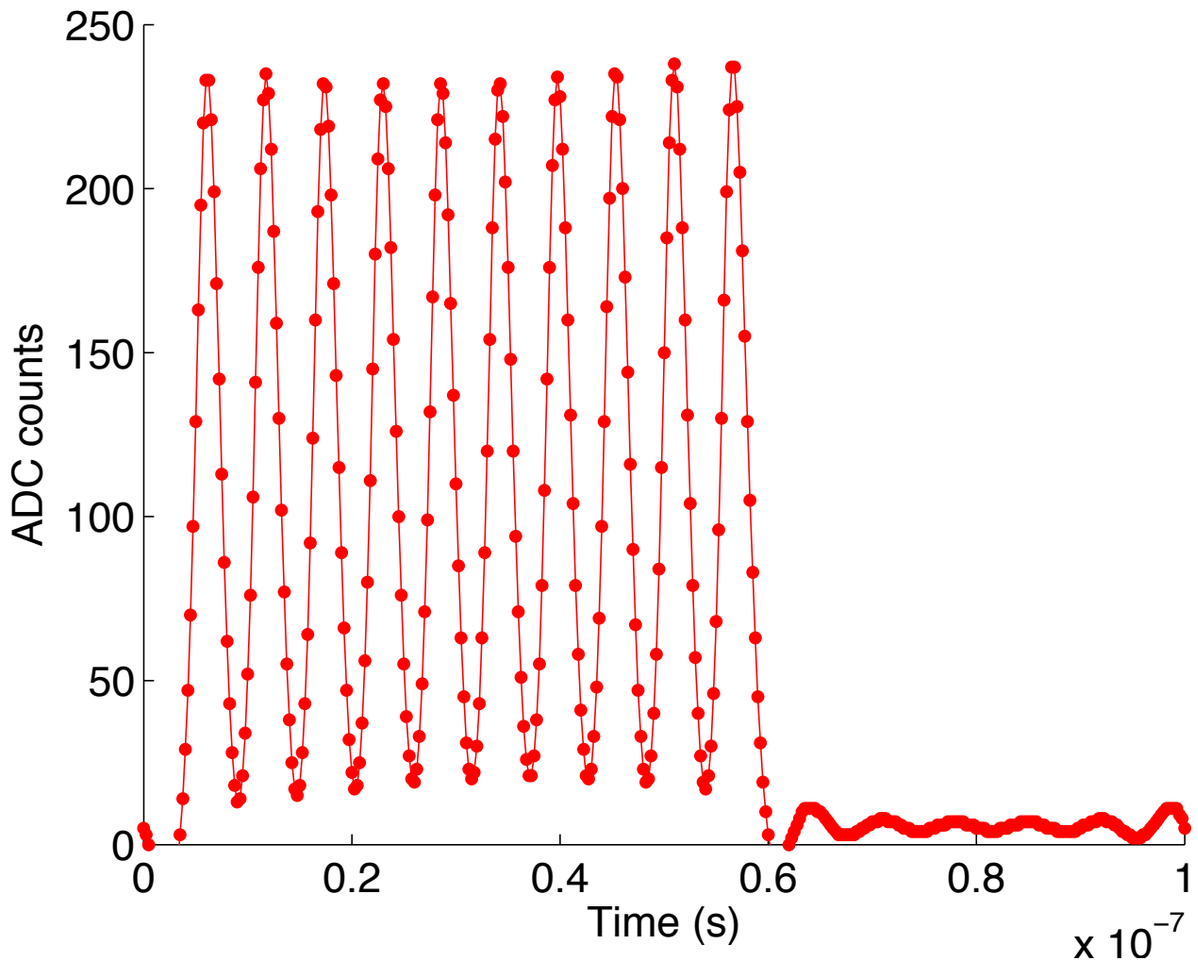


2 Gs/s

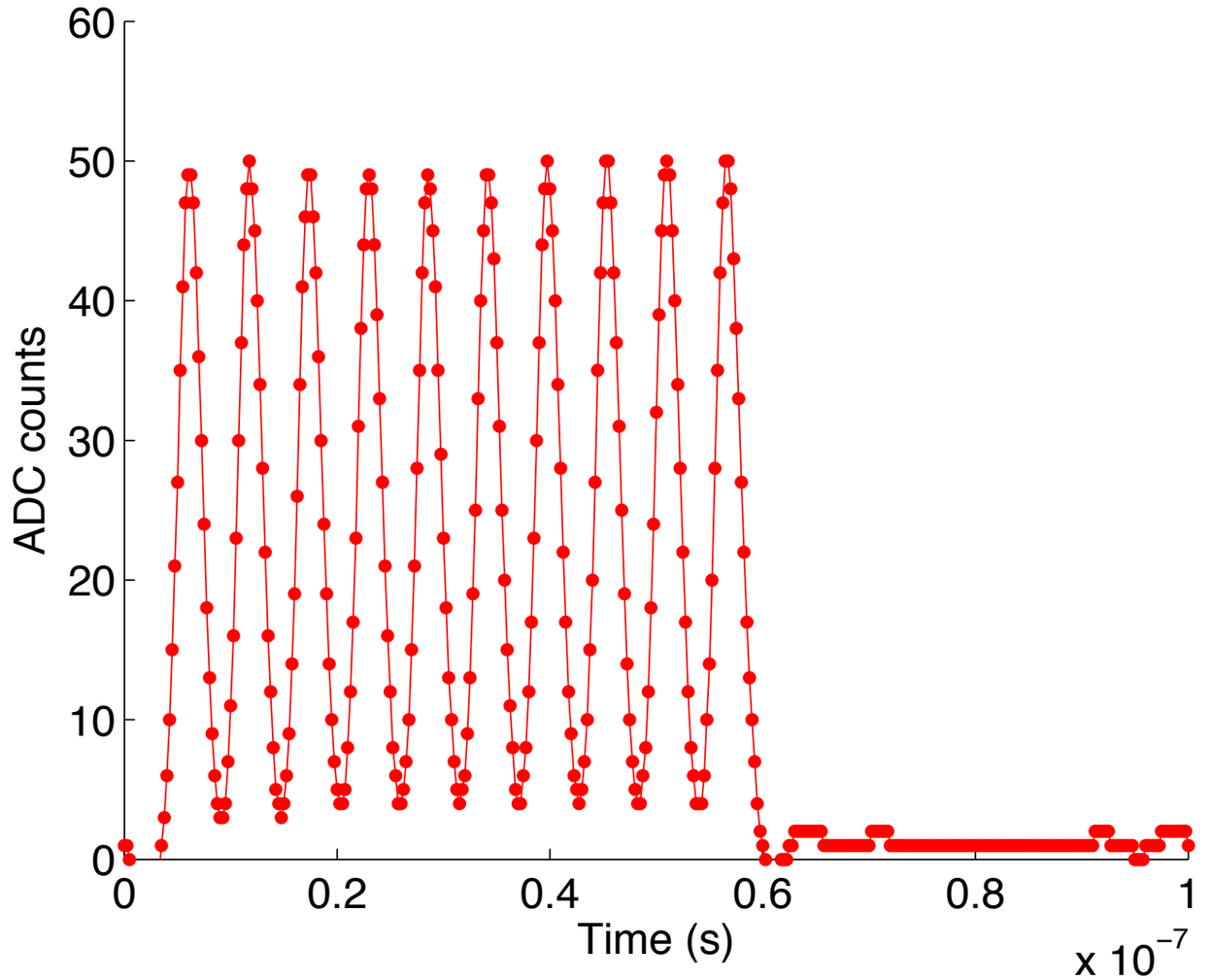


Limited ADC resolution(4GS/s with 8bits ADC)

1ADC = I_{max} / 256



1ADC = I_{max} 5/ 256



Trade-off between max dynamic range & resolution

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Summary

At present, we are working to understand the calorimeter

We are specifying a fast DAQ system to acquire the Compton signal.

Next plan : study the PMT response to the signal from the crystal.