Propagation efficiency of optical photons - SLitrani

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Outline

1. Comparison of SLitrani and Geant4 results for energy deposit

2. Detection efficiency
   - simulating broken PMTs

3. Energy threshold of veto

4. Detection window

SLitrani

SLitrani is an updated version of Litrani.
It is a Monte-Carlo program, built upon ROOT, that simulates light propagation.

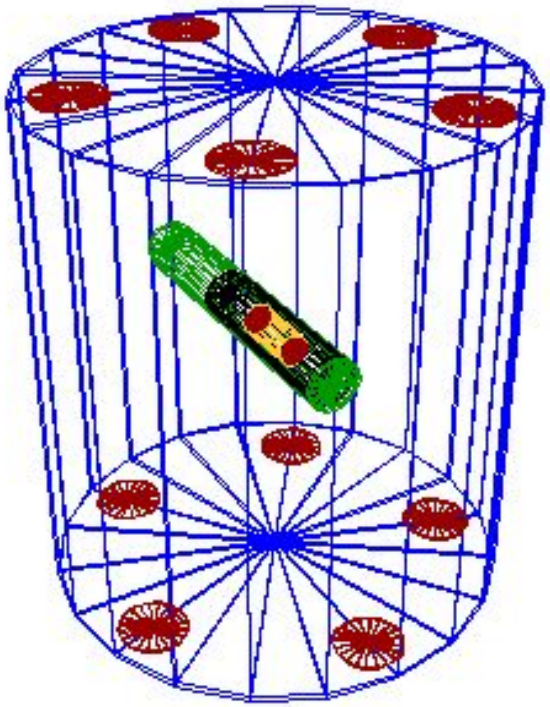
INPUT :

- *Geometry* → volumes and wrapping
- *Cross section* of processes
- *Light yield*, *emission spectrum* and *decay time* of scintillators
- *Optical properties*
- *Quantum efficiency* of detectors

OUTPUT :

- *Deposit of energy in volumes*
- *Production* of optical photons
- *Propagation* of optical photons
- *Detection* of optical photons

Geometry - Proof of Principle (PoP)

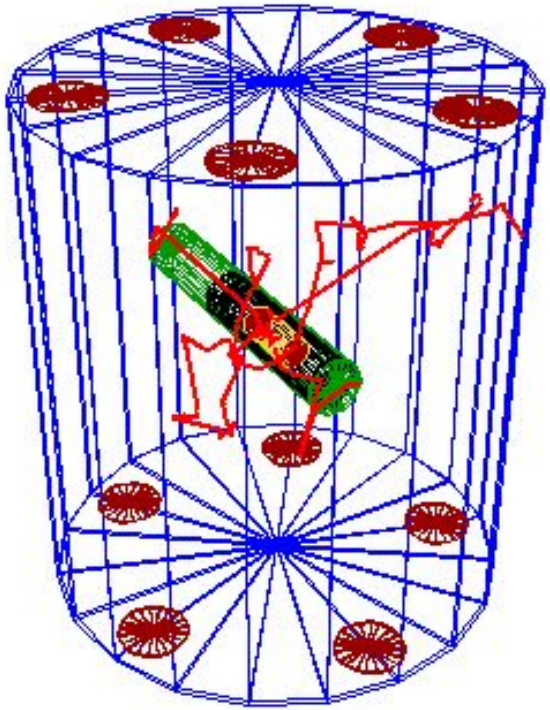


volume	*wrapping*	*filling*
Vessel	*Iron & Lumirror*	*Pseudocumene+PPO*
Copper Tube	*Copper*	*Vacuum*
Enclosure	*Copper*	*Vacuum*
Crystal	*Teflon*	*NaI*

Vessel PMTs	Hamamatsu R5912
Crystal PMTs	Hamamatsu R11065

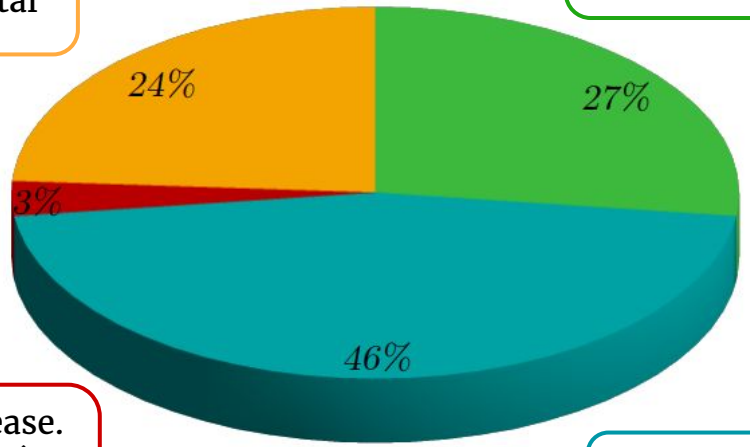
Monte Carlo simulation

To simulate the decay of potassium (^{40}K) , we generate gammas with energy ***E = 1.46 MeV***, uniformly distributed within the crystal volume.



Energy release *only* in crystal

Energy release in crystal *and* in **scintillator**



No energy release. Gamma *doesn't interact* with the apparatus

Energy release *only* in **scintillator**

Production of optical photons

Photoelectric effect
&
Compton scattering

↓

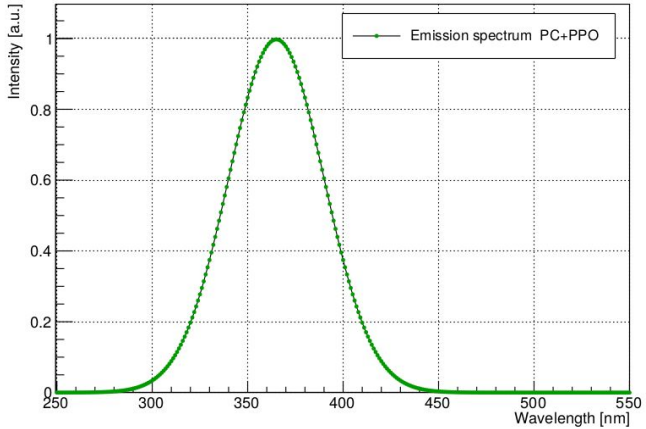
Energy release in scintillators (Pseudocumene and NaI)

↓

Depending on emission spectrum, light yield and decay time of scintillator

↓

Production of optical photons

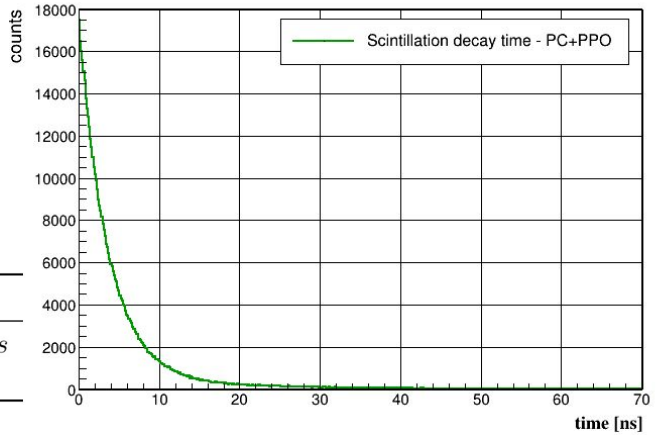


Emission spectrum of liquid scintillator

Gaussian distribution:
$< \lambda > = 365\ nm$
$\sigma = 25\ nm$

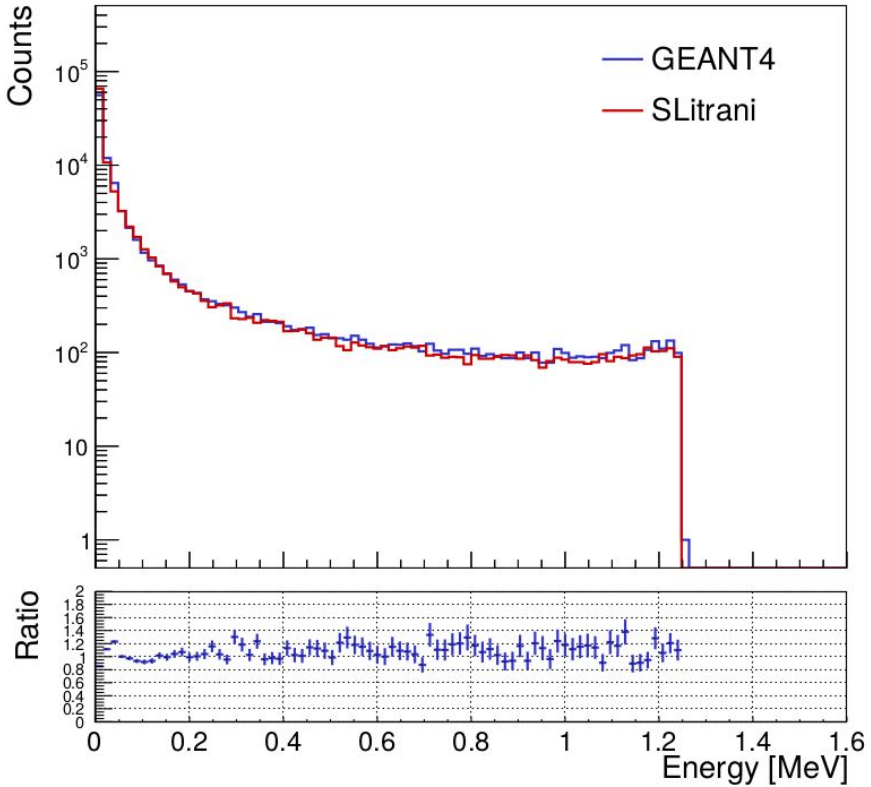
Scintillation decay time of liquid scintillator

	$i=1$	$i=2$	$i=3$
τ_i	$3.57\ ns$	$17.6\ ns$	$59.9\ ns$
q_i	89.5%	6.3%	4.2%



Comparison between SLitrani and Geant4

Energy deposited in veto
10 000 simulated events



➔ Average energy deposited by each event in veto:

< E > = 0.78 MeV (GEANT)

< E > = 0.72 MeV (SLitrani)

Energy deposited in veto:

Same initial conditions lead to same results within 10% .

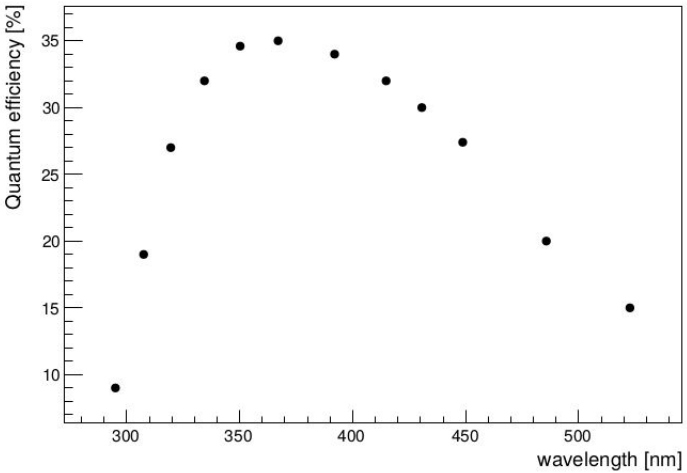
Propagation and detection of optical photons

Taking into account optical properties of all materials, SLitrani allows us to compute the *propagation of optical photons* through the geometry.

- **Attenuation length** of PC+PPO (~400 nm) = 7 m
- **Reflectance** of Lumirror (~350 – 400 nm) :

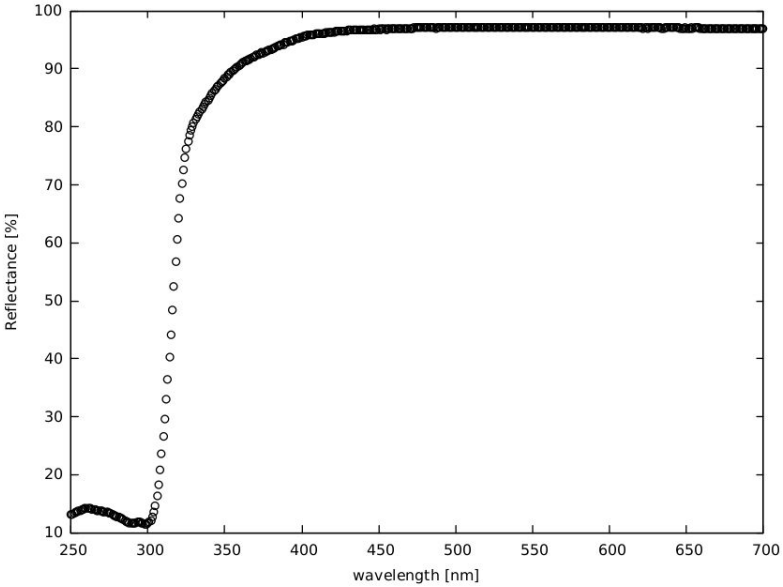
$$R = \frac{Reflected\ radiation}{Incidence\ radiation} = 90 - 95\%$$

According to quantum efficiency:



35% of optical photons

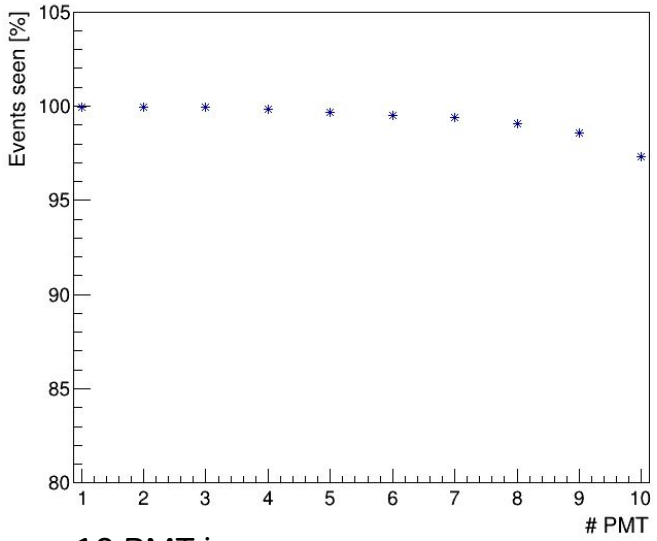
Photoelectrons



Detection efficiency

***Detection efficiency of veto system**: events detected [%] vs number of PMT in coincidence*

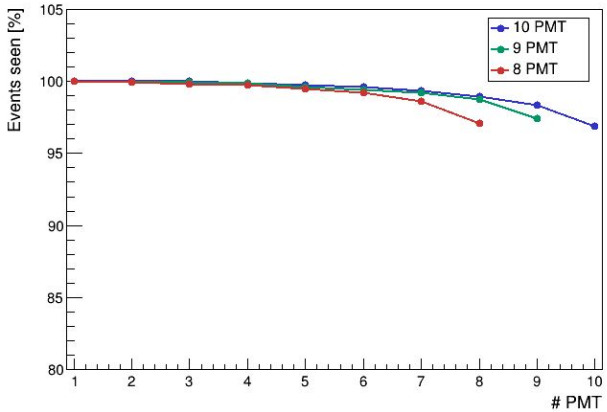
n PMT in **coincidence** → Events is considered **detected** if turn on at least *n* PMT → PMTs **turned on** if at least 1 photoelectron is detected



10 PMT in coincidence → Efficiency > 95%

Most of events turn on all PMTs

Simulating **broken PMTs:**

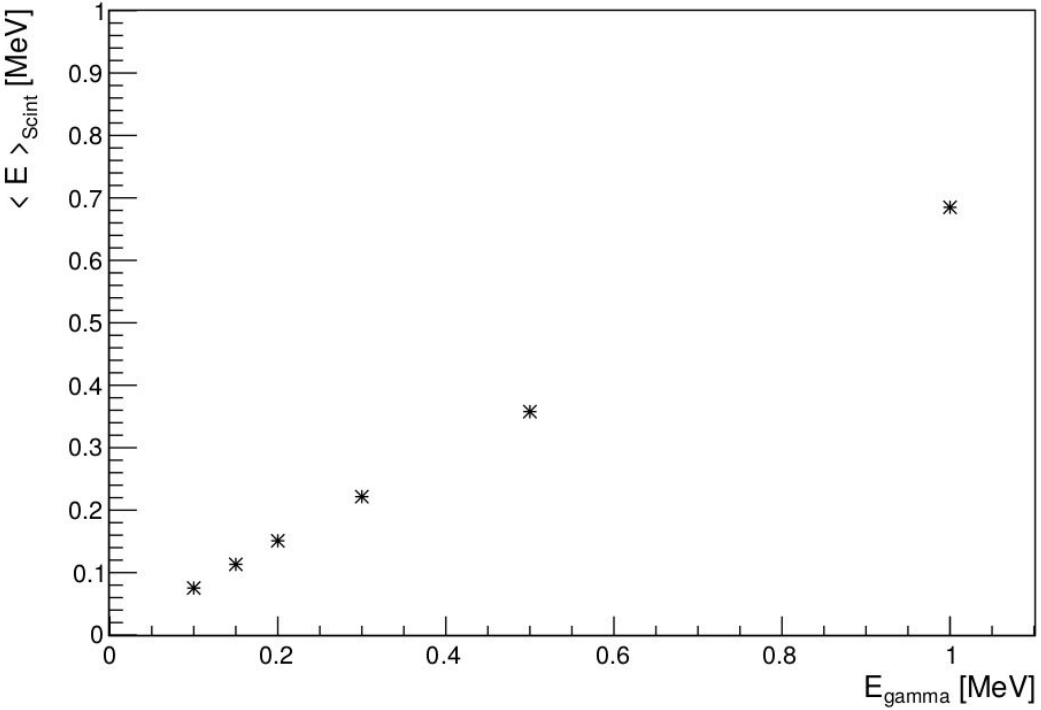


➔ *The damage of one or more PMTs doesn't affect the veto efficiency*

Veto detection efficiency close to 100%

Energy threshold of veto

*To study the **energy threshold** of the veto, we generated gammas with different energy in the crystal (E_{gamma}). These gammas simulate different energy release in scintillator ($\langle E \rangle_{Scint}$).*



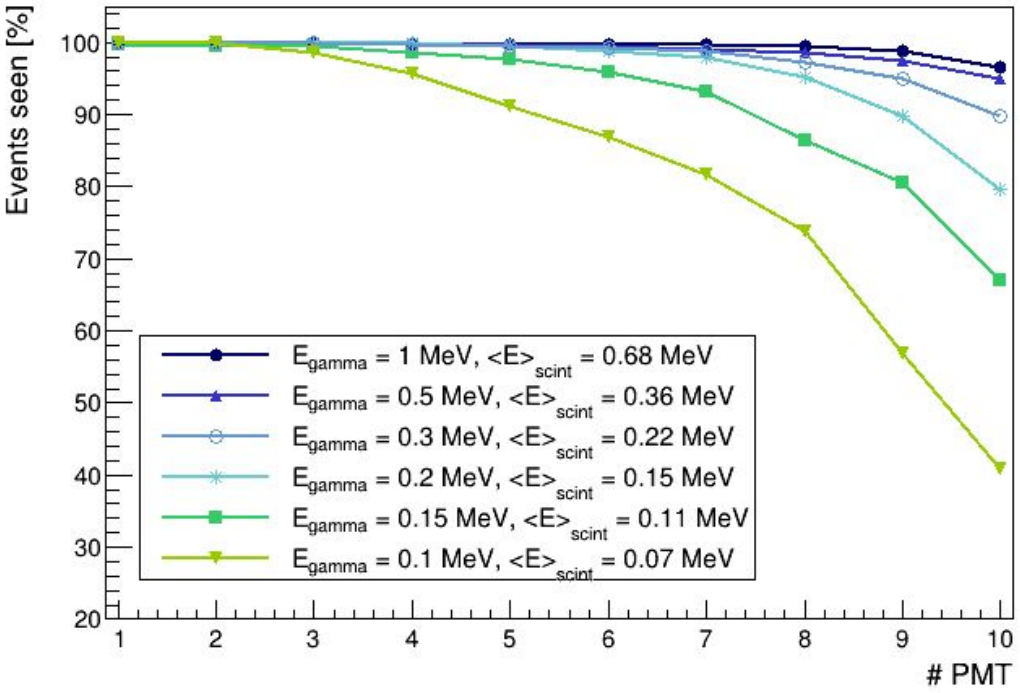
Different energy for gammas generated in crystal

(E_{gamma})

Different value of the mean energy release in scintillator

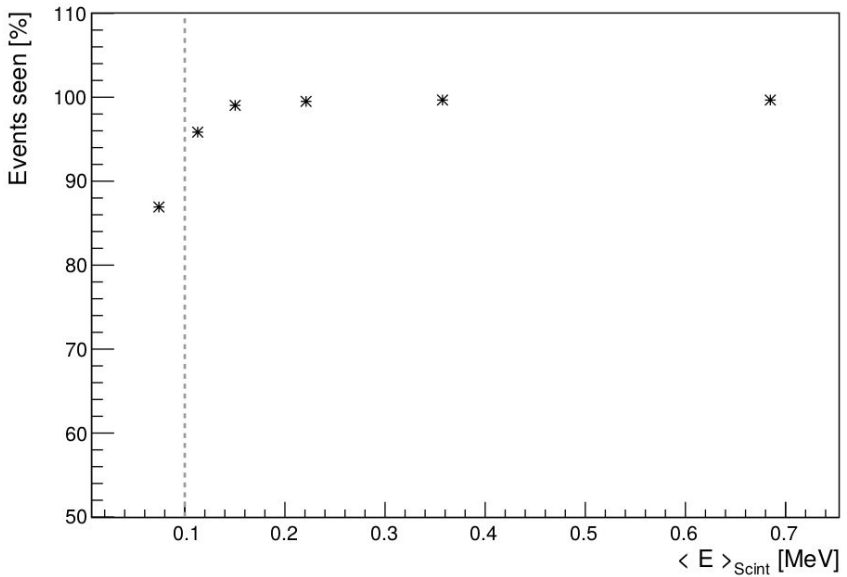
($\langle E \rangle_{Scint}$)

Energy threshold of veto



Gammas of low energy → low detection efficiency

For a coincident request of 6 PMTs:

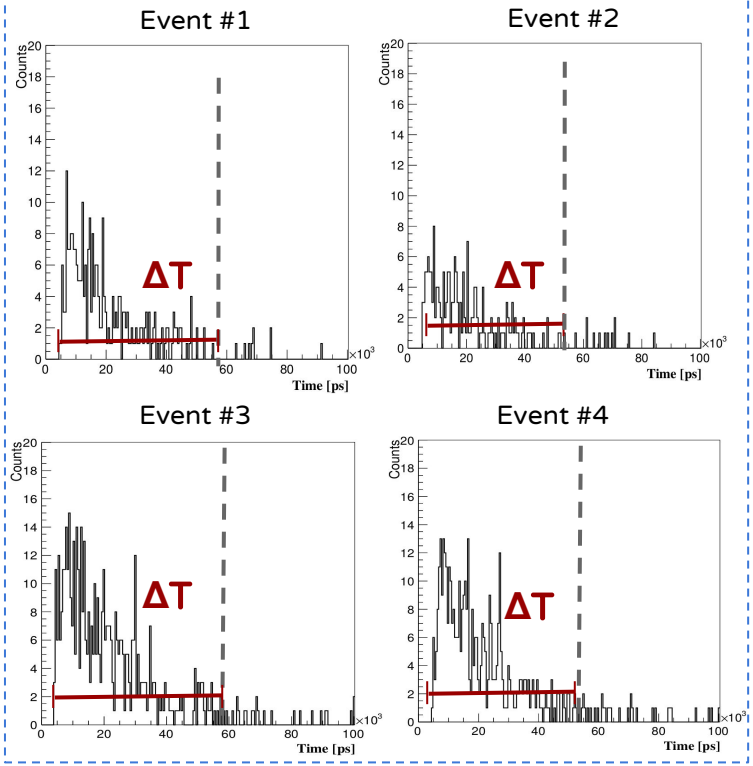


The detection efficiency is greater than 90% if the energy release is greater than **0.1 MeV.**

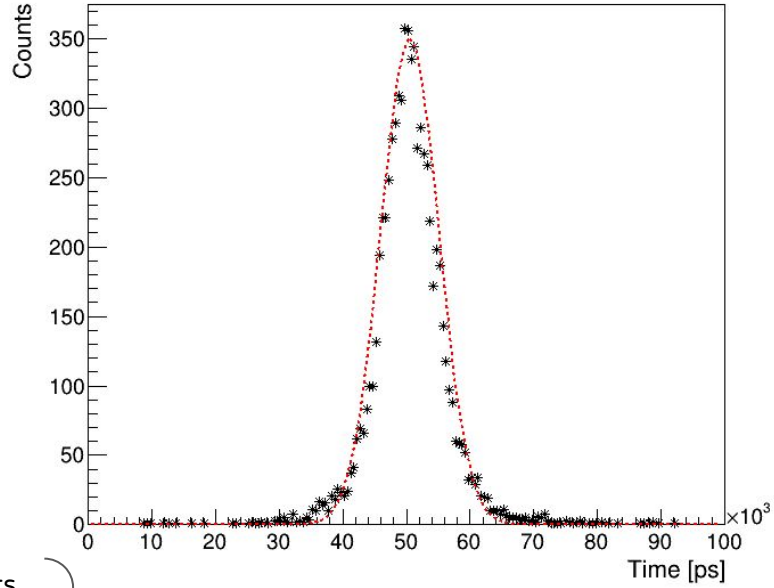
Acceptable threshold for the veto of SABRE

Detection window

Some SLITRANI histograms of the ***time of arrival of optical photons*** *detected by veto (per event):*



➔ **Detection window**: distribution of the interval time (**ΔT**) to detect the 95% of optical photons for each event.



Dark counts contribution is negligible in this window (~ 2 kHz)

Detection window: 50 *ns*

Conclusions

1. ***SLitrani*** *and* ***Geant4*** *provide similar results for the computation of energy release*

2. The **detection efficiency** of veto for 1.46 MeV gammas: *the SABRE set up allows an efficiency close to 100%*

3. The **energy threshold** of veto: *SABRE active veto can detect energy release until 0.1 MeV → this threshold allows an excellent background rejection*

4. The **detection window** of event: *the interval time to detect an event is 50 ns*

Forward studies:

- ➢ *This simulation could be used to understand the measurements currently underway for the* ***characterization of the SABRE set up****.*

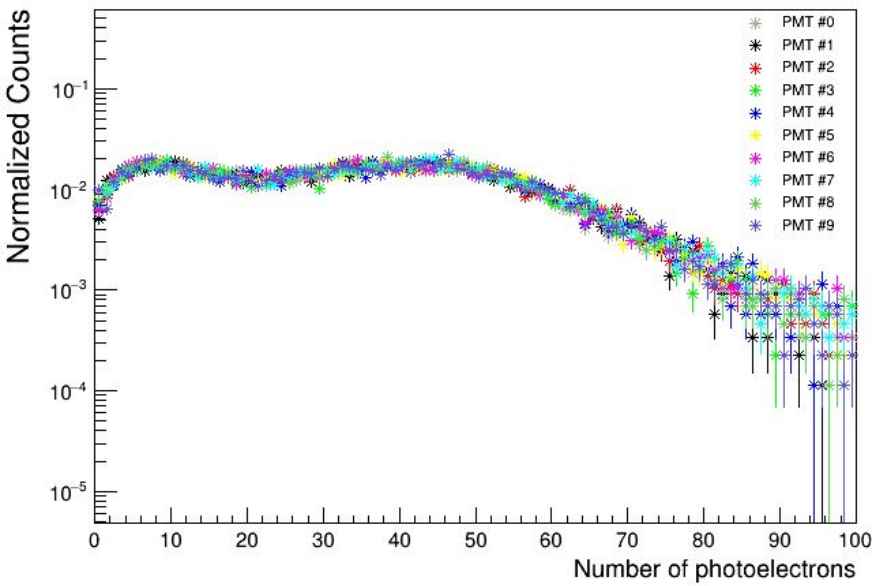
- ➢ *The results will be compared with an* ***analogous study*** *developed* ***in GEANT4*** *.*
  (see Lindsey talk)

Thank you for your attention

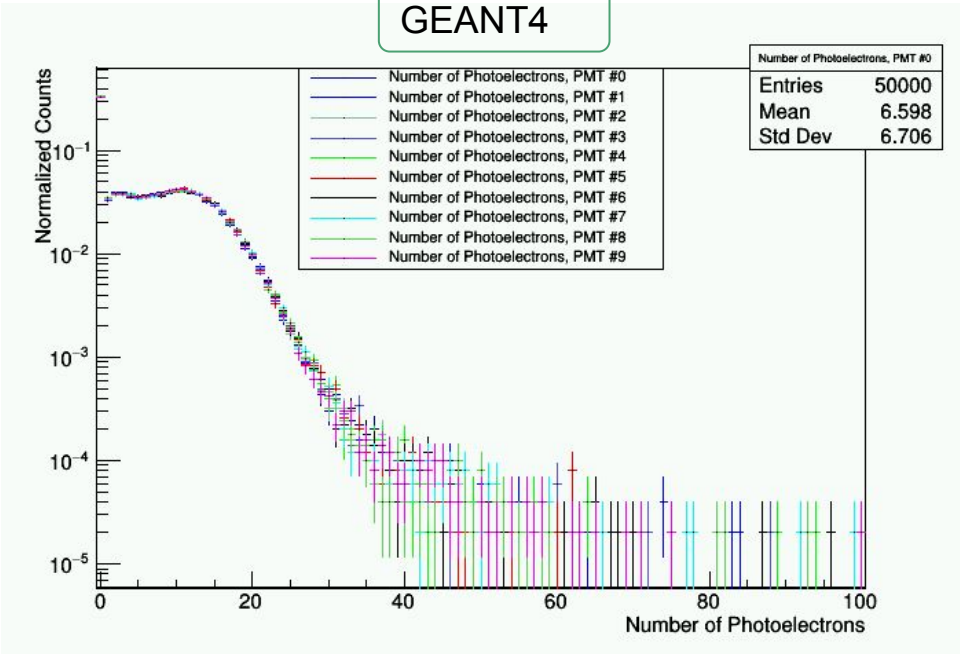
Comparison SLITRANI - GEANT4

Number of photoelectrons seen by each PMT.

SLITRANI



GEANT4



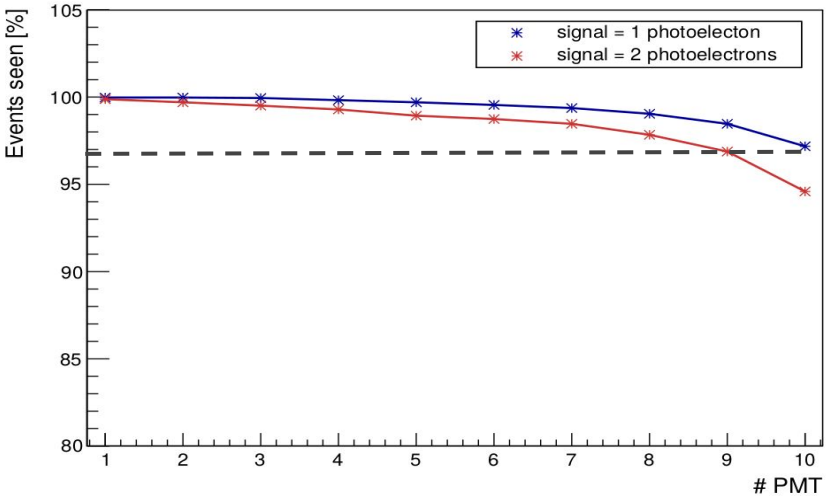
It includes only events with a positive energy release in scintillator

- SLITRANI computes a greater number of photoelectrons seen by each PMT.

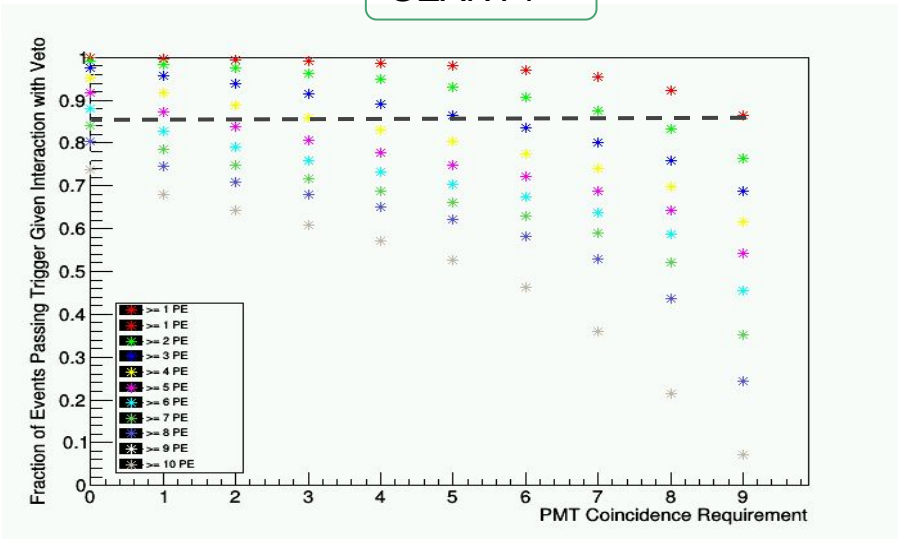
Comparison SLITRANI - GEANT4

Events seen with different trigger

SLITRANI



GEANT4



- **Efficiency** computed in SLITRANI is greater than efficiency computed in GEANT4:

If trigger is 1 photoelectrons:

SLITRANI: *efficiency > 97%*

GEANT4: *efficiency > 86%*