NPS Energy Resolution Simulation

Ho San KO

PHEN Institut de Physique Nucléaire d'Orsay

22. Feb. 2018

Outline

- Geant4 Simulation Geometry
- Results

  -Resolution

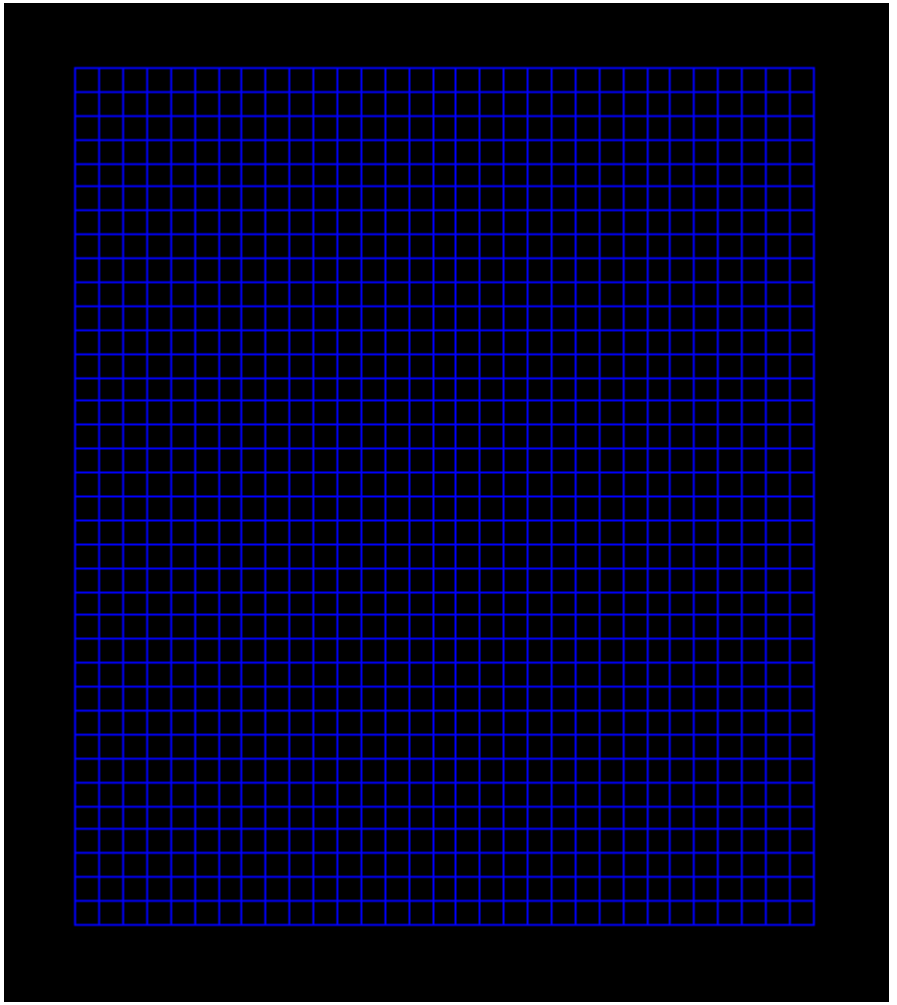
  -Parameters
- Conclusion

Purpose of the Simulation

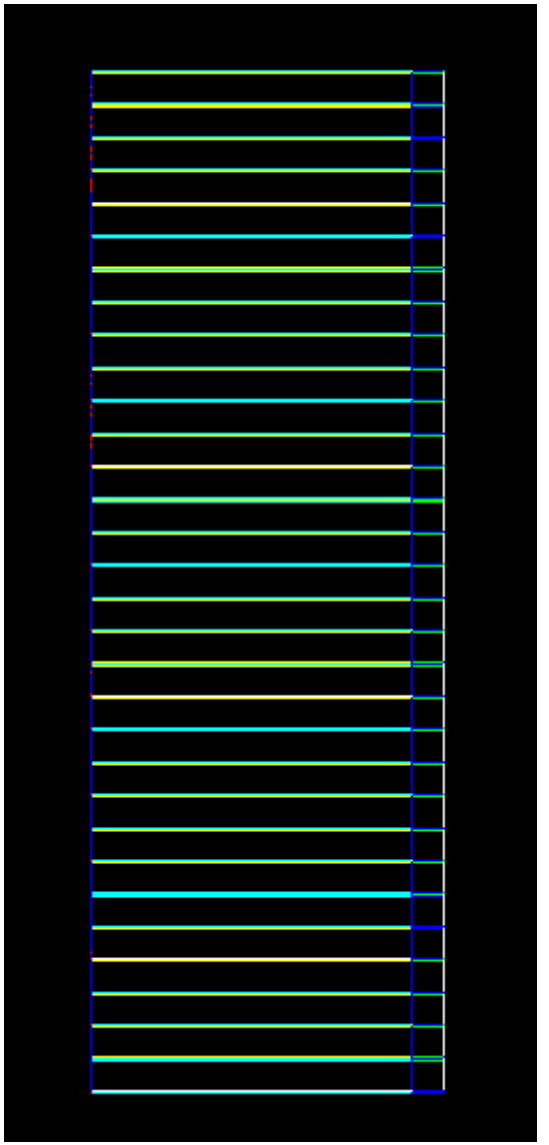
- Energy Resolution

  -Check the dependency of the energy resolution of the NPS on the distance between the crystals(gap).

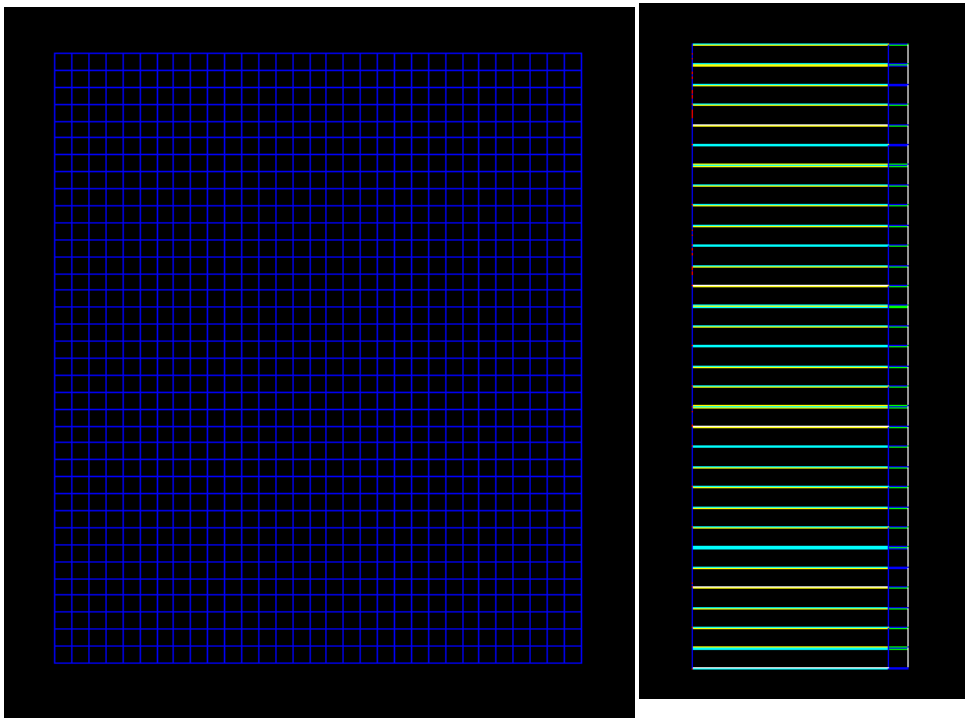
Simulation Geometry



31X36 PbWO4 crystals with PMT attached.



Simulation Geometry



- 20.5 X 20.5 X 200.5 mm3.
- Each crystals are wrapped with VM2000 wrapper (65um thick).
- PMTs have the same size of the surface with that of crystal.

  -20.5 X 20.5 mm2
- Between crystals, there are gaps.

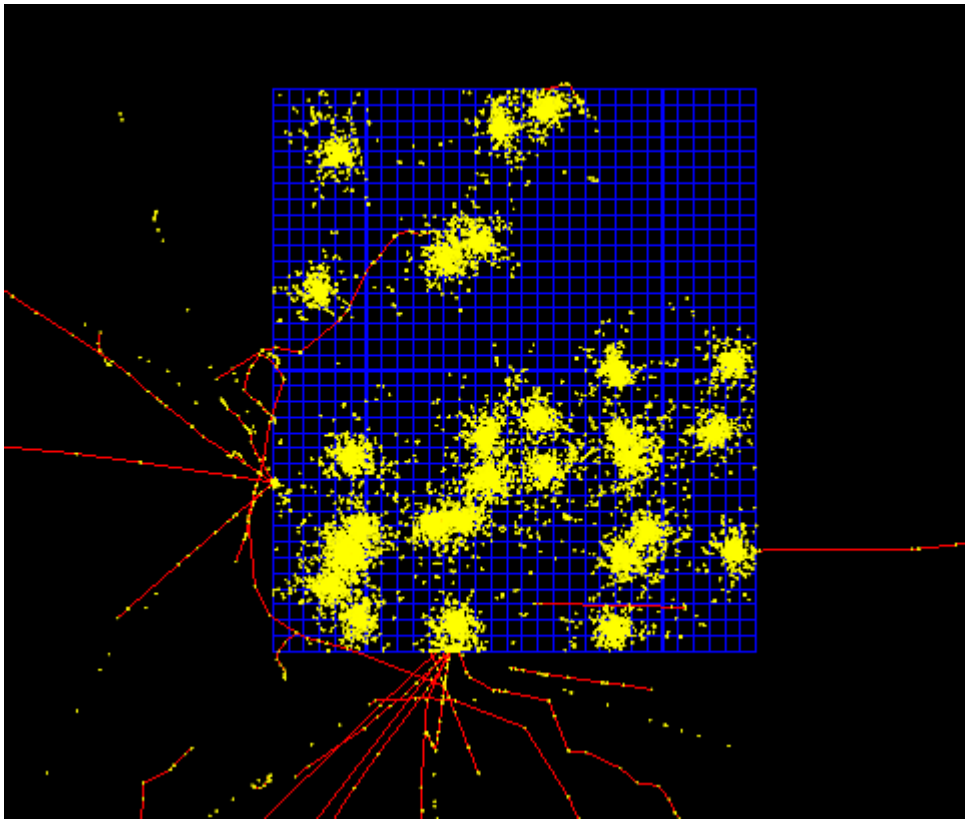
  -0, 0.5, 1, 1.5, 2mm

  -gaps are filled with air.

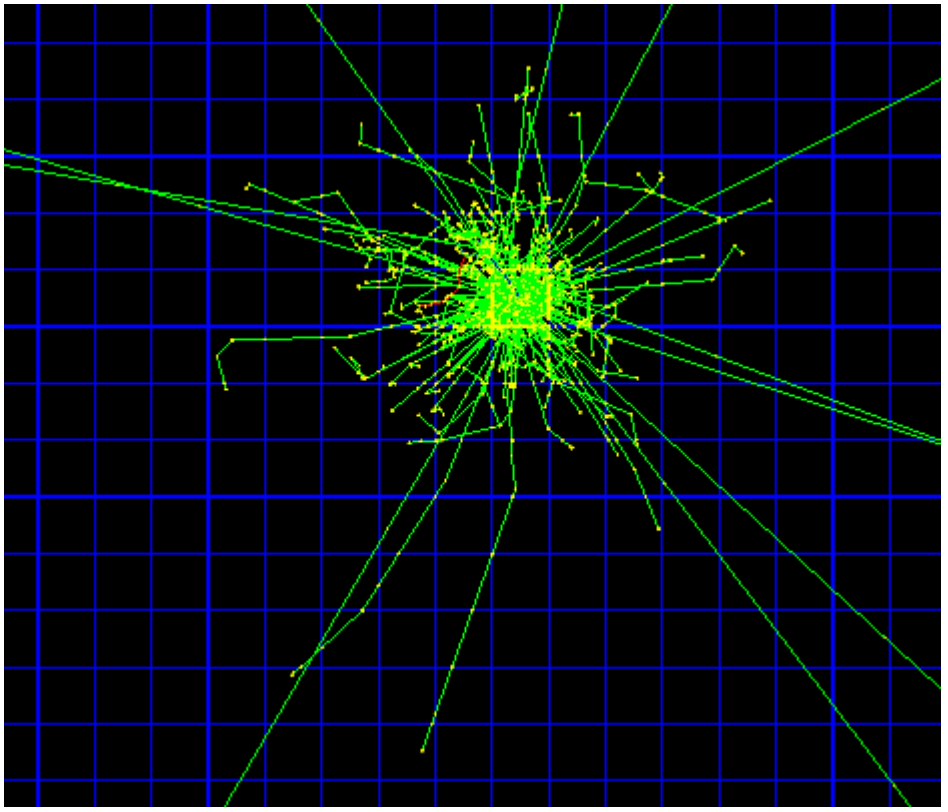
►PMTs are glasses covered with thin Al.

Scintillated photons travel from crystal to PMT(glass), collected and counted on Al surface.

Gamma Source



Several events of gamma hitting the NPS
Electron tracks drawn



Shower created by one gamma
Gamma tracks drawn(mostly)

- Gamma was used as primary particle : 0.5, 1, 3.25, 5.5, 7.75, 10GeV
- They are distributed all over the surface of the NPS.

Optical Photon Physics in Geant4

- The PbWO4 scintillates and makes photons and they are collected at the photocathode of the PMT.
- In Geant4, the user can also make Optical Photons (OP) with some parameters.

  -light emission range of the OP.

  -refractive Index

  -attenuation length

  -light yield, decay time and etc.

  – Ref. Zhu, A study on the properties of lead tungstate crystals Nucl. Inst. Meth. Phys. A 376 (1996) 319-334

Optical Photon Physics in Geant4

- Optical properties of the VM2000 is provided in Geant4 library[G4REALSURFACEDATA]

- Optical properties in the border between material is also provided.[G4REALSURFACEDATA]

  -polished crystal surface + air + VM2000 wrapper

  -Gean4 User's Guide for Application Developers.

  -M. Janecek, W. W. Moses, IEEE Trans. Nucl. Sci. 57 (3) (2010) 964-970

Energy Deposition

- 1GeV gamma(example)

  -10k events generated for ~5k events collected at the calorimeter.

  -one simulation takes

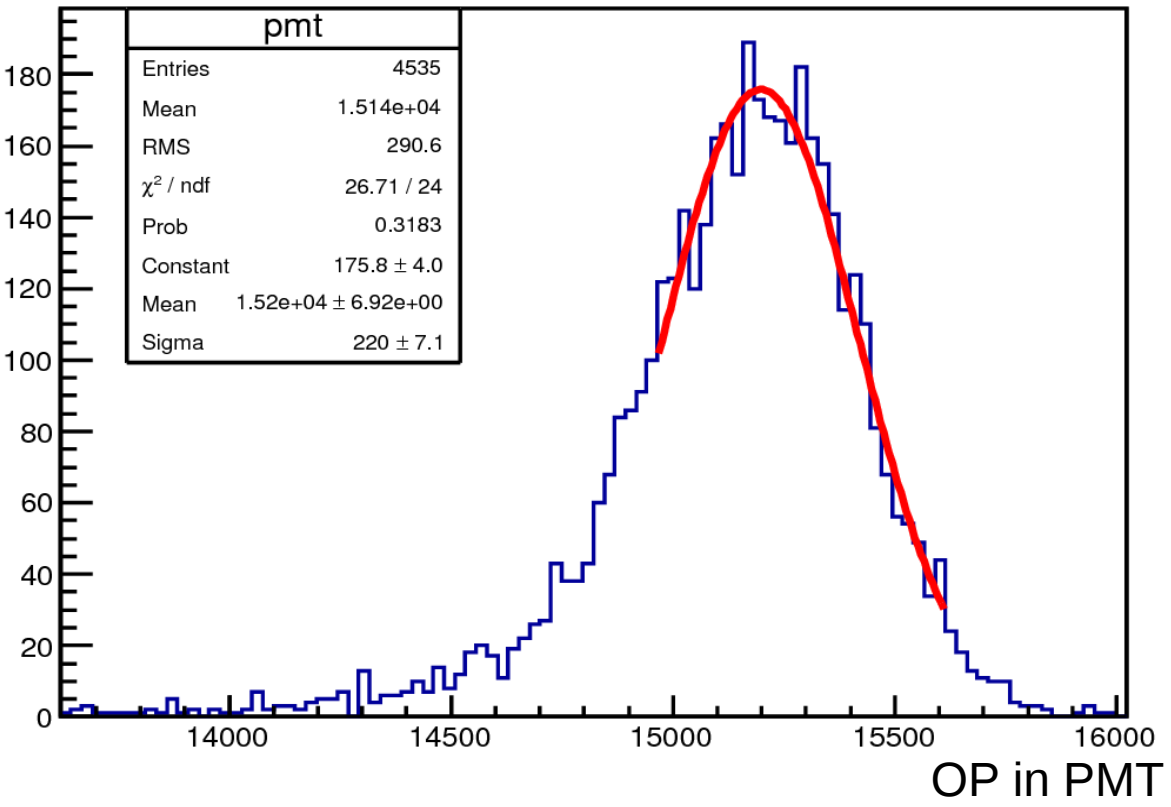
  ex) 3.3hrs/250evt/1GeV

- Light Yield : ~15/MeV
- Use fitted Gaussians'

  -mean values

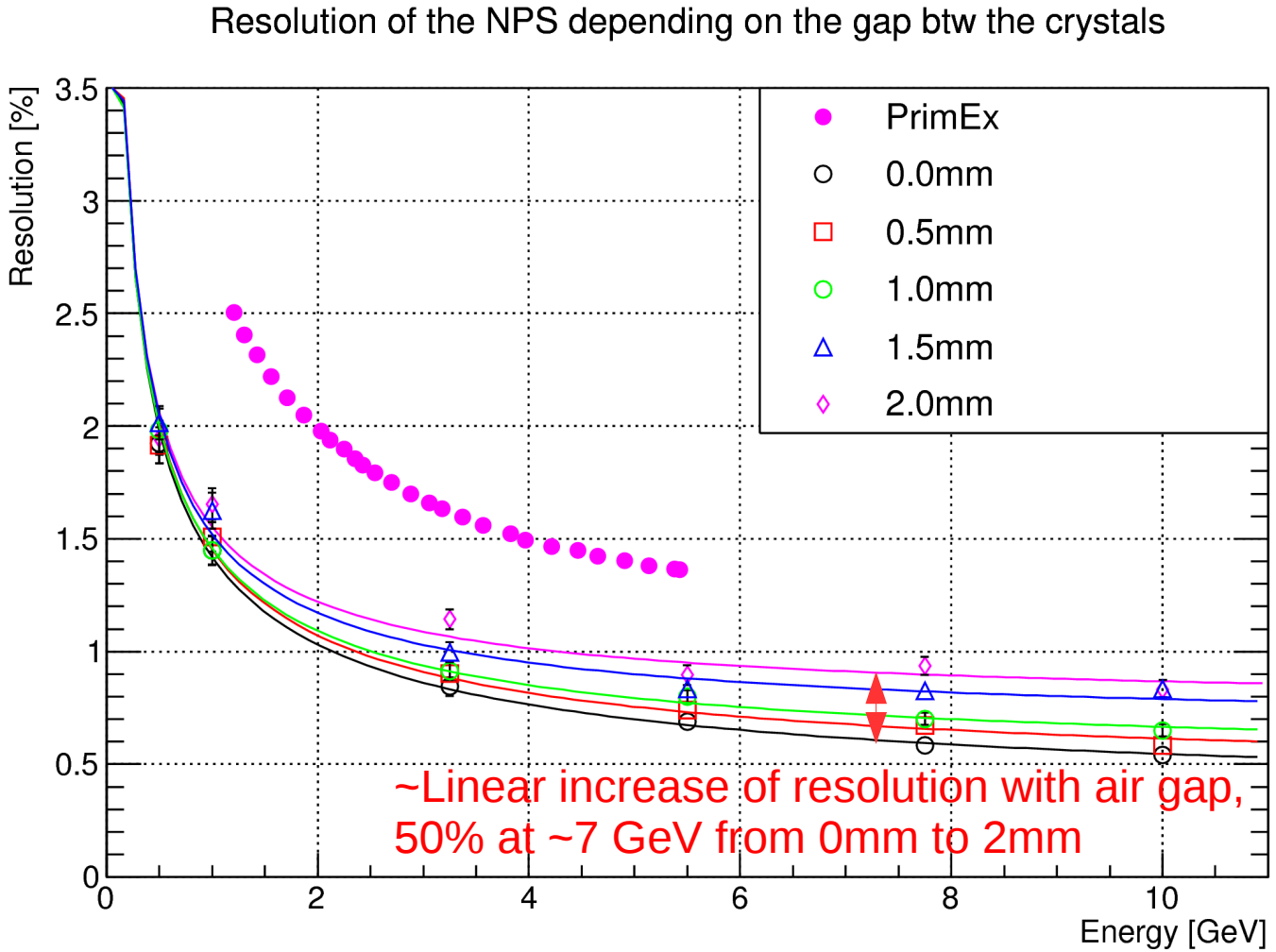
  -sigmas

  for the resolution.



Variables : 1. size of the gap between the crystals
2. energy of the primary source; gamma

Resolution



Fitting function : $\frac{\sigma}{E} = A \oplus \frac{B}{\sqrt{E}} \oplus \frac{C}{E}$

Parameter “C” is fixed to 0.

-When “C” is introduced;
“A”, “B” and “C” are unconstrained.

And “C” : energy independent
~ electronic noise.
(not in simulation)

Simulation results are more optimistic than those of PrimEx.

Mis-calibration

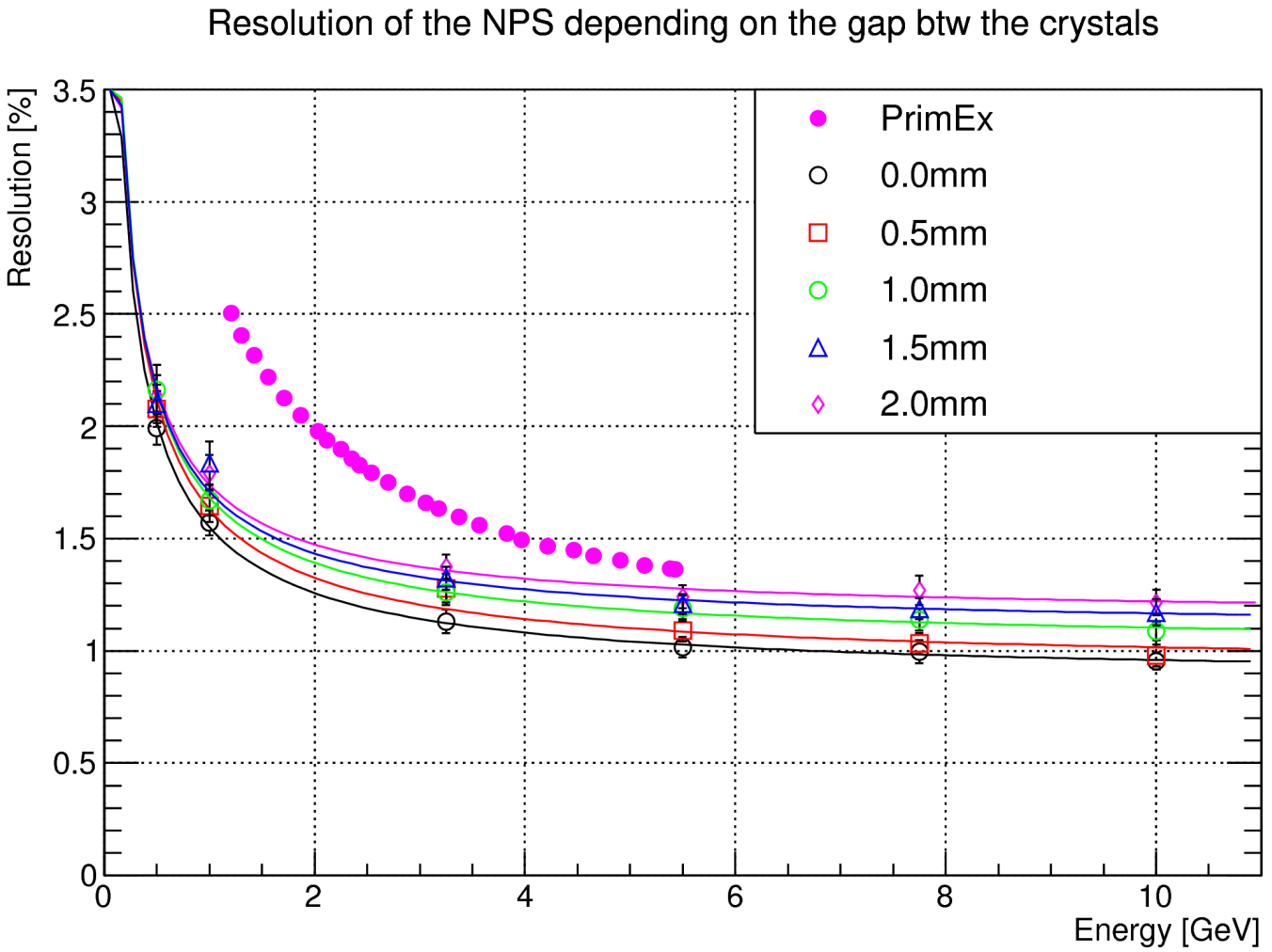
- In real situation, each crystal will have calibration coefficient.
- Some crystals will systematically overestimate the energies and some others will underestimate them.

  → With simulation result, we can make similar effects by modifying the energies in each crystals with Gauss(1%, 3% sigma) random.

- Each crystal by applying a calibration coefficient randomly chosen in a Gaussian distribution (sigma : 0.01 or 0.03).

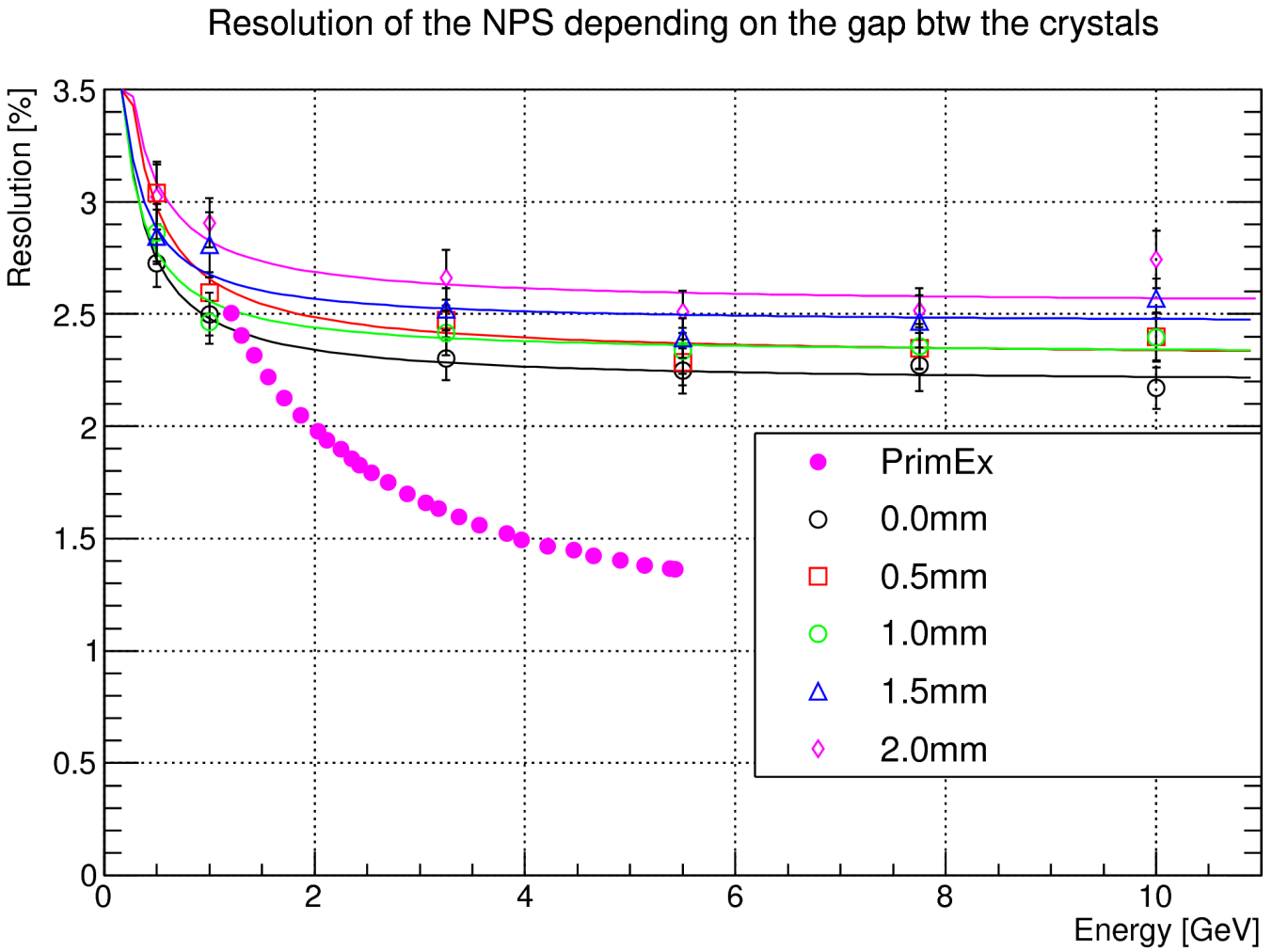
Resolution

- 1% miscalibration.



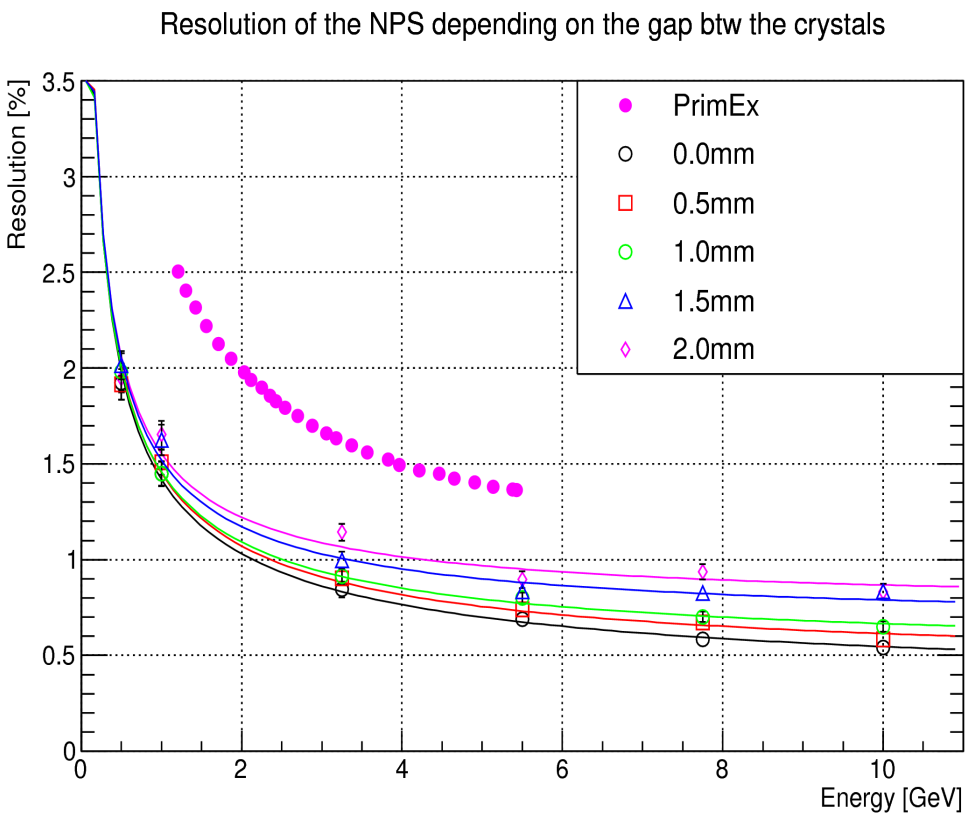
Resolution

- 3% miscalibration.

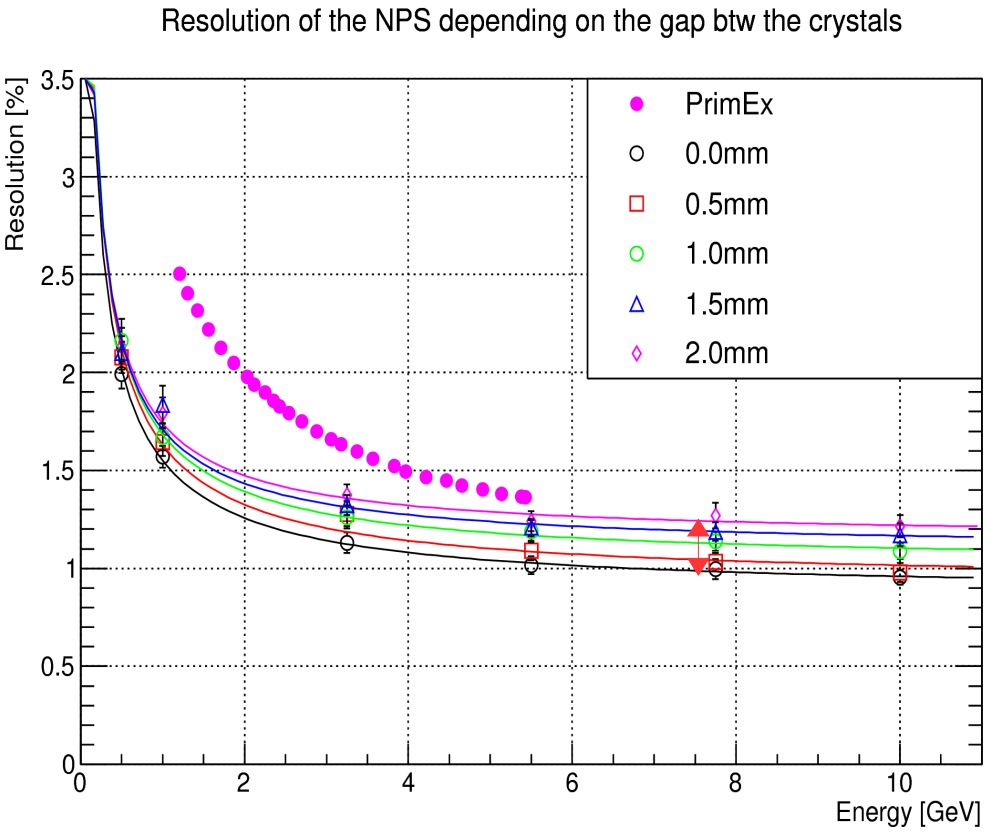


Control of the relative calibration of the crystals is very important for a good energy resolution!

Resolution



No miscalib.



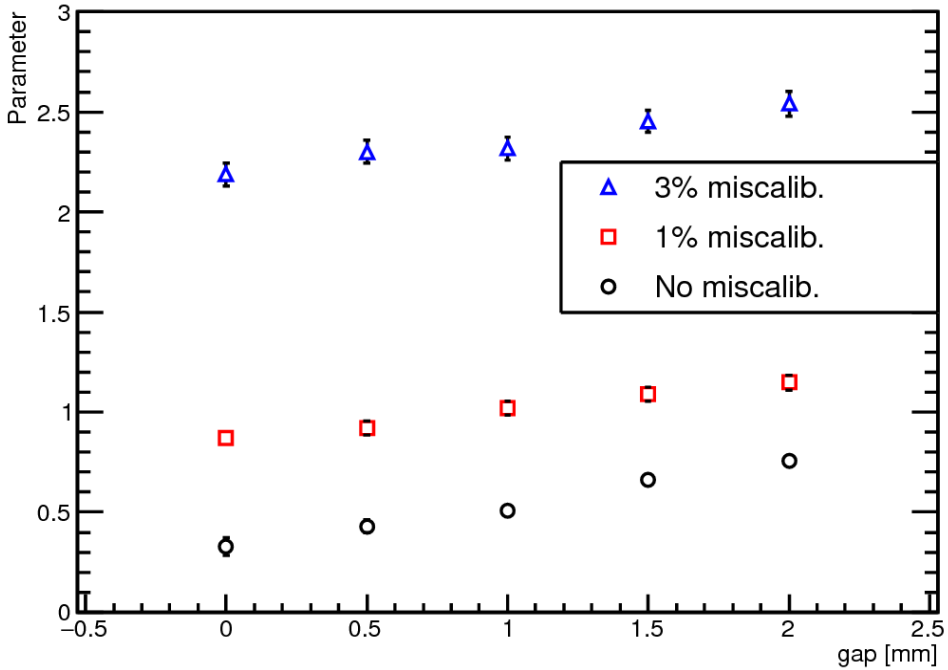
1% miscalib.

With 1% miscalibration, energy resolution increases by 30% between 0 and 2mm gap (E > 3 GeV)

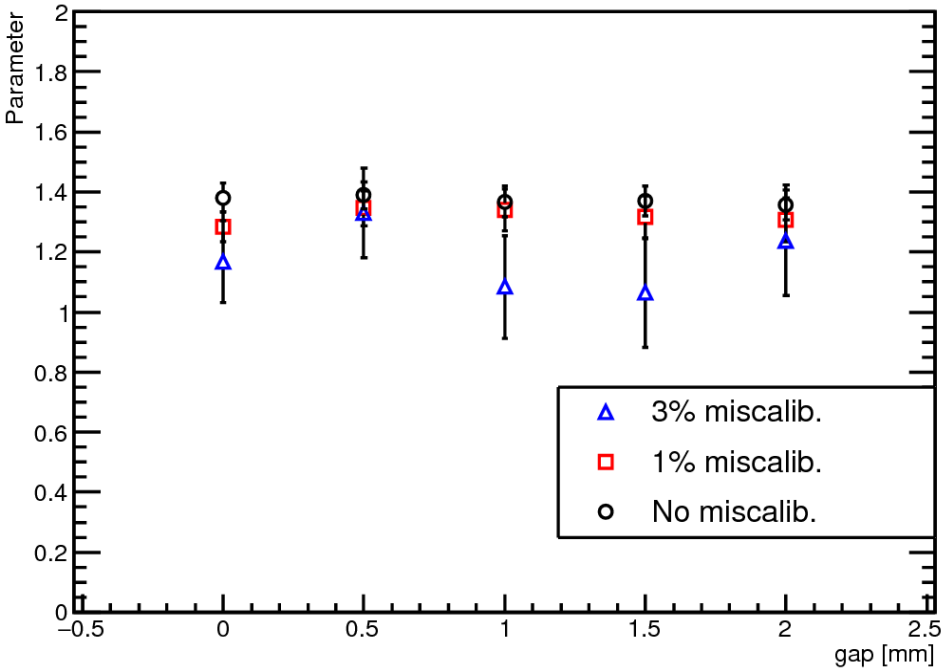
Results Summary

$$\frac{\sigma}{E} = A \oplus \frac{B}{\sqrt{E}} \oplus \frac{C}{E}$$ C = 0

A



B



Air gap & miscalibration affect mostly on A.

B is ~50% lower than that of PrimEx.

PrimEx's photo collection efficiency was Lower than 15/MeV?

PrimEx : A = 0.9%, B = 2.5%, C = 1%.

Conclusion

- NPS energy resolution has been simulated, including optical photons with a realistic light yield.
- Energy resolution increases :

  -from 1.0% to 1.2% with a 1mm air gap and 1% miscalibration at 7 GeV.

  -from 1.0% to 1.3% with a 2mm air gap and 1% miscalibration at 7 GeV.
- Control of the crystal-to-crystal calibration has a much bigger effect than air gap effect.

  -from 0.6% to 1.0% with a 0mm air gap and 1% miscalibration at 7 GeV.

  -from 0.6% to 2.2% with a 0mm air gap and 3% miscalibration at 7 GeV.