Crystalline effects for electromagnetic processes in GEANT4

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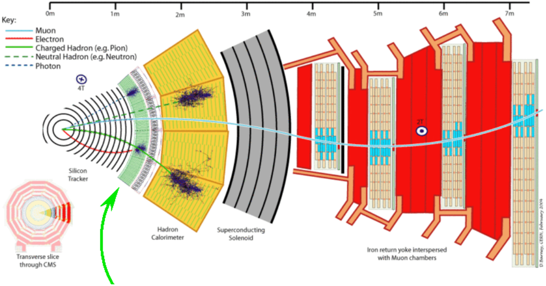
Outlines

- Motivation.
- Amorphous versus ordered substance.
- What are orientation effects and where they are manifested?
- What have done and what are the results?
- Applications and conclusions.

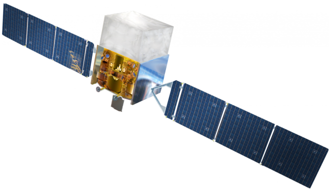
Motivation

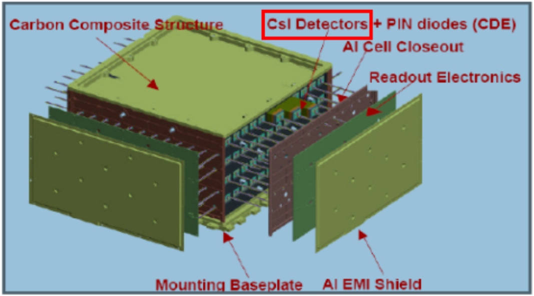


Electromagnetic Calorimeter

The electromagnetic calorimeter is an important part of any high energy experimental setup.
And ordered structure influences on electromagnetic processes strongly.

Motivation



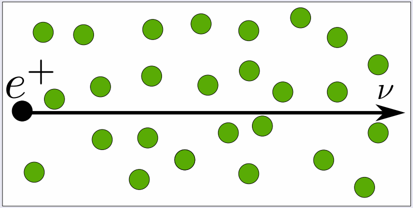


Schematic view of the GLAST imaging calorimeter.

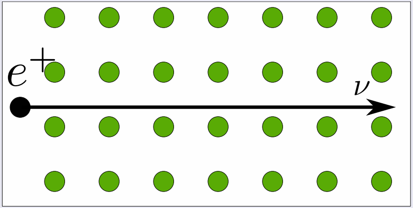
CsI scintillators are in the Fermi Large Aperture Telescope.

Amorphous versus ordered substance

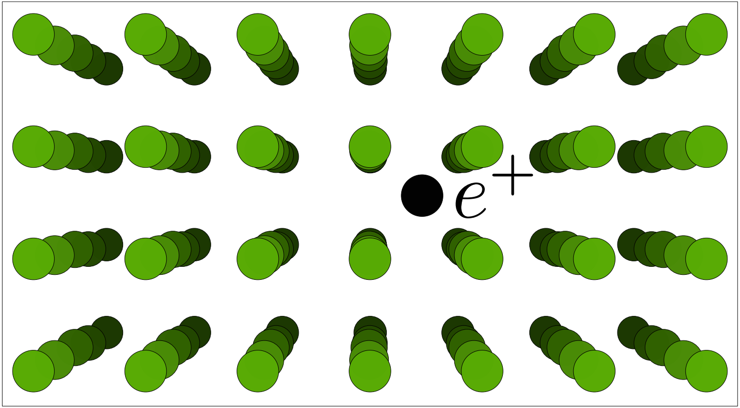
Amorphous substance, random distribution



Ordered substance, crystal lattice

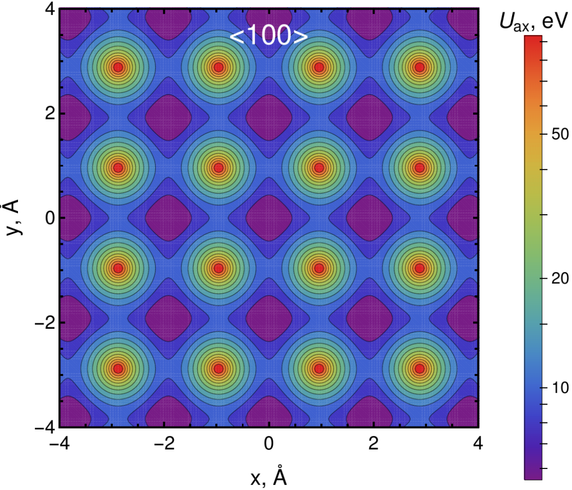


The difference is that an interaction is coherent in ordered medium. As result electron-positron production and bremsstrahlung are increased in crystals.

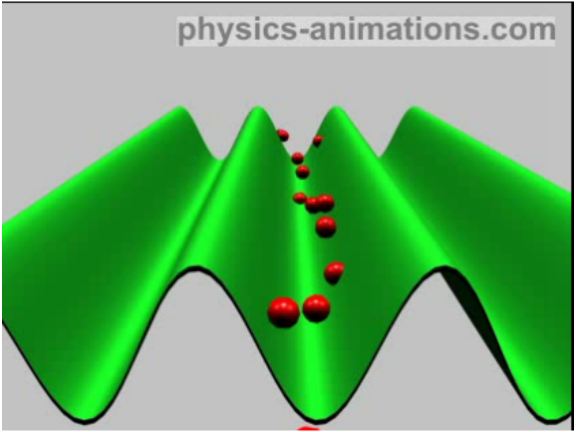


Interactions are anisotropic in ordered medium.

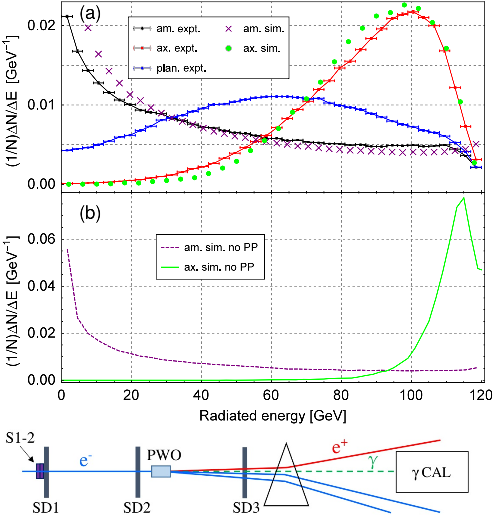
Electrostatic potential for crystalline axis



Channelling effect

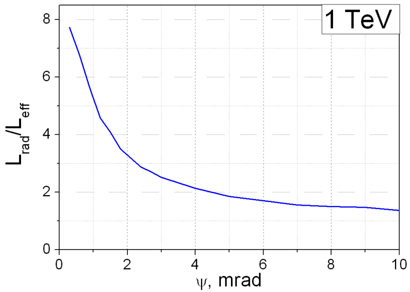


This is a simple explanation of channelling effect.

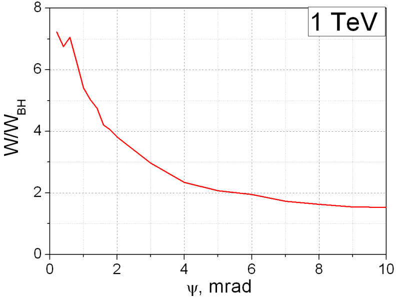


[1] L.Bandiera, V.V.Tikhomirov, et al., Phys. Rev. Lett.,121 (2018) 021603

Angular dependence of increasing e^- e^+ pair production (PP) and intensity of coherent bremsstrahlung in comparison to random orientation in $PbWO_4$ crystal.

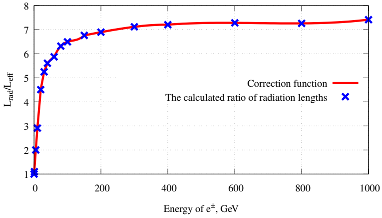


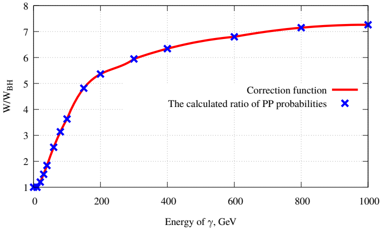
Coherent Bremsstrahlung



Pair production

Correction functions $\phi(E)$ for cross-sections





We take values of increasing for bremsstrahlung and PP if particle moves along the crystalline axis. Using correction coefficients we change the cross-sections in GEANT4 by multiplying it on these values. It has not angle dependence and this is approximation.

[2] V.G.Baryshevsky, V.V.Haurylavets, et al., Nucl. Instrum. Methods Phys. Res. B, 402 (2017) 35.

Correction functions for cross-sections

For electron-positron pair production in GEANT4 two models are used:

G4BetheHeitlerModel up to 80 GeV and
G4PairProductionRelModel more than 80 GeV.

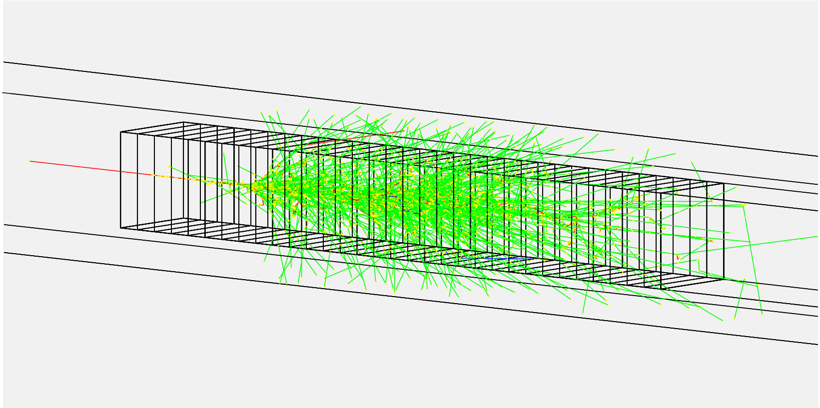
For bremsstrahlung in GEANT4 two models are used:

G4SeltzerBergerModel up to 1 GeV and
G4eBremsstrahlungRelModel more than 1 GeV.

$$\sigma^{`} = \sigma * \phi(E) \tag{1}$$

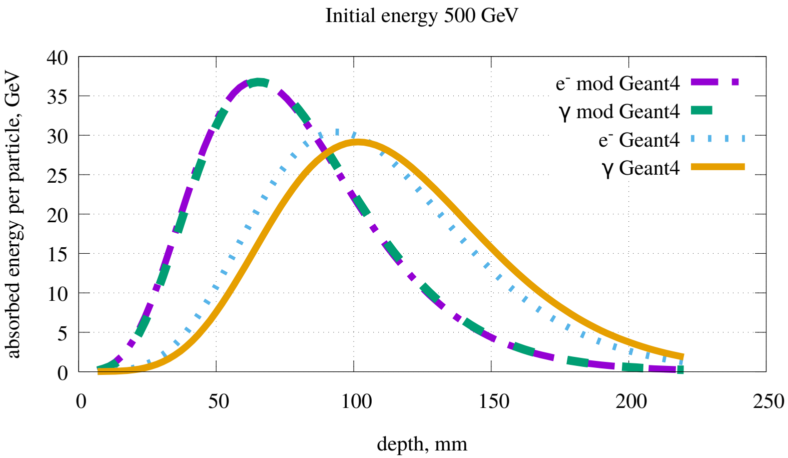
where σ is a cross-section from standard GEANT4.

ECAL crystal

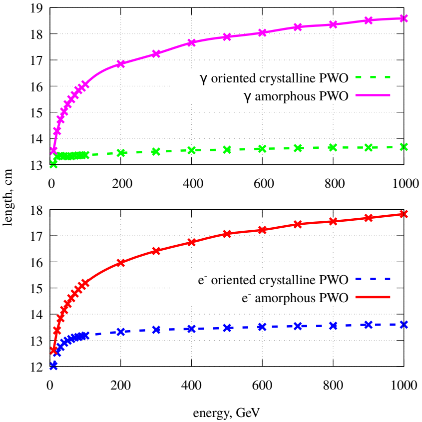


The electromagnetic shower is simulated in lead-tungstate (PWO) crystal.

The maximum is shifted to the enter surface.



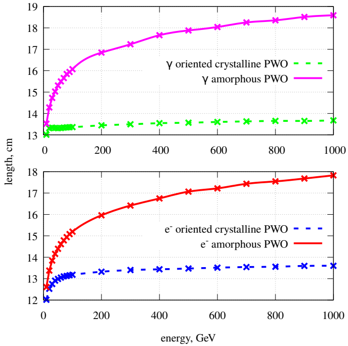
The length of electromagnetic shower



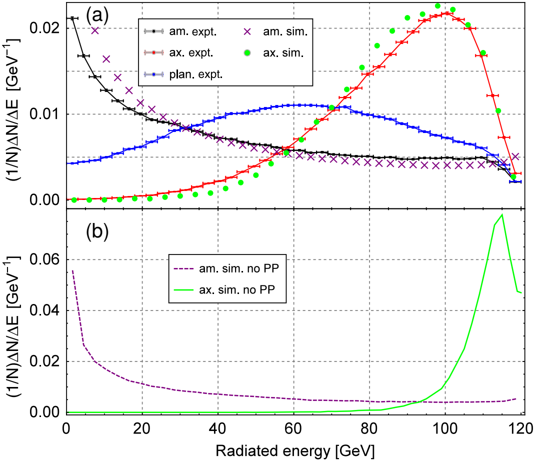
Shower length is 90% of energy absorption of primary particle.

[3] L. Bandiera, V. Haurylavets, V. Tikhomirov, Compact electromagnetic calorimeters based on oriented scintillator crystals, DOI: 10.1016/j.nima.2018.07.085

Applications and conclusions



- Decreasing detector size for high energy particles.
- The influence of crystalline structure on energy deposition in scintillators, and as result on optic signal.

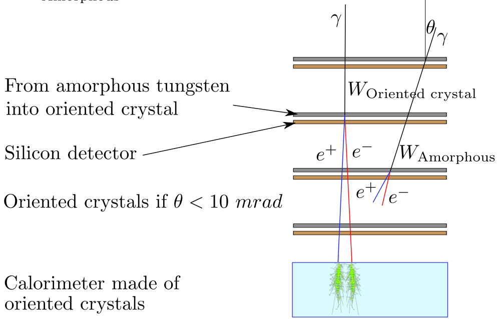


- Using crystals for an efficient positron sources.

[1] L.Bandiera, V.V.Tikhomirov, et al., Phys. Rev. Lett.,121 (2018) 021603

Applications and conclusions

$$\frac{W_{\text{Oriented Crystal}}}{W_{\text{Amorphous}}} \approx 6 \text{ at } E = 300GeV,\ \theta < 1\ mrad$$



- Decreasing detector sizes of gamma space telescopes for point-like sources (technical limitation).

[3] L. Bandiera, V. Haurylavets, V. Tikhomirov, Compact electromagnetic calorimeters based on oriented scintillator crystals, DOI: 10.1016/j.nima.2018.07.085

Thank you

Thank you for attention!