C++ implementation of Bethe-Heitler, 5D, Polarized, $\gamma \to e^+e^-$ Pair Conversion Event Generator

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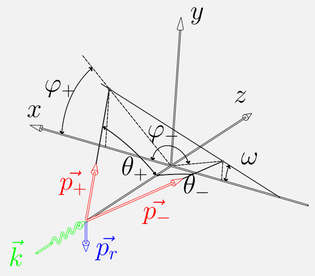
$\gamma \to e^+e^-$: 5D phase space



- $+, -, r =$ positron, electron, recoil.
- ϕ azimuthal, θ polar angles.
- $\Omega \equiv \phi_+,\ \phi_-,\ \theta_+,\ \theta_-,\ x_+ = E_+/E_\gamma$

Generator Properties

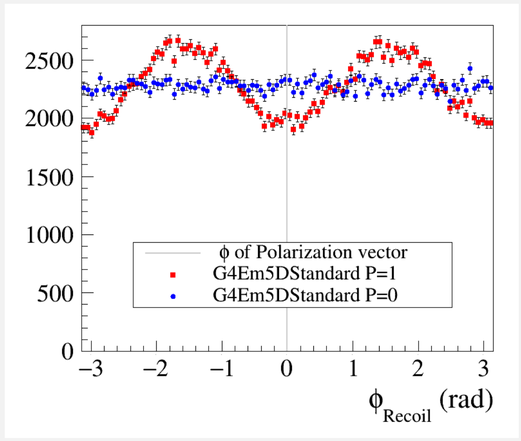
- Exact down to threshold, without any low-energy nor small-angle approximations
- Yielding a sampling of the Bethe-Heitler (5D) differential cross section, that is, not a simple product of 1D projections
- Nuclear or electron ("triplet") recoil
- Strict energy-momentum conservation

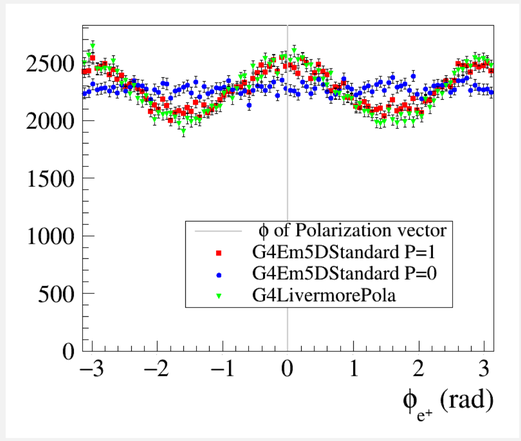
Geant4 Gamma Conversion Model 5D

- Implemented as Geant4 G4BetheHeitler5DModel
- Linear polarization only
- Inherited from G4BetheHeitlerModel for total cross section calculation
- Local Physics List Em5DStandard in some examples
- Generation of nuclear conversion, triplet or both
- Conversion on free electrons / nucleus or screening form factor for conversion on atoms

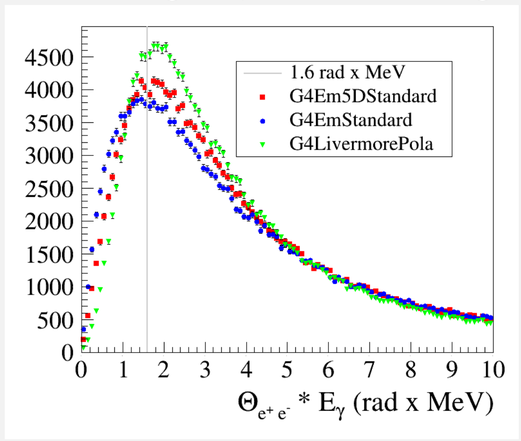
Results, compared to Geant4 models

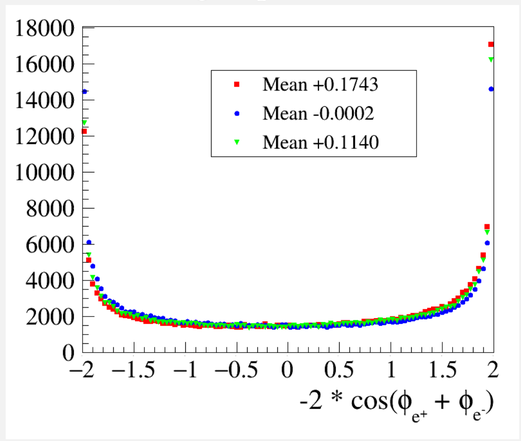
640 MeV Ar gas example.





Azimuthal Angles (ϕ). Left: recoil, Right: e^+. The line $\phi = 0$ give polarization direction.



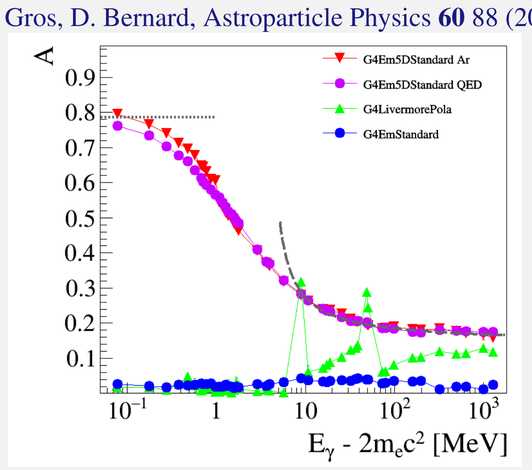


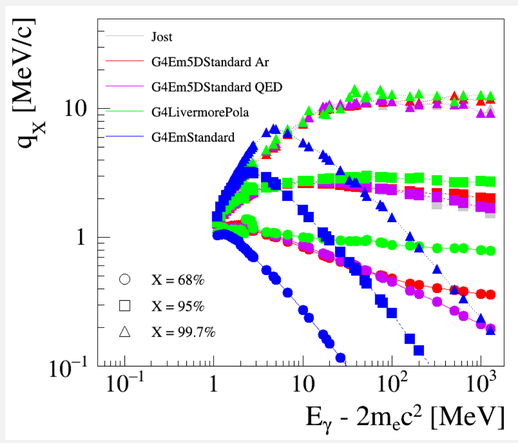
Left: Open Angle $\Theta_{e^+e^-} * E_\gamma$, Right: $-2 * \cos(\phi_{e^+} + \phi_{e^-})$ asymmetry. Vertical line at 1.6 MeV radian is Olsen prediction, H. Olsen, Phys. Rev. **131**, 406 - 415 (1963).

Polarization Asymmetry and Nuclear Recoil Momentum

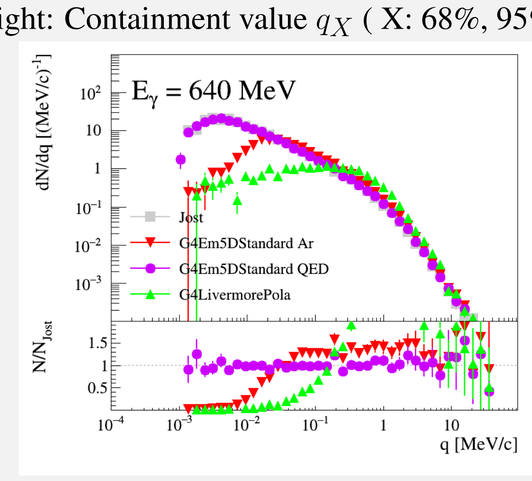
Polarization asymmetry for different models and the distributions of the nuclear recoil q_X comparing with the Jost model

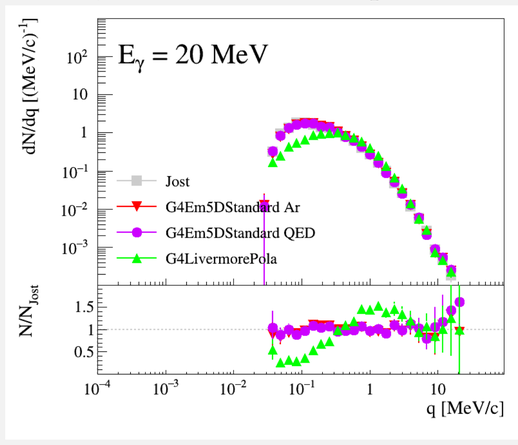
Ph. Gros, D. Bernard, Astroparticle Physics **60** 88 (2017)..





Left: The horizontal line denote low-energy asymptotic value $1/7$. The dashed curves denote high-energy asymptotic expression. V. F. Boldyshev and Y. .P. Peresunko, Yad. Fiz. **14**, 1027 (1971). Right: Containment value q_X (X: 68%, 95% and 99.7%) as a function of the photon energy.



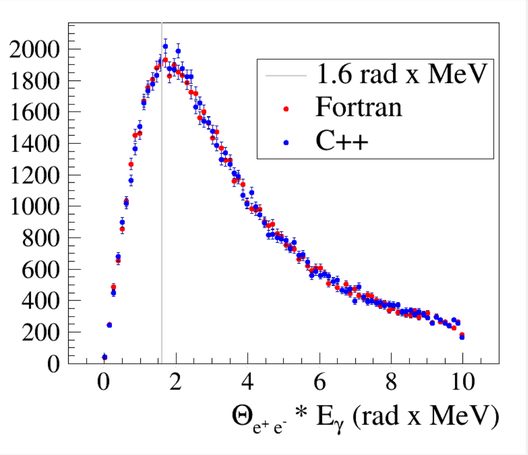


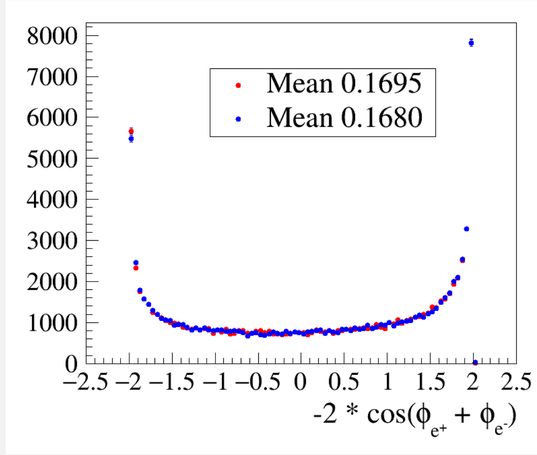
The comparison with Jost analytic distribution. R. Jost, et al. Phys. Rev. **80**, 189 (1950). No screening for "Jost" and "G4BetheHeitler5D QED" distributions.

Comparison with FORTRAN

The C++ code verified by comparison of distributions with distributions obtained with Fortran code. Denis Bernard, arXiv:1802.08253 [hep-ph].

The example of comparison for 10 GeV gamma.





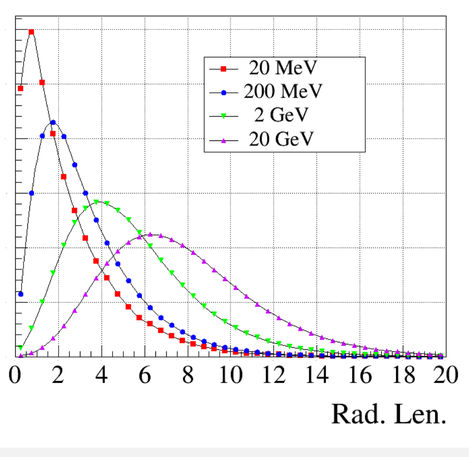
Left: $\Theta_{e^+e^-} * E_\gamma$. Vertical line at 1.6 MeV radian is the high-energy prediction by Olsen, H. Olsen, Phys. Rev. **131**, 406 - 415 (1963). Right: Polarization asymmetry $-2 * \cos(\phi_{e^+} + \phi_{e^-})$

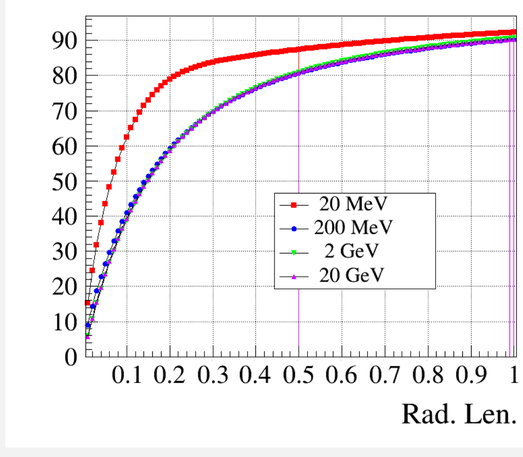
The code was submitted to Geant4 EM group as a possible physics model of polarized gamma conversion in Geant4 framework and will be available in future release of Geant4.

Electromagnetic Showers

We see full agreement between different $\gamma \to e^+e^-$ conversion models: G4BetheHeitler5DModel, G4BetheHeitlerModel and G4PolarizedGammaConversionModel.

The profiles obtained with 5D model in Argon gas.





Left: Longitudinal, Right: Cumulative Transversal shower profiles.

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