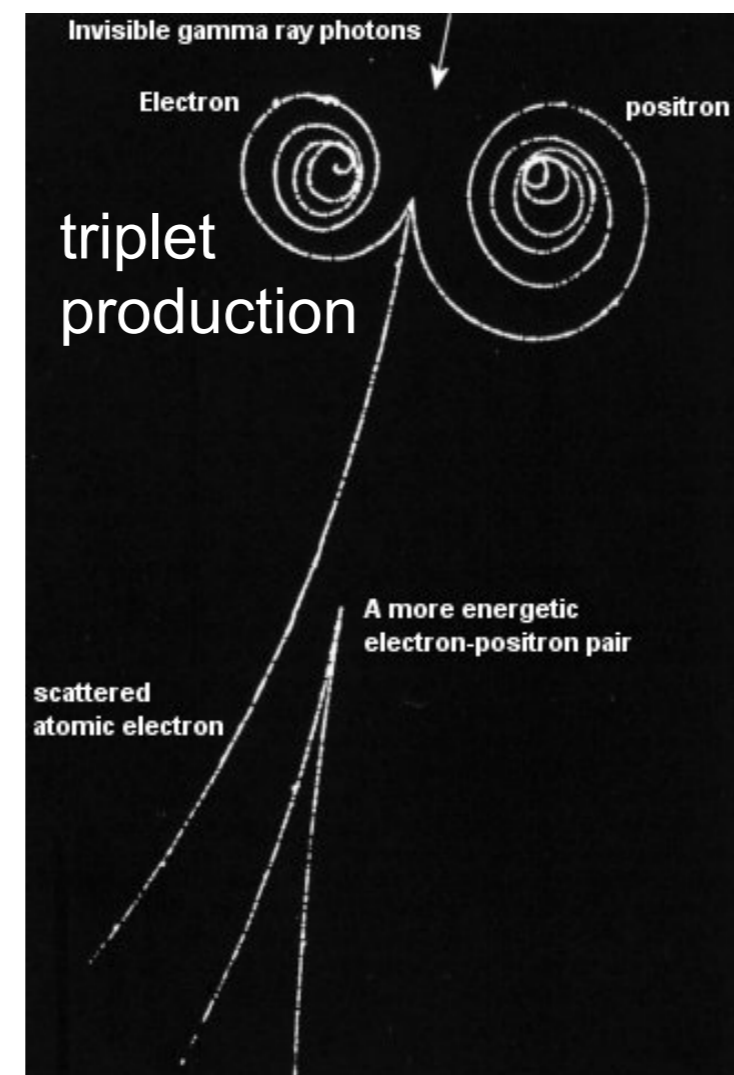
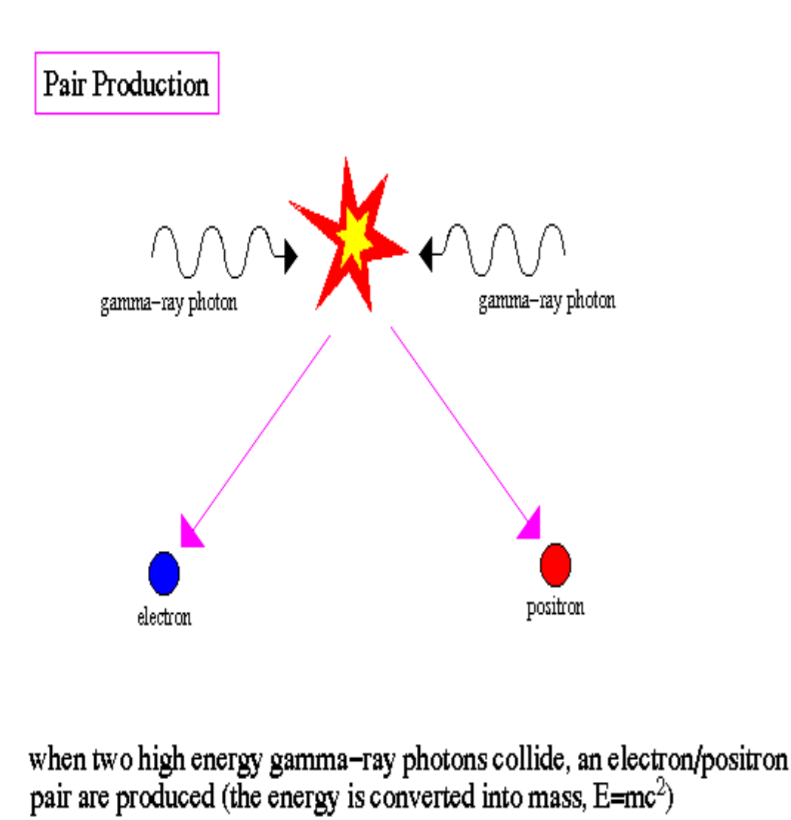
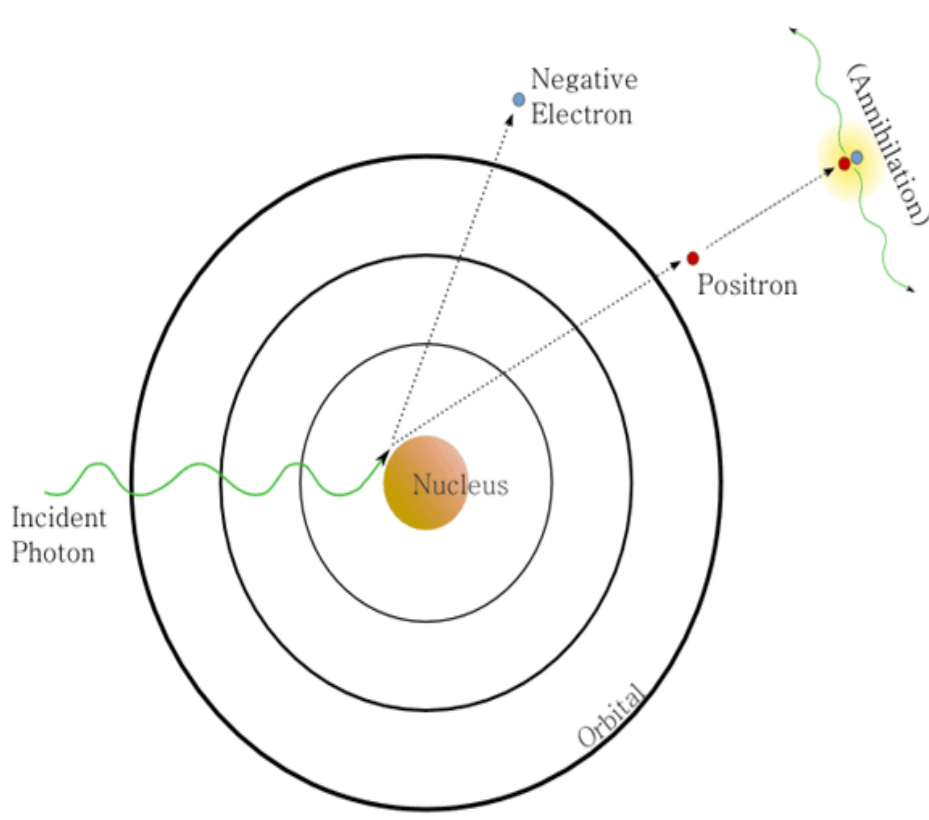


Validation of Geant4 Electron Pair Production by Photons

M. Begalli¹, G. Hoff², M. G. Pia³, P. G. Saracco³

$E > 2m_e (=1.022 \text{ MeV})$



$E > 4m_e$

Pair production:

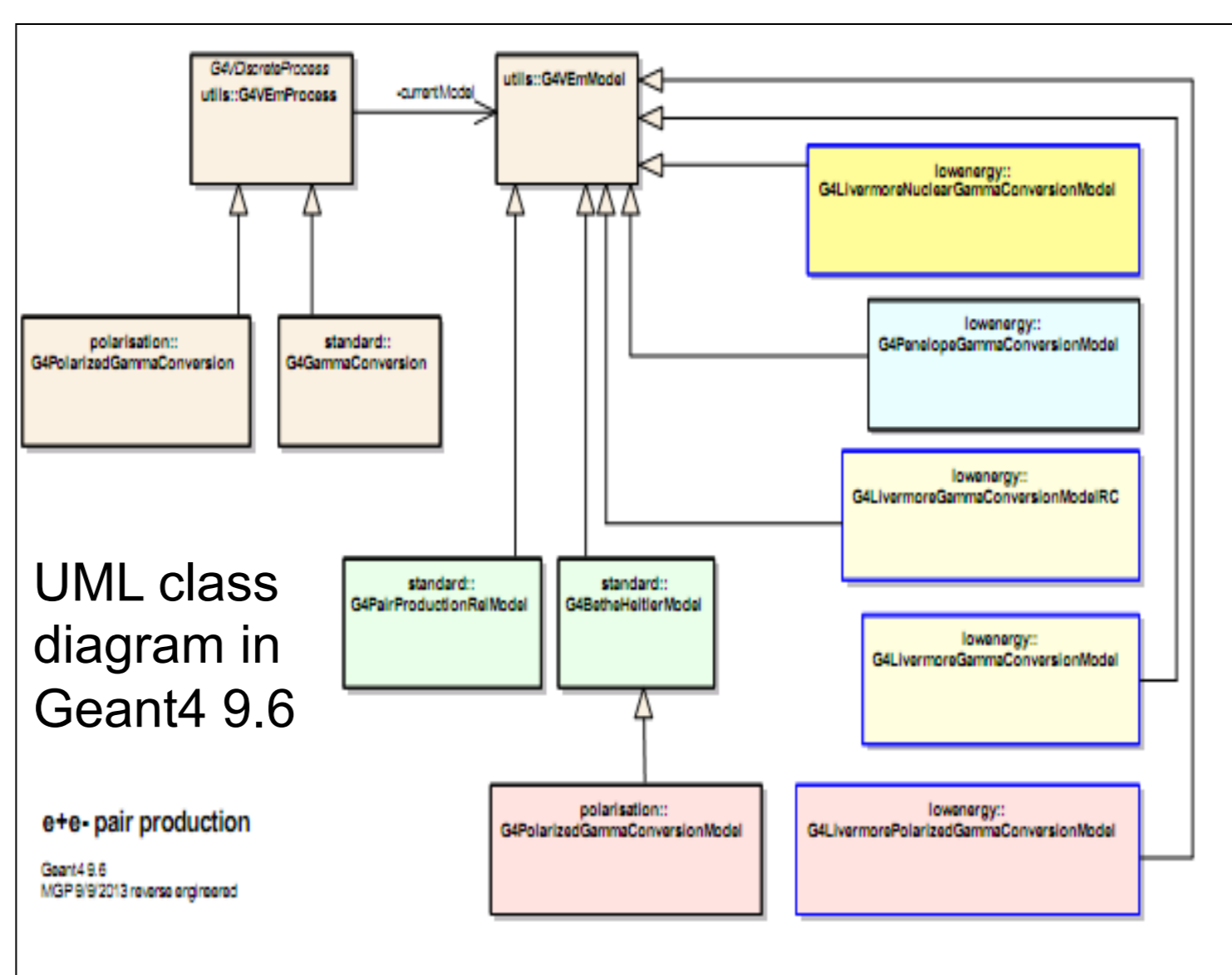
- occurs when a photon interacts with the field of the atomic nucleus or with an electron from the atom (triplet production)
- important issue in various experimental domains
- Bethe and Heitler (1934) => theoretical model for multiple scattering induced radiation assuming the scatterings are independent (valid for energies below TeV)
- above TeV => Landau, Pomeranchuk and Migdal, the so called LPM effect.

Photon conversion models are implemented in all general-

purpose Monte Carlo systems:

- MCNP(X)
- PENELOPE
- ITS
- FLUKA
- ETRAN
- EGS(nrc)

based on Hubbell, Gimm, Overbo (tabulations in EPDL97 and XCOM)



Geant4*

EGS5, EGSnrc } users may choose among the libraries by Storm and Israel, EPDL, XCOM, or add a "personal" library

CORSIKA – delegates pair-production to EGS

Triplet production → in EGS(nrc), Penelope2011 and Geant4

LPM effect → in CORSIKA, FLUKA, EGS5 (published) and Geant4

Important for cosmic ray physics

* Geant4-standard uses a parametrization by Urban, already used in GEANT 3
Geant4-lowenergy-Livermore uses EPDL97

Experimental data:

Collected from the literature:

- Experimental cross sections
- Total cross section: 162 measurements
- materials: Al, Fe, Ni, Cu, Ge, Se, Zr, Mo, Rh, Cd, Sn, Ce, Ta, W, Pt, Au, Pb, Bi, U

Format

- Tables, text
- Figures: digitized, digitization error estimated

Evaluation of experimental data

- Systematic effects: identified whenever possible
- Outliers

Data Analysis:

Quantitative appraisal of capabilities and differences:

Compatibility with experiment

Goodness-of-fit test
 χ^2 test
 $\alpha = 0.01$

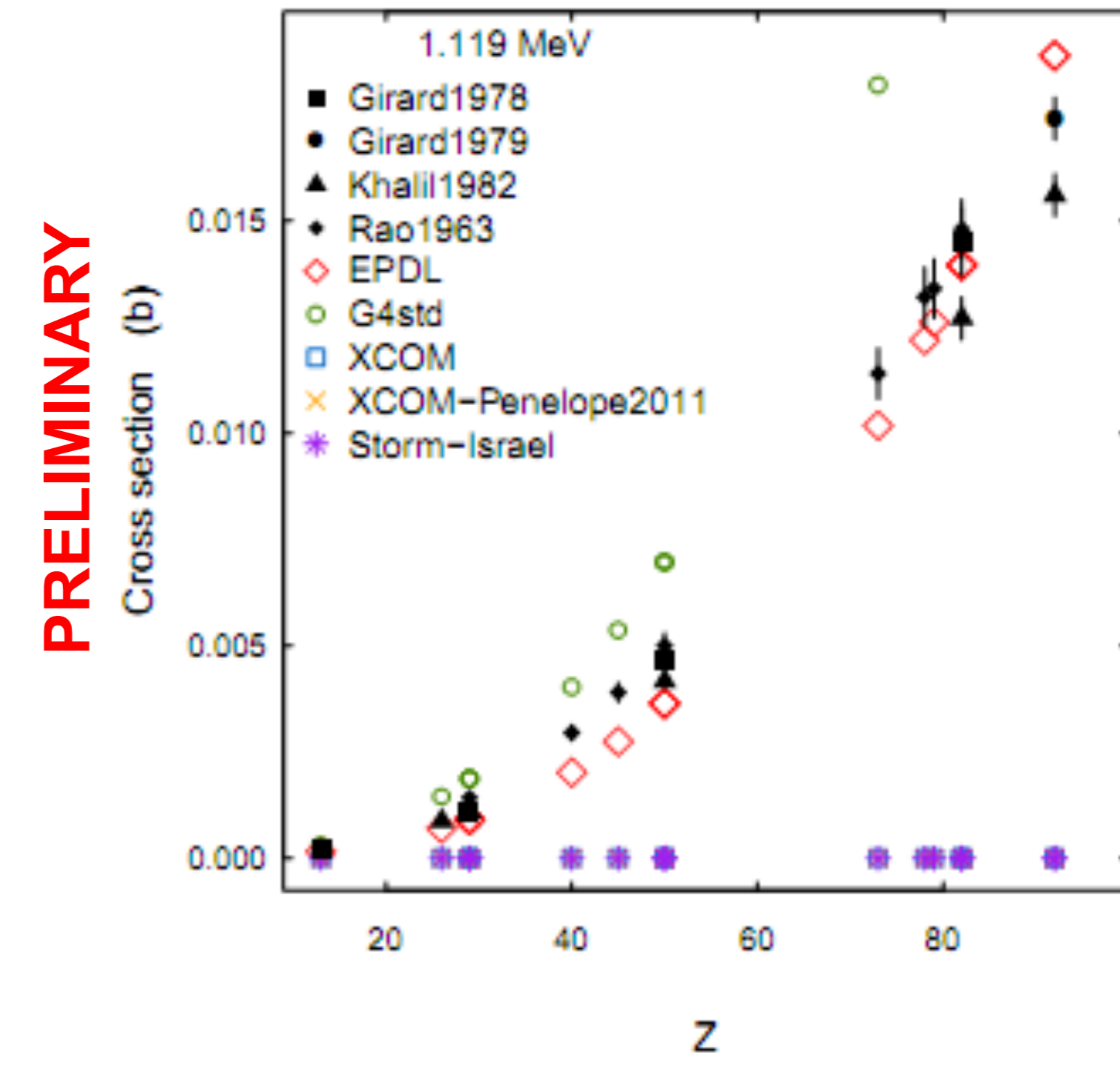
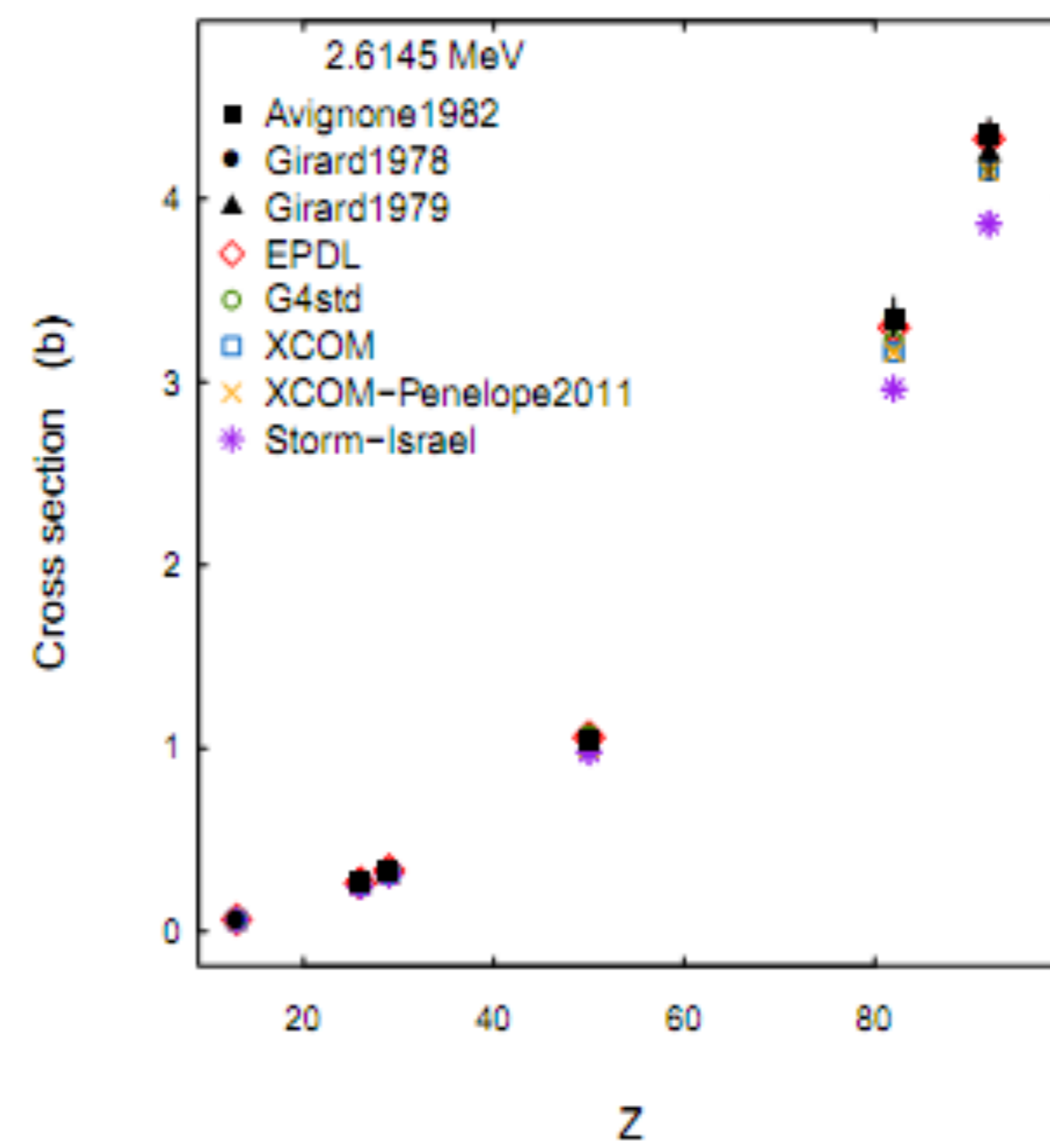
$\alpha \geq 0.01$ → pass
 $\alpha < 0.01$ → fail

Difference across categories

- Contingency tables
- Fisher exact test
- Barnard test
- χ^2 test

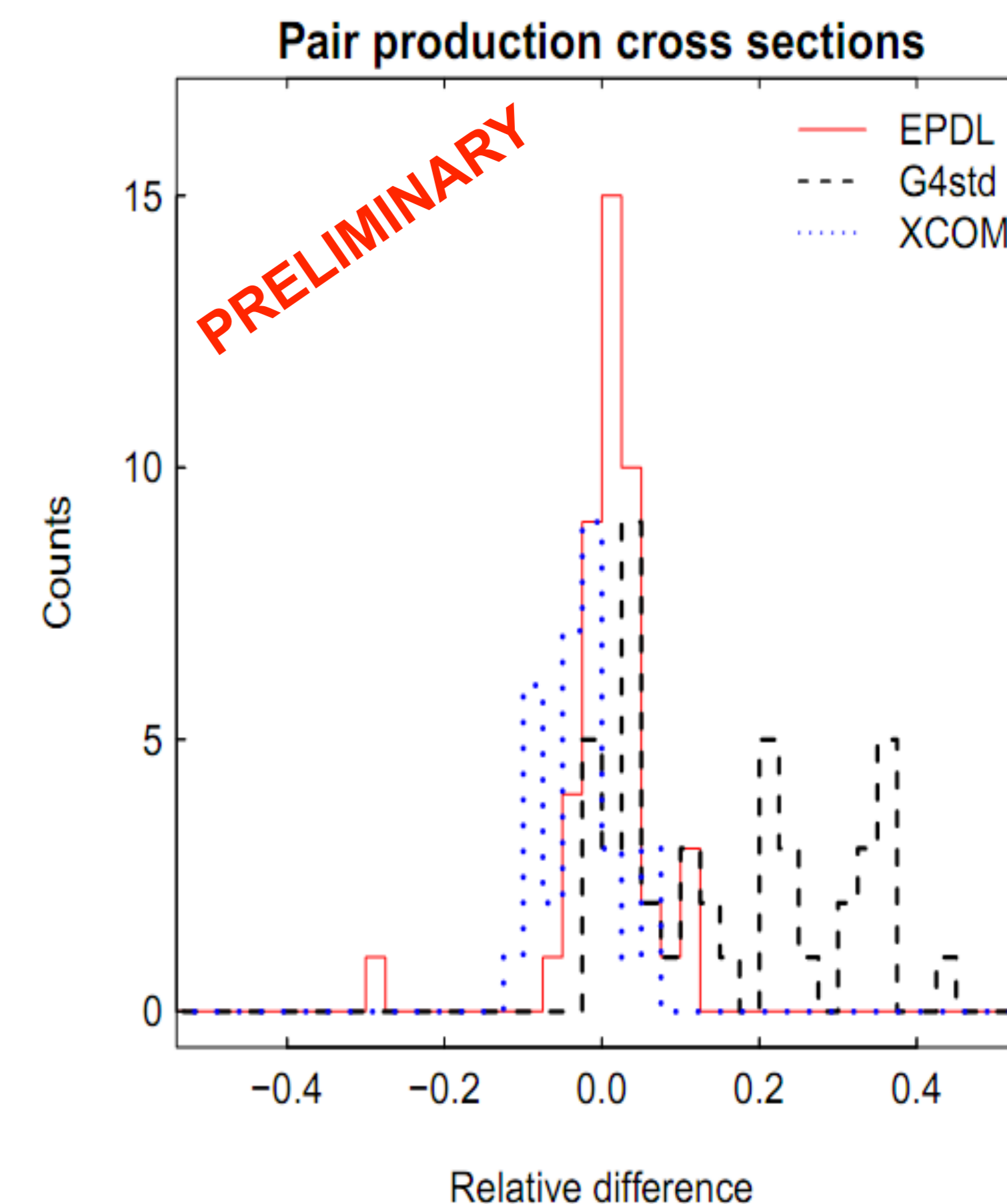
Ongoing work:

Pair production is **Important in all energy ranges**.
The first phase of the project is focussed on the validation of total cross sections, validation of angular distributions will follow.
The preliminary results shown below concern the low energy range close to the threshold.



$E < 3.3 \text{ MeV}$

Preliminary comparison between experimental data near threshold and EPDL, Geant4-Standard and XCOM



Preliminary

EPDL => compatible with experimental data starting from approximately 100 keV above the threshold (p-value of the χ^2 test > 0.05)

Geant4 standard, NIST XCOM, Penelope (based on XCOM) } → fail (p-value < 0.001)