Simulation Studies for a Polarimeter at the International Linear Collider (ILC)

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Overview

Polarization measurement at the ready-to-collide electron beam, i.e. on the last km

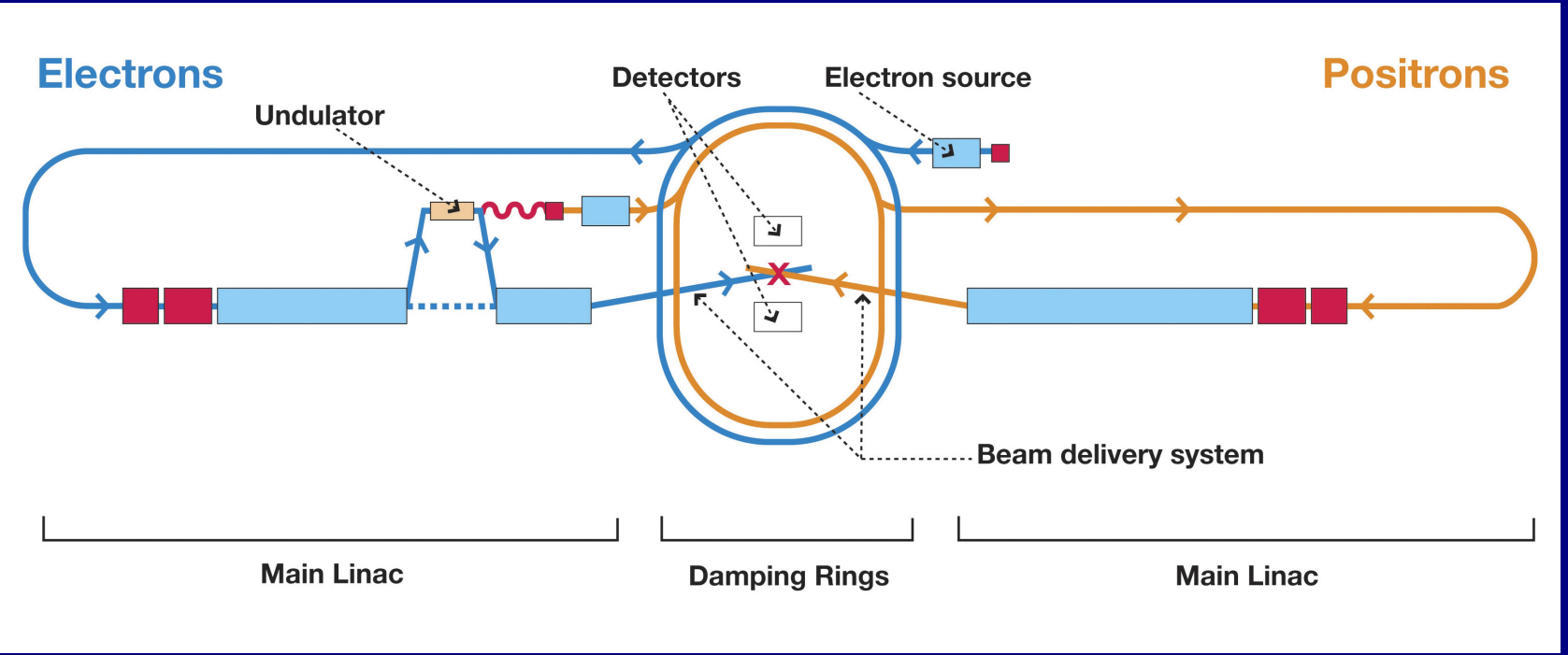


Figure: Sketch of the ILC

The Polarimeter

- Compton scattering at laser photons extracts single electrons from the beam
- Magnet chicane serves as spectrometer and guides electrons to detector
- Electron detection by Cerenkov radiation in gas volume using photomultiplier tubes

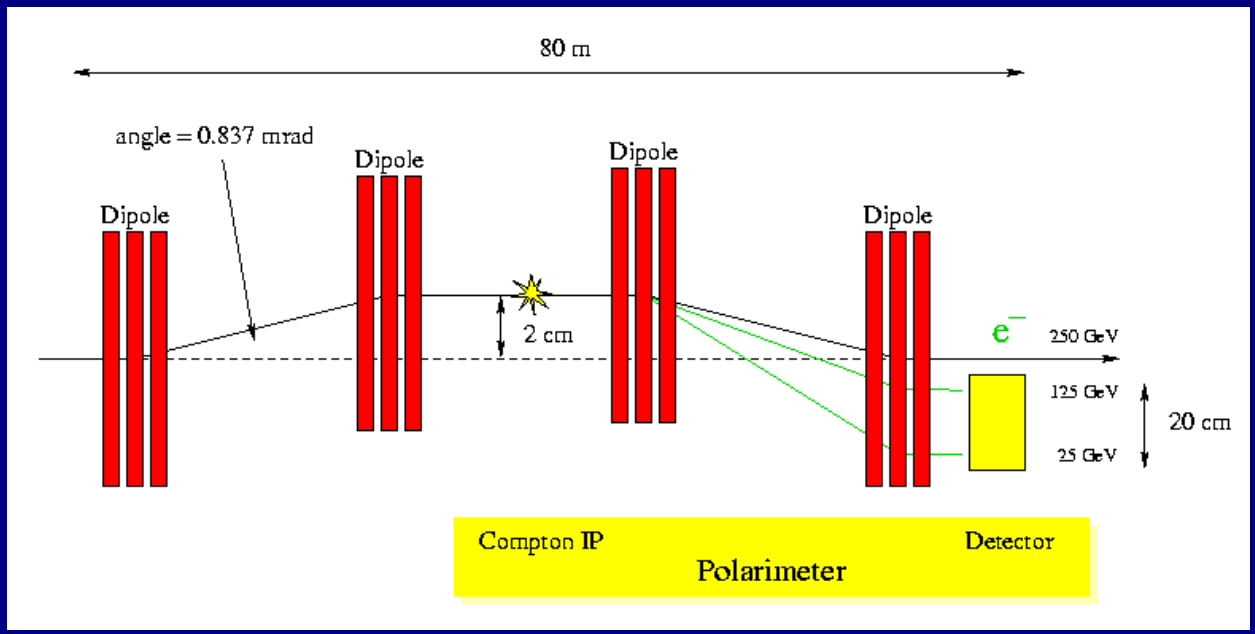


Figure: Sketch of polarimeter chicane

Conflicts

- Trying to keep ILC as short as possible to reduce costs
- Laser-Wire experiment measuring beam extension uses same chicane as polarimeter and also laser Compton scattering
- Might scattered particles disturb our measurements?

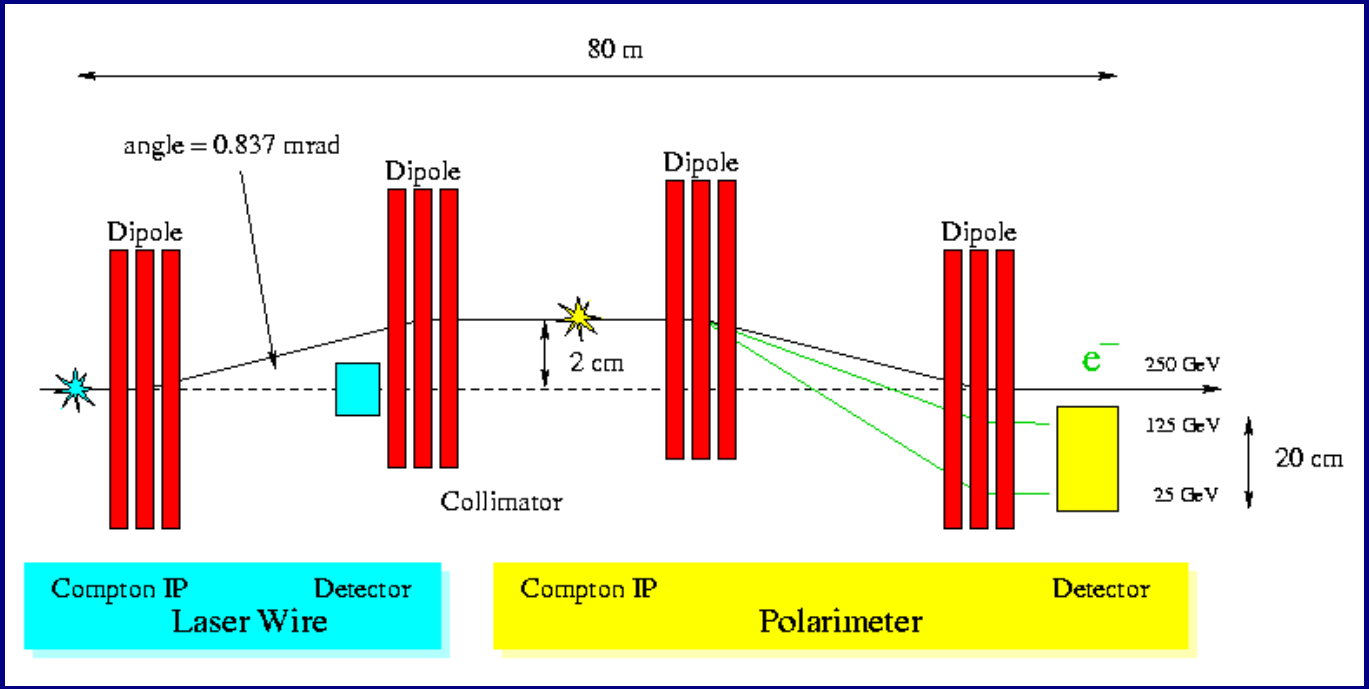
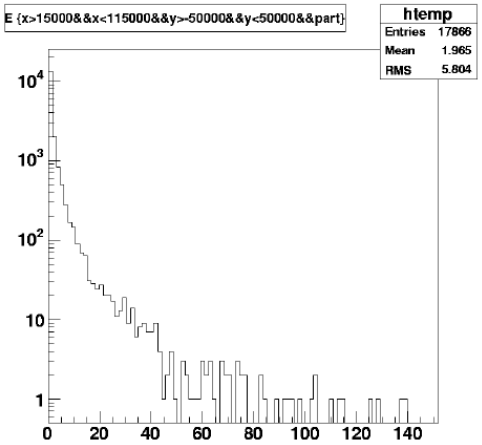


Figure: Sketch of polarimeter chicane

Conflicts

Background caused on polarimeter detector- spectrum



- The polarimeter detector is assumed to be 10cm by 10cm
- The background is 3.51TeV per shot, about 30% of the 12TeV polarimeter signal

Figure: Slide from a talk on Laser-Wire experiment

- Plot contains different assumptions, but made nevertheless an impact like a bomb (precision of 0.25% envisaged)
- Polarization group decided to cross-check $\longrightarrow$ my job

My Toolkit

The programs for simulation and data analysis are developed at CERN and different universities, no commercial software

- BDSIM: extension toolkit for
- GEANT 4: object-oriented detector simulation toolkit
- ROOT: Program for data analysis

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Especially BDSIM still under development, i.e.

- the documentation is incomplete or sketchy
- there were some nice bugs (and are certainly more)
- some functions are not implemented yet

My Toolkit: BDSIM

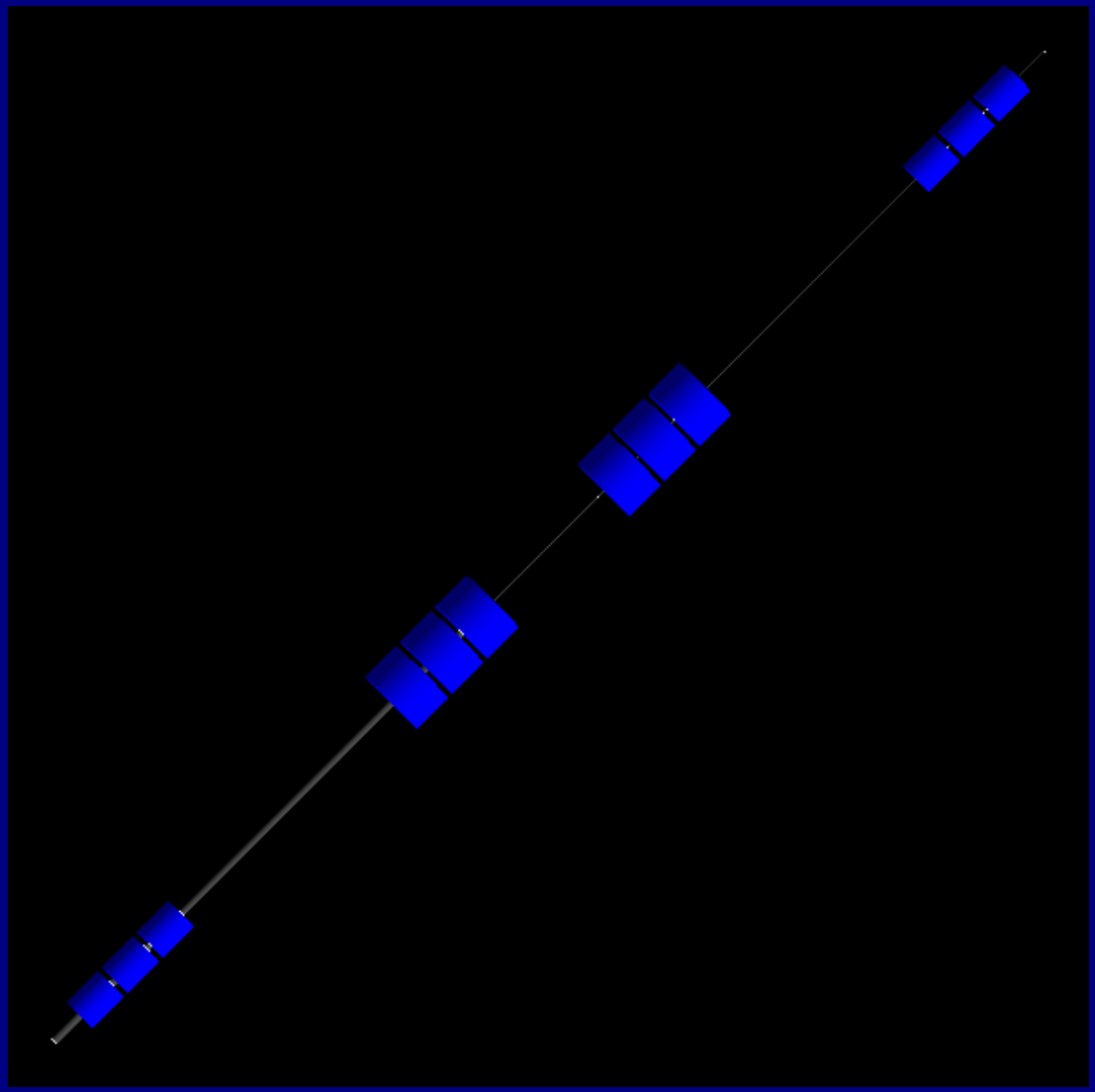

Figure: Beam line in event display

My Toolkit: BDSIM

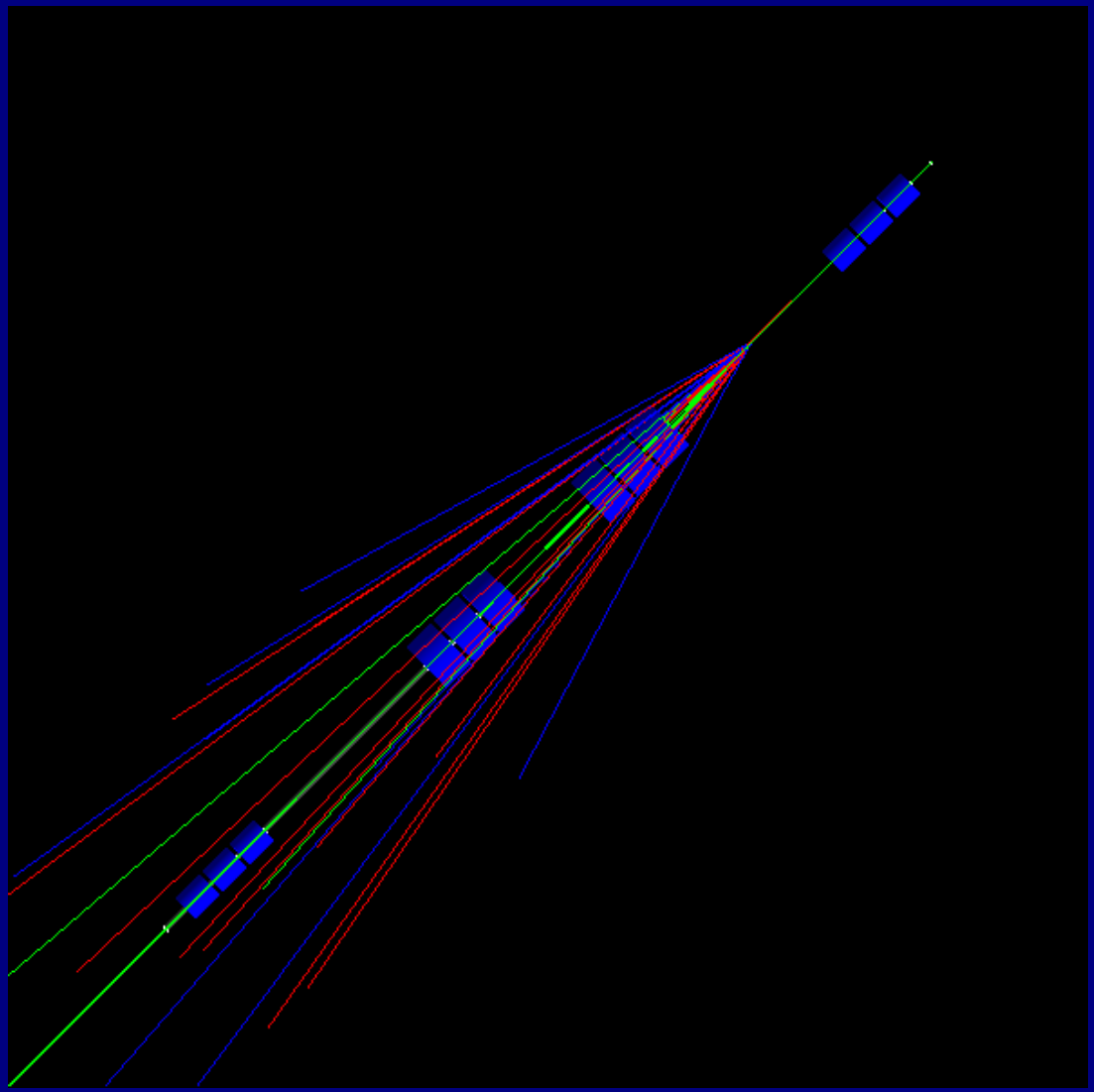

Figure: Beam line with particle shower (red: e^-, green: γ, blue: e^+)

Results: Energy Spectra of Background due to Laser-Wire

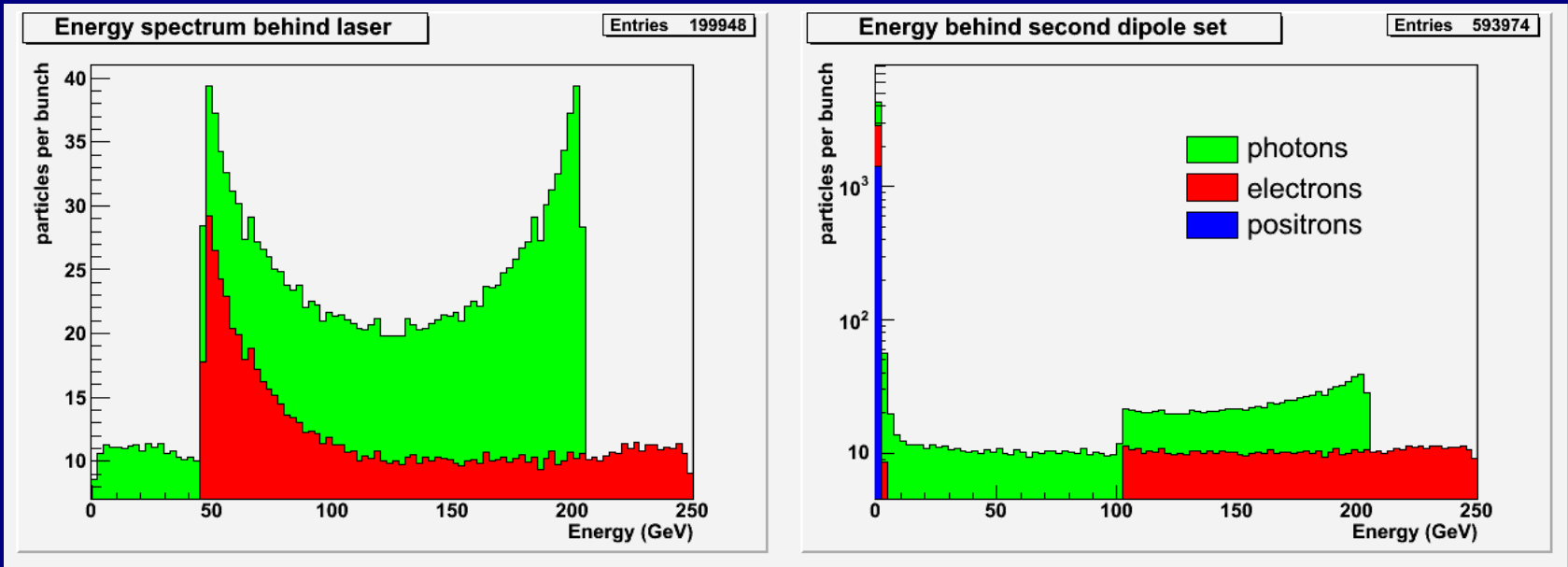

Figure: Energies of particles scattered by LW laser (curves added up)

- Only Laser-Wire laser running
- Left plot: axial symmetry at E = 125 GeV reflects energy conservation
- Right plot: cut-off due to electrons hitting beampipe → low-energy particle showers

Results: Energy Spectra of Background due to Laser-Wire

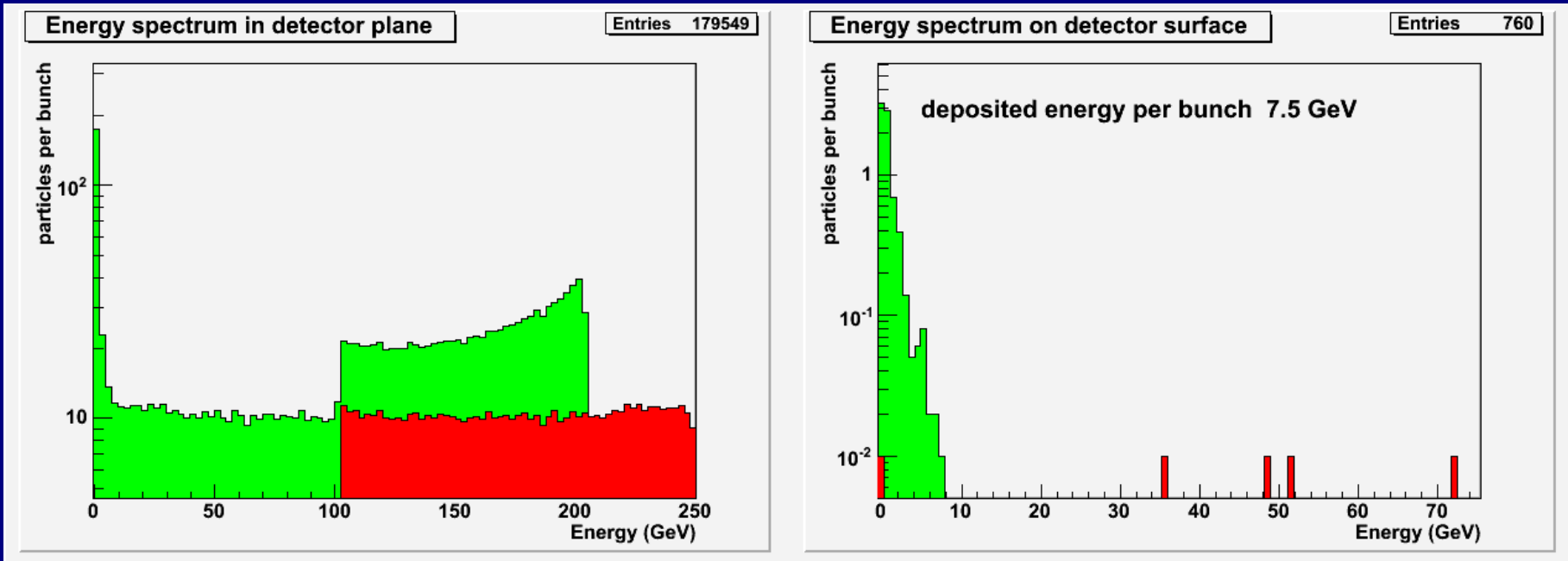

Figure: Energies of particles scattered by LW laser (curves added up)

- Statistical accuracy yet insufficient: one electron makes 10% of energy deposit $\longrightarrow$ larger data sample needed
- Energy deposit $\sim$ GeV $\longrightarrow$ still undesirable. Solution?

Results: Shielding against the Background

Shield against unwanted particles using a collimator

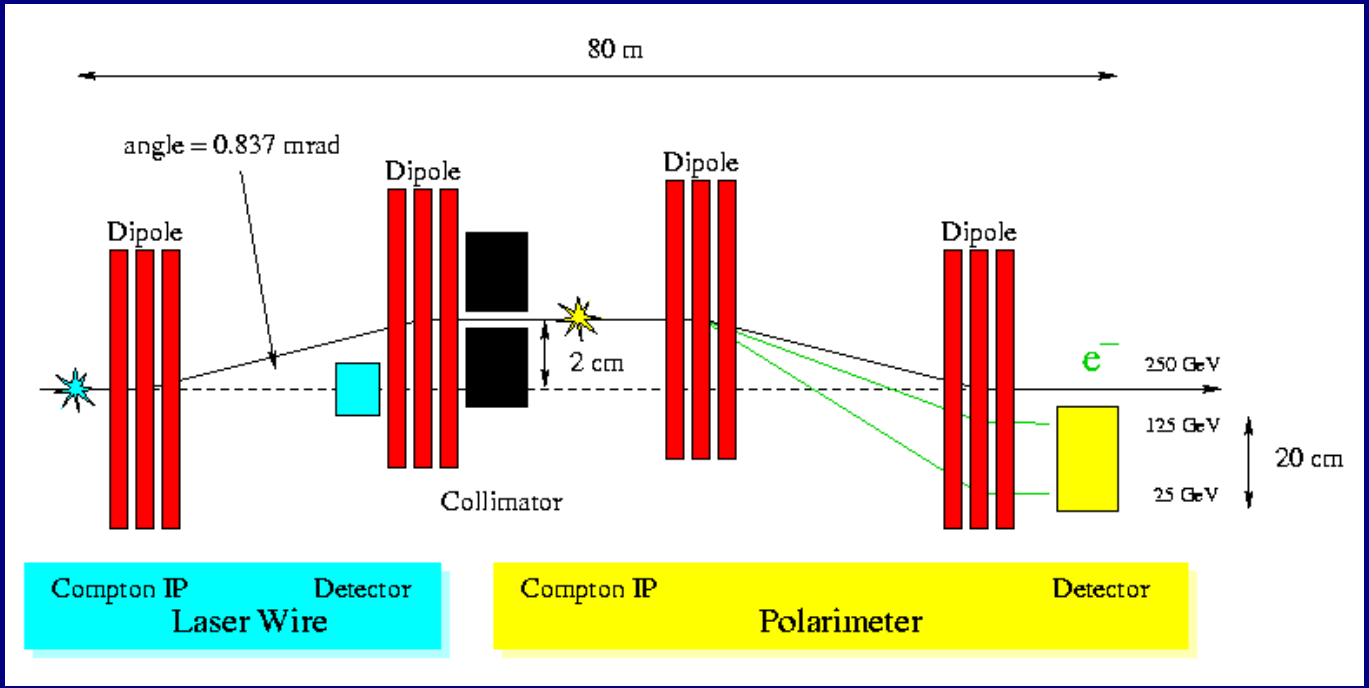

Figure: Sketch of polarimeter chicane

- How long?
- Which aperture radius?

Answer: Play with simulation to find optimal configuration.

Results: Energy Spectra for Collimator length = 1 m

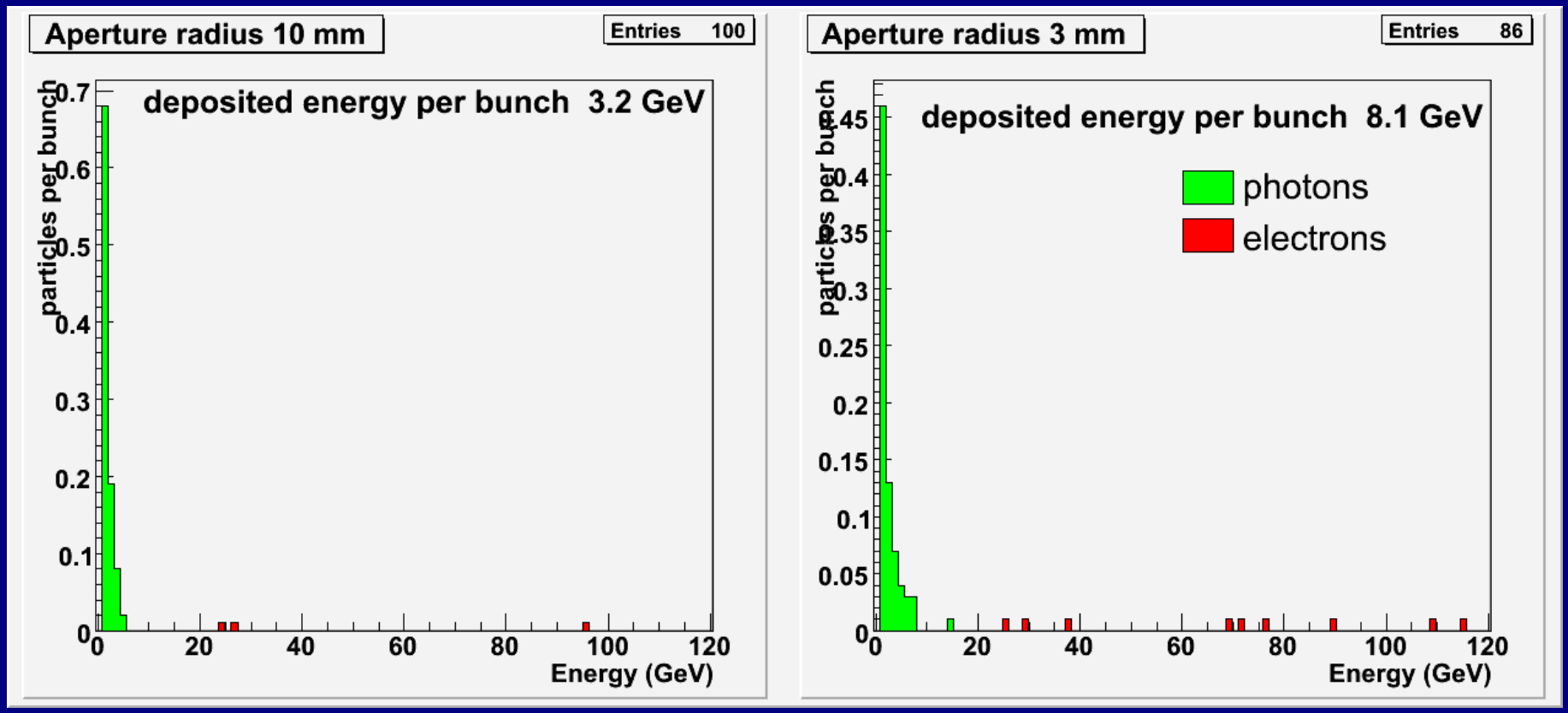

Figure: Energies of particles hitting the detector surface

Smaller aperture: less photon background, but more electrons → more energy deposit

Results: Origin of photons hitting the detector surface

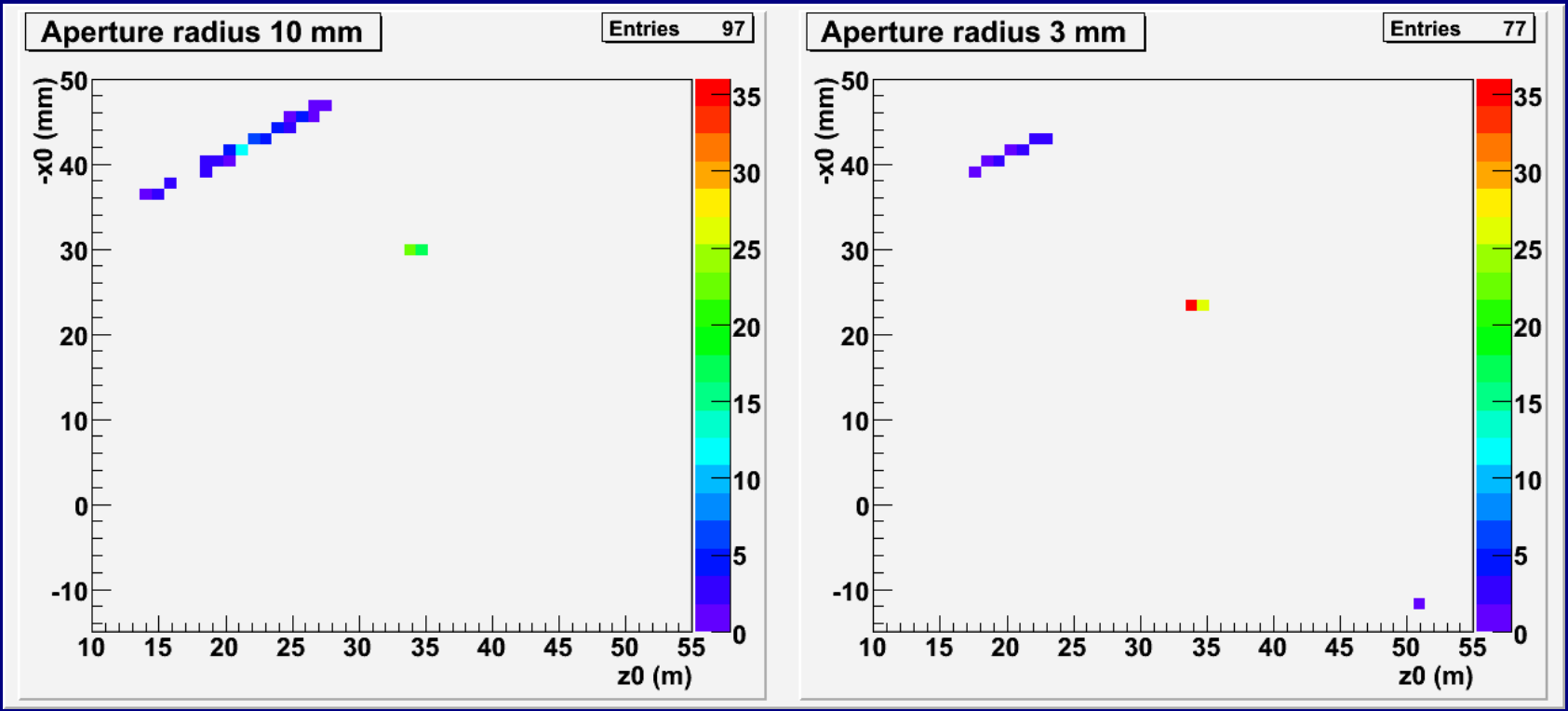

Figure: x vs. z coordinates of photon production, collimator length = 1 m

- Larger aperture $\longrightarrow$ more photons from beampipe hits (upper left line) pass collimator (spot in the middle)
- Smaller aperture $\longrightarrow$ more high-energy electrons are absorbed

Results: Energy Spectra for Collimator length = 3 m

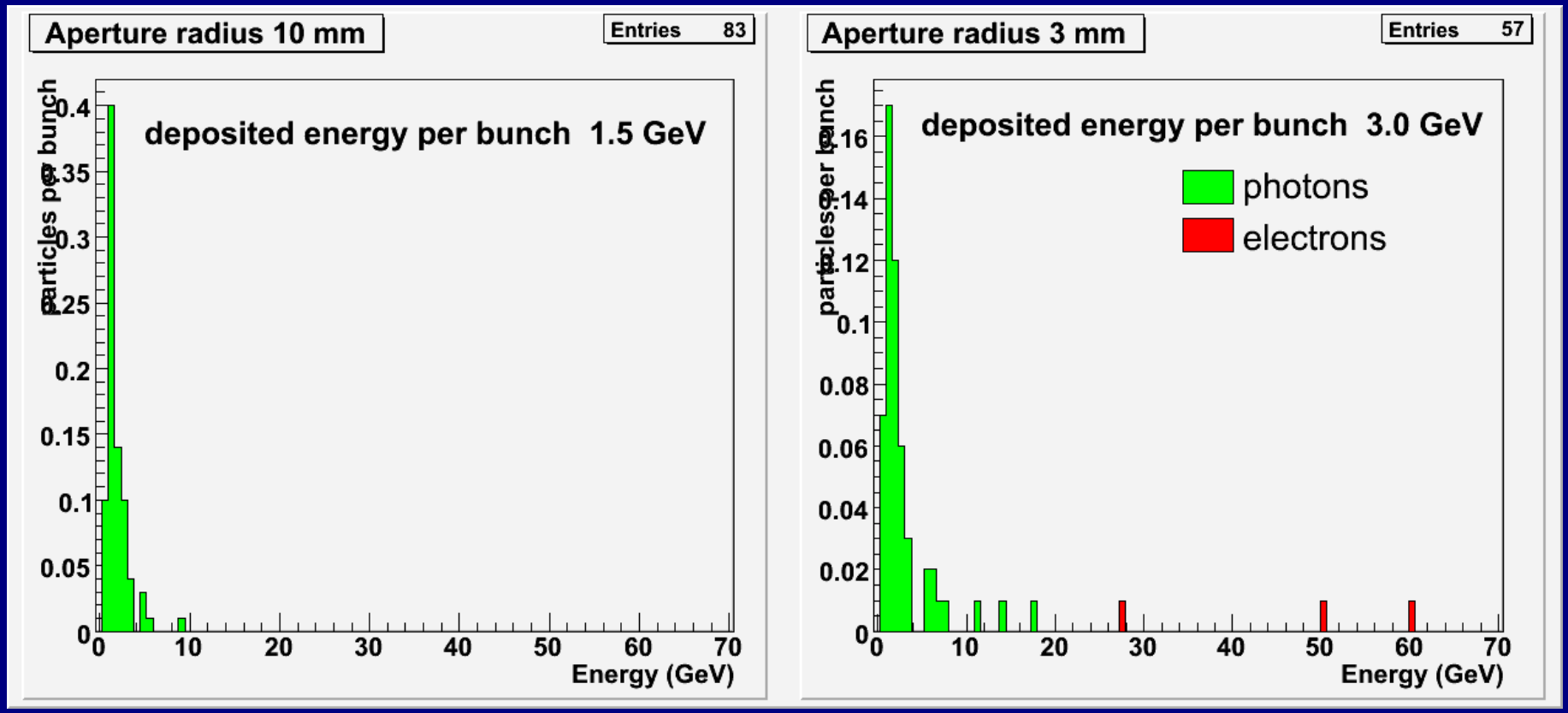

Figure: Energies of particles hitting the detector surface

Energy deposit reduced by factor 5

Summary

- Effect of Laser-Wire experiment smaller than expected
- A well-dimensioned collimator can reduce the background by a factor ≥ 5
- Longer collimator $\Rightarrow$ less low-energy photon background
- Smaller aperture cuts away more scattered electrons at higher energies
  - Causes more particle showers $\Rightarrow$ less good for polarimeter
  - Improves beam quality $\Rightarrow$ good for following experiments

Outlook

Things left to do (partially already started)

- Test more collimator sizes
- Add more details of beamline:
  - Laser-Wire detector (converter)
  - vacuum chamber with specific dimensions
  - detector volume
- Investigate polarization dependence of background
- Insert spatial extension for (so far point-like) bunch and laser
- ...

Many thanks for your attention!

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References:

- V. Gharibyan, N. Meyners, K.P. Schüler, *The TESLA Compton Polarimeter*, `http://www-flc.desy.de/lcnotes/notes/LC-DET-2001-047.ps.gz`, 2001.
- ILC website, `http://www.linearcollider.org`
- BDSIM website, `http://ilc.pp.rhul.ac.uk/bdsim.html`
- GEANT 4 website, `http://geant4.web.cern.ch/geant4`
- ROOT website, `http://root.cern.ch`
- Laser-Wire group website, `http://www.pp.rhul.ac.uk/~lbbd`

Polarization Measurement

- Basic idea: Compton scattering cross section depends on electron helicity P · photon helicity λ
- Laser with same (+) and opposite (-) helicity

  measured asymmetry $\varepsilon = A \cdot P = \dfrac{N^- - N^+}{N^- + N^+}$
- Very sensitive to background ($N^{\pm} \longrightarrow N^{\pm} + \mathrm{BG}$):

  $\varepsilon = \dfrac{N^- - N^+}{N^- + N^+ + 2 \cdot BG}$