# Simulation of Laserwire in BDS

G. Penn

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# LWS as CLIC diagnostic

Beam emittance diagnostics:

- needed by physics experiments
- evaluate performance
- commissioning lattice – “emittance bumps”

LWS is non-destructive (small total cross section)

- relative number of electrons intersecting laser beam
- transverse density scan if small enough laser width
- does not directly measure beam angles

Concerns about background and statistical noise

# Thomson scatter

In electron rest frame, photon is upshifted by $\gamma_0$, so $\nu' \approx \gamma_0 \nu_0$

(or $2\,\gamma_0$ if originally antiparallel)

If photon energy is still less than electron rest mass, nearly elastic collision, with scattering angle distribution (in rest frame)

$$d\sigma/d\Omega \propto 1 + \cos^2\theta$$

Photons which are nearly backscattered then get upshifted by another factor of $2\,\gamma_0$ when go back to lab frame

Scattered frequencies as high as $2\,\gamma_0^2 \times$ initial frequency

- with angles $< 1 / \gamma_0$ (much smaller deflection for electrons)
- still a small fraction of electron energy

# Compton Scatter

Define $\xi = h\nu'/m_e c^2$ , where $\nu'$ is the laser frequency in the electron rest frame – key parameter for behavior

When $\xi > 1$, can't ignore energy exchange in electron rest frame.

Net result:

- the photon can acquire most of the electron's energy
- final electron energy is at least $m_e^2c^4 / 2\,h\nu_0$, so final $\gamma > \gamma_0 / 2\,\xi$
- typical angle of photon, maximum angle of electron

  $\sim \xi / \gamma_0 \approx h\nu_0 / m_e c^2$

- electrons with largest angle have energy $\sim \gamma_0\, m_e c^2 / \;\xi$

# Scaling for LWS signal

Main demands for LWS: large signal, good resolution

electron beam params: $\varepsilon_X$, $\varepsilon_Y$, $\sigma_X$, $\sigma_Y$, $\tau_B$, charge -- only control size

laser: peak power $P_L$, $\sigma_L$, $\tau_L$, $\lambda$

look at measuring Y profile:

need $\lambda < \sigma_L < \sigma_Y$ and $\sigma_Y / \sigma_X > \lambda / 2 \pi \sigma_L$ = angle of laser cone

number of scatters $\propto N_e P_L (\lambda / \sigma_Y) [\tau_L / (\tau_L^2 + \tau_B^2)^{1/2}] \underbrace{(\lambda / E_B)}_{\text{Compton regime only}}$

take as large $\lambda$, $\tau_L$ as acceptable

want large $\xi = h\nu'/m_e c^2 = 5\, E_B[\mathrm{TeV}] / \lambda[\mu\mathrm{m}]$

For higher energies, need more laser power for same signal.

# CLIC parameters:

electrons: 0.67 nC per bunch

20 μ spot size, 20 x 680 nm normalized emittance

energy 1.5 TeV, typical angle 0.3 – 11 nrad

laser: 0.25 μ wavelength, 5 μ width, 1 mJ per pulse

0.12 ps matches 35 μm bunch length

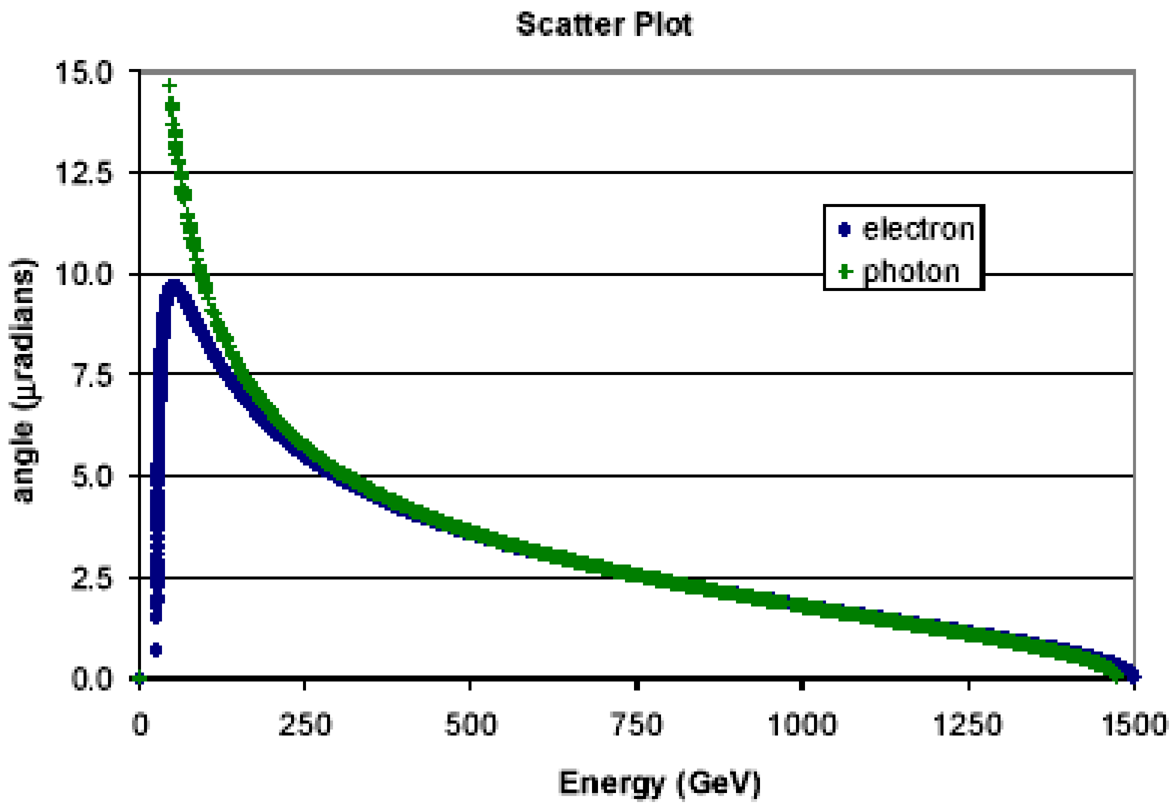
scatter params: $h\nu_0 / m_e c^2 \approx 10^{-5}$ $\xi_0 \approx 30$

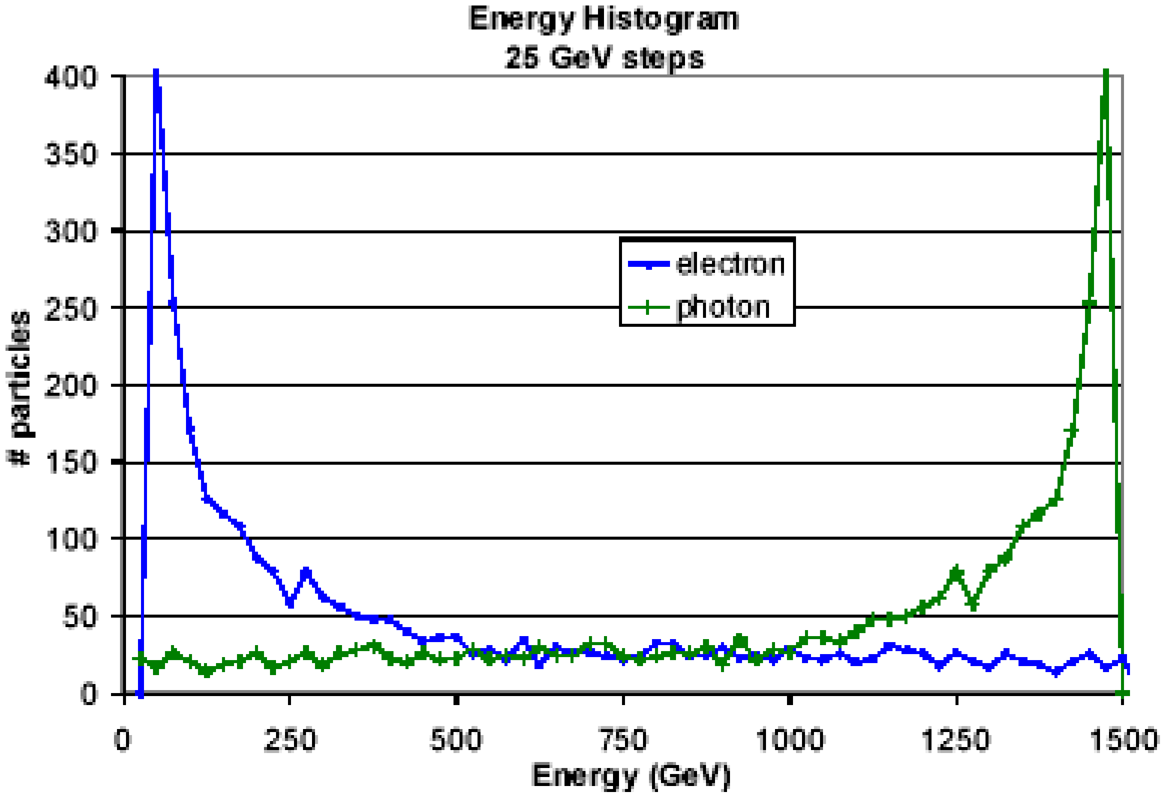
diagnostics: gas detector, signal is from low energy electrons

A) strong sextupoles at 20 + 40 m; B) long 100 gauss dipole field

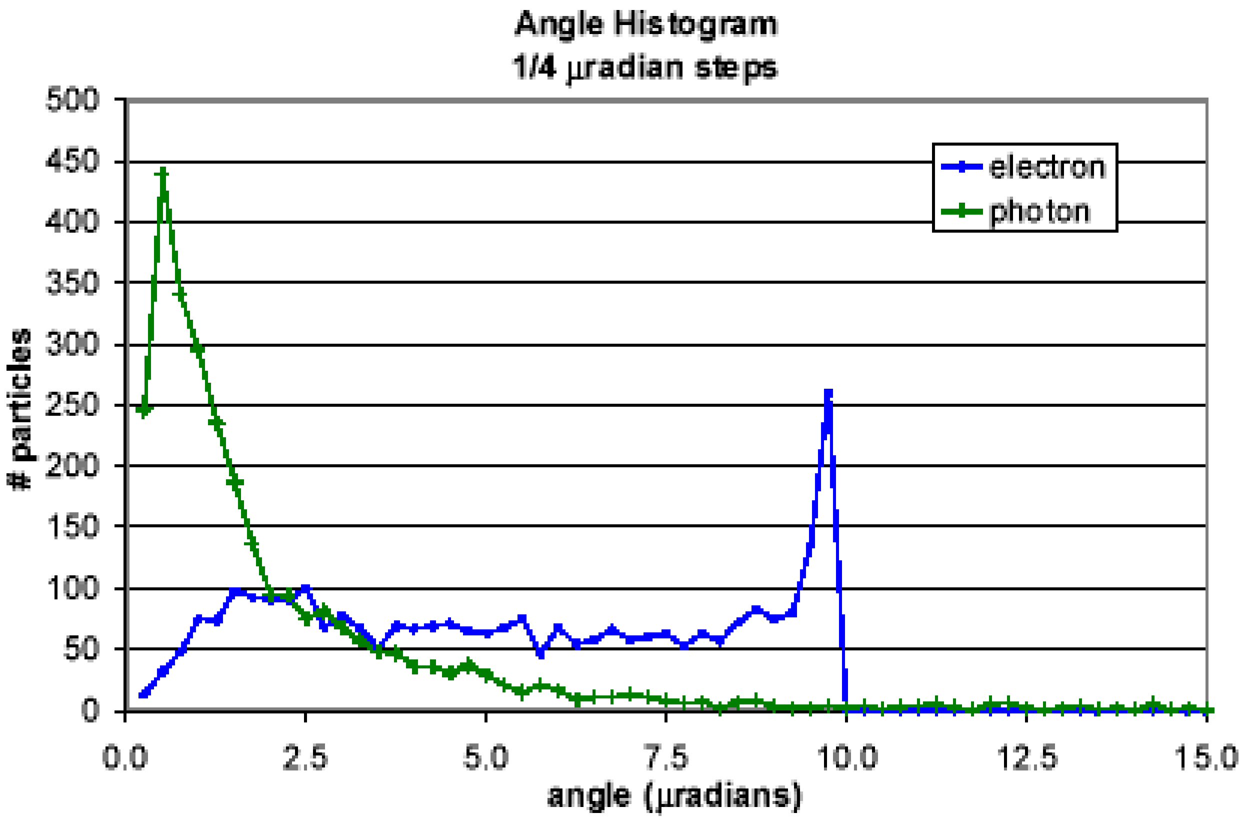
roughly **3000** scattering events per pulse

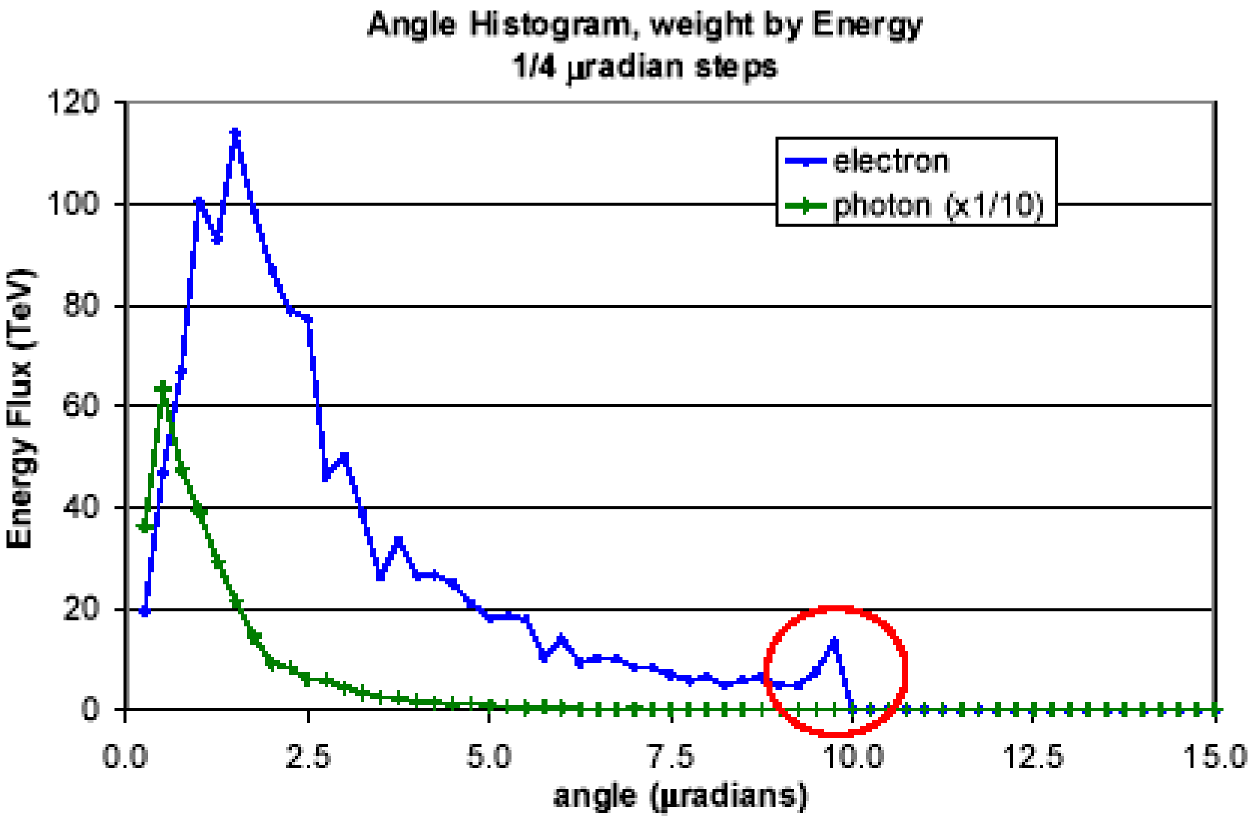
# CLIC parameters 1.5 TeV no emittance



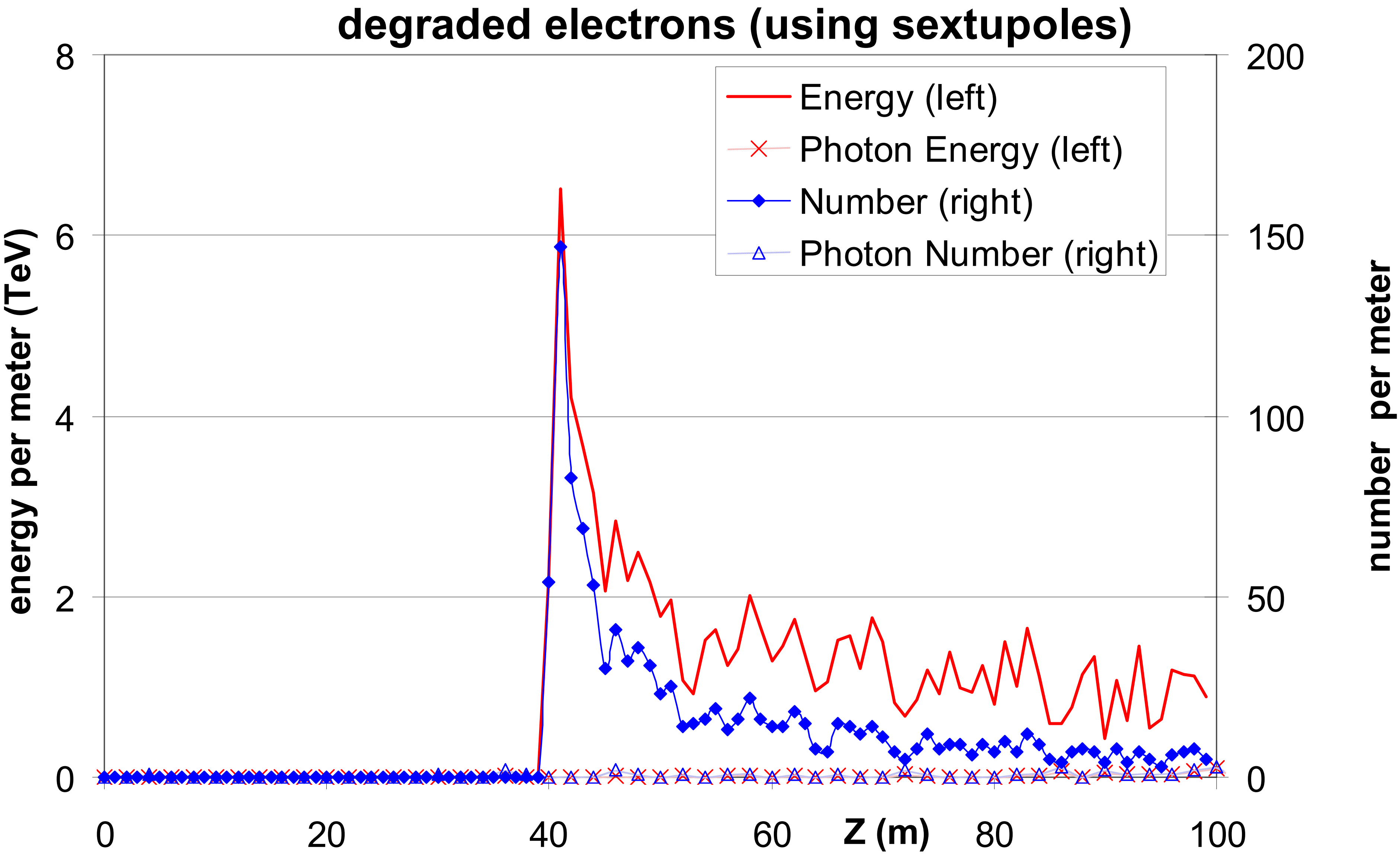


# CLIC parameters, 1.5 TeV no emittance

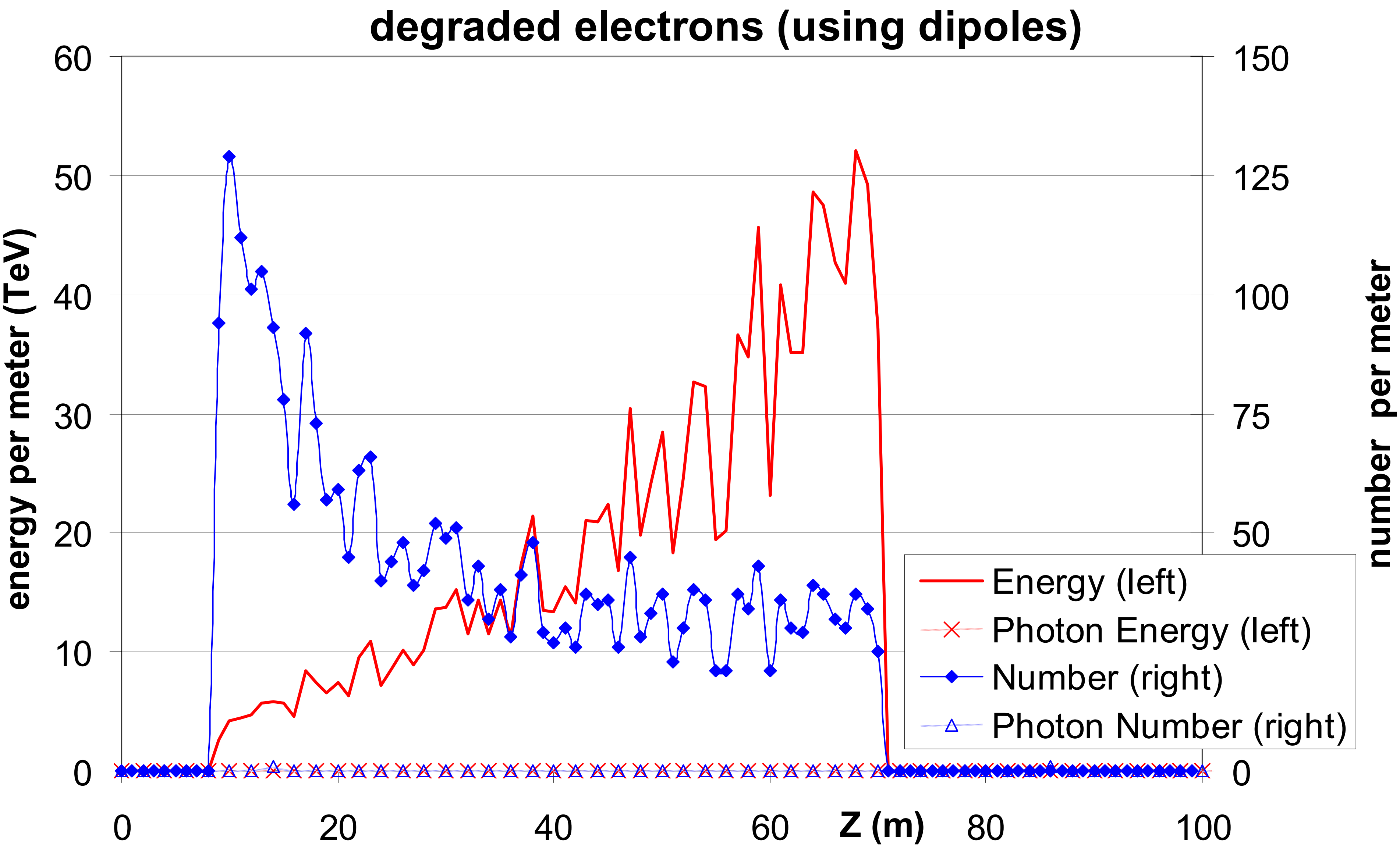




# CLIC – using sextupoles



# CLIC – using dipoles
# note: beampipe is straight



# CLIC Results

Degraded electrons can be swept out of the beam by magnetic fields.

Short Sextupoles:

peak has **15%** of scattered electrons, but less peaked in energy

feasibility will depend on detection method, lattice design

Long Dipoles:

simple design works well

signal is similar to secondaries produced by lost TeV particles

Background estimate, 1 TeV particle / meter hitting pipe – reasonable?

Measure photons?  Harder to separate from halo and SR

# CLIC Simulations

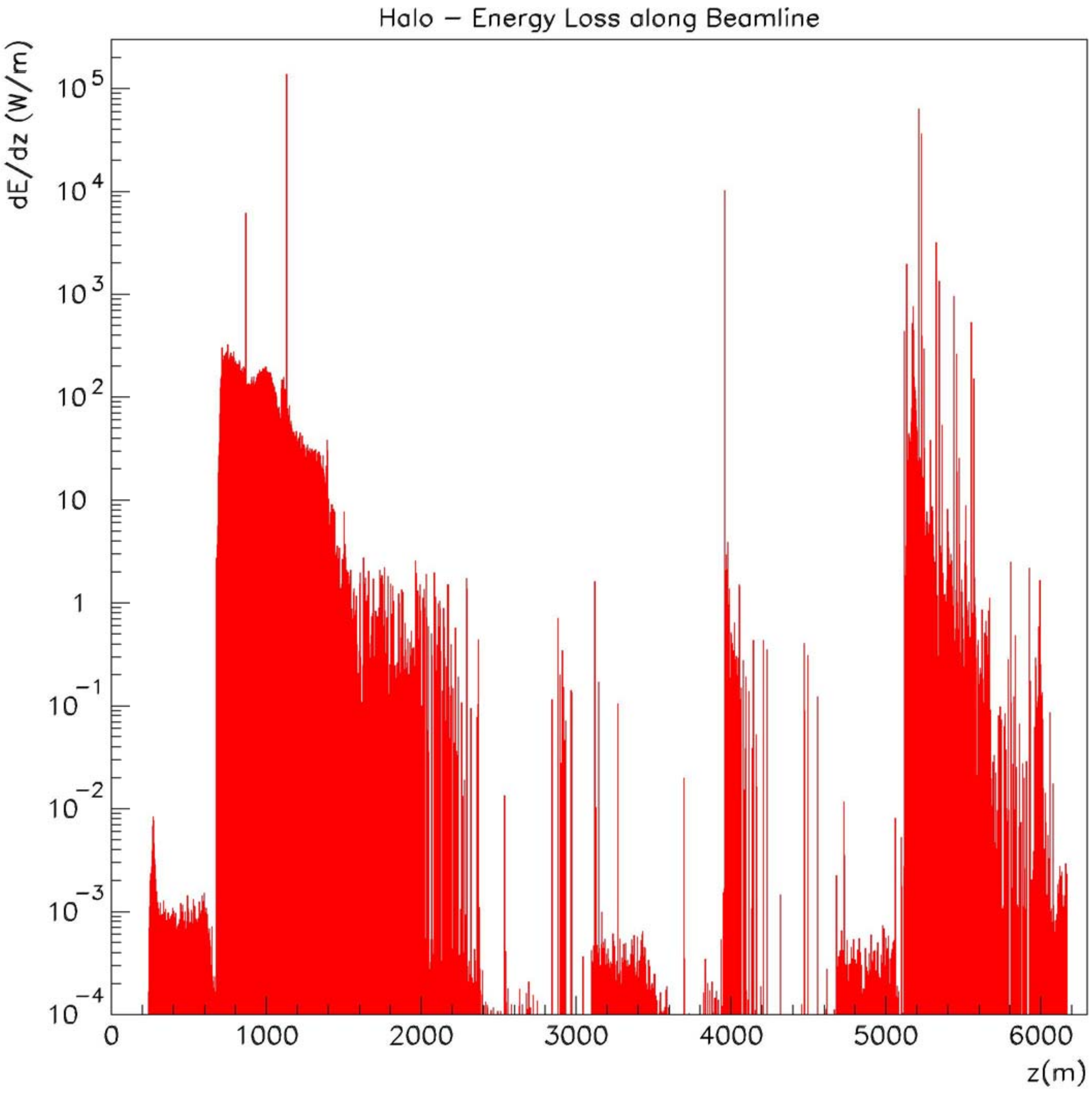
GEANT4 results, for GeV deposited in detector

- with 1 halo electron hitting beampipe per meter (very clean beam).
- corr to time-average of 3.7 mW per meter, for CLIC timing

| **System** | **Signal** | **Noise** |
|---|---|---|
| sextupoles, shielded Pb detector | **65** | **120** |
| sextupoles, shielded gas detector | **0.14** | **0.10** |
| dipole, unshielded gas detector | **0.78** | **0.05** |
| dipole, 500 GeV beam | **1.8** | **0.016** |

Noise caused by spray of secondaries from (mostly local?) losses

For sextupoles, have large bending angles, maybe can separate signal from background based on direction.



graph obtained from G. Blair

# Laser Parameters

Design parameters compared with currently available lasers:

| | **Design** | **Nd:YAG** | **Ti:Sapphire** |
|---|---|---|---|
| wavelength | **250 nm** | **266 nm** | **800 nm** |
| bunch length (FWHM) | **150 fs** | **3 ns** | **50 fs** |
| energy per pulse | **1 mJ** | **200 mJ** | **0.7 mJ** |
| rep rate | **100 Hz** | **10 Hz** | **1 kHz** |
| energy fluct | **?** | **8 %** | **1 %** |
| peak power | **5 GW** | **0.05 GW** | **1 GW after triple?** |
| eff. overlap energy | **1 mJ (by def)** | **0.1 mJ*** | **0.2 mJ** |

*enhanced by overlap with multiple bunches in pulse train

# Simulation Goals:

For further research and GEANT4 simulations:

collimation and other noise reduction

optimize detector design for degraded electrons

fit more carefully into beam delivery system (BDS) design

look into enlarging beam cross-section, if necessary

study sources of background: characterize beam halo, losses

second look at photons