Study of ee$\rightarrow\gamma\gamma$

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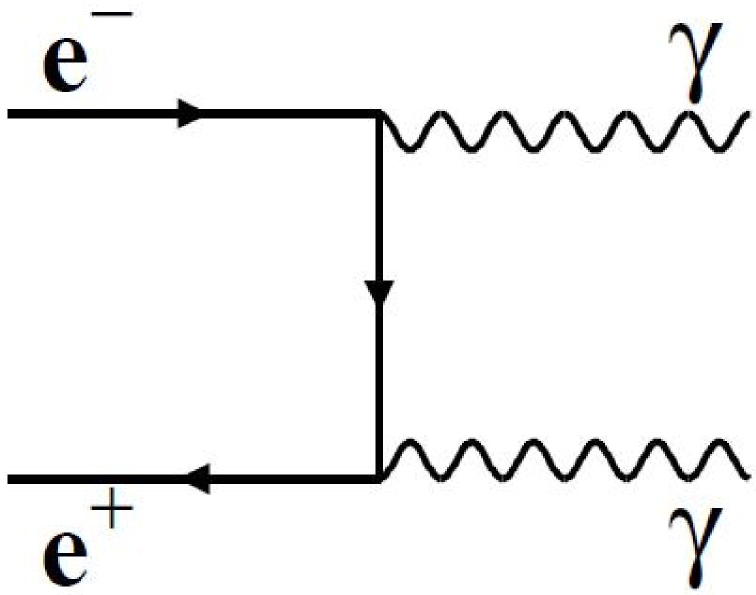
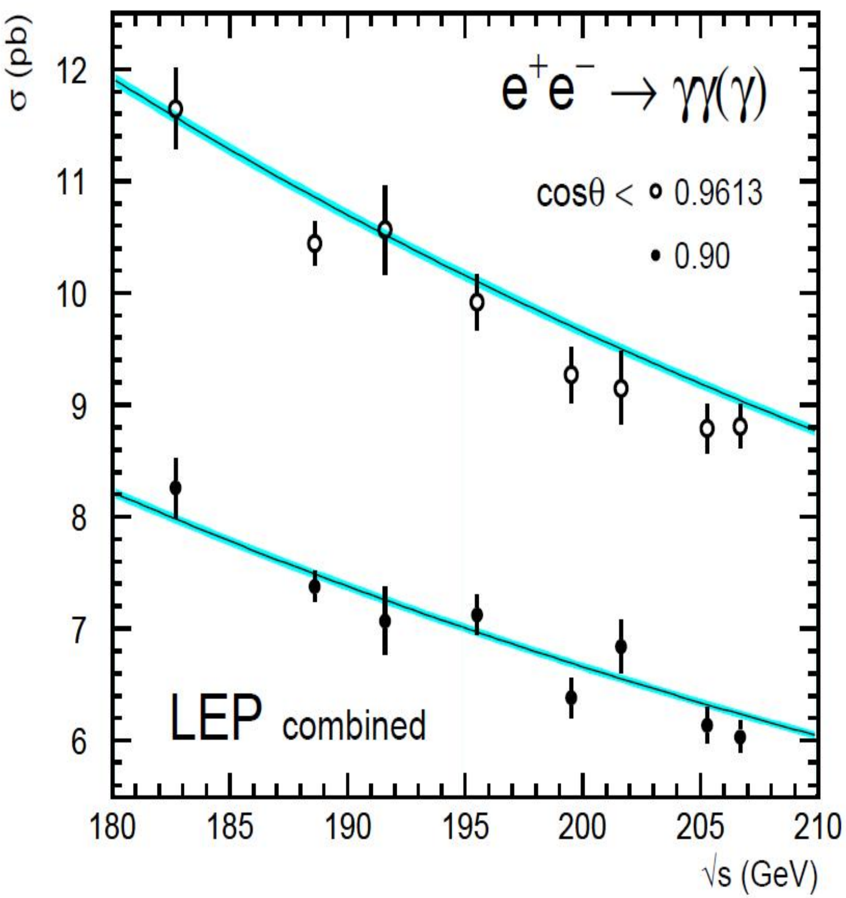
Signal process

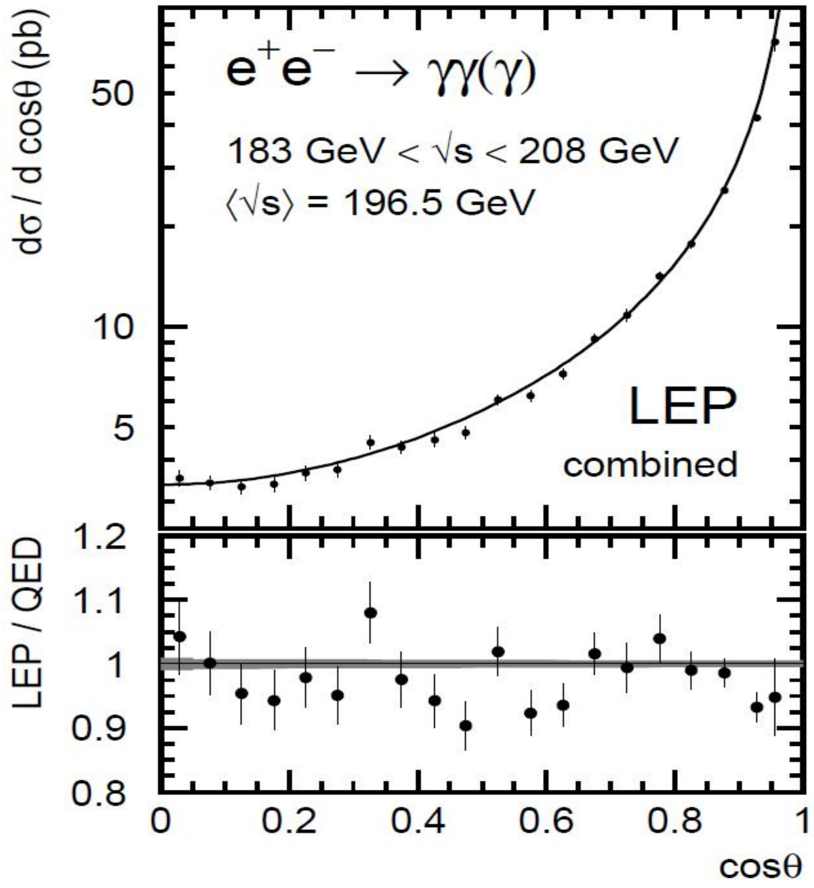
- $e^+e^- \rightarrow \gamma\gamma$ provides possibility to test various QED extensions, in particular to probe a finite size of the electron
- Need to measure absolute cross-section and angular spectrum of $\gamma\gamma$



$$\left(\frac{d\sigma}{d\Omega}\right)_{\rm Born} = \frac{\alpha^2}{s}\left[\frac{1+\cos^2\theta}{1-\cos^2\theta}\right]$$

Results from LEP





New physics with $e^+e^- \rightarrow \gamma\gamma$

- QED cut-off parameter (finite electron size)
  - The most sensitive way to search for non-zero electron size
  - The most precise limit from combination of the LEP data: $4.6\mathrm{x}10^{-17}$cm (431 GeV)
- Compactified extra dimensions: 4D→(4+n)D
  - The Plank mass is actually 1 or few TeV; the “observed” very large M_{PL} is simply because we put wrong number of dimensions in our formula
- Excited electron e* exchanged in the t-channel

Finite electron size

$$\left(\frac{d\sigma}{d\Omega}\right)_{\Lambda_\pm} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Born}} \pm \frac{\alpha^2 s}{2\Lambda_\pm^4}(1+\cos^2\theta)$$

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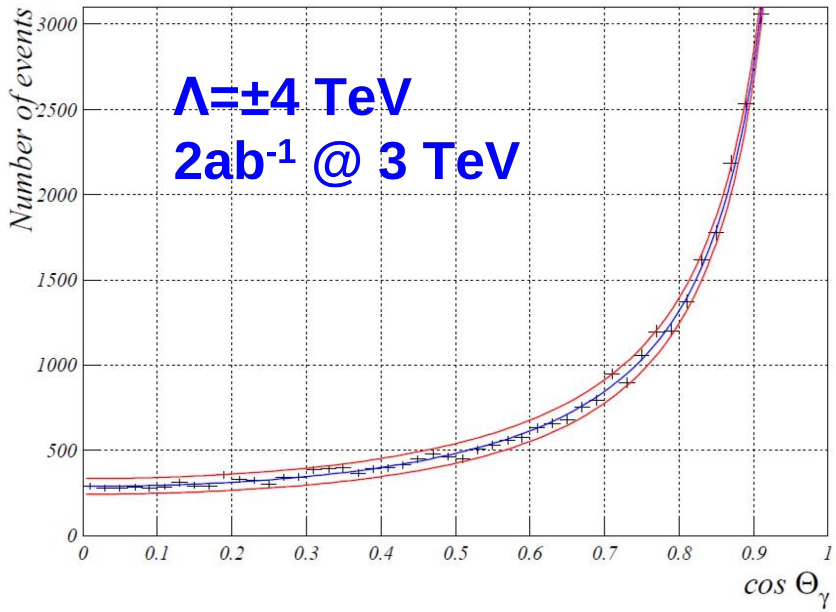


Extra dimensions and excited electrons

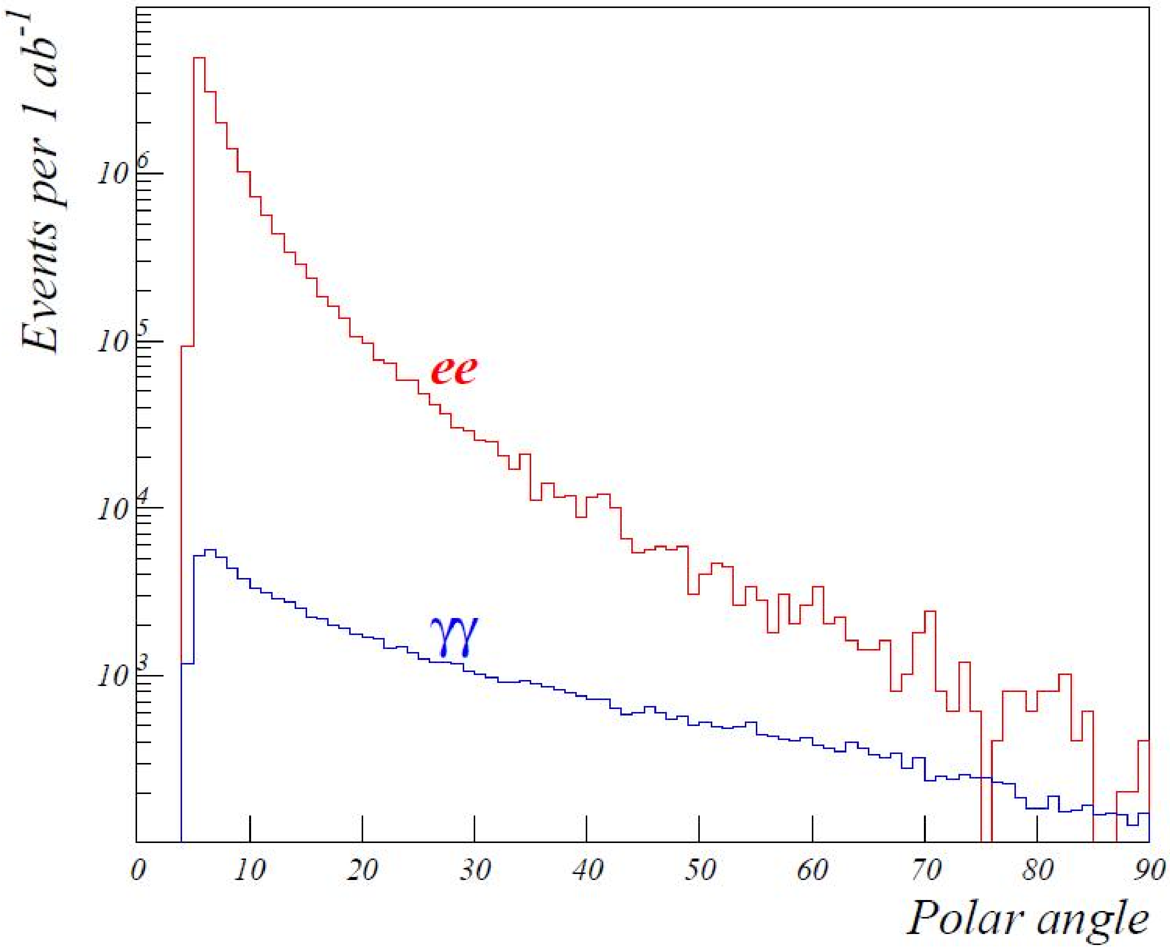
$$\left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{M_s}} = \left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{Born}} - \frac{\alpha s}{2\pi}\,\frac{\lambda}{M_s^4}\,(1+\cos^2\theta) + \frac{s^3}{16\pi^2}\,\frac{\lambda^2}{M_s^8}\,(1-\cos^4\theta)$$

$$\lambda = \pm 1$$

$$\left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{e^*}} = \left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{Born}} + \frac{\alpha^2}{16}\frac{f_\gamma^4}{\Lambda^4} s\sin^2\theta\left[\frac{p^4}{(p^2-M_{\mathrm{e^*}}^2)^2} + \frac{q^4}{(q^2-M_{\mathrm{e^*}}^2)^2}\right] - \frac{\alpha^2}{2s}\frac{f_\gamma^2}{\Lambda^2}\left[\frac{p^4}{(p^2-M_{\mathrm{e^*}}^2)} + \frac{q^4}{(q^2-M_{\mathrm{e^*}}^2)}\right],$$

$p^2 = -\frac{s}{2}(1-\cos\theta)$ and $q^2 = -\frac{s}{2}(1+\cos\theta)$

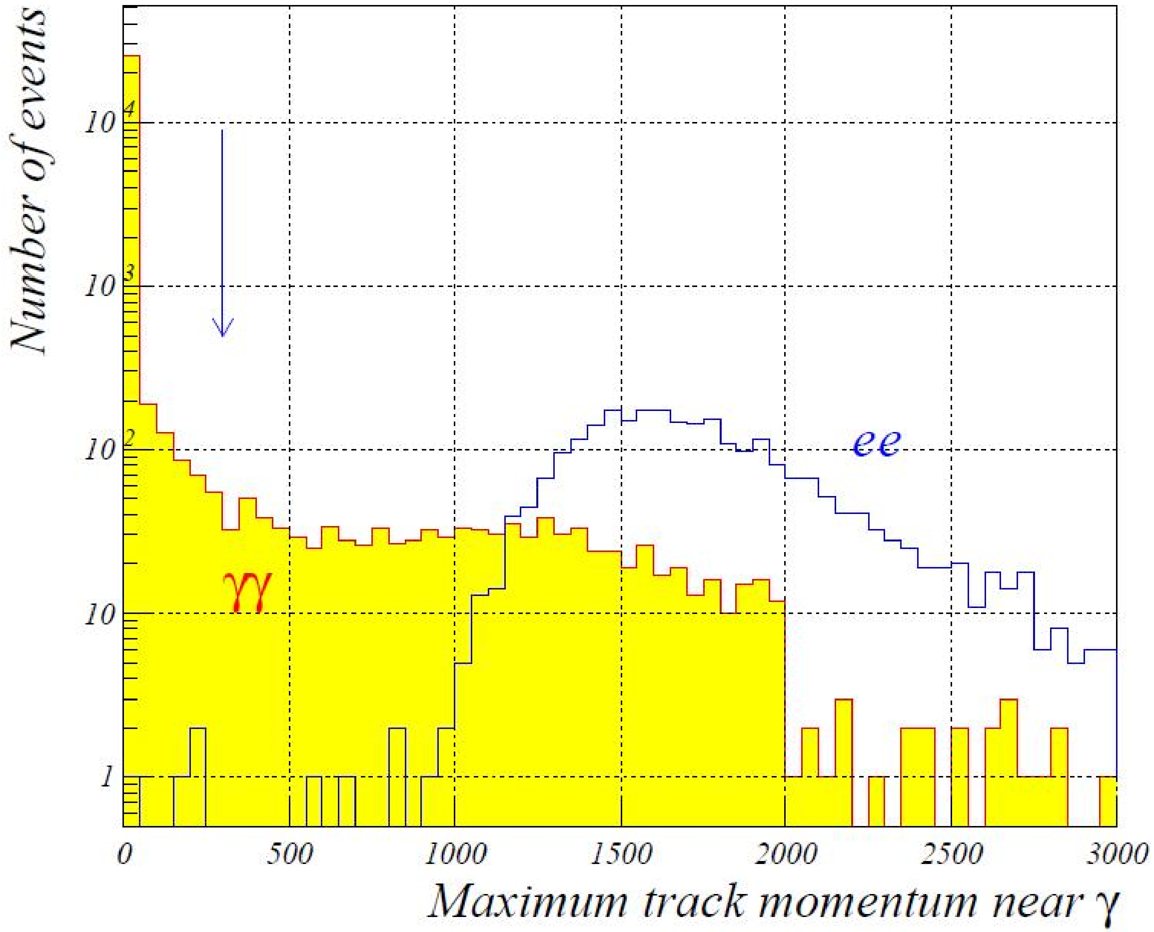
Signal and main background



Selection cuts

- Two photons, the most energetic above 1300 GeV, another above 1200 GeV
- No third photon above 50 GeV
- Back-to-back photons: $\pm 10^{o}$ in θ, $\pm 10^{o}$ in φ
- Track veto: no tracks with $|p|>300$ GeV/c within 20^{o} from a photon candidate (even “bad tracks”!)

Track veto

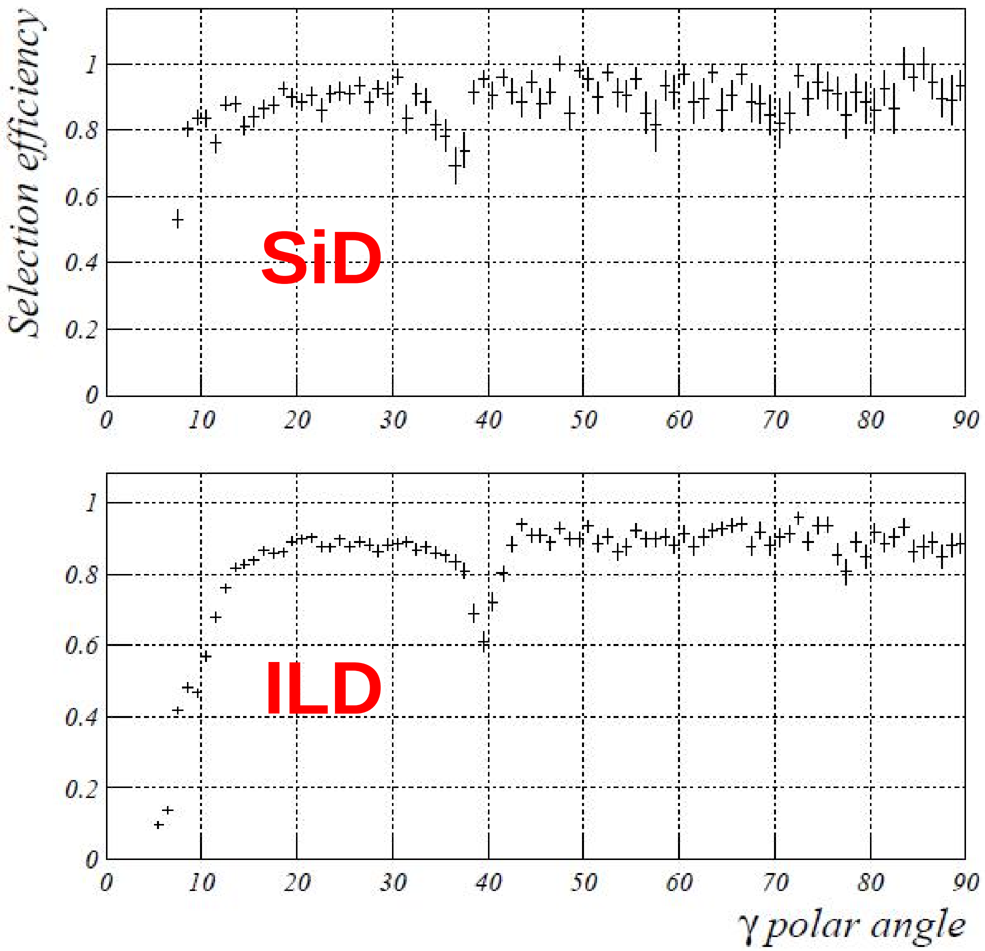


Number of events
10^4
10^3
10^2
10
1
0
500
1000
1500
2000
2500
3000
Maximum track momentum near γ
γγ
ee

“Bad track” issue

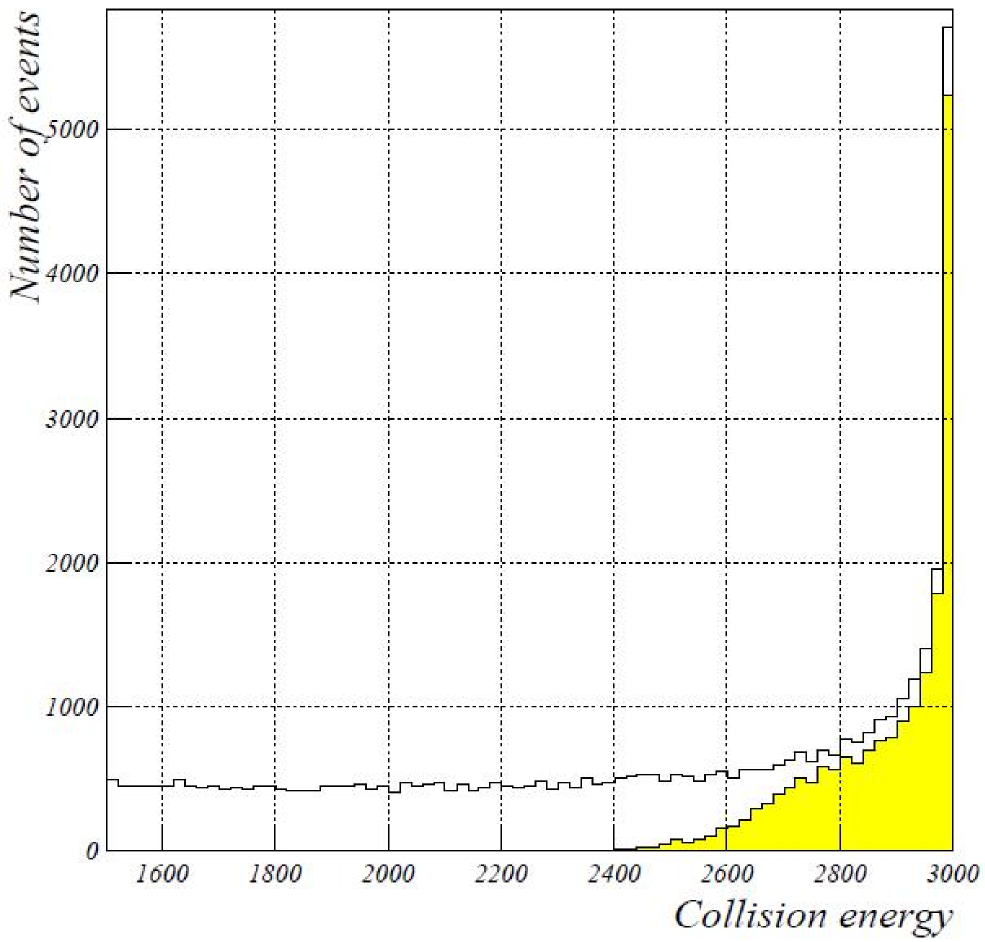
- We study the absolutely extreme part of the kinematic space. Our signal is made of 1.5 TeV photons, background are 1.5 TeV electrons
- At 1.5 TeV/c the track momentum resolution approaches $\sigma(p)/p=15\%$ - the limit of “good track” definition.
- In the forward region nearly all electrons are reconstructed as good photons (no good track!)
- Hence, the “track veto” must reject also the “bad tracks”

Selection efficiency



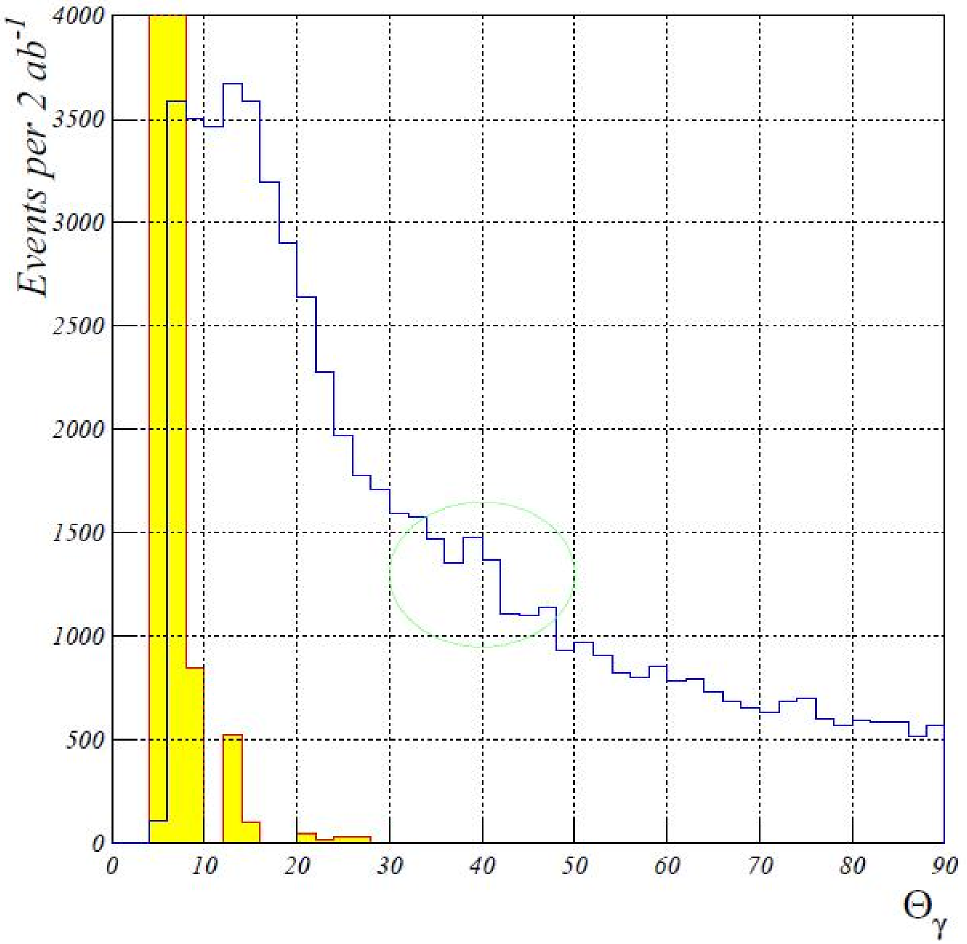
- Efficiency and angular acceptance much better than at LEP
- Angular coverage: down to 8-9º for SiD, down to 12-13º for ILD

Selected collision energy

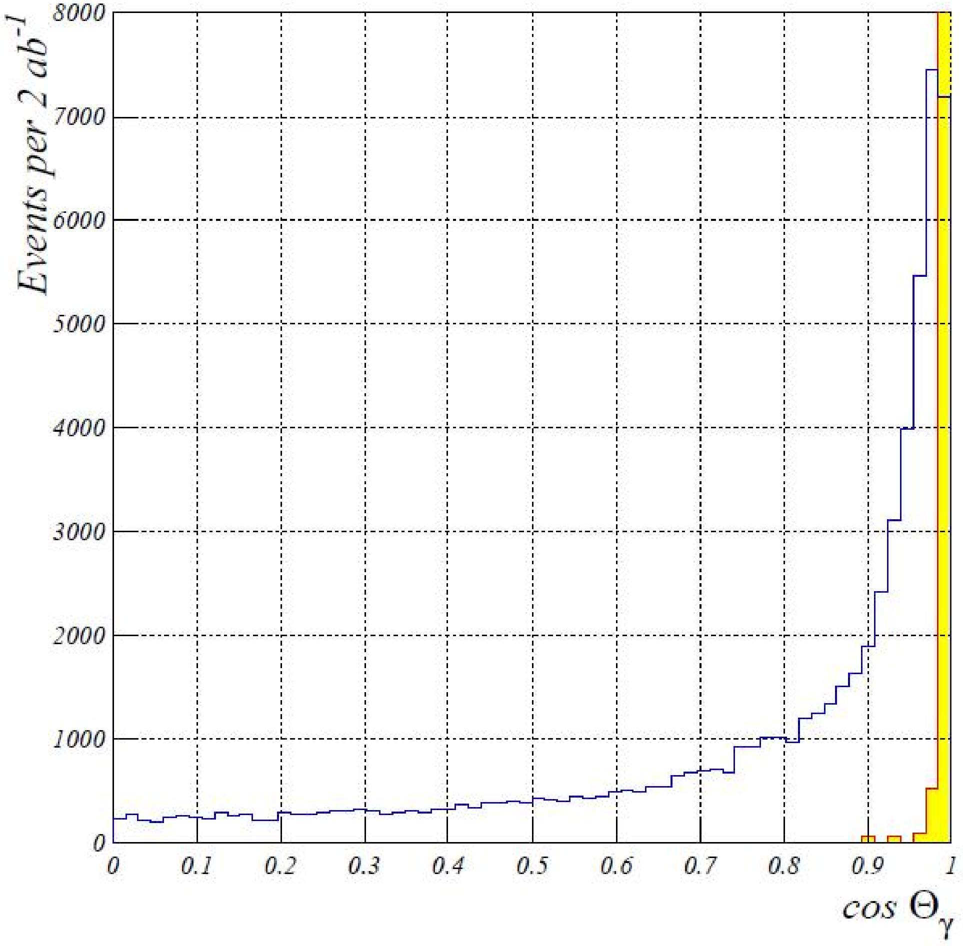


- Selection cuts ensure nearly nominal collision energy
- Average √s: 2878 GeV
- Reduced √s will somewhat reduce sensitivity

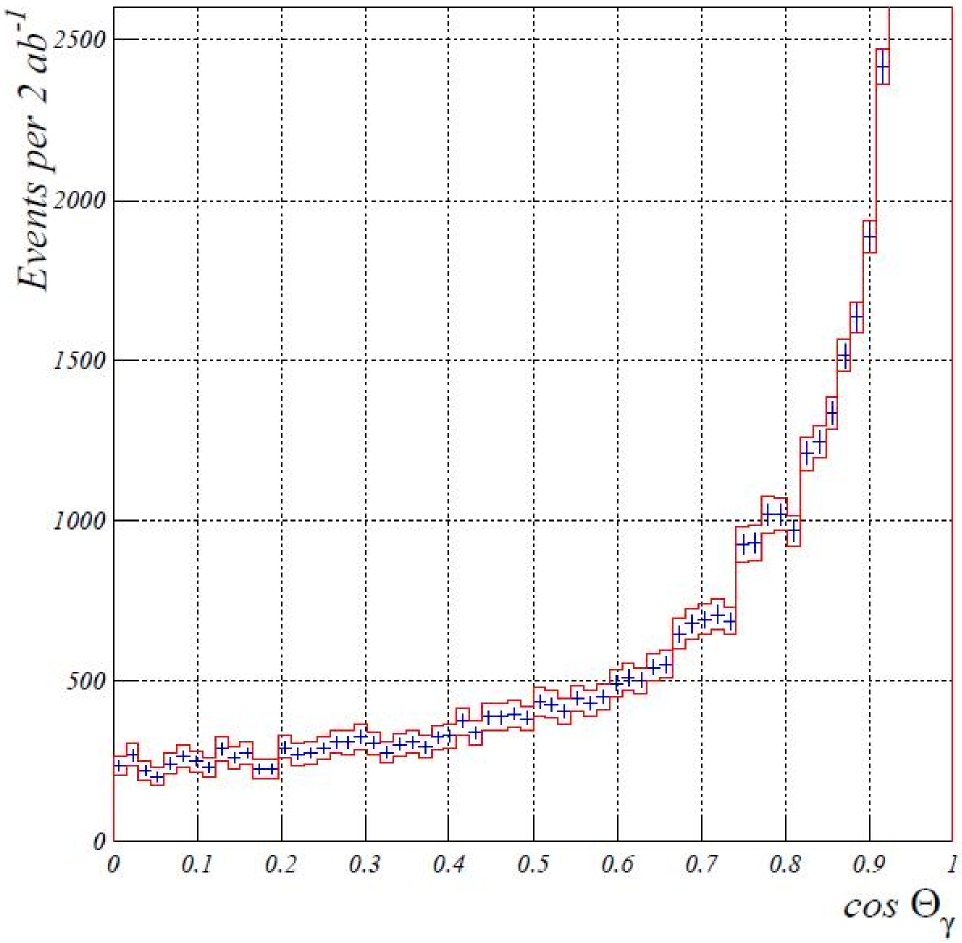
Signal versus ee background



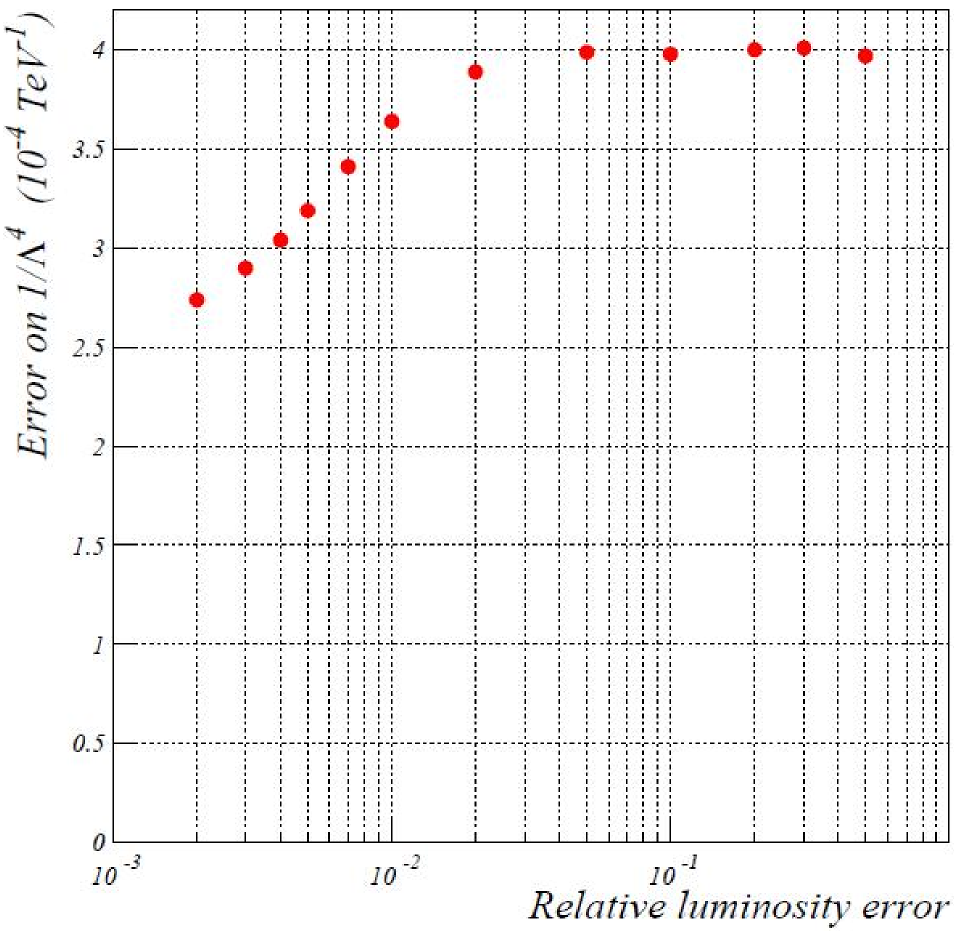
Signal versus ee background



Finite electron size ±4 TeV



Result: sensitivity to electron size versus precision on luminosity



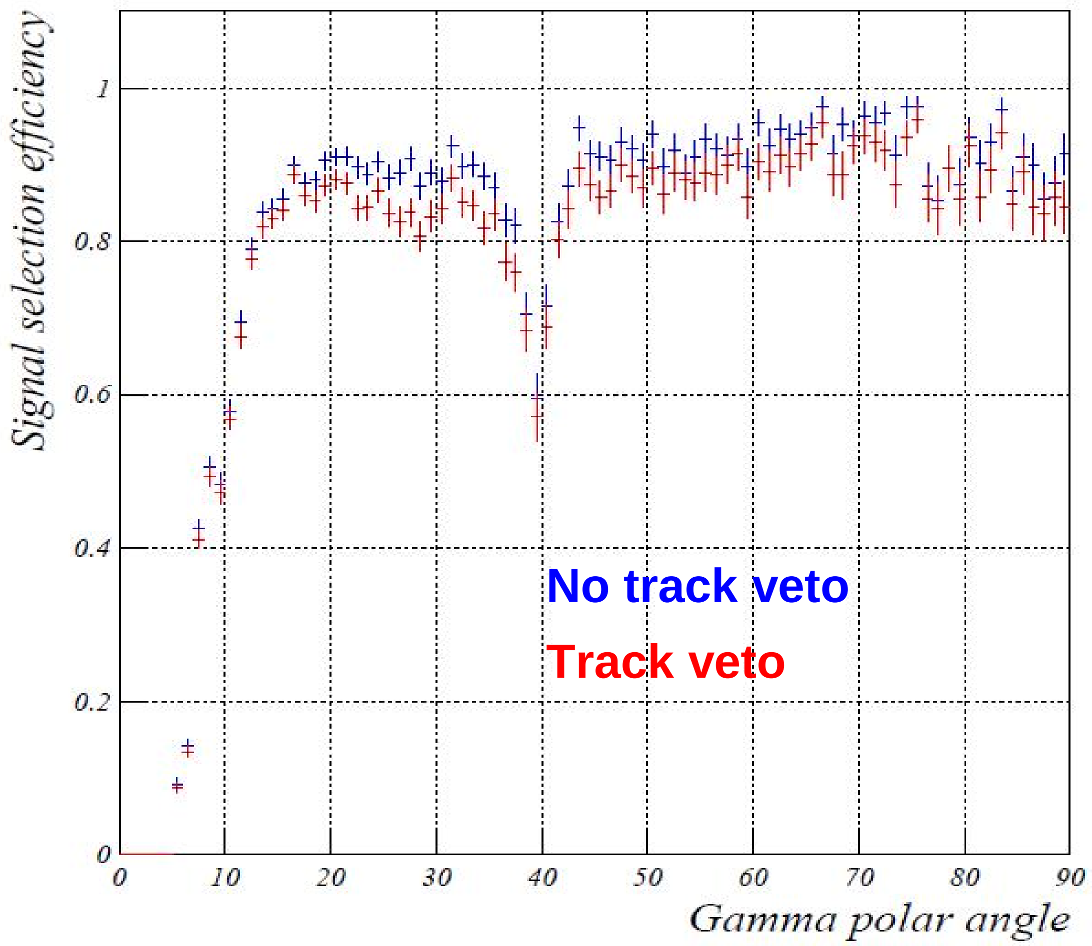
- Sensitivity is improved by precise luminosity, but not dramatically.
- For σ(L)/L=0.5%, the 95% CL exclusion limit is **Λ>6.33 TeV**
- For comparison: at LEP the limit was Λ>431 GeV

Summary

- CLIC is the best place for QED tests
- Preliminary result on sensitivity to electron size: 6.33 TeV or 3.1×10^{-18}cm
  - LEP: 431 GeV or 4.6×10^{-17}cm
- To do next:
  - Add (small) background from $\gamma e \rightarrow \gamma e$
  - Estimate systematic errors (other than lumi)
  - Repeat the ILD study with SiD geometry
  - Test more models of New Physics

Spare slides

Track veto: Is selection efficiency still acceptable?



θ reconstruction