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The Effects of Beam Dynamics on CLIC Physics Potential

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Compact Linear Collider (CLIC) (Basic parameters [1] , numbers in *italic* denote 2003 update [2])

- Center of mass energy, $\sqrt{s}$=*0.5*, 1, *3* and 5 TeV
- Luminosity (in 1% of energy), L=(*1.5*, 1.5, *3.2* and 2.4) x 10^{34} $cm^{-2}s^{-1}$
- Collision freq. fcoll=$f_{rep}.k_b$=(*200*, 150, *100*, 50)x154Hz
- Number of particles/bunch, N =(4, 4, 4, 4)x10^9
- Hor. beam size, σ_x=(*202*, 115, *60*, 31)nm
- Vert. beam size, σ_y=(*1.2*, 1.75, *0.7*, 0.78)nm
- Bunch length, σ_z=(*35*, 30, *35*, 25) μm
- Trans. emitt. x-comp., $\gamma\varepsilon_x$=(*200*, 130, *68*, *78*)x10^{-8}rad.m
- Trans. emitt. y-comp., $\gamma\varepsilon_y$=(*1*, 2, *1*, 2)x10^{-8} rad.m
- Energy spread, $\Delta E/E$=(*0.25*, 0.7, *0.35*, 0.7)%

Limitations on the parameters from beam dynamics (1)

- **Luminosity**,
  $L = H_D N^2 f_{rep} n_b / (4\pi\sigma_x\sigma_y)$
  where $\sigma_{x,y} \sim \sqrt{\beta_{x,y}\varepsilon_{x,y}/\gamma}$ and $N f_{rep} n_b \sim \eta P$. Typically transverse emittances are $\varepsilon_x >> \varepsilon_y$, and β-functions $\beta_x >> \beta_y$, therefore $\sigma_x >> \sigma_y$; nominal parameters are σ_x=60nm, σ_y =0.7nm for 3 TeV design.

  Beam-beam effects:

  →Beamstrahlung, is a process of energy loss by the incoming electron due to its interaction with the electron (positron) bunch moving in the opposite direction, the parameter $\Upsilon = 2\hbar\omega_c/3E_0$, $\langle\Upsilon\rangle \sim 8$ for CLIC 3 TeV, the interest for physics $L_1 = L(E_{cm} \geq 0.99 * E_{cm,0})$, current parameters $n_{\gamma/e}$=1.7, $\delta E/E \approx 20\%$, $L_1 \approx 0.4 * L$

  →Coherent (e^+e^-) pairs from photons, at CLIC ~10^8 pairs/bunch-crossing →increase backgrounds

Limitations on the parameters from beam dynamics (2)

→Beam delivery system:

due to synchrotron radiation in the bends, quadrupoles and multipoles →decrease in the luminosity ~1.7 factor

- **Spread in the c.m. energy**,

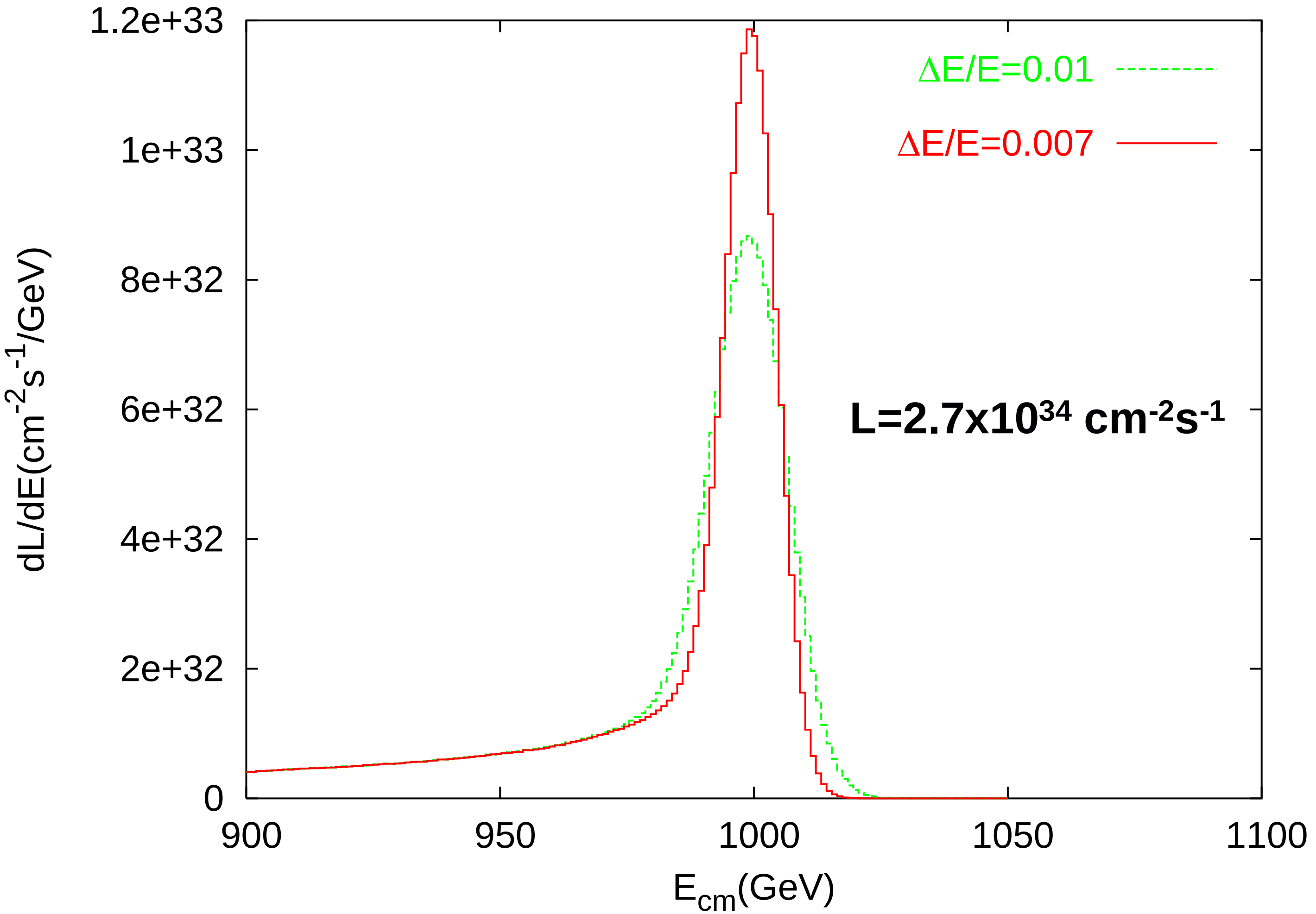
  →Intrinsic beam energy spread (for Gaussian) ~ 0.3%--1%

  →Initial state radiation (ISR) is a process of photon radiation by the incoming electron due to its interaction with other collision particle, with the scale factor λ.

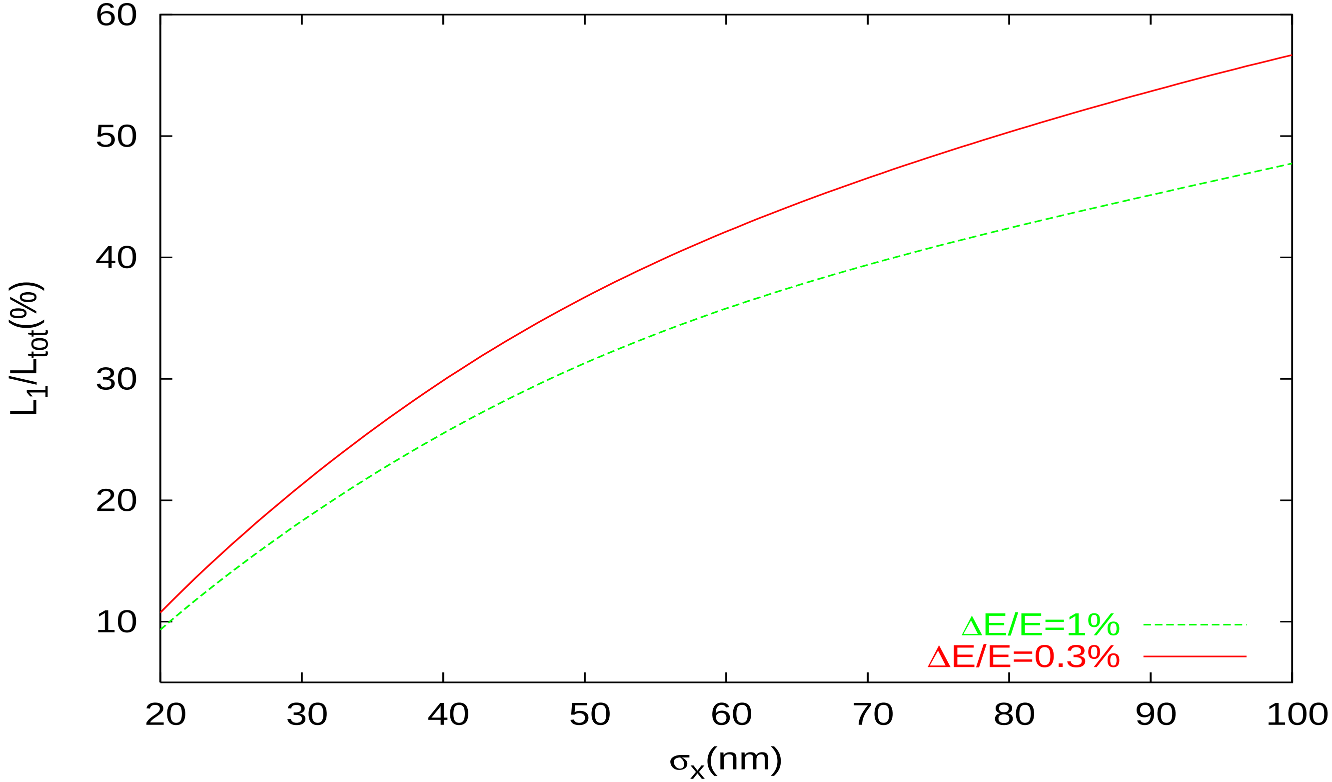
  →Beamstrahlung with the parameters N_c and Υ.

  (long tail down to large energy losses),
- Another issue is due to error in the calibration of the beam energy

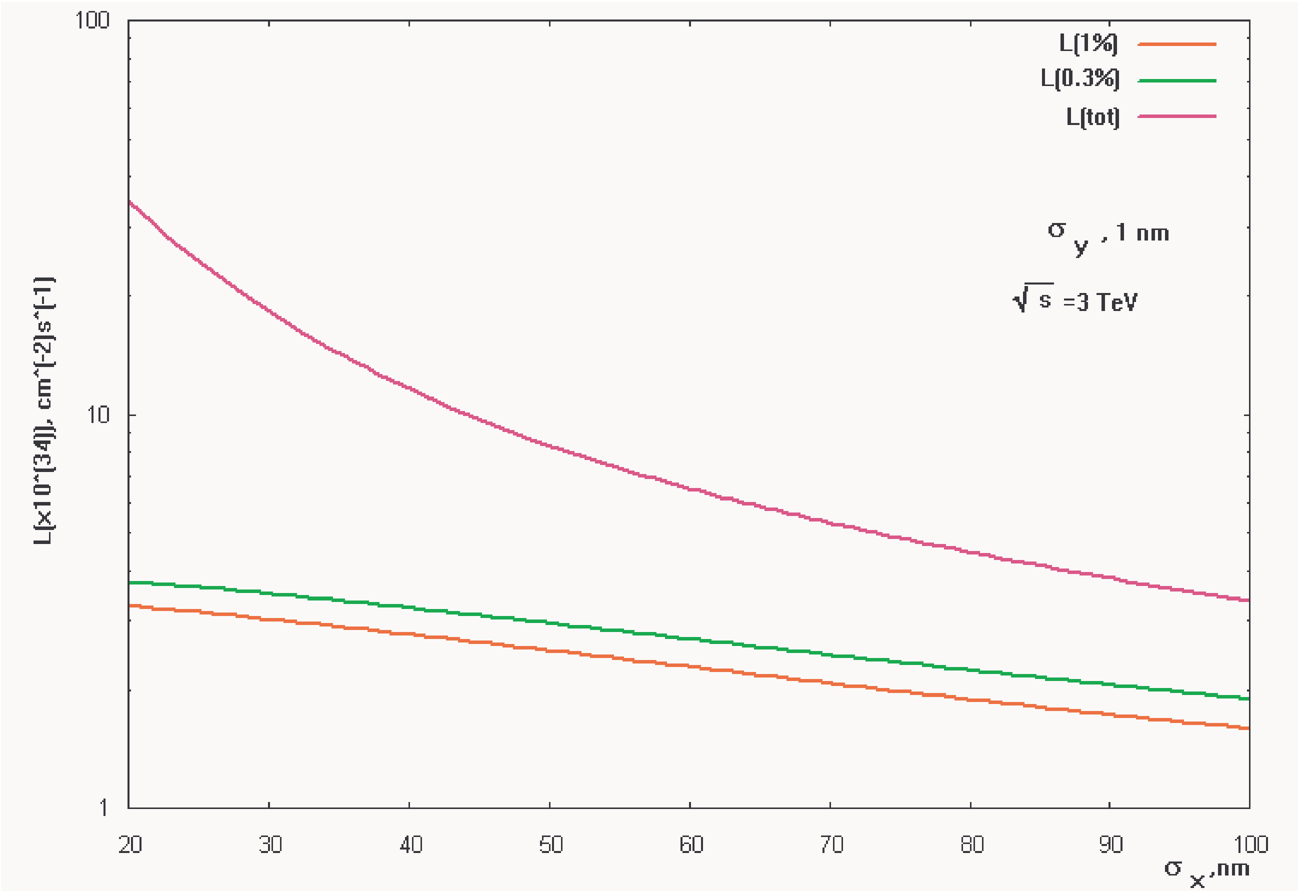
e^+e^- luminosity spectrum obtained from GUINEA-PIG for two values of beam energy spread $\Delta E/E$



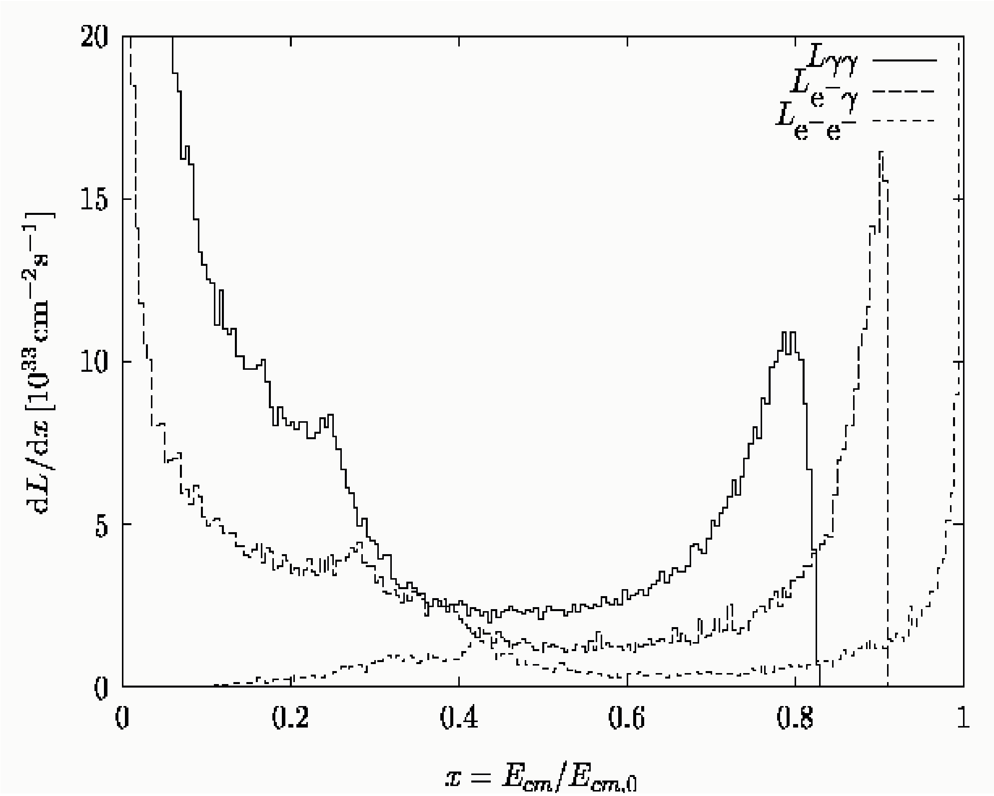
In the collision, beam particles lose energy because of beamstrahlung. This limits the maximum luminosity that can be achieved at the nominal cms energy. For some fixed parameters, the beamstrahlung is a function of the horizontal beam size [3].



A **larger horizontal beam size** leads to the emission of fewer beamstrahlung photons and consequently to a **better luminosity spectrum**. However, total luminosity is reduced.



$e^{-}\gamma$ luminosity spectrum*



- For a dedicated experiment one can convert only one electron beam, increase the distance between the conversion and the interaction points and obtain a more monochromatic $e\gamma$ spectrum with suppressed low energy part ($x=W_{e\gamma}/E_{cm,0}$).

Distance from conversion point to IP, b=1 cm. $L_{geom}=1.2\times10^{35}\ cm^{-2}s^{-1}$.

***Luminosity spectrum from a simulation program for TESLA (D. Schulte PhD Thesis, 1996)**

Resonance production of excited electrons [2]

- A typical consequence of compositeness is the appearance of excited leptons (l*) and quarks (q*).
- Production via $e\gamma \rightarrow e^*$ and subsequent decays $e^* \rightarrow e\gamma$ (0.28), $e^* \rightarrow eZ$ (0.11) and $e^* \rightarrow \nu W$ (0.61)
- Current limits on the masses: $m^*>223$ GeV from single production assuming $f=f'=\Lambda/m^*$ [HERA], and $m^*>100$ GeV from pair production [LEP].
- Relatively small limits for excited muon and tau $m^*>94.2$ GeV [LEP]

Excited lepton-lepton-gauge boson interaction vertices are implemented into the MC event generator

$$V^{\nu}_{l^{*}l'V} = \frac{g_e}{2\Lambda} q^{\nu} \sigma_{\mu\nu} (1-\gamma_5) f_V$$

- **Total decay widths:**

Γ=1.15 GeV at m*=200 GeV → Γ/m*=0.57%

Γ=3.38 GeV at m*=500 GeV → Γ/m*=0.68%

Γ=6.93 GeV at m*=1 TeV → Γ/m*=0.69%

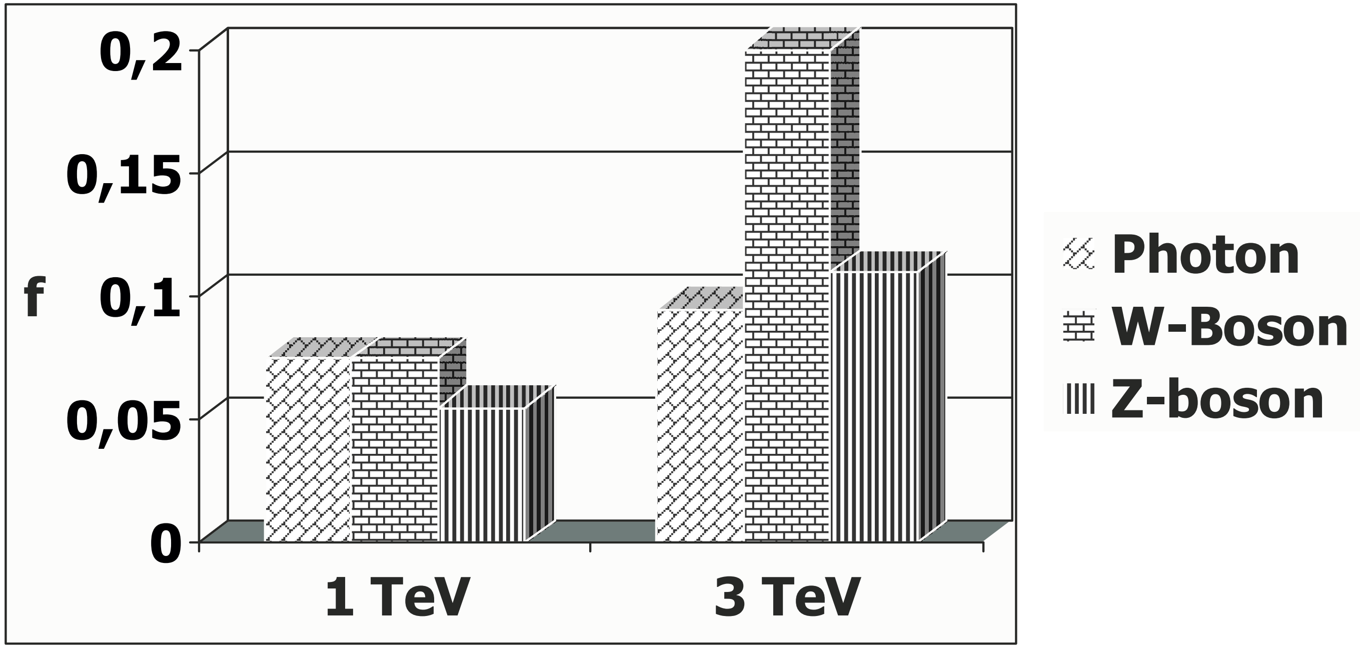
Γ=20.92 GeV at m*=3 TeV → Γ/m*=0.70%

Γ=34.88 GeV at m*=5 TeV → Γ/m*=0.70%

Narrow width: If we take Λ=5 TeV, Γ′/m*=0.028% for m*=1 TeV.

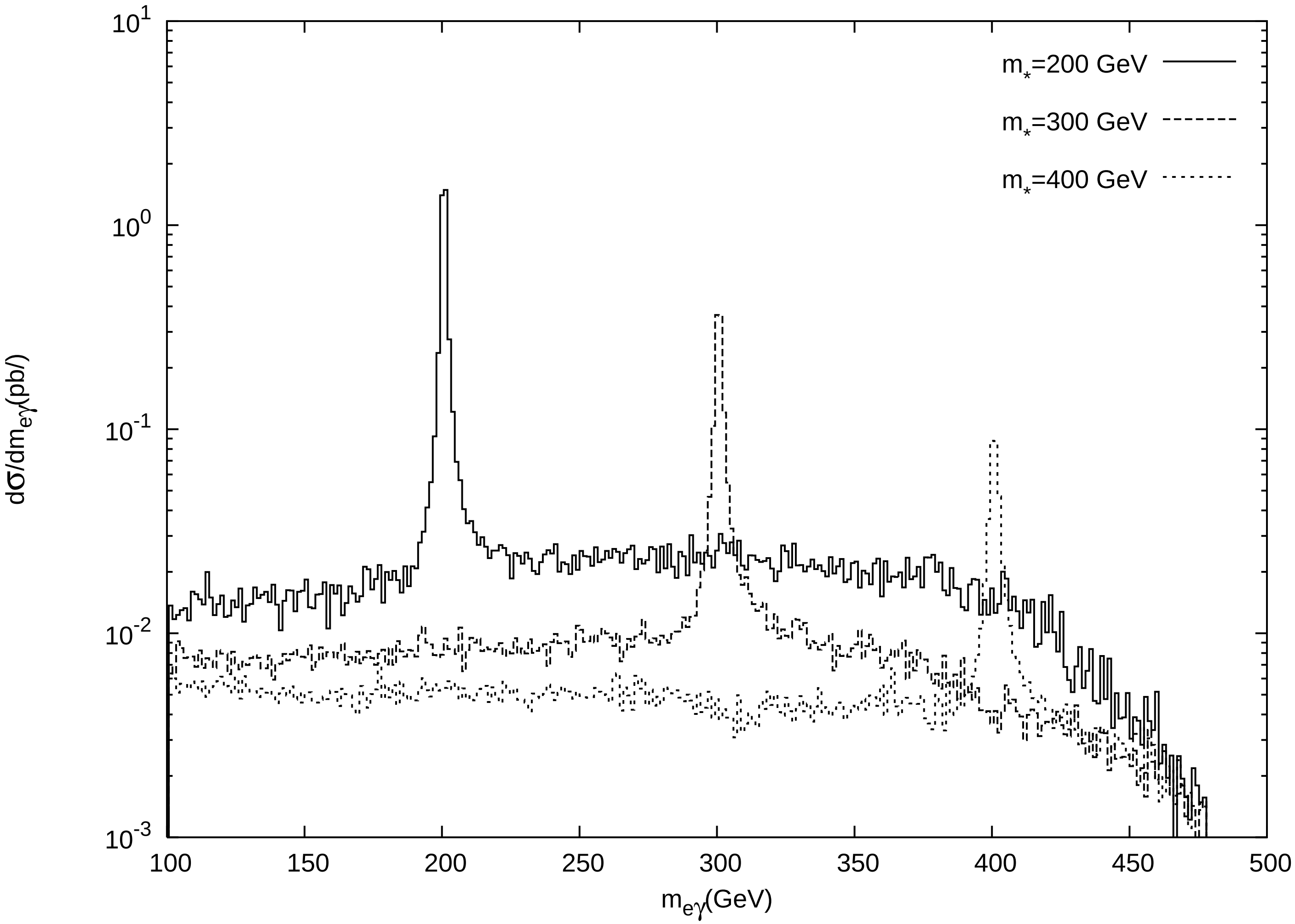
Excited electrons can be observed down to the couplings f=f′=0.05 at √s=1 TeV and f=f′=0.1 at √s=3 TeV.

$e\gamma \rightarrow e^* \rightarrow l V$: m*=750 GeV, Λ=m*

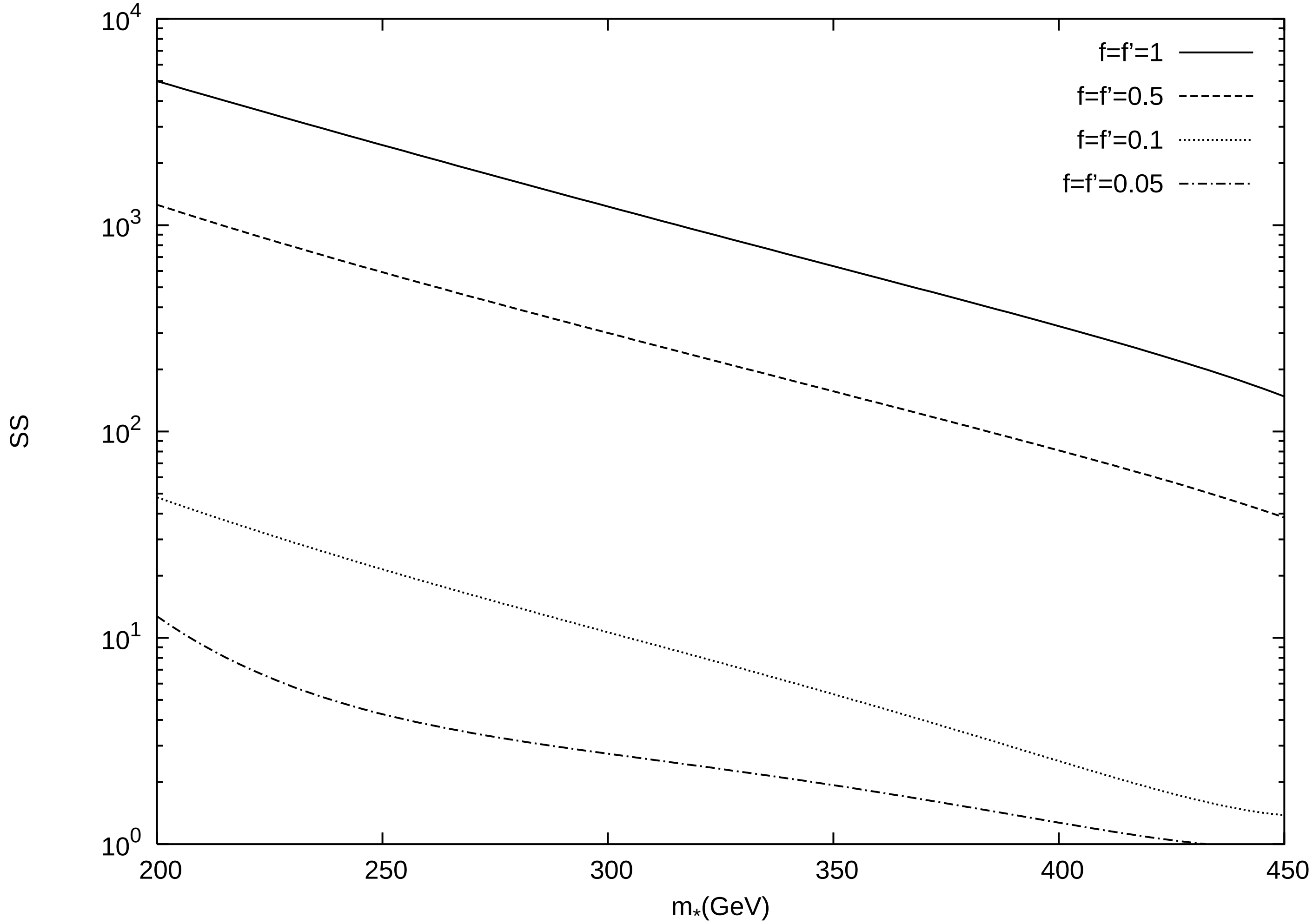


Single production of excited electron at CLIC with √s=500 GeV [4].

$e^+e^- \rightarrow e^*e^+ \rightarrow e^-\gamma e^+$

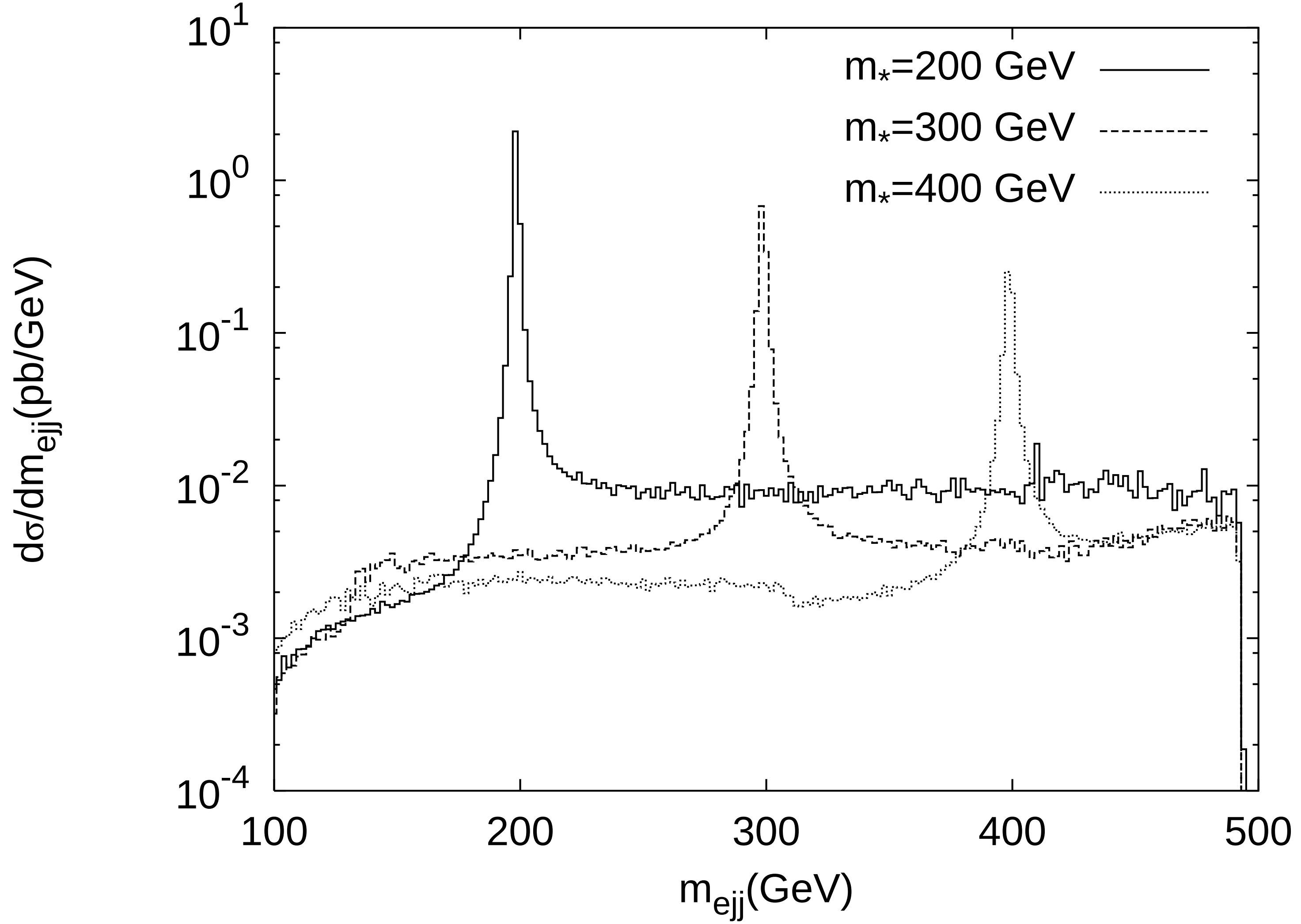


Statistical significances depending on the mass of excited electron for different coupling parameters.

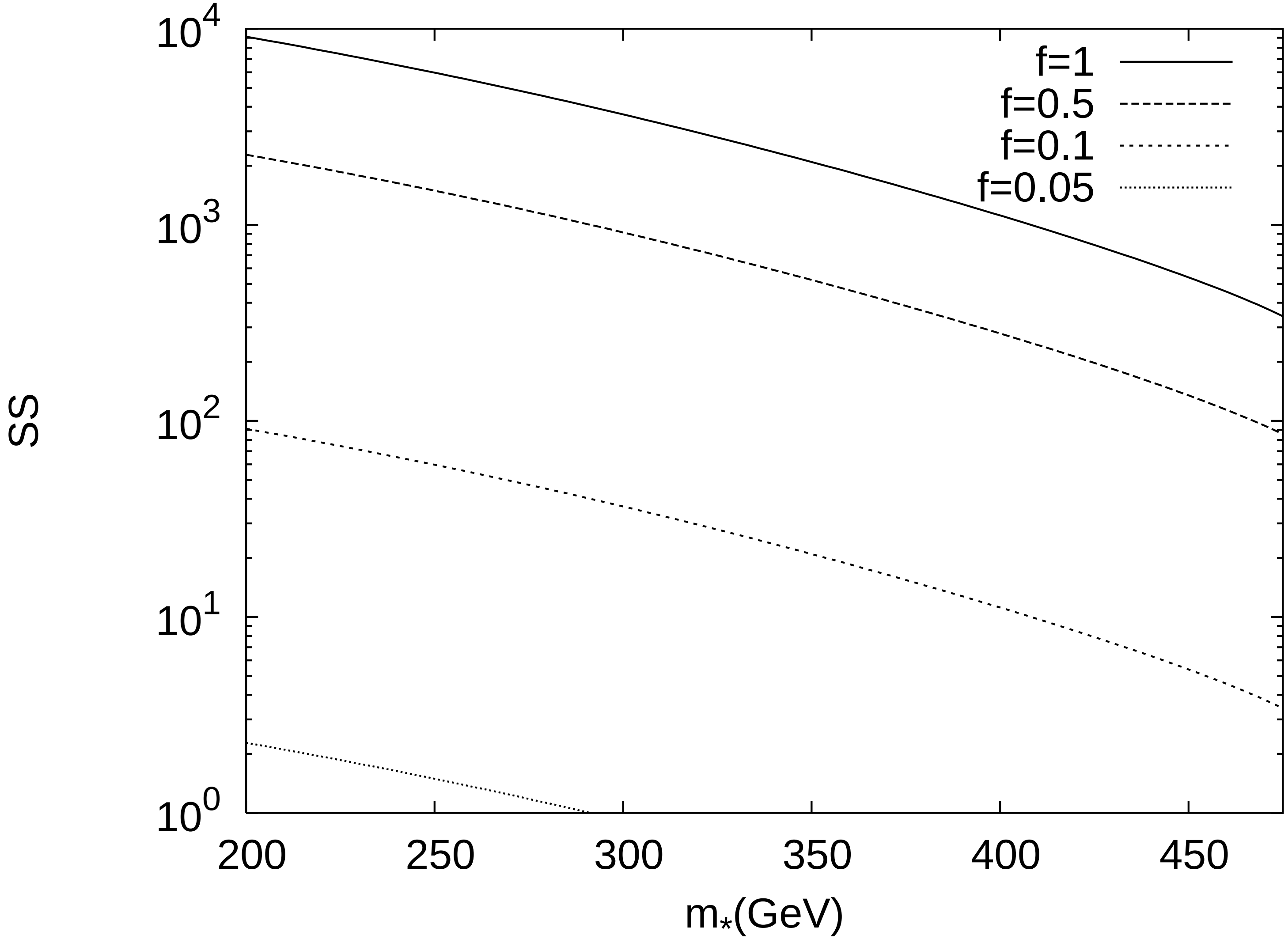


Single production of excited neutrino at CLIC with √s=500 GeV [5].

$e^+e^- \rightarrow \nu^* e^+ \rightarrow e^- W^+ e^+$



Statistical significances depending on the mass of excited neutrino for different coupling parameters.



Effects of the ISR+beamstrahlung (on the cross sections) and luminosity (on the number of events)

$m^*=450$ GeV	ISR+ Beams.	$L_1(\Delta E/E=1\%)$ $[L_{0.7}(\Delta E/E=0.7\%)]$
Resonance, $e\gamma \to e^* \to lV$	30% at res.	47% (43%)
Single e^*, ν^* $e^+e^- \to e^*e^+$, $e^+e^- \to \nu^*\nu$	6%	- [-]

Conclusion

- Resonance productions of e* at CLIC based eγ colliders have been studied to see the effects of the parameter limitations from the beam dynamics.

- For the completeness, single production of excited electrons and neutrinos have also been studied at CLIC e^+e^- .

- Further studies on the resonances(for example: bileptons L^{--}) in e^-e^- collisions are continuing.

- Full simulations including the beam-beam interaction using GUINEA-PIG and interface with the event generators (PYTHIA) and detector simulation (SIMDET or GEANT4) using CALYPSO and HADES are under study.

References

1. R.W. Assmann et al., A 3 TeV e^+e^- Linear Collider Based on CLIC Technology, CERN-2000-008, p.73, (2000)
2. E. Accomando et al., Physics at the CLIC Multi-TeV Linear Collider, CERN-2004-005, p.179, (2004)
3. Daniel Schulte, CLIC: Beam Dynamics and Limitations on Main Parameters , in this workshop.
4. O. C,Çakır, A. Yılmaz and S. Sultansoy, single production of excited electrons at future ee ep and pp colliders, hep-ph/0403307 (2004)
5. O. Çakır, İ. Türk Çakır, Z. Kırca, single production of excited neutrinos at future ee ep and pp colliders, hep-ph/0408171 (2004)