

# 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)  $\times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- Collision freq.  $f_{\text{coll}}=f_{\text{rep}} \cdot k_b=(200, 150, 100, 50) \times 154 \text{ Hz}$
- Number of particles/bunch,  $N=(4, 4, 4, 4) \times 10^9$
- Hor. beam size,  $\sigma_x=(202, 115, 60, 31) \text{ nm}$
- Vert. beam size,  $\sigma_y=(1.2, 1.75, 0.7, 0.78) \text{ nm}$
- Bunch length,  $\sigma_z=(35, 30, 35, 25) \mu\text{m}$
- Trans. emitt. x-comp.,  $\gamma\epsilon_x=(200, 130, 68, 78) \times 10^{-8} \text{ rad.m}$
- Trans. emitt. y-comp.,  $\gamma\epsilon_y=(1, 2, 1, 2) \times 10^{-8} \text{ rad.m}$
- Energy spread,  $\Delta E/E=(0.25, 0.7, 0.35, 0.7)\%$

## Limitations on the parameters from beam dynamics (1)

- **Luminosity,**

$$L = H_D N_{\text{rep}}^2 n_b / (4\pi\sigma_x\sigma_y)$$

where  $\sigma_{x,y} \sim \sqrt{\beta_{x,y}\epsilon_{x,y}}/\gamma$  and  $N_{\text{rep}} n_b \sim \eta P$ . Typically transverse emittances are  $\epsilon_x \gg \epsilon_y$ , and  $\beta$ -functions  $\beta_x \gg \beta_y$ , therefore  $\sigma_x \gg \sigma_y$ ; nominal parameters are  $\sigma_x = 60\text{nm}$ ,  $\sigma_y = 0.7\text{nm}$  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  $L_1 = L(E_{\text{cm}} \geq 0.99 E_{\text{cm},0})$ , 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  $\sim 10^8$  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  $\sim 1.7$  factor

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

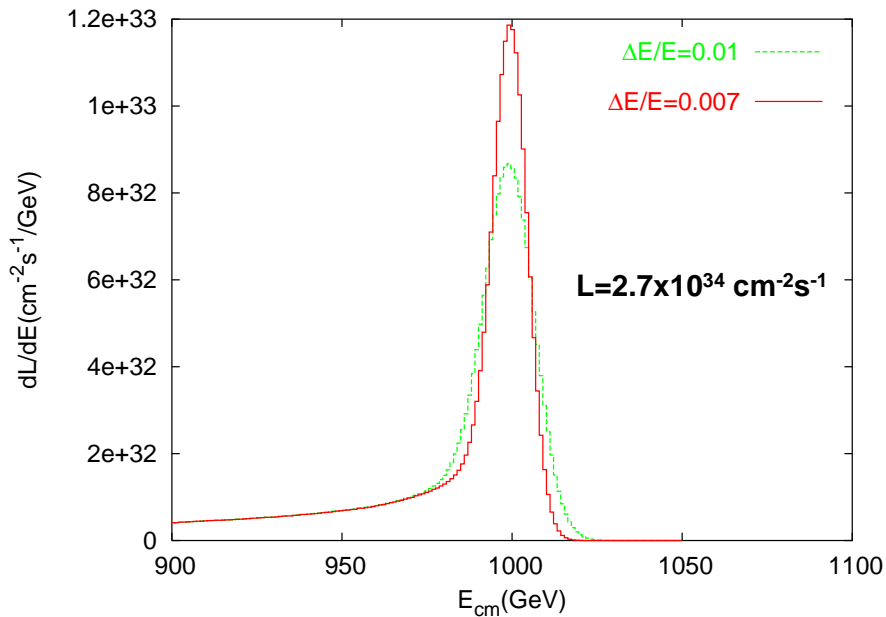
→ Intrinsic beam energy spread (for Gaussian)  $\sim 0.3\% - 1\%$

→ 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  $\lambda$ .

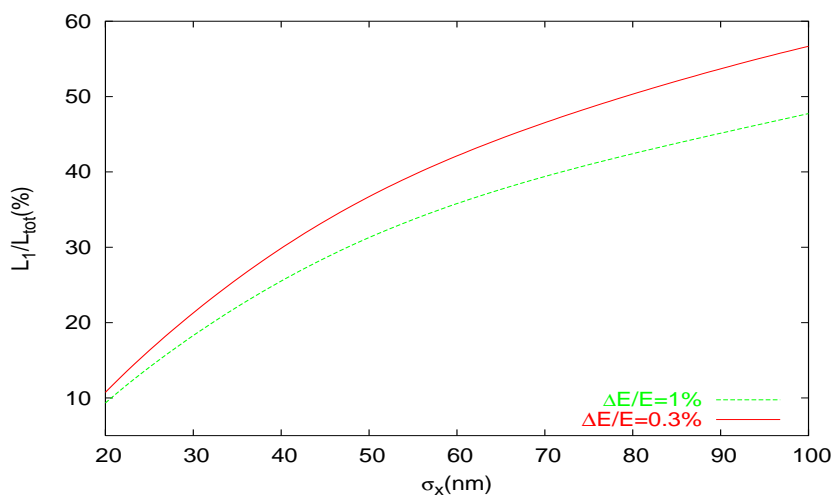
→ Beamstrahlung with the parameters  $N_c$  and  $\Upsilon$ .  
(long tail down to large energy losses),

- Another issue is due to error in the calibration of the beam energy

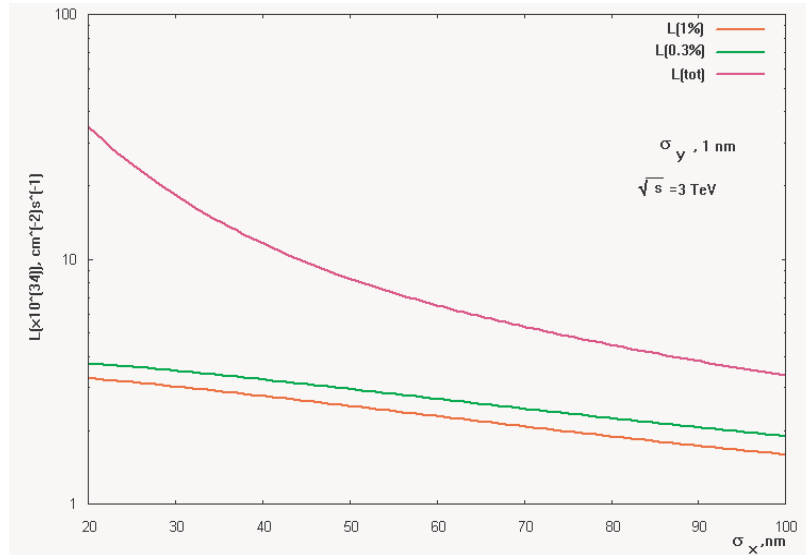
$e^+e^-$  luminosity spectrum obtained from GUINEA-PIG for two values of beam energy spread  $\Delta E/E$



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].

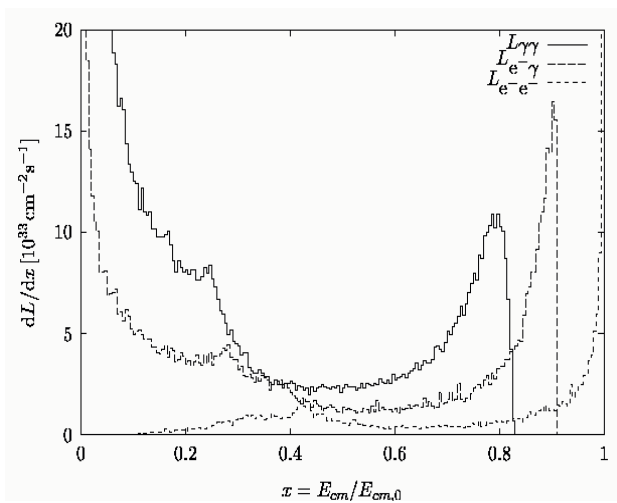


A larger horizontal beam size leads to the emission of fewer beamstrahlung photons and consequently to a **better luminosity spectrum**. However, total luminosity is reduced.



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CERN, 30 August 2004

## $e\gamma$ 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.  $L_{geom}=1.2 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ .

\*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

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

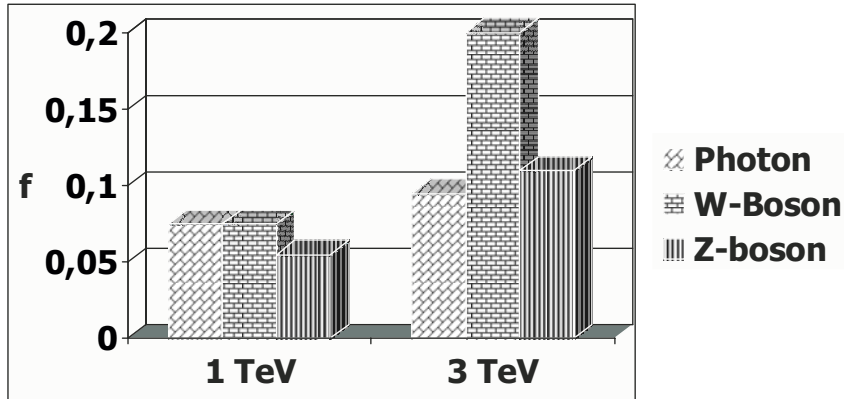
• **Total decay widths:**

$\Gamma = 1.15$ GeV at $m^* = 200$ GeV	$\rightarrow \Gamma/m^* = 0.57\%$
$\Gamma = 3.38$ GeV at $m^* = 500$ GeV	$\rightarrow \Gamma/m^* = 0.68\%$
$\Gamma = 6.93$ GeV at $m^* = 1$ TeV	$\rightarrow \Gamma/m^* = 0.69\%$
$\Gamma = 20.92$ GeV at $m^* = 3$ TeV	$\rightarrow \Gamma/m^* = 0.70\%$
$\Gamma = 34.88$ GeV at $m^* = 5$ TeV	$\rightarrow \Gamma/m^* = 0.70\%$

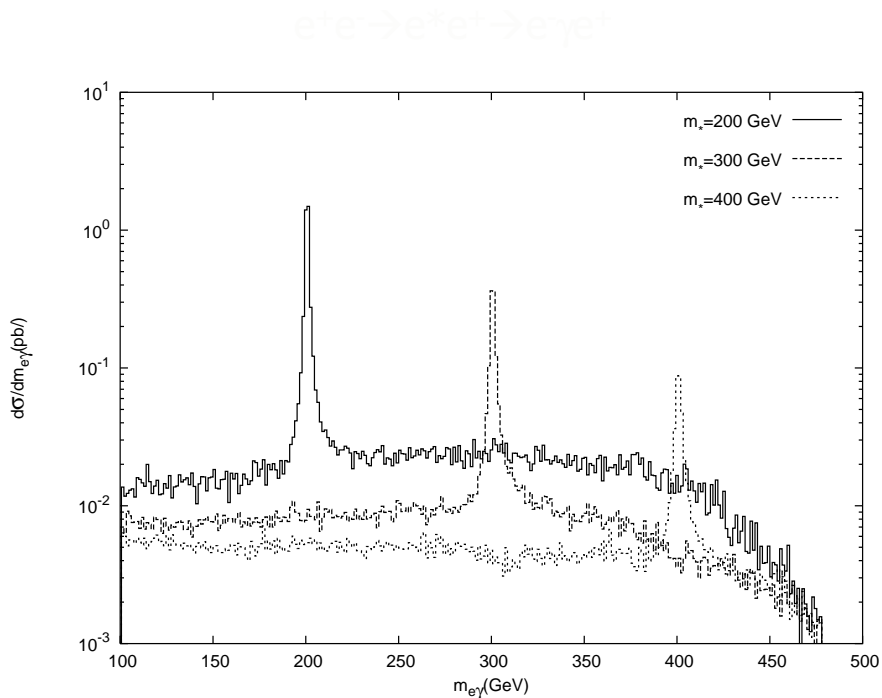
**Narrow width: If we take  $\Lambda = 5$  TeV,  $\Gamma/m^* = 0.028\%$  for  $m^* = 1$  TeV.**

Excited electrons can be observed down to the couplings  $f=f'=0.05$  at  $\sqrt{s}=1$  TeV and  $f=f'=0.1$  at  $\sqrt{s}=3$  TeV.

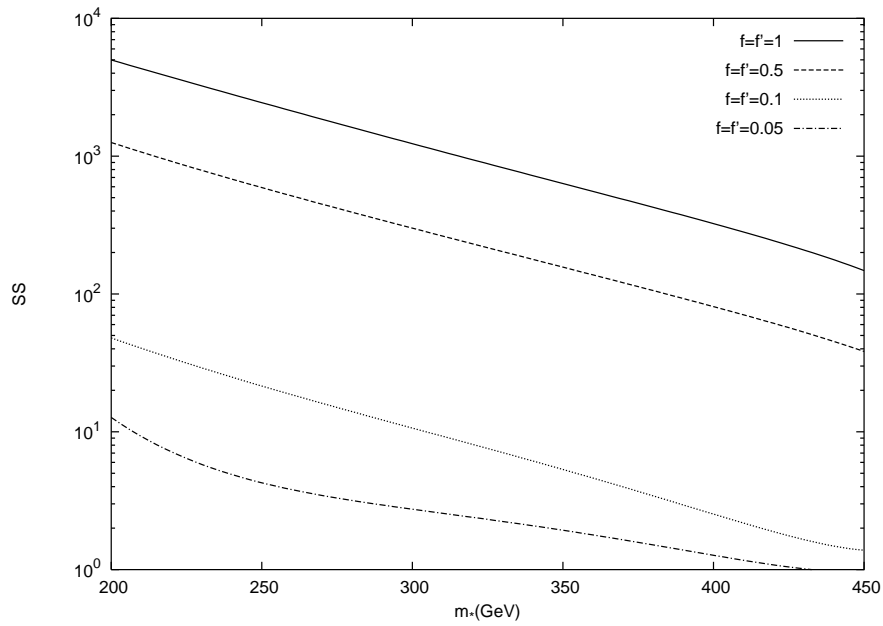
$e\gamma \rightarrow e^* \rightarrow lV$ :  $m^*=750$  GeV,  
 $\Lambda=m^*$



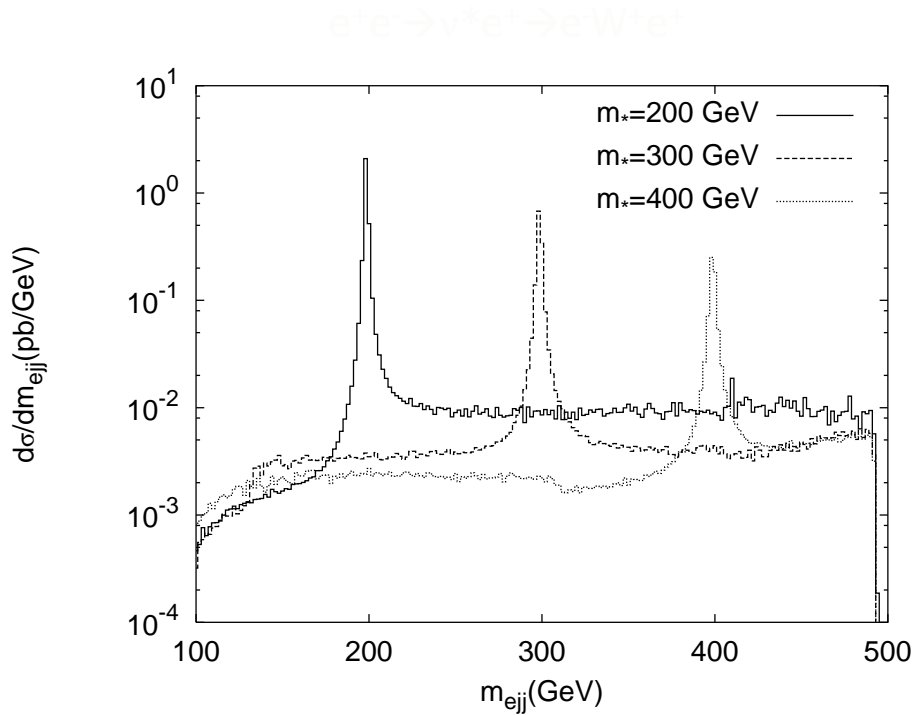
Single production of excited electron at CLIC with  $\sqrt{s}=500$  GeV [4].



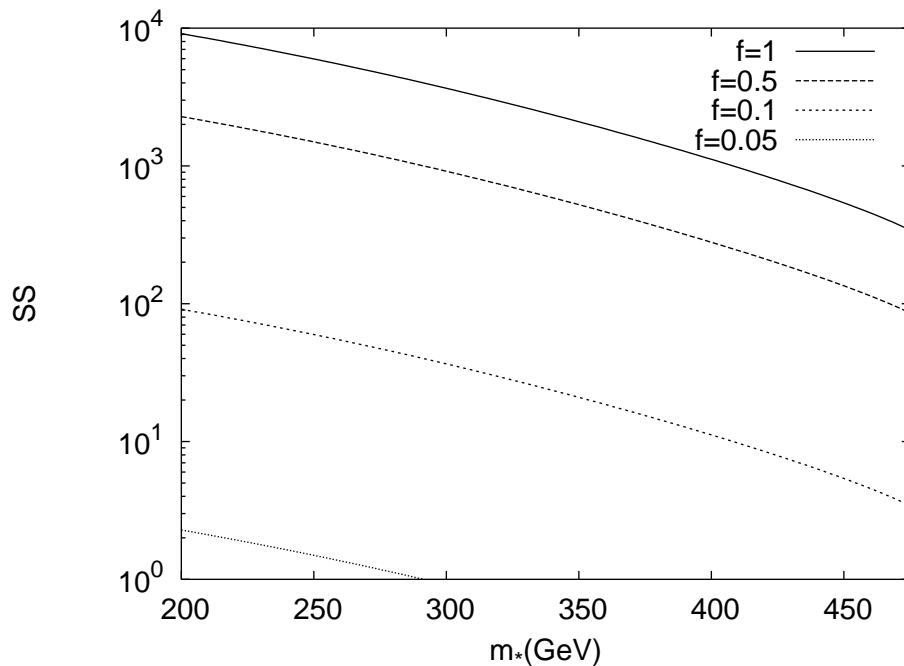
Statistical significances depending on the mass of excited electron for different coupling parameters.



Single production of excited neutrino at CLIC with  $\sqrt{s}=500$  GeV [5].



**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, $e\gamma \rightarrow e^* \rightarrow lV$	30% at res.	47% (43%)
Single $e^*, \nu^*$ $e^+e^- \rightarrow e^*e^+,$ $e^+e^- \rightarrow \nu^*\nu$	6%	- [-]



# Conclusion

- Resonance productions of  $e^*$  at CLIC based  $e\gamma$  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

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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)
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