Electron and Photon Interactions at Very High Energies

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Overview

- Overall introduction
- Higgs sector
- Supersymmetry
- Heavy Majorana neutrinos
- Inverse neutrinoless double beta decay
- Photon collider — general attractions
- Compton polarimetry at SLC
- Deeply virtual Compton scattering
- Radiative Corrections and polarization effects
- Compatibility of e^+e^- and e^-e^- interaction regions
- Specific machine aspects (CLIC)

Overall Introduction

Definitions

- Moeller scattering; e^-e^- ∏ …
- Bhabha scattering: e^+e^- ∏ …
- Compton scattering: γC ∏ … (C = charged particle)

Additive Quantum Numbers of Different e^-e^- initial states

Table 1. Additive quantum numbers of different-helicity e^-e^- initial states: judicious choices of polarization parameters can tune the final-state representations, fix chiral couplings of the incoming electrons.

	Q_{el}	S_Z	L	L_e	I_3^W	Y_W
$e_L^- e_L^-$	-2	1	2	2	-1	-2
$e_L^- e_R^-$	-2	0	2	2	-1/2	-3
$e_R^- e_R^-$	-2	-1	2	2	0	-4

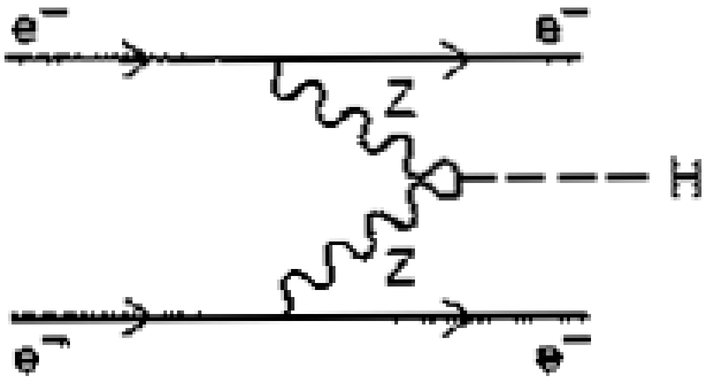
Advantages of using e^-e^- interactions

- e^- can be highly polarized (e^+ cannot!)
- Easily available
- Clearly described (no form factor)

Clean description, clean experimentation

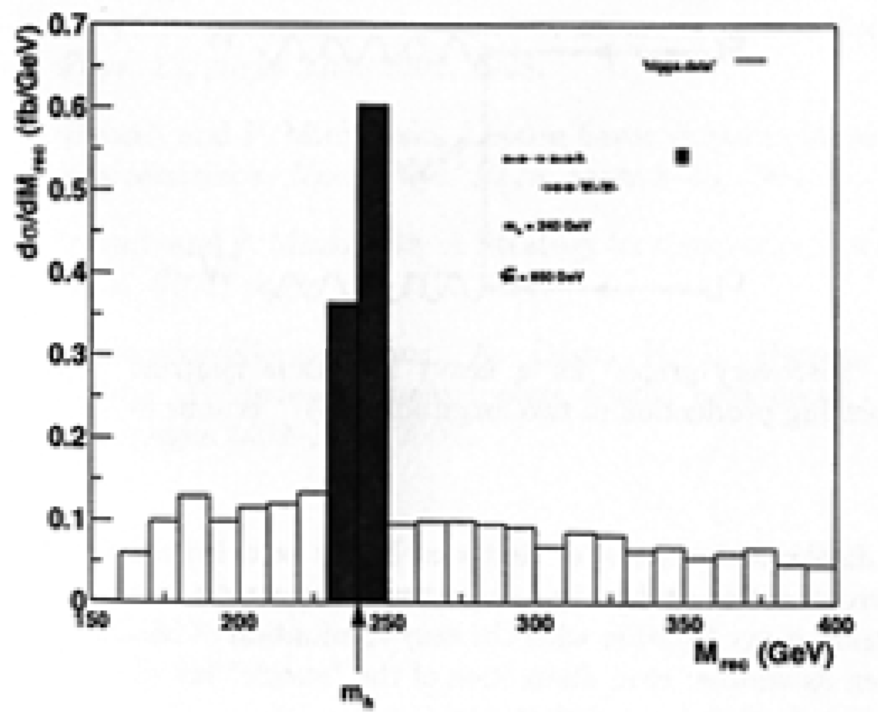
Higgs Sector

The Clear Signal for H Production in $e^- e^-$ Interactions



Clean, clear signal for H production!

Differential cross section of standard H^0 scalar production



Differential cross section of standard H^0 scalar production for m_h = 240 GeV — at c.m. energy of 850 GeV, and the background reaction $e^-e^- \prod e^-e^- W^+W^-$, with respect to the recoil mass.

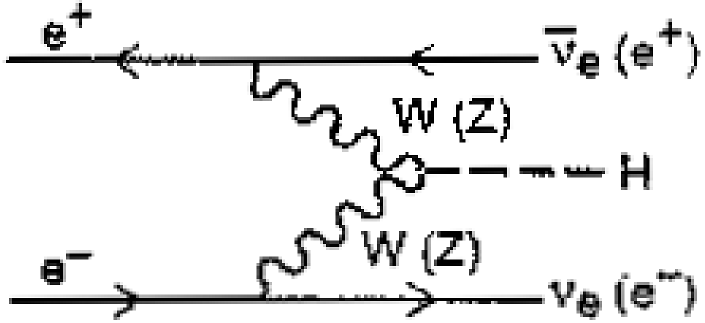
Examples for Outstanding Possibilities of e^-e^- Collisions

- In the context of this Lomonosov conference, it will be useful to consider a few specific examples of the capabilities of using highly polarized electron beams as the principal input to experimentation. While there is no need to be exhaustive, I will give a few outstanding interactions that delineate the strengths of this particular <in| state.
- Altogether, we cannot find a better defined initial state than two monoenergetic pointlike electrons of chosen spin orientation.
- The ILC will be the first machine where we find the option of colliding e^+e^+, e^+e, or e^-e^- at full energy as well as, at slightly reduced energy, $\gamma\gamma$ and $e^-\gamma$, but still at full luminosity.

Let us look at a few illustrative examples.

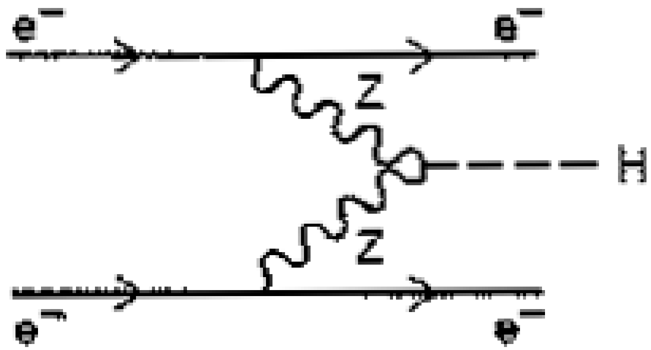
A Study of the Higgs Sector

The standard production process of the neutral Higgs boson is by e+e- annihilation into a virtual Z boson, followed by "Higgsstrahlung".



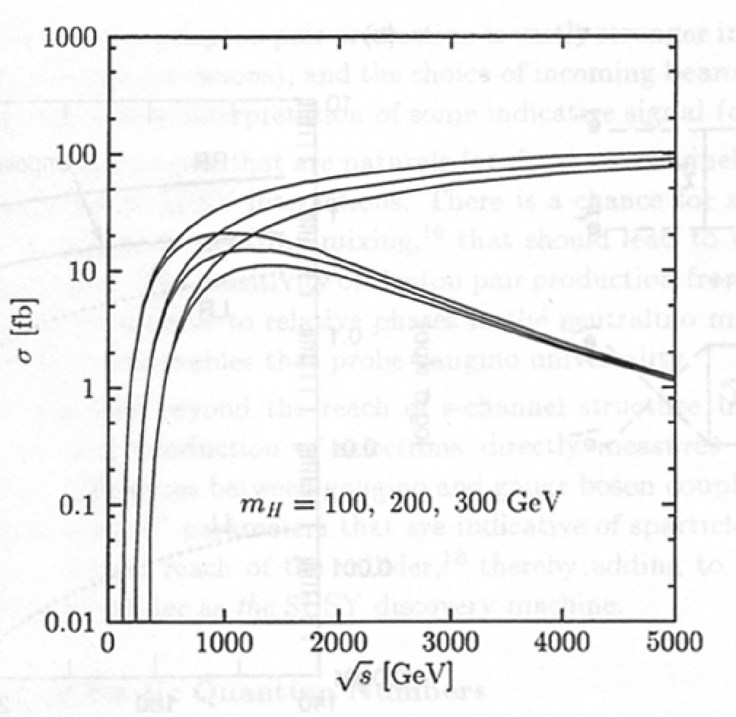
Alternatively e^+ and e^- emit virtual W's or Z's that fuse into an H^0, where the kinematics are not fully measurable because of the emitted neutrinos.

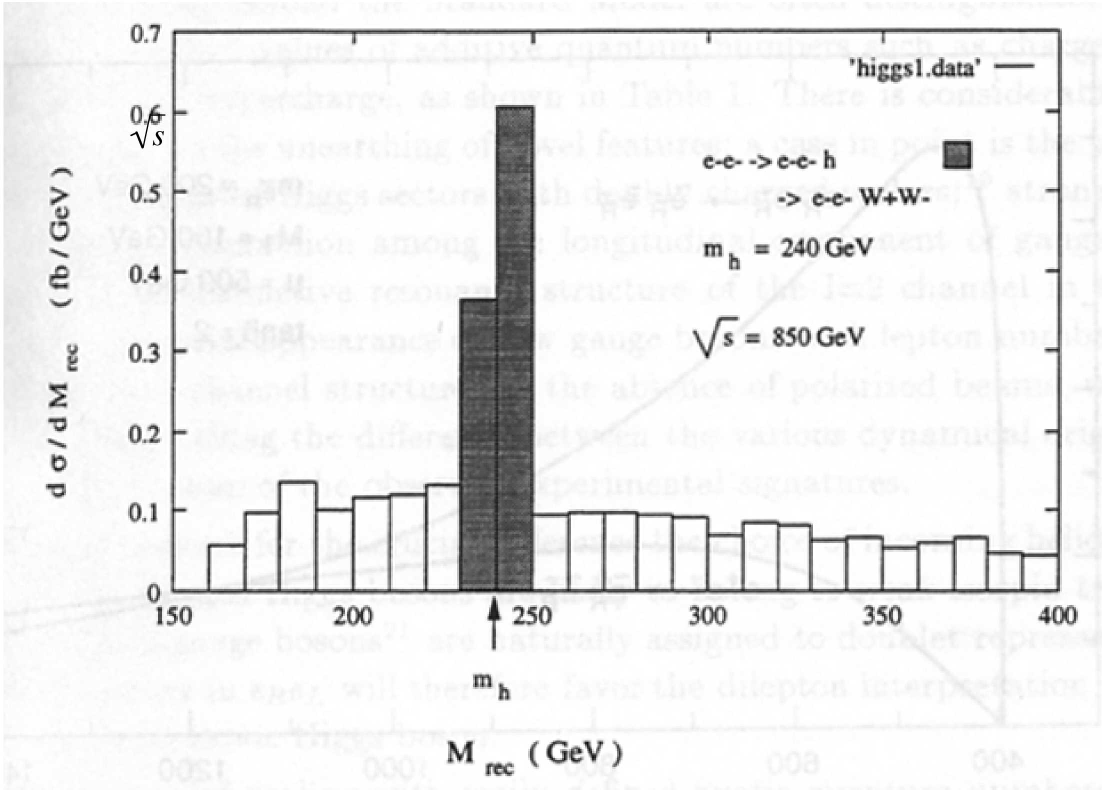
The preferable mode of Higgs boson production in e^-e^- interactions, where the final-state electrons define the Higgs mass fully, is



Central Production Cross Section for Higgs Bosons

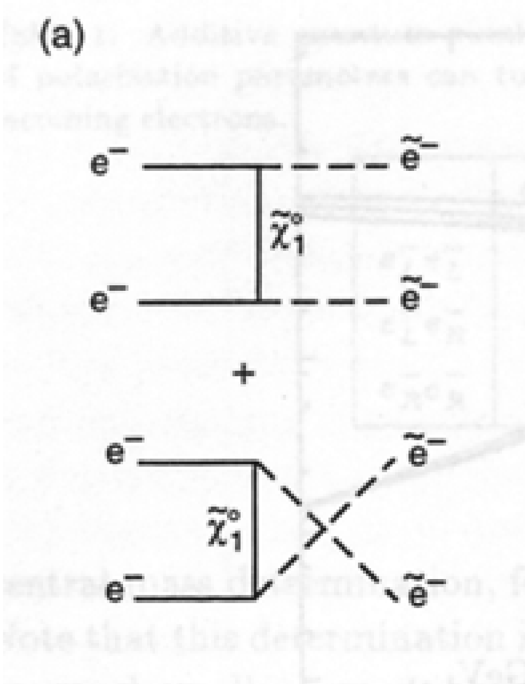
Rises steeply and saturates above $3m_H$

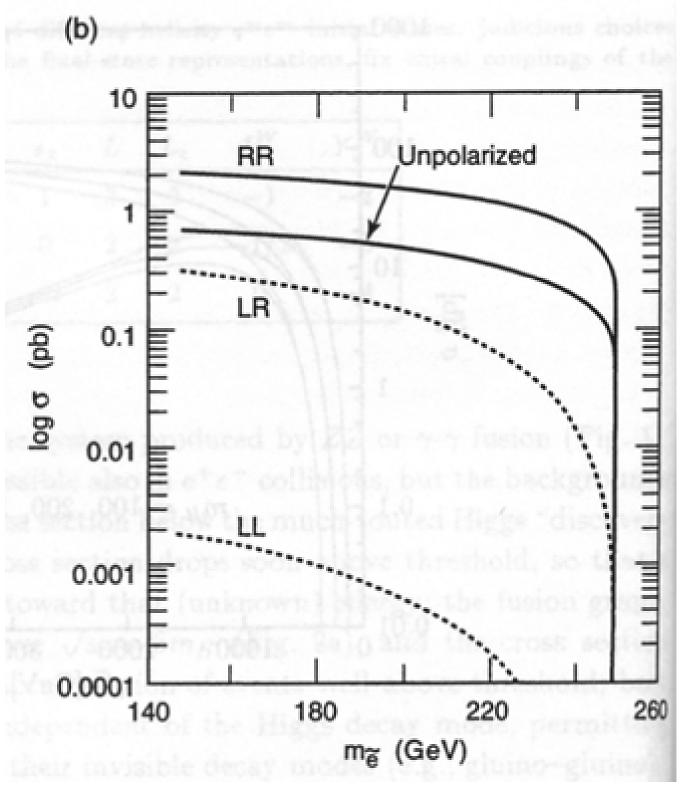




Supersymmetry

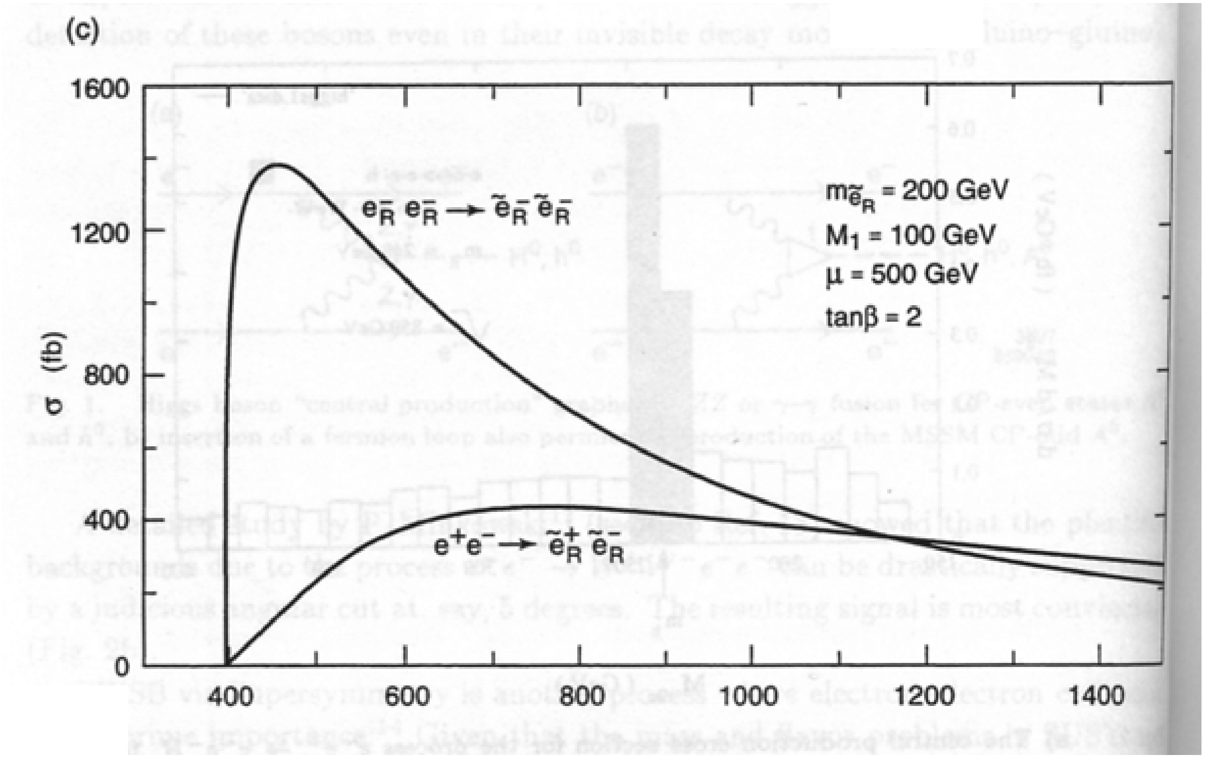
Supersymmetry Applications





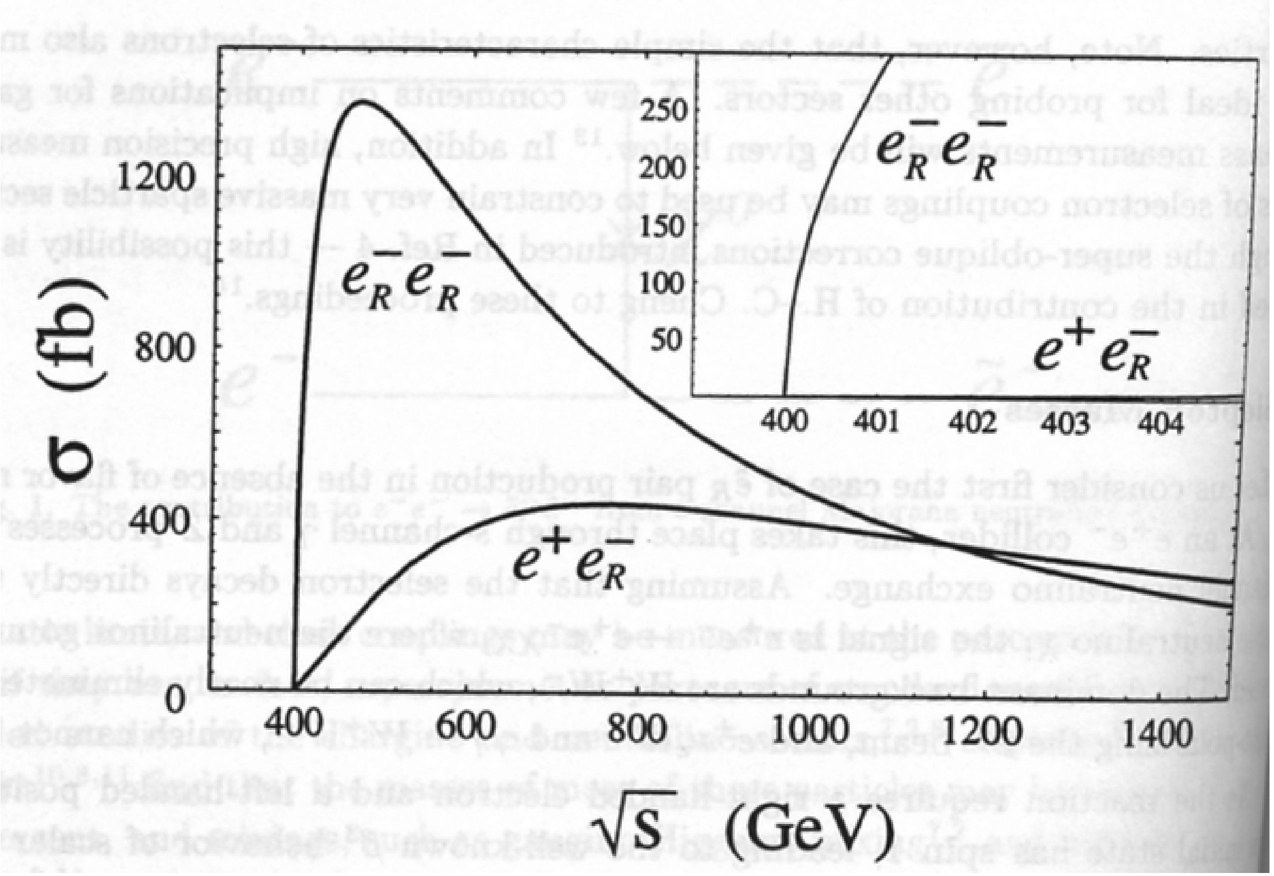
Selectron pair production in e^-e^- collisions. a) Basic graphs with neutralino exchange. b) The cross-section as a function of the selectron mass shows a strong polarization dependence. The e_Re_R mode is vastly preferred, backgrounds can be identified by e_Le_L operation.

Supersymmetry Applications



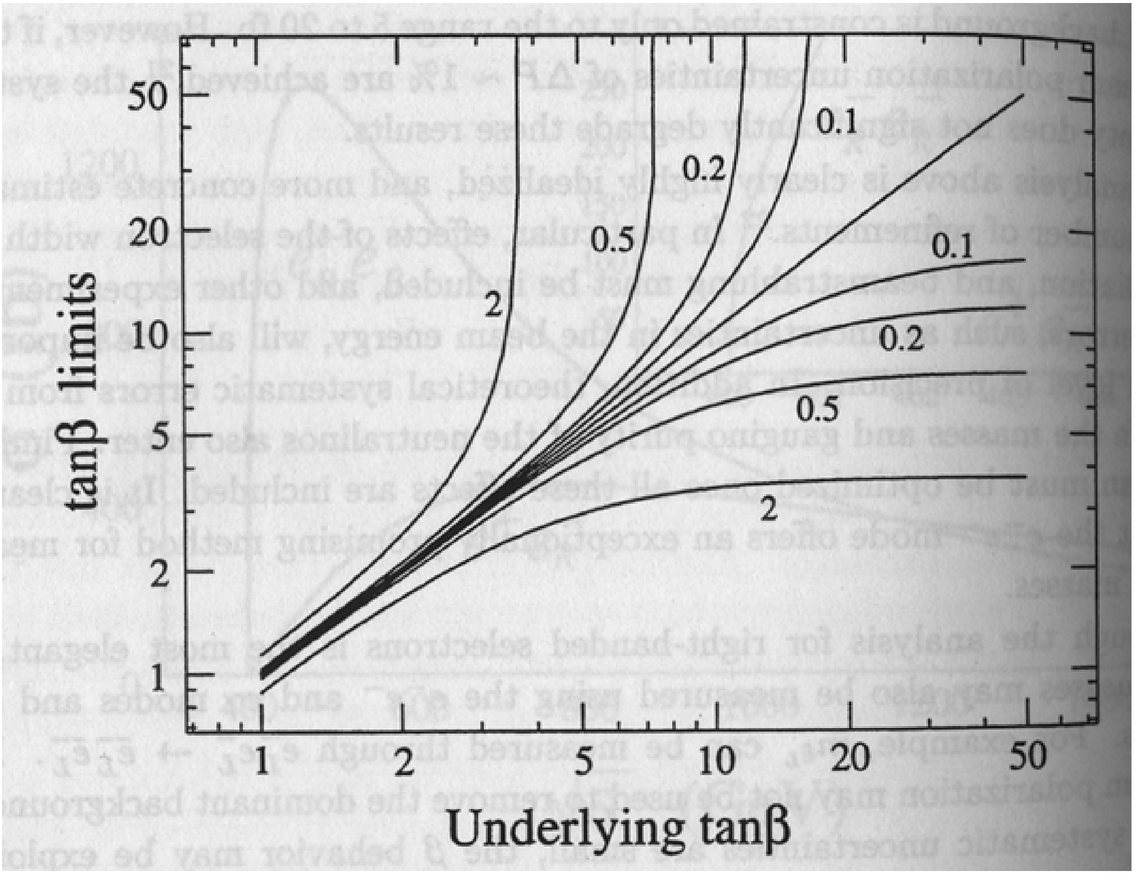
Selectron pair production in e^-e^- collisions. c) The sharp turn-on at threshold show why e^-e^- collisions are the natural choice for slepton pair production; mass determination is at least an order of magnitude better than in e^+e^- annihilation.

Supersymmetry Applications



Cross sections for selectron pair production. Note the huge advantage of e^-e^- vs. e^+e^-.

Supersymmetry Applications



Measurement of tanß, which has important implications for Yukawa couplings and other SUSY measurements.

Heavy Majorana neutrinos

Feynman diagrams for heavy Majorana neutrino exchange

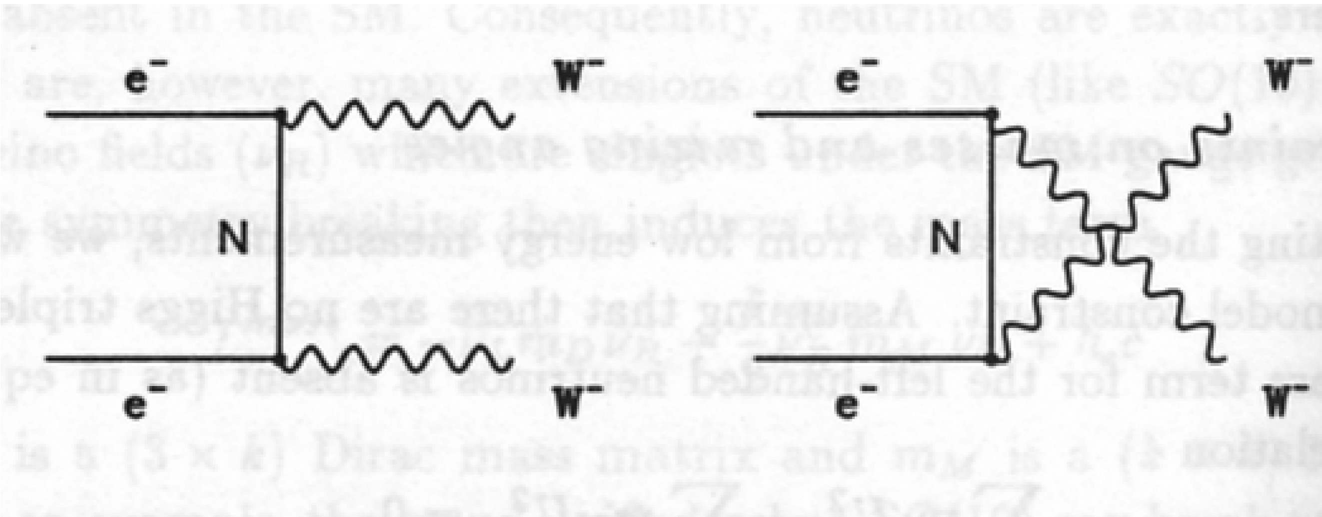
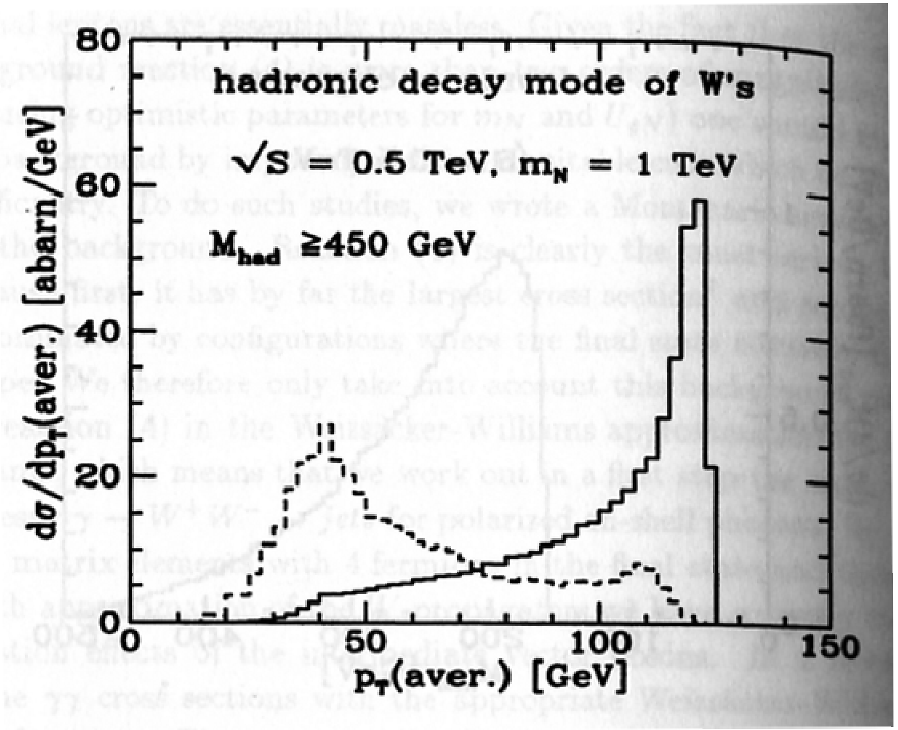
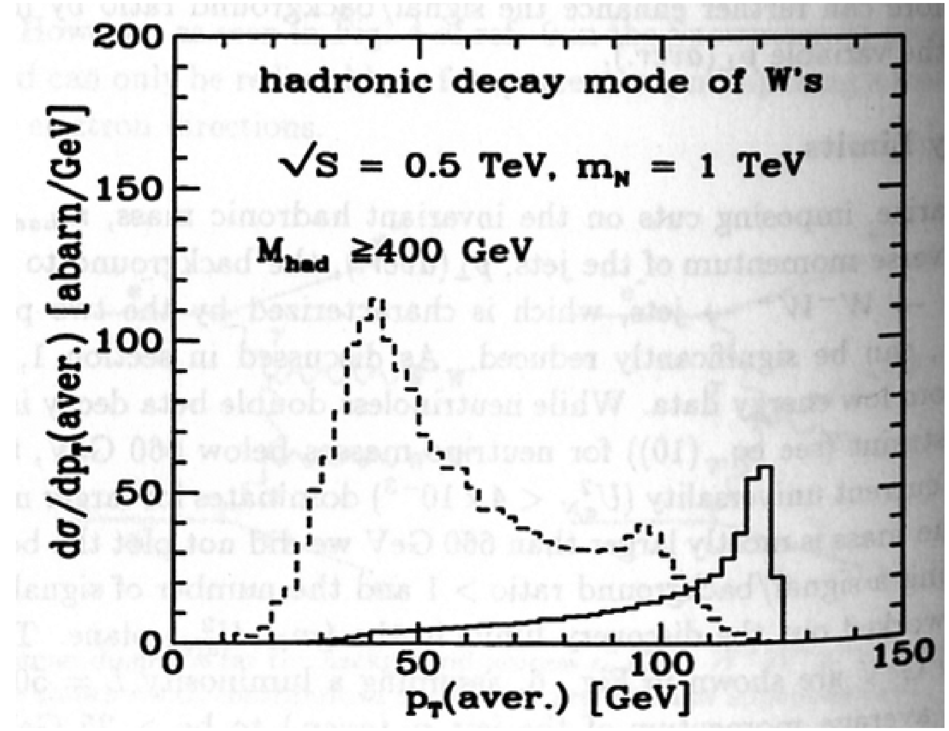


Fig. 1. Feynman diagrams for the process $e_L^- e_L^- \to W^- W^-$.

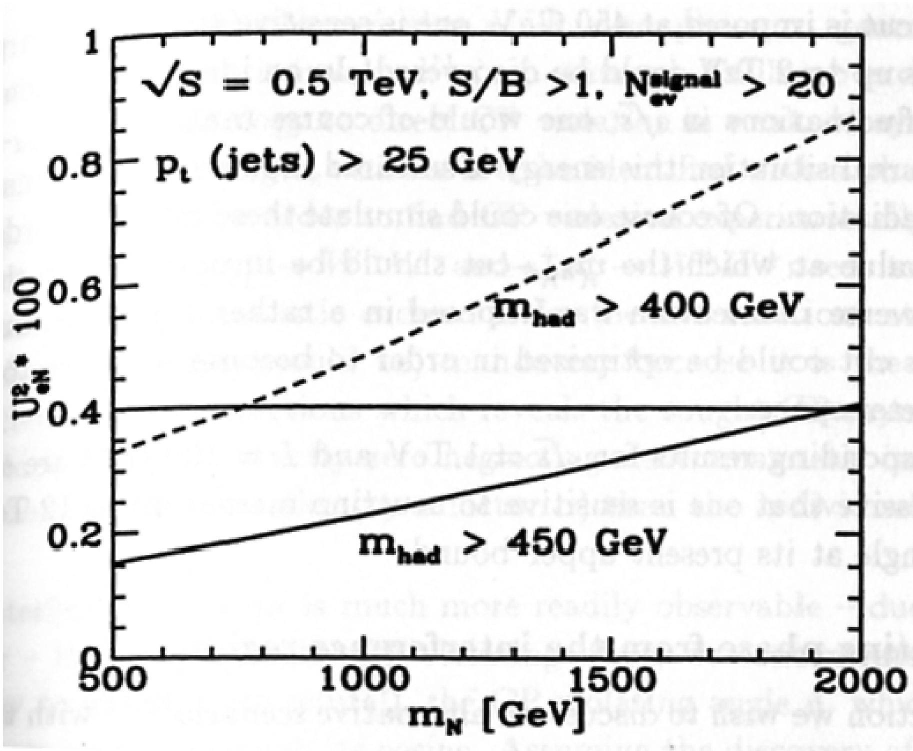
Heavy Majorana neutrinos

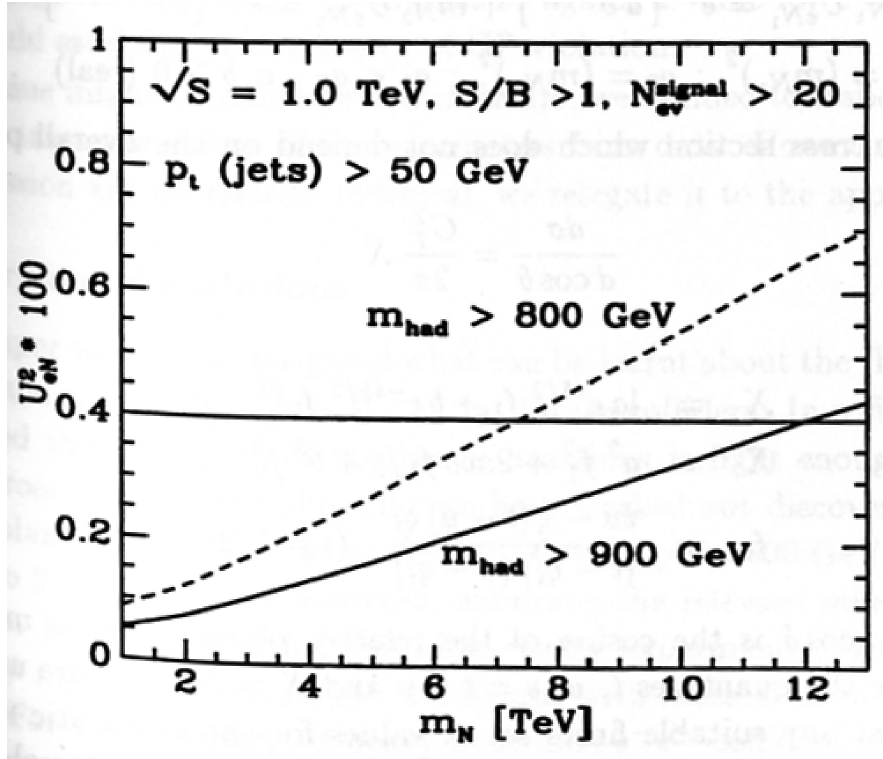




Discovery limits for heavy Majorana neutrinos

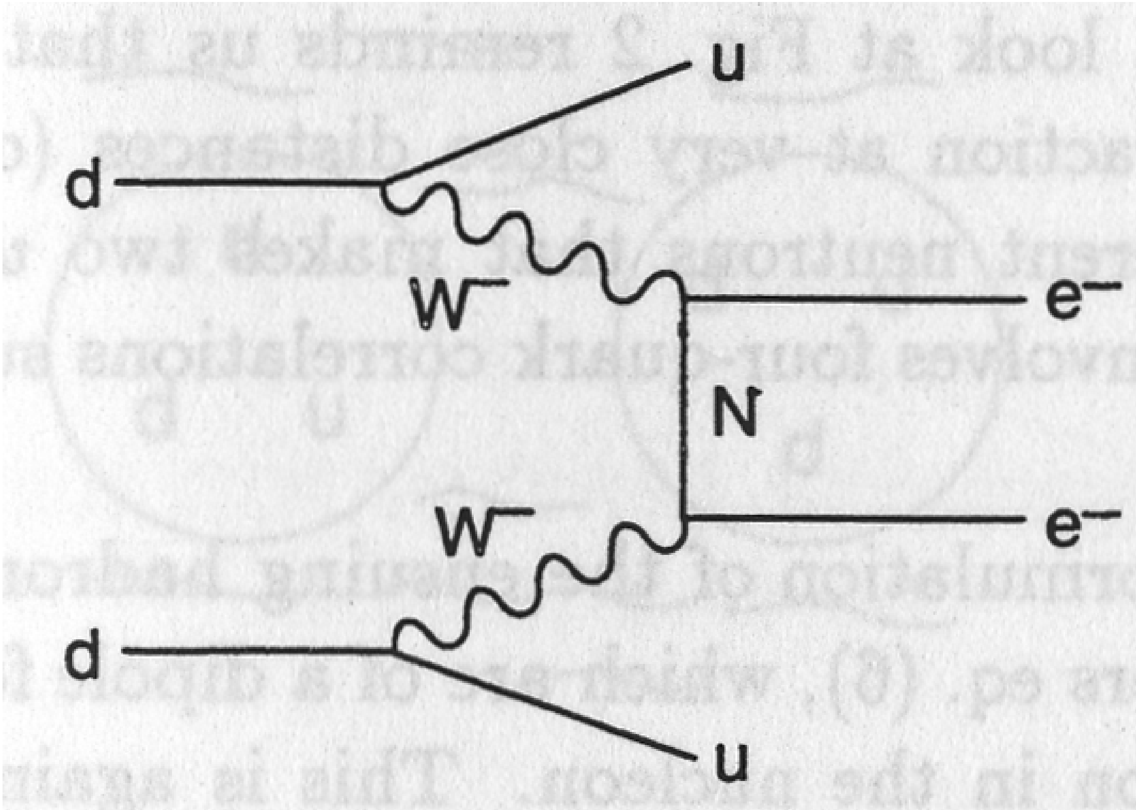
Heavy Majorana neutrinos





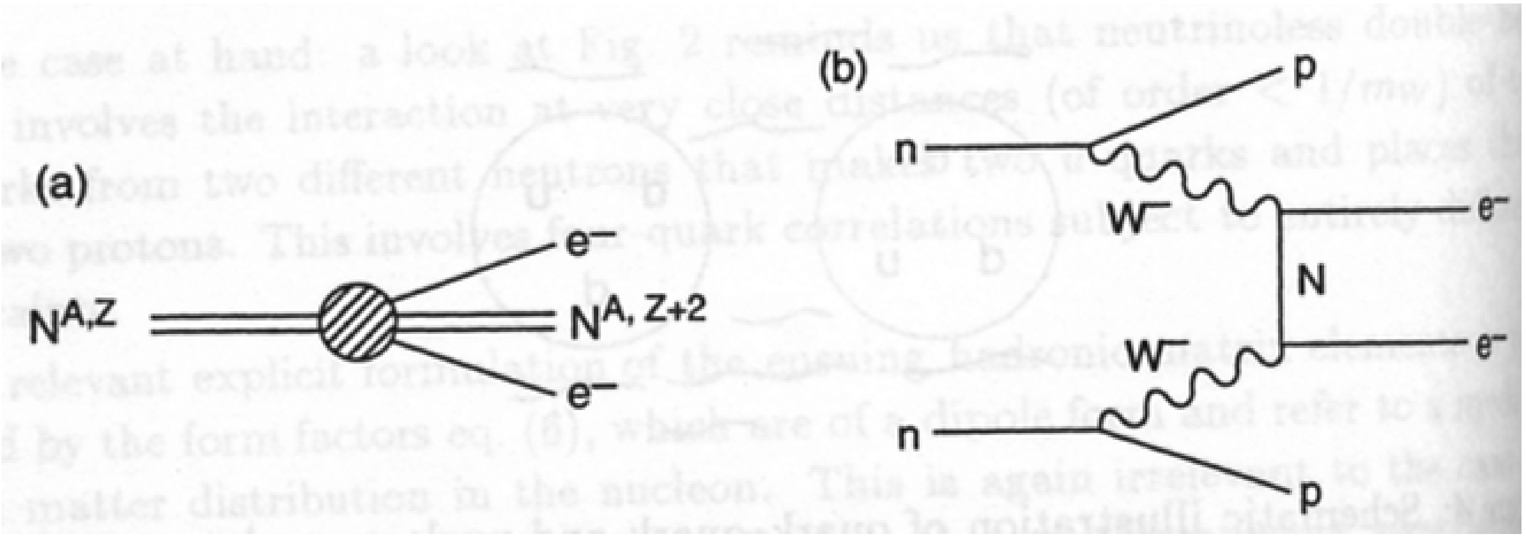
Inverse neutrinoless double beta decay

Neutrinoless Double Beta Decay



The quark-level subprocess in neutrinoless double beta decay mediated by a Majorana neutrino N.

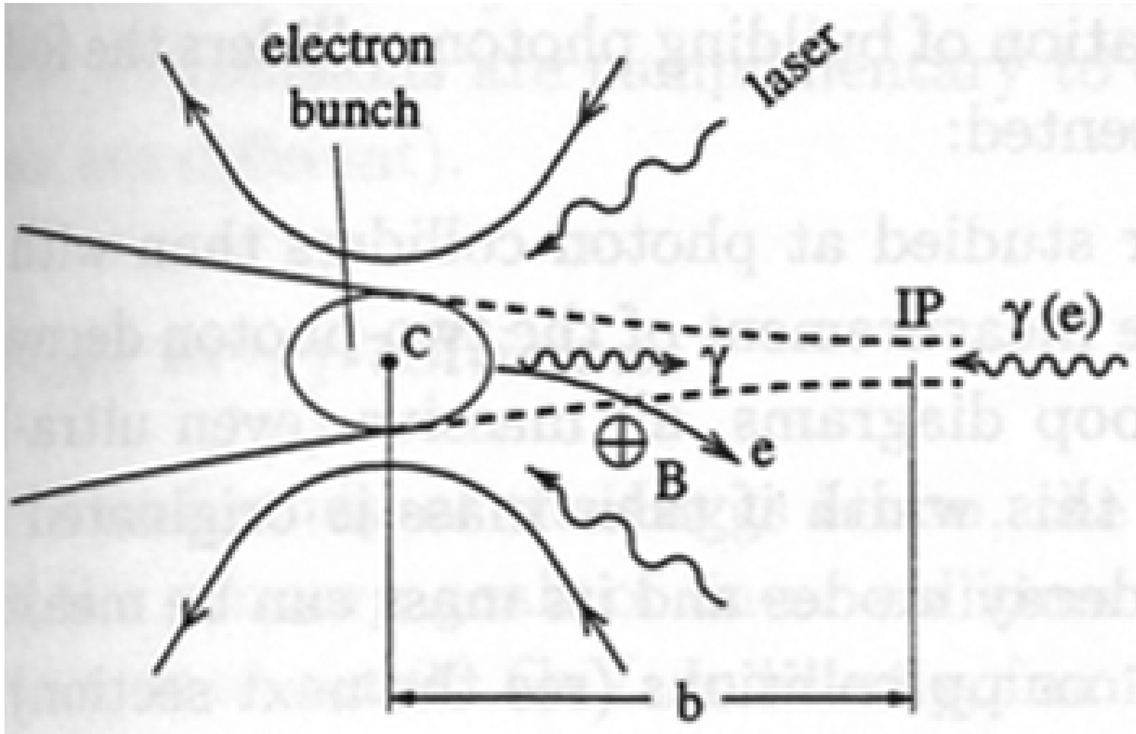
Neutrinoless Double Beta Decay



The constraints on the quark-level diagram for neutrinoless double beta decay process shown in previous slide are imposed on the nuclear (a) and nucleon (b) level.

Photon collider — general attractions

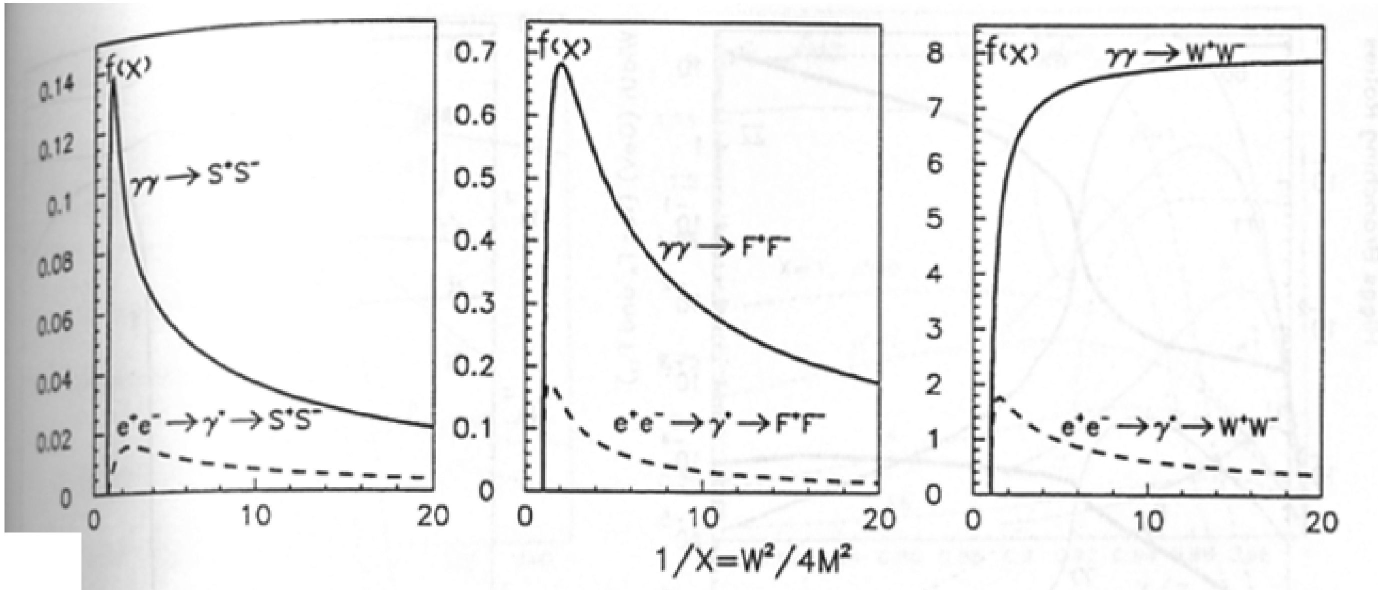
Photon Colliders



Scheme for γγ, γe collisions

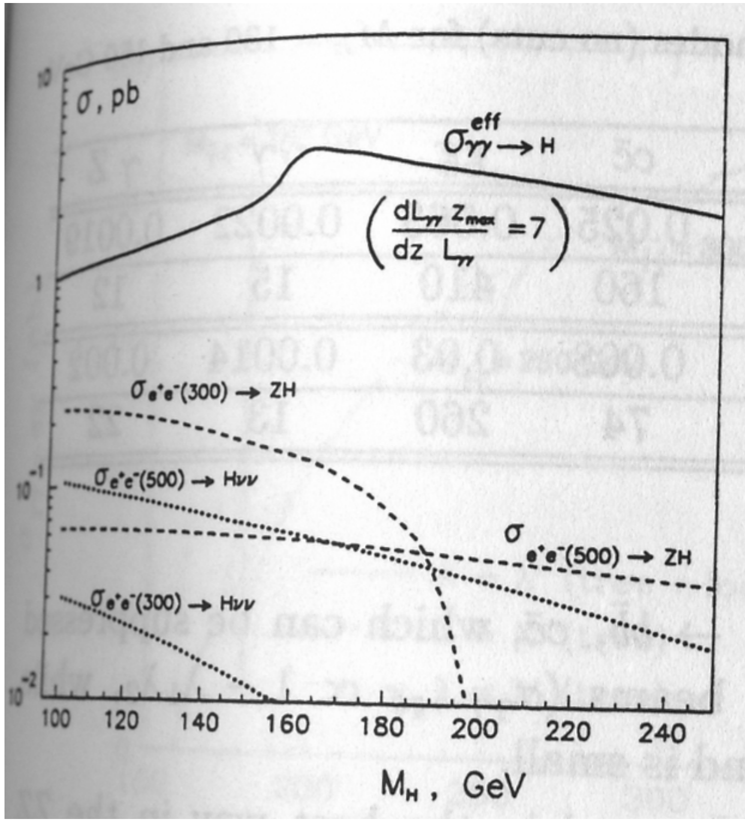
Photon Colliders
$\gamma\gamma$ and γe Collisions

The special usefulness of $\gamma\gamma$ collisions — no overall charge, no polarization



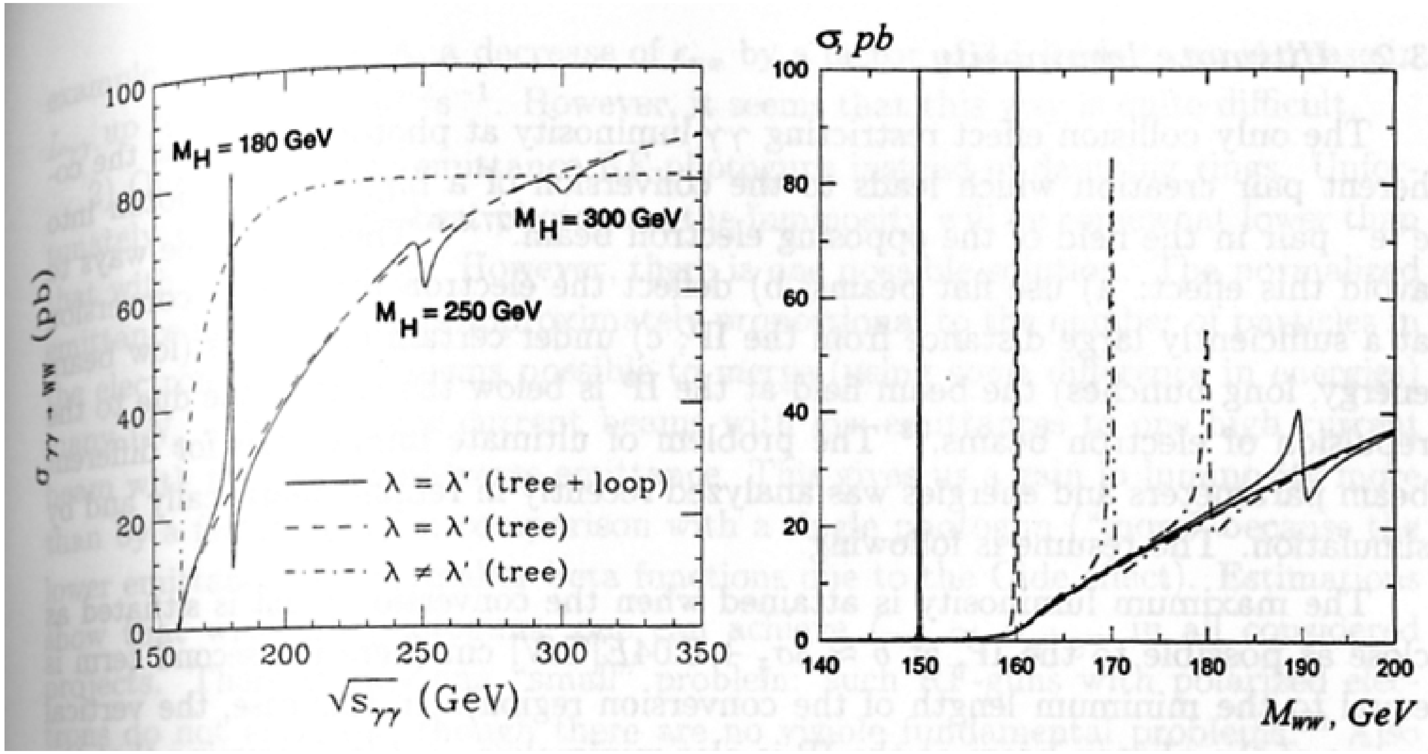
Comparison of cross sections for charged pair production in e^+e^- and $\gamma\gamma$ collisions. The cross section $\sigma = (\pi\alpha^2/M^2)f(x)$, P=S (scalars), F (fermions), W (W-bosons); M is particle mass, $x = W^2_{p\bar{p}}/4M^2$. The functions $f(x)$ are shown.

Photon Colliders
Higgs production in γγ collisions



Comparison of Standard Model Higgs production in γγ and e^+e^- collisions.

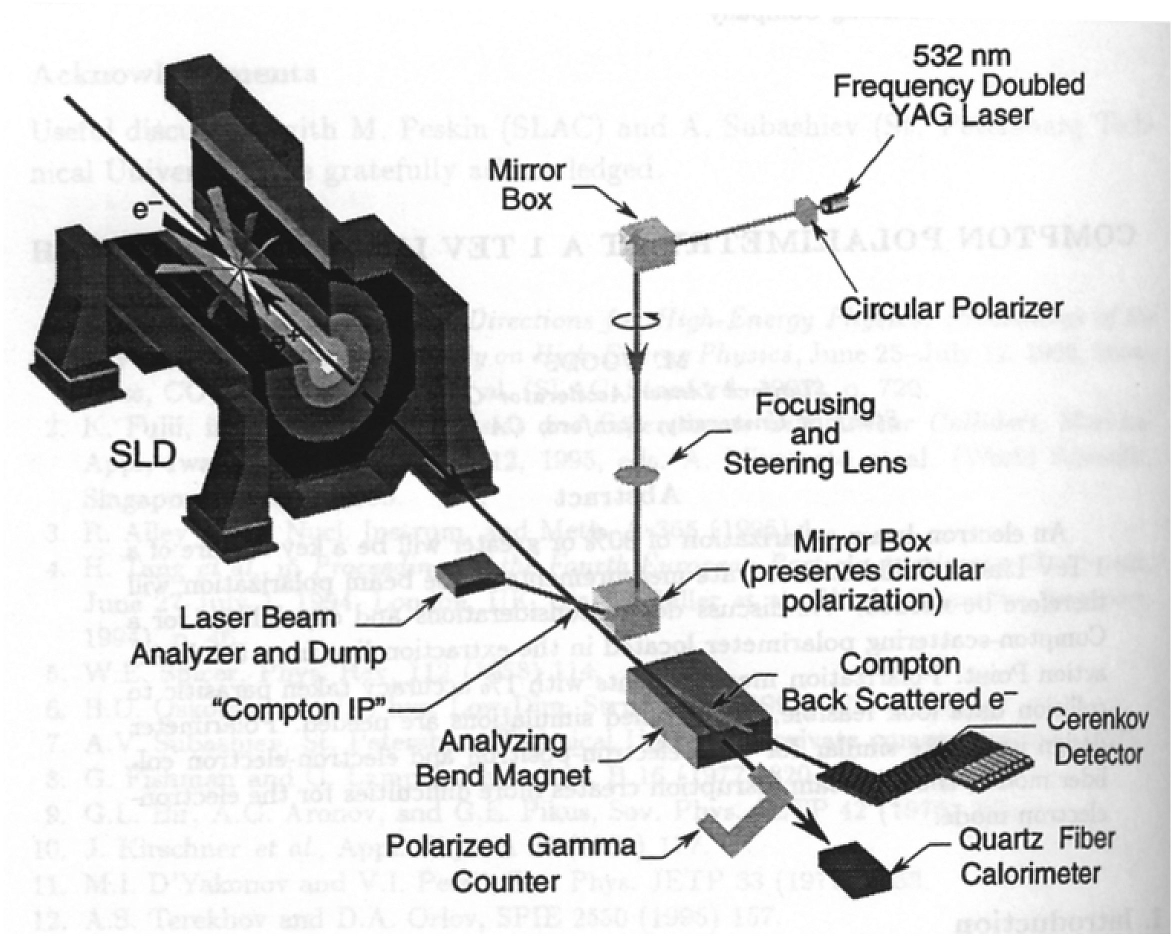
Photon Colliders
Producing WW in $\gamma\gamma$ collisions



The $\gamma\gamma$ Π WW cross section for various Higgs masses. The influence of Higgs masses on WW production.

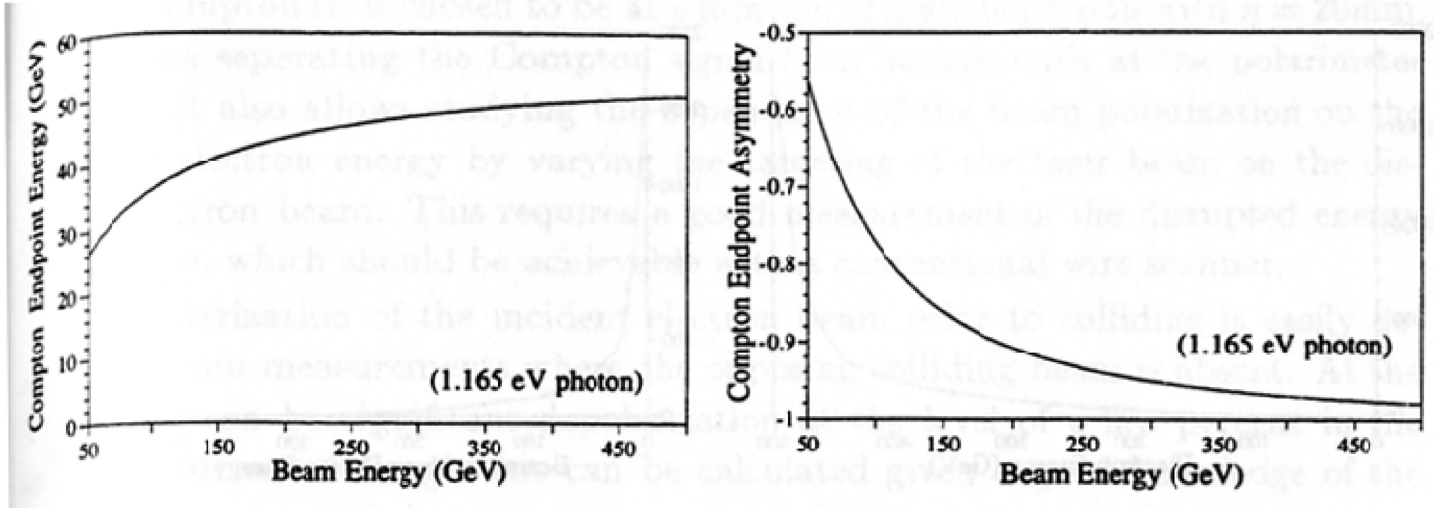
Compton polarimetry at SLC

Compton Polarimetry



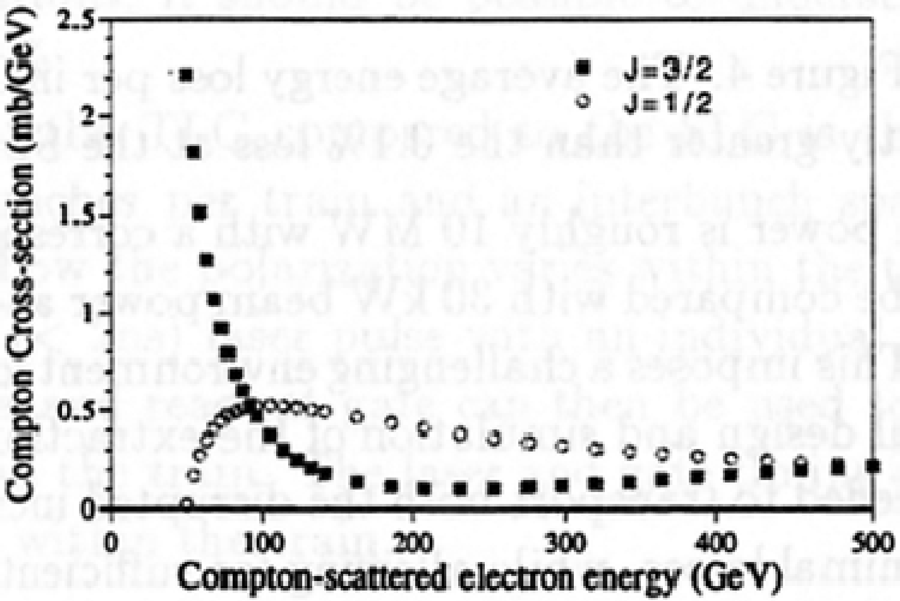
Compton polarimeter for the 1 TeV Linear Collider being tried out at the SLD experiment.

Compton Polarimetry



Compton electron endpoint energy and endpoint asymmetry vs beam energy

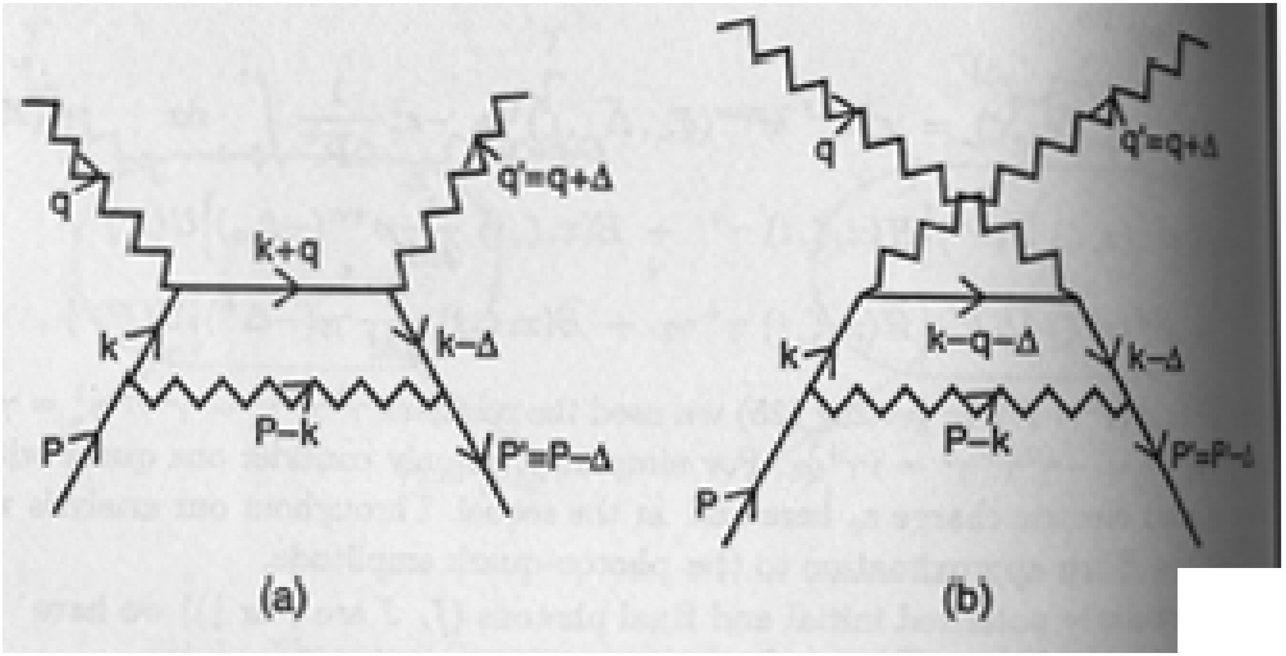
Compton Polarimetry



Compton scattering cross-sections for the J=3/2 and J=1/2 polarization states

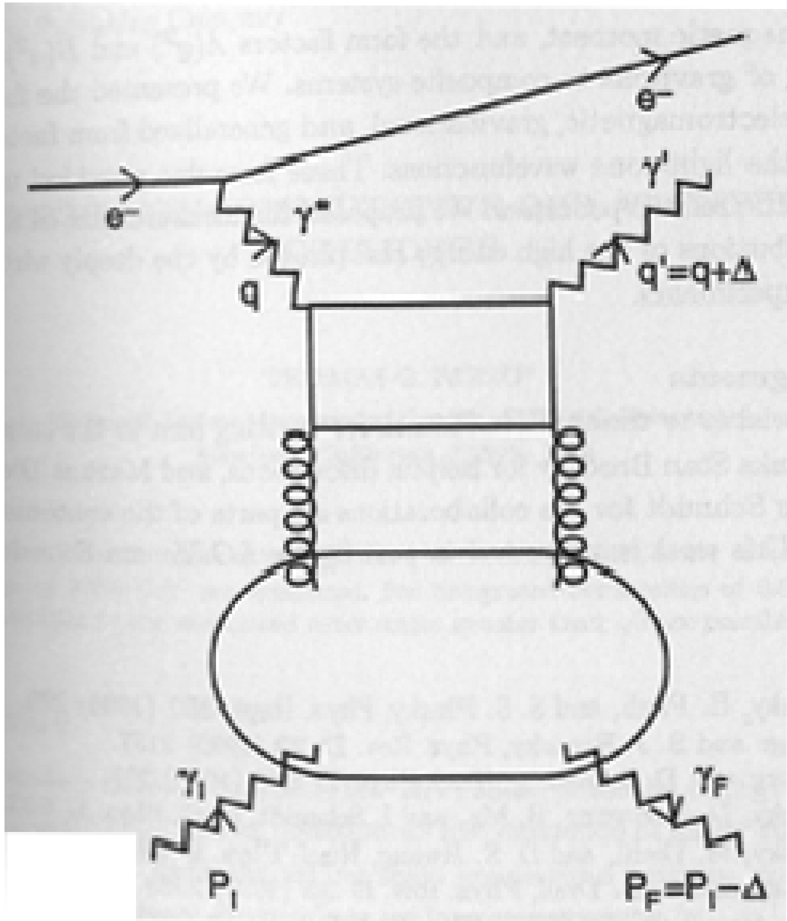
Deeply virtual Compton scattering

Deeply virtual Compton scattering



One-loop covariant Feynman diagrams for virtual Compton scattering.

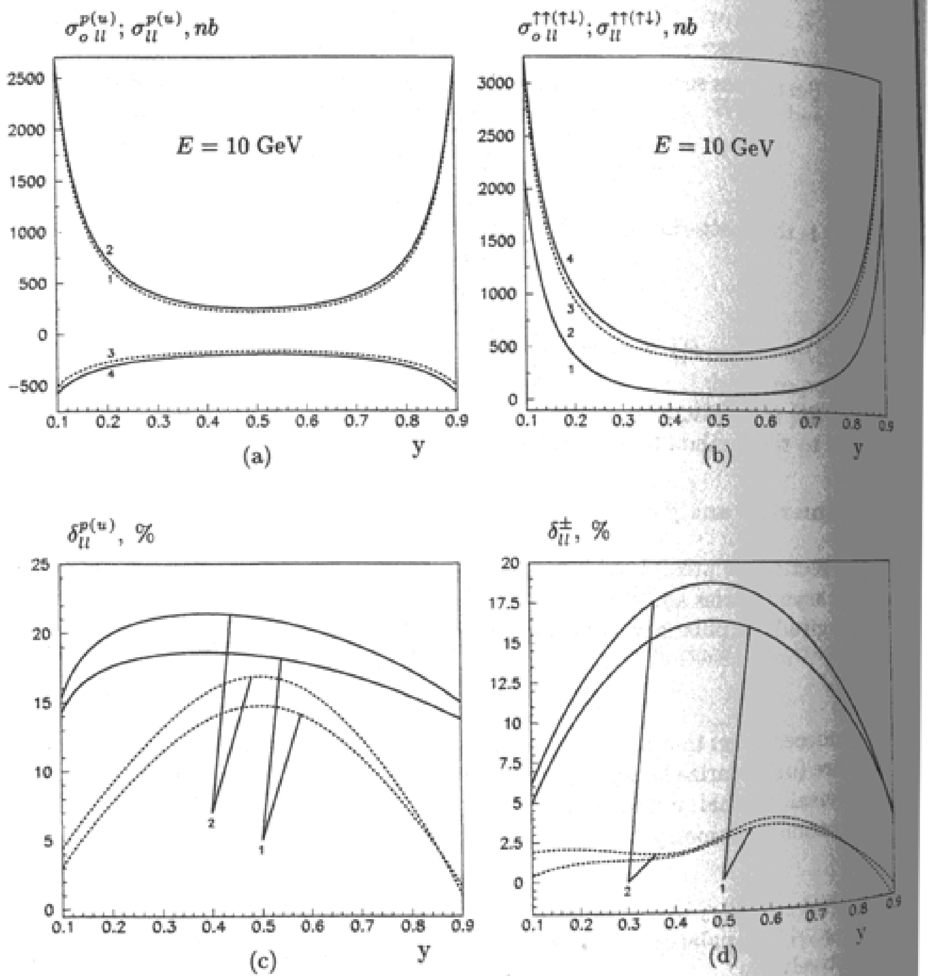
Deeply virtual Compton scattering



The virtual Compton amplitude $\gamma^*(q) + \gamma_I(P) \Pi \gamma(q') + \gamma_F(P')$

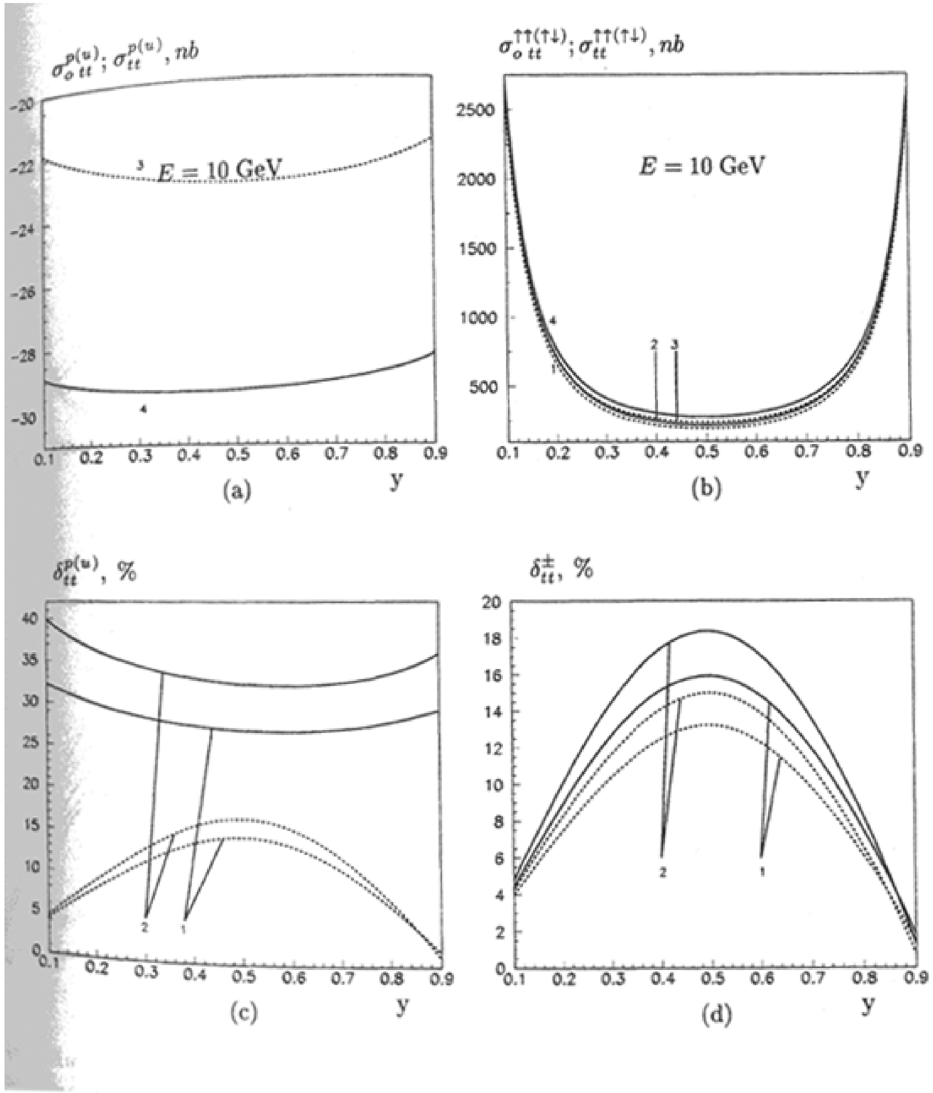
Radiative Corrections and Polarization Effects

Radiative Corrections



y-dependence of e^-e^--scattering cross section and corrections to it. $S=2mE$. (a): $\sigma_o^u(1)$, $\sigma^u(2)$, $\sigma_{o\,ll}^p(3)$, $\sigma_{ll}^p(4)$; (b): $\sigma_{o\,ll}^{\uparrow\uparrow}(1) \simeq \sigma_{ll}^{\uparrow\uparrow}(2)$, $\sigma_{o\,ll}^{\uparrow\downarrow}(3)$, $\sigma_{ll}^{\uparrow\downarrow}(4)$; (c): $\delta_{ll}^{p(u)}$ -solid(dashed) line; (d): δ_{ll}^{+} -dashed, δ_{ll}^{-} -solid line. E=10(1), 100(2) GeV.

Radiative Corrections

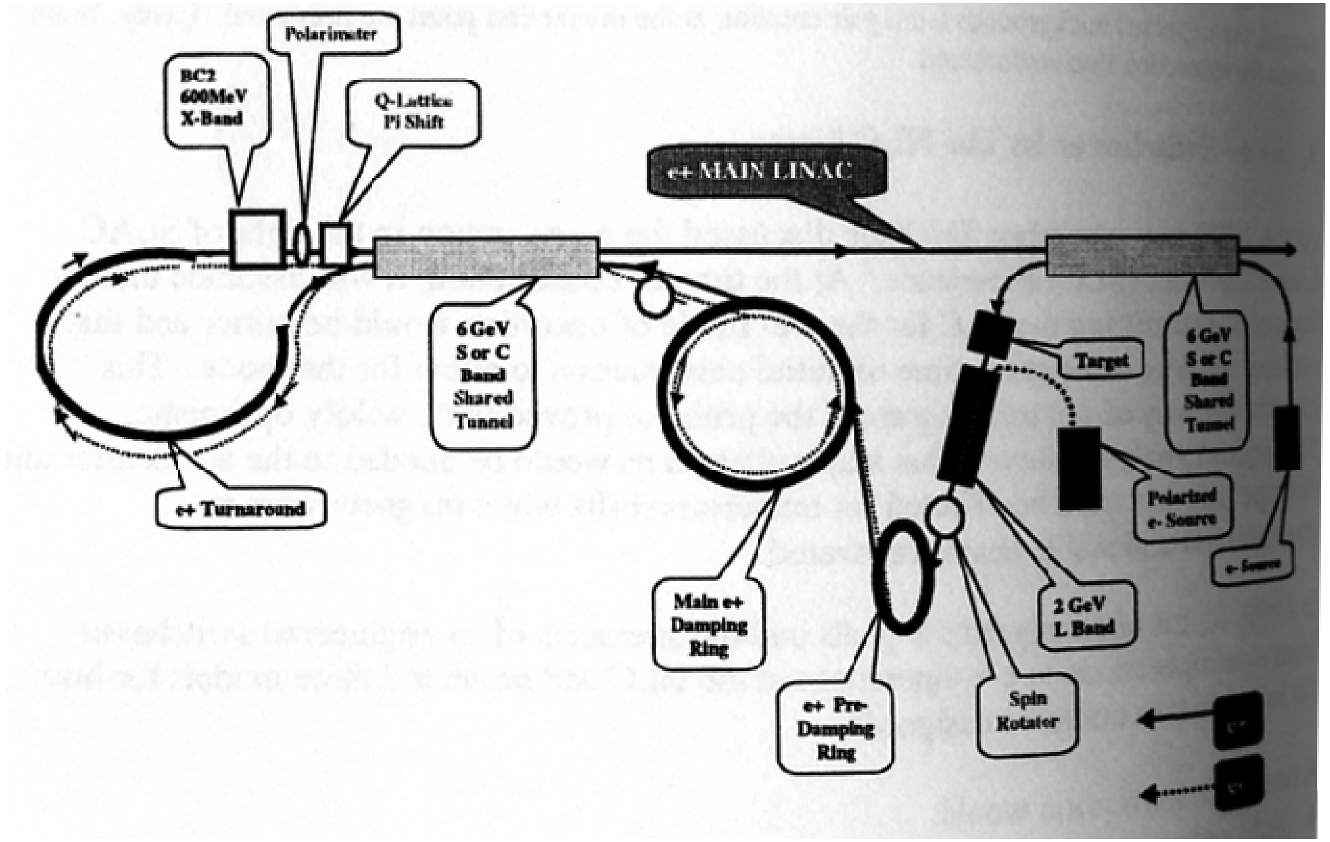


y-dependence of e^-e^--scattering cross section and corrections to it. $S=2mE$. (a): $\sigma^{p}_{o\,tt}(3)$, $\sigma^{p}_{tt}(4)$; (b): $\sigma^{\uparrow\uparrow}_{o\,tt}(1)$, $\sigma^{\uparrow\uparrow}_{tt}(2) \simeq \sigma^{\uparrow\downarrow}_{o\,tt}(3)$, $\sigma^{\uparrow\downarrow}_{tt}(4)$; (c): $\delta^{p(u)}_{tt}$ -solid(dashed) line; (d): δ^{+}_{tt} -dashed, δ^{-}_{tt} -solid line. E=10(1), 100(2) GeV.

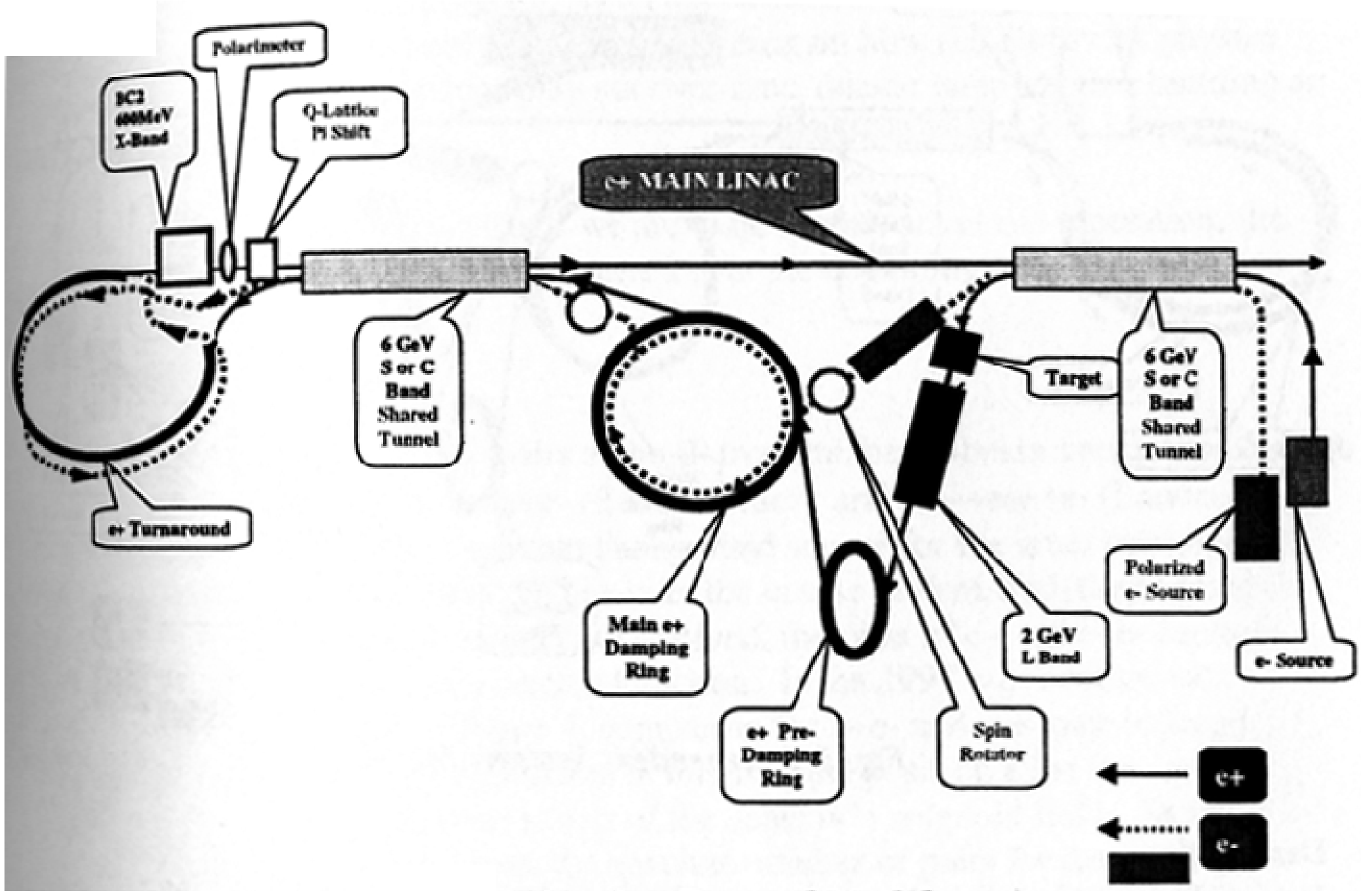
Compatibility of e^+e^- and e^-e^- Interaction Regions

These compatibility issues are being evaluated at the Stanford Linear Accelerator site.

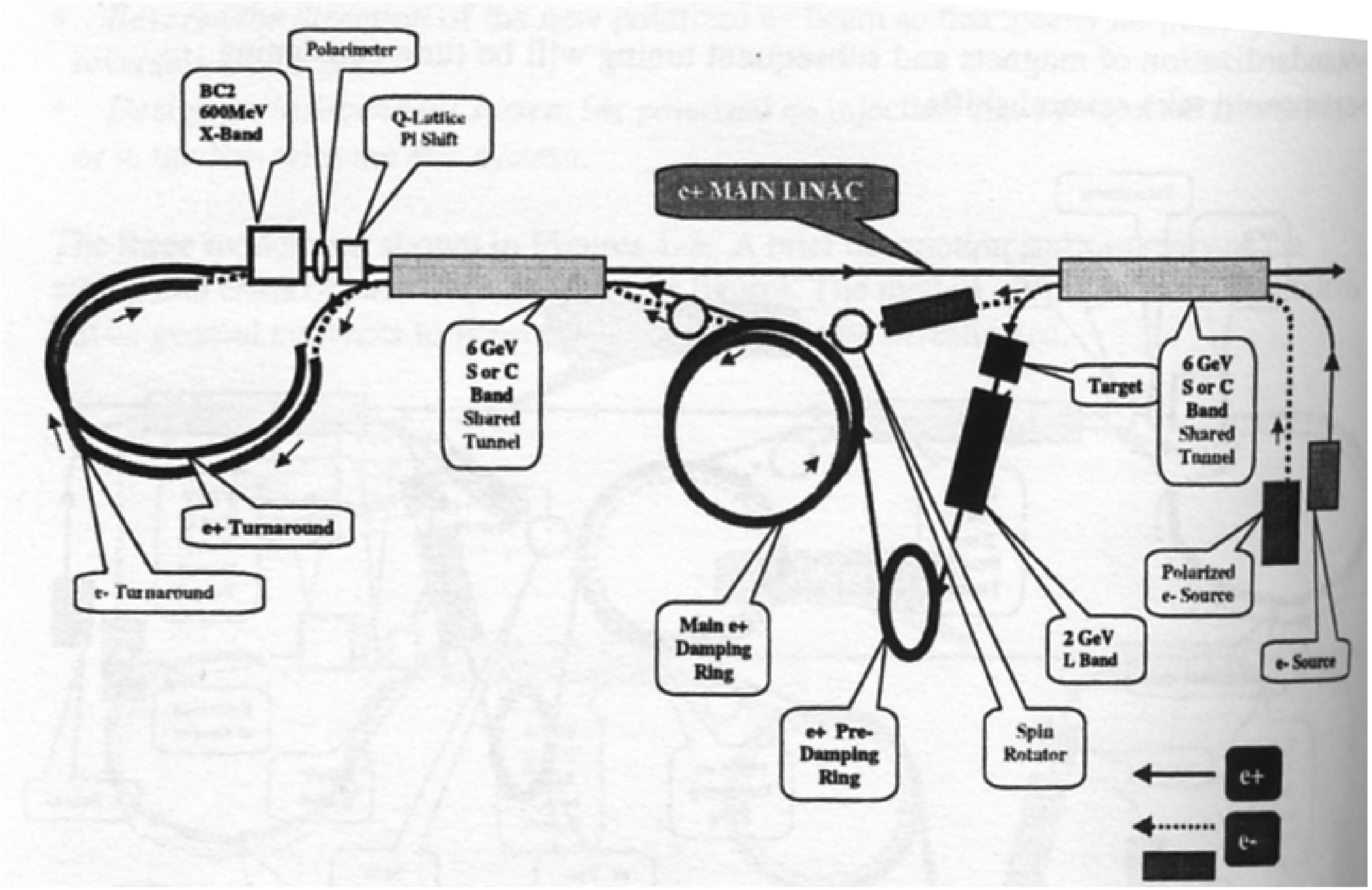
Polarity Reversal Model



Direction Reversal Model



Independent Systems Model

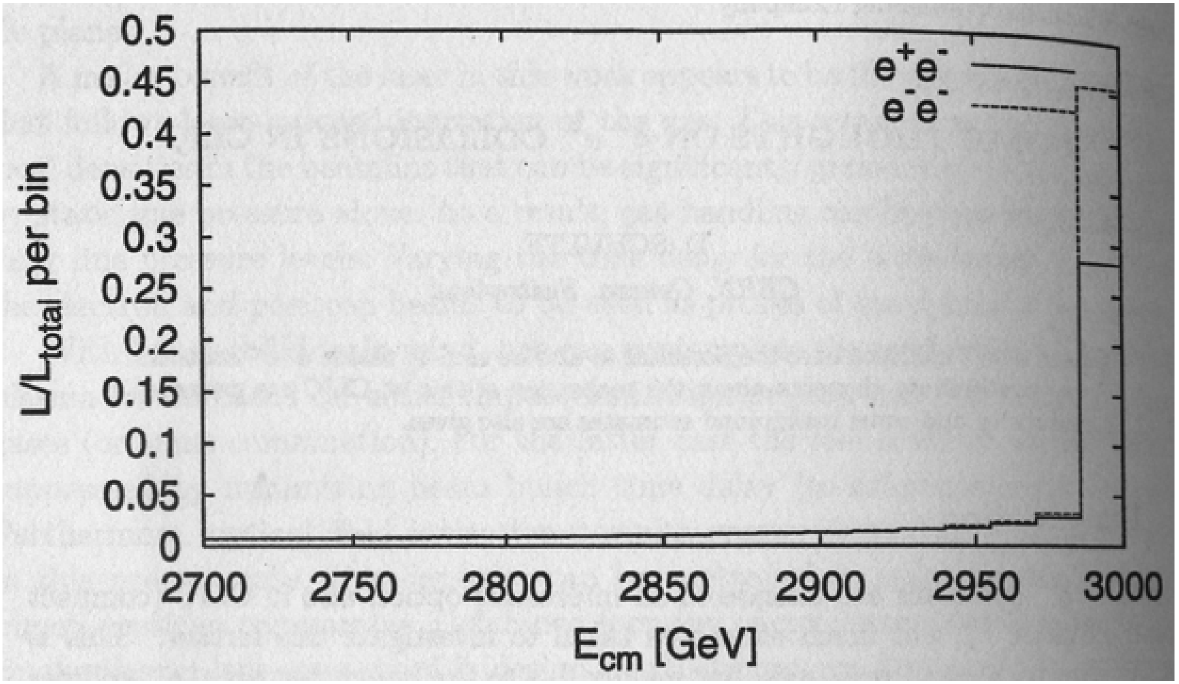


Specific Machine Aspects (CLIC)

- The CERN laboratory plans to have a high-energy linear collider that can go to relatively high energies and good luminosities. It is worthwhile considering the advisability of planning for electron-electron as well as electron-positron interactions in that machine project.

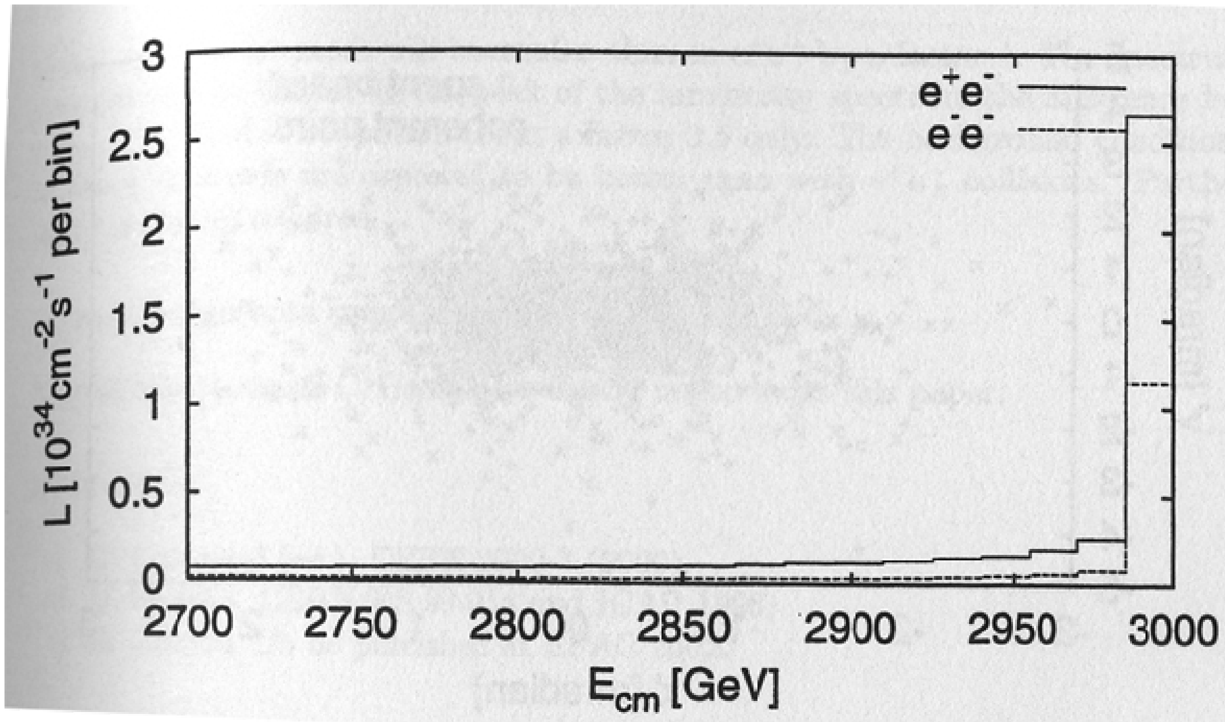
- It is also significant that, irrespective of the interaction and detection equipment, the relative luminosities of e+e- and e-e- colliders are considerably in favor of the e-e- version, as shown in the two figures added below.

Specific Machine Aspects (CLIC)



The relative luminosity spectrum for the e^+e^- and the e^-e^- case.
The bins have a width of $0.5\%E_{cm}$.

Specific Machine Aspects (CLIC)



The absolute luminosity spectrum for the e^+e^- and the e^-e^- case.