The study of the photon structure functions at the ILC energy range

On behalf of the FCAL Collaboration

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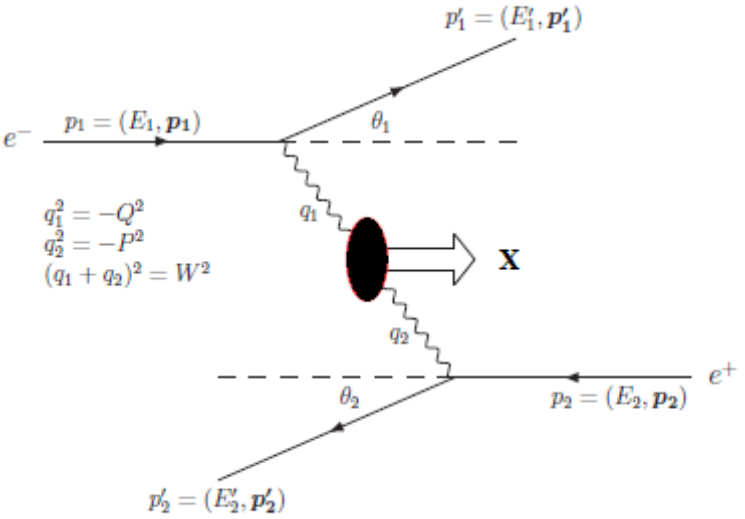
Outline

- Motivation
- Measurement of the F_2^γ structure function
- Expectations for ILC/CLIC
- The first results for the photon structure function

Is the study of photon structure important?

In spite of many studies of the photon structure, still it is needed to bring our understanding of the photon to the same level as HERA has achieved for the proton. This will offer new insights in QCD.

- As the beam energy at the ILC/CLIC will be higher, it is expected that it will be possible to measure the evolution of the photon structure function in a wider range.

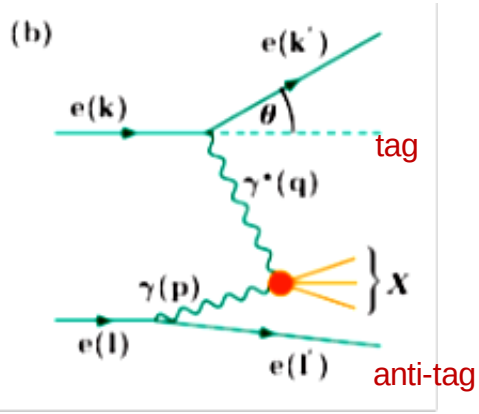


- The experimental measurement of the structure function for virtual photons is up to now a difficult task (the interaction of two virtual photons is a 'golden' process to study the parton dynamics – DGLAP and/or BFKL).
- The possibility of tagging both electrons would allow to measure W^2 independently of the hadronic final state.
- A new light on the photon structure could be shed by spin-dependent structure functions, which have not been measured so far – this would be possible in the polarized e^+e^- collisions in the future linear collider.

Photon structure function & its measurement

The single-tag process

$e^+e^- \rightarrow e^+e^-X$



$$\frac{d\sigma(e\gamma \rightarrow eX)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4} \cdot \left[\{1+(1-y)^2\}F_2^\gamma(x,Q^2) - y^2 F_L^\gamma(x,Q^2)\right]$$

$$Q^2 = 4E_b E' sin^2(\theta/2)$$

$$x = \frac{Q^2}{Q^2 + W^2 + P^2}$$

$$y = 1 - \frac{E}{E_b} cos^2(\theta/2)$$

$$W^2 = \left(\sum_h E_h\right)^2 - \left(\sum_h \vec{p}_h\right)^2 .$$

x – fraction of parton momentum with respect to the target photon

y – energy lost by the inelastically scattered electrons

E_b (E') – energy of the beam electrons (the scattered electrons)

E_h $(\vec{p}_h)$ – energies (momenta) of final state particles

P^2 - Virtuality of the target photon

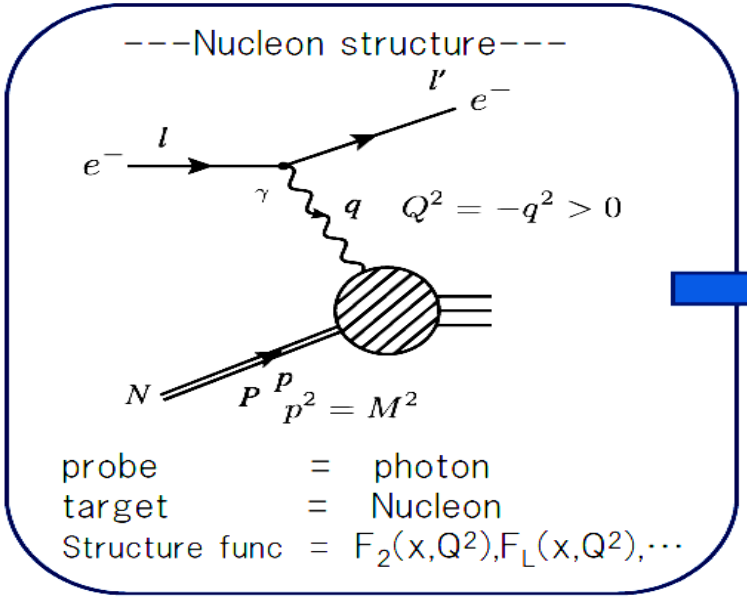
All presented further results relate to the PYTHIA generator level

Photon structure function

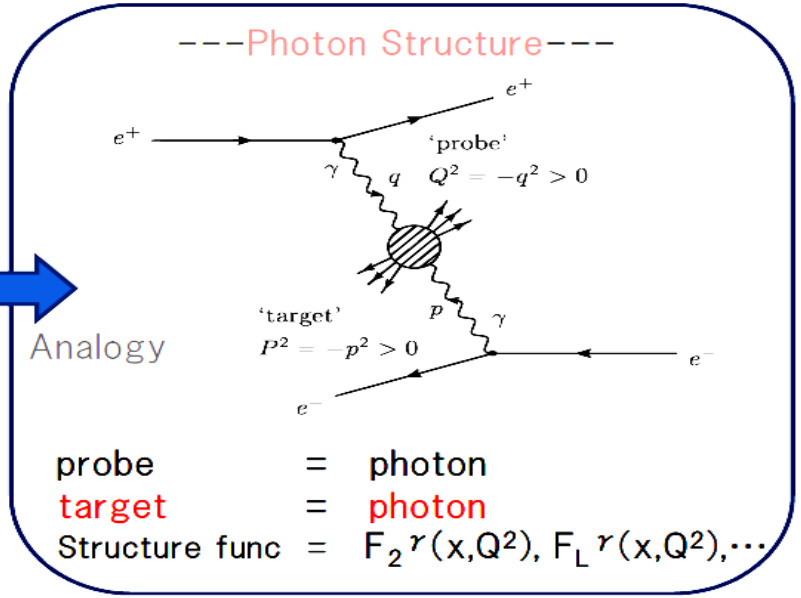
Deep inelastic eγ scattering

Analogy with studies of the proton structure functions at HERA

HERA

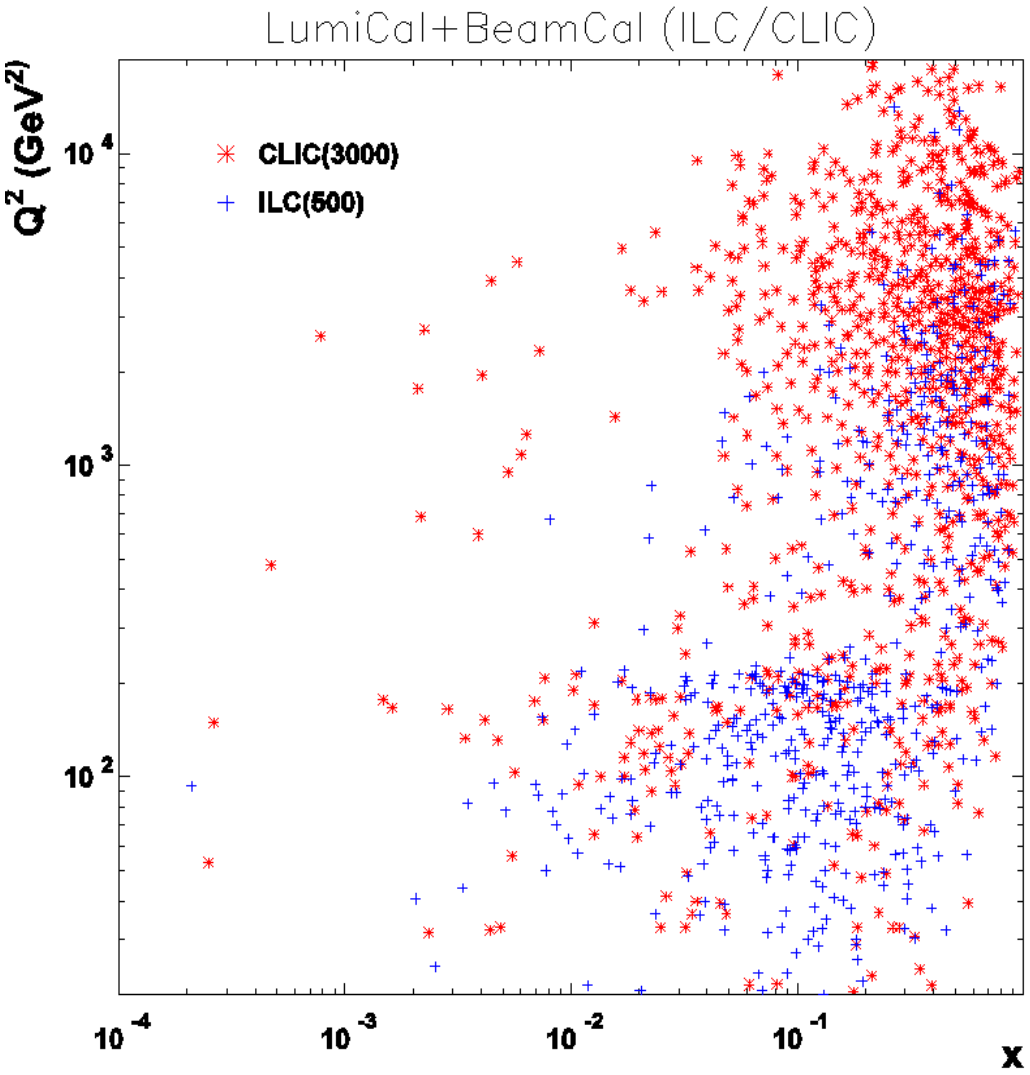


LC



Possible synergy with HERA studies

Expected values of kinematic variables



ILC

LumiCal
31 – 78 mrad

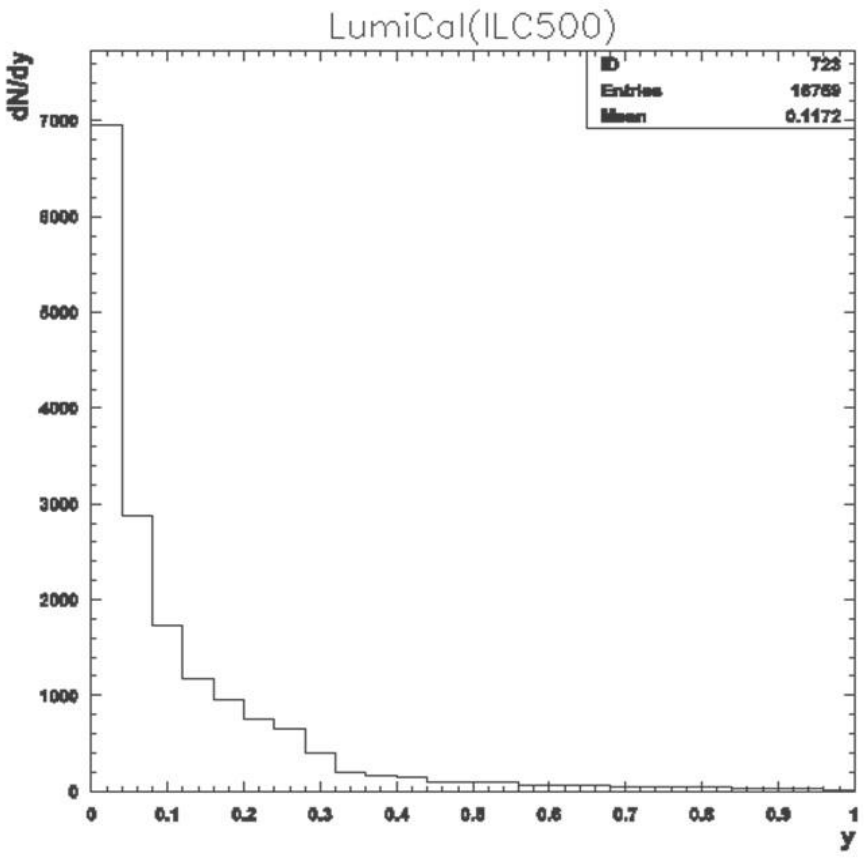
BeamCal
5.8 – 43.5 mrad

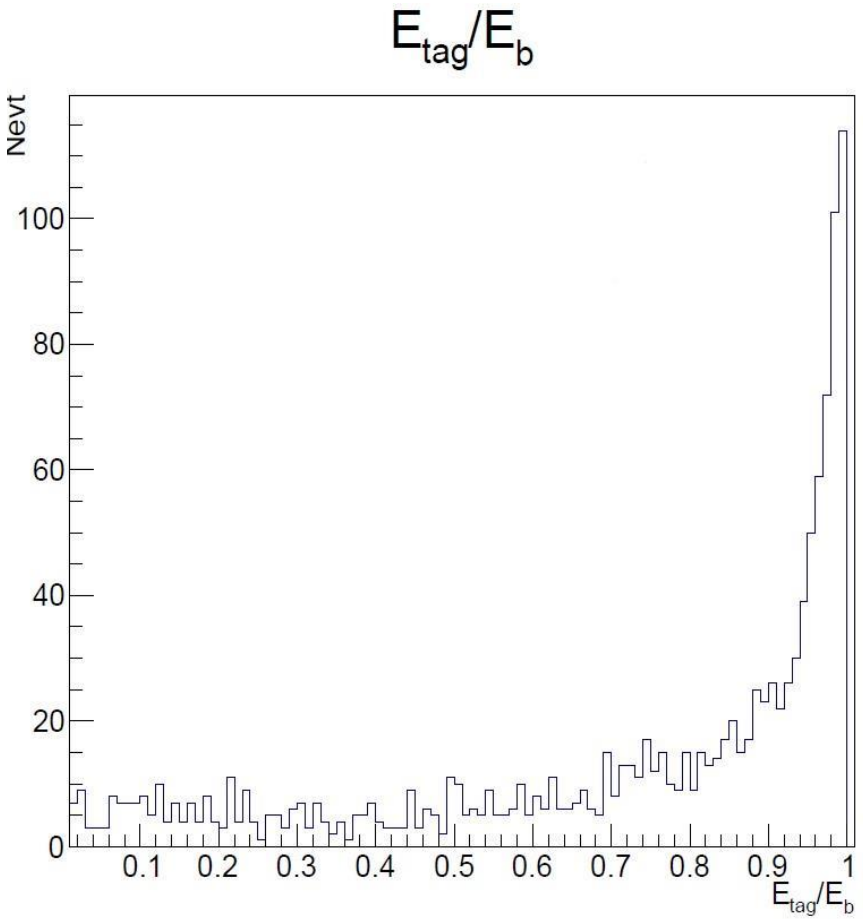
CLIC

LumiCal
38 – 110 mrad

BeamCal
10 – 40 mrad

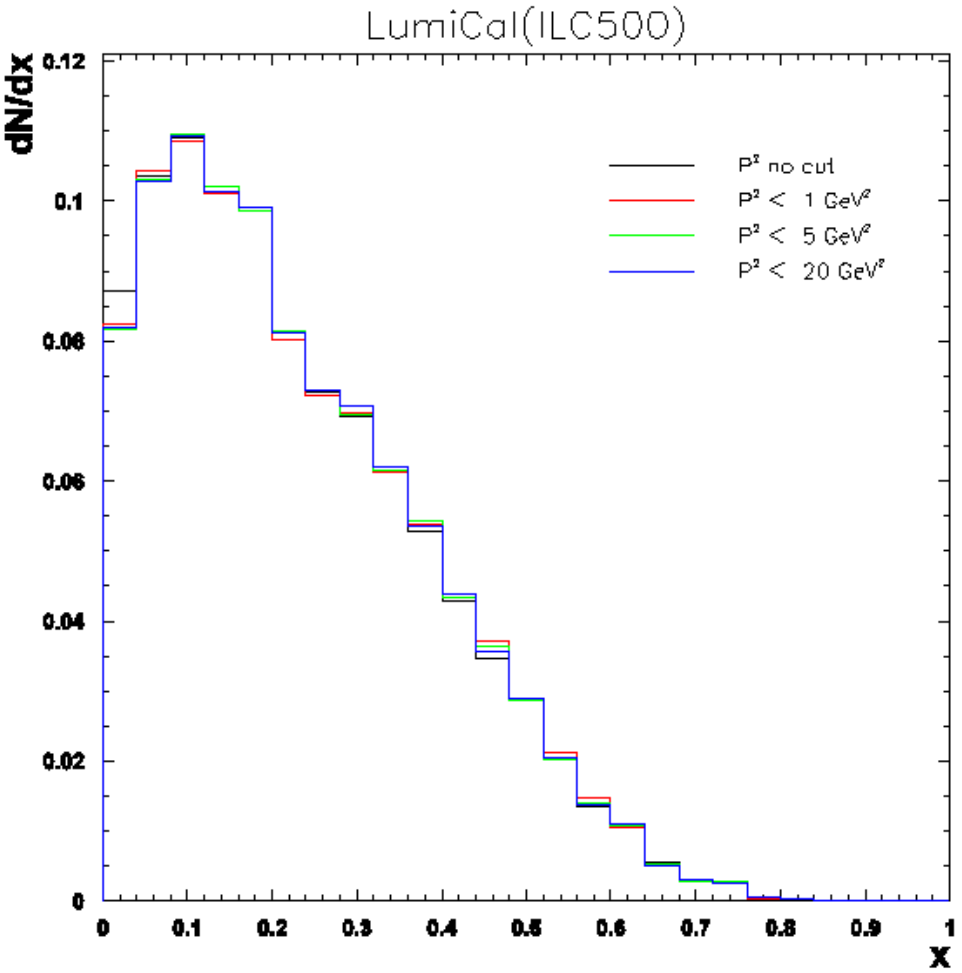
Expected values of kinematic variables





For LumiCal, the accepted angular range cover 31 – 78 mrad and
the mean value of y is less than 0.12 $\Longrightarrow$ F^{γ}_{L} term can be neglected.

Expected values of kinematic variables

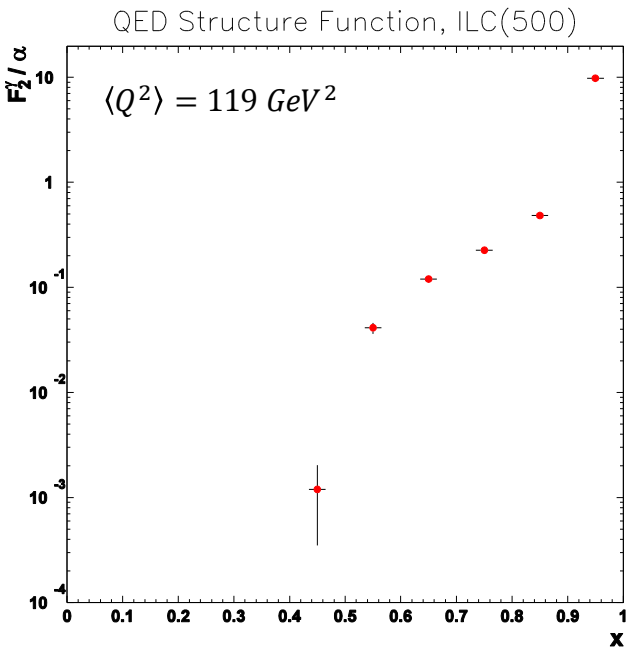


Weak dependence of the x distribution on **P^2** cut .
In real experiments (like those at LEP) the value $P^2 = 0$ was often used.

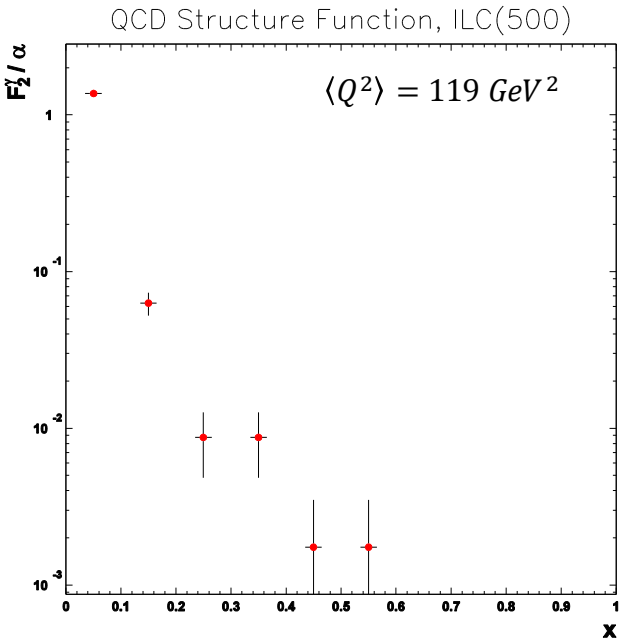
Photon structure function

PYTHIA Monte Carlo studies

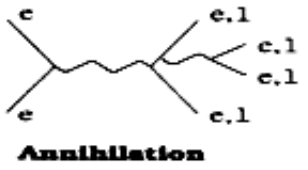
$e^+e^- \rightarrow e^+e^- \gamma^*\gamma \rightarrow \mu^+\mu^-$

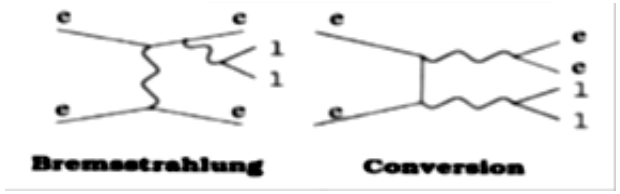


$e^+e^- \rightarrow e^+e^- \gamma^*\gamma \rightarrow$ **hadrons**



possible background :





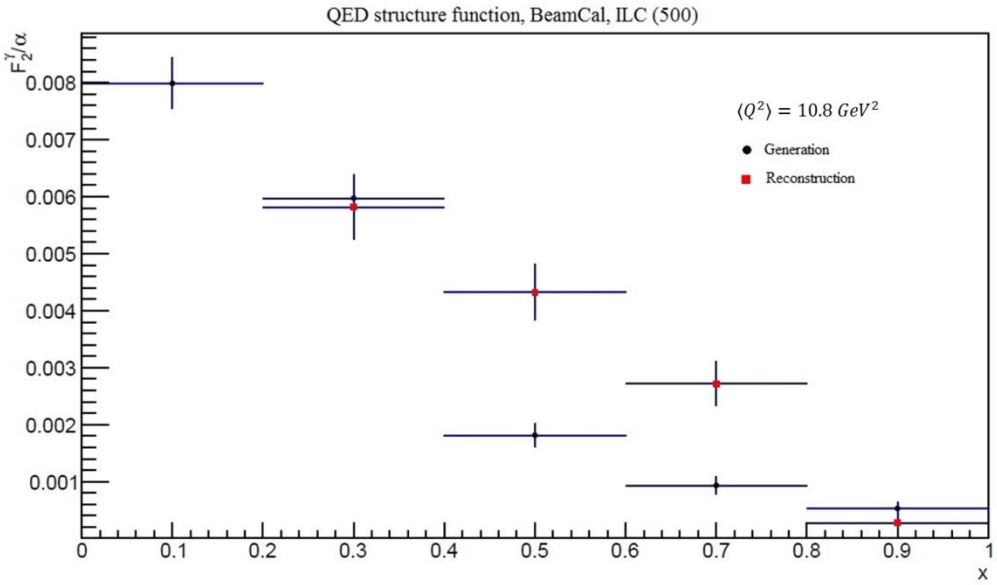
The expected dominant background :

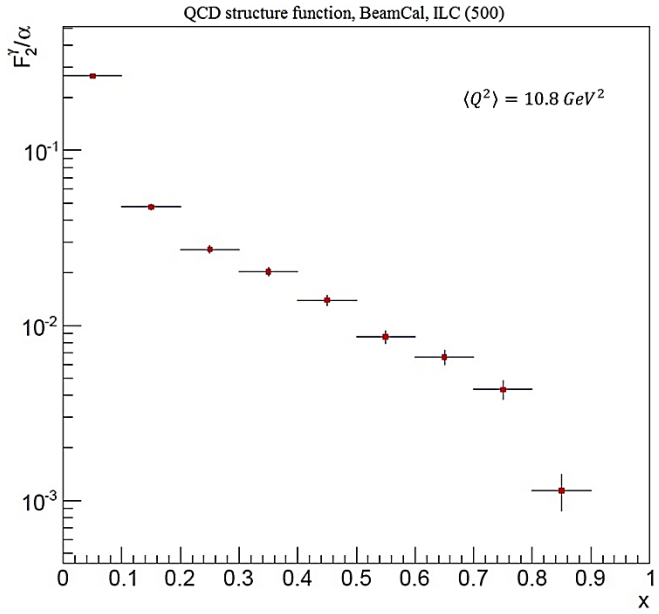
$e^+e^- \rightarrow e^+e^- \tau^+\tau^-$

$Z^0 / \gamma \rightarrow$ hadrons

These processes as possible background will be studied in the next step of analysis

Photon structure function





Very preliminary results for generation and reconstruction level

Scattered electrons tagged at the BeamCal

Summary and Outlook

- Information from LumiCal detector can be used to study the photon structure function.
- To extend the range of x and Q^2 variables other detectors like BeamCal, ECAL should be used.
- At ILC/CLIC it will be possible to move the upper limit of Q^2 towards higher values.
- It is necessary to consider the background (beamstrahlung, annihilation, etc.).
- The PYTHIA generator level results will be compared with other available Monte Carlo generators: WHIZARD, HERWIG as well as those used in LEP experiments after their adaptation to ILC/CLIC conditions: PHOJET, TWOGAM, BDK, …
- The next steps towards of the complete analysis will include: the use of the reconstructed variables (up to now it was done for BeamCal) and the estimation of systematic effects, including background.

BACKUP

Event selection

At first we are concentrating on single-tagged events with electron measured in LumiCal. The optimal choice of the event selection should include cuts like:

- An electron candidate observed with energy $E_{tag} > 0.7E_b$ and polar angle in the range $31 < \theta < 78$ mrad.
- No deposited energy with value $E_a > 0.2E_b$ in the detector on the opposite side (an anti-tag cut) – low virtuality of the quasi-real photon.
- At least 3 tracks originated from the hadronic final state have to be present.
- The visible invariant mass W_{vis} of the hadronic system should be in the range 3 GeV < W_{vis} < 0.6 E_b The upper limit should reduce expected background of annihilation events.

The W_{vis} will be reconstructed from tracks measured in tracking detectors together with energy depositions – clustrers in electromagnetic and hadronic calorimeters of the main detector ILD