Hadron Production in Photon-Photon Processes at the International Linear Collider

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HELMHOLTZ ASSOCIATION

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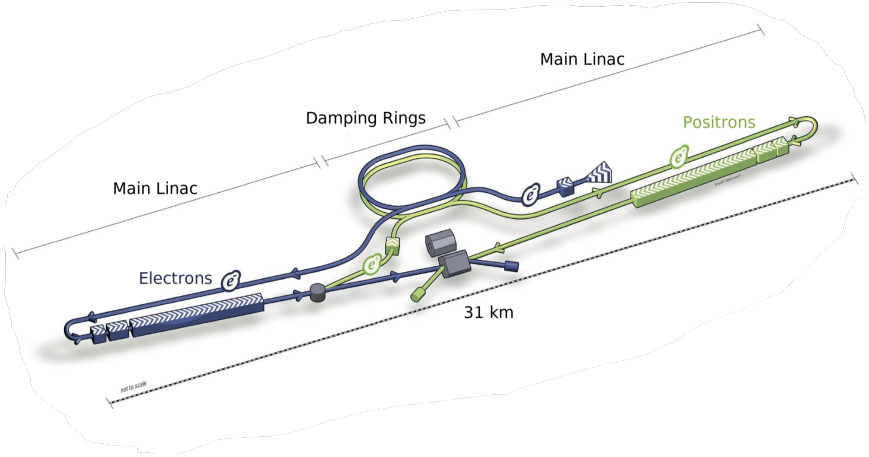
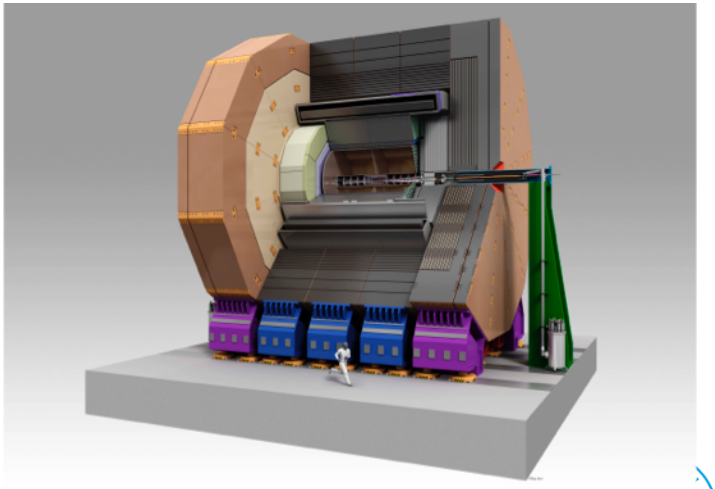
DESY

Introduction

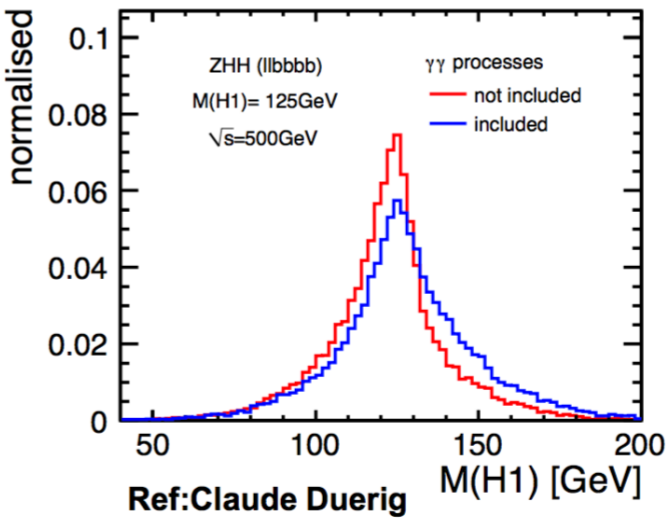
- The International Linear Collider (ILC) is a proposed e^+e^- collider
  - Tunable $\sqrt{s}$ = 250 - 500 GeV
  - Clean experimental environment
- International Large detector - proposed detector for ILC
- $\gamma\gamma \rightarrow$ low Pt hadron backgrounds an issue
  - Approximately 1.2 photon-photon events per bunch crossing
  - Overlay of low Pt hadrons





Motivation

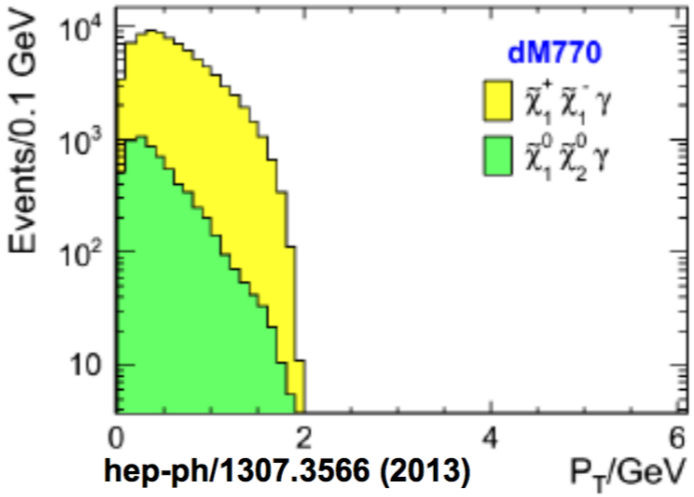
- Overlay of soft hadrons affects a few specific but important cases e.g. :
  - Measurement of Higgs self coupling from double-Higgs production - rare process
    - Overlay degrades the mass resolution
  - Signals of new particles with small mass differences (dark matter candidates)
    - Visible decay products very soft and thus similar to hadron overlay



Need more differential methods to remove gamma-gamma background

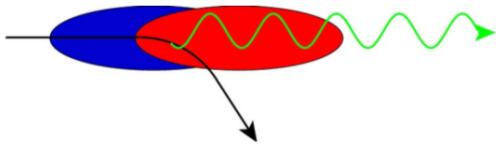
- Identify gamma-gamma collision products by explicit reconstruction

Very important to have detailed simulation

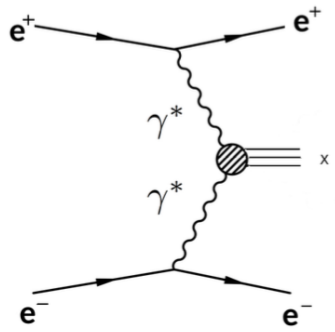


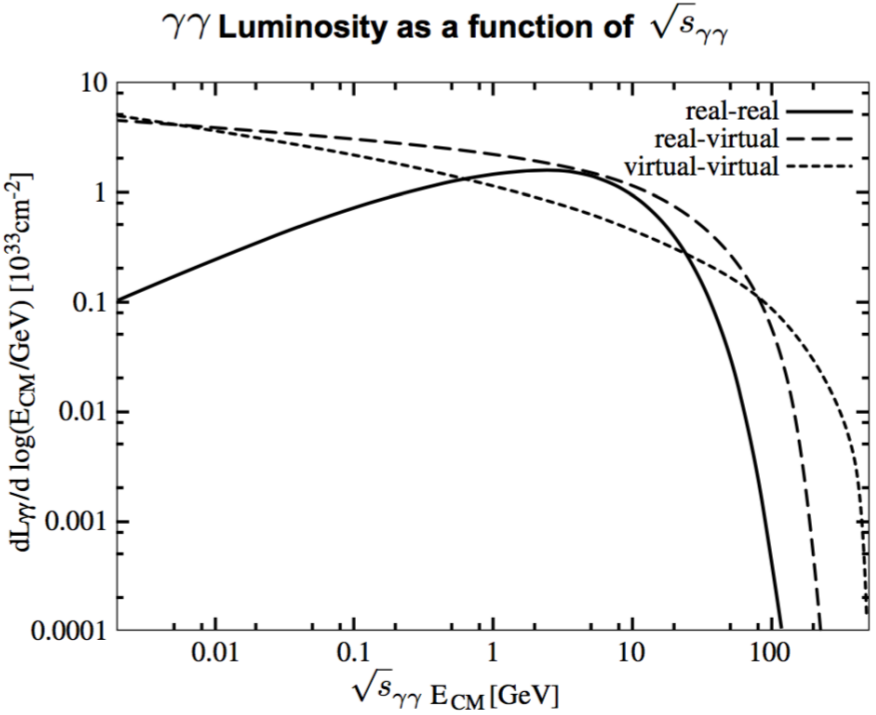
Photon Sources

- $e^+ e^-$ beams are accompanied by :
- **Real photons $f_r(x)$:**
  - Beamstrahlung - emission of **real** photons in high electrical field of oncoming bunch



- **Virtual photons $f_v(x)$:**
  - Weizsaecker-Williams process - emission of **virtual** photons which can interact with an oncoming photon or an electron



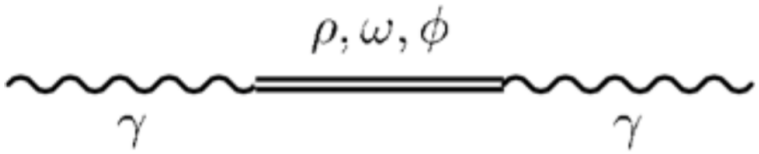


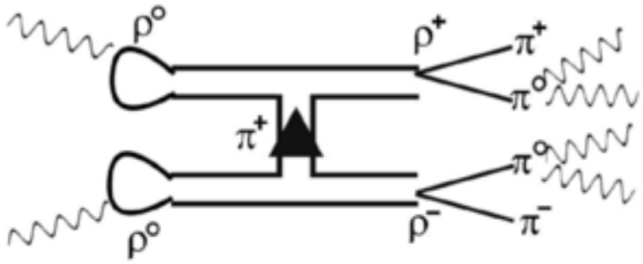
Ref:hep-ph/0406010v1(2004)

$$L_{\gamma\gamma} = f_v(x_1)f_v(x_2) + [f_v(x_1)f_r(x_2) + f_r(x_1)f_v(x_2)] + f_r(x_1)f_r(x_2)$$

Photon-Photon Interactions

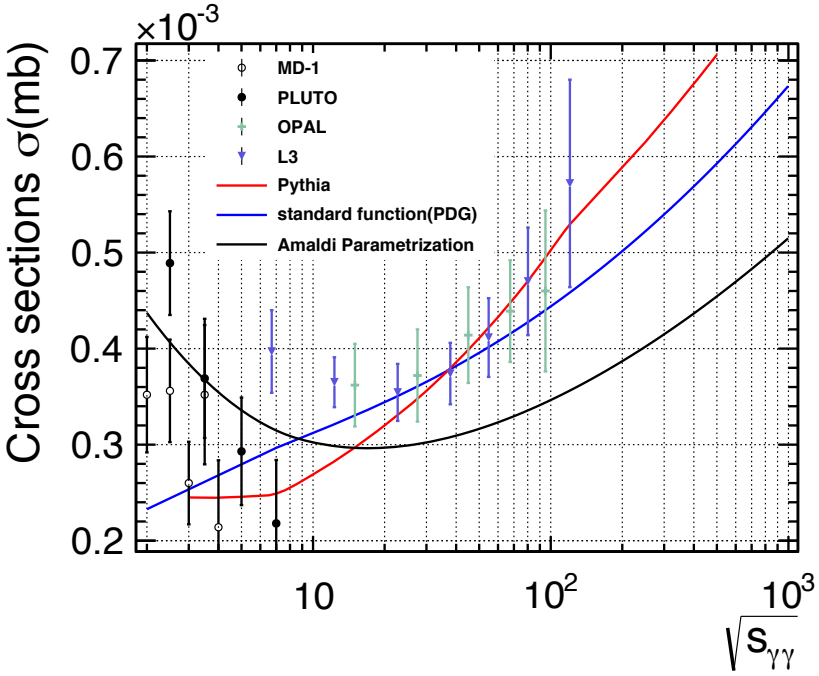
- Photons interact in different ways
- Vector meson dominance -Most dominating subprocess
- What are vector mesons? - $\rho, \omega, \phi, J/\psi, \Upsilon$
- Photon fluctuates into a vector meson since it has got the same quantum properties
- Photon is a hadron 1/400 of the time
- Highest probability to fluctuate into rho meson
- Production of huge amount of low Pt hadrons





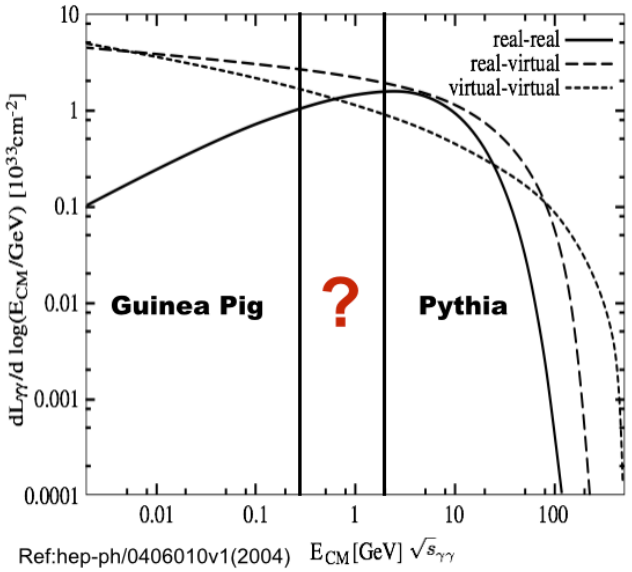
Monte-Carlo generator for $\gamma\gamma \rightarrow$ low Pt hadron processes

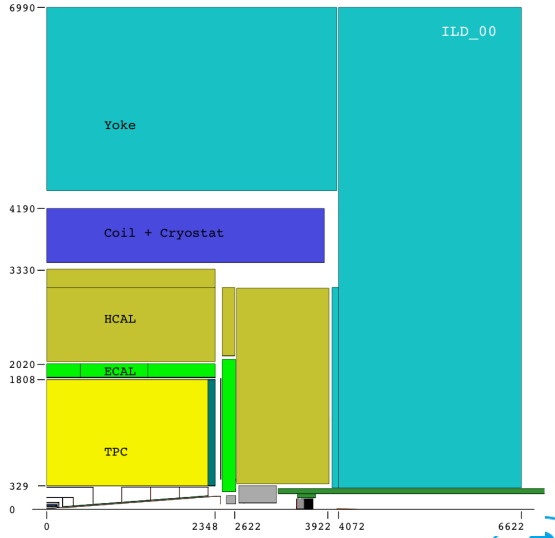
- Important to develop an efficient MC generator for $\gamma\gamma \rightarrow$ low Pt hadron processes
- Pythia 6.4 maybe a good choice
- Comparison of $\gamma\gamma \rightarrow$ low Pt hadron process cross sections from Pythia with PDG, Amaldi et.al(hep-ph/9305247) and data from LEP,PETRA and VEPP
- $\sqrt{s_{\gamma\gamma}}$ > 10 GeV : Good description of LEP data with Pythia
- $\sqrt{s_{\gamma\gamma}}$ < 10 GeV: Measurements have large uncertainties and widespread
- Detailed study of event properties of Pythia - can be used $\sqrt{s_{\gamma\gamma}}$ > 2 GeV



A dedicated event generator for $\gamma\gamma$ processes

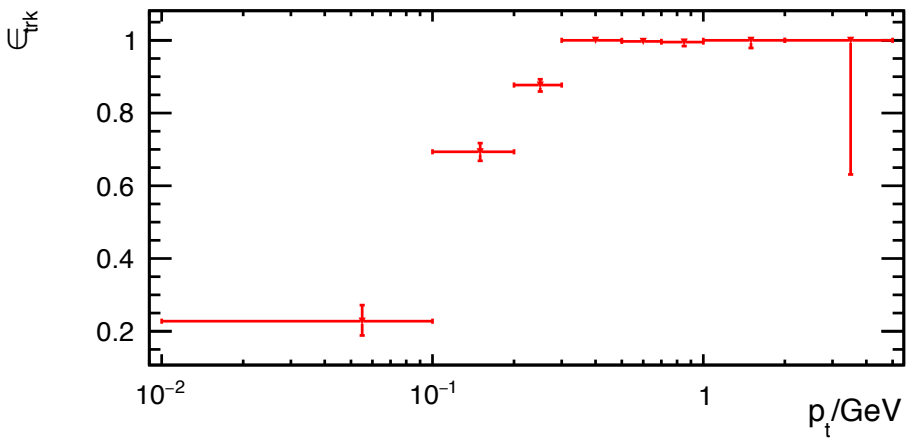
- For $\sqrt{s_{\gamma\gamma}}$ > 2 GeV Pythia 6 used to simulate $\gamma\gamma \rightarrow$ low pT hadron processes
- Below $2\pi_m$ pure QED beam-beam interactions modeled by dedicated programs - Guinea Pig
- Need to evaluate the impact of uncovered region - how can it be modeled?
- Dedicated generator developed in ILC community to study low energy region by Tim Barklow
- The particles below 2 GeV - Very low Pt
- Could these particles be observed in the detector?
- How important is it to model this area?

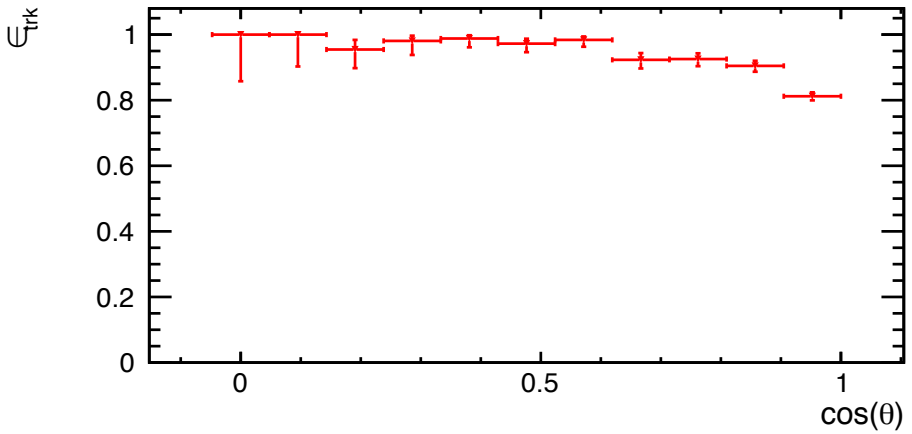




Reconstruction efficiency for tracks

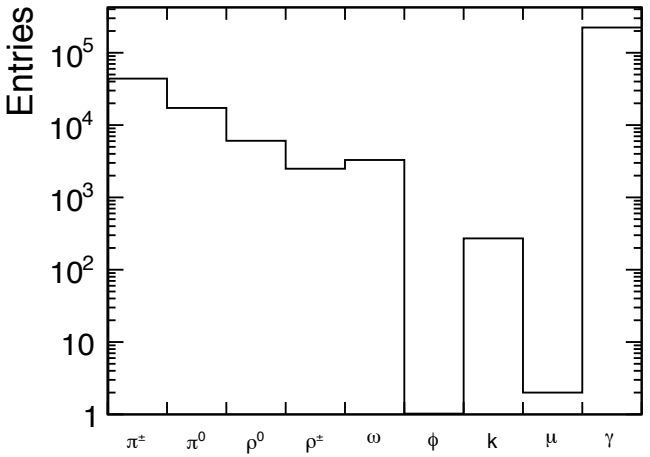
- Tracking Efficiency of the detector studied
- $\gamma\gamma \rightarrow$ low pT hadron events simulated using GEANT4 detector simulation
- Momentum efficiency > 65%
- Angular efficiency > 80 %
- The events below 2 GeV need to be modeled

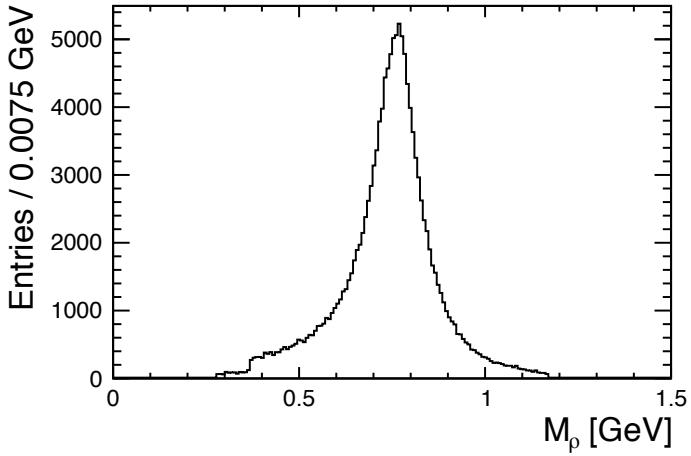




Barklow Generator for $\sqrt{s_{\gamma\gamma}}$ < 2 GeV

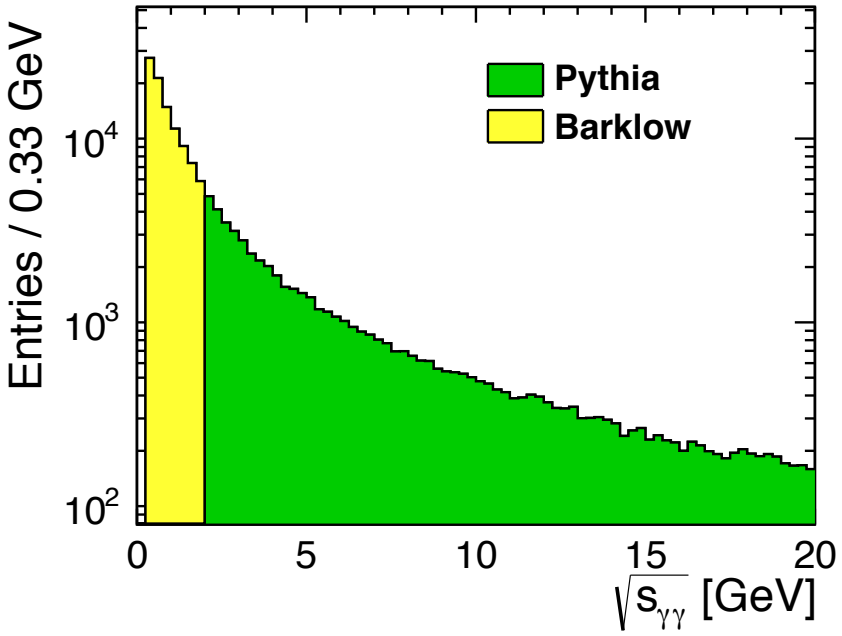
- Barklow Generator - good choice for $\sqrt{s_{\gamma\gamma}}$ < 2 GeV
- The Barklow generator produces different events like $\gamma\gamma \rightarrow \pi^0\pi^0, \pi^{\pm}, \rho^0\rho^0, \rho^{\pm}, \omega$
- The cross-sections for producing ρ^0 is greater than that for $\rho^{\pm}$
- Until recently a much simpler version of Barklow generator used - produced $\rho^{\pm}$ without width and produced no ρ^0s
- Corrections were implemented and a better version of generator was developed





$\gamma\gamma \rightarrow$ low pT hadron event generator

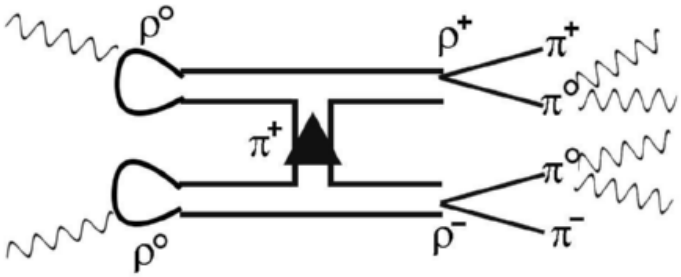
- The low and high energy regime for $\gamma\gamma \rightarrow$ low pT hadron events modeled
- The events from Pythia and Barklow generator integrated into Whizard to give $\gamma\gamma \rightarrow$ low pT hadron events
- The improved generator produces events:
  - $\sqrt{s_{\gamma\gamma}}$ > 2 GeV - Pythia
  - $\sqrt{s_{\gamma\gamma}}$ < 2 GeV - Barklow Generator



An efficient generator for simulating $\gamma\gamma \rightarrow$ low pT hadron processes developed

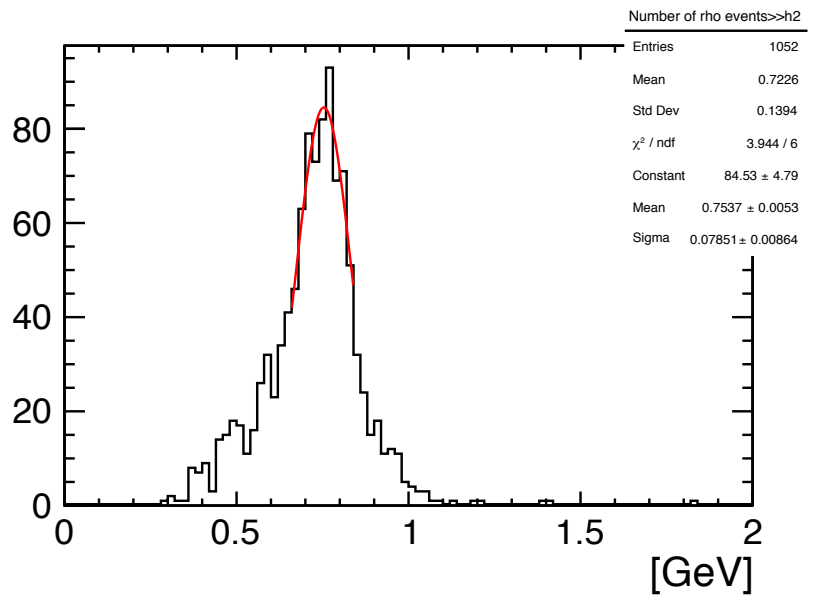
Method Development to remove backgrounds

- The invariant mass of decay products of rho meson gives rho mass
- Rho meson used as a tag to remove $\gamma\gamma$ events
- Vertices of $\gamma\gamma$ overlay events displaced from that of signal vertices
- Primary step - separating events as



$\gamma\gamma \to \pi^+\pi^-$	34%
$\gamma\gamma \to \pi^0\pi^0$	6%
$\gamma\gamma \to \rho^+\rho^-$	2 %
$\gamma\gamma \to \rho^0\rho^0$	3%
$\gamma\gamma \to \rho^0\omega$	**1%**

- $\gamma\gamma \to \rho^0\rho^0$ events - rho meson decay to two π^+ and two π^-
- Events with exact 2 +ve and 2 -ve tracks selected
- Invariant mass calculated and the mass closest to rho meson chosen
- $\gamma\gamma \to \pi^+\pi^-$ and $\gamma\gamma \to \pi^0\pi^0$ have invariant mass $2m_\pi$
- Applying cut on $2m_\pi$ invariant mass removes overlay for such events
- Work in progress



Conclusion and Outlook

- Although physics environment at ILC is very clean $\gamma\gamma$ backgrounds is still an issue
- The impact of this overlay is found on a very few specific but important events
- The existing generators could cover the impact only partially
- With the study of the $\gamma\gamma \rightarrow$ low Pt hadron processes and the event properties of generators which could produce such events an efficient generator to study $\gamma\gamma \rightarrow$ low Pt hadron processes developed
- OUTLOOK:
  - With the generator developed events are studied better
  - The events could be reconstructed from the low Pt hadrons and could be found if they come from a photon-photon process
  - The method developed will be applied on Higgsino analysis