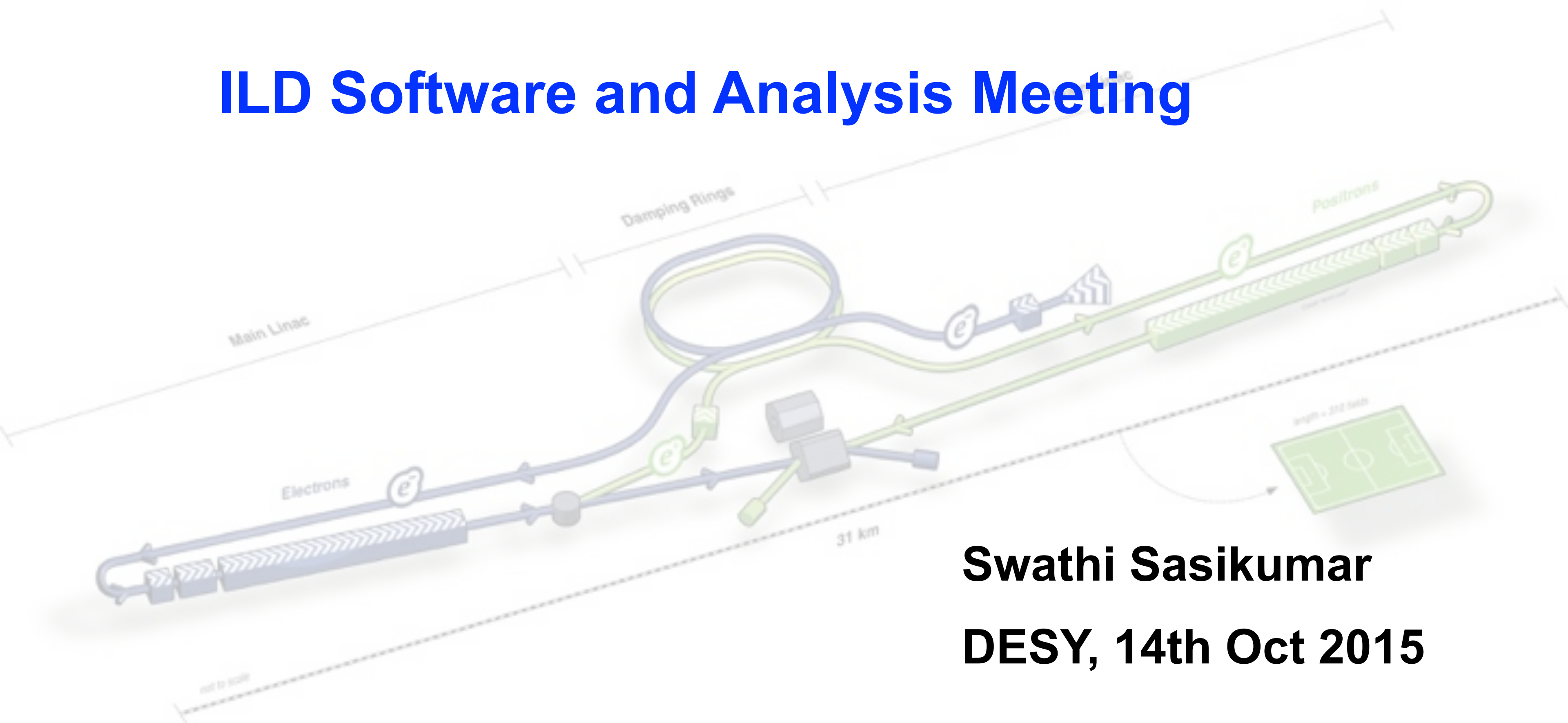
Hadron Production in Photon-Photon Processes at International Linear Collider

ILD Software and Analysis Meeting



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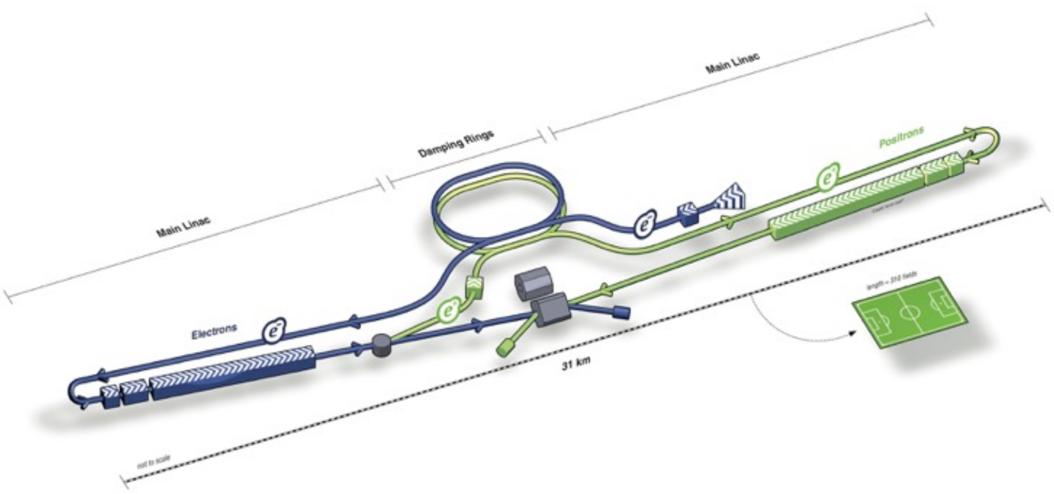
DESY, 14th Oct 2015

HELMHOLTZ ASSOCIATION PIER DESY

Contents

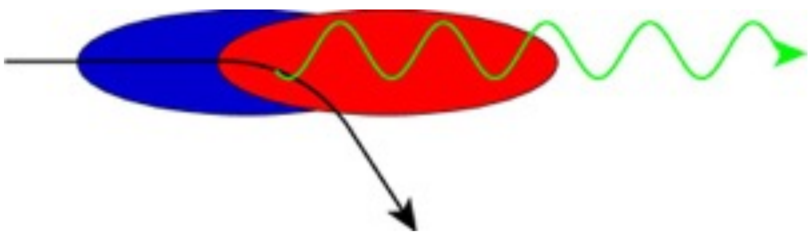
Introduction

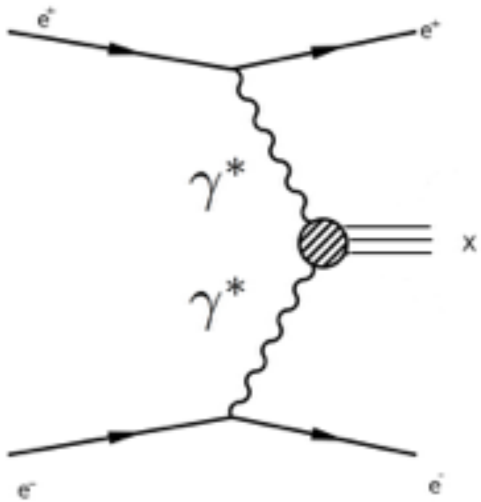
- The International Linear Collider - A precision machine
  - Ideal for Higgs analysis
  - Very Clean conditions
- The International Large detector being developed to meet the precision goals of the ILC physics program.
- The Gamma-gamma background standing as the biggest challenge
- The rate of gamma-gamma interaction is million times higher than the Higgs productions



Photons in an e^+e^- Collider

- e^+e^- beams are accompanied by photons
  - Beamstrahlung - emission of real photons in high electrical field of oncoming bunch
  - Synchrotron photons are backscattered gaining higher energy
  - Weizsaecker-Williams process - emission of virtual photons which can interact with an oncoming photon or an electron
- Cross sections are large due to high interactions among particles





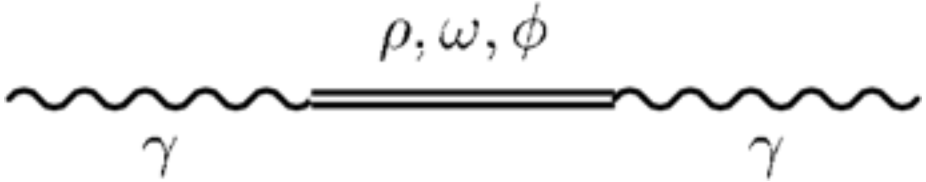
Sub-processes in Photon Interactions

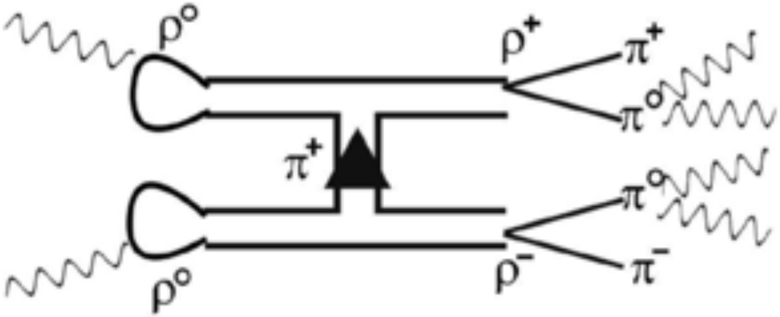
- Direct Interactions(DIR) - Real photons interacts directly
- Vector Meson Dominance(VMD) - Photon fluctuates into a vector meson
- Anomalous Interactions(GVMD) - Photon fluctuates into a $q\bar{q}$ pair of larger virtuality
- Deep inelastic Scattering(DIS) - A process of probing the Hadrons with very high energy leptons.

Subprocesses	Cross-sections (nb)
VMD * VMD	239.2
DIR * VMD	87.52
GVMD * DIR	9.77
GVMD * GVMD	12.05

Vector Meson Dominance

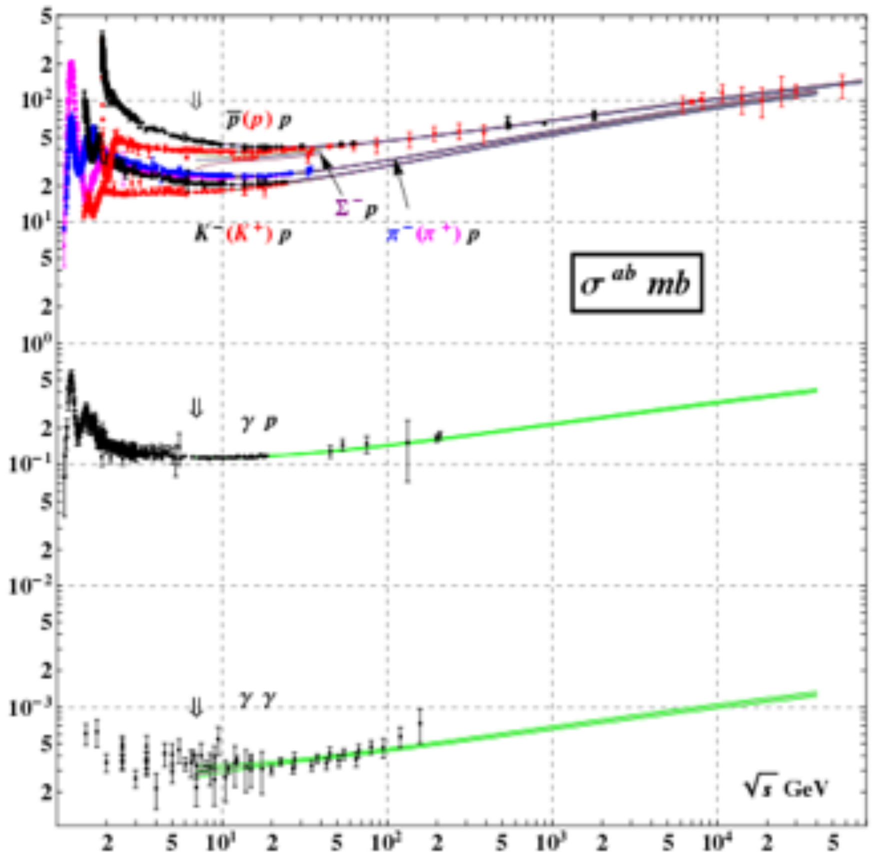
- Vector meson dominance the most dominating subprocess in photon-photon processes
- A photon fluctuates into a vector meson (ρ,ω,ϕ, j/ψ, Υ) (same quantum properties)
- The highest probability for the photon to fluctuate is into a Rho meson.
- Production of number of low momentum soft Hadrons.
- Pion exchange as nuclear force in protons and neutrons





Hadron Interactions in VMD

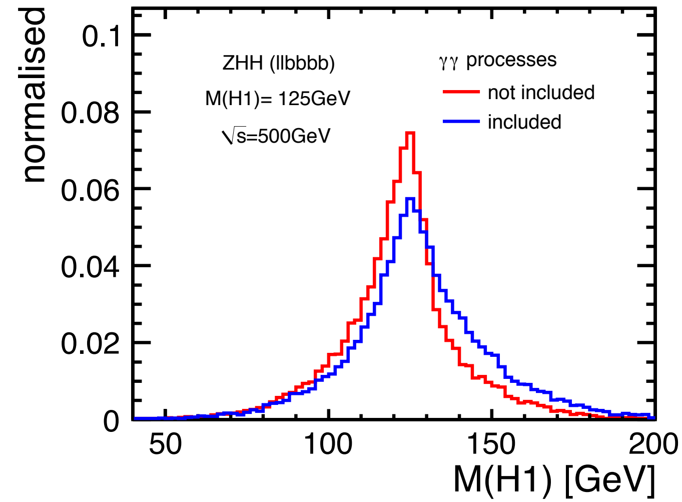
- A photon is a hadron a fraction 1/400 of the time
- Rise in gamma-gamma cross sections much similar to hadronic cross sections
- All event classes known for ordinary hadron-hadron interactions are found to occur here
- Behaves more like a Hadron collider than a lepton collider

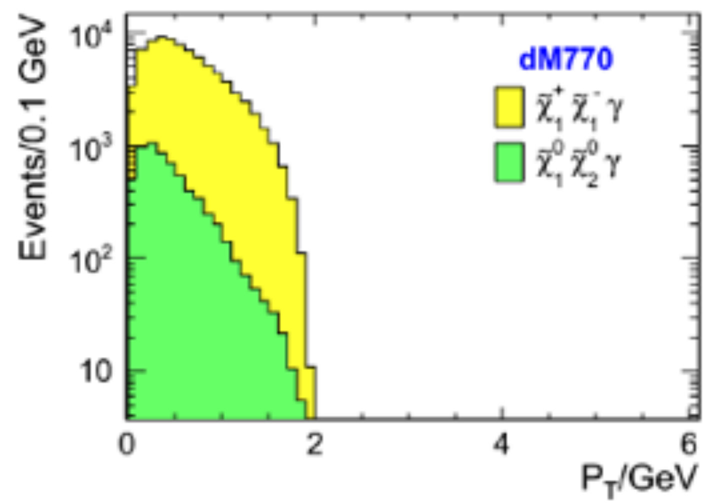


Reference : Particle Data Group 2014

Impact of hadron overlay

- Hadron Pile up reduce precision for a few specific but important cases.
- Higgs self-coupling measurements which are very rare processes
- Signals for new particles with small mass differences (dark matter candidates)
- kT algorithm methods not sufficient to remove the overlay in these cases





Studies from Peskin, Barklow and Chen

- The Monte-Carlo programs used to model the processes at the ILC are based on theoretical approaches dating back to early 1990s.
- This is the model we partially use for simulations in ILD
- Rate of hadron production for accelerator design proposed for 500GeV linear collider evaluated using three components
  - Photon-photon Luminosity spectrum
  - Cross section for hadron production
  - Realistic detector simulation

Hadron Production in $\gamma\gamma$ Collisions as a Background for e^+e^- Linear Colliders*

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ABSTRACT

Drees and Godbole have proposed that, at the interaction point of an e^+e^- linear collider, one expects a high rate of hadron production by $\gamma\gamma$ collisions, providing an additional background to studies in e^+e^- annihilation. Using a simplified model of the $\gamma\gamma$ cross section with soft and jet-like components, we estimate the expected rate of these hadronic events for a variety of realistic machine designs.

Photon-Photon Luminosity Spectra

- The spectra entering the $\gamma\gamma$ cross section at e^+e^- linear collider described in terms of photon-photon luminosity function

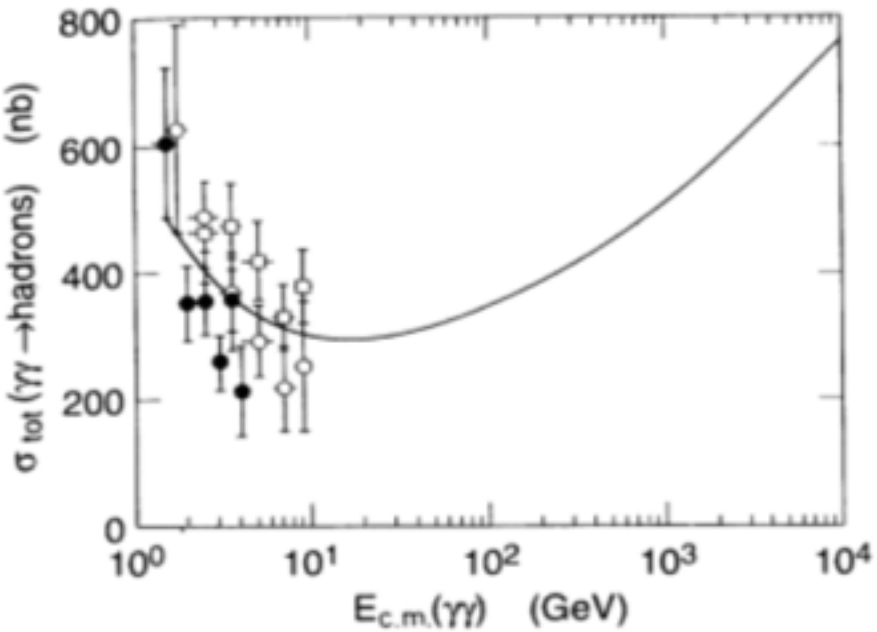
- Contributions from two sources -
  - Beamstrahlung ($f_r(x)$) - the energy spectrum from the real photons could be estimated from the experiments
  - Bremsstrahlung($f_v(x)$) - The energy spectrum from the virtual photons have to be calculated theoretically

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

Total Cross Sections

- Determination of photon-photon hadronic cross sections essential for computing hadronic backgrounds
- Photon-photon total cross section proportional to ρ-ρ total cross section
- The parametrization of Amaldi *et al.* give cross sections as

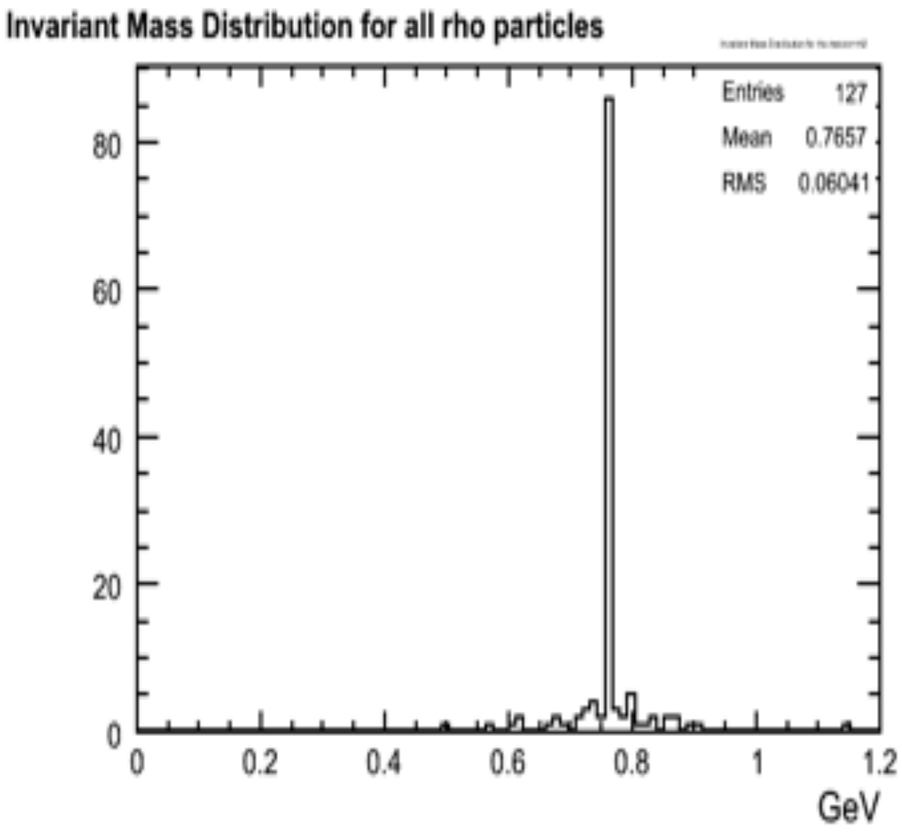
$$\sigma(\gamma\gamma -> hadrons) = \sigma_0(1 + (630 * 10^{-3})[ln(s)^{2.1} + (1.96)s^{-0.37})$$



(Ref: Peskin *et al*, PRD, 49(3209) 1994)

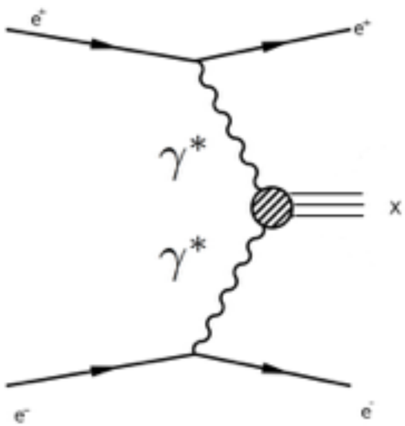
Shortcomings of Barklow, Peskin Methods

- The rho meson has a mass of 770 MeV and a width of 145 MeV.
- Barklow generator produces Rho mesons of same mass and no width at all.
- Most of the events having two rho mesons have charged Rhos
- Clear indication of something wrong at the fundamental level
- Unrealistic results - as a consequence reduced efficiency of ILD



Pythia 6.4 - as an event generator

- A computer simulation program for particle collisions at very high energy (fortran)



- The initial e^- and e^+ s have fixed energy in Pythia. So the usage of gamma/e^+ - gamma/e^- beams give unrealistic results
- Usage of Gamma - gamma beams with varying energy is preferred - more realistic results
- Missing of Deep Inelastic scattering process - trying to include by changing some parameters

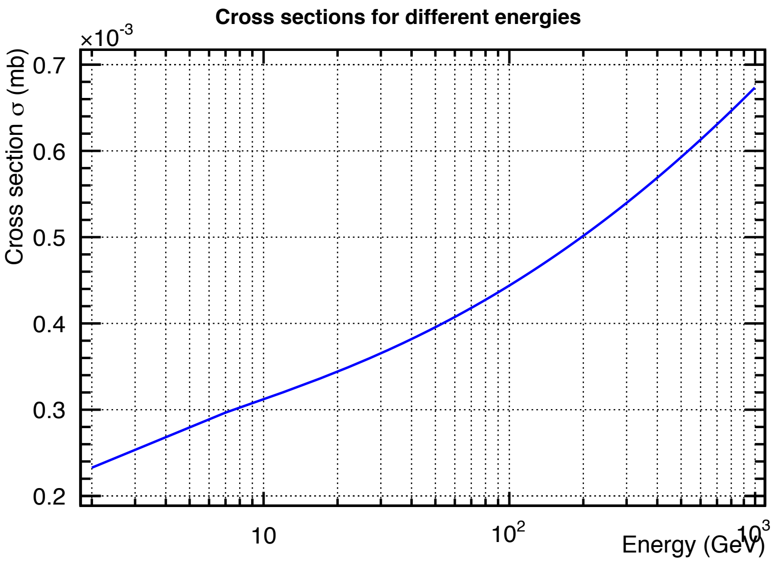
The Theory of Hadronic Cross Sections

- The standard theory for calculating hadronic cross sections as per PDG:

$$\sigma^{\gamma\gamma} = \delta^2[H \ln^2(\frac{S}{S_M^{\gamma\gamma}}) + P^{\gamma\gamma}] + R_1^{\gamma\gamma}(\frac{S}{S_M^{\gamma\gamma}})^{-\eta_1}$$

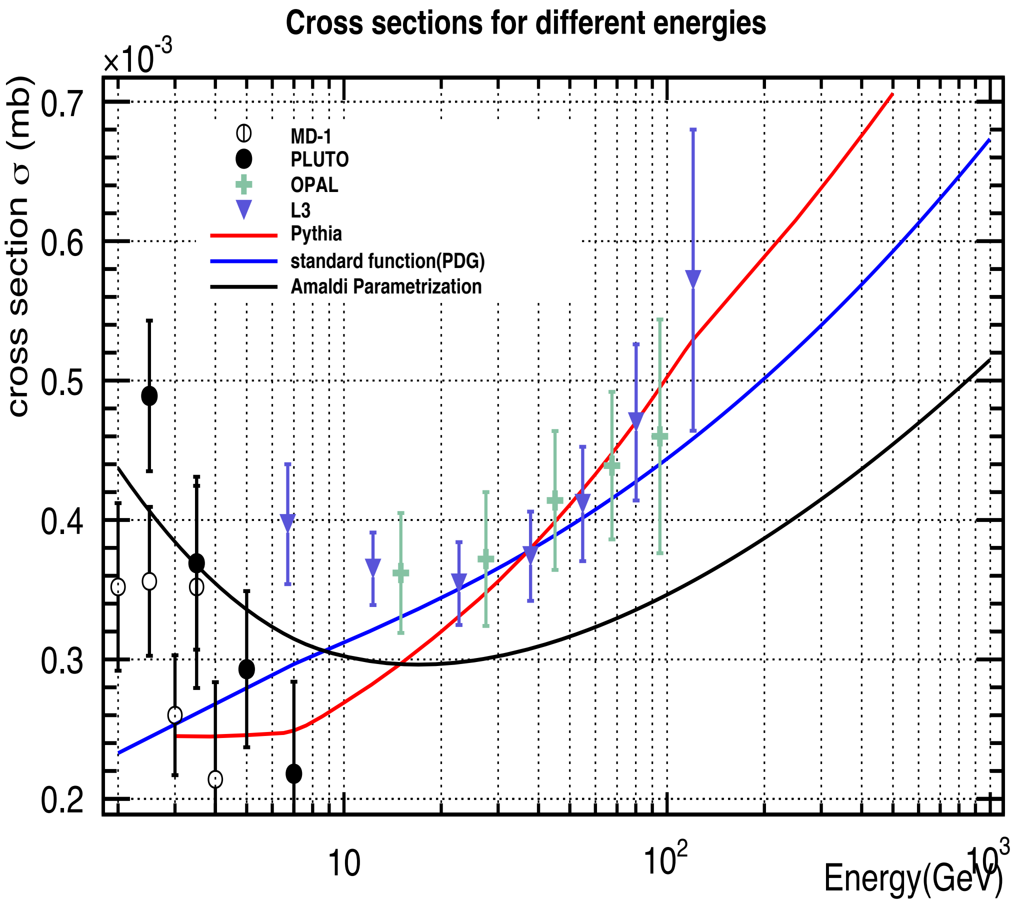
(Ref: Particle data group 2014)

- R: Regge term defines the cross section at low energies where the interactions are explained using meson exchange
- P : Pomeronchuk term defines the cross section at higher energies where the interactions are explained using pomeron exchange.
- H: $H = \pi(\frac{\hbar c^2}{M^2})$ The Heisenberg term defines the rise in cross section with energy



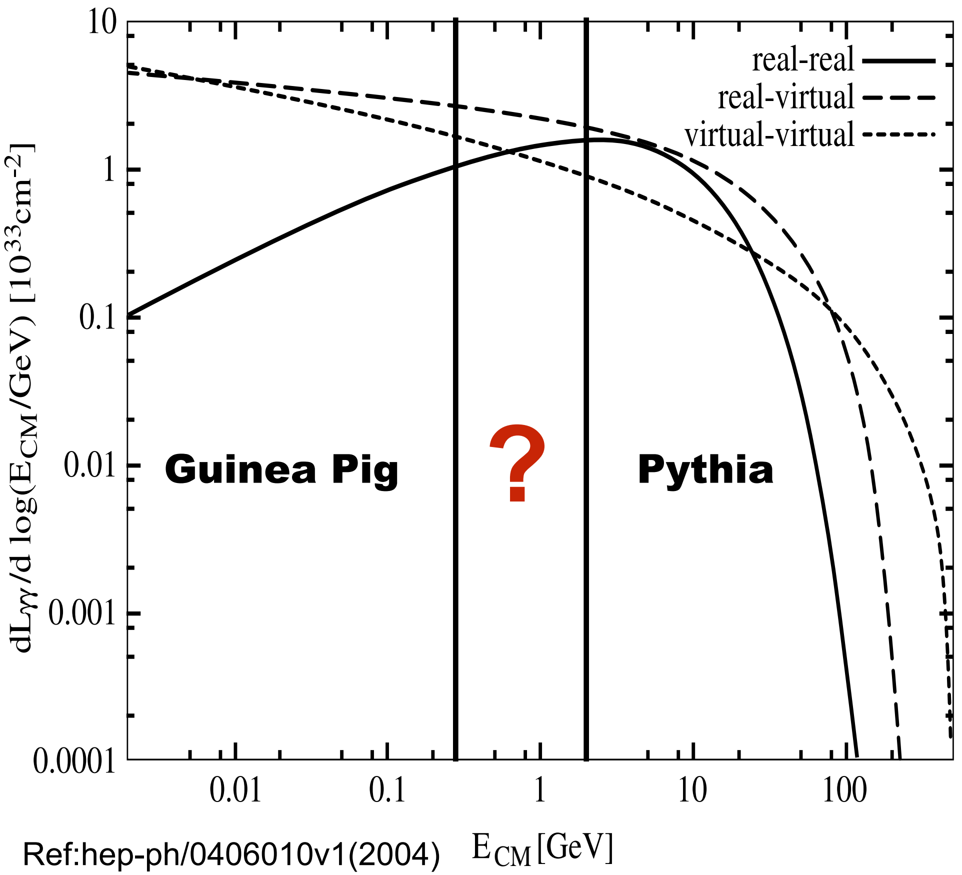
Total Cross Sections

- The results from Pythia very much in accordance with the standard function and the measured data.
- Data for gamma-gamma cross sections at very high energies not available
- Pythia seems to be quiet okay for evaluating gamma-gamma backgrounds



Shortcomings with Pythia

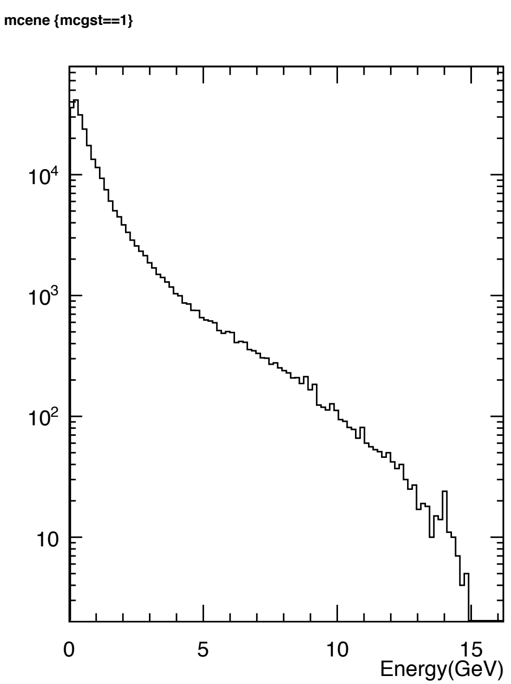
- Hadron productions initialized at 300MeV
- Crucial to understand processes at these energies
- Pythia cannot simulate for energies below 2.5GeV
- Trying for various solutions
  - By changing few parameters
  - Looking at Barklow's methods

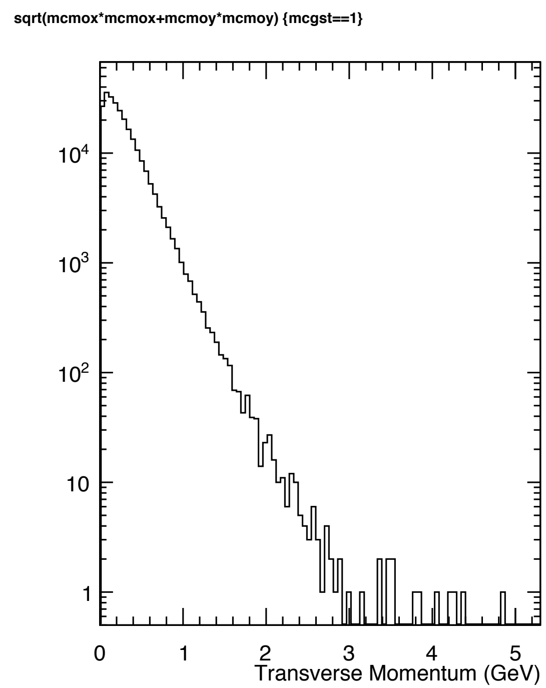


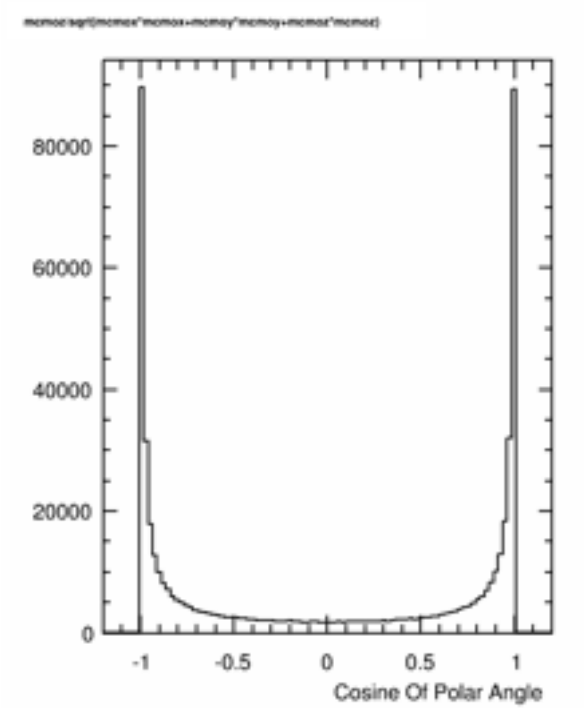
Ref:hep-ph/0406010v1(2004)

Pythia as a tool

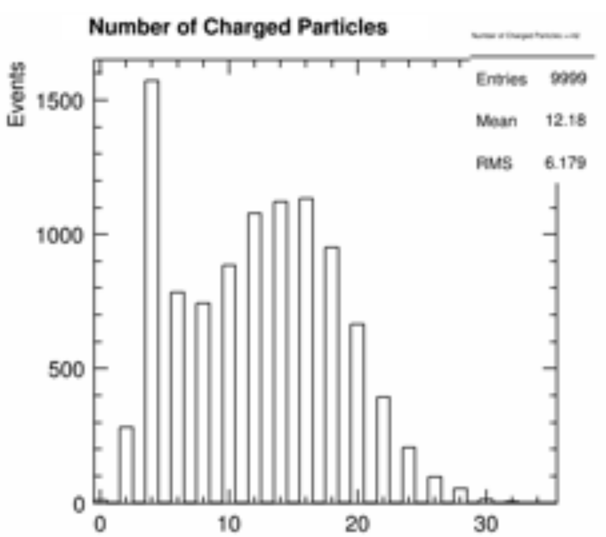
- Using Pythia to evaluate the properties of particles in the Hadronic interactions
- Plotting for Energy, Transverse Momentum and Cosine of Polar angle at 30 GeV centre of mass energy we have

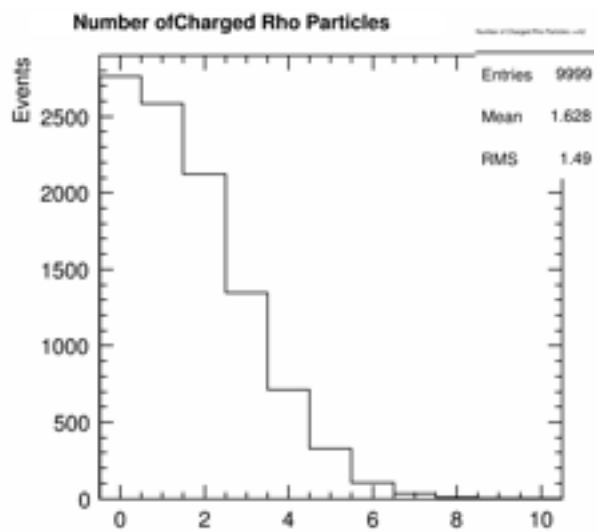


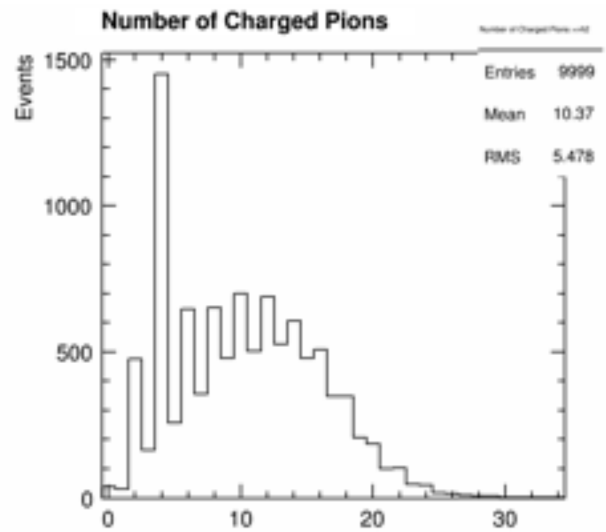


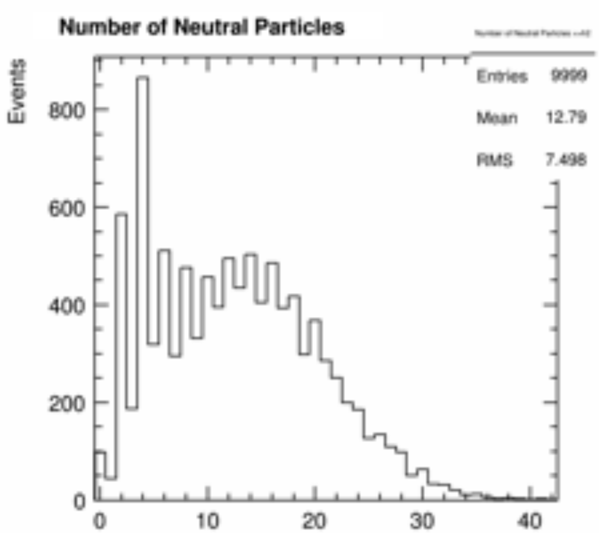


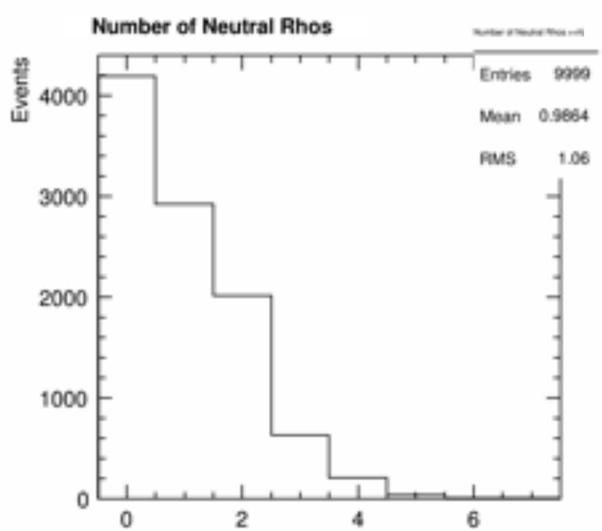
Number of Particles

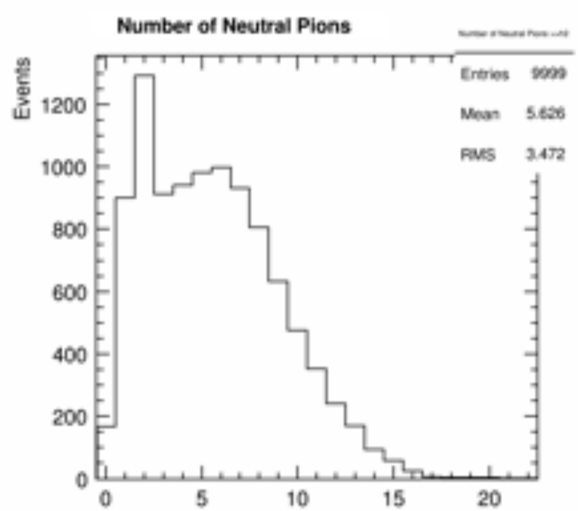












Summary

- Gamma-gamma background a major threat for building ILC as a precision machine
- VMD being the most dominating process give more hadronic interactions resulting into a hadron pileup
- The studies from Peskin *et al.* being used for designing the ILC but we cannot completely depend on these generators
- Pythia at this point seems to be a nice answer for understanding more about the Gamma-Gamma interactions
- Pythia at lower energies is still an issue 😟