Hadron Production in Photon-Photon Processes at International Linear Collider

9th Annual Meeting of the Helmholtz Alliance "Physics at the Terascale"

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Outline

- Introduction
- Total Cross Sections
- Event Properties
- Towards an improved description
- Summary and Outlook

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Introduction

- The DBD simulations:
  - $\gamma\gamma$ backgrounds a challenge
  - overlaid number of events on each physics event
  - $\gamma\gamma$ => low p_T hadron event generation by T.Barklow
- Remove $\gamma\gamma$ backgrounds by applied k_T algorithm methods
- In 95 % of the cases k_T algorithm a success in regaining physics performance
- Few important cases still an exception to k_T algorithm method

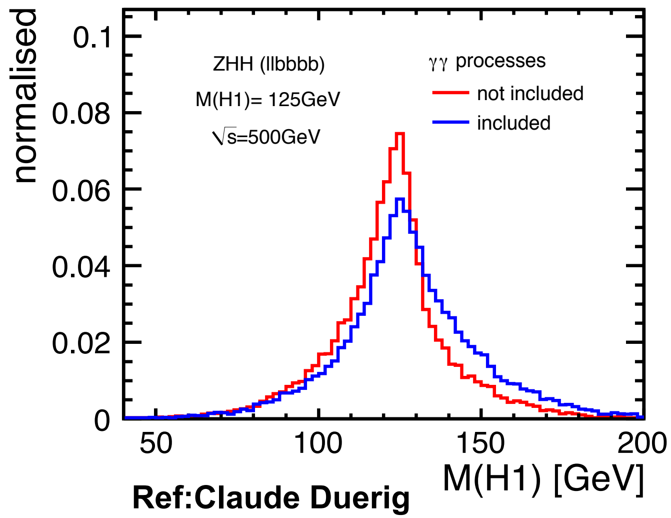
Impact of Hadron Overlay

- 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)
- They are low p_T particles moving in forward direction
- Much similar to $\gamma\gamma$ backgrounds

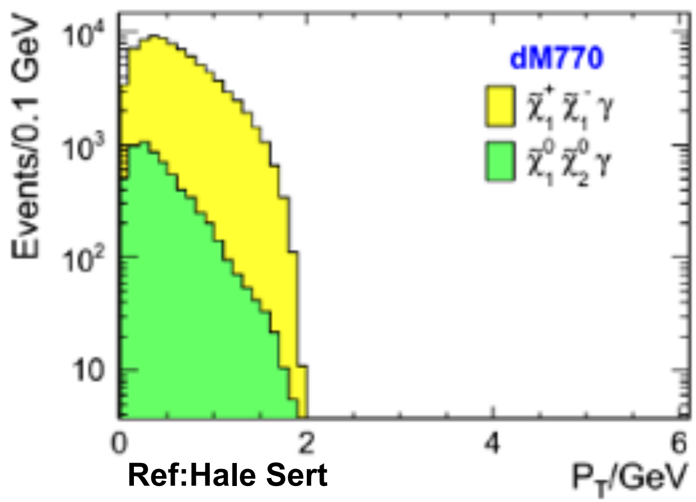
Need more differential methods to remove gamma-gamma background

- Identify gamma-gamma collision products by explicit reconstruction

Very important to have detailed simulation



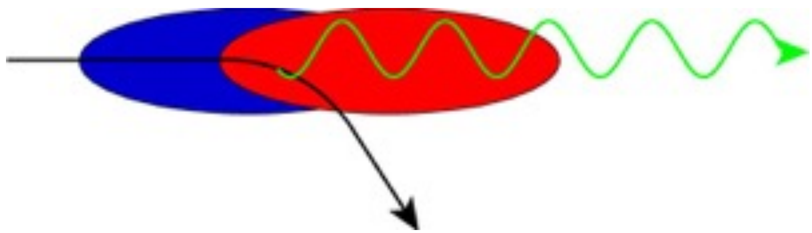
Ref:Claude Duerig

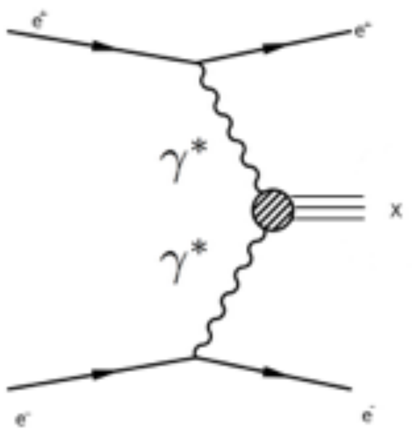


Ref:Hale Sert

Photons in an e^+e^- Collider

- $e^+ e^-$ beams are accompanied by :
- **Real photons $f_r(x)$:**
  - Beamstrahlung - emission of **real** photons in high electrical field of oncoming bunch
  - Synchrotron photons are backscattered gaining higher energy
- **Virtual Photons $f_v(x)$:**
  - Weizsaecker-Williams process - emission of **virtual** photons which can interact with an oncoming photon or an electron
- The spectra entering the $\gamma\gamma$ cross section is contributed from this sources -the photon

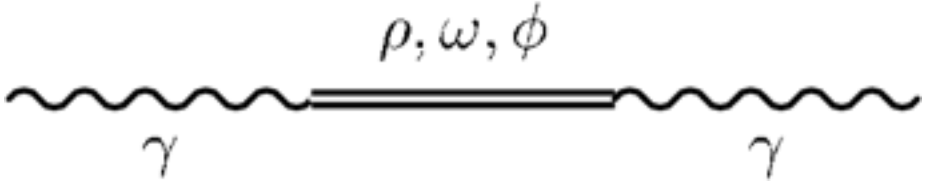


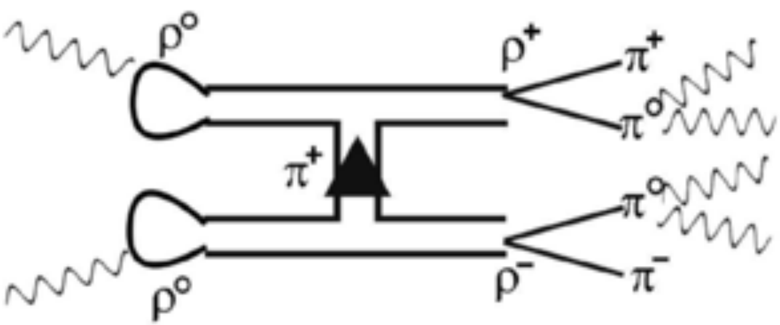


$$L_{\gamma\gamma} = f_v(x_1)f_v(x_2) + [f_v(x_1)f_r(x_2) + f_r(x_1)f_v(x_2] + f_r(x_1)f_r(x_2)$$

Vector Meson Dominance

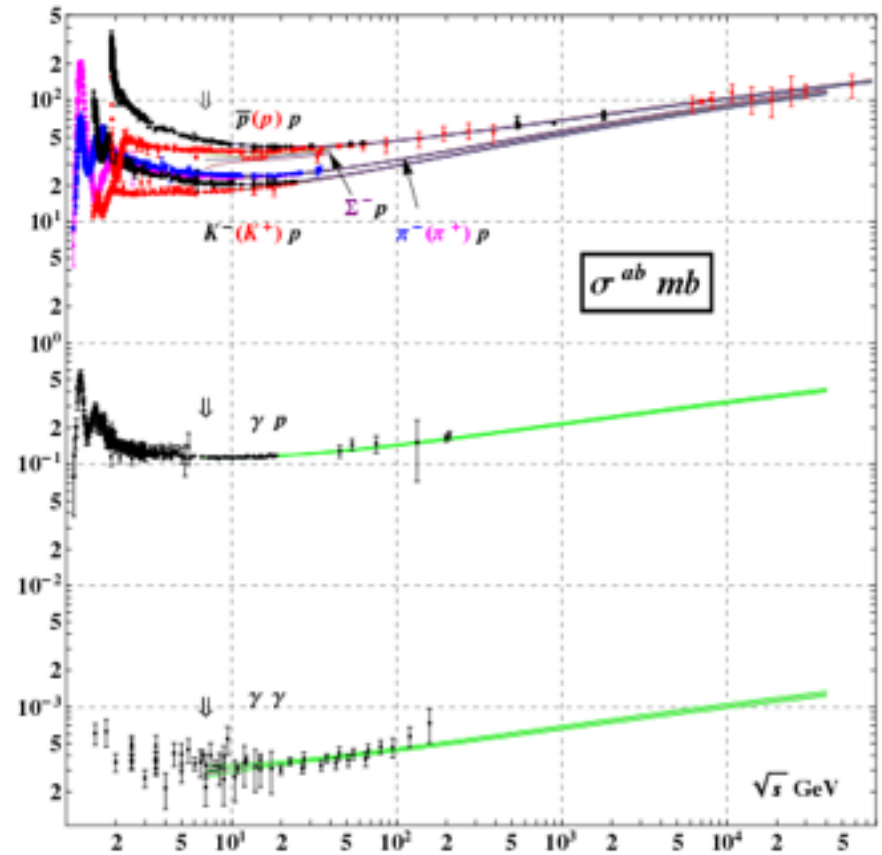
- Photons interact in different ways
- Vector meson dominance the most dominating subprocess in photon-photon processes
- A photon fluctuates into a vector meson (ρ,ω,ϕ, j/ψ, Υ) (same quantum properties)
- The highest probability for the photon to fluctuate is into a Rho meson.
- Production of number of low momentum soft Hadrons.





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

Current $\gamma\gamma$ => low pt hadron simulation

- The $\gamma\gamma$ => low pt hadron processes simulated by methods provided by T.Barklow
- Based on a blend of
  - Pythia events at $\sqrt{s_{\gamma\gamma}}$ > 10 GeV
  - Paper by Chen, Barklow and Peskin for 0.3 GeV< $\sqrt{s_{\gamma\gamma}}$ <10GeV
- Integrated into Whizard which provides the $\gamma\gamma$ => Hadron processes

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.

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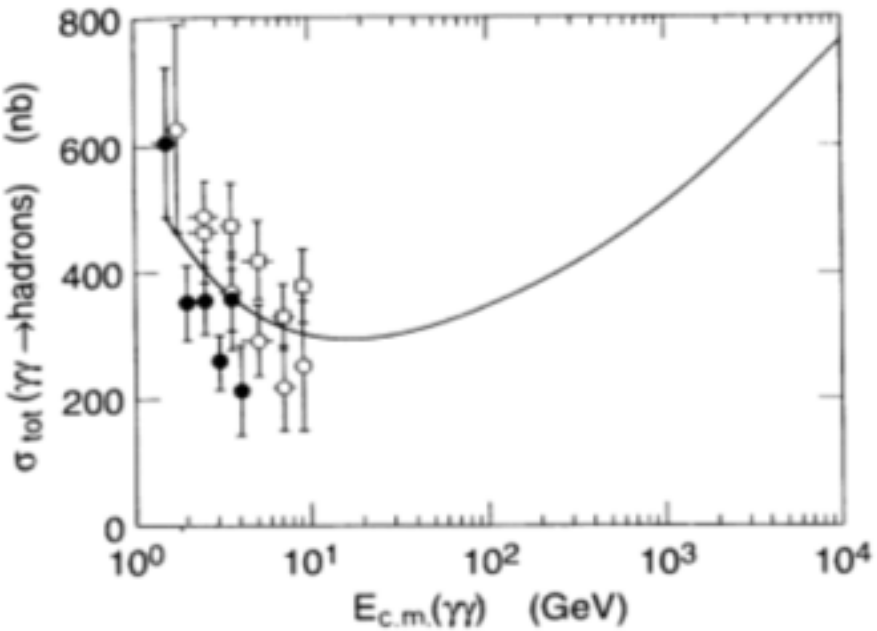
Total Cross Sections from Chen, Barklow and Peskin

- 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)

$\gamma\gamma$ - Processes in Pythia 6.4

- 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

- 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

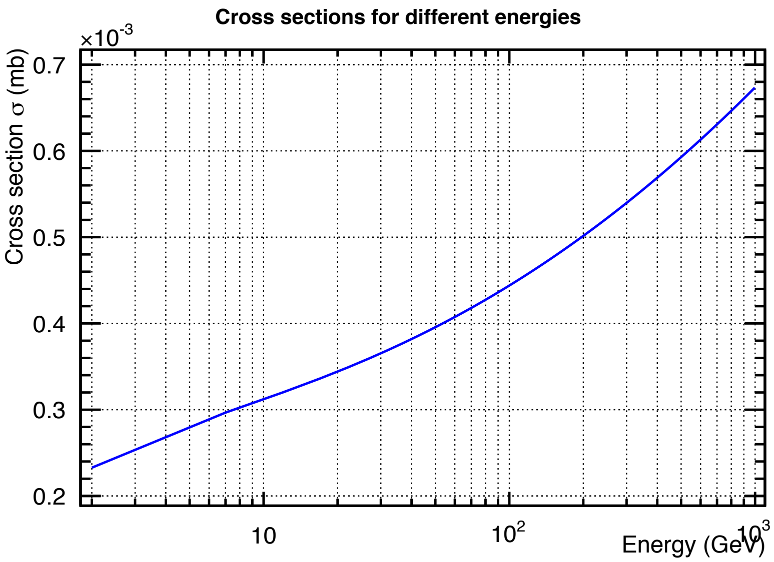
Update: Total cross section from PDG

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

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

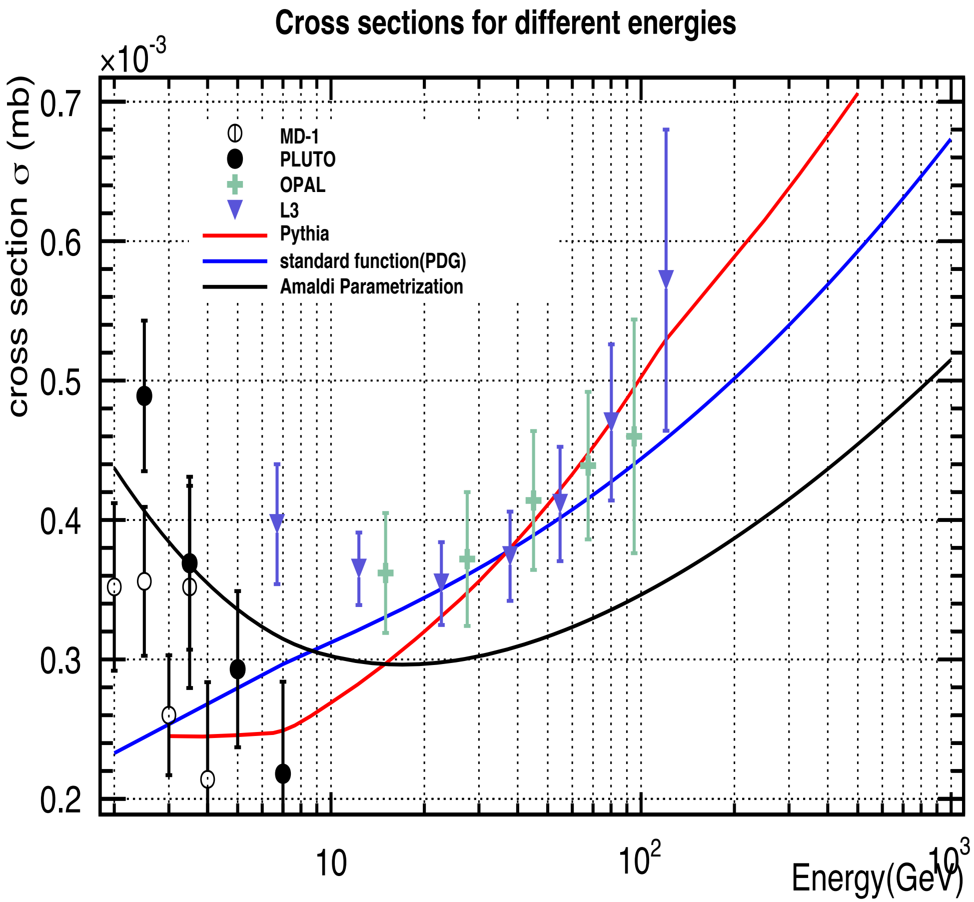
(Ref: Particle data group 2014)

- 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



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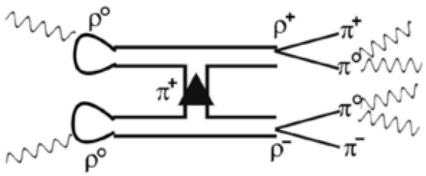
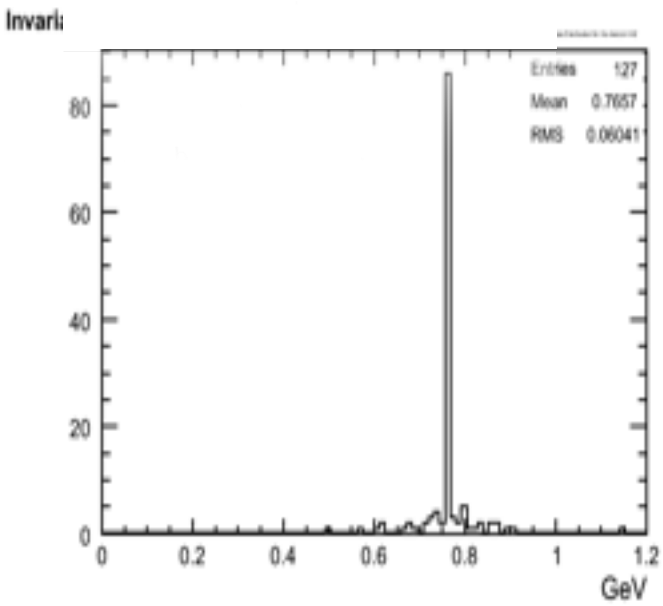
Event Properties

- Taking a look at the individual events from $\gamma\gamma$=> low pT hadrons
- m_ρ = 770 MeV and Γ_ρ= 145 MeV
- Barklow generator produces Rho mesons of same mass and no width at all.
- Most of the events having two rho mesons are $\rho^\pm$ and no ρ^0
- Events formulated in a way to have three following possibilities
  - $\pi^+\pi^-$
  - $\pi^\pm\rho^\pm$
  - $\rho^+\rho^-$
- Should have neutral Rhos and more complex events too

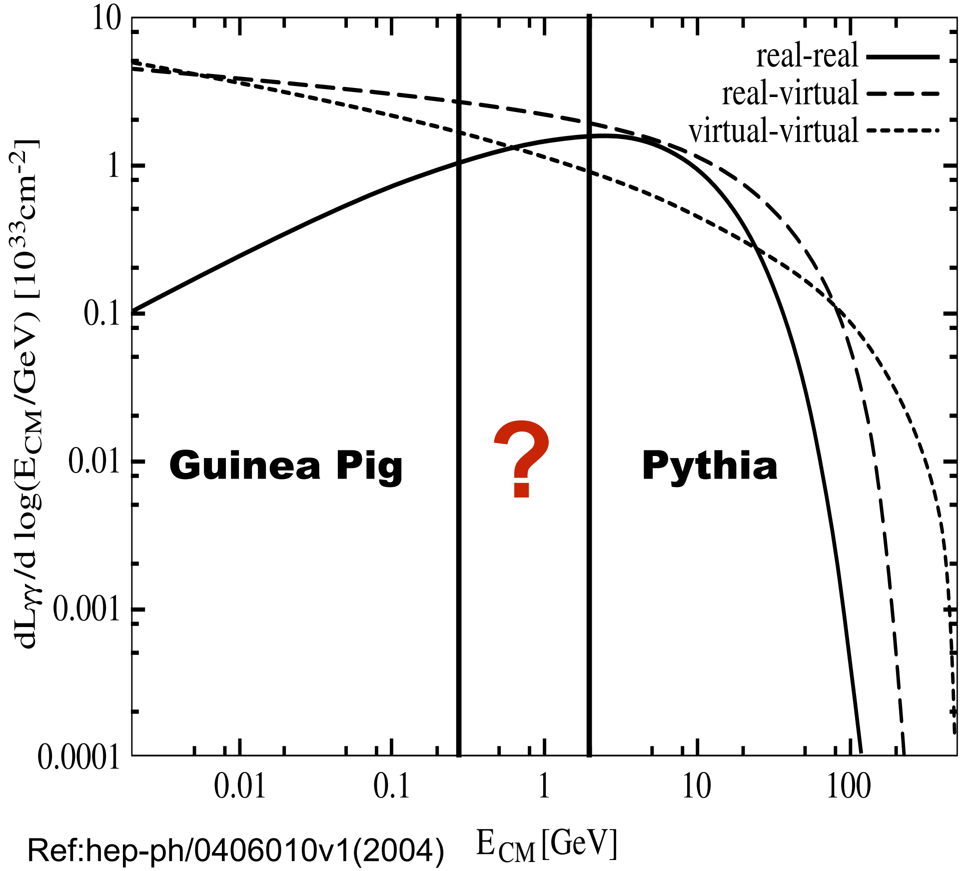




Two groups of rhos:
- **One with correct width -Pythia**
- **One with zero width-not pythia**

Shortcomings with Pythia

- Pythia can create very nice events with all variety of rhos and complex events
- 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)

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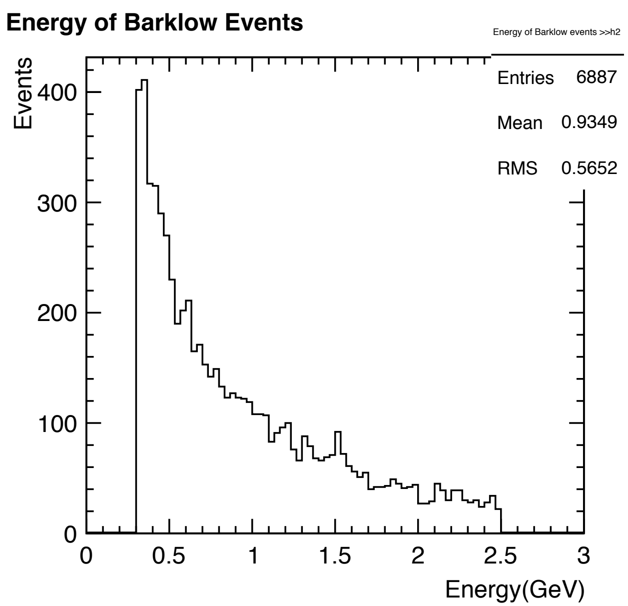
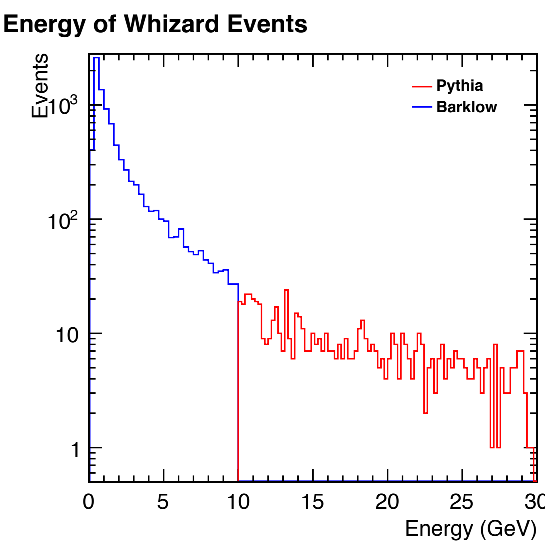
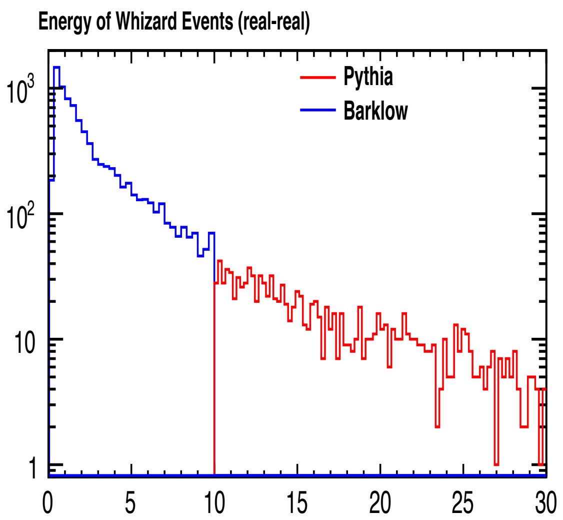
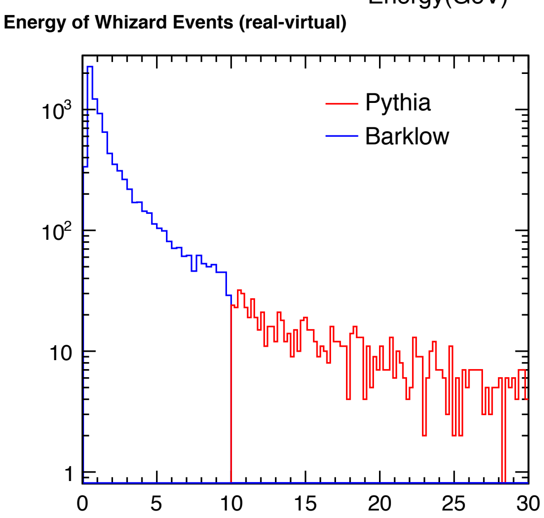
Status of events in Current Simulation

- Whizard events a blend of events from pythia and Barklow generator.
- Events upto 10GeV from Barklow generator
- Events above 10GeV from Pythia
- Can Use Pythia to generate events from 2.5GeV to 10 GeV









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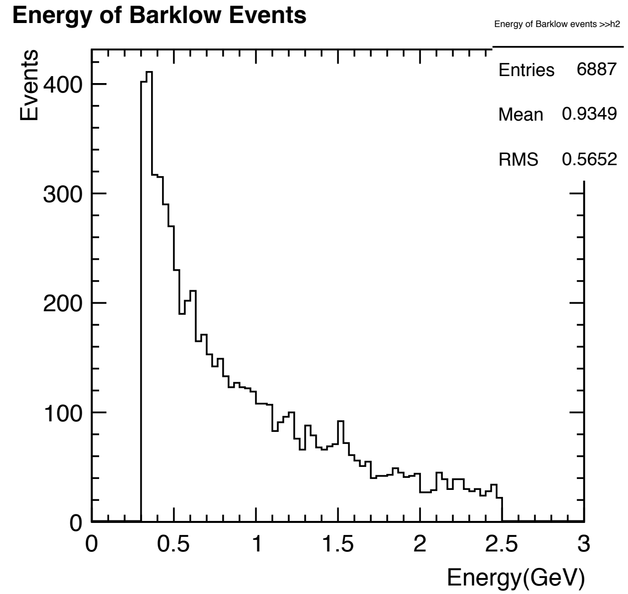
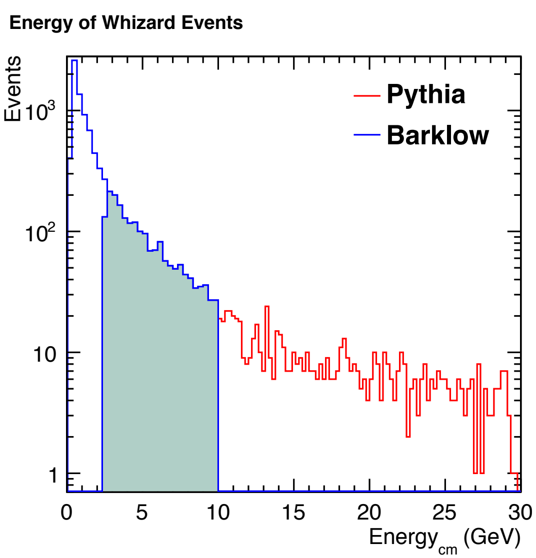
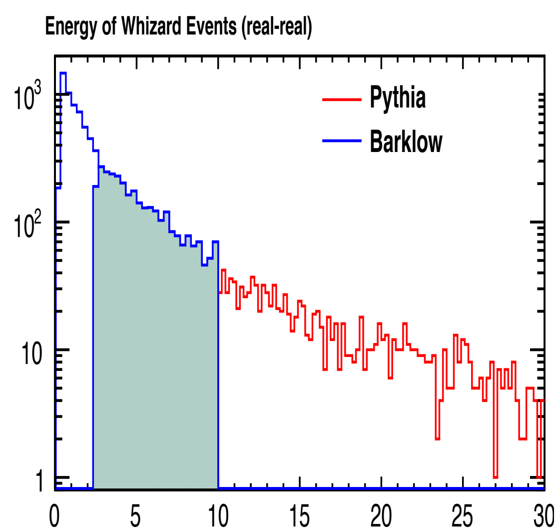
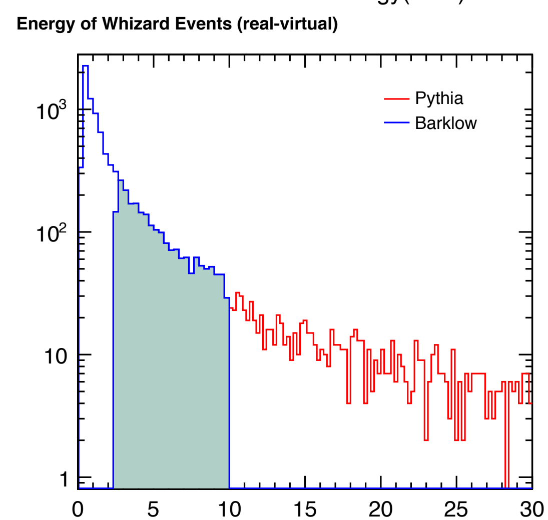
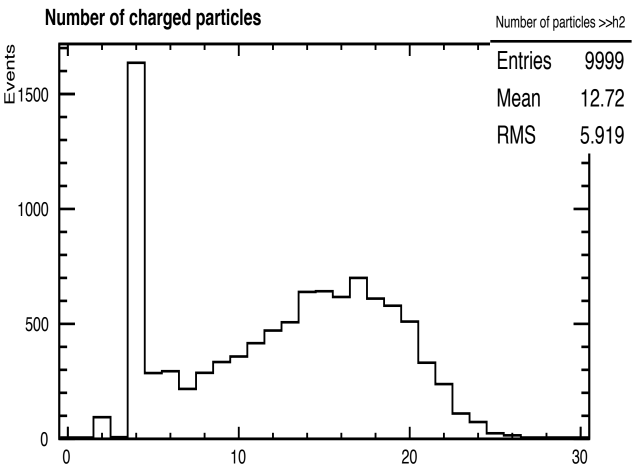


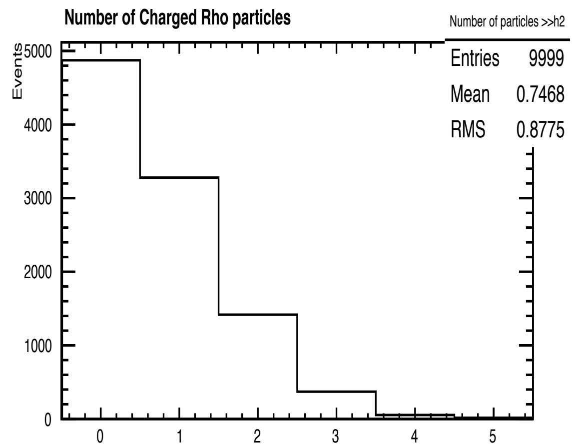


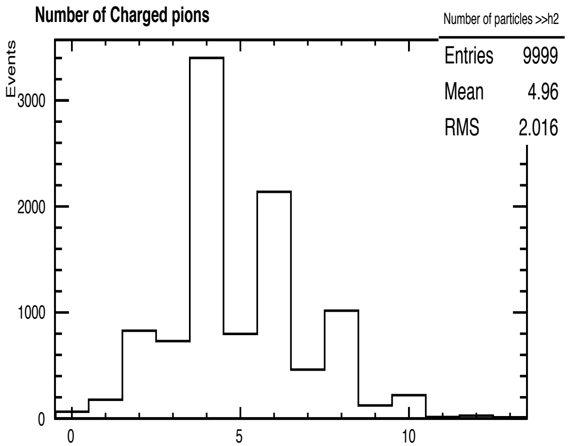


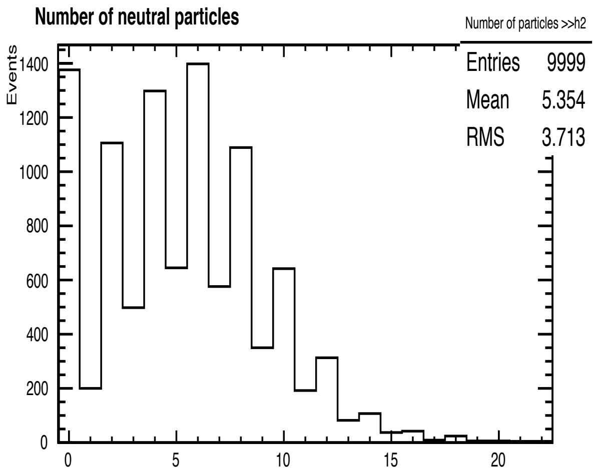


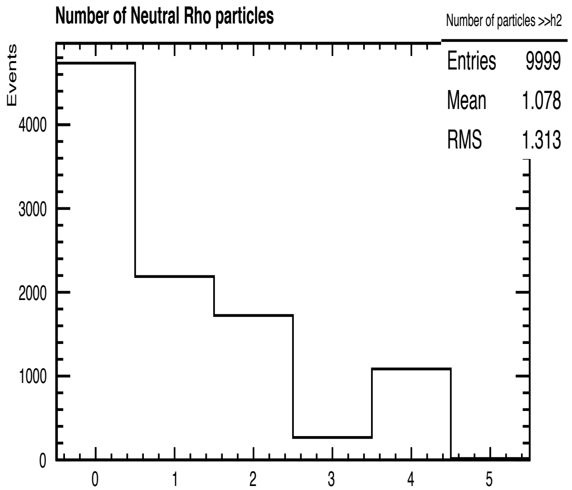
Number of Particles (CMS=6GeV)

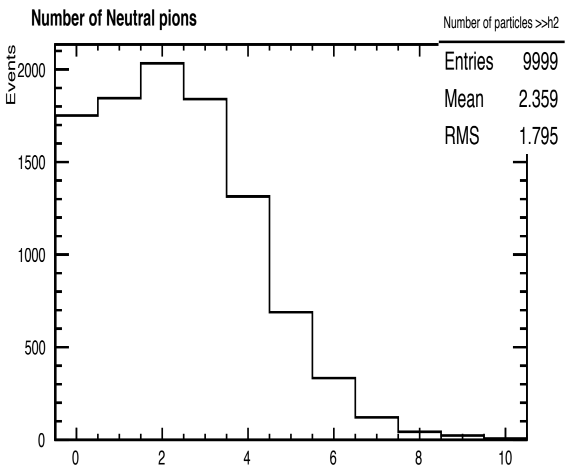












Summary and Outlook

- Summary:
  - Through the detailed study of the events show that reconsidering the events in Whizard is important
  - Very important to have better simulation ways to remove $\gamma\gamma$ backgrounds
- Outlook:
  - Try to change the cut of Pythia from 10 GeV to 2.5 GeV in Whizard
  - Try to bring Pythia for lower energies by changing parameters
  - How much important is the 0.3-2.5 GeV range and solutions
  - Check alternative programs
  - Improve Barklow generator

Back up slides

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