

Hadron Production in Photon-Photon Processes at International Linear Collider

International Workshop on Linear Colliders

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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
 - ▶ $\gamma\gamma \Rightarrow$ 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



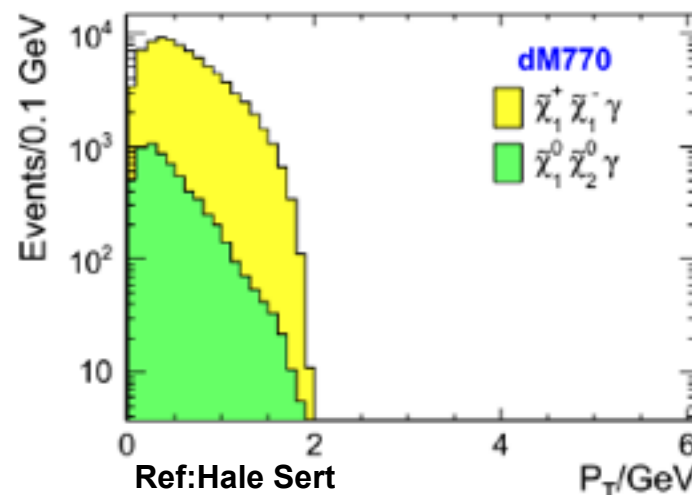
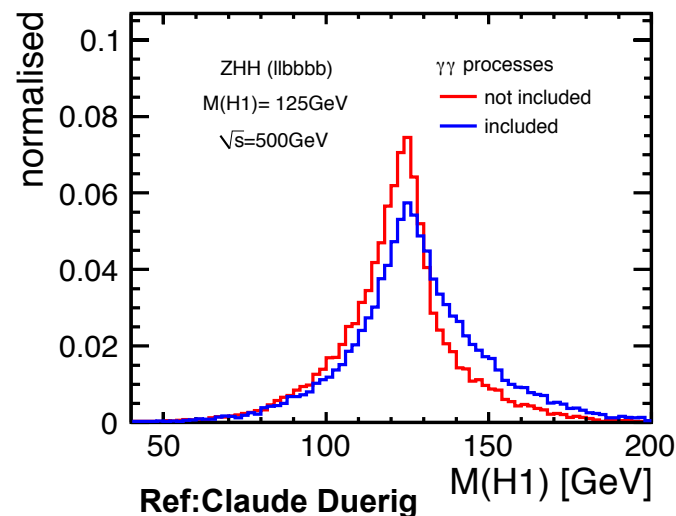
Impact of Hadron Overlay

- 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

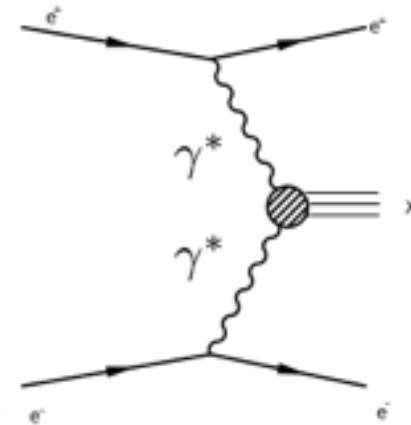
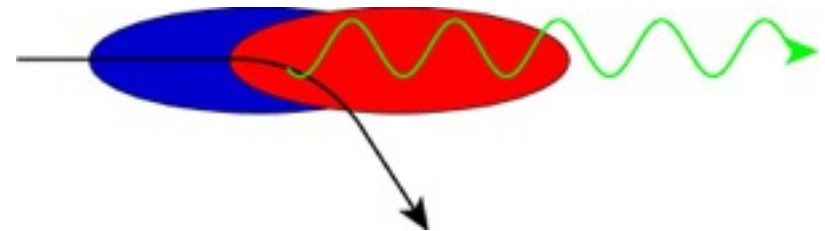
- Identify gamma-gamma collision products by explicit reconstruction

Very important to have detailed simulation



Photons in an e^+e^- Collider

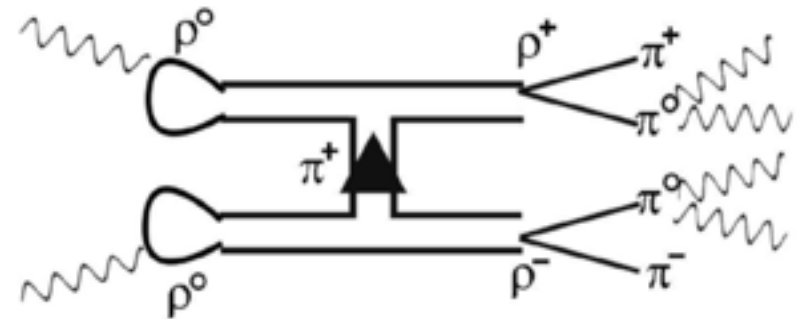
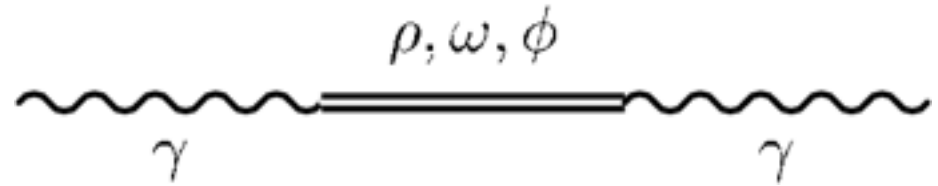
- e^+e^- beams are accompanied by :
- Real photons $f_r(x)$:
 - ▶ Beamstrahlung - emission of **real** photons in high electrical field of oncoming bunch
 - ▶ Synchrotron photons are backscattered gaining higher energy
- Virtual Photons $f_v(x)$:
 - ▶ Weizsaecker-Williams process - emission of **virtual** 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



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

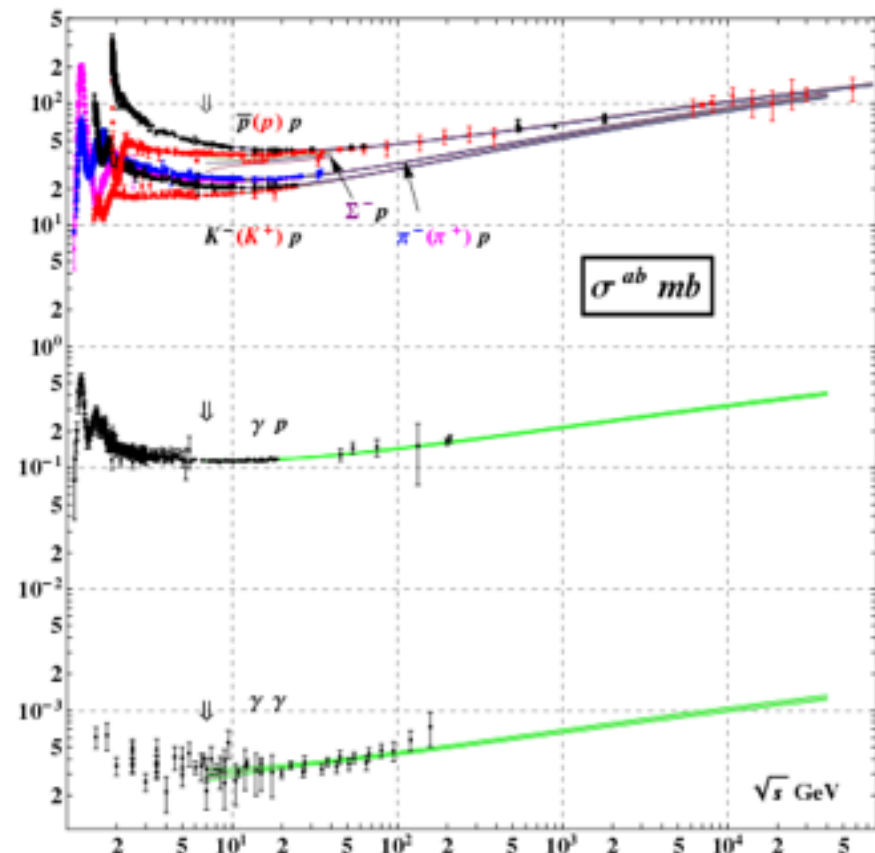
Vector Meson Dominance

- Photons interact in different ways
- Vector meson dominance the most dominating subprocess in photon-photon processes
- A photon fluctuates into a vector meson ($\rho, \omega, \phi, j/\psi, \Upsilon$) (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 $\gamma\gamma \Rightarrow$ low pt hadron simulation

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

arXiv:hep-ph/9305247v1 11 May 1993

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

PIBIN CHEN, TIMOTHY L. BARKLOW, AND MICHAEL E. PESKIN

*Stanford Linear Accelerator Center
Stanford University, Stanford, California 94309*

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.



Outline

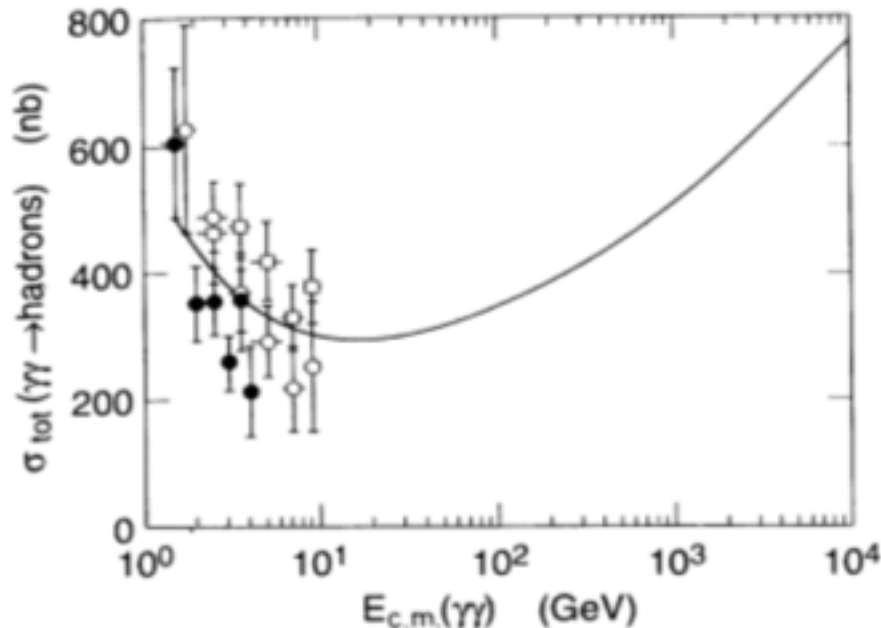
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Total Cross Sections from Chen, Barklow and Peskin

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

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



(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



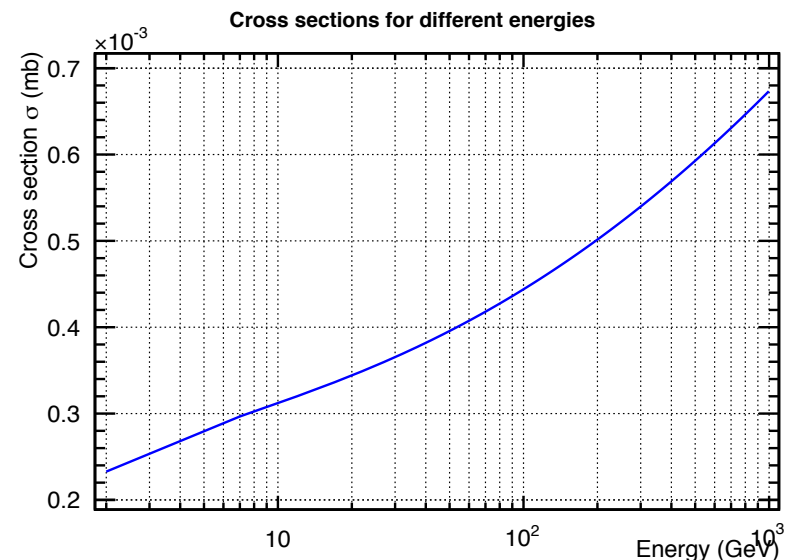
Update: Total cross section from PDG

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

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

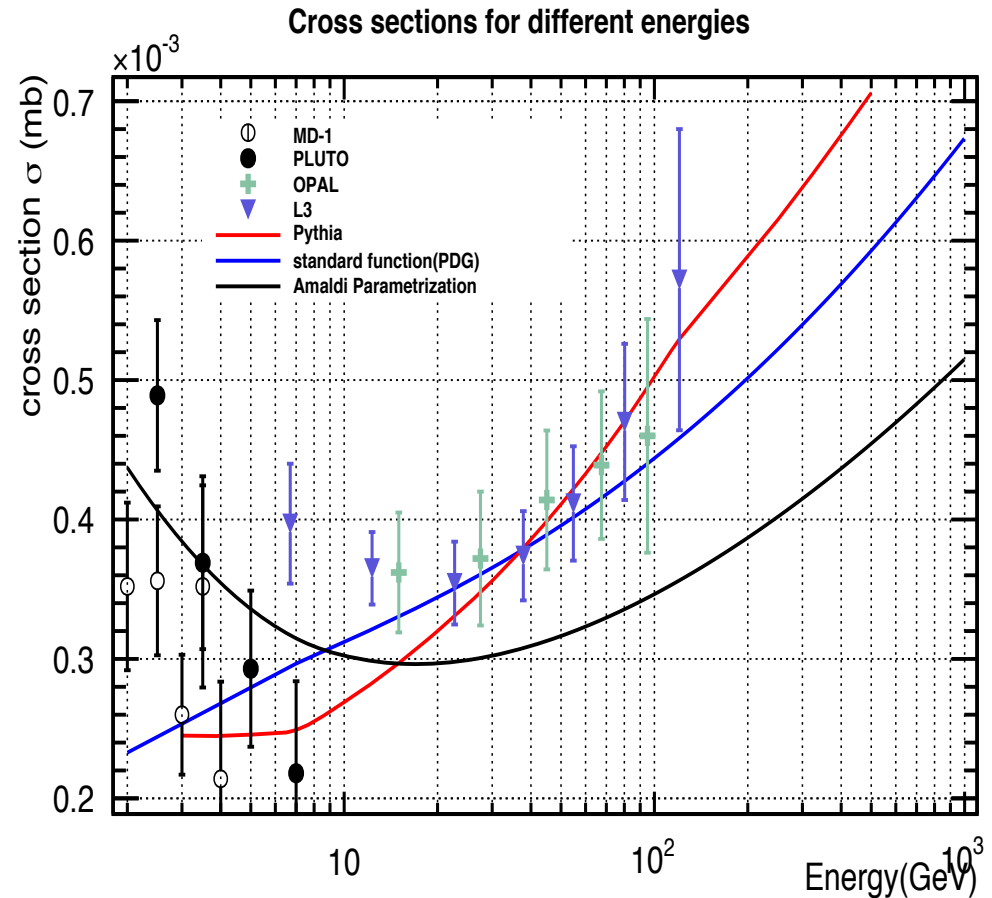
(Ref: Particle data group 2014)

- 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: $H = \pi \left(\frac{\hbar c^2}{M^2} \right)$ 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



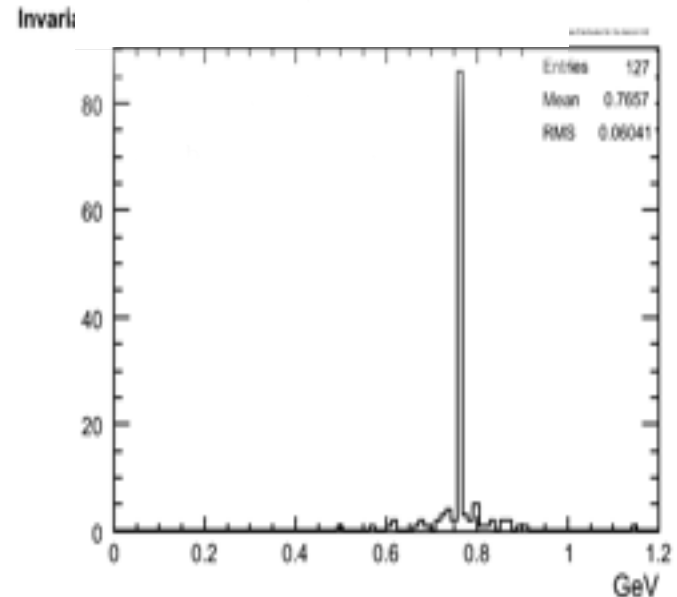
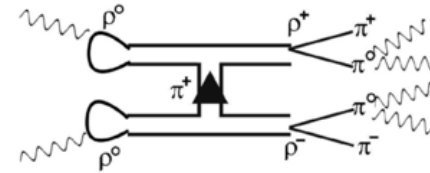
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Event Properties

- Taking a look at the individual events from $\gamma\gamma \Rightarrow$ low pT hadrons
- $m_\rho = 770$ MeV and $\Gamma_\rho = 145$ MeV
- Barklow generator produces Rho mesons of same mass and no width at all.
- Most of the events having two rho mesons are ρ^\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

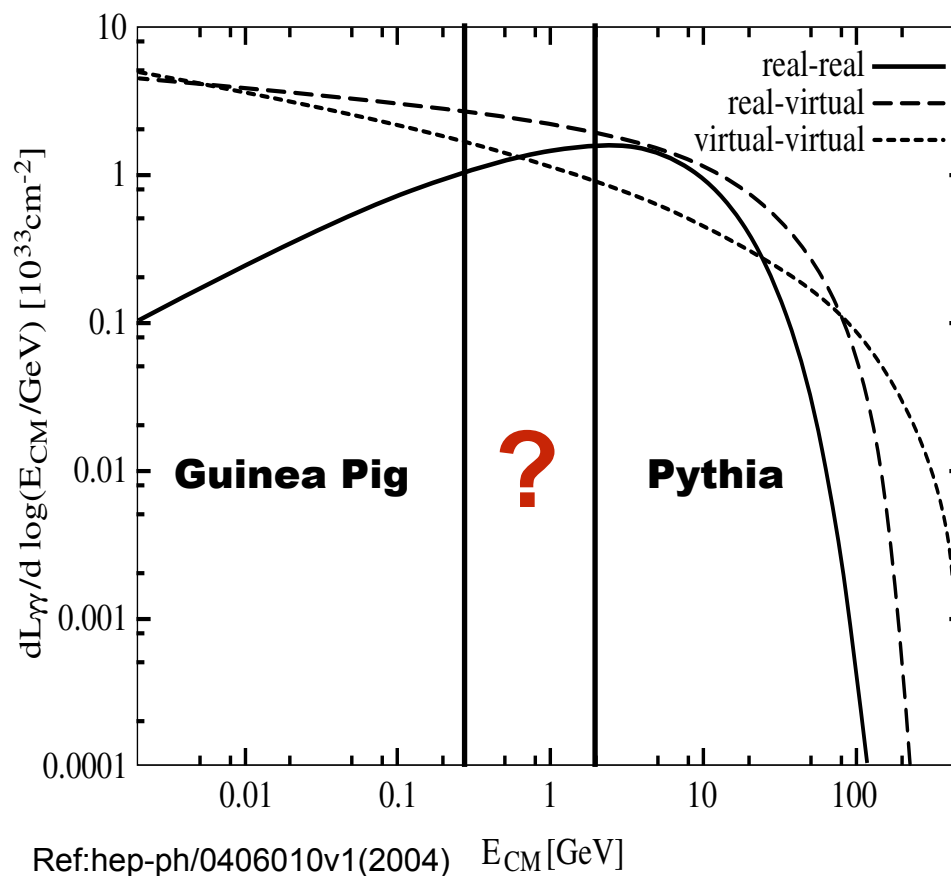


Two groups of rhos:

- 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



Outline

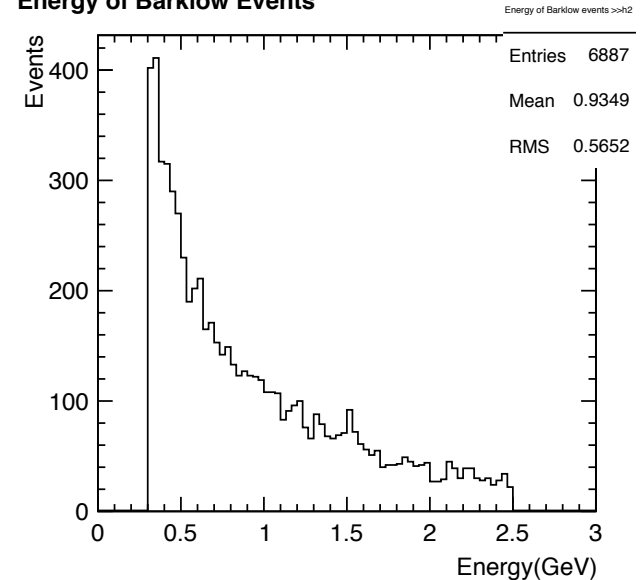
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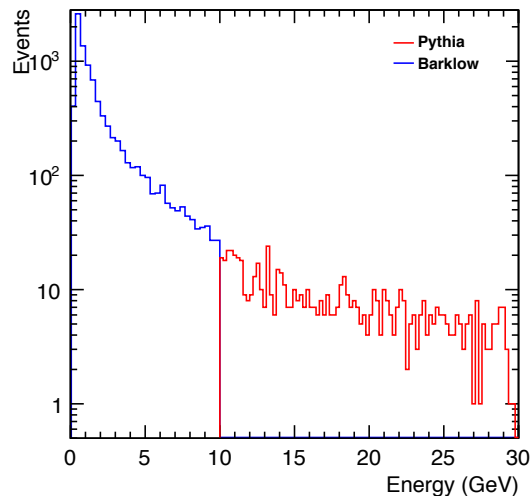
Status of events in Current Simulation

- > 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

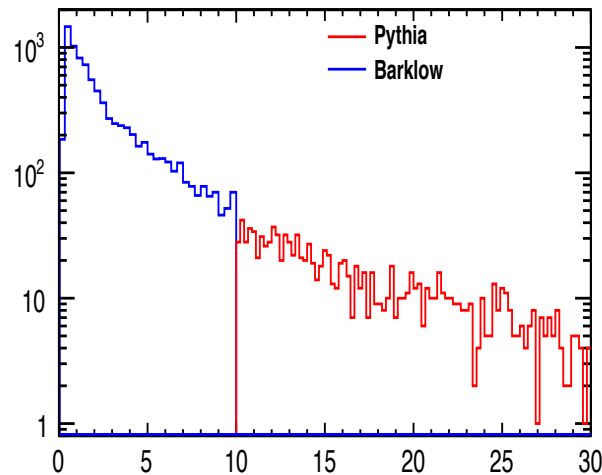
Energy of Barklow Events



Energy of Whizard Events



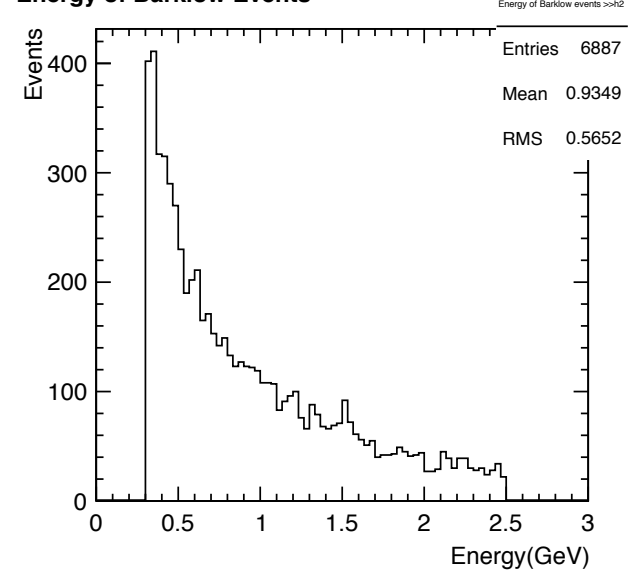
Energy of Whizard Events (real-real)



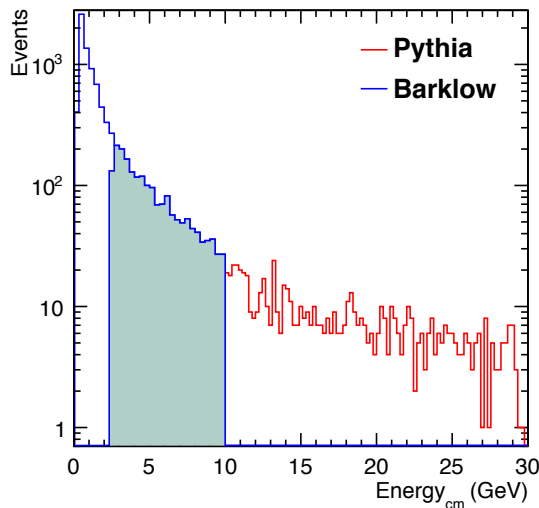
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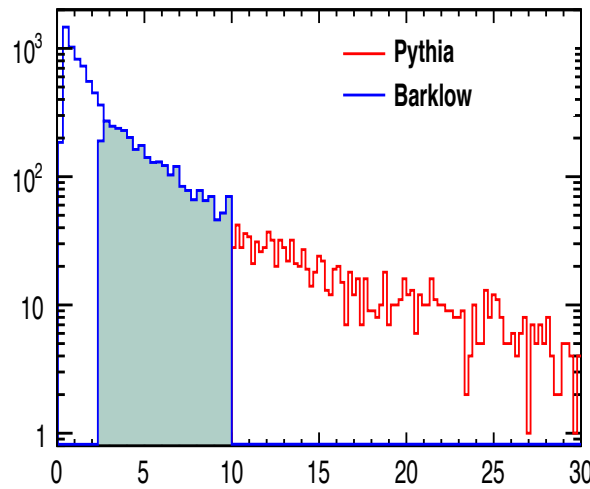
Energy of Barklow Events



Energy of Whizard Events



Energy of Whizard Events (real-real)

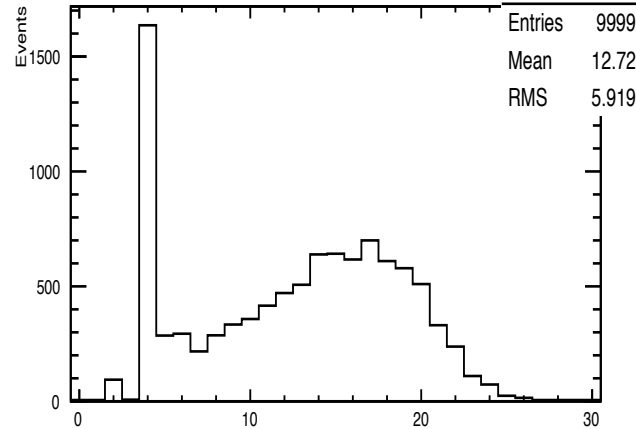


Number of Particles (CMS=6GeV)

Number of charged particles

Number of particles >>h2

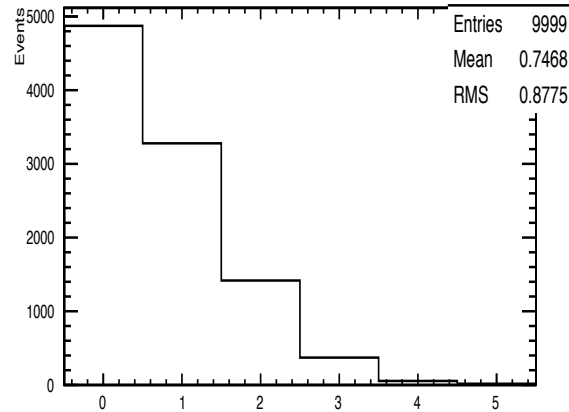
Entries 9999
Mean 12.72
RMS 5.919



Number of Charged Rho particles

Number of particles >>h2

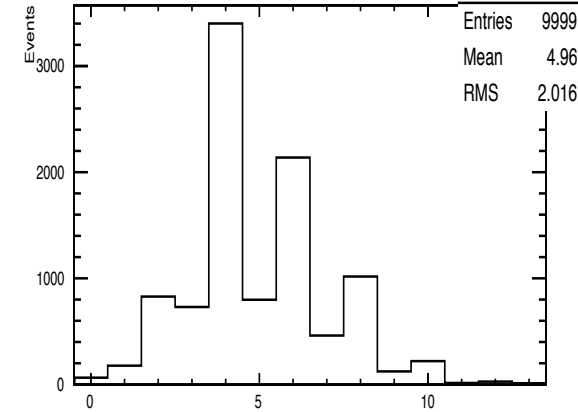
Entries 9999
Mean 0.7468
RMS 0.8775



Number of Charged pions

Number of particles >>h2

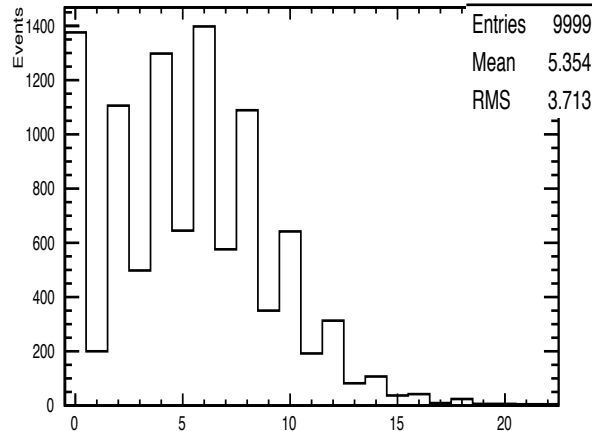
Entries 9999
Mean 4.96
RMS 2.016



Number of neutral particles

Number of particles >>h2

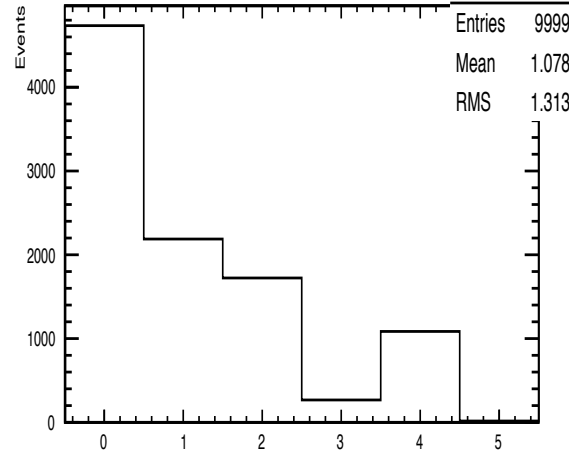
Entries 9999
Mean 5.354
RMS 3.713



Number of Neutral Rho particles

Number of particles >>h2

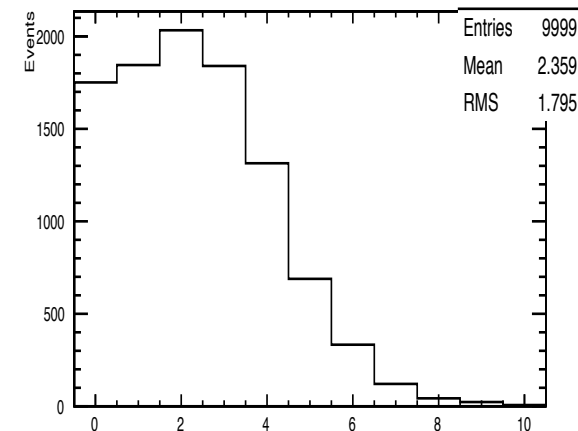
Entries 9999
Mean 1.078
RMS 1.313



Number of Neutral pions

Number of particles >>h2

Entries 9999
Mean 2.359
RMS 1.795



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



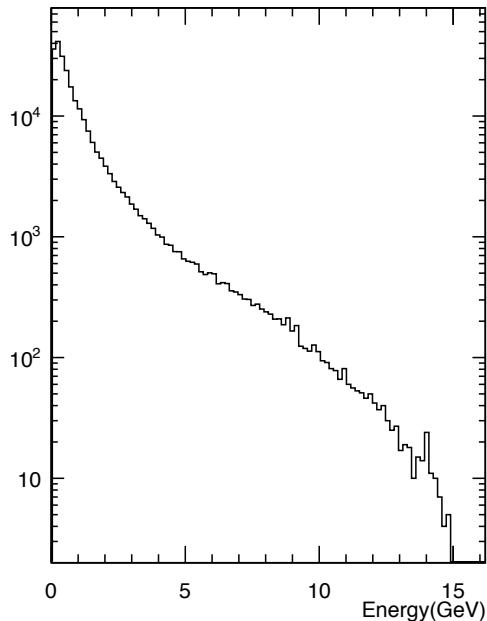
Back up slides



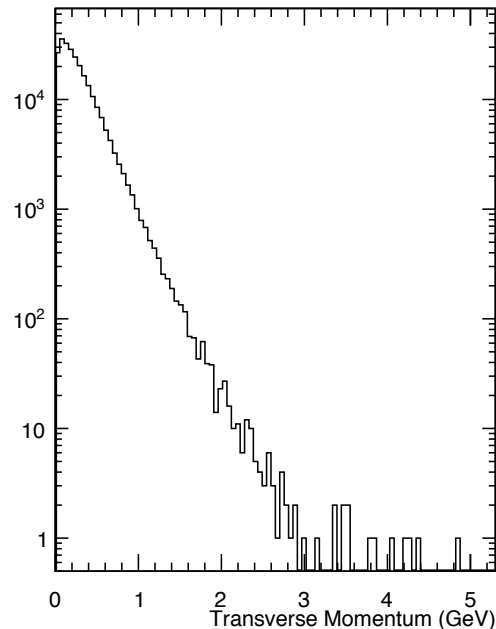
Pythia as a tool

- 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

`mcene {mcgst==1}`



`sqrt(mcmox*mcmox+mcmoy*mcmoy) {mcgst==1}`



`mcmod*sqrt(mcmox*mcmox+mcmoy*mcmoy+mcmz*mcmz) {mcgst==1}`

