Standard Model Higgs Production

Gluon Fusion
SM Higgs Production contd.

Higgsstrahlung and WW,ZZ fusion

Higgsstrahlung

WW,ZZ fusion
H \rightarrow \gamma \gamma
Event Generation, Reconstruction, Digitization

- Used CMKIN, v. 4.3.1, part of CMS OO framework. Is front end for various MC event generators, including Pythia, Herwig, Alpgen, etc.
- Used Pythia only. Generated 455 events
- Higgs mass set at 170.0 GeV. So the fermions in the previous production diagrams are essentially top quarks.
- Forced higgs generation by gluon fusion only and decay exclusively into 2 gammas.
- Reconstruction and Digitization performed by OSCAR v. 3.7.0 (GEANT4 based) and ORCA v. 8.7.3 respectively.
- The Generation, Reconstruction and Digitization took about 3 days for 455 events, with reconstruction taking up most of the time.
Goals

• To understand the reconstruction chain.
• To get familiarized with the format of the ROOT files, as the actual data is going to be in the ExRootAnalysis framework.
• Understand LHC physics
• To understand the difficulties involved in reconstructing the higgs mass in the H-> \( \gamma \gamma \) decay channel, at least to first first first order.
ExRootAnalysis

- User-extendable package to produce root files from fully reconstructed data
- By default, includes generator level info, GEANT4 level objects, trigger primitives (L1 and HLT), track objects, vertex info, jets, Calorimeter hits, electron candidates, photon candidates, muon candidates and more (see http://cmsdoc.cern.ch/swdev/viewcvs/viewcvs.cgi/*checkout*/ORCA/Examples/ExRootAnalysis/doc/RootTree.html)
- Really easy to use (getting the final root file, however, is a little more complicated).
Some Interesting Plots
Determining Parentage of Reconstructed Gammas

• Easy to determine parentage of generated gammas....just look through the event list!

• Harder for reconstructed gammas. Need to match generated gammas from higgs to reconstructed gammas. An r cut was employed, where r is defined as:

\[ r = \sqrt{\Delta \eta^2 + \Delta \phi^2} \]

• Where \( \Delta \eta \) and \( \Delta \phi \) are the differences between the eta of the generated gamma and reconstructed gamma, and the phi of the generated gamma and reconstructed gamma respectively. Both were chosen to be 0.018, corresponding to spatial extent in \( \eta - \phi \) space of the individual EM calorimeter crystals.
Δ η vs Δ φ

delta phi vs delta eta

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<tr>
<td>Integral</td>
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Results of $\Delta \eta$ vs $\Delta \phi$ cut

**PT of gammas coming from higgs, generated**

![Graph showing PT distribution for generated gammas from higgs]

**GammaPTGen_h**
- Entries: 910
- Mean: 76.97
- RMS: 39.48
- Underflow: 0
- Overflow: 0
- Integral: 910

**PT of gammas coming from higgs, reconstructed**

![Graph showing PT distribution for reconstructed gammas from higgs]

**GammaPTRecon_h**
- Entries: 819
- Mean: 77.17
- RMS: 39.02
- Underflow: 0
- Overflow: 0
- Integral: 819
N.B.

- 112899 gammas generated in total
- Only 1249 gammas reconstructed (1.1%)
- But out of these 1249 gammas, 819 matched to gammas from higgs (~2/3)
- So reconstruction of high energy gammas (those gammas with PT > 10 GeV considerably more efficient than low energy gammas)
- ExRootAnalysis is smart enough to use calorimeter info to return weighted values for eta and phi. Translates into better spatial resolution
Invariant mass of higgs

Invariant mass of Higgs from gammas, reconstructed

Invariant mass of Higgs from gammas, generated

| HinvMass_r | Entries  | 376 |
|           | Mean     | 146.7 |
|           | RMS      | 35.29 |
|           | Underflow| 0    |
|           | Overflow | 0    |
|           | Integral | 376  |

| HinvMass_g | Entries  | 455 |
|           | Mean     | 170 |
|           | RMS      | 0.8404 |
|           | Underflow| 0   |
|           | Overflow | 0   |
|           | Integral | 455 |
Conclusions

- Out of 455 generated higgs, was able to find both gammas and reconstruct the higgs mass to fairly good accuracy (found both gammas and was able to get invariant mass between 160 and 180 GeV in 247 events)

- For SM higgs in the 115-180 Gev mass range three decay channels are important, $H \rightarrow \gamma \gamma$, $t \bar{t}$ production with $H \rightarrow b \bar{b}$ decay and VBF production followed by $H \rightarrow \tau \bar{\tau}$

- Although most gammas are not reconstructed, the high energy ones are and this is important for higgs discovery in the $H \rightarrow \gamma \gamma$ channel.

- Even accounting for optimistic reconstruction, if SM higgs exists in low to mid mass range (about 50 – 180 GeV), one can use $H \rightarrow \gamma \gamma$ channel for higgs discovery.