Delphes Simulation Studies on Higgs Pair Production in Muon Collider

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- Signal: $\mu^+ + \mu^- \rightarrow v_\mu + \bar{v}_\mu + H + H$
- Background:
  - $\mu^+ + \mu^- \rightarrow v_\mu + \bar{v}_\mu + b + \bar{b} + Z$
  - $\mu^+ + \mu^- \rightarrow v_\mu + \bar{v}_\mu + b + \bar{b} + H$
  - $\mu^+ + \mu^- \rightarrow v_\mu + \bar{v}_\mu + b + \bar{b} + b + \bar{b}$

Reconstructing two Higgs bosons

- Anti-k_t Jets:

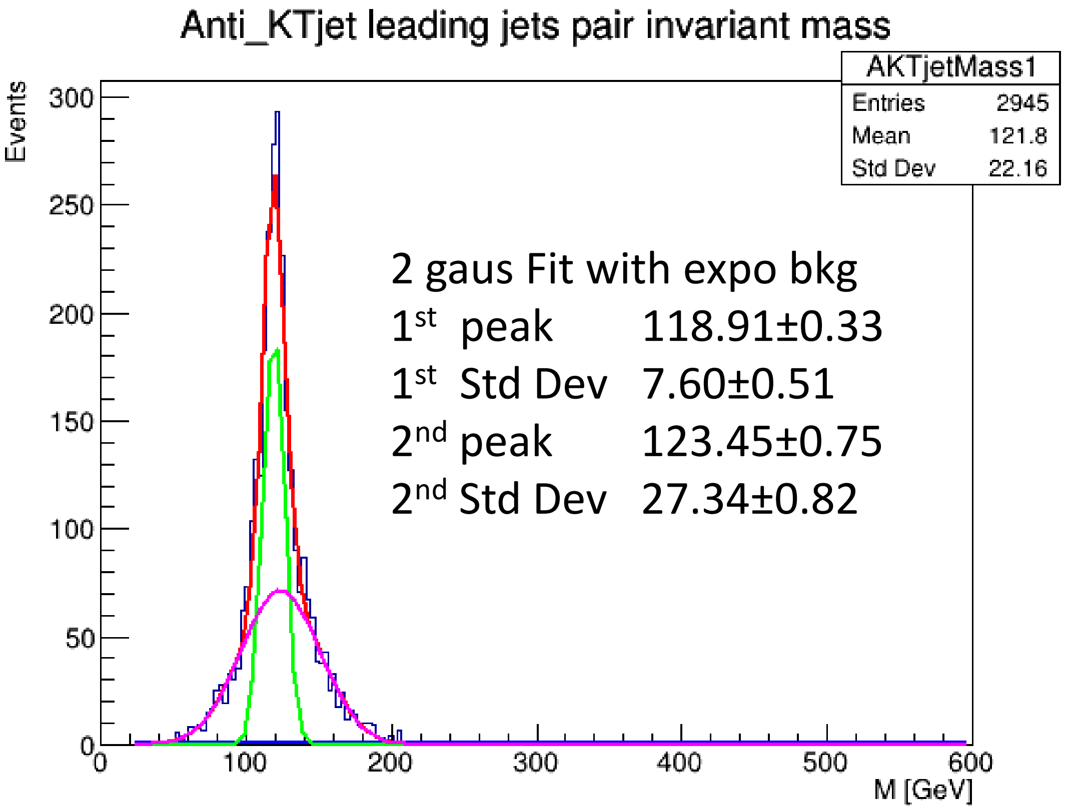
1. Single jets pair optimize:
   - Simply leading and sub-leading jets pair, ordering by how far it is from 125GeV
2. **Dual jets pair optimize:**
   - **Minimize the sum of the distance from jets pair to 125GeV**

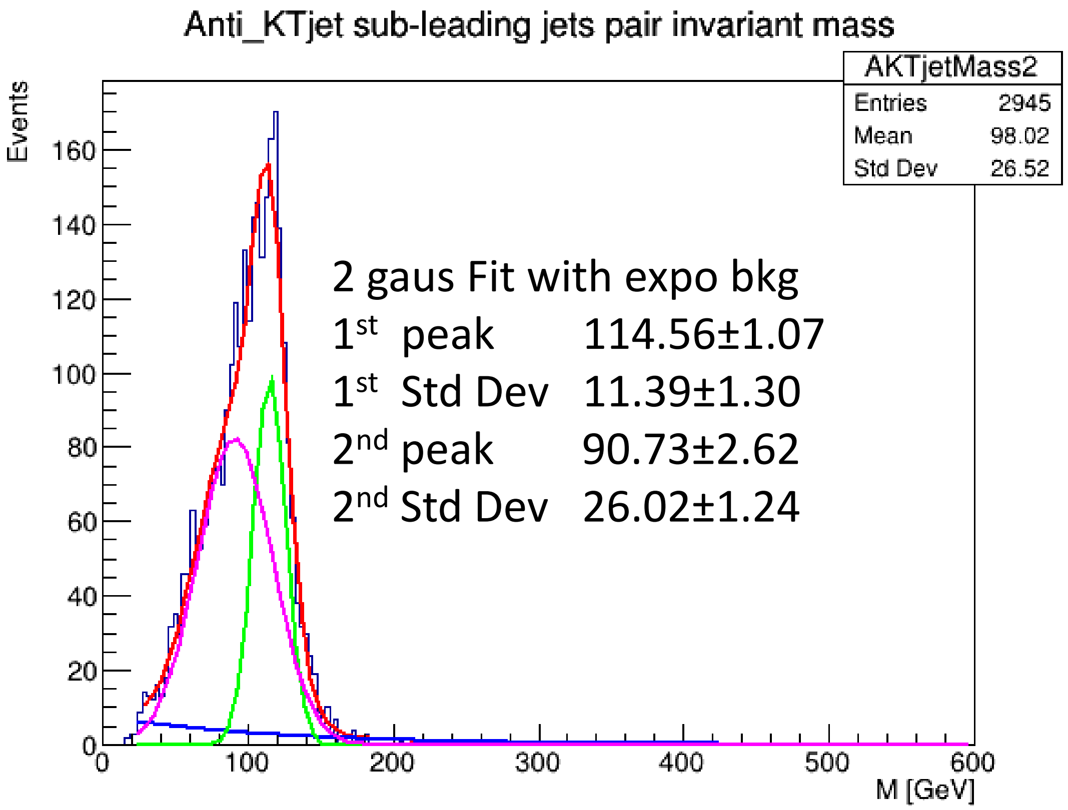
Double gaussian fit with exponential background

- Fit to curve:
  - $f(x) = A_1 \exp[-\frac{1}{2}\left(\frac{x-\mu_1}{\sigma_1}\right)^2] + A_2 \exp[-\frac{1}{2}(\frac{x-\mu_2}{\sigma_2})^2] + \exp(A_3 - \lambda x)$
  - Tight bound on almost all parameters

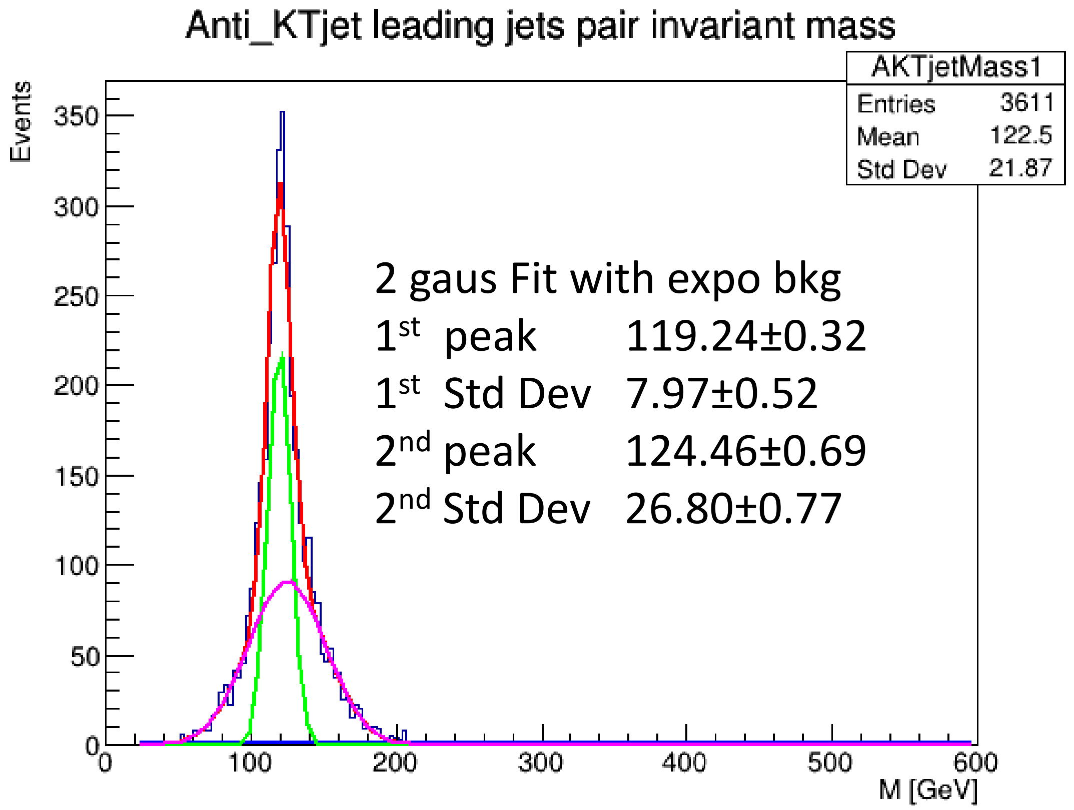
```
TF1 *jetpair1fit = new TF1("jetpair1fit", "gaus+gaus(3)",25,600);
TF1 *jetpair2fit = new TF1("jetpair2fit", "gaus+gaus(3)+expo(6)",25,600);
TF1 *fSignal = new TF1("fSignal","gaus+gaus(3)",20,600);
TF1 *fBackground = new TF1("fBackground","expo", 20,600);
Double_t param[8];

jetpair2fit->SetParameters(200,133,10,20,100,10,2,-0.0001);
jetpair2fit->SetParLimits(0,80,200);
jetpair2fit->SetParLimits(1,110,130);
jetpair2fit->SetParLimits(2,5,25);
jetpair2fit->SetParLimits(6,0,8);
jetpair2fit->SetParLimits(7,-1,-0.0001);
jetpair2fit->SetParLimits(4,50,109);
jetpair2fit->SetParLimits(5,5,30);

jetpair1fit->SetParameters(300,120,10,40,125,10,2,-0.0001);
jetpair1fit->SetParLimits(0,100,400);
jetpair1fit->SetParLimits(1,110,120);
jetpair1fit->SetParLimits(2,5,30);
/*jetpair1fit->SetParLimits(6,0,8);
jetpair1fit->SetParLimits(7,-1.5,-0.0001);*/
jetpair1fit->SetParLimits(4,120,140);
jetpair1fit->SetParLimits(5,5,40);
```

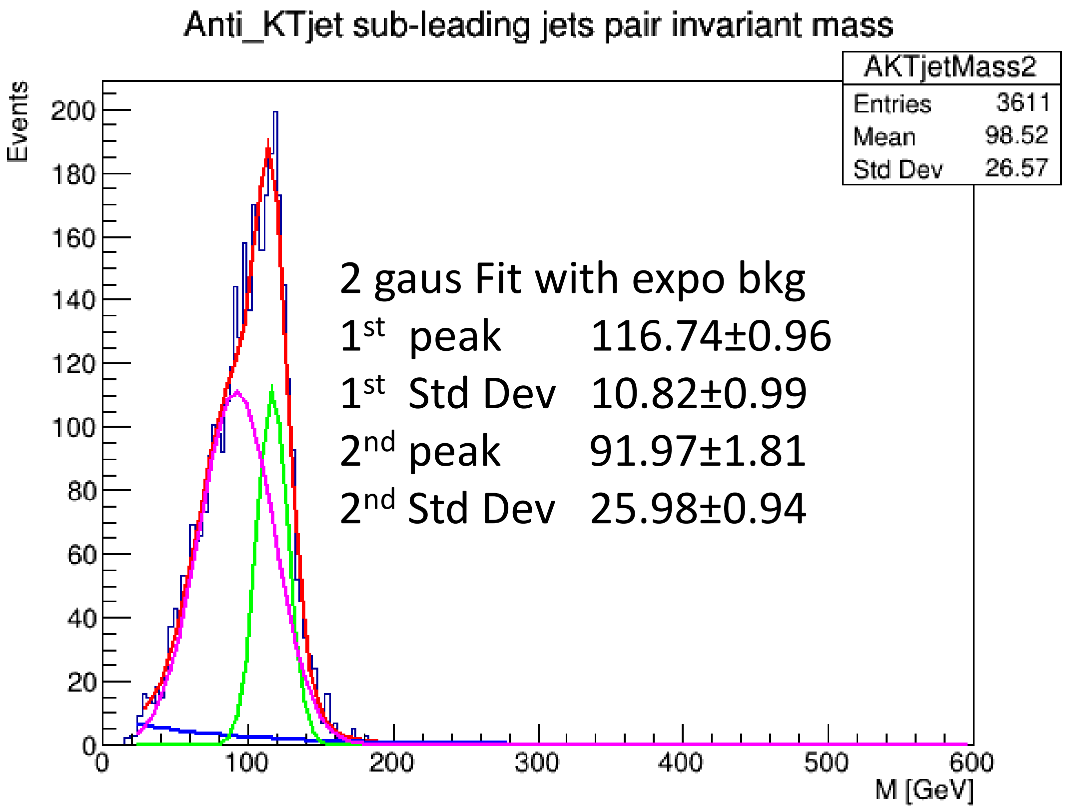
Anti-k_t jet for 10k events (nJets = 4)





Anti-k_t jet for 10k events (nJets ≥ 4)





Appendix: data card for run anti-k_t jet algo

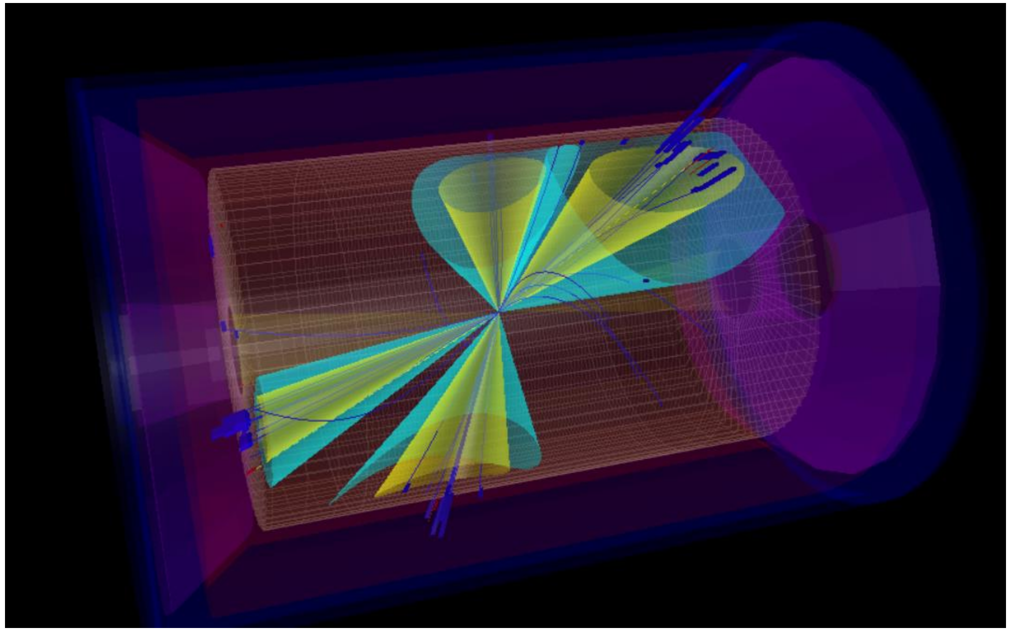
```
################
# Jet finder AKT
################

module FastJetFinder FastJetFinderAKt {
    #  set InputArray Calorimeter/towers
    set InputArray EFlowMerger/eflow

    set OutputArray AKTjets

    # algorithm: 1 CDFJetClu, 2 MidPoint, 3 SIScone, 4 kt, 5 Cambridge/Aachen, 6 antikt
    set JetAlgorithm 6
    set ParameterR 0.5

    set JetPTMin 20.0
}
```

Appendix: Dual jets pair optimize

- Anti-k_t Jets:
  1. Arbitrarily pick two from all jets
  2. Choosing one pair that is closest to 125GeV from the rest to be the respective sub-leading jets pair.
  3. Stored all info in a 2d array. Finally choosing the choice with smallest sum of distance from 125GeV

Appendix: For exactly for 4 jets in one event

1. C_2^4 different choices for picking the “leading” jets pair, then the remain two just forms the “sub-leading” jets pair.
2. Store the invariant masses and entry info into a 2d array AKTjetspair[C_2^4] [6].
3. Final decision is the one that minimize the sum of the distance from 125GeV



Appendix: For at least 4 jets (nJet = n) in one event

1. C_2^n choices for the “leading” jets pair.
2. Loop through remain C_2^{n-2} choice for “sub-leading” jets pair choosing the one which closest to 125GeV
3. Store the invariant masses and entry info into a 2d array AKTjetspair[C_2^n] [6].
4. Final decision is the one that minimize the sum of the distance from 125GeV