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High Energy Accelerator Experiments Group Tohoku University

STUDY OF CHARGED HIGGS BOSONS SEARCH AT THE ILC FOR A COLLISION ENERGY OF 1 TEV

Presentation by Christian Drews

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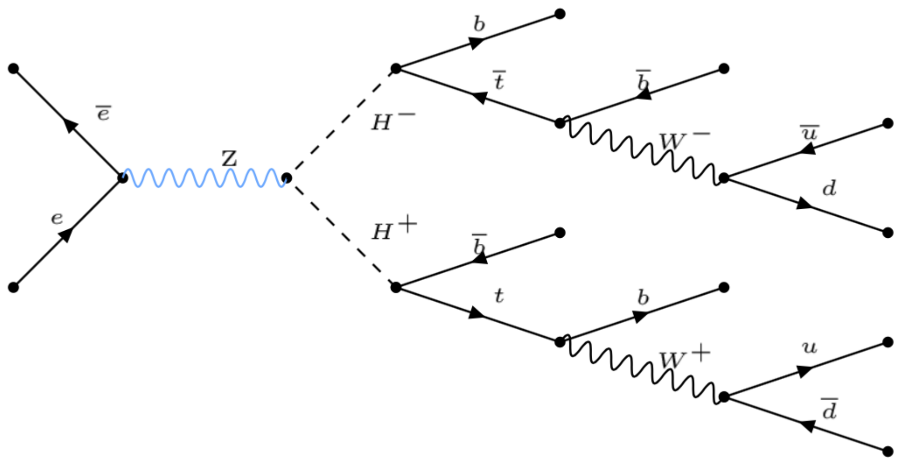
Professor Arno Straessner (TU Dresden)

Overview

- $m_{H\pm}$ = 350 GeV
- e^+e^- -> H^+H^- -> tb tb -> Wbb Wbb $\xrightarrow{W\to 2\text{ jets}}$ 8 jets (hadronic)

  Wbb Wbb $\xrightarrow[W\to\nu l]{W\to 2\text{ jets}}$ 6 jets + lepton
- Background:
  - ttH/ttZ/ttg -> ttbb
  - tt -> bWbW
  - HA -> bbbb (SUSY)



Lepton Selection

Using the IsolatedLeptonTaggingProcessor

From MarlInReco

	Total (%)	w/o tau (%)
Lepton Tag	60.3	90.4
Correct Tag	60.0	90.0
False Lepton Tagged	0.3	0.4
Electron	29.5	89.4 (w/o tau and myon)
Myon	30.3	90.5 (w/o tau and electron)
False Lepton Tag in hadronic	**2.1**	

Neutrino Four-vector

- Method 1: Missing-Energy-Method (MEM)

$$p_{\text{vis}} = \sum_{i=1}^{N_{\text{PFO}}} p_i \qquad p_{\text{CMS}} = (1000, 0, 0, 1000 \cdot \sin(0.014/2))$$

$$p_{\nu,\text{MEM}} = (p_{\text{CMS}} - p_{\text{vis}})$$

  - Should I Sum pfos or jets? LCFIplus doesn't cluster all particles to jets?

- Method 2: Neutrino-Direction-Method (NDM)
  - Using the Direction of Missing-Energy-Method and calculationg the Enerty by fixing W-Mass

$$E_{\nu,\text{NDM}} = \frac{m_W^2}{E_l(1-\alpha)} \qquad \alpha = \frac{\vec{p}_{\nu,\text{MEM}} \cdot \vec{p_l}}{|\vec{p}_{\nu,\text{MEM}}||\vec{p_l}|}$$

$$p_{\nu,\text{NDM}} = (E_{\nu,\text{NDM}}, E_{\nu,\text{NDM}} \frac{\vec{p}_{\nu,\text{MEM}}}{|\vec{p}_{\nu,\text{MEM}}|})$$

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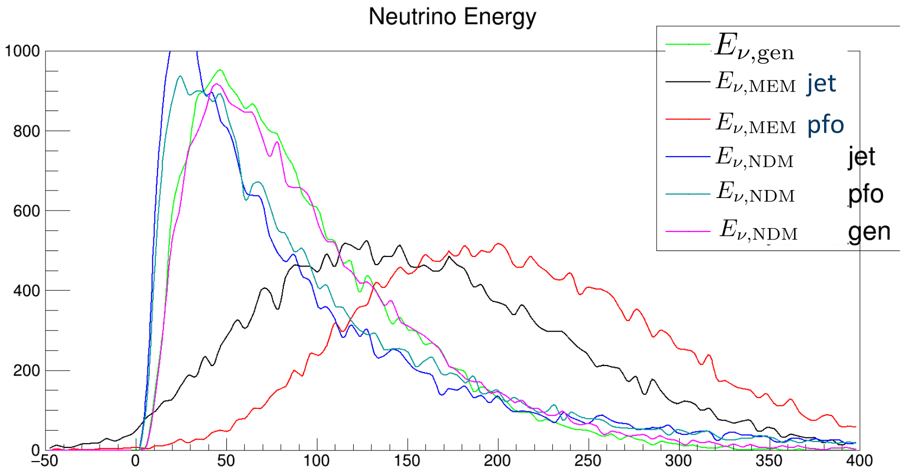
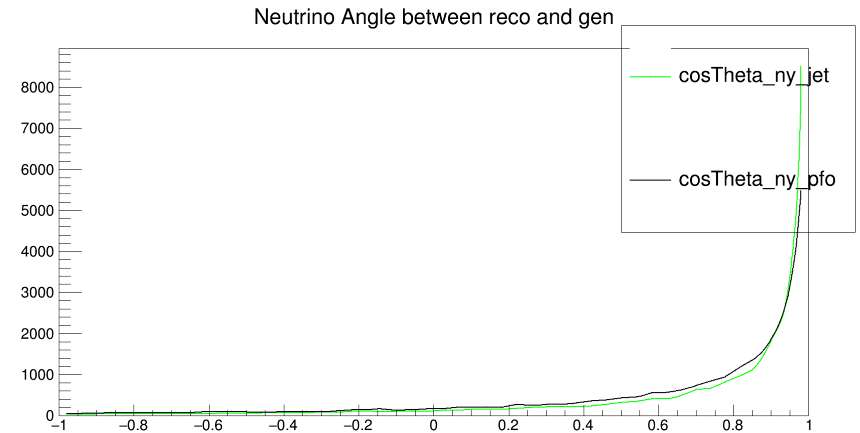
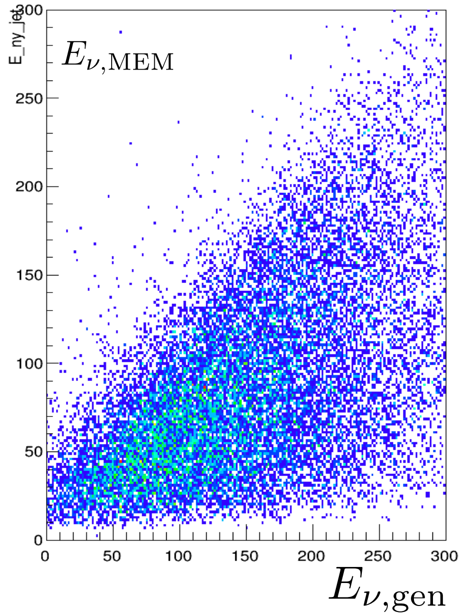
Neutrino Four-vector

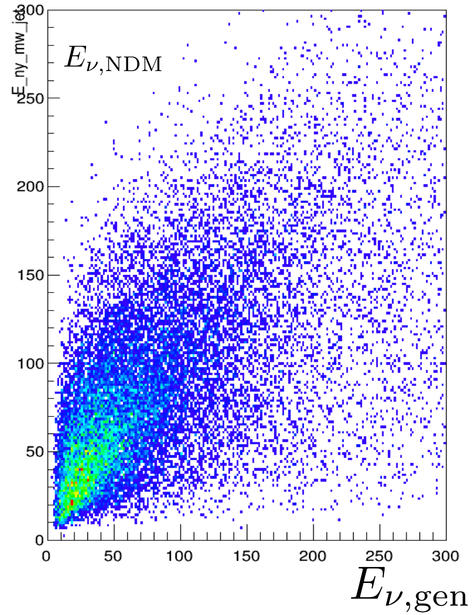


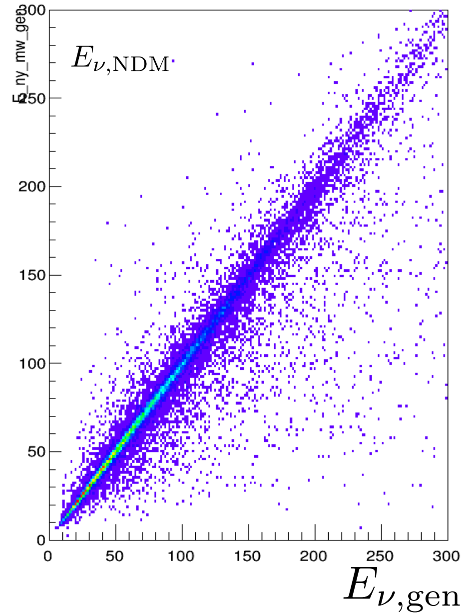


Neutrino Four-vector

Neutrino direction from Generator



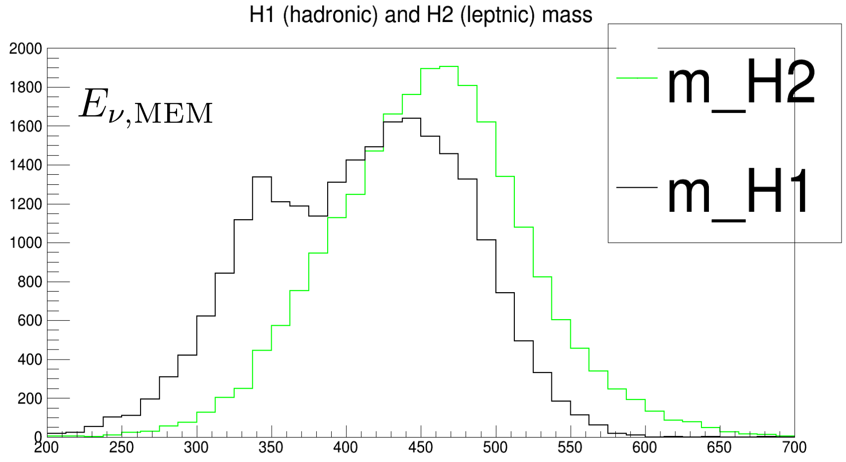


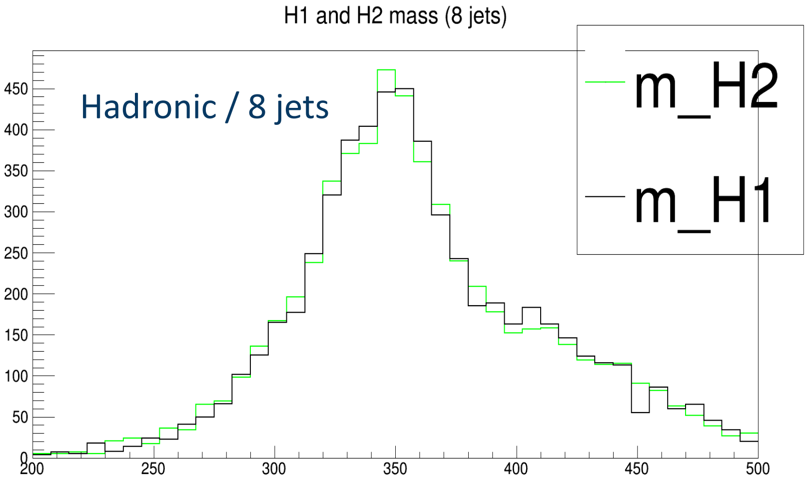


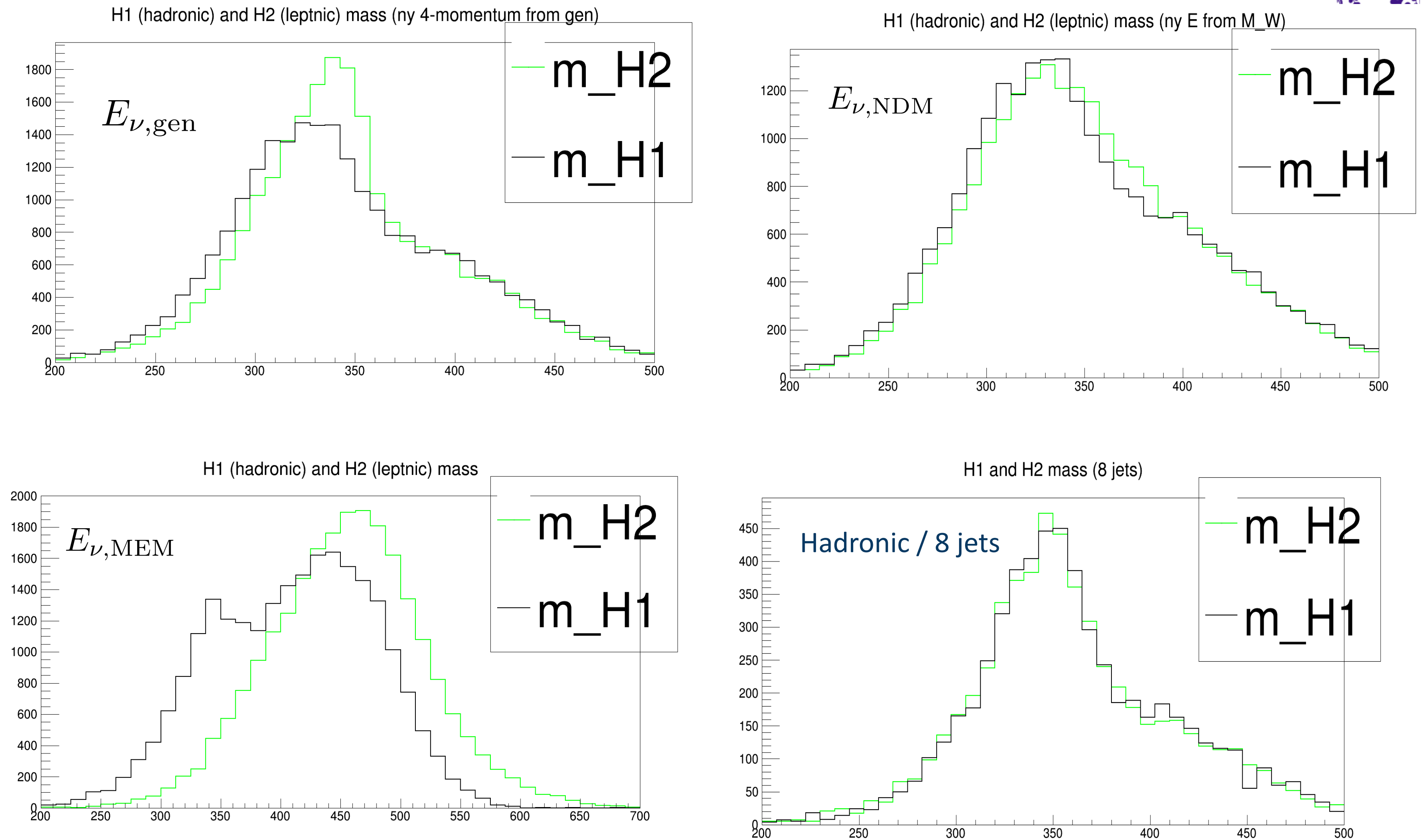
Higgs mass reconstructed with Jet pairing

- Chi^2 minimization method

$$\chi^2 = \left| \frac{(m_{j_1j_2j_3j_4})^2 - (m_{j_5j_6j_7j_8})^2}{2\sigma_{H^+}^2} \right| + \left(\frac{m_{j_2j_3j_4} - M_t}{\sigma_t} \right)^2 + \left(\frac{m_{j_6j_7j_8} - M_t}{\sigma_t} \right)^2 + \left(\frac{m_{j_3j_4} - M_W}{\sigma_W} \right)^2 + \left(\frac{m_{j_7j_8} - M_W}{\sigma_W} \right)^2$$






H1 (hadronic) and H2 (leptnic) mass (ny 4-momentum from gen)
$E_{\nu,\mathrm{gen}}$
m_H2
m_H1
H1 (hadronic) and H2 (leptnic) mass (ny E from M_W)
$E_{\nu,\mathrm{NDM}}$
m_H2
m_H1
H1 (hadronic) and H2 (leptnic) mass
$E_{\nu,\mathrm{MEM}}$
m_H2
m_H1
H1 and H2 mass (8 jets)
Hadronic / 8 jets
m_H2
m_H1

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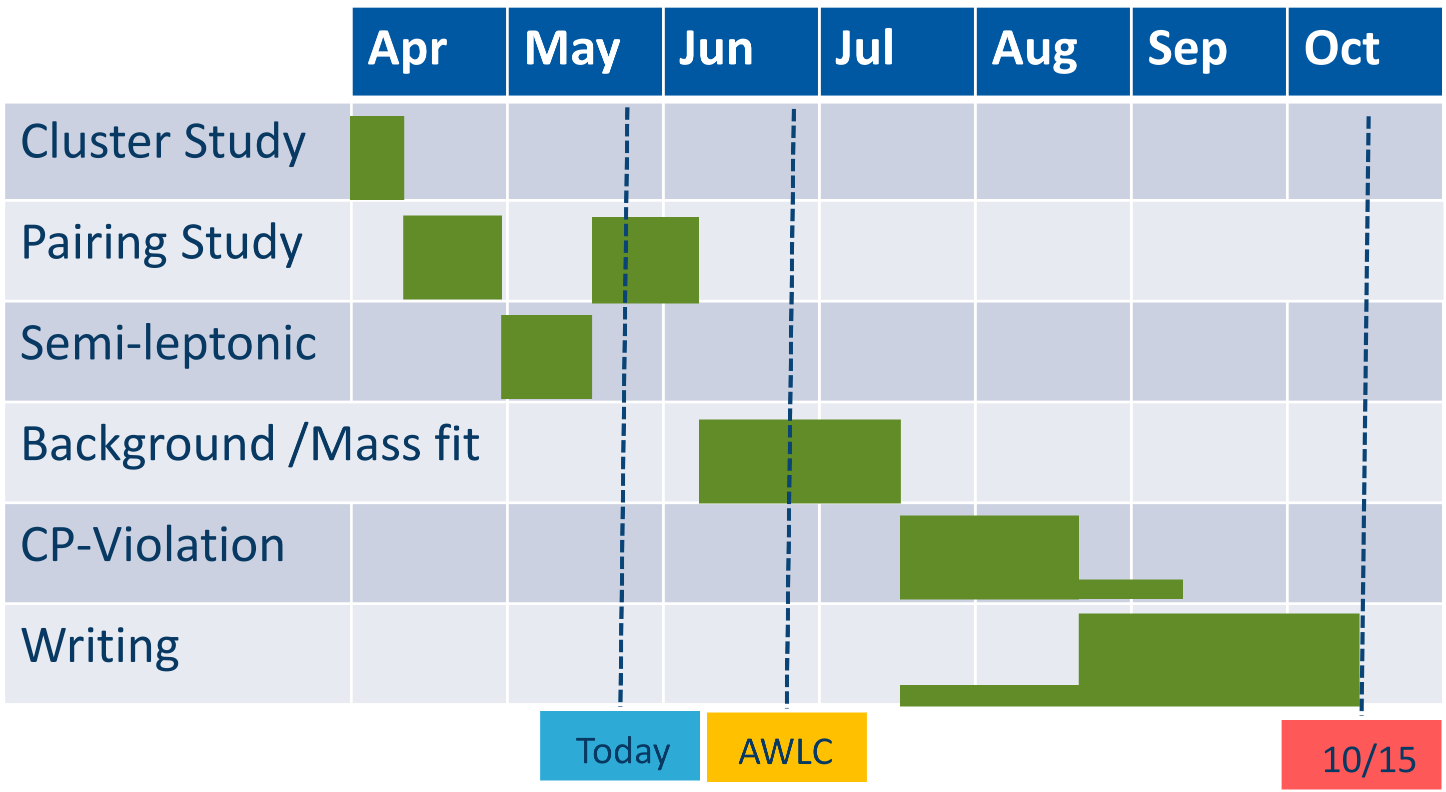
Schedule



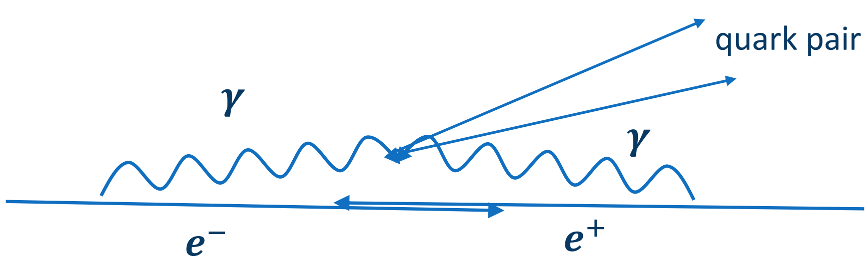
Plan

- Check Chi^2 Pairing with 3D display
- Develop extra conditions for pairing
- Include semi-leptonic mode (6 jets)
- Background study with cuts
- Goal:
    - mass fit -> mass resolution measurement
    - Detection efficiency
      -> cross section times branching ratio
- Bonus:
    - Research how to distinguish H+ and H-
    - Study of CP-violation measurement

Backup

Analysis Strategy – Beam Background

- In average 2.7 beam background events per bunch crossing
- In these samples old number of 4.1 events per bunch crossing
- Has major influence on jet clustering
- Use kt-algorithm from fastjet package to reduce backgrond
  - R: Generalized radius of jets
  - Vary R to optimal mass resolution
- Use Satoru Jetfinder for clustering



Fastjet Finder – kt Algorithm (beam background removal)

- Calculate the distance between to all tracks

$$d_{ij} = \min(p_{Ti}^2, p_{Tj}^2)\frac{\Delta R_{ij}}{R}$$

  with $\Delta R_{ij} = (\eta_i - \eta_j)^2 + (\phi_i - \phi_j)^2$

  η pseudo rapidity, ϕ azimuth

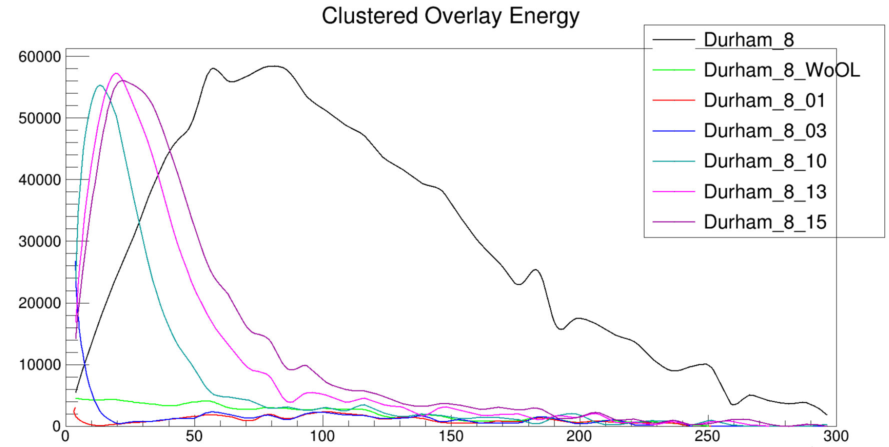
- Find smallest d_{ij}
- If $d_{ij} < d_{iB} = p_{Ti}^2$ merge tracks, if not remove Track (B: Beam)
  - Remove particles that are closer to the beam than to the closest track
- Continue to step one until there are only the requested number of jets

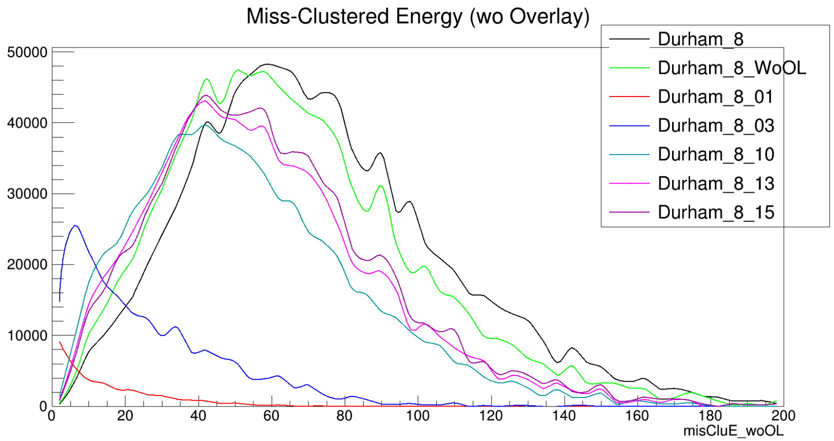
Choose R for kt algorithm

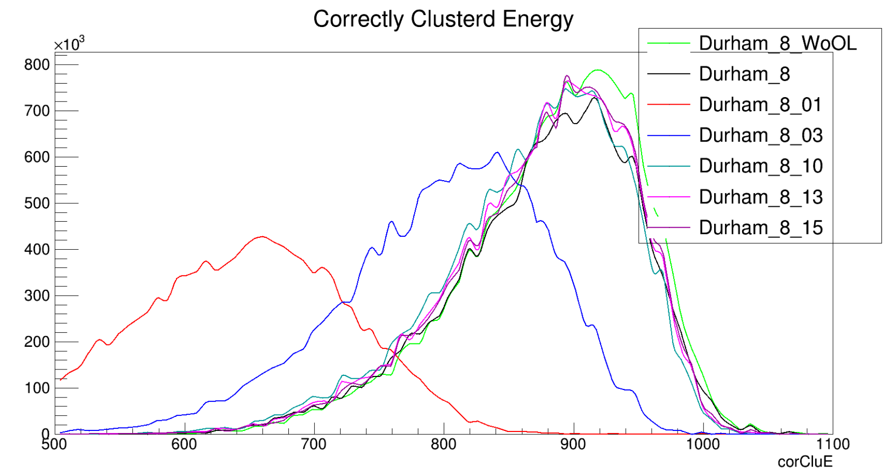
Durham_8: w/o correction

Durham_8_WoOL: overlay removed by generator information

Durham_8_13: R = 1.3

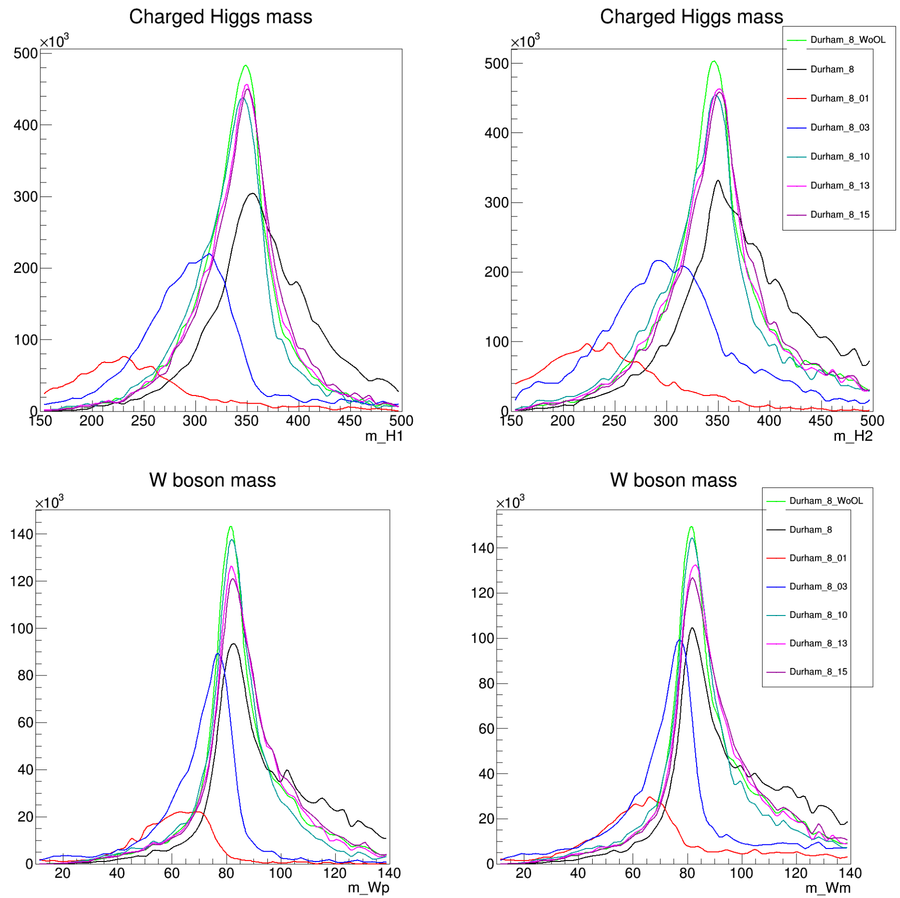


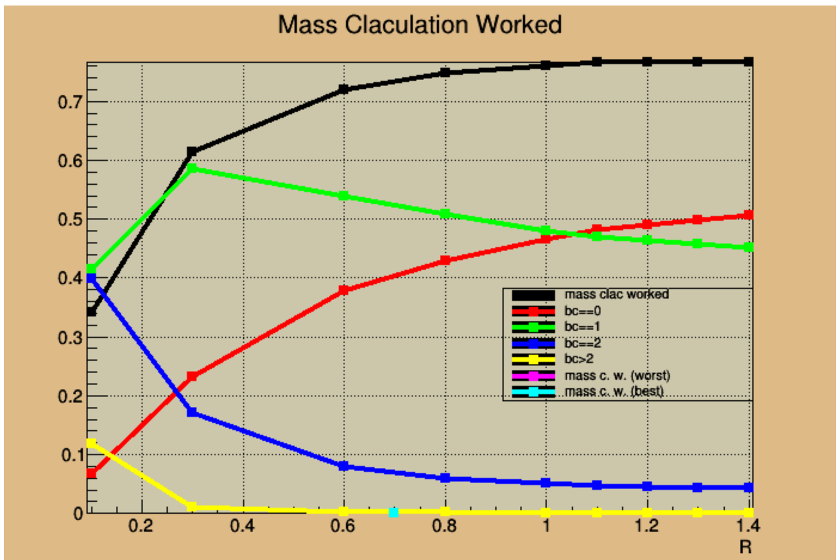


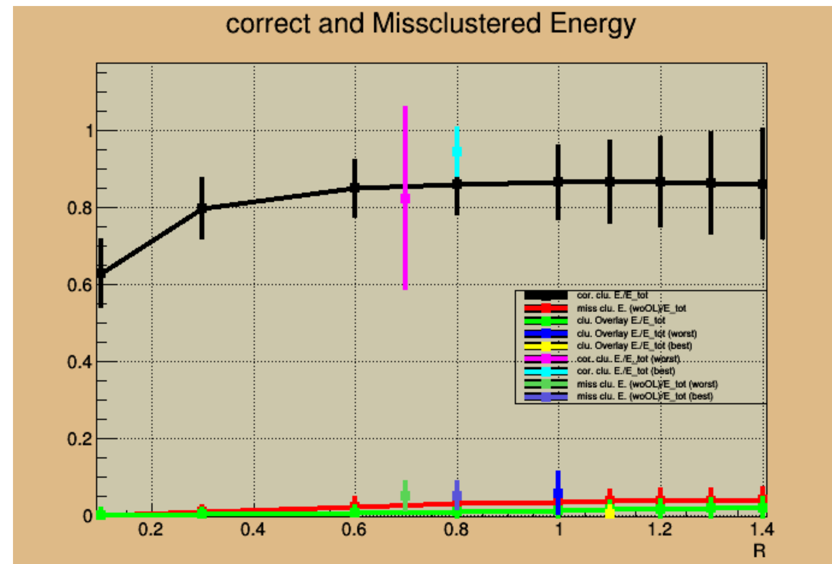


Choose R for kt algorithm

- For W mass R = 1.0 seems best
- For H mass R = 1.3 seems best
- Maybe b-jets have a wider spread
- I will continue with 1.3




Mass Claculation Worked
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
R
mass clac worked
bc==0
bc==1
bc==2
bc>2
mass c. w. (worst)
mass c. w. (best)


correct and Missclustered Energy
1
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
R
cor. clu. E./E_tot
miss clu. E. (woOL)/E_tot
clu. Overlay E./E_tot
clu. Overlay E./E_tot (worst)
clu. Overlay E./E_tot (best)
cor. clu. E./E_tot (worst)
cor. clu. E./E_tot (best)
miss clu. E. (woOL)/E_tot (worst)
miss clu. E. (woOL)/E_tot (best)

Analysis Strategy - Chi^2

	w/o overlay	R: 1.3	with overlay	
B-tag efficiency	44.6	42.5	38.0	the 4 b-jets have highest b-tag in the event
Clustering works well	50.7	49.4	40.2	For every color singlet there are 2 jets with a major fraction from this singlet
Clustering works	95.8	95.6	92.5	Clustering works well + one color singlet hos only one jets with a major fraction from this singlet
Pairing works	27.8	25.0	17.2	Jet pairing agrees with major color singlet fraction in jet

$$\chi^2 = \left| \frac{(m_{j_1 j_2 j_3 j_4})^2 - (m_{j_5 j_6 j_7 j_8})^2}{2\sigma_{H+}^2} \right| + \left(\frac{m_{j_2 j_3 j_4} - M_t}{\sigma_t} \right)^2$$

$$+ \left(\frac{m_{j_6 j_7 j_8} - M_t}{\sigma_t} \right)^2 + \left(\frac{m_{j_3 j_4} - M_W}{\sigma_W} \right)^2 + \left(\frac{m_{j_7 j_8} - M_W}{\sigma_W} \right)^2$$

Analysis Strategy - Chi^2

- Choose σ from pairing with generator information
- Optimize for c for maximal pairing efficiency

$$\chi^2 = c_H \left| \frac{(m_{j_1 j_2 j_3 j_4})^2 - (m_{j_5 j_6 j_7 j_8})^2}{2\sigma_{H^+}^2} \right| + c_t \left(\frac{m_{j_2 j_3 j_4} - M_t}{\sigma_t} \right)^2$$

$$+ c_t \left(\frac{m_{j_6 j_7 j_8} - M_t}{\sigma_t} \right)^2 + c_w \left(\frac{m_{j_3 j_4} - M_W}{\sigma_W} \right)^2 + c_w \left(\frac{m_{j_7 j_8} - M_W}{\sigma_W} \right)^2$$

$$\sigma_H = \sigma_t = 80\ GeV,\ \sigma_W = 48\ GeV$$

Analysis Strategy - Chi^2

- Choose σ from pairing with generator information
- Optimize for c for maximal pairing efficiency

$$\chi^2 = c_H \left| \frac{(m_{j_1 j_2 j_3 j_4})^2 - (m_{j_5 j_6 j_7 j_8})^2}{2\sigma_{H^+}^2} \right| + c_t \left(\frac{m_{j_2 j_3 j_4} - M_t}{\sigma_t} \right)^2$$

$$+ c_t \left(\frac{m_{j_6 j_7 j_8} - M_t}{\sigma_t} \right)^2 + c_w \left(\frac{m_{j_3 j_4} - M_W}{\sigma_W} \right)^2 + c_w \left(\frac{m_{j_7 j_8} - M_W}{\sigma_W} \right)^2$$

$$+ c_{\cos\theta_{HH}} \left(\frac{1 - \cos\theta_{HH}}{\sigma_{\cos\theta_{HH}}} \right)^2 + c_{\theta_{HH}} \left(\frac{\theta_{HH}}{\sigma_{\theta_{HH}}} \right)^2 + c_E \left(\frac{E_{H^-} - E_{H^+}}{\sigma_E} \right)^2 + c_p \left(\frac{\vec{p} - \vec{p}_{H^+}}{\sigma_p} \right)^2$$

Analysis Strategy - Chi^2

- First test optimization for c_H and c_cos
- c_H ~ 0.2 / c_cos ~ 30 (σ_cos = 1)
- Pairing efficiency 25 -> 27.5 %

$$\chi^2 = c_H \left| \frac{(m_{j_1 j_2 j_3 j_4})^2 - (m_{j_5 j_6 j_7 j_8})^2}{2\sigma_{H+}^2} \right| + c_t \left(\frac{m_{j_2 j_3 j_4} - M_t}{\sigma_t} \right)^2$$

$$+ c_t \left(\frac{m_{j_6 j_7 j_8} - M_t}{\sigma_t} \right)^2 + c_w \left(\frac{m_{j_3 j_4} - M_W}{\sigma_W} \right)^2 + c_w \left(\frac{m_{j_7 j_8} - M_W}{\sigma_W} \right)^2$$

$$+ c_{\cos\theta_{HH}} \left(\frac{1 - \cos\theta_{HH}}{\sigma_{\cos\theta_{HH}}} \right)^2$$

Analysis Strategy - Chi^2