For robust and (reasonable) fast jet clustering

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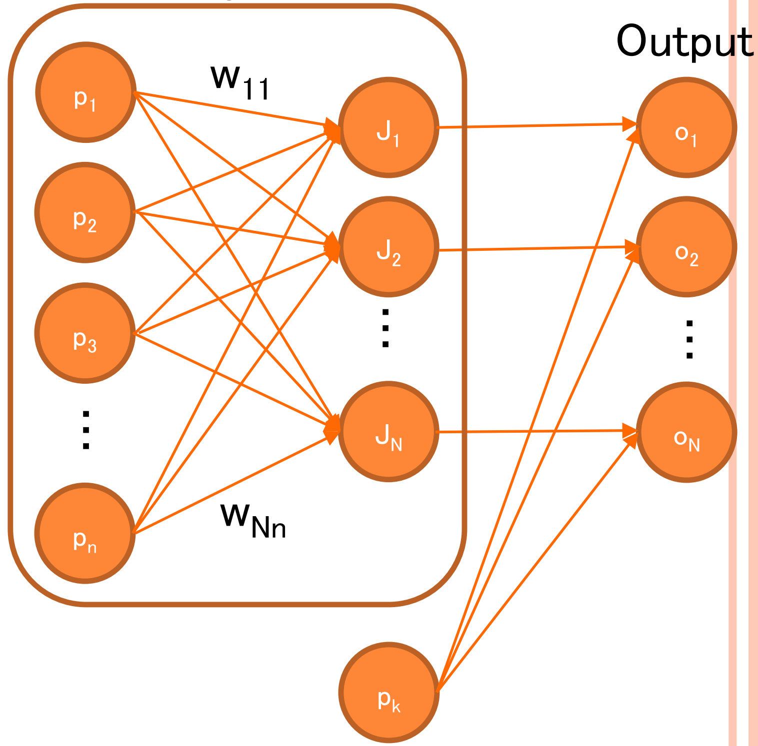
Neural network jet clustering
Network architecture



- Create reference jets:
  - $J_j = \sum w_{jk} p_k, 0 \leq w_{jk} \leq 1$
  - p_k: track 4-momentum in an event
  - J_j: (reference) jet 4-momentum
  - Default: Durham clustering result
- Introducing the objective function for jet clustering:

$$L = \sum_j^N \sum_i^n h_j d(p_i \ ,J_j \ )^2$$

h_j: $1 \ if \ d(p_i \ ,J_j \ )^2 \ is \ smallest, 0 \ if \ other$ – NN output

- Network training: adjust w_{jk} to minimize L
- Learning Method: Back Propagation(usual way for Neural Network)
  - Basic idea can be seen everywhere
- $d(p_i \ ,J_j \ )^2$: take Jade distance measure $d_{ij}^2 = \frac{2E_i E_j (1-\cos\theta_{ij})}{E_{vis}^2}$

Status

- In NN case, it takes much CPUtime to complete NN training
  - Needs much epoch(iteration)
  - It is very difficult to impose parameter constraint

    → It leads to instability of parameter convergence

- I found different way which realizes more robust and stable jet clustering than NN case
  - And, consuming less (and reasonable?) CPU time than NN training
  - Very quick convergence

- I' m trying this way and check some results

METHOD

- NN: parameters are changed track by track
  - Do not(cannot) consider a correlation of parameters
- So, change all the parameters at once

- Jade distance measure brings some changes

→jet mass is sensitive to form jets?
- So, define an objective function:

$$L = \sum_i m(jet)_i^2 = \sum_{i,j,k} w_{ij} w_{ik} (E_j E_k - \overrightarrow{p_j} \cdot \overrightarrow{p_k})$$

constraints: $0 \leq w_{ij} \leq 1, \sum_i w_{ij} = 1$

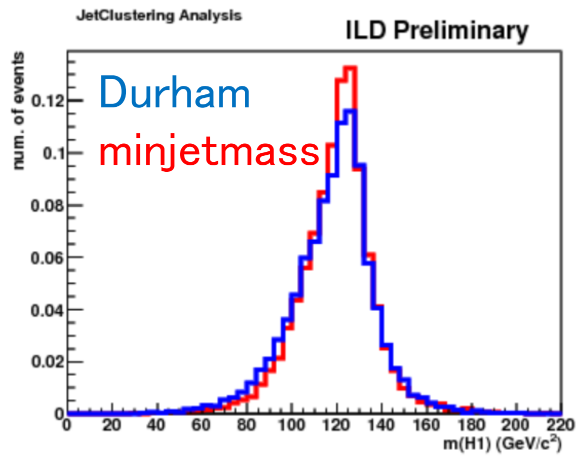
i: jet number, j,k: track number

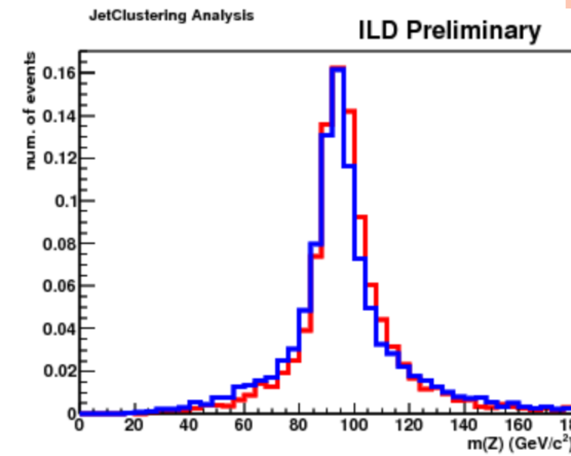
minimize L under the constraints

- This can be realized using same way as kinematic fit
  - Need Lagrange multipliers method
  - Need first and second derivatives of parameter wij
  - Jacobian matrix is sparse, so not difficult to solve
- Just O(10) iteration is necessary(NN: O(1000) iteration)
  - Can obtain result in less CPUtime

PRELIMINARY RESULTS

- Using qqhh→qq(bb)(bb): 6 jet clustering
  - Use same event as original Durham clustering
  - Jet matching with MC truth is performed(cos θ >0.9 for all the b jets)
  - v01-17-10
  - Mass distribution:

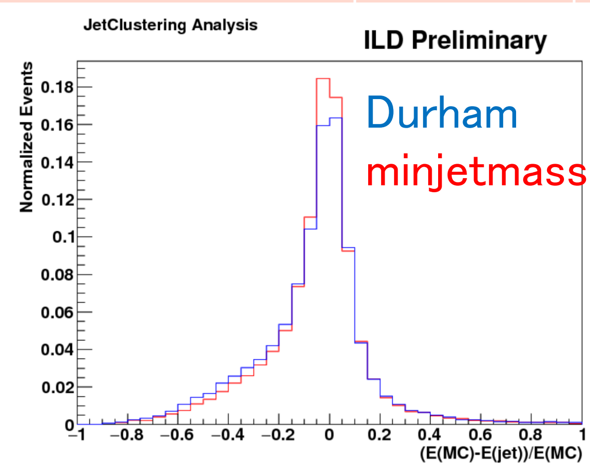




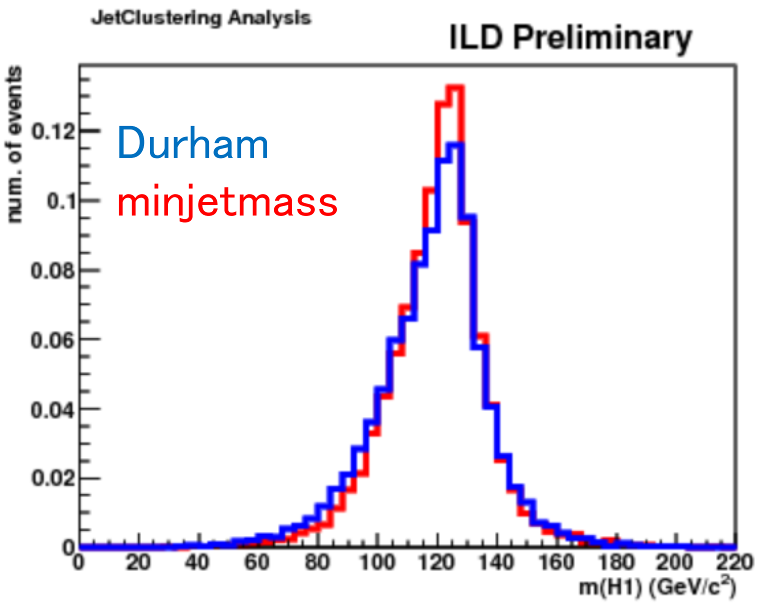
  - Num. of MC matched events:
    - ～2% more events are matched

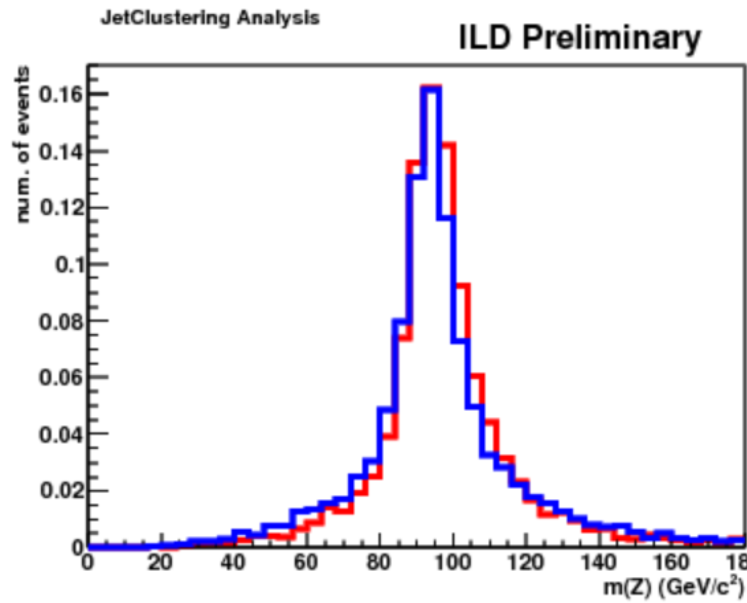
Method	Durham	minjetmass
Num. of events	7004	7112

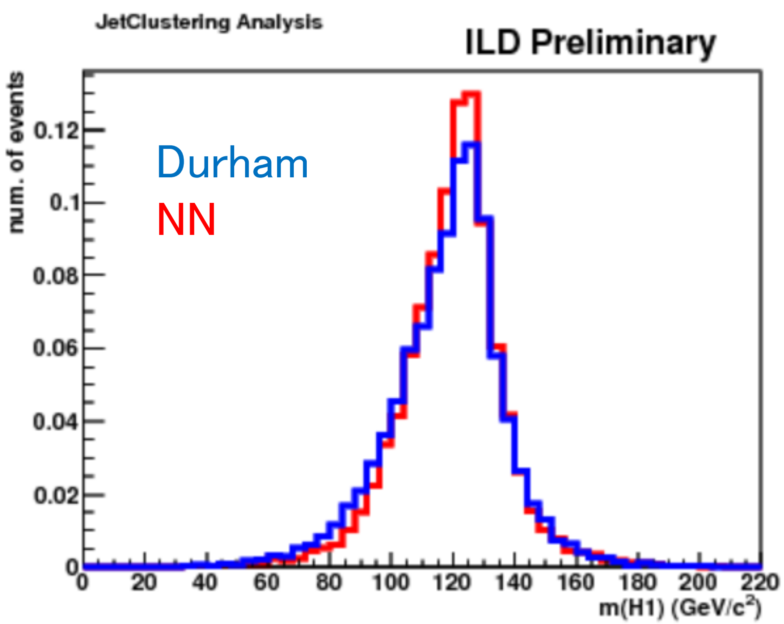
  - Jet Energy Resolution of bjets
    - Better JER

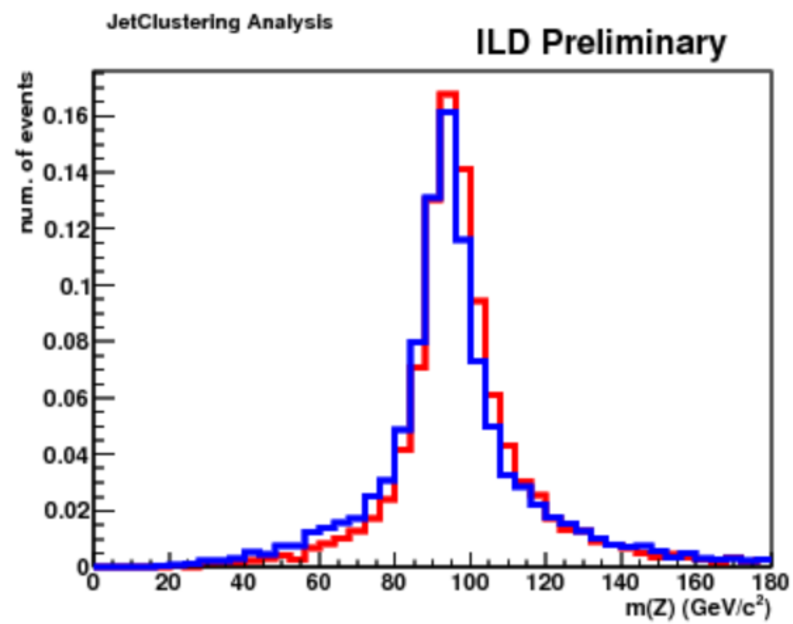


Mass resolution

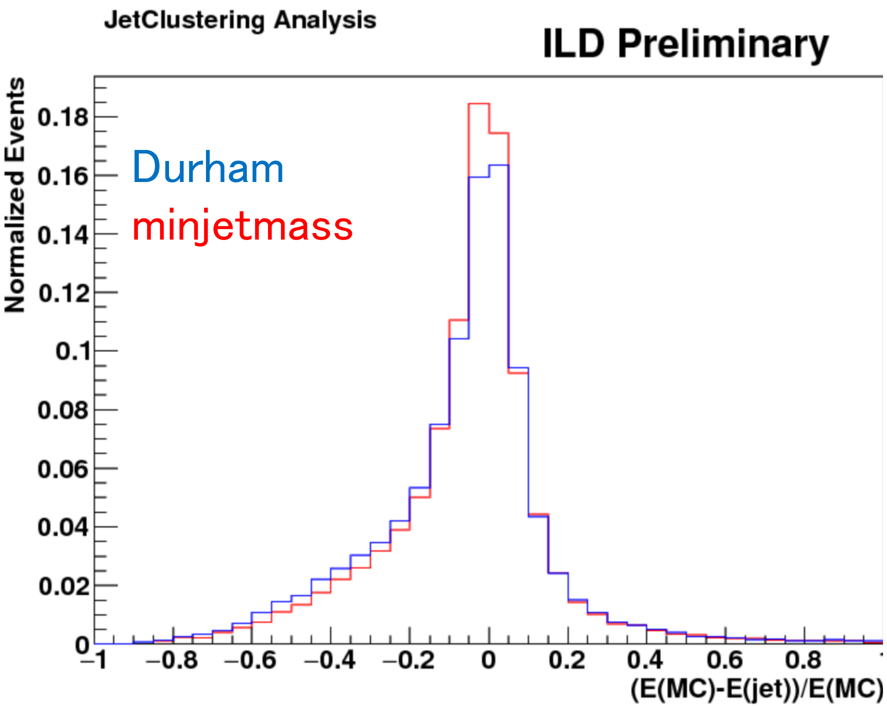


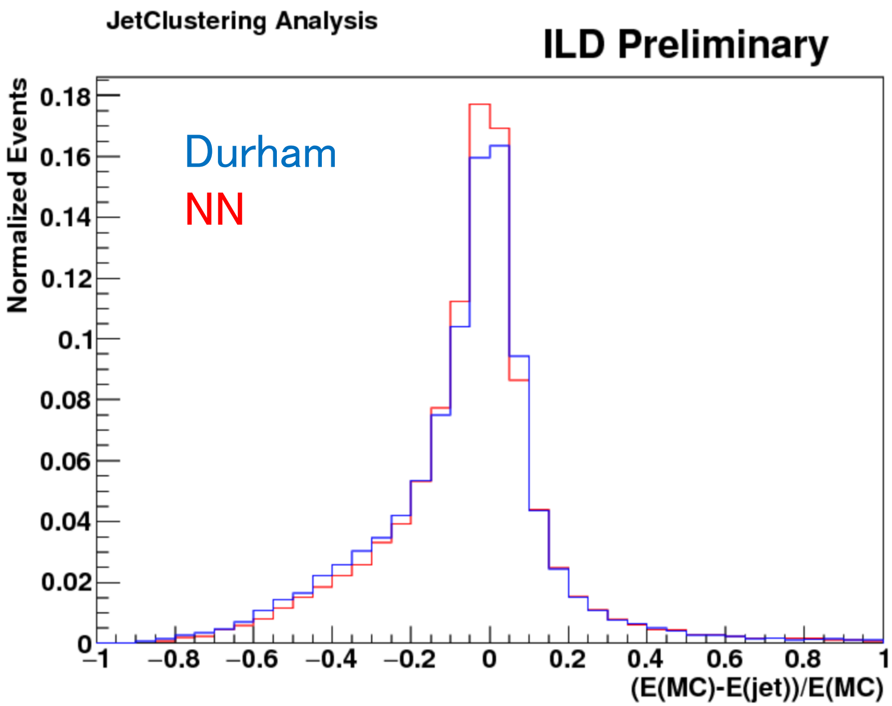






JET ENERGY RESOLUTION OF BJETS





- Start to check more
  - Inside jets
  - Energy fraction from each color singlet state
  - Etc.

BACKUPS

Realistic situation

- In realistic analysis, how is the situation changed?
  - Compare between NN and orig. Durham result
  - Using same qqHH sample, 6 jet clustering
  - Btag>0.3 is imposed for 4 bjet candidates in a event
  - Higgs masses are reconstructed using χ^2 mass constraint
- Compare the remained event
  - @ χ^2<5.0, ～10% signal event is increased
  - @ χ^2<5.0, ZZH event contamination is ～2%
- Going good direction, but of course, not enough

qqHH	Btag>0.30	Chi2<5.0	Chi2<10.0	Chi2<15.0
NN	6721	4217	5422	5935
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ZZH	Btag>0.30	Chi2<5.0	Chi2<10.0	Chi2<15.0
NN	3311	966	1791	2302
Org. Durham	3343	936	1836	2328

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  - So far, trained with Durham(default)