# Jet clustering using (Real) Neural Network (Very primitive)

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02/04/2017

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

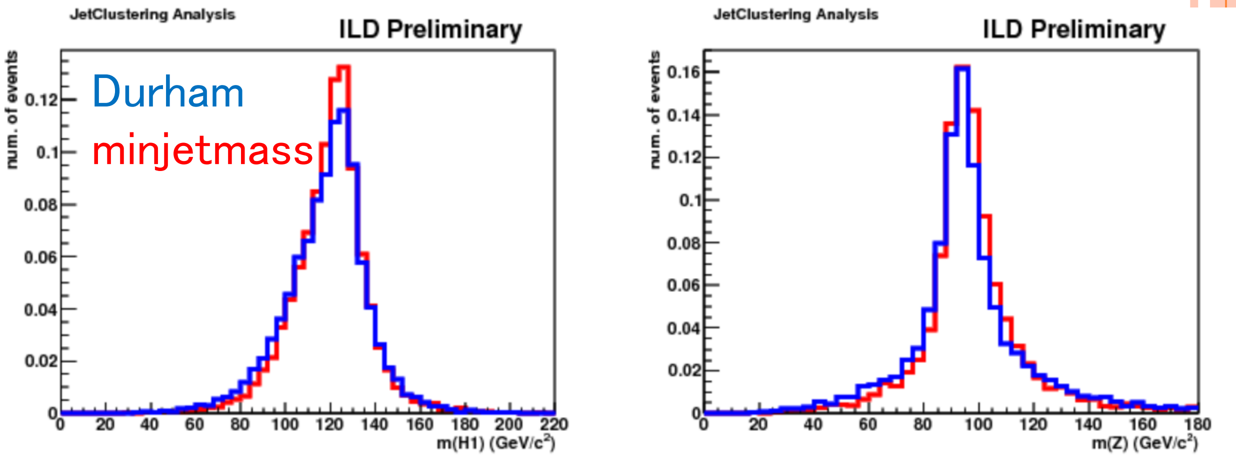
i: jet number, j,k: track number

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

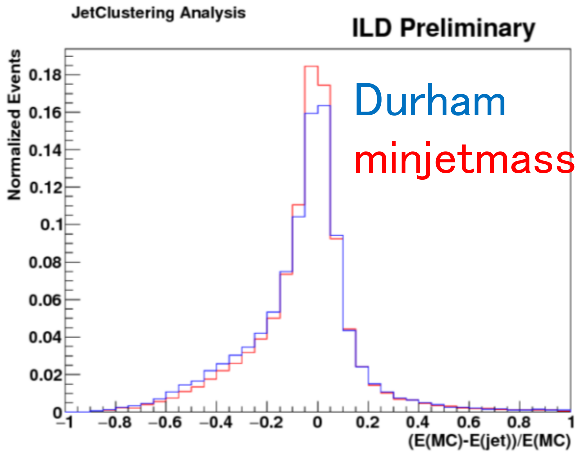
- Using qqhh→qq(bb)(bb): 6 jet clustering
  - Use same event as original Durham clustering
  - Jet matching with MC truth is performed(cos $\theta$ >0.9 for all the b jets)
  - v01-17-10
  - Mass distribution:



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

| Method | Durham | minjetmass |
|---|---|---|
| Num. of events | 7004 | 7112 |

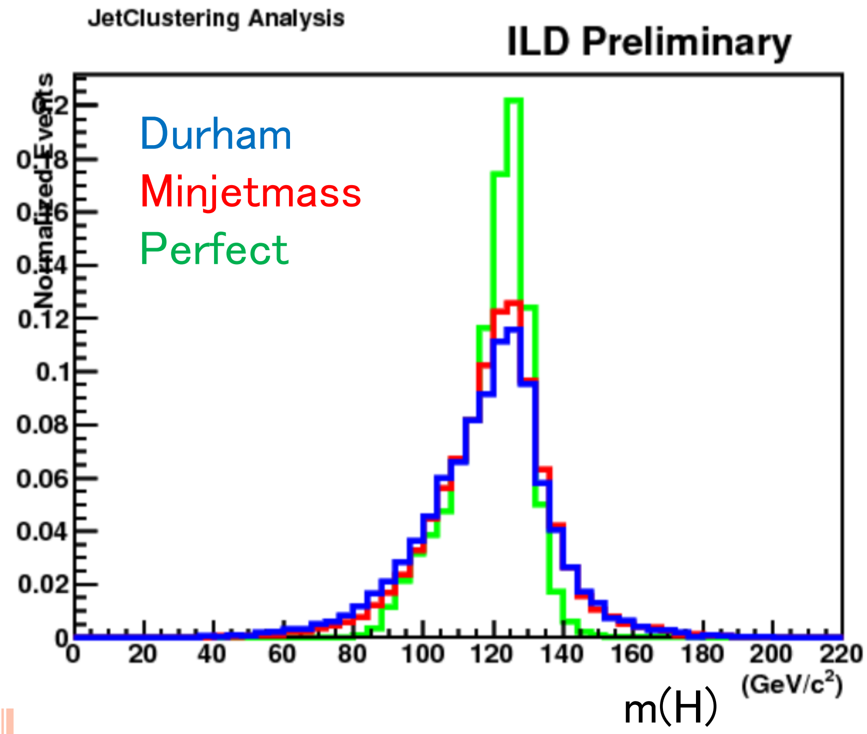
- Jet Energy Resolution of bjets
  - Better JER

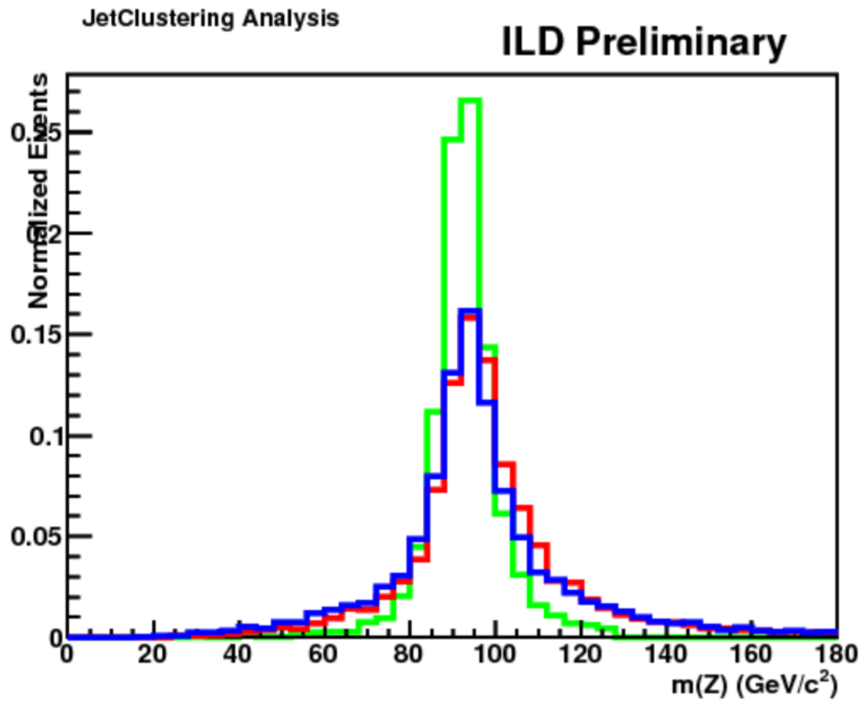


# Mass distribution

- Improvement is far from enough!!

- Prospect
  - We can obtain "answer" for each particle → can we have some hint??





# Status

- Now, we can use “supervised” Neural Network
  - Can we use it to improve track assignment efficiency to jets?

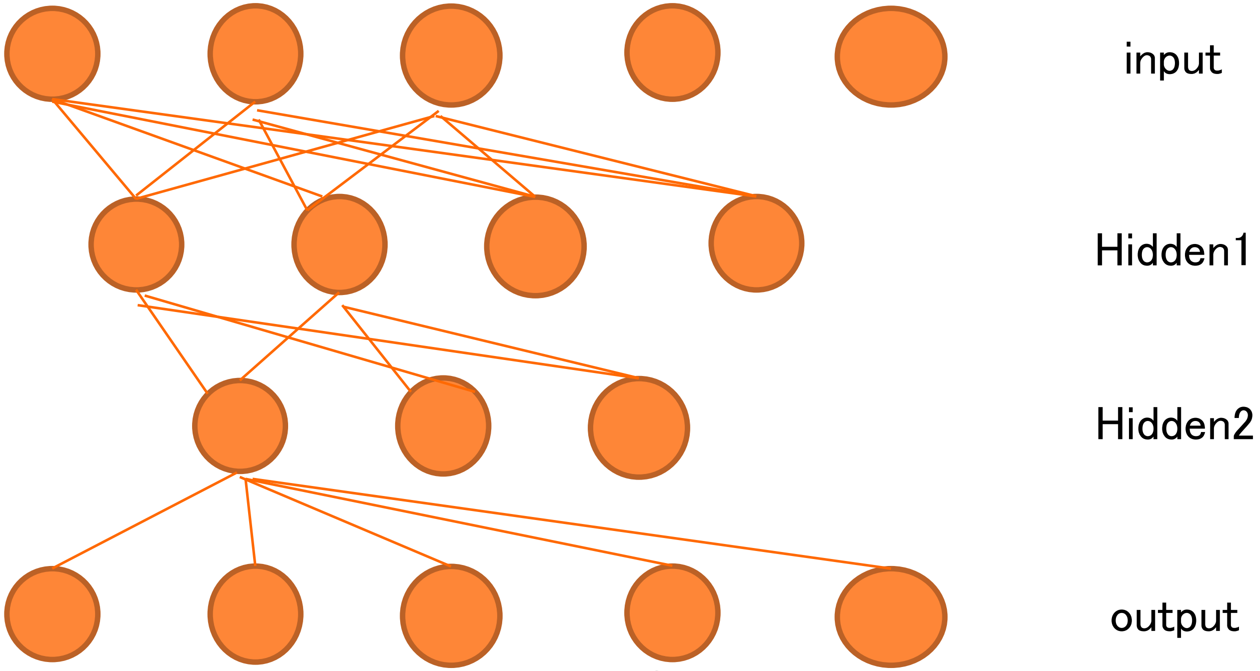
- Try to introduce (real) neural network to assign tracks into each color singlet state

- Cannot use TMVA because it is a binary classifier
  - Need to introduce (tricky) idea to use it
  - So, create network architecture by my own

- Maybe, Deep Learning is necessary
  - Simple way is to add extra hidden layer(s) to the network

# Network architecture(schematic)

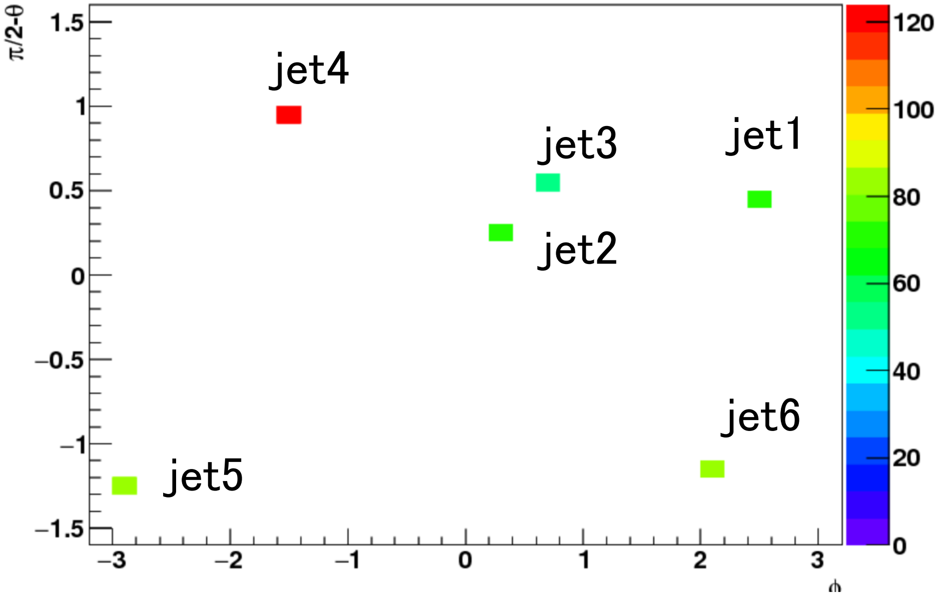
- 4-layers’ neural network



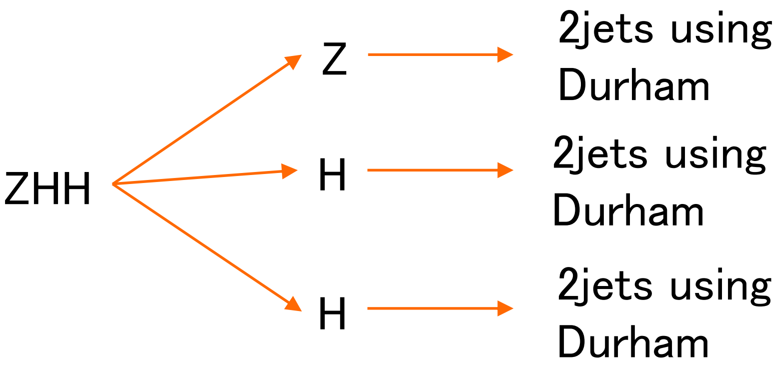
- Output: assignment probability for each jet
  - Assign tracks to highest probability jet
- Input: so far, very primitive
  - Jet 4-momentum coming from Durham jet clustering
  - Durham distance measure between tracks
  - Track 4-momentum

# NOTATION

- Numbering jets: counter-clockwise direction on $(\phi, \pi/2-\theta)$ plane



- Create jets: perfect Durham jet clustering



# VERY PRELIMINARY RESULTS

- Using 15 ZHH→(qq)(bb)(bb) events: 6 jet assignment
- Train network with 15 events
- Check assignment efficiency using same events
- How many tracks can be assigned correctly

| | jet1 | jet2 | jet3 | jet4 | jet5 | jet6 |
|---|---|---|---|---|---|---|
| NN | 306 | 258 | 225 | 254 | 203 | 129 |
| Durham | 275 | 249 | 187 | 233 | 221 | 181 |
| Total tracks | 470 | 363 | 360 | 391 | 355 | 242 |

- Energy fraction of main color singlet state
  - Mean over 15 events

| % | jet1 | jet2 | jet3 | jet4 | jet5 | jet6 |
|---|---|---|---|---|---|---|
| NN | 82.4 | 87.9 | 81.6 | 79.7 | 74.2 | 71.6 |
| Durham | 72.8 | 68.9 | 67.3 | 80.1 | 72.3 | 73.6 |

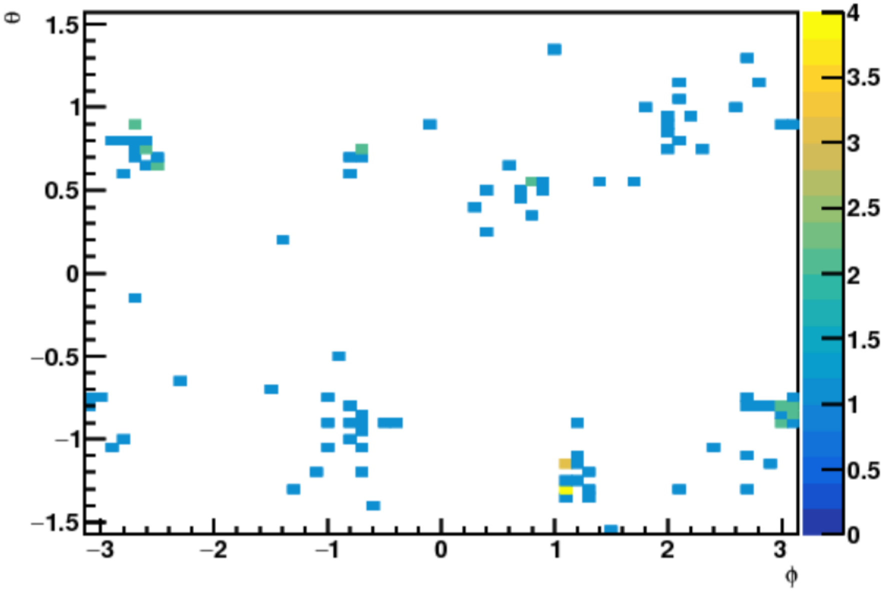
# PROBLEMS

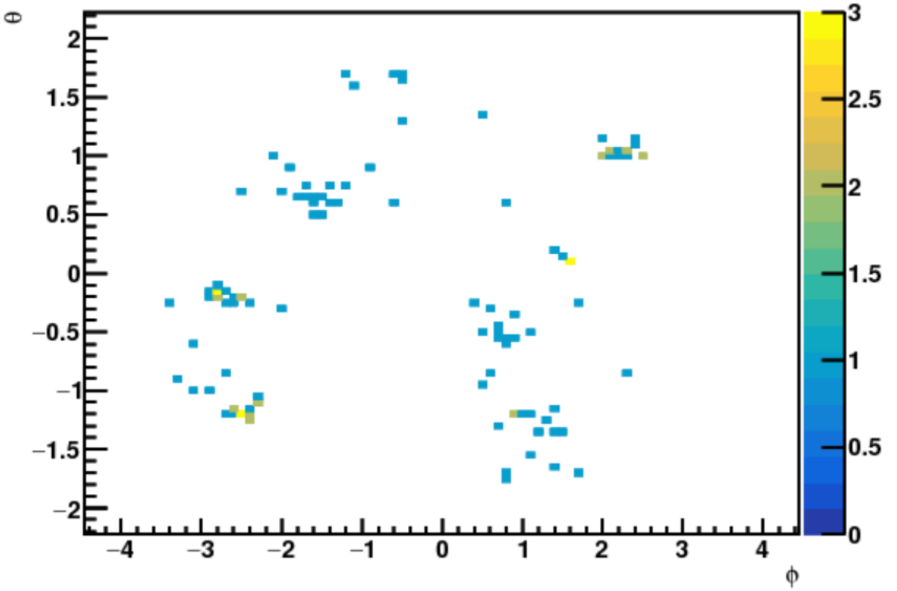
- Of course, general Neural Network problems are applied
  - Over–fitting(over training) to training events: cannot apply to test events
  - Training will take much CPUtime
    - But, when training is completed, applying it is very fast

- And, there is jet clustering specific problem
  - Can this be directly applied to other 6–jet events?
    - e.g.) ZZZ and ZZH can be reconstructed well too.
  - At least, 4–jet and 6–jet trainings are necessary

# PROSPECTS

- Can we extract some features from these pictures?





- Look like image processing…
- Convolutional neural network?

# BACKUPS