Université Catholique de Louvain

# Energy Reconstruction and Particle Identification using Neural Network

February 22, 2017

SDHCAL analysis meeting

# Outline

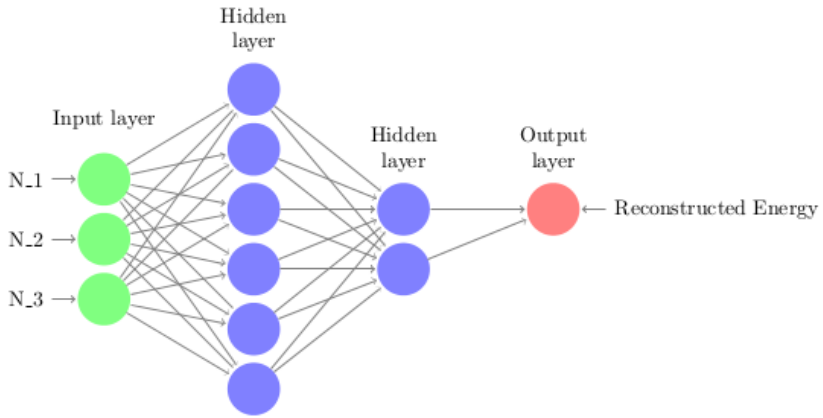
# Hadronic energy reconstruction in SDHCAL: Artificial Neural Network Technique

Goal: Study of the hadronic energy reconstruction using Neural Network Technique applied in Monte Carlo simulation and beam tests data

# Energy reconstruction: Artificial Neural Network Technique

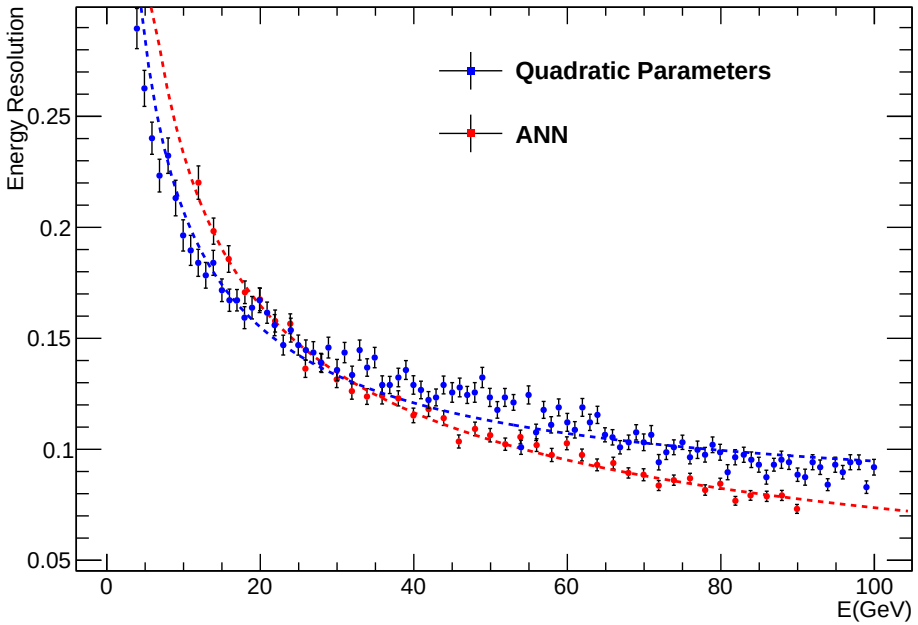
## Simulation Study

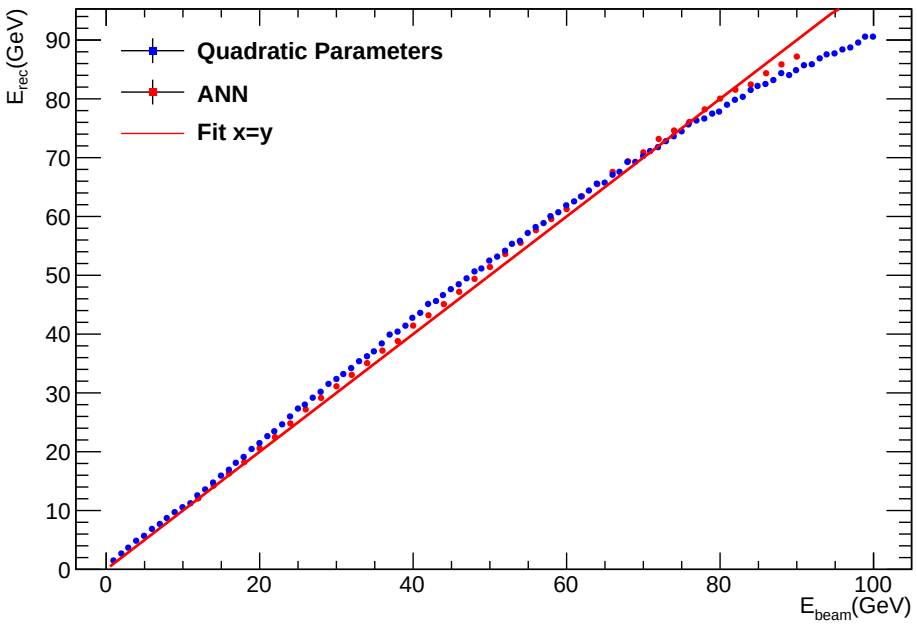
- TMultiLayerPerceptron of root package.
- 2 hidden layers with 6 and 2 neurons
- $\sqrt{\frac{\sum_{i=0}^{N}(E^{i}_{\mathrm{beam}}-E^{i}_{\mathrm{rec}})^{2}}{N}}$
- The input variables: $\mathrm{N_1}$,$\mathrm{N_2}$,$\mathrm{N_3}$ .
- The output variable is the reconstructed energy: $\mathrm{E_{rec}}$ .
- Training Samples: Odd energies, 1-99 GeV (50 training samples)
- Test Samples: Even energies, 10-90 GeV (40 test samples)



# Energy reconstruction: Artificial Neural Network Technique

## Simulation Study



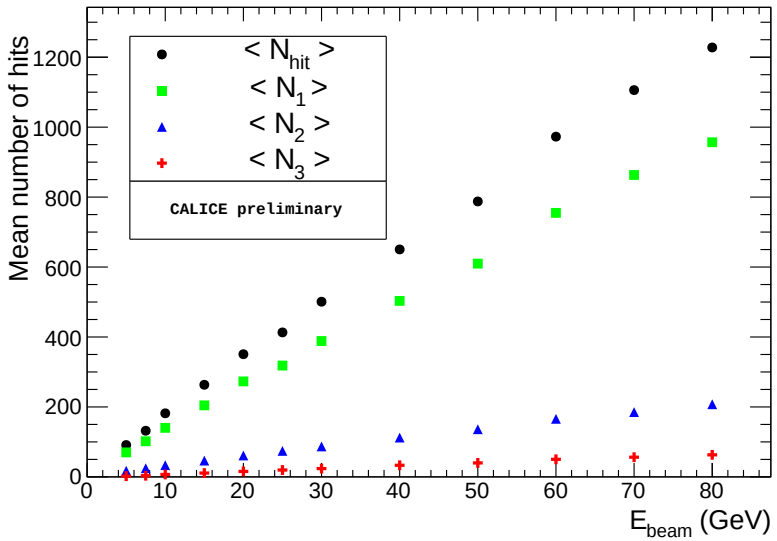



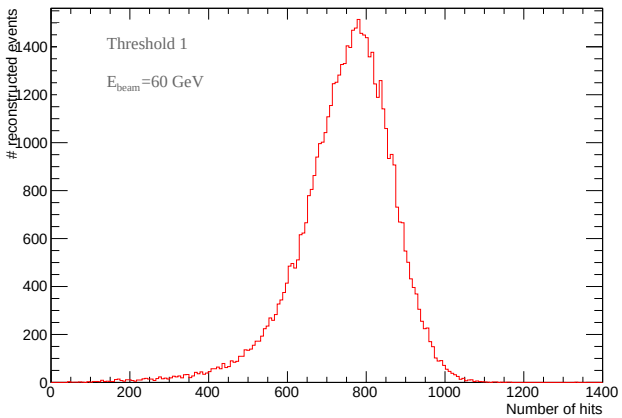

- The Neural Network technique provides a very good improvement in energy resolution at energies higher than 40 GeV.
- Good linearity in the range of $\pm 5\%$.

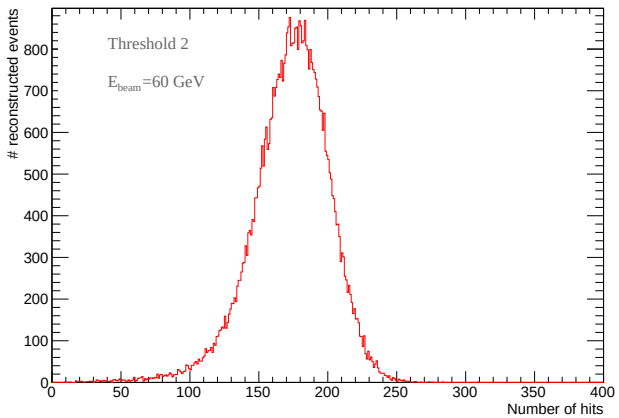
# Energy reconstruction: Artificial Neural Network Technique

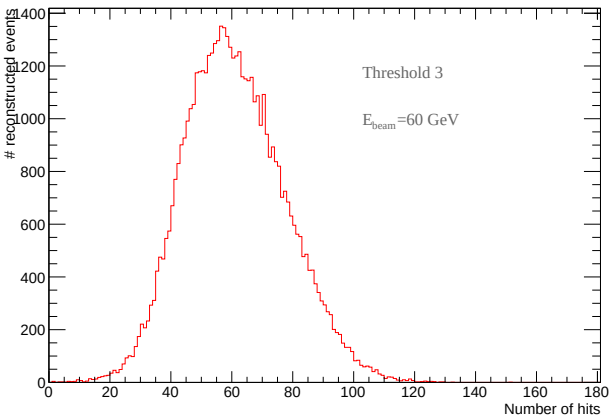
## Beam Tests Data

- Architecture of the ANN : One hidden layer of 8 neurons.
- The input variables: $\mathrm{N_1}$,$\mathrm{N_2}$,$\mathrm{N_3}$ .
- The output variable is the reconstructed energy: $\mathrm{E_{rec}}$ .
- Data SPS H2 and H6 taken during 2012
  - Training Samples: Trained with Simulation samples, odd energies:1-99GeV
  - Test Samples: 2012 tests beam data: Energies(5,7.5,10,15,20,25,30,40,50,60,70 and 80 GeV)



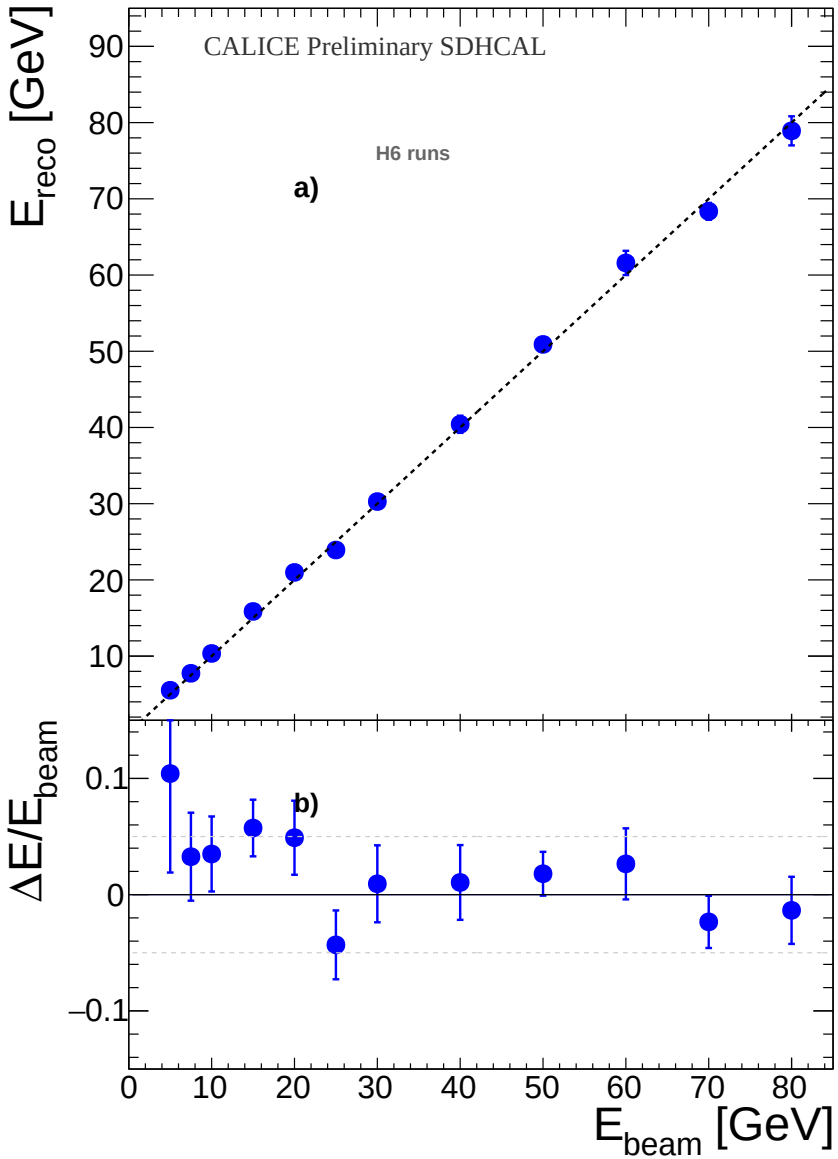



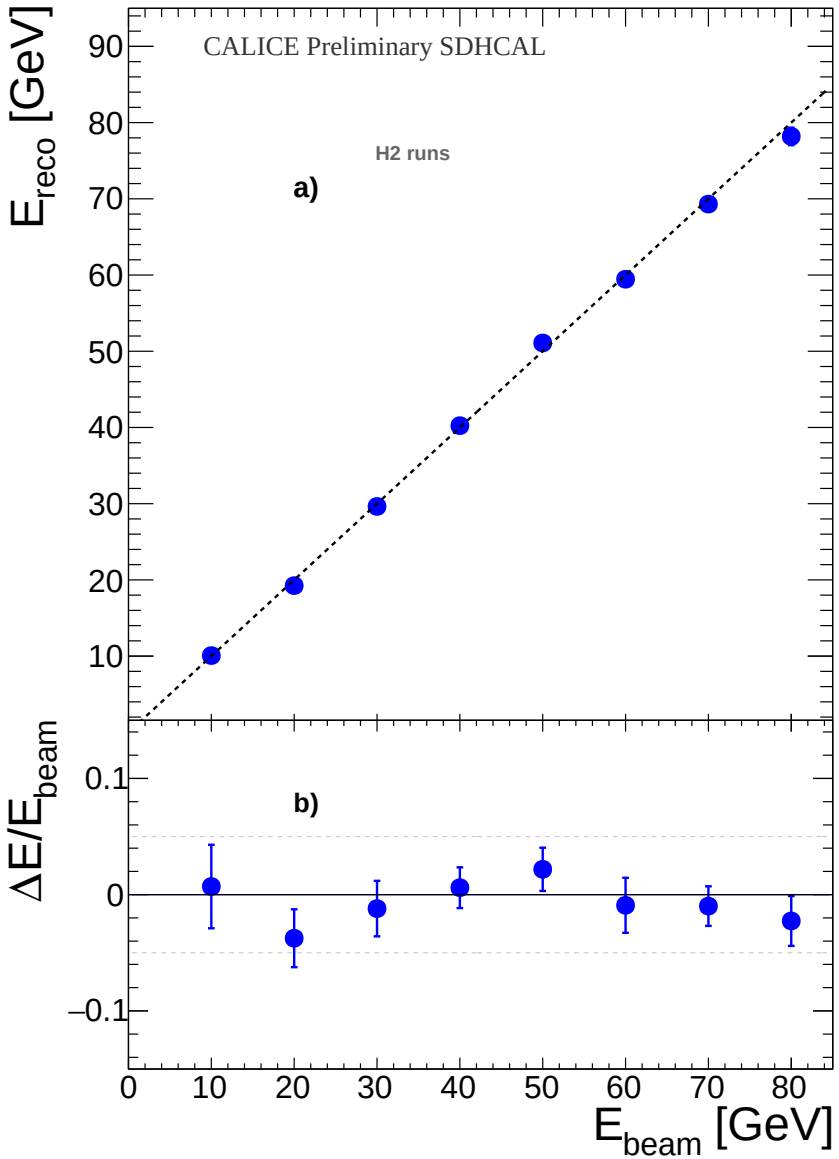



# Energy reconstruction: Artificial Neural Network Technique

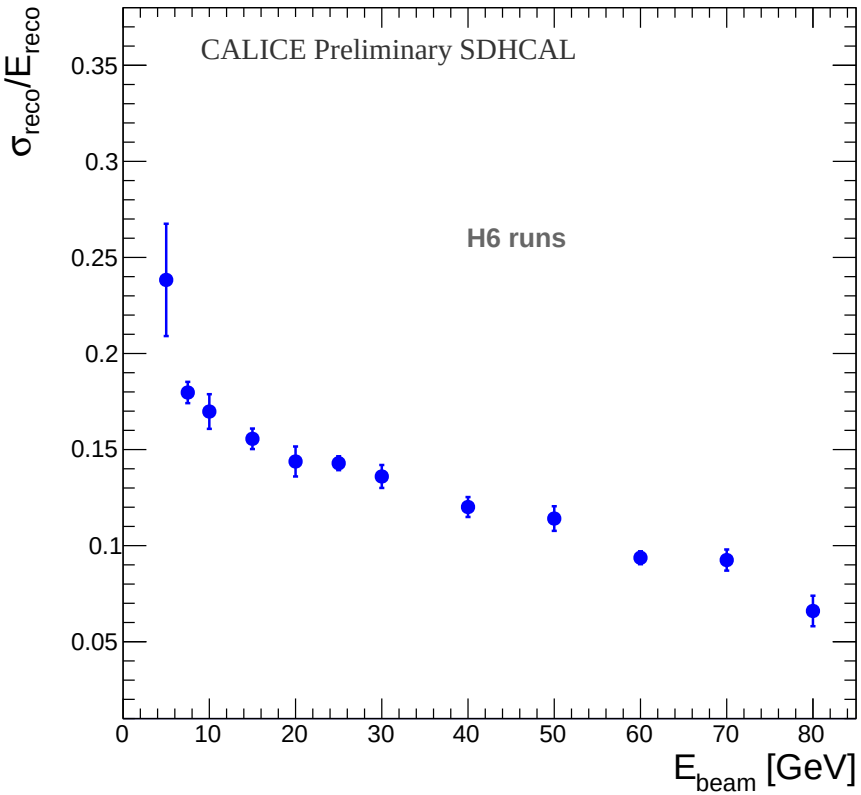
## Beam Tests Data

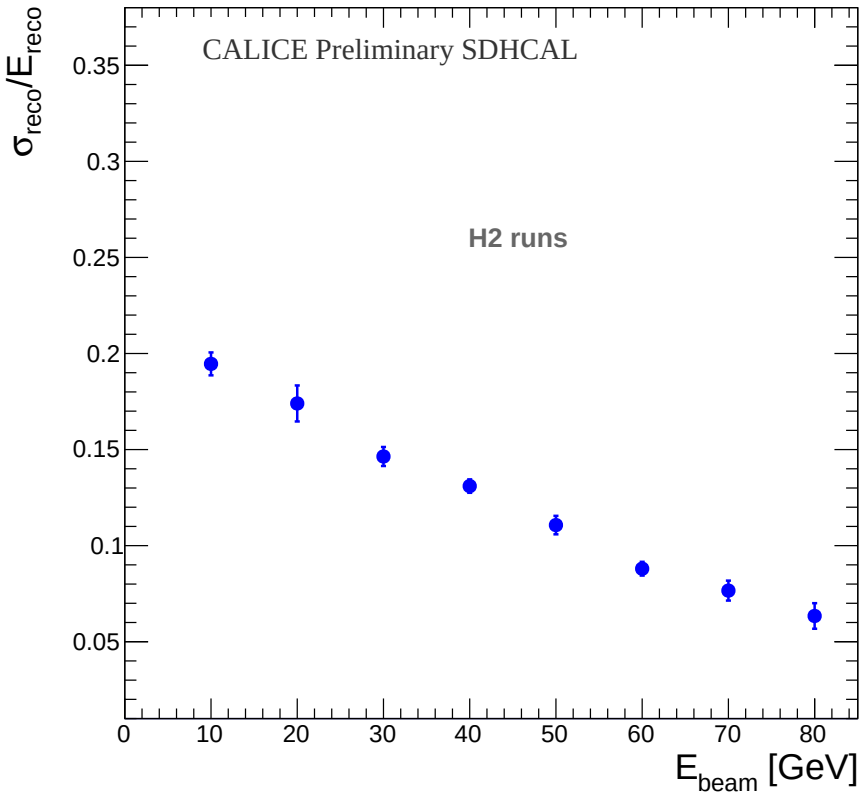


# Energy reconstruction: Artificial Neural Network Technique

## Beam Tests Data




The Neural Network technique leads to an improvement in energy resolution reaching 20% at 80 GeV for H2 data compared to the quadratic method.

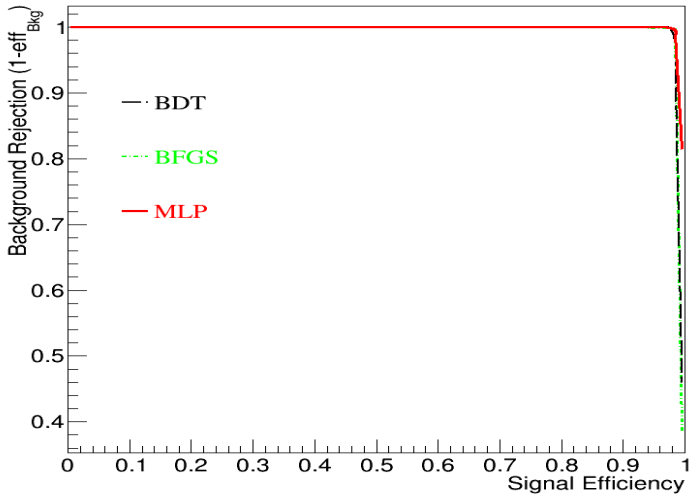
# Particle identification using MVA in SDHCAL

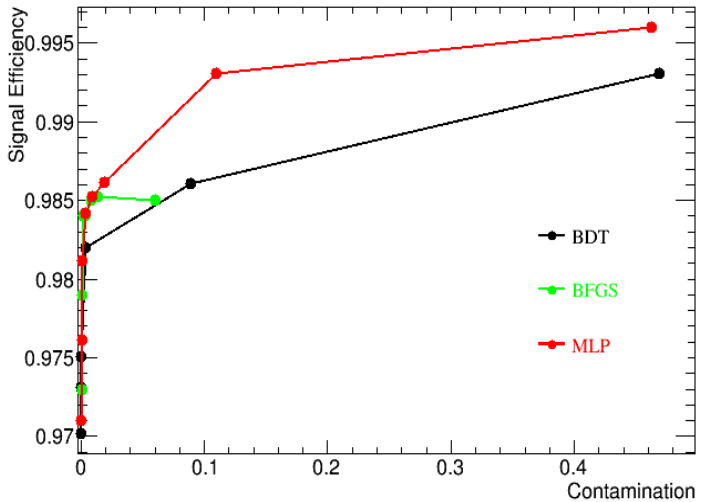
Goal: Development of a particle classifier based on MVA for pion event selection used in the study of the hadronic energy reconstruction in SDHCAL.

# Pion identification using MVA in MC simulation

## The TMVA methods

- PID:
  - Application:
    - Event selection
    - Better estimation in energy reconstruction
  - Separation EM vs Hadron: Shower topology
- Tool: Traditional cuts, MVA.
- TMVA of root, Methods: MLP, BFGS and BDT
- Energy: 80 GeV
  - Background: electrons and muons
  - Signal: pions



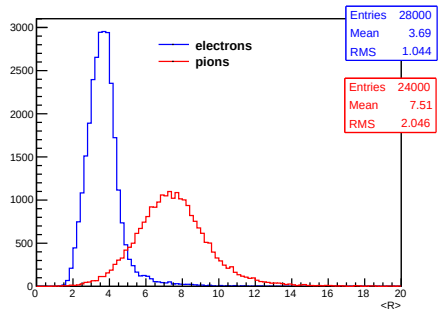



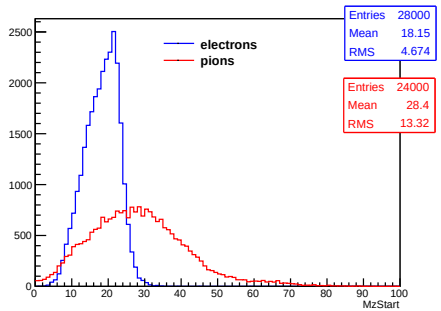

| Method | Cut | Efficiency(%) | Contamination(%) | Significance |
|---|---|---|---|---|
| MLP | 0.87 | 97.1 | 0.008 | 31.03 |
| BFGS | 0.98 | 97.3 | 0.01 | 31.14 |
| BDT | 0.1 | 97 | 0.007 | 31.03 |

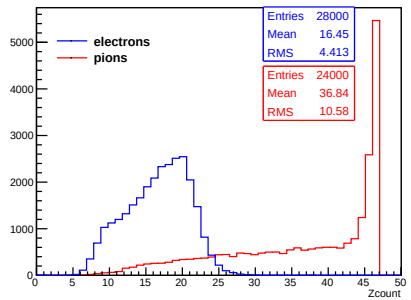
# Pion identification using MVA in MC simulation

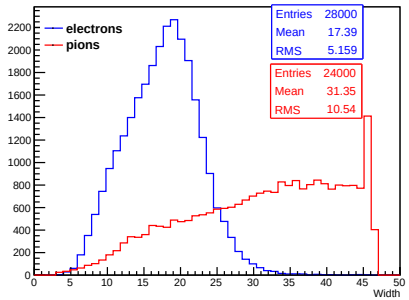
## Performance of MLP method in Pion identification

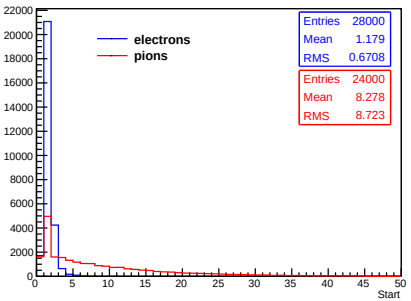
- TMVA of root.
- Method: Multilayer perceptron MLP.
- Training and Test
  - Background: 28000 electron events with energies: 2,3,8,10,15,20,25,30,40,50,60,70 and 80 GeV
  - Backgound: 9000 muons events with energies: 0.5, 2 and 10 GeV $\Longrightarrow$ Mixed Background
  - Signal: pion events with energies: 5,7.5,10,15,20,25,30,40,50,60,70 and 80 GeV
- Variables: the total number of hits, start, width, mean radius, longitudinal centre of gravity of the shower

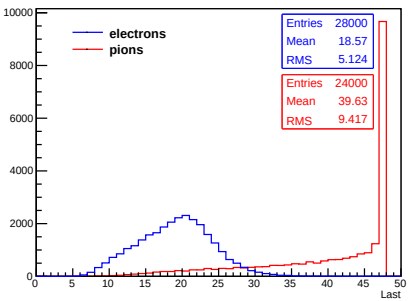


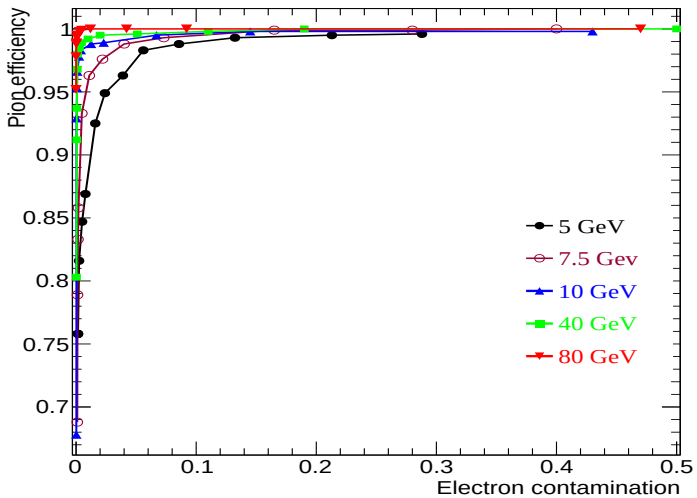



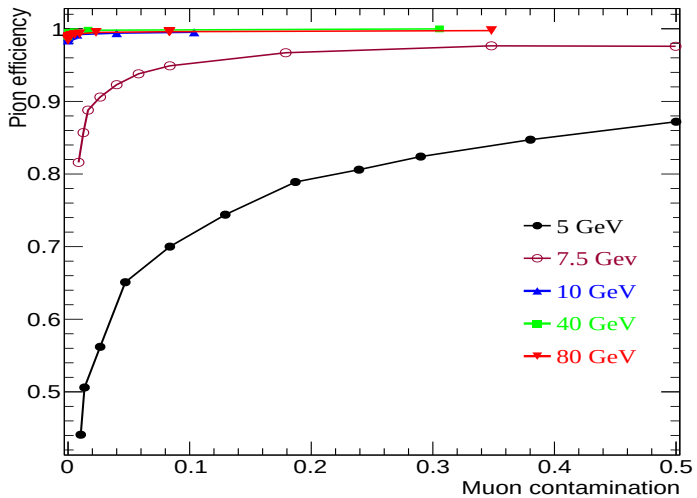



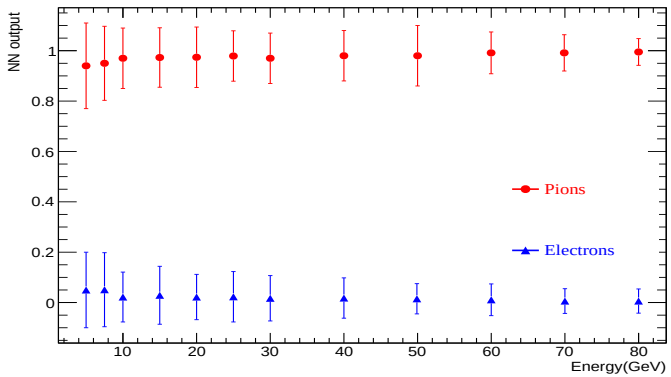
# Pion identification using MVA in MC simulation

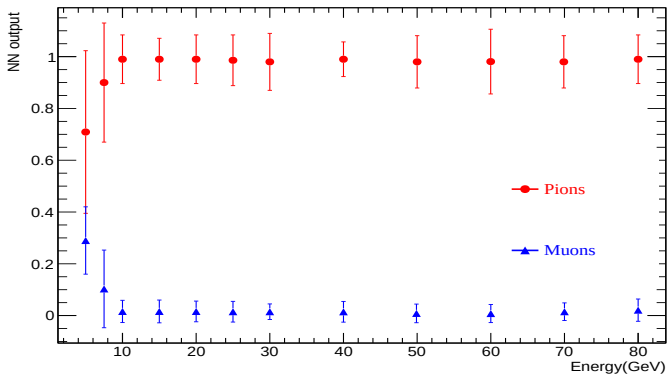
## Performance of MLP method in Pion identification

- Good electron/muon separation for the whole energy range
- Good Pion efficiency exceeding 90% for almost the whole energy range with a low electron and muon contaminations($\approx$ 1%)



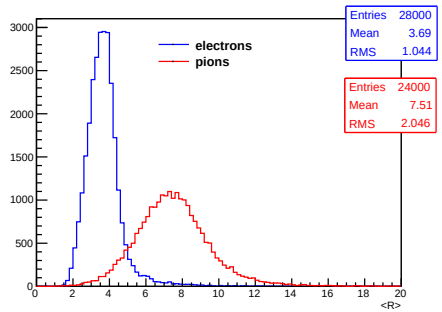



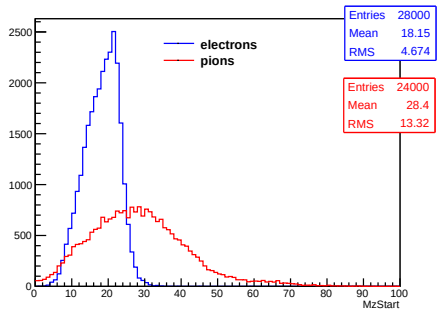



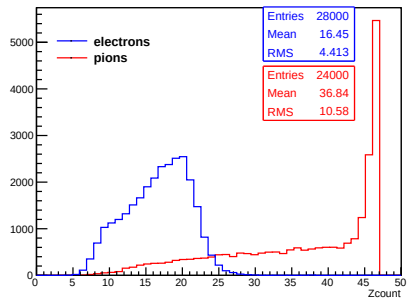
# Pion identification using MVA in Beam Tests Data

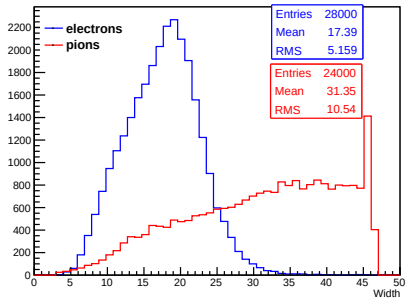
## Validation of MLP with beam tests Data

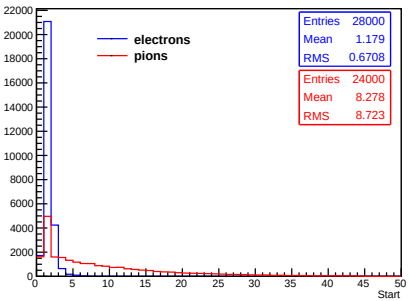
- Method: MLP
- Training and Test
  - Background: 28000 electron events with energies: 2,3,8,10,15,20,25,30,40,50,60,70 and 80 GeV
  - Backgound: 9000 muons events with energies: 0.5, 2 and 10 GeV $\Longrightarrow$ Mixed Background
  - Signal: 24000 pion events with energies(mixed): 5,7.5,10,15,20,25,30,40,50,60,70 and 80 GeV
- Validation: H2 and H6 beam tests data.
- Variables: the total number of hits, start, width, mean radius, longitudinal centre of gravity of the shower

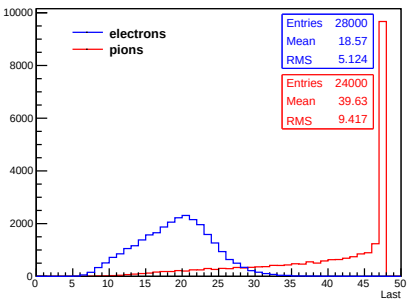


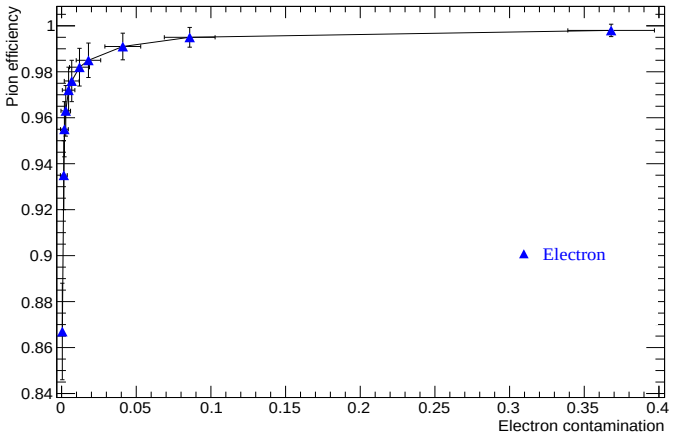



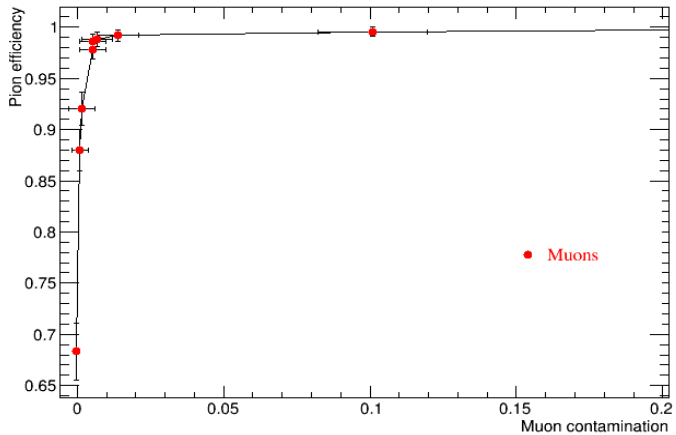



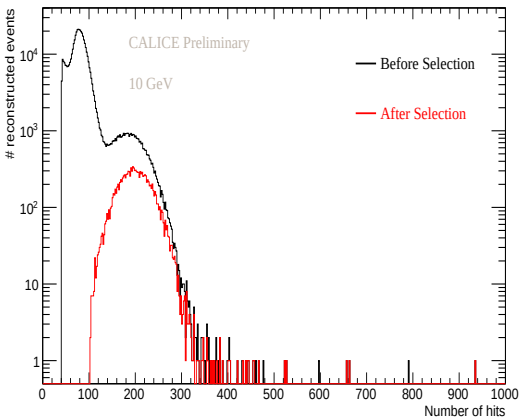
# Pion identification using MVA in Beam Tests Data

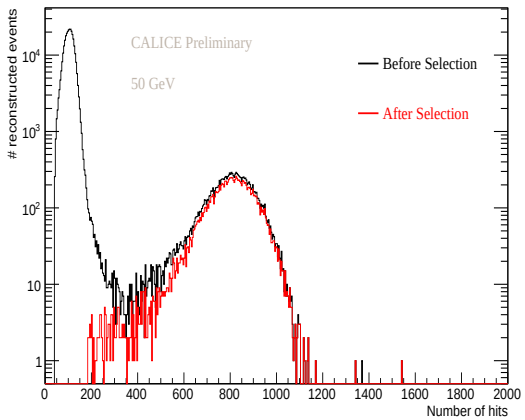
## Validation of MLP with beam tests Data

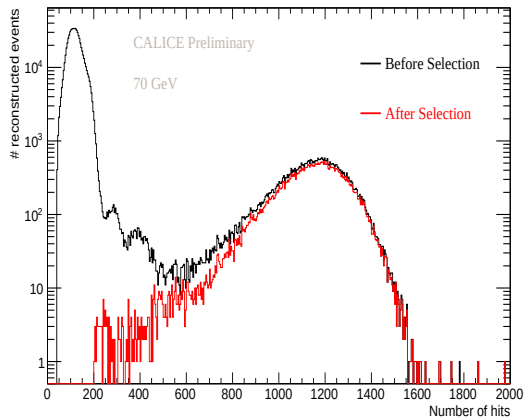
- Good Pion efficiency of 98% for the whole energy range with an electron and muon contaminations of $\approx 1\%$
- Results of MVA event selection is in agreement with the classic event selection



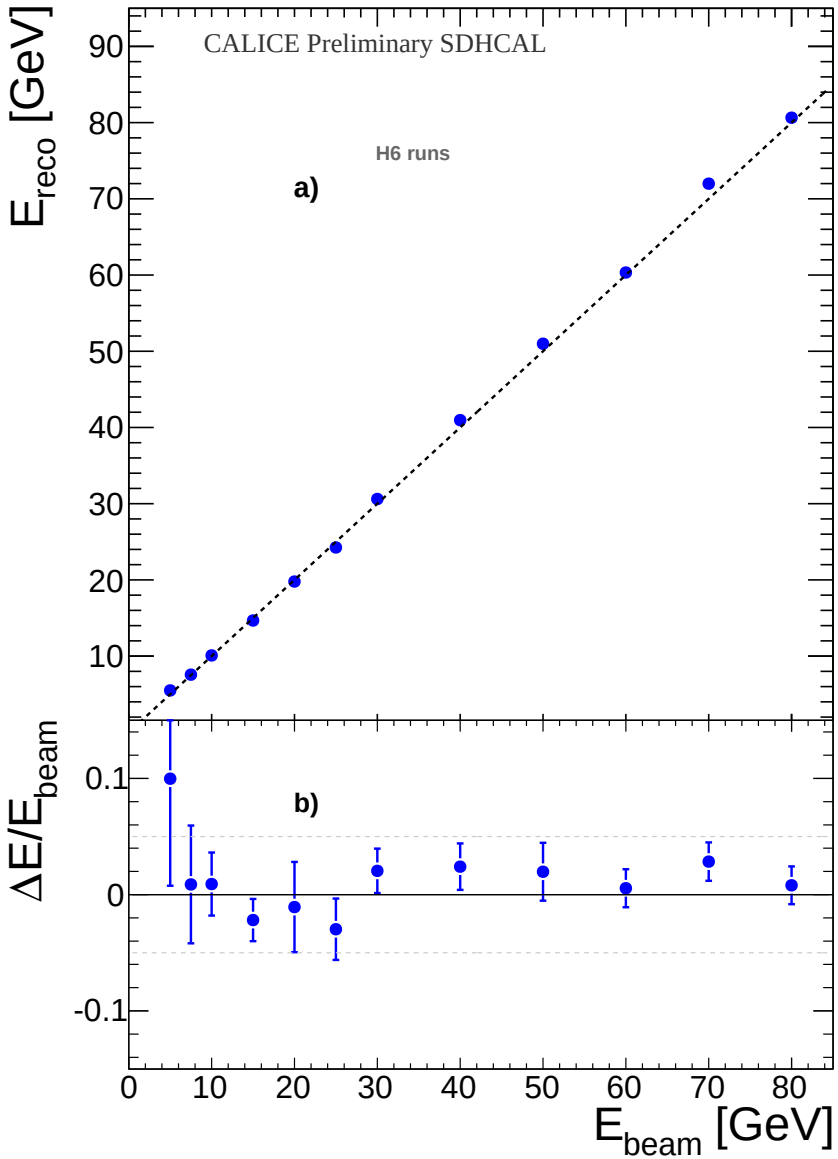



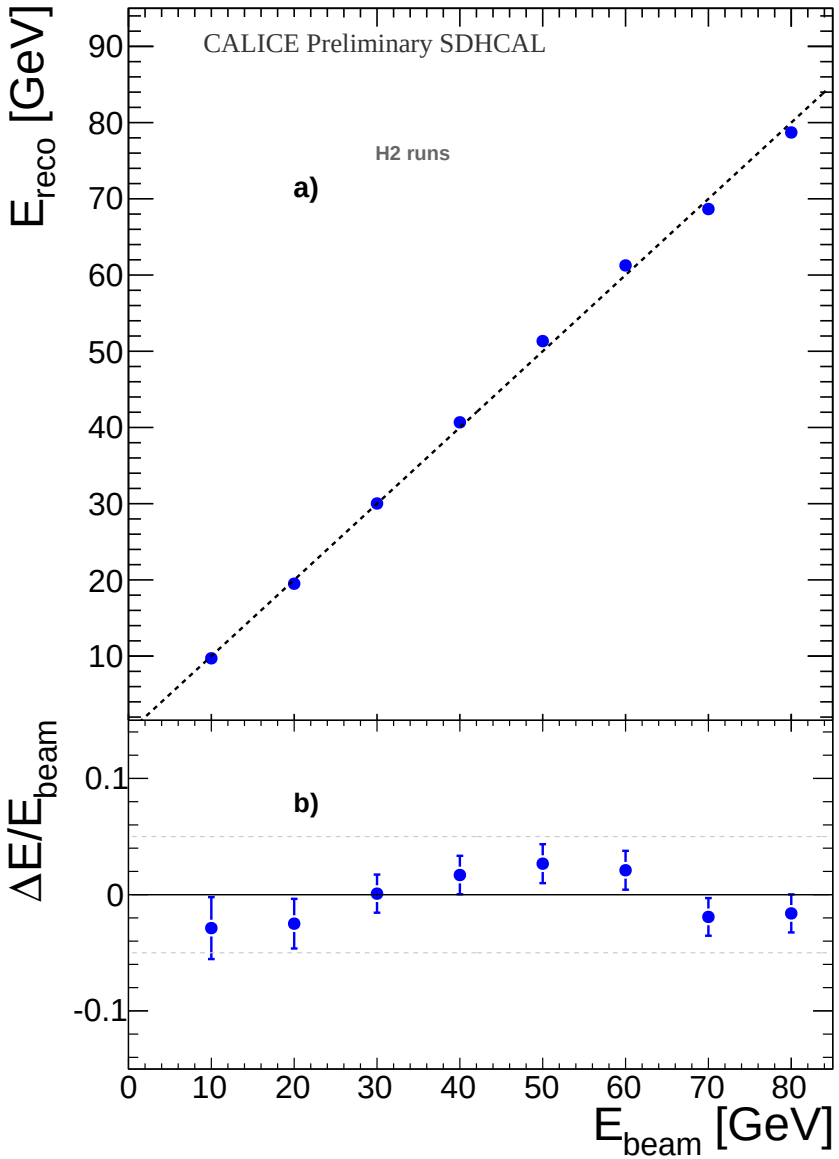



# Pion identification using MVA in Beam Tests Data: Energy reconstruction

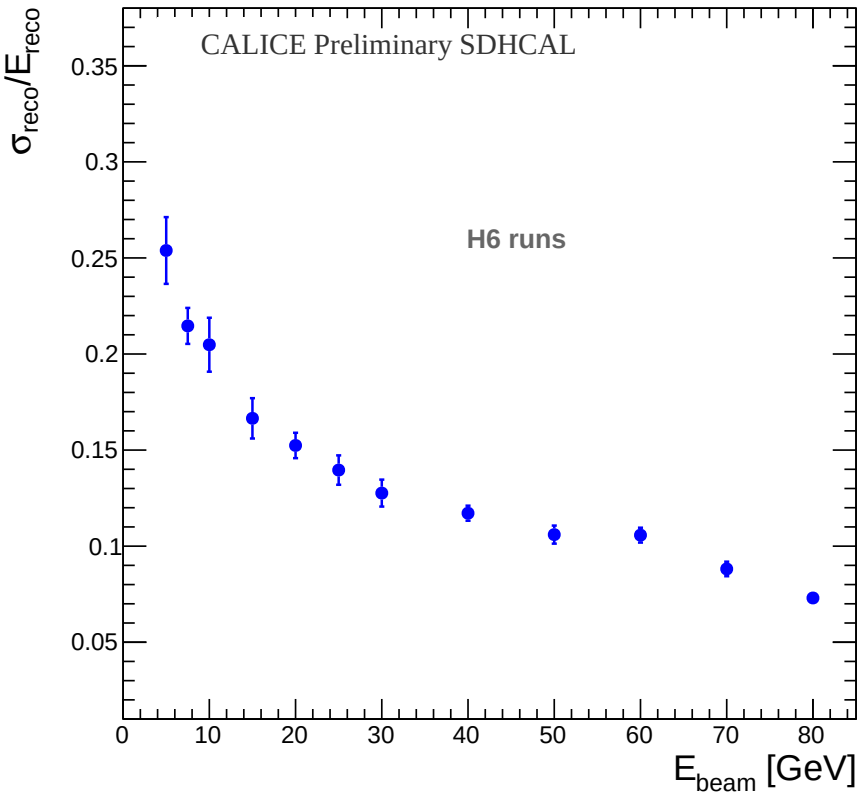
## Quadratic Parametrization

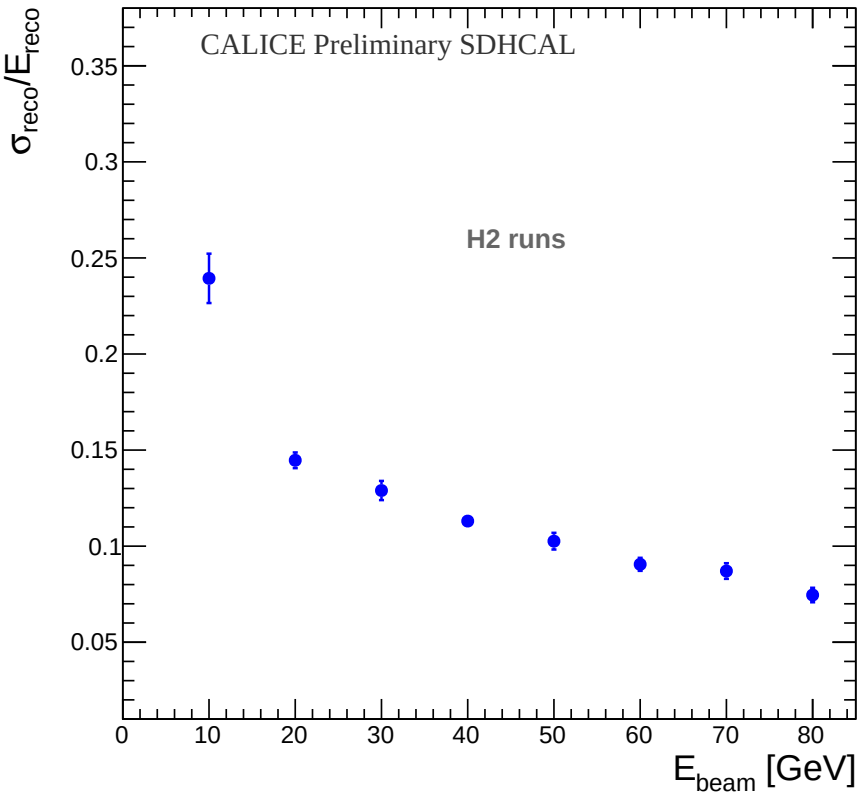


# Pion identification using MVA in Beam Tests Data: Energy reconstruction

## Quadratic Parametrization




- Good linearity in the range of $\pm 5\%$
- Good energy resolution in agreement with the previous results

# Conclusion

# Conclusion

1. Neural Network has been applied for energy reconstruction in SDHCAL
   - A linear response (within $\pm$ 5%)
   - A significant improvement in energy resolution compared to the quadratic method reaching 20% at 80 GeV
2. A particle classifier based on MVA has been developped and applied for pion event selection used after in energy reconstruction
   - Pion identification with MVA is reliable: High pion efficiency with low muon and electron contamination have been obtained
   - MVA based event selection is in agreement with the classic selection
   - Resulted selection exploited in energy reconstruction: A linear response (within $\pm$ 5%) and good energy resolution