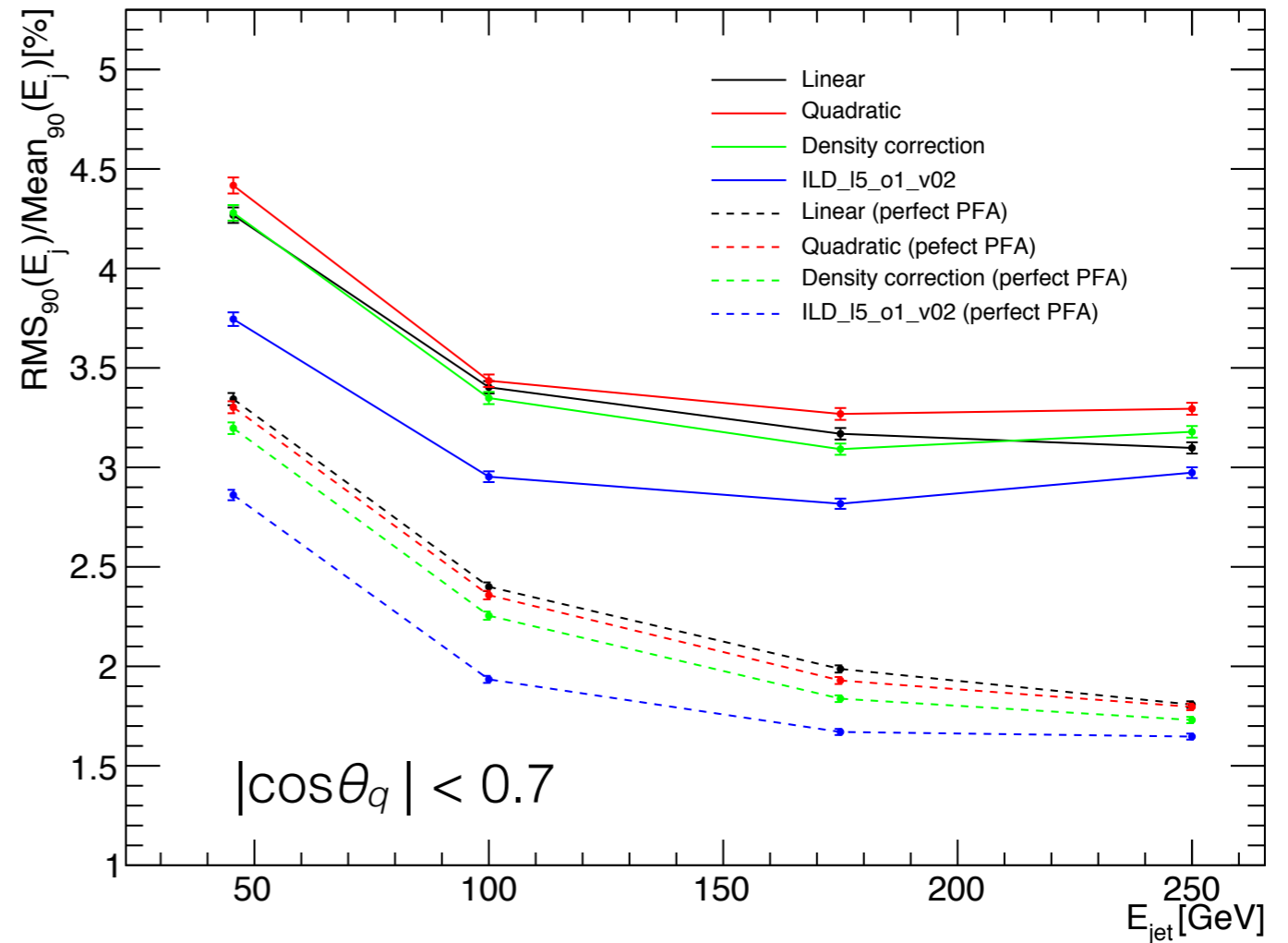
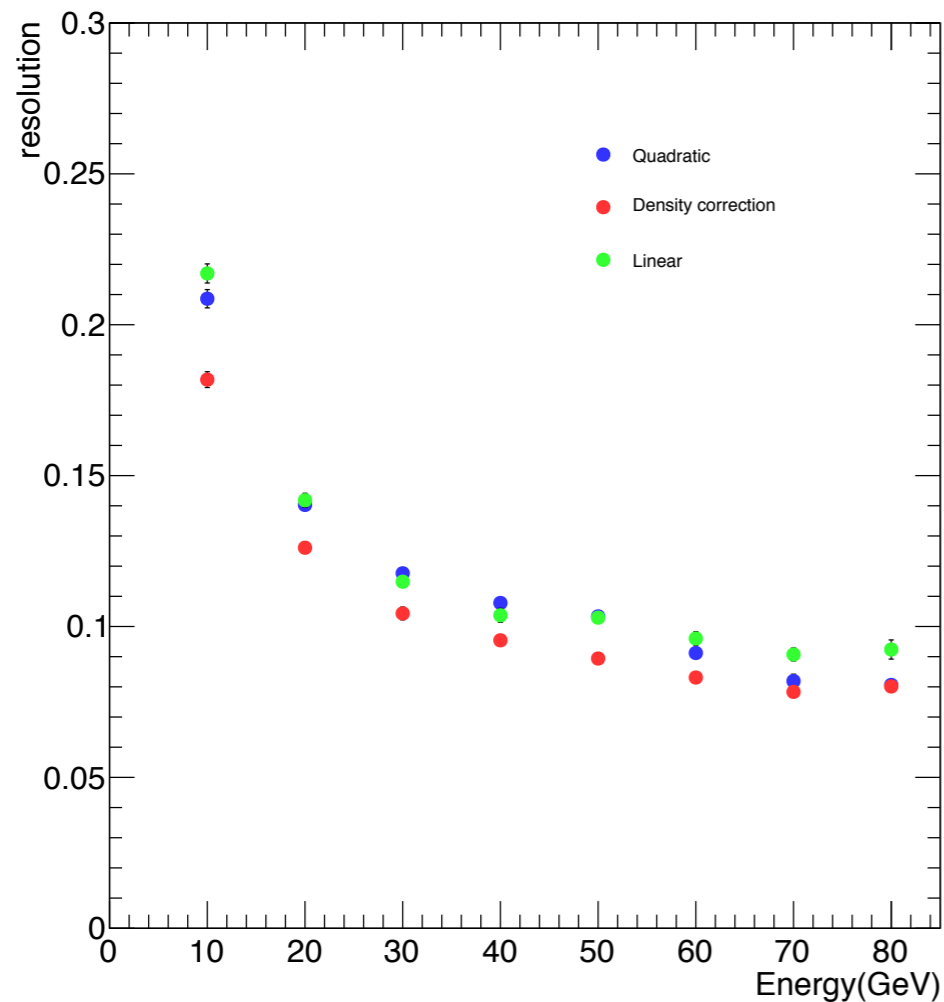


# SDHCAL energy reconstruction by using convnet

Bo Li (IPNL)

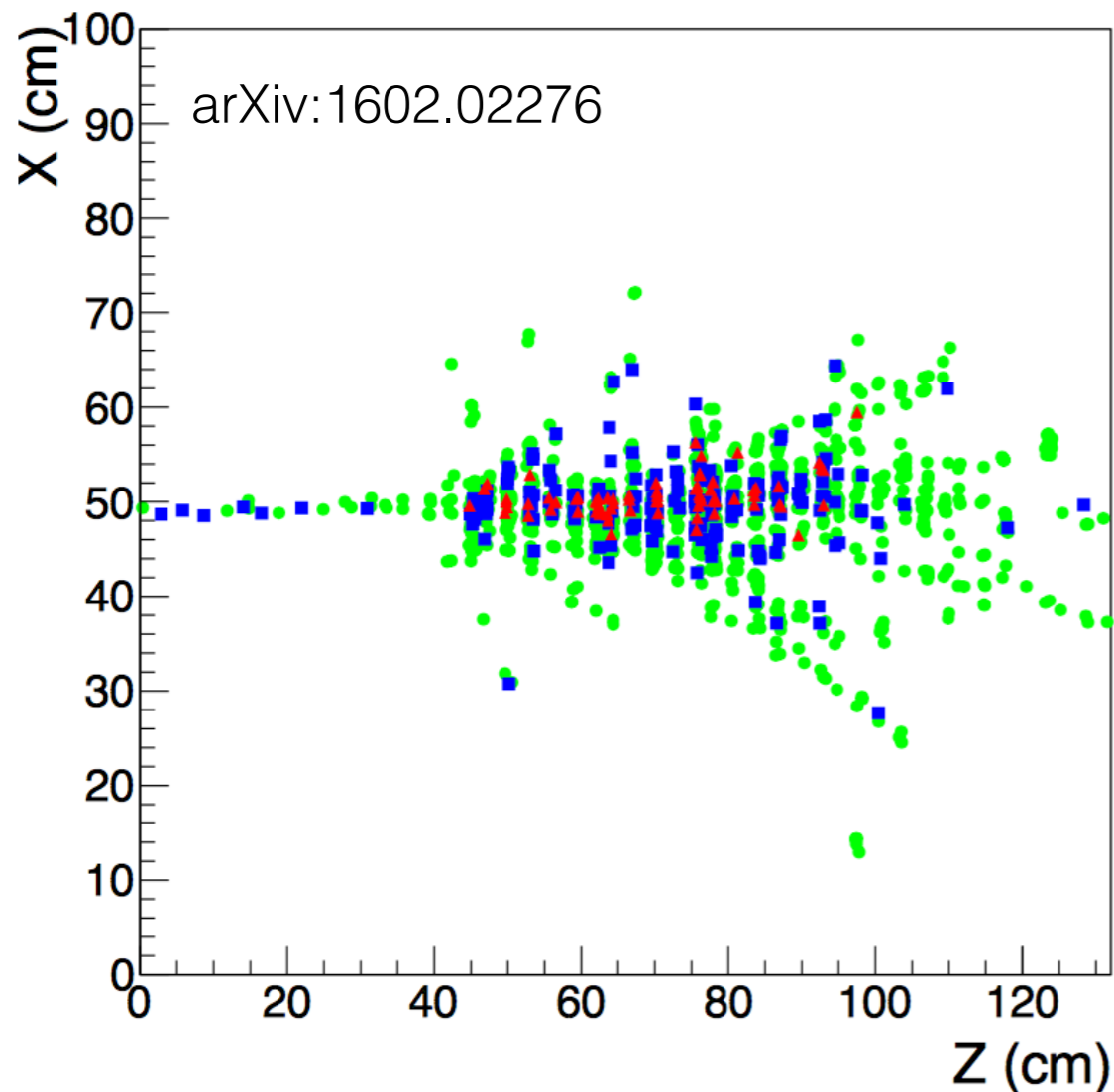
SDHCAL meeting  
July 2

# Energy resolution



Improving the energy resolution of SDHCAL by software is one of direction we can pursue to achieve better jet energy resolution.

# Which way



70 GeV pion

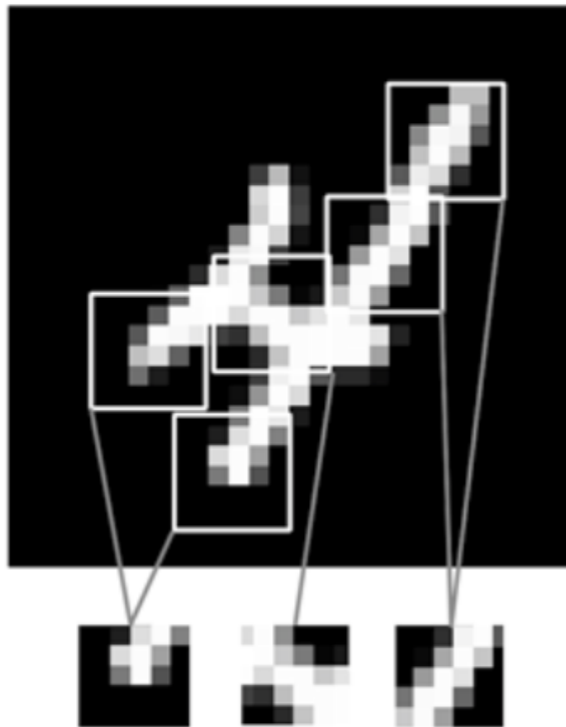
Variables that relate to the shower energy

- hit number
- energy density at a local area
- cluster shape/topology
- ...

A way to take them into account once and for all ?

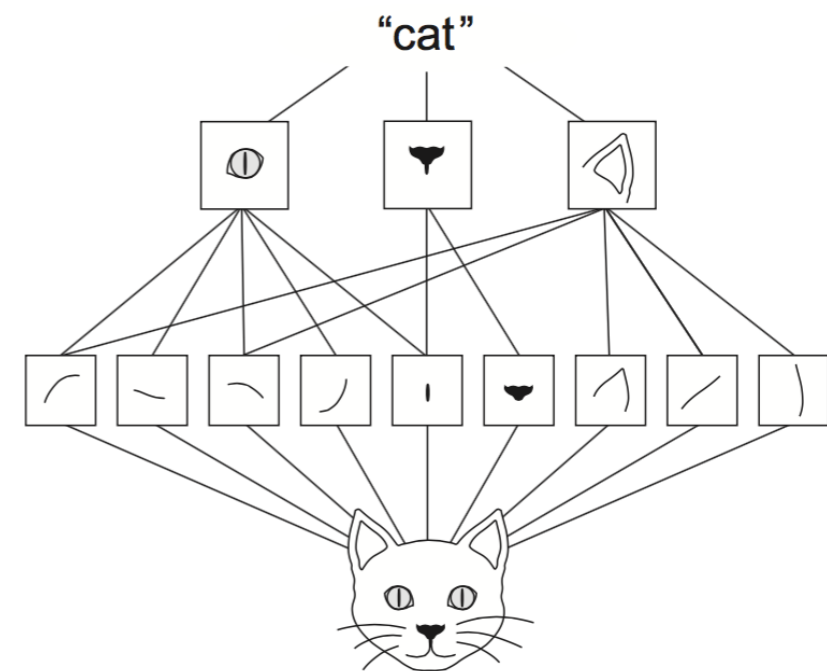
# Convnet

In a convnet (convolutional neural network), neuron in one layer is only connected by the neurons in small region of previous layer



from *Deep Learning with Python*

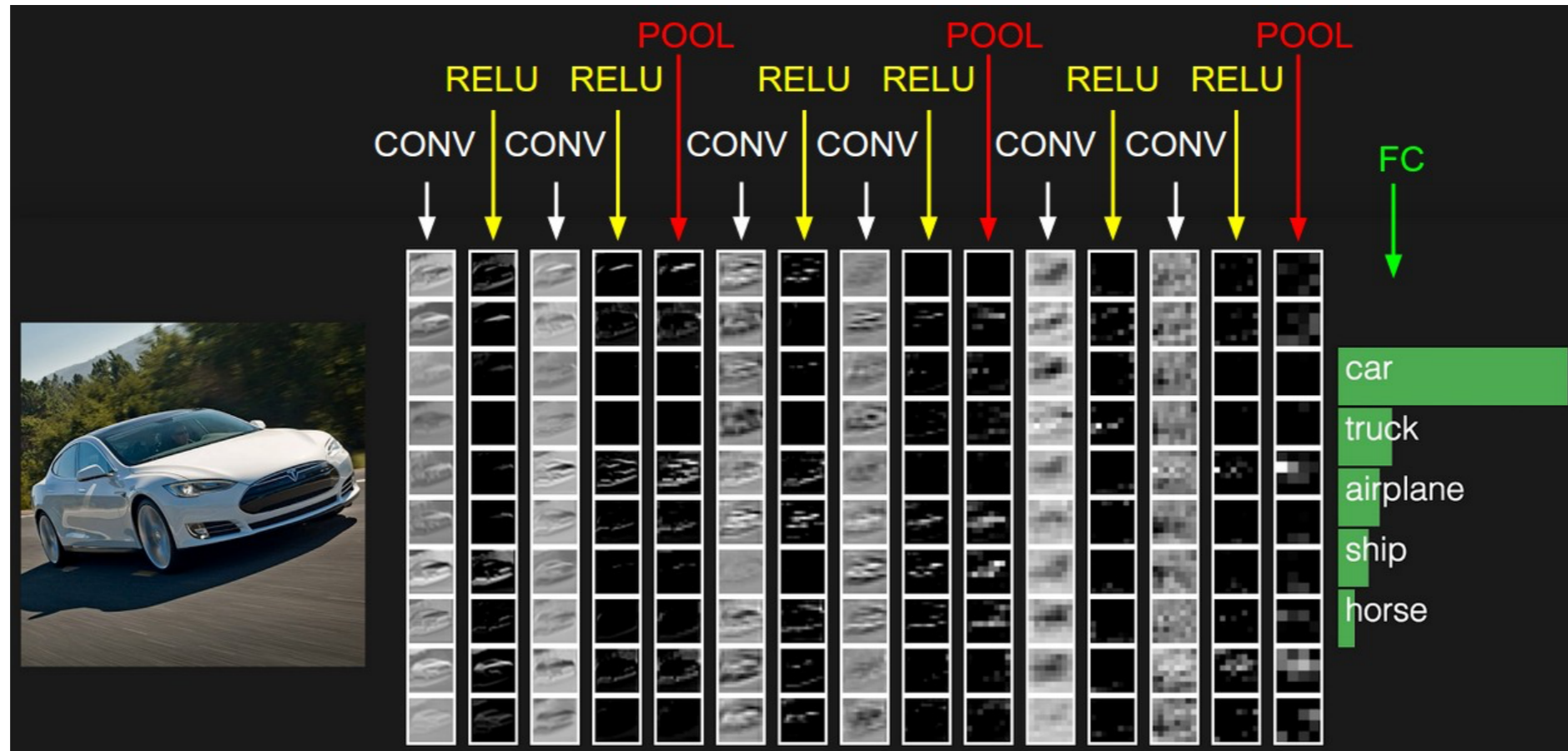
Pixels of a digit as input of convnets



Spatial hierarchy of cat

- Convolution layers learn local patterns
- The patterns they learn are translation invariant
- It can learn spatial hierarchies of patterns

# Activation on layer



<http://cs231n.github.io/convolutional-networks>

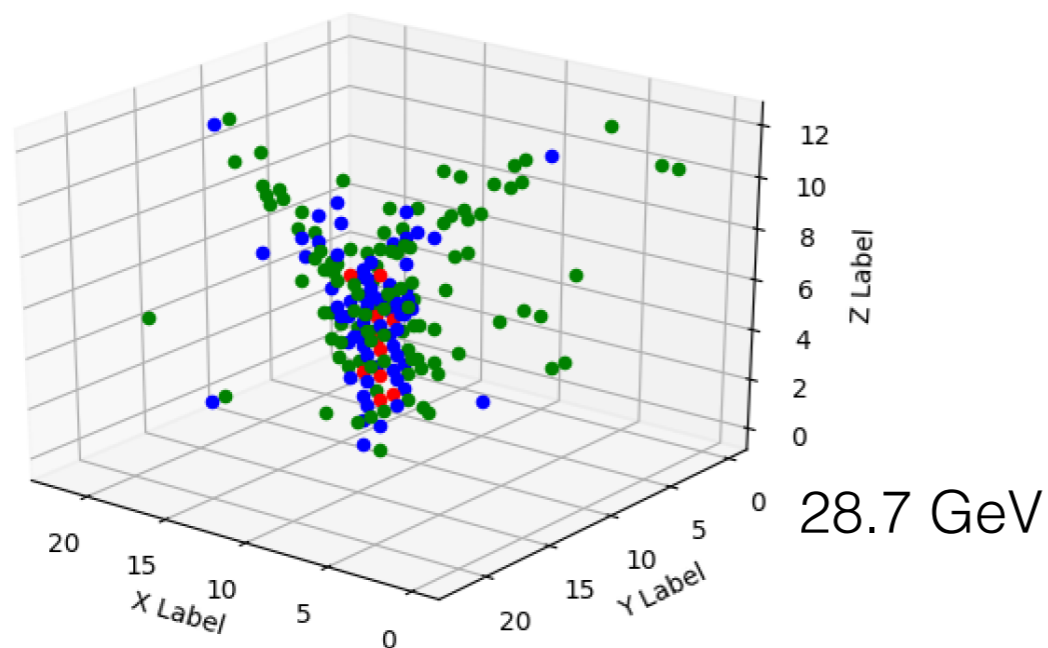
In this sense, convnet is not 'black box' any more

So, convnet is probably our right choice for energy reconstruction (regression)

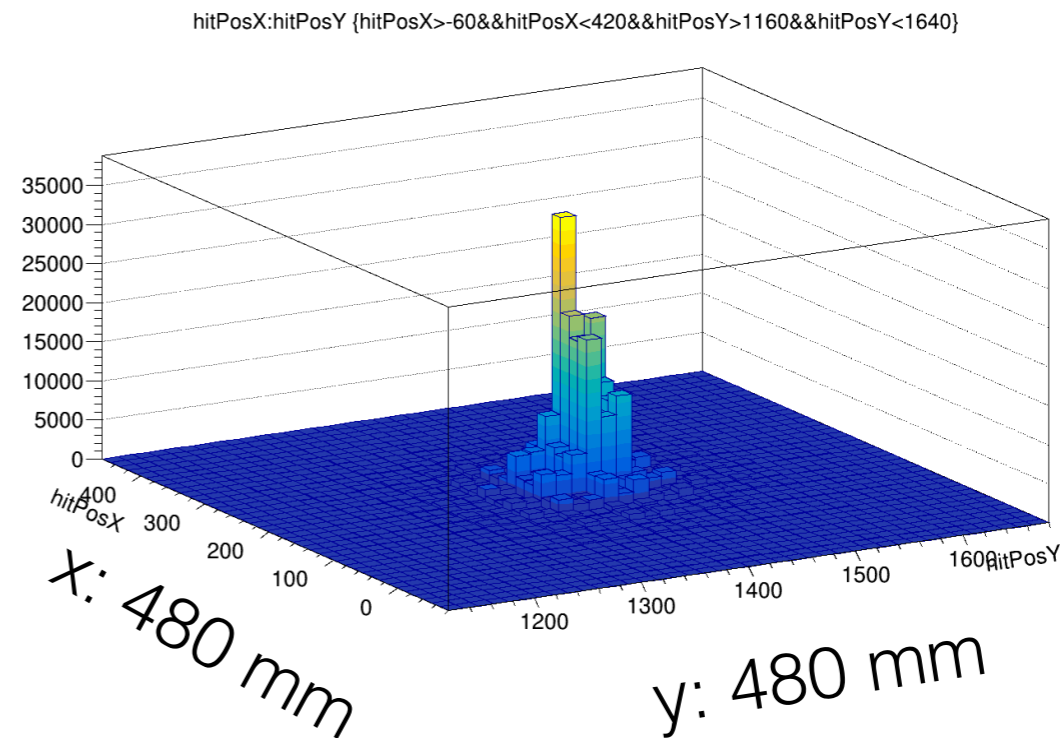
# Data preprocessing

Simulation:

- training samples: K0Long, 2 - 100 GeV
- test samples: K0Long, 10, 20, ... , 80 GeV
- ILD\_I5\_o2\_v02 (SDHCAL), endcap
- ILCSoft v01-19-05



Hit map of 1k events



96% hits in this region

event number

cell number

normalized energy

data shape: (120000, 48, 48, 48, 1), data type : float18, ~ 22 GB !

data shape: (120000, 24, 24, 24, 1), data type : float18, ~ 3 GB

# Building convnets

- I tried to build a convnet model by Keras 2.2.0 (Ubuntu-16.04, cuda-9.0, tensorflow-1.8.0)

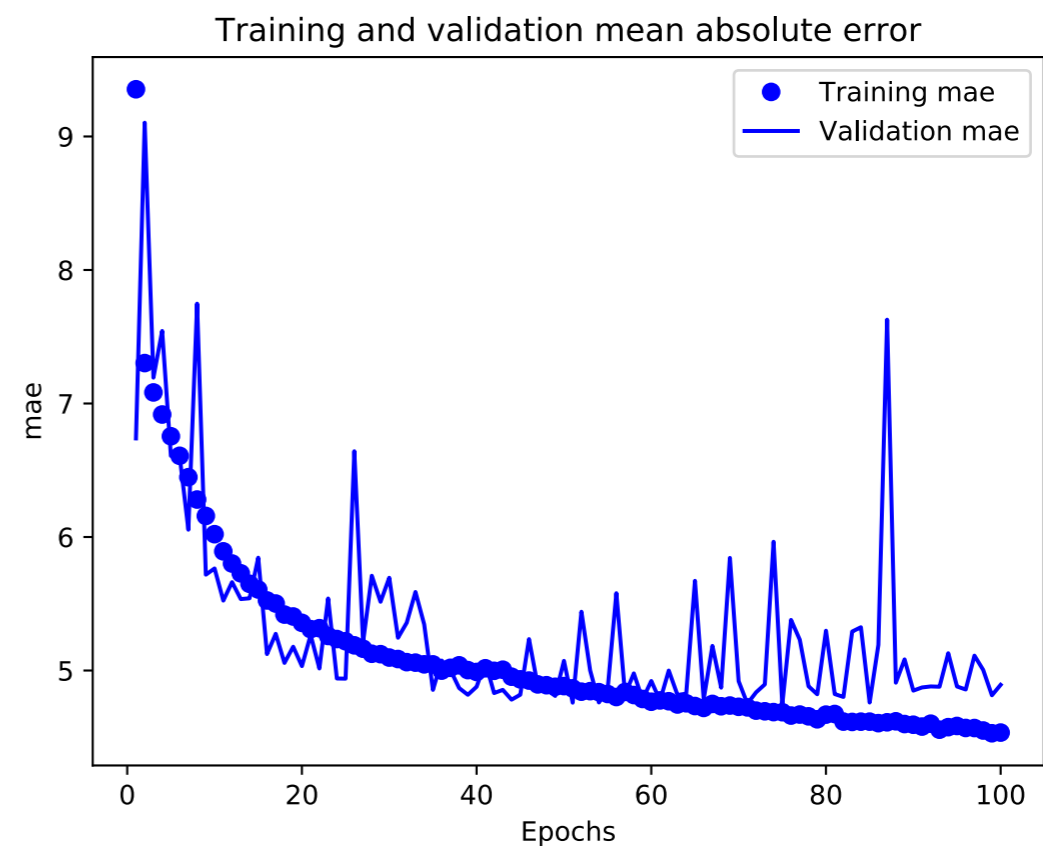
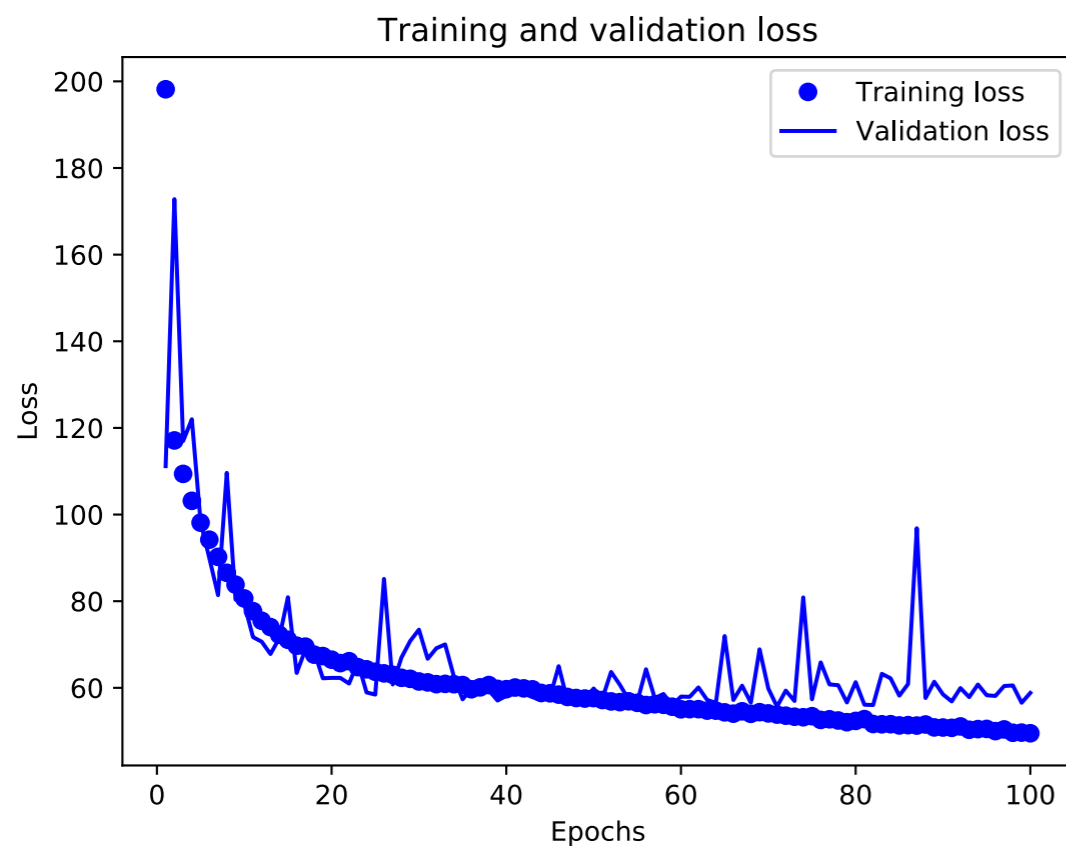
Layer (type)	Output Shape	Param #
conv3d_1 (Conv3D)	(None, 23, 23, 23, 16)	144
average_pooling3d_1 (Average)	(None, 11, 11, 11, 16)	0
conv3d_2 (Conv3D)	(None, 10, 10, 10, 32)	4128
average_pooling3d_2 (Average)	(None, 5, 5, 5, 32)	0
conv3d_3 (Conv3D)	(None, 4, 4, 4, 32)	8224
flatten_1 (Flatten)	(None, 2048)	0
dense_1 (Dense)	(None, 32)	65568
dense_2 (Dense)	(None, 1)	33
Total params: 78,097		
Trainable params: 78,097		
Non-trainable params: 0		



- Training network on a GeForce GTX 1080 Ti GPU

# Loss and error

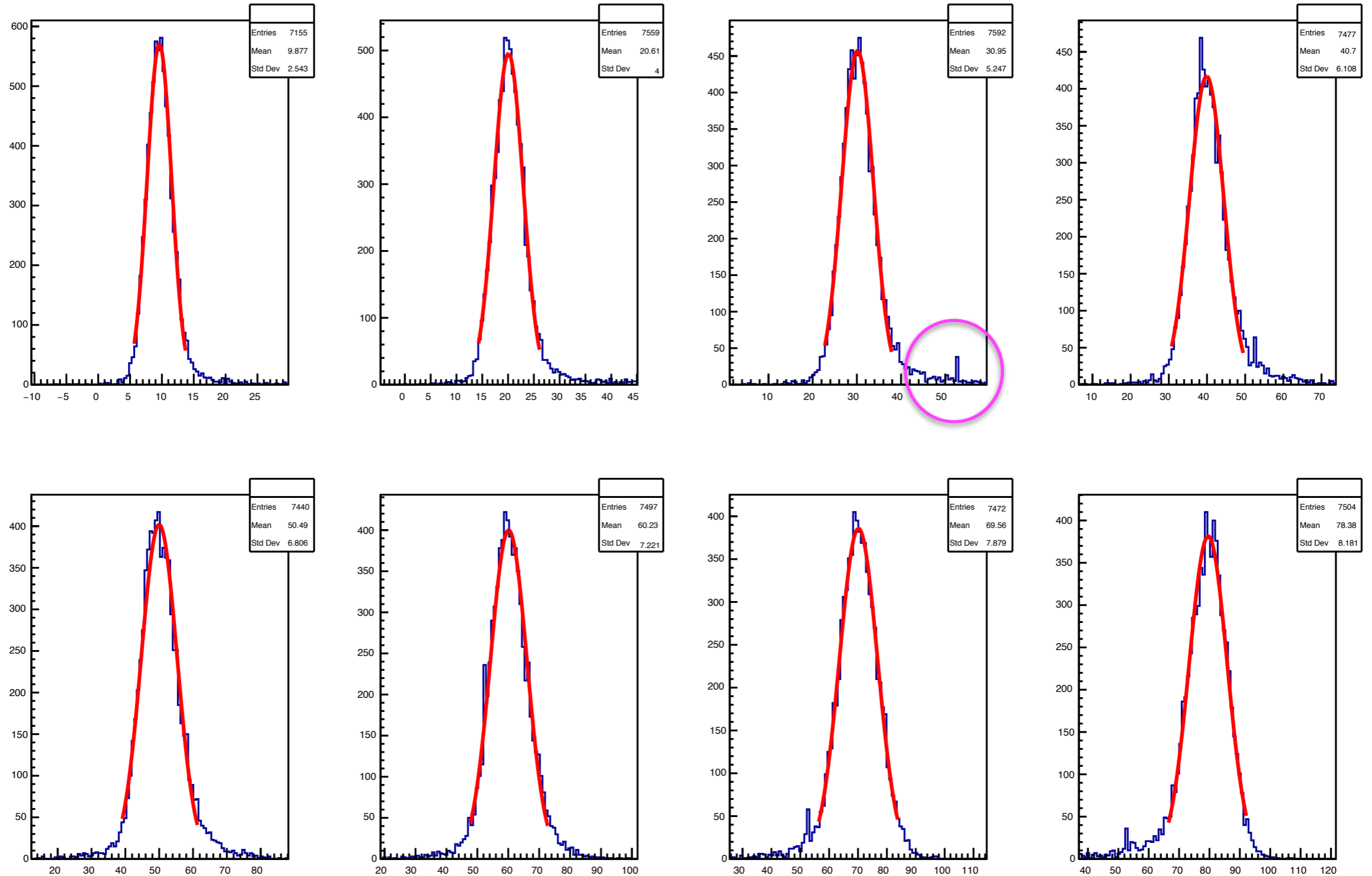
The loss is a function of difference between prediction of network and the target



The training is going to be overfitting after 100 epochs

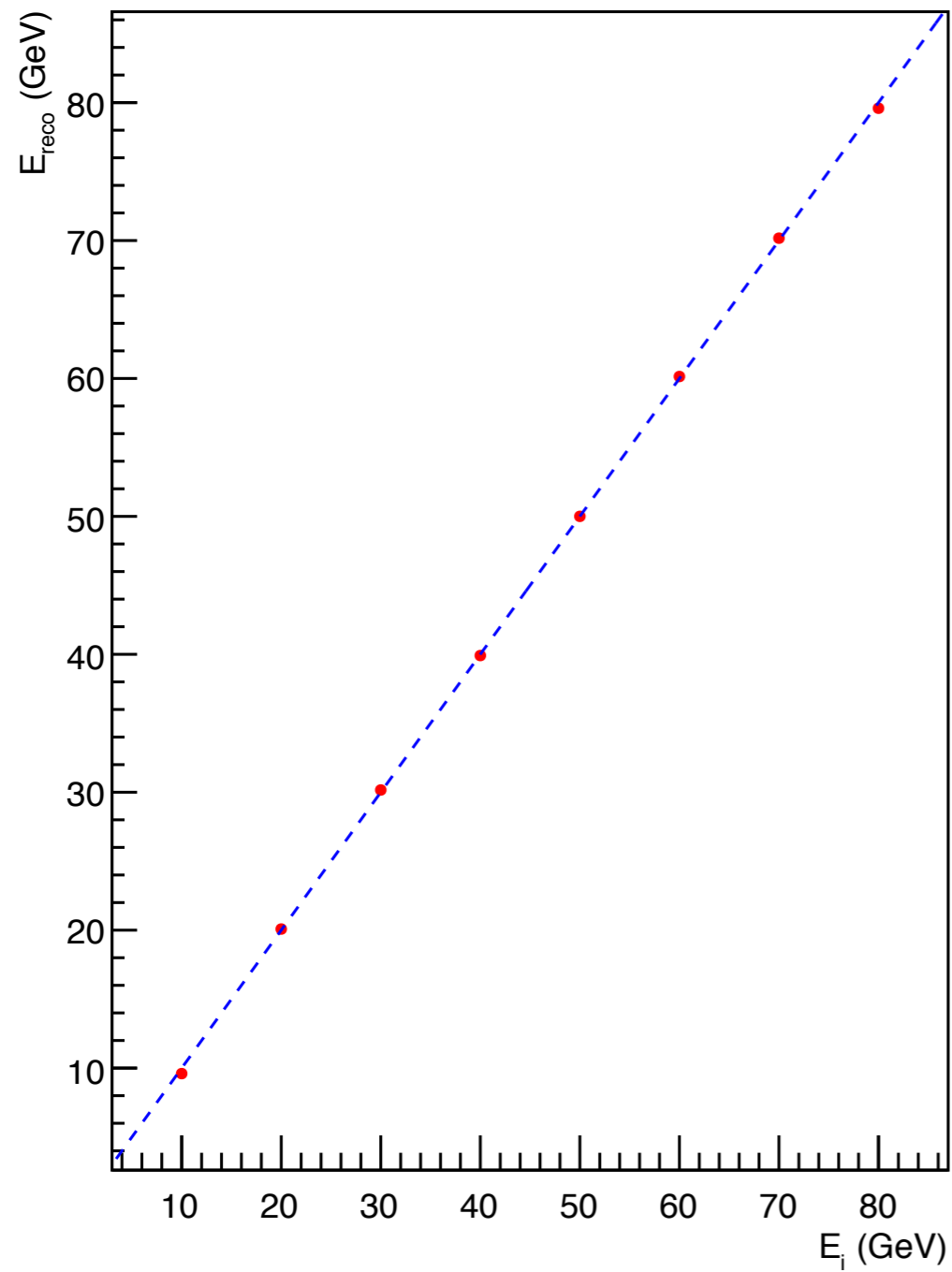


# Reconstructed energy of test samples

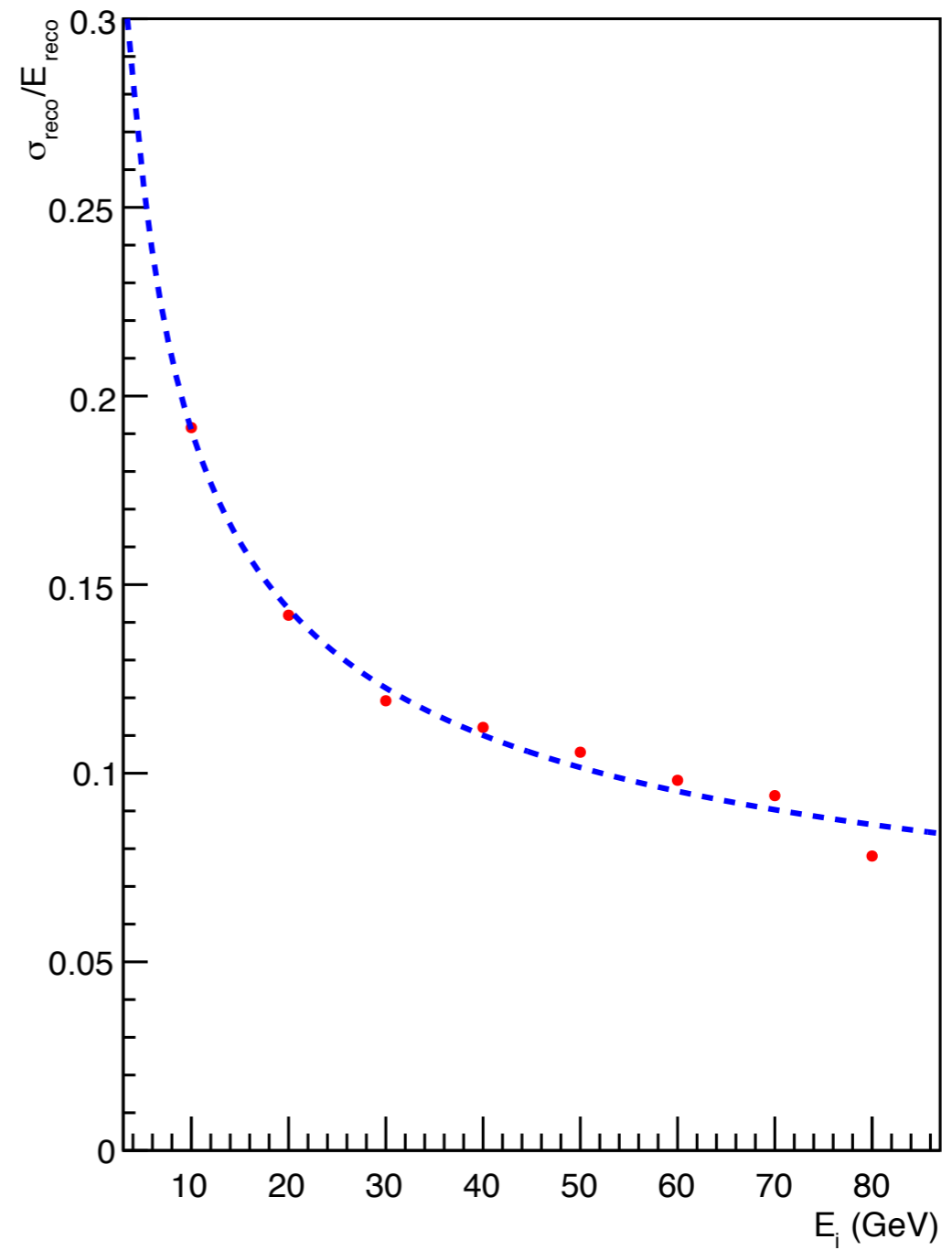


# Performance

Linearity



Resolution



# Summary

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- It is proposed that convnet can be used for SDHCAL energy reconstruction
- A very naive convnet model is built, but its performance on energy reconstruction is not so bad
- Issues:
  - overfitting
  - 'thorn' in the reconstructed energy
  - understand what the convnet learned from data
  - find a good convnet model for our case