ZDC energy reconstruction by CNN

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Brief outline

- Motivation
  - Improve ZDC reconstruction performance using a ML (CNN) technique
    - CNN is a powerful tool in image recognition tasks
- Works to be reported in this slides
  - Simulation using EIC tool
    - Inject neutrons (γ) with various energy steps; ranges 1-300 GeV
  - Reconstruction with a traditional formulation

$$E = \mathrm{aE}_{WSi} + \mathrm{bE}_{PbSi} + \mathrm{cE}_{Hcal}$$

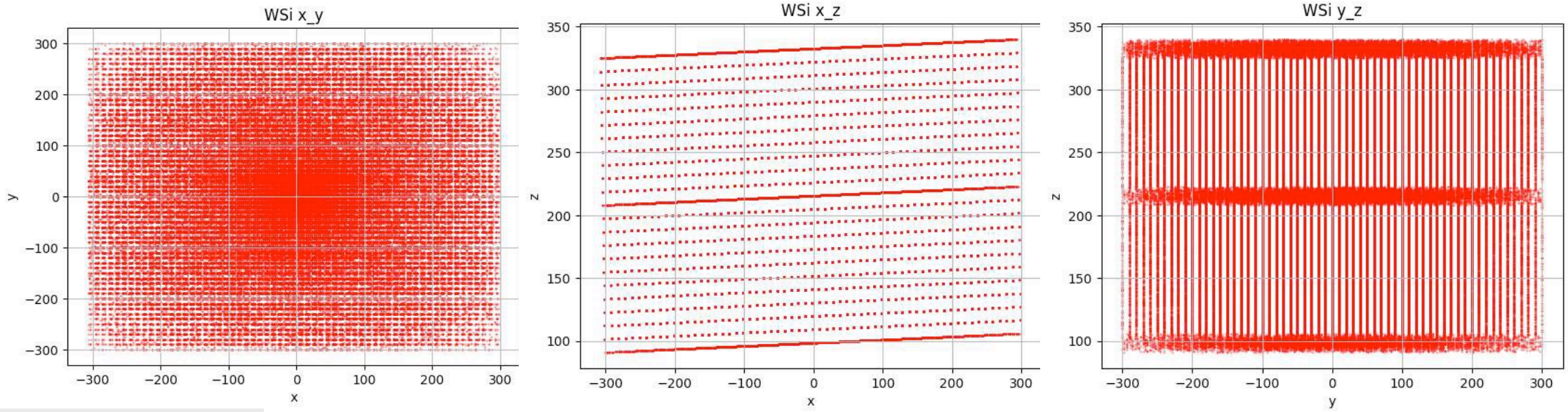
  - Reconstruction with a CNN method
    - Convert ZDC hits into three images for each event
      - 66 pixels x 66 pixels for X-Y, X-Z, Y-Z
  - Comparison of reconstruction performance

MC Simulation

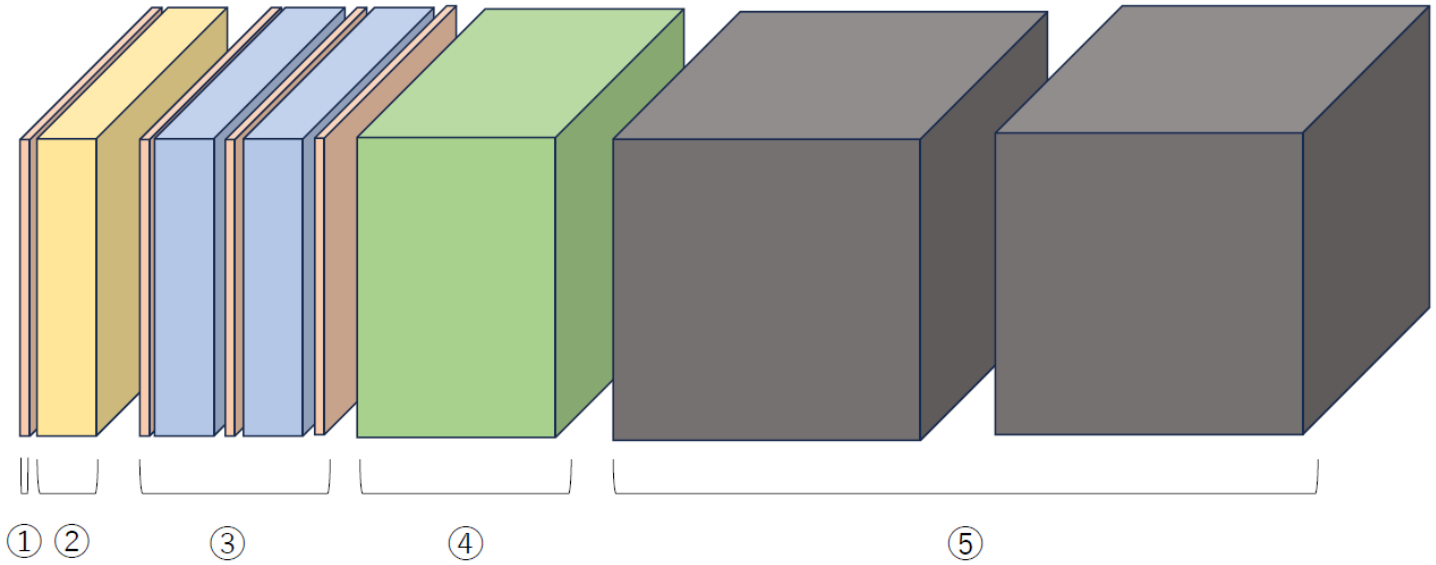
Source codes: https://get.epic-eic.org

- Inject neutrons to ZDC
  - Direction
    - cosine distribution
  - Energies
    - 0, 1, 2, …, 10, 20, …100, 200, 300 GeV
  - Particles
    - Neutron, Photon (No report)

↓ Hit map in WSi



ZDC in the simulation tool



① : SiliconPixcel calorimeter
② : Electron magnetic calorimeter
③ : WSi calorimeter

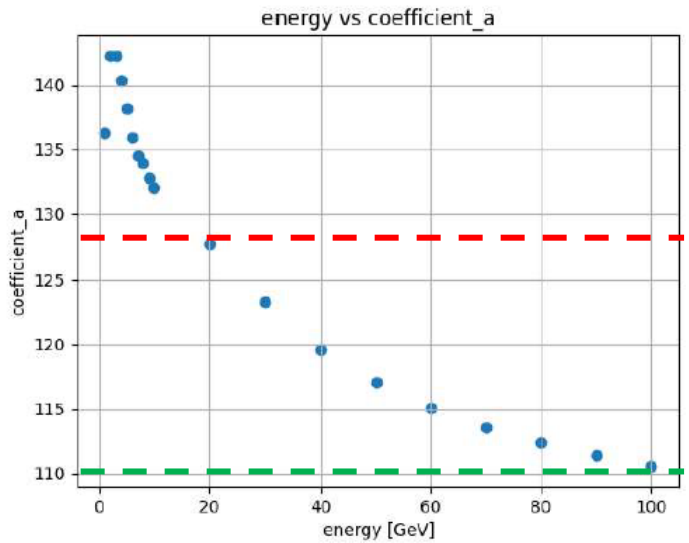
④ : PbSi calorimeter
⑤ : Hadron calorimeter

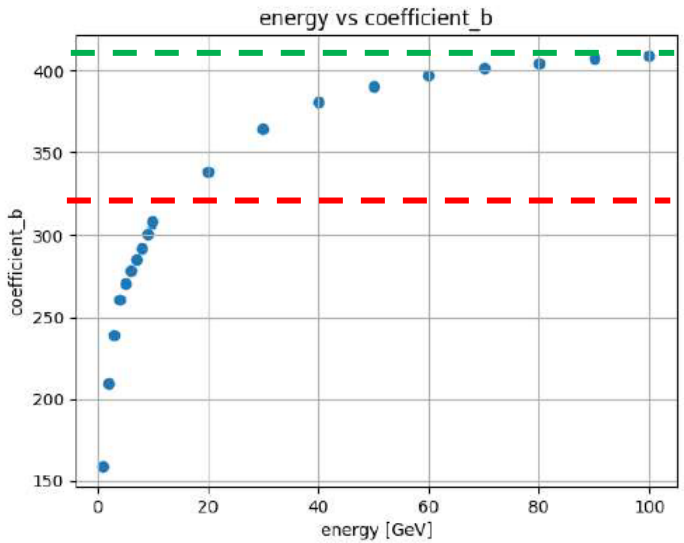
	# of Layers	Shimizu-san study	In MC data
Wsi	23	12 cm	23.4 cm
PbSi	12	40.2 cm	40.9 cm
Hcal	15+15	98 cm	97.8 cm
Total length		162 cm	180.4 cm

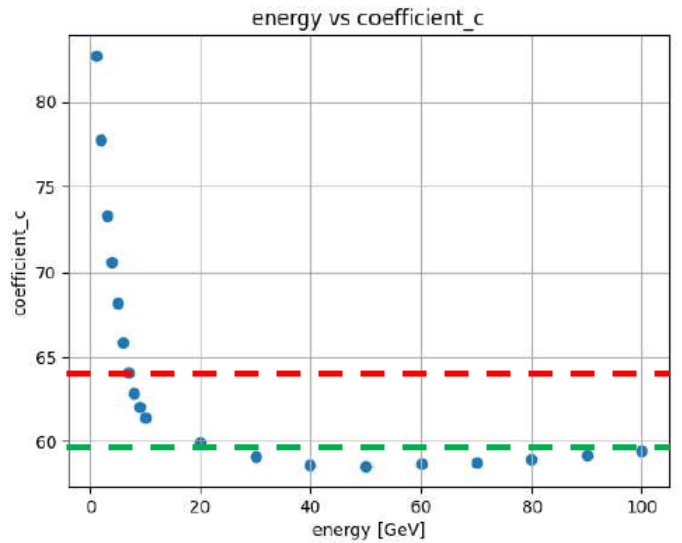
Reconstruction w/ traditional method

- Determine below coefficients using MC data

$$E = \mathrm{aE}_{WSi} + \mathrm{bE}_{PbSi} + \mathrm{cE}_{Hcal}$$



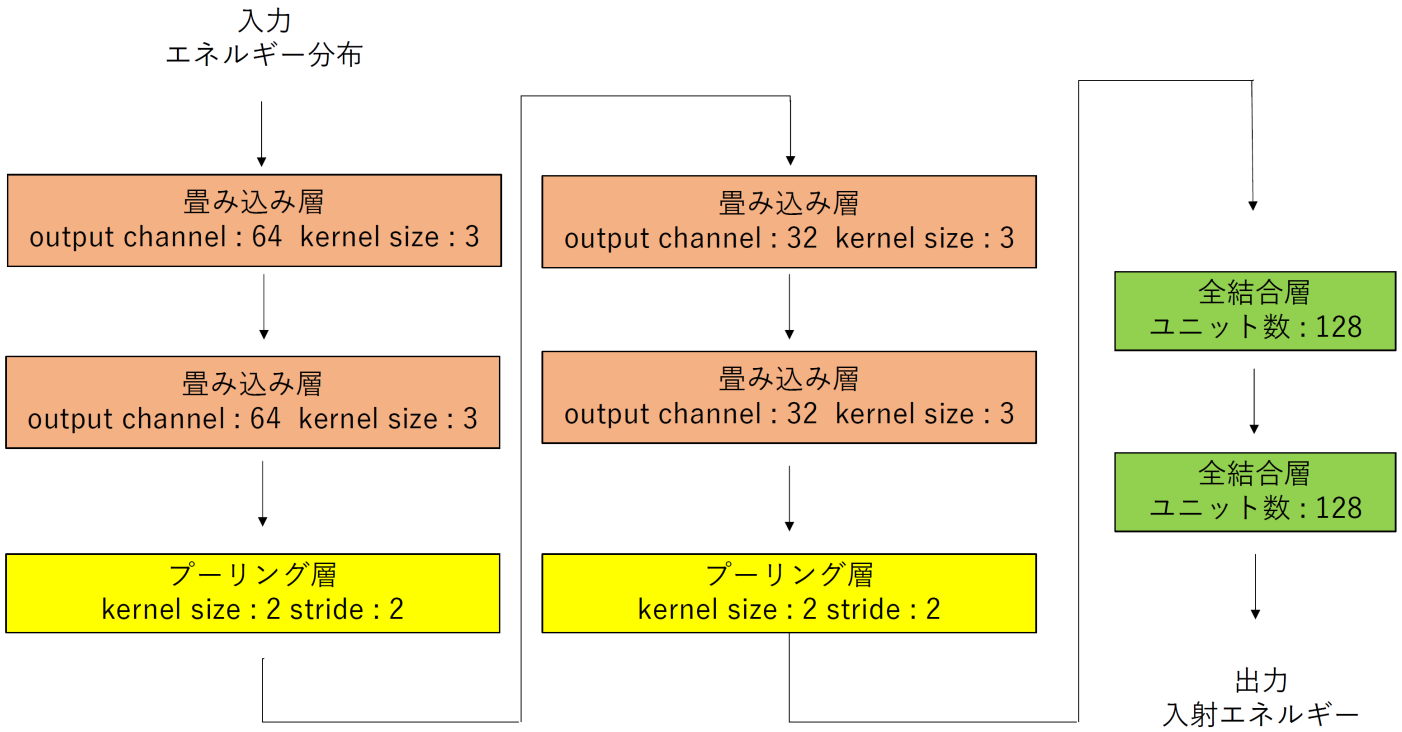




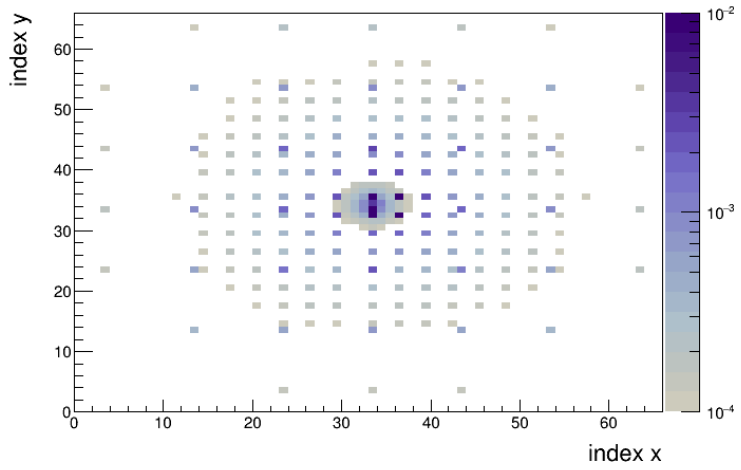
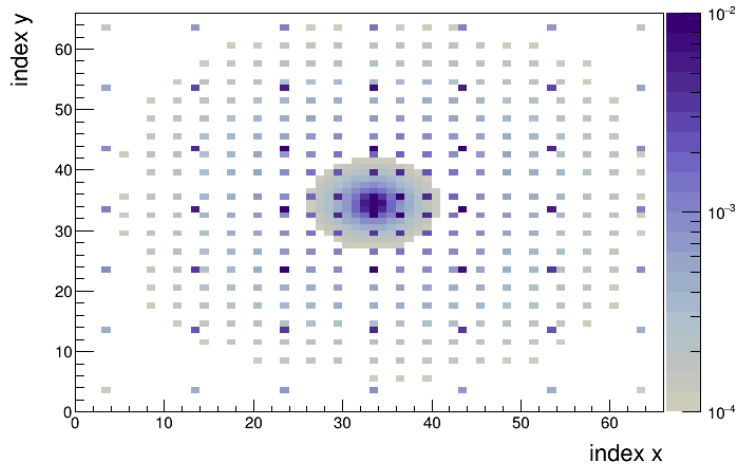
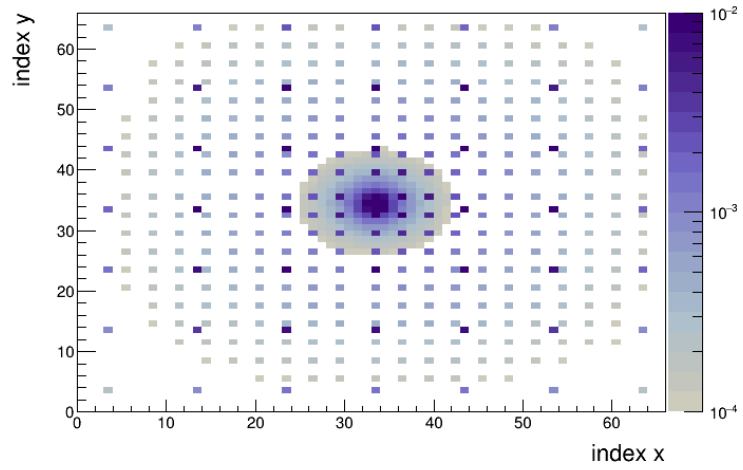
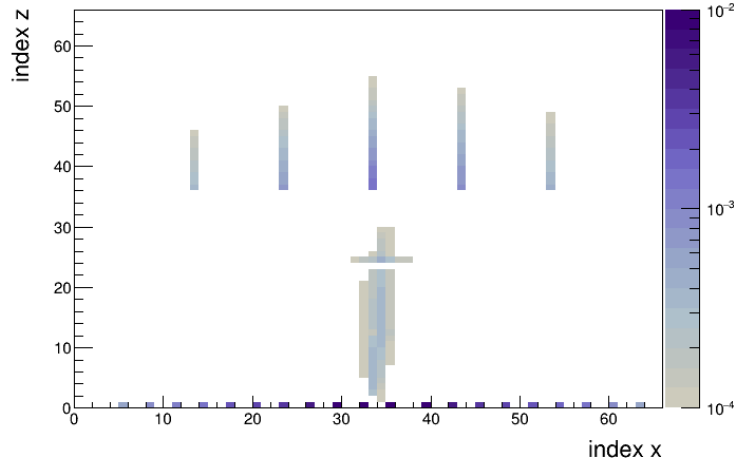
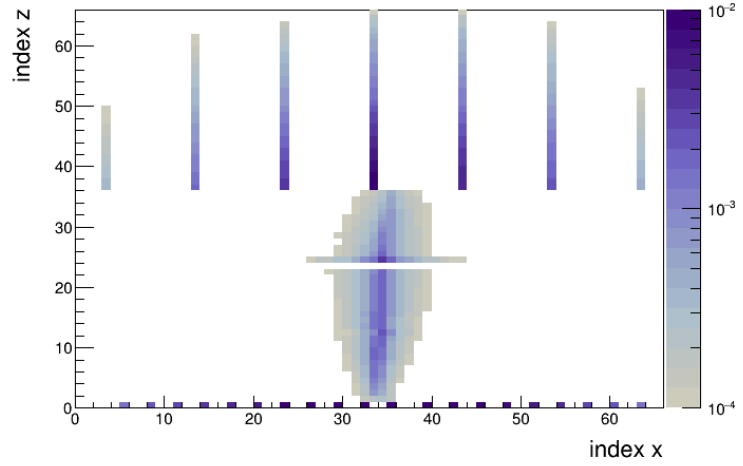
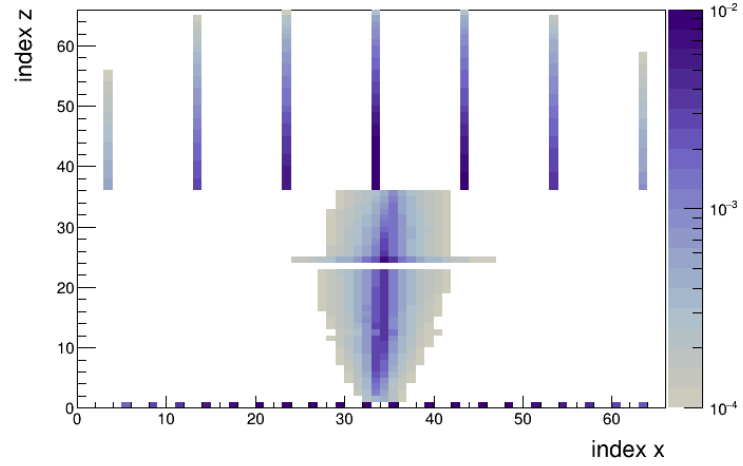
Points; Exclusive fit, Red lines Average of excl. fit, Green line; inclusive fit

CNN training

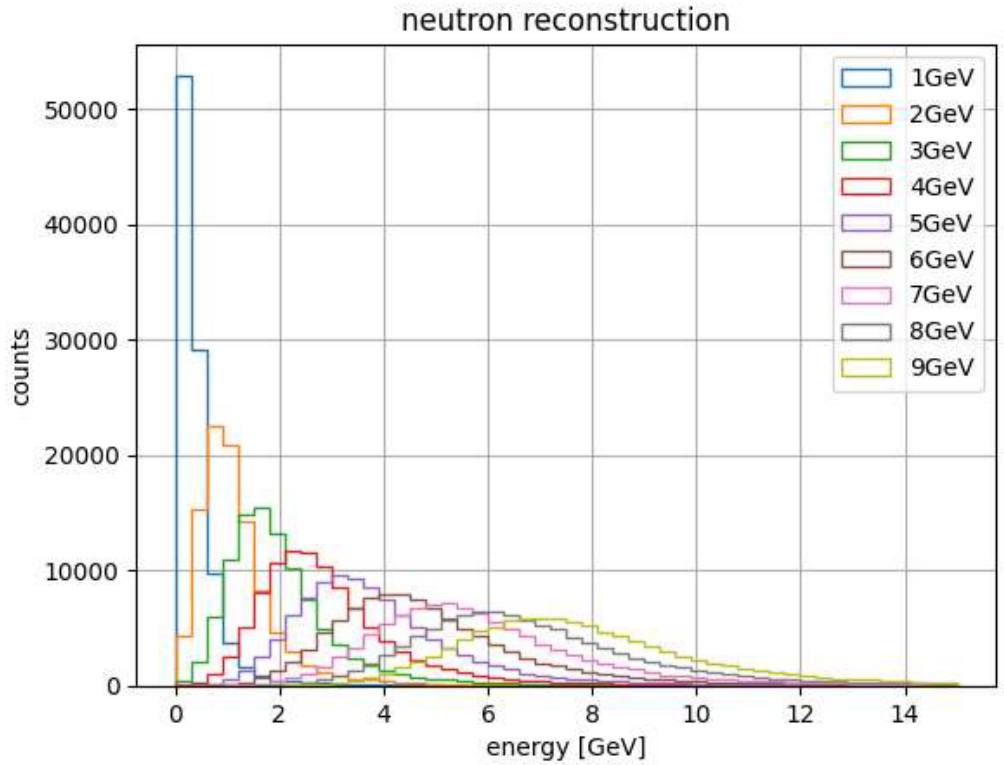
- Input
  - 66 x 66 pixeled hit maps per each event
  - X-Y, X-Z, Y-Z images
- Train with various energies
  - Steps 0 – 300 GeV
  - → Need to generate uniform energy input data
  - 100000 events per energy
- Running on local PC

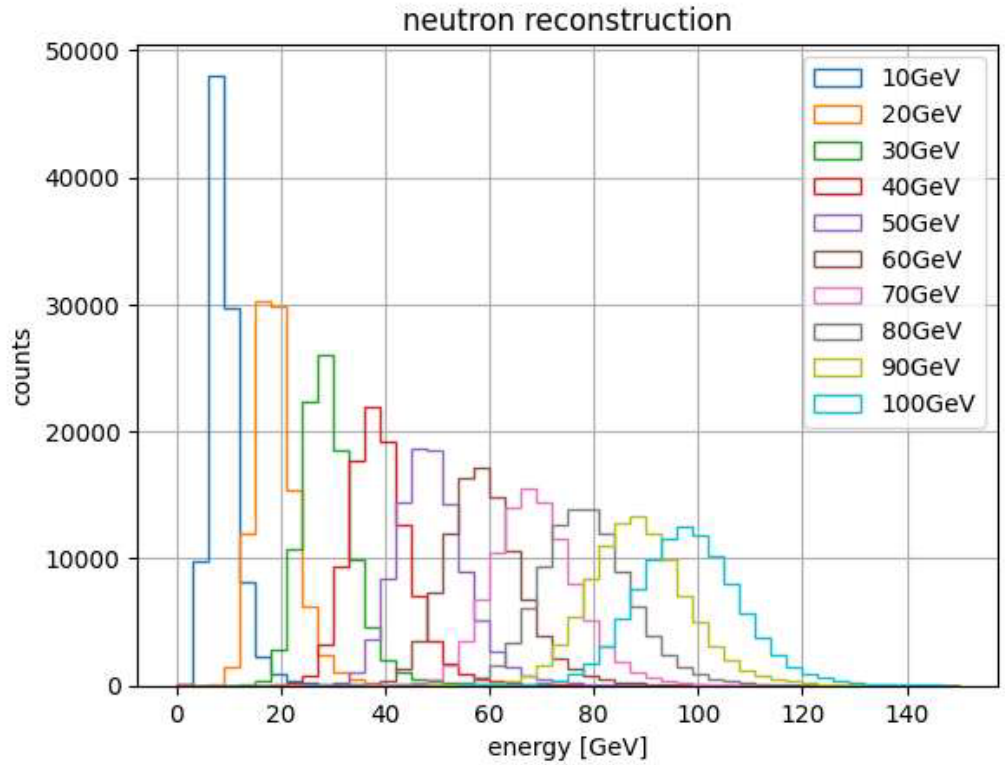


Ex) Averaged images

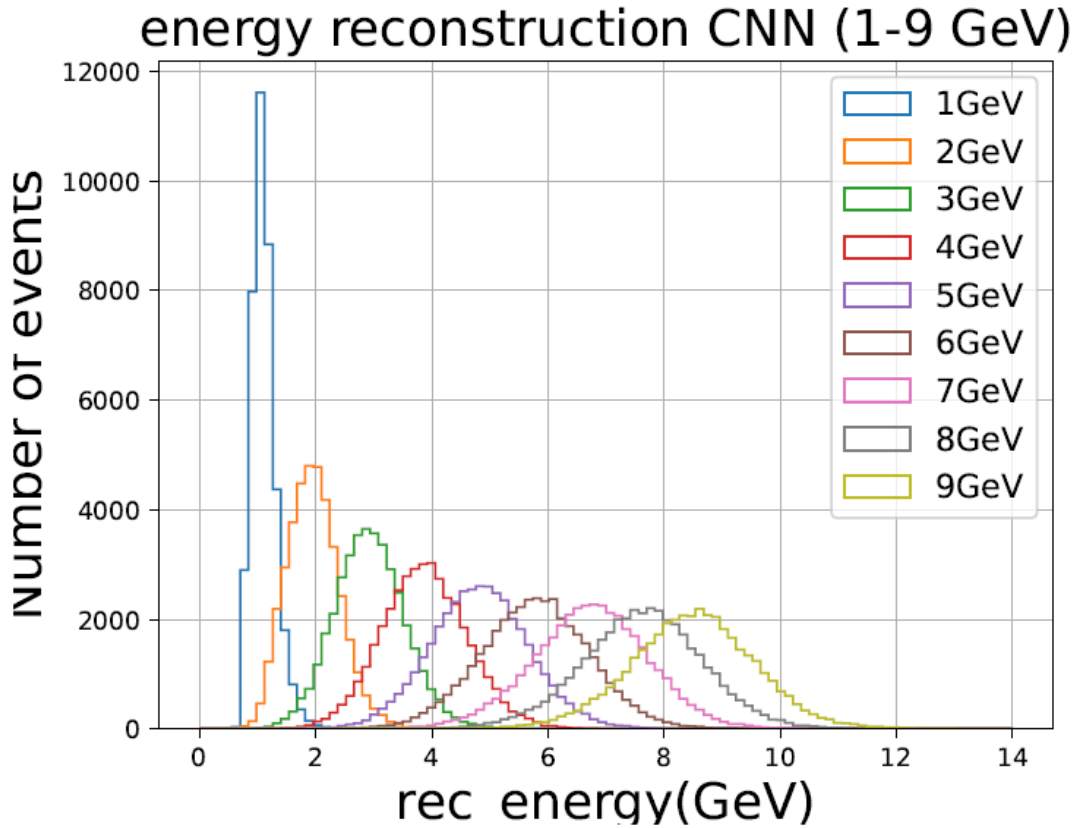
	10 GeV	50 GeV	90 GeV
X-Y			
X-Z			

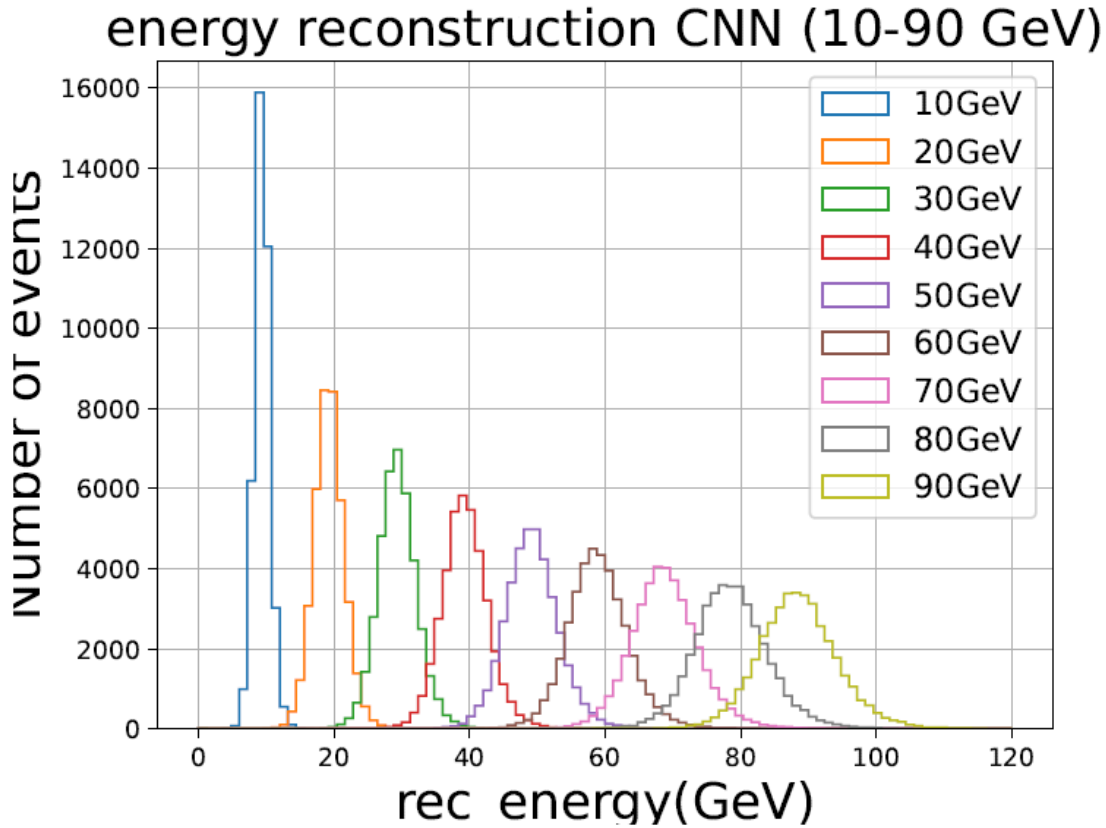
Reconstructed energy (Trad. method)

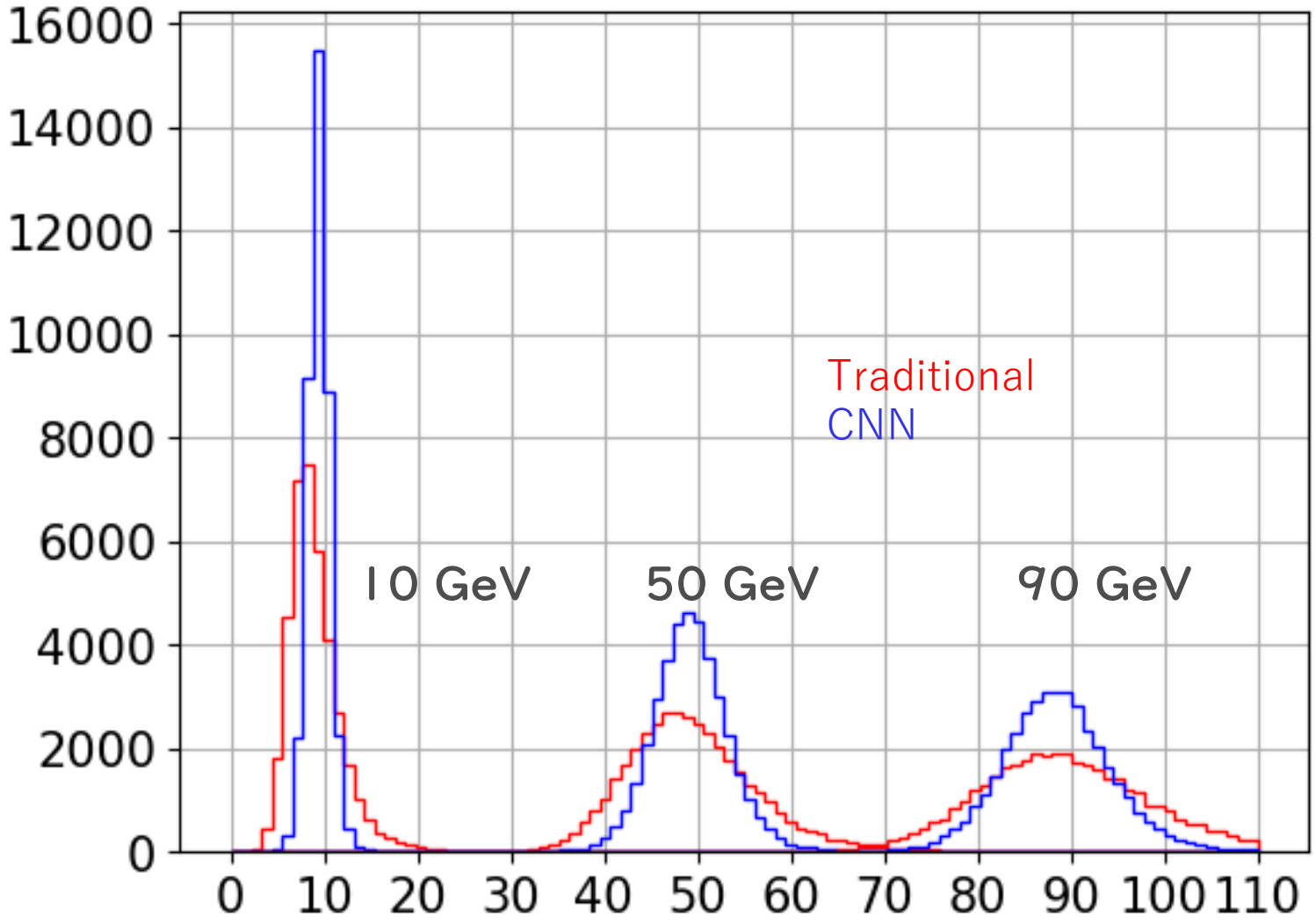




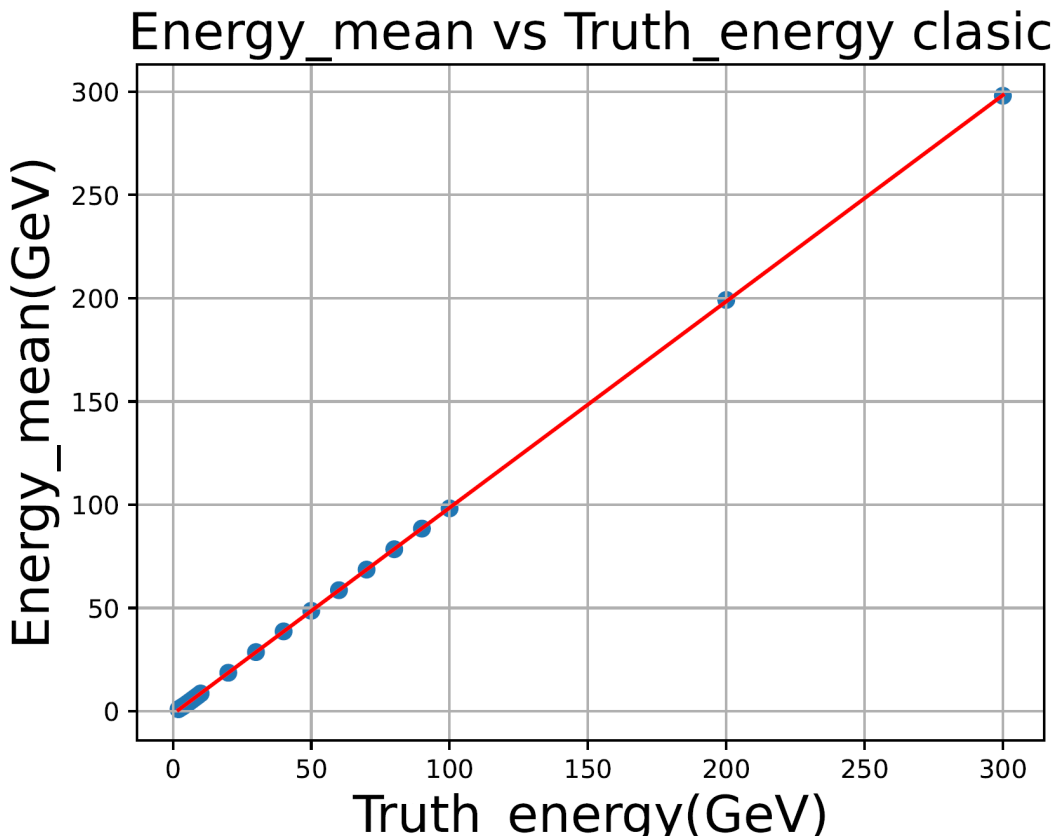
Reconstructed energy (CNN)

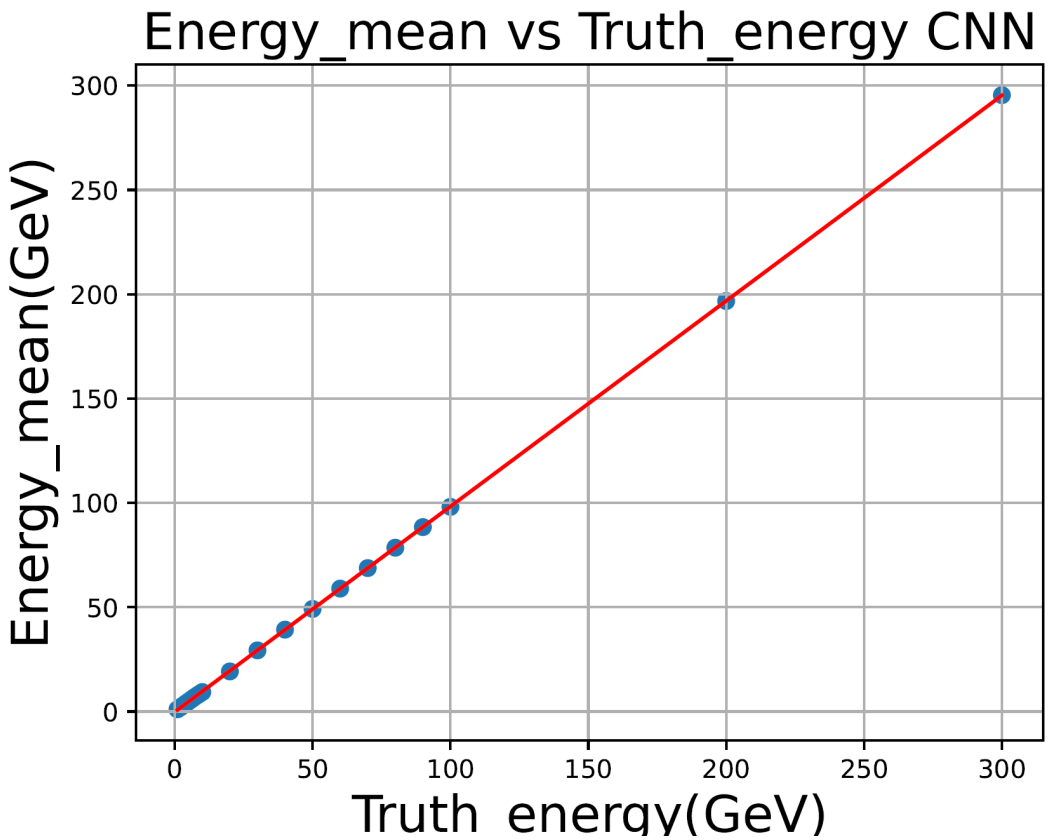





16000
14000
12000
10000
8000
6000
4000
2000
0
0
10
20
30
40
50
60
70
80
90
100
110
Traditional
CNN
10 GeV
50 GeV
90 GeV

Linearity

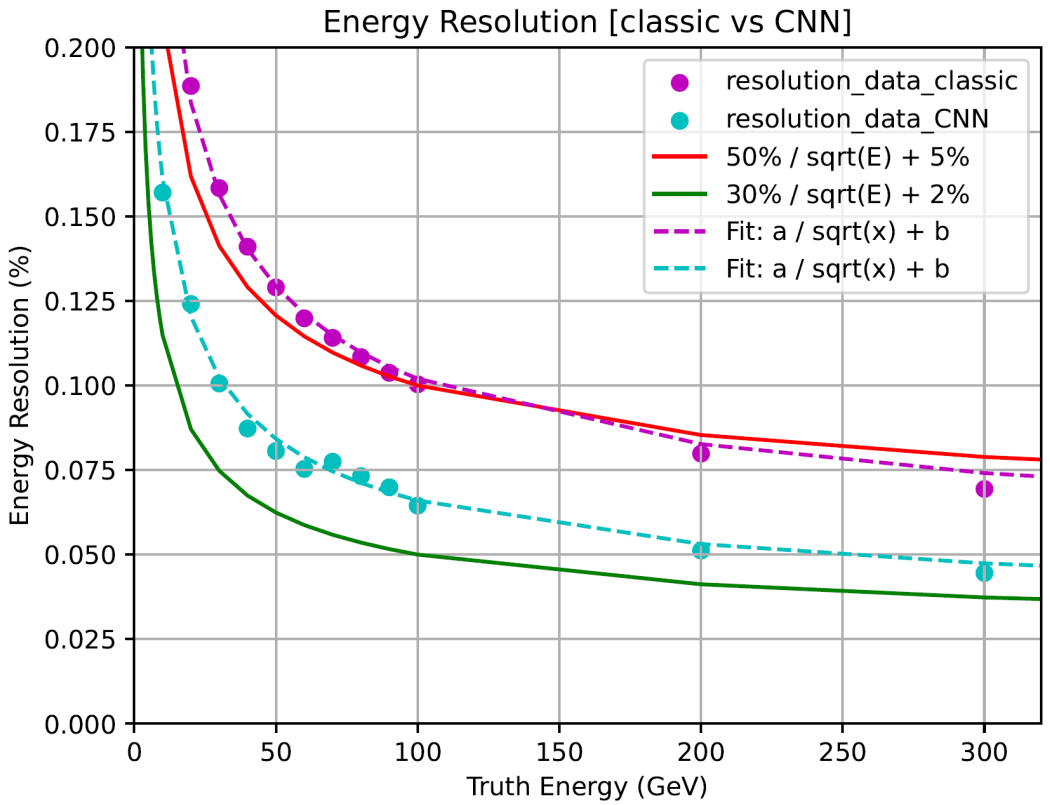




$$y = A\mathrm{E}_{\mathrm{truth}} + B$$

	A	B
Trad. method	0.999 ± 0.001	1.32 ± 0.06
CNN	0.985 ± 0.001	-0.19 ± 0.04

Energy resolution



- CNN shows better reconstruction performance
  - Need to be careful because training sample has discrete energy distribution
    → Uniform sample generation is ongoing

	a	b
Trad. method	0.66 ± 0.01	0.04 ± 0.01
CNN	0.44 ± 0.01	0.02 ± 0.01

Conclusion and Plan

- Compare neutron energy reconstruction performance using traditional and CNN methods
  - CNN seems to have possibility to improve energy reconstruction
    - Need to improve training process

Short term plans

- Check position (or angle) reconstruction performance
- Check photon reconstruction performance
- Generate uniform energy sample

Future prospects in the next year

- Hope to have one master student and at least one bachelor student
- Run this on FPGA (Available; Alveo and Versal)
- Some hardware studies