Using Deep Learning in Event Reconstructions & Detector Designs

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提问 ：

在一个探测器 和 它指定的物理目标 以及 其工程条件之下，

应该需要　什么传感器的：

大小？　数量？　布置 ？

使得： 探测器设计 能够得进一步的优化

之后，如何应用结果在 物理分析 ？

使用 深度学习 (Deep Learning) 在 Daya Bay 探测器 为实例进行探索

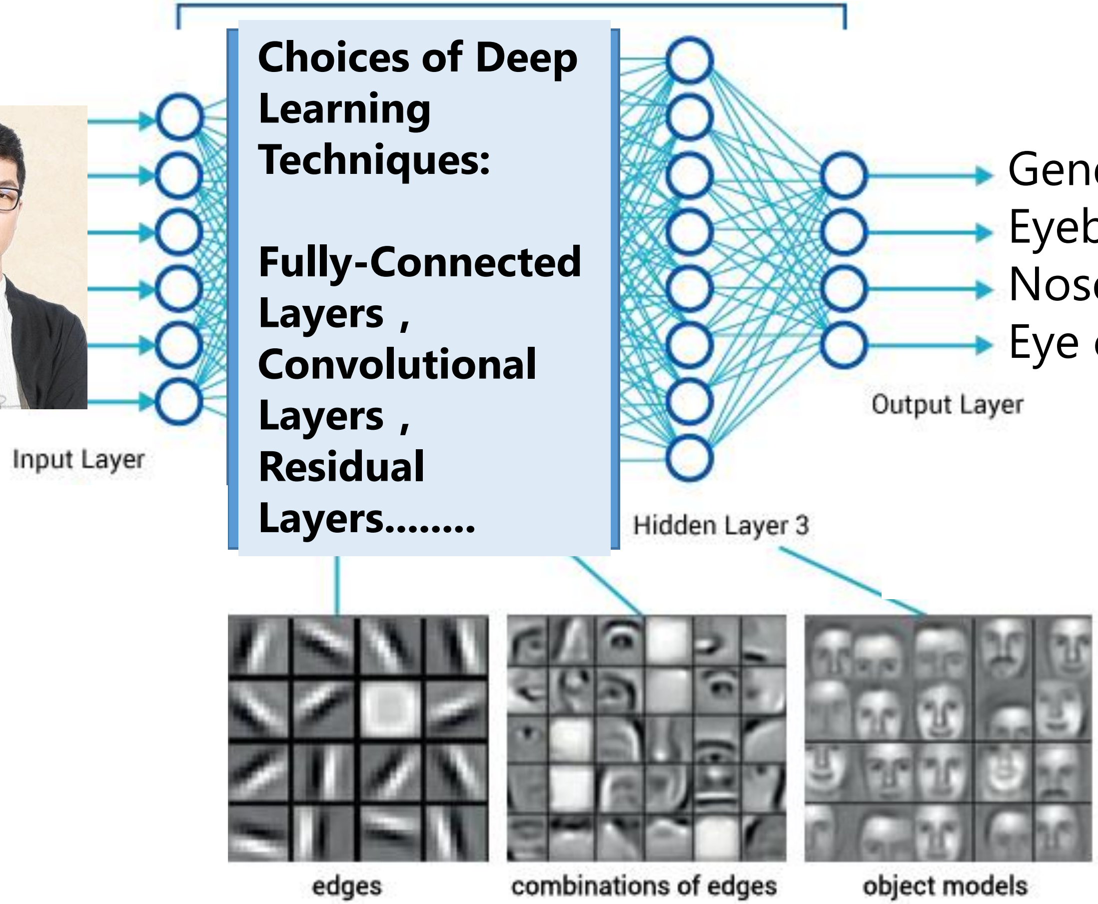
使用的是：

Tensorflow、Keras、TFLearn 等神经网络框架 和 API ＋ 没有 GPU ＋ 陈申见老师的服务器

Deep Learning （深度学习）, What Can It Do ?

Regression and Classification Problems

Deep Neural Network



Choices of Deep Learning Techniques:

Fully-Connected Layers , Convolutional Layers , Residual Layers........

Gender,
Eyebrow length,
Nose shape,
Eye color

Optimal placement / move of stones to win a 围棋 game

19 X 19 boardgame

Deep Neural Network 的 优势 在哪里？

1. **Fast**

   (example: AlphaGo)

2. **Low amount of input data**

   (Resource optimization)

3. **Cheap learning**

   (No function f (input data) = output needed)

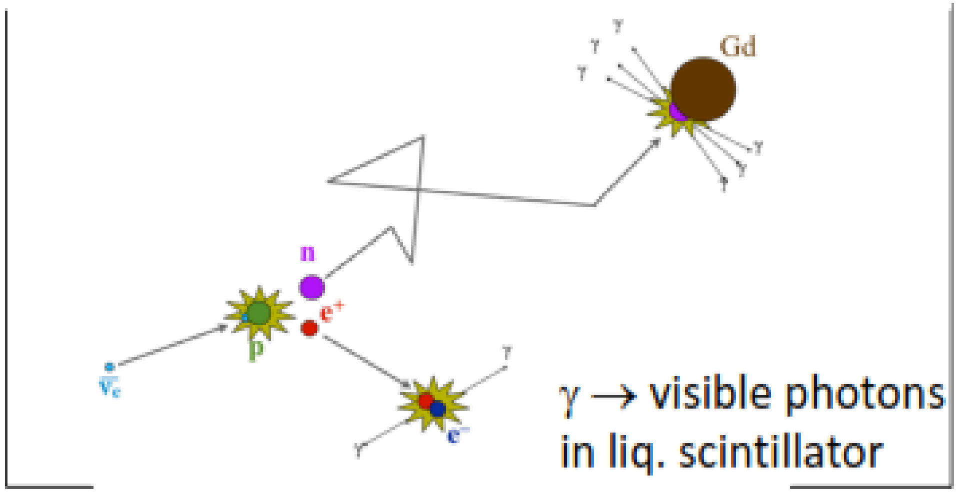
4. **Universal function approximation theorem**

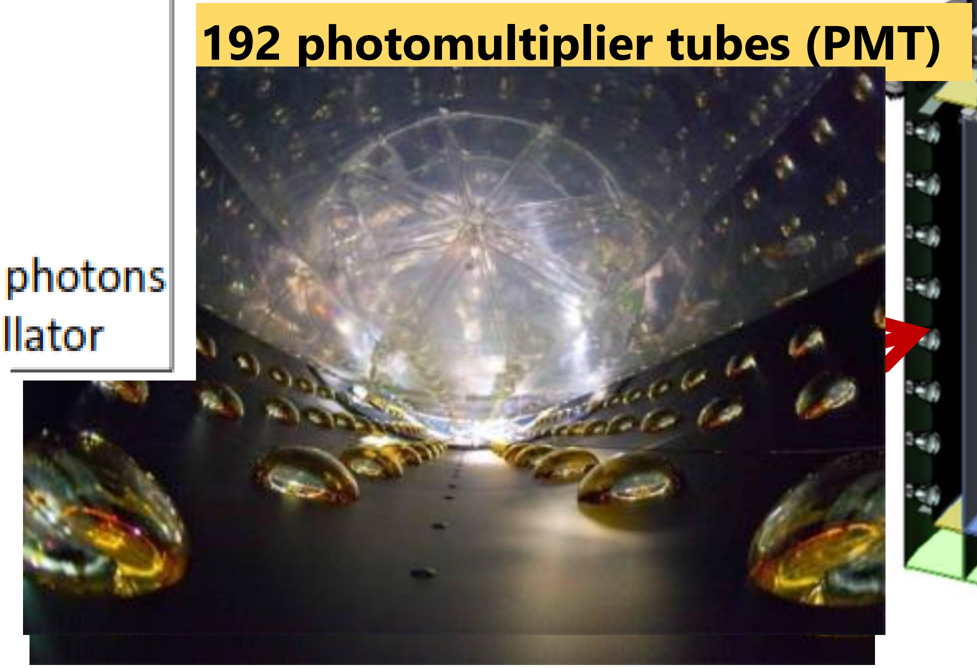
   (Any unknown, complex function, least square fittings，non-linear fittings)

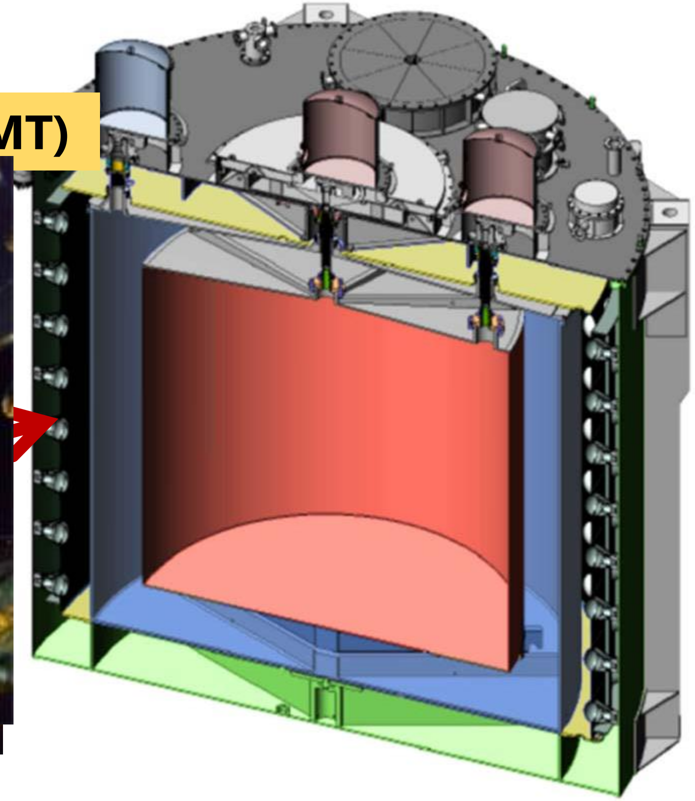
Any connections with physics detectors ?

Daya Bay Antineutrino Detector

$\bar{\nu}_e$ detected via inverse beta-decay (IBD):

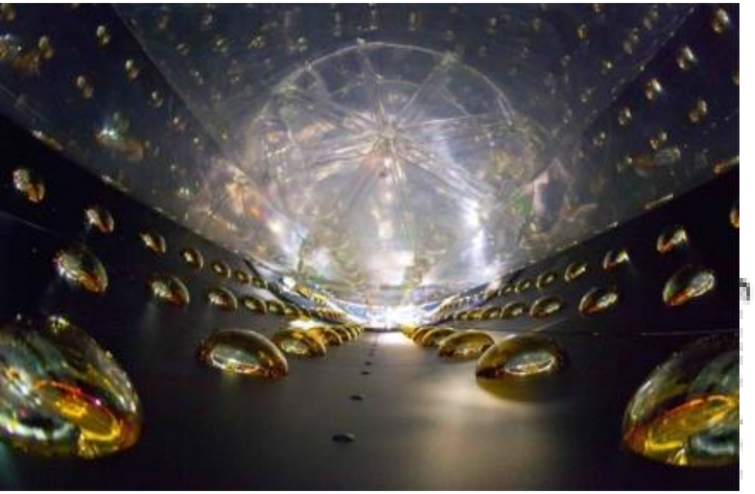


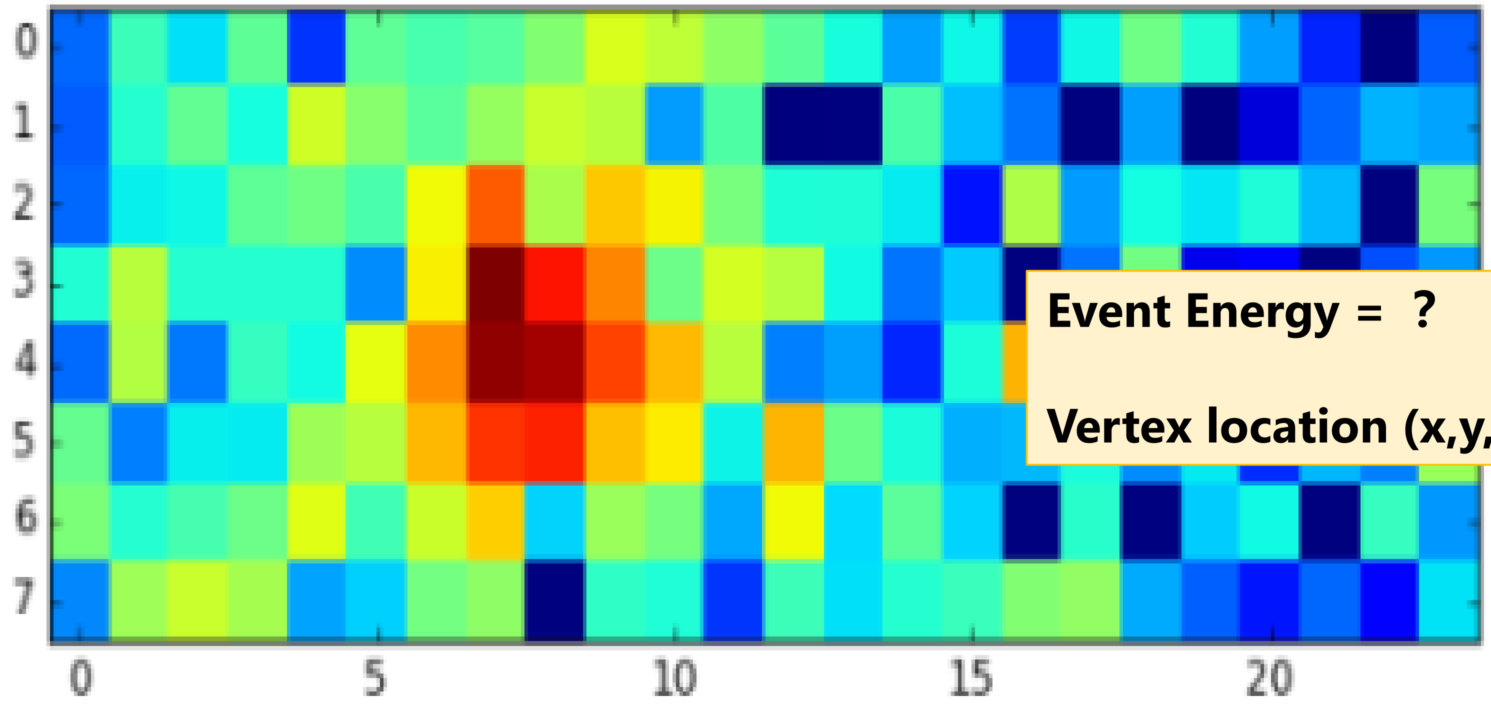




Daya Bay sensors are PMT to detect light from antineutrino interactions

8 X 24 PMT Charge Information of One Antineutrino Event



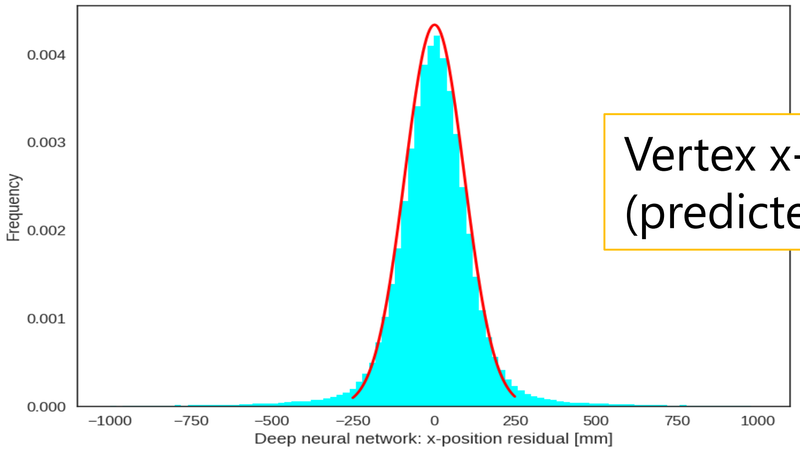


Event Energy = ?

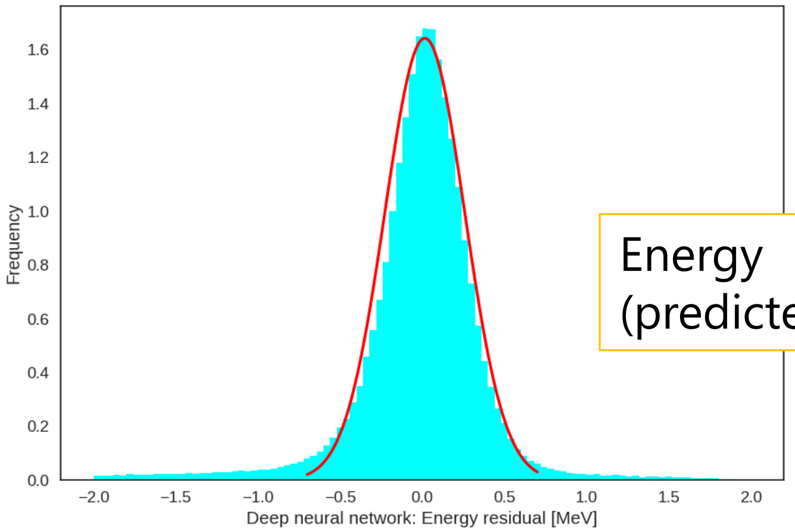
Vertex location (x,y,z) = ?

Input to Deep Neural Network as 8 x 24 pixel image for training to predict event energy and vertex location (x,y,z)

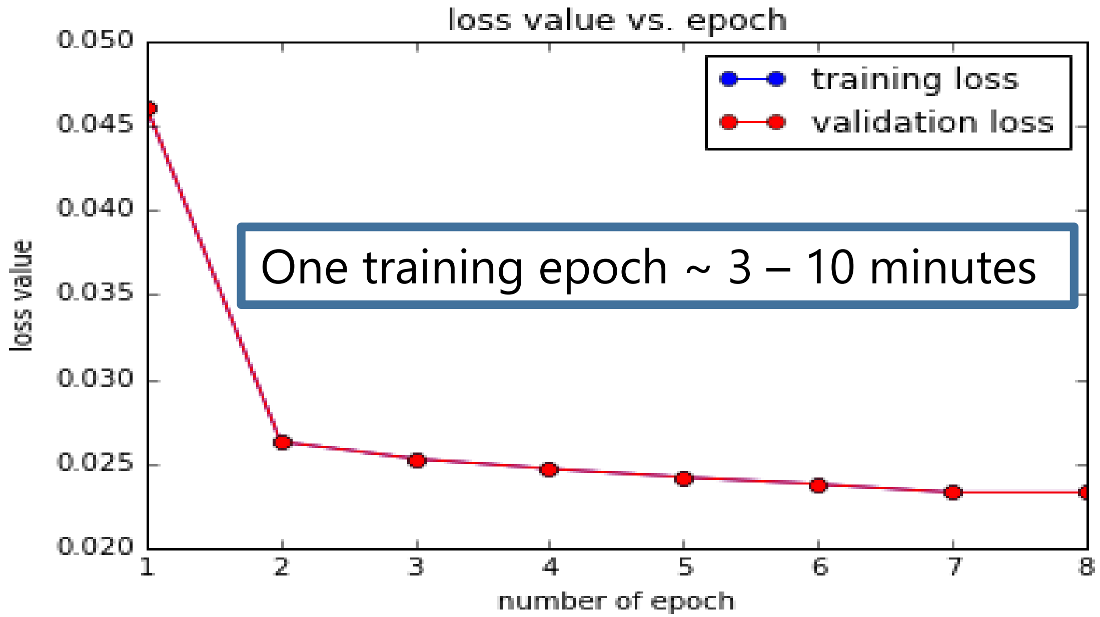
Event Reconstruction with Deep Neural Network



Vertex x-position
(predicted – truth)



Energy
(predicted – truth)

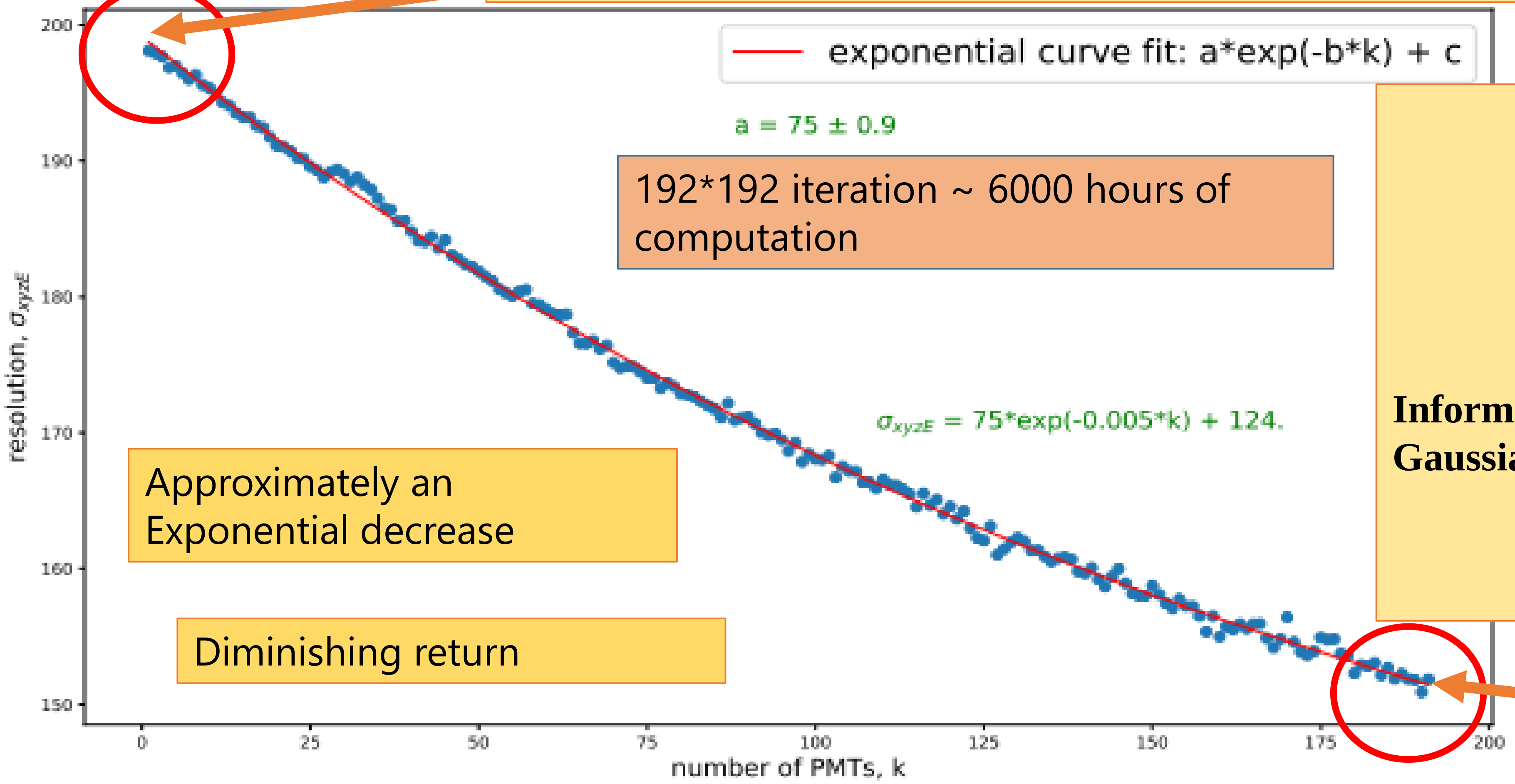


One training epoch ~ 3 – 10 minutes

Resolution σ = Sigma from Gaussian fit

Resolution σ(x,y,z,E) vs. number of PMTs (greedy algorithm)

YOUR MOST IMPORTANT SENSORS FOR PHYSICS and TRIGGER ANALYSIS



192*192 iteration ~ 6000 hours of computation

Approximately an Exponential decrease

Diminishing return

$$\frac{\mathrm{d}\sigma}{\mathrm{dk}} \sim -b\sigma$$

$$\Rightarrow$$

$$\frac{\mathrm{d}\ln\sigma}{\mathrm{dk}} \sim -b$$

Information entropy H for Gaussian = ln σ

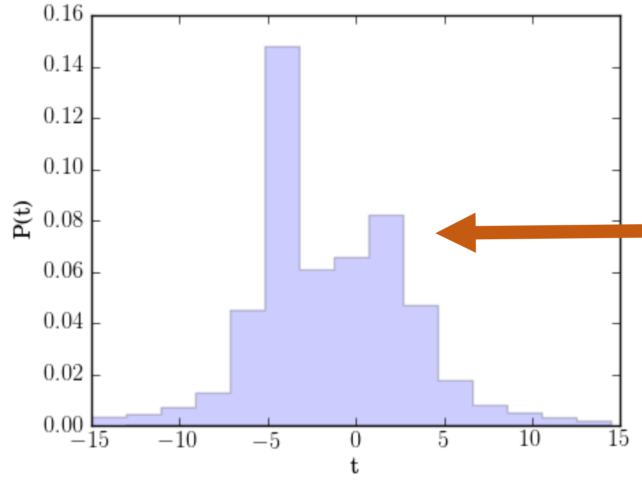
$$\frac{\mathrm{dH}}{\mathrm{dk}} \approx \text{constant}$$

NON-SATURATION

Coverage of one PMT multiplied by k

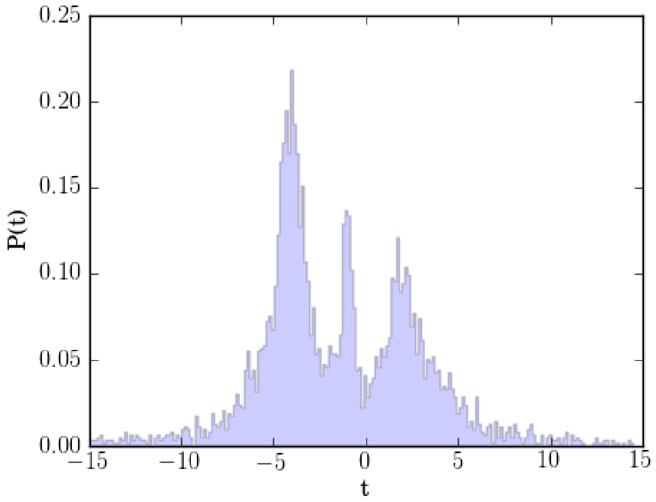
Decay constant is PMT size-dependent

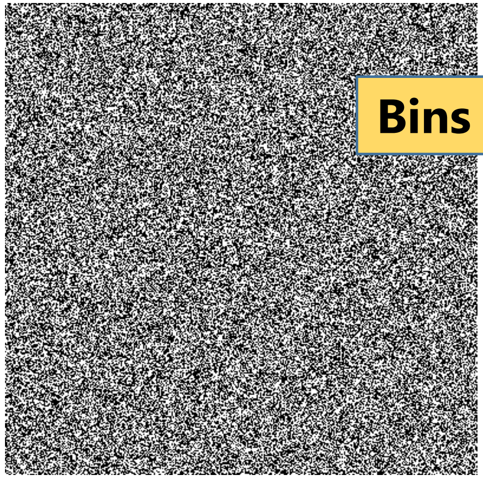
What sensor size(s) is the best ?



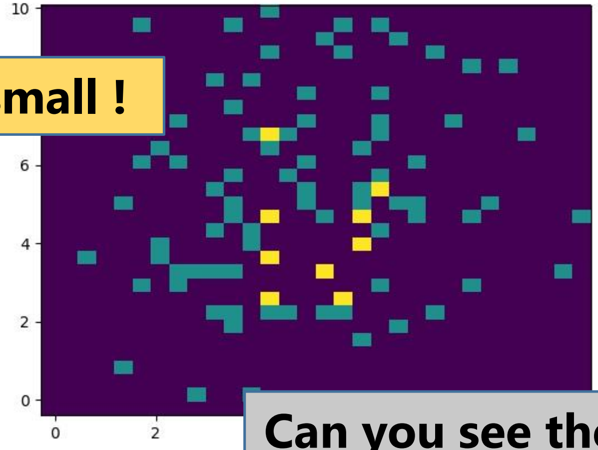
Bins too large !

Too sparse !





Bins too small !



Can you see the Gaussian ?

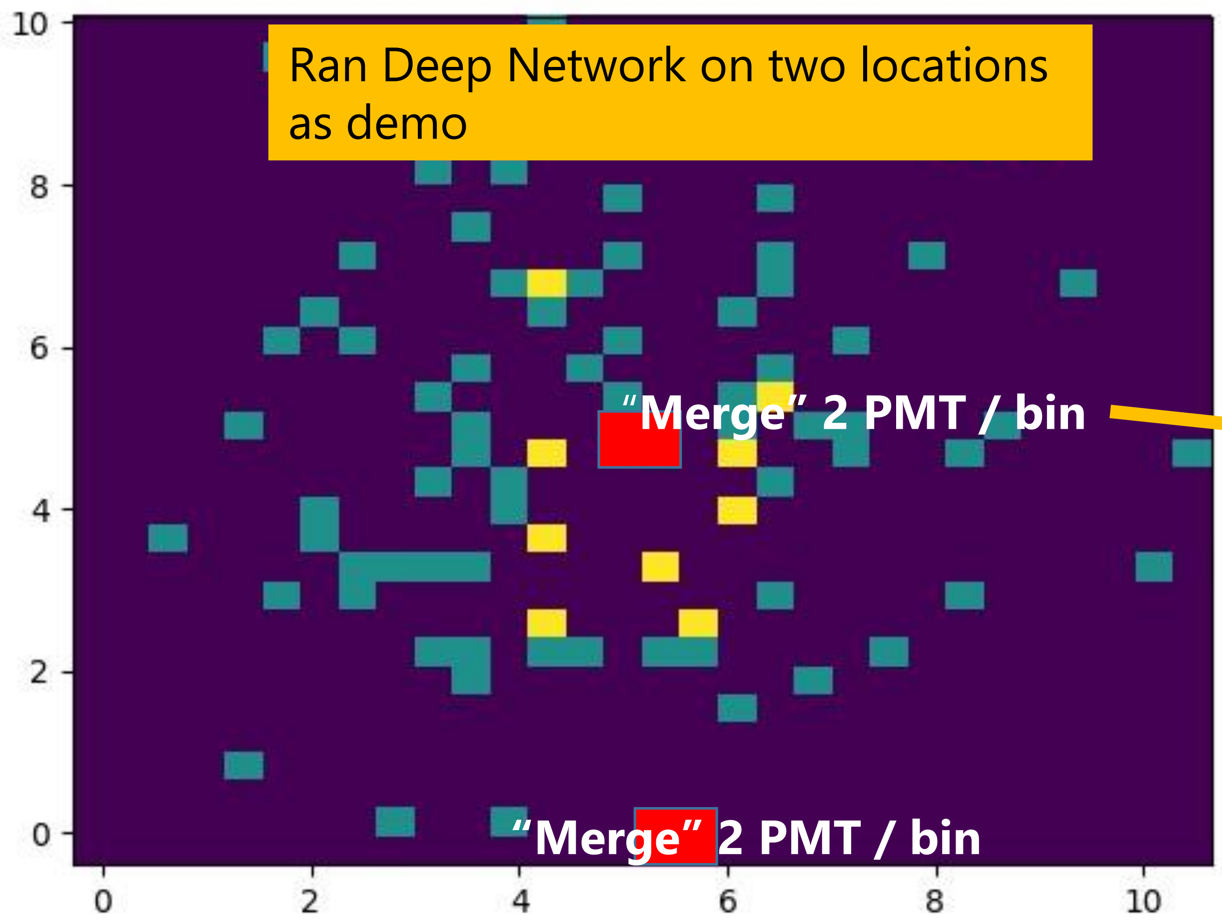
Use Deep Learning to Find Best Sensor Size at Each Location

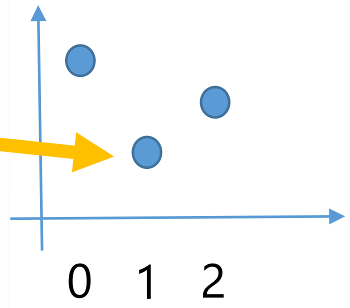
Developed an

Autoencoder + Multi-

Fully-Connected Layer

Deep Neural Network





Summary

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通过深度学习：

1. Resolution (x,y,z,E) vs. number of PMTs (or coverage) is approximately an **exponentially decreasing function**;

2. The Daya Bay detector is in a **non-saturation mode**;

3. Sensors can be ranked for **physics and trigger analysis**;

4. Deep learning can be used to search for optimal PMT size at each detector location. **A mixture of PMT/sensor sizes is possible**.

NJU already have one Master student（钱志强）who have graduated (this year) with thesis on event reconstruction and detector design with deep learning techniques.

Detector Designing Softwares can be SMARTER and FASTER with the help of Deep Machines

Constraints

1. Computation power and speed (Nvidia CUDA，RAM。。。)
2. Collaboration and co-operation with other groups, institutions
3. Training of new people

THANK YOU

BACKUP