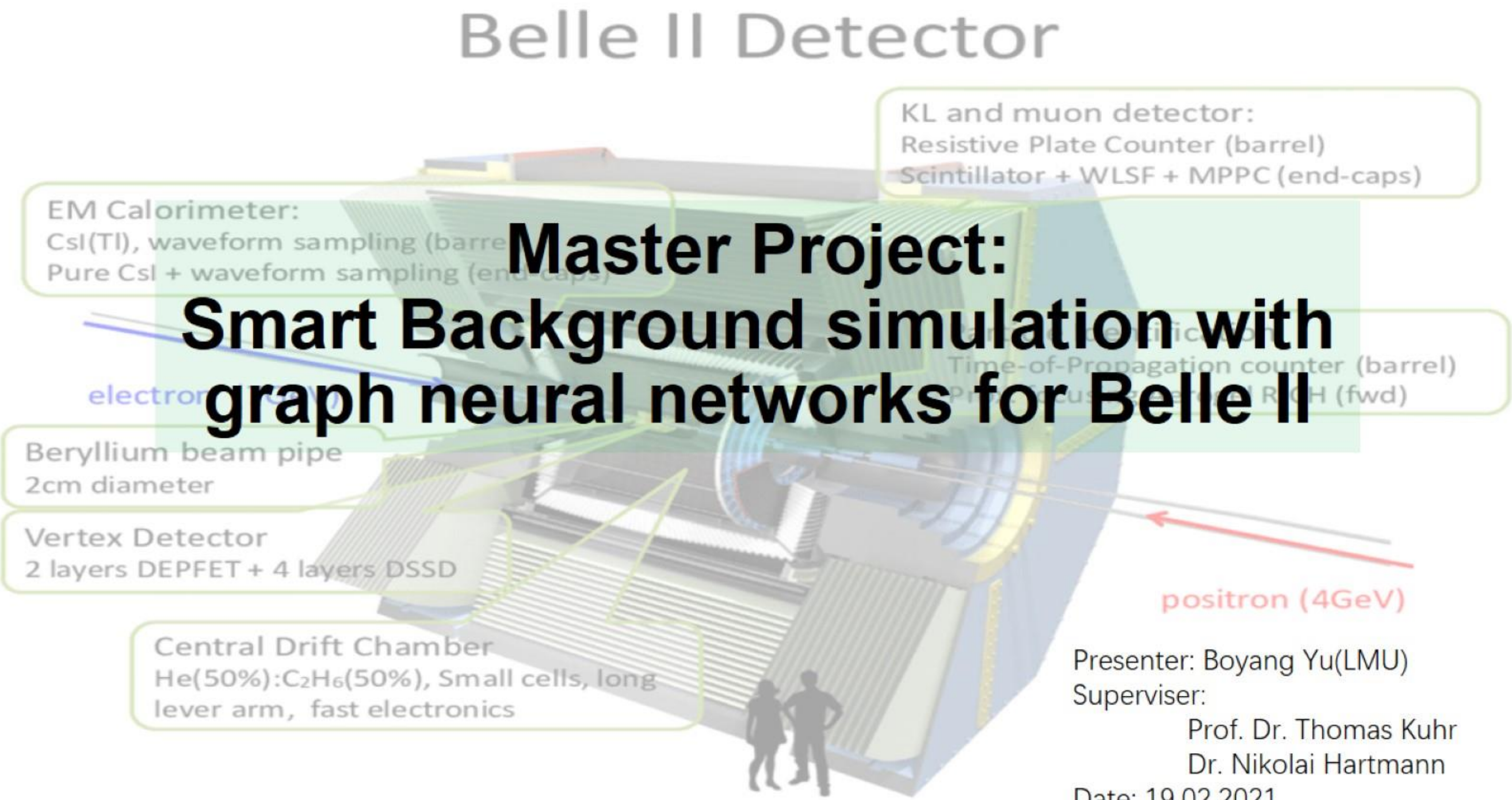
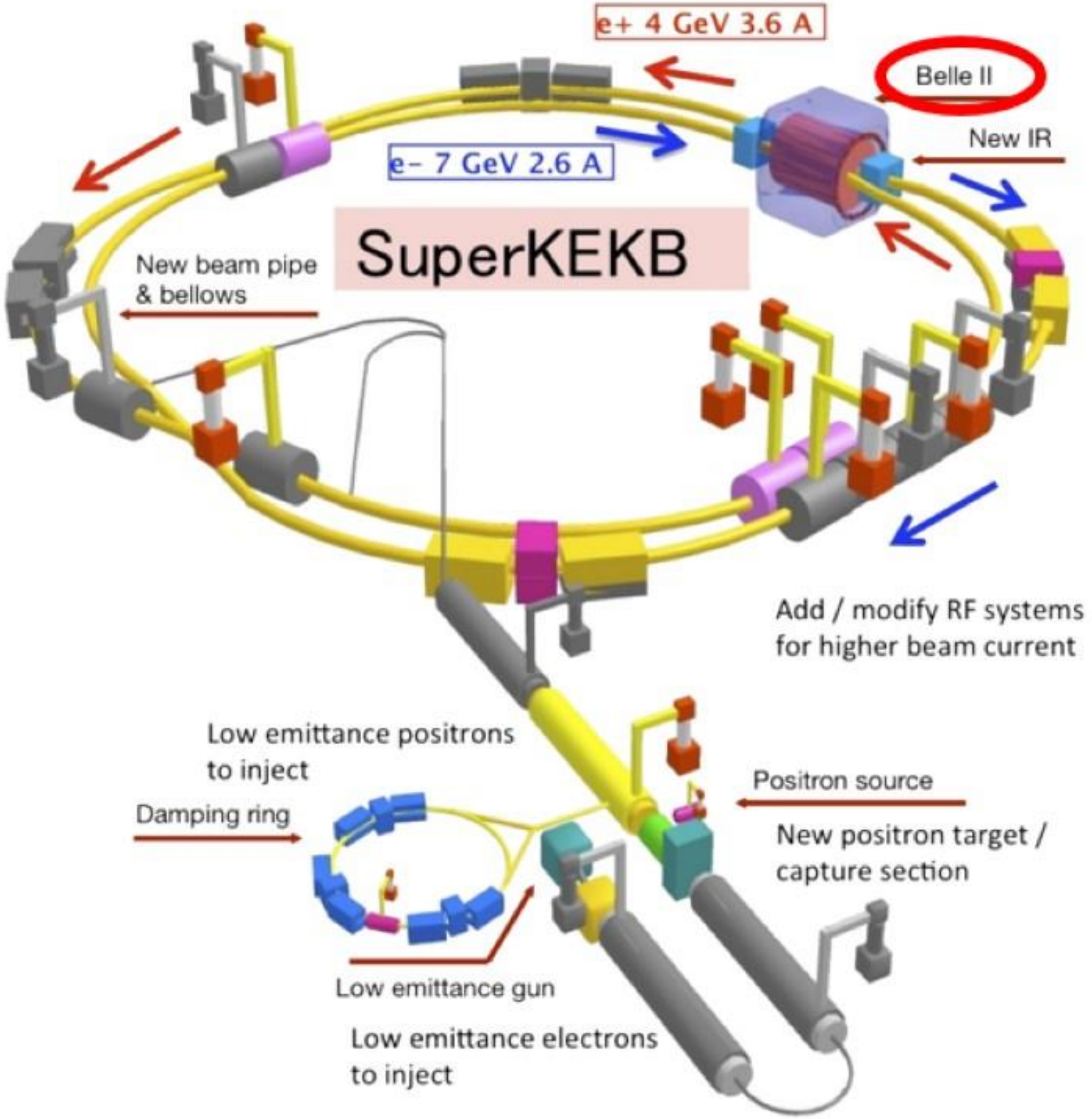


Master Project:
Smart Background simulation with graph neural networks for Belle II

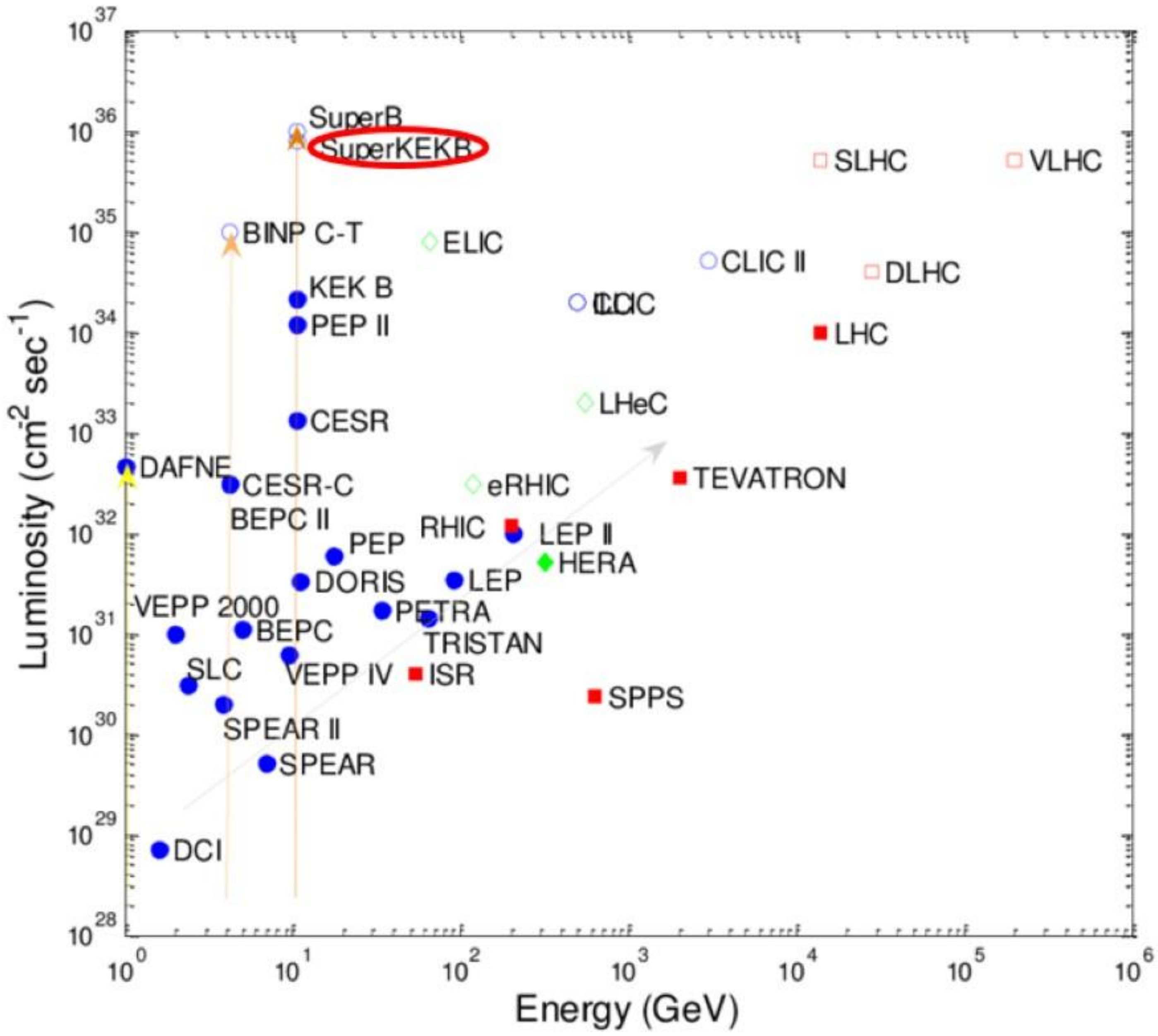
Presenter: Boyang Yu(LMU)
Superviser:
Prof. Dr. Thomas Kuhr
Dr. Nikolai Hartmann
Date: 19.02.2021

Belle II Experiment

The Belle II experiment is designed to study the properties of B mesons and is currently being commissioned at the SuperKEKB accelerator at KEK in Tsukuba, Ibaraki Prefecture, Japan. The Belle II detector was moved into the collision point of SuperKEKB in April 2017 and started taking data in early 2018.

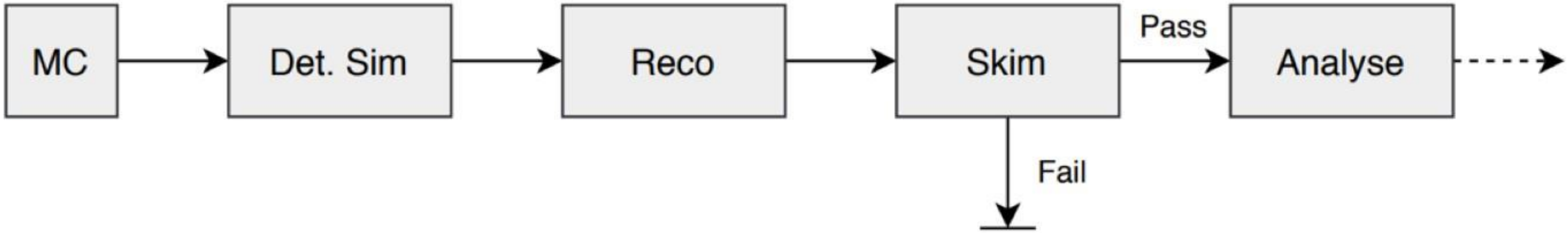


Very High Luminosity
means
Tremendous Dataset

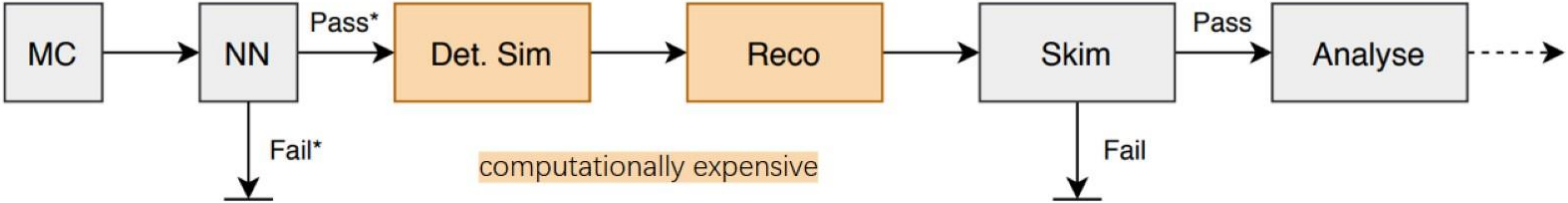


Biscari, Caterina. (0002). Accelerators R&D. Proceedings of Science.

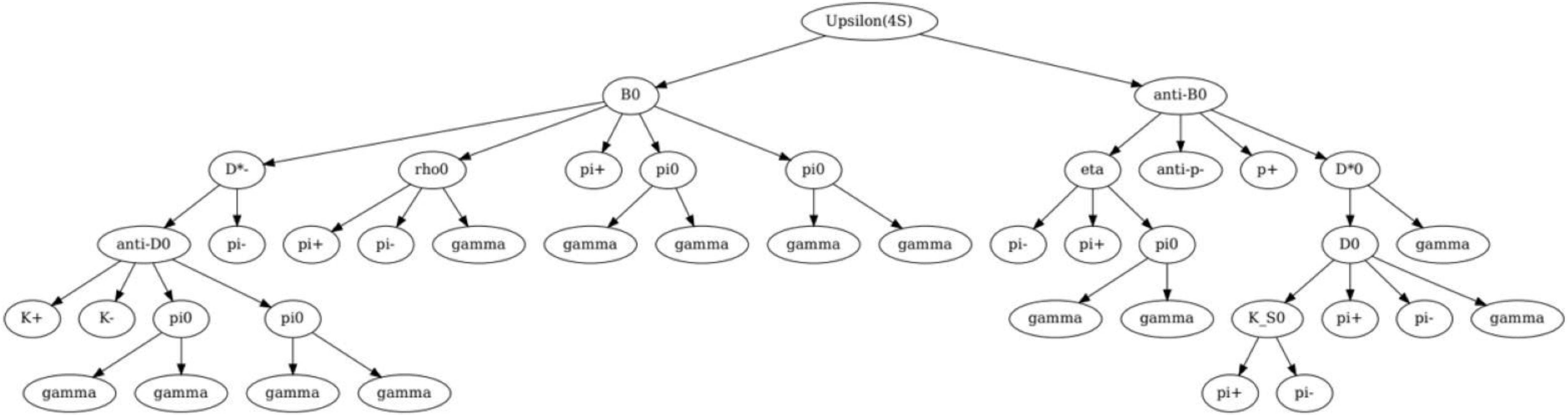
Current Monte Carlo Simulation data flow



Simulation with smart background selection



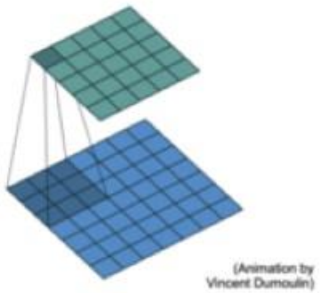
Tree Structures of Particle Decay inspire the use of Graph Neural Network

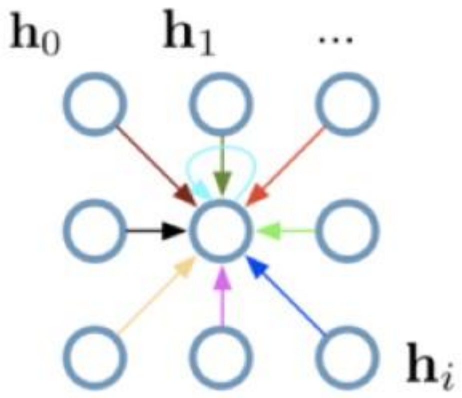


Using Deep Graph Library (DGL)

CNN vs GCN

Single CNN layer with 3x3 filter:





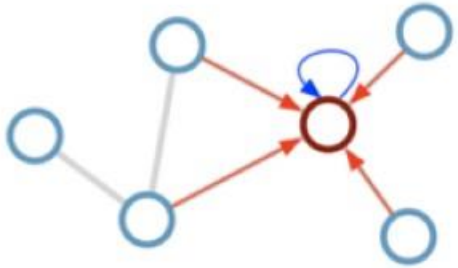
Full update:

$$\mathbf{h}_4^{(l+1)} = \sigma\left(\mathbf{W}_0^{(l)}\mathbf{h}_0^{(l)} + \mathbf{W}_1^{(l)}\mathbf{h}_1^{(l)} + \cdots + \mathbf{W}_8^{(l)}\mathbf{h}_8^{(l)}\right)$$

Convolutional Neural Network (CNN)

Consider this undirected graph:

Calculate update for node in red:

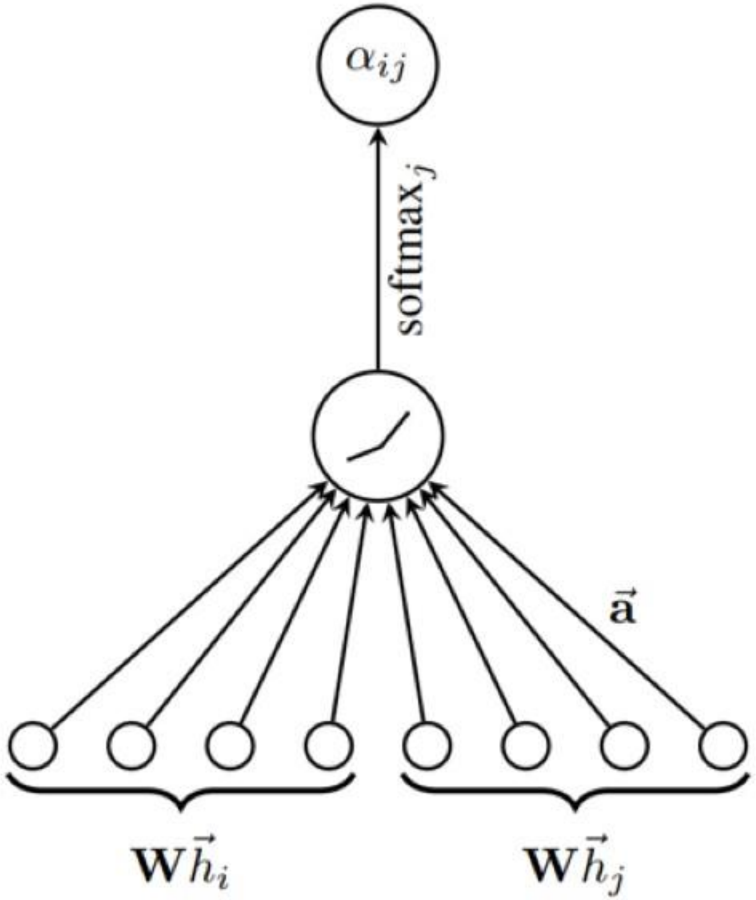


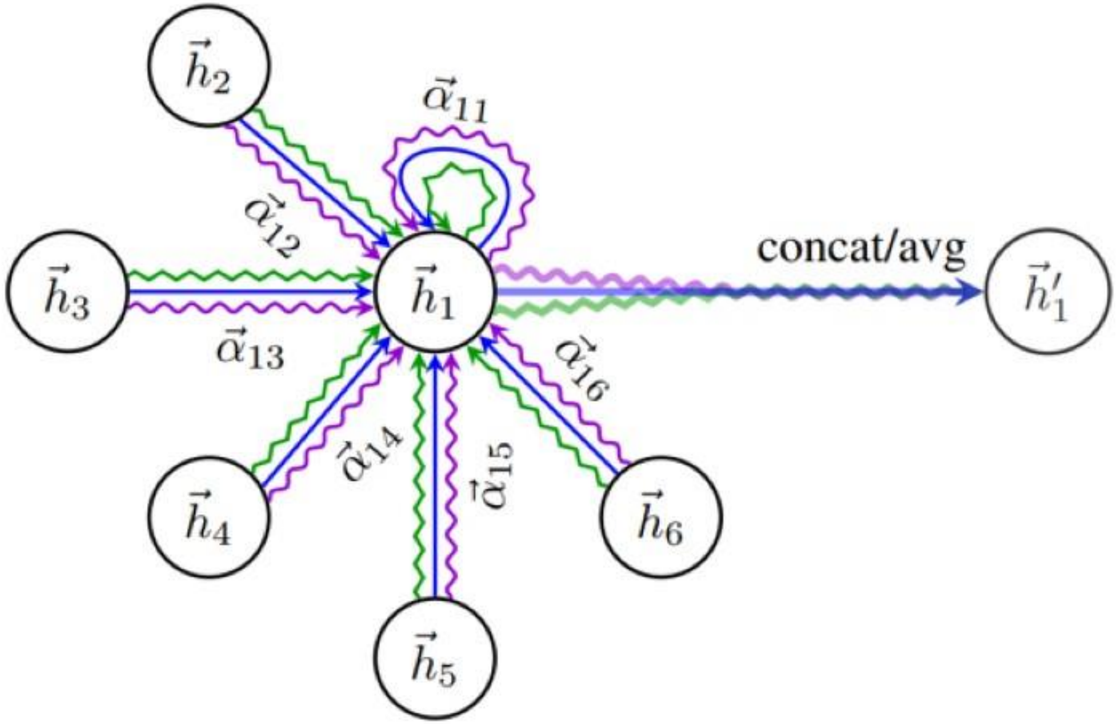
Update rule:

$$\mathbf{h}_i^{(l+1)} = \sigma\left(\mathbf{h}_i^{(l)}\mathbf{W}_0^{(l)} + \sum_{j\in\mathcal{N}_i}\frac{1}{c_{ij}}\mathbf{h}_j^{(l)}\mathbf{W}_j^{(l)}\right)$$

Graph Convolutional Network (GCN)

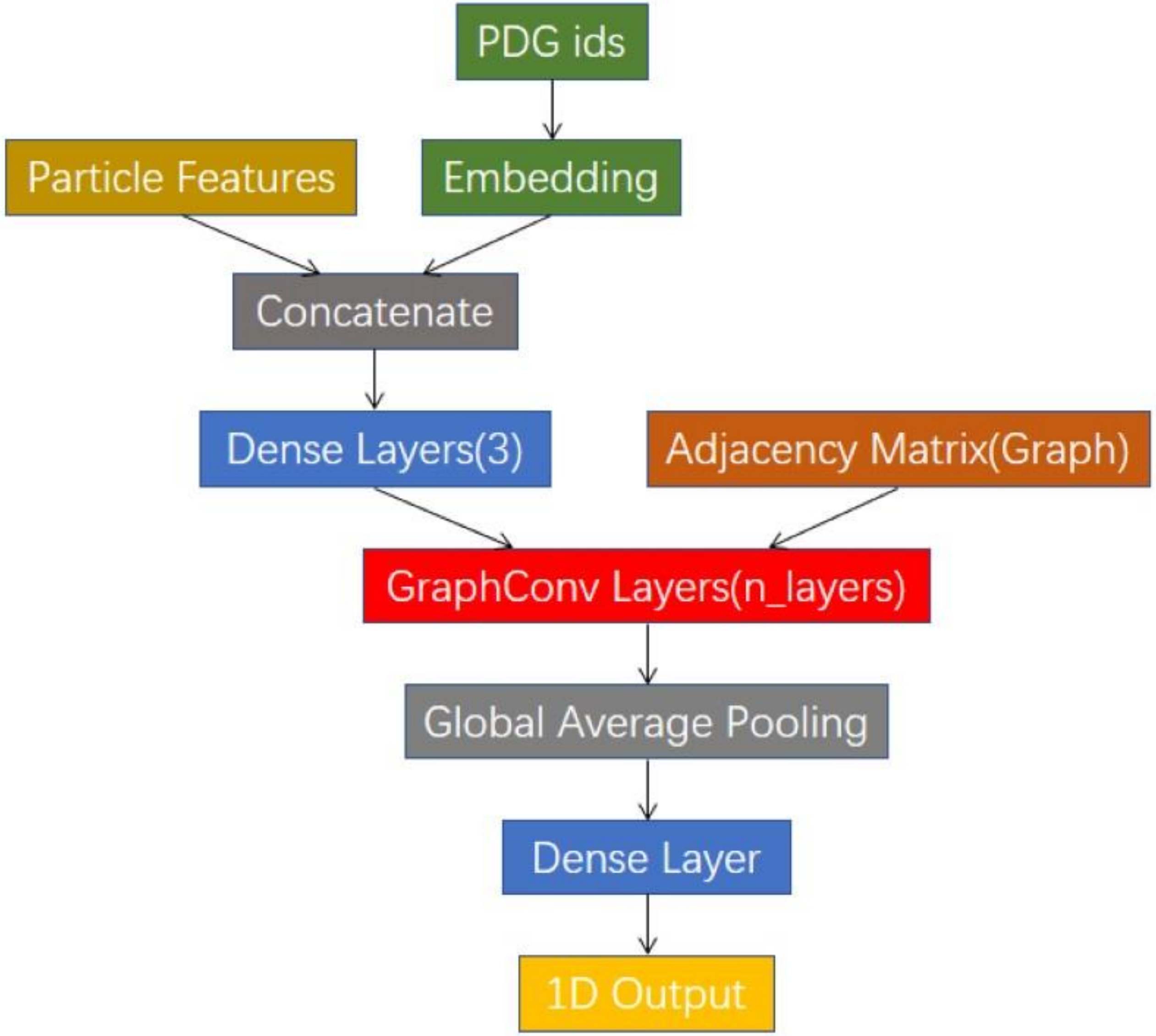
Graph Attention Networks



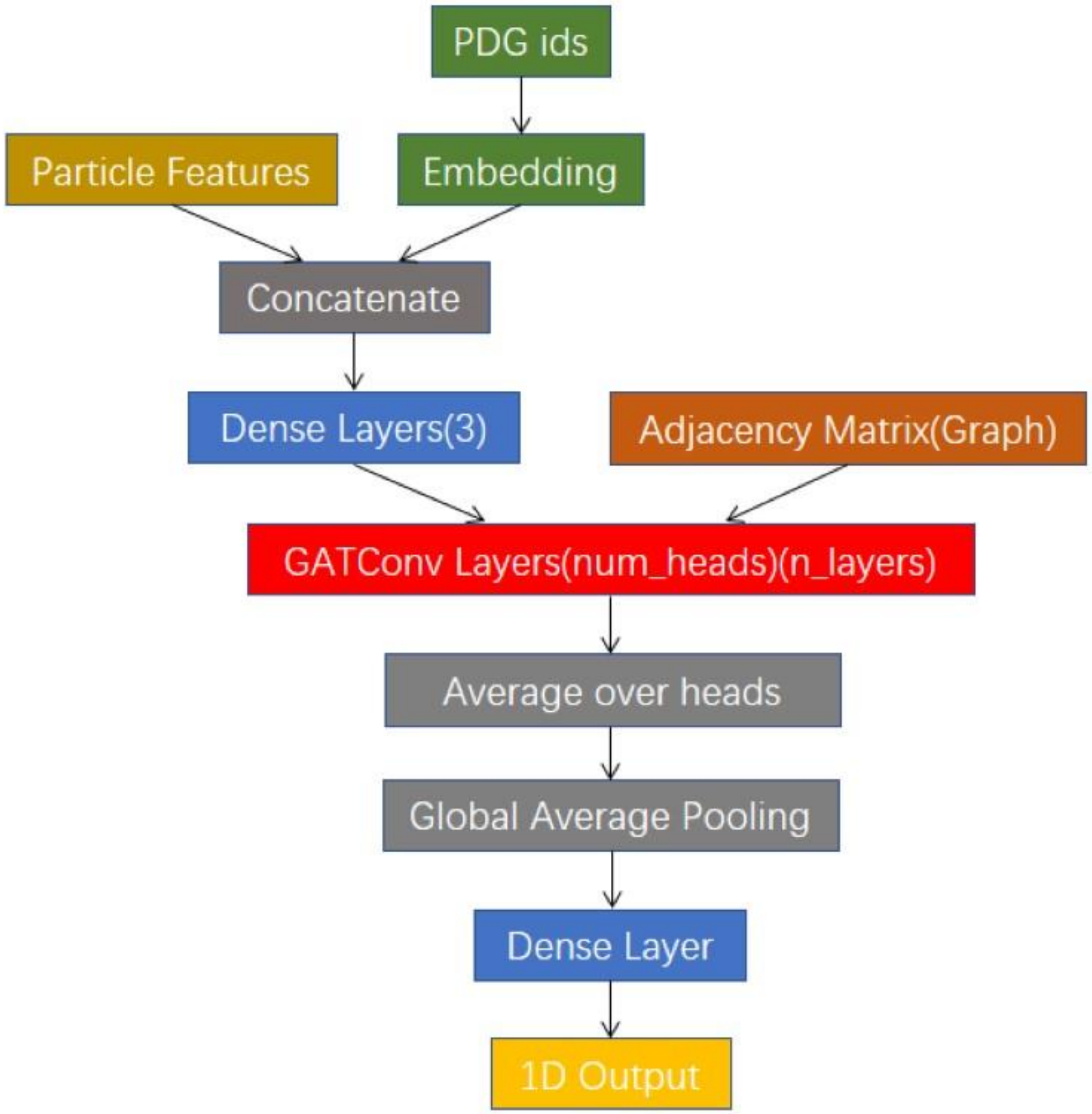


$$\alpha_{ij} = \frac{\exp\left(\text{LeakyReLU}\left(\vec{\mathbf{a}}^T[\mathbf{W}\vec{h}_i \| \mathbf{W}\vec{h}_j]\right)\right)}{\sum_{k \in \mathcal{N}_i} \exp\left(\text{LeakyReLU}\left(\vec{\mathbf{a}}^T[\mathbf{W}\vec{h}_i \| \mathbf{W}\vec{h}_k]\right)\right)}$$

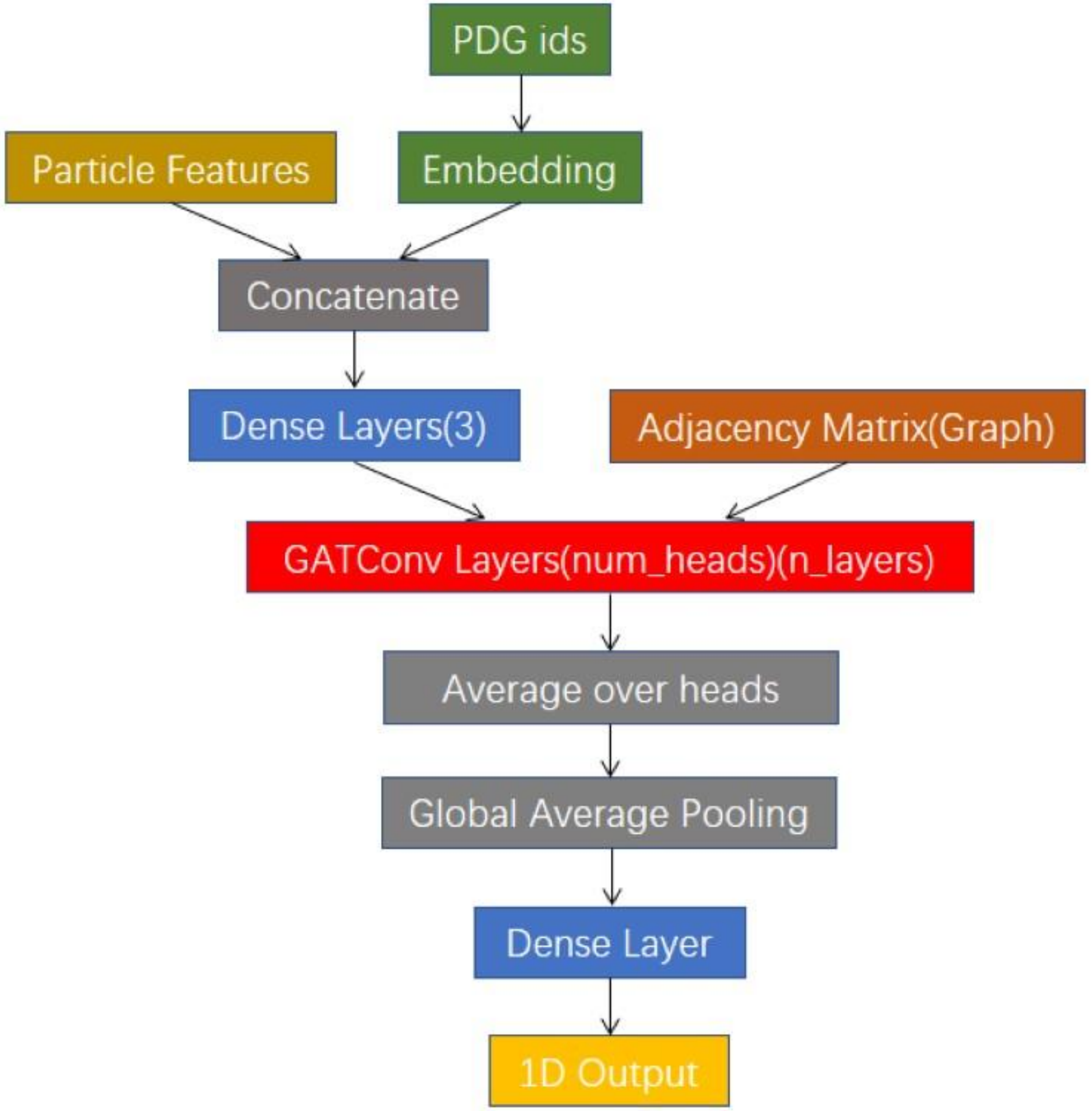
$$\vec{h}'_i = \Big\Vert_{k=1}^{K} \sigma\left(\sum_{j \in \mathcal{N}_i} \alpha_{ij}^k \mathbf{W}^k \vec{h}_j\right)$$



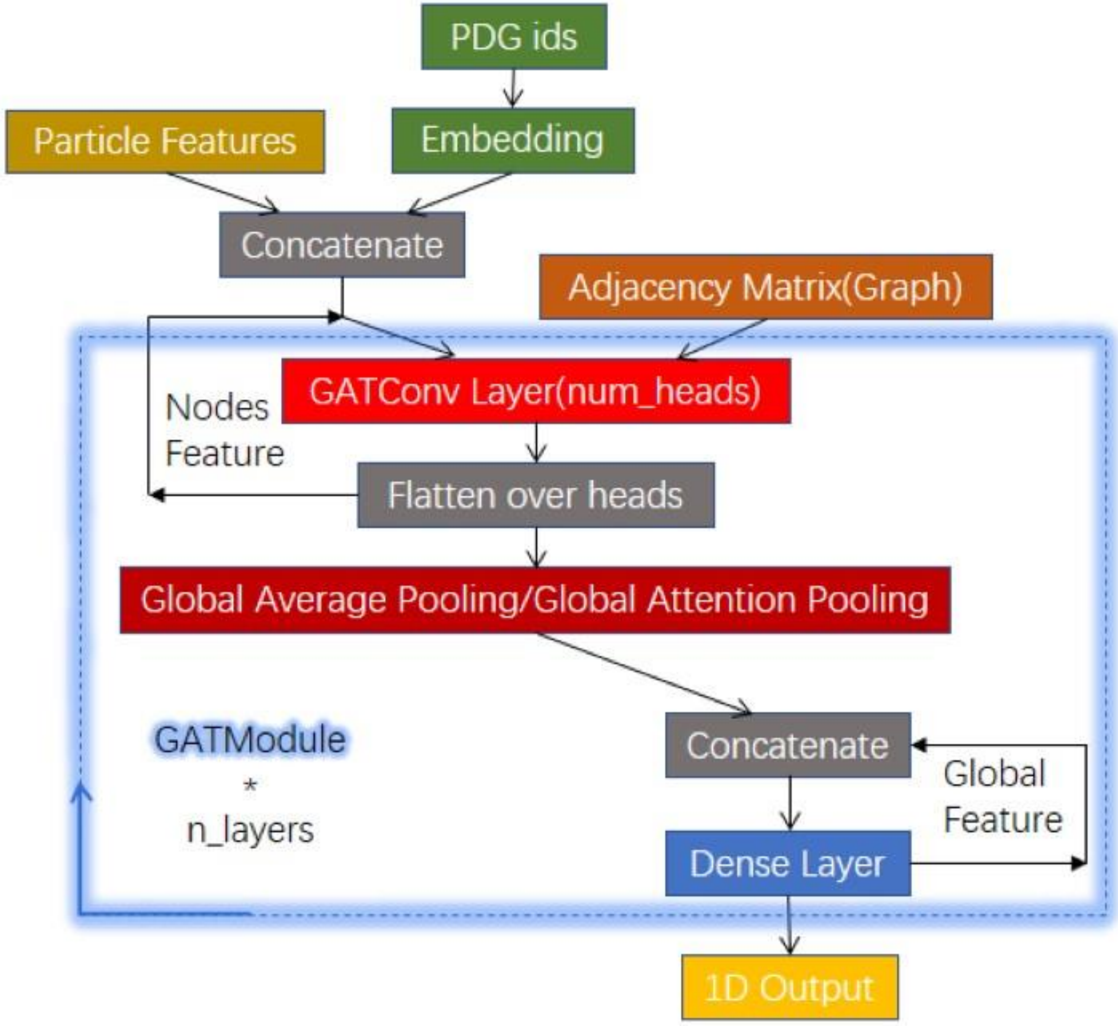
GCNModel



GATModel

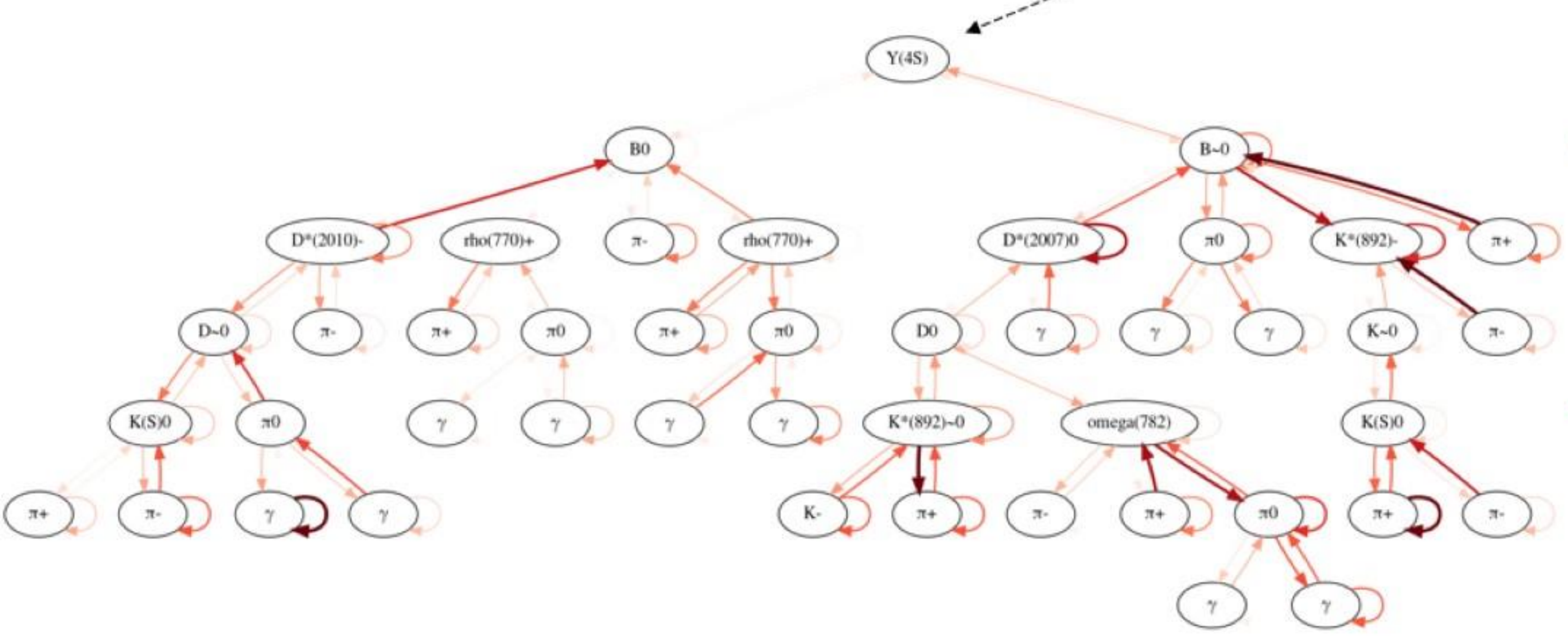


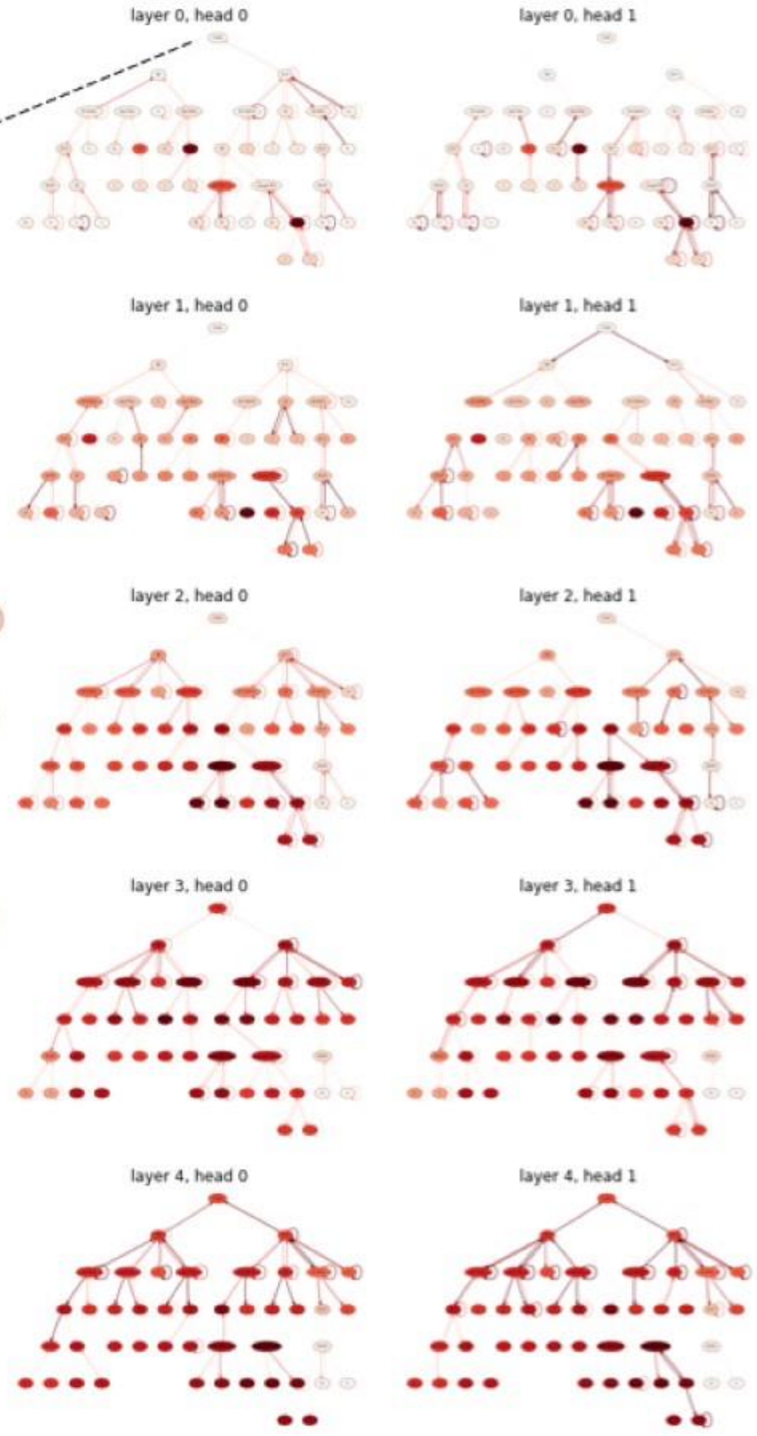
GATModel



SimpleGATModel
w/o
GlobalAttentionPooling

Visualization of Node/Edge-Attentions for SimpleGATModel with GlobalAttentionPooling





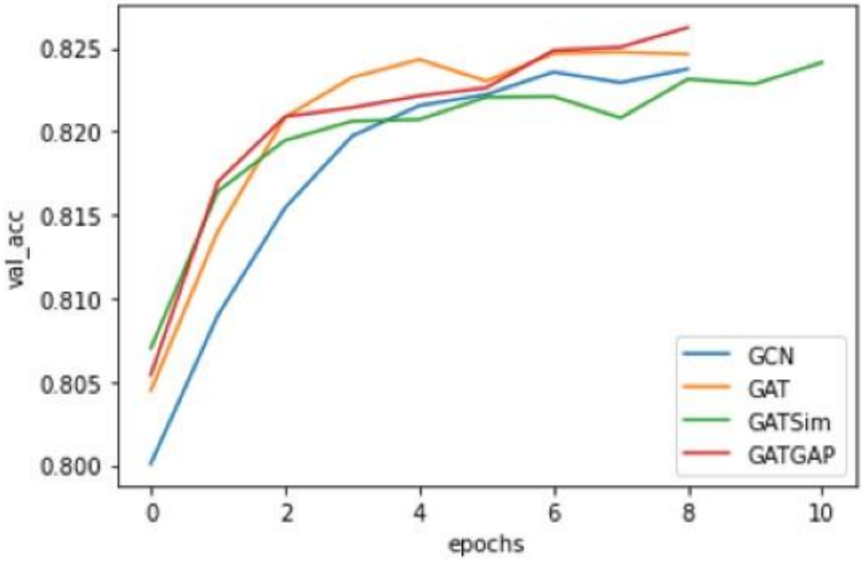
Comparison

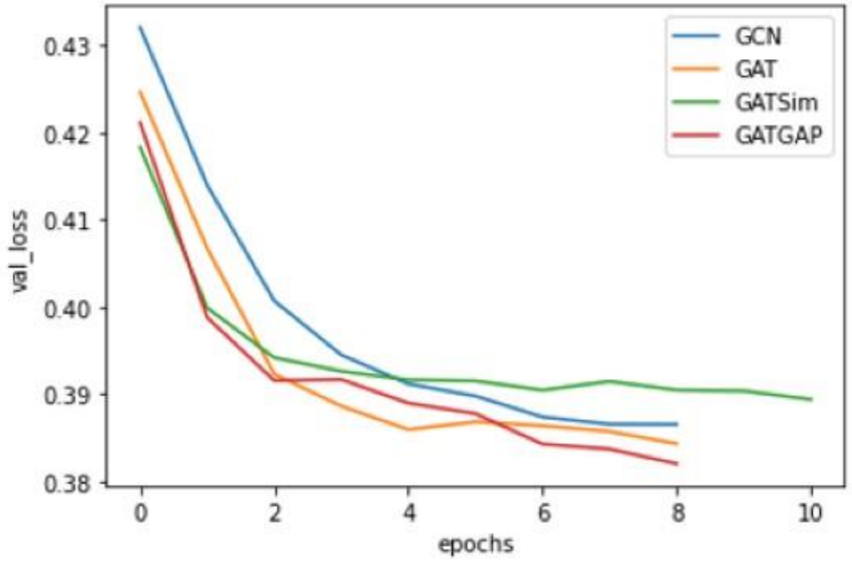
Parameters:

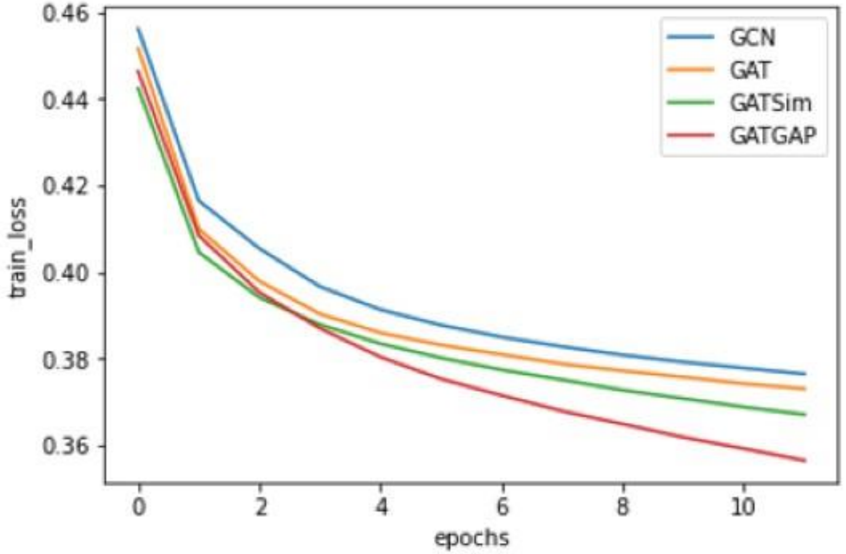
- n_heads = 2
- n_layers = 5
- n_units = 128
- batch_size = 128
- n_train = 0.9M
- n_val = 0.1M
- n_test = 0.5M

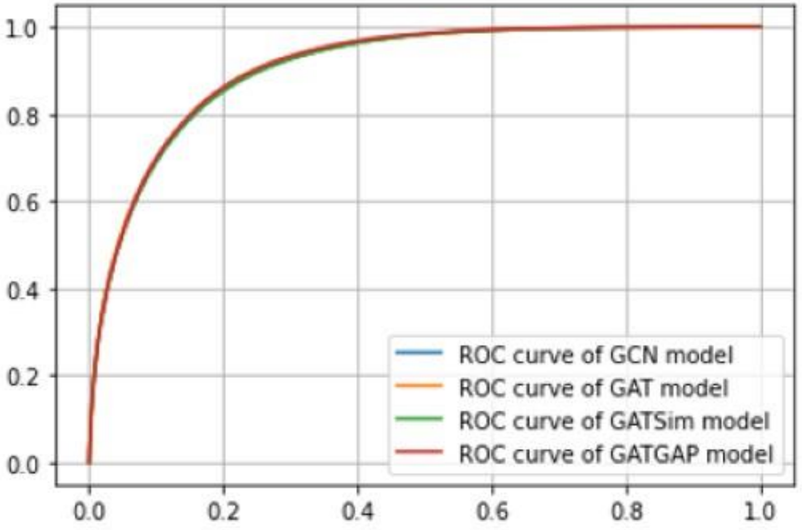
EarlyStopping:

- patience = 3
- delta = 1e-5









	GCN	GAT	GATSim	GATGAP
TrainingTime	2600.13s	3322.27s	3678.66s	4490.48s
AUCValues	0.90679	0.90846	0.90683	0.91010

Next steps:

- More tuning
- Speed up rate
- Bias mitigation

Thank You for Watching!

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