

Belle II Detector

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

EM Calorimeter:
CsI(Tl), waveform sampling (barrel)
Pure CsI + waveform sampling (end-caps)

KL and muon detector:
Resistive Plate Counter (barrel)
Scintillator + WLSF + MPPC (end-caps)

electron (e^-)

Time-of-Propagation counter (barrel)
Proton Focusing Ring (fwd)

Beryllium beam pipe
2cm diameter

Vertex Detector
2 layers DEPFET + 4 layers DSSD

Central Drift Chamber
He(50%):C₂H₆(50%), Small cells, long
lever arm, fast electronics

positron (4GeV)



Presenter: Boyang Yu(LMU)

Supervisor:

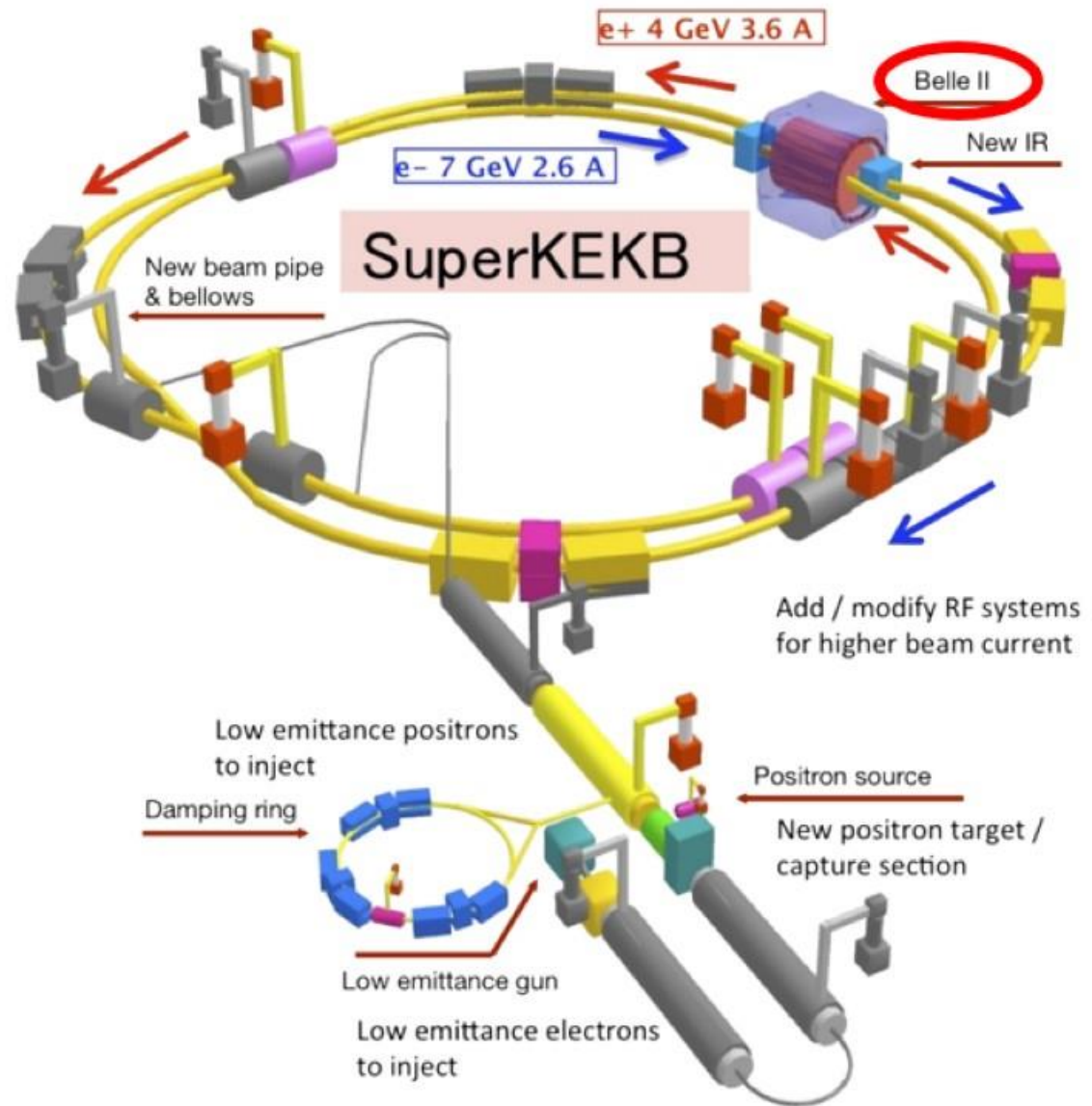
Prof. Dr. Thomas Kuhr

Dr. Nikolai Hartmann

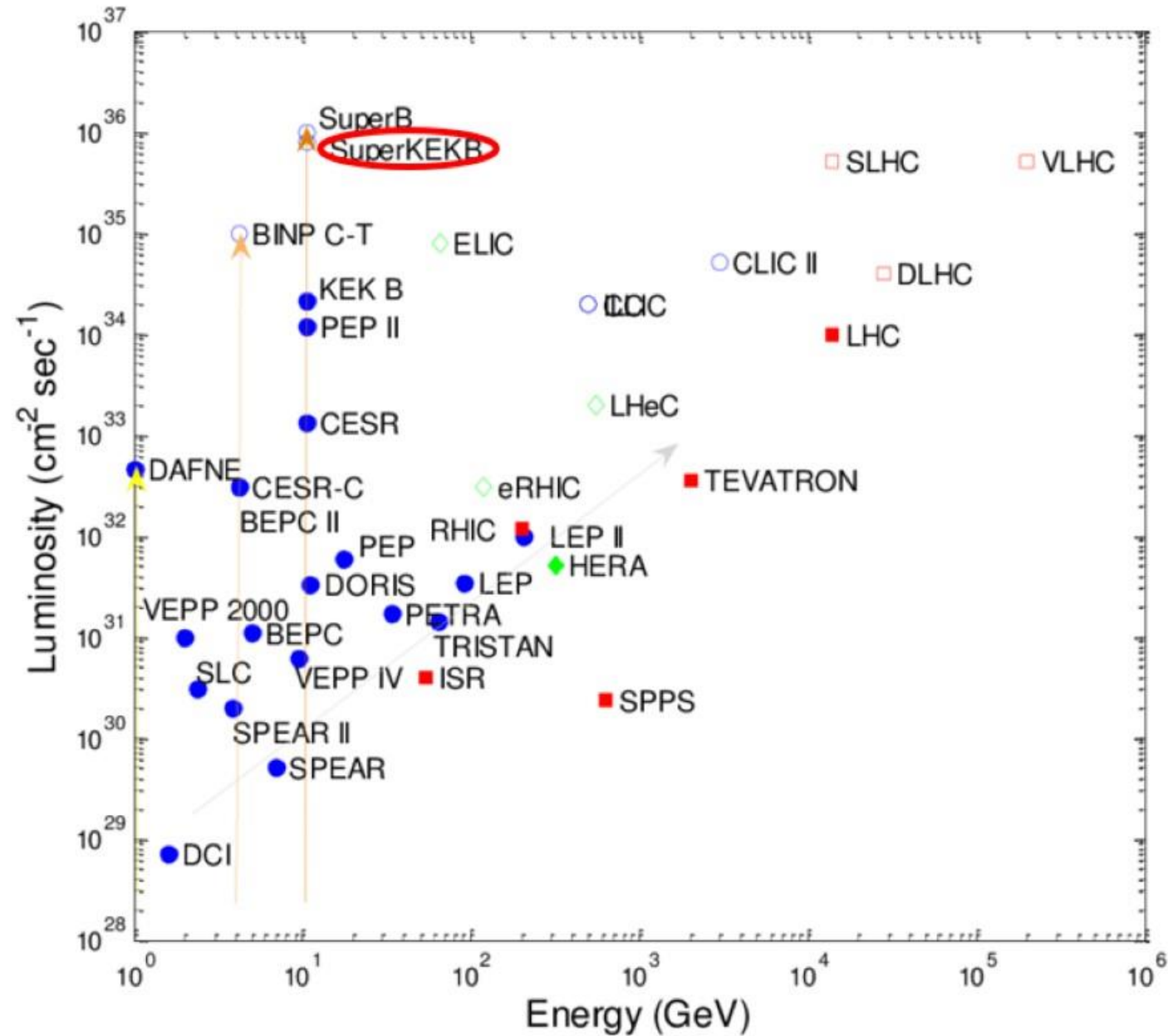
Date: 19.02.2021

Belle II Experiment

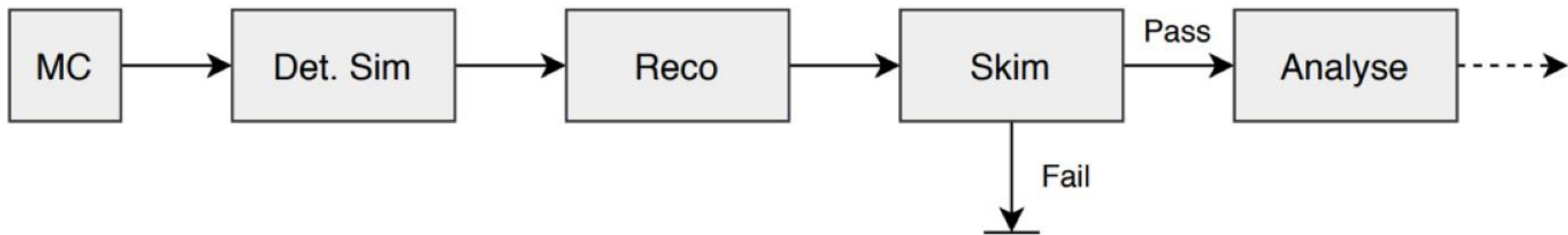
The Belle II experiment is designed to study the properties of B mesons and is currently being commissioned at the SuperKEKB accelerator at KEK in Tsukuba, Ibaraki Prefecture, Japan. The Belle II detector was moved into the collision point of SuperKEKB in April 2017 and started taking data in early 2018.



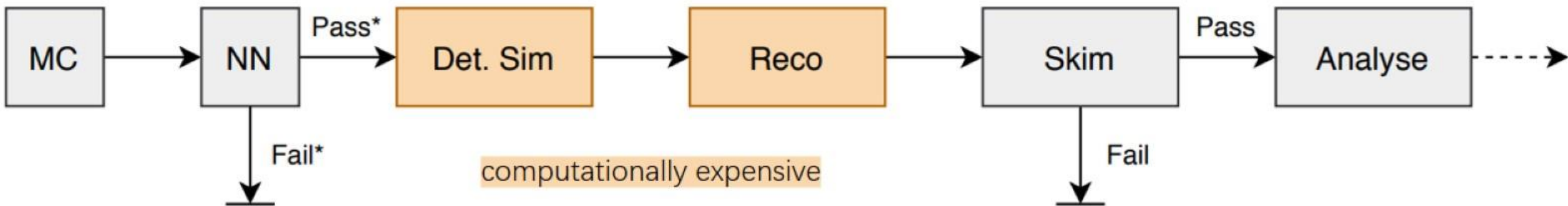
Very High Luminosity
means
Tremendous Dataset



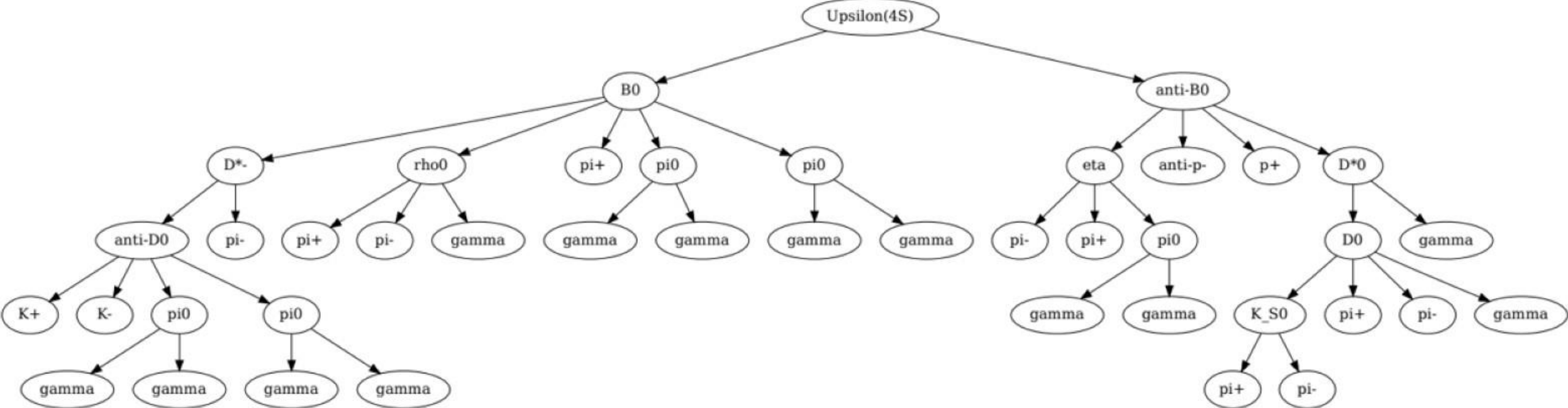
Current Monte Carlo Simulation data flow



Simulation with smart background selection



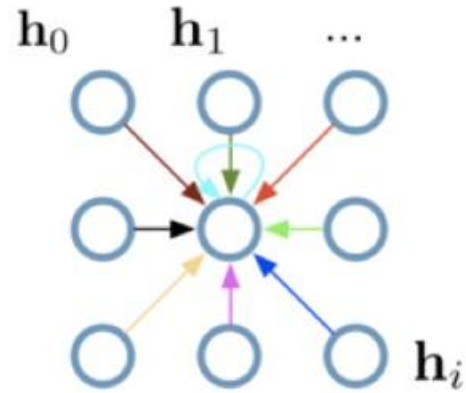
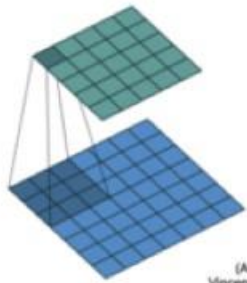
Tree Structures of Particle Decay inspire the use of Graph Neural Network



Using Deep Graph Library (DGL)

CNN vs GCN

Single CNN layer
with 3x3 filter:

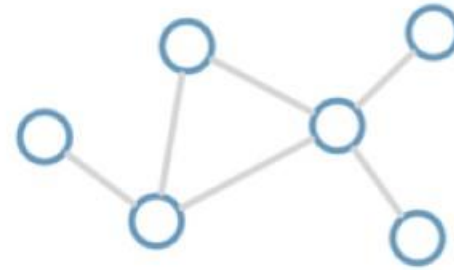


Full update:

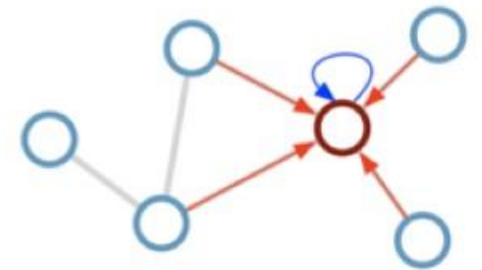
$$\mathbf{h}_4^{(l+1)} = \sigma \left(\mathbf{W}_0^{(l)} \mathbf{h}_0^{(l)} + \mathbf{W}_1^{(l)} \mathbf{h}_1^{(l)} + \dots + \mathbf{W}_8^{(l)} \mathbf{h}_8^{(l)} \right)$$

Convolutional Neural Network (CNN)

Consider this
undirected graph:



Calculate update
for node in red:

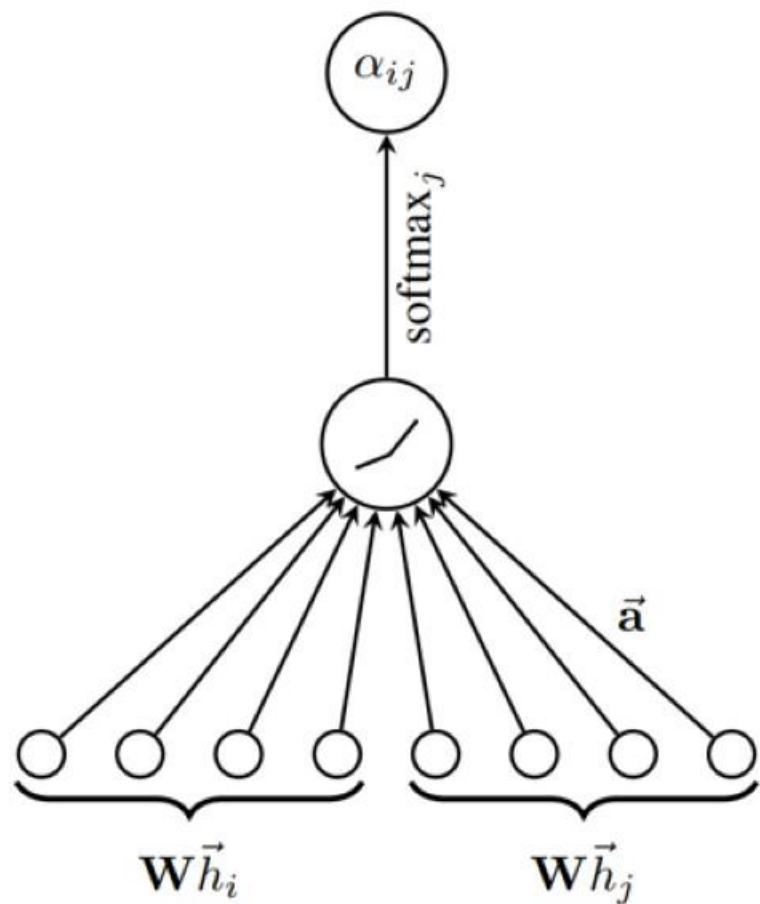


Update rule:

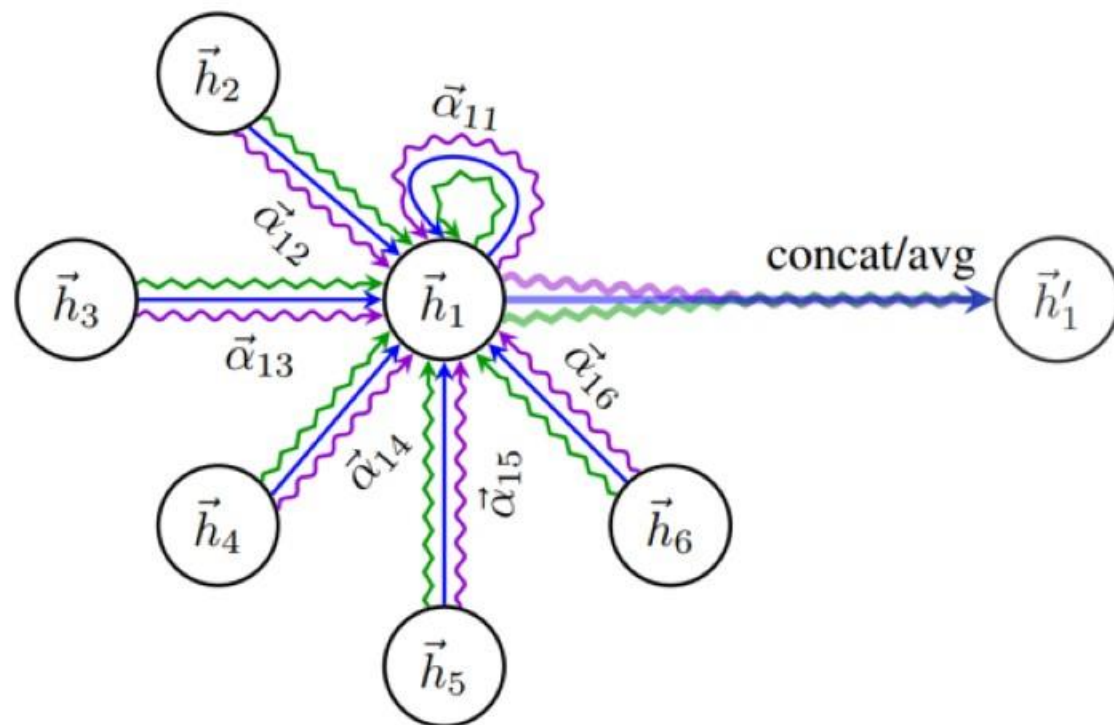
$$\mathbf{h}_i^{(l+1)} = \sigma \left(\mathbf{h}_i^{(l)} \mathbf{W}_0^{(l)} + \sum_{j \in \mathcal{N}_i} \frac{1}{c_{ij}} \mathbf{h}_j^{(l)} \mathbf{W}_j^{(l)} \right)$$

Graph Convolutional Network (GCN)

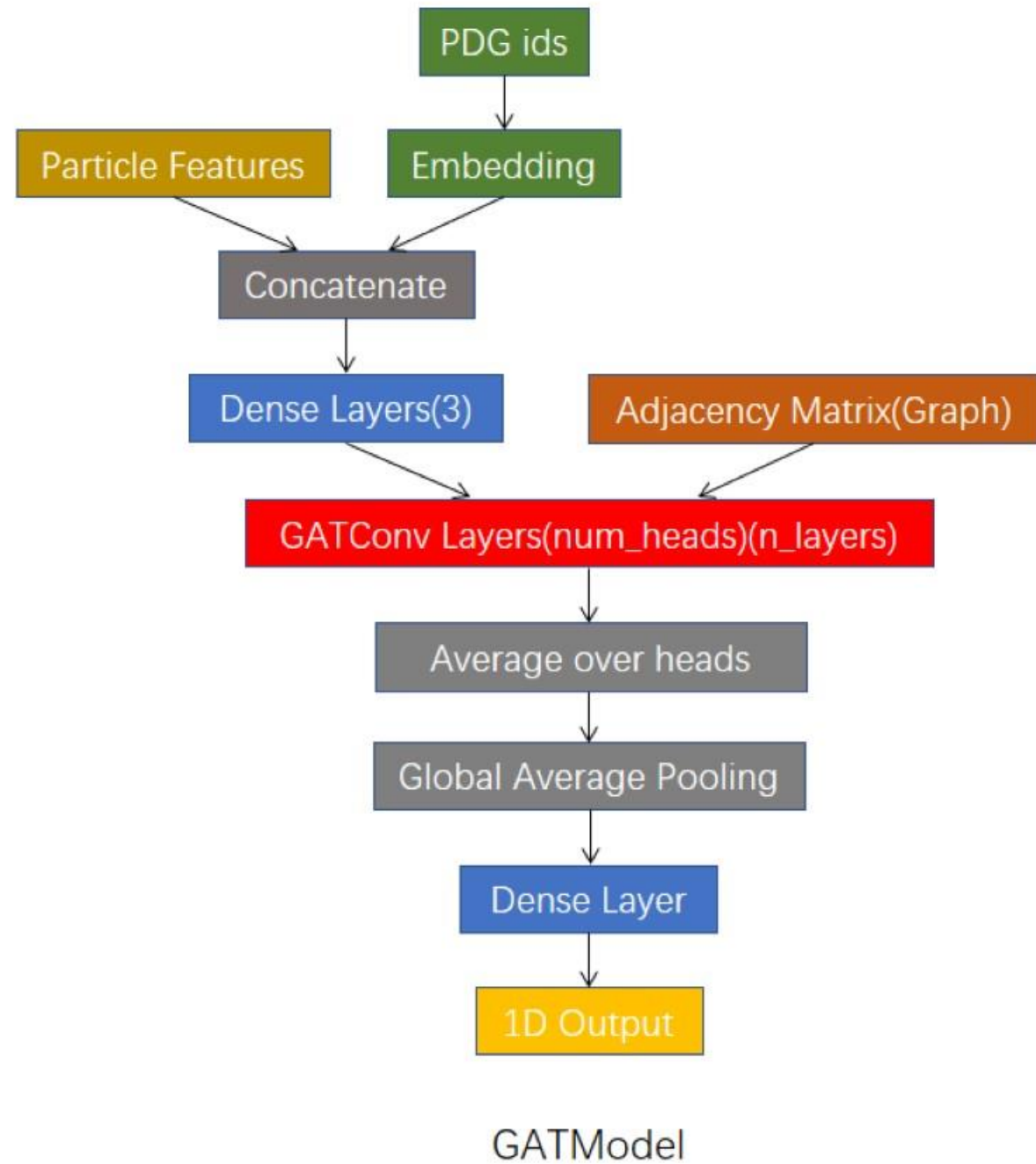
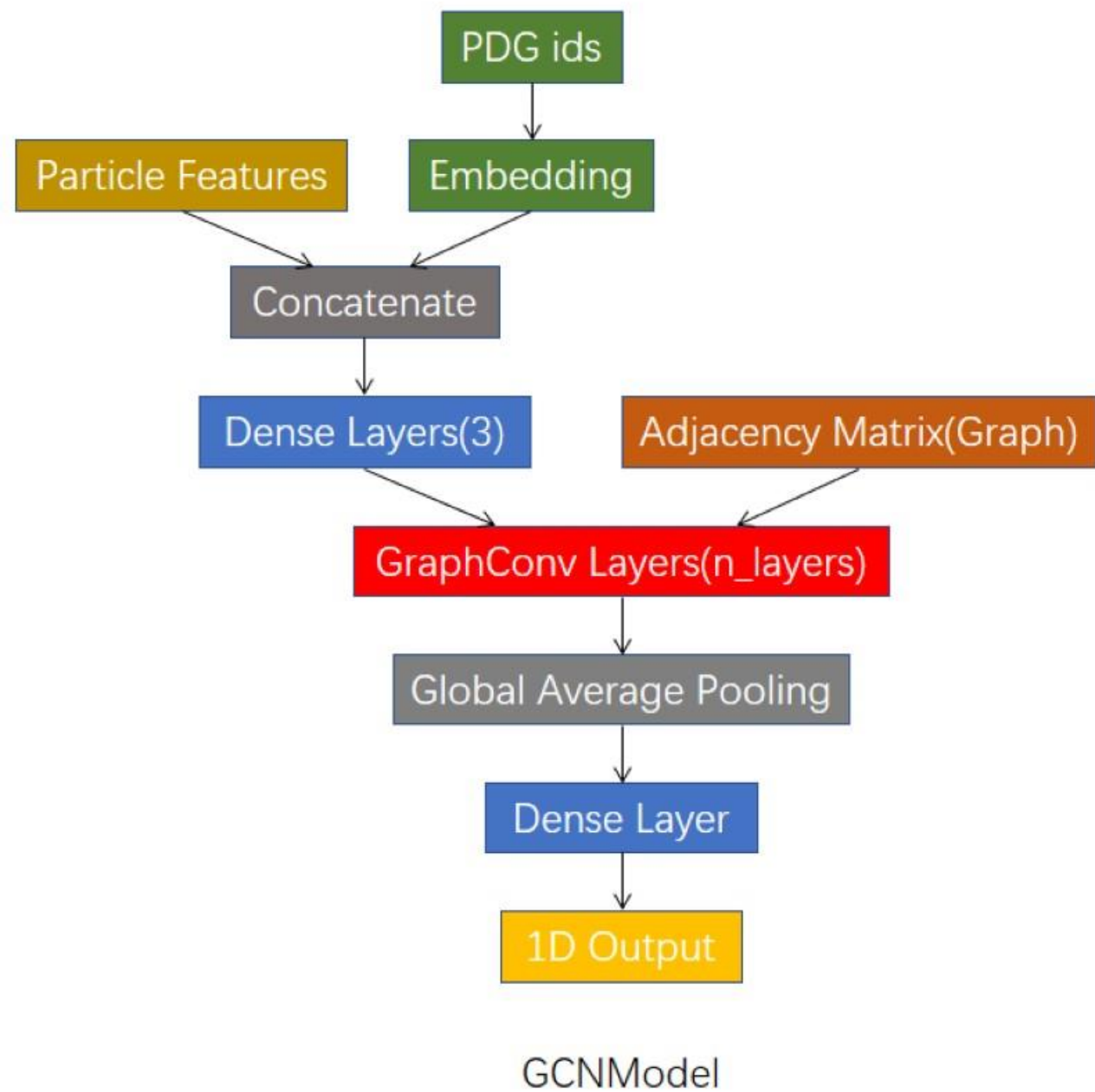
Graph Attention Networks

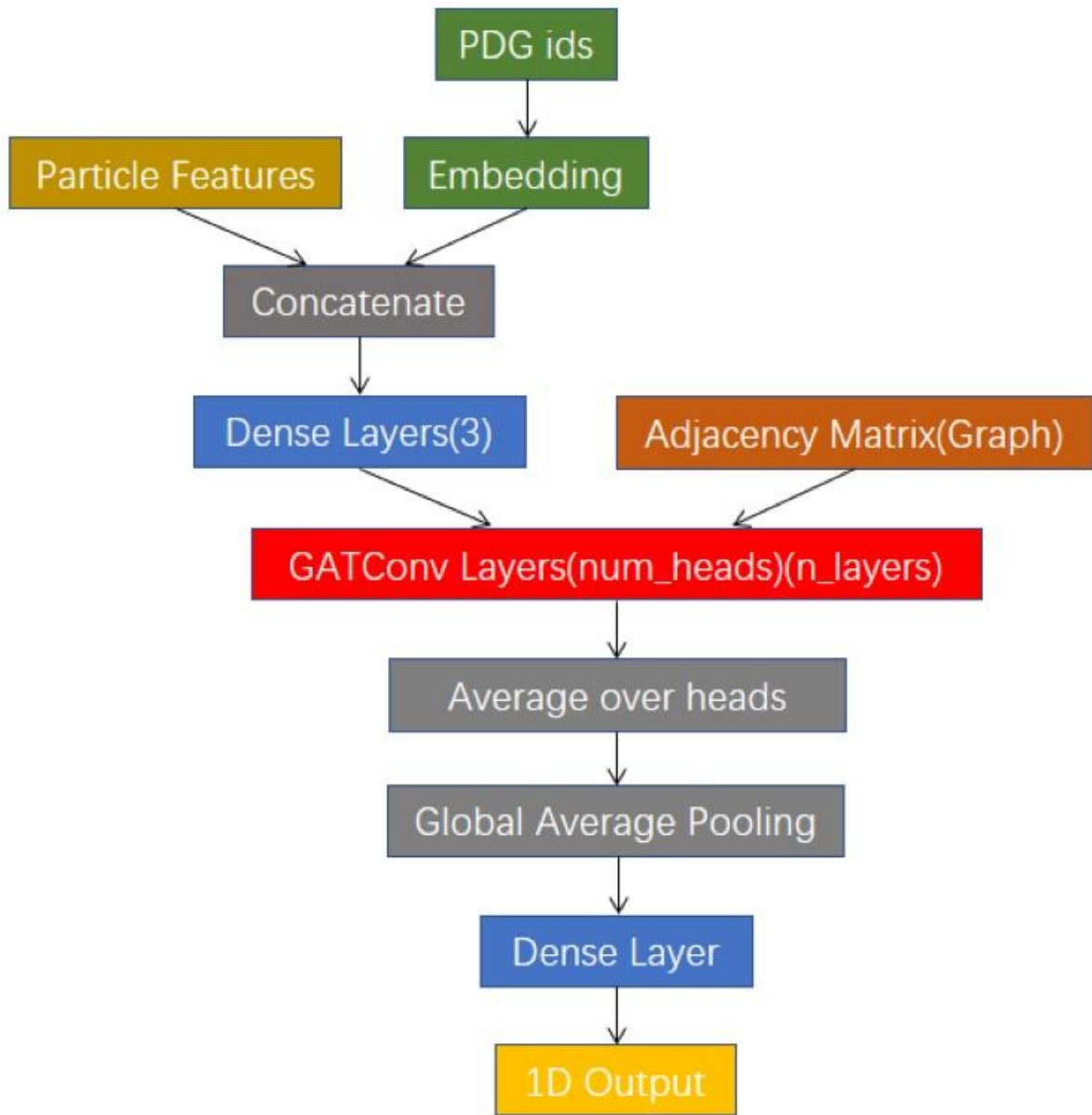


$$\alpha_{ij} = \frac{\exp\left(\text{LeakyReLU}\left(\vec{a}^T[\mathbf{W}\vec{h}_i \parallel \mathbf{W}\vec{h}_j]\right)\right)}{\sum_{k \in \mathcal{N}_i} \exp\left(\text{LeakyReLU}\left(\vec{a}^T[\mathbf{W}\vec{h}_i \parallel \mathbf{W}\vec{h}_k]\right)\right)}$$

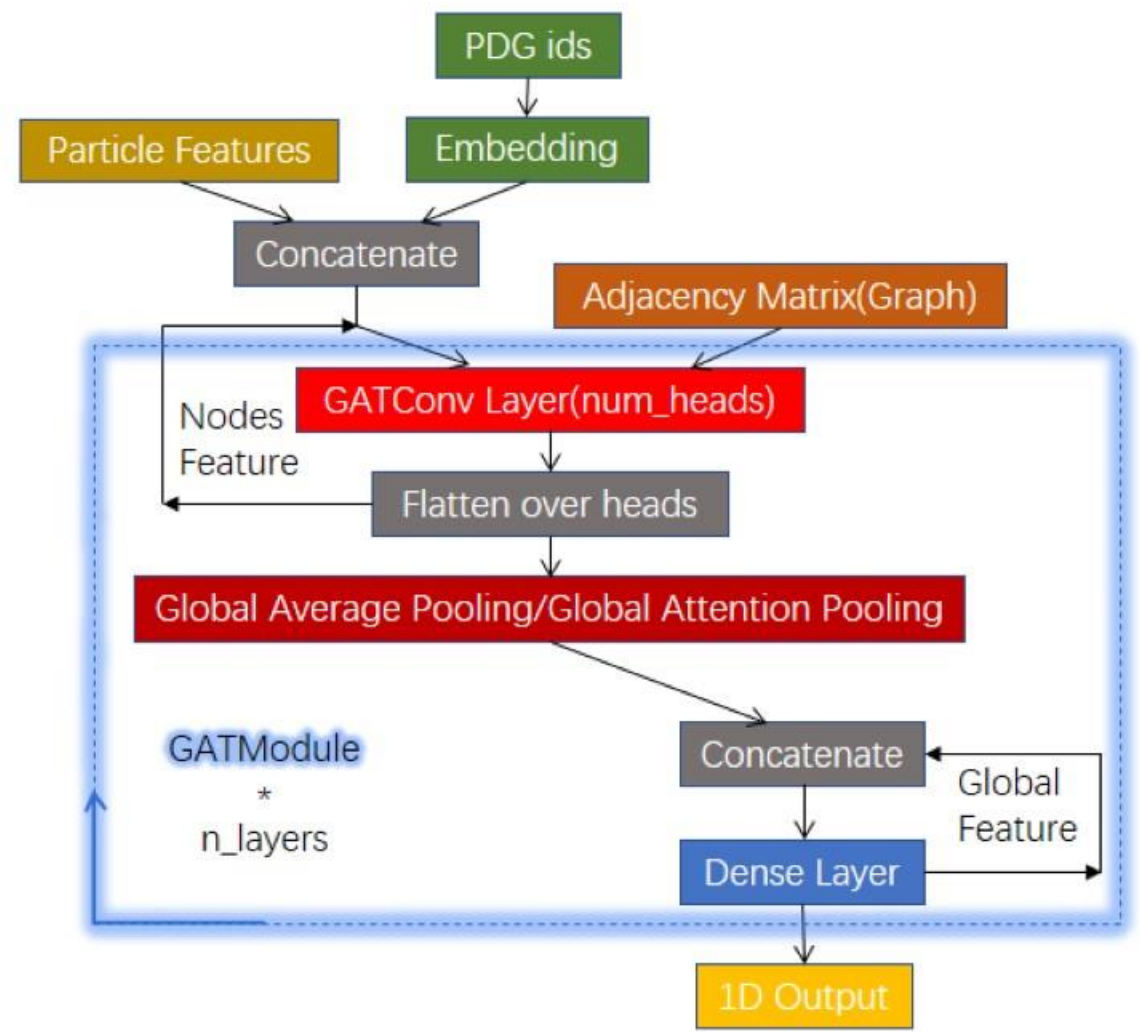


$$\vec{h}'_i = \big\|_{k=1}^K \sigma \left(\sum_{j \in \mathcal{N}_i} \alpha_{ij}^k \mathbf{W}^k \vec{h}_j \right)$$



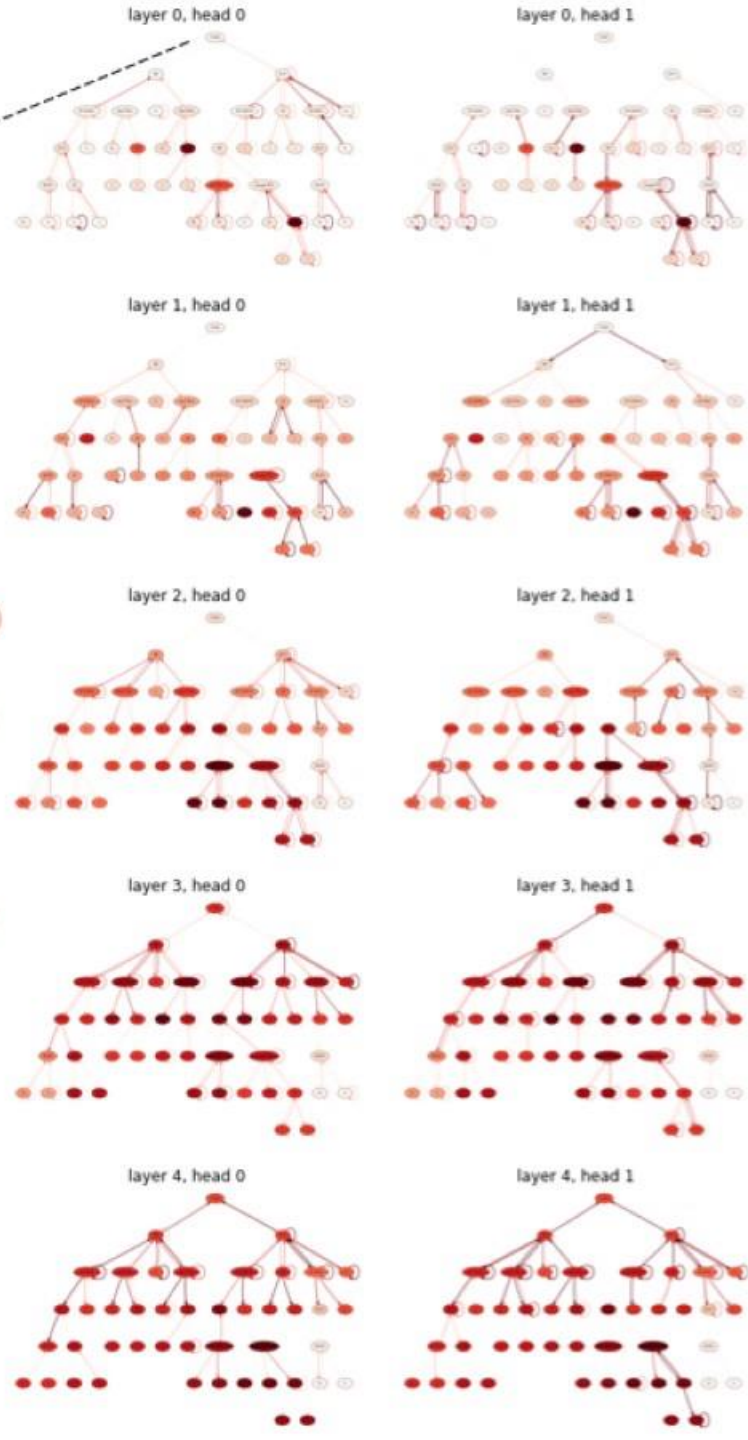
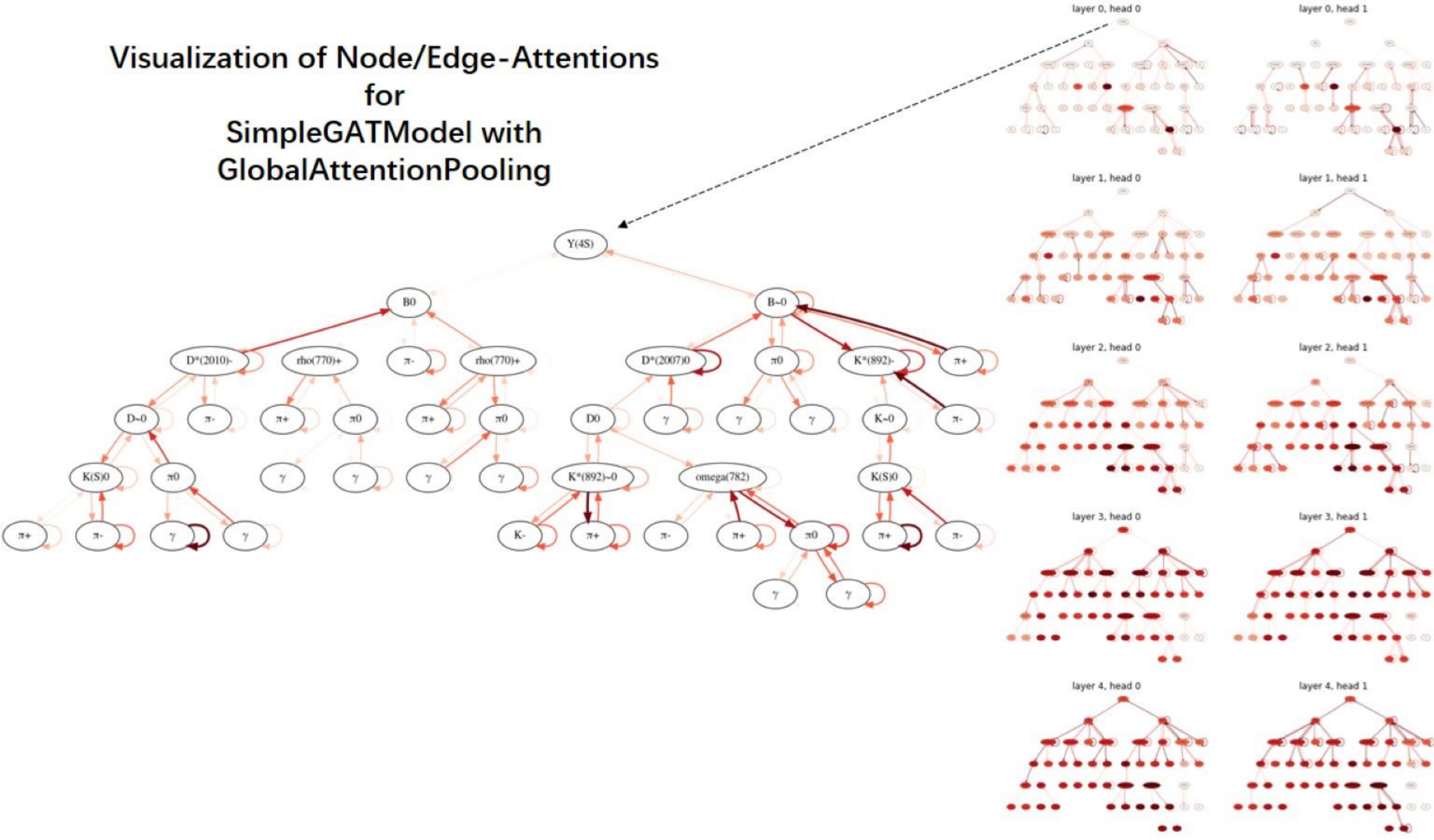


GATModel



SimpleGATModel
w/o
GlobalAttentionPooling

Visualization of Node/Edge-Attentions for SimpleGATModel with GlobalAttentionPooling



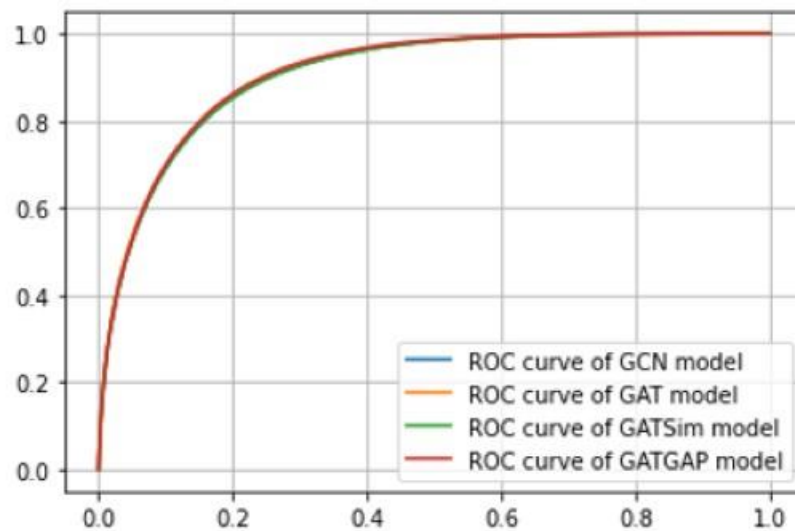
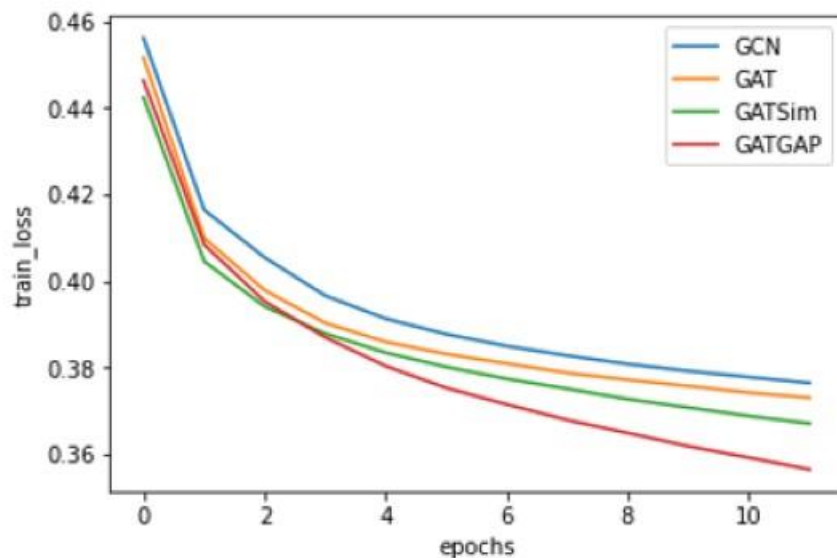
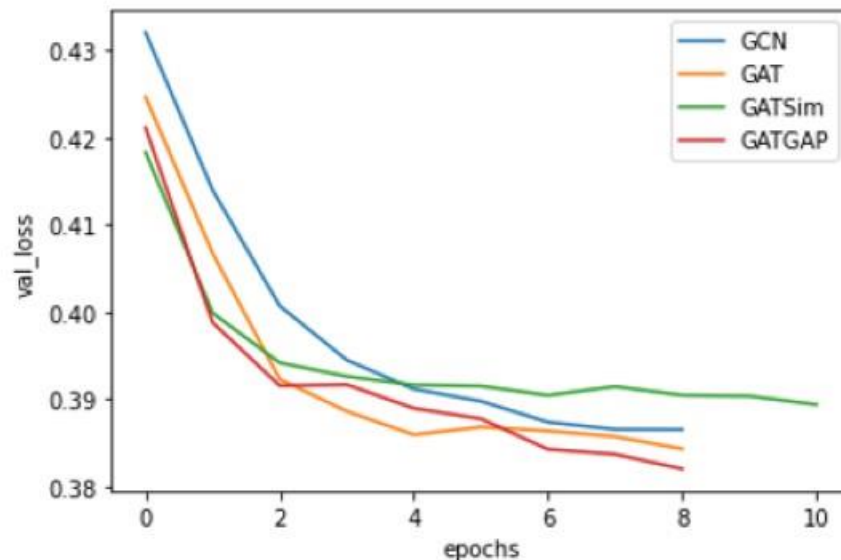
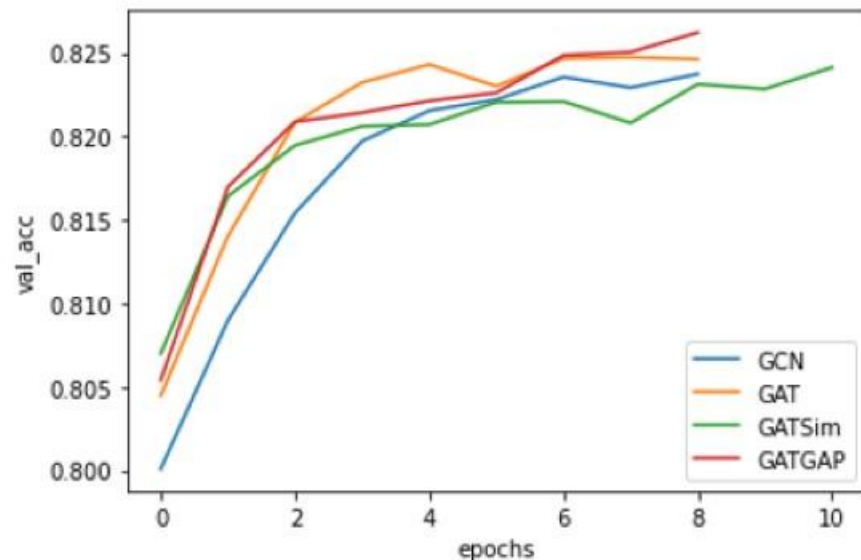
Comparison

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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Particle Identification
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