ZDC-ML Roadmap

2025/11/13

ZDC Internal weekly

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ZDC-ML Roadmap: Until the end of 2025

Alan

Phase 1A (NOW): v6	Phase 2A (~11/30): v7	Phase 3 (~12/31): v8
HCAL has been added (as a parallel path)	Losses coupling	Physics-Informed Neural Network (PINN)
	Z-X plane learning	

Yen-Chen

Phase 1B (~11/28): v3 -> v6	Phase 2B (~12/12): v6 & v7	Phase 3 (~12/31): v8
Understand framework structure	ECAL-HCAL coupling: Energy conservation layer	Physics-Informed Neural Network (PINN)

At the stage, we build a network that can learn ECAL and HCAL showering pattern in parallel. However we need to relax the constraint and weighting.
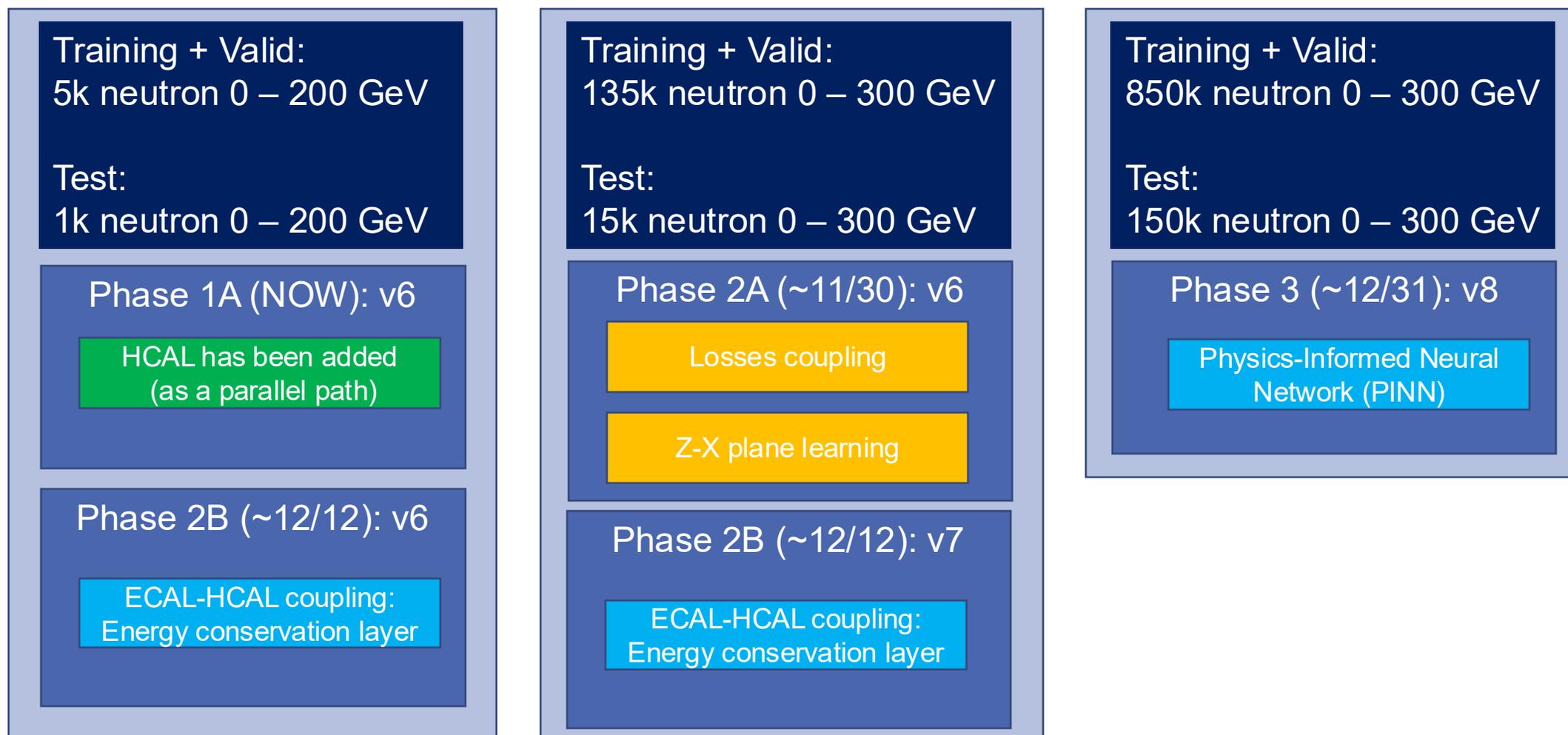
Next step would be:
- Let the model to learn more features rather than fine-tuning manually.
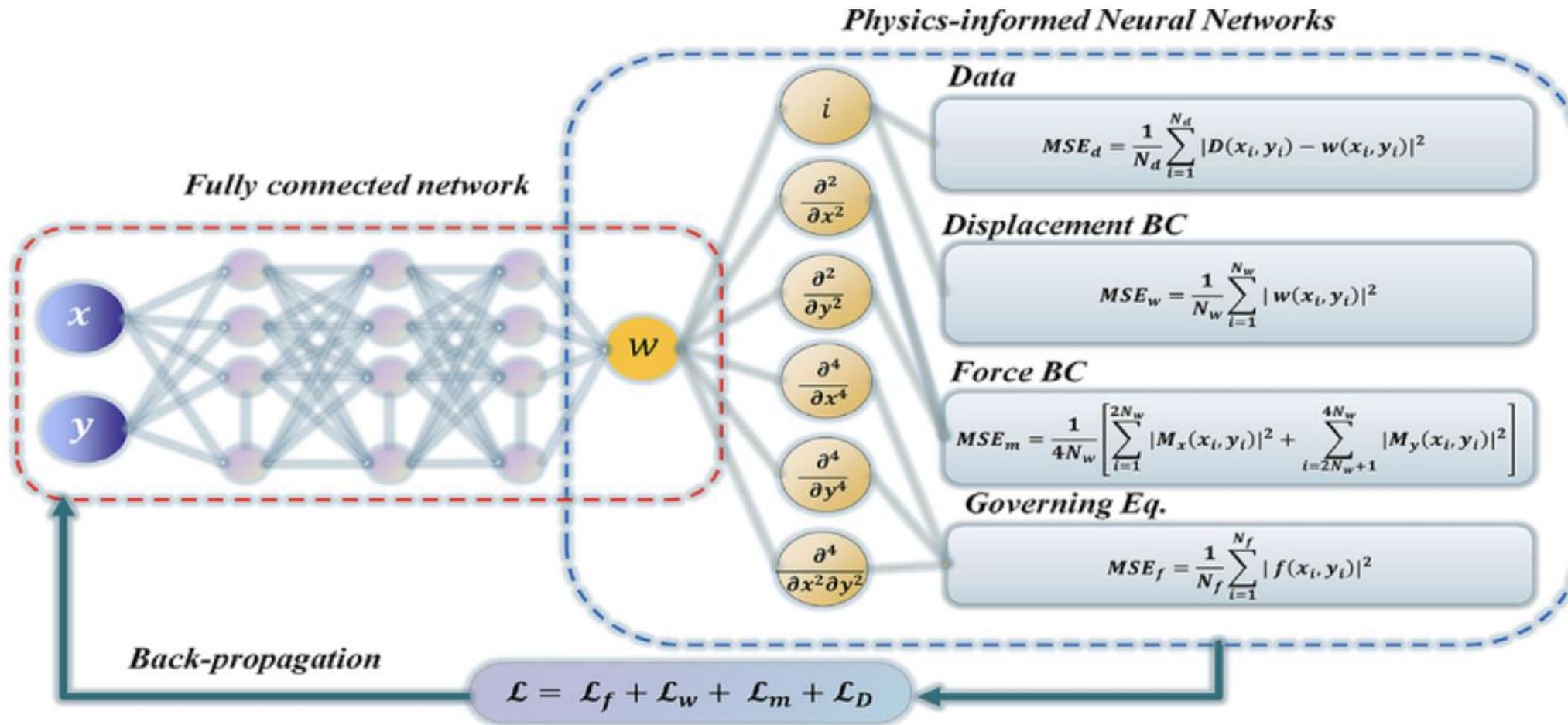- ECAL-HCAL information exchange

Final target:
- Apply PINN, which should cover much more physics feature than energy conversation.

ZDC-ML Roadmap: Sample preparation

In order to let the model to learn more features along the relaxation, we need to increase the number of events.

Training + Valid:
5k neutron 0 – 200 GeV

Test:
1k neutron 0 – 200 GeV

Phase 1A (NOW): v6
HCAL has been added
(as a parallel path)

Phase 2B (~12/12): v6
ECAL-HCAL coupling:
Energy conservation layer

Training + Valid:
135k neutron 0 – 300 GeV

Test:
15k neutron 0 – 300 GeV

Phase 2A (~11/30): v6
Losses coupling

Z-X plane learning

Phase 2B (~12/12): v7
ECAL-HCAL coupling:
Energy conservation layer

Training + Valid:
850k neutron 0 – 300 GeV

Test:
150k neutron 0 – 300 GeV

Phase 3 (~12/31): v8
Physics-Informed Neural Network (PINN)

ZDC-ML framework: 2026 ~

- I can still work with Yen-Chen in the coding side, but it would be better for him to work on the main analysis.

- Afterwards Yen-Chen can try to work with particle classification, which should be easy to modify the code (Just add a features into the generator and output particle types).
  - Here I think the most challenge task would be generating the Lambda particle or the pions in different decay channels, but this would be nice for him to learn more physics about particle decay.
  - As the modification can be done in either v6, v7 and v8; we don't have to generate too much events to start working with.

Physics-informed Neural Networks

Fully connected network

Data

$$MSE_d = \frac{1}{N_d} \sum_{i=1}^{N_d} |D(x_i, y_i) - w(x_i, y_i)|^2$$

Displacement BC

$$MSE_w = \frac{1}{N_w} \sum_{i=1}^{N_w} |w(x_i, y_i)|^2$$

Force BC

$$MSE_m = \frac{1}{4N_w} \left[\sum_{i=1}^{2N_w} |M_x(x_i, y_i)|^2 + \sum_{i=2N_w+1}^{4N_w} |M_y(x_i, y_i)|^2 \right]$$

Governing Eq.

$$MSE_f = \frac{1}{N_f} \sum_{i=1}^{N_f} |f(x_i, y_i)|^2$$

Back-propagation

$$\mathcal{L} = \mathcal{L}_f + \mathcal{L}_w + \mathcal{L}_m + \mathcal{L}_D$$

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