# DEVELOPMENT OF ALGORITHM FOR PREDICTION OF PARAMETERS OF SECONDARIES IN HADRONIC SHOWERS IN HIGHLY GRANULAR CALORIMETERS USING A NEURAL NETWORK

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## Detector ILD for future lepton collider experiments

- Proposed collider projects: ILC, CLIC, FCC, CEPC
- Aimed at PFA reconstruction: precision tracking, highly granular calorimeters and muon system
- Scintillator-steel hadron calorimeter with about 10 million channels (tiles with SiPM readout)
- iLCSoft – software package for simulation and reconstruction

**CALICE collaboration** develops highly granular calorimeters for future experiments

- test of different technologies
- validation of simulations
- development of calibration and reconstruction techniques

## Reconstruction and event selection

- Official reconstruction chain, 0.5 MIP cut for hits, official start finder algorithm
- For analysis: only events with found start at 3–6 AHCAL layers

## Features used in the analysis

**Highly granular calorimeters provide unique information (calorimetric observables) about hadronic shower development**

- Number of isolated hits in a shower
- Number of track hits within a shower
- Mean shower hit energy
- Shower radius
- Longitudinal shower centre of gravity

**Additional features (24 "ring" observables)**

- Number of isolated hits in a ring
- Energy sum in a ring

## Motivation and goal

- **Motivation**: detailed validation of simulations
- **Goal**: prediction of parameters of secondaries in hadronic showers using calorimetric observables

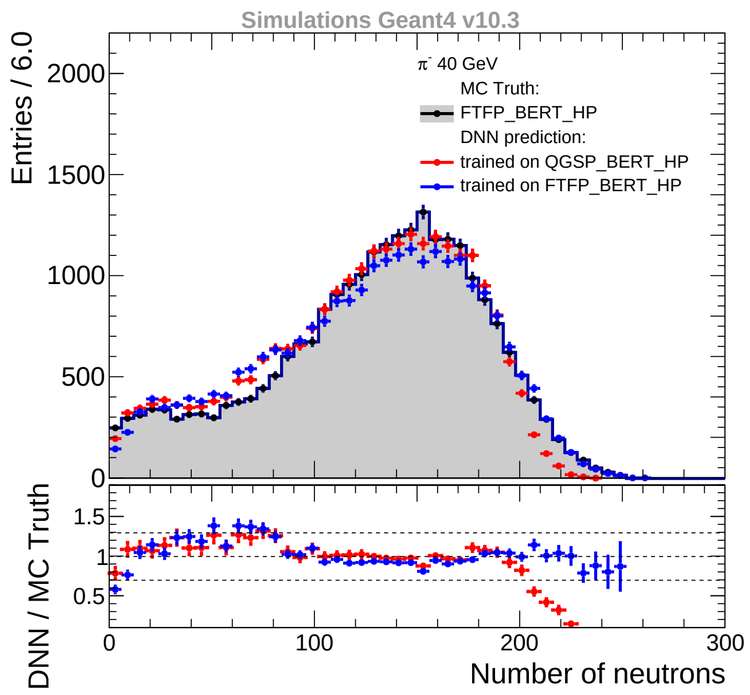
## Monte Carlo samples

- CALICE AHCAL technological prototype geometry and layout
- centrally generated samples of negative pions, 10–80 GeV, 500 kevt / sample
- Geant4 v10.3, physics lists: FTFP_BERT_HP and QGSP_BERT_HP
- official digitisation

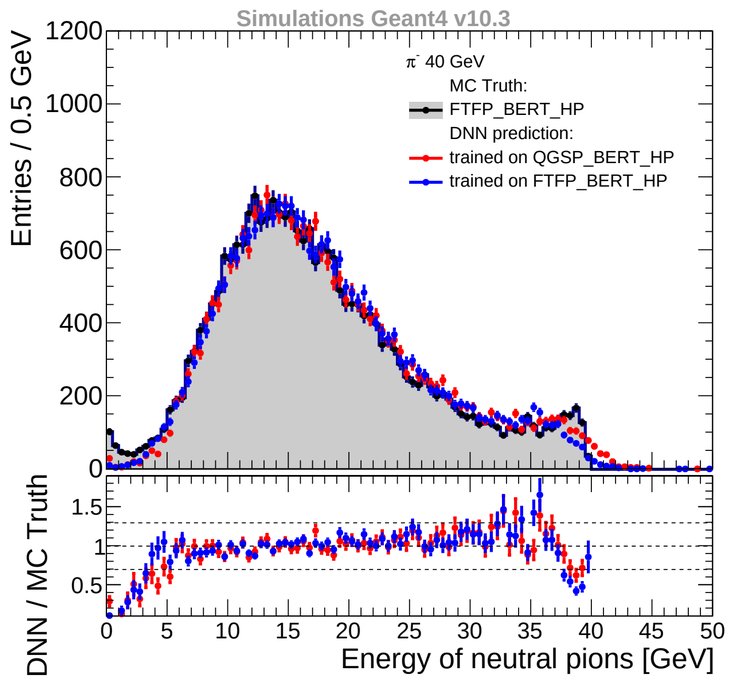
## Neural network structure and hyperparameters

- **29 input features and 1 target** (true from mc collection): number of neutrons produced in hadron-nucleus interactions and sum of neutral pion energies
- Number of neurons: 29 / 128 / 64 / 32 / 1
- Activation function: ReLU for hidden layers; linear $\left(\mathrm{f(y)} = \mathrm{y}\right)$ for output layer
- Learning rate (lr): from 0.1 to 0.0000001
- Batch size (bs): from 1 to 256 $\Rightarrow$ Events come in batches iteratively
- Number of epochs: 10-200
- Loss function: weighted MSE (or divided by $\sigma^2$ or Huber Loss) $\mathrm{Loss} = \frac{1}{\mathrm{N}} \cdot \sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{W_i} \cdot (\mathrm{Xpred_i} - \mathrm{Xtrue_i})^2, 1 \leq i \leq N$, $\mathrm{Xpred}$ – prediction, $\mathrm{Xtrue}$ – from MC collection and $\mathrm{W_i}$ – weights from pdf of target variable

## Prediction of number of neutrons in 40 GeV pion-induced shower




## Prediction of energy of neutral pions in 40 GeV pion-induced shower

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