Simulation Results of Proton-Endcap ECal of the ePIC Experiment at Electron-Ion Collider

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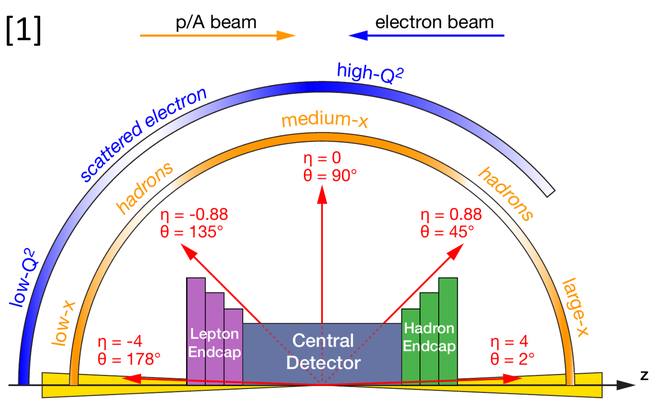
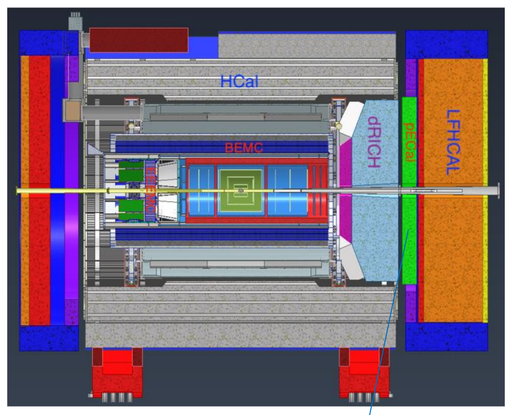
ePIC Detector

[1]

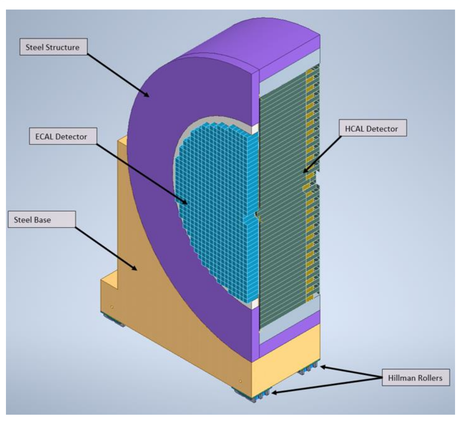




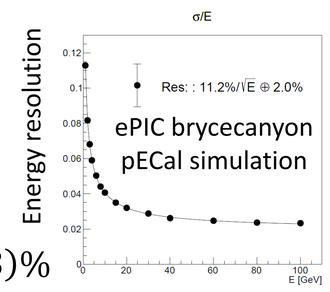
- ❑ p/A beam: Forward/positive direction
- ❑ Electron beam: Backward/negative direction
- ❑ Hadron endcap (W/ScFi pECal): Sampling ECal, good energy resolution
- ❑ Lepton endcap (EEEMC): Homogeneous ECal, excellent energy resolution

Focus on pECal

pECal Designs [1]

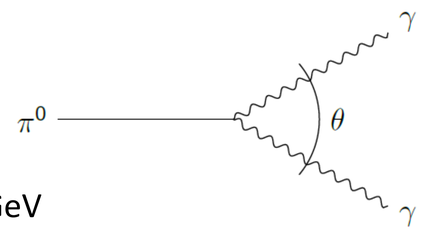


- ❑ $1.4 < \eta < 4$
- ❑ $14 < R < 173$ cm
- ❑ Length $= 30$ cm
- ❑ e/h ratio ~ 1
- ❑ $\frac{\sigma}{E} = \frac{(10-12)\%}{\sqrt{E}} \oplus (1-3)\%$
- ❑ π^0/γ separation up to ~50 GeV
- ❑ Heavy-flavor jet identification

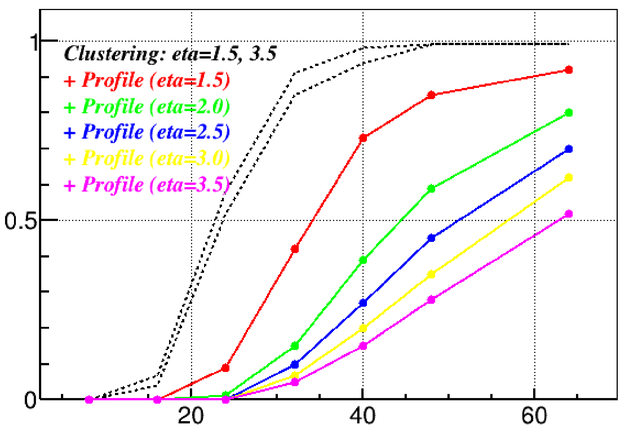


$\pi^0 \to \gamma\gamma$ Separations

- ❑ "Usual" criteria: $\pi^0 \to \gamma\gamma$ distinguished if two photons are separated by one tower size
- ❑ pECal: Tower size 2.5x2.5 cm at z = 350 cm
- ❑ $\theta_{min} = \frac{2m_{\pi^0}}{E_{\pi^0}} = \frac{2.5\ cm}{350\ cm} = 0.007 \Rightarrow E_{\pi^0} = 38$ GeV



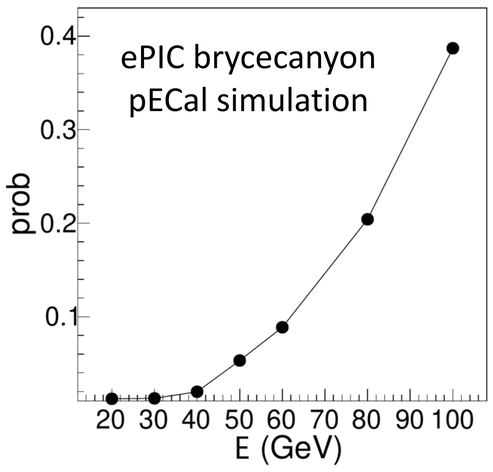
Pi0 merging prob vs p



Merging probability [1]
(~75% at 60 GeV at $\eta = 2$)
from shower profile cut by

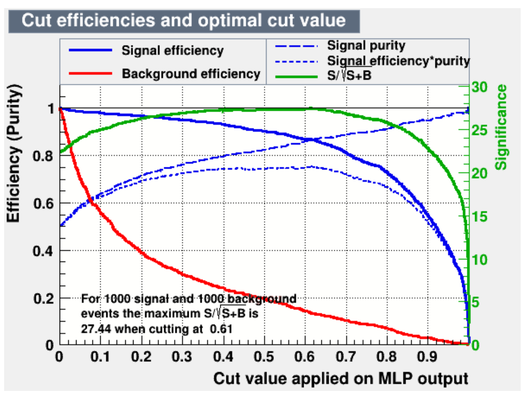
$$\chi^2 = \sum_i \left(\frac{E_i^{meas} - E_i^{pred}}{\sigma_i} \right)^2$$

Merging prob



Merging probability
(~10% at 60 GeV at $\eta = 2$)
from neural network
Input:

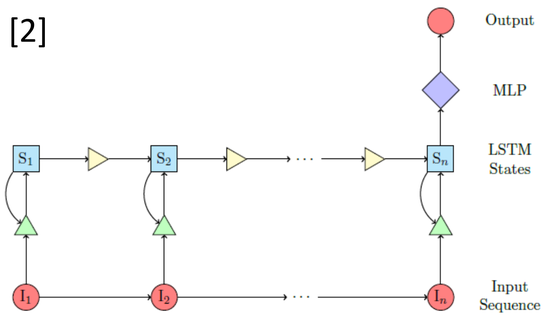
- ❑ 5x5 tower energies
- ❑ pECal x and y positions



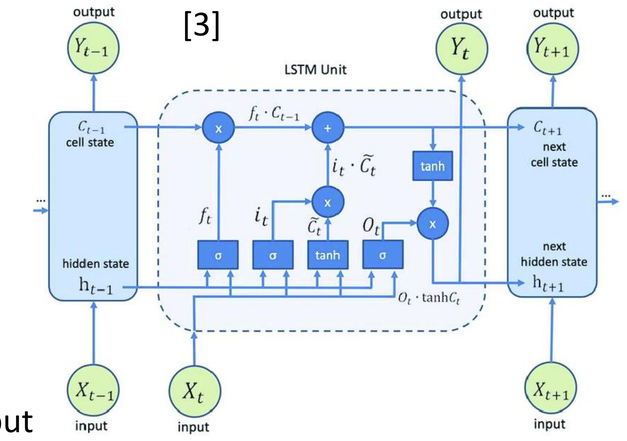
- ❑ MLP with one hidden layer
- ❑ NN output: Single cut value
- ❑ $>$ cut value: Single γ (signal)
- ❑ $<$ cut value: Merged $\gamma\gamma$ (background)
- ❑ Optimal cut: Max $S/\sqrt{S+B}$
- ❑ Left figure: $E_\gamma = E_{\pi^0} = 60$ GeV

Long Short-Term Memory

[2]



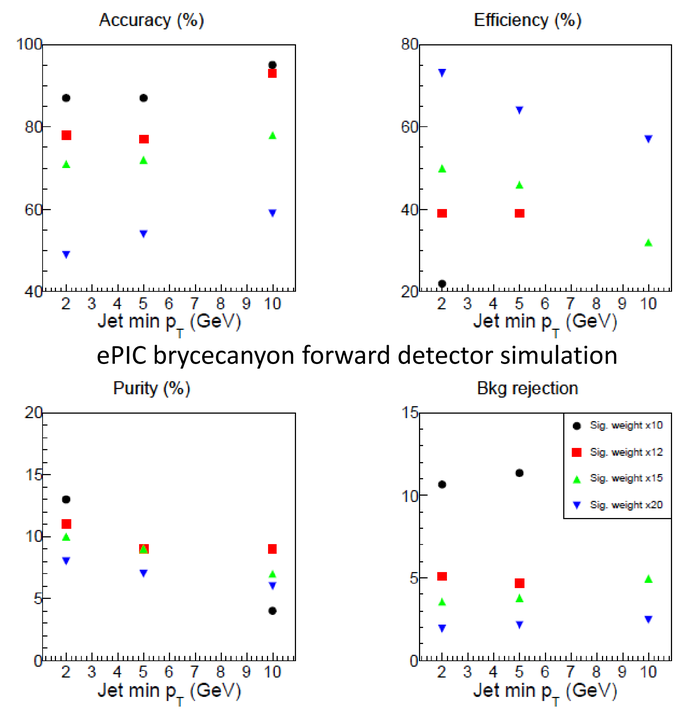
[3]



- ❑ Input: Jet constituents
- ❑ LSTM deals with variable-sized input
- ❑ Cell states memorize previous input
- ❑ Previous hidden state (h_{t-1}) and current input (X_t) produce forget gate (f_t), input gate (i_t), cell candidate ($\widetilde{C}_t$), and output gate (O_t)
- ❑ Previous cell state (C_{t-1}) and cell candidate ($\widetilde{C}_t$) produce current cell state: $C_t = f_t \cdot C_{t-1} + i_t \cdot \widetilde{C}_t$
- ❑ Cell state (C_t) has memory and produces the next hidden state (h_{t+1}) and the current output (Y_t): $Y_t = h_{t+1} = O_t \cdot \tanh C_t$

Heavy-Flavor Jet Identifications

- ❑ Use LSTM to identify HF jets
- ❑ Input: Jet constituents
  - Four momentum
  - Track mom, E/HCal energy
- ❑ Pythia DIS events:
  $e + p \to q(jet) + X$
  $Q^2_{min} > 10\ \mathrm{GeV}^2$
- ❑ Jet flavor ID: Use the flavor of the hard-scattered quark q for its closest jet
- ❑ Signal: HF jets; Bkg: LF jets
- ❑ $N_{HF}: N_{LF} \approx 1:18$
- ❑ Large weight on signal (HF)
- ❑ Best overall performance: Weight signal by factor 15
- ❑ 70% accuracy, 50% efficiency, 10% purity, 4x bkg rejection



ePIC brycecanyon forward detector simulation

Summary and Outlook

- ❑ pECal energy resolution meets the yellow report requirement.
- ❑ For $\pi^0 \to \gamma\gamma$ separations, MLP performs much better than the χ^2 cut based on the shower profile analysis.
- ❑ LSTM gives reasonable performance for heavy-flavor jet identifications by using the tracking and forward E/HCal.
- ❑ Including vertex and dRICH PID will give better jet ID in the future.

References

- ❑ [1] EIC yellow report. Nucl. Phys. A 1026, 122447 (2022)
- ❑ [2] Phys. Rev. D 94, 112002 (2016)
- ❑ [3] Remote Sens. 14, 1803 (2022)

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