Heavy-flavor jet identification at forward direction of ePIC

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UCLA

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ePIC detector

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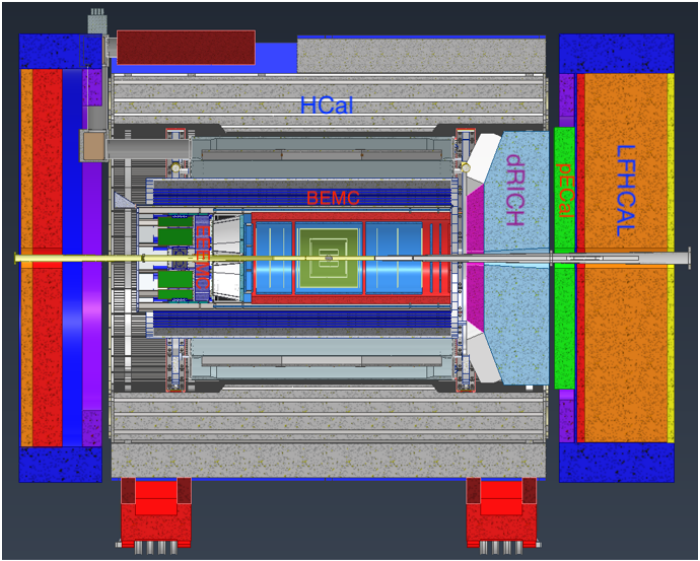

Forward ECal (pECal) designs

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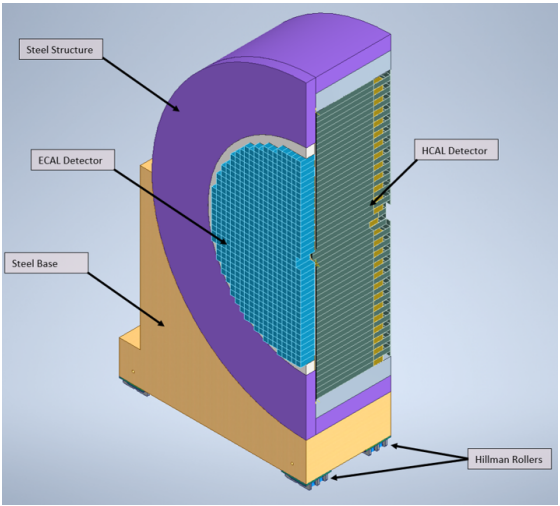
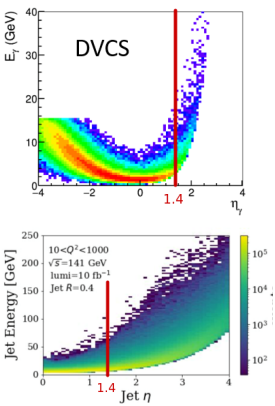
- Sampling ECal:
  - Measure photons and hadrons at the forward region.
  - Good energy resolution [(10–12)%/$\sqrt{E}\oplus$ (1–3)%].
- pECal with W/ScFi structure:
  - Beehive with fibers of radius 0.235 mm.
  - Absorber: 97% Tungsten + 3% epoxy.
  - Fiber: 100% polystyrene.



High-level input of pECal

- η coverage: 1.4 to 4.
- Radius: $R_{in} = 14$ cm, $R_{out} = 173$ cm.
- Integration length along z-axis: 30 cm.
- Total weight: $\sim$20 tons.
- Number of readout channels: $\sim$15k.
- Readout must work in magnetic field, neutron fluxes up to 10^{12} n/cm^2.
- Fit in limited space (small X0).
- Hadron compensation with e/h ratio $\sim$1.
- Good π^0/γ separation up to $\sim$50 GeV.
- Optimal reconstruction of jets.
- Ability to identify heavy-flavor jets.



Heavy-flavor jet reconstruction at forward direction

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- Study the jet reconstruction capability at the forward direction.
- Use tracking, pECal, and LFHCAL.
- Focus on the energy resolution of $b/\bar{b}$ jets.
- Nihal, currently a student at California Bridge Program, learned the PYTHIA, ROOT, and ePIC software framework, plotted these resolutions.

Energy resolutions for $b/\bar{b}$ jets (From Nihal)

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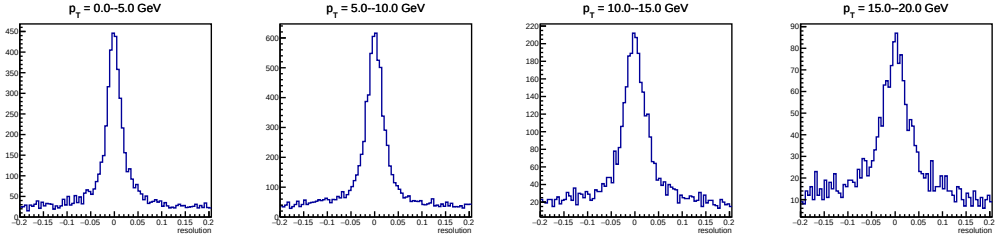
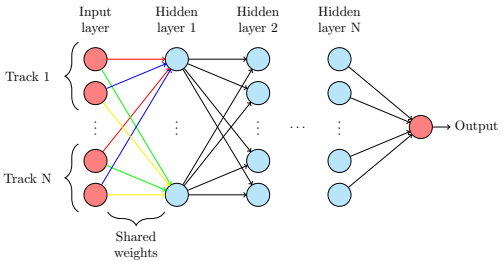
- Pythia events: $e(\gamma) + p(g) \rightarrow b + \bar{b}$.
- Find the true and reco jets closest to b and $\bar{b}$.
- Resolution $= \frac{E_{reco} - E_{true}}{E_{true}}$.
- Good resolution up to $p_T^{jet} = 20$ GeV for 18x275 GeV beams.

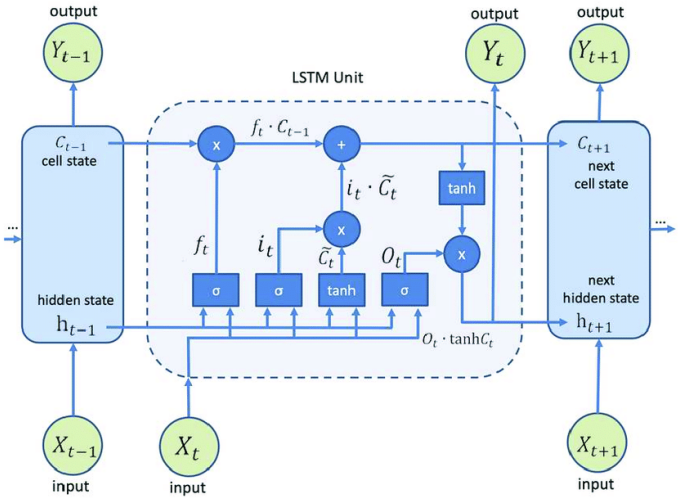


HF jet identification

- Purposes:
  - Identify HF jets.
  - Use HF decay electrons as the jet axis.
- Input:
  - Four momenta of jet constituents.
  - Tracking momentum, pECal and LFHCAL energy.
  - ~~dRICH PID.~~
  - ~~Vertex and DCA.~~
- NN methods: BDT, LSTM.
- LSTM accepts variable-sized inputs.
- Figures from [PRD 94, 112002].



Introduction to LSTM



- Previous hidden state (h_{t-1}) and current input (X_t) produce forget gate (f_t), input gate (i_t), cell candidate ($\tilde{C}_t$), and output gate (O_t).
- Previous cell state (C_{t-1}) and cell candidate ($\tilde{C}_t$) produce current cell state: $C_t = f_t \cdot C_{t-1} + i_t \cdot \tilde{C}_t$.
- Cell state (C_t) has memory and produces the next hidden state (h_{t+1}) and the current output (Y_t): $Y_t = h_{t+1} = O_t \cdot tanhC_t$.

Performance of jet HF ID

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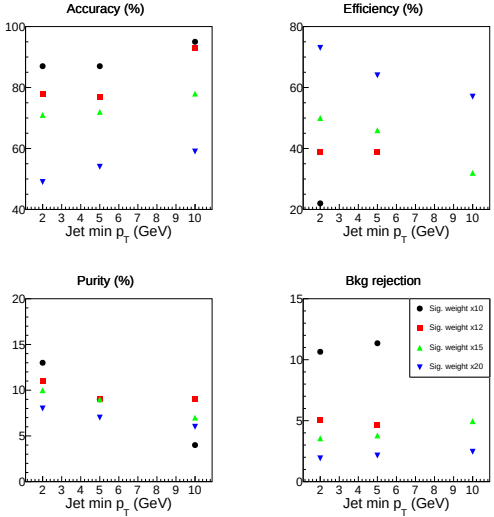
- Pythia DIS events: $e + p \rightarrow q(jet) + X$, $Q^2_{min} > 10$ GeV^2.
- Jet flavor ID: Only consider the jet closest to the hard-scattered quark q, identify the quark flavor q as the jet flavor.
- Signal: HF jets; Bkg: LF jets.
- $N_{LF} : N_{HF} = 169619 : 9685 \approx 17.5 : 1$.
- Training: Use LSTM, large weight on signal.
- Best overall performance: Weight signal by factor 15.
- 70% accuracy, 50% efficiency, 10% purity, 4 times bkg rejection.



Summary

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- The technology choices for all ECals in ePIC were defined.
- Performance of calorimeters were extensively verified with realistic simulations to meet YR requirements.
- Tracking, pECal, and LFHCAL provide good energy resolutions for the HF jets in the forward direction.
- LSTM gives reasonable performance for heavy-flavor jet identification.
- Including vertex and dRICH PID will give better jet ID in the future.