BDT-Based π^0 Reconstruction in KLOE Data

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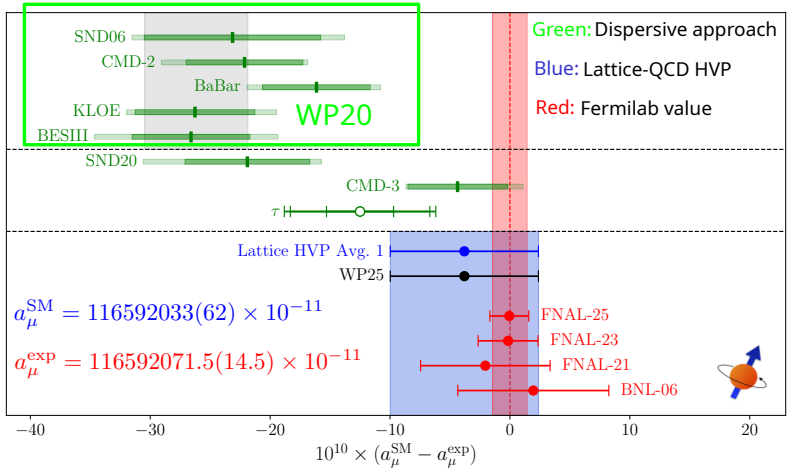
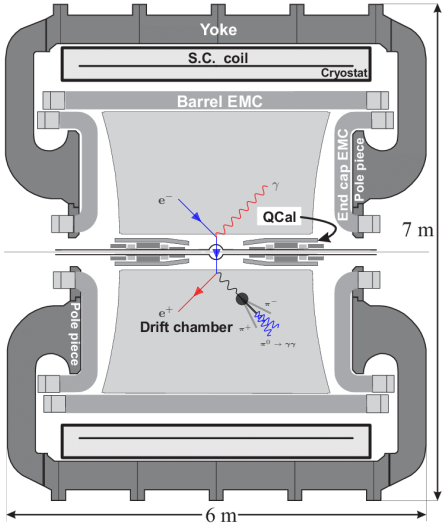
Particle physicists are puzzled, again!

- The Hadronic Vacuum Polarization (HVP) tension with other experiments.
- Bottleneck: Accurate π^0 particle reconstruction from 3 photons.

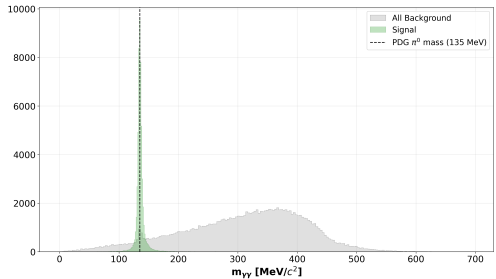


π^0 identification: A challenge for experimentalists

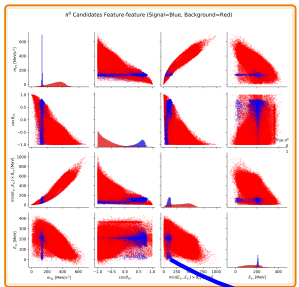


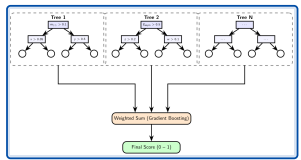
The Combinatorial Challenge

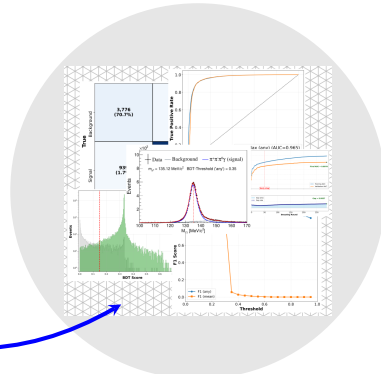
- $\gamma_1, \gamma_2, \gamma_3 \Rightarrow$ 3 candidate pairs:
  - (1,2), (1,3), (2,3)
- Only **1** pair originates from $\pi^0 \to \gamma\gamma$
- The other **2** are combinatorial background
- Traditional cut-based methods (single features) cannot fully resolve this ambiguity (high purity and high efficiency required)



Will BDT help? It does!







The BDT achieves high purity ($\sim 97\%$) and high efficiency ($\sim 98\%$) π^0 selection, outperforming a conventional cut-based selection (using $m_{\gamma\gamma}$ alone) by an absolute $\sim 10\%$ in both metrics.

Let's take a closer look at it?

BDT-Based π^0 Reconstruction in KLOE Data

Bo Cao[1] on behalf of the *KLOE-2 Collaboration*

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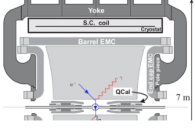
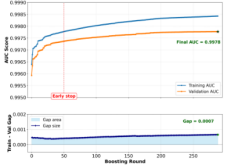
Motivation

The challenge: The QCD process $e^+e^- \to \pi^+\pi^-\pi^0\gamma$ produces three photons in the final state [1]: the two photons from the single $\pi^0 \to \gamma\gamma$ decay, together with the additional radiative photon. Only one of the three possible diphoton combinations corresponds to the true π^0, the rest are combinatorial background.

This work: A Gradient-Boosted Decision Tree (XGBoost [2]) to identify the correct π^0 pair using kinematic correlations. Data were collected by the KLOE detector at DAΦNE collider [3].



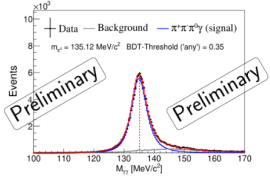
Training & Validation (pair-level)



- Training AUC (Area Under the Curve): **0.9984**
- Validation AUC: **0.9978**
- AUC gap: 0.0007 - negligible overfitting!

BDT Score Separation

The π^0 Mass Peak



- Pristine π^0 peak at 135 MeV/c^2
- Combinatorial background **drastically reduced**
- Correct pair identified in **>98%** of signal events

F1 Optimization

Aug 19, 2026, 12:20 PM
5m
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Thank you! Find me at Poster [29] for the full analysis.