Contribution ID: **17** Type: **口头报告**

Advancing fully hadronic final state searches at the LHC: The case of HH(4b)

Monday, 14 July 2025 11:30 (30 minutes)

We show that fully hadronic final state searches at the LHC—exemplified by the $HH(4b)$ flagship analysis—can achieve a 5–10× improvement in sensitivity by transitioning from jet-based methods to jet-free, event-level analysis powered by large-scale AI models. Existing approaches depend heavily on jet tagging, whose performance has plateaued despite sophisticated ML developments. Our strategy trains a universal classifier to distinguish $X \to Y_1 Y_2 \to b\bar{b}b\bar{b}$ signals from QCD and $t\bar{t}$ backgrounds over a wide mass range, while estimating $Y_{1,2}$ masses via multiclass classification. The method can be validated with $ZZ(4b)$ events and is fully calibratable. We argue that this unified, event-level, AI-driven framework sets a new paradigm for sensitivity enhancement, offering a powerful path toward precision Higgs self-coupling measurements and other key physics goals at the LHC.

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Session Classification: 人工智能和机器学习的应用