Hyperon reconstruction method with machine learning in Pb-Pb collisions at ALICE

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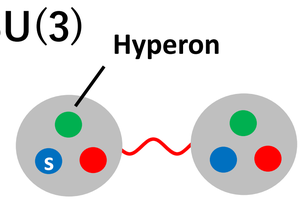
Introduction

■ Baryon-Baryon (B-B) interactions in flavor SU(3)

✓ Further understanding of QCD
  ➢ Exotic hadrons
✓ Determination of EoS in dense nuclear matter
  ➢ Neutron star's core

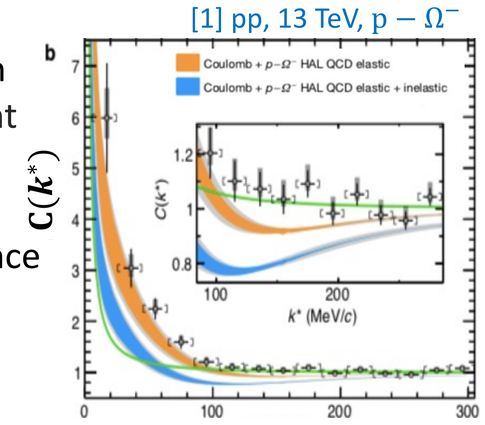


ex : $\Lambda-\Lambda$, $p-\Xi^-$, $p-\Omega^-$

■ Current understanding

✓ Two particle correlation function ($\mathbf{C}(\boldsymbol{k}^*)$)
  • Measured attractive force consistent with Lattice QCD calculations, but not sufficient to conclude existence of bound states
➢ Need more data for further understanding
  • Systematic study of source size dependence
  ➢ Large emission source (Pb-Pb)
  • More statistics in low k*

[1] pp, 13 TeV, $p-\Omega^-$



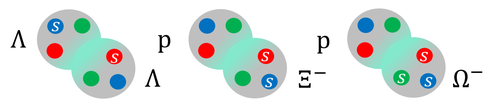
Relative momentum $\mathbf{k}^*$ (MeV/c)

[1] ALICE collaboration, Nature 588 (2020) 232-238

■ Possible B-B bound systems

✓ $\Lambda\Lambda$, $p\Xi^-$, $\Lambda\Xi^-$ & $p\Omega^-$ in Pb-Pb
  ① Correlation function
    ➢ Scattering length, effective length
  ② Mass reconstruction
    • Hyperons from dibaryon decays

Dibaryons as molecule state



➢ Hyperon reconstruction in Pb-Pb is the key for these analyses

→ Solution : Hyperon reconstruction with machine learning

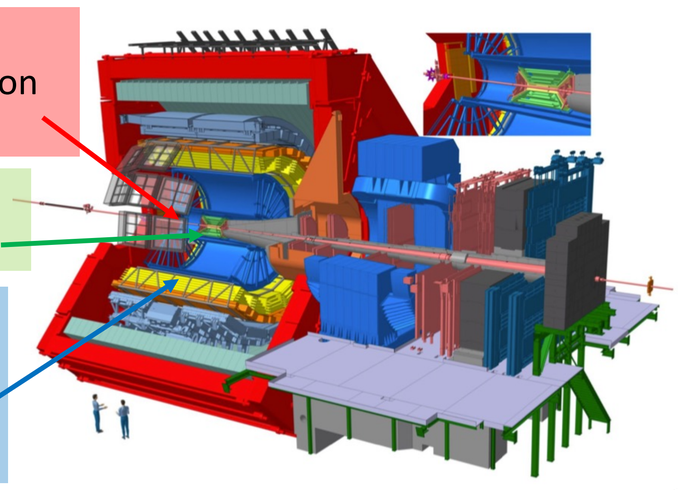
ALICE detector

- $B = 0.5$ T
- $|\eta| < 0.9$

V0 detector
➢ Centrality selection and trigger

ITS (Inner Tracking System)
➢ Vertex reconstruction

TPC (Time Projection Chamber)
➢ Tracking charged particle in 3D
➢ PID by energy loss measurement



Λ reconstruction with BDT

■ Procedure for BDT

✓ Software package : hipe4ml (https://doi.org/10.5281/zenodo.5070131)
  • BDT algorithm : XGBoost
① Training with background and signal samples
  • BG samples : Sideband pairs, True samples : Λ from MC
② Trained BDT is applied to real data
  • Data set : Pb-Pb 5.02 TeV, 0-10% centrality

Training data

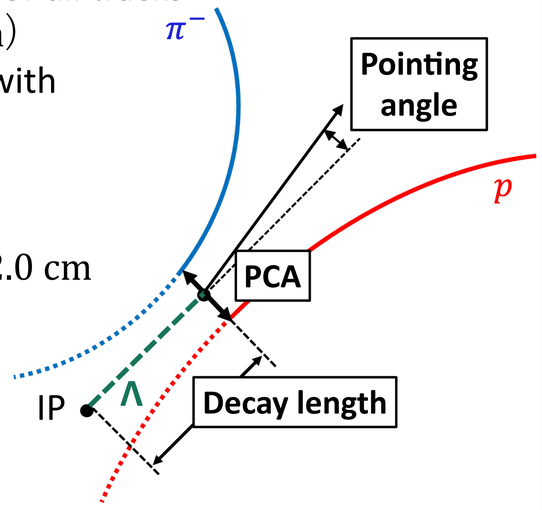
Background samples + **Signal samples** → hipe4ML → **Real data**

■ Training details

① Λ reconstruction using KFParticle package

✓ Secondary vertex finding by Kalman Filter for all tracks
  • $\Lambda \rightarrow p\pi^- \ (\mathrm{B.R.} = 63.9\ \%, c\tau = 7.89\ \mathrm{cm})$
➢ Signal and background samples prepared with loose secondary vertex selections

Loose vertex cuts for Λ
- Cosine Pointing Angle (CPA) > 0.8
- DCA between daughter tracks (PCA) < 2.0 cm
- Decay length < 100 cm

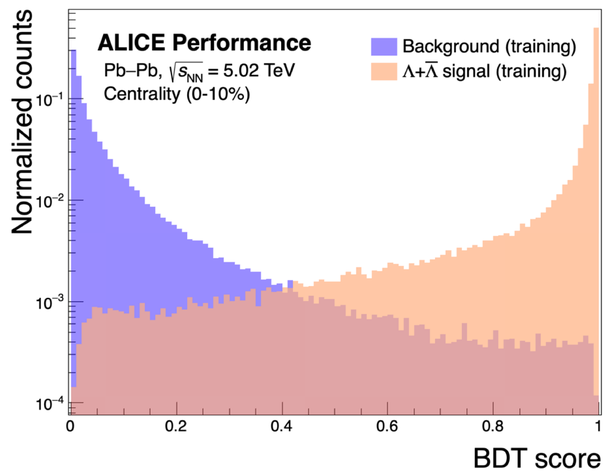


② Training inputs

✓ Signal : Injected $\Lambda(\bar{\Lambda})$ from MC
  • ~ 0.1M samples
✓ Background : Sideband pairs
  • ~ 0.1M samples
✓ BDT input parameters
  • Daughter tracks
    - DCA, dE/dx inTPC
  • Reconstructed Λ
    - CPA, PCA, Decay length

③ Training results

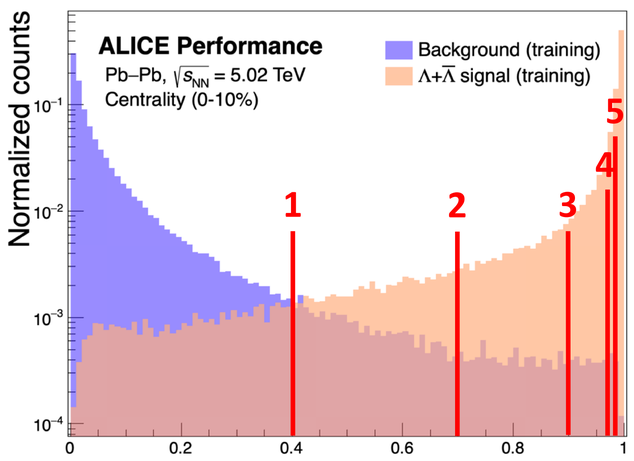
➢ Possible to separate signal and background above BDT score = 0.4.



BDT results for Λ

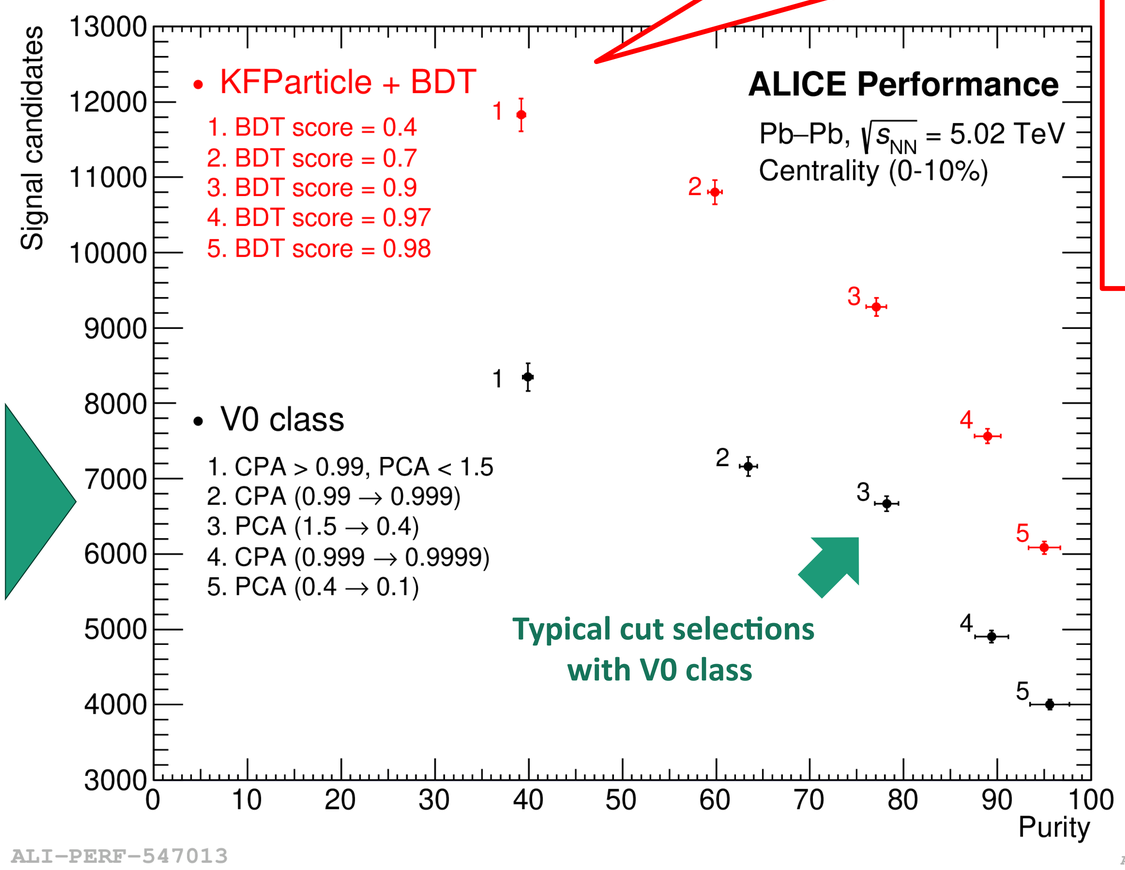
■ Extraction of signal candidates

✓ Calculation of purity and signal candidates with different BDT score thresholds
➢ Comparison with ALICE standard method (V0 class)
  ✓ Using common track selections and ...
    BDT : Apply BDT score threshold
    V0 : CPA and PCA variations for V0 cut selections
      • CPA : 0.99 -> 0.9999, PCA : 1.5 -> 0.1



Common Track selections

- $|\eta| < 0.8$
- $0.05 < \mathrm{DCA} < 3$ cm
- $N\sigma$ (dE/dx in TPC) $< 5\sigma$
- p_T cuts
  - Pion : $p_T < 1.5$ GeV/c
  - Proton: $p_T < 3.0$ GeV/c



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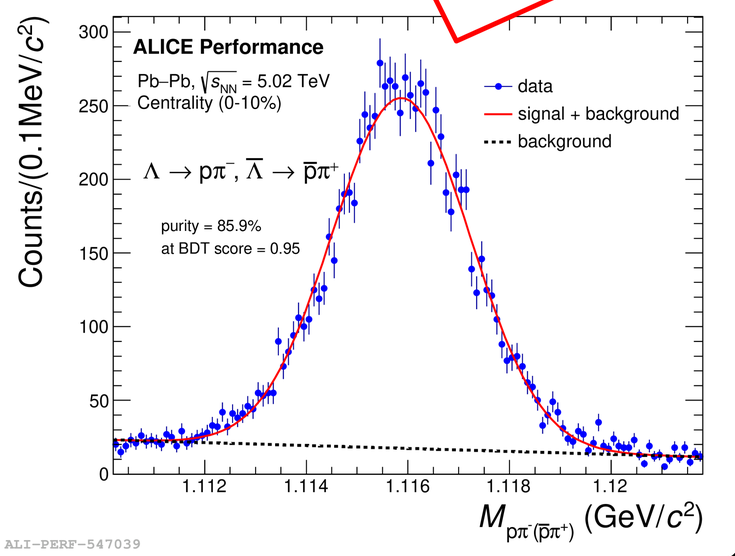
- **Purity reaches about 90% at BDT score threshold = 0.97.**
- **BDT works better than V0 class**
  - **More signal candidates & better purity**
    - **With BDT, purity is higher than 90% while keeping the same level of statistics.**
      - **Data point 3 = with typical cut selections for V0 class**

- **BDT score threshold = 0.95 looks good by a balance between purity and significance.**
  - **Significance is dropping above BDT score = 0.95.**
  - **Purity (~ 86%) is sufficient for the hyperon pair analysis.**



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Summary

- **Improvement of hyperon purity and efficiency in Pb-Pb for further understanding of baryon-baryon interactions**
  → Reconstruction with BDT
- **Good balance between purity and significance at BDT score threshold = 0.95**
- **Better results with BDT with respect to standard reconstruction method**

Future plans

- **Reconstruction of cascade particles (Ξ, Ω) with BDT in Pb-Pb**

➢ **Multi-strange dibaryon searches in Pb-Pb**
  • H dibaryon : ${}^1S_0$, NΩ dibaryon : ${}^5S_2$
➢ **$p\Omega^-$ Correlation function measurement in Pb-Pb**