Dimuon Invariant Mass Spectra with the Muon Telescope Detector (MTD) at STAR in p+p collisions at $\sqrt{s} = 200$ GeV

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Abstract

Dileptons ($\ell^+\ell^-$) are produced throughout all stages of heavy-ion collisions (HIC) through various production mechanisms. Since leptons have a small interaction cross section with the strongly interacting medium, they carry pristine information about the medium’s properties. Dileptons produced within the intermediate mass region (IMR, $M_{\ell\ell} < M_{\eta\eta} < M_{T}\gamma$) result predominantly from the decay of correlated charm but also arise from thermal radiation of the hot and dense medium. The inverse slope parameter of the thermally produced dileptons in the IMR provides a measure of the medium’s temperature at early times which is free from radial flow effects [1]. The installation of the Muon Telescope Detector (MTD) at STAR allows a measurement of the dimuon ($\mu^+\mu^-$) production in HICs over a large invariant mass range for the first time. Data has been collected with the full MTD from Au+Au collisions at $\sqrt{s}_{NN} = 200$ GeV and from p+p collisions at $\sqrt{s} = 200$ GeV. These two datasets allow for new opportunities to measure the dimuon invariant mass spectra at STAR. Before any dimuon measurements can be made, muons must be identified. This poster presents muon identification employing Deep Neural Networks (DNN) and compares it with other multi-variate techniques. Applications of the DNN technique for data-driven purity measurements are discussed.

Introduction and Motivation

Dileptons provide an excellent penetrating probe of the medium

- Leptons interact through the electromagnetic force, not via strong force – they carry pristine information about the medium’s properties
- Dilepton pairs are created throughout the entire lifetime of the system – physics from all stages can be probed by studying the invariant mass spectra
- NA60’s dimuon measurements in In+In [2] showed that precise dilepton measurements can provide information about chiral symmetry restoration and the created medium’s temperature at early times

Muon Telescope Detector (MTD) at STAR

- Multi Resistive Plate Chamber (MRPC) based detector installed outside magnet
- Efficient for $p_T > 1.0$ GeV/c
- Provides ~45% azimuthal coverage in $|\eta| < 0.5$
- Provides hit location with spatial resolution of ~2cm in $\Delta Y$ and $\Delta Z$
- Provides precise time resolution ~100 ps of hits

Schematic diagram of MTD strips

MTD $\Delta Z$ for simulated $\mu$ and $\pi$ in p+p collisions at $\sqrt{s}=200$ GeV

Multivariate Muon Identification

- Classifiers are compared by observing their background rejection power as a function of signal efficiency.
- Deep Neural Networks (DNN) and Boosted Decision Trees (BDT) are found to be significantly more powerful than traditional techniques.
- DNNs are found to be (1-3%) better than BDTs and DNNs are more robust against small differences between MC and data.

Data Driven Muon Purity Measurement

1. Evaluate DNN for tracks in data (grey)
2. Generate signal and background templates by evaluating DNN on simulated tracks
3. Template fit the data distribution (grey) to extract the yield of $\mu$, $\pi$, $K$, and $p$

Summary and Outlook

- Top: Raw $\mu^+\mu^-$ invariant mass spectra in p+p collisions at $\sqrt{s}=200$ GeV for traditional PID and for DNN PID.
- DNN PID substantially improves the significance of the $\omega$, $\phi$, and $\Psi(2S)$ resonances.
- Bottom: The simulated $\mu^+\mu^-$ invariant mass spectra for p+p collisions at $\sqrt{s}=200$ GeV for the MTD’s kinematic acceptance.
- The $c'c$ contribution is determined using the Pythia Event Generator [3].
- Final background and efficiency estimations are in progress.

References