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First look at beauty and beauty-jet tagging via secondary vertexing with ALICE in p+p collisions at $\sqrt{s} = 7$ TeV

MinJung Kweon

Physikalisches Institut, Universität Heidelberg,
Heidelberg, 69120, Germany
minjung@physi.uni-heidelberg.de

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The heavy flavour single electron data from RHIC indicate strong coupling of heavy quarks to the medium. The LHC extends greatly the kinematic range to high transverse momentum which enables new tests of heavy quark jet dynamics. Jets containing beauty hadrons have distinctive properties from other types of jets, which enhance their clear identification. We first introduce a method to preferentially select electrons from beauty hadron decay by reconstructing secondary vertices and show the results of this approach on simulated data. A preliminary look at the heavy flavour electron analysis and the beauty analysis in p+p collisions at $\sqrt{s} = 7$ TeV is also presented.

1. Introduction

Heavy quark jets are considered to be important independent probes of parton energy loss in the medium formed in heavy-ion collisions due to their large mass. The heavy flavour single electron data from RHIC revealed that heavy quarks are suppressed almost as much as light quark/gluon jets, which indicates strong coupling of heavy quarks to the medium[1].

The LHC extends greatly the kinematic range to high transverse momentum. Through the measurement of the nuclear modification factors of charm and beauty hadrons in Pb+Pb collisions, we expect to obtain insight into the color-charge and quark mass dependence of the energy loss mechanism. This requires precision measurements in p+p collisions as a baseline.

Jets containing b hadrons have distinctive properties from other types of jets. Through semileptonic decay, b hadrons produce leptons with relatively high rate(branching ratio ~ 20 % including decays via charm hadrons). These leptons have large transverse momenta relative to the jet axis due to large mass of the b quark. This, together with the harder fragmentation of b quarks with respect to lighter ones, makes them easier to separate from lepton sources in generic jets. Long lifetimes of b hadrons allow for tagging via displaced vertices. In addition, the large mass of b hadrons gives power to identify b jets by partially reconstructing b hadrons.

2. Heavy flavour measurement at ALICE

The expected $c\bar{c}$ and $b\bar{b}$ production yields for p+p collisions at $\sqrt{s} = 7$ TeV are 0.10 and 0.003 per event, respectively[2]. These values are about 10(100) times larger than RHIC for charm[3](beauty[4]), therefore provide rich heavy-flavour physics programs. The main analyses in ALICE are hadronic decays of open charm hadrons, single lepton decays of open charm and beauty hadrons and di-lepton decays of heavy quarkonium. In addition, combined analyses such as e-D^0 correlations and B-Jet studies are being performed in $\mid \eta \mid < 0.9$.

3. Heavy flavour measurement via single electron decays

ALICE has very good electron PID capabilities over a large kinematical range using the Time Projection Chamber(TPC), the Transition Radiation Detector(TRD), the Time Of Flight(TOF) and the Electromagnetic Calorimeter(EMCAL) which allow to use semileptonic electron decay channels of open heavy flavour hadrons. In addition, the TRD and EMCAL L1 trigger on single electrons will provide high statistics on high p_T electron samples. The excellent spatial resolution of the Inner Tracking System(ITS) provides a method to select displaced vertex.

The test beam measurements at the CERN PS with electron and pion beam show that the TRD gives factor 100 pion rejection with 90 % electron efficiency up to 10 GeV/c[5]. It is shown from the EMCAL test beam results that the EMCAL gives 700 rejection power at energy 40 GeV with 90 % electron efficiency[6].

3.1. *Heavy flavour electron measurement*

Utilizing the electron PID capabilities we can reconstruct inclusive and heavy flavour electron spectra. We first build an inclusive electron spectrum containing electrons from signal heavy flavour decays, hadronic decays(mainly π^0 and η Dalitz decays) and γ conversions in the material, then subtract the background electrons.

The background description is done via an electron cocktail. For electrons from hadronic decays we use the measured hadron(π^0) spectrum and use m_T scaling for the sources where no measurement is available yet. To describe γ conversion electrons, we use well understood material budgets. By requiring a hit on the most inner detector, we obtain ~ 1.2 % X_0.

3.2. *Beauty, beauty-jet tagging*

The beauty tagging method used in this analysis relies on the reconstruction of displaced secondary vertices from semi-leptonic electron decays of beauty hadrons. This analysis scheme has been used by CDF to tag b-jets in semi-leptonic muon decays[7]. Using the identified electron as a seed, it constructs a secondary vertex by attaching displaced hadron tracks, then applies a vertex χ^2 cut to select the secondary vertex candidates. The vertexing is done based on the Kalman Filter.

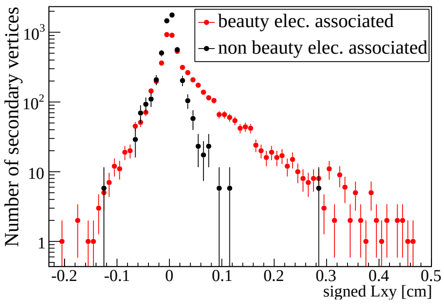

Fig. 1. Signed decay length distribution from beauty decayed electrons(red circle) and background electrons(black circle) associated to secondary vertices. The distributions are normalized to have the same number of entries.

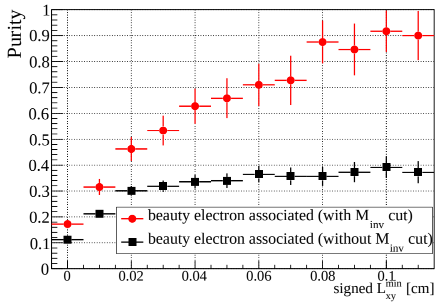

Fig. 2. Purity as a function of the minimum *Signed* L_{xy} cut for signals and backgrounds. $2.0 < M_{inv} < 5.2$ GeV/c^2 and single track $p_T > 2$ GeV/c cuts are applied.

The resulting distinctive variables of the secondary vertex candidates to which we apply further cuts to tag beauty decayed electrons are the followings:

- Sign assigned decay length(distance between primary and secondary vertex)

$$Signed\ L_{xy} = |\mathbf{r}|\frac{\mathbf{r}\cdot\mathbf{p}}{|\mathbf{r}\cdot\mathbf{p}|} \tag{1}$$

- Secondary vertex χ^2/NDF
- Invariant mass(M_{inv}) of the partially reconstructed secondary particle
- Impact parameter of the secondary particle

Figure 1 shows the distribution of *Signed* L_{xy} for the secondary vertices associated with signal and background electrons from PYTHIA simulation. The signal has distinctive distribution due to its larger decay length. Therefore we can define cuts to preferentially select electrons from beauty hadron decays. The secondary vertexing algorithm is symmetric in its treatment of *Signed* L_{xy} for the tracking resolution, so the tracking related mistag rate due to detector resolution effects can be obtained from the negative tag rate. In addition to *Signed* L_{xy}, the invariant mass cut is powerful to suppress charm electron background due to the large difference of the mass from charm and beauty hadrons. Figure 2 shows the purity as a function of the minimum *Signed* L_{xy} cut. Together with $2.0 < M_{inv} < 5.2$ GeV/c^2 and single track $p_T > 2$ GeV/c cuts, we obtain ~ 80 % purity by applying a cut of 800 μm on the minimum *Signed* L_{xy}. Without the invariant mass cut, we obtain ~ 35 % purity while leaving the other cuts the same.

The beauty jet tagging is done by applying the same beauty tagging method with jet associated tracks. The ALICE jet reconstruction performance with charged tracks is shown in other presentations at this workshop.

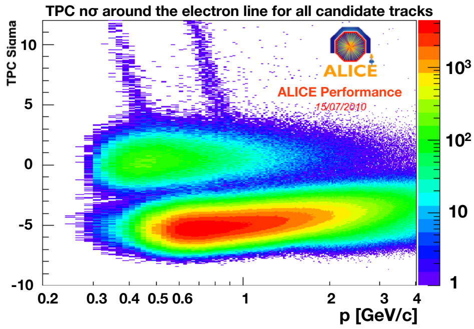

Fig. 3. Number of σs from the TPC dE/dx electron line after TOF PID 3 σ cut from the electron line.

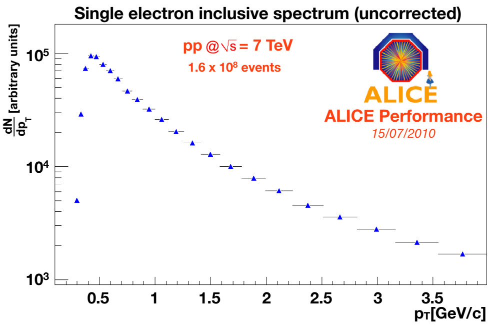

Fig. 4. Single electron inclusive spectrum obtained from 1.6×10^8 minimum bias events in p+p collisions at $\sqrt{s} = 7$ TeV. The spectrum is not corrected for the acceptance and efficiencies.

4. Preliminary look of p+p at $\sqrt{s} = 7$ TeV

The Inclusive electron spectrum has been measured with ALICE in p+p collisions at $\sqrt{s} = 7$ TeV. The combination of cuts on signals in TOF and TPC provide a very clean electron sample for momenta to 4 GeV/c. For higher momenta the analysis is ongoing to understand the performance of TRD and EMCAL with real data. To select a pure sample of electrons, tracks within 3 σ from TOF electron line are selected first. Then n σ cut is applied from TPC dE/dx electron line of Bethe-Bloch parameterization describing the linear energy loss in the TPC. To minimize the pion contamination, we use a momentum dependent cut at lower bound and a constant 3 σ cut at upper bound. Figure 3 shows the number of σ from the TPC dE/dx electron line after TOF PID cut. The very clear separation between electrons and pions is evident.

Figure 4 shows the resulting single electron inclusive spectrum obtained from 1.6×10^8 minimum bias events. The spectrum is not corrected for acceptance and efficiencies and not unfolded in p_T. It includes electrons from heavy flavours, hadron Dalitz decays, γ conversions in the material and misidentified hadrons. We estimate a hadron contamination of $25 \sim 30$ % at 4 GeV/c by calculating the yield via a gaussian fit of the dE/dx projection for this momentum region. The contamination is less than 1 % around 2 GeV/c.

To understand the electron identification performance with the TRD, we check the response of the TRD to pions from K^0 decays and to electrons from γ conversions. Our current understanding is that the TRD provides two additional orders of magnitude in pion rejection power with a 70 % electron efficiency at 2 GeV/c.

It is crucial to have a precise understanding on the material budgets to estimate γ conversions into electrons. Figure 5 shows the radial distance distribution of the γ conversion points for real and MC data, which gives an agreement within 5 %.

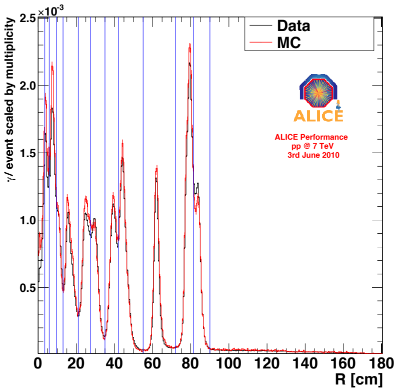

Fig. 5. Radial distance distribution of the γ conversion points, real and MC data.

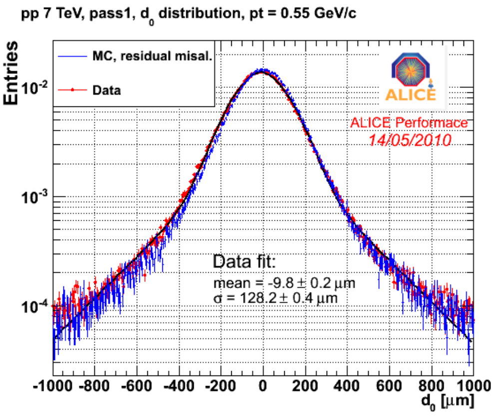

Fig. 6. Transverse impact parameter distribution with beam diamond vertex constraint in real and MC data

Impact parameter resolution is the convolution of the track position and the primary vertex resolution. Figure 6 shows the transverse impact parameter distributions of tracks for real and MC data. MC and data agree within 10 %.

5. Conclusions

ALICE shows excellent electron identification and vertexing performance and this allows the analysis of heavy flavour electrons and beauty electron tagging. The heavy flavour electrons analysis is ongoing in p+p collisions at $\sqrt{s} = 7$ TeV together with the detailed understanding of electron identification performance of the detectors and material budgets. The beauty-jet tagging is also on its way to be analysed with data. We wait for the Pb-Pb collisions foreseen in November 2010, which will provide a tool to understand heavy flavour energy loss in the medium.

Acknowledgments

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