Measurement of electrons from heavy-flavour decays with ALICE at LHC

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• Introduction
  • Electron identification in ALICE
  • Charm and beauty production in pp at $\sqrt{s}=7$ TeV
  • Electrons from PbPb collisions at $\sqrt{s}_{NN}=2.76$ TeV
Heavy-flavour production

Measure the $c\bar{c}$ and $b\bar{b}$ production cross sections through **semileptonic decays** of open charm and open beauty hadrons:

**Proton-proton collisions**
- Test of pQCD description of heavy flavour production in pp
- Reference for the study of medium effects in heavy-ion collisions

**Heavy-ion collisions**
- Heavy quarks in the produced medium
- Reference for quarkonia studies
- Elliptic flow

Branching Ratios:
- $c \rightarrow e + X \quad \mathcal{O} (9.6\%)$
- $b \rightarrow e + X \quad \mathcal{O} (11\%)$
- $b \rightarrow c \rightarrow e + X \quad \mathcal{O} (10\%)$
Heavy-flavours probes of the medium

- Heavy flavors are produced in the **INITIAL** partonic collisions → present from the early time of the medium, in the **HIGHEST DENSITY** phase

- Travel and interact in the medium → **FULL collision history**

- Test models of **in-medium partonic energy loss**: → dependence on mass / flavour / color

\[ R_{AA}^{π} < R_{AA}^{D} < R_{AA}^{B} \]

**Separation between charm and beauty → ALICE !!!**
Heavy-flavours in ALICE

- Excellent vertex resolution
- Excellent momentum resolution ...
- .. and particle identification over a wide momentum range

- Forward rapidity: muons
- Mid-rapidity:
  - Hadronic decays and \textit{electrons}
  - Direct measurement of \textit{beauty}

\begin{tabular}{|l|c|c|}
\hline
System & $\sqrt{s_{NN}}$ [TeV] & Events \\
\hline
pp & 7 & $1.8 \cdot 10^8$ \\
Pb-Pb & 2.76 & $1.7 \cdot 10^7$ \\
\hline
\end{tabular}
Electron identification in ALICE

**Time Of Flight**
compatibility cut to expected time of flight for electron hypothesis ($\pm 3\sigma$)
Rejects kaons up to 1.5 GeV/c and protons up to 3 GeV/c

**Time Projection Chamber**
dE/dx in $\sigma$'s around the electron
Bethe Bloch parametrization
→ select entries in the top half of the distribution
Electron identification in ALICE

**Transition Radiation Detector**
Energy deposit + TR
Electron likelihood cut fixed at 80% electron efficiency
Strong π suppression!

*See M. Fasel's poster*

**ElectroMagnetic Calorimeter**
TPC-EMCal matching, E/p cuts
*See S. Sakai's poster*
Inclusive electrons in pp at $\sqrt{s}=7$ TeV

**Inclusive electron spectrum**

Electron ID with TOF-TRD-TPC

**Cocktail of “background” electrons**

- Dalitz decays. Input: the measured $\pi^0$ spectrum
- Heavier mesons by $m_T$ scaling
- Photon conversions
- $J/\psi$, $\Upsilon$
- QCD photons ($\gamma$, $\gamma^*$)

**pp, $\sqrt{s}= 7$ TeV, $\int$ Ldt $= 2.6$ nb$^{-1}$ cocktail:**

- $(e^+ + e^-)/2$
- $\pi^0$ conv. of $\gamma_{\text{meson}}$
- $\eta$, $\omega$, $\phi$, $\eta'$, $\rho$, $J/\psi$
- $\Upsilon$ direct $\gamma$, $\gamma^*$

ALICE Preliminary
7% normalization error
Charm and beauty production in pp

Inclusive – cocktail

Electrons from heavy flavour hadron decays (charm and beauty)

Compared to FONLL

Cacciari et al.

See M. Fasel's poster (TRD) and S. Sakai's poster (EMCal: consistent analysis!)
Direct beauty measurement in pp

Beauty $c\tau \approx 500 \, \mu m \rightarrow$
Isolate beauty decays by the large impact parameter of the electron
Residual bkg's subtracted

High resolution on impact parameter: 50 $\mu m$ at 2 GeV/c
Data very well described by MC

Well described by FONLL predictions

See M. Kweon's poster
More beauty results in pp

Alternative way to measure beauty:

(inclusive $e$) − (cocktail)

(electrons from decay of ALICE D mesons)

Beauty / charm
From proton-proton ...  

... to Pb-Pb collisions !!!
PbPb: Inclusive electron spectra

Inclusive electron spectra in 6 centrality bins
- PID with TOF and TPC:
  → spectra between 1.5 and 6 GeV/c where hadron contamination is <10%

Electron cocktail
- Analogue to pp analysis
- Input: charged $\pi$ spectra

All PbPb results → Y. Pachmayer's poster
PbPb: Inclusive and cocktail - 0-10%

Inclusive – cocktail = electrons from heavy flavour decays

... Only??

\[ \text{cocktail: } \frac{(e^+ + e^-)}{2} \]

\[ \text{conv. of } \gamma_{\text{meson}} \]

\[ \pi^0, \eta, \phi \]

\[ \eta', \rho, \omega \]

\[ \text{direct } \gamma, \gamma' \]

Inclusive \( \frac{e^+ + e^-}{2} \)

\( 1/2p_T^2N/d\eta dp_T dy \)

\( y |< 0.8 \)

\( \text{Pb-Pb, } \sqrt{s_{NN}} = 2.76 \text{ TeV} \)

0-10% central

\( p_T (\text{GeV/c}) \)

Ratio

\( \text{Inclusive electron / Cocktail} \)

\( \text{Sys. error from inclusive electrons} \)

\( \text{Total sys. error} \)
PbPb: Inclusive and cocktail - 0-10%

Inclusive – cocktail = electrons from heavy flavour decays

... Only??

\[ \text{cocktail: } \frac{(e^+ + e^-)}{2} \]

\[ \text{conv. of } \gamma_{\text{meson}} \]

\[ \pi^0, \eta, \phi, \eta', \rho, \omega, \text{direct } \gamma, \gamma' \]

Inclusive \[ \frac{e^+ + e^-}{2} \]

\[ \frac{1}{2\pi} p_T^2 N/dp_T dy (\text{GeV/c})^2, |y|<0.8 \]

Pb-Pb, \( \sqrt{s_{\text{NN}}} = 2.76 \text{ TeV} \)
0-10% central

Low \( p_T \) region:
Excess?
pp, PbPb peripheral and PbPb central

At low $p_T$: hint for an excess
Increases towards more central collisions

Consistent with thermal radiation?
Thermal photons observed at RHIC
Nuclear modification factor ...

... of electrons from heavy flavour hadron decays, for $p_T > 3.5$ GeV/c:

$$R_{AA} (p_T) = \frac{1}{< T_{AA} >} \times \frac{dN_{AA}}{dp_T} \times \frac{d\sigma_{pp}}{dp_T}$$

pp reference at 2.76 TeV:
Scaled from the spectrum at 7 TeV with FONLL

Large uncertainty at low $p_T$
Most central: 0-10%

Low $p_T$ region: $R_{AA}$ dominated by systematic uncertainties

Excess under investigation

$R_{AA}$ of electrons from heavy flavour hadron decays
Electron $R_{AA}$: central vs peripheral

Electrons from heavy flavour hadron decays

$\rightarrow$ CHARM + BEAUTY

Suppression in central collisions

Large uncertainties
Electron and muon $R_{AA}$

Electrons: Mid-rapidity $|\eta| < 0.8$

Muons: Forward rapidity $-4 < \eta < -2.5$

Same suppression within large sys. uncertainties

$Muons \rightarrow X. \ Zhang's \ talk$
Summary

- Excellent performance of LHC
- ALICE exploits its particle ID and vertex resolution
- Single electron analysis very successful!
- **Proton-proton**
  - Charm + beauty production at mid-rapidity
  - Selection of pure beauty decays
  - Well described by FONLL

- **PbPb**: after 6 months!
  - Charm + beauty spectra
  - Nuclear modification factor → suppression of heavy flavours in central collisions
  - Pure beauty very soon
  - Exciting hints concerning properties of the medium produced at these new energies
Related Posters

- **pp analysis with the TRD detector**
  Markus Fasel, “Hunting electrons from heavy-flavour hadron decays with the ALICE Transition Radiation Detector in proton-proton collisions at $\sqrt{s} = 7$ TeV”

- **pp analysis with the EMCal detector**
  Shingo Sakai, “Measurement of electrons from heavy-flavor decays in p-p and Pb-Pb collisions with the ALICE EMCal”

- **Direct beauty measurement in pp**
  MinJung Kweon, “Study of beauty production in pp collisions at $\sqrt{s} = 7$ TeV with ALICE, using displaced electrons”

- **PbPb analysis**
  Yvonne Pachmayer, “Measurement of the Nuclear Modification Factor of Electrons from Heavy Flavour Decays at Mid-Rapidity in Pb-Pb Collisions at $\sqrt{s_{NN}} = 2.76$ TeV with ALICE”
Electron selection efficiency

TOF (3σ electron compatibility cut) and TPC (top-half dE/dx cut)

In pp: also TRD
0.35 (acc) * 0.80 (PID ε) down
Electron identification in ALICE

**Time Of Flight**
compatibility cut to $\text{ToF}_{\text{electron}} (\pm 3\sigma)$
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and protons up to 3 GeV/c

**Time Projection Chamber**
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**Transition Radiation Detector**
Electron likelihood cut fixed at 80% electron efficiency
See M. Fasel’s poster

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The electron cocktail

All sources of electrons:

- **Dalitz decays of light neutral mesons** \((\pi^0, \eta, \omega, \eta', \varphi \rightarrow \gamma e^+e^-)\)
- **Photon conversions in material**
- **Direct radiation** (direct photon conversions, virtual photons \(\gamma^* \rightarrow e^+e^-\))
- **Weak kaon decays** (e.g. \(K^\pm \rightarrow \pi^0 e^\pm\nu_e\))
- **Dielectron decays of vector mesons** (\(\rho, \omega, \varphi \rightarrow e^+e^-\))
- **HEAVY FLAVOR DECAYS** (open charm and beauty, \(J/\psi, \Upsilon\))

Current cocktail ingredients:

- **Neutral pions** (based on the measured \(\pi\) spectra)
- **Heavier mesons**: \(\eta, \rho, \omega, \varphi, \eta'\)
- **Photon conversions**
- **\(J/\psi, \Upsilon\)**, direct photons
pp collisions at $\sqrt{s}=7$ TeV

pp, $\sqrt{s} = 7$ TeV, $\int L dt = 2.6$ nb$^{-1}$

cocktail: $(e^+e^-)/2$

+ Data

$\pi^0$, $\gamma$ conversion

$\eta$, $\omega$, $\phi$

$\eta'$, $\rho$, $J/\psi$

$\gamma$, direct radiation

ALICE Preliminary

7% normalization error

$\int L dt = 2.6$ nb$^{-1}$

pp, $\sqrt{s} = 7$ TeV

ALICE Preliminary

inclusive electrons / cocktail, $|y|<0.8$
pp systematics on the spectrum

ALICE Performance 19/05/2011

7% error on cross-section not included
pp systematics on the cocktail
PbPb systematics on the spectrum

ALICE Performance
20/05/2011
PbPb systematics on the cocktail

\( \text{Pb-Pb}, \sqrt{s_{NN}} = 2.76 \text{ TeV} \)

- 0-10% central
- 60-80% central

ALICE Performance
19/05/2011

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- From the PbPb note:
Inclusive/cocktail, pp and more centrality bins