Measurement of electrons from beauty-hadron decays in pp collisions at √s = 13 TeV

Jiyeon Kwon
Inha University

CENuM Workshop
4 July 2020

Motivation

- **Heavy quarks: charm & beauty**
  - Large masses ($m_q \gg \Lambda_{QCD}$)

    → Produced via hard scatterings in early stage of heavy-ion collisions, compared to the formation time of the QGP. ($t_{charm} \sim 1/m_c \sim 0.1$ fm/c << $\tau_{QGP} \sim O(10$ fm/$c)$)
  - Long lifetime

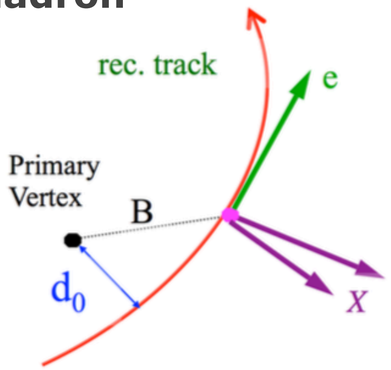
    → Experience the full evolution of the system created in collisions → Natural probe of the QGP

- **Parton energy loss in the medium**
  - Prediction for parton energy loss in the medium: $\Delta E_g > \Delta E_{u,d,s} > \Delta E_c > \Delta E_b$
  - By separating beauty quarks from charm quarks, the mass dependence of the parton energy loss in the QGP can be studied.

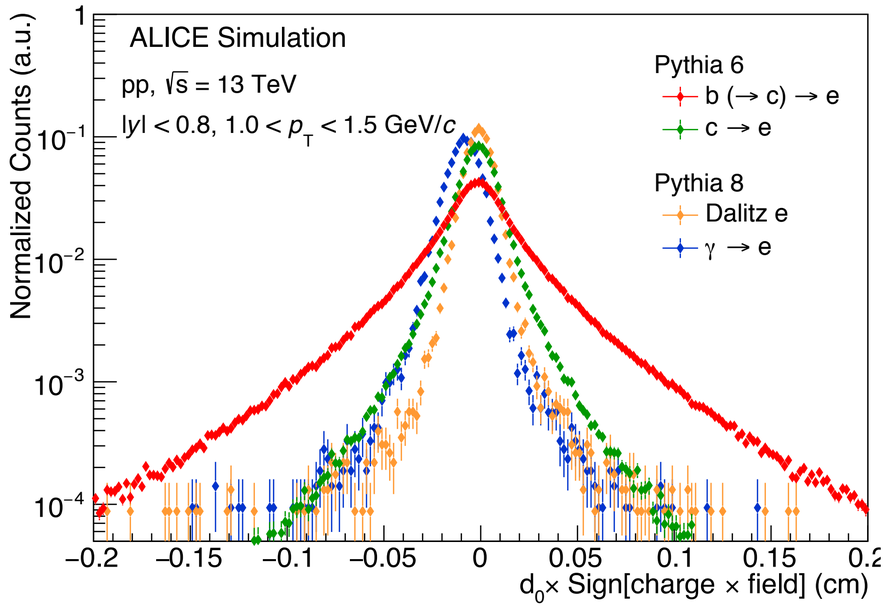
- **pp collisions**
  - Verify pQCD calculations at LHC energies.
  - Reference measurements for p-Pb and Pb-Pb collisions

Strategy

- **Beauty production measurement via electrons from semi-leptonic decays of beauty-hadron**
  - Substantial branching ratio: b → e + X (~11%), b → c → e + X (~10%)
- **Impact parameter (IP):**
  Distance of the closest approach of a particle's reconstructed track to the primary vertex.
- **b quarks hadronise mainly to B mesons which has long lifetime (cτ ≃ 500 μm)**
  ⇒ **Larger impact parameter of B→e**



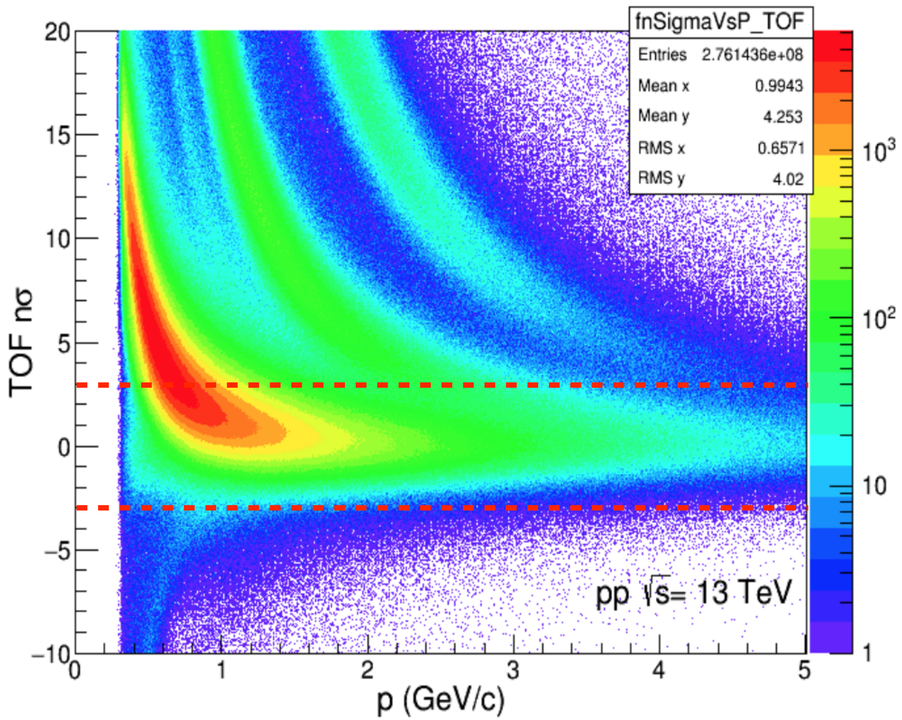
- **IP distributions of electron contributions from:**
  - Semi-leptonic beauty-hadron decays → **SIGNAL!**
  - Semi-leptonic charm-hadron decays
  - Dalitz decays of light mesons
  - Photon conversions in the detector material
- **Beauty electrons are measured by fitting Monte Carlo templates of IP distributions of signal and background contributions for each p_T bin.**



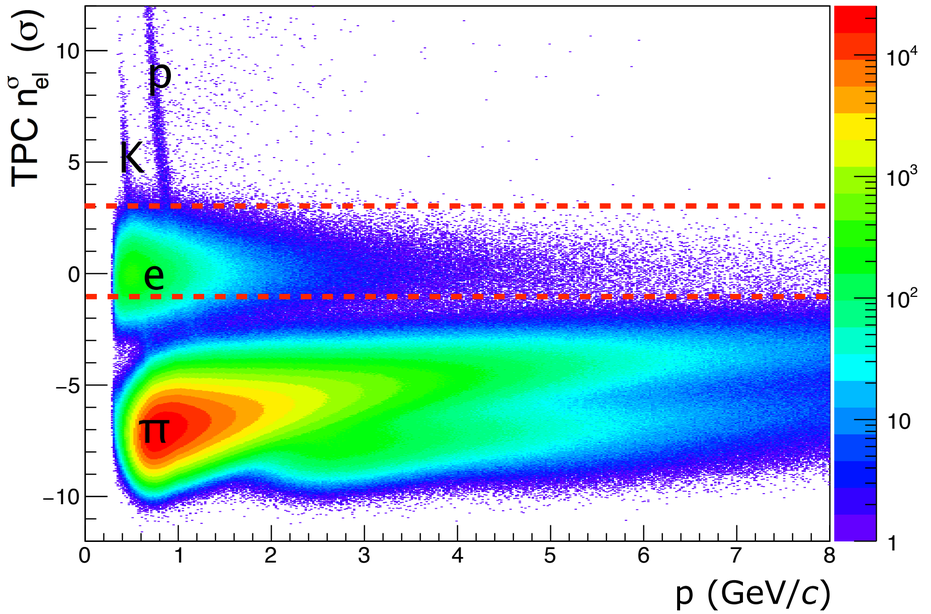
Electron identification

- Electrons are identified using the Time Projection Chamber (TPC) and the Time-of-Flight detector (TOF).

  - The Time-of-Flight detector (TOF)
    - TOF measures the velocity β of the particles.
    - |TOF nσ| < 3σ

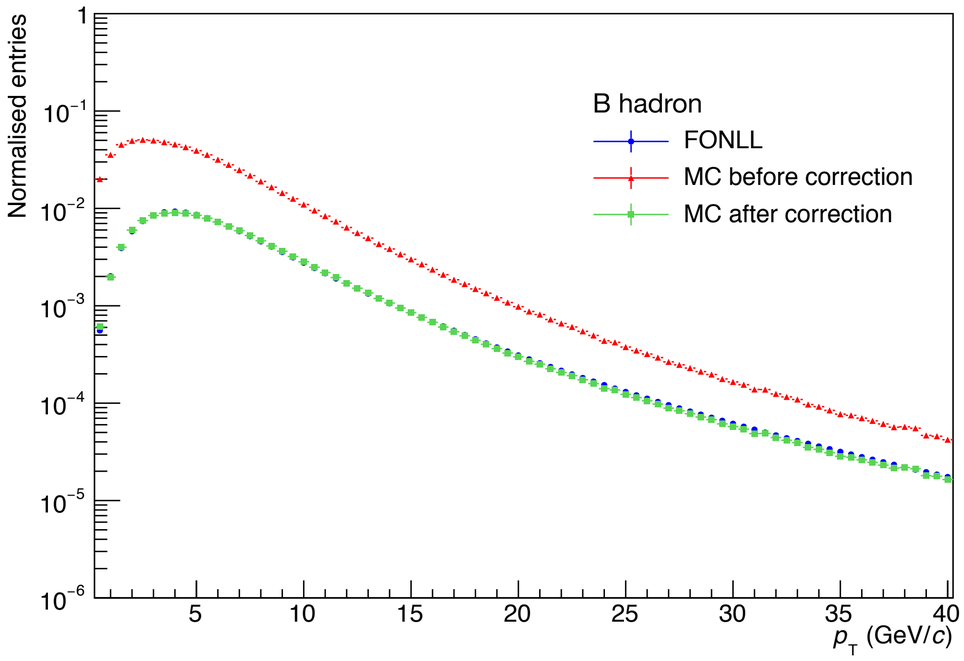


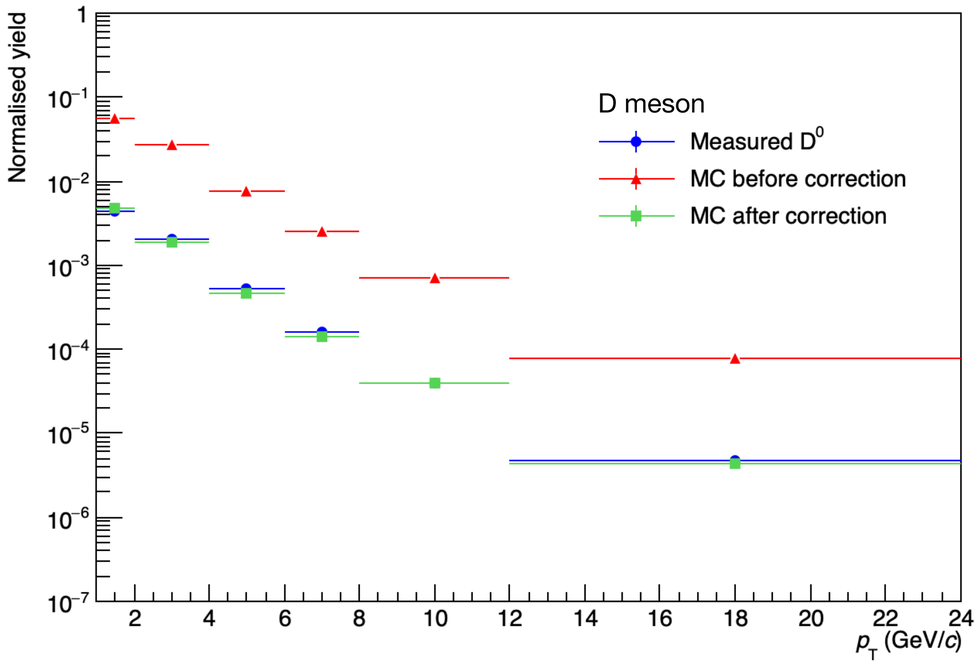
  - Time Projection Chamber (TPC)
    - TPC measures ionisation energy loss of charged particles passing through the gas volume in the TPC.
    - -1σ < TPC nσ < 3σ



MC template correction: p_T correction of B hadron and D meson

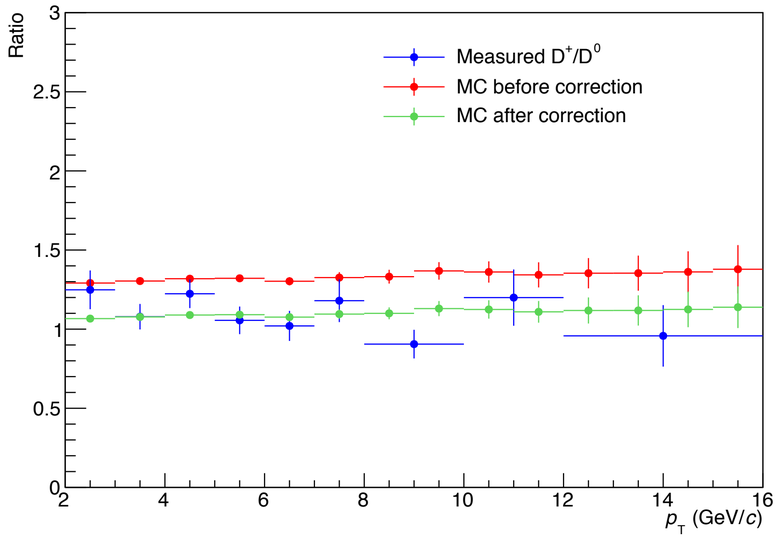
- IP of decay daughter depends on p_T of electron sources, but there's a discrepancy between data and MC.
- $w_B = \dfrac{B\ hadron\ p_T\ spectrum\ by\ FONLL\ calculation}{B\ hadron\ p_T\ spectrum\ in\ MC}$ $\qquad$ $w_D = \dfrac{Measured\ D^0\ p_T\ spectrum}{D^0\ p_T\ spectrum\ in\ MC}$
- With the weighting factor, the p_T of electrons from B hadron (or D meson) are weighted according to the p_T of mother B hadron (or D meson).

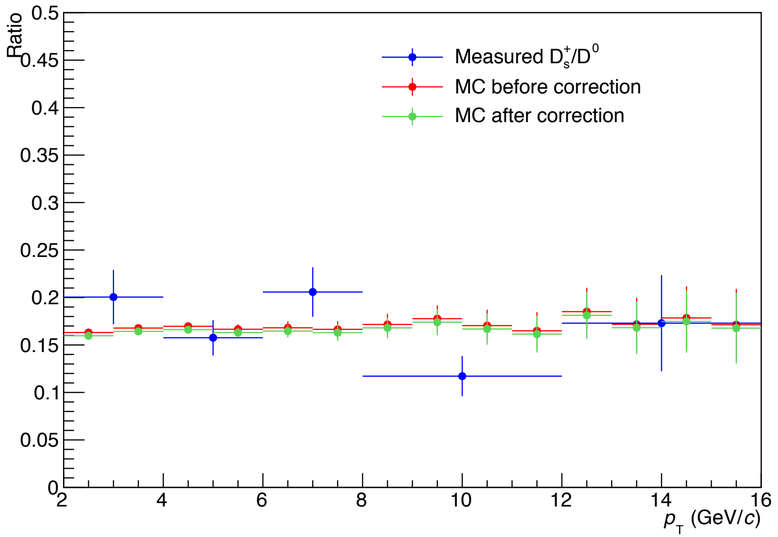


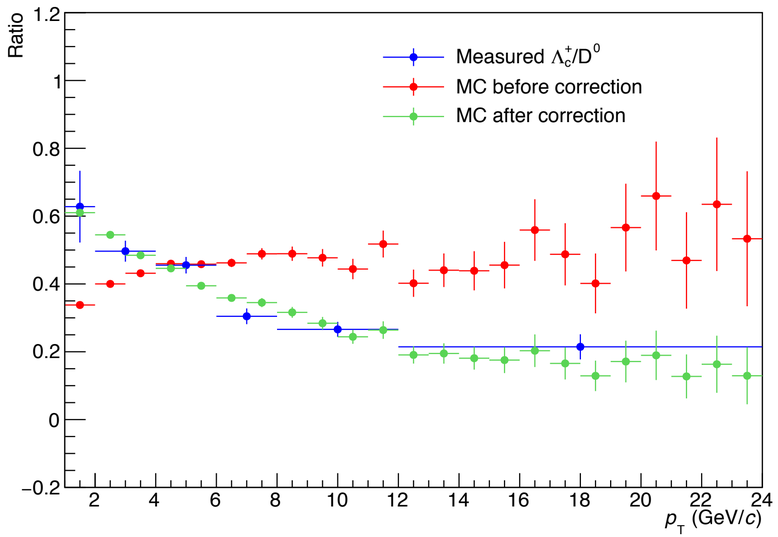


MC template correction: Yield correction for D hadrons (D^+, D_s^+ and Λ_c^+)

- Wrong fraction of different charm species affects a shape of the charm template, because the each charm species have different decay lengths.
- The relative fraction of different D hadrons is corrected by scaling the yield of the D^+, D_s^+ and Λ_c^+.
- $$w = \frac{Measured\ D\ hadron}{Measured\ D^0} \times \frac{D^0\ in\ MC}{D\ hadron\ in\ MC}$$

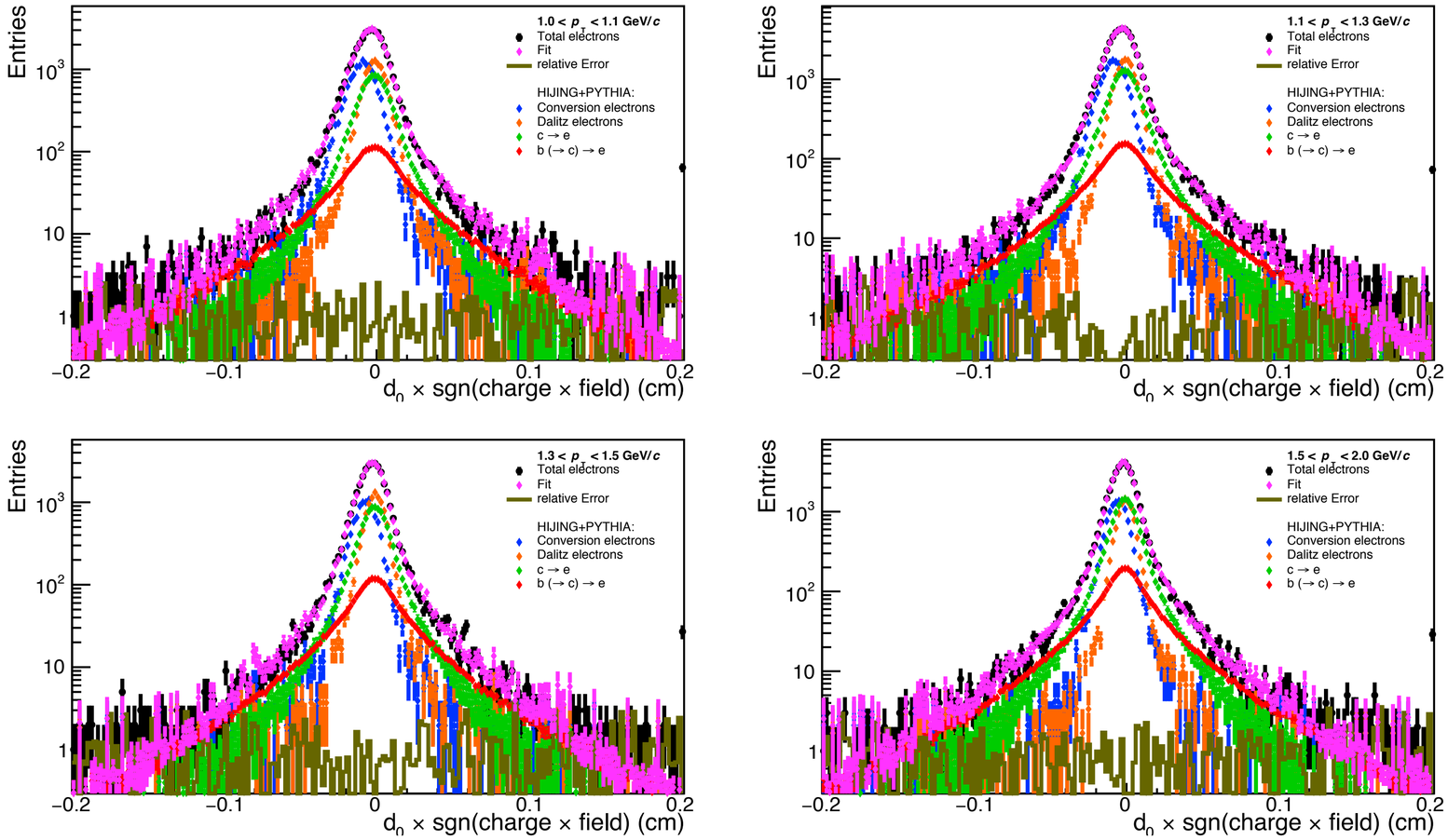






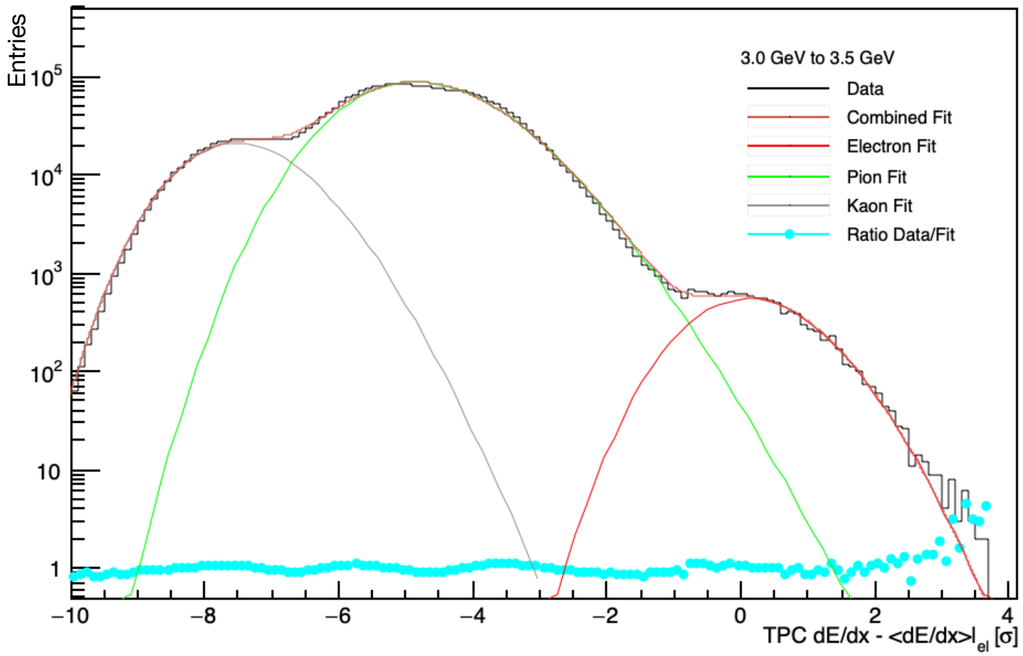
Fitting MC templates to data

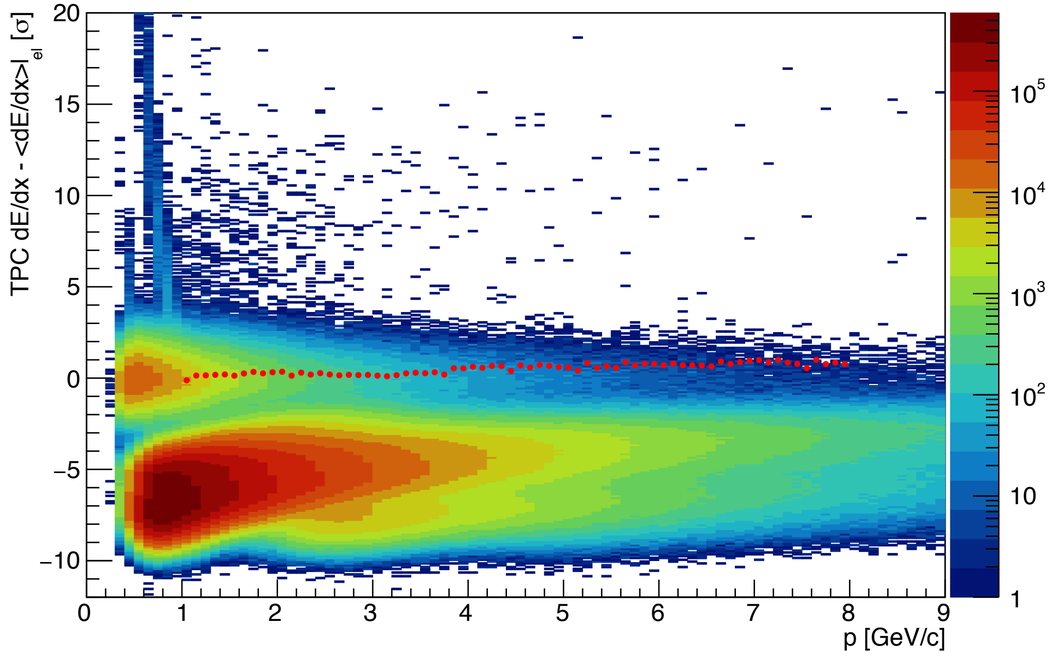
- Raw yield of beauty electrons is measured by fitting MC templates to data.



Data-driven TPC eID efficiency

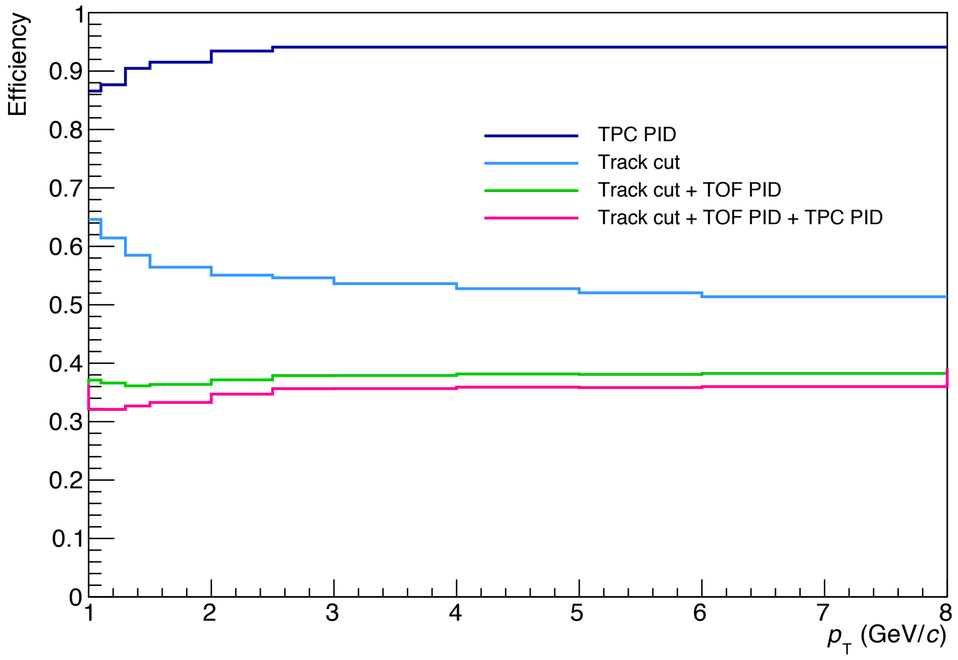
- The TPC nσ distributions of electrons are plotted in different momentum bins and fitted with functions which describes each contributions of the particles.
- $TPC\ eID\ efficiency = \dfrac{integral\ of\ the\ electron\ fit\ in\ -1 < TPCn\sigma < 3}{total\ integral\ of\ the\ electron\ fit}$





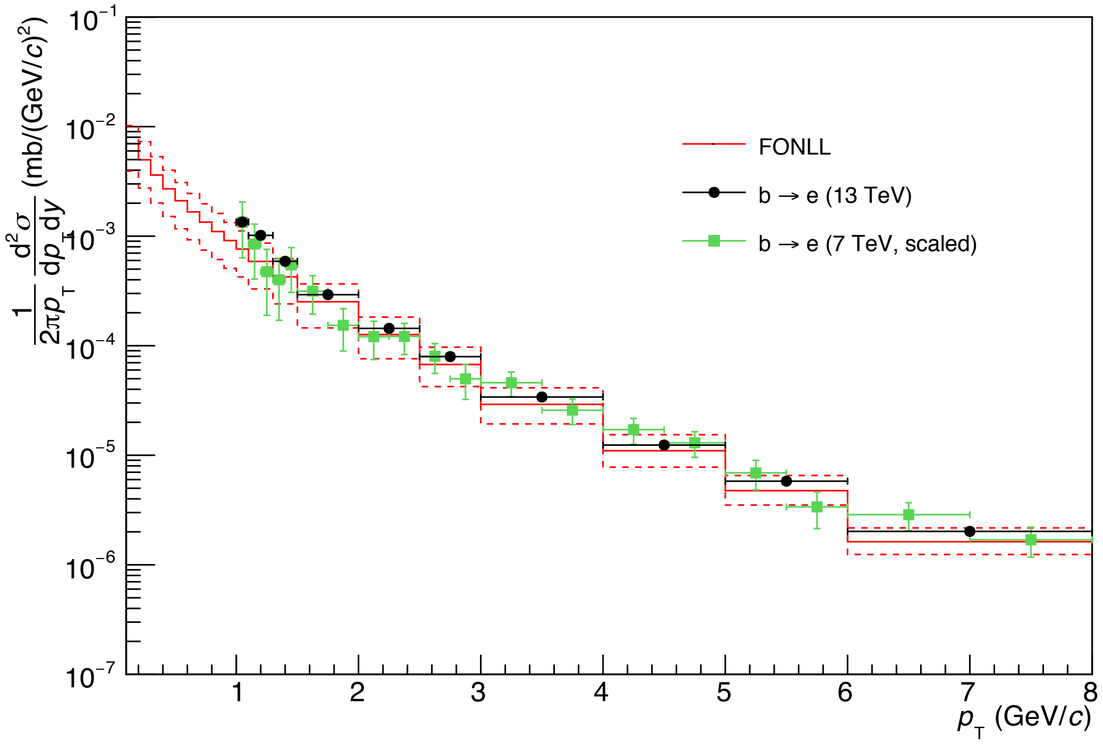
Efficiency correction

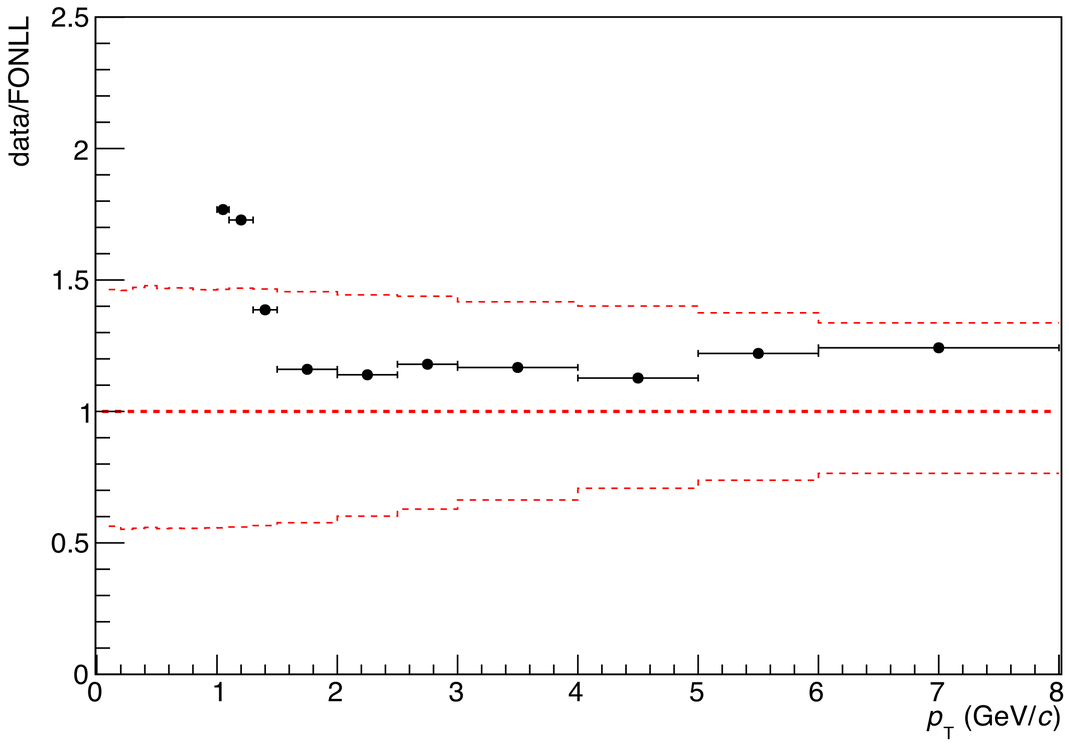
- Raw yield of beauty electrons is corrected by the track cut efficiency and PID efficiency for electron selection.
- The track cut and TOF PID efficiencies are calculated from MC: $Efficiency = \frac{(N\ of\ beauty\ electrons\ after\ cuts)}{(N\ of\ beauty\ electrons\ before\ cuts)}$
- Total efficiency including data-driven TPC PID efficiency is used to correct raw yield.



Invariant differential cross section of beauty electrons

- Invariant differential cross section: $$\frac{1}{2\pi p_{\mathrm{T}}}\frac{\mathrm{d}^2\sigma^e}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y} = \frac{1}{2}\frac{1}{2\pi\, p_{\mathrm{T}}^{\mathrm{centre}}}\frac{1}{\Delta y \Delta p_{\mathrm{T}}}\frac{N^e_{\mathrm{raw}}(p_{\mathrm{T}})}{(\varepsilon^{\mathrm{geo}}\times\varepsilon^{\mathrm{reco}}\times\varepsilon^{\mathrm{eID}})}\frac{\sigma_{\mathrm{V0}}}{N^{V0}_{\mathrm{ev}}}$$
- Cross section of 7 TeV is scaled to 13 TeV using a FONLL ratio of 13 TeV to 7 TeV.





Summary and outlook of the analysis

- Beauty production is studied via measurement of electrons from semi-leptonic decays of beauty-hadron in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE.
- Electrons are identified using the Time Projection Chamber (TPC) and the Time-of-Flight detector (TOF).
- MC templates are corrected for p_T spectra and yields of mother particles.
- Raw yield is obtained by fitting the corrected MC templates to data and corrected with reconstruction and PID cut efficiencies.
- Invariant differential cross section is calculated and compared with FONLL calculation and scaled 7 TeV result.
- Systematic uncertainties will be studied.

Backup

Dataset and quality cuts

Data		MC general purposed		MC enhanced		Remarks
Period	N of events	Period	N of events	Period	N of events	pass2, AOD
LHC16k	128.88M	LHC18f1	37.45M	LHC18f4b	24.91M	
LHC16l		LHC18d8				

Event selection	
Cut	Value
Trigger	kINT7
$\|V_z\|$	< 10 cm
NcontribVertex	> 0
NcontribSPDVertex	> 0
$\|V_z - V_{z.spd}\|$	< 0.5 cm
vertexResolution	< 0.25 cm

Track selection	
Cut	Value
Number of clusters on TPC	100
Number of clusters on TPC for PID	80
Number of cluster on ITS	3
Ratio of TPC clusters	0.6
Number of hits in SPD layers	2
DCA_r	< 1 cm
DCA_z	< 2 cm
$\|\eta\|$	< 0.8
Kink daughters	Rejected
TOF nσ	$\|n\sigma_{TOF}\| < 3$
TPC nσ	$-1 < n\sigma_{TPC} < 3$