Universität
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Summary of
“Measurement of electrons from beauty hadron decays at $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 2.76 TeV”

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HD group meeting

Outline

[Motivation of the measurement]

[Analysis method and key components of this analysis]

[Results]

- [p_T differential cross section and comparison to the alternative methods]
- [Total cross section]

Motivation of b→e measurement in pp collisions

- Heavy quarks are produced dominantly via initial hard parton scatterings, therefore their production cross section constitute a prime benchmark for the pQCD calculations in a new energy domain

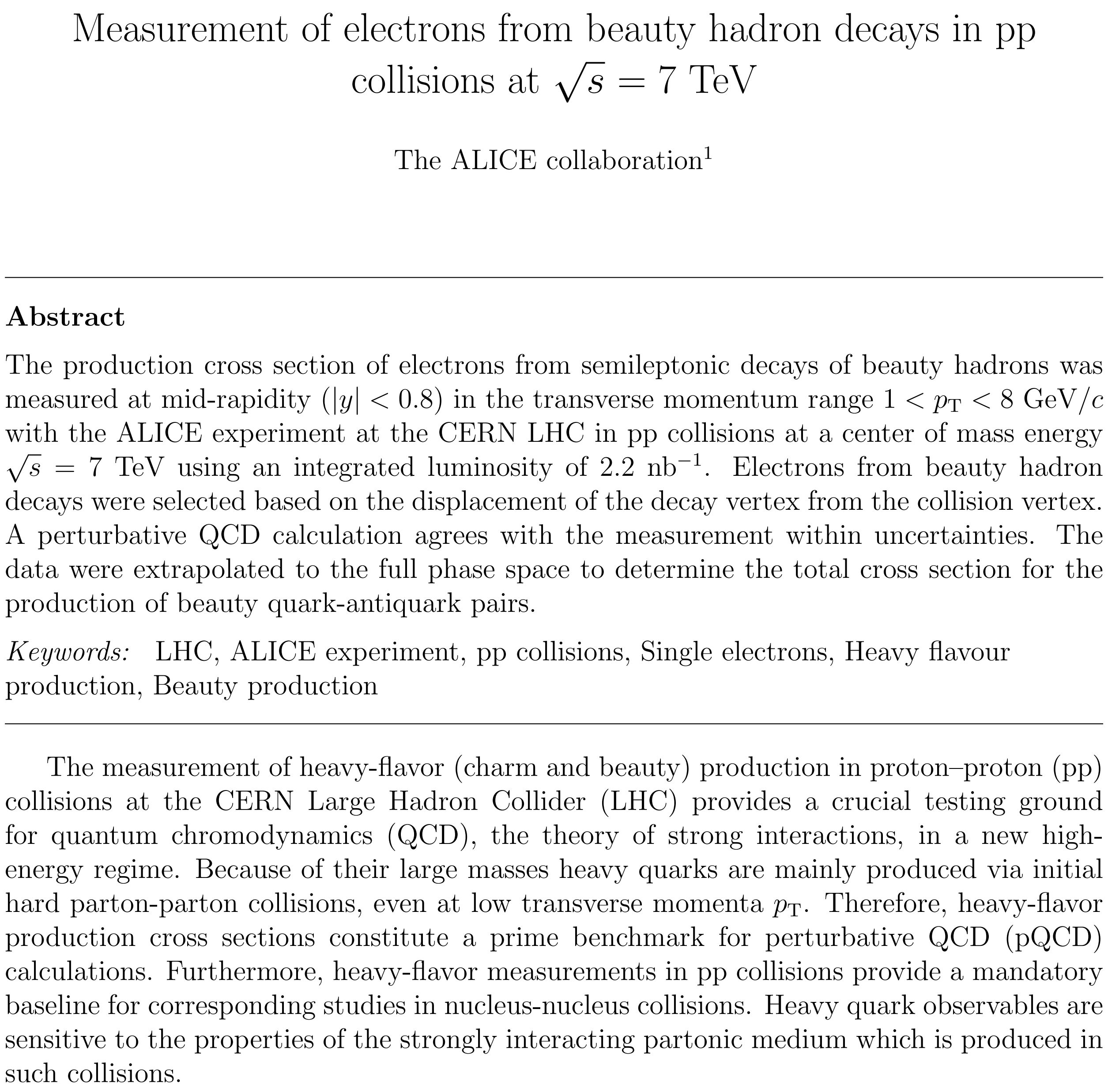
- In pp collisions at LHC, investigated at $\sqrt{s}$ = 7 TeV in various channels
  - Beauty hadrons at forward rapidity with LHCb and at mid rapidity with CMS (high p_t only)
  - Electrons and muons from semi-leptonic decays of heavy flavour hadrons with ATLAS (high p_t only) and with ALICE (down to low p_t)
  - At low p_t, J/ψ from beauty hadron decays at mid rapidity with ALICE
  - At low p_t, D mesons at mid rapidity with ALICE

  ➡ Good agreement with higher oder pQCD calculation

✓What is missing...

➡ Separation of leptons from charm and beauty hadron decays at low p_t: important for the total beauty production cross section and provide baseline for the PbPb measurement

Papers



Measurement of electrons from beauty hadron decays in pp collisions at $\sqrt{s} = 7$ TeV

The ALICE collaboration[1]

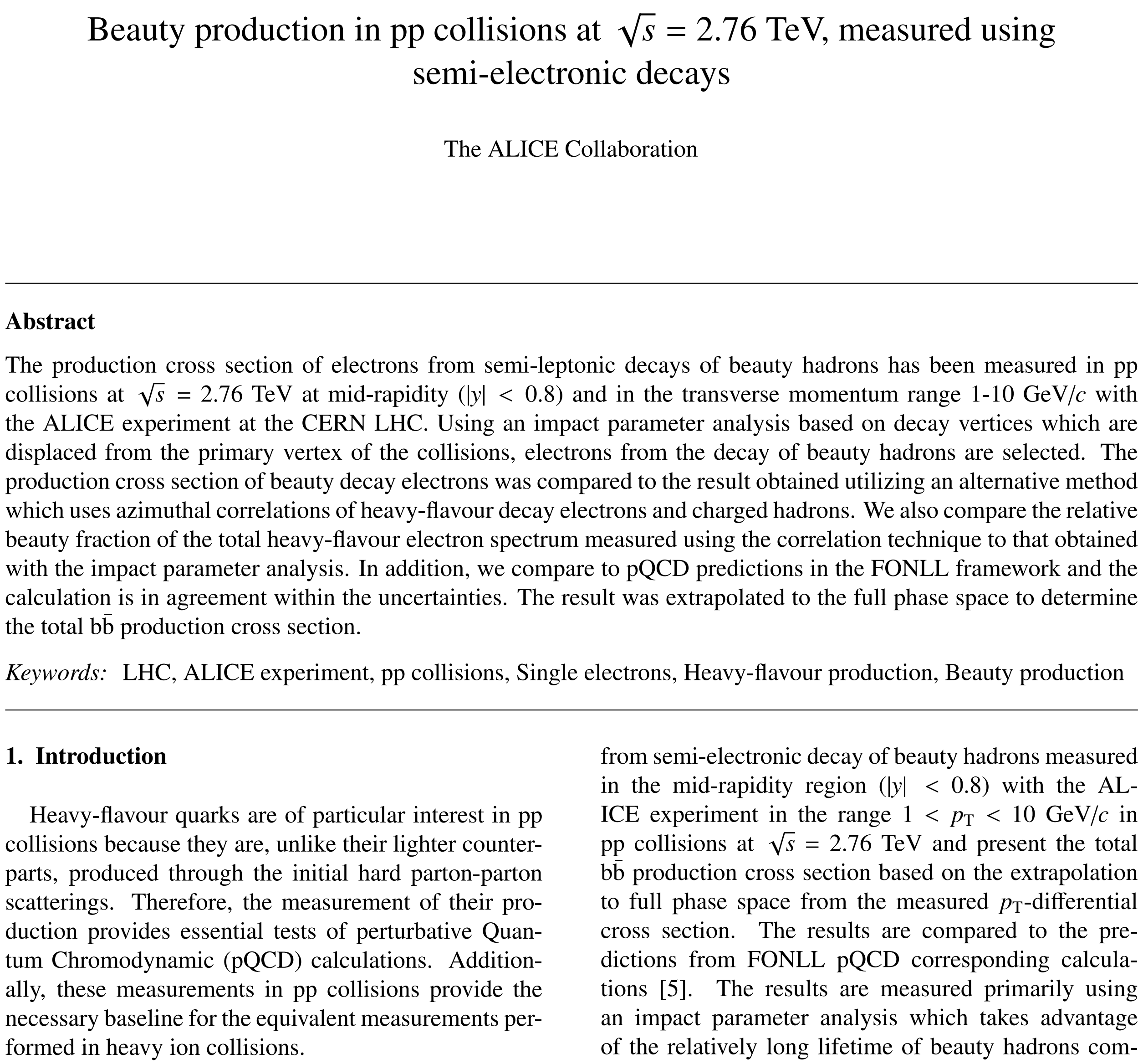
Abstract

The production cross section of electrons from semileptonic decays of beauty hadrons was measured at mid-rapidity ($|y| < 0.8$) in the transverse momentum range $1 < p_{\mathrm{T}} < 8$ GeV/c with the ALICE experiment at the CERN LHC in pp collisions at a center of mass energy $\sqrt{s} = 7$ TeV using an integrated luminosity of 2.2 nb^{-1}. Electrons from beauty hadron decays were selected based on the displacement of the decay vertex from the collision vertex. A perturbative QCD calculation agrees with the measurement within uncertainties. The data were extrapolated to the full phase space to determine the total cross section for the production of beauty quark-antiquark pairs.

Keywords: LHC, ALICE experiment, pp collisions, Single electrons, Heavy flavour production, Beauty production

The measurement of heavy-flavor (charm and beauty) production in proton–proton (pp) collisions at the CERN Large Hadron Collider (LHC) provides a crucial testing ground for quantum chromodynamics (QCD), the theory of strong interactions, in a new high-energy regime. Because of their large masses heavy quarks are mainly produced via initial hard parton-parton collisions, even at low transverse momenta p_{T}. Therefore, heavy-flavor production cross sections constitute a prime benchmark for perturbative QCD (pQCD) calculations. Furthermore, heavy-flavor measurements in pp collisions provide a mandatory baseline for corresponding studies in nucleus-nucleus collisions. Heavy quark observables are sensitive to the properties of the strongly interacting partonic medium which is produced in such collisions.

final iteration is being done with referee



Beauty production in pp collisions at $\sqrt{s} = 2.76$ TeV, measured using semi-electronic decays

The ALICE Collaboration

Abstract

The production cross section of electrons from semi-leptonic decays of beauty hadrons has been measured in pp collisions at $\sqrt{s} = 2.76$ TeV at mid-rapidity ($|y| < 0.8$) and in the transverse momentum range 1-10 GeV/c with the ALICE experiment at the CERN LHC. Using an impact parameter analysis based on decay vertices which are displaced from the primary vertex of the collisions, electrons from the decay of beauty hadrons are selected. The production cross section of beauty decay electrons was compared to the result obtained utilizing an alternative method which uses azimuthal correlations of heavy-flavour decay electrons and charged hadrons. We also compare the relative beauty fraction of the total heavy-flavour electron spectrum measured using the correlation technique to that obtained with the impact parameter analysis. In addition, we compare to pQCD predictions in the FONLL framework and the calculation is in agreement within the uncertainties. The result was extrapolated to the full phase space to determine the total $\mathrm{b\bar{b}}$ production cross section.

Keywords: LHC, ALICE experiment, pp collisions, Single electrons, Heavy-flavour production, Beauty production

1. Introduction

Heavy-flavour quarks are of particular interest in pp collisions because they are, unlike their lighter counterparts, produced through the initial hard parton-parton scatterings. Therefore, the measurement of their production provides essential tests of perturbative Quantum Chromodynamic (pQCD) calculations. Additionally, these measurements in pp collisions provide the necessary baseline for the equivalent measurements performed in heavy ion collisions.

from semi-electronic decay of beauty hadrons measured in the mid-rapidity region ($|y| < 0.8$) with the ALICE experiment in the range $1 < p_{\mathrm{T}} < 10$ GeV/c in pp collisions at $\sqrt{s} = 2.76$ TeV and present the total $\mathrm{b\bar{b}}$ production cross section based on the extrapolation to full phase space from the measured p_{T}-differential cross section. The results are compared to the predictions from FONLL pQCD corresponding calculations [5]. The results are measured primarily using an impact parameter analysis which takes advantage of the relatively long lifetime of beauty hadrons com-

first draft is ready for IRC

Data Analysis

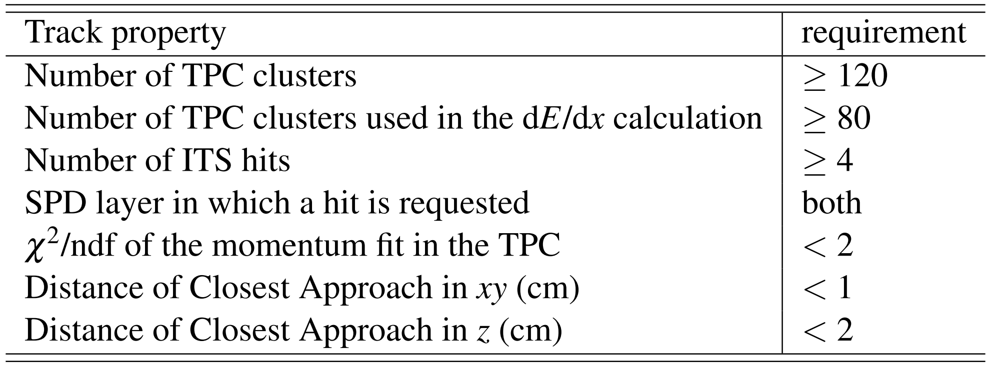
Data set

- LHC10d pass2 (2.2 nb^{-1}) for 7 TeV
- LHC11a pass2 (0.9 nb^{-1}) for 2.76 TeV

Outline of analysis

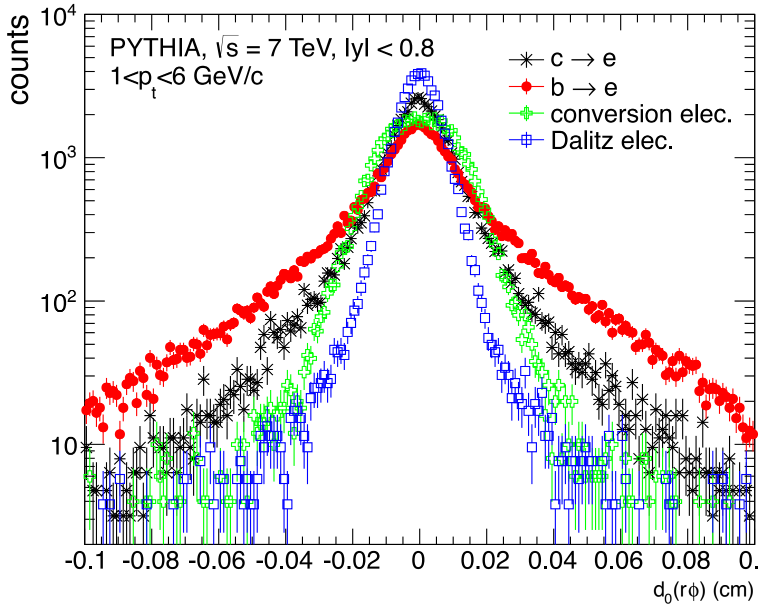
1. Charged particle tracks selected fulfilling track quality and eID cuts (composed with electrons from conversion, Dalitz/di-, charm hadron decays, beauty hadron decays)
2. Minimum impact parameter cut applied to increase S/B
3. Subtract remaining non-HFE and charm hadron decay electron backgrounds based on ALICE measurement
4. Unfold background subtracted electron spectra

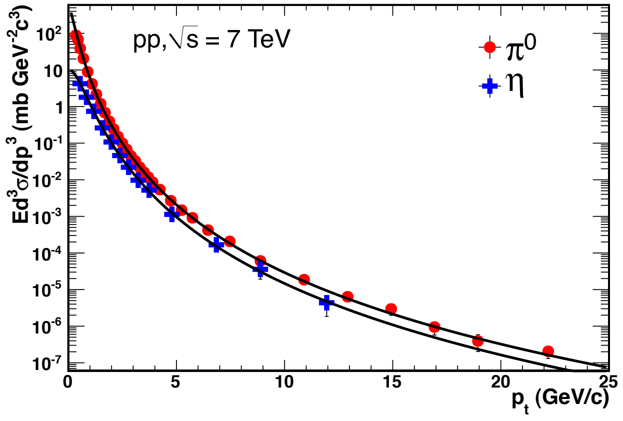
Table 1: Track selection cuts.

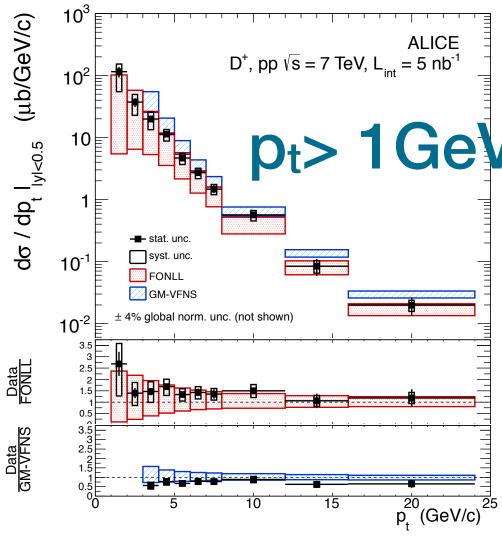


Track property	requirement
Number of TPC clusters	≥ 120
Number of TPC clusters used in the dE/dx calculation	≥ 80
Number of ITS hits	≥ 4
SPD layer in which a hit is requested	both
χ^2/ndf of the momentum fit in the TPC	< 2
Distance of Closest Approach in xy (cm)	< 1
Distance of Closest Approach in z (cm)	< 2

TPC-TOF(|σ TOF|<3, 0(-1)<σ TPC<3)



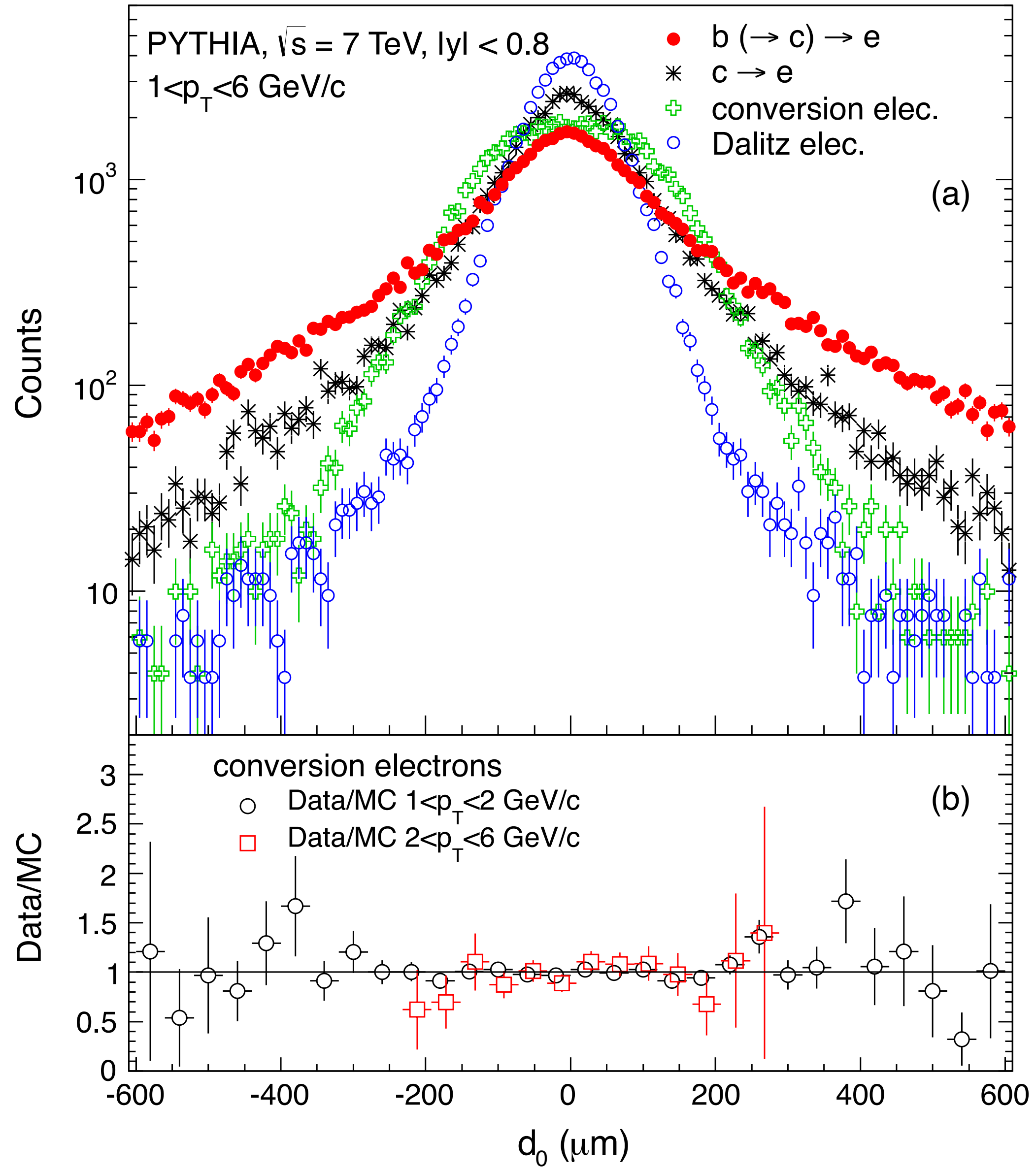


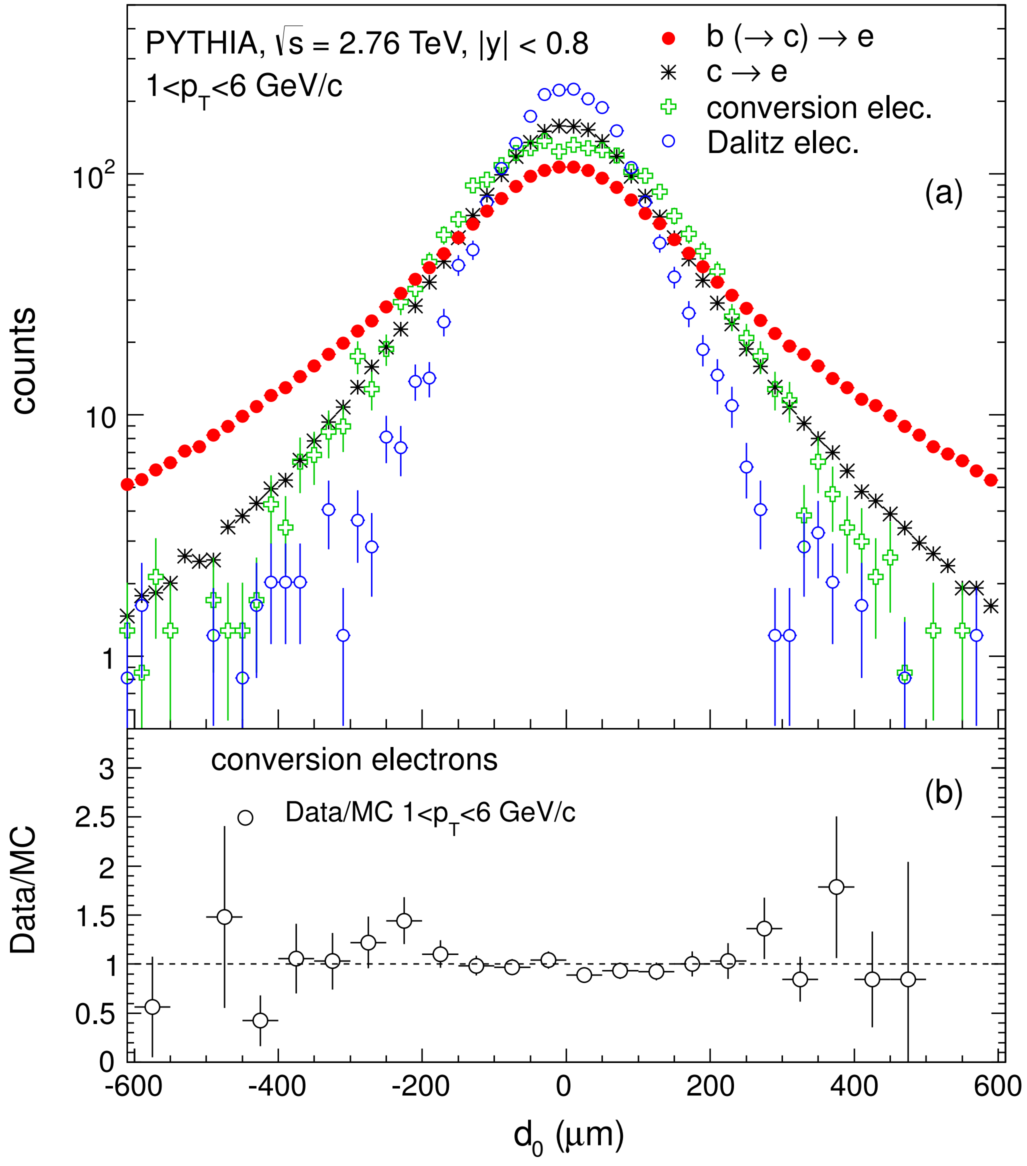


p_t> 1GeV/c

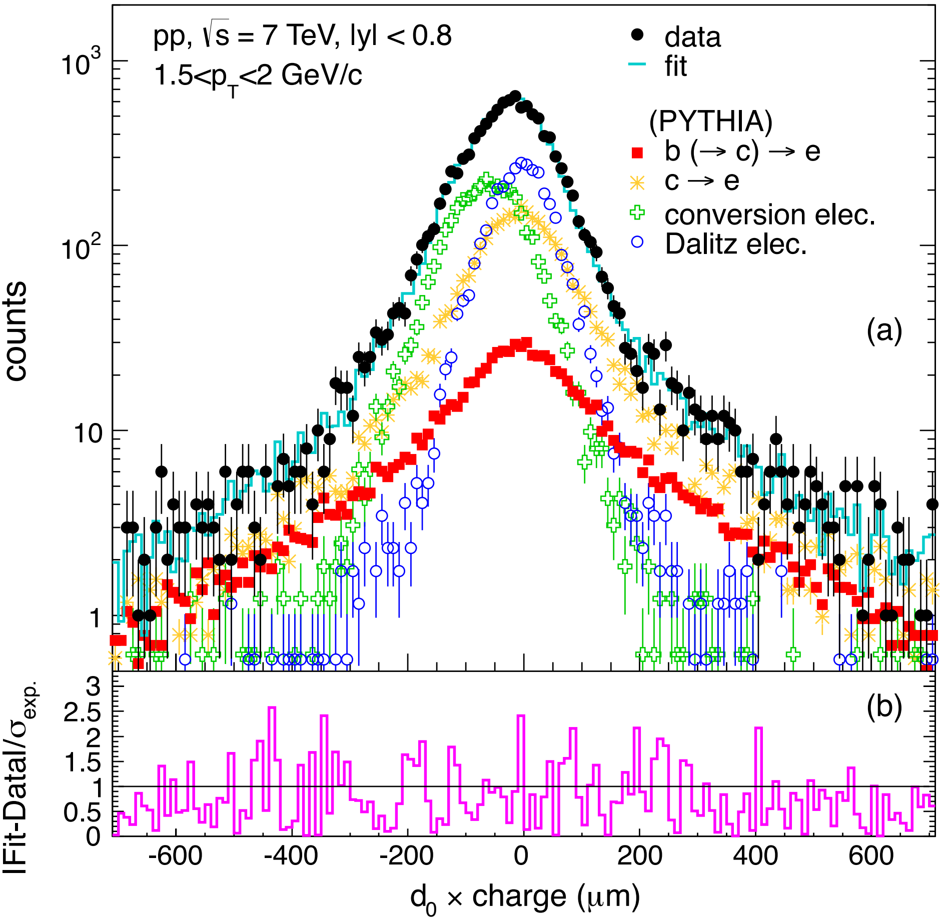
Agreement between data and MC of key variable(impact parameter) (1)

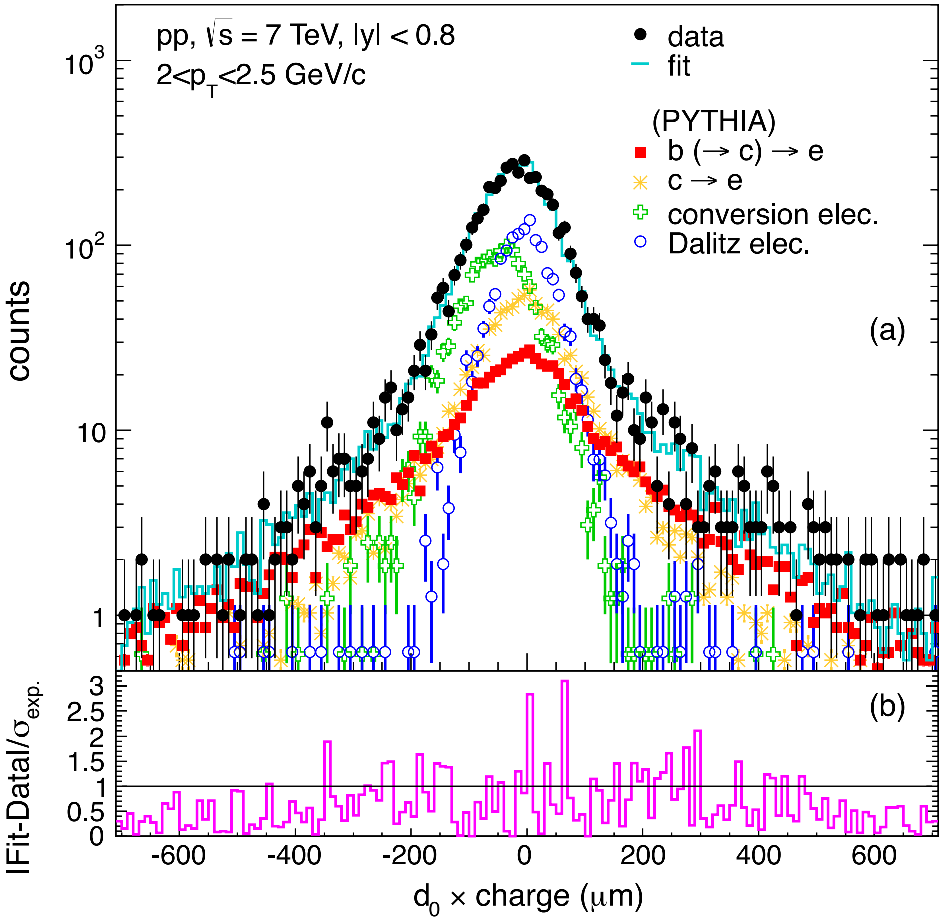
Use of conversion electrons identified by V0 finder
- Only identifiable source

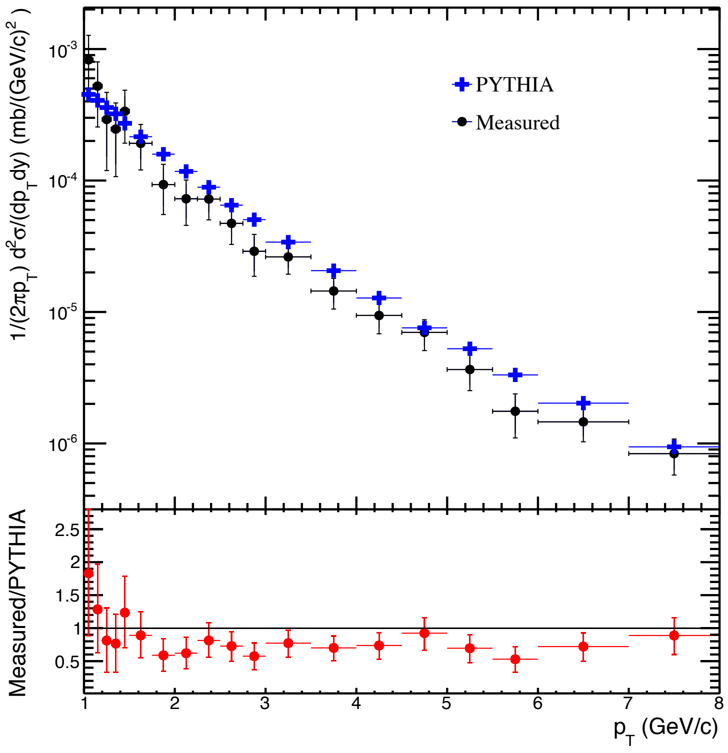




Agreement between data and MC of key variable(impact parameter) (2)

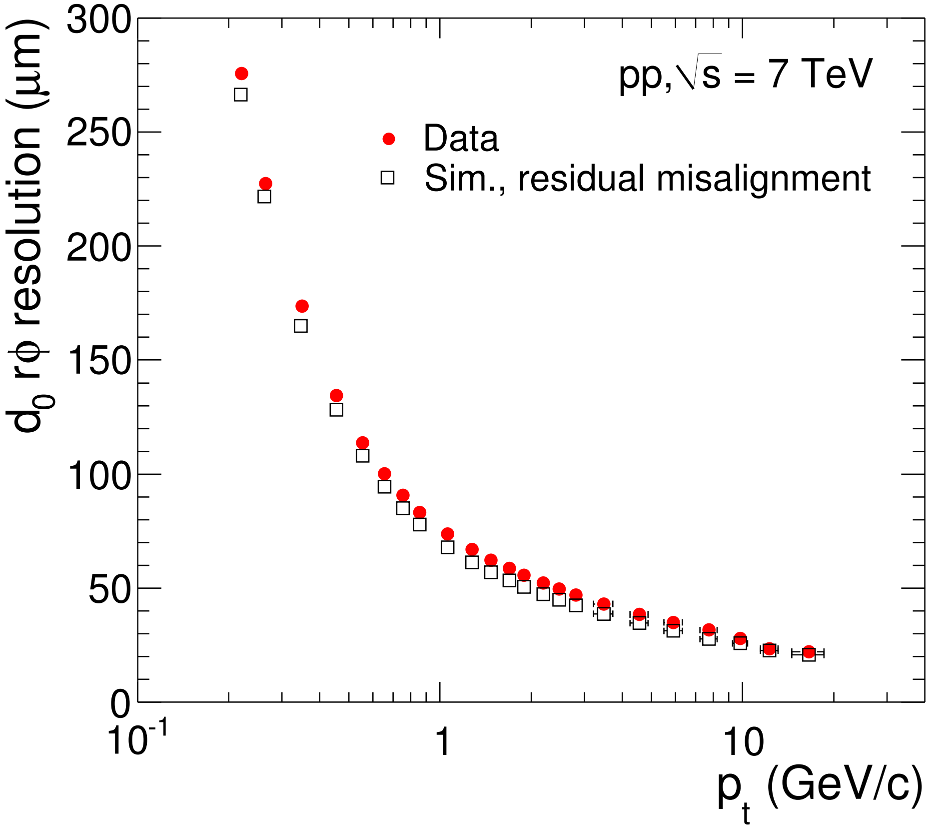


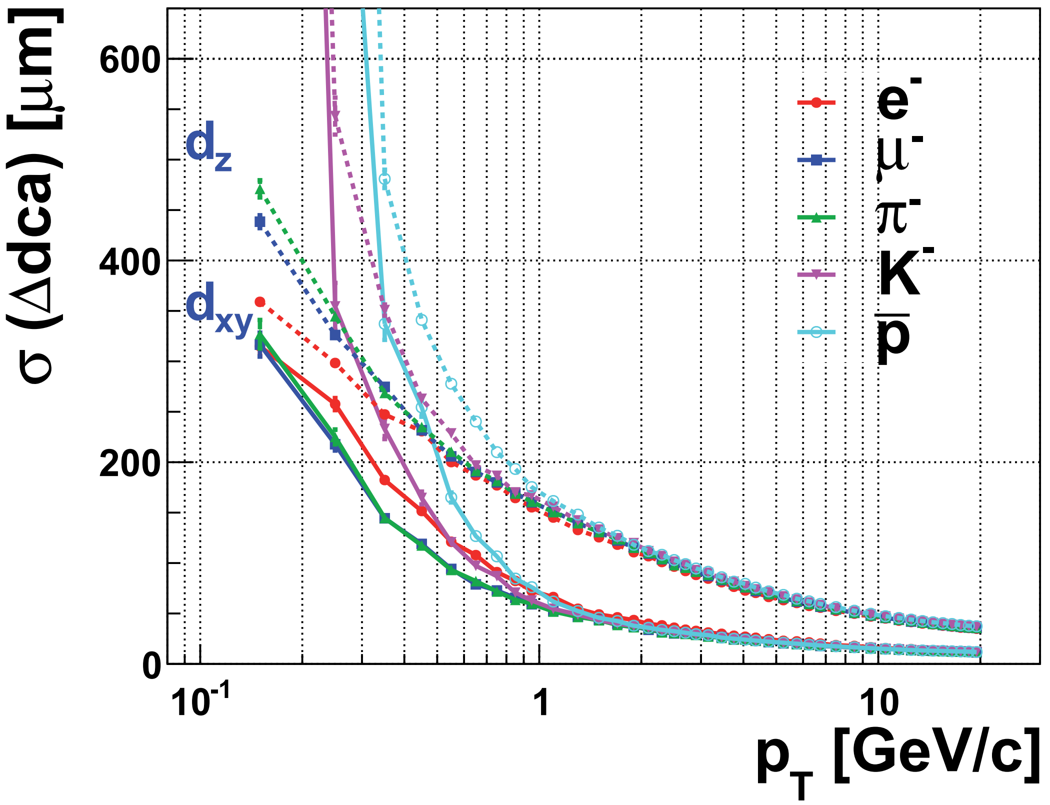




- The d_0 distribution of the data sample is well described by the cocktail of signal and backgrounds (The differences between the data and the cocktail of the signal and backgrounds are consistent with statistical variations).
- The yields of signal and backgrounds obtained by this procedure agree with those obtained in this analysis within statistical uncertainties.

Agreement between data and MC of key variable(impact parameter) (3)





- Impact parameter resolution measured for charged tracks in data is reproduced within 10 % by the MC
- MC simulation shows that the electron Bremsstrahlung effect is limited to $p_T < 1$ GeV/c. At higher p_T, the particle species dependences is negligible

⇒ Full analysis was repeated after smearing the d_0 resolution in the MC by 10%, considering the maximum differences in the d_0 distribution in data and simulation

It is well known that the particle multiplicities predicted by Pythia Perugia 0 tune are underestimated at LHC. How this does affects the result?

The difference in the particle multiplicities would appear as a difference in the primary vertex resolution. The effect of the difference in the particle multiplicities between data and simulation was already included in that of the d_0 resolution as a convolution of the track position the primary vertex resolution.

Agreement between data and MC of key variable(impact parameter) (4)

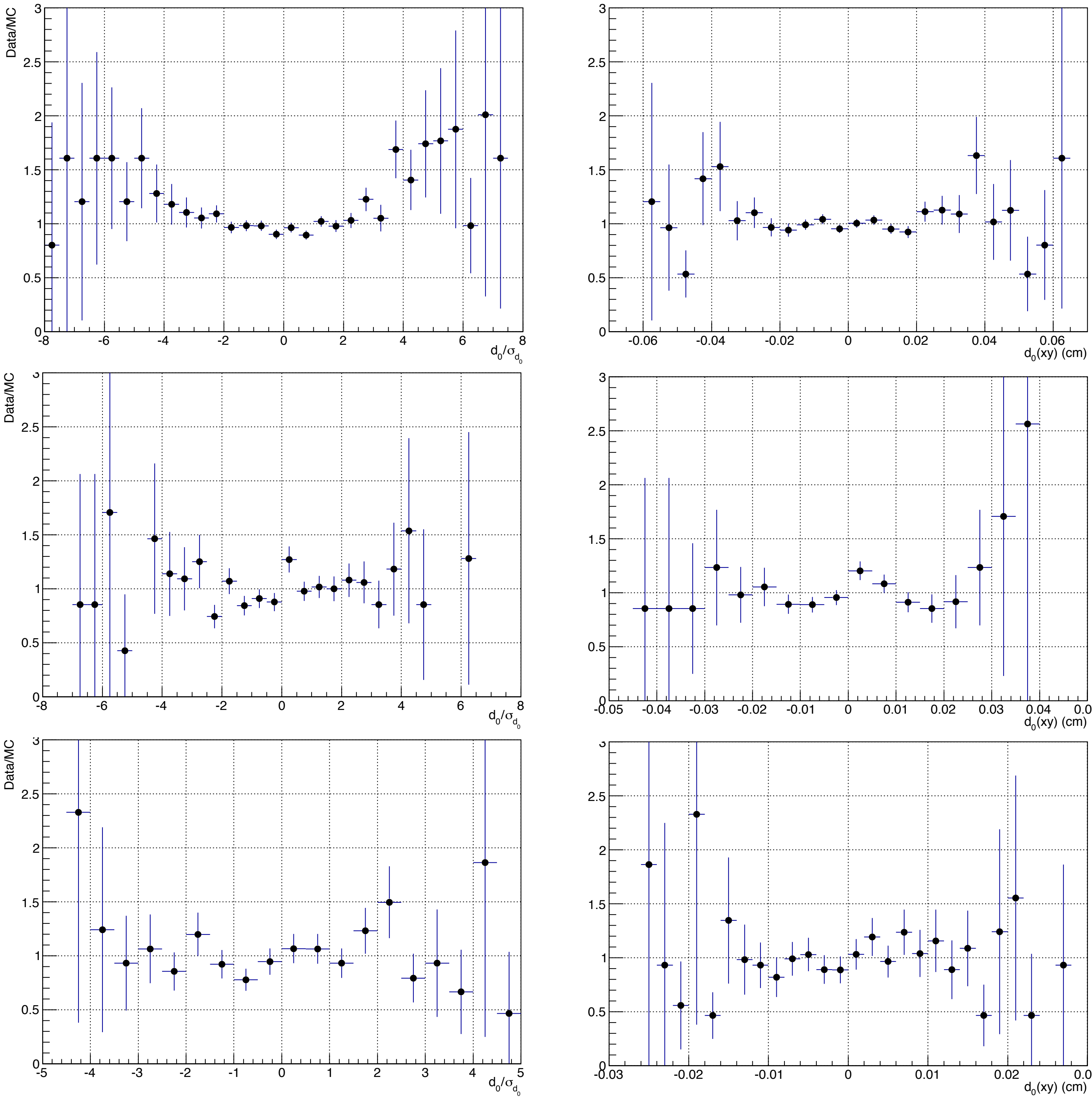
Impact parameter significance

Impact parameter (cm)

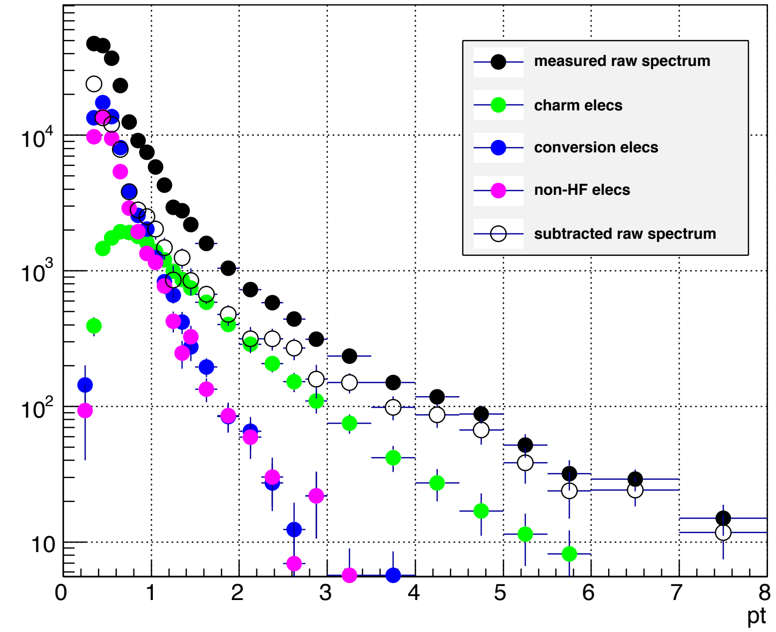
$1.0 < p_t < 1.5$ (GeV/c)

$1.5 < p_t < 2$ (GeV/c)

$2 < p_t < 6$ (GeV/c)

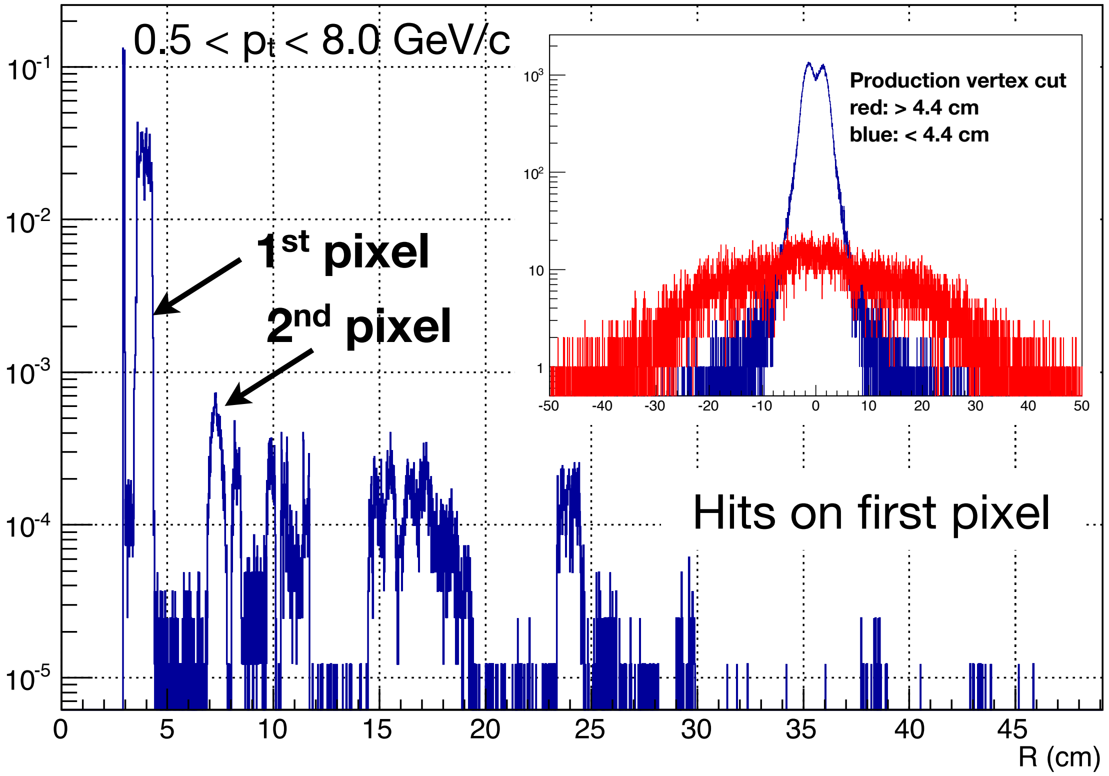


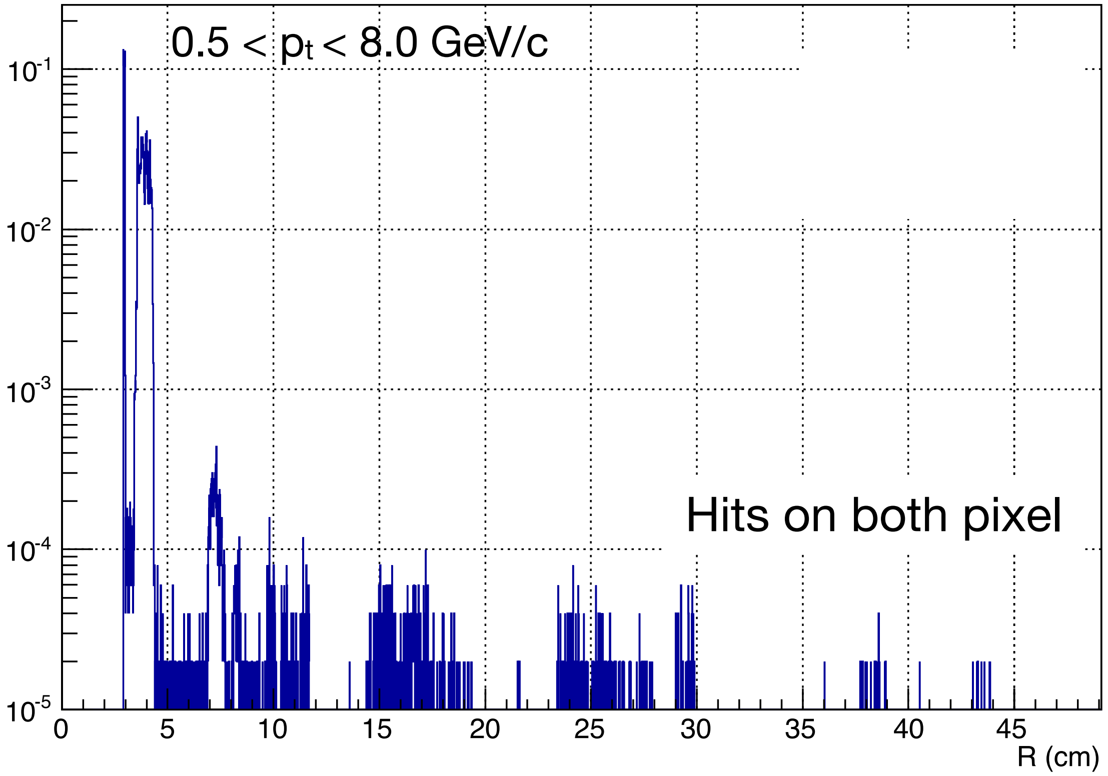
Raw spectra using the cut based on the impact parameter significance



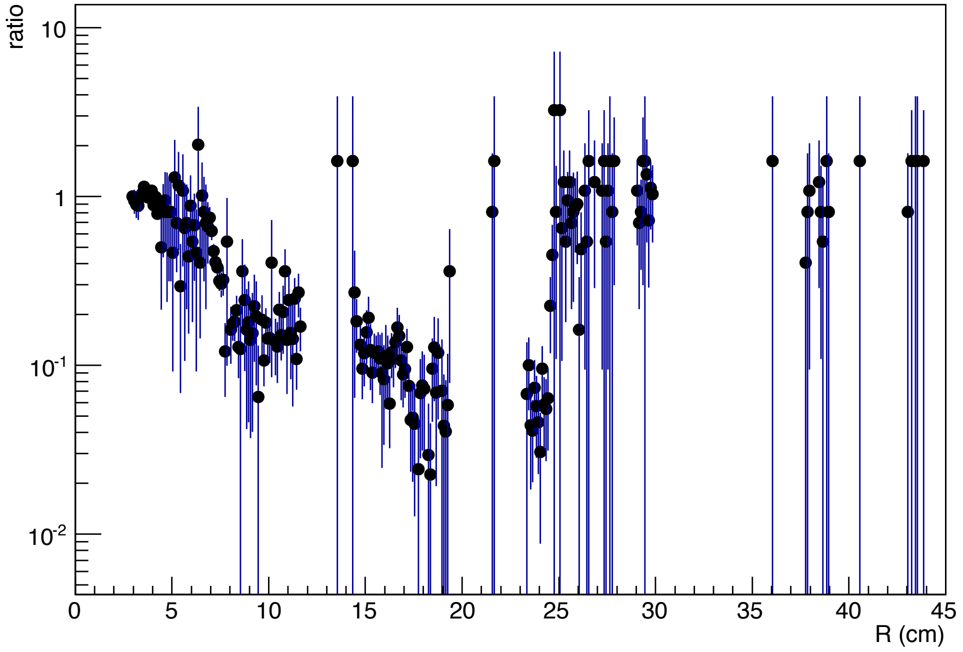
- **At $2<p_t<6$, both gives similar good agreement between data and MC (within statistical fluctuation)**

Effect on fakes on different pixel hit requirements





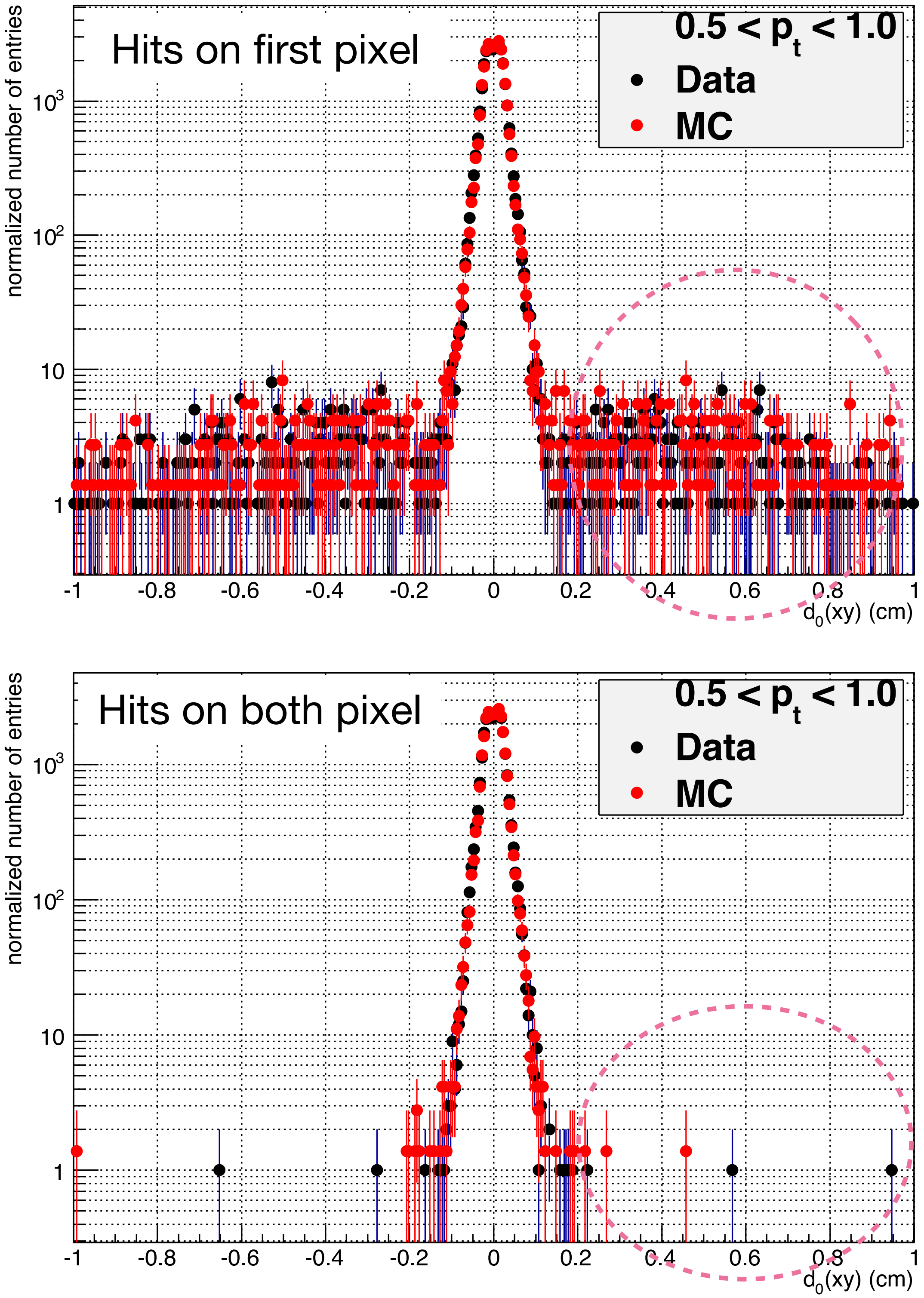
- **Electron production vertex distribution with different hit requirement on pixel (standard HFE cuts applied)**



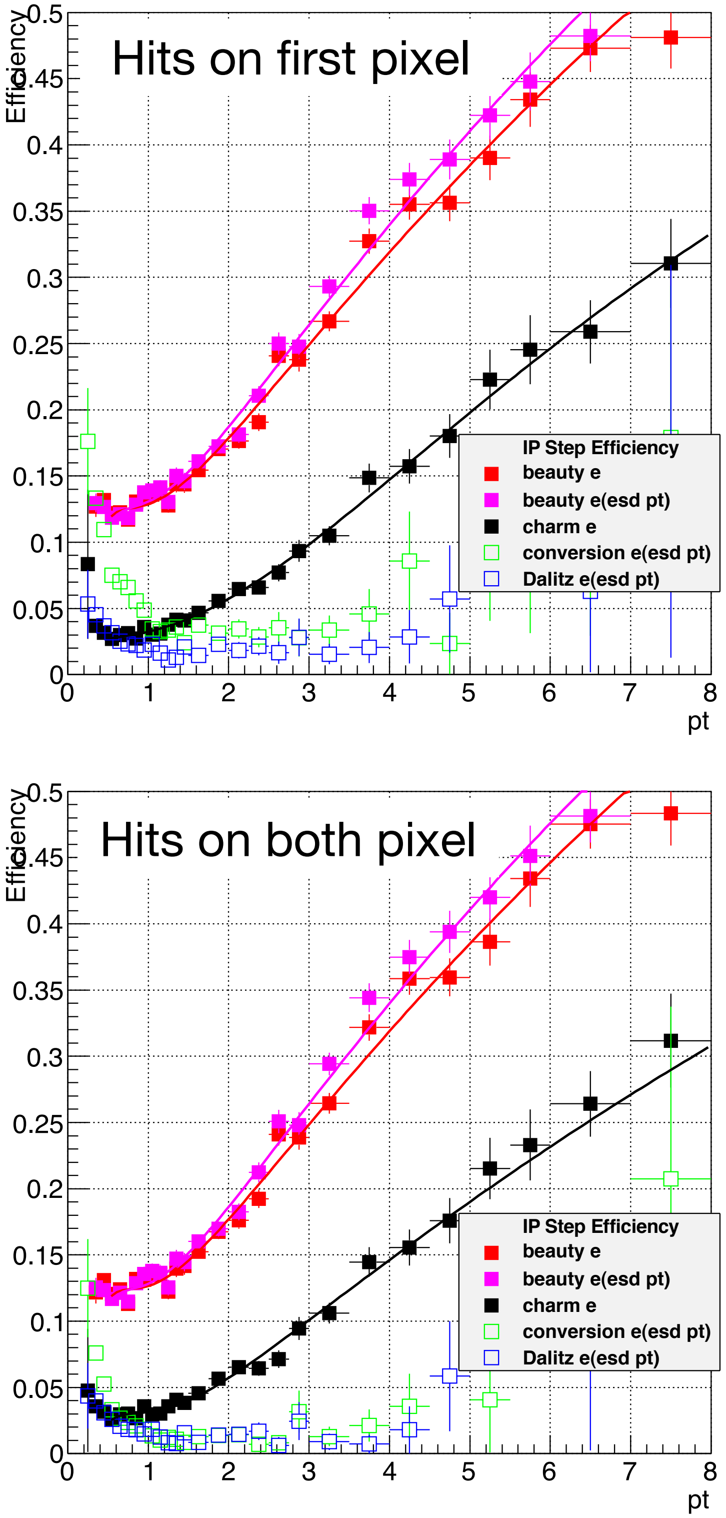
- **"Hits on both pixel" requirement is effective to reduce the fake tracks produced outside of the first pixel.**

Impact parameter dist. with different pixel hit requirements

Impact parameter distribution in xy plane



Impact parameter cut efficiencies

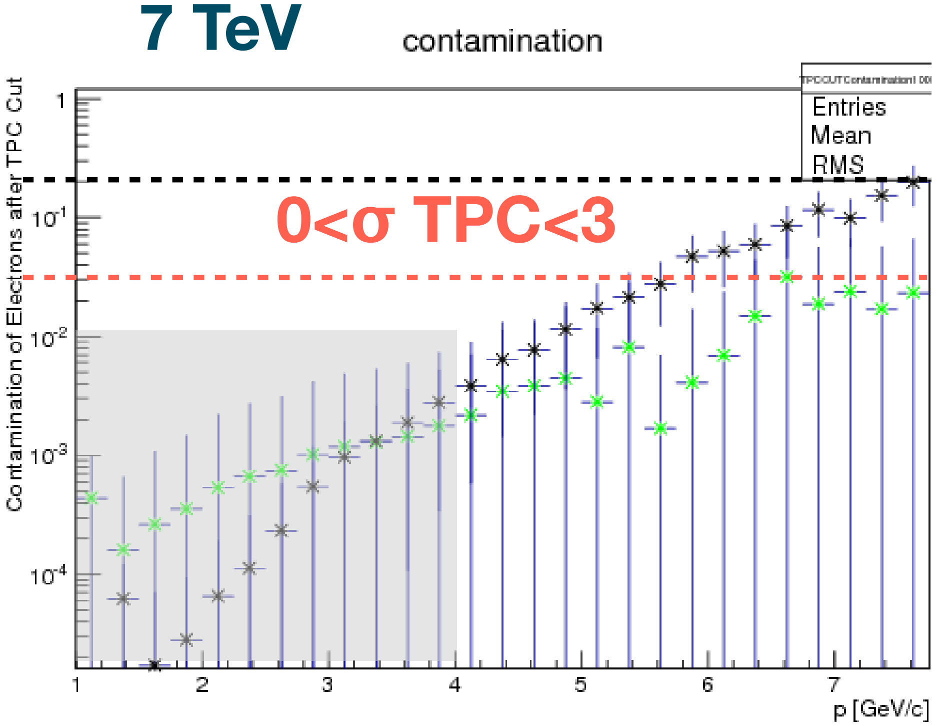


- **The fake tracks are also reproduced in MC**
- **Better to remove them as much as possible to reduce any possible discrepancy of fakes between data and MC, and to increase S/B**

Hadron contamination: less suffer than inclusive analysis

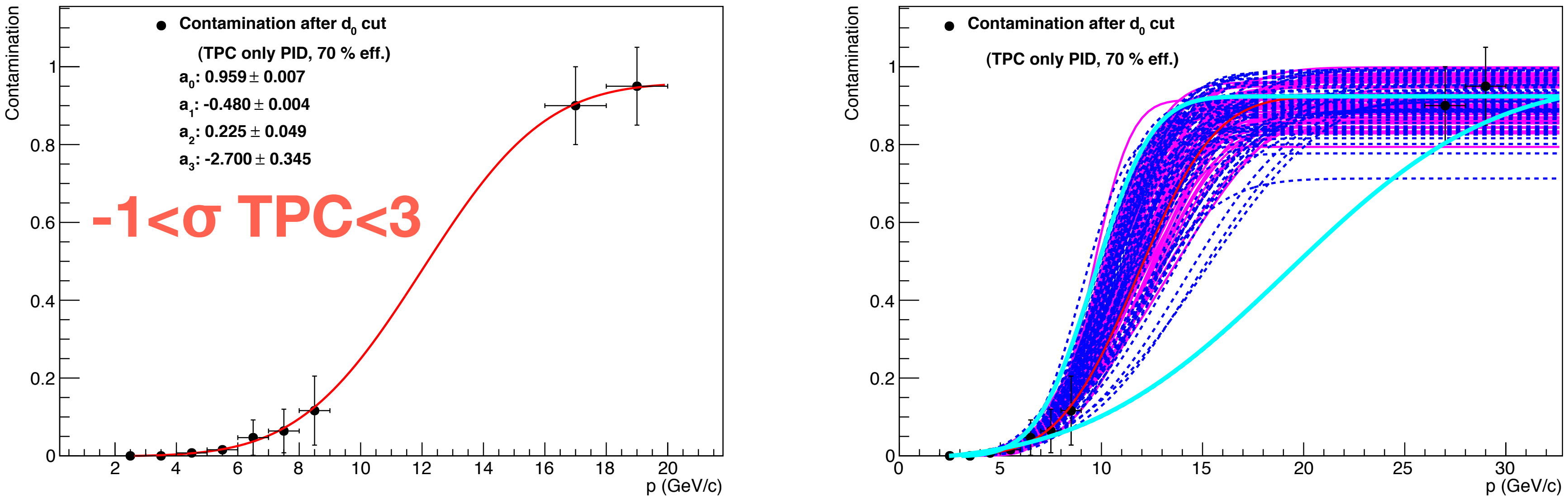
PID with TPC-TOF(|σ TOF|<3, 0(-1)<σ TPC<3)

7 TeV



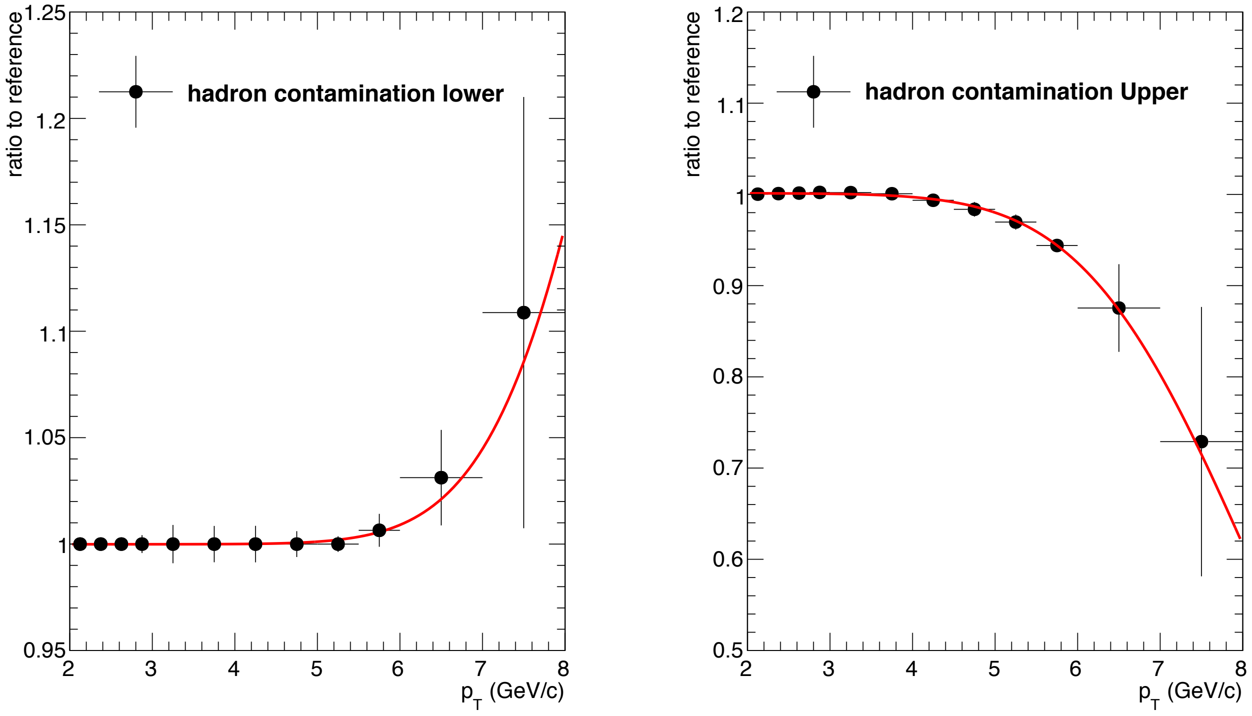
0<σ TPC<3

2.76 TeV



-1<σ TPC<3

Uncertainties were estimated by considering lower and upper limit of contamination estimation.

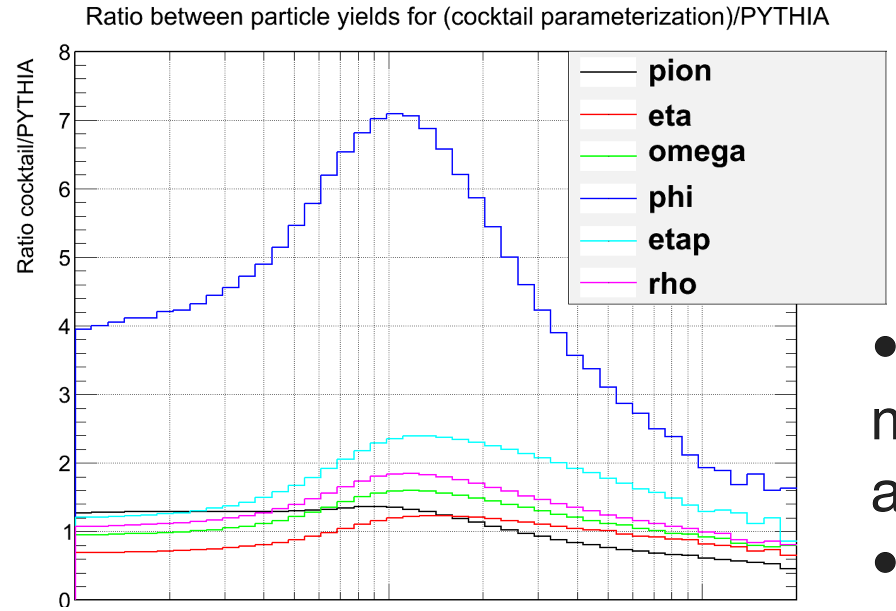


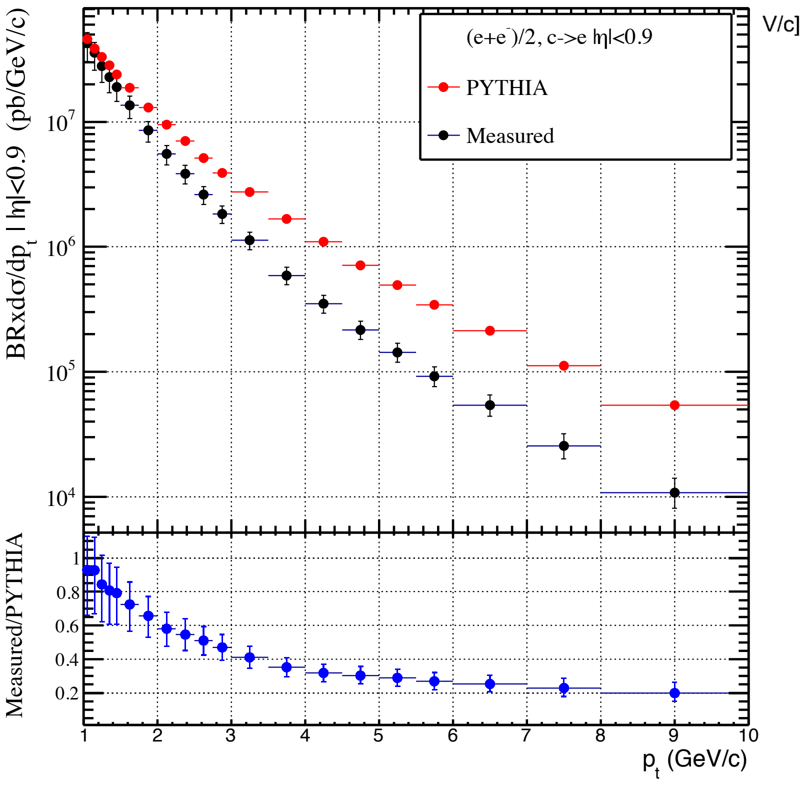
Hadron contamination level is significantly reduced by impact parameter cut

Hadron contamination < 3 % at p = 8 GeV/c.

Background estimation

The PYTHIA simulation does not reproduce precisely the p_T-differential yields of background sources measured in data. Therefore, the p_T distributions of the relevant electron sources in PYTHIA were re-weighted to match the distributions measured with ALICE



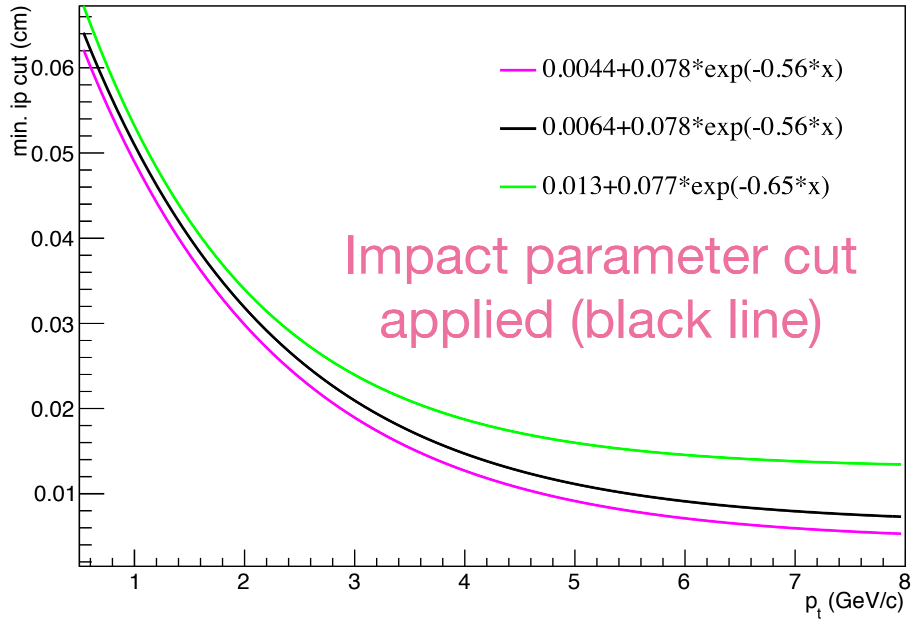


The production cross sections of π^0 and η mesons, the dominant sources of electrons from Dalitz decays and from photons which convert in material into e^+e^- pairs, were measured with ALICE in pp collisions

- D^0, D^+, and D^+_s meson production cross sections were measured with ALICE in 1 < pT < 16 GeV/c, 1 < pT < 24 GeV/c, and 2 < pT < 12 GeV/c, respectively.
- Based on a FONLL pQCD calculation the measured p_T-differential cross sections were extrapolated to pT = 50 GeV/c.
- Contribution from the unmeasured high-p_T region to the electron yield from D-meson decays was estimated to be ≤ 10% for electrons with p_T < 8 GeV/c.
- A contribution from Λ_c decays was included using a measurement of the ratio $\sigma(\Lambda_c)/\sigma(D^0 + D^+)$ from ZEUS.

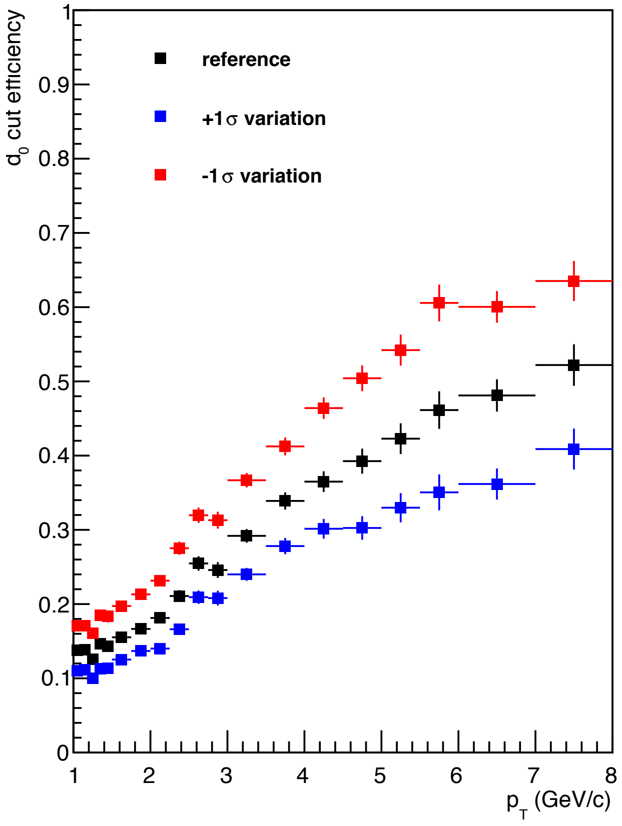
- For 2.76 TeV, D meson cross sections were obtained by applying a $\sqrt{s}$ -scaling to the cross sections measured at $\sqrt{s}$ = 7 TeV.
- ALICE measurements at 2.76 TeV (limited precision and p_T coverage) were found to be in agreement with the scaled 7 TeV measurements within statistical uncertainties.

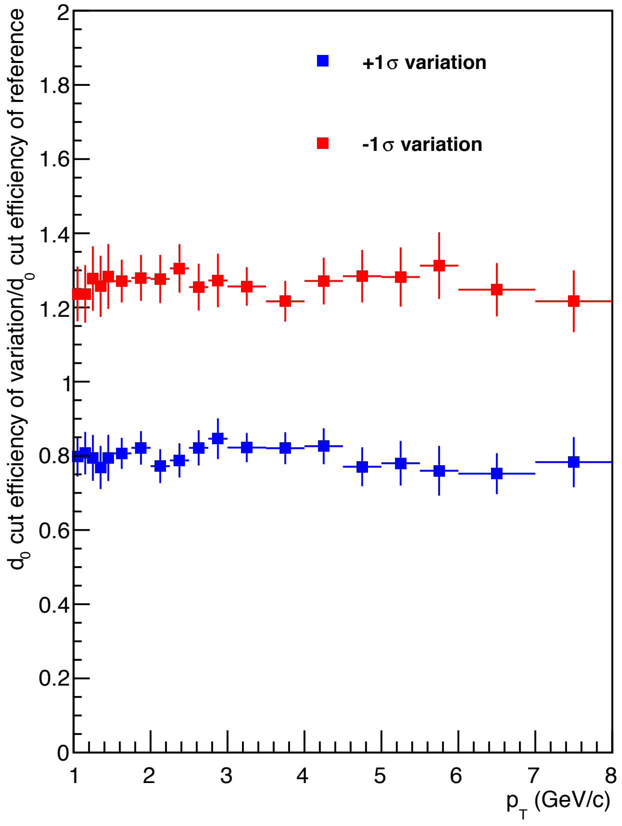
Impact parameter cut and raw spectra of signal and backgrounds

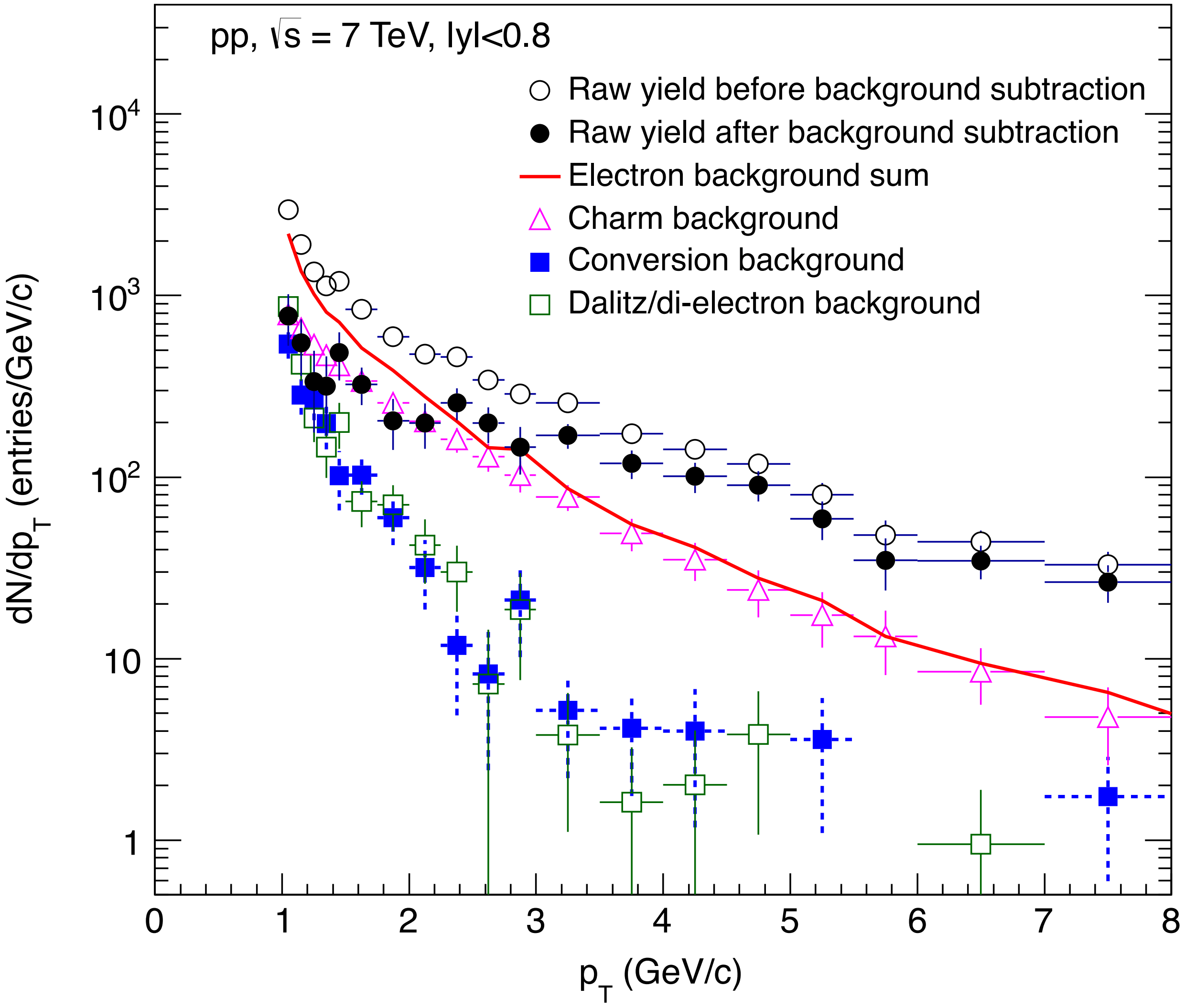


Impact parameter cut applied (black line)

p_T dependent impact parameter cut was optimized to increase S/B based on MC





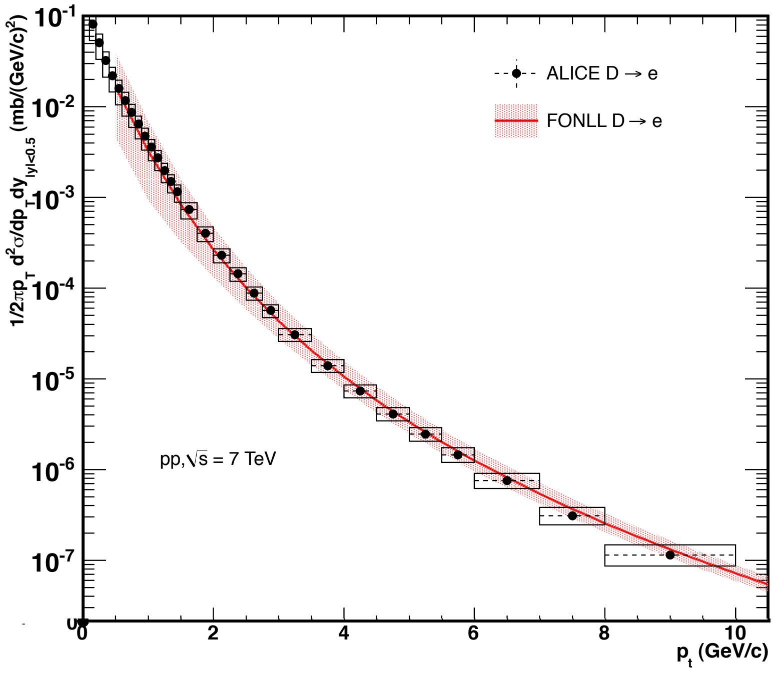


Variation of the selection cuts to estimate systematic uncertainties

Variable	Looser cut	Reference cut	Stronger cut
All analyses:			
N. of TPC tracking clusters	≥ 100	≥ 120	≥ 140
N. of TPC PID clusters		≥ 80	≥ 100, ≥ 120
DCA to the primary vertex in xy (z)	< 2cm ($<$ 4cm)	< 1cm ($<$ 2cm)	< 0.5cm ($<$ 1cm) < 0.3cm ($<$ 0.5cm)
Number of ITS hits	≥ 3	≥ 4	≥ 5
TOF compatibility with e hypothesis	$\leq 4\ \sigma_{TOF-PID}$	$\leq 3\ \sigma_{TOF-PID}$	$\leq 2\ \sigma_{TOF-PID}$
TPC dE/dx cut	$-0.254 < \sigma_{TPC-dE/dx} < 3$ $-0.126 < \sigma_{TPC-dE/dx} < 3$	$0 < \sigma_{TPC-dE/dx} < 3$	$0.126 < \sigma_{TPC-dE/dx} < 3$ $0.254 < \sigma_{TPC-dE/dx} < 3$
Impact parameter cuts	$0.0044+0.078\times e^{-0.56\times p_t}$	$0.0064+0.078\times e^{-0.56\times p_t}$	$0.013+0.077\times e^{-0.65\times p_t}$

NonHFE backgrounds: Uncertainty of input meson spectra (same spectra as used for inclusive HFE analysis)

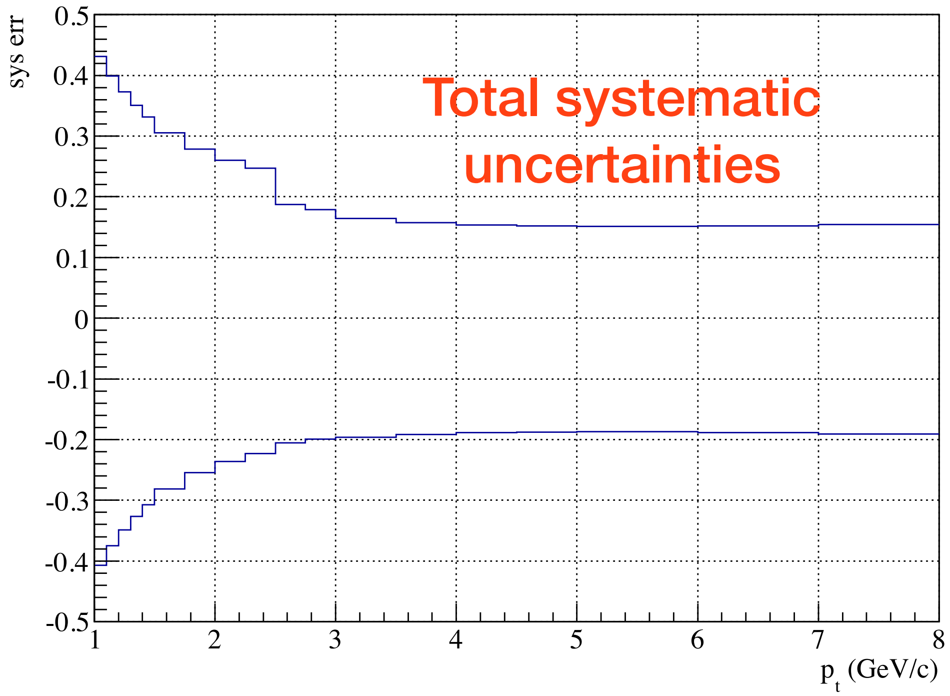
Charm backgrounds: Uncertainty of D meson spectra



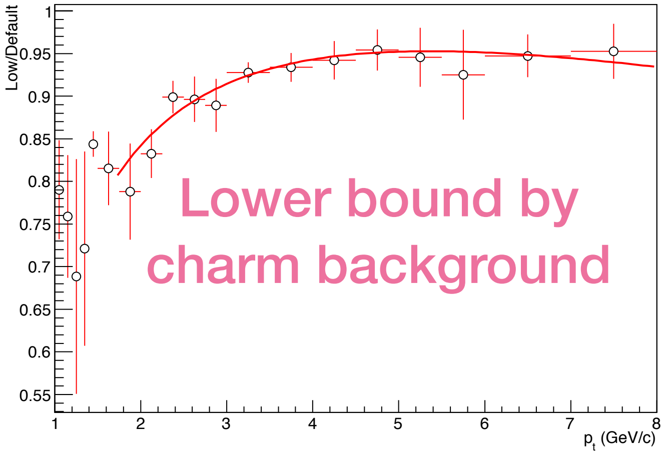
Overview over the contributions to the systematic uncertainties

p_{T} range (GeV/c)	1 – 8
Error source	systematic uncertainty [%]
Track matching	± 2
ITS number of hits	$^{+1}_{-4}$
TPC number of tracking clusters	$^{+15}_{-7}(^{+3}_{-4})$ for $p_{\mathrm{T}} < 2.5(>2.5)$ GeV/c
TPC number of PID clusters	± 2
DCA to primary vertex in xy (z)	± 1
TOF matching and PID	± 5
TPC PID	$+5(^{+2}_{-5})$ for $p_{\mathrm{T}} < 3(>3)$ GeV/c
Minimum d_0 cut	± 12
Charge dependence	$^{+1}_{-7}$
η dependence	-6
Unfolding	± 5
Light hadron decay background	$\approx 10(<2)$ for $p_{\mathrm{T}} = 1(>2)$ GeV/c
Charm hadron decay background	$\approx 30(<10)$ for $p_{\mathrm{T}} = 1(>3)$ GeV/c

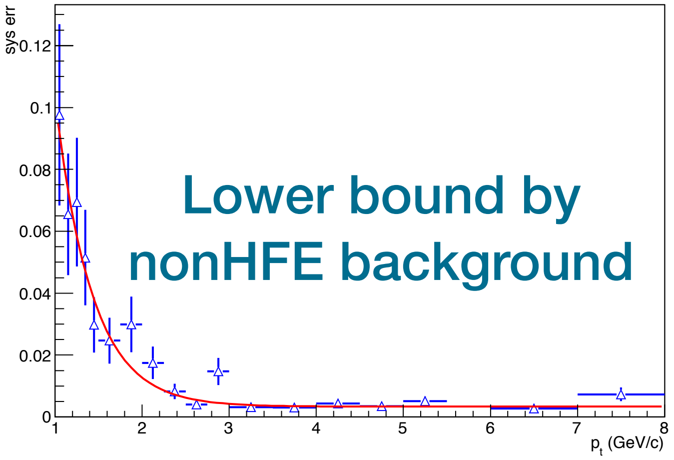
7 TeV



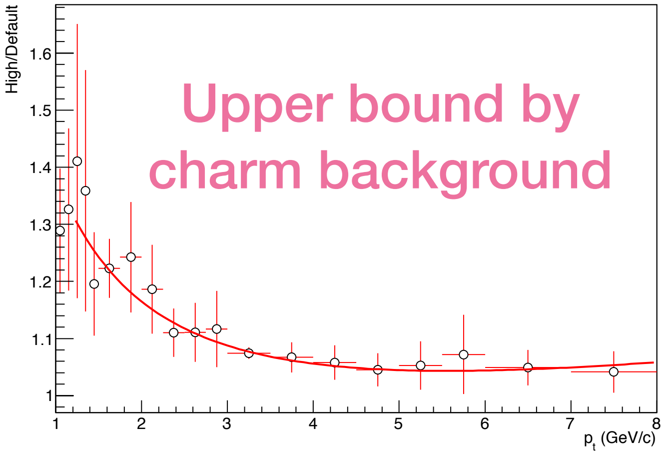
Total systematic uncertainties



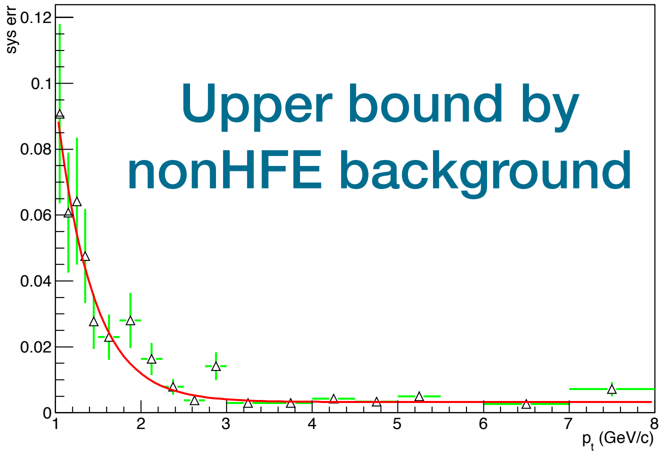
Lower bound by charm background



Lower bound by nonHFE background

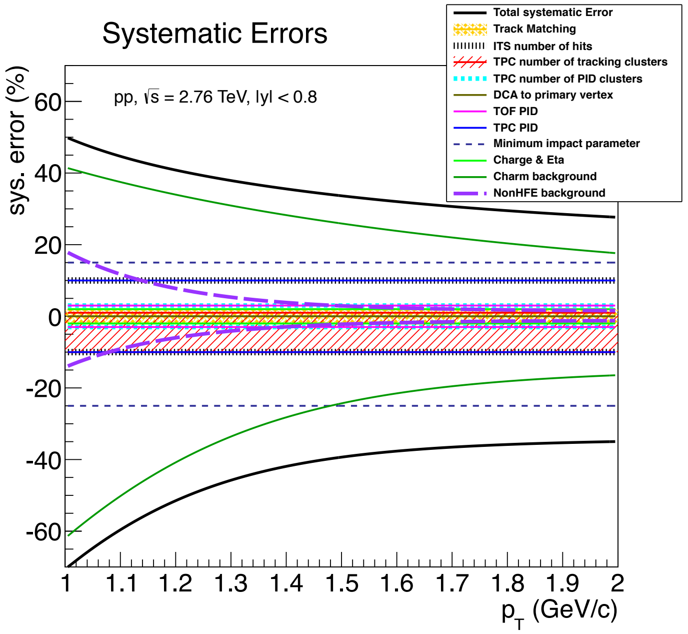


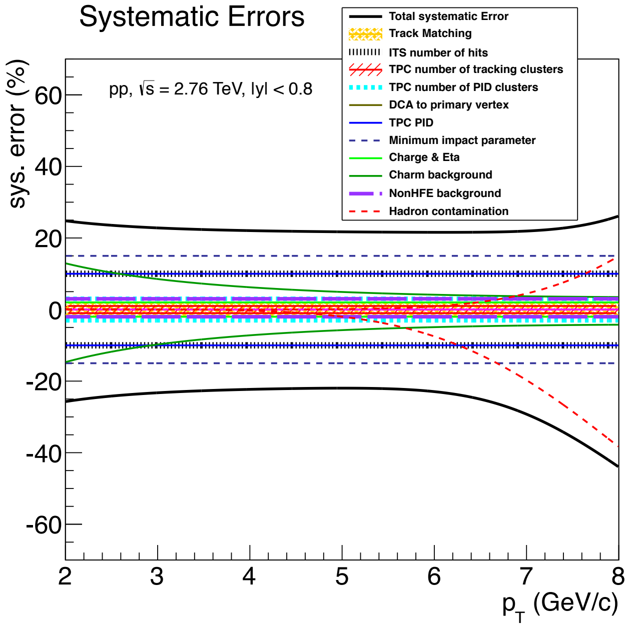
Upper bound by charm background



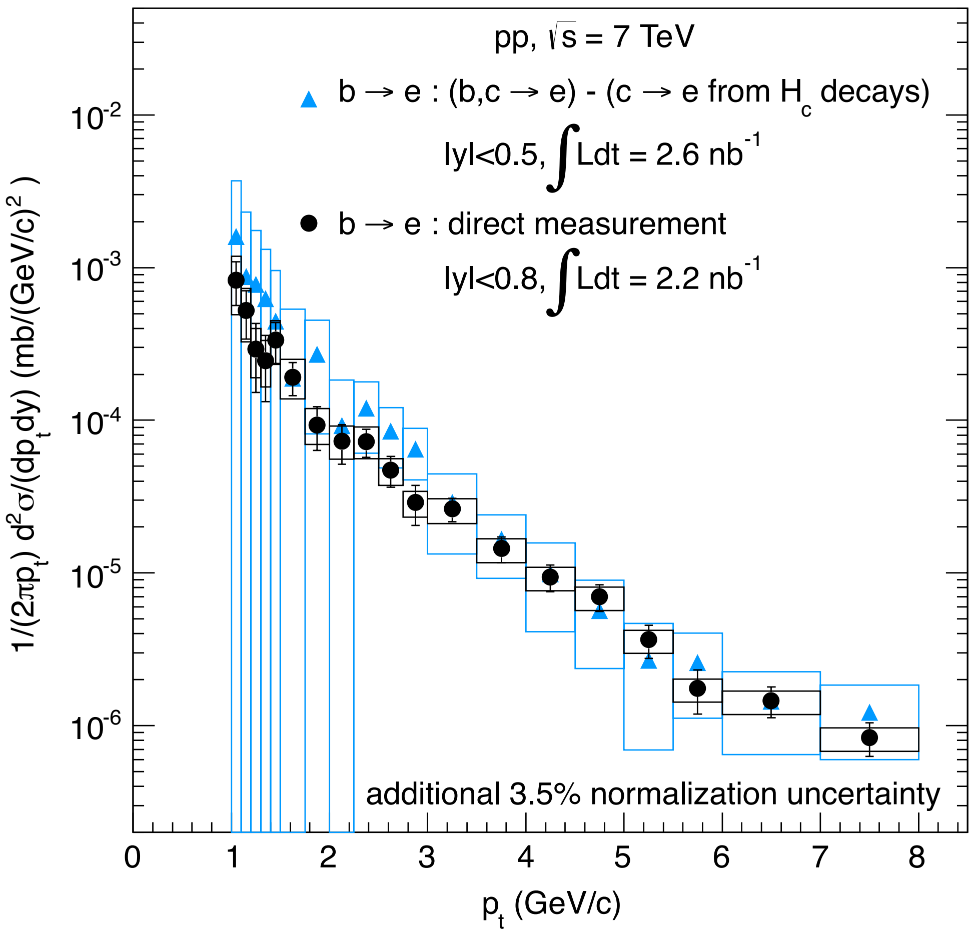
Upper bound by nonHFE background

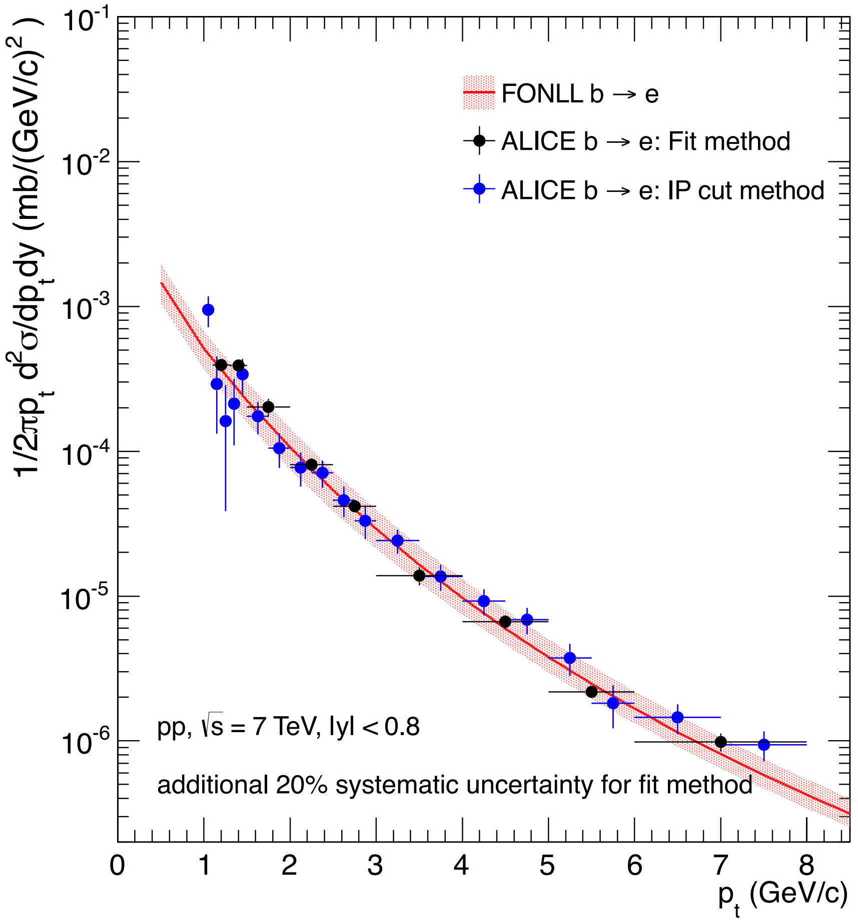
2.76 TeV



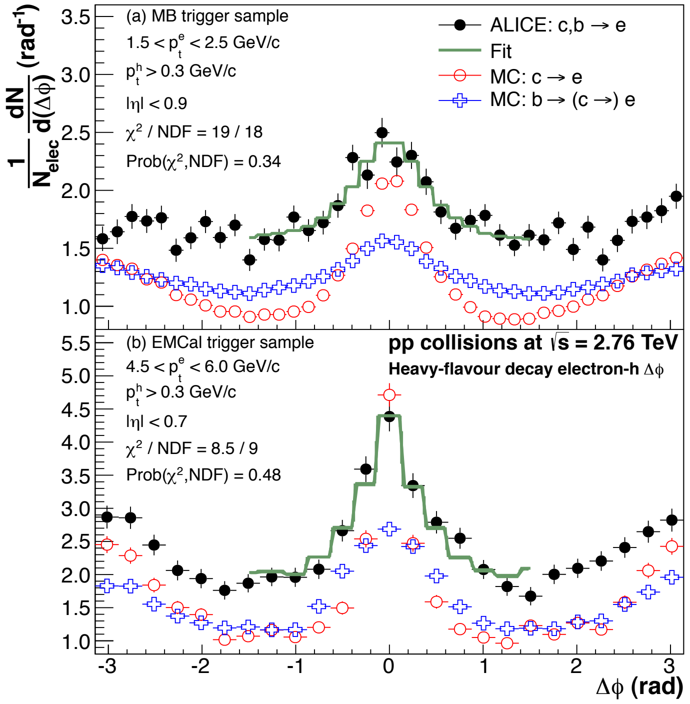


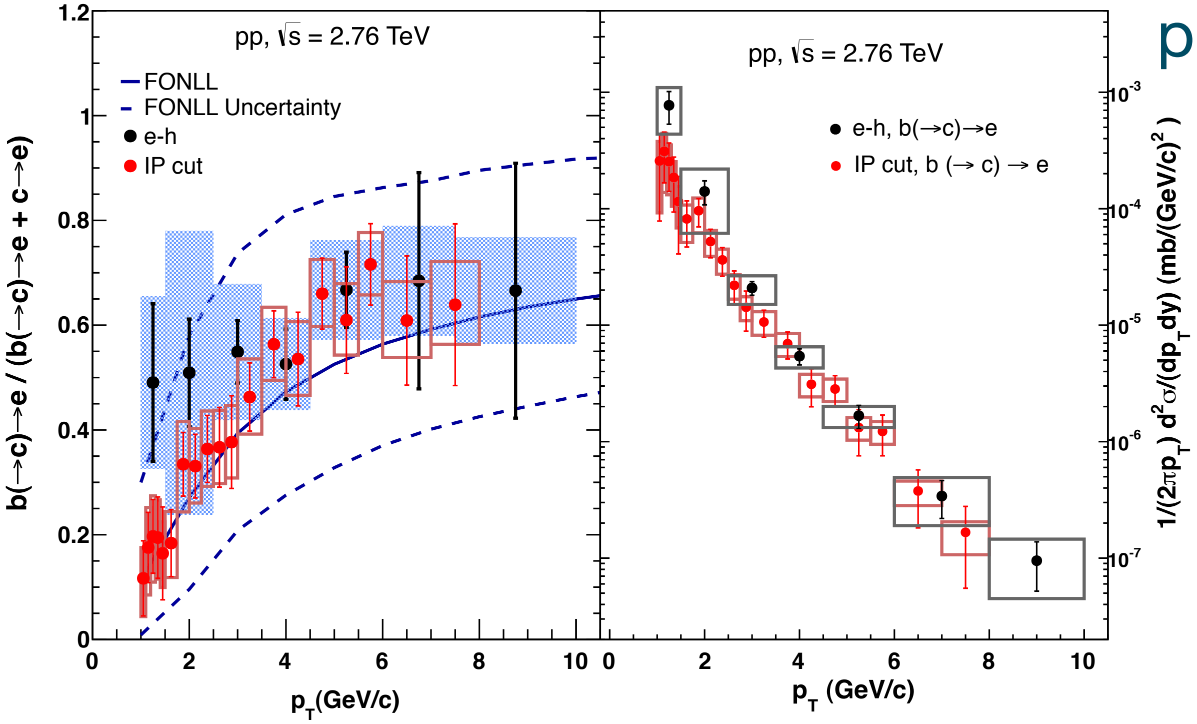
Alternative measurements



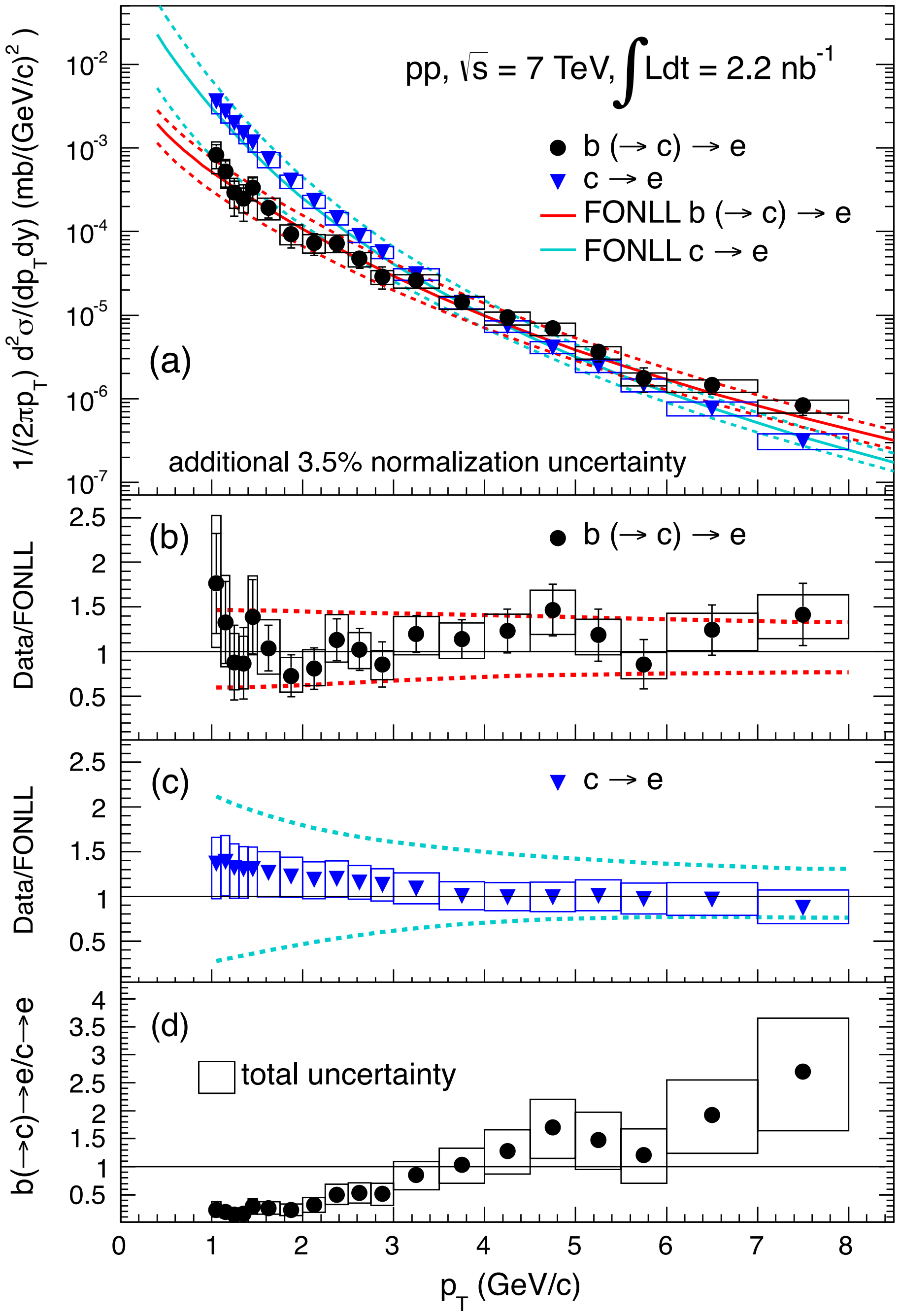


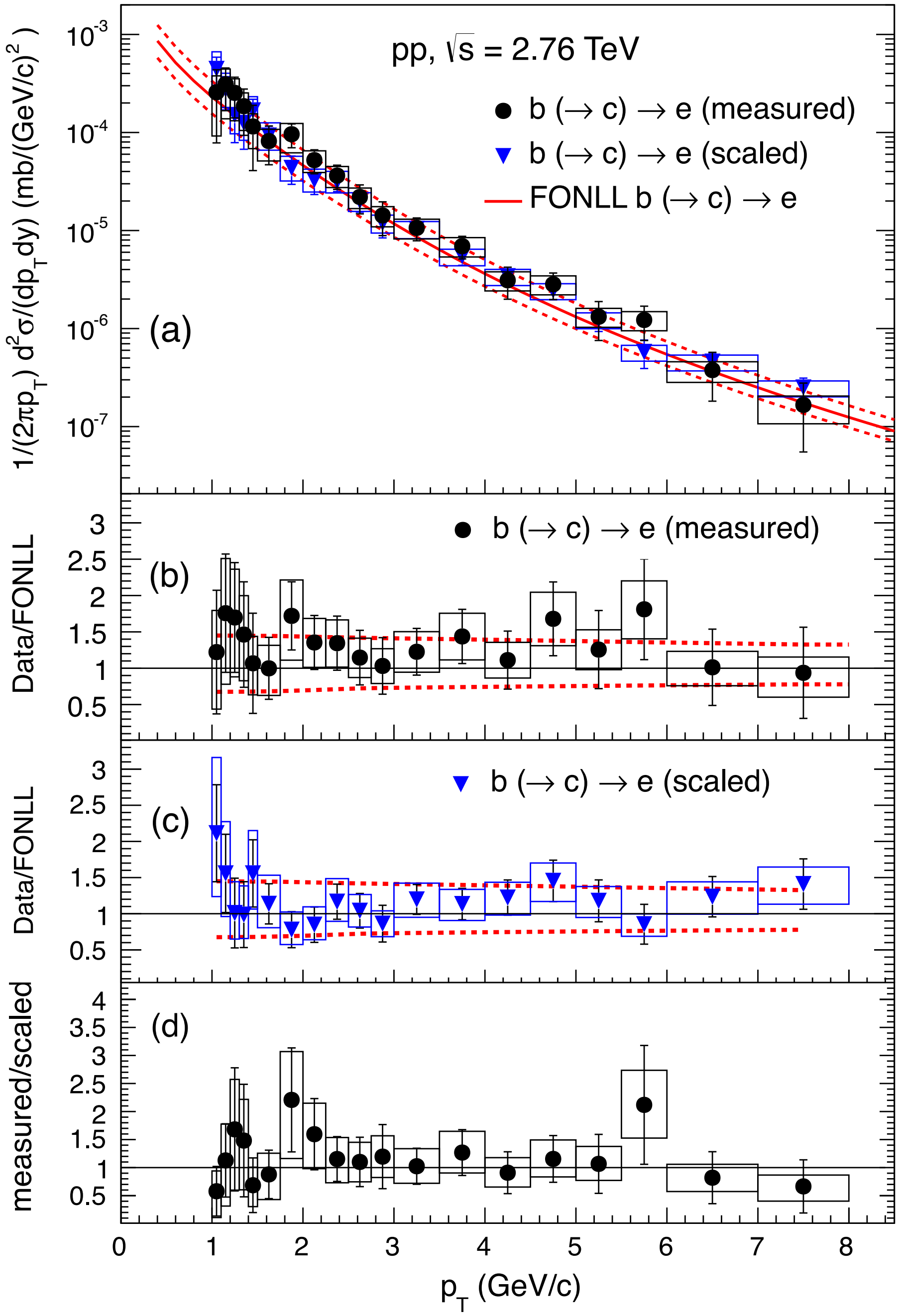
Within the uncertainties, these alternative approaches to access the beauty electron p_T-differential cross section agree with the result obtained using the impact parameter cut.

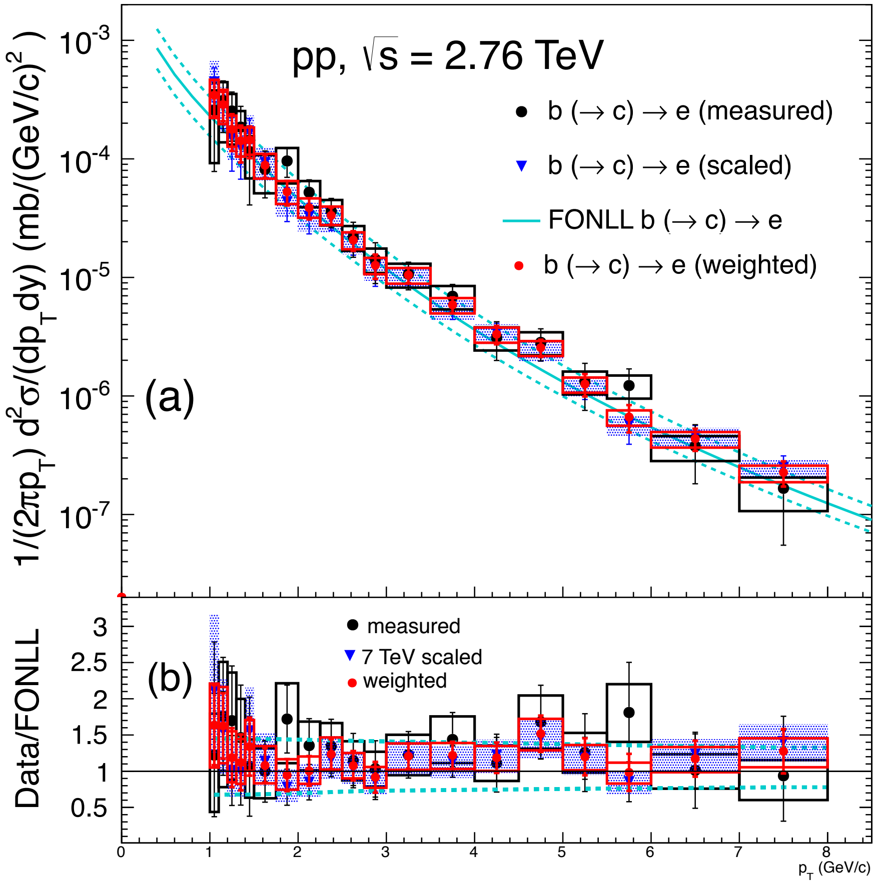




p_T-differential cross sections and weighted average







Will use weighed average as a reference for R_{AA}

- Over the full accessible pt range, FONLL predictions are in good agreement with the data
- Beauty hadron decays take over from charm as the dominant source of electrons from heavy-flavor hadron decays close to electron p_T of 4 GeV/c.

Calculation of total cross section

- p_t range of measured p_t differential cross section:
  - $1(0.5) < p_t < 8$ GeV/c for b→e (b,c→e)
- Extrapolation based on FONNL shape
  - down to 0 p_t for $d\sigma(b\rightarrow e)/dy$ (51% unmeasured based on FONLL)
  - to full rapidity for total $b\bar{b}$ cross section

$$\frac{d\sigma(b,c\rightarrow e)}{dy} = \frac{\sigma_{vis} * \beta_{b,c}}{\Delta y} \quad \text{where} \quad \beta_{b,c} = \frac{\sigma_{FONLL}(b,c\rightarrow e, 0GeV/c < p_{\mathrm{t}} < \infty, y_{min} < y < y_{max})}{\sigma_{vis,FONLL}}$$

$$\frac{d\sigma_{b,c}}{dy} = \frac{\sigma_{vis} * \gamma_{b,c}}{\Delta y} \quad \text{where} \quad \gamma_{b,c} = \frac{\sigma_{FONLL}(b,c, 0GeV/c < p_{\mathrm{t}} < \infty, y_{min} < y < y_{max})}{\sigma_{vis,FONLL}}$$

$$\sigma_{b,c} = \frac{\alpha_{b,c} * \sigma_{vis}}{BR(b,c\rightarrow e)} \quad \text{where} \quad \alpha_{b,c} = \frac{\sigma_{FONLL}(b,c\rightarrow e, 0 < p_{\mathrm{t}} < \infty, -\infty < y < \infty)}{\sigma_{vis,FONLL}}$$

- Statistical, Systematic and normalization uncertainties:
  - scaled by multiplication factors
- Extrapolation uncertainties:
  - each parameter is recalculated for different variation of mass, scale and PDF in FONLL
  - cross section obtained after variation is compared to the cross section obtained using the central value from FONLL and quadratically summed

Total cross sections (7 TeV)

Beauty

$$\sigma_{b\rightarrow e}(p_{\mathrm{t}} > 1 GeV/c, |y| < 0.8) = 6.61 \pm 0.54(stat)^{+1.92}_{-1.86}(sys) \pm 0.231(norm)\mu b$$

$$\frac{d\sigma(b\rightarrow e)}{dy} = 8.40 \pm 0.69(stat)^{+2.43}_{-2.36}(sys)^{+0.19}_{-0.40}(extr) \pm 0.29(norm)\mu b$$

$$\frac{d\sigma_b}{dy} = 42.25 \pm 3.47(stat)^{+12.25}_{-11.88}(sys)^{+1.08}_{-2.23}(extr) \pm 1.49(norm)\mu b$$

$$\sigma_{\mathrm{b\bar{b}}} = 280 \pm 23(\mathrm{stat})^{+81}_{-79}(\mathrm{sys})^{+7}_{-8}(\mathrm{extr}) \pm 10(\mathrm{BR})\ \mu\mathrm{b}$$

Charm

$$\sigma_{HF\rightarrow e}(p_{\mathrm{t}} > 0.5 GeV/c, |y| < 0.5) = 37.73 \pm 3.17(stat)^{+13.3}_{14.44}(sys) \pm 1.32(norm)\mu b$$

Visible cross section of beauty decays are subtracted from visible cross section of charm decay

$$\sigma_{c\bar{c}} = 10.0 \pm 1.7(stat)^{+5.1}_{-5.5}(sys)^{+3.5}_{-0.5}(extr) \pm 0.4(BR)mb$$

D mesons: $\sigma_{\mathrm{c\bar{c}}} = 8.5 \pm 0.5(\mathrm{stat})^{+1.0}_{-2.4}(\mathrm{sys})^{+4.0}_{-0.4}(\mathrm{extr})\ \mathrm{mb}$

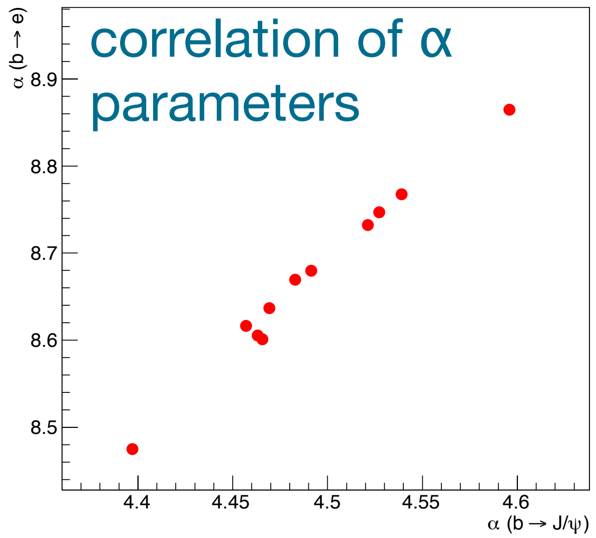
Two independent measurement in ALICE

b→e $\sigma_{\mathrm{b\bar{b}}} = 280 \pm 23(\mathrm{stat})^{+81}_{-79}(\mathrm{sys})^{+7}_{-8}(\mathrm{extr}) \pm 10(\mathrm{BR})\ \mu\mathrm{b}$

b→J/ψ $\sigma_{\mathrm{b\bar{b}}} = 282 \pm 74(\mathrm{stat})^{+58}_{-68}(\mathrm{sys})^{+8}_{-7}(\mathrm{extr})\ \mu\mathrm{b}$

Extrapolation is done based on same model (FONLL)

Weighted average of total cross section



weighted average

$$\bar{\sigma}_b = \sum_{i=0}^{1} \sigma_{b,i} w_i$$

where $\sigma_{b,i}$ are the individual cross sections and w_i are the weighting factors

Statistical and systematic errors between two measurements are uncorrelated, but extrapolation errors are correlated(via α)

$$\sigma_{b,c} = \frac{\alpha_{b,c} * \sigma_{vis}}{BR(b,c \rightarrow e)} \quad \text{where} \quad \alpha_{b,c} = \frac{\sigma_{FONLL}(b,c \rightarrow e, 0 < p_{\mathrm{t}} < \infty, -\infty < y < \infty)}{\sigma_{vis,FONLL}}$$

error matrix

$$E = \begin{pmatrix} \sigma^2_{error(b\rightarrow e)} & r\sigma_{error(b\rightarrow e)}\sigma_{error(b\rightarrow J/\psi)} \\ r\sigma_{error(b\rightarrow e)}\sigma_{error(b\rightarrow J/\psi)} & \sigma^2_{error(b\rightarrow J/\psi)} \end{pmatrix}$$

find the weights minimizing $\sigma^2 = w^T E w$ subject to $\sum w_i = 1$

weights and errors

$$w = \frac{E^{-1}u}{u^T E^{-1} u} \qquad \sigma^2_{stat,sys,extr} = w^T E_{stat,sys,extr} w$$

Reference:
L.Lyons et al., NIM A 270 (1988) 110
"How to combine correlated estimates of a single physical quantity"

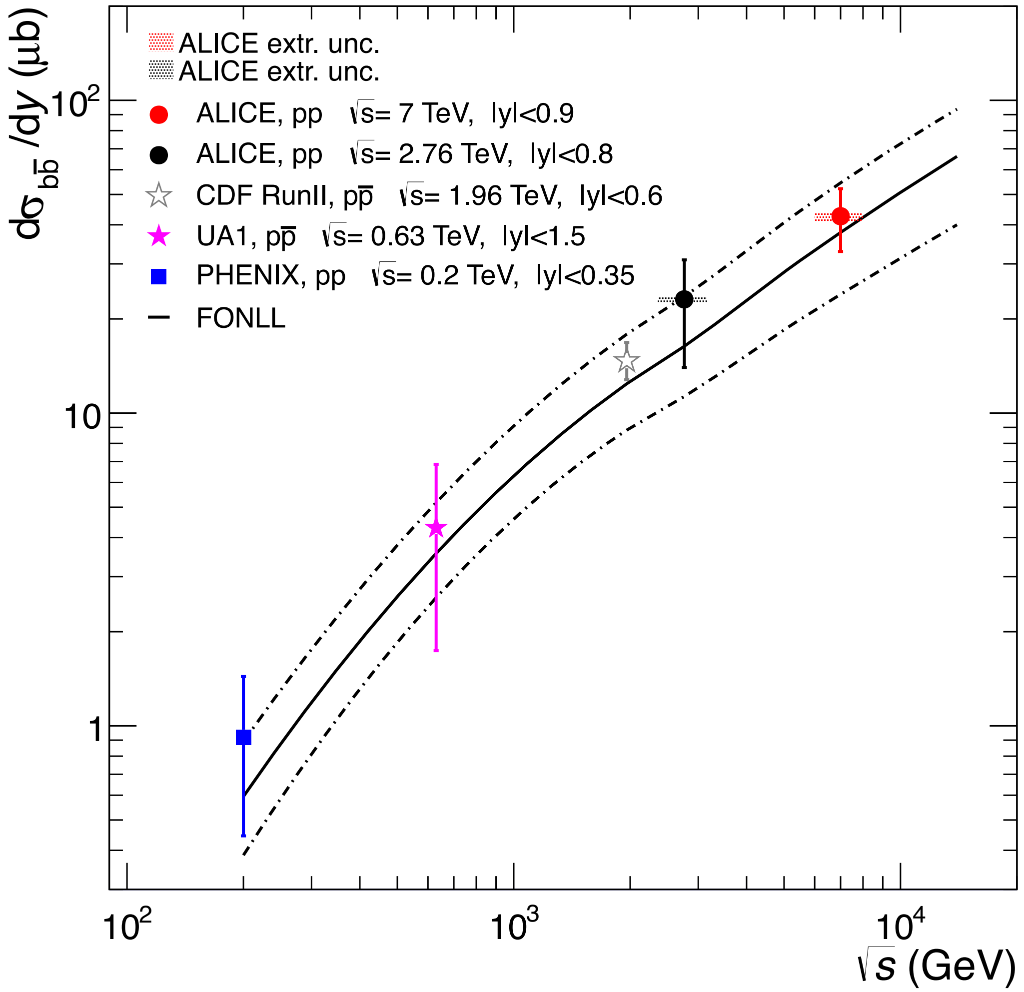
Total beauty cross sections and energy dependence

Weighted average

$$w_{b\to e} = 0.499,\; w_{b\to J/\psi} = 0.501$$

$$\sigma_{b\bar{b}} = 262 \pm 34(stat)^{+48}_{-49}(sys) \pm 7(extr)\mu b$$ + additional 3.5 % normalization uncertainty

$d\sigma_b/dy$ at mid-rapidity as a function of $\sqrt{s}$ in pp and pp̄ collisions



Total cross section for 2.76 TeV
(calculated in a same way)

$$\sigma_b = 129 \pm 15.2(stat)^{+40.9}_{-48.6}(sys)^{+3.38}_{-3.05}(extr) \pm 2.45(norm) \pm 4.36(BR)\mu b$$

$$\frac{d\sigma(b\to e)}{dy} = 4.53 \pm 0.53(stat)^{+1.44}_{-1.71}(sys)^{+0.08}_{-0.10}(extr) \pm 0.09(norm)\mu b$$

FONLL agrees with the measurement within uncertainty

Summary

In summary,① p_{t}-differential invariant production cross sections of electrons from beauty and from charm hadron decays were measured in pp collisions at $\sqrt{s} = 7$ TeV. and at 2.76 TeV ②The agreement between FONLL predictions and the data reported here suggests that higher order pQCD calculations can reliably describe heavy-flavor production even at low p_{t} in the highest energy hadron collisions accessible in the laboratory today. Furthermore,③ these new data provide a crucial baseline for heavy-flavor production studies in the hot and dense matter created in Pb-Pb collisions at the LHC.

Outlook of beauty analysis (from short term to long term)

- Measurement of electrons from beauty hadron decays in pp collisions at $\sqrt{s}$ = 8 TeV using TRD Level-1 triggered events
- Measurement of the nuclear modification factor of electrons from beauty hadron decays in Pb-Pb collisions at $\sqrt{sNN}$ = 2.76 TeV
- Measurement of the nuclear modification factor of electrons from beauty hadron decays in p-Pb collisions
- Beauty jet identification in pp collisions
- Measurement of beauty jet R_{AA} in Pb-Pb collisions
- Measurement of medium modified fragmentation function of beauty jet in Pb-Pb collisions

BACKUP

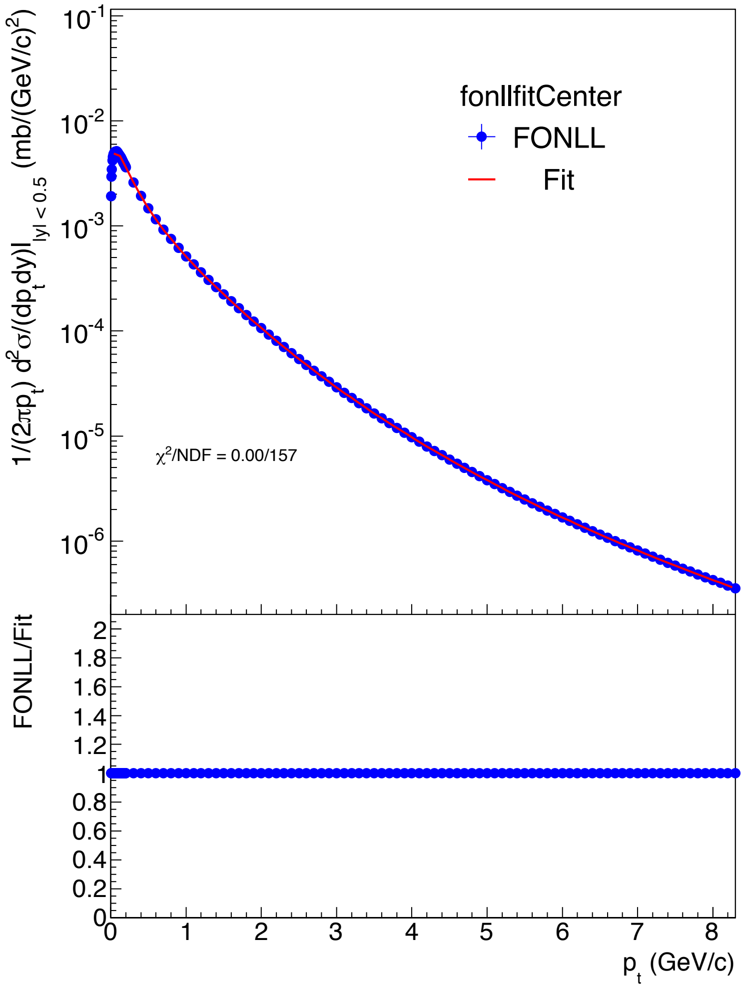
Fit method to calculate total cross section (I)

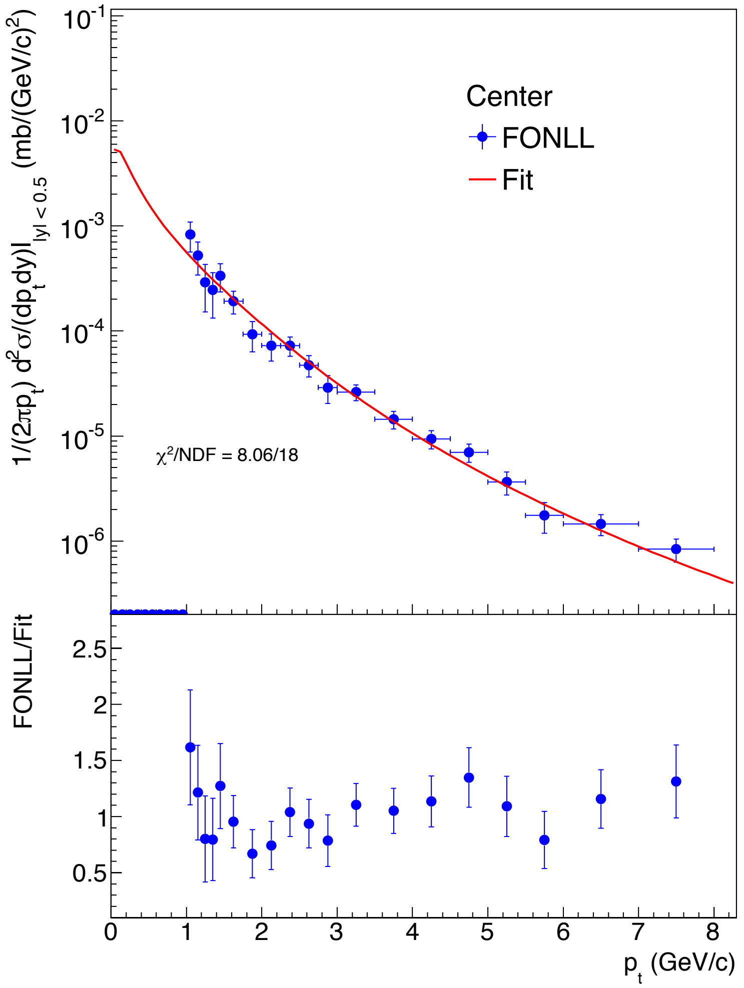
$$\frac{d\sigma(b \rightarrow e)}{dy}$$

(Thanks to Markus Fasel and Ralf)

Extrapolation down to 0 p_t

- FONLL data points are interpolated via TSpline3(Tsallis fit for charm)
- Fit the measured p_t spectra with the normalization as a free parameter





Fit method to calculate total cross section (II)

Statistical uncertainties: same as the one from visible cross section

Systematic uncertainties: one from visible cross section + propagation of systematic uncertainties to extrapolation (sum linearly)

- systematic uncertainties are correlated
- move up and down all data points by the systematic uncertainties
- fit the central FONLL prediction to the data points after moving
- evaluate the difference from the fit of central prediction using central data points

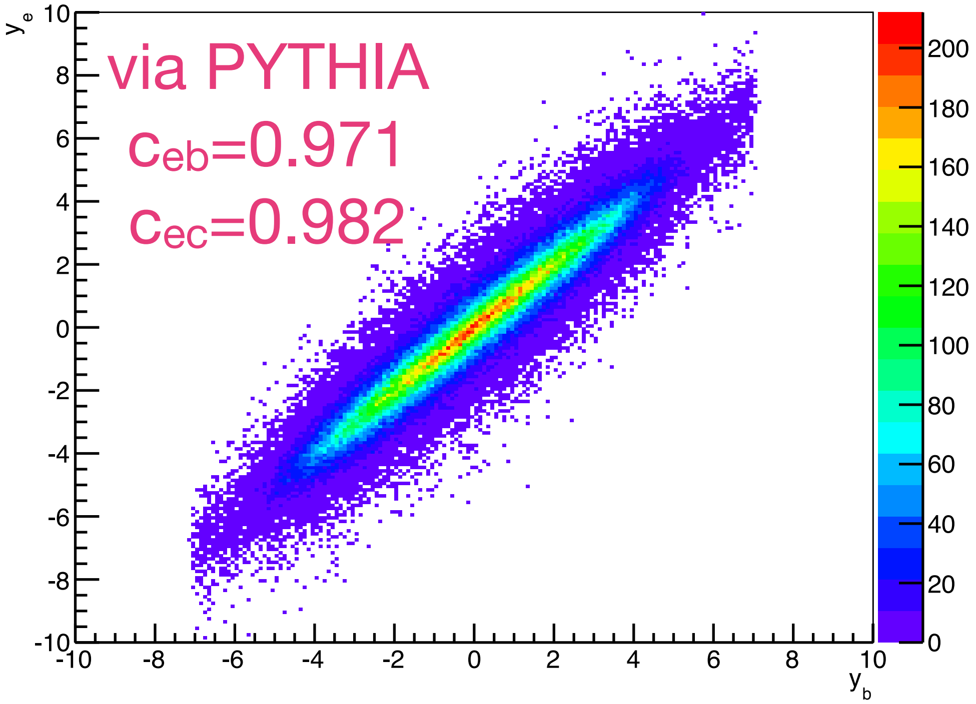
Extrapolation uncertainties:

- fit is done for different variation of mass, scale and PDF in FONLL
- cross section obtained after variation is compared to the cross section obtained using the central value from FONLL and quadratically summed

- fit error from measured data points fit (with statical errors) is quadratically added

Fit method to calculate total cross section (III)

$$\frac{d\sigma_b}{dy} = \frac{1}{BR(b \rightarrow e) * C_{eb}} \frac{d\sigma(b \rightarrow e)}{dy}$$


via PYTHIA
c_{eb}=0.971
c_{ec}=0.982

BR(beauty) = 0.2046±0.0067
BR(charm) = 0.096±0.004

$$\Delta \frac{d\sigma_b}{dy}\Big|_{BR} = \frac{1}{BR^2 * C_{eb}} \frac{d\sigma(b \rightarrow e)}{dy} \Delta(BR)$$

Extrapolation based on FONLL $\frac{d\sigma_b}{dy}$ curve shape

$$\sigma_b = \frac{\int \frac{d\sigma_b}{dy}_{FONLL} dy}{\int_{y_{\min}}^{y_{\max}} \frac{d\sigma_b}{dy}_{FONLL} dy} \times \left(\frac{d\sigma_b}{dy}_{measured} \times \Delta y \right)$$

Extrapolation error based on line shape of upper and lower limit

Beauty, charm cross sections with fit method

$$\frac{d\sigma(b \to e)}{dy} = 8.24 \pm 0.34(stat)^{+2.17}_{-2.11}(sys)^{+0.33}_{-0.49}(extr) \pm 0.29(norm)\mu b$$

$$\frac{d\sigma_b}{dy} = 41.46 \pm 1.71(stat)^{+10.93}_{-10.63}(sys)^{+1.68}_{-2.50}(extr) \pm 1.45(norm) \pm 1.41(BR)\mu b$$

$$\sigma_b = 275 \pm 11.3(stat)^{+72.6}_{-70.6}(sys)^{+13.2}_{-21.7}(extr) \pm 9.64(norm) \pm 9.35(BR)\mu b$$

$$\frac{d\sigma(HF \to e)}{dy} = 92.99 \pm 3.16(stat)^{+30.5}_{-30.08}(sys)^{+31.58}_{-11.46}(extr) \pm 3.25(norm)\mu b$$

$$\frac{d\sigma(c \to e)}{dy} = 84.52 \pm 3.50(stat)^{+32.73}_{-32.24}(sys)^{+32.03}_{-12.15}(extr) \pm 3.55(norm)\mu b$$

$$\frac{d\sigma_c}{dy} = 889.18 \pm 36.85(stat)^{+344.27}_{-339.16}(sys)^{+336.97}_{-127.79}(extr.) \pm 37.35(norm) \pm 36.74(br.)\mu b$$

$$\sigma_c = 7.59 \pm 0.31(stat)^{+2.94}_{-2.9}(sys)^{+3.18}_{-2.49}(extr) \pm 0.32(norm) \pm 0.31(br)mb$$

Calculation of total cross section at 2.76 TeV

- p_T range of measured p_T differential cross section:
  - $1 < p_T < 8$ GeV/c
- Extrapolation based on FONNL shape
  - down to 0 p_T for $d\sigma(b \rightarrow e)/dy$ (64.3% unmeasured based on FONLL)
  - to full rapidity for total $b\bar{b}$ cross section

$$\frac{d\sigma(b,c \rightarrow e)}{dy} = \frac{\sigma_{vis} * \beta_{b,c}}{\Delta y} \quad \text{where} \quad \beta_{b,c} = \frac{\sigma_{FONLL}(b,c \rightarrow e, 0GeV/c < p_{\mathrm{t}} < \infty, y_{min} < y < y_{max})}{\sigma_{vis,FONLL}}$$

$$\frac{d\sigma_{b,c}}{dy} = \frac{\sigma_{vis} * \gamma_{b,c}}{\Delta y} \quad \text{where} \quad \gamma_{b,c} = \frac{\sigma_{FONLL}(b,c,0GeV/c < p_{\mathrm{t}} < \infty, y_{min} < y < y_{max})}{\sigma_{vis,FONLL}}$$

$$\sigma_{b,c} = \frac{\alpha_{b,c} * \sigma_{vis}}{BR(b,c \rightarrow e)} \quad \text{where} \quad \alpha_{b,c} = \frac{\sigma_{FONLL}(b,c \rightarrow e, 0 < p_{\mathrm{t}} < \infty, -\infty < y < \infty)}{\sigma_{vis,FONLL}}$$

- Statistical, Systematic and normalization uncertainties:
  - scaled by multiplication factors
- Extrapolation uncertainties:
  - each parameter is recalculated for different variation of mass, scale in FONLL
  - cross section obtained after variation is compared to the cross section obtained using the central value from FONLL and quadratically summed

Note: Only CTEQ6.6 is available for 2.75 TeV in FONLL (checked it gave negligible effect at 7 TeV analysis)

Total cross sections

Visible cross section

$$\sigma_{b\rightarrow e}(p_{\mathrm{T}} > 1GeV/c, |y| < 0.8) = 3.44 \pm 0.41(stat)^{+1.09}_{-1.30}(sys) \pm 0.066(norm)\mu b$$

$$\frac{d\sigma(b \rightarrow e)}{dy} = 4.53 \pm 0.53(stat)^{+1.44}_{-1.71}(sys)^{+0.08}_{-0.10}(extr) \pm 0.09(norm)\mu b$$

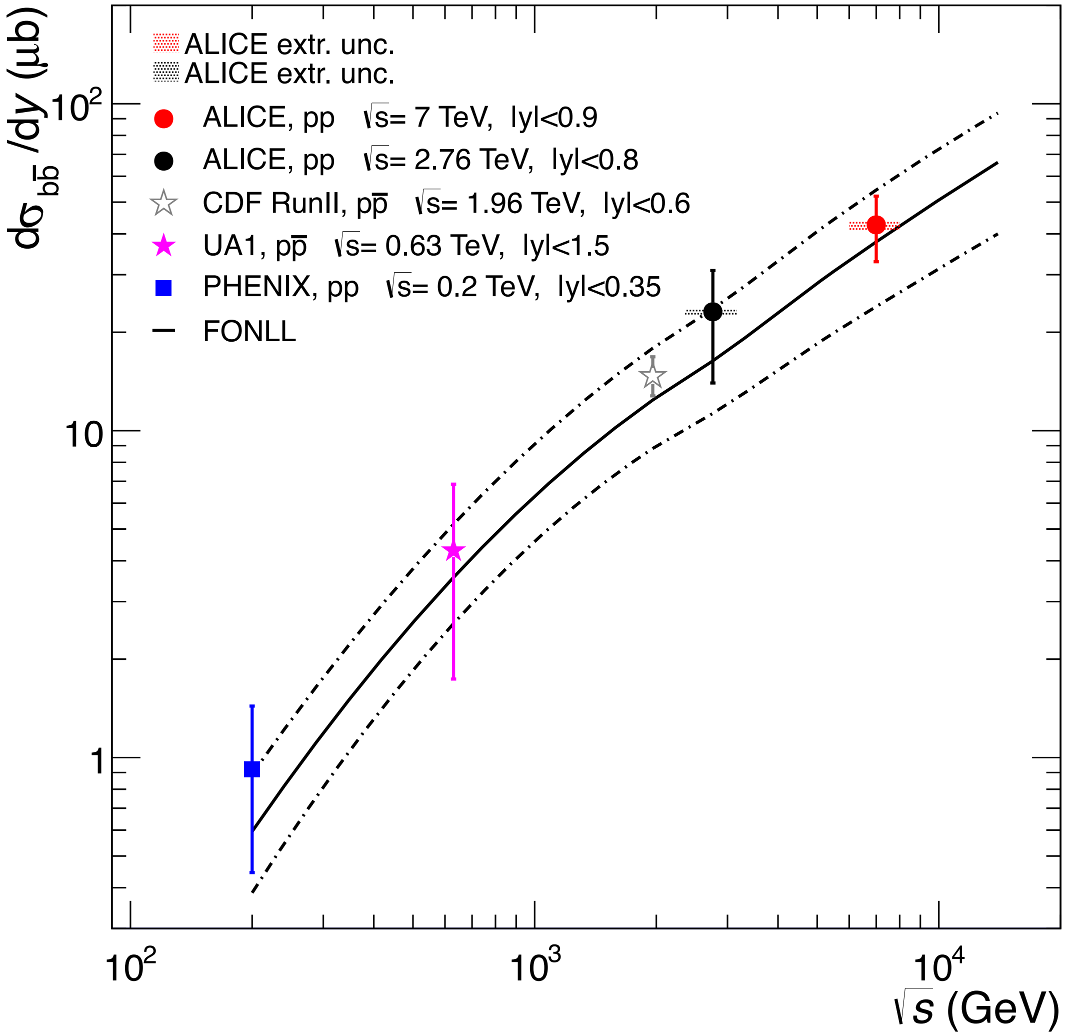
$$\frac{d\sigma_b}{dy} = 23.14 \pm 2.72(stat)^{+7.33}_{-8.70}(sys)^{+0.49}_{-0.65}(extr) \pm 0.44(norm)\mu b$$

$$\sigma_b = 129 \pm 15.2(stat)^{+40.9}_{-48.6}(sys)^{+3.38}_{-3.05}(extr) \pm 2.45(norm) \pm 4.36(BR)\mu b$$

FONLL predicts

$$\sigma_b = 95.5^{+139}_{-66.5}\mu b$$

Fig. 6



FONLL agrees with the measurement within uncertainty

Efficiency (2.76 TeV)