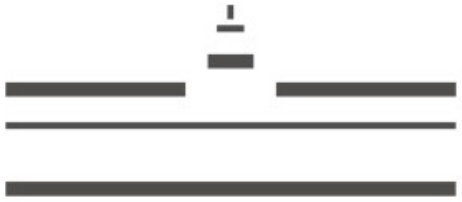


Measurement of electrons from heavy-flavour hadron decays in pp and p-Pb collisions with ALICE at the LHC

Markus Heide
for the ALICE collaboration

WWU Münster
Institut für Kernphysik
Strangeness in Quark Matter 2013
26th of July 2013

Westfälische Wilhelms-Universität Münster

Motivation

charm and beauty are produced in hard scatterings during initial stage of hadronic collisions

in pp collisions:

- test of pQCD calculations
- reference for Pb-Pb collisions

→ probe for energy loss mechanisms in Quark-Gluon Plasma:

$\Delta E_g > \Delta E_c > \Delta E_b$?

(Dokshitzer & Kharzeev, PLB 519 (2001) 199)

in p-Pb collisions:

- measure cold nuclear matter effects, such as
  - nuclear shadowing
  - k_T broadening

measurement via decay electrons:

- large branching ratios: $c \rightarrow e \approx 10\ \%$
  $b \rightarrow e \approx 11\ \%$
  $b \rightarrow c \rightarrow e \approx 10\ \%$

- possibility of **separating b → e from c → e** via track impact parameter and via electron-hadron azimuthal angular correlations

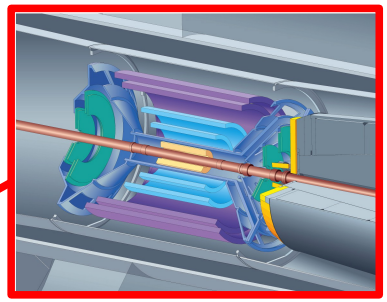
A Large Ion Collider Experiment

Detectors used for c/b → e measurements: central barrel, |η| < 0.8

Time Of Flight: electron identification via time of flight

ElectroMagnetic Calorimeter:

electron identification via energy-momentum matching (E/p ≈ 1), trigger



Inner Tracking System:

tracking, vertexing
→ separate charm and beauty via impact parameter

Time Projection Chamber:

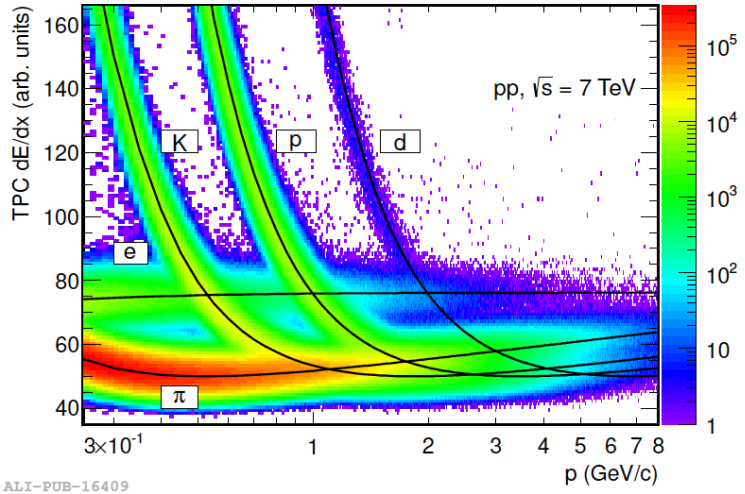
electron identification via dE/dx, tracking

Transition Radiation Detector:

electron identification via dE/dx + transition radiation, tracking

Electron Identification in ALICE

Phys. Rev. D 86, 112007

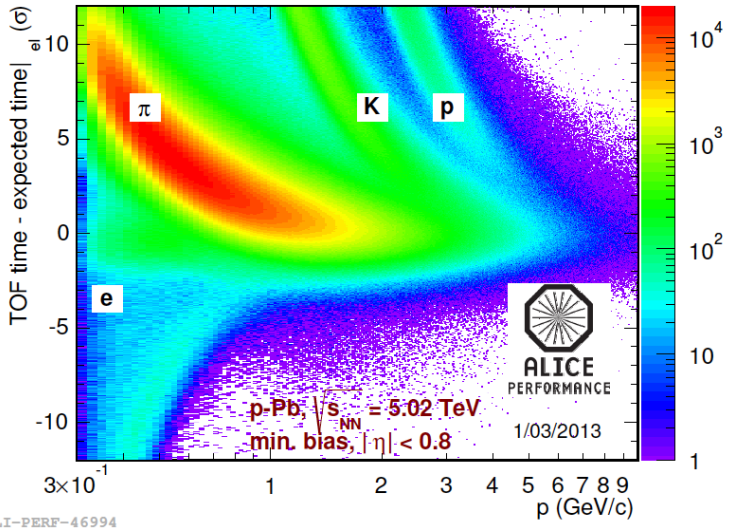


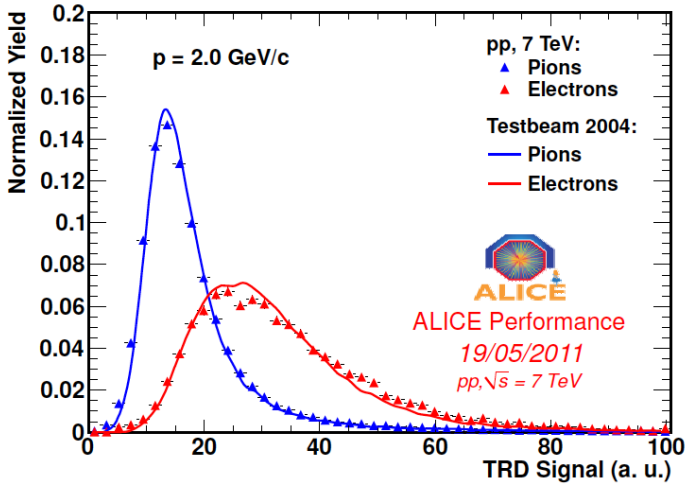
TPC

dE/dx

TOF

time of flight



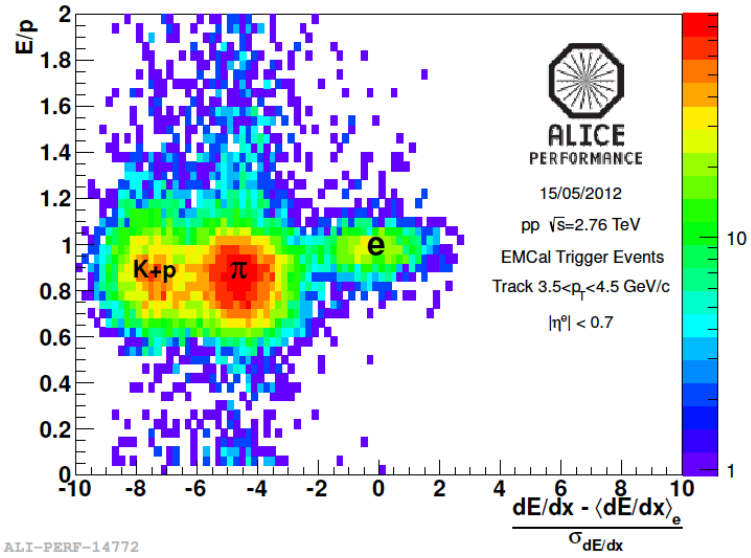


TRD

dE/dx
+
transition radiation

EMCal

E/p



Electron Background Subtraction

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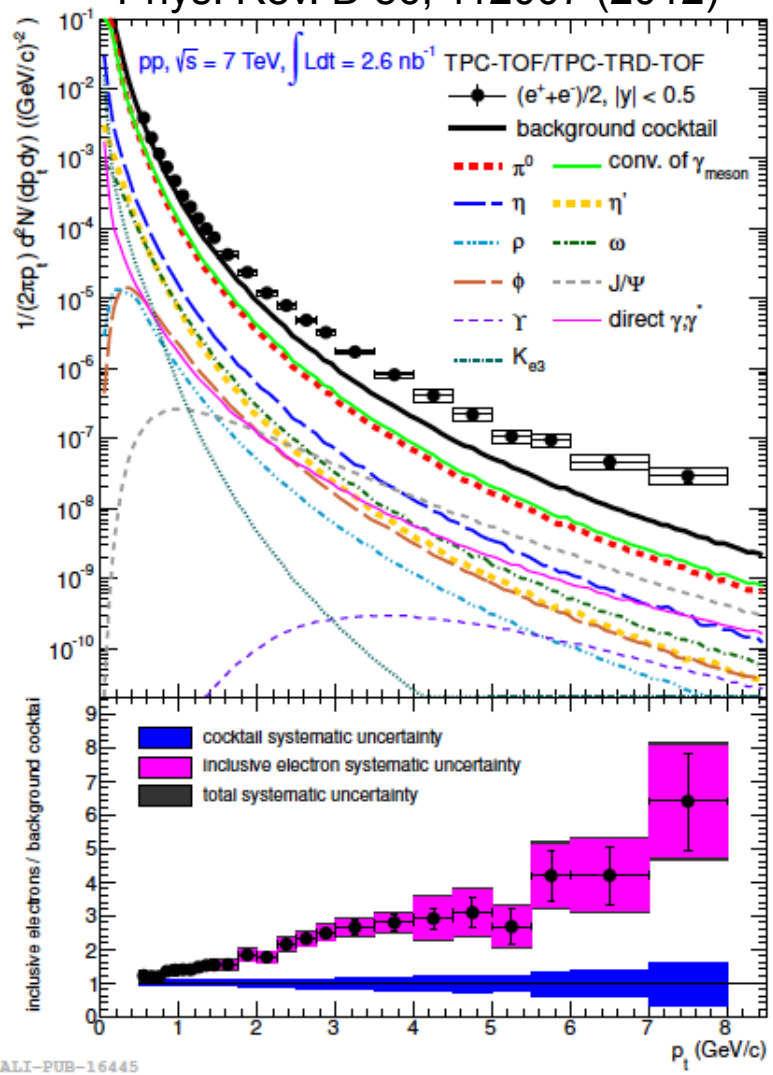
two alternative methods:

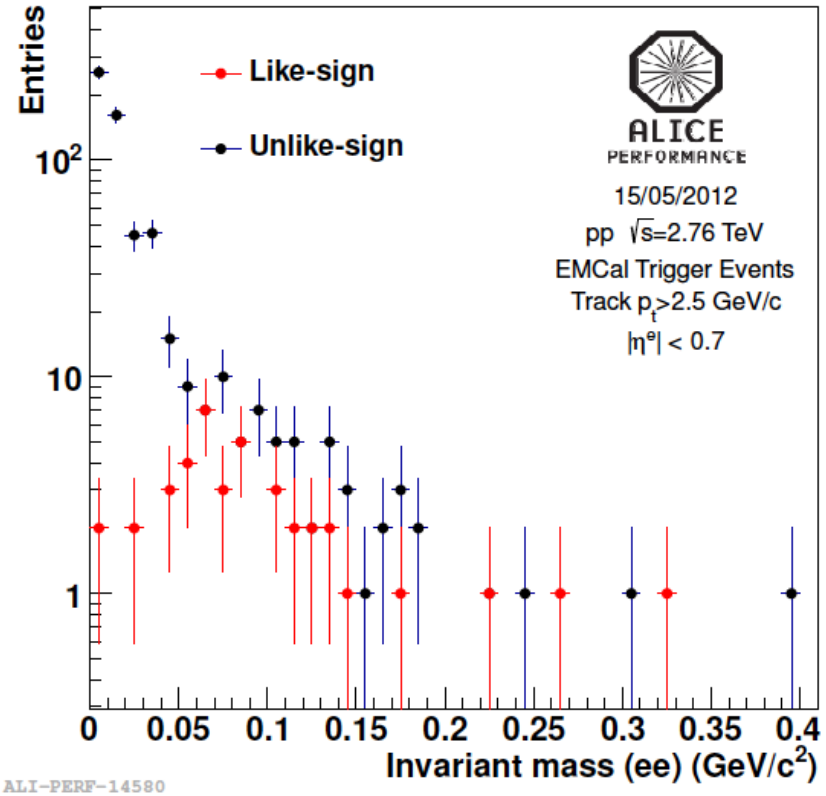
1.) cocktail subtraction based on measured hadron production cross sections

Phys. Rev. D 86, 112007 (2012)



2.) reconstruction of $e^+ + e^-$ pairs from γ conversions and Dalitz decay of neutral mesons via invariant mass

reconstruction of like-sign pairs to estimate combinatorial background to γ conversions



Proton-Proton Collisions, $\sqrt{s} = 7$ TeV

electrons from heavy-flavour hadron decays:

c → e
b → e

analysis of minimum bias data

p_T-differential production cross section:

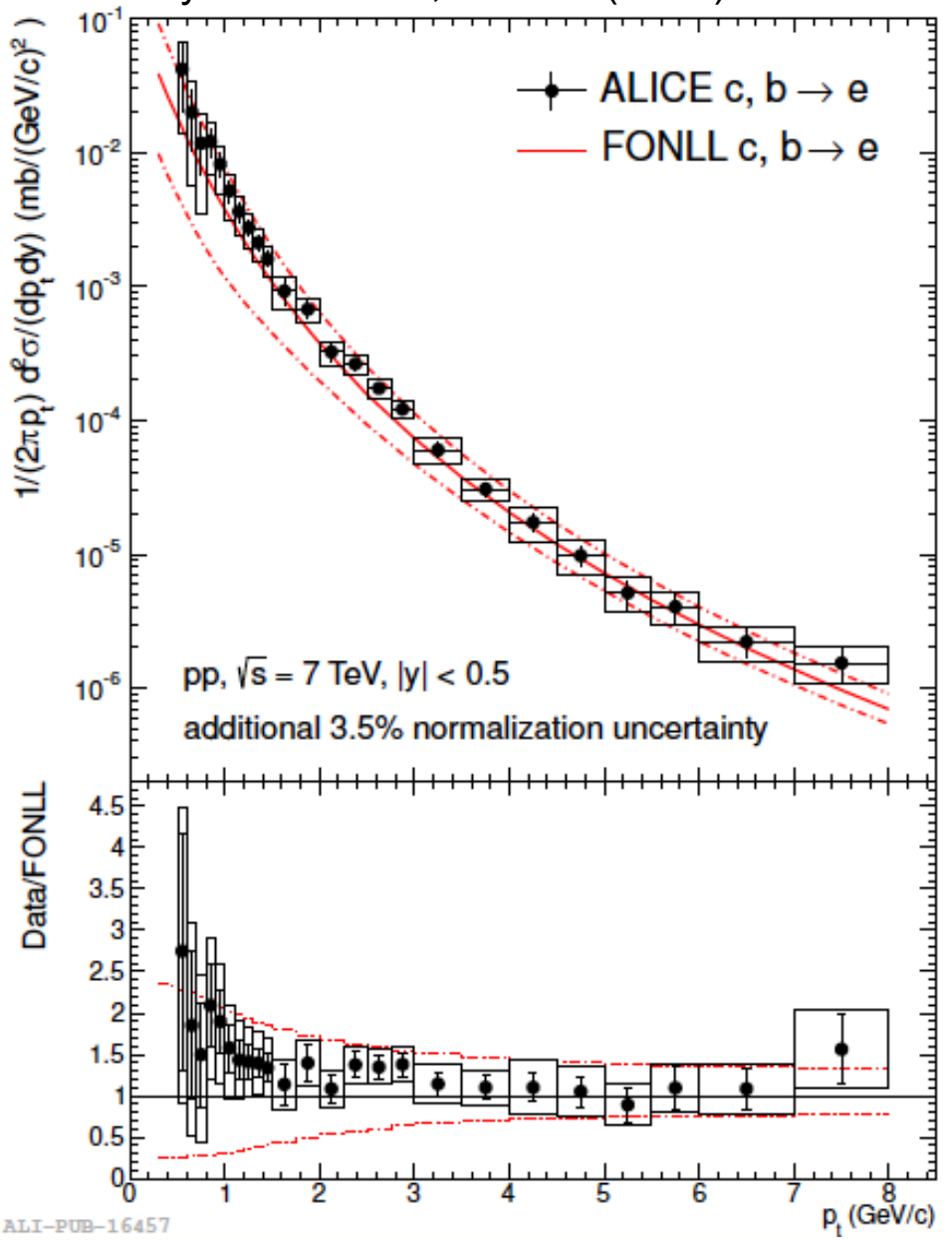
- **well described by FONLL calculations**

  FONLL: Cacciari et al., JHEP 9805 (1998) 007
  Cacciari et al., JHEP 0103 (2001) 006

- **further predictions by GM-VFNS and k_t-factorization also in good agreement**

  GM-VFNS: Bolzoni & Kramer, Nucl. Phys. B 872 (2013) 253-264
  k_t-fact.: Maciula & Szczurek, arXiv:1306.6808v1

Phys. Rev. D 86, 112007 (2012)



Proton-Proton Collisions, $\sqrt{s} = 7$ TeV

electrons from heavy-flavour hadron decays:

$c \rightarrow e$
$b \rightarrow e$

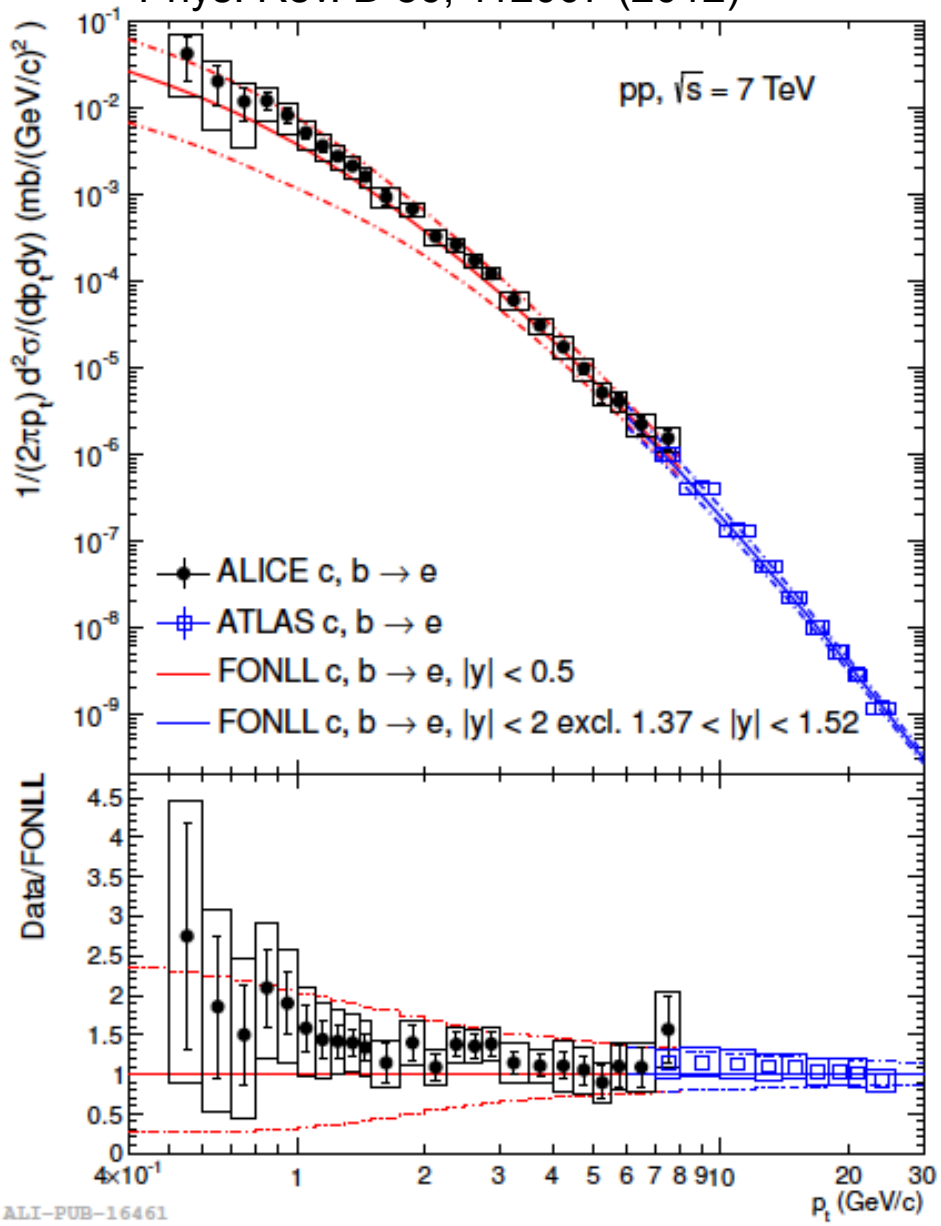
analysis of minimum bias data

p_T-differential production cross section:

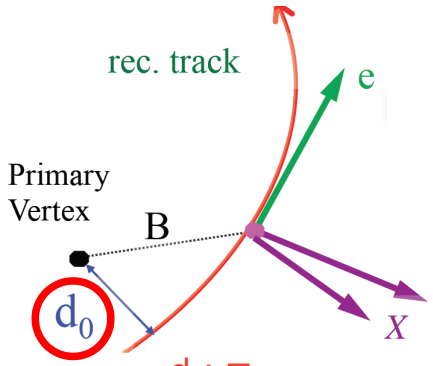
- **well described by FONLL calculations**
- **measurements in p_T region complementary to ATLAS results**

ATLAS: Physics Letters B 707 (2011) 438

Phys. Rev. D 86, 112007 (2012)



Proton-Proton Collisions, $\sqrt{s} = 7$ TeV

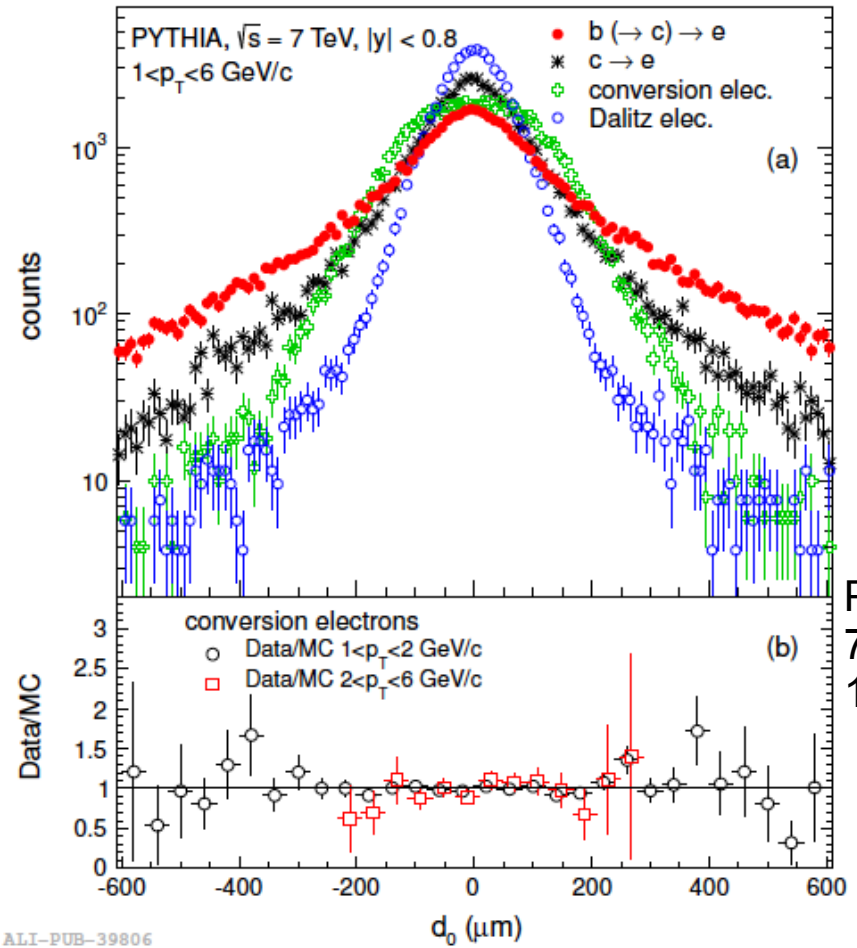


d_0: **Transverse impact parameter**

separate measurement of b → e decays

decay lengths:

$c\tau(D^0)$ = 123 μm
$c\tau(D^{+/-})$ = 312 μm
$c\tau(B)$ ~ 500 μm



Phys. Lett. B 721 (2013) 13-23

electrons from beauty decays: wide impact parameter distribution

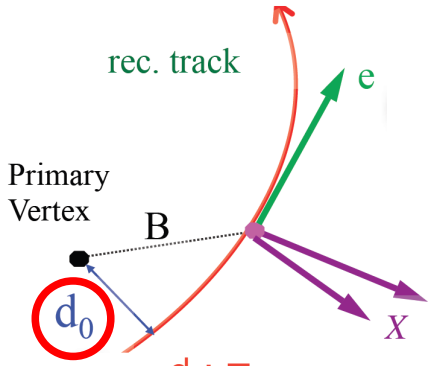
excellent impact parameter resolution of ALICE Inner Tracking System:

σ_{d0} < 75 μm for p_T > 1 GeV/c

⇩

beauty can be distinguished from charm

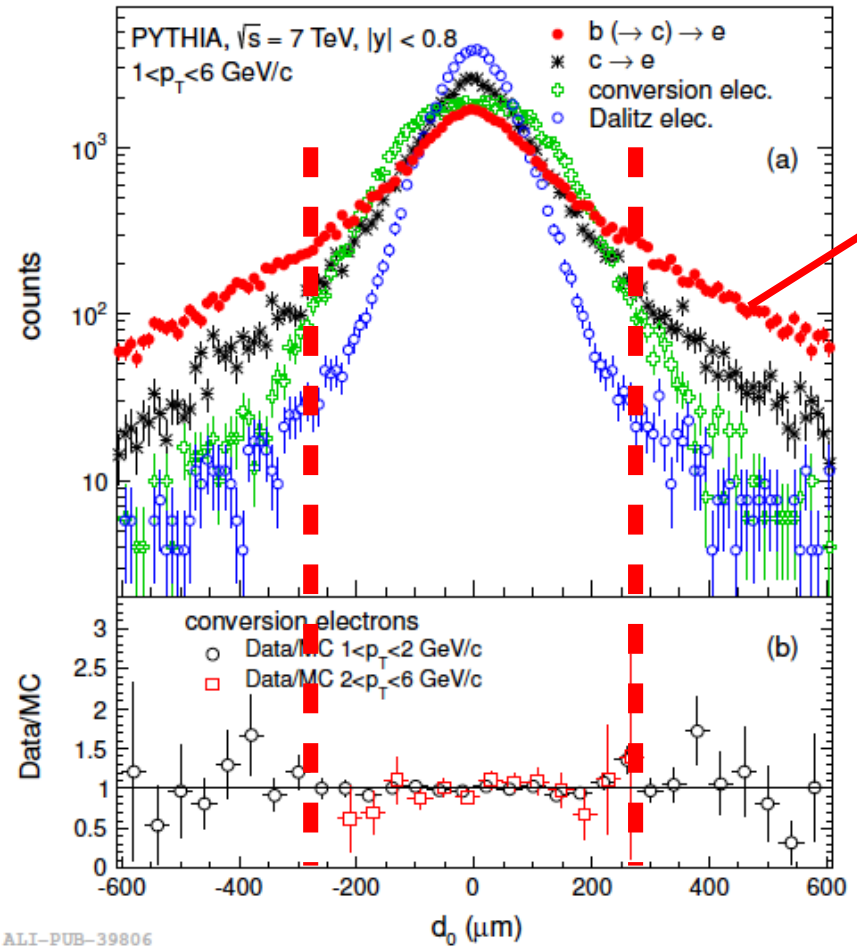
Proton-Proton Collisions, $\sqrt{s} = 7$ TeV



d_0: Transverse impact parameter

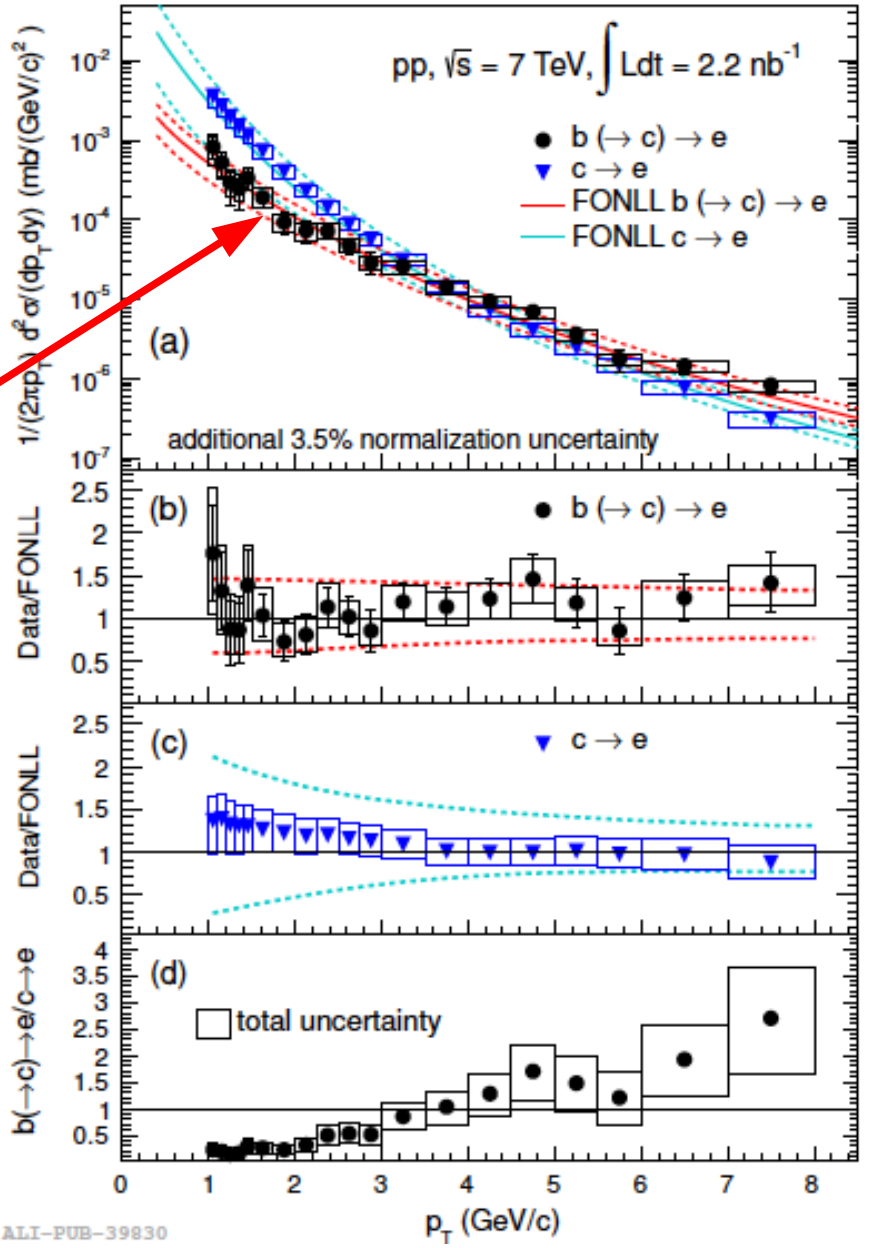
separate measurement of b → e decays

- **select electrons with large impact parameter to primary vertex**
- **subtract background using simulations**



Phys. Lett. B 721 (2013) 13-23

minimum bias data



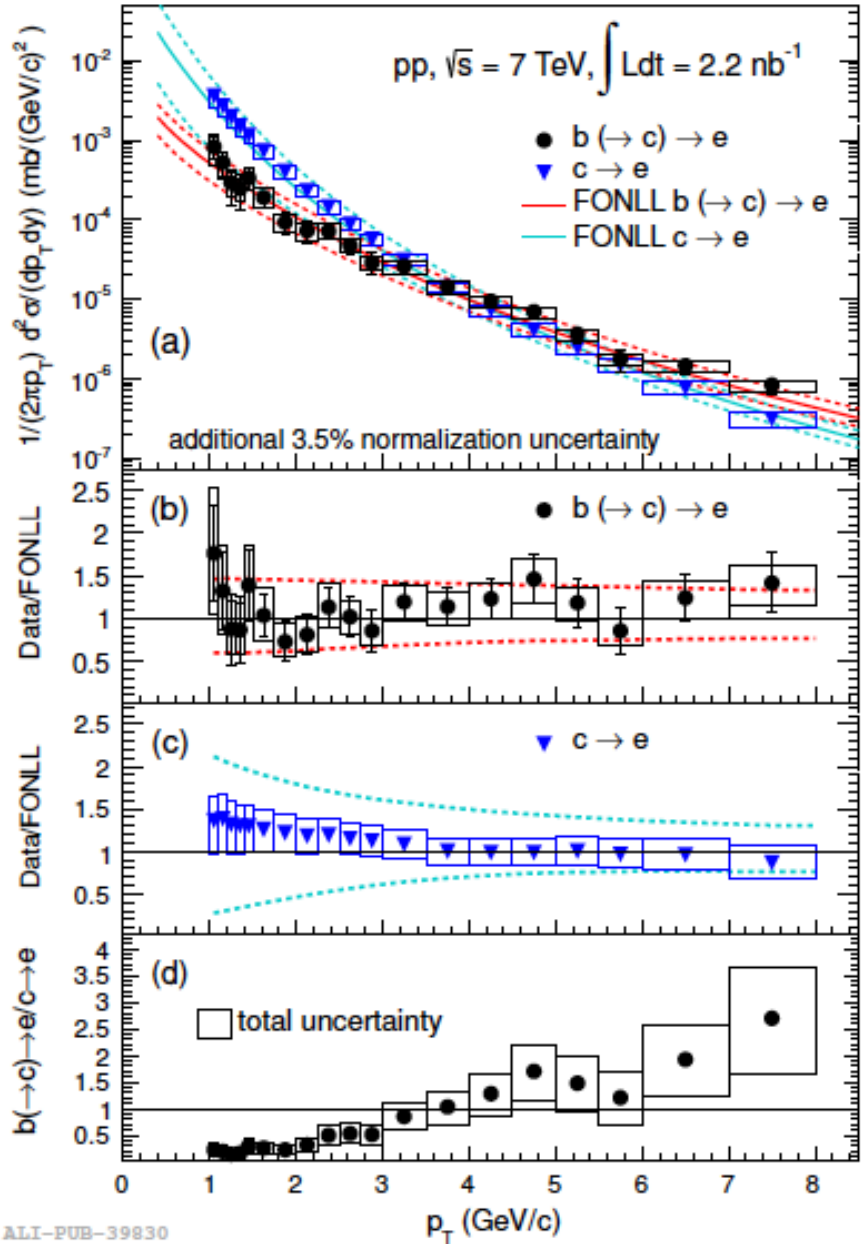
Proton-Proton Collisions, $\sqrt{s} = 7$ TeV

separate measurement of b → e decays

p_T-differential production cross section of electrons from beauty hadron decays:

- **well described by FONLL calculations**
  FONLL: Cacciari et al., JHEP 9805 (1998) 007
  Cacciari et al., JHEP 0103 (2001) 006
- **further calculations from GM-VFNS and k_t-factorization also in good agreement**
  GM-VFNS: Bolzoni & Kramer, Nucl. Phys. B 872 (2013) 253-264
  k_t-fact.: Maciula & Szczurek, arXiv:1306.6808v1
- **beauty** takes over as dominant electron source relative to **charm** at p_T ~ 4 GeV/c

Phys. Lett. B 721 (2013) 13-23



Proton-Proton Collisions, $\sqrt{s} = 7$ TeV

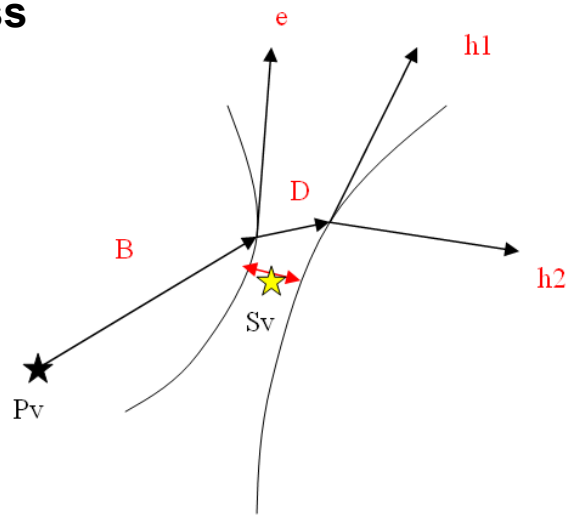
separate measurement of b → e decays

alternative method:

- **reconstruction of displaced e-h vertices**

cut on:

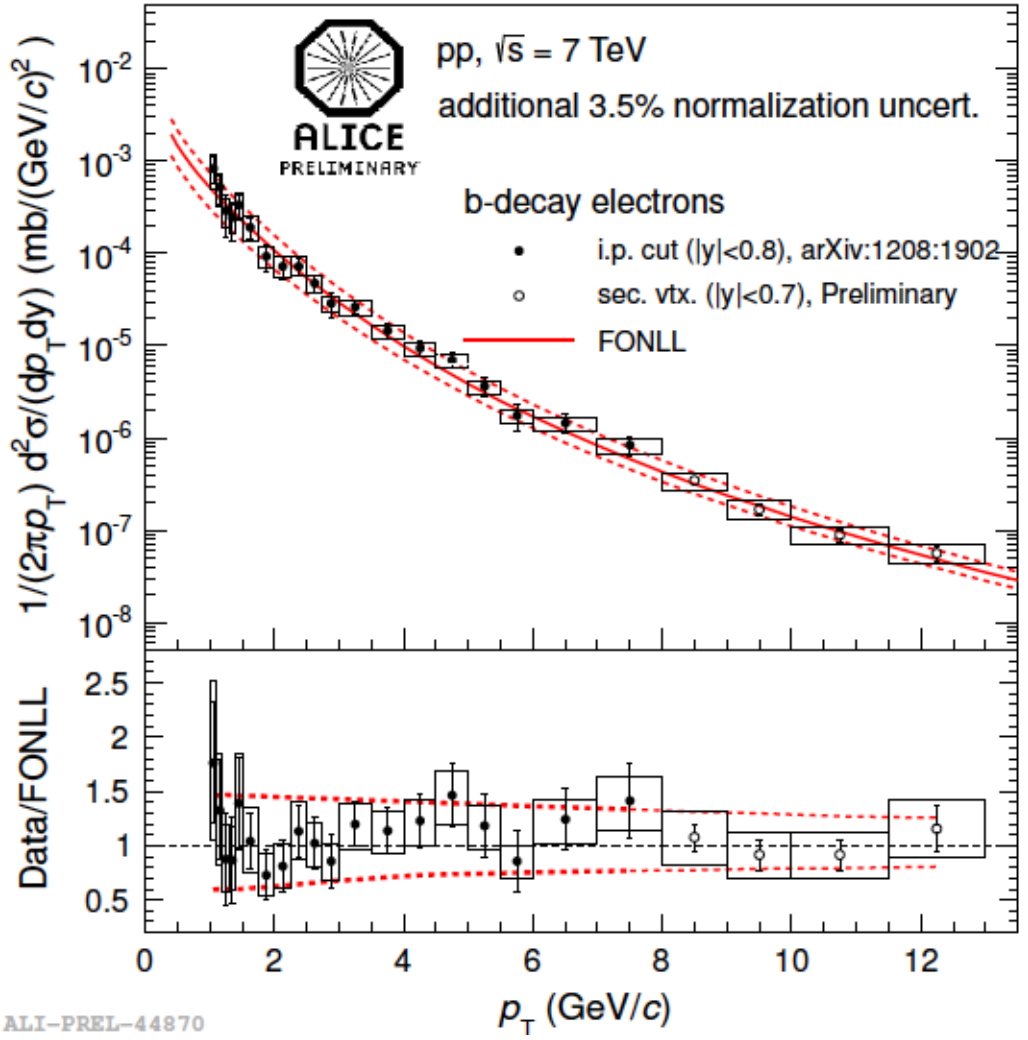
- **distance to primary vertex**
- **invariant mass**
- **p_T of hadron**



independent cross-check for impact parameter method

analysis of EMCal-triggered events

→ cross-section measurement extended up to p_T = 13 GeV/c



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Proton-Proton Collisions, $\sqrt{s} = 7$ TeV

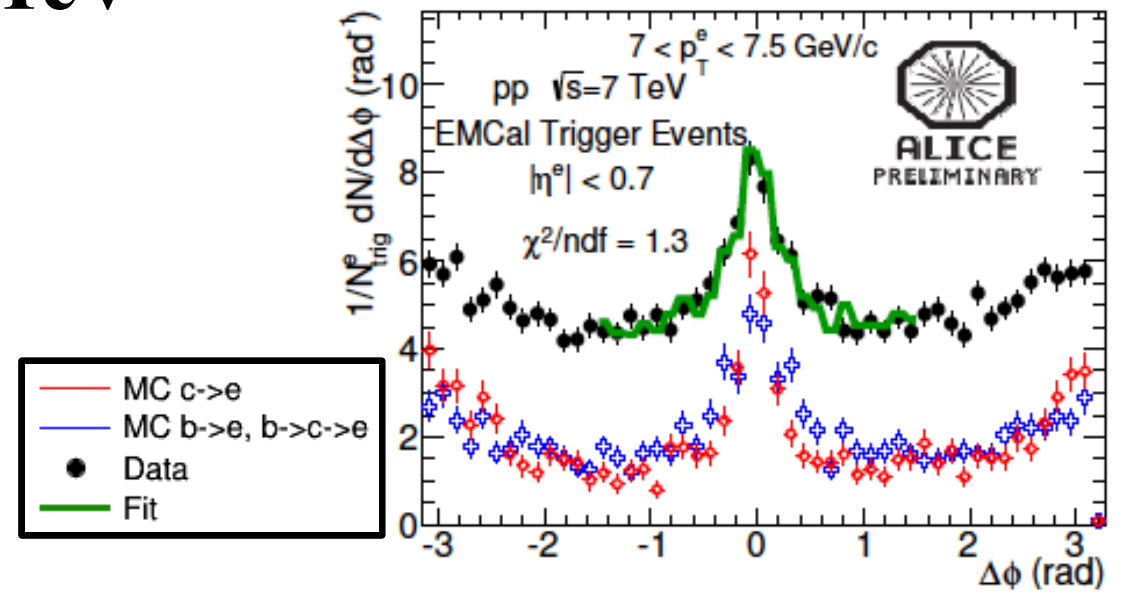
separate measurement of b → e decays

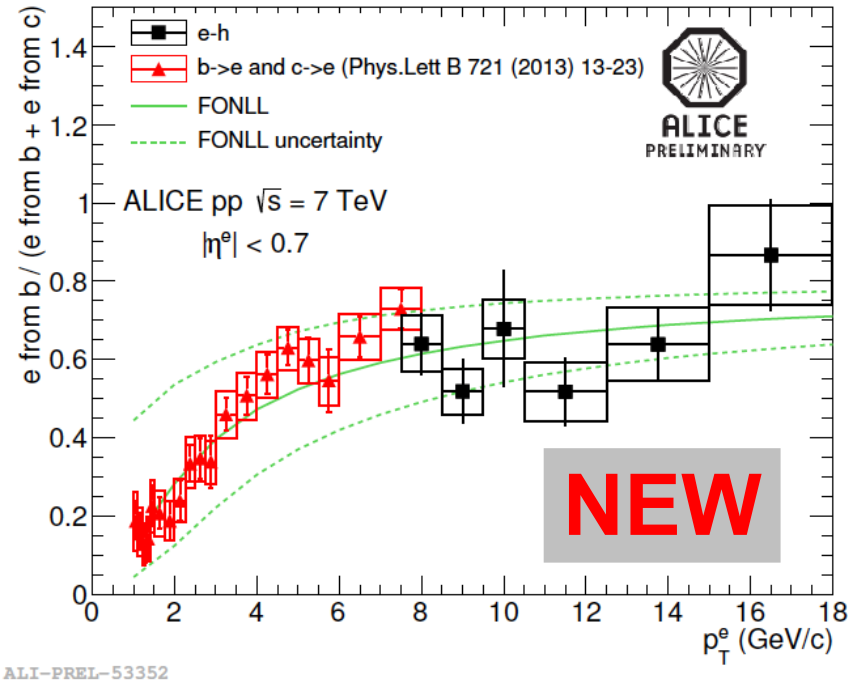
third method:

- **via electron-hadron azimuthal correlations**
- **near-side peak wider for beauty than for charm hadron decays**
- **comparison to PYTHIA templates**

analysis of EMCal-triggered events

→ ratio of e(b)/e(c+b) up to 18 GeV/c





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Proton-Proton Collisions, $\sqrt{s} = 7$ TeV

separate measurement of b → e decays

third method:

- **via electron-hadron azimuthal correlations**
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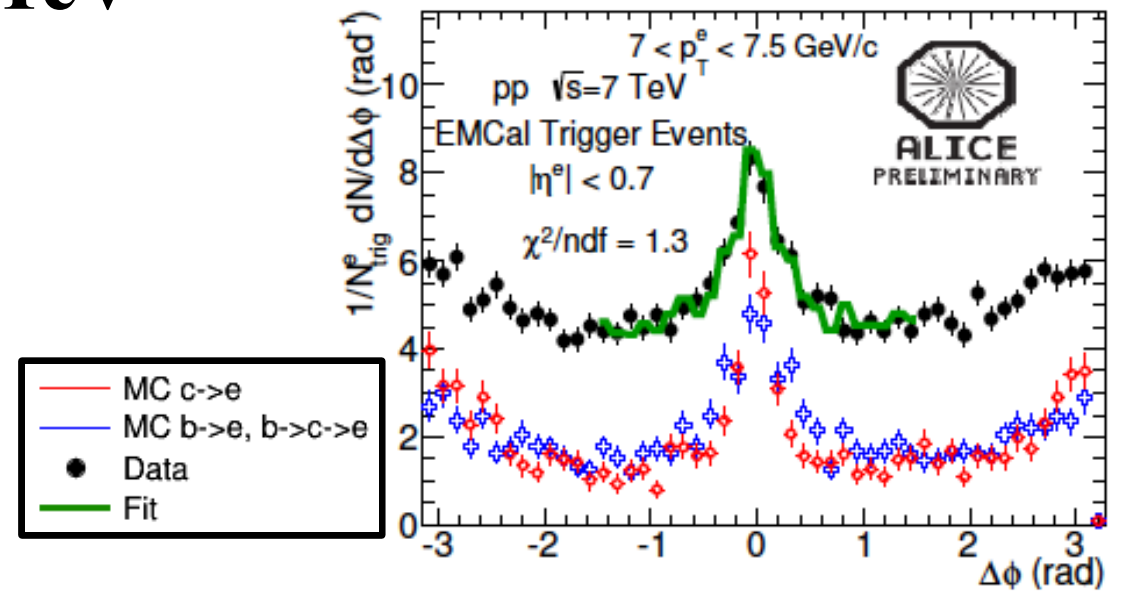
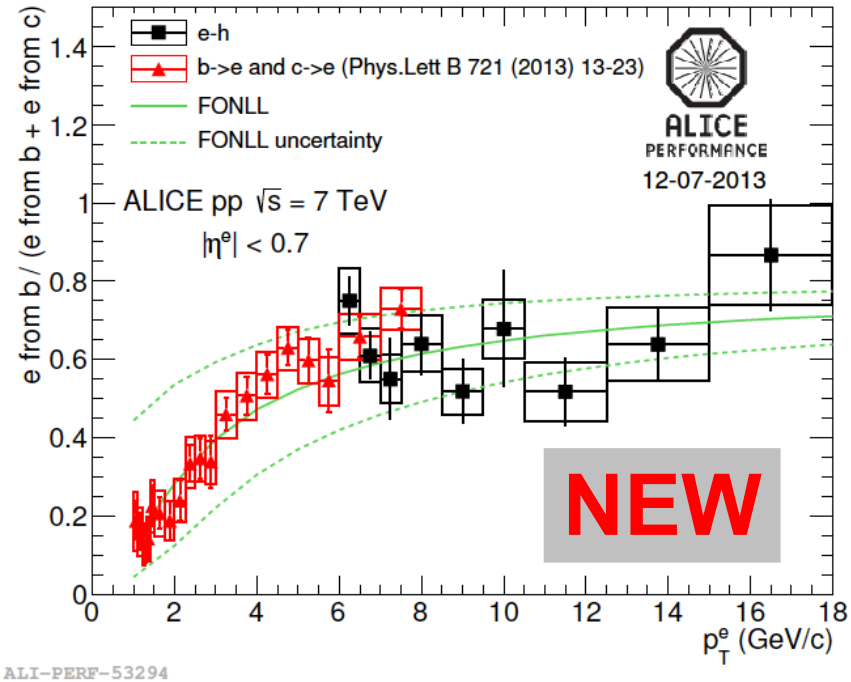
independent cross-check for impact parameter method





Proton-Proton Collisions, $\sqrt{s} = 2.76$ TeV

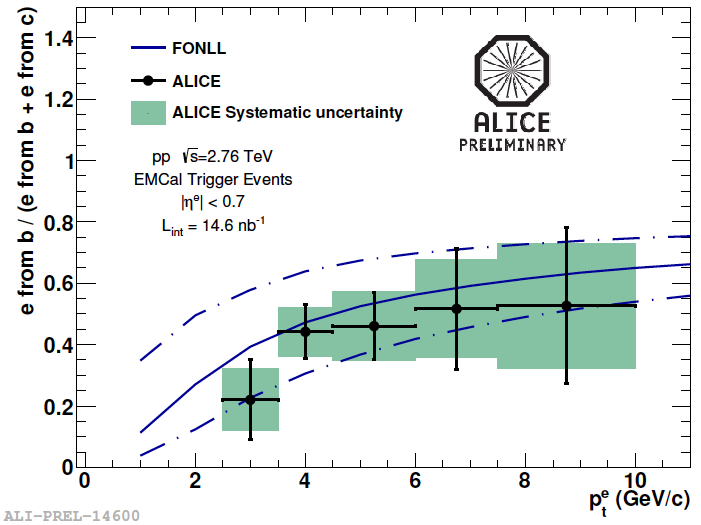
reference energy for Pb-Pb collisions

c → e electron ID by
b → e TPC and EMCal

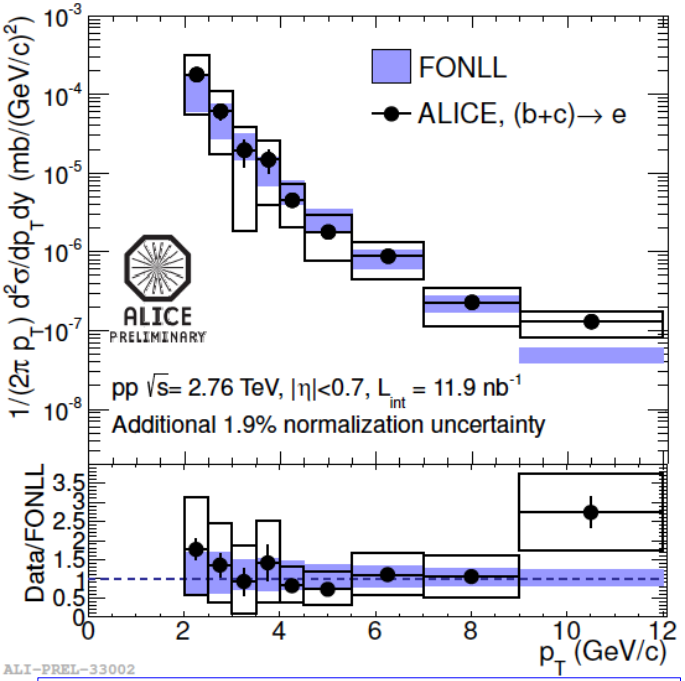
b → e

ratio e(b)/e(b+c) determined via e-h correlations

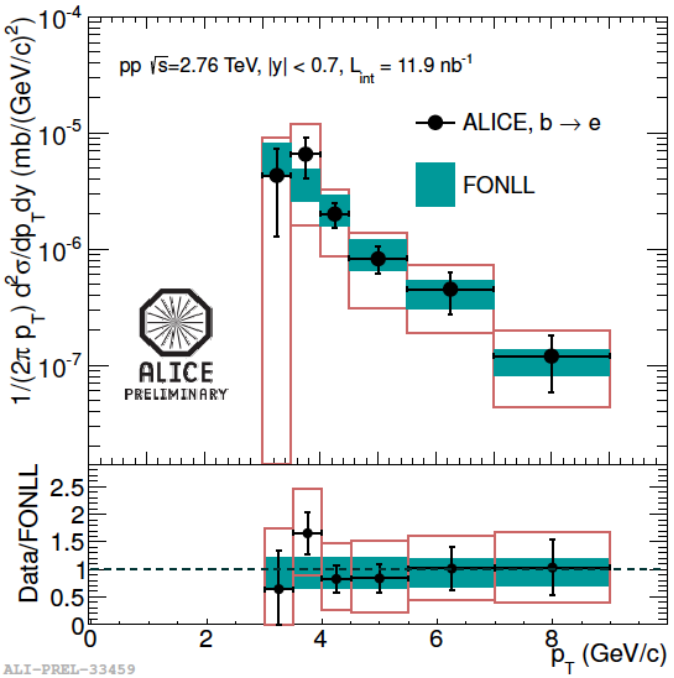
EMCal-triggered data



minimum-bias data



all measurements well described by FONLL calculations



soon to come:
measurements using electron ID by TPC + TOF
→ lower p_T !

soon to come:
measurements using impact parameter method
→ lower p_T !

p-Pb Collisions, $\sqrt{s_{NN}} = 5.02$ TeV

main purpose of measurements:

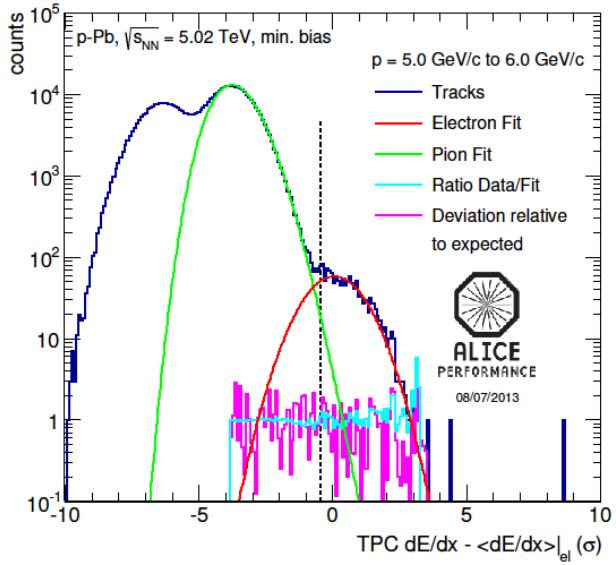
separate cold from hot nuclear matter effects

cold nuclear matter effects:

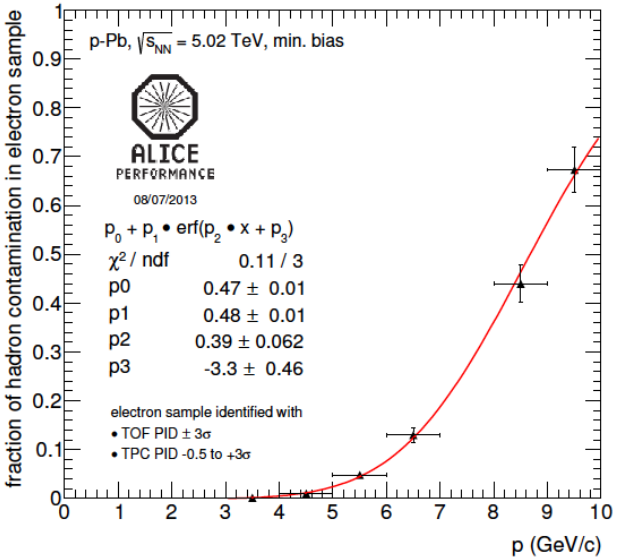
- **nuclear shadowing**
- **Cronin effect**

p-Pb Collisions, $\sqrt{s_{NN}} = 5.02$ TeV

electron identification - two separate strategies:



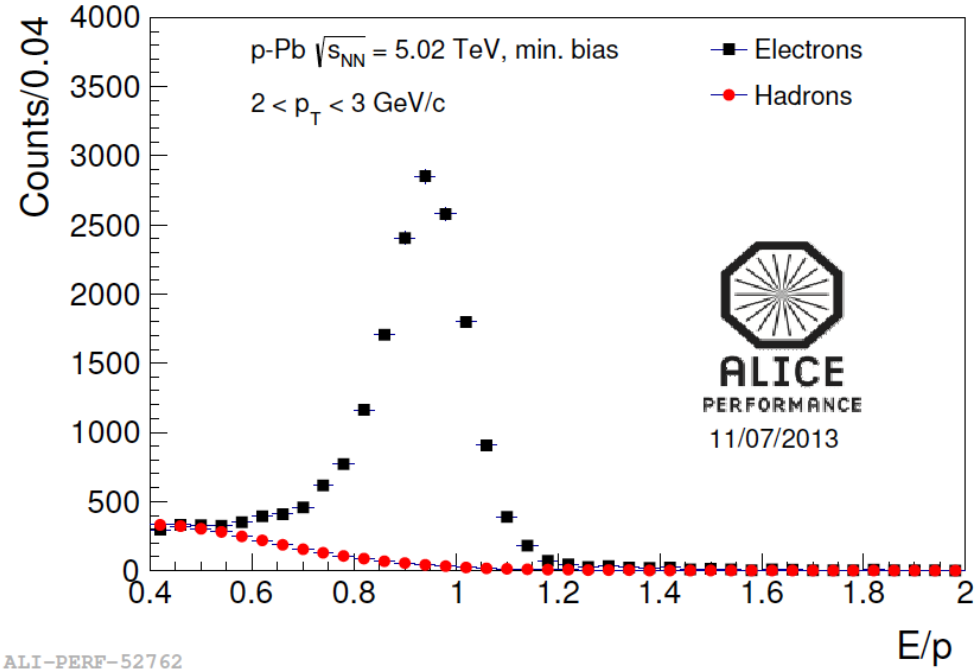
ALI-PERF-51853



ALI-PERF-51876

TPC-TOF method:

- apply TOF PID
- determine hadron contamination with TPC dE/dx fits in p_T slices
- fit p_T-dependent contamination



ALI-PERF-52762

TPC-EMCal method:

- select electron candidates with TPC
- select pure hadron sample with TPC
- determine hadron contamination with EMCal E/p distributions of electron candidates and hadrons

p-Pb Collisions, $\sqrt{s_{NN}}$ = 5.02 TeV

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electrons from heavy-flavour hadron decays:

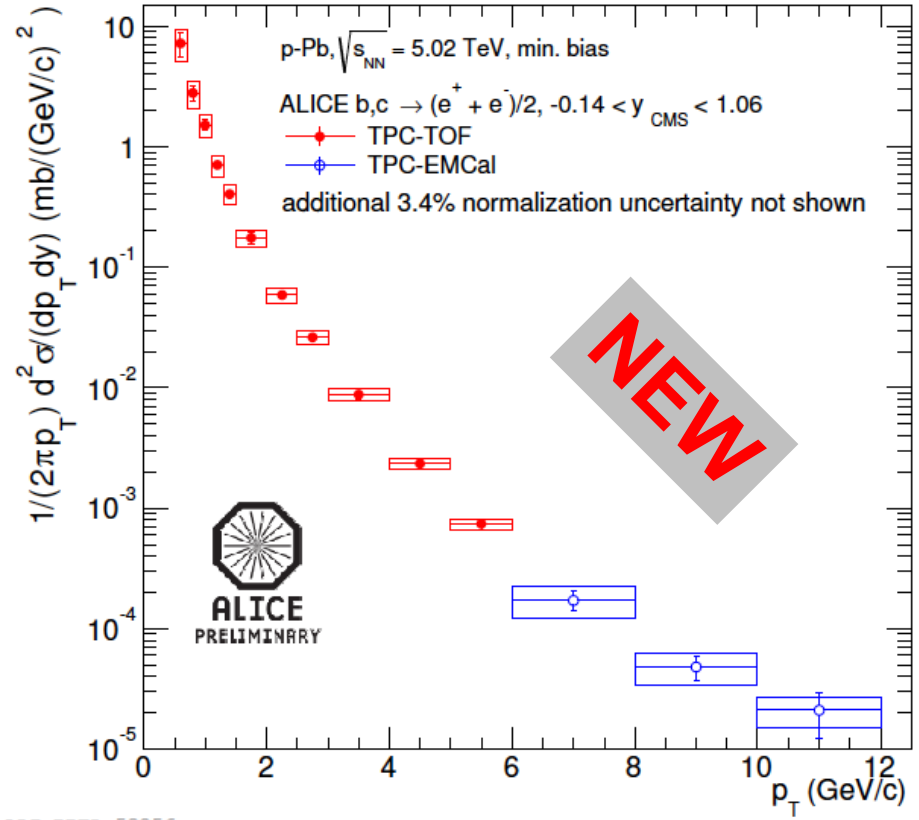
$c \rightarrow e$

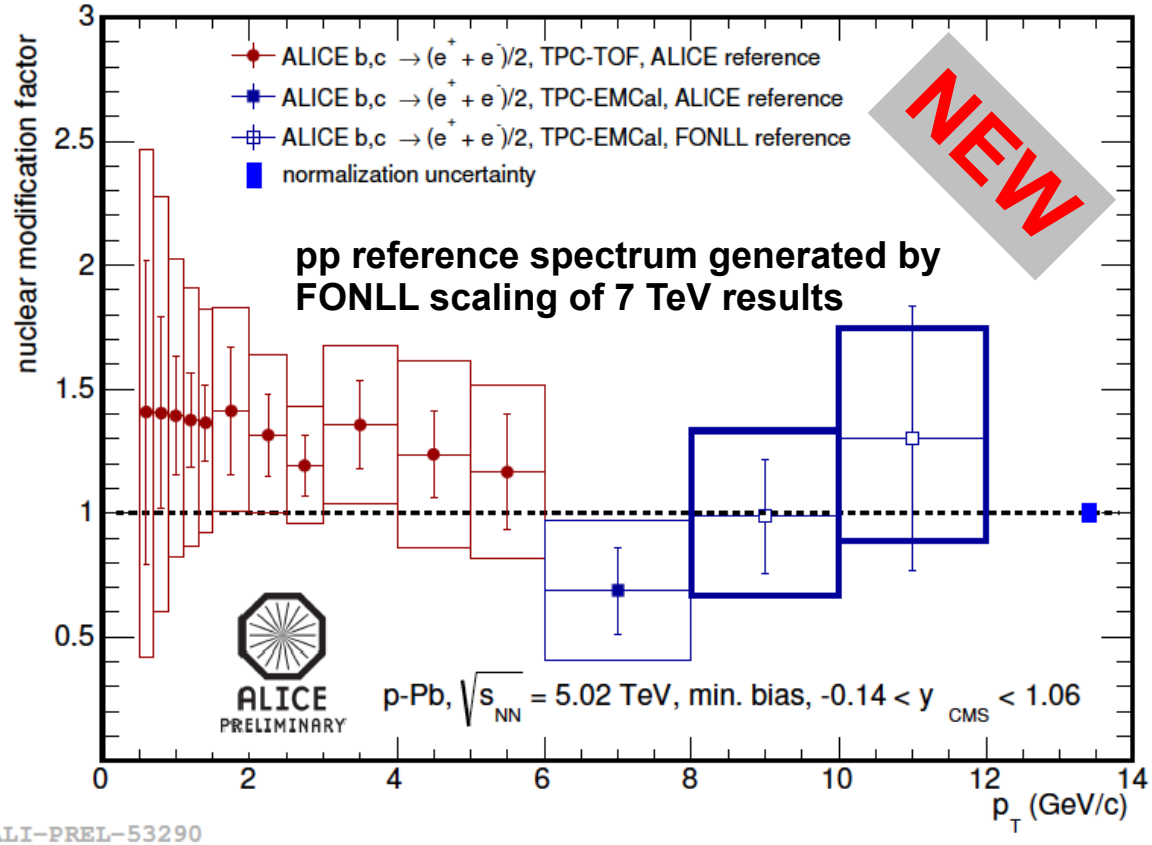
$b \rightarrow e$

combining spectra from minimum bias data with two different PID methods:

p_T < 6 GeV/c:
TPC-TOF

p_T > 6 GeV/c:
TPC-EMCal





p-Pb Collisions, $\sqrt{s_{NN}}$ = 5.02 TeV

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electrons from heavy-flavour hadron decays:

$c \rightarrow e$

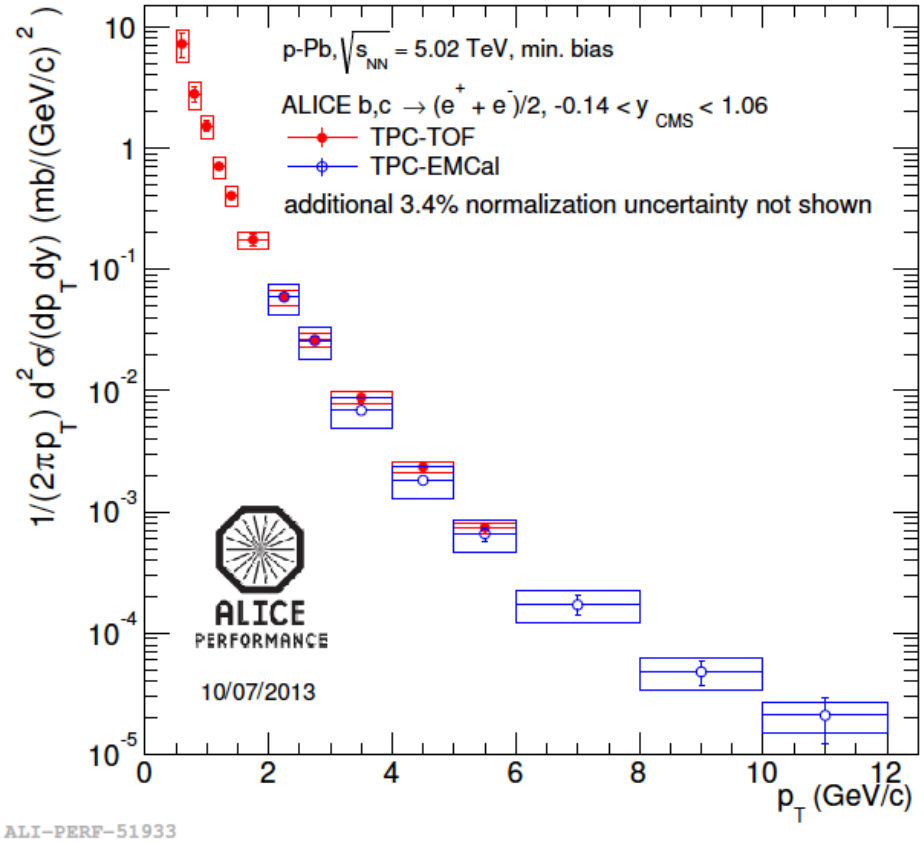
$b \rightarrow e$

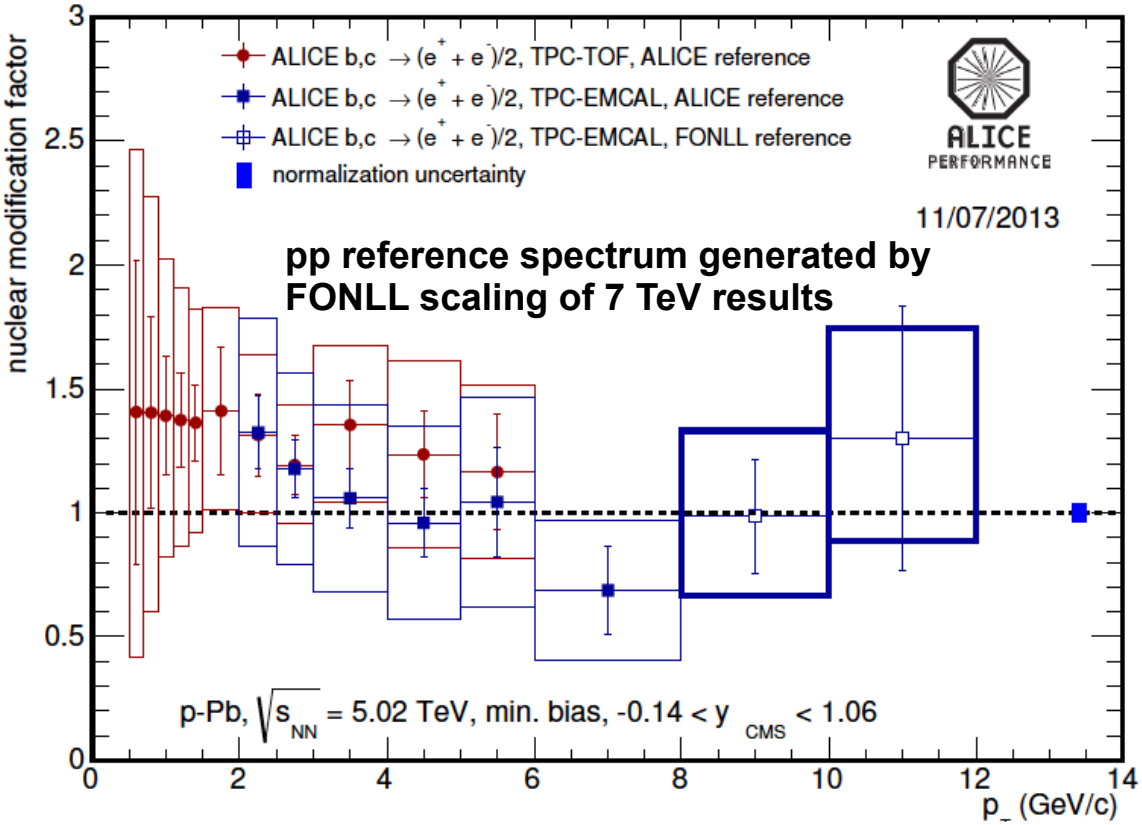
combining spectra from minimum bias data with two different PID methods:

p_T < 6 GeV/c: TPC-TOF

p_T > 6 GeV/c: TPC-EMCal

good agreement in overlap region





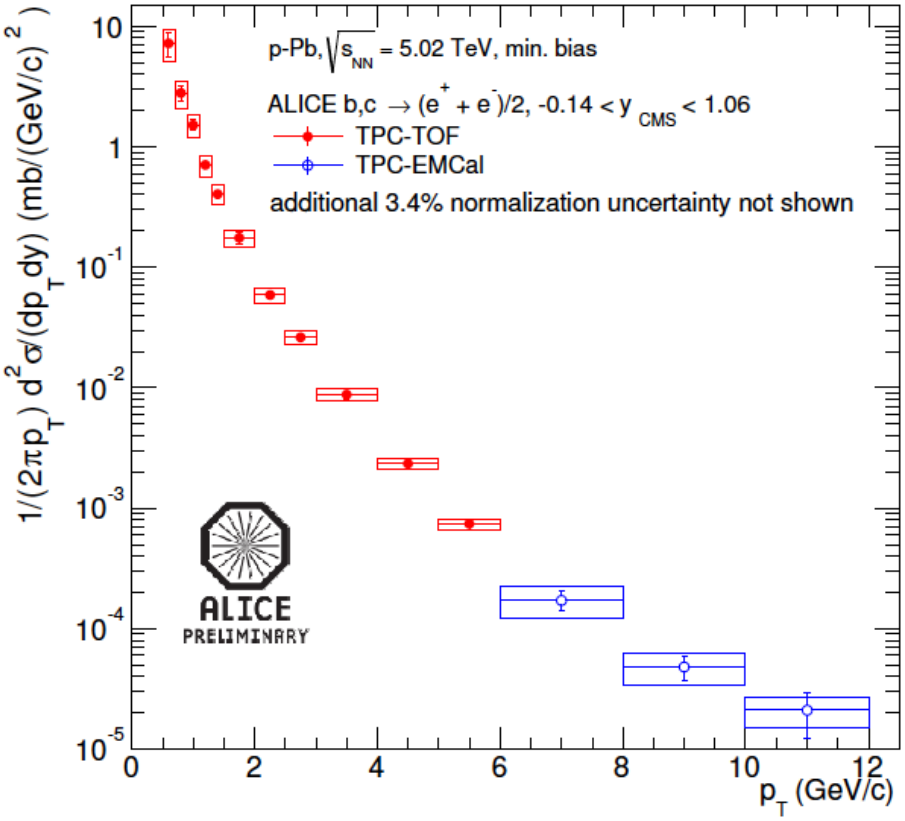
p-Pb Collisions, $\sqrt{s_{NN}}$ = 5.02 TeV

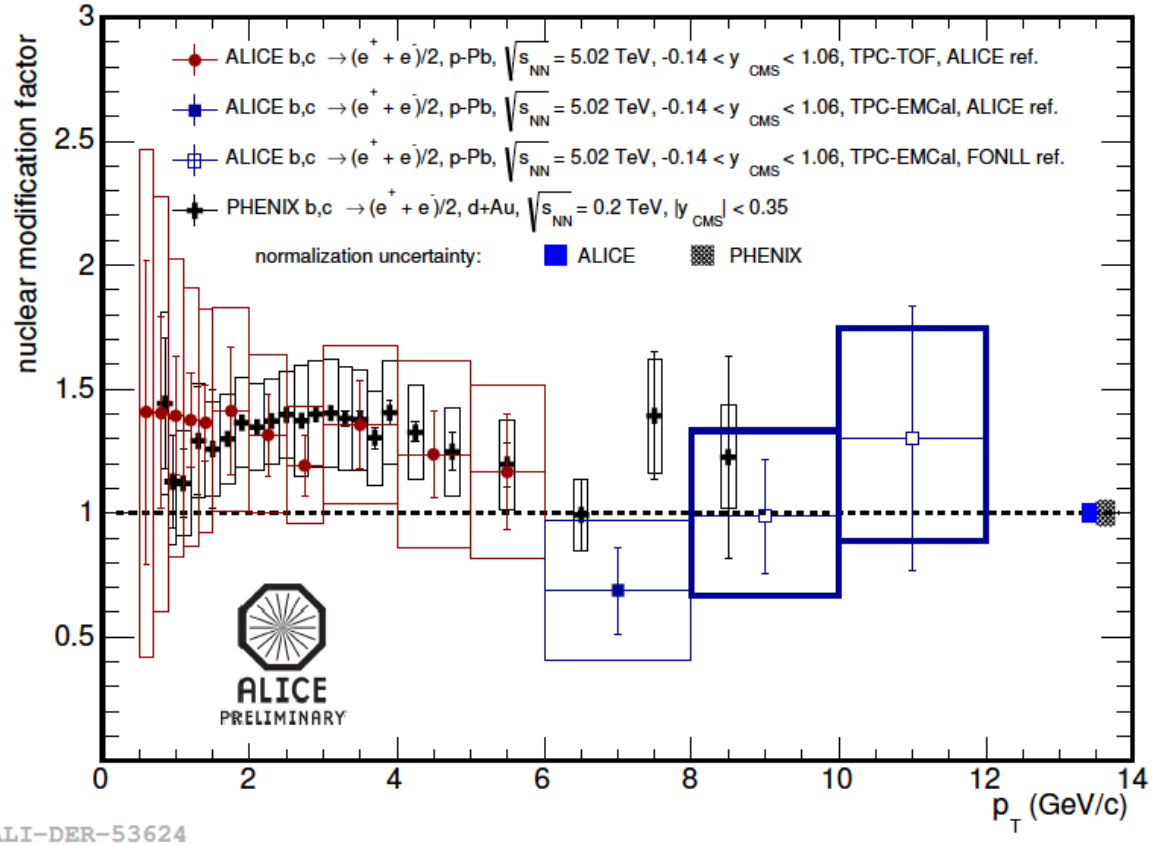
electrons from heavy-flavour hadron decays:

$c \rightarrow e$

$b \rightarrow e$

p_T dependence of R_{pPb} comparable to behaviour observed at PHENIX for d-Au at $\sqrt{s_{NN}}$ = 0.2 TeV





ALI-DER-53624

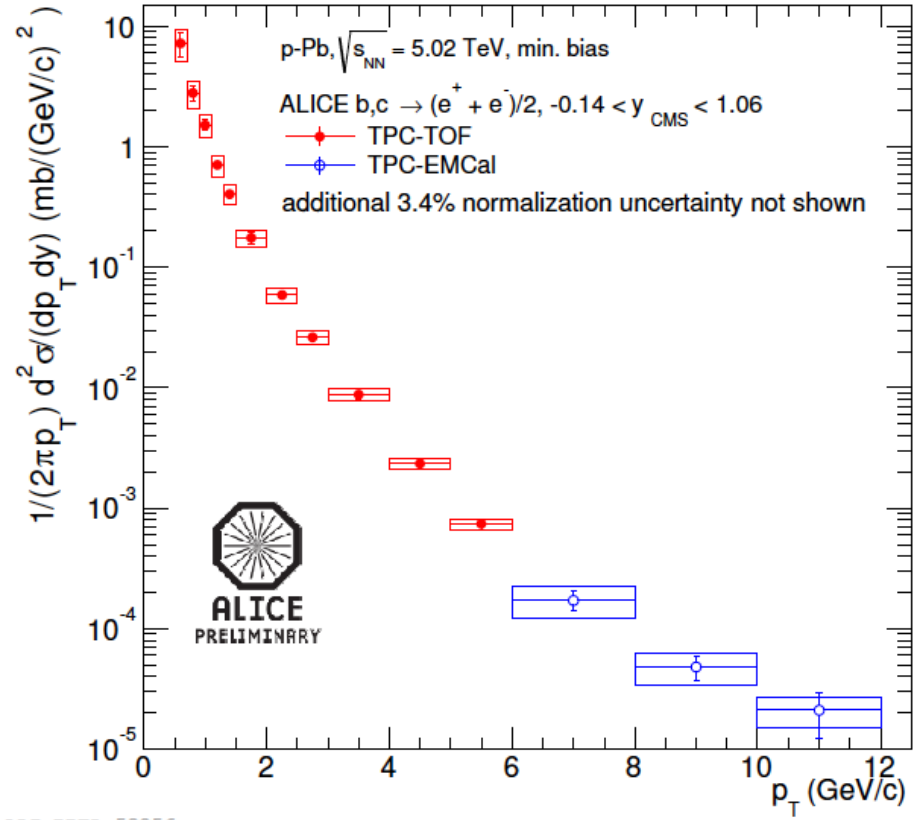
p-Pb Collisions, $\sqrt{s_{NN}}$ = 5.02 TeV

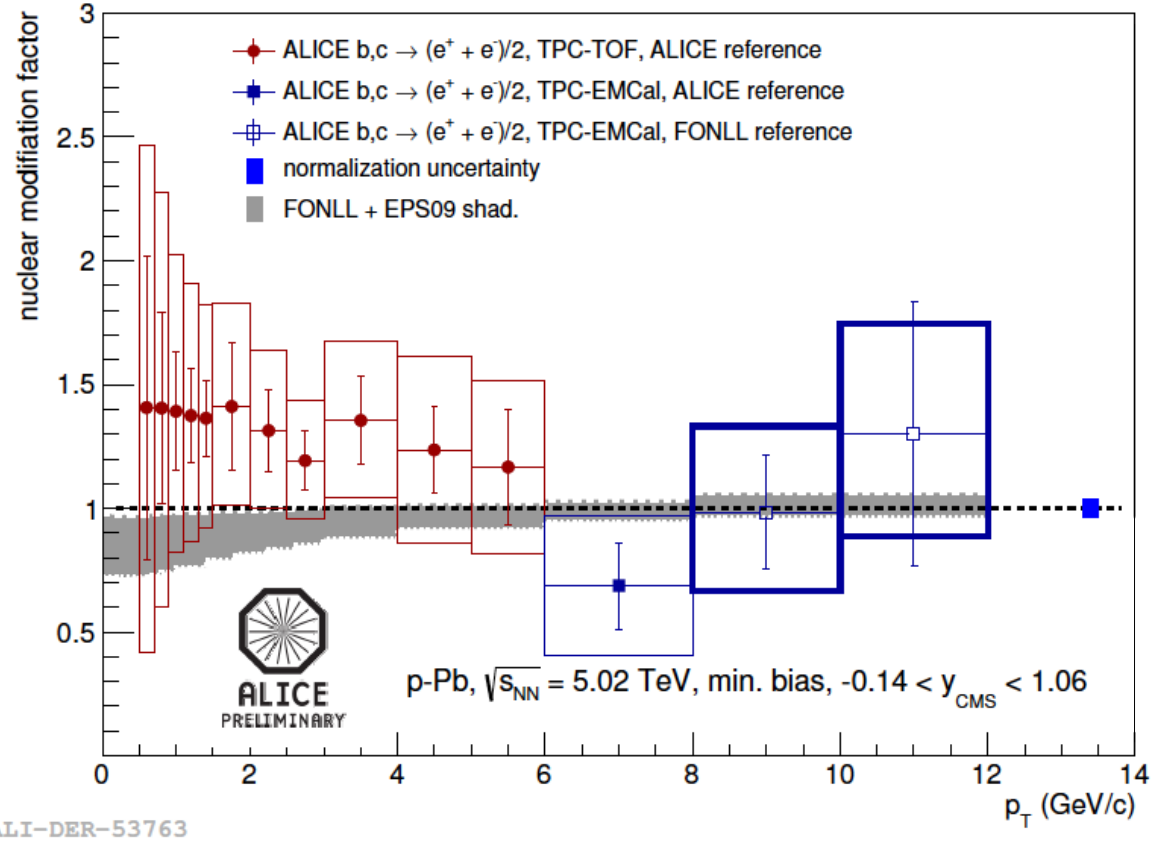
electrons from heavy-flavour hadron decays:

$c \rightarrow e$

$b \rightarrow e$

predictions of nuclear modification of the PDF from EPS09 agree with measurements within uncertainties





Summary

- production of inclusive heavy-flavour and beauty decay electrons measured for pp collisions at $\sqrt{s}$ = 2.76 TeV and 7 TeV

- b → e cross sections obtained from different methods are consistent with each other

- measured cross sections of inclusive heavy-flavour and beauty decay electrons in proton-proton collisions described by FONLL calculations within uncertainties

- first ALICE R_{pPb} measurements of inclusive heavy-flavour decay electrons:
  - show similar trends as PHENIX R_{dAu} results
  - agree with EPS09 shadowing predictions within uncertainties

Outlook

- p_T-differential cross-sections for pp collisions at $\sqrt{s}$ = 2.76 TeV soon available down to lower p_T:
  - for inclusive heavy-flavour decay electrons
  - for beauty hadron decay electrons

- electron-hadron azimuthal angular correlations in p-Pb collisions:
  - near/away-side peak enhancement and ridge in η, as observed in di-hadron correlations?

- a more detailed look at e-h correlation studies:

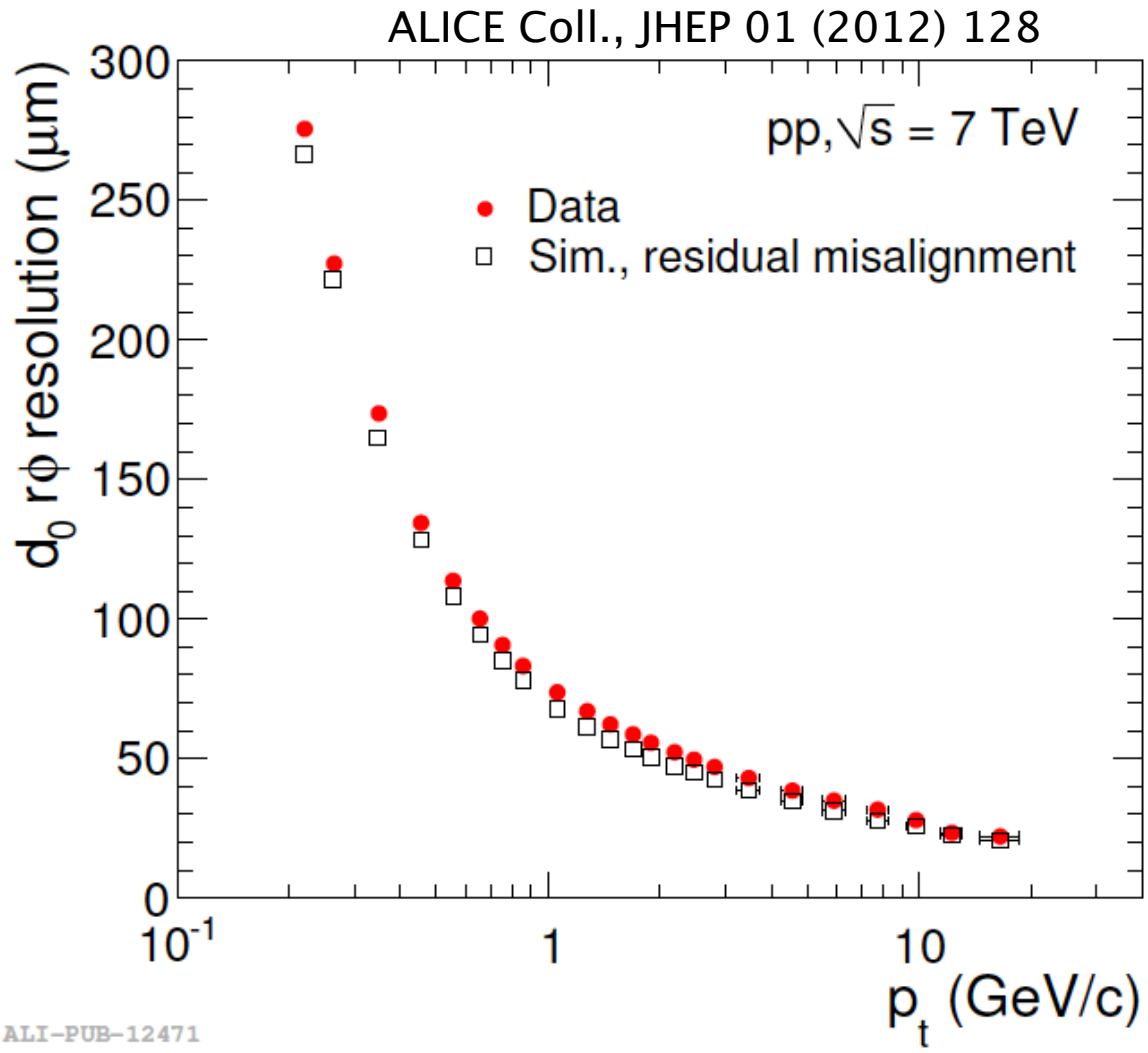
Poster: E. Pereira

- R_{PbPb} measurements for heavy-flavour electrons:

Talk: D. Thomas, Thursday, 15:00

Backup

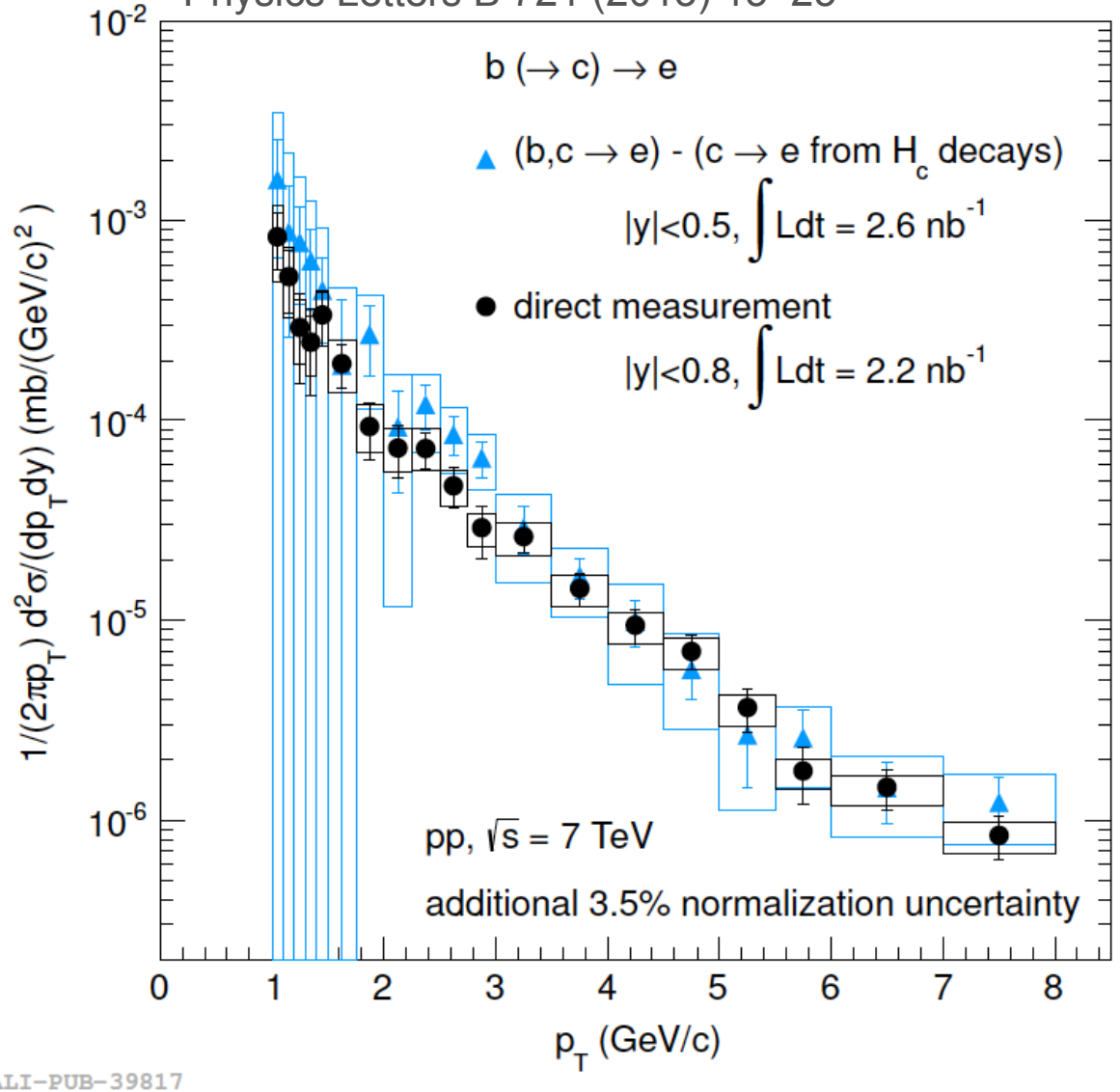
Transverse Impact Parameter Resolution



p_T-differential b → e Cross Section $\sqrt{s}$ = 7 TeV

systematic uncertainties clearly **reduced** compared to direct subtraction of c → e sprectrum from inclusive heavy-flavour electron spectrum

Physics Letters B 721 (2013) 13–23



Total b → e Cross Section for $\sqrt{s}$ = 7 TeV

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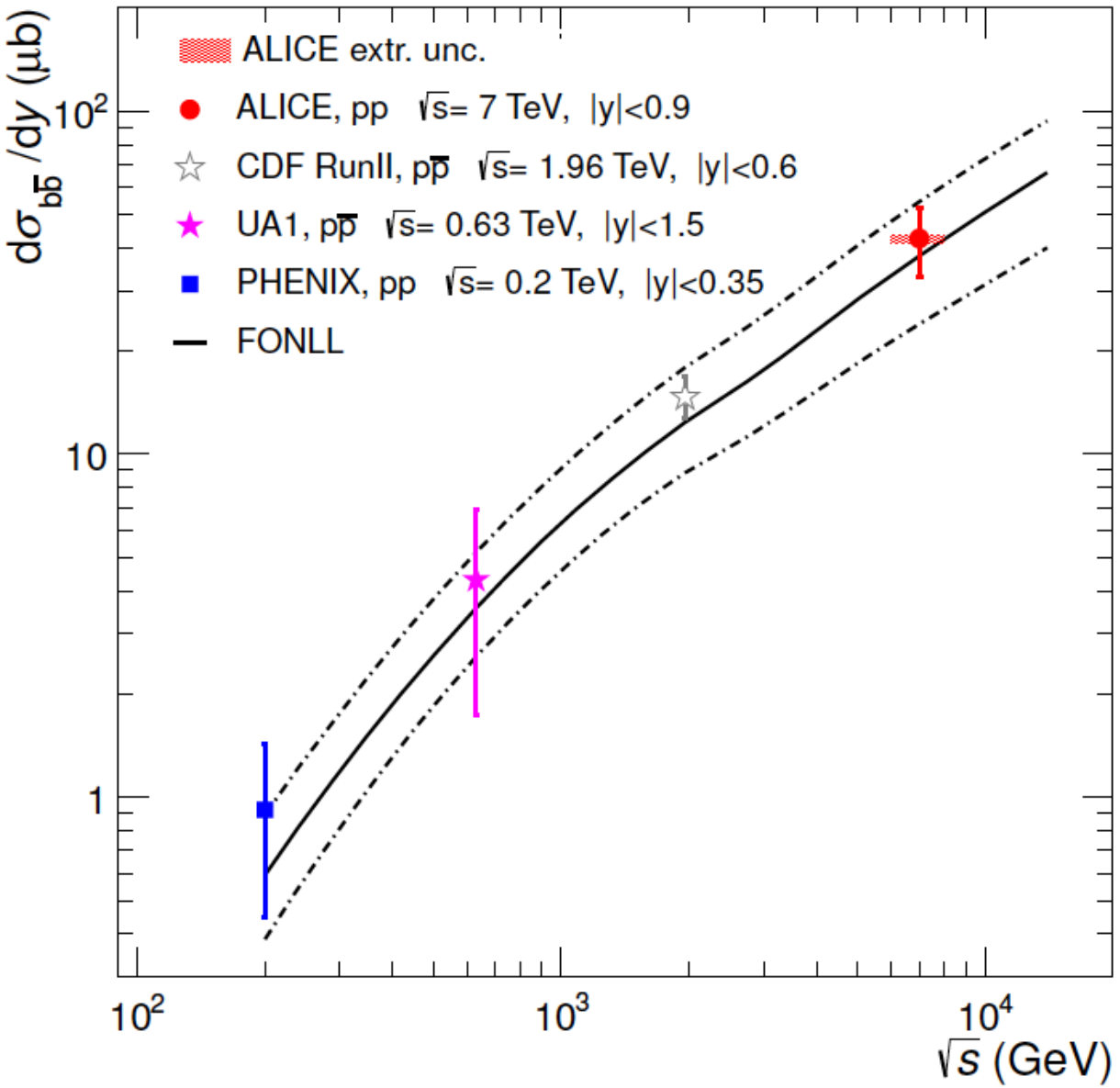


extrapolation from visible to total $b\bar{b}$ production cross section

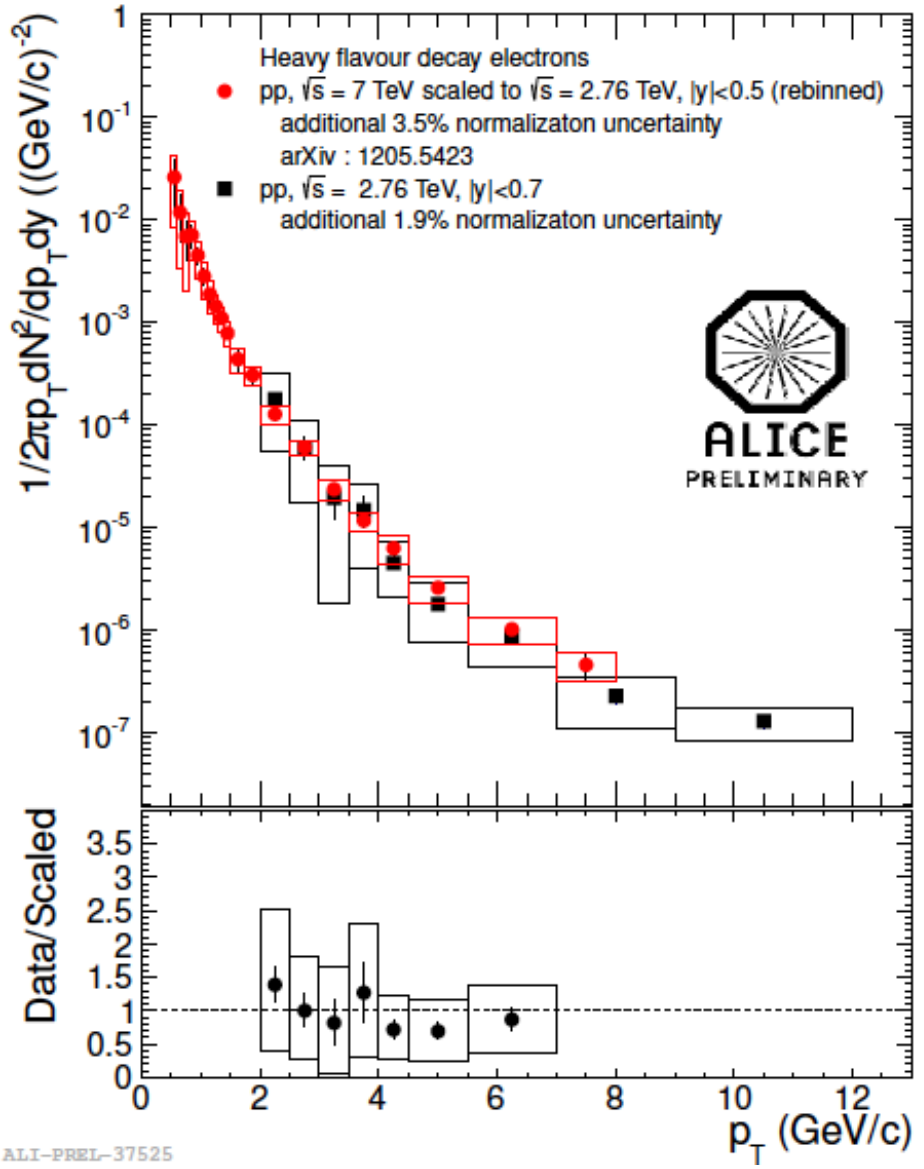
Proton-Proton Collisions, $\sqrt{s} = 2.76$ TeV

FONLL-scaled spectrum from 7 TeV used as reference for Pb-Pb collisions → lower uncertainties

electrons from heavy-flavour hadron decays:

c → e
b → e

FONLL-scaled spectrum from $\sqrt{s}$ = 7 TeV is consistent with result at 2.76 TeV

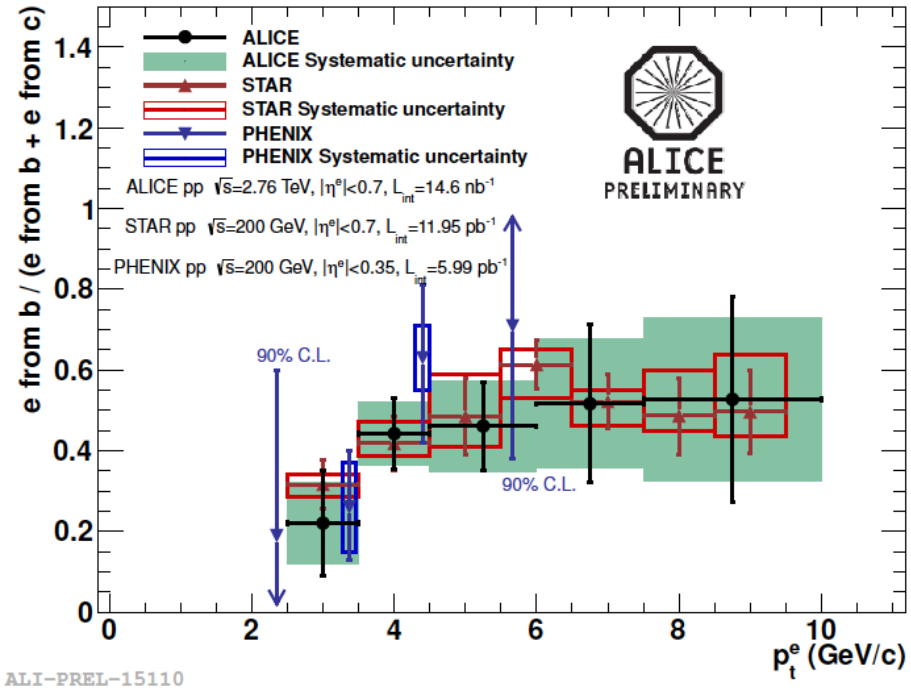


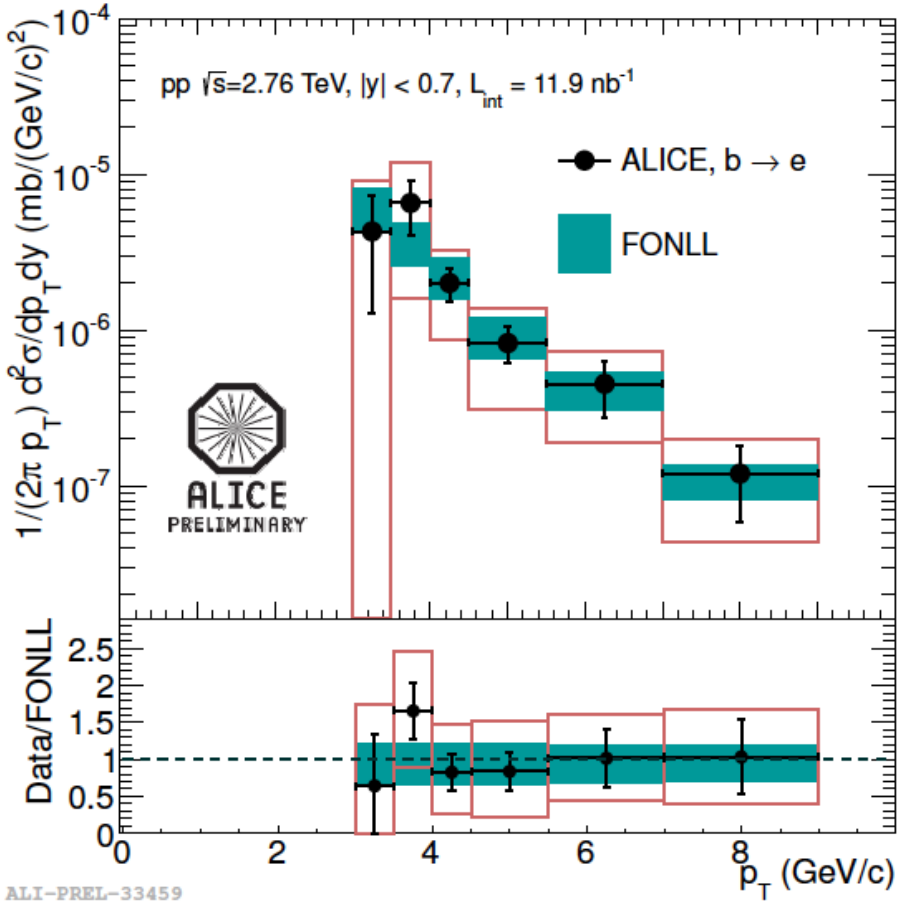
Proton-Proton Collisions, $\sqrt{s} = 2.76$ TeV

electrons from b → e decays:

ratio e(b)/e(c+b) via e-h correlations

→ calculate p_T-differential cross-section

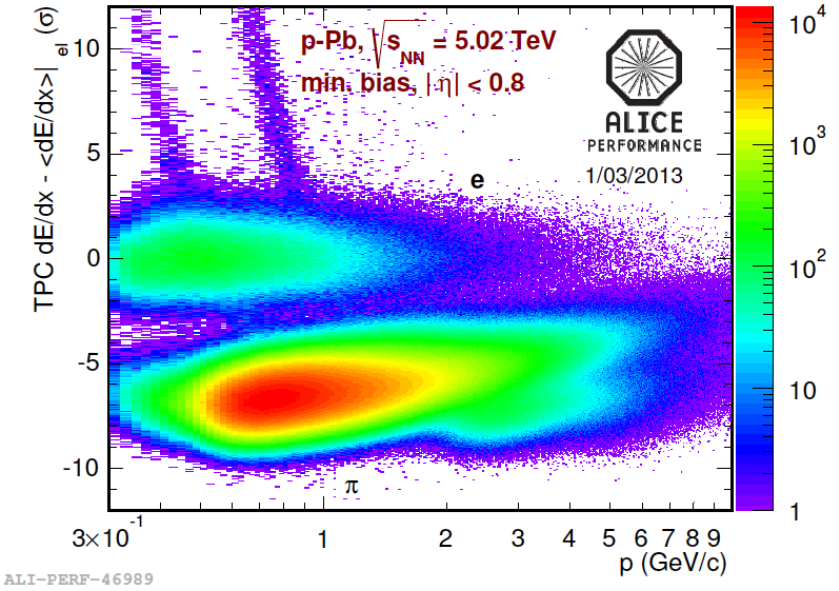




ratio comparable to RHIC results

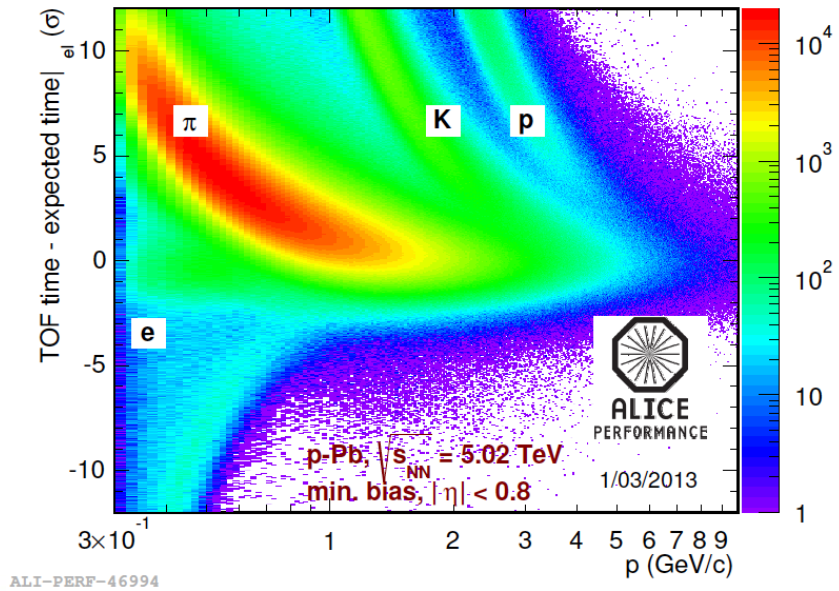
p-Pb Collisions, $\sqrt{s_{NN}} = 5.02$ TeV

electron identification - two separate strategies:



TPC

+



TOF

TPC + EMCal