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

Markus Fasel (Ruprecht-Karls Universität Heidelberg)

on behalf of the ALICE Collaboration

ALICE
A JOURNEY OF DISCOVERY

BMBF Forschungsschwerpunkt
ALICE Experiment
201
ALICE

Outline

- Motivation
- Measurements in proton-proton collisions
- Measurements in Pb-Pb collisions
  - Nuclear modification factor
  - Elliptic flow
- Summary

Motivation

In proton-proton collisions

- Test of perturbative QCD
- Reference for heavy-ion collisions

In heavy-ion collisions

- Study of partonic energy loss in the hot and dense medium
  - Heavy quarks are produced in initial hard collisions
  - Experience radiative and collisional energy loss

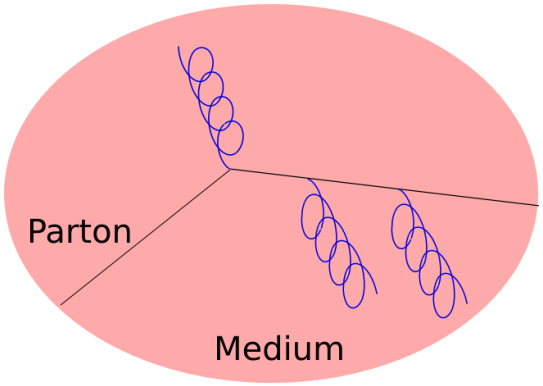
$$\Delta E_g \geq \Delta E_c \geq \Delta E_b \ ?$$

(Dokshitzer and Kharzeev, PLB 519 (2001) 199–206)

  - Thermalisation of heavy quarks in the medium?

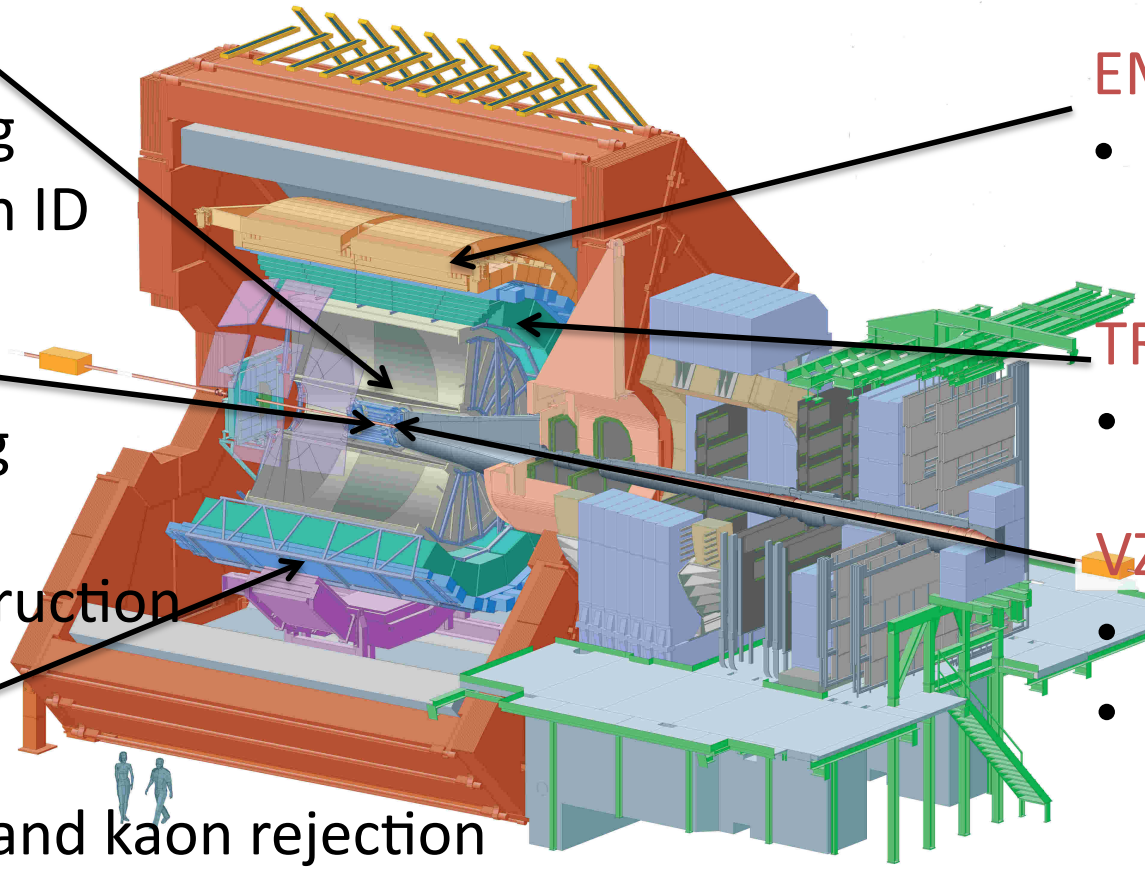
Why electrons?

- Large branching ratios (≈10%)
- Large signal-to-background at high p_T
- Separation of charm and beauty



ALICE apparatus

Detectors used in the electron measurement



TPC
- Tracking
- Electron ID

ITS
- Tracking
- Vertex reconstruction

TOF
- Proton and kaon rejection

EMCal
- Electron ID

TRD
- Electron ID

VZERO
- Trigger
- Centrality determination

Datasets

In proton-proton collisions:

- √s= 7 TeV: L_{int} = 2.6 nb^{-1} min. bias events
- √s = 2.76 TeV: L_{int} = 0.5 nb^{-1} min. bias events
  L_{int} = 11.9 nb^{-1} EMCAL-triggered events

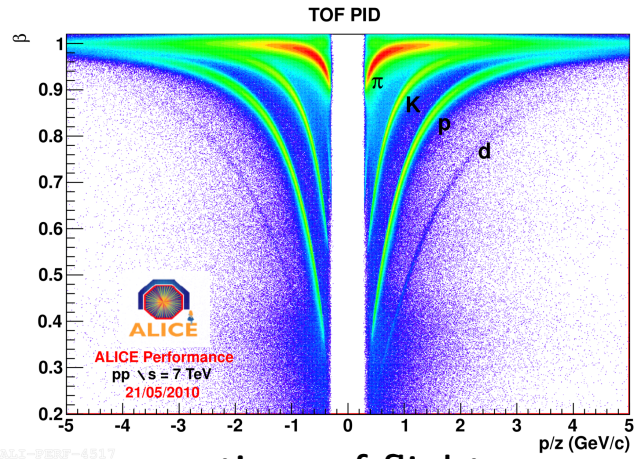
In Pb-Pb collisions:

- Centrality 0-10%: 17 M min. bias events
  0.7 M EMCAL-triggered events
- Centrality 20-40%: 11.5 M min. bias events
  1.3 M EMCAL-triggered events

Min. Bias Trigger: VZERO and ITS inner pixels
EMCAL Trigger: 4x4 towers, energy threshold at 3 GeV

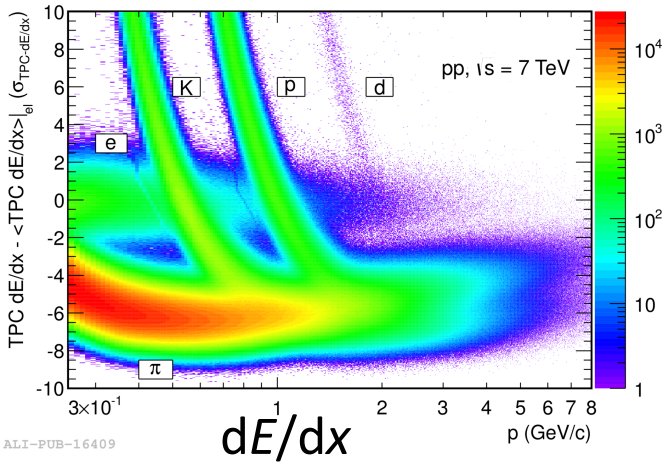
Electron identification in ALICE

TOF



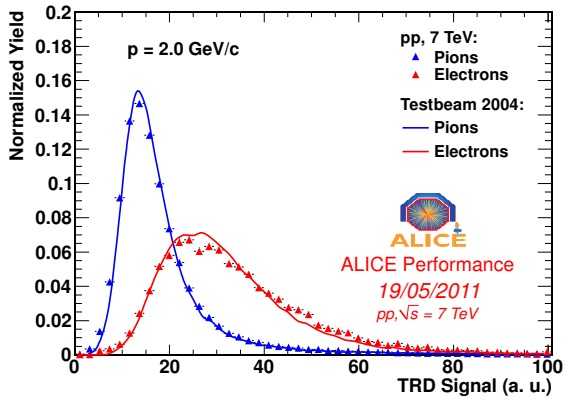
time-of-flight

TPC



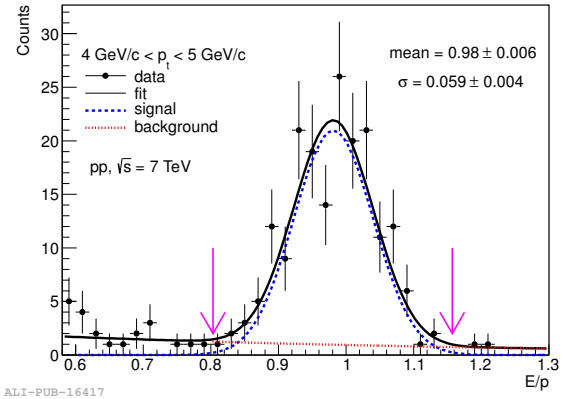
d*E*/d*x*

TRD



dE/dx + transition radiation

EMCAL



E/*p*

arXiv:1205.5432

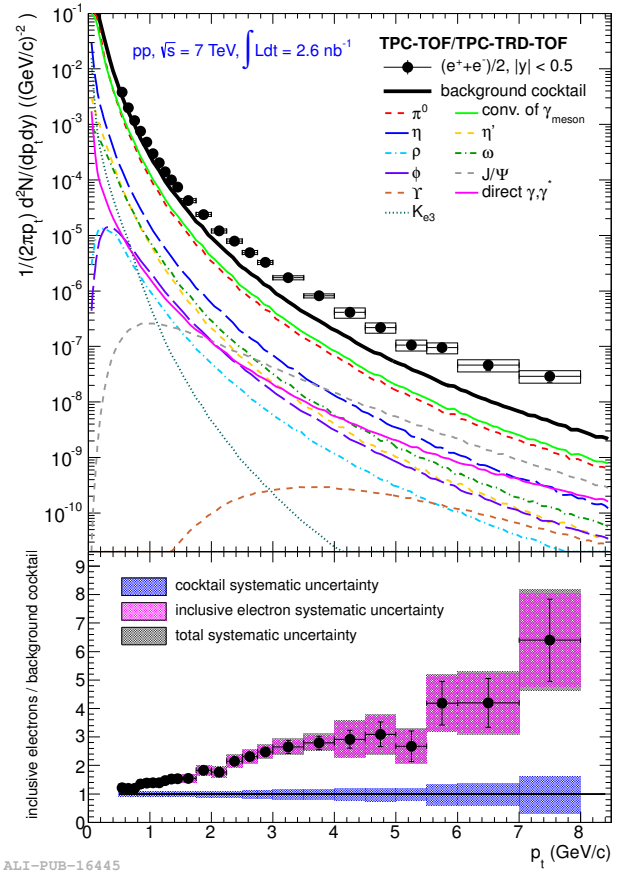
Background subtraction

The electron sample contains background from various sources

- Conversion of real and virtual photons (including direct photons)
- Dalitz decay of light mesons (π^0,η,..)
- Dielectron decay of light vector mesons (ρ,ω,ϕ)
- Dielectron decay of quarkonia (J/ψ,Υ)

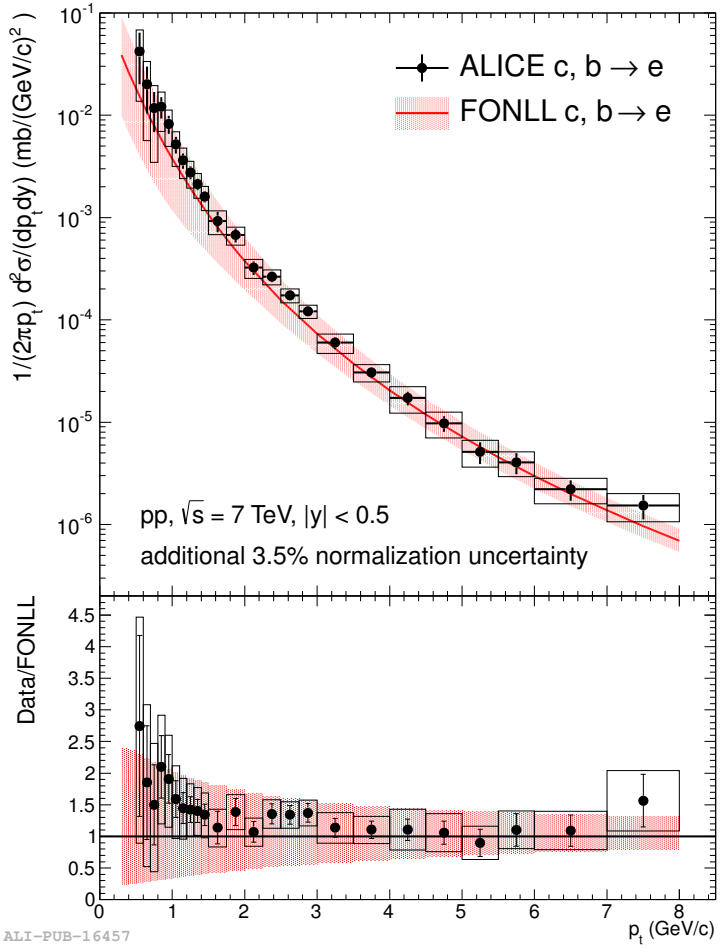
Two methods for background estimation

- Cocktail method
- Reconstruction of “photonic electrons” via invariant mass



arXiv:1205.5432

Cross section in proton-proton collisions at √s = 7 TeV

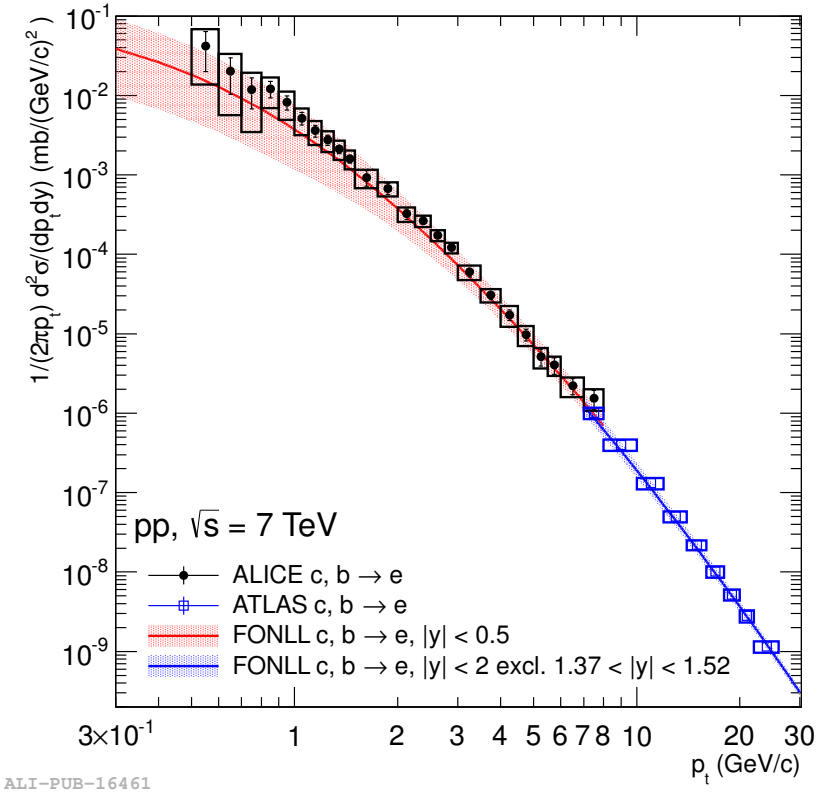


Non-photonic electron cross section: good agreement with FONLL pQCD calculation

ALICE: arXiv: 1205.5432

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

Cross section in proton-proton collisions at √s = 7 TeV



ATLAS: PLB 707 (2011) 438

Non-photonic electron cross section: good agreement with FONLL pQCD calculation

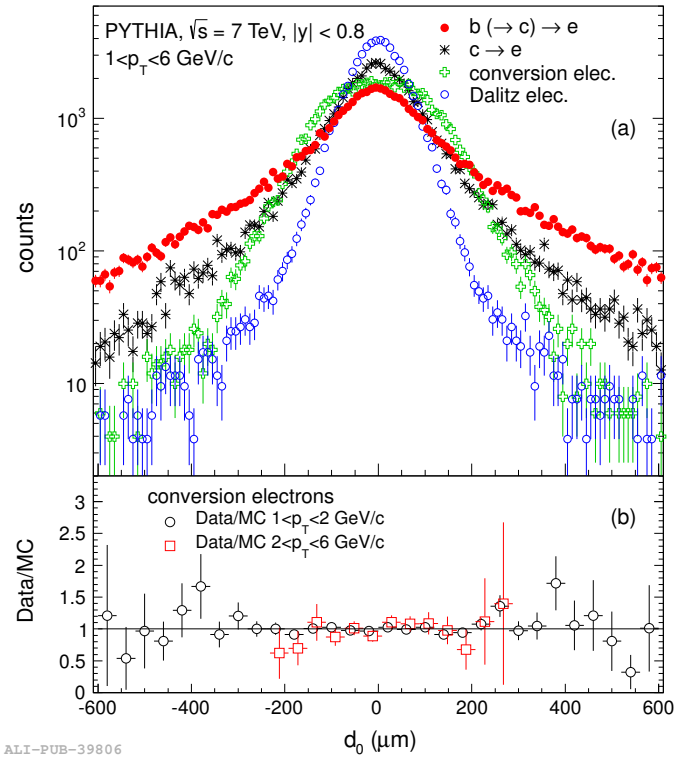
Extension of the p_T reach towards low p_T (compared to ATLAS)

- covering ≈50% of the midrapidity charm cross section and ≈90% of the midrapidity beauty cross section

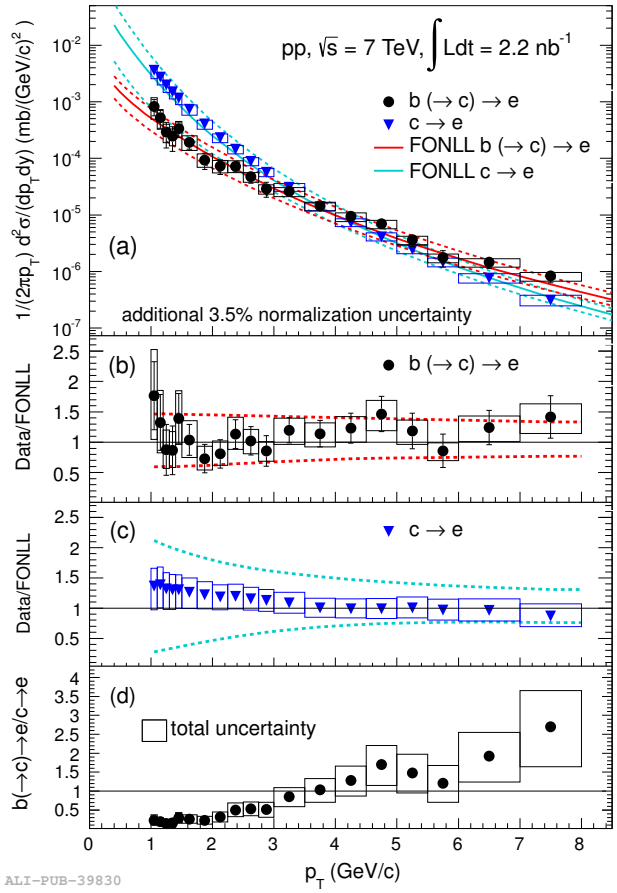
ALICE: arXiv: 1205.5432

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

Extraction of the contribution from beauty hadron decays



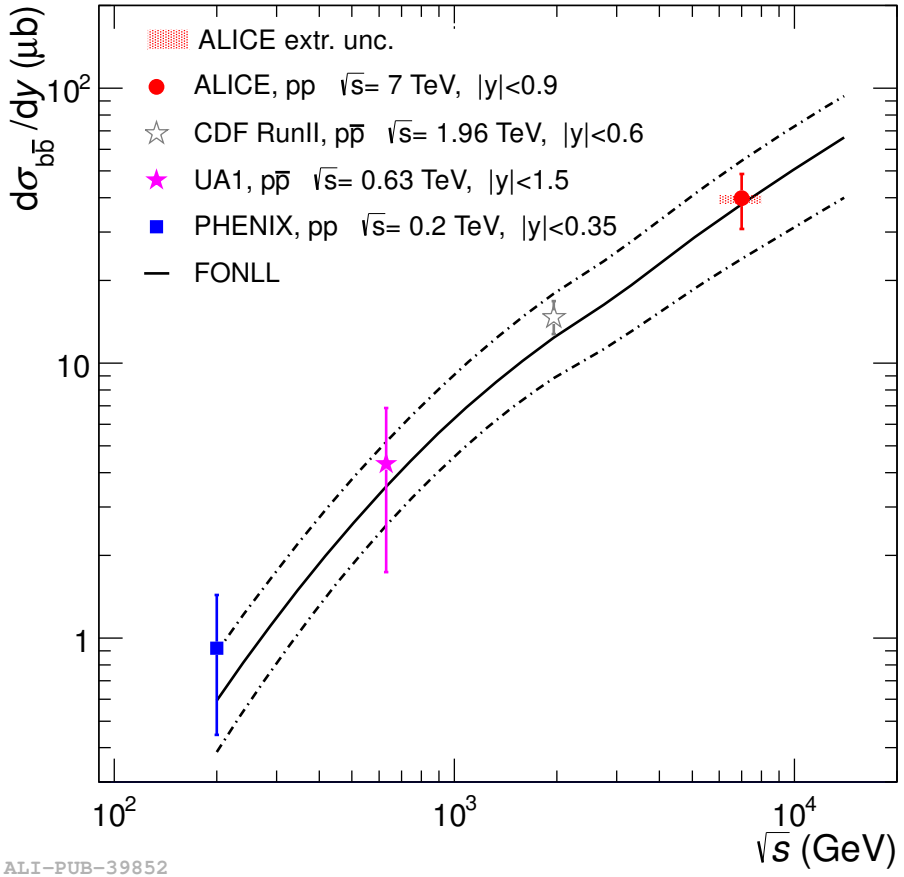
cτ of
- b: ≈ 500 μm
- c: ≈ 100 -300 μm



Selection of tracks with a large radial distance to the primary vertex

arXiv:1208.1902

√s dependence of the total beauty cross section



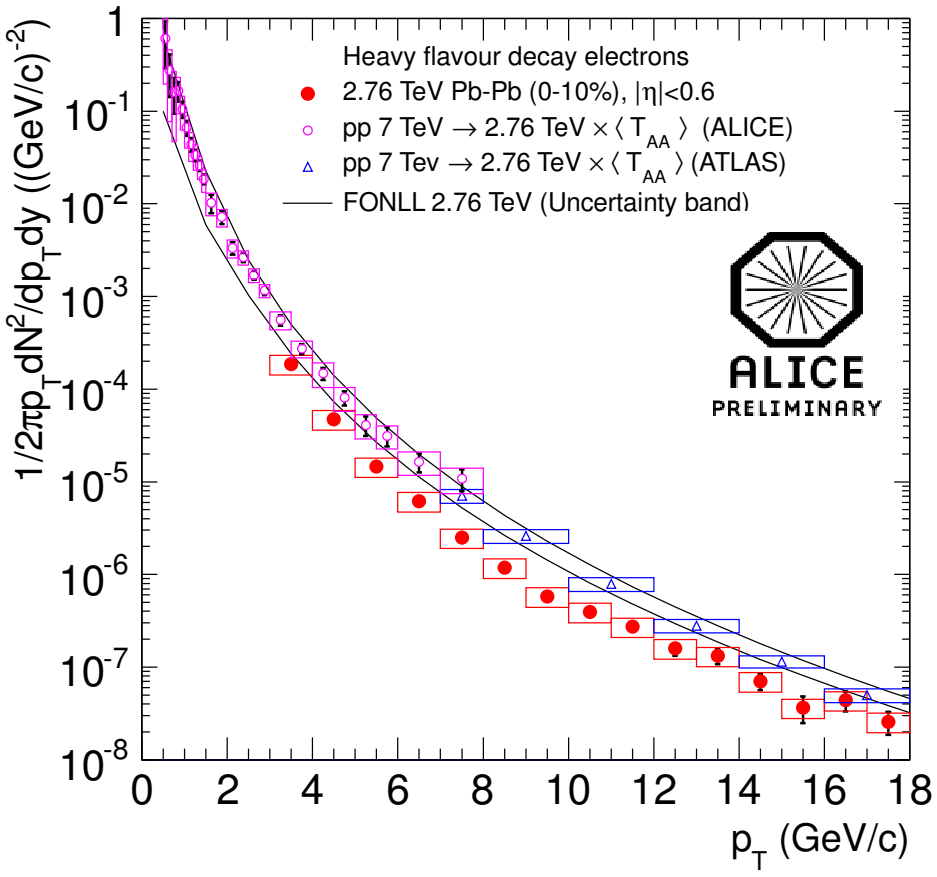
Total beauty cross section at √s = 7 TeV

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

Well described by FONLL pQCD

arXiv:1208.1902

Nuclear modification factor



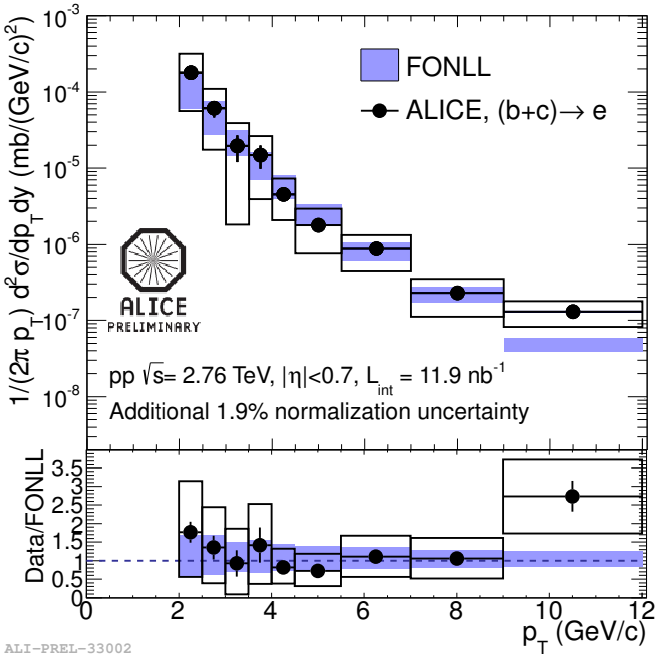
The nuclear modification factor is defined as

$$R_{\mathrm{AA}} = \frac{1}{< \mathrm{T_{AA}} >} \times \frac{\mathrm{d}N_{PbPb}/\mathrm{d}p_{\mathrm{T}}}{\mathrm{d}\sigma_{pp}/\mathrm{d}p_{\mathrm{T}}}$$

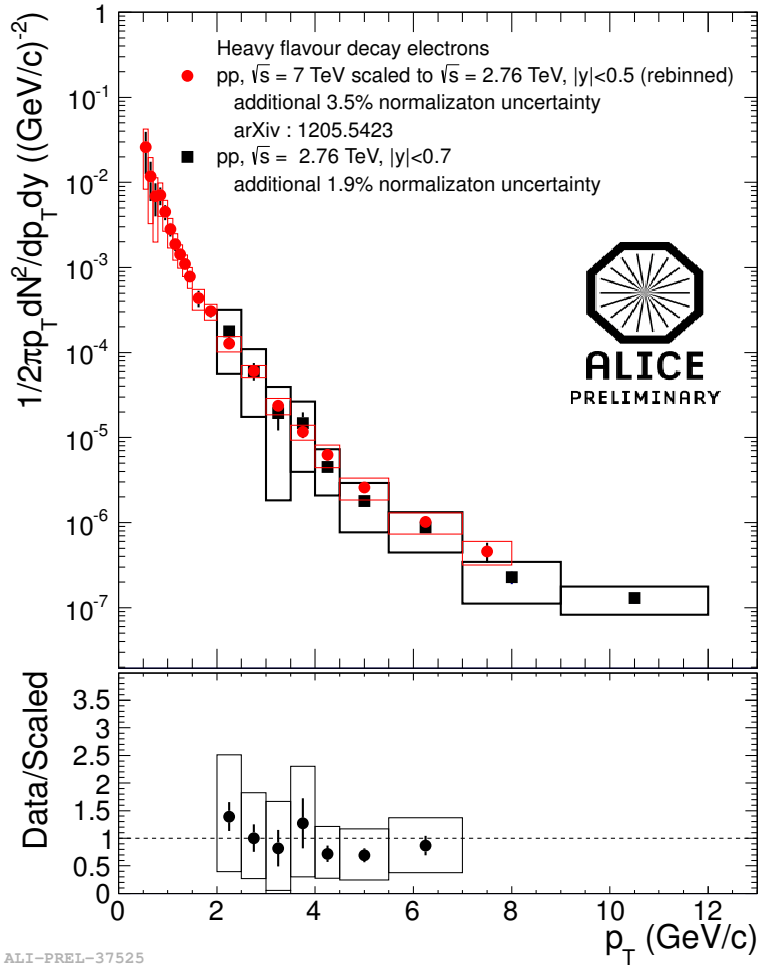
- $<T_{AA}>$: Nuclear overlap
- dN_{PbPb}/dp_T: Measurement in PbPb
- $d\sigma_{pp}/dp_T$: Reference from pp collisions at the same energy

The proton-proton reference

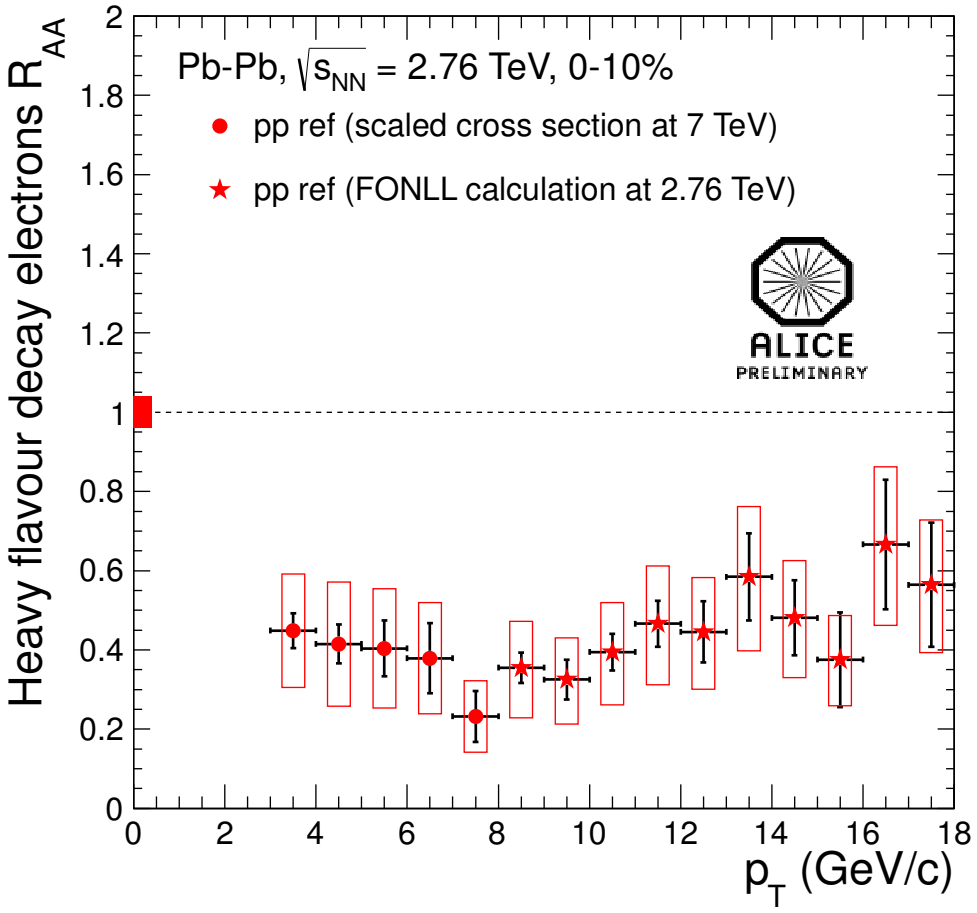
Electrons from heavy-flavour hadron decays studied in pp collisions at 2.76 TeV



Large uncertainties ⇒ Use FONLL-scaled spectrum at 7 TeV



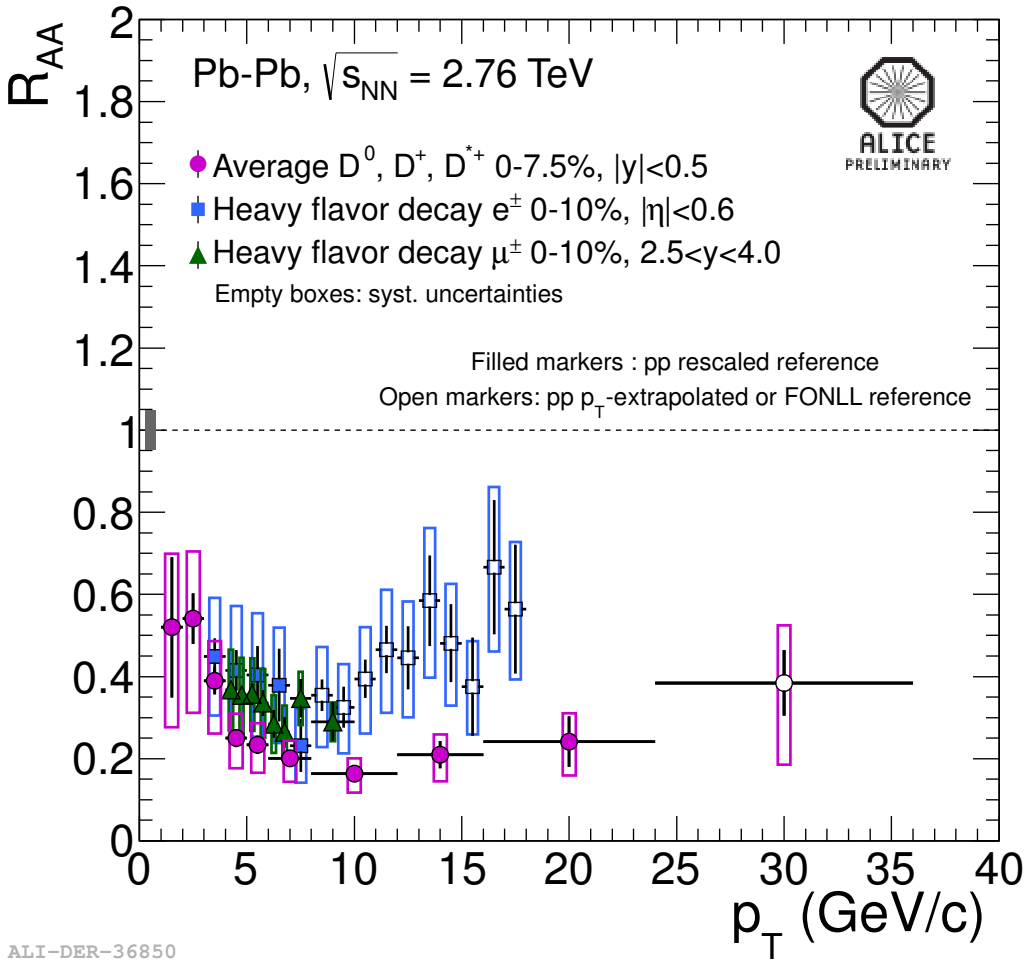
Nuclear modification factor in central Pb-Pb collisions



ALI-PREL-31917

Electrons from heavy-flavour hadron decays are suppressed at high p_T

Nuclear modification factor in central Pb-Pb collisions



Electrons from heavy-flavour hadron decays are suppressed at high p_T

Same suppression as in the semi-muonic channels at forward rapidity

Compatible with D-mesons considering decay kinematics

Elliptic flow of electrons from heavy-flavour hadron decays

Elliptic flow v_2 introduced via:

$$E\frac{\mathrm{d}^3N}{\mathrm{d}^3p} = \frac{1}{2\pi p_{\mathrm{T}}}\frac{\mathrm{d}^2N}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}\left[1+\sum_{k=1}^{\infty}2v_k\cos(k(\varphi-\Psi_{RP}))\right]$$

Ψ_{RP} : angle of the reaction plane

v_2: second harmonic coefficient

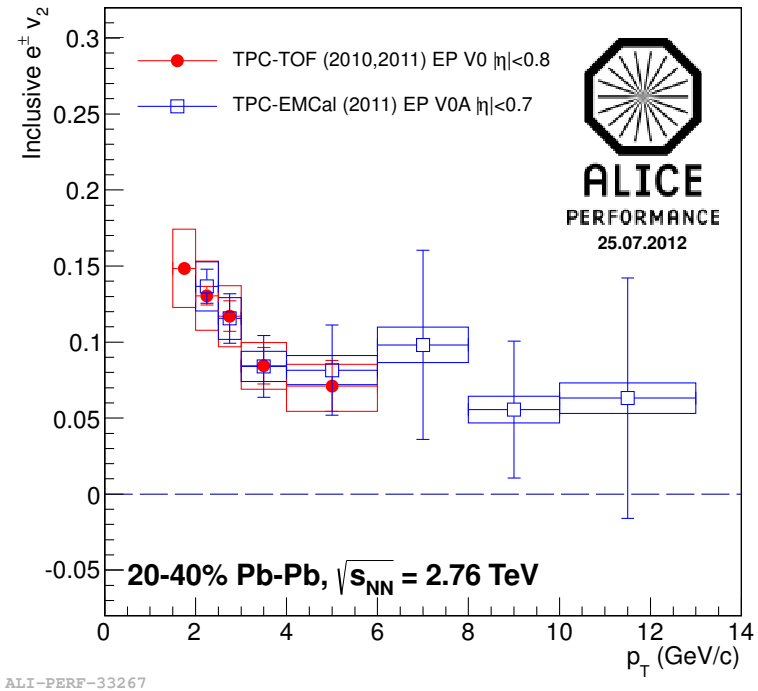
The elliptic flow of electrons from heavy flavour hadron decays is obtained via

$$v_2^{hfe} = \frac{(1+R)v_2^{inclusive} - v_2^{background}}{R}$$

with $R = \frac{N^{hfe}}{N^{background}}$

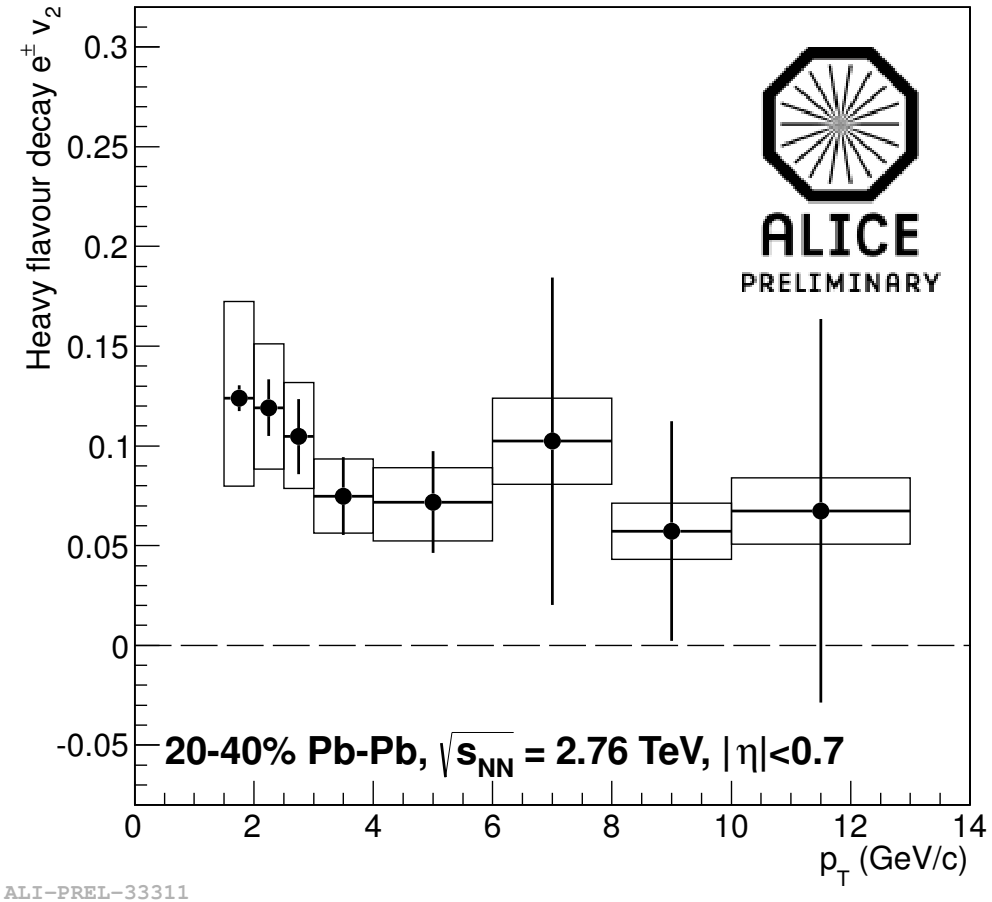
Event plane reconstructed with VZERO

Inclusive electrons:



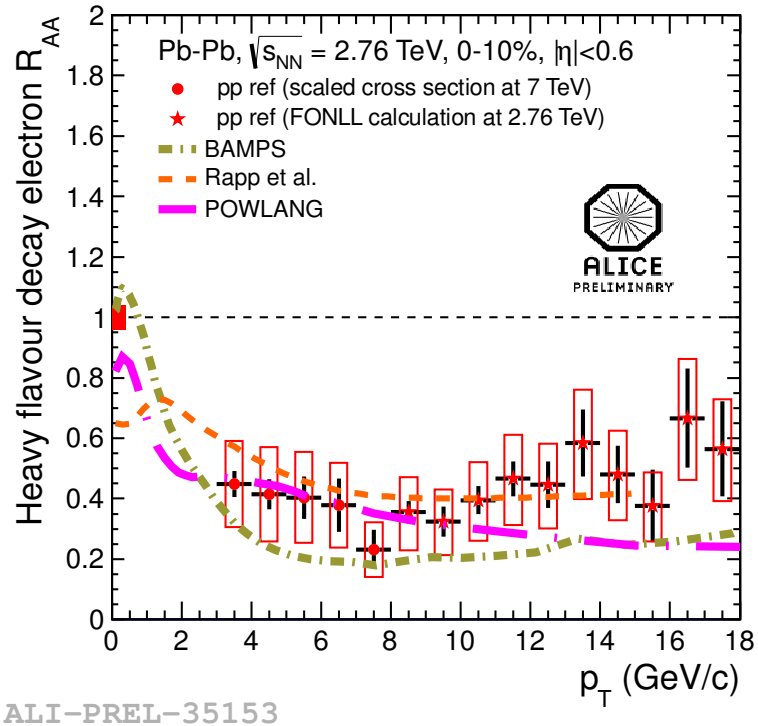
Background v_2 obtained using a cocktail

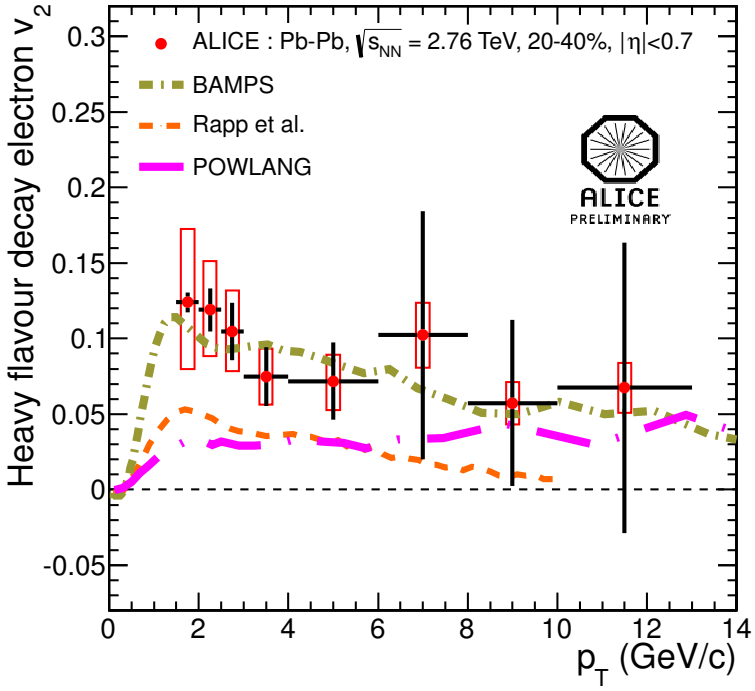
Elliptic flow in mid-central collisions



Non-zero elliptic flow of electrons from heavy-flavour hadron decays observed at low p_T

Comparison to models





ALI-PREL-35153

- Rapp et al. and POWLANG describe the R_{AA} but underpredict elliptic flow
- BAMPS describes elliptic flow but slightly underpredicts the R_{AA}

BAMPS: arXiv:1205.4945 Rapp et al: arXiv:1208.0256 POWLANG: arXiv:1208.0705

Summary

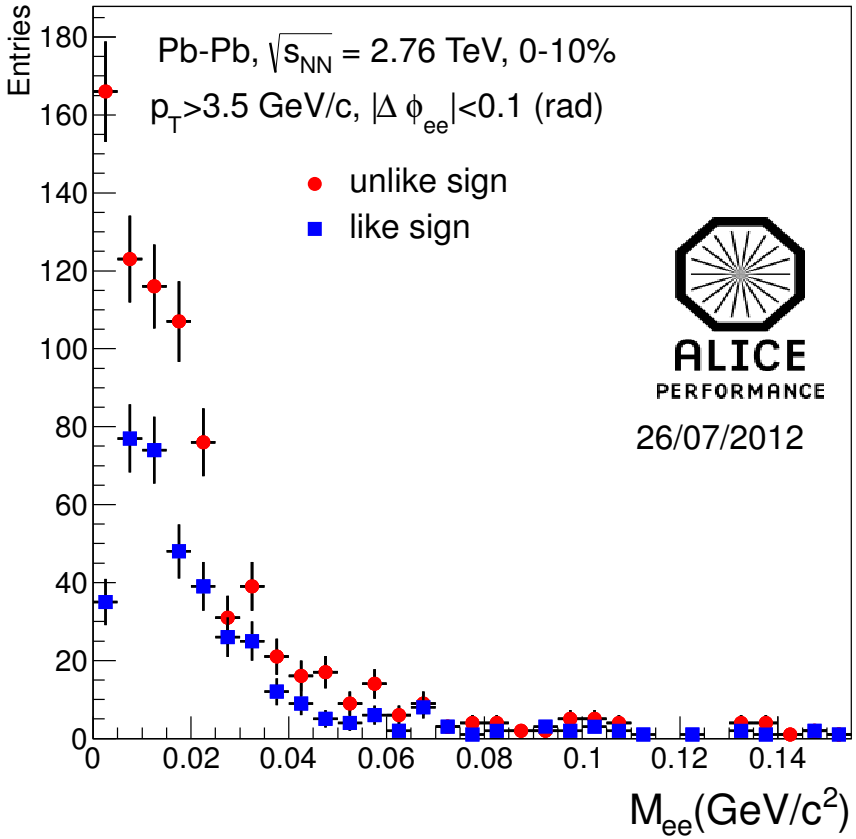
- Measurements in proton-proton collisions show good agreement with FONLL
- Suppression of electrons from heavy-flavour hadron decays over a wide p_T range
- Non-zero elliptic flow of electron from heavy-flavour hadron decays

Perspectives:

- Separate measurement of the nuclear modification factor for charm and beauty

BACKUP

Determination of "photonic" background via invariant mass



Number of photonic electrons calculated via

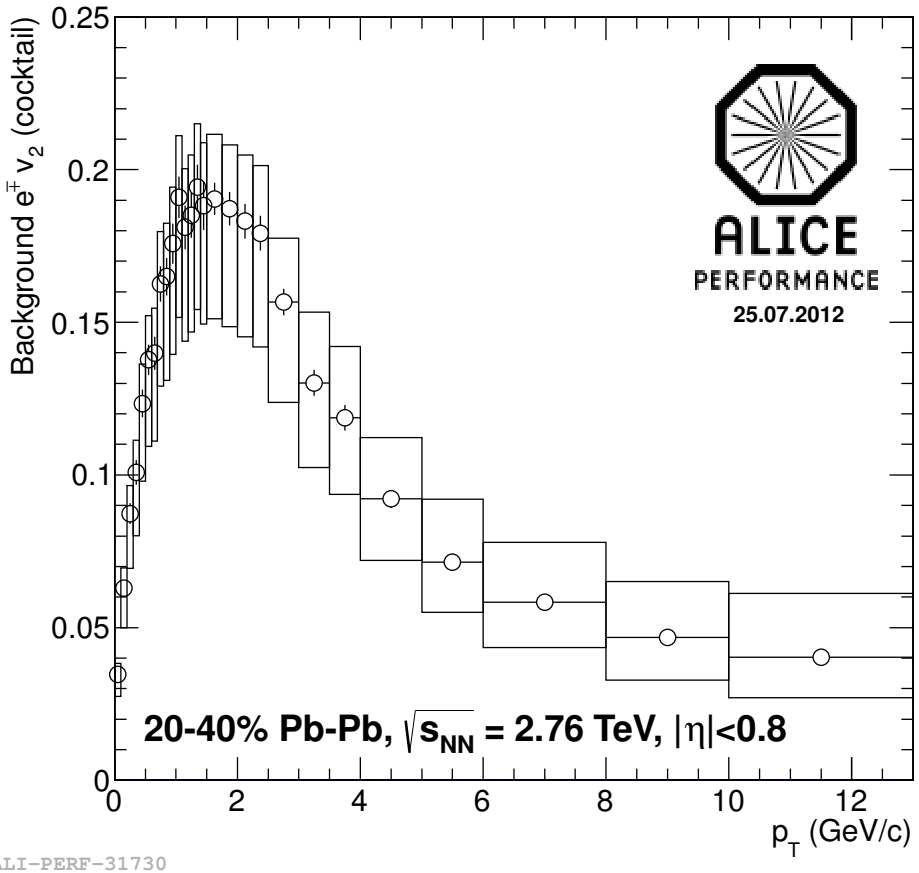
$$N_{e\gamma} = \frac{N_{ULS} - N_{LS}}{\varepsilon_{\gamma}}$$

N_{ULS}: unlike sign tracks

N_{LS}: like sign tracks

ε_{γ}: Photon reconstruction efficiency (from simulation)

Elliptic flow: Cocktail of background electrons



Calculation based on measured v_2 and p_T spectra of electron sources

Assumptions:

- charged pions as π^0 input
- η: via m_T-scaling
- direct photons: $v_2 = 0$
- J/ψ : not included