



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

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For the ALICE Collaboration

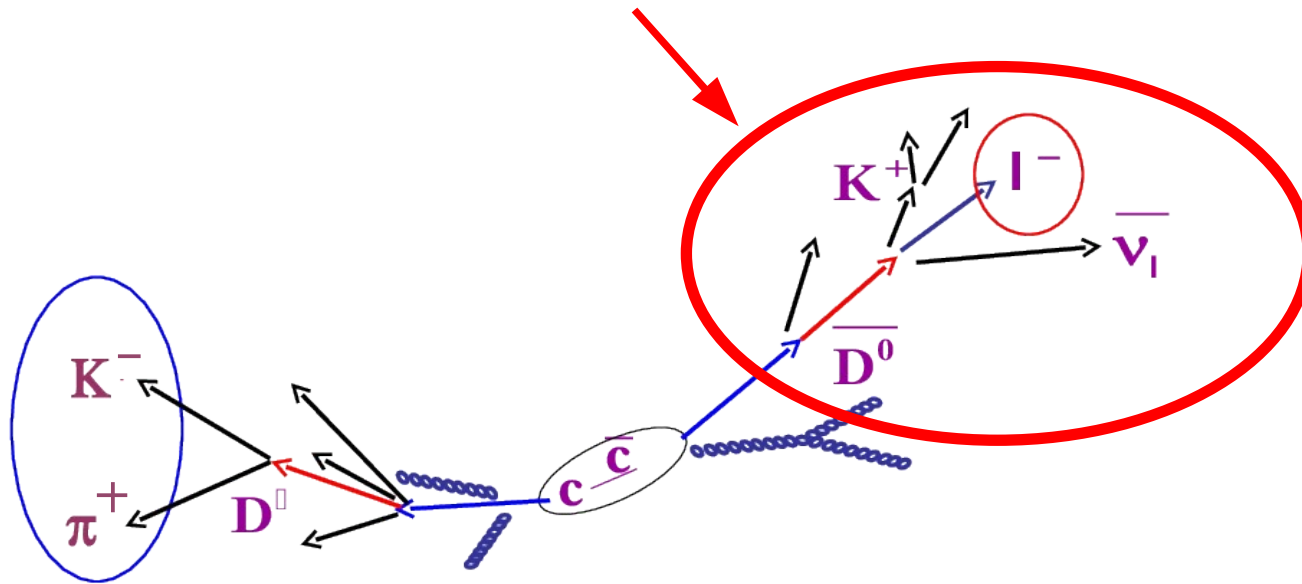
- *Introduction*
  - *Electron identification in ALICE*
- *Charm and beauty production in pp at  $\sqrt{s}=7$  TeV*
- *Electrons from PbPb collisions at  $\sqrt{s}_{NN}=2.76$  TeV*



# 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:



Branching Ratios:

$$\begin{aligned} c \rightarrow e + X & \quad \mathcal{O}(9.6\%) \\ b \rightarrow e + X & \quad \mathcal{O}(11\%) \\ b \rightarrow c \rightarrow e + X & \quad \mathcal{O}(10\%) \end{aligned}$$

## Proton-proton collisions

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

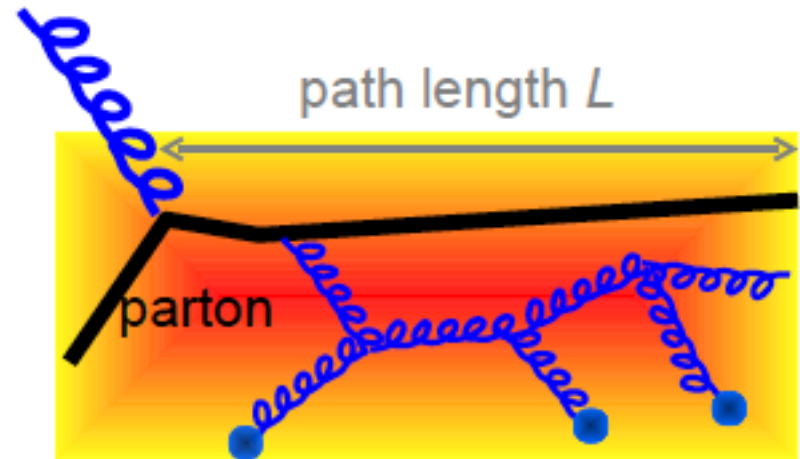
## Heavy-ion collisions

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

# 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



$$R_{AA}^{\pi} < R_{AA}^D < R_{AA}^B$$

Separation between charm and beauty → ALICE !!

# Heavy-flavours in ALICE

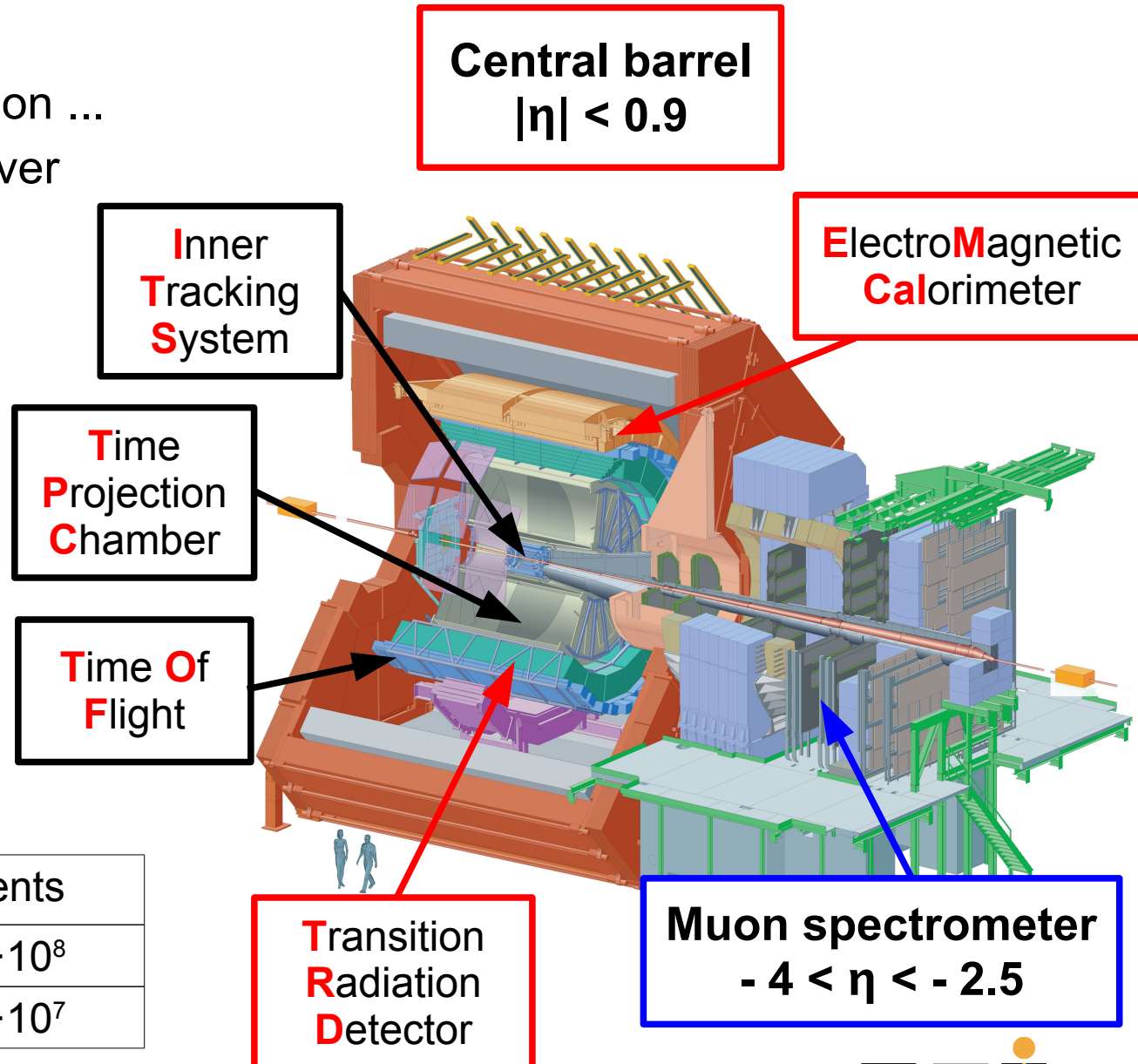


- Excellent vertex resolution
- Excellent momentum resolution ...
- .. and particle identification over a wide momentum range

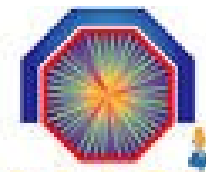


- Forward rapidity: muons
- Mid-rapidity:
  - Hadronic decays and **electrons**
  - Direct measurement of **beauty**

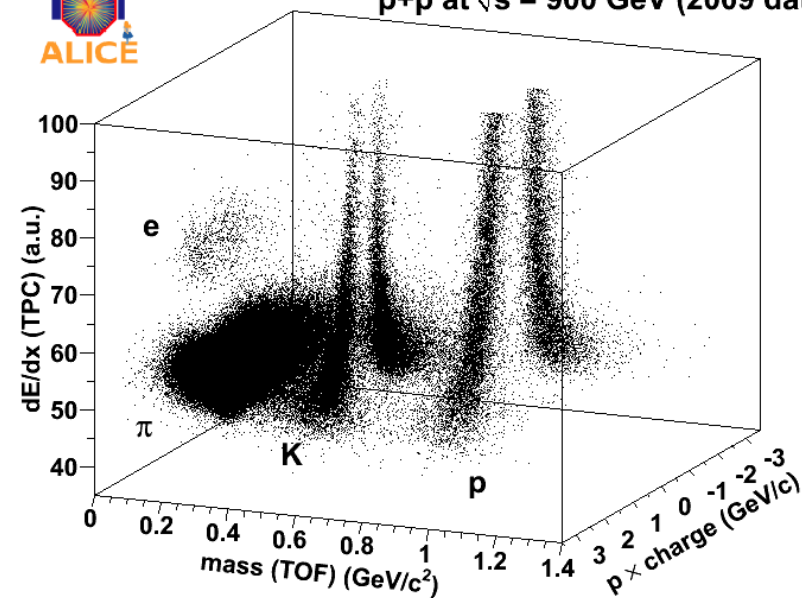
System	$\sqrt{s_{NN}}$ [TeV]	Events
pp	7	$1.8 \cdot 10^8$
Pb-Pb	2.76	$1.7 \cdot 10^7$



# Electron identification in ALICE



ALICE Performance 12/10/2010  
p+p at  $\sqrt{s} = 900$  GeV (2009 data)



## Time Of Flight

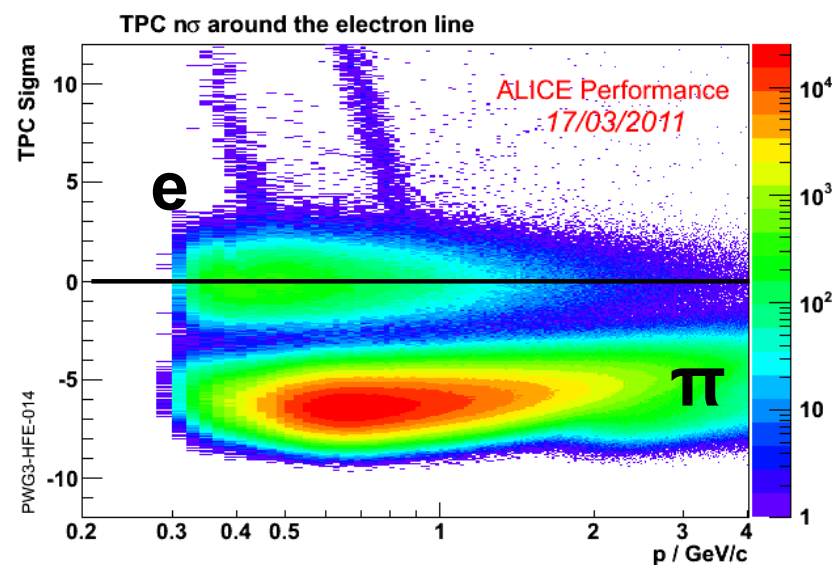
compatibility cut to expected time of flight for electron hypothesis ( $\pm 3\sigma$ )

Rejects kaons up to 1.5  $\text{GeV}/c$  and protons up to 3  $\text{GeV}/c$

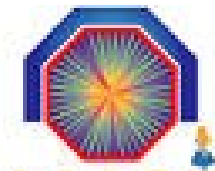
## Time Projection Chamber

$dE/dx$  in  $\sigma$ 's around the electron  
Bethe Bloch parametrization

→ select entries in the top half of the distribution



# Electron identification in ALICE



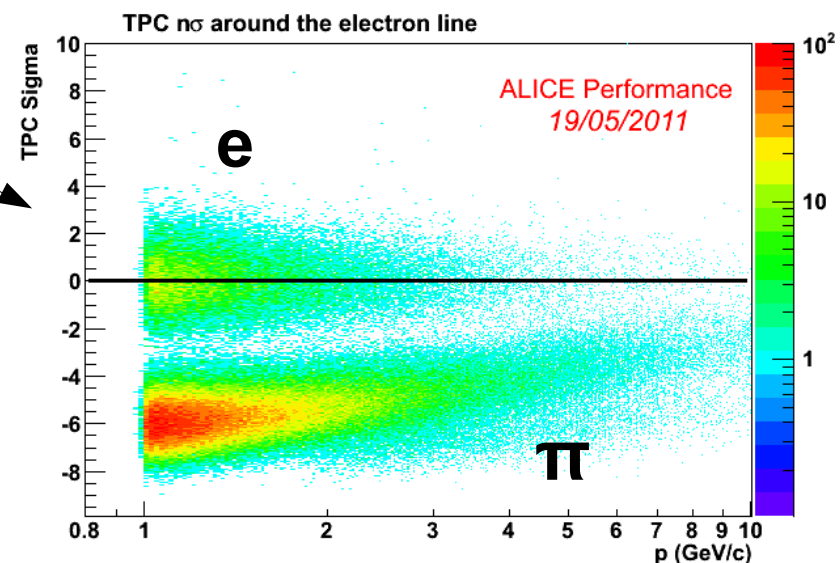
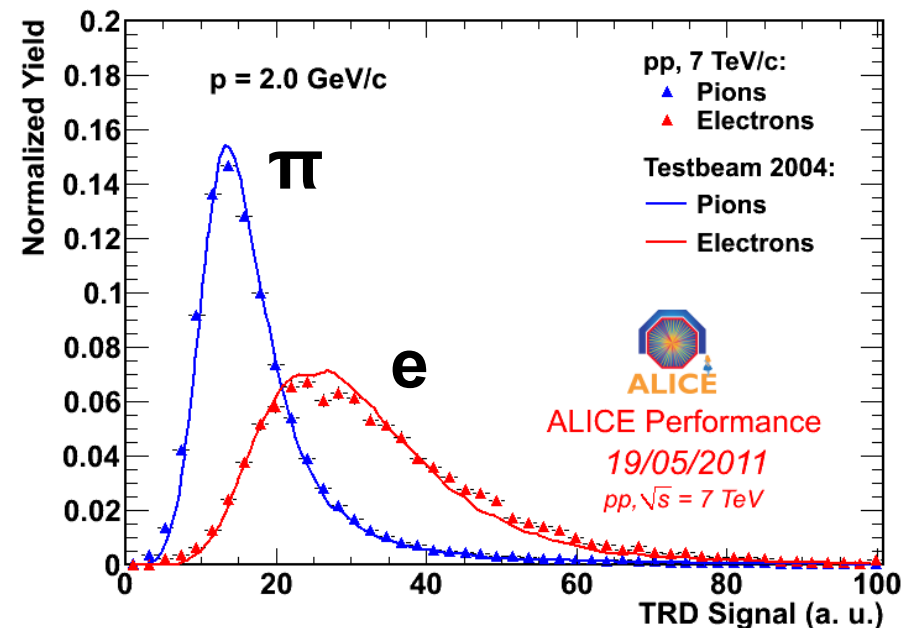
## Transition Radiation Detector

Energy deposit + TR

Electron likelihood cut fixed at 80%  
electron efficiency

Strong  $\pi$  suppression !

See *M. Fasel's poster*



## ElectroMagnetic Calorimeter

TPC-EMCal matching, E/p cuts

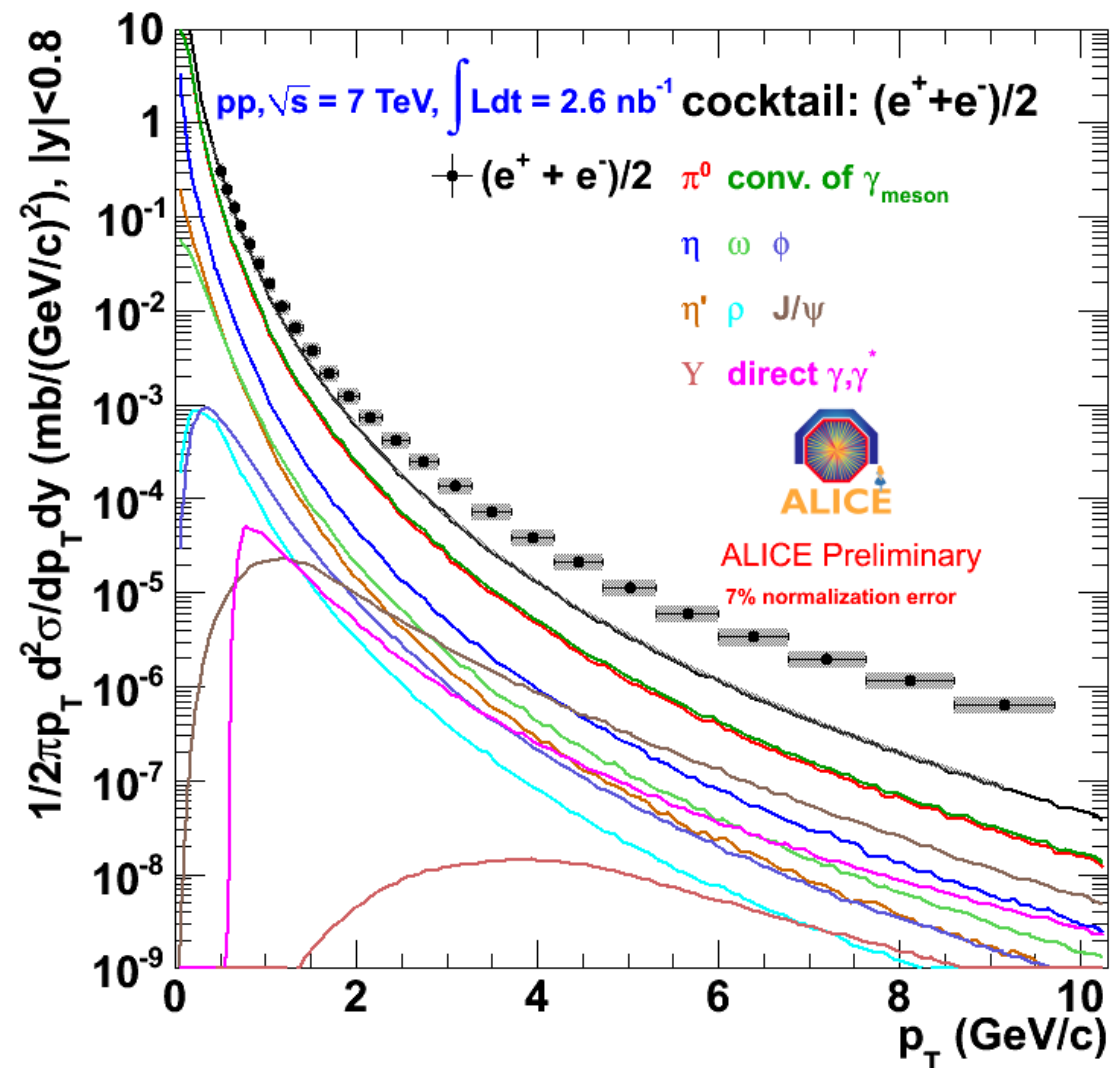
See *S. Sakai's poster*

## 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 ( $\gamma$ ,  $\gamma^*$ )



# Charm and beauty production in pp



Inclusive – cocktail

=

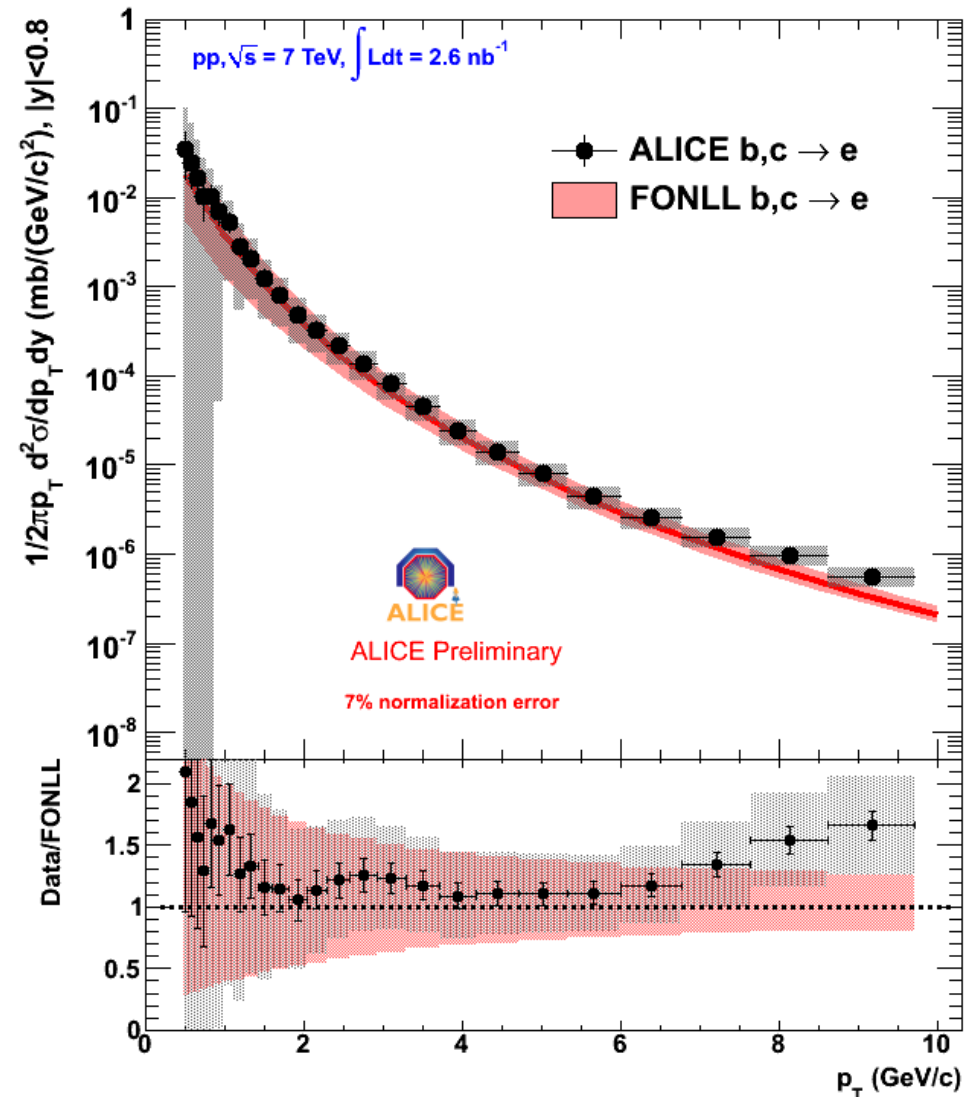
Electrons from heavy  
flavour hadron decays  
(charm and beauty)

Compared to FONLL

Cacciari et al.

arXiv:hep-ph/980340, hep-ph/0102134

See *M. Fasel's poster (TRD)*  
and *S. Sakai's poster (EMCal: consistent analysis!)*





# Direct beauty measurement in pp

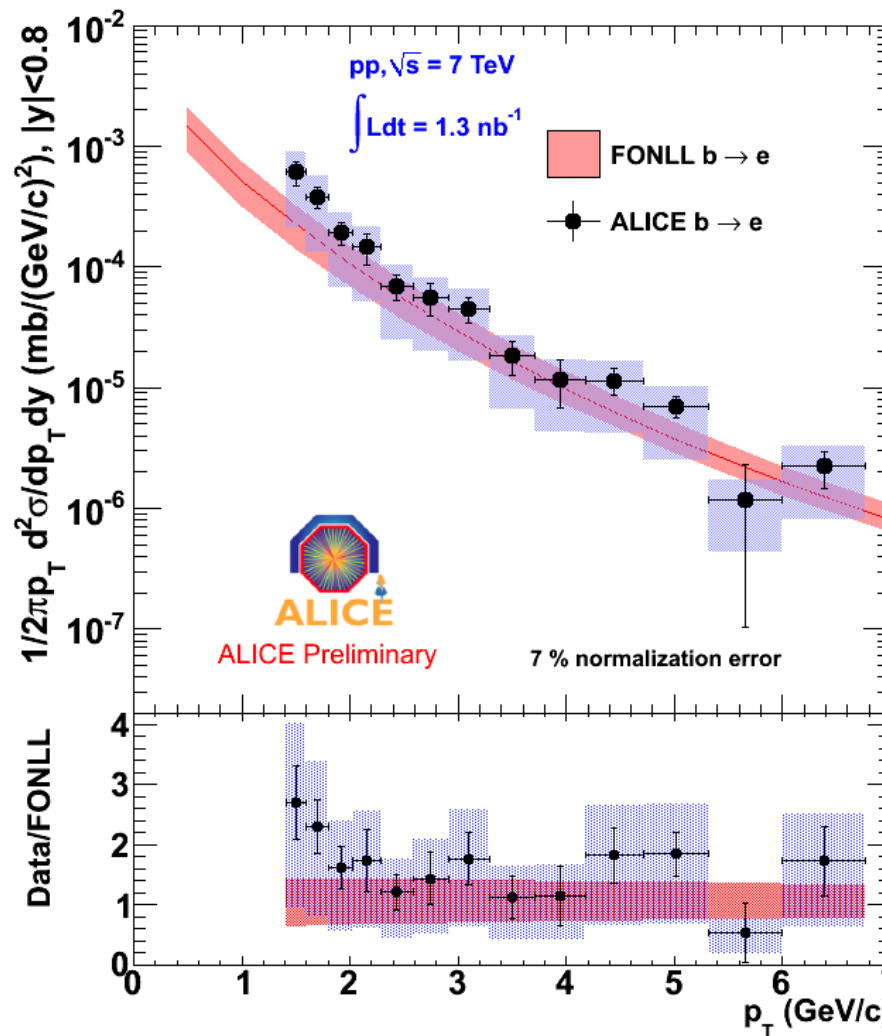
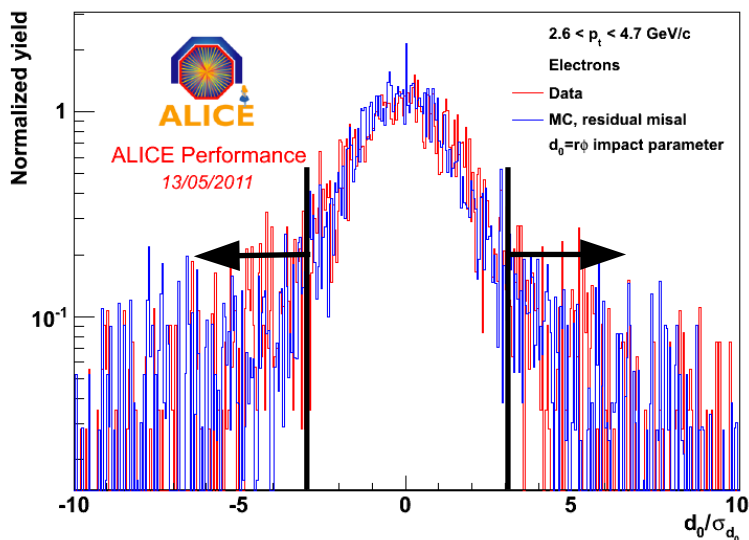


Beauty  $c\tau \approx 500 \mu\text{m} \rightarrow$   
 Isolate beauty decays by  
 the large impact parameter  
 of the electron

Residual bkg's subtracted

High resolution on impact  
 parameter:  $50 \mu\text{m}$  at  $2 \text{ GeV}/c$

Data very well described by MC

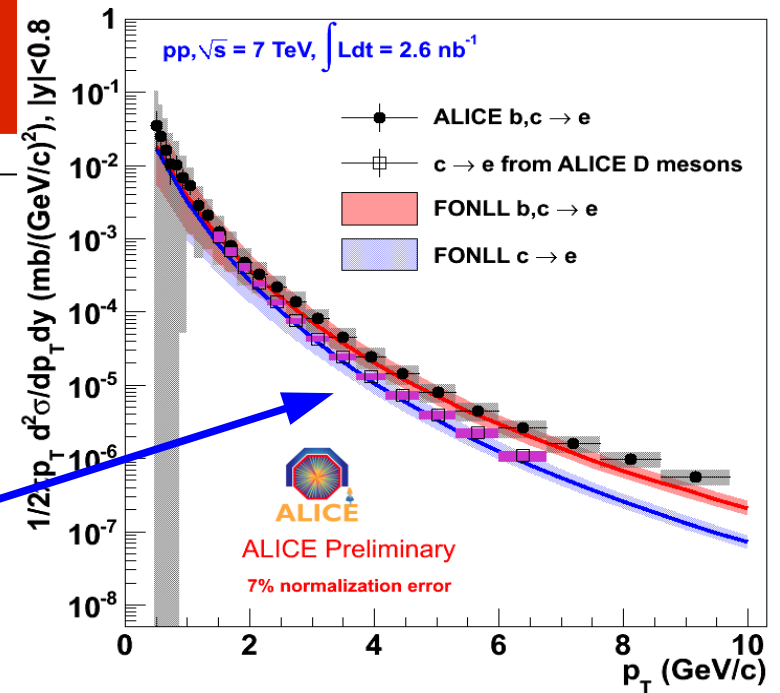


Well  
 described  
 by FONLL  
 predictions

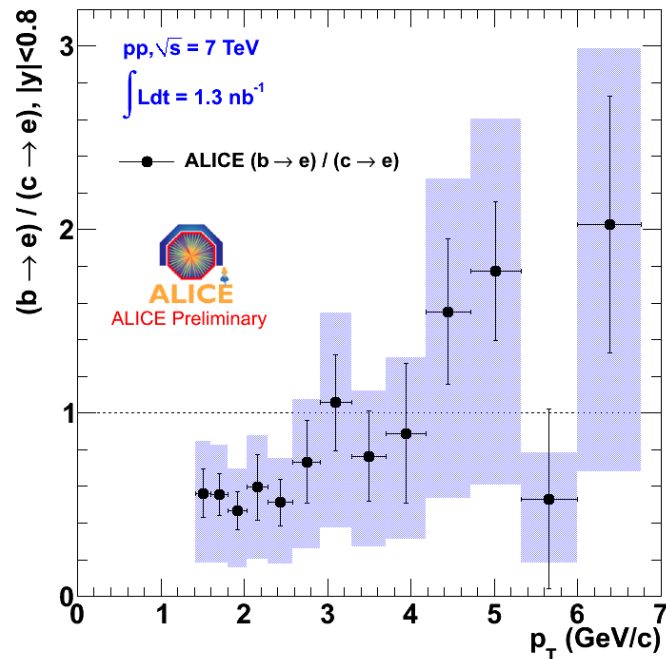
See M. Kweon's poster

# More beauty results in pp

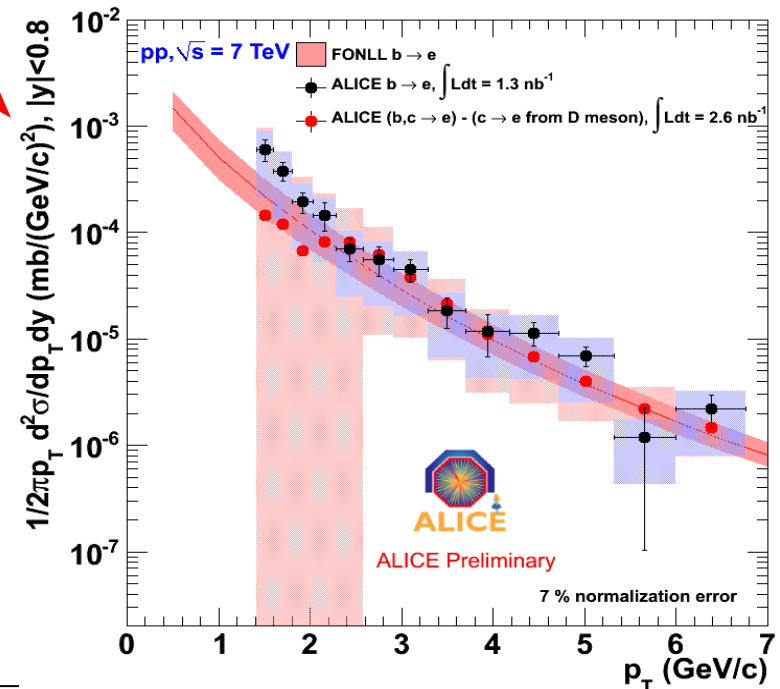
Alternative way to measure beauty:  
 (inclusive e) – (cocktail)  
 –  
 (electrons from decay of ALICE D mesons)



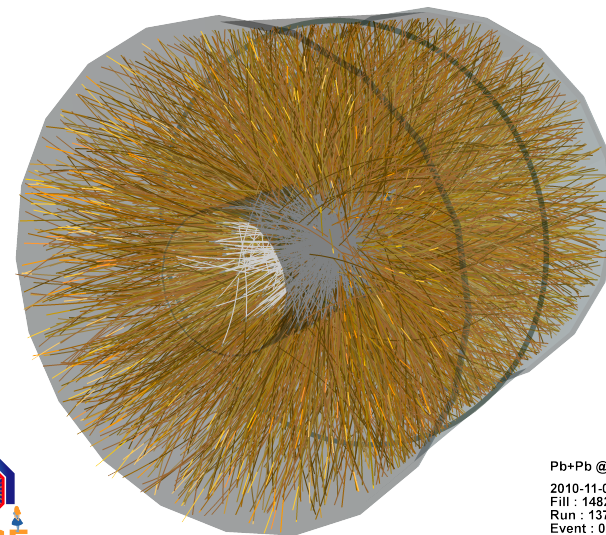
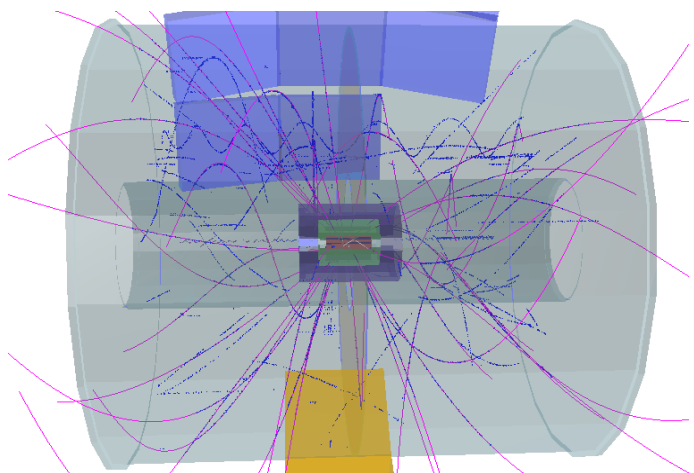
## Beauty / charm



=



# From proton-proton ...



Pb+Pb @ sqrt(s) = 2.76 ATeV  
2010-11-08 11:30:46  
Fill : 1482  
Run : 137124  
Event : 0x0000000D3BBE693

## ... to Pb-Pb collisions !!!



# PbPb: Inclusive electron spectra

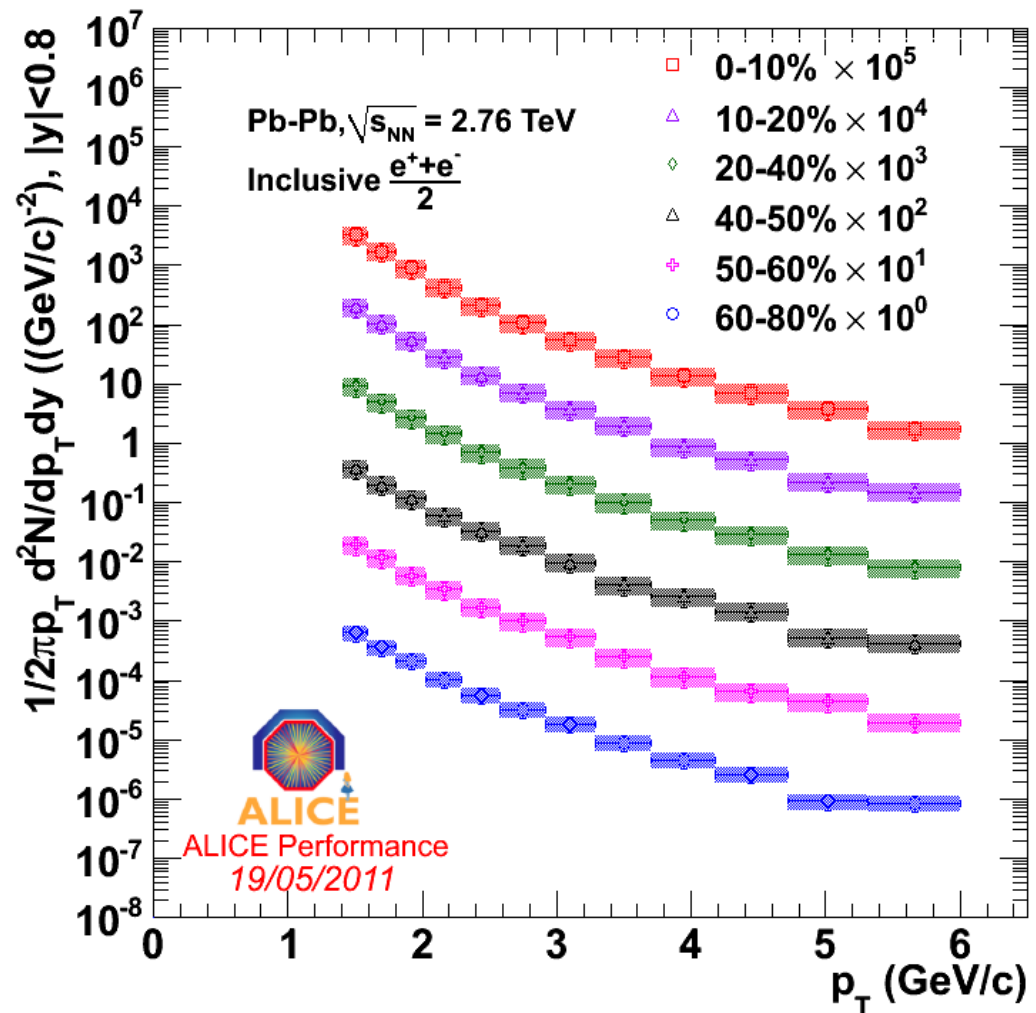


## Inclusive electron spectra in 6 centrality bins

- 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

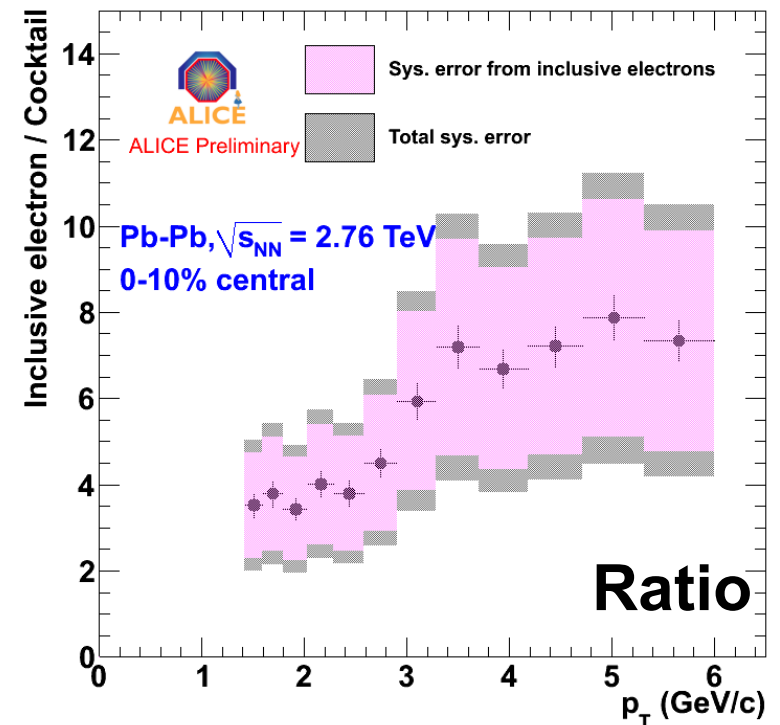
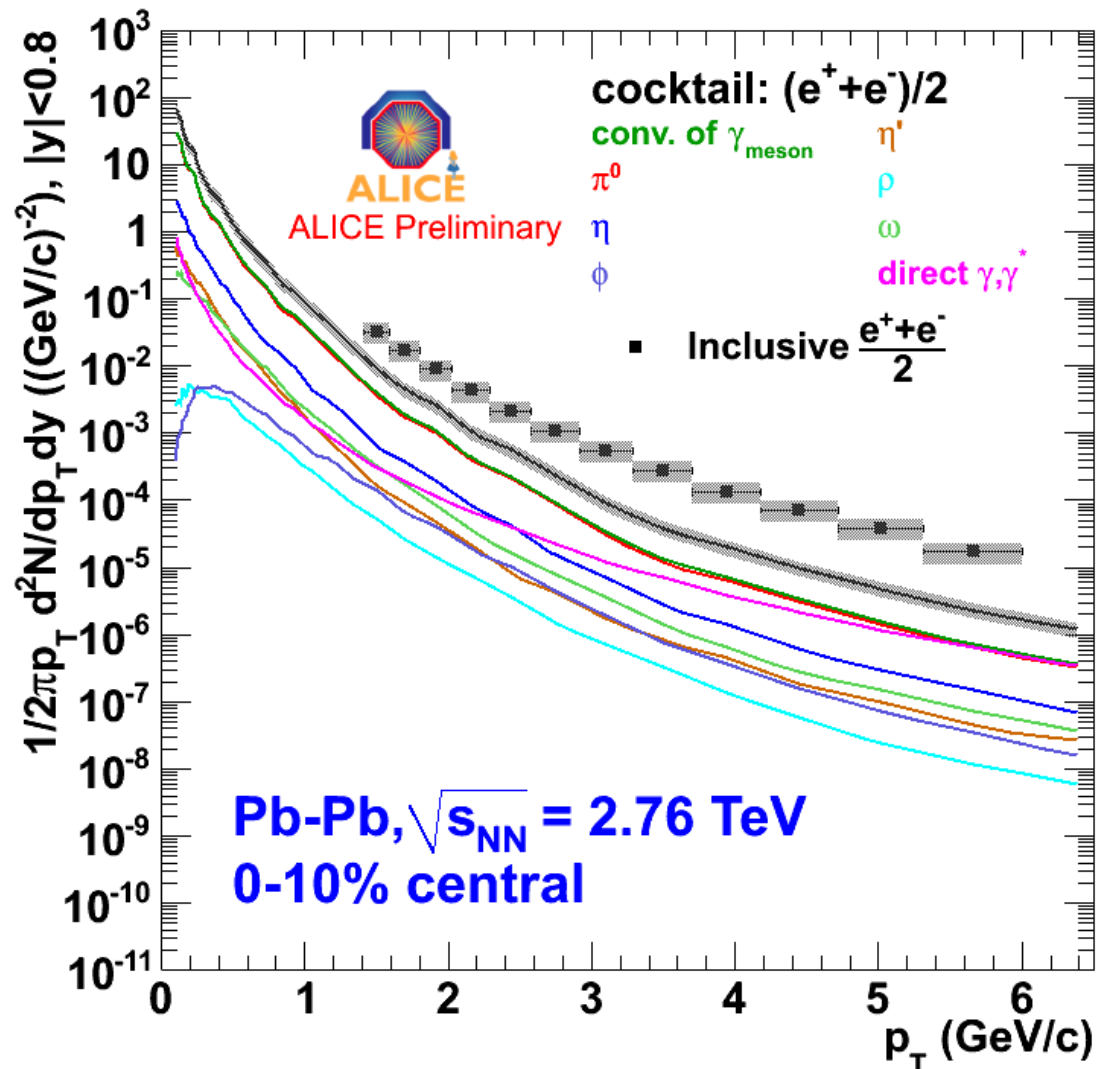


**All PbPb results → Y. Pachmayer's poster**

# PbPb: Inclusive and cocktail - 0-10%



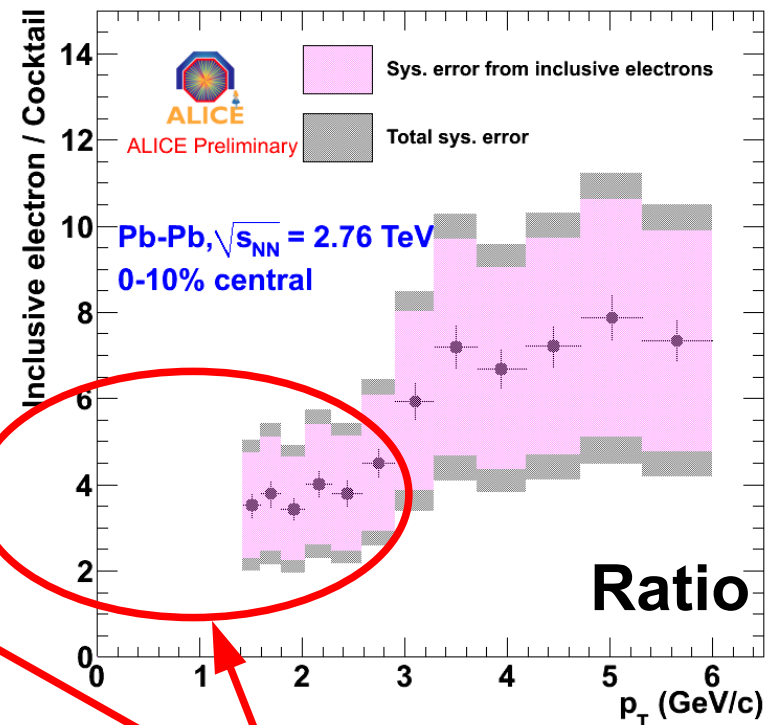
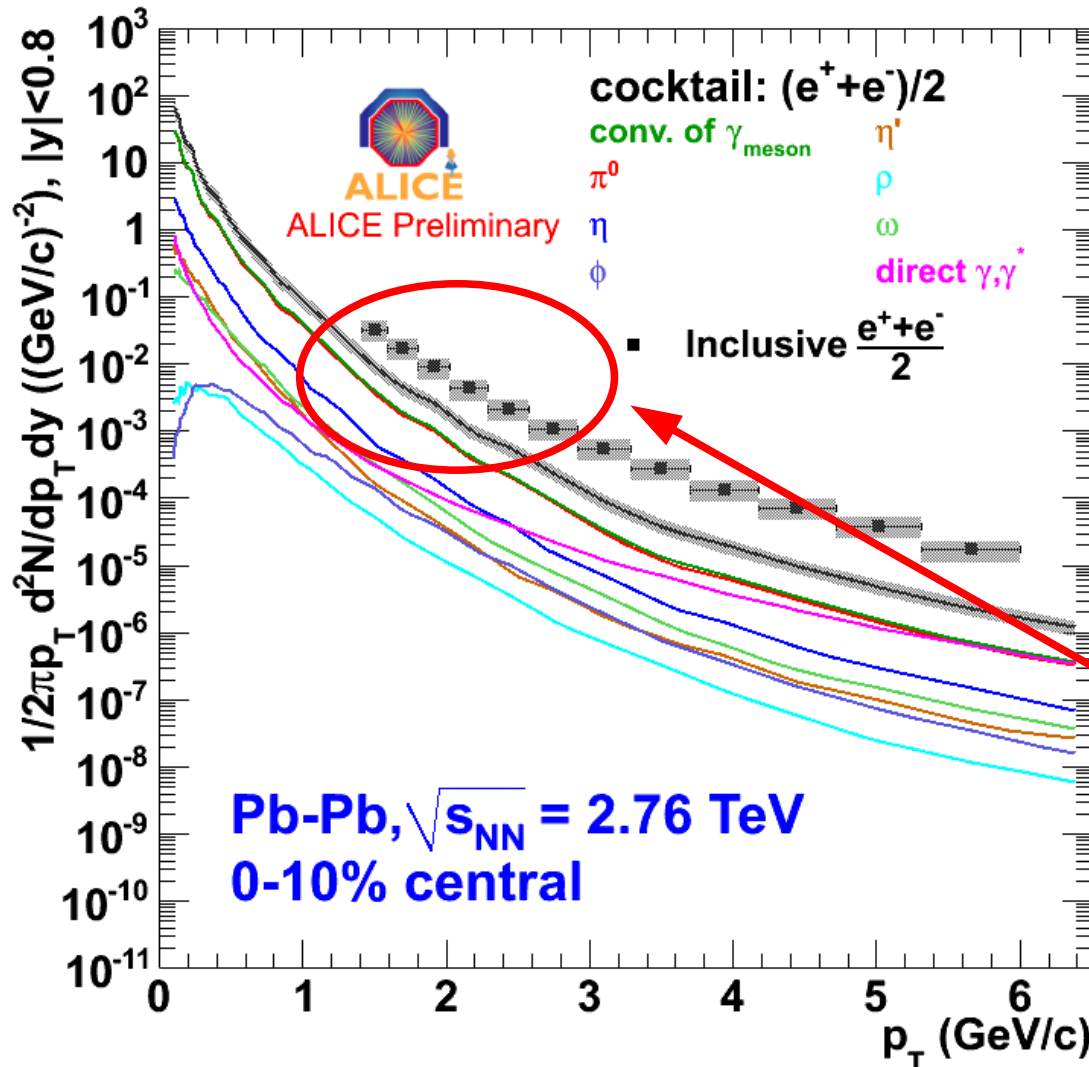
Inclusive – cocktail = electrons from heavy flavour decays  
... Only??



# PbPb: Inclusive and cocktail - 0-10%



Inclusive – cocktail = electrons from heavy flavour decays  
... Only??



Low  $p_T$  region:  
Excess ?

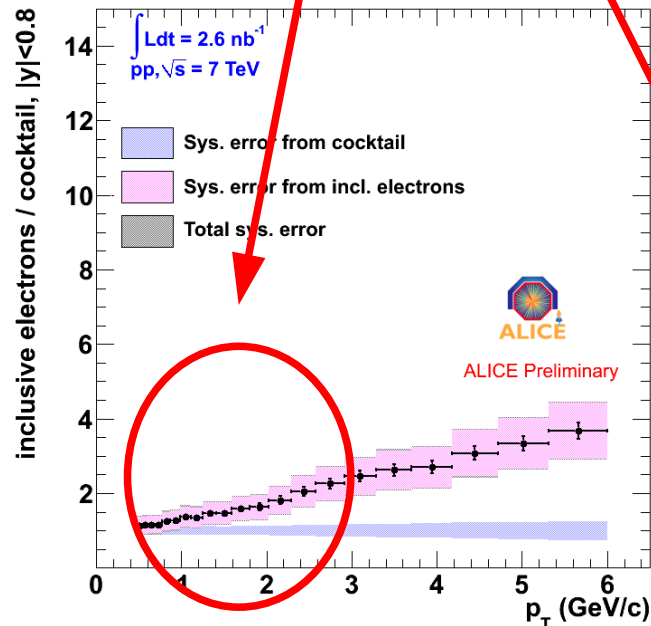
# pp, PbPb peripheral and PbPb central



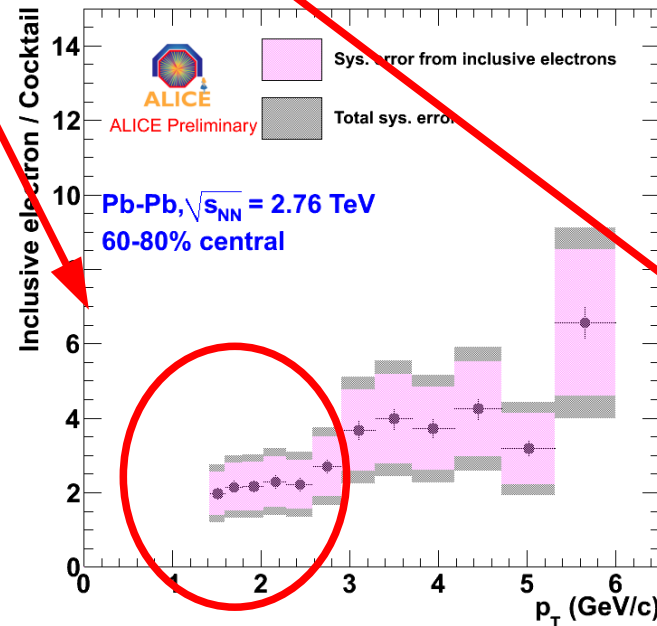
**At low  $p_T$ : hint for an excess**  
**Increases towards more central collisions**

Consistent with thermal radiation?  
Thermal photons observed at RHIC

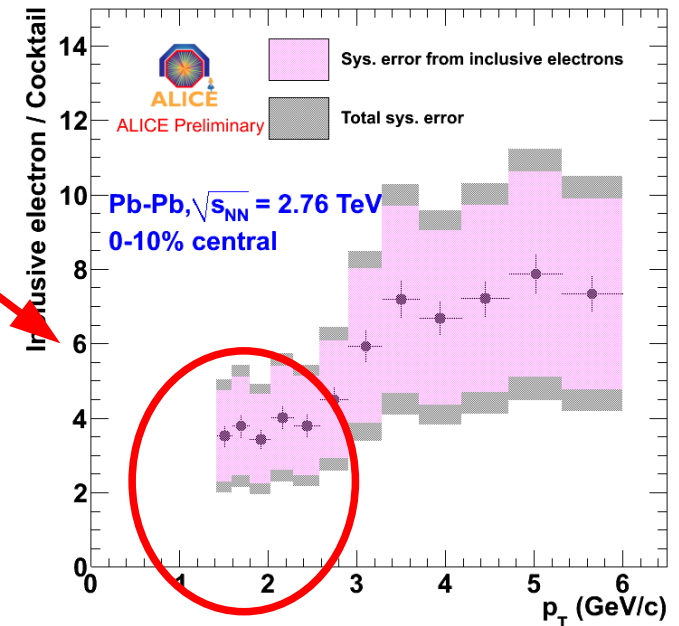
pp



60-80%



0-10%



# Nuclear modification factor ...

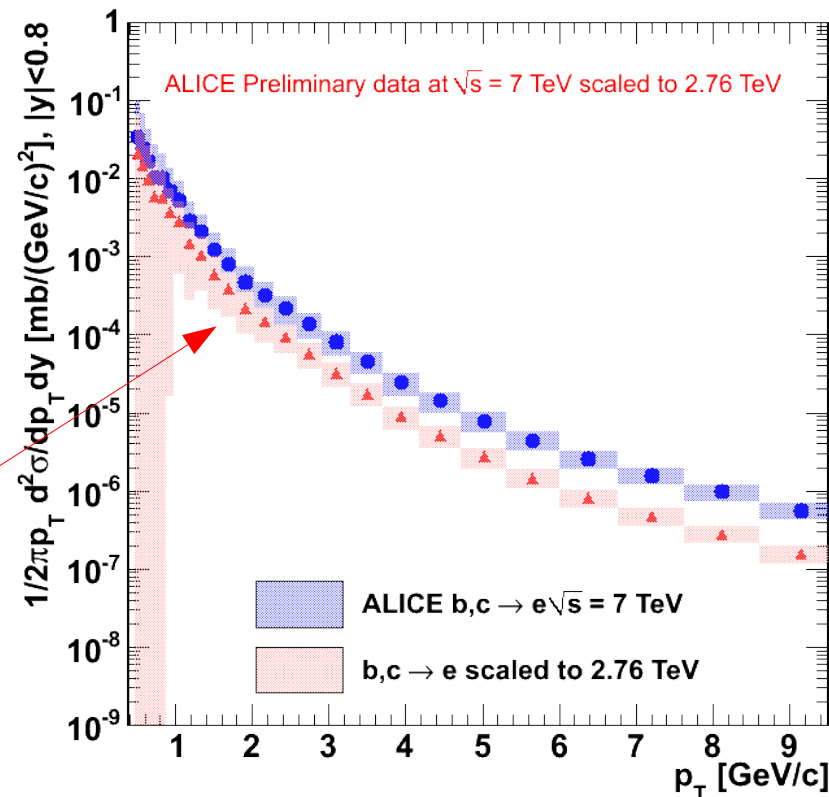


... of electrons from heavy flavour hadron decays, for  $p_T > 3.5$  GeV/c :

$$R_{AA}(p_T) = \frac{1}{\langle T_{AA} \rangle} \times \frac{dN_{AA} / dp_T}{d\sigma_{pp} / dp_T}$$

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

Large  
uncertainty  
at low  $p_T$

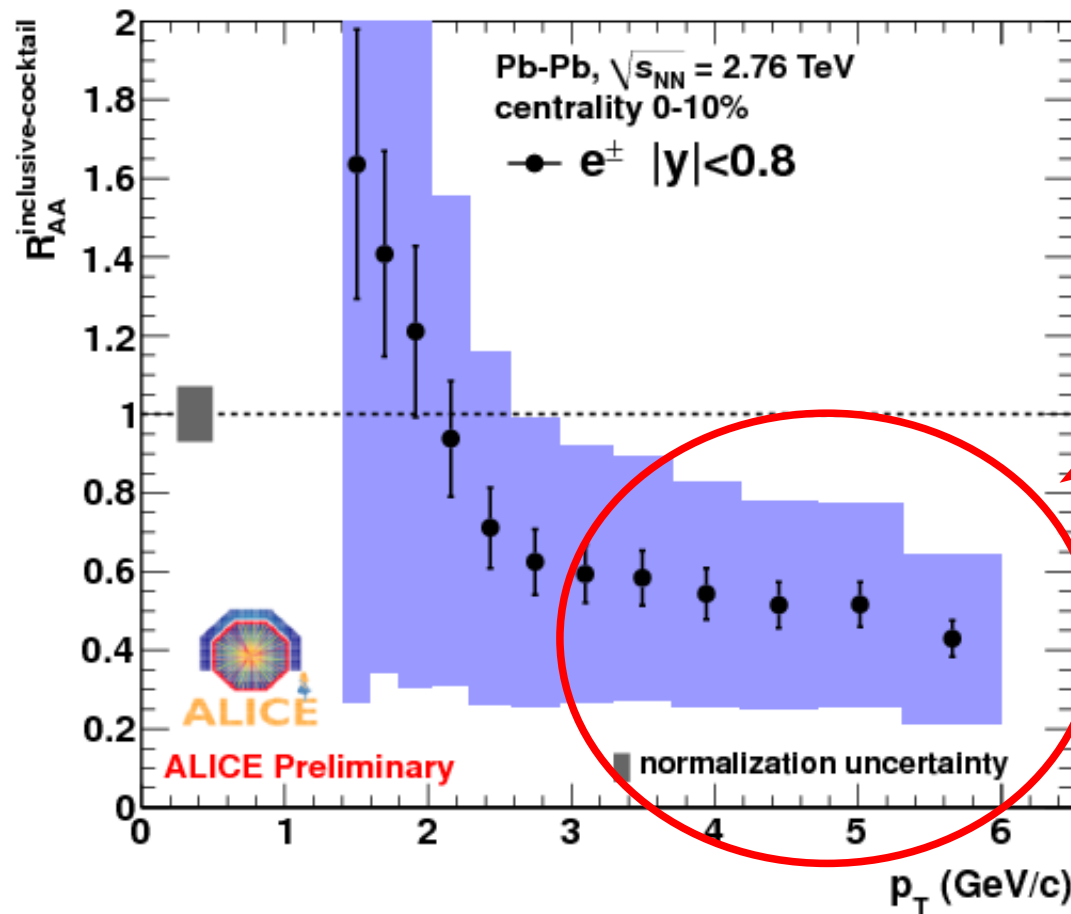




# (Inclusive – cocktail) electron $R_{AA}$



Most central: 0-10%

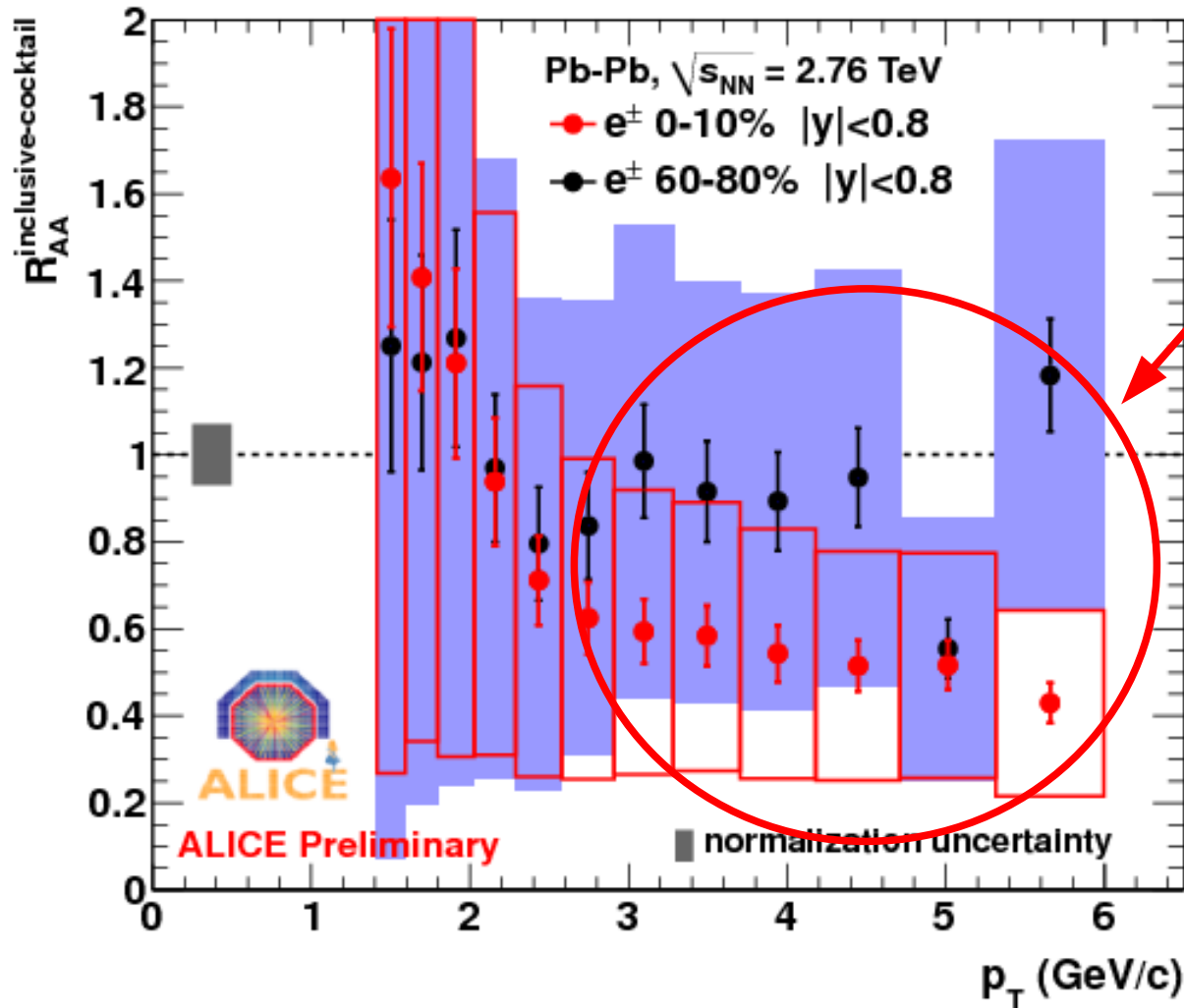


$R_{AA}$  of electrons  
from heavy  
flavour hadron  
decays

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

Excess under  
investigation

# Electron $R_{AA}$ : central vs peripheral



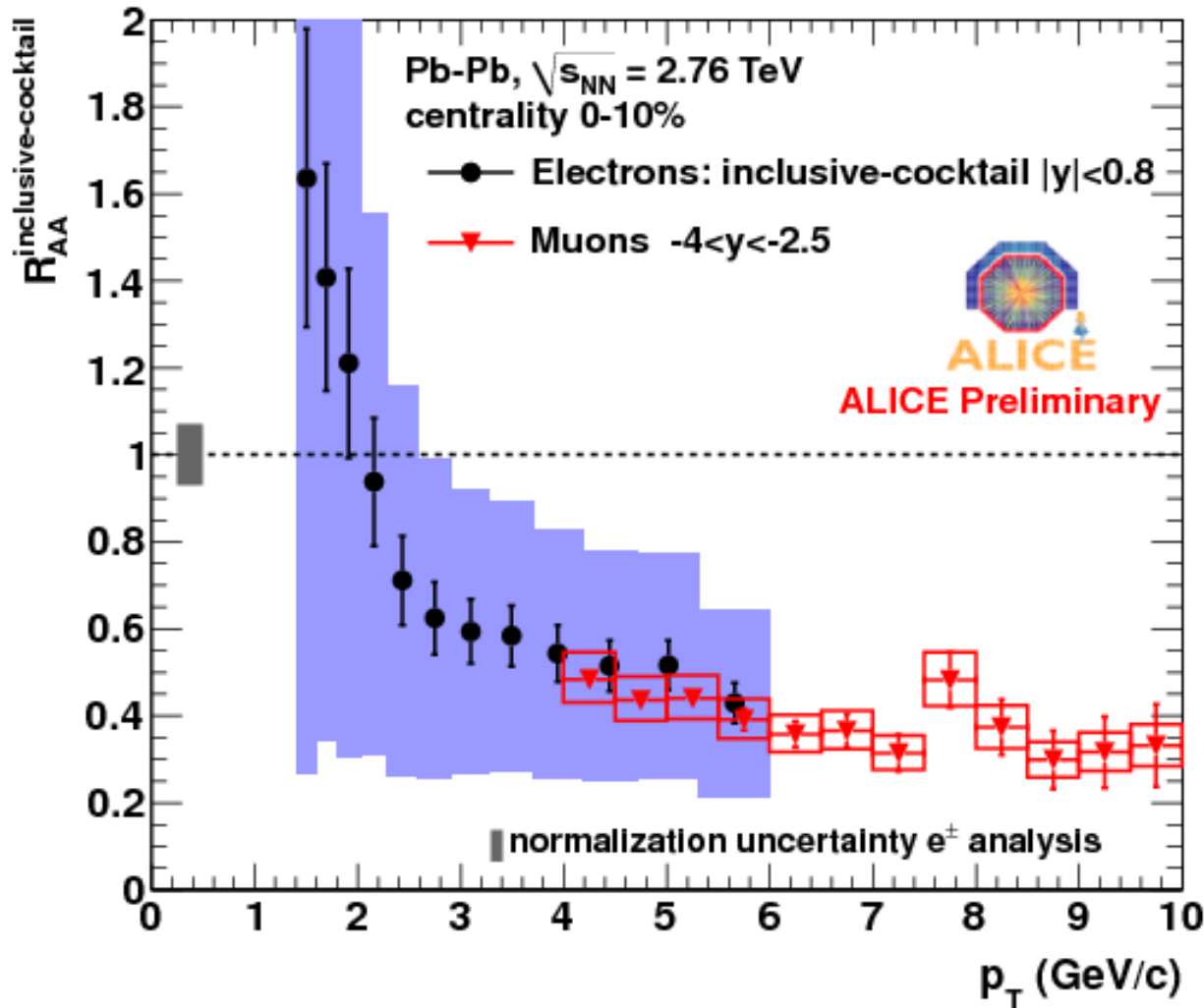
Electrons from heavy flavour hadron decays

→ 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 → X. Zhang's talk*

- 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





- **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**

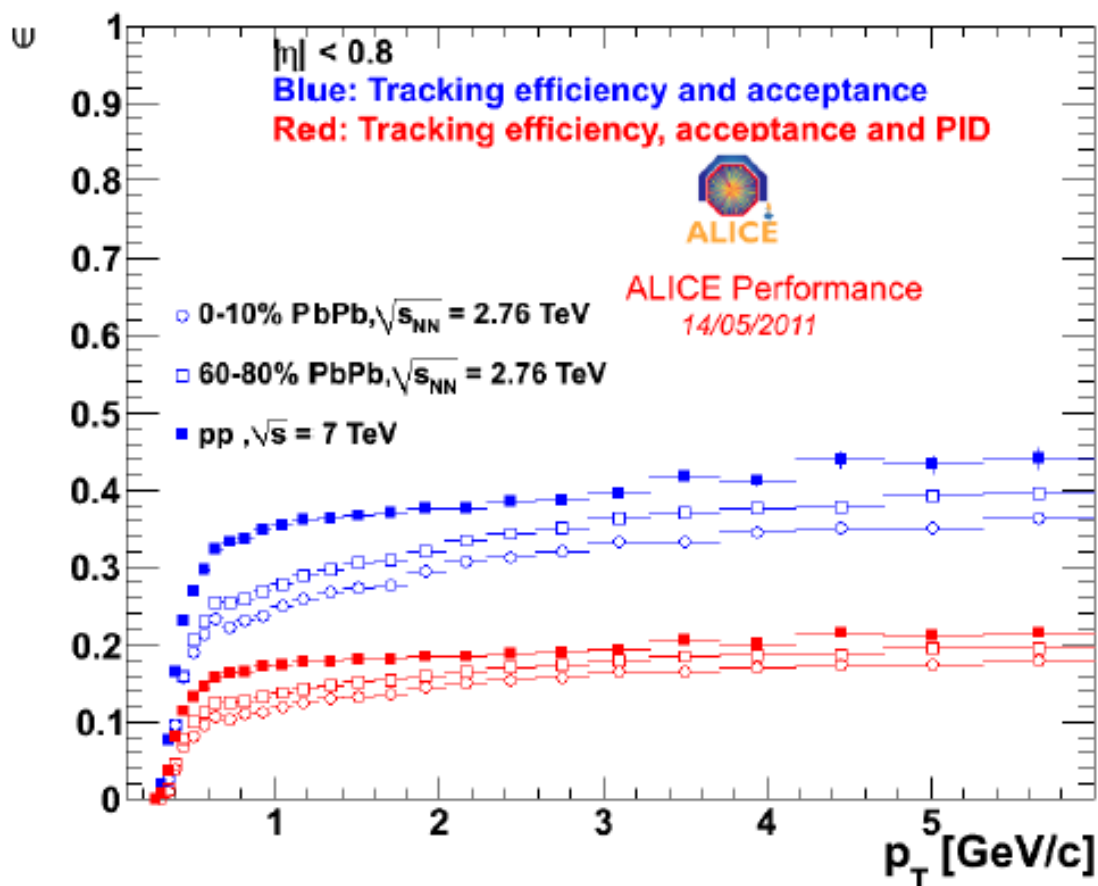
[Yvonne Pachmayer](#), “Measurement of the Nuclear Modification Factor of Electrons from Heavy Flavour Decays at Mid-Rapidity in Pb-Pb Collisions at  $\sqrt{s}_{NN} = 2.76$  TeV with ALICE”

# BACKUP

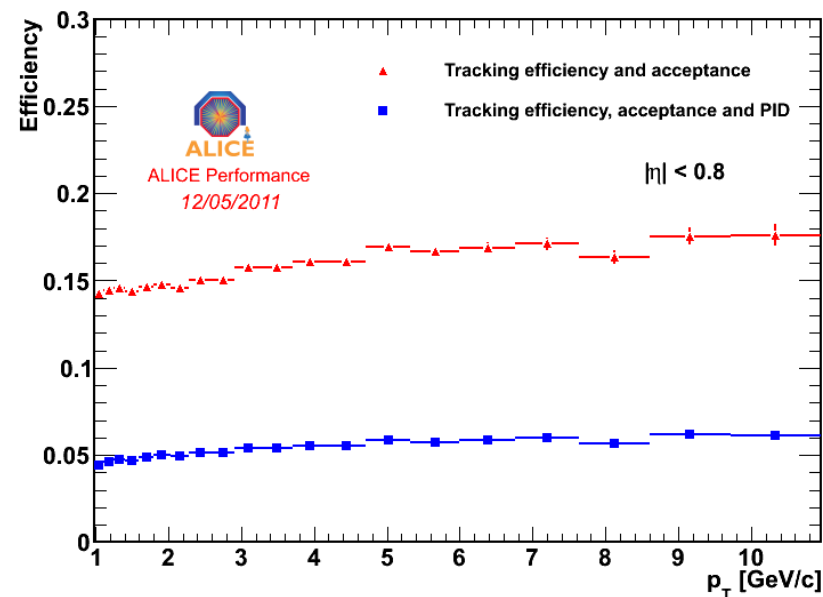
# Electron selection efficiency



TOF ( $3\sigma$  electron compatibility cut) and  
TPC (top-half dE/dx cut)



In pp: also TRD  
0.35 (acc) \* 0.80 (PID  $\epsilon$ ) down



## Time Of Flight

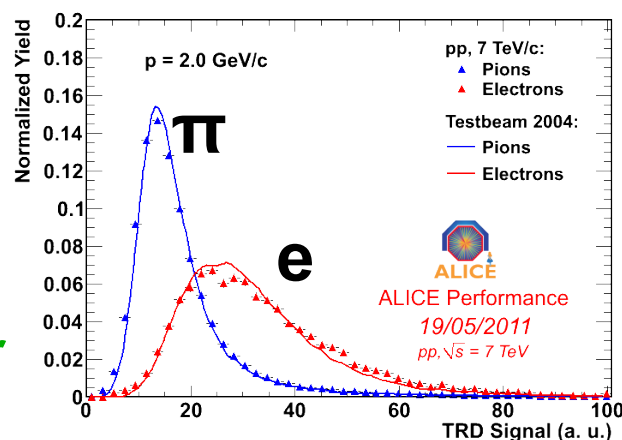
compatibility cut to  $\text{ToF}_{\text{electron}} (\pm 3\sigma)$

Rejects kaons up to 1.5 GeV/c  
and protons up to 3 GeV/c

## Transition Radiation Detector

Electron likelihood cut  
fixed at 80% electron  
efficiency

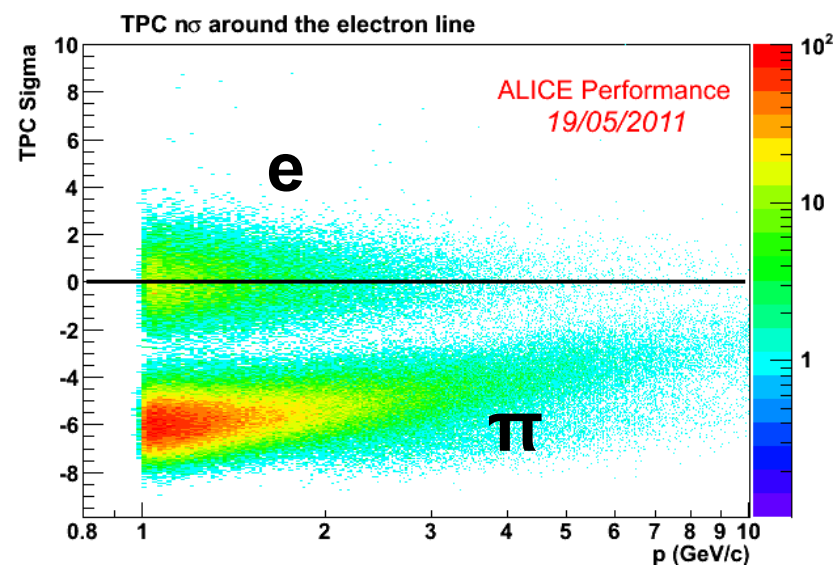
*See M. Fasel's poster*



## Time Projection Chamber

dE/dx in  $\sigma$ 's around the electron  
Bethe Bloch parametrization

→ select entries in the top half  
of the distribution



## ElectroMagnetic Calorimeter

TPC-EMCal matching, E/p cuts

*See S. Sakai's poster*



# The electron cocktail

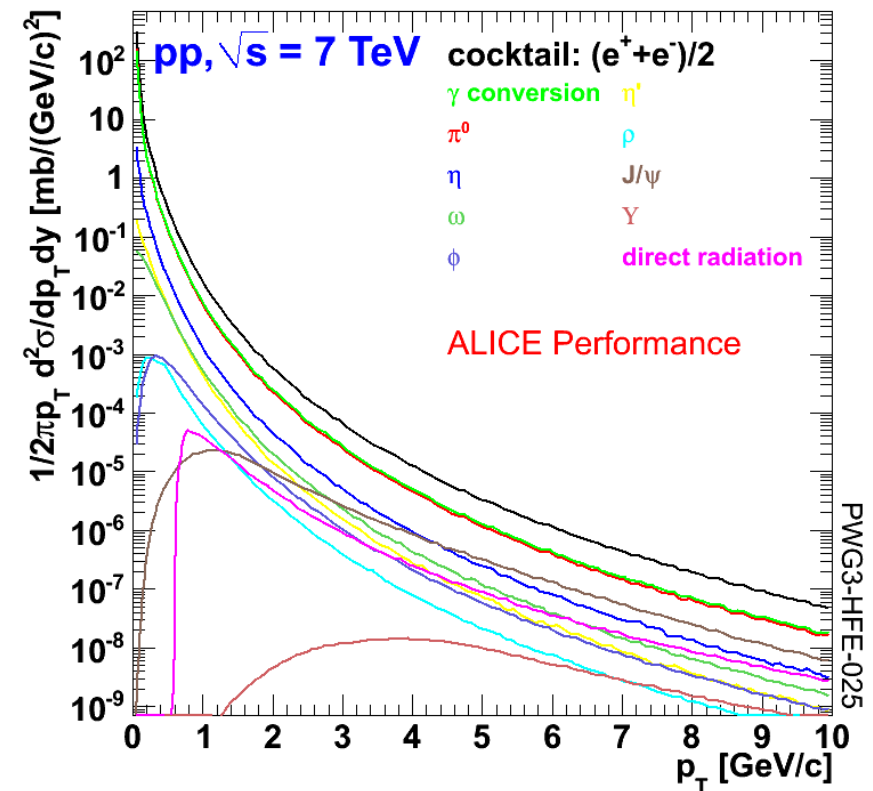


## All sources of electrons:

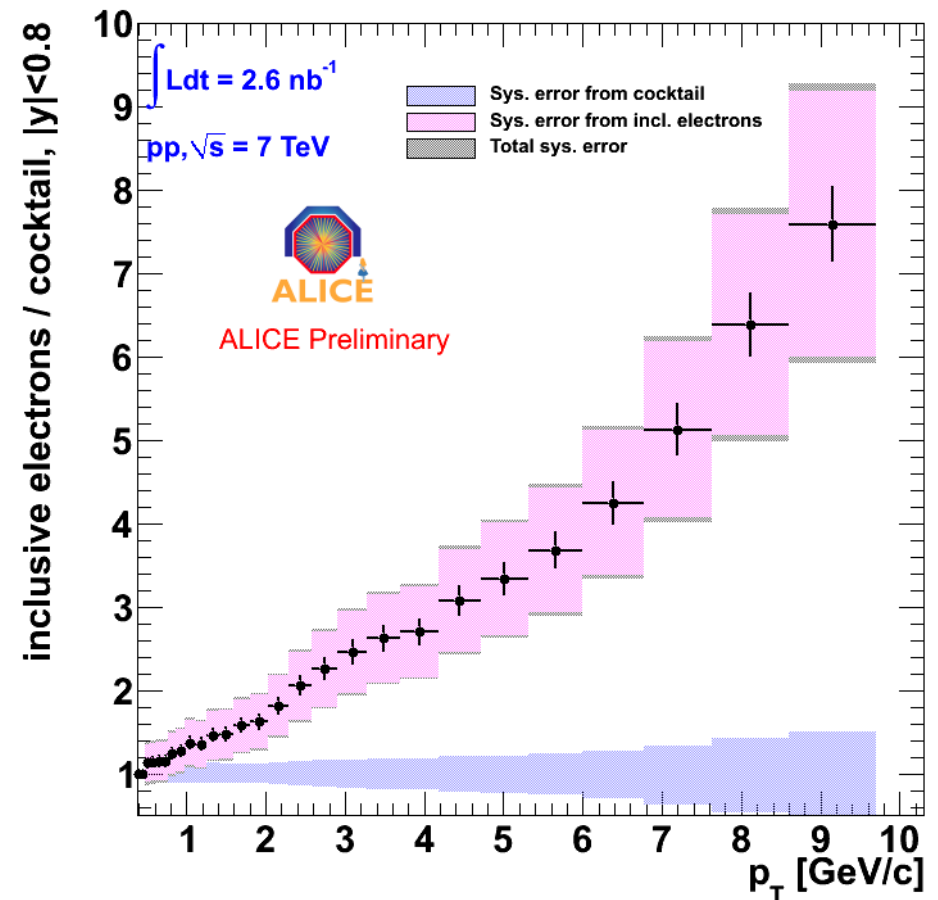
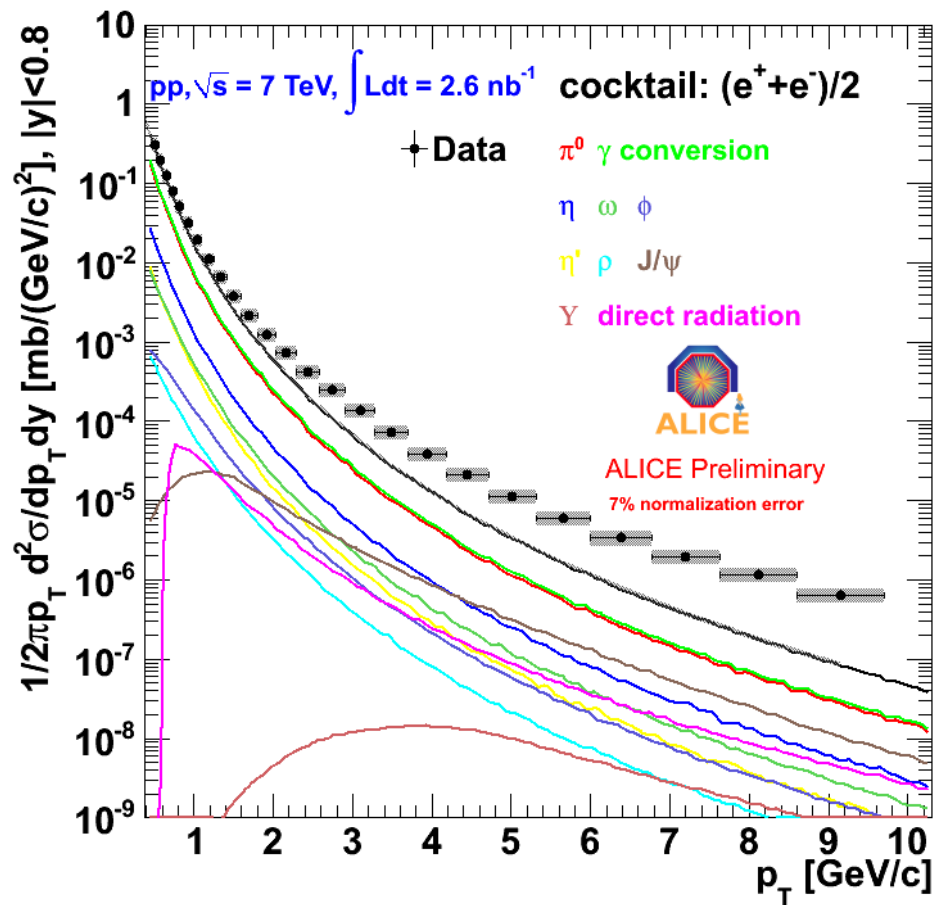
- **Dalitz decays of light neutral mesons** ( $\pi^0, \eta, \omega, \eta', \phi \rightarrow \gamma e^+ e^-$ )
- **Photon conversions in material**
- **Direct radiation** (*direct photon conversions, virtual photons  $\gamma^* \rightarrow e^+ e^-$* )
- **Weak kaon decays** (e.g.  $K^\pm \rightarrow \pi^0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

## Current cocktail ingredients:

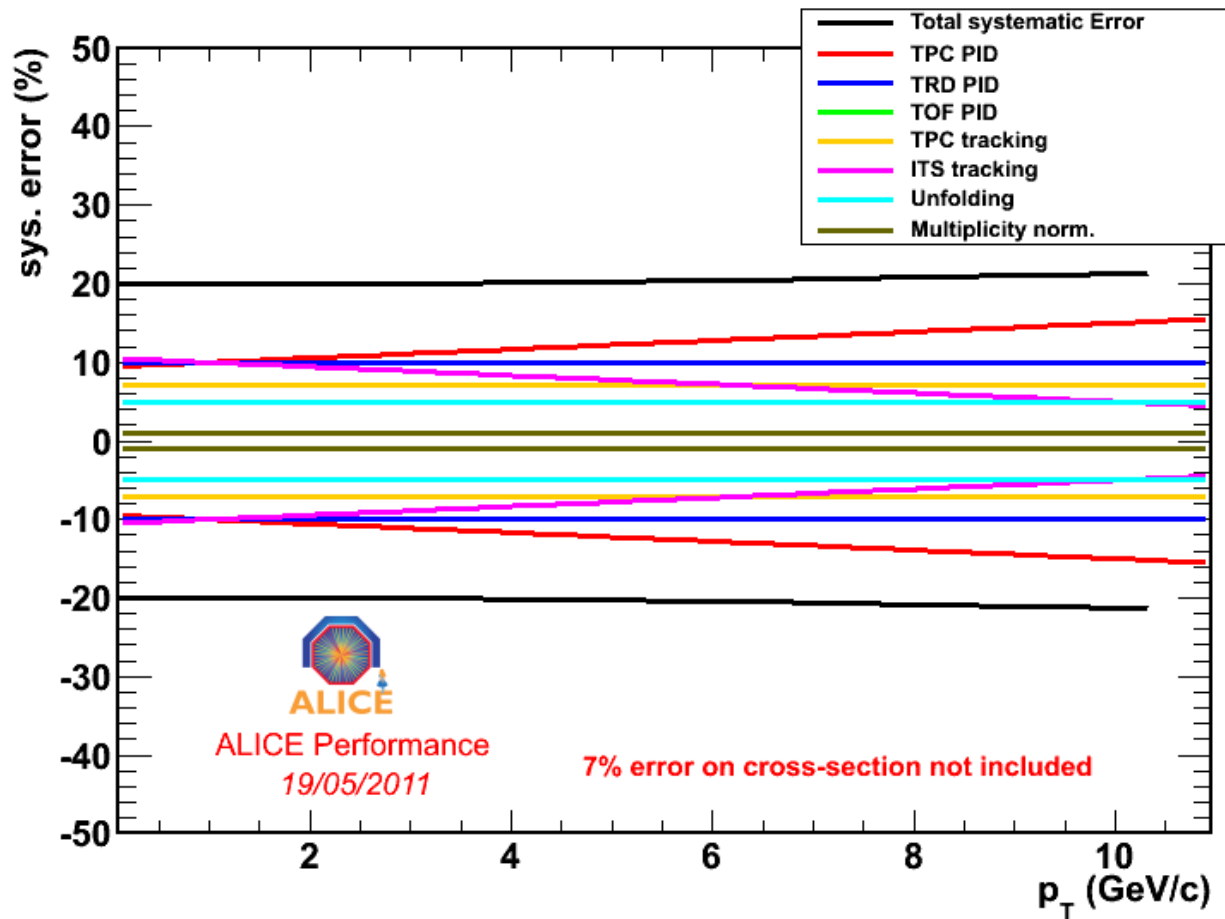
- **Neutral pions (based on the measured  $\pi$  spectra)**
- **Heavier mesons:  $\eta, \rho, \omega, \phi, \eta'$**
- **Photon conversions**
- **$J/\psi, \Upsilon$ , direct photons**



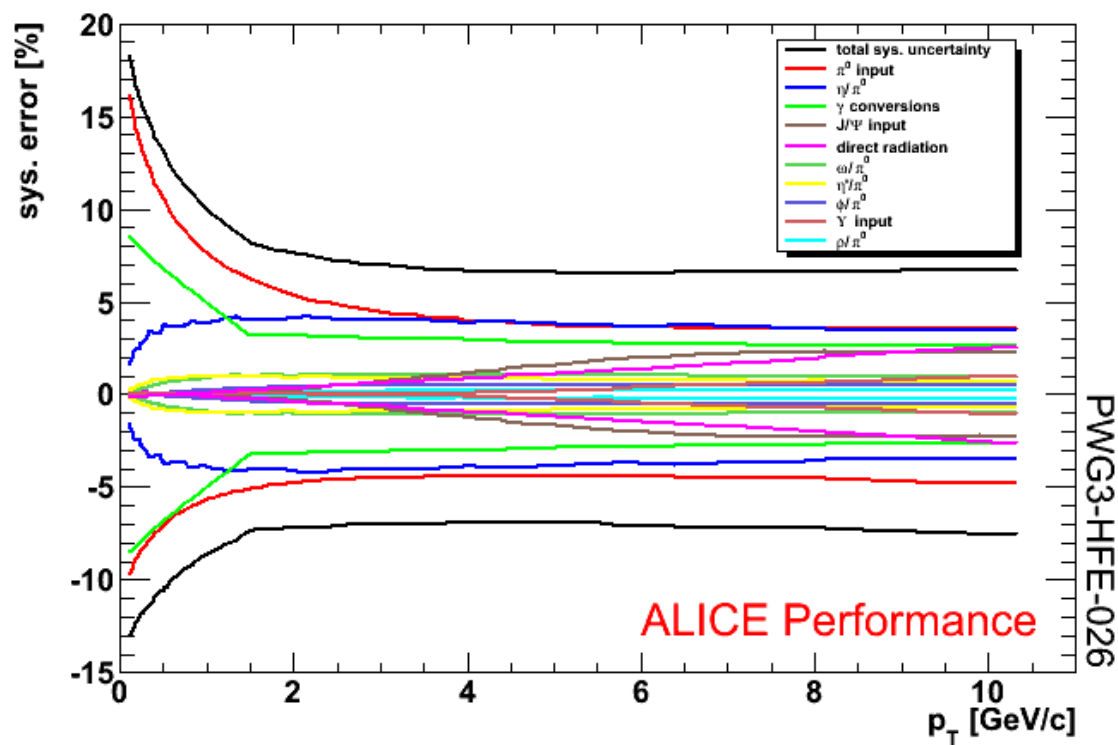
# pp collisions at $\sqrt{s}=7$ TeV



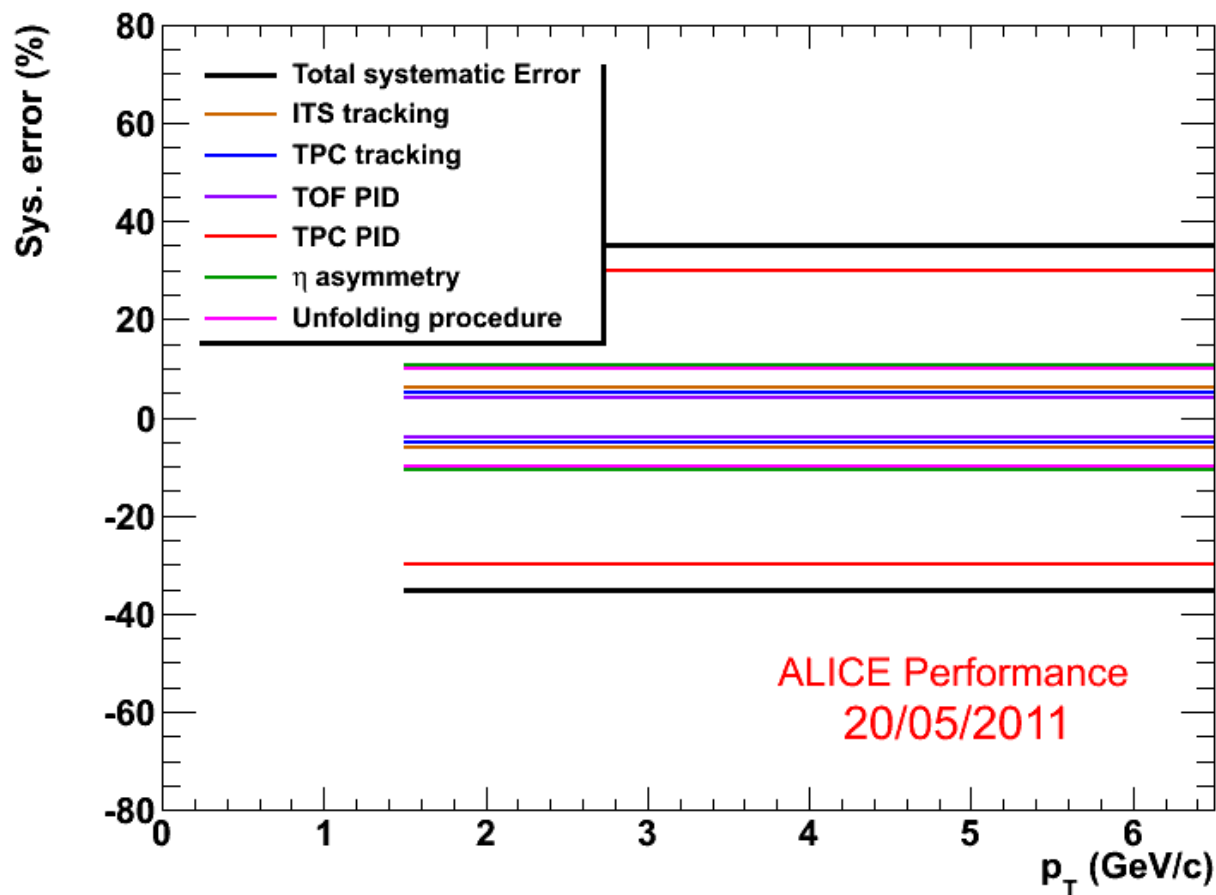
# pp systematics on the spectrum



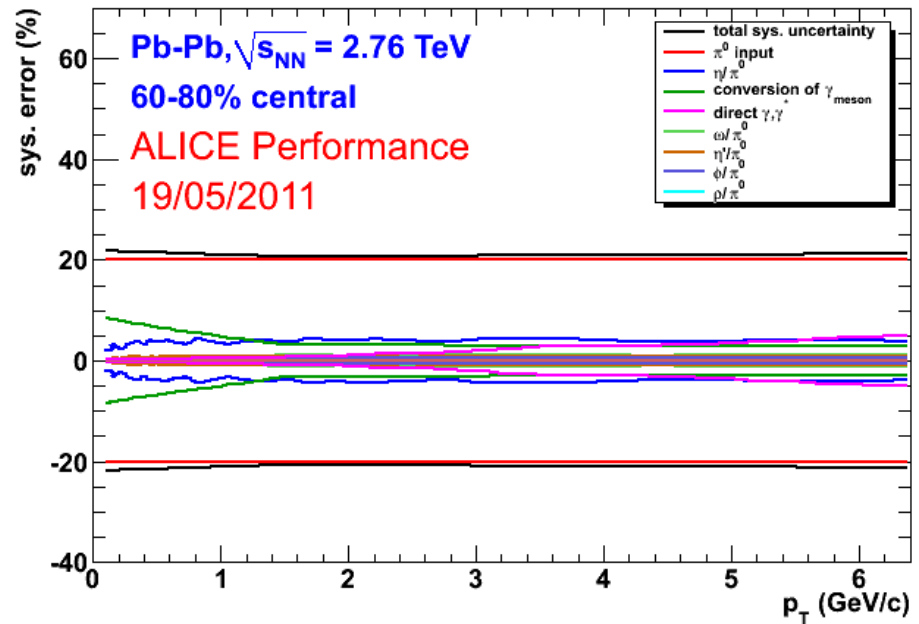
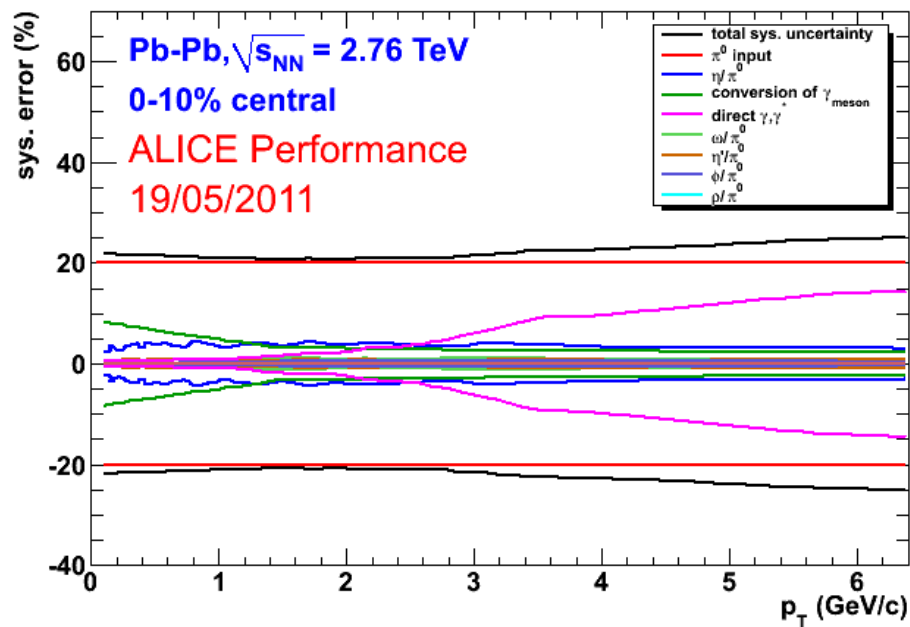
# pp systematics on the cocktail



# PbPb systematics on the spectrum



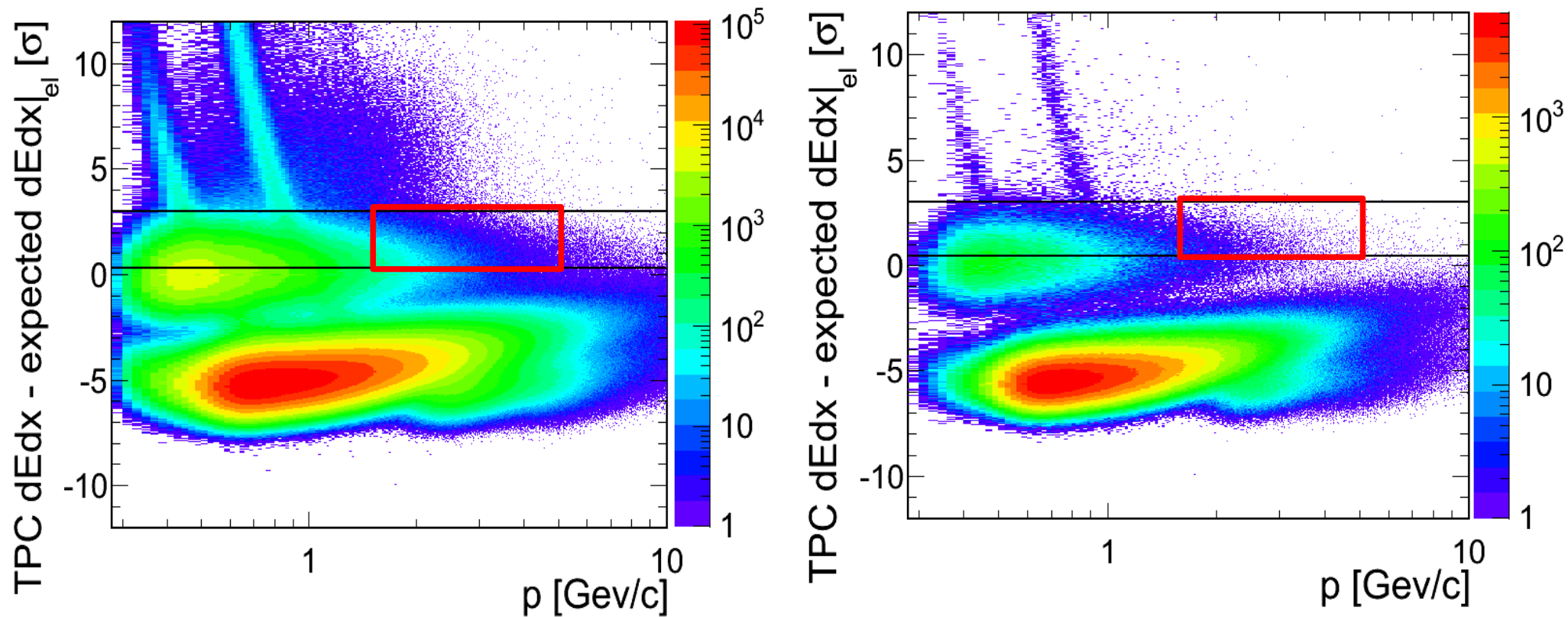
# PbPb systematics on the cocktail



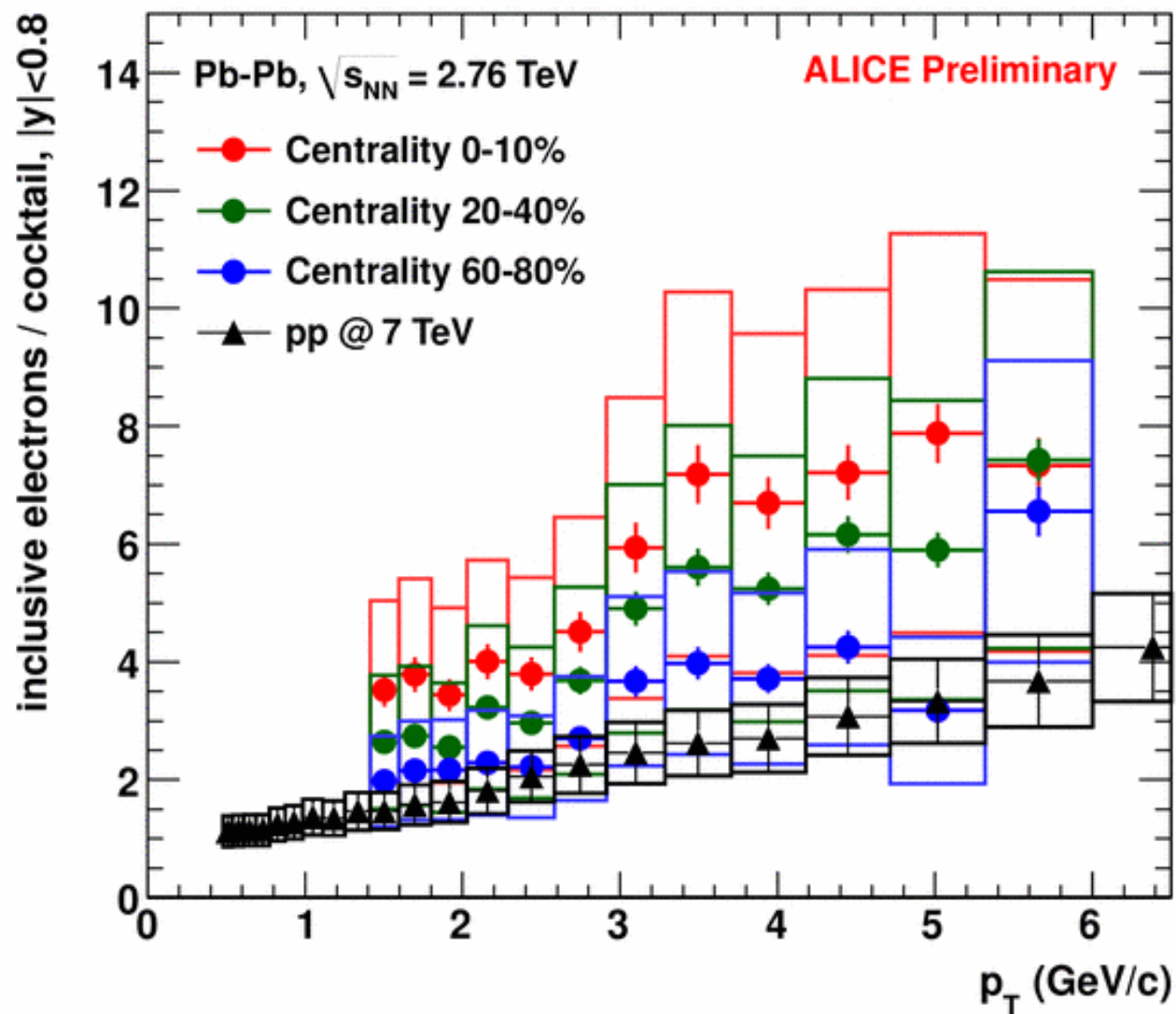
# PbPb: PID central vs peripheral



- From the PbPb note:



# Inclusive/cocktail, pp and more centrality bins



ALI-PREL-5147