Open Heavy Flavour Measurement using Leptonic Final States at the ALICE Experiment

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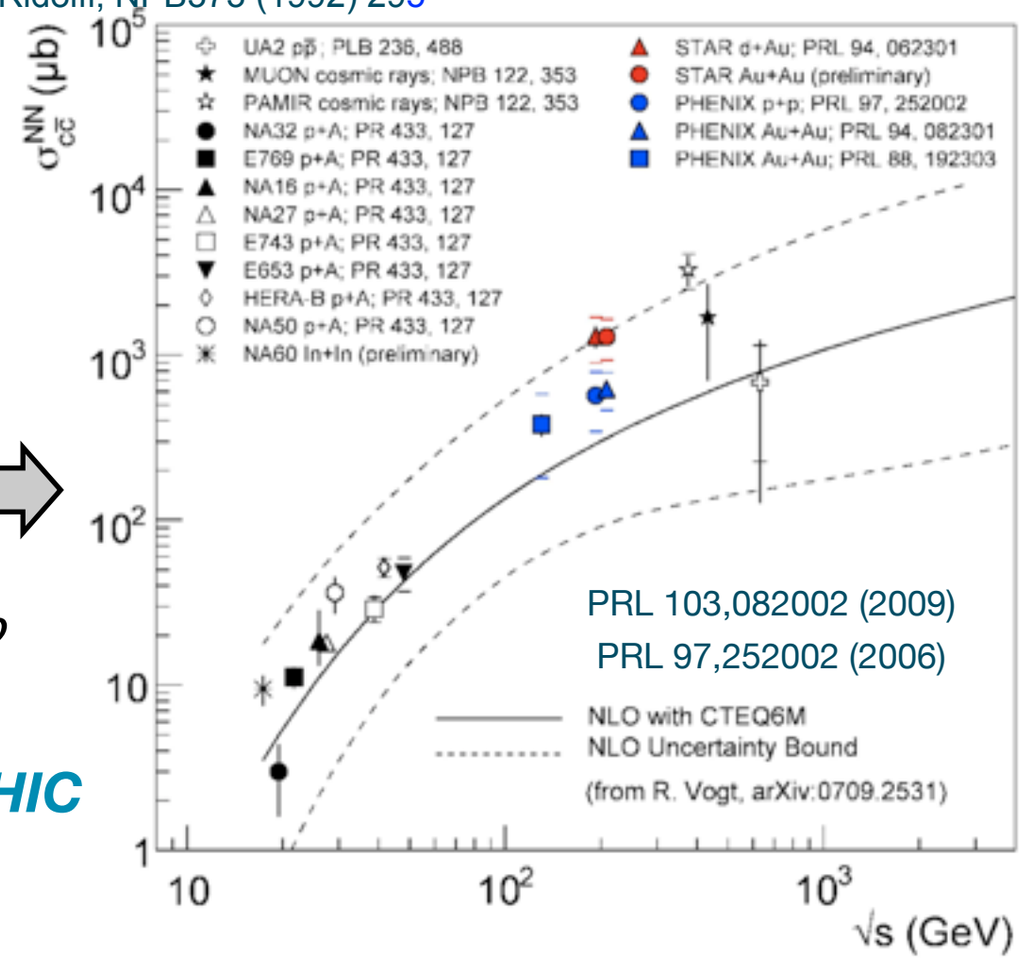
Open heavy flavour measurement via lepton channels

Theoretical uncertainty of a factor 2-3 MNR code (NLO): Mangano, Nason, Ridolfi, NPB373 (1992) 295

system: $\sqrt{s_{NN}}$:	p+p 14 TeV charm/beauty	p+p 7 TeV charm/beauty
$\sigma_{NN}^{Q\bar{Q}}[mb]$	11.2/0.5	6.9/0.23
$N_{total}^{Q\bar{Q}}$	0.16/0.007	0.10/0.003

Measurement at lower energy



PHENIX @200 GeV, p+p

$$\sigma_{c\bar{c}} = 567 \pm 57(stat) \pm 193(sys)\mu b$$

$$\sigma_{b\bar{b}} = 3.2^{+1.2}_{-1.1}(stat)^{+1.4}_{-1.3}(sys)\mu b$$

Cross sections cc(bb) at LHC x10(x100) larger than at RHIC

Branching Ratios:

$c \rightarrow l + X$	9.6 %
$b \rightarrow l + X$	11 %
$b \rightarrow c \rightarrow l + X$	10 %

High rate of lepton production from semi-leptonic decay

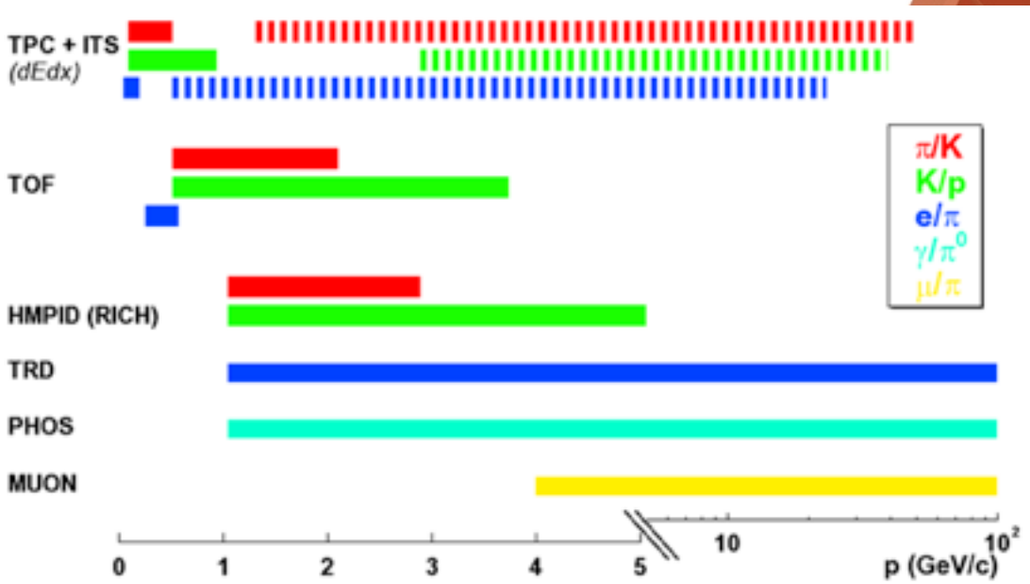
Complementary to heavy flavor hadronic decays(Andrea's talk)

- **Proton-proton collisions**
  - Measurement of heavy flavour production(charm and beauty) in p+p will provide important test of pQCD in a new energy domain and heavy ion reference
- **Heavy-ion collisions**
  - Heavy quark energy loss in the medium

Leptons in ALICE

Electrons at Mid Rapidity (|η|<0.9)

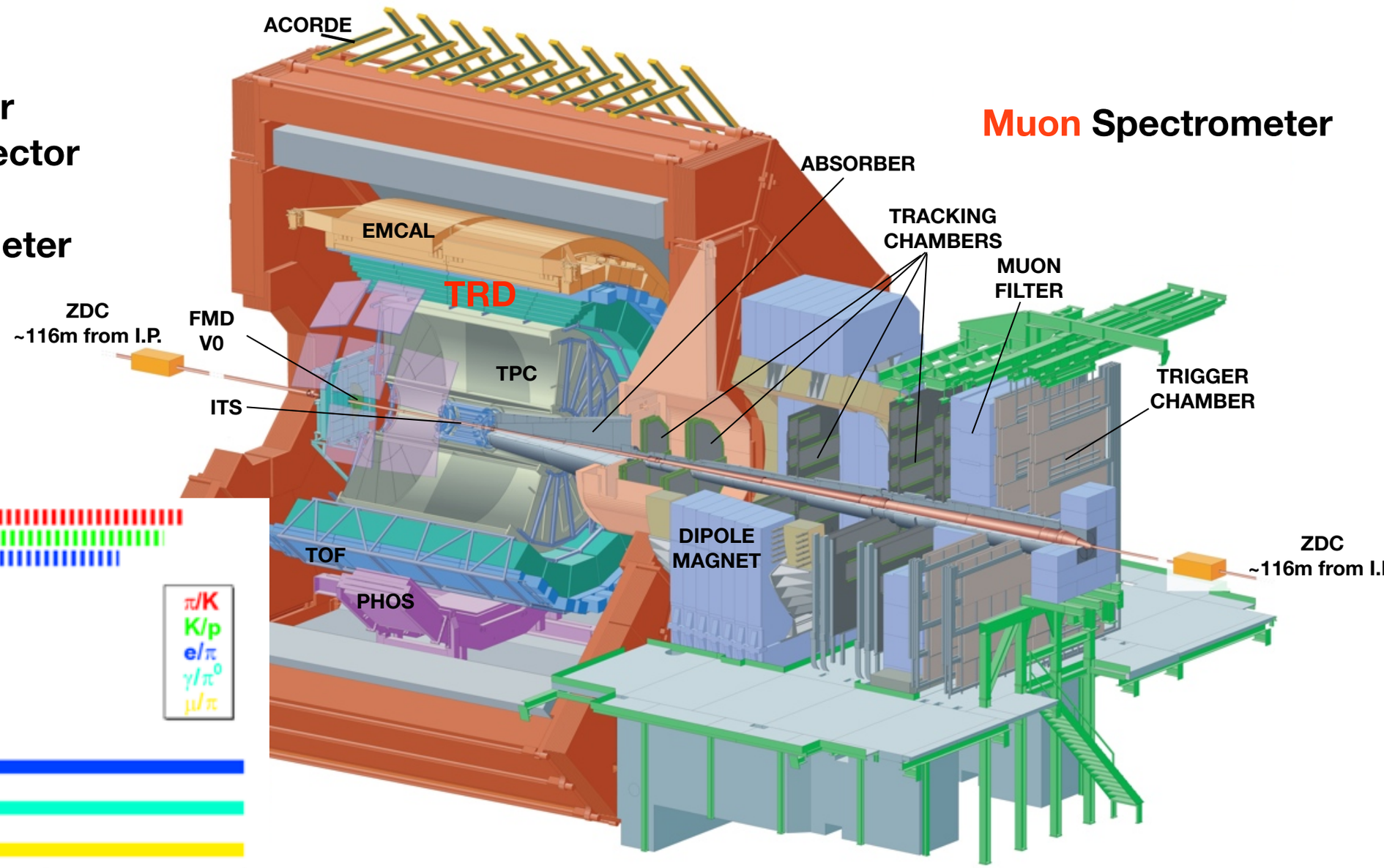
Inner Tracking System
Time Projection Chamber
Transition Radiation Detector
Time Of Flight
ElectroMagnetic Calorimeter



capable from ~ 100 MeV to above 50 GeV

Muons at Forward Rapidity(-4<η<-2.5)

Muon Spectrometer



Collaboration: 31 countries, 109 institutes, > 1000 people

Trigger and Data Sample for p+p at 7 TeV

Trigger

- "Minimum bias", based on interaction trigger:
  - SPD($|\eta|<2$) or V0-A($2.8<|\eta|<5.1$) or V0-C($-3.7<|\eta|<-1.7$)
    - at least one charged particle in 8 η units
    - ~95% of σ_{inel}

} Activated in coincidence with the BPTX beam pickups

- Single-muon trigger:
  - Muon trigger chamber and MinBias Trigger detectors
    - forward muon in coincidence with Min Bias

Data

- Since March 31st 2010 until PbPb collision started, collected
  - ~8.5×10^8 minimum bias triggers
  - ~1.3×10^8 muon triggers
- Analysis shown here is based on
  - 1.6 nb^{-1} for electrons
  - 3.49 nb^{-1} for muons

Analysis Approach via Electrons

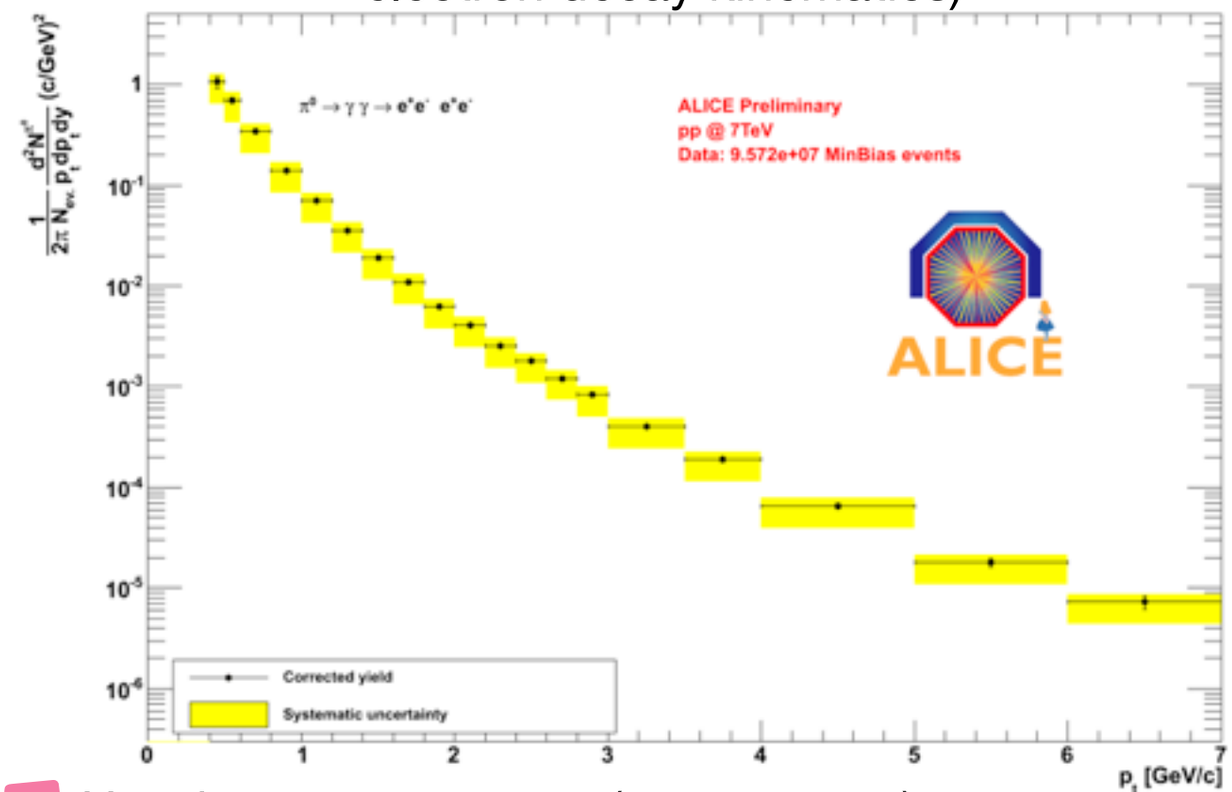
(1) Measure inclusive electron transverse momentum spectrum

(2) Build background contributions spectrum described with an electron cocktail (photonic, Dalitz/dielectron decays of mesons, weak kaon decay, direct radiation, J/ψ and ϒ)

(3) Measure heavy flavor semi-electronic decays by subtracting (2) from (1)

Electron Cocktail

- π^0 Dalitz decay sources: the π^0 measured spectrum (Fit with Hagedorn function and use PYTHIA electron decay kinematics)



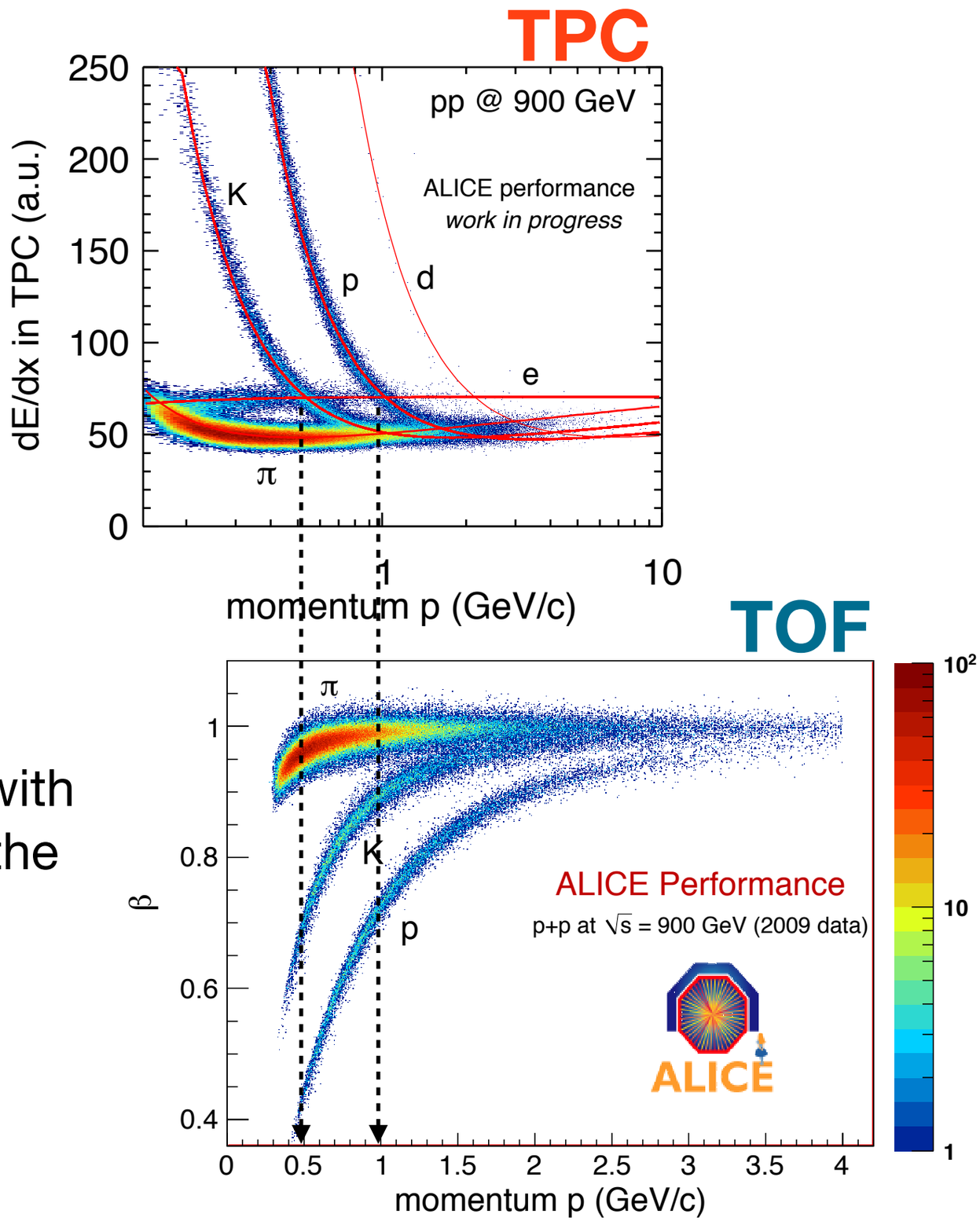
- Heavier meson sources(η, η', ρ, ω, φ): implemented via m_T scaling(verified for η)
- Photon conversion sources:
  - Calculate photon conversion in the beam pipe and 1/3 of the first pixel layer (0.5 % X_0)
  - Use the ratio of conversion to Dalitz electrons to estimate the $e^{\pm}$ contributions

$$\frac{Conv.}{Dalitz} = \frac{BR^{\gamma\gamma} \times 2 \times \left(1 - e^{-\frac{7}{9} \times \frac{X}{X_0}}\right) \times 2}{BR^{Dalitz} \times 2}$$

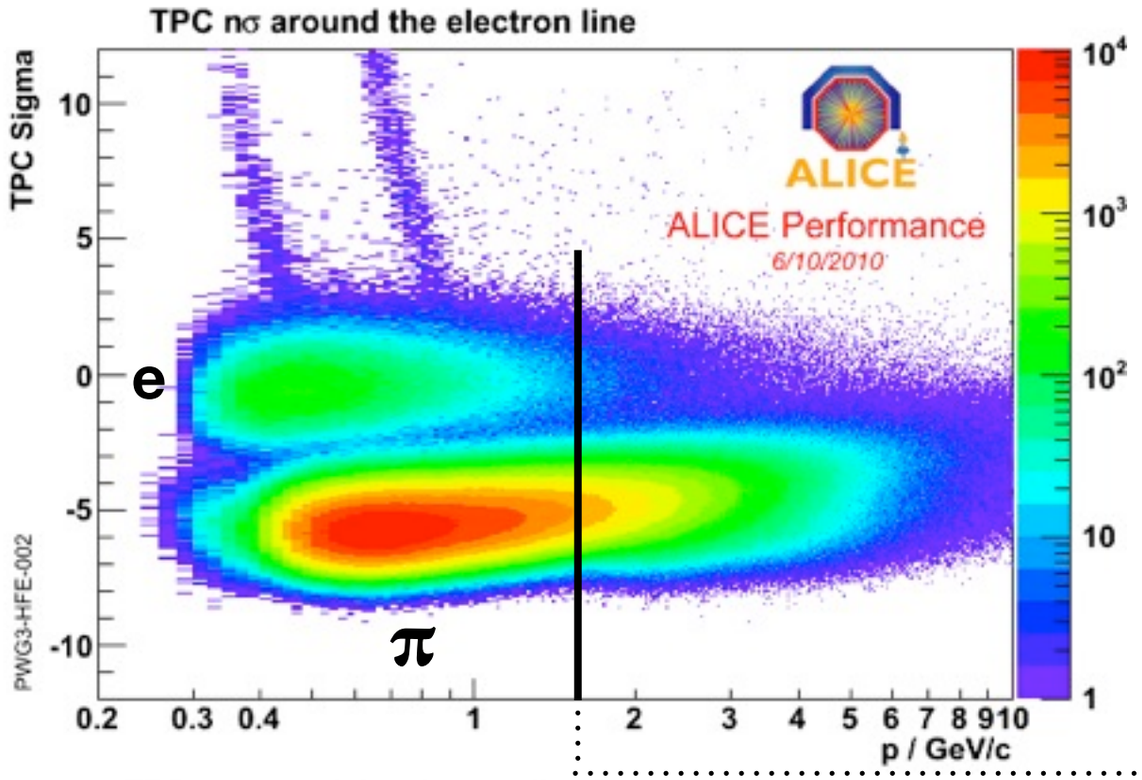
Electron Identification

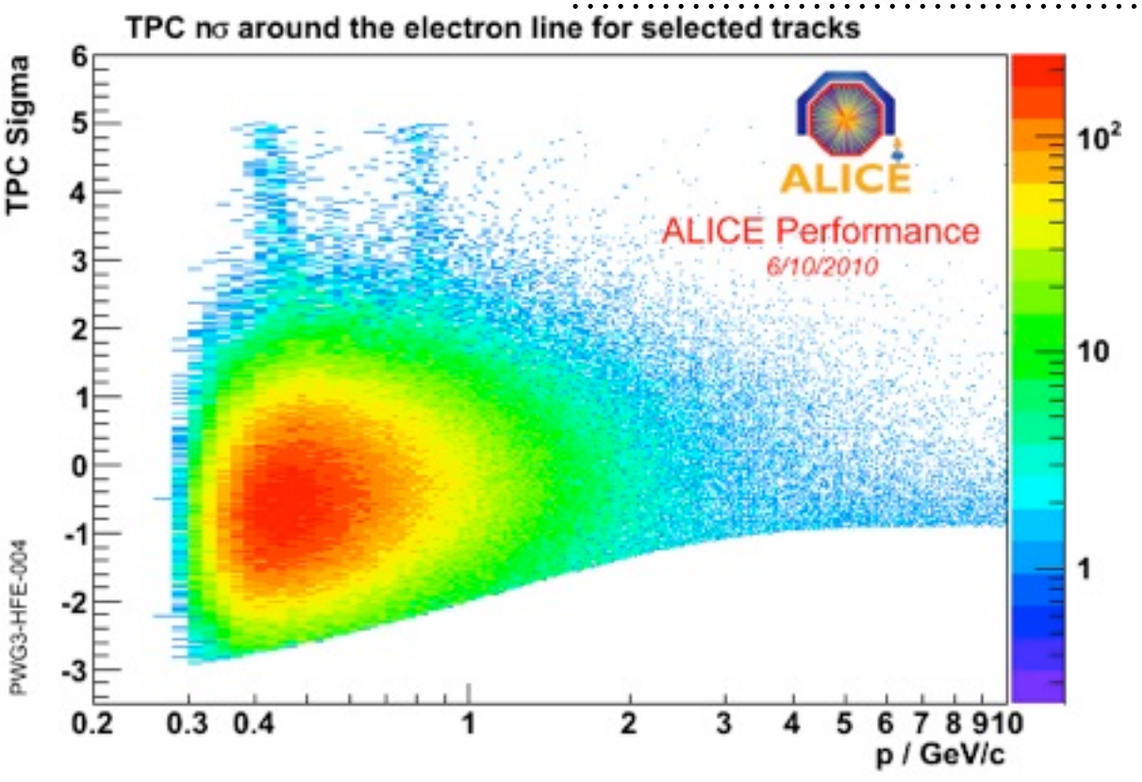
- **Currently up to 4 GeV/c based on the Time Projection Chamber and the Time of Flight detector** (TOF resolves TPC crossings)

- Soon extend to higher momentum with the Transition Radiation Detector and the ElectroMagnetic Calorimeter

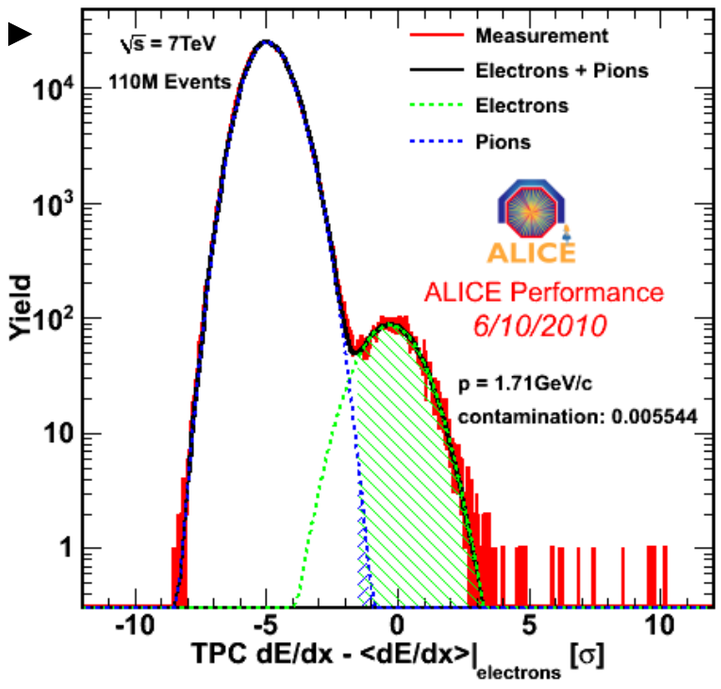


Electron Identification in Steps

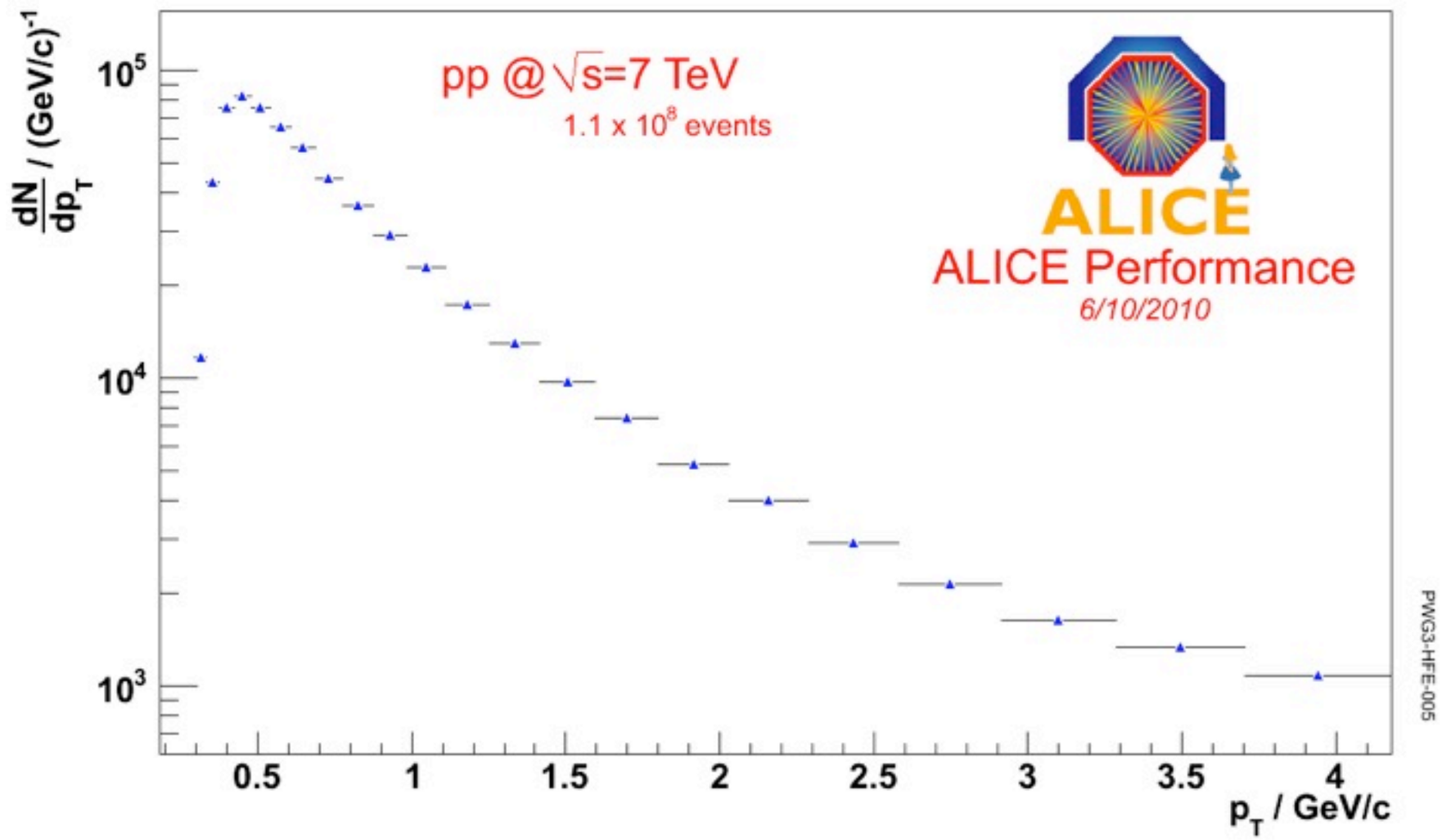




- **Kaon & Proton Rejection with TOF(3 from the electron line in TOF)**
  - Current ToF resolution: 130 ps → clean rejection of
    - K (for p < 1.5 GeV/c)
    - p (for p < 3 GeV/c)
- **Further hadron rejection with TPC**
  - Momentum dependent cut on number of sigmas from the electron line in TPC
- **Subtract remaining hadron background**
  - Gaussian fits of TPC dE/dx distributions in momentum slices → hadron contamination as function of momentum p (< 4 GeV/c)



Uncorrected Inclusive Electron Spectrum

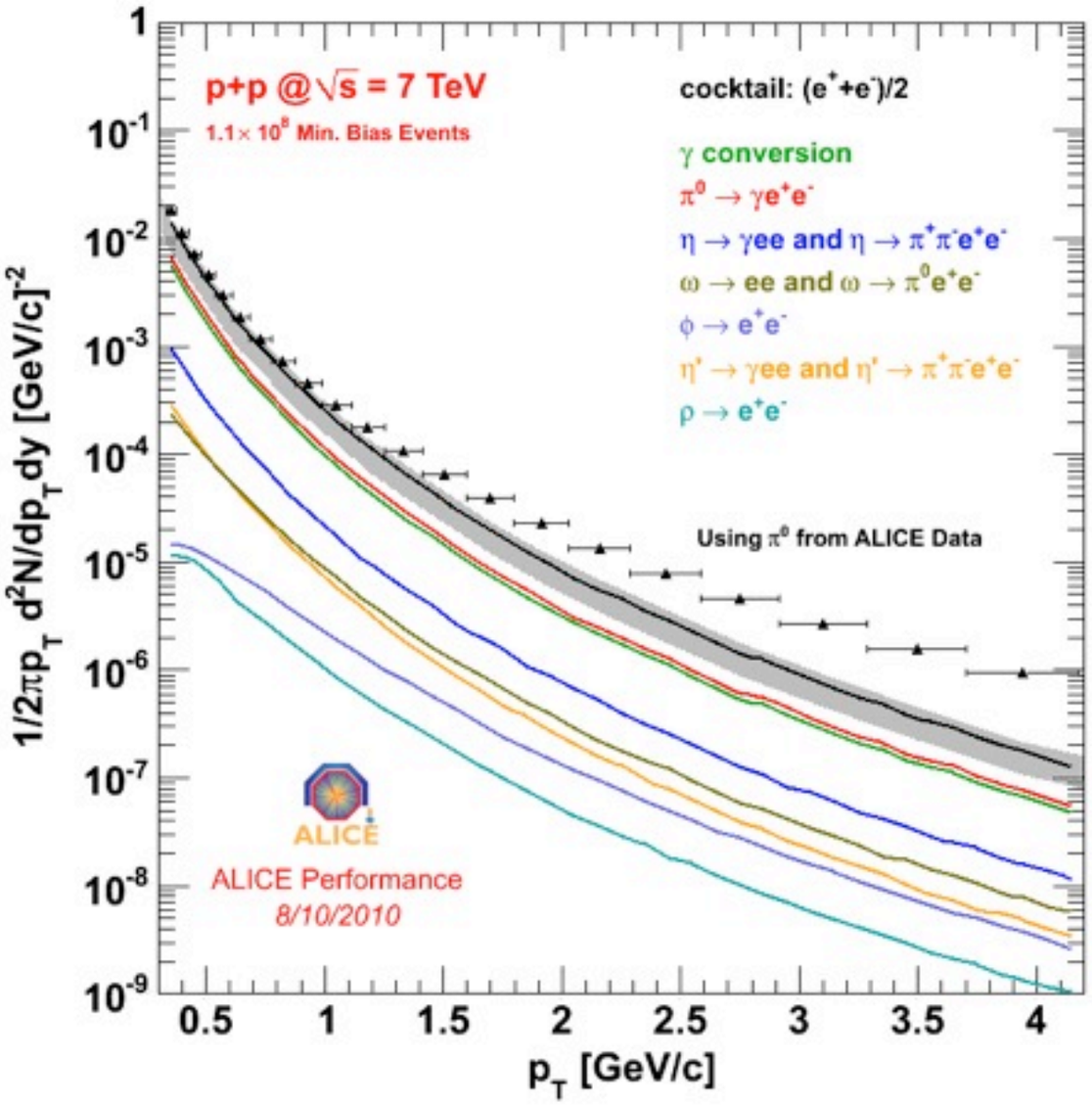


- **Corrections to the raw electron spectrum for**
  - **geometrical acceptance**
  - **reconstruction efficiency**
  - **detector resolution**

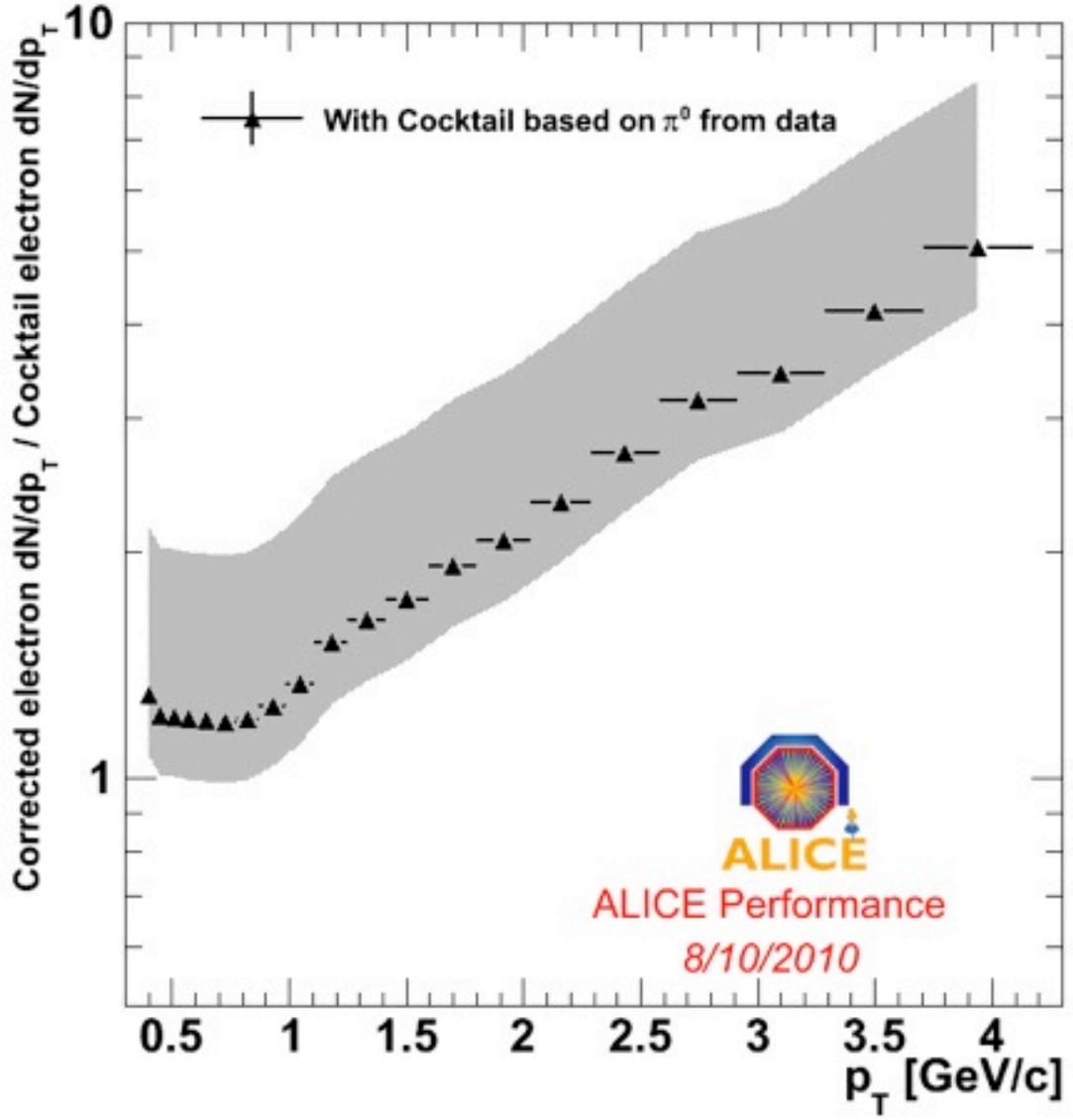
  with PYTHIA+PHOJET

Cocktail and Corrected Inclusive Electron Spectrum

Data & Cocktail



Ratio Data/Cocktail



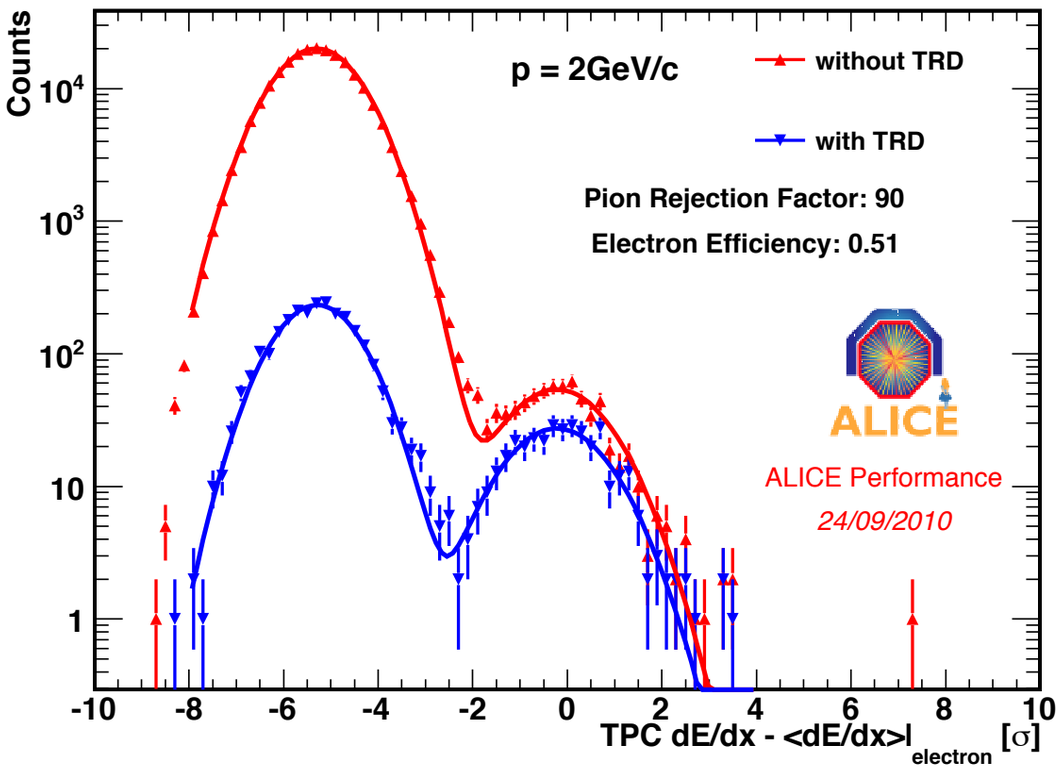
Excess from open heavy flavors (including J/ψ, direct radiation)

- Systematic errors on input π^0 spectrum (+20% −40%) is propagated to the cocktail
  (Will be reduced in near future!)
- No systematic errors are shown yet on the corrected inclusive electron spectrum

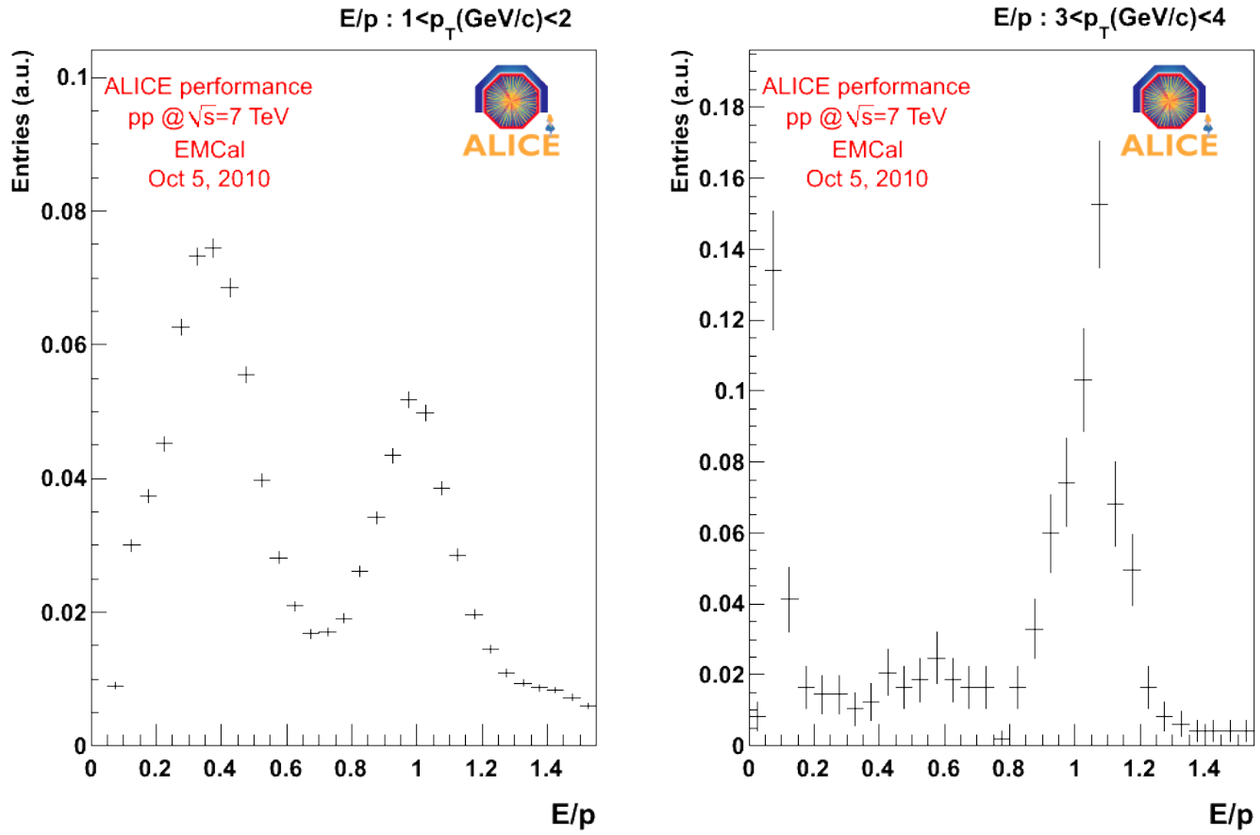
Perspectives

Extend good electron identification at higher momentum with TRD and EMCal

Transition Radiation Detector
TPC dE/dx slice w/o and with TRD



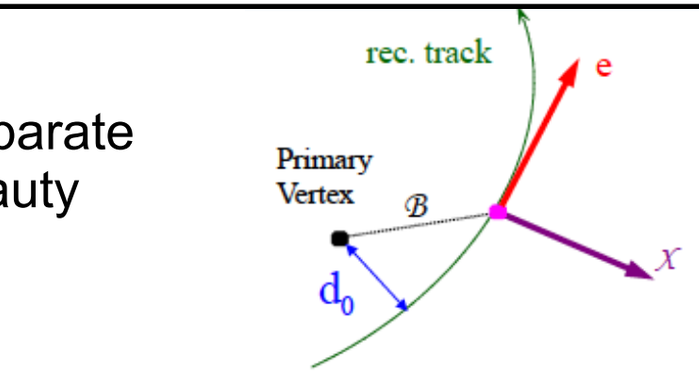
ElectroMagnetic Calorimeter
E/p distributions

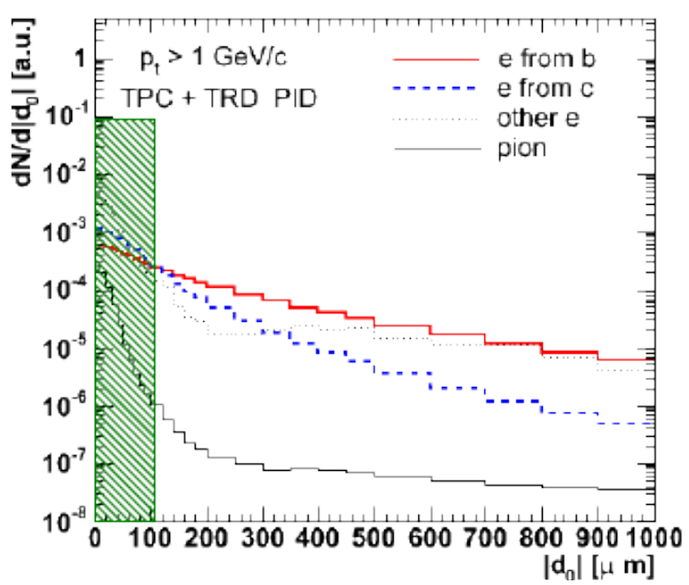


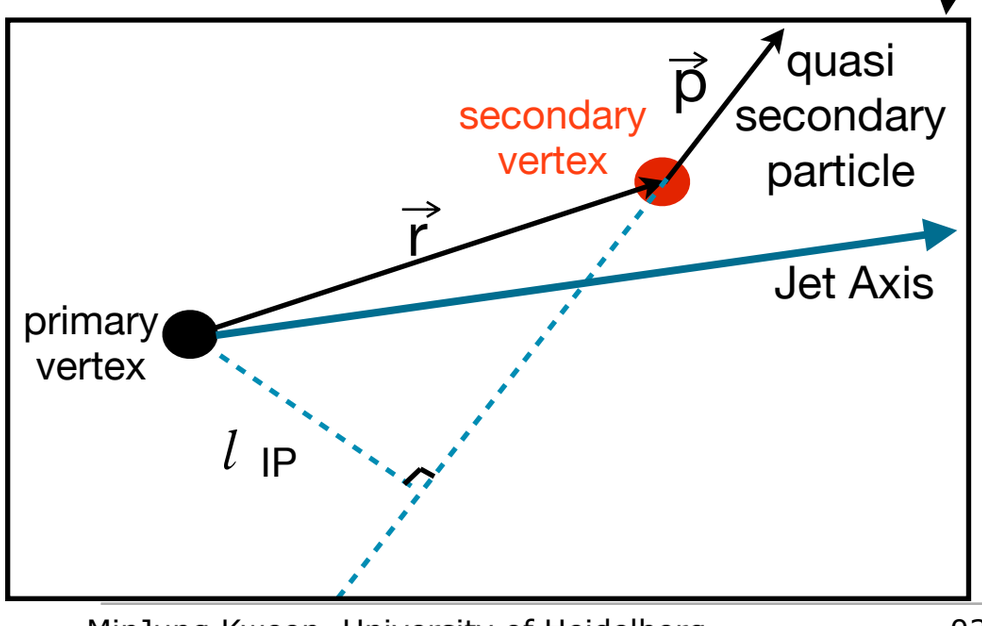
- Provide good e/π separation from 1 to ~15 GeV/c
- Provide possibility to trigger (L1) on high p_T identified particles

Separation of beauty contributions

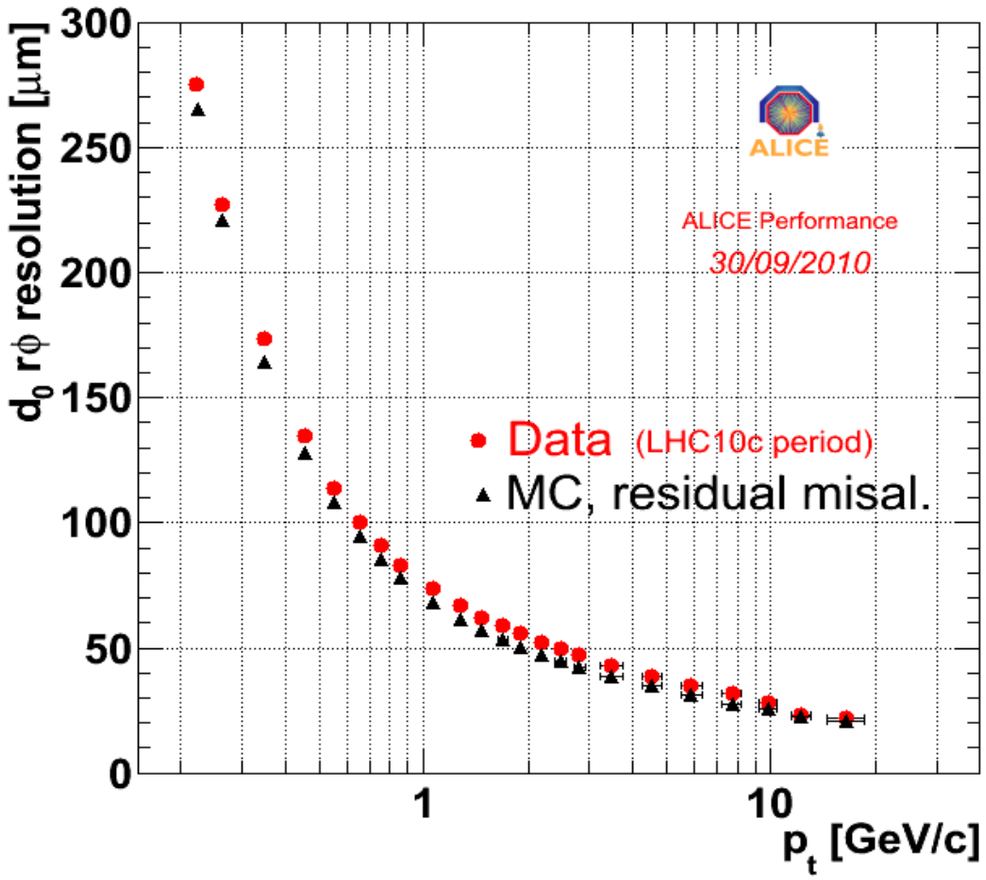
Separate beauty







- Select electrons from heavy flavour decays via minimum distance of closest approach cuts → increase S/B
- B jet tagging by selecting jets containing secondary vertex

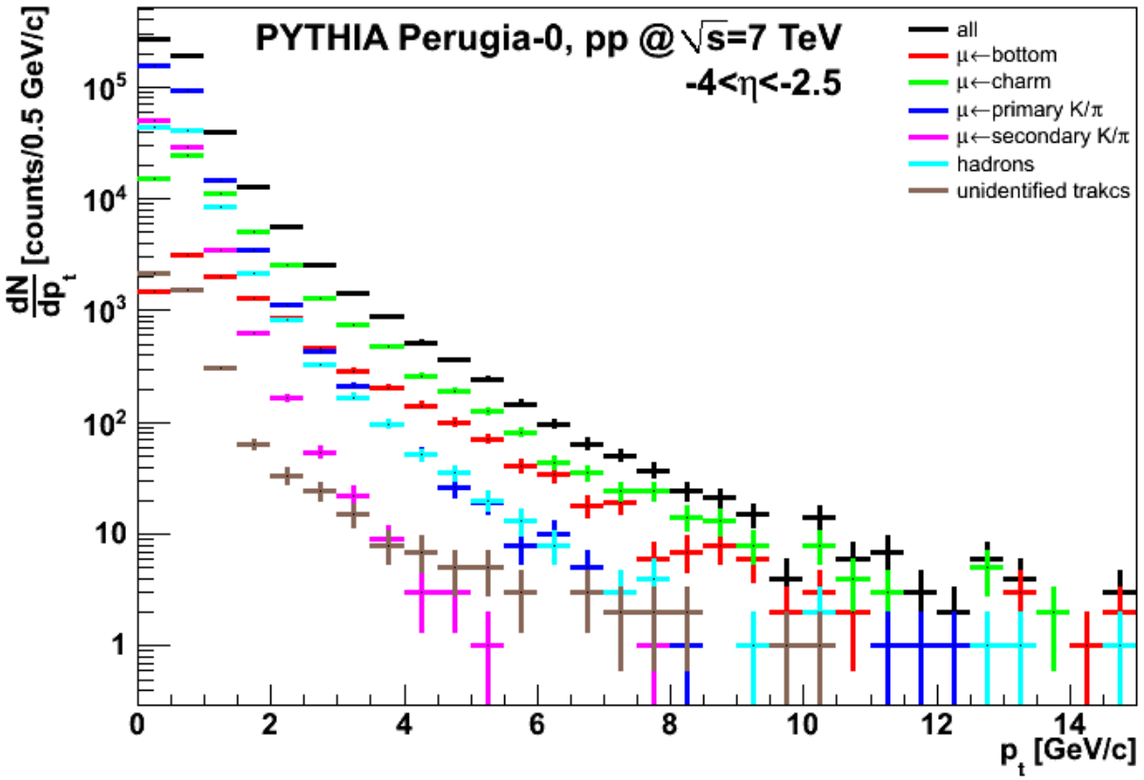


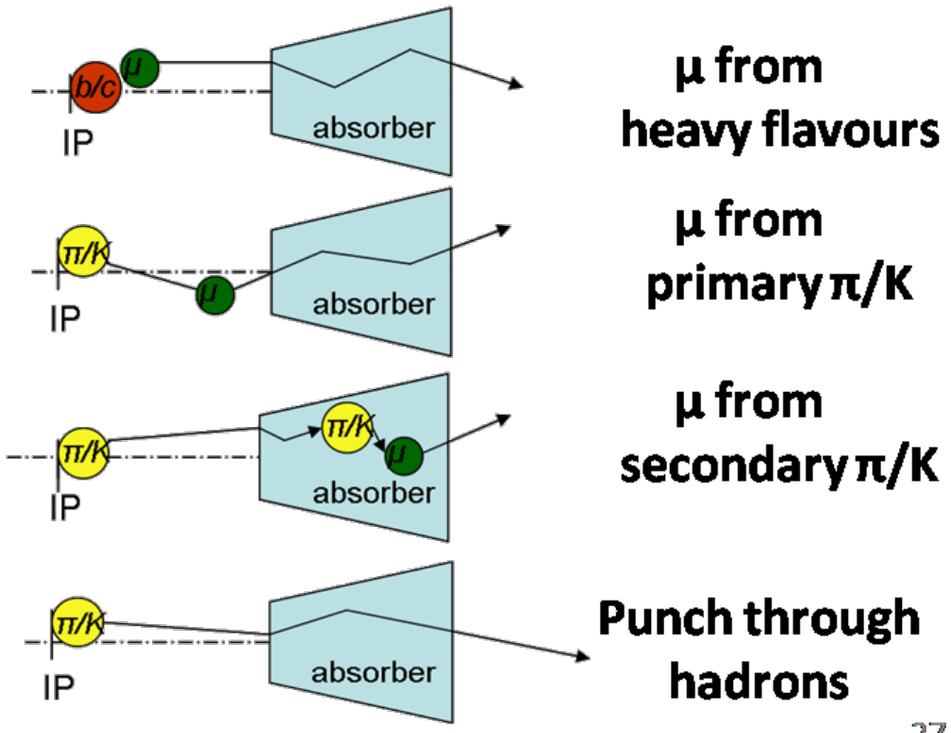
Excellent vertex capabilities, impact parameter resolution → (~ 75 μm at 1 GeV/c)

Analysis is ongoing in both directions

Analysis Approach via Muons

Muon sources(MC)





Analysis approach

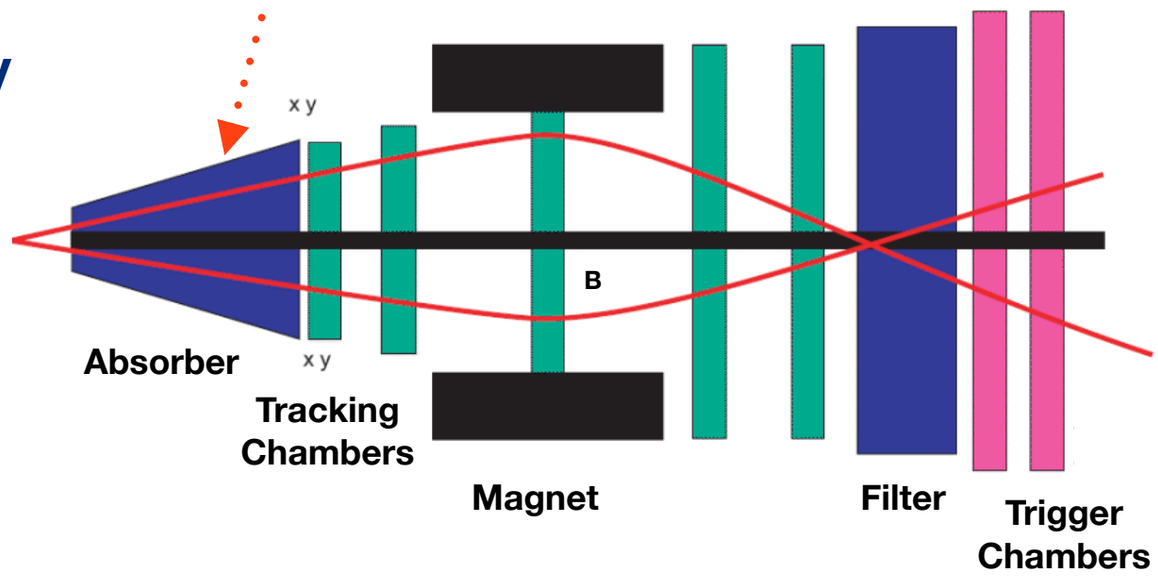
(1) Remove hadrons and low p_t secondary muons by requiring a muon trigger signal

(2) Remove decay muons by subtracting MC dN/dp_t normalized to data at low pt

- alternative method: use muon distance of closest approach to primary vertex

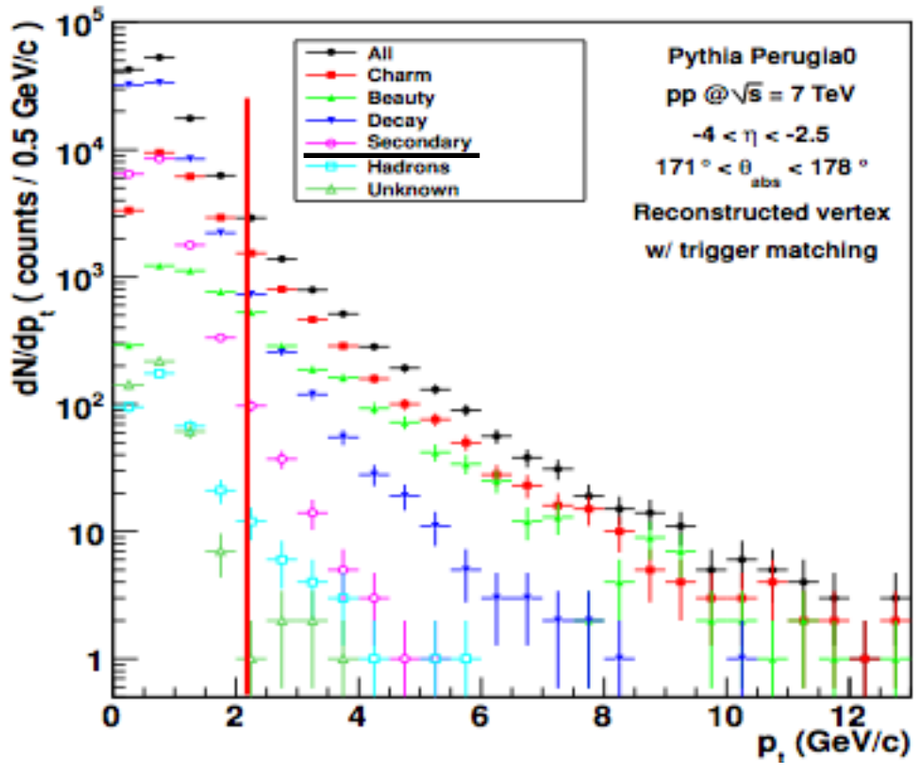
(3) What is left are muons from charm and beauty

(4) Apply efficiency corrections

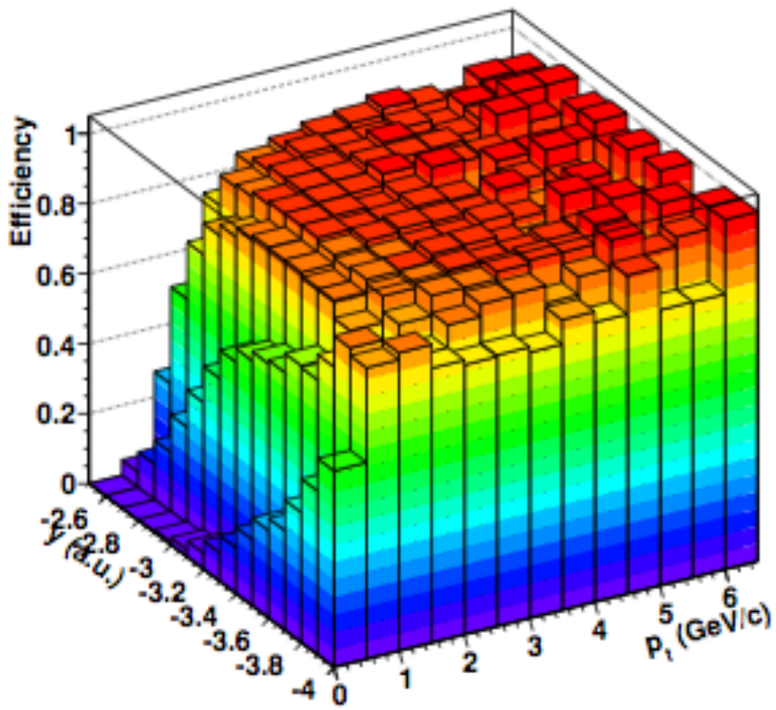


Background subtraction and Efficiency Estimation

- **Most delicate analysis step: subtraction of residual secondary and decay muons from π, K**
  - **p_t > 2 GeV/c: secondary contribution small(~ 3 %)**
  - **use different PYTHIA tunes (Perugia-0 and ATLAS-CSC), vary secondary yields to evaluate systematics**
- **Resulting systematic error on HF muons:**
  - **30 % → 20 % from low to high p_t**

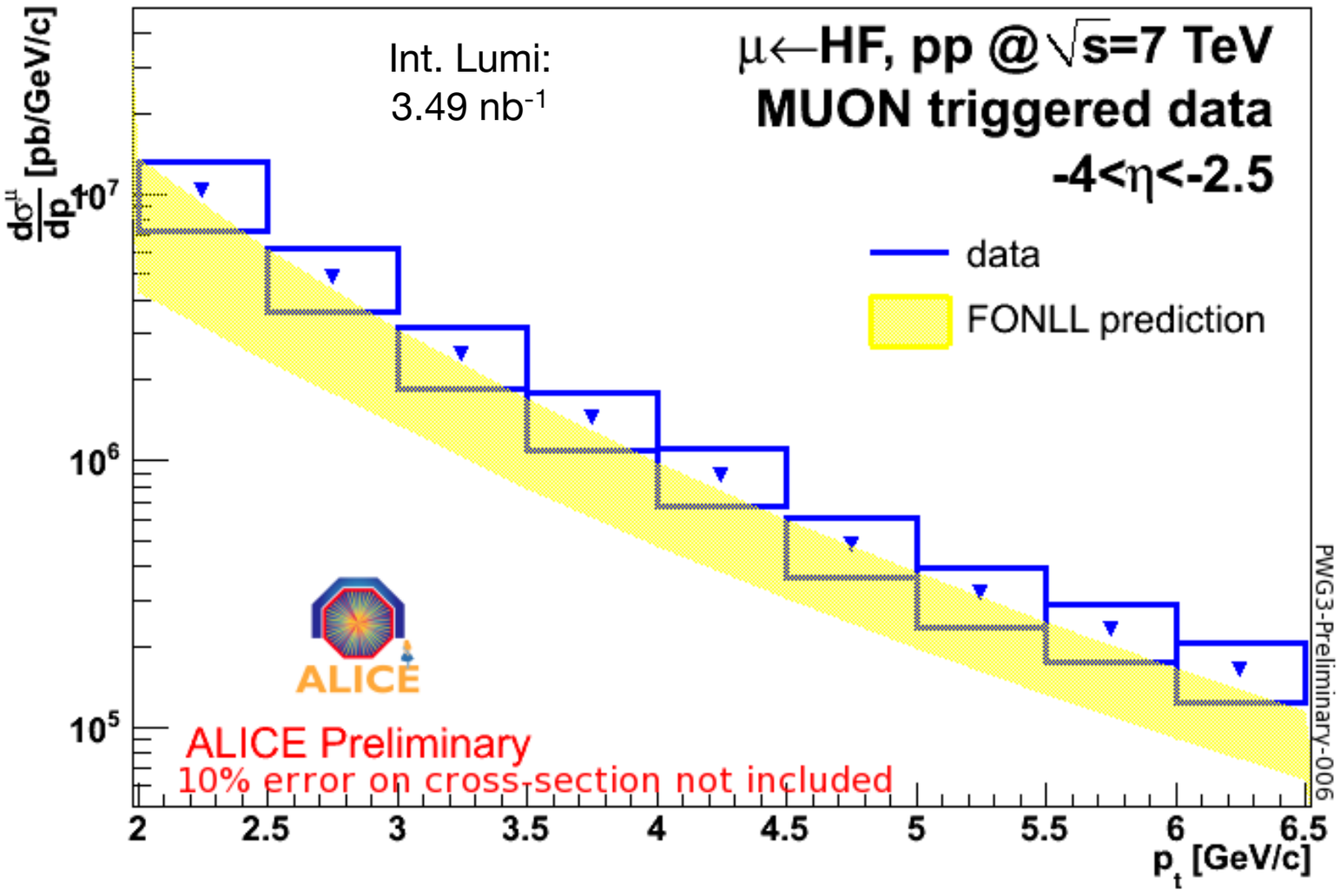


- **Efficiency > 87 % for p_t > 2.5 GeV/c**



Combined Charm and Beauty Cross Section

The pQCD (FONLL) calculation reproduces the shape and is in agreement with data within errors.



Next steps:

- muon DCA method will allow to reduce systematics due to background subtraction
- improved spectrometer alignment already deployed
- extend p_t reach(up to 20 GeV/c) by increasing the statistics

- Extract beauty cross section (dominates muon spectrum above few GeV/c)
- prepare reference for Pb-Pb R_{AA}

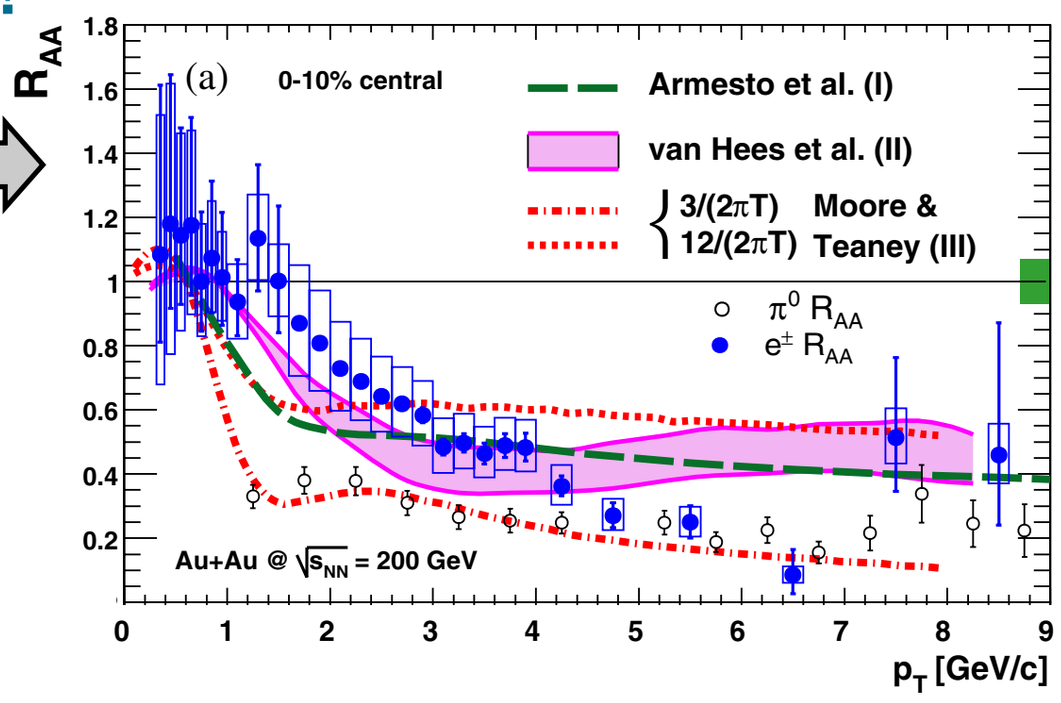
Summary

- An inclusive electron spectrum is compared to cocktails describing electrons from meson decays and photon conversions
- An excess is observed at high p_t coming from heavy flavor, J/ψ decays and direct radiation
- Analysis based on impact parameter is ongoing to separate the beauty contribution

- The differential production cross section as a function of p_t of muons from HF have been measured in 2 GeV/c < p_t < 6.5 GeV/c, –4 < η < –2.5
- The results are in agreement with the FONLL predictions within errors

- **Analysis on the Pb+Pb data is ongoing!**

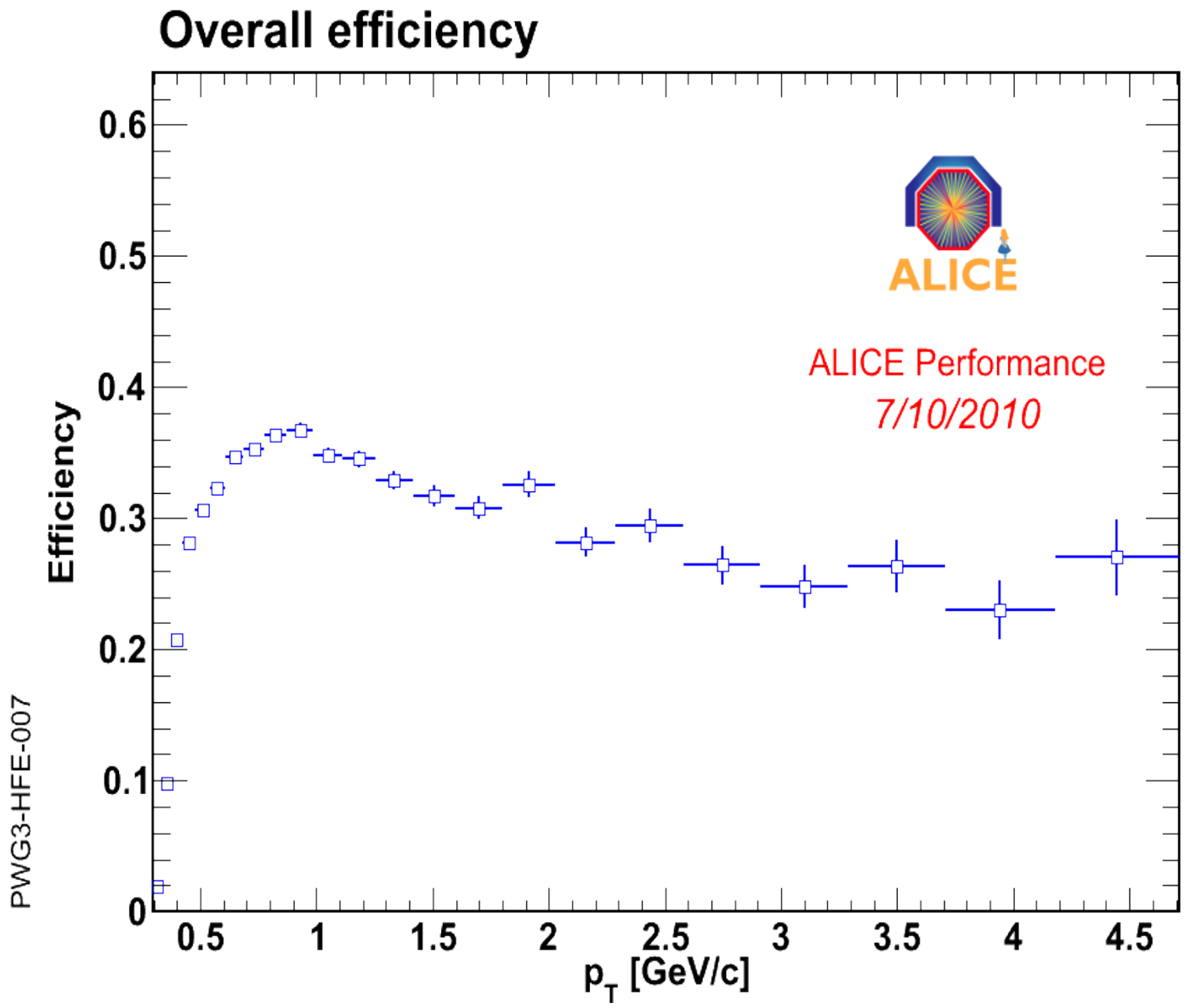
We got surprise by the result of heavy quark energy loss at RHIC!



Exciting to see the result of heavy quark energy loss at LHC!

BACKUP SLIDES

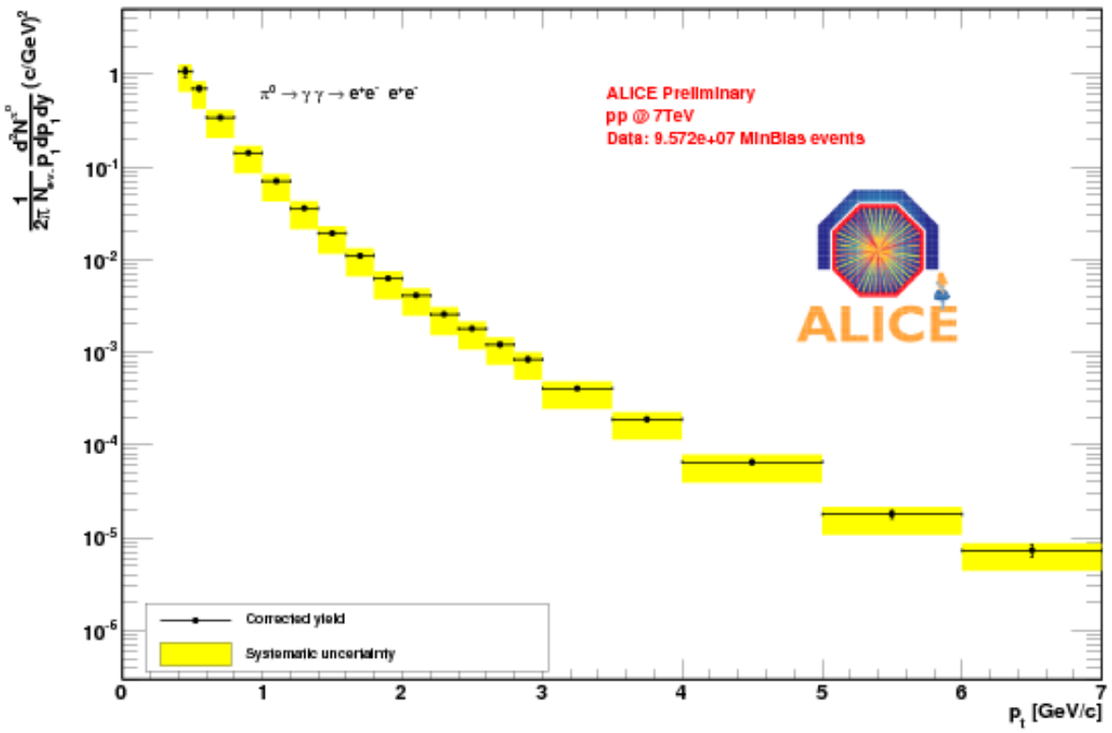
Heavy Flavor Electron overall efficiency:



Cocktail Ingredient(input π^0 spectrum)

- **DATA: ALICE measured π^0 spectrum**

  reconstructed with photon conversions → K. Koch (Monday 11)



OR

- **NLO prediction for π^0**

  B.Jager, A. Schaefer, M. Stratmann, W. Vogelsang

  Phys. Rev. D67 (2003) 054005

Spectra are fit with the Hagedorn function:

$$E\frac{d^3\sigma}{dp^3} = \frac{c}{\left(p_0 + p_T/p_1\right)^n}$$

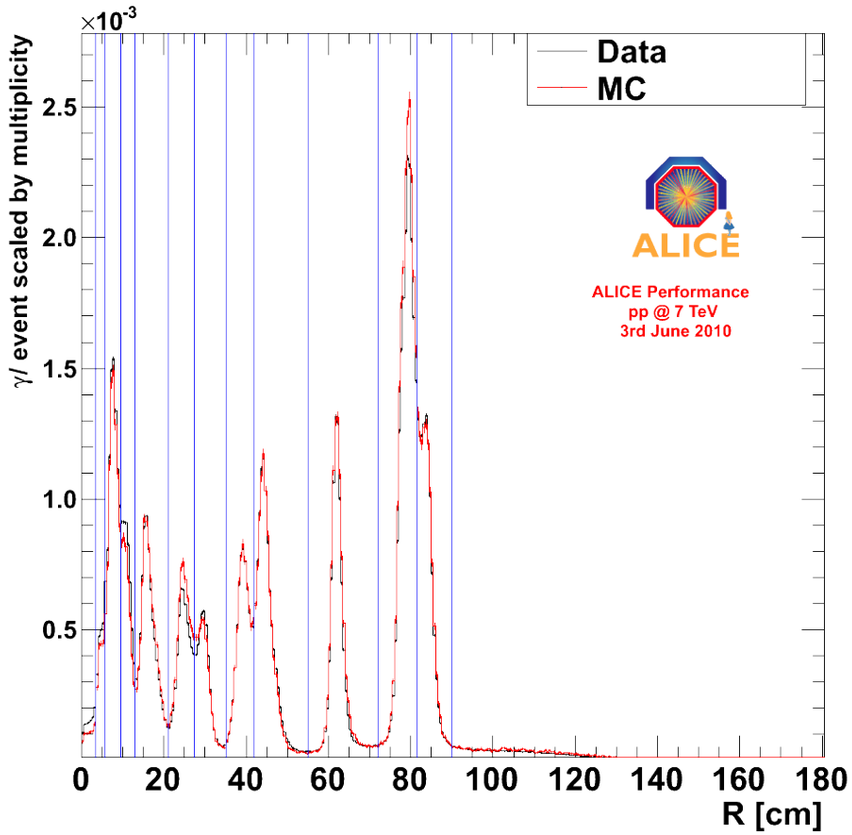
Cocktail Ingredient(Other mesons and Conversion electrons)

Heavier mesons:

- Included: **η, η', ρ, ω, φ**
- Implemented via **m_T scaling**

$$E\frac{d^3\sigma}{dp^3} = \frac{c \times meson/pion}{\left(p_0 + \sqrt{m_T^2 - m_\pi^2}/p_1\right)^n}$$

Verified for η in ALICE !



Electrons from photon conversions

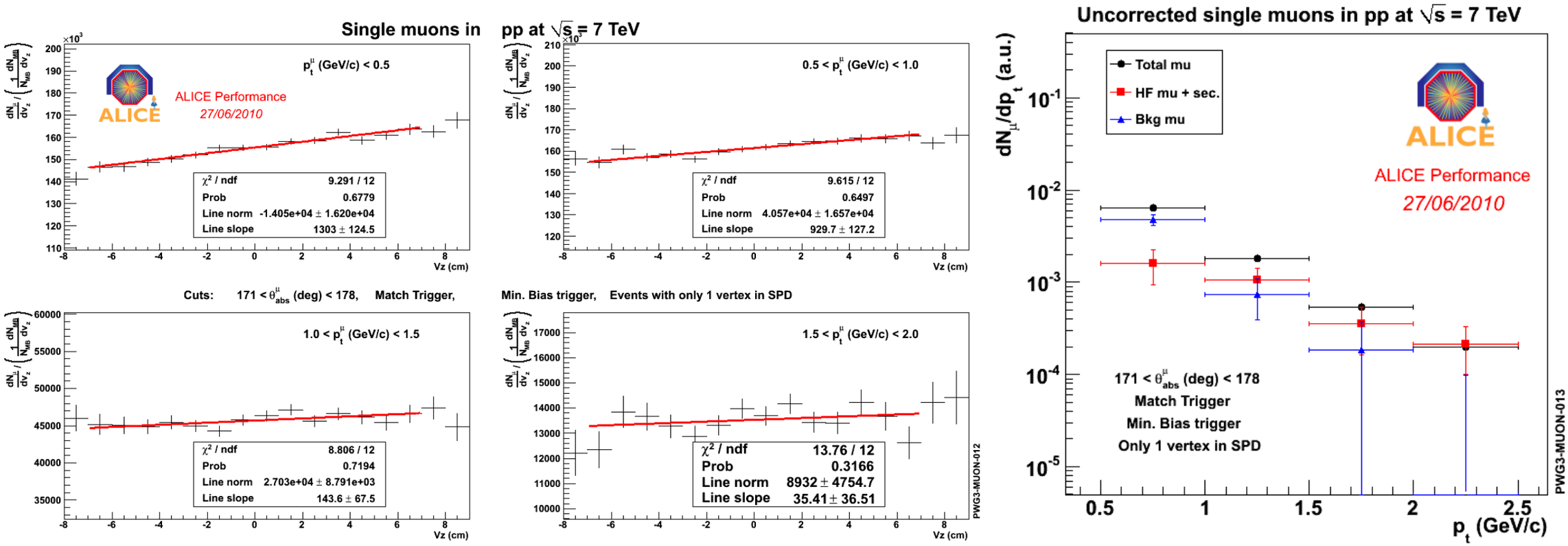
- Not rejected: those from the beam pipe and ~1/3 of first pixel layer (≈0.5 % X_0)
- Ratio of conversions to Dalitz electrons:

$$\frac{Conv.}{Dalitz} = \frac{BR^{\gamma\gamma} \times 2 \times \left(1 - e^{-7/9 \times X/X_0}\right) \times 2}{BR^{Dalitz} \times 2}$$ **= 0.739**

$\mu \leftarrow$Primary K/π Subtraction: Vertex Unfolding Fitting

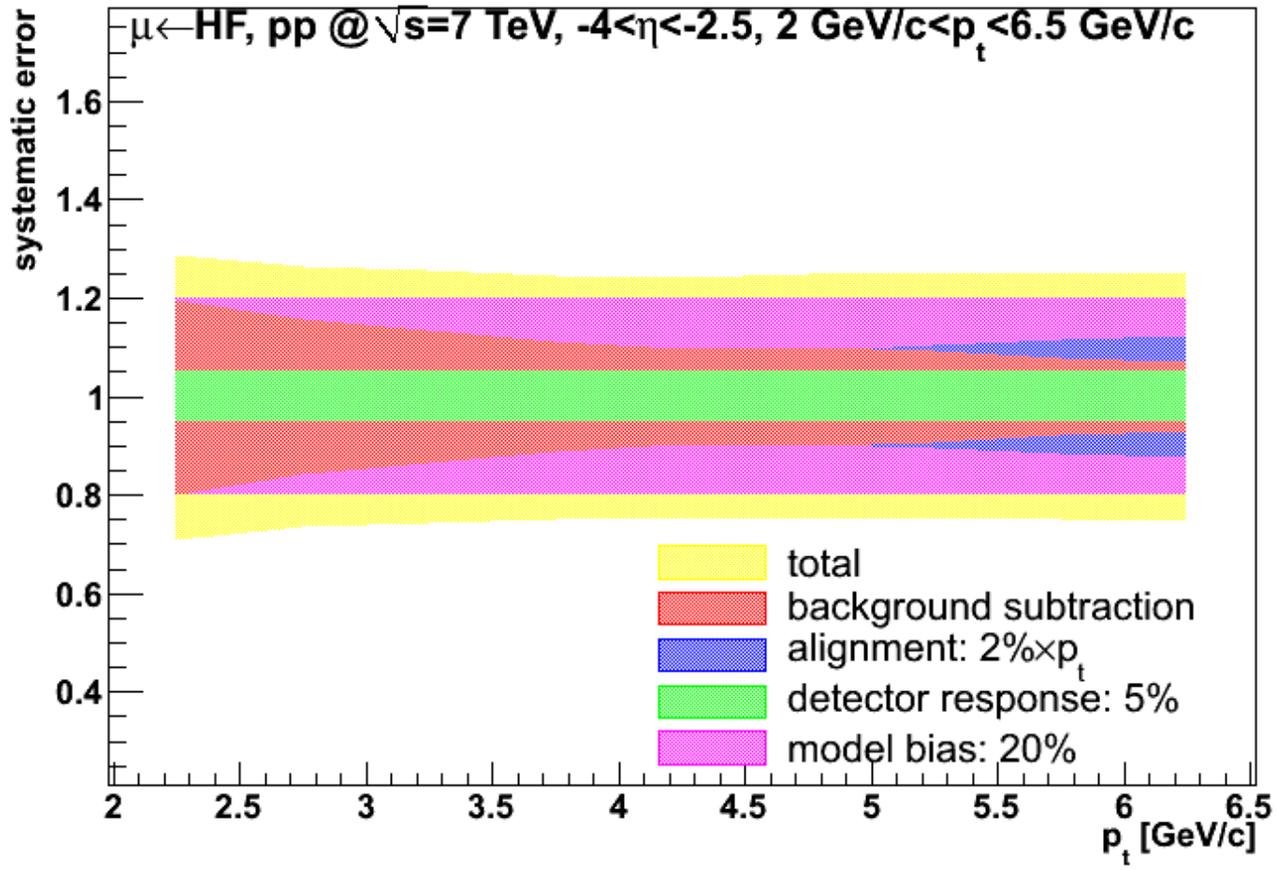
$$\frac{d^2N_\mu}{dp_t dv_z} = \frac{d^2N_\mu^{c/b}}{dp_t dv_z} + \frac{d^2N_\mu^{primary\ K/\pi}}{dp_t dv_z} + \frac{d^2N_\mu^{secondary\ K/\pi}}{dp_t dv_z}(neglected)$$

$$\frac{1}{\rho(v_z)}\frac{d^2N_\mu}{dp_t dv_z} \sim \frac{d^2N_\mu^{c/b}}{dp_t dv_z} + (L+v_z)\times\left(\frac{1}{L+<v_z>}\frac{d^2N_\mu^{primary\ K/\pi}}{dp_t dv_z}\right)$$



- Method has been already successfully tested on simulations;
- expected linear increase of muon yield w/ the vertex position evidenced with data;
- high statistics is needed.

Systematic Error

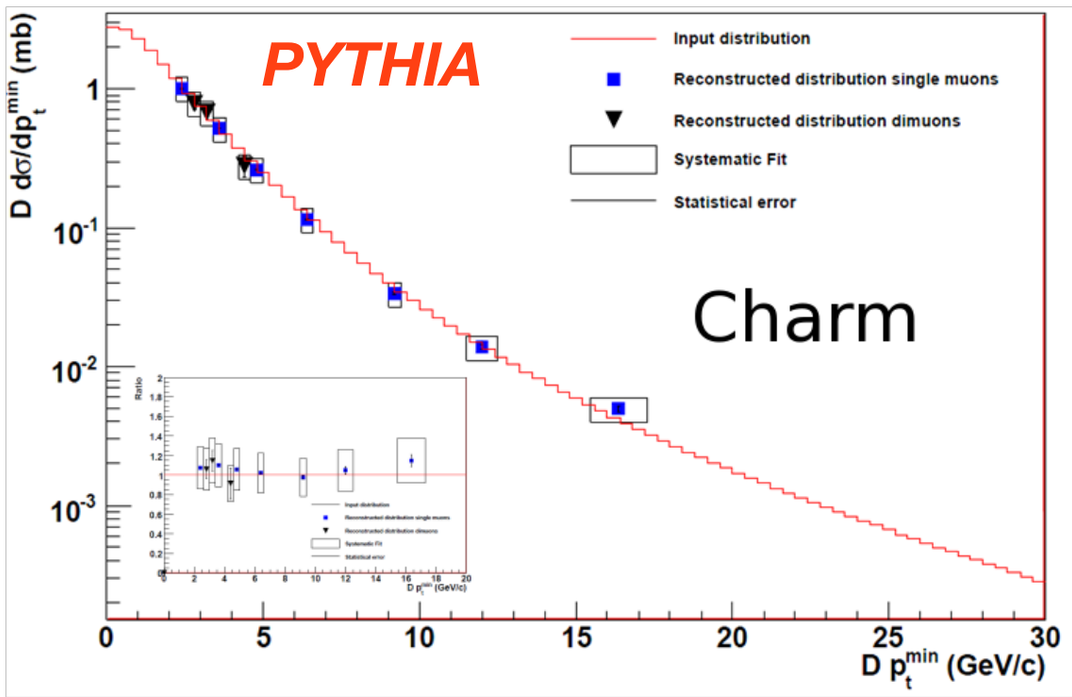


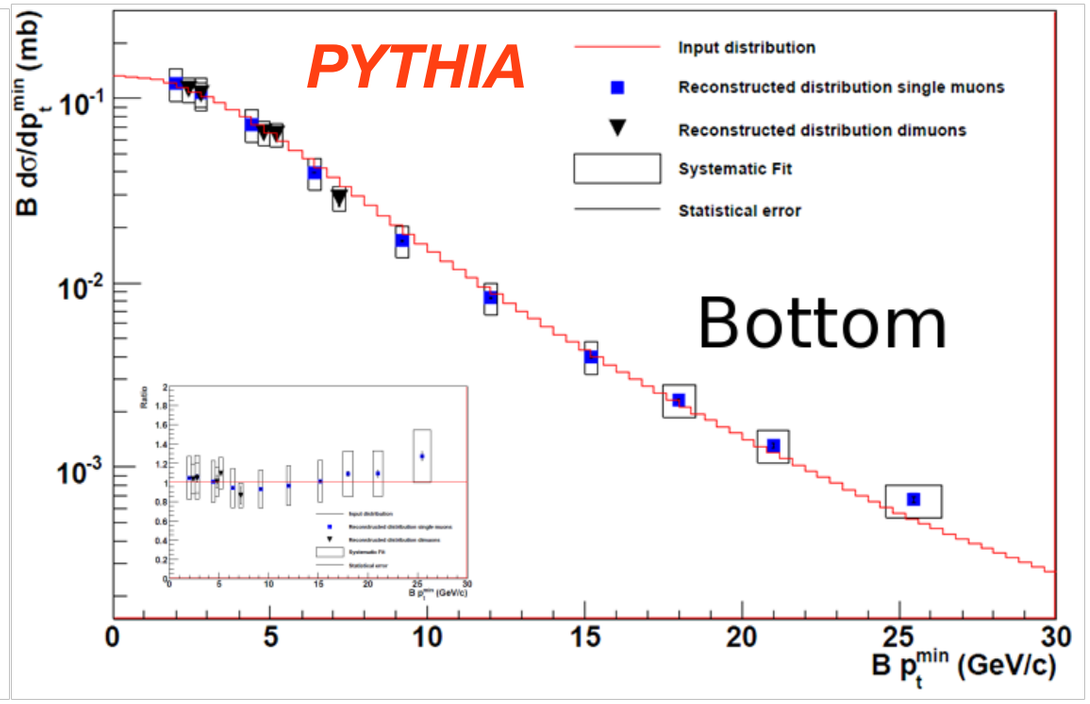
- background subtraction: from 20% to 7% with p_t;
- alignment: 2% $\times$ p_t;
- detector response: 5%;
- model bias: 20%;
- min-bias cross section: 10% (not included);
- total: from 29% to 24.4% with p_t;

Charm and Beauty Separation

D and B separation by fitting with pQCD shapes

Simulated results in p+p @ 14 TeV via (di)muons





- Input distributions are well reconstructed; nice agreement between single muon and dimuon channels
- Systematic errors are 20% for B and D in the single muon channel and, 15% for B and 20% for D in the dimuon channel
- This analysis procedure is currently applied to p+p data at 7 TeV