Heavy flavour & quarkonium at forward and central rapidity in p-p and Pb-Pb with ALICE at LHC

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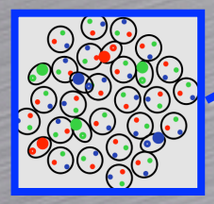
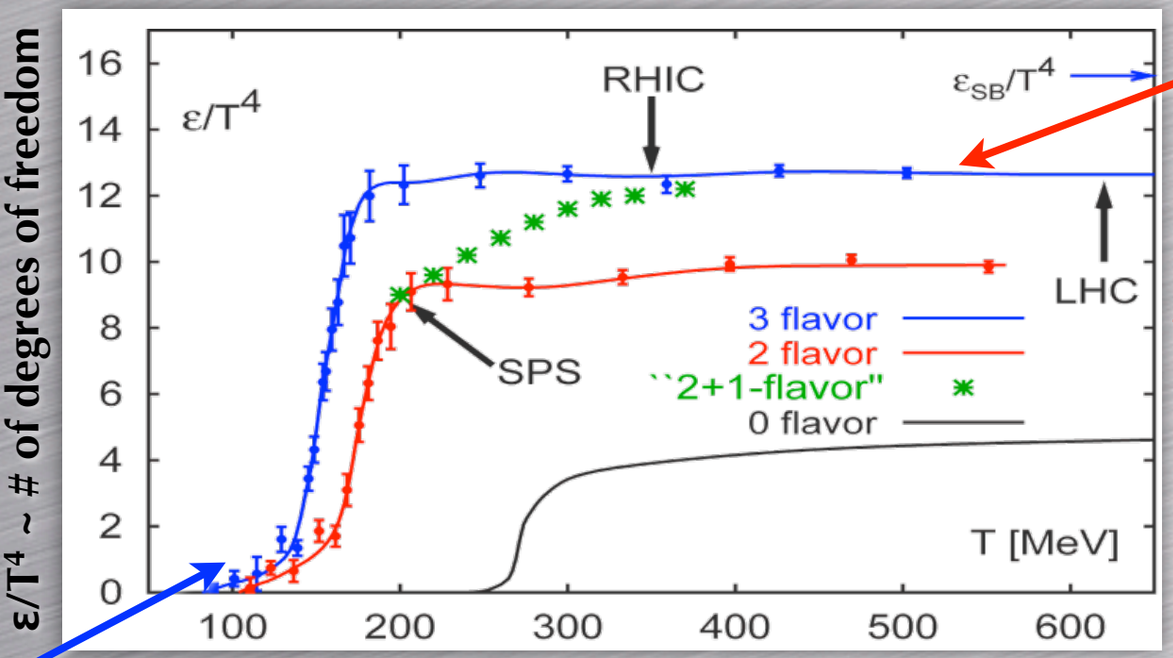
Outline

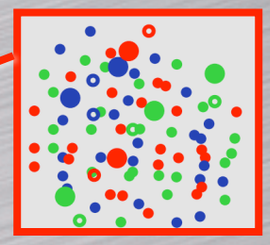
- Introduction:
  - The Quarks and Gluons Plasma
  - Heavy flavour physics
- The ALICE detector and its performance
- Open heavy flavour in p-p
  - At central rapidity
  - At forward rapidity
- Quarkonium production
- First look at Pb-Pb collisions

The Quark-Gluon Plasma (QGP)



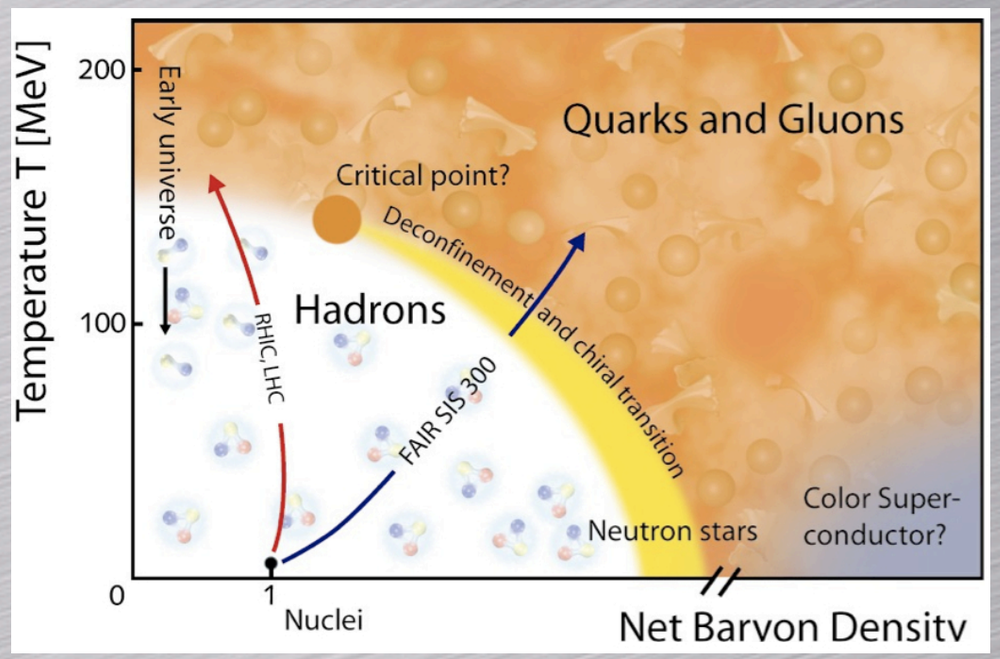
few degrees of freedom - confined





many degrees of freedom - deconfined

- Lattice QCD predict a phase transition toward a deconfined matter of quarks and gluons (QGP)
- $T_c \sim 175$ MeV → $\varepsilon_c \sim 0.3 - 1$ GeV/fm^3
- Creation of QGP in laboratory by colliding heavy ions at very high energy
  - LHC in 2010: Pb-Pb @ 2.76 TeV/nn

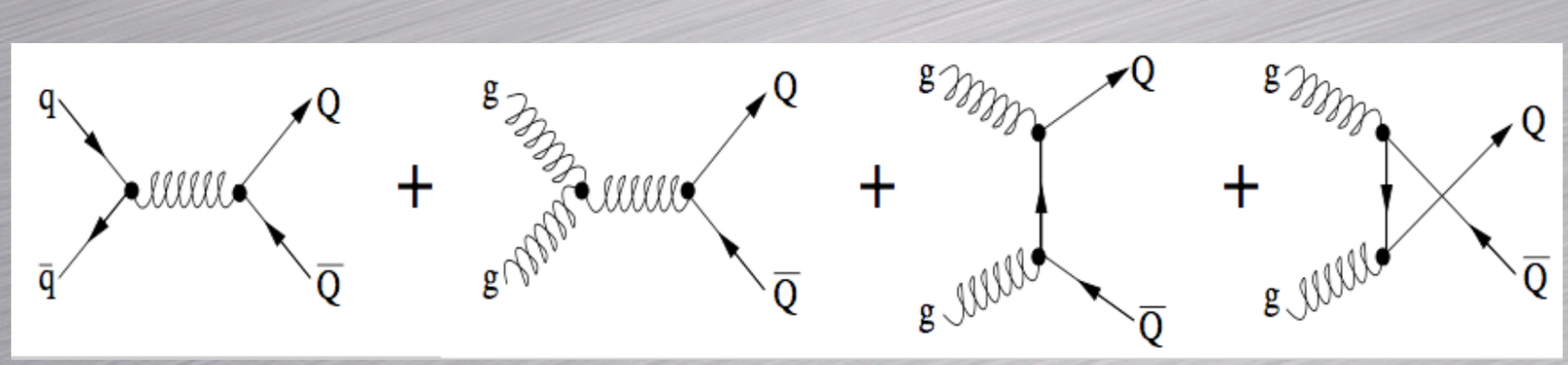


The production of heavy flavour

- Due to their high mass, the heavy quark pairs are produce in the early stages of the collision

$$\tau_{formation} \sim \frac{1}{m_{q\bar{q}}} \sim 0.02\ fm/c\ (beauty)$$

- Created by the primary partonic collisions



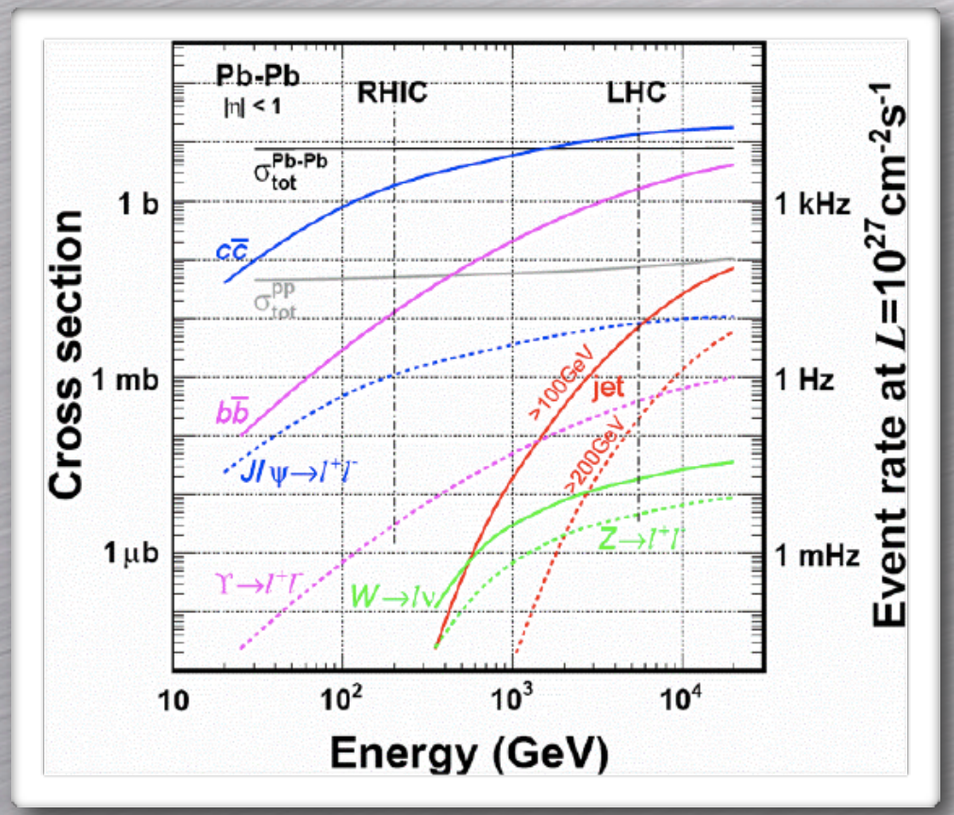
- No modification of the production of the heavy flavour in Pb-Pb due to the medium (except shadowing effect measured in p-A collisions)
- Life time of the heavy flavour much longer than the QGP life time $\tau(D^0)$ ~100 μm/c
  - heavy flavour = good observable to study the QGP

LHC: a heavy flavour factory

Production yield prediction for Charm and Beauty @ LHC

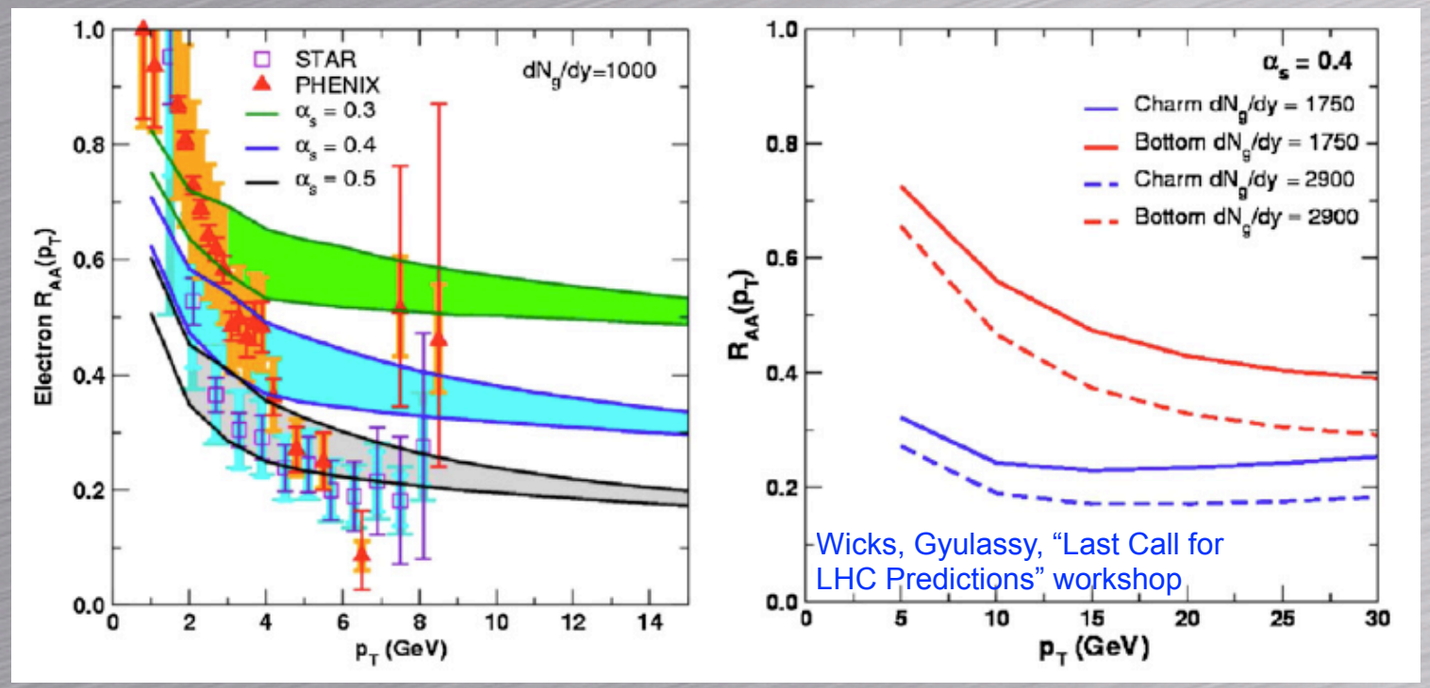
System $\sqrt{s_{nn}}$	pp 14 TeV	pp 7 TeV	PbPb (0-5%) 5.5 TeV	PbPb (0-5%) 2.76 TeV
$\sigma_{NN}^{Q\bar{Q}}\ (mb)$	**11.2** / **0.5**	**6.9** / **0.23**	**3.4** / **0.14**	**2.1** / **0.075**
$N_{tot}^{Q\bar{Q}}$	**0.16** / **0.007**	**0.10** / **0.003**	**90** / **3.7**	**56** / **2**

Source: MNR Code (about a factor 2 uncertainty on these numbers)



Why study Heavy Flavour & quarkonia @ LHC ?

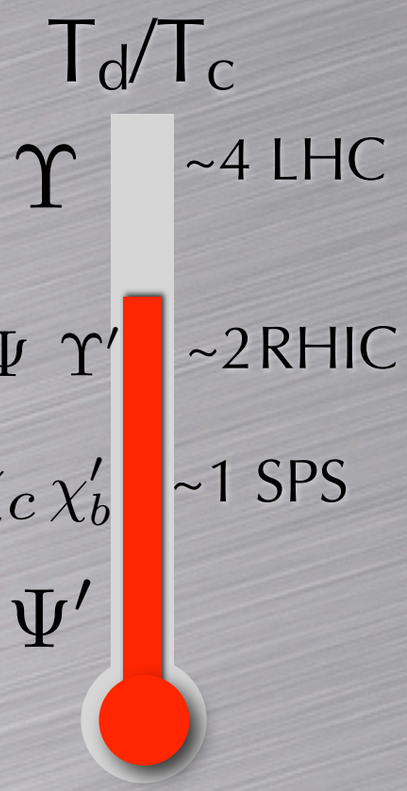
- In proton-proton:
  - Test of pQCD in a new energy domain
  - Reference for study of medium effect in PbPb
- In Pb-Pb:
  - Energy loss of heavy quark sensitive to energy density
  - Dissociation of quarkonium -> temperature of the system

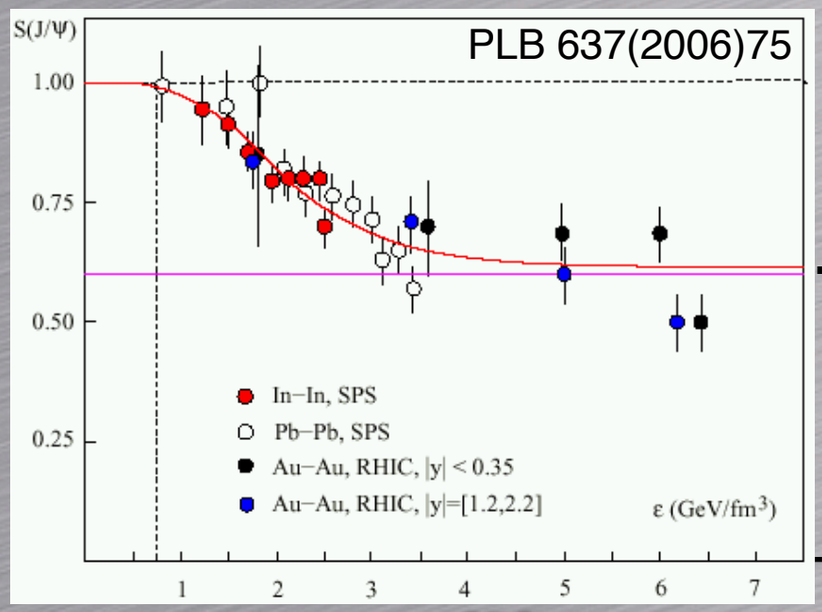


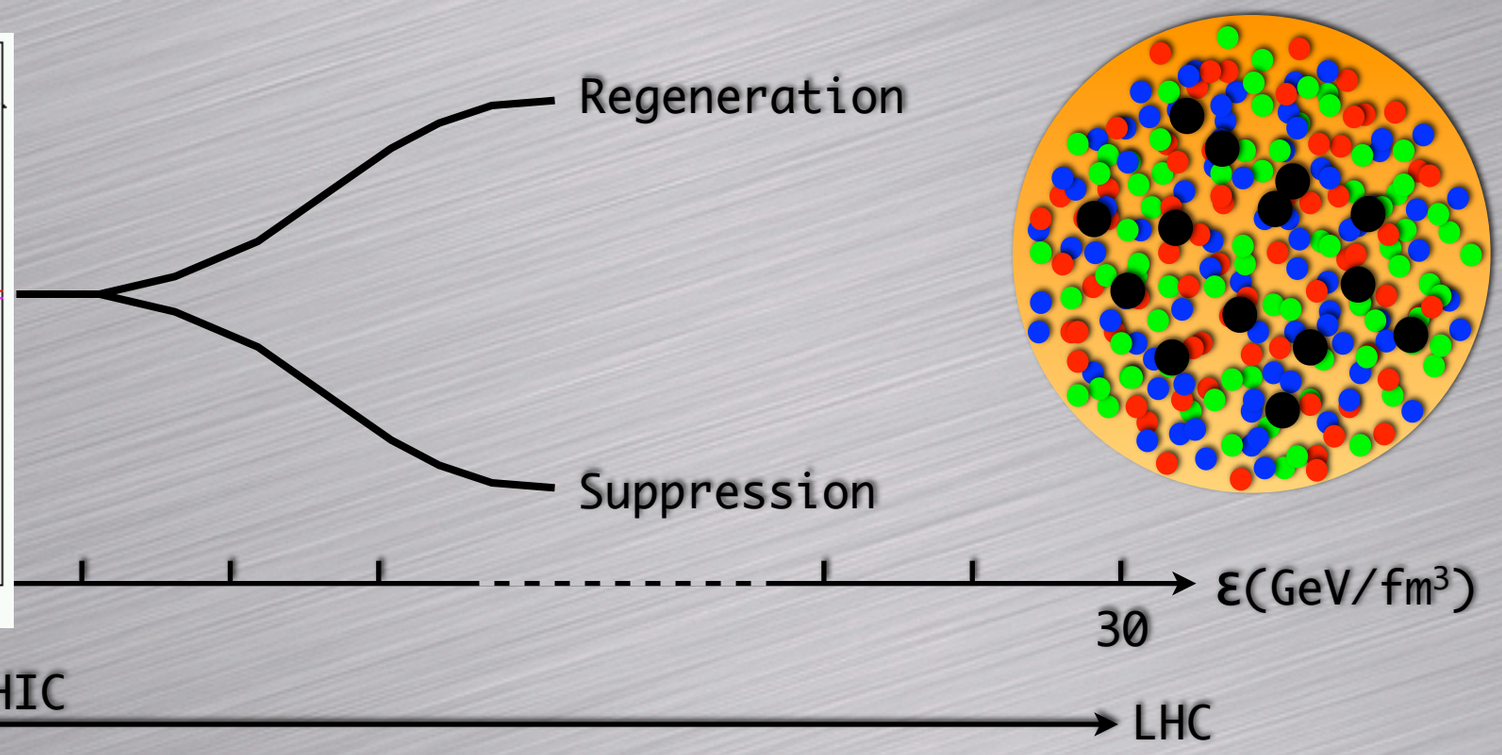
$$R_{AA}(p_t,\eta) = \frac{1}{\langle N_{coll}\rangle}\frac{d^2N_{AA}/dp_t d\eta}{d^2N_{pp}/dp_t d\eta}$$

Quarkonia suppression

- Dissociation of the quarkonia due to colour screening
- Threshold effect with a dissociation temperature different for each quarkonia function of the binding energy
- Upsilon will only dissociate at LHC
- Possible regeneration for the charmonium due to in medium coalescence of charm quarks

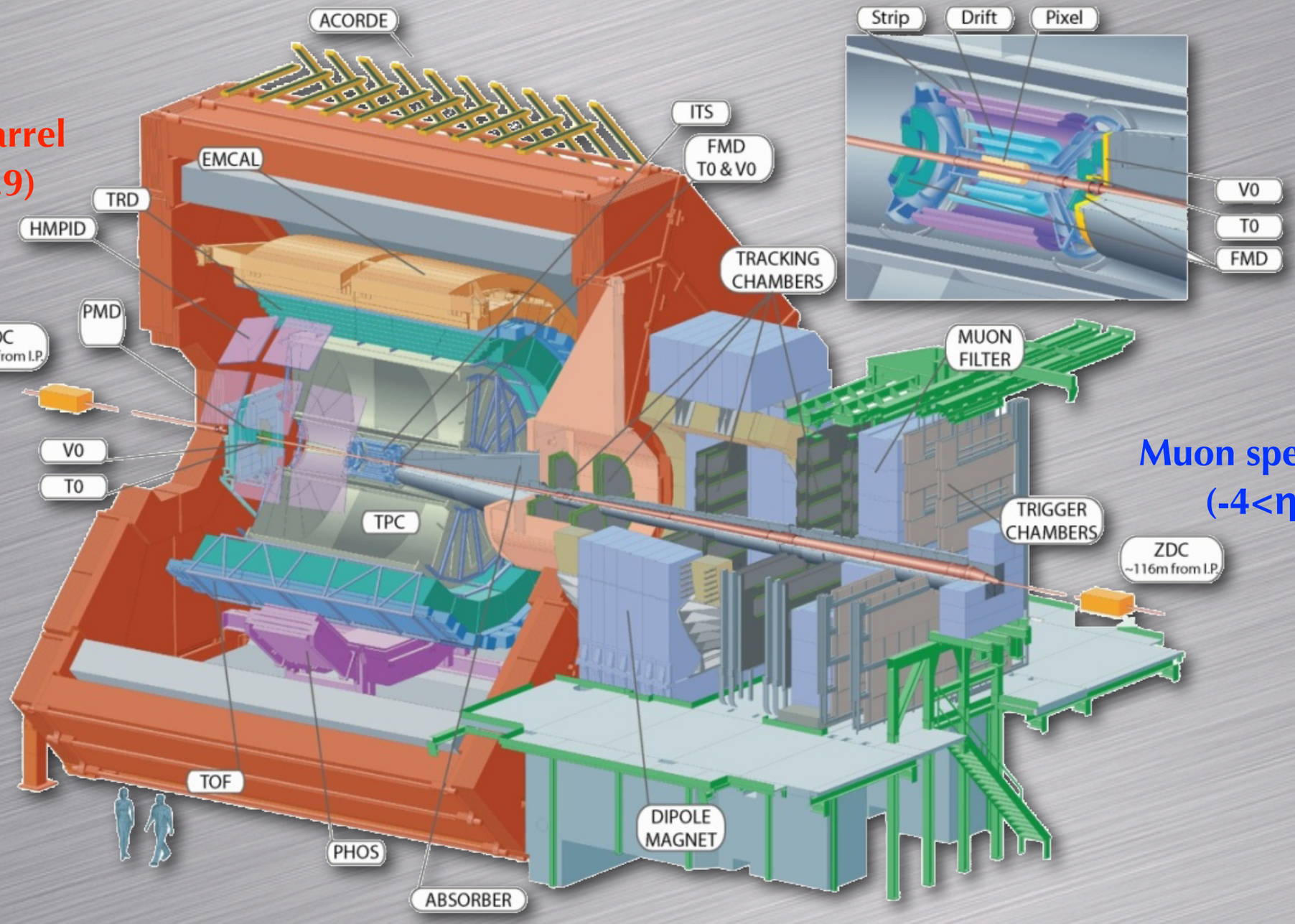






The ALICE detector in 2010

Central barrel
(|η|<0.9)

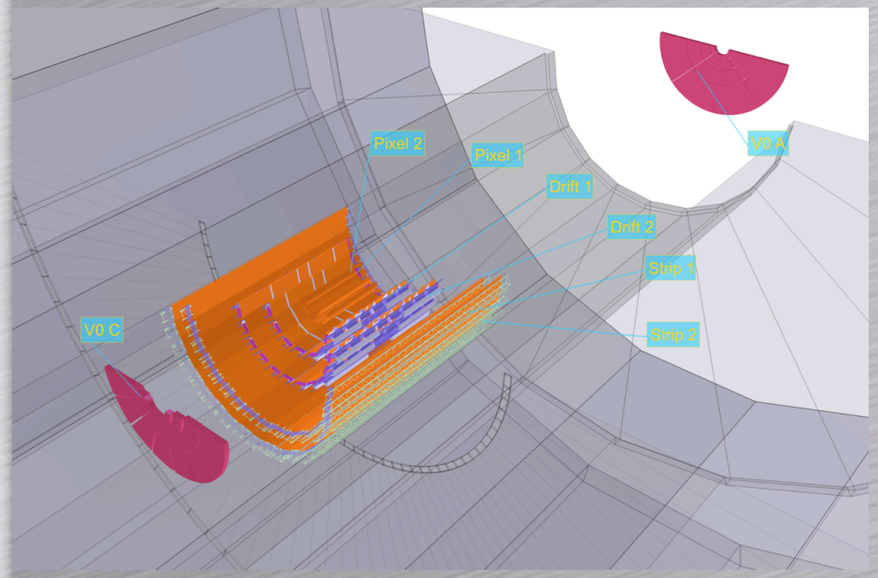


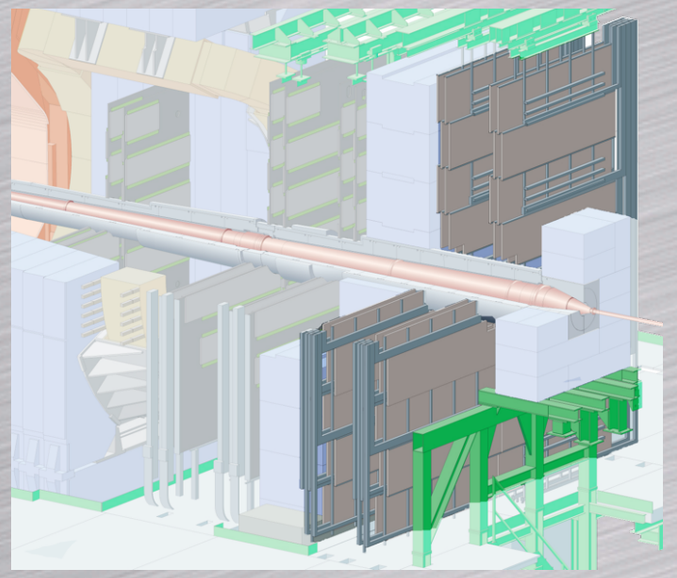
Muon spectrometer
(-4<η<-2.5)

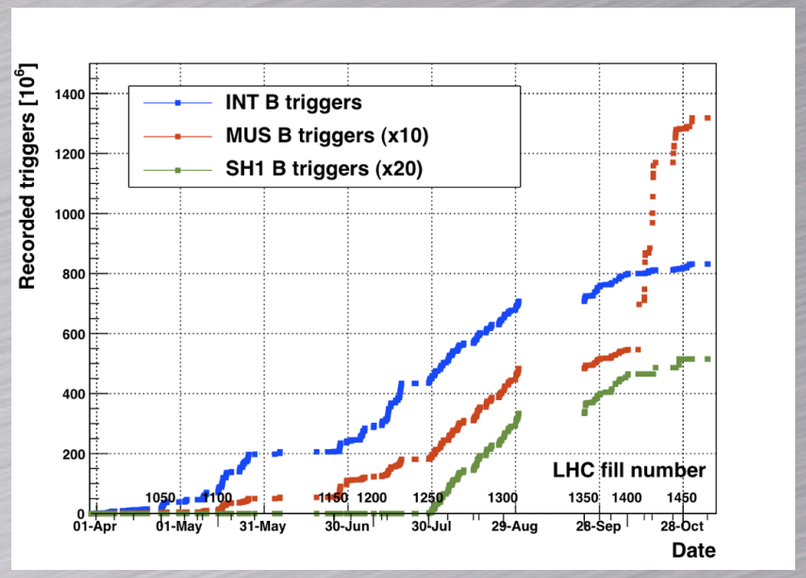
TRD (7/18), EMCAL (4/12), PHOS (3/5), others (100%)

After Christmas break works: EMCAL (12/12), TRD (10/18)

Trigger and data sample in p-p

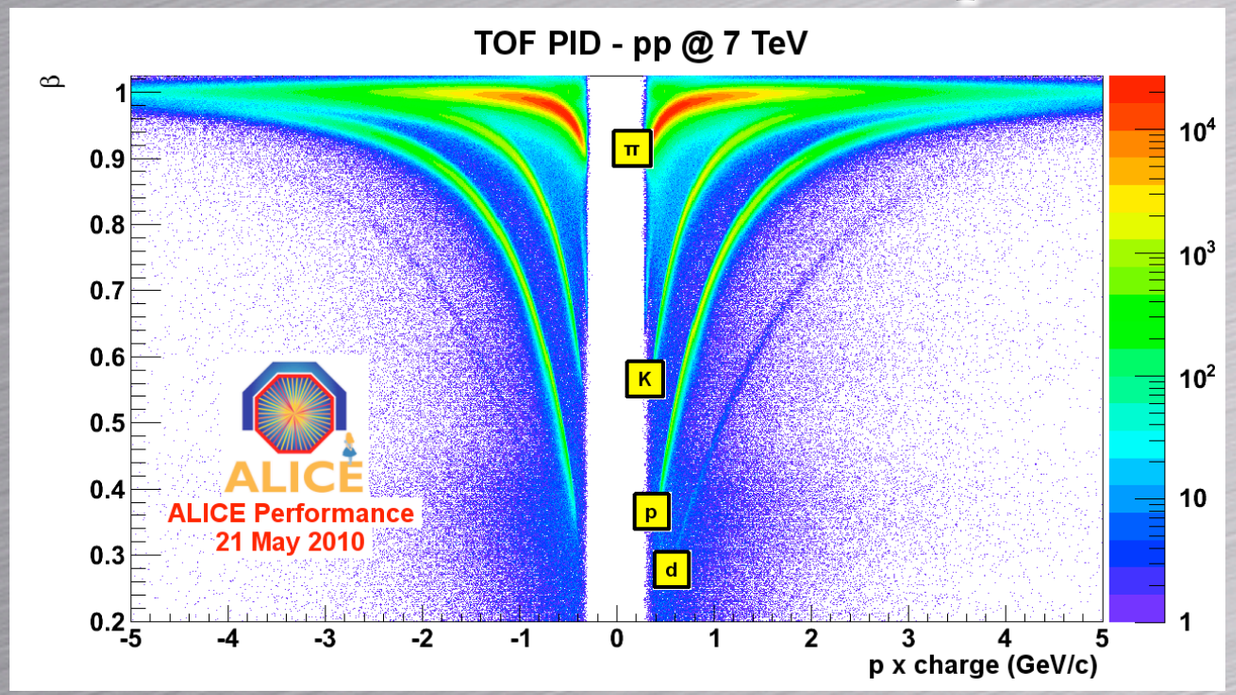


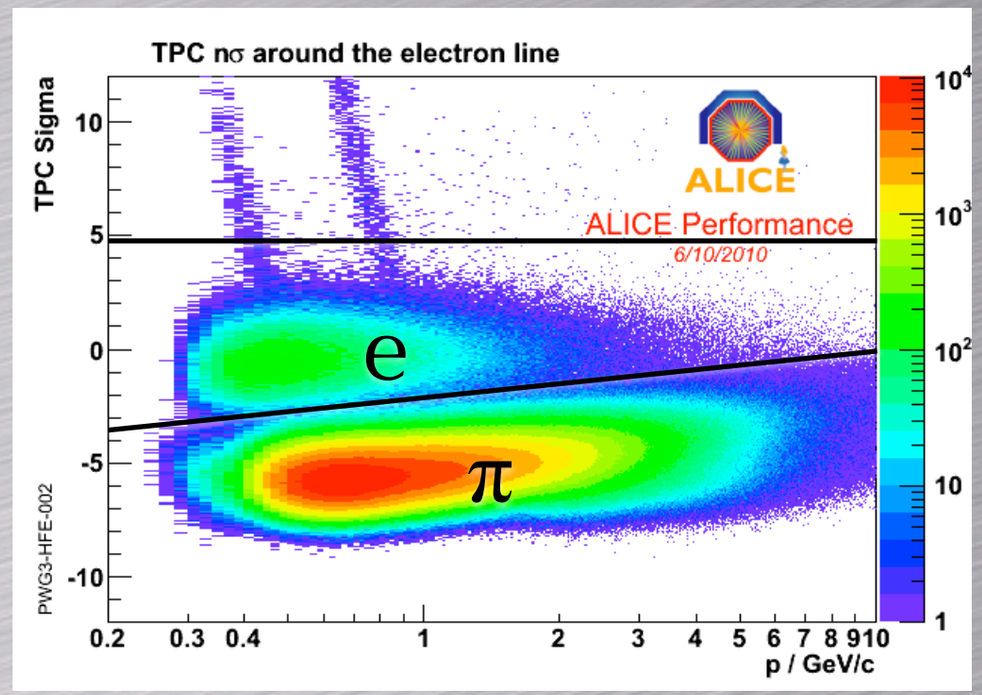




- Only the 7 TeV data are used for heavy flavour (too small statistic for 900 GeV and 2.36 TeV samples)
- Minimum bias trigger (INT1B) based on detection of one charged particle in SPD or V0 (8 units of of rapidity)
- Muon trigger(MUSB): at least one muon in the forward spectrometer in coincidence with minimum bias trigger
- 800×10^6 minimum bias events
- 130×10^6 muon triggers

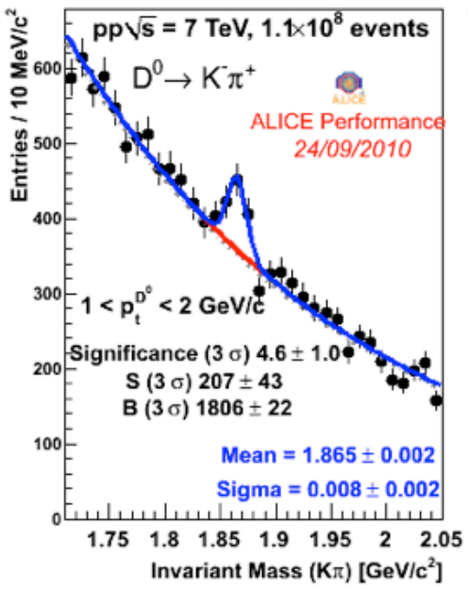
Heavy flavour @ central rapidity: PID performances

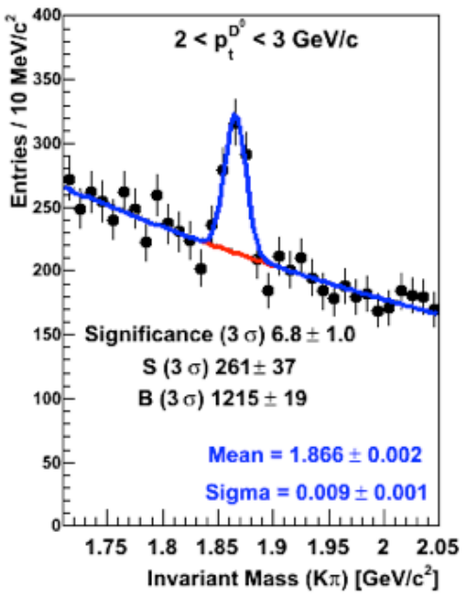


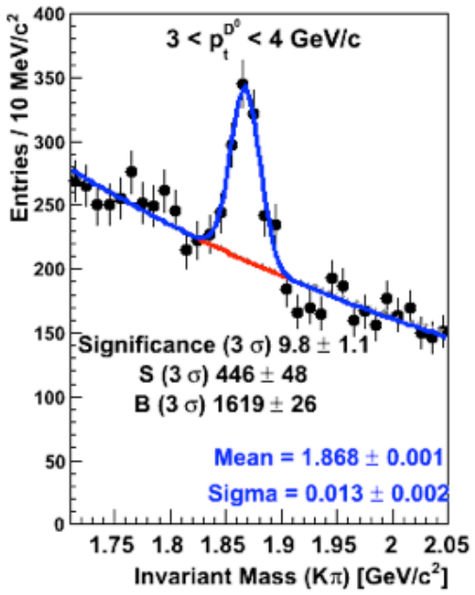


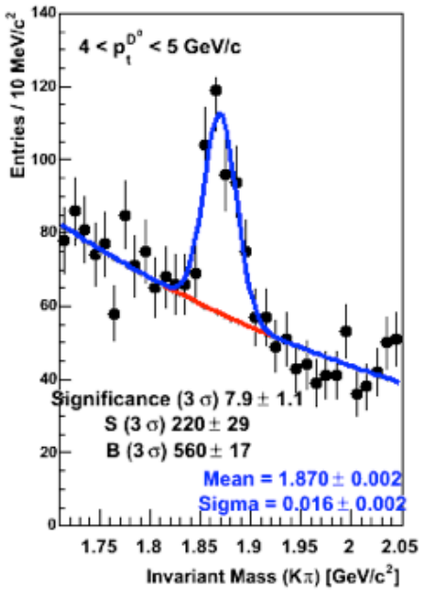
- Electron ID using TOF & TPC dE/dx
  - TOF: reject kaons (p<1.5 GeV/c) & protons (p<3 GeV/c)
  - TPC: asymmetric cut around the electron Bethe-Bloch line
- D → hadrons
  - Kaons identification with TPC and TOF
  - Displaced vertex topology with reconstructed D pointing to the primary vertex

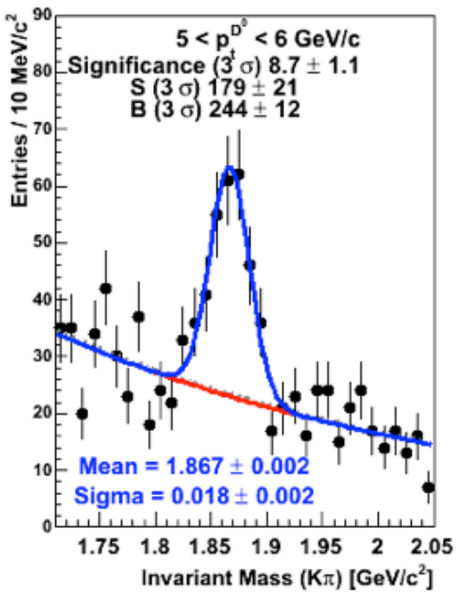
$D^0 \rightarrow K^-\pi^+$ signals

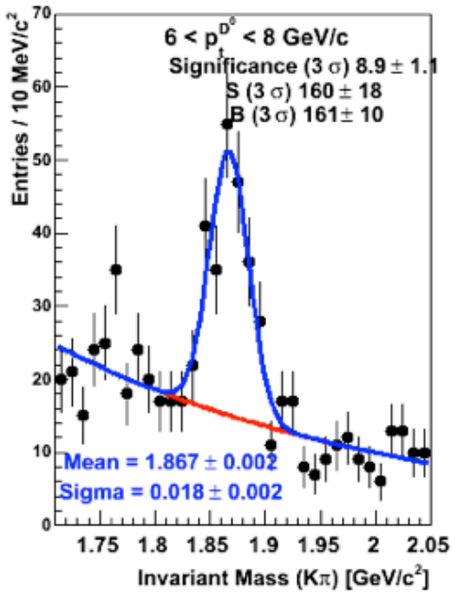


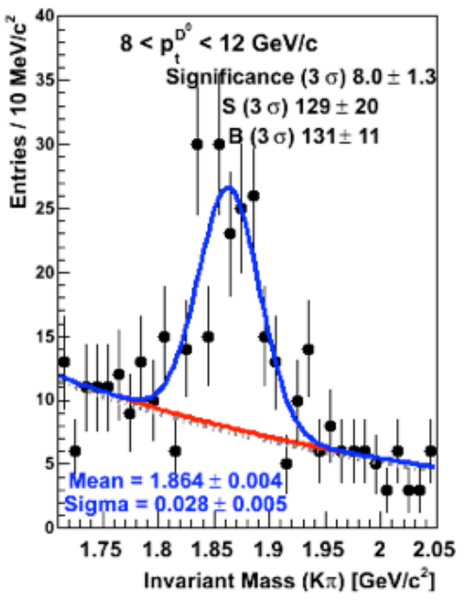






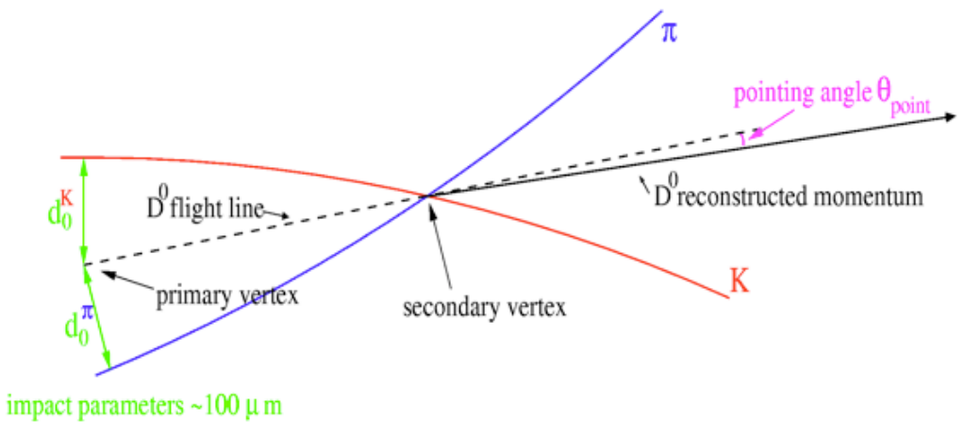




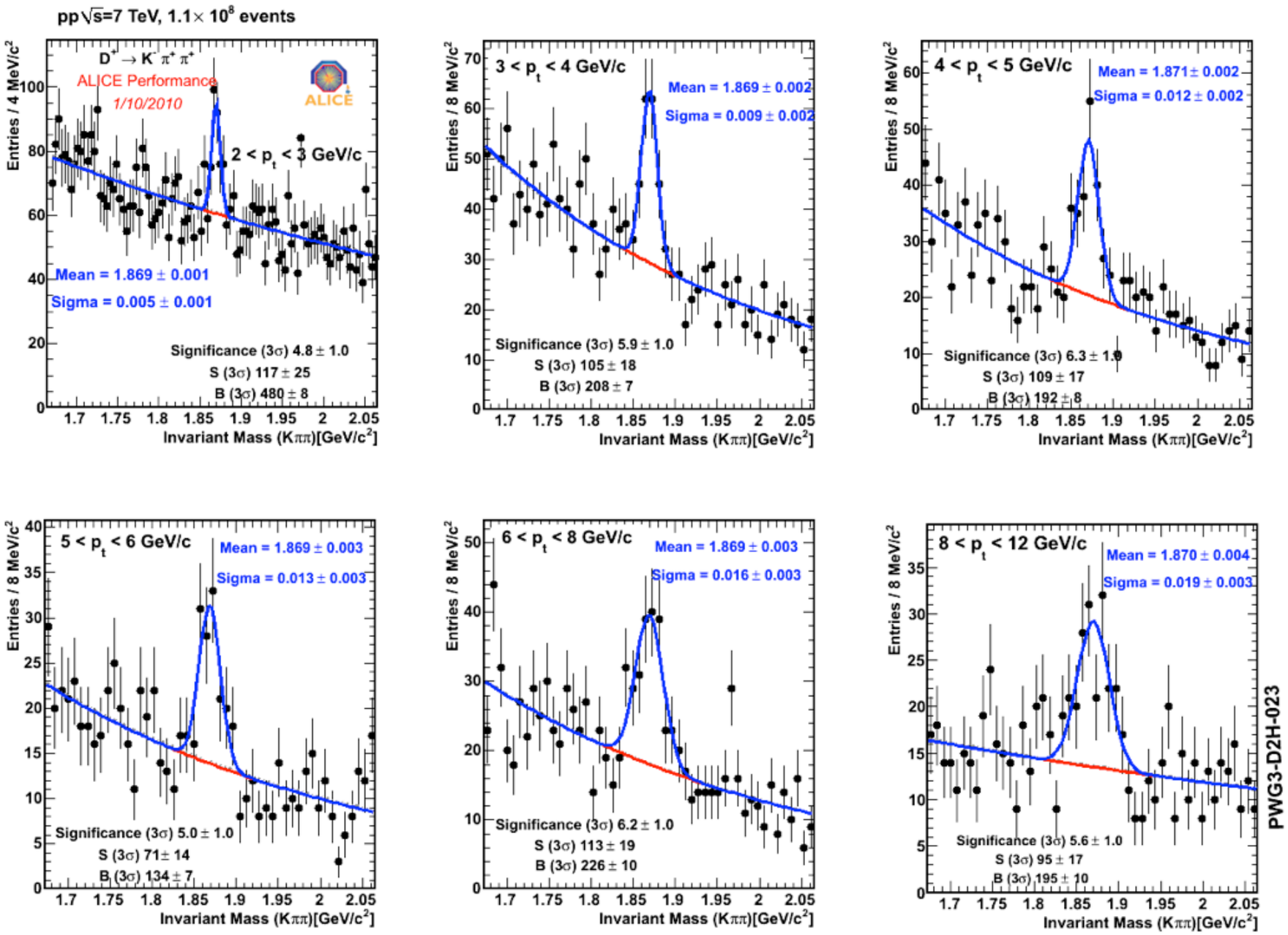


PWG3-D2H-021

- 10^8 events
- 7 pt bins: 1-12 GeV/c
- Topology based criteria
- Analysis @ pt<1 GeV/c under way

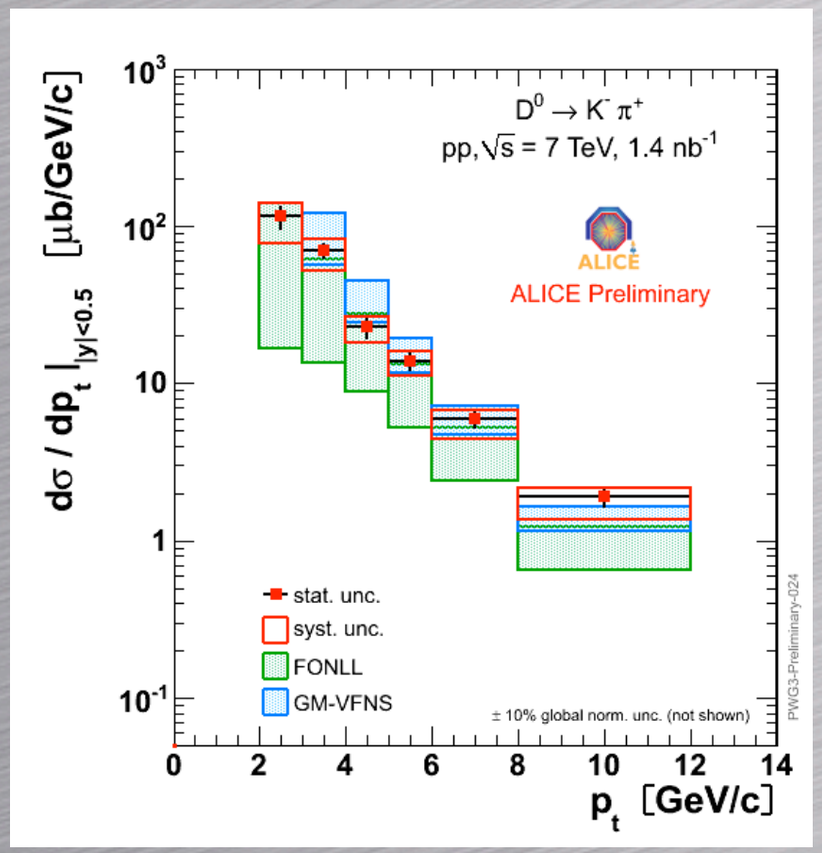


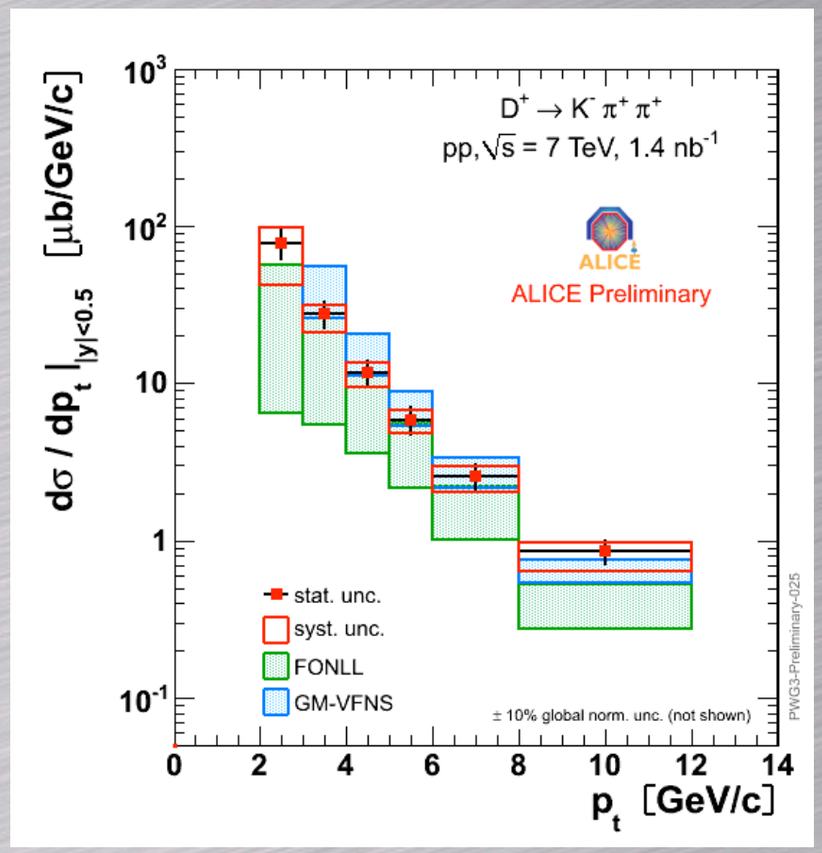
$D^+ \rightarrow K^-\pi^+\pi^+$ signals



- 10^8 events
- 6 pt bins: 2-12 GeV/c
- Topology based criteria

$d\sigma/dp_t$ in $|y| < 0.5$

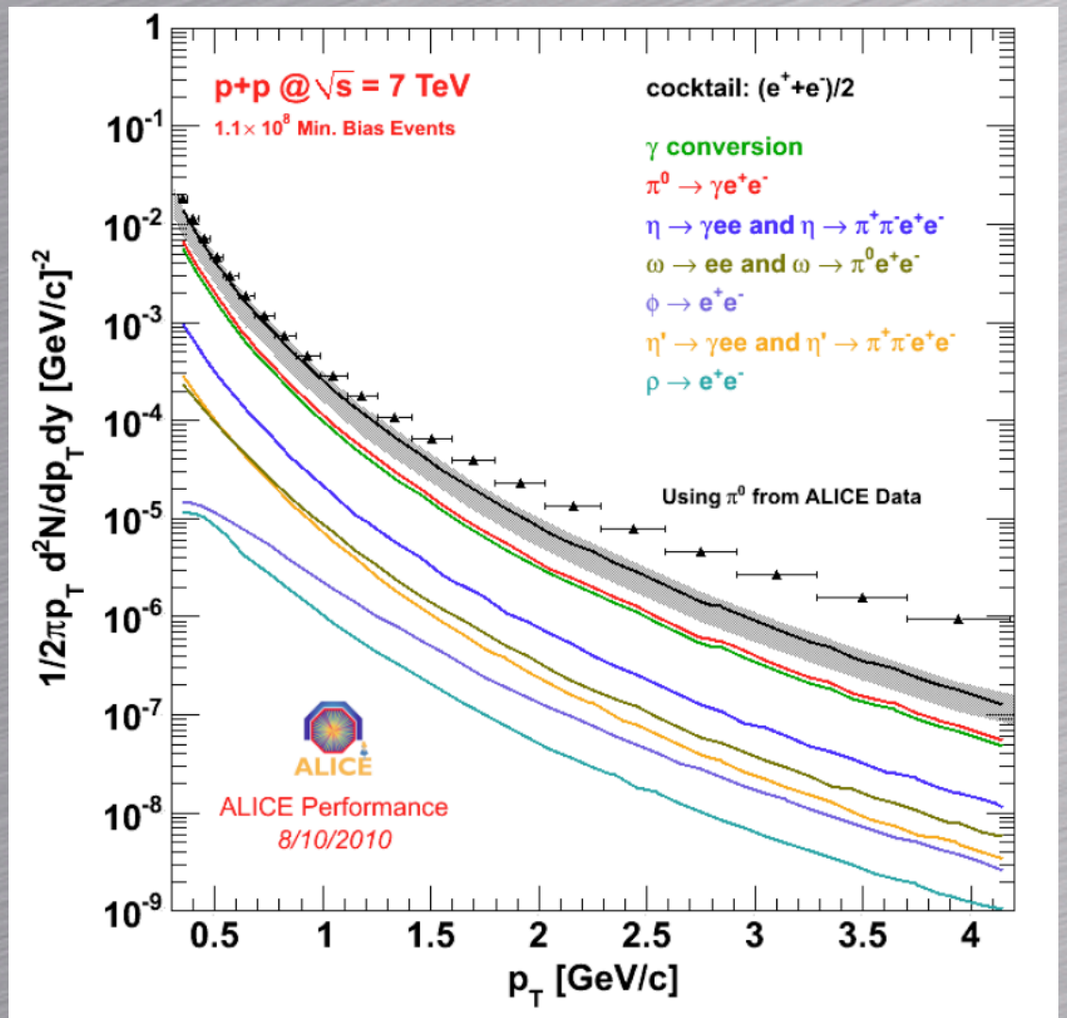




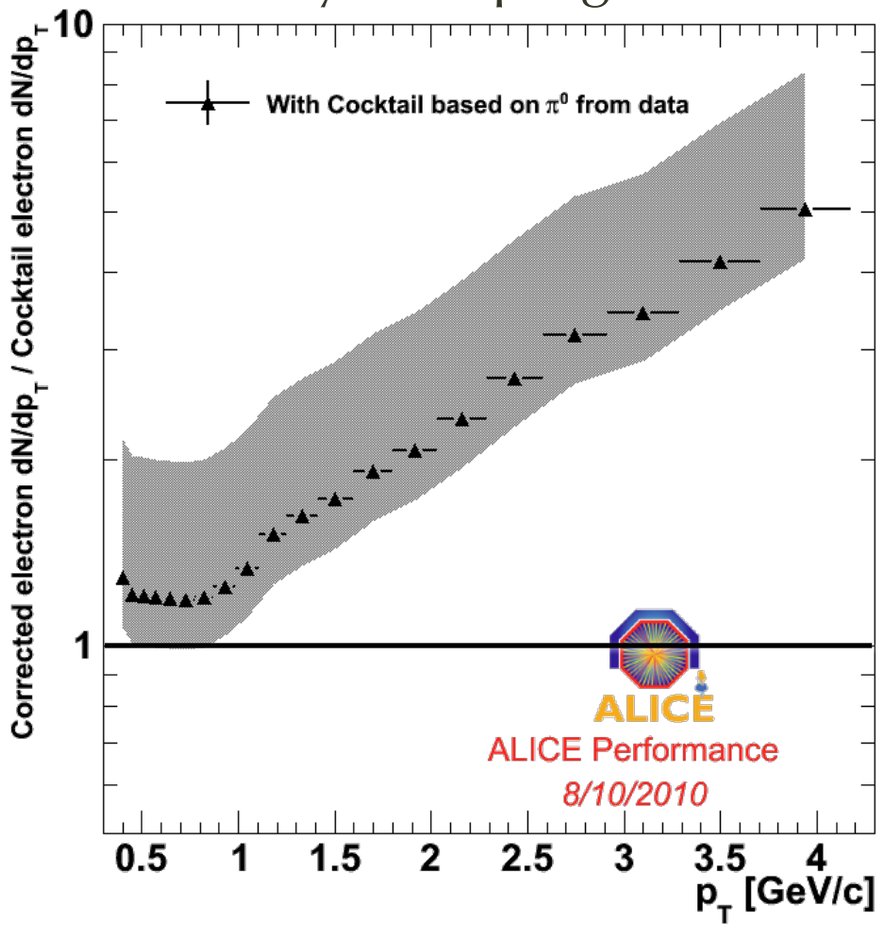
- Raw yields corrected for efficiency and acceptance
- B feed-down corrections:
  - Done using FONLL calculations
  - Correction using D meson impact parameter distributions (à la CDF) ongoing
- Absolute normalization using MB cross section extract from Van der Meer scan

Single electrons from heavy flavour

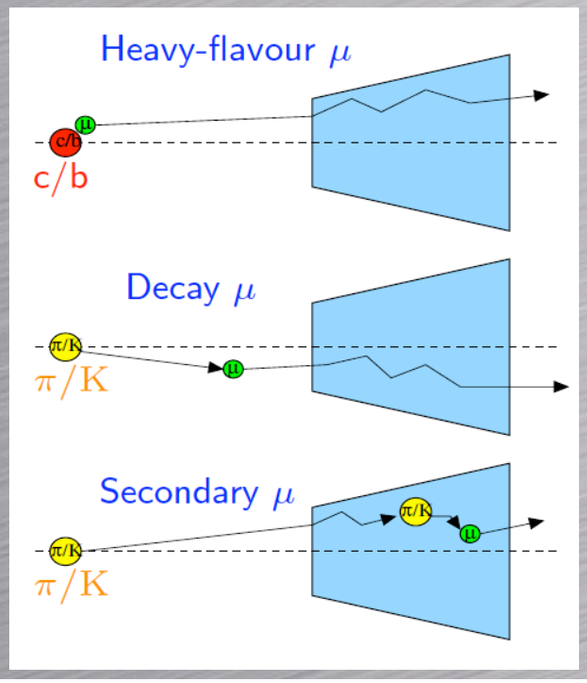
- Electron ID using TOF and TPC dE/dx (being extend to TRD and EMCAL)
- Contamination from <1% to 15% at 4 GeV/c
- Inclusive electron spectrum compared with cocktail of sources (conversion electrons from $\pi 0$ decays are derived from data)
- Heavy flavour signal above the cocktail

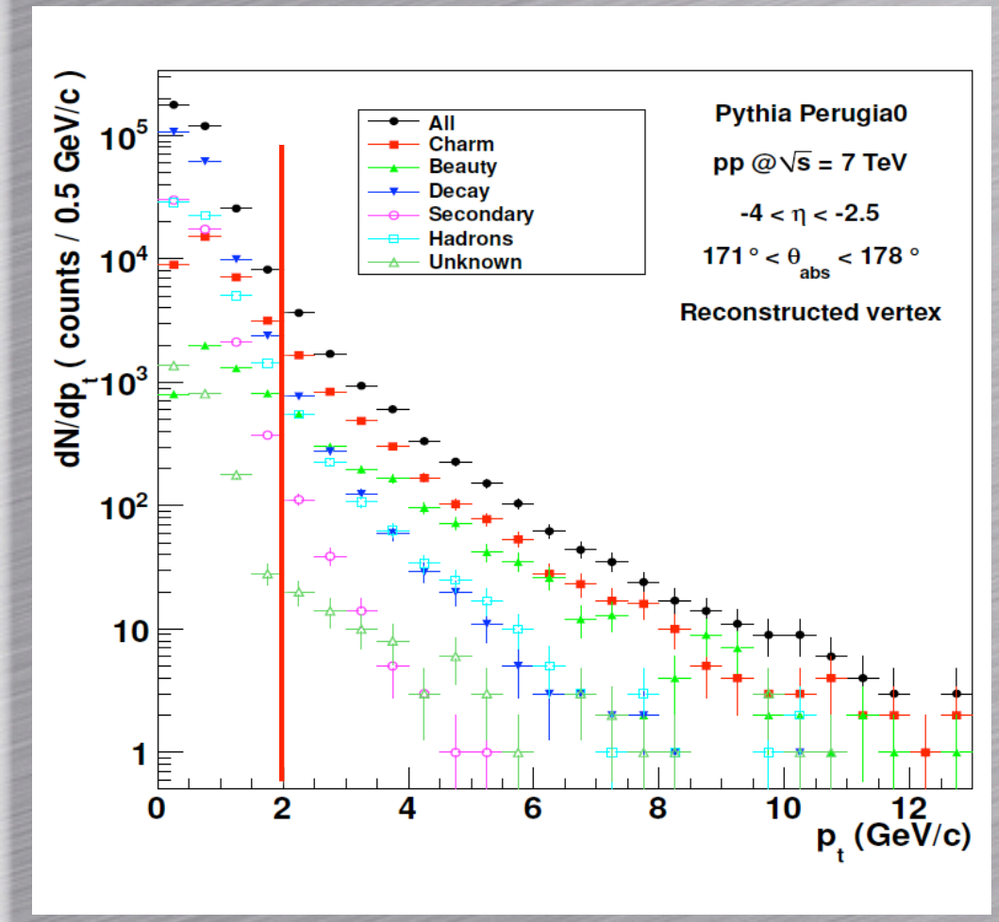


Analysis in progress



Single muons: background subtraction

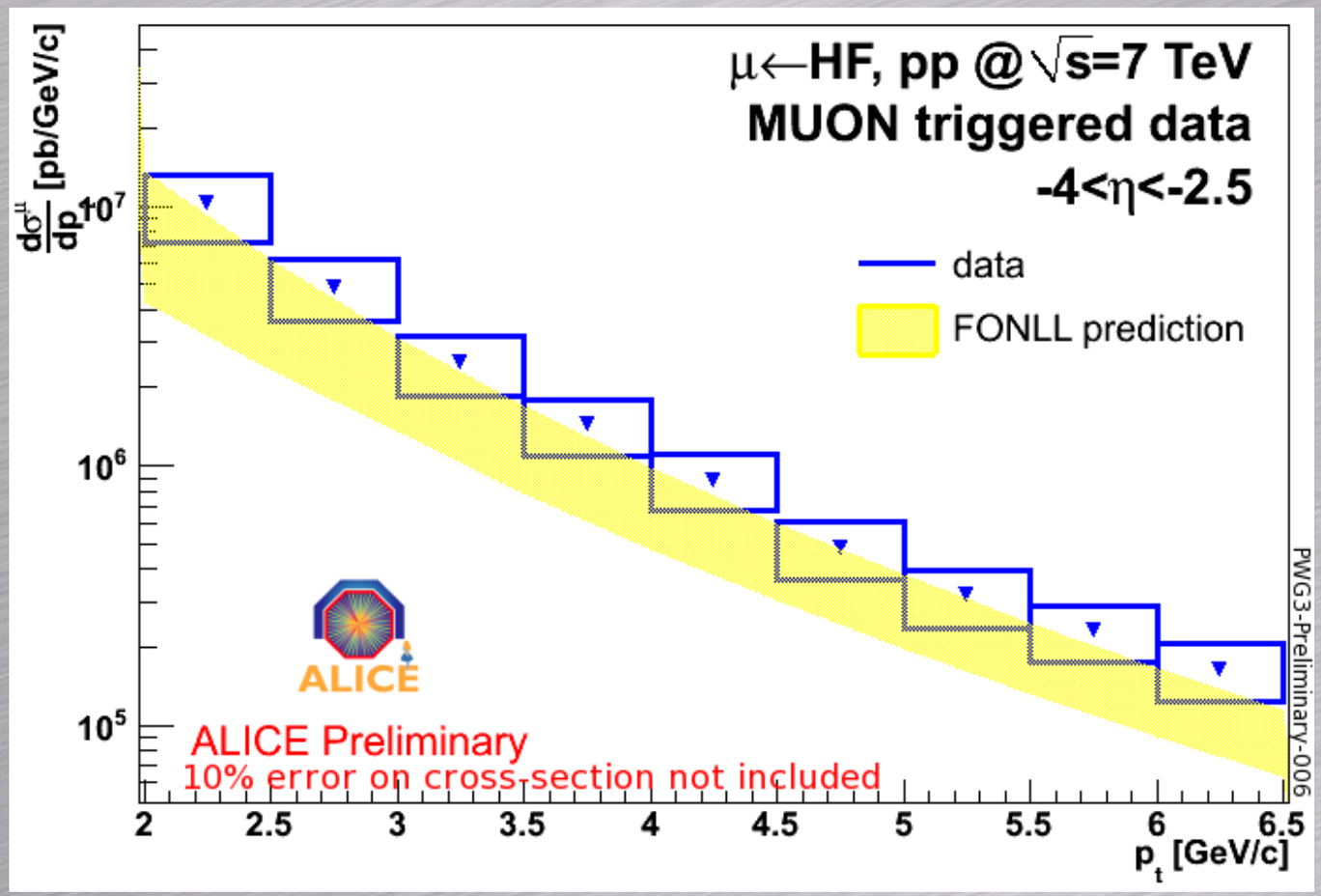




- Perform analysis in the region $p_t > 2$ GeV/c
  - Small secondary muons contribution ~3 %
  - Main bkg = decay muons from π and K ~25 %
- Subtract decay muons contribution using MC
- Use 2 Pythia tunes (Perugia-0 and ATLAS-CSC)
- decay muons dN/dp_t normalized to data at low p_t (0.5 - 1 GeV/c) where its contribution is dominant
- alternatively use the Distance of Closest Approach to primary vertex

Resulting systematic error from 30% to 20% from low to high p_t

Forward single muons: result

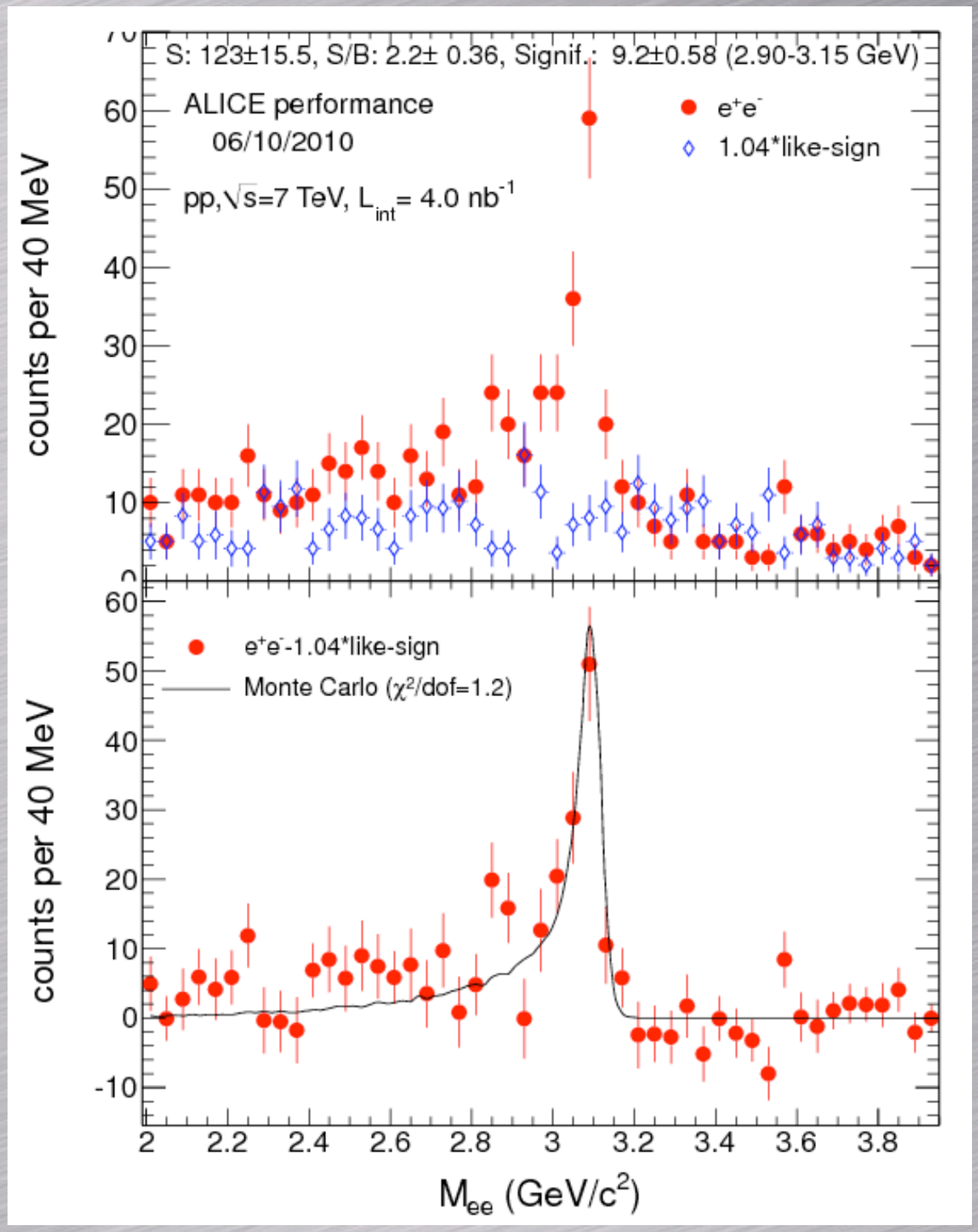


- Analysis performed using ~2.10^6 events → L = 3.49 nb^{-1}
- Absolute normalization using minimum bias cross section

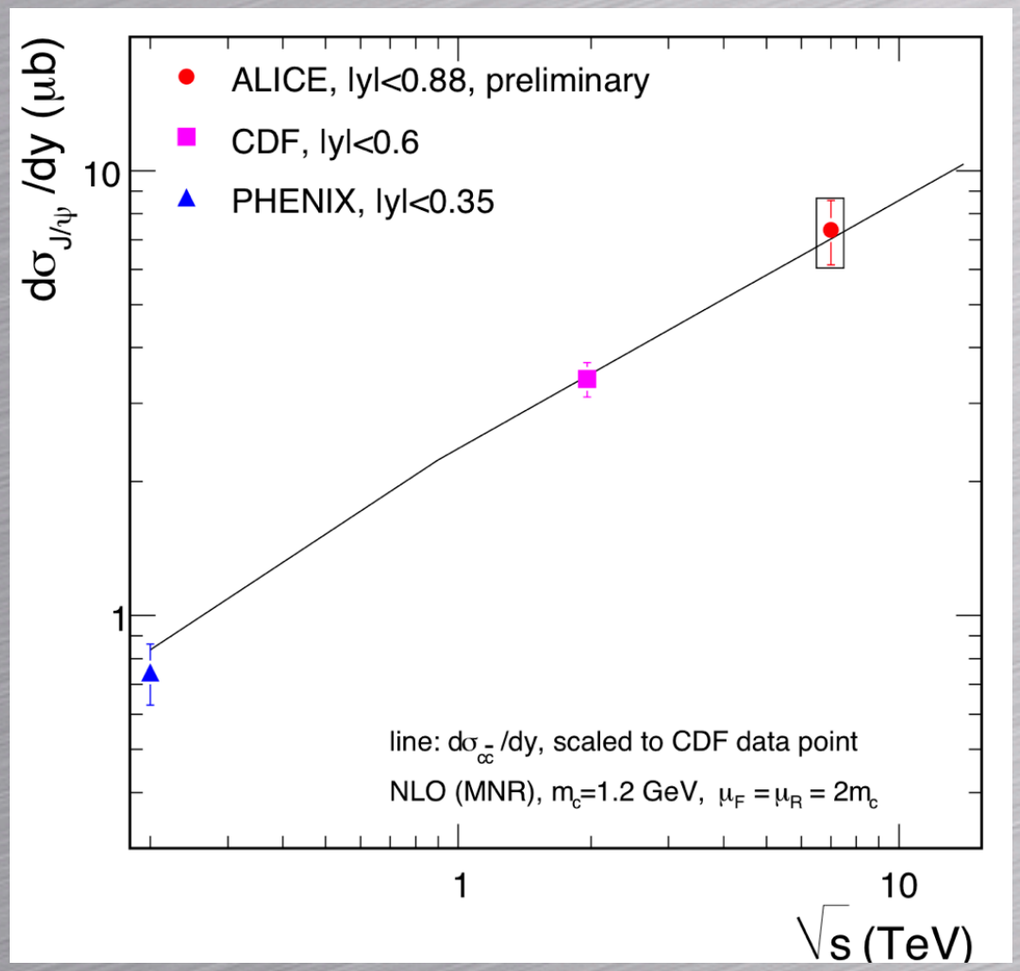
Measured cross sections compatible with semileptonic decay of open-charm and open-beauty hadrons calculated with pQCD (FNOLL)

J/ψ in e^+e^-

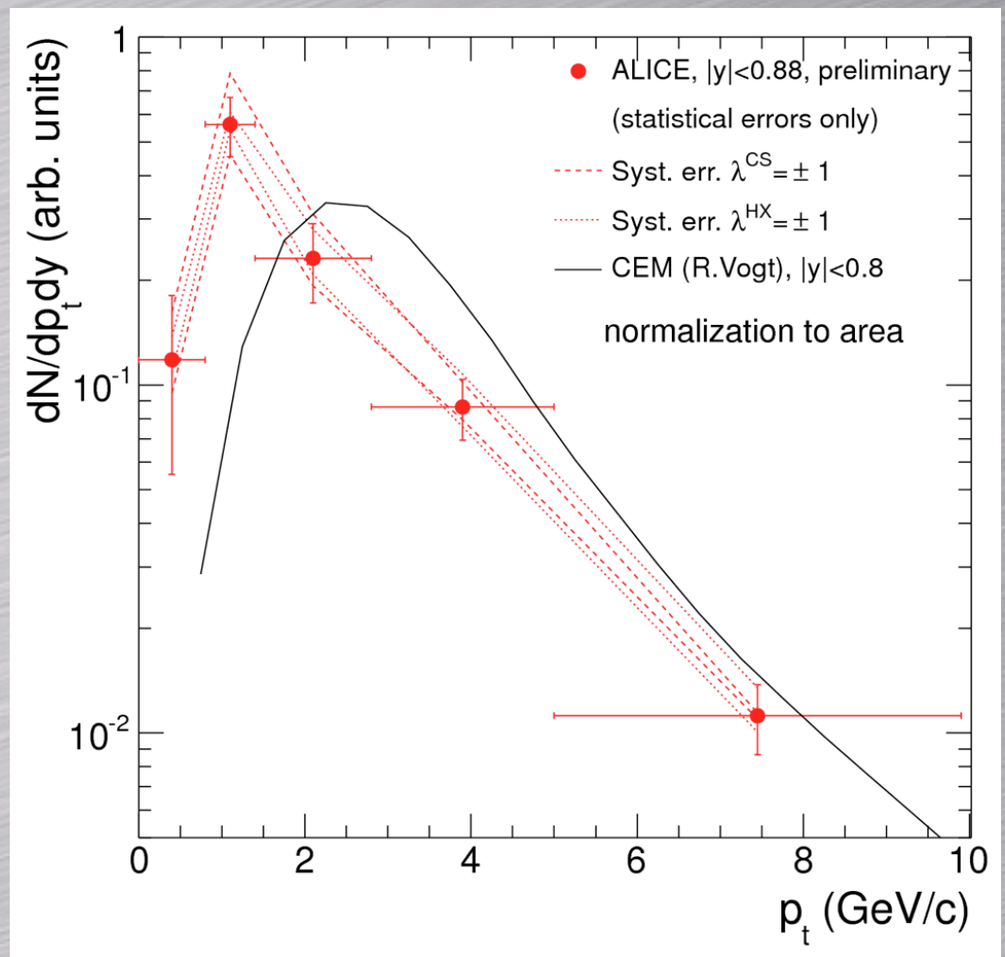
- Data sample: 10^8 MB → L=4 nb^{-1}
- High quality tracks in TPC and ITS
- e-PID using TPC dE/dx
- No B feed-down, inclusive J/ψ
- Like-sign background subtraction
- Signal extraction by bin counting in $2.9 < M_{ee} < 3.15$ GeV/c^2



J/ψ in e^+e^-: results



- p_t integrated cross section using 10^8 well calibrated events ($L = 1.4\ nb^{-1}$)

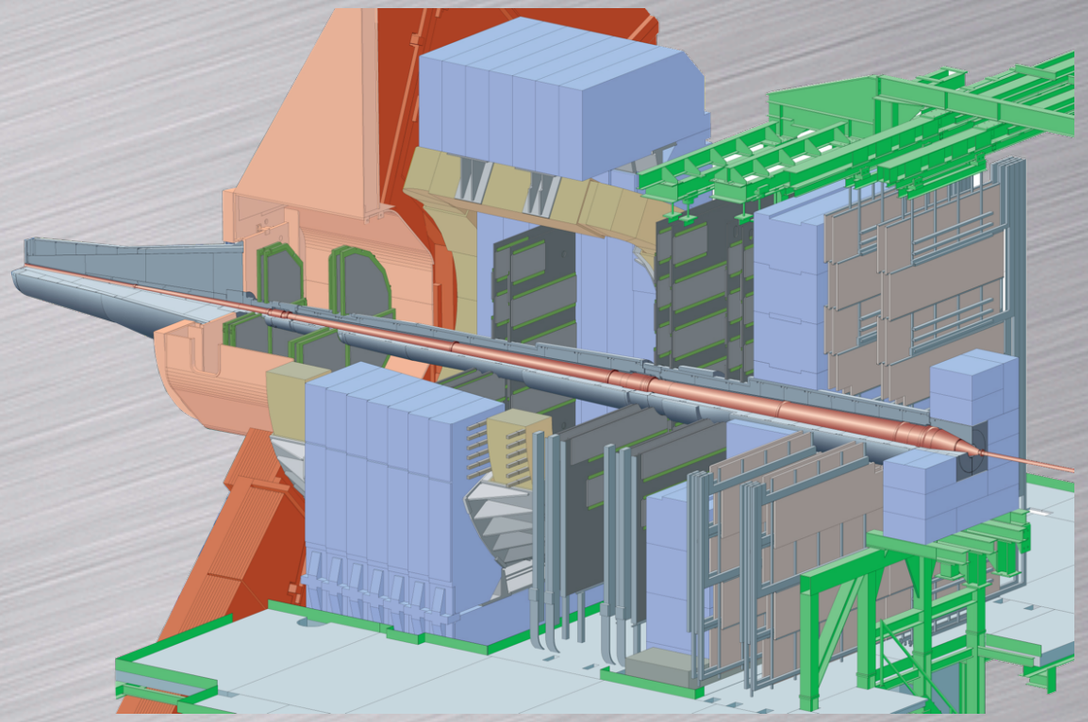


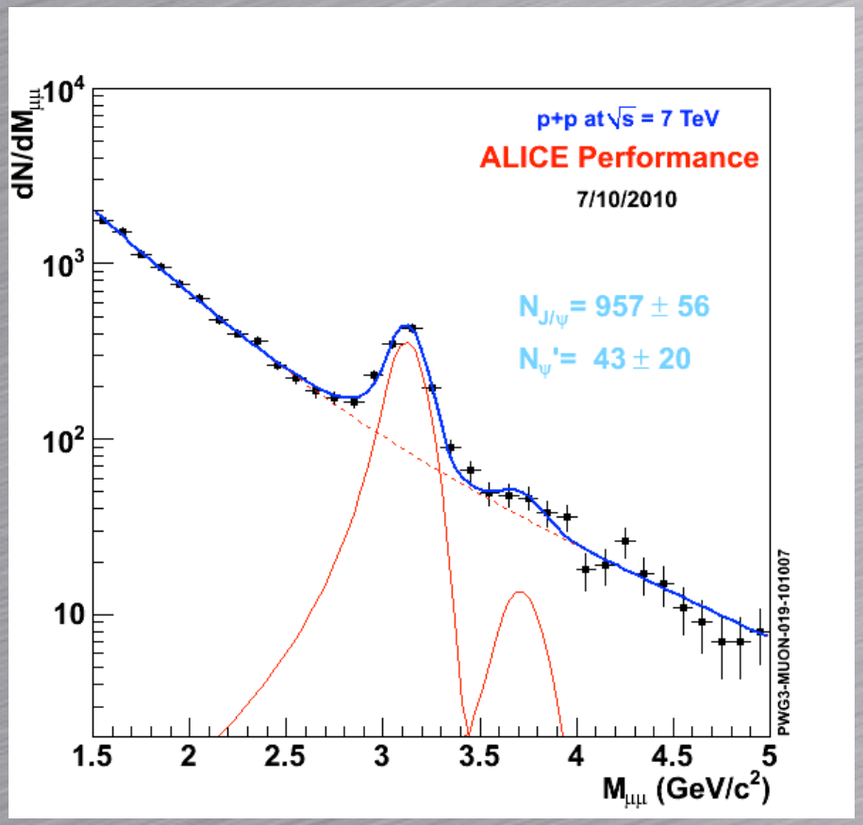
- dN/dp_t using 3.10^8 events with partial calibration

$$d\sigma/dy_{|y|<0.88}\ (\mu b) = 7.36 \pm 1.22\ (stat) \pm 1.32\ (syst)\ ^{+0.88}_{-1.84}\ (syst.\ pol.)$$

J/ψ in $\mu^+\mu^-$

- **Data sample:** luminosity = 13.6 nb^{-1}
- **Kinematic coverage:** $-4.0 < y < -2.5$





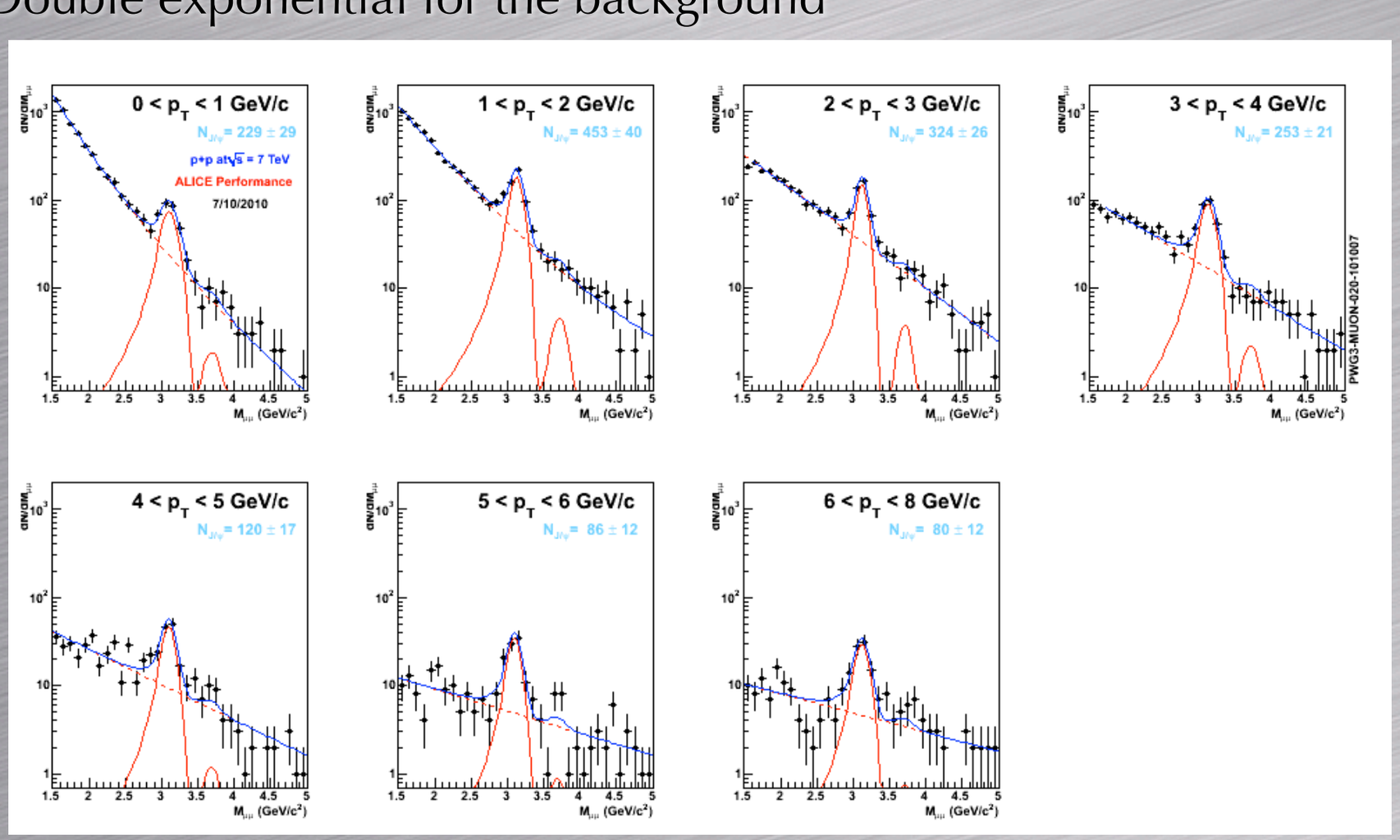
Example of invariant mass spectra with L=6.9 nb^{-1}

Event selection :

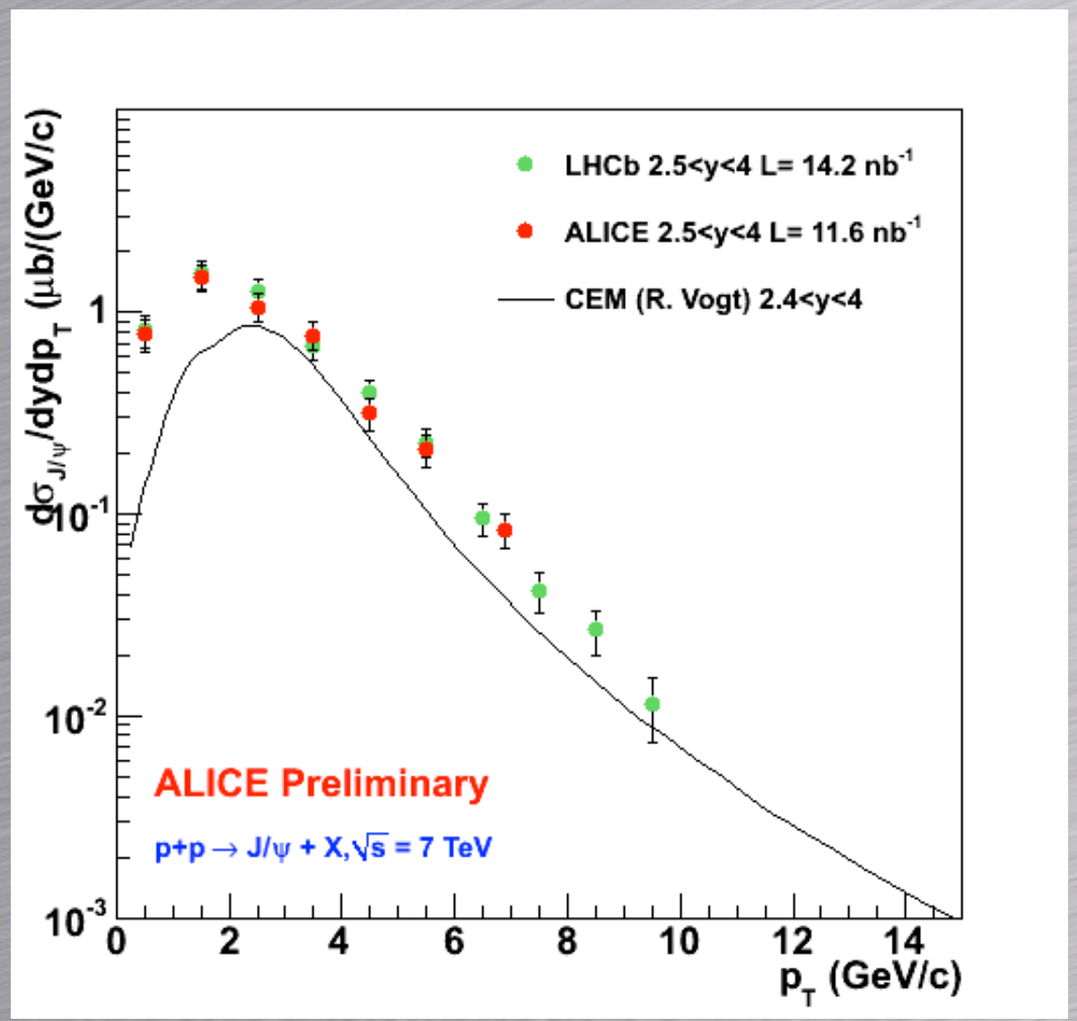
- Coincidence with MB trigger
- At least one of the 2 muon tracks matches a muon trigger track
- At least one vertex reconstructed by the ITS
- Cut on the track position at the end of the front absorber

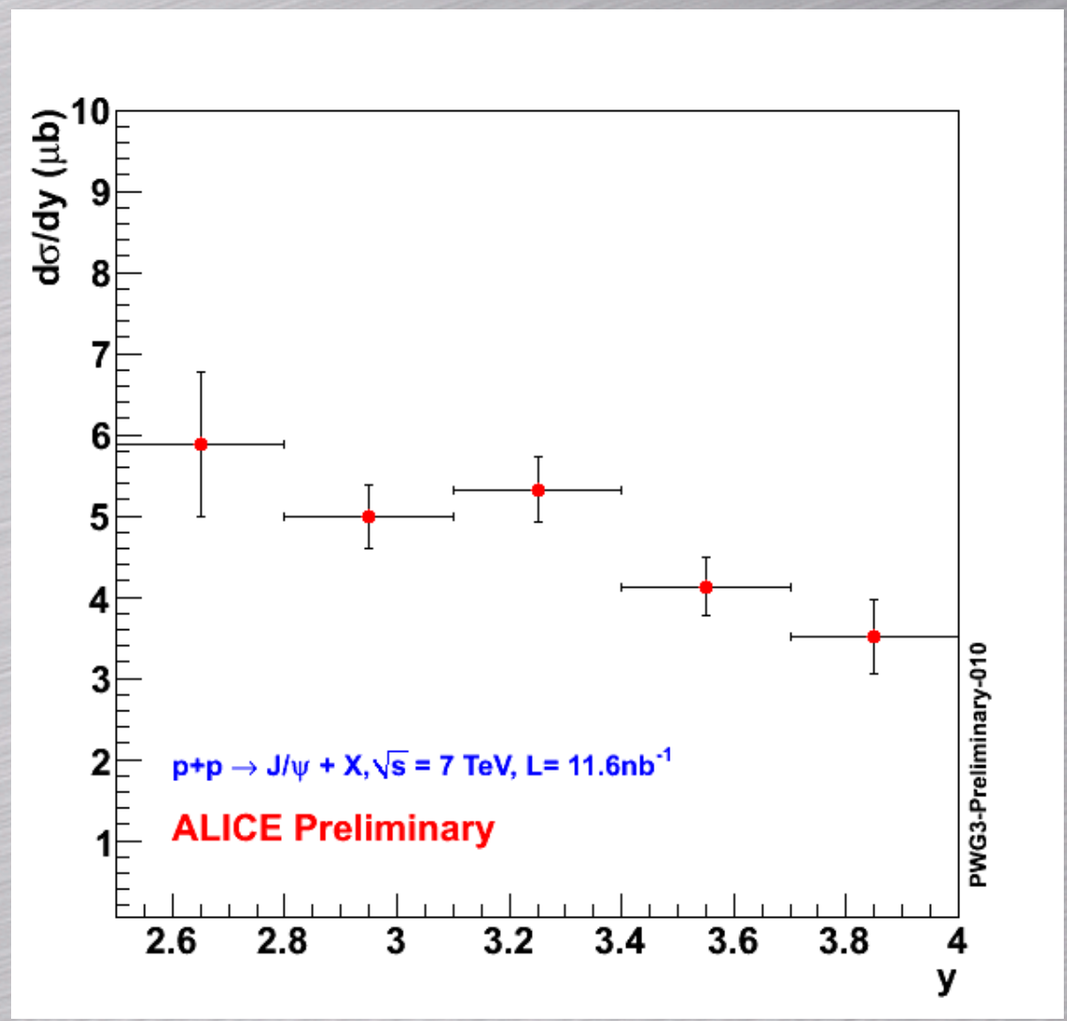
J/ψ in $\mu^+\mu^-$: analysis

- 7 pt bins from 0 to 8 GeV/c with L = 11.6 nb^{-1}
- 5 rapidity bins from 2.5 to 4.0
- Number of J/ψ extracted from a fit of the invariant mass spectrum :
  - Crystal ball shape for the J/ψ and ψ′
  - Double exponential for the background



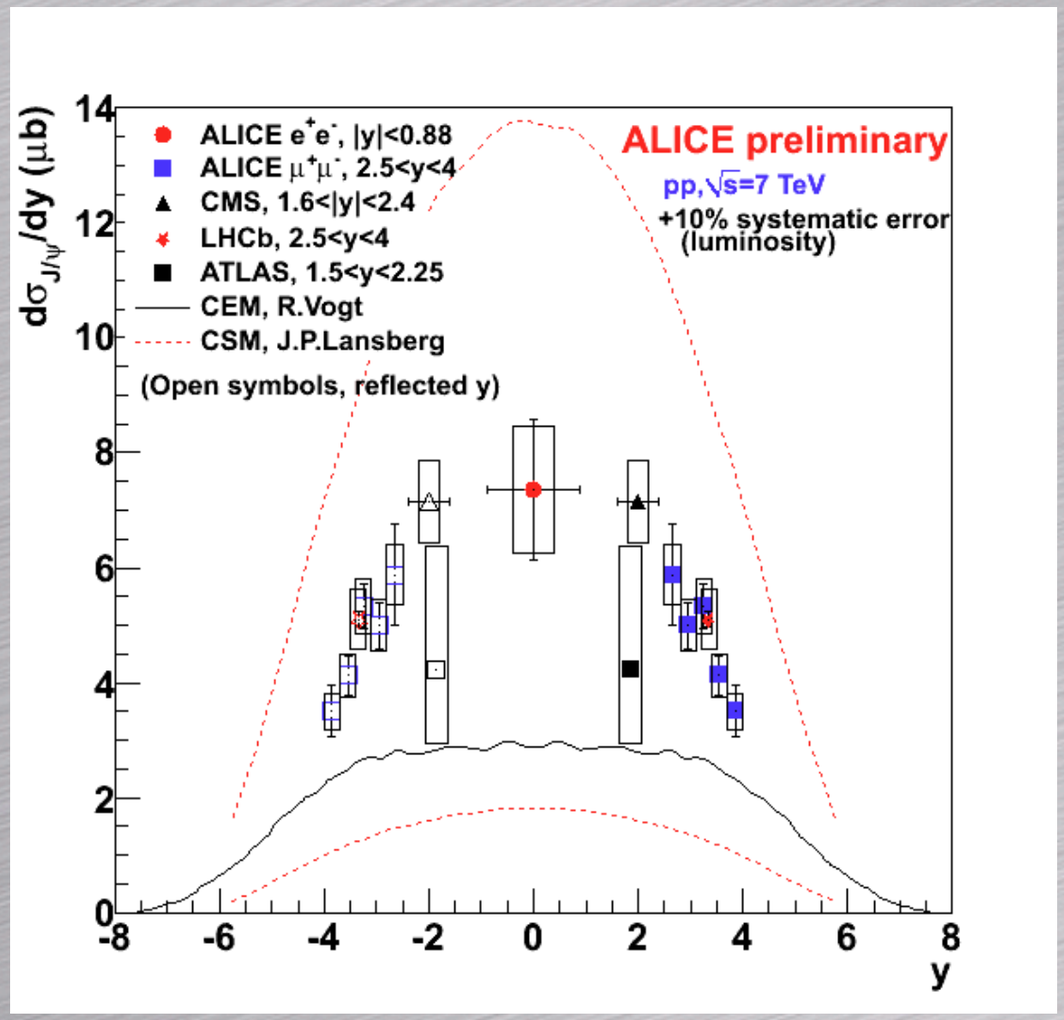
J/ψ in $\mu^+\mu^-$: Results





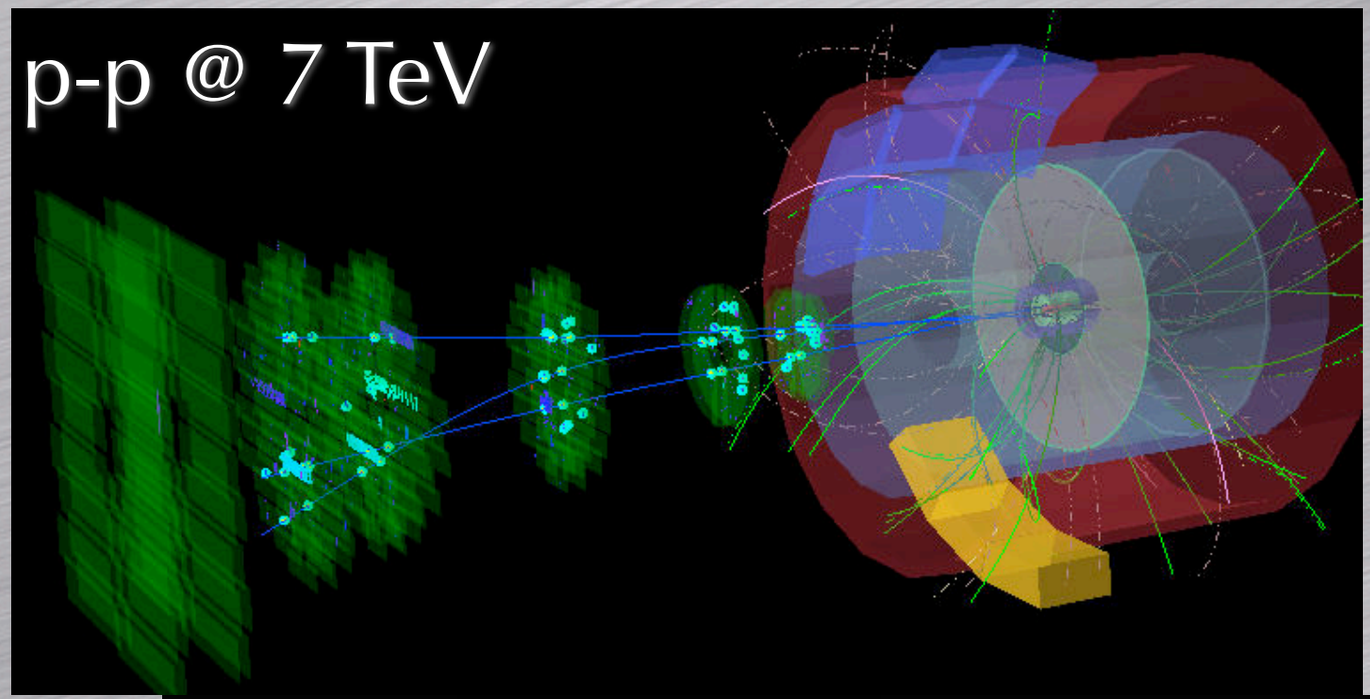
- Very good agreement with LHCb data in the same rapidity range
- Color Evaporation Model calculation underestimate the results especially at low pt
- J/ψ from B-decay need to be subtracted for meaningful comparison

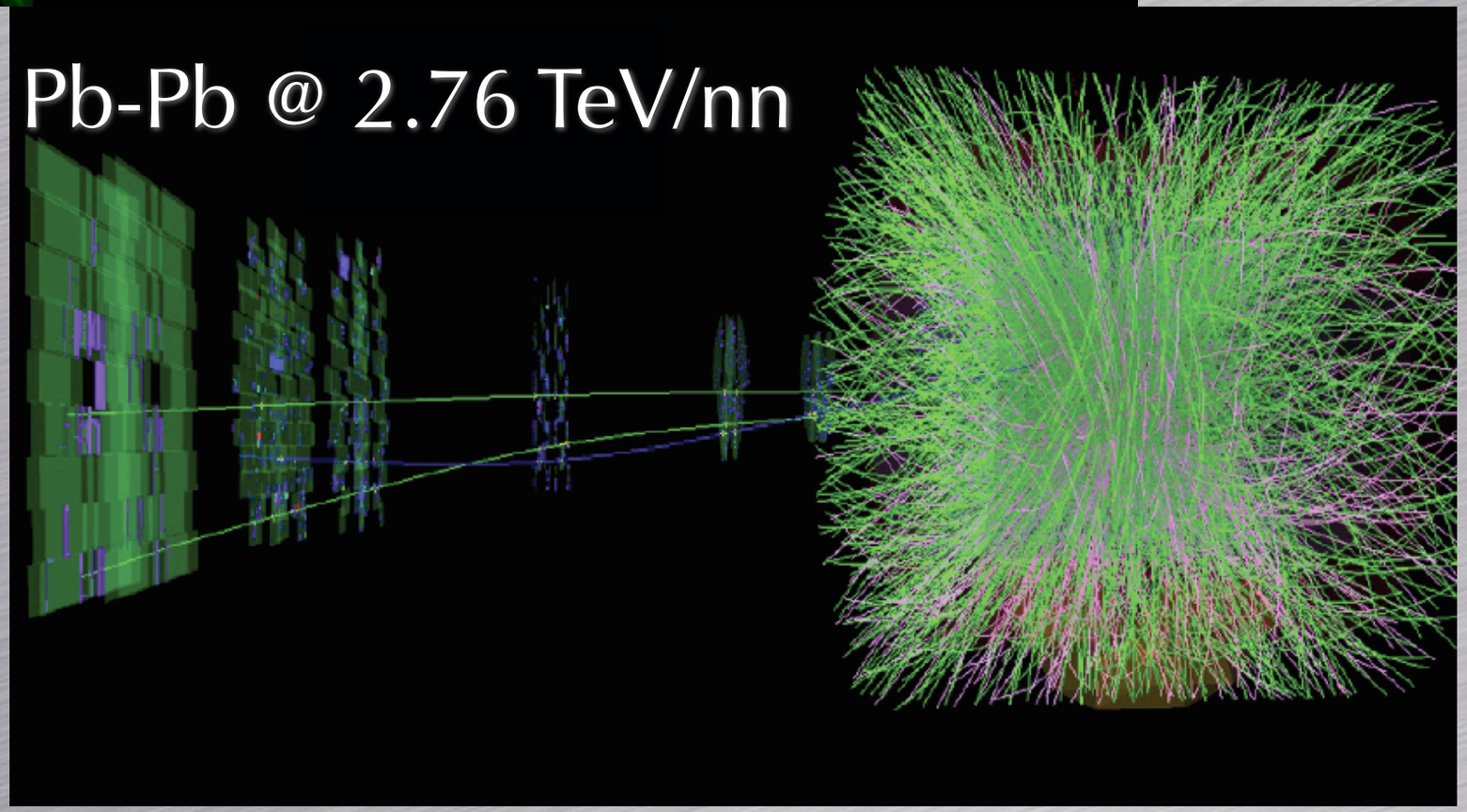
$d\sigma_{J/\psi}/dy$: $J/\psi \rightarrow \mu^+\mu^-$ & $J/\psi \rightarrow e^+e^-$



- J/ψ production cross section measured in the two rapidity ranges covered by the ALICE experiment
- Results in good agreement with other LHC experiments
- No B feed-down correction

From p-p to Pb-Pb

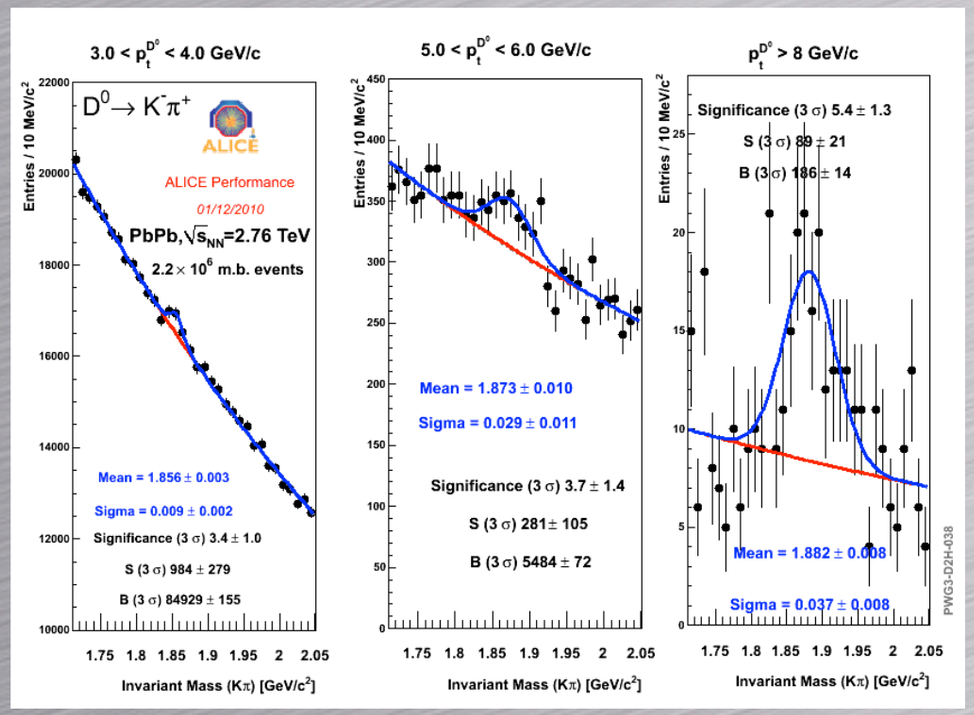




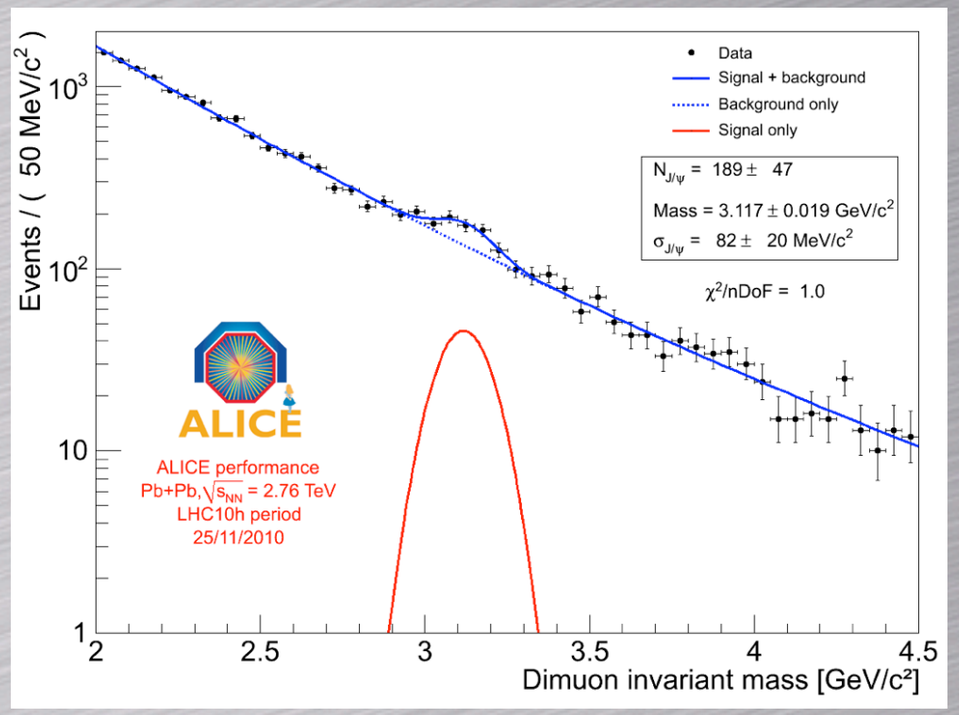
- About 45.10^6 events recorded from November 8th to December 6th

First look at the signals in Pb-Pb

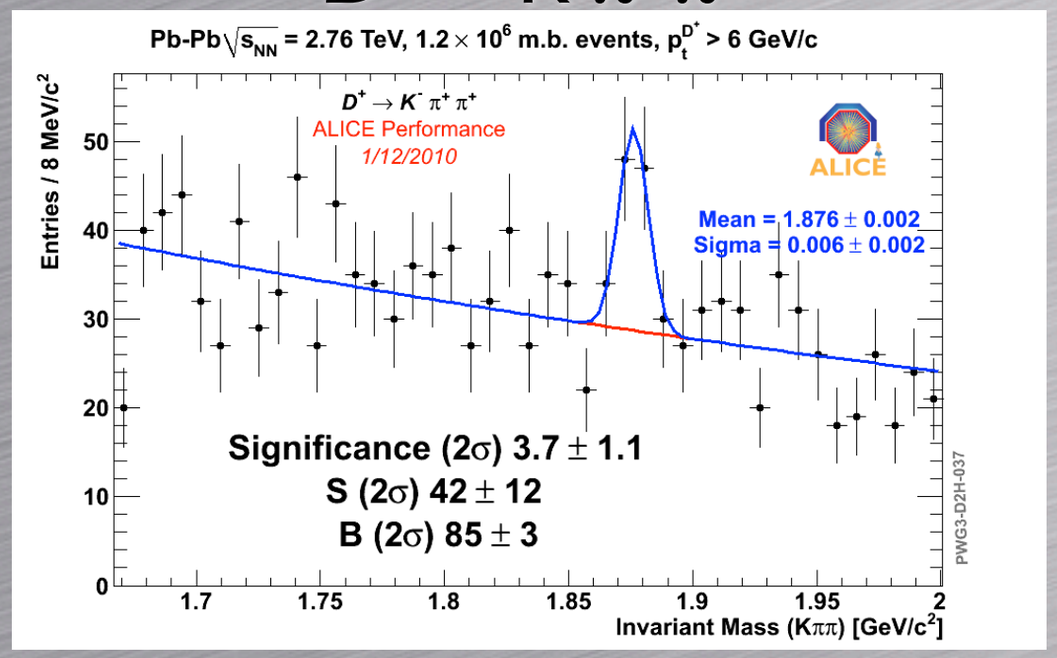
$D^0 \rightarrow K^-\pi^+$



$J/\psi \rightarrow \mu^+\mu^-$



$D^+ \rightarrow K^-\pi^+\pi^+$



- Promising signals already visible
- Analysis underway

Conclusions

- ALICE Heavy flavour program is diverse, and the analysis in p-p is well advance
- We shown first results in pp for:
  - $D^0 \rightarrow K^-\pi^+$
  - $J/\psi \rightarrow e^+e^-$
  - $D^+ \rightarrow K^-\pi^+\pi^+$
  - $J/\psi \rightarrow \mu^+\mu^-$
  - D,B → μ + X
  - D, B → e + X
- Others signals are under study:
  - $D^0 \rightarrow K\pi\pi\pi$
  - $D^* \rightarrow D^0\pi$
  - $D_s \rightarrow KK\pi$
- p-p results are the reference for in medium effect analysis in Pb-Pb
- Analysis in Pb-Pb is progressing