Introduction to J/ψ analysis
$J/\psi \rightarrow e^+e^-$

Ionut Arsene,
Uinversity of Oslo
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Motivation

- See lecture on heavy quarkonia (wednesday)

Introduction

- Reference with analysis description: ALICE Collaboration, arXiv: 1105.0380
- Study inclusive J/ψ production in pp collisions at √s=13 TeV at mid-rapidity using the ALICE central barrel
- Reconstruct J/ψ via its dielectron decay channel
  - J/ψ → e^+e^- (5.97%)
    - → $e^+e^-\gamma$ (0.88%)
- Inclusive J/ψ:
  - Prompt (short lifetimes – not-distinguishable experimentally)
    - Direct J/ψ (directly produced in the collision)
    - Feed-down from higher mass charmonia: χ_c(1P), ψ(2S,3S…)
  - Non-prompt (long lifetimes - ~500 μm)
    - J/ψ from B-mesons decay

Introduction

- J/ψ production cross-section:

$$\sigma_{J/\psi} = \frac{N_{J/\psi}}{(A \times \varepsilon)\, BR(J/\psi \rightarrow ee)} \times \frac{\sigma_{MB}}{N_{MB}}$$

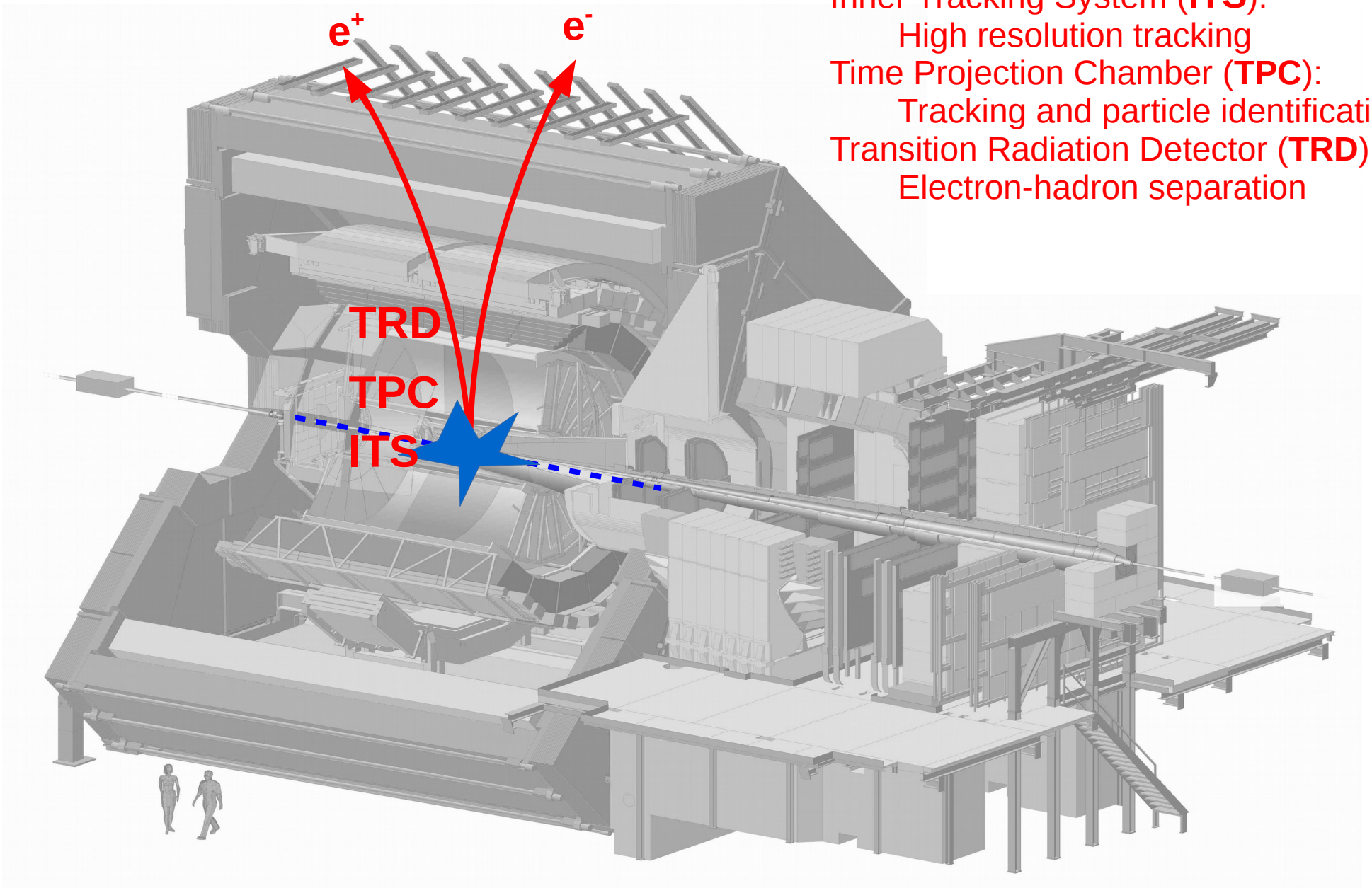
- $N_{J/\psi}$ – raw number of J/ψ counts
- $(A \times \varepsilon)$ – acceptance and efficiency correction
- σ_{MB} – total cross-section of the minimum bias trigger
- N_{MB}- number of inspected minimum bias events

Event selection

- Select good collision candidates
  - Minimum bias trigger fired
  - Reject background events
  - Reject pile-up events
- Good event vertex position ($|z|<10$ cm)
  - Ensure good detector coverage

Electron selection

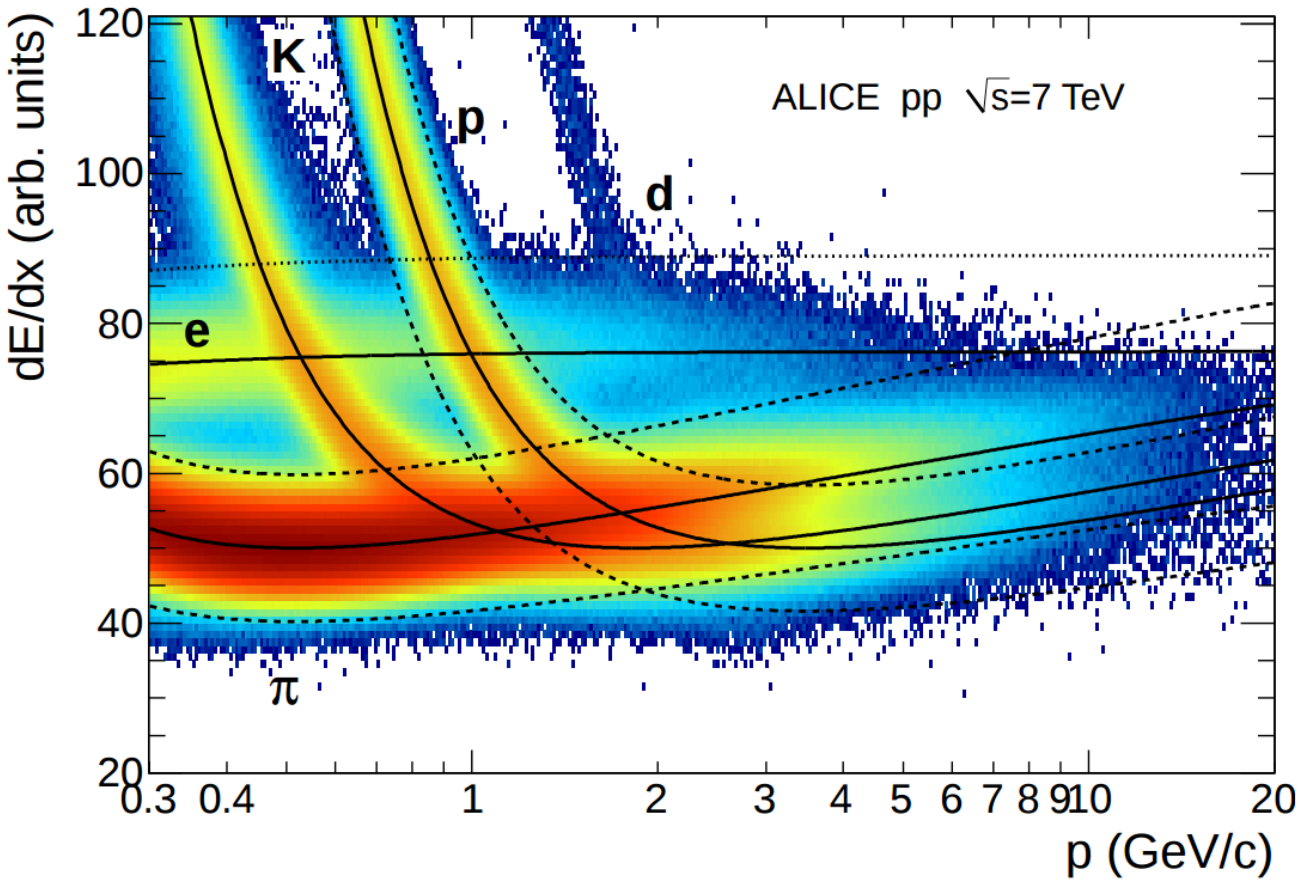
Inner Tracking System (**ITS**):
High resolution tracking
Time Projection Chamber (**TPC**):
Tracking and particle identification
Transition Radiation Detector (**TRD**):
Electron-hadron separation



Kinematic and track quality selection

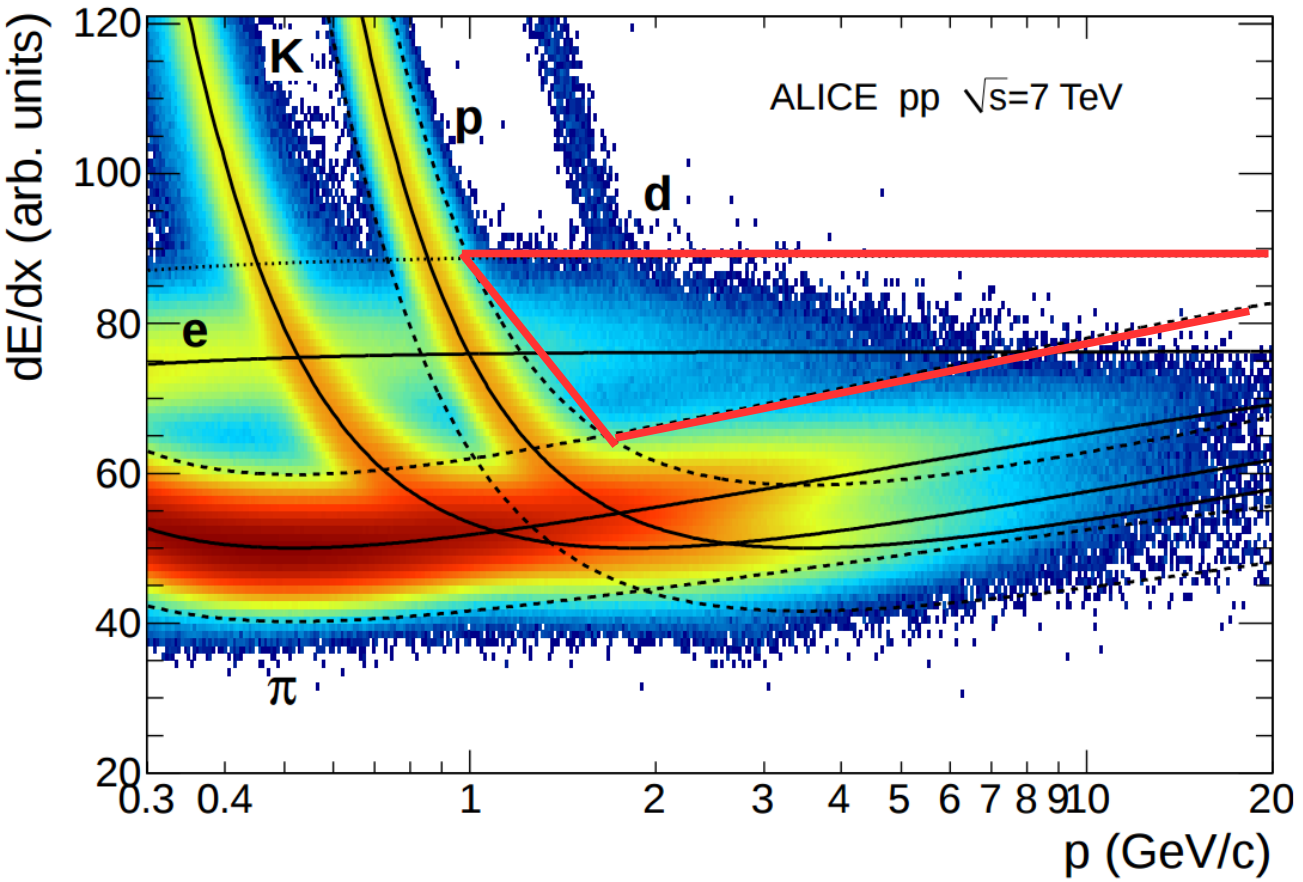
- Kinematics
  - $m_{J/\psi}$=3.1 GeV/c^2: decay into electron pairs with large “momentum kick”
  - A J/ψ at rest generates 2 electrons of P ~ 1.55 GeV/c
    - This motivates using high kinematic cuts (p_T>1 GeV/c)
  - ALICE detector coverage: |η|<0.9
- Primary tracks: |DCA_{xy}|<1cm, |DCA_z|<3cm
- Track quality:
  - ITS: request at least 1 hit in the SPD (innermost 2 layer of the ITS)
  - TPC: 70 clusters (out of 159); χ^2/ndf<4

Electron identification



- Electrons identified using the specific energy loss in the TPC gas (dE/dx)
- $|n\text{-}\sigma^{e}|<3$, $n\text{-}\sigma^{\pi}>3$, $n\text{-}\sigma^{p}>3$

Electron identification



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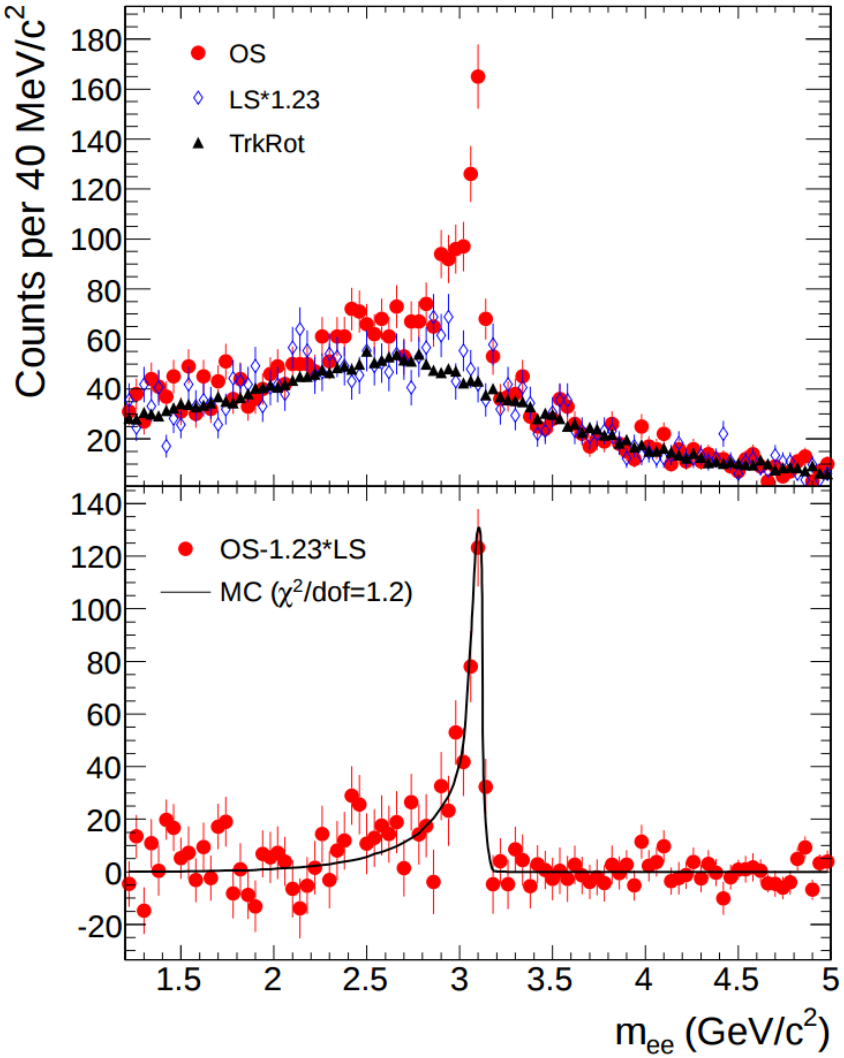
Electron selection

```
//_____________________________________________________________
Bool_t SelectElectron(AliReducedTrackInfo* track) {
  //
  // select electrons for J/psi decays
  //

  // Kinematic cuts
  if(track->Pt()<1.0) return kFALSE;
  if(TMath::Abs(track->Eta())>0.9) return kFALSE;

  // track quality
  if(track->ITSncls()<4) return kFALSE;
  if(track->TPCncls()<100) return kFALSE;

  // PID
  if(TMath::Abs(track->TPCnSig(0))>3.0) return kFALSE;
  if(track->TPCnSig(1)<3.0) return kFALSE;
  if(track->TPCnSig(3)<3.0) return kFALSE;

  return kTRUE;
}
```

Signal extraction

- Invariant mass distribution for e^+e^- pairs
- Note: J/psi peak does not follow a typical Breit-Wigner distribution
  - Electron energy loss via Brehmsstrahlung
  - Radiative J/psi decay
- Signal obtained by summing the background subtracted number of counts in a specified signal region (2.92 – 3.16 GeV/c²)
- Background estimation methods:
  - Same-event like-sign
  - Mixed event unlike-sign
  - Track rotation
  - Function fits



$$m^2 = 2m_e^2 + 2\left[\sqrt{m_e^2 + P_1^2}\sqrt{m_e^2 + P_2^2} - \vec{P}_1\vec{P}_2\right]$$

2-particle loop to build the invariant mass spectrum

```
// build unlike-sign invariant mass distribution
for(Int_t i=0;i<positrons.GetEntries();++i) {
  AliReducedTrackInfo* posTrack = (AliReducedTrackInfo*)positrons.At(i);
  for(Int_t j=0;j<electrons.GetEntries();++j) {
    AliReducedTrackInfo* negTrack = (AliReducedTrackInfo*)electrons.At(j);

    Float_t mass = 5.1e-4*5.1e-4+ 5.1e-4*5.1e-4 +
    2.0*(TMath::Sqrt(5.1e-4*5.1e-4+posTrack->P()*posTrack->P())*TMath::Sqrt(5.1e-4*5.1e-4+negTrack-
    >P()*negTrack->P()) -
    posTrack->Px()*negTrack->Px() - posTrack->Py()*negTrack->Py() - posTrack->Pz()*negTrack->Pz());

    if(mass<0.0) {
      mass = 0.0;
    }
    else mass = TMath::Sqrt(mass);
    histMassUS->Fill(mass);
  }
}
```

Like-sign (LS) background

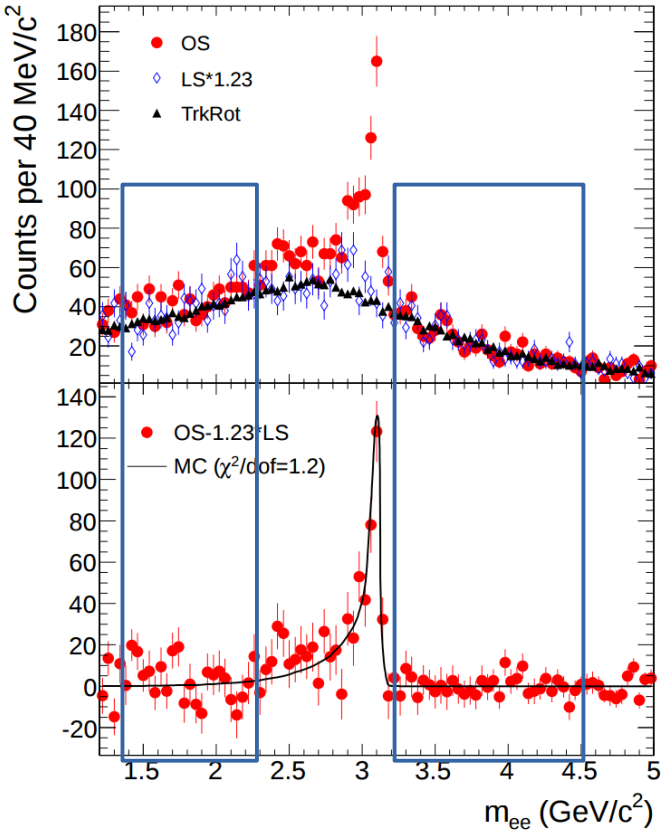
- Obtained by constructing the invariant mass spectrum for like-sign electron pairs (e+e+ and e-e-)

$$LS = 2\sqrt{N_{pp} \times N_{mm}}$$

- LS background is self-normalized

Mixed event (ME) background

- Obtained by constructing the invariant mass spectrum of unlike-sign electron pairs, where the e+ and e- belong to different events
- ME background needs to be normalized to match the SE distribution:
  - Use side-bands around the J/psi signal region

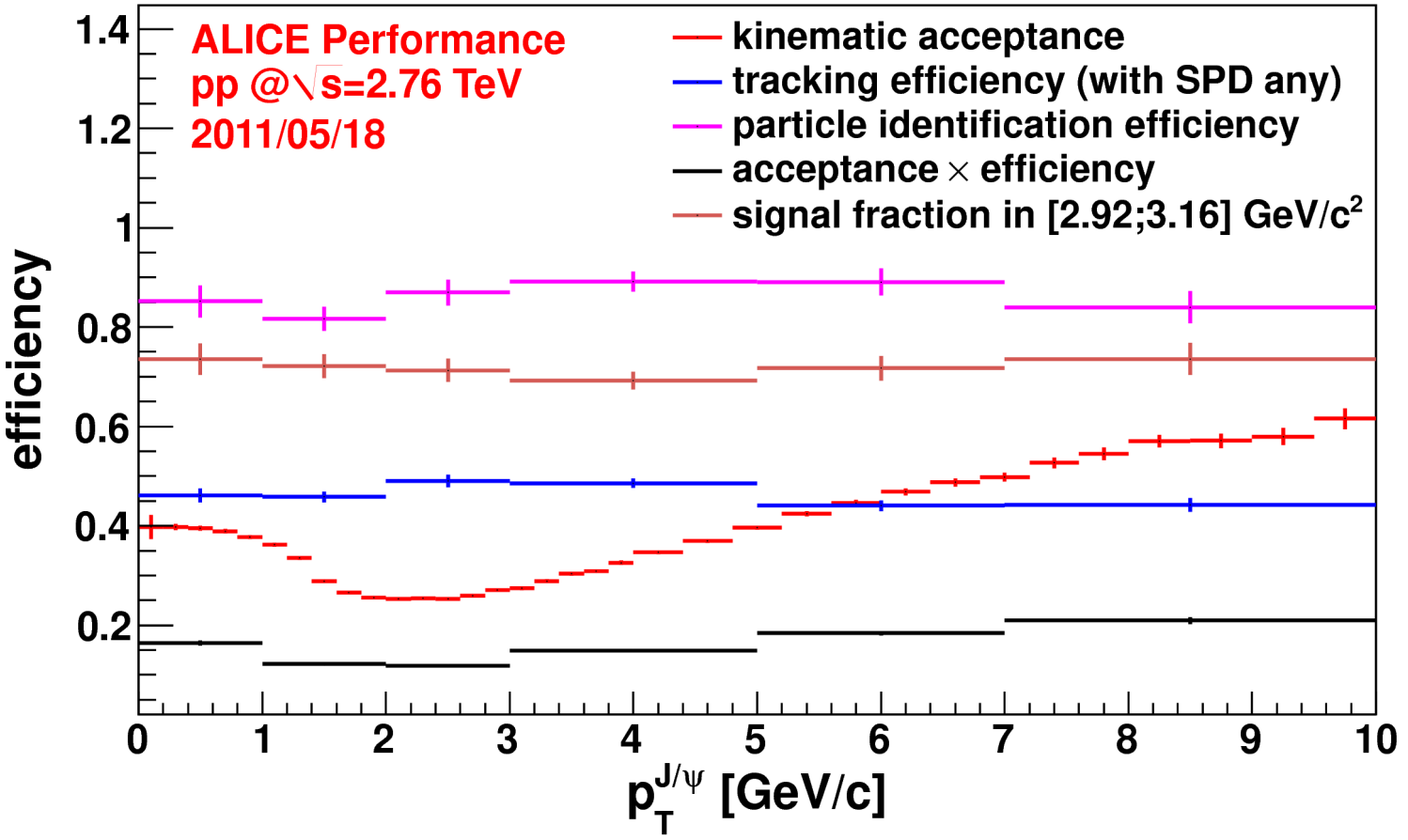


Mixed event (ME) background

- Obtained by constructing the invariant mass spectrum of unlike-sign electron pairs, where the e+ and e- belong to different events
- ME background needs to be normalized to match the SE distribution:
  - Use side-bands around the J/psi signal region
  - Normalize to the like-sign event distribution

Acceptance and efficiency correction

- Acceptance and efficiency corrections obtained using Monte-Carlo simulations with embedded J/psi particles
  - $A \times \varepsilon = N_{rec} / N_{gen}$

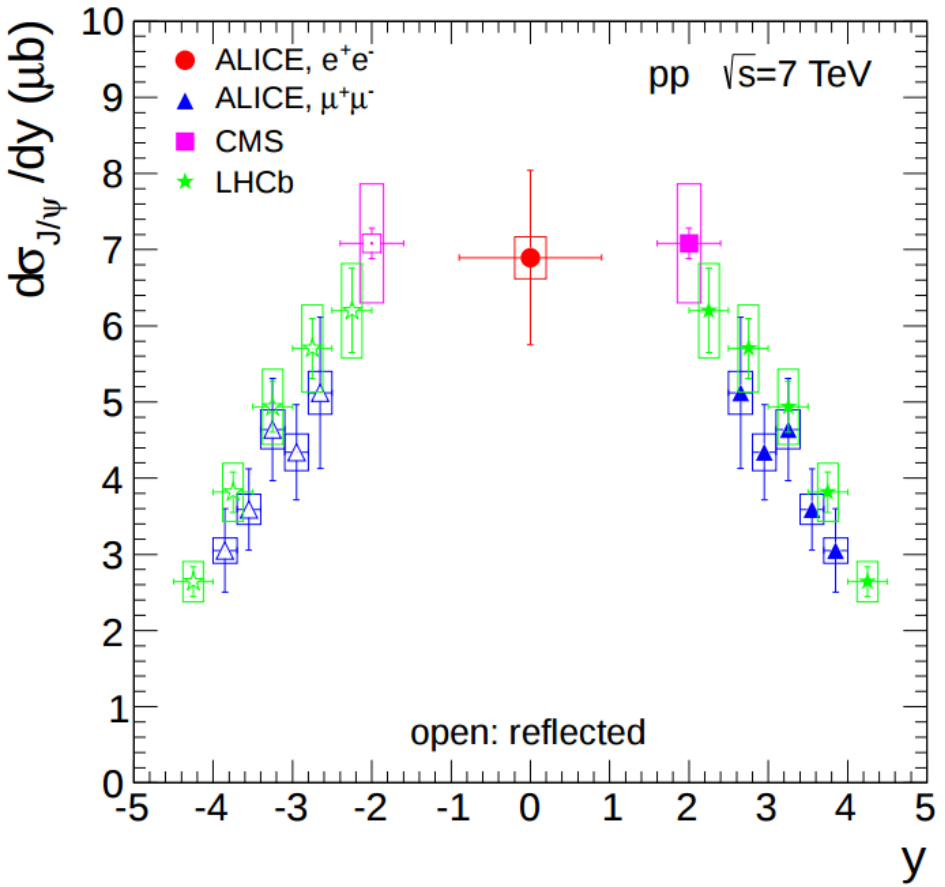


Normalization

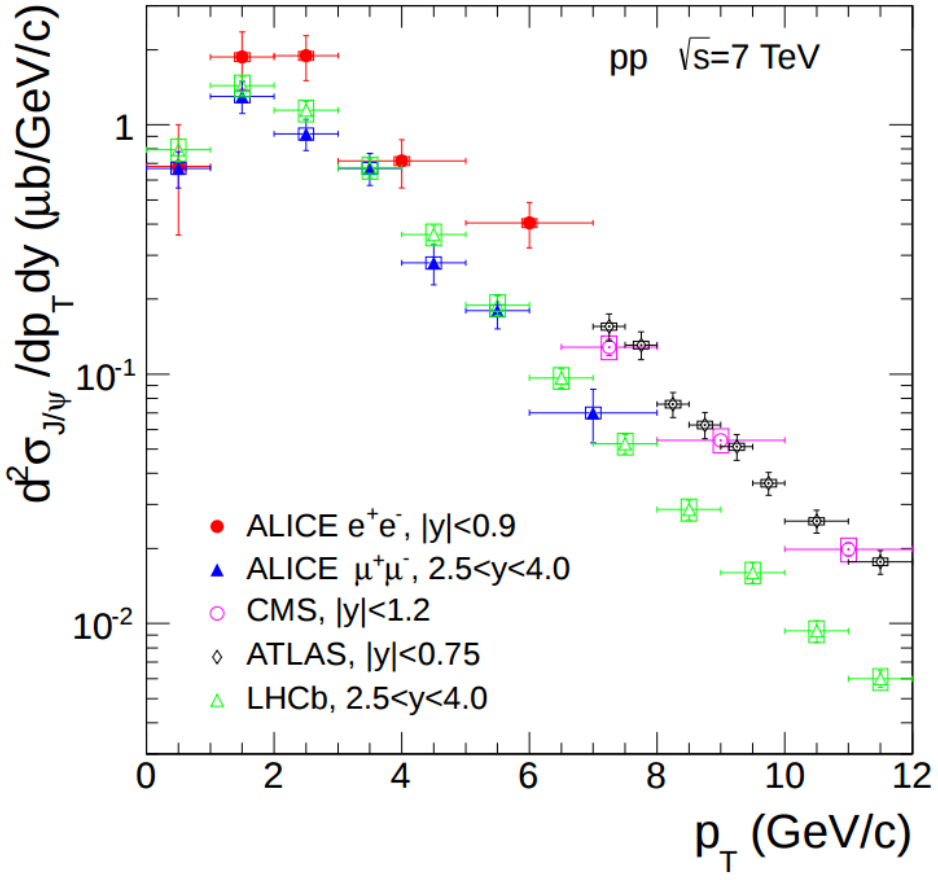
- Cross-section of the MB trigger measured using van der Meer scans
- Number of inspected MB events
  - All events which passed the event selection criteria (including the MB trigger condition)

Corrected inclusive cross-section

p_T-integrated cross-section



p_T-differential cross-section



Exercises

- Electron identification using the TPC dE/dx

- Constructing an invariant mass distribution
  - Unlike-sign distribution
  - Like-sign distribution

- Extracting the J/psi signal