Physics with the ALICE TRD

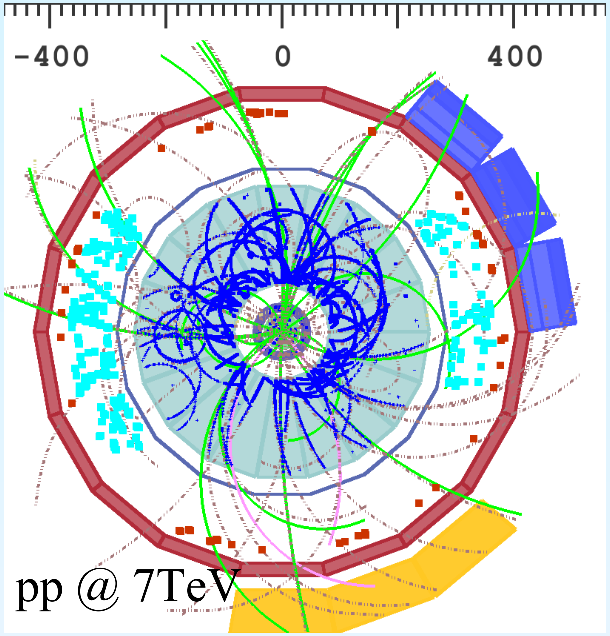
Yvonne Pachmayer, University of Heidelberg
for the **ALICE Collaboration**

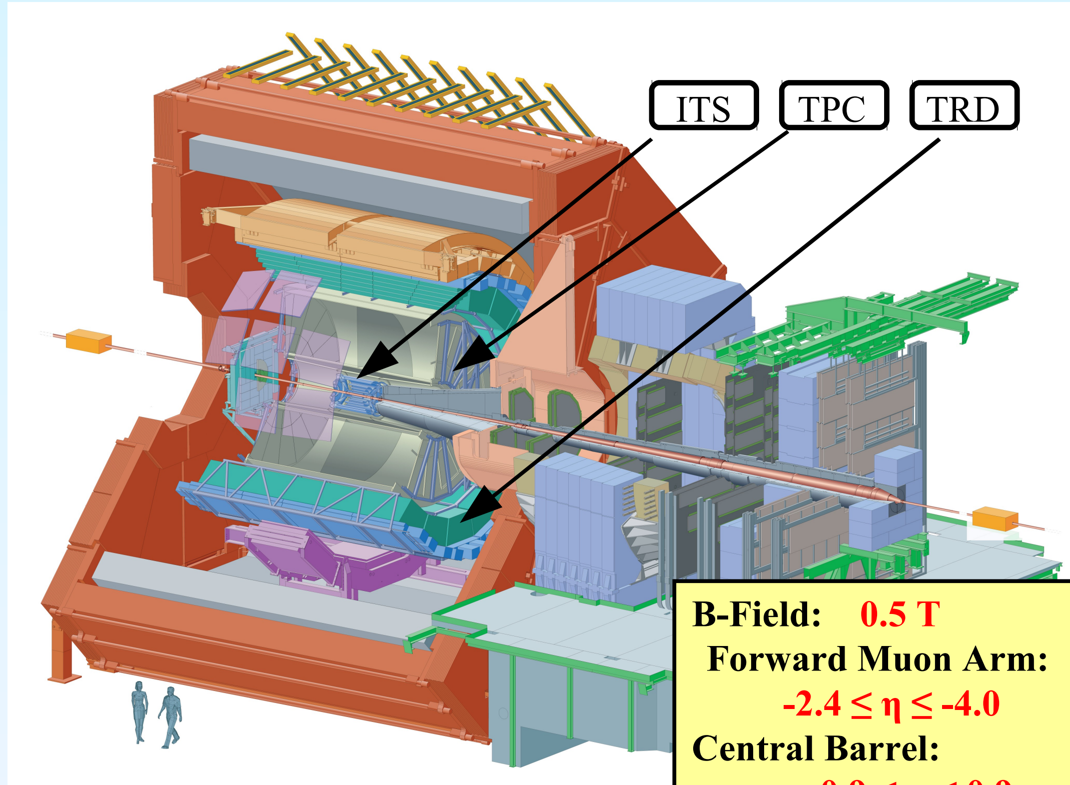
BMBF Forschungsschwerpunkt
ALICE Experiment 201
ALICE

EMMI

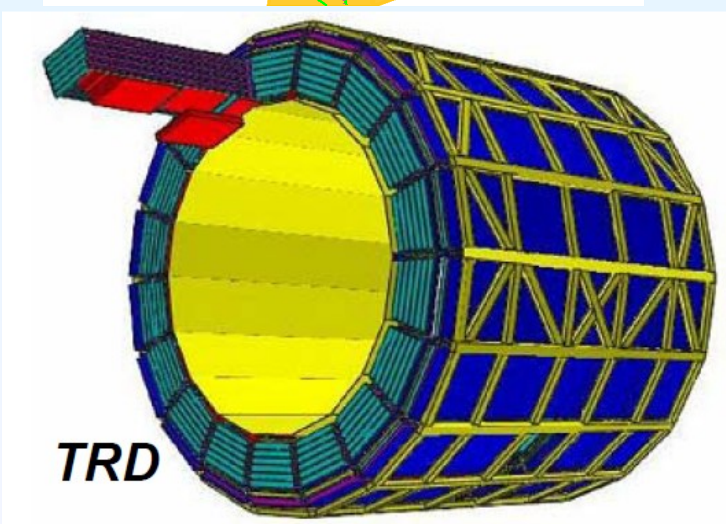
- **ALICE TRD**
- **Physics cases (examples)**
  - Quarkonia
  - Jets
  - Open Charm and Beauty
- **Conclusion and outlook**

A Large Ion Collider Experiment





B-Field: 0.5 T
Forward Muon Arm:
$-2.4 \leq \eta \leq -4.0$
Central Barrel:
$-0.9 \leq \eta \leq 0.9$



- Dedicated experiment to study all aspects of heavy ion collisions at LHC
- TRD for
  - Electron ID at p > 1 GeV/c
  - Fast (6 μs) triggering for high-p_T + PID
  - Improving the momentum resolution

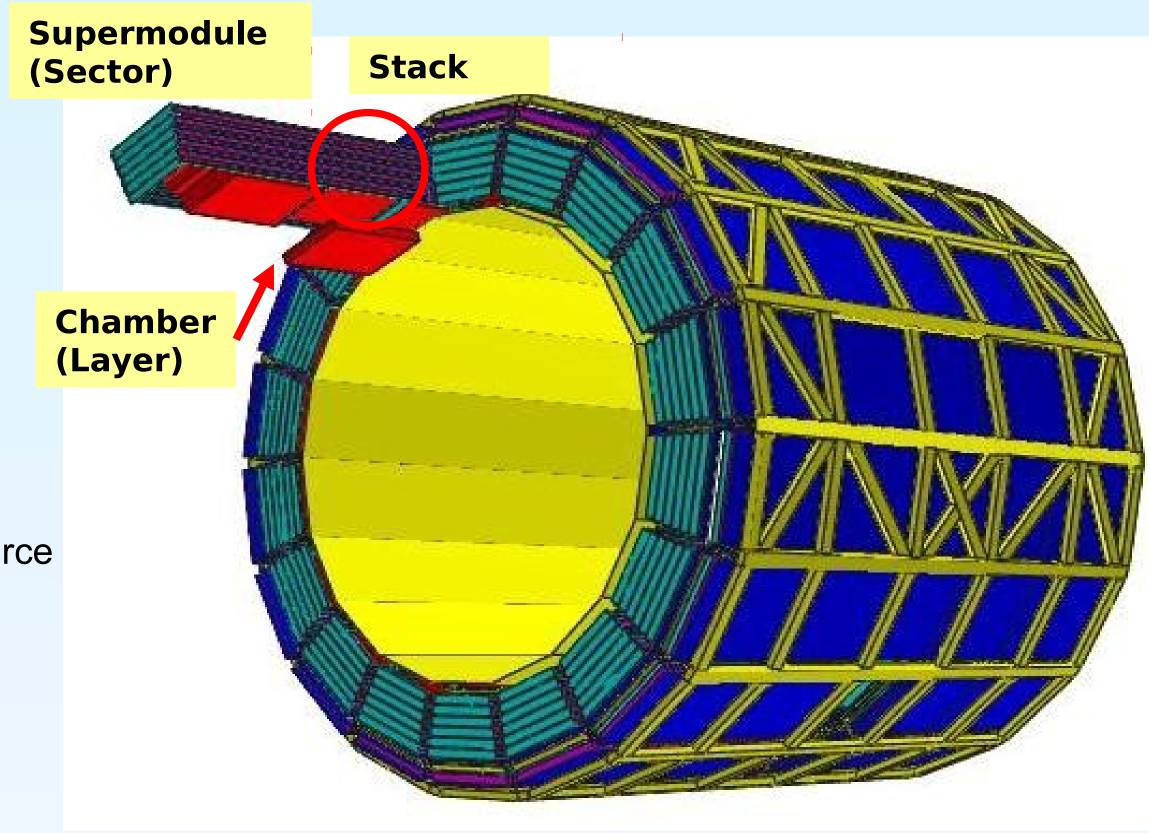
Transition Radiation Detector (TRD)

- **Parameters :**
  - Radial position: $2.9 < r < 3.7$ m
  - $|\eta| < 0.9$, $0 < \phi < 2\pi$
  - 522 modules (18 super-modules) → ~675 m^2
  - ~25 m^3 Xe/CO_2 (85:15)
  - 1.15 M readout channels
    - Gain Calibration with Krypton source

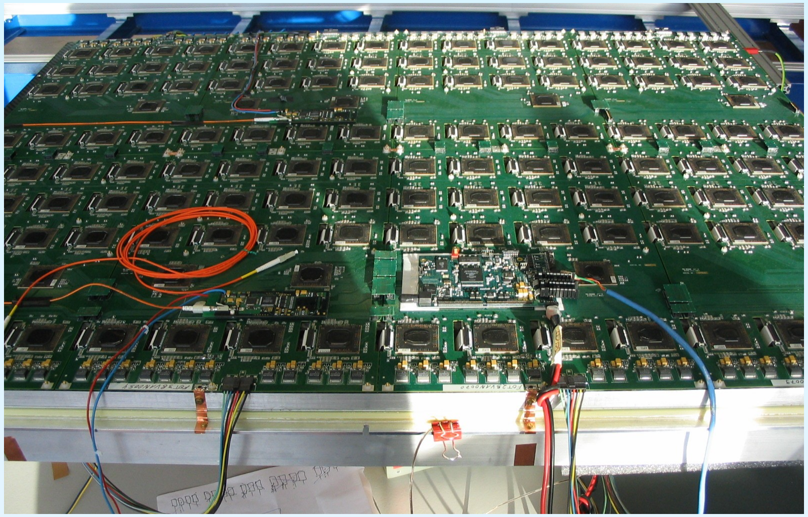
→ J. Stiller

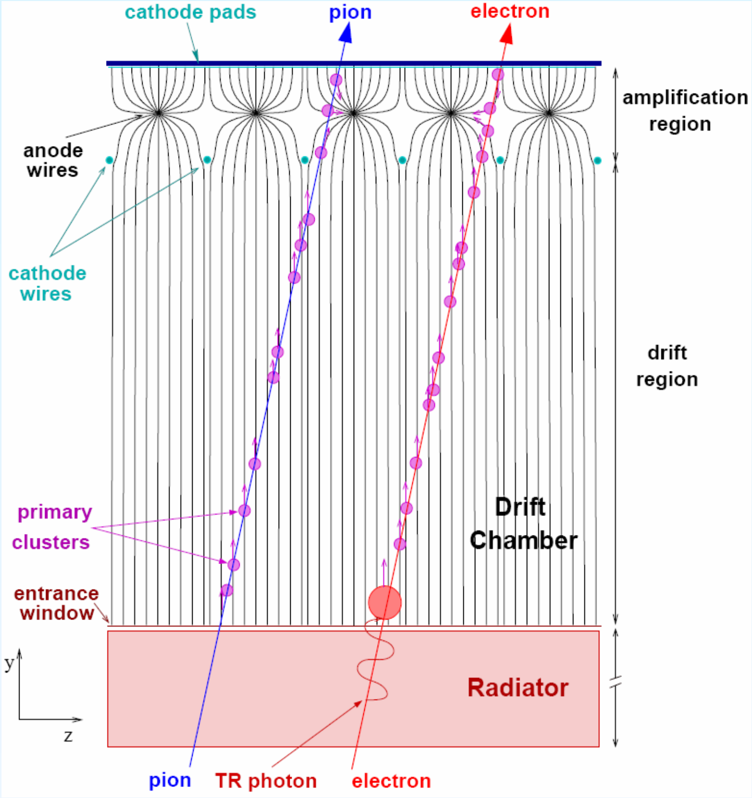
  - ≈ 25% X_0
  - weight ~ 30 t
  - total power: up to 65 kW
  - Detector Control System

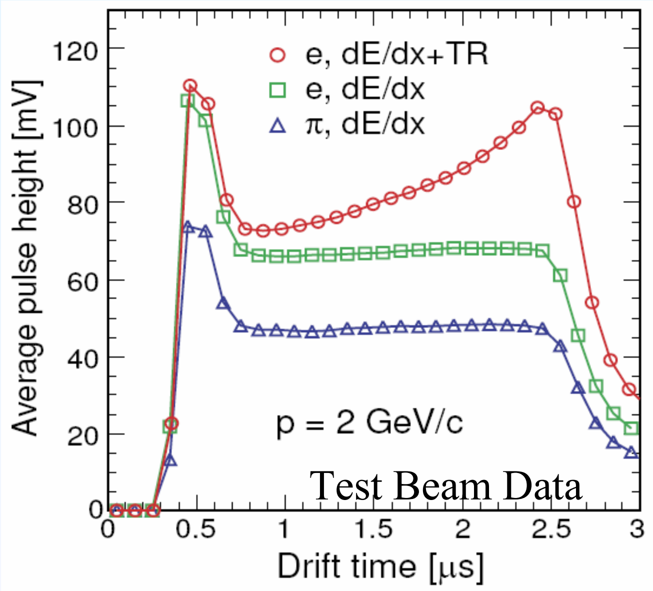
→ O. Busch



ALICE TRD Working Principle

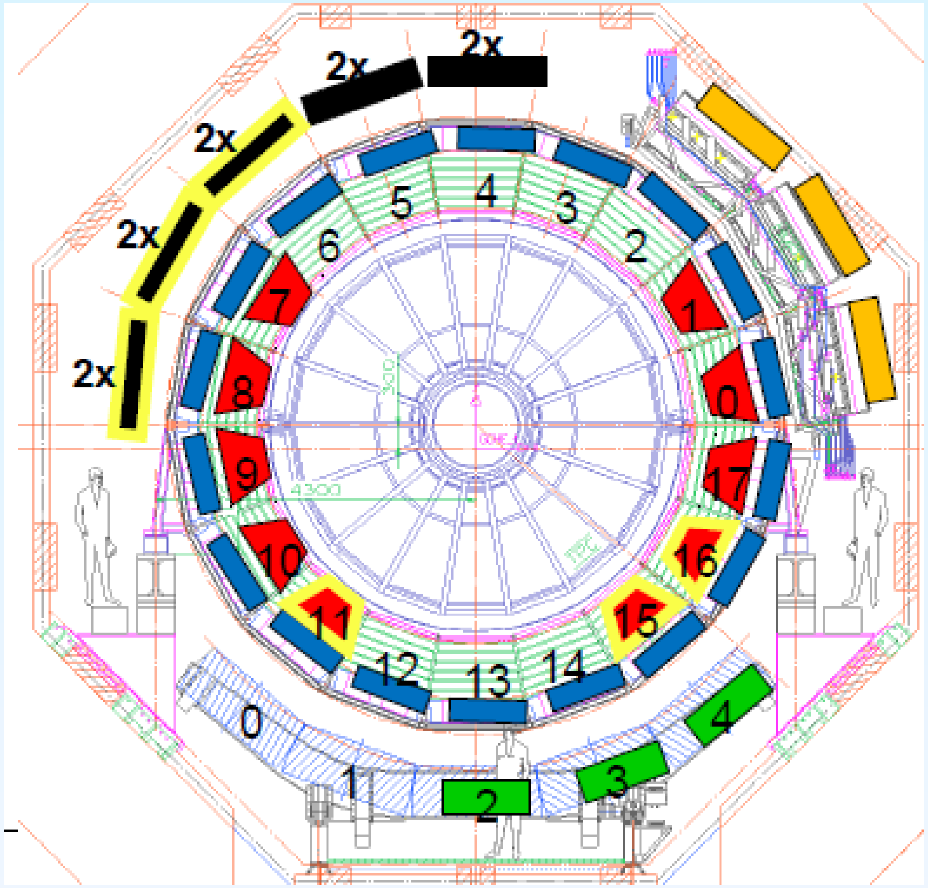


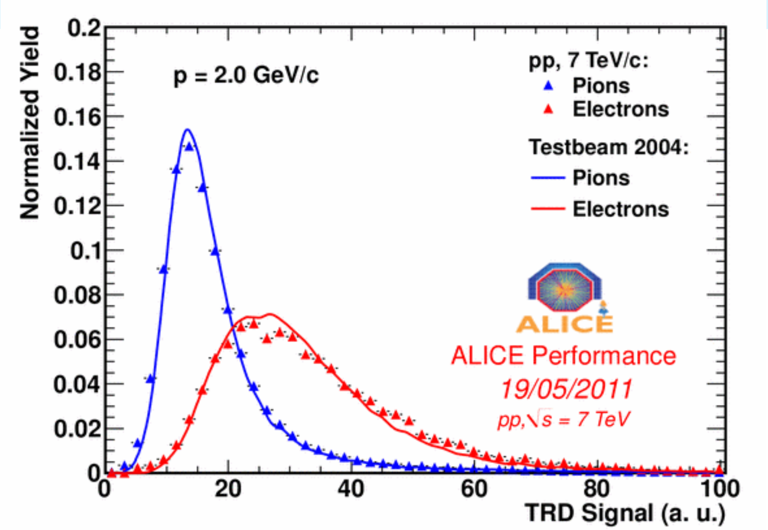


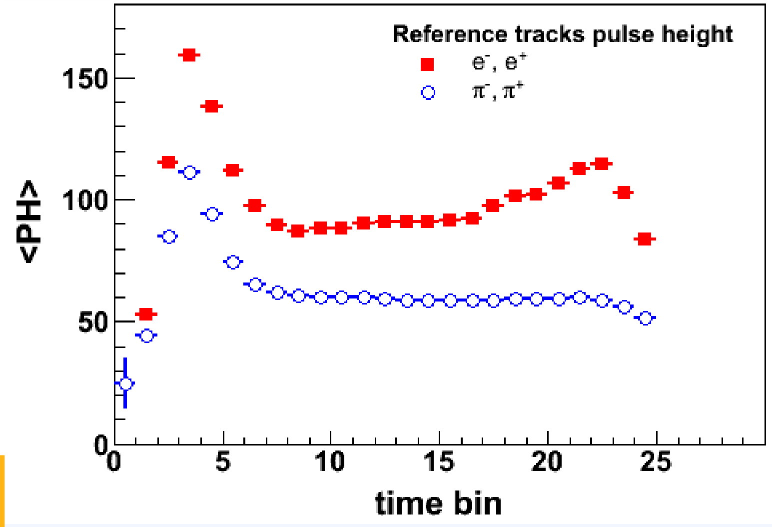


- **Charged particles at γ > 1000 give T.R. Photons**
  - Pion m = 140 MeV/c $\rightarrow p_\pi \approx$ 140 GeV/c
  - Electron m = 0.5 MeV/c $\rightarrow p_e \approx$ 0.51 GeV/c (significant T.R. photons)

PID Performance







→ C. Blume

Physics Motivation for the ALICE TRD

Systematic measurements in p+p, p+A, A+A

- **Di-electron channel**
  - Low mass vector mesons
  - J/ψ → e+e-
  - ψ' → e+e-
  - Υ → e+e-
  - Υ' → e+e-
  - $q + \bar{q} \rightarrow$ e+e- Thermal
  - $q + \bar{q} \rightarrow$ e+e- Drell-Yan
- **Single electron channel**
  - D → e + anything
  - B → e + anything
- **Coincidences of electrons and muons**
- **Trigger for jets**

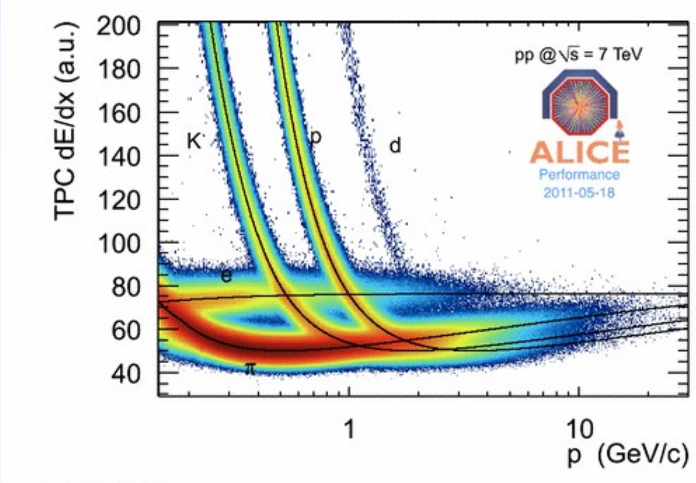
→ TRD significantly expands the physics objectives of ALICE

➔ Provide information about the de-confined QGP medium state

- e.g. J/ψ suppression or enhancement

➔ Initial scattering information and effect of the medium to it

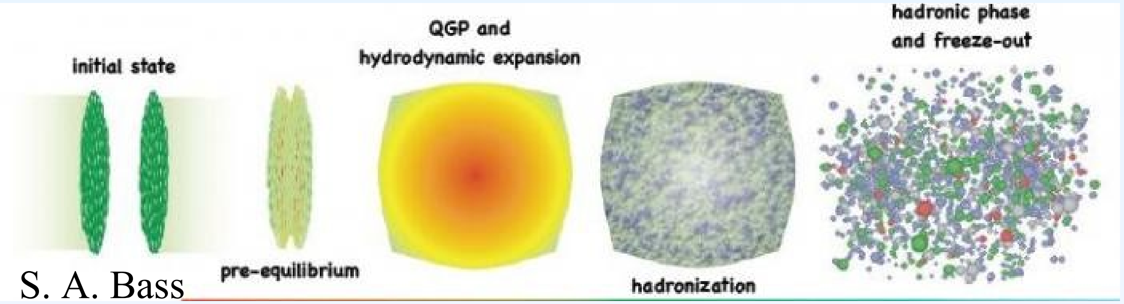
- e.g. Jet quenching



Heavy Flavour Production
Open and Hidden

- **Important probes to study the de-confined medium produced in nucleus-nucleus collisions**
- **Heavy-flavour quarks (c, b)**
  - originate from initial scattering processes
  - produced on a very short time scale ($\approx 1/(2m_q) \leq 0.1$ fm/c)

  → sensitive to the full history of the collision



S. A. Bass

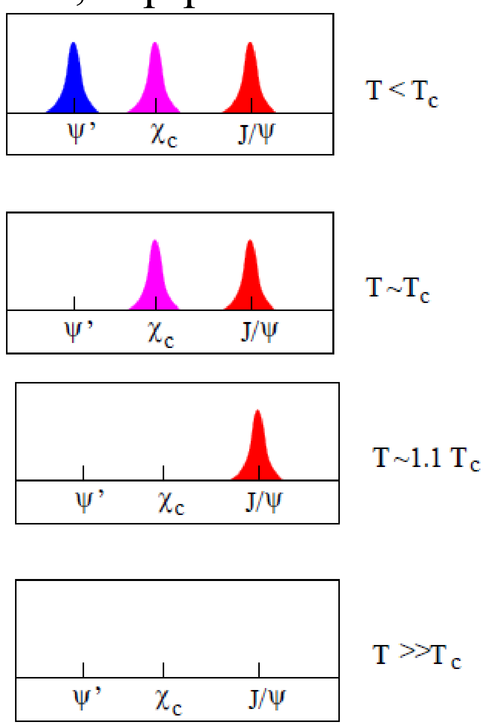
Quarkonia
From SPS/RHIC TO LHC

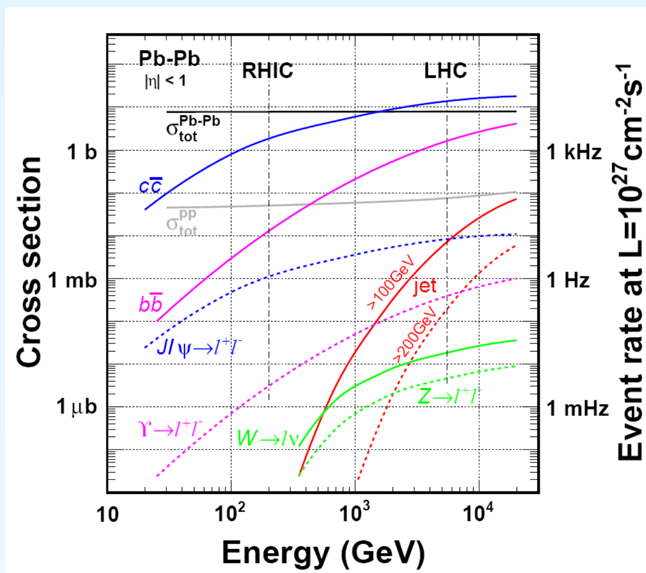
- **Charmonium dissociation**
- **LHC: larger initial charm production than at RHIC**

→ increase in J/ψ yield – fingerprint of statistical hadronization at LHC

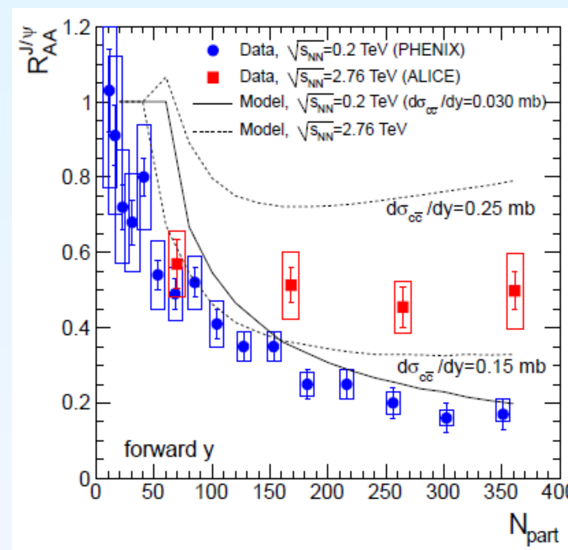
→ direct signal for de-confinement

H. Satz, hep-ph/0602245





=> Hard probes become abundantly available at LHC



A. Andronic et al arXiv:1106.6321

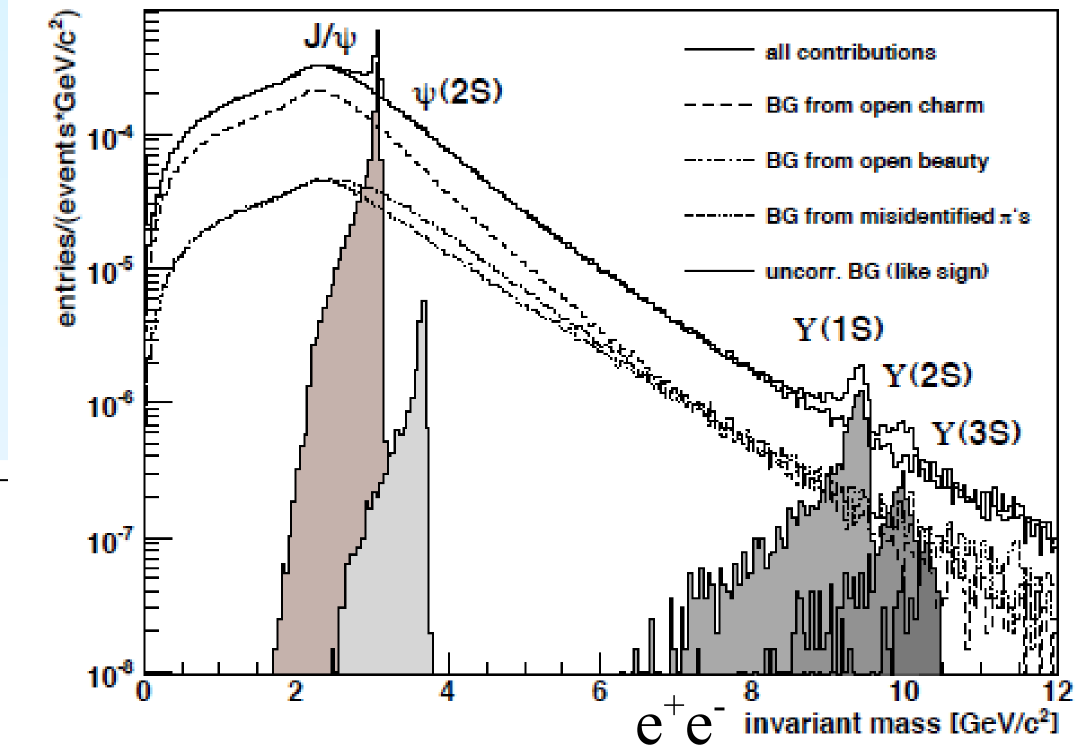
Quarkonia with ALICE TRD
Simulation (I)

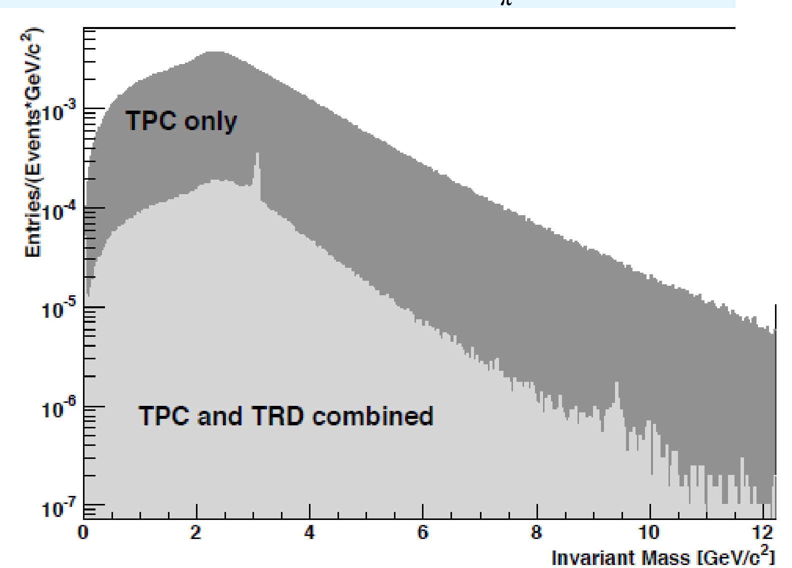
2×10^{8} central PbPb events generated with Hijing (10% most central)

W. Sommer (Univ. Frankfurt) PhD thesis

Parametrized response of barrel detectors

Full TRD
TPC and TRD PID
Electron $p_t > 1$ GeV/c
Electron efficiency: 0.9
Pion efficiency momentum dependent at $p=2$ GeV/c $\varepsilon_\pi < 10^{-4}$



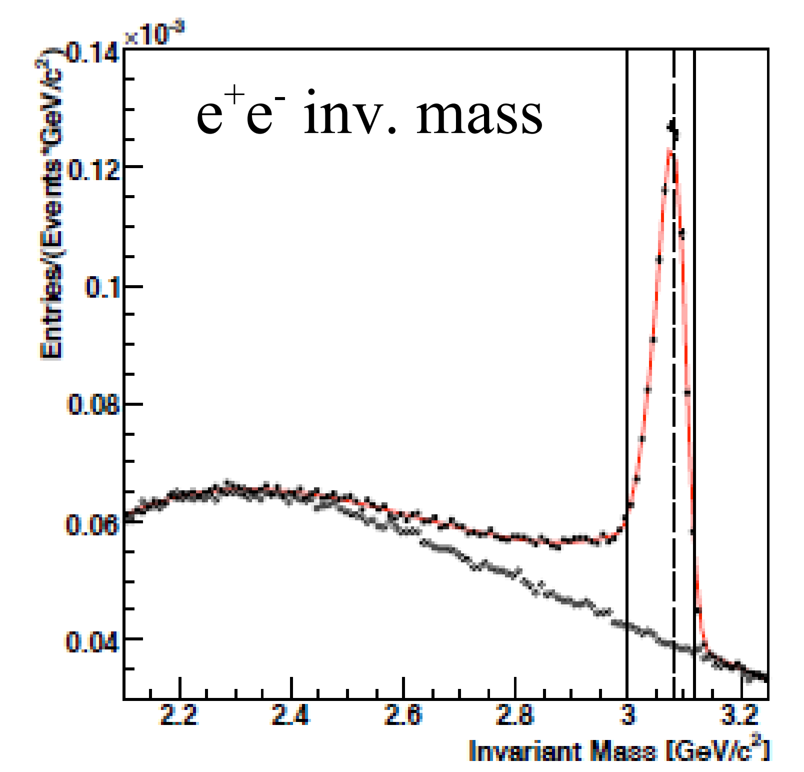


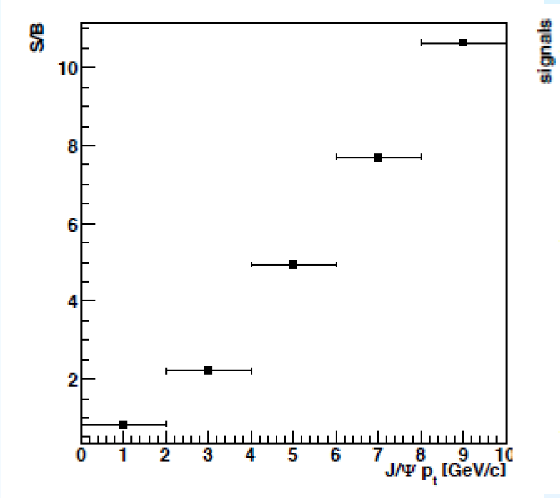
→ *Huge discrimination power*
→ *Large reduction of combinatorial background*

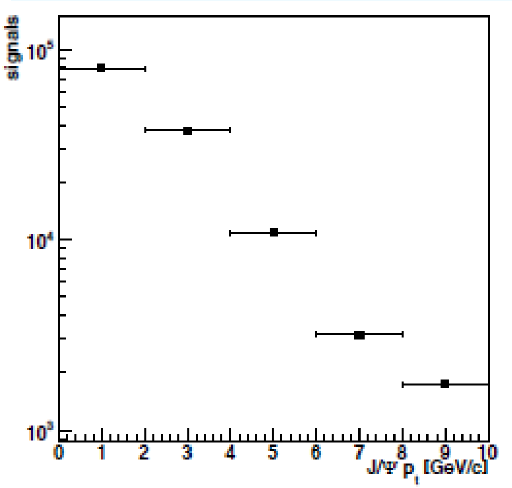
Quarkonia with ALICE TRD
Simulation (II)

2×10^8 central events generated with Hijing (10% most central)
Parametrized response of barrel detectors

W. Sommer (Univ. Frankfurt) PhD thesis





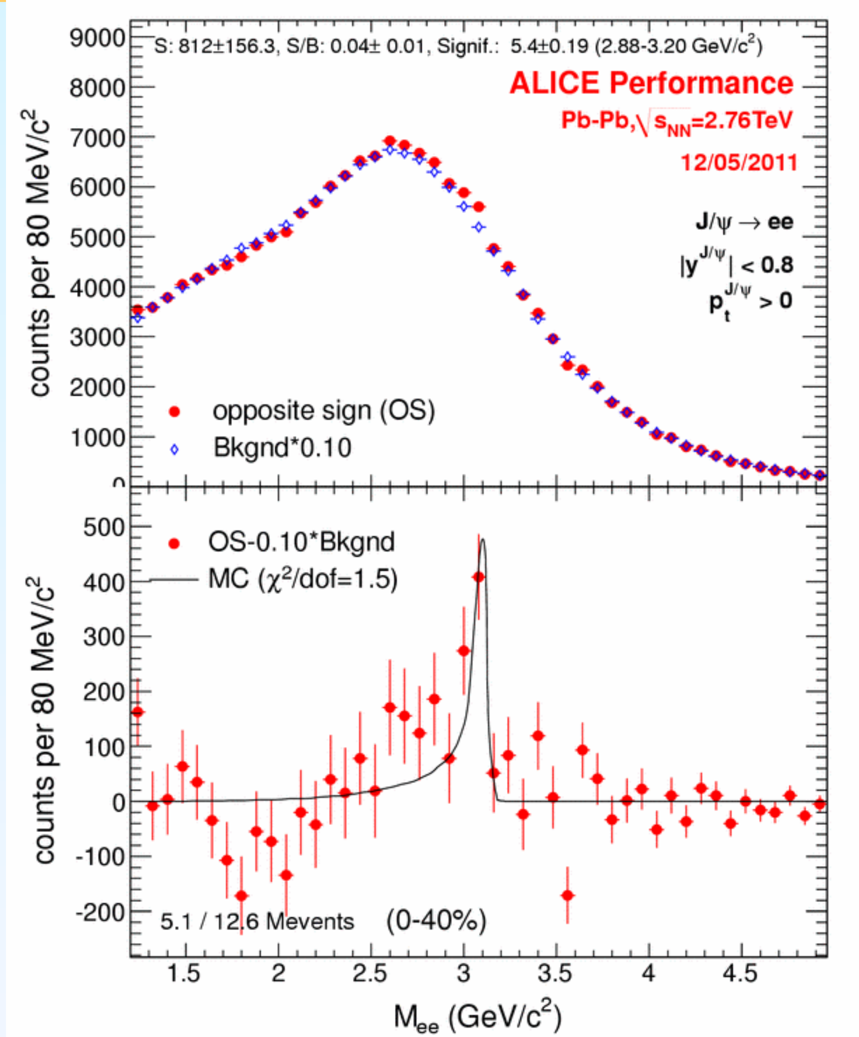


→ Good mass resolution and signal/background ratio
→ Dedicated trigger will increase statistics significantly

J/ψ
S/B = 1.47
Significance = 284
FWHM 65 MeV/c^2

Real Data: Pb-Pb @ 2.76 TeV
No TRD PID

- **Centrality: 0 - 40%**
- **Statistics: 5.1 M collisions**
- **Tuned track selection and PID cuts**
  - TPC PID only: $|n\sigma_e| < 2$, $n\sigma_\pi > 3.5$, $n\sigma_p > 3.5$
    cut on standard deviation of
    $(dE/dx - \langle dE/dx_{e\,hyp} \rangle)/\sigma$



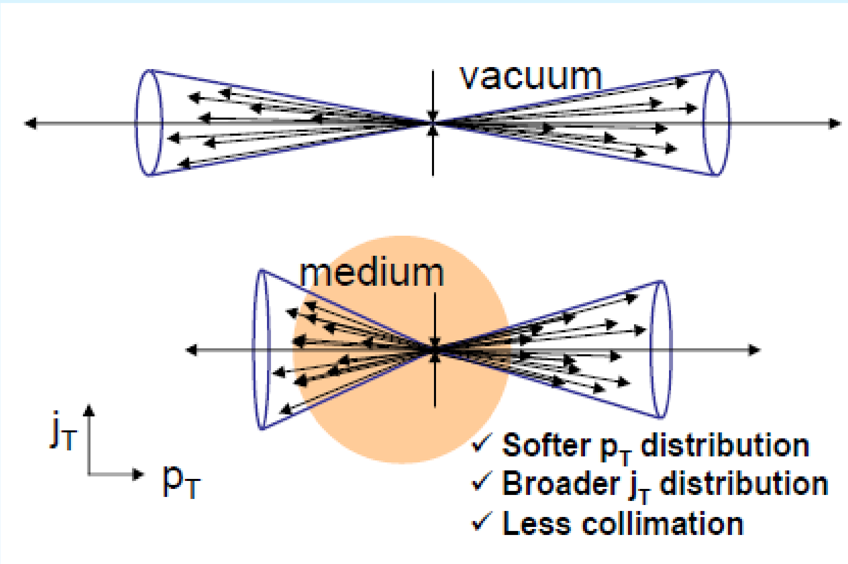
J/ψ

S/B = 0.04 ± 0.01

Significance = 5.4 ± 0.19

→ TRD PID will significantly improve S/B ratio

Jet Energy and Shape Measurements



- **In Pb+Pb:**
  - Jet quenching as a probe of medium property
  - Ncoll scaling violation
  - Modification in momentum distribution

J. Stachel, ESQGP 2008

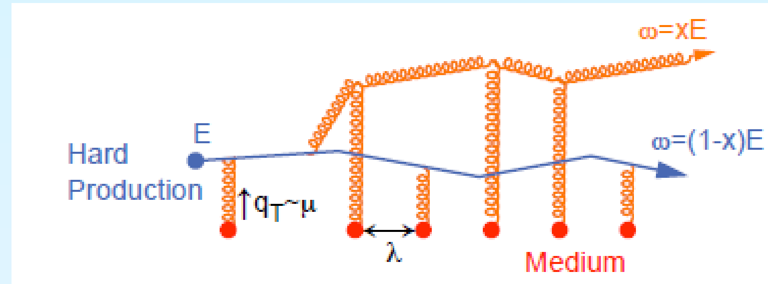
ALICE TRD provides
→ necessary trigger to enhance statistics
→ electron identification

→ J. Klein

Energy Loss in the Medium

- **Radiative energy loss**
  - Several models available
  - BDMPS:

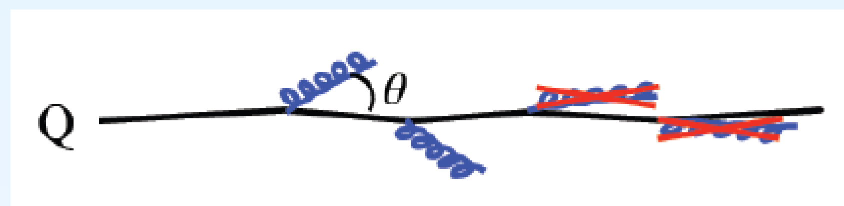
$$\langle \Delta E \rangle \propto \alpha_s C_r \hat{q} L^2$$



Casimir factor
3 for gg coupling
4/3 for qg coupling

Transport coefficient related to medium characteristics and gluon density

- **Dead cone effect**
  - Gluon radiation is suppressed for angles $\theta < M_Q/E_Q$



→ Heavy flavour energy loss should be smaller than the one of light hadrons:

$$\Delta E_g > \Delta E_{charm} > \Delta E_{beauty}$$

RAA (light hadrons) < RAA (D) < RAA (B)

Open Charm and Beauty

- **AA collisions**
  - Study hot and high density medium
  - Normalization for quarkonia
- **pA collisions**
  - Disentangle initial and final state effects
- **pp collisions**
  - Test pQCD in a new energy domain 3.5 – 7 x $\sqrt{s}_{Tevatron}$
    - c production at upper edge of FONLL prediction, at Tevatron and RHIC
  - Probe gluon PDF down to $x_{Bjorken} \sim 10^{-4}$
    - ALICE aims to measure charm cross section $p_t < 1$ GeV/c
  - Reference for pA and AA collisions

Reconstruction of Electrons from Semi-electronic c/b Decays

Semi-electronic decays:

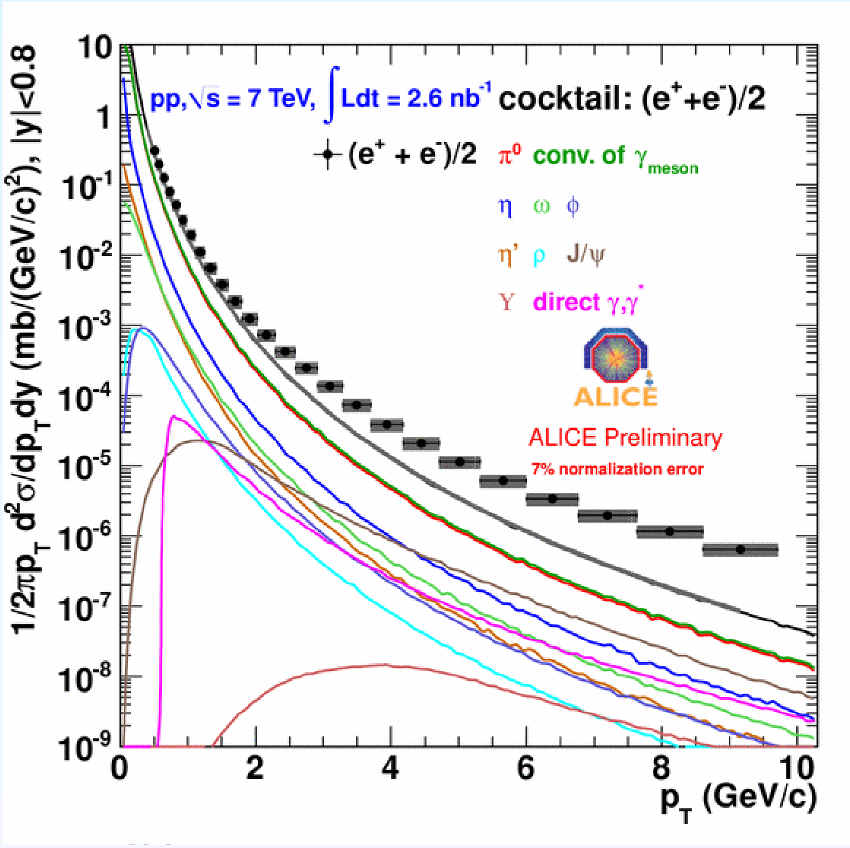
$D^0 \rightarrow e^+ +$ anything

$D^\pm \rightarrow e^\pm +$ anything

$B^\pm \rightarrow e^\pm +$ anything

$B \rightarrow D \rightarrow e^\pm +$ anything

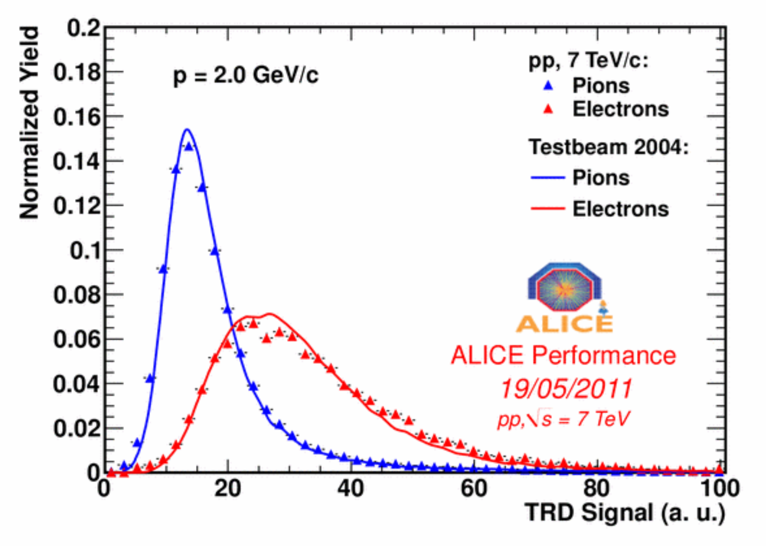
- **Analysis Strategy**
  - Electron Identification with TOF, TPC and TRD
  - Remaining hadron contamination determined via fits of dE/dx in momentum slices
  - Requirement of a hit in the innermost layer of ITS (r = 3.9 cm) to reduce bkg from photon conversion
  - Acceptance and Efficiency Correction (PID, selection, reconstruction, ...)
  - Subtraction of the background via data-tuned MC cocktail



Electron Identification with the TRD (I)

- **Based on the charge measured in a single tracklet**
- **Reference charge deposit distributions**
  - Electrons and pions
    - Test beam data (Discrete momentum steps)
    - Lookup table
  - Muons, kaons, protons
    - Scaled via parameterization from GEANT
  - Overall normalization
    - Test beam data compared to pions from K^0-decays
- **Probabilities for full track calculated via Bayes' theorem**

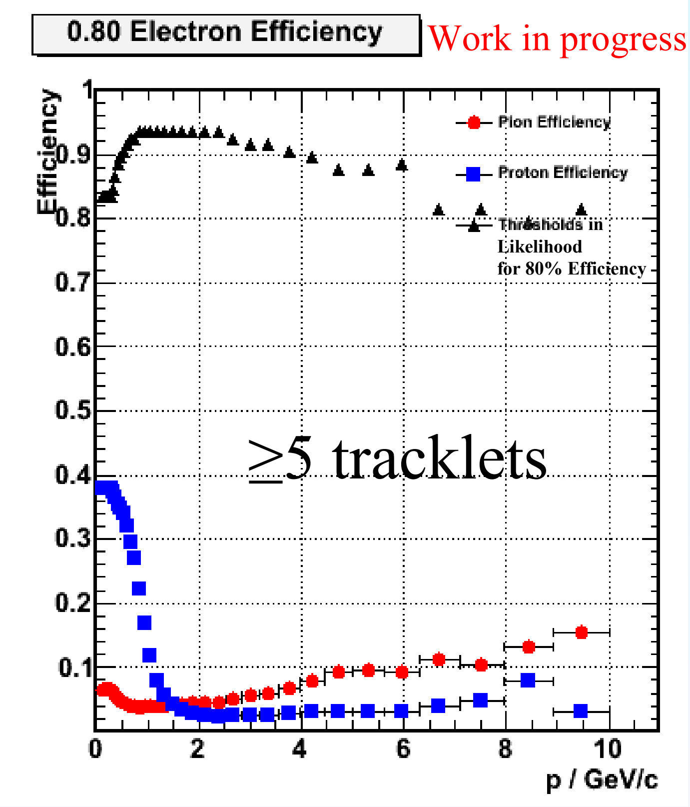
Simplest method of TRD PID: Likelihood on total charge

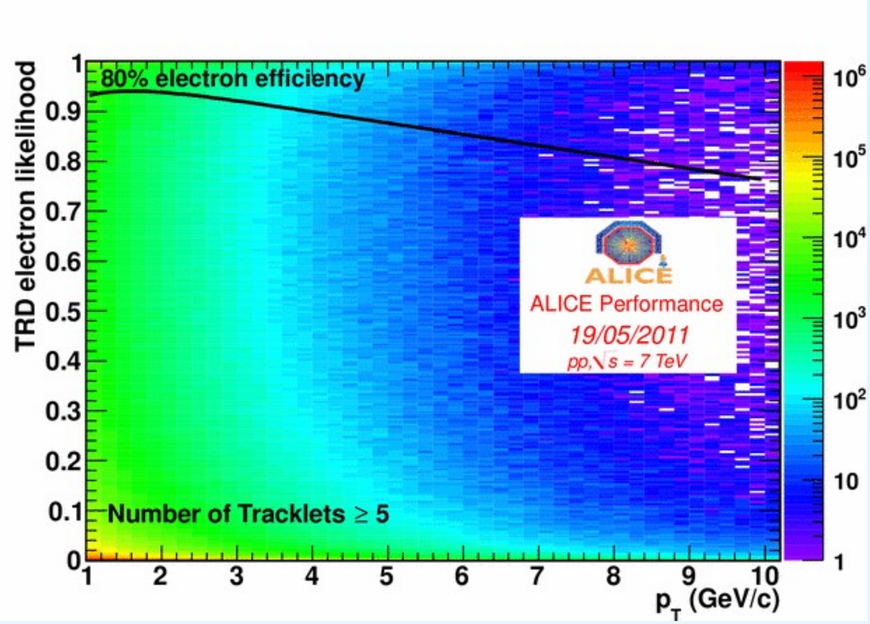


→ C. Blume, X. Lu

Electron Identification with the TRD (II)

- **Likelihood distribution**
  - Momentum dependent cut for constant electron efficiency
  - Tuned with electron tracks from conversion

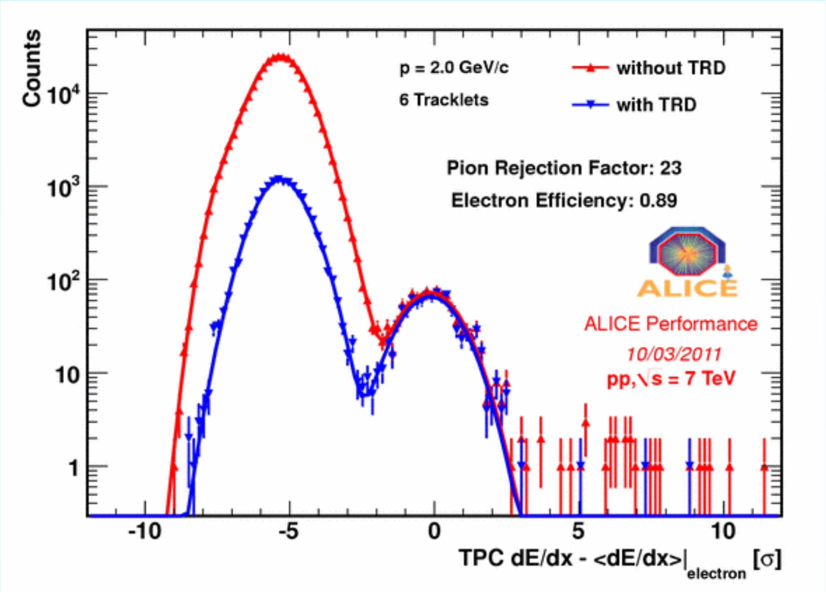


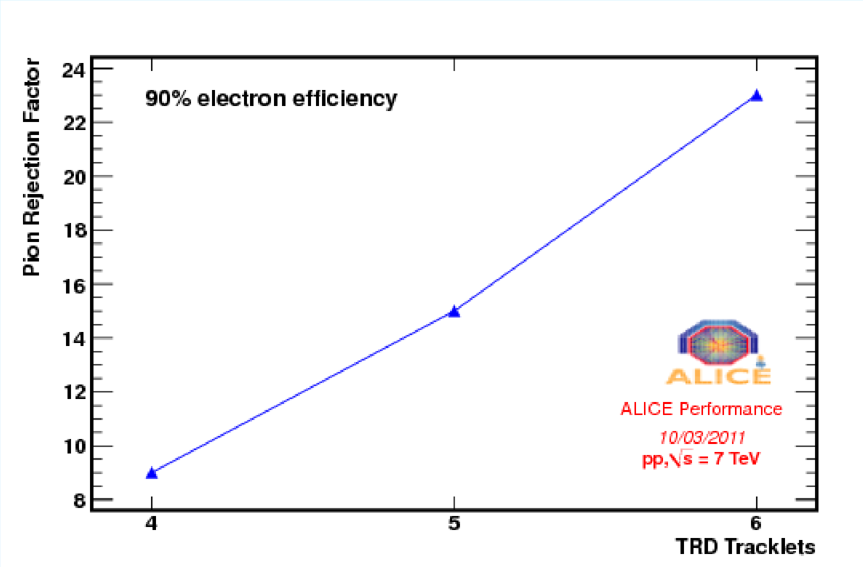


- **Rejection power (Pions/Protons)**
  - Determined with pions from K^0-decays
- **Threshold parameterized & used in analysis**

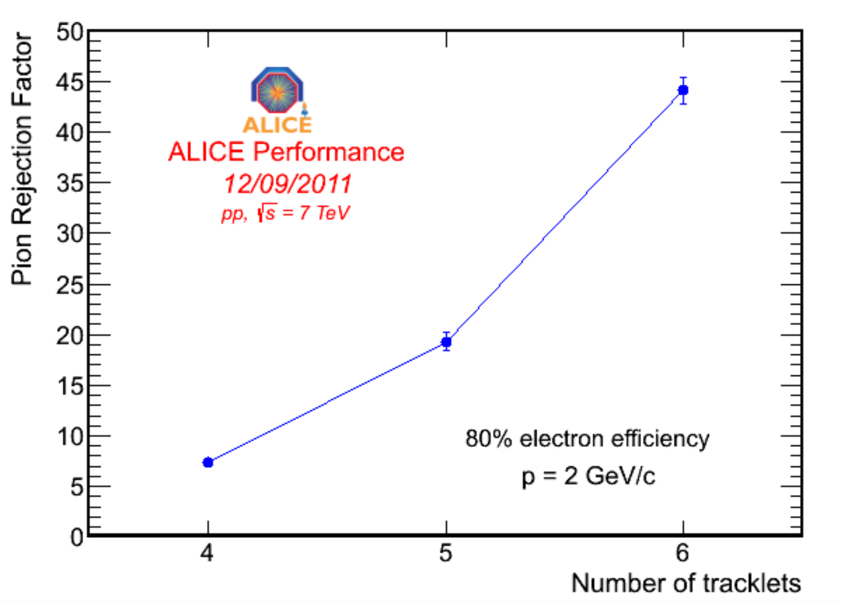
M. Fasel (Univ. Darmstadt) PhD thesis

Electron Identification with the TRD (III)





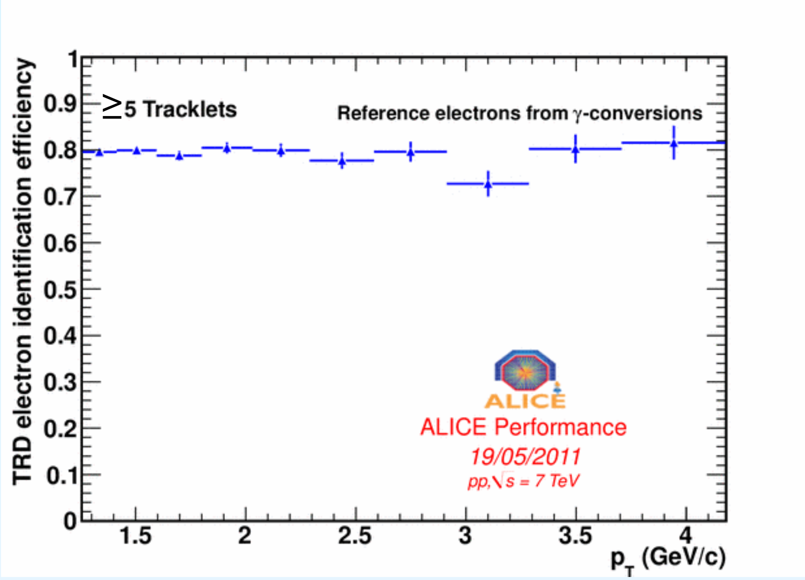
- **Thresholds determined for**
  - Various electron efficiencies: 0.8, 0.85 … 0.9
  - Number of tracklets: ≥4, ≥5, 6

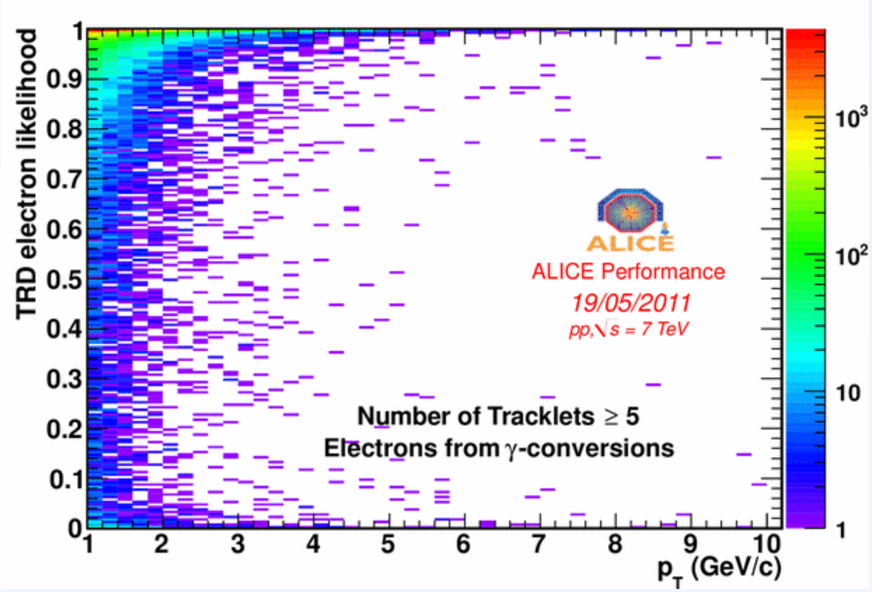


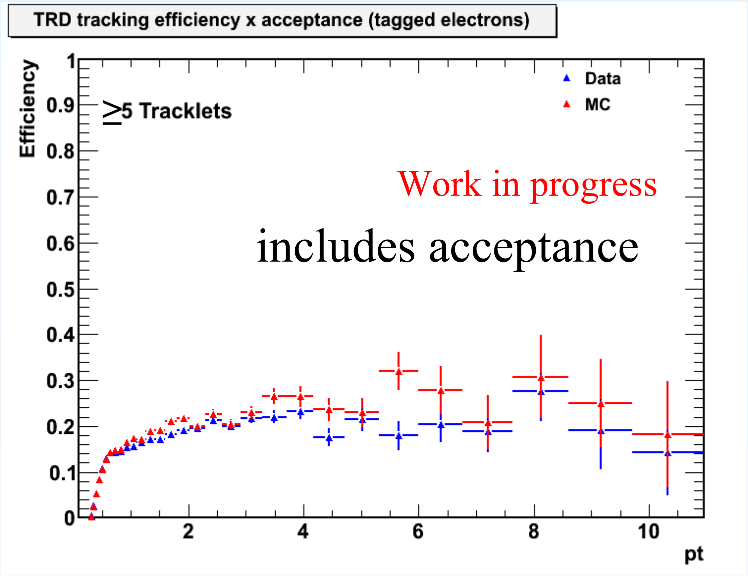
M. Fasel (Univ. Darmstadt) PhD thesis

Cross-Checks and Efficiency Evaluation

- **Cross-Check with electrons from conversion**
  - Electron identification efficiency
  - Electron likelihood
  - Tracking efficiency in MC (realistic detector description)



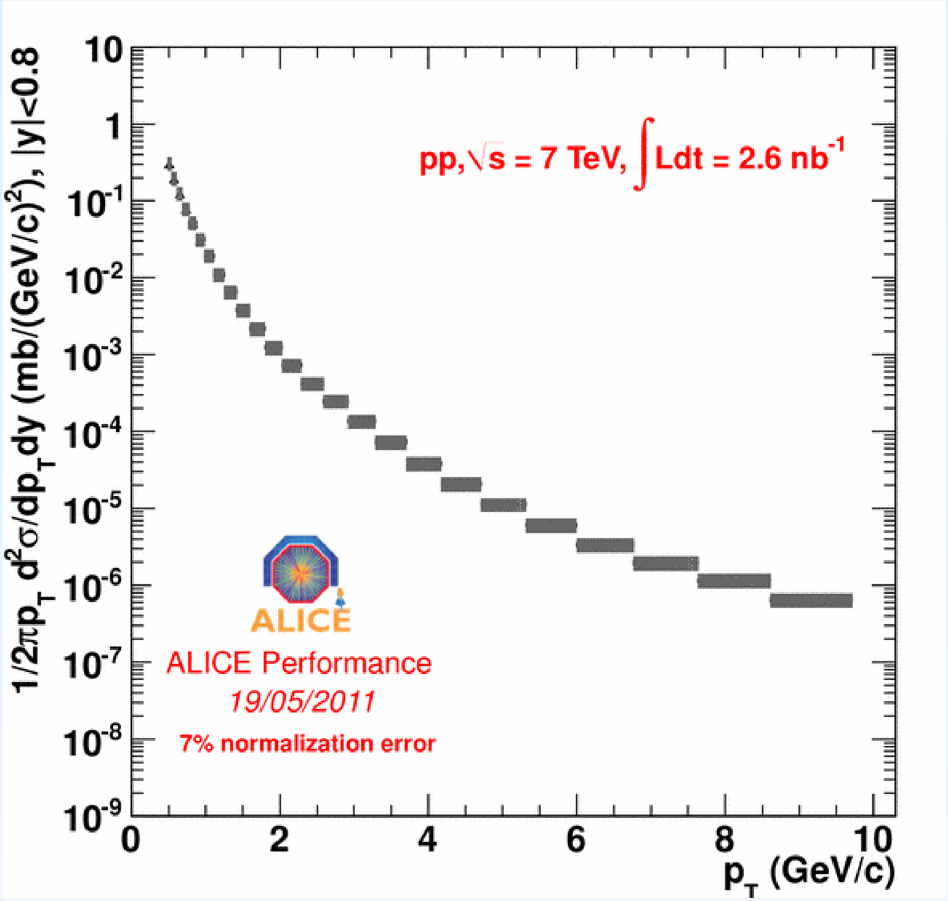




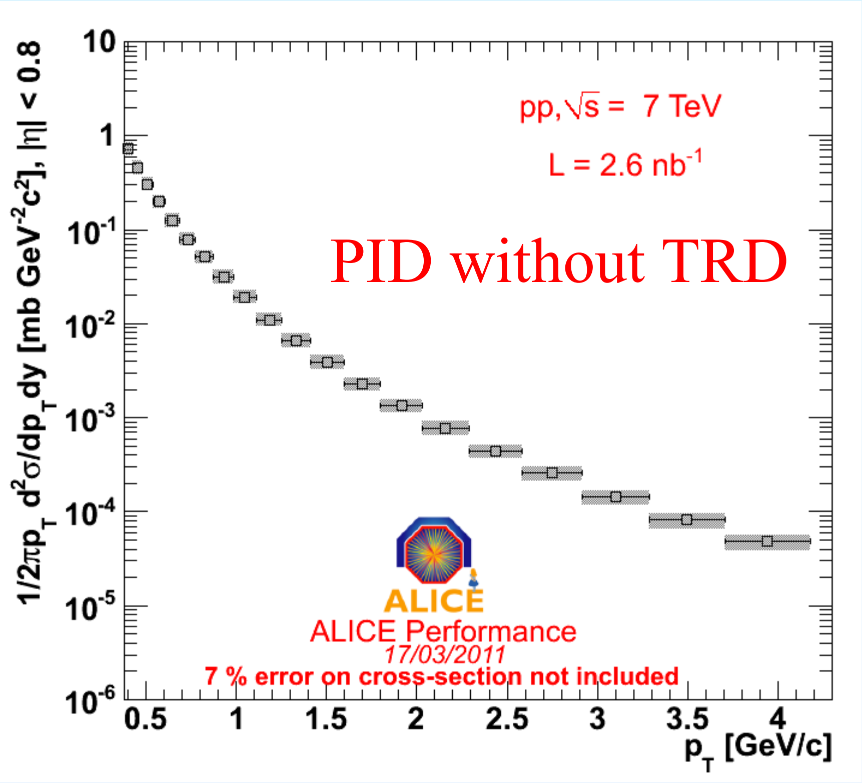
M. Fasel (Univ. Darmstadt) PhD thesis

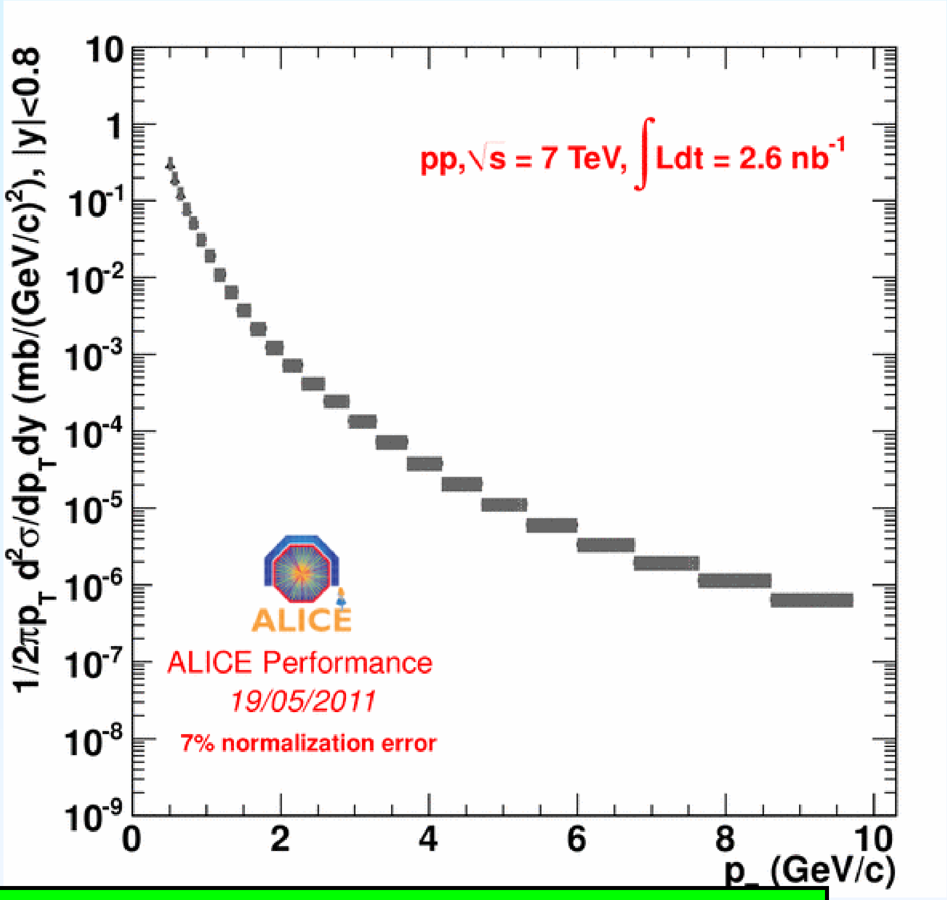
Inclusive Electron Spectrum

- **Electron identification**
  - TOF: 3σ electron hypothesis
  - TRD: slides before
  - TPC: 0-3σ_e
- **Efficiency and acceptance corrected**
- **Converted to cross-section with VdM results**
- **Systematic Uncertainty**
  - Variation of applied cuts
    - TRD: # tracklets, efficiency → 10%
  - Total error: 20%



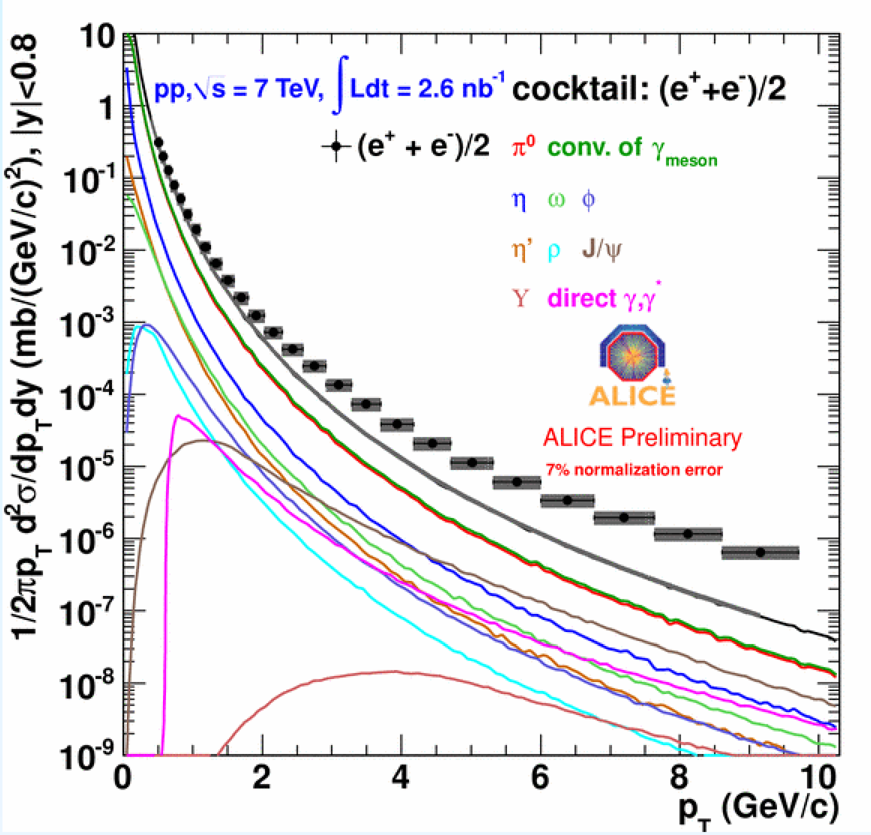
Inclusive Electron Spectrum

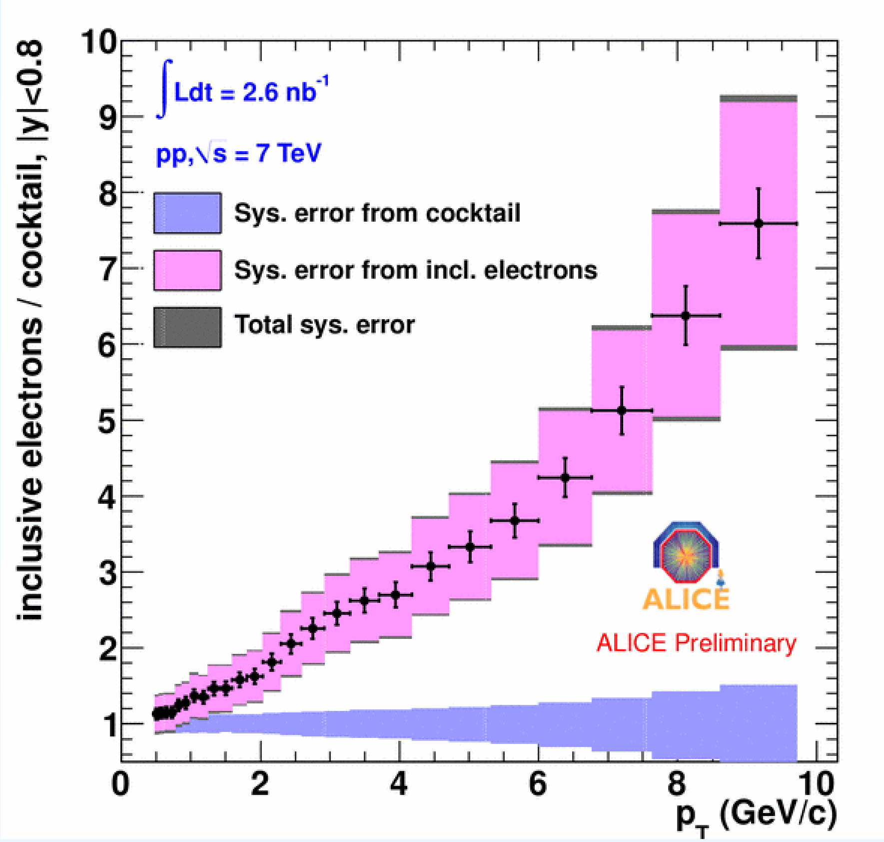




→ TRD increases pt reach (now only limited by statistics)
→ TRD decreases systematic uncertainty of PID

Inclusive Electrons compared to Cocktail

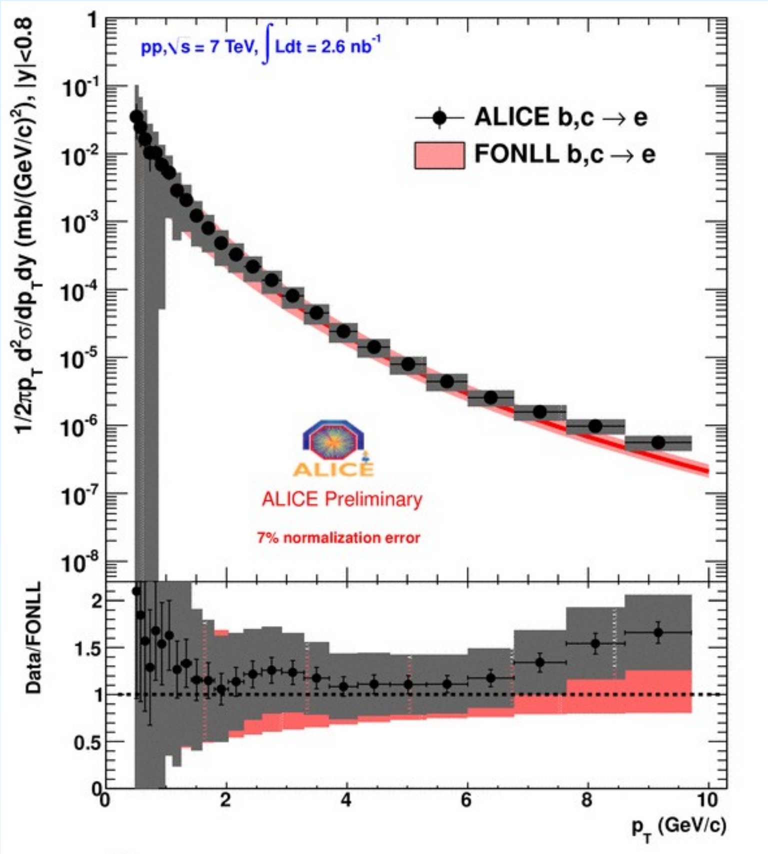


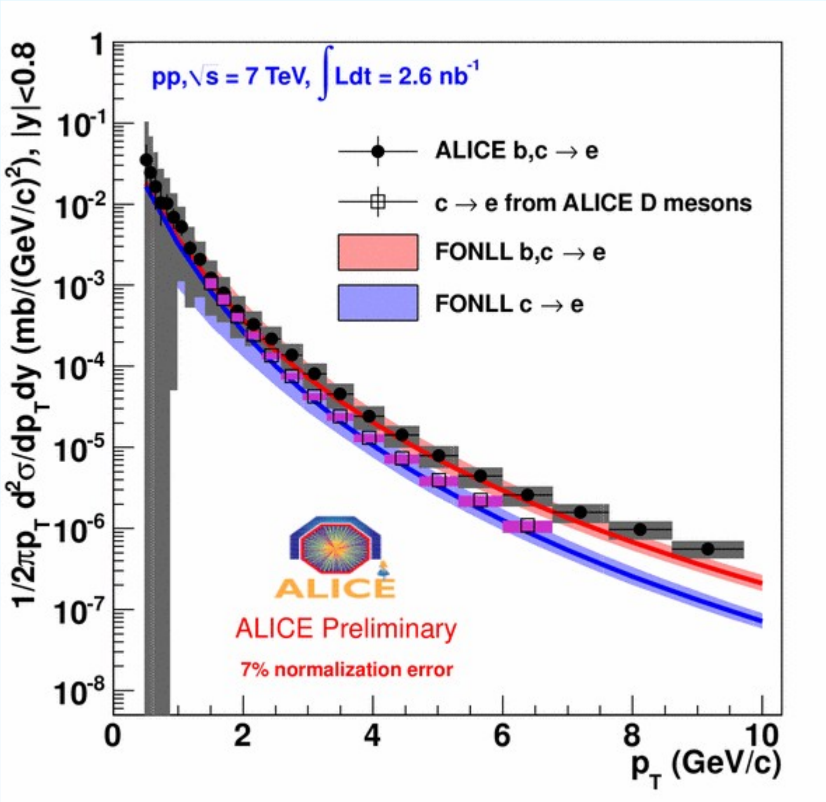


- **Cocktail contains**
  - γ conversion ($\pi^0 \rightarrow \gamma\gamma$, $\gamma \rightarrow e^+e^-$)
  - π^0, η, η' Dalitz decays
  - ρ, φ, J/Ψ, Υ decays
  - QCD photons based on NLO calculations (W. Vogelsang)

- π^0 input based on charged pion measurement with ALICE
- Heavier mesons implemented via m_T scaling
- J/Ψ, Υ parametrized from ALICE and CMS measurements
- Systematic uncertainty: ~ ±7% above p_t > 2 GeV/c

Electrons from Semi-electronic c/b Decays





→ FONLL b + c in agreement with data
→ Consistent with prompt charm measurement from D mesons, where charm dominates

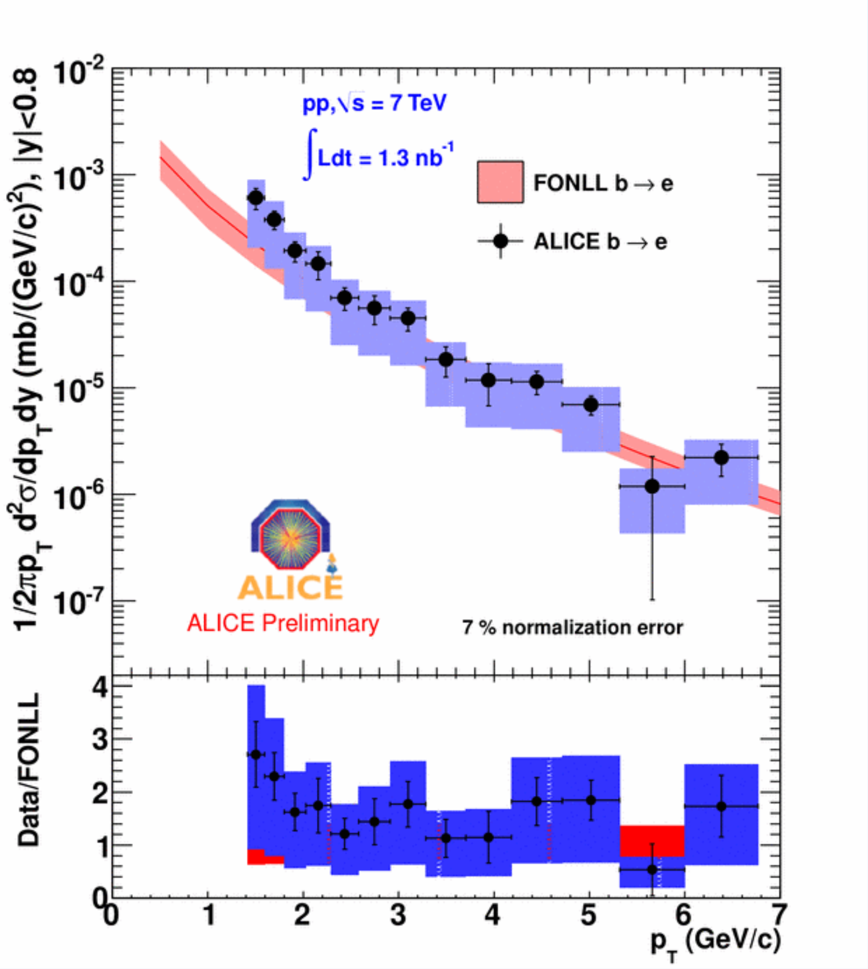
Beauty Decay Electrons

- **Analysis Strategy: selection of electrons from displaced vertex with inner tracking system**

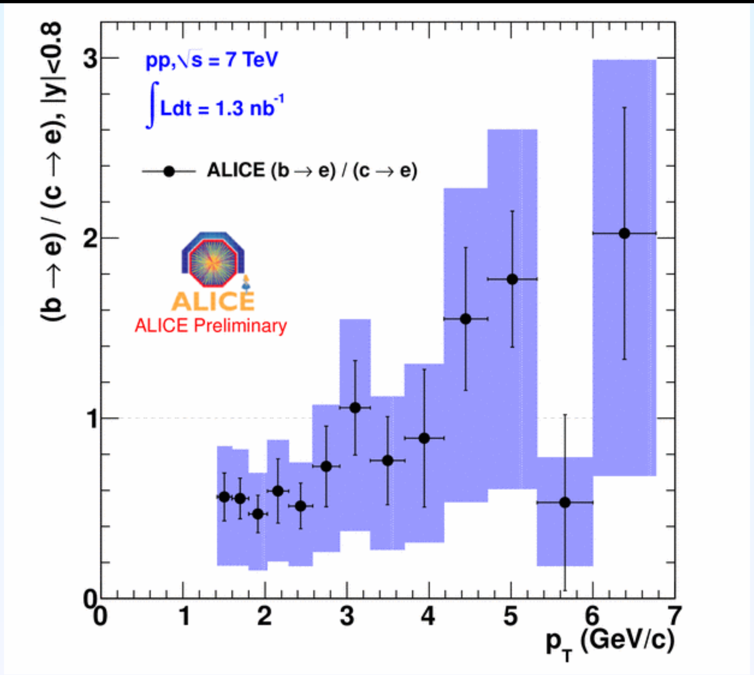
Semi-electronic decays:

$B^{\pm} \rightarrow e^{\pm}$ + anything

$B \rightarrow D \rightarrow e^{\pm}$ + anything

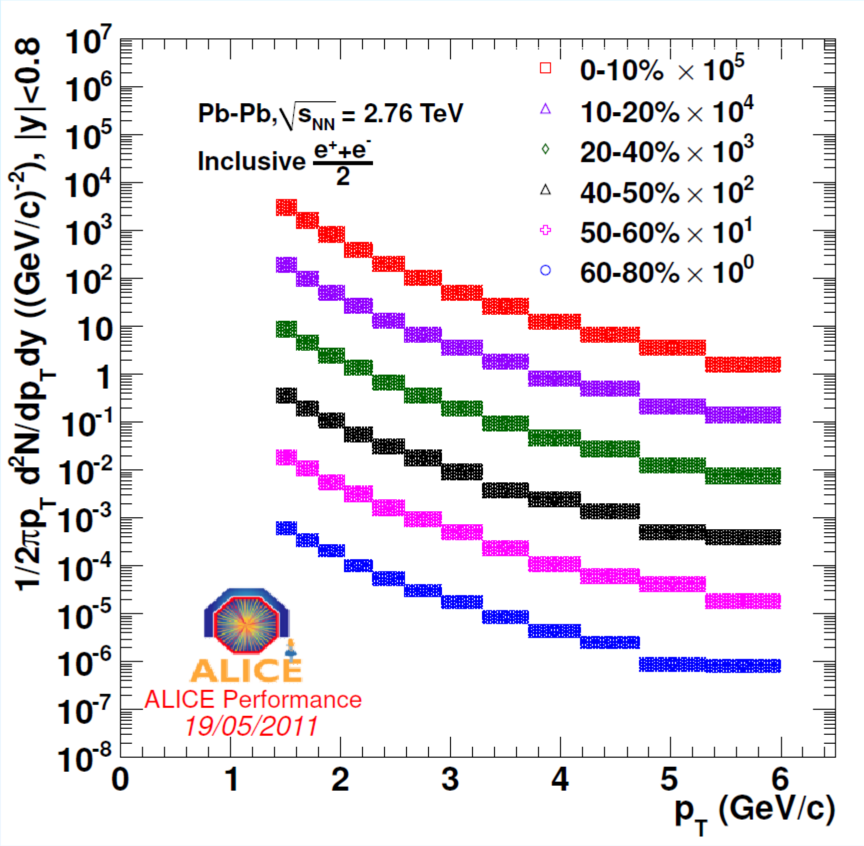


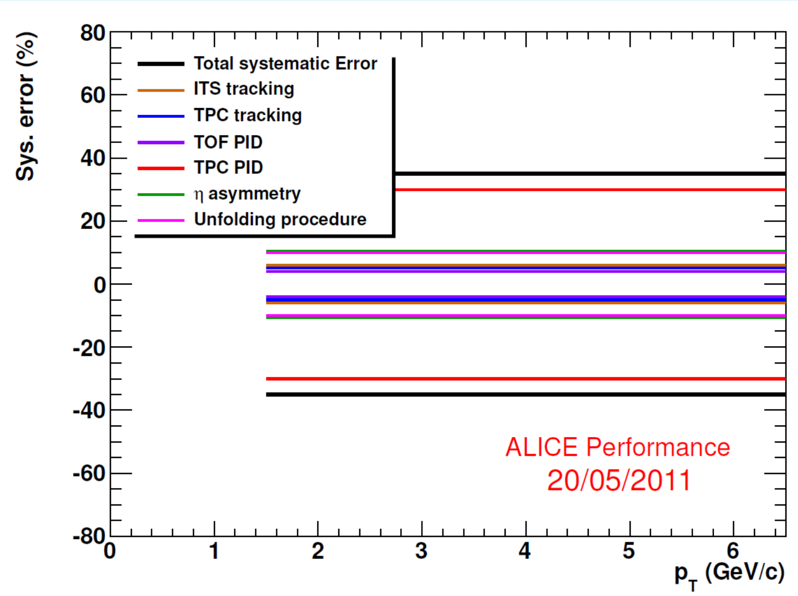
→ FONLL in agreement with data
→ b/c ratio increases with p_T



Electrons from Heavy Flavour Decays in Pb-Pb

- **Analysis of Pb-Pb @ 2.76 TeV ongoing**
- **TRD not yet included**
  - → **PID systematic uncertainty 30%**
  - → **No high p_t reach**
- **TRD performance studies in Pb-Pb ongoing**





→ C. Blume

Conclusion and Outlook

- **TRD significantly expands the physics reach in ALICE**
  - Quarkonia, open heavy flavour, jets, …

    → Study the de-confined medium produced in nucleus-nucleus collisions
- **TRD provides good electron identification**
- **TRD allows to enhance rare probes due to trigger capabilities**

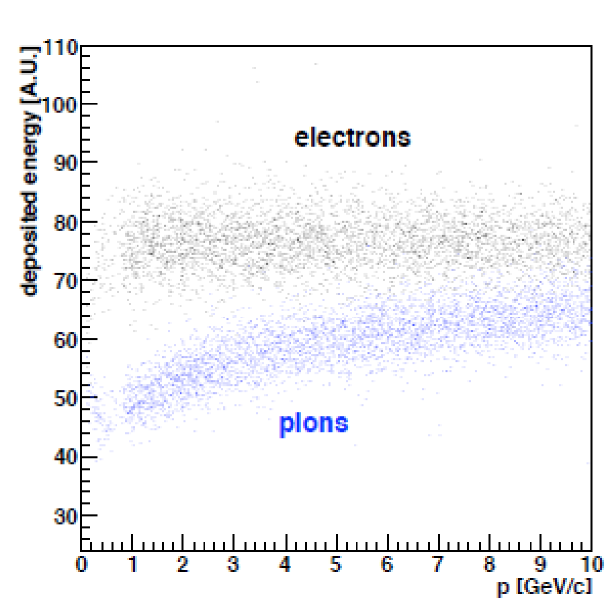
- **Further more powerful PID methods with TRD under development**
  - 2D likelihood, neural networks, ...
- **Apply TRD PID algorithm in further analysis strategies**
  - First year PbPb statistics will soon hopefully significantly increase

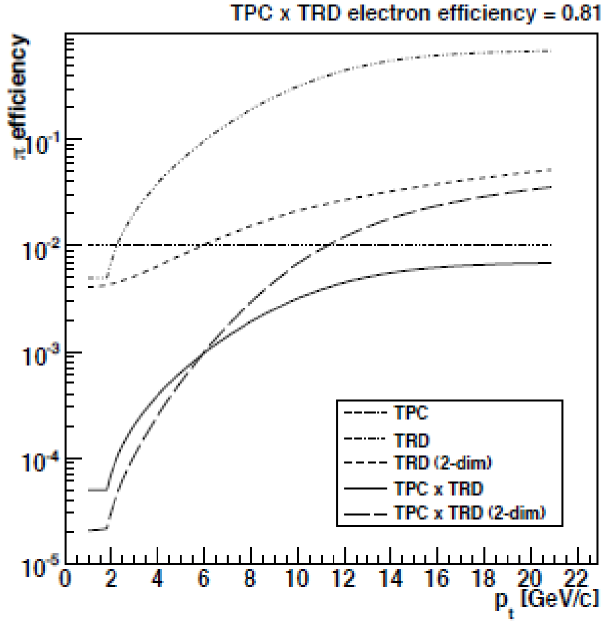
    → Allows TRD to come into the game (Performance studies in Pb-Pb already started)
- **...**

Back-Up

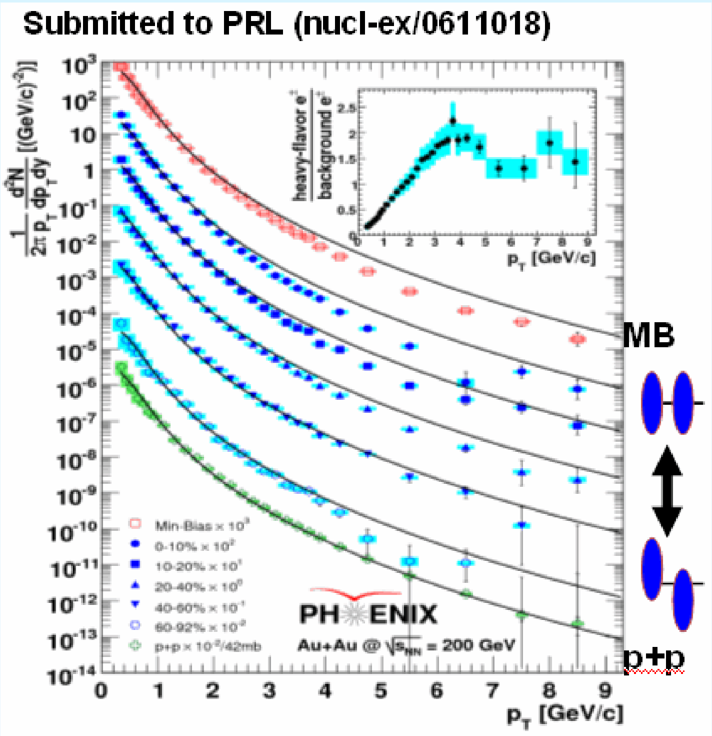
Quarkonia Simulation

Pion Efficiency

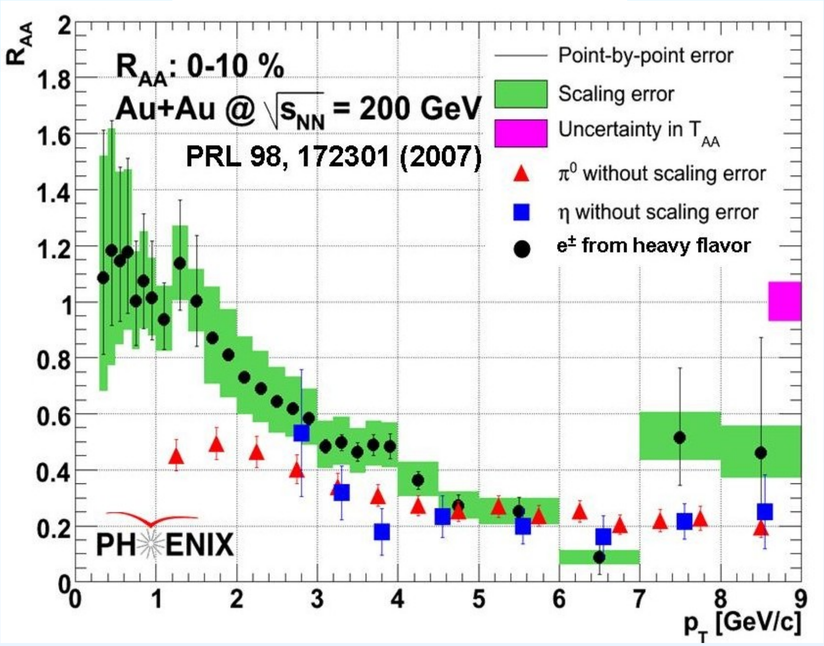




Nuclear Modification Factor at RHIC Energies



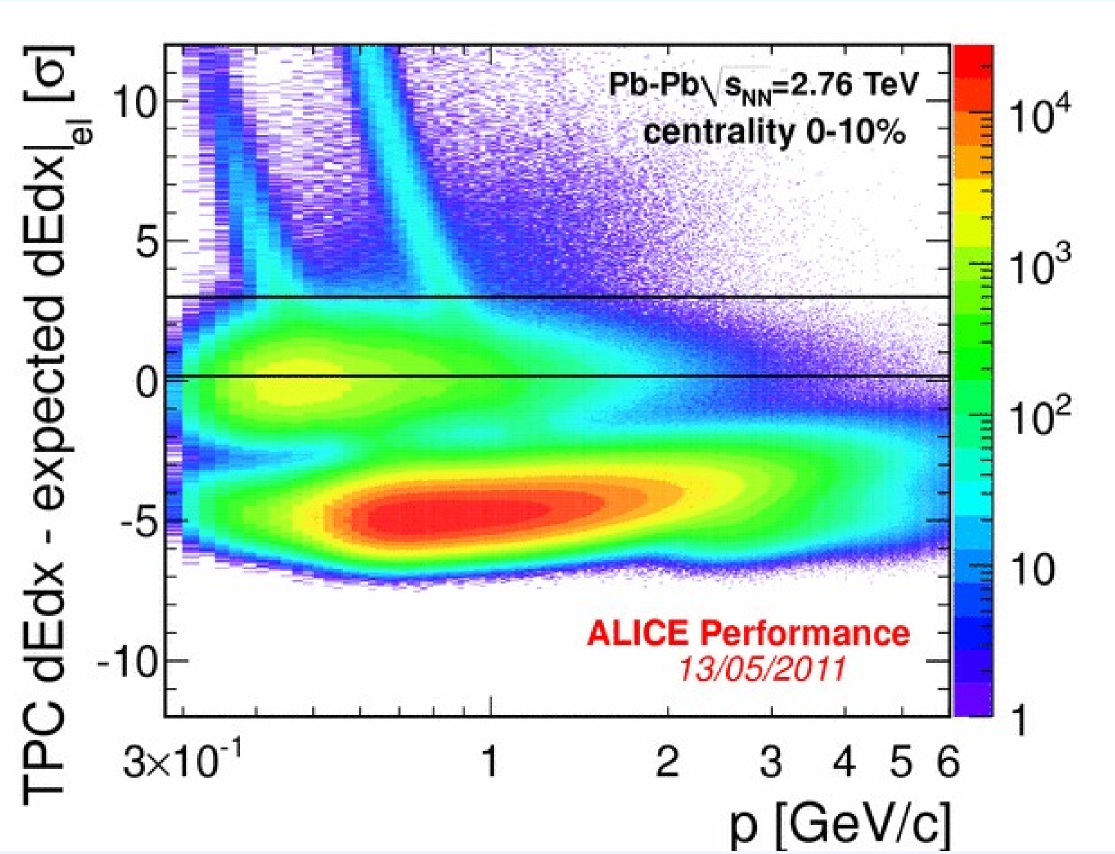
$$R_{AA} = \frac{dN^{e}_{AA}/dp_T}{\langle N^{AA}_{\mathrm{coll}}\rangle\, dN^{e}_{pp}/dp_T}$$



- **RAA of electrons from heavy flavour decays**
  - At high p_t similar suppression like light hadrons
  - Beauty contribution should dominate at p_t > 4 GeV/c

    → disentangle charm and beauty contribution

TPC nsigma



Pb-Pb √sNN=2.76 TeV
centrality 0-10%
ALICE Performance
13/05/2011
TPC dEdx - expected dEdx|el [σ]
p [GeV/c]
10
5
0
-5
-10
3×10⁻¹
1
2
3
4
5
6
10⁴
10³
10²
10
1