Perspectives for the measurement of beauty production via semileptonic decays in ALICE

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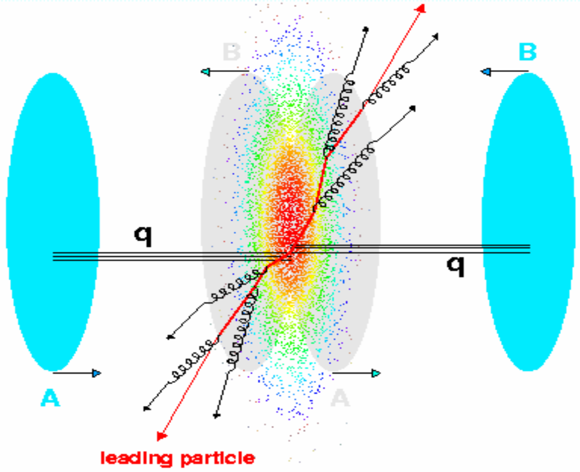
for the ALICE *collaboration*

Contents

- Motivation: energy loss
- ALICE detector highlights
- Performances: electron separation and vertexing
- $B \rightarrow e+X$: attainable statistics and errors
- $B \rightarrow e+X$: sensitivity of energy loss measurement
- $B \rightarrow \mu+X$: strategy and performance
- Conclusions

Physics motivation



- b production cross section
- transverse momentum spectrum

In AA:
- quarkonia dissociation (not covered here)
- energy loss

In pp:
- (p)QCD test bench
- AA, pA baseline

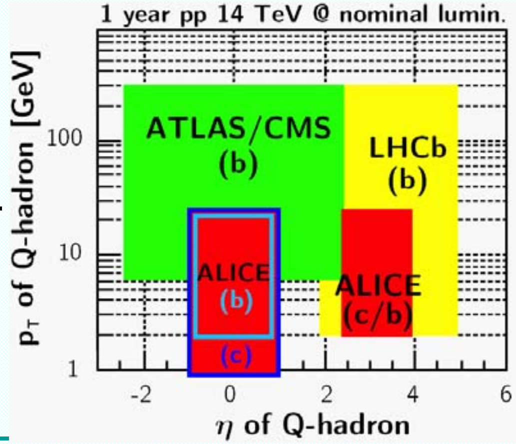
(+pA) disentangle medium effects

Heavy quarks:
- abundant yield
- produced early
- travel ~4 fm in the medium

probe the collision dynamics!

	PbPb (0-5% centr.) 5.5 TeV	pp 14 TeV
σ_{QQ}(NN) [mb]	0.21	0.51
N_{QQ} per collision	4.56	0.0072

ALICE: very low p_t explored, complementary to other LHC exps.



HERA-LHC workshop CERN-2005-14

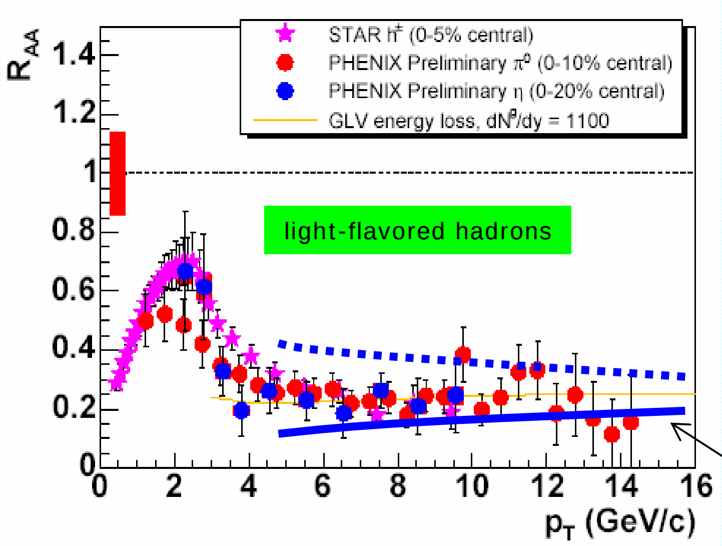
High p_t suppression at RHIC

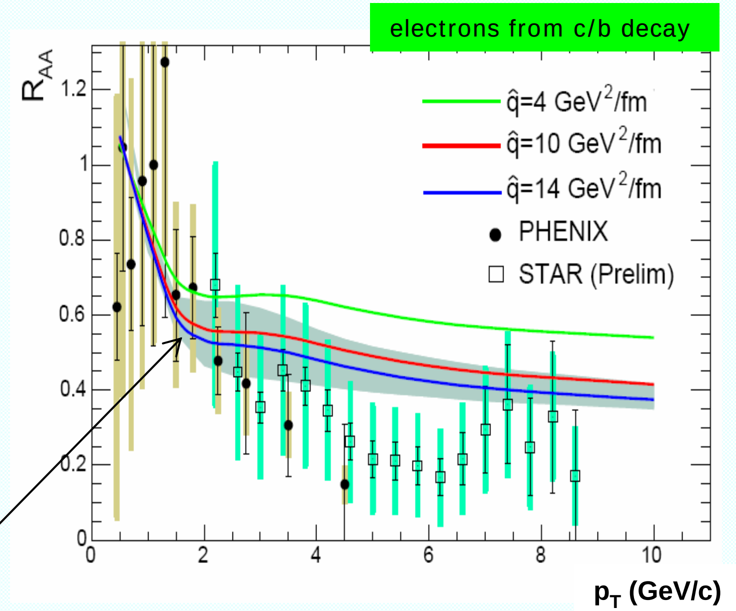
- Method: compare mesons' p_t distribution in pp and AA:

$$R_{AA}^{D,B}(p_t) = \frac{1}{N_{coll}} \times \frac{dN_{AA}^{D,B}/dp_t}{dN_{pp}^{D,B}/dp_t}$$

=1 if no medium effect

- Observed at RHIC for light flavors and charm
- Reproduced by $\hat{q}$ = 4-14 GeV^2/fm (see next slide)

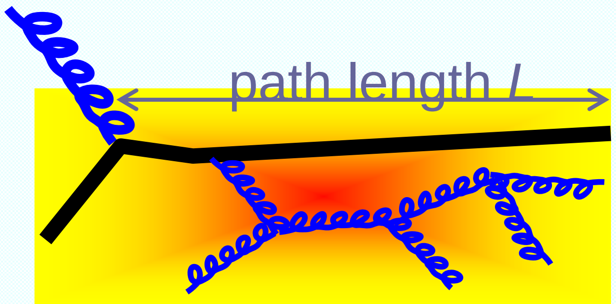




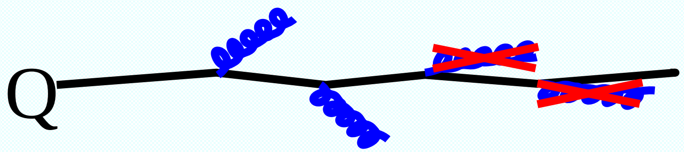
Calculations: Armesto, Dainese, Salgado, Wiedemann, PRD71 (2005) 054027

Possible explanation: *gluonsstrahlung*

- interactions may occur by gluon in-medium radiation (quenching)
- the amount of quenching depends on:
  - color charge: C_R=4/3, 3 if quark or gluon, resp. (Casimir factor)
    - heavy/light probes (b,c vs. direct pions)
  - quark mass (beauty/charm comparison)
    - *dead cone* effect



Dokshitzer, Kharzeev, PLB519 (2001) 199
Armesto, Salgado, Wiedemann, PRD69 (2004) 114003



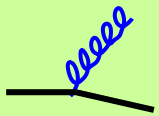
medium dependence

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

Baier, Dokshitzer, Mueller, Peigné, Schiff, (BDMPS), NPB483 (1997) 291

mass dependence

Gluonstrahlung probability



$$\propto \frac{1}{[\theta^2 + (m_Q / E_Q)^2]^2}$$

Energy loss at LHC

- A promising strategy: study the **p_t-dependent ratio…**
  - …R_{AA} of D or B mesons produced in AA and pp: **quark energy loss**

$$R_{AA}^{D,B}(p_t) = \frac{1}{N_{coll}} \times \frac{dN_{AA}^{D,B}/dp_t}{dN_{pp}^{D,B}/dp_t}$$

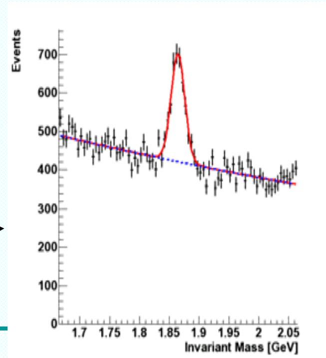
  - …between R^B_{AA} and R^D_{AA} (beauty/charm ratio): **mass dependence**

$$R_{D(B)/h}(p_t) = R_{AA}^{B}(p_t) \big/ R_{AA}^{D}(p_t)$$

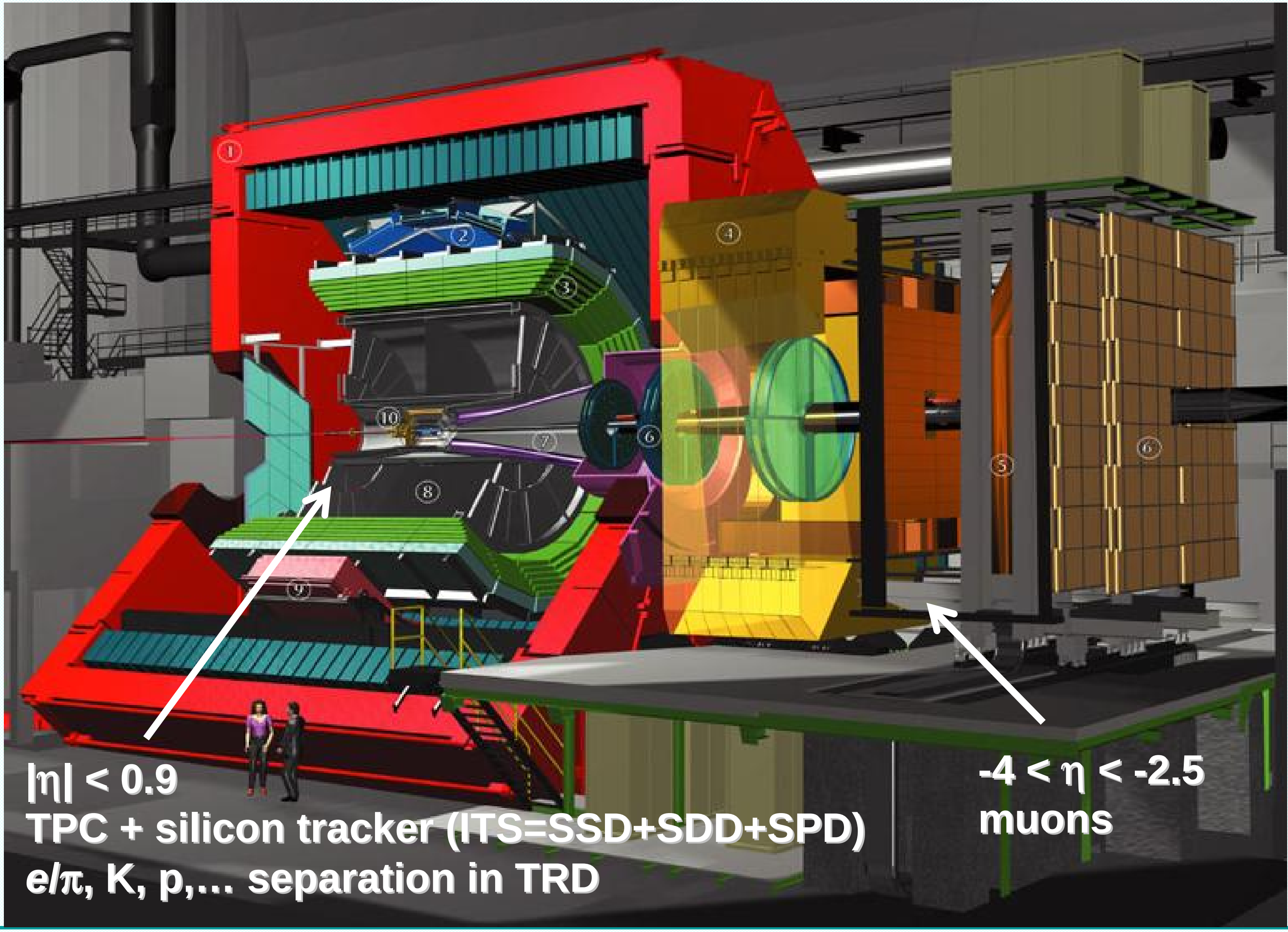
  - …between $R^{B/D}_{AA}$ and R^h_{AA} (heavy/light probes): **color charge dependence**

$$R_{D(B)/h}(p_t) = R_{AA}^{D(B)}(p_t) \big/ R_{AA}^{h}(p_t)$$

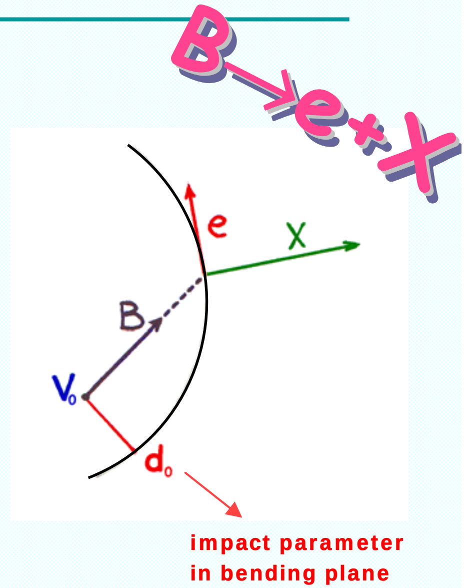
NB: study of charm detection performance done!
see ALICE “Physics Performance Report”, J. Phys. G30 1517-1763 & CERN/LHCC 2005-030



The ALICE Detector

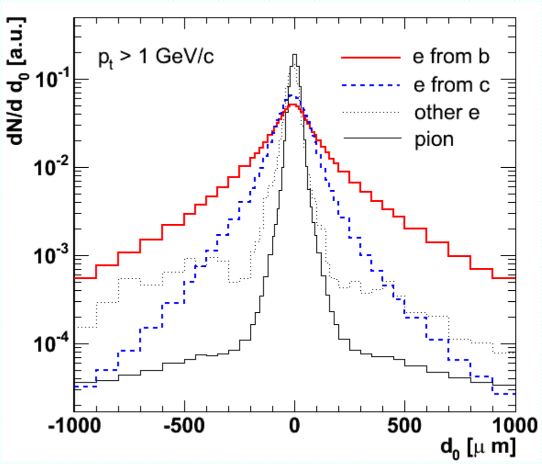


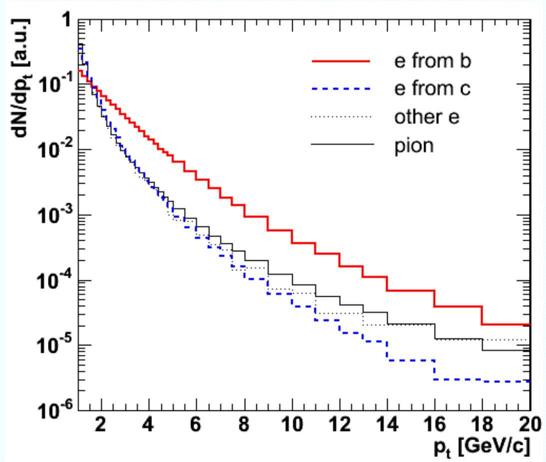
Detection strategy: B→e+X



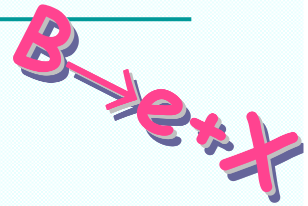
- Background sources:
  - pions misidentified as electrons
  - charm decay electrons
  - Dalitz decays
  - photon conversions
  - strangeness decays
- signal: <1 electron/ev out of ~10^3 (all p_t's)!

- Detection strategy
  - electron ID in TPC + TRD
  - p_T cut-off
  - impact parameter cut-off
  - specific for pp: primary vertex optimization
- $c\tau$~500μm → compare with 100-300 μm from charm
- m_b~5 GeV → hard p_t spectrum

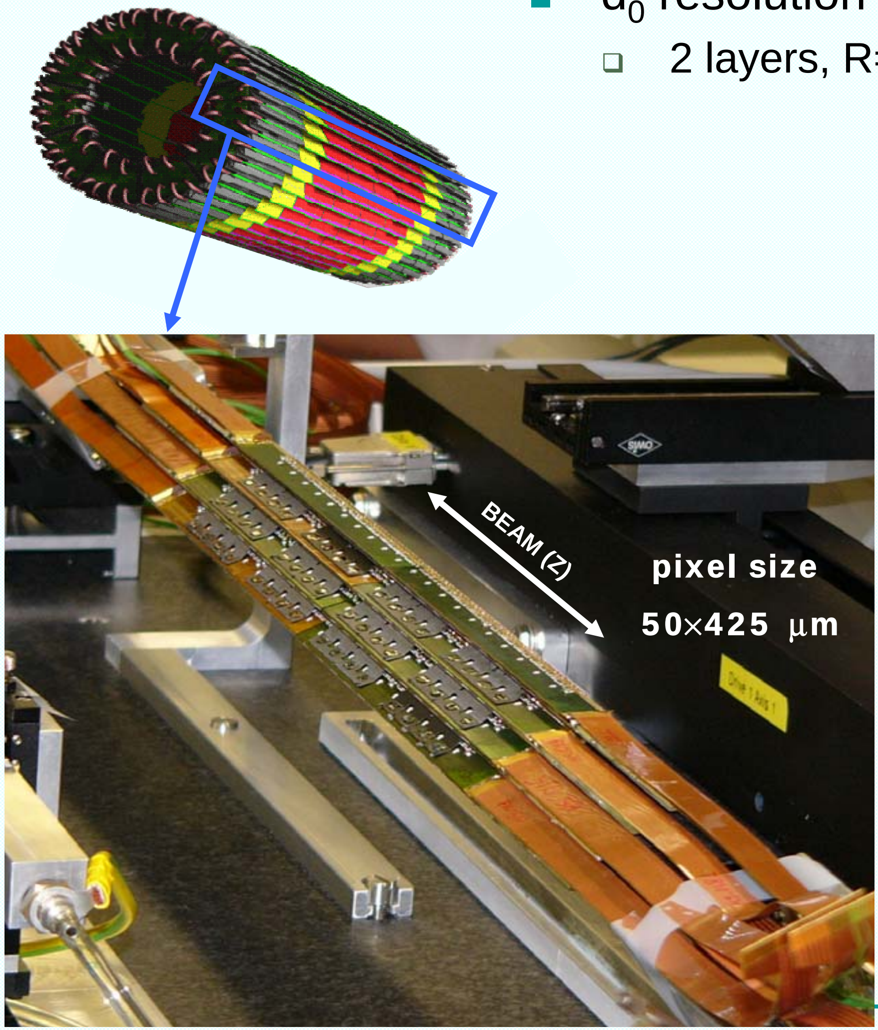


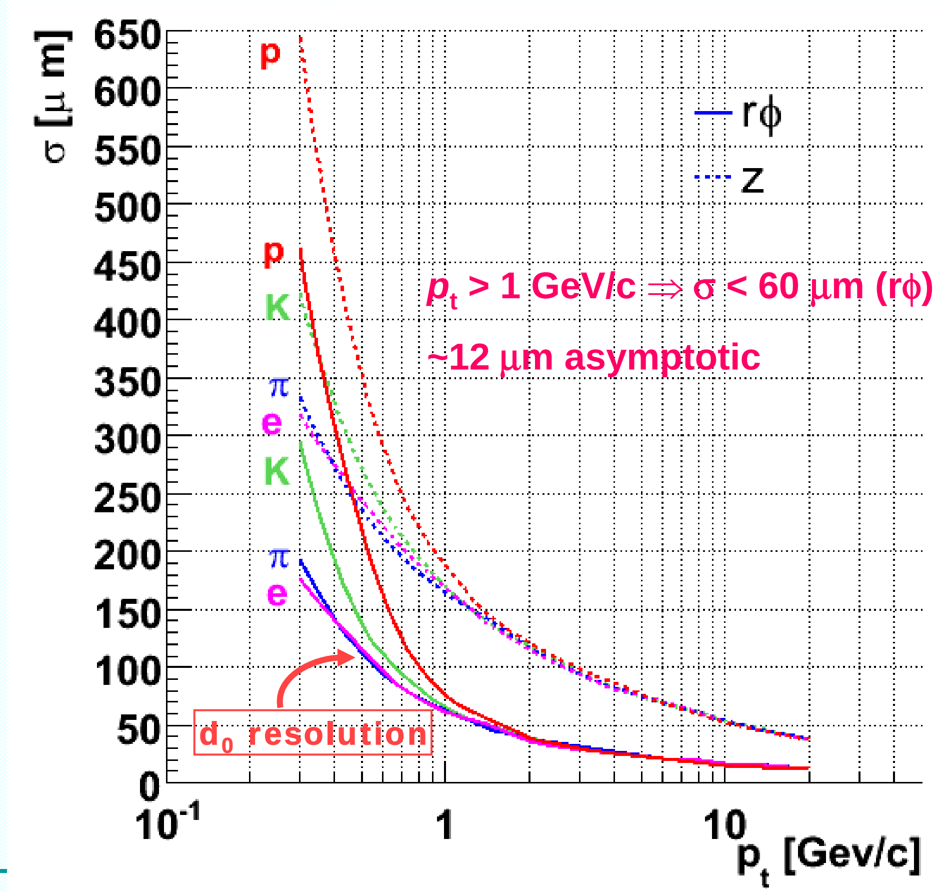


Impact parameter resolution



- d_0 resolution **S**ilicon **P**ixel **D**etector
  - 2 layers, R=4 and 7 cm, ~10^7 channels

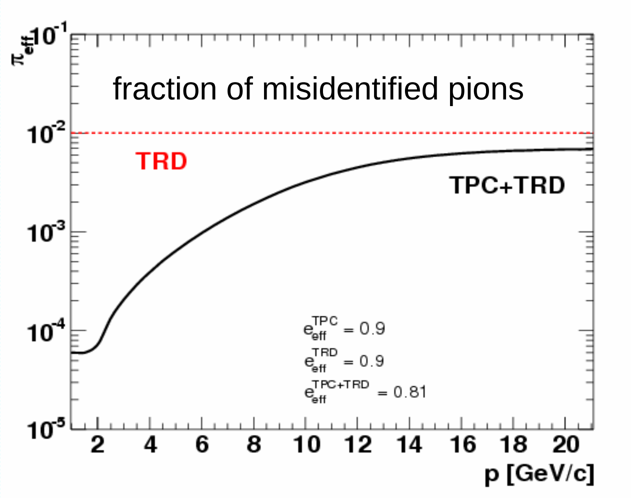


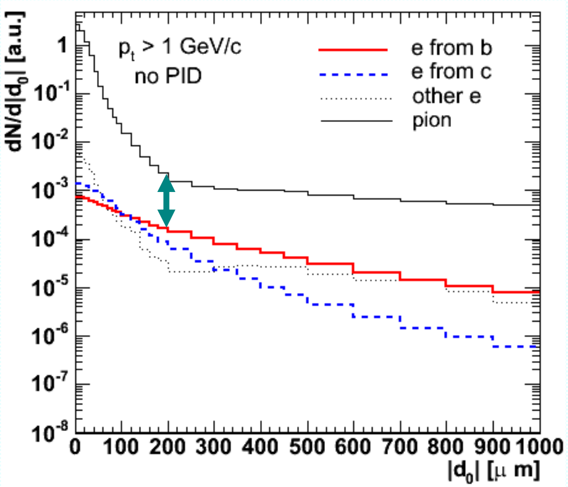


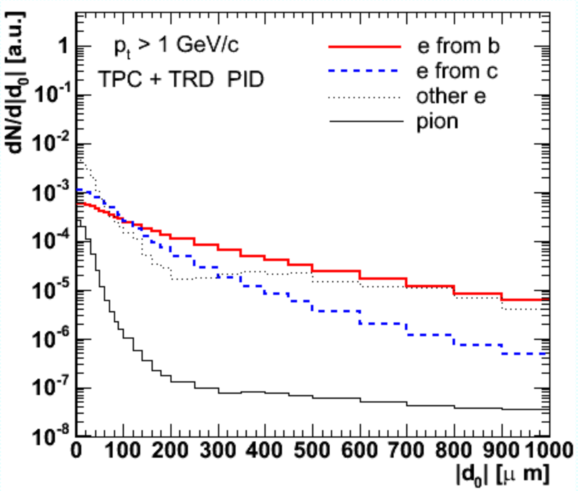
Electron separation

B→e+X

- Combined strategy TRD+TPC
  - TRD rejects 99% of pions and 100% of heavier hadrons (90% electron efficiency)
  - TPC (via dE/dx analysis) rejects again 99% of pions at 90% electrons efficiency (at low p_t's)





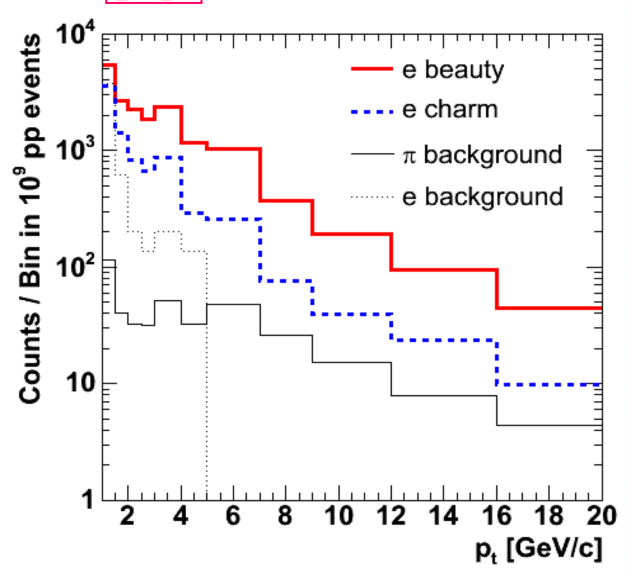


Electron spectra from b

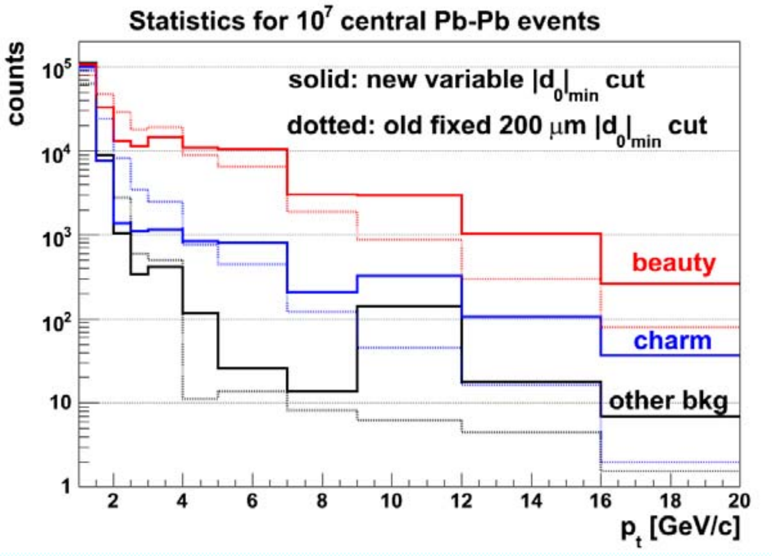
B→e+X

- Results for electrons detection in:
  - pp, 14 TeV, 10^9 events ("one year run")
  - PbPb, "one month run" 10^7 events
    - ALICE standard 'underlying' event → $dN^{CH}/dy=6000$
  - systematic and statistical errors studied in detail

pp



PbPb

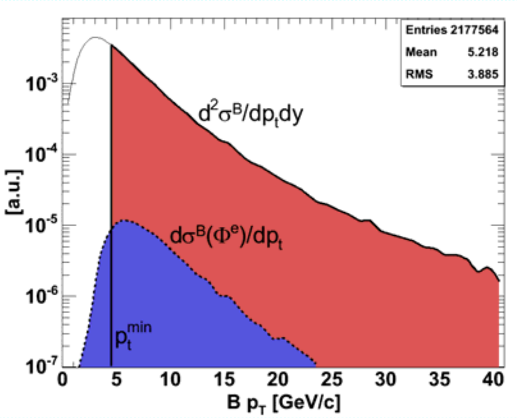


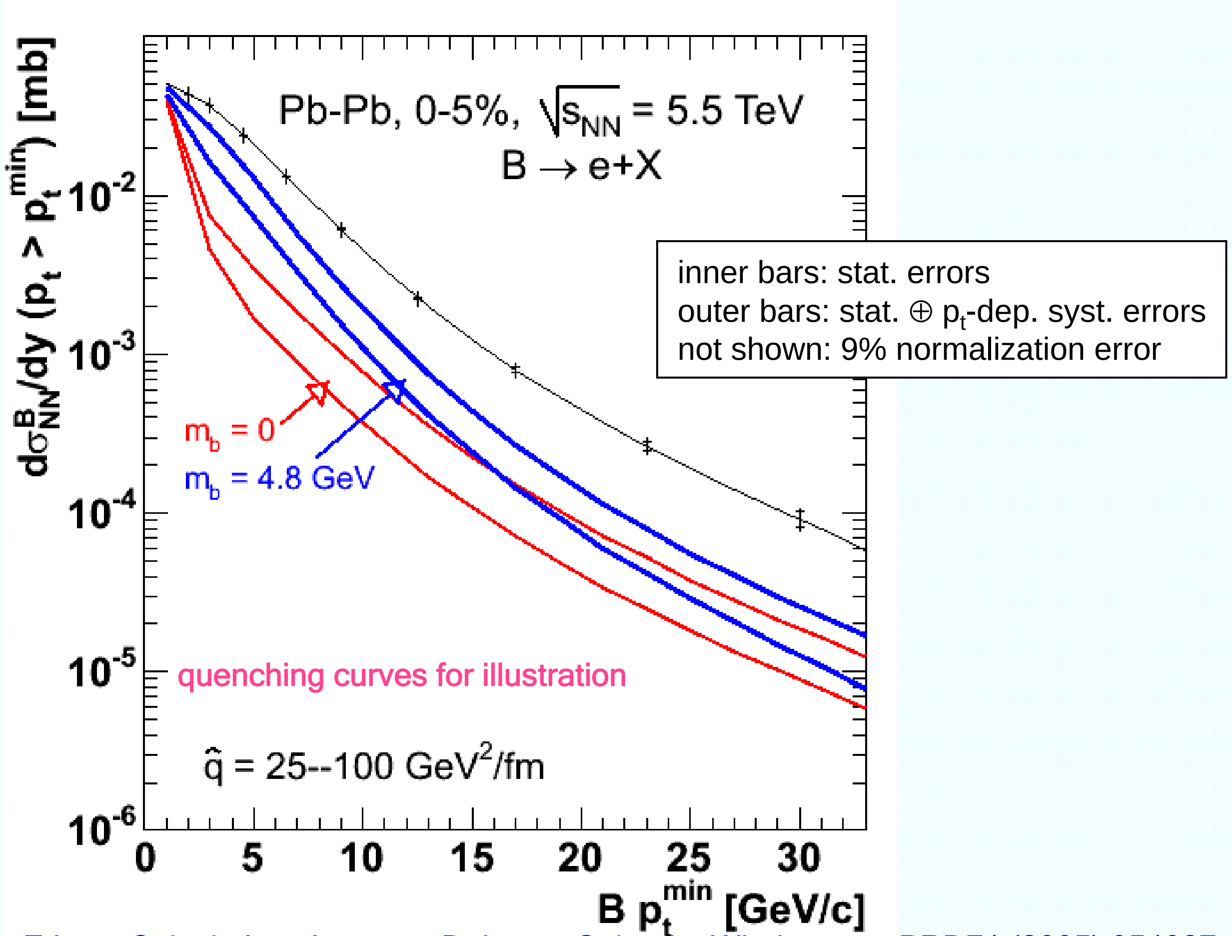
B-meson level cross section

Using electrons in
$2 < p_t < 20$ GeV/c

MC-based procedure à la UA1*

obtain B meson
$2 < p_t^{min} < 30$ GeV/c





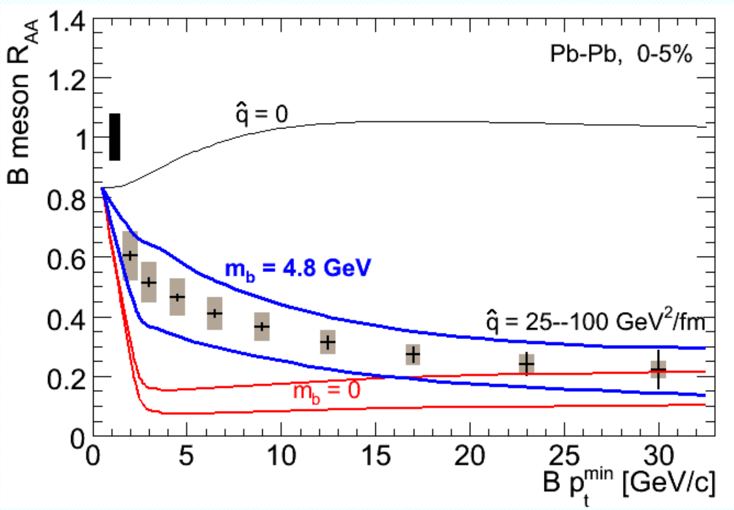
E Loss Calculation: Armesto, Dainese, Salgado, Wiedemann, PRD71 (2005) 054027

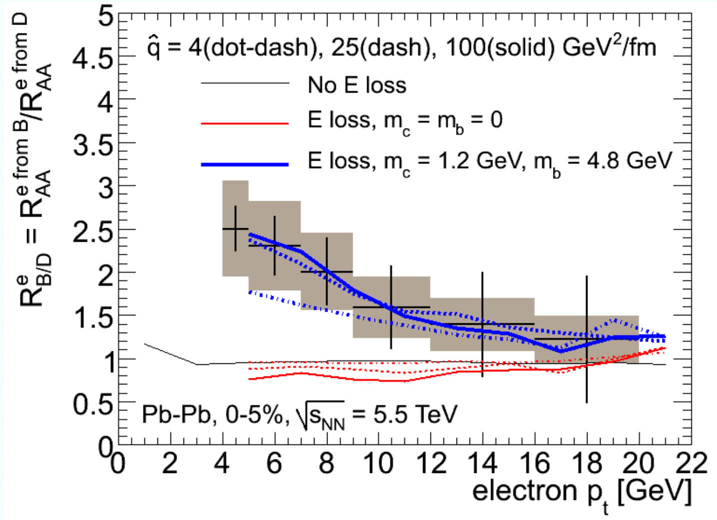
* C. Albajar et al., UA1 Coll., Phys Lett B213 (1988) 405, Phys Lett B256 (1991) 121

Beauty quenching

B→e+X

- Reconstruction of meson-level cross section (details on request…)
- R_{AA} (RHIC-like analysis) sensitivity to quenching/mass
- R_{BD} (pure quark, no quark/gluon effect) prefers mass effect





$$R_{AA}^{D,B}(p_t) = \frac{1}{N_{coll}} \times \frac{dN_{AA}^{D,B}/dp_t}{dN_{pp}^{D,B}/dp_t}$$

$$R_{BD}^{e}(p_t) = \frac{R_{AA}^{e\_from\_B}(p_t)}{R_{AA}^{e\_from\_D}(p_t)}$$

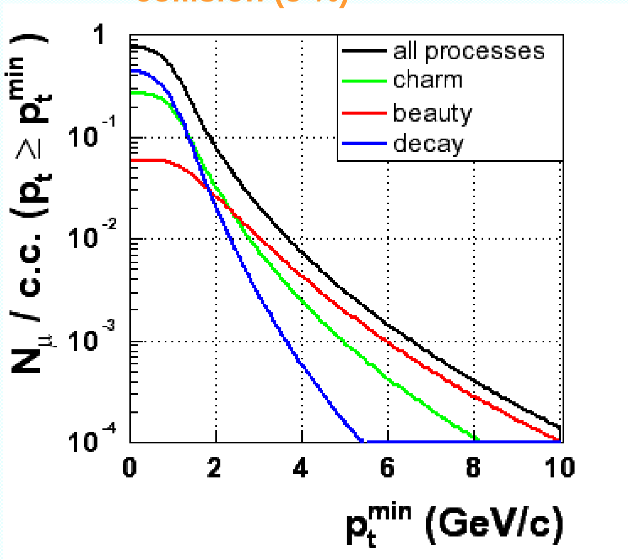
NB: study of charm detection performance done!
see ALICE "Physics Performance Report", J. Phys. G30 1517-1763 & CERN/LHCC 2005-030

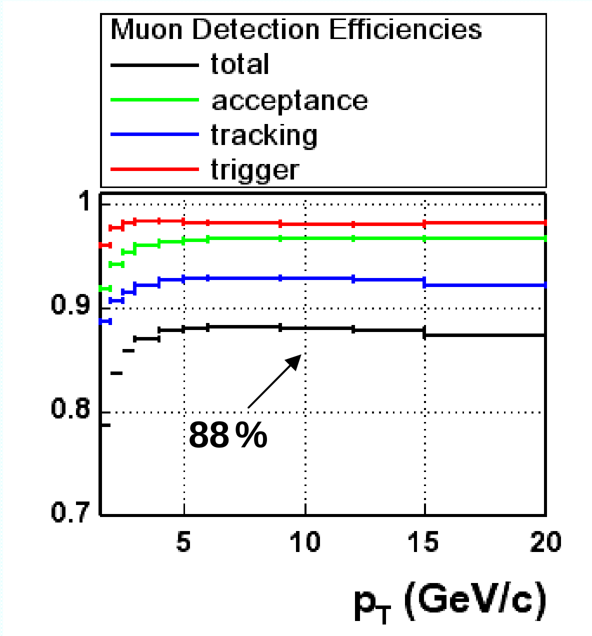
Beauty in the muon channel

$B \to \mu + X$

- Muon spectrometer:
  - pseudorapidity coverage: $-4 < \eta < -2.5$
  - absorber + tracking chambers layers + trigger chambers (22 layers)
  - 15 interaction lengths, but p_t as low as 1-1.5 GeV/c
  - p_t resolution ~ 2%

5 $b\bar{b}$ pairs / central Pb-Pb collision (5 %)





%	$\mu^\pm$	$\mu^+\mu^-$	$\mu^\pm\mu^\pm$
A_{geom}	12	5	3
A_{track}	75	46	51
ε_{track}	62	29	34
$\varepsilon_{trigger}$	53	17	23
$\varepsilon_{trigger}$	29	4	7

$$B^+ \to \overline{D^0}\,\ell_1^+ \nu_\ell \quad \hookrightarrow \ell_2^- X'$$

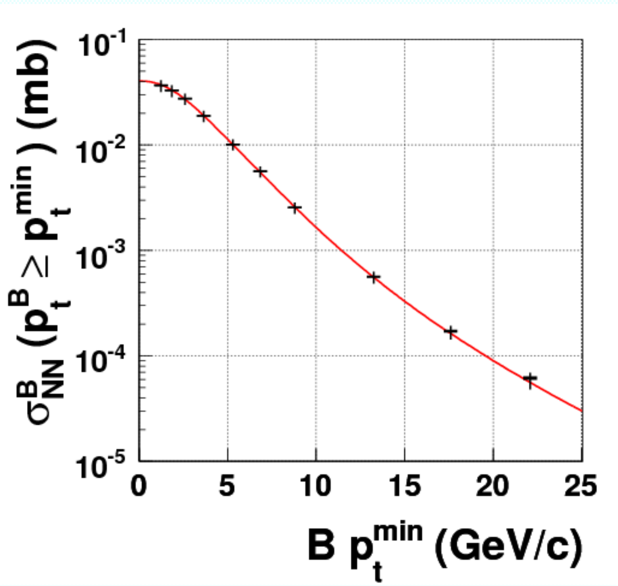
$$\overline{B^0} \to D^+ \ell_3^- \overline{\nu_\ell} \quad \hookrightarrow \ell_4^+ X''$$

B-meson level cross section

B→μ+X

- Method:
  - combined fit of 3 muon data samples (singles, low mass OS, high mass OS) w/fixed shape and b amplitude as the only free parameter
  - MC to derive σ^{B} vs p_t^{min} with p_t as low as 1 GeV/c !

  (UA1 method, see C. Albajar et al., UA1 Coll., Phys Lett B213 (1988) 405, Phys Lett B256 (1991) 121)
  - evaluate stat. and syst. errors



p_T[GeV/c]	1.5-2	1-2.5	2.5-3	3-4	4-5	5-6	6-9	9-12	12-15	15-20
Signal (fit)	4%	4%	3%	3%	2%	2%	3%	4%	8%	12%
Efficiency	10%									
Total p_T-dep.	11%	11%	10%	10%	10%	10%	10%	11%	13%	16%
Decay of π,K	4%									
Normalisation	9%									
Total p_T-indep	10%									

Conclusions

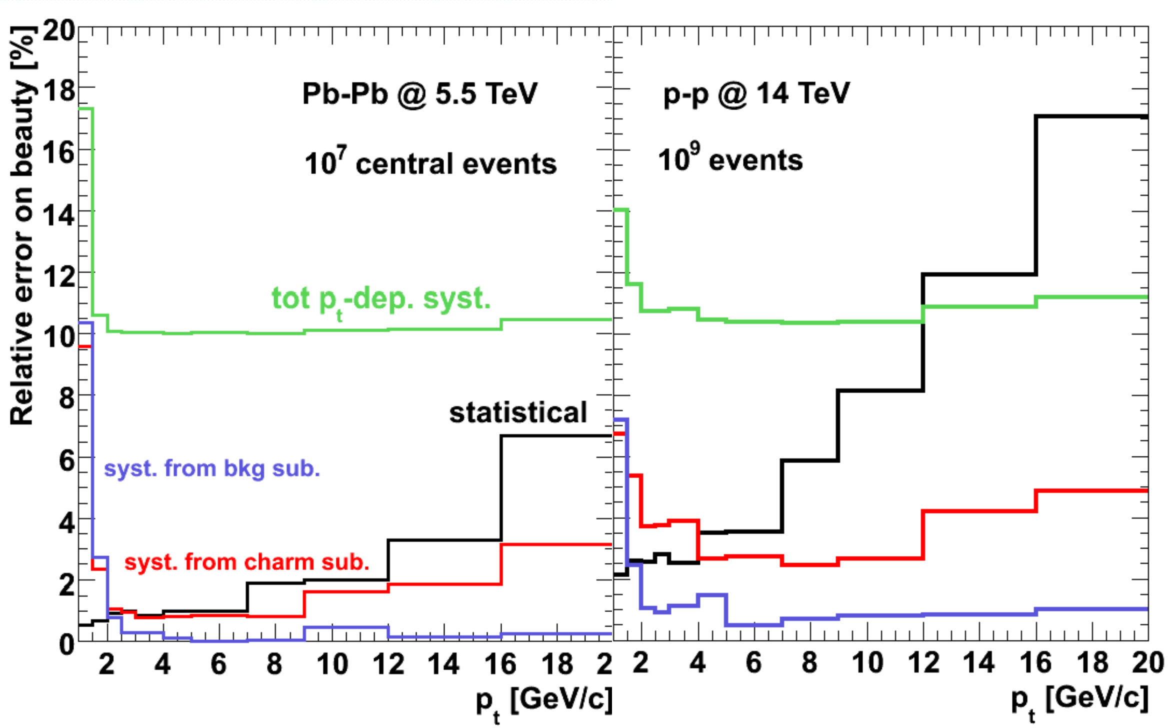
- Heavy flavors can play an outstanding role as QCD test bench in AA reactions at LHC:
  - at low p_t explore small-x region
  - **at high p_t probe the QCD extended medium via energy loss**
- The studies outlined in this talk suggest that ALICE has a good potential in this field:
  - **semielectronic decays in central barrel ($-0.9<\eta<0.9$)**
  - **semimuonic decays in muon arm ($-4< \eta< -2.5$)**

Same observable (E_{loss}) from two different analyses in the same experiment!

- … and a lot has been left out:
  - charm hadronic and semileptonic decays
  - e-μ coincidences
  - indirect J/ ψ
  - b tagging via topological selections
- (Lot of) work in progress in the ALICE Physics Working Group 3 “heavy flavors”…

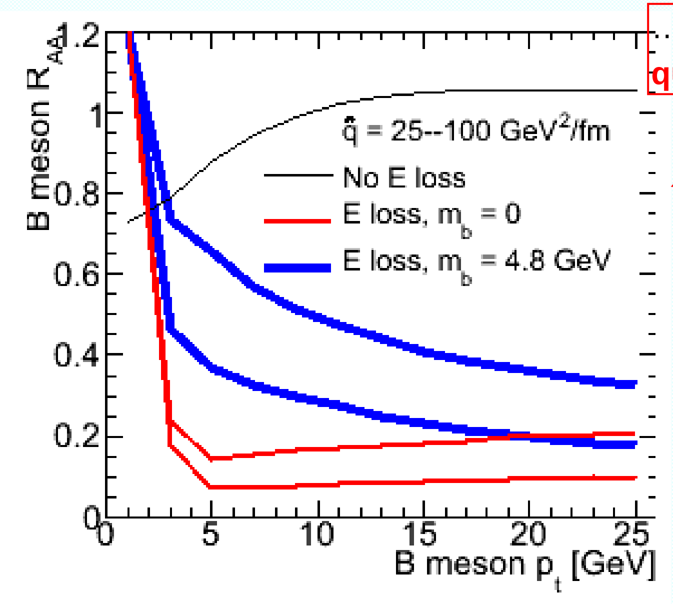
Errors evaluation on e's spectra

- Estimation of errors:
  - MC corrections (efficiency, acceptance, etc.) fixed at 10%, p_t-independent.
  - indetermination on charm subtraction evaluated using as reference our study on hadronic charm detection
  - normalization error not shown

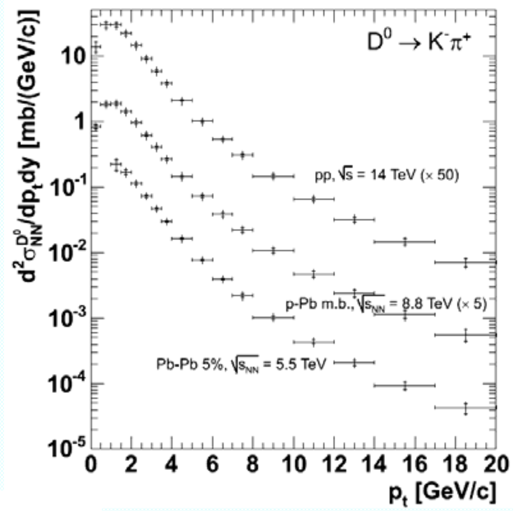


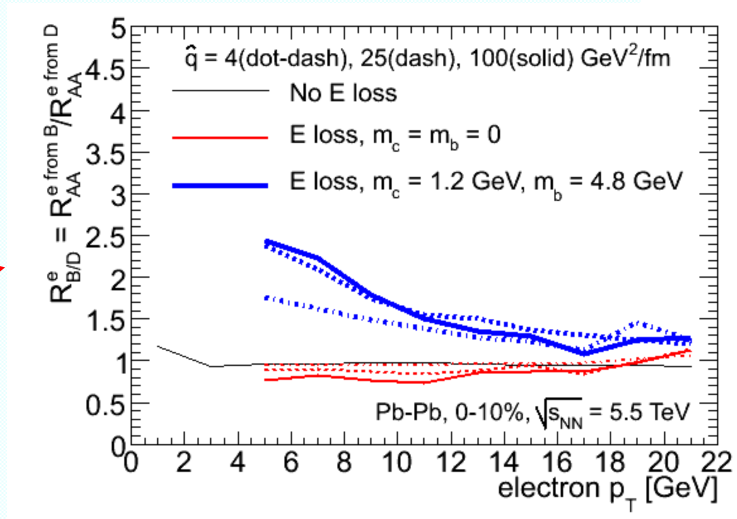
Energy loss at LHC

- A promising strategy: study the **p_t-dependent ratio…**



…R_{AA} of D or B mesons produced in AA and pp:
quark energy loss





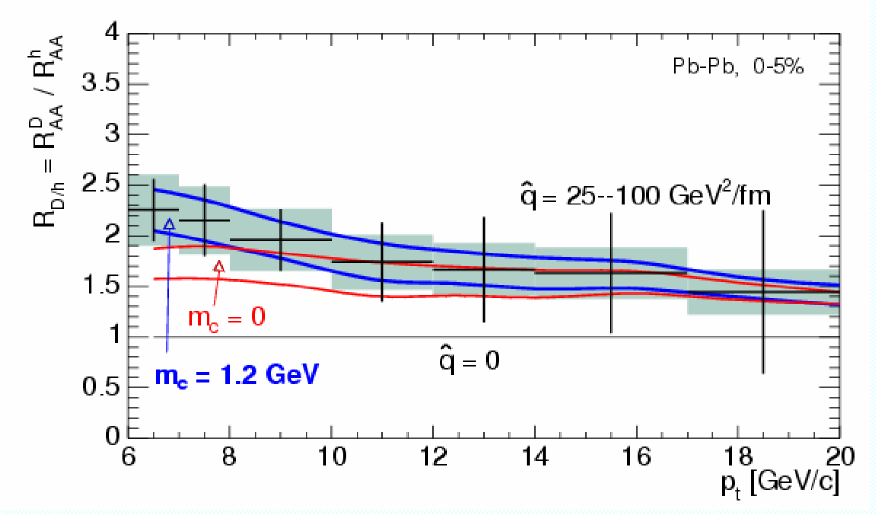
study of charm energy loss done! see

…between R^B_{AA} and R^D_{AA} (beauty/charm ratio):
pure quark analysis

Calculation of energy loss at LHC energies:
Armesto, Dainese, Salgado, Wiedemann, PRD 71 (2005) 054027.

Charm/light ratio

- $R_{(D)Bh}$ mass+color charge effect



$$R_{D/h}(p_t) = R^D_{AA}(p_t) \big/ R^h_{AA}(p_t)$$

Extraction of a minimum-p_T-differential cross section for B mesons

Using UA1 MC method (*), also adopted by ALICE μ

(thanks to R.Guernane for useful discussions)

The B meson cross section per unit of rapidity at midrapidity with $p_T{}^B > p_T{}^{min}$ is obtained from a scaling of the electron-level cross section measured within a given electron phase space Φ^e

$$\frac{d\sigma^B}{dy}(p_T^B > p_T^{\min}) = \sigma^{e,beauty}(\Phi^e)\Big|_{meas} \times \left.\frac{\frac{d\sigma^B}{dy}(p_T^B > p_T^{\min})}{\sigma^B(\Phi^e)}\right|_{MC}$$

The semi-electronic B.R. is included here

$$= \sigma^{e,beauty}(\Phi^e)\Big|_{meas} \times \mathcal{F}_{e\rightarrow B}$$

The phase space used is $\Phi^e \equiv \{\Delta p_T, \Delta\eta, \Delta d_0\}$ where Δp_T are the previously used bins, $\Delta\eta$ = [-0.9, 0.9] and Δd_0 = [200,600] μm

(*) C. Albajar et al., UA1 Coll., Phys Lett B213 (1988) 405
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Extraction of a minimum-p_T-differential cross section for B mesons

Using UA1 MC method, also adopted by ALICE μ

Systematic error for $\mathcal{F}_{e \to B}$

- semi-electronic decay B.R.: **~ 3 %**

- dependence on the shape of the B meson p_T distribution used as input in the MC: can be minimized using a proper choice of p_T^{min} for a given phase space $\Phi^e \rightarrow$ see following slides

- Monte Carlo correction for the efficiency of the selection cuts: this is, in principle, depending on the B meson p_T distribution, and should be then evaluated at this stage of the analysis. For the present feasibility study we account for it with a 10% systematic.

Extraction of a minimum-p_T-differential cross section for B mesons

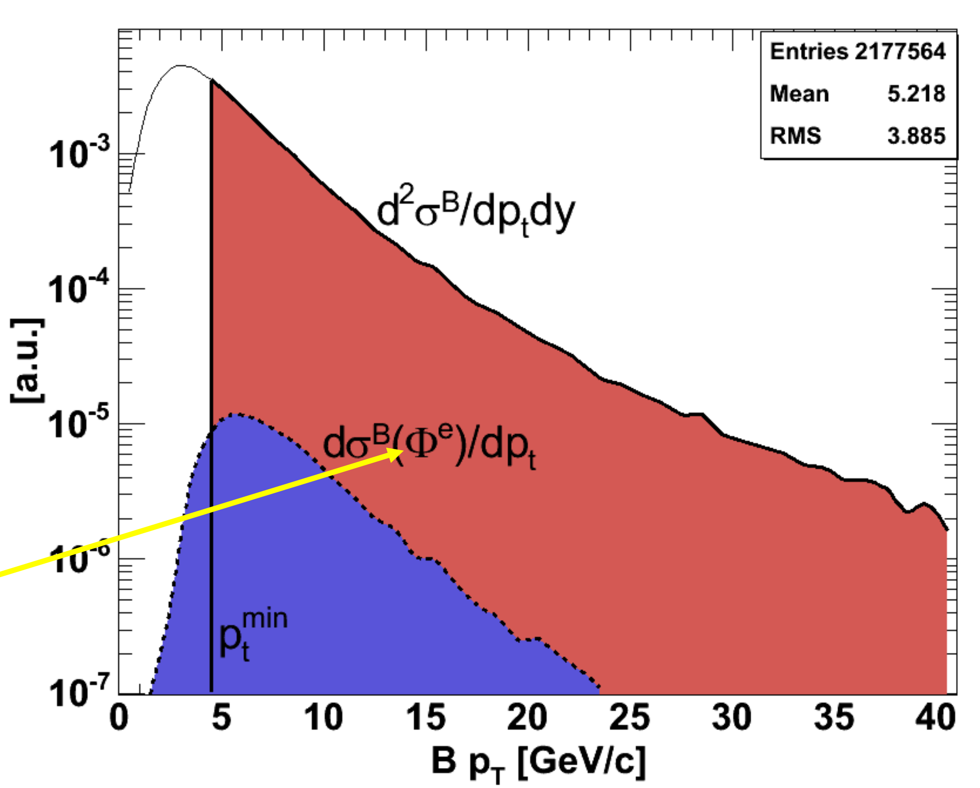
Using UA1 MC method, also adopted by ALICE μ

Evaluation of $\mathcal{F}_{e\to B}$ and determination of the optimal p_T^{min}

1) we used the $B \to e + X$ decays from PYTHIA.

$\mathcal{F}_{e\to B}$ is the ratio of the red area to the blue one.

here Δp_T^e = [3,4] GeV/c



Extraction of a minimum-p_T-differential cross section for B mesons

Evaluation of $\mathcal{F}_{e \to B}$ and determination of the optimal p_T^{min}

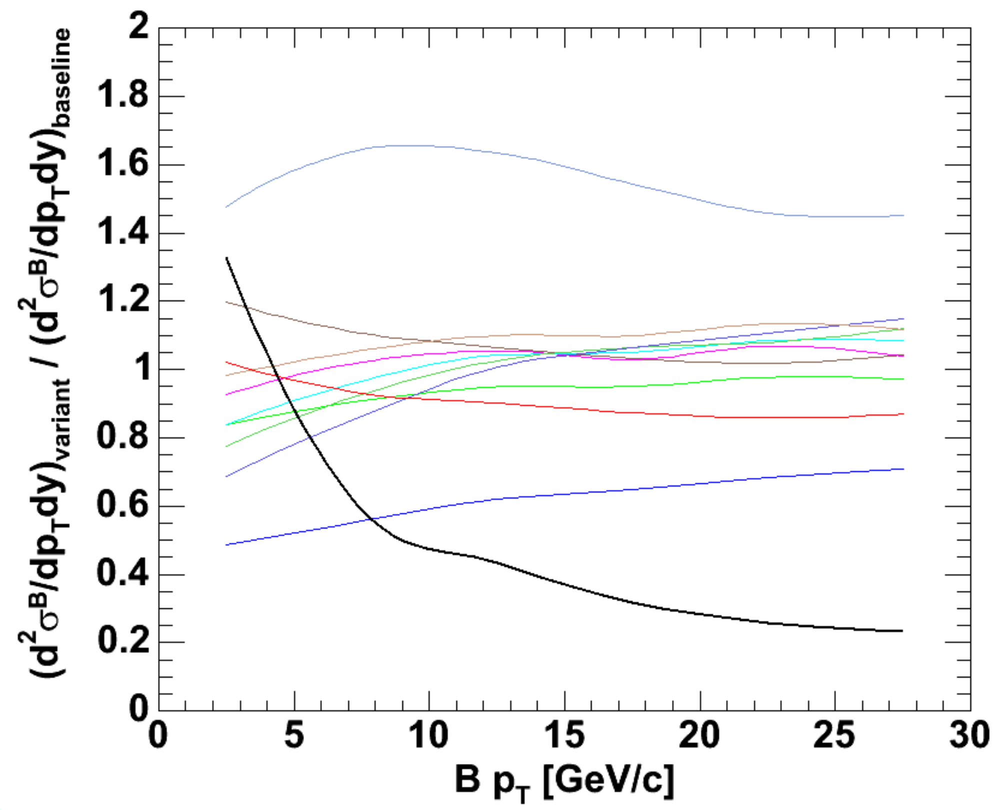
2) in the HVQNMR program we changed the theory parameters:

a) quark mass and scales

b) nuclear modification of the PDFs

c) $b \to B$ fragmentation (Peterson)

d) add the quenching ($\hat{q}$ = 100 GeV^2/fm (*))



(*) N. Amesto, A. Dainese, C. A. Salgado, U. A. Wiedemann, hep-ph/0501225

Extraction of a minimum-p_T-differential cross section for B mesons

Evaluation of $\mathcal{F}_{e\rightarrow B}$ and determination of the optimal p_T^{min}