Measurement of electrons from charm and beauty-hadron decays in p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE at the LHC

Jan Wagner for the ALICE Collaboration

Motivation

The ALICE detector

Analysis strategy

Results

Motivation - charm and beauty

Charm and beauty quarks (heavy-flavour, “HF”):

- Large mass -> production in initial hard partonic interactions

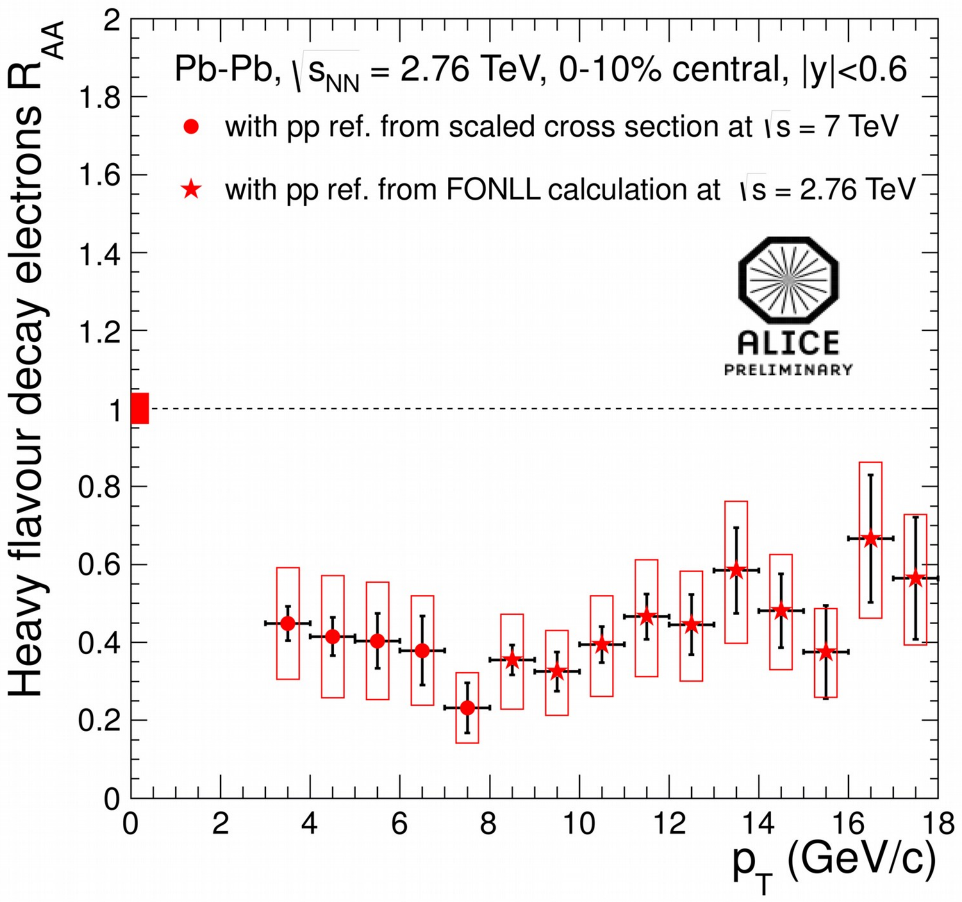
Heavy-ion collisions:

- Heavy quarks interact with the medium
- Modification of the momentum distribution due to energy loss

->Observed strong suppression of HF yield at high p_T

- Experimental observable: nuclear modification factor R_{AA}:

$$R_{AA}=\frac{1}{\langle N_{coll}\rangle}\frac{dN_{AA}/dp_T}{dN_{pp}/dp_T}$$



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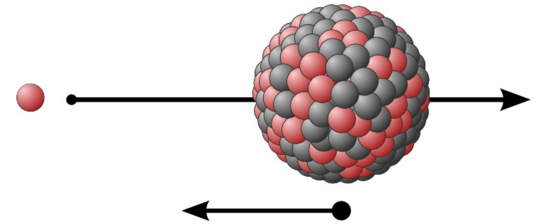
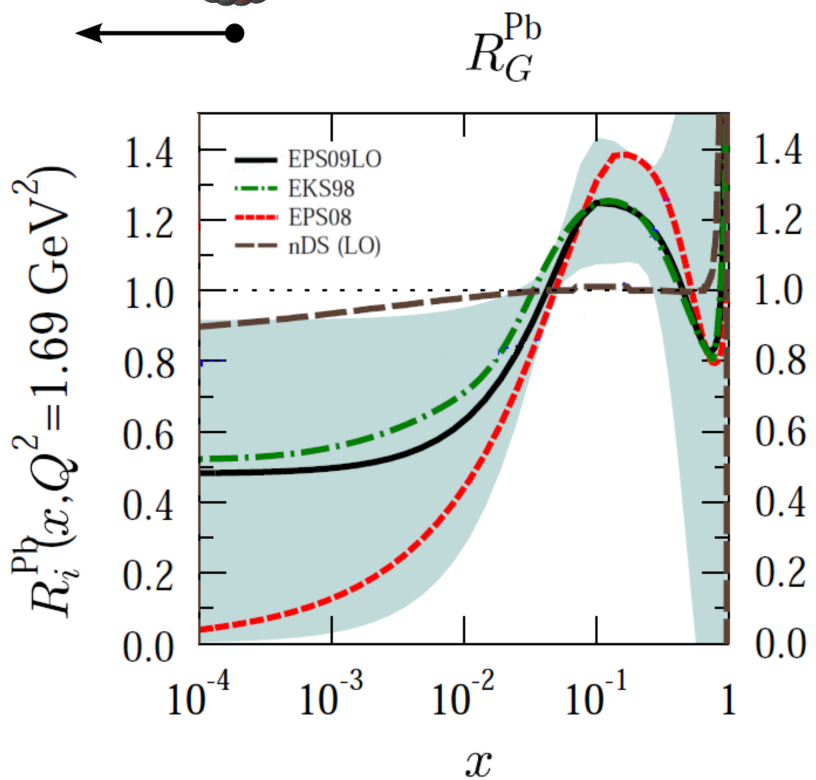
p-Pb collisions: measuring initial state effects

- Initial state effects might play a role for Pb-Pb collisions
- p-Pb collisions:
  - no extended hot and dense medium
  - only cold nuclear matter effects:
    - Modified (g)PDF in nuclei
      - Shadowing / saturation at low x
    - k_{T} broadening
- Measure nuclear modification factor R_{pPb} of HF hadron yield to quantify cold nuclear matter effects





$$R_{\mathrm{pPb}} = \frac{1}{A} \frac{d\sigma_{\mathrm{pPb}}/dp_{\mathrm{T}}}{d\sigma_{pp}/dp_{\mathrm{T}}}$$

K.J. Eskola et al., JHEP, 0904:065, 2009.

How to measure charm and beauty production?

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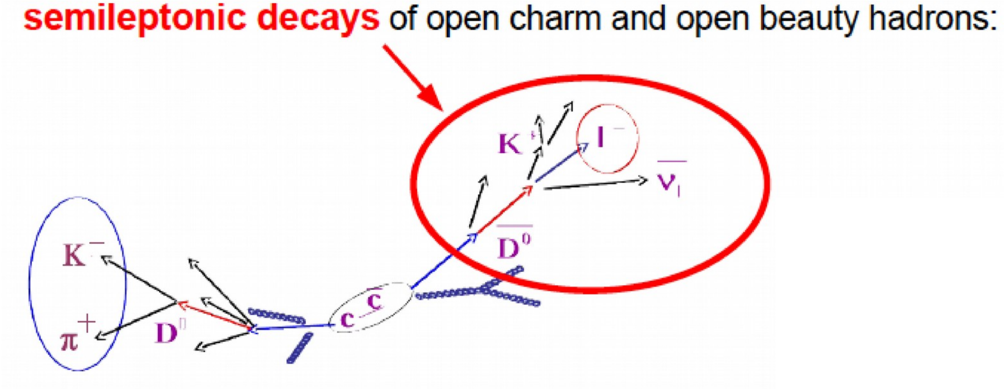
- Direct reconstruction of charm and beauty mesons in hadronic decay channels, e.g. $D^0 \rightarrow \pi^+ + K^-$ (BR ~3.88%)
  - Analysis based on fully reconstructed decay topologies displaced from the interaction vertex
  - D^0, D^+, D^{*+} and D_s^+ cross section measured in pp, p-Pb and Pb-Pb collisions

->Talk: F. Colamaria

- Inclusive measurement via semileptonic decays,

  e.g. c -> e + anything (BR ~9.6%)
  - Indirect measurement via inclusive electron spectrum from HF hadron decays
  - Background: all other sources of electrons (most important: γ conversions and Dalitz decays)



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A Large Ion Collider Experiment

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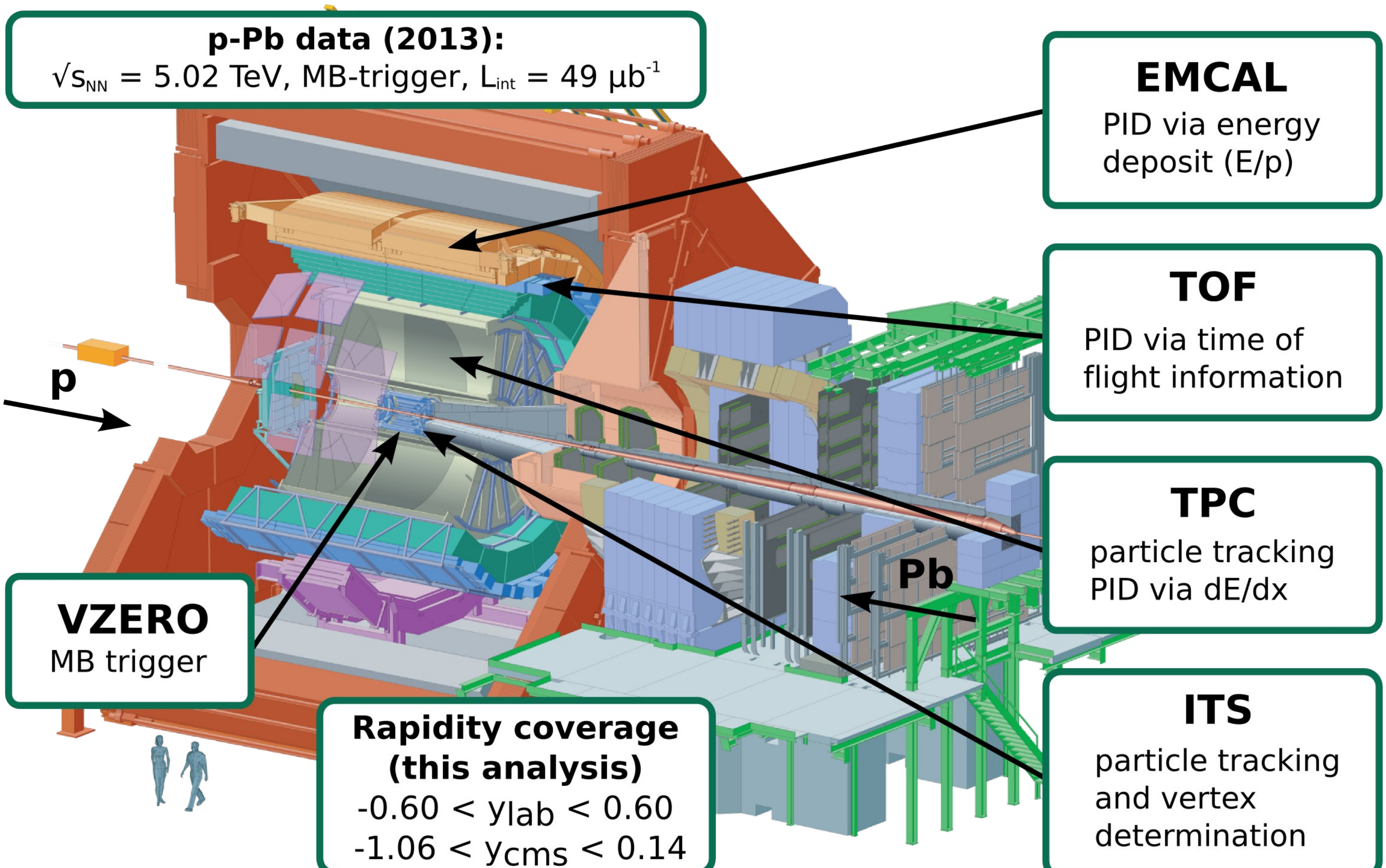

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Analysis strategy

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- Measure raw electron spectrum with optimized tracking cuts and PID strategies (TPC:d*E*/d*x*, TOF:Time-Of-Flight, EMCal:*E*/*p*)
- Subtract the contribution of background electrons (two alternative methods)
- Correct for reconstruction efficiency and geometric acceptance
- Separation of electrons from charm and beauty quarks via impact parameter cut

-> Get p_T differential cross section of electrons from heavy-flavour hadron decays and beauty-hadron decays

- Combine with pp reference to calculate nuclear modification factor R_{pPb}

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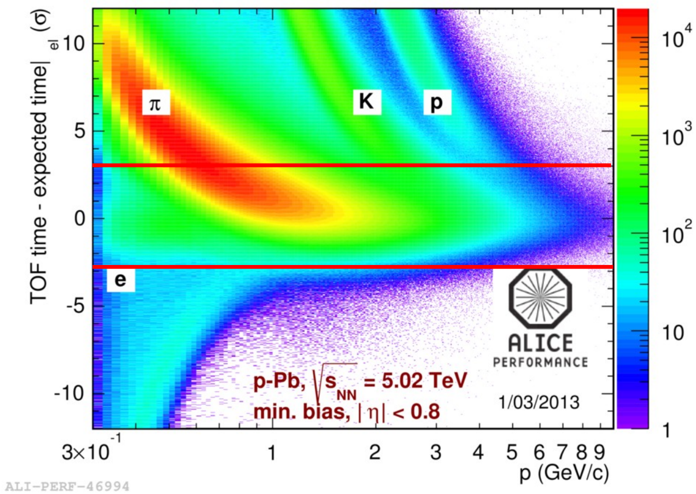
Analysis strategy

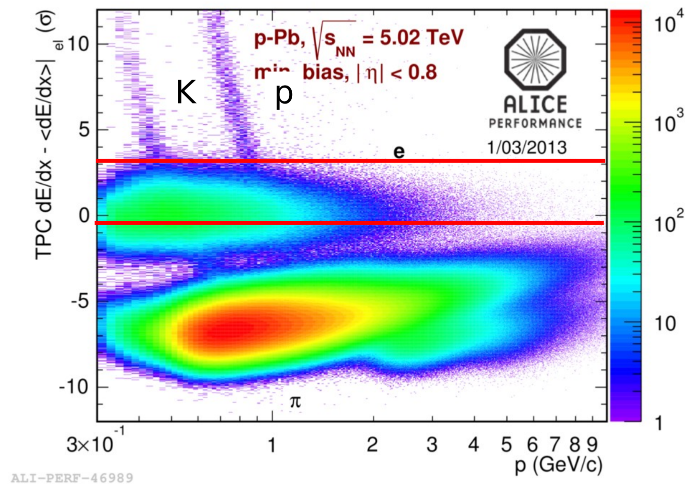
Identification of electrons

Subtraction of background electrons

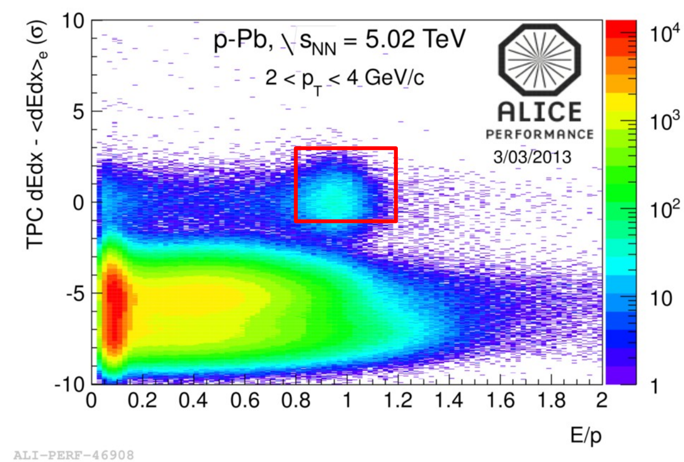
Separation of charm and beauty electrons

Electron identification: TOF, TPC & EMCal PID





- TOF symmetric 3σ cut around expected electron Time-of-Flight
- TPC $-0.5\sigma < dE/dx < 3\sigma$
- Negligible K and p contribution after TOF+TPC, increasing pion contamination with p_T
- Hadron contamination estimated by fits to the d*E*/d*x* in momentum slices
- High p_T analysis done using the TPC and EMCal detectors:
  $-1\sigma < dE/dx < 3\sigma$ & $0.8 < E/p < 1.2$



Non-HF electron background – cocktail with pion input

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- Inclusive electron distribution contains electrons from all sources

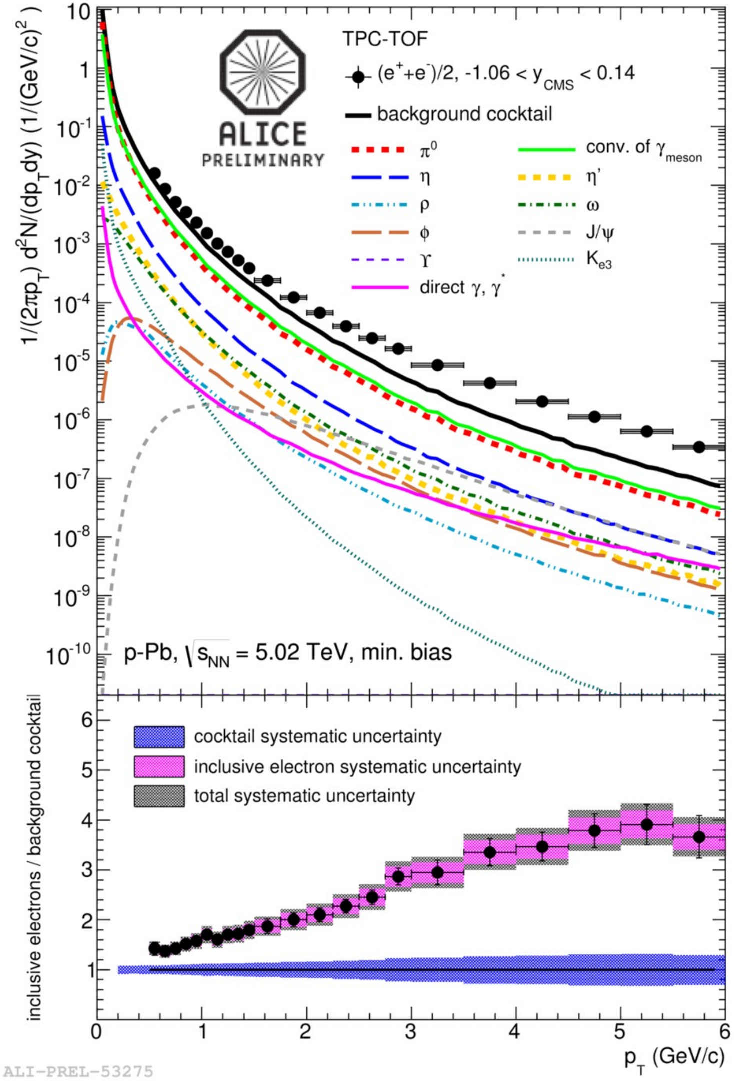
  Cocktail:

  Electrons from all other sources than heavy-flavour hadrons

- Input for cocktail: measured charged pion dN/dp_T spectrum under the assumption:

$$\frac{dN}{dp_T}(\pi^0) = \frac{dN}{dp_T}\frac{(\pi^+ + \pi^-)}{2}$$

- Contributions from other mesons added using m_T scaling



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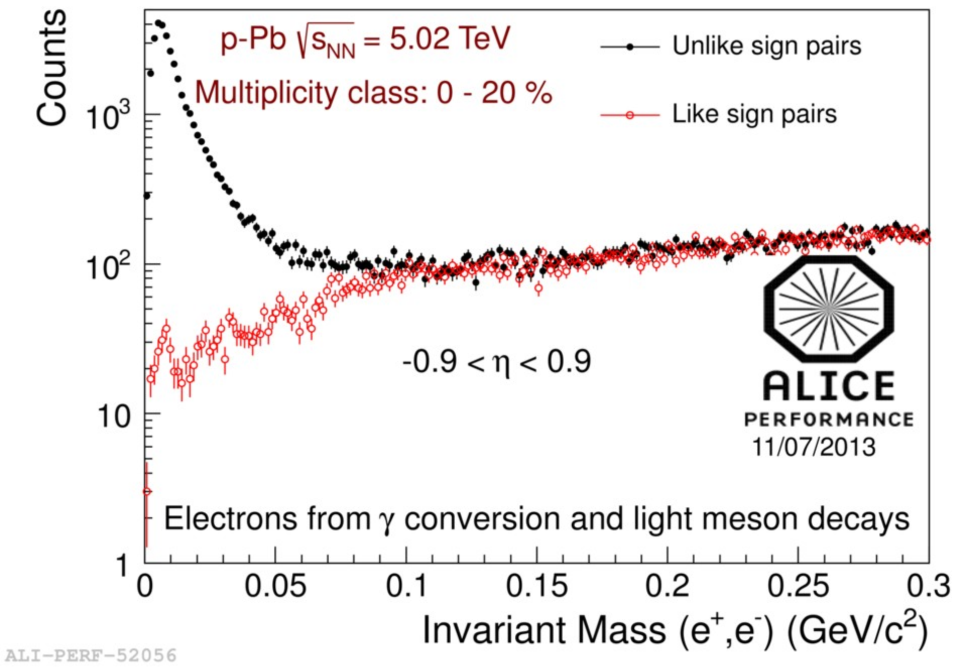
Electron background subtraction

Main contribution to background electrons: photon conversions and Dalitz decays of light mesons (= "photonic" electrons)

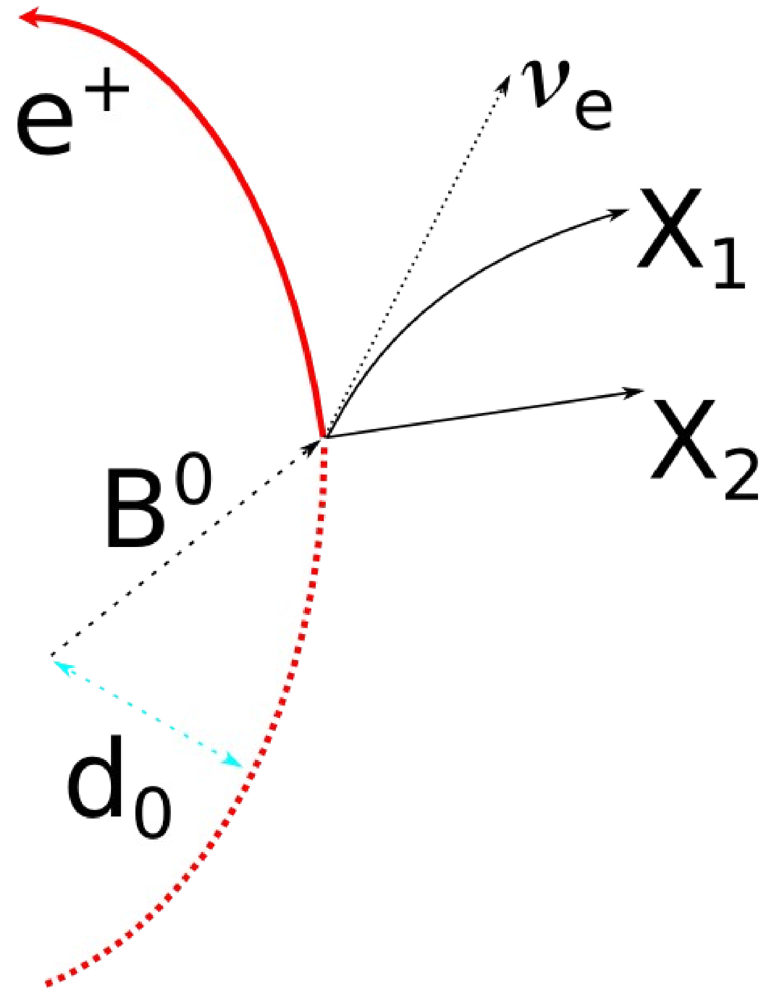
$\pi^0 \rightarrow \gamma\gamma ; \gamma_{conversion} \rightarrow e^+ e^-$ $\pi^0 \rightarrow \gamma e^+ e^-$

- Photonic electrons come in e^+e^- pairs with small invariant mass
- Combinatorial background subtraction with like-sign technique
- Remaining contribution taken from cocktail (weak Kaon decays "K_{e3}" & J/ψ)



Separation of charm and beauty

- Apply cut on electron impact parameter (IP) d_0 to increase S/B for b->e
- Remaining background removed by cocktail approach based on measured pion and D-meson cross sections



IP distribution for different electron sources

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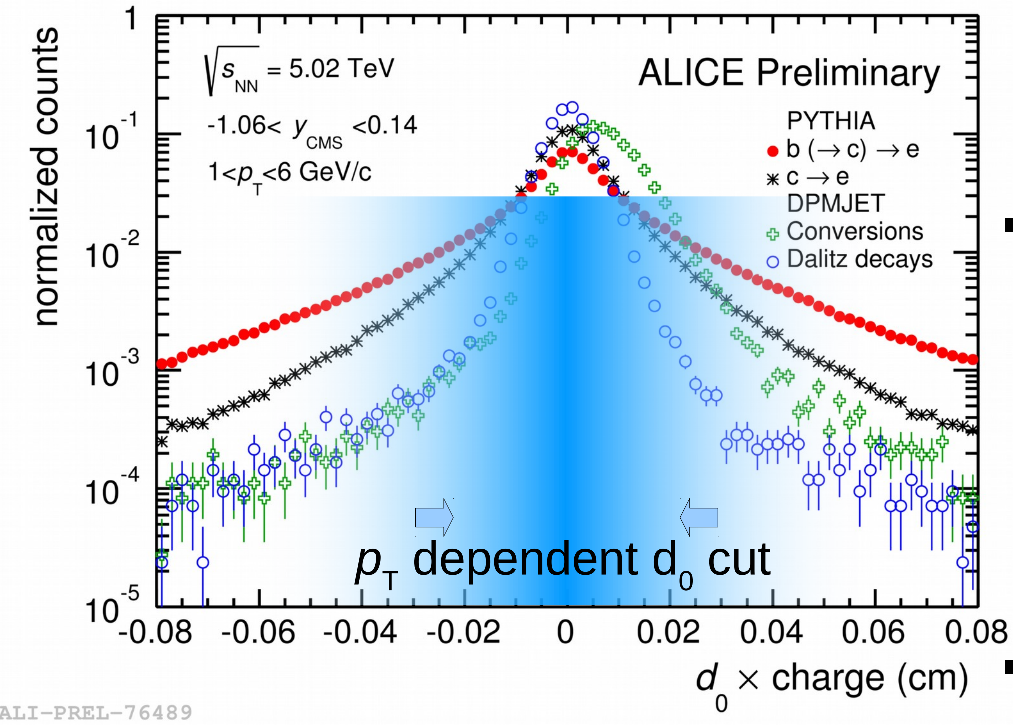

- Exploit long life time of beauty hadrons compared to charm hadrons:

  cτ(D^0) = 123 µm
  cτ(B^0) = 455 µm

- p_T dependent cut on the minimum electron impact parameter:

> optimize S/B for b->e decays with MC simulations

- Looser cut on minimum IP with increasing p_T due to lower statistics / less background

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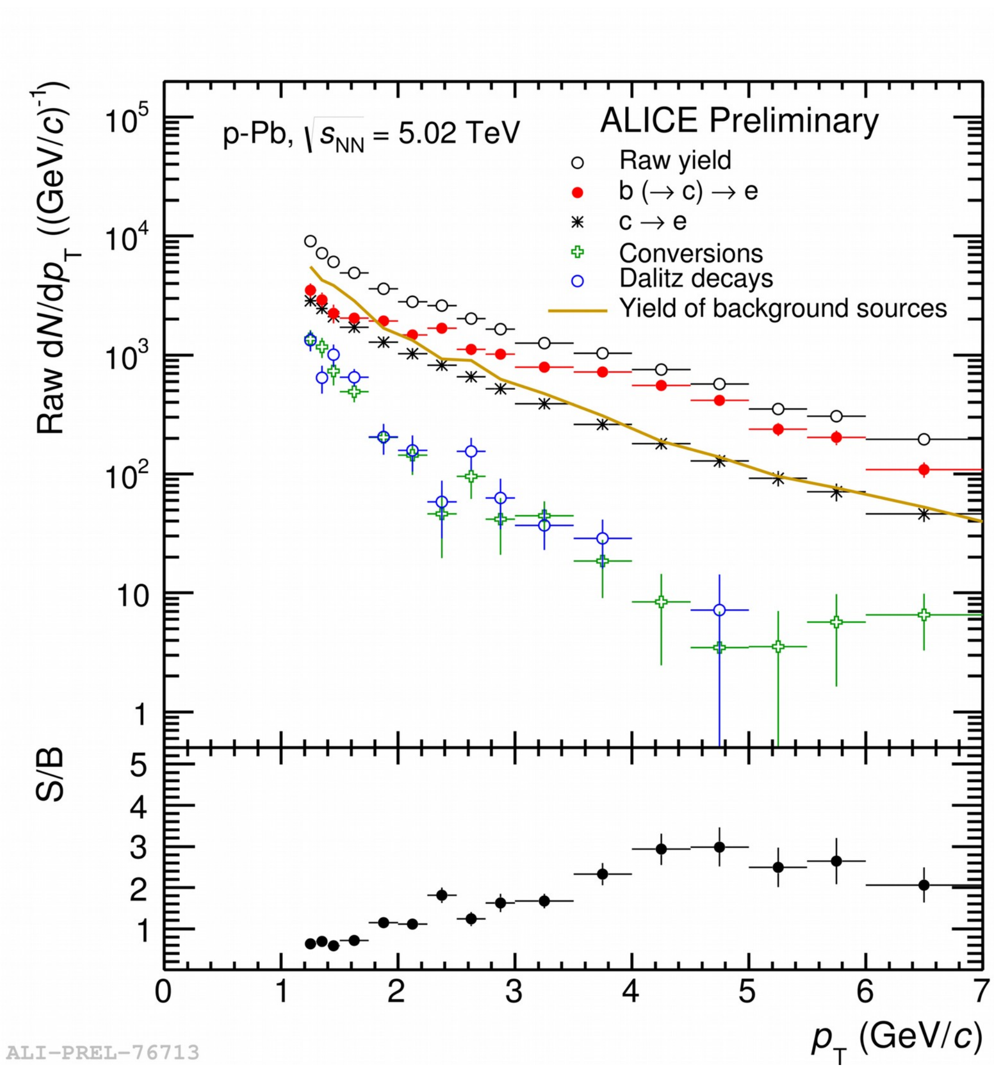
Raw electron yield contributions after impact parameter cut



- Increased e<-b contribution with simultaneous suppression of non-HF electrons
- Remaining fraction of electrons from charm-hadron decays needs to be estimated using MC simulations
- MC is weighted with prompt D-meson cross sections measured with ALICE (arXiv:1405.3452) and an estimate for the Λ_c->e contribution(ZEUS) (Eur.Phys.J., C44:351–366, 2005)

Results

Cross section of electrons from heavy-flavour hadron decays

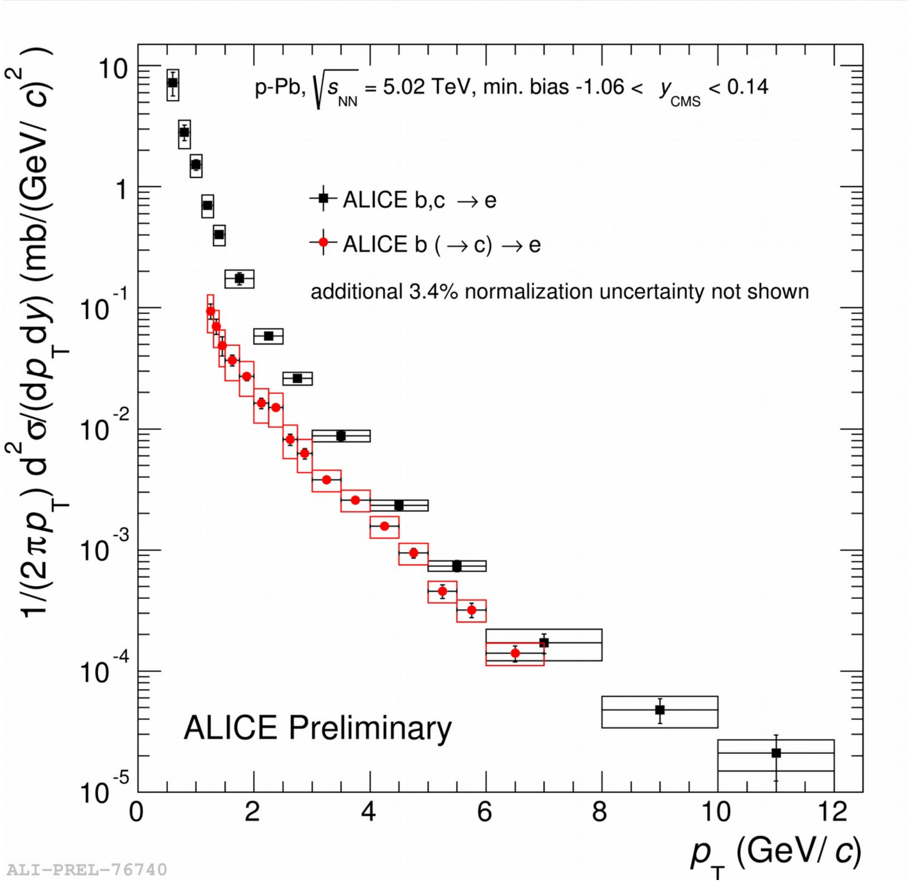
Reference from pp collision

Nuclear modification factor

Electrons from HF - cross section

- Correction for the reconstruction efficiency and acceptance of the detector
- Systematics:
  - Measurement & detector: 7% - 29%
  - Cocktail: 6% - 8.5%
  - Minimum bias p-Pb collision cross section: 3.4%
  - Specific for the b->e measurement:
    - D-meson input: hadron and p_T dependend 10% - 20%
- Different slope for electrons from beauty-hadron decays:

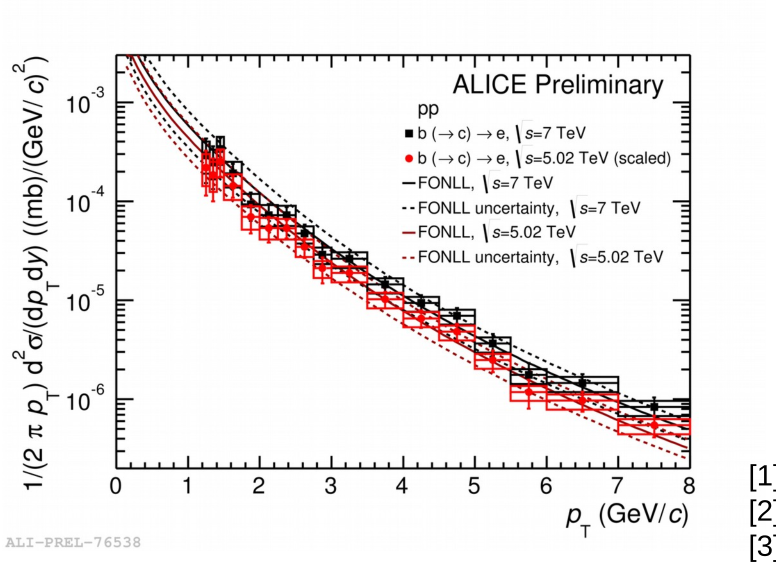
  beauty contribution dominant in high p_T region

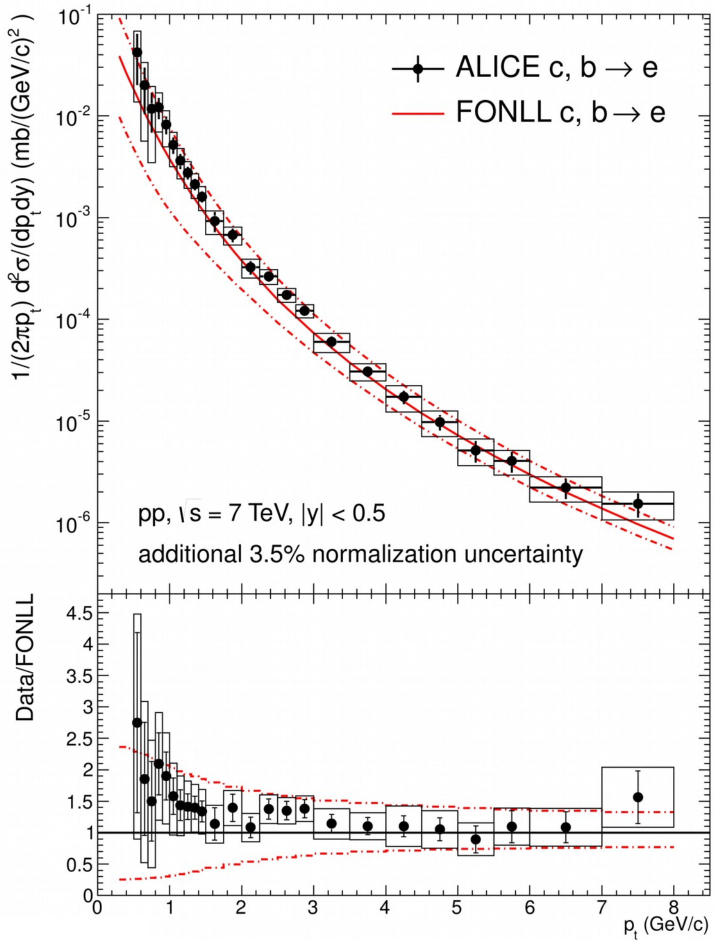


Reference for R_{pPb}

- Cross section in pp collisions at √s = 7 TeV for electrons from heavy-flavour[1] and beauty[2] decays:

  Extrapolation to 5.02 TeV based on the √s dependence from FONLL pQCD calculations"[3]





[1] B. Abelev et al. (ALICE Collaboration) Phys. Rev. D 86, 112007 (2012)
[2] B. Abelev et al. (ALICE Collaboration) Phys. Lett. B721, 13-23 (2013)
[3] R. Averbeck et al. arXiv:1107.3243 [hep-ph], Jul 2011

Nuclear modification factor

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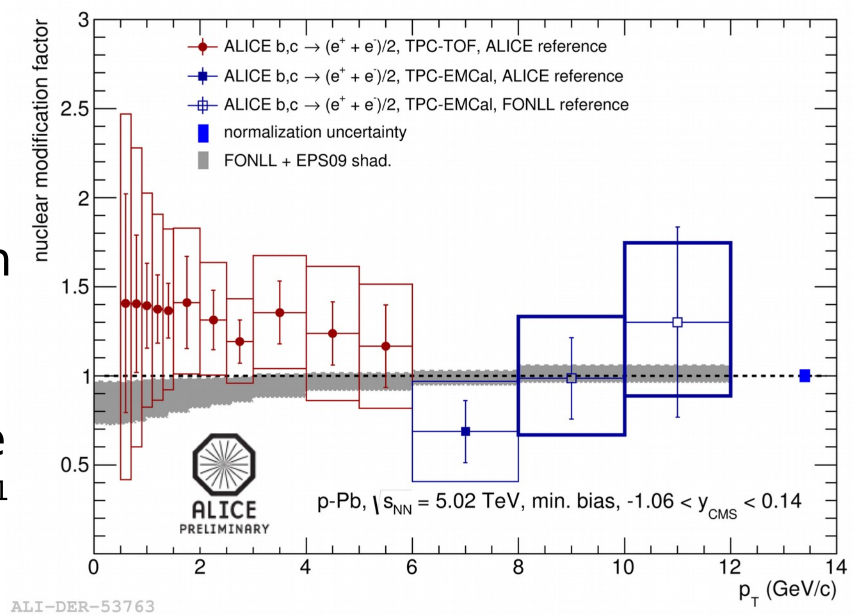
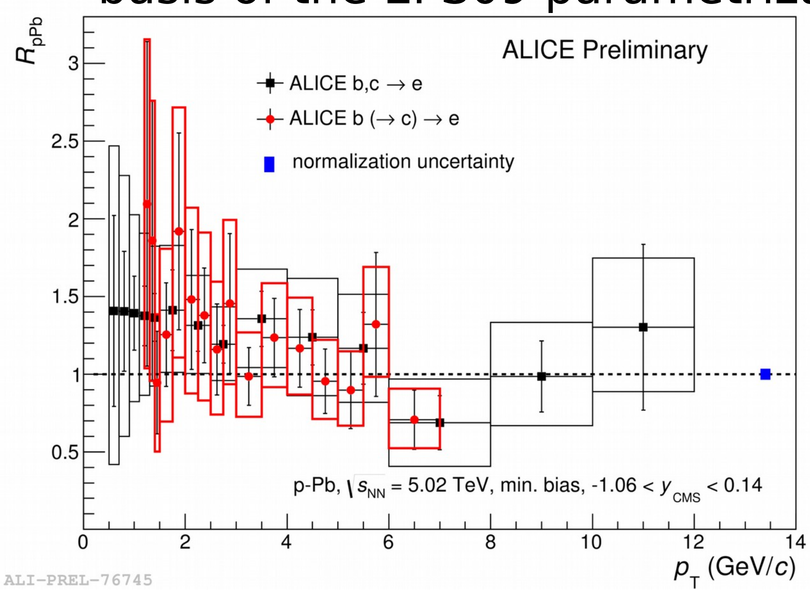
- R_{pPb}(c,b->e) compatible with unity and model calculations which include:
  - Binary scaling of the cross section in pp collisions to the p-Pb collision system
  - Shadowing effects calculated on the basis of the EPS09 parametrization.[1]





- R_{pPb} for beauty-decay electrons compatible with unity and with HF decay electron R_{pPb}

Suppression seen in Pb-Pb collisions is an effect of the hot and dense medium

[1]K.J. Eskola et al., JHEP, 0904:065, 2009.

->Talk: M. Völkl

Summary

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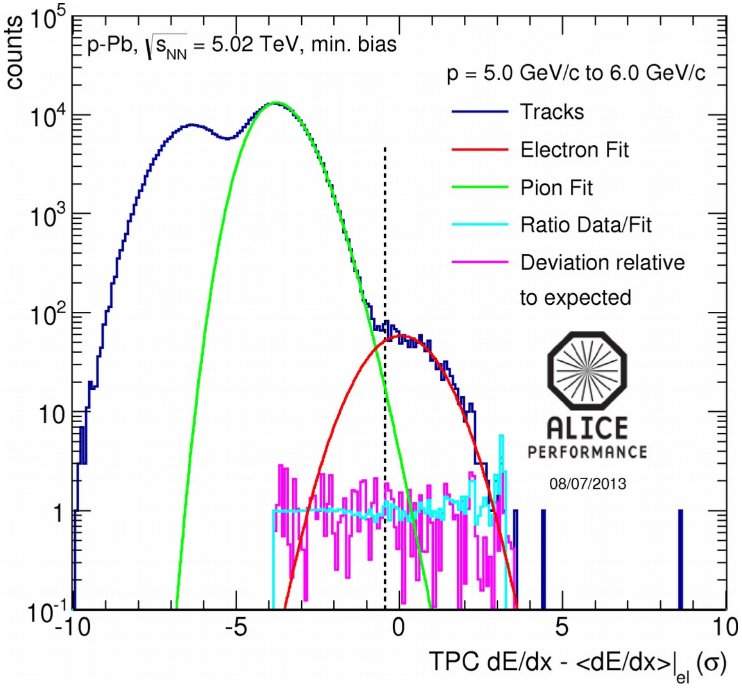
- Selection of electron candidates with TPC, TOF and EMCal detectors
- Background subtraction using electron cocktail or invariant mass approach
- Separation of electrons from beauty-hadron decays using a p_{T} dependent impact parameter cut
- Measurement of HF cross section in p-Pb collisions using the semileptonic decay channel
- R_{pPb} consistent with unity and model calculations including shadowing predictions
- Initial state effects are small, suppression seen in Pb-Pb collisions is a final state effect

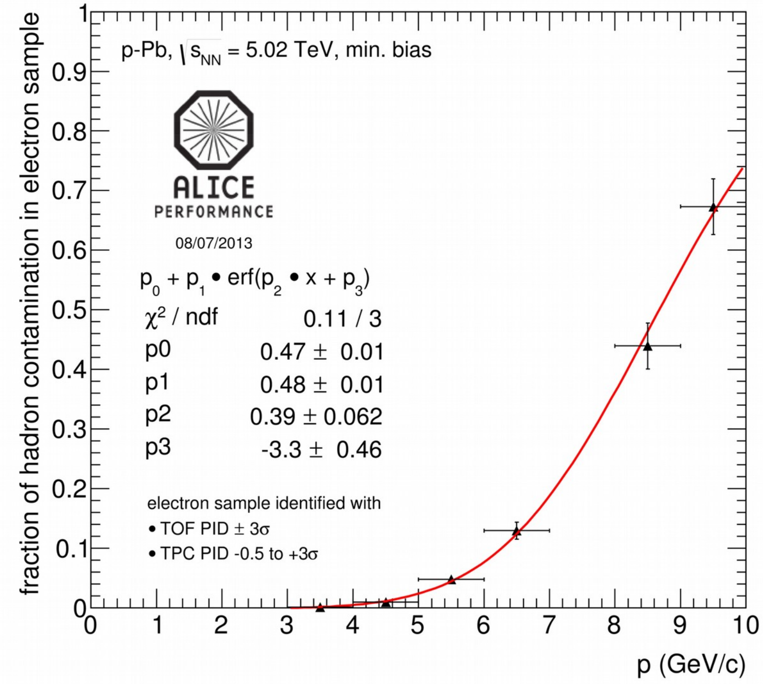
Outlook

- Analysis in multiplicity bins for p-Pb collisions

Backup

Hadron contamination





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- Fits to electron and pion dE/dx in momentum slices (Kaon+Proton negligible)
- Obtain hadron contamination as function of particle momentum

R_{pPb} vs results from PHENIX

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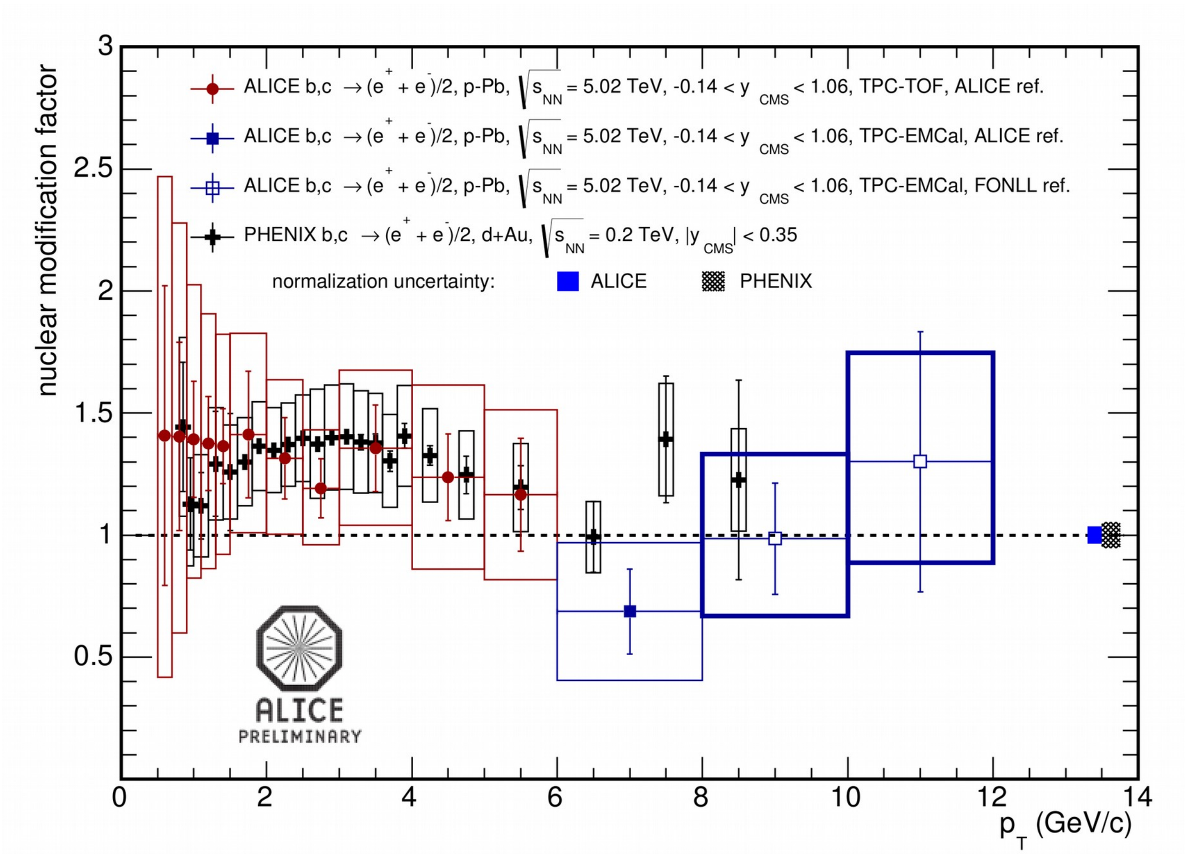
- PHENIX results in d-Au collisions at √s = 0.2 TeV



A. Adare et al. (PHENIX Collaboration)
Phys. Rev. Lett., 109:242301, Dec 2012.

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