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INFN Istituto Nazionale di Fisica Nucleare Sezione di Bari

Measurement of azimuthal correlations between D mesons and charged hadrons with ALICE at the LHC

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ALICE

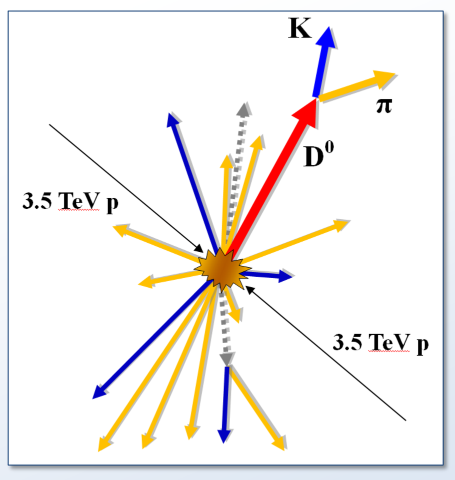
Physics Motivations

D-hadron azimuthal correlations can give us access to the charm production and fragmentation mechanism and provide further insight into the heavy quark interaction with the medium created in heavy-ion collisions. Specific goals of the analysis for the different collision systems:

pp:
- Characterize charm quark jets and study their properties
- Possible sensitivity to the different charm production mechanisms
- Provide a reference for p-Pb and Pb-Pb collisions

p-Pb:
- Assess cold nuclear matter effects
- Search for double ridge (i.e. long-range ridge-like structures in near and away side regions) as observed in h-h correlations

Pb-Pb:
- Study medium-induced modifications to charm fragmentation and hadronization
- Study energy loss dependence on path length in the medium
- Possibly sensitive to relative contributions of radiative and collisional energy loss [1]



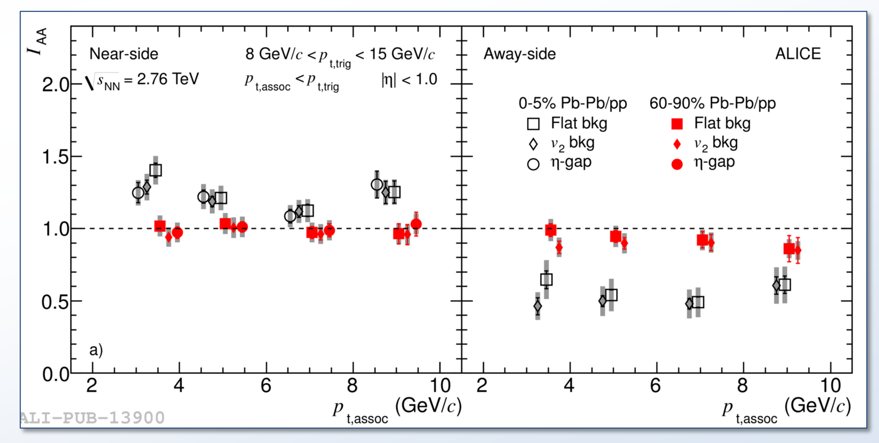
Related Measurements

Δφ distributions of hadron-hadron correlations [2]

Comparison between pp and Pb-Pb central collisions via I_{AA} observable:

$$I_{AA} = \frac{Y_{AA}}{Y_{pp}}, \qquad Y = \frac{1}{N_{trig}} \int \frac{dN(\Delta\varphi)}{d\Delta\varphi}\, d\Delta\varphi$$

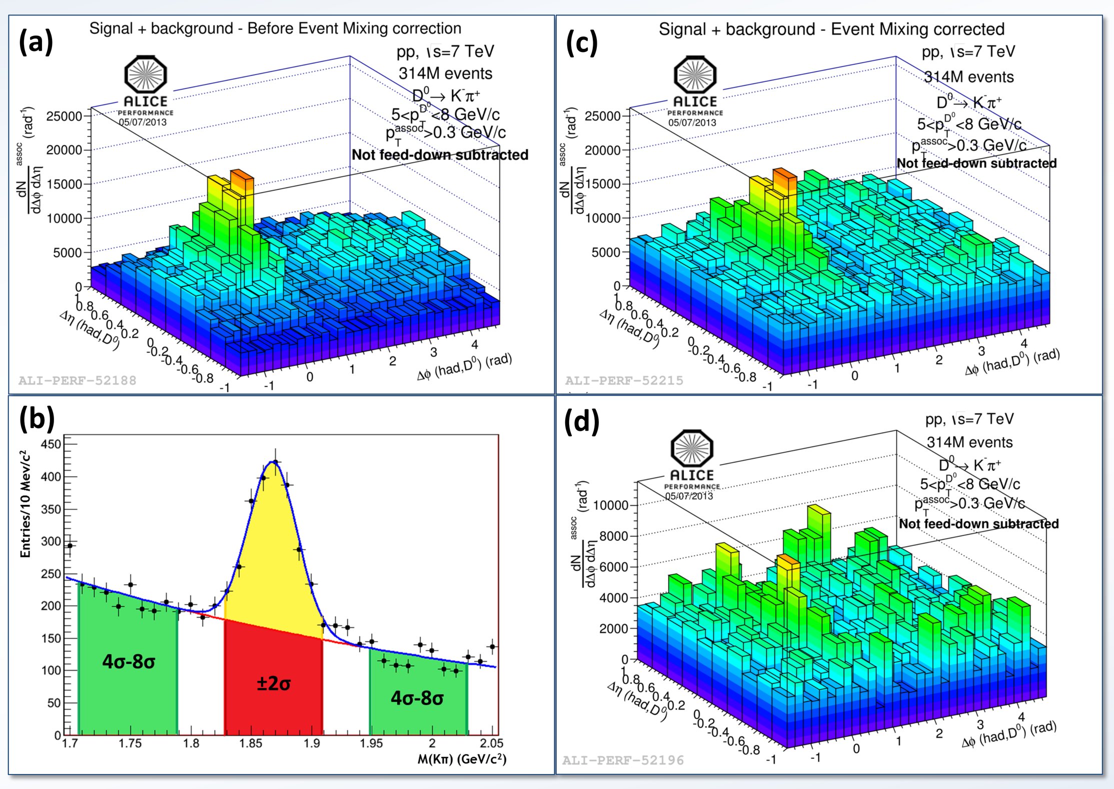
- **Suppression of away side yield by ~40%**
  Due to parton energy loss in the medium and due to the «surface bias»
- **Enhancement of same side yield by 20-30%**
  Still not well understood, probably an interplay of: p_T spectrum redshift, different quark/gluon jet fraction, medium modification of fragmentation



Description of the Analysis

Analysis performed on: - pp collisions at $\sqrt{s} = 7$ TeV (3.1· 10^8 events)
- p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV (10^8 events)

Analysis strategy
- D meson and associated charged track selection
  - → D mesons (trigger particles) reconstructed in the central barrel from hadronic decays and selected exploiting their displaced decay vertex topology, PID and reconstruction quality selection on the daughter tracks
  - → Associated tracks reconstructed in the central barrel and selected with cuts on the quality of the reconstruction
- Evaluation of (Δφ,Δη) correlations of selected D candidates in invariant mass peak region with selected associated tracks (panel a)
  - → Peak region defined in ±2σ from the centre of the peak (panel b)
- Removal of correlations from background D-meson candidates via sideband subtraction
  - → Sideband regions defined in 4-8σ from the centre of the peak (panel b)
  - → Correlation distribution evaluated also in this region and then subtracted from signal region correlation distribution, after event-mixing correction (panel d: correlation pattern after event-mixing correction and sideband subtraction)



- Corrections applied on the correlation distributions:
  - ➢ For detector spatial inhomogeneities and limited acceptance, exploiting the event-mixing technique
    - → correlating D mesons from an event with tracks from other events with similar properties (panel c);
  - ➢ For associated track and D-meson reconstruction and selection efficiencies
    - → weighting each correlation entry by the inverse of the product of the track and D-meson efficiencies: $w = (\epsilon_{track} \cdot \epsilon_D)^{-1}$
  - ➢ For correlations from D mesons produced in B-meson decays
    - → subtracting the «feed-down» contribution, evaluated using Monte Carlo templates
  - ➢ For secondary tracks contamination, i.e. tracks from strange-hadron decays or produced in interaction of particles with the detector material
    - → contribution evaluated via Monte Carlo studies
- Projection along Δφ axis (to reduce statistical fluctuations)
- Evaluation of systematic uncertainties
- Fit to fully corrected azimuthal correlation distributions and extraction of physical observables (near-side yield, near-side peak width, baseline height)
- Comparison of the distributions and of the physical observables in pp/p-Pb collisions and with predictions from several PYTHIA tunes

Analysis Results

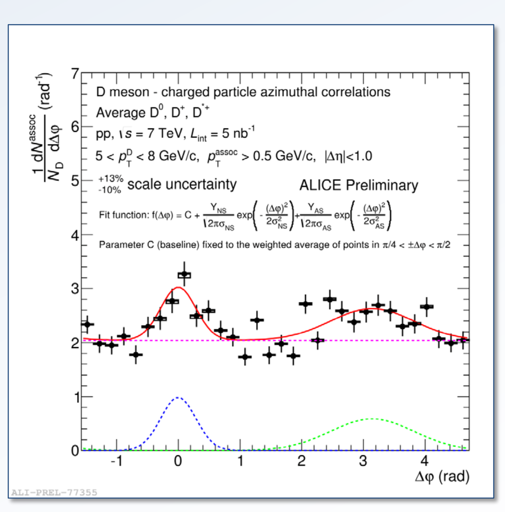
Δφ correlation distributions - Average of D⁰, D⁺, D*⁺ mesons

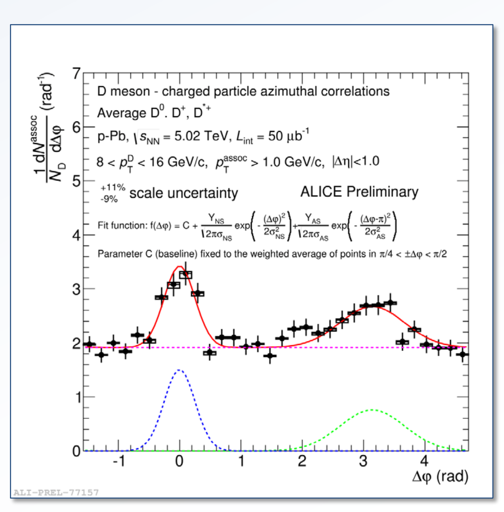
Average of the results from the three D-meson species, weighted with statistical and uncorrelated systematic uncertainties

$$\left\langle \frac{1}{N_D}\frac{dN^{assoc}}{d\Delta\varphi} \right\rangle_{D\,avg} = \frac{\sum_{i=meson} w_i \frac{1}{N_{D_i}} \frac{dN_i^{assoc}}{d\Delta\varphi}}{\sum_{i=meson} w_i}, \text{ with weights: } w_i = \frac{1}{\sigma_{i,stat}^2 + \sigma_{i,uncorr\ syst}^2}$$

Results obtained for:
- Three D-meson p_T ranges: 3-5, 5-8, 8-16 GeV/c (only last two for p-Pb)
- Three associated track p_T lower thresholds (p_T > 0.3, 0.5, 1 GeV/c)

Fit function:
- **Two Gaussians** (fixed means at 0 and π) + **constant value**, evaluated from a weighted average of the points in the transverse regions, i.e. $[\pi/2 - \pi/4, \pi/2 + \pi/4]$.

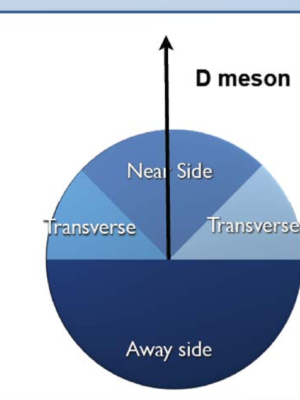


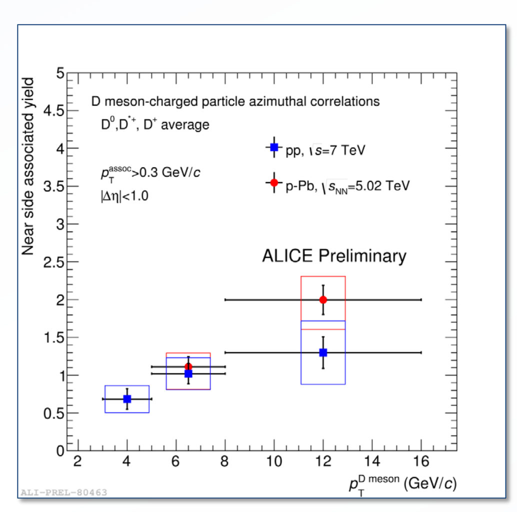


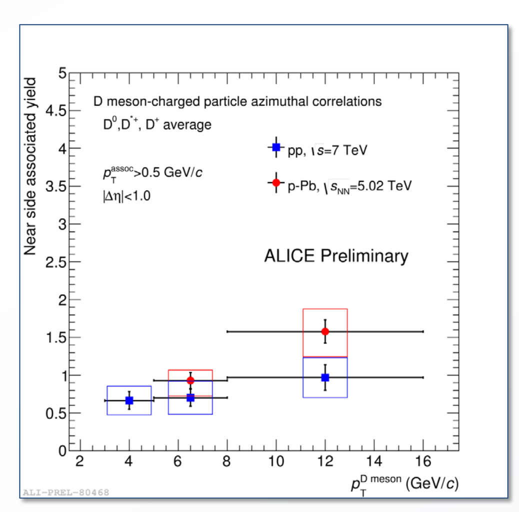
Near-side associated yield as a function of D-meson p_T

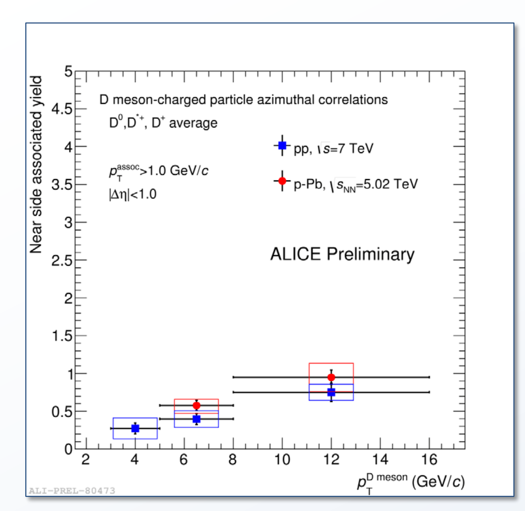
- Near-side yield extracted from the fit to the average correlation distributions
- Shown here for the three associated track p_T thresholds, as a function of D-meson p_T

The yields in pp collisions at $\sqrt{s} = 7$ TeV and p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV are compatible within uncertainties.







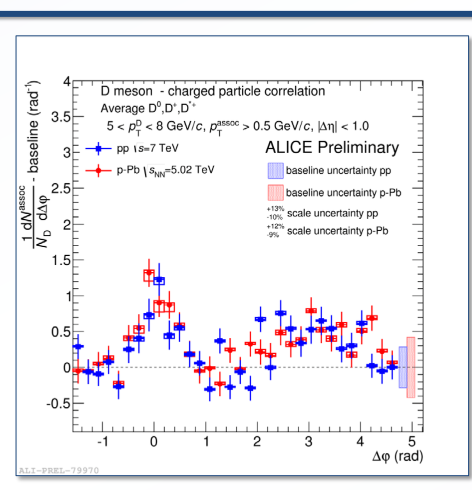


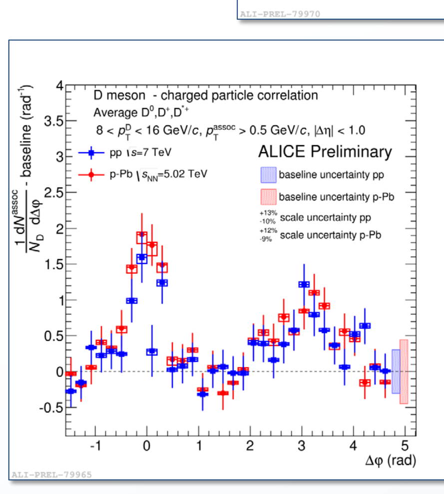
Comparison of Δφ correlation distributions in pp and p-Pb collisions

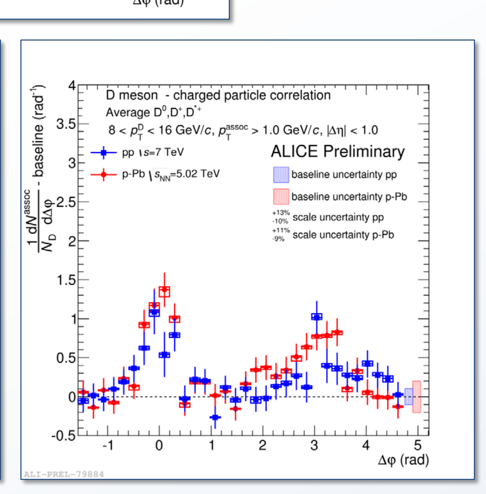
The comparison of the results is performed after subtracting the baseline, evaluated from the fit to the distributions, assuming no azimuthal anisotropy induced by initial state effects or collectivity in p-Pb collisions.

Compatibility within uncertainties found for the azimuthal correlation distributions in pp collisions at $\sqrt{s} = 7$ TeV and in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, for all the kinematic ranges considered in the analysis.

From these results, no differences due to possible cold nuclear matter effects can be spotted.





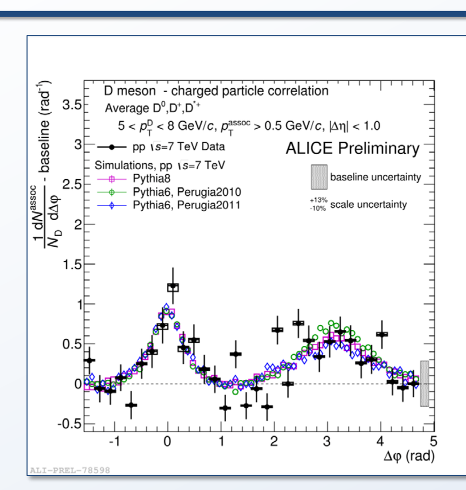


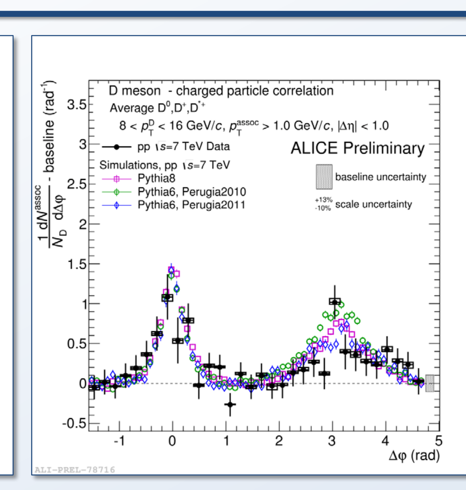
Comparison of p-Pb Δφ correlation distributions with PYTHIA

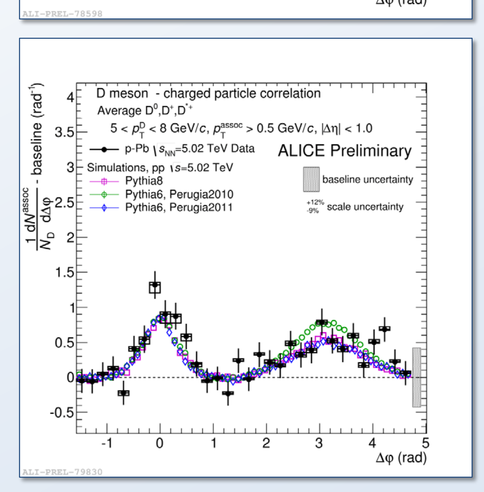
Data results are compared to expectations from Monte Carlo simulations, produced using different tunes of the PYTHIA generator.

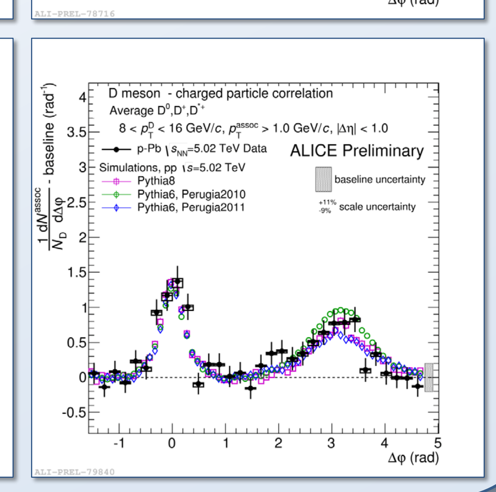
The comparison is performed after subtracting the baseline for both data and simulations, assuming no azimuthal anisotropy induced by initial state effects or collectivity in p-Pb collisions.

Both the shape of the distributions and the yield in the near and and away side peaks are well reproduced by the simulations, for all the kinematic ranges addressed. Evolution of the near-side peak with D-meson p_T and associated track p_T threshold is also well described by the PYTHIA tunes considered.





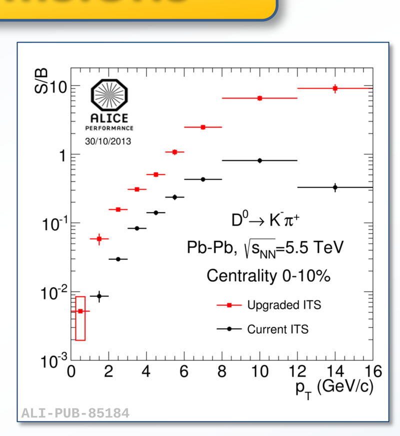




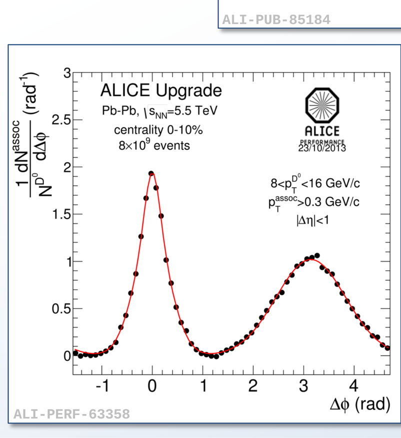
Perspectives for Pb-Pb Collisions

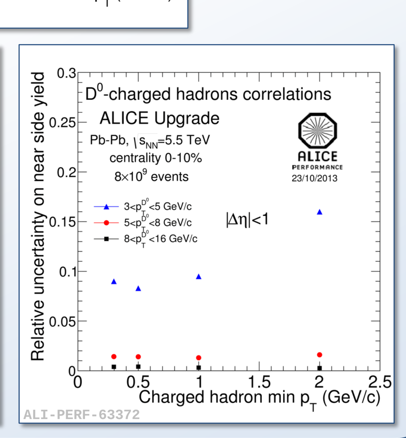
D-hadron correlation analysis not feasible in Pb-Pb with current statistics and detector performance.
→ Limiting factor: high statistical fluctuations in the Δφ distributions, induced by background subtraction.

After ALICE Upgrade (during LS2, 2018-2019) [4], [5]
- Dramatic improvement of ITS tracking and vertexing performance
- From Monte Carlo studies, D⁰ S/B increases by a factor up to 10
- Expected statistics in Pb-Pb: 10^{11} events



D-hadron correlation analysis after ALICE upgrades
Pb-Pb analysis performance estimated using template of correlation distributions from PYTHIA
- Statistical fluctuations greatly reduced in the azimuthal correlation distributions
- Statistical uncertainty on near side yield below 1% for p_T(D⁰) > 8 GeV/c (about 10% for 3 < p_T(D⁰) < 5 GeV/c)





Conclusions and Outlook

- D-hadron correlation analysis could provide relevant information on the properties of charm production, fragmentation and hadronization and, in Pb-Pb collisions, on in-medium charm quark energy loss.
- The analysis was performed and completed for pp and p-Pb collisions.
- Both the Δφ correlation distributions and the near side yields are compatible in pp and p-Pb collisions, and are in good agreement with PYTHIA, for all the kinematic ranges studied.
- The upgrade of the ALICE detector and the larger statistics collected with the upgraded detector will allow for precise measurements of D-hadron azimuthal correlations also in Pb-Pb, enabling a comparison of the results in the three collision systems over a wide p_T range.

References

[1] *M. Nahrgang et al.*, arXiv:1310.2218
[2] *ALICE Collaboration* 2012, Phys. Rev. Lett. 108, 092301 (2012)
[3] *ALICE Collaboration* 2012, JHEP 01 (2012) 128
[4] Letter of Intent for the Upgrade of the ALICE Experiment, CERN-LHCC-2012-012
[5] Upgrade of the ALICE Inner Tracking System, CERN-LHCC-2013-024 ; ALICE-TDR-017
[6] F. Colamaria, Measurements of D-hadron azimuthal correlations with ALICE at the LHC, CERN-THESIS-2014-036 (PhD thesis)