Heavy flavour in heavy ion collisions

- Heavy quarks produced in the initial stage of the collisions.
- Light quarks and gluons can be produced or annihilated during the entire partonic phase of the medium.
- Heavy quarks preserve their flavour and mass identity while traversing the medium.

What are the observables?

- The properties of the QGP are studied by measuring various final state observables such as multiplicity, particle yields and transverse momentum distribution of particles.
- Nuclear modification factor.
- Jets.
- Azimuthal anisotropy.

Nuclear modification factor

$$R_{\mathrm{AA}}^{\mathrm{P}} = \frac{\mathrm{Y}_{\mathrm{AA}}^{\mathrm{P}}}{\langle N_{coll} \rangle \, \mathrm{Y}_{\mathrm{pp}}^{\mathrm{P}}},$$

$<N_{coll}>$ average number of binary nucleon-nucleon collisions.

Y^{P} is the invariant yield of the particle, P, in A-A (pp) collisions at a AA pp given (same) center-of-mass energy.

$<N_{coll}>$ estimated by the product of the average nuclear overlap function of the nucleus-nucleus collision, calculated with the Glauber model, and the inelastic proton-proton cross section

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- No QGP, $R_{AA} = 1$
- Energy loss $R_{AA} < 1$ (suppression of yield)
  - can be explained using the mechanism of partonic energy loss via elastic and inelastic collisions in the QCD medium

Nuclear modification factor

- Energy loss

  Gluon > light quarks > heavy quarks

  $R_{AA}^{\pi\pm} < R_{AA}^{D} < R_{AA}^{B}$

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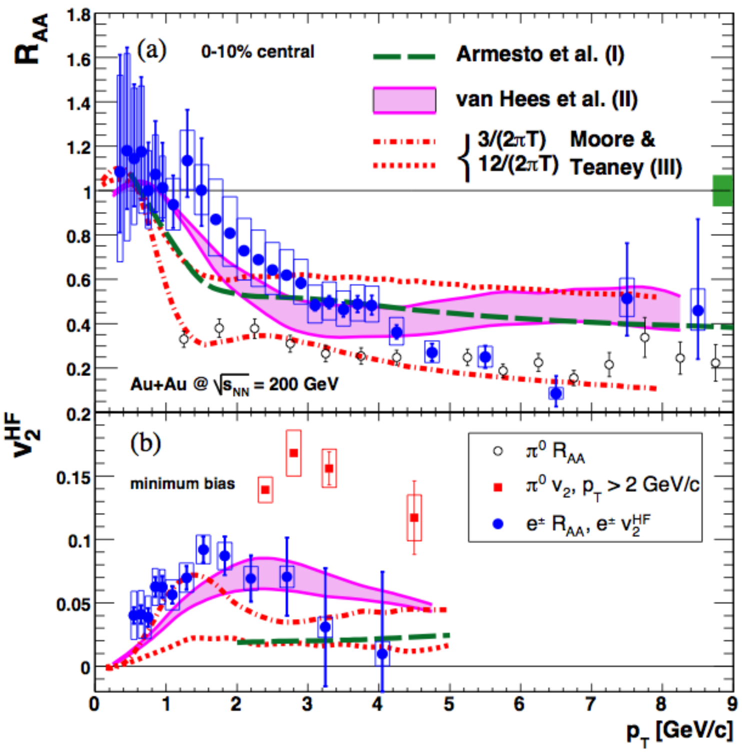

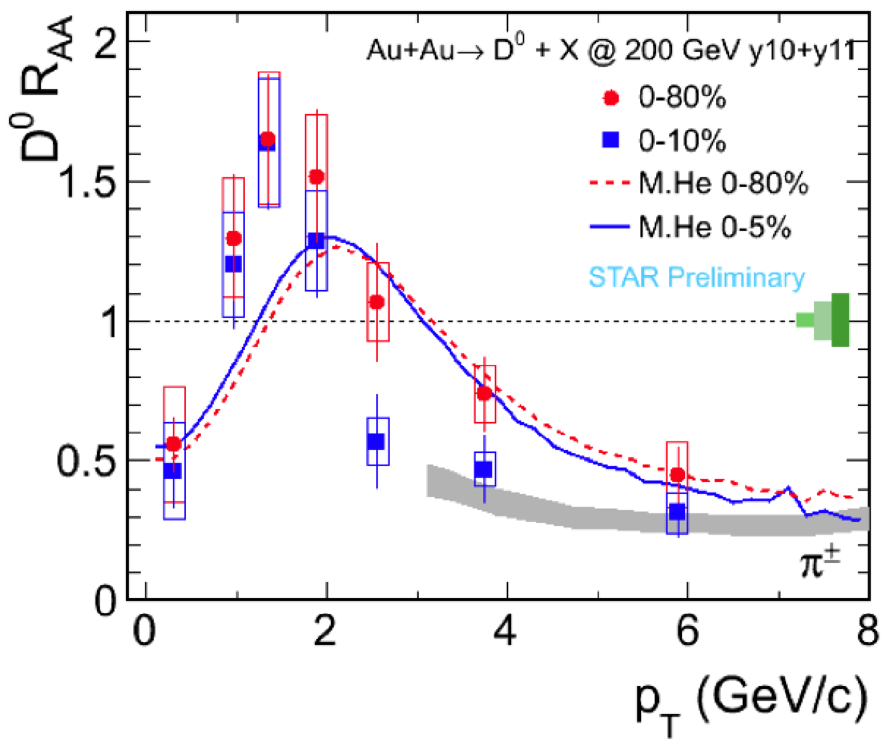

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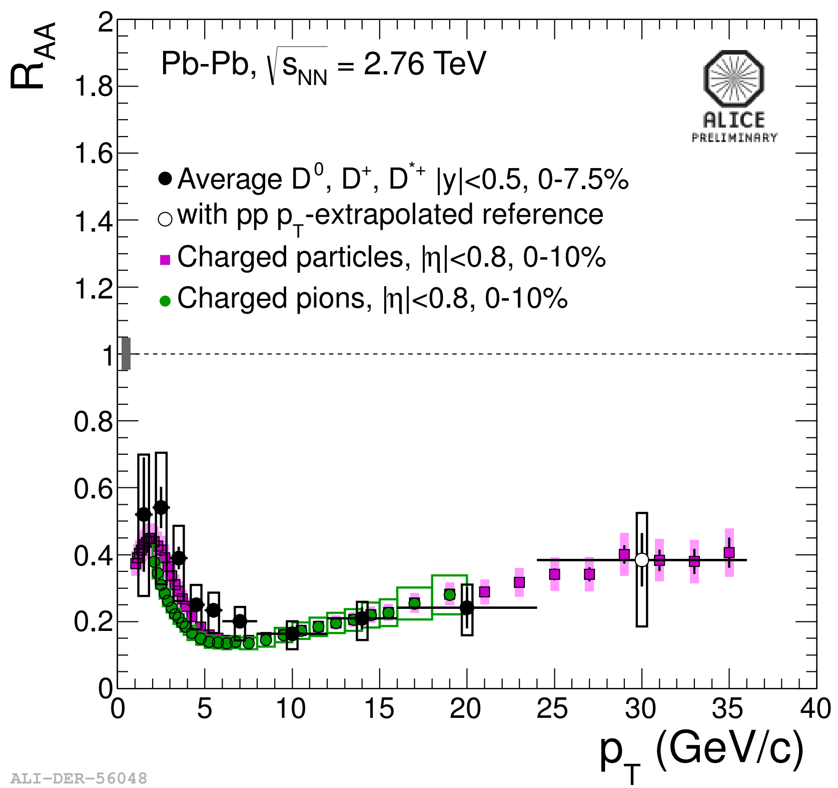
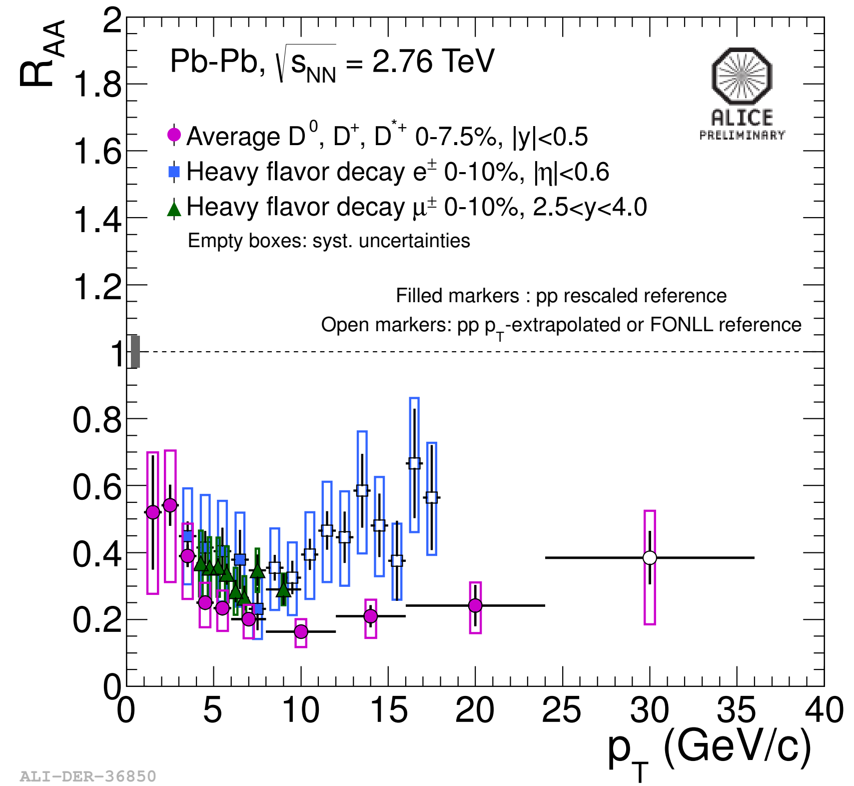
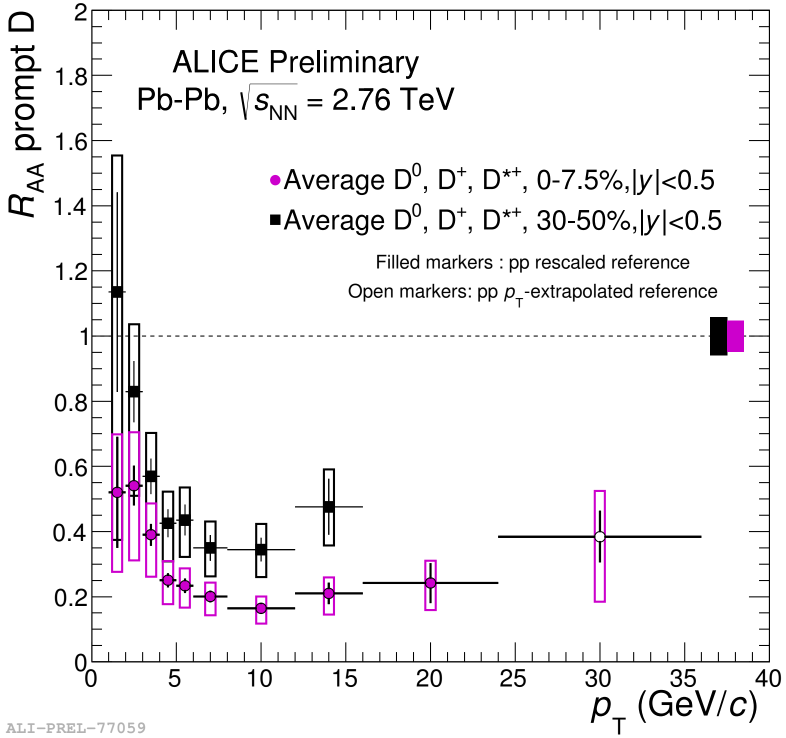
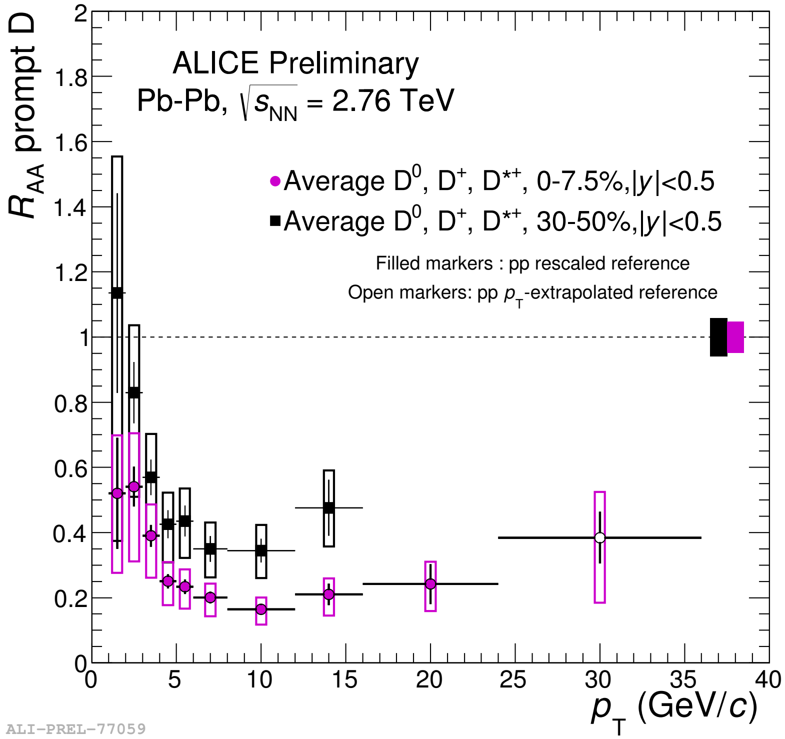


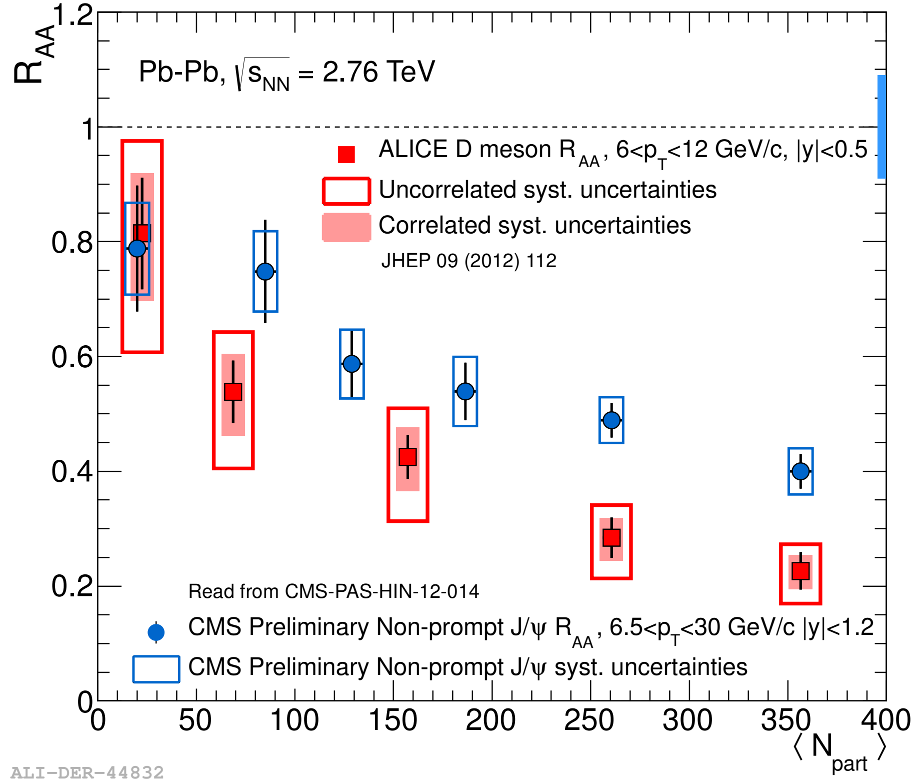


R_{AA} vs centrality



R_{AA} vs centrality



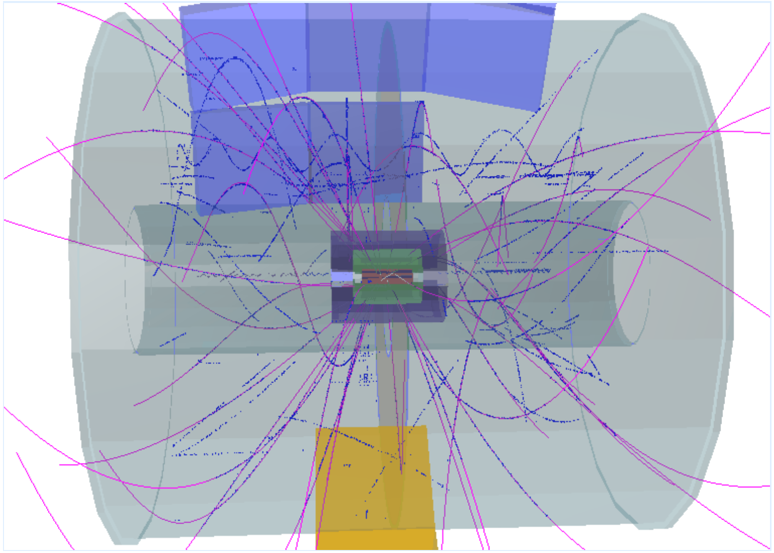


$R_{AA}^{D} < R_{AA}^{B}$

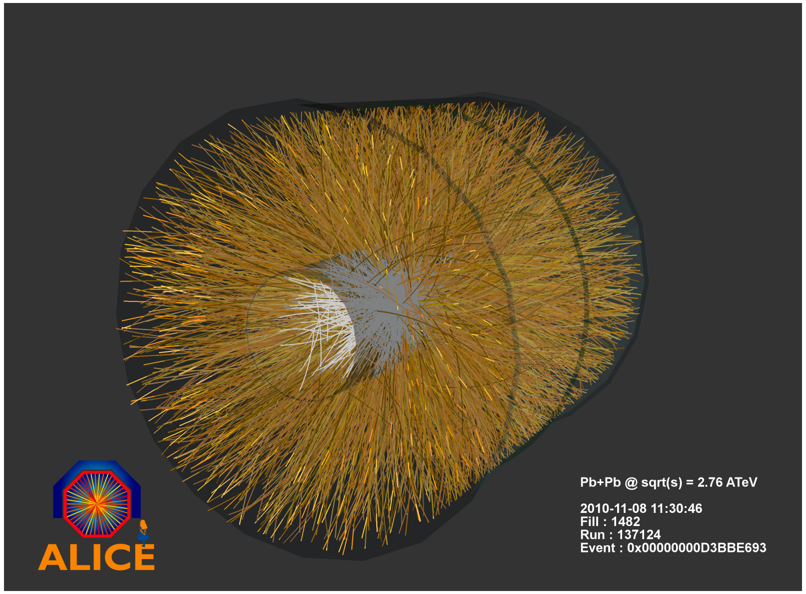
Proton ion collisions

- To understand the measurements in Pb-Pb collisions, we need to understand cold nuclear matter effects
  - Effects because of the presence of multiple nucleons.
- The parton distribution function of quarks and gluons might be different.
- Partons can loose energy by radiation in the initial state.
- Partons can undergo multiple soft scattering – k_T broadening.
- Use proton-ion collisions to study these effects.

pp



Pb-Pb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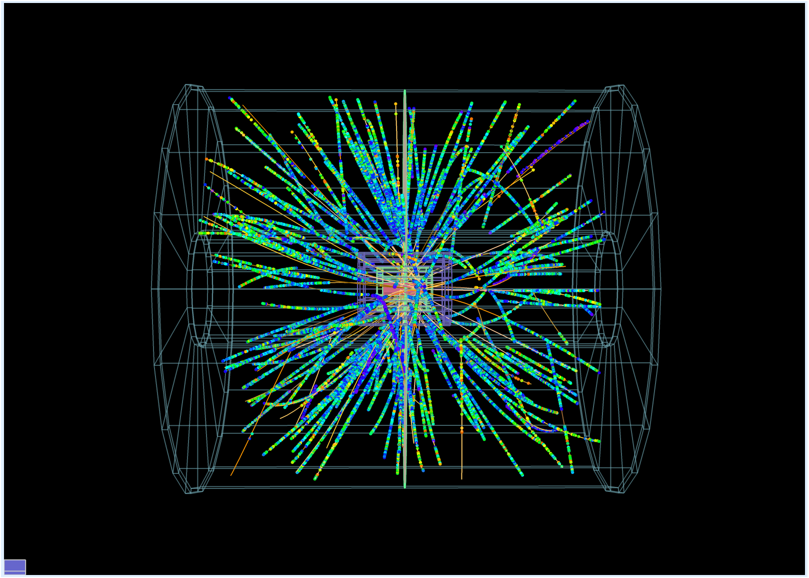
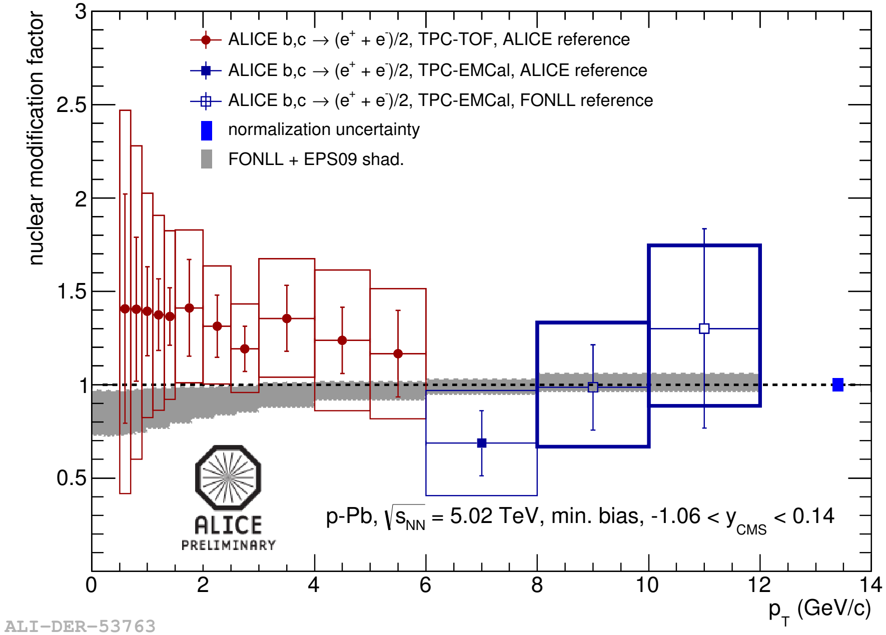
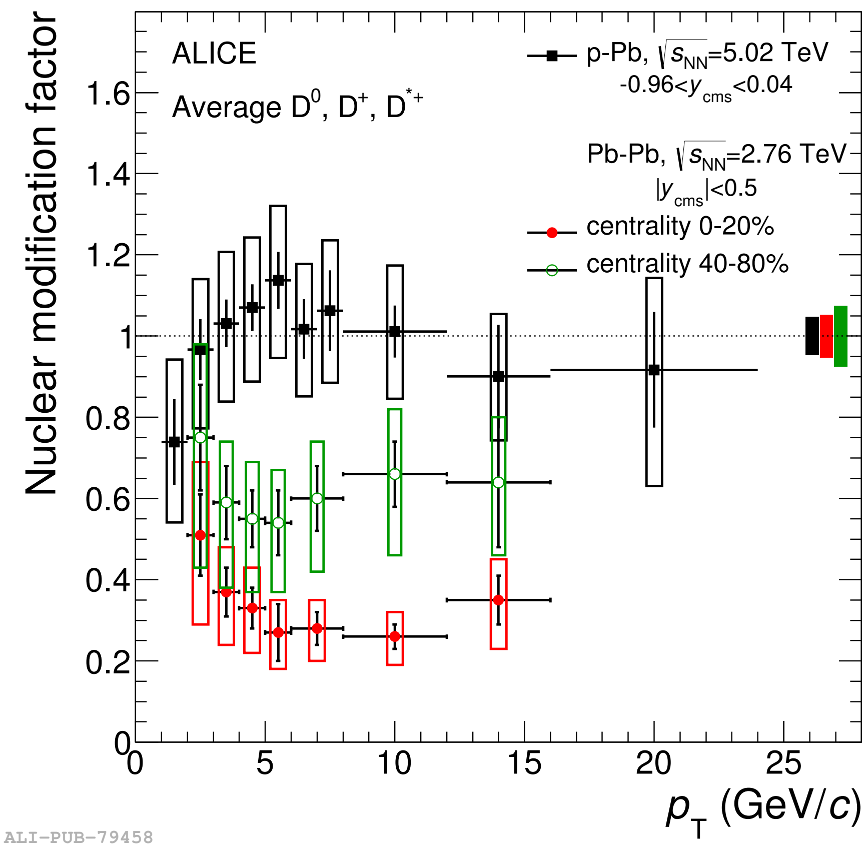
Pb+Pb @ sqrt(s) = 2.76 ATeV
2010-11-08 11:30:46
Fill : 1482
Run : 137124
Event : 0x00000000D3BBE693

P-Pb



R_{pPb}





R_{AA} is not due to cold nuclear matter effects at high pT

Jets

- Energetic partons originate in the hard scattering
  - Back-to-back configurations.
- They evolve as parton showers and hadronize.
  - Experimentally observed as back-to-back jets.
- What is a jet??
  - Group of particles emitted in a narrow cone, expected to be originating from the fragmentation of a parton.

Jet quenching

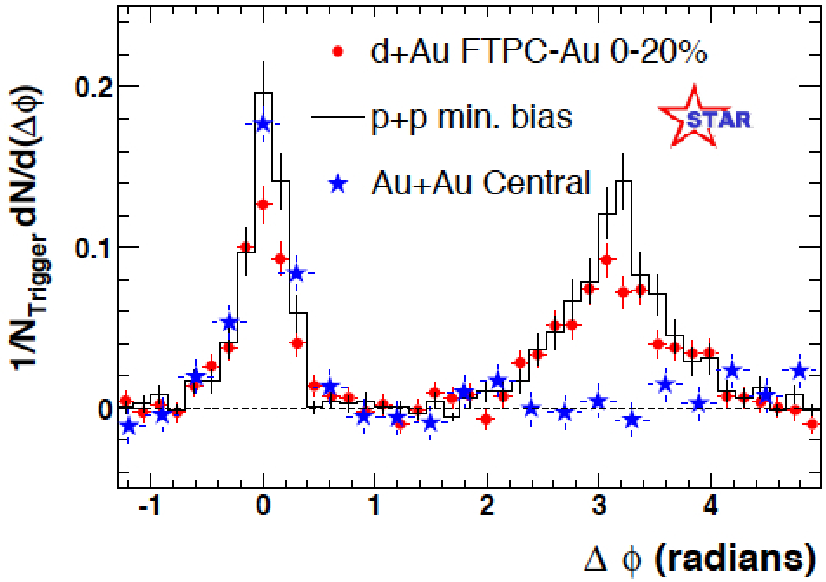
- In QGP, before fragmentation, the partons loose energy in the medium due to gluon radiation and multiple scattering.
  - Jet queching
- Direct measurement of jets is difficult in nuclear collisions due to large background especially for low p_T jets.
- Azimuthal angular correlations of high p_T particles are an alternative probe for these back-to-back jets.
- Particles from a single jet generate an enhances correlation at $\Delta\varphi \sim 0$ (near-side).
- Particles originating from back-to-back jet will jet generate an enhances correlation at $\Delta\varphi \sim \pi$ (away-side).

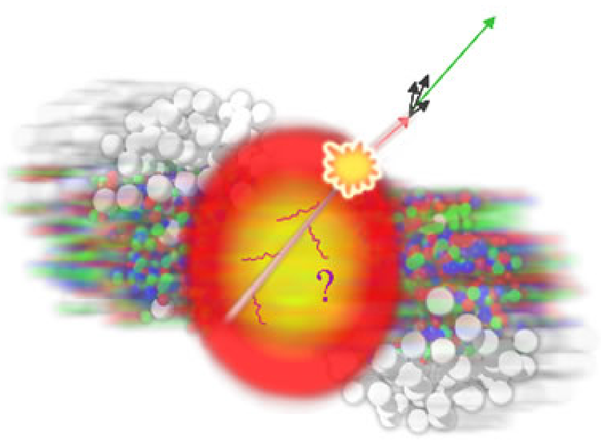
Azimuthal angular correlation

- STAR experiment at RHIC measured the Δφ correlation of high pT hadrons.
  $p_T^{Trig} > 4$ GeV/c
  $p_T^{Asso} > 2$ GeV/c

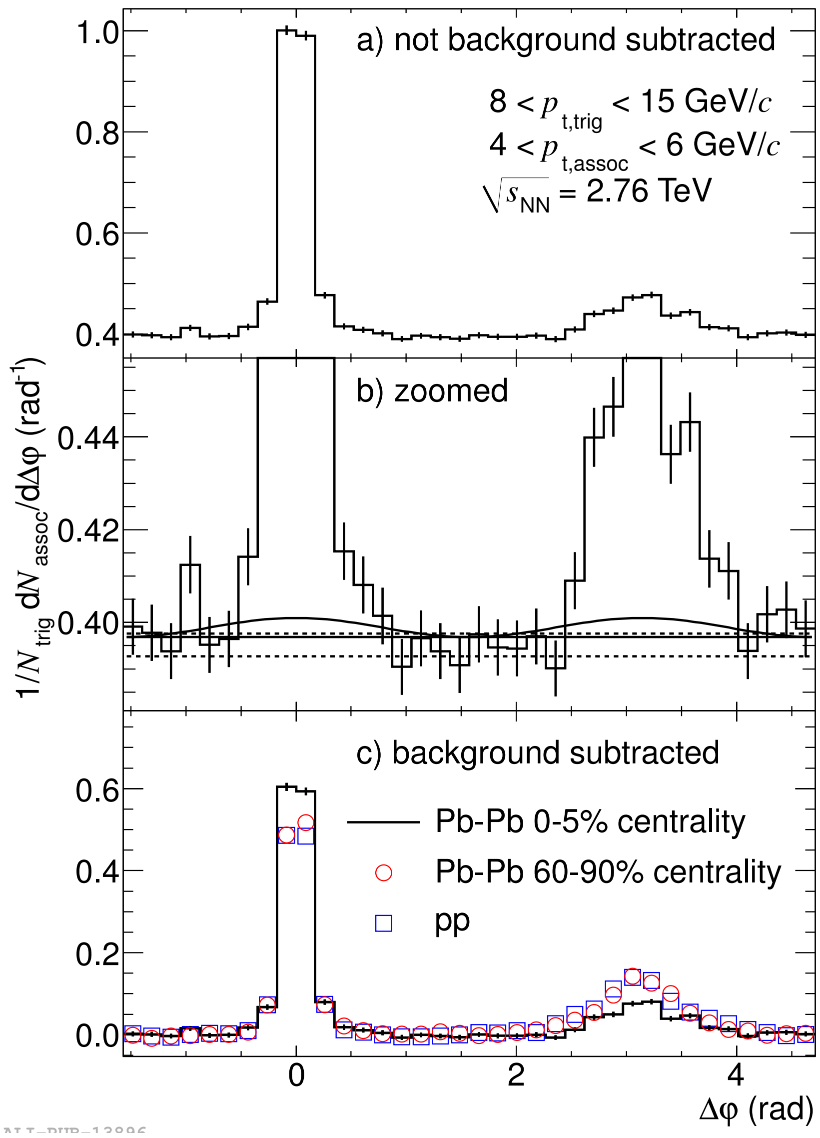
- Away side suppressed for central Au+Au collisions.

- Interpretation of the results
  - Near side : created from partons produced near the surface of medium.
  - Away side : parton has to travel a significant distant, loosing more energy.





Azimuthal angular correlation



In ALICE:

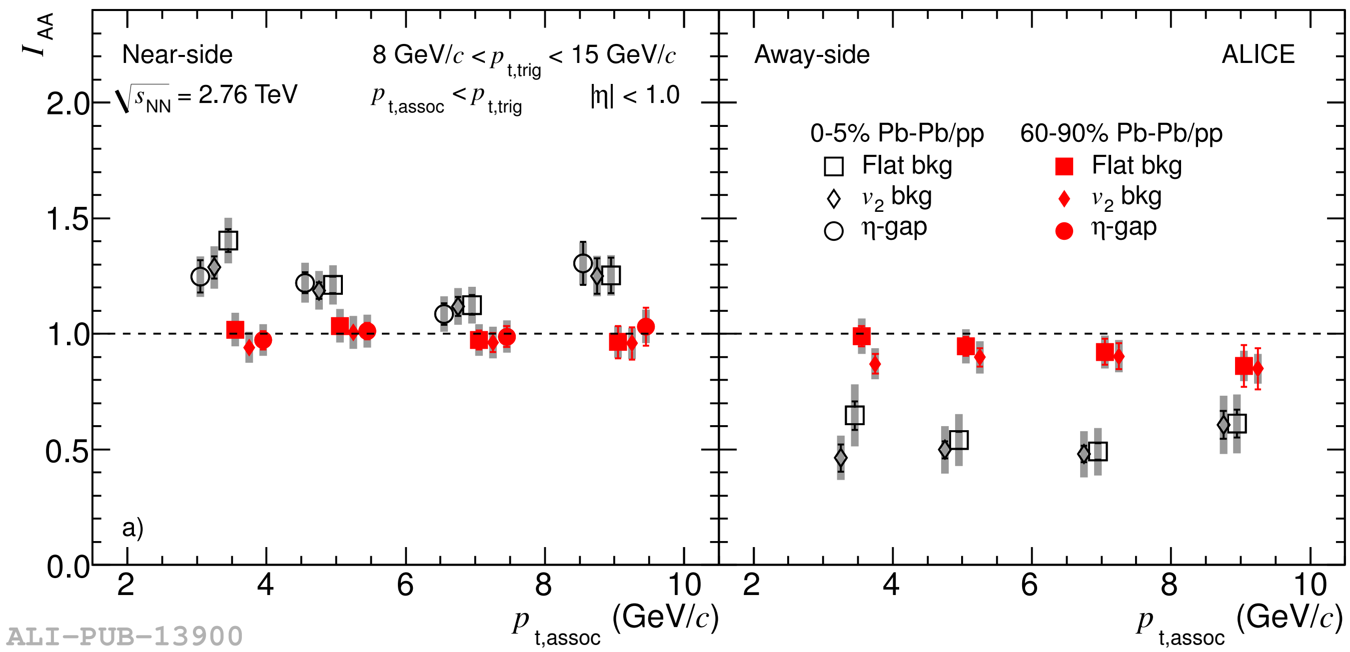
$8 < p_T^{Trig} < 15$ GeV/c

$4 < p_T^{Asso} < 6$ GeV/c

- Quantitative analysis done by measuring the yield on near side and away side (I_{AA}).

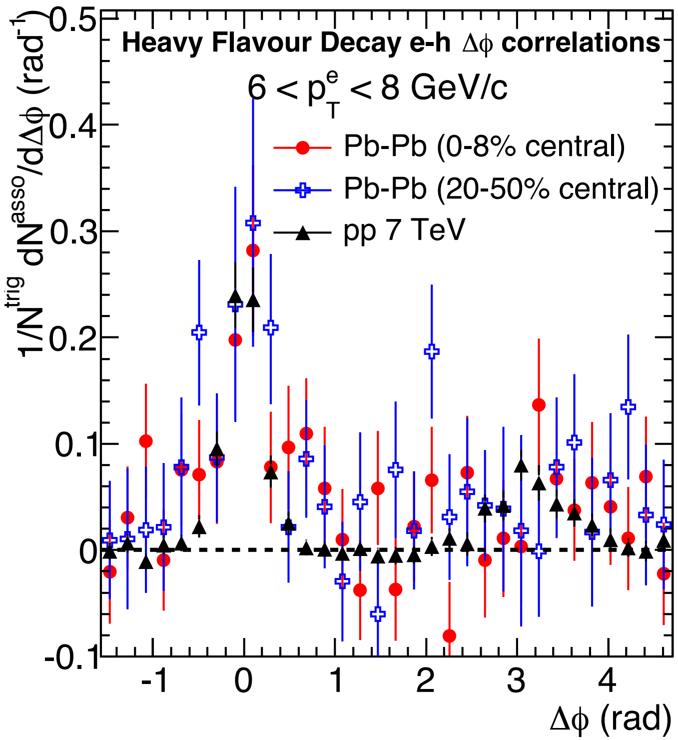
$$I_{AA} = Y_{Pb\text{-}Pb} / Y_{pp}$$

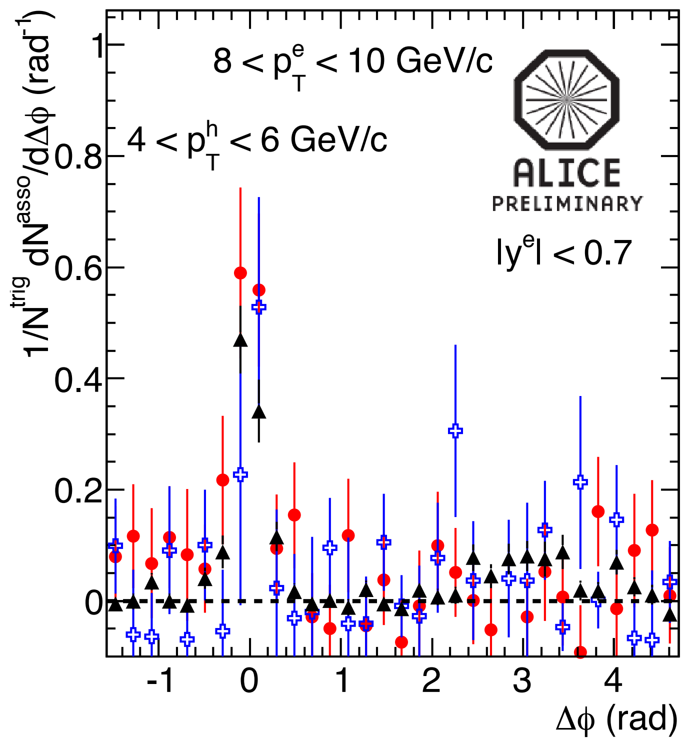
I_{AA}



Away side 50% suppressed.

Azimuthal angular correlation in HF??





Trigger : Electrons from
B/D decay
Associated : Hadrons.

Statistics is too poor to understand anything ☹

Next LHC run??