Introduction

Charmonia, bound states of c and ʿheavy quarks, are useful probes to study the properties of the Quark Gluon Plasma (QGP) which can be considered as a deconfined state of quarks and gluons. The high color density in the QGP screen the charm quark binding potential, resulting in suppression of the resonances yields. The strongly bound J/ψ and the weakly bound ψ(2S) states have received a lot of attention in the context of QGP studies: the results from NA60 collaboration, in Pb-Pb collisions at √sNN = 17 GeV, showed a bigger ψ(2S) suppression, compared to the J/ψ one, in agreement with simulation melting scenario in a QGP.

It was soon discovered that charm states can also be suppressed by Cold Nuclear Matter (CNM) effects in proton-nucleus (p-A) collisions, where the formation of QGP is not expected. Several mechanisms such as nuclear parton shadowing, c bar break-up via interaction with nucleons and initial/final state energy loss, were taken into account to describe experimental data.

Results

The E866 experiment at the Fermilab has studied the J/ψ and ψ(2S) production in 800 GeV p-A collisions: a stronger ψ(2S) suppression relative to J/ψ at central rapidity was observed, while at forward rapidity no difference was found. This result was interpreted in term of pair break-up: at central rapidity the time for the Čerenkov state to cross the nucleus is larger than the formation time of the resonances: the loosely bound ψ(2S) can be more easily dissociated than the J/ψ. Conversely, at forward rapidity the crossing time is smaller than the formation time and the nuclear effects are expected to be the same, independently of the resonance being produced.


The PHENIX collaboration at RHIC recently published results in d-Au collisions at √sNN = 200 GeV. The ψ(2S) suppression is larger than the J/ψ one and increasing from peripheral to central collisions. The stronger ψ(2S) suppression is unexpected because at RHIC energies the crossing time of the Čerenkov state is expected to be comparable to the formation time of the resonance.

[PHENIX Collaboration: PRL 111 (2013) 202301]

In this poster we present the inclusive ψ(2S) production, in p-Pb collisions, at the nucleon-nucleon center of mass energy √sNN = 5.02 TeV, studied with the ALICE detector at the CERN LHC [ALICE Collaboration: JHEP 12 (2014) 073]. The measurement has been performed as a function of rapidity (y), transverse momentum (p_T) and collision centrality. ALICE data can shed further light on the Čerenkov suppression in p-Pb collisions.

The ALICE Forward Muon Spectrometer

The ψ(2S) is detected in the dimuon decay channel, using the Forward Muon Spectrometer, which covers the pseudorapidity range ±4 ≤ η ≤ 2.5, and is composed by:

- a front absorber;
- 10 planes of tracking chambers;
- a dipole magnet (3 T field integral);
- 4 planes of trigger chambers behind an iron wall.

Data sample and signal extraction

Data sample and kinematic cuts:

- 2012 data sample, √sNN = 5.02 TeV, two rapidity regions studied (inverting the beam direction in the LHC):
  - forward: 0.65 ≤ η ≤ 0.18 ~ 5.81 ± 0.18 nb^−1;
  - backward: 4.0 ≤ η ≤ 4.57 ± 0.17 nb^−1;
- muons are in the range ±4 ≤ η ≤ 2.5;
- muon radial position at the absorber end is in the range: 17.6 ≤ R ≤ 89.5 cm;
- muon p T CDA ≤ 6 standard deviation (CDA = transverse distance to the primary vertex);
- dimuon in the range: 2.5 ≤ √s ≤ 4;
- muon trigger-tracking matching;
- dimuon trigger: detection of two opposite sign muon candidates above a 1 GeV/c p_T threshold.

Signal extraction:

- Charmonium yields are extracted through a fit to the opposite-sign invariant mass spectra, using a combination of signal and background shapes:
  - signal: extended Crystal Ball (CB2) or pseudo-Gaussian functions for J/ψ and ψ(2S);
  - background: variable width Gaussian or 4th-degree polynomial times exponential functions;
- ψ(2S) position and width are tied to the J/ψ, using the following formulas:
  - ∑(ψ(2S)) = ∑(J/ψ) (σ(μ2S)/σ(J/ψ))^2
- tail parameters of CB2 and pseudo-Gaussian functions.

The ratio between the ψ(2S) and J/ψ cross section suppressions in p-Pb collisions at √sNN = 5.02 TeV with ALICE

At LHC energies the ψ(2S) suppression can not be related to Čerenkov state break-up in the nuclear medium because this process becomes relevant only if the charm quark formation time t is smaller than the time tabs of the Čerenkov pair. Estimates for t are in the range between 0.05 and 0.15 fm/c [Phys. Rev. C 61 (2000) 054906]. The average proper time is: t = c/γvabs, where γ is the average length of nuclear matter traversed by the Čerenkov pair along the beam direction in the nuclear rest frame and γ = E/√(E^2 − m^2) [Phys. Rev. C 87 (2013)].

- Forward rapidity: γvabs ≤ 7-10 fm/c: breakup effects alone can hardly explain the bigger difference between the ψ(2S) and J/ψ suppression.
- Backward rapidity: γvabs ≤ 10 fm/c: breakup effects are excluded.

Other final state effects, including the interaction of the Čerenkov pair are required to explain the bigger ψ(2S) suppression.

Conclusions

The ALICE Collaboration has studied the ψ(2S) production in p-Pb collisions at √sNN = 5.02 TeV, as a function of rapidity, transverse momentum and event activity.

- The weakly bound ψ(2S) is more suppressed than the strongly bound J/ψ.
- This difference increases with event activity at backward rapidity, while at forward rapidity the ψ(2S) and J/ψ suppression follow a similar trend.
- The relative suppression of the two states integrated over event activity is comparable to the one measured by PHENIX in d-Au collisions at √sNN = 2.0 TeV and mid-rapidity.
- The ψ(2S) suppression is not explained by theoretical prediction based on shadowing and energy loss.

Other final state effects, like the interaction of the Čerenkov pair with hadronic matter, should be invoked to explain the larger ψ(2S) suppression.

Nuclear modification factor

The effects of the nuclear matter on the charmonium states can be quantified with the nuclear modification factor R_AA:

- ALICE data show a larger ψ(2S) suppression compared to the J/ψ one. Being the same for J/ψ and ψ(2S), theoretical predictions (based on shadowing and on energy loss) do not describe the observed ψ(2S) suppression.