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The ALICE Forward Muon Spectrometer

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Abstract. The physics capabilitites of the ALICE forward muon spectrometer are reviewed.

Keywords. Heavy ion collision, LHC, QGP, Upsilon, muon

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1. Introduction

The LHC heavy ion physics program aims at investigating the properties of strongly interacting matter at extreme energy density where the formation of the Quark Gluon Plasma (QGP) is expected [1]. Among the most promising observables, heavy quarkonium states are especially relevant since they provide, via their leptonic decays, an essential probe of the earliest and hottest stages of heavy ion collisions. From the early predictions of charmonium suppression by Debye screening in a deconfined medium [2] to the recent results from the NA50 collaboration [3], a lot of effort has been devoted to the subject (for reviews see [4]). The LHC energy is ideal for a spectroscopy of the whole set of resonances. In particular, because a much higher temperature than that expected to be reached at RHIC is needed to dissolve the Υ meson, the spectroscopy of the Υ family at LHC energies should reveal an unique set of information on the characteristics of the QGP [5]. The LHC beam energy regime brings however the challenge of extracting, for the first time, the quarkonia signals in the presence of a significant and highly complex particle environment which requires excellent detector capabilities and high precision measurements. The ALICE detector will allow to identify the quarkonium states through both the dielectron and the dimuon channels. For this purpose the apparatus is equipped with a Transition Radiation Detector in its central part and with a forward muon spectrometer at small angles.

After a brief description of the forward muon spectrometer, its expected performances are reviewed.

2. Description of the spectrometer

The ALICE forward muon spectrometer (Fig. 1) covers the angular acceptance $2\,^\circ < \Theta < 9^\circ$ ($2.5 < \eta < 4$). It makes use of the usual techniques for muon identification at small angles. The spectrometer consists of a front absorber placed 90 cm from the interaction point, a 15 m long small angle absorber, a large dipole magnet with a 3 Tm integrated field, 10 high granularity tracking chambers, a muon filter made of a 1.2 m thick iron wall and 4 large area trigger chambers [6–9].

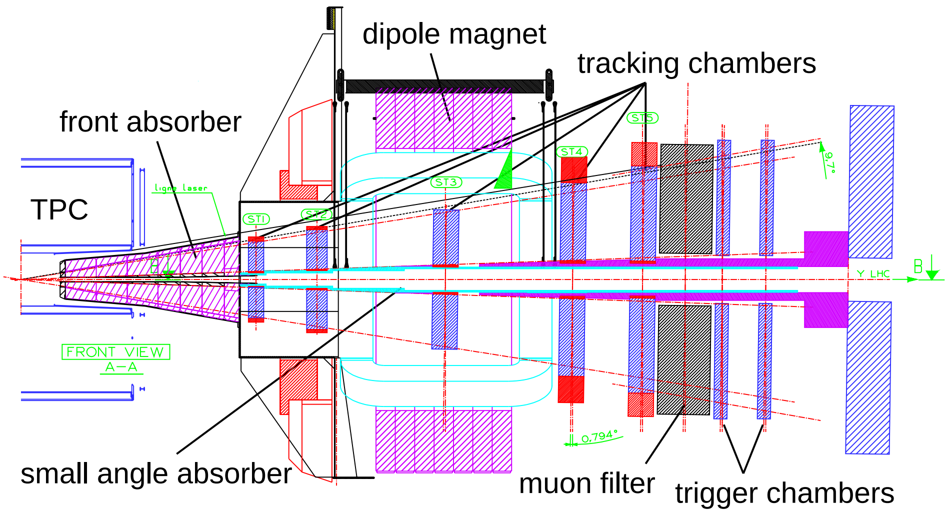

Figure 1. Schematic layout of the ALICE forward muon spectrometer

3. Expected performances

The goal of the forward muon spectrometer is to measure the full set of onium resonances from the ϕ to the Υ, with a high statistics, a low background and a high resolution. An important specification of the spectrometer is its mass resolution which has to be about $100\ \mathrm{MeV}$ at $10\ \mathrm{GeV}$ to allow the separation of the Υ substates. Therefore a lot of simulations has been done in order to understand the mass resolution and to keep it as good as possible. These simulations have been performed in the framework of the ALICE software AliRoot [10]. They consist of i) transport of particles through the apparatus, ii) digitalization of the detector response, iii) reconstruction of raw clusters, and iv) tracking of the reconstructed points. A very detailed description of all the relevant detector components is included. In particular, as far as the front and small angle absorbers are concerned, the flanges, dips, recesses and spaces as well as the different materials were taken into account [9]. The input to the simulation consists of one Υ embedded into one central PbPb event. The latter is generated according to the HIJING model which foresees the largest charged particle multiplicity ($[\mathrm{dN_{ch}}/\mathrm{d}\eta]_{\eta=0} = 6000$). In addition a safety factor of two is applied such that one nominal background event (or “background level 1”) actually consists of two times one HIJING central PbPb event.

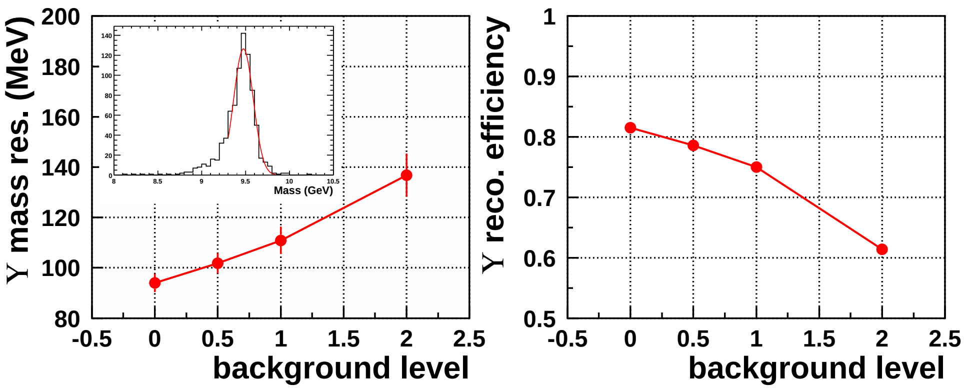

Figure 2. Left: Υ mass resolution, from one single Gaussian fit to the mass distribution between 9.30 and 9.85 GeV, as a function of the background level with respect to the nominal background. The inset shows the corresponding mass distribution for background level 1. Right: Υ reconstruction efficiency as a function of the background level with respect to the nominal background.

The corresponding Υ mass resolution is shown in Fig. 2 left as a function of the background level. The obtained resolution without any background (background level 0) of ~ 92 MeV is larger than the intrinsic mass resolution of the spectrometer by about 10 MeV. This is the result of muon energy losses which spread the mass distribution on the left side of the Υ nominal mass (inset in Fig. 2 left). With background level 1 the mass resolution increases up to 110 MeV. This value is extracted from a single Gaussian fit to the mass distribution. When performing a two Gaussian fit to account for the particular shape of the mass distribution, the corresponding resolution is 94.5 MeV. Such a resolution should allow to unfold the contribution from Υ' and Υ'' resonances.

The Υ reconstruction efficiency is shown in Fig. 2 right as a function of the background level. For background level 1 the total Υ reconstruction efficiency is 75%. This value corresponds to the convolution of the following efficiencies:

geometrical acceptance .... $\sim 95\%$
chamber intrinsic efficiency & resolution .... $\sim 96\%$
tracking .... $\sim 95\%$
tails in mass distribution (3σ mass cut) .... $\sim 93\%$
multi-hit deconvolution .... $\sim 92.5\%$

The efficiency increases towards 80% for lower background level. The trigger efficiency for Υ is 90% [8].

The expected statistics after one month of Pb beams is shown in Tab. 1. For J/ψ, the rate and S/B are very good and permit a high-precision measurement of its production. Because of less favourable S/B, the ψ' can be measured at best with an accuracy of the order of 10% The S/B is far better in the Υ mass range. It is larger than unity in all cases and the significance is very good. However the rates are small, especially for the Υ''.

Table 1. Signal, signal-to-background and significance for different onium states in 10% most-central PbPb reactions with a luminosity of $5 \cdot 10^{26}~\mathrm{cm^{-2}s^{-1}}$ and a running time of 10^{6} s. S and B are extracted according to the interval of $\pm 1\sigma$ around the resonance nominal mass. The input cross-sections are from [11] and assume no suppression/enhancement. See [7] for more details.

	S	S/B	$S/\sqrt{S+B}$
J/ψ	230000	0.72	310
ψ'	4600	0.03	12
Υ	1800	7.10	39
Υ'	540	2.50	19
Υ''	260	1.50	12

In addition to quarkonia measurements, the spectrometer should allow measurements of the open bottom cross-section. This is possible because the background from pions and kaons decay is small and because muons from charm decay can be efficiently removed with a high p_{t} threshold. When applying a p_{t} cut of $\sim 3~\mathrm{GeV/c}$ on each muon, the correlated signal from bottom decay appears with a large relative yield all over the invariant mass. This should allow to extract the full correlated signal from bottom decay including both the high and the low invariant mass regions. In the high invariant mass region each muon comes from the direct decay of a B meson. In the low invariant mass region, the correlated signal from bottom is dominated by the so-called B-chain channel where the two muons come from the decay of a single B meson via a D meson. Similar measurements of the charm cross-section should be achievable with appropriate analysis strategies.

4. Summary

The ALICE muon spectrometer has a broad physics program and excellent capabilities for quarkonia physics. This will be further improved by means of a High Level Trigger which is currently under study. In addition, exciting possibilities should be opened by measuring muons in correlation with hadrons and electrons from the central part of ALICE [12].

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