# Vector Meson production in ALICE at the LHC

L. Massacrier for the ALICE Collaboration

*Université de Lyon, Université Lyon 1, CNRS/IN2P3, Institut de physique nucléaire de Lyon, Villeurbanne*

**Abstract.** ALICE is the experiment dedicated to the study of the quark gluon plasma in heavy-ion collisions at the LHC. The study of the in-medium properties of light vector mesons ($\rho$, $\omega$ and $\phi$) through their leptonic decay channel is interesting because leptons have negligible final state interactions. Indeed, they leave the hadronic medium with no distortions providing a clean tool to probe the properties of the medium. pp collisions are used as baseline for the heavy ion study. We present the results of light vector meson measurements in pp collisions at $\sqrt{s} = 7$ TeV in the dielectron and dimuon channels. The dielectron study is performed in the rapidity range |y| < 0.9 and the dimuon one for a rapidity range -4.0 < y < -2.5. Methods used for background subtraction are described. $p_{\mathrm{T}}$ distributions of $\phi$ and $\rho + \omega$, as well as the ratio of the $\phi$ yield over the $\rho + \omega$ yield are shown. The status of the Pb-Pb analysis at $\sqrt{s_{NN}} = 2.76$ TeV is also presented.

**Keywords:** Quark Gluon Plasma, ALICE, Light Vector Meson, dimuon, dielectron
**PACS:** 14.40.Be,13.20.Jf,25.75.-q

We are presenting the light vector meson ($\rho$, $\omega$, $\phi$) analysis in pp collisions. It is interesting in itself at a new center of mass energy, and most relevant to ALICE in view of a comparison with Pb-Pb collisions. The vector meson study is performed among others in the dilepton decay channel. Leptons are interesting to probe the Quark Gluon Plasma (QGP) because of their negligible final state interactions. Thanks to their short lifetime (between 1.3 fm/c for the $\rho$ to 46 fm/c for the $\phi$) [1], light vector meson's yields and spectral functions should be modified by the hot hadronic and QGP medium. The lifetime of the $\rho$ is even more interesting as it is shorter than that of QGP at LHC (10 fm/c). The $\rho$ spectral function can be used to reveal in-medium modifications of hadron properties and to study the chiral symmetry restoration. Strangeness production can be measured from the ratio of the $\phi$ yield over the $\rho + \omega$ yield as a function of the centrality in Pb-Pb collisions. A first look at the Pb-Pb data shows that a similar analysis is possible as these vector mesons are clearly identified above the background. Therefore, no quantitative results are given in this proceeding in Pb-Pb collisions as the analysis is still ongoing.

ALICE (A Large Ion Collider Experiment) [2] is made of three main parts: a central barrel embedded in a 0.5 T solenoidal magnetic field, a muon spectrometer, and several detectors at small angles. The central barrel consists of a Time Projection Chamber (TPC) and an Inner Tracking System (ITS) allowing charged particle trajectography. It contains several detectors for Particle IDentification (PID) such as the Time Of Flight detector (TOF), the High Momentum Particle IDentification Detector (HMPID), the Transition Radiation Detector (TRD) and the ElectroMagnetic CALorimeter (EMCAL). The trajectography is best performed in the pseudo-rapidity domain $|\eta|< 0.9$. The muon spectrometer covers the acceptances $-4 < \eta < -2.5$. It is composed of hadron absorbers, a dipole magnet delivering a field of 0.7 T, ten proportionnal multi-wire chambers grouped in five tracking stations, four resistive plate chambers for triggering, and an iron wall to filter muons. Among the detectors at small angles we have to mention the VZERO and ZDC detectors used to perform an event physics selection for the analysis, based on timing considerations. For pp collisions, the ALICE minimum bias trigger requires at least one hit in the first two silicon pixel layers of the ITS (SPD) or in the VZERO scintillators. The single muon trigger is defined as a coincidence of a minimum bias trigger with a muon in the trigger chamber of the spectrometer. During the 2010 data taking, 800 million minimum bias interactions and 100 million muon triggers were recorded.

## Inclusive light vector meson production in the dimuon channel in $pp$ collisions at $\sqrt{s} = 7$ TeV

The low-mass dimuon analysis is performed in the rapidity range $-4 < y < -2.5$. The data sample corresponds to an integrated luminosity of 85 $nb^{-1}$. In order to obtain a clean sample of muons, only tracks reconstructed in muon chambers and matching a muon trigger track are selected. The background was evaluated using two methods: the like sign pair technique and the event mixing technique. For the like sign technique, the background evaluation is calculated as: $N_{+-} = 2 \times R\sqrt{N_{++}N_{--}}$ where $N_{--}(N_{++})$ is the number of negative (positive) dimuon pairs respectively. The R factor is defined as $R = \frac{A_{+-}}{\sqrt{A_{++}A_{--}}}$ where $A_{+-}$,$A_{++}$ and $A_{--}$ are the acceptances for "+-","++" and "- -" pairs. The event mixing technique is based on the combination of muons coming from different events. Events containing only one muon, satisfying the same selection cuts as for data, are mixed to construct uncorrelated dimuons. The event mixing spectrum is then normalized to the integral of the combinatorial background evaluated with the like-sign pair technique. The two methods are in good agreement for muon pair $p_{\mathrm{T}}$ greater than 1 GeV/$c$. The invariant mass spectrum is extracted after background subtraction with the event mixing technique. The different contributions are fitted using an hadronic cocktail in realistic simulations, (Fig. 1 left). The free parameters of the fit are the normalizations of $\eta$, $\omega$, $\phi$ and the charm. The ratio of the cross sections of $\rho$ over $\omega$ is fixed to 1. Simulations were performed to extract acceptance $\times$ efficiency corrections. The corrected $p_{\mathrm{T}}$ distributions of $\rho + \omega$ (Fig. 1 middle) and $\phi$ (Fig. 1 right) were extracted and fitted with a function proportionnal to $p_{\mathrm{T}} \times (1 + (p_{\mathrm{T}}/p_0)^2)^{-n}$. From the $p_{\mathrm{T}}$ spectra (see Fig. 2 left), the ratio $\frac{N_\phi}{N_\rho + N_\omega}$ is found to be $0.42 \pm 0.02$. It is constant in the $p_{\mathrm{T}}$ range 1 to 6 GeV/c, and above Pythia [3] value (0.31). It provides a reference value for a new tune of Pythia at 7 TeV.

## Inclusive light vector meson production in the dielectron channel in $pp$ collisions at $\sqrt{s} = 7$ TeV

A similar analysis is ongoing in the dielectron channel. Peaks are already visible and this is promising in view of getting some quantitave results soon. We present here

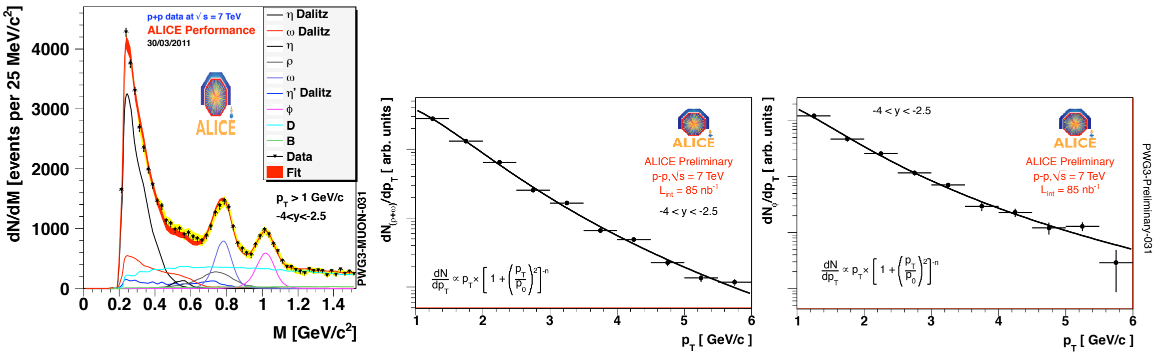


**FIGURE 1.** Left: Invariant mass spectra in pp collisions after background subtraction by event mixing (yellow band for systematics on background subtraction). The fit is obtained with an hadronic cocktail generator (red band for uncertainties on cocktail ingredients). Middle: Corrected $p_{\rm T}$ distribution of $\rho+\omega$ in pp collisions. Right: Corrected $p_{\rm T}$ distribution of $\phi$ in pp collisions. The fit is performed for the two $p_{\rm T}$ distributions with a function proportionnal to: $p_{\rm T}\times(1+(p_{\rm T}/p_0)^2)^{-n}$.

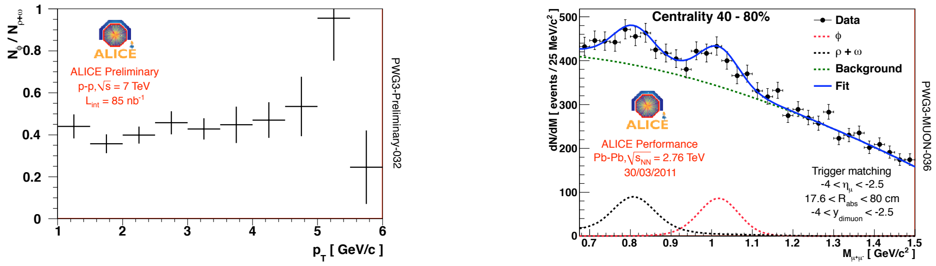


**FIGURE 2.** Left: Ratio $\frac{N_\phi}{(N_\rho+N_\omega)}$ as a function of $p_{\rm T}$ in pp collisions, in the rapidity range -4 < $y$ < -2.5. Right: Dimuon invariant mass spectra in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, for peripheral events (40% to 80% of the total inelastic cross section).

the first signals observed. The low mass dielectron analysis is performed in the central barrel of ALICE for rapidity |y| < 0.9. Thanks to its excellent PID, ALICE can isolate a clean sample of electrons with small contaminations. In the present analysis, TPC and TOF are used for single electron identification. In the future, EMCAL and TRD will be used to extend the analysis at higher $p_{\rm T}$. Several processes contribute to the dielectron spectra at low masses: $\pi^0\to e^+e^-\gamma$, $\eta\to e^+e^-\gamma$, $\eta'\to e^+e^-\gamma$, $\rho\to e^+e^-$, $\omega\to e^+e^-$, $\omega\to e^+e^-\ \pi^0$, $\phi\to e^+e^-$, $\phi\to e^+e^-\ \eta$. A cut on the opening angle of the dielectron (opening angle > 0.4 rad) is applied to reject photon conversion. Other quantitative cuts are applied to select the tracks ($p_{\rm T}$ > 1 GeV/$c$, cut on the Distance of Closest Approach to reject secondary tracks). Invariant mass spectra were reconstructed and the background evaluated using like-sign electron pairs. The number of background pairs is given by $N_{+-}=2\times\sqrt{N_{++}N_{--}}$ where $N_{--}$ $(N_{++})$ is the number of negative (positive) dielectron pairs respectively. The invariant mass plot was extracted from a data sample of 2.9 $\times 10^8$ minimum bias events, (see Fig. 3 left). The light vector meson peaks are clearly visible. Fig. 3 right is the invariant mass spectra after background subtraction.

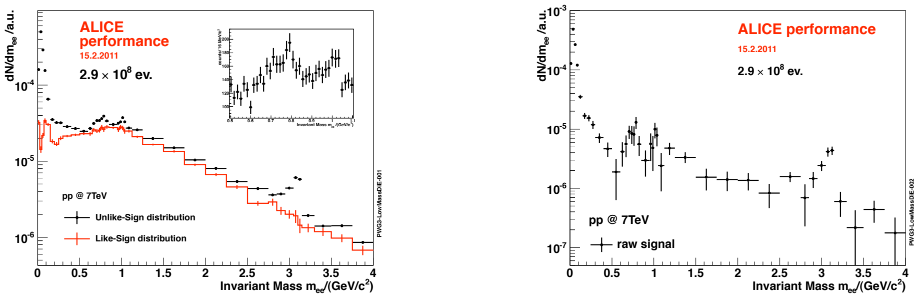


**FIGURE 3.** Left: Invariant mass spectra in pp collisions of dielectron opposite sign pairs in black. In red, the combinatorial background is evaluated with the like-sign dielectron pairs. The plot is performed for variable bin sizes and is normalized to the number of events and bin size. Right: Invariant mass spectra in pp collisions after background subtraction. From left to right, the four peaks observed corresponds to: $\pi^0$ Dalitz decay, $\rho+\omega$ resonances, $\phi$ resonance and J/$\psi$ resonance.

## Inclusive light vector meson production in the dimuon channel in $Pb-Pb$ collisions at $\sqrt{s_{NN}} = 2.76$ TeV

Concerning the Pb-Pb analysis, 6.6 $\times$ $10^6$ minimum bias events were analyzed. A centrality selection was performed using VZERO scintillators. After event physics selection, the electromagnetic contamination in the centrality bin 0-80% is negligible. Fig. 2 right shows that $\phi$ and $\rho+\omega$ resonances can been seen in Pb-Pb collisions, in a centrality bin corresponding to 40% to 80% of the total inelastic cross section. Muons selected satisfy the same criteria as in the pp analysis. Cuts on the radial coordinate of the track at the end of the frontal absorber, 17.6 cm < $R_{abs}$ < 80 cm, and on the dimuon rapidity -4 < $y_{dimuon}$ < -2.5, were added to select muons in the geometrical acceptance of the spectrometer. The background is fitted by a simple polynomial function and the resonances with pseudo-gaussian functions. This analysis is still in progress.

In summary, in the dimuon channel, in pp collisions, the $p_{\mathrm{T}}$ spectra of $\phi$ and $\rho+\omega$ were extracted for a $p_{\mathrm{T}}$ range between 1 GeV/$c$ and 6 GeV/$c$ where the background is well understood and the statistic sufficient. The ratio of the $\phi$ yield over $\rho+\omega$ yield was measured and found to be 0.42 $\pm$ 0.02, constant with $p_{\mathrm{T}}$ and larger than Pythia [3] predictions. A similar analysis is possible in the dielectron channel, where the light vector meson peaks were clearly observed. First light vector meson signals were also clearly observed above the background, in the dimuon channel in peripheral Pb-Pb collisions, indicating a promissing analysis to come.

## REFERENCES

1. C. Amsler et al. (Particle Data Group), Physics Letters B667, 1 (2008) and 2009
2. K.Aamodt et al., "The ALICE experiment at the CERN LHC", 2008, JINST 3 S08002.
3. P. Z. Skands, Phys. Rev. D82 (2010) 074018