Heavy flavor production in ATLAS with exclusive decay channels containing J/$\psi \to \mu^+\mu^-$ final state.

G. Chiodini [1] , N. Orlando [1, 2] and S. Spagnolo [1 , 2] and the ATLAS Collaboration.

[1]Istituto Nazionale di Fisica Nucleare sez. di Lecce, Italy.

[2]Dipartimento di Fisica, Università del Salento, Italy.

Heavy flavor are copiously produced at LHC in proton-proton collisions at $\sqrt{s} = 7$ TeV, with a cross-section of about 0.24 (4.4) mb for inclusive $b\bar{b}$ ($c\bar{c}$). The production mechanisms are described by perturbative QCD and the hadronization process by non-perturbative QCD. Finally, the hadrons decays into exclusive final states by electro-weak theory. Despite the large background from inelastic processes with a cross section of about 60 mb, the decays described in this report are clearly reconstructed in ATLAS detector.

These studies are important already in the early phase. In fact, heavy flavor exclusive final states can be used as detector calibration candles to measure efficiency, resolution, scale, alignment, magnetic field and material mapping. In addition, it is important to understand heavy flavor hadro-production and polarization at the highest energy and smallest x regimes never reached before LHC. Heavy flavors are also background to other rare and interesting processes and to simulate them accurately is crucial for discovery. In a later phase, with and integrated luminosity above 1 fb^{-1}, heavy flavor open up the studies of B mesons rare decays and mixing and CP-violation phenomena.

The ATLAS experiment showed excellent performances in term of muon trigger, muon tracking, and vertexing; key features for a significant B-physics program. The high level muon trigger implement single muon and di-muon trigger hypothesis seeded by one or two first-level muons, respectively. The di-muon trigger can also be seeded by only one muon and the software algorithms execute a full scan to find the second muon.

Heavy flavor production in ATLAS with decays containing J/$\psi \to \mu^+\mu^-$ resonance are the most clean and easy to trigger channels. The measurements of the J/ψ production cross-section separated in prompt and not-prompt are the first step in order to reconstruct exclusive decay channel containing the J/ψ resonance. In fact, these channels are contained in the non-prompt fraction of the J/ψ signal.

In order to measure a production cross section of J/ψ the detector effect must be unfolded from the observed distributions. This is obtained by weighting each event with the inverse of the overall detection probability: $w^{-1} = A(\vec{p_1}, \vec{p_2}) \cdot M \cdot \epsilon_{trk} \cdot \epsilon_{trig}(\vec{p_1}, \vec{p_2}) \cdot \epsilon_{\mu^+}(\vec{p_1}) \cdot \epsilon_{\mu^-}(\vec{p_2})$, where A is the J/ψ di-muon decay kinematic acceptance given by the ATLAS detector fiducial volume, M is the bin migration factor to account for p_T resolution effects in data, ϵ_{trig} is the trigger efficiency, $\epsilon_{\mu^\pm}$ is the single muon off-line reconstruction efficiency, and $\vec{p_j}$ is the j-th muon's vector momentum. The kinematical acceptance depends on unknown J/ψ polarization and the relevant uncertainty was estimated and included into systematic error. Quarkonia polarization measurements are priority goals with the larger 2011 data statistics.

The double differential cross-section $\frac{d^2\sigma}{dp_T dy} = \frac{N^w}{\Delta p_T \Delta y}$ is extracted from binned likelihood fit to mass spectra in 4x15 (y,p$_T$) bins, with a total yield of 32000 events. The inclusive J/ψ production cross-section as a function of J/ψ transverse momentum in the 0.75< $|\eta|$ <1.5 rapidity bin is shown in Figure 1. A good agreement is found between ATLAS and CMS in the overlapping p$_T$ range. With increasing statistics in 2011 and the higher p$_T$ trigger thresholds the range of the ATLAS quarkonia measurements will extend up to p$_T$ of about 70 GeV.

The non-prompt fraction f$_B$ is given by the fraction of J/ψ coming from B-hadrons decays. The measurement of f$_B$ is performed by a simultaneous likelihood fit to the pseudo-proper-time and invariant mass distribution described by probability density function that include a model for prompt and non-prompt component of the signal and a model for the prompt and non-prompt component of the background as well ([1],[2]). The pseudo-proper-time is defined in analogy to the B proper time, but because the decay is only partially reconstructed, the Lorentz boost is evaluated by the J/ψ PDG mass and transverse momentum:

$$\tau = \frac{L}{\beta\gamma c} = \frac{L_{xy} m_B}{p_T(B)} \to \tau' = \frac{L_{xy} m^{PDG}(J/\psi)}{p_T(J/\psi)}, \quad (1)$$

where L$_{xy}$ is the distance of Jψ vertex from primary vertex measured in the transverse plane. It

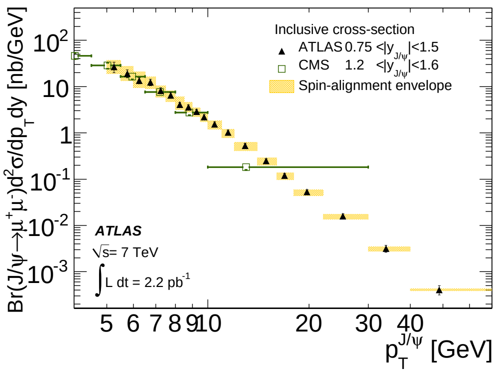

Figure 1. Inclusive J/ψ production cross-section as a function of J/ψ transverse momentum in the 0.75< $|\eta|$ <1.5 rapidity bin. The luminosity uncertainty (3.4%) is not shown.

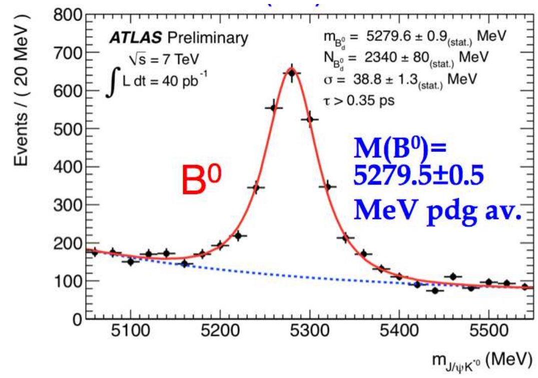

Figure 2. Invariant mass distribution of $\mu^+\mu^-\pi^\pm K^\mp$ with $\mu^+\mu^-$ mass compatible with J/ψ and $\pi^\pm K^\mp$ mass compatible with K*.

turns out that J/ψ resonances produced with a p$_T$ above 30 GeV have a non-prompt fraction of about 70%.

Fully reconstructed charged and neutral B meson decays with J/ψ in final state were observed with the following yield: 5300 B$_u$, 2500 B$_d$, and 400 B$_s$[3].

The most simple fully reconstructed B hadron decay with J/ψ in the final state is the charged B hadron decay: B$^\pm \rightarrow$ J/ψ K$^\pm$. A high statistics observation was already possible with early 2010 data, thanks to the clear event topology and muon trigger signature. The signal yield was evaluated from an unbinned maximum-likelihood fit with a Gaussian signal model and linear background model. The signal candidates are found from muon pair selected in a tight J/ψ mass window. The muon pair mass is refitted, using J/ψ world average mass, to a third track, using K mass hypothesis, The muon pair and the third track forming a common vertex are refitted using J/ψ world average mass, requiring chi^2/dof<6, and overall p$_T$ above 10 GeV. B-meson mass is calculated using K mass hypothesis to the third track. The event-by-even mass errors are used in the Gaussian width of the signal probability density function.

The signal-to-background ratio is significantly improved by requiring a finite transverse decay length L$_{xy}$ > 300 μm. The measured mass is M(B$^\pm$)=5283.2$\pm$2.5 MeV to be compared to the PDG value M(B$^\pm$)=5279.1$\pm$0.4 MeV.

The entire 2010 data were necessary to clearly observe the neutral B mesons with J/ψ and two tracks in the final state: B$_s \rightarrow$ J/$\psi\phi$(K$^+$K$^-$) and B$^0 \rightarrow$ J/ψK*(K$^+\pi^-$). The reconstruction strategy for these two channels is similar. The muon pair is refitted with J/ψ world average mass with a third and fourth opposite charge tracks to a common vertex with chi2/dof<2(2.5 for B$_s$). The two tracks are considered to be Kπ and πK for B^0 and KK for B$_s$, with an invariant mass compatible with K* and ϕ mass, respectively. For the B^0 channel the hypothesis with invariant mass nearest to K* mass is retained and the other rejected. The signal yield is extracted similarly to the charged B meson but with an additional exponential component to model the background for the B^0 channel.

The signal-to-background ratio is increased significantly with a proper time τ cut of 0.35 and 0.4 ps for B$_d$ and B$_s$ respectively. The event-by-event proper time in the exclusive channels is computed exactly from equation 1 (left side), because the B's are fully reconstructed. The mass measurements are very near to the PDG value: M(B$_s$)= 5366.1$\pm$0.9 MeV and M(B^0)= 5279.5$\pm$0.5 MeV.

REFERENCES

1. The ATLAS Collaboration. ATL-COM-PHYS-2011-082, "Measurement of the differential cross sections of inclusive, prompt and not-prompt J/ψ production in proton-proton collisions at $\sqrt{s}$ = 7 TeV". Nuclear Physics B 850, 387 (2011).
2. N. Orlando, on behalf of the ATLAS Collaboration. "J/ψ production cross section and non-prompt fraction measurement with the ATLAS detector". Nuovo Cimento C 34 06 (2011).
3. G. Chiodini, on behalf of ATLAS Collaboration. ATL-PHYS-PROC-2011-071, "Heavy flavor production with exclusive decay channels in ATLAS." DIS2011 Proceeding.