MEASURING THE $J/\psi \to \mu^+\mu^-$ PRODUCTION CROSS SECTION WITH CMS

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The workflow of the measurement of the J/ψ cross section in the di-muon decay channel with CMS at the LHC will be described. Some preliminary muon results from the 2009 run will be shown as well.

1 Introduction and motivations

Although J/ψ mesons have been studied extensively since their discovery, the underlying production mechanism at hadron colliders is still not well understood. Three processes dominate J/ψ hadro-production: prompt J/ψ's produced directly, prompt J/ψ's produced indirectly (via decay of heavier charmonium states such as ψ' and χ_c) and non-prompt J/ψ's from the decay of a b hadron.

The *Large Hadron Collider* (LHC) will produce large yields of J/ψ mesons. This will permit the *Compact Muon Solenoid*[1] (CMS, Fig. 1) to make a measurement of the J/ψ differential production cross section in the first few months after the LHC startup.

The studies of quarkonia with CMS can probe higher momentum values than feasible at previous experiments, extending the test of different production mechanisms. CMS precise tracking permits to disentangle the prompt J/ψ production from that coming from b hadron decays, and therefore allows to determine the b hadron cross section with a relatively small integrated luminosity. Last but not least, the J/ψ differential cross section measurement is also an excellent test for CMS itself, permitting to monitor the detector performances, to study calibration and alignment of many subdetectors, and to tune muon reconstruction and identification.

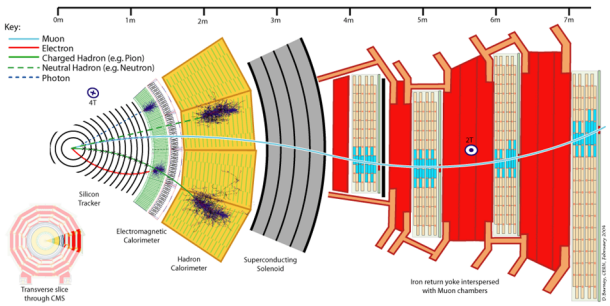

Figure 1: A projection on the xy plane of the CMS barrel. The schematic behavior of muons, electrons, hadrons and photons is shown.

2 J/ψ cross section

The J/ψ differential cross section times its branching ratio into two muons will be measured in the muon pseudorapidity region $|\eta| < 2.4$. It is based on the following expression:

$$\frac{\mathrm{d}\sigma(J/\psi) \cdot Br(J/\psi \to \mu^+\mu^-)}{\mathrm{d}p_T} = \frac{N_{fit}^{J/\psi}}{A \cdot \epsilon \cdot L \cdot \Delta p_T}, \tag{1}$$

where:

- $N_{fit}^{J/\psi}$ is the number of reconstructed J/ψ's in a given p_T bin; it will be extracted with a fit to the invariant mass of the two reconstructed muons.
- A is the detector geometrical and kinematical acceptance; it will be determined by Monte Carlo simulation.
- ϵ is the trigger and reconstruction efficiency. It can be evaluated from Monte Carlo simulation and data-driven methods.
- L is the integrated luminosity.
- Δp_T is the transverse momentum bin size.

The fitting function on the di-muon invariant mass (Fig. 2) has to take into account the resolution of CMS, the final state radiation for each muon and the background yield.

The di-muon mass resolution changes with pseudorapidity, due to the increasing material thickness traversed by muons and the varying lever arm of the tracker with respect to η. It has been evaluated to be about 17 MeV/c^2 at $\eta = 0$ (along the vertical axis) and 40 MeV/c^2 for $|\eta| = 2.4$ (the maximum range in CMS for fully reconstructed muons).

2.1 Measurement of the fraction of J/ψ from b decays

b hadrons have a proper lifetime of about[2] 1.5 ps. This implies that J/ψ mesons from the decays of b hadrons are likely to be displaced with respect to the primary vertex. The extraction of the fraction of J/ψ's coming from B decays is done by a simultaneous maximum likelihood fit to the invariant mass and pseudo-proper decay length[3], defined as:

$$\ell_{xy}^{J/\psi} \equiv \frac{L_{xy}^{J/\psi} \cdot M_{J/\psi}}{p_T^{J/\psi}}, \tag{2}$$

where $\ell_{xy}^{J/\psi}$ is the component of the decay length (defined as the distance between the vertex formed by the two muons of the J/ψ decays and the primary vertex of the event) projected on the

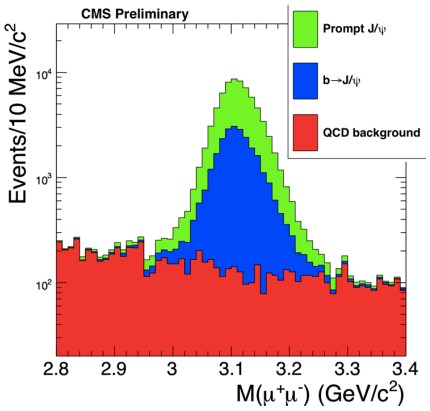

Figure 2: Invariant mass of the two reconstructed muons. The equivalent integrated luminosity is 3 pb^{-1}. The center of mass energy is 14 TeV.

J/ψ transverse momentum direction and $M_{J/\psi}$ and $p_T^{J/\psi}$ are the di-muon mass and transverse momentum, respectively. The results of a Monte Carlo simulation for the measurements of the J/ψ cross section and the fraction of J/ψ's from b decays can be seen in Fig. 3.

3 Looking towards the LHC runs

Even before the LHC was producing collision events, the knowledge of the detector had improved thanks to the data acquired from cosmic runs in the last years. During the so-called CRAFT run[4] in the summer of 2009, about 300 million cosmic muons, passing through the muon stations and the inner silicon tracker, in the 3.8 T axial magnetic field, have been collected, giving important information about the behavior of many components of CMS. The muon performance is as expected (Fig. 4).

In December 2009 the LHC produced events at $\sqrt{s} = 900$ GeV and 2360 GeV, which was the first opportunity for CMS to test the detector behavior with collision data. In Fig. 4, the expected di-muon invariant mass shape is shown for $L = 1$ nb^{-1}.

3.1 A first J/ψ candidate

In December 2009, CMS collected about 300 mb^{-1} at $\sqrt{s} = 2.360$ TeV, and one di-muon has been reconstructed in an invariant mass compatible with a J/ψ (Fig. 5). With a vertex position

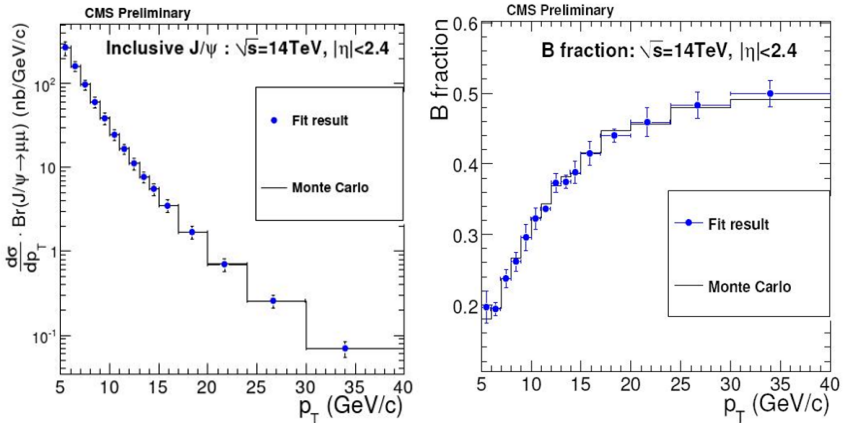

Figure 3: Inclusive cross section vs J/ψ p_T (left); non-prompt J/ψ fraction vs J/ψ p_T (right). The equivalent integrated luminosity is 3 pb^{-1}.

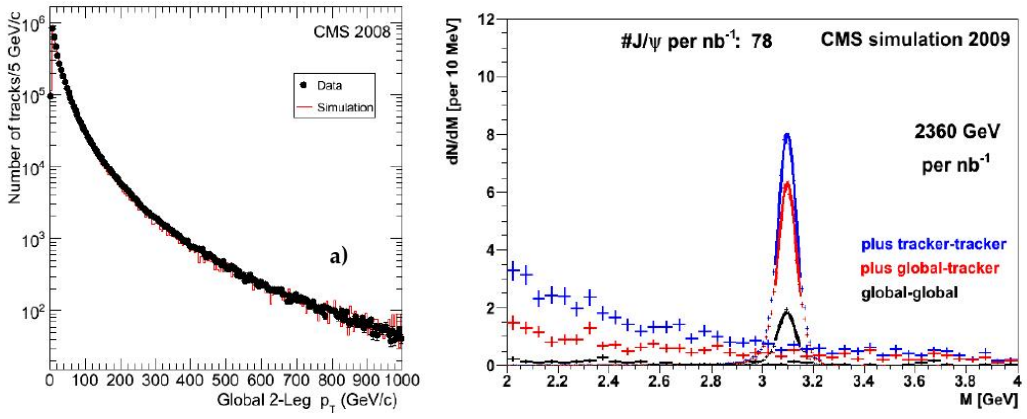

Figure 4: Number of reconstructed tracks vs p_T acquired during the CRAFT run (left). Simulation of the reconstructed di-muon invariant mass in the J/ψ window, for two types of reconstructed muons (right).

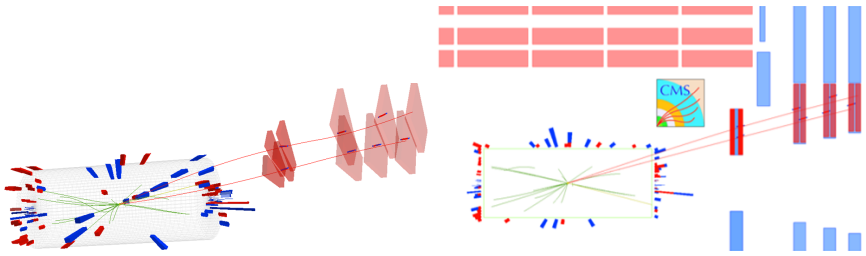

Figure 5: Event display of a di-muon event, showing the reconstructed trajectories of the two muons (red lines).

compatible with the primary vertex (-17±81 μm) and an expected signal-background ratio of 14 in $[3.0, 3.2]$ GeV/c^2, this event is compatible to come from a prompt (i.e. not from a b hadron decay) J/ψ.

4 Conclusion

The CMS collaboration is ready to make the measurement of the J/ψ cross section at 7 TeV c.o.m. energy. In the next few months several hundred thousand J/ψ's are expected to be reconstructed.

Acknowledgments

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References

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