Comments by VU-Nikhef in Amsterdam on LHCb-PAPER-2012-030:

Measurement of the cross-section ratio $\sigma(\chi_c \to J/\psi\gamma)/\sigma(J/\psi)$ for prompt χ_c and J/ψ production at $\sqrt{s} = 7$ TeV

Dear authors of this paper,

We discussed the draft with Nikhef and VU Amsterdam group members on Friday 3rd. First of all we want to say that we are very happy with these nice results which may in the end decide between different theoretical descriptions of heavy quark production.

Splitting the results over several papers has the disadvantage that we have to refer between these papers. However, we should not assume that the reader first should collect all the other papers, before he/she will be able to understand this paper.

Therefore, in addition to referring to a fit model in another paper, the essentials of it should be given in this paper.

We are worried about the background for low $p_T^{J/\psi}$ under the reconstructed χ_{cJ} masses. Do we understand its shape well enough to extract the yields correctly?

As for the cross-section ratio results: Why don't we give the integral result for our range in p_T and y as well? It would be nice as a result in the conclusion and in the abstract.

The section on the experimental method did not convince. So we propose a better structured approach which moves disturbing information to following sections where they are correctly explained.

- Lines 12-14.
  This sentence is difficult to understand before reading the discussion about the polarization. Also the argument that "the prompt fraction has important consequences for the J/ψ polarization" does not convince as a reason to publish. As alternative for "In addition ... polarization" we propose:
  "Polarization of J/ψ influences the observed yields. This is also true for the polarization of the χ_{cJ} states. These polarizations have also to be taken into account for the analysis of prompt J/ψ production."

- Lines 15,21.
  Remove "In this Letter". Or do it at least for the second time.

- Line 35.
  This sentence suggests that the SPD is following the preshower. And that this constitutes the whole calorimeter. Why not use the same description as in the other paper?

- Lines 73-74.
  - Some of us do not like the term "pseudo-decay time". We propose: "projected proper decay time".
  - The prompt time peak will have a non-Gaussian shape. What is the systematic uncertainty contribution to out results by cutting so close to $t_z = 0$? Especially, as the prompt J/ψ contribution is determined in a completely different way.

- Figure 1a.
  Why do we show the selected J/ψ candidates at all? Are these prompt J/ψ candidates? Probably not. The spectrum does not show a relevant part of the background.

- Figure 1b,c.
  The background fit function is not given. Does the fit function describe low $p_T^{J/\psi}$ bins well? Did we check that on random γ and J/ψ pairs from mixed events?

- Lines 108.
  - Why is Fig. 2 given so far away from this sentence?
  - Why is $\epsilon^{2S}_{J/\psi}/\epsilon^{dir}_{J/\psi}$ not presented? It would be best to discuss its value equal to unity here, and its consequence, $R_{2S} \approx 1$, as well.
  - It is said that χ_{cJ} efficiencies are shown, but those for $J = 0$ are not presented.

- Lines 111-112.
  - The comment on the difference between χ_{c1} and χ_{c2} could be more specific: "In the $p_T^{\gamma} > 0.65$ GeV/c cut more photons from χ_{c2} decays survive than from χ_{c1} decays."
  - Remove "... and is small ...uncertainties". No need to compare with the final uncertainties, because we take these differences into account, I assume.
  - What about χ_{c0} decays?

- Lines 125, 126 and 128.
  Replace '>' by "larger than".

- Figure 2.
  The size of text in the figure is smaller than that in the text.

- Lines 149,151.
  - Replace 'measured' by 'calculated'.
  - What is meant with "expected value"?
  - The statement "measurements are in good agreement" seems to be contradicted in line 212, where an "underestimate of 10.9%" is given for the cross-section ratio, due to a problem in the calorimeter and thus to a disagreement in the photon efficiency.

- Lines 155-157.
  Reformulate this complicated sentence. We propose:
  "The simulations normally assume unpolarized χ_c and J/ψ particles. The efficiencies and, therefore, the result of Eq. (1) depend on the assumption of the polarization of these particles. The simulations have been reweighted to various polarization schemes and the results are shown in Table 1."

- Line 159.
  The direction of which of the two muons?

- Line 166.
  From the definition of m_{χ_c} it can have both positive and negative values. Why do we consider only positive ones in Table 1?

- Lines 200-201.
  This could have been avoided if the analysis was repeated for the data set of 36 pb^{-1}. Why is this not done? It is the source of the second largest systematic uncertainty. What is the contribution due to the extrapolations? What would have been the uncertainty if the the full data set was used?

- Lines 214-215.
  Why is the calorimeter calibration not tuned in the simulation? What does it mean? Does the simulation give about the same signal resolution? Or is the data smeared

by other Gaussian effects that are not in the simulation? As it is written, it seems an easy excuse for something we do not understand.

- Lines 230-232.
  - Replace by "The measurements show a different trend, but are still consistent ...".
  - Replace "with $p_T^{J/\psi}$ roughly below 5 GeV/c" by "and with $p_T^{J/\psi} \leq 5$ GeV/c".

- Line 239.
  This seems very unusual. Do the authors of [18] agree with this procedure? Is there an explanation why the model fails for "prompt J/ψ cross-section"? As prompt χ_c is part of this cross section it may also be part of the problem.

- Lines 291.
  The author name 'Wcas' is printed wrongly. Probably the use of the newest LHCb style will cure this problem.

- Experimental method. Lines 84-153.
  This section was considered by most of us to be unnecessary difficult to read. Eq. (1) drops out of the blue air and it takes a long way before all the components are mentioned. The information about $R_{2S} = 1$ and the $\phi(2S)$ polarization can better be discussed in the context of sections 3.1 and 3.2.
  Below we propose a text which takes into account all our small and large problems we have with the present text. (We use the operation dfrac in stead of frac for divisions to improve the readability of the equation.)

3 Experimental Method

The fraction of prompt J/ψ produced via $\chi_c \to J/\psi\ \gamma$ decay is investigated, for which only the contributions of this decay, the decay $\psi_{2S} \to J/\psi\ X$, where X means any final state, and direct production are significant to prompt J/ψ. The cross-section ratio of the production of prompt χ_c that decay into $J/\psi + \gamma$ and production of prompt J/ψ can be expressed in the yields of the three χ_{cJ} $(J = 0, 1, 2)$ signals, $N_{\chi_{cJ}}$, and the prompt yield, $N_{J/\psi}$, as

$$\frac{\sigma(\chi_c \to J/\psi\ \gamma)}{\sigma(J/\psi)} \approx \frac{\sigma(\chi_c \to J/\psi\ \gamma)}{\sigma^{dir}(J/\psi) + \sigma(\psi_{2S} \to J/\psi\ X) + \sigma(\chi_c \to J/\psi\ \gamma)}$$
$$= \frac{\sum_{J=0}^{2} \dfrac{N_{\chi_{cJ}}}{\epsilon_{sel}^{\chi_{cJ}} \epsilon_{\gamma}^{\chi_{cJ}}} \cdot \dfrac{\epsilon_{J/\psi}^{dir}}{\epsilon_{J/\psi}^{\chi_{cJ}}}}{N_{J/\psi} R_{2S} + \sum_{J=0}^{2} \dfrac{N_{\chi_{cJ}}}{\epsilon_{sel}^{\chi_{cJ}} \epsilon_{\gamma}^{\chi_{cJ}}} \cdot [\dfrac{\epsilon_{J/\psi}^{dir}}{\epsilon_{J/\psi}^{\chi_{cJ}}} - R_{2S}]}, \tag{1}$$

$$\text{with } R_{2S} = \frac{1 + f_{2S}}{1 + f_{2S} \dfrac{\epsilon_{J/\psi}^{2S}}{\epsilon_{J/\psi}^{dir}}} \text{ and } f_{2S} = \frac{\sigma(\psi(2S) \to J/\psi\ X)}{\sigma^{dir}(J/\psi)}. \tag{2}$$

The fraction f_{2S} is used to link the prompt $\psi(2S)$ contribution to direct J/ψ; R_{2S} takes into account different J/ψ efficiencies. The reconstruction and selection efficiencies for direct J/ψ, for J/ψ from $\psi(2S)$ decay, for J/ψ from χ_{cJ} decay , for γ from χ_{cJ} decay, and for the subsequent selection of χ_{cJ} are $\epsilon_{J/\psi}^{dir}$, $\epsilon_{J/\psi}^{2S}$, $\epsilon_{J/\psi}^{\chi_{cJ}}$, $\epsilon_{\gamma}^{\chi_{cJ}}$, and $\epsilon_{sel}^{\chi_{cJ}}$, respectively.

The efficiency terms in Eq. (1) are determined in simulation studies and are partly validated with control channels in the data. In section 3.1 the results for the efficiency ratios $\epsilon^{2S}_{J/\psi}/\epsilon^{dir}_{J/\psi}$, $\epsilon^{dir}_{J/\psi}/\epsilon^{\chi_{cJ}}_{J/\psi}$ and the product $\epsilon^{\chi cJ}_{sel}\epsilon^{\chi cJ}_{\gamma}$ will be discussed.

The prompt yields $N_{J/\psi}$ and N_{χ_c} yields are extracted in bins of $p_T^{J/\psi}$ in the range of 2 - 15 GeV/c according to the methods described in Refs [2,3]. In Ref. [2] a smaller data sample is used to determine the prompt J/ψ fractions for bins of $p_T^{J/\psi}$ and rapidity. These results are applied to the present J/ψ sample without repeating the full analysis. Read the discussion in Section 4 on systematic uncertainties for detailed information. The selection of the χ_{cJ} candidates is discussed in the previous section.

Tjeerd Ketel for the Nikhef and VU group, 6 February 2012.