Reply to the referee's comments concerning the paper "Search for exclusive photoproduction of $Z_c^{\pm}$ (3900) at COMPASS" (17.11.2014)

Red- questions from the referee

Blue - answers to the referee

The reviewed paper "Search for exclusive photoproduction of $Z_c(3900)$ at COMPASS" is the first attempt to look for the Z_c state in a process other than e+e- annihilation. Already this circumstance can justify publication of this work in Phys. Lett. B. However, there are some questions to the text of the paper and its logics, which should first be addressed.

Q1 What is the resolution in the invariant mass of mu+mu- near the J/psi mass? And similarly, what is the resolution in the invariant mass of J/psi near 3900 MeV? It would be useful to justify selection of the J/psi as well as of the signal range of M(J/psi pi+) in terms of the corresponding resolution.

A1 The resolution for J/psi mass varies slightly from year to year but is around 50 MeV. The J/psi-pi mass resolution at 3900 MeV is estimated to be about 15 MeV. Taking into account mass resolution of the COMPASS setup (15 MeV), the measured width of Z_c ($46 \pm 10_{\text{stat.}} \pm 20_{\text{syst.}}$ MeV, BES-III) and uncertainty of Z_c mass (± 6 MeV, BES-III) our signal range 3.84-3.96 GeV should include most of the expected Z_c signal.

Corrections to the text of the Letter:

" ...that is 3 times larger than the mass resolution."

" In order to quantify possible contribution from the Z_c decay we define the signal range 3.84 GeV/c^2 < $M_{J/\psi\ \pi^{\pm}}$ < 3.96 GeV/c^2. It is selected according to the measured mass and width of Z_c, their uncertainties, observed in the previous experiments, and the COMPASS setup resolution for $M_{J/\psi\ \pi^{\pm}}$ of about 15 MeV/c^2."

Q2 It is worth emphasizing that the result for the partial width into J/psi pi has strong model dependence because it is based on theoretical estimates of Ref. [14]. How trustworthy is their estimate? For example, can it predict a cross section of the "simpler" process of J/psi photoproduction? J/psi.

The diagram in Fig. 1(a) is indeed formally showing that the $Z_c(3900)$ can be produced via photoproduction of the J/psi. However, it completely ignores the experimental fact that the $Z_c(3900)$ was not observed just in the "continuum" of the multihadronic e+e- annihilation, among events containing J/psi pi. It was observed in the decays of the so called Y(4260) → J/psi pi+ pi- which nature is unknown. I'm mentioning this fact just to remind that production of these exotic charged states can be very complicated.

A2 The main result of the Letter is definitely the upper limit for the cross section multiplied by the BR (Eq. 9). This result is model independent. The result for the upper limit of the partial width is used as an example how our main result can be interpreted within a theoretical framework. It indeed has a strong model dependence. In order to emphasize this we put the next phrase to the text:
" While the results in Eq. (8) and (9) are model independent, the result for the partial width $\Gamma_{J/\psi\ \pi}$ is strongly model dependent."

As for reliability of the theoretical calculations in [14], they are beyond the scope of our Letter. Concerning the referee's question on the cross section of the "simpler" process J/psi photoproduction, it has been used by authors of [14] for tuning of Λ parameter of N-pi-N in the calculation of the cross section of the process, shown in Fig 1b of our manuscript [private communication].

Q3 Table I. In all intervals of sqrts but (12.3,14.1) GeV the upper limit is larger than 3.7. It is natural to assume that in the full range of sqrts the upper limit, which is kind of average, will also be larger than 3.7, which is not the case.

Table 1: Estimation of the upper limit of the number of produced $Z_c^{\pm}(3900)$ events.

Sample	$N_{J\psi\ \pi}$ 3.84-3.96	$\bar{N}_{bkg}$ $\pm\sigma_{N_{bkg}}$	$N_{Z_c}^{UL}$ CL=90%	$\sigma_{Z_c}/\sigma_{J\psi}\times$ $BR(J\psi\ \pi)$, 10^{-3}
Full	51	49.7 ± 3.4	15.1	3.7
$\sqrt{s_{\gamma N}} < 12.3$ GeV	20	14.8 ± 1.4	12.8	10.0
12.3 GeV $< \sqrt{s_{\gamma N}} < 14.1$ GeV	8	12.7 ± 1.4	4.7	3.7
14.1 GeV $< \sqrt{s_{\gamma N}} < 15.4$ GeV	14	11.4 ± 1.3	9.5	4.5
15.4 GeV $< \sqrt{s_{\gamma N}}$	9	11.9 ± 1.3	5.4	6.0

A3 Since the full range contains the full set of events from the subranges one would expect that the upper limit for the full range is lower than in each of the subranges. Due to statistical fluctuations in the number of observed events that is not true for the subrange 12.3 GeV $< \sqrt{s_{\gamma N}} < 14.1$ GeV. Table 1 illustrates the situation in detail.

Q4 The authors do not provide any information about how they estimate systematic effects that lead to a quite sizable systematic uncertainty of 35%. A few sentences describing such estimates would be helpful.

But even knowing the resulting value of the systematic uncertainty it is not immediately clear how it affects the upper limit because it is a multicomponent quantity (background, acceptance etc.). A proper procedure would be to convolve the probability density function $g(N_{Z_c})$ with that for systematic effects. Although I'm not insisting on doing that, it would be nice to have some argumentation, see the paragraph above.

A4 We thank, in particular, for this comment. It led to the following changes in the Letter:

"The main contribution to the systematic uncertainty of the result shown in Eq. (8) comes from the background description in the signal range of the $J/\psi\ \pi$ spectrum. Changes of the fitting function and the fitting ranges shift the result within $\pm 15\%$. The absolute normalization is performed with a relative accuracy of about 25% that includes our limited knowledge of the ratio $R_a = 0.5 \pm 0.1_{\rm syst.}$ and systematic errors in the estimation of the nonexclusive contamination in the reference J/ψ sample (15%), determined from the p_T dependence of the energy balance ΔE. Nevertheless, this relatively large uncertainty may change the upper limit just by up to 3%. Contribution of the absolute normalization remains small with respect to the contribution related to the background fitting even for result in Eq. (9), where the uncertainty of the $\sigma_{\gamma\ N \to J/\psi\ N}$ measurement by NA14 contributes. So, the systematic uncertainty of the results in Eq. (8) and (9) is about 15%."

Q5 The authors write in conclusion:

"..., the decay channel $Z_c \to J/psipi$ can not be the dominant one." Where does it follow from? If the authors deduce this from (8), they have to provide some arguments that the cross section of the Z_c photoproduction is at least not negligible compared to that of the J/psi.

Of course, one could use the additional information coming from BES-3. It is known that they observed a so called $Z_c(3885)$+- state decaying into DD* with parameters somewhat different from those of the $Z_c(3900)$+-, but not too far. If one assumes that they deal with two decay modes of the same state, then the ratio of the partial widths is

Gamma(DD*)/Gamma(J/psi pi)=6.2 +- 1.1 +- 2.7,

so that indeed the J/psi pi mode is not dominant. See M. Ablikim et al., Phys. Rev. Lett. 112, 022001 (2014), arXiv:1310.1163. But once again, this is completely independent additional information.

A5 In the conclusion we emphasized again that our result for the partial width $\Gamma_{J/\psi\ \pi}$ is a model dependent:

"The obtained result was treated within the framework of Z_c production mechanism proposed in Ref. [14]. In case the assumptions made therein are correct, the decay channel $Z_c^{\pm}(3900) \to J/\psi\ \pi^{\pm}$ can not be the dominant one."

Q6 Minor comments

page 3, paragraph 3, line 4 after (3)
as $J/\psi \rightarrow$ as a J/ψ
4,2,2 after (7)
Gaussian $\rightarrow$ Gaussians
5,1,1
of process in Eq. (2) -¿ of the process in Eq. (2)
5,3,(10)
$\Gamma_{tot} \rightarrow \Gamma_{\mathrm{tot}}$
5,4,2
Here "the acceptance ratio" is denoted a whereas on 5,1,2 it is defined as R_a.
5,4,3
nonexclusive -¿ the nonexclusive
5,4,4
The uncertainty of σ... $\rightarrow$ The uncertainty of the σ...
6,References
[2] was published in arXiV:1304.0121
[8] is published in J. Phys. G 41, 075003 (2014).

A6 We implemented all the proposed corrections.
We also corrected the misprints in Eq. 4.