Stabilility dependence of the yield on Crystal Ball parameter α

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Abstract

We studied events where a nearby miss of a Pb nucleus and a proton creates a J/ψ particle which then decays into two muons. By their energy, we can calculate the energy of the photon and gluons, that changed into the J/ψ. The gluons carried energy for strong interaction between the Pb nucleus and the proton. The data can be compared with theorethical predictions. The main goal for us was to determine whether data fitting is reliable (due to the usage of two parametres generated by simulation). We showed that the effect is minimal in range $\pm 20\%$ of the computed value of α (parameter used in fitting procedure based on Crystall Ball function). The research was made with the help of ENPP (experimental nuclear and particle physics) group from physics department at Faculty of Nuclear Sciences and Physical Engineering in Prague, CTU.

1 General idea

Every nucleus is composed of protons and neutrons (except hydrogen) and they both consist of elementary particles (quarks, gluons etc.). All quarks inside proton/nucleus interact with every other quark by a particle (called gluon). This interaction holds protons (and neutrons) inside the nucleus, although protons have the same electric charges. There are various theories about gluons and their composition inside protons or even nuclei, as well as experiments trying to prove which of them are right and which are wrong.

Our main interest were events inside a detector (detector ALICE in CERN) which is a part of LHC. There were protons and nuclei of Pb accelerated to energy of about 5 TeV. Usually, the main concern is to collide both substances together. This time we wanted them to pass without collision, and thus create a possibility, that a particle would be created. In this case the particle is called J/ψ. We studied dimuon decay channel (for detection see. fig 1).

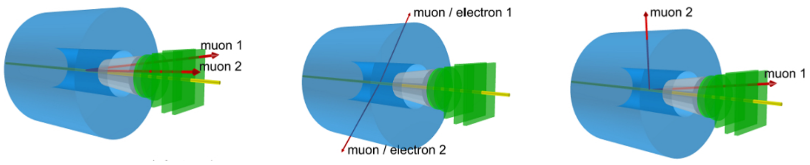

Figure 1: Here you can see different possibilities of dimuon detection.[1]

By the energy and rapidity of those muons you can calculate the energy of the J/ψ, which you can compare with the theoretical prediction. However, the data that is coming out of the detector is "raw"[1]. Therefore, there is a macro that will create a graph– number of events dependent on energy of muons (fig. 2, created by J. Adam).

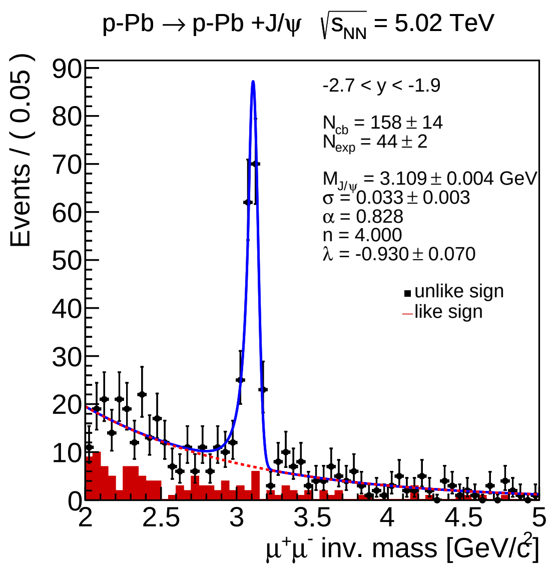

Figure 2: Graph showing detected events, dependent on the energy/mass of the muons. N_{cb} is the surface(= number of events) under the Crystal Ball fit and N_{exp} is the surface under the exponencial function.

[1]By raw we mean numbers, that won't give you the information you need.

2 Trust the graph

All that was written above was just an introduction into the problematics and it had been already researched by other scientists [2]. So research we did was about a function called Crystal Ball (function formula see fig. 3) that is used during data fitting. It consists of several parameters, that change the curve and what more, the parameters change the surface under the curve (see Fig. 4–6 for better illustration[2]).

$$f(x,\alpha,n,\bar{x},\sigma) = N \cdot \begin{cases} exp\left(-\frac{(x-\bar{x})^2}{2\sigma^2}\right), & \text{for } \frac{x-\bar{x}}{\sigma} > -\alpha \\ A \cdot \left(B - \frac{x-\bar{x}}{\sigma}\right)^{-n}, & \text{for } \frac{x-\bar{x}}{\sigma} \leq -\alpha \end{cases}$$

Figure 3: This is the function formula of Crystal Ball[5]

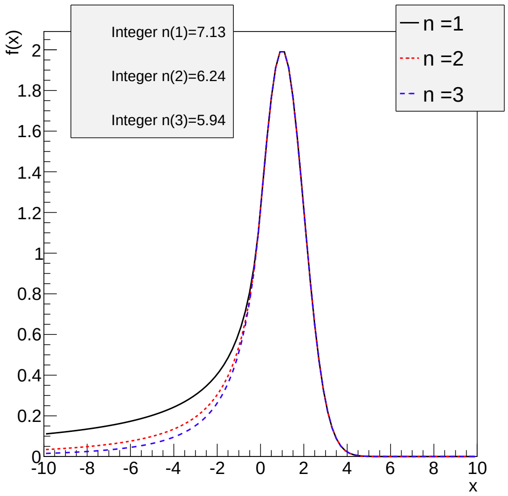

Figure 4: The parameter called "n" is fairly similar to α. See fig. 6

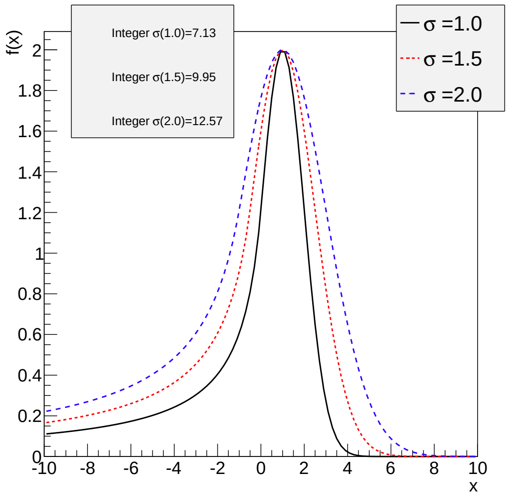

Figure 5: This parameter is similar to the one used in Gauss function.

The parameter we focused on is called α and it changes the lean of the curve (see fig. 6). So it also changes N_{cb}(=surface between the exponential and Crystal Ball function) and N_{exp}(=surface under the exponential function). During data gathering, there is a simulation, based on random numbers, that can (somehow) calculate the right value of α. But what if it was wrong? Let's say $\pm 5\%$. Will it make a "huge" difference? Hence, we created a macro, where you specify what should the $\pm$difference be and it will show you the dependence of N_{cb} and N_{exp} on α. There are two rapidity bins inside the detector, so two graphs are shown (one for each).

[2] These graphs were created with the help of following sources: [3] and [4]

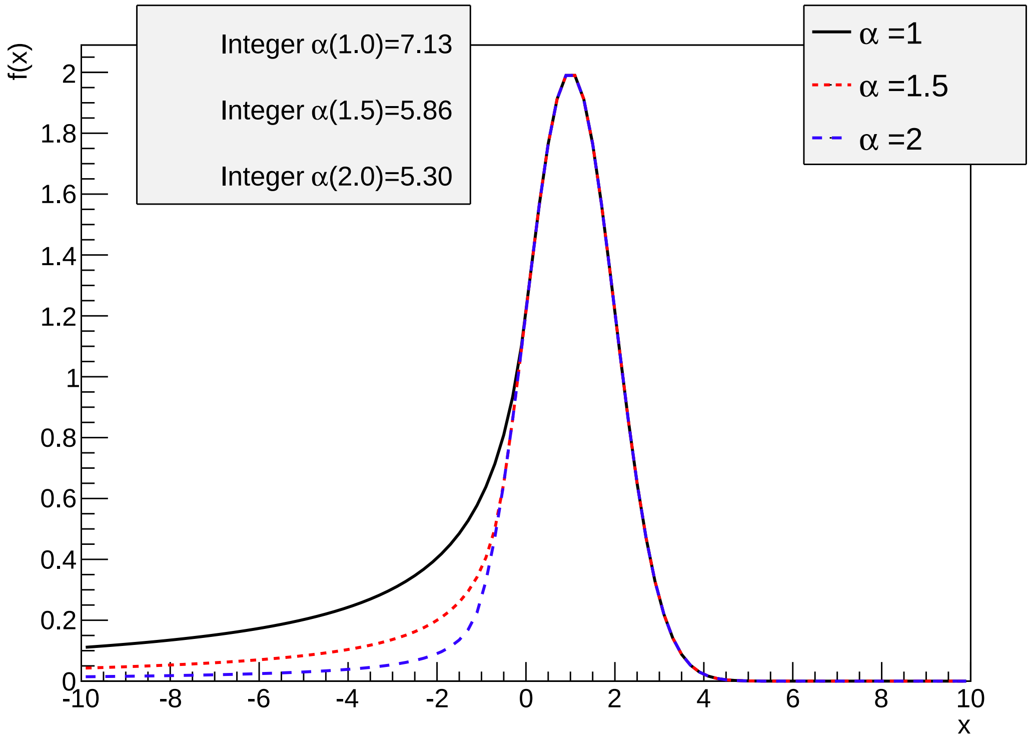

Figure 6: Here is the graph that shows the Crystal Ball function with the different values of α. It was our main interest to find out what effect it has on the yield.

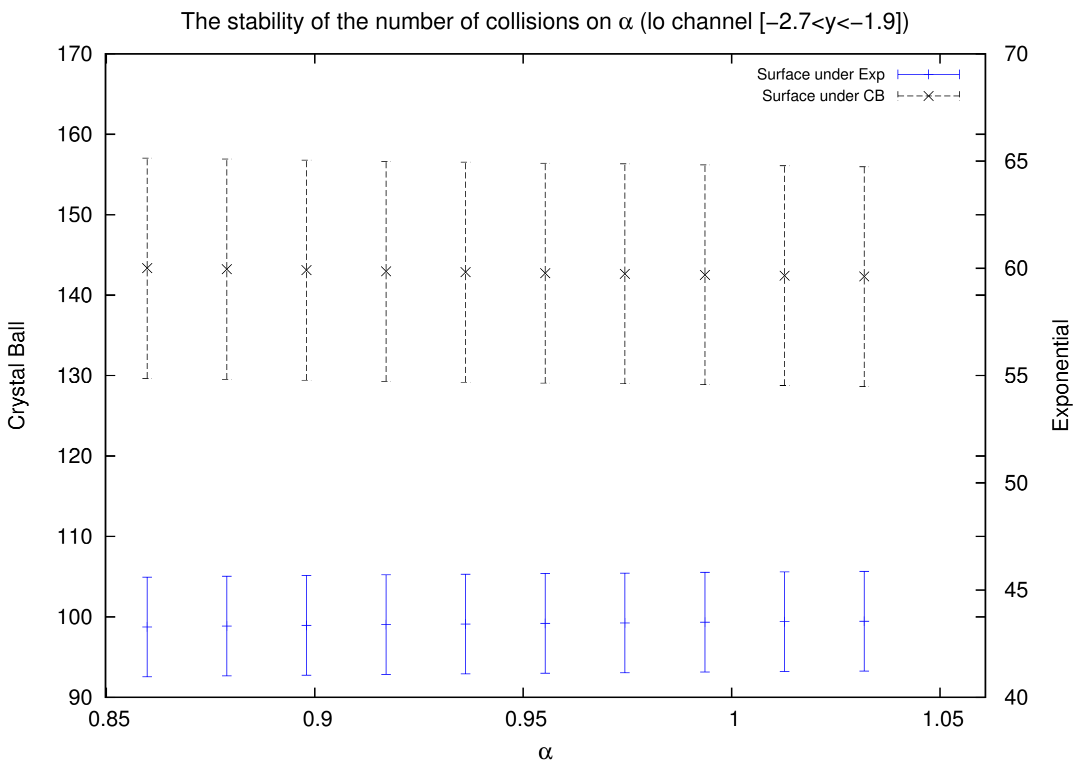

Figure 7: During the whole α–range the average value of N_{cb} and N_{exp} remains inside it's own error.

Both graphs have the α difference $\pm 20\%$ and the values are still inside the error. This is important because it means that the data fitting, which creates the N_{cb} and N_{exp}, is reliable.

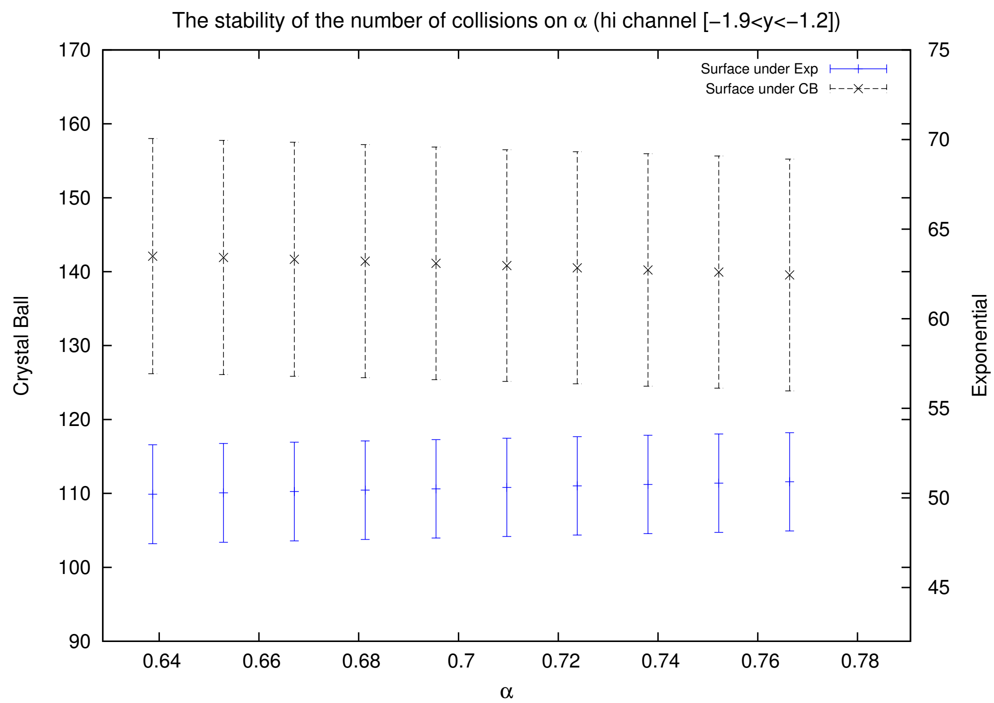

Figure 8: The values here are more dependent on α but still the average values remain inside the error.

3 Conclusions

To sum it up, we were looking into the problematics of Pb-p collisions. We showed the fitting procedure based on Crystall Ball and exponential function. By alernating the value of α parameter we showed that the fitting method has been proved as applicable to the data.

References

[1] J. Adam, "Alice results on ultra-peripheral p-pb and pb-pb collisions." https://indico.cern.ch/event/297878/session/3/contribution/17/material/slides/0.pdf.

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[5] *Col. of authors*, "Crystal ball function." Wikipedia, December 2013. http://en.wikipedia.org/wiki/Crystal_Ball_function, last checked: 07.11.2014.