Vol. 6 (2013) *Acta Physica Polonica B Proceedings Supplement* No 4

ANALYSIS METHOD OF ϕ-MESON PRODUCTION IN PROTON–PROTON COLLISIONS IN THE NA61/SHINE EXPERIMENT AT THE CERN SPS*

Antoni Marcinek

The Marian Smoluchowski Institute of Physics, Jagiellonian University
Reymonta 4, 30-059 Kraków, Poland

(Received August 6, 2013)

Fitting strategy for the analysis of ϕ-meson production in proton–proton collisions in the NA61/SHINE experiment at the CERN SPS is discussed along with possible methods to correct for the particle identification efficiency.

DOI:10.5506/APhysPolBSupp.6.1111
PACS numbers: 25.75.Dw

1. Introduction

There are many models of hadron production suitable for the CERN SPS energy domain, which differ significantly with respect to predicted scaling properties for multiplicities of hadrons if energy or size of the colliding system is varied. Especially interesting is treatment of the strangeness production, which is subject to several peculiar effects. Because of its $s\bar{s}$ composition, ϕ meson provides particularly tight constrains on those models. In a purely hadronic scenario, being strangeness-neutral, it should be insensitive to strangeness-related phenomena. On the other hand, if the amount of available strange quarks is determined in a partonic stage of the collision, the ϕ is expected to react more sensitively than singly strange particles.

NA49 experiment published results on ϕ production at SPS in pp, pPb collisions at 158 GeV [1] as well as PbPb collisions at $20A$–$158A$ GeV [2]. Due to limited statistics, only single differential spectra of transverse momentum $p_{\rm t}$ and rapidity y were measured. The goal of the proposed analysis is to obtain ϕ multiplicities in pp collisions at 5 energies in the NA61/SHINE experiment, preferably in terms of double differential y, $p_{\rm t}$ spectra. First, the analysis method is to be trained on the 158 GeV sample from the run

* Presented at the Symposium on Applied Nuclear Physics and Innovative Technologies, Kraków, Poland, June 3–6, 2013.

in 2009, because for this energy consistency cross check is possible with the NA49 result. After training, the analysis is planned to be applied to lower energy samples taken in 2009 and high statistics samples at the top SPS energy taken in 2010 and 2011.

2. The analysis method

Analysis is to be done by means of invariant mass spectra fits in the $\phi \to K^+K^-$ decay channel, for which the branching ratio is about 50%.

The most important part of the data selection is the selection of kaon candidates. In the NA61/SHINE experiment, particle identification (PID) is performed using energy loss dE/dx in the gas of time projection chambers and, in a limited acceptance, using time of flight. Currently, tracks are accepted as kaons if their dE/dx is within $\pm 5\%$ of the value predicted for their momenta by the assumed Bethe–Bloch curve. Due to resolution of dE/dx measurement, there are always some pions and protons misidentified as kaons. The cut has to be tight enough to prevent too high contamination, so not all kaons are accepted and, consequently, some ϕ mesons are lost.

A correction due to this effect is needed. One approach is to utilize the knowledge of dE/dx distributions and make a cut with a constant, known efficiency in the whole kaon phase space [1, 2]. Another way is to obtain the PID efficiency from the tag-and-probe method [3]. It requires two samples of track pairs to build invariant mass spectra. In the probe sample, both tracks need to pass the PID cut. Assuming that N_ϕ denotes the corrected number of ϕ mesons and ε is the kaon PID efficiency, number of resonances measured in the probe sample is $N_{\mathrm{p}} = N_\phi \varepsilon^2$. The tag sample is built from track pairs in which at least one of tracks has to pass the PID cut. Consequently, the yield measured for this sample is $N_{\mathrm{t}} = 2N_\phi \varepsilon(1-\varepsilon) + N_\phi \varepsilon^2$. Doing a simultaneous fit to both samples, one can get values of N_ϕ along with ε.

To extract ϕ signal from invariant mass spectrum, signal and background components need to be parametrised. For the background estimation, an event mixing method is used. In this method, kaon candidate from the current event is paired with candidates from an arbitrary number of previous events to fill the mixed events invariant mass spectrum. This method provides a fully uncorrelated background, however *e.g.* due to conservation laws, the true background is built of correlated pairs. Because of this, in general, the method does not work, but it may give satisfactory estimation in certain rare cases, like the ϕ one. The signal is parametrised with the Voigt function to take into account the Lorentz shape of the resonance and the Gaussian broadening due to detector momentum resolution. This gives the following fit function

$$f(m) = N \times V(m - m_\phi, \sigma, \mathit{\Gamma}) + N_{\mathrm{bkg}} \times \mathrm{Mixed}(m)\,.$$

Above, N is the signal yield. In a fit to a single sample, it is a free parameter. In the simultaneous fit to tag-and-probe samples, it is a function of N_ϕ and ε. Initially, the fit is done for the probe sample only, without binning of y, p_{t}. The ϕ invariant mass m_ϕ and the detector resolution parameter σ obtained in this way are fixed in following fits, where due to low statistics or low signal to background ratio, unconstrained fits are unreliable. Due to high correlation of σ and Γ, the resonance width is fixed to the PDG value of $\Gamma = 4.26\,\mathrm{MeV}$ [4].

To test the method, it is applied to 1.7 M preselected *pp* events at 158 GeV collected by NA61/SHINE. Figure 1 shows an example simultaneous fit to both samples in the unbinned ϕ phase space, which matches to the phase space of NA49 analysis in [1]. One can see that both the signal and background are well described. However, in the tag sample the signal to background ratio is low due to high number of pions taken into account, what in the case of binned y, p_{t} gives high statistical uncertainties of N_ϕ (see Fig. 2). This might be improved by requiring all the tracks in the tag sample to pass a broad PID cut which has 100% efficiency for kaons, but reduces number of pions. Two versions of analysis method are tested on a 2D y, p_{t} phase space. Their results are compared in Fig. 2. Yields from fits to the probe sample only (black circles) have to be corrected for PID efficiency and some more effects (see the next paragraph), therefore, in most bins they are systematically lower than the PID corrected (red/grey squares) results of simultaneous fits to two samples. This agrees with the expectations.

Still several ingredients need to be developed. They include corrections for geometrical acceptance and decay of kaons, reconstruction efficiency, non-target interactions contribution, and trigger bias. Also systematic uncertainties due to signal extraction ambiguities and corrections need to be studied.

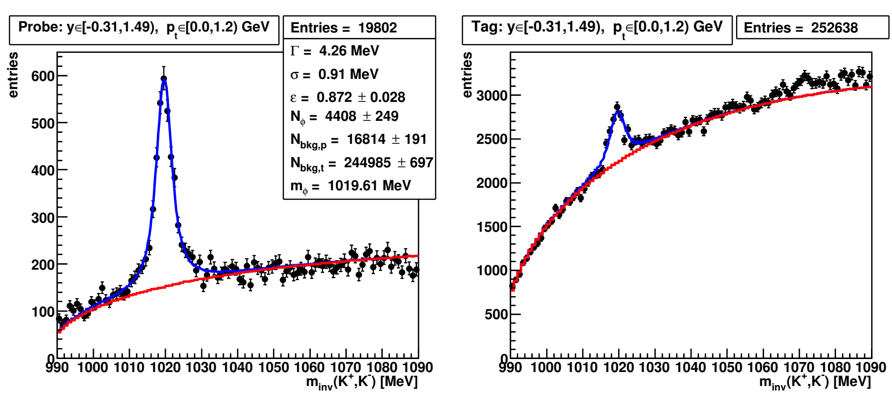

Fig. 1. Result of a simultaneous fit to tag-and-probe samples in an unbinned phase space of ϕ, defined with an indicated center-of-mass y and p_{t} ranges.

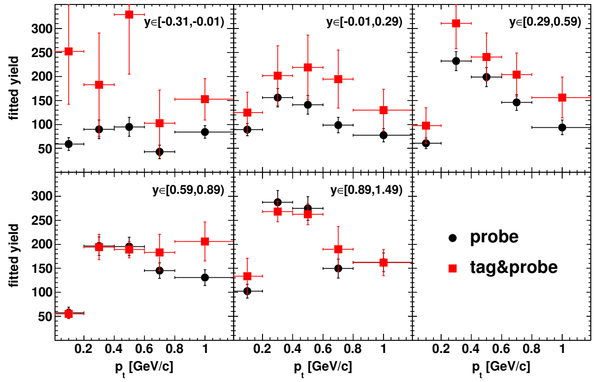

Fig. 2. Comparison of yields resulting from fits to NA61/SHINE data in two versions of the analysis method for 5 center-of-mass rapidity bins. See the text for the meaning of symbols.

3. Conclusion

Analysis method of ϕ-meson production in the NA61/SHINE experiment is being developed. Fitting strategy along with possibility to use the tag-and-probe method for PID efficiency correction was discussed. Within the tested statistics, tag-and-probe method in the present form yields too high statistical uncertainties, but there seems to be a possibility to improve it. Also the steps to be still developed were listed.

This contribution reports on the technical work motivated by and tested using experimental data of the NA61/SHINE Collaboration at CERN SPS. The author gratefully acknowledges the contribution of NA61/SHINE to the results presented. This work is supported by the Foundation for Polish Science — MPD program, co-financed by the European Union within the European Regional Development Fund and the National Science Centre of Poland, grant UMO-2012/04/M/ST2/00816.

REFERENCES

[1] S. Afanasiev *et al.* [NA49 Collaboration], *Phys. Lett.* **B491**, 59 (2000).
[2] C. Alt *et al.* [NA49 Collaboration], *Phys. Rev.* **C78**, 044907 (2008).
[3] R. Aaij *et al.* [LHCb Collaboration], *Phys. Lett.* **B703**, 267 (2011).
[4] J. Beringer *et al.* [Particle Data Group], *Phys. Rev.* **D86**, 010001 (2012).