Vol. 40 (2009) ACTA PHYSICA POLONICA B No 4

UNICOR — EXPERIMENT INDEPENDENT HBT ANALYSIS*

D. Miśkowiec

GSI Helmholtzzentrum für Schwerionenforschung GmbH
Planckstr. 1, 64291 Darmstadt, Germany

(Received February 11, 2009)

I report on a two-particle analysis package in which the algorithmic part is strictly separated from the input data format such that it can be used to analyze data from different experiments. After introducing the analysis scheme and briefly discussing some aspects of the implementation I go through a collection of histograms obtained by running the package on data from three heavy-ion experiments.

PACS numbers: 25.75.Gz, 25.75.Ld

1. Introduction

The experimental femtoscopy results discussed in this workshop originate from analysis of two-particle correlation functions at low relative momenta [1]. A typical correlation analysis involves *(i)* looping over events, *(ii)* looping over track pairs within the event, *(iii)* calculating the momentum difference, *(iv)* filling the pair histogram at the bin corresponding to this difference, *(v)* repeating all the above but with a double loop over events and taking the two particles from different events (event mixing), and *(vi)* dividing the true pair distribution by the mixed one to get the correlation function. The analysis is typically performed on calibrated experimental data but may still require some experiment specific procedures (accessing the track momentum, ultimate determination of the particle id) and cuts (event- and track-quality, two-track separation). These parts, however, turn out to be about an order of magnitude less laborious (in terms of the number of lines of code) than the universal *i.e.* experiment independent ones like pairing, event mixing, kinematics, and histogramming. Obviously, the subsequent fitting or unfolding of the correlation functions and the analysis

* Presented at the IV Workshop on Particle Correlations and Femtoscopy, Kraków, Poland, September 11–14, 2008.

of the extracted correlation parameters are even less experiment dependent (with the single exception of the momentum resolution correction). A natural question arises whether the analysis software can be split into the experiment specific and the experiment independent pieces, such that the same correlation analysis can be run on various data sets by changing only the thin interface part. In addition to saving work and reducing programming errors this could facilitate comparison between the experiments and between data sets with differing formats within the same experiment.

In this (admittedly, very technical) paper I am presenting my attempt in this direction. The results seem promising. UNICOR can at present deal with data from CERES [2], ALICE [3], and CBM [4]; FOPI [5] is to be included in future. In Secs. 2 and 3 I present the implementation. Examples of the resulting histograms will be shown in Sec. 4. It should be mentioned that the idea of a thin interface to various data formats is similar to the one adopted by the United Generators project at GSI [6].

2. Analysis scheme

UNICOR is written in C++ and strongly based on the ROOT data analysis framework [7], commonly used in high energy physics experiments. The analysis scheme is shown in Fig. 1. Thin interfaces translate between the format of the stored data and the format expected by the analysis. Each interface is provided by a class inheriting from the event class with which the events were stored on one side and from the `DEvent` class on the other, the latter providing the link to the subsequent analysis which then proceeds independently of the data origin. The main functionality of the analysis consists in calculating and histogramming track pair variables;

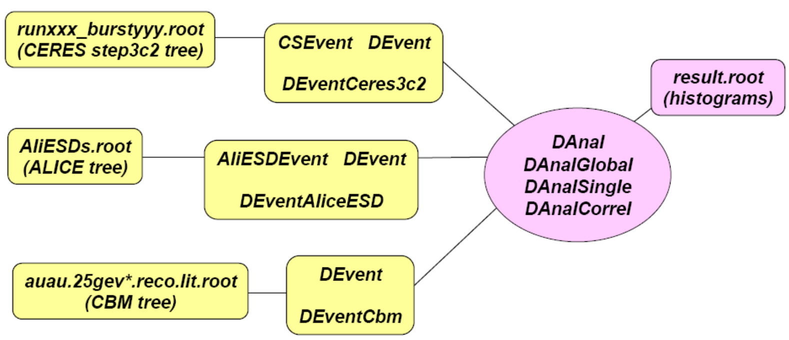

Fig. 1. Analysis scheme. Thin interfaces handle the specific data format of the CERES, ALICE, and CBM experiments. The subsequent correlation analysis is identical for all three experiments.

for better control, however, also some event and single track variables are being histogrammed. The only trace of the data source remains in the pseudorapidity range of the resulting histograms which was a pragmatic measure to reduce their size.

3. Multidimensional histograms

Multidimensional histograms are the second special feature of UNICOR. In a typical correlation analysis three-dimensional (three components of the momentum difference vector) correlation functions are produced for several pair-p_{t} and rapidity bins. Azimuthal analyses like the ones in Refs. [8–10] require, in addition, cuts on the emission angle. This results in a three-dimensional array of three-dimensional histograms, and the user has to keep track of the p_{t}, rapidity, and angle associated to each correlation function histogram. A six-dimensional histogram provides a much more elegant solution while requiring the same amount of memory. In the presented analysis actually two additional dimensions were used, one with three bins indicating the source of the pairs (true pairs, mixed pairs, and true pairs with one of the two particles rotated by 180$^{\mathrm{o}}$), and the other storing the collision centrality. In the limit of small bin size this histogram thus would contain the full information about the two-particle correlations. In practice, the computer memory limits the maximum number of bins of the multidimensional histogram. For some types of analysis a pair ntuple may be a better choice than a histogram.

The UNICOR multidimensional histogram class inherits from ROOT's one-dimensional histogram. The parent class provides functionality like mathematical operations *etc.* The multidimensional histograms should be, ideally, moved from UNICOR to ROOT, complementing its existing classes for one-, two-, and three-dimensional histograms.

4. Collection of results

In this section I am presenting histograms resulting from running UNICOR on the data from three experiments: minimum bias $\mathrm{Pb}+\mathrm{Au}$ collisions at 158 $A\,\mathrm{GeV}/c$ measured by CERES at CERN SPS, pp collisions at $\sqrt{s} = 10$ GeV simulated for ALICE at CERN LHC, and central $\mathrm{Au}+\mathrm{Au}$ at 25 $A\,\mathrm{GeV}/c$ simulated for CBM at the future SIS300 accelerator in Darmstadt. The particle identification and two-track resolution cuts are far from optimum and the sole purpose of this collection of figures is to demonstrate that one single analysis can be run on data collected by different experiments and at quite different energies and collision systems.

Fig. 2 shows the raw multiplicity, flow vector, and event vertex for the three experiments. The charged particle multiplicity in the CERES acceptance (top left) in this run has a shape typical for minimum bias nuclear collisions. The multiplicities in ALICE central barrel (top center) reach 150 and more even in *pp* collisions. The central gold–gold events in CBM are peaked around 700 charged particles. The raw flow vector distributions in CERES and ALICE are centered at the origin reflecting the azimuthal symmetry of their acceptance. This is not the case for CBM which uses a dipole magnet (middle right). The bottom row shows the longitudinal coordinate of the reconstructed event vertex, normalized such that useful events are contained in the range (−1,1). The CERES target consists of 13 disks

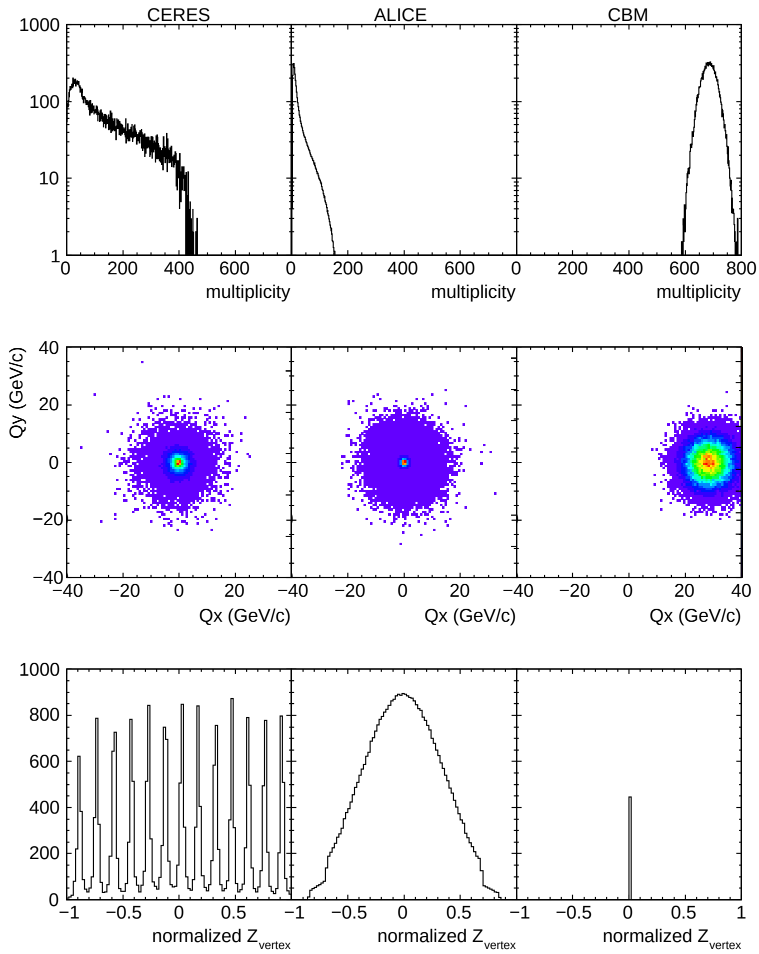

Fig. 2. Global observables: raw multiplicity (top), flow vector (middle), and the longitudinal position of the event vertex (bottom) for CERES, ALICE, and CBM (left, middle and right, respectively). Counts were scaled arbitrarily.

(bottom left); the LHC beam intersection results in a Gaussian distribution, and the ideal vertex simulation of CBM in a δ function (bottom center and right, respectively).

The pseudorapidity distributions of π^- for the three experiments are shown in Fig. 3. CERES and CBM are fixed target experiments and the midrapidity of the analyzed datasets is at 2.9 and 2.0, respectively. The central barrel of the ALICE experiment covers ± 0.9 pseudorapidity units around midrapidity; the nonuniformities visible in the figure are caused by the particular track quality and particle identification cuts applied in this analysis.

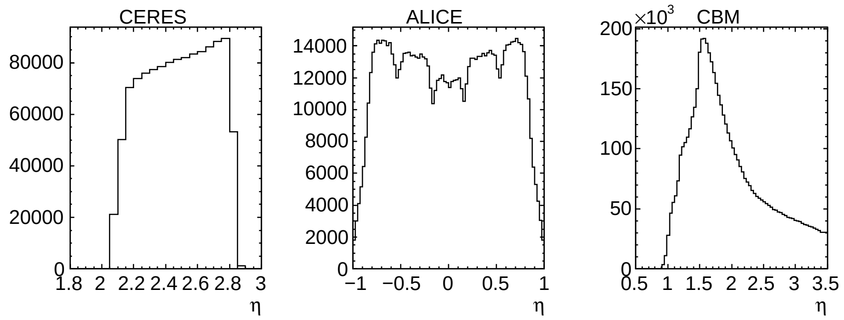

Fig. 3. Pseudorapidity distribution of the analyzed negative pions for CERES, ALICE, and CBM (from left to right).

Finally, correlation functions for negative pions are shown in Fig. 4. The CERES correlation function (left) was analyzed with a weak pion identification and without the two-track resolution cut; an enhancement originating from the Bose–Einstein quantum statistics is nevertheless clearly visible. The other two correlation functions are flat, as expected for simulated data.

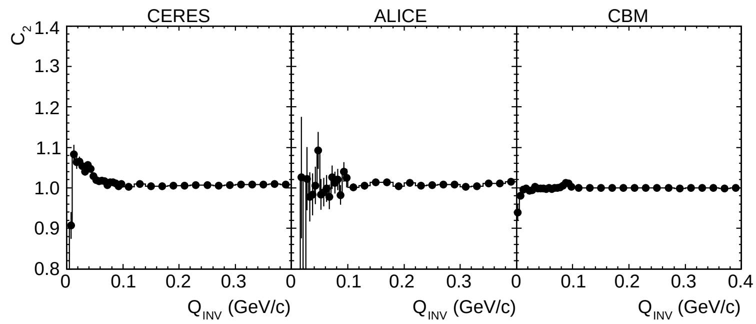

Fig. 4. Two-pion correlation function for π^- from CERES, ALICE, and CBM (from left to right). ALICE and CBM data are simulated and their C_2 should be flat.

The quality of the ALICE correlation function (center) suffers due to the wide two-track resolution cut and not yet optimized particle identification. Please note that while only one-dimensional projections are presented in Fig. 4 complete six-dimensional correlation functions are available as a multidimensional histogram. Whether the variables chosen for the axes and the bin sizes are sufficient to study *e.g.* the out-side-long [11] radii in a system other that the pair rest frame remains to be verified.

5. Summary

A universal two-particle correlation package was developed. The software allows to analyze various data sets without changing a single line in the algorithmic part of the analysis. Further refinement is planned, even if the package is not intended to compete with sophisticated analyses that are necessary *e.g.* to study exotic particles, and where the complete information of the experiment must be optimally used. The suitability of the package for analysis of pion pairs was demonstrated by running it on experimental and simulated data from CERES, ALICE, and CBM.

REFERENCES

[1] M.A. Lisa *et al.*, *Ann. Rev. Nucl. Part. Sci.* **55**, 357 (2005).

[2] `http://www.physi.uni-heidelberg.de/Forschung/kp/ceres/`

[3] `http://aliceinfo.cern.ch/`

[4] `http://www.gsi.de/fair/experiments/CBM/`

[5] `http://www-fopi.gsi.de/`

[6] `http://wiki.gsi.de/cgi-bin/view/Personalpages/UnitedGenerators`

[7] `http://root.cern.ch/`

[8] M.A. Lisa *et al.*, *Phys. Lett.* **B496**, 1 (2000).

[9] J. Adams *et al.*, *Phys. Rev. Lett.* **93**, 012301 (2004).

[10] D. Adamová *et al.*, *Phys.Rev.* **C78**, 064901 (2008).

[11] G.F. Bertsch, *Nucl. Phys.* **A498**, 173c (1989); S. Pratt, *Phys. Rev.* **D33**, 1314 (1986).