THE NA61/SHINE EXPERIMENT AT THE CERN SPS*

Emil Kaptur

for the NA61/SHINE Collaboration

Institute of Physics, University of Silesia
Uniwersytecka 4, 40-007 Katowice, Poland

(Received December 13, 2013)

The aim of the NA61/SHINE ion programme is to explore the QCD phase diagram within the range of thermodynamical variables accessible by the SPS. In addition, the experiment provides precision hadron production measurements for description of the neutrino beam of the T2K experiment at J-PARC and for simulation of cosmic-ray showers for the Pierre Auger Observatory, KASCADE-Grande and KASCADE experiments. The main physics goals of the NA61/SHINE ion programme are the study of the properties of the onset of deconfinement and the search for signatures of the critical point of strongly interacting matter. These goals are pursued by performing an energy (beam momentum $13\,A$–$158\,A\,\mathrm{GeV}/c$) and system size ($p+p$, p+Pb, Be+Be, Ar+Ca, Xe+La) scan. The architecture and performance of the detector will be discussed. Moreover, an overview of the recent NA61/SHINE status, results and plans will be presented.

DOI:10.5506/APhysPolB.45.457
PACS numbers: 25.75.Ag, 25.75.Dw

1. Physics programme

The NA61/SHINE [1] experiment collects data with various types of beams — from secondary hadron beams (p at 13–158 GeV/c, π^- at 158 and 350 GeV/c, K^- at 158 GeV/c) to ion beams (secondary Be and primary Ar and Xe at $13\,A$–$150\,A\,\mathrm{GeV}/c$).

The NA61/SHINE programme covers:

- Search for the critical point and study of the properties of the onset of deconfinement through spectra, fluctuations and correlations analysis in light and heavy ion collisions.
- Study of high p_T particle production.

* Presented at the XXXIII Mazurian Lakes Conference on Physics, Piaski, Poland, September 1–7, 2013.

- Precision measurements of particle production for improvements in ν beam simulations at J-PARC for the T2K experiment, and improvements in air shower simulations for the Pierre-Auger and KASCADE cosmic-ray experiments.

The current status of data taking of the NA61/SHINE is presented in Fig. 1.

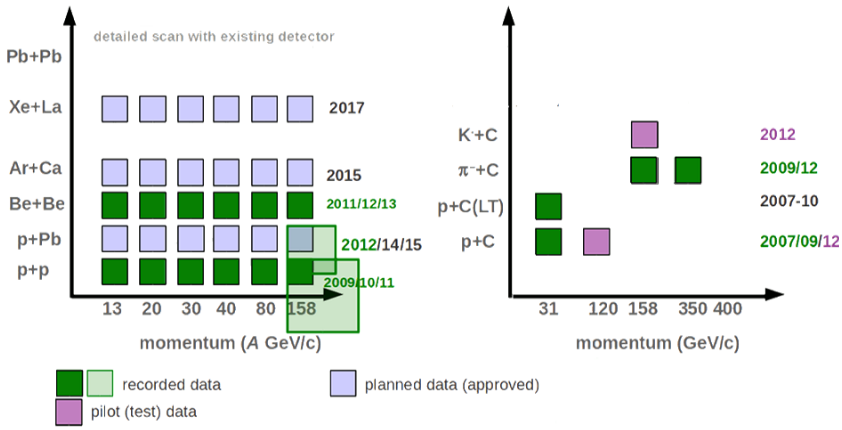

Fig. 1. Status of the NA61/SHINE data taking within heavy ion programme (left) as well as the neutrino and cosmic-ray programmes (right).

2. Detector

NA61/SHINE is a fixed target experiment in North Area of SPS. Figure 2 shows the experimental set-up.

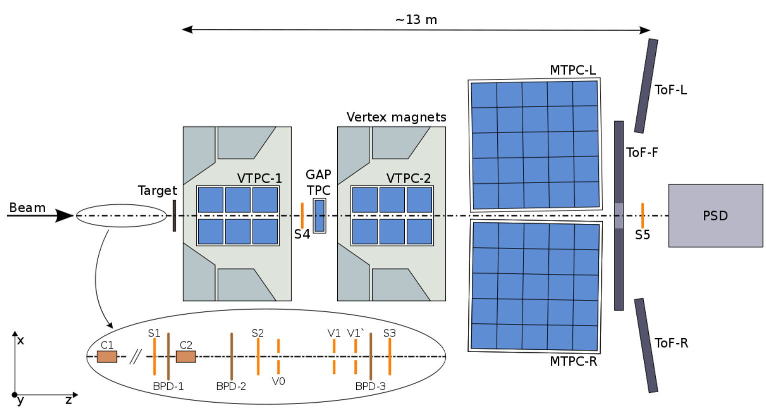

Fig. 2. The NA61/SHINE detector set-up.

The main tracking and particle identification (via the specific energy loss) detectors are five Time Projection Chambers (TPCs). Two of them, named Vertex TPCs (VTPCs), are placed in the magnetic field of superconducting magnets allowing for momentum determination with resolution up to $\sigma(p)/p^2 \approx 10^{-4}\,(\mathrm{GeV}/c)^{-1}$. Additional two Main TPCs (MTPCs) are placed downstream of the magnets and symmetric to the beam line. The last one Gap TPC is placed between the magnets and used to track the particles going forward.

The TPCs are complemented with three Time-of-Flight (ToF) detectors to aid in particle identification at low particle momenta.

For ion beams, Projectile Spectator Detector is used as a high resolution centrality detector.

Additionally, a wide array of beam detectors allows for precise beam identification and position measurements.

3. Selected results from inelastic $p + p$ collisions

3.1. Analysis methods

The presented results show inclusive spectra of identified hadrons produced in inelastic $p + p$ interactions at 20, 31, 40, 80, 158 GeV/c. Two analysis methods were used:

- for π^- spectra the h^- method [2, 3], which is based on fact that the majority of negatively charged particles are π^- mesons. The contribution of other particles is subtracted using simulations based on the EPOS model;
- for all hadrons the specific energy loss (the dE/dx method), which uses the energy loss in the TPC gas to identify particles. In each bin of p, p_{T} and charge, a sum of Gauss functions is fitted to the dE/dx spectrum. For each track its Likelihood value for being a given hadron is calculated based on the fitted dE/dx distribution.

The results are corrected for particles from weak decays (feed-down) and detector effects using Monte Carlo models. Out of target interactions are subtracted using events recorded with empty liquid hydrogen target.

3.2. y–p_{T} particle spectra

Thanks to the high acceptance of the NA61/SHINE detector ($\approx 50\%$), double differential spectra of identified particles in the large phase-space domain are measured. Figure 3 shows double differential spectra of pions, negative kaons and protons at 158 GeV/c. An ongoing ToF identification will provide supplementary information at low transverse momentum and mid-rapidity.

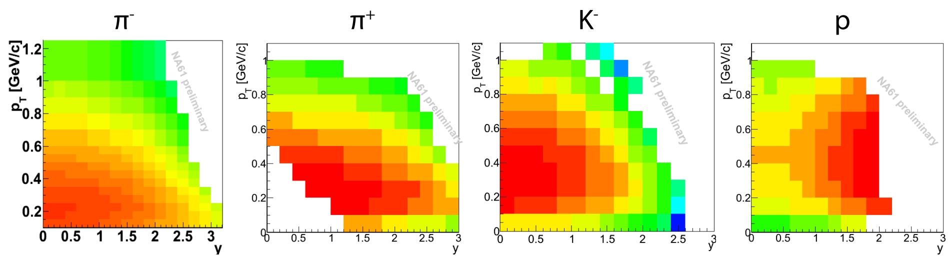

Fig. 3. h^- (π^-) and dE/dx (π^+, K^-, p) identified particle spectra at 158 A GeV/c.

3.3. Study of the onset of deconfinement

Study of inelastic $p+p$ interactions provides important reference data to the study of the onset of deconfinement [4].

The inverse slope parameter T of the transverse mass spectra shows different behaviour in central Pb+Pb [5] ("step") than in $p+p$ (smooth increase) interactions (Fig. 4).

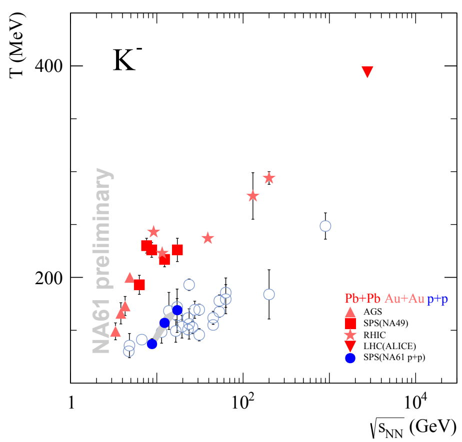

Fig. 4. Inverse slope parameter of m_{T} spectra in Pb+Pb and $p+p$ collisions. The NA61/SHINE data provide reference to the data from heavy ion collisions.

Increase of the internal degrees of freedom in NA49 Pb+Pb interactions [5] is visible in pion multiplicity as a "kink" structure, while in $p+p$ the structure is not visible (Fig. 5).

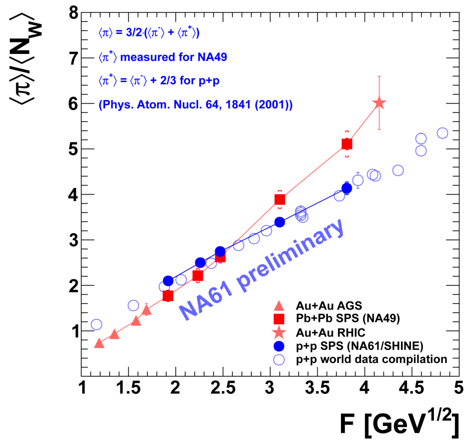

Fig. 5. Mean pion multiplicity per wounded nucleon in central Pb+Pb and $p+p$ collisions. The NA61/SHINE points (full/blue) agree very well with the world data (empty/blue). The NA61/SHINE data will provide reference to the rest of the NA61/SHINE ion programme. The data is plotted in function of the Fermi's energy measure $F = \left[\frac{(\sqrt{s_{NN}}-2m_N)^3}{\sqrt{s_{NN}}}\right]^{1/4}$.

4. Summary

A selection of NA61/SHINE results, concentrated on the $p+p$ interactions and their comparison with central Pb+Pb collisions, was presented.

The NA61/SHINE data on $p+p$ interactions provide reference for the further study of the onset of deconfinement and search for the critical point. The mean multiplicity of π^- per wounded nucleon increases slower with energy in $p+p$ than in central Pb+Pb collisions (“kink”). The two dependencies cross at about 40 A GeV/c.

REFERENCES

[1] `https://na61.web.cern.ch/na61/xc/index.html`

[2] A. Aduszkiewicz, Ph.D. Thesis, in preparation.

[3] NA61/SHINE Collaboration, `arXiv:1310.2417 [hep-ex]`.

[4] M. Gazdzicki, M. Gorenstein, *Acta Phys. Pol. B* **30**, 2705 (1999).

[5] S.V. Afanasiev *et al.* [NA49 Collaboration], *Phys. Rev.* **C66**, 054902 (2002).