News from NA61/SHINE
Strong Interactions Programme

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Abstract

The experimental research of **Heavy Ion Collisions** is an invaluable contribution to the investigation of the QCD theory. The **NA61/SHINE** aims to provide the information about conditions of matter in the vicinity of predicted **critical end point** and **the onset of deconfinement**. This is performed by a comprehensive two-dimensional scan of **energy and system size** dependence of following measurements: particle spectra, yields and fluctuations.
The experimental data on particle kinematics of **p+p** and ion collisions: **Be+Be**, **Ar+Sc**, **Xe+La** and **Pb+Pb** delivers new information on the suspected onset of deconfinement. New measurements are added to the famous plots of **kink**, **horn** and **step** – (vaguely) corresponding to: **entropy production**, **strangeness to entropy ratio** and **temperature respectively**.
The NA61 experiment searches for **the critical end point** studying the **strongly intensive measures** of fluctuations of transverse momentum, multiplicity or intermittency. Despite promising results delivered by the NA49 [1], the NA61/SHINE does not register the predicted **hill of fluctuations**.

Strong interactions at SPS

The main goal of the NA61/SHINE research programme is to probe the QCD phase diagram of temperature and baryo-chemical potential (T, μ_B) and search for the indications of phase transitions: **the onset of deconfinement** and **the critical point** of the strongly interacting matter. Appearance of both phenomena is expected in the SPS energy range [2, 3].
The analysis of the ion collisions data provides the key information on system size and energy dependence of hadron production. Moreover, obtained mean multiplicities allow to extract (fit) **chemical freeze out parameters** in ion collisions at SPS energies, extending the set of measured points in the QCD phase diagram.

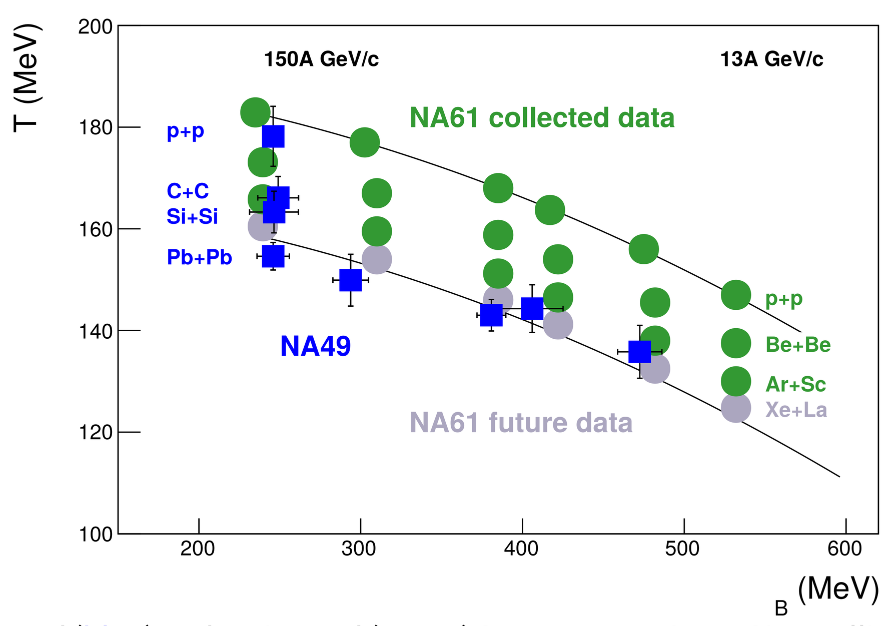

Figure 1: Measured (blue) and estimated (green) freeze-out points of ion collisions at NA61/SHINE.

The Search for Critical Point

The strategy of looking for **the critical point** (CP) of strongly interacting matter is based on the search for a non-monotonic behavior of CP signatures such as **fluctuations of transverse momentum, multiplicity, intermittency**, etc. when the system freezes out close to the CP. NA61/SHINE uses the strongly intensive measures of $\Delta[p_T, n]$, $\Sigma[p_T, n]$ and Φ_{p_T} to study transverse momentum and multiplicity fluctuations [4, 5]. In the Grand Canonical Ensemble these values do not depend on volume and volume fluctuations. Moreover, $\Delta[p_T, n]$ and $\Sigma[p_T, n]$ have two reference values: **equal to zero** in case of no fluctuations and **equal to one** in case of independent particle production. The recent NA61/SHINE results [5] show no sign of any anomaly, that can be attributed to the CP, neither in p+p, nor centrality selected Be+Be collisions.
On the other hand a maximum for Si+Si and C+C was observed by NA49 in transverse momentum and multiplicity fluctuations at 158A GeV/c (see Refs. [5, 1] and references therein).

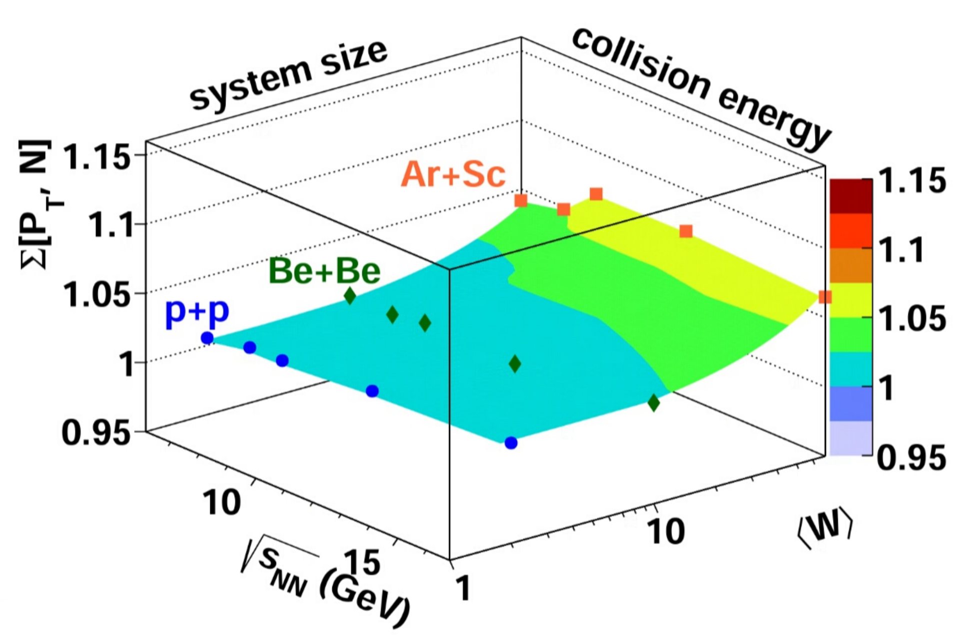

Figure 2: The fluctuations measures from N61/SHINE with the newest preliminary results form Ar+Sc interactions.

Acknowledgments

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The Search for the Phase Transition

The properties of the suspected phase transition are studied by looking for the following properties of identified hadron production [6]:

Kink – The majority of the particles produced in high energy interactions are **pions**, thus being the main **carriers of the entropy** created in the ion collisions. The entropy, on the other hand, should depend on the state of matter present at the early stage of collisions. **Deconfined matter** is expected to lead to a final state with **higher entropy** than that created by **confined matter**. Therefore an **enhancement of pion production** is expected as a signal of the onset of production of deconfined matter.

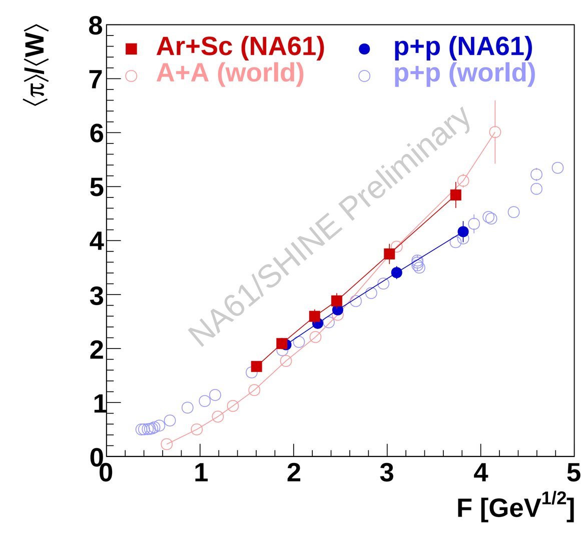

Figure 3: "The kink" in mean pion production.

Recently published preliminary data of **Ar+Sc** shows an interesting, two-fold trends – in lower beam energies Ar+Sc **follows p+p tendency**, while for higher beam energies it **behaves exactly like heavy ions (Pb+Pb)**.

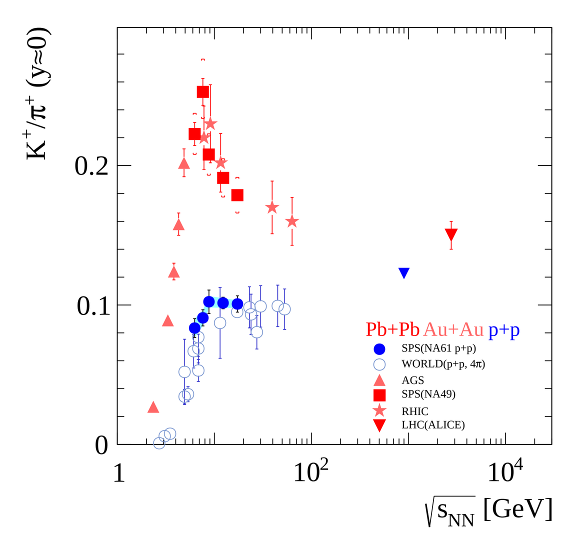

Figure 4: "The horn" in mean kaon production.

Horn – **The strangeness to entropy ratio** increases at low (AGS-SPS) energy region due to the fact that the mass of the strange degrees of freedom is significantly higher than the system temperature. As the fireball temperature reaches $T \approx T_C$ we suspect a **mixture of confined and deconfined states** [7] and therefore a constant decrease of the ratio to the level characteristic for the deconfined state in higher energies (RHIC-LHC). The most pronounced effect of this phenomenon is visible in $\langle K^+ \rangle / \langle \pi^+ \rangle$ ratio.

The NA61's results on p+p collisions show non-monotonic behavior, suggesting qualitative similarity to collisions of heavy ions [8]. There are other studies [9] suggesting a phase transition in case of proton collision. All together it might lead to a change of paradigm of qualitative difference of p+p and heavy ion collisions.

Step – The energy density at the early stage increases with increasing collision energy. At the energies where we expect pure confined or deconfined state to be produced, this leads to an increase of the initial temperature and pressure. As an effect, an **increase of the transverse expansion of matter** is expected. In the mixed phase however, it is claimed [7] that **the temperature and pressure stays approximately constant**. Therefore the slope of the transverse mass spectra should remain stable in the phase transition region.

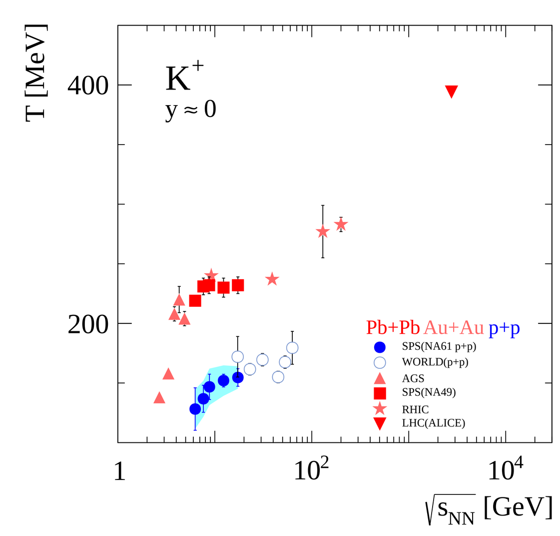

Figure 5: "The step" in inverse slope parameter of transverse mass spectra.

Conclusions

- Signatures described here are in agreement with models considering **the onset of deconfinement** in the SPS energy range.
  On the other hand they are also explainable within other models [10] – therefore are not sufficient source to discriminate **non phase-transition models**.
- There are **no signatures of an enhancement** of strongly intensive measures in the ion collisions the SPS energy range. We await the results from more massive ions – **Xe+La** and **Pb+Pb** – and other experiments operating in lower beam energies and higher baryon densities (NICA).

References

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