Electromagnetic effects on charged pion spectra at SPS energies



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Outline

- Introduction to EM effects.
- NA61/SHINE experiment.
 - Data sets, centrality.
- Data analysis and results on Ar+Sc collisions.
 - Pb+Pb collisions.
 - Conclusions.





Introduction

Heavy ion collisions at SPS energies



- Charged spectators generate electromagnetic fields.
- These modify charged pion spectra in the final state.
- We use this effect as a new source of information on the **space-time evolution of the system**.

NA61/SHINE experiment



3D Visualization Ar+Sc collision NA61/SHINE http://shine3d.web.cern.ch/shine3d/



Performance

- Total acceptance ~ 80%.
- Momentum resolution $\sigma(p)/p^2 \sim 10^{-4} \text{ GeV}^{-1}$
- Track reconstruction efficiency > 95%.

NA61/SHINE experiment



This is just a beginning!

Data taking schedule:

taken data (green), approved for 2018 (<mark>red</mark>), proposed extension (gray).



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Data sets, centrality

• NA61/SHINE experiment, ⁴⁰Ar + ⁴⁵Sc @ 150A GeV/c.

Pb + Pb @ 30A GeV/c.

• Reference: NA49 experiment, Pb + Pb @ 158A GeV/c.

A. Rybicki, Acta. Phys. Polon. B42 (2011) 867.



- Centrality selection is defined by the Projectile Spectator Detector (PSD):
 - \rightarrow Forward rapidity calorimeter.
- Dedicated Glauber simulations.

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Data analysis: Ar+Sc @ 150A GeV/c

• Simple PID, done with cuts on dE/dx of ±5% from pion Bethe-Bloch.



Data analysis: Ar+Sc @ 150A GeV/c



 Stability of π⁺/π⁻ ratios has been investigated in detail.

 $\rightarrow \pi^+/\pi^-$ ratios appear far more robust than π^+ or π^- spectra taken separately.

- Systematic biases estimated on the level of ±0.06.
- This includes:
 - \rightarrow kaon contamination,
 - \rightarrow pion Bethe-Bloch precision,
 - \rightarrow feed-down from weak decays.

*Note: centrality is estimated by the total number of wounded nucleons and the Ar spectator mass.



Data analysis: Ar+Sc @ 150A GeV/c





• NOTE: the strongest EM effects for the beam rapidity and at low p_{T} .

- New data on spectator-induced EM effects on charged pion spectra in Ar+Sc collisions at 150A GeV/c.
- \rightarrow **First observation** of such an effect in Ar+Sc collisions.
- \rightarrow First observation of spectator-induced EM effects in small systems at SPS.

Ar+Sc compared to Pb+Pb



- The following picture emerges:
 - → Peripheral Pb+Pb collisions (spectator charge \approx 70 e.u.) **large** effect, $\pi^+/\pi^- \approx 0$.
 - → Intermediate Ar+Sc collisions (spectator charge ≈ 8 e.u) visible effect, breaks isospin symmetry.
 - → Central Ar+Sc collisions (spectator charge ≈ 3 e.u.) still visible shadow of effect.

Ar+Sc @ 150A GeV/c: MC simulation





• ⁴⁰Ar: parametrization of experimental data (Fourier-Bessel).

• ⁴⁵Sc: Saxon-Woods.

Includes radial expansion of the spectator system with given surface velocity (see Iwona Sputowska talk)



Ar+Sc data compared to MC simulation



- MC simulation done by Vitalii Ozvenchuk (IFJ PAN).
- Our data bring new information on the space-time evolution of π production in Ar+Sc collisions $\rightarrow d_{\rm E}$.
- Stable spectator cannot describe data: significant expansion velocity $\rightarrow \beta$.



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Space-time evolution of the system...

Original information: A. Rybicki, X WPCF, 2015 Slide from: I. Sputowska, XIII WPCF, 2018



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First insight into EM effects in Pb+Pb collisions from NA61/SHINE (?)



Conclusions

- New data on spectator-induced EM effects in Ar+Sc collisions from NA61/SHINE were presented.
- First observation of these effects in small systems at SPS energies.
- Electromagnetic effects brings us new information on space-time evolution of the Ar+Sc system, especially on that of charged π meson production.
- A **first comparison of pion emission distances** from the spectator system has been made between Ar+Sc and the Pb+Pb collisions.
- Significant **expansion velocity of the Ar spectator system** is needed to explain the data.
- EM effects in Ar+Sc can improve our knowledge on the **pion emission** source, complementary to the presently restarted HBT analysis in NA61/SHINE (see Barnabas Porfy talk).

Electromagnetic effects on charged pion spectra at SPS energies



Thanks for your attention! **S**



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Extra slides

Ar+Sc data compared to MC simulation





Electromagnetic effects

• EM effects influence the emission of π mesons, namely modify the ratio of π^+/π^- .

• Dependence on p_T.

- Visible as a drop of π^+/π^- ratio at low p_{τ} and pion velocity close to spectator velocity.
- A.Rybicki and A.Szczurek Phys. Rev. C75, 054903 (2007).

Centrality based on PSD energy



 $E_{F} \rightarrow$ sum of PSD energies for modules 1-16, 21, 22, 27, 28.

- "Central" from T2 trigger \rightarrow 146k events, 1000 < E_F < 1800 [GeV/c].
- "Intermediate" from T2 trigger \rightarrow 138k events, 2800 < E_r < 3100 [GeV/c].

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Trigger influence

- T2 trigger eliminates many events in this region,
 - \rightarrow shifts a bit mean centrality **but** does not change π^+/π^- ratio.
 - → small shift of mean centrality has weak effect on EM. (A. Rybicki, A. Szczurek)

