Electromagnetic effects on charged pion spectra at SPS energies

Mirosław Kiełbowicz
for the NA61/SHINE collaboration

H. Niewodniczański Institute of Nuclear Physics
Polish Academy of Sciences

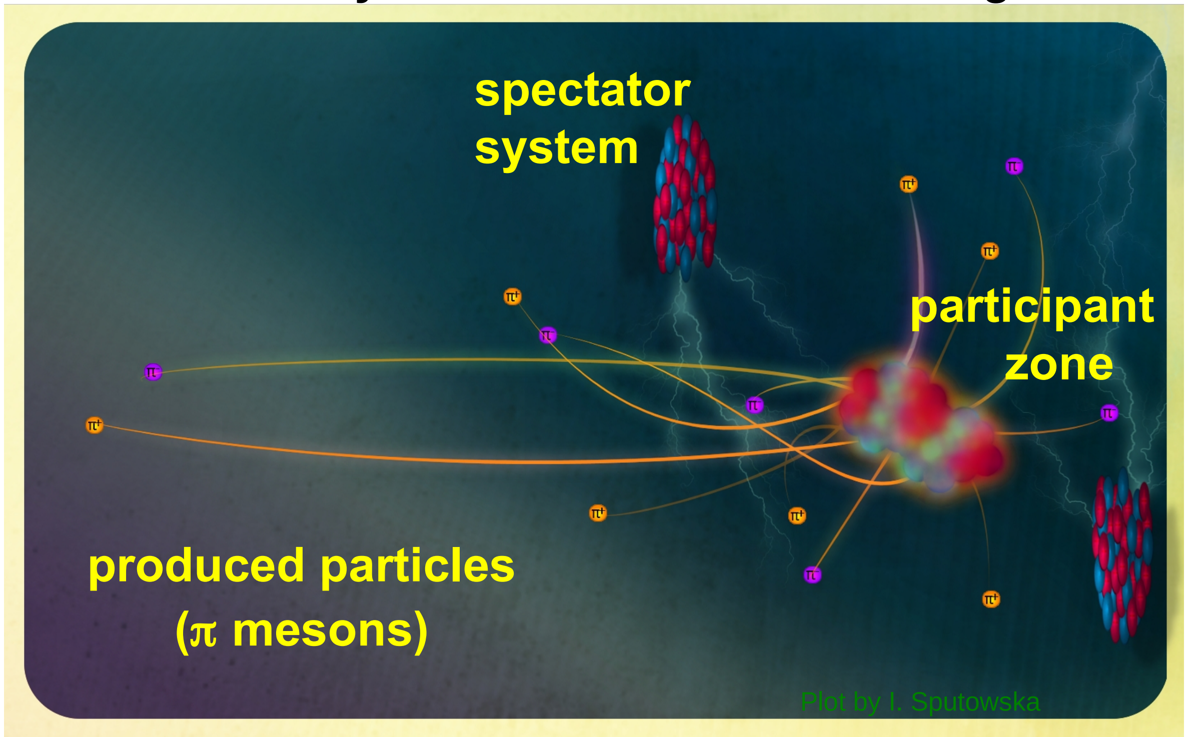
kielbowicz.miroslaw@gmail.com

Outline

- Introduction.
- The NA61/SHINE experiment.
- Results on EM effects.
- Monte Carlo simulation.
- 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**.

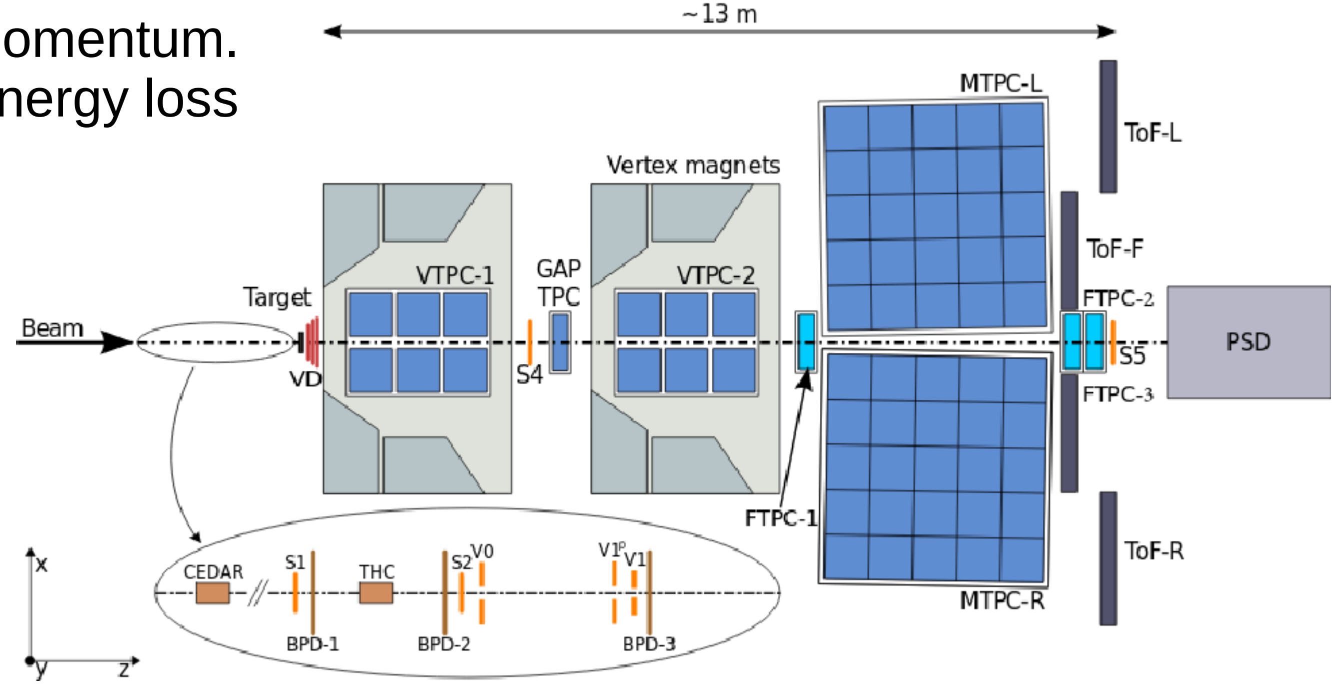
NA61/SHINE experiment

Eight (!) TPCs → particle tracks in 3D

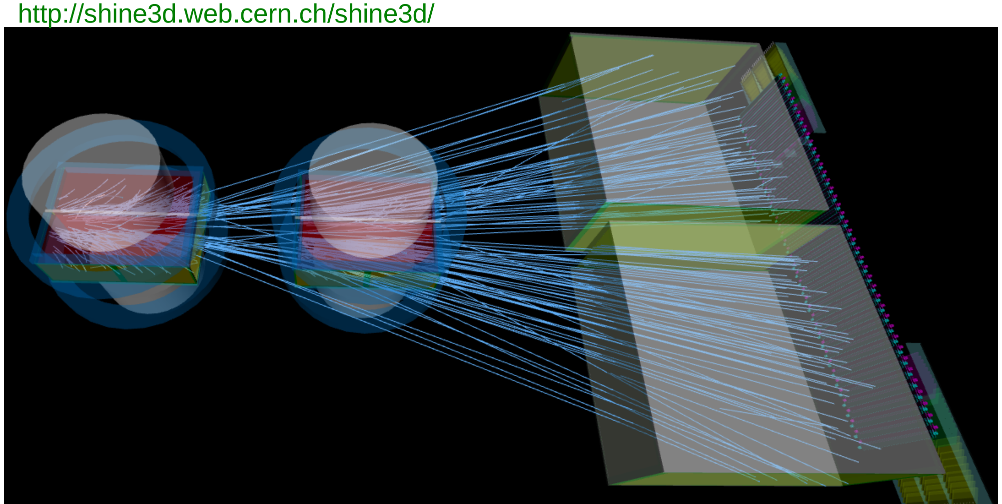
- Curvature → charge and momentum.
- Particle identification via Energy loss (dE/dx).

PSD → centrality of the collision.

Many different projectile-target configurations.



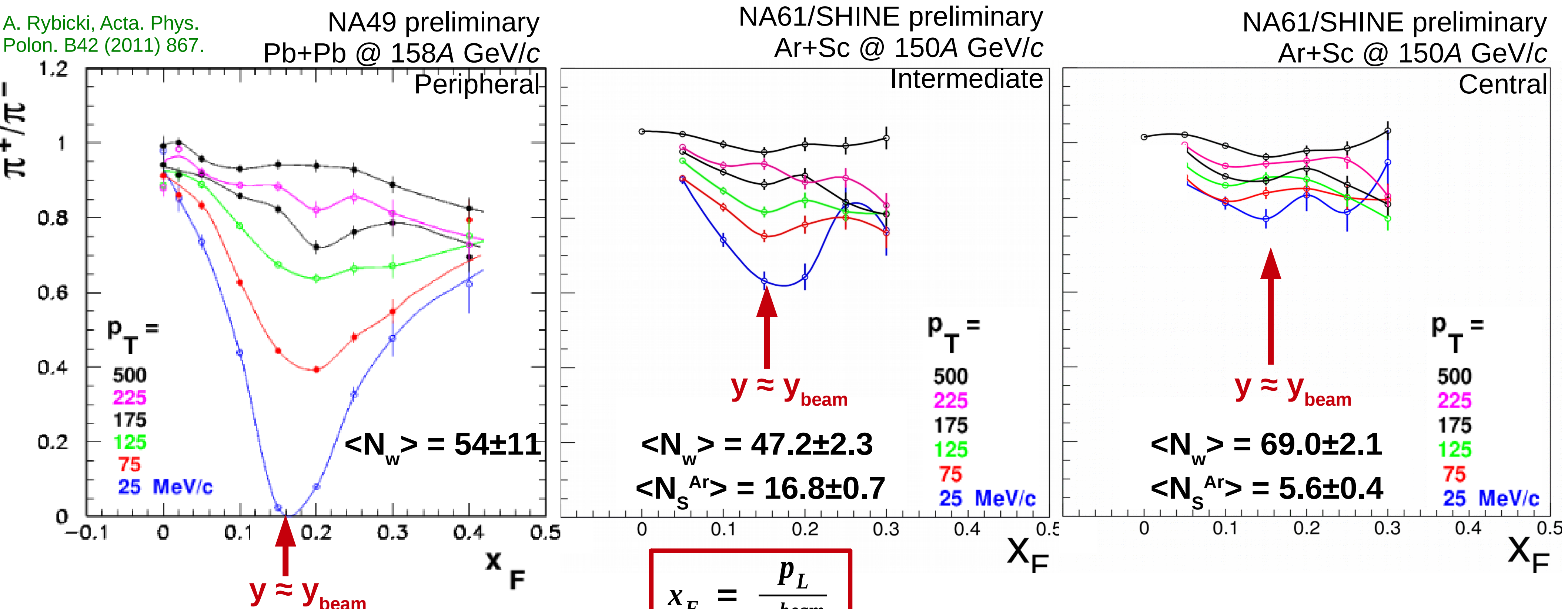
3D Visualization Ar+Sc collision NA61/SHINE
http://shine3d.web.cern.ch/shine3d/



Performance

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

Electromagnetic effects in Ar+Sc collsions



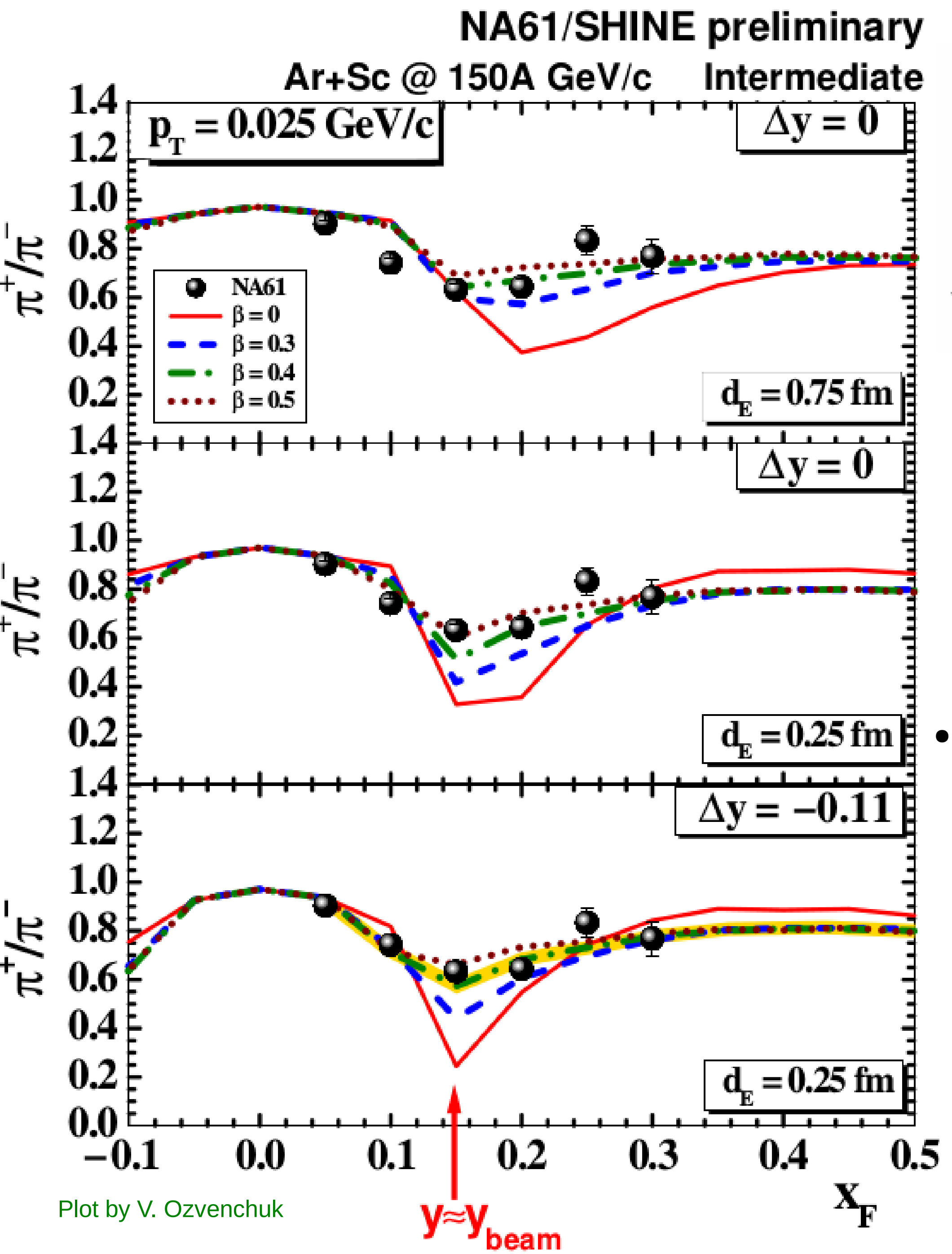
$\boxed{x_F = \frac{p_L}{p_L^{beam}}}$ c.m.s.

$\langle N_w \rangle$ - number of wounded nucleons.

$\langle N_S^{Ar} \rangle$ - number of Ar spectator nucleons.

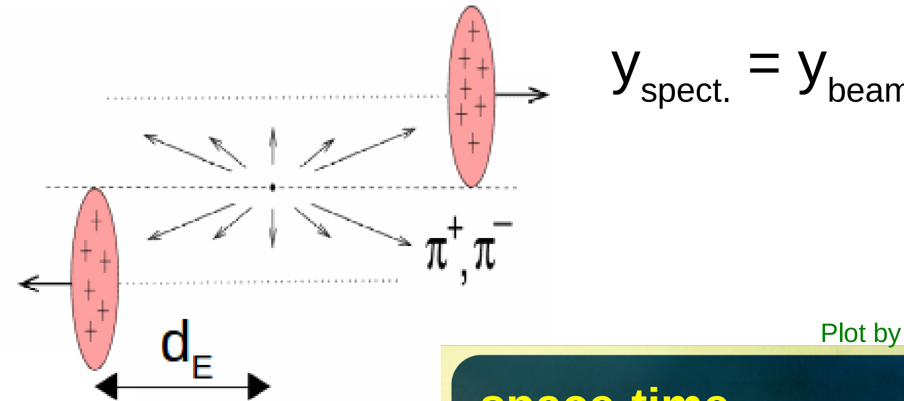
- The following picture emerges:
  - → Peripheral Pb+Pb collisions (spectator charge ≈ 70) - **large** effect, $\pi^+/\pi^- \approx 0$.
  - → Intermediate Ar+Sc collisions (spectator charge ≈ 8) - **visible** effect, breaks isospin symmetry.
  - → Central Ar+Sc collisions (spectator charge ≈ 3) - **possible**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

Ar+Sc data compared to MC simulation

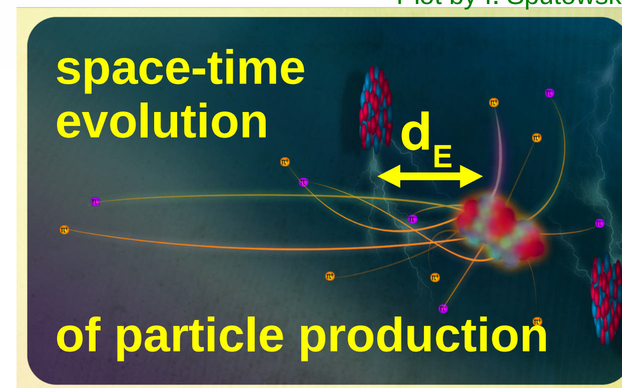


Plot by V. Ozvenchuk

A. Rybicki, A. Szczurek, Phys. Rev. C75, 054903 (2007)

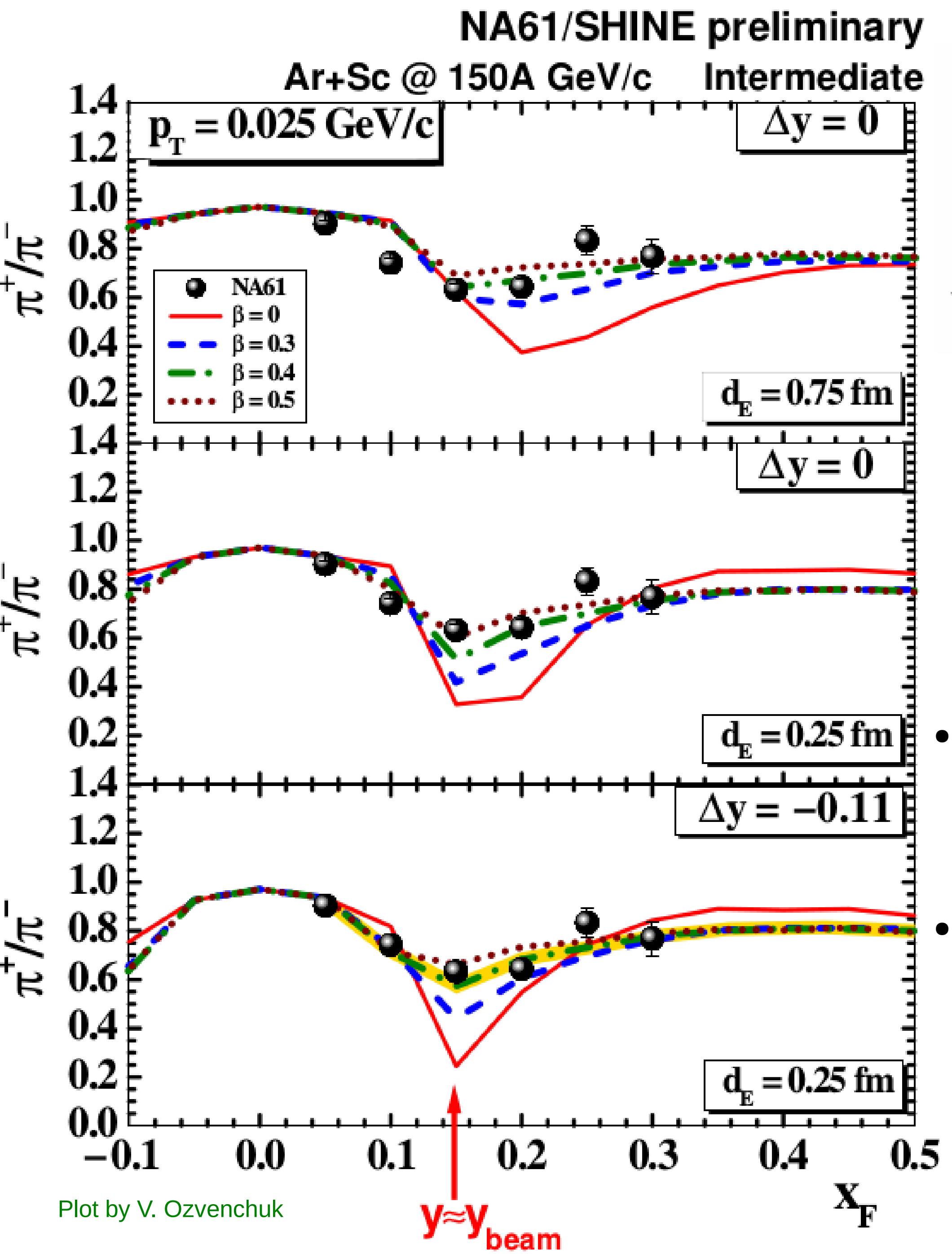


Plot by I. Sputowska



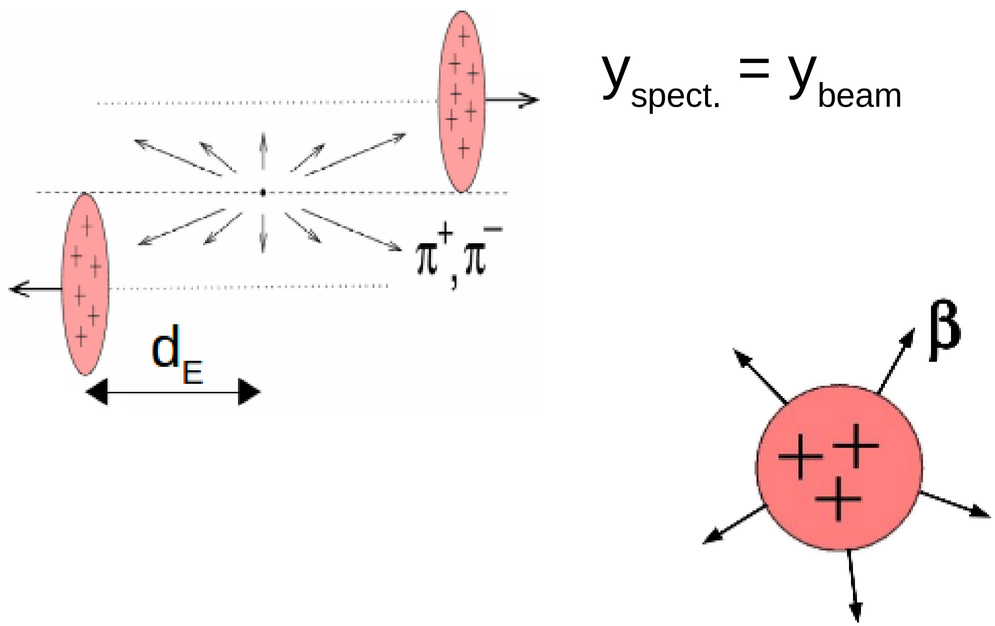
- Stable spectator cannot describe the experimental data.
  (Contrary to Pb+Pb, A. Rybicki et al., APPB 46,737 (2015)).

Ar+Sc data compared to MC simulation



Plot by V. Ozvenchuk

A. Rybicki, A. Szczurek, Phys. Rev. C75, 054903 (2007)



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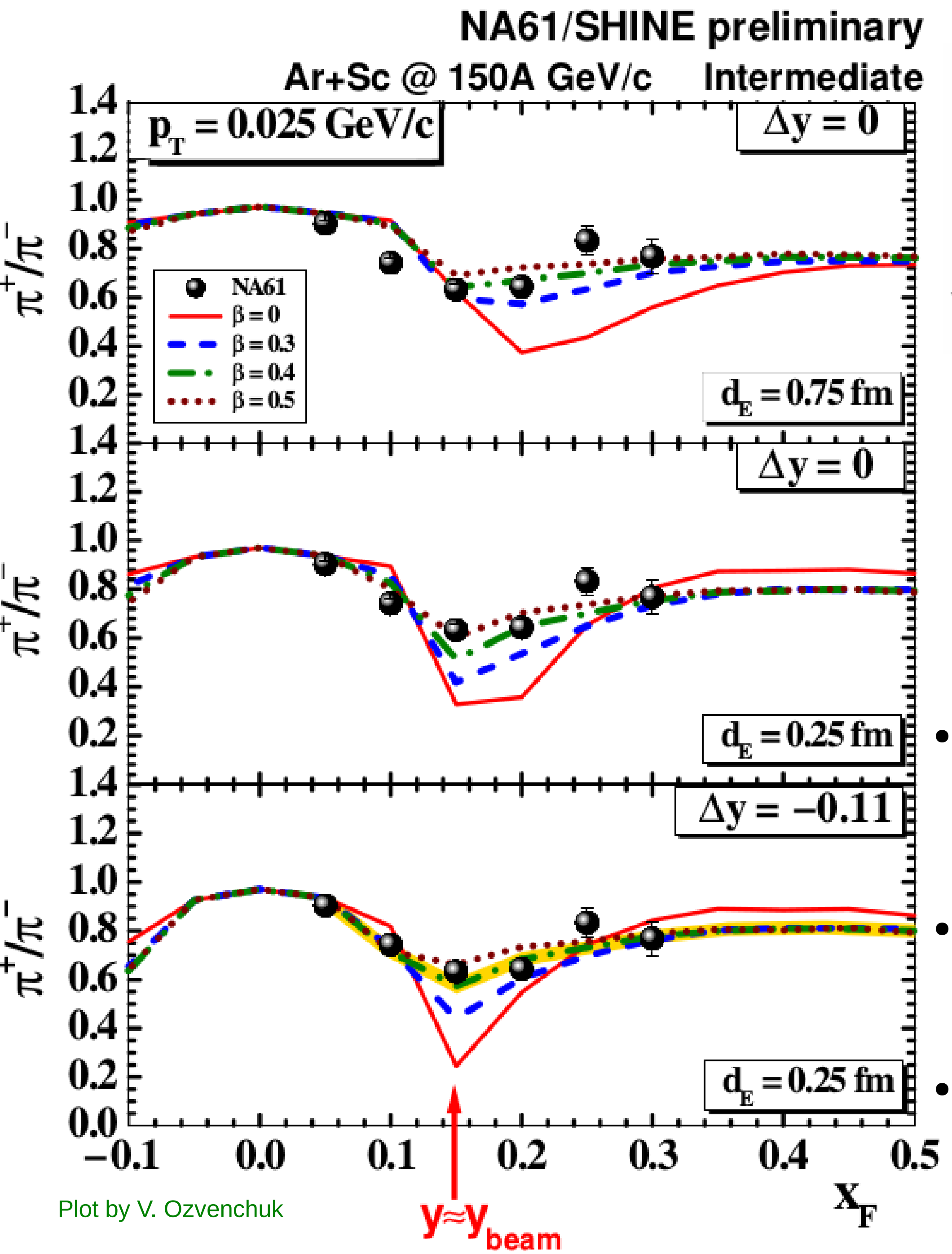
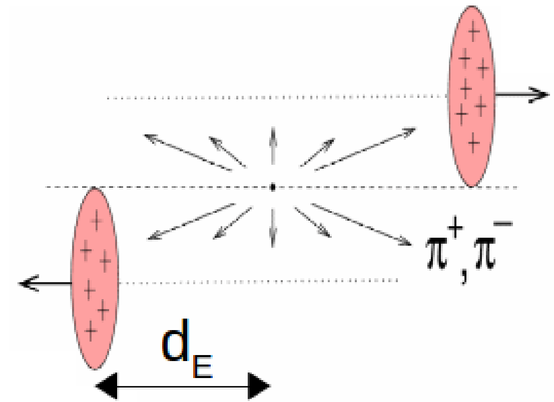
  (Contrary to Pb+Pb, A. Rybicki et al., APPB 46,737 (2015)).
- One needs significant expansion velocity **β** of the charge cloud.

Ar+Sc data compared to MC simulation



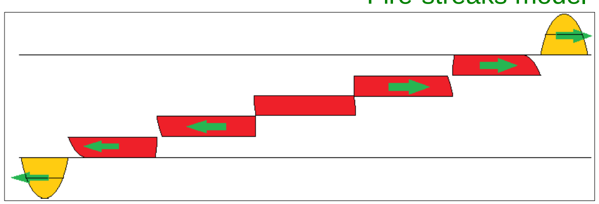
Plot by V. Ozvenchuk

A. Rybicki, A. Szczurek, Phys. Rev. C75, 054903 (2007)



$y_{spect.} = y_{beam} + \Delta y$

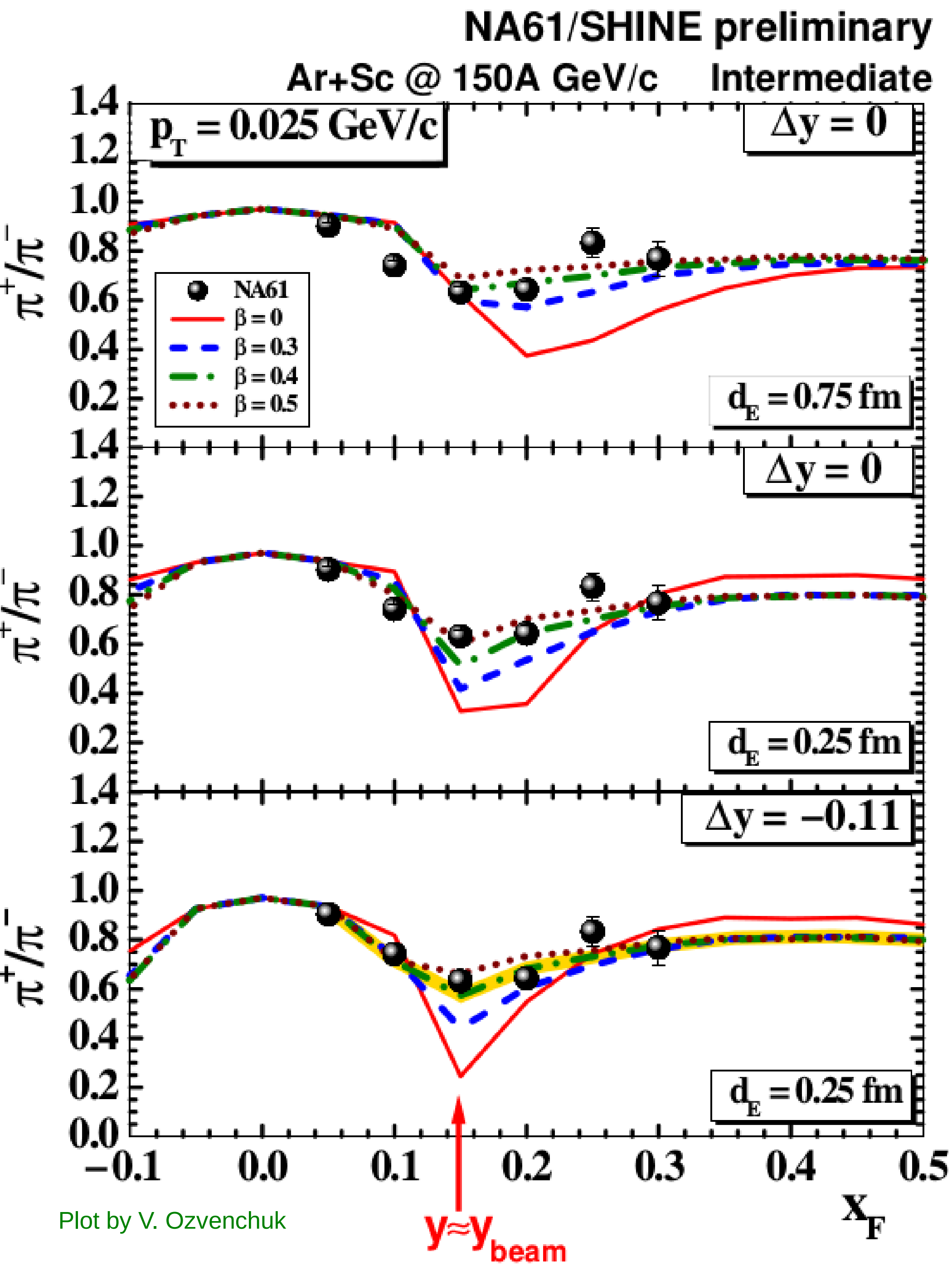
Fire-streaks model



→ see Andrzej Rybicki talk.

- Stable spectator cannot describe the experimental data.
(Contrary to Pb+Pb, A. Rybicki et al., APPB 46,737 (2015)).
- One needs significant expansion velocity **β** of the charge cloud.
- Optimal description: charge cloud moves **slower** than spectator system → presence of participant charge?

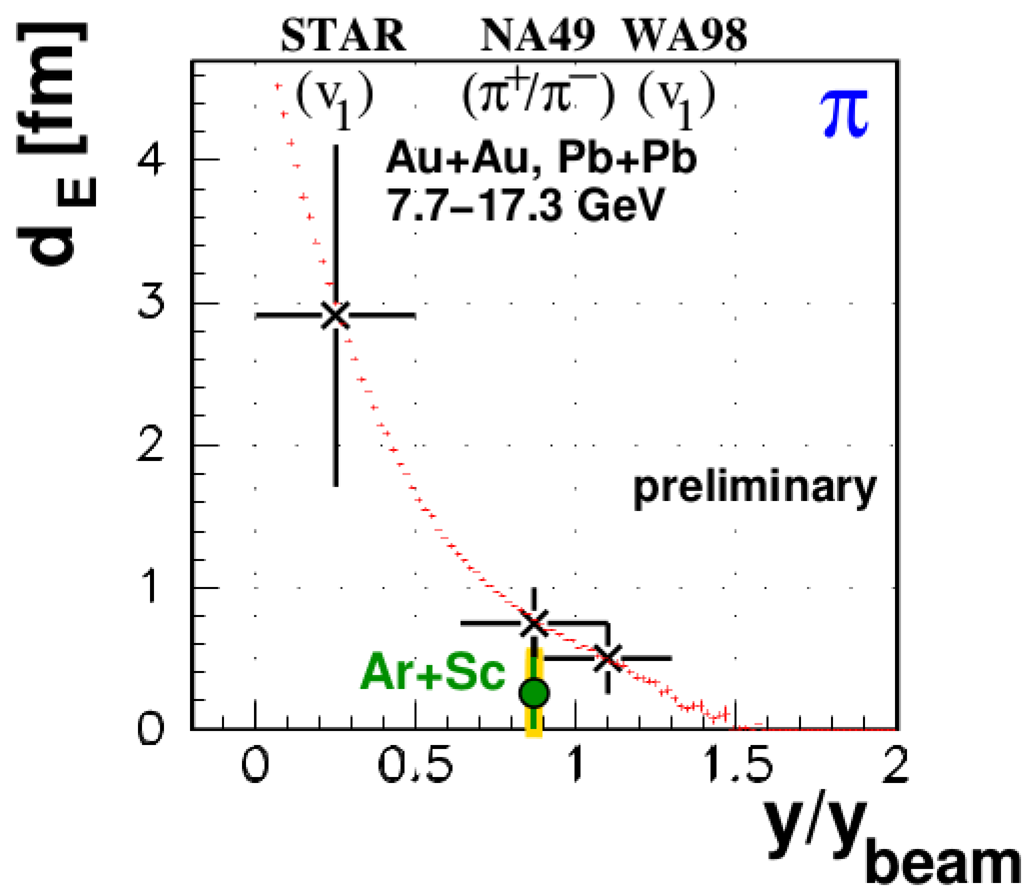
Ar+Sc data compared to MC simulation



- New information on the space-time evolution of **π** production in Ar+Sc:

$d_E = (0.25 \pm 0.25)$ fm

(preliminary)



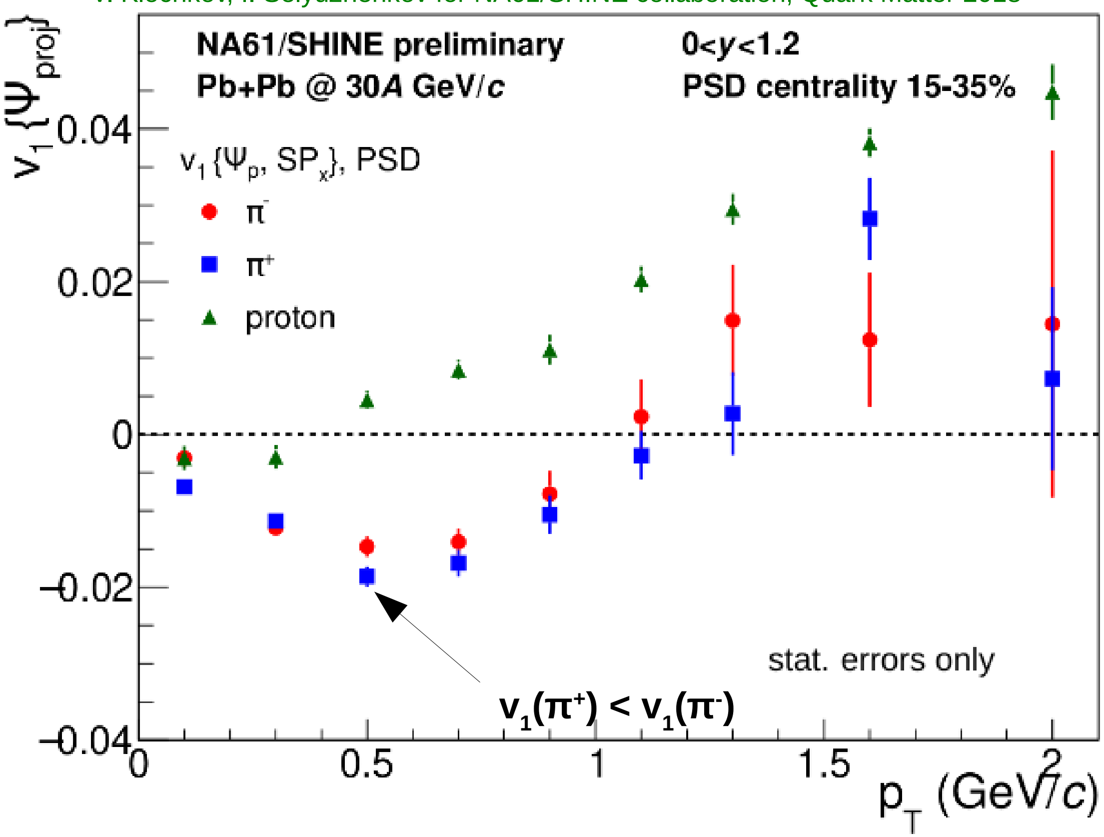
First insight into EM effects in Pb+Pb collisions from NA61/SHINE

- Difference between π^+ and π^- in v_1 is sensitive to the EM effects.

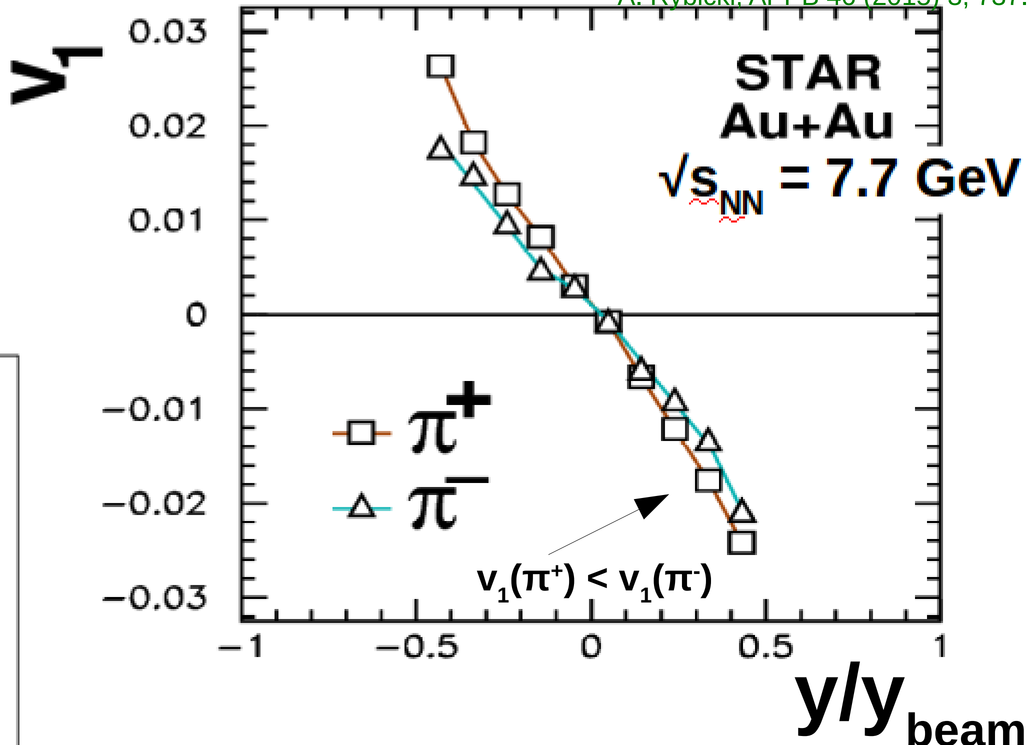
  → **Charge splitting of directed flow.**

A. Rybicki, A. Szczurek, Phys. Rev. C87 (2013) no.5, 054909.

V. Klochkov, I. Selyuzhenkov for NA61/SHINE collaboration, Quark Matter 2018



L. Adamczyk et al. STAR, Phys. Rev. Lett. 112, (2014) 162301.
A. Rybicki, A. Szczurek, Phys. Rev. C87 (2013) 054909.
A. Rybicki, APPB 46 (2015) 3, 737.



- Significant mass dependence of the directed flow v_1.

Conclusions

- **New preliminary 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 bring 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 performed for Ar+Sc and Pb+Pb/Au+Au collisions. Consistently, faster pions are emitted closer to the spectator system.
- We obtained new insight into the interplay between EM effects on pion emission and the spectator system:
  →**expansion** of the **effective charge cloud** is needed,
  →possible hint of the presence of participant charge at high rapidity.

Electromagnetic effects on charged pion spectra at SPS energies

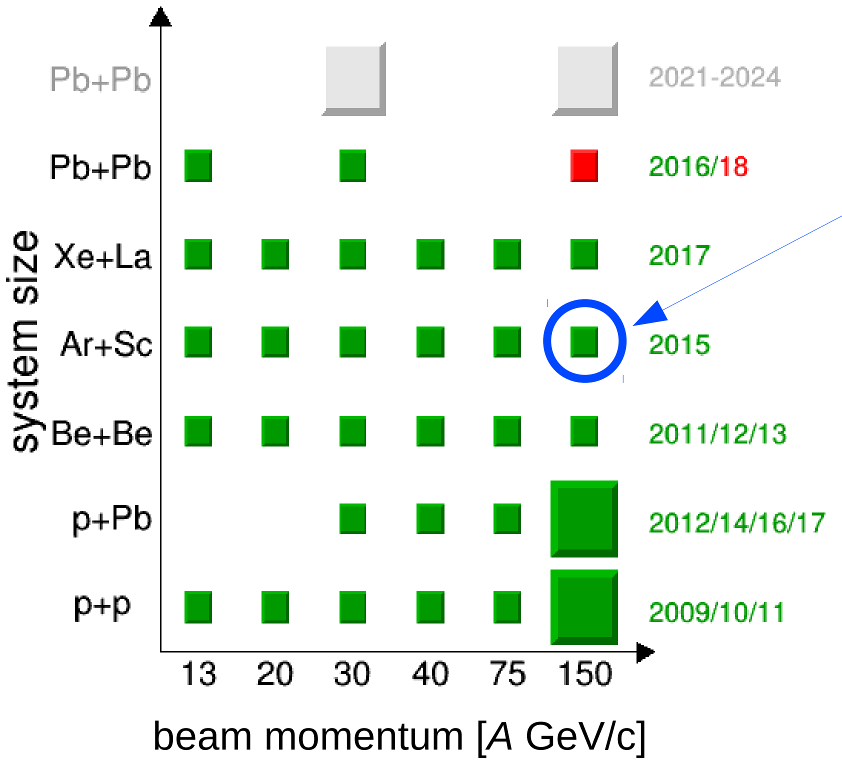
Thanks for your attention!

Mirosław Kiełbowicz

This work was supported by the National Science Centre, Poland
under grant no. 2014/14/E/ST2/00018.

Extra slides

NA61/SHINE experiment



This is just a beginning!

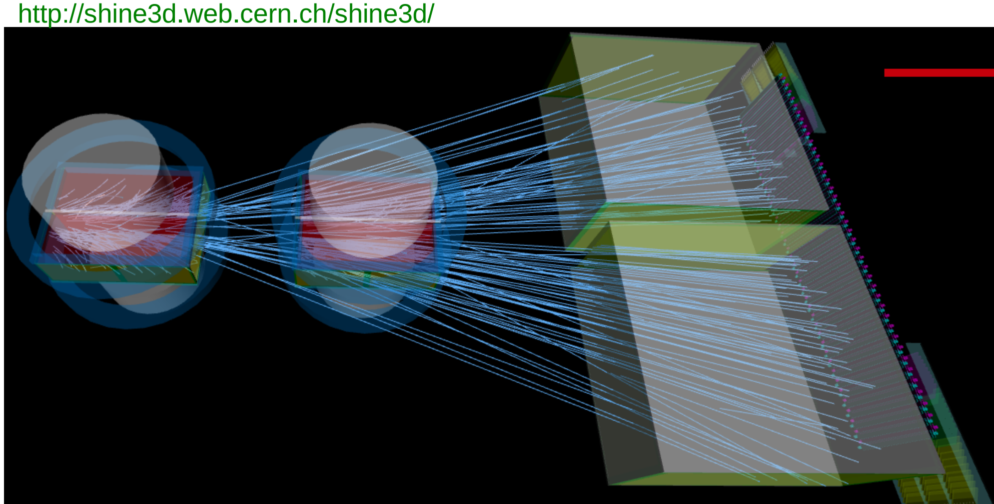
Data taking schedule:

taken data (green),

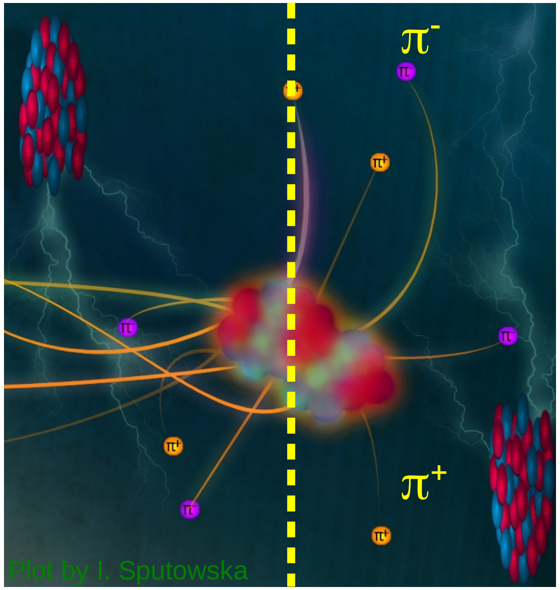
approved for 2018 (red),

proposed extension (gray).

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



Forward hemisphere in the collision c.m.s.

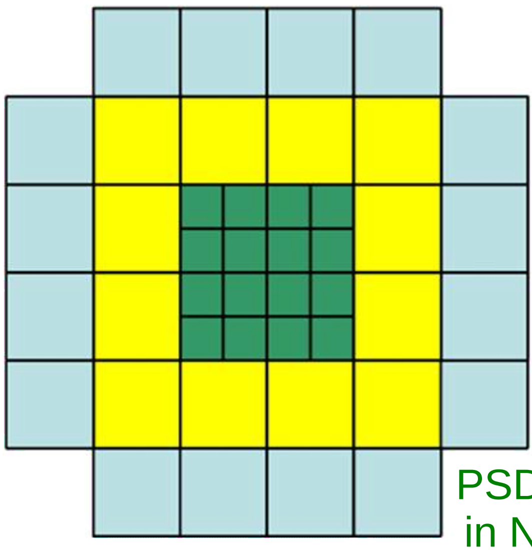


Data sets, centrality

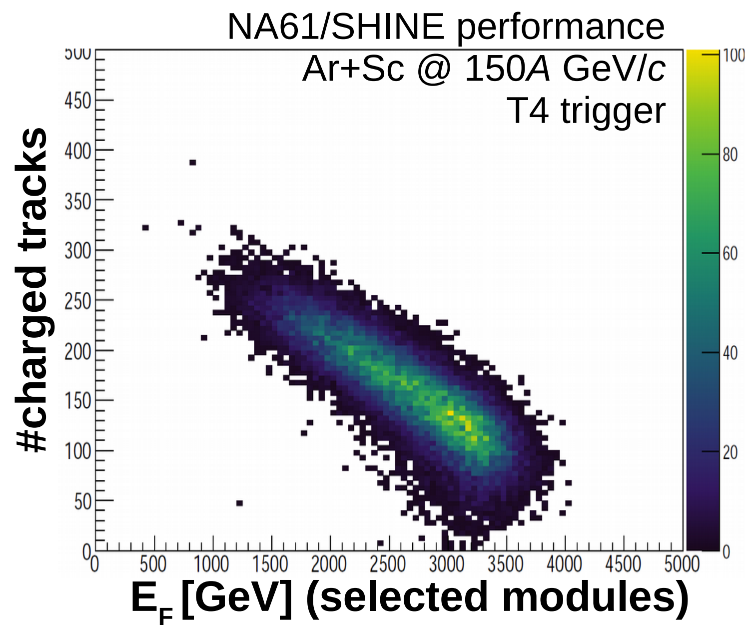
- **NA61/SHINE** experiment, ^{40}Ar + ^{45}Sc @ 150*A* GeV/*c*.
  Pb + Pb @ 30*A* GeV/*c*.

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

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



PSD calorimeter in NA61/SHINE



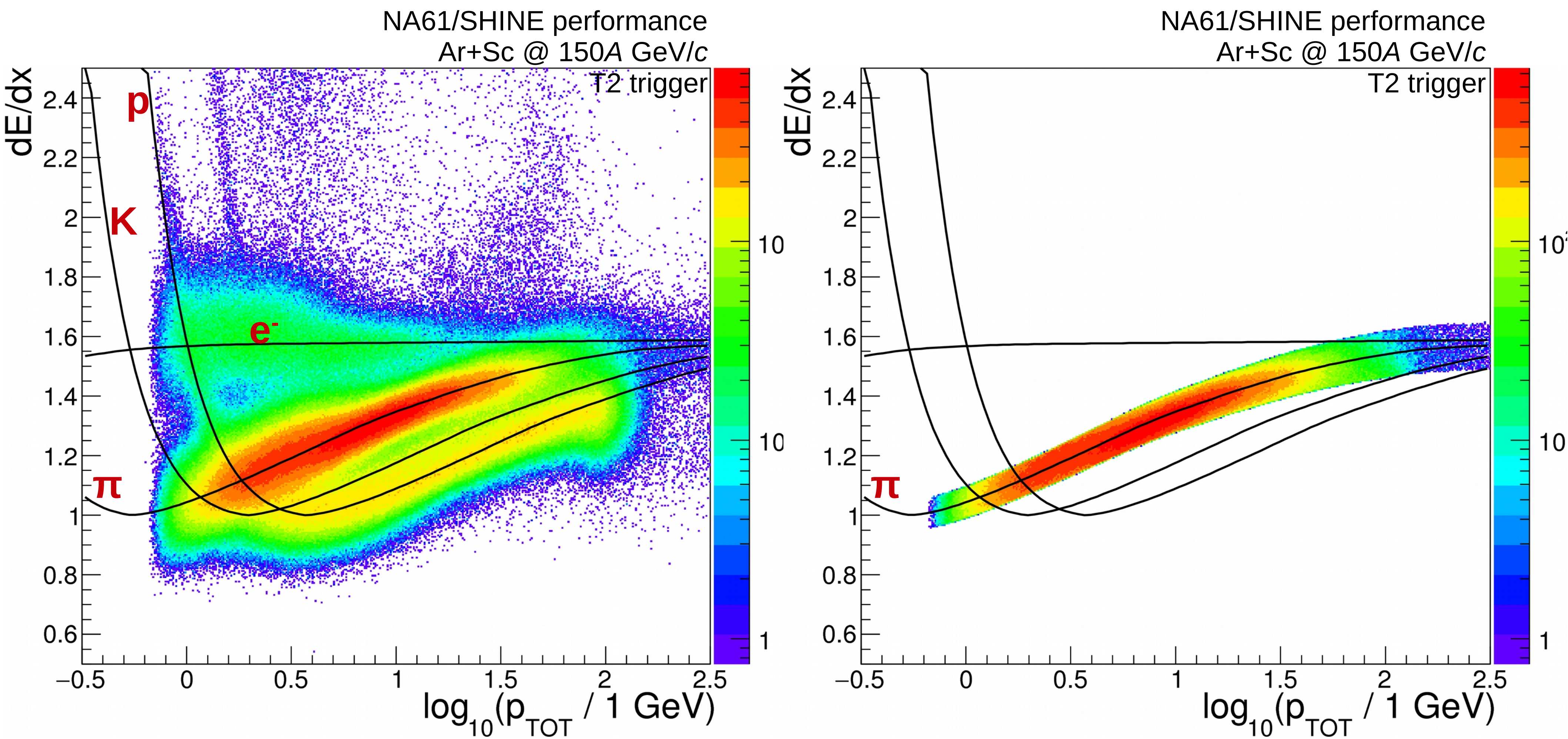
- Centrality selection is defined by the **P**rojectile **S**pectator **D**etector (PSD):

  → Forward rapidity calorimeter.

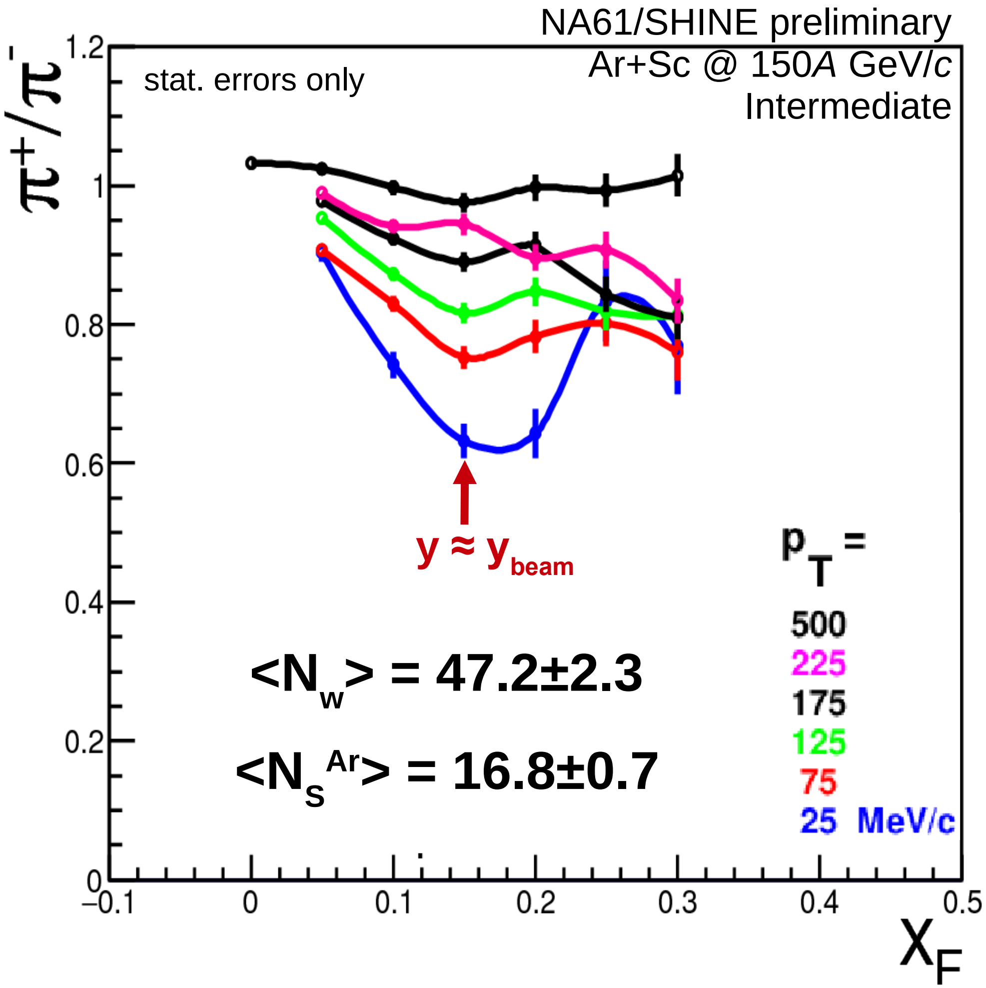
- Dedicated Glauber simulations.

Data analysis: Ar+Sc @ 150*A* 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.

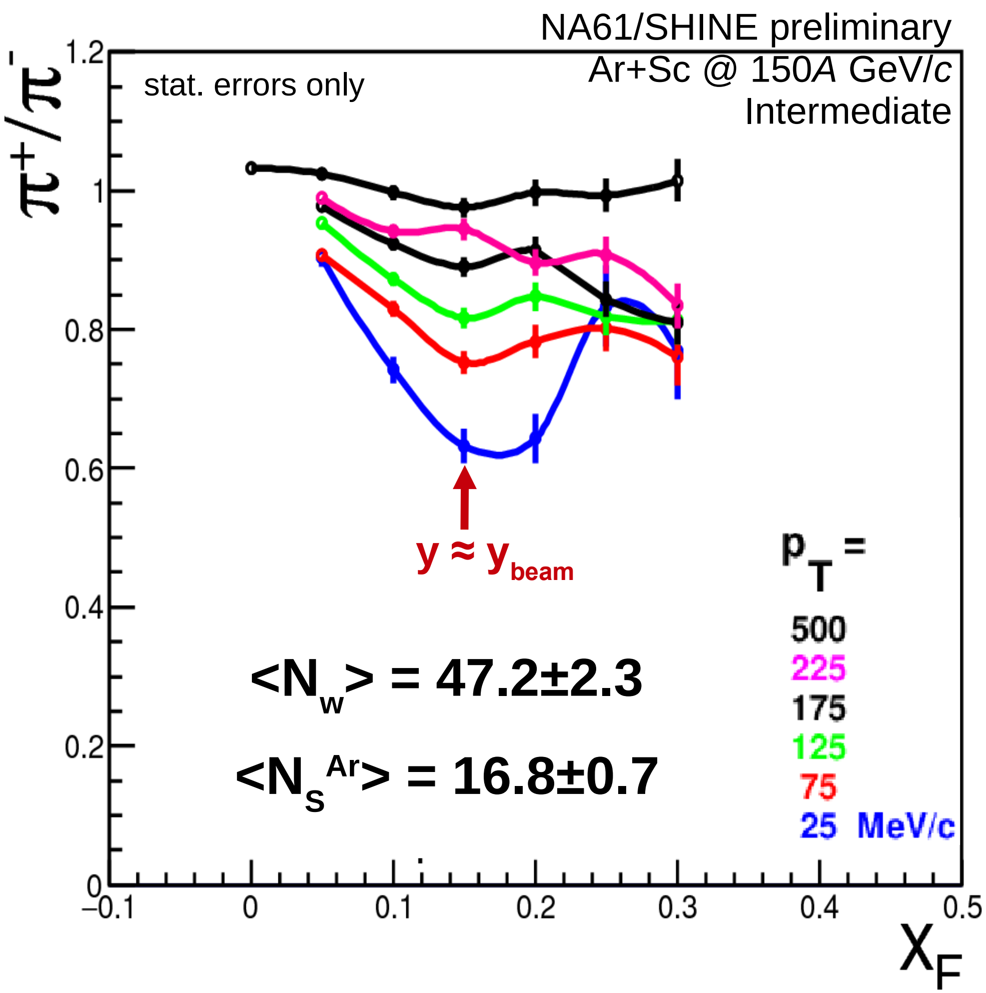
  → **π^+/π^- ratios** appear far more **robust** than π^+ or π^- spectra taken separately.
- Systematic biases estimated on the level of **±0.06**.
- This includes:
  - → kaon contamination,
  - → pion Bethe-Bloch precision,
  - → feed-down from weak decays.

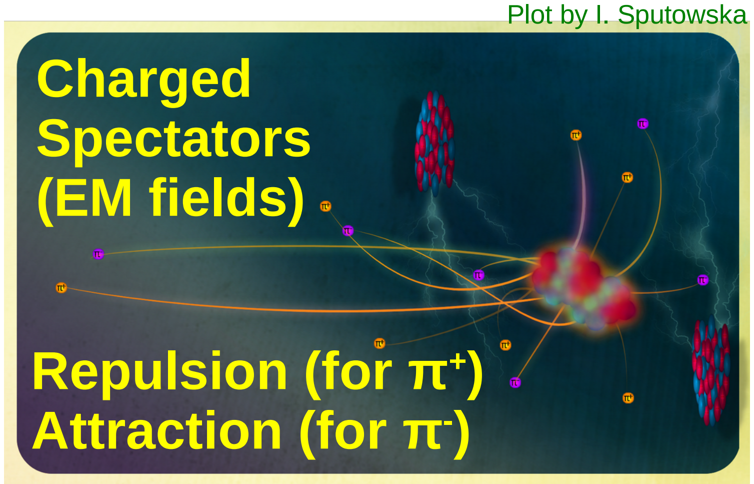
*Note: centrality is estimated by the total number of wounded nucleons and the Ar spectator mass.

$$x_F = \frac{p_L}{p_L^{beam}}$$

(c.m.s.)

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

→ **First observation** of such an effect in Ar+Sc collisions.

→ **First observation** of spectator-induced EM effects in **small systems** at SPS.