New results on Coulomb effects in meson production in relativistic heavy ion collisions

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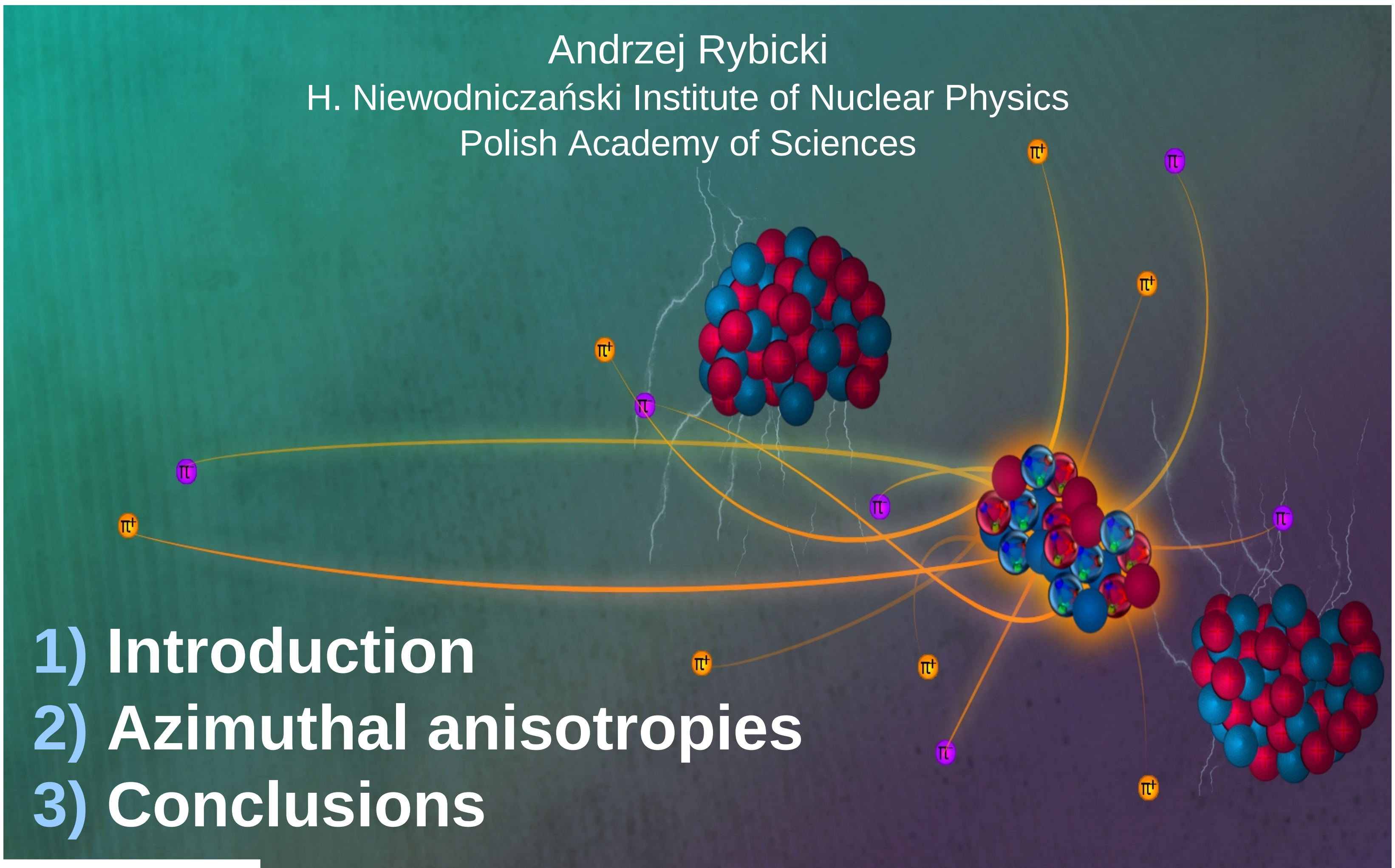
H. Niewodniczański Institute of Nuclear Physics
Polish Academy of Sciences



I. Sputowska

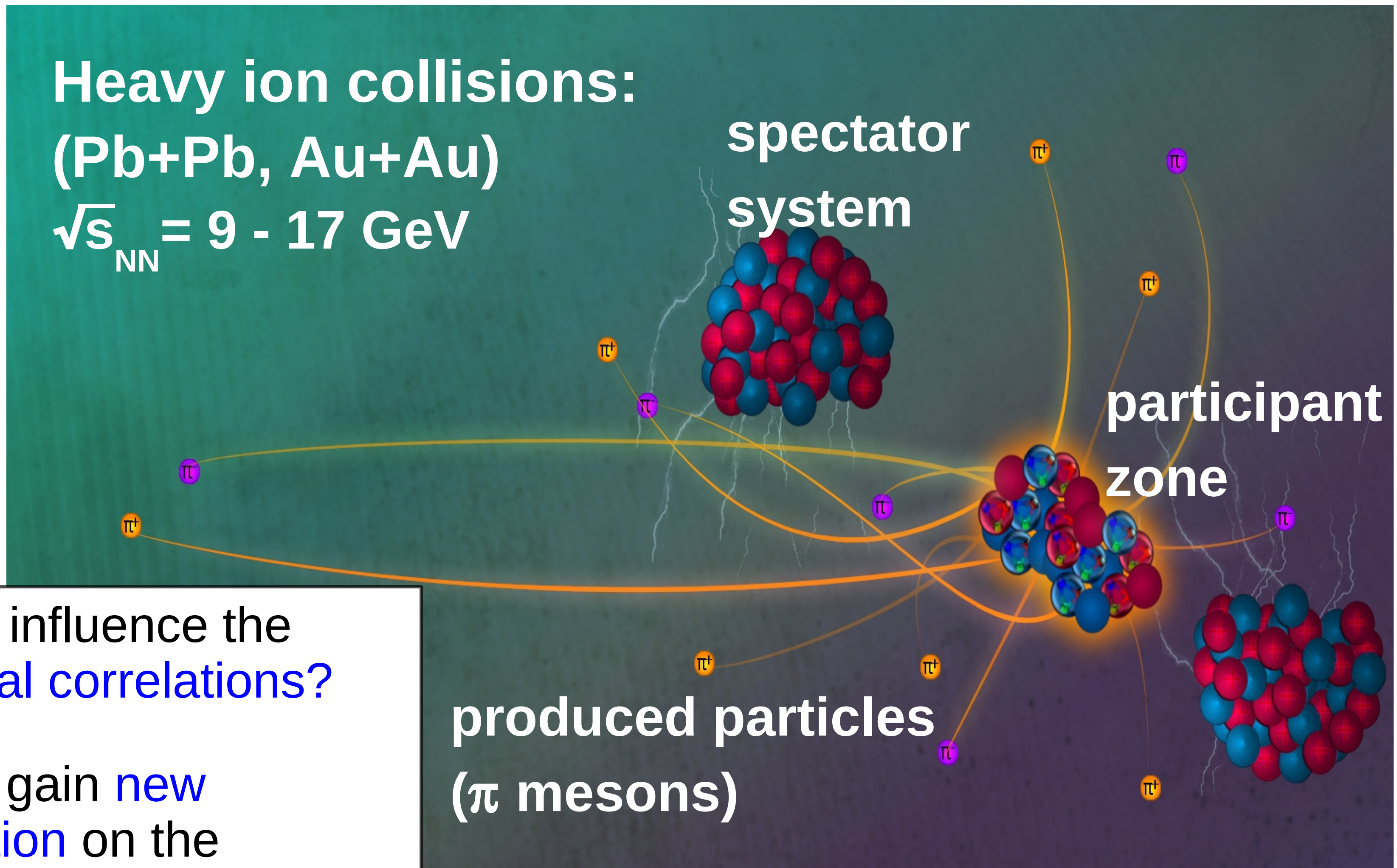
1) Introduction
2) Azimuthal anisotropies
3) Conclusions

work in collaboration with
Antoni Szczurek
Mariola Kłusek-Gawenda

1) Introduction

- Coulomb effects modify the spectra of charged mesons.

  A.R., A. Szczurek, Phys. Rev. **C75** (2007) 054903,
  A.R., Acta Phys. Polon. **B42** (2011) 867



I. Sputowska

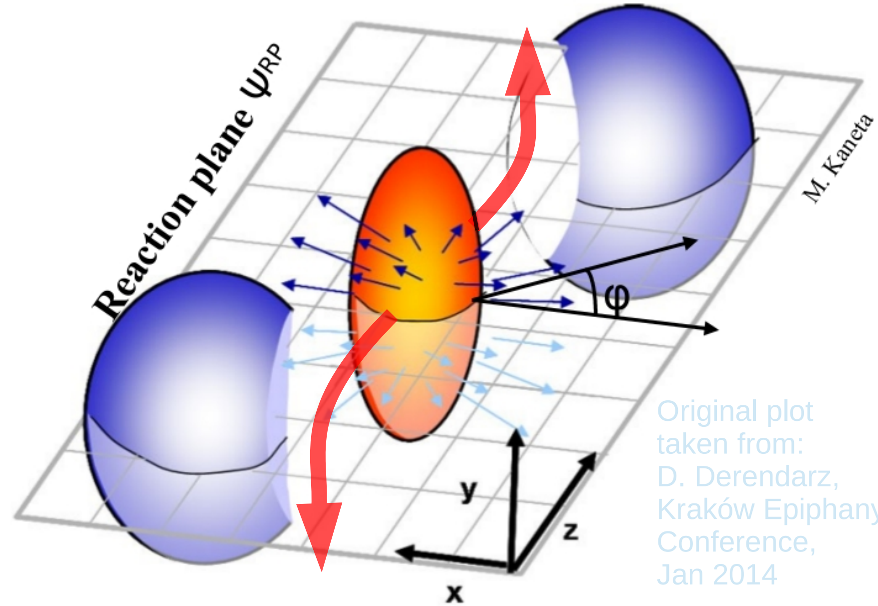
- Do they influence the azimuthal correlations? (YES)
- Can we gain new information on the dynamical evolution of the participant system? (YES)

2)
Azimuthal anisotropies

See also:
A. R. and A. Szczurek, Phys. Rev. **C87** (2013) 054909.
Technical details:
A.R. and A. Szczurek, Phys. Rev. **C75** (2007) 054903.

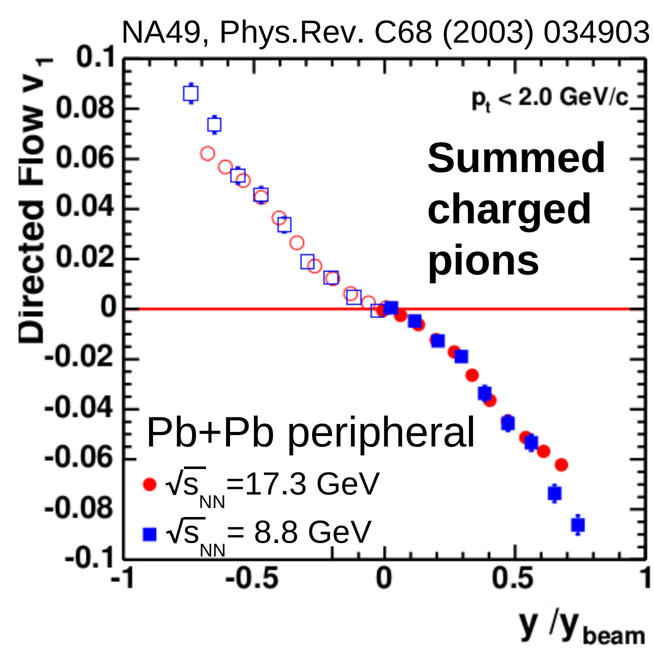
- *Directed flow:*

$$v_1 \equiv \langle \cos(\phi - \Psi_{RP}) \rangle$$



- Reflects sidewards collective motion.

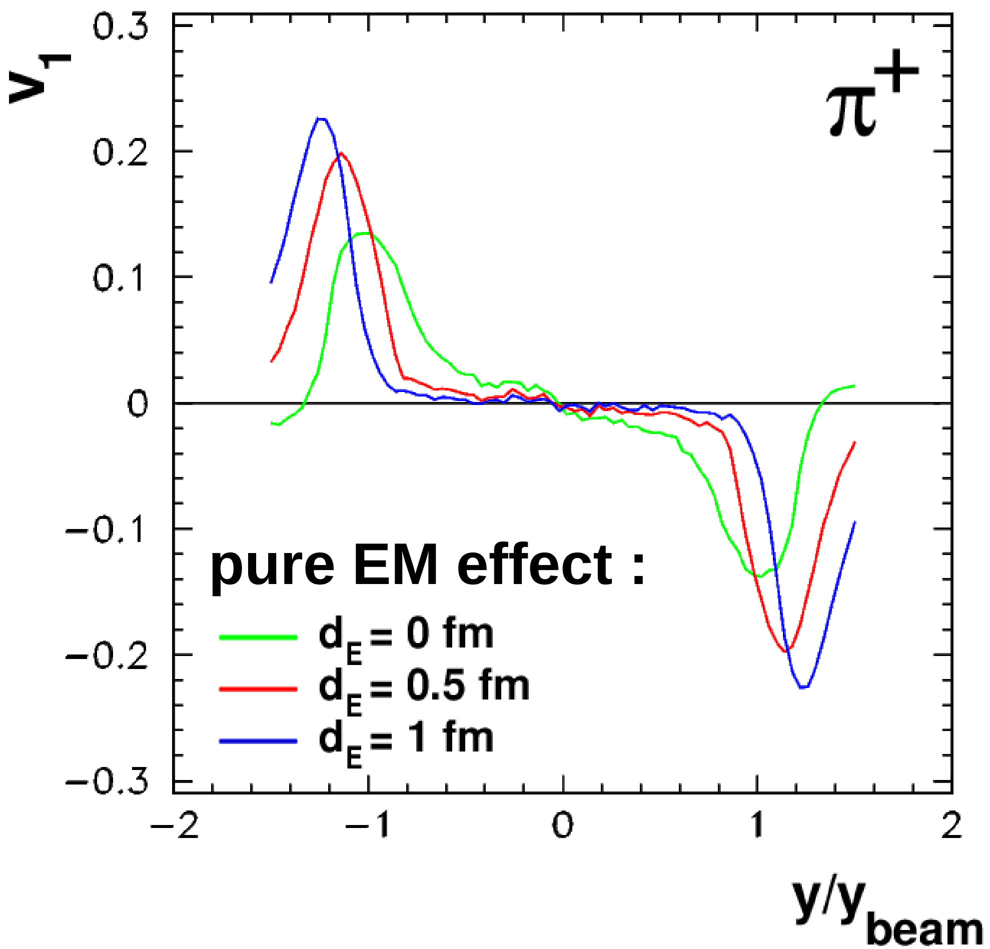
$$y = \frac{1}{2}\ln\left(\frac{E+p_L}{E-p_L}\right)$$

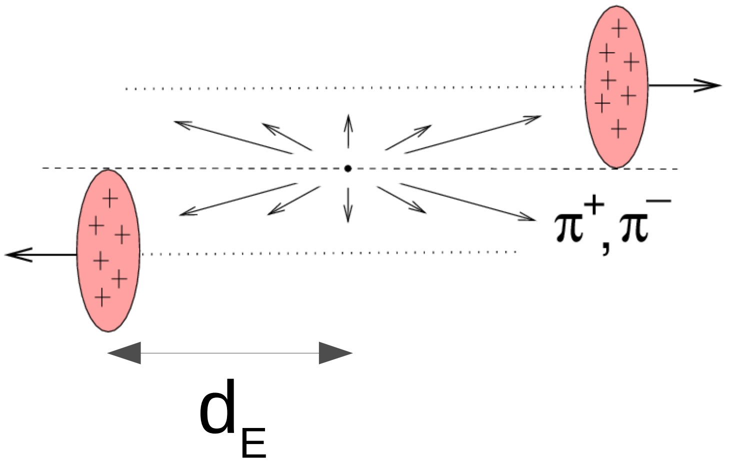


- *What is the role of Coulomb effects ?*

- *Directed flow:* $v_1 \equiv \langle \cos(\phi - \Psi_{RP}) \rangle$

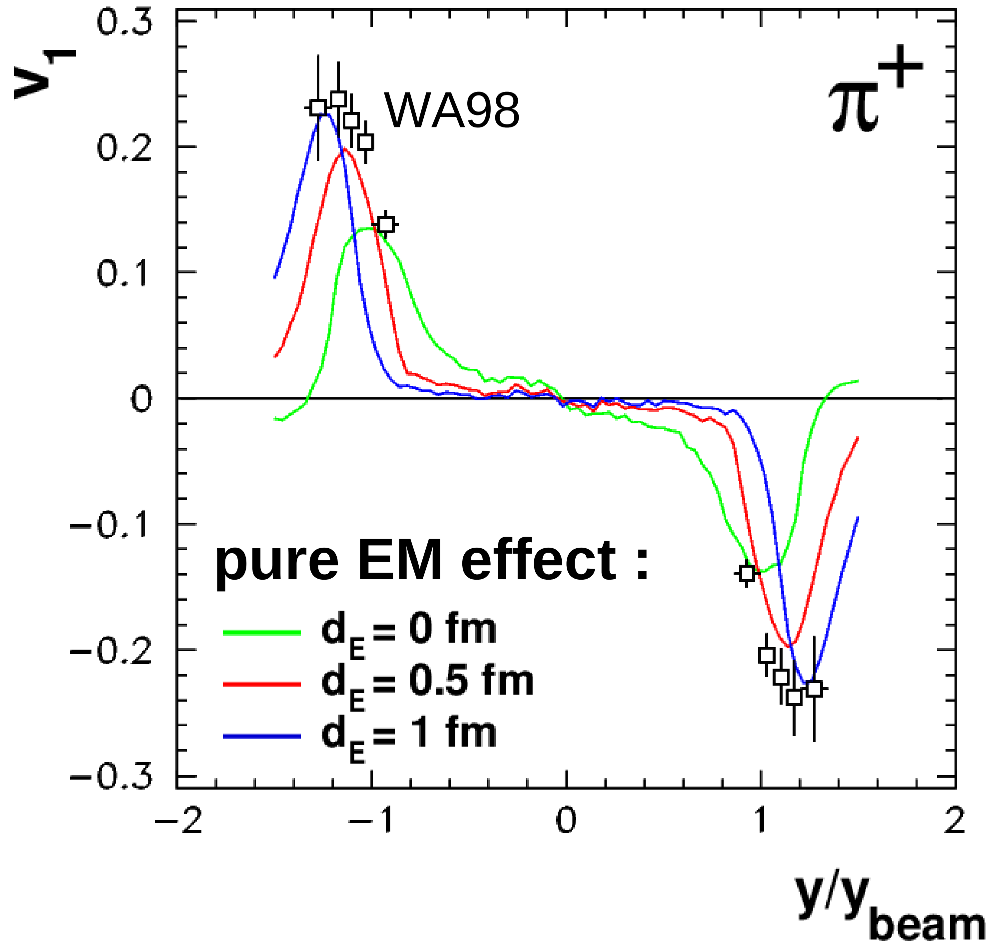
Pb+Pb peripheral, $\sqrt{s_{NN}}$=17.3 GeV

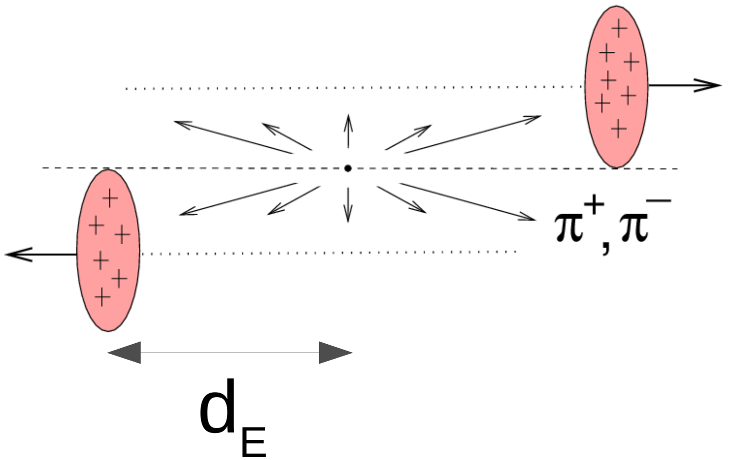




- *Directed flow:* $v_1 \equiv < \cos(\phi - \Psi_{RP}) >$

Pb+Pb peripheral, $\sqrt{s_{NN}}$=17.3 GeV





pure EM effect
is comparable
to exp. data

→ d_E < 1 fm

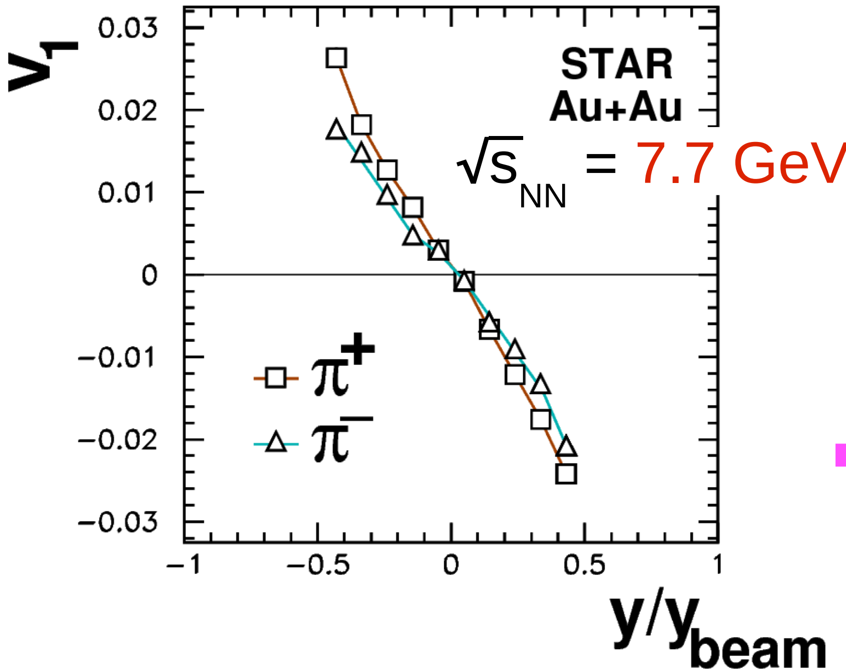
data points from:
H. Schlagheck (WA98 Collaboration),
Nucl. Phys. A **663**, 725 (2000).

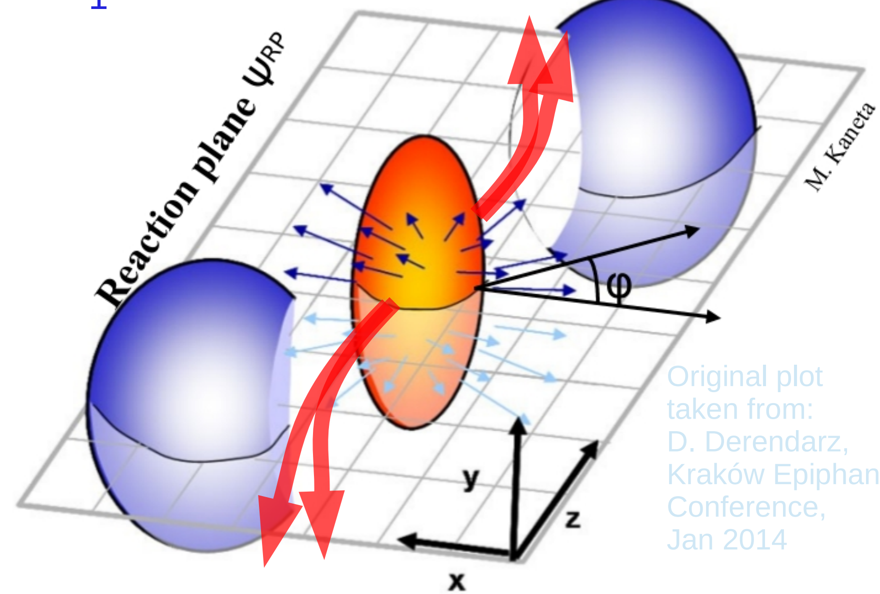
2.1)
Azimuthal anisotropies – Part II

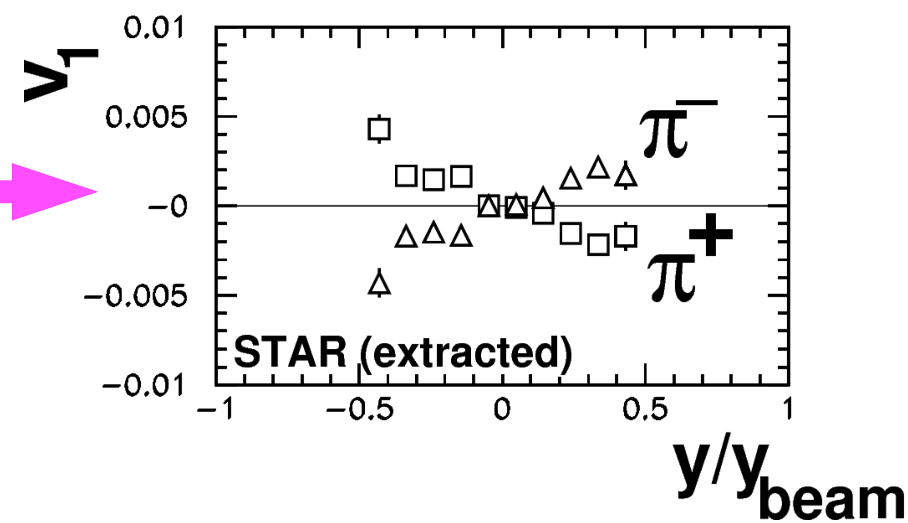
See also:
A. R. and A. Szczurek, arXiv:1405.6860 [nucl-th],
May 27, 2014

L. Adamczyk et al. (STAR Collaboration), Phys. Rev. Lett. 112, 162301 (2014)

$v_1 \equiv \langle \cos(\phi - \Psi_{RP}) \rangle$



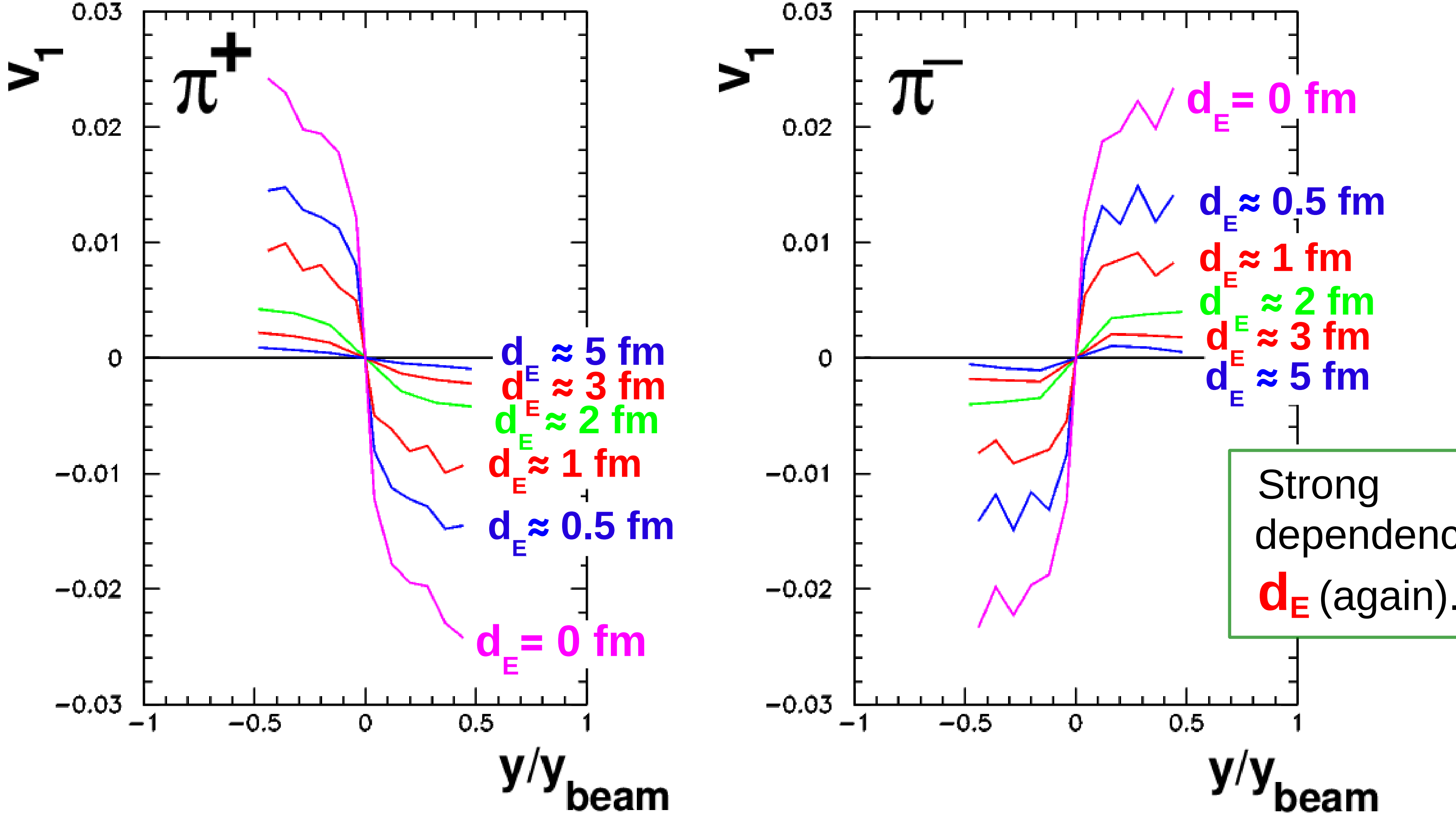




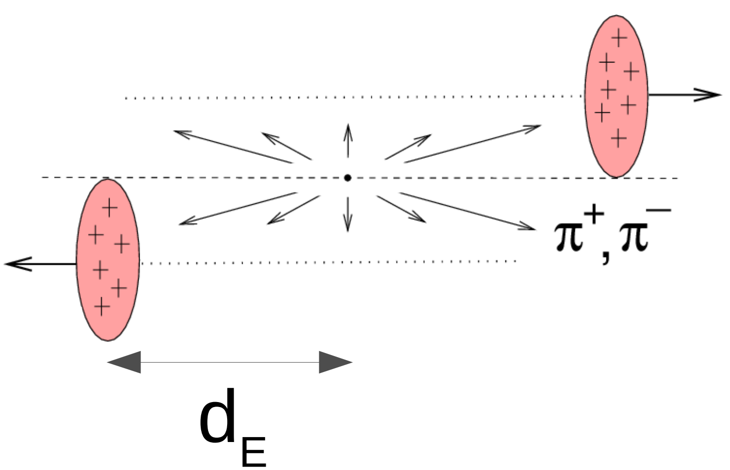
We assume:
- $v_1^{\pi^+} \approx v_1^{flow} + v_1^{\pi^+,EM}$
- $v_1^{\pi^-} \approx v_1^{flow} + v_1^{\pi^-,EM}$

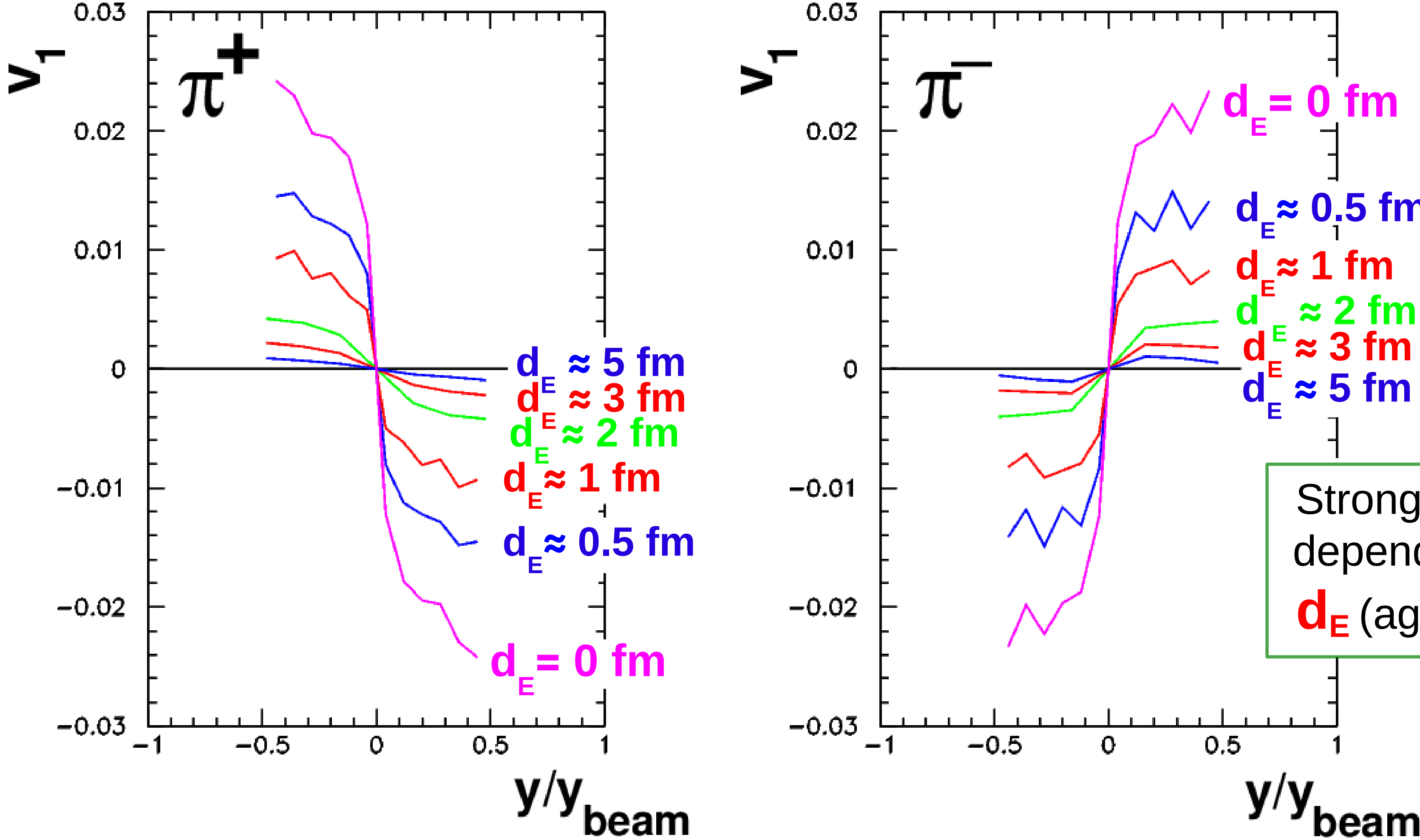
We know:
- $v_1^{\pi^+,EM} \approx -v_1^{\pi^-,EM}$

This gives:
- $v_1^{\pi^+,EM} \approx (v_1^{\pi^+} - v_1^{\pi^-})/2$
- $v_1^{\pi^-,EM} \approx -(v_1^{\pi^+} - v_1^{\pi^-})/2$



Strong dependence on **d_E** (again).





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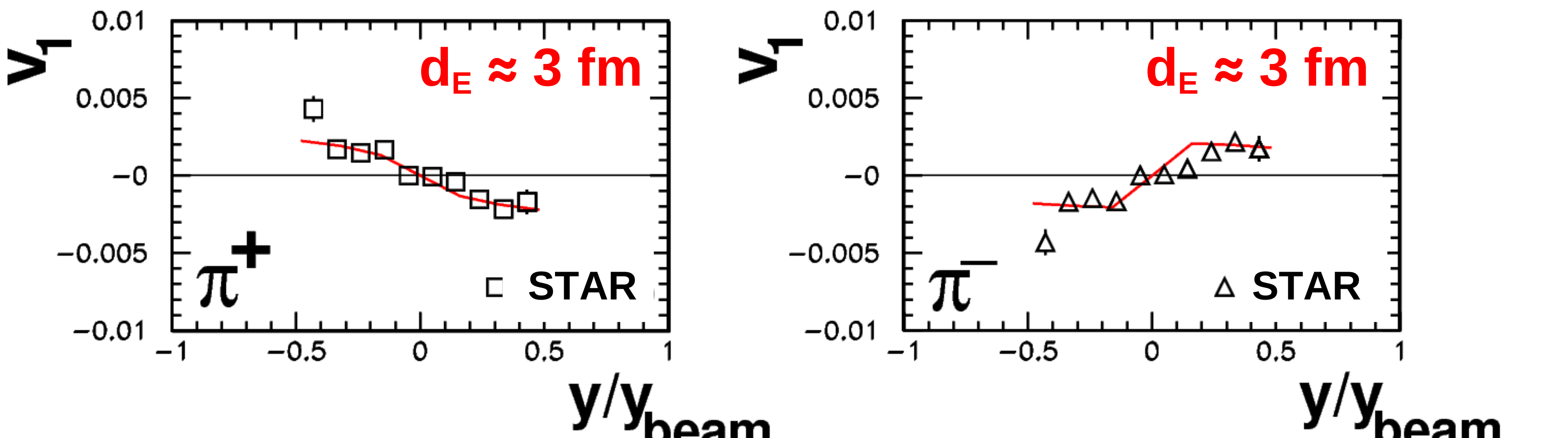
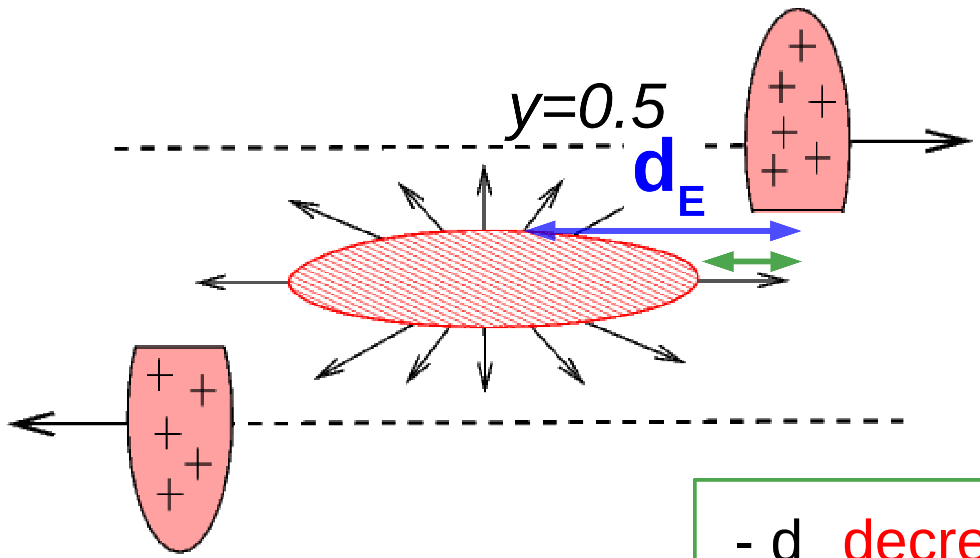


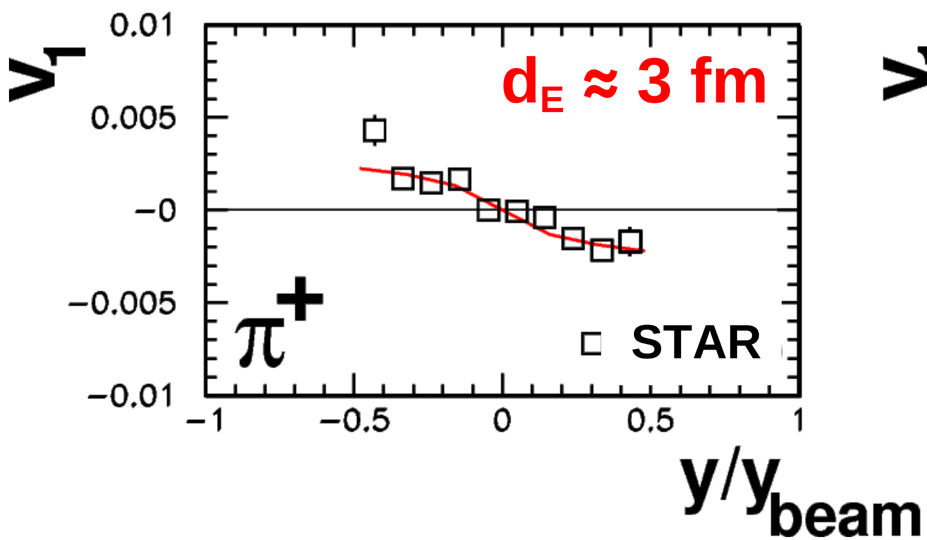
Rapidity dependence of pion emission

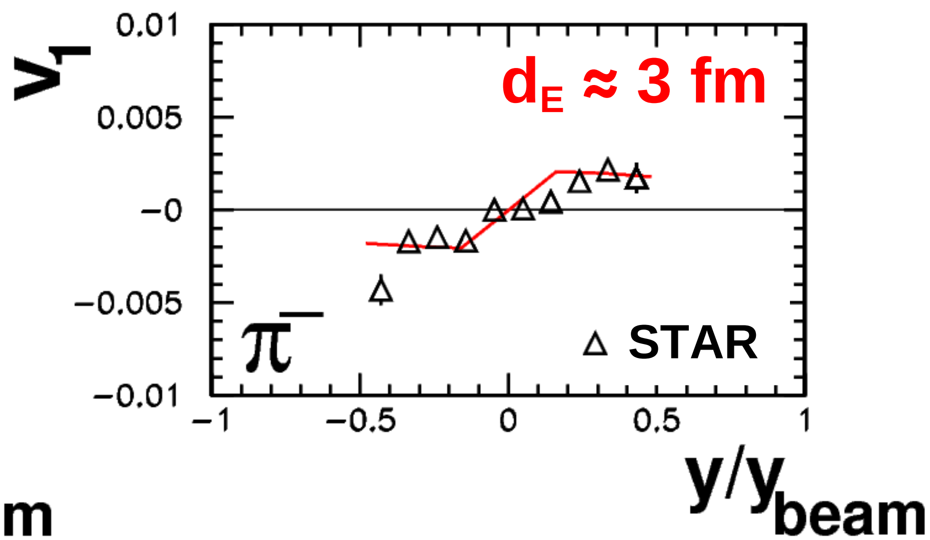


$d_E \approx 3$ fm (STAR, small y)

$d_E < 1$ fm (WA98, $y \approx y_{beam}$)

- d_E decreases with increasing pion rapidity
- reflects the longitudinal evolution of the system





3) Conclusions

- In heavy ion collisions, **Coulomb fields** are generated by charged spectators.
- These Coulomb fields not only modify the spectra of charged mesons but also lead to **azimuthal distortions**.
- These effects are sensitive to the **distance d_E** between the pion emission site and the spectator(s).
- d_E decreases with increasing pion rapidity, **reflecting the longitudinal evolution of the system**.
- This proves that the spectator-induced Coulomb field constitutes a **new source of information** on the **space-time properties** of the system created in the heavy ion collision, completely independent from other sources such as pion interferometry.

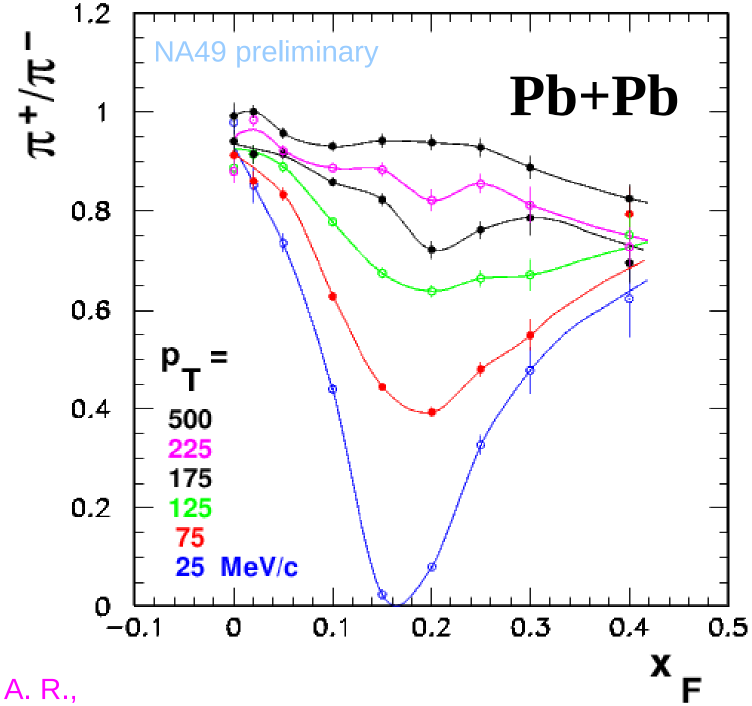
Thank you!

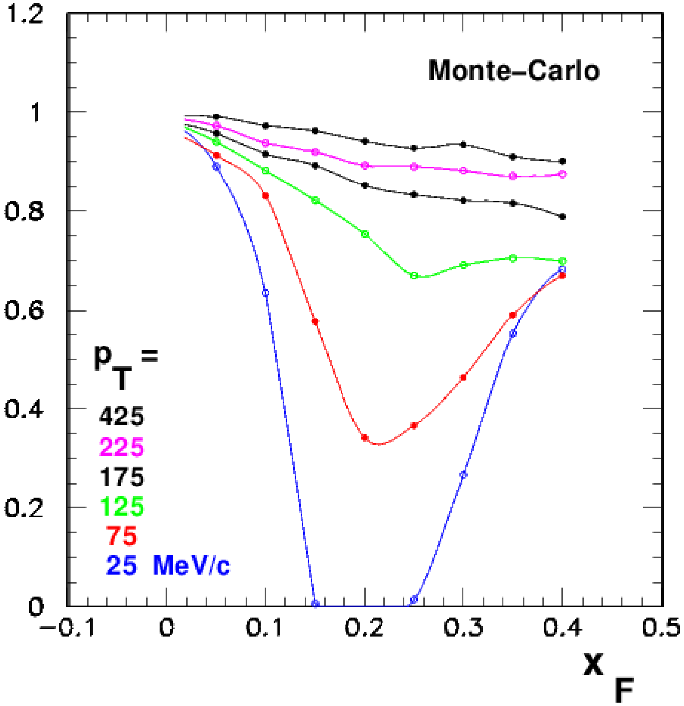
Acknowledgments.

This work was supported by the Polish National Science Centre

(on the basis of decision no. DEC-2011/03/B/ST2/02634).

Extra slides



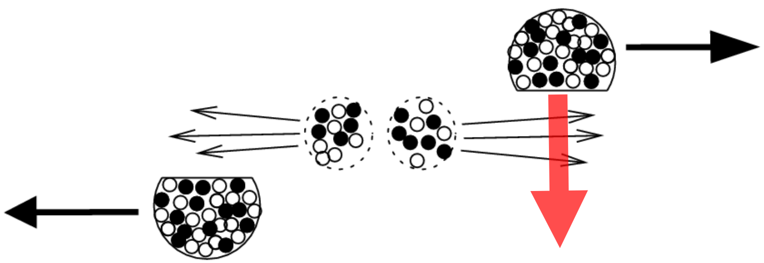


A. R. and A. Szczurek, Phys. Rev. **C75** (2007) 054903

A. R., Acta Phys. Polon. **B42** (2011) 867

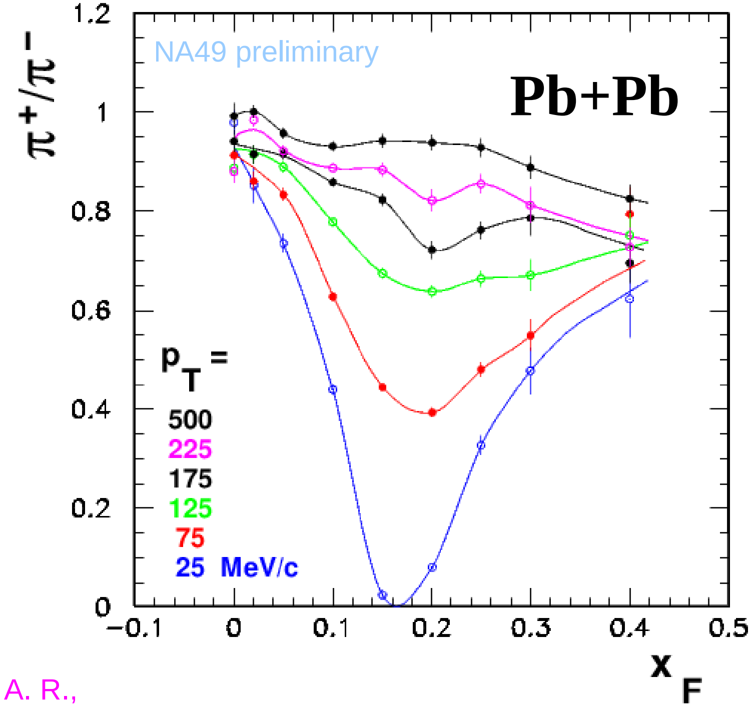
$$x_F = \frac{p_L}{p_L^{MAX}}$$

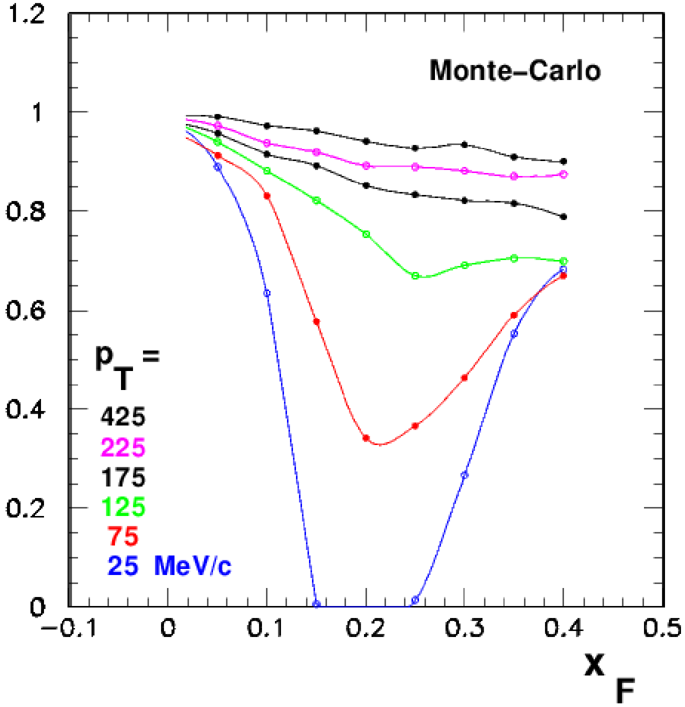
(c.m.s.)

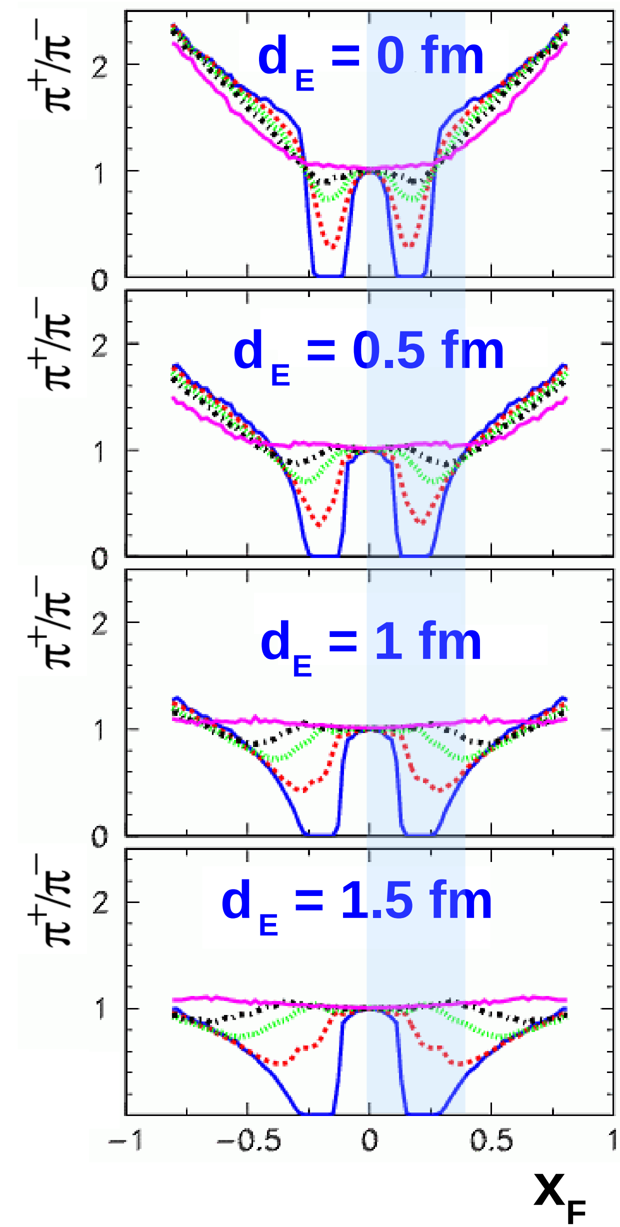


Repulsion (for π^+)
Attraction (for π^-)

- Pb+Pb peripheral, $\sqrt{s_{NN}}$=17.3 GeV
- Minimum at x_F= 0.15 = m_π/m_p





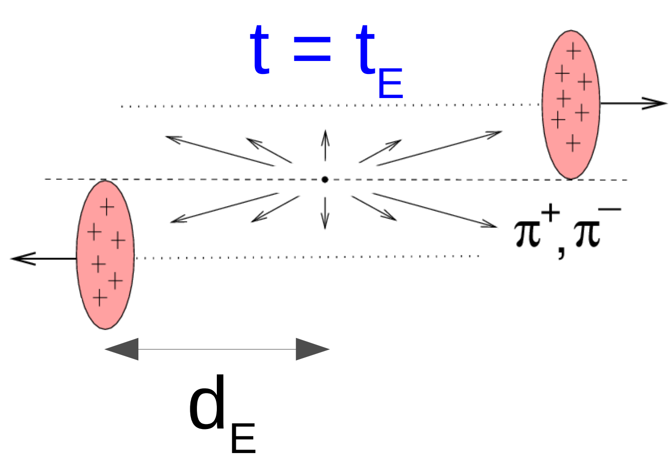


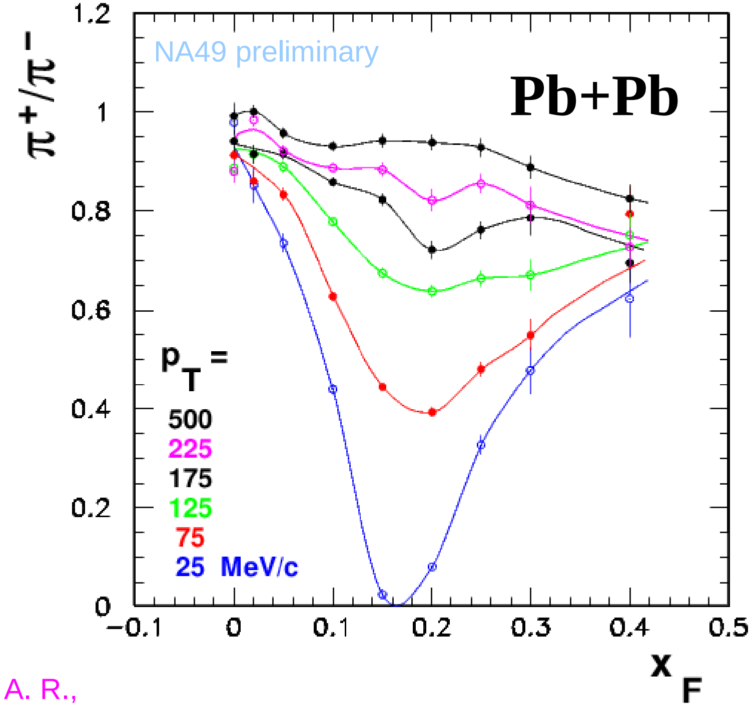
A. R.,
Acta Phys. Polon.
B42 (2011) 867

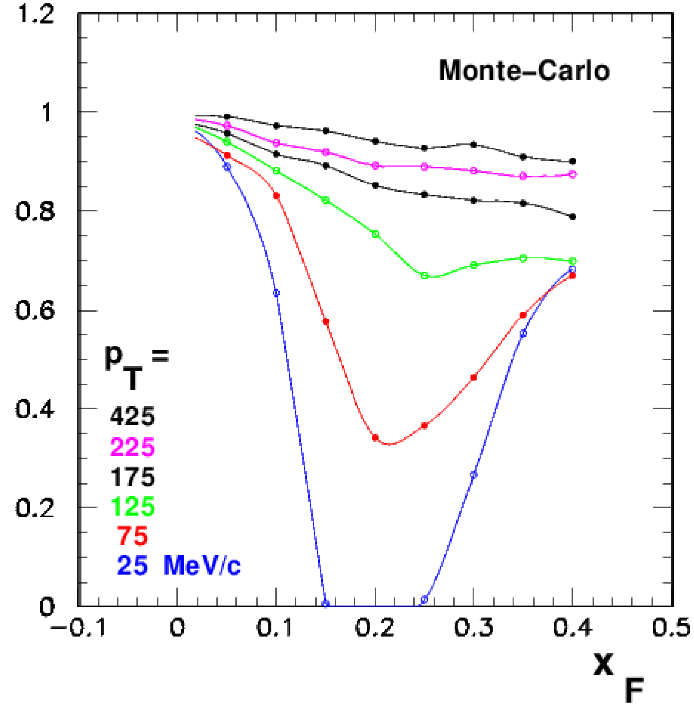
$$x_F = \frac{p_L}{p_L^{MAX}}$$

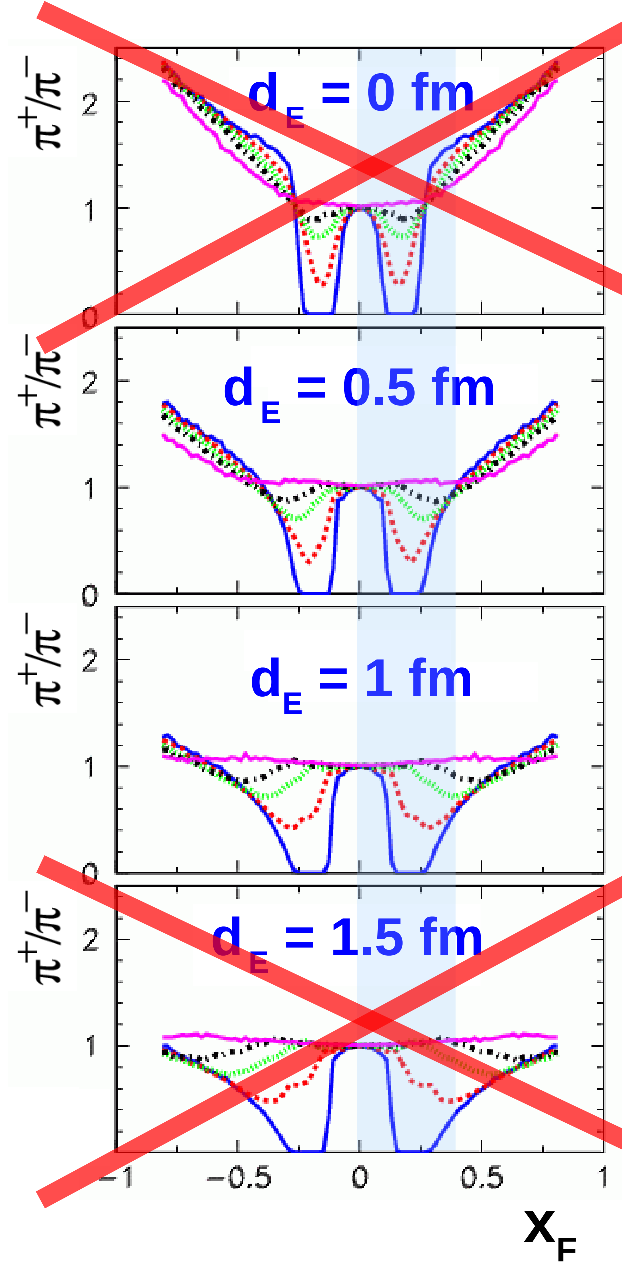
(c.m.s.)

Best description for:
50% * (d_E = 0.5 fm) +
50% * (d_E = 1 fm)









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

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50% * (d_E = 0.5 fm) +
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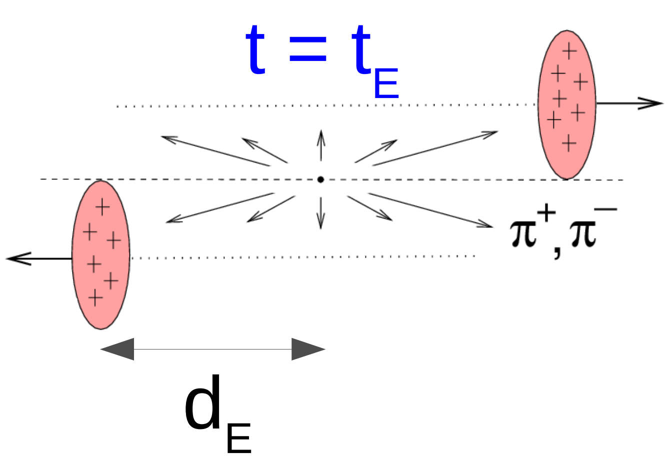
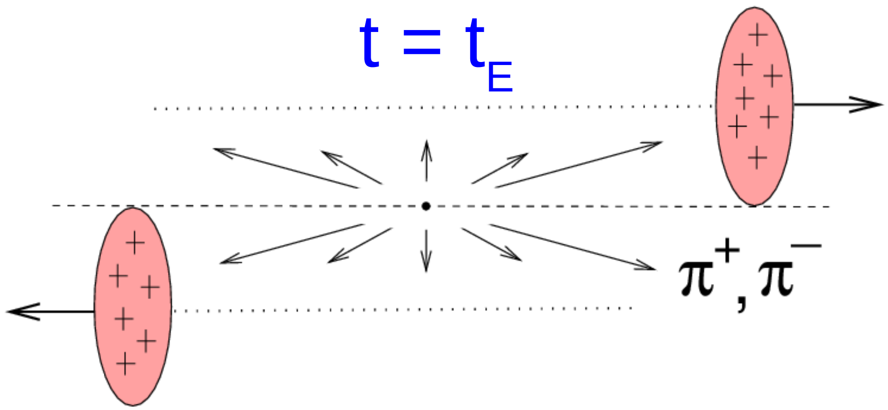
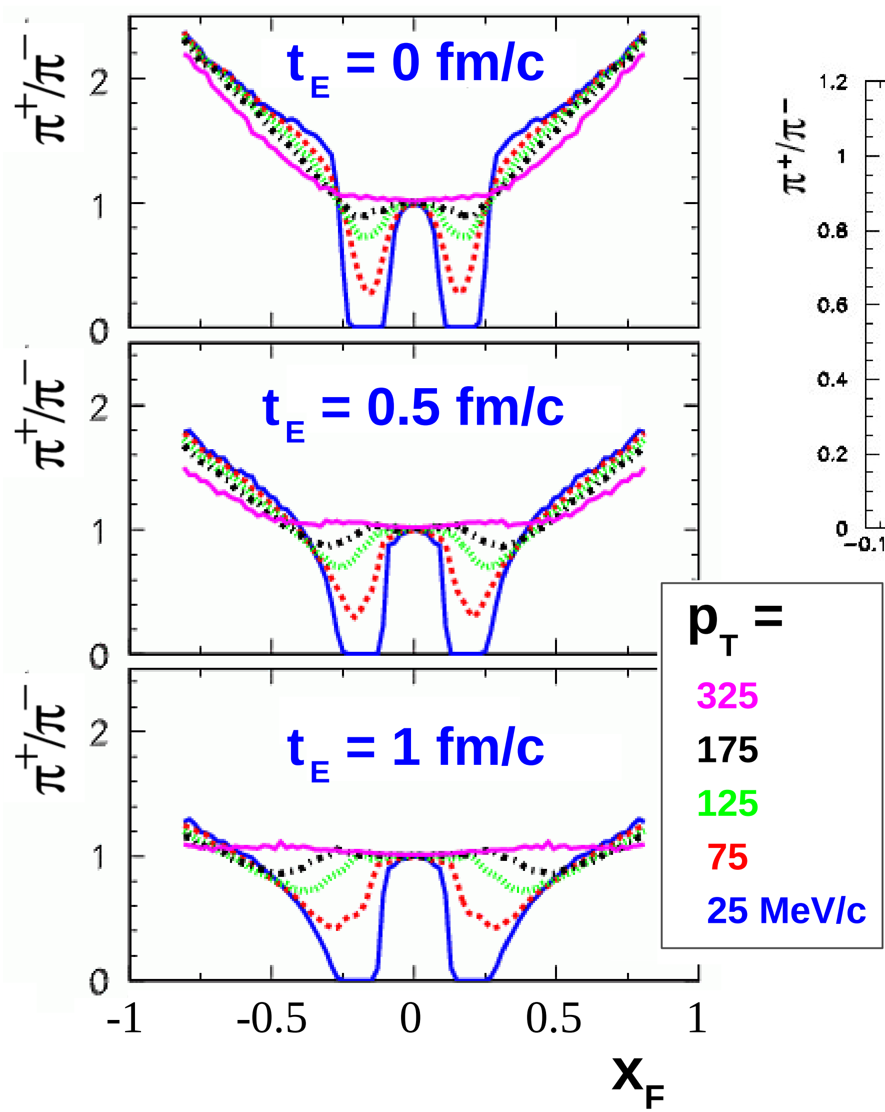
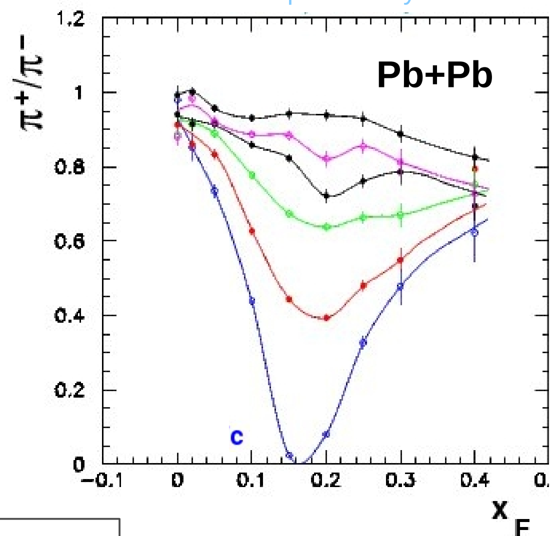




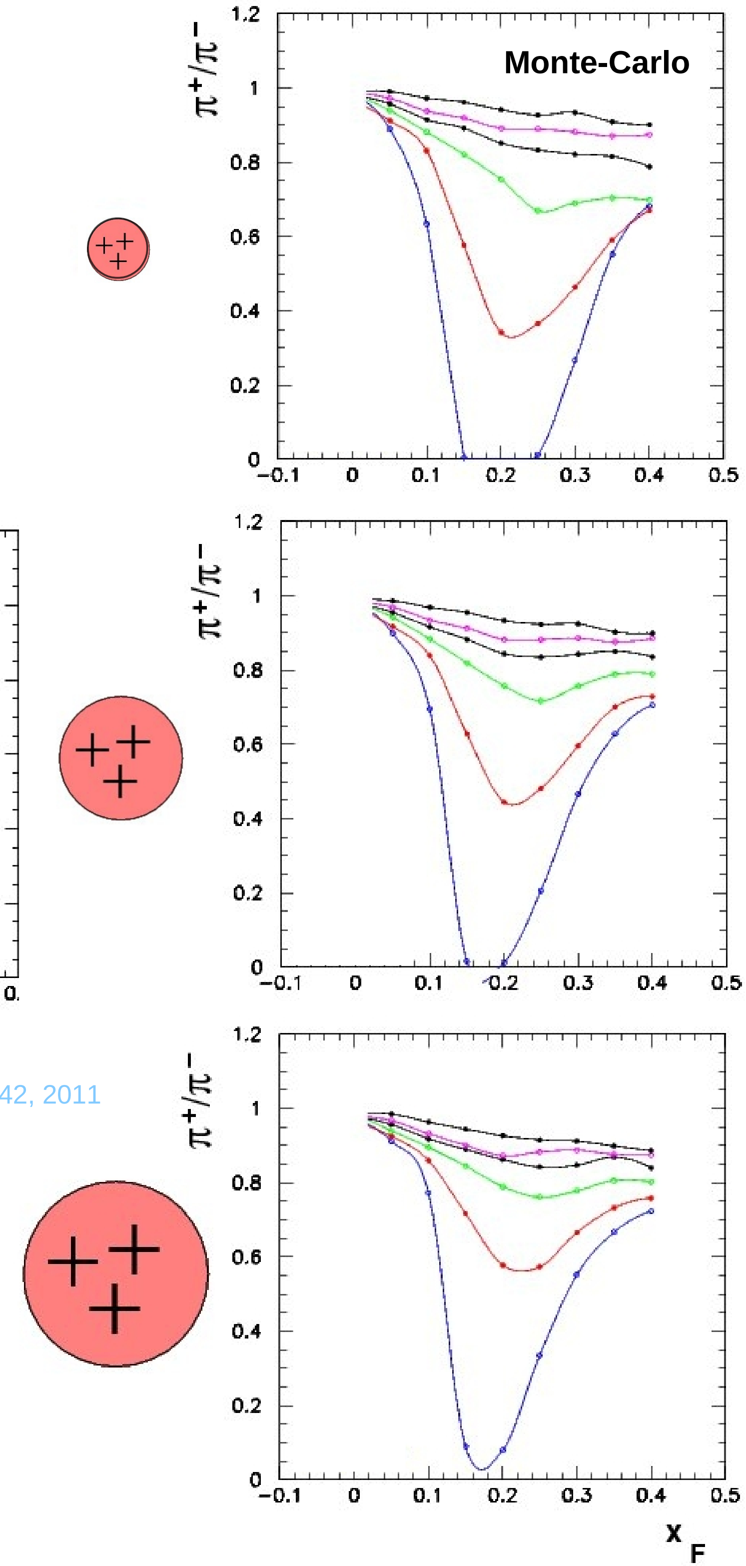
.Szczurek, PRC 75, 2007



NA49 preliminary



A.R., Acta Phys. Pol. B42, 2011



A.R., Acta Phys. Pol. B42, 2011

Source-size dependence of charged pion ratios (1)

A. Rybicki, habilitation thesis,
Report no. 2040/PH,
H. Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, 2010.

d_E = 1 fm

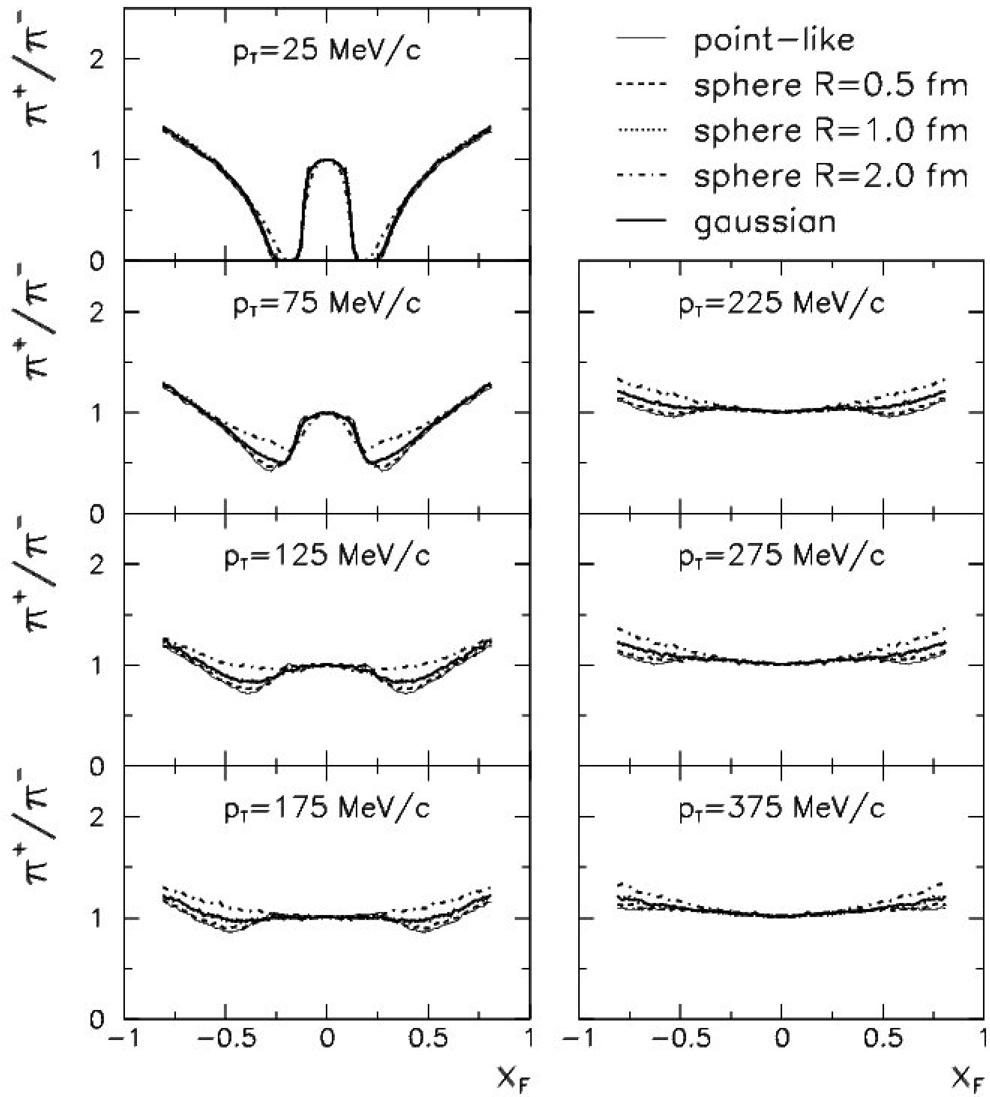
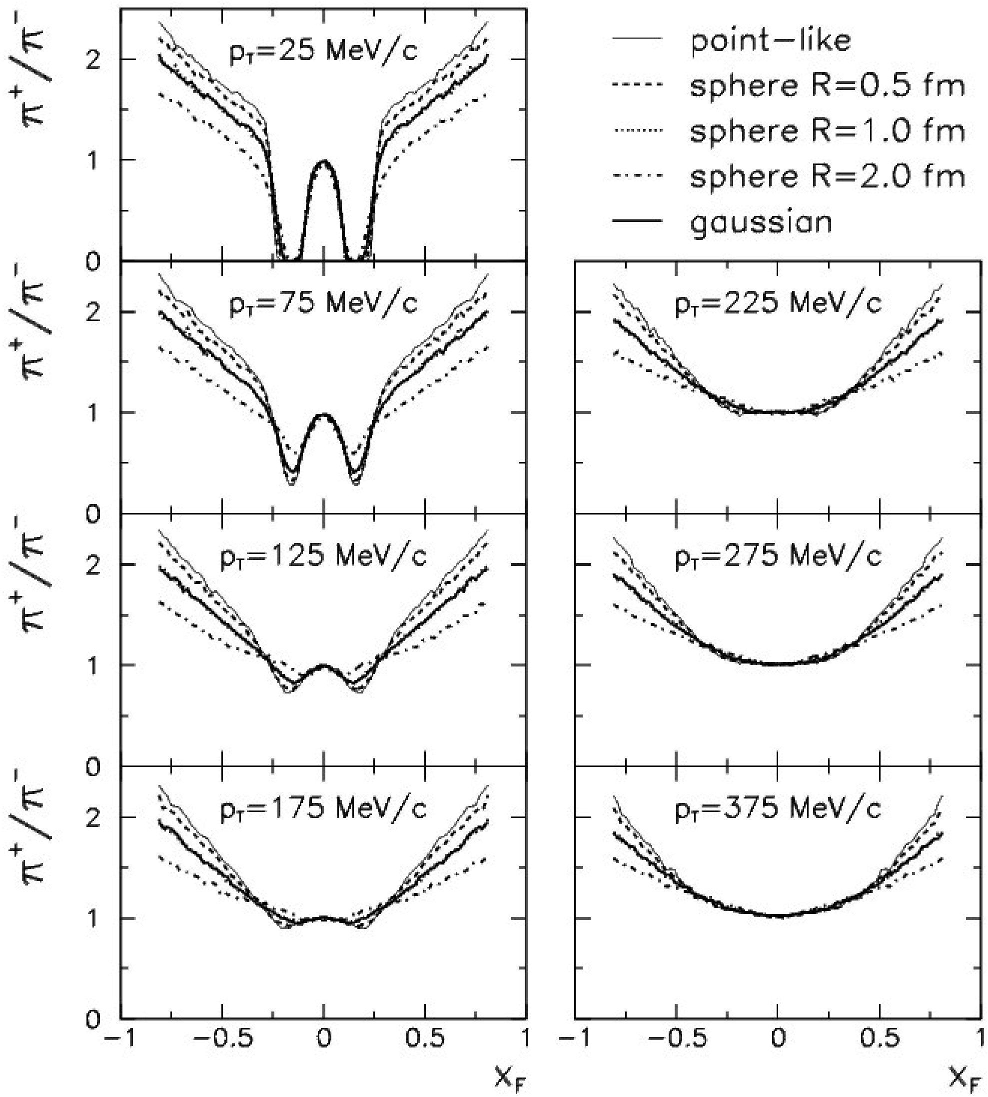


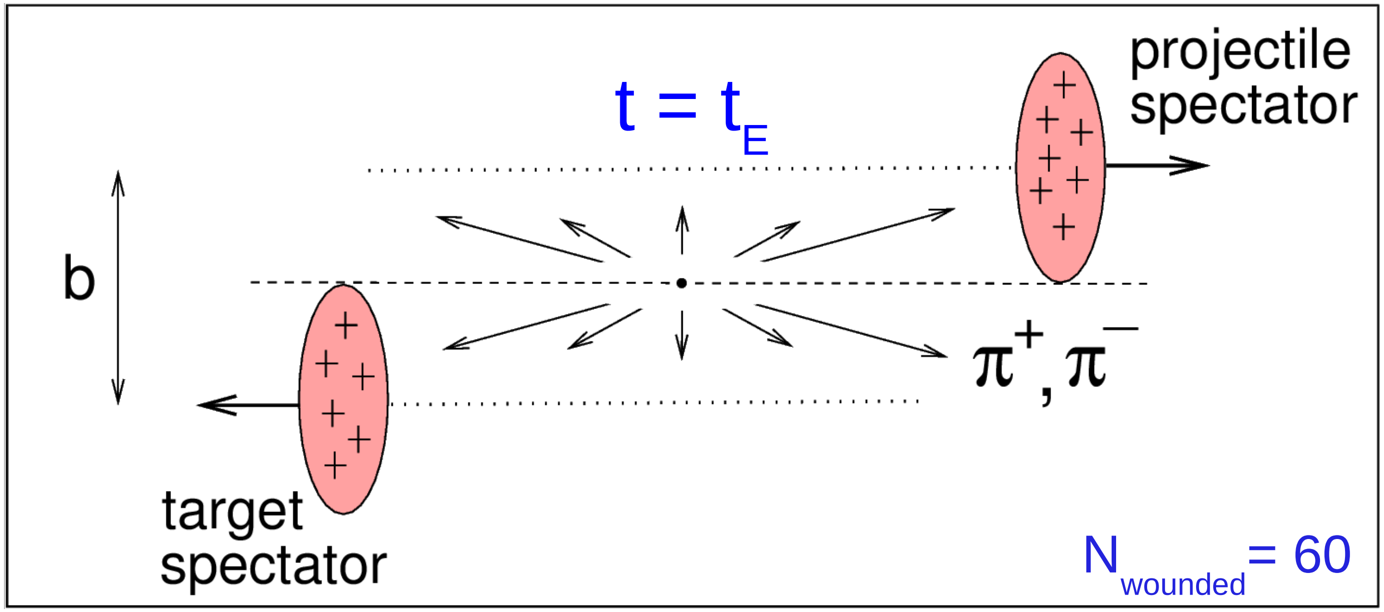
Figure 4.8: Dependence of the π^+/π^- ratio in the final state of the peripheral Pb+Pb reaction on the size and shape of the initial pion emission zone. The simulation assumed $t_E = 1$ fm/c.

Source-size dependence of charged pion ratios (2)

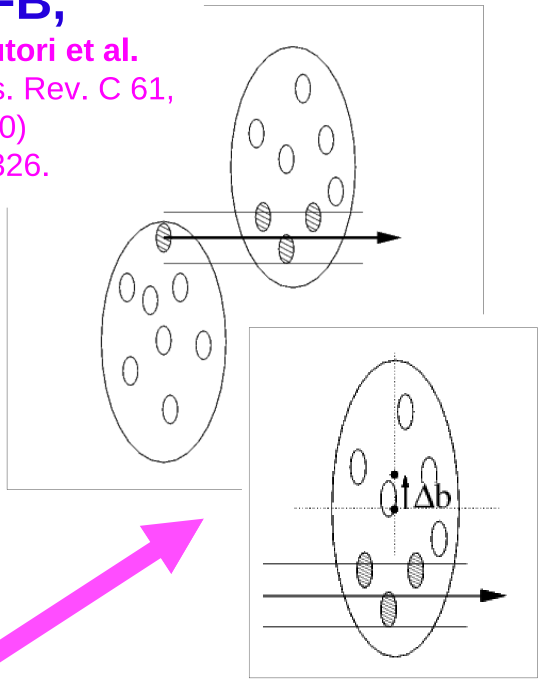
A. R. and A. Szczurek,
Phys. Rev. **C75** (2007) 054903.

d_E = 0 fm





Monte Carlo,
HFB,
Mizutori et al.
Phys. Rev. C 61, (2000) 044326.



- the collision takes place at a given impact parameter b.
- the spectator systems = uniform spheres (in their rest frames).
- the pion emission - single point in space. The emission time t_E is a free parameter.
- the initial distribution of the emitted pions is assumed similar to N+N collisions (scaled). Full azimuthal symmetry is assumed.
- charged pions are traced in the spectator EM field.

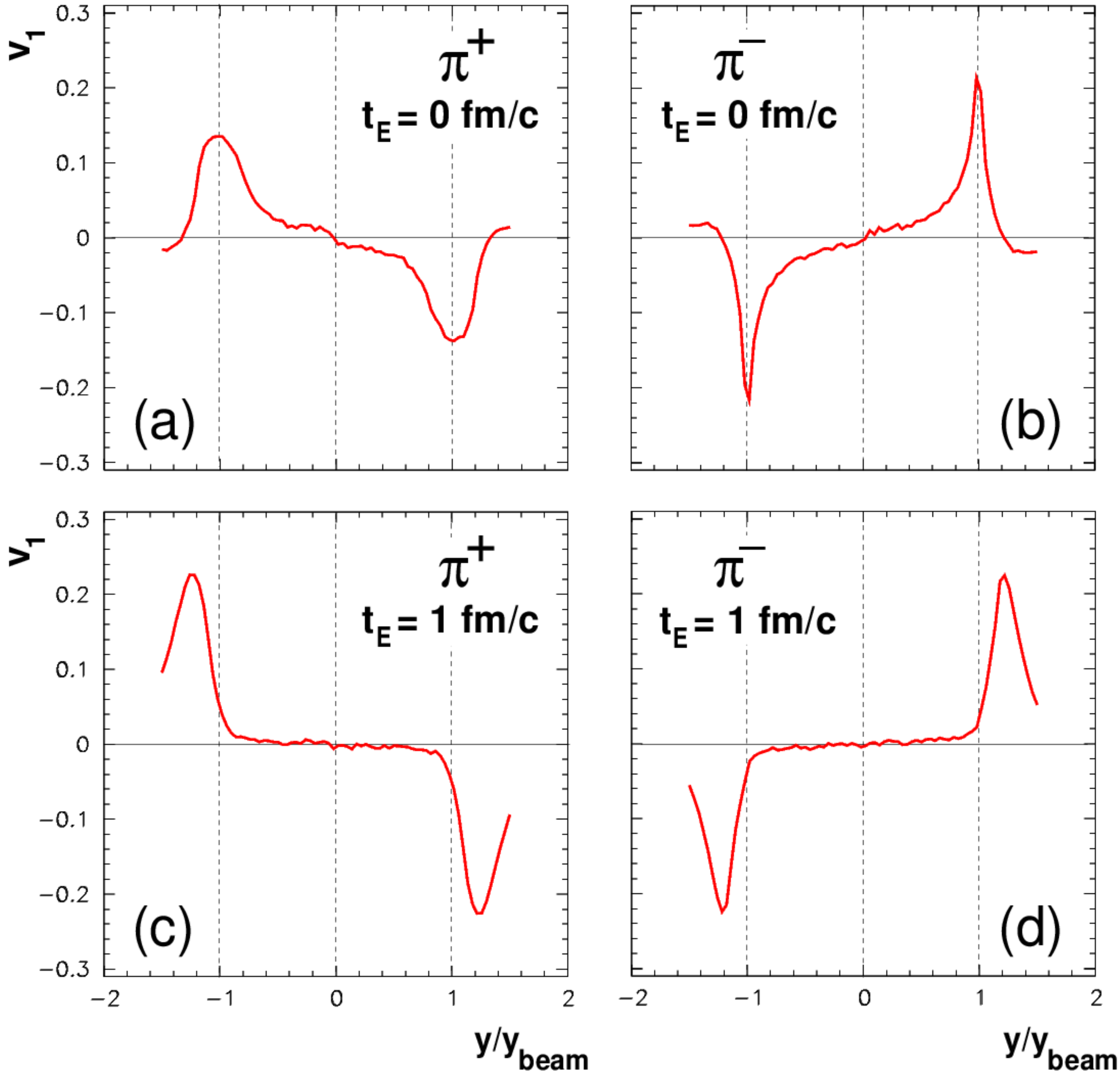
precise NA49 data on N+N collisions
C. Alt et al., Eur. Phys. J. C45 (2006) 343.

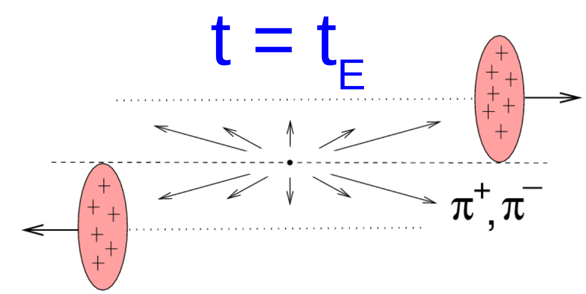
typically 42,000,000 pions.

includes retardation, etc.

Pb+Pb peripheral, $\sqrt{s_{NN}}$=17.3 GeV

0 < p_T < 1 GeV/c

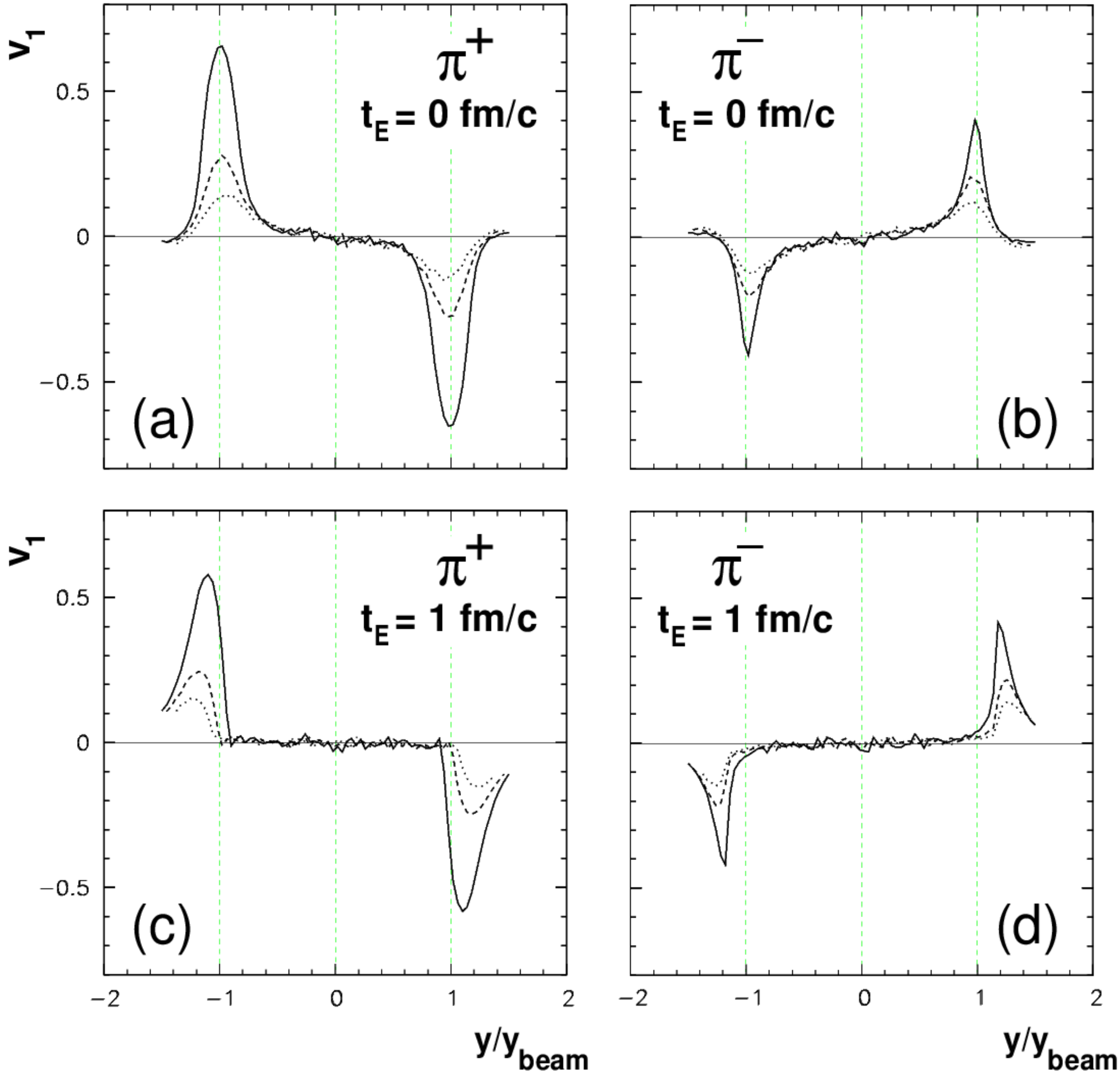


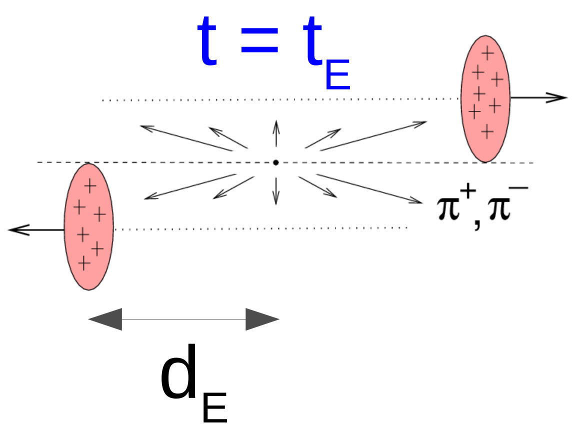


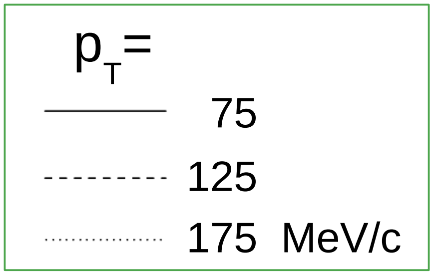
Dependence on initial conditions.

Dependence on transverse momentum

Pb+Pb peripheral, $\sqrt{s_{NN}}$=17.3 GeV

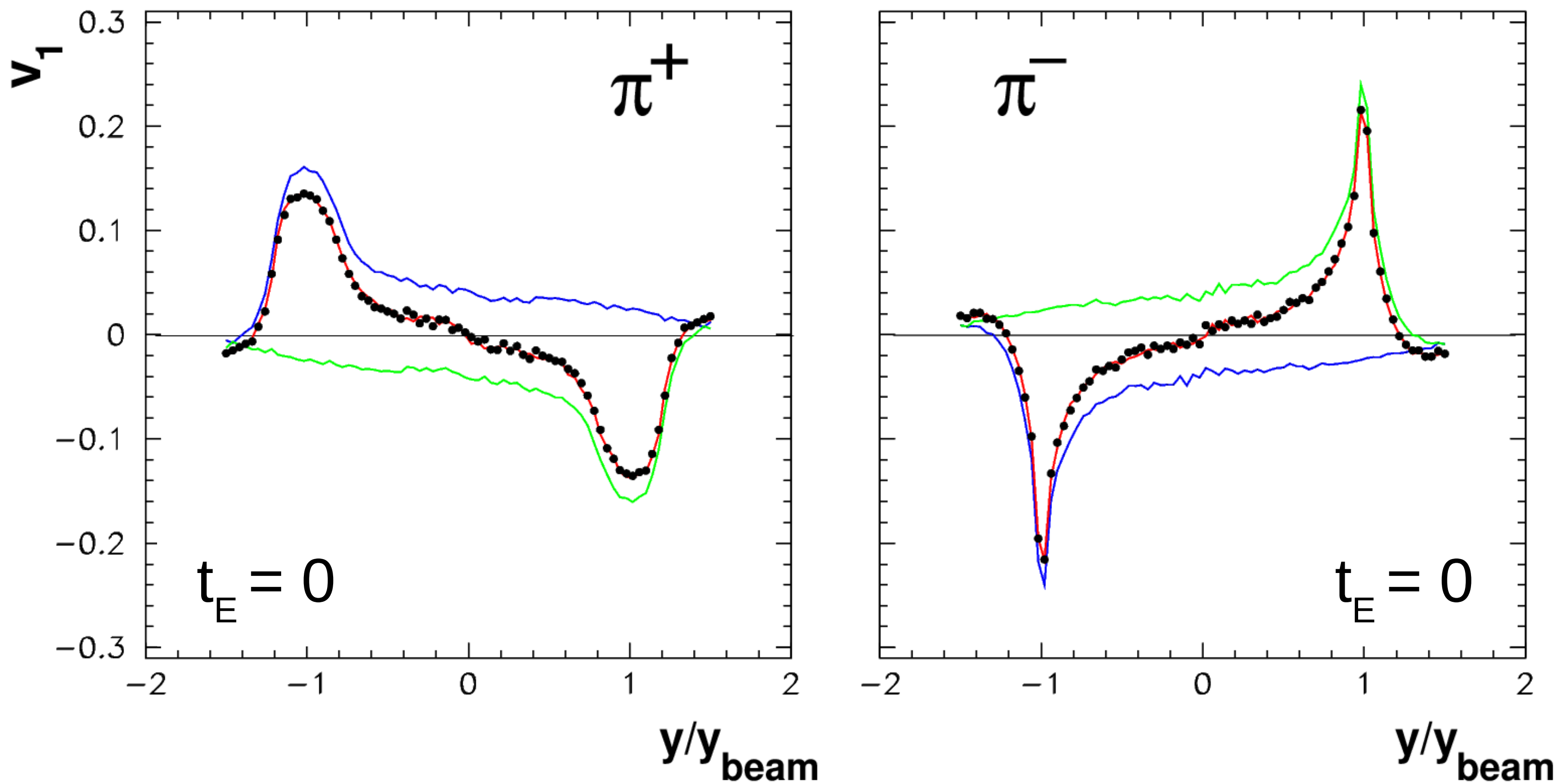






Side remark on the two spectators

Pb+Pb peripheral,
$\sqrt{s_{NN}}$=17.3 GeV
$0 < p_T < 1$ GeV/c



Green solid – only **projectile spectator**
Blue solid – only **target spectator**
Red solid – **both spectators**

Dots - direct addition:
v_1(projectile) + v_1(target) = v_1(both spectators)

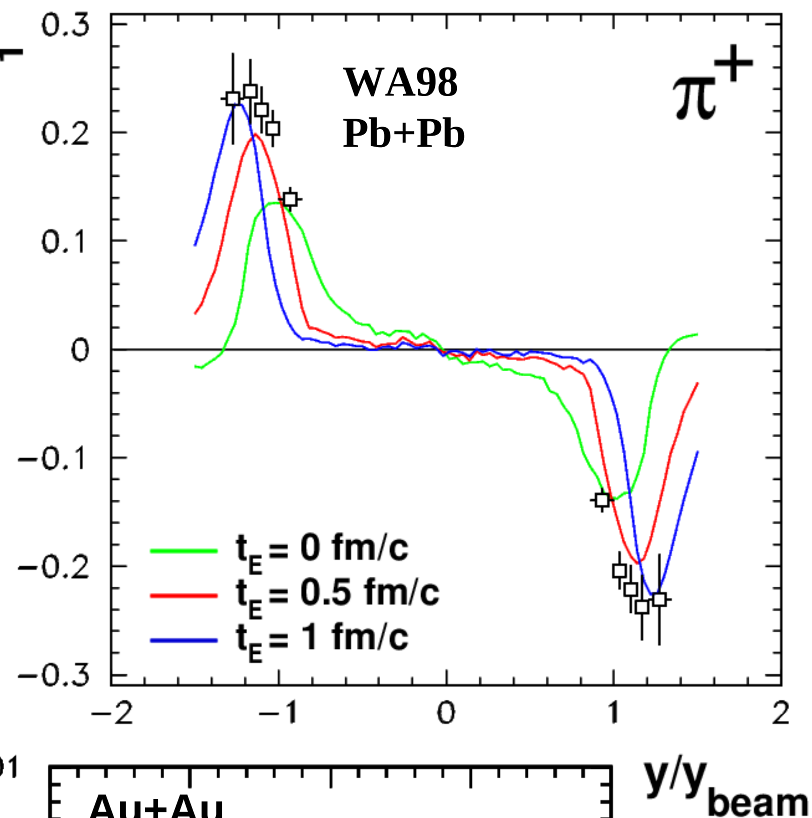
NA49 / NA61

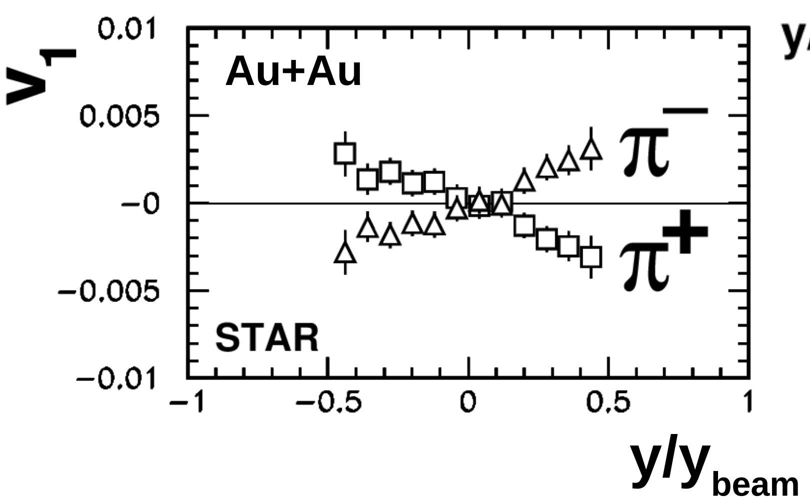
Experiments (data exists or could come):

WA98

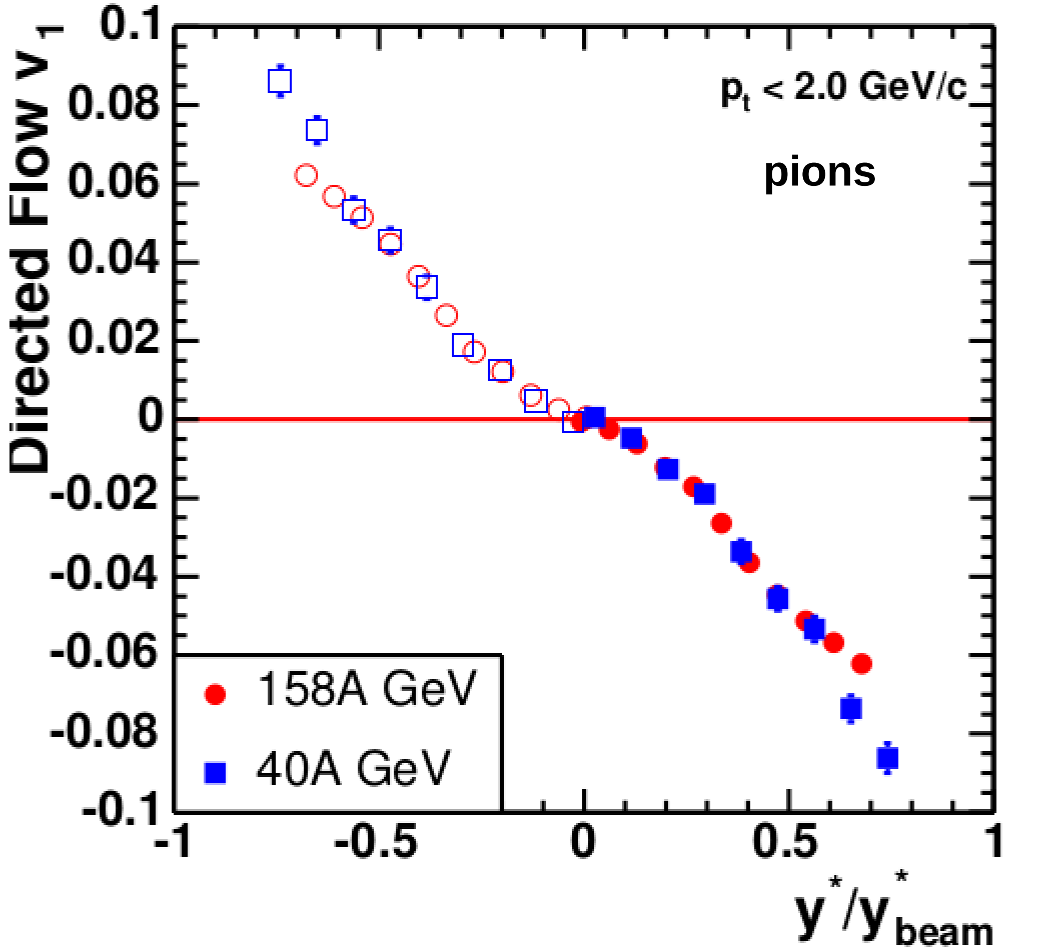
STAR

NICA → *research proposal*, Dec 2012





NA49, Phys.Rev. C68 (2003) 034903



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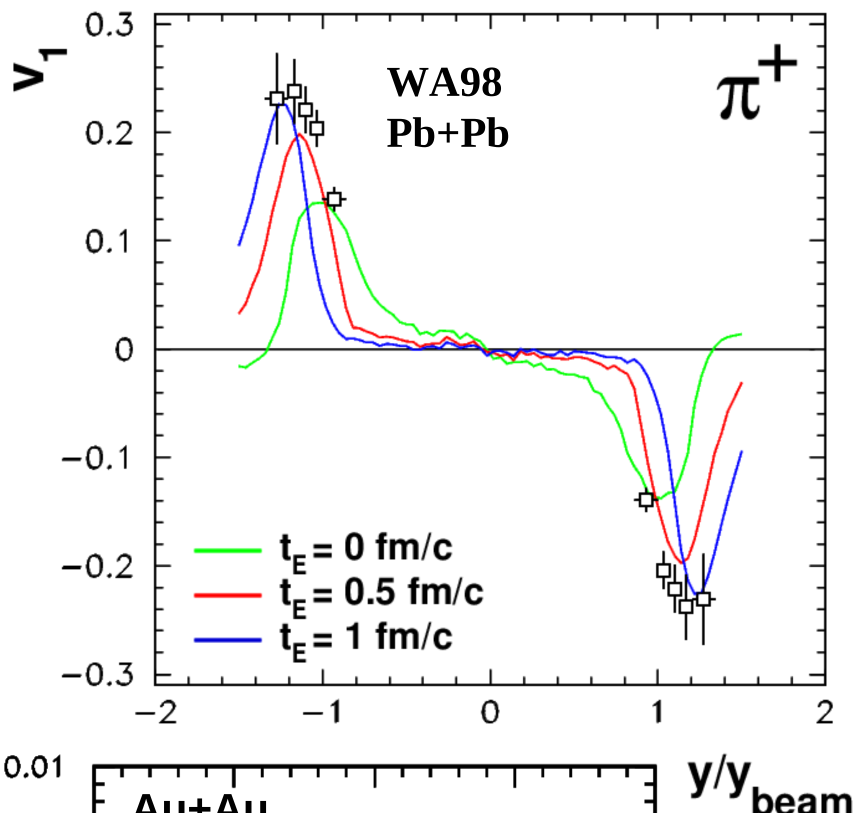

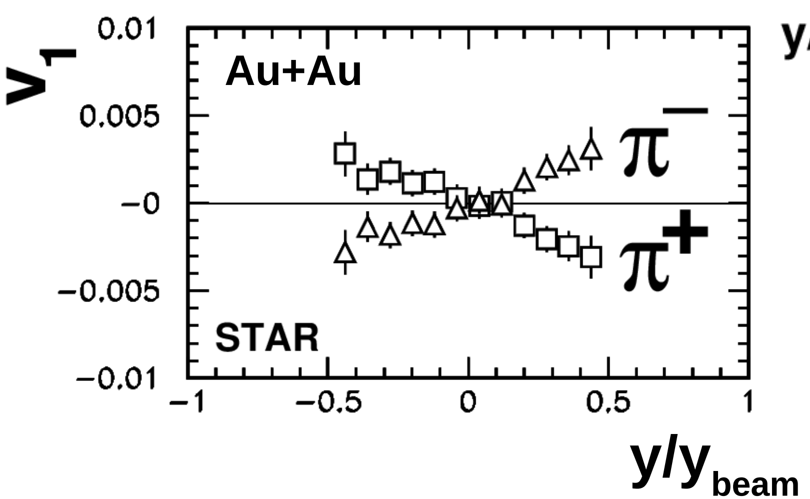

NA49, Phys.Rev. C68 (2003) 034903