Electromagnetic effects in heavy ion collisions: can we hope for a "new femtoscopy"?

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H. Niewodniczański Institute of Nuclear Physics
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work in collaboration with
Antoni Szczurek
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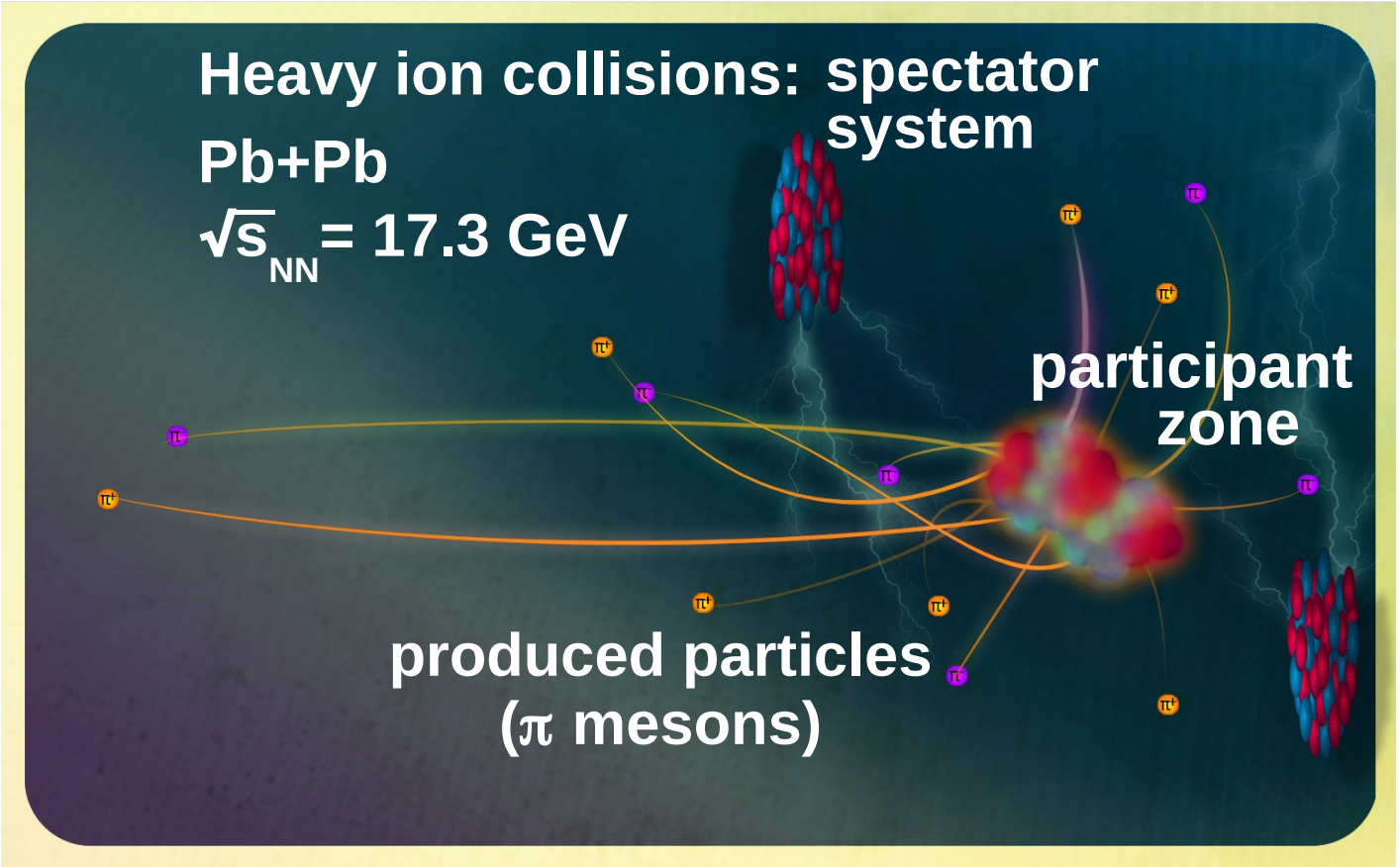
Mariola Kłusek-Gawenda
Vitalii Ozvenchuk
Mirosław Kiełbowicz

1) Introduction ;
2) EM effects in heavy ion collisions ;
3) Space-time evolution of the system ;
4) NA61 experiment ;
5) Summary & outlook.

1) Introduction

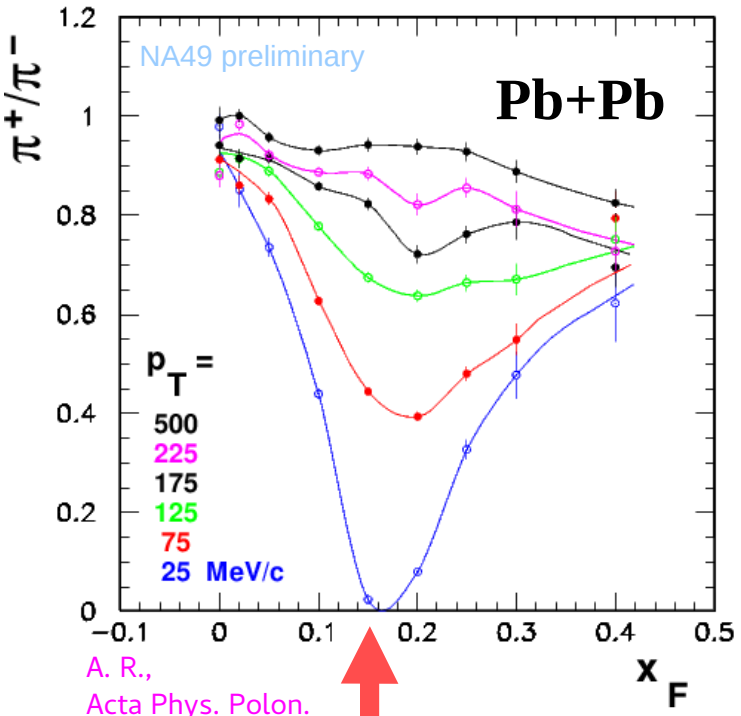


by I. Sputowska

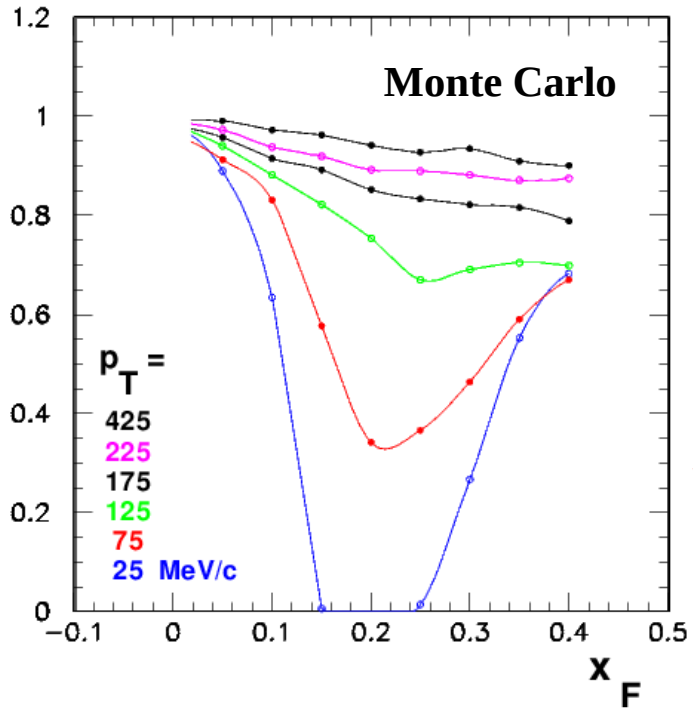
- Charged spectators in non-central collisions generate electromagnetic fields.

- Can we use them as a new source of information on the space-time evolution of the system ?

2) EM effects in heavy ion collisions



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



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

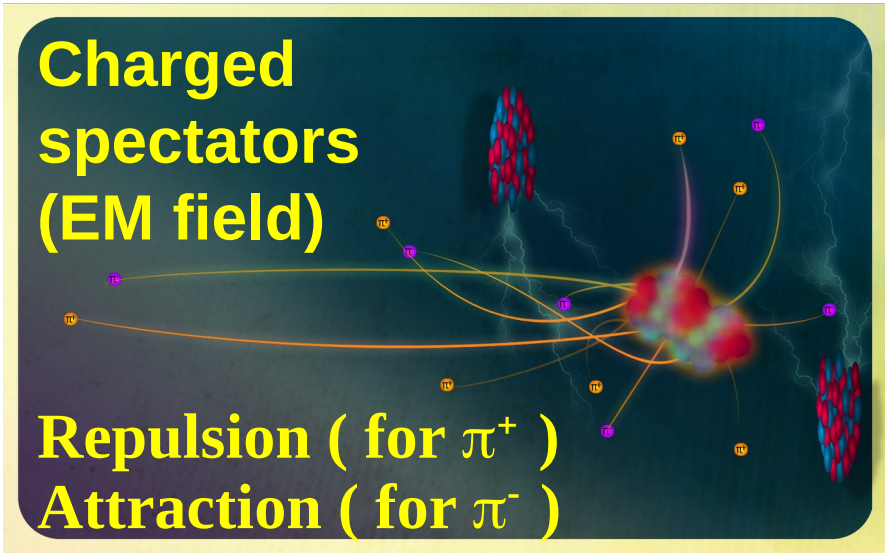
NA49,
$\sqrt{s_{NN}}$=17.3 GeV
Pb+Pb,
peripheral

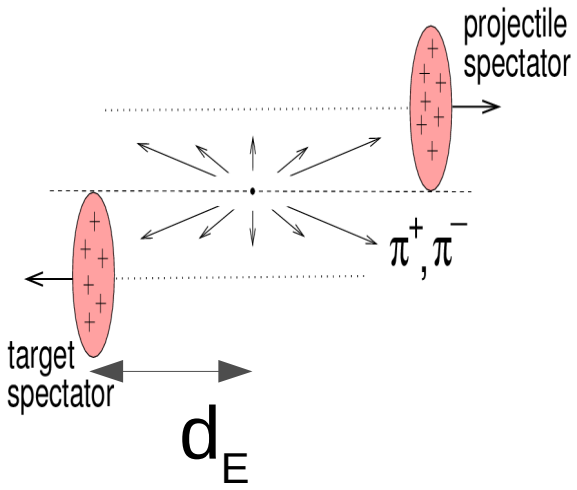
y = y_{beam}

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

$d_E \approx 0.75$ fm !

(c.m.s.)





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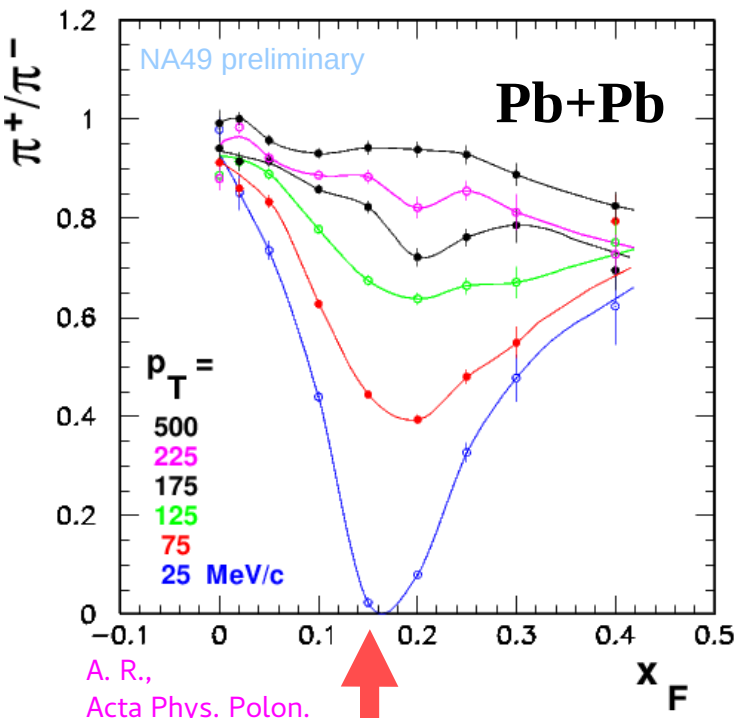

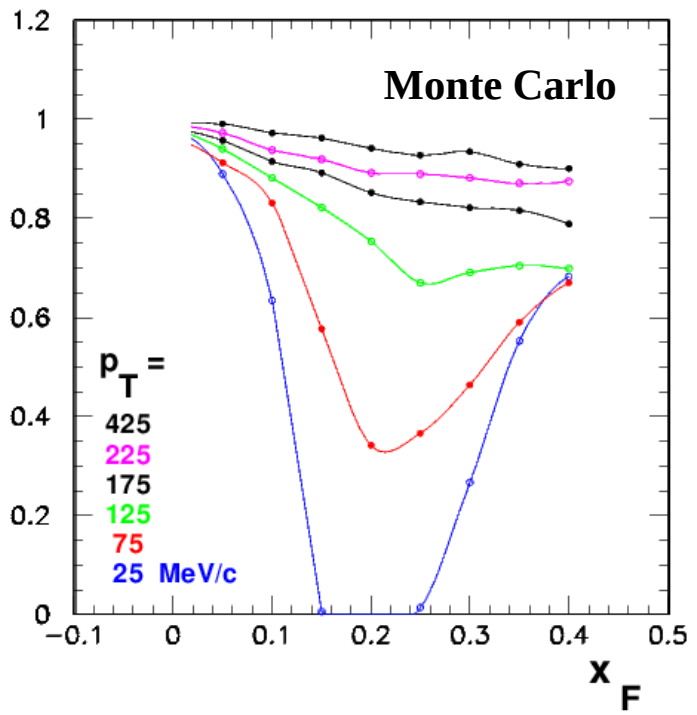

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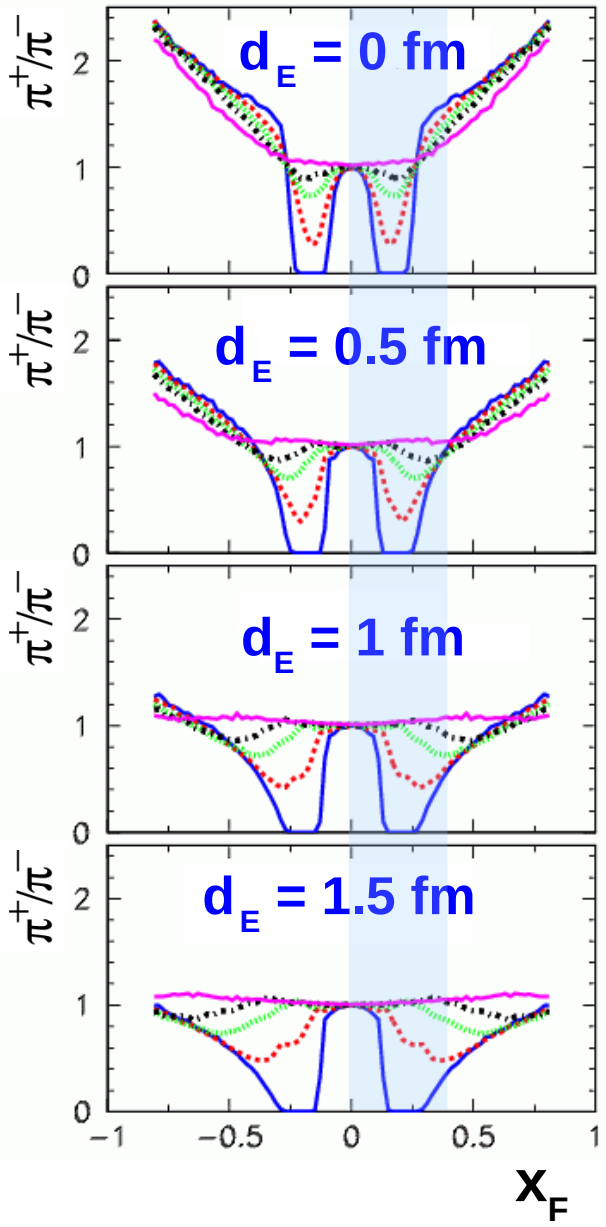

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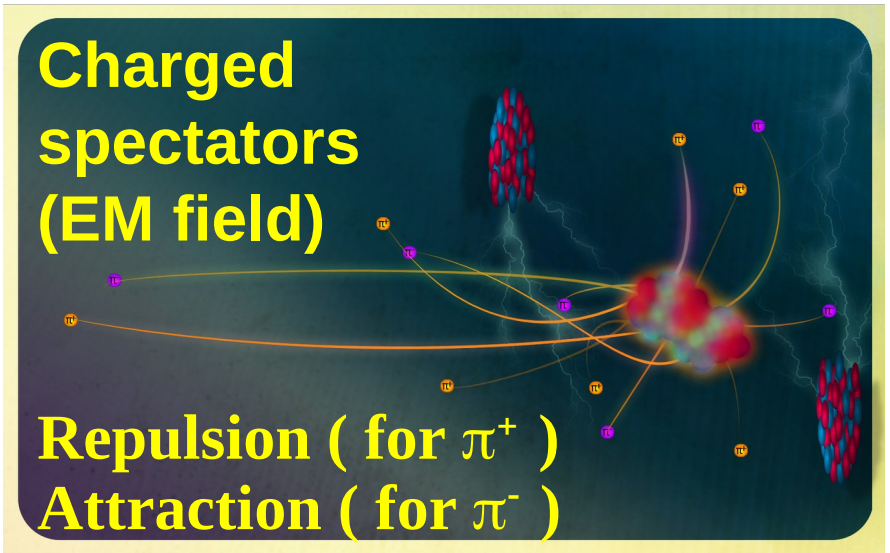

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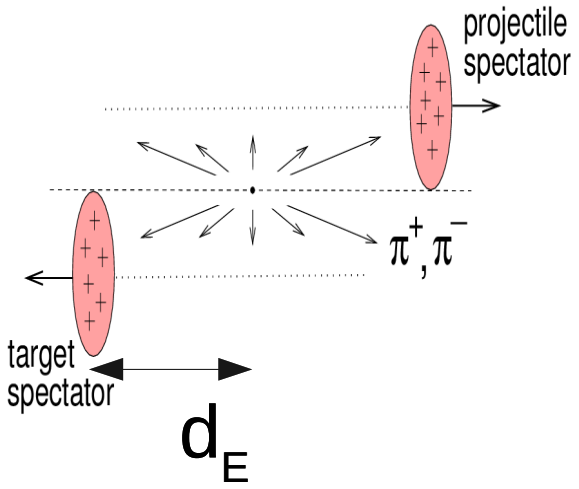

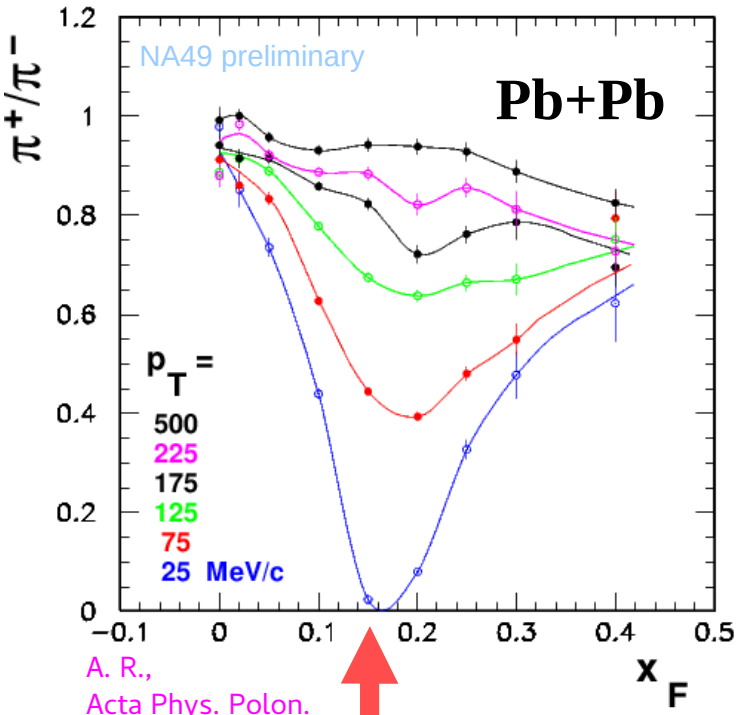

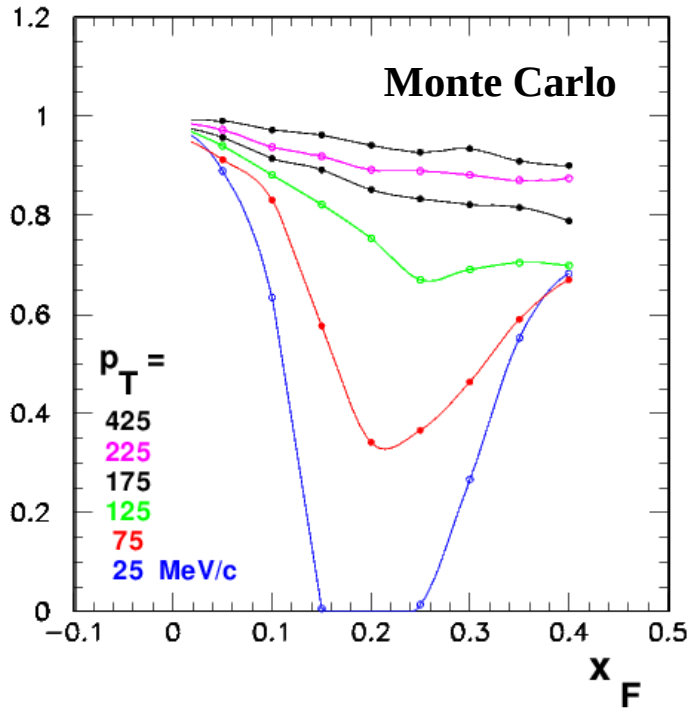

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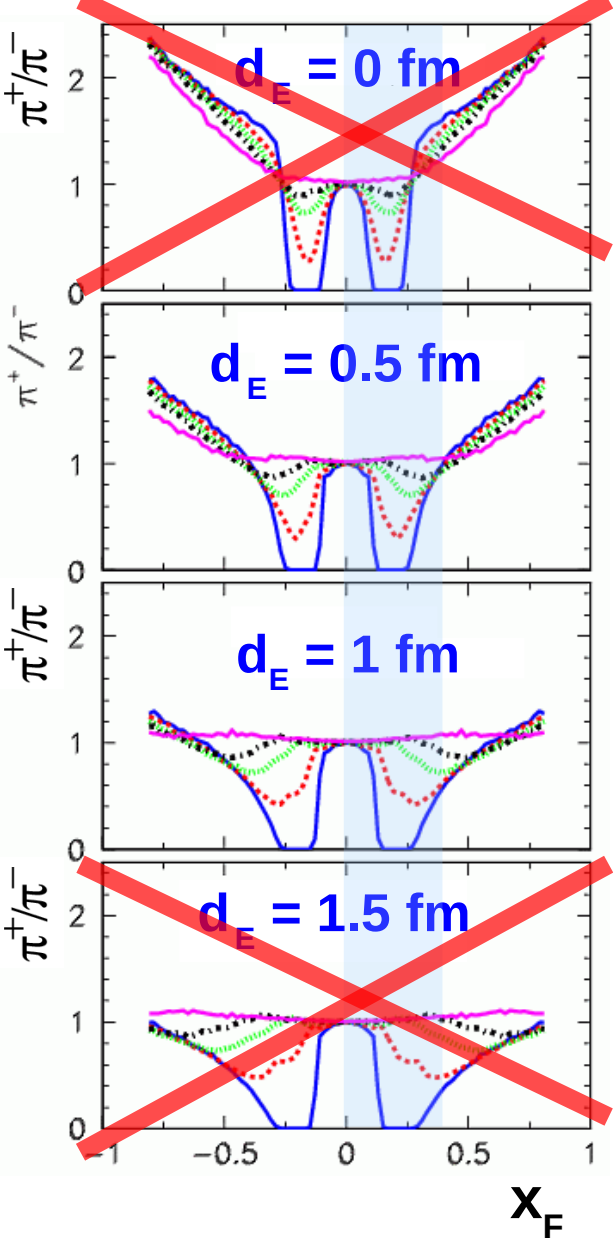

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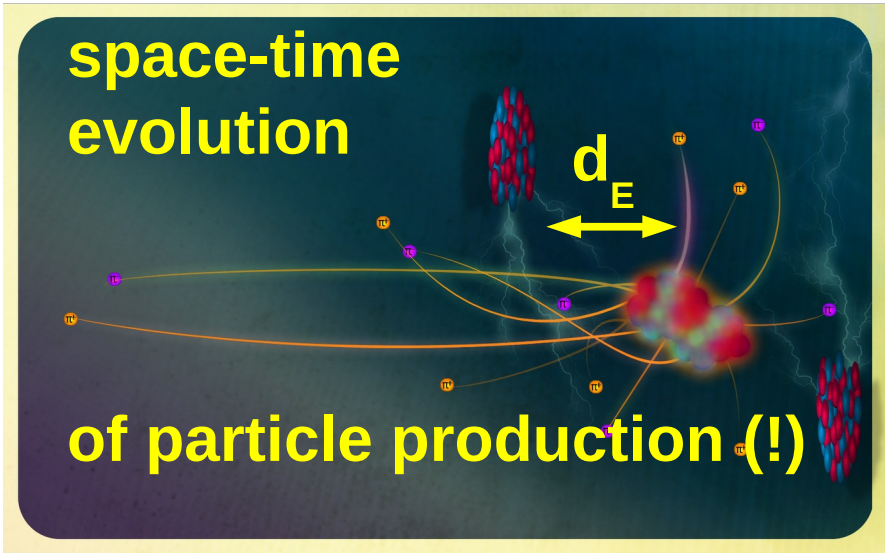

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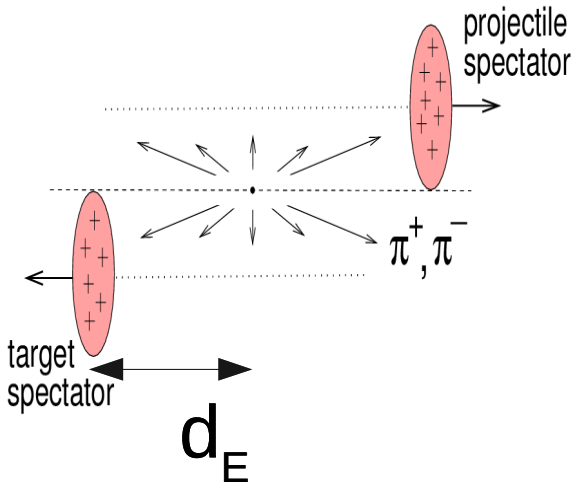
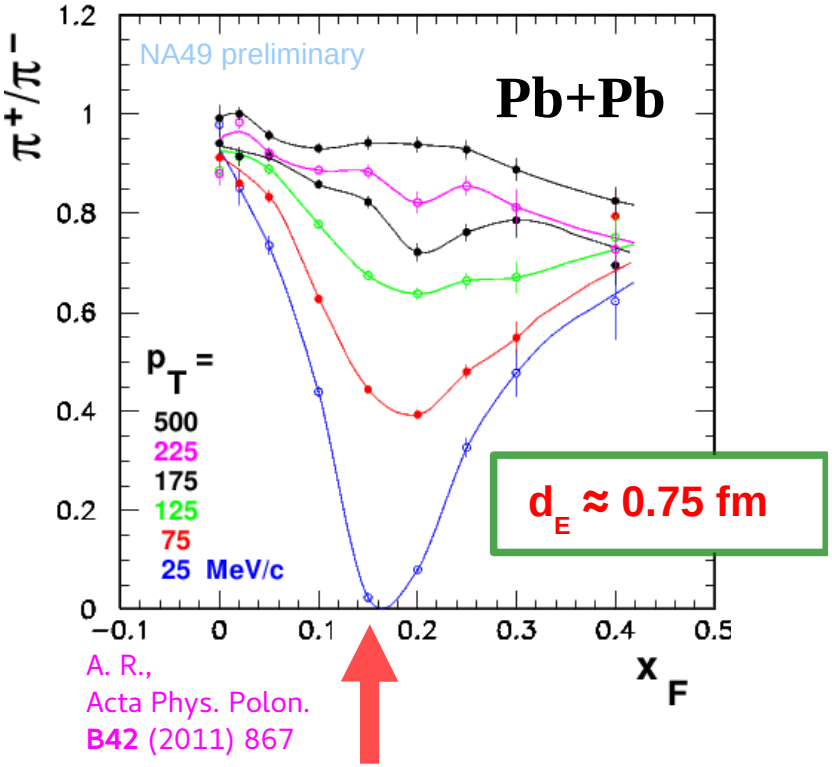
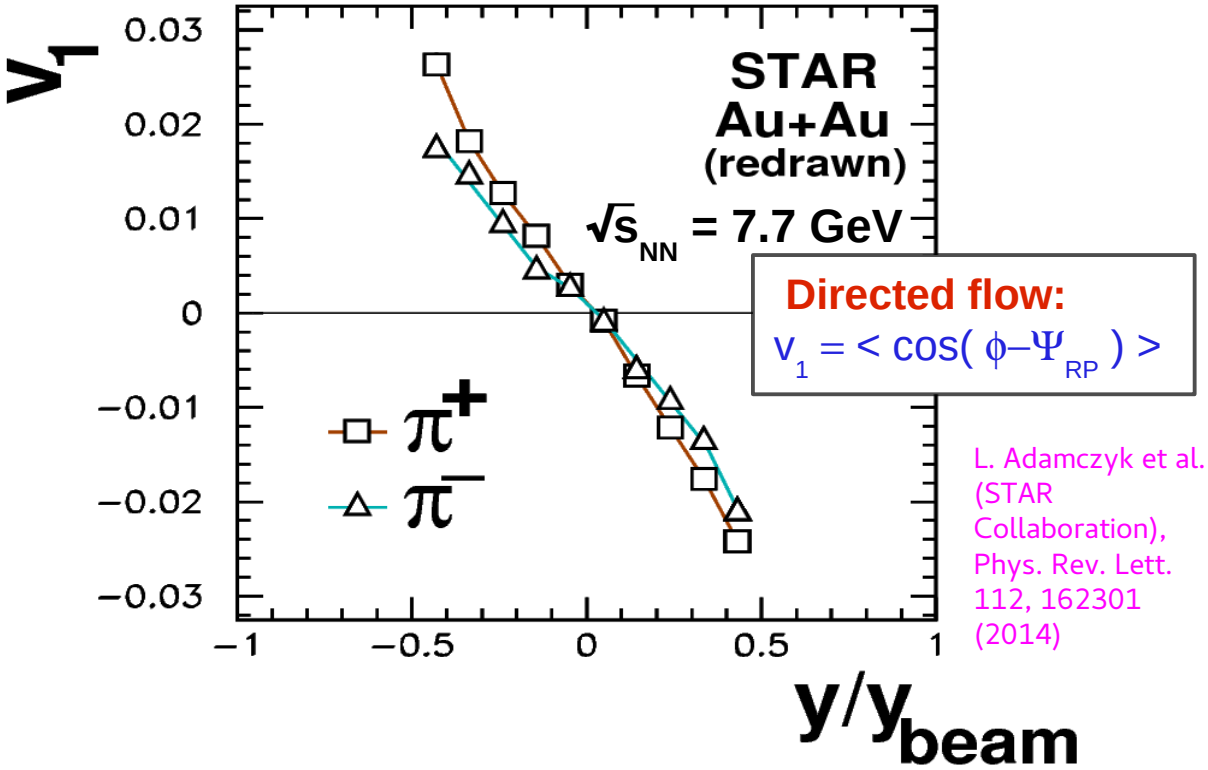
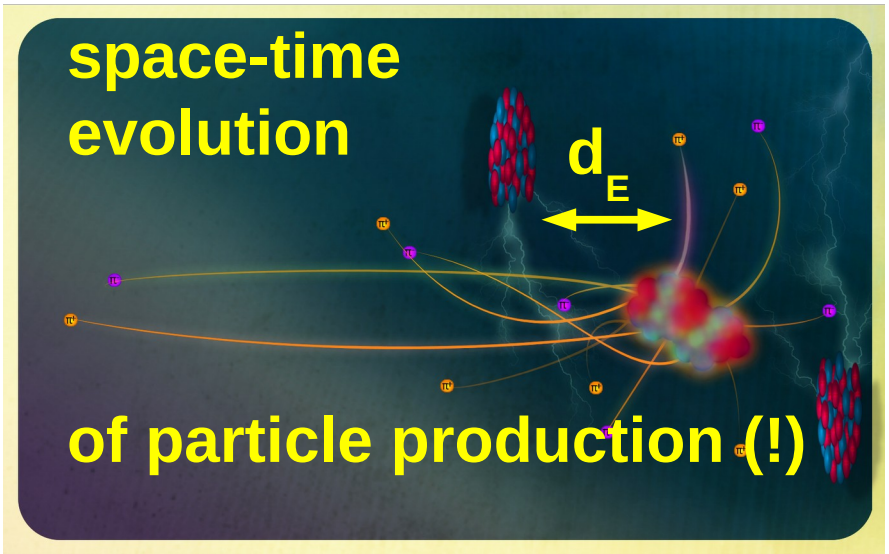






$$y = \frac{1}{2} \ln \left(\frac{E+p_L}{E-p_L} \right)$$



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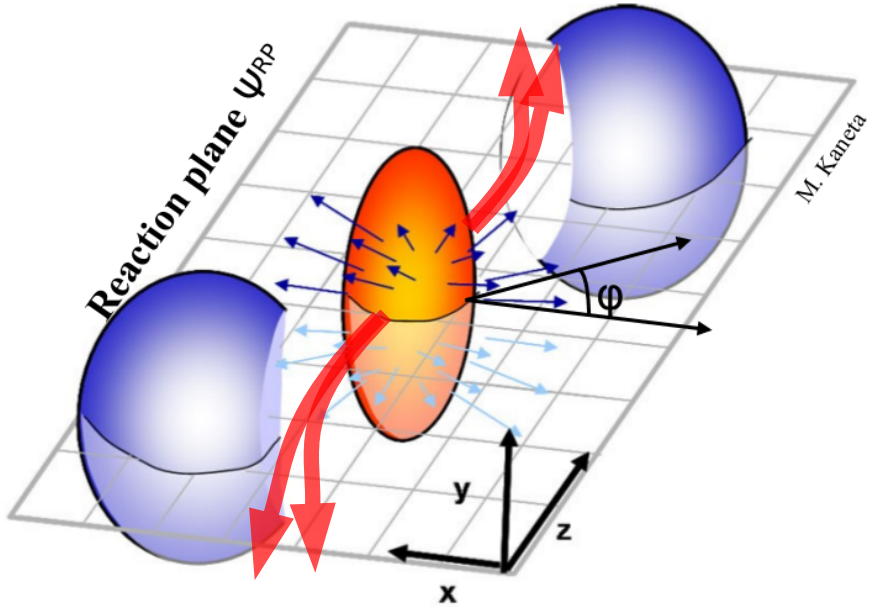

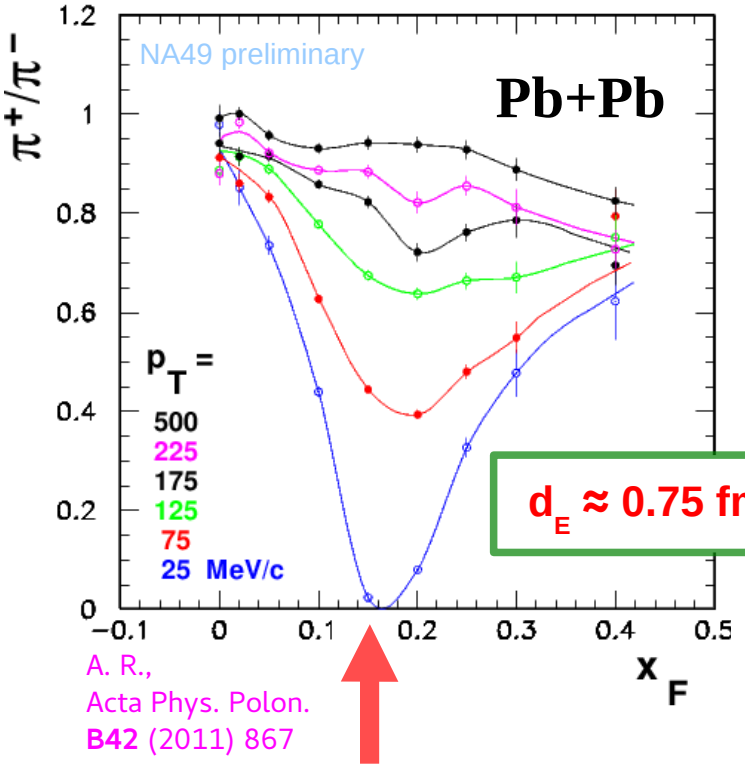

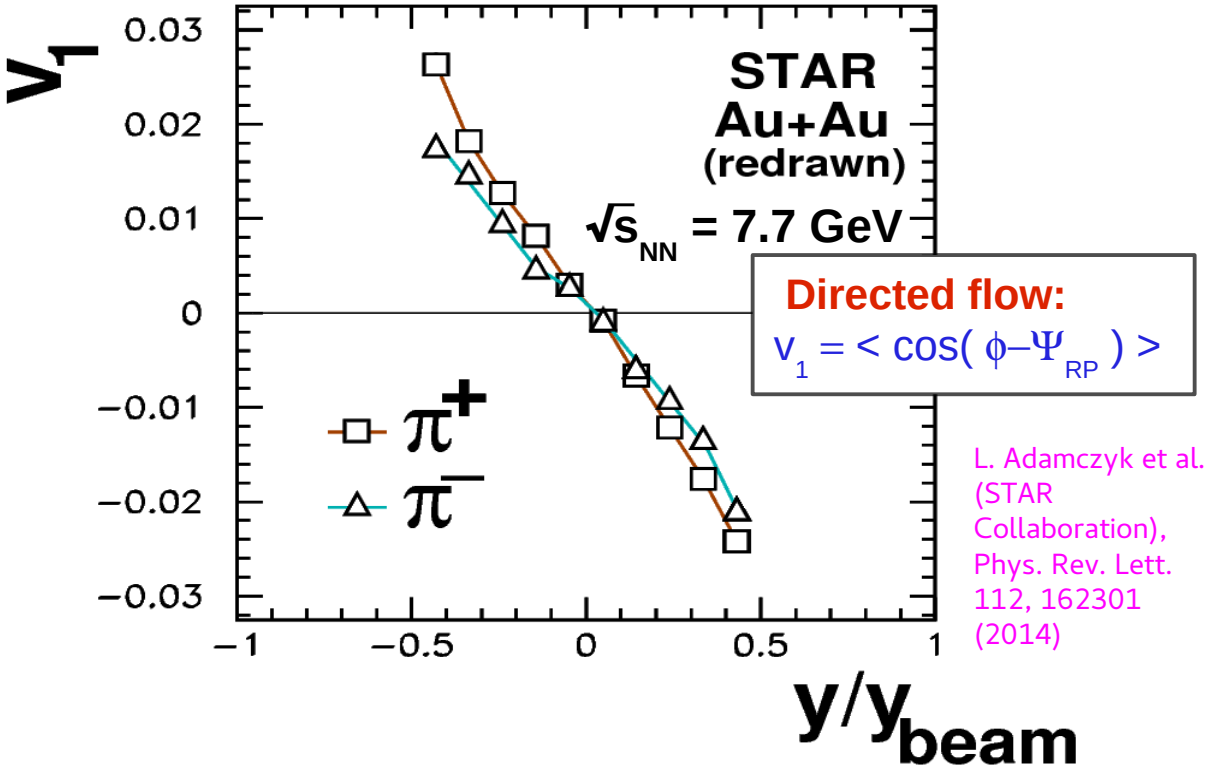

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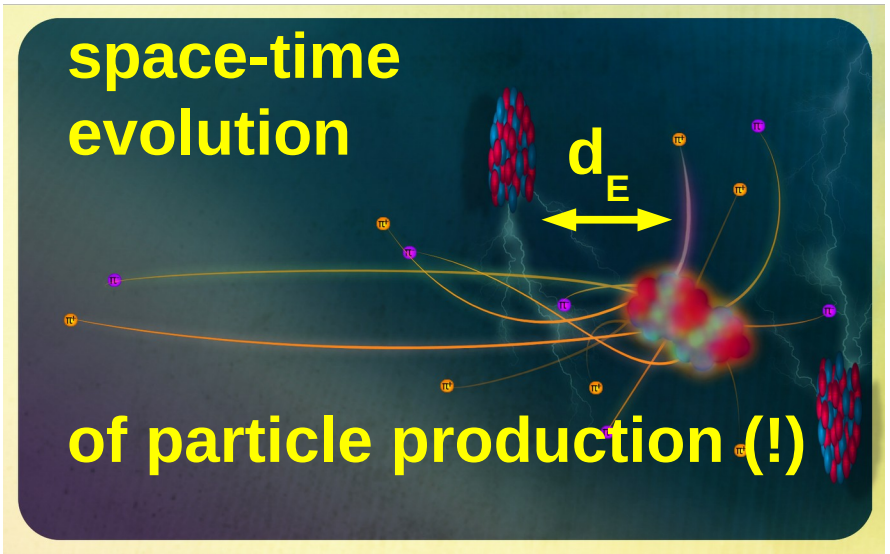

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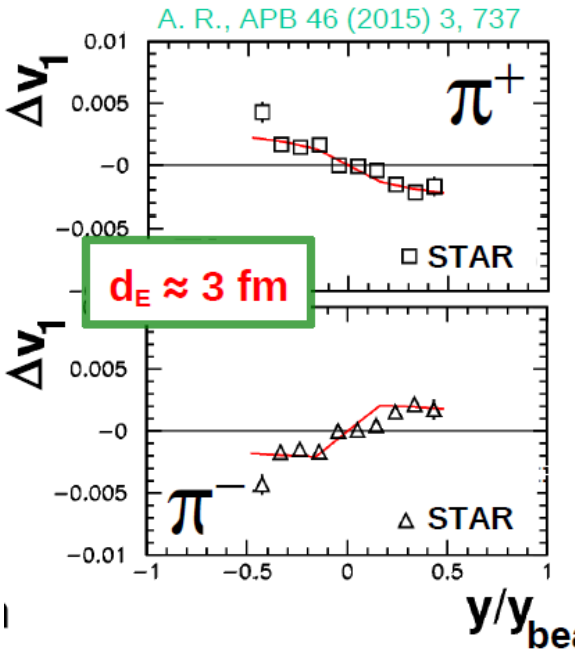

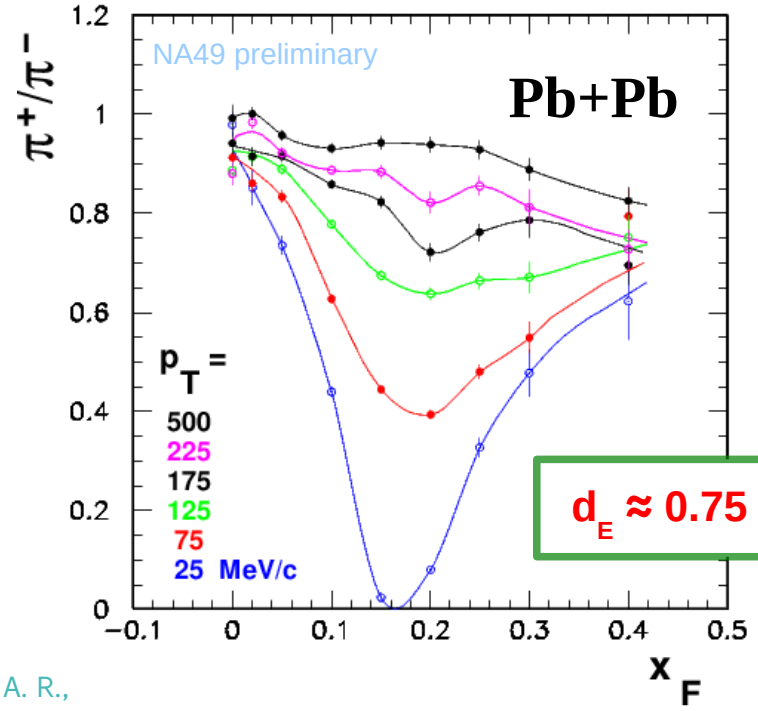

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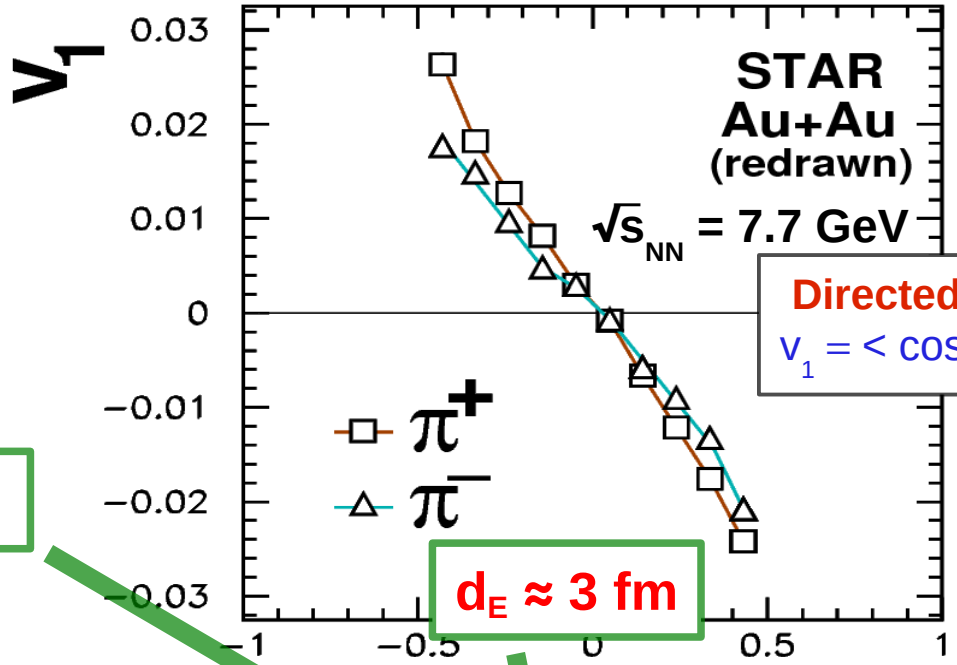
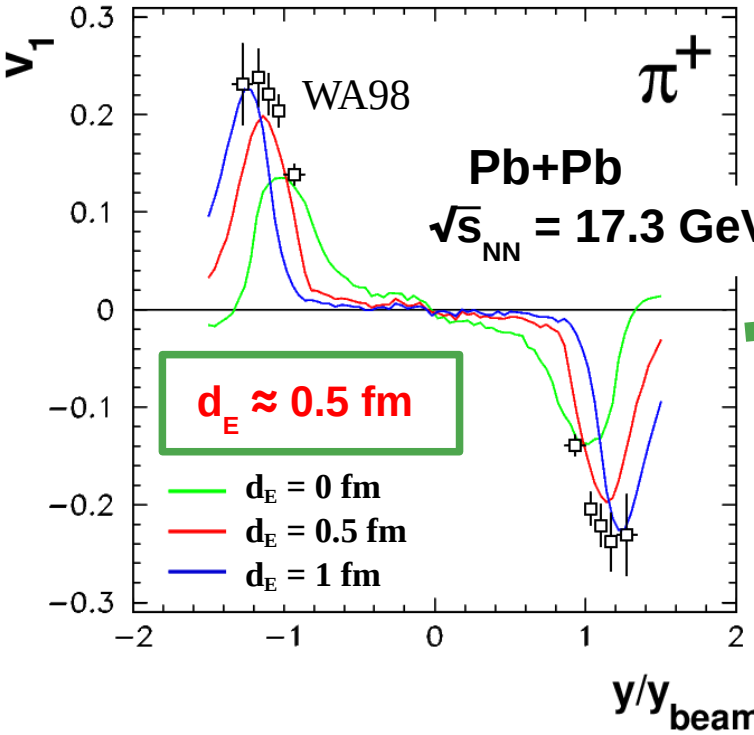


Directed flow:
$v_1 = \langle \cos(\phi - \Psi_{RP}) \rangle$

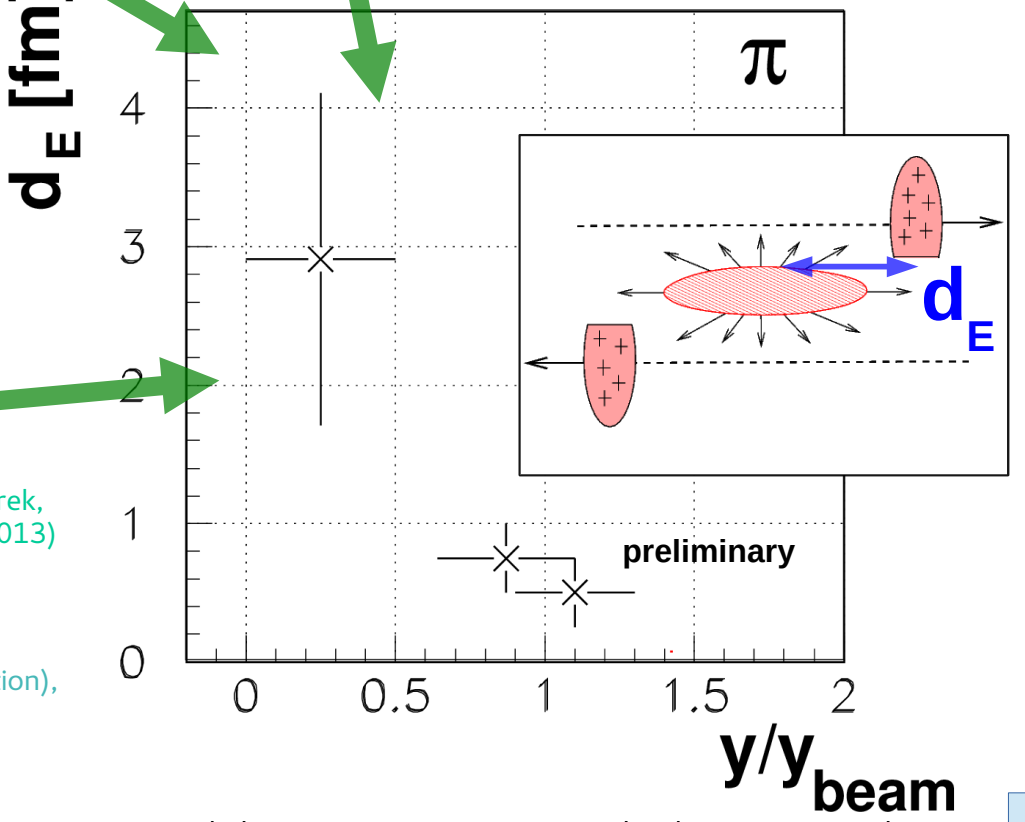
L. Adamczyk et al. (STAR Collaboration), Phys. Rev. Lett. 112, 162301 (2014)

$d_E \approx 3$ fm

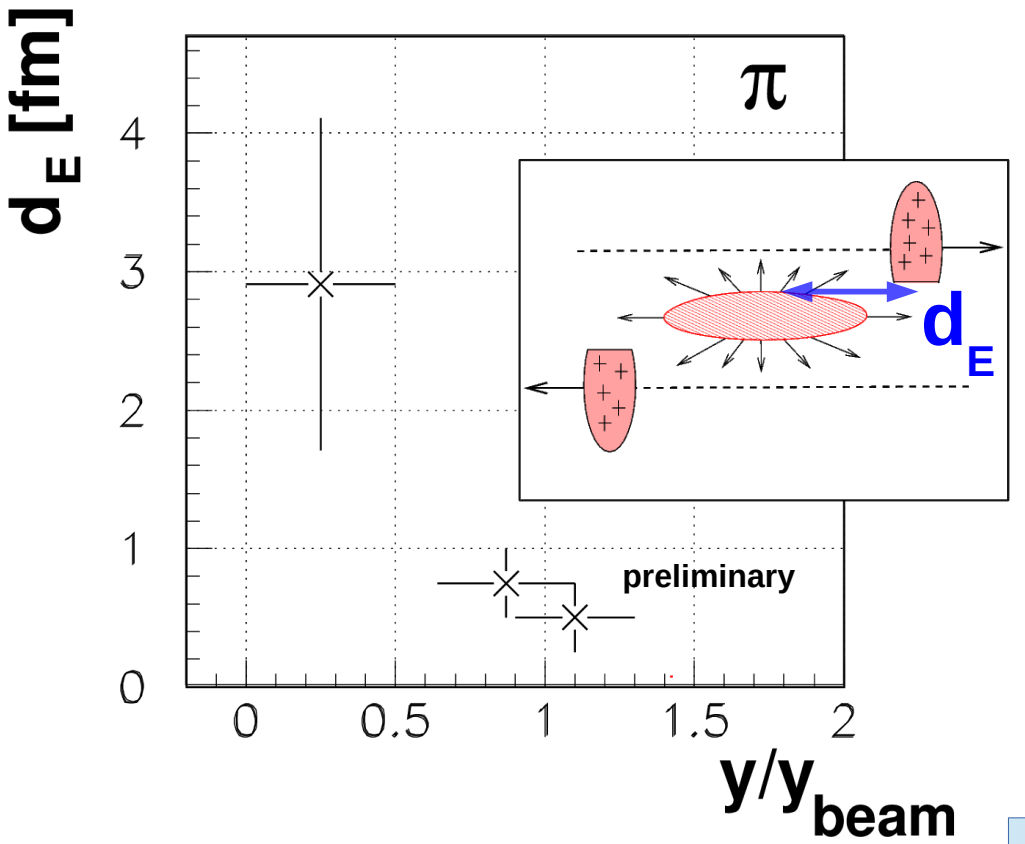


A. R. and A. Szczurek, Phys. Rev. **C87** (2013) 054909.

H. Schlagheck (WA98 Collaboration), Nucl. Phys. A **663** (2000) 725.



3) Space-time evolution of the system …



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Toy Monte Carlo model:

- pion production from resonances ;
- $\Delta \rightarrow p\pi$ and $\rho \rightarrow \pi\pi$;
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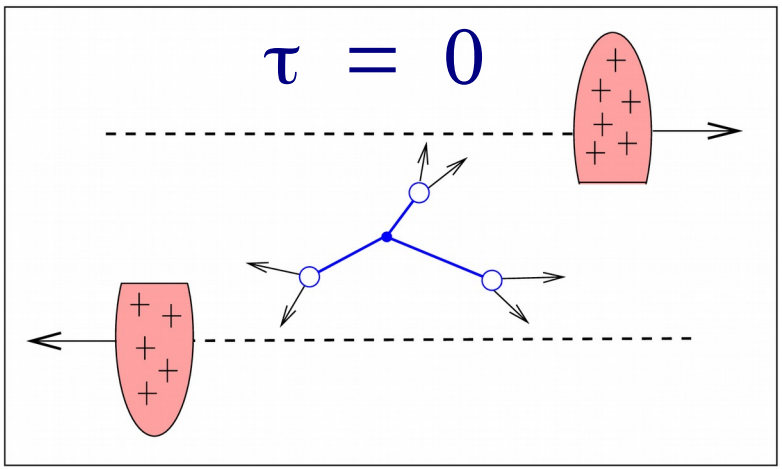
- baryon stopping of the Δ ;
- Breit-Wigner's, lifetimes, etc.



many thanks to
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L. Leśniak H.G. Fischer

Input:
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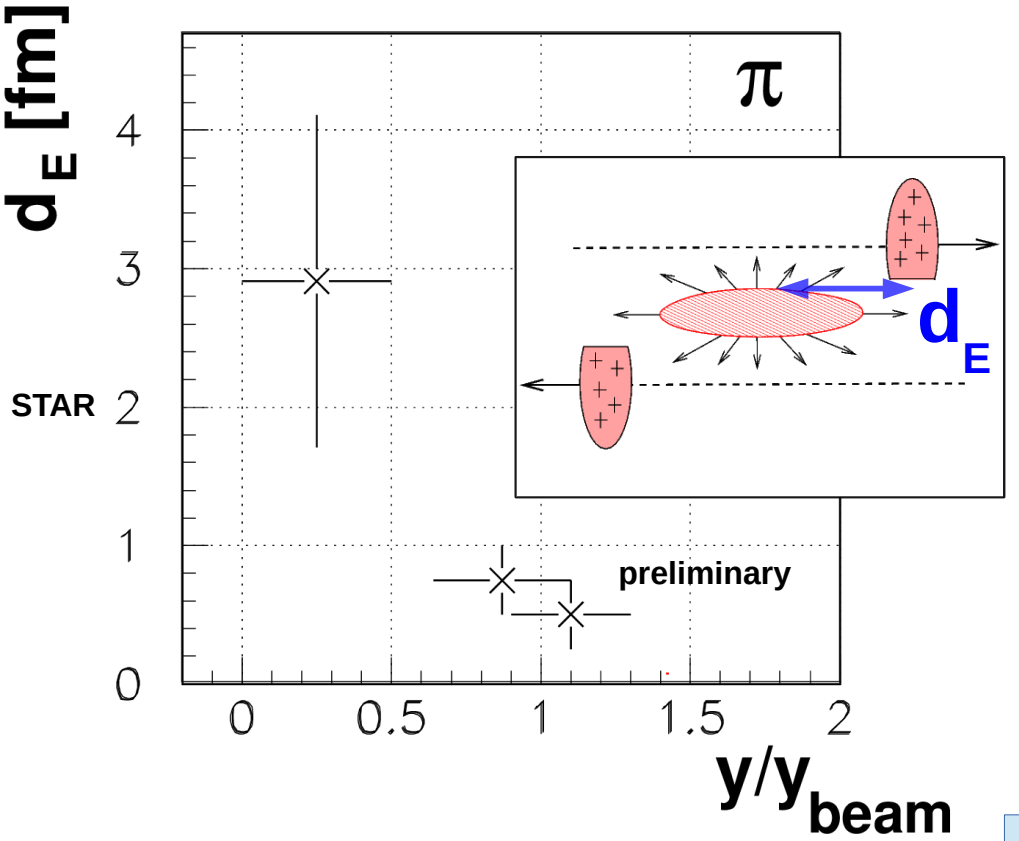
- M.Aguilar-Benitez et al., Z. Phys. C 50 (1991) 405.
- D. Drijard et al., Z. Phys. C 21 (1984) 321.
- D.E.Groom et al., Eur. Phys. C. 15 (2000) 1.
- A.R., CERN-THESIS-2003-005, and references therein.



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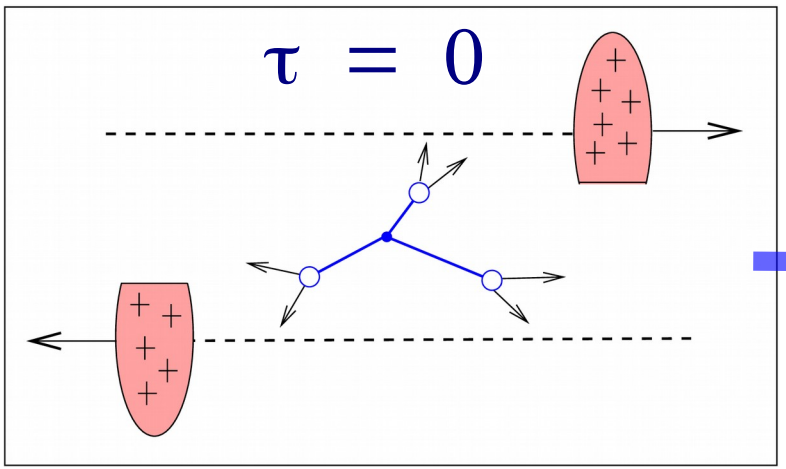

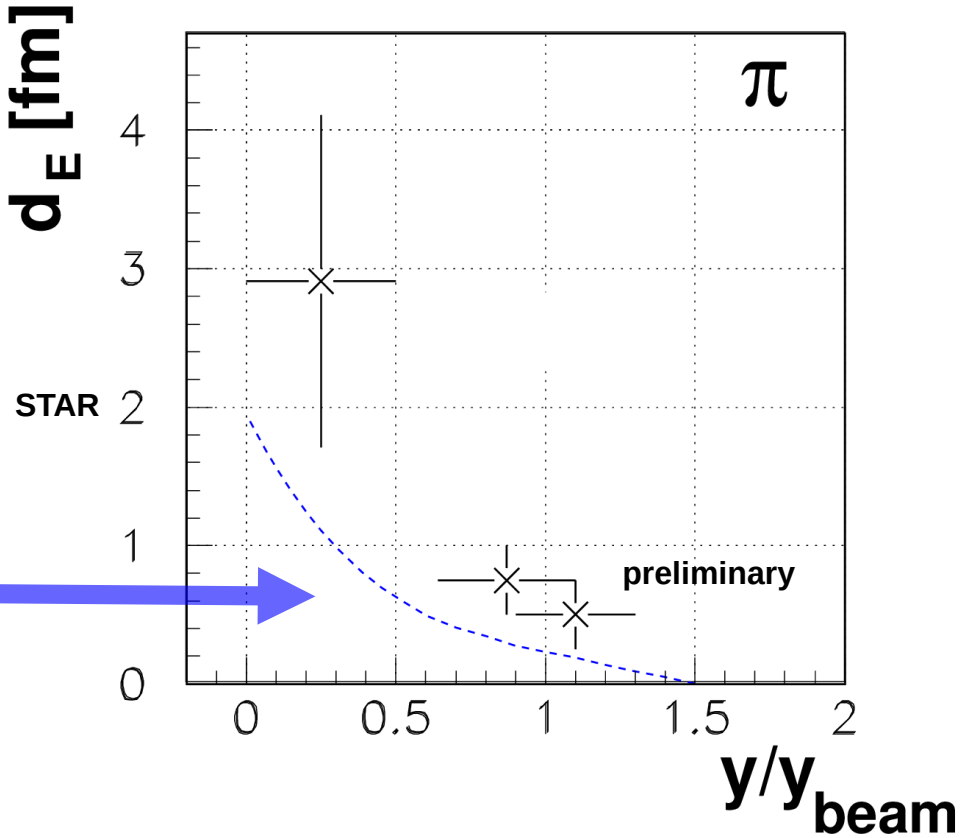

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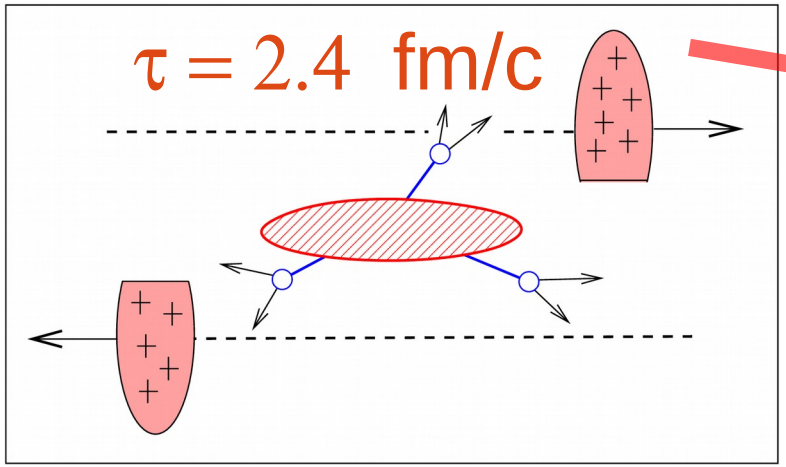

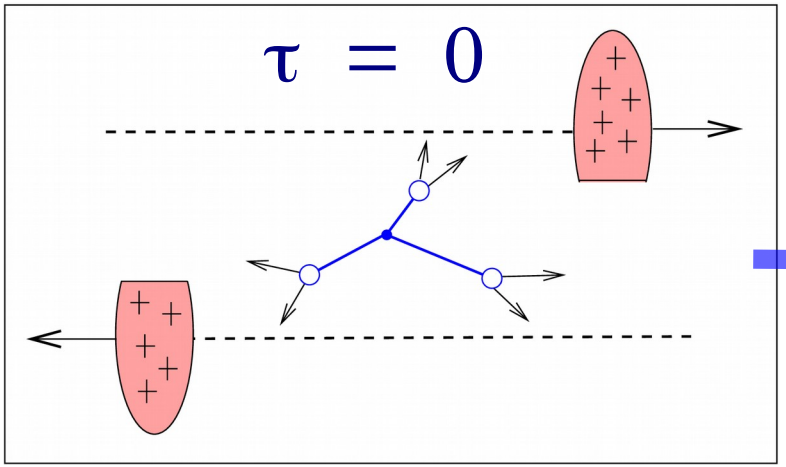

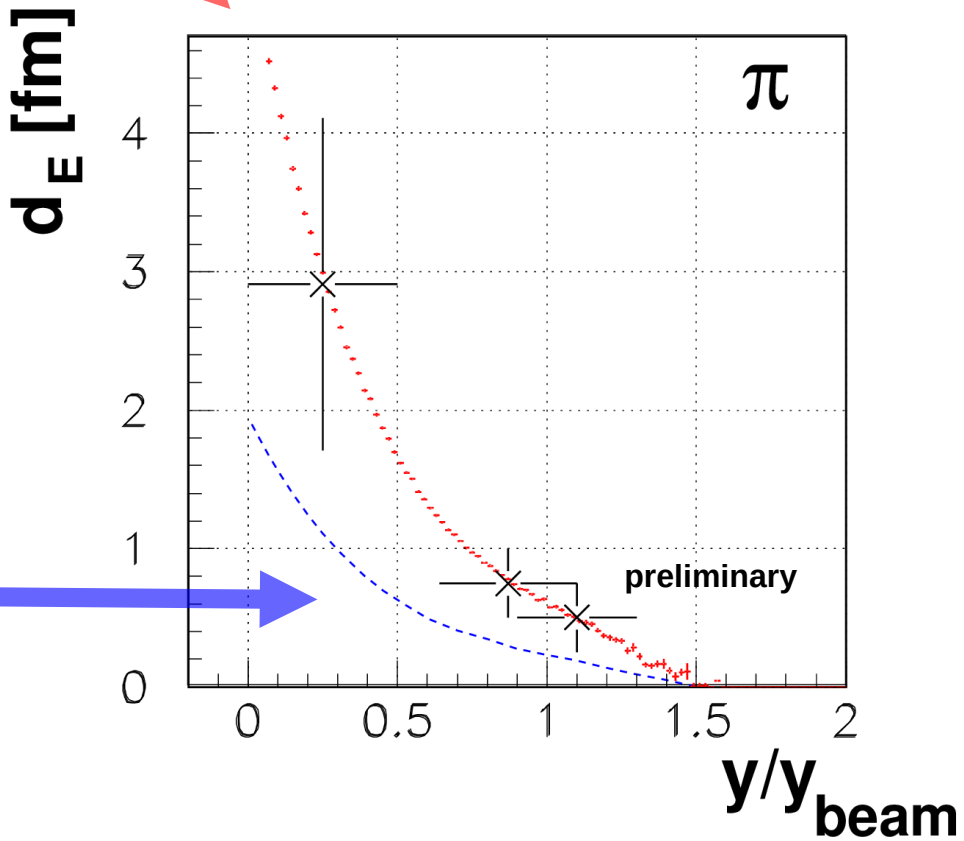

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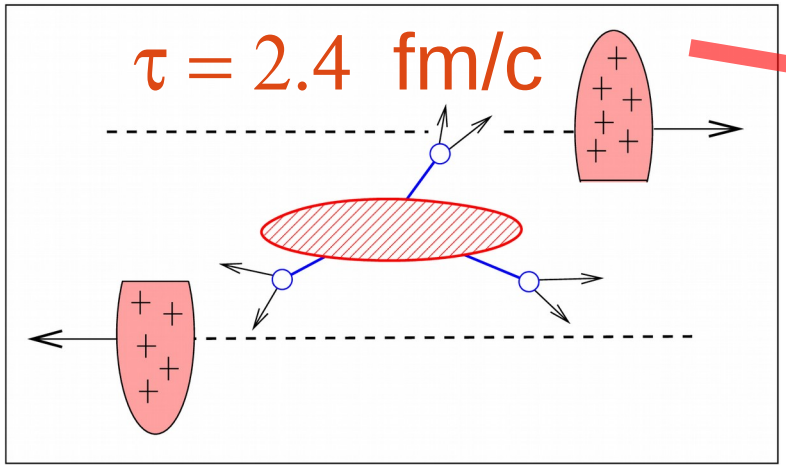

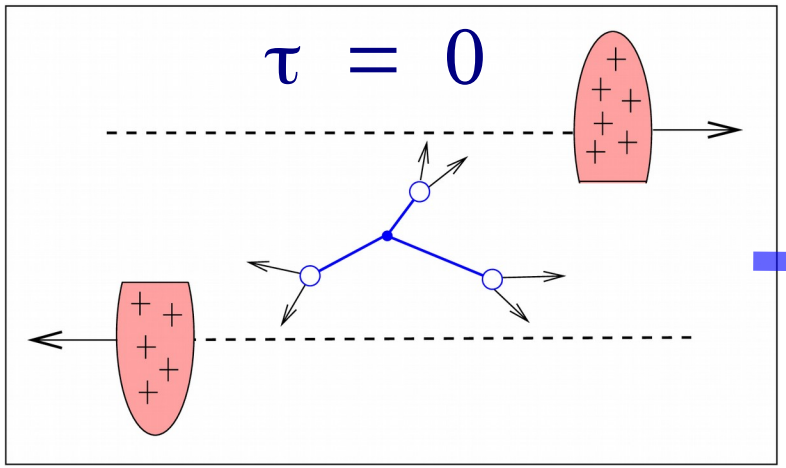

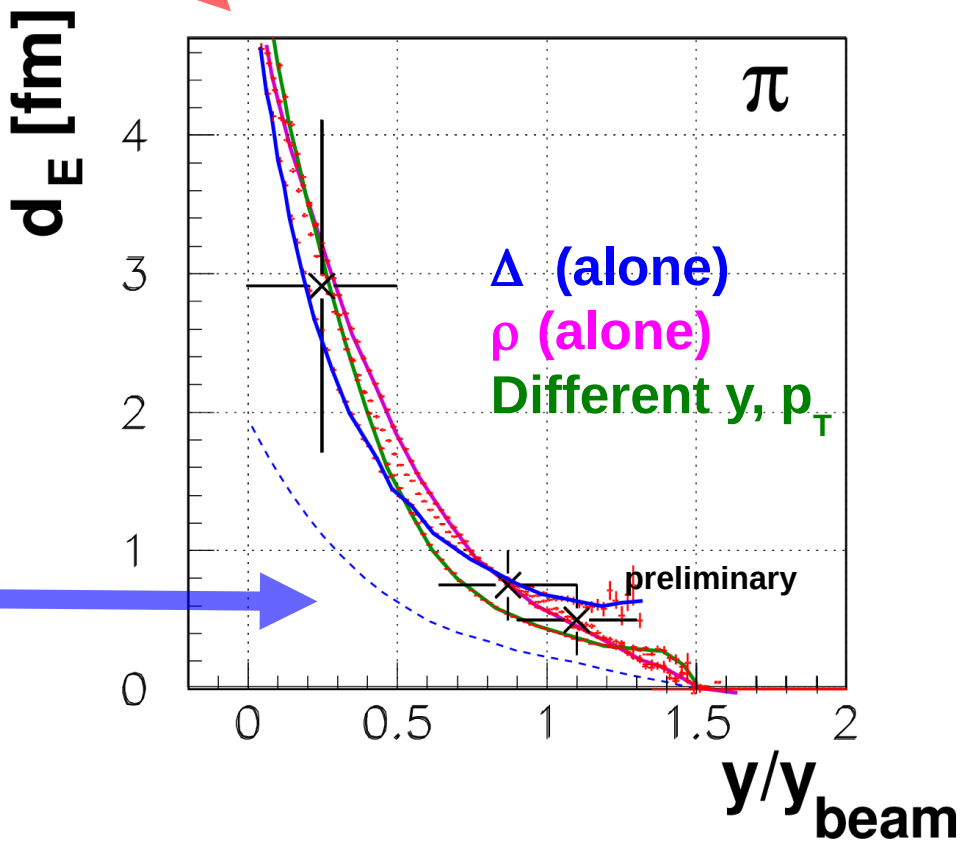

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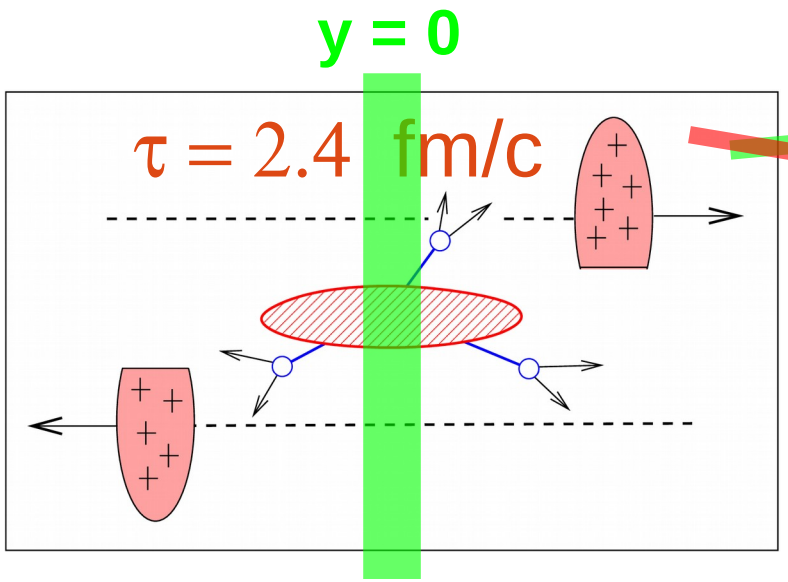
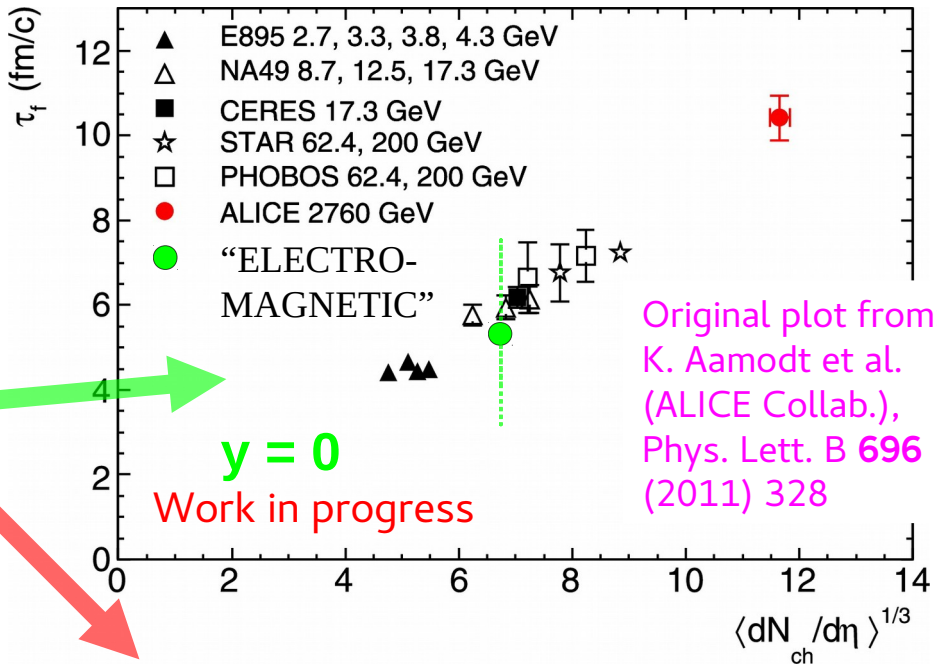
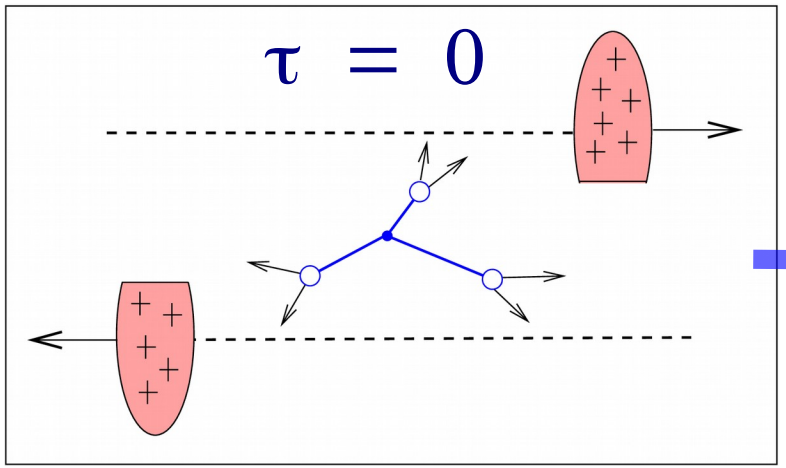
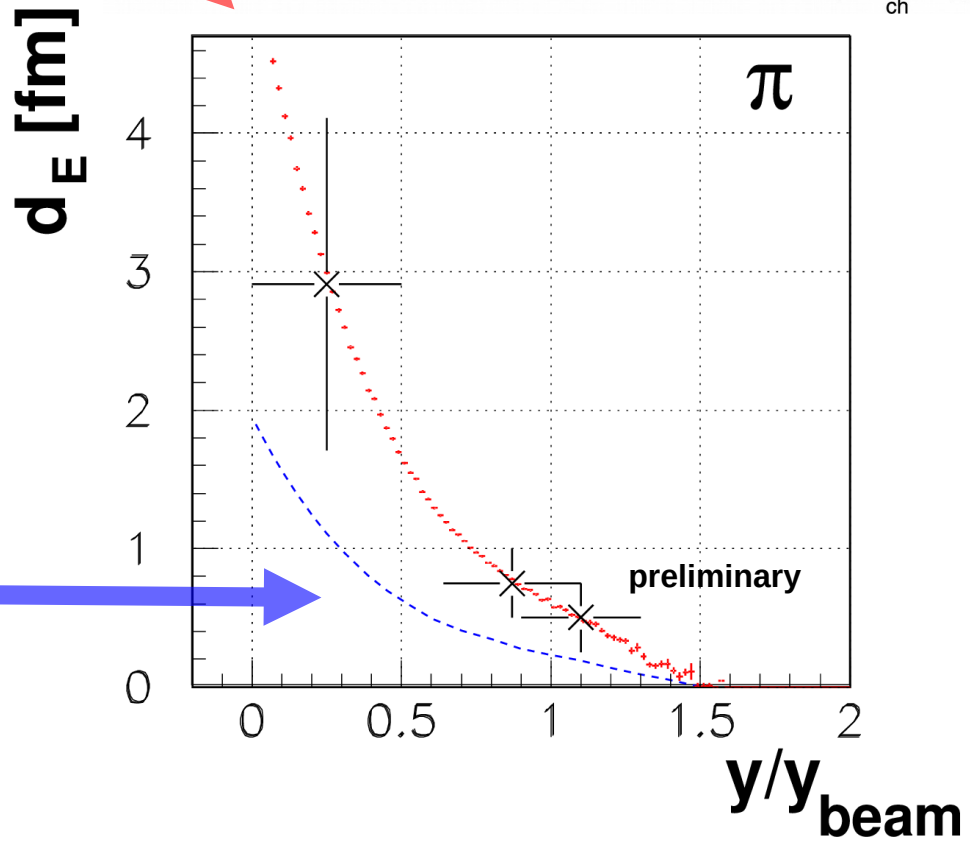




Original plot from: K. Aamodt et al. (ALICE Collab.), Phys. Lett. B **696** (2011) 328

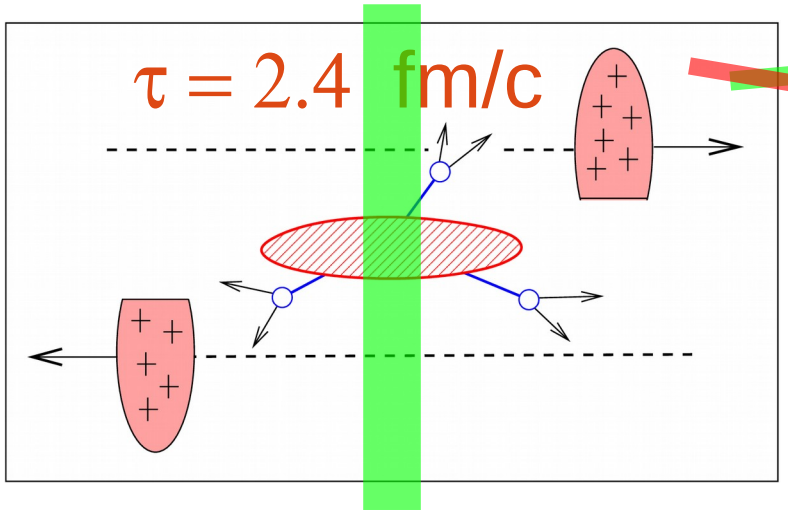


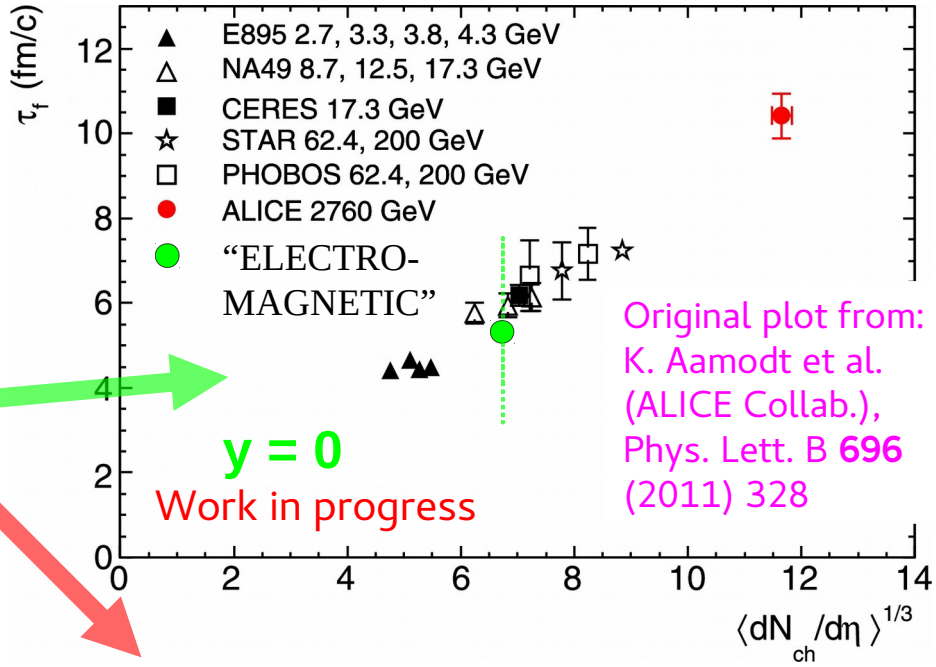


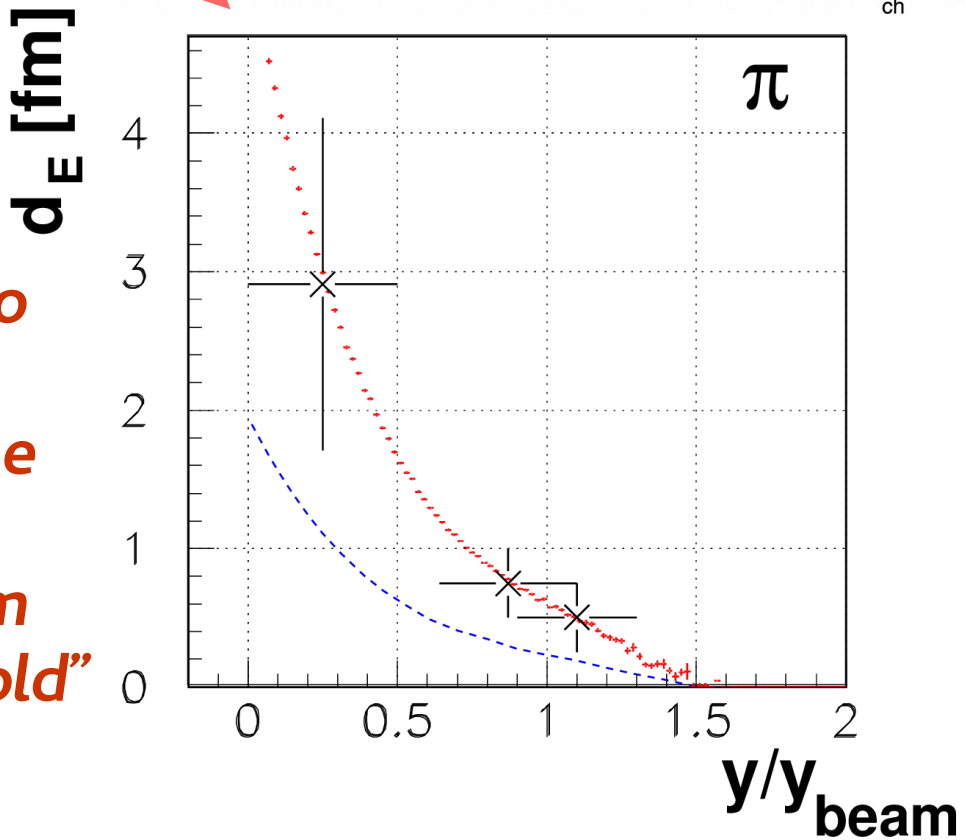
4) NA61

starting activity: N.D., A. Rybicki,

V. Ozvenchuk, A. Matyja, M. Kiełbowicz

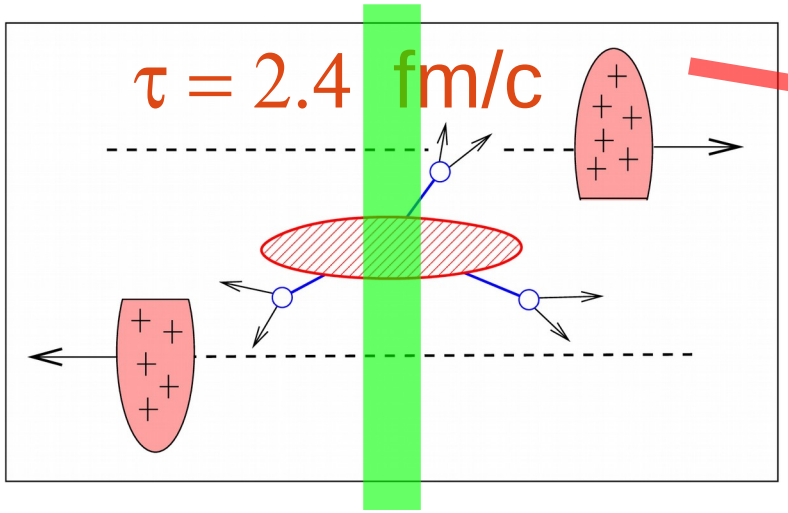




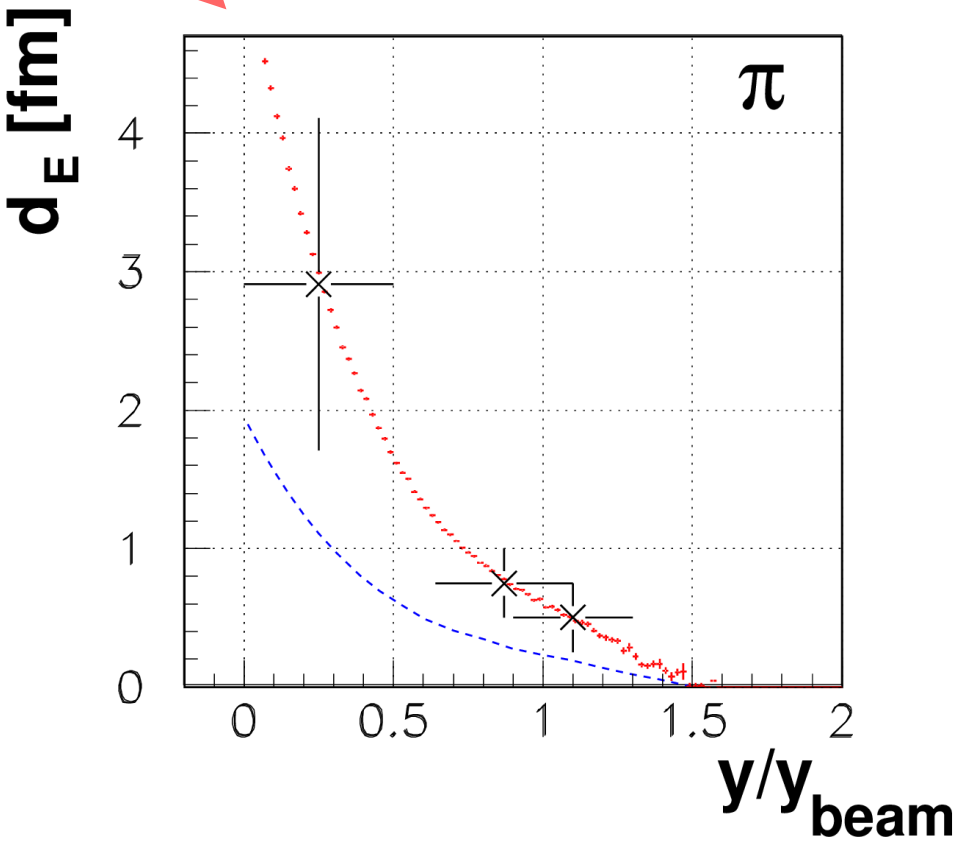


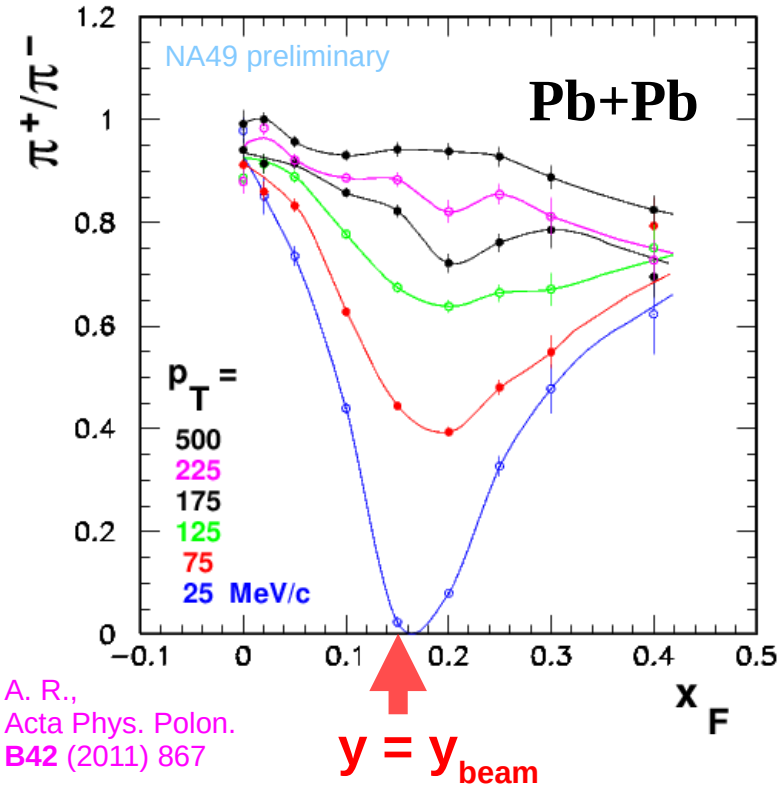
- ***What do we need now in order to better understand:***
  (a) the space-time evolution of the system …
  (b) the longitudinal evolution from "hot" (QGP?) matter at y=0 to "cold" (hadronic/nuclear) matter at y=y_{beam} ?

- We need:
  - new experimental data on EM effects on (a) flow (b) π^+/π^- ratios that would improve/confine our phenomenological knowledge (so that we can draw safe conclusions);



- Thus we need precise data on their dependence on:
  Collision geometry (reaction type, centrality),
  Energy,
  Particle type,
  Rapidity,
  p_T.





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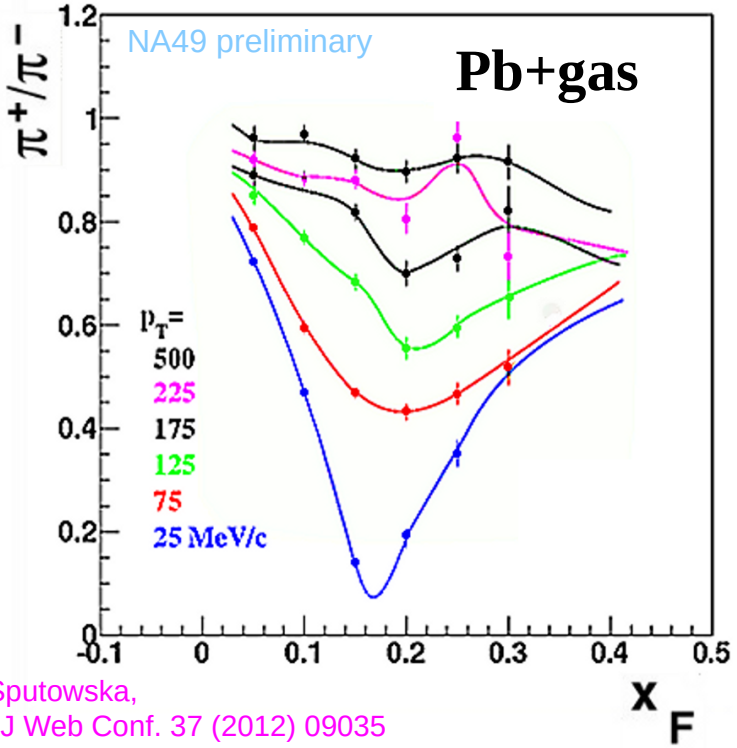

I. Sputowska,
EPJ Web Conf. 37 (2012) 09035

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

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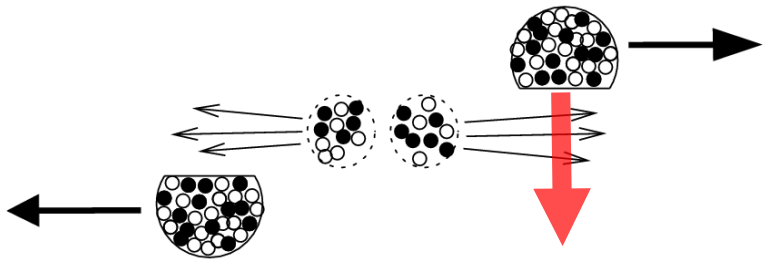
  Rapidity,
  p_T.



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

4) Summary & outlook

• EM effects in heavy ion collisions are sensitive to the distance d_E between the pion emission site and the spectator(s).

• They can be used as a new source of information on the longitudinal space-time evolution of the system.

• Plan (2015-2020):

1. Get more data on these effects (NA61/SHINE, SPSC-P-330-ADD-8, NICA, EPJA vol. 52 (2016)) ;
2. Clarify the situation at LHC.

Thank You!

Acknowledgments.

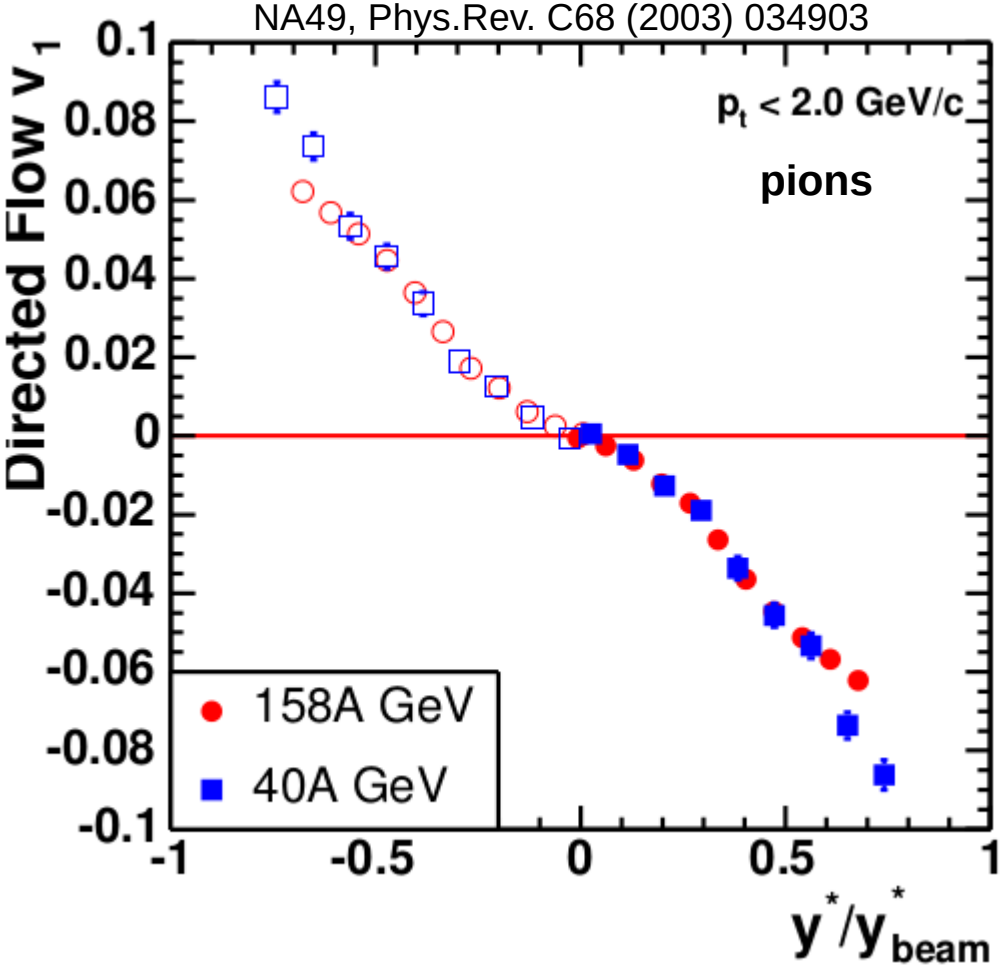
This work was supported by the National Science Centre, Poland (grant no. 2014/14/E/ST2/00018).

Extra slides

- We need:
  - model-independent (experimental) data on EM effects on (a) flow (b) $\pi+/\pi-$ ratios that would improve/confine our phenomenological knowledge (so that we can draw safe conclusions);

- Thus we need precise data on their dependence on:
  Collision geometry (reaction type, centrality),
  Energy,
  Particle type,
  Rapidity,
  pT.

NA49, Phys.Rev. C68 (2003) 034903

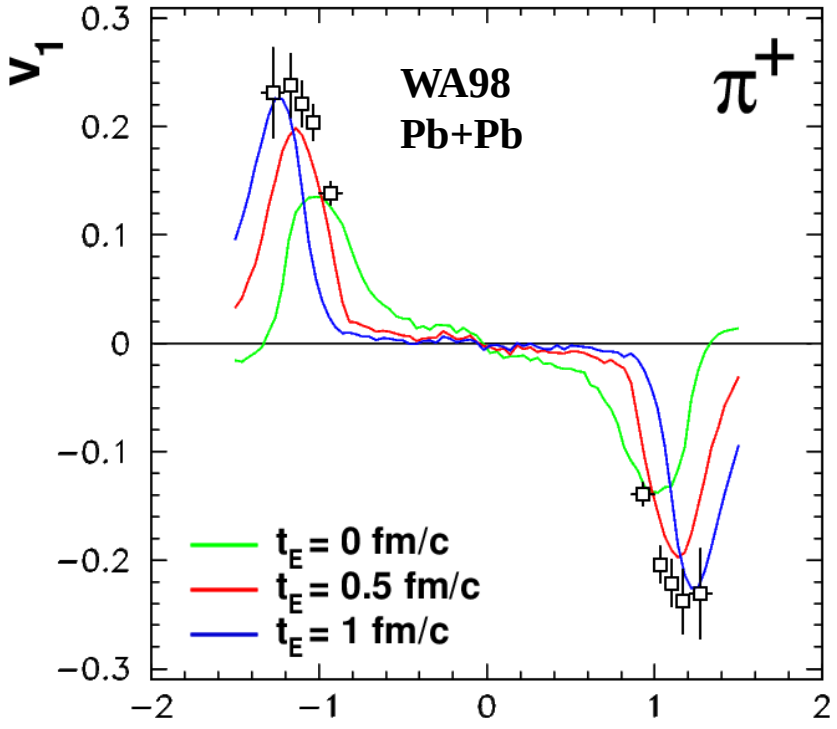


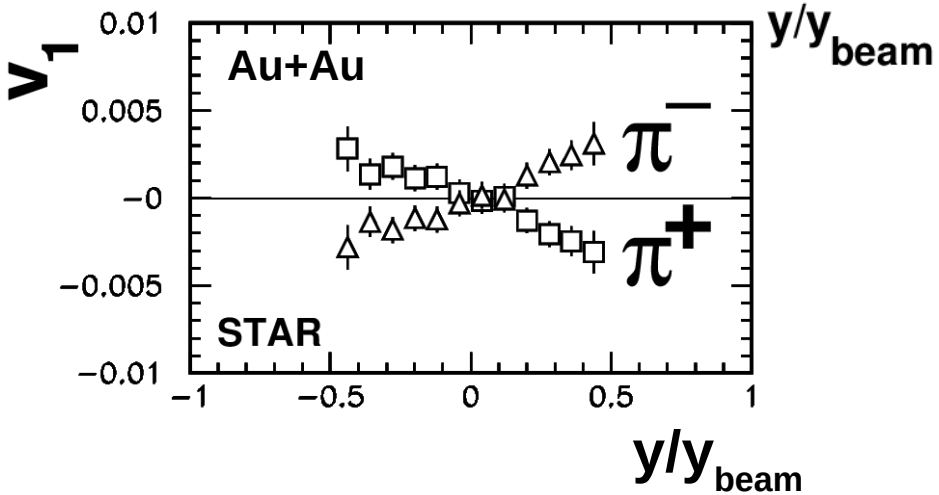
Experiments (data exists or could come):

WA98

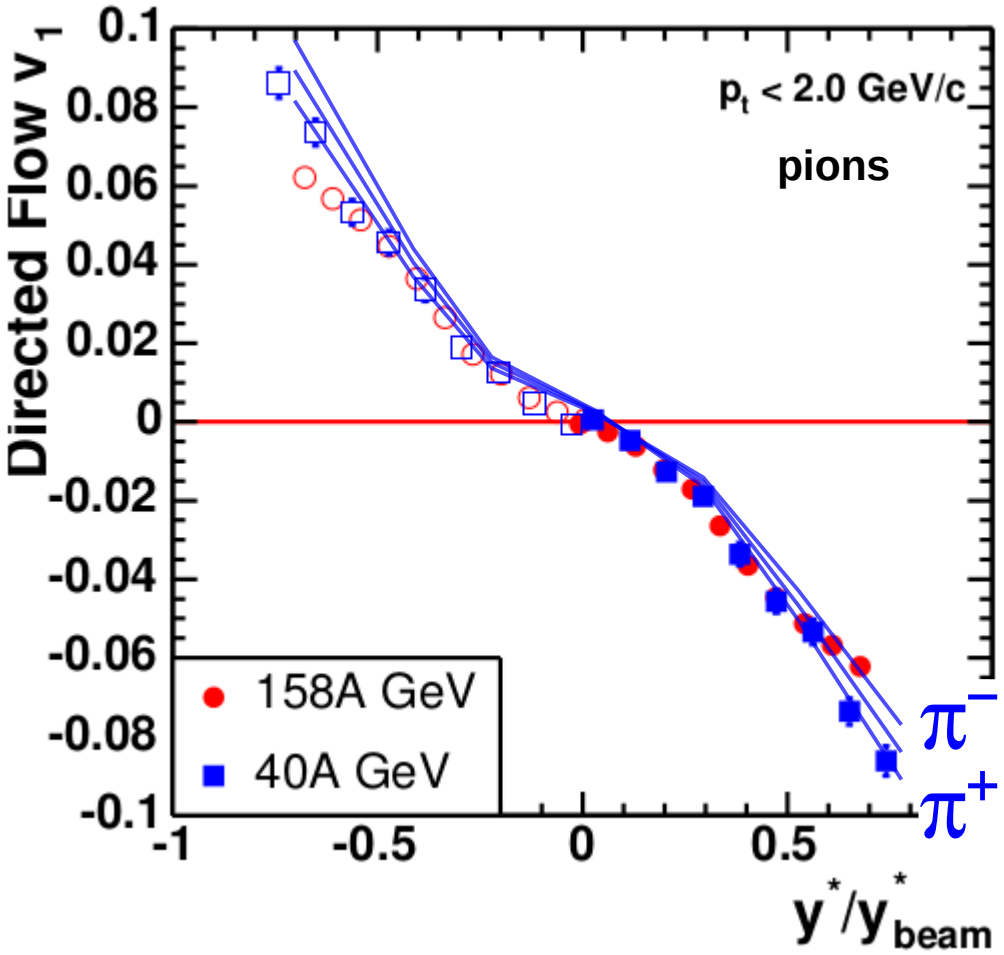
STAR

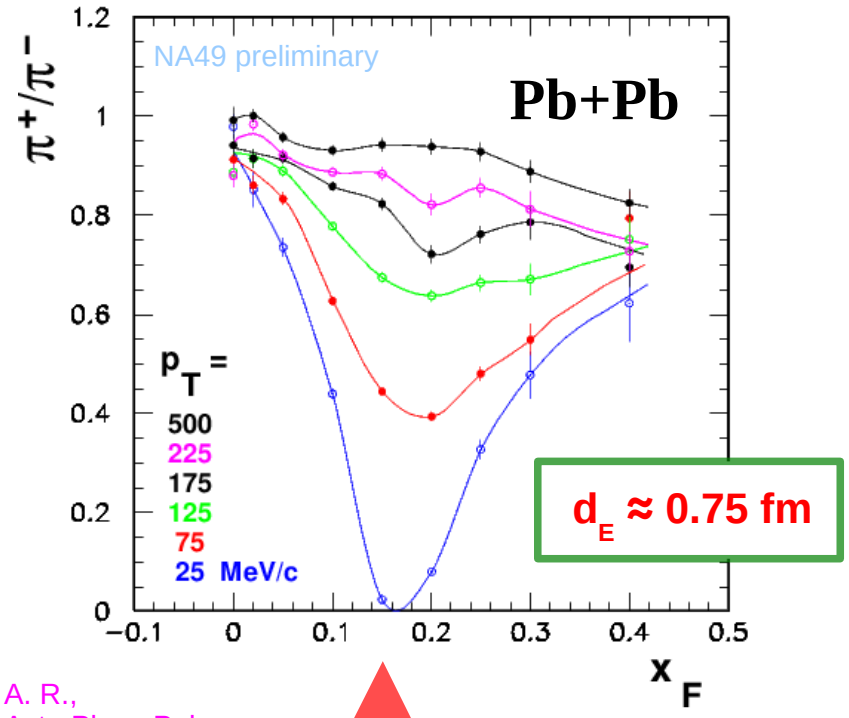
NICA → *research proposal*, Dec 2012



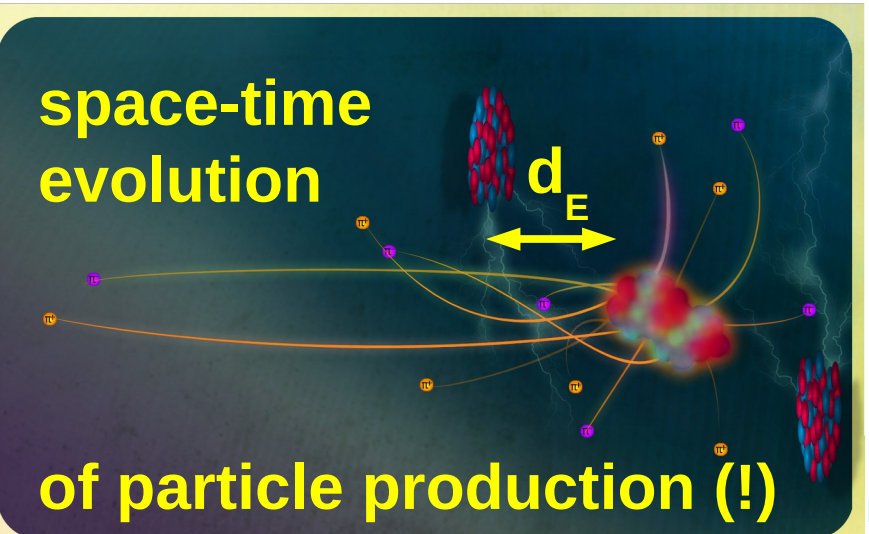


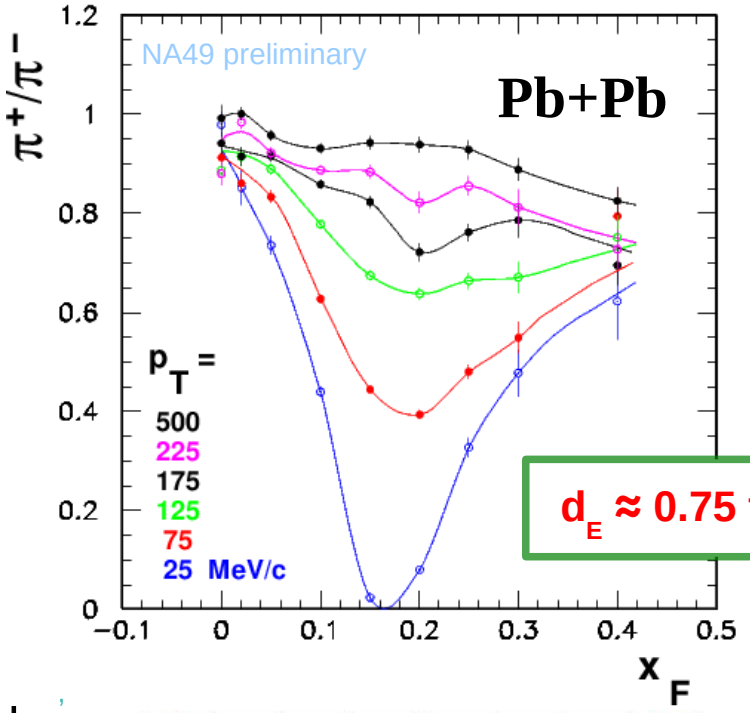
NA49, Phys.Rev. C68 (2003) 034903



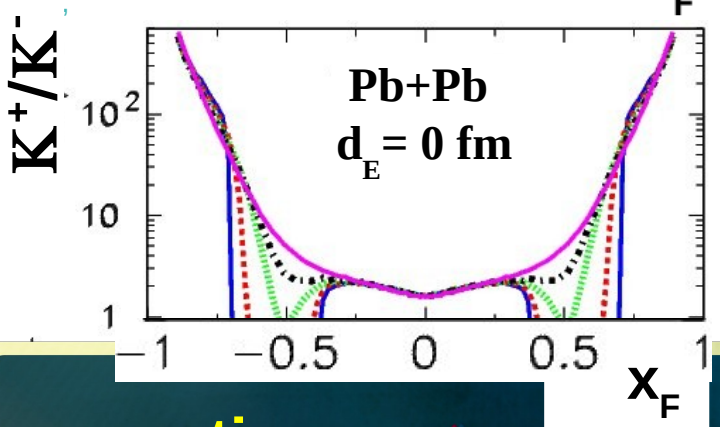


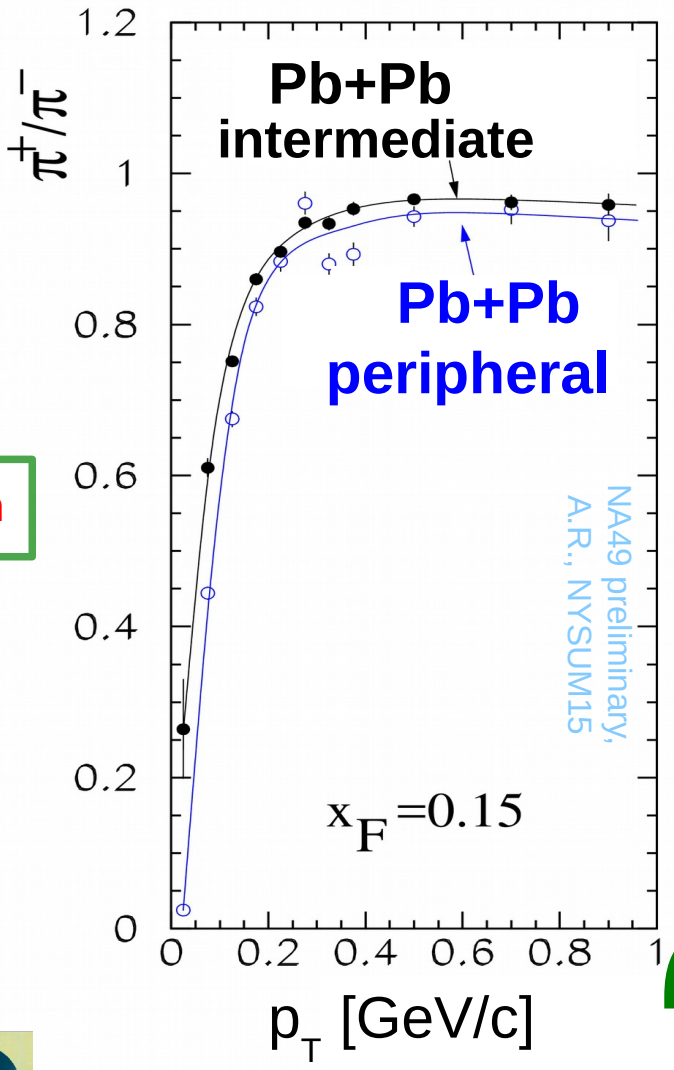
A. R.,
Acta Phys. Polon.
B42 (2011) 867





$d_E \approx 0.75$ fm



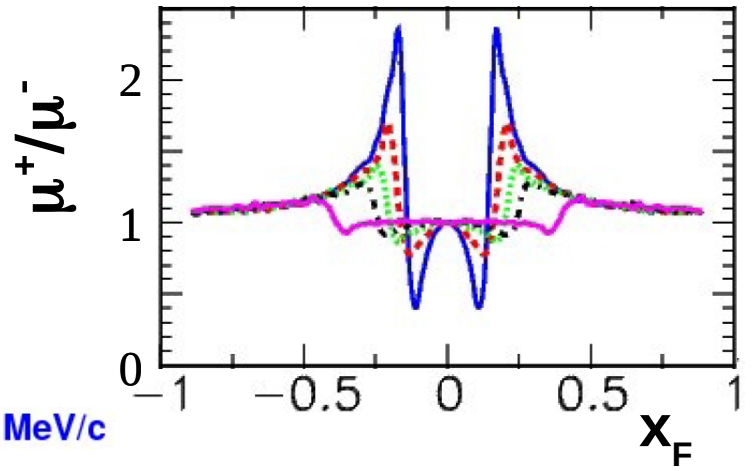


Pb+Pb, SPS, 17.3 GeV

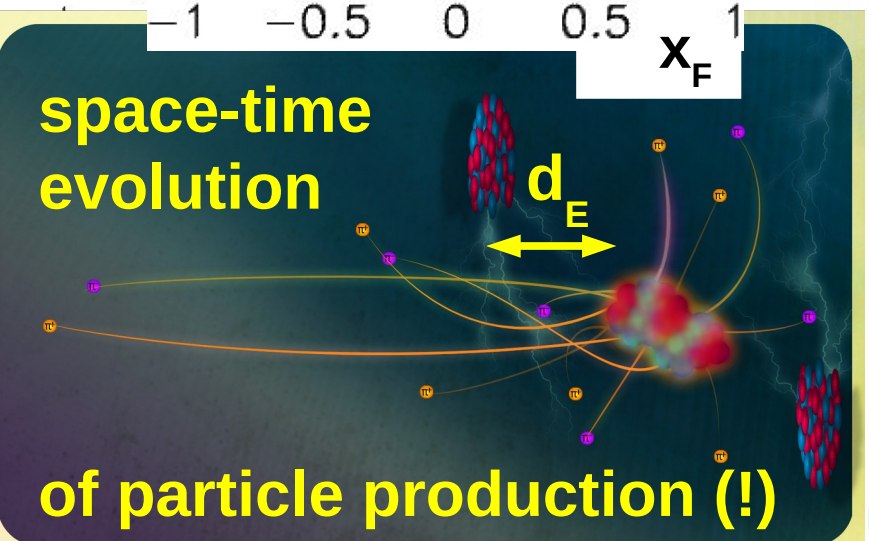
UPC, Au+Au, 200 GeV

($\gamma\ \gamma \rightarrow \mu^+\mu^-$)

b=112 fm, d_E = 0 fm

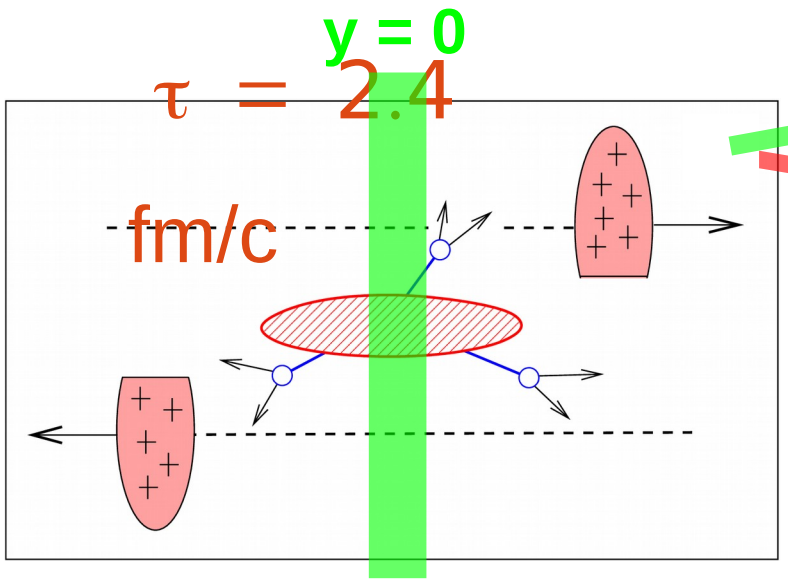


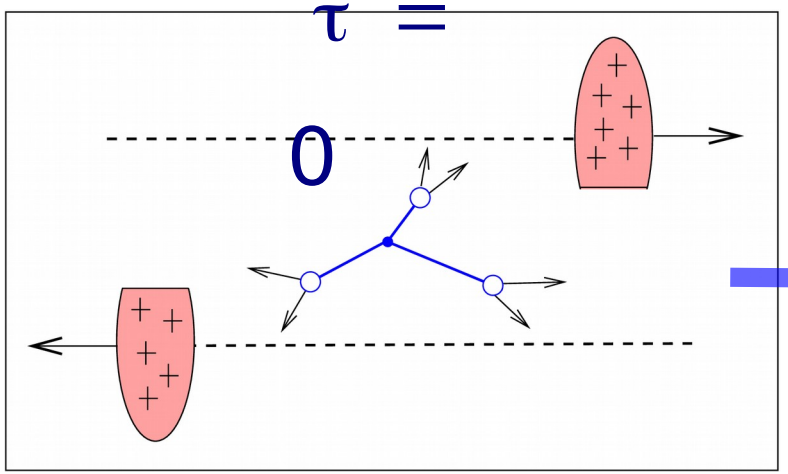
in progress

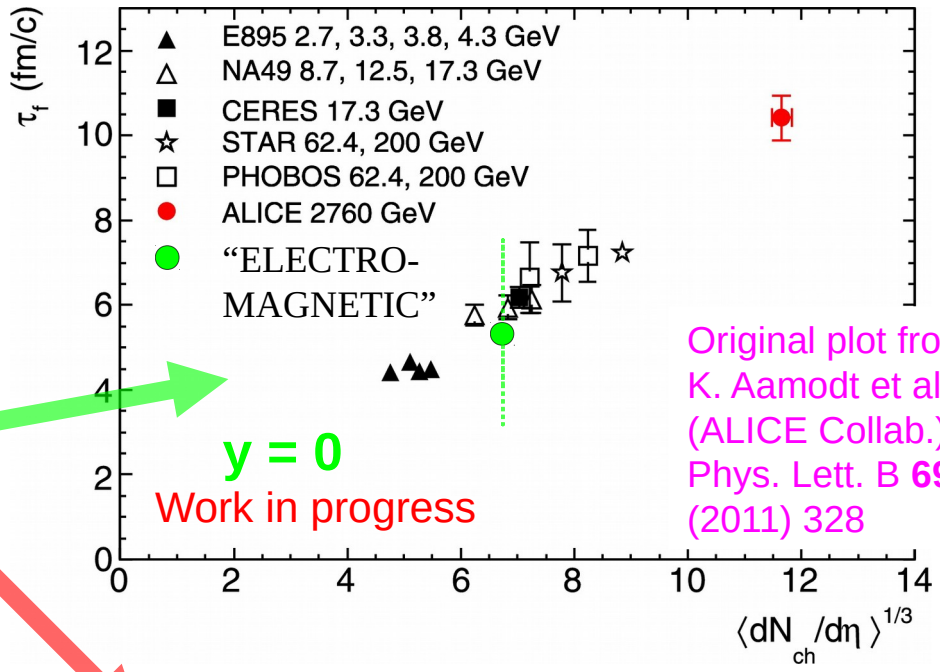


by I. Sputowska

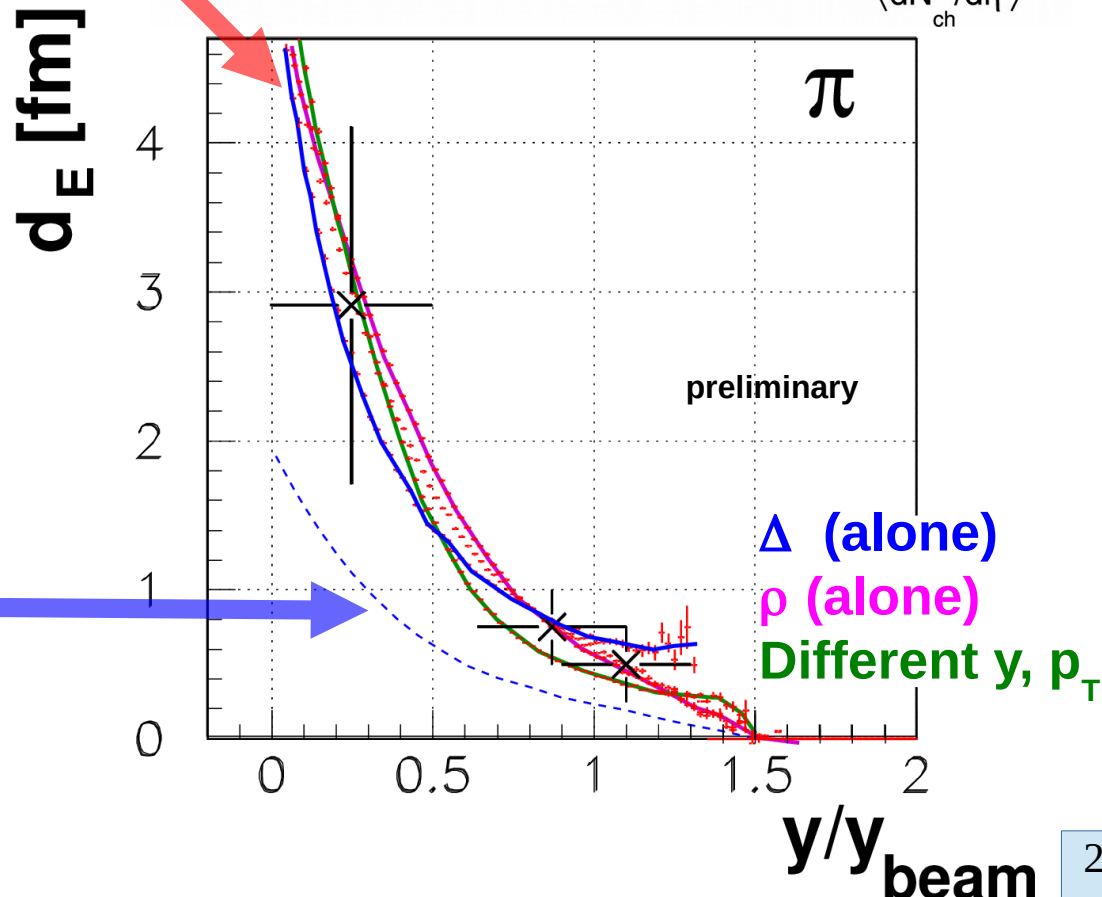
3) Space-time evolution

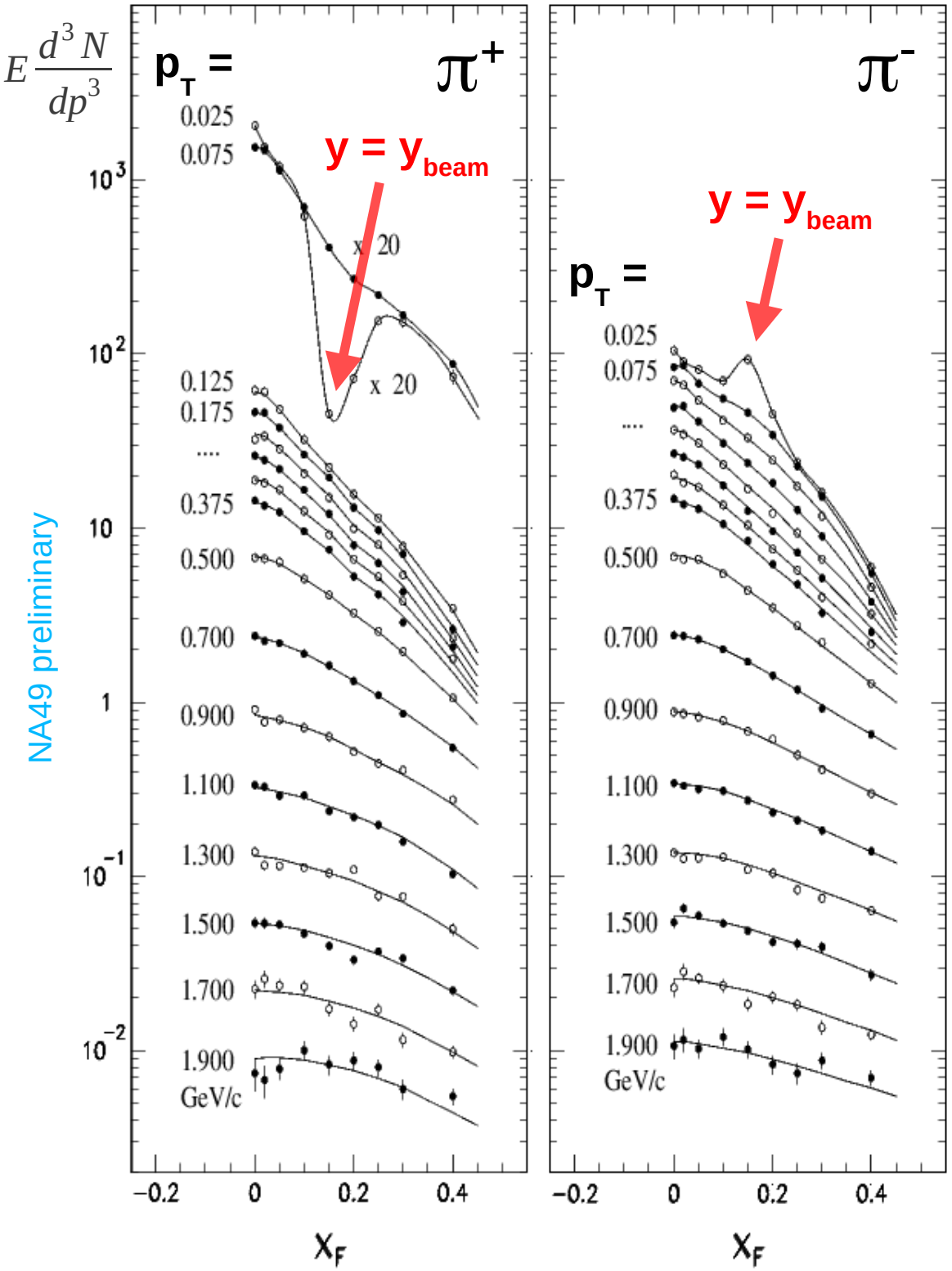






Original plot from: K. Aamodt et al. (ALICE Collab.), Phys. Lett. B **696** (2011) 328





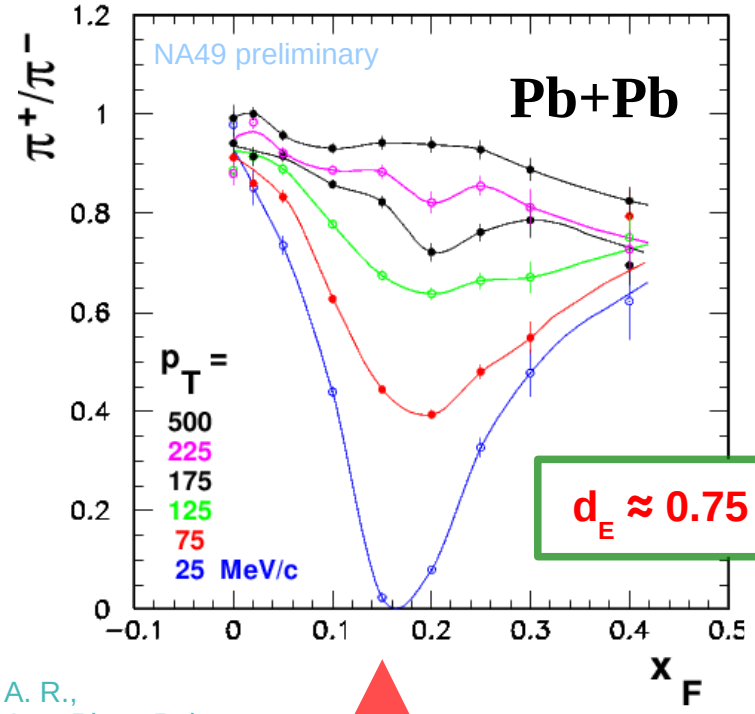
NA49, 158 A GeV/c

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

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

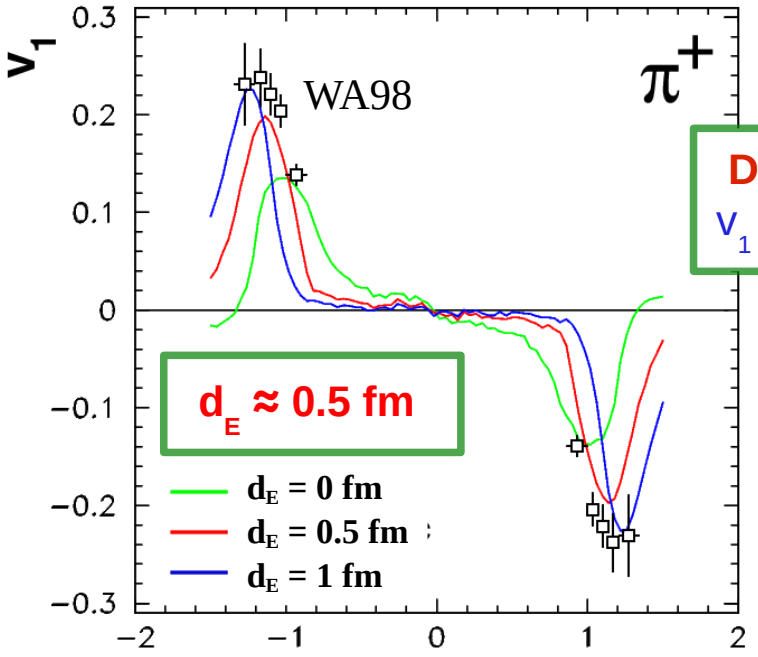
(c.m.s.)

Pb+Pb, peripheral



$d_E \approx 0.75$ fm

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



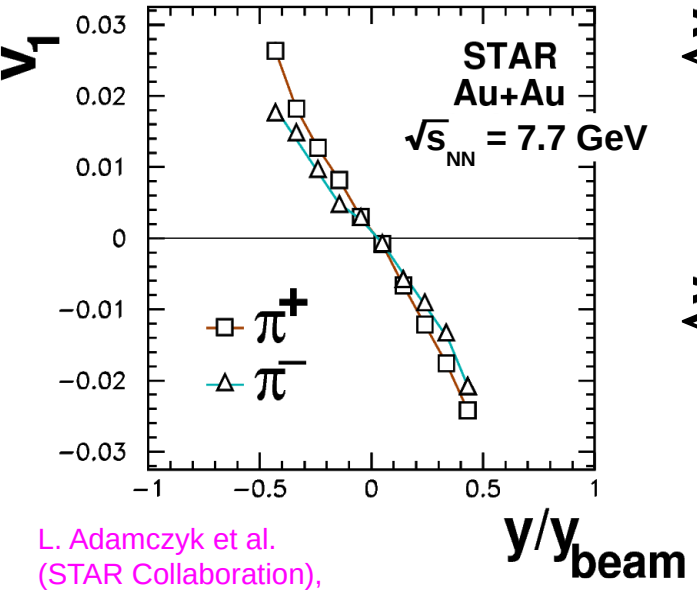
$d_E \approx 0.5$ fm

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

A. R. and A. Szczurek,
Phys. Rev. **C87** (2013)
054909.

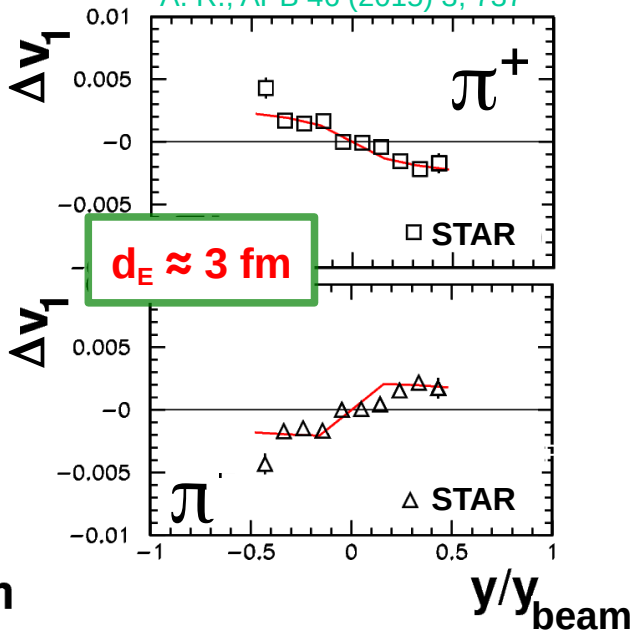
H. Schlagheck
(WA98 Collaboration),
Nucl. Phys. A **663** (2000)
725.

$y = y_{beam}$

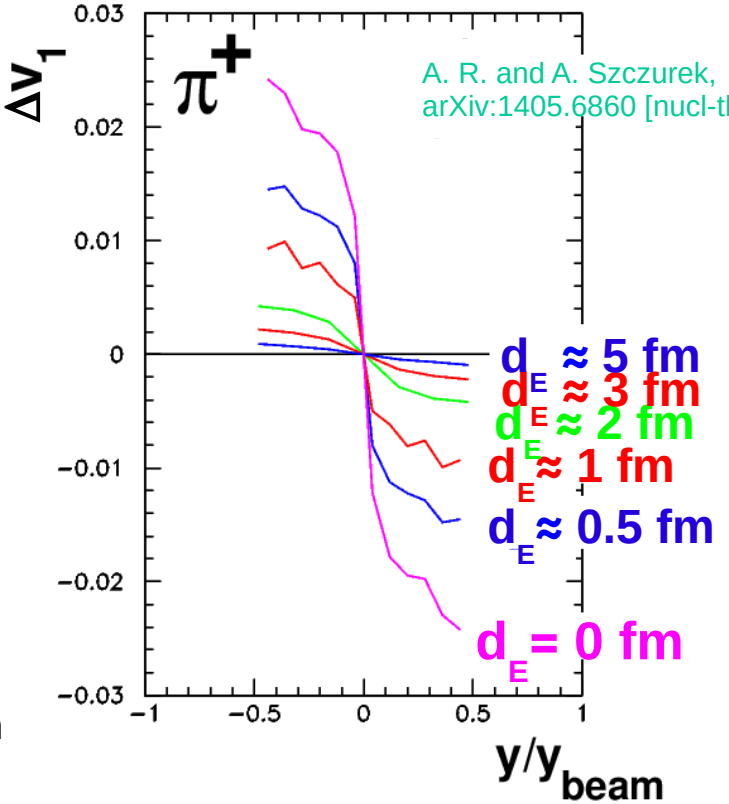


L. Adamczyk et al.
(STAR Collaboration),
Phys. Rev. Lett. 112, 162301 (2014)

A. R., APB 46 (2015) 3, 737



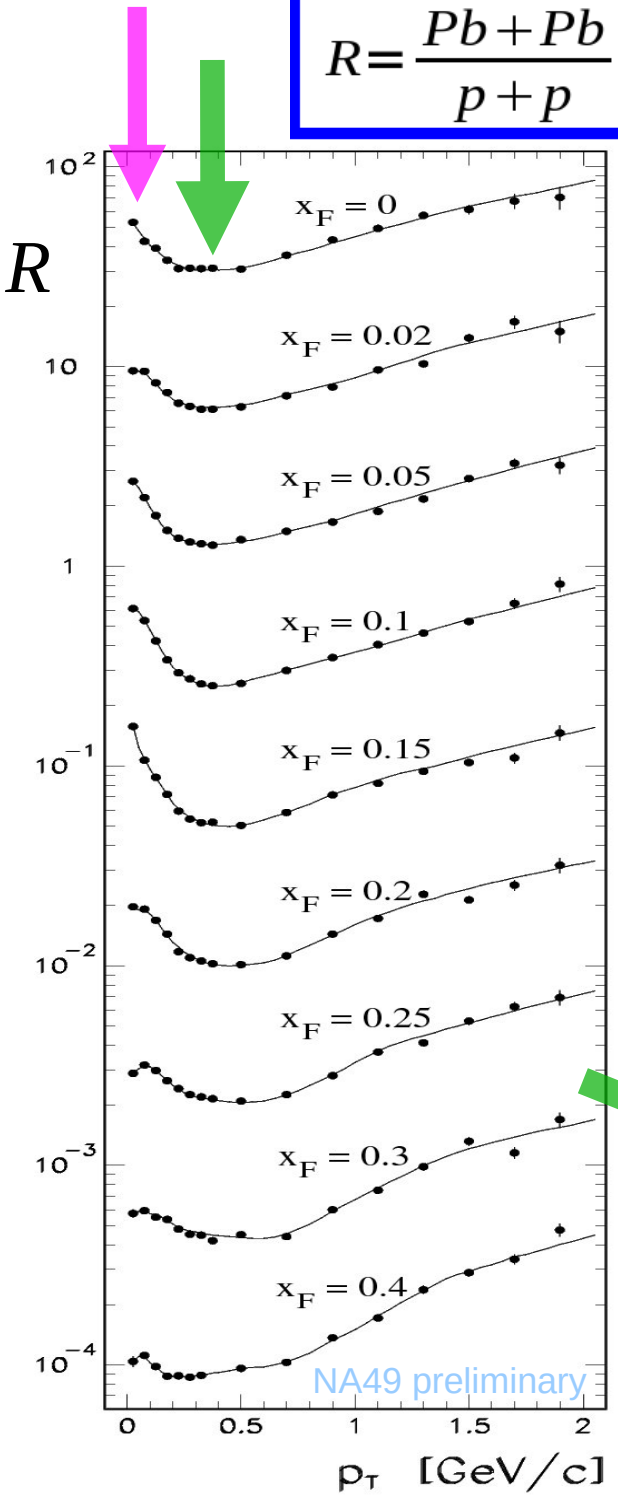
$d_E \approx 3$ fm

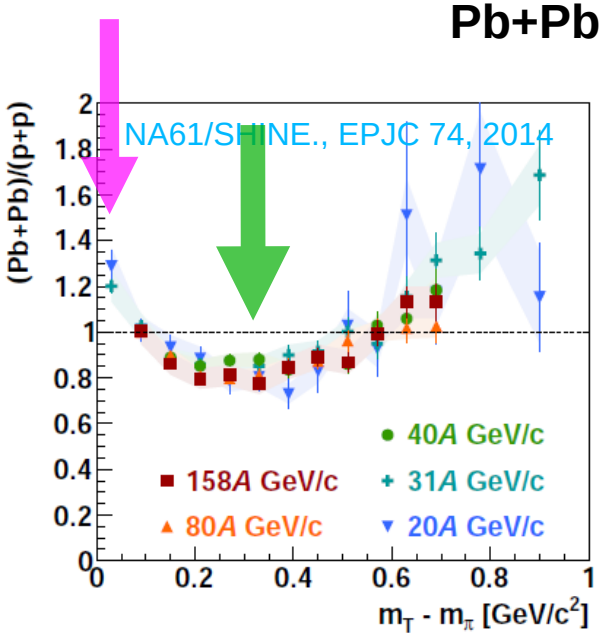


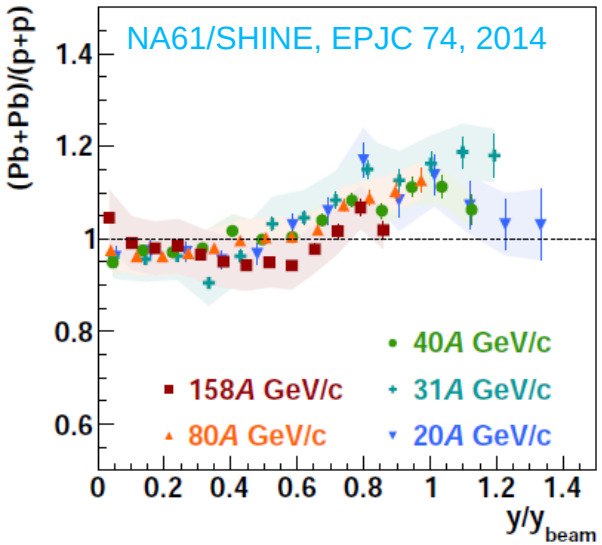
A. R. and A. Szczurek,
arXiv:1405.6860 [nucl-th].

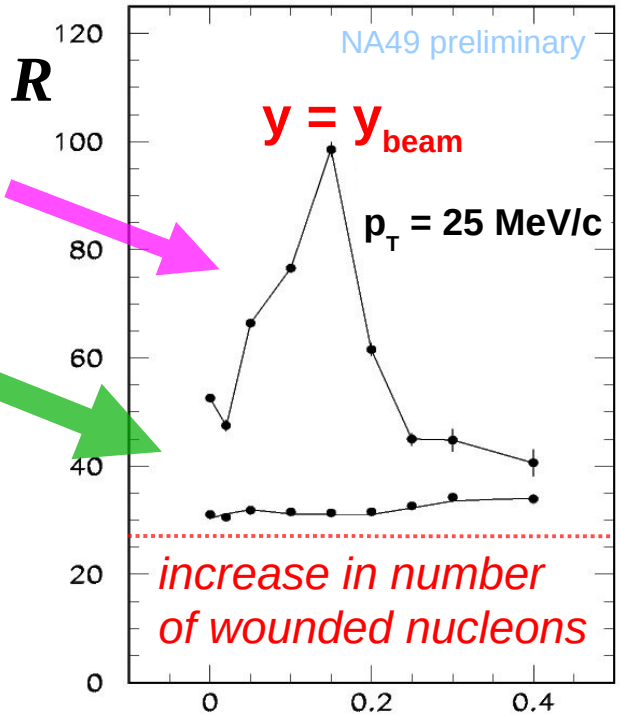
$$R = \frac{Pb+Pb}{p+p}$$

- NA49: $(\pi^+ + \pi^-)/2$; **Pb+Pb peripheral.**
- NA61/SHINE: π^- only; **Pb+Pb CENTRAL.**



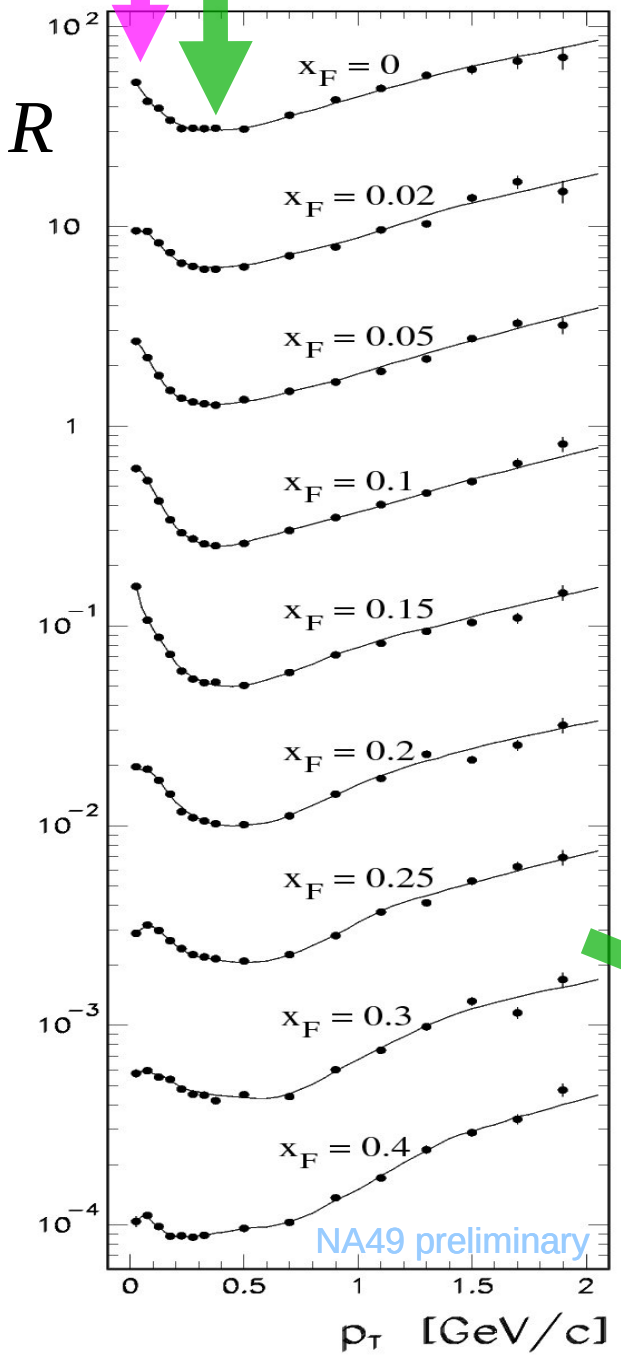


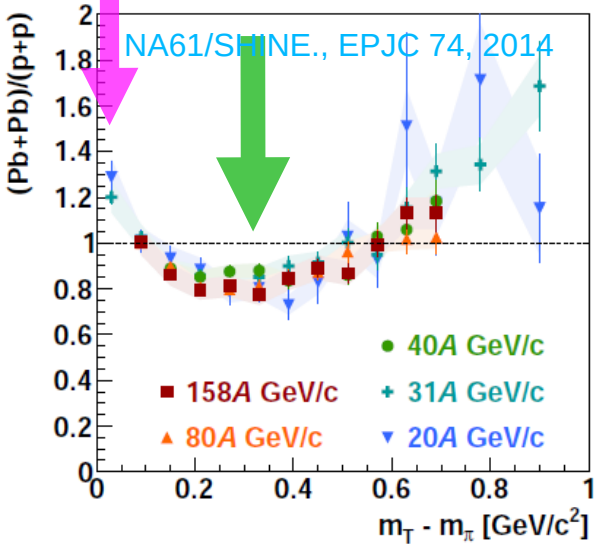


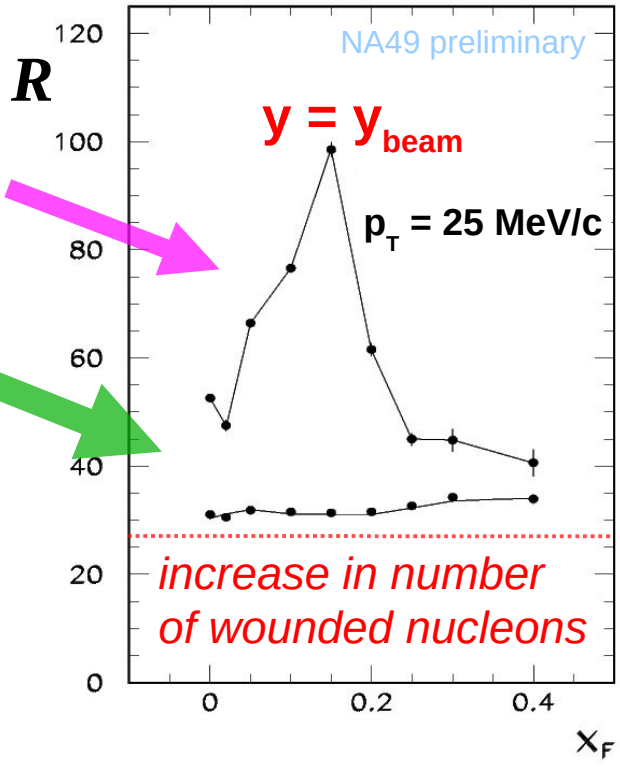


$$R = \frac{Pb+Pb}{p+p}$$

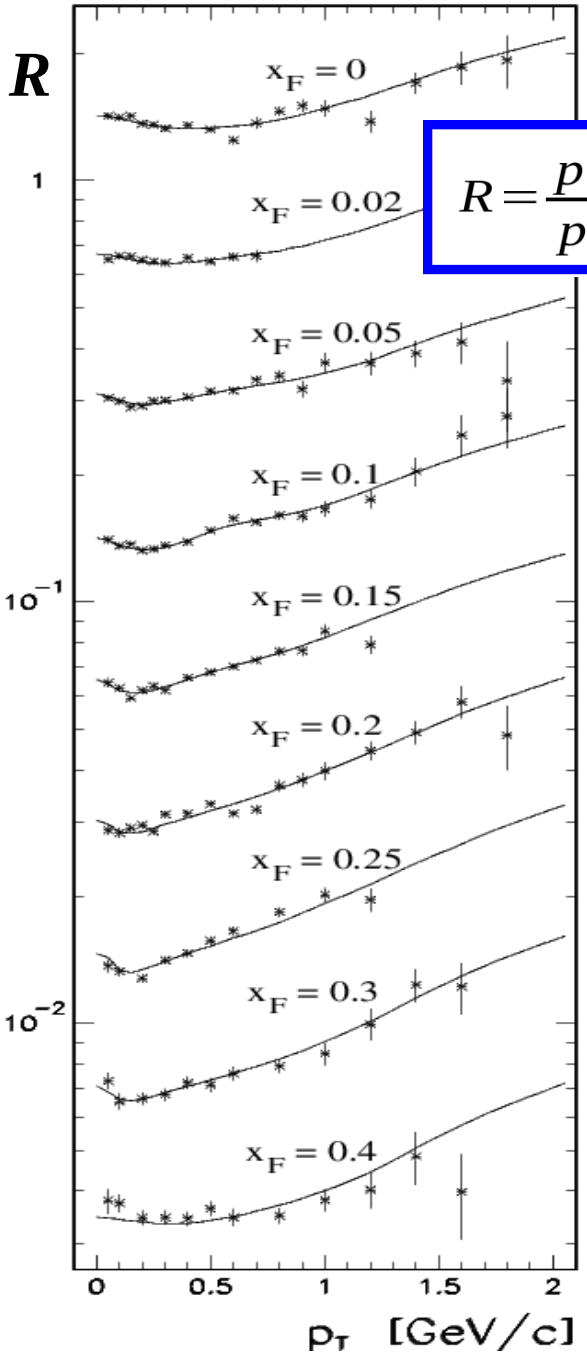
- NA49: $(\pi^+ + \pi^-)/2$; **Pb+Pb peripheral.**
- NA61/SHINE: π^- only; **Pb+Pb CENTRAL.**





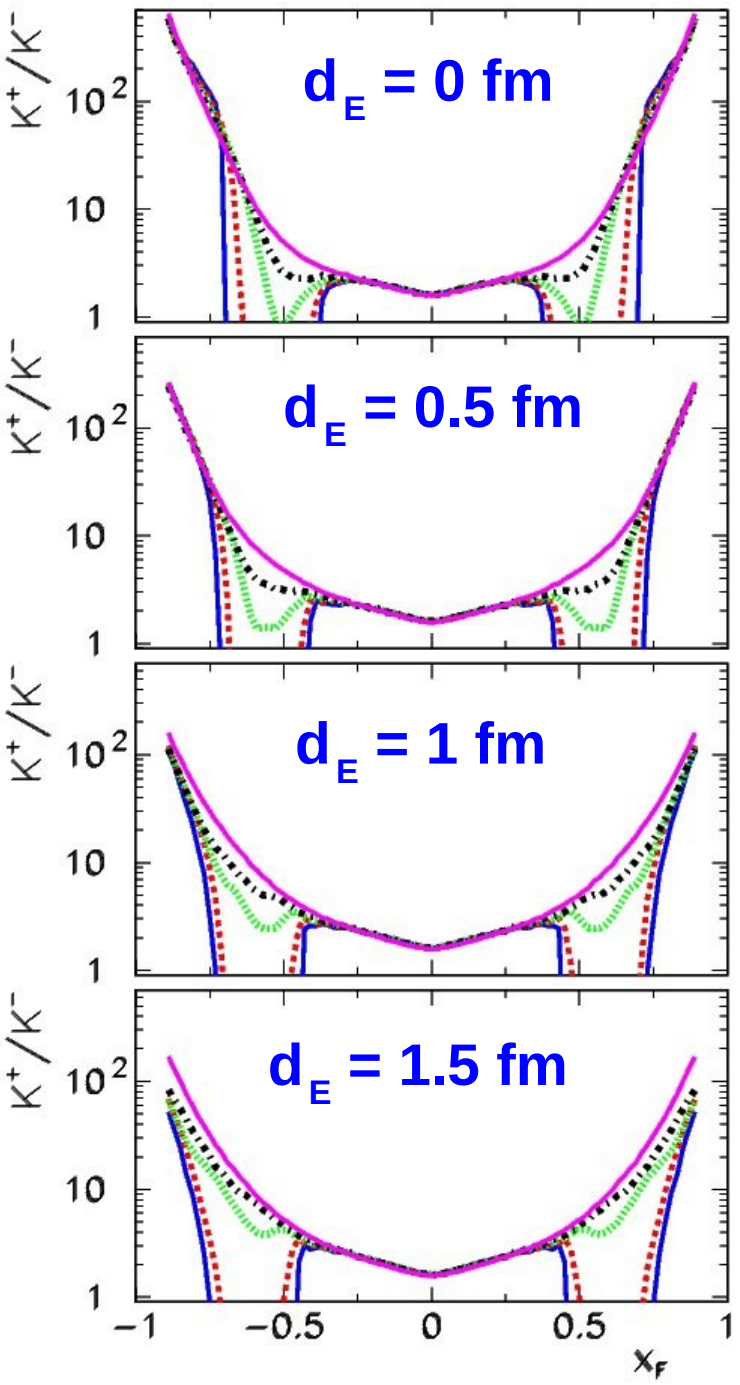


$$R = \frac{p+C}{p+p}$$

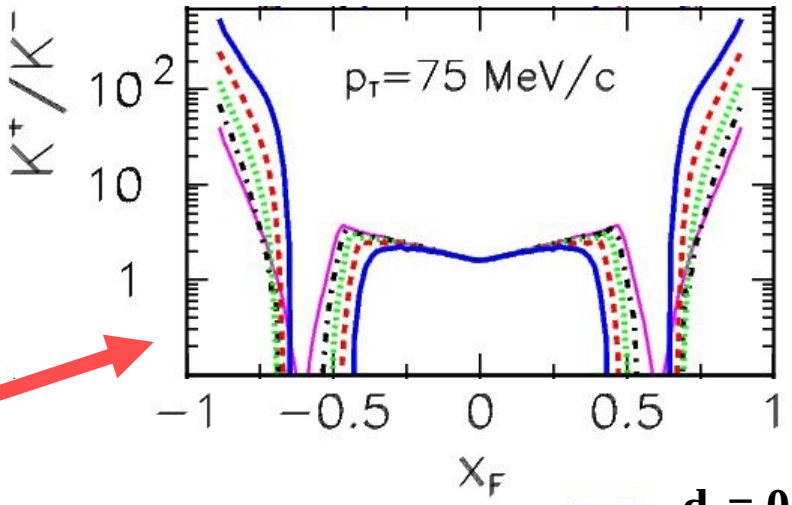


Based on: C. Alt et al., EPJC 49, 2007

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



Acta Phys.Polon.Supp. 5, 2012



d_E = 0 fm
d_E = 0.5 fm
d_E = 1 fm
d_E = 1.5 fm
d_E = 2 fm

p_T =
25 MeV/c
75 MeV/c
125 MeV/c
175 MeV/c
325 MeV/c

- Large effect above x_F=0.5.
- Dependence on initial conditions.
- **Very high x_F**