Charged pion production and π+/π- ratios in Pb+Pb collisions at SPS energies

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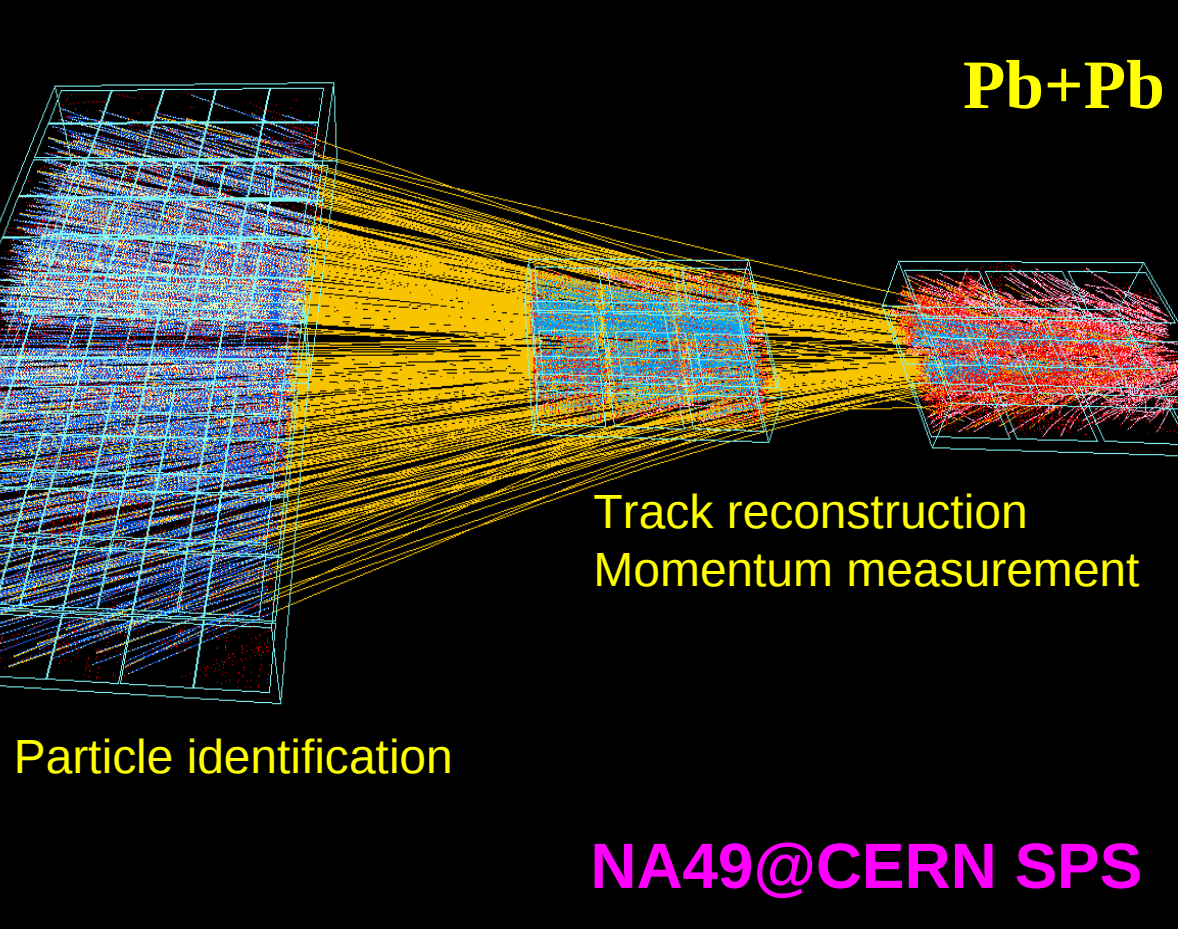
1) **Motivation**
2) **π^+/π^- ratios**
3) **Comparison:**

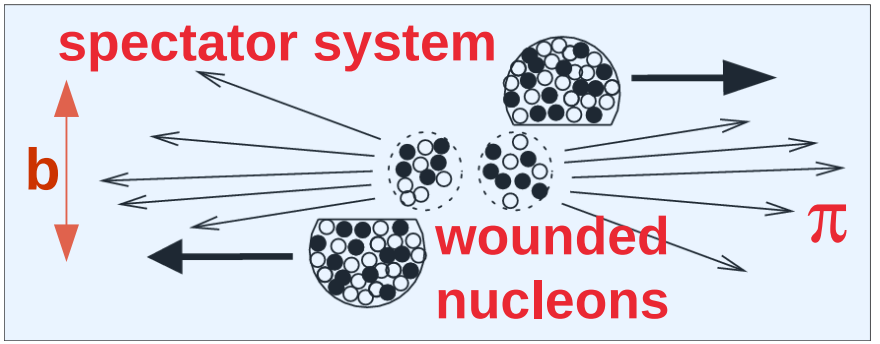
   Pb+Pb / p+p
4) **Summary**

work in collaboration with
Antoni Szczurek
Mariola Kłusek-Gawenda

1)
Motivation



Pb beam



- **Data on peripheral Pb+Pb reactions:**
  E_{beam} = 158 A GeV, b ≈ 11 fm, $N_{wounded\ nucleons}$ ≈ 54 **($\sqrt{s_{NN}}$ = 17.3 GeV)**

13 A GeV?

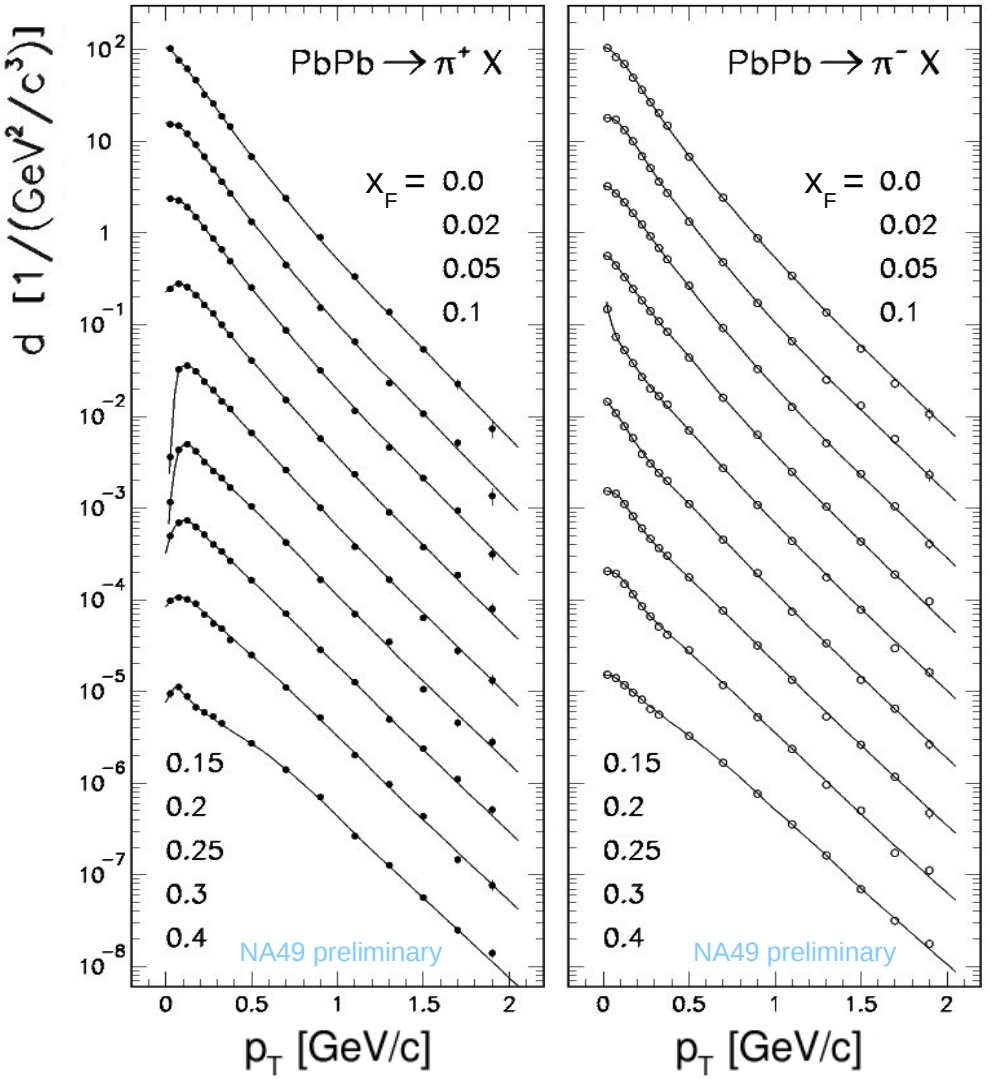
- **More such data is to come (new project IFJ PAN + SHINE) ;**
- **Useful for your community ?**

The Data

NA49, 158 A GeV

Pb+Pb (peripheral)

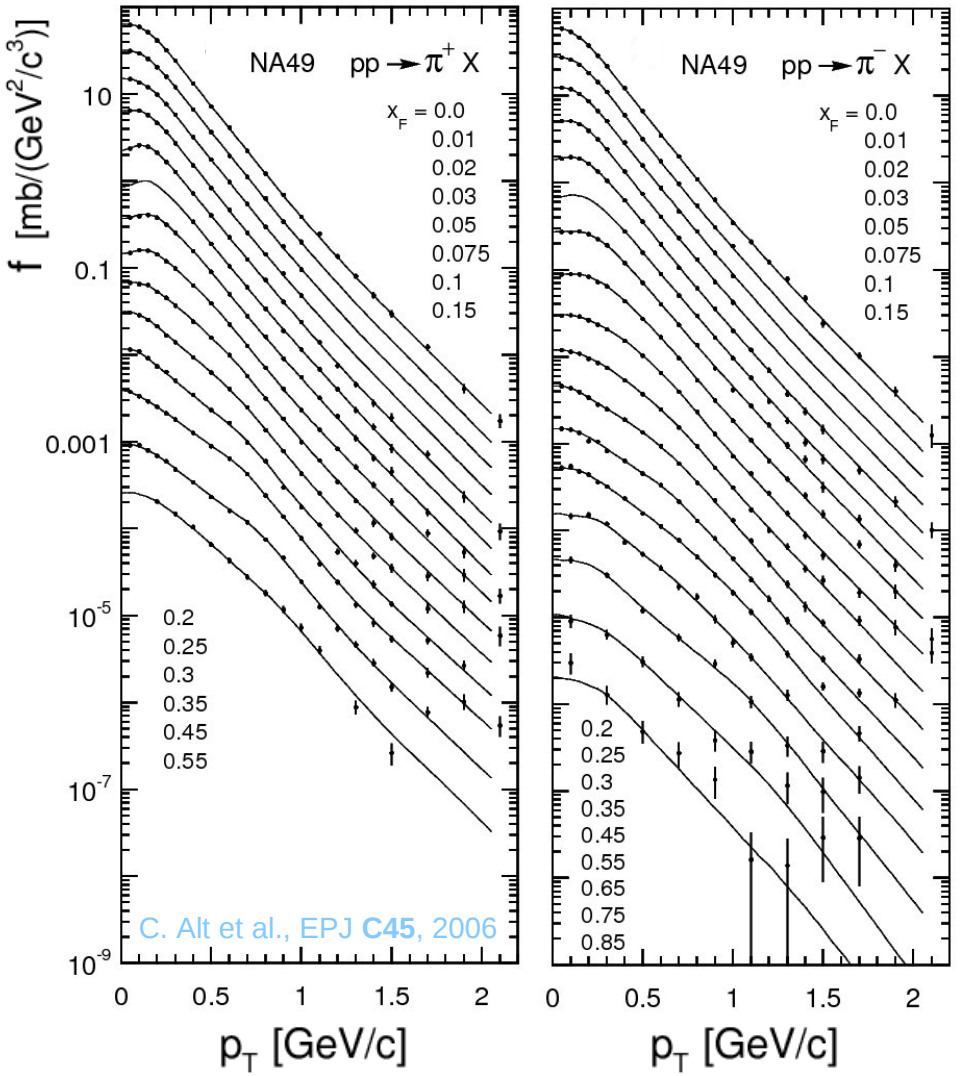
$$d = E\frac{d^3N}{dp^3}$$



A.R., PoS (EPS-HEP2009)

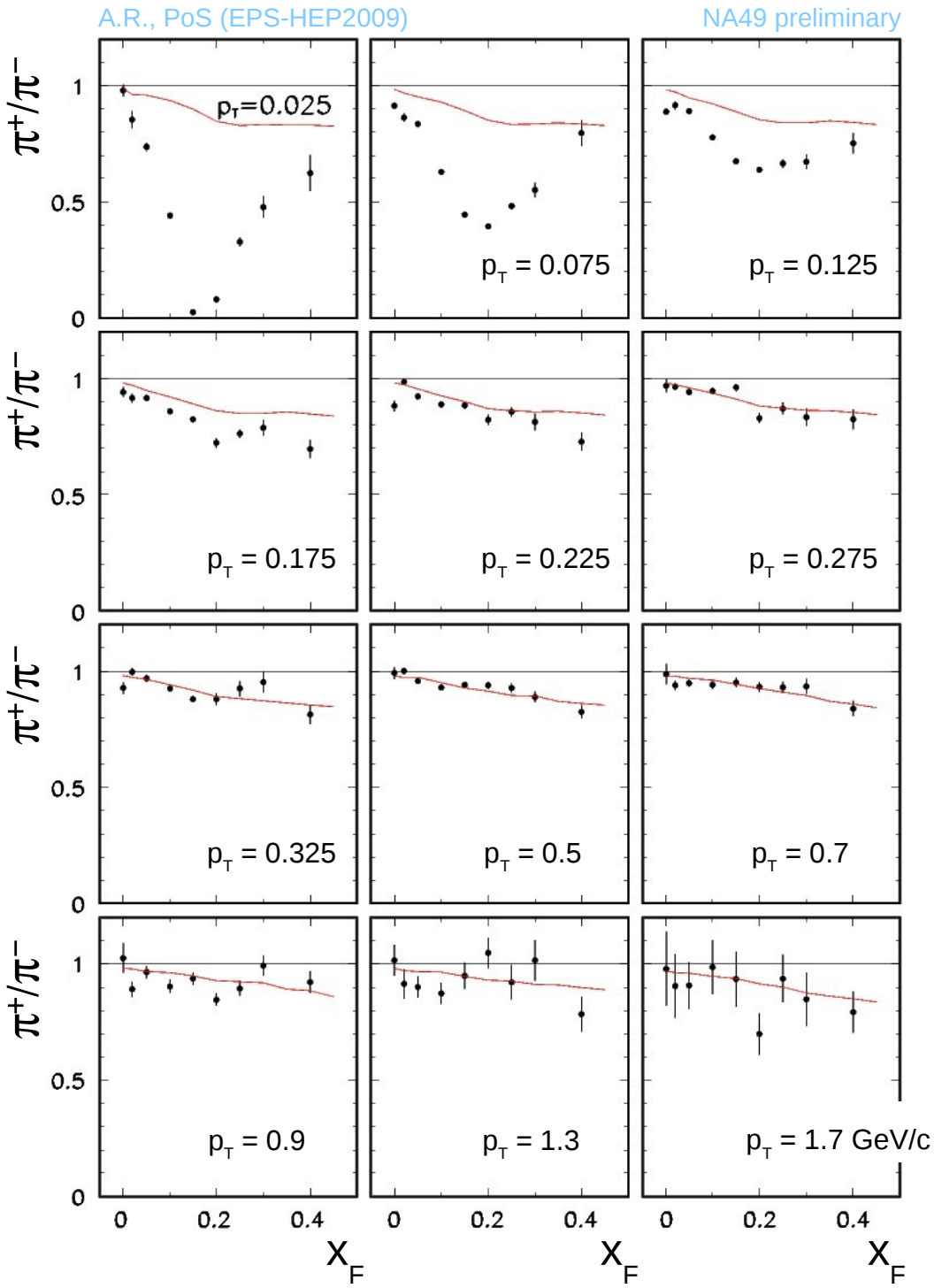
p+p

$$f = E\frac{d^3\sigma}{dp^3}$$



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

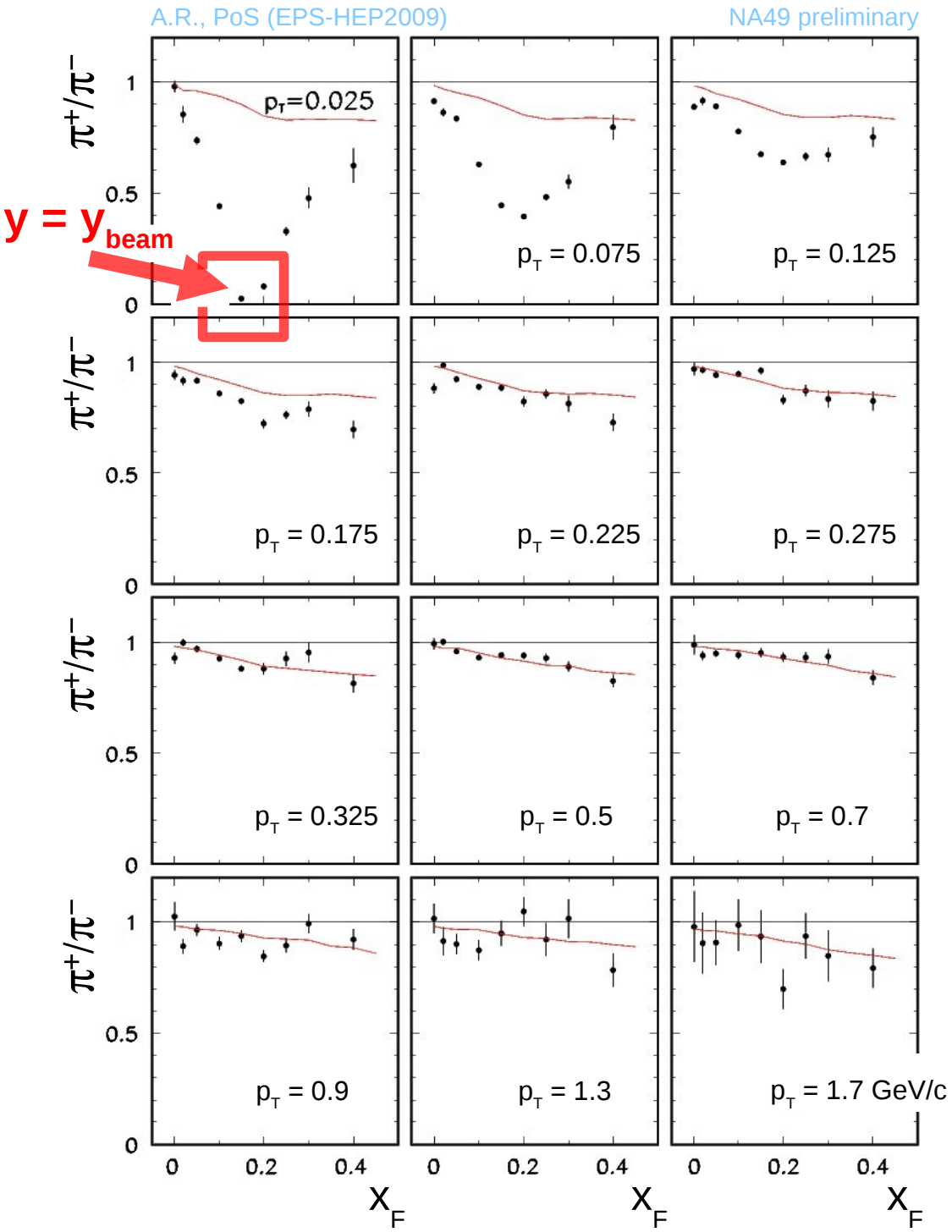
2)
π+/π- ratios



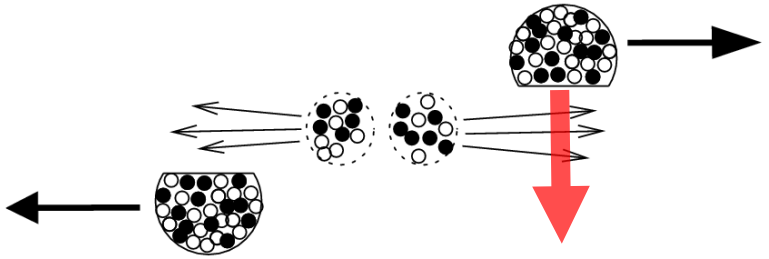
Pb+Pb peripheral

prediction from p+p
(40% protons, 60% neutrons)

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



$y = y_{beam}$



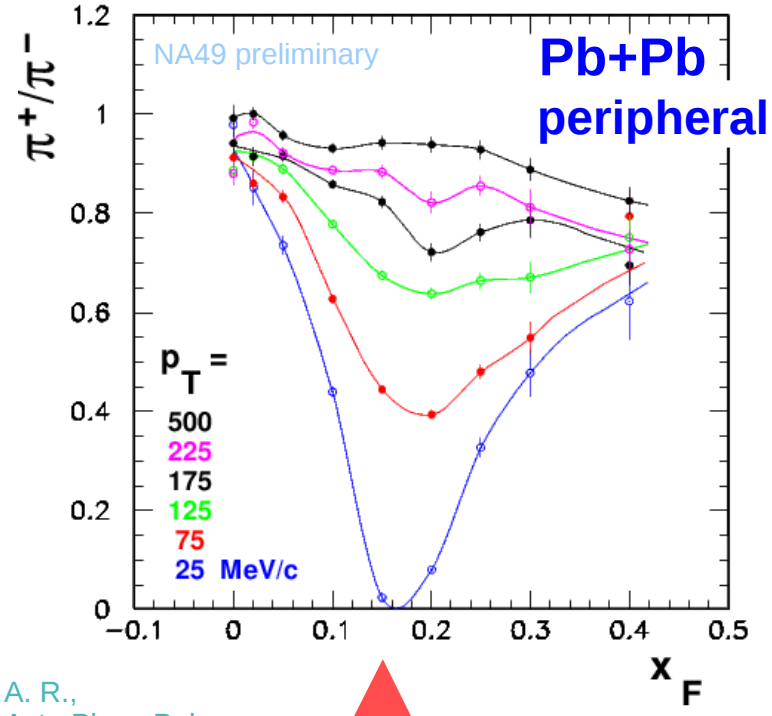
Repulsion (for π^+)
Attraction (for π^-)

Coulomb effect

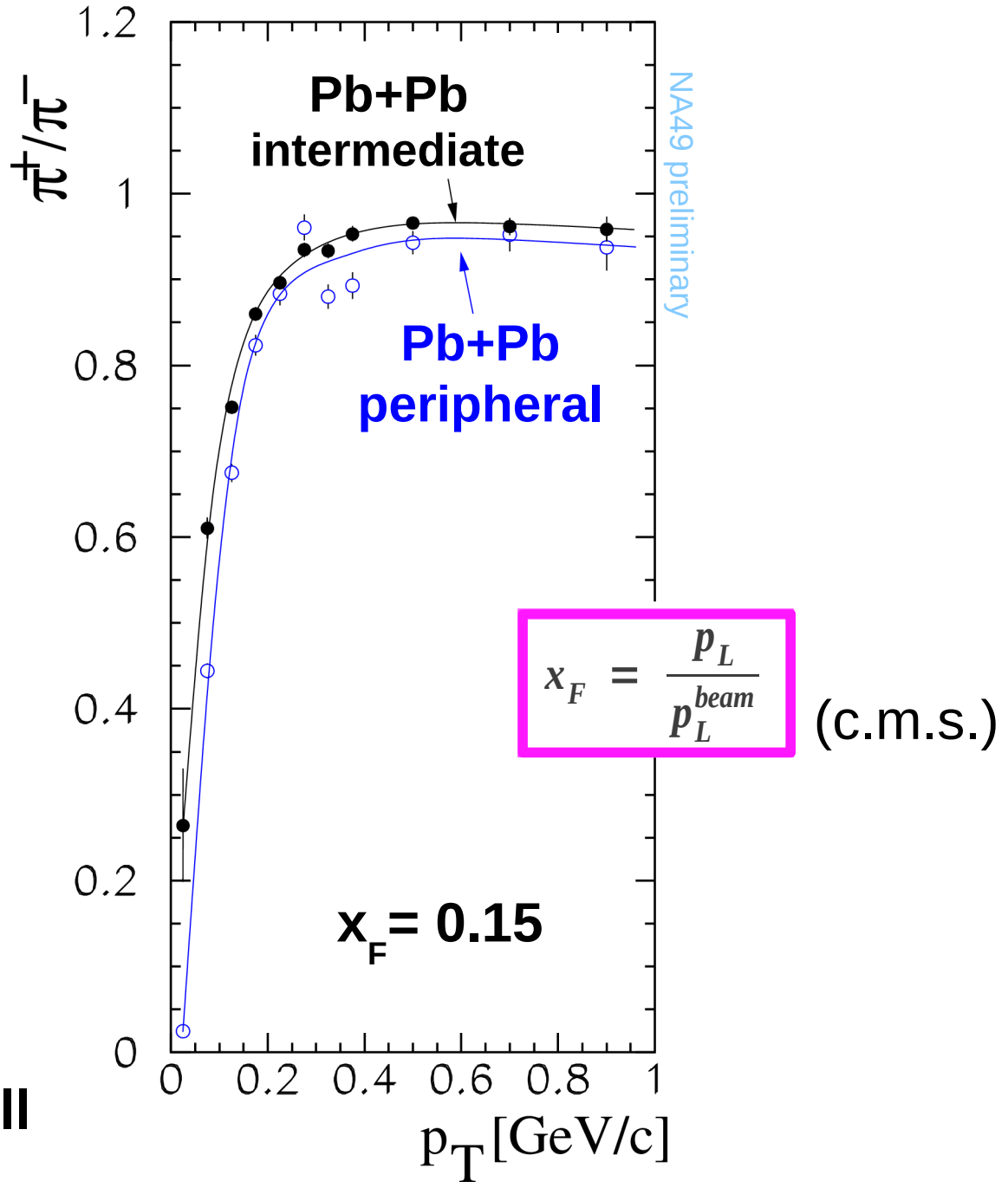
Pb+Pb peripheral

prediction from p+p
(40% protons, 60% neutrons)

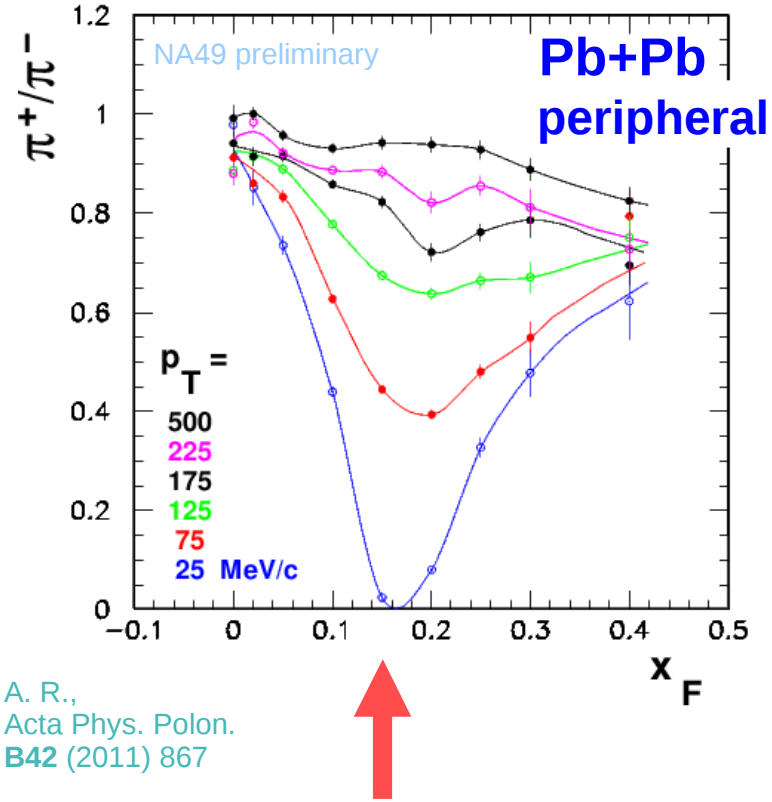
$$x_F = \frac{p_L}{p_L^{beam}}$$ (c.m.s.)



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



- **The Coulomb effect is still very strong at intermediate centrality.**



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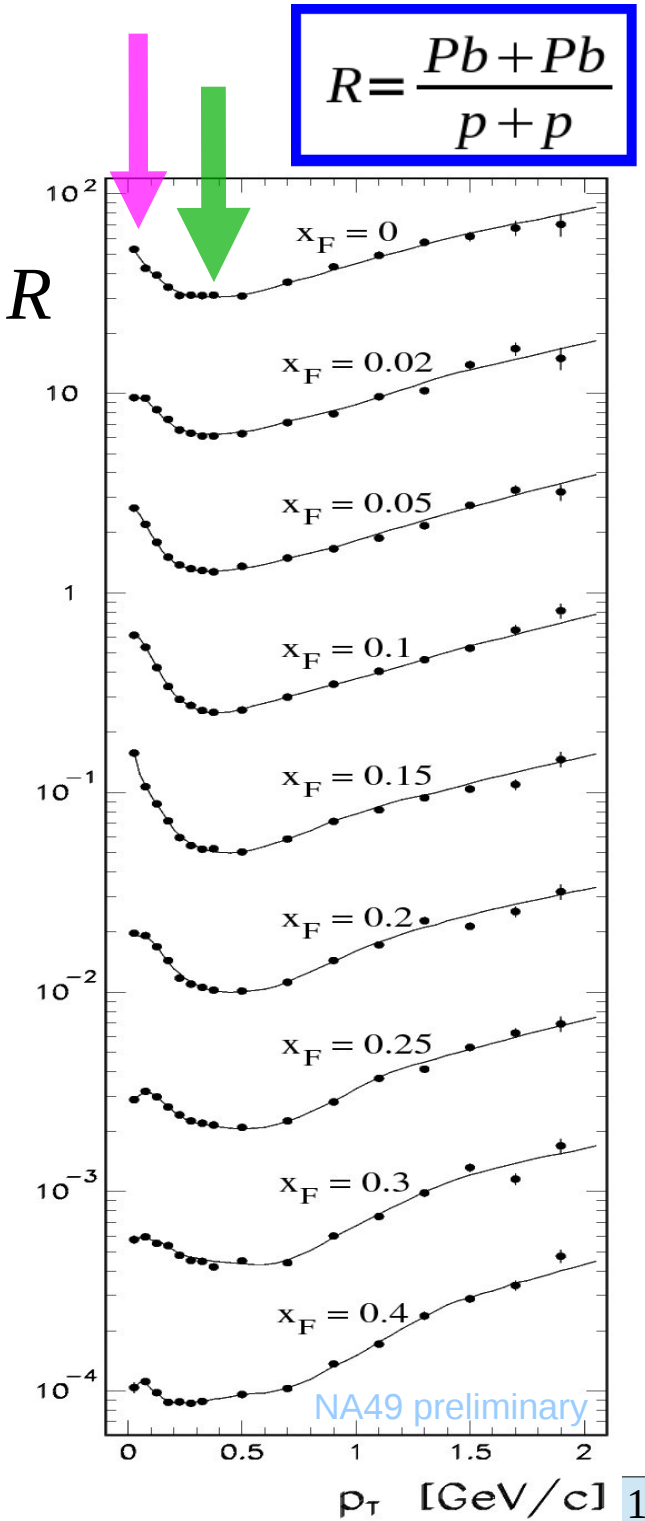
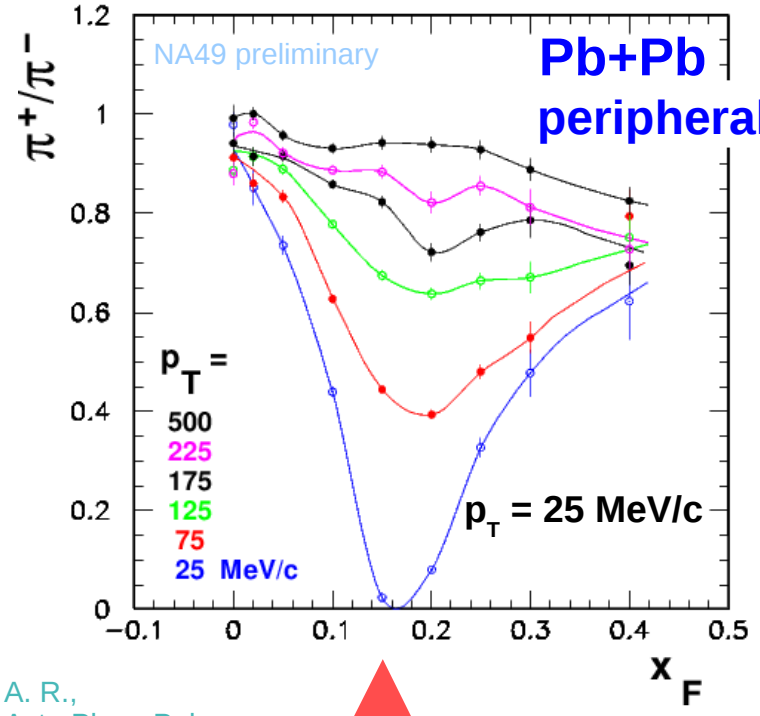
3) (Pb+Pb) / (p+p) ratios

- **We use the averaged spectra :** $\langle\pi\rangle = \frac{\pi^+ + \pi^-}{2}$
- **And study the ratios :** $R = \frac{Pb+Pb}{p+p}$





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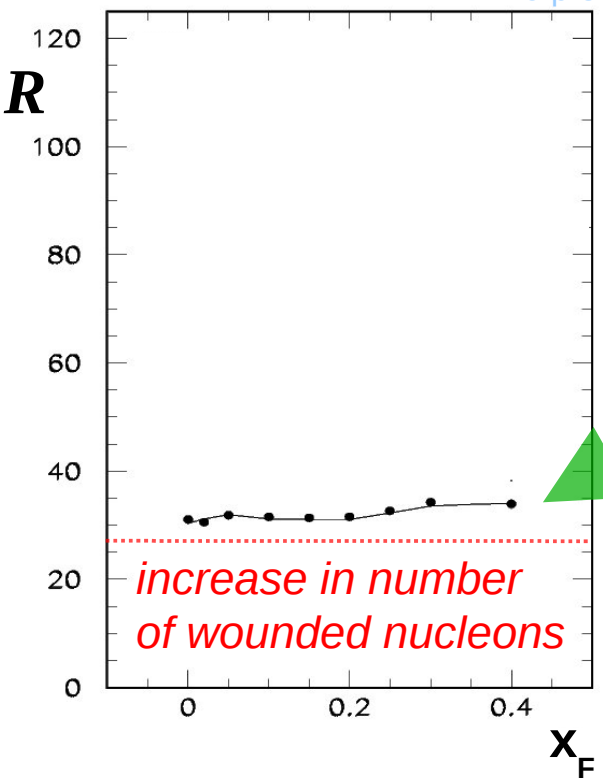
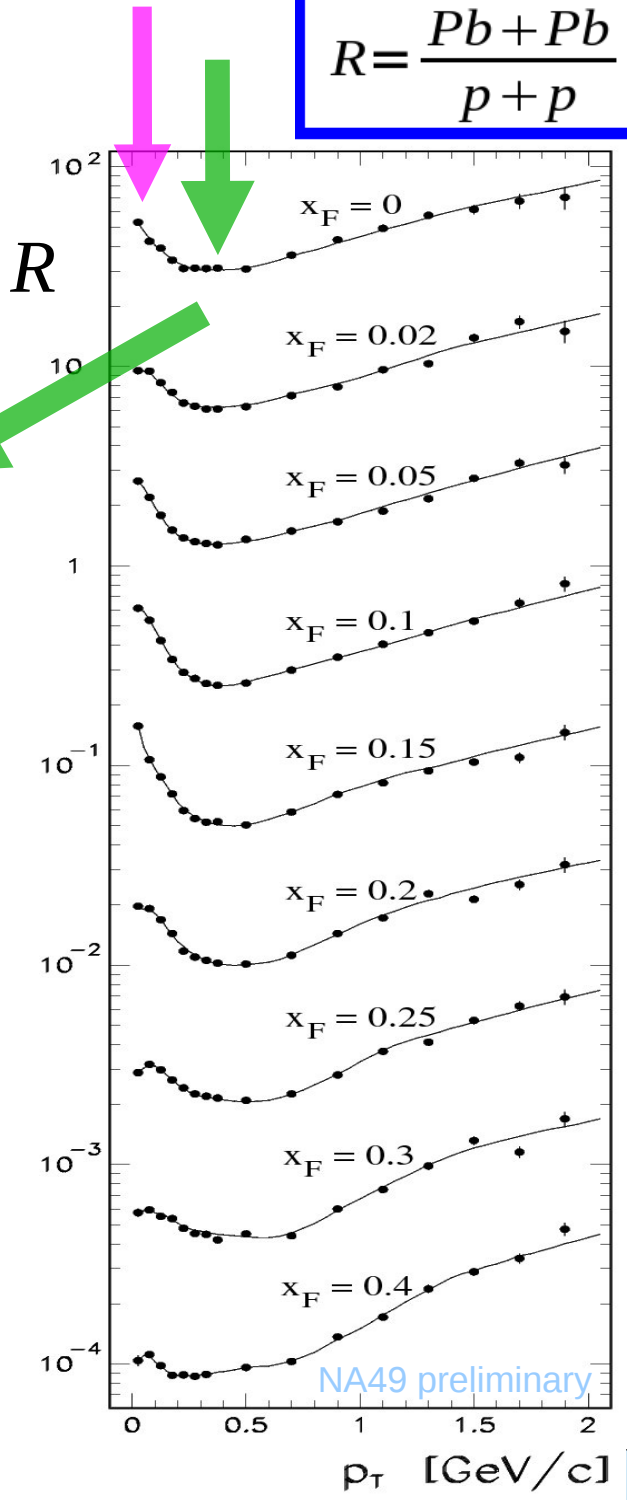
$y = y_{beam}$

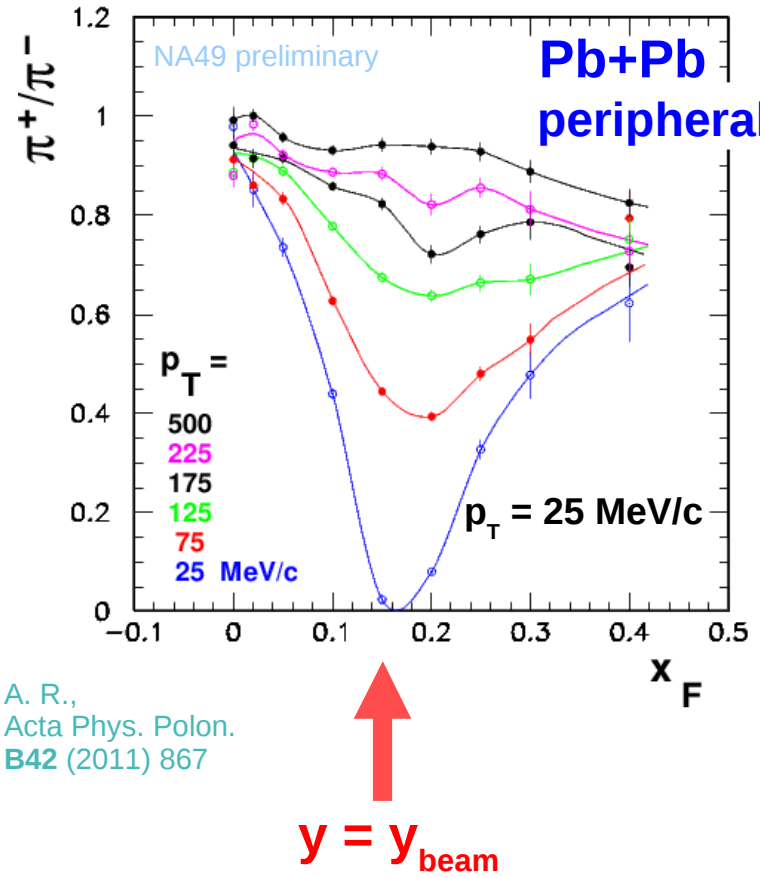


$$R = \frac{Pb+Pb}{p+p}$$



- **Coulomb depletion of π^+/π^- ...**
- **... goes together with enhancement of (charge-averaged) pion production.**

$$\langle\pi\rangle = \frac{\pi^+ + \pi^-}{2}$$



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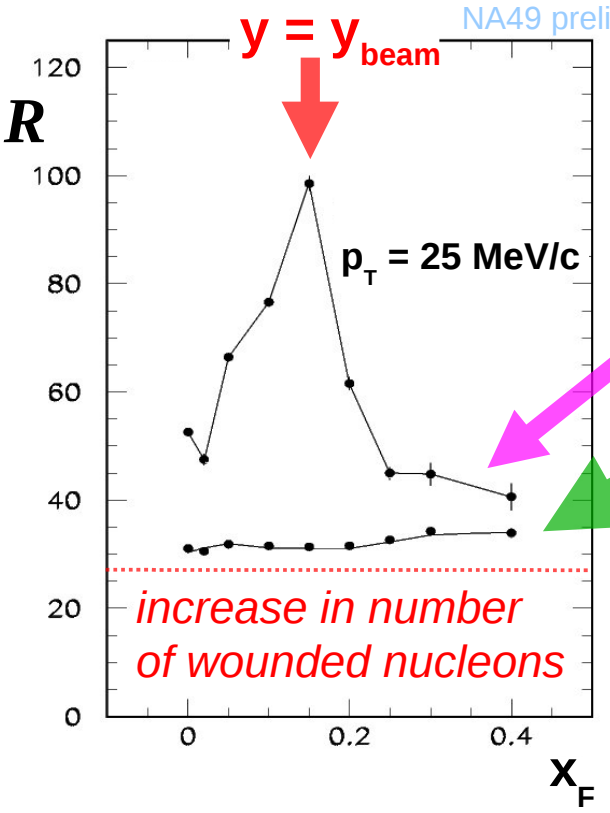
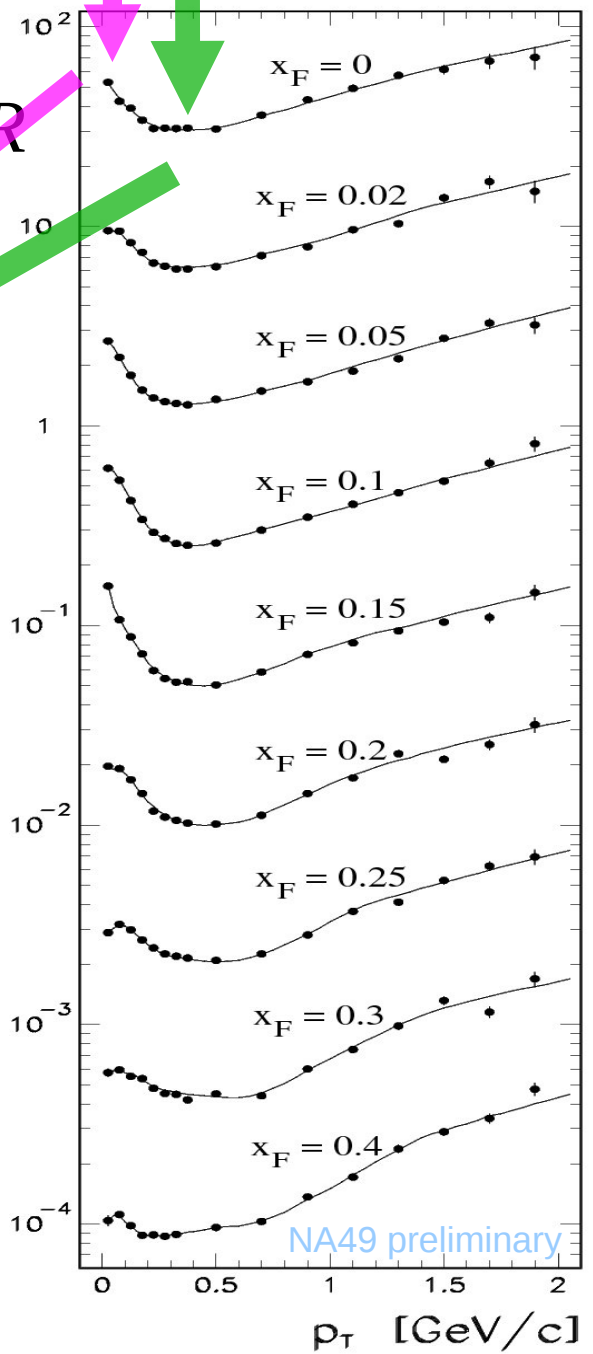


$$R = \frac{Pb+Pb}{p+p}$$



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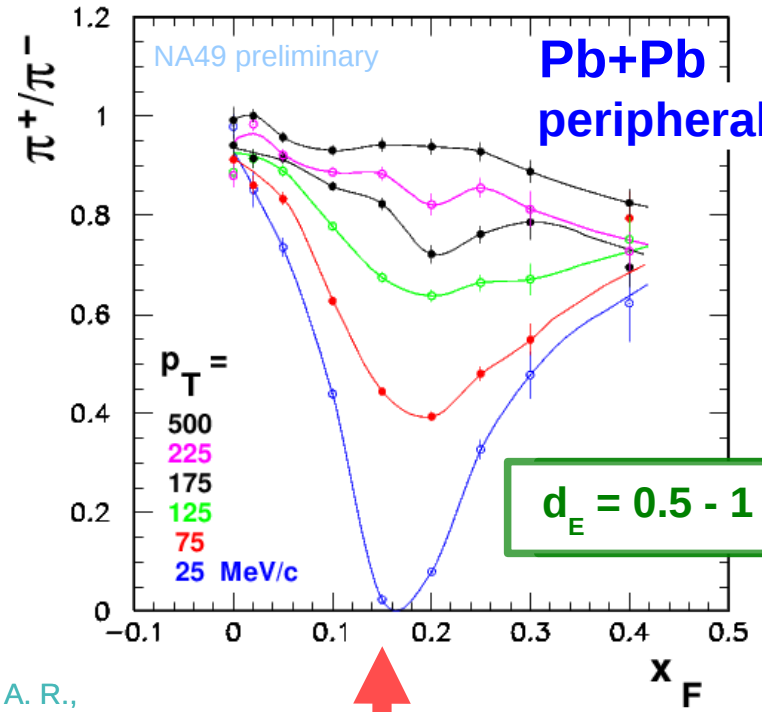

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Acta Phys. Polon.
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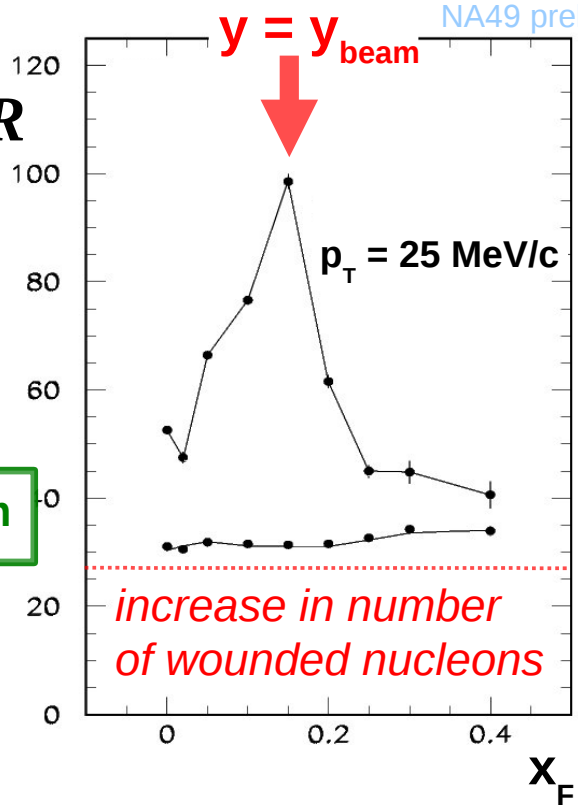
$y = y_{beam}$



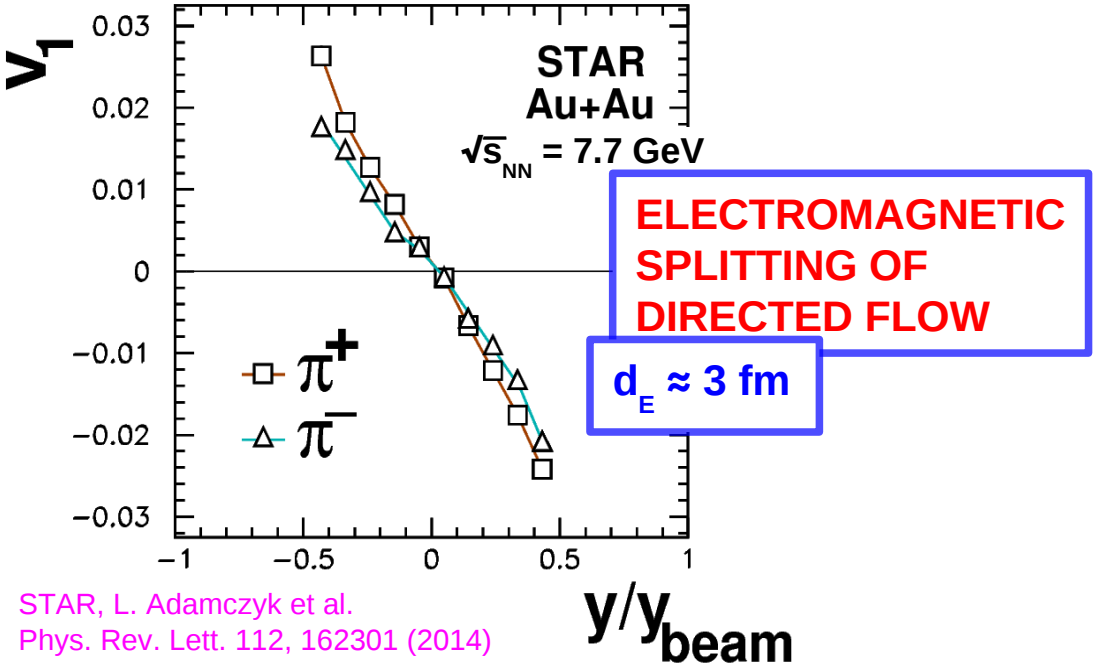
d_E = 0.5 - 1 fm

(1) EM effects are sensitive to the pion emission distance d_E

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

(2) d_E decreases with increasing rapidity of the pion

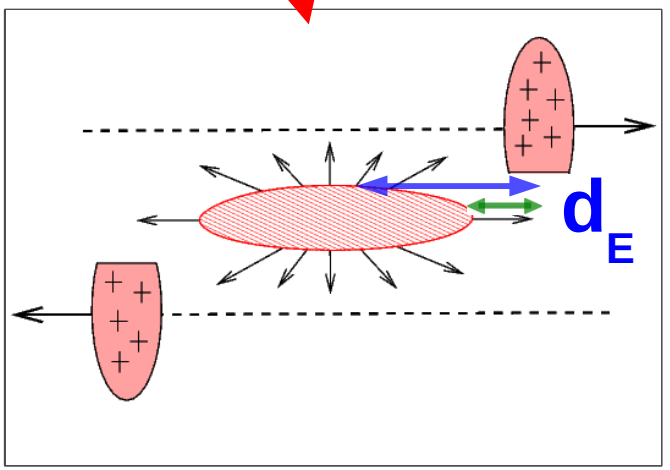
A.R., A.Szczurek,
M. Kłusek-Gawenda
AP**B46** (2015) 737



ELECTROMAGNETIC SPLITTING OF DIRECTED FLOW

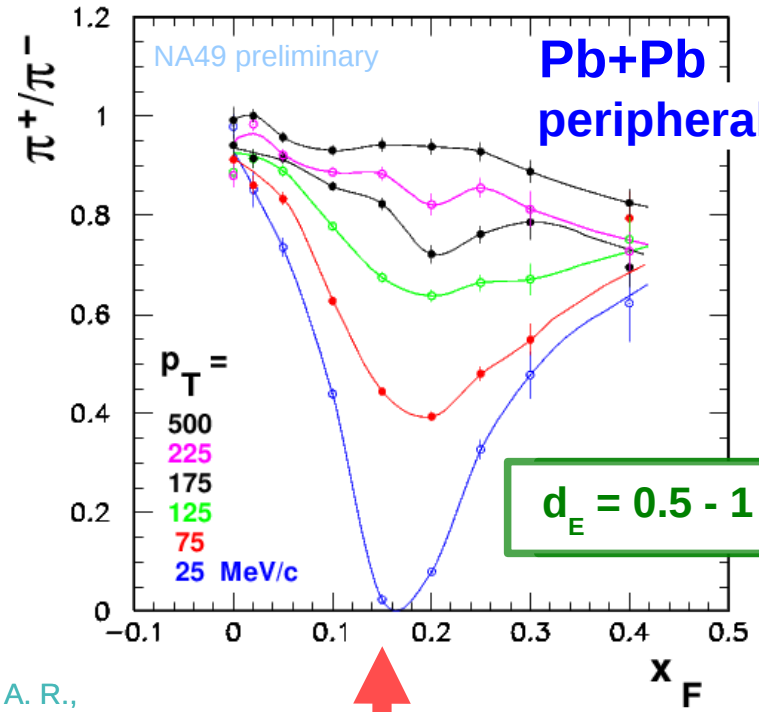
$d_E \approx 3$ fm

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



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

$d_E \approx 3$ fm (small y)



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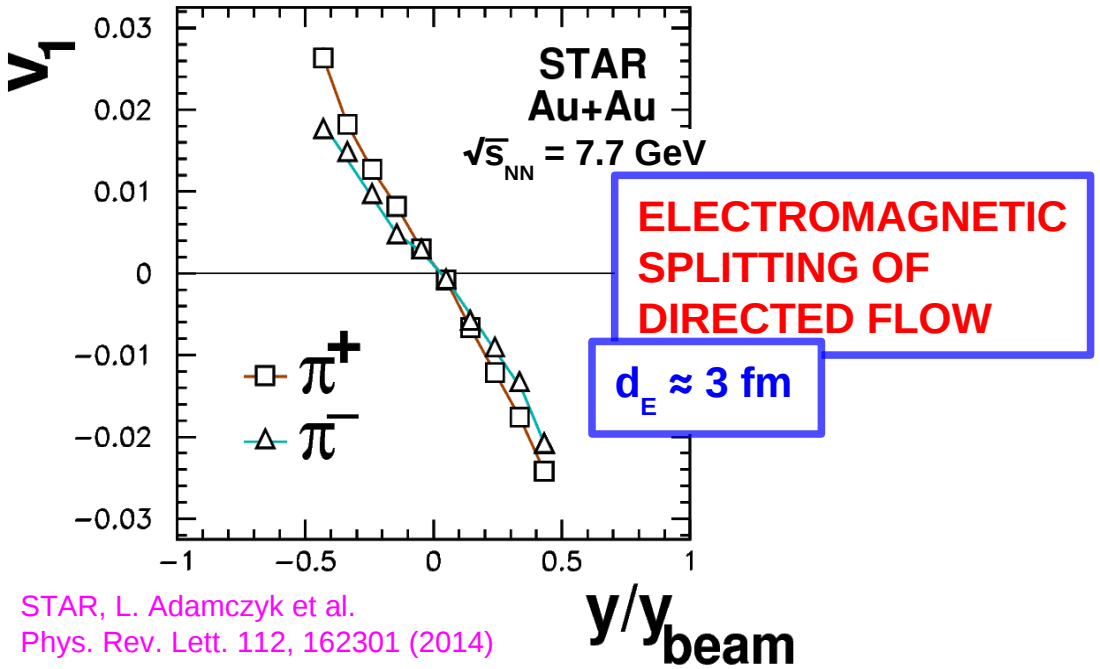

STAR, L. Adamczyk et al.
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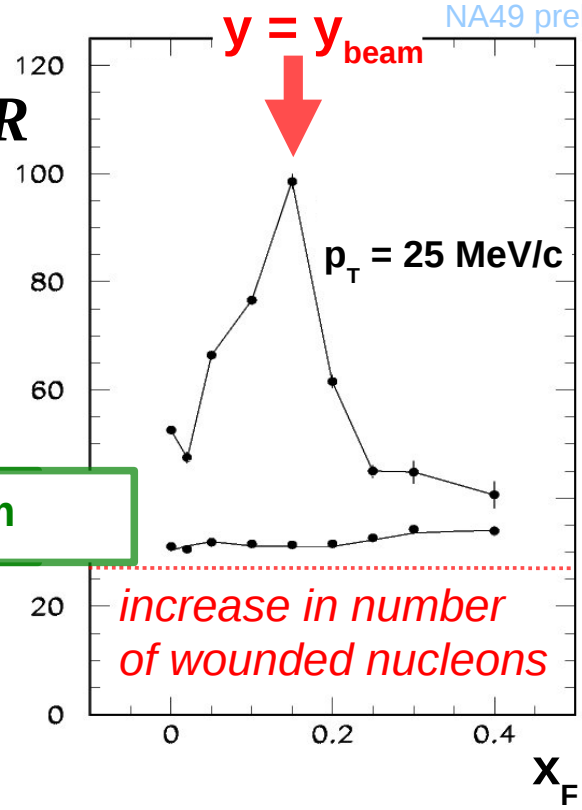

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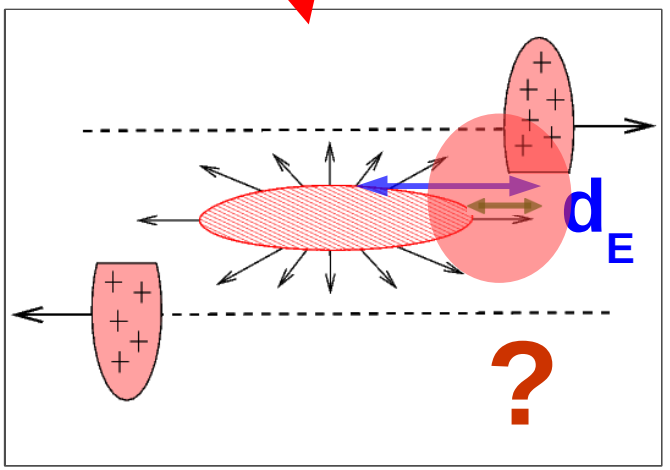


ELECTROMAGNETIC SPLITTING OF DIRECTED FLOW

$d_E \approx 3$ fm

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

$d_E \approx 3$ fm (small y)

4) Summary

- Double differential data on charged pion production and π^+/π^- ratios are available from NA49. More to come from NA49+NA61/SHINE (dedicated program aimed at such studies is just starting).

- A conglomerate of different phenomena becomes apparent from the data:
  - isospin effects on π^+/π^- ratios;
  - large Coulomb effects;
  - enhancement of pion production near spectator rapidity.

- These issues can be studied in more detail as a function of reaction type, centrality, and energy (13-158 A GeV).

- If this is interesting for your community please let me know !!! :-)

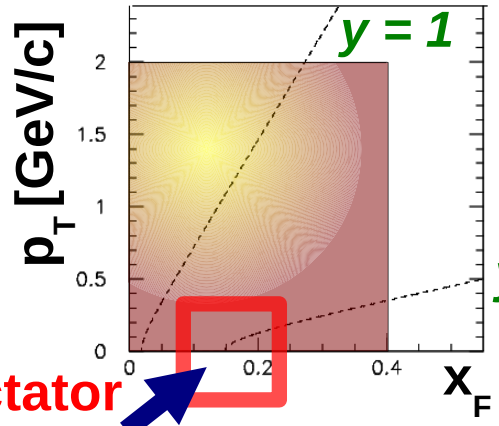
(andrzej.rybicki@ifj.edu.pl)

Note: the presented analysis of (Pb+Pb)/(p+p) ratios from NA49 followed the approach proposed in an earlier work by H.G.Fischer (CERN/SPSC 2007-031).

Acknowledgments.

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

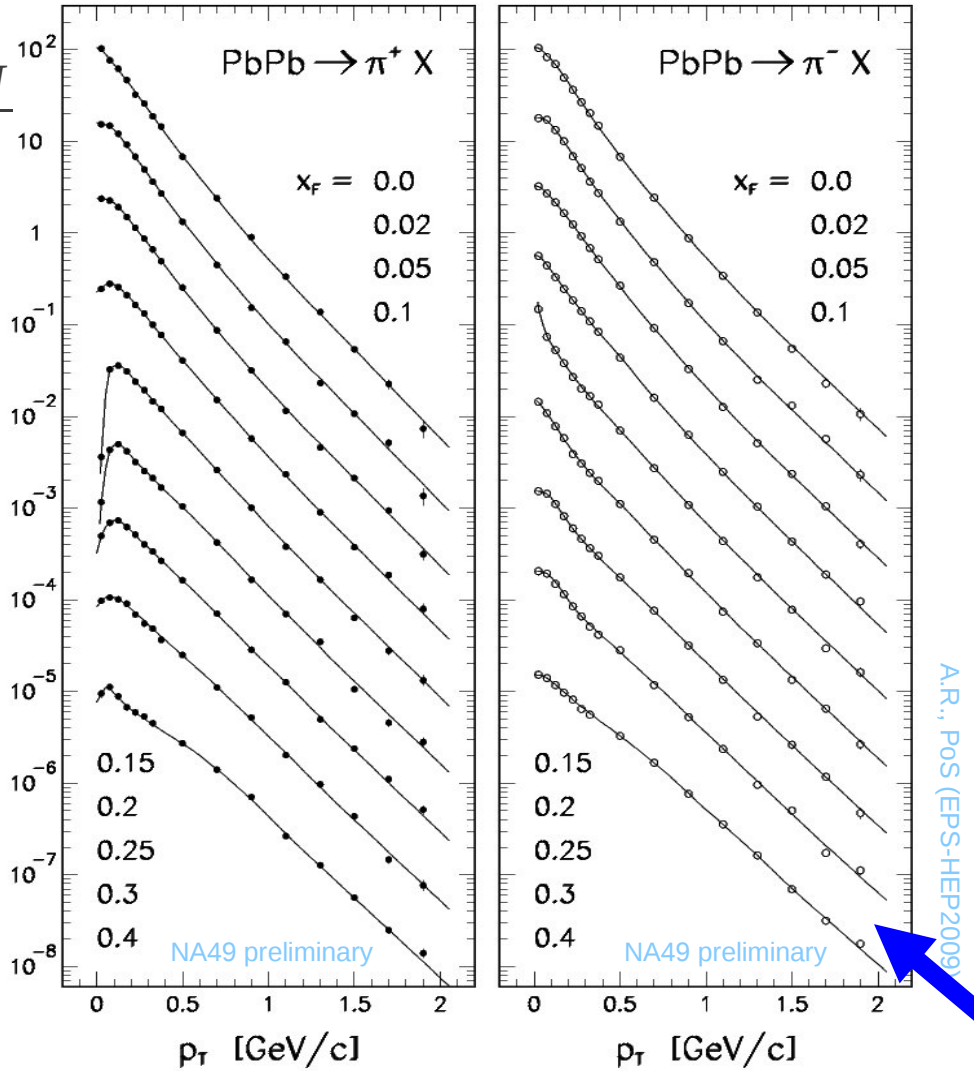
Extra slides

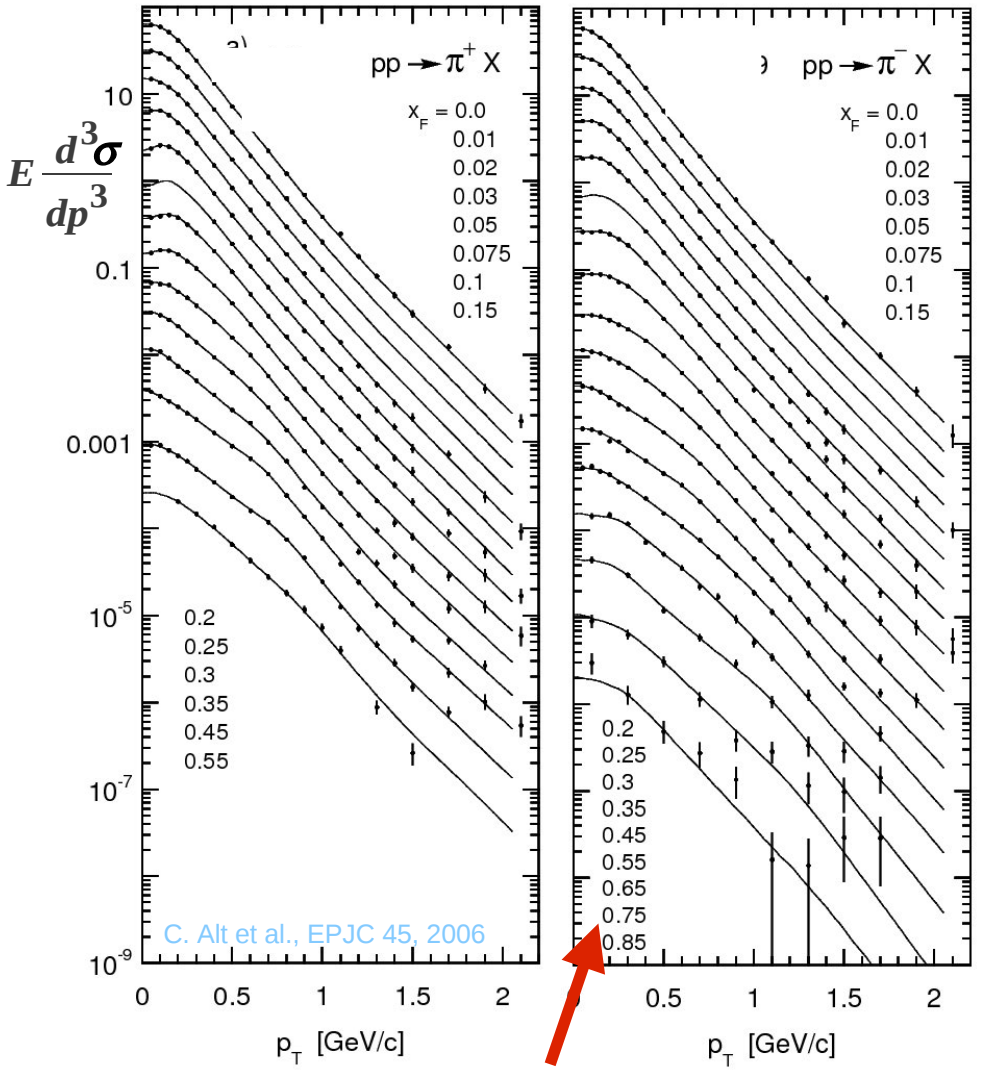


$$x_F = \frac{p_L}{p_L^{beam}}$$ (c.m.s.)

$y = y_{beam} \approx 2.9$

spectator system !

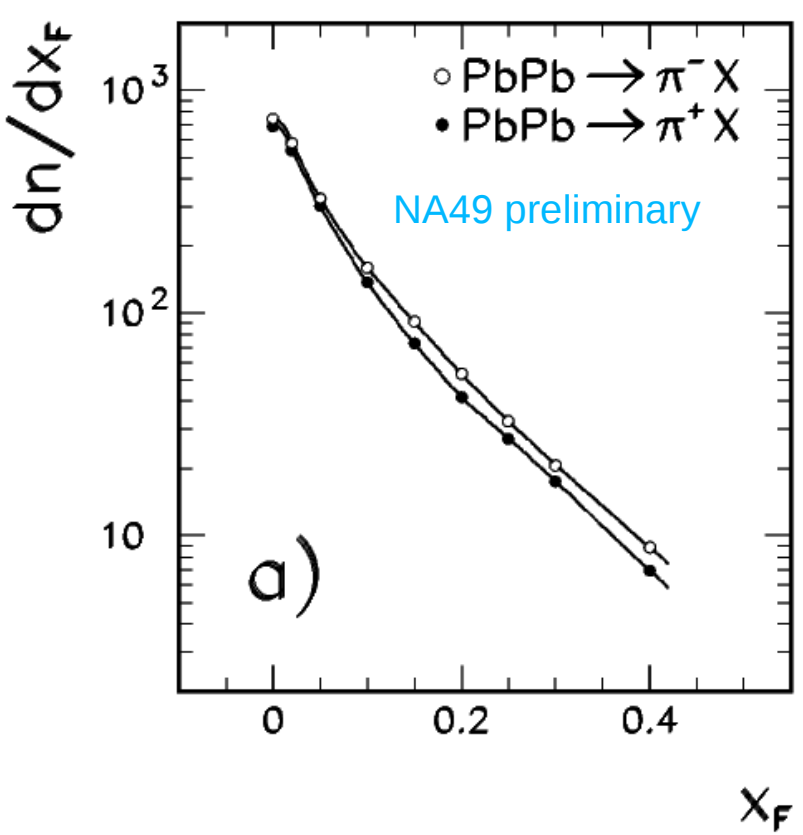


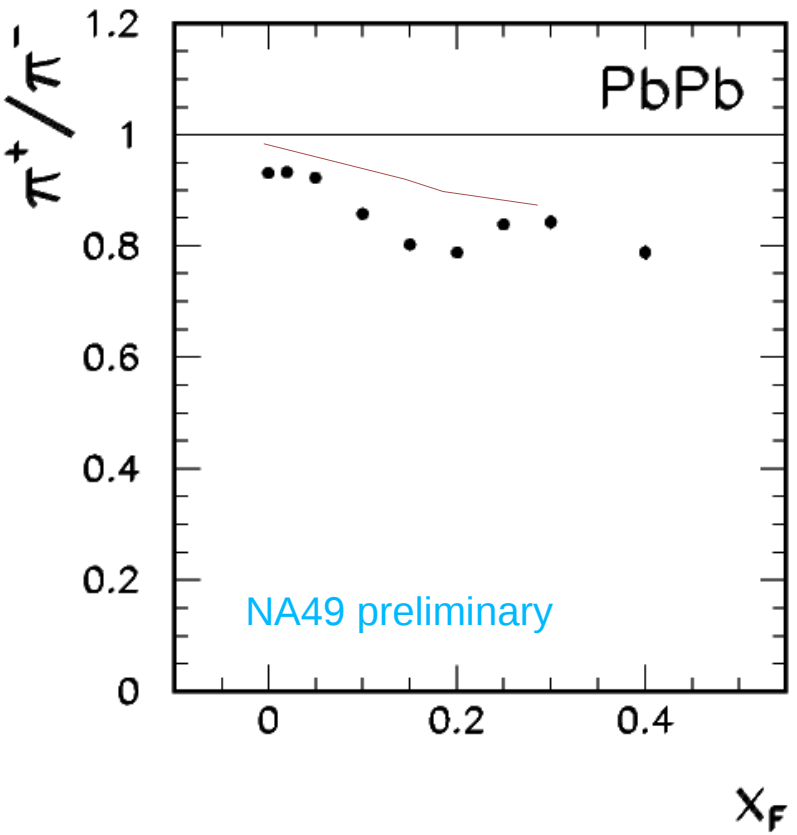


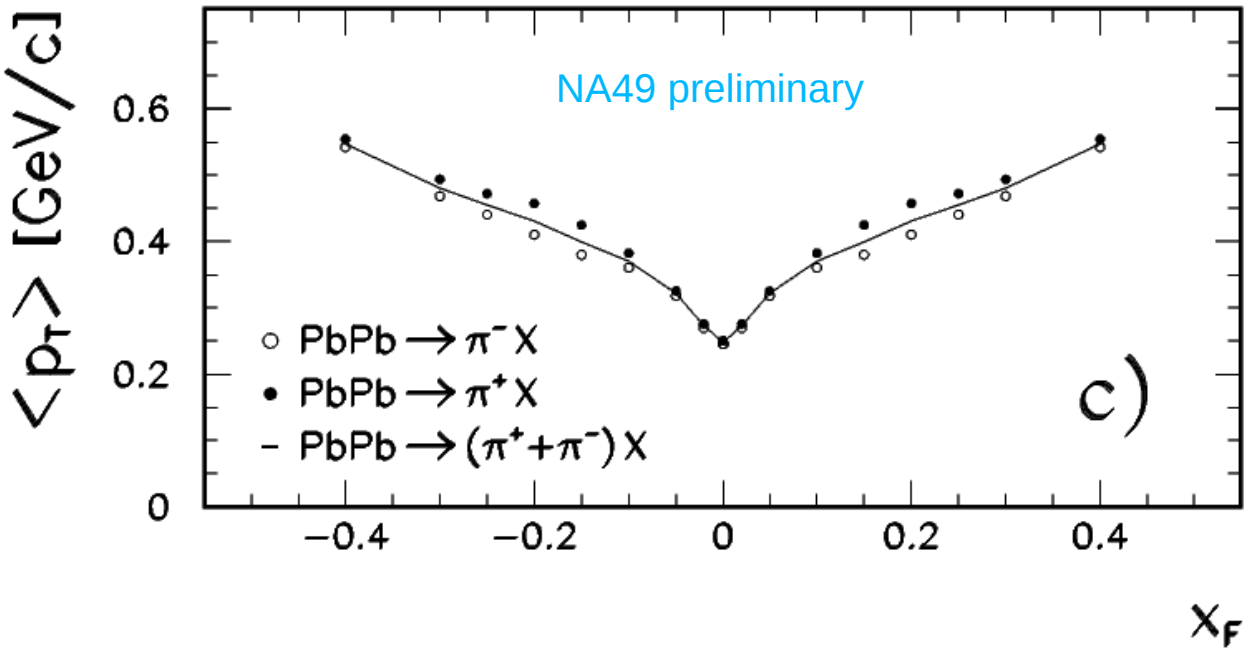
A.R., PoS (EPS-HEP2009)

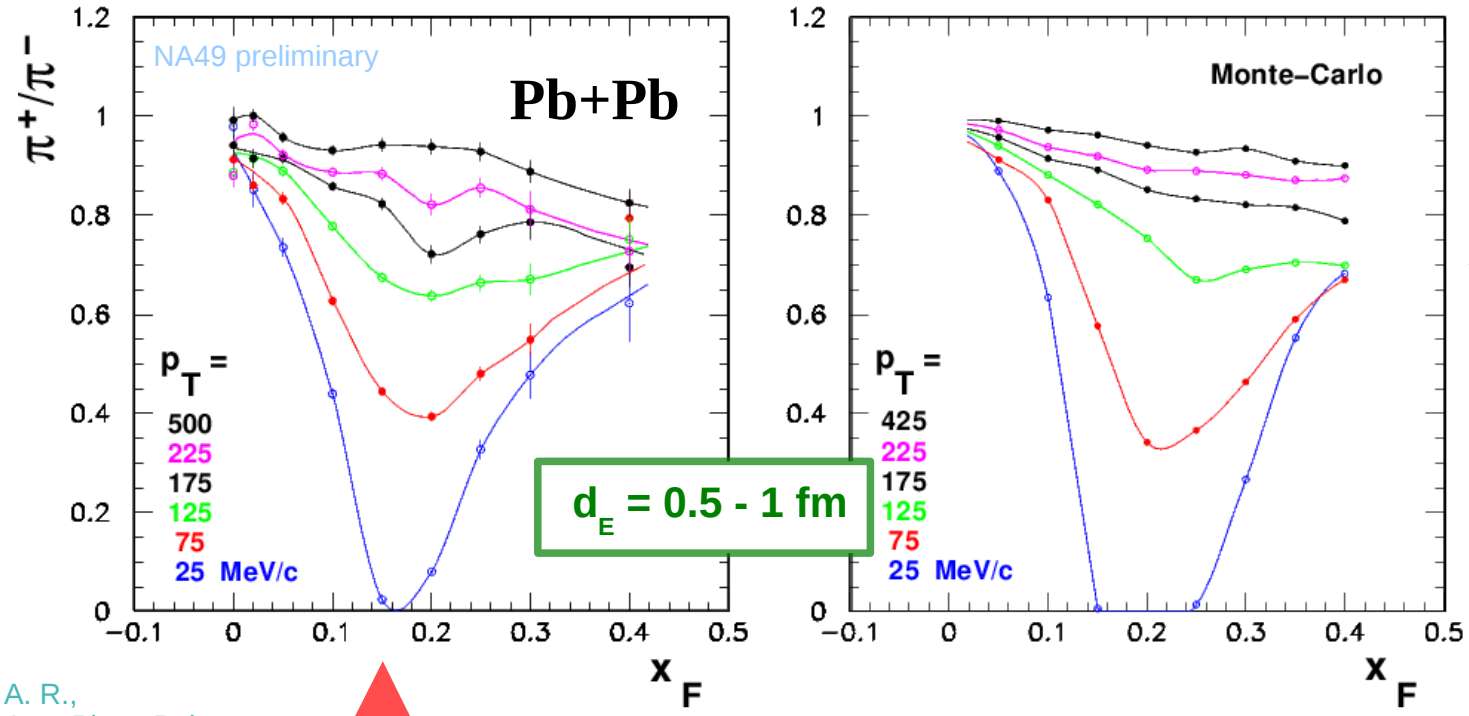
p+p

Pb+Pb peripheral


dn/dx_F
10^3
10^2
10
PbPb → π⁻ X
PbPb → π⁺ X
NA49 preliminary
a)
0
0.2
0.4
x_F


π⁺/π⁻
1.2
1
0.8
0.6
0.4
0.2
0
PbPb
NA49 preliminary
0
0.2
0.4
x_F


<p_T> [GeV/c]
0.6
0.4
0.2
0
NA49 preliminary
PbPb → π⁻ X
PbPb → π⁺ X
PbPb → (π⁺+π⁻) X
c)
−0.4
−0.2
0
0.2
0.4
x_F



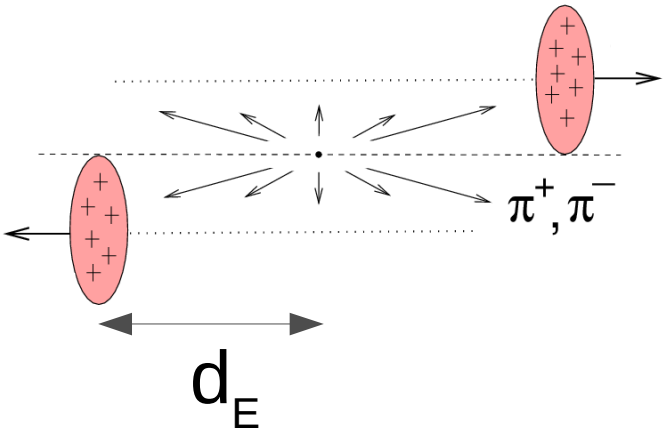
A. R. and A. Szczurek, Phys. Rev. **C75** (2007) 054903

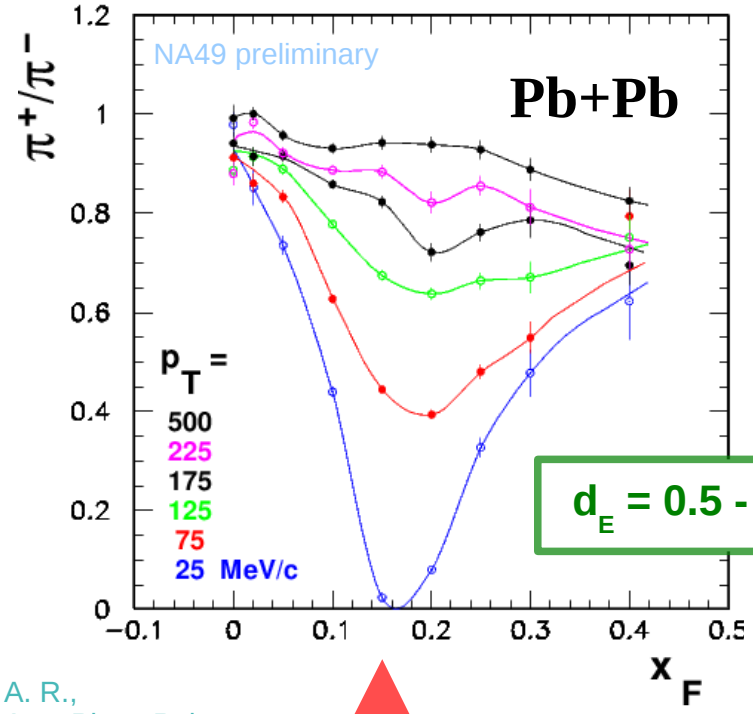
$$x_F = \frac{p_L}{p_L^{beam}}$$ (c.m.s.)

d_E = 0.5 - 1 fm

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

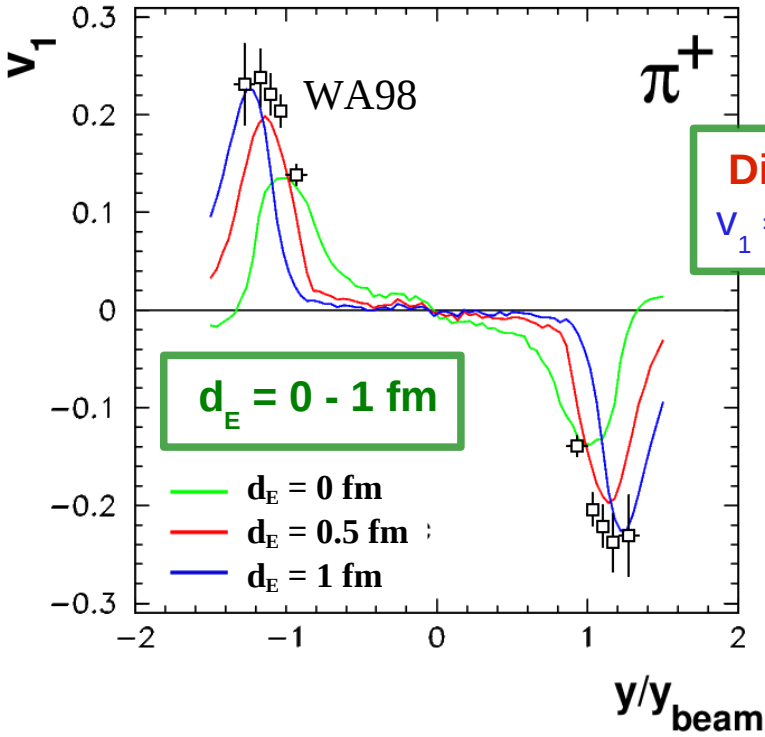
$y = y_{beam}$





d_E = 0.5 - 1 fm

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

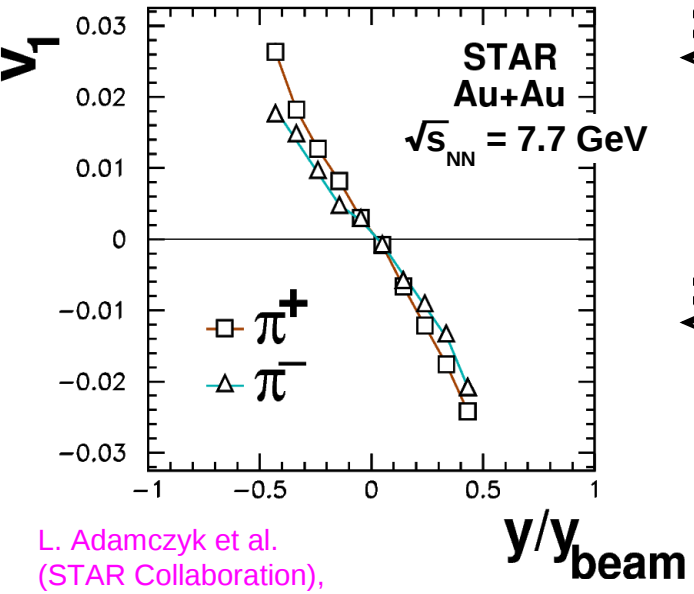


Directed flow:
$v_1 = < \cos(\phi - \Psi_{RP}) >$

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

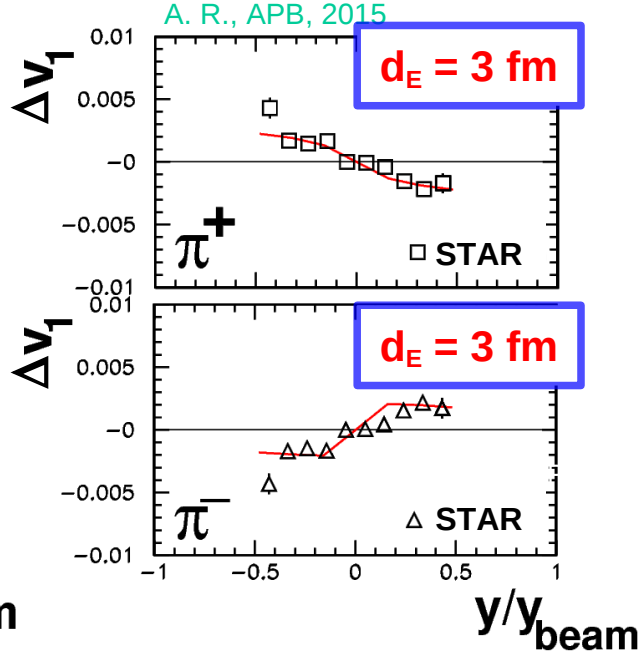
H. Schlagheck
(WA98 Collaboration),
Nucl. Phys. A **663** (2000)
725.

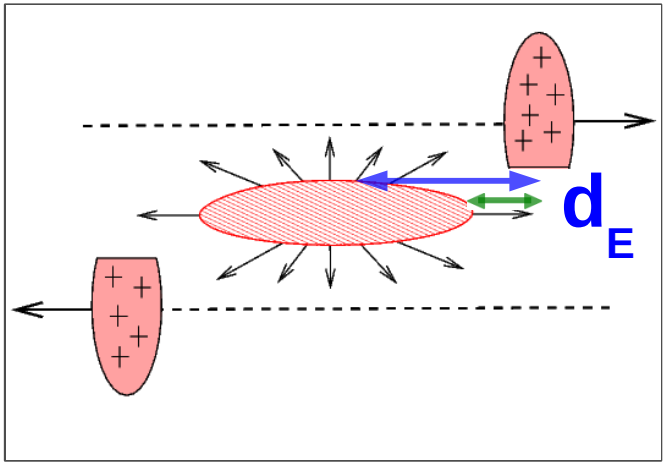
$y = y_{beam}$



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

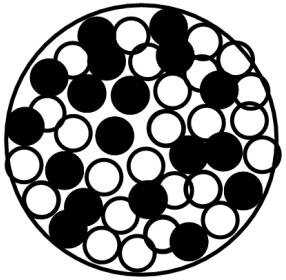
A. R., APB, 2015





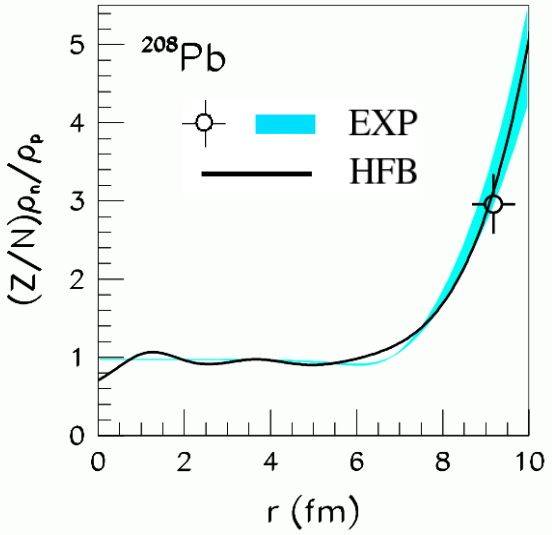
d_E < 1 fm ($y \approx y_{beam}$)

$d_E \approx$ 3 fm (small y)

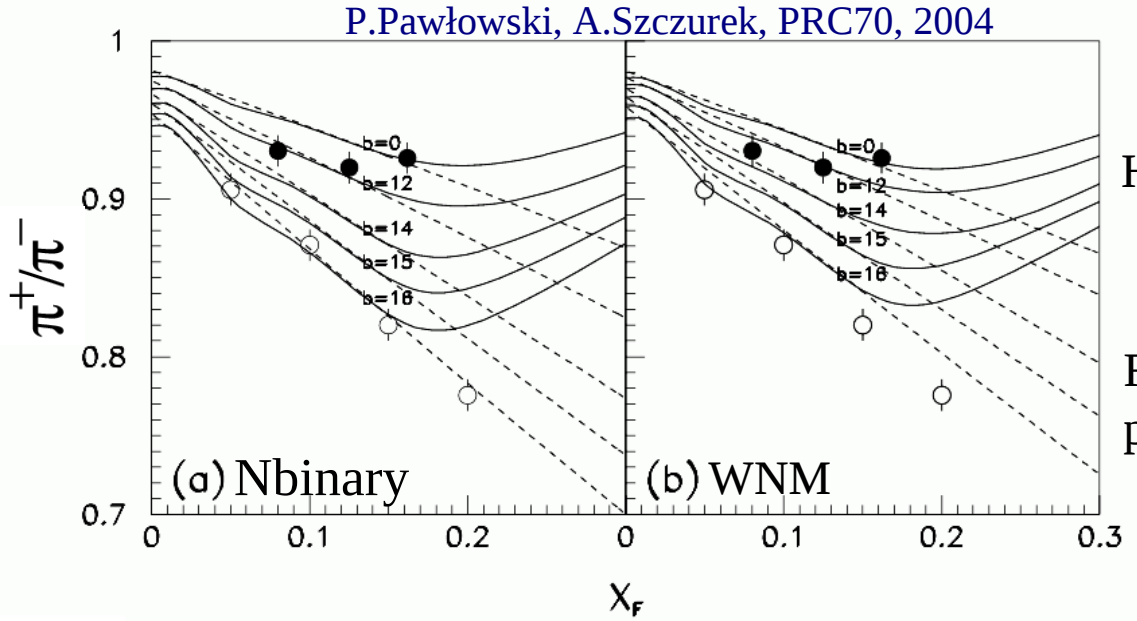


Hypothesis no. 1: the “neutron halo” ?

A.Trzcińska et al., PRL87,2001
R.Schmidt et al.,PRC67,2003
S.Mizutori et al.,PRC61,2000

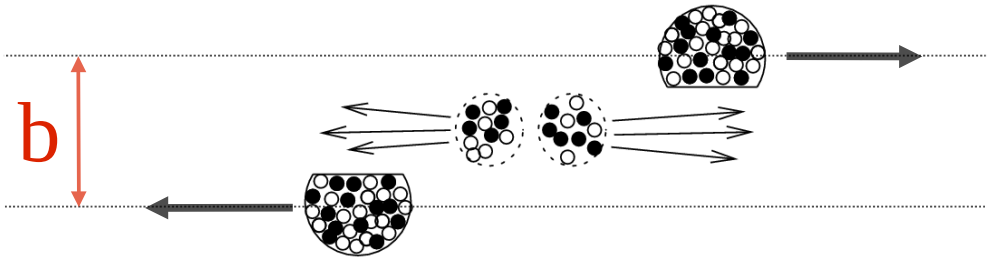


P.Pawłowski, A.Szczurek, PRC70, 2004



HIJING

Fit to NA49 p+p/n+p



- **Analysis of collision geometry:** **b**
  = 10.9 ± 0.5 fm
- **Not possible to obtain 75% n, 25 % p**