

# Comparative studies of pion spectra in p+p and Pb+Pb collisions

Andrzej Rybicki

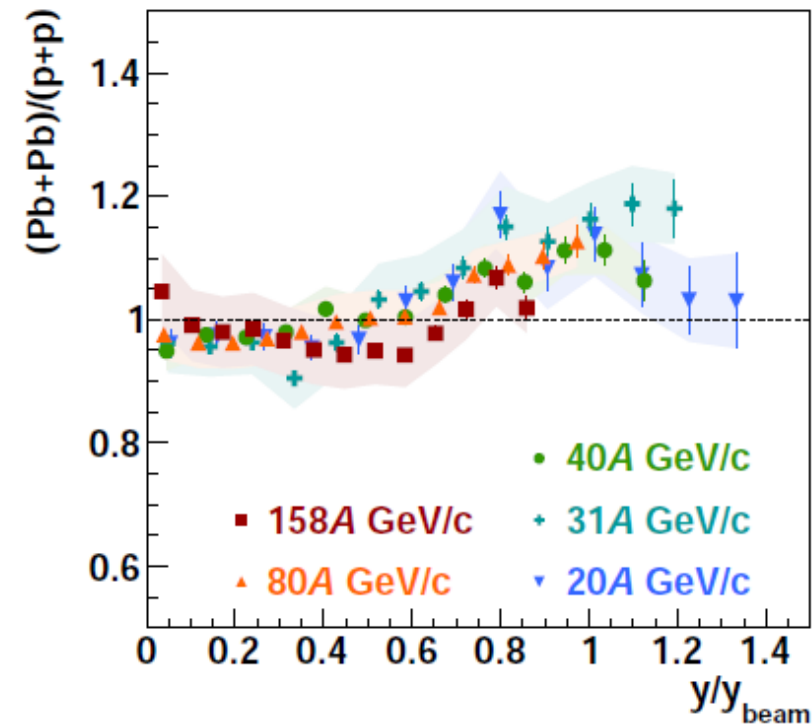
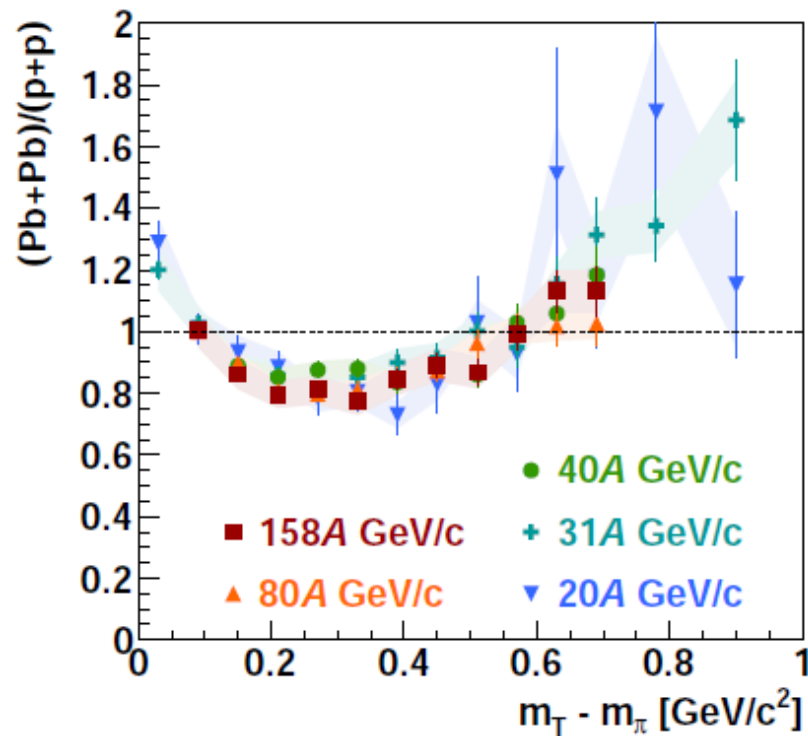
H. Niewodniczański Institute of Nuclear Physics  
Polish Academy of Sciences

- 1) Motivation
- 2) Particle production ratios
- 3) EM effects
- 4) Summary

# **1)** ***Motivation***

# Comparison with Pb+Pb spectra

N. Abgrall et al. (NA61/SHINE Collaboration),  
Eur. Phys. J. C 74 (2014) 3, 2794



- The  $\pi^-$  spectra in Pb+Pb collisions divided by p+p results, normalised to unity before dividing
- The transverse mass spectra at mid-rapidity in Pb+Pb are higher at very low and very high  $m_T$
- The rapidity spectra do not differ much between Pb+Pb and p+p
- Ratio of the spectra does not change with the collision energy



2)

*Particle production ratios*

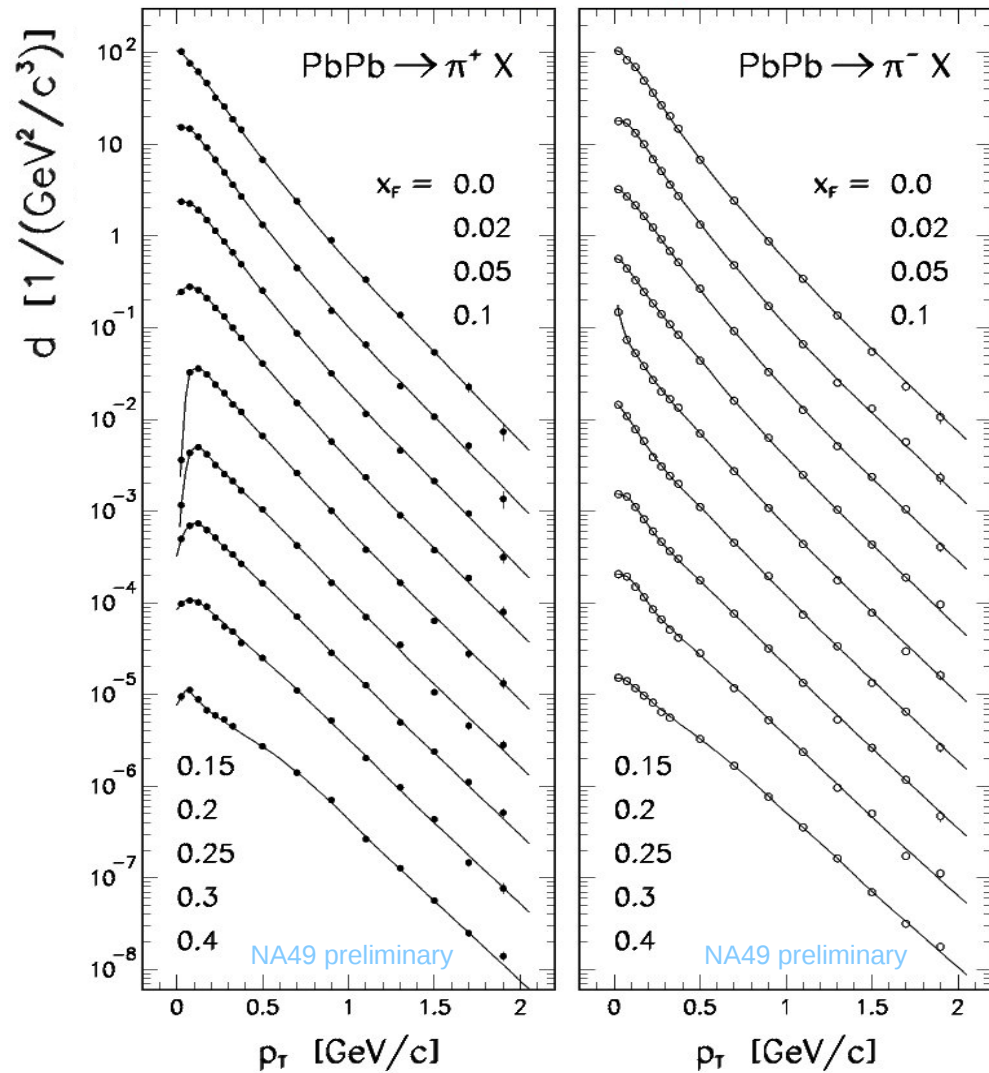
*( (Pb+Pb) / (p+p) )*

# The Data: NA49, $\sqrt{s_{NN}}=17$ GeV (158 A GeV/c)

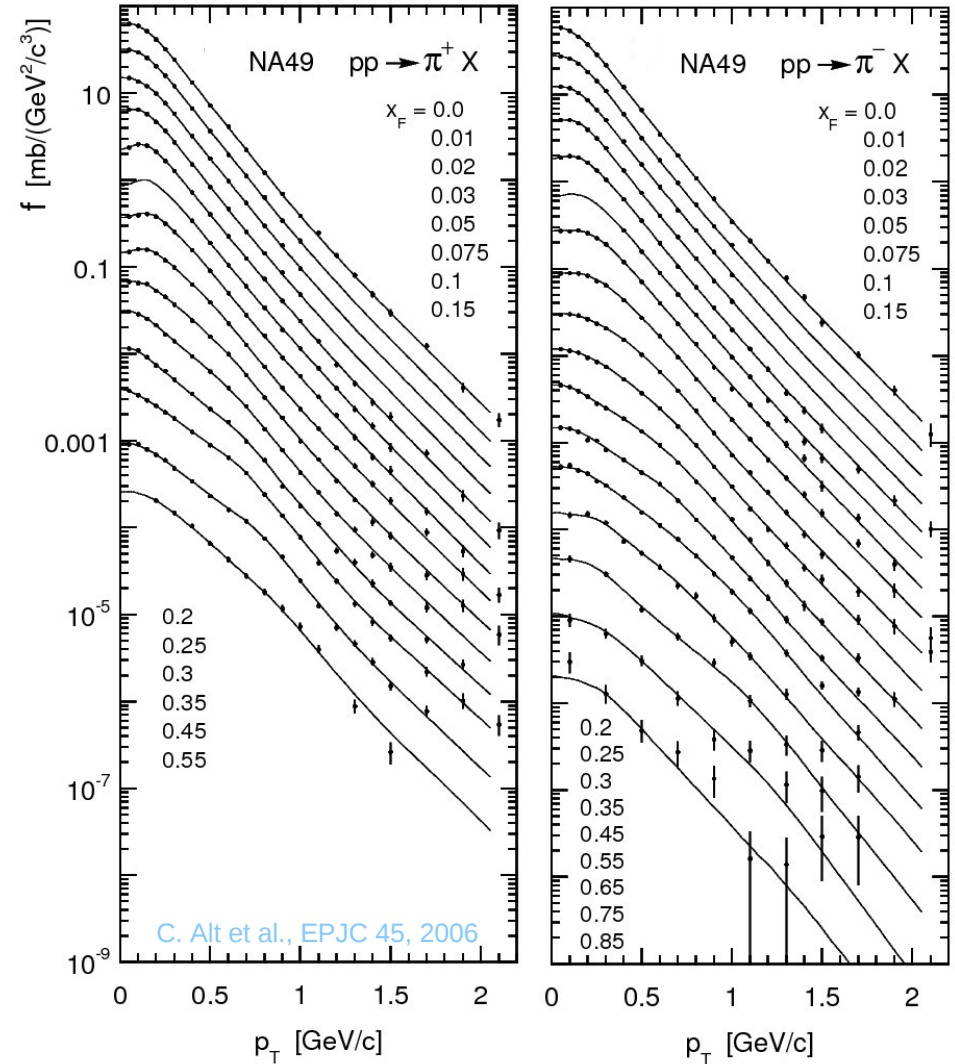
**p+p**  $f = E \frac{d^3\sigma}{dp^3}$

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

**Pb+Pb (peripheral)**



A.R., POS (EPS-HEP2009)

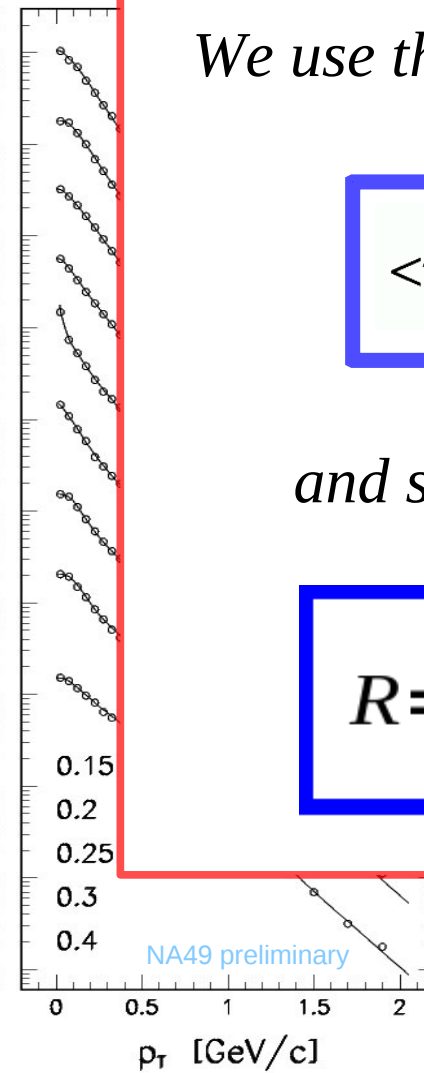
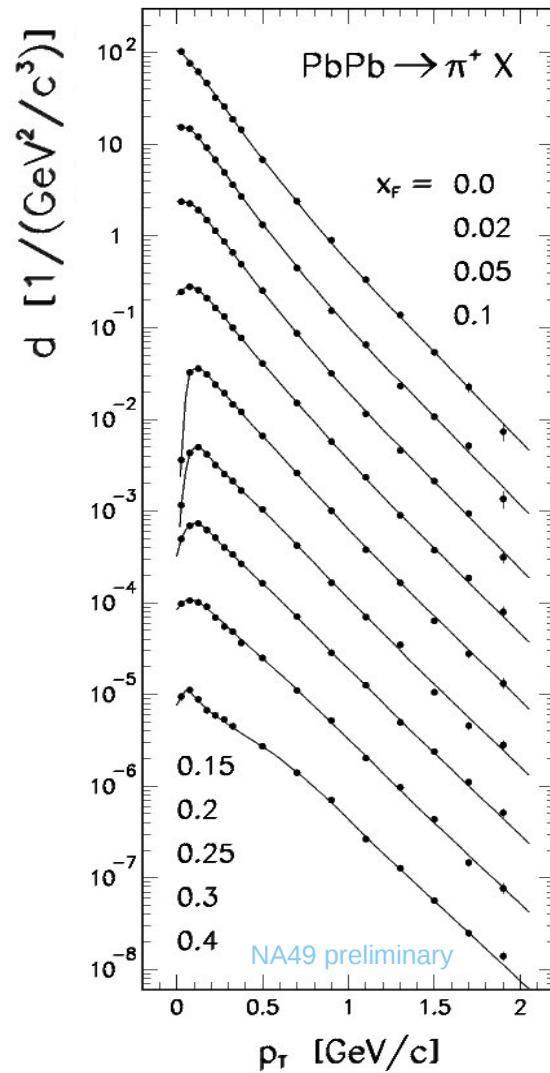


$$x_F = \frac{p_L}{p_L^{beam}} \quad (\text{c.m.s.})$$

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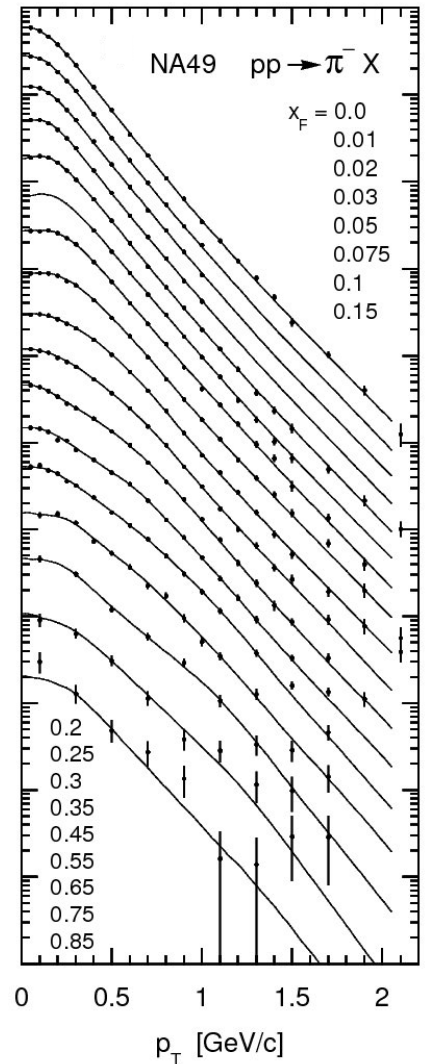
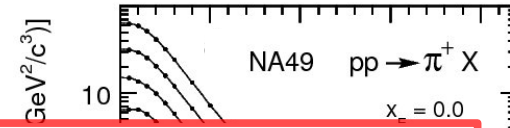


$d = E \frac{d^3 N}{V^3}$

*We use the averaged spectra*

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

*and study the ratios*

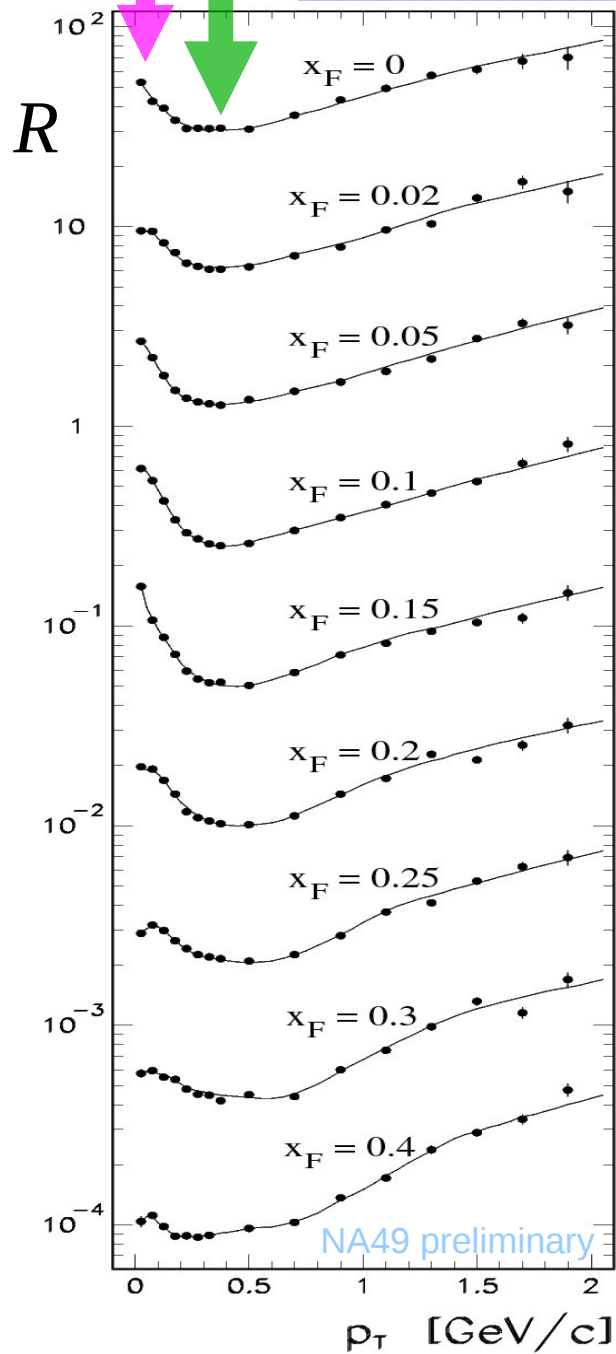
$$R = \frac{Pb + Pb}{p + p}$$


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

(c.m.s.)

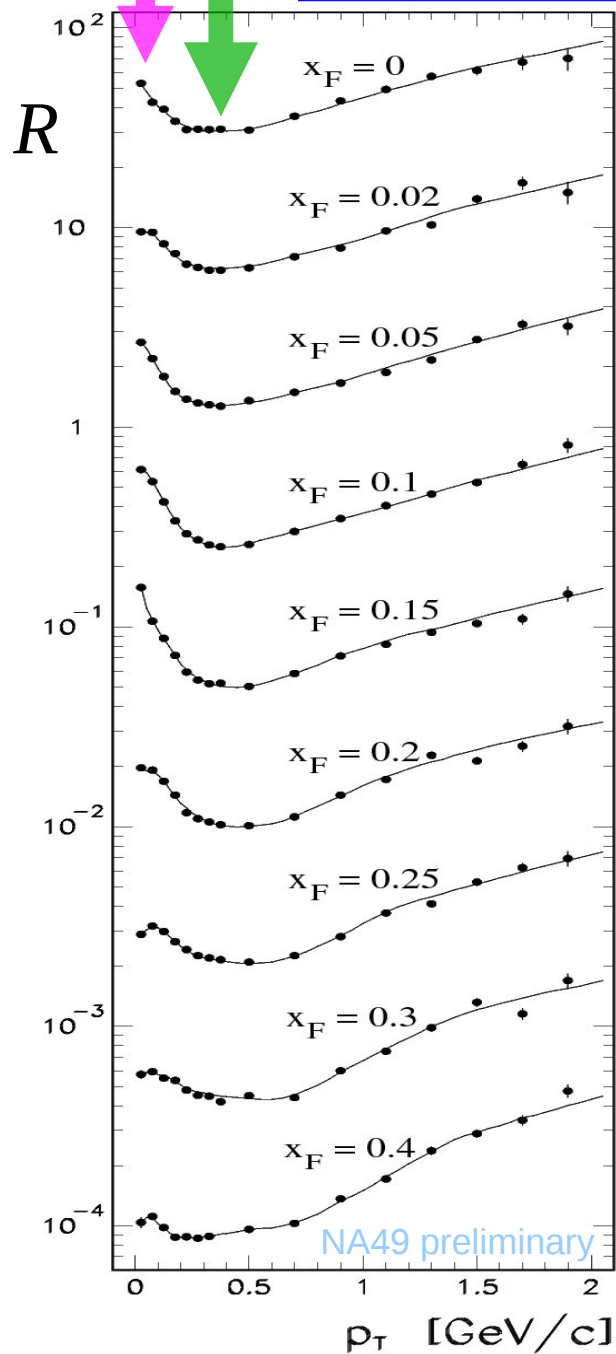
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- NA49:  $(\pi^+ + \pi^-)/2$ ;  
Pb+Pb peripheral.

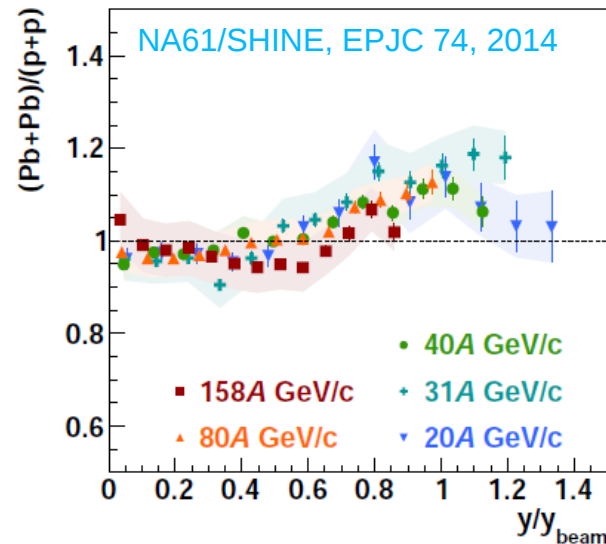
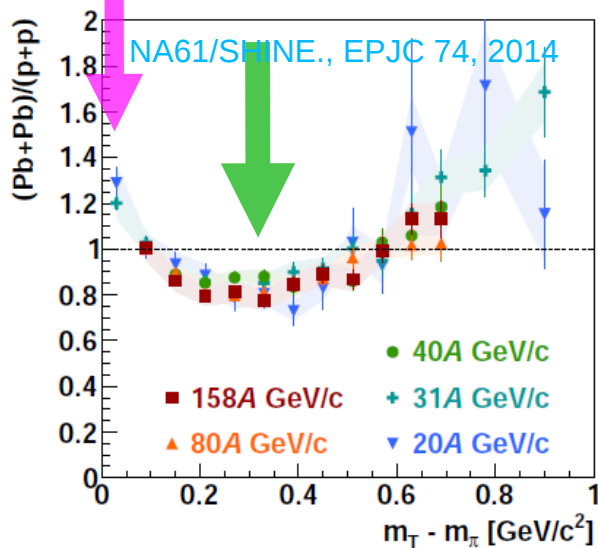


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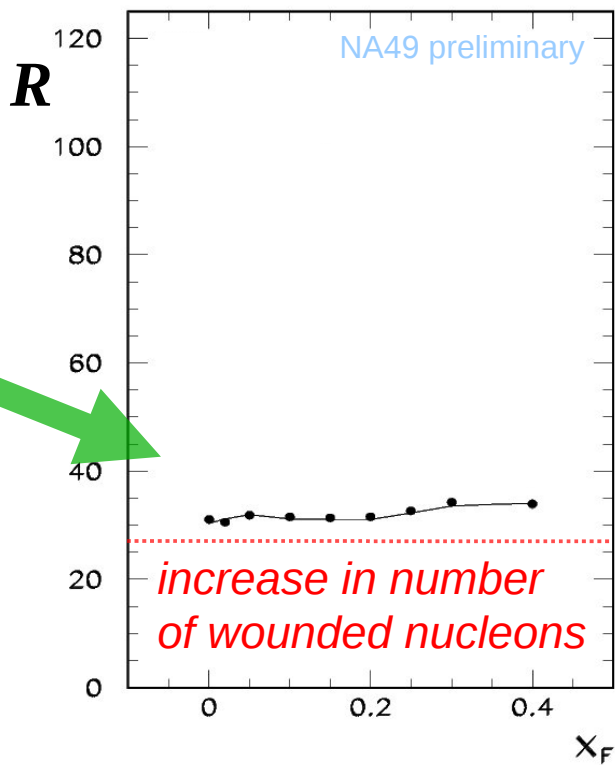
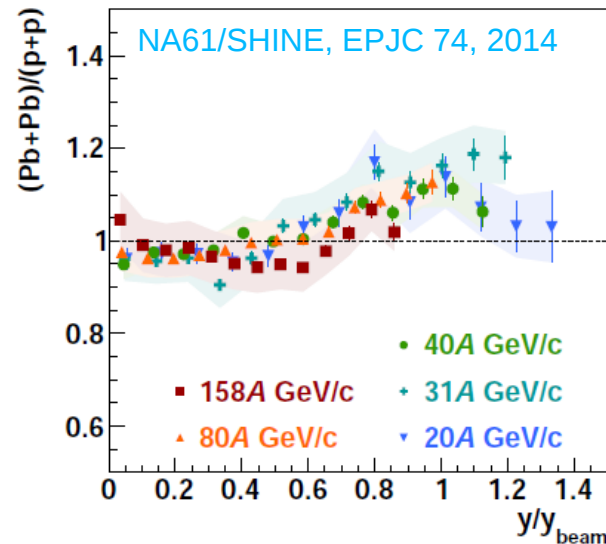
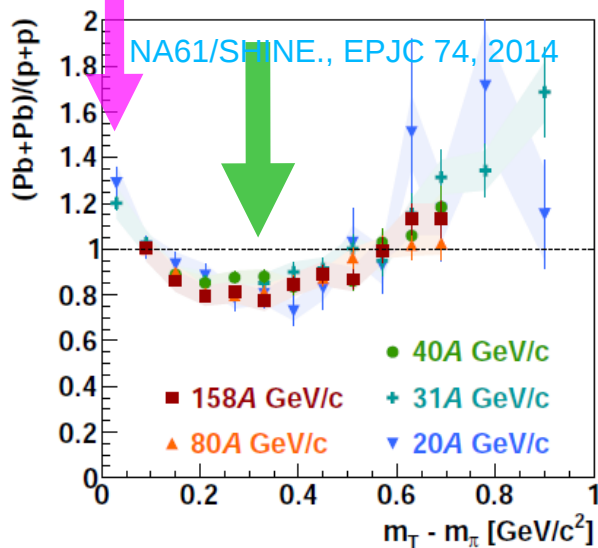
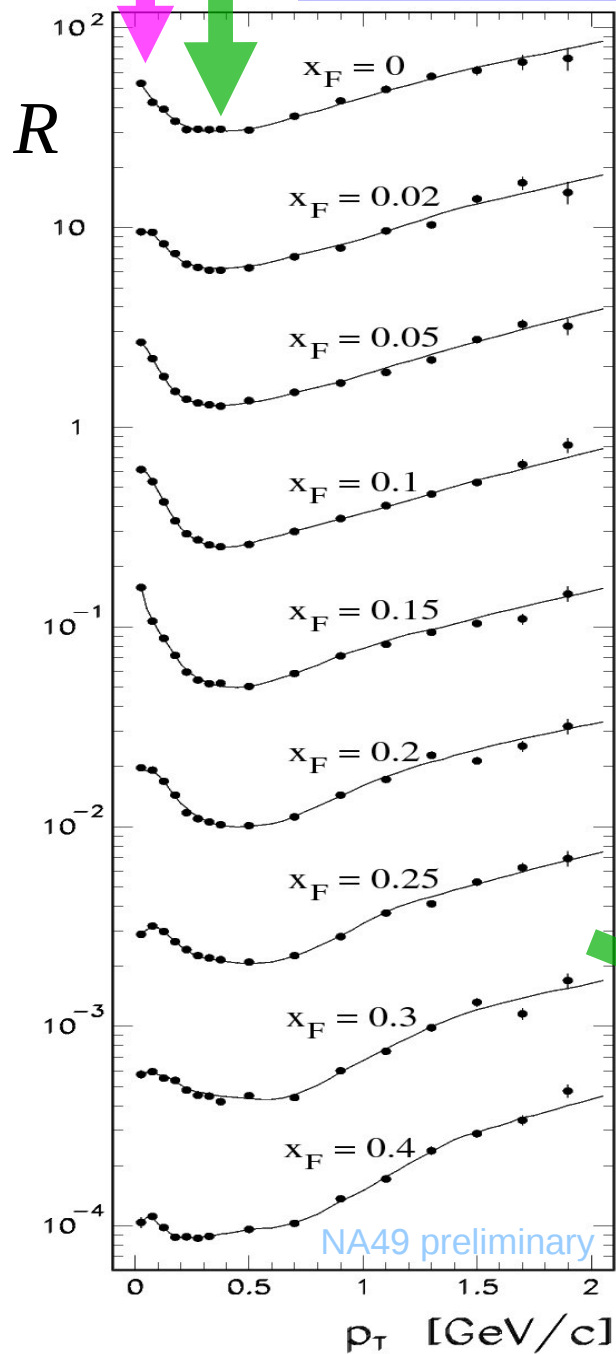
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- NA61/SHINE:  $\pi^-$  only; Pb+Pb CENTRAL.





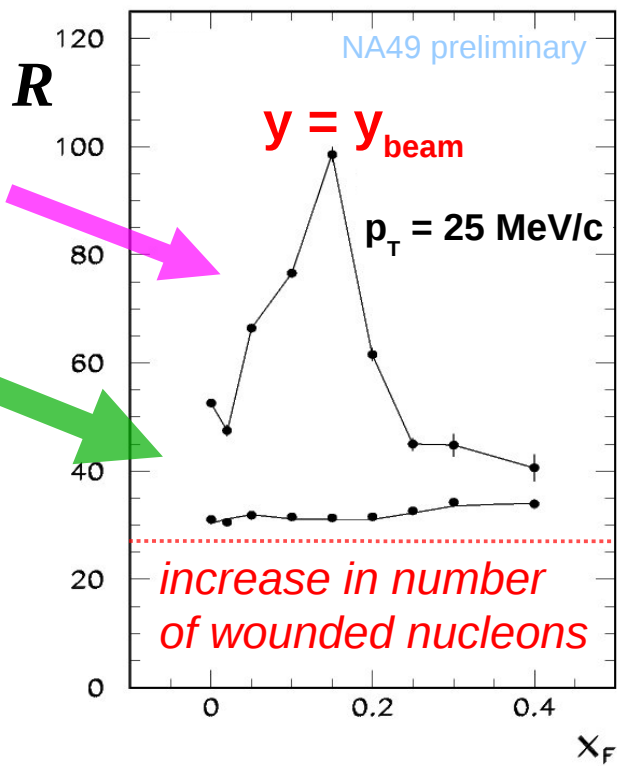
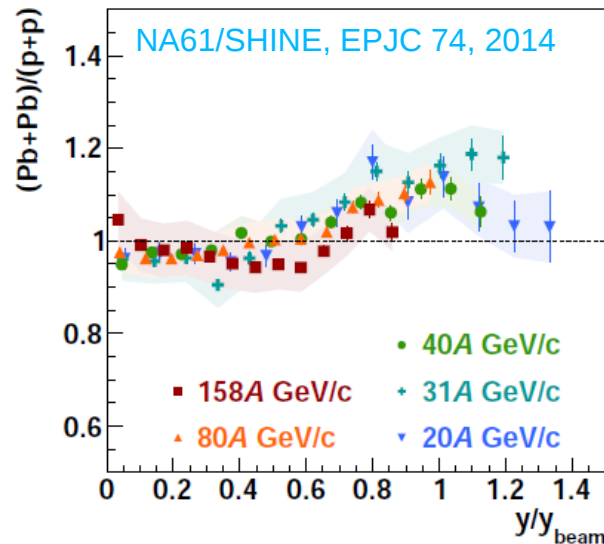
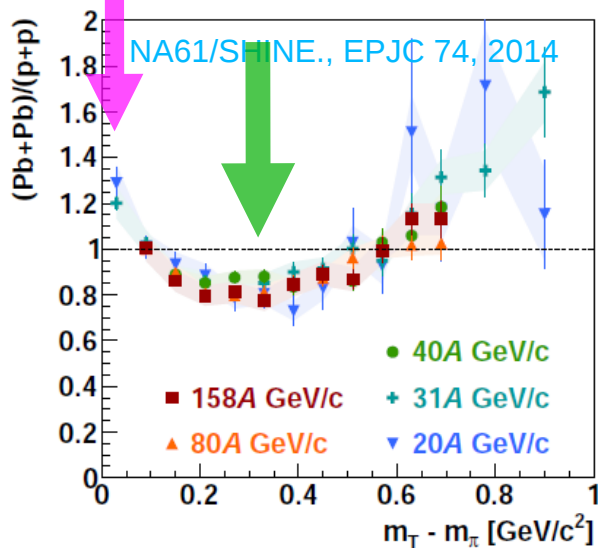
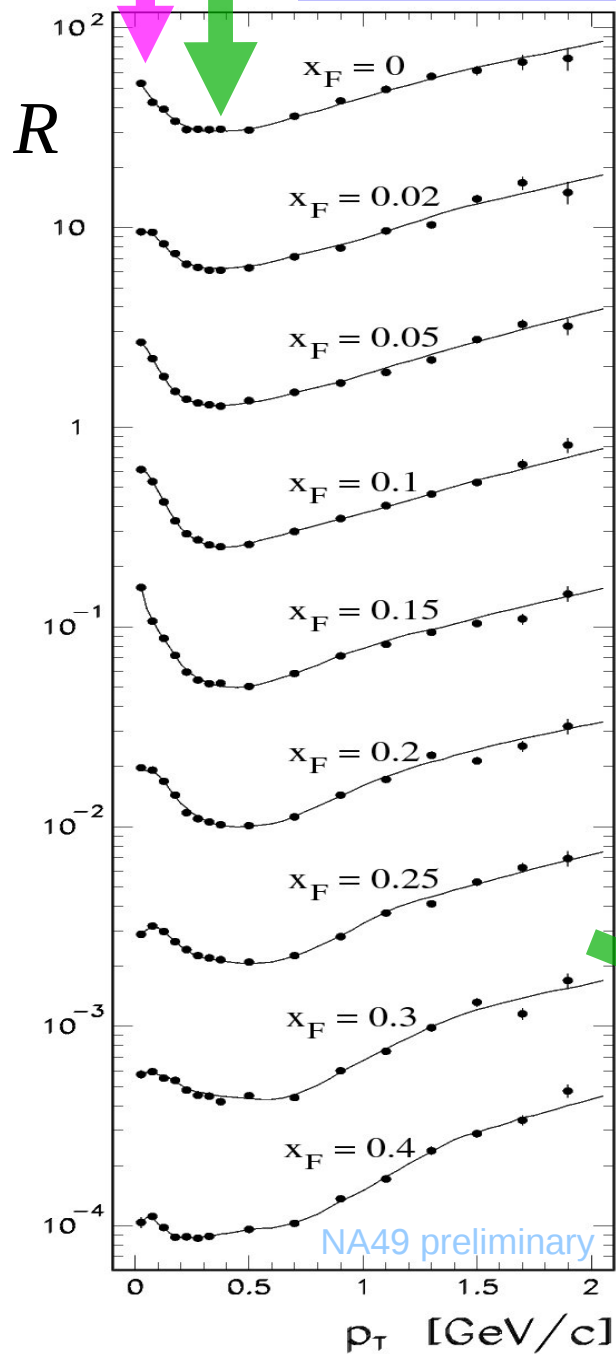
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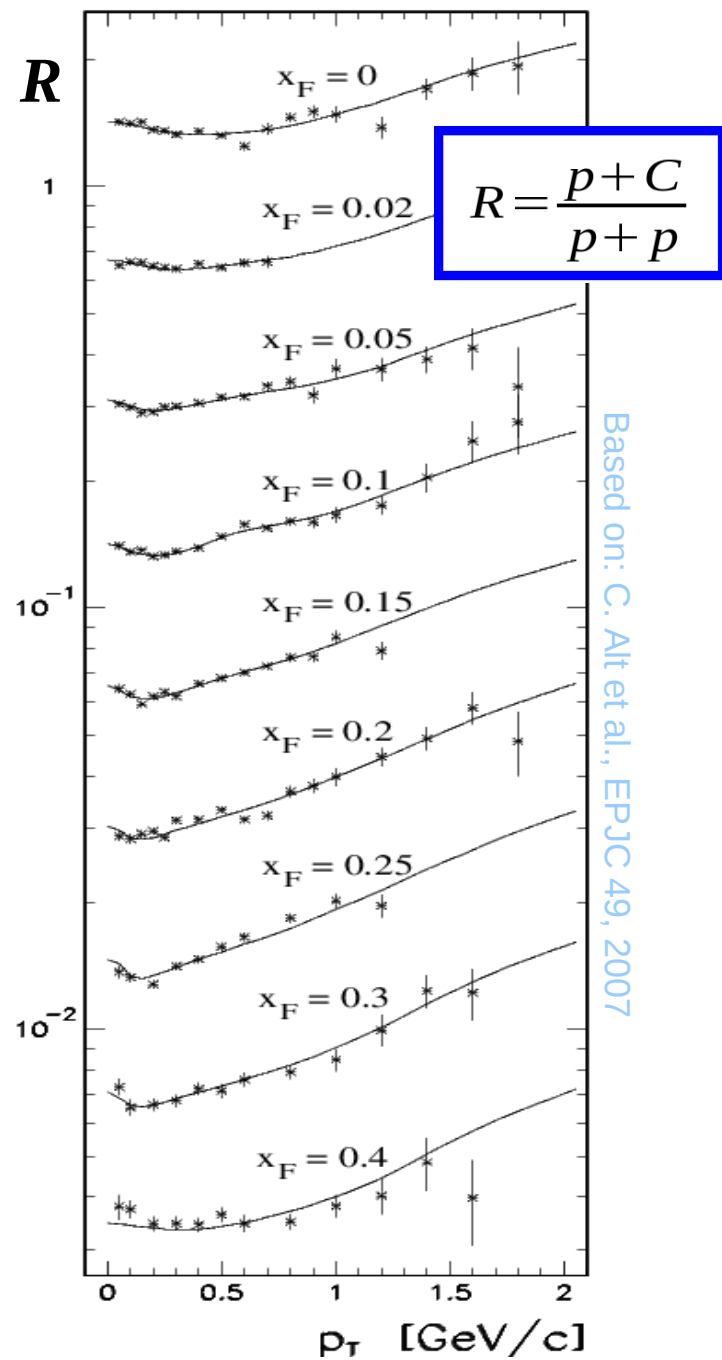
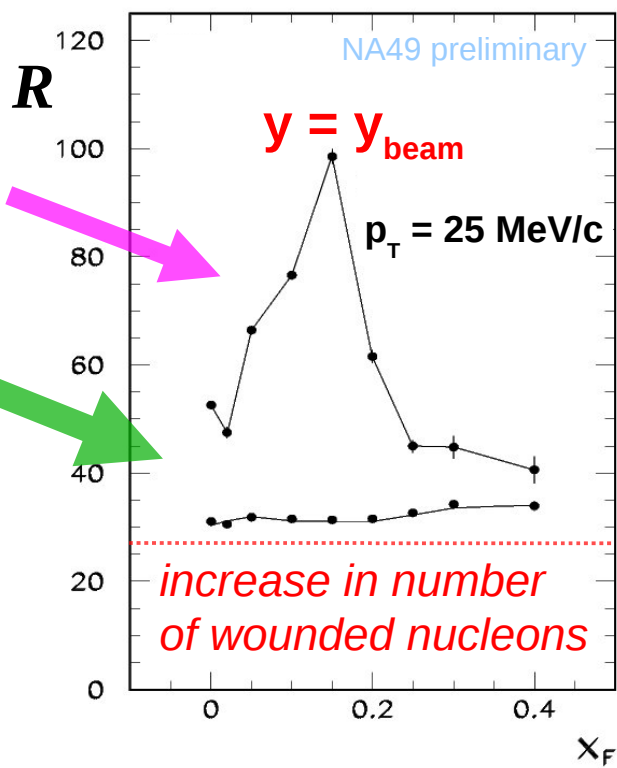
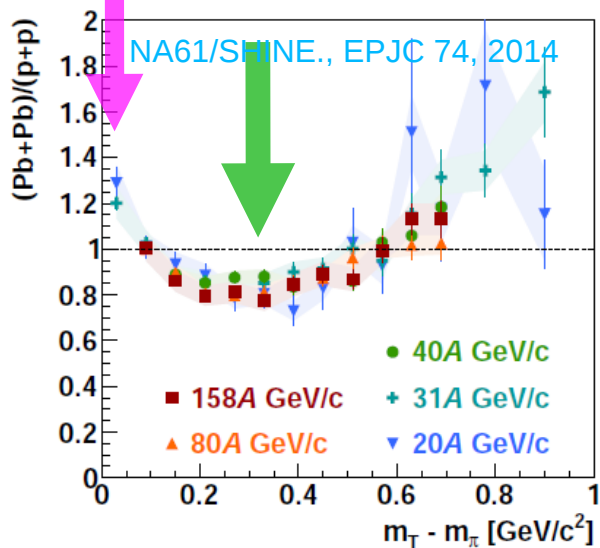
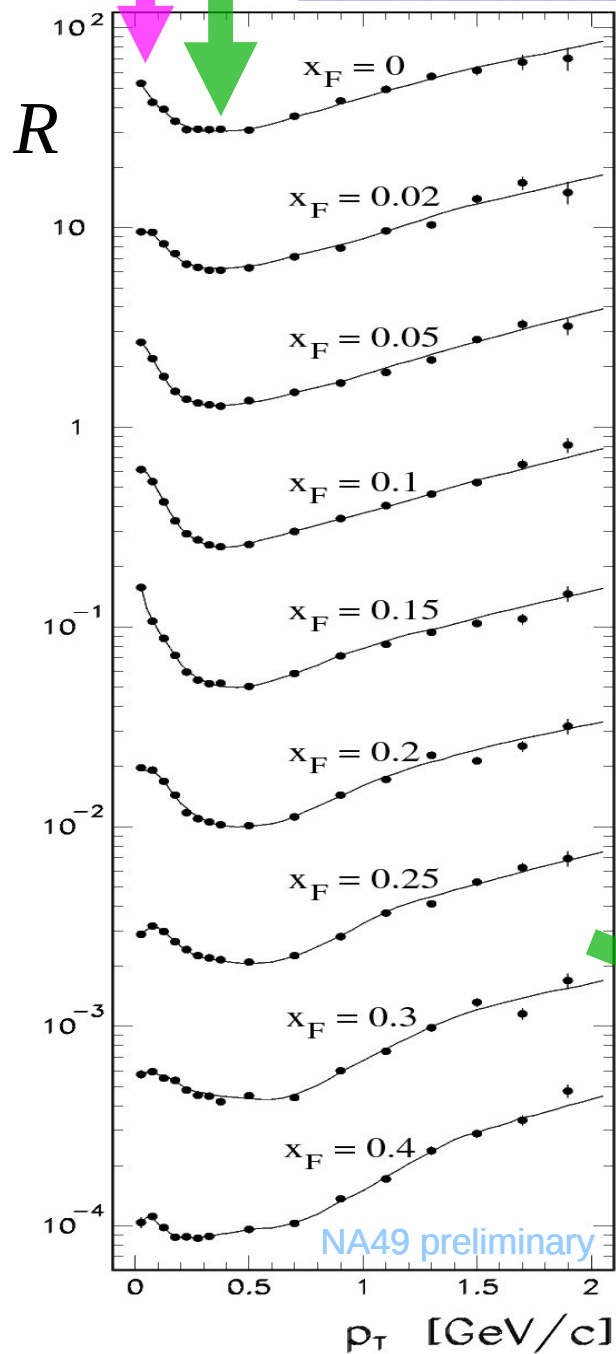
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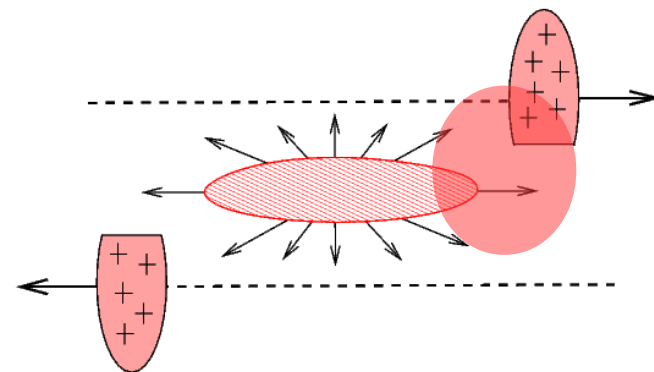
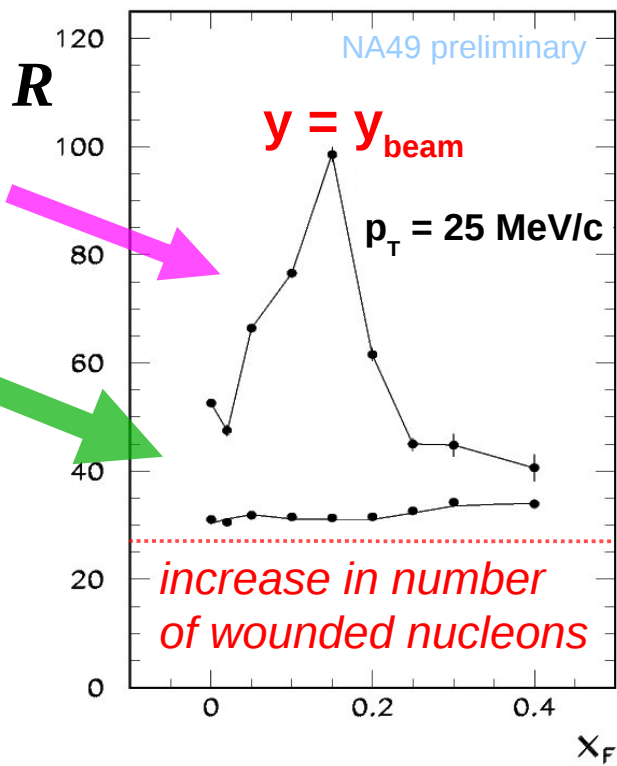
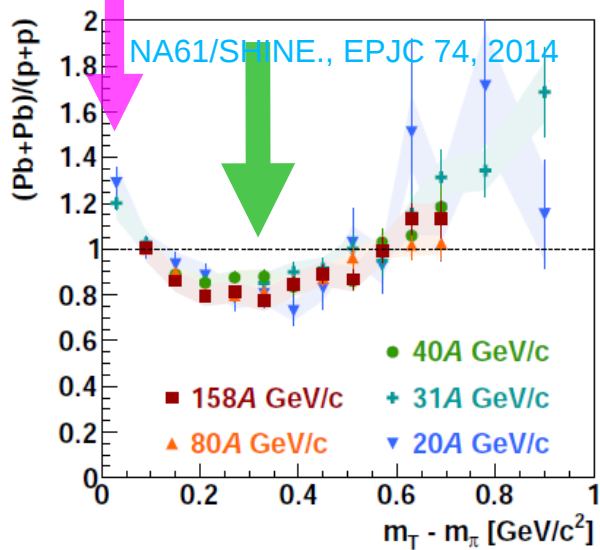
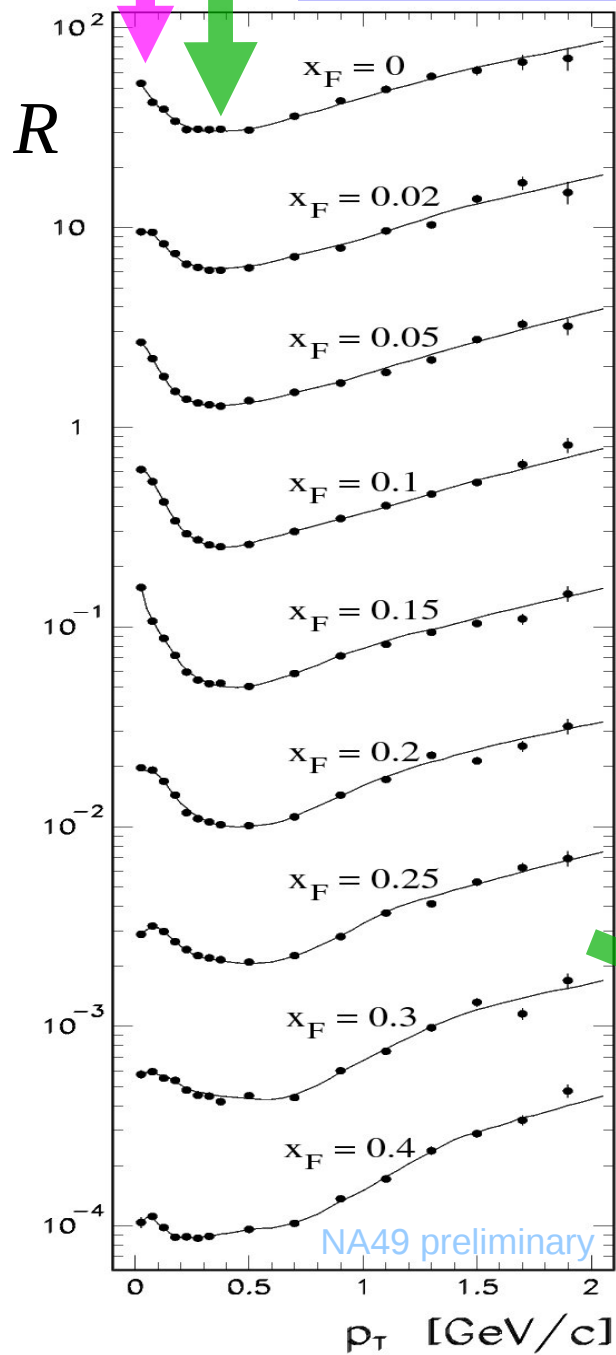
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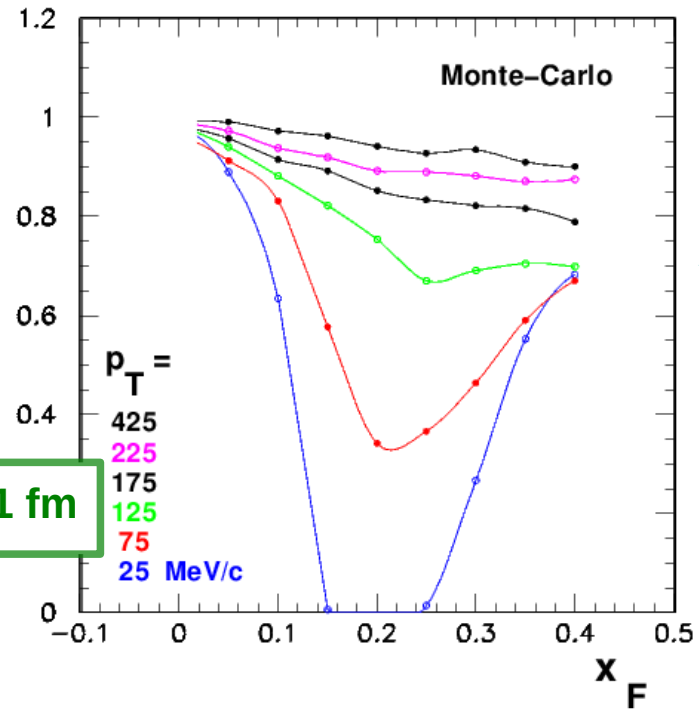
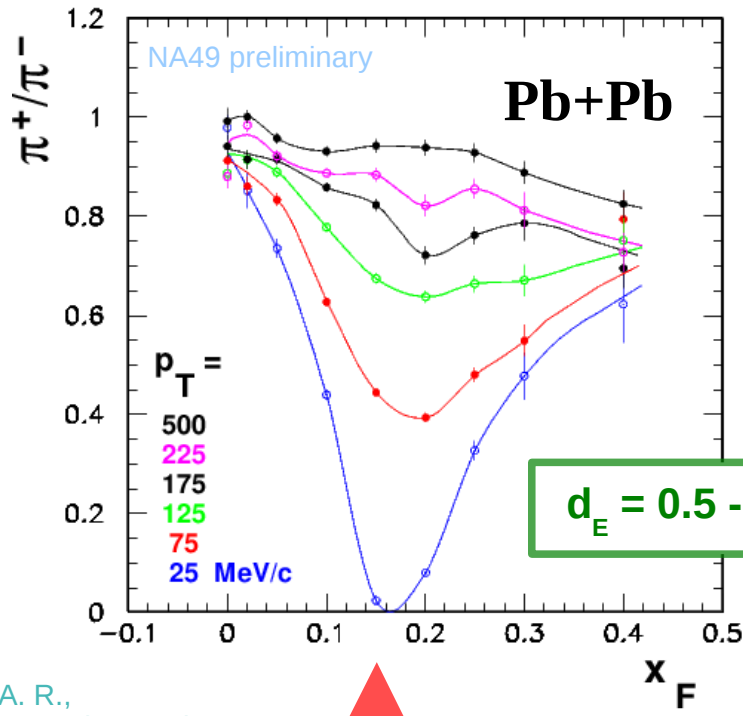
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**3)**

## ***EM Effects***

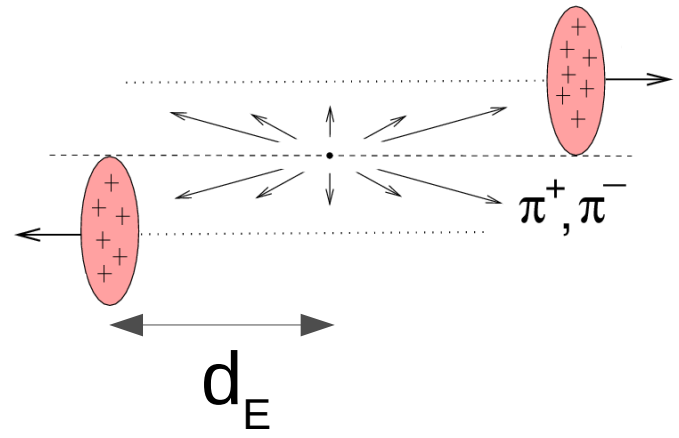


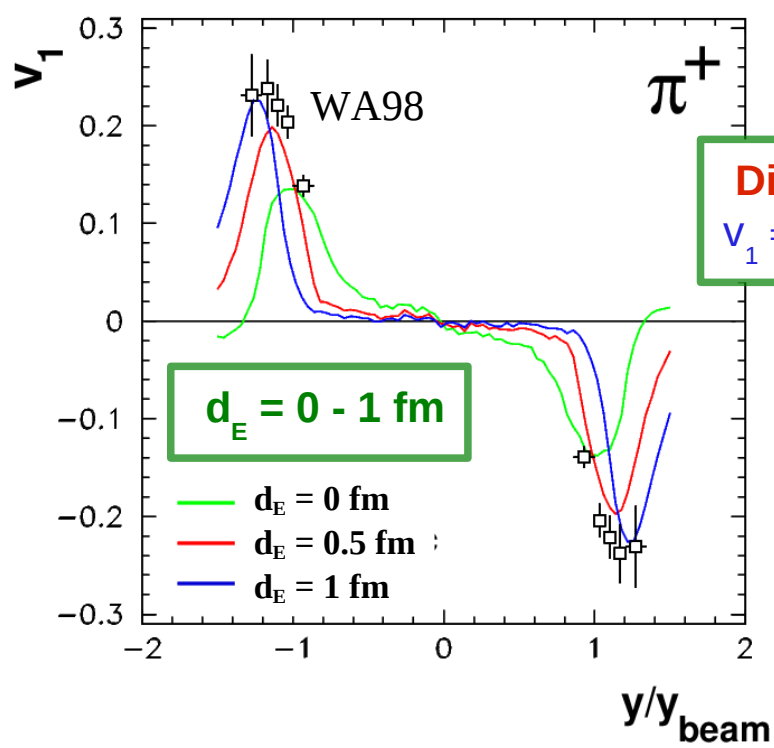
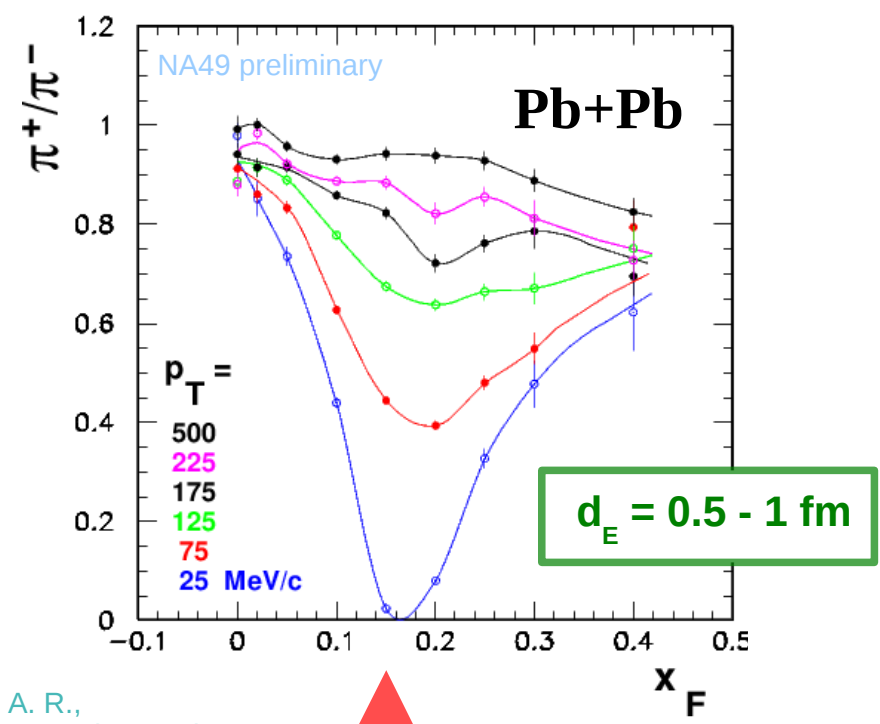
A. R. and A. Szczurek,  
 Phys. Rev. C75 (2007)  
 054903

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

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

$y = y_{beam}$





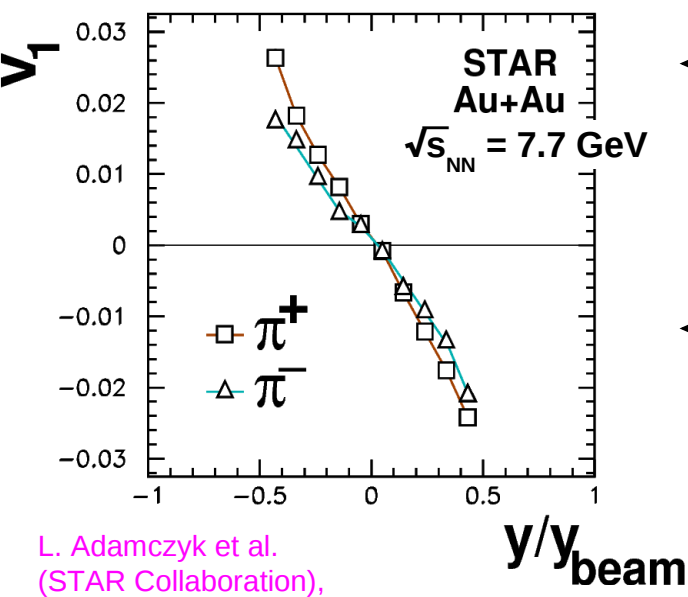
**Directed flow:**  
 $v_1 = \langle \cos(\phi - \Psi_{RP}) \rangle$

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

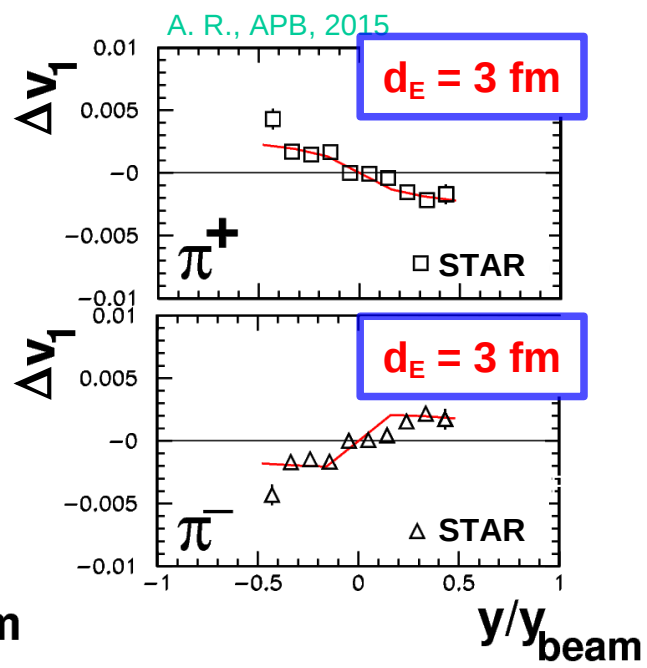
H. Schlagheck  
 (WA98 Collaboration),  
 Nucl. Phys. A 663 (2000)  
 725.

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

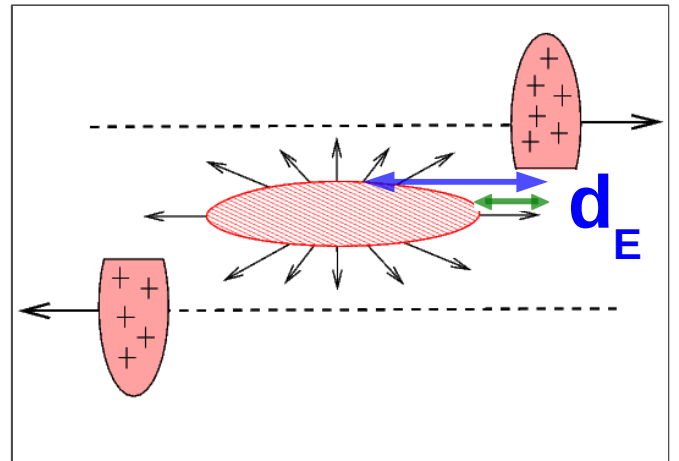
$y = y_{\text{beam}}$



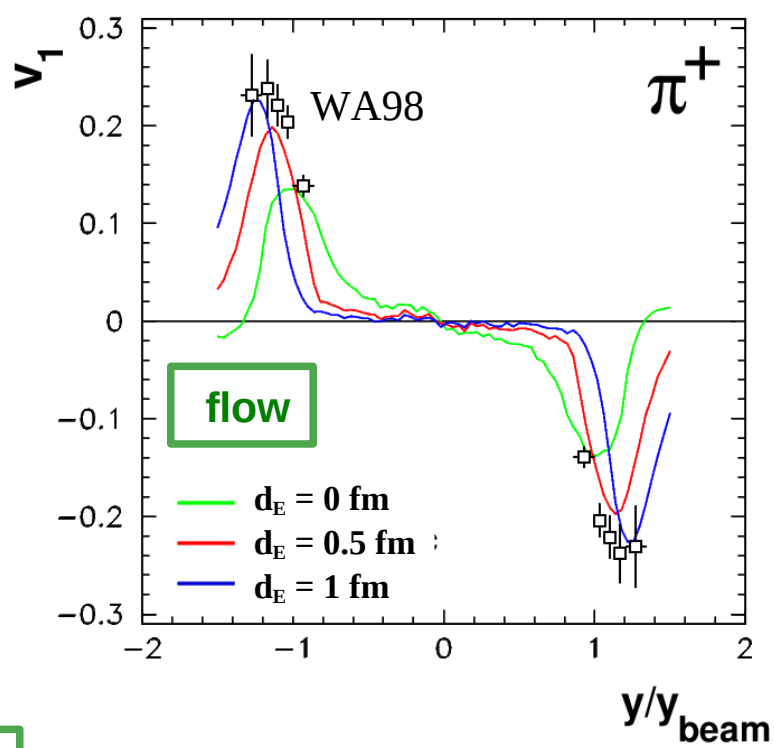
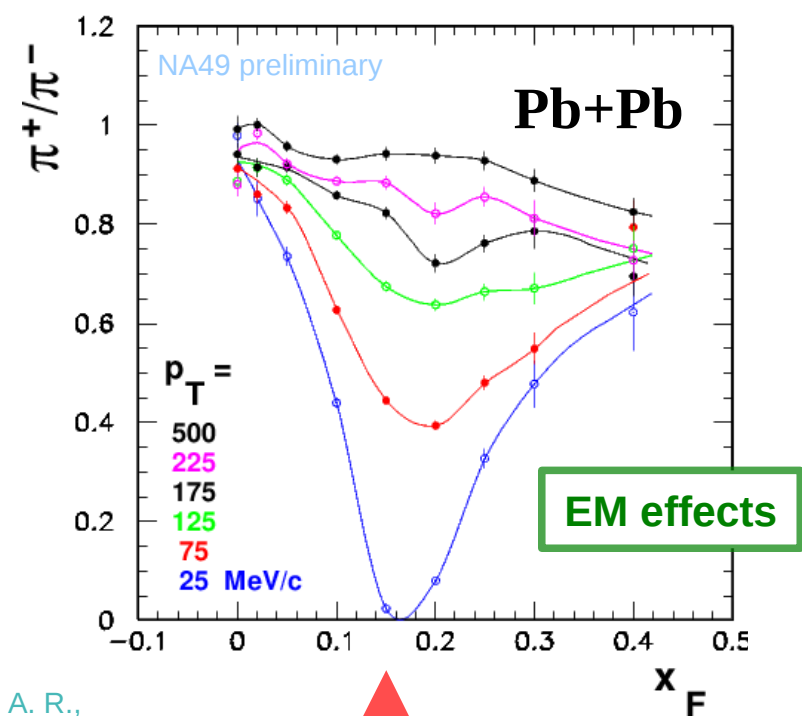
L. Adamczyk et al.  
 (STAR Collaboration),  
 Phys. Rev. Lett. 112, 162301 (2014)



A. R., APB, 2015



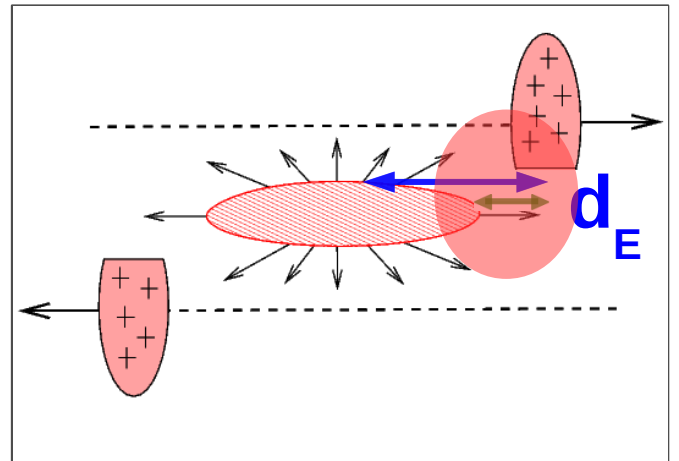
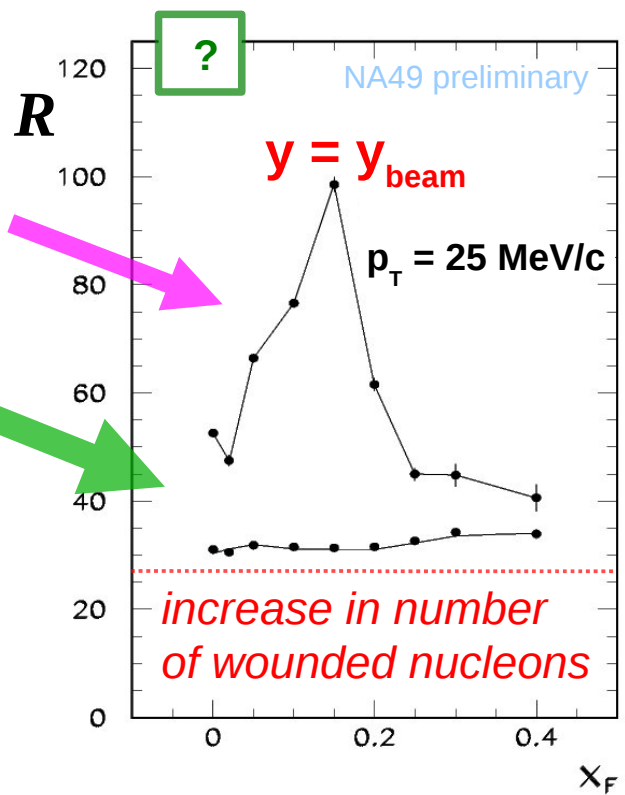
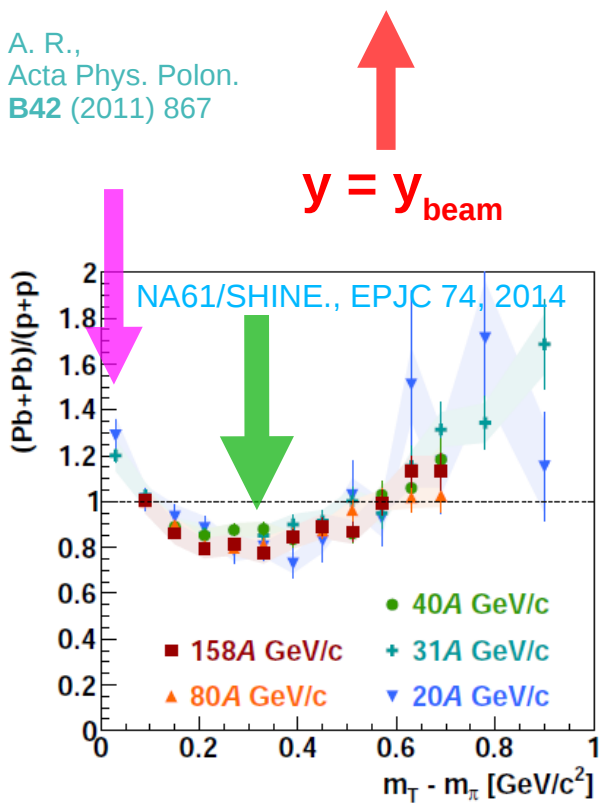
$d_E < 1 \text{ fm}$  ( $y \approx y_{\text{beam}}$ )  
 $d_E \approx 3 \text{ fm}$  (small  $y$ )



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

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

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



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



## 4) Summary

- Two complementary studies of the change of shape of pion spectra from elementary to nuclear reactions (NA61/SHINE, NA49) were presented.
- The evolution of (Pb+Pb)/(p+p) pion production ratios seen by NA61/SHINE as a function of  $y$  and  $m_T$  reflects a characteristic two-dimensional pattern as a function of longitudinal and transverse momentum.
- The exact role of spectator nucleons in this pattern requires clarification.
- EM effects could contribute to this clarification.
- At least partial information on the energy dependence of the above pattern is already available.
- Better understanding of this phenomenology will become available with high statistics A+A data samples.

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). The analysis of electromagnetic effects was performed together with A. Szczurek.

# Acknowledgments.

This work was supported by the Polish National Science Centre (on the basis of decision no. DEC-2011/03/B/ST2/02634).