Comparative studies of pion spectra in p+p and Pb+Pb collisions ("part 2")

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1) Motivation ("part 1") ;
2) EM effects on π^+, π^-,
   … and $\pi^+ + \pi^-$ spectra ;
3) MC & exp. data ;
4) Conclusions.

Work done together with
Antoni Szczurek (1,2)
Vitaliy Ozvenchuk (1)
Łukasz Rozpłochowski (3)
Karol Karpiński (3)
Julian Sacharczuk (2)

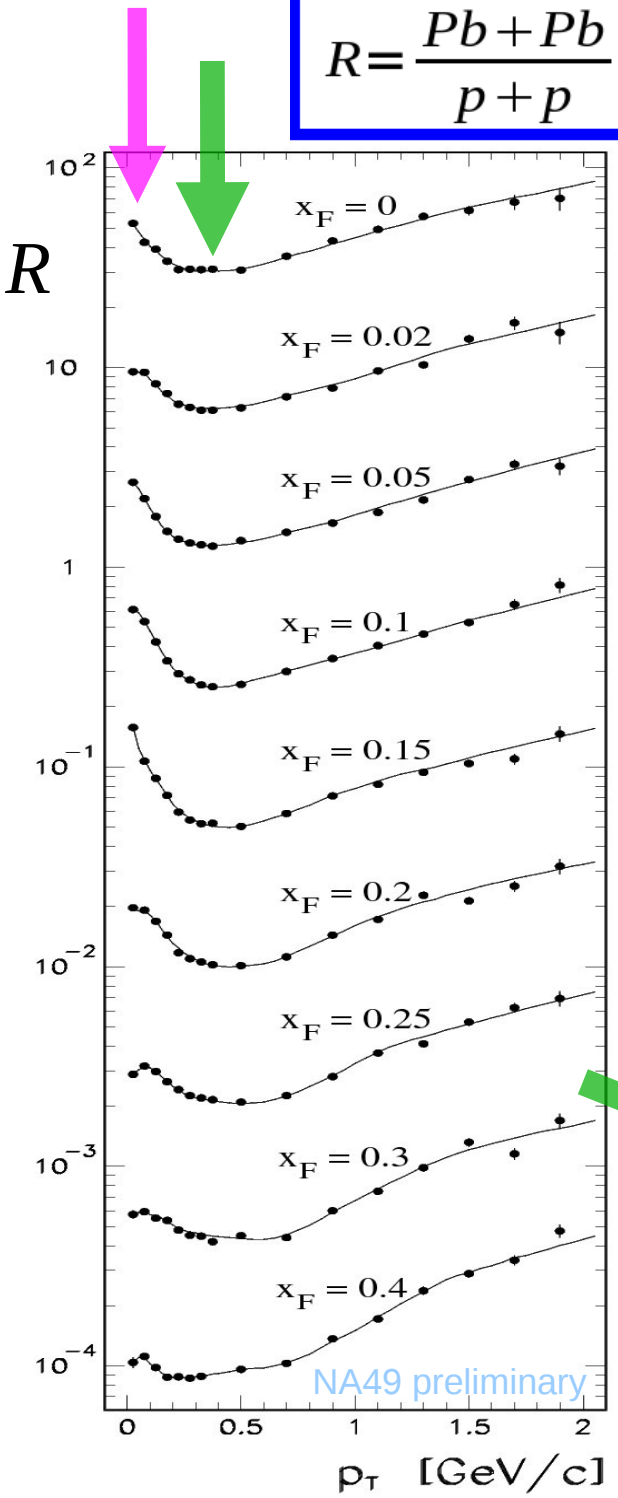
Summer students

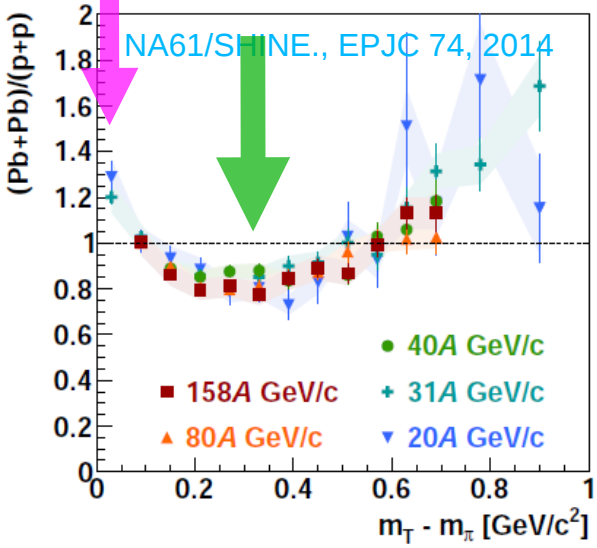
From:
(1) IFJ PAN
(2) Univ. Rzeszów
(3) Univ. Bydgoszcz

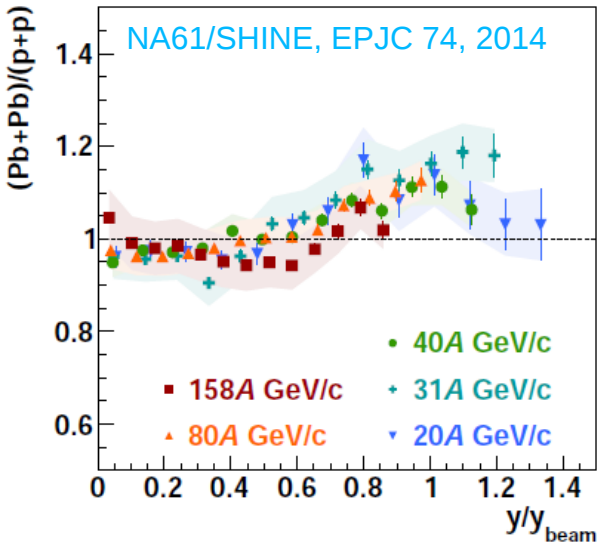
1)
Motivation

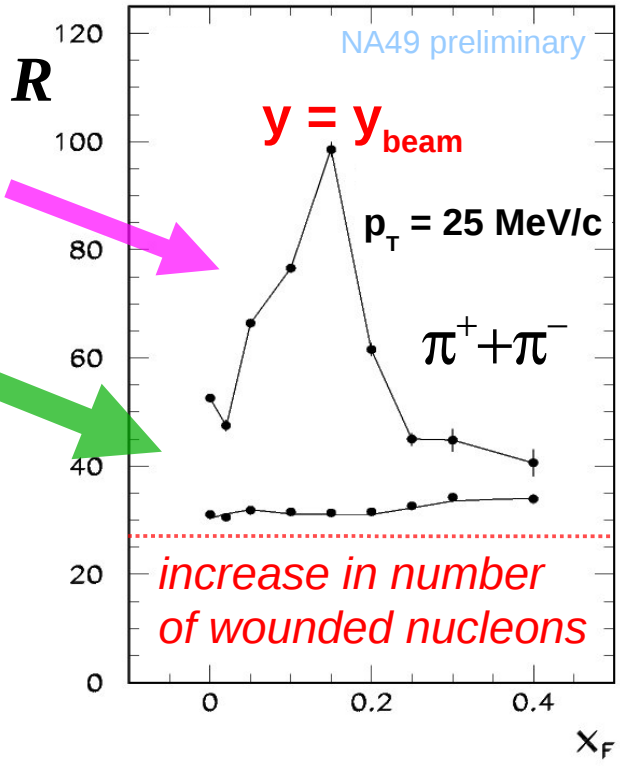
$$R = \frac{Pb+Pb}{p+p}$$

- NA49: $(\pi^+ + \pi^-)$; **Pb+Pb peripheral, 158A GeV/c.**
- NA61/SHINE: π^- only; **Pb+Pb CENTRAL.**









WNM

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

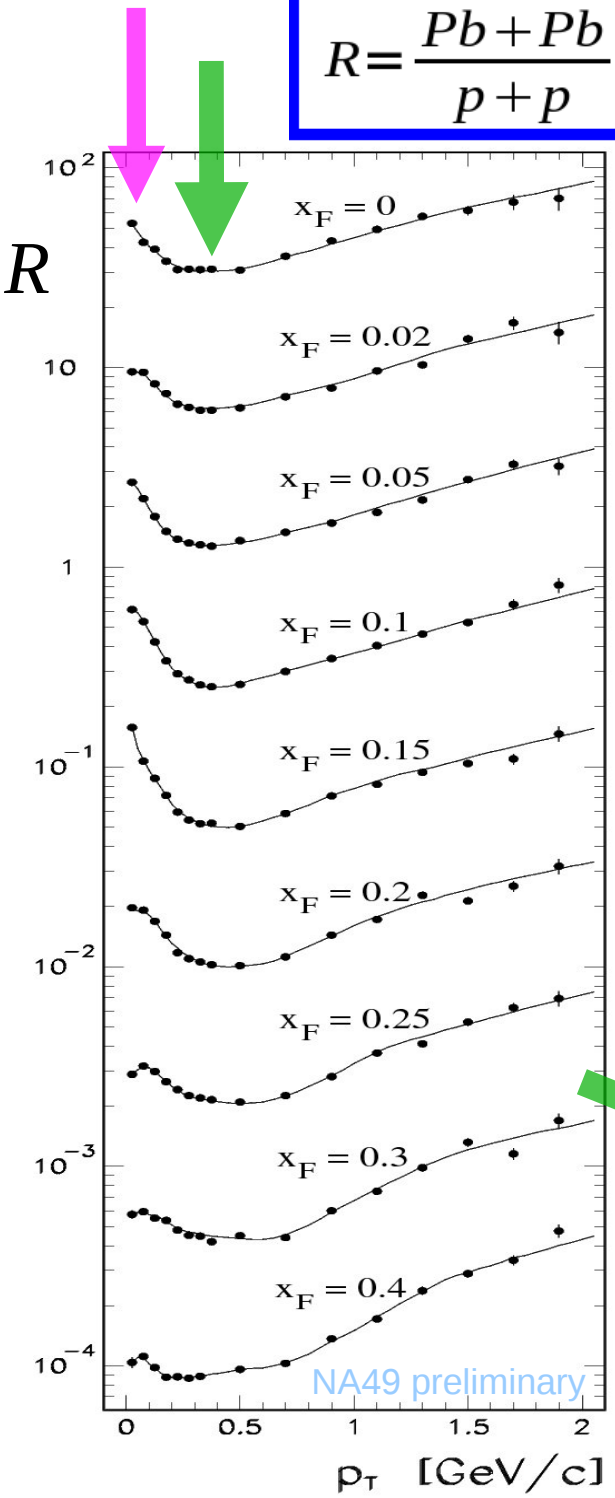
(c.m.s.)

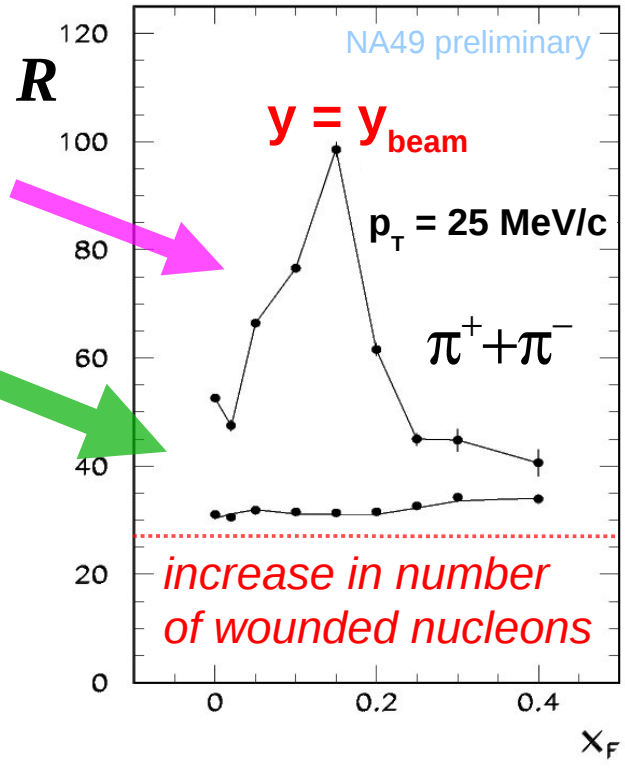
$$R = \frac{Pb+Pb}{p+p}$$

A.R. (2015):

$\pi^+ + \pi^-$ spectra – no isospin effects ;

EM effects will (roughly) cancel out .





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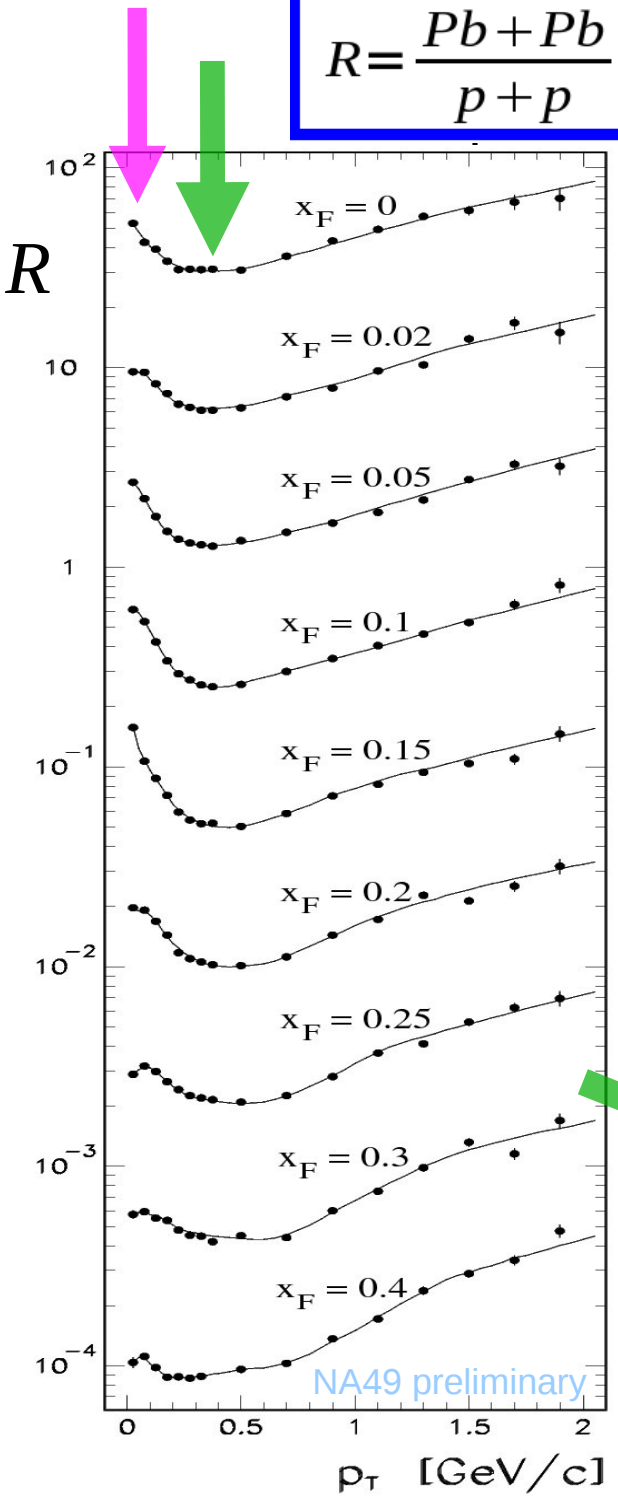
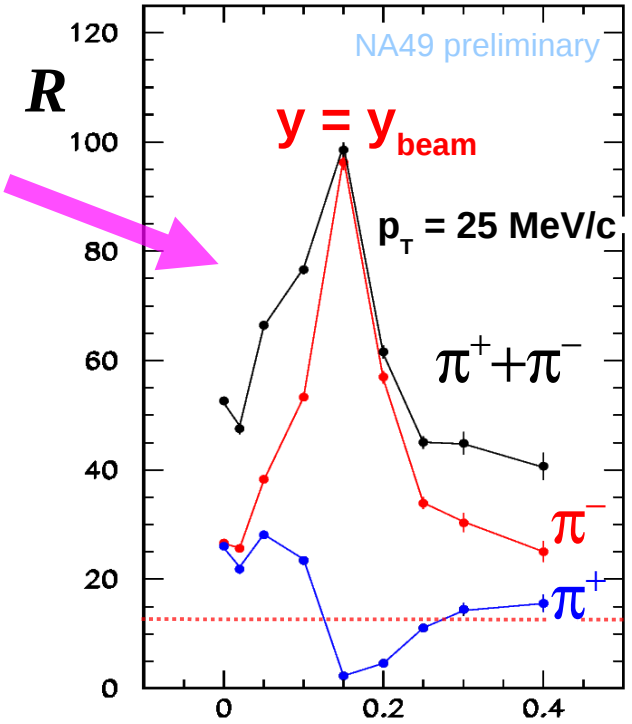
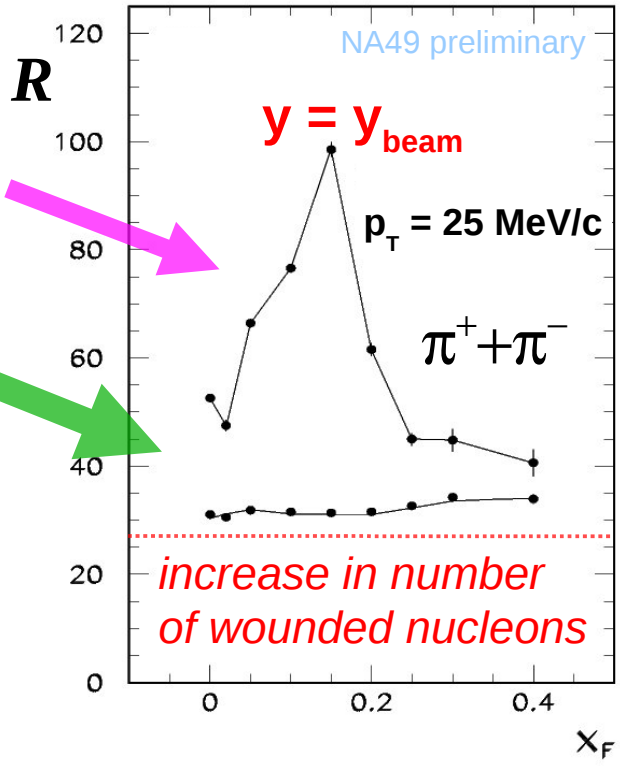




$\frac{1}{2}$ WNM



WNM

- isospin symmetry is broken ;
- π^- enhancement ;
- EM + hadronic or nuclear effects.

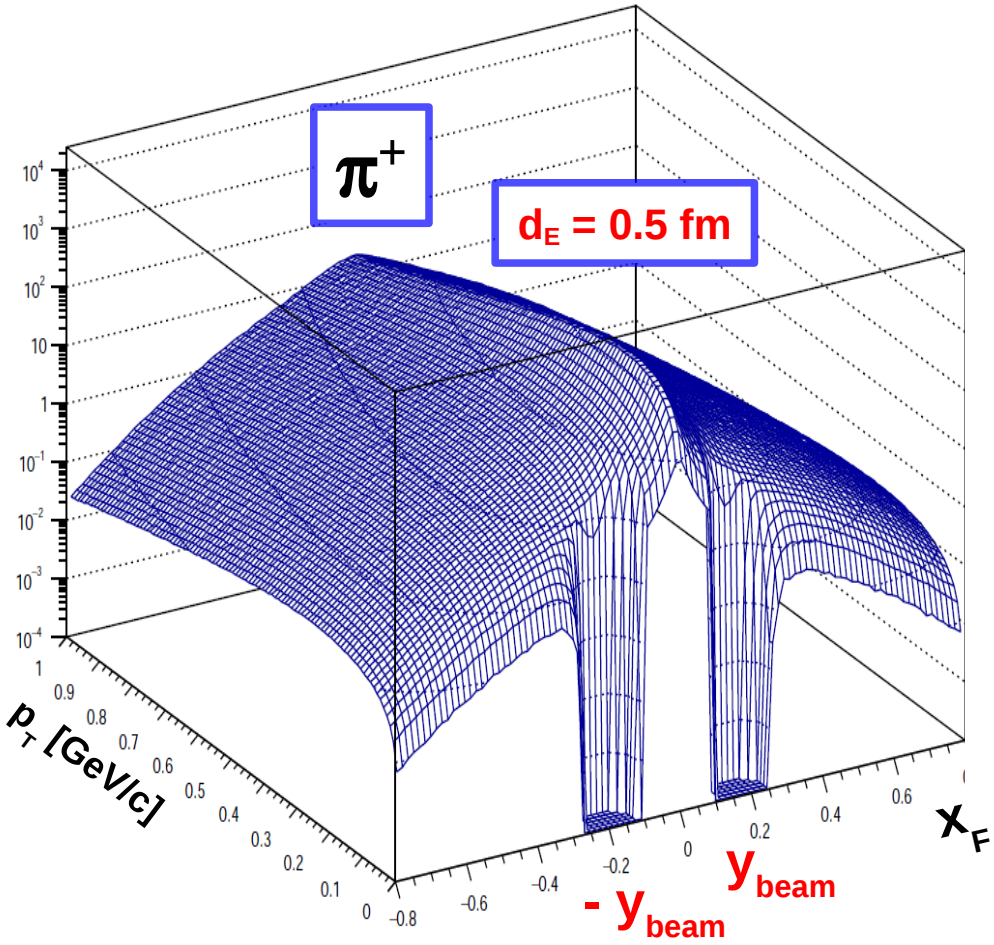
$$x_F = \frac{p_L}{p_L^{beam}}$$

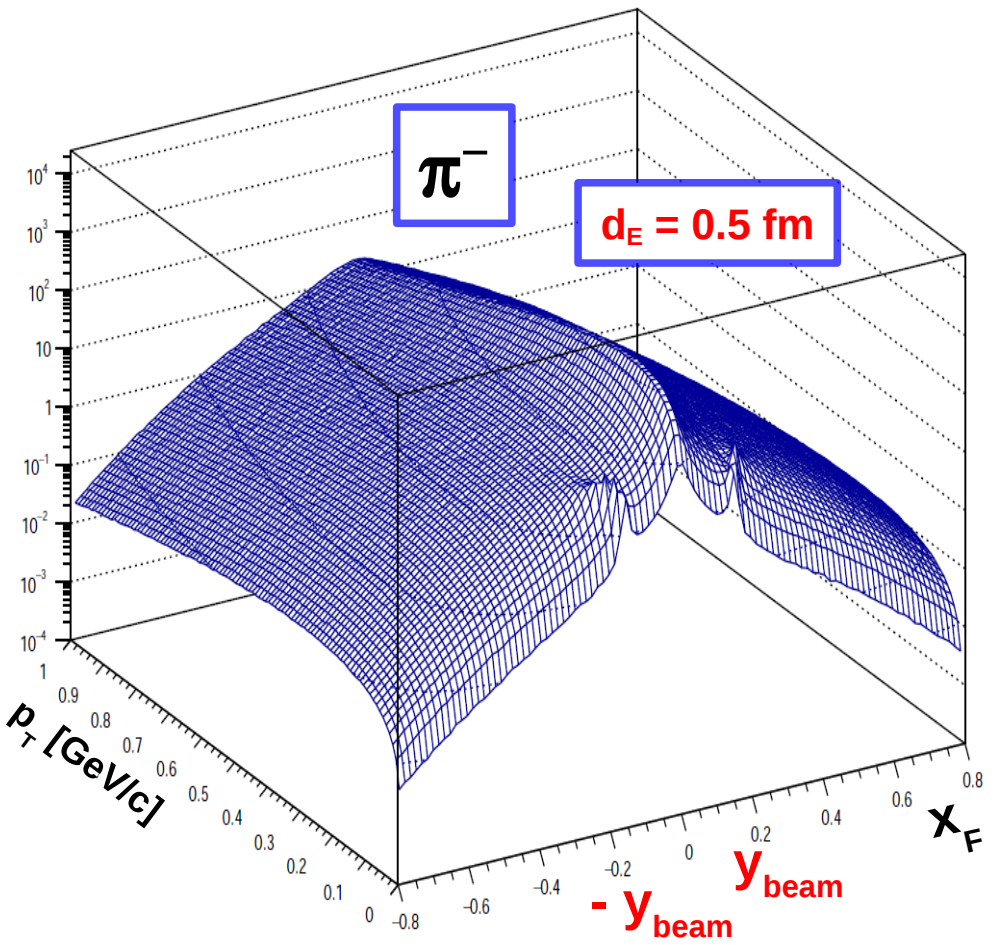
(c.m.s.)

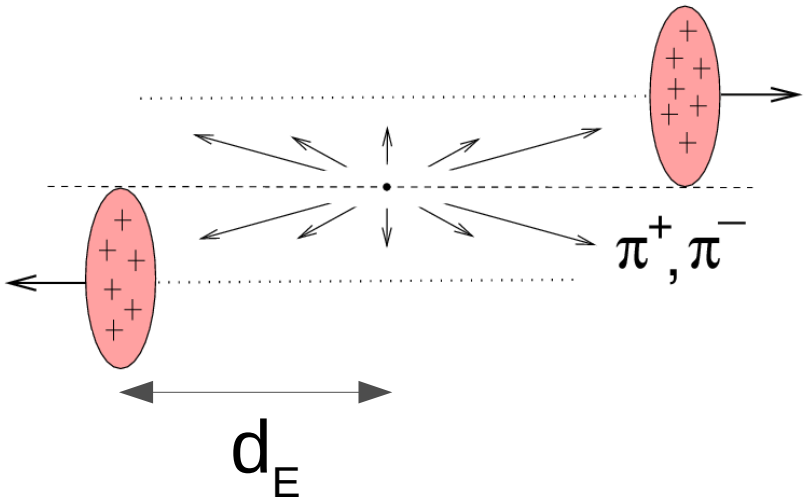
2)

EM effects on π^+, π^-,

… and $\pi^+ + \pi^-$ spectra



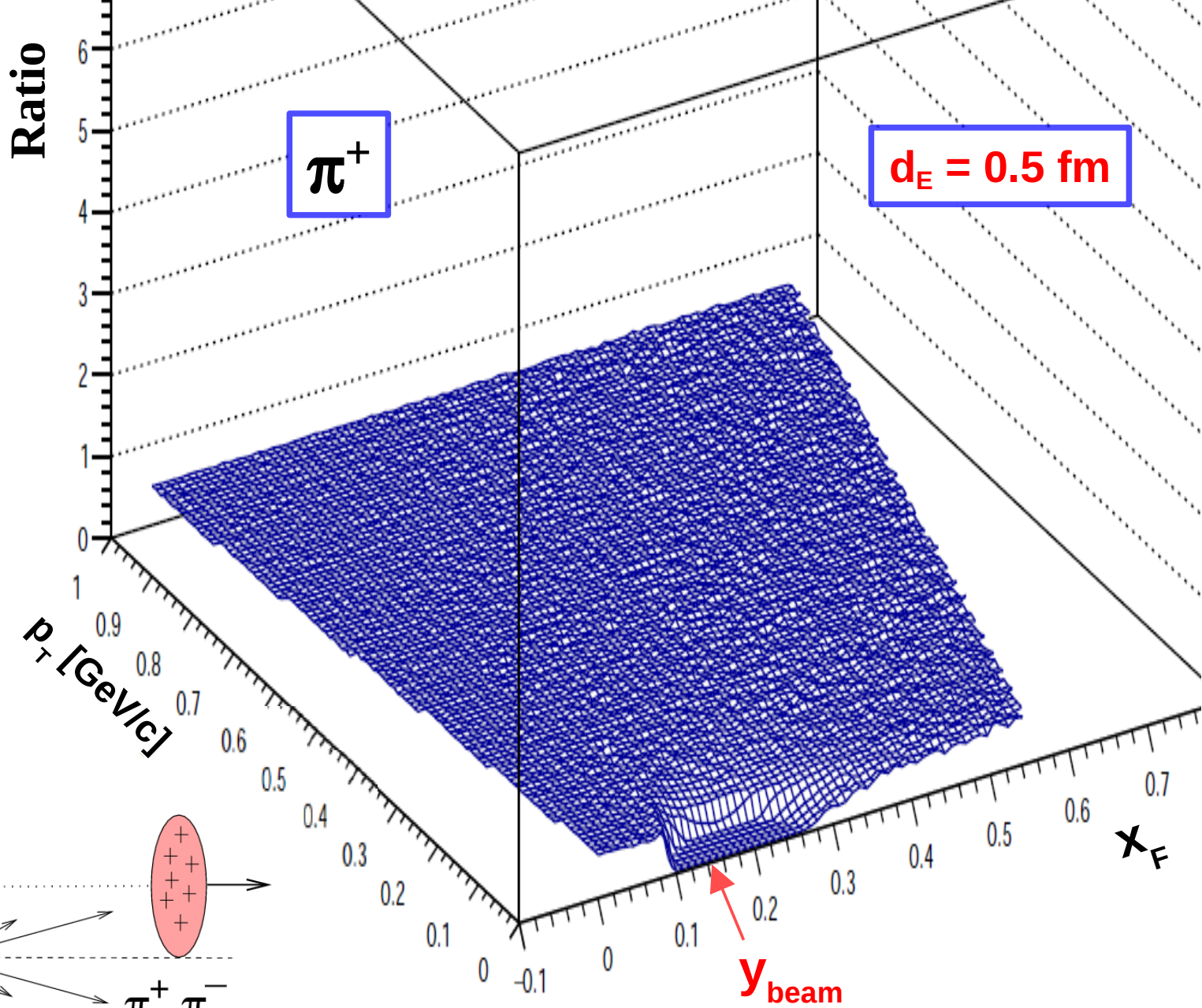


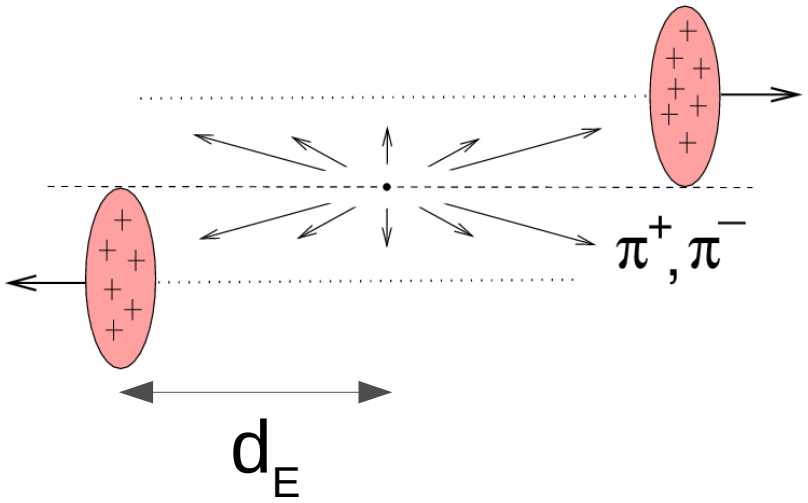


EM Monte Carlo [version (1)]:

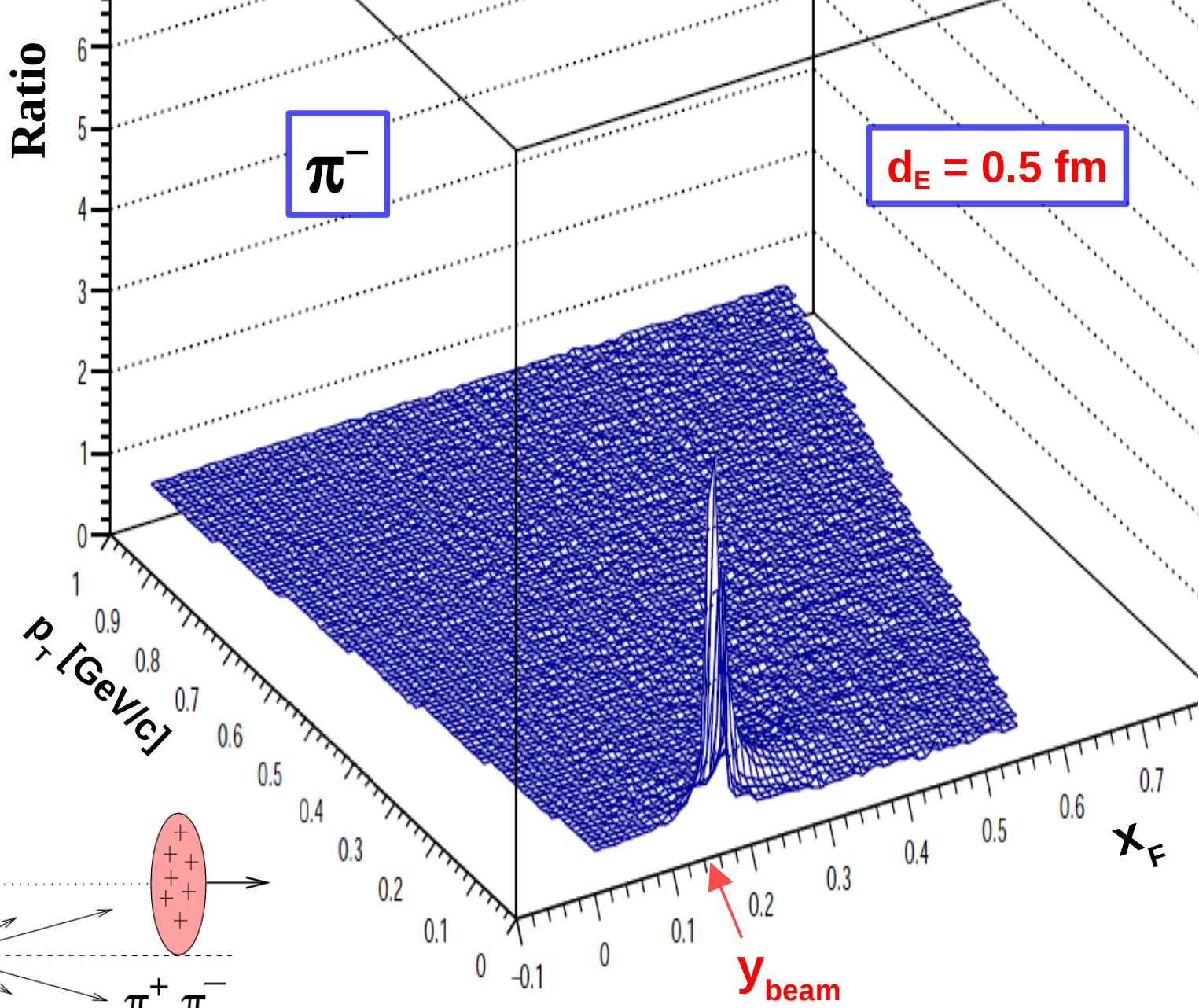
- initial distribution of pions is assumed similar to N+N ;
- no isospin effects ($\pi^+=\pi^-$), no flow, etc.
- charged pions are traced in the spectator EM field.

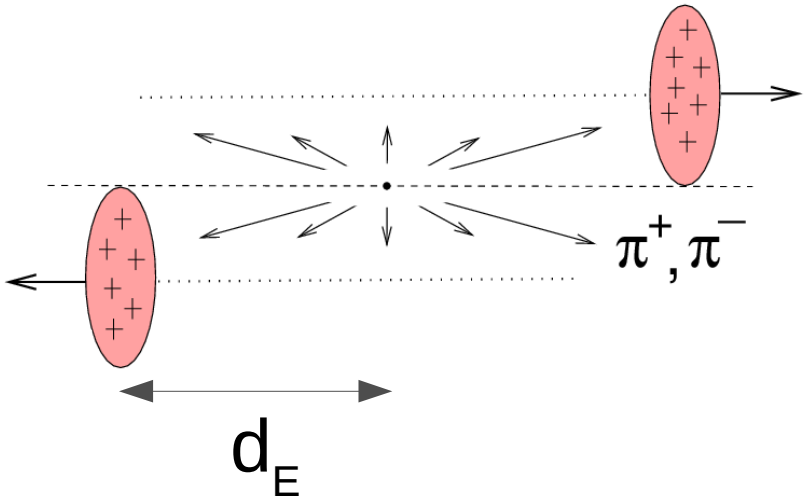
$$\text{Ratio} = \frac{\pi^+_{\text{final}}}{(\pi^+ + \pi^-)_{\text{initial}}}$$



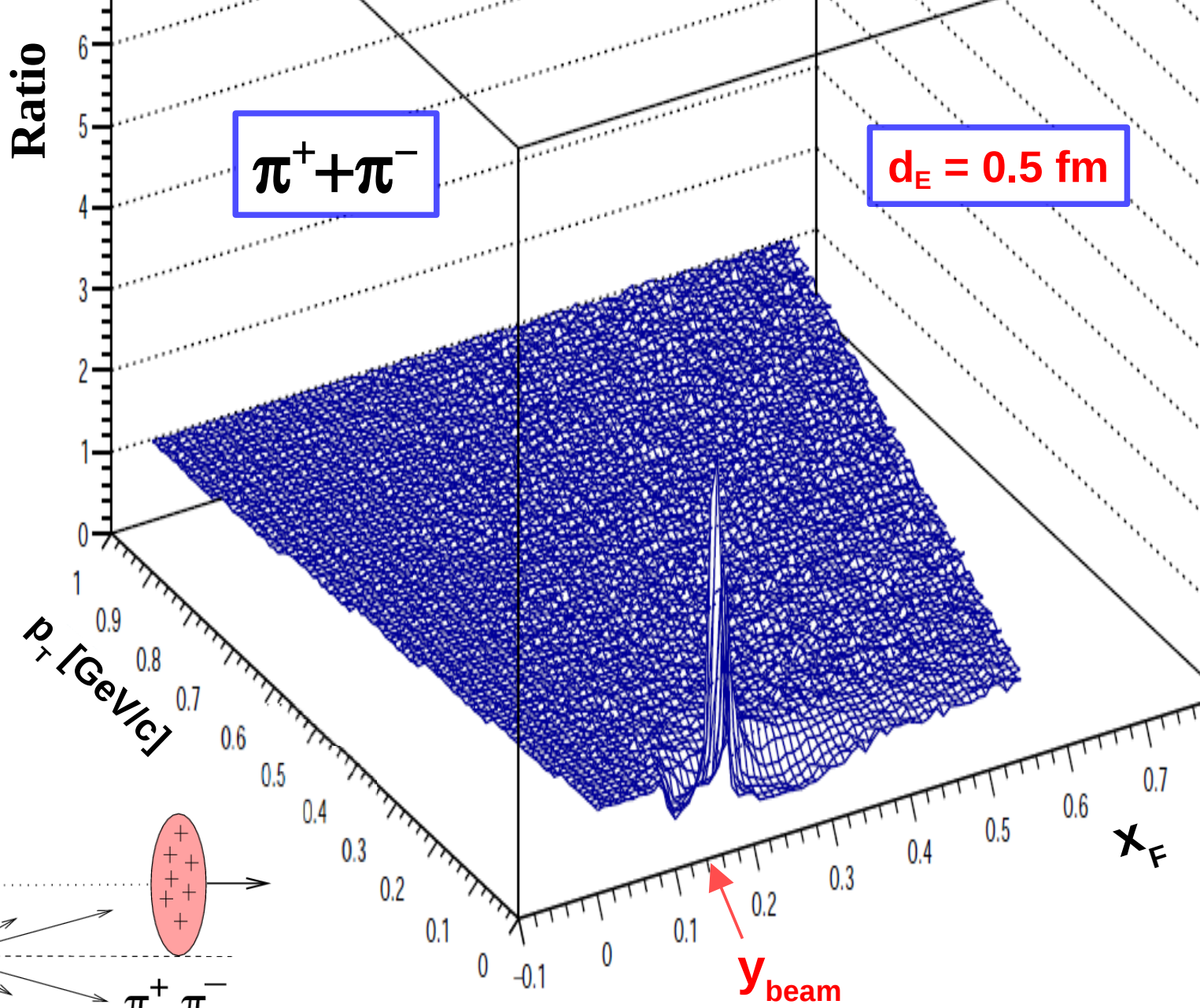


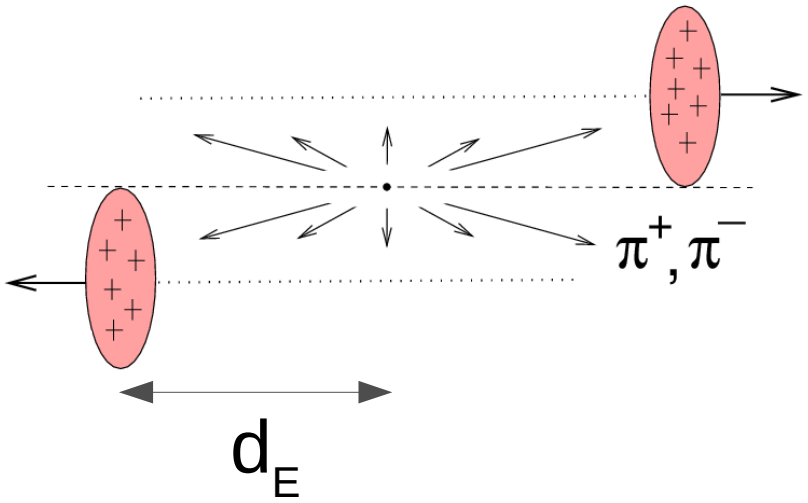
$$\text{Ratio} = \frac{\pi^-_{\text{final}}}{(\pi^+ + \pi^-)_{\text{initial}}}$$





$$\text{Ratio} = \frac{(\pi^+ + \pi^-)_{\text{final}}}{(\pi^+ + \pi^-)_{\text{initial}}}$$





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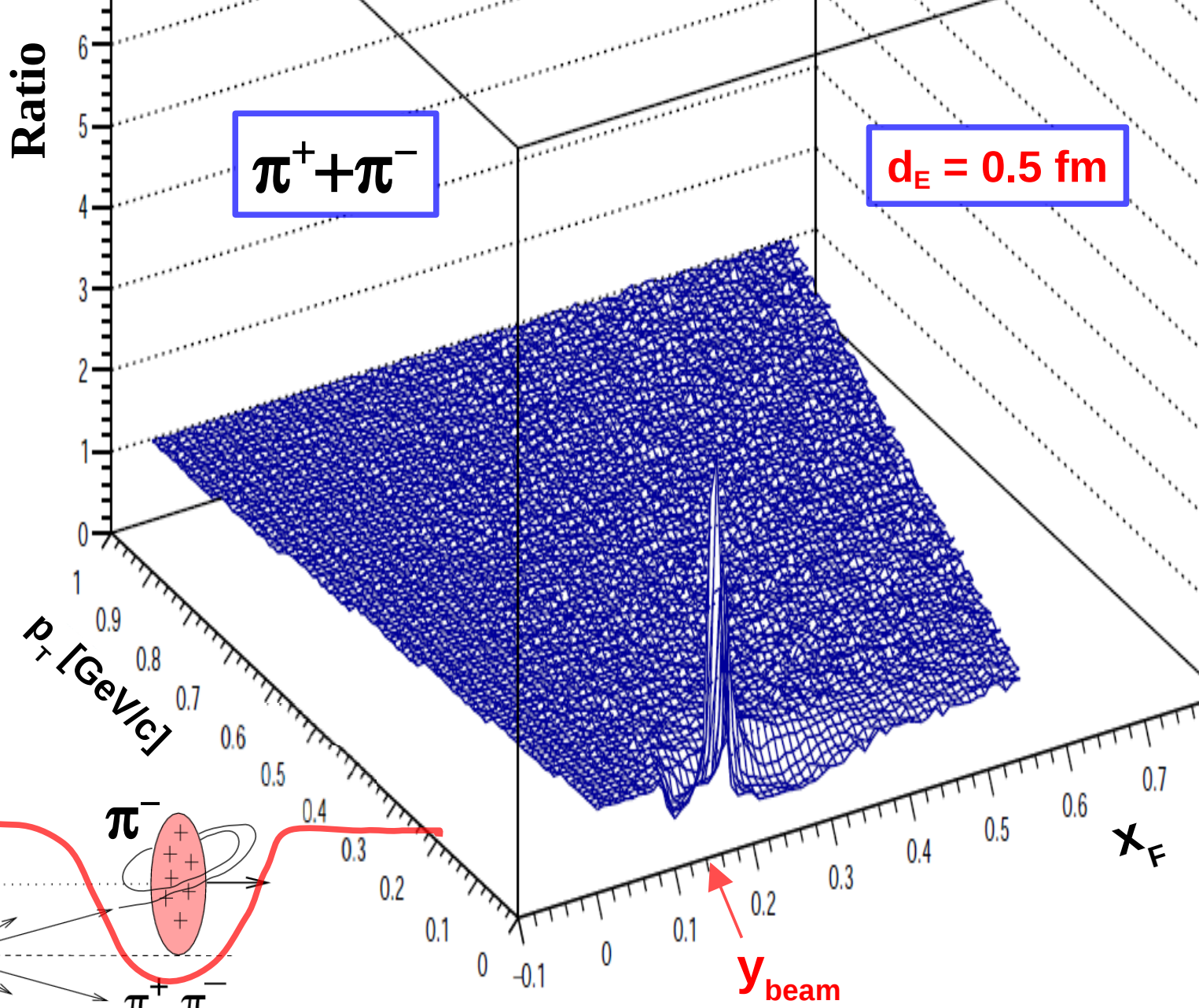

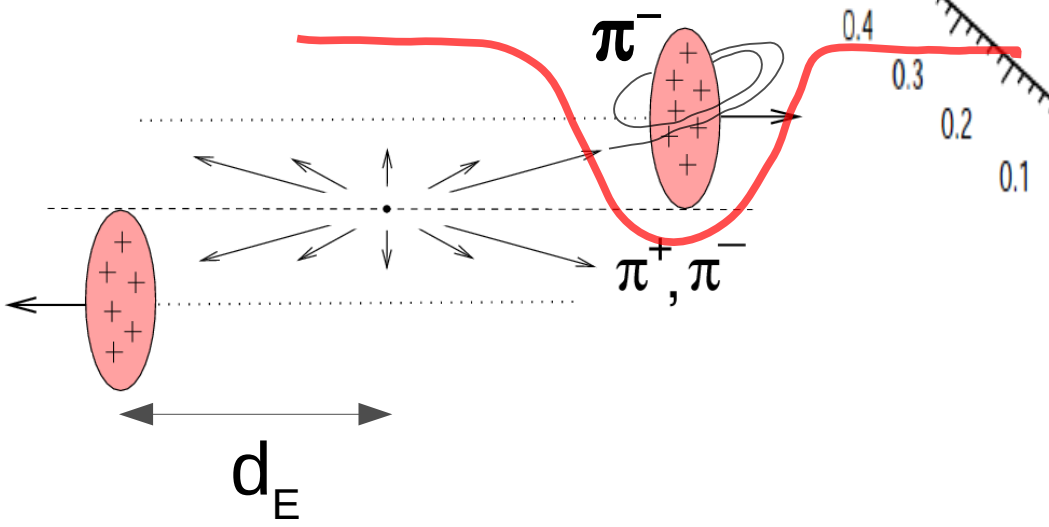

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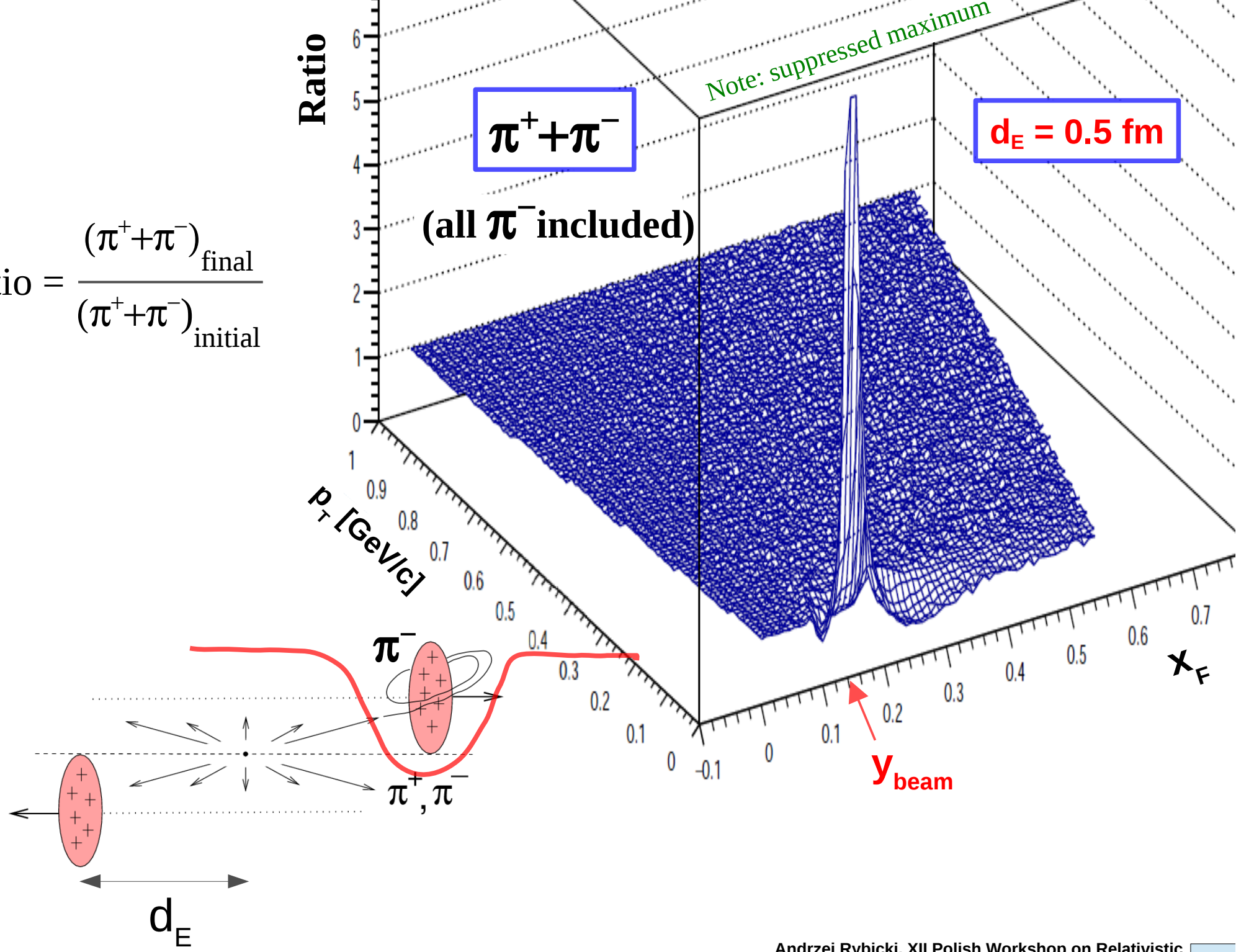
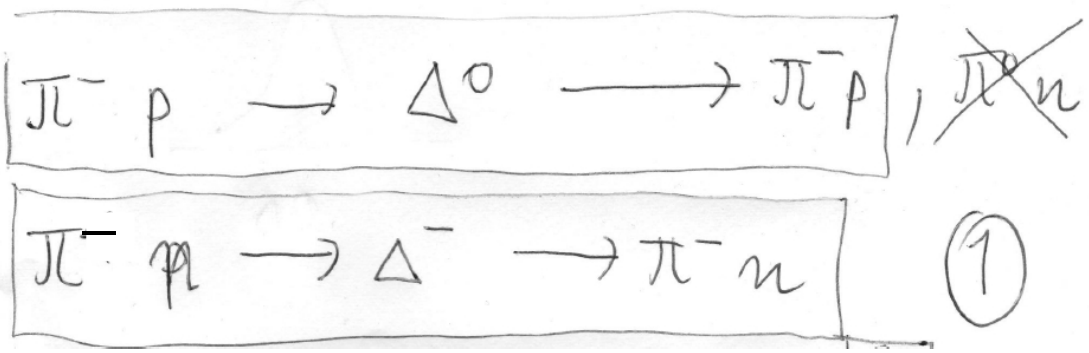
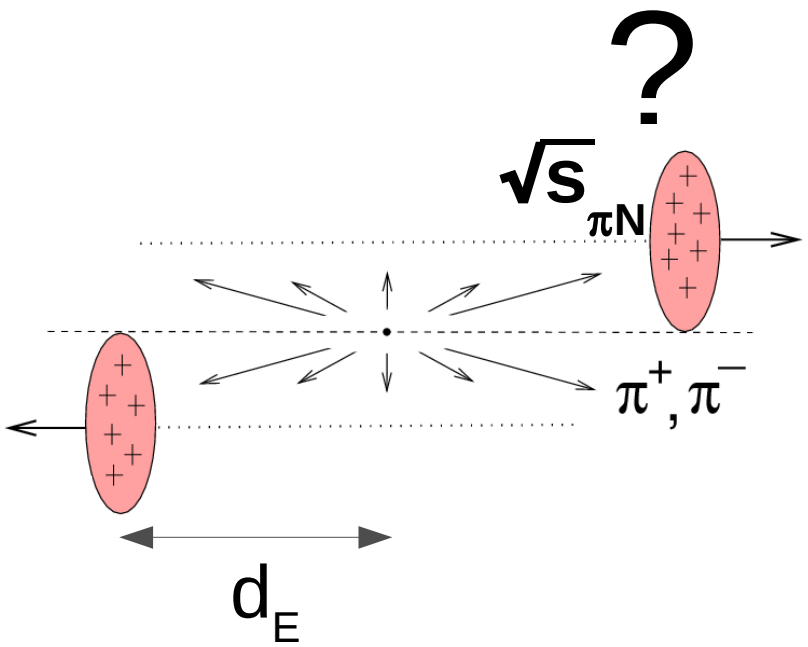
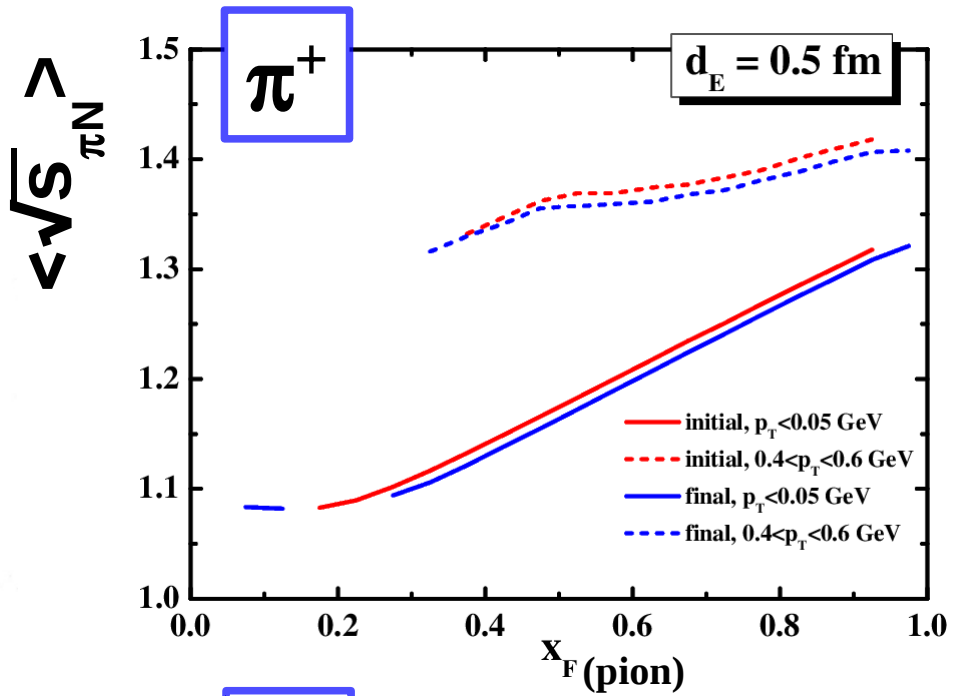
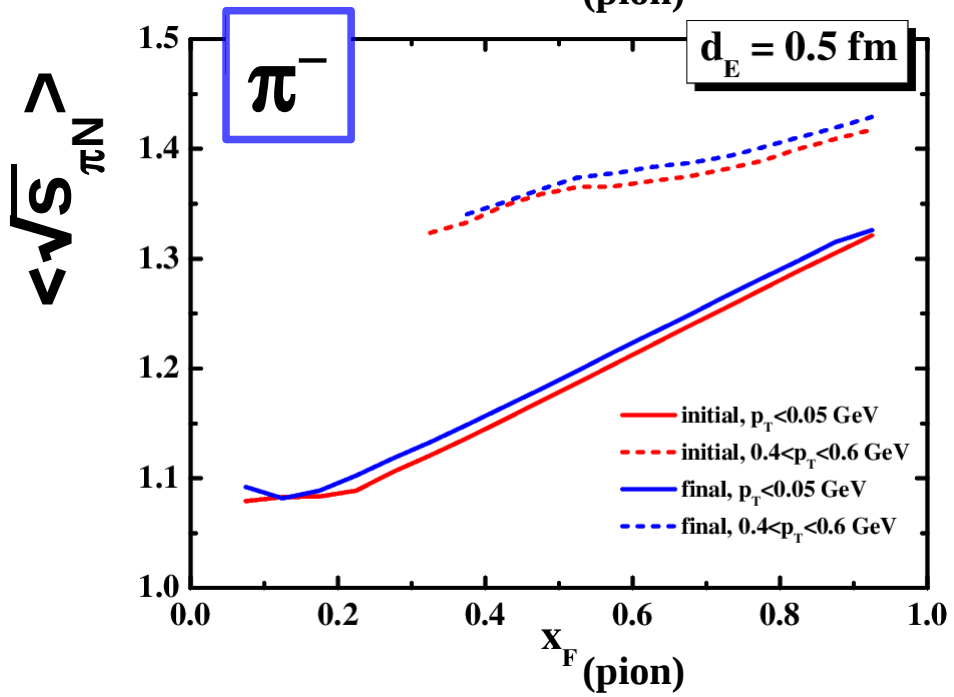


Digression: $\sqrt{s}_{\pi N}$

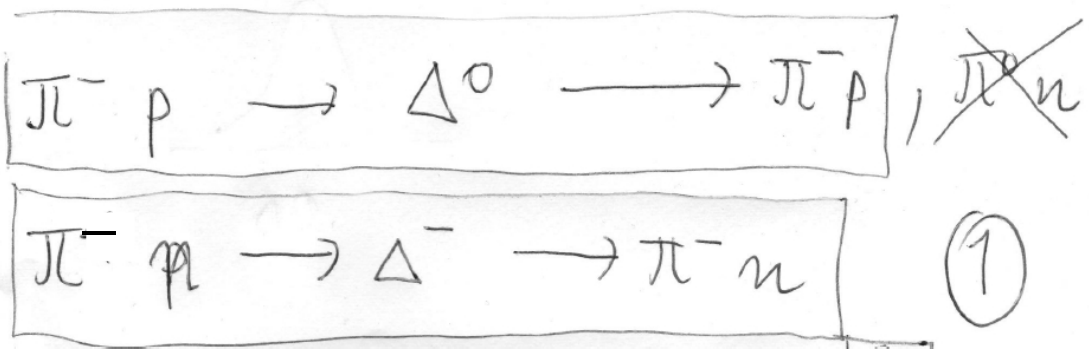


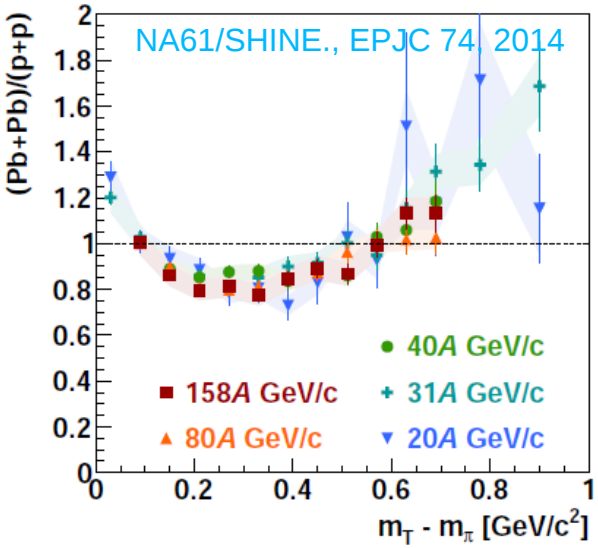


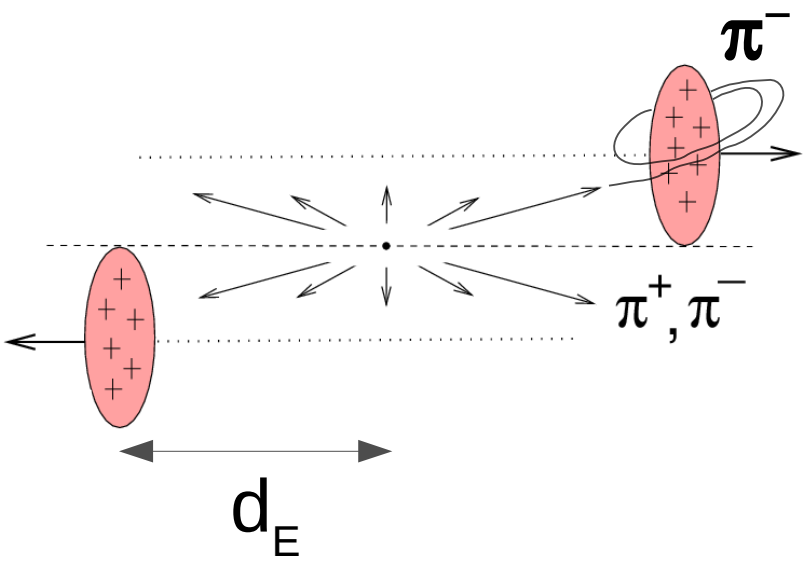




EM Monte Carlo [version (2)]



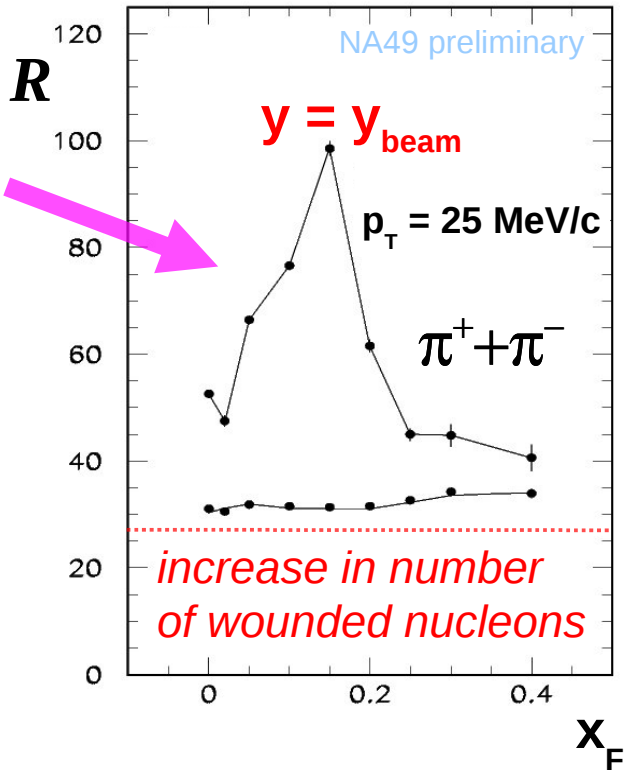


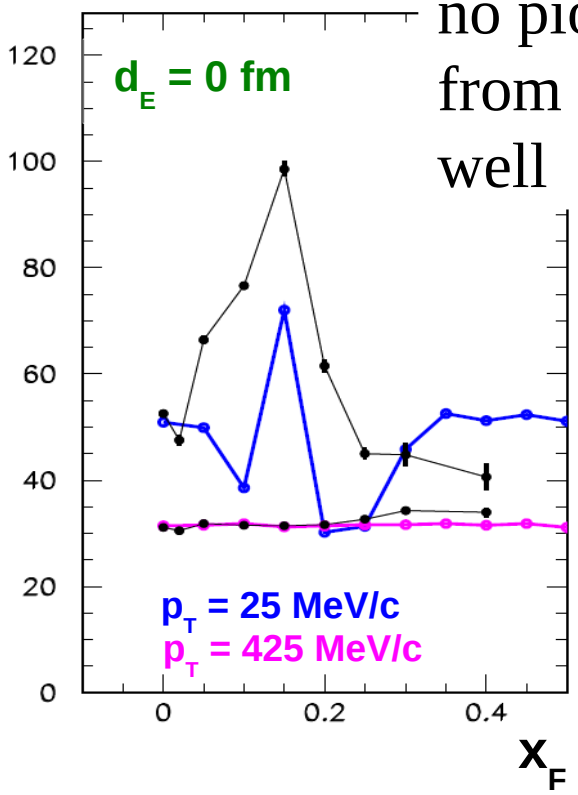


- initial distribution of pions with parametrized “flow” ;
- with isospin effects ($\pi^+ \neq \pi^-$) ;
- inclusion of π^- from potential well ; (optional)
- Clebsch–Gordan. (optional)

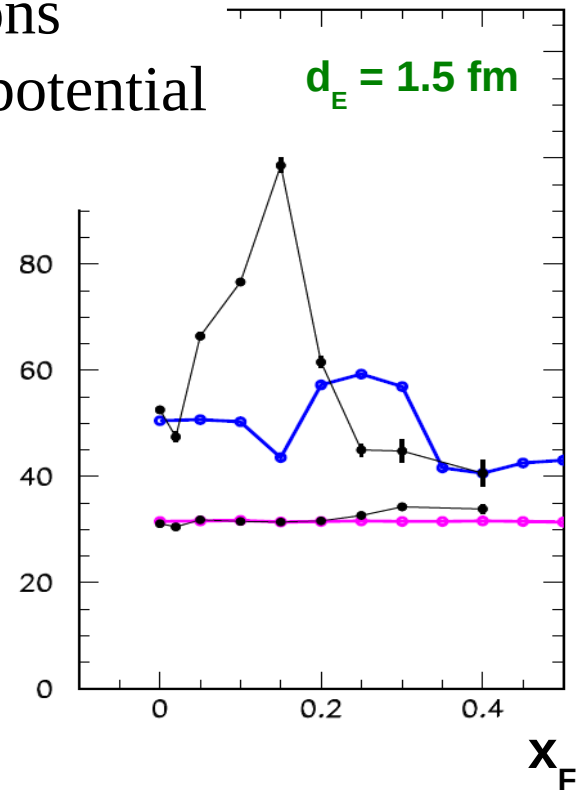
3)

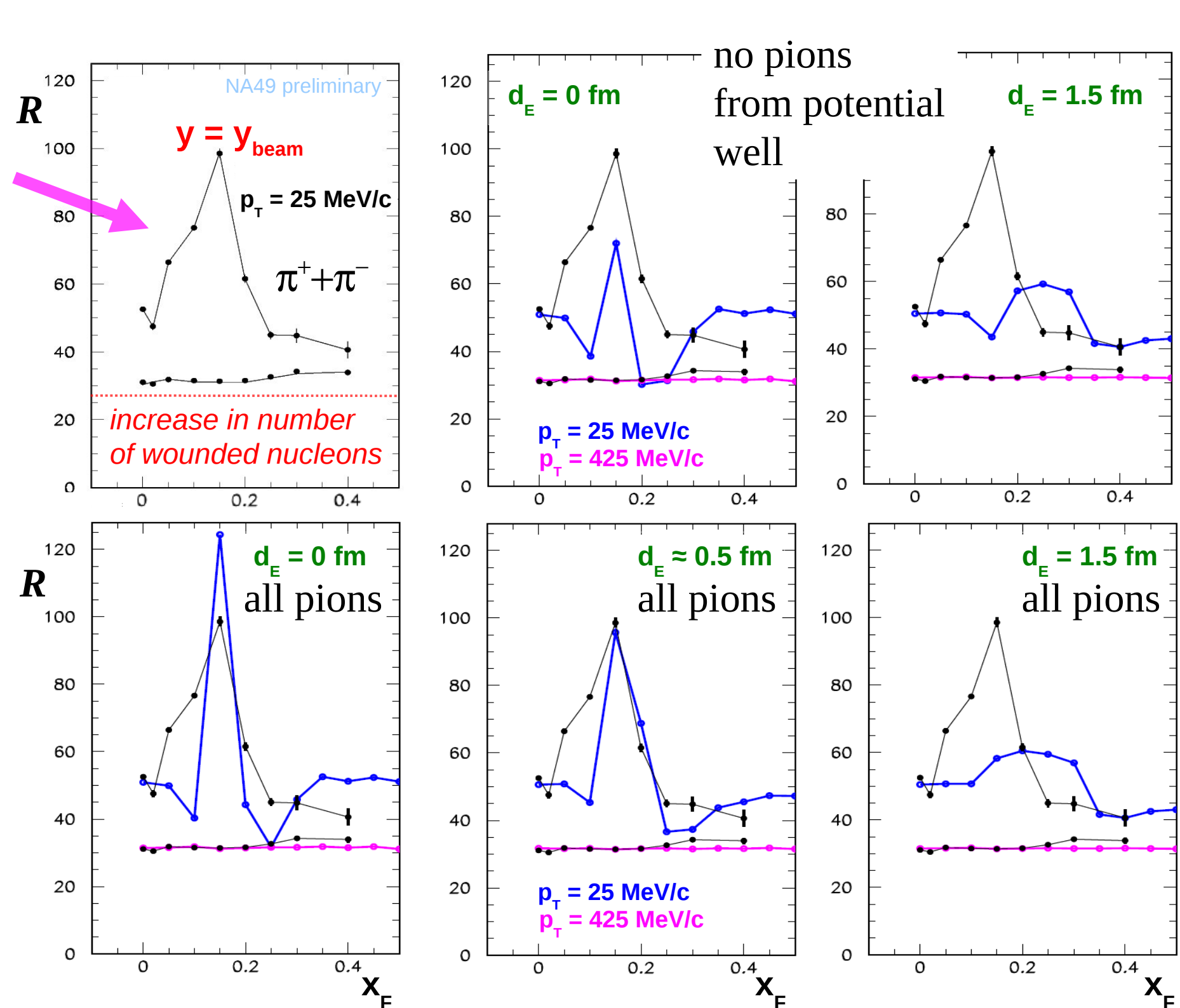
MC & experimental data

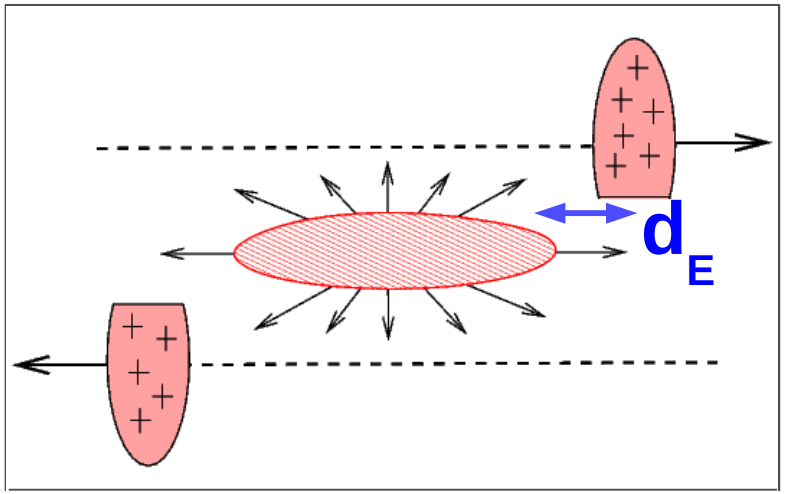


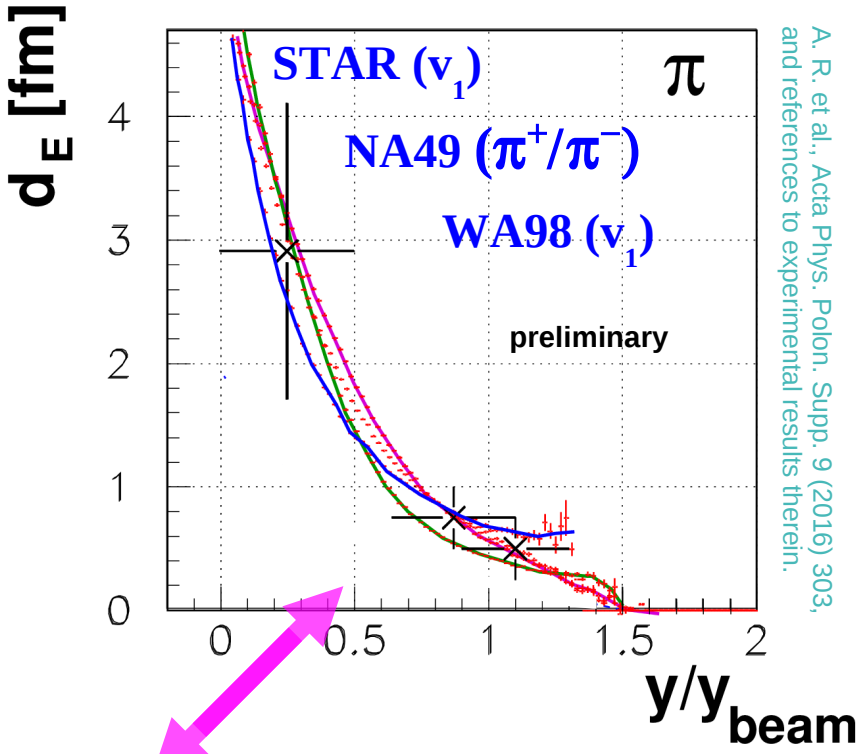


no pions
from potential
well

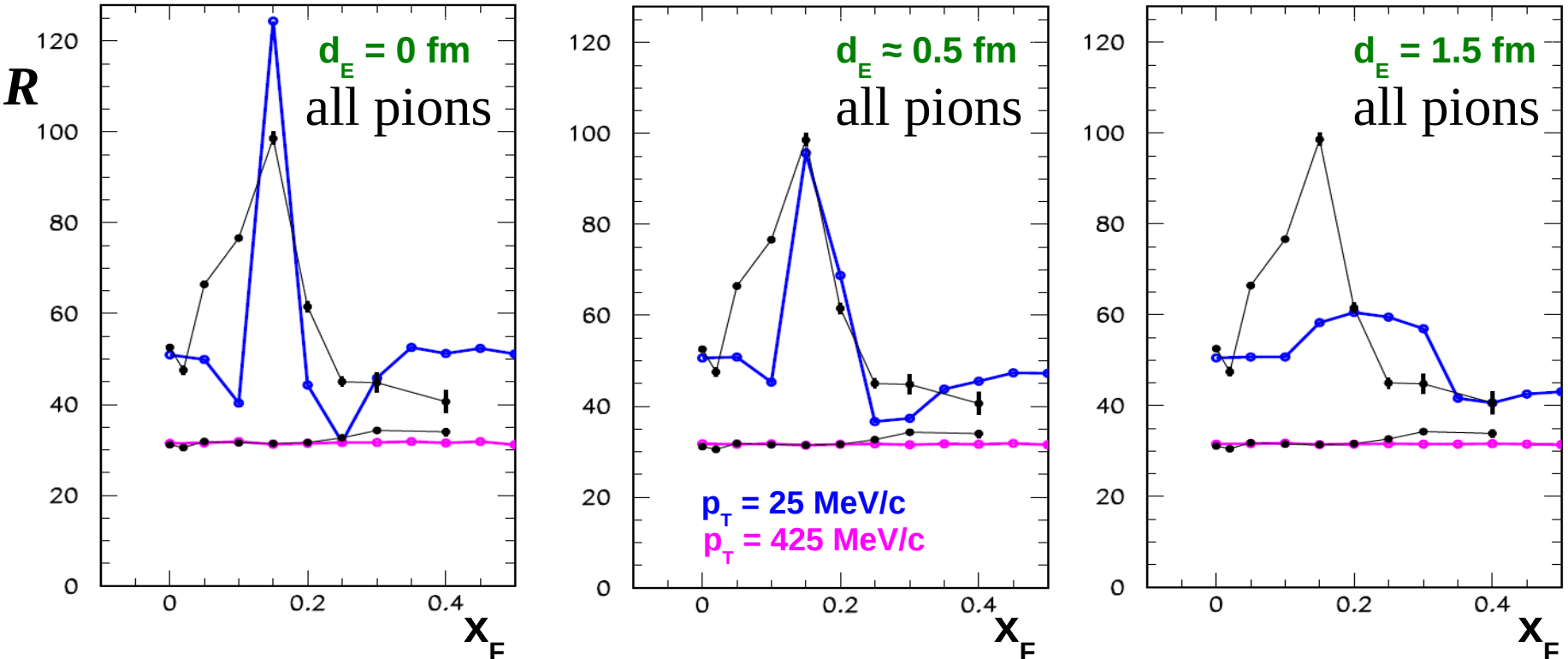


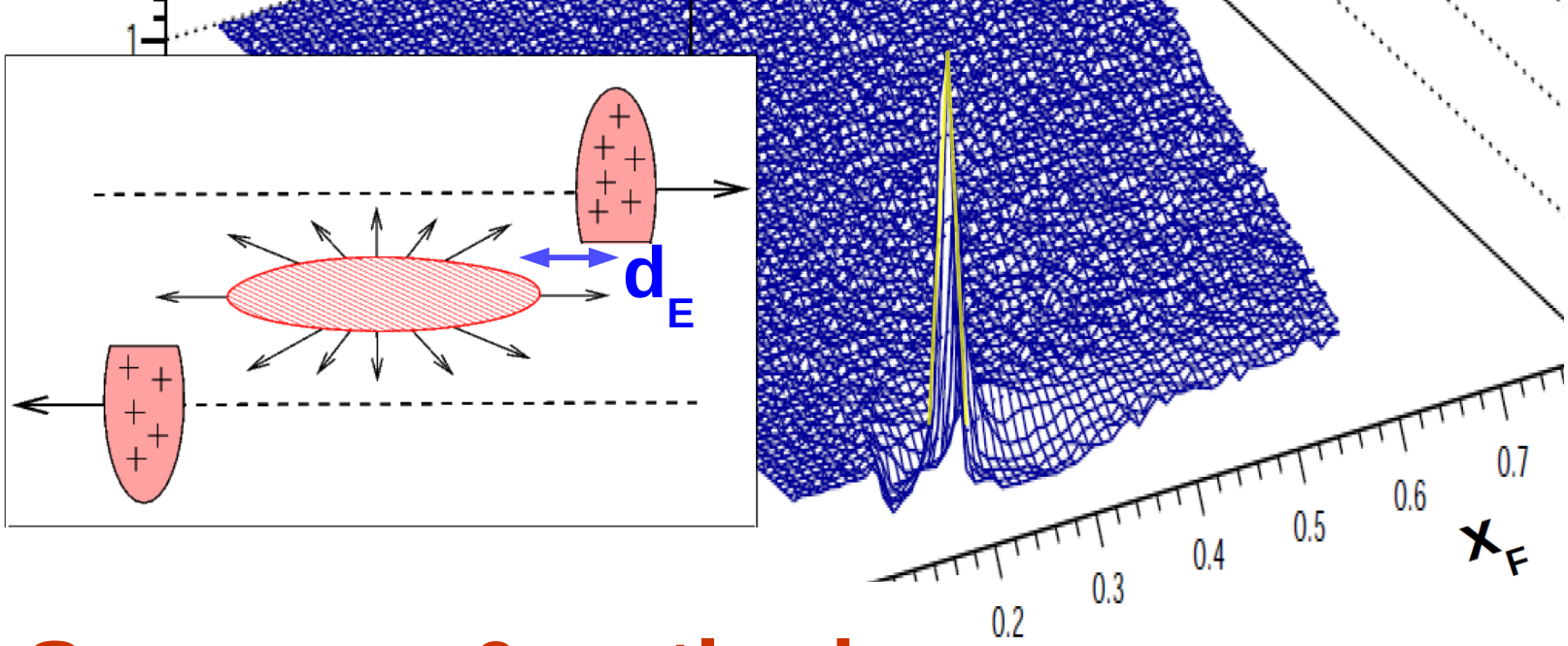

R
NA49 preliminary
y = y_beam
p_T = 25 MeV/c
π⁺+π⁻
increase in number
of wounded nucleons
d_E = 0 fm
p_T = 25 MeV/c
p_T = 425 MeV/c
no pions
from potential
well
d_E = 1.5 fm
R
d_E = 0 fm
all pions
d_E ≈ 0.5 fm
all pions
d_E = 1.5 fm
all pions
x_F





Strong dependence on d_E (again!)





4) Summary & outlook

- The enhancement of (essentially) π^- production at $y \approx y_{beam}$, low p_T appears as a complex phenomenon, involving both EM and strong interaction effects.
- It appears sensitive to d_E (and thus reflects the space-time evolution of the system).
- This is complementary to EM effects on π^+/π^- ratios and directed flow.
- NA61/SHINE has (again) unique capabilities to provide new measurements here.

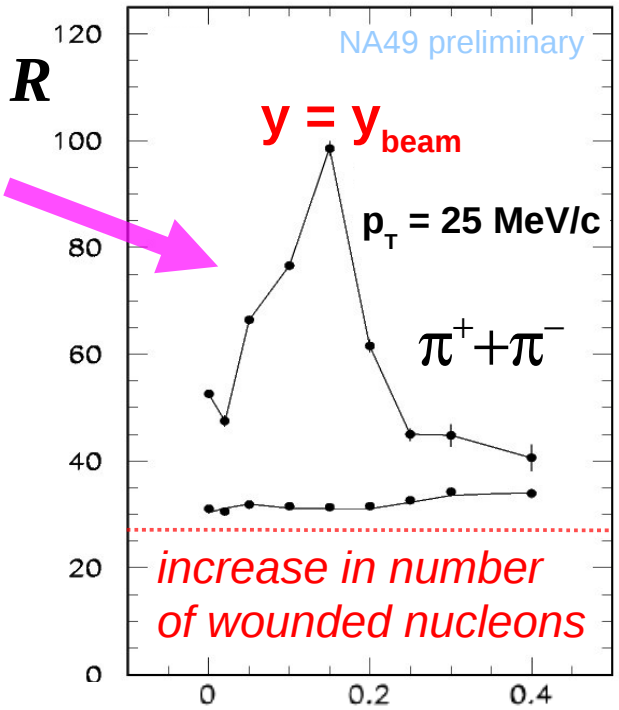
Note: the presented analysis of (Pb+Pb)/(p+p) ratios from NA49 followed the approach proposed in an earlier work by H.G.Fischer (CERN/SPSC 2007-031)

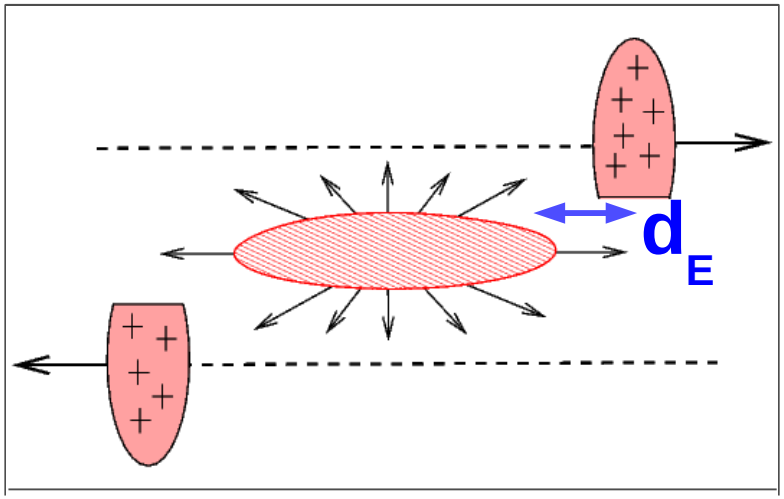
Acknowledgments.

This work was supported by the National Science Centre, Poland

(grant no. 2014/14/E/ST2/00018).

Extra slides





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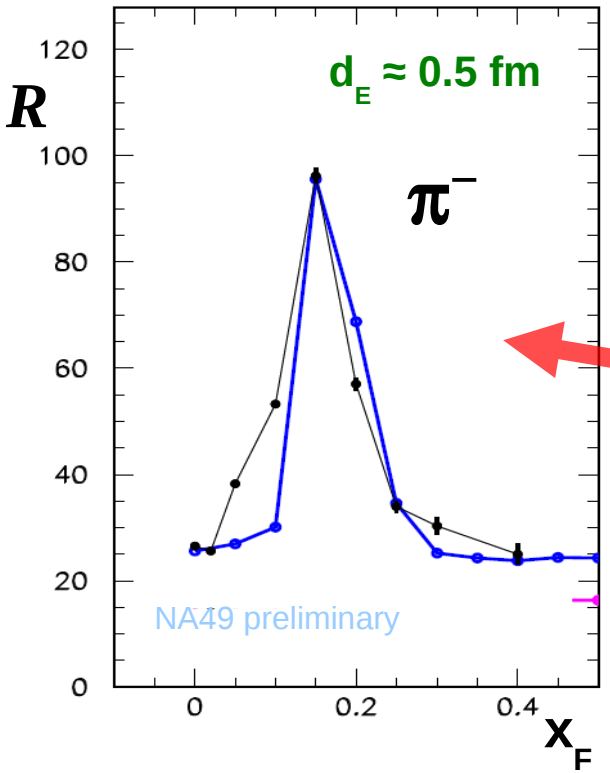

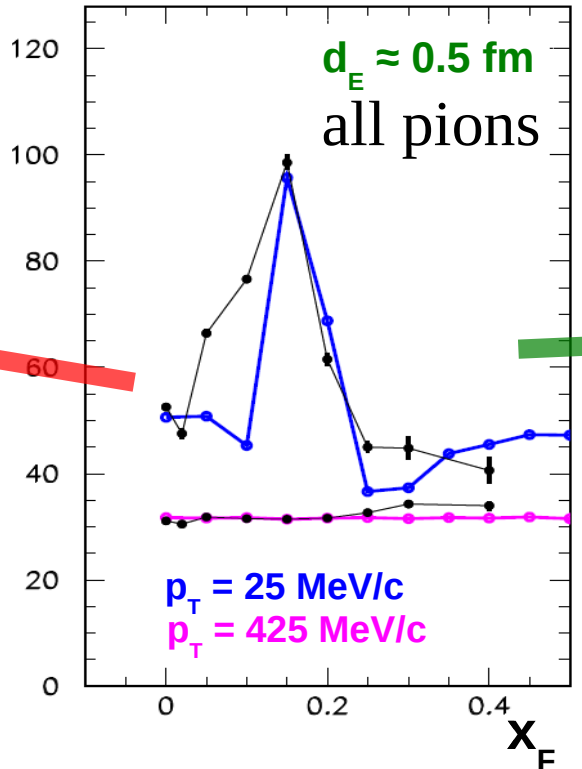

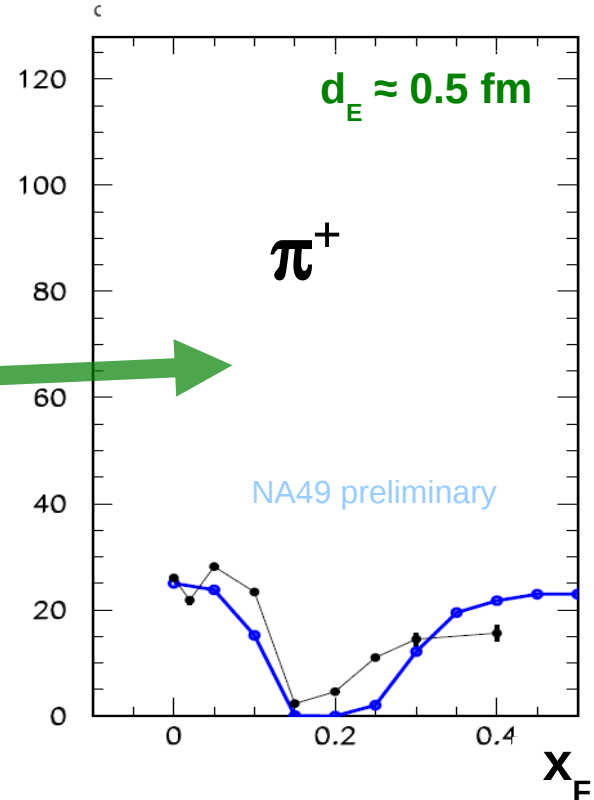

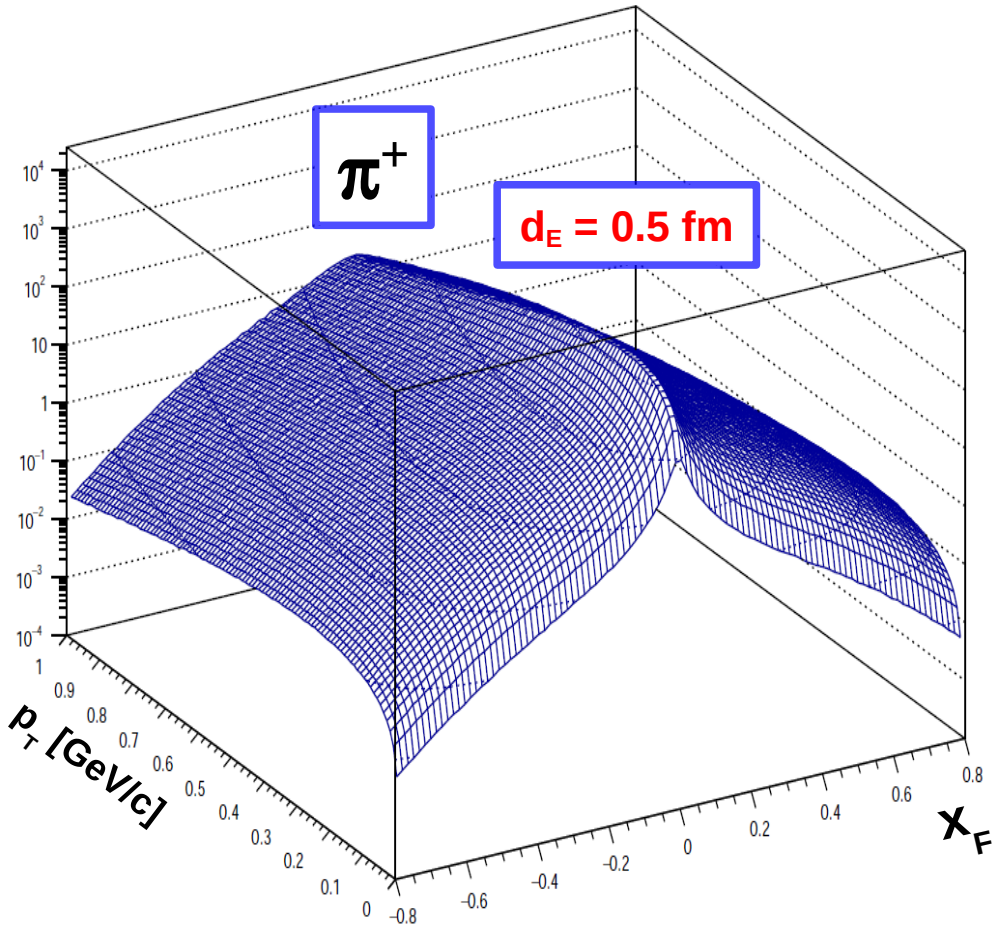

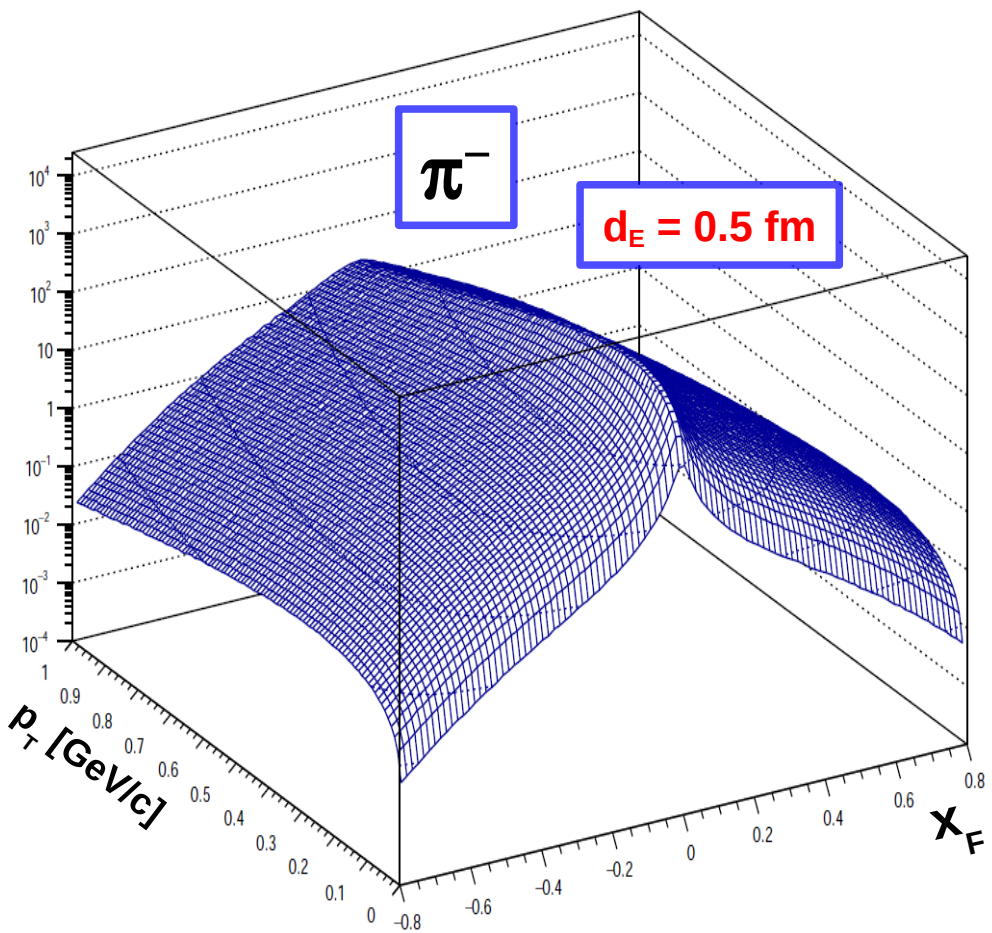

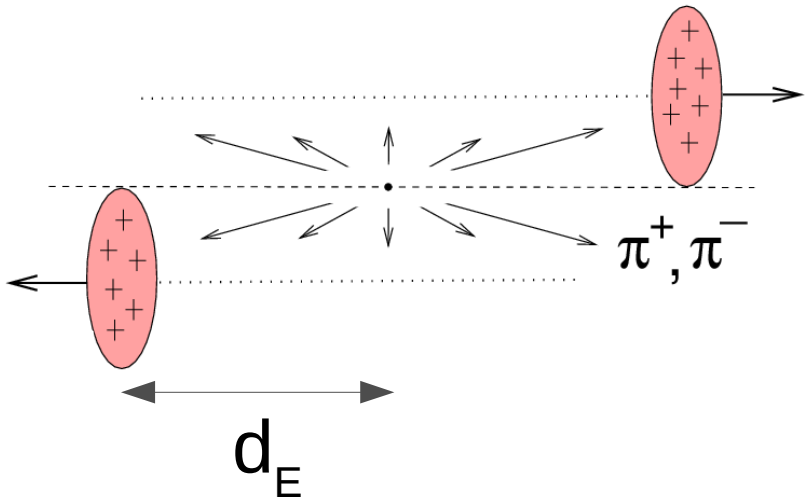

EM Monte Carlo [version (1)]:

- initial distribution of pions is assumed similar to N+N ;
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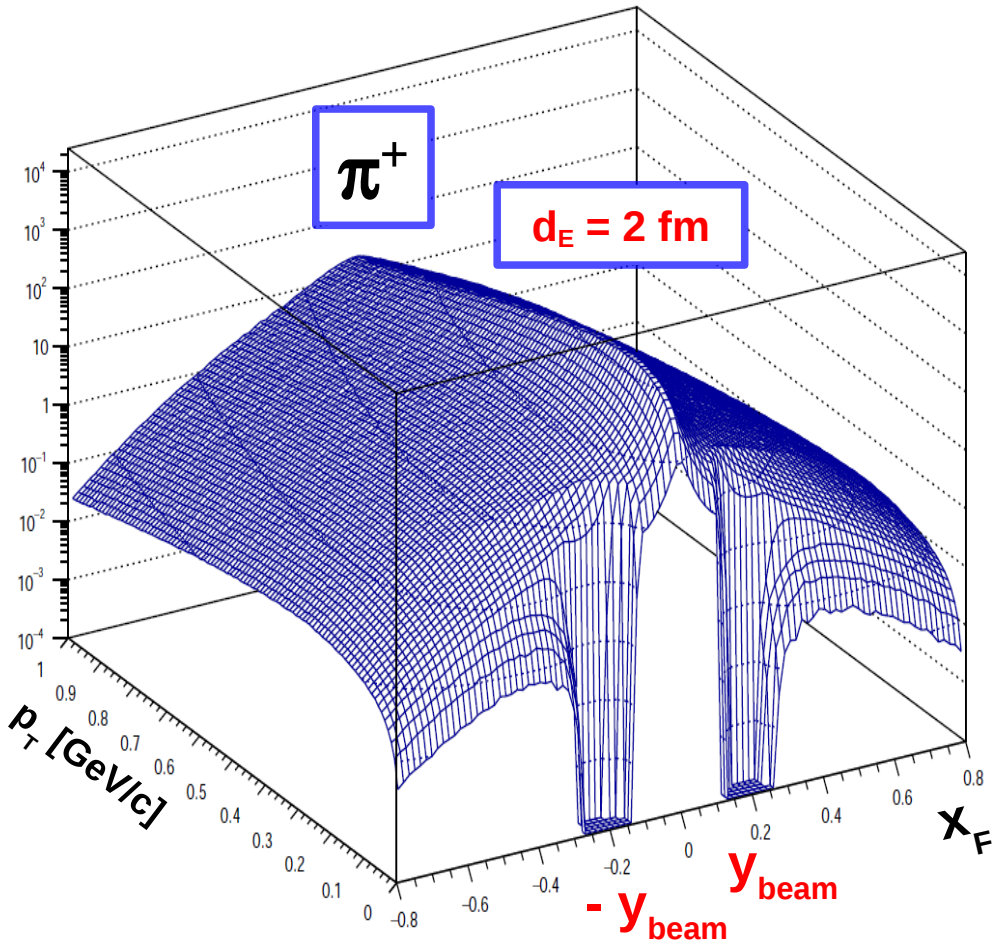
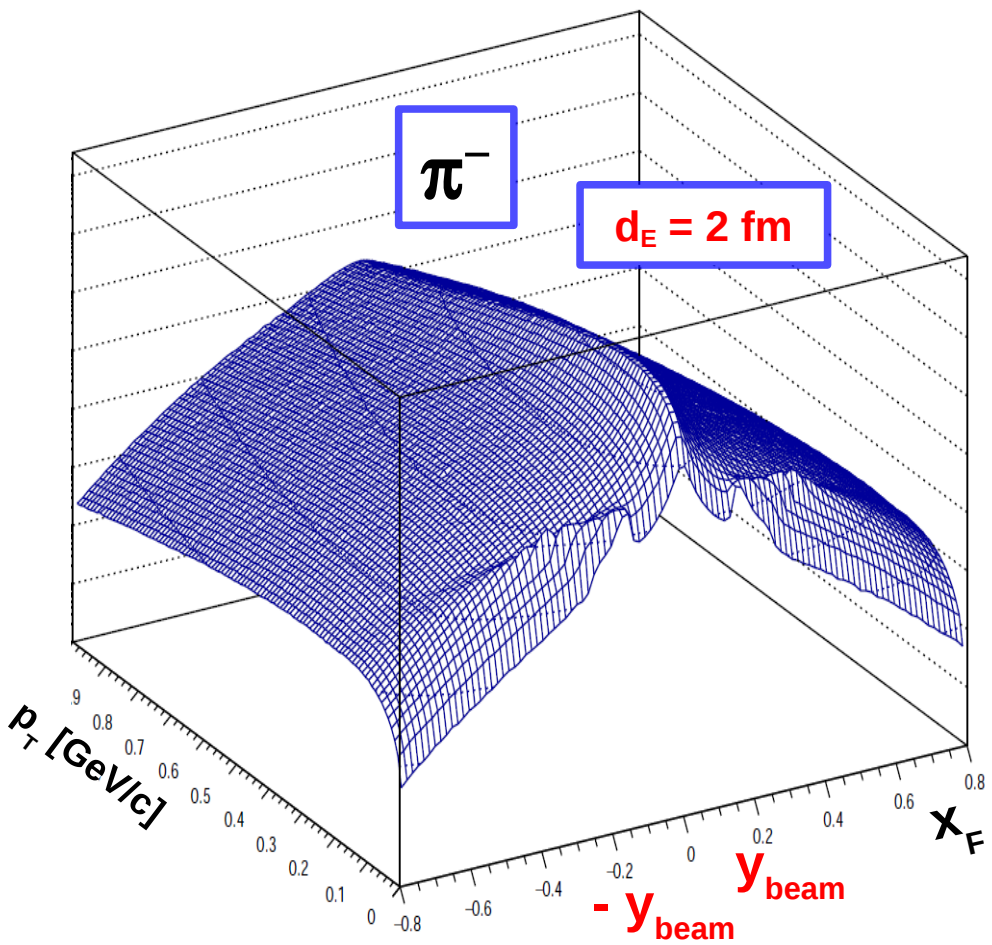
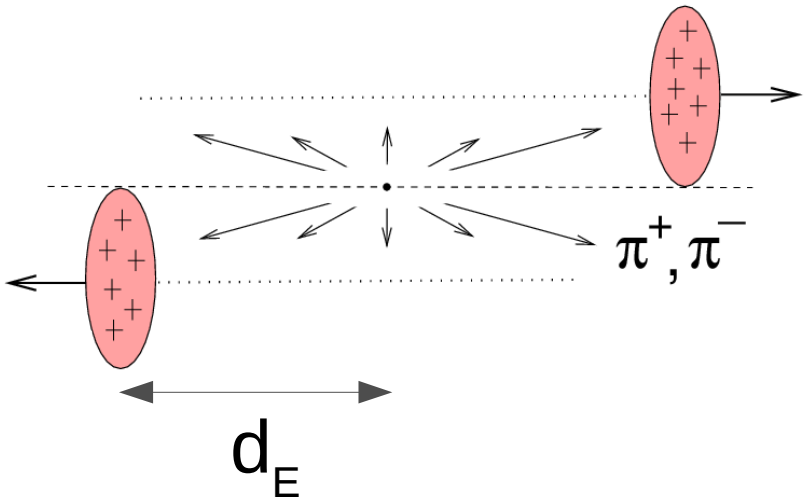
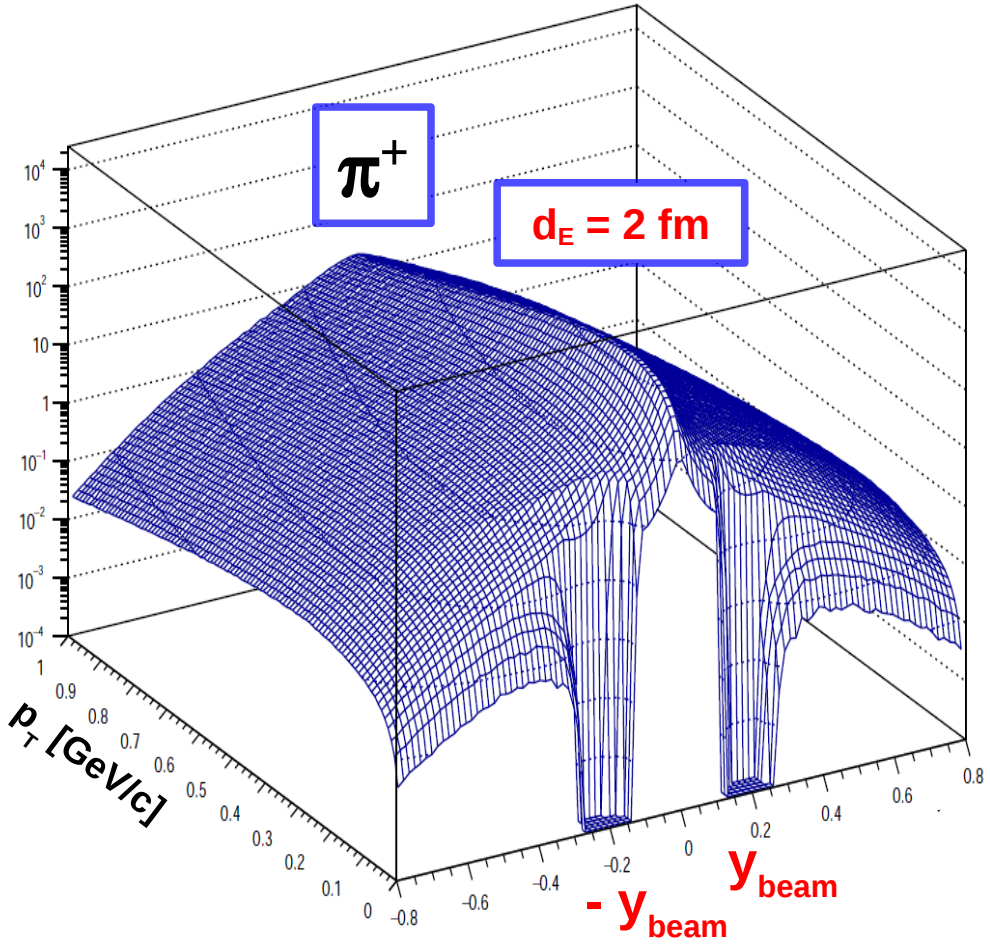
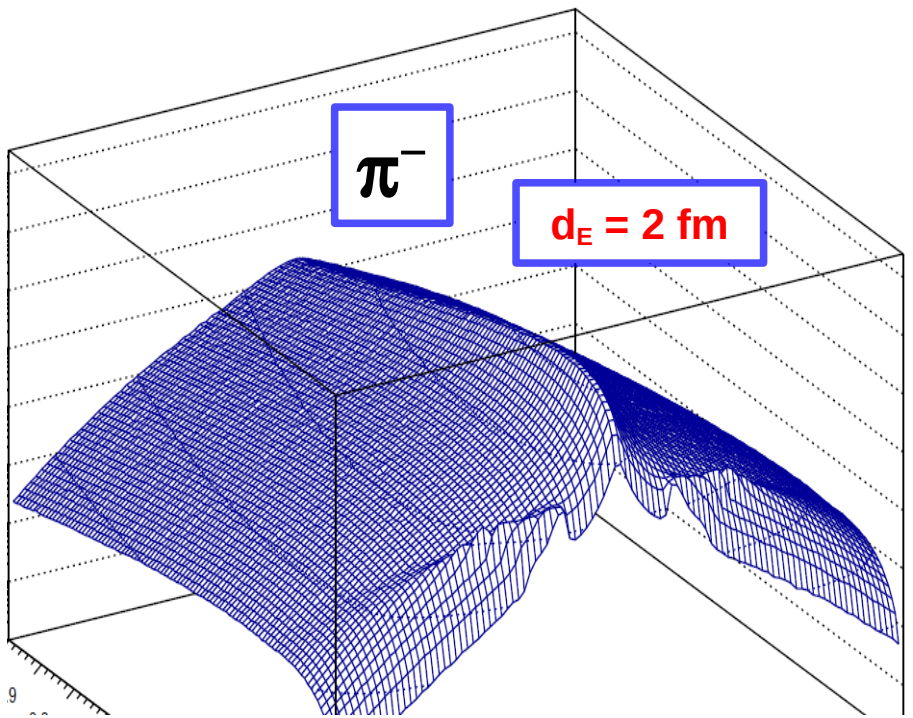
- charged pions are traced in the spectator EM field.

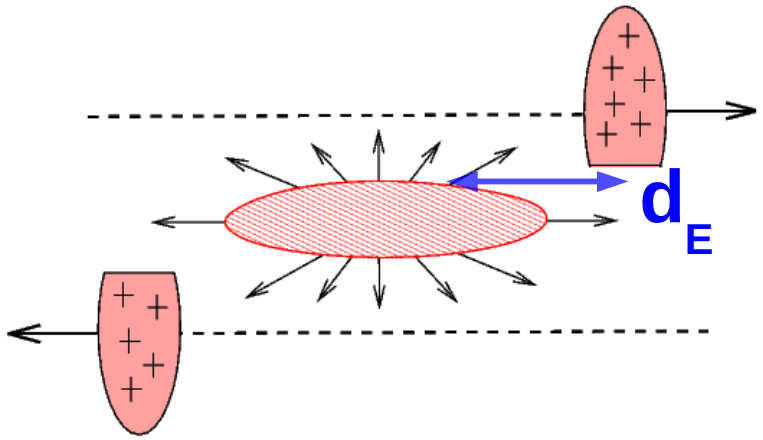

π+
d_E = 2 fm
p_T [GeV/c]
x_F
y_beam
- y_beam

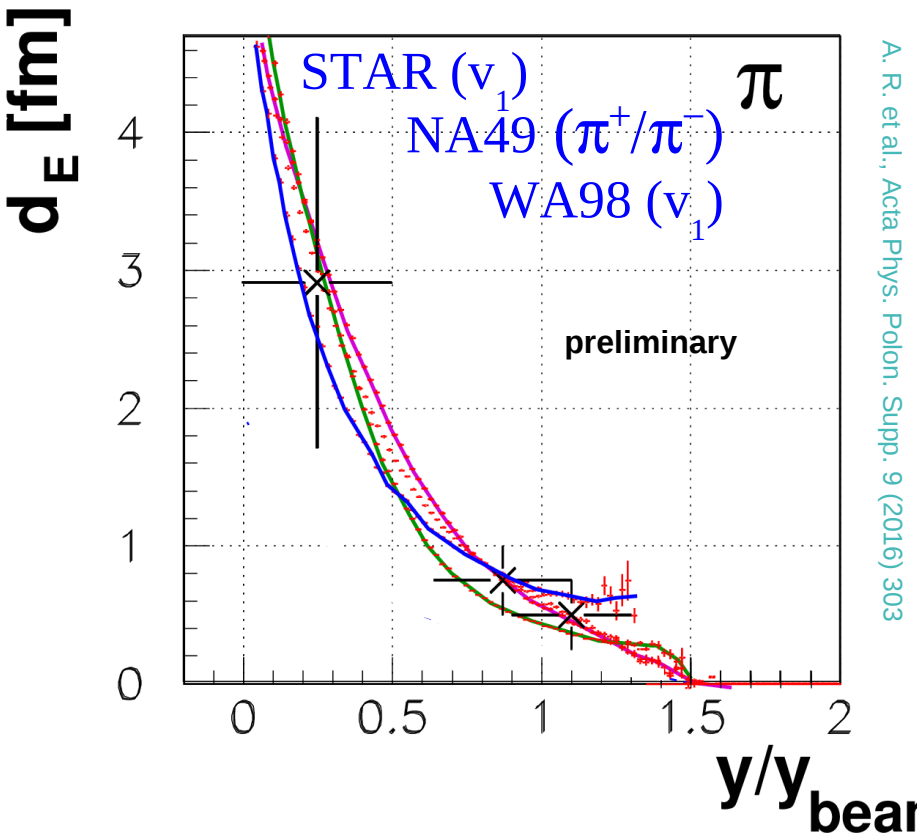

π−
d_E = 2 fm
p_T [GeV/c]
x_F
y_beam
- y_beam


π+, π−
d_E









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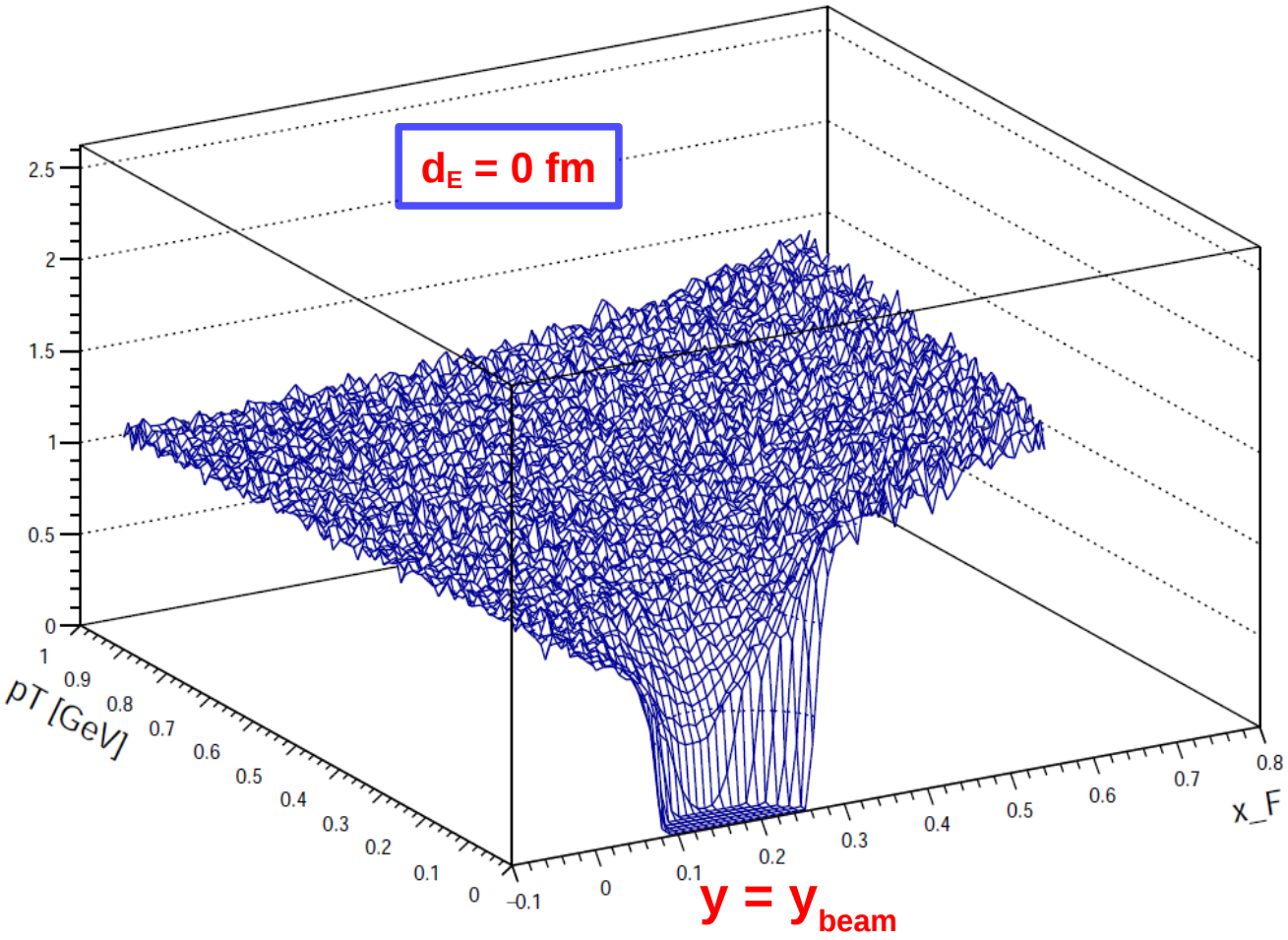
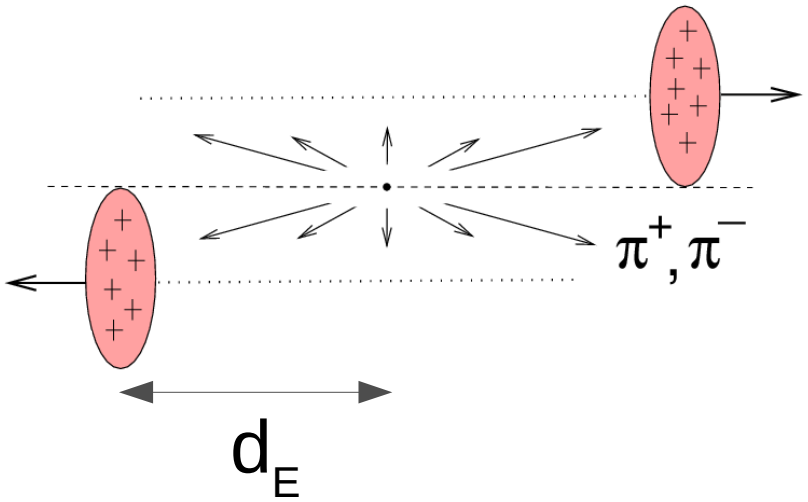
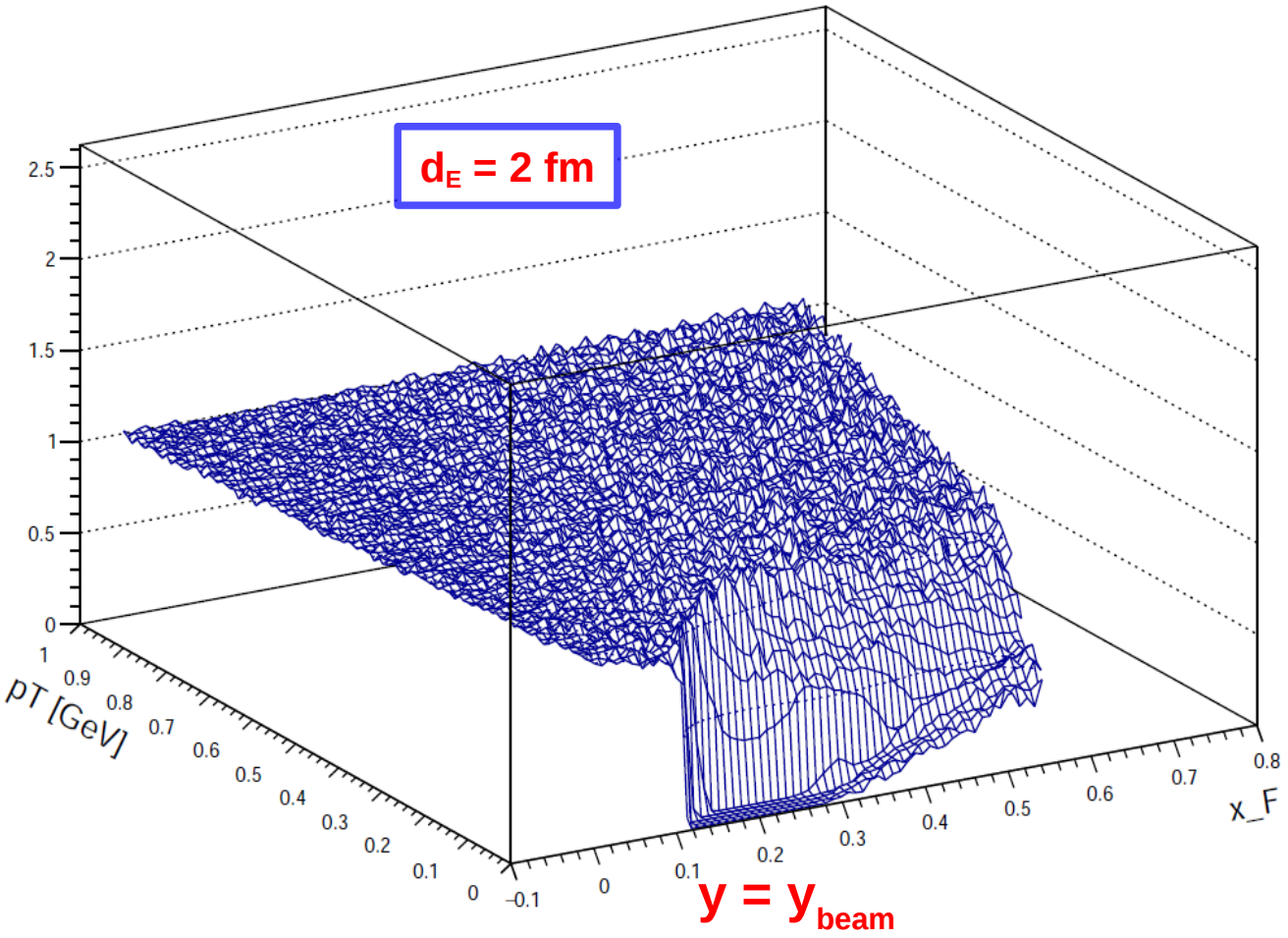
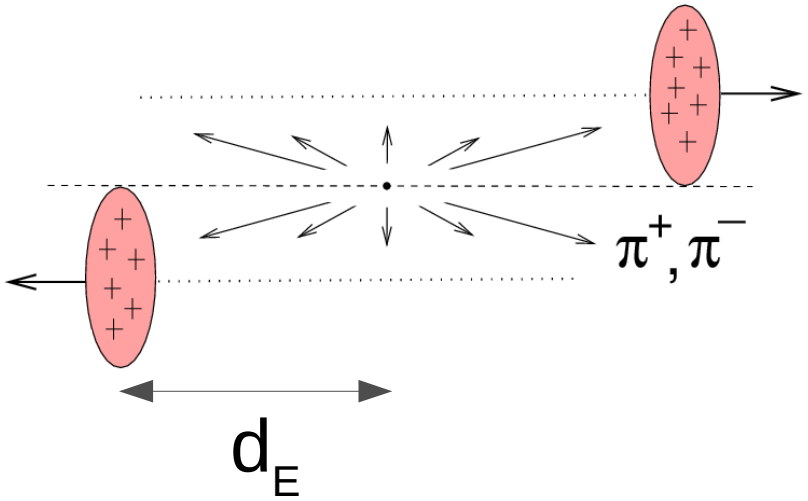
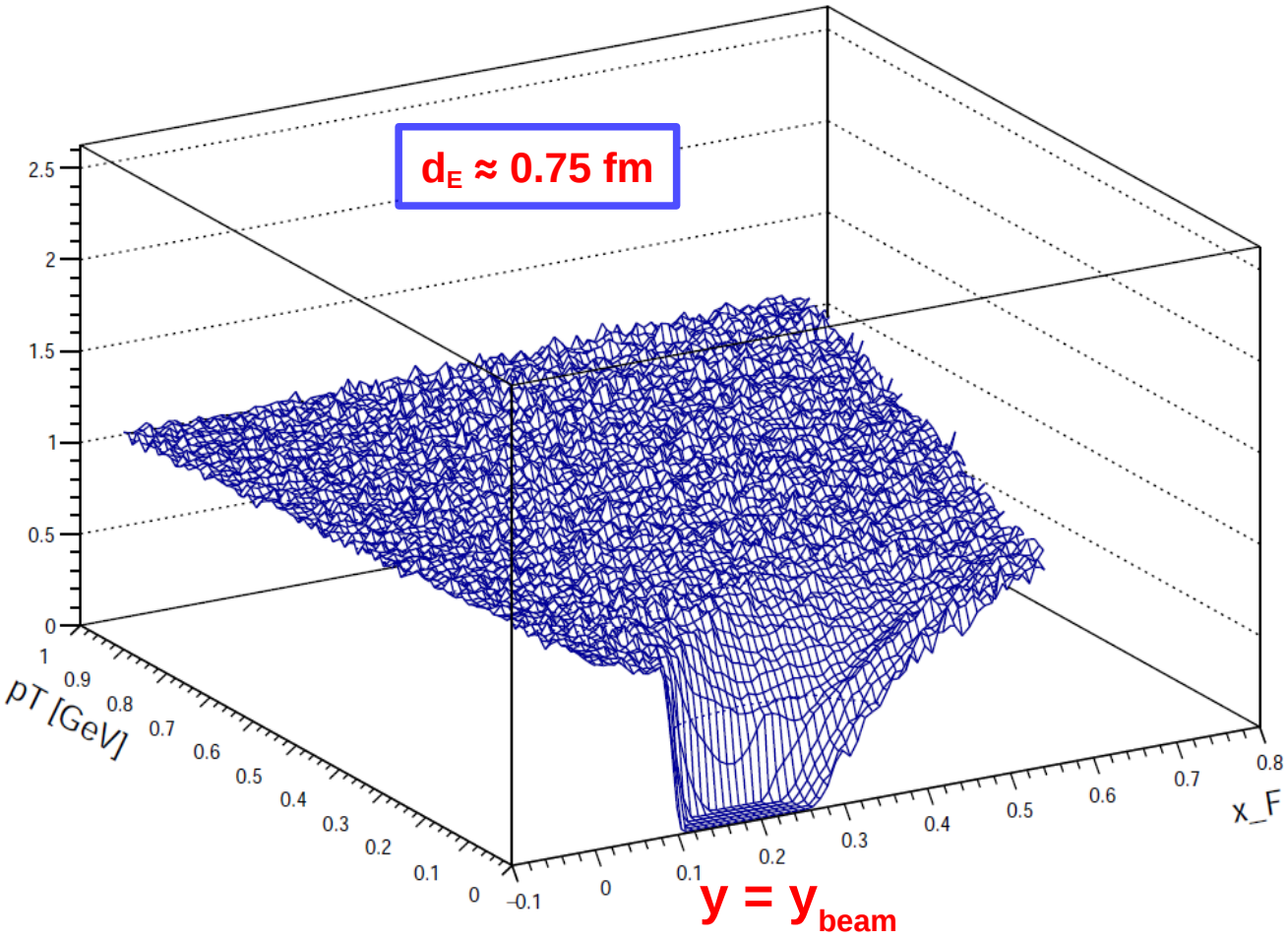
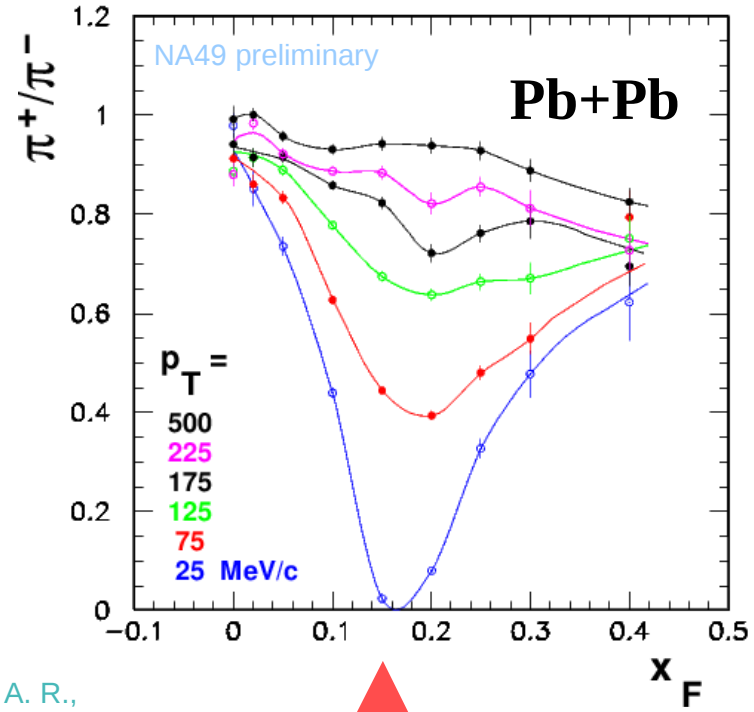

d_E = 0 fm
2.5
2
1.5
1
0.5
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
pT [GeV]
−0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x_F
y = y_{beam}


π^+, π^-
d_E

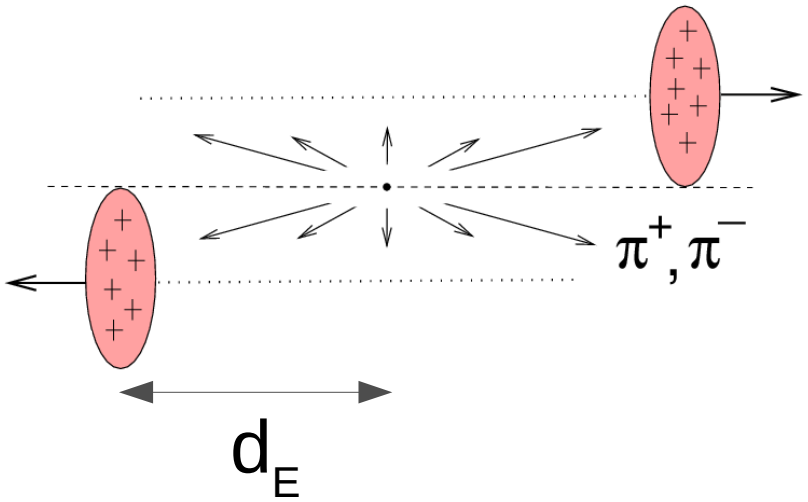

d_E = 2 fm
2.5
2
1.5
1
0.5
0
pT [GeV]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
x_F
y = y_{beam}

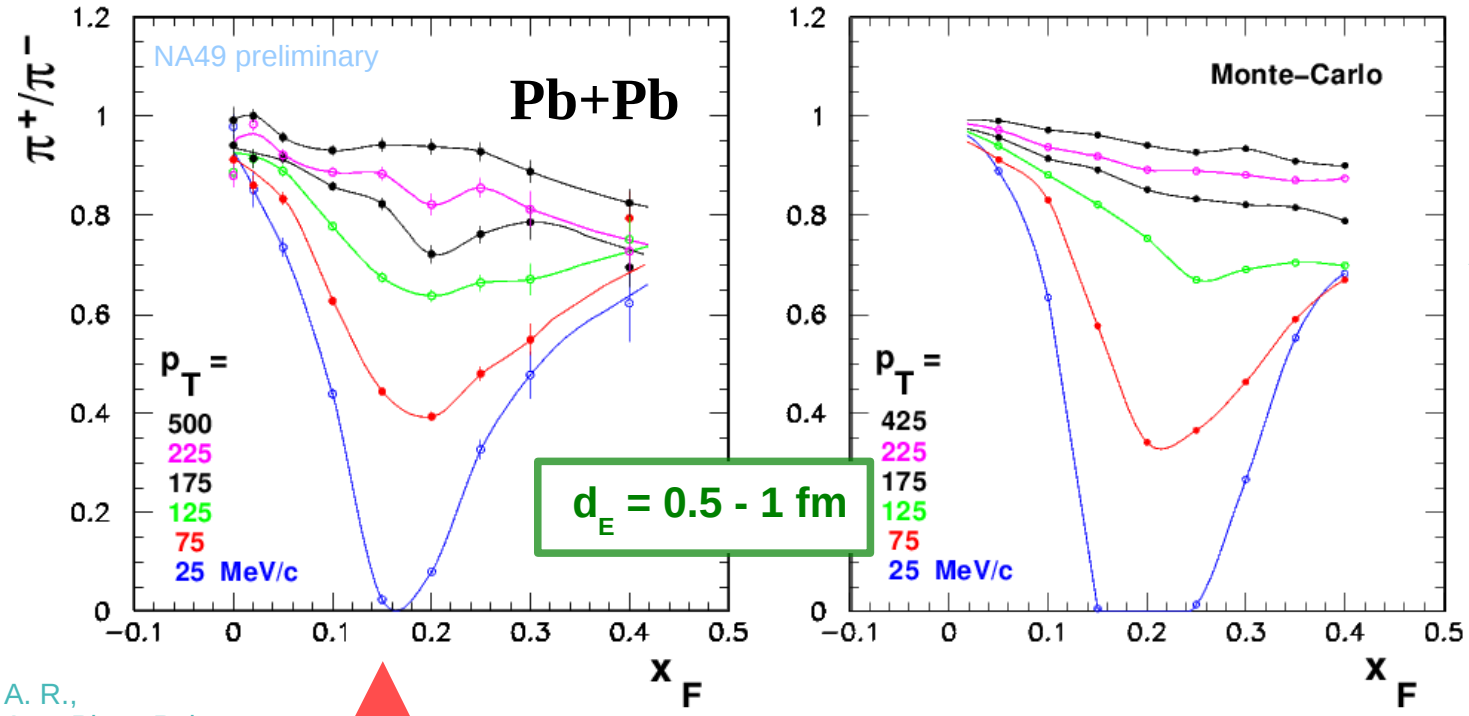

π^+, π^-
d_E





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





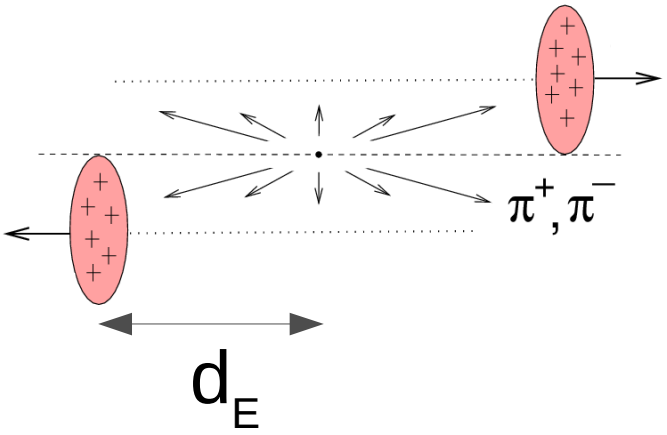
A. R. and A. Szczurek, Phys. Rev. **C75** (2007) 054903

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

d_E = 0.5 - 1 fm

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

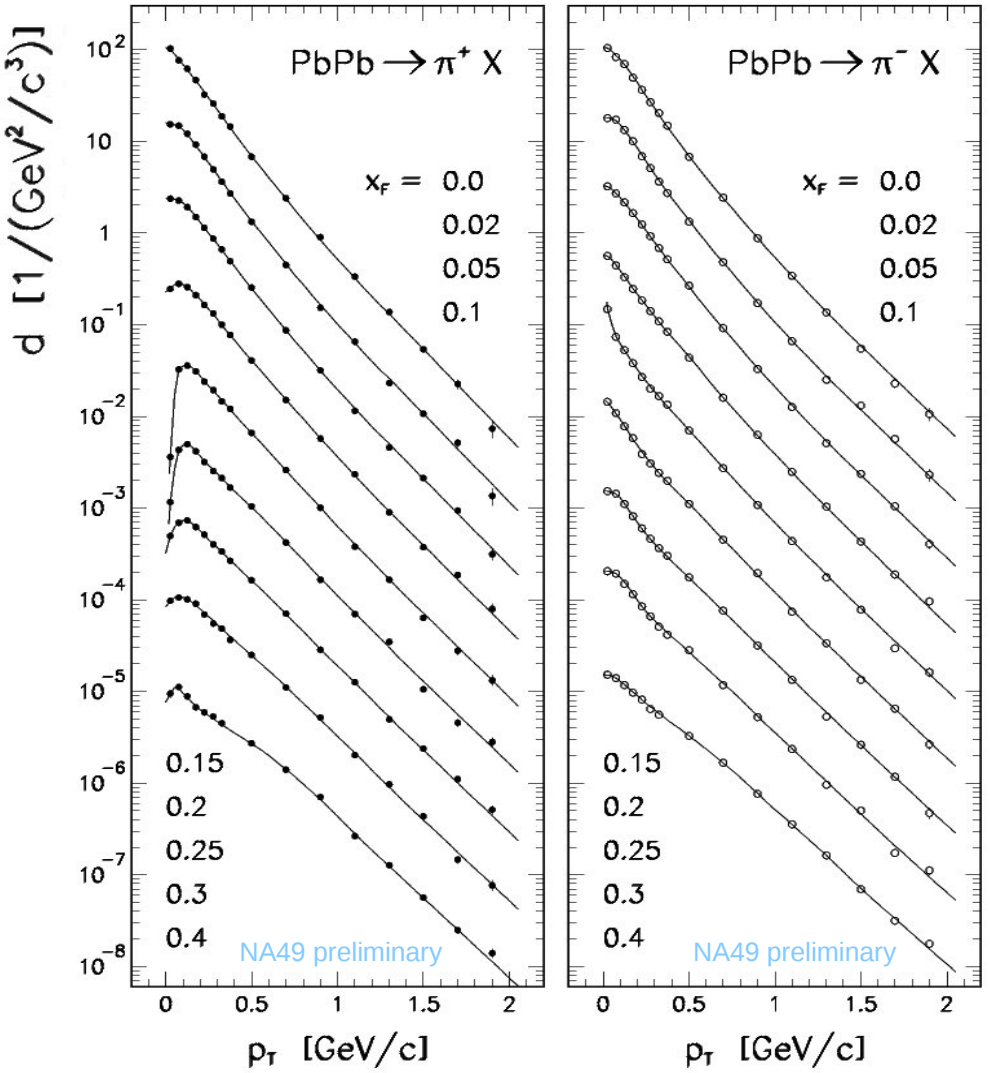
$y = y_{beam}$



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

Pb+Pb (peripheral)

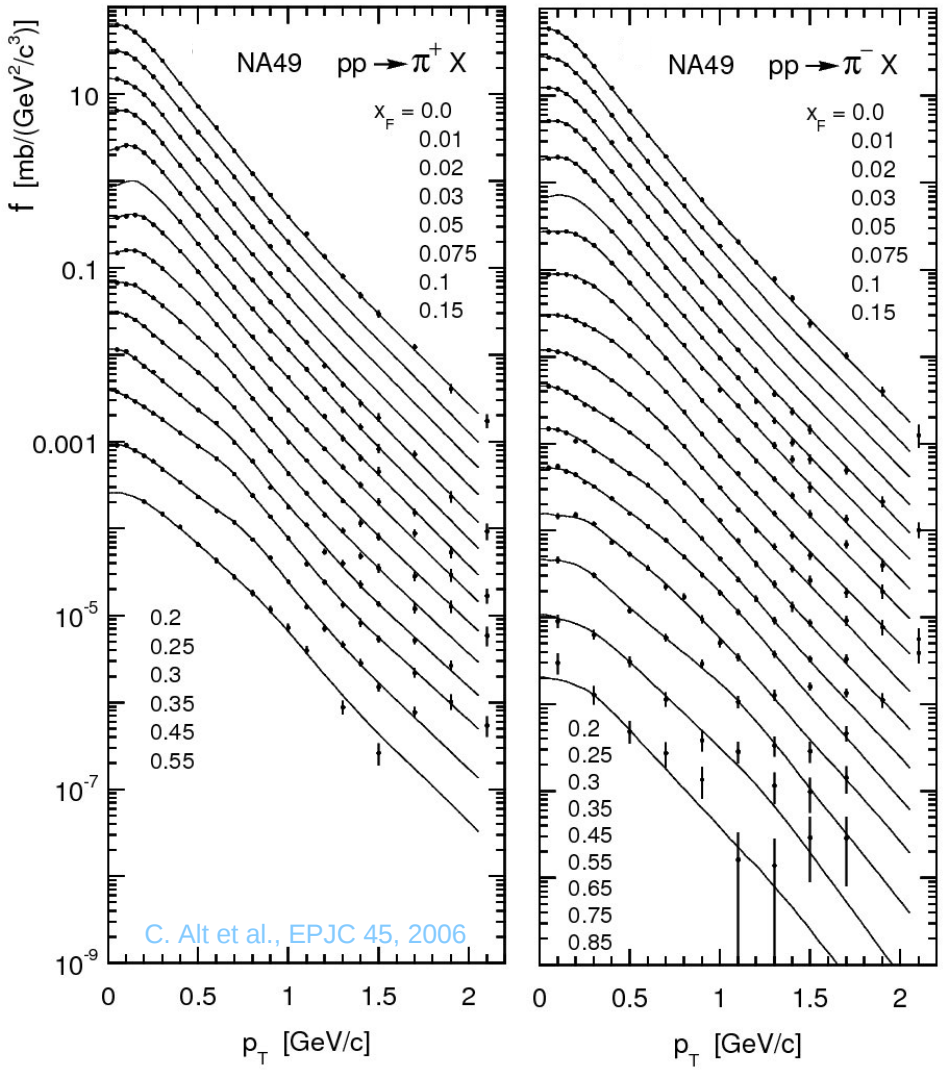
$$d = E\frac{d^3N}{dp^3}$$



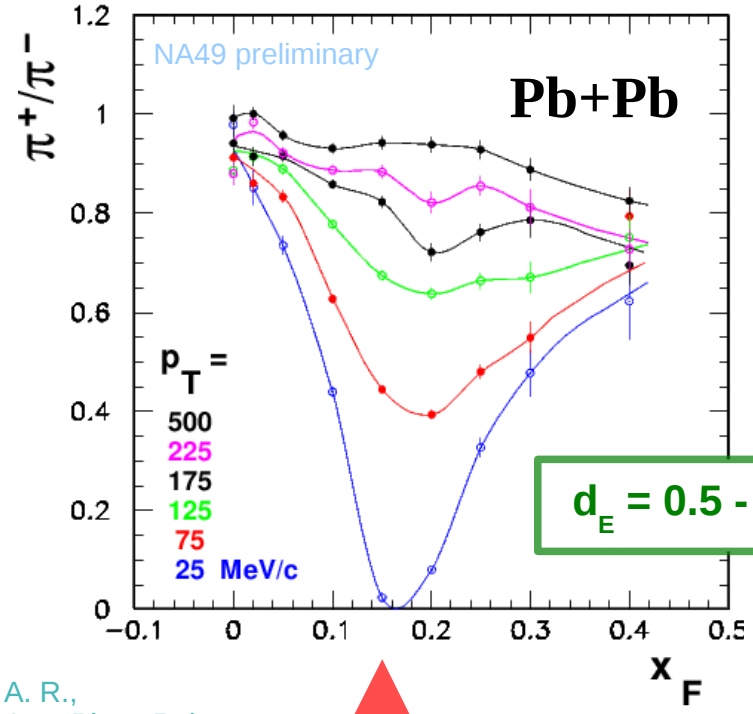
A.R., PoS (EPS-HEP2009)

p+p

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

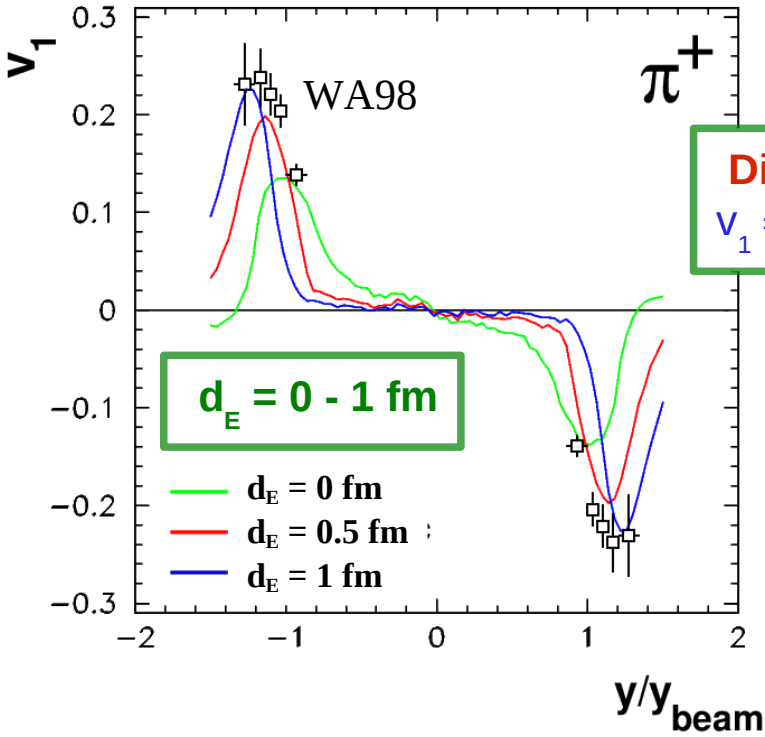


$$x_F = \frac{p_L}{p_L^{beam}}$$ (c.m.s.)



d_E = 0.5 - 1 fm

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

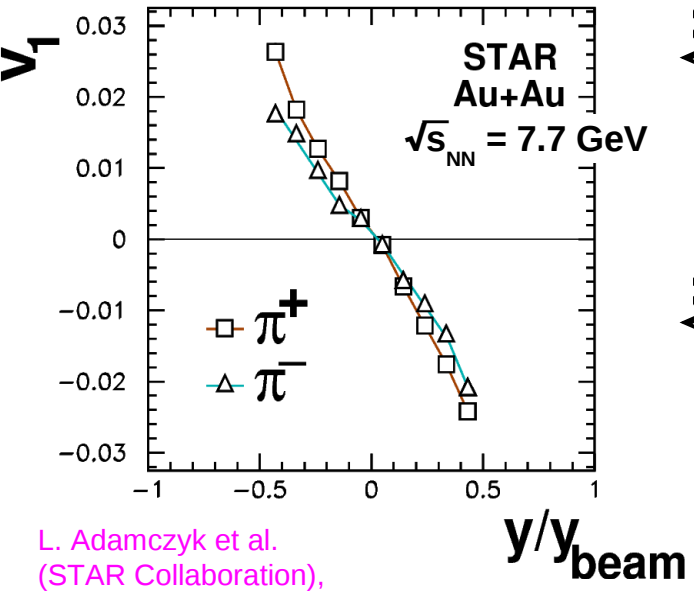


Directed flow:
$v_1 = < \cos(\phi - \Psi_{RP}) >$

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

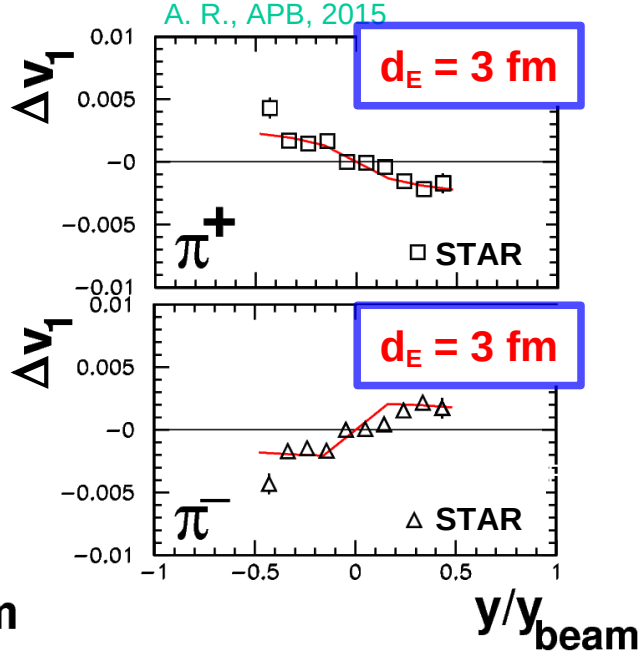
H. Schlagheck
(WA98 Collaboration),
Nucl. Phys. A **663** (2000)
725.

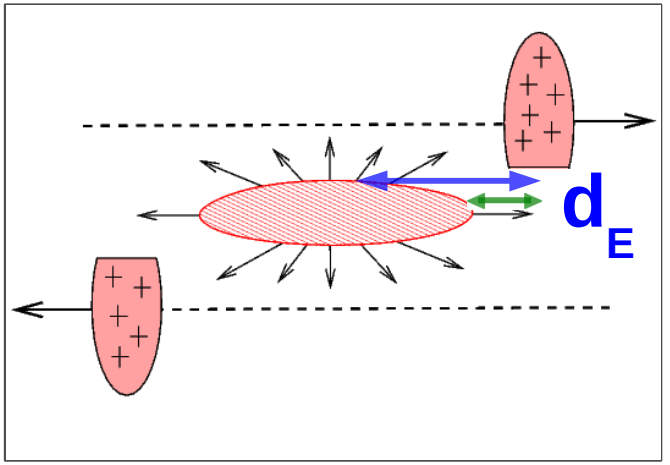
$y = y_{beam}$



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)