Quark Matter 2005, Budapest

p+p and p+A physics at SPS – and their relation to A+A

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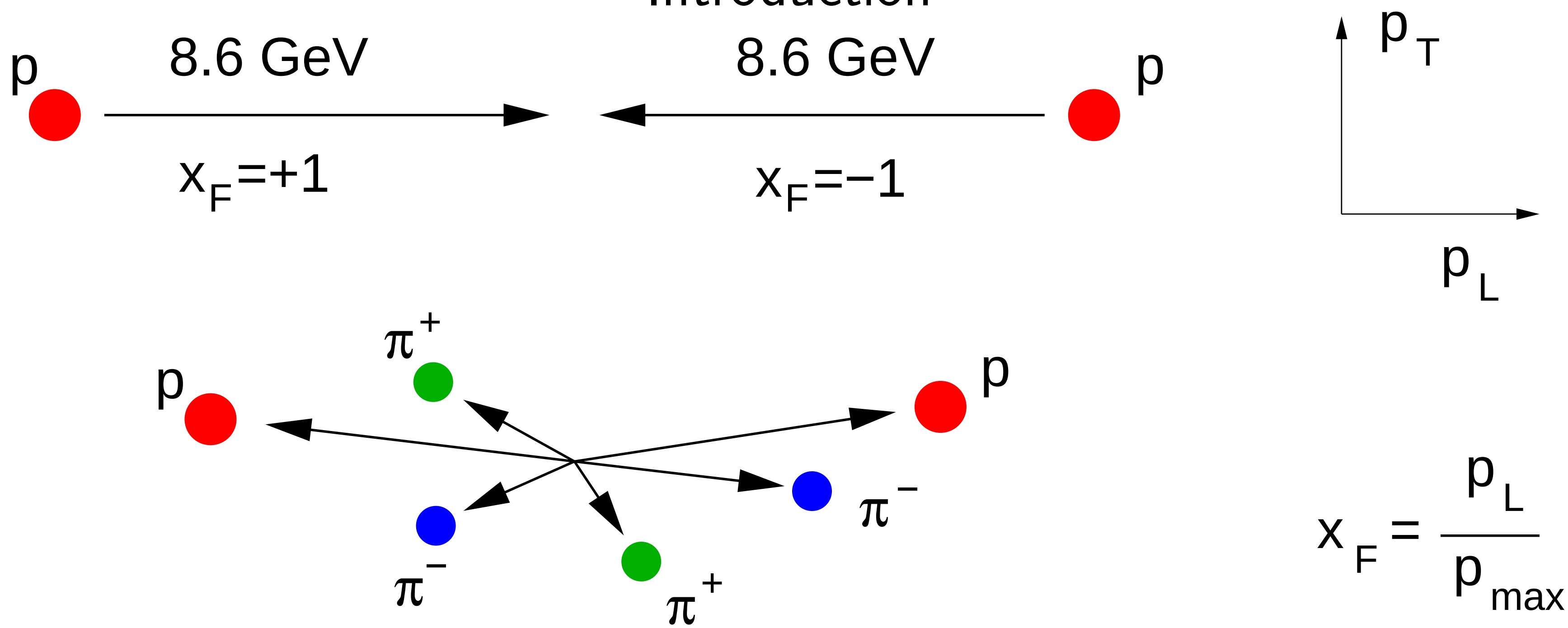
for the NA49 Collaboration

- Why both p+p and p+A is needed as a reference for A+A?
- How to understand baryon and pion production in p+p and p+A?
- How to relate p+p and p+A to A+A?

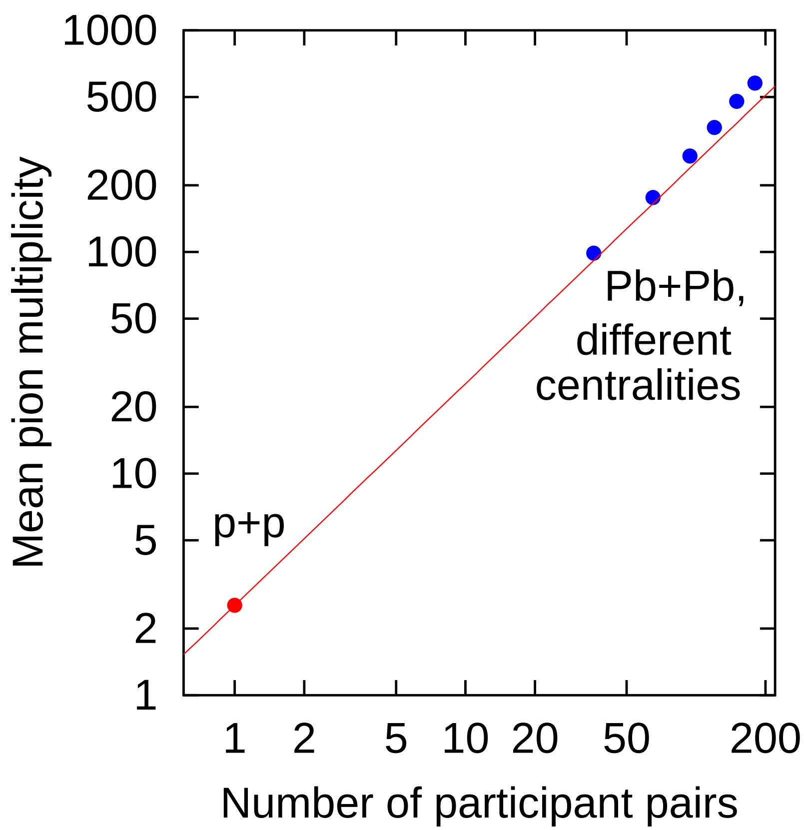
Introduction



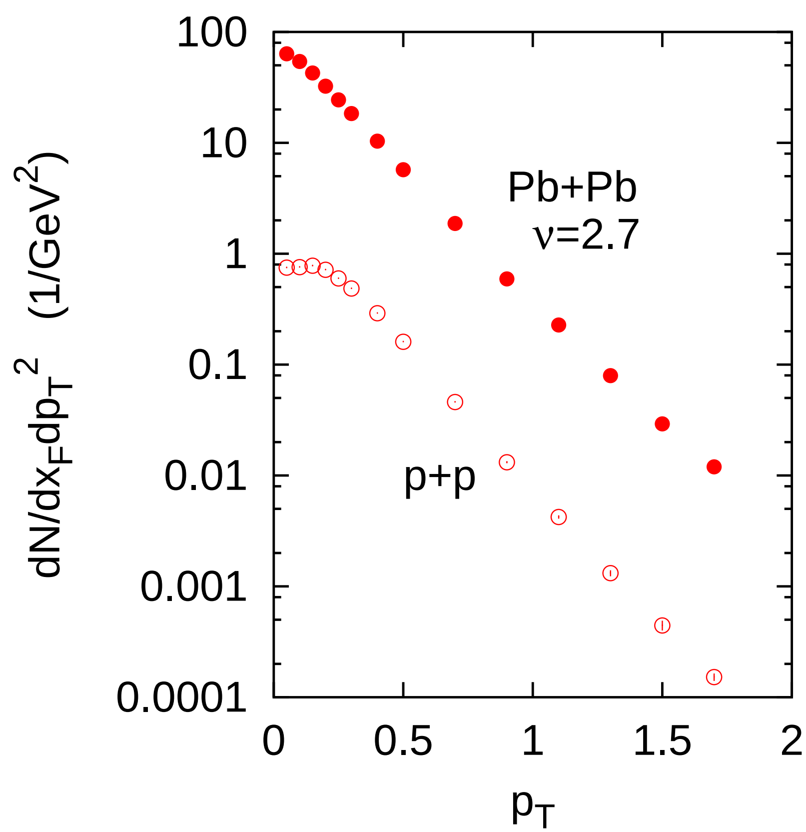
- Exponential damping in p_T, 95% of particles below 1 GeV
- Soft hadronic sector: no QCD calculations available
- This talk: no models, but conclude on phenomenological pictures based on experimental information

Question 1. Why p+A is needed as reference?

- Pion multiplicity



- Pion production (per event)



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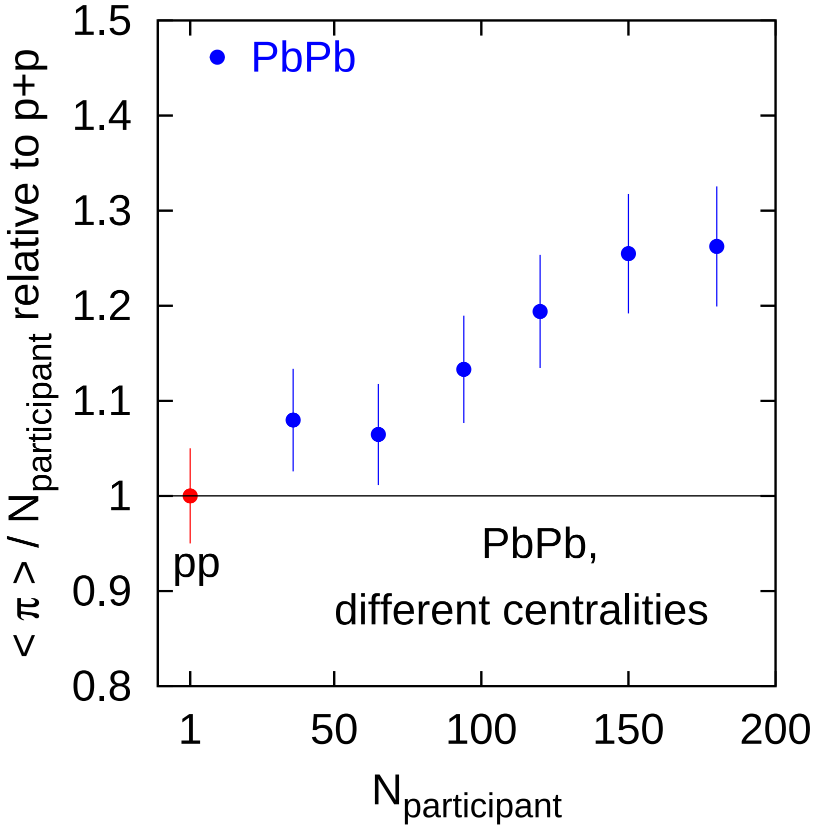
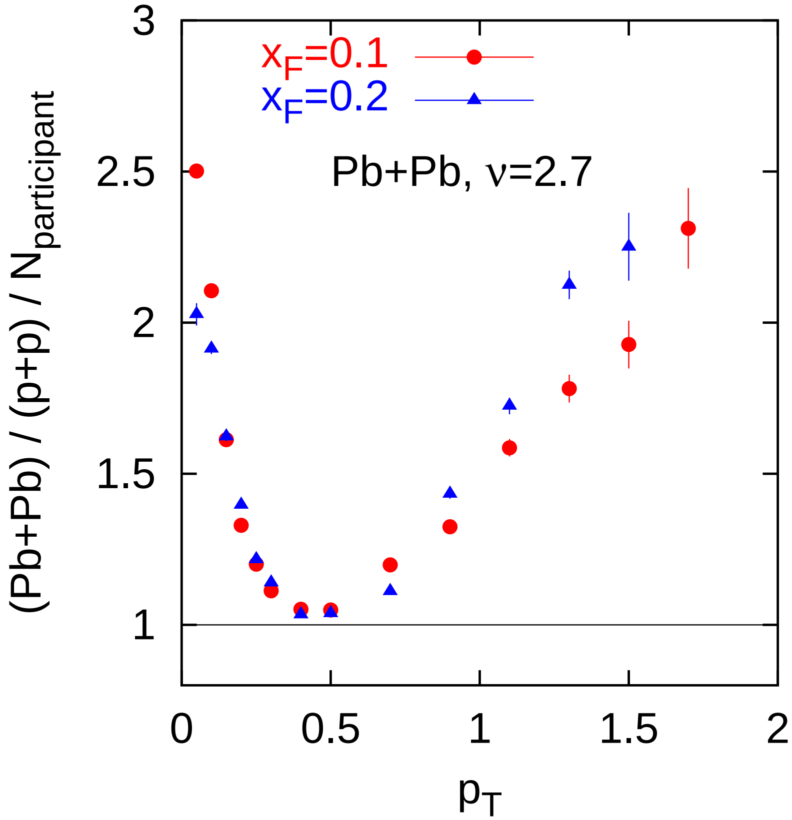
- Increased production in A+A !?
- Increase of high p_T yield !?





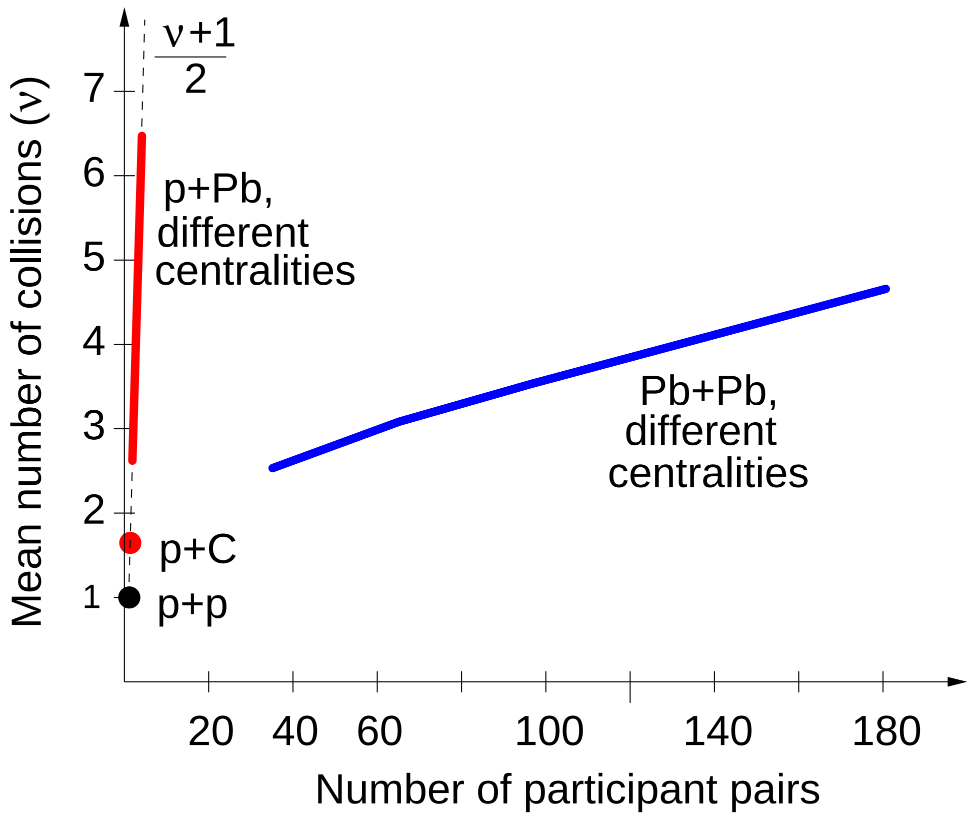
$\longrightarrow$ New phenomena: difference not present in p+A

$\longrightarrow$ Multiple collision effects controlled by p+A

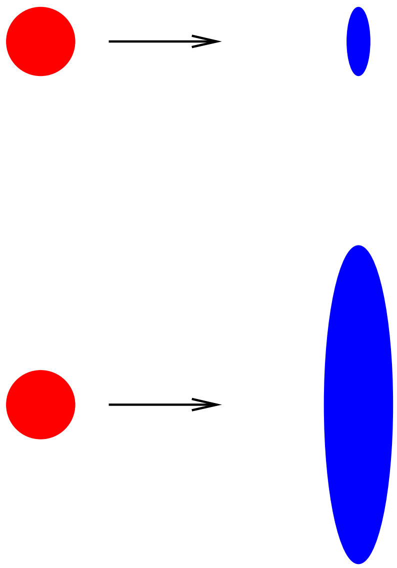
Question 2. How to relate p+p and p+A to A+A?

Geometrical quantities characterising to the collision:

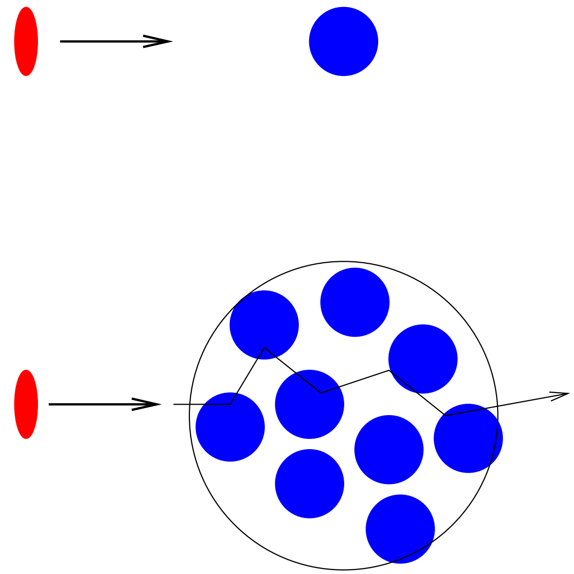
- Number of interacting nucleon pairs (participants, $N_{participant}$)
  (to first order, particle production in A+A proportional to $N_{participant}$)
- Number of collisions (ν)



Question 3. What is special about p+A?



Probes the projectile traversing nuclear matter
$\Rightarrow$ probes the system after the first collision



Probes the target, "multiple collisions" by the same projectile

This talk concentrates on:

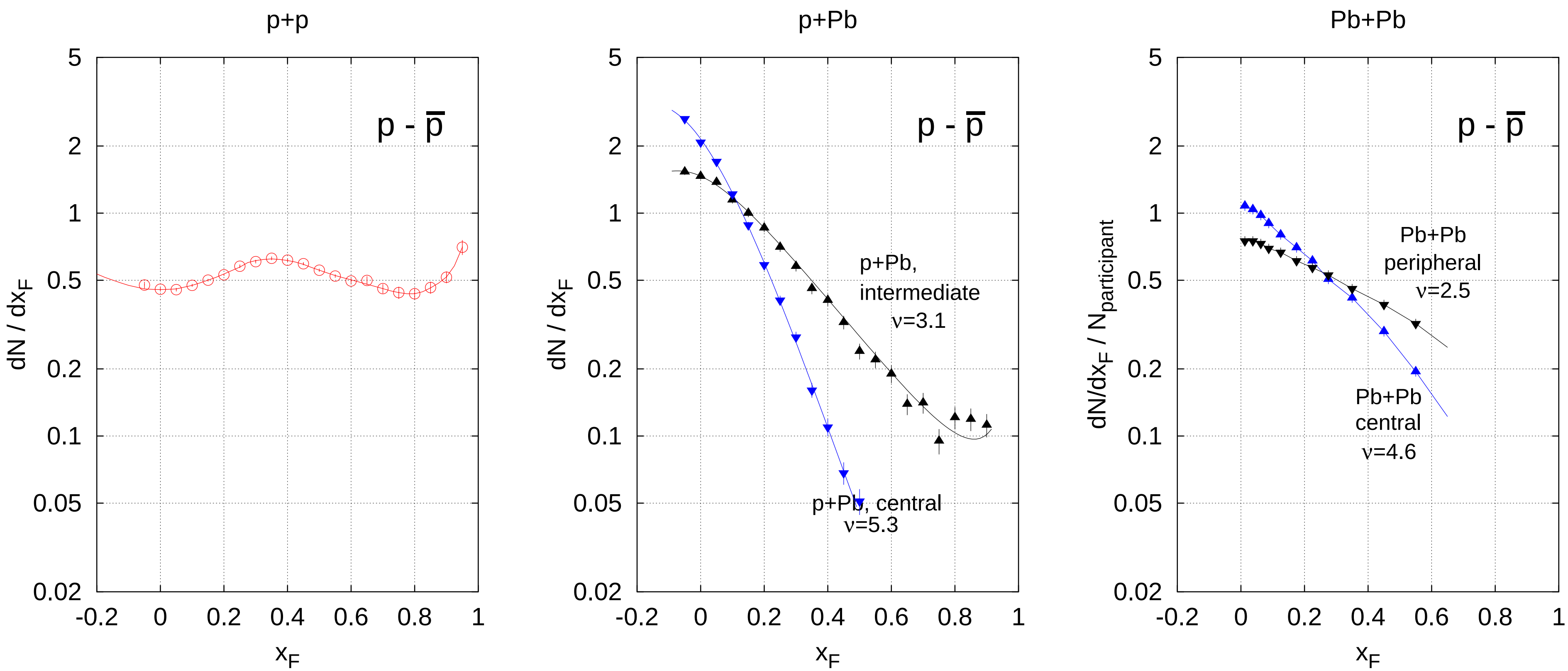
Baryons:

- How does the Baryon number (BN) of the initial state translate to the final state?
  $\Rightarrow$ BN conservation imposes constraints
- Evolution from p+p to p+A and A+A

Pions:

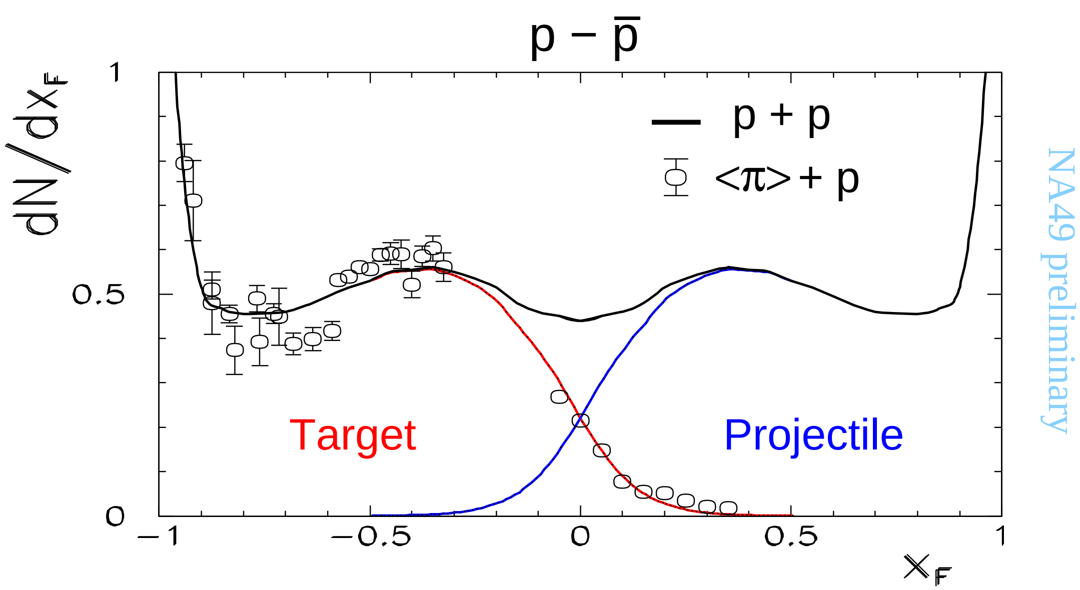
- Relation to baryons
- Where do they originate from
- Evolution from p+p to p+A and A+A

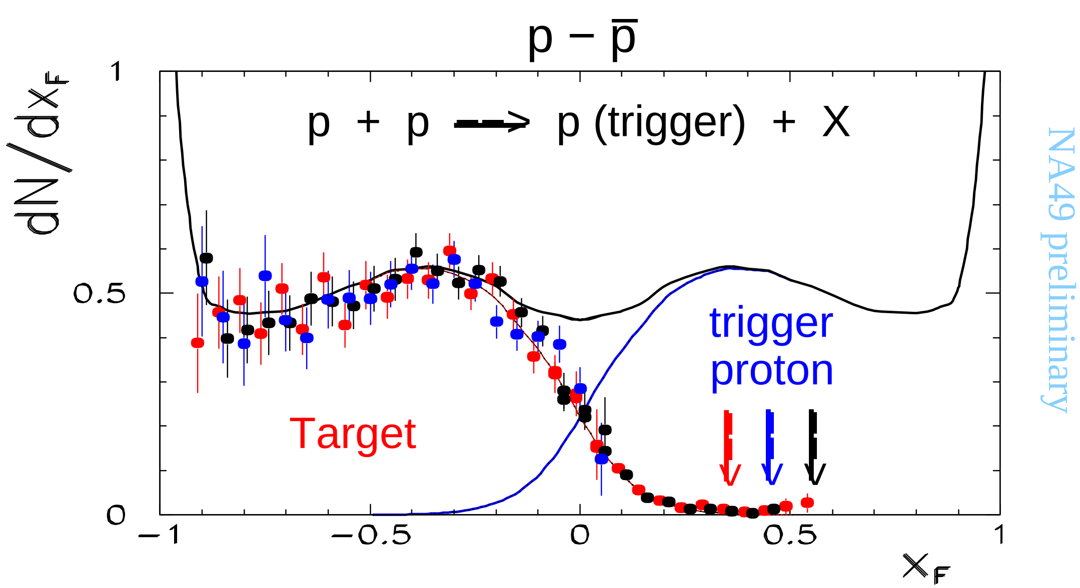
Baryons: stopping in nuclear reactions



$\longrightarrow$ experimental possibility: non-baryonic beam

Baryon density in h+h interactions



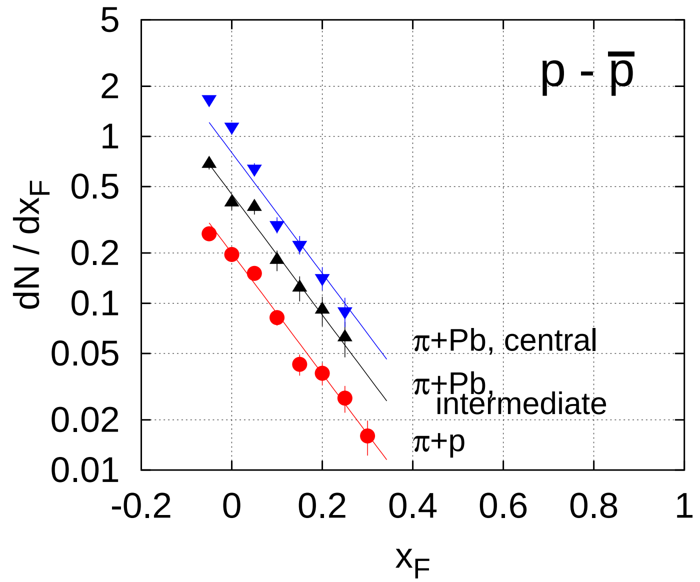


- Baryon number free projectile:
  pion beam

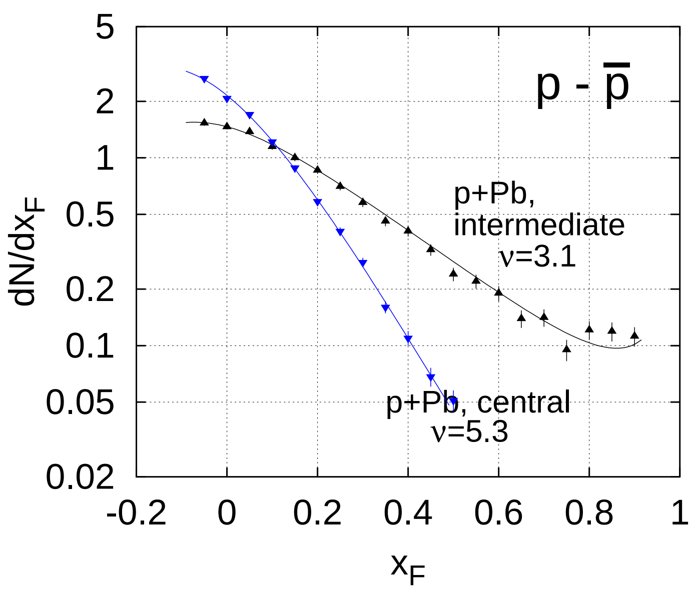
- Fixing baryon number in the forward hemisphere

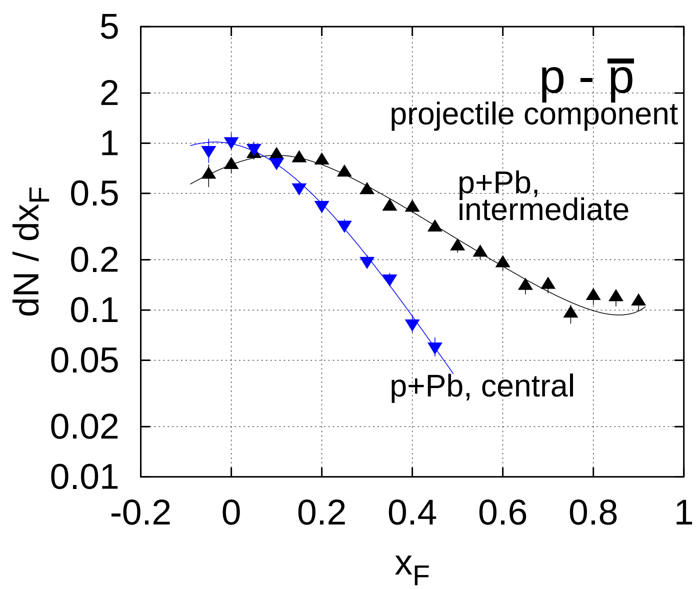
- Two component picture: target and projectile contribution

Components of baryon number transfer in h+A collisions



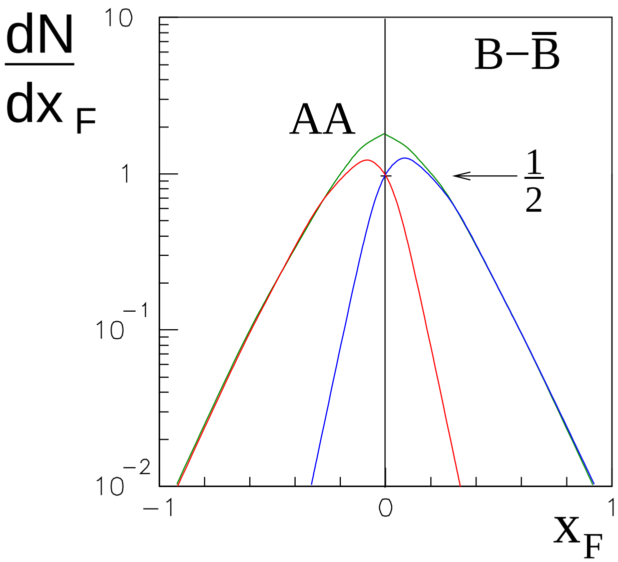
- π+A: measurement of target component: **pileup**

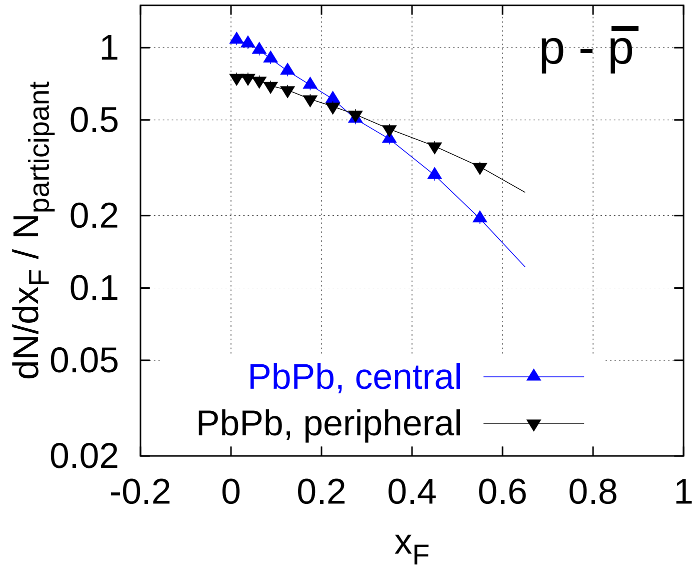




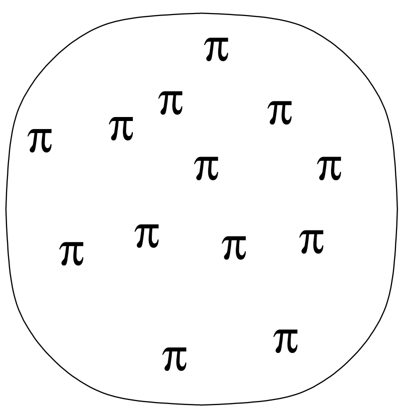
- p+A: modified projectile component

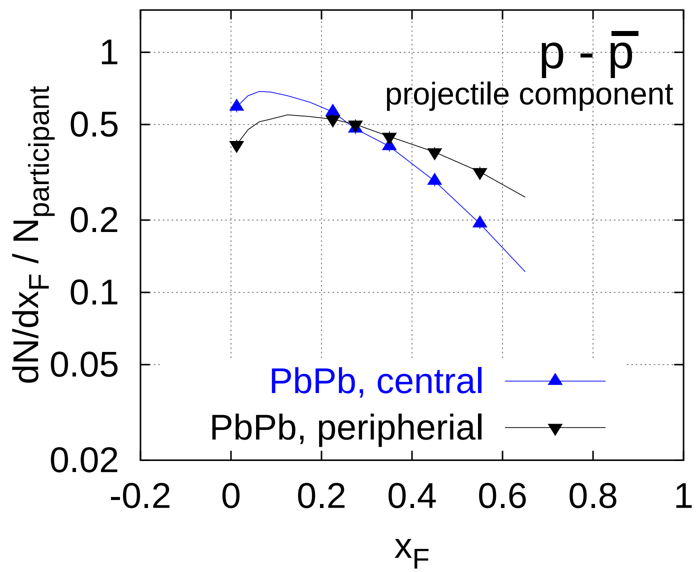
Components of baryon number transfer in A+A collisions



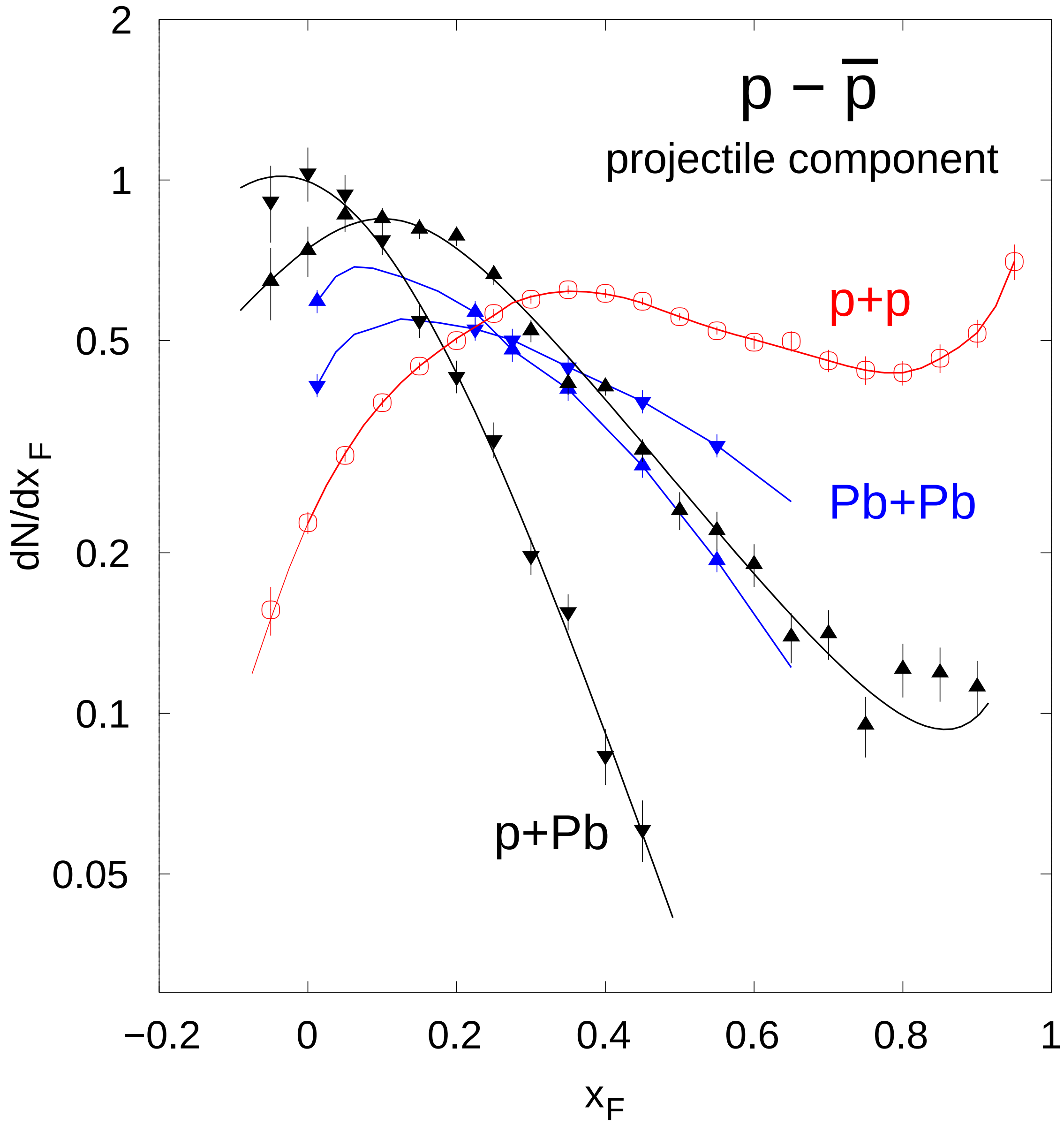


- A+A: modified target and projectile component.



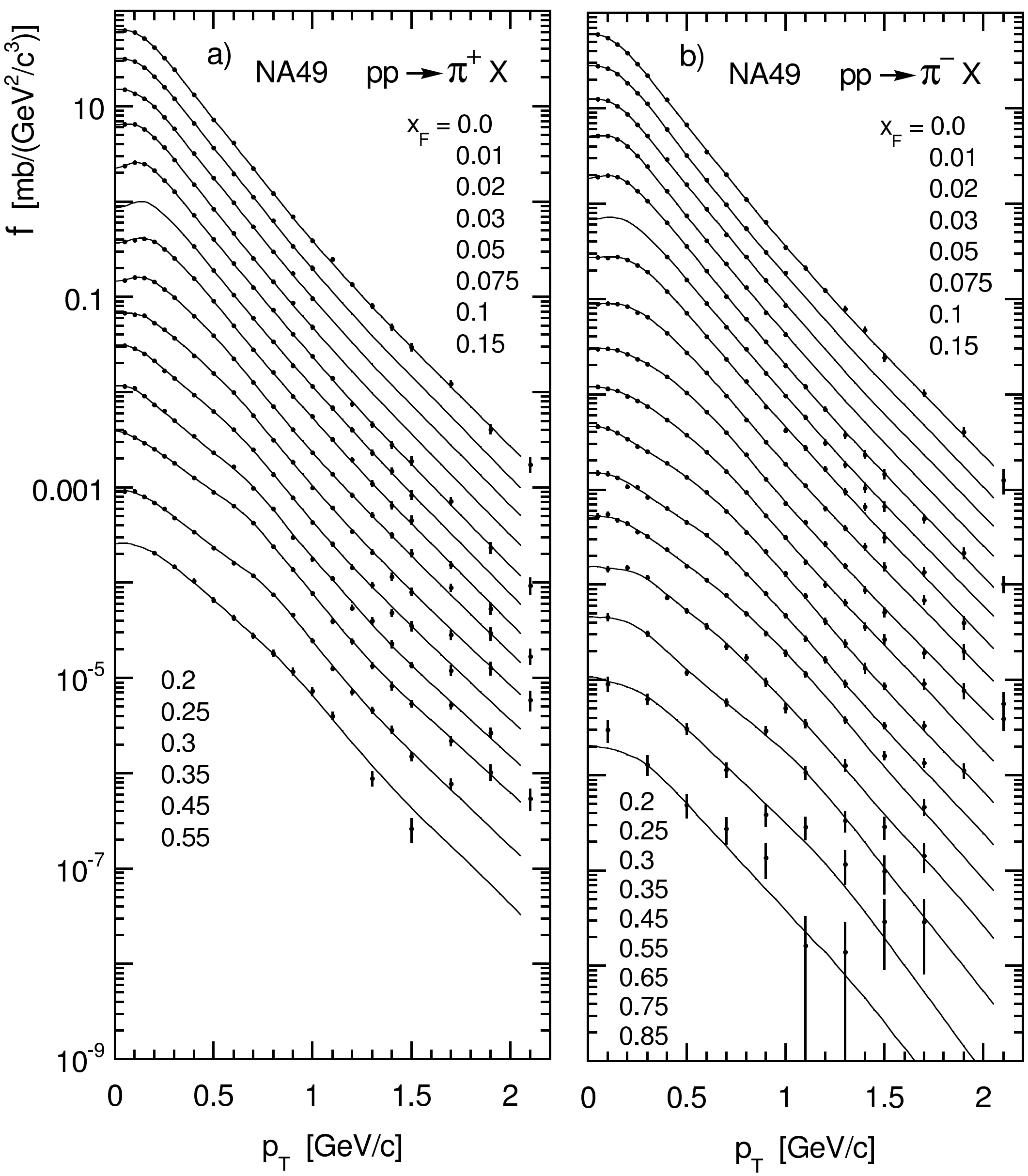


- Projectile component from symmetry argument (components are equal at $x_F = 0$)



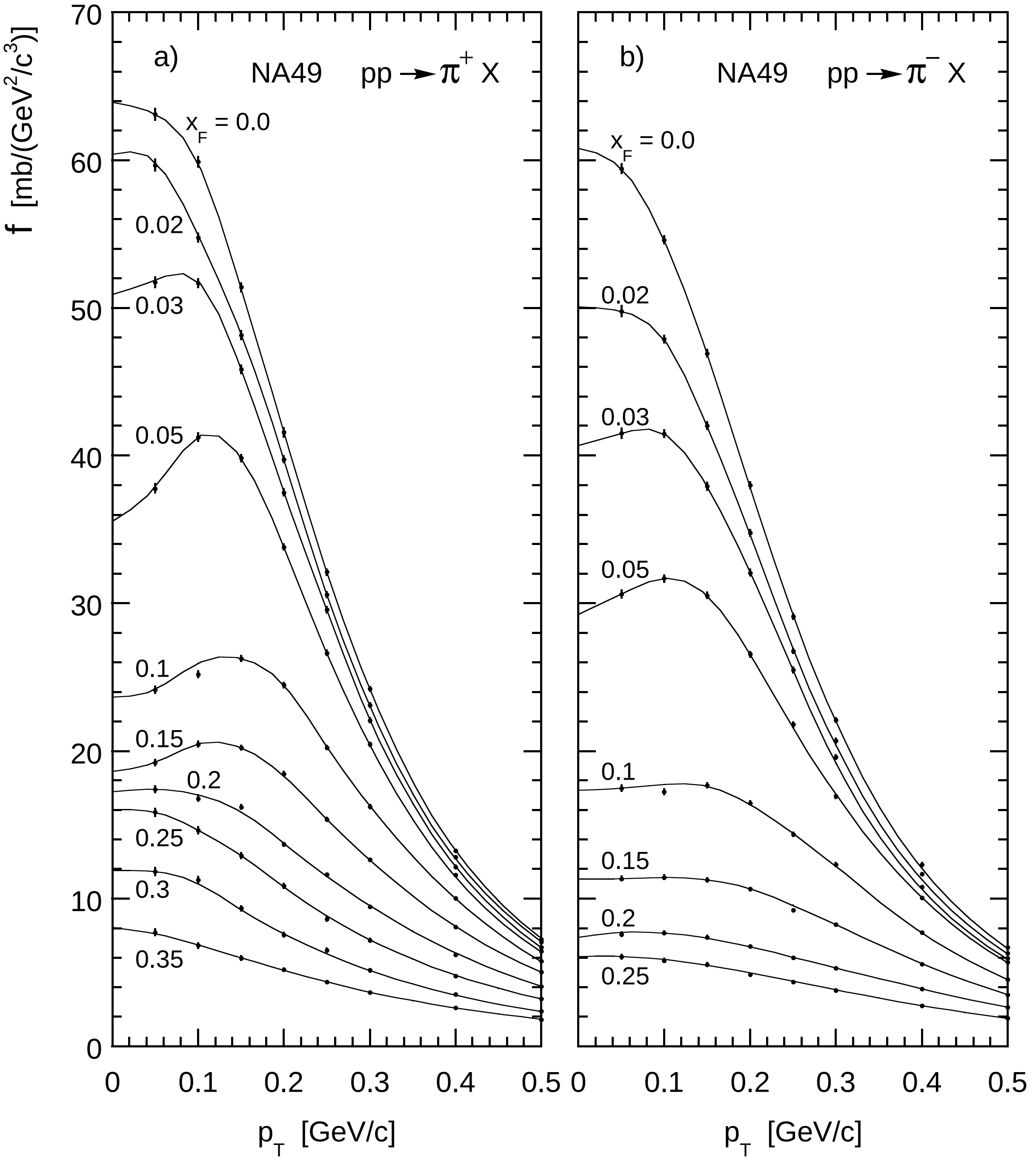
- Common, smooth evolution of baryon number transfer
- Question 2: How to relate pA to AA: $\Rightarrow$ extract projectile component

Pion production: p+p interactions at 158 GeV beam from NA49



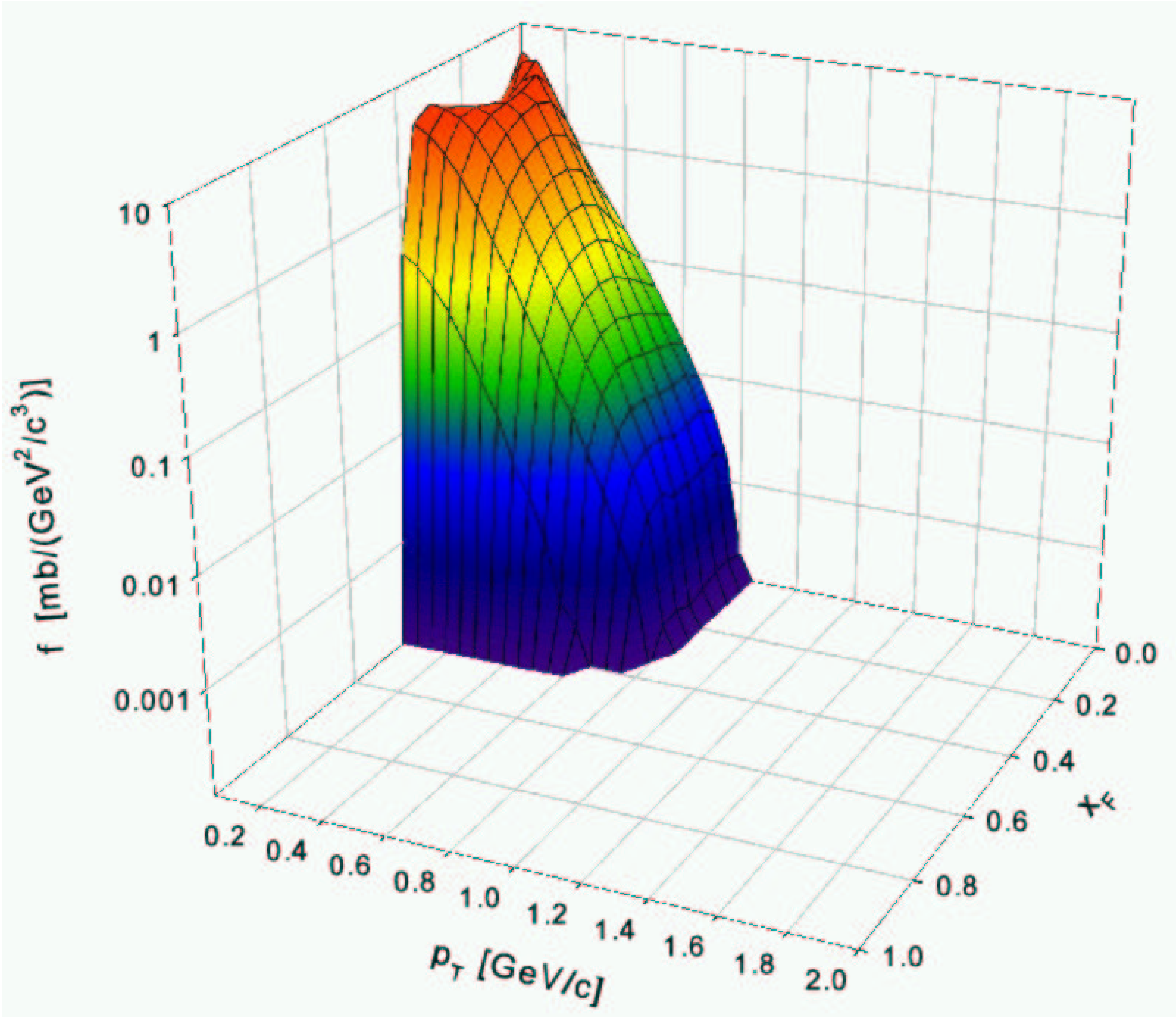
Question 4:
Where do these pions originate from?

Question 5:
Is there a "2-component" picture for pions?

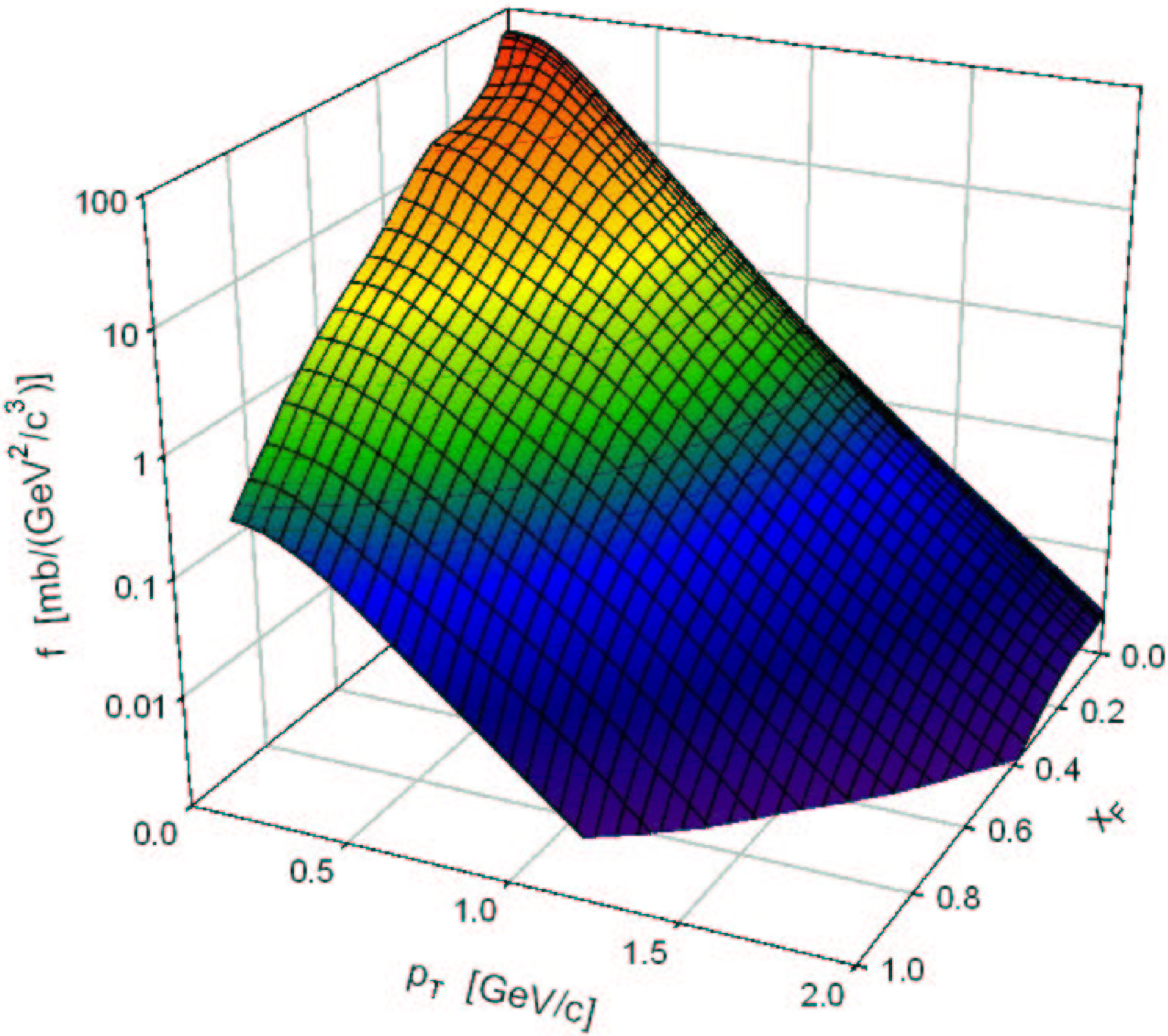


. . . surprising structures at low p_T?

Effect of low-q resonances on pion spectra: $\Delta^{++} \to \pi^{+}$



π^+ in p+p collisions from NA49



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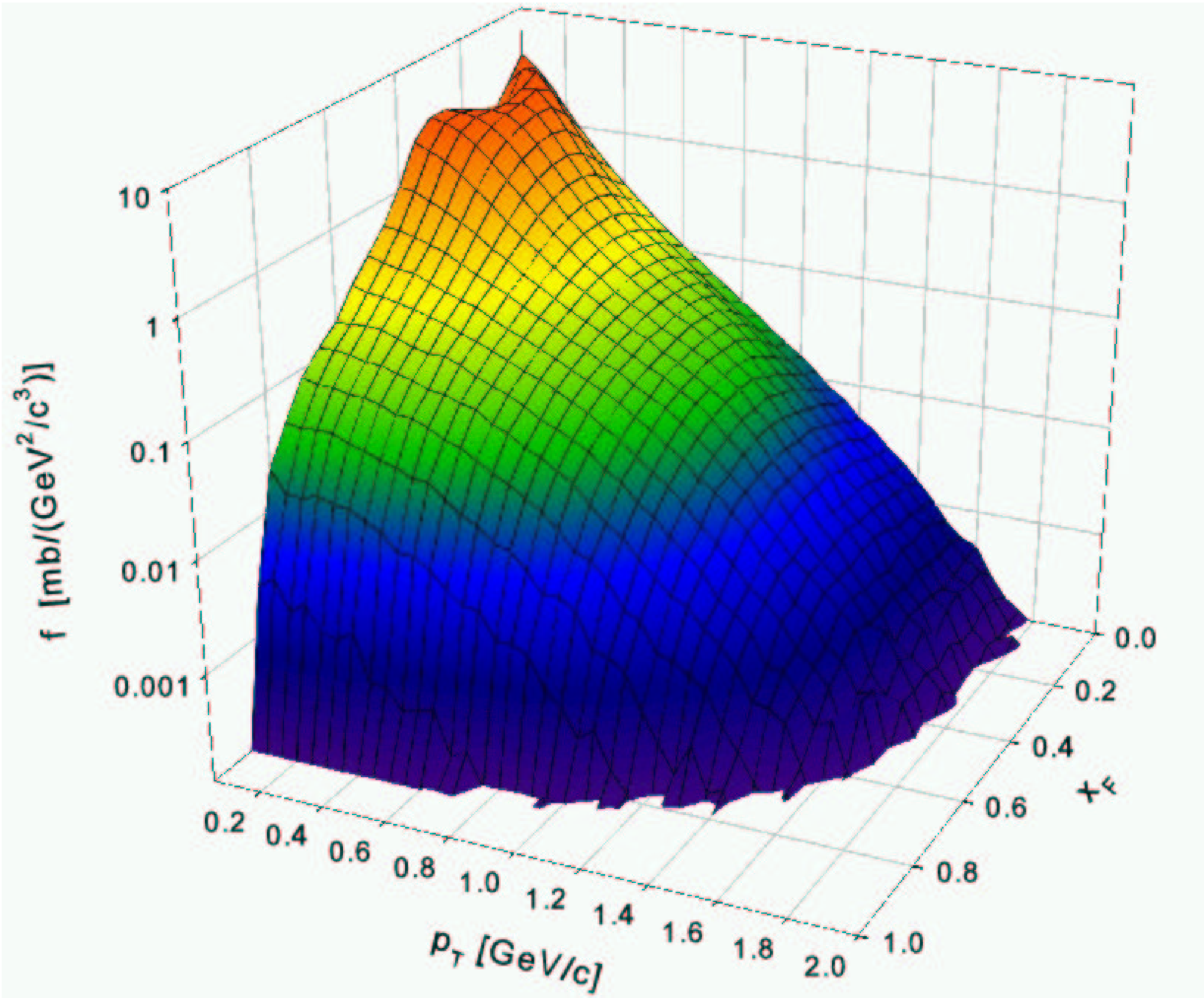
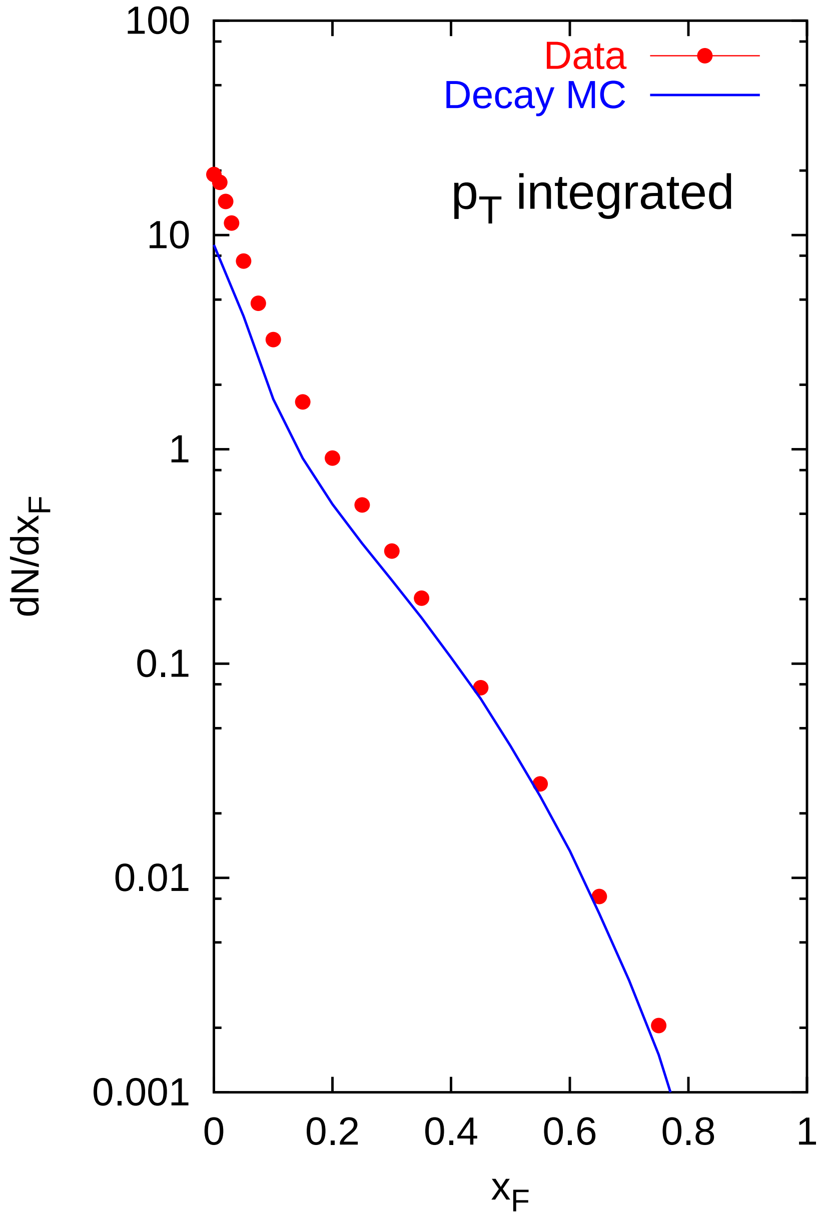
... Breit-Wigner shape of Δ^{++} resonance opened up



(Question 4. What is the source of pions in p+p?)

Resonance contribution to negative pions



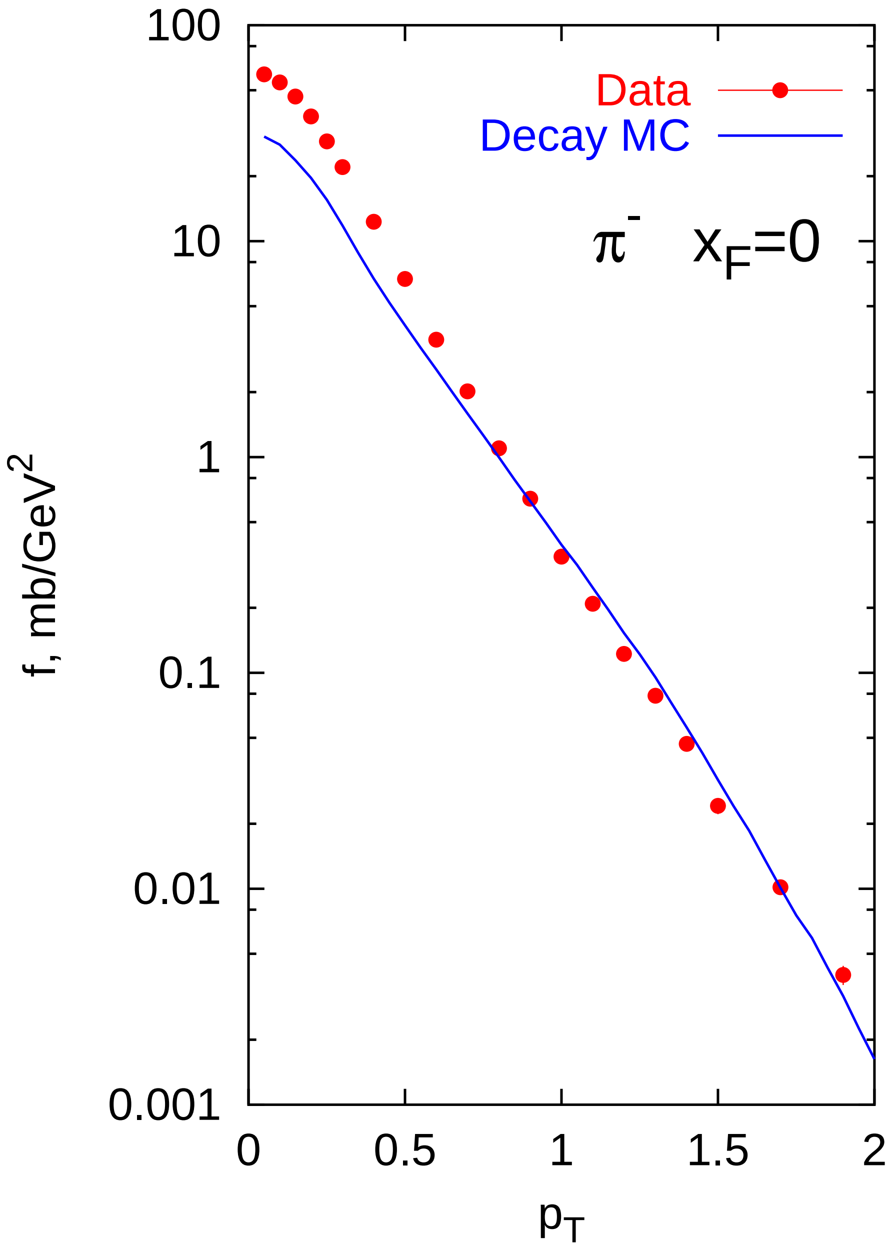
- Sum up measured resonances:

η^0	Δ^0
ω^0	Δ^-
ρ^0	$N^*(1440)$
ρ^-	$N^*(1520)$
f_2^0	$N^*(1680)$
ρ_3^0	
ρ_3^-	
f_4^0	

- Take only 2-π decays, to avoid double counting (3π for η and ω)

  $\Rightarrow$ Cascading not included, so lower limit is given

- Large (20-30%) systematic error to be considered

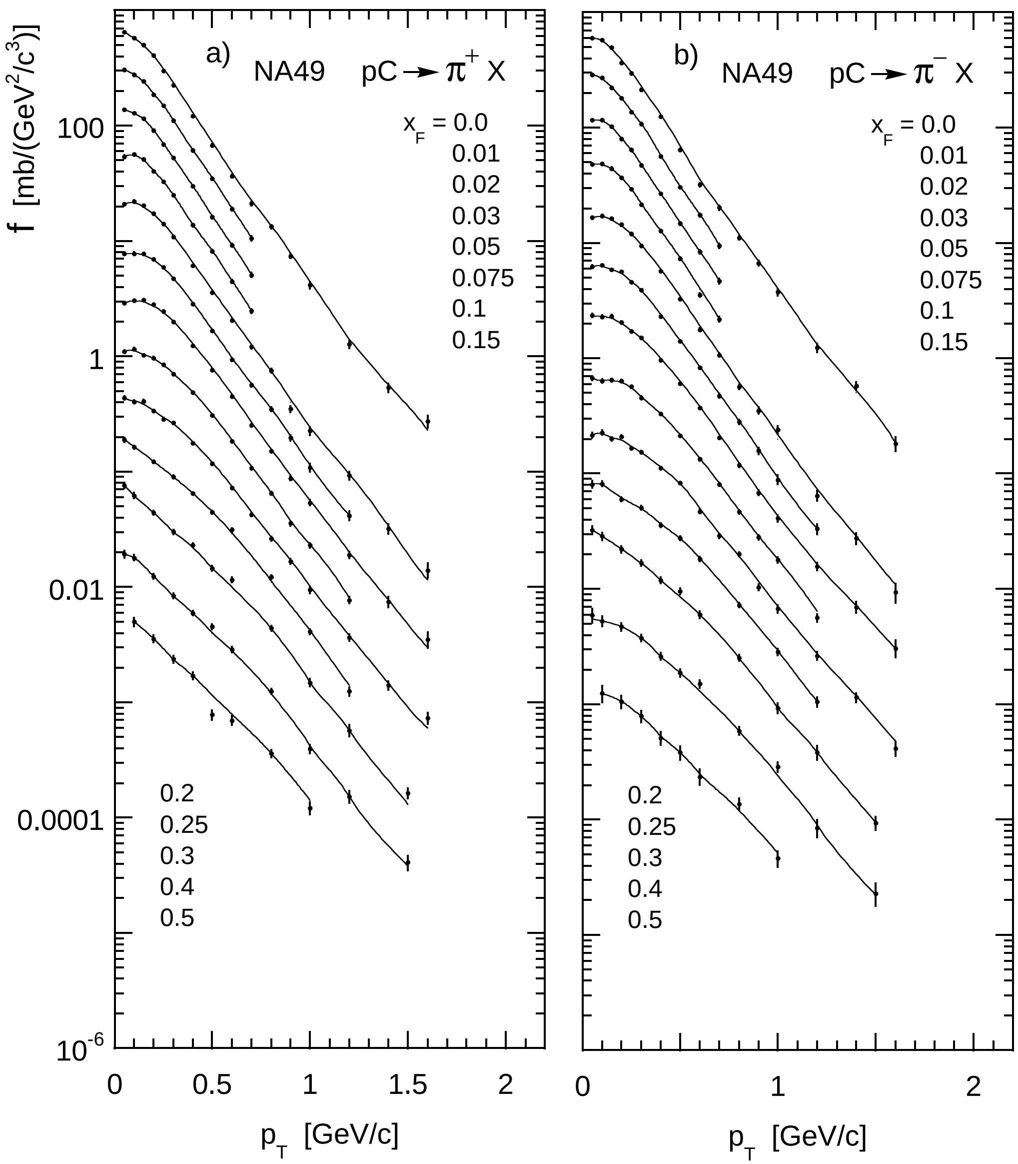


- Underestimated low-p_T yield: room for cascading (e.g. $N^* \to \Delta\pi$)
- Conclusion: no "direct" pion production even at high p_T and high x_F; main source is resonance decay!

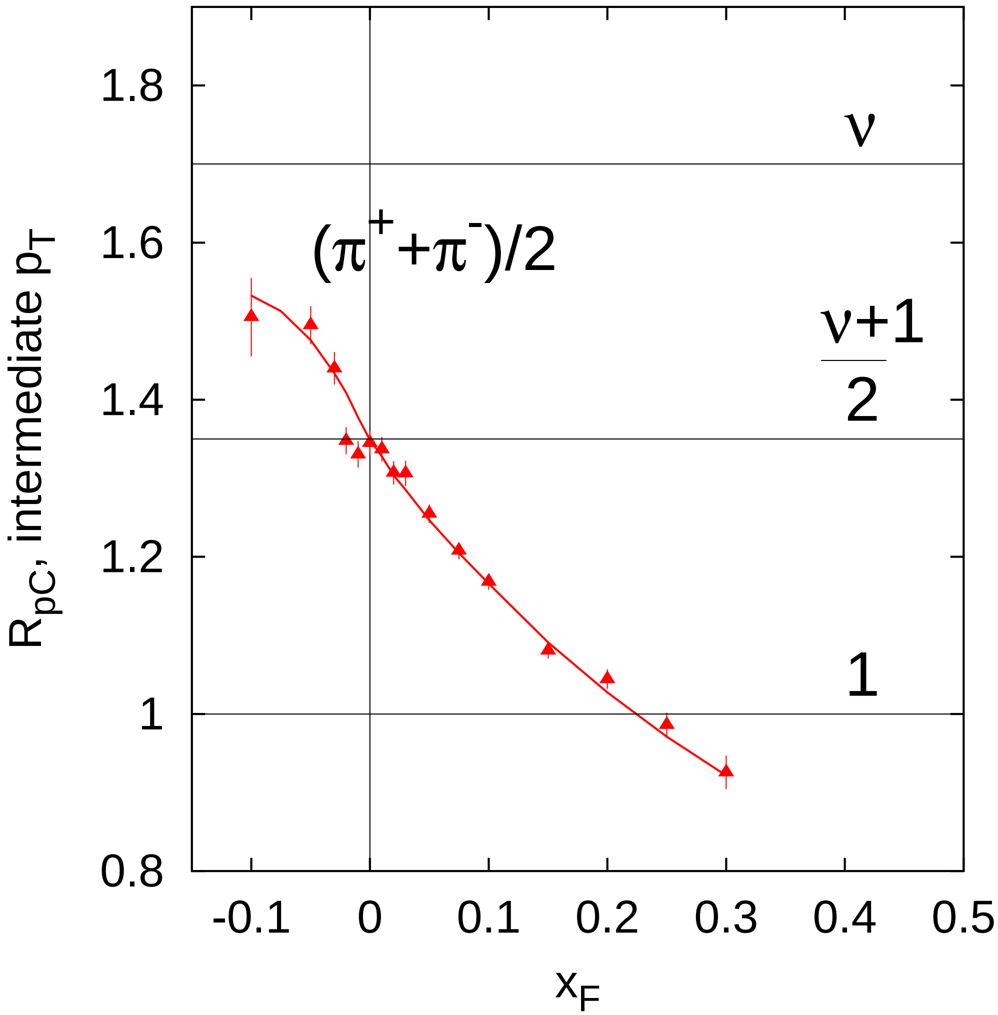
$\Rightarrow$ Where does hard scattering set in?

$\Rightarrow$ Large x: not just reflecting partonic structure!

Pion production in p+C interactions at 158 GeV beam



Question 5: Is there a two-component picture for pions?

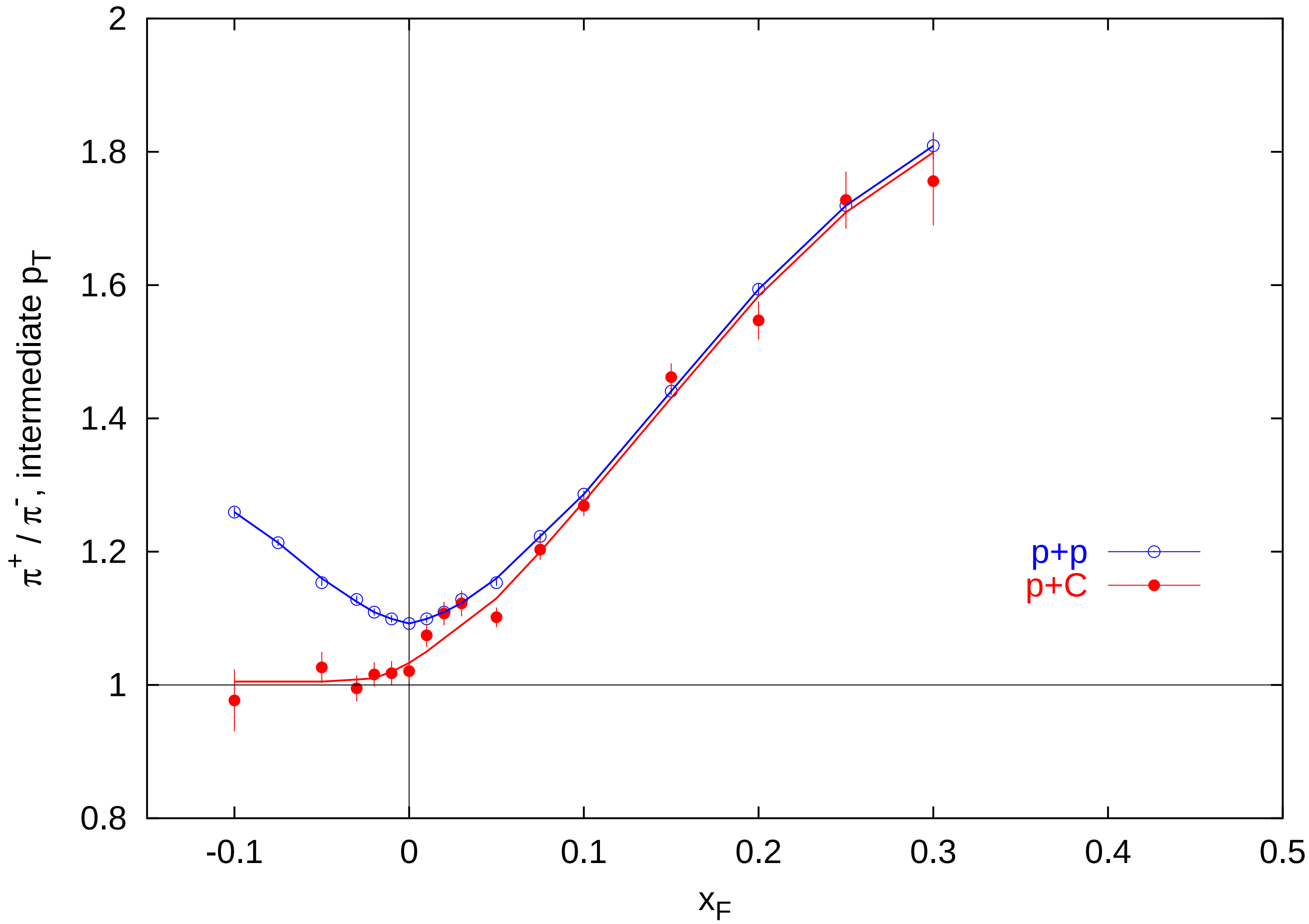


- Intermediate p_T region: 0.3 – 0.6 GeV

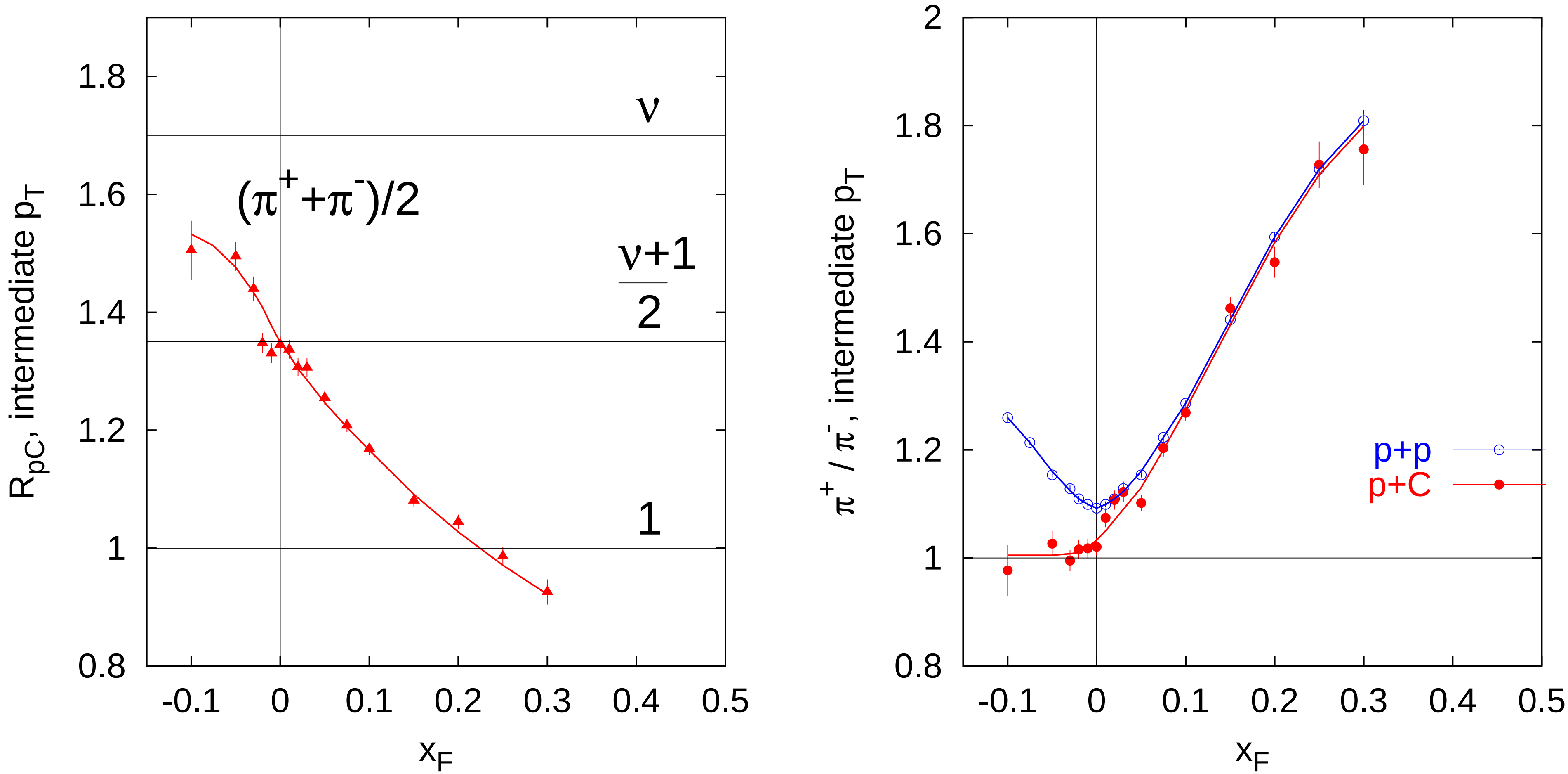
- $R_{pC} = \frac{(dN/dx_F)_{p+C}}{(dN/dx_F)_{p+p}}$

Take advantage of isospin effect:

π^+/π^- ratio in p+p and p+C

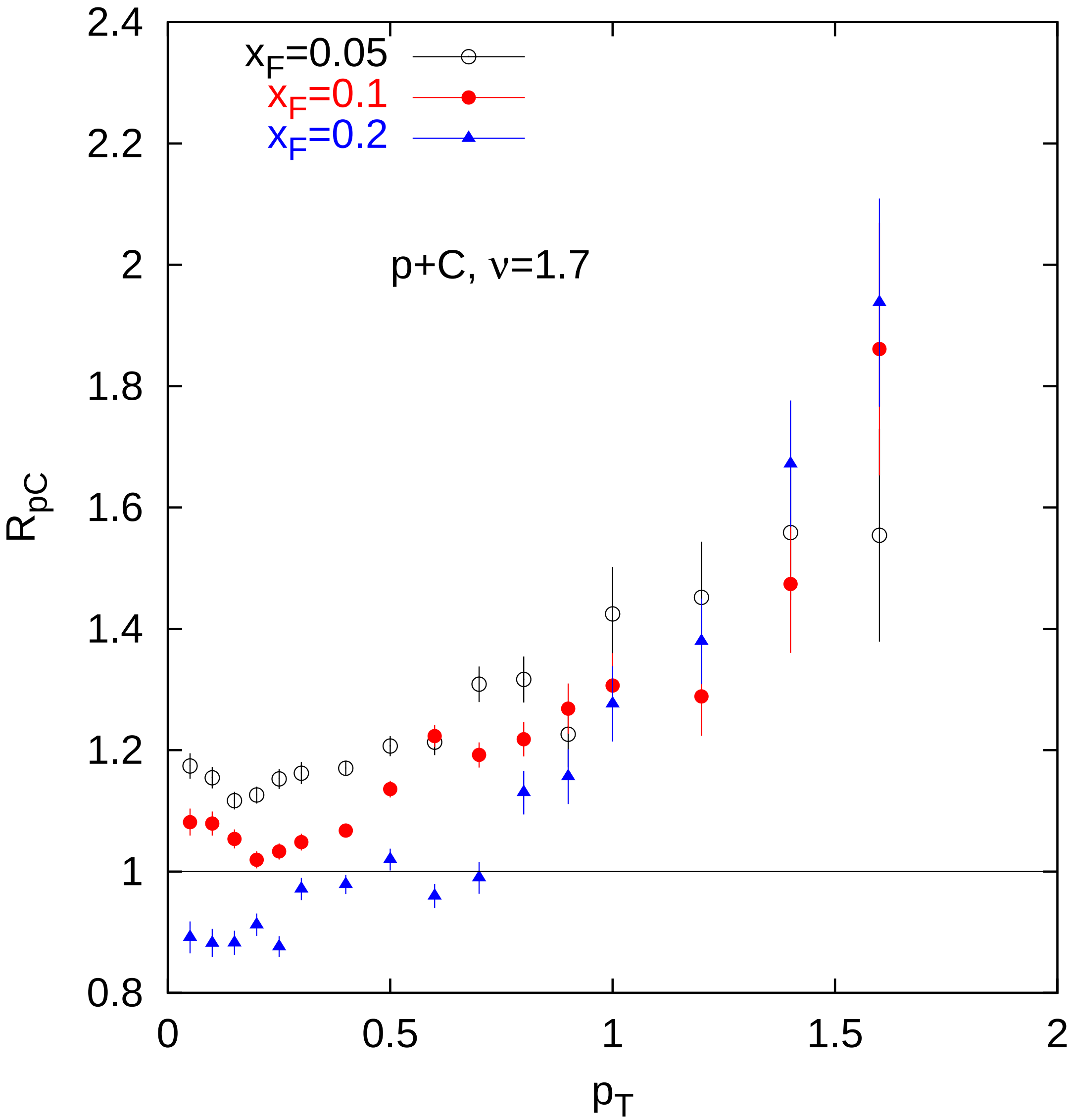


• backwards: close to 1 in p+C, following from isospin



- Target component does not reach far: at $x_F = 0.1$, it's fully projectile dominated

Transverse direction: increase with p_T

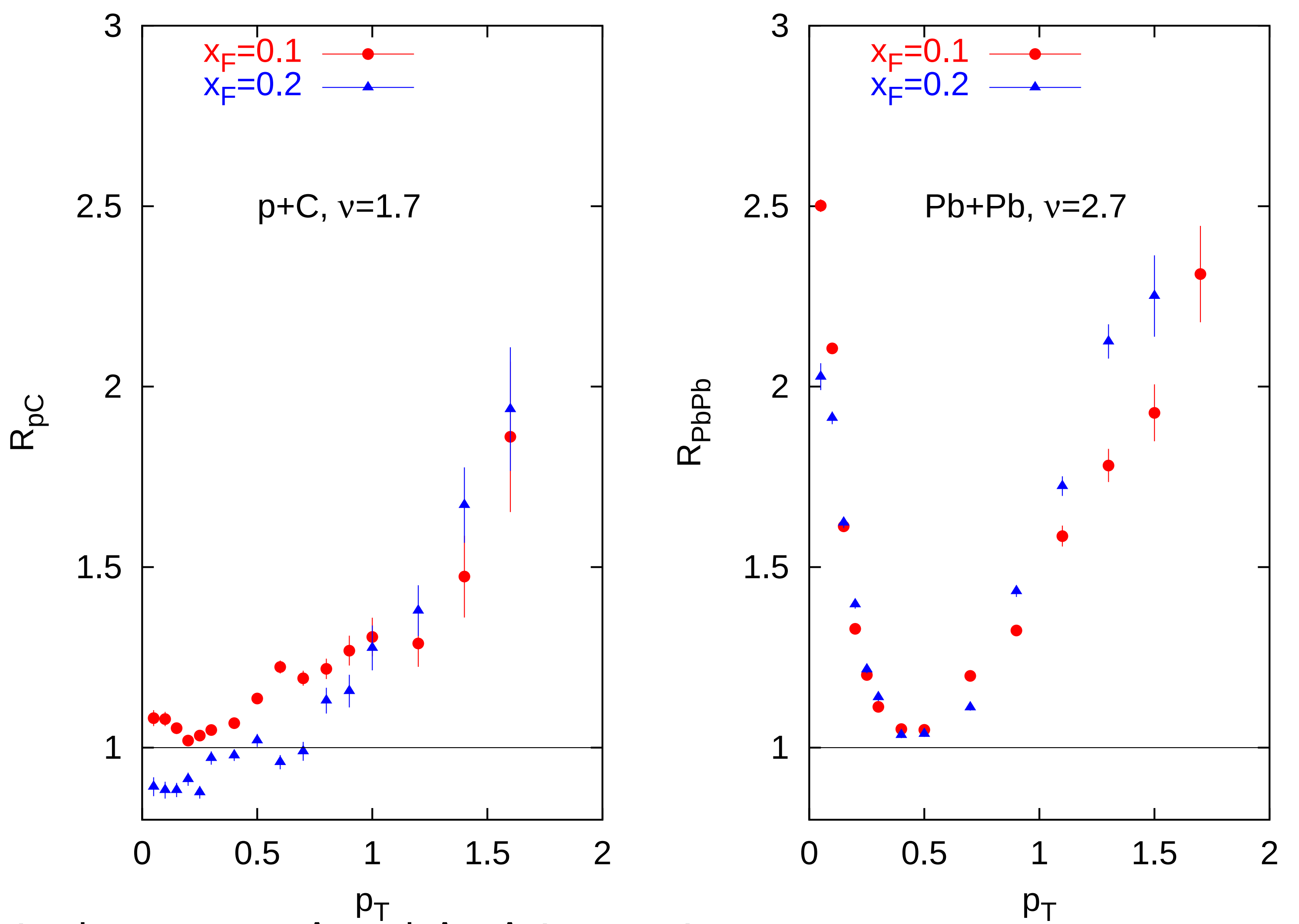


Conclusion:
pion production in p+A can be understood as

- modifield projectile component
- target component, as in p+p piled up ν times

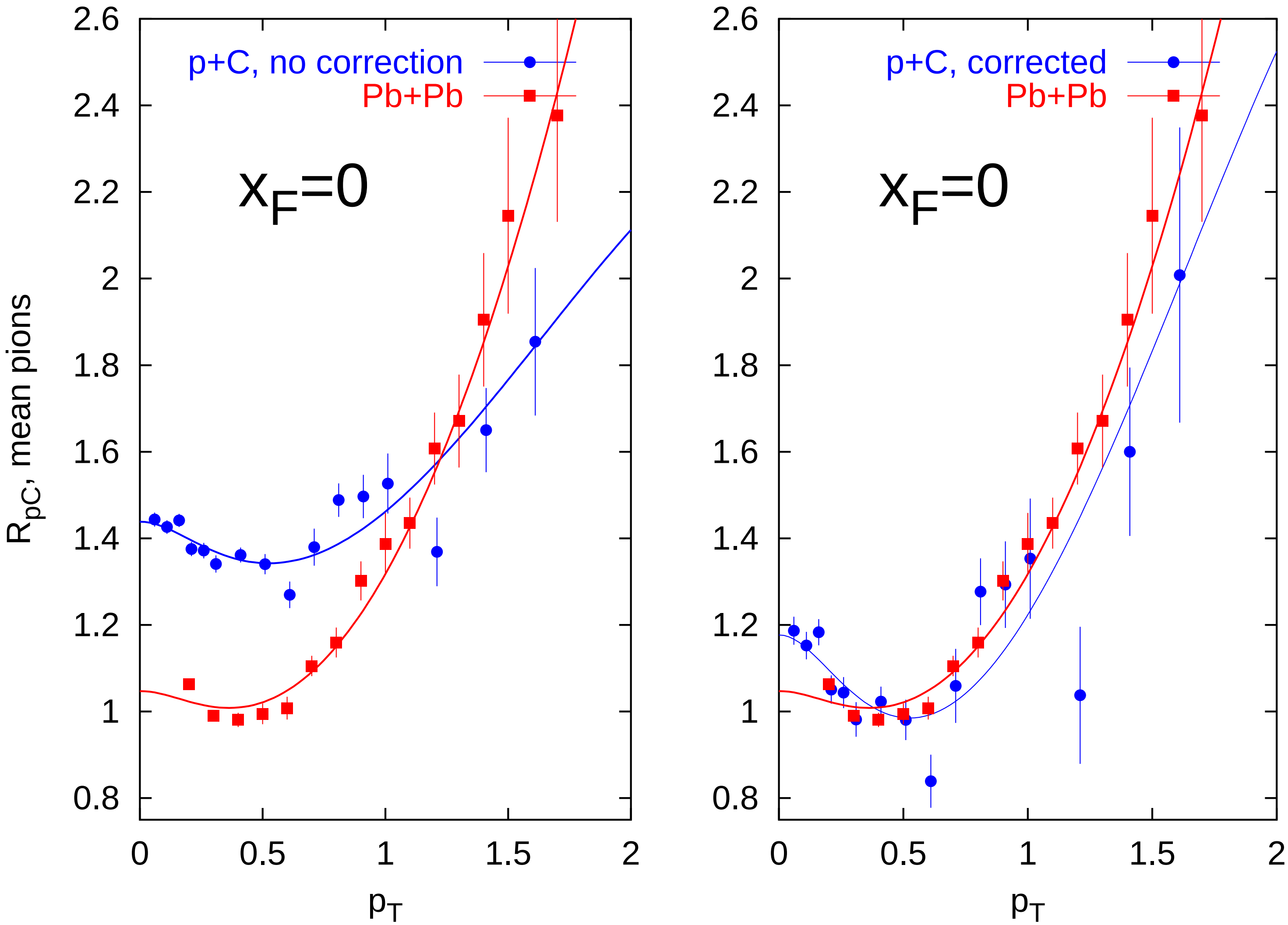
Question 2. How to compare p+p and p+A to A+A?

- projectile component: direct comparison



→ similarity between p+A and A+A interactions

- $x_F = 0$ (midrapidity): target + projectile overlap

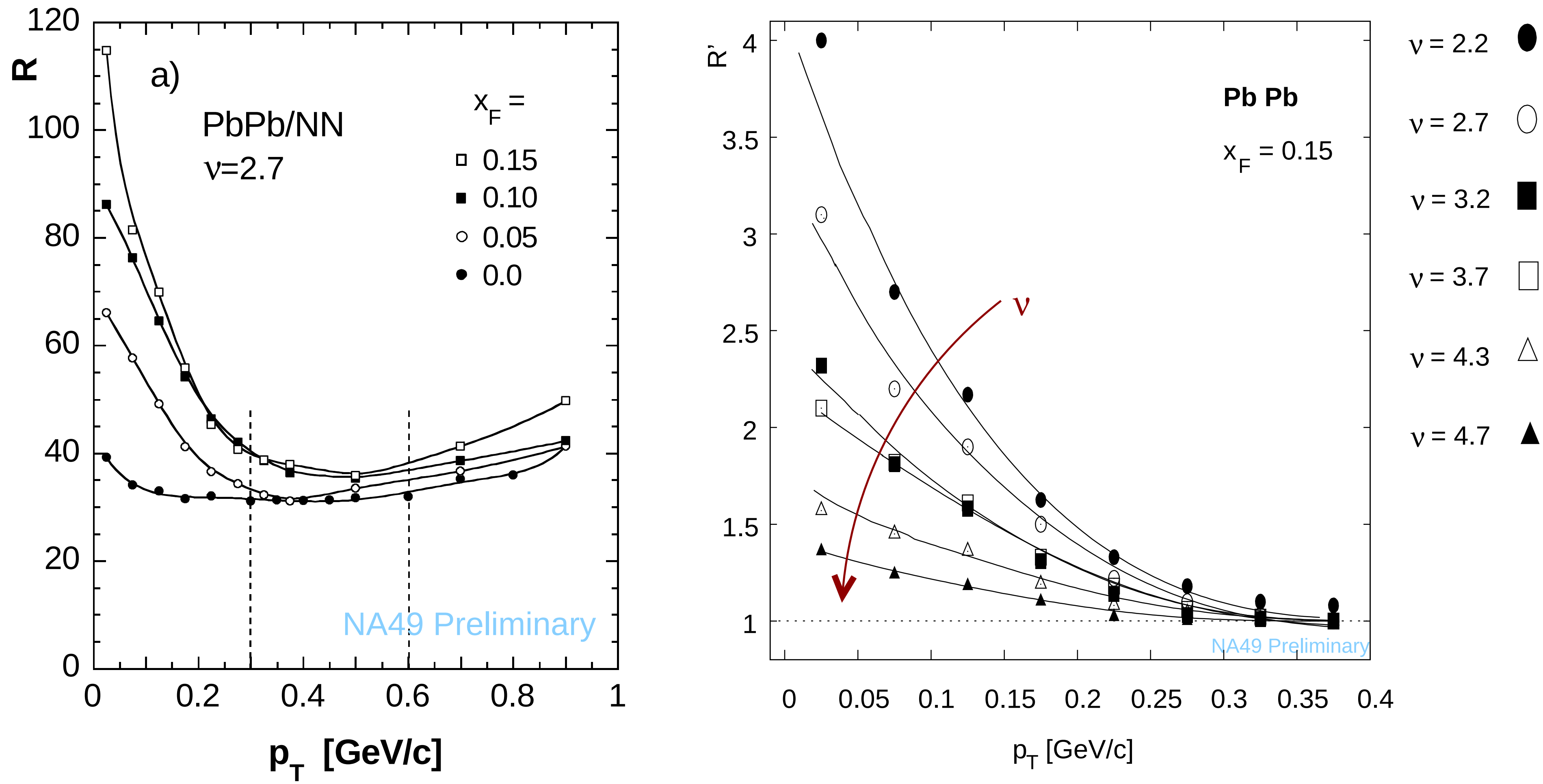


At $x_F = 0$ (by symmetry of p+p):

$$R_{corr} = 2R - \nu$$

Question 7. Where are the evident final state effects?

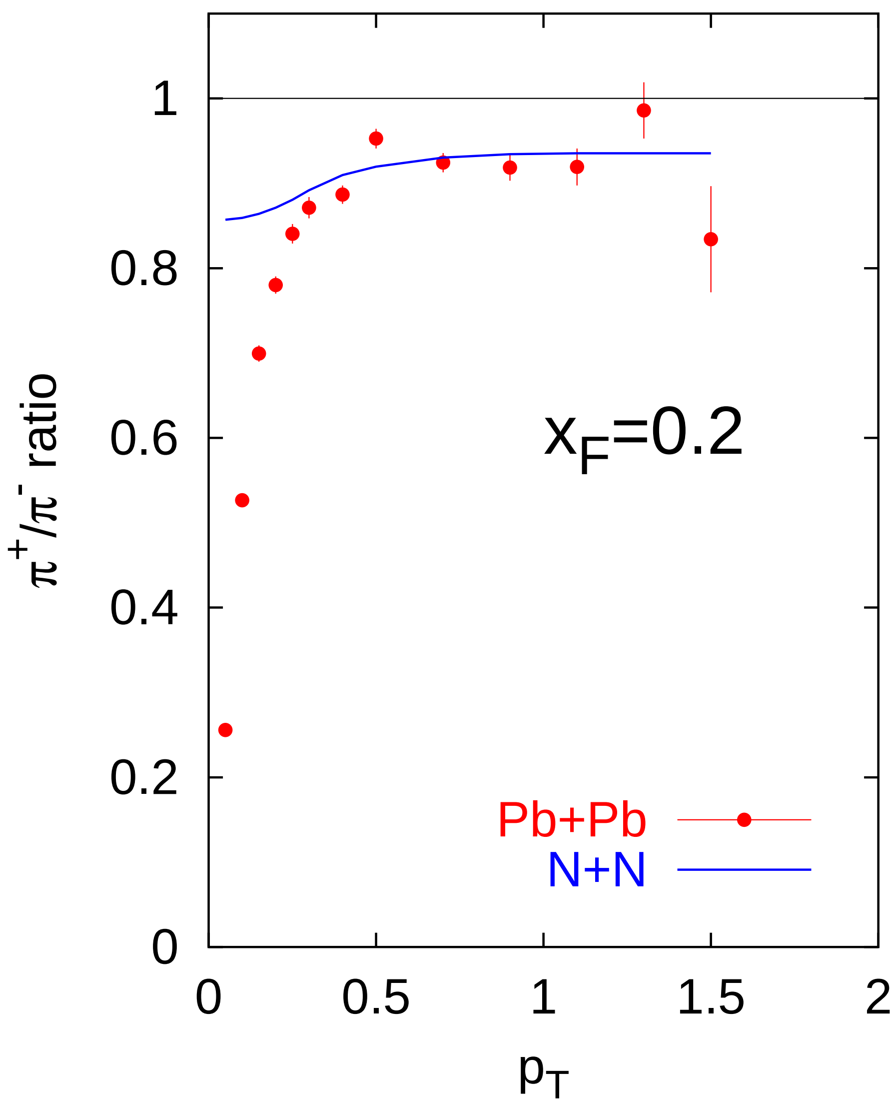
- Low-p_T enhancement

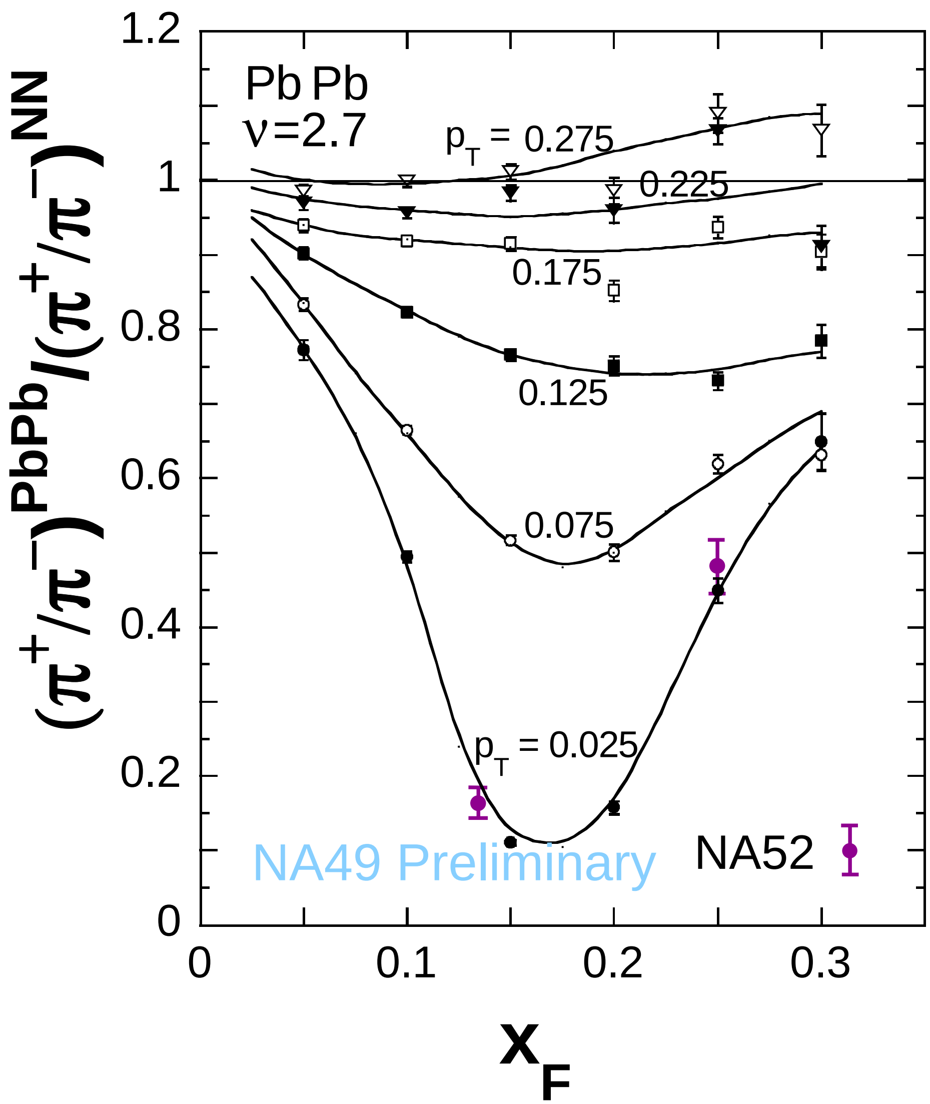


$x_F = 0.15 = m_\pi / m_{proton}$; $\beta_{pion} = \beta_{spectator}$

Enhancement vanishes at higher centrality: spectator system (spectator excitation)

- Coulomb effect in π^+/π^- ratio





Conclusions

Both for baryons and pions:

- 2 component picture, target and projectile
- Multiple collision effect: modified projectile component (stopping, high p_T increase)

How to relate p+p and p+A to A+A?

- Extract projectile component, multiple collision effects determined by p+A
- $x_F = 0$: Normalisation problem due to the overlap of target and projectile

Comparison of p+p and p+A to A+A:

- Baryon stopping: present in p+A, multiple collision effect
- Increase of pion yield at higher p_T: already present in p+A
- Example of real collective (final state) effect: Coulomb and spectator excitation