Status and plans of NA49 pp/pA programme

- Study wide range of hadronic interactions
  - pp, np, πp
  - pC
  - pPb at controlled centrality
  - PbPb at controlled centrality
- Aim: extract purely experimental (model independent) information about soft hadronic sector of QCD

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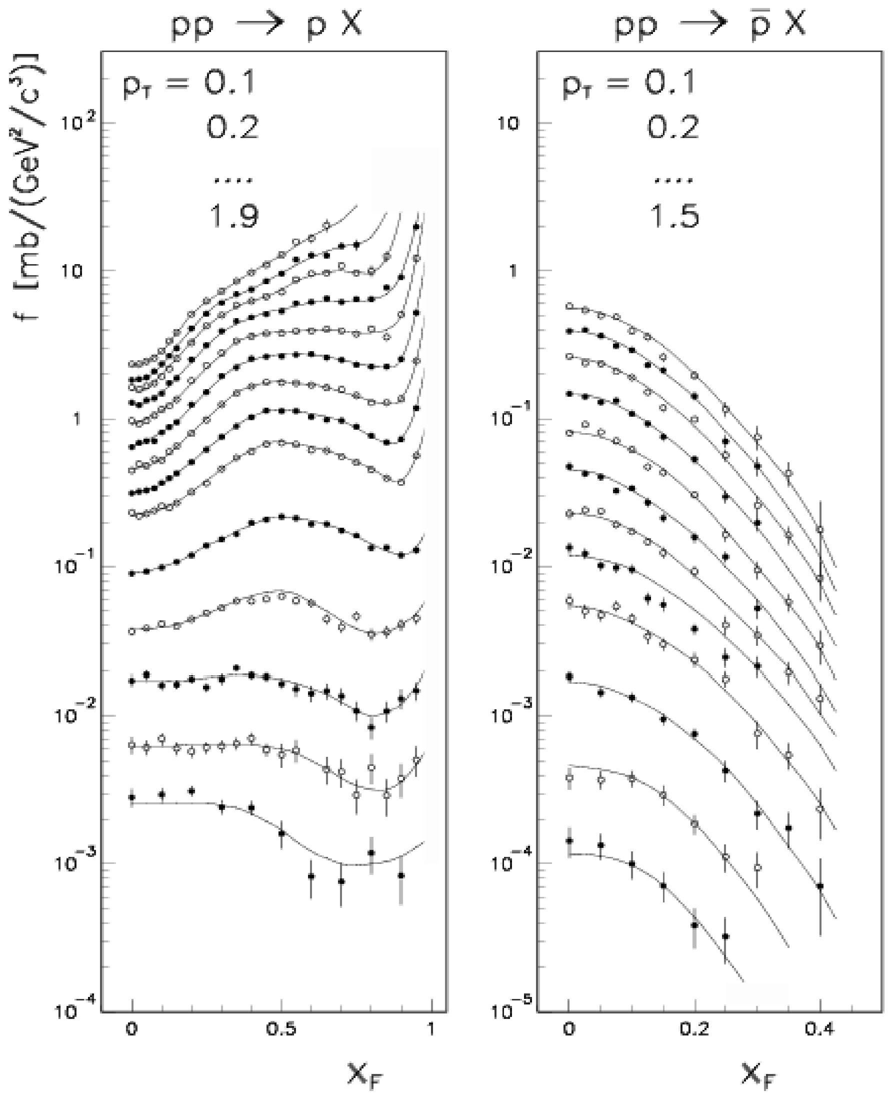
Status of final data analysis

- Published very detailed papers on
  - $\pi^{+/-}$ in pp collisions, *EPJC 45 (06) 343*
  - $\pi^{+/-}$ in pC collisions, *EPJC 49 (07) 897*
  - Discussion of pC results, *idem p. 919*
- Pursue exploitation of data sets in elementary pp collisions
  - Final data on p, $\bar{p}$
- Study pC collisions
  - Final data of K, p in preparation
- Study pPb collisions
- Study PbPb collisions



Pions in pPb (1)

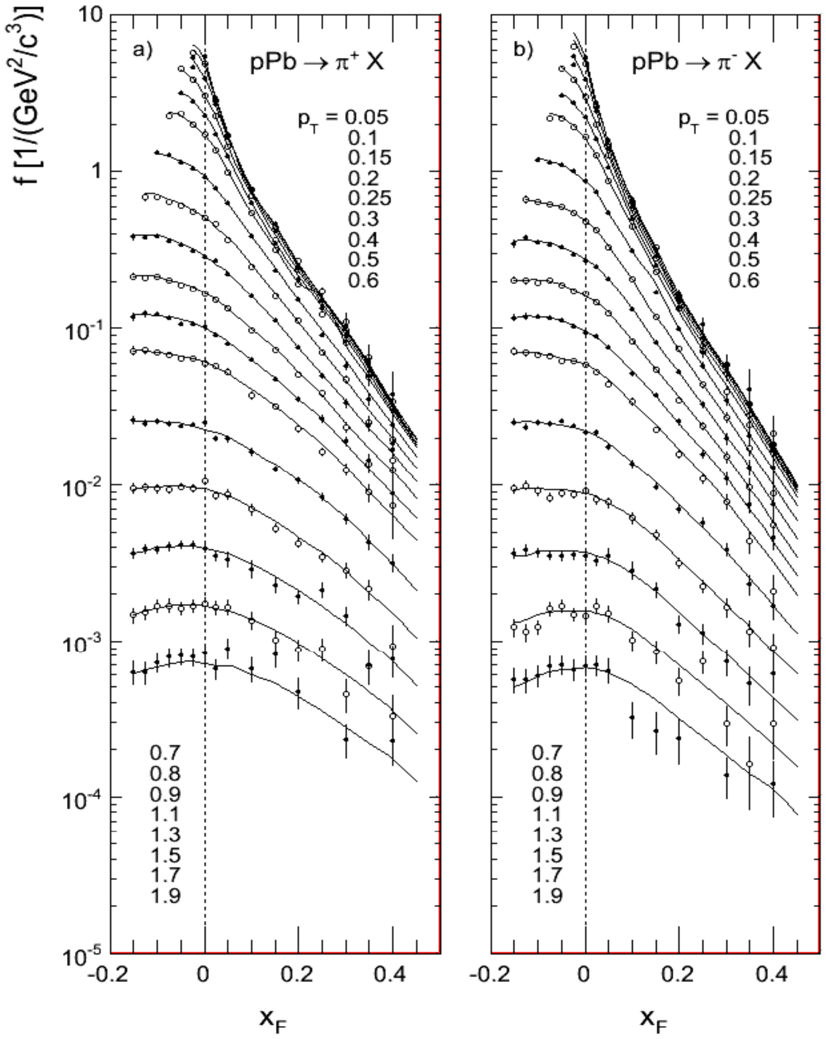
- Data sample divided into 5 centrality bins using number of collisions ν, deduced from grey proton measurement

  ν = 2.9, 4.2, 5.2, 6.1, 6.9

- Bins chosen to achieve quality equivalent to pp data

- Extended x_F-range down to -0.2
  - Allows to exploit asymmetric situation
  - Represents an asset rather than a drawback of pA collisions

ν = 4.2



Pions in pPb (2)

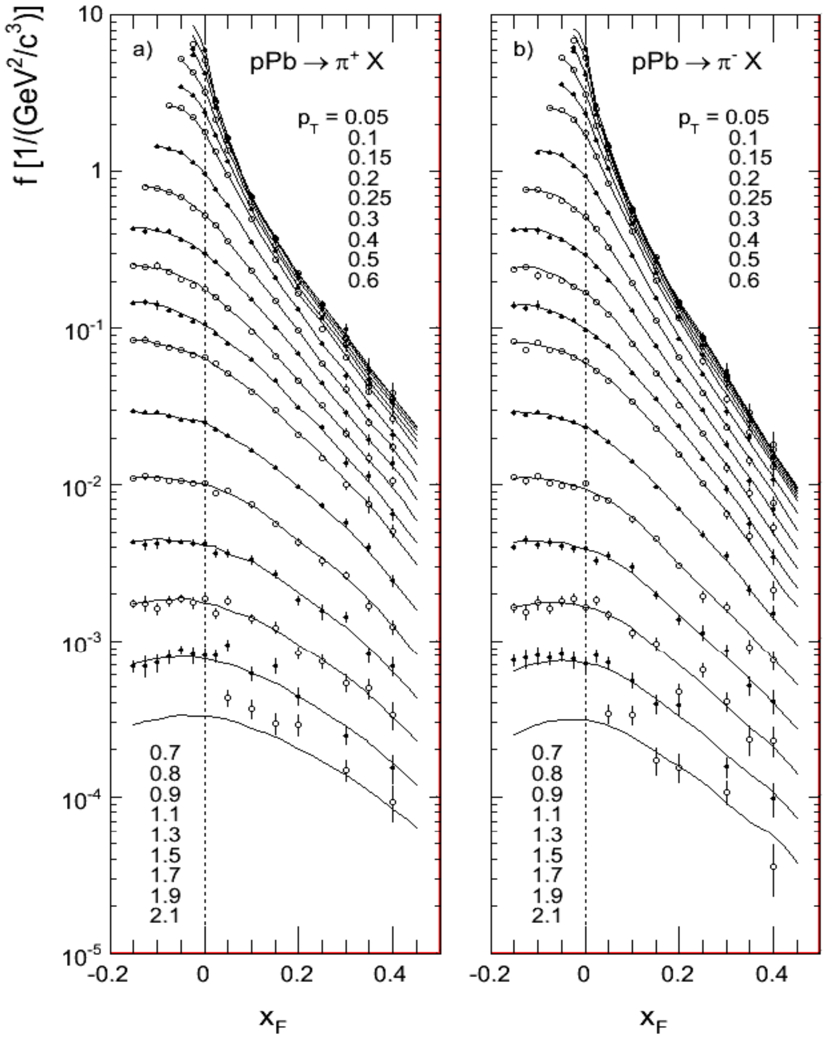
- Data sample divided into 5 centrality bins using number of collisions ν, deduced from grey proton measurement

  ν = 2.9, 4.2, 5.2, 6.1, 6.9

- Bins chosen to achieve quality equivalent to pp data

- Extended x_F-range down to -0.2
  - Allows to exploit asymmetric situation
  - Represents an asset not a drawback of pA collisions

ν = 5.2



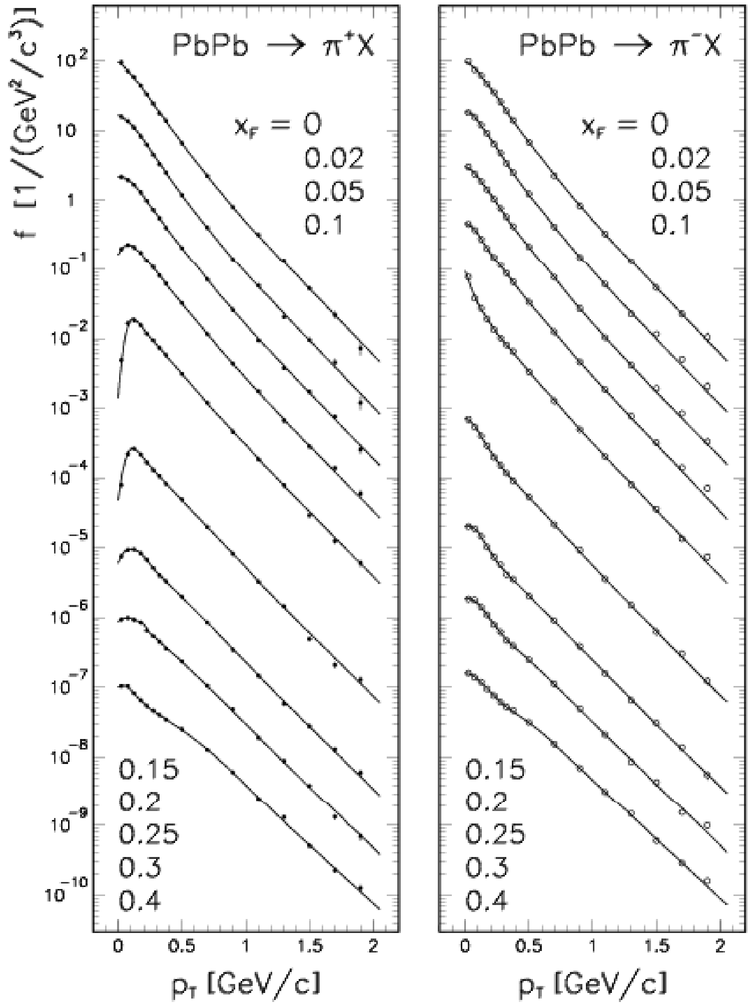
Pions in PbPb (1)

- Special run with
  - Min. bias trigger
  - Low beam intensity to minimize accidental δ (spirals)

- Data sample divided into 7 centrality bins using track multiplicity

- Final data shown in peripheral bin $150<n_{ch}<300$

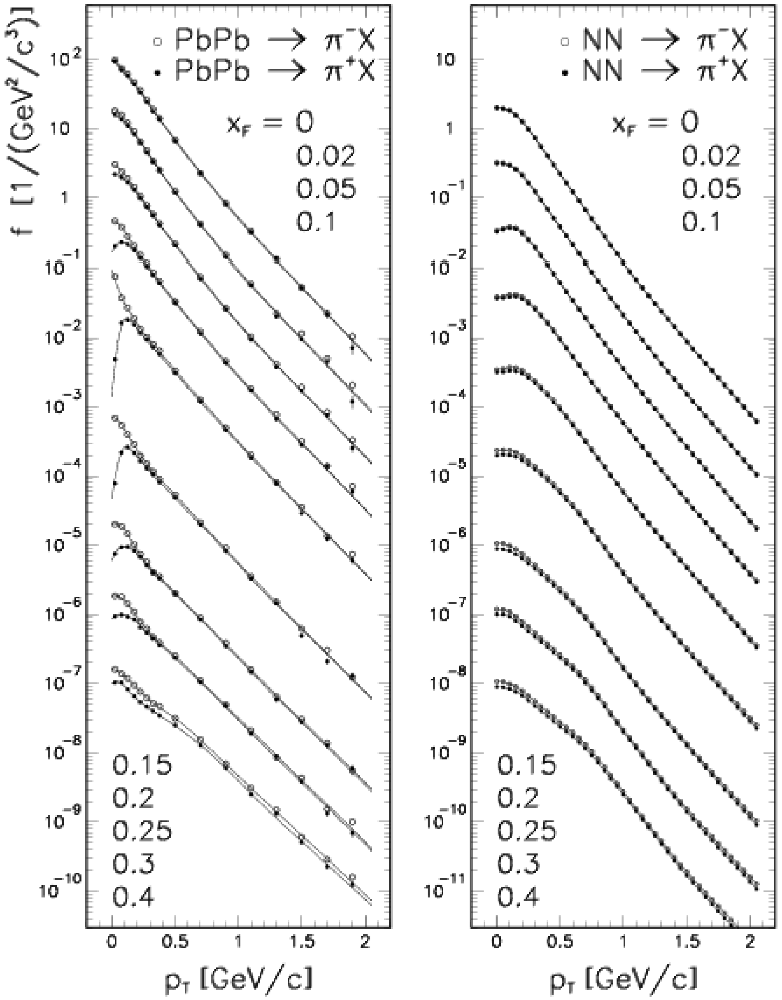
$150<n_{ch}<300$



Pions in PbPb (2)

- Split between π^+ and π^- at low p_T
- Not seen in elementary NN collisions

➔ <u>Coulomb effect</u>

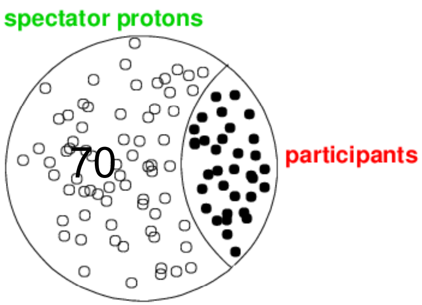


Pions in PbPb (3)

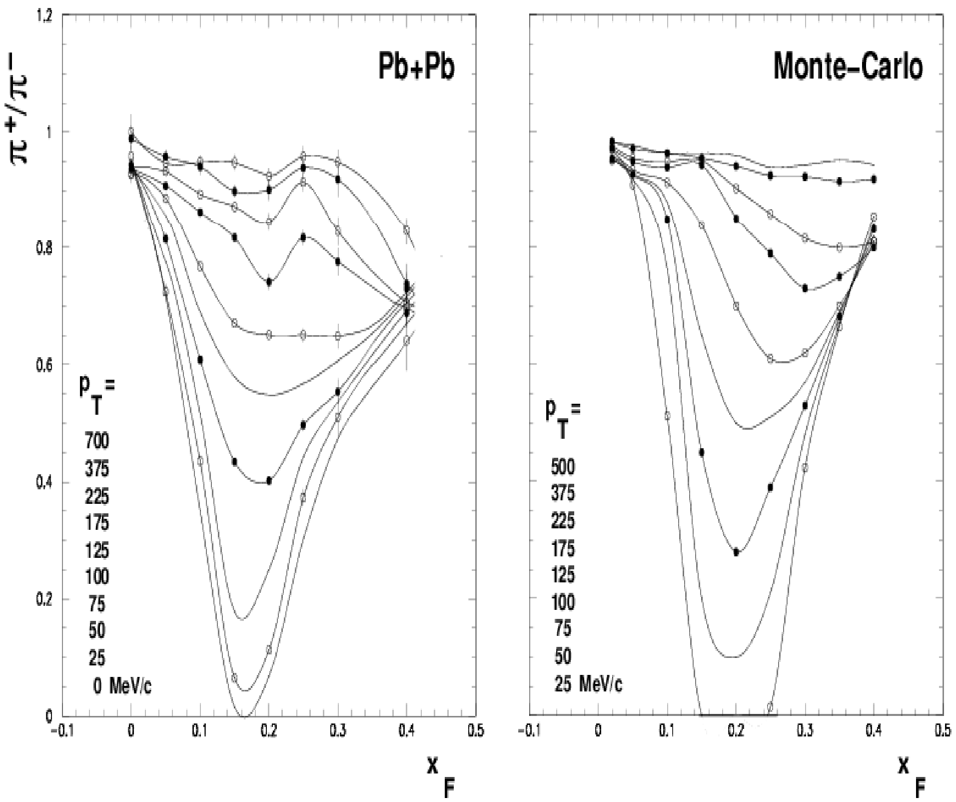
Coulomb effect

- π^+/π^- ratio reaches zero at

  $\mathbf{x_F=0.15 = m_\pi/m_p}$
- Gives information about number of participants



- No indication of π absorption
- Sensitive to three time scales
  - Participant hadroniz.: few fm/c
  - Coulomb interaction: ~ 50 fm/c
  - Nuclear disintegr.: ~ 100 fm/c



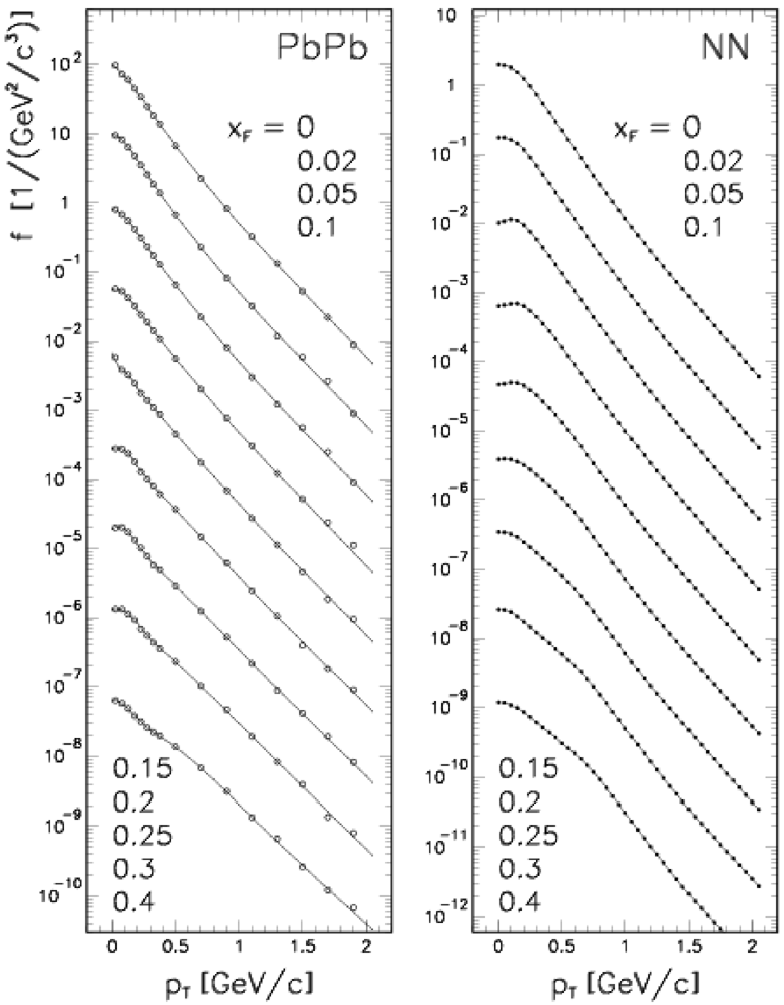
Comparison PbPb – NN (1)

- Use <π> yield, $(\pi^+ + \pi^-)/2$, in order to eliminate Coulomb effect

- Build subsequently ratio

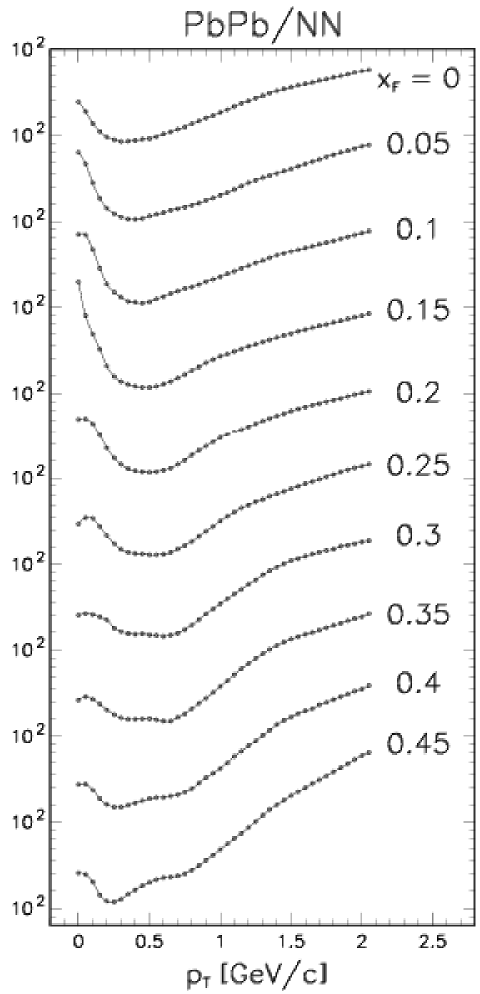
$$R^{PbPb} = f^{PbPb}/f^{NN}$$

for comparison with NN



Comparison PbPb – NN (2)

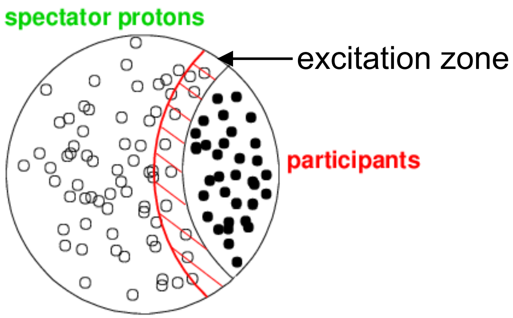
- R^{PbPb} as function of p_T reveals that PbPb is nowhere conformal to NN
  - Minimum at p_T around 0.4 GeV/c
  - Enhancement at low p_T with strong x_F dependence
  - Enhancement at high p_T (Cronin)



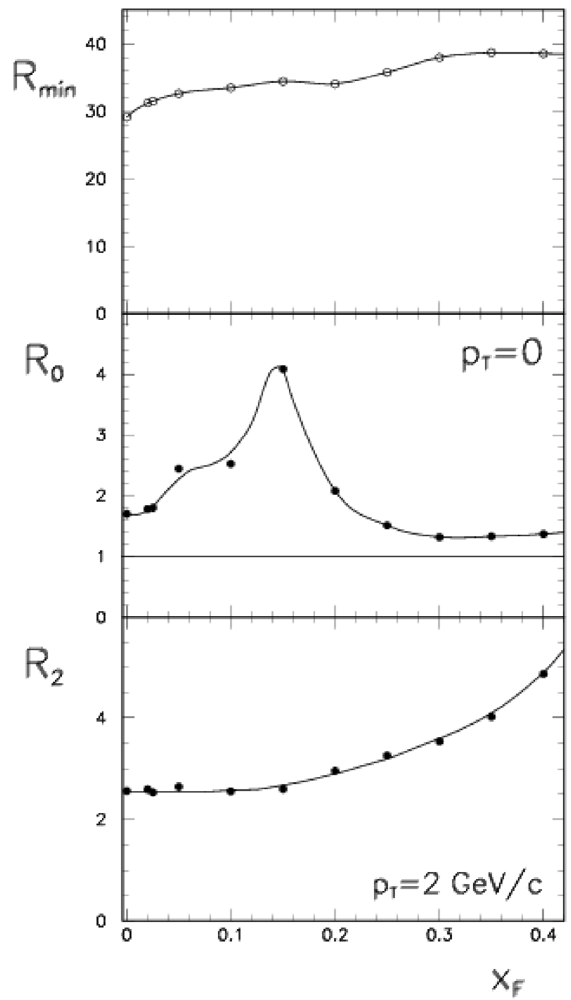
Comparison PbPb – NN (3)

- Minimum of R^{PbPb} in x_F gives upper limit of participant number at about 30

- Low p_T enhancement is maximal at x_F around 0.15 (Coulomb effect)



- High p_T enhancement increases with x_F (Cronin effect)



Comparison pPb – NN

- Choose centrality in pPb equal to PbPb by interpolation in ν

- Build subsequently ratio

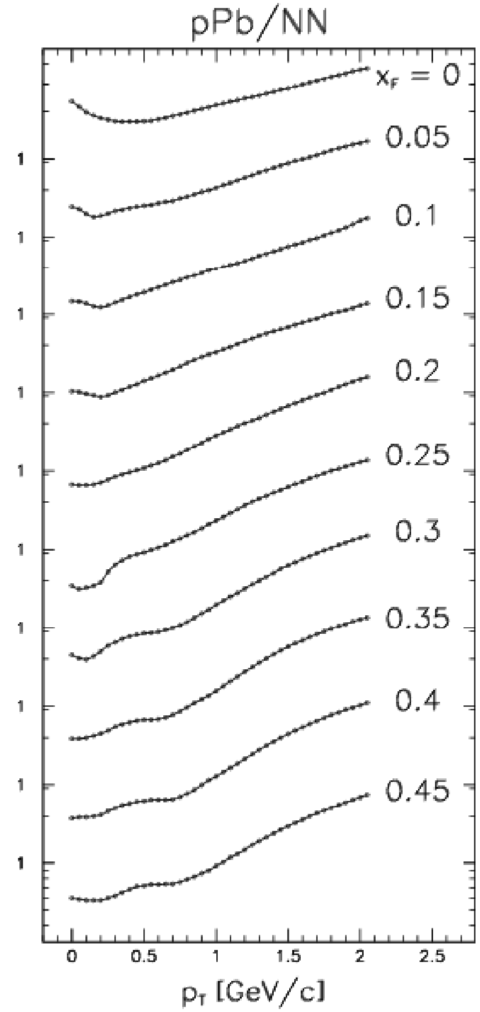
  $R^{pPb} = f^{pPb}/f^{NN}$

  for comparison with NN

  – No x_F-dependent enhancement at low p_T

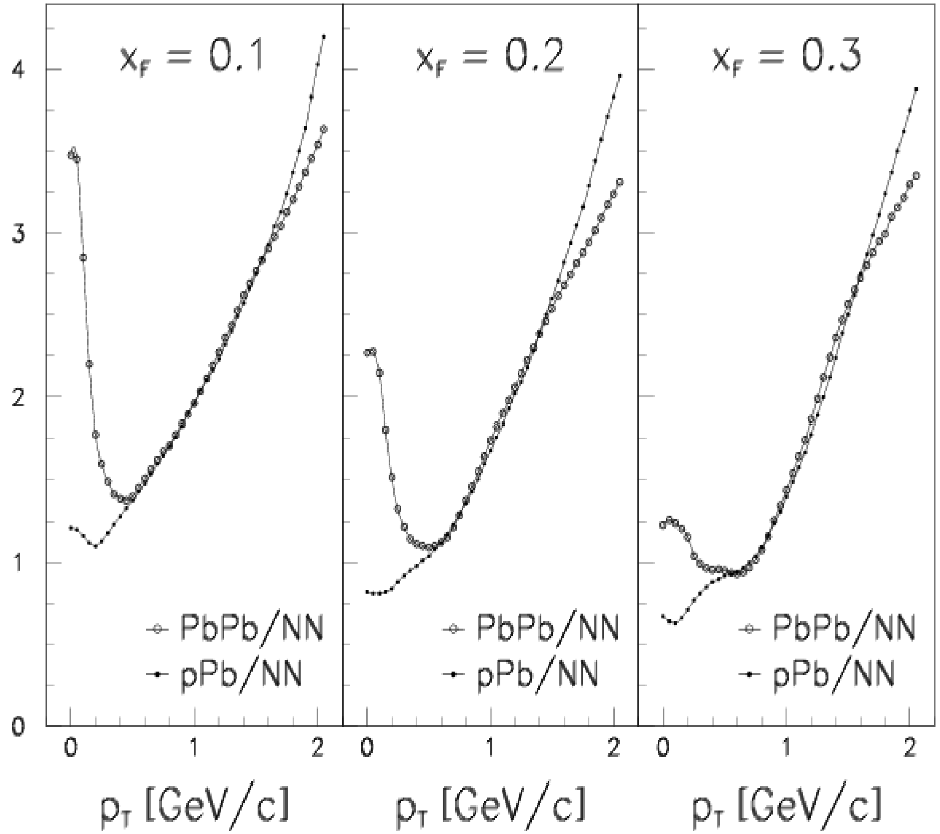
    ➔ No spectator system on projectile side

  – Steady enhancement with p_T (Cronin effect)



Comparison pPb – PbPb

- Use normalization factor for PbPb to allow direct shape comparison
  - Perfect shape equivalence in wide p_T (0.5 and 1.5 GeV/c) and x_F range
- Subtract R^{pPb} (no spectator) to isolate spectator contribution
- Subsequently integrate spectator contribution over p_T



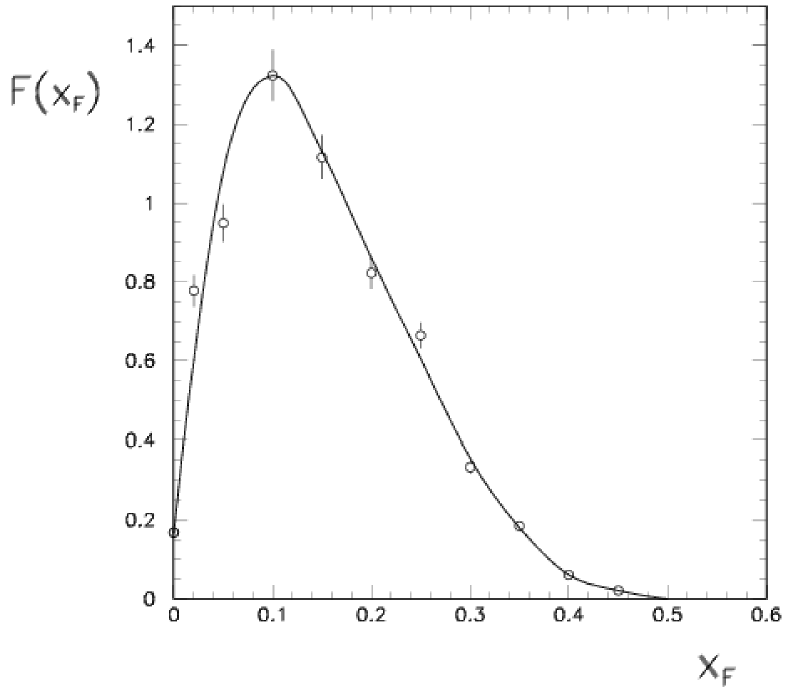
Spectator contribution in PbPb

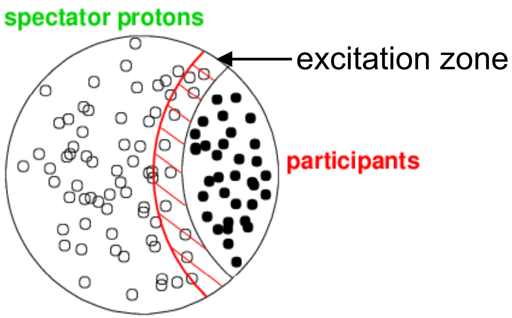
- Invariant yield of spectator fragmentation

- Integration over x_F gives
  - $\langle \pi^{spect} \rangle$ = 31.8 per event
  - $\langle \pi^{total} \rangle$ = 211.4 per event

  ➔ 15% of all produced π come from spectators

- Including π^o production leads to 24 excited projectile nucleons fragmenting into π



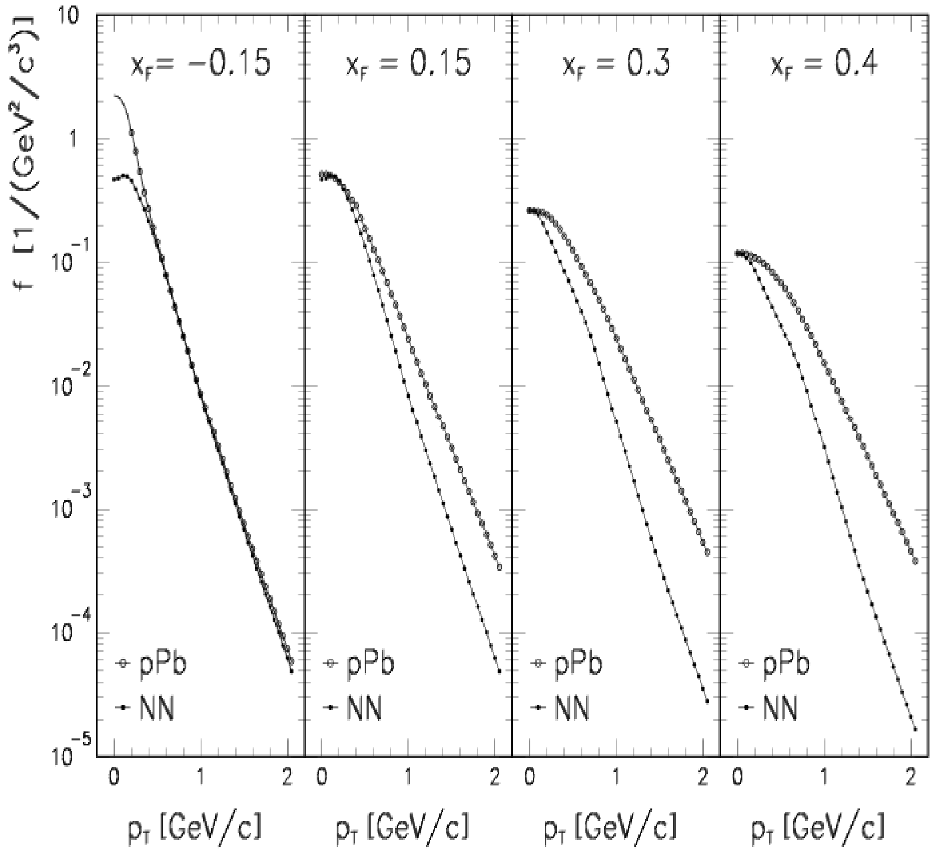


- Many more nucleons excited elastically
- Fragmentation time of spectator nucleons is smaller than the assumed scale of 100 fm/c (see Coulomb)

High p_T enhancement in pPb (1)

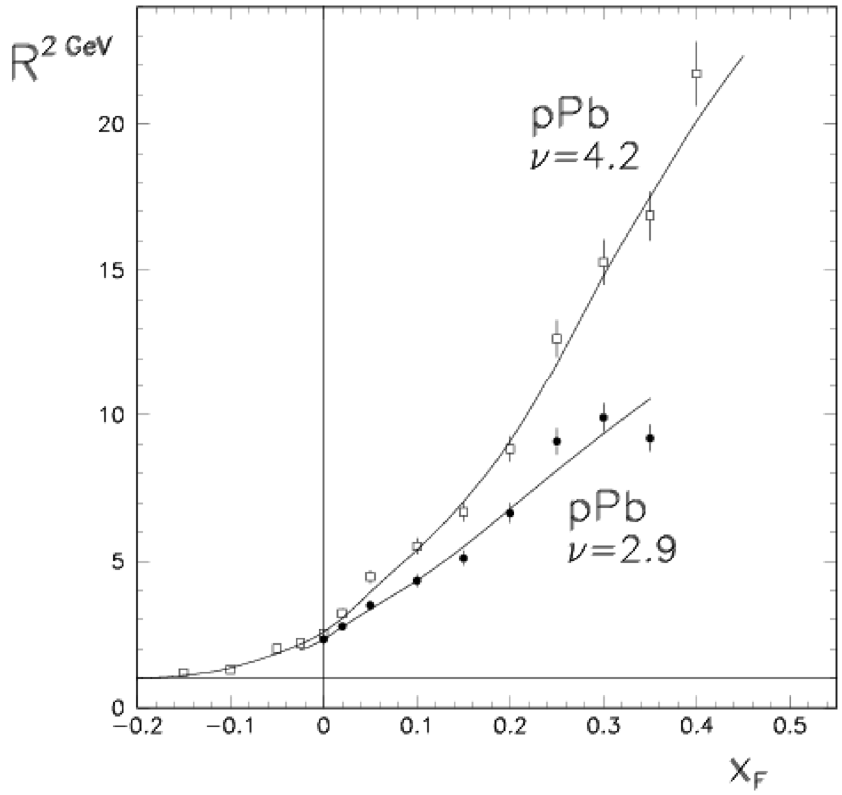
- Compare p_T distribution in pPb to NN using a normalization factor at low p_T
  - At negative x_F contribution of target spectator fragmentation; for p_T>0.4 GeV/c identical shape
  - At positive x_F yield enhancement with increasing p_T
- Define yield ratio at p_T=2 GeV/c

$$R^{2GeV} = c \cdot f^{pPb}/f^{pp}$$



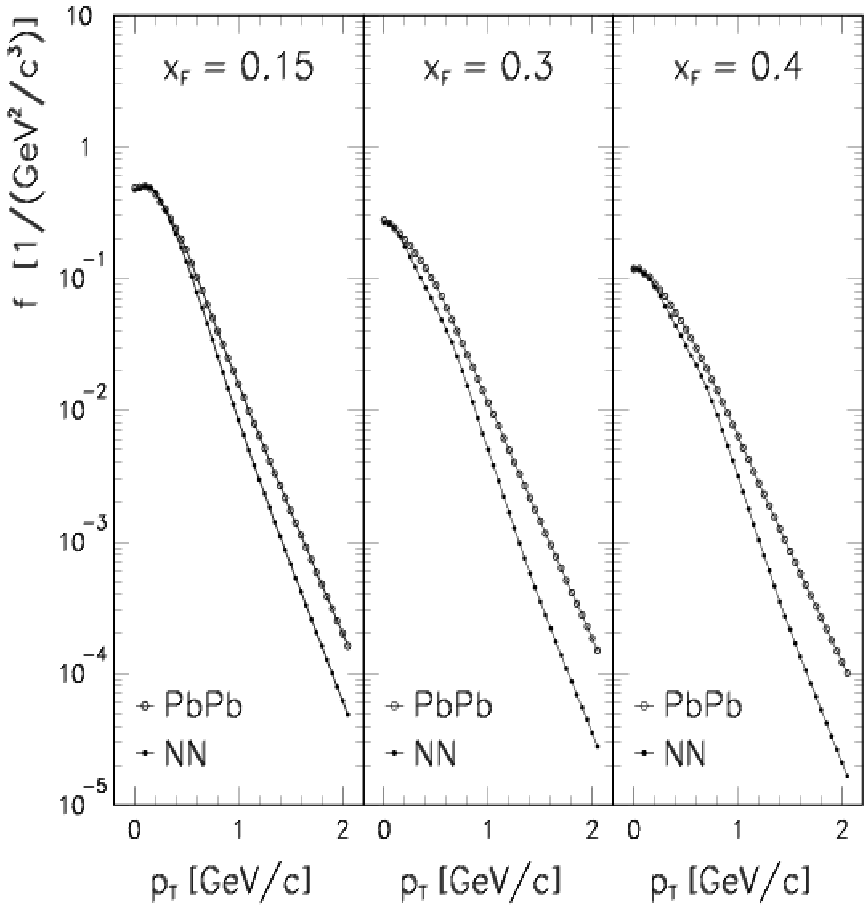
High p_T enhancement in pPb (2)

- Show yield increase over NN at p_T=2 GeV/c for two bins of centrality
  - First measurement of Cronin effect at $x_F \neq 0$
  - Strong asymmetric enhancement vanishes at x_F=-0.2
  - Measurement at x_F=0 reveals only small part of the effect



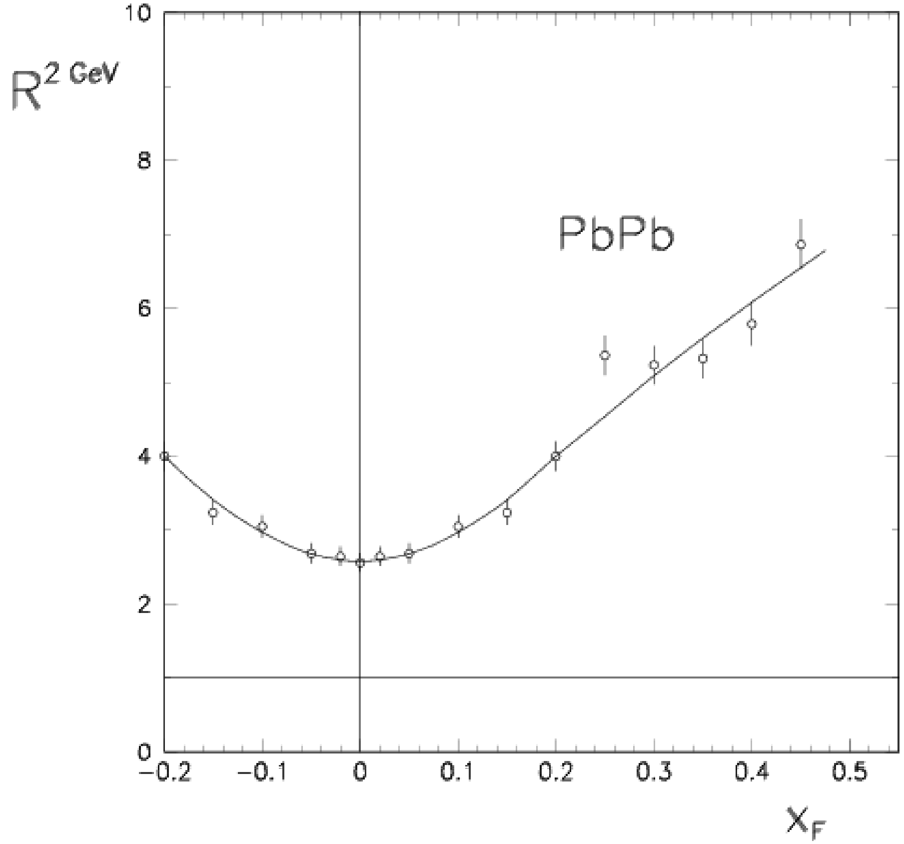
High p_T enhancement in PbPb (1)

- Spectator subtracted cross section
- Compare p_T distribution to NN using a normalization factor at low p_T
- Yield enhancement at high p_T increasing with x_F



High p_T enhancement in PbPb (2)

- Shows symmetric behaviour around x_F=0 due to symmetry of interaction
- Goes horizontally through x_F=0
- Different from pPb
- How to compare pPb and PbPb



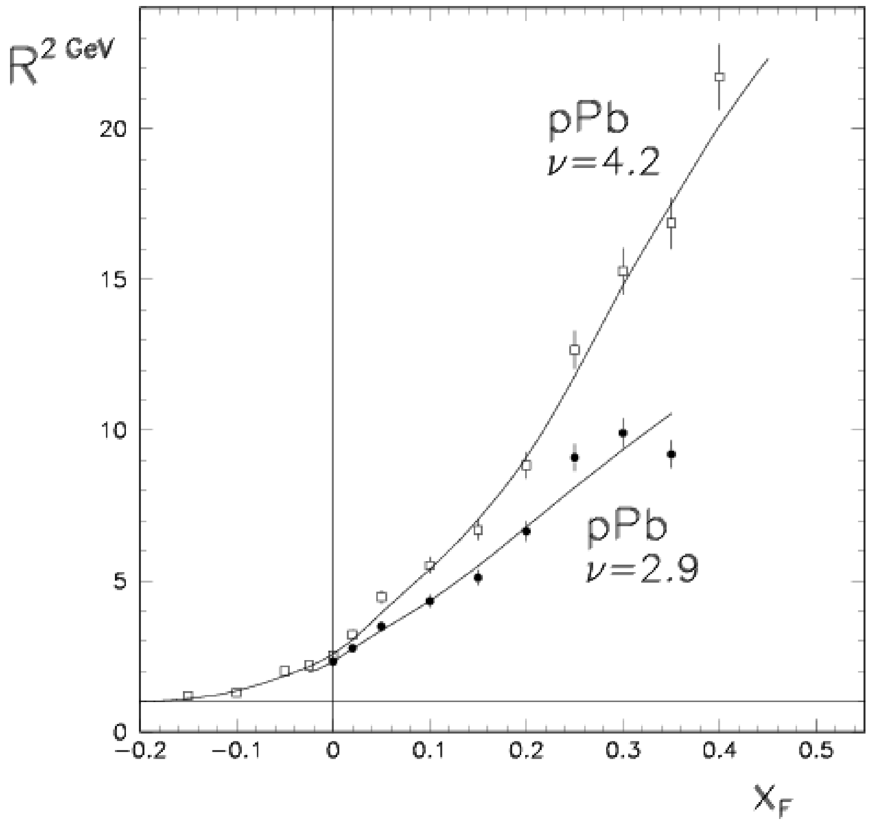
Comparison high p_T enhancement pPb – PbPb

- Inert target contribution in pPb: Each target nucleon hit once contributes no yield enhancement over NN

  $R^{2GeV} = (\nu \cdot 1 + 1 \cdot E)/(\nu + 1)$ at $x_F = 0$

  $$E = (\nu + 1) \cdot R^{2GeV} - \nu$$

- For $x_F \neq 0$ shape of feed-over from target to projectile hemisphere needs to be known, see pC paper *EPJC 49 (2007) 919*
- Yield enhancements in pPb and PbPb show qualitatively the same behaviour
- Measured Cronin effect in pPb has to be corrected up by large factors



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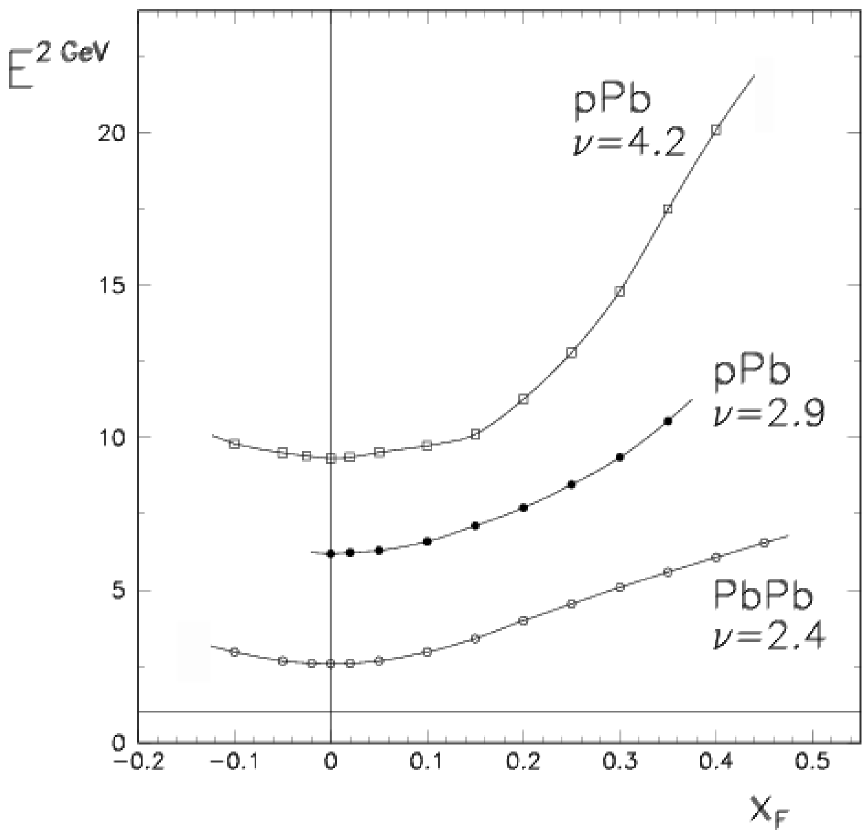

Summary

- Different types of hadronic interactions are inspected and compared using experimental data on equal level of precision and phase space coverage, including centrality determination
- This allows model independent extraction of a number of phenomena
- Final state Coulomb interaction in (peripheral) PbPb collisions gives independent information on participant number and on the time scales of participant fragmentation as well as nuclear disintegration
- First purely experimental extraction of spectator fragmentation into pions with quantitative results on the number of excited spectator nucleons and their contribution to the total pion yield
- First study of the Cronin effect in pA collisions at x_F values off $x_F=0$ where only a small part of the overall effect is visible. Two component nature of hadronic fragmentation used to extract the projectile part of the enhancement. This yields important correction factors at $x_F< 0.2$
- First study of Cronin effect in AA collisions at x_F values off $x_F=0$, showing qualitative similarity between pA and AA collisions
- Once more no indication of anything qualitatively new in AA collisions