Precision measurements of inclusive hadron production in p+p and p+C interactions at the CERN SPS

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Introduction

- Data obtained with NA49 experiment
- Beam momentum 158 GeV/c

1. Hadron-proton interactions
   - ➜ p + p
   - n + p
   - $\pi^{\pm}$ + p
2. Hadron-nucleus interactions
   - d + p
   - ➜ p + C
   - p + Pb (with controlled centrality)
   - $\pi^{\pm}$ + Pb
3. Nucleus-nucleus interactions
   - Pb+Pb

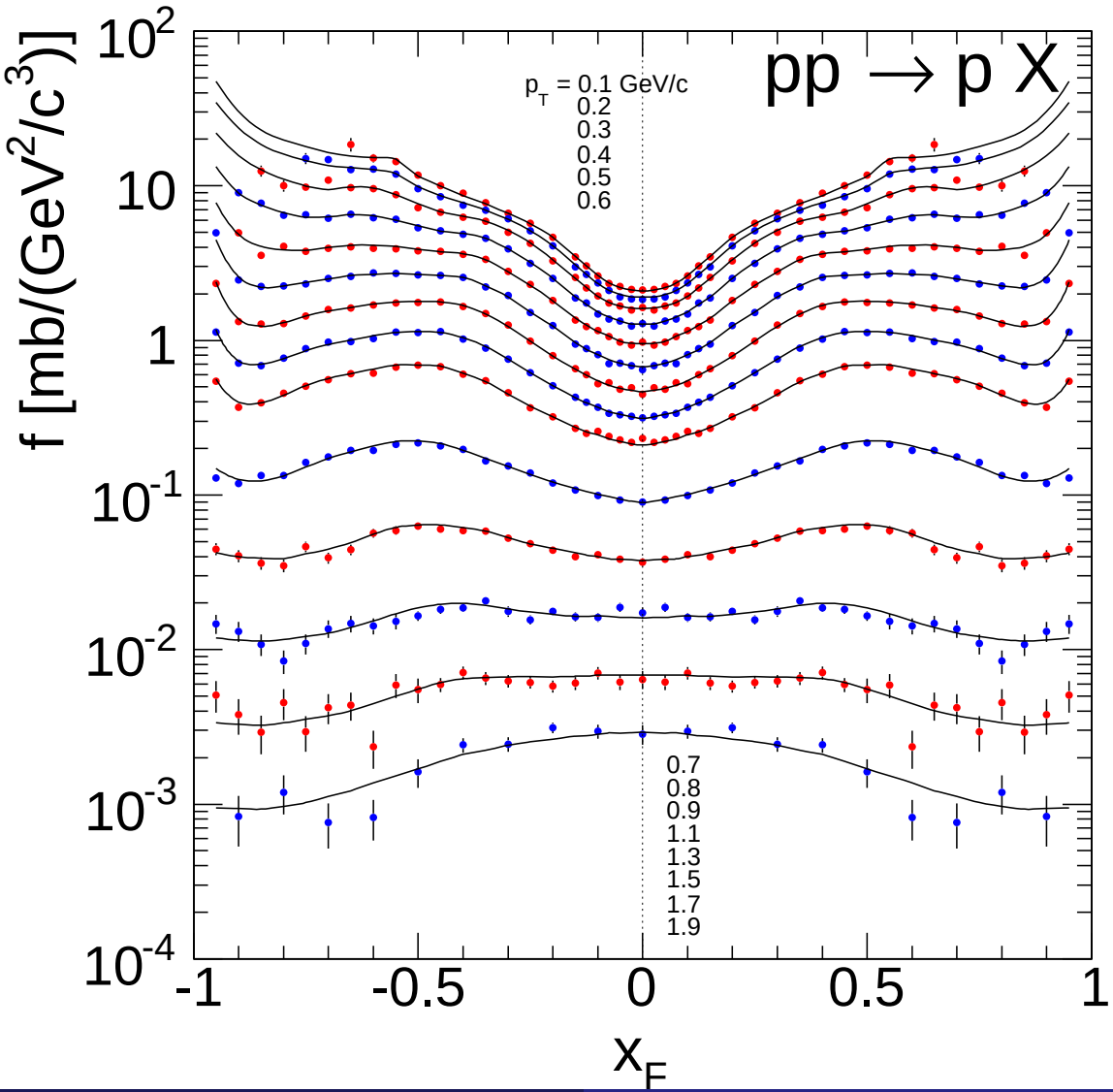
- Precision data in variety of reactions, syst. $<3\%$
- Maximum phase space coverage
- Detailed comparison with existing measurements
- Model independent analysis and interpretation of the data

Outline

1. Proton production
   - Inclusive proton distributions in p+p and p+C collisions
   - Proton and neutron p_T integrated distributions
   - Two (Three) component mechanism
   - Experimental extraction of the components
2. Kaon production
   - Inclusive kaon distributions in p+p and p+C collisions
   - Kaon distribution ratio between p+C and p+p collisions
   - K^+/K^- ratio
   - K^+/π^+ ratio

Proton distributions in p+p collisions

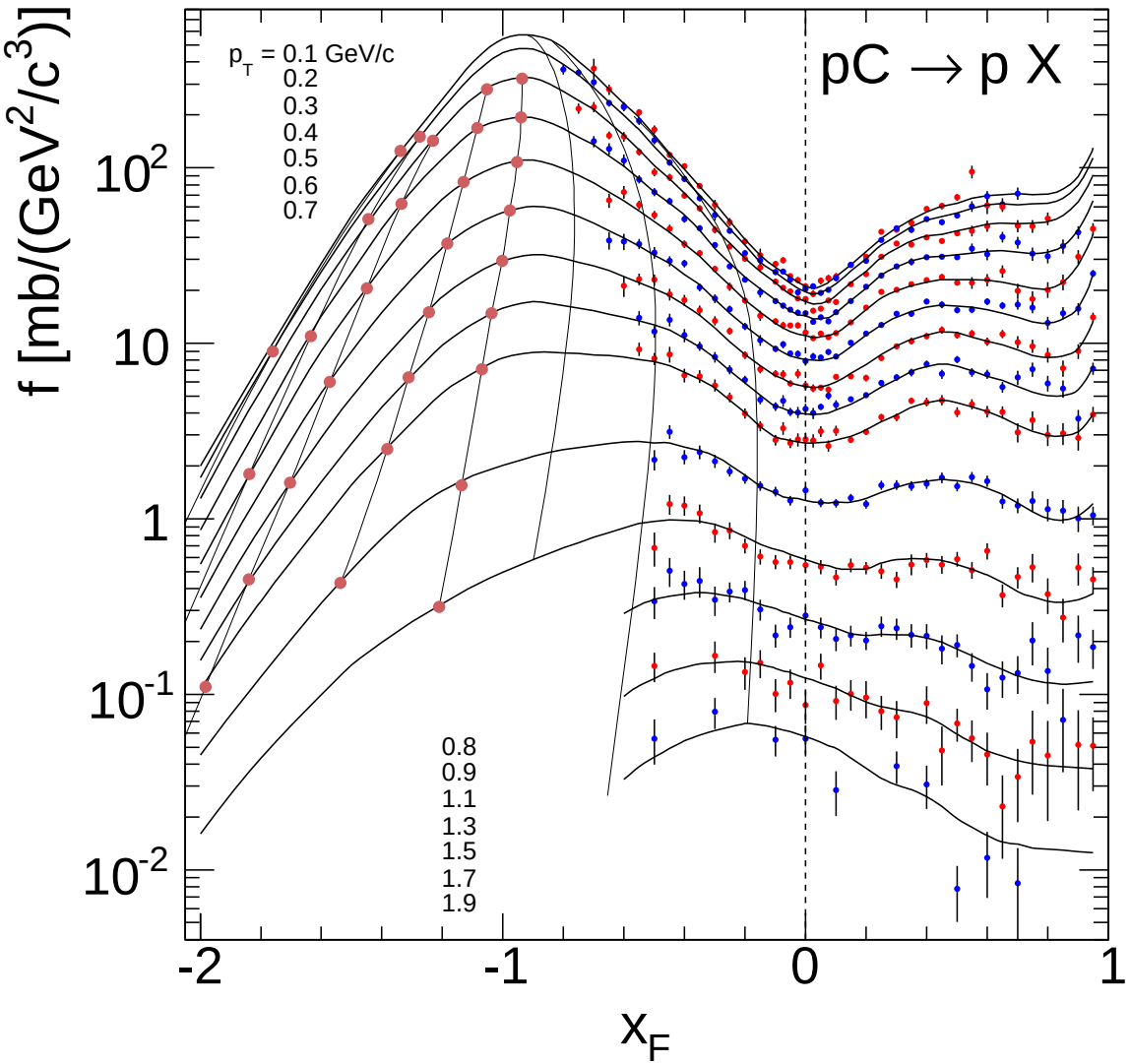
Eur. Phys. J. C65 (2010) 9-63



- Used variables:
  - $x_F = 2p_L^*/\sqrt{s}$
  - transverse momentum – p_T
- $x_F = 0 \div 0.95$ and $p_T = 0 \div 1.9$ GeV/c

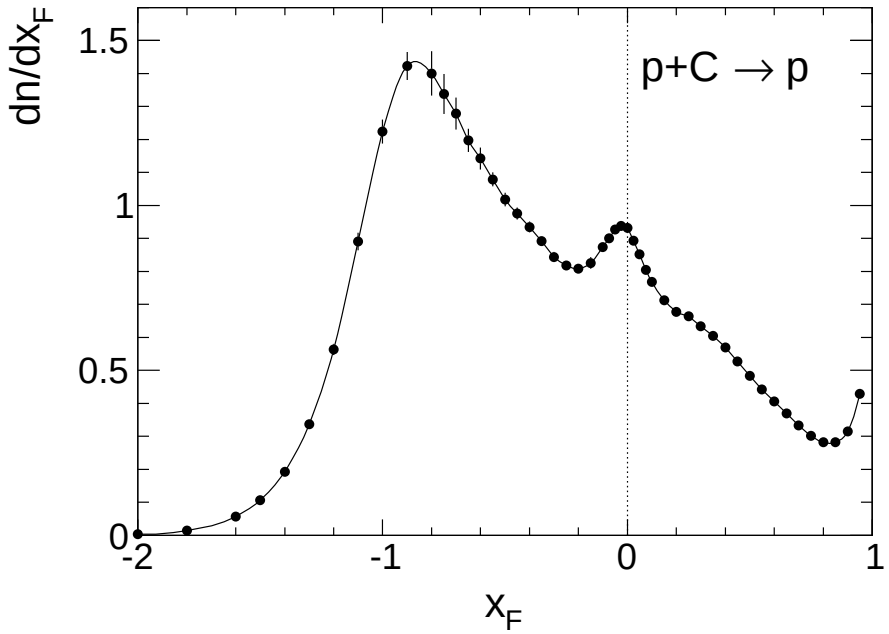
Proton distributions in p+C collisions

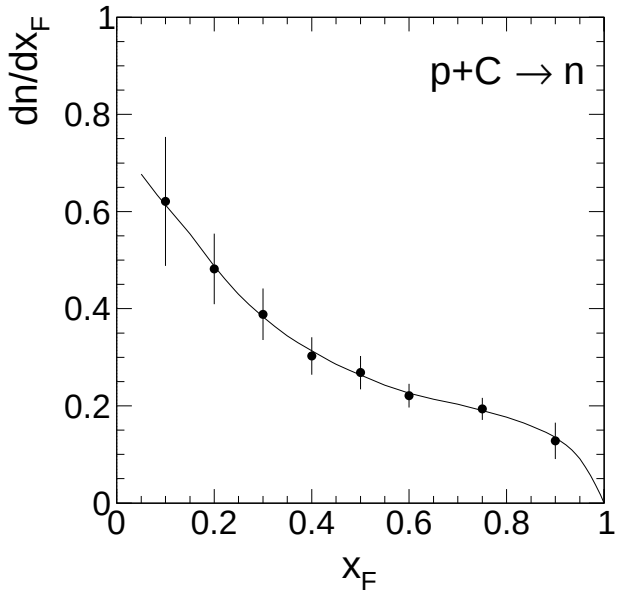
Eur. Phys. J. C73 (2013) 2364

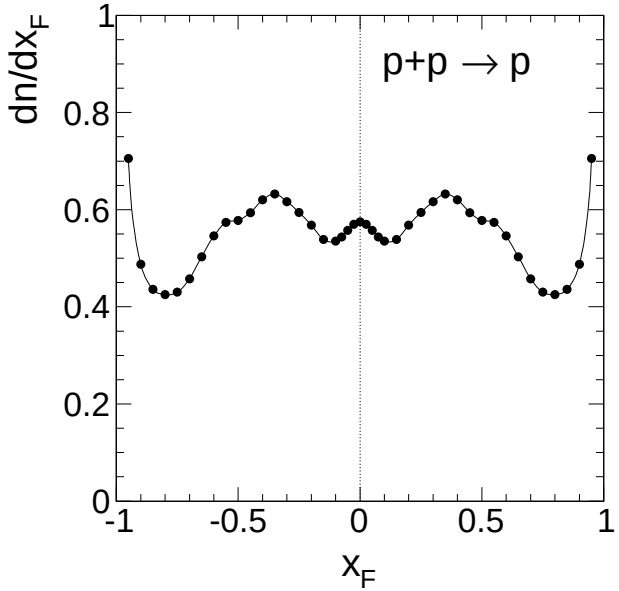


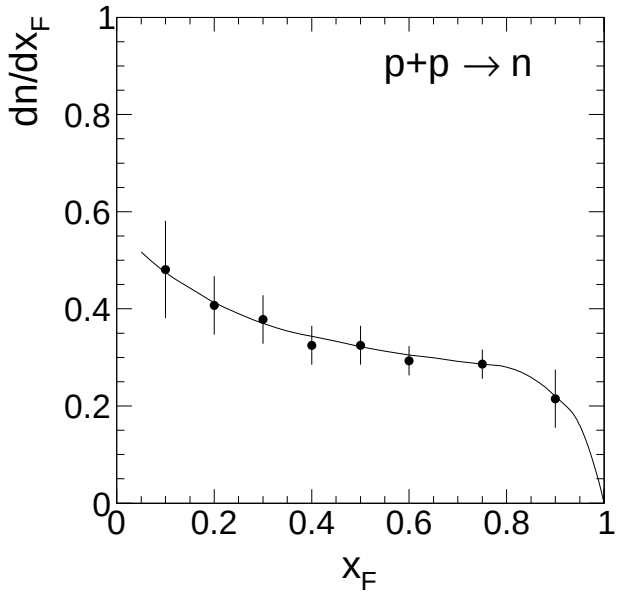
- Data from Fermilab at 400 GeV/c beam momentum Phys. Rev. C20, 764 (1979)
- *s*-dependence is negligible
- Measurement from x_F =-2 to x_F = 1
- No indication of diffractive structure close to x_F = -1
- Maximum of the distributions is at x_F = -0.92

Proton and neutron p_T integrated distributions

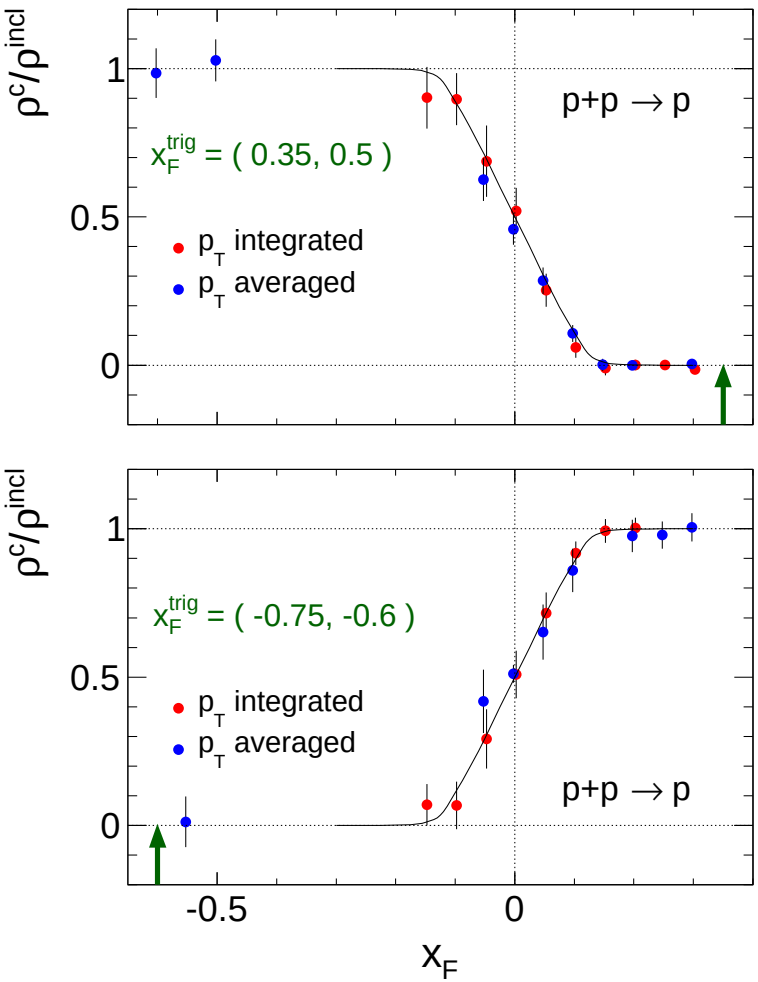






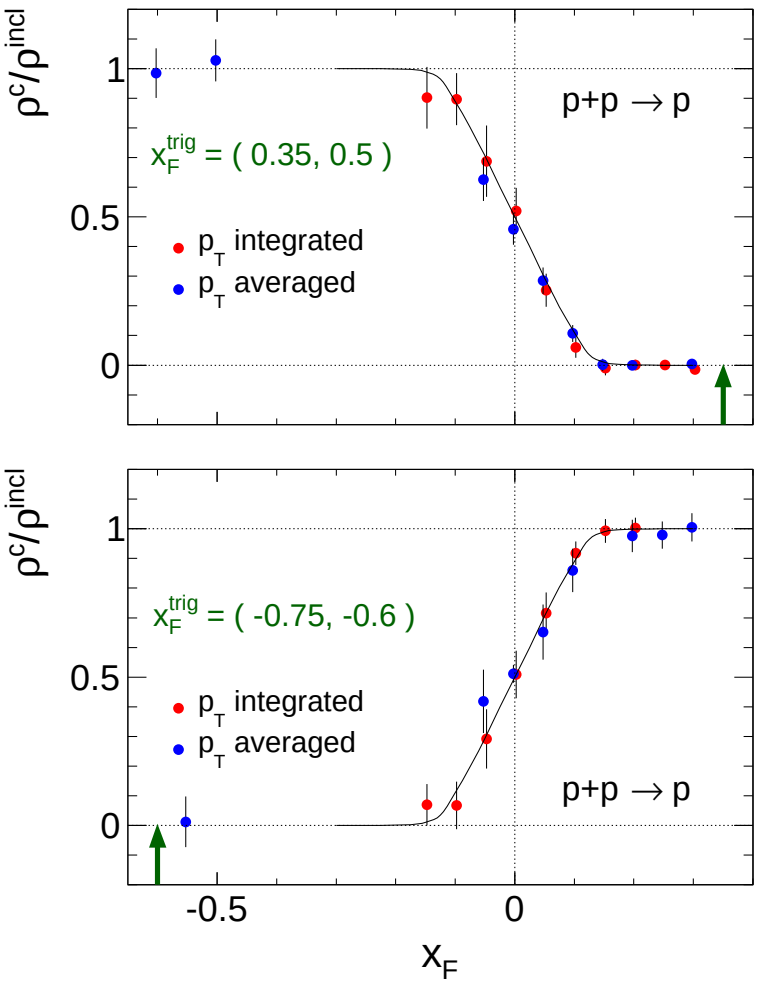


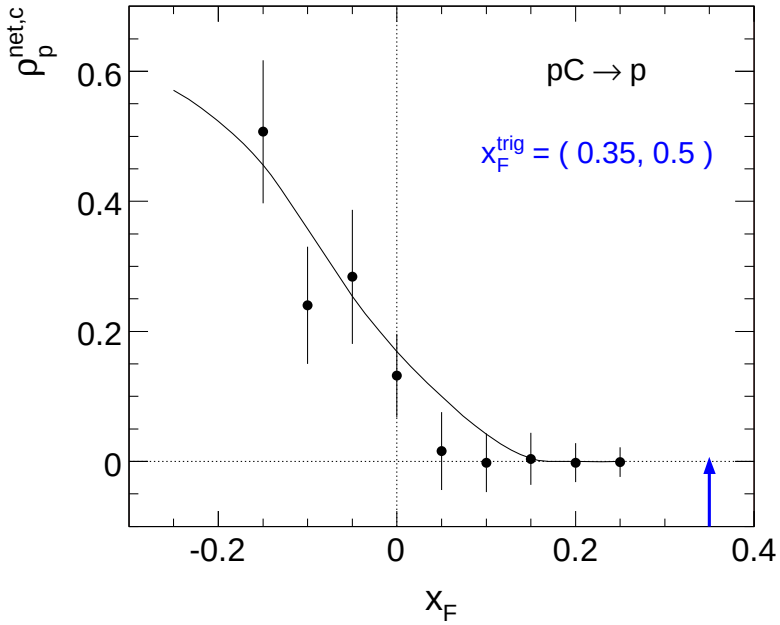
Net proton overlap function



- Net baryons = baryons - pair produced baryons
- Pair produced baryons are extracted from measured antiprotons taking into account the isospin effect
- Study of net proton overlap function between target and projectile fragmentation by fixing the baryon number
- Proton is fixed at large $|x_F|$, excluding pair produced protons:
  - projectile hemisphere: $0.35 < x_F < 0.5$
  - target hemisphere: $-0.75 < x_F < -0.6$
- Overlap range is $|x_F| < 0.2$

Net proton overlap function

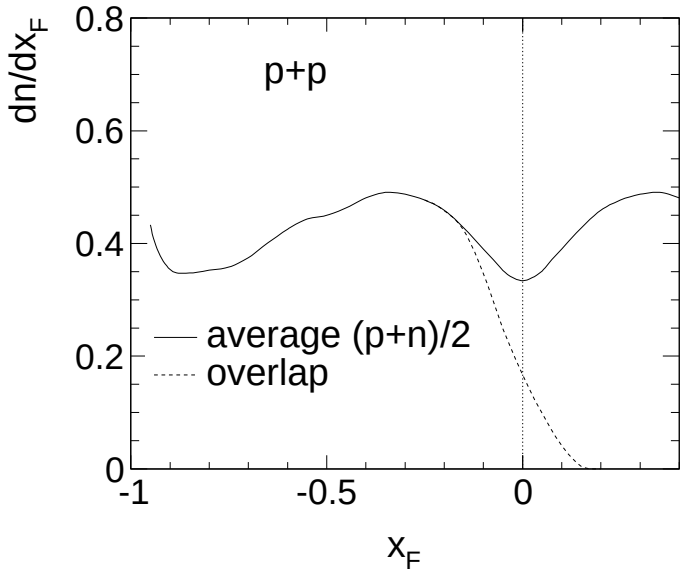


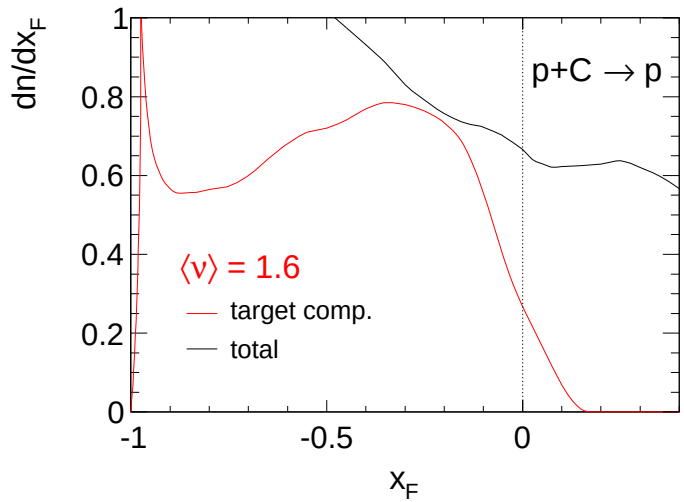


- The same overlap range in p+C $|x_F| < 0.2$

Target and projectile component of protons in p+C

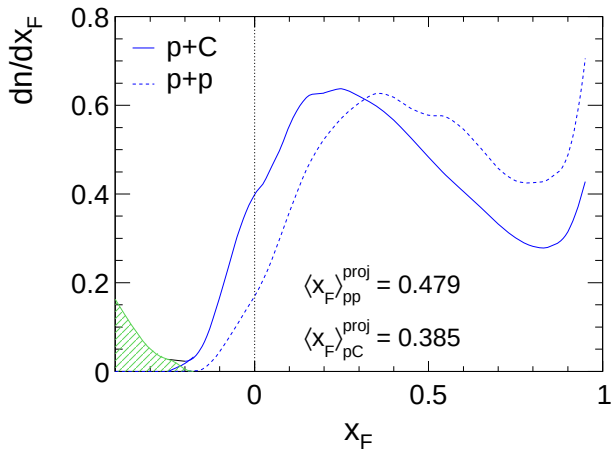
Target fragmentation





- Target component predicted from p+p collisions
- Isoscalar nucleus – average between protons and neutrons, multiplied by $\langle \nu \rangle = 1.6$

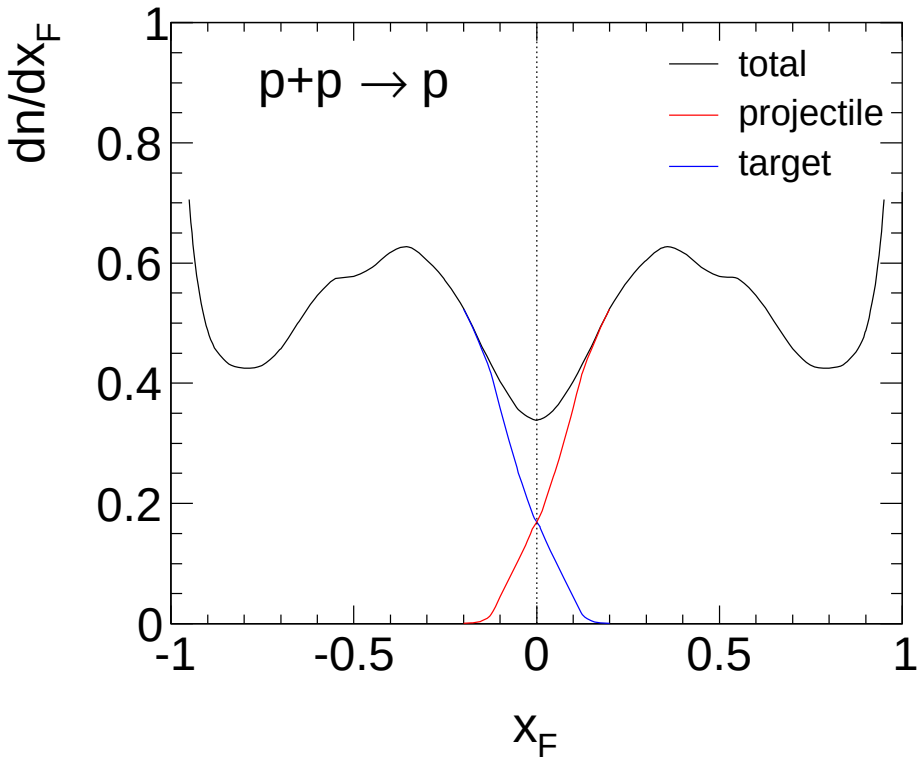
Projectile fragmentation



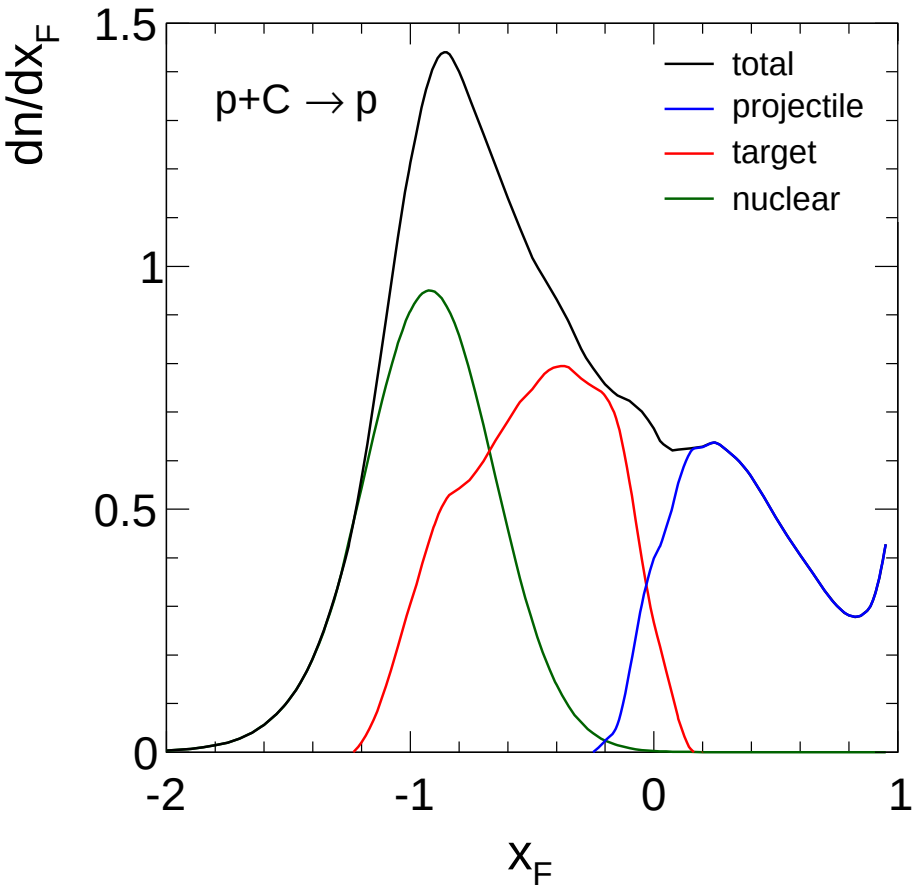
- Shift in $x_F \sim 0.1$
- Verifies baryon number conservation
- Below x_F = -0.2 onset of nuclear component

Two/three component mechanism

- Projectile fragmentation
- Target fragmentation

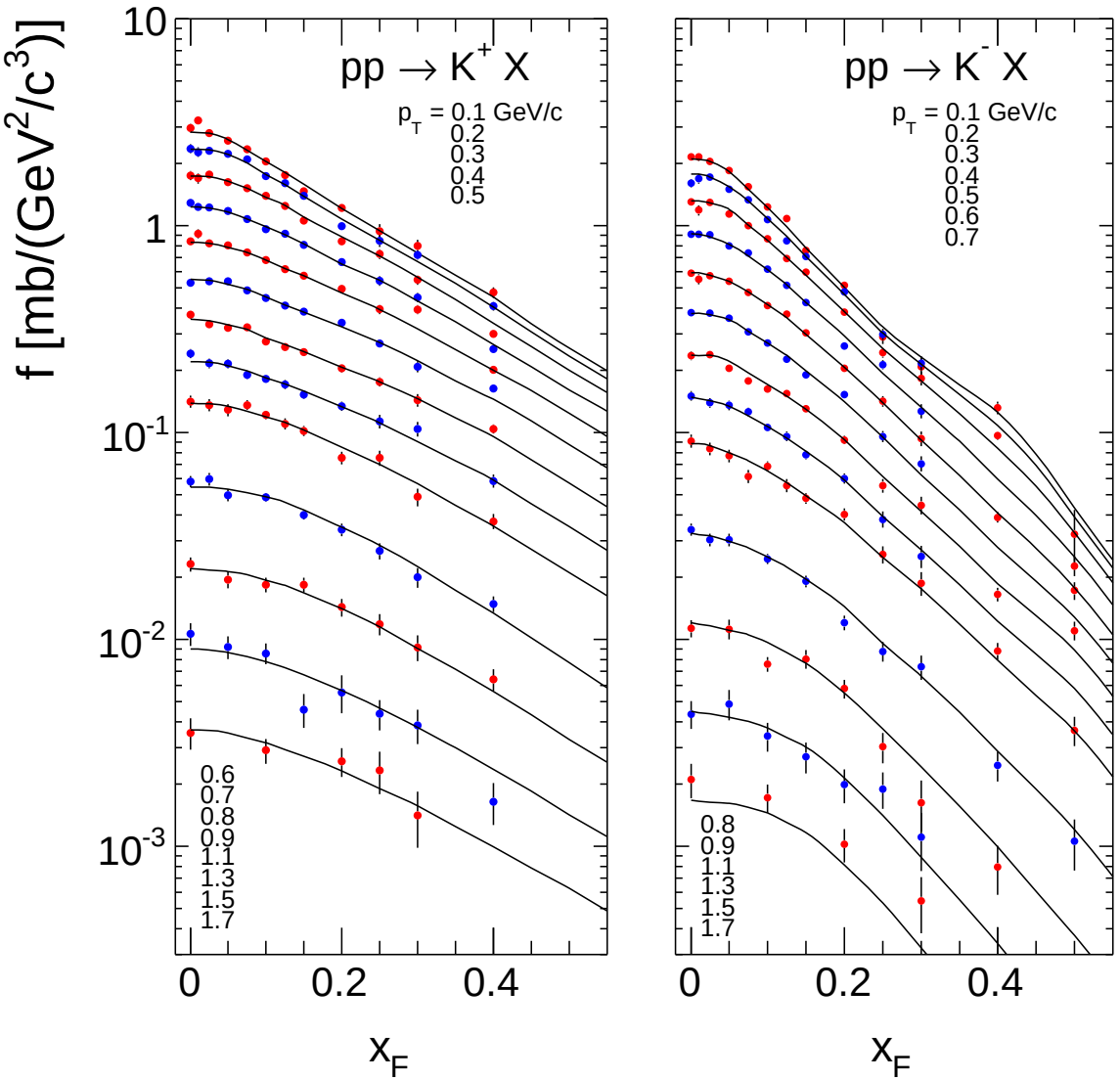


- Projectile fragmentation
- Target fragmentation (no diffractive peak)
- Nuclear cascading



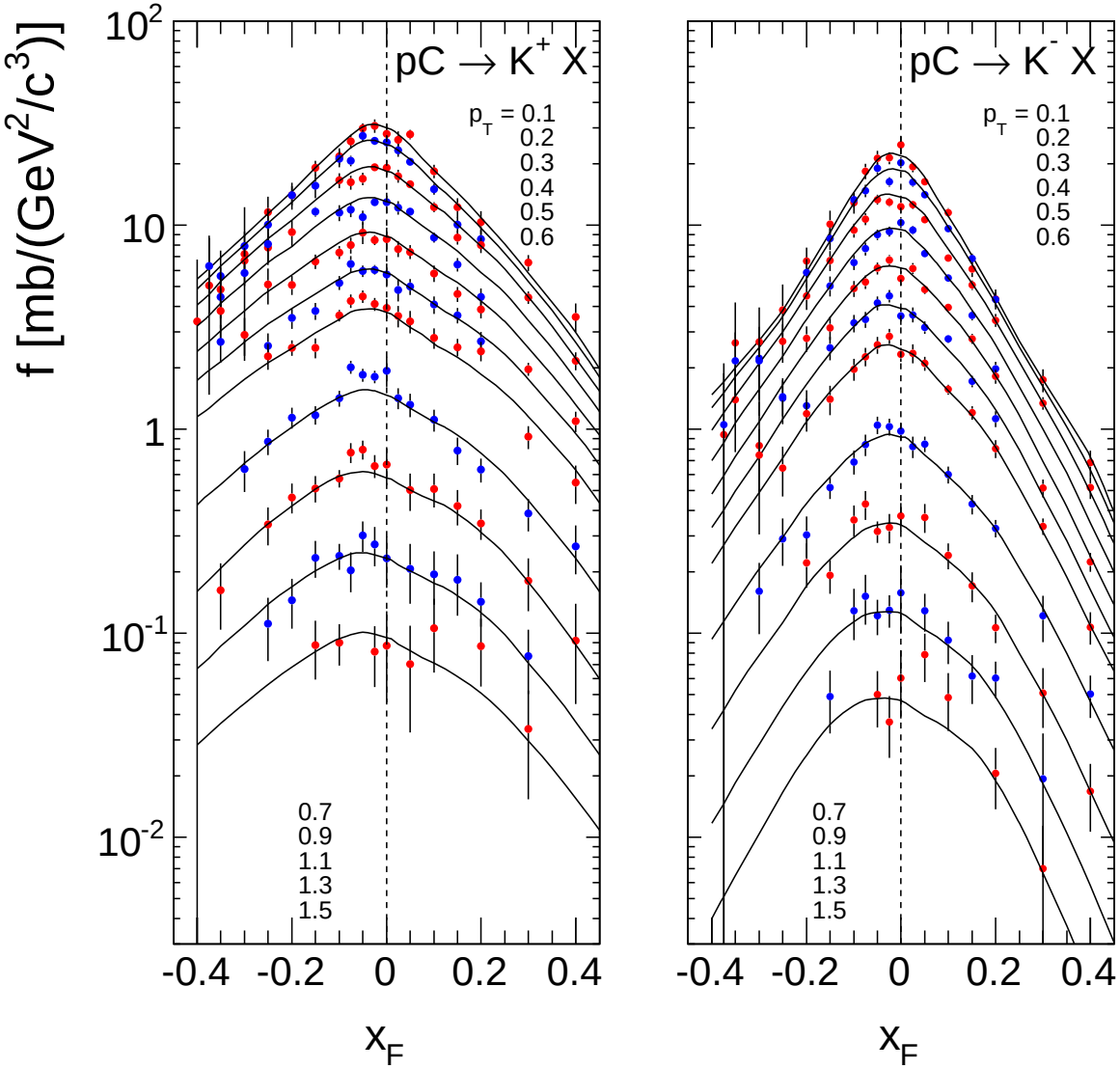
Kaon distributions in p+p collisions

Eur. Phys. J. C68 (2010) 1-73



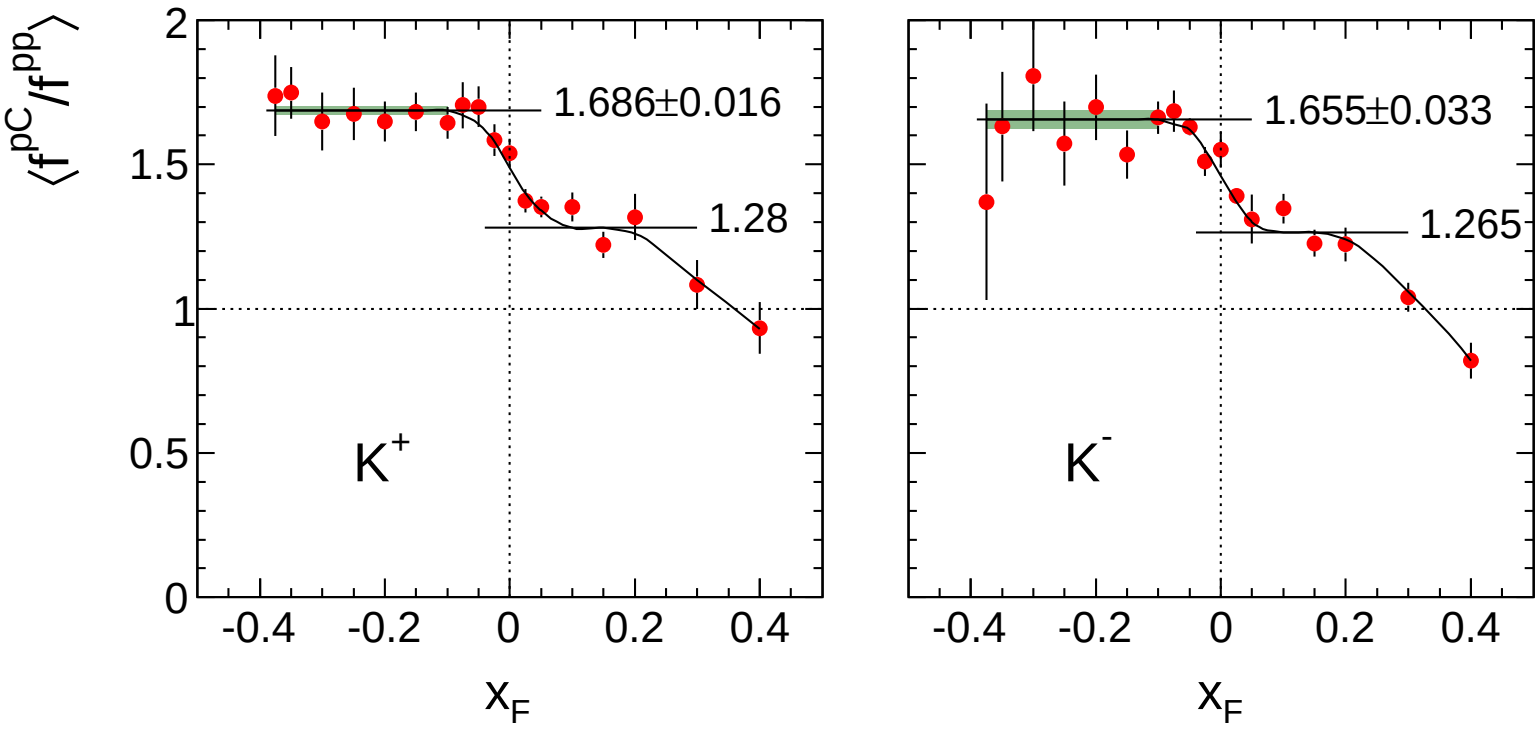
- $x_F = 0 \div 0.4$ and $p_T = 0 \div 1.7$ GeV/c for K^+
- $x_F = 0 \div 0.5$ and $p_T = 0 \div 1.7$ GeV/c for K^-

Kaon distributions in p+C collisions



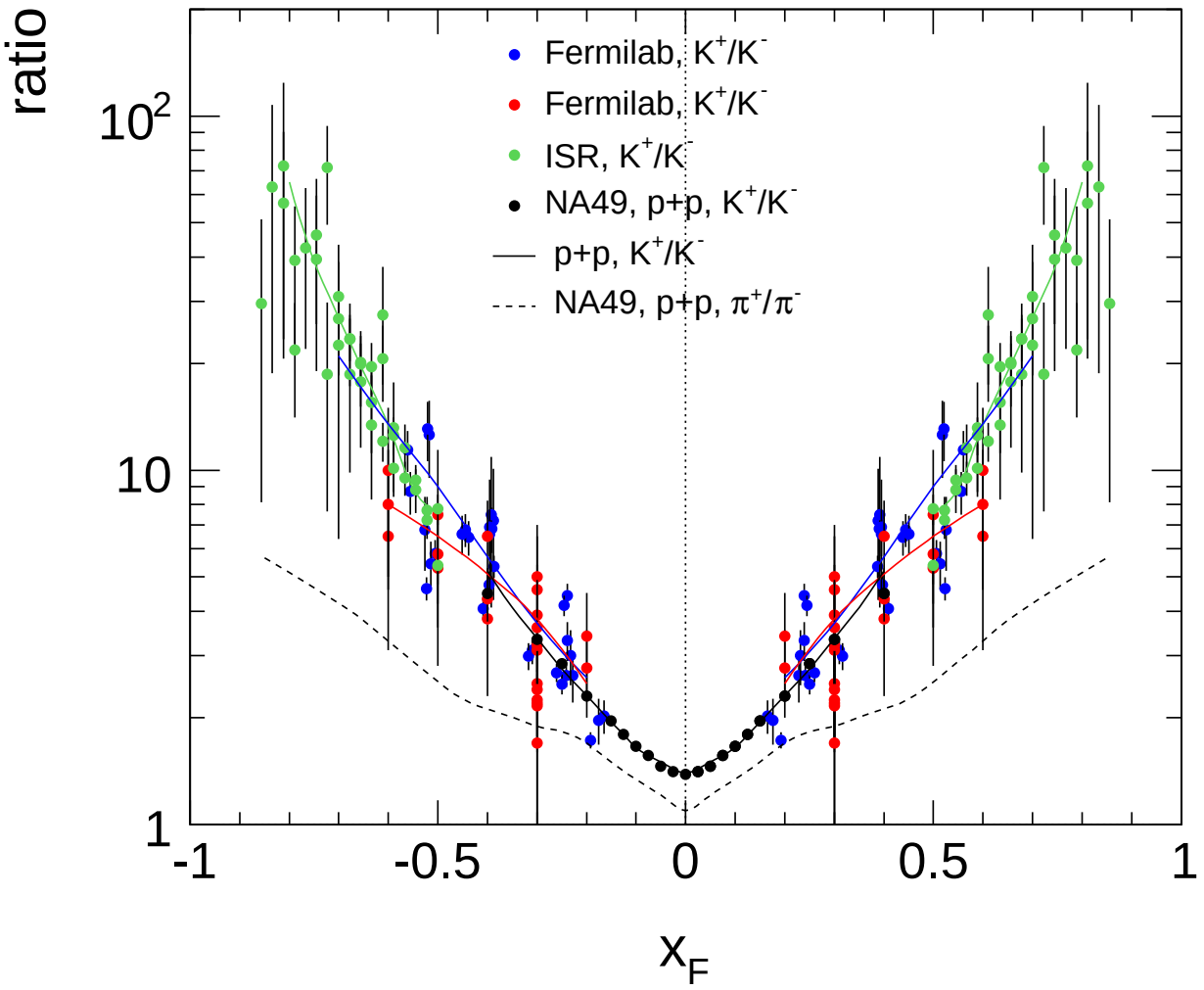
- $x_F = -0.4 \div 0.4$ and $p_T = 0 \div 1.5$ GeV/c for K^+
- $x_F = -0.375 \div 0.4$ and $p_T = 0 \div 1.5$ GeV/c for K^-

Kaon ratio p+C to p+p collisions



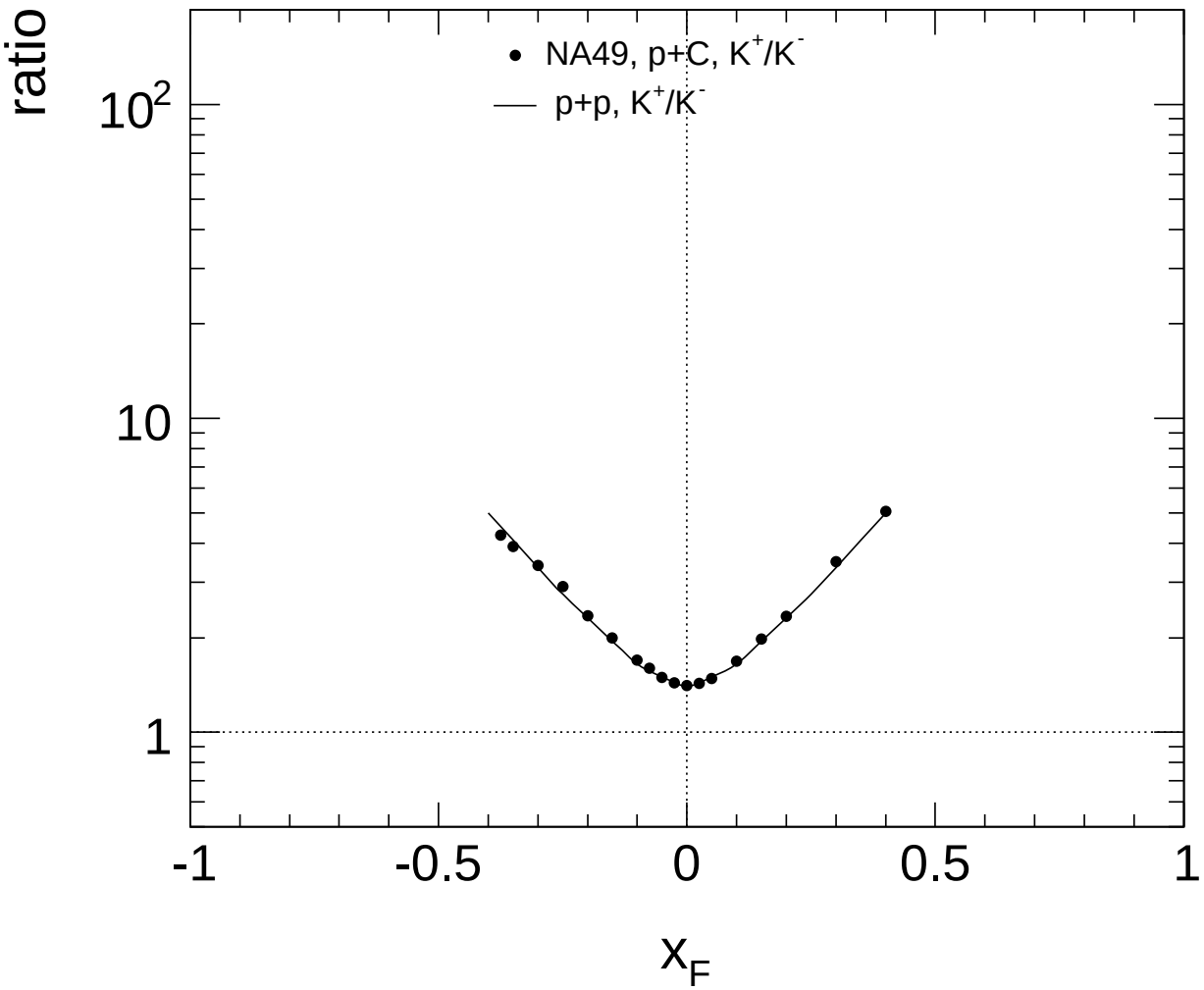
- Target pile-up – mean number of collisions, $x_F < -0.1$
- Overlap function, $|x_F| < 0.1$
- Kaon enhancement, $0.1 < x_F < 0.2$
- Kaon transfer towards center ("stopping"), $x_F > 0.2$

K^+/K^- ratio in p+p collisions



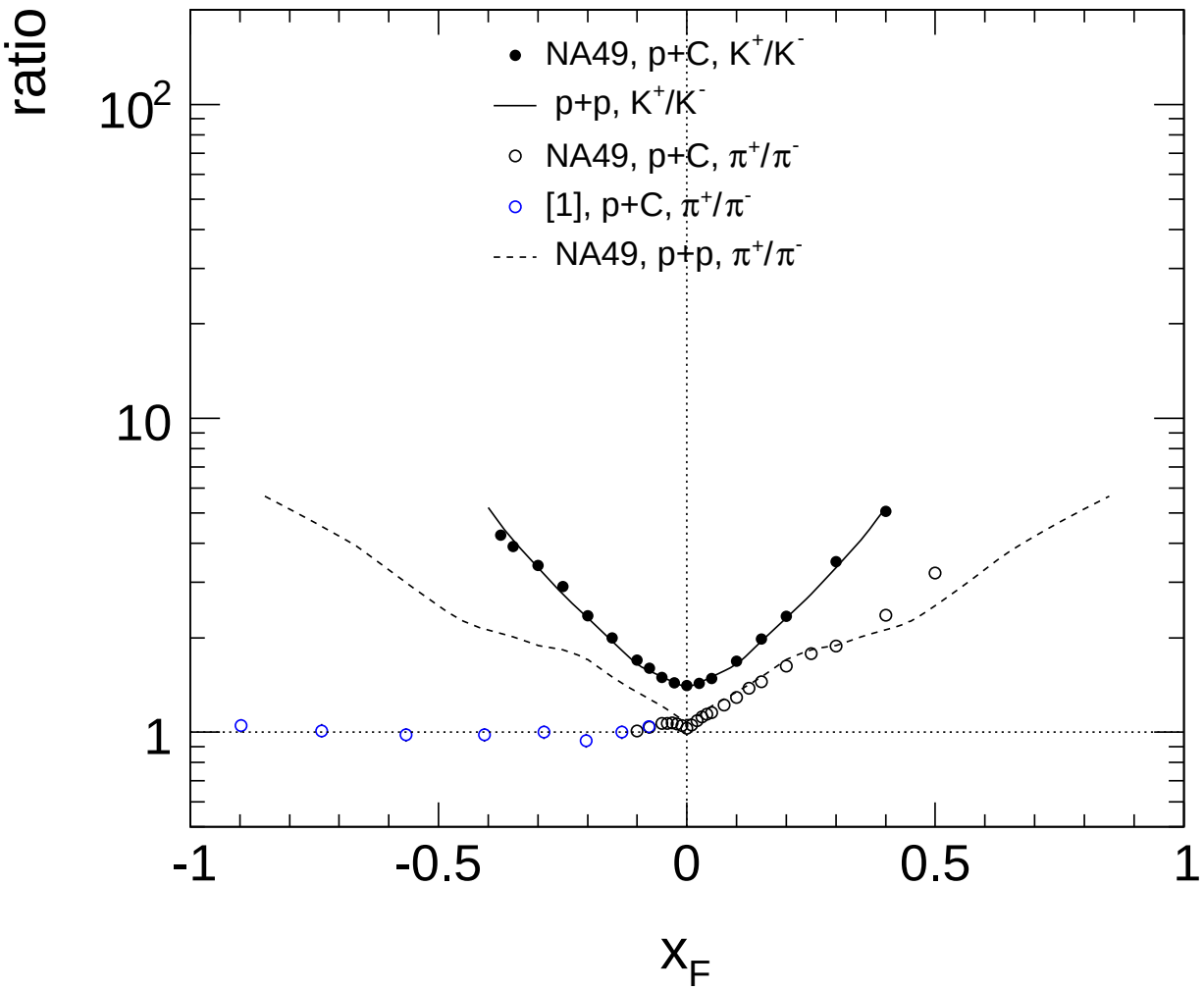
- Extension of x_F scale using other data:
  - from Fermilab
    Phys. Rev. D17, 1292 (1978)
    Phys. Rev. D26, 1497 (1982)
  - from ISR
    Nucl. Phys. B56, 333, (1973)
- π^+/π^- ratio in p+p from NA49
  Eur. Phys. J. C45, 343 (2006)

K^+/K^- ratio in p+A collisions



- K^+/K^- ratio is similar in p+p and p+C collisions, while K^+ and K^- change

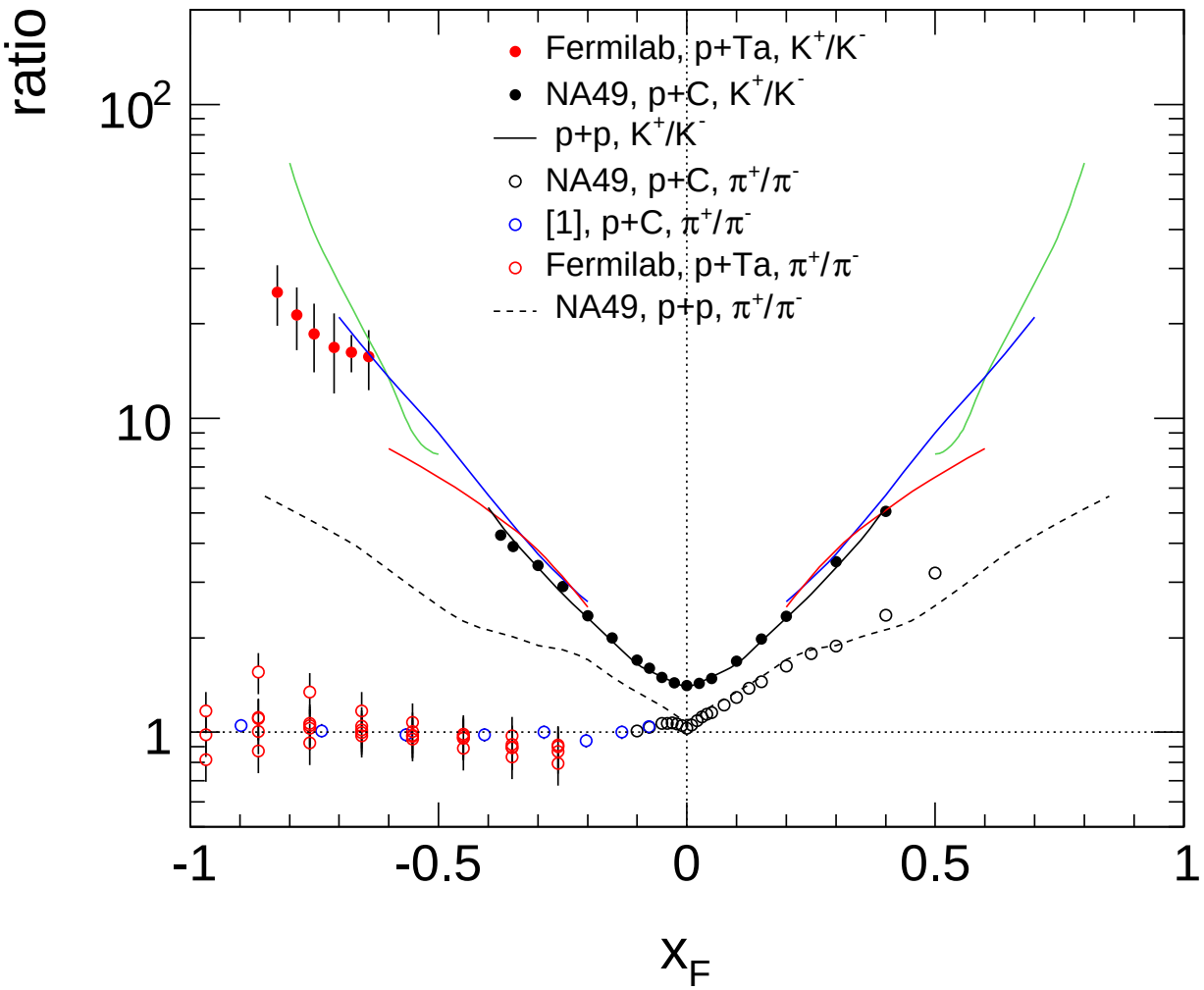
K^+/K^- ratio in p+A collisions



- K^+/K^- ratio is similar in p+p and p+C collisions, while K^+ and K^- change
- π^+/π^- ratio in similar in p+p and p+C in the forward hemisphere
- π^+/π^- ratio in different in p+p and p+C in the nucleus hemisphere due to the isospin symmetry

- π^+/π^- ratio in p+p from NA49 **Eur. Phys. J. C45, 343 (2006)**
- π^+/π^- ratio in p+C from NA49 **Eur. Phys. J. C49, 897 (2007)**
- [1] – Eur. Phys. J. C73 (2013) 2329

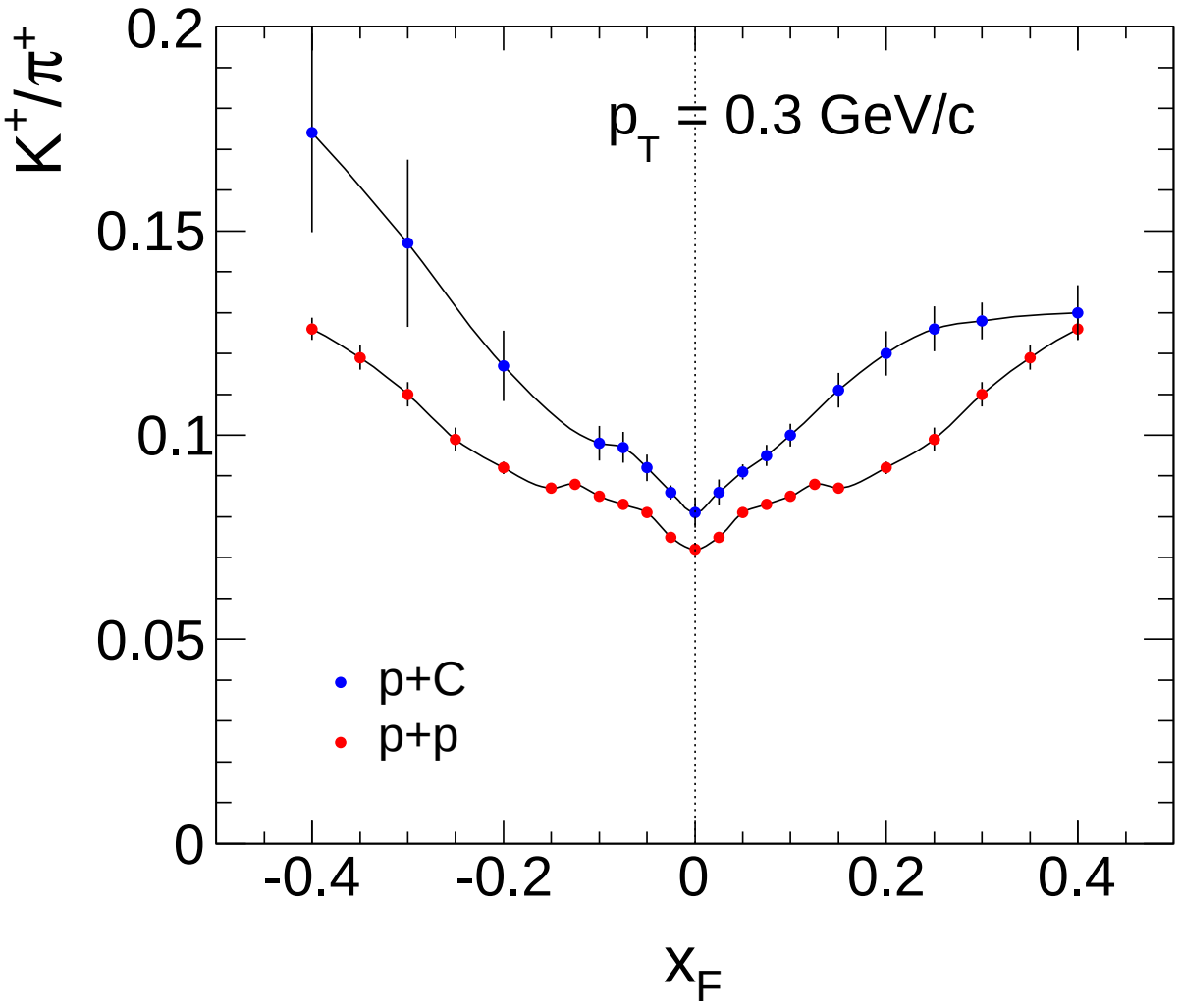
K^+/K^- ratio in p+A collisions



- π^+/π^- ratio in p+p from NA49 **Eur. Phys. J. C45, 343 (2006)**
- π^+/π^- ratio in p+C from NA49 **Eur. Phys. J. C49, 897 (2007)**
- [1] – Eur. Phys. J. C73 (2013) 2329
- Fermilab p+Ta Phys. Rev. C22, 700 (1980)

- K^+/K^- ratio is similar in p+p and p+C collisions, while K^+ and K^- change
- π^+/π^- ratio in similar in p+p and p+C in the forward hemisphere
- π^+/π^- ratio in different in p+p and p+C in the nucleus hemisphere due to the isospin symmetry
- K^+/K^- ratio is similar also in p+Ta collisions in the nucleus hemisphere
- π^+/π^- in the backward is about 1 for p+A

K^+/π^+ ratio in p+A collisions



- Increase of K^+/π^+ ratio in p+C collisions with respect to p+p collisions
- In the backward region is due to the isospin effect
- In the forward region is due to the kaon enhancement of 28% compared to pion enhancement of 10%
- There is a strangeness enhancement already in p+C collisions

Conclusions

- Precise measurement, with wide acceptance coverage, of inclusive cross sections of baryon and kaon in p+p and p+C collisions is performed with the same detector at 158 GeV/c beam momentum
- Extraction in a model independent way the two (three) components of hadronization process
- K^+/K^- ratios are similar in p+p and p+C collisions
- Different behaviour of K^+/K^- and π^+/π^- ratios in the nucleus hemisphere due to the isospin symmetry
- Increase of K^+/π^+ ratio in p+C collisions with respect to p+p collisions in the nucleus hemisphere is due to the isospin effect