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High p_t anti-proton and meson production in cumulative pA reaction at 50 GeV/c

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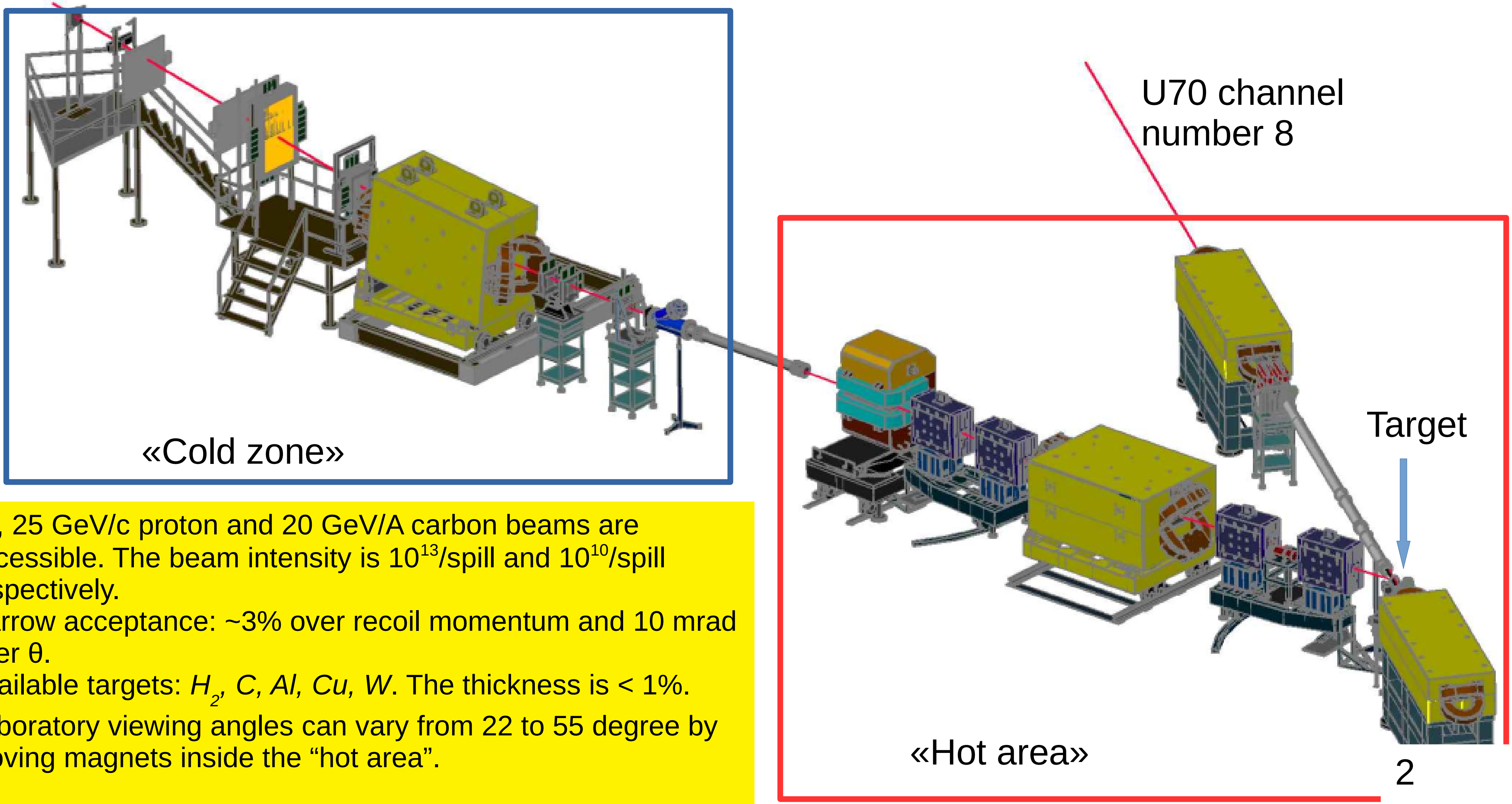
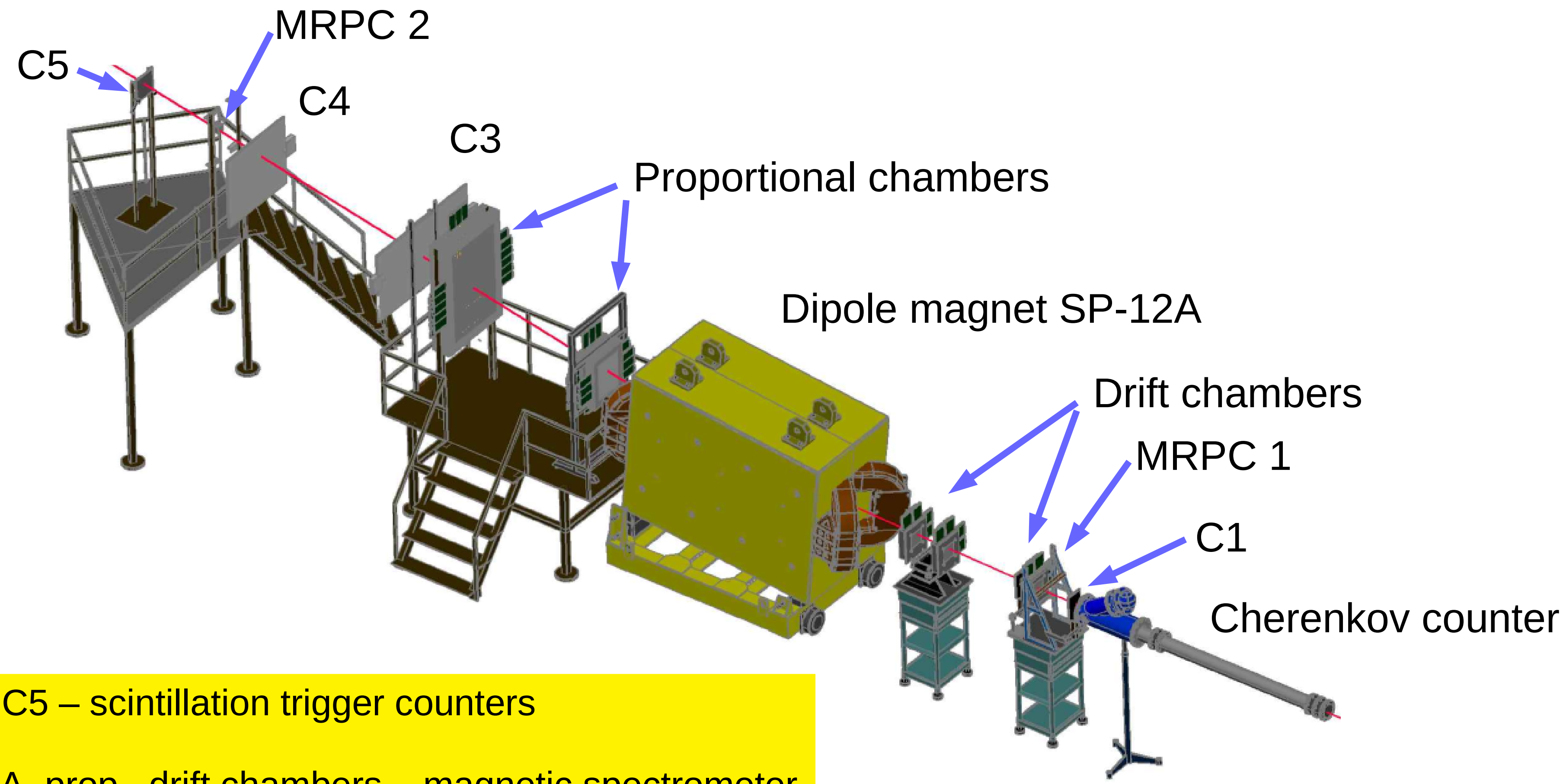
Single arm spectrometer of the “SPIN” experiment (set to 40 degree)



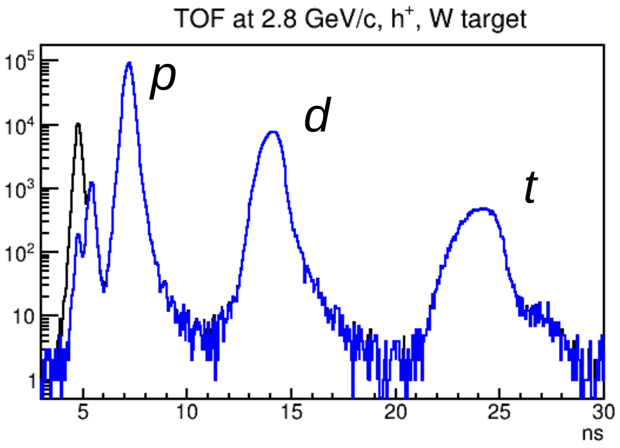
- 50, 25 GeV/c proton and 20 GeV/A carbon beams are accessible. The beam intensity is 10^{13}/spill and 10^{10}/spill respectively.
- Narrow acceptance: ~3% over recoil momentum and 10 mrad over θ.
- Available targets: H_2, *C, Al, Cu, W*. The thickness is < 1%.
- Laboratory viewing angles can vary from 22 to 55 degree by moving magnets inside the “hot area”.

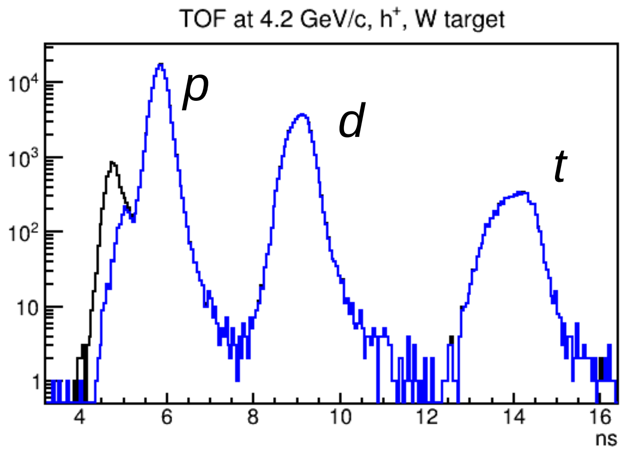
Spectrometer composition in the "cold zone"

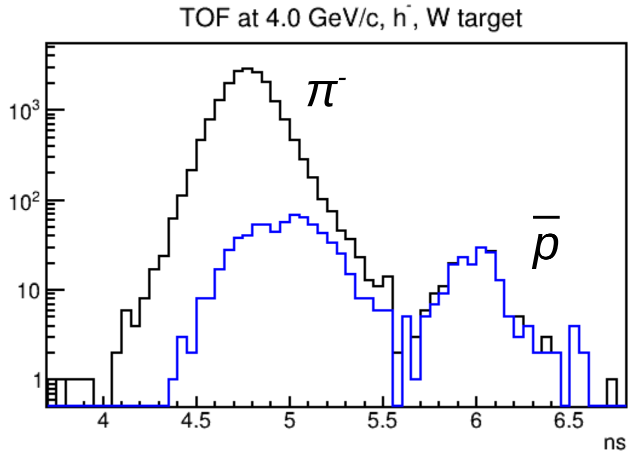


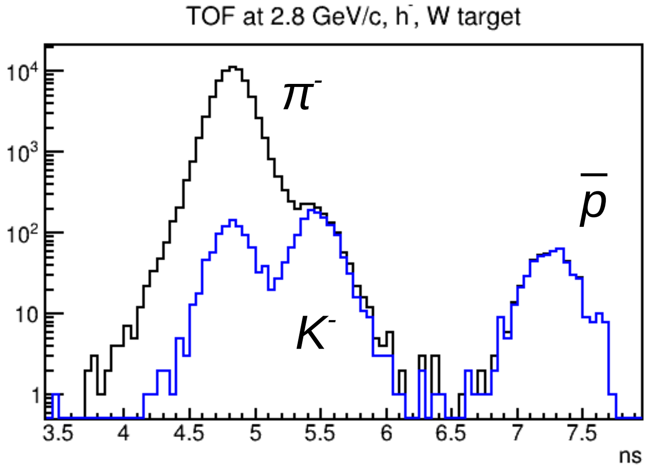
- C1 … C5 – scintillation trigger counters
- SP-12A, prop., drift chambers – magnetic spectrometer
- MRPC1, MRPC2 – TOF system

Time of Flight particle identification









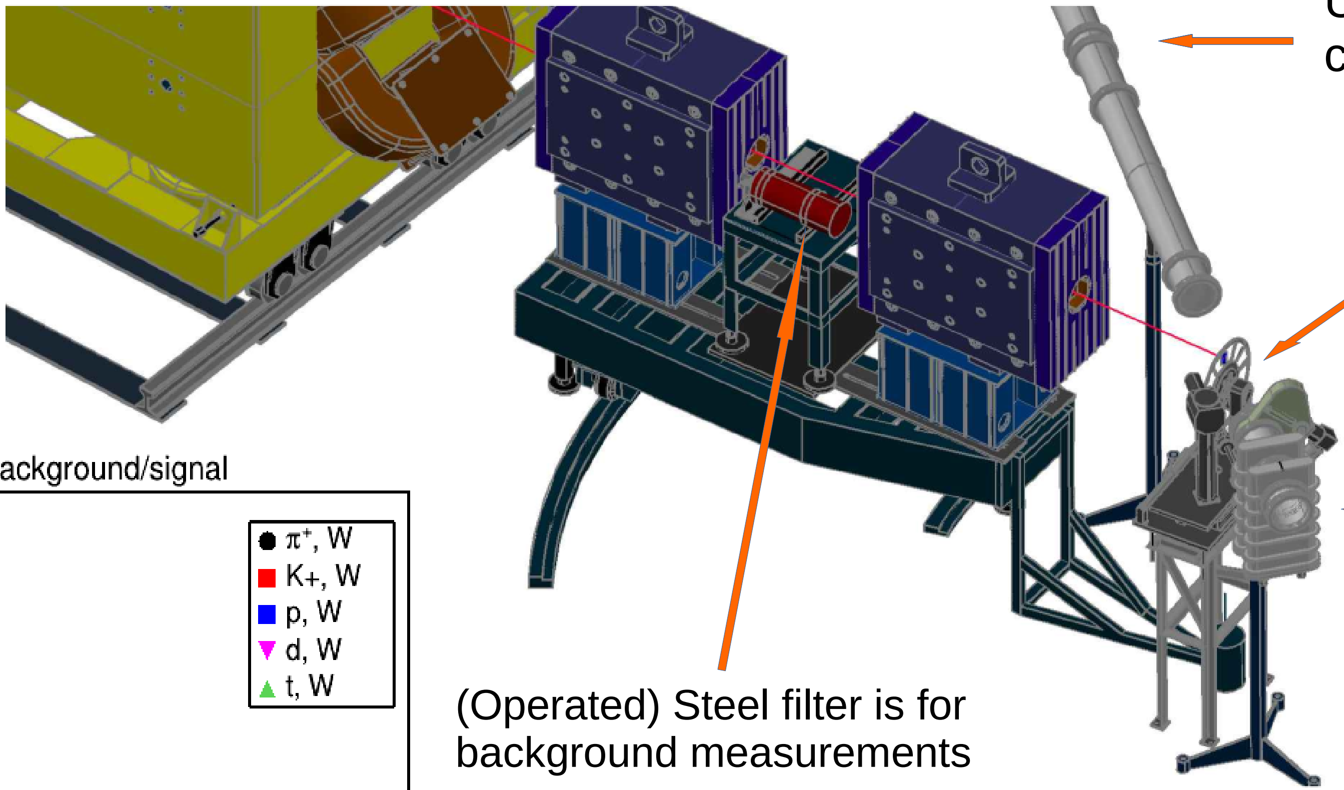
The TOF time resolution is 120 ps.

Black histograms include all TOF events.

Blue histograms contain events without the cherenkov signal.
The cherenkov counter efficiency is 99%

K fraction extracted by fitting *K*- *π* area with two Gaussian functions.

“Hot area”. Upstream detector part.

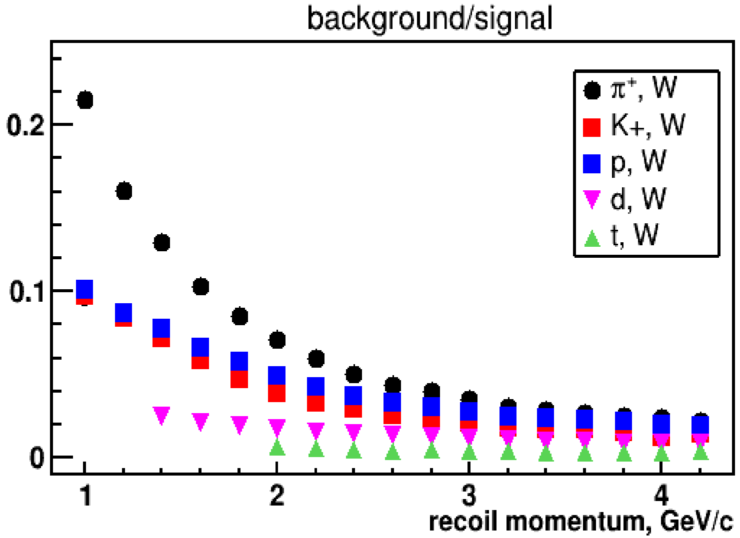


U70
channel 8

Operated target
station

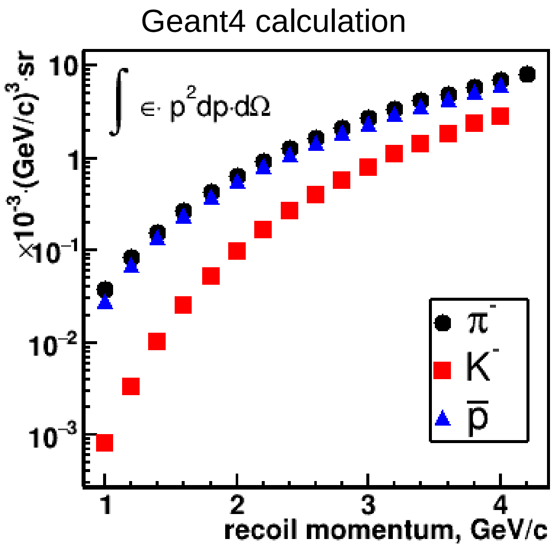
Beam
profilometer

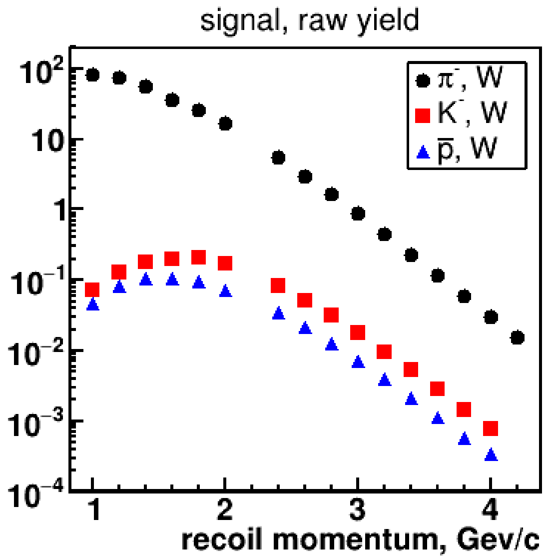
(Operated) Steel filter is for
background measurements

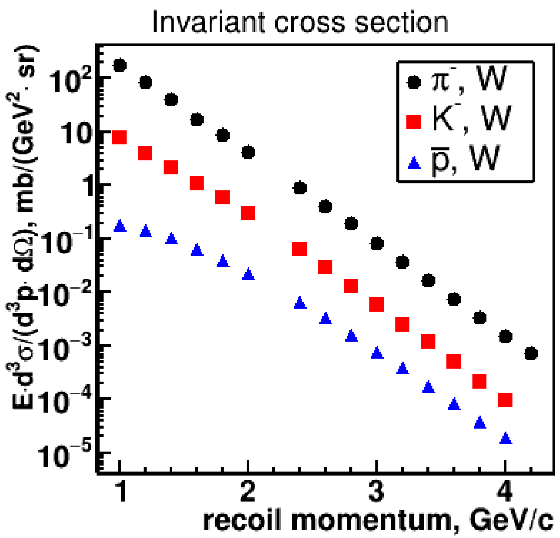


Background = «filter + target» - «filter + no_target» + «no_target»

Cross-section recovery algorithm







Using geant4, for a particle appearing in a detector phase space, survival probability tables (ε(p) acceptance) for passing through the spectrometer are calculated

In the first approximation, the inclusive cross section is calculated from the ratio of experimental yields and the acceptance integral.

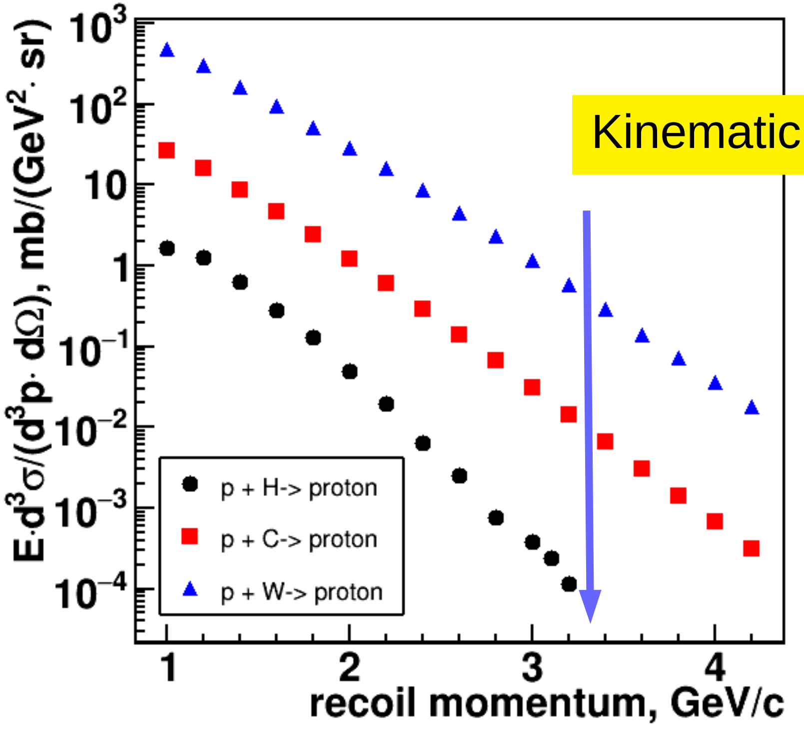
The cross section function is set at experimental points. When connecting points by using a cubic spline, a continuous cross-section function is obtained.

In a few iterations, the inclusive cross-section is adjusted so that the integral of this cross-section with the acceptance tables reproduces the experimental data with an accuracy of 1%

Detector sensitivity to the cumulative signal.

A cumulative effect is the effect of the birth of particles in a kinematic region inaccessible to interactions with a “free” nucleon.

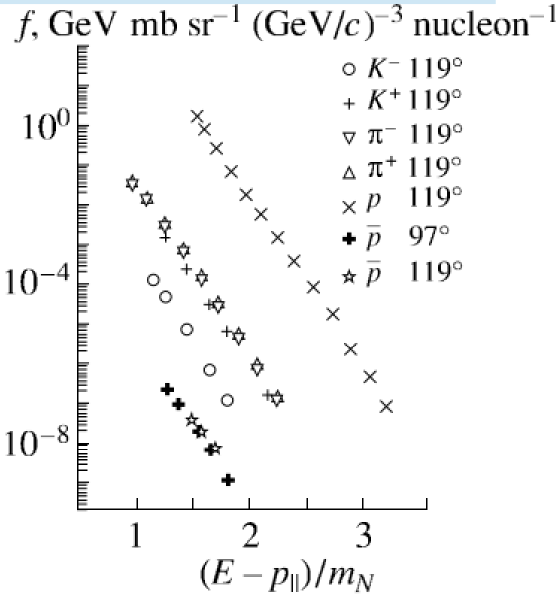
Invariant cross-sections of protons knocked out from H, C and W targets.



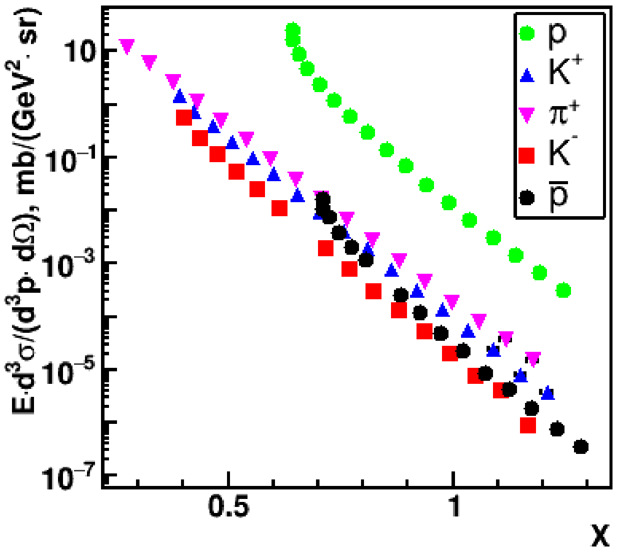
Kinematic limit for protons at recoil angle 40 deg

Comparison with a well known experimental data.

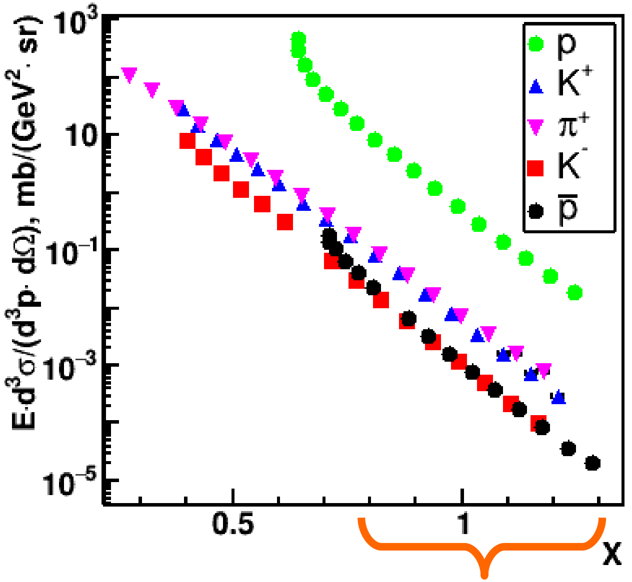
Г.А. Лексин, ЯФ, т. 65, № 11, 2002, стр. 2042 — 2051



C target



W target



Large fraction of cumulative processes

- В.С. Ставинский, Физика Элементарных Частиц и Атомного Ядра, т. 10, вып. 5, 1979, стр. 949-995
- С.В. Бояринов и др., ЯФ, т. 57, № 8, 1994, стр. 1452 - 1461

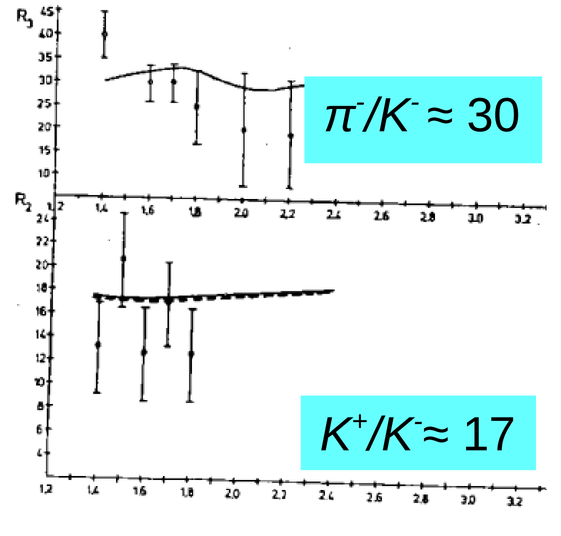
$$\mu + X\, m \rightarrow m_c + [(X\, m) + m_b]$$

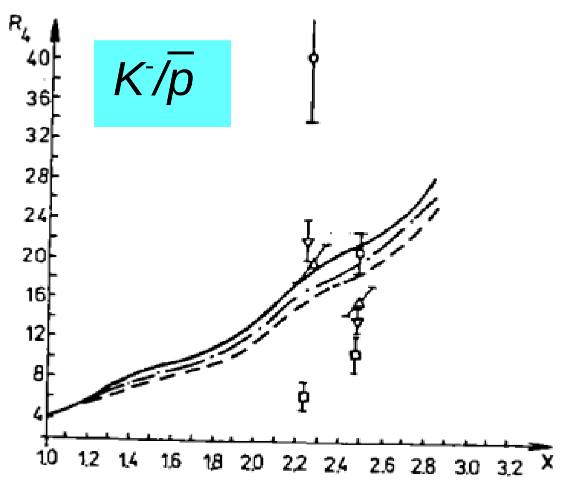
$$X = \left(\frac{E_c - \beta_\mu p_c \cos\theta_c}{m}\right)\left(1 - \frac{E_c + m_b}{E_\mu}\right)^{-1} + \frac{m_b^2 - m_c^2 - \mu^2}{2m\,(E_\mu - E_c - m_b)}$$

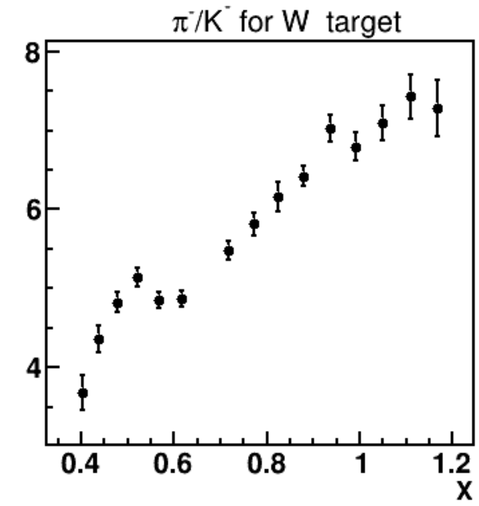
- ✔ Nuclear scaling
- ✖ Super scaling
- ✔ $\pi^+ \approx \pi^- \approx K^+$
- ✖ $K^+/K^- \approx 10$
- ✖ $\bar{p} \sim K^-$

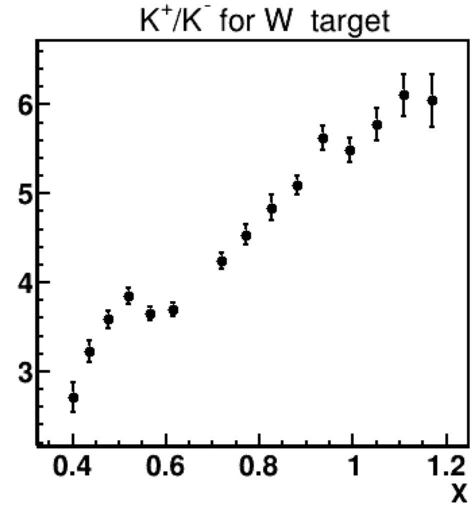
A. V. Efremov et. al., preprint JINR E2-93-224, 1993

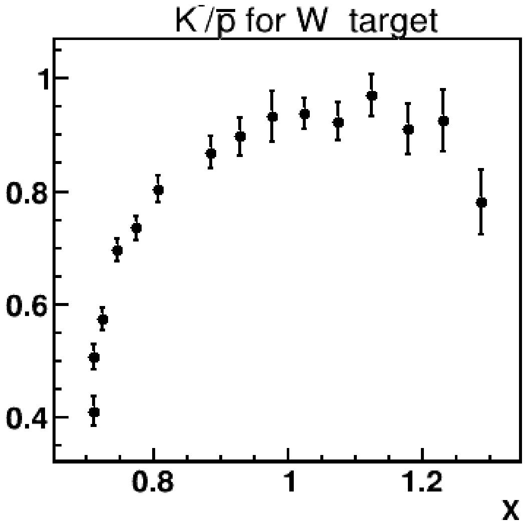
Some theoretical predictions compared to our data.





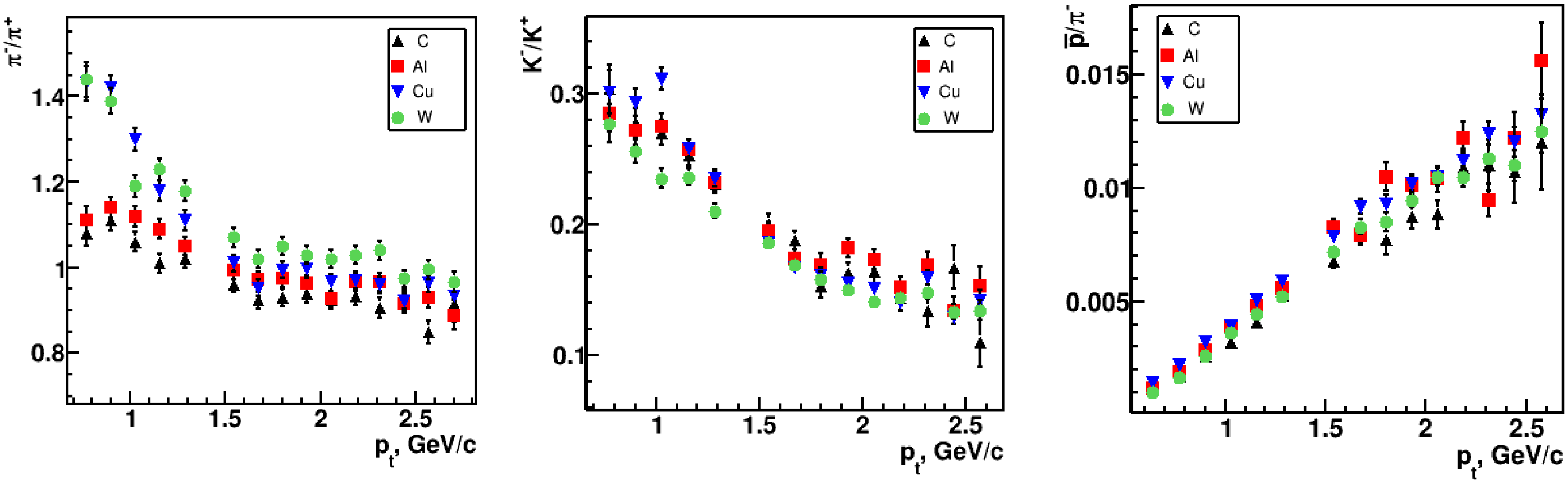






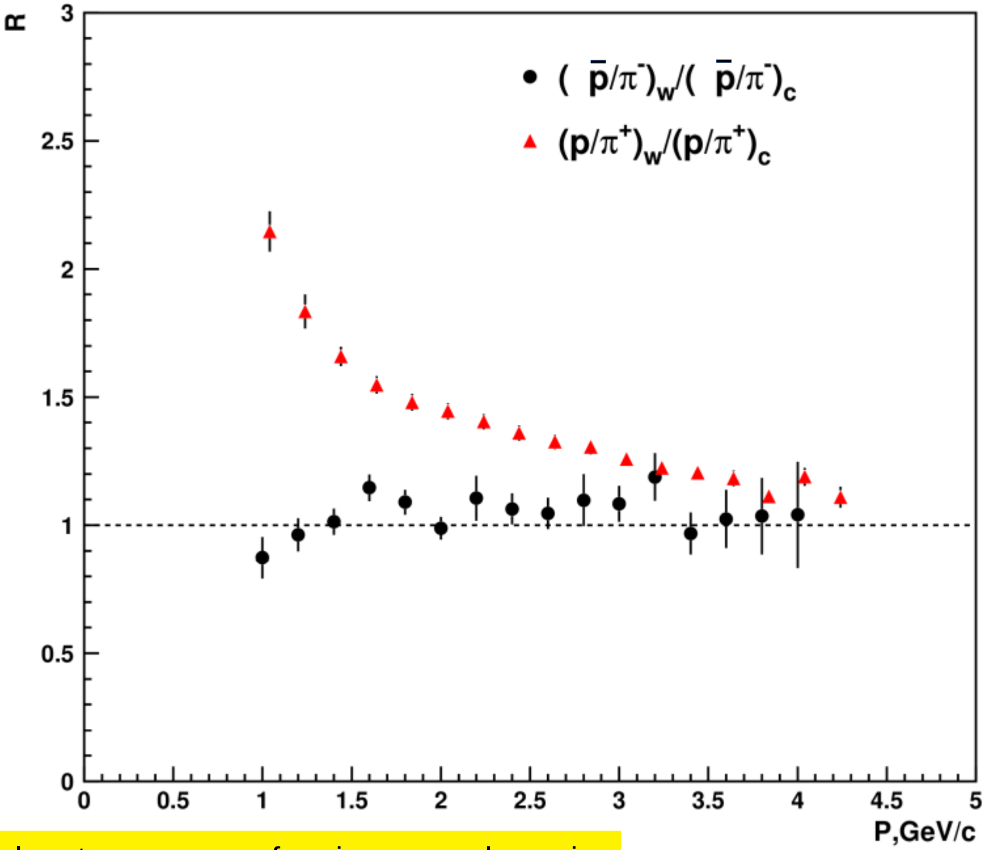
Perhaps, the cumulative particle consideration based on *qq* interaction can be too simple.

Ratios which are weakly dependent on a nucleus size.



- Due to stratification up to 10% of the π^-/π^+ ratio when move from *C* to *W* target it is impossible to completely exclude the influence of nucleus.
- K^- and K^+ interact in the nucleus in the same way.
- It is possible that for $\bar{p}$ a nuclear transparency is observed: The radius of *W* is 2.5 times the radius of *C*. For the 1 ÷ 4 GeV/c the total $\bar{p}p$ cross-section is more then 2 time large than for $\pi^- p$.

Double relations indicate that the transparency of the nucleus for $\bar{p}$ is greater than for knocked-out protons.



The indication of the nuclear transparency for pions was shown in N. Antonov et al., JETP LETTRS Vol. 108 № 12 2018, p 783

Indication of “higher twist” contribution to the inclusive spectra

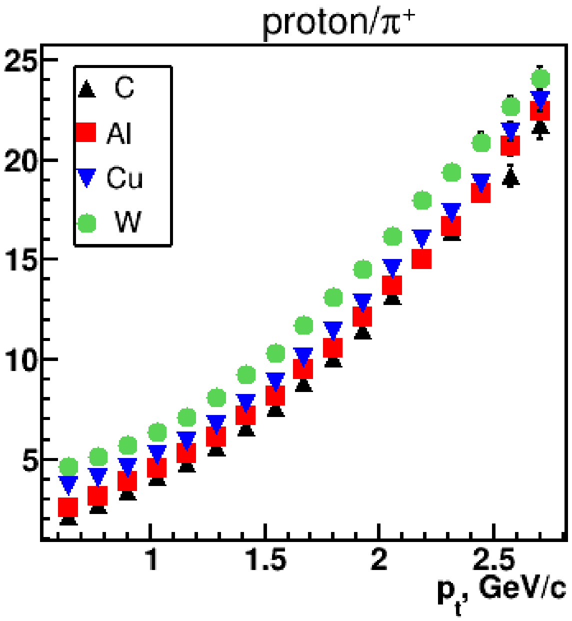
Stanly J. Brodsky
https://www.bnl.gov/rhic/news/011508/story2.asp#figA2

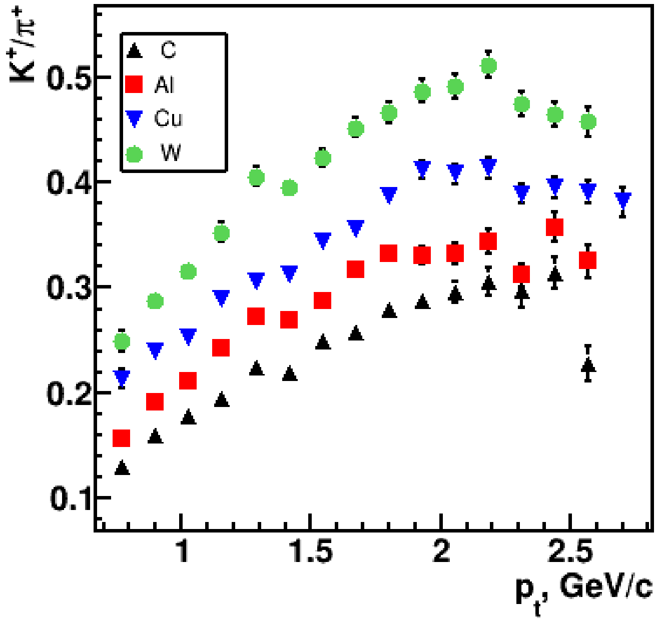
- Rising yield of baryons.
- Non-decreasing *K/π* ratio

The appearance of colourless quark states

$$\frac{E \cdot d\sigma}{d\vec{p}} \sim \frac{f(x_t)}{p_t^n}$$

$n > 4$





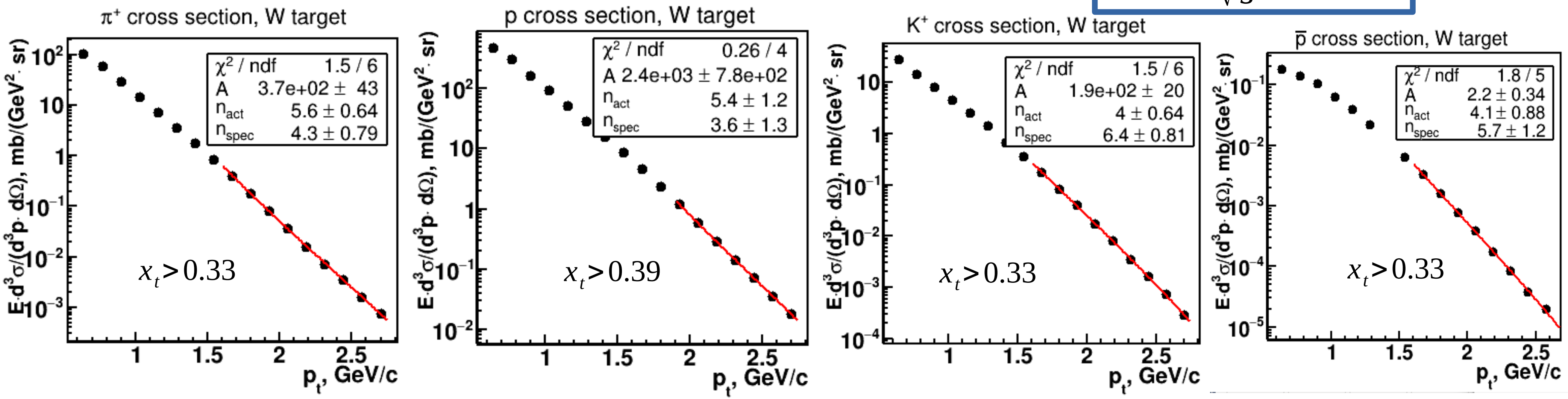
The fraction of K^+ mesons rise with increasing nucleus size

F. Arleo et. al., Phys. Rev. Lett. 105, 062002 (2010)

D. Antreasyan, et. al., Phys. Rev. D, Vol. 19, Num. 3, 1979, p764

experiment:

$$x_t = \frac{2 p_t}{\sqrt{s}} > 0.35$$



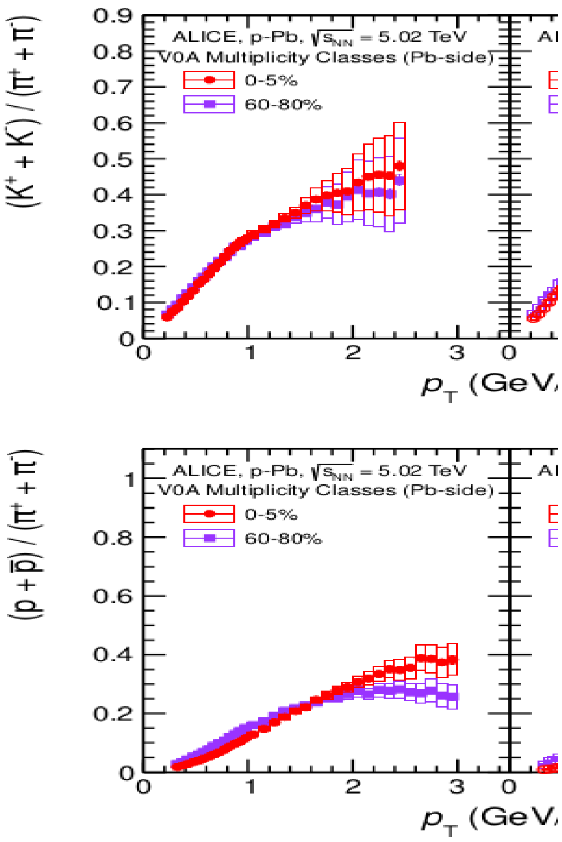
Fitting intervals were selected based on the minimum of χ^2 and the accuracy of parameter recovery at the level of 10%. Within errors there is no dependency on the nucleus size.

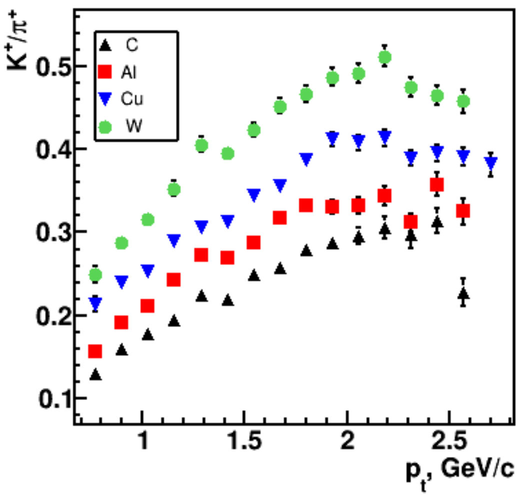
Averaged over *C, Al, Cu, W* fit parameters:

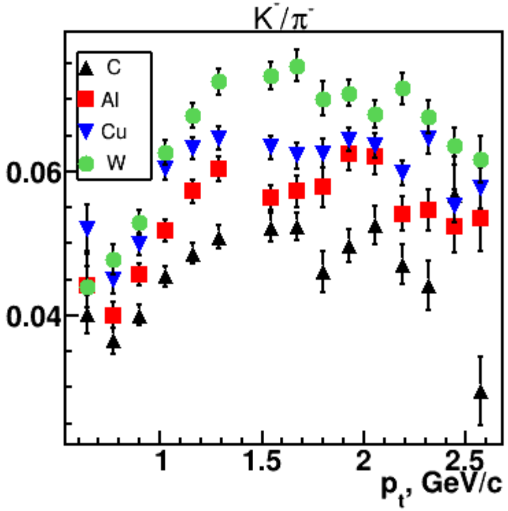
$$E\frac{d\sigma}{d^3 p} \sim \frac{\left(1 - x_T\right)^{2 n_{spec} - 1}}{p_T^{2 n_{act} - 4}}$$

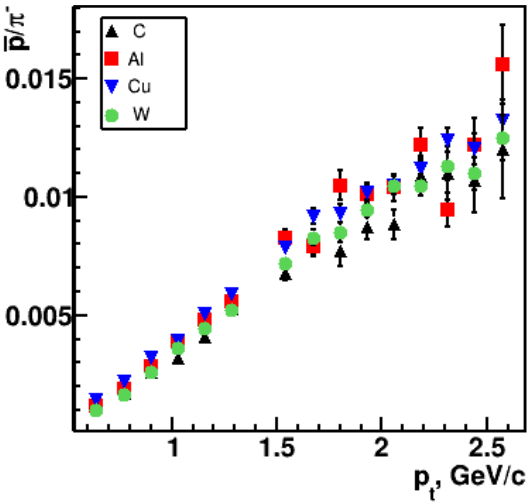
	$\bar{p}$	K^-	K^+	π^-	π^+	p
$\langle n_{act} \rangle$	4.7 ±0.5	4.4 ±0.5	4.5 ±0.4	5.6 ±0.4	5.8 ±0.4	5.6 ±0.6
$\langle n_{spec} \rangle$	5.3 ±0.7	6.5 ±0.7	6.0 ±0.5	4.7 ±0.4	4.4 ±0.4	3.7 ±0.7

Possible “similarity” for the measured relations with the data at ultra-high energies in *pA* interactions.









Despite the huge difference in √s there are 3 joining properties:

- increase of baryon yield
- similar K^+/π^+ ratios
- growth of the $\bar{p}/\pi^-$ *ratio*

CERN-PH-EP-2013-135, July 25, 2013
Nucl. Phy. A932 (2014) 146-151

Summary

- A violation of the cumulative "super-scaling" was observed for a large p_t domain.
- The possible nuclear transparency is observed for cumulative π mesons and $\bar{p}$.
- The probable similarity of relations between mesons and $\bar{p}$ at transverse momentum up to 2.5 GeV/c with the data obtained at *TeV* energies is indicated.

Thank you for your attention!