Study of cumulative processes in hadronic collisions in correlation with strangeness and charm production at SPS and NICA energies

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The Outline

- Formation of cumulative particles on flucton
- Correlation between cumulative processes and strangeness and charm production
- The concept of a new compact detector
- Estimation of yields and particle identification

Formation of cumulative particles on fluctons

1957 - in Dubna protons in backward hemisphere were registered

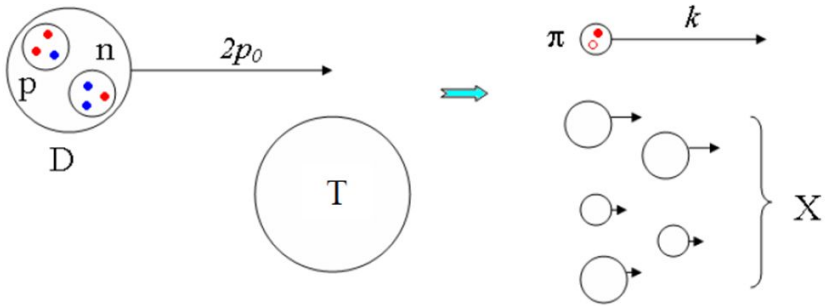
G.A. Leksin et al., ZhETF 32, 445 (1957)

1957 - D.I. Blokhintsev proposed that nuclear **fluctons** are clots of cold, dense nuclear matter consisting of several nucleons.

Blokhintsev D.I., JETP 33 (1957) 1295

1971 - this effect was confirmed by a group of researchers led by A.M. Baldin and V.S. Stavinsky in Dubna.

A. M. Baldin, et al. AIP Conf. Proc. 2 (1971), 131-139
A.M. Baldin et al., Yad. Fiz. 18 (1973) 79
Stavinsky V.S. // Phys. Elem. Part. Atom. Nucl. 1979. V. 10. № 5. P. 949

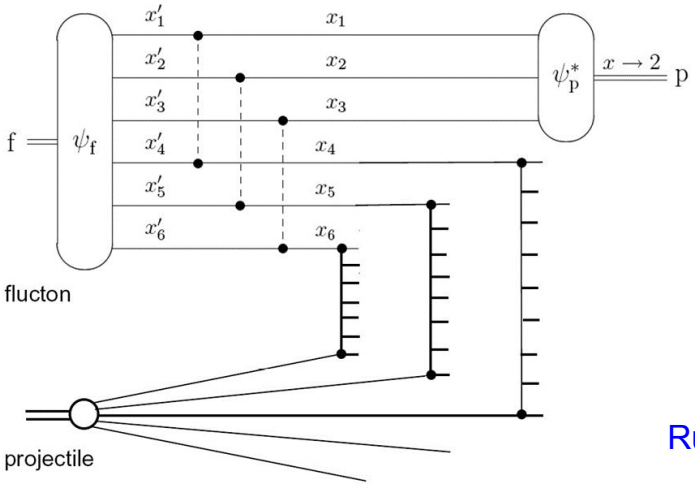


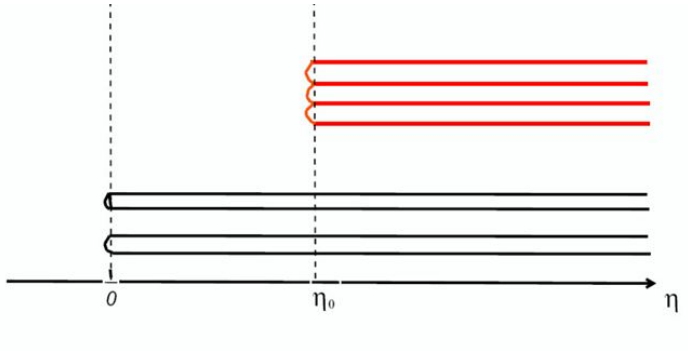
Schematic illustration of Baldin and Stavinsky's experiments in Dubna: D + T => π + X (D - projectile deuterons; T - some target)

V. Vechernin, in materials of the IVth Russian-Spanish Congress, 2017, JINR, Dubna

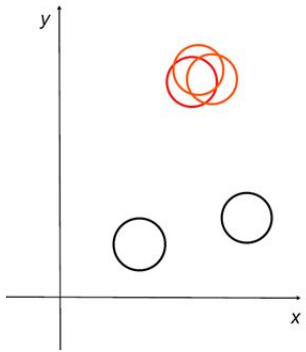
Cumulative processes in correlation with charm and strangeness production

- An **interesting new mechanism** of the production of strange and multistrange hyperons along with heavy flavors as a result of flucton fragmentation in the cumulative **process was proposed by V.V. Vechernin**.
- The flucton remnants interact with the projectile and form quark-gluon strings, which are compressed in the transverse plane, which leads to an **increased yield of strangeness and charm.**



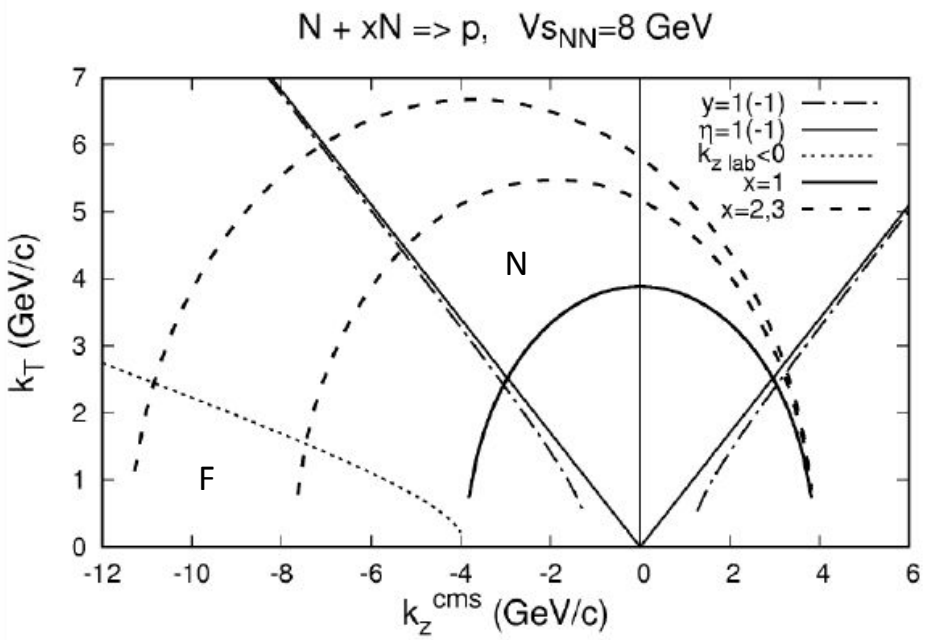


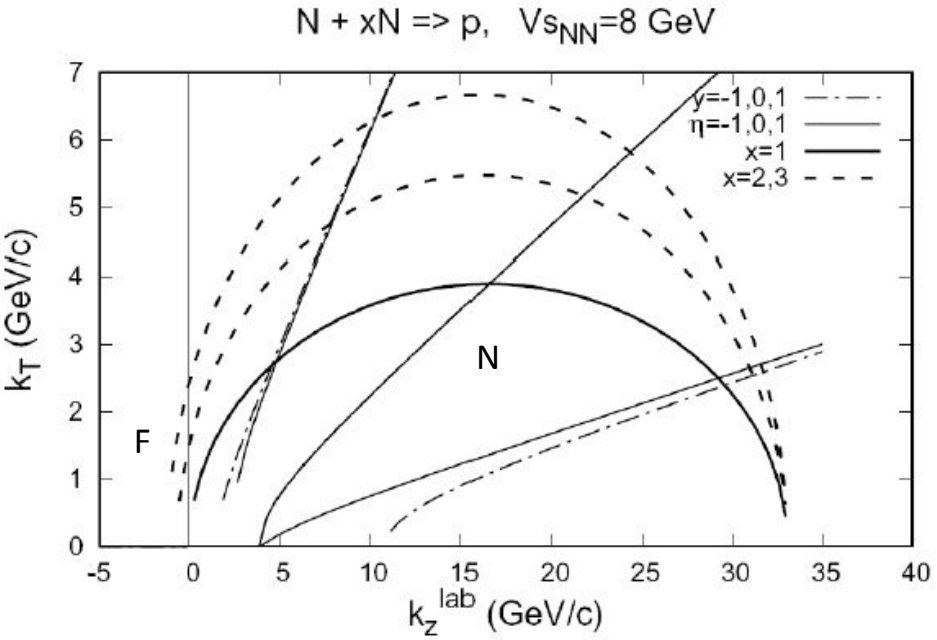
V. Vechernin, in materials of the IVth Russian-Spanish Congress, 2017, JINR, Dubna



V.V. Vechernin, Physics of Particles and Nuclei 52 (4) 604-608 (2021)

Kinematic boundaries for pA collisions in collider mode





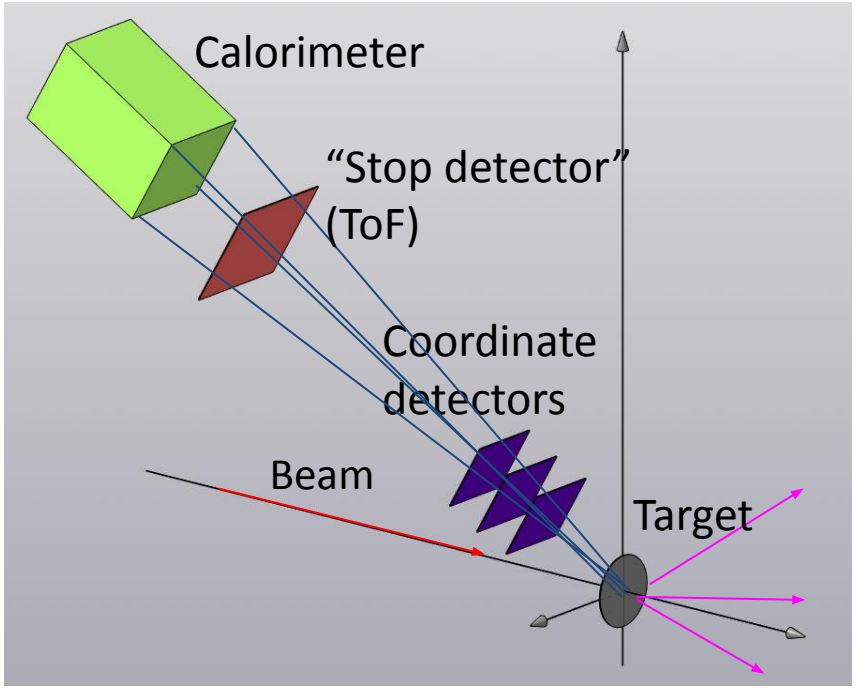
x - cumulative number, y - rapidity, η - pseudorapidity, N - NICA acceptance, F - backward hemisphere in lab system

The concept of a new compact detector

Compact detector system to search for cumulative effects could be proposed in experiments on a fixed target (NA61, BM@N).

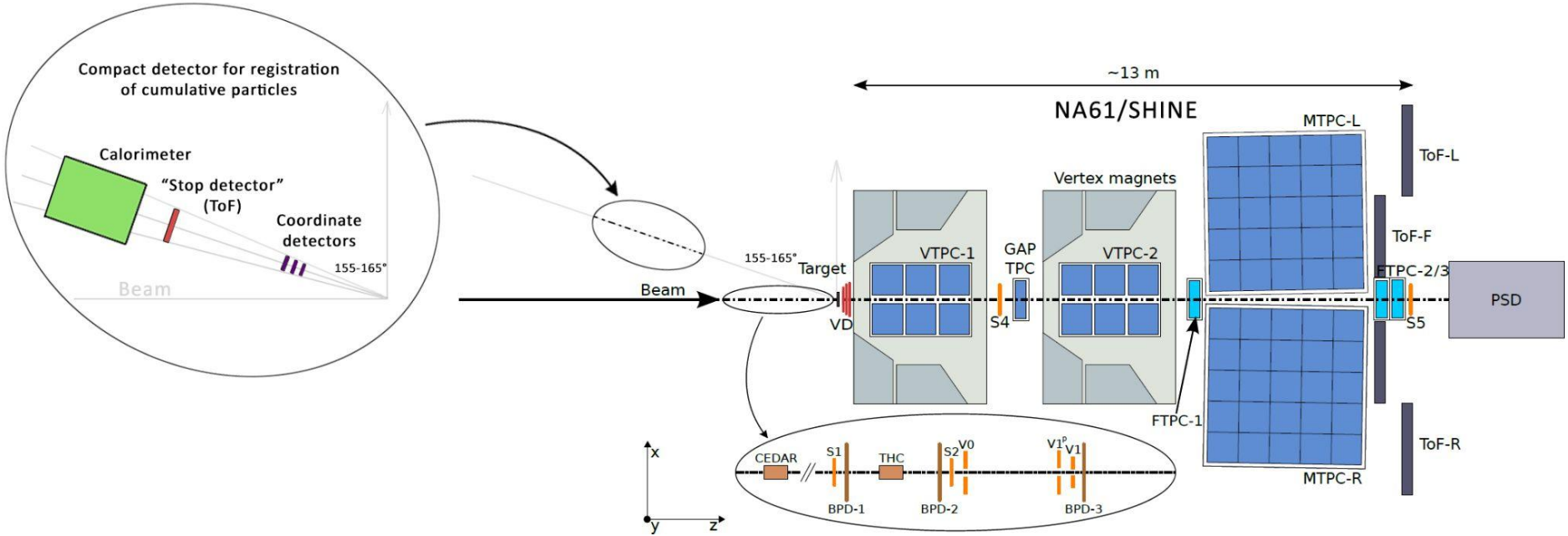
Key Ideas:

- determination of the type of particles outside magnetic field by time-of-flight + calorimeter
- determination of vertex by coordinate detectors



Possible addition to NA61 experimental setup

(not to scale)

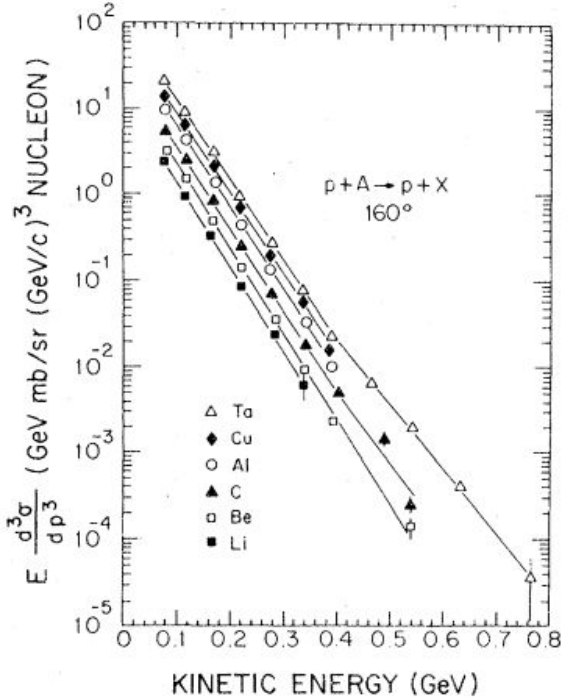


Estimation of yields of cumulative protons

$$f(x, k_\perp) = \frac{E}{A} \cdot \frac{d^3\sigma}{dp^3} \xrightarrow{fitted} C(\theta) exp\left(-\frac{x}{x_0}\right)$$

$$x = \left(1 - \frac{E}{E_0}\right)^{-1} \cdot \left[\frac{E - \beta_0 p \cos(\theta)}{m_p} - \frac{m_p}{E}\right]$$

E , p- energy/momentum of registered proton, E_0 - energy of incident particle



Bayukov Y.D., Efremenko V.I., Frankel S. et al. // Phys. Rev. C. 1979. V. 20. № 2. P. 764.

Estimation of yields of cumulative protons

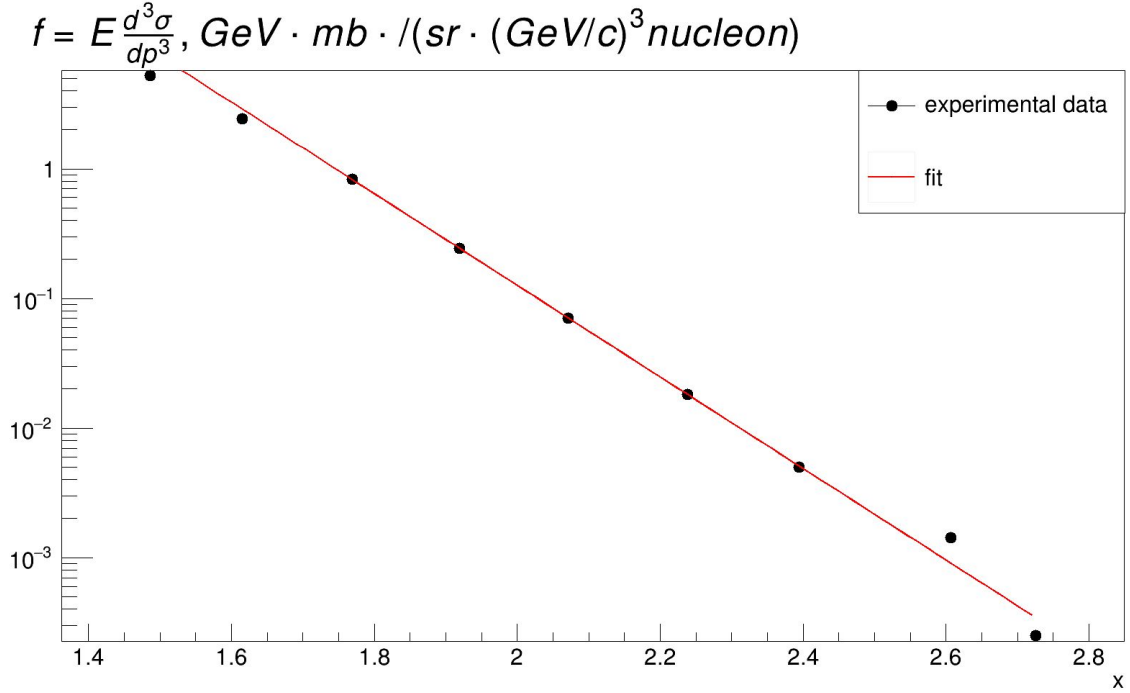
$$\sigma = \int_a^b C exp(-\frac{x}{x_0})dx, \quad \frac{mb}{sr \cdot nucleon}$$

$$L = \frac{\rho}{A} \cdot d \cdot N_A \cdot j, \quad cm^{-2}$$

$$N = A \cdot \sigma \cdot L \cdot acc, \quad cumulative\ particles$$

acc - acceptance of detector, j - number of pA collisions, d - width of target,
ρ - density of target, L - luminosity

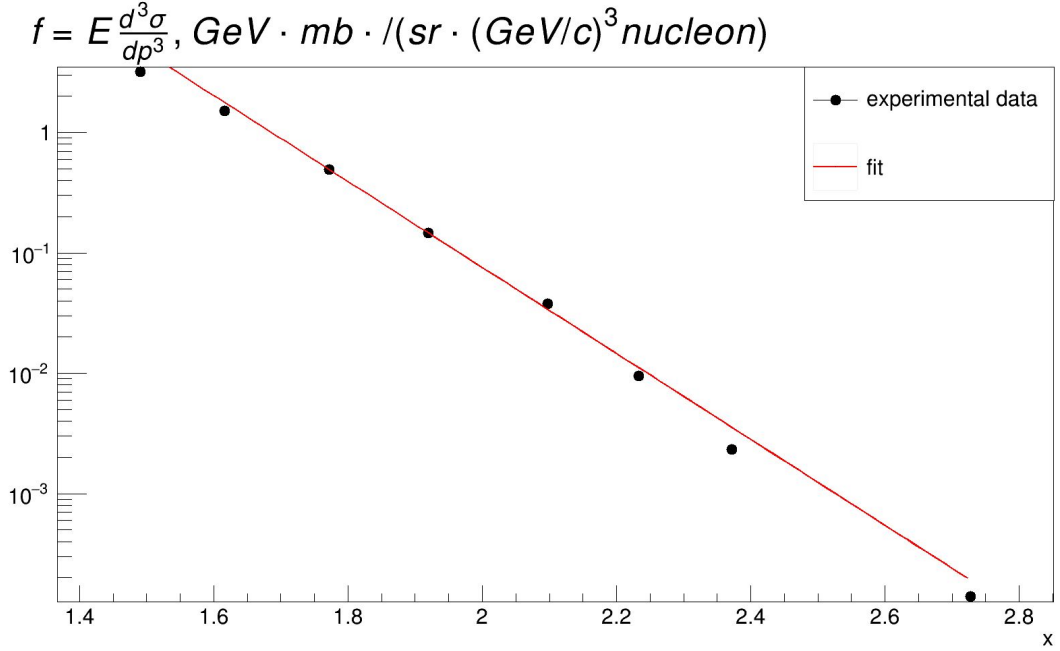
Estimation of yields of cumulative protons



400 GeV p+C collisions, registration angle 160 degrees

Points from article by Bayukov Y.D., Efremenko V.I., Frankel S. et al. // Phys. Rev. C. 1979. V. 20. № 2. P. 764.

Estimation of yields of cumulative protons



400 GeV p+Be collisions, registration angle 160 degrees

Points from article by Bayukov Y.D., Efremenko V.I., Frankel S. et al. // Phys. Rev. C. 1979. V. 20. № 2. P. 764.

Summary table:

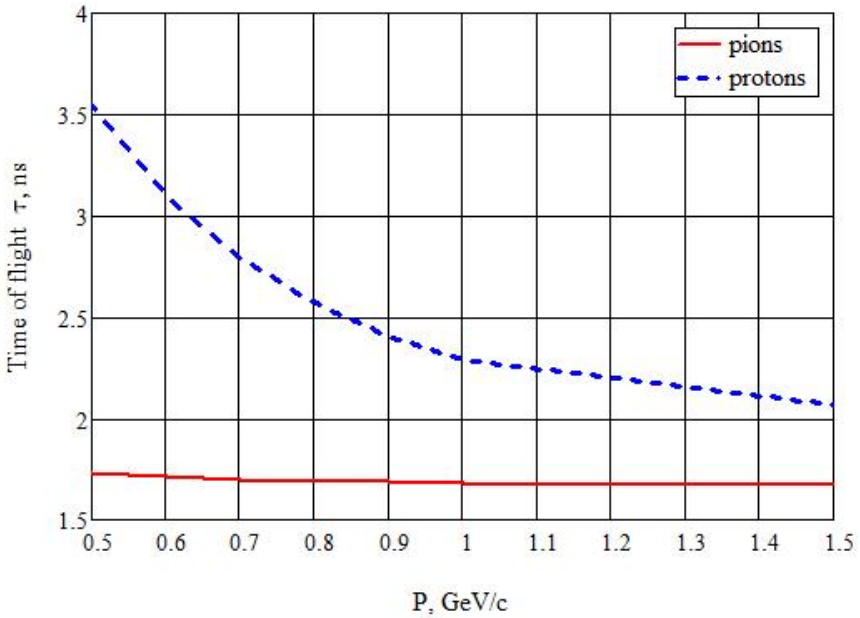
x	Be	C
1.5 – 2	1.79	3.51
2 – 3	0.03	0.06

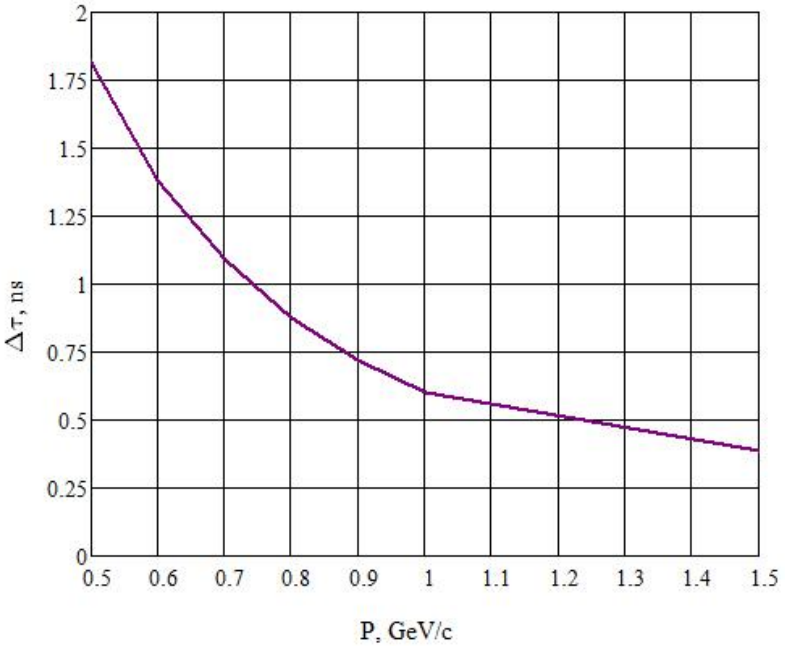
Table 1: Number of cumulative events per 10^6 pA collisions

Time-of-flight for protons and pions

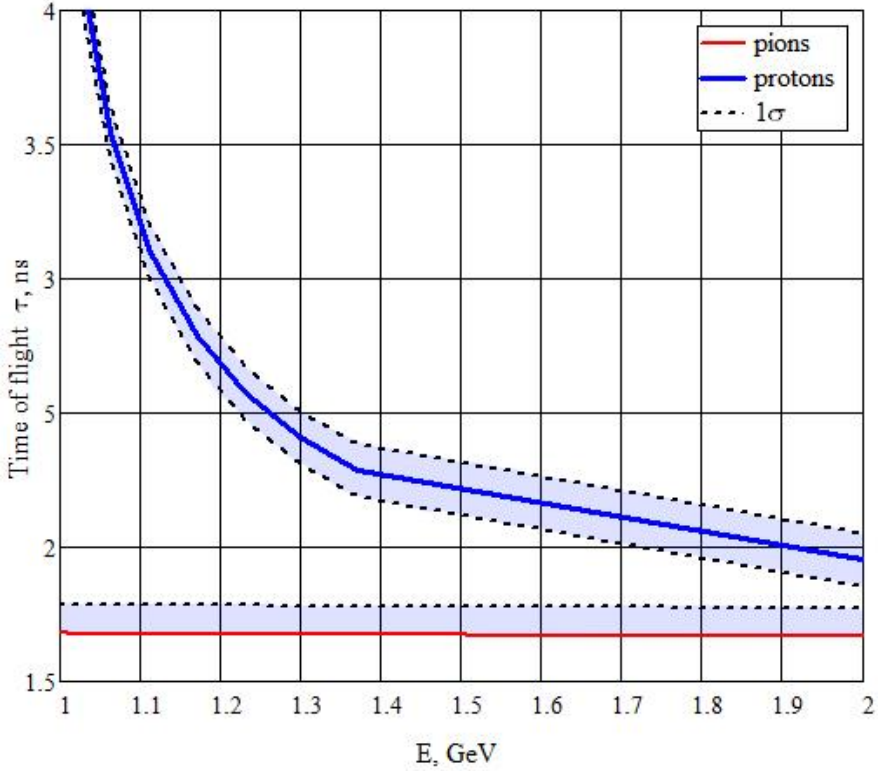
$$\tau = \frac{L}{\beta C};\ \beta = \frac{p}{\sqrt{p^2 + m^2}} \qquad \Delta\tau = \frac{L}{C}\left(\frac{1}{\beta_p - \beta_\pi}\right)$$

Flight base: $L = 0{,}5\ m$





Correlations Energy and ToF



$$E = \sqrt{m^2c^4 + p^2c^2}$$

Flight base: $L = 0{,}5\ m$

Summary

- Based on new mechanism of charm and strangeness production (V.V. Vechernin) new concept of compact detector for registration of cumulative particles in fixed target experiment is proposed.
- Yields of cumulative particles were estimated to be 1.82 for p+Be reaction and 3.57 for p+C reaction per 1 million pA collisions for given width and acceptance.
- Modern tof systems with resolution of ~100 ps and calorimeter with moderate energy resolution will allow us to separate protons from pions.

Acknowledgments

The authors are grateful to V.V. Vechernin for valuable remarks and discussions.

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Thank you for your attention!

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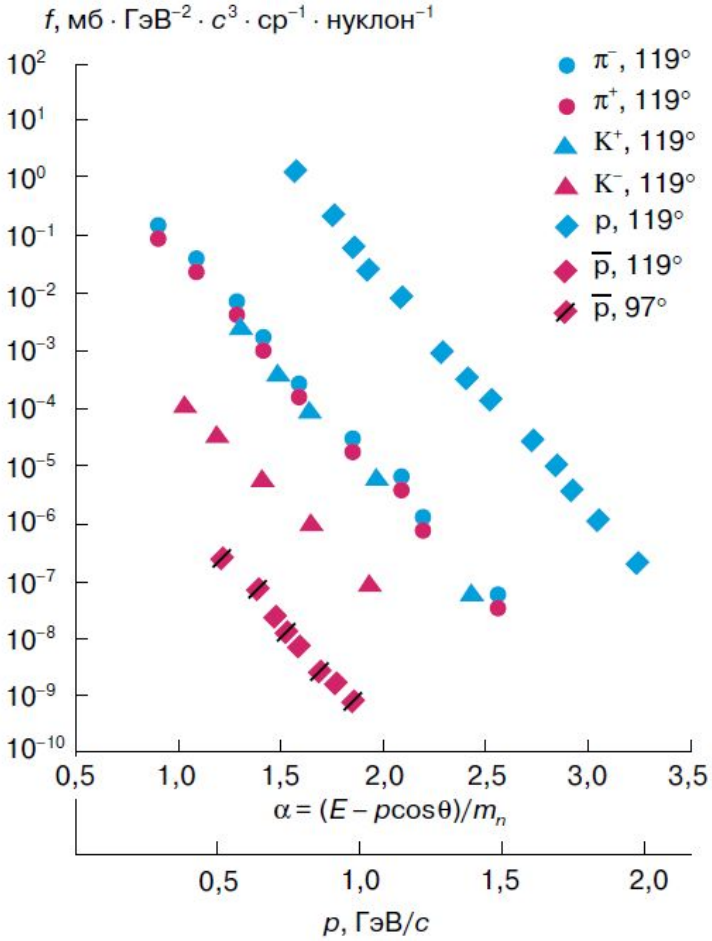

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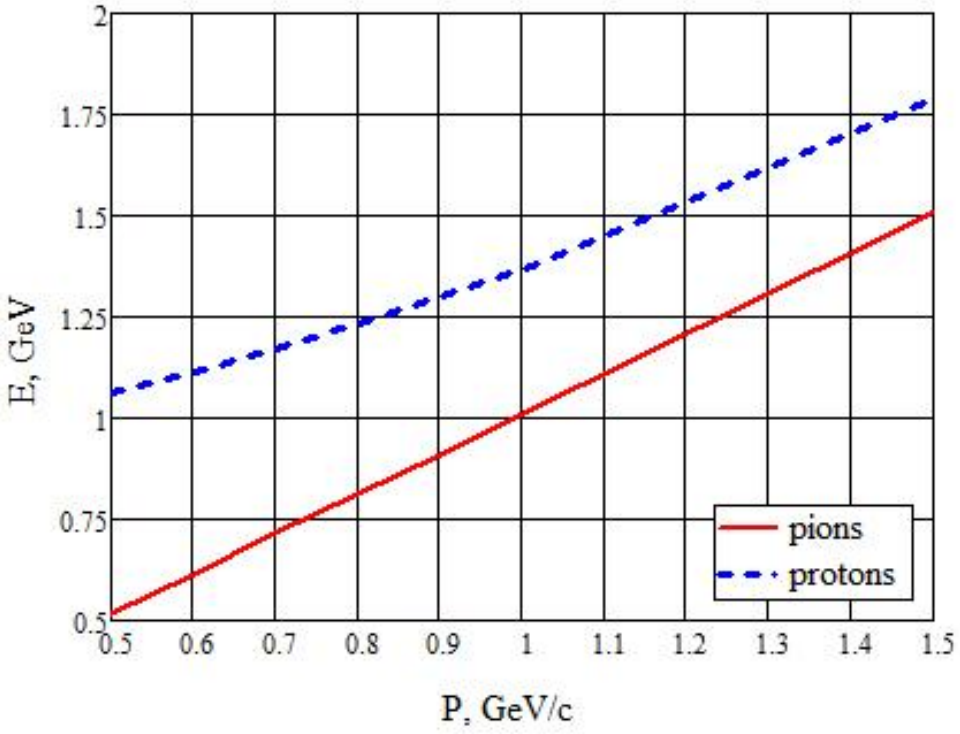
E, GeV
P, GeV/c
pions
protons
2
1.75
1.5
1.25
1
0.75
0.5
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5