Cumulative production of nucleons by heavy baryonic resonances in proton-nucleus collisions

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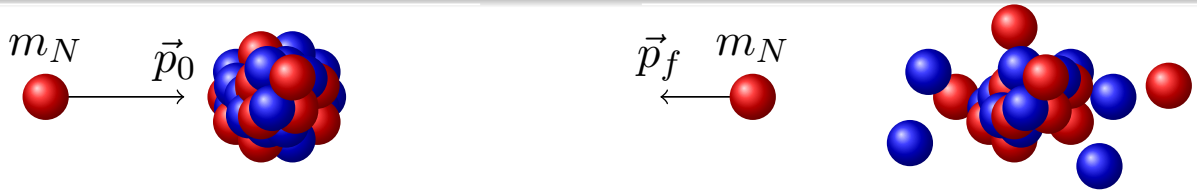
Outline

Introduction

Cumulative effect

- It is a creation of particle in p+A collision with energy outside the kinematical boundary of p+p interactions at the same beam energy.
- Discovered in 1971 in Dubna (Baldin, Leksin).



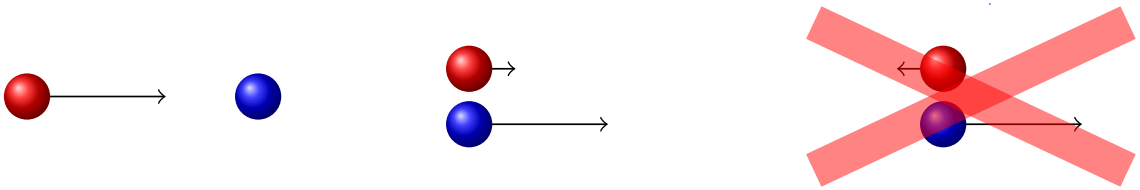
(a) Initial state.

(b) Final state.

Рис. 1: Cumulative nucleon production.

A. Motornenko, M. I. Gorenstein, Journal of Physics G (2017)

Ways of production or cumulative nucleons



(a) Initial state. (b) Final state. (c) Final state.

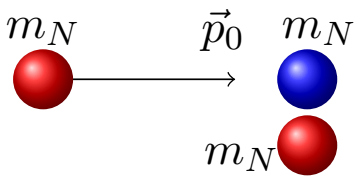
Рис. 2: Nucleon production in $N + N \to N + N$ reaction.

(a) Nucleon collision with moving nuclear nucleon.

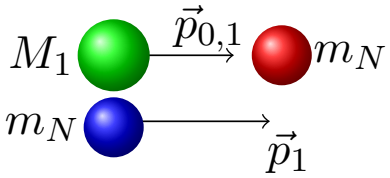
(b) Nucleon collision with coupled nuclear nucleons.

Рис. 3: Cumulative nucleon production.

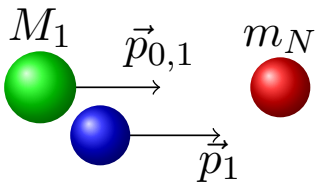
Cumulative nucleon production due to 2 successive collisions



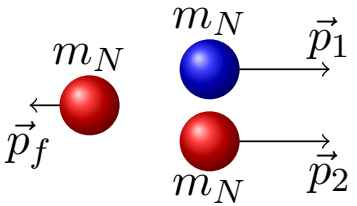
(a) Initial state.



(b) Intermediate state.



(c) Intermediate state.



(d) Final state.

Рис. 4: Nucleon production in $N + 2N \to 3N$ reaction.

Maximal energy of cumulative nucleon and resonance mass and momentum

$$\frac{\partial p_f}{\partial p_i} = 0 \qquad \Rightarrow \qquad p_1 = ... = p_n = p = \frac{p_0 + p_f^*}{2} \tag{1}$$

$$E_f^* = nm_N + \sqrt{p_0^2 + m_N^2} - n\sqrt{m_N^2 + \left(\frac{p_0 + \sqrt{E_f^{*2} - m_N^2}}{n}\right)^2} \tag{2}$$

$$M_k^2 = \left(E_0 + km_N - k\sqrt{m_N^2 + \left(\frac{p_0 + p_f^*}{n}\right)^2}\right)^2 - \left(p_0 - k\left(\frac{p_0 + p_f^*}{n}\right)\right)^2 \tag{3}$$

$$p_{0,k} = p_0 - k\frac{p_0 - p_f^*}{n}, \tag{4}$$

Maximal energy of cumulative nucleon

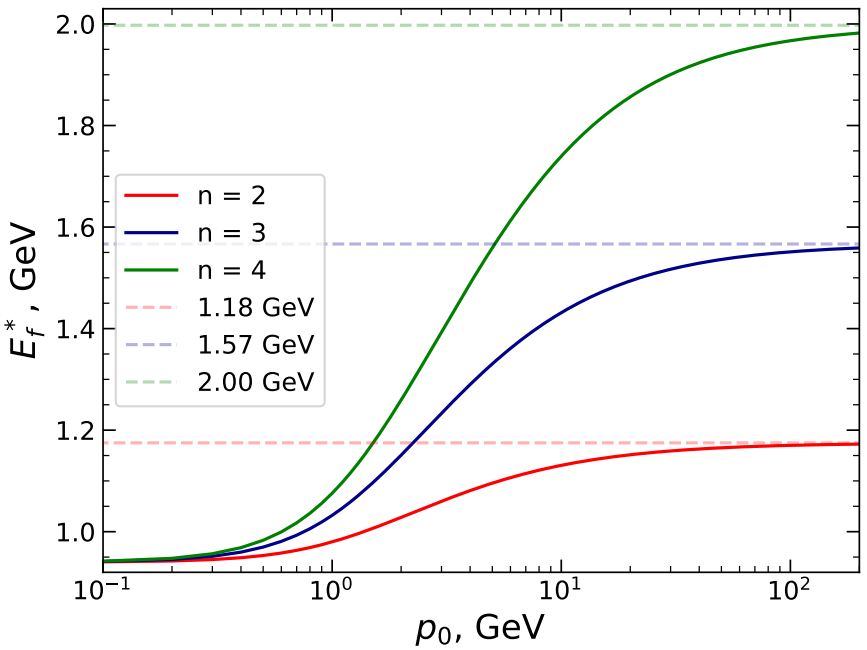


Рис. 5: Maximal energy of cumulative nucleon after 2, 3 and 4 successive collisions.

Resonance mass for n = 4

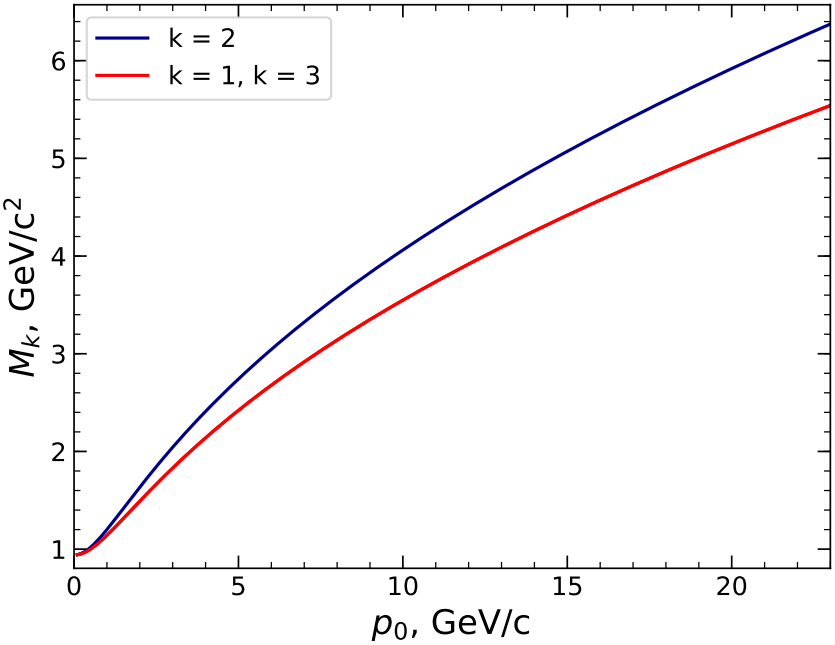


Рис. 6: Mass or resonance after 1, 2 and 3 successive collisions in 4 collision event.

Resonance momentum for n = 8

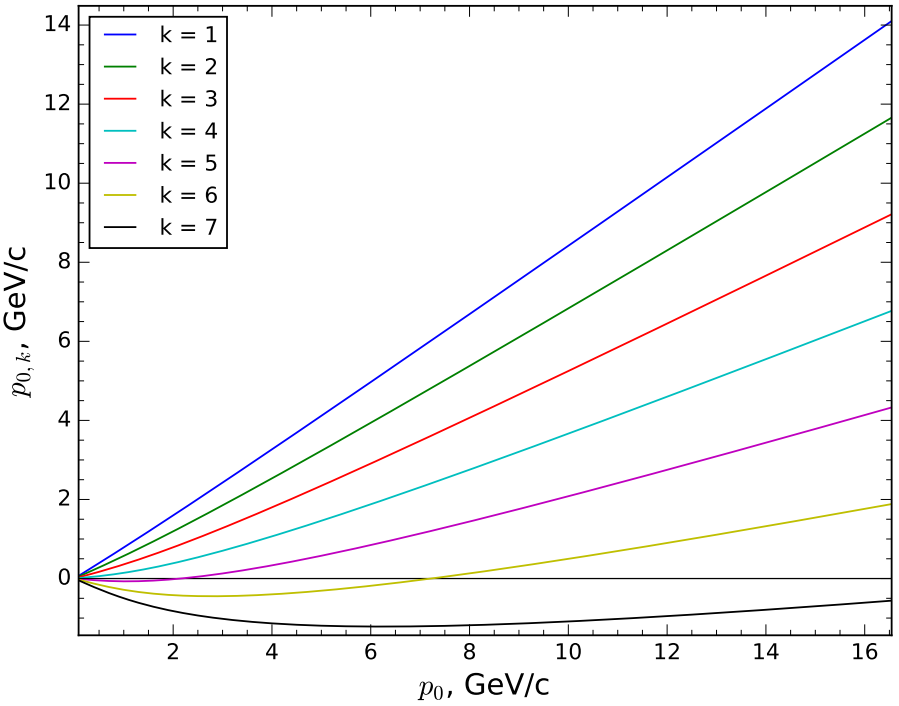
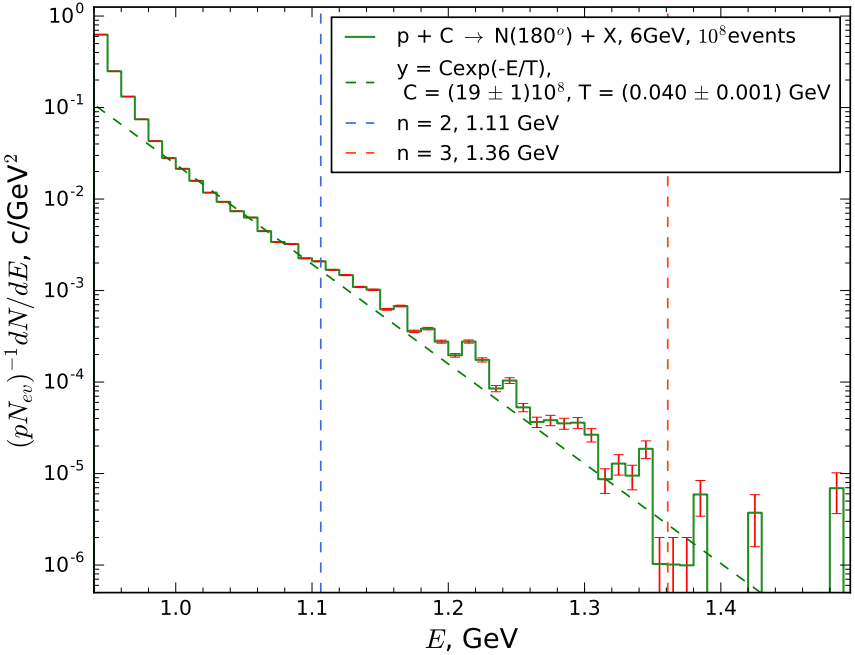


Рис. 7: Momentum or resonance after 1 - 7 successive collisions in 8 collision event.

UrQMD simulations



- p+C reactions,
- $p_{\text{lab}} = 6$ Gev/c,
- 10^8 collisions.

Рис. 8: Cumulative nucleons spectrum.

UrQMD simulations

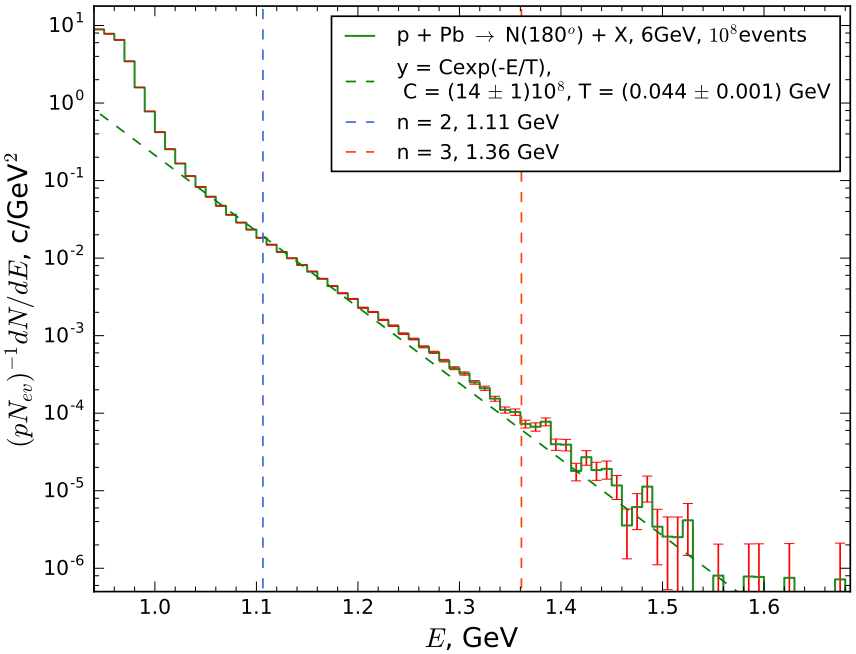
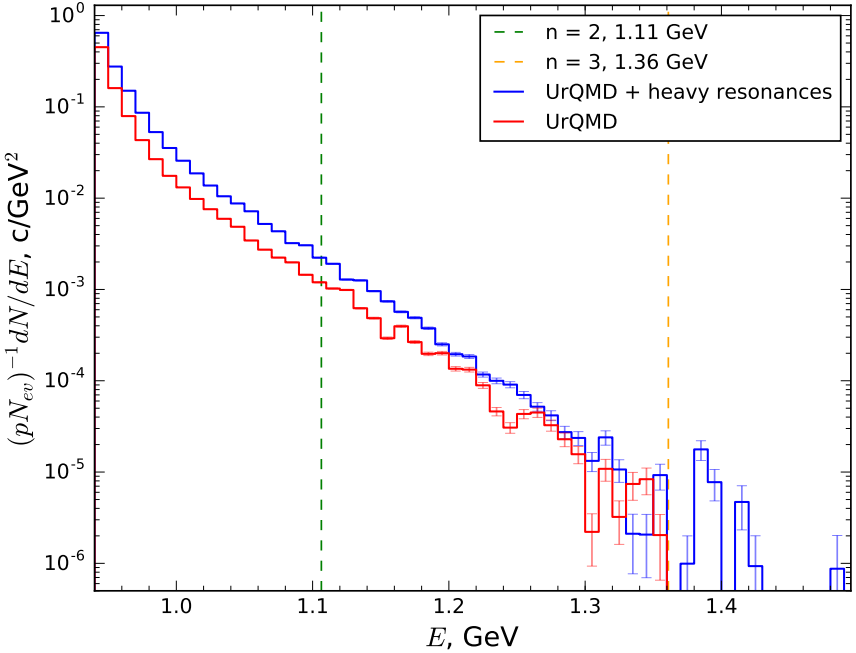


Рис. 9: Cumulative nucleons spectrum.

- p+Pb reactions,
- $p_{\text{lab}} = 6$ Gev/c,
- 10^8 collisions.

UrQMD and UrQMD+HR simulations



- p+C reactions,
- $p_{\text{lab}} = 6$ Gev/c,
- 10^8 collisions.

Рис. 10: Cumulative nucleons spectrum.

UrQMD and UrQMD+HR simulations

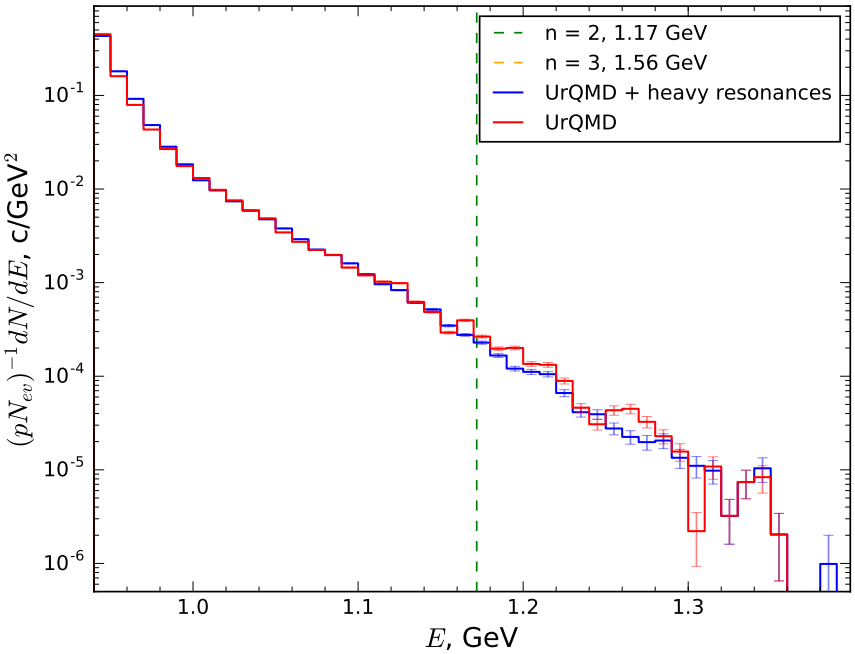


Рис. 11: Cumulative nucleons spectrum.

- p+Pb reactions,
- $p_{\text{lab}} = 158$ Gev/c,
- 10^8 collisions.

UrQMD and UrQMD+HR simulations

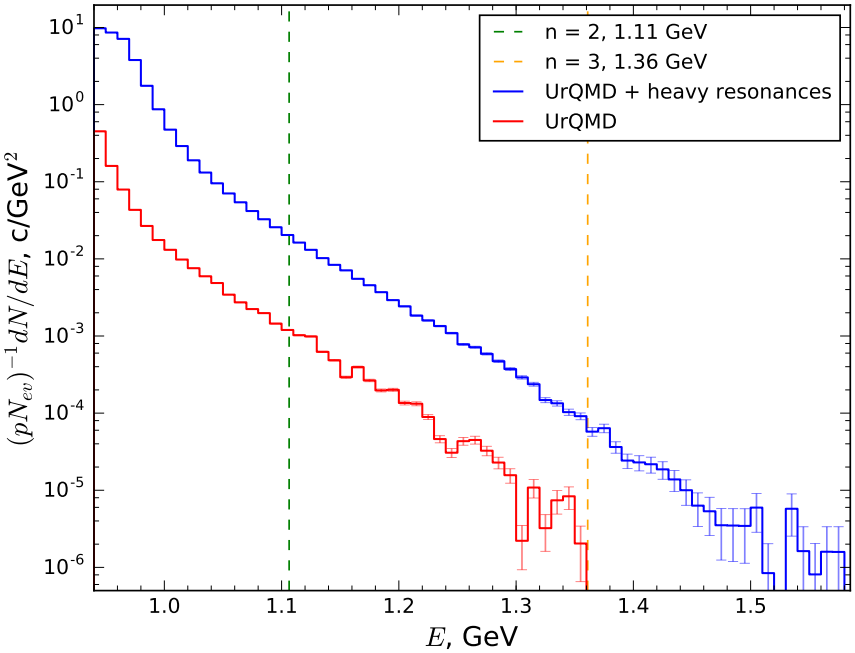


Рис. 12: Cumulative nucleons spectrum.

- p+Pb reactions,
- $p_{\text{lab}} = 6$ Gev/c,
- 10^8 collisions.

UrQMD and UrQMD+HR simulations

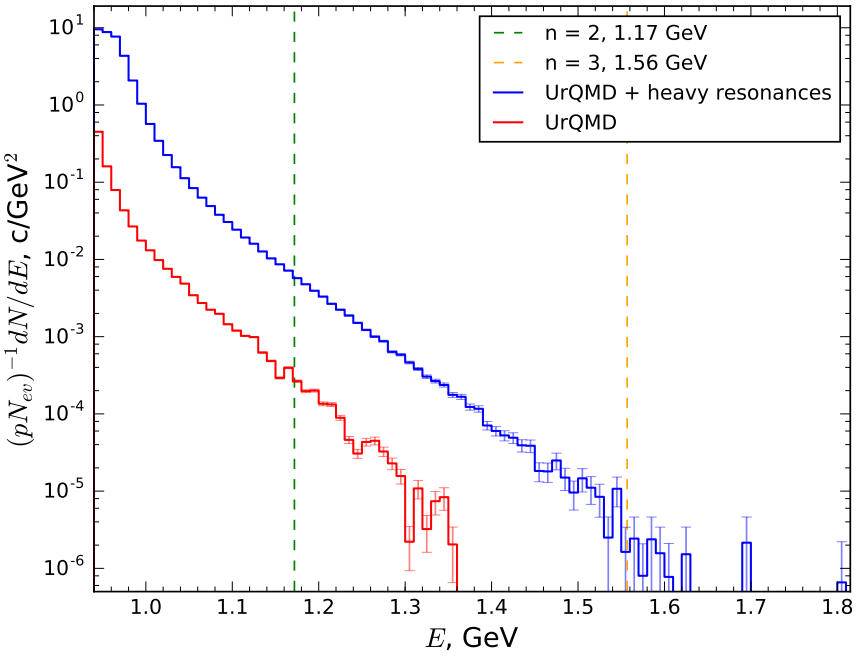


Рис. 13: Cumulative nucleons spectrum.

- p+Pb reactions,
- $p_{\text{lab}} = 158$ Gev/c,
- 10^8 collisions.

Summary

- Production of cumulative nucleons is possible only after 2 or more successive collisions.
- Creating of cumulative nucleons that move backwards requires existence of heavy resonances.
- Baryonic resonances with masses more than masses of well known baryonic resonances should exist and can be discovered soon. Experimental studies of cumulative effect is one of the best ways to find them.