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Double cumulative photon spectra at mid rapidity and high p_T in C+Be collisions at 2.0 and 3.2 AGeV.

I.Alekseev, A.Dolgolenko, G.Dzubenko, A.Golubev, V.Goryachev, S.Kiselev, K.Mikhailov[1], D.Romanov, P.Polozov, M. Prokudin, G. Sharkov, A. Stavinskiy, V.Stolin, D. Svirida, N. Zhigaredva
Institute for Theoretical and Experimental Physics, Moscow, 117218, Russia

Abstract

The photon spectra in central rapidity region were measured in C+Be collisions at beam energy 2.0 and 3.2 AGeV. The experiment was done in ITEP accelerator. The FLINT setup was wide acceptance (35^0-73^0 in lab. system) electromagnetic calorimeter. The energy range of measured photons was from 1 to 3 GeV. It was shown that most photons produced in the flucton-flucton interaction and it was up to 6 nucleons involved into interaction. Such kind of the interaction could be called “double cumulative” interaction.

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1 Speaker, *Konstantin.Mikhailov@itep.ru*

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1. Introduction

Study of cumulative processes discovered in the ITEP and JINR [1,2] and studied intensively since the mid 70's of the last century gave a number of interesting results and led to the establishment of the basic regularities of cumulative processes (see, eg, [3,4]). On the issue of the mechanism of cumulative particle production consensus has not been reached yet. To explain the cumulative effect Blokhintsev suggested the presence of local multi-nucleon fluctuations (so-called, fluctons) in the nuclei [5]. Experimental data show significant commonality fluctons properties and the assumed properties of cold dense matter. The direct identification of nonequilibrium fluctons with drops of cold dense matter seems impossible. The main problem is the relatively small number of nucleons in the drop. Therefore, the experiment in the region of maximum reachable order of cumulativity is very relevant, especially in connection with the development of theoretical concepts of the phase diagram of nuclear matter at high baryon densities [6]. The maximum order of cumulativity reached in proton-nucleus collisions are about 3-4 [7]. It is extremely difficult to move into larger cumulative numbers, because the data CLAS [8] suggest that the probability of detection of three-nucleon fluctuations is less than the square of the probability of detecting two-nucleon fluctuations. More promising is to search flucton-flucton interaction in the collision of two nuclei, as it could double the number of nucleons in the resulting drop. This paper presents new results of the FLINT experiment [9,10], which aimed at search flucton-flucton interaction with maximum cumulative order.

2. The experimental scheme

The experiment was performed at the ITEP accelerator complex. The experimental setup is shown in Fig. 1. Carbon nuclei accelerated to kinetic energy of 2.0 GeV per nucleon in one exposure, and 3.2 GeV per nucleon in another, interacted with foil target which was inside the synchrotron ring. Two modules of electromagnetic calorimeters were placed at angles of 35-73 degrees in lab. system. Each module consists of 64 lead glass channels [10]. The intensity of the carbon beam was about 10^8 ions per cycle every 4 seconds. The duration of beam spill was about 0.5 seconds. The efficiency of beryllium target was about 5%. The quality of beam was monitored by four-scintillator telescope (so-called "0 monitor" in Fig.1). The trigger was the signal with amplitude exceeding the threshold which corresponds to photons with an energy of 1 GeV emitted at an angle greater than 55^0 (2 GeV emitted at an angle less than 55^0). Such a trigger corresponds to cumulative photon production.

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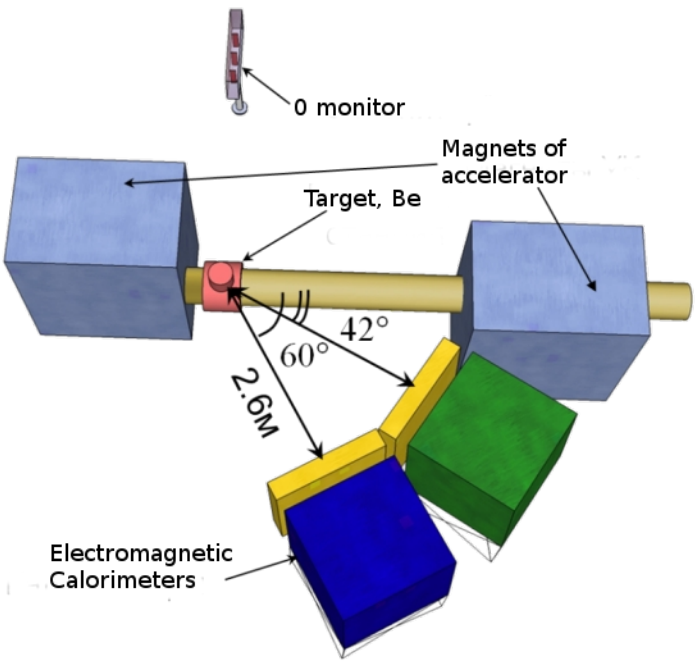

Figure 1: The FLINT experimental setup in current experiment

3. Data analysis

The data acquisition system (DAQ) for the FLINT experiment was developed at ITEP[11]. The DAQ based on VME create consists of an amplitude-to-digital conversion of signals from the detectors, recording information into the buffer and transfer to hard disc on the server computer via ethernet. There was possible effective eliminate background signals due to digitize the signal by flash ADC.

Lead glass in the electromagnetic calorimeter channel has a cross section 100x100mm^2[10]. In the presence of a trigger on the cumulative photon most of the energy of the photon stands out in one channel. In this case, the part of the electromagnetic shower can leak mainly in one nearby glass. It was verified that the slope of the photon spectrum is changed by less than 5% while the share of leakage varies from 10% to 25%. The spectra presented in this paper were obtained with the restriction on the part of the shower in a nearby glass was less than 15%.

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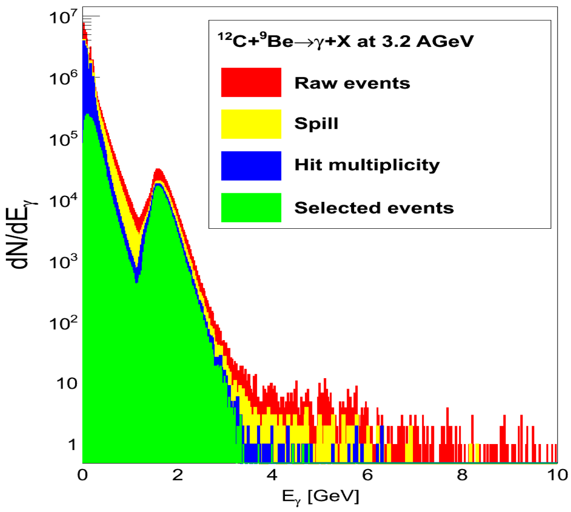

Figure 2: The photon spectra in Be+C interaction at 3.2 GeV/nucleon integrated over polar angle 35-53^0.

The photon spectra in Be+C interaction at 3.2 GeV/nucleon integrated over polar angle 35-53^0 is shown in Figure 2. There are several specific areas in the spectrum. Peak at 2 GeV corresponds to trigger on the cumulative photon. In the energy range from 0 to 1 GeV is seen falling spectrum which corresponds to trigger was in any other channel. Approximately exponential spectrum is observed in the energy range from 2 to 3 GeV. The spectral slope becomes flatter at energy greater than 3 GeV. This region corresponds to the background. We applied a few cuts to remove the background. Cuts were on the beam quality, on the hit multiplicity in the calorimeter, and on the shape of the signal from the calorimeter. The results of sequential application of these cuts are also shown in Fig. 2. After the application of all cuts the shape of the spectrum of energies above 2GeV is similar to the exponential.

4. Results and discussion

Experimental energy spectra of photons for different incident energies and emission angles in the reaction C+Be->gamma+X are shown in Fig.3 (2.0 AGeV) and Fig.4 (3.2 AGeV). It can be seen that the shape of the spectra is the exponential. The values of cross-sections and slope parameters decrease with increasing emission angle of photons and increase with increasing initial energy. Spectra were fitted by an exponential function: 1/pdN/dE=Const*exp(-E/E0). The slope parameters versus photon emission angle are show in Fig.5. Values of the slope are typical for cumulative processes. The angular dependence of the slope parameter looks natural on a qualitative level due to the movement of the center of mass.

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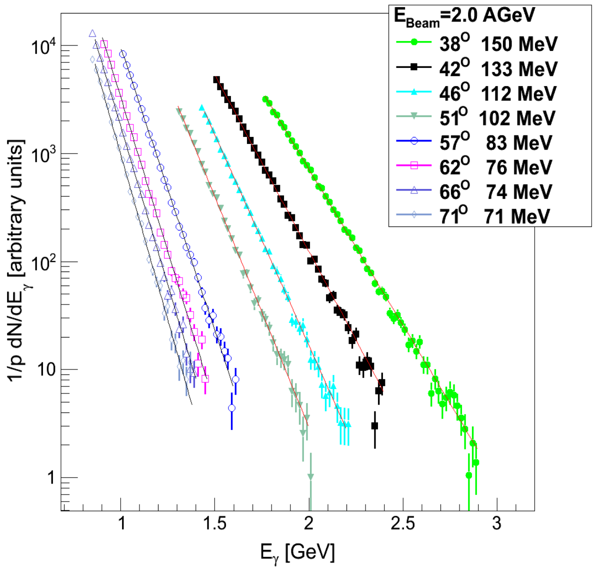

Figure 3: The photon spectra in the reaction C+Be→γ+X at 2.0 AGeV.

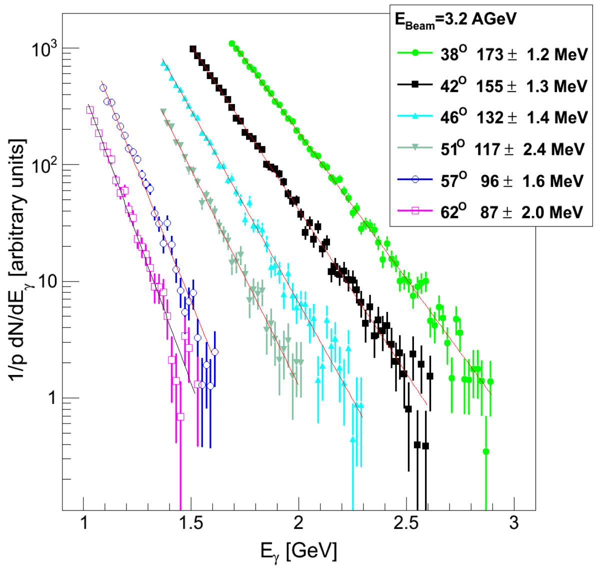

Figure 4: The photon spectra in the reaction C+Be→γ+X at 3.2 AGeV.

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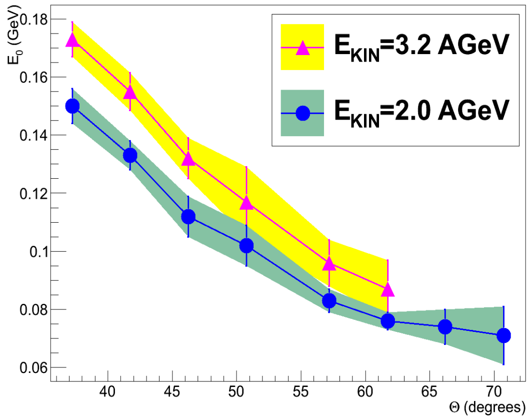

Figure 5: The slope parameters versus photon emission angle

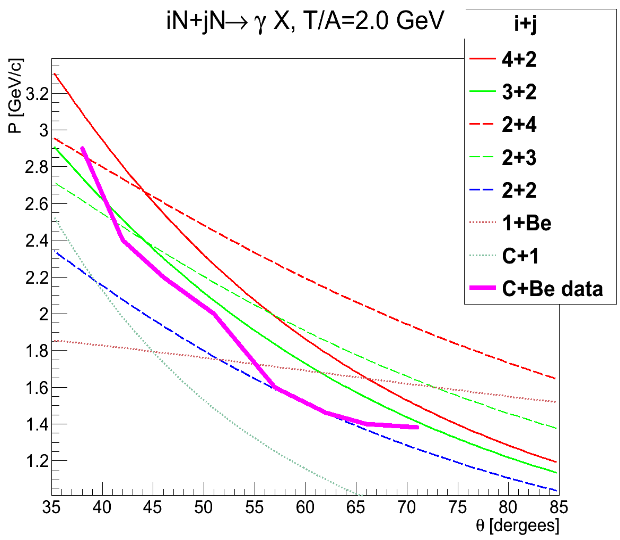

Figure 6: The kinematical limits of the reaction iN+jN→γ+X at 2 AGeV (in terms of momentum versus emission angle in Lab. system)

The kinematical limits of the reaction iN+jN→γ+X at 2 AGeV (in terms of momentum versus emission angle in lab. system) are shown in Fig.6. Indexes **i** and **j** mean number of nucleons take part in the reaction. The maximum values of the momentum which corresponding to the experimental data (see Fig.3) are also shown in Fig.6. One can see that spectra are measured far beyond the kinematical limits of NN interaction. More over the data can not be described in nucleon-flucton or flucton-nucleon hypothesis. One can conclude that the minimum number of nucleons involved into reaction should be upto six.

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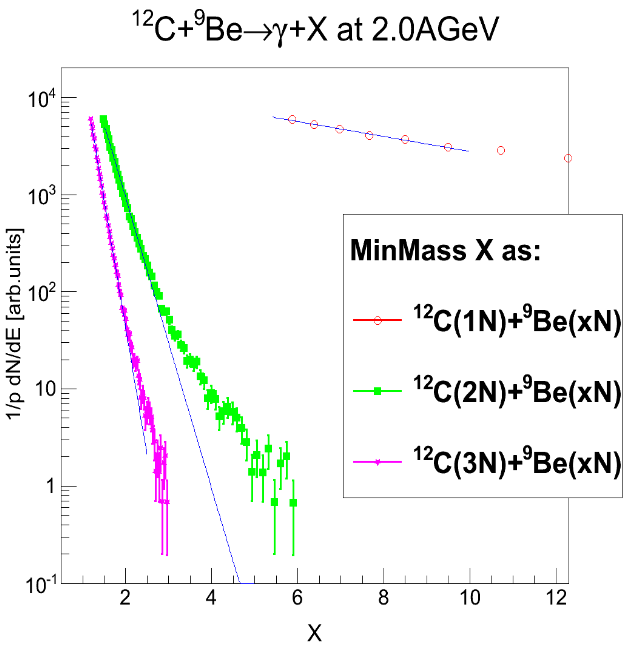

Figure 7: The photon spectra versus cumulative number.

Fig.7 shows the photon spectra produced in the reaction C+Be→γ+X at 2 AGeV (integrated over angle region from 35 to 55 degrees) versus cumulative number [3]:

$$X\cdot m_N=\frac{E_0 E-p_0 p\cos\theta-m^2/2}{T_0-E}, \quad (1)$$

where E_0, p_0, T_0 are initial energy, momentum and kinetic enegry of the projectile, and E, p, θ, m are energy, momentum, emission angle and mass of produced particle.

There are three sets of points in Fig.7. Red empty circles correspond to nucleon-flucton interaction hypothesis, green filled rectangulars correspond to two-nucleon-flucton interaction, and magenta star symbols correspond to three-nucleon-flucton interaction. The cumulative numbers X are calculated in the corresponding hypothesis. Most points in first hypothesis are beyond kinematics of N+Be reaction ($X=9$), as shown in Fig.6. In case of second hypothesis all point of the spectrum are in the region of cumulative number form $X=2$ to $X=6$. The dependence of spectrum has an unnatural break near $X=3$. The spectrum looks more natural in third hypothesis. The cumulative number is changed from $X=1$ to $X=3$ in that case. The spectrum has been fitted to the exponential function $const\cdot\exp(-X/X_0)$. The slope parameter are $X_0=5.6$ in fisrt hypothesis, $X_0=0.29$ in second hypothesis, and $X_0=0.16$ in third hypothesis. The last one is very close to typical value of the slope of the cumulative number [2,7]. Based on these naive notions, it is clear that the third hypothesis seems the most reasonable.

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Conclusions

The photon spectra in the reaction C + Be → γ + X was measured in wide angular reange with tht FLINT setup. Spectra as a function of photon energy are exponential. The slope of the spectra depends on the initial energy and on the emission angle. Preliminary analysis of the data shows that the photons are produced in the flucton-flucton interaction with up to 6 nucleons involved into interaction.

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