

CHECK OF THE STRUCTURE  
IN PHOTON PAIRS SPECTRA AT AN  
INVARIANT MASS OF ABOUT  $38 \text{ MeV}/c^2$

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# Abstract

The recent results of check of the structure in photon pairs spectra at about  $38 \text{ MeV}/c^2$  [1] are presented.

The search was conducted in the effective mass spectra of photon pairs produced in the  $d(2.0 \text{ GeV}/n) + \text{C}$ ,  $d(3.0 \text{ GeV}/n) + \text{Cu}$  and  $p(4.6 \text{ GeV}) + \text{C}$  reactions.

The experimental data was obtained at internal beams of the JINR Nuclotron.

[1]. E. van Beveren and G. Rupp. arXiv:1202.1739; 1204.3287.

----- Исходное сообщение -----

Тема: ArXiv:1203.4198

Дата: Thu, 17 May 2012 19:04:52 +0100

От: eef@teor.fis.uc.pt

Кому: Khachik Abraamyan <abraam@sunhe.jinr.ru>

Копия: George Rupp <george@ist.utl.pt>

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Dear Dr. Khachik Abraamyan and collaborators,

It was a pleasant surprise to read your article on "Resonance structure in diphoton and two-neutral-pion systems in Deuterium-Carbon interactions" ArXiv:1203.4198.

I am sorry that I did not come across your 2006 work nucl-ex/0607027 before today.

Your result is spectacular as it does not seem to fit into any type of model for strong interactions and worth to offer you my congratulations.

Do you yourself have an explanation for the resonance at 360 MeV?

Actually, I was browsing in Google through data for diphotons where I found your work. **The reason is that I myself and my collaborator George Rupp are interested in diphoton data from 30 to 50 MeV** (see arXiv:1202.1739 and arXiv:1204.3287).

Unfortunately, your lower limit is 100 MeV, but I wonder whether that is a limitation of your setup at the JINR Nuclotron, or that it could be lowered to 30 MeV.

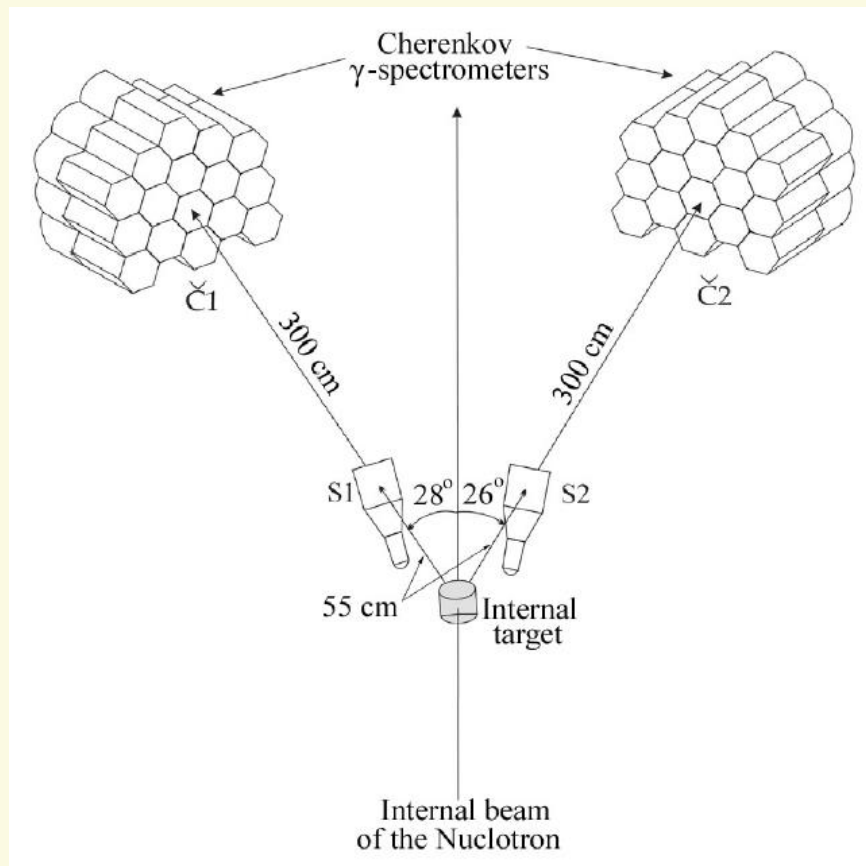
Kind regards,  
Eef van Beveren

# The plan of the report

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- The experiment
- From the first results
- Recent results
- Conclusion, outlook

# PHOTON-2 setup on internal beams of the NUCLOTRON



# EXPERIMENT

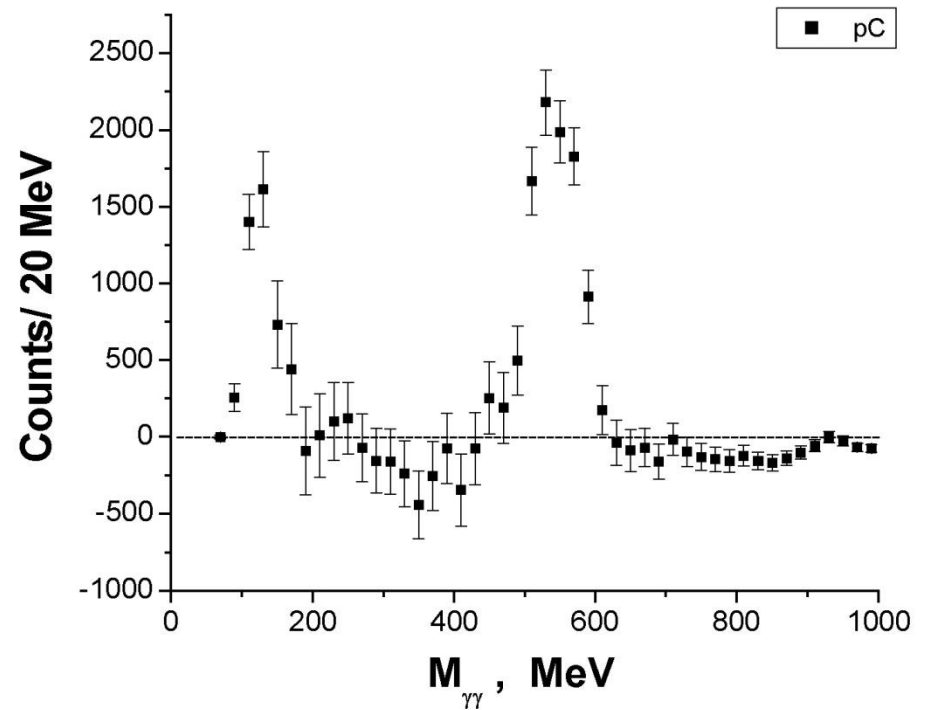
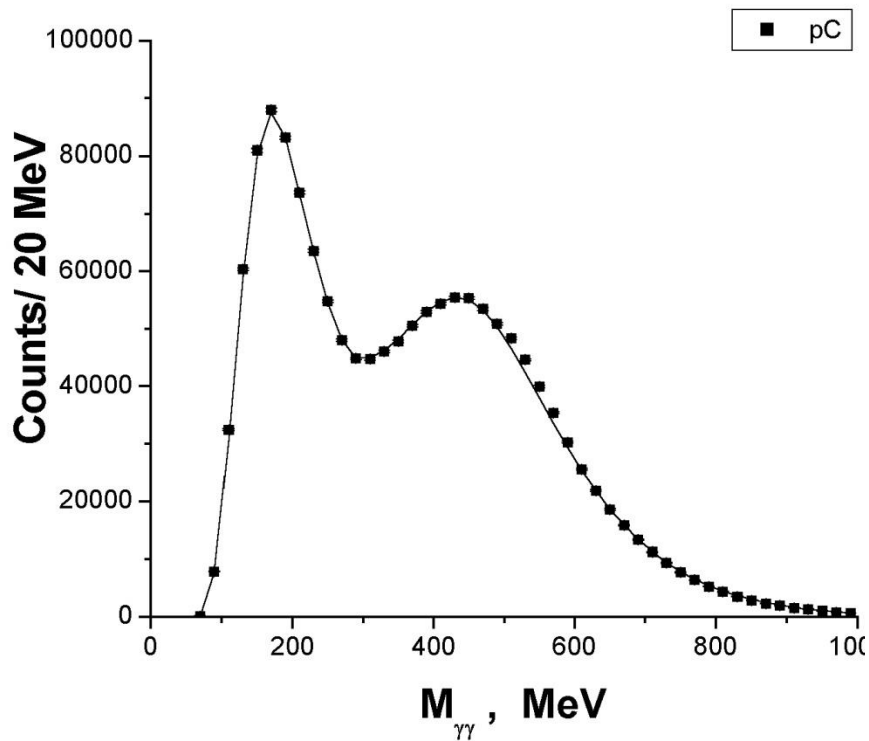
The data acquisition of production of neutral mesons and  $\gamma$ -quanta in  $dC$  interactions has been carried out with internal beams of the JINR Nuclotron.

The PHOTON-2 setup includes 32  $\gamma$ -spectrometers of lead glass. The modules of the  $\gamma$ -spectrometer are assembled into two arms of 16 units. These modules in each arm are divided into two groups of 8 units. The output signals in each group are summed up linearly and after discrimination by amplitude are used in fast triggering. In this experiment, the discriminator threshold was at the level of 0.4 GeV. Triggering takes place when there is a coincidence of signals from two or more groups from different arms. (The block-scheme of electronic equipment is in sl. № 44.)

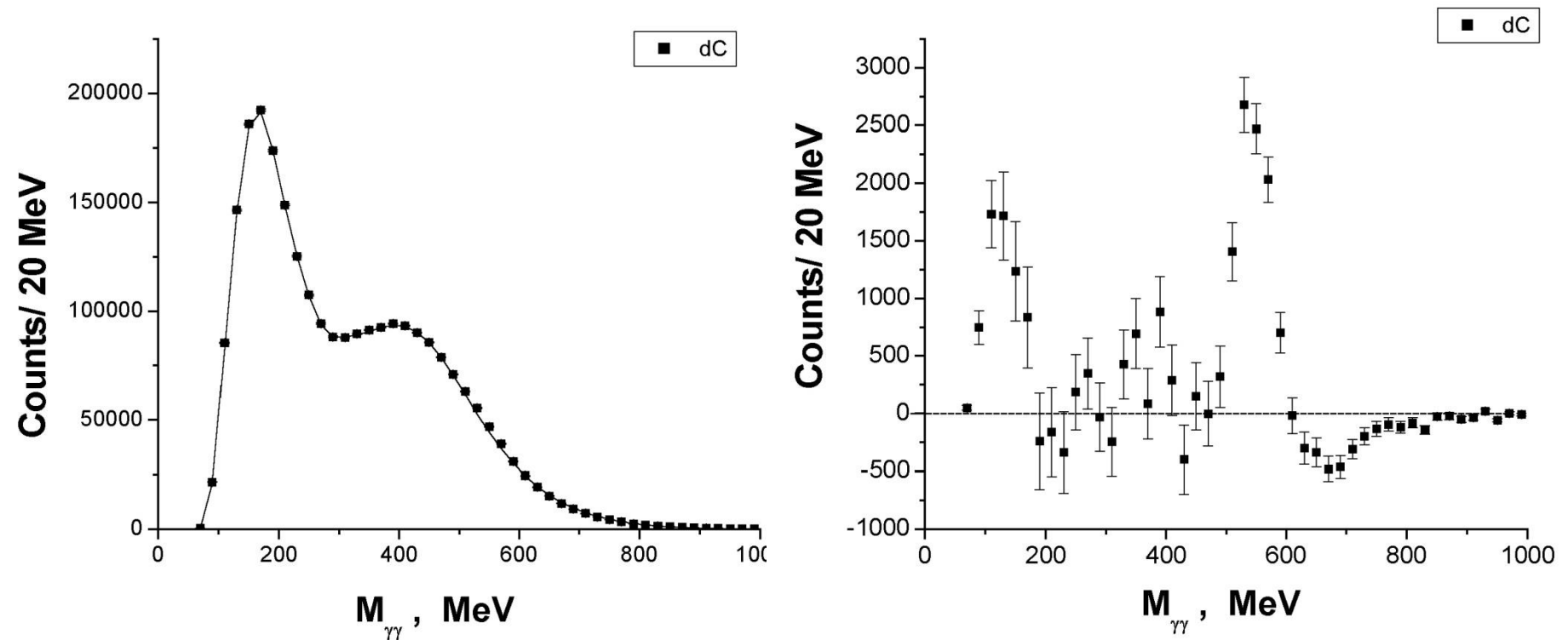
Detailed description of the experiments is in:

*Kh. U. Abraamyan et al., Phys. Rev. C 80, 034001 (2009); arXiv:0806.2790.*

Invariant mass distributions of  $\gamma\gamma$  pairs without (left) and with (right) the background subtraction.  
The reaction  $p(5.5 \text{ GeV}/c)+C$ , minimal cuts:  $E_\gamma \geq 50 \text{ MeV}$



Invariant mass distributions of  $\gamma\gamma$  pairs without (left) and with (right) the background subtraction.  
The reaction  $d(5.5 \text{ GeV}/c)+C$ , minimal cuts:  $E_\gamma \geq 50 \text{ MeV}$ .





## First results

To search for the suggested effect we have analyzed the effective masses of pairs of photons produced in  $pC$ ,  $dC$  and  $dCu$  interactions.

To search for a signal in the region **from 30 to 50 MeV** we have analyzed photon pairs detected in the same arm of the spectrometer. Below are the first results of this analysis for photons that detected in the Right arm (situated at an angle of  $26^\circ$ ).

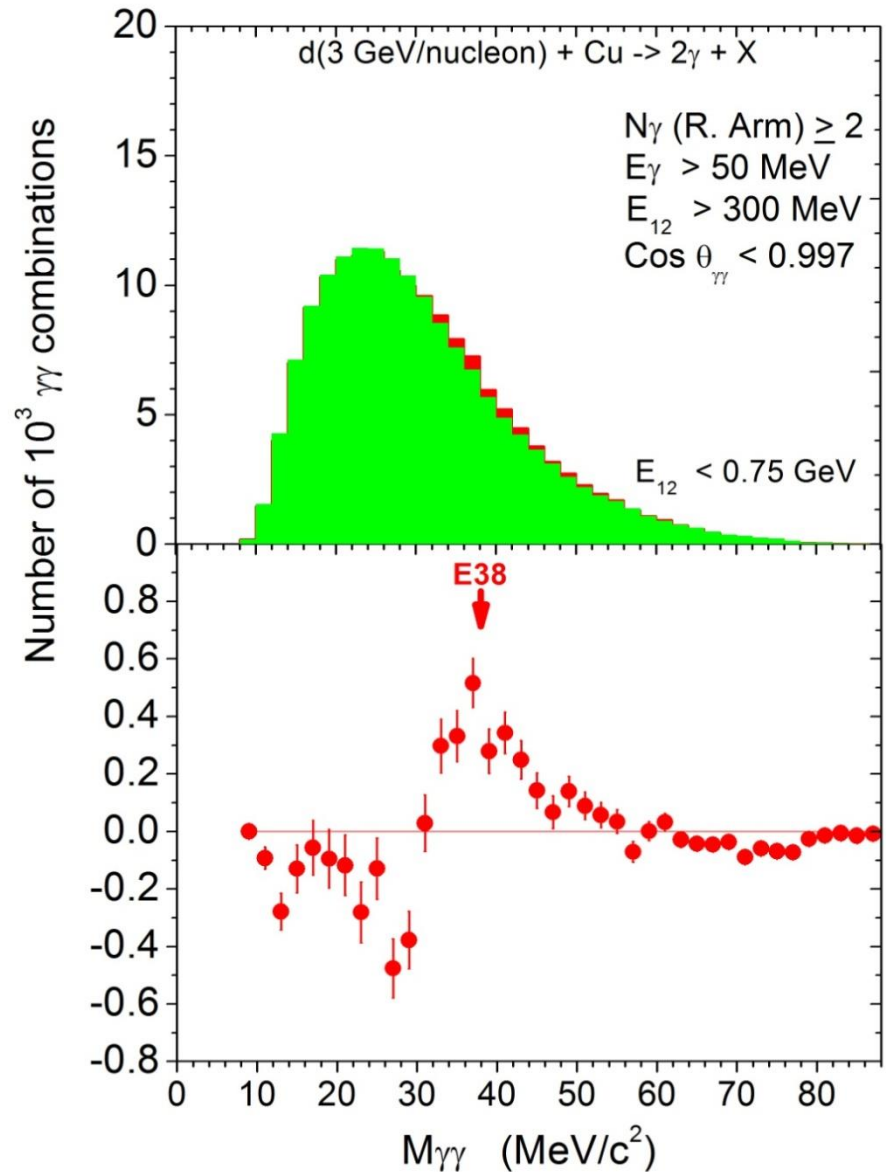
**I. d(3 GeV/n)+Cu****1) Soft selection criteria:**

(i) the energies of photons,  
 $E_\gamma > 50 \text{ MeV}$ ,

(ii) the sum of the energies  
of two photons,  
 $300 < E_{12} < 750 \text{ MeV}$ ,

(iii) opening angles of  
photons,  $\text{Cos } \theta_{\gamma\gamma} < 0.997$ .

1(a): The background is  
normalized to the total pair  
number.



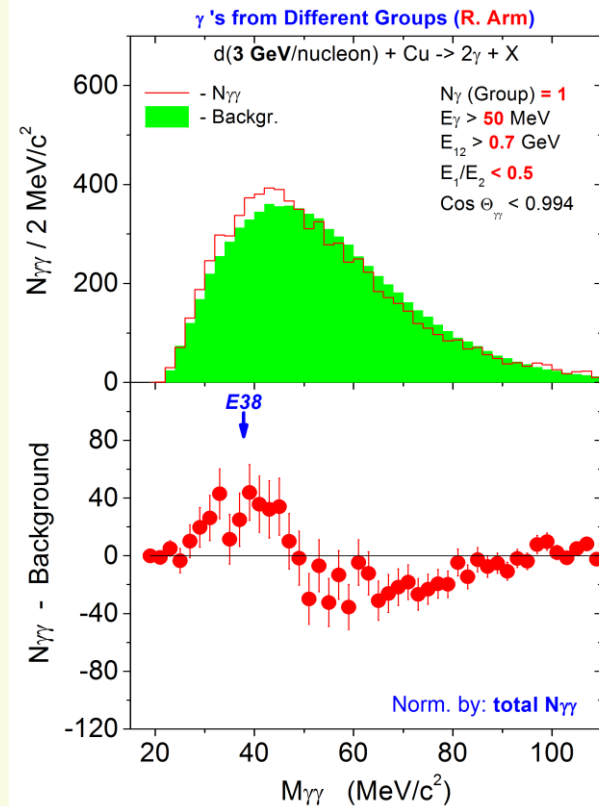
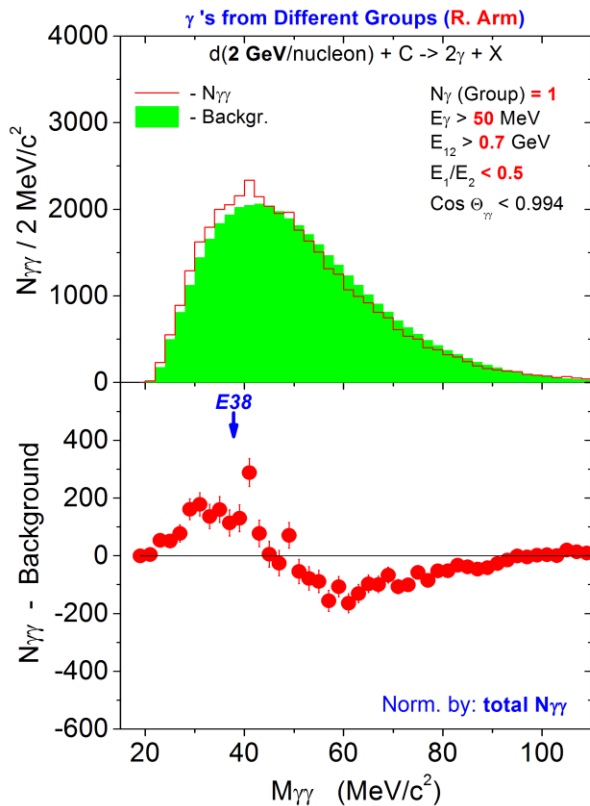
## Recent results

To elucidate the nature of the detected enhancement, at first we have investigated the dependence of its position on the energies of separate photons and photon pairs: **for pairs of photons inside different groups of the modules; in combinations of photons only from different groups.**

Also, we have applied a method of “**miscalibration**” of modules to break the calibration of the units of  $\gamma$ -spectrometer and to blur the signal.

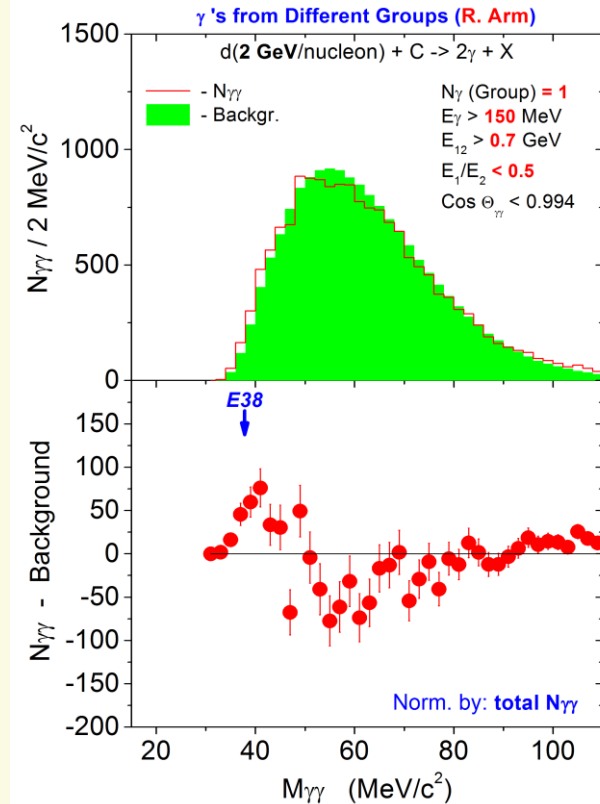
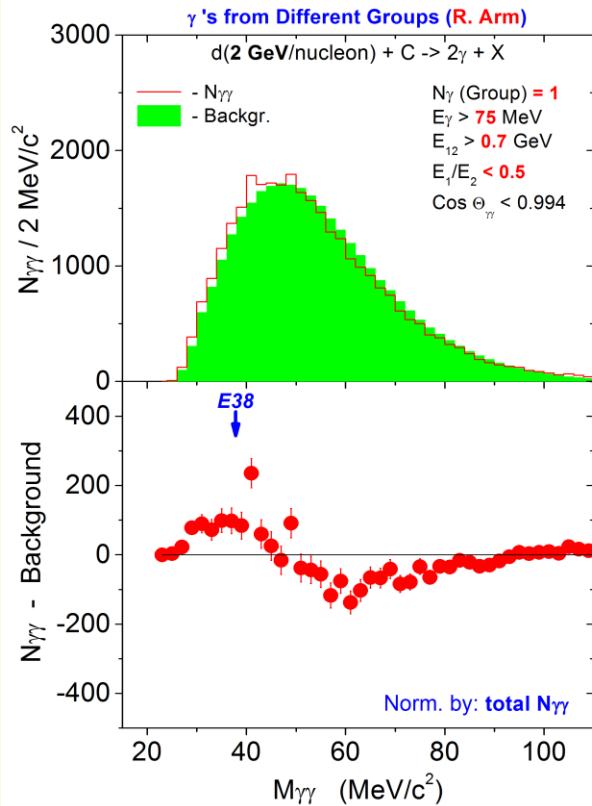
# 1. Soft selection criteria

The invariant mass distributions of  $\gamma\gamma$  pairs selected from **different groups**, for the  $d(2 \text{ GeV/n})+C$  (left) and  $d(3 \text{ GeV/n})+Cu$  reactions.



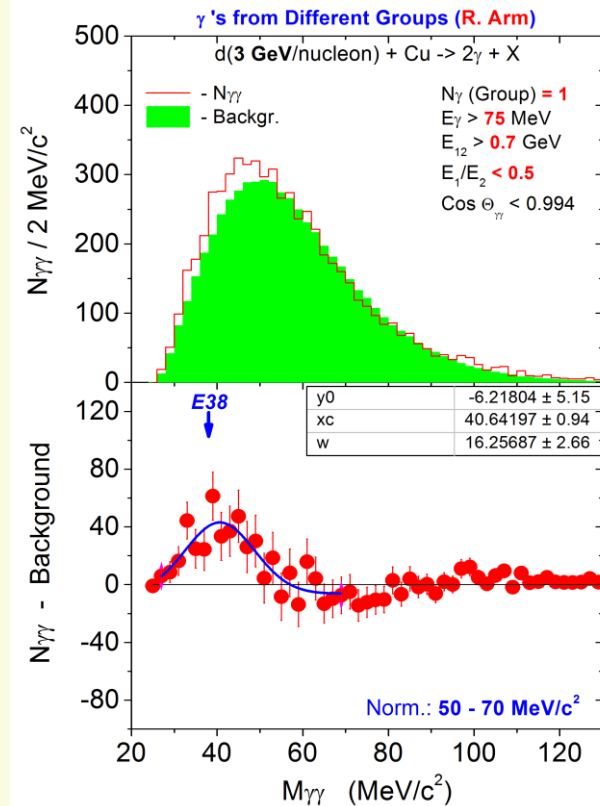
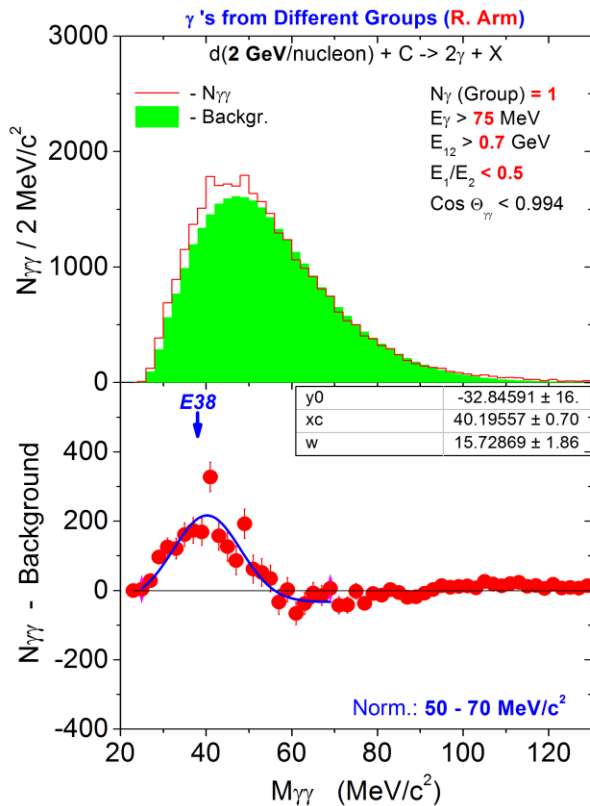
## 2. Different selection criteria

The invariant mass distributions of  $\gamma\gamma$  pairs selected from **different groups**, for the  $d(2 \text{ GeV/n})+C$  reaction.



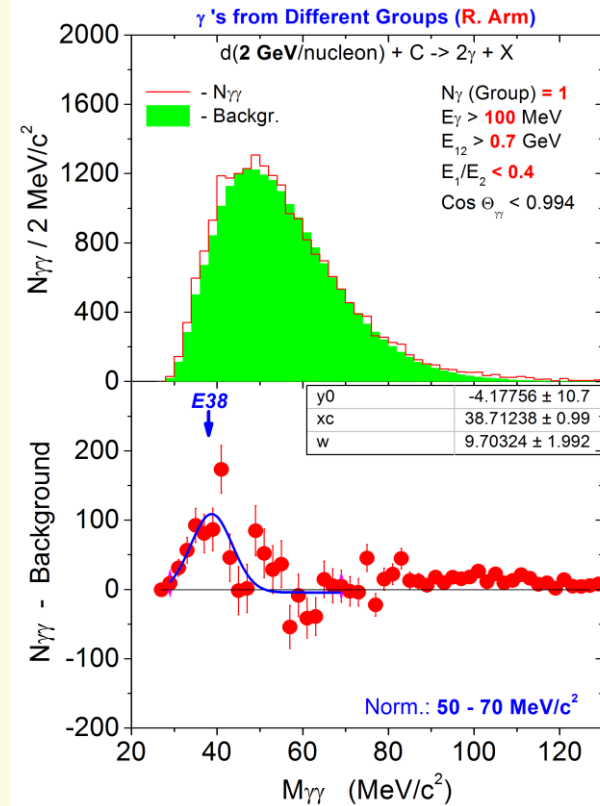
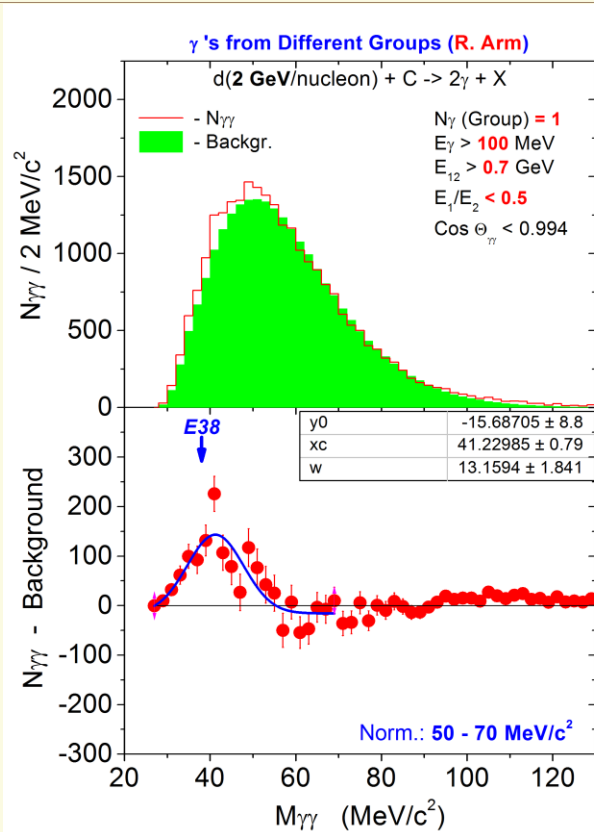
### 3. The background normalization and approximation

The invariant mass distributions of  $\gamma\gamma$  pairs selected from **different groups**, for the  $d(2 \text{ GeV/n})+C$  (left) and  $d(3 \text{ GeV/n})+Cu$  reactions.



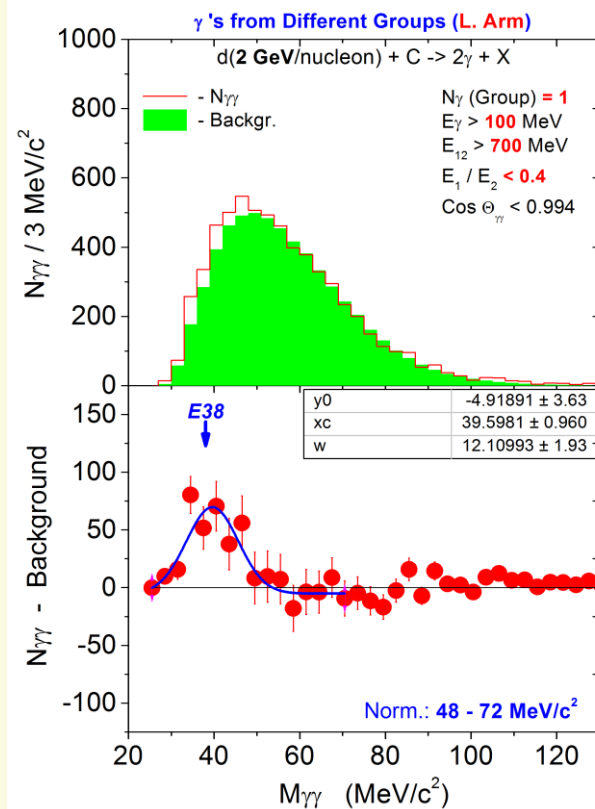
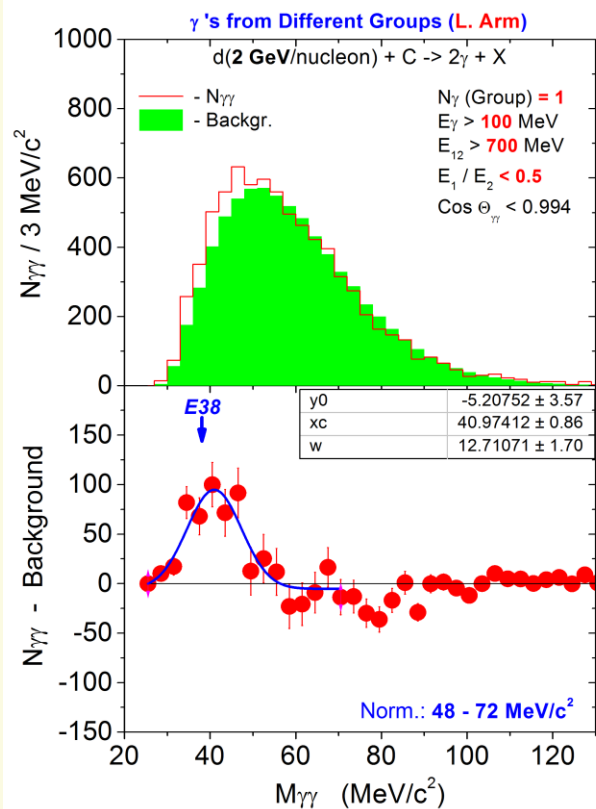
## 4. Different E1/E2 restrictions

The invariant mass distributions of  $\gamma\gamma$  pairs selected from **different groups**, for the  $d(2 \text{ GeV/n})+C$  reaction.



## 5. $\gamma\gamma$ pairs detected in the **Left Arm** of the $\gamma$ -spectrometer

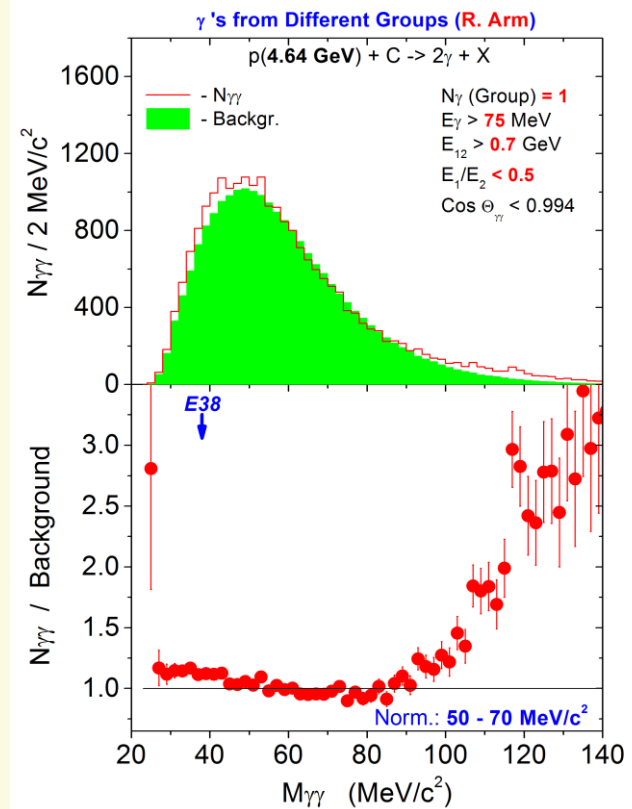
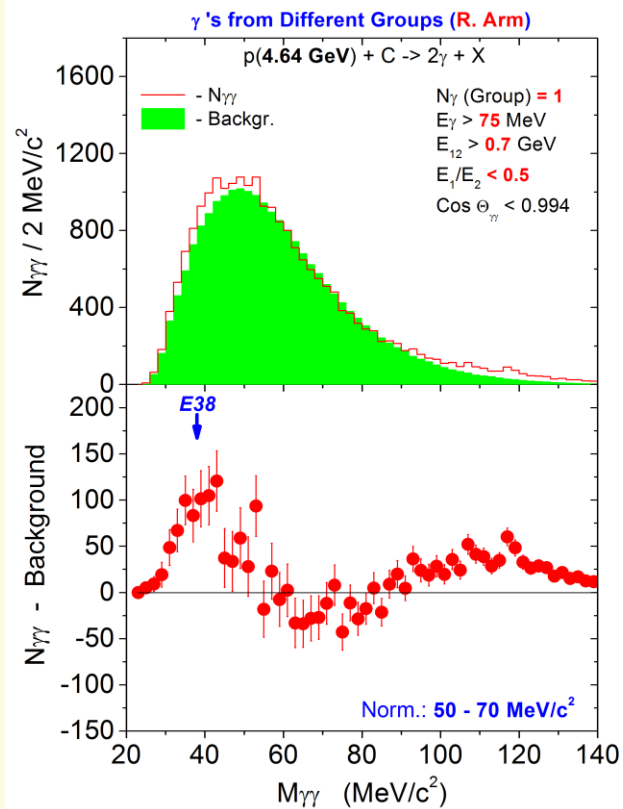
The invariant mass distributions of  $\gamma\gamma$  pairs selected from **different groups**, for the  $d(2 \text{ GeV/n})+C$  reaction.





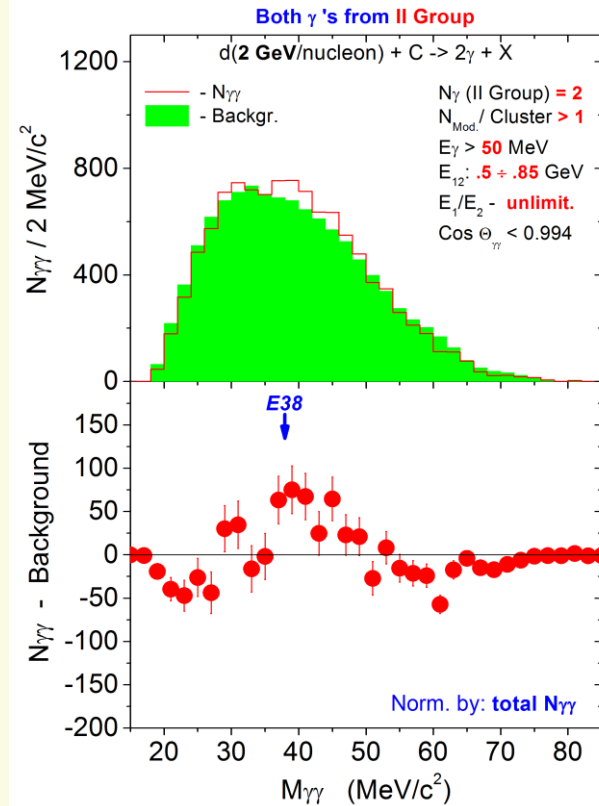
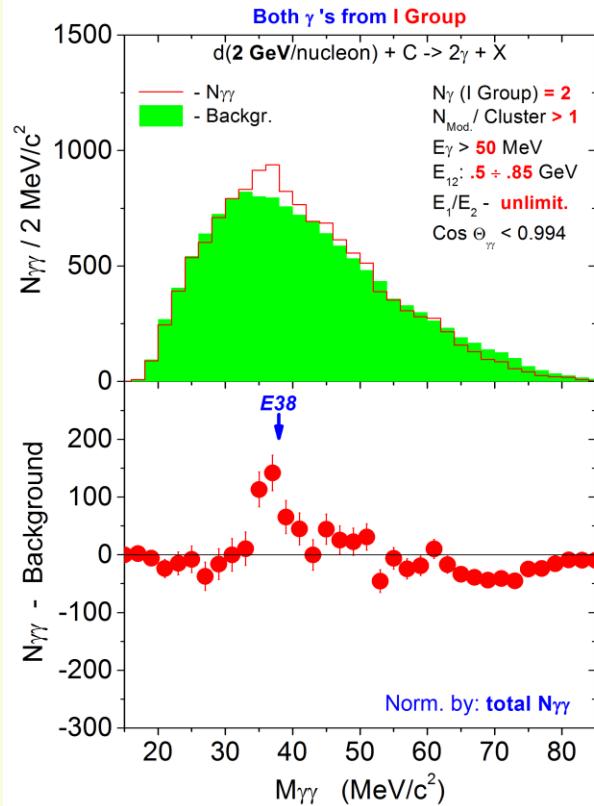
## 6. Pion signal

The invariant mass distributions of  $\gamma\gamma$  pairs selected from **different groups**, for the  $p(4.64 \text{ GeV})+C$  reaction.



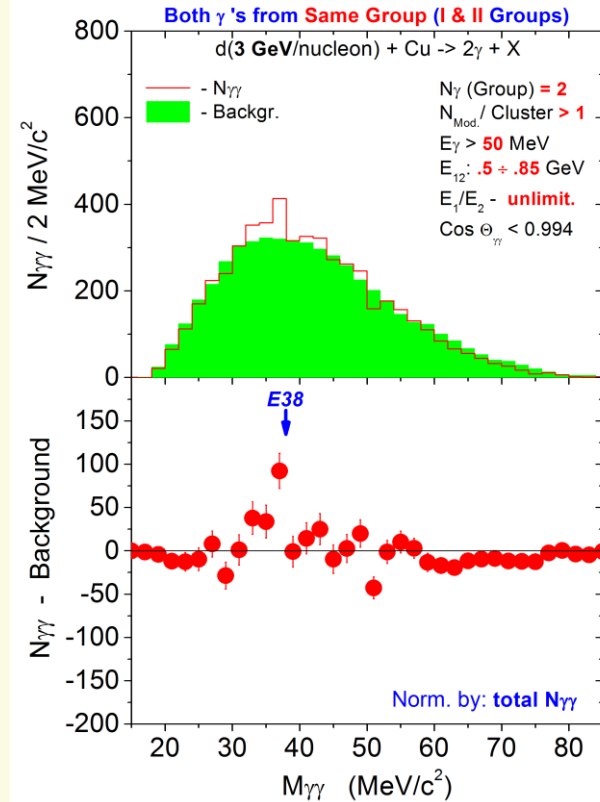
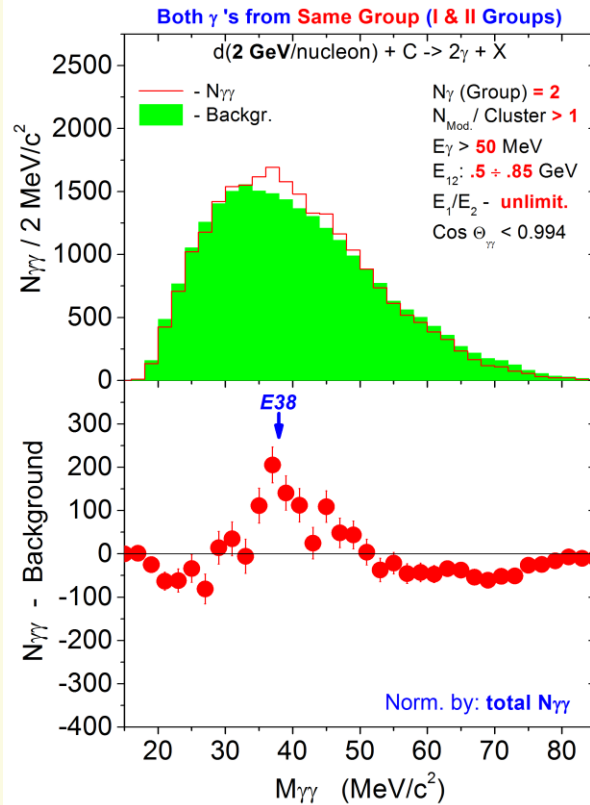
## 7. $\gamma$ 's from Same Group

The invariant mass distributions of  $\gamma\gamma$  pairs selected from **I group** (left), and **II group** (right) of the Right Arm, for the  $d(2 \text{ GeV/n})+C$  reaction.



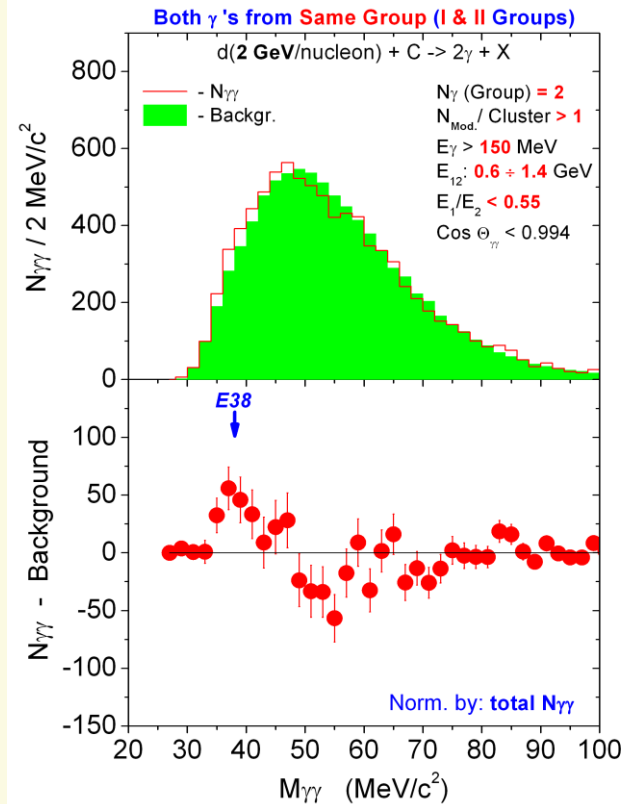
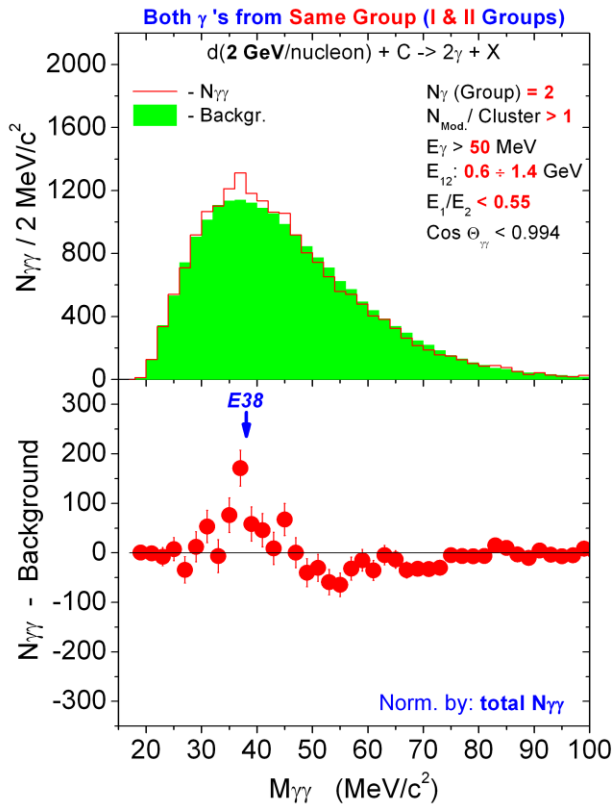
## 8. $\gamma$ 's from Same Group

Sum of the data for **I** and **II** groups of the Right Arm,  
for the  $d(2 \text{ GeV/n})+C$  (left) and  $d(3 \text{ GeV/n})+Cu$  reactions.



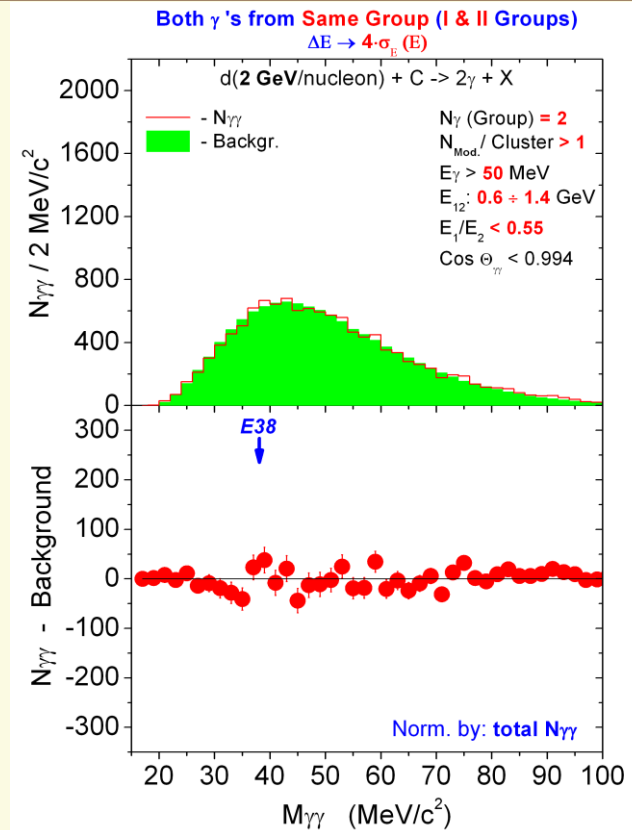
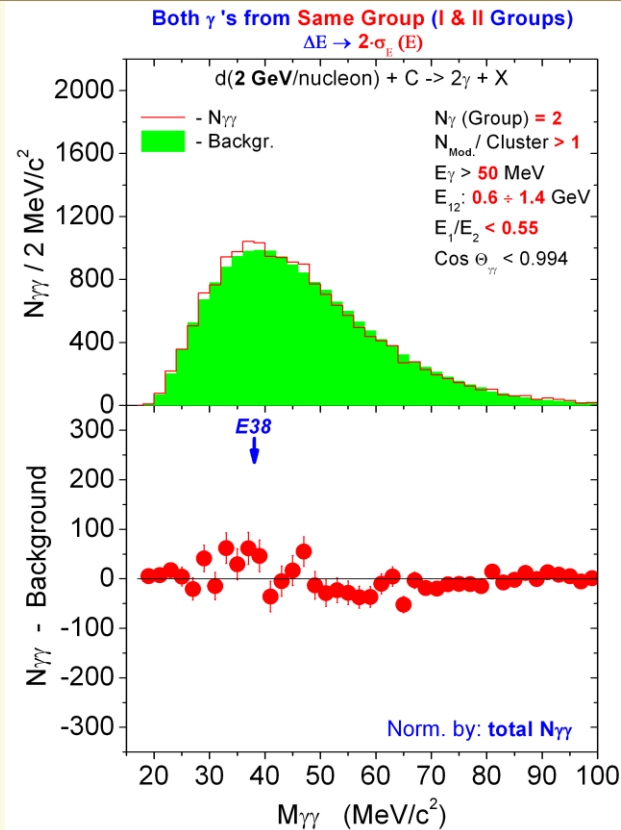
## 8. $\gamma$ 's from Same Group, another selection criteria

Sum of data for **I** and **II** groups of the Right Arm,  
for the  $d(2 \text{ GeV/n})+C$  reaction, at  $E_\gamma > 50 \text{ MeV}$  (left) and  $E_\gamma > 150 \text{ MeV}$ .



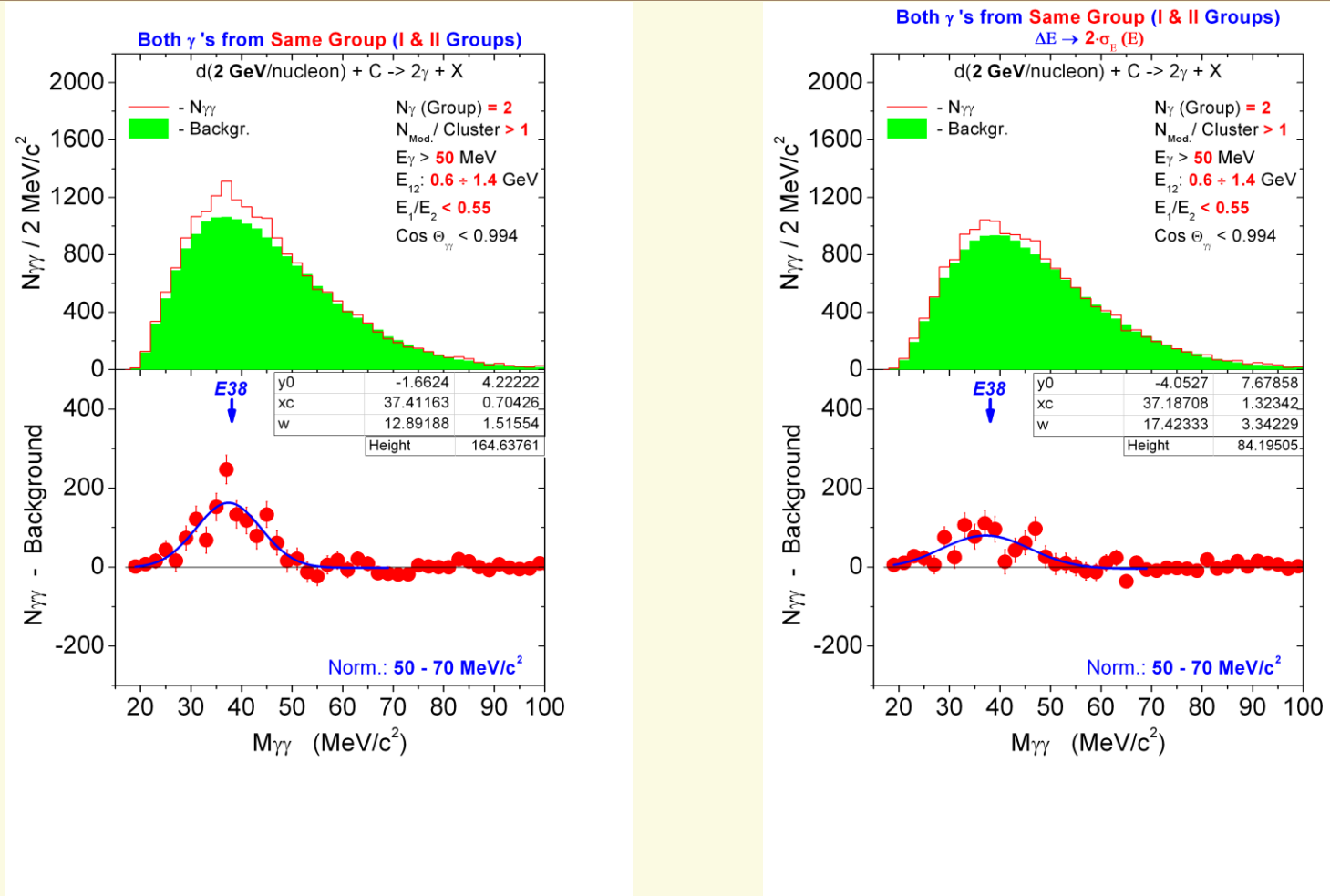
## 8. "Miscalibration" of modules

The same as in previous slide (left picture), but after a "miscalibration" of the modules: with the extension of the standard error in the energies (amplitudes in each module) up to  $2\sigma$  (left) and up to  $4\sigma$  (right).



## 9. “Miscalibration” of modules

The same as in previous slides but after the backgrounds normalization.



## Conclusion

- Thus, there is a signal at  $\sim 38 \text{ MeV}/c^2$  in spectra of photon pairs in  $d+C$  and  $d+\text{Cu}$  reactions, as well as in the reaction  $p+C$ .
- Position of the signals from  $\pi^0$  and  $\eta$  mesons in these experiments indicate that the uncertainty in the position of the observed signal does not exceed 3 MeV.
- New experiments are required to be carried out under conditions appropriate for registration of pairs of two photons within the invariant mass interval of 30-50 MeV. Some scanning in the beam energy and mass will clarify the effect.

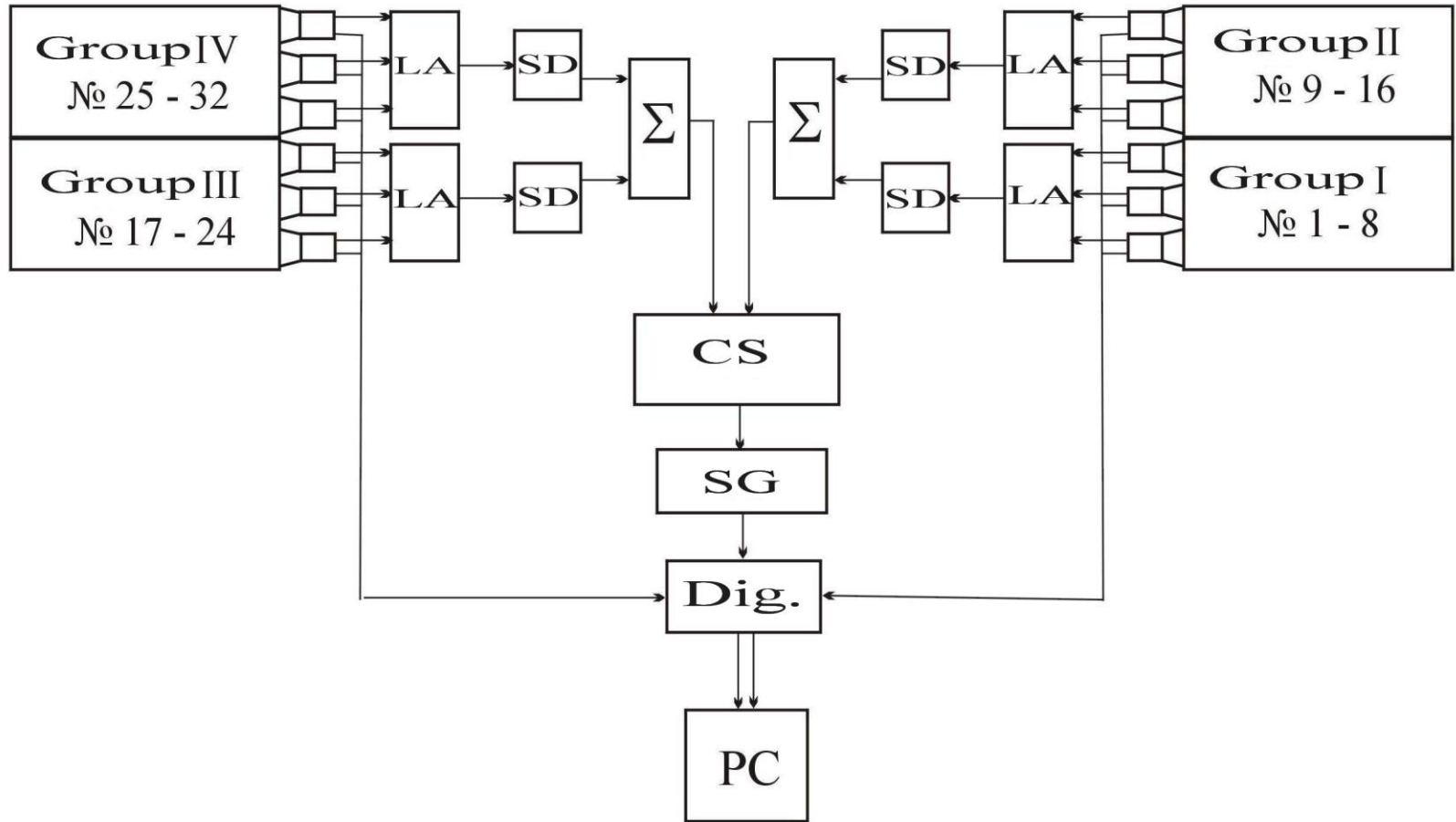
**We are grateful to S. Gevorgyan, M. Kapishin, V. Kekelidze, A. Litvinenko, D. Madigozhin, and Yu. Potrebenikov for numerous fruitful discussions and hope for further joint work.**

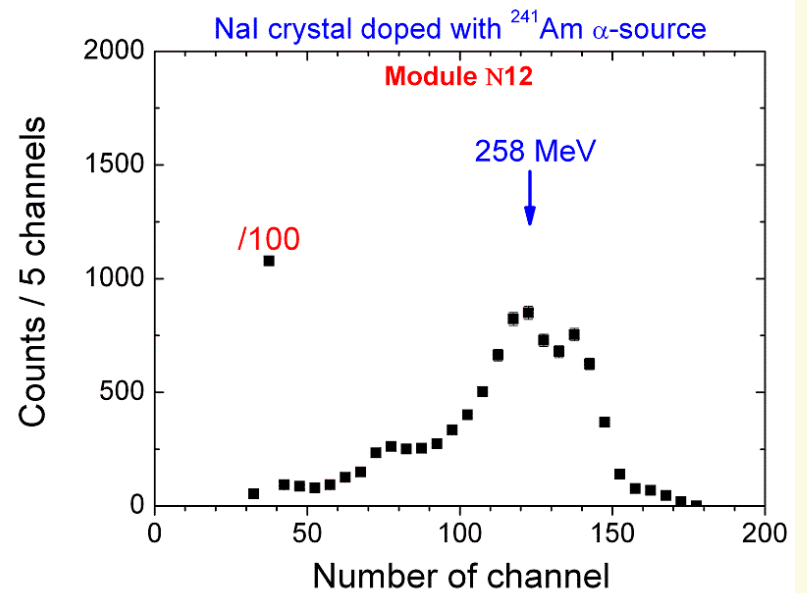
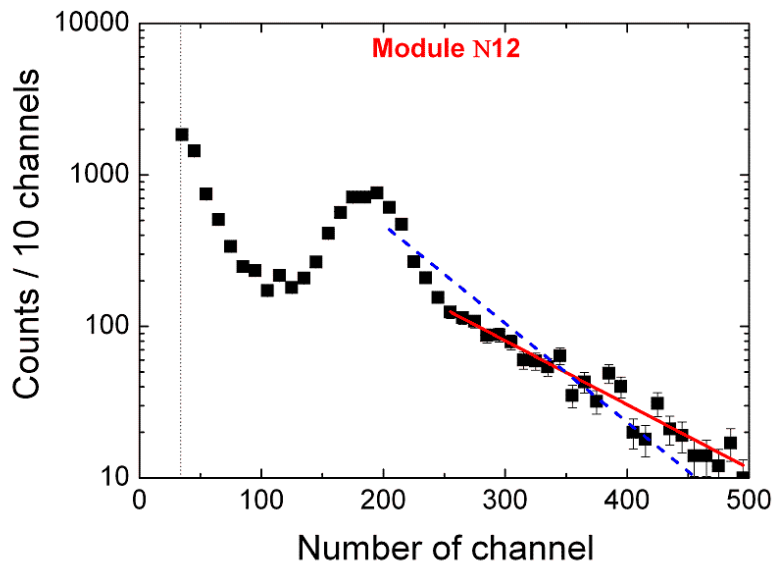
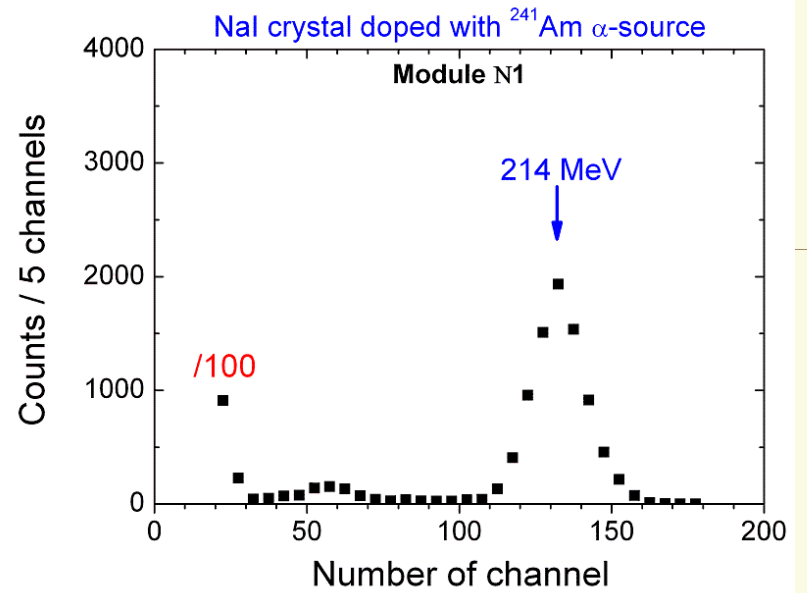
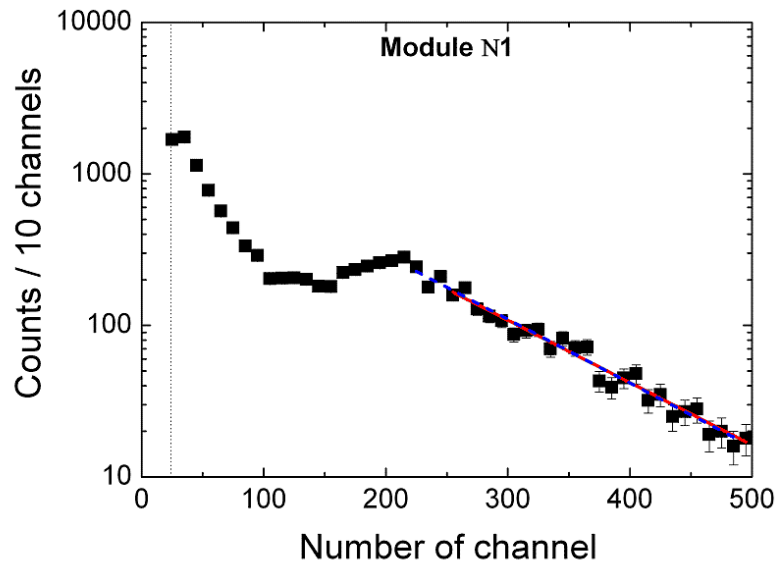
**We thank S. Afanasev, A. Elishev, A. Kovalenko, A. Malakhov, and the staff of the Nuclotron for their help in conducting the experiments.**



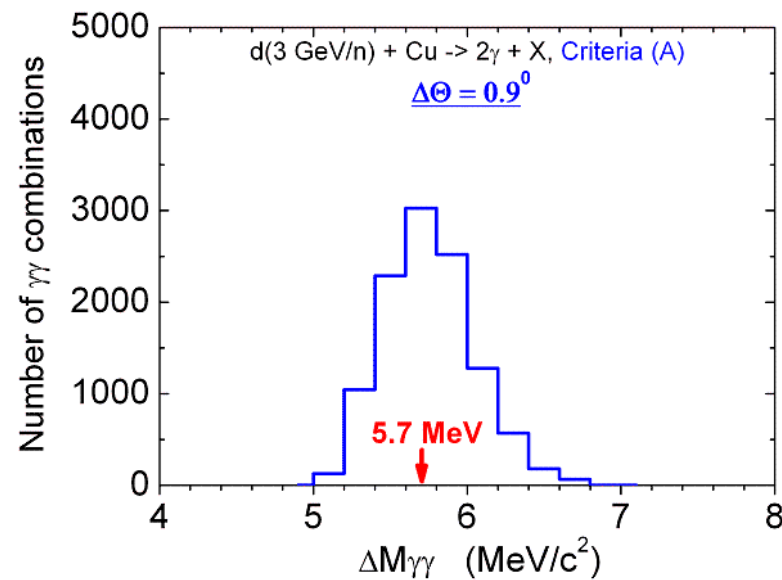
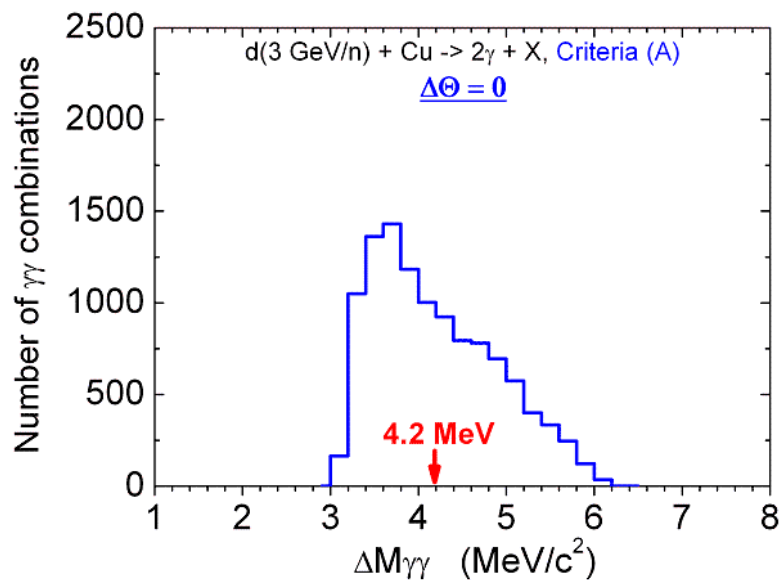
***Thank you for attention!***

# The block-scheme of electronic equipment





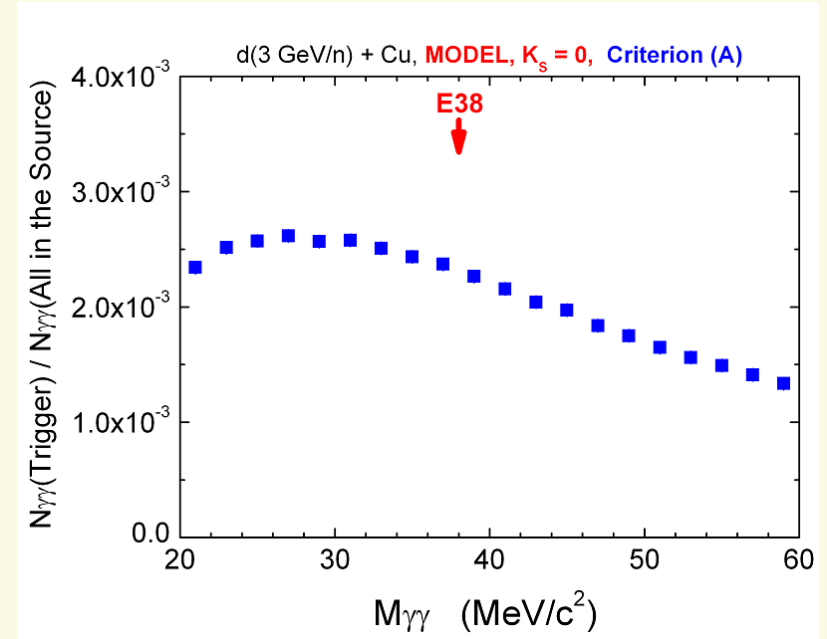
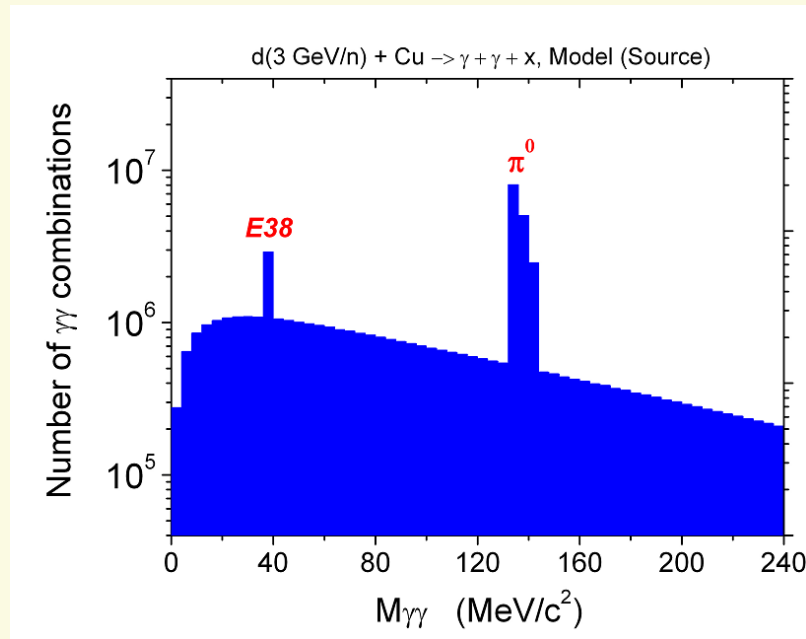
Distributions of calculated value of  $\Delta M_{\gamma\gamma}$  for photon pairs selected from the Right arm of the  $\gamma$ -spectrometer, under the Criteria (A), for the vicinity of the E(38) mass:  $36 < M_{\gamma\gamma} < 40$  MeV/ $c^2$ , at  $\Delta\Theta = 0^\circ$  (left figure) and at the maximum value of  $\Delta\Theta = 0.9^\circ$  (right figure).



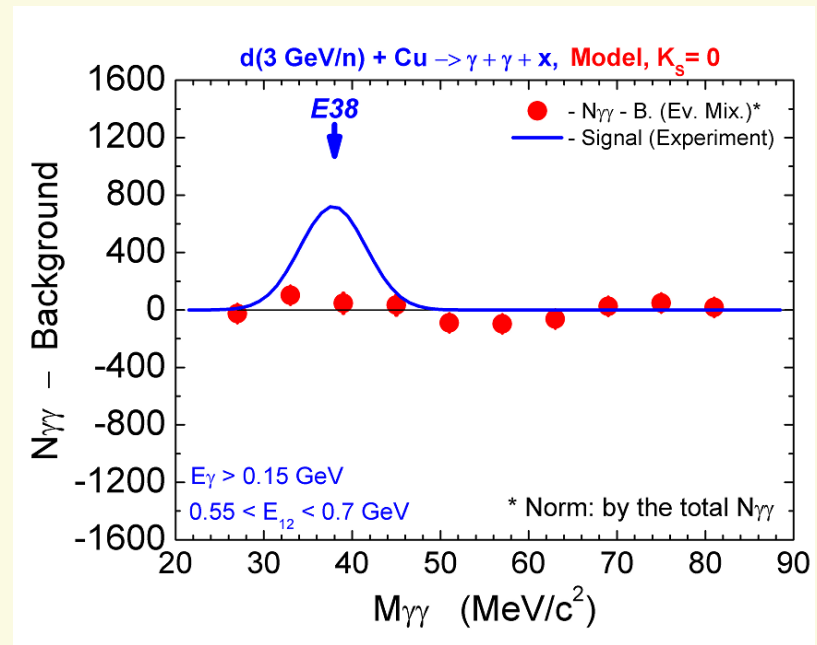
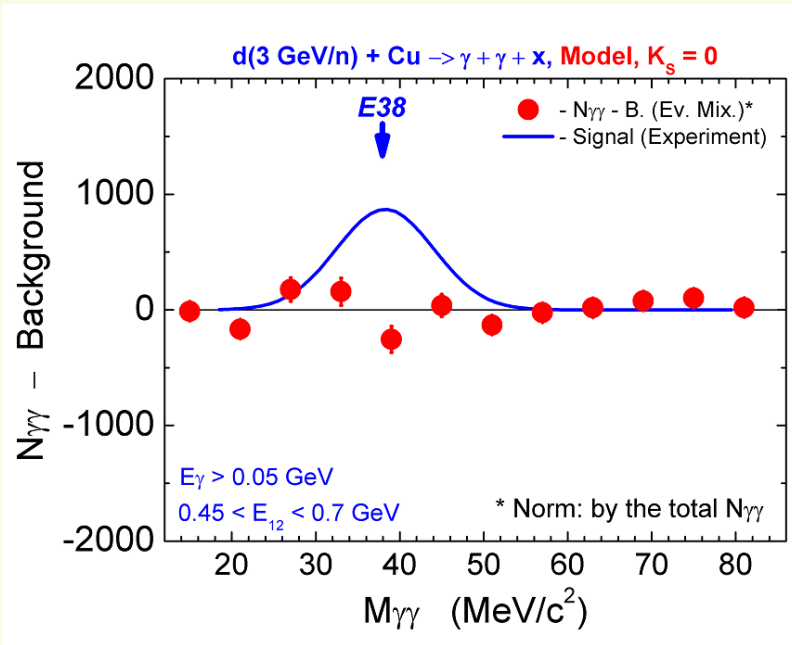
## Data simulation

- ❑ To simulate  $pC$ -,  $dC$ - and  $dCu$ - reactions we used a two-phases transport code [*K.K. Gudima et al. LANL Report LA-UR-01-6804, Los Alamos, 2001*]
- ❑ The following  $\gamma$ -decay channels are taken into account:
  - ✓ the direct decays of  $\pi^0, \eta, \eta'$  hadrons into two  $\gamma$ 's;
  - ✓  $\omega \rightarrow \pi^0 \gamma$ ;
  - ✓  $\Delta \rightarrow N \gamma$ ;
  - ✓ the Dalitz decays of  $\eta \rightarrow \pi \pi \gamma, \eta \rightarrow \gamma e e, \pi^0 \rightarrow \gamma e e$ ;
  - ✓  $\eta' \rightarrow \rho^0 \gamma, \Sigma \rightarrow \Lambda \gamma$ ,
  - ✓ the  $\pi N$  and  $NN$ -bremsstrahlung.

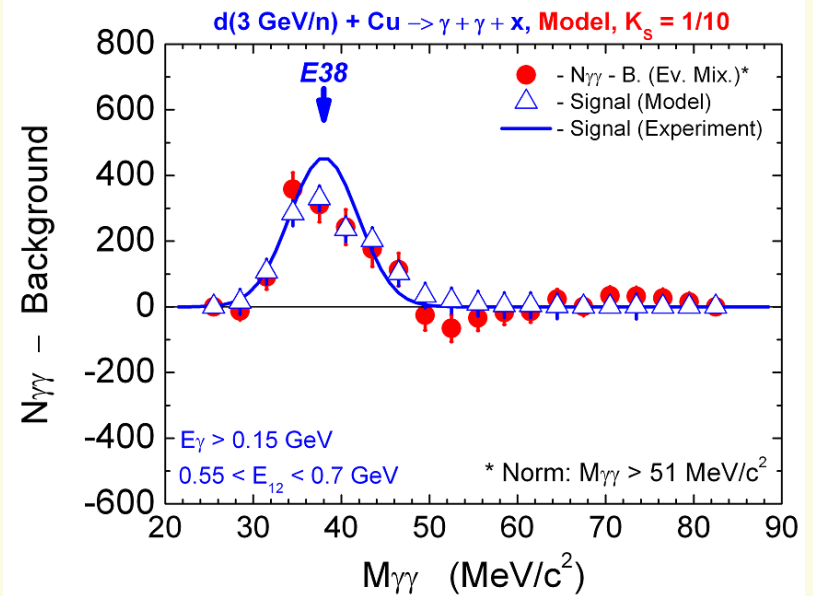
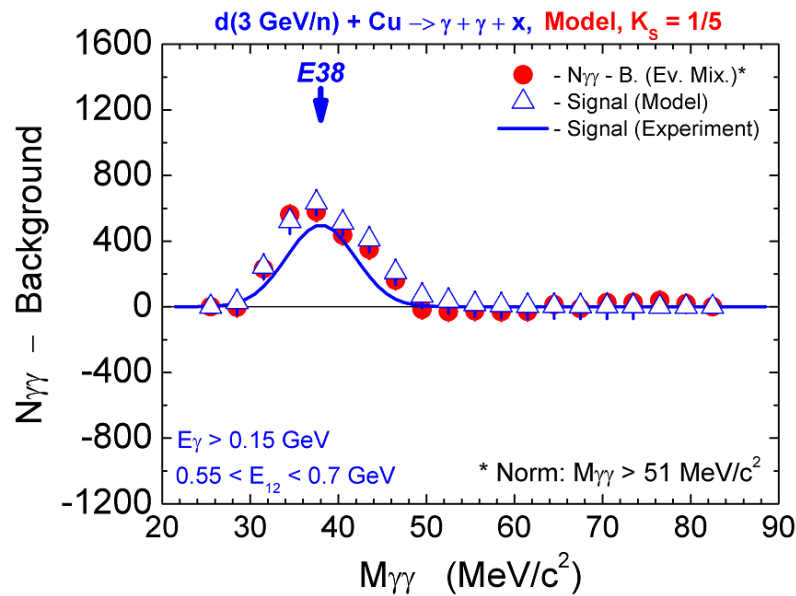
The effective mass distribution (per 4 MeV/\$c^2\$) of  $\gamma\gamma$  pairs for all  $\gamma$ -quanta in the modeled source (left figure) and ratio of the number of triggered  $\gamma\gamma$  pairs under real experimental conditions (at  $E_{\gamma} > 50$  MeV (criterion (A))) on the total number in the modeled source, depending on the effective mass (per 2 MeV/\$c^2\$) of  $\gamma\gamma$  pairs for the Model after excluding of events with  $\gamma\gamma$  pairs from the E(38) boson.



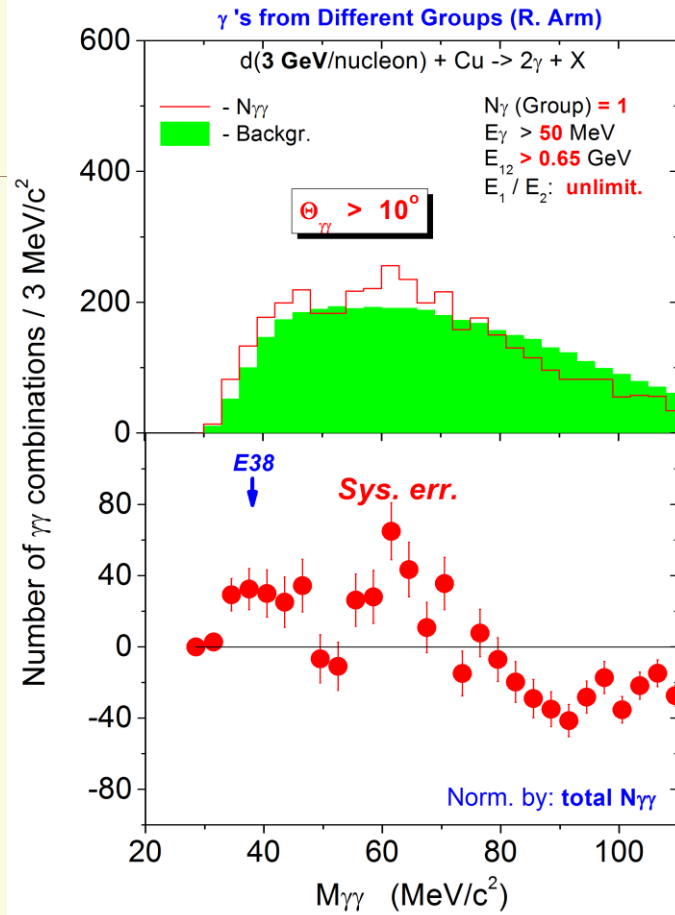
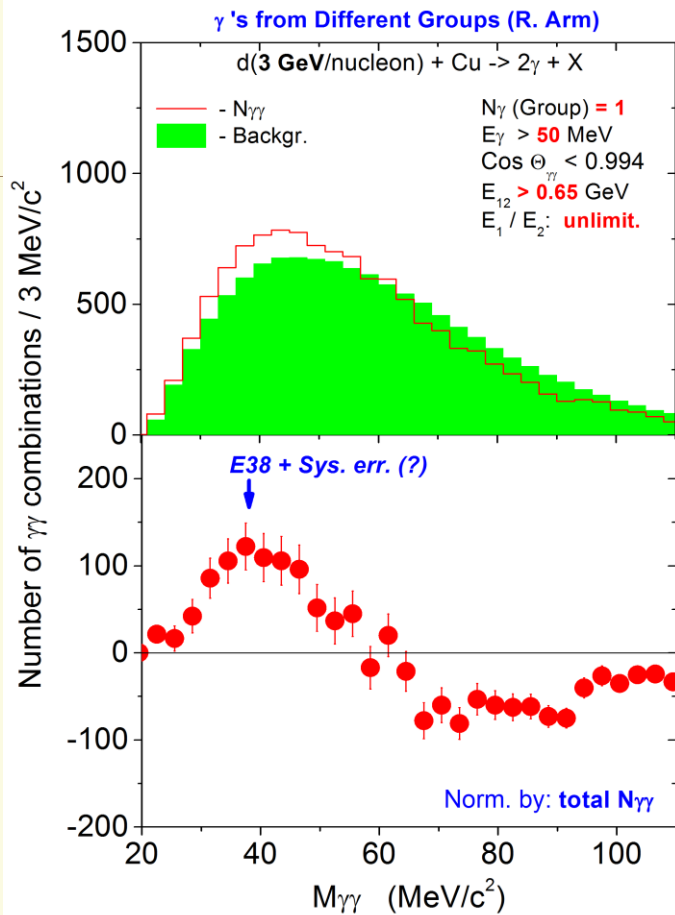
Invariant mass distributions (per 6 MeV/\$c^2\$) of  $\gamma\gamma$  pairs satisfying criteria (A) at  $450 < E_{12} < 700$  MeV (left figure) and criteria (C) at  $550 < E_{12} < 700$  MeV (right figure) after the background subtraction obtained for the model after exclusion of events containing the reaction of bremsstrahlung. The background is normalized to the total pair number. The curves are the experimental signal after the background subtraction (Gaussian approximation) proportional to the total number of  $\gamma\gamma$  pairs in the spectrum.

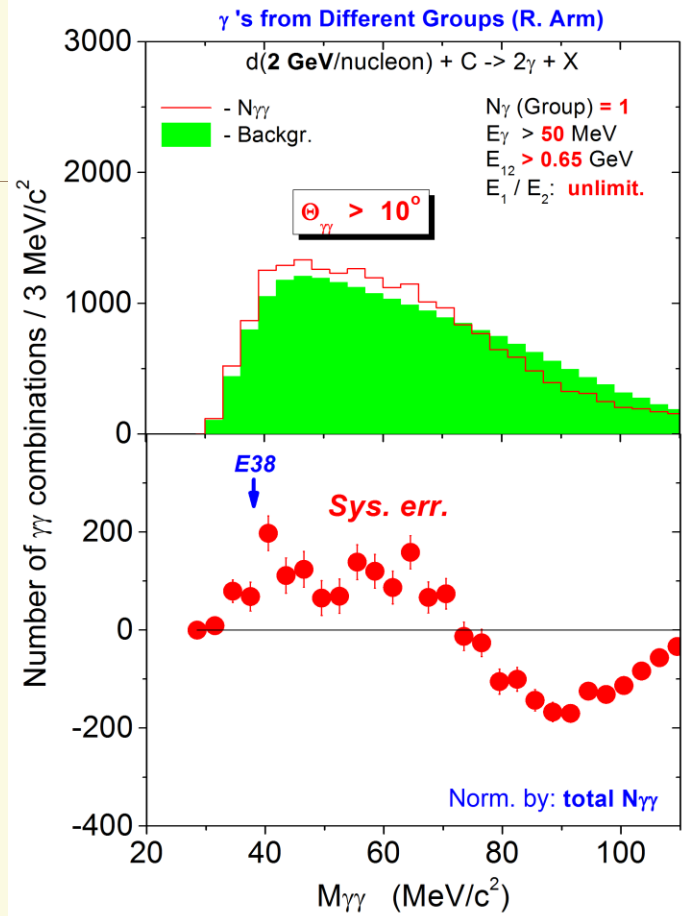
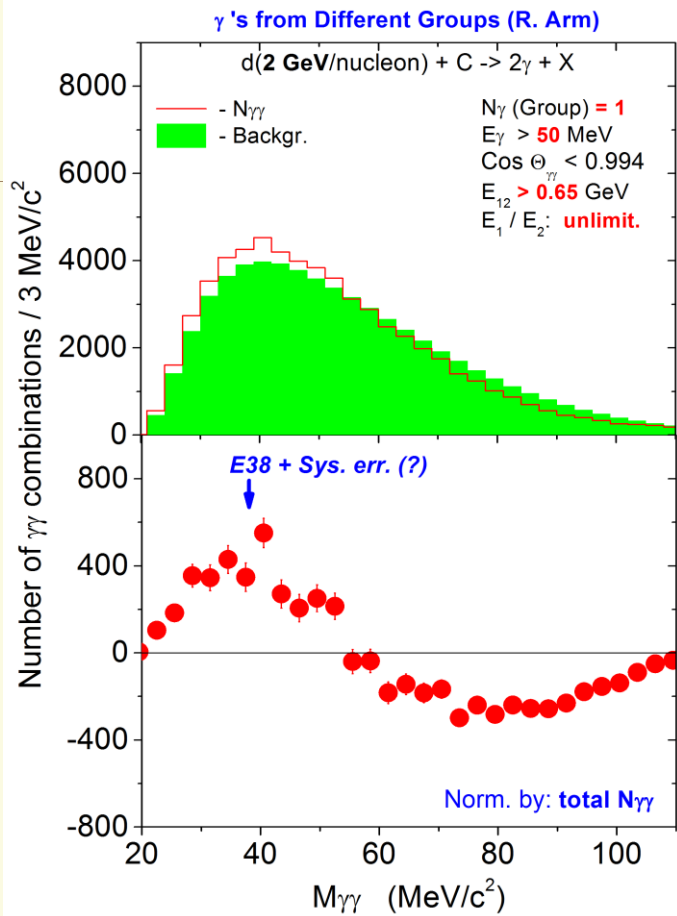


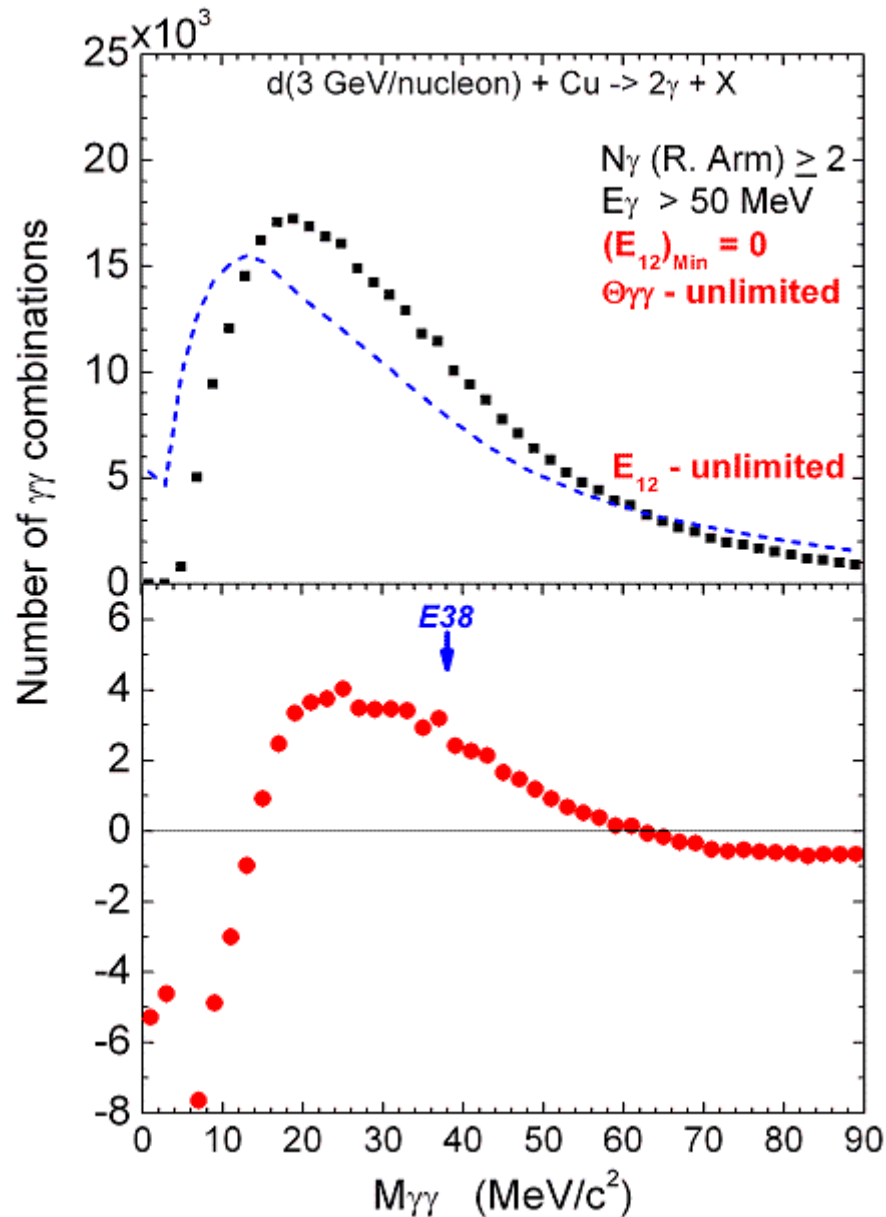
The same as in Fig. \hspace{-0.2ex} \ref{Fig: Signal extraction CriteriaC}, but with the signal in the simulated data reduced by a factor  $K_S = 1/5$  (among the events, containing a photon from the bremsstrahlung, each 5th event was taken) (left figure) and by a factor  $K_S = 1/10$  (right figure).



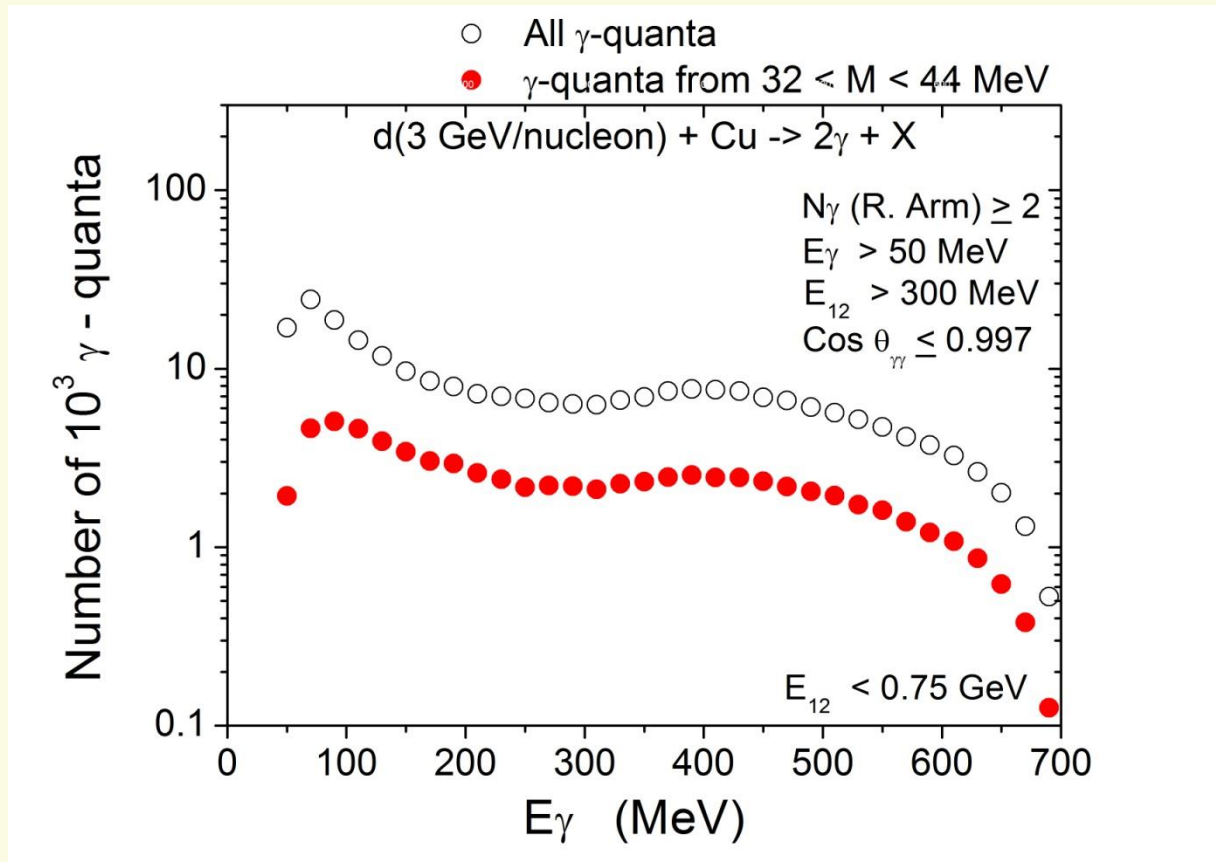




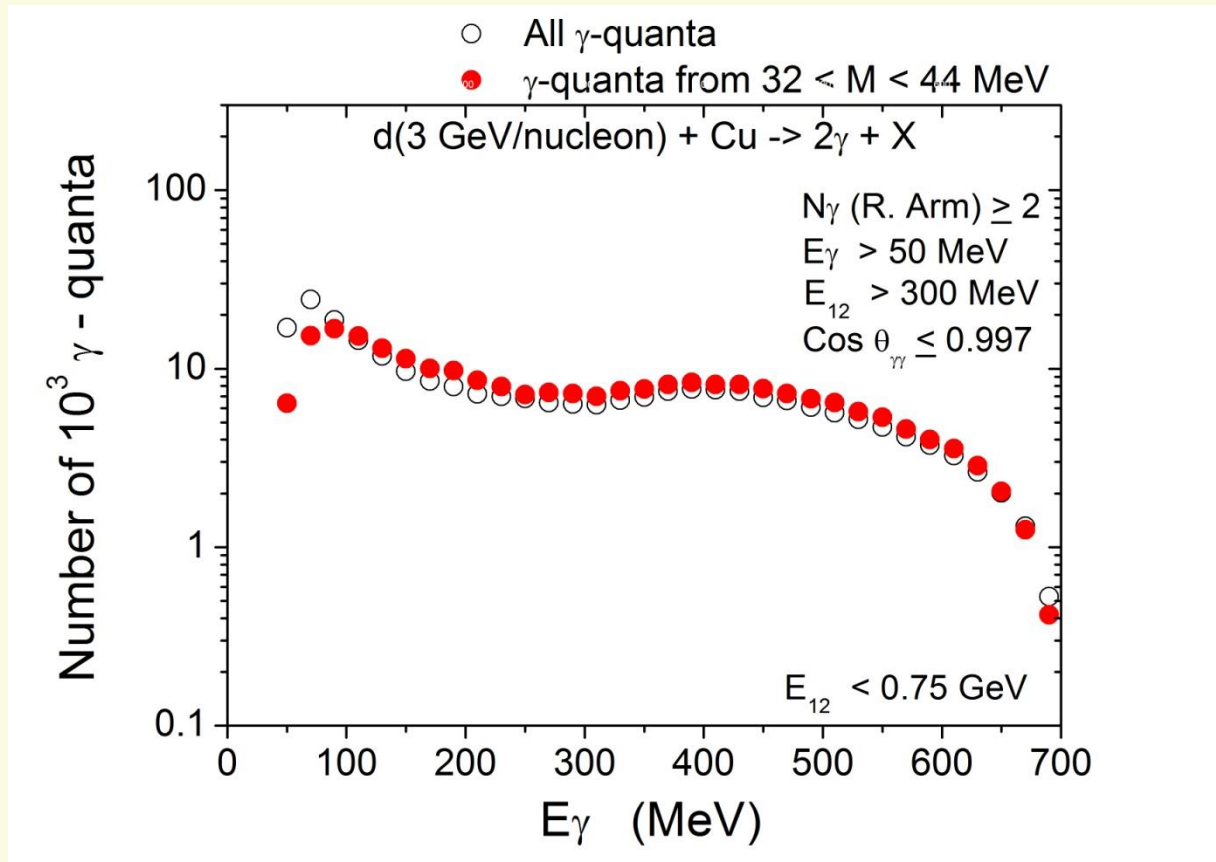




# The energy distributions of $\gamma$ -quanta in the spectrum (sl. №11) (without normalization)



# The energy distributions of $\gamma$ -quanta in the spectrum (sl. №11) (after normalization)



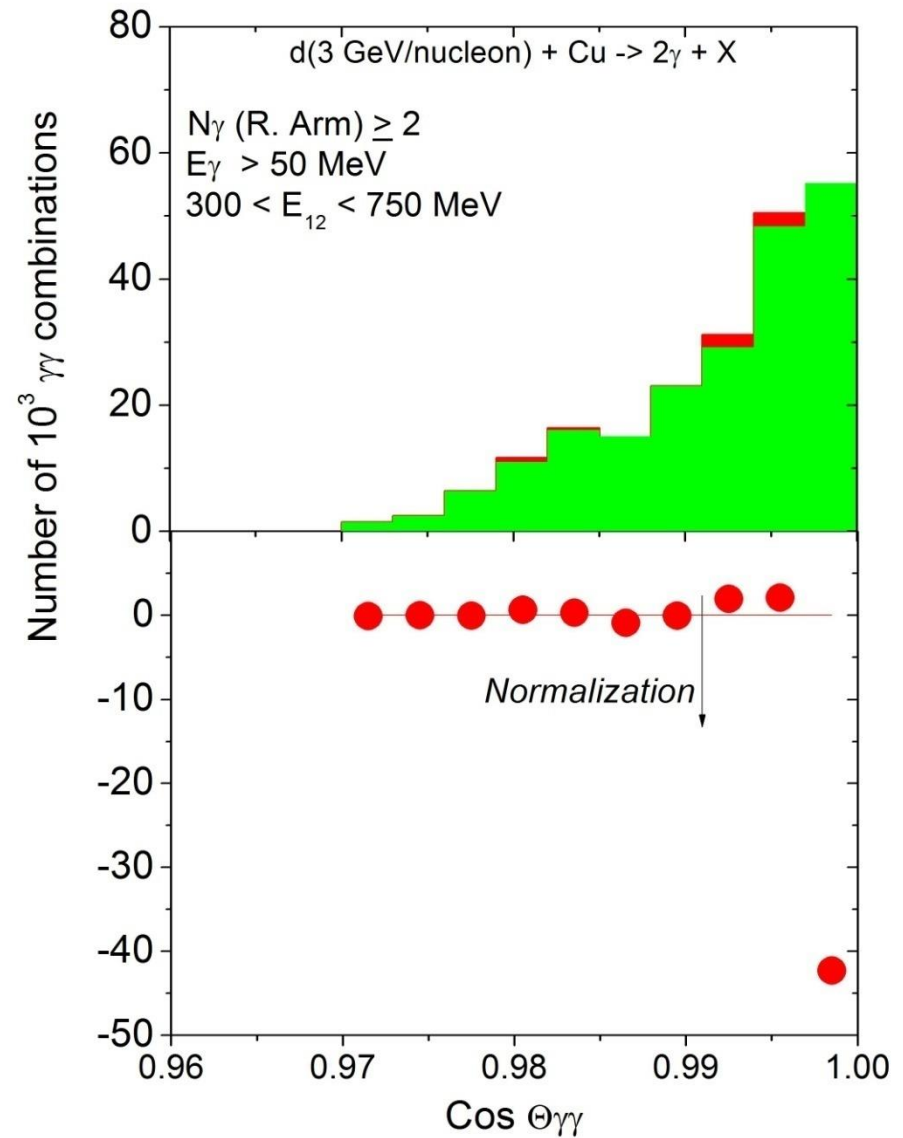
I. d(3 GeV/n)+Cu

## 1) Soft selection criteria:

(i) the energies of photons,  
 $E_\gamma > 50 \text{ MeV}$ ,

(ii) the sum of the energies  
of two photons,  
 $300 < E_{12} < 750 \text{ MeV}$ ,

The background is  
normalized to the number of  
pairs in a range  
 $\text{Cos } \Theta_{\gamma\gamma} < 0.991$ .



# arXiv:1204.2349v1

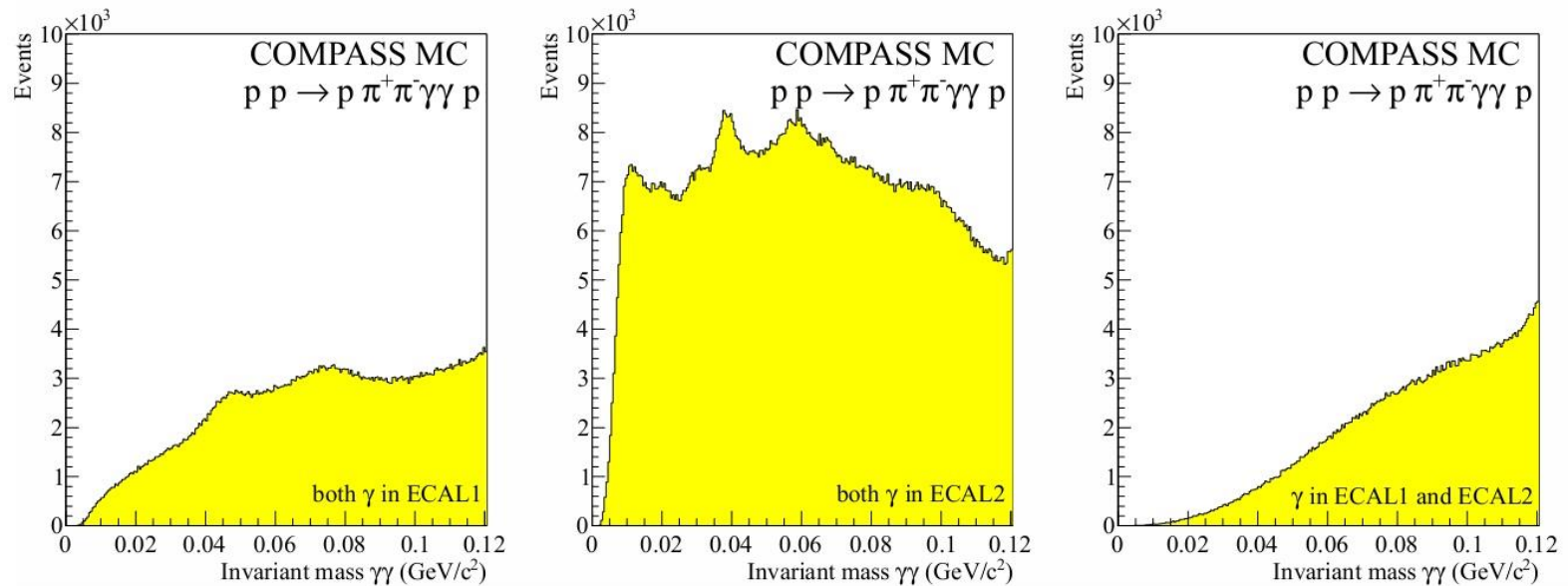


FIG. 3. Two-photon mass spectra below the  $\pi^0$  peak obtained from simulation of in-target interactions  $pp \rightarrow p\pi^-\pi^+\pi^0p$  for the analysis described in Ref. [2]. The plots show the spectra for the two photons reconstructed in different combinations of the calorimeters in the two spectrometer stages. The visible peaks are caused by secondary interactions of the outgoing hadrons.

Dear colleagues!

---

I am writing with a request regarding your results listed in arXiv: 1204.2349 v1. Would you be able to conduct quantitative analysis of spectra presented in Figure 3.

- 1. Compare these spectra with experimental data in the same conditions (if possible), determine the difference between simulated and experimental normalized spectra;
- 2. Get the same spectra for pairs of  $\gamma\gamma$  taken from different events (i.e. the so-called event mixing; we have done it, for example, in the work PRC **80**, 034001 (2009));
- 3. Change the selection criteria of photons, for example, increase the minimum energy of photons, and determine the position of the peaks with the new criteria.
- ...

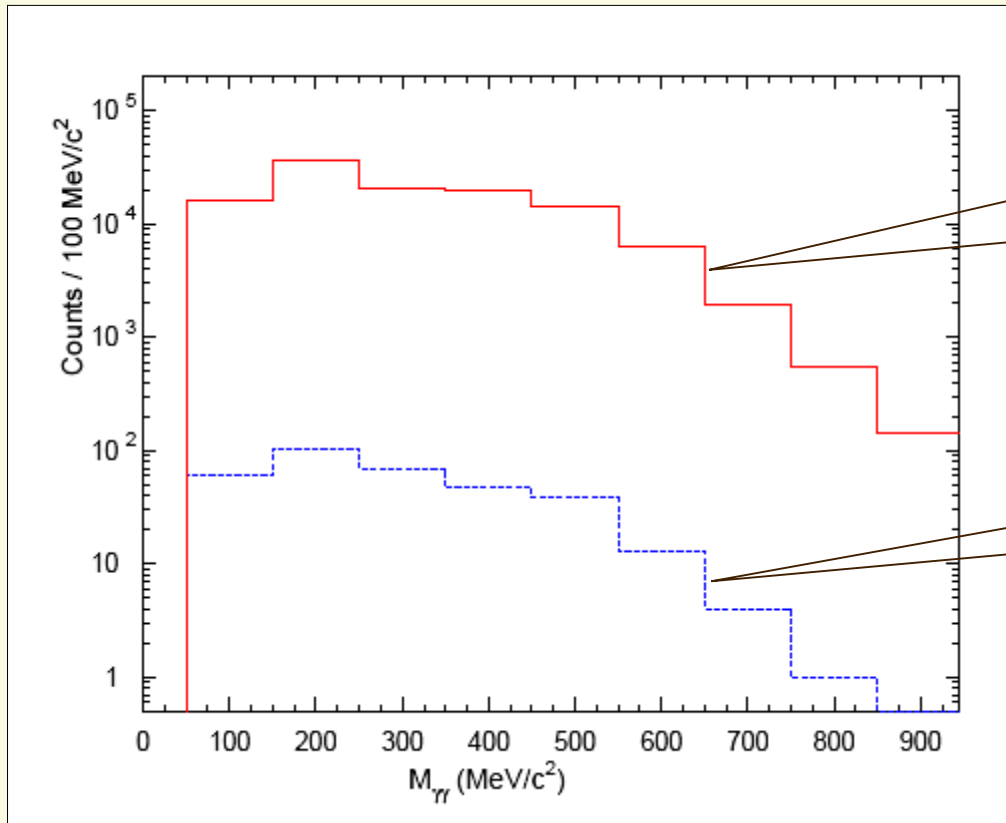


# Check of the observed effect

*The dominant part of background comes from the  $\pi^0 \rightarrow \gamma\gamma$  decay. Other sources of background are charged particles as well as neutrons and particles from a general background in the accelerator hall.*

1. The contribution of the general background in the experimental hall was estimated from the measurements with empty target: this source contributes less than 1% and is quite smoothly distributed with respect to  $M\gamma\gamma$ .
2. Contributions of the given sources were estimated by special measurements with and without veto-detectors  $S1$  and  $S2$  and by comparison of data obtained at different beam intensities. The total contribution of above sources is less than **10%** and becomes negligible (**< 1%**) after subtraction of event mixing background.

Invariant mass distributions of  $\gamma\gamma$  pairs in two different runs of measurement under condition  $E_\gamma \geq 50$  MeV: with the empty target (dashed histogram) and with the internal carbon target (solid histogram) in the reaction  $dC \rightarrow \gamma + \gamma + X$  at 2.75 GeV/c per nucleon.



**With the  
internal  
carbon target**

**Without  
target**

The invariant mass distributions of  $\gamma\gamma$  pairs in the right arm of the spectrometer in the reaction  $d+C$  (left) and  $d+Cu$  (right).

