A Resonance Structure in the γγ Invariant Mass Spectrum in pC- and dC-Interactions

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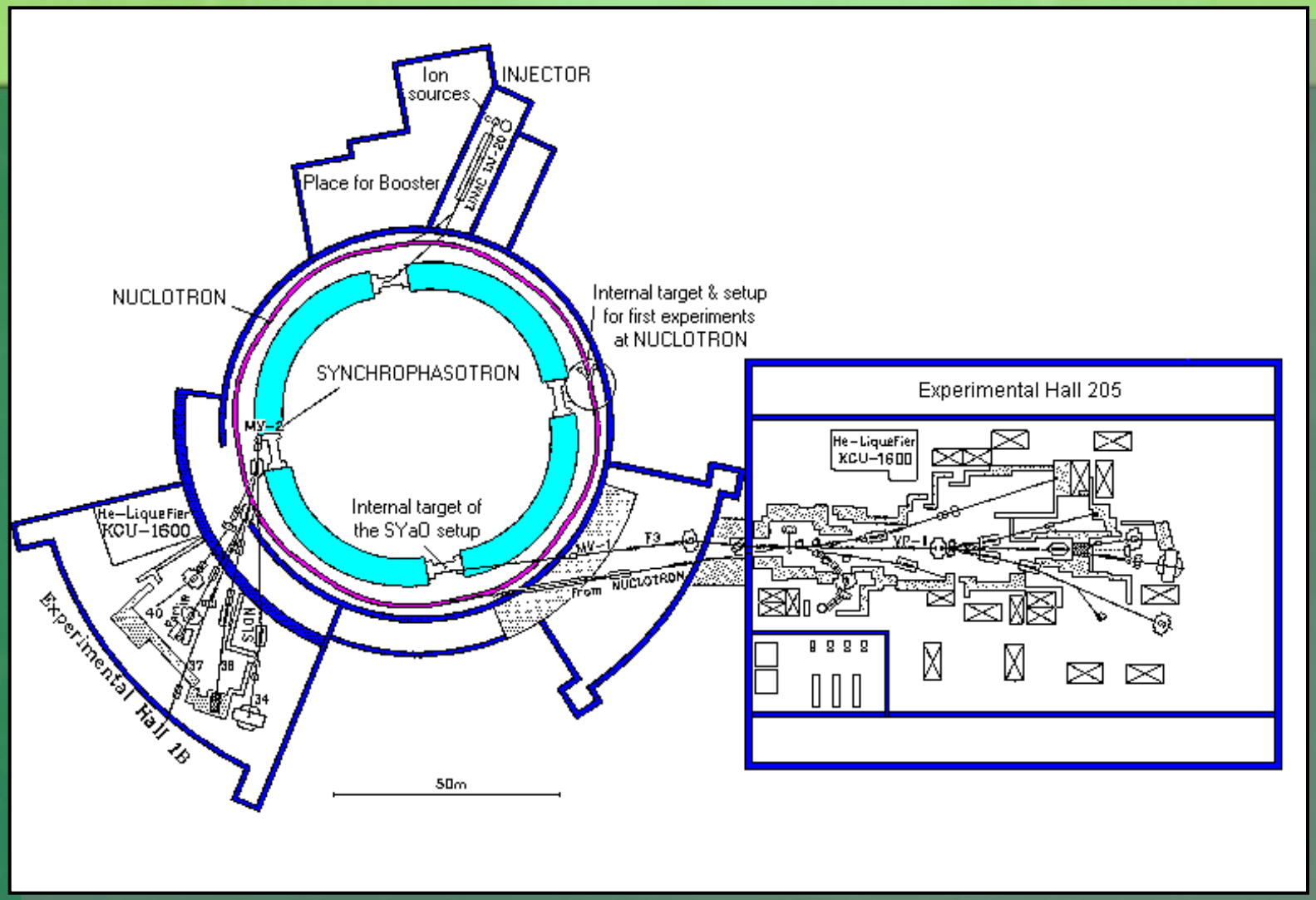
The plan of the report

- The experimental results.
- Data simulation.
- Possible mechanisms of the observed effect.
- Conclusion.

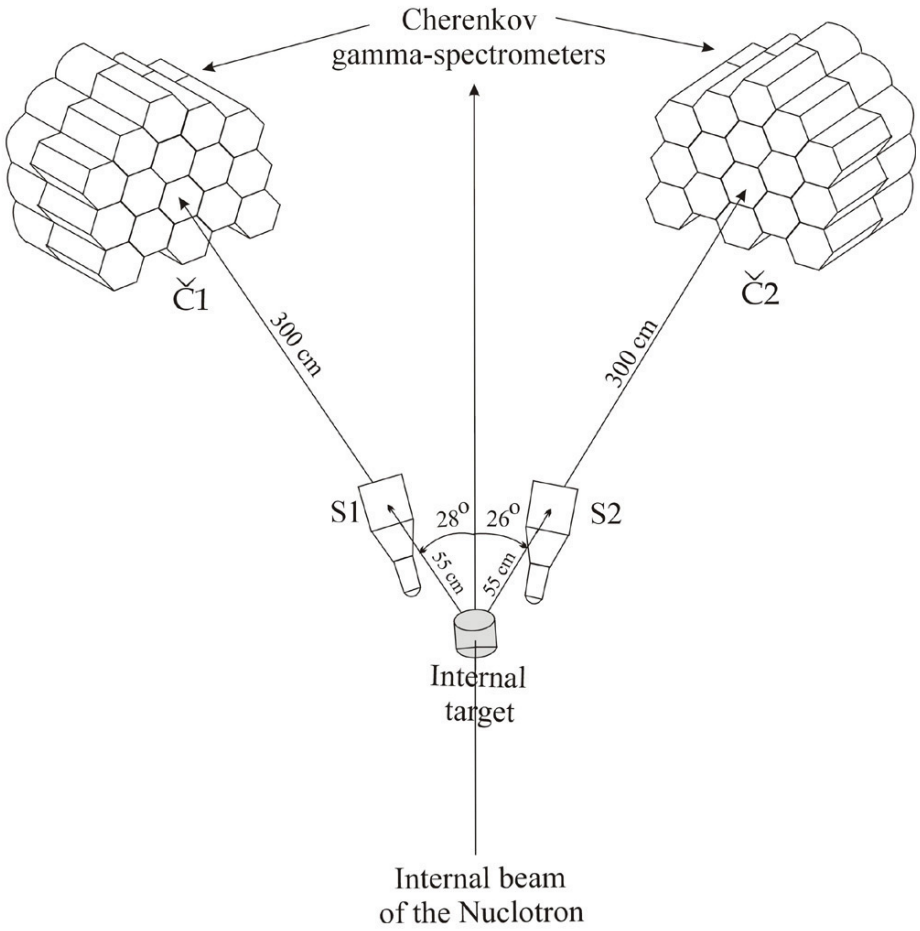
Abstract

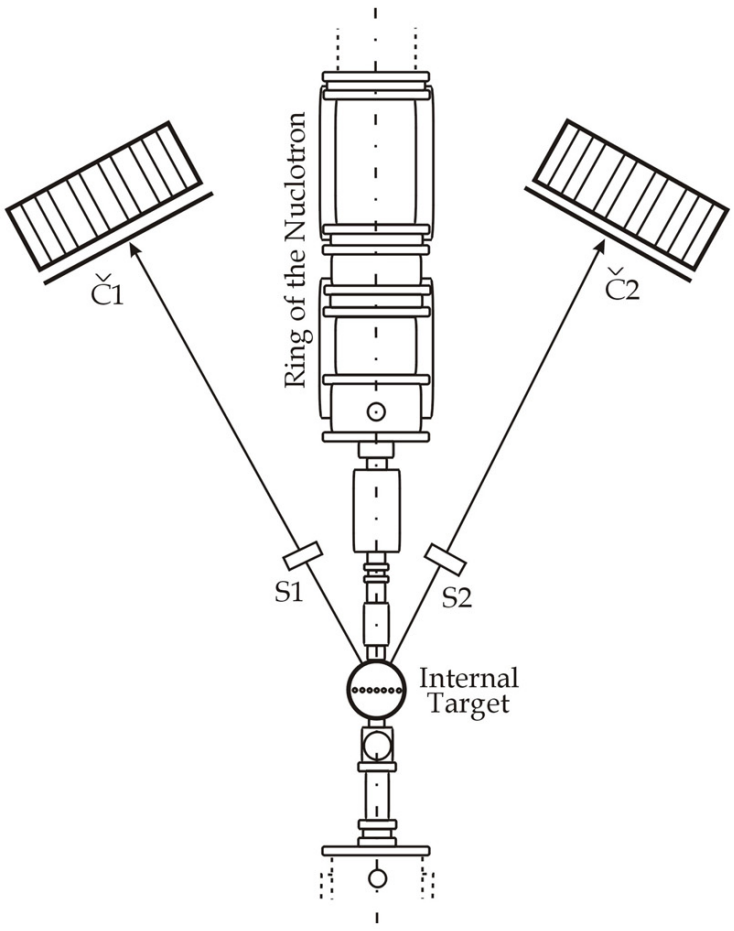
- Firstly a resonant structure was observed in the invariant mass spectrum of two photons at
  $M_{\gamma\gamma} = 360 \pm 7 \pm 9 MeV$
  in dC-interacions at momentum *2.75 GeV/c* per nucleon
- Estimates of width and production cross section are:
  $\Gamma = 49.5 \pm 18.6 MeV$ and $\sigma_{\gamma\gamma} = 98 \pm 24 \pm 93 - 67 \mu b$
- The collected statistics amount ***2339 ± 340*** events of *1.5*10^6* triggered interactions of a total quantity ***10^{12}*** of dC-interactions
- This resonant structure wasn't observed in pC-interactions at 5.5 GeV/c.

PHOTON-2 setup on internal beams of the NUCLOTRON



PHOTON-2 setup on internal beams of the NUCLOTRON

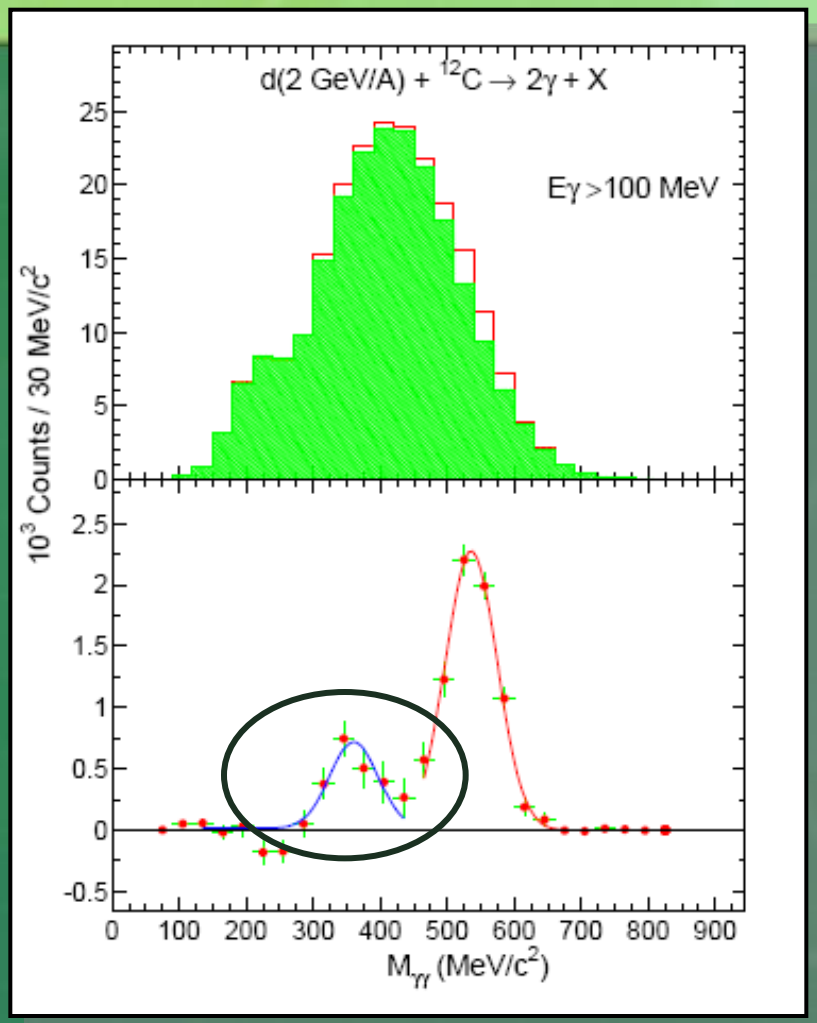


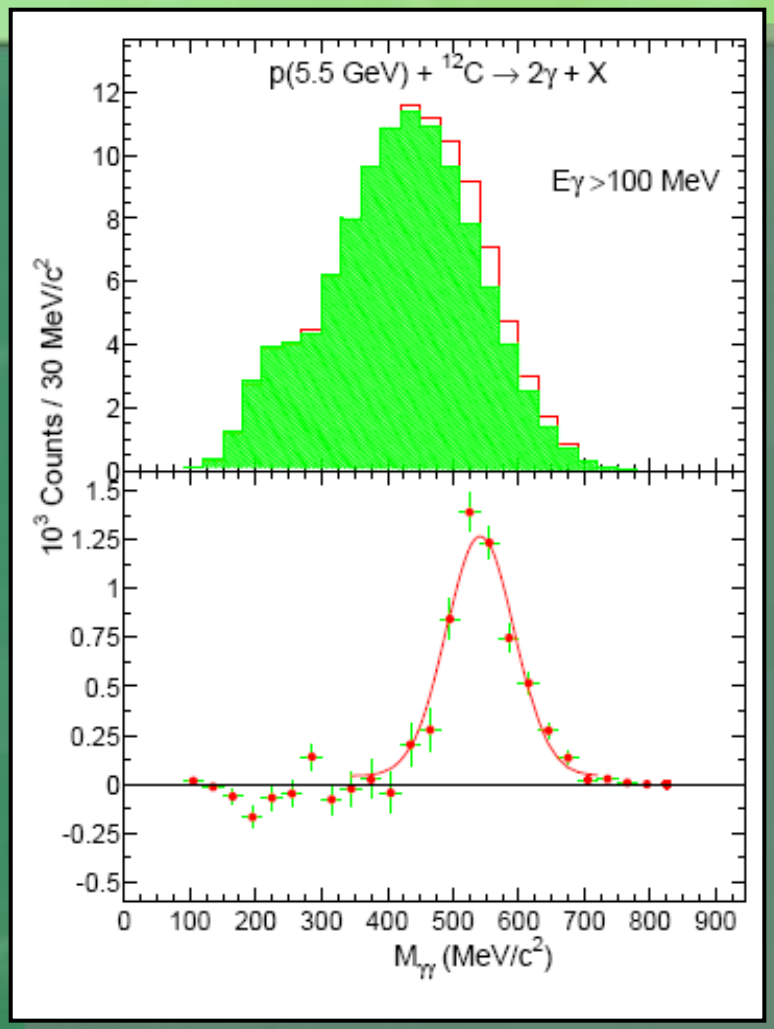


Selection criteria to background subtraction

1) the number of photons in an event, $N\gamma = 2$
2) the energies of photons, $E\gamma \geq 100$ MeV
3) the summed energy in real and random events ≤ 1.5 GeV

Invariant mass distributions of γγ pairs satisfying the criteria (1) − (3) without (upper panel) and with (bottom panel) the background subtraction. The curves are the Gaussian approximation of experimental points.





Check of the observed effect

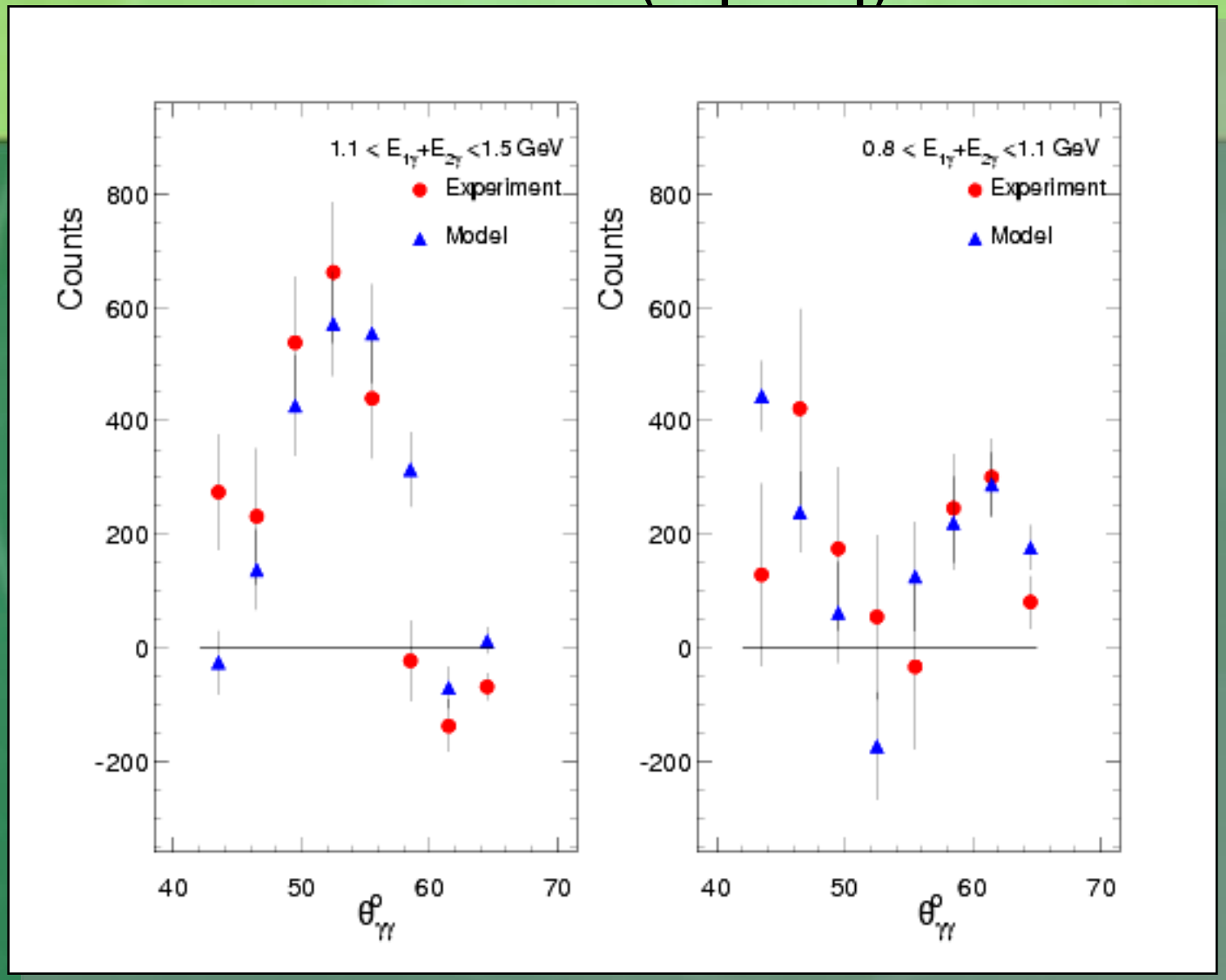
The dominant part of background comes from the $\pi^0 \rightarrow \gamma\gamma$ *decay. Other sources of background are charged particles as well as neutrons and particles from a general background in the accelerator hall.*

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*γγ. (sl. №24)
2. Contributions of the given sources were estimated by special measurements with and without veto-detectors *S*1 and *S*2 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 (sl. №25 27)

Check of the observed effect

3. To elucidate the nature of the detected enhancement , we investigate the dependence of its position and width on the opening angle of two photons and their energy selection level: both maxima survive and located practically at the same values of *M*γγ. (sl. №28, 29)
4. Pair distributions over the opening angle Θ γγ for different intervals of the sum of two-photon energy. (second slide)
5. Investigations of systematic errors. (sl. №30)
6. Similar analysis within the wavelet method. (sl. №31)
7. Comparisons with another experiments. (sl. №32-34)
8. Model simulation under the experimental conditions (see below).

Distribution of the opening angle of γγ pairs in dC collisions for the two selections of (E1γ + E2γ).



Data simulation

- To simulate pC- and dC- reactions we used a two-phases transport code [*K.K. Gudima et al. LANL Report LA-UR-01-6804, Los Alamos, 2001*]
- The following γ-decay channels are taken into account:

✓ the direct decays of **π^o,η,ή** hadrons into two **γ**'s;

✓ **ω → π^oγ**;

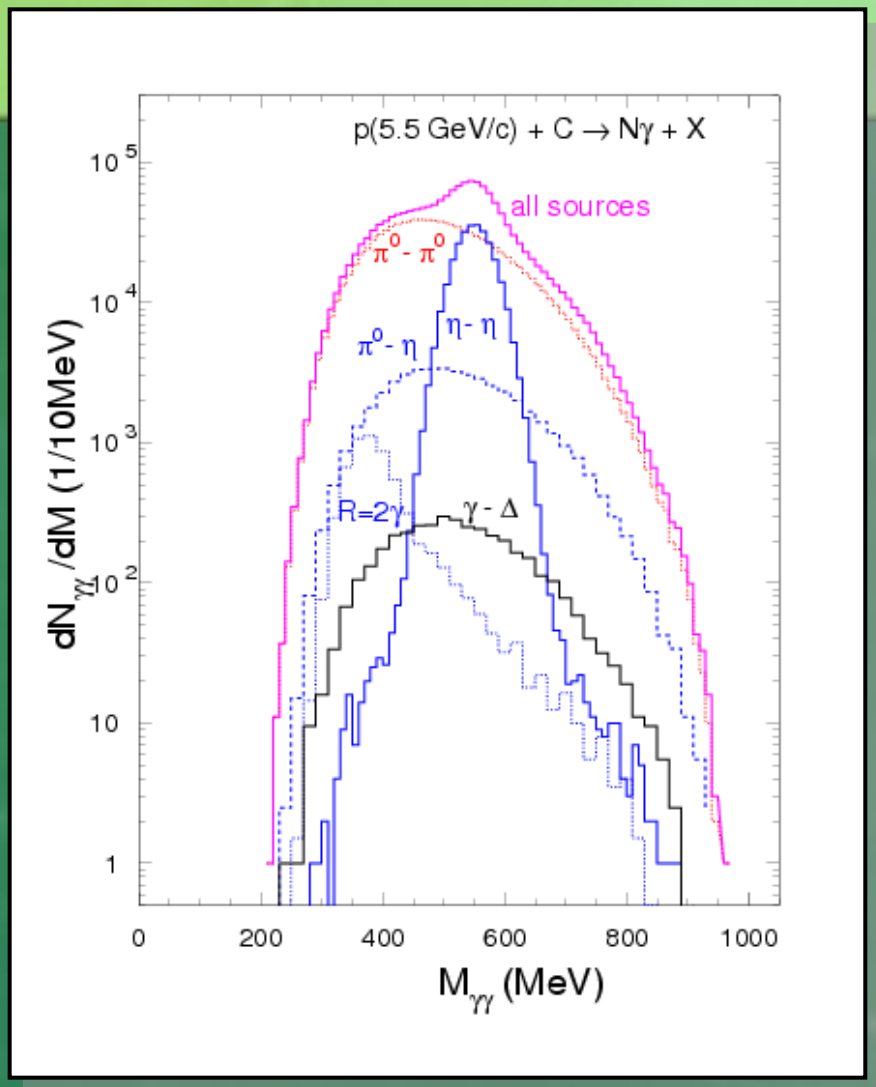
✓ **Δ → *N*γ**;

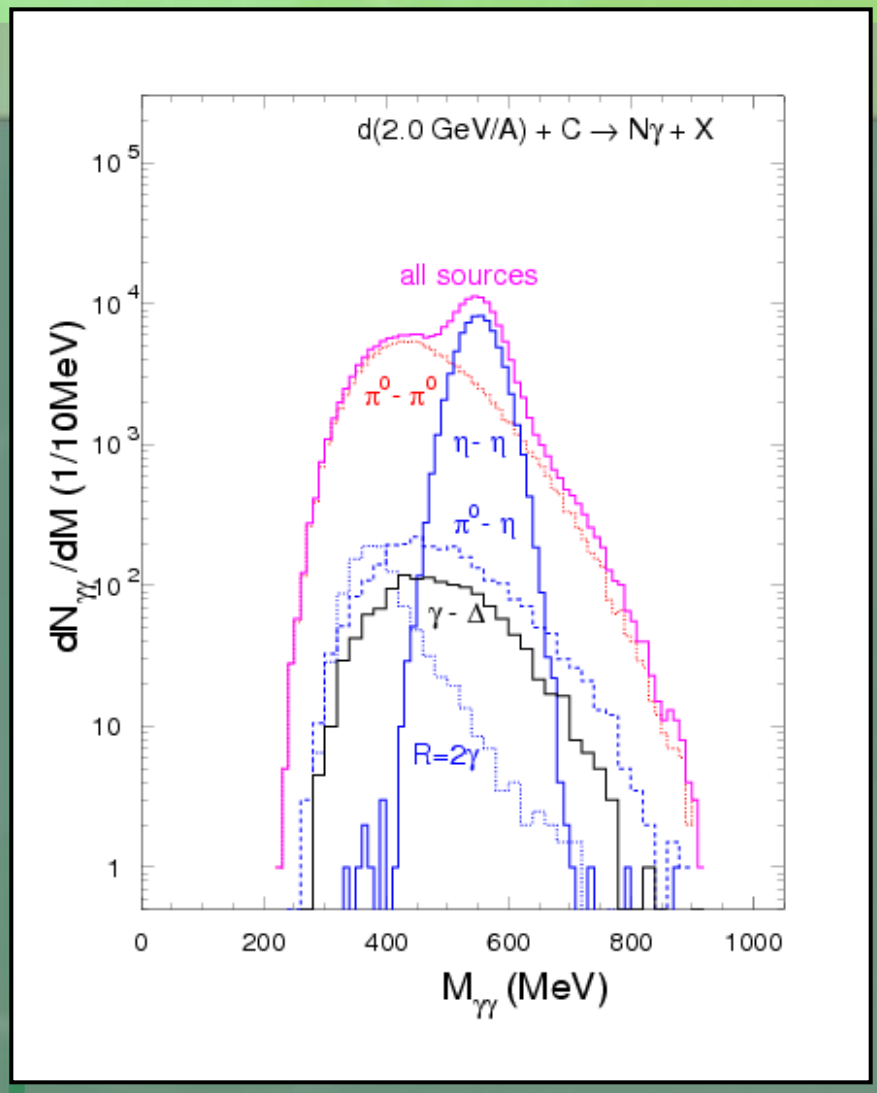
✓ the Dalitz decays of **η → ππγ**, **η → γee**, **π^o → γee**;

✓ **ή → ρ^oγ**, **Σ →Λγ**,

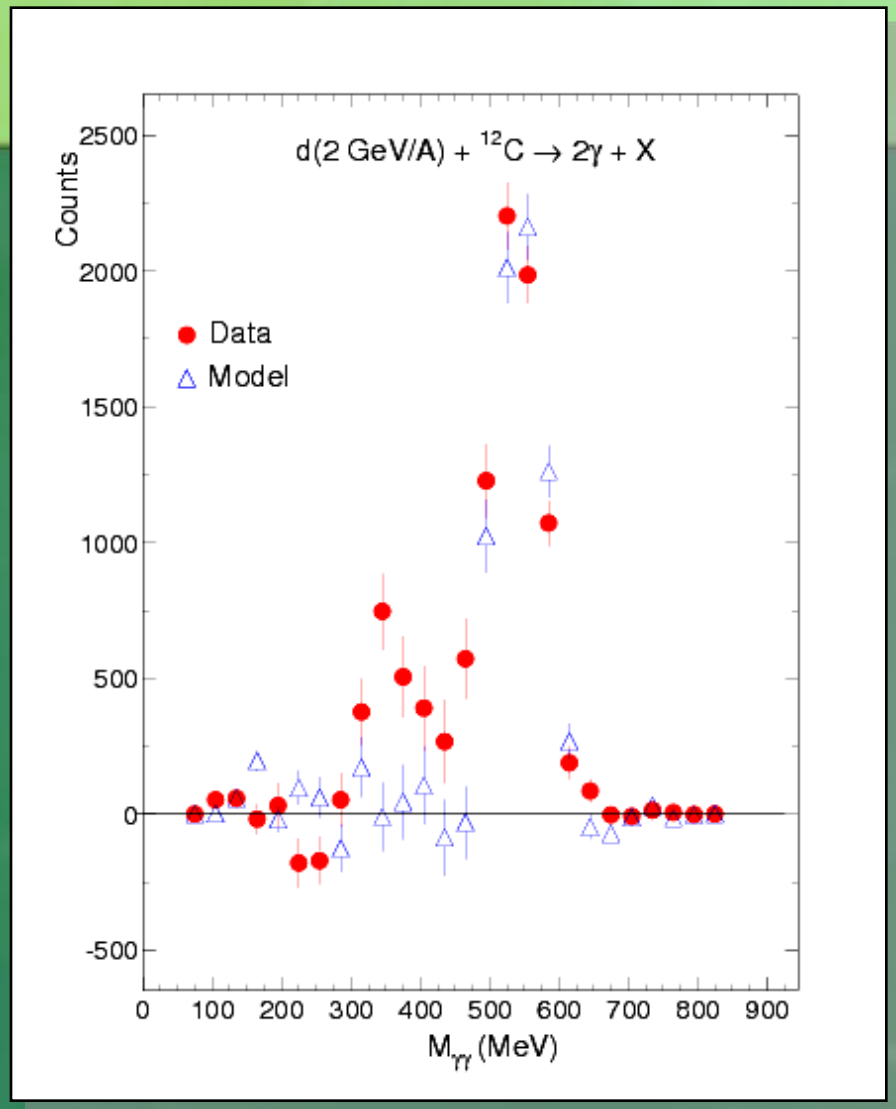
✓ the **π*N*** and ***NN***-bremsstrahlung.

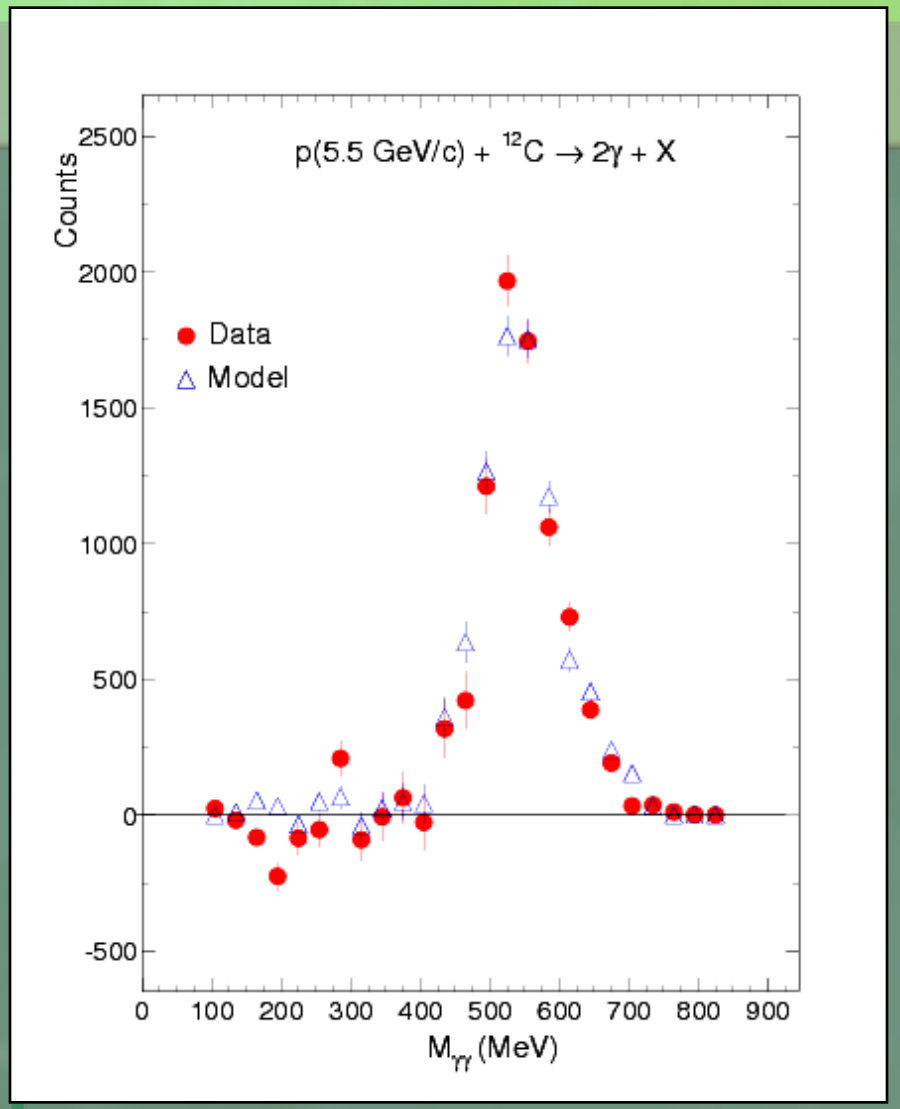
The calculated γγ invariant mass distribution in pC and dC collisions for selected events with Nγ = 2.



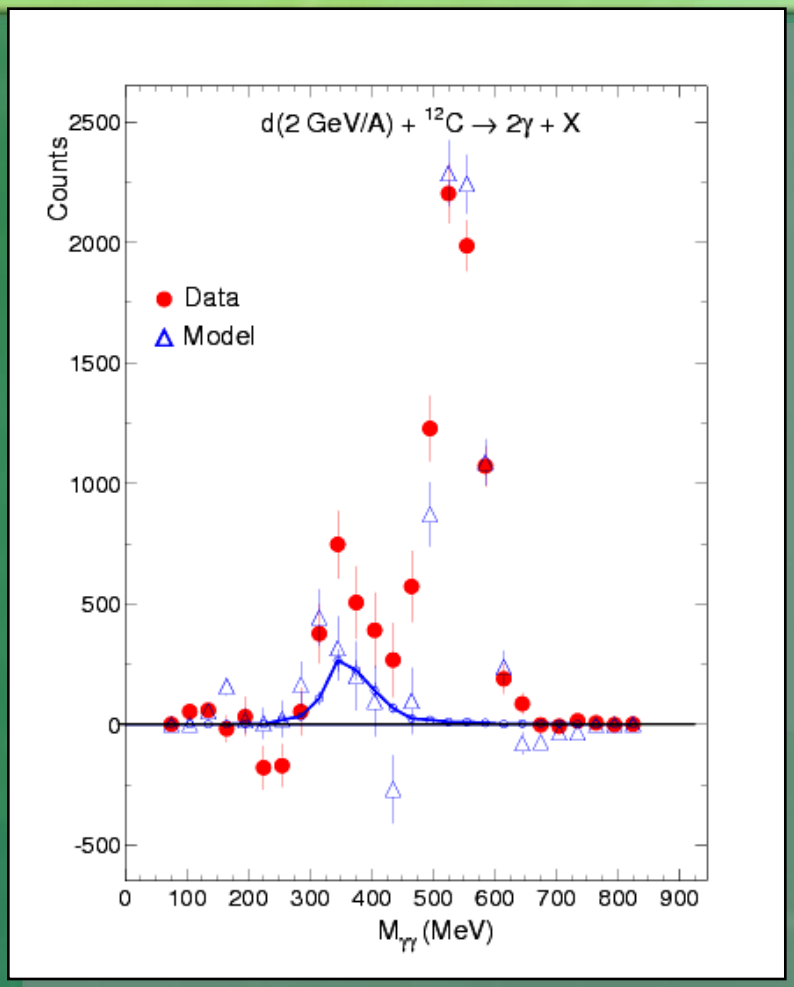


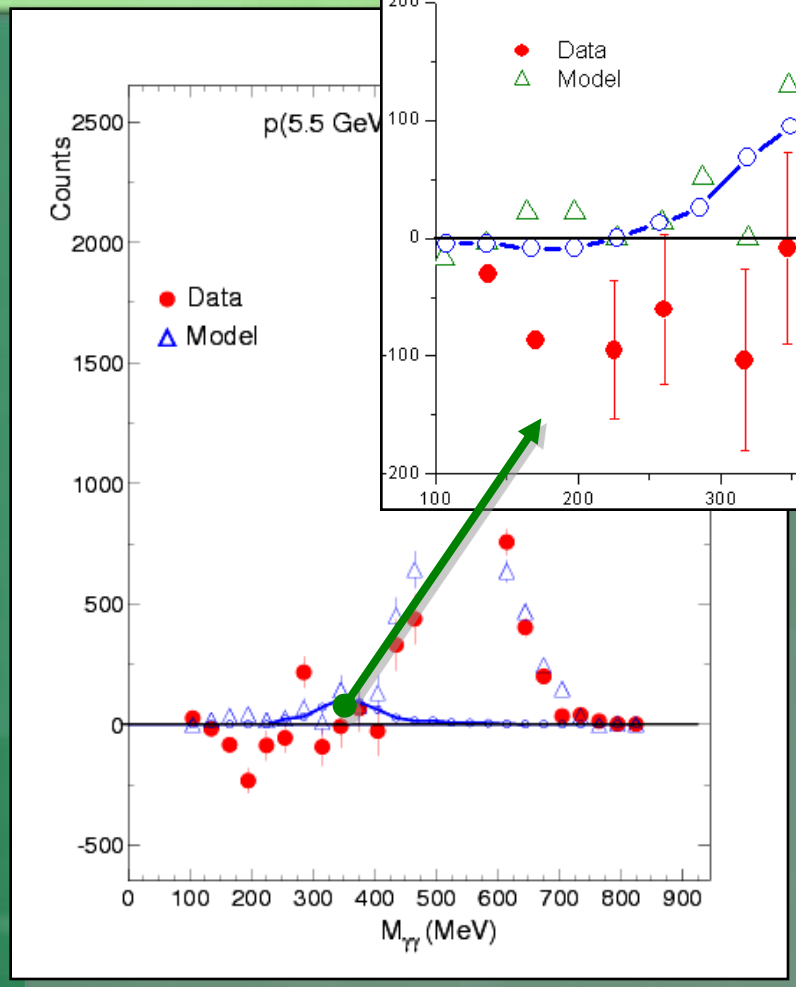
The invariant mass distributions of γγ pairs from the dC (left) and pC (right) reactions after background subtraction.





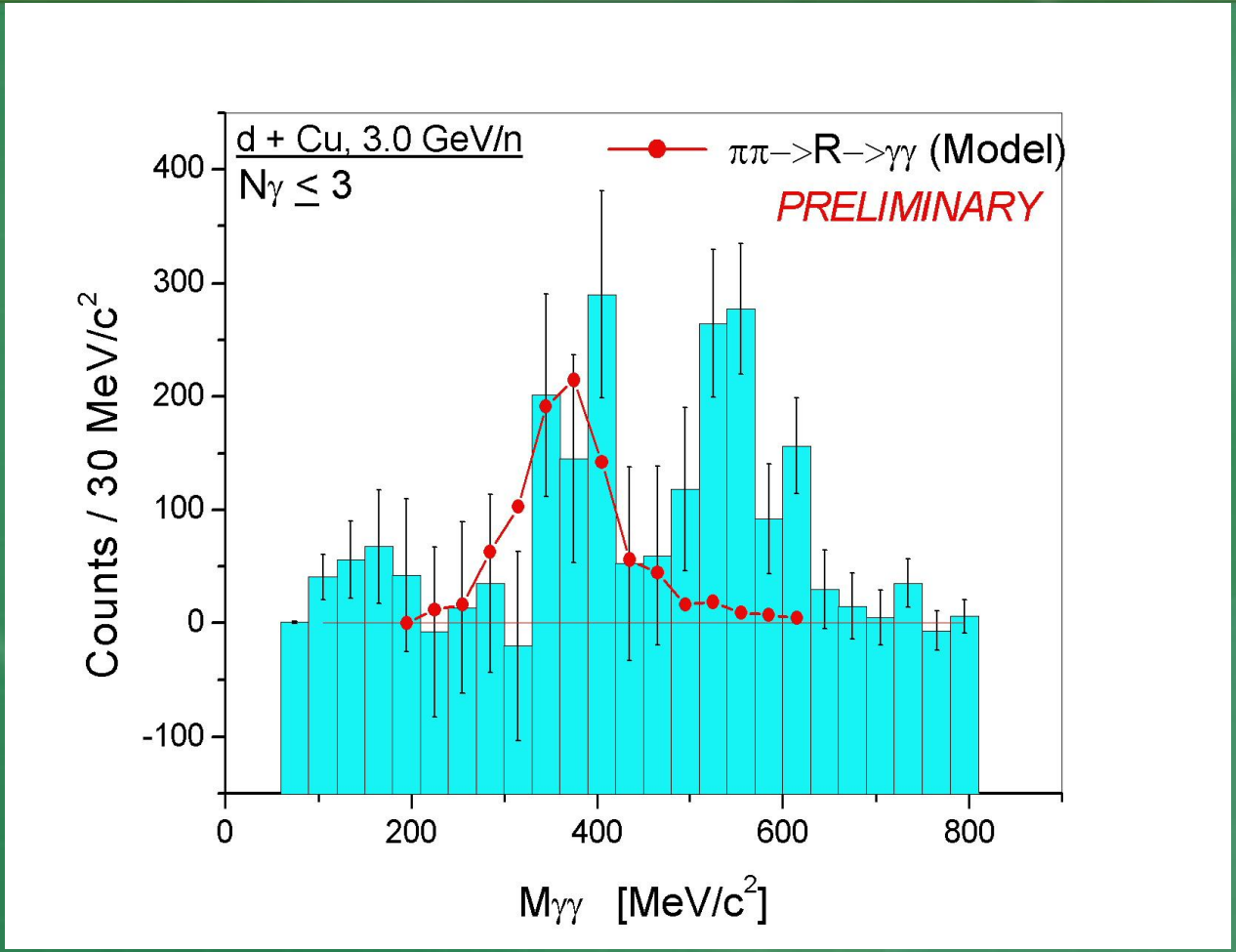
Invariant mass distributions of γγ pairs from the pC and dC reactions after background subtraction. Both experimental (circles) and simulated (triangles) points are obtained under the same conditions. The contribution of photons from the R decay is shown by the solid line.





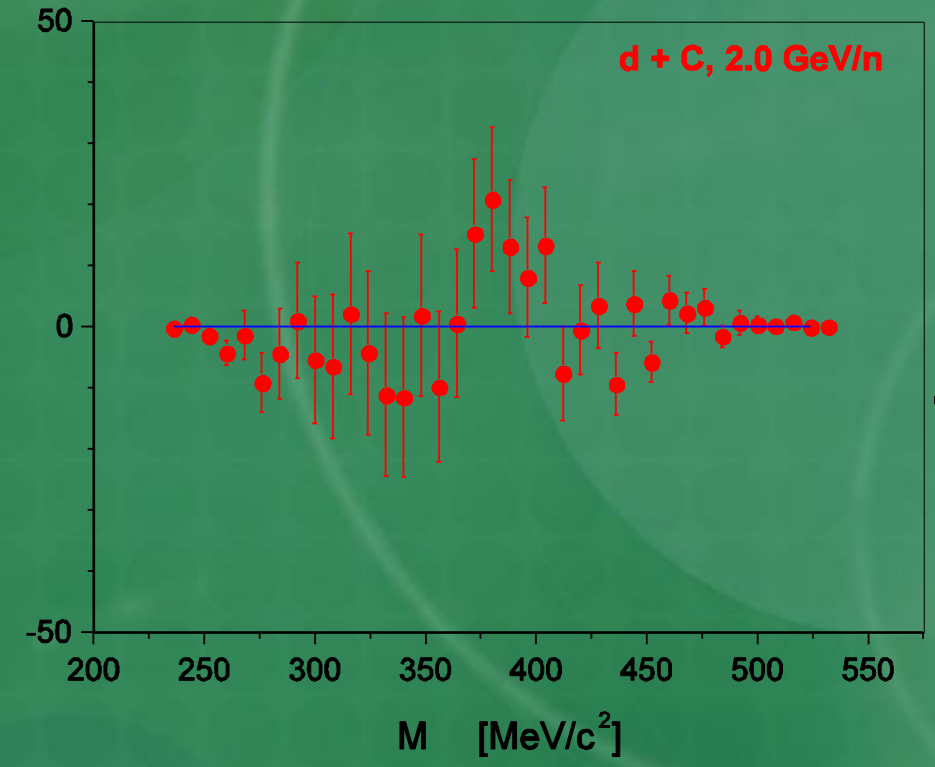
New preliminary results

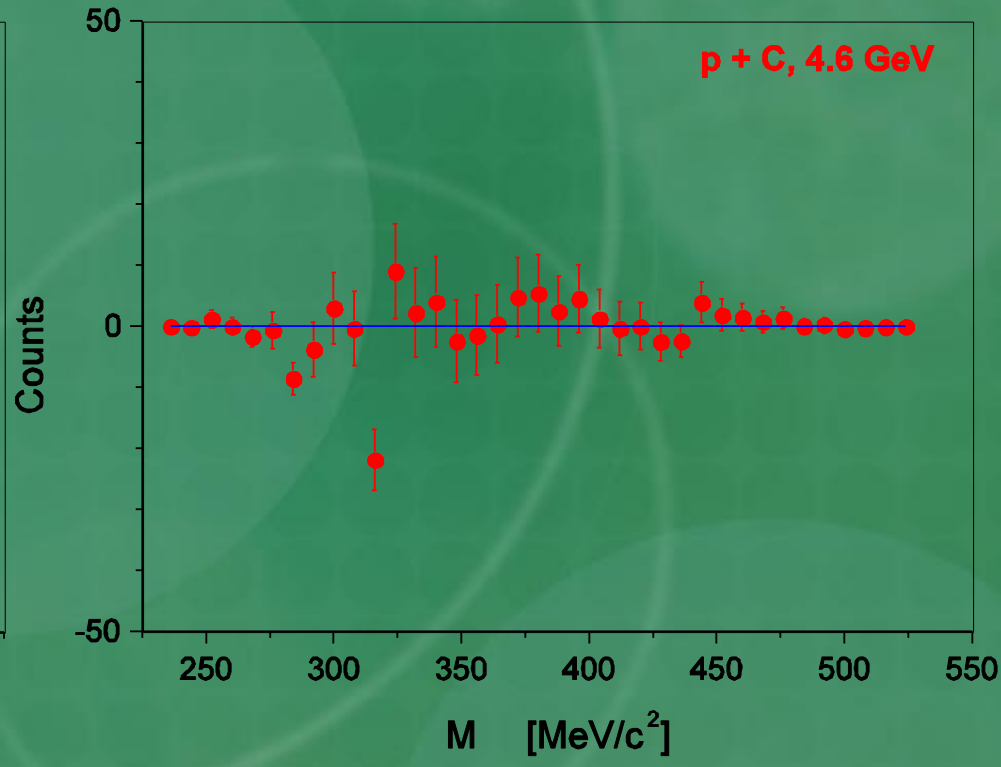
The invariant mass distributions of γγ pairs from the dCu reaction after background subtraction.



The invariant mass distributions of $\pi^o\pi^o$ pairs from the dC (left) and pC (right) reactions after background subtraction. Normalization of the backgrounds by the total numbers of pairs in the spectra.

PRELIMINARY





Dibaryon mechanism (I)

Recently the idea of nontrivial dibaryon state becomes more attractive. The proposed mechanism $NN \rightarrow d^* \rightarrow NN\gamma\gamma$ proceeds through a sequential emission of two photons:

one is caused by production of the decoupled baryon resonance d^* ,

second is its subsequent decay.

[*A.S. Khrykin et al. arXiv: 0710.3331*, ***PRC64*** *(2001) 034002*, ***NPA721****(2003)625*]

Dibaryon mechanism (II)

Very attractive candidate for its realization might be a model of the intermediate σ-dressed dibaryon. In this model the short-range *NN*-interaction is described with the *s*-channel σ exchange associated with the intermediate dibaryon production treated as a σ-dressed six-quark bag. As the result we have decrease of the assumed σ- mass, it is estimated $M\sigma \sim 350 \quad 380$ MeV. Therefore it should enhance the near-threshold pion and double-pion production. *[V.I.Kukulin et al. J.Phys.G30(2004)287, 30(2004),309]*

This mechanism is now under investigation.

Concluding remarks

1. Following a experiment at the JINR Nuclotron the resonans-like enhancement was observed in two-gamma spectrum in dC-interactions (2.75 GeV/c per nucleon).

   Estimates of its characteristics are:

   Mγγ=360 7 9 MeV, Γ=49 19 MeV, σγγ ~ 98 μb

2. A structure like this was not observed in the Mγγ spectrum from pC (5.5 GeV/c) interactions while the η meson was clearly seen in both the cases.

Concluding remarks

3. To understand the nature of the observed effect were attempted some dynamic mechanisms:

- production of the hypothetic *R* resonance in ππ interactions during the evolution of the nuclear collision;
- formation of the *R* resonance with participation of photons from the Δ decay;
- the $\pi^0\pi^0$ interaction effect in the $3\pi^0$ channel of the η decay;
- a particular decoupled dibaryon mechanism.

Concluding remarks, outlook

4. The dibaryon mechanism is discussing as a possible explanation of observed enhancement. In this way it can be considered as σ-meson.
5. From the experimental side: new experiments are required to be carried out under conditions appropriate for registration of pairs of two photons within the invariant mass interval of 300-400 MeV. Some scanning in the beam energy will clarify the possible resonance structure of this effect. By varying the opening angle of the PHOTON-2 spectrometer it is possible to get information about momentum spectra of the resonance-like structure which could be a test of the *R* production mechanism.

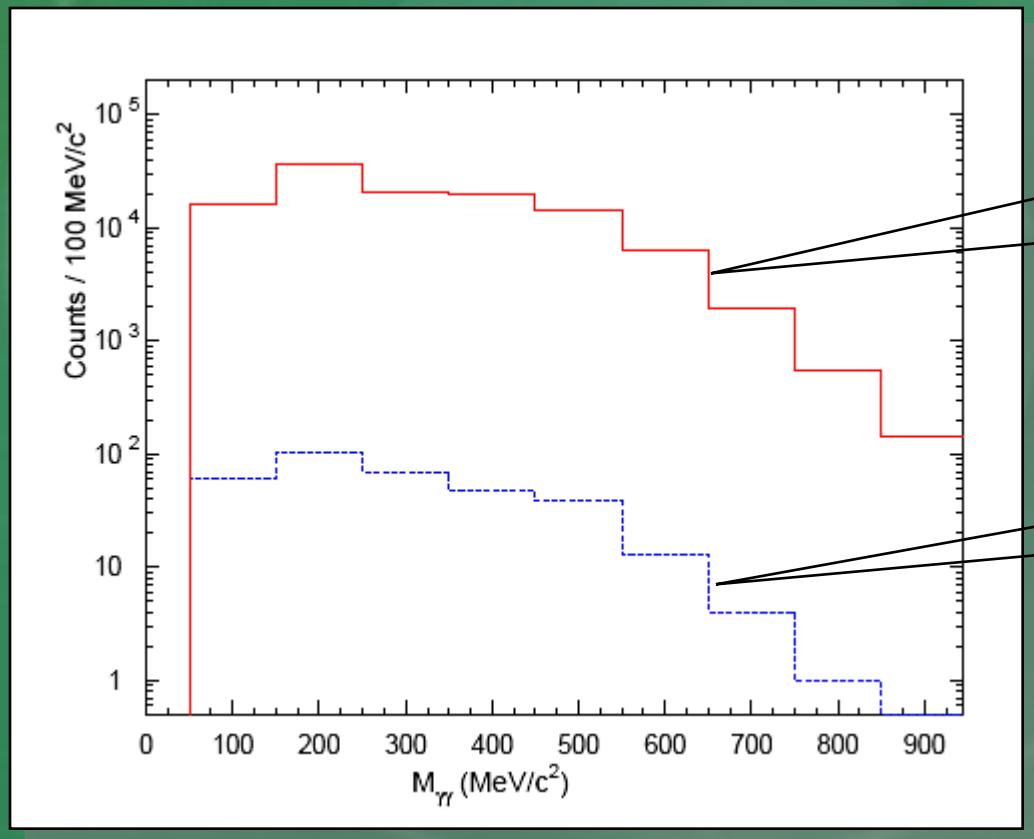
Acknowledgements

We thank S.B.Gerasimov, E.E.Kolomeitsev and E.A.Strokovsky for fruitful discussions and reading the manuscript. We are grateful to A.S.Danagulyan, H. Machner, V.D.Kekelidze, A.S.Khrykin, V.I.Kukulin, V.A.Nikitin, A.M..Sirunyan, O.V.Teryaev, G.A.Vartapetyan, for discussions and valuable remarks.

Furthermore, we would like to thank S.V.Afanasev, V.V.Arkhipov, A.S.Artemov, A.F. Elishev, A.D. Kovalenko, V.A.Krasnov, A.G.Litvinenko, A.I. Malakhov, G.L.Melkumov, S.N Plyashkevich and the staff of the Nuclotron for their help in conducting the experiment, as well as B.V.Batyunya, A.V. Belozerov, A.G.Fedunov, for their help in analyzing data.

Thank you for attention!

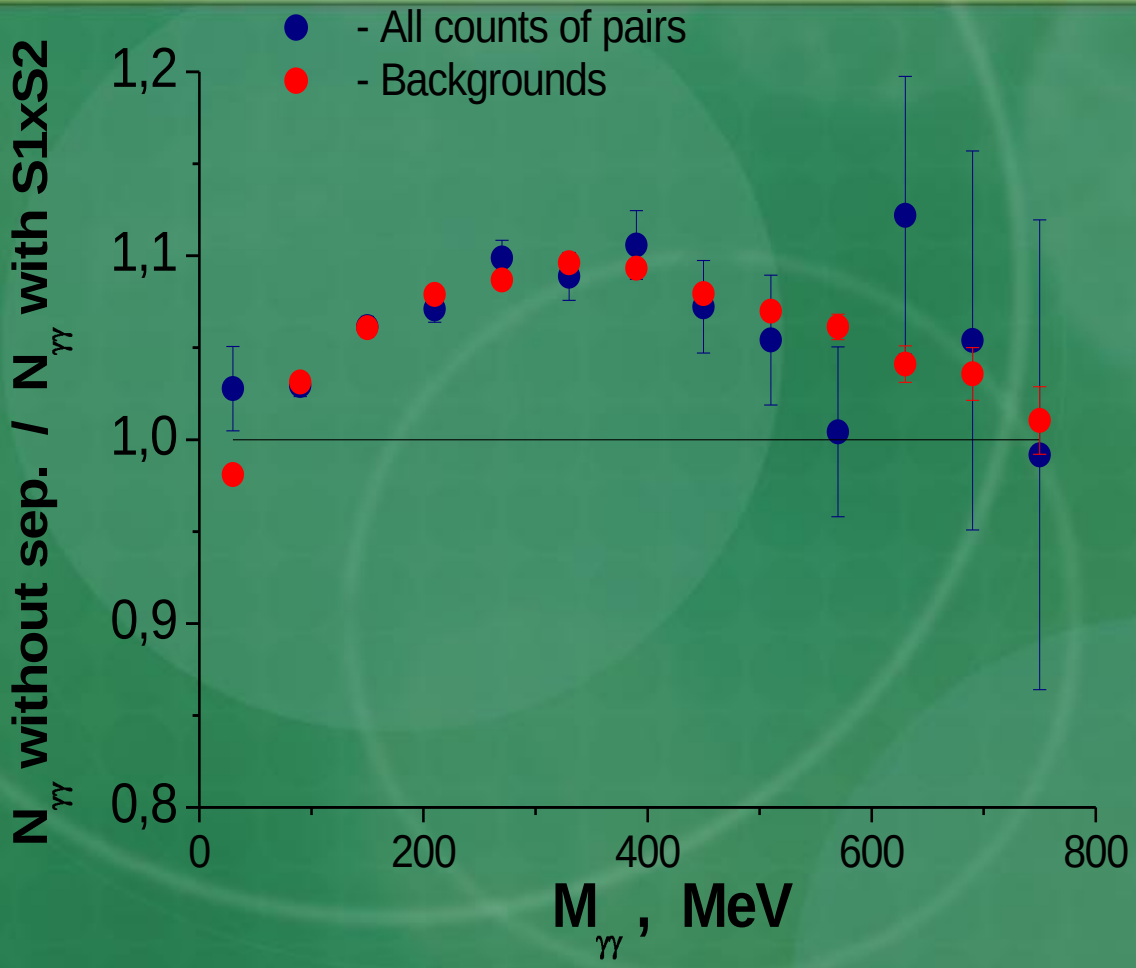
Invariant mass distributions of γγ pairs in two different runs of measurement under condition Eγ ≥ 50 MeV: with the empty target (dashed histogram) and with the internal carbon target (solid histogram) in the reaction dC = γ +γ +X at 2.75 GeV/c per nucleon.



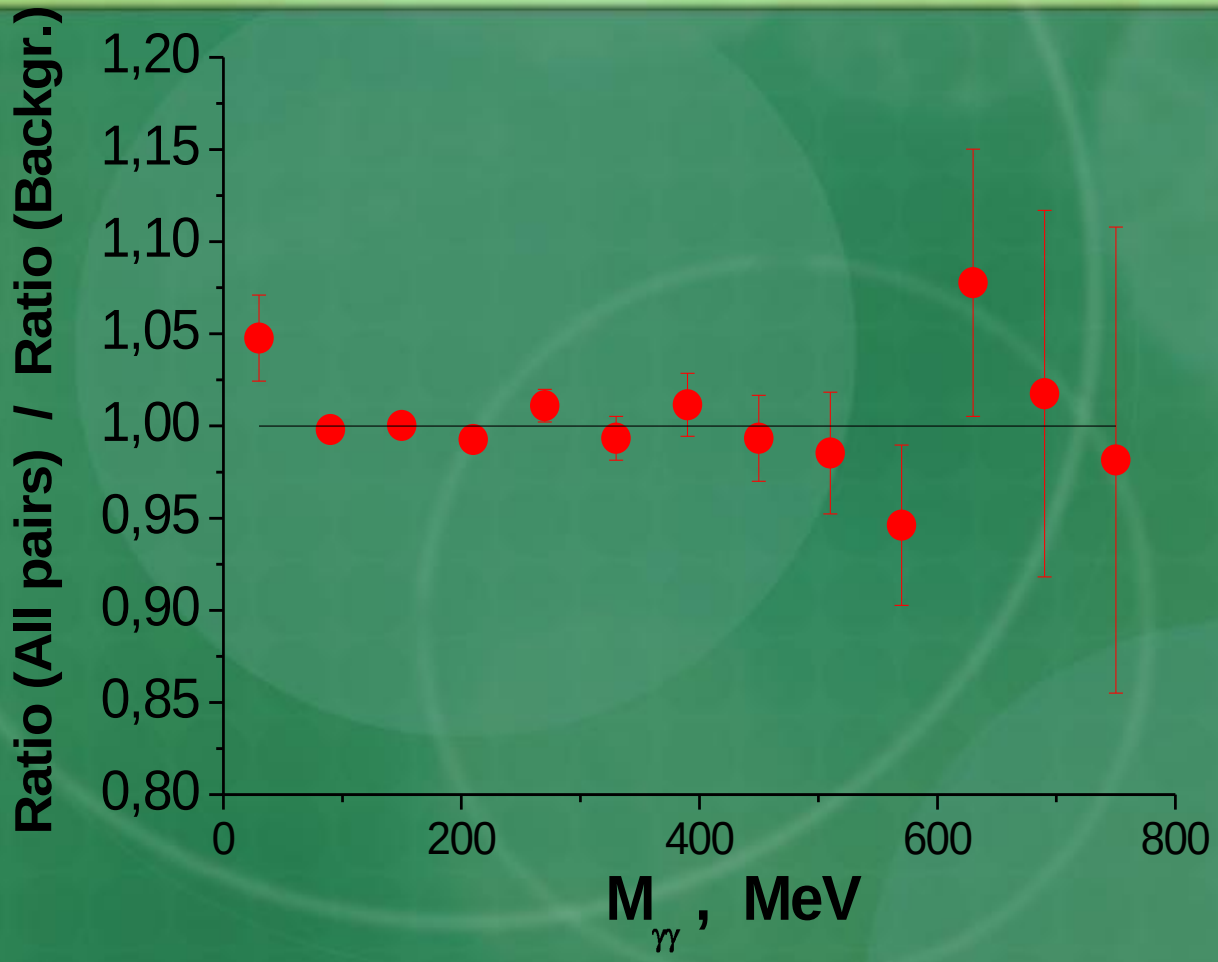
With the internal carbon target

Without target

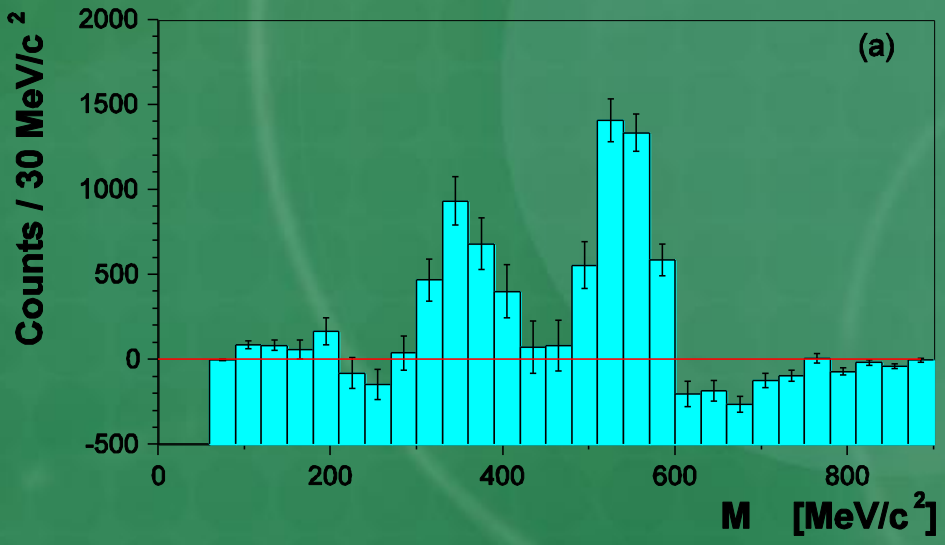
Charged particles contribution

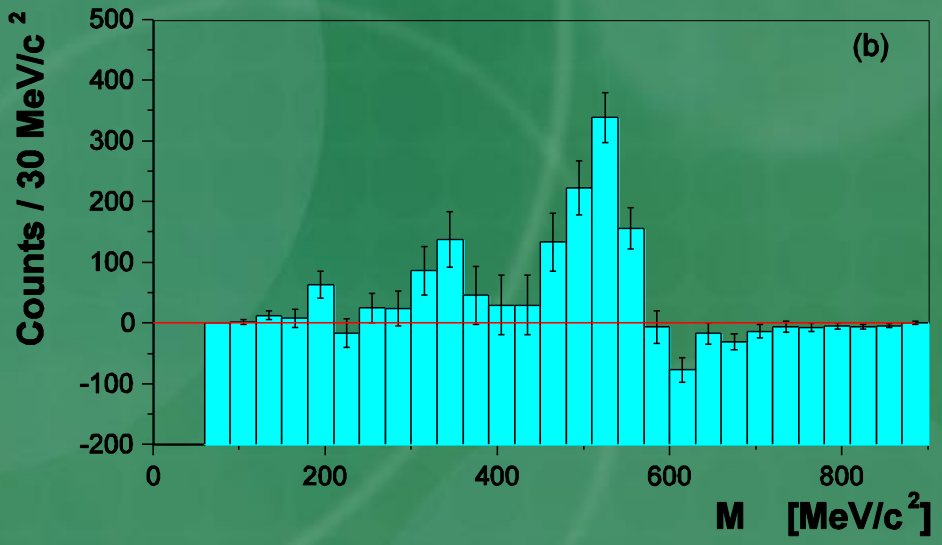


Charged particles contribution after background subtraction

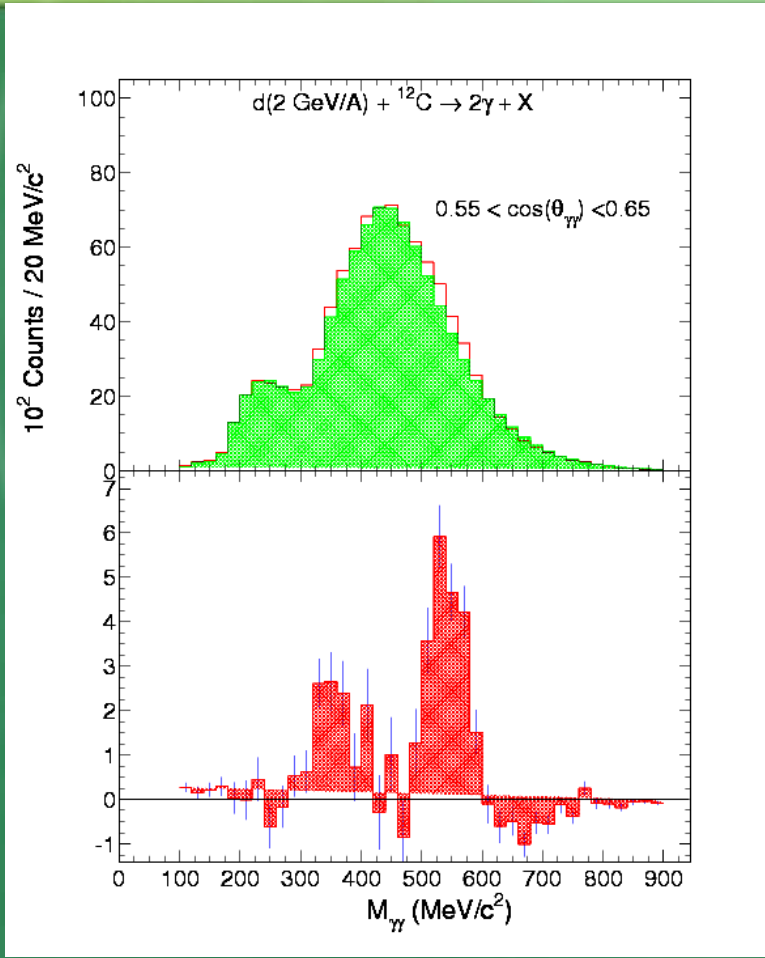


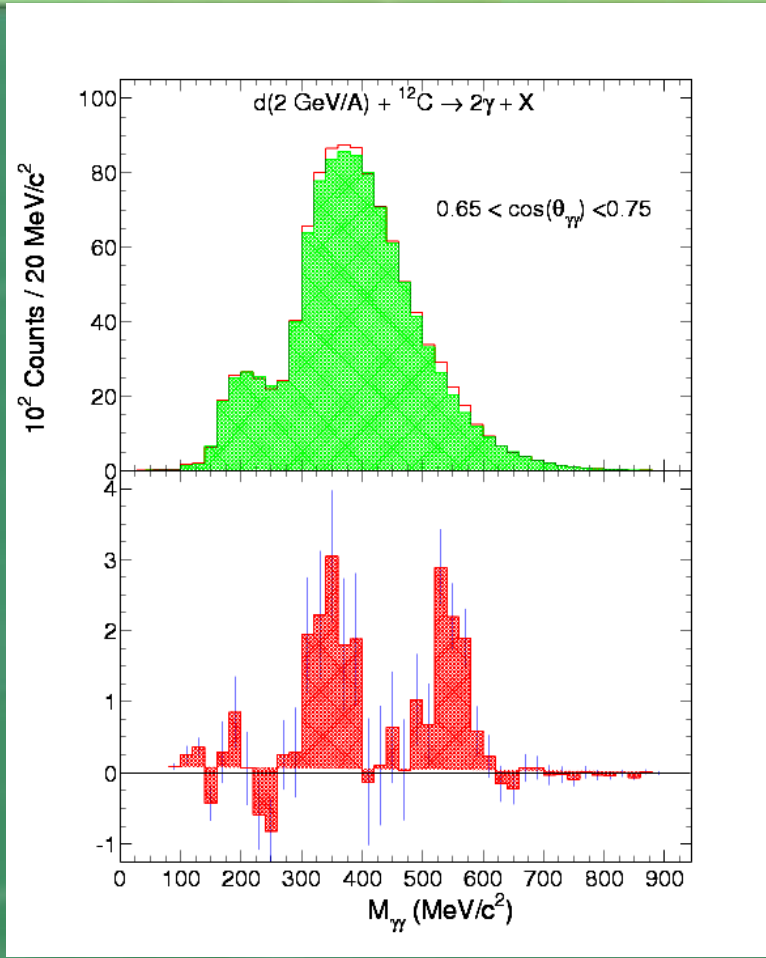
Invariant mass distributions of γγ pairs satisfying the criteria (1) − (2) after background subtraction in the reaction dC = γ +γ +X at 2.75 GeV/c per nucleon for two different beam intensities: 503 events/cycle (a) and 85 events/cycle.



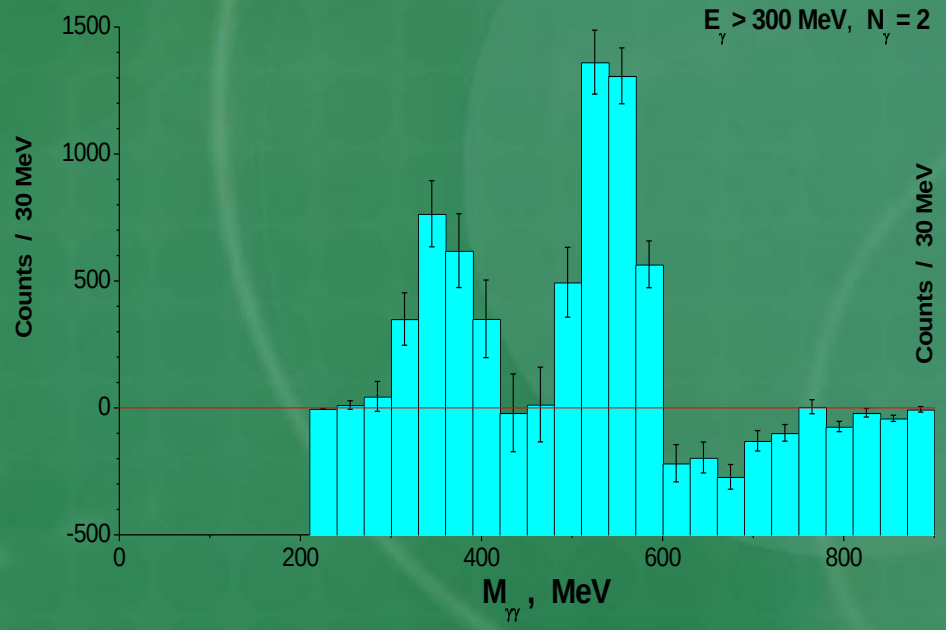


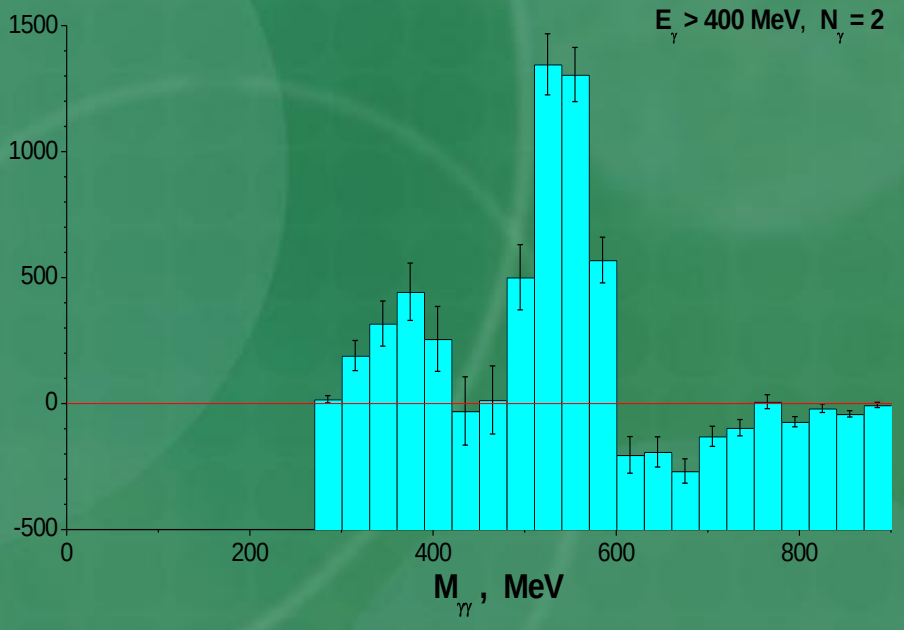
The invariant mass distributions of two photons for the opening angles 0.55 < cos (Θγγ) < 0.65 (left) and 0.65 < cos (Θγγ) < 0.75 (right) under the selection criteria (1) − (2).



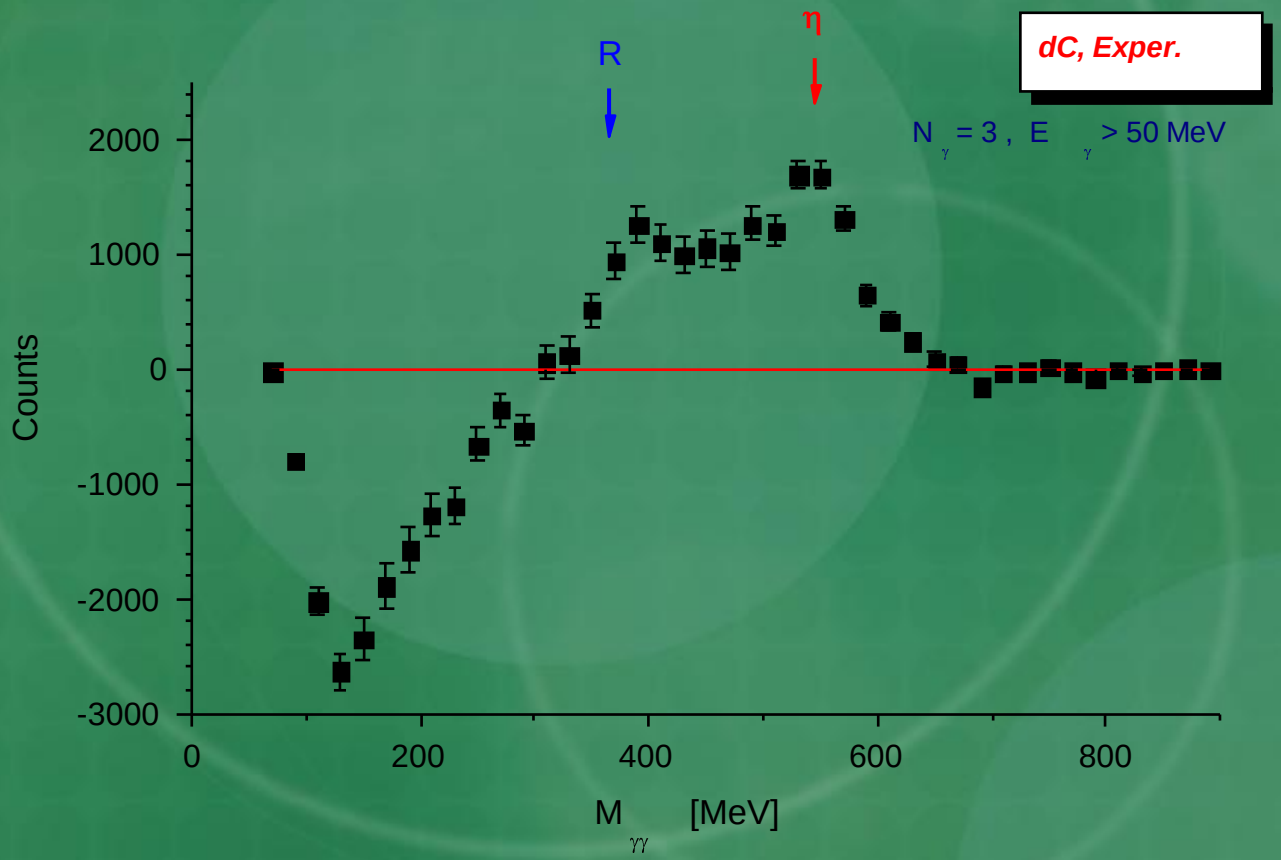


Invariant mass distributions of γγ pairs satisfying the criteria (1) − (2) after background subtraction in the reaction dC = γ +γ +X at 2.75 GeV/c per nucleon for two energy selection levels.



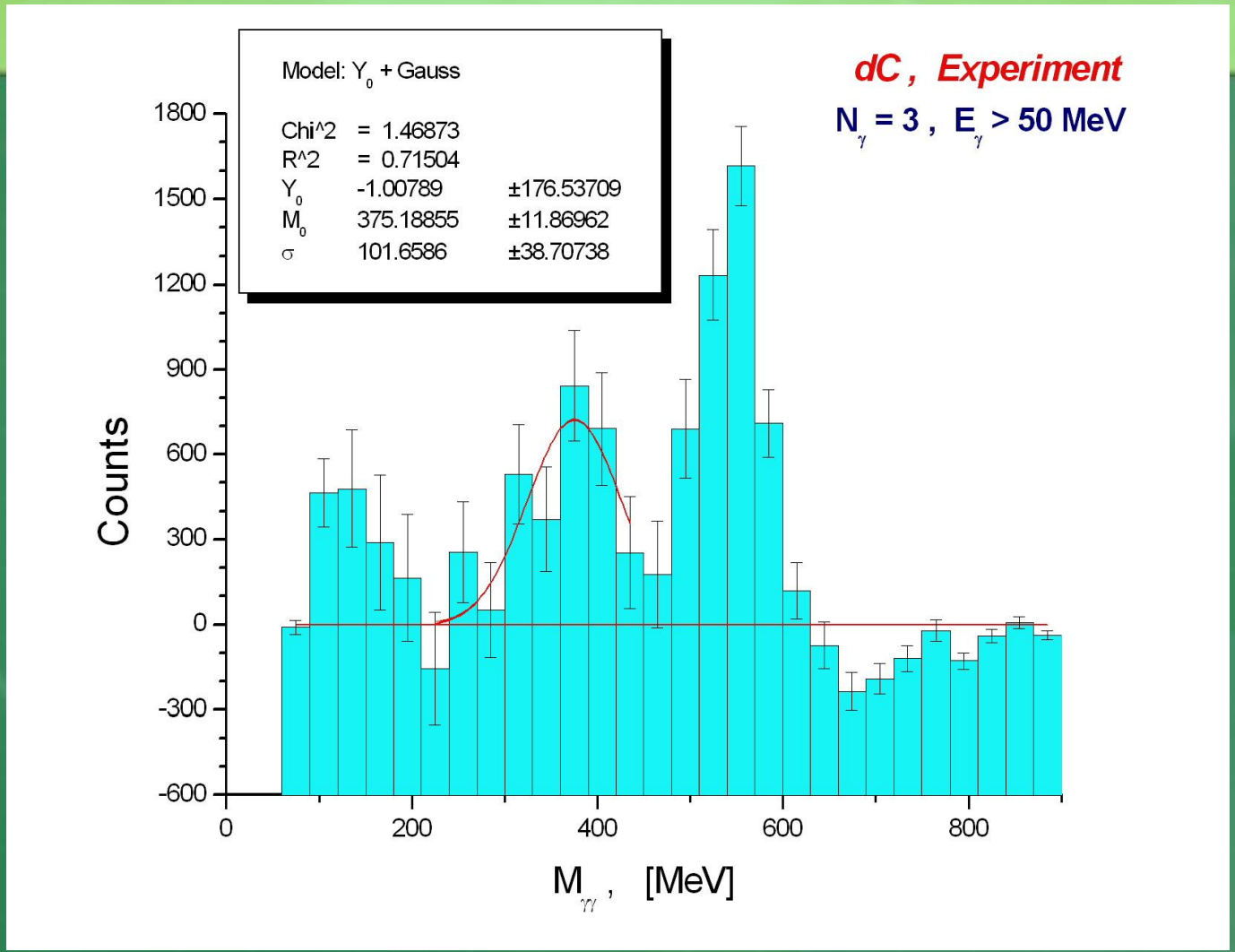


Nγ=3

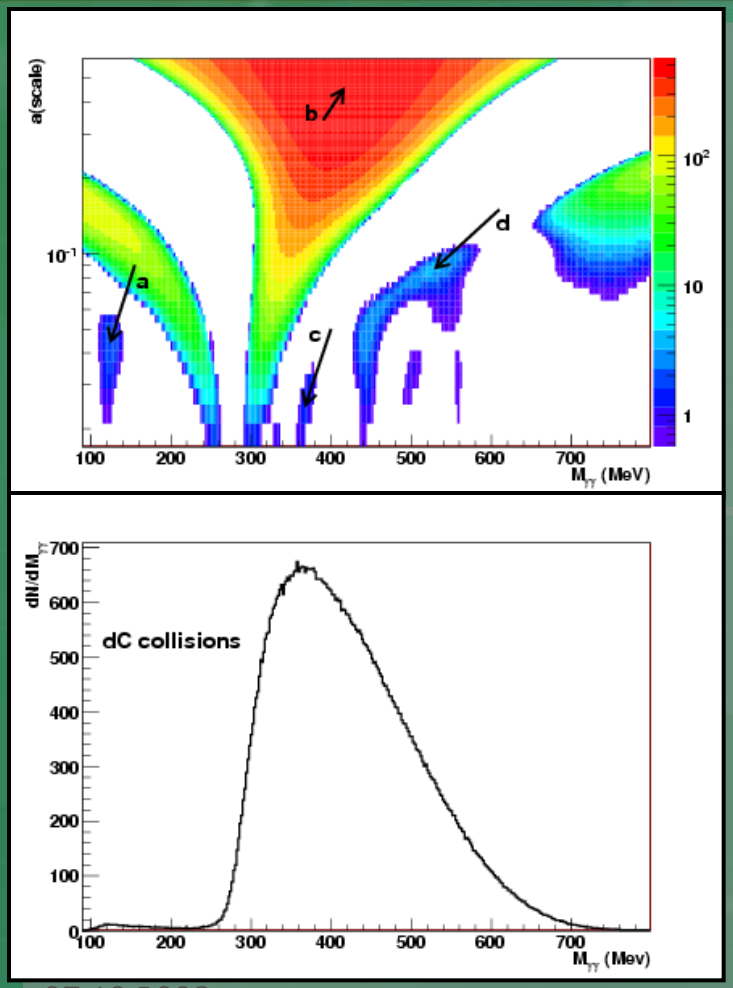

dC, Exper.
R
η
N γ = 3 , E γ > 50 MeV
Counts
2000
1000
0
-1000
-2000
-3000
0
200
400
600
800
M γγ [MeV]

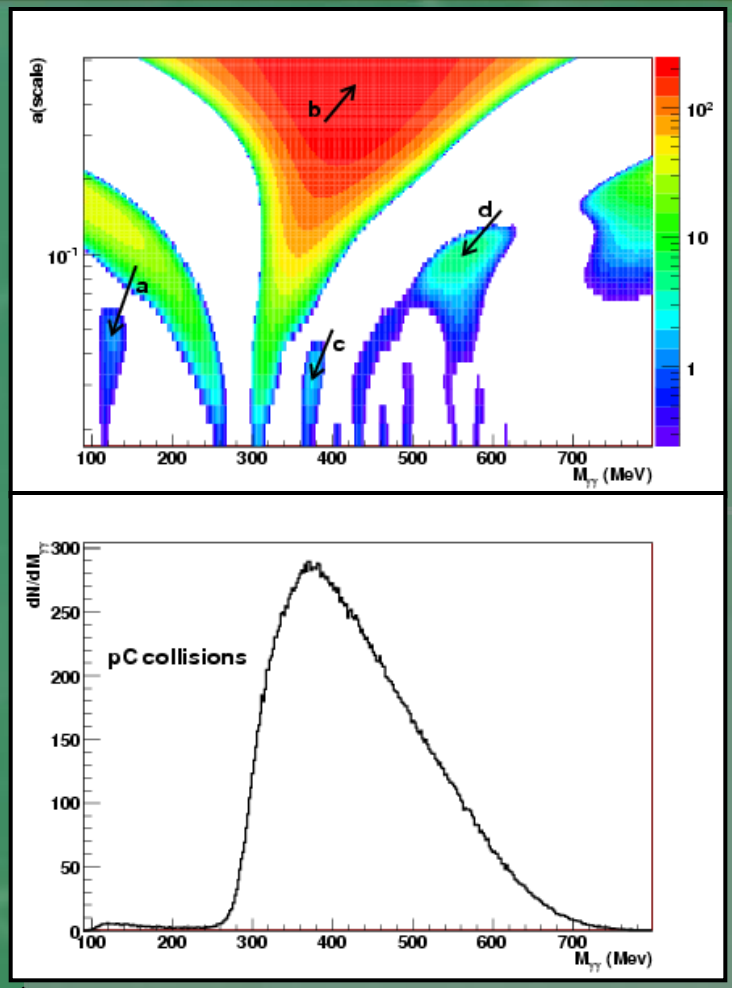
Nγ=3: 1γ in the L.Arm, 2γ in the R.Arm +

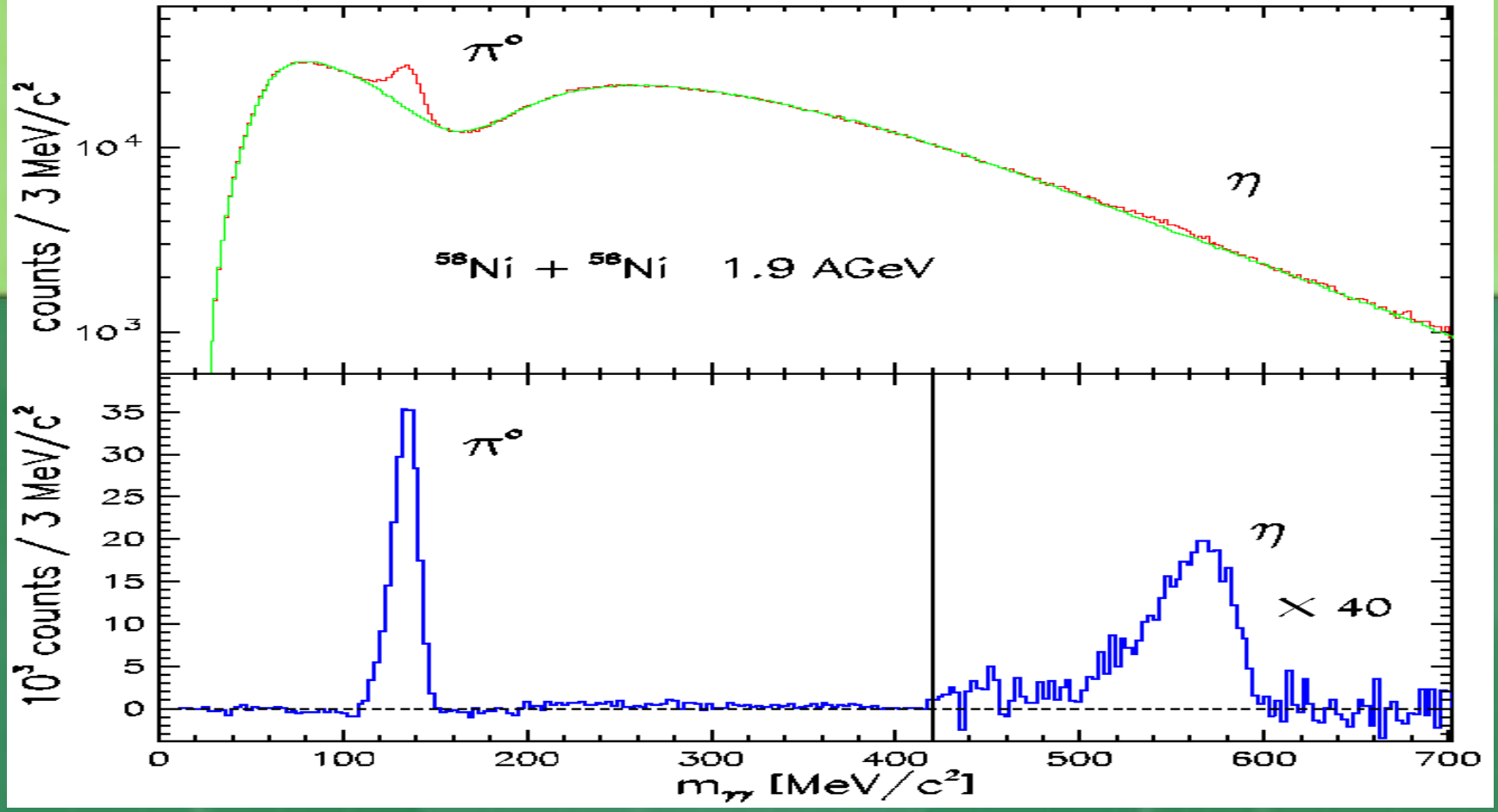
2γ in the L.Arm, 1γ in the R.Arm



The invariant mass distribution of γγ pairs and the biparametric distribution of the GW of the 8-th order for dC (left) and pC (right) interactions. The distribution is obtained with an additional condition for photon energies Eγ1/Eγ2 > 0.8 and binning in 2MeV.







A.Taranenko et.all, Czech.J.Phys. 50S4 (2000) 139, nucl-ex/9910002.
Results of the invariant-mass analysis of photon pairs (TAPS). The upper frame shows the invariant-mass spectrum which corresponds to the η trigger in the experiment 58Ni+58Ni at 1.9 AGeV. The combinatorial background (dotted line) was determined by event mixing. The lower frame shows the invariant-mass distribution after background subtraction and demonstrates the quality of the background determination.

Comparison with experiments on the “TAPS”
1. Z.Phys.A359, 65(1997): C+C reaction, 2.0A GeV

	TAPS	PHOTON-2
Opening angles	65º-102º	42º-66º
η energies (GeV)	> 0.70	> 1.01
Mean values	0.85	1.21
O.R. energies	> 0.457	> 0.652
Mean values	0.552	0.782
Total cr. sect. (b)	2.021	0.612
Arm’s area (m²)	0.578	0.424
Arm’s solid angle (sr)	0.257	0.047
En.res. σ/E (m.v.,%)	3.0	6.1
Sig./B. in 300-420:	~ 0.0014 [a]	0.027

(<0.004)

[a] Sig. ~ √6 · 10^5

Necessary statistics for same observation in the experiment on TAPS (Z.Phys.A359, 65(1997): C+C reaction, 2.0A GeV)

$\sim 3 \cdot 10^{12} \cdot (\Delta\Omega_{PHOTON} / \Delta\Omega_{TAPS})^2 \cdot (\Delta M_{PHOTON} / \Delta M_{TAPS})^2 \cdot [(S/B)_{PHOTON} / (S/B)_{TAPS}]^2$

S/B=0.0014

$\sim 3 \cdot 10^{12} \cdot (0.047 / 0.257)^2 \cdot (3.0 / 6.1)^2 \cdot (0.027 / 0.0014)^2$

$= 9 \cdot 10^{12}$ ***interactions***,

S/B<0.004 :

$> 1.1 \cdot 10^{12}$ ***interactions.***

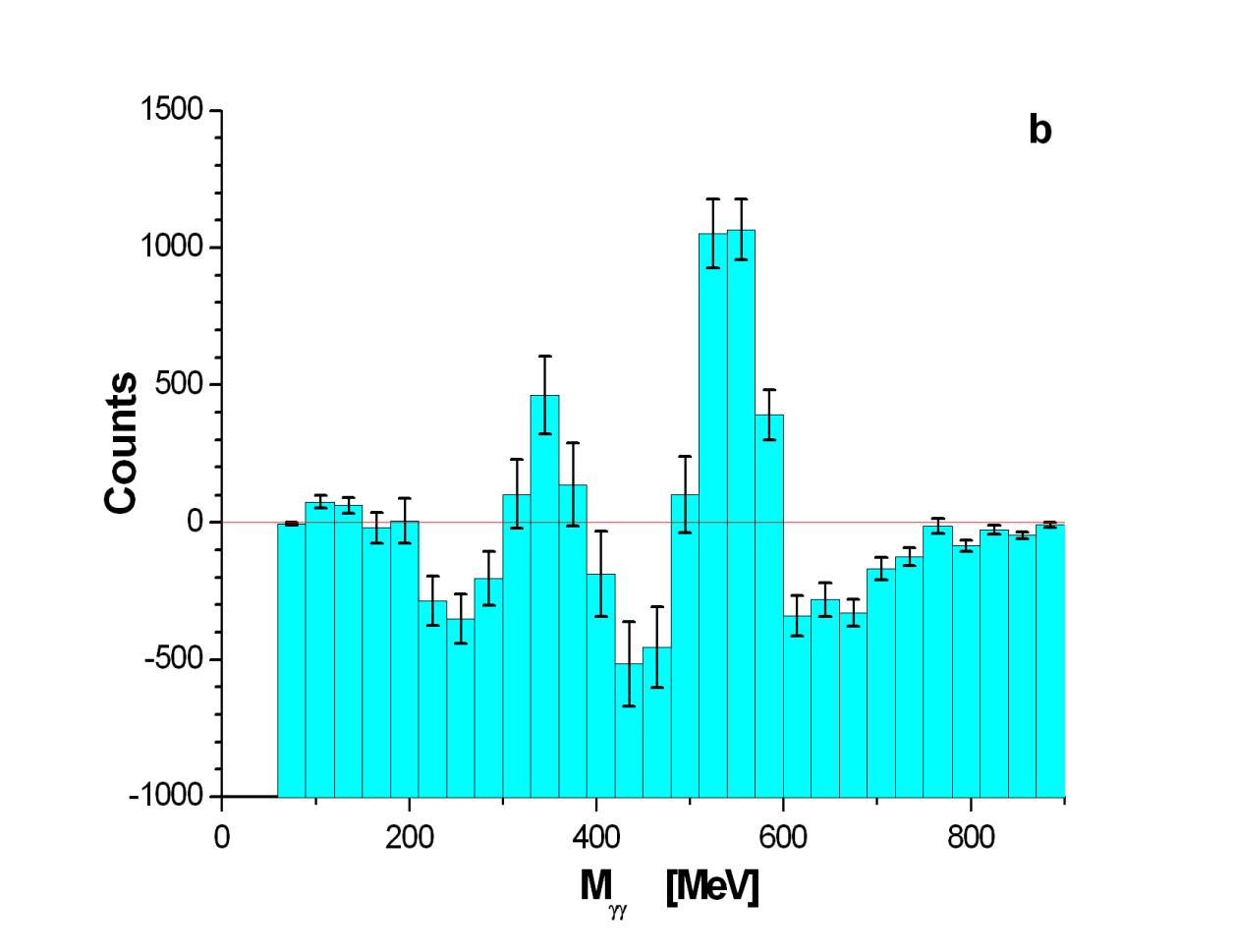
$N_{cycle} > (1.1 \cdot 10^{12}) / (5 \cdot 10\text{^}6 \cdot \omega) =$

= 4 500 000 accelerator cycles,

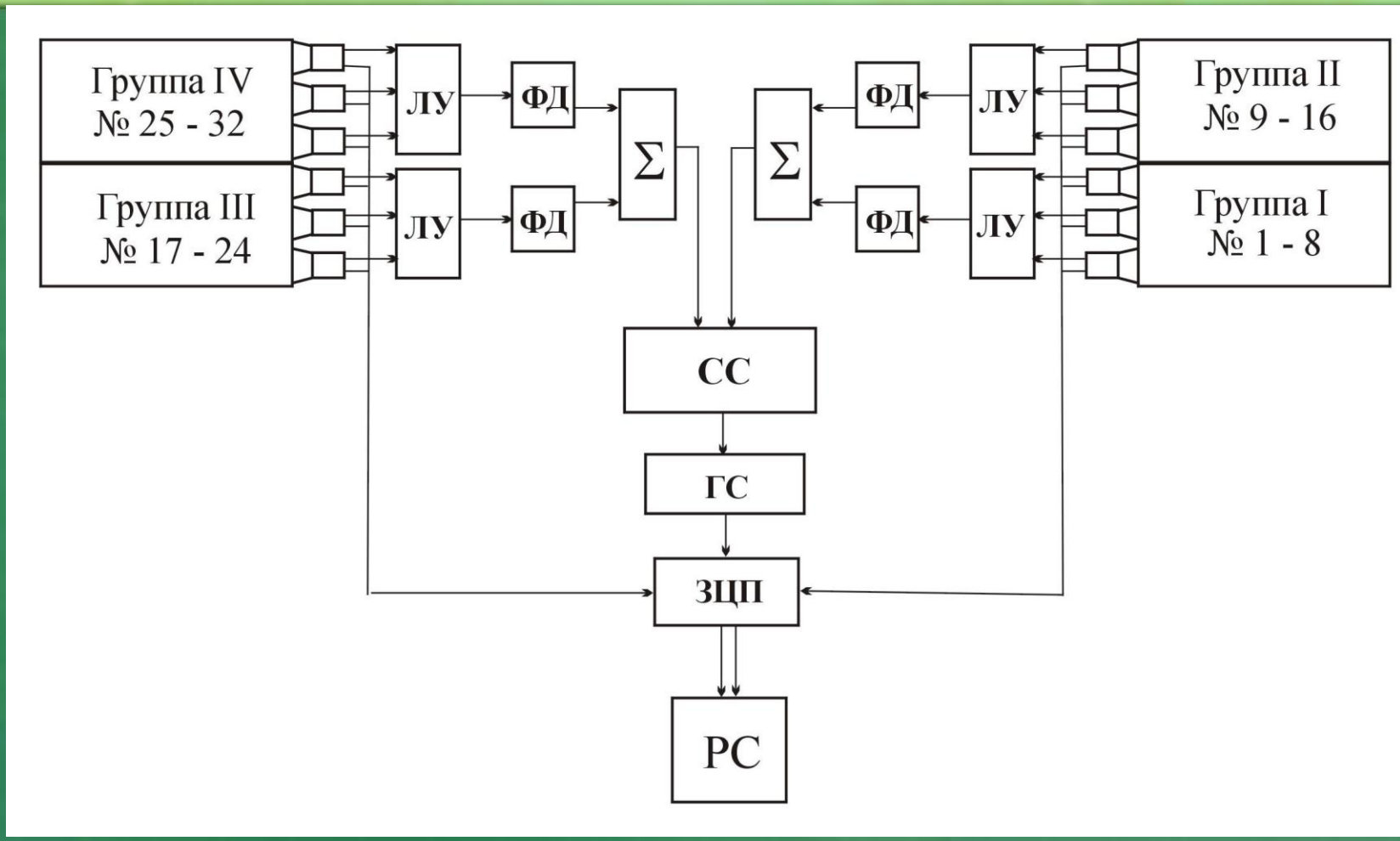
$\omega = \rho x \cdot (N_A / A) \cdot \sigma(CC) = 0.049, \quad \rho x = 0.487$ g/cm ²

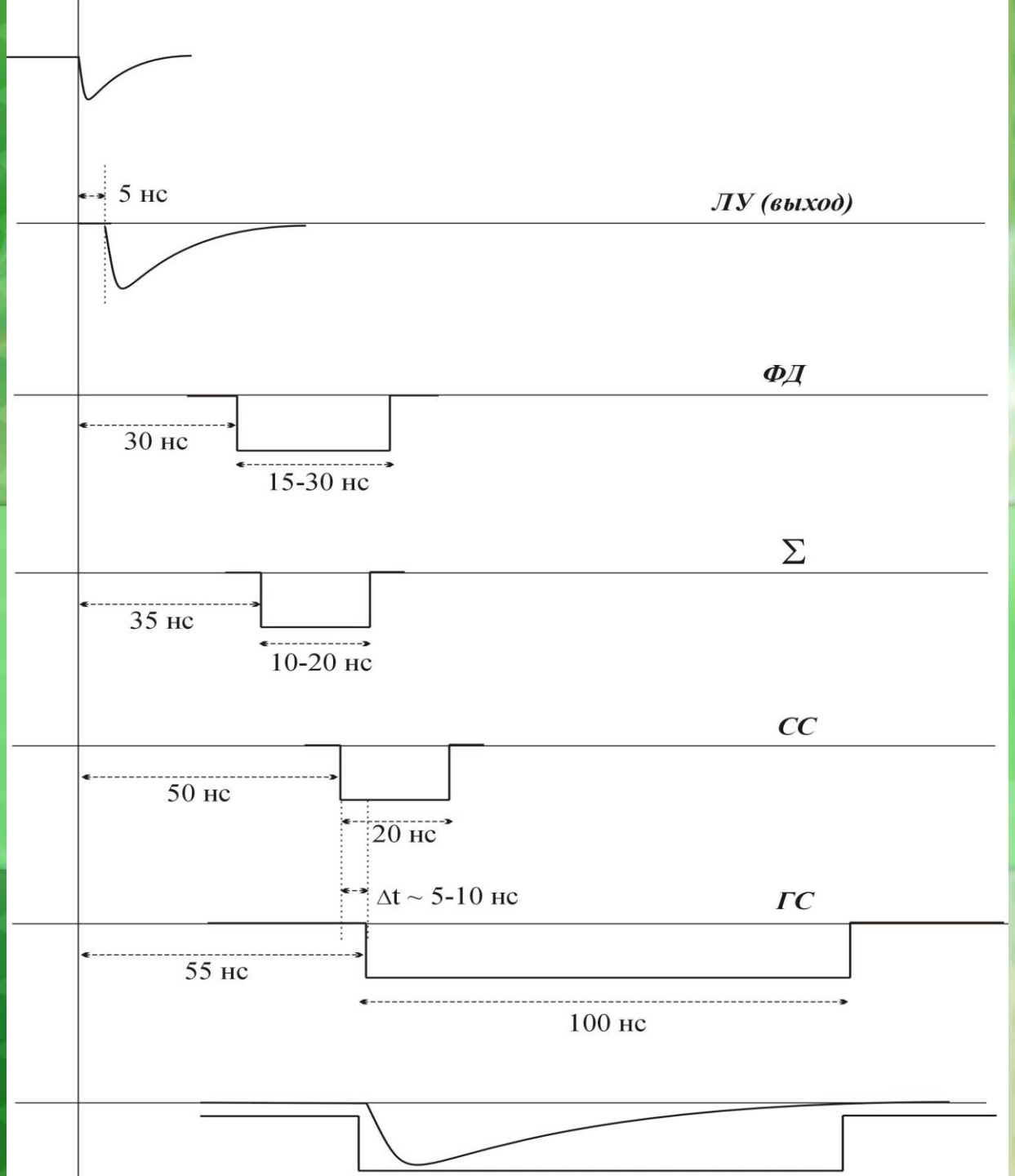
For indication (+3 st.err.) : > 550 000 acceler. cycles

Invariant mass distributions of γγ pairs satisfying the criteria (1) − (2) after background subtraction in the reaction dC = γ +γ +X at 2.75 GeV/c per nucleon. Normalization of the background by the total number of pairs in the spectrum.

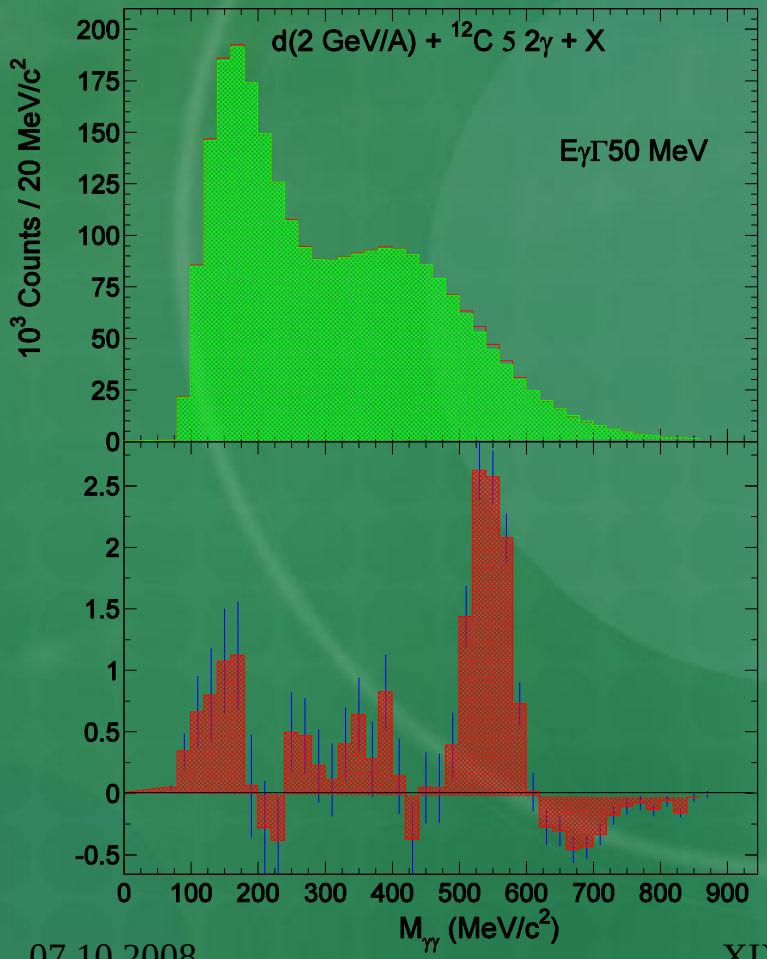


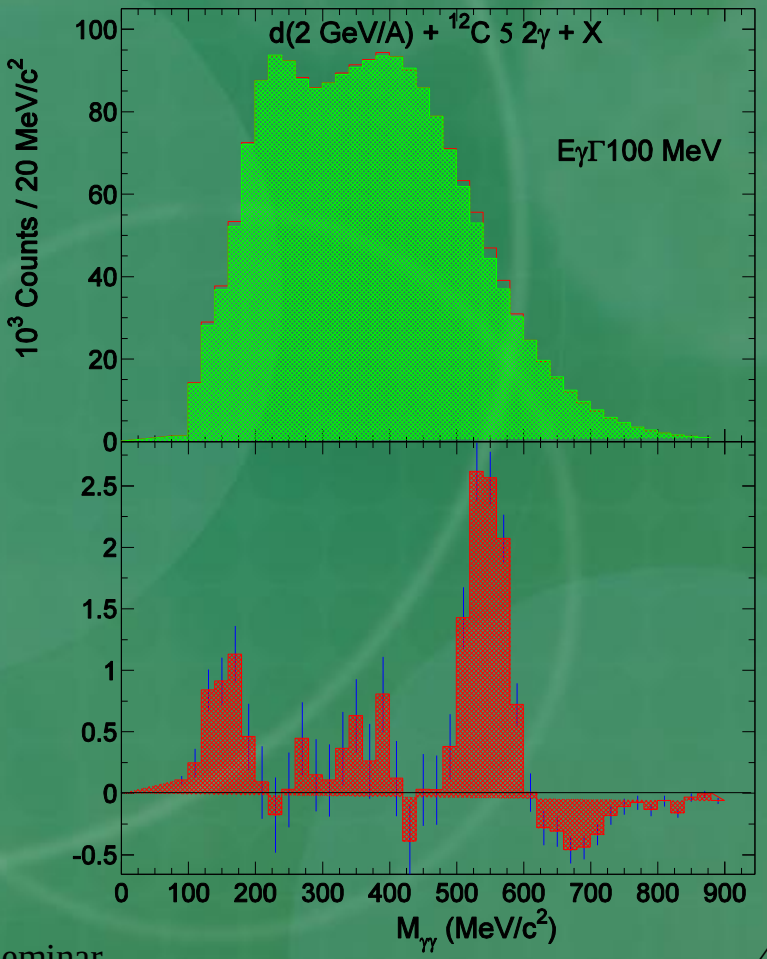
Блок-схема электронной аппаратуры



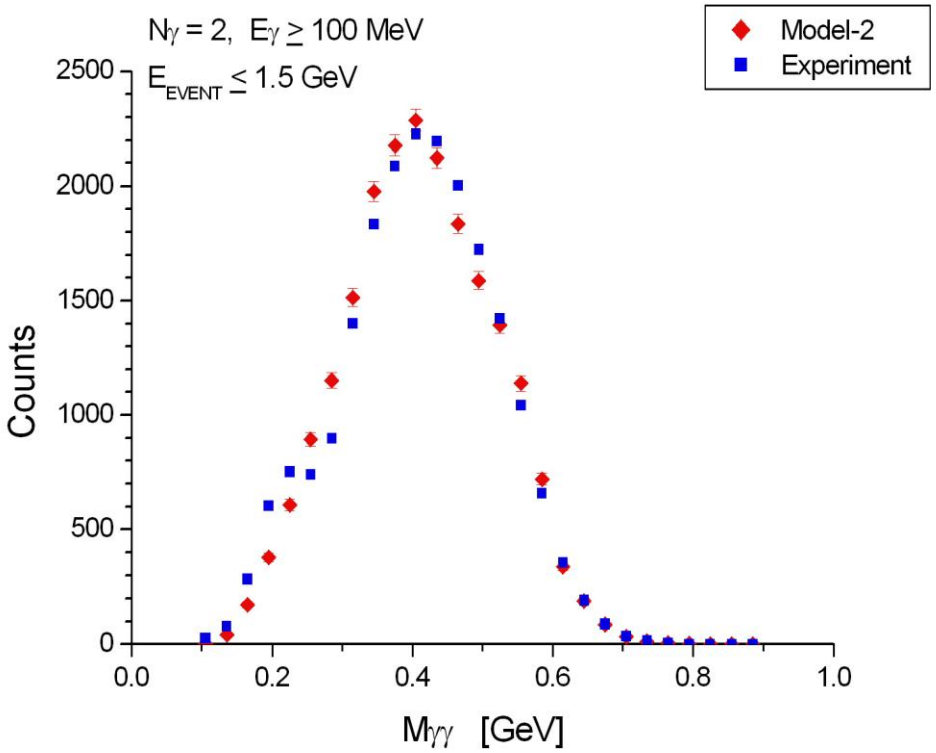

5 нс
ЛУ (выход)
ФД
30 нс
15-30 нс
Σ
35 нс
10-20 нс
СС
50 нс
20 нс
Δt ~ 5-10 нс
ГС
55 нс
100 нс

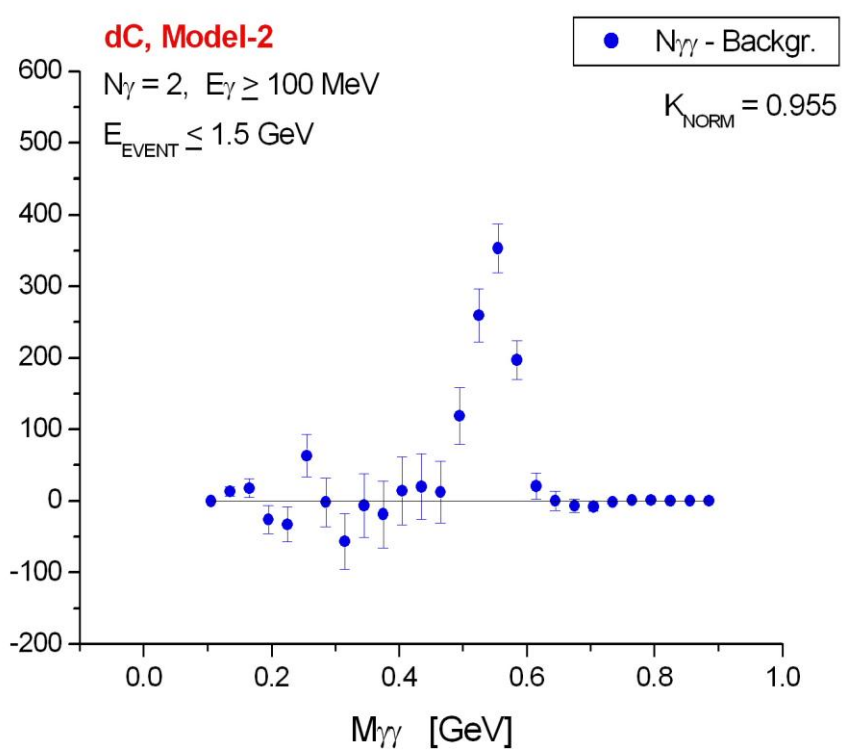
Invariant mass distributions of γγ pairs from the dC reaction. The top shaded histograms show the background cotribution. The bottom histograms are invariant spectra after the background subtraction.



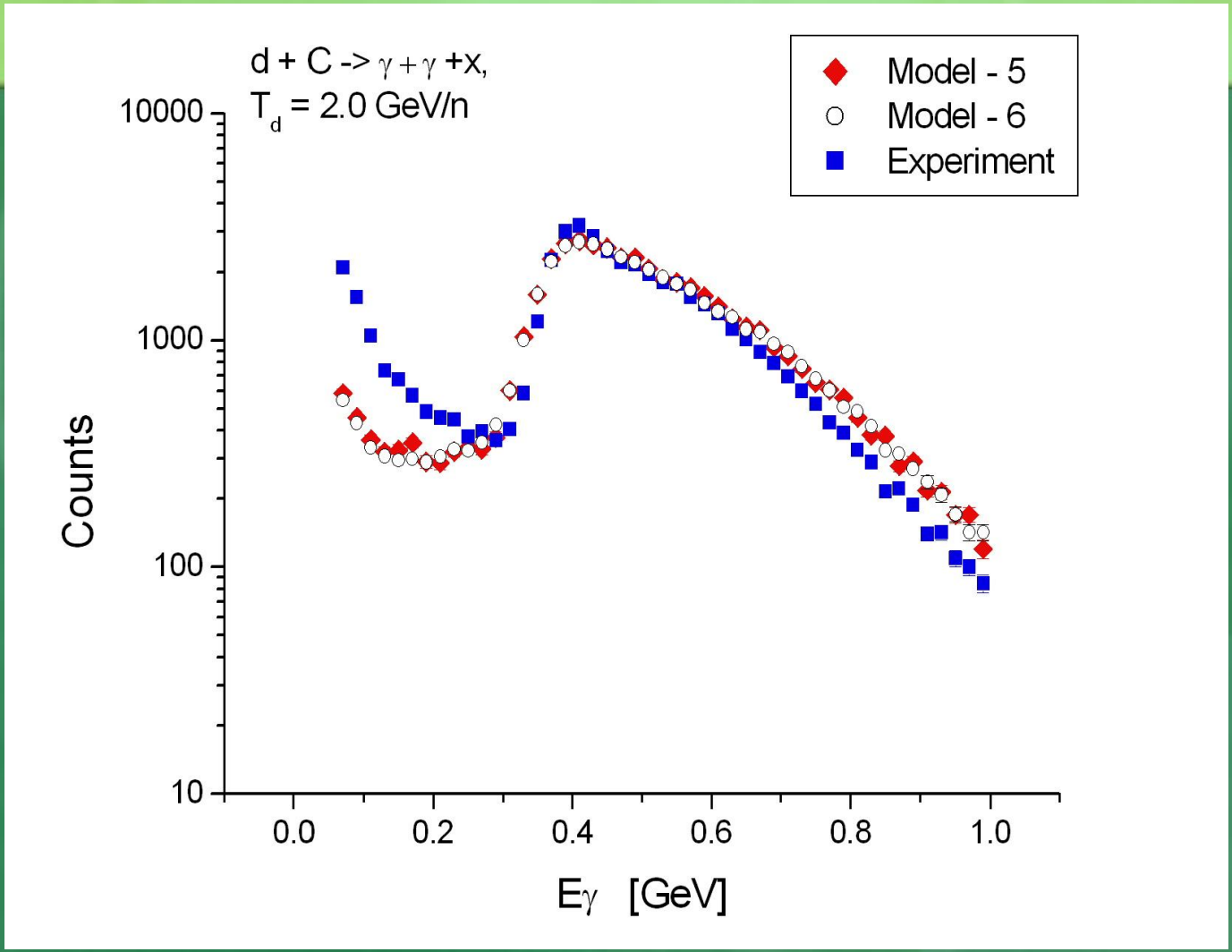


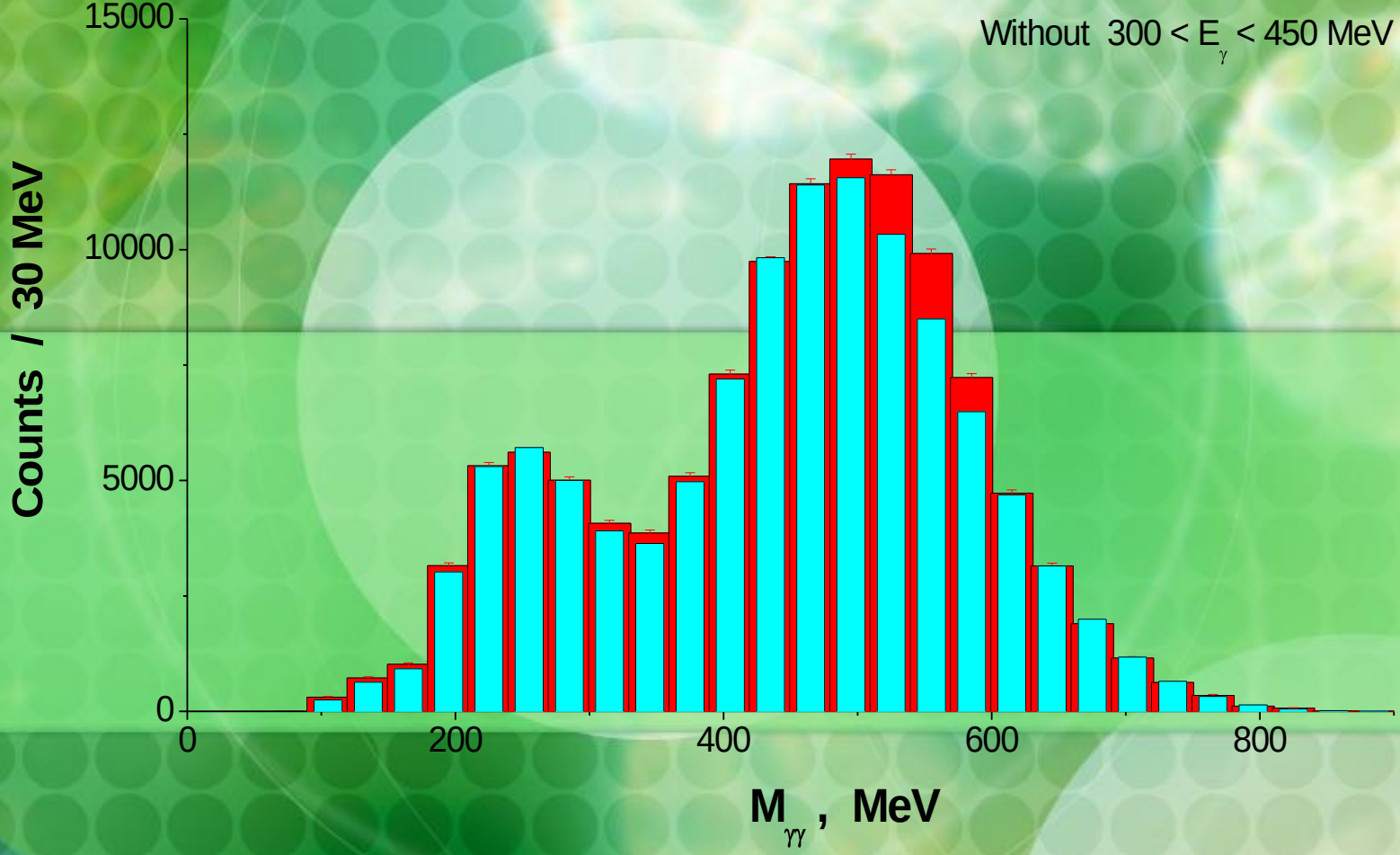
Распределение по инвариантной массе пар γ-квантов до и после вычитания фона: моделированные данные в реальных условиях эксперимента, без включения резонанса.

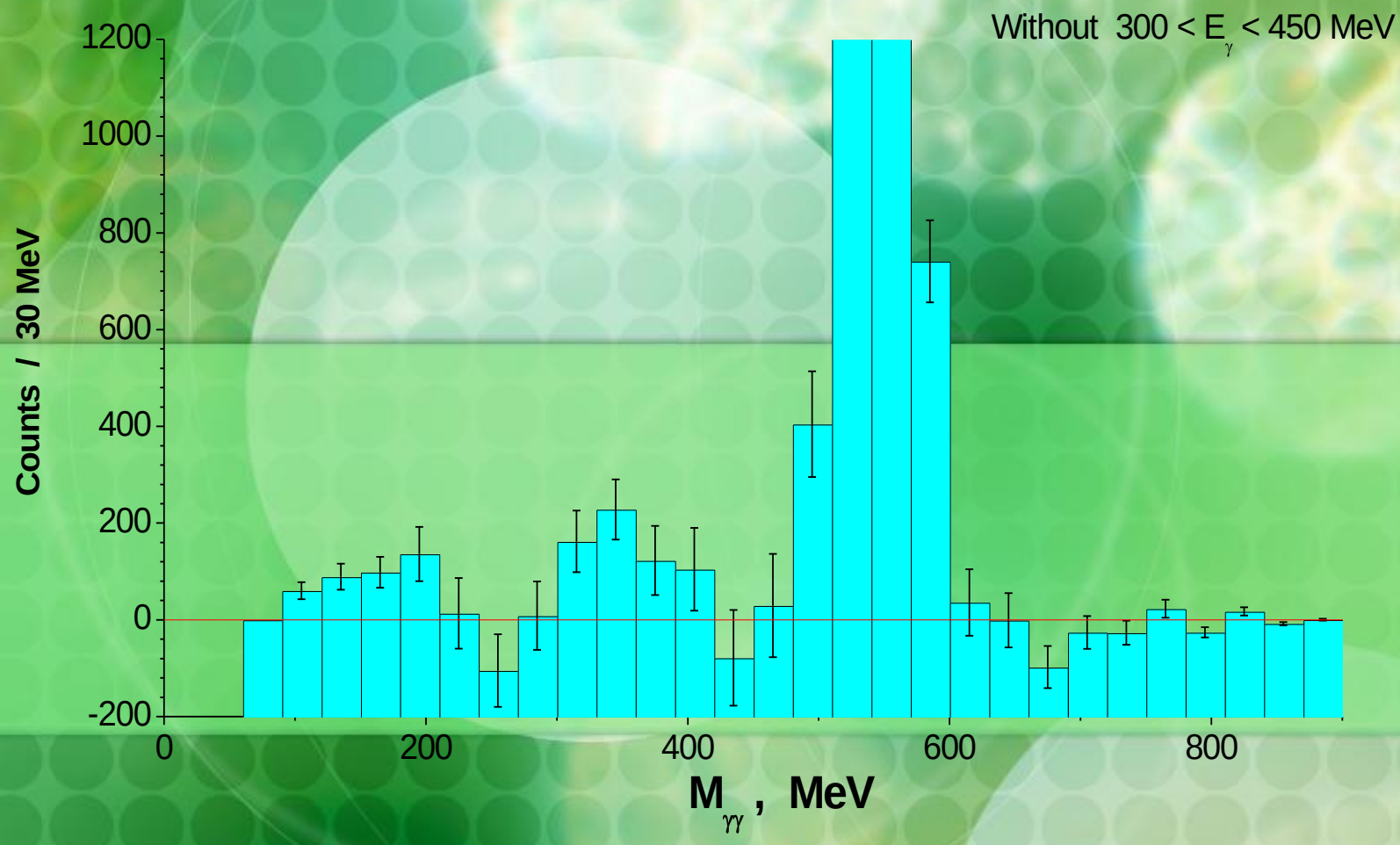




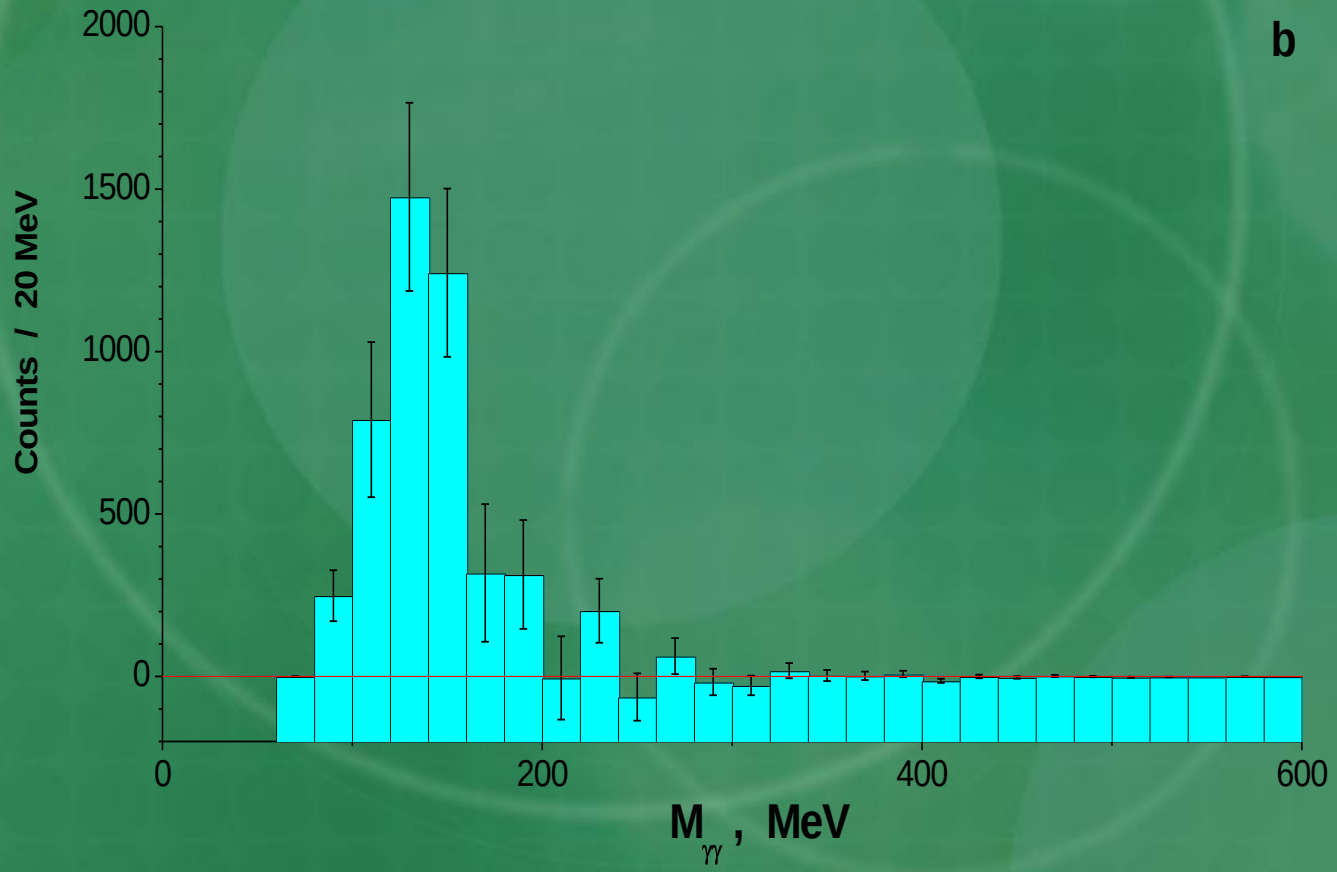
Energy distribution of γ-quanta in the dC reaction

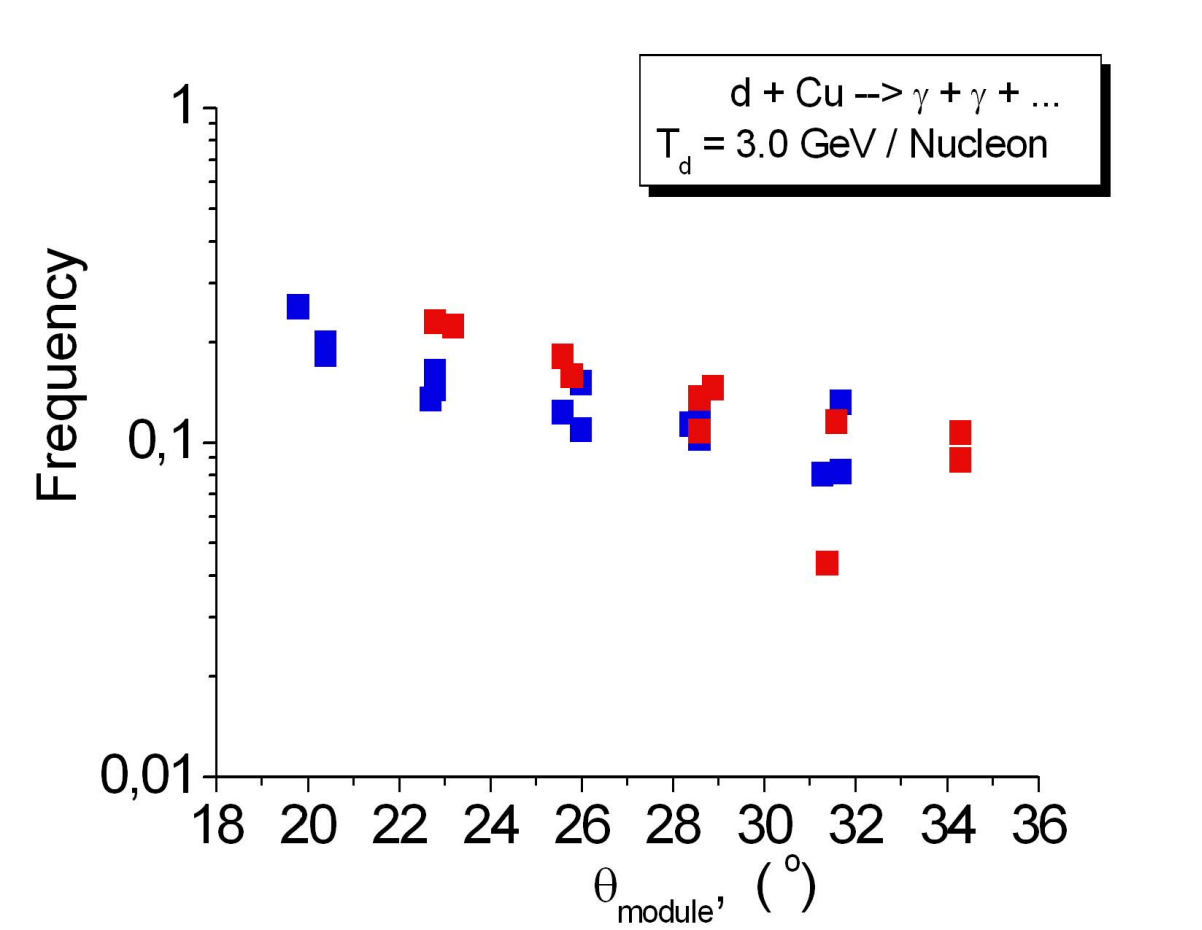


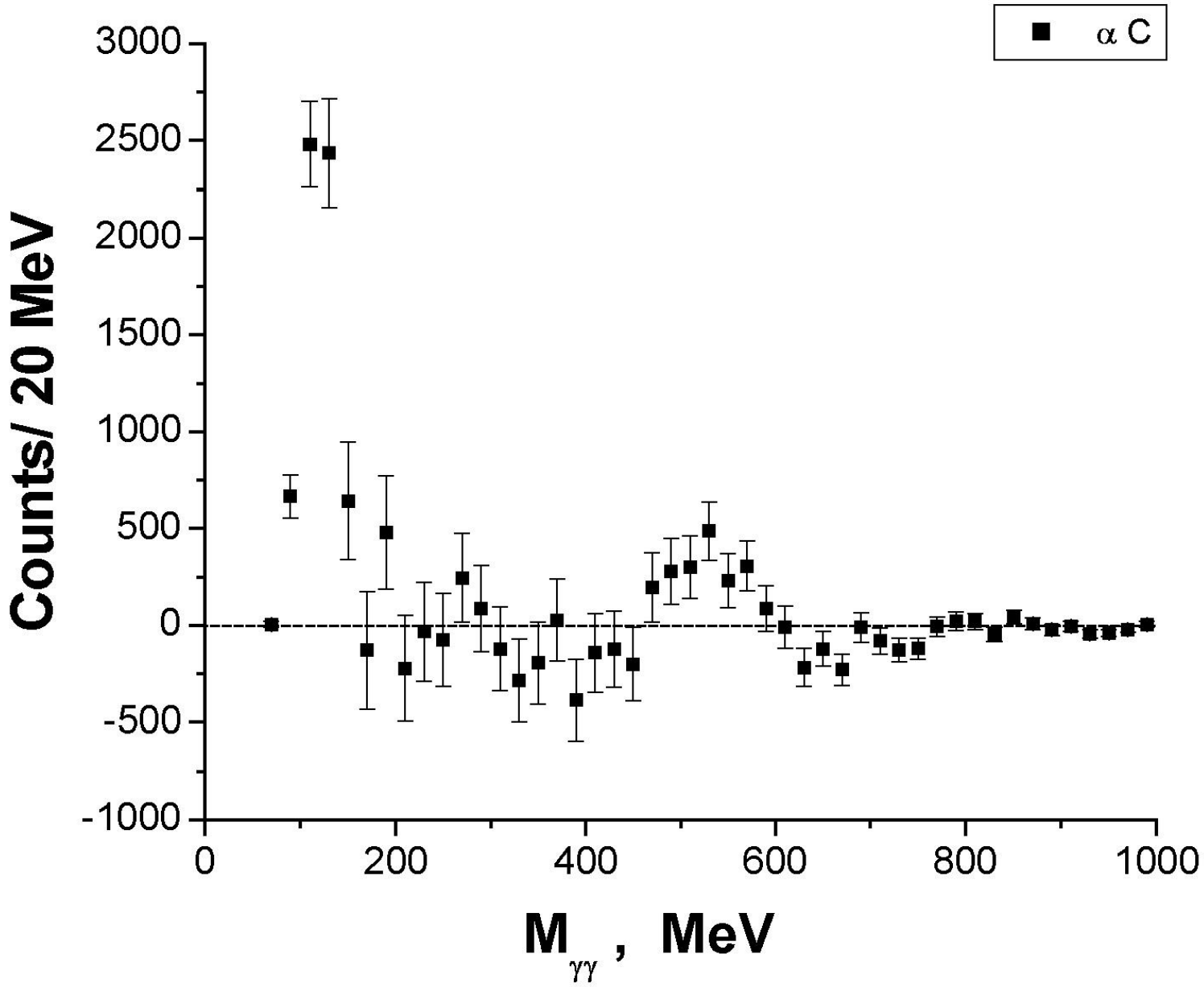

Without 300 < E$_\gamma$ < 450 MeV
Counts / 30 MeV
15000
10000
5000
0
0
200
400
600
800
M$_{\gamma\gamma}$, MeV


Without 300 < E$_\gamma$ < 450 MeV
Counts / 30 MeV
1200
1000
800
600
400
200
0
-200
0
200
400
600
800
M$_{\gamma\gamma}$, MeV

Спектр эффективных масс пар γ-квантов за вычетом фона в реакции d + C→ γ + γ + x, Ed = 1.98 ГэВ/н, Eγ > 100 МэВ. Di = 50 mV




d + Cu --> γ + γ + ...
T_d = 3.0 GeV / Nucleon
Frequency
1
0,1
0,01
18
20
22
24
26
28
30
32
34
36
θ_module, (°)


α C
Counts/ 20 MeV
3000
2500
2000
1500
1000
500
0
-500
-1000
0
200
400
600
800
1000
M γγ , MeV