



BECQUEREL
PROJECT

Проект
БЕККЕРЕЛЬ

Beryllium (Boron)

Clustering

Quest in

Relativistic Multifragmentation

<http://becquerel.jinr.ru>

Proposal on exposures of NTE to beam of ^{11}C nuclei at 400 A MeV

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Predeal-Romania

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Beryllium (Boron)

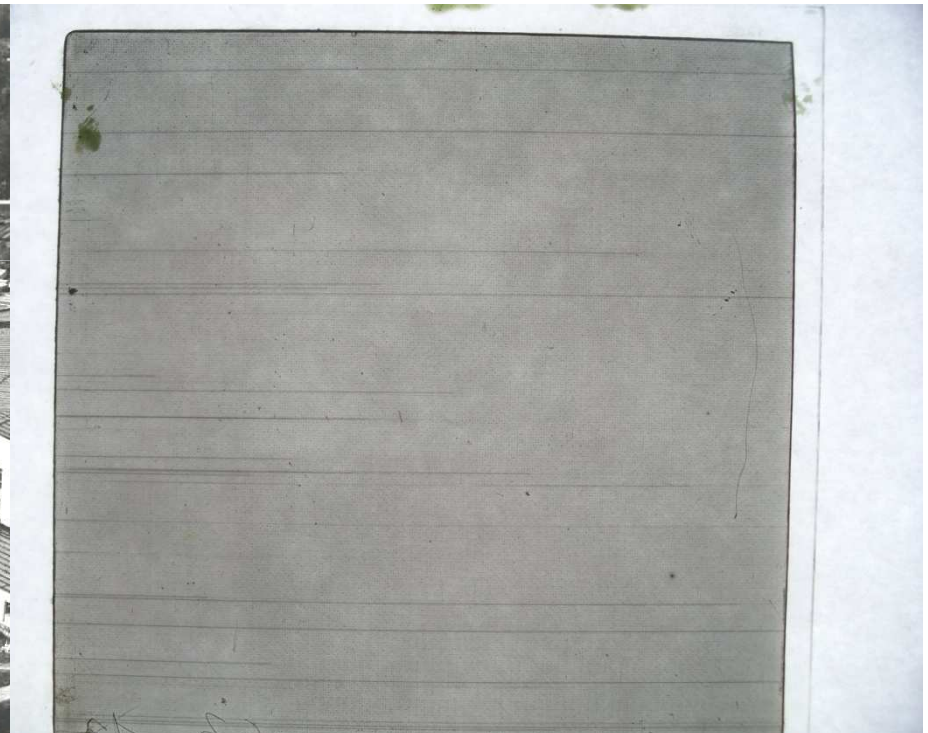
Clustering

Quest in

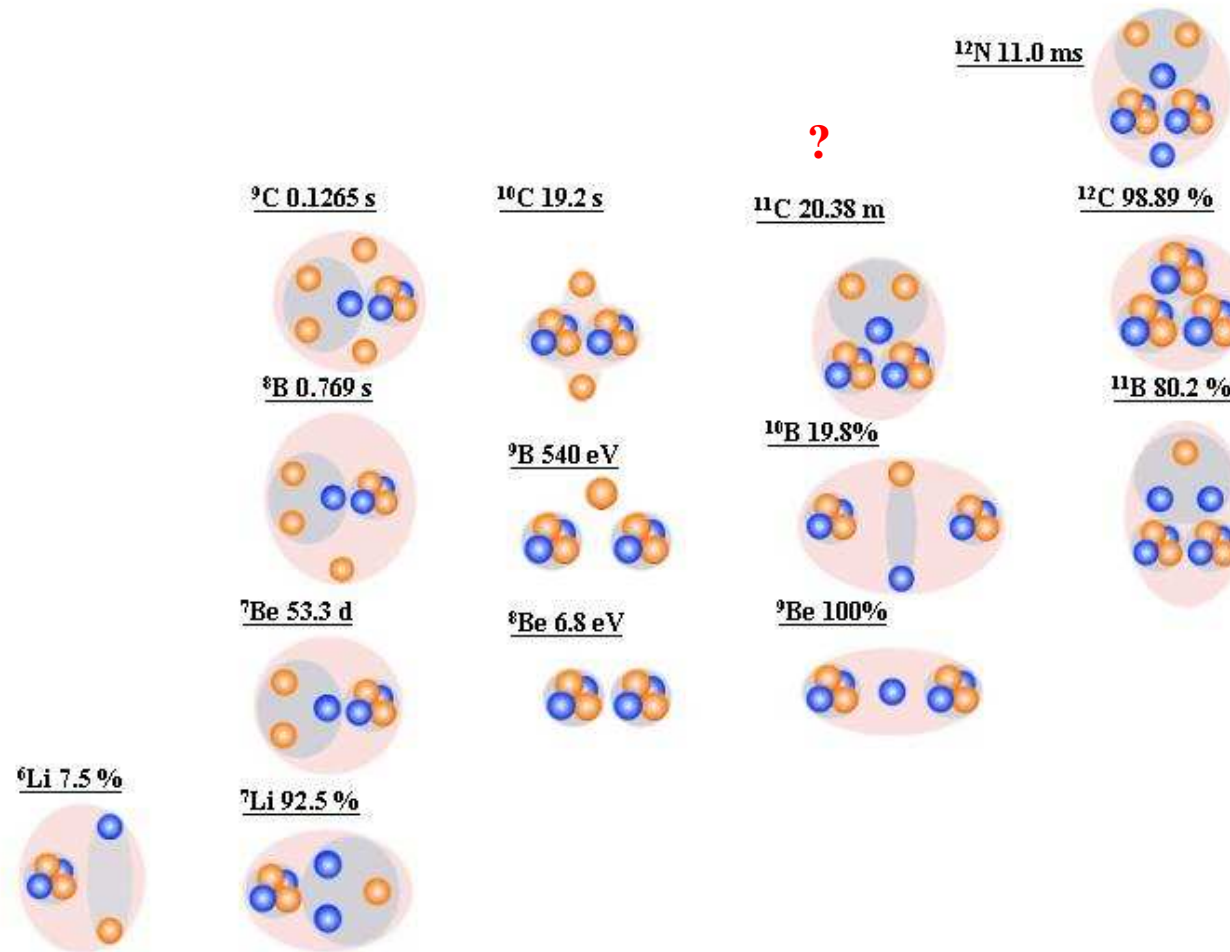
Relativistic Multifragmentation

<http://becquerel.jinr.ru>

BECQUEREL at the JINR Nuclotron is devoted systematic exploration of clustering features of light stable and radioactive nuclei.



Motivation



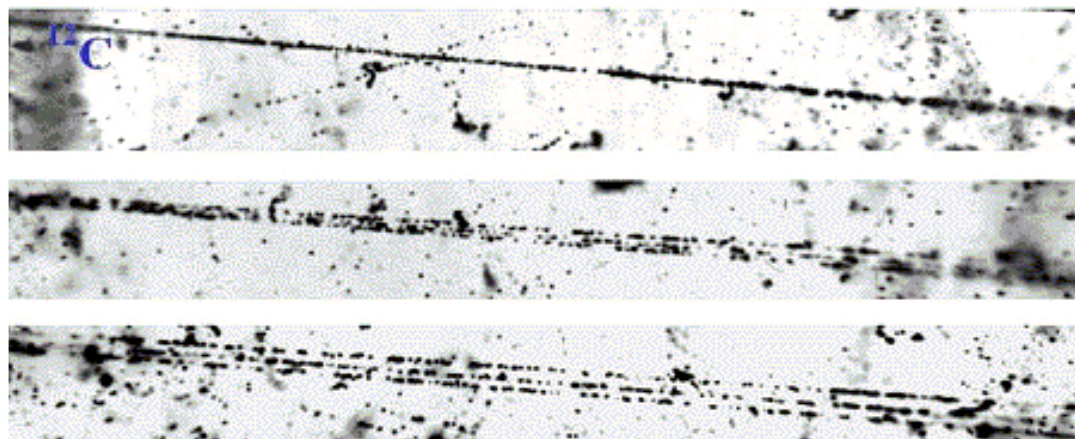
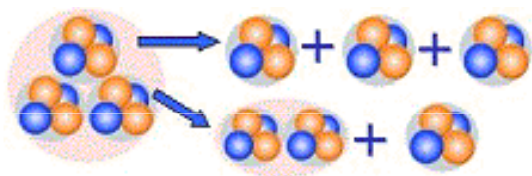
The fragmentation of a large variety of light nuclei was investigated using the emulsions exposed to few A GeV nuclear beams at JINR Nuclotron. A nuclear track emulsion is used to explore the fragmentation of the relativistic nuclei.

ELEMENTARY PARTICLES AND FIELDS
Experiment

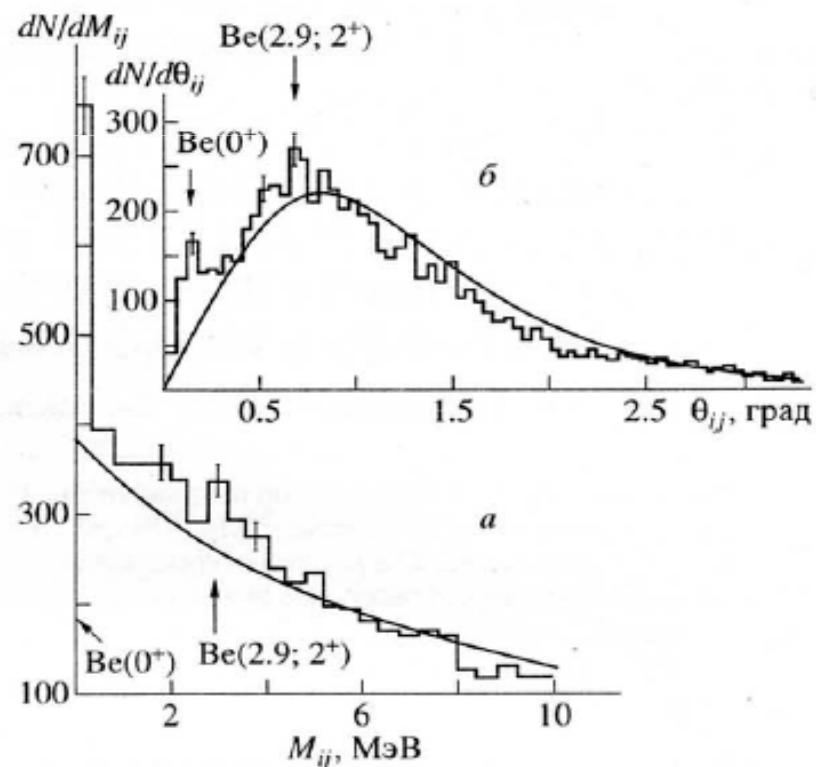
Coherent Dissociation $^{12}\text{C} \rightarrow 3\alpha$ in Lead-Enriched Emulsion
at 4.5 GeV/c per Nucleon

V. V. Belaga, A. A. Benjaza¹⁾, V. V. Rusakova, J. A. Salamov²⁾, and G. M. Chernov

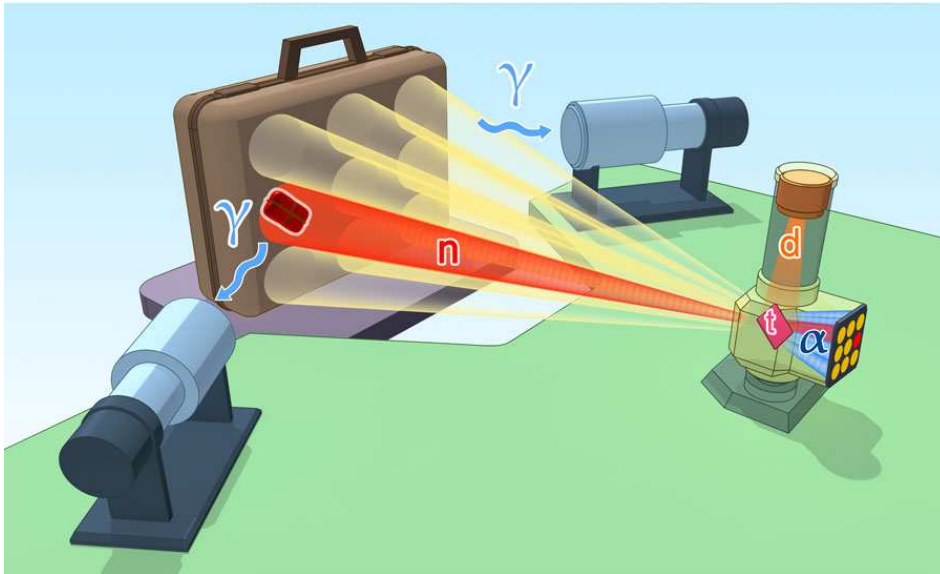
$^{12}\text{C} \rightarrow 3\alpha$, 3.65 A GeV



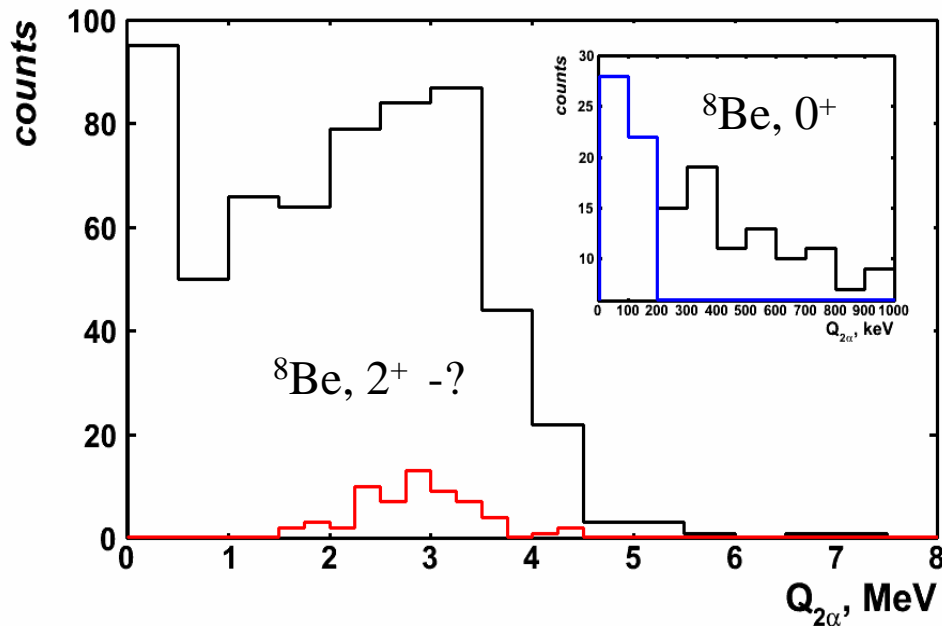
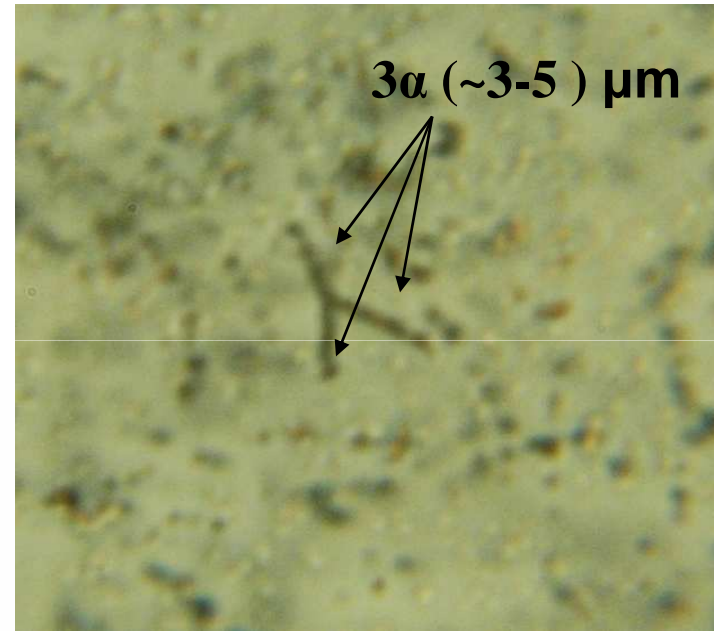
(PAVICOM image)



<http://neutrontech.ru>



DVIN - explosives detector on the basis of fast tagged neutron method for complex program for population safety in transport

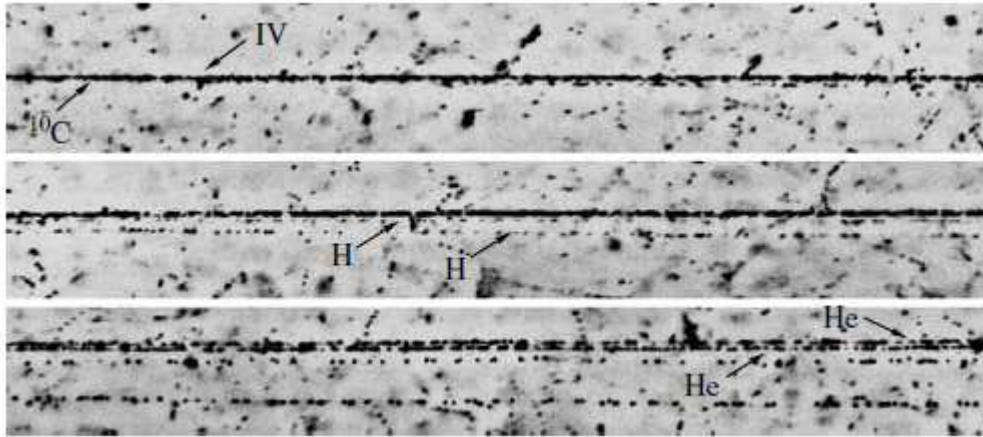


$$M_{2\alpha} = \left[2(m_\alpha^2 + E_{\alpha 1} E_{\alpha 2} - p_{\alpha 1} p_{\alpha 2} \cos(\Theta_{12})) \right]^{\frac{1}{2}}$$

$$Q_{2\alpha} = M_{2\alpha} - 2 \cdot m_\alpha$$

Fragmentation of relativistic ^{10}C (1.2 A GeV)

<http://arxiv.org/abs/1309.4241>



Charge-topology distribution of fragments from white stars, N_{ws} , where the total charge of relativistic fragments is $\sum Z_{fr} = 6$, and from $\sum Z_{fr} = 6$ events, N_{fr} , accompanied by target fragments or product mesons

Channel	$N_{ws}, \%$	$N_{fr}, \%$
2He + 2H	186 (81.9)	361 (57.6)
He + 4H	12 (5.3)	160 (25.5)
3He	12 (5.3)	15 (2.4)
6H	9 (4.0)	30 (4.8)
Be + He	6 (2.6)	17 (2.7)
B + H	1 (0.4)	12 (1.9)
Li + 3H	1 (0.4)	2 (0.3)
$^9\text{C} + n$	—	30 (4.8)

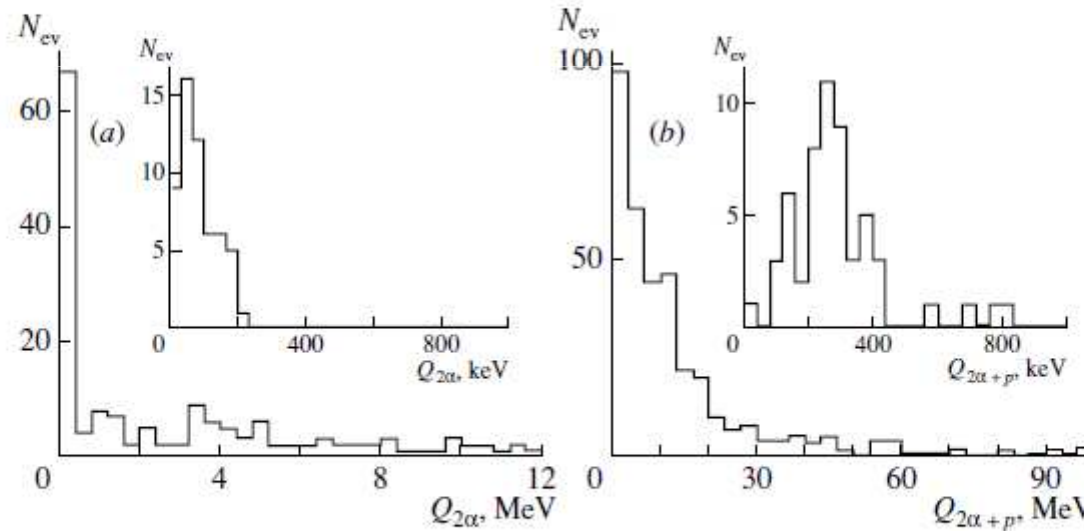
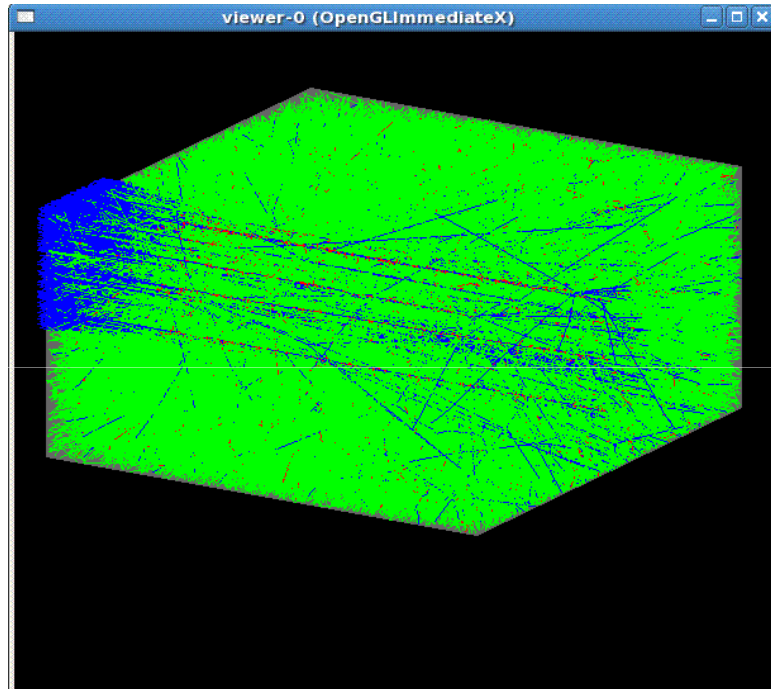
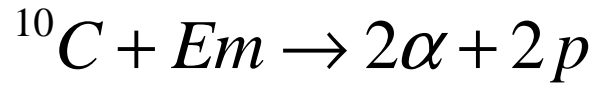


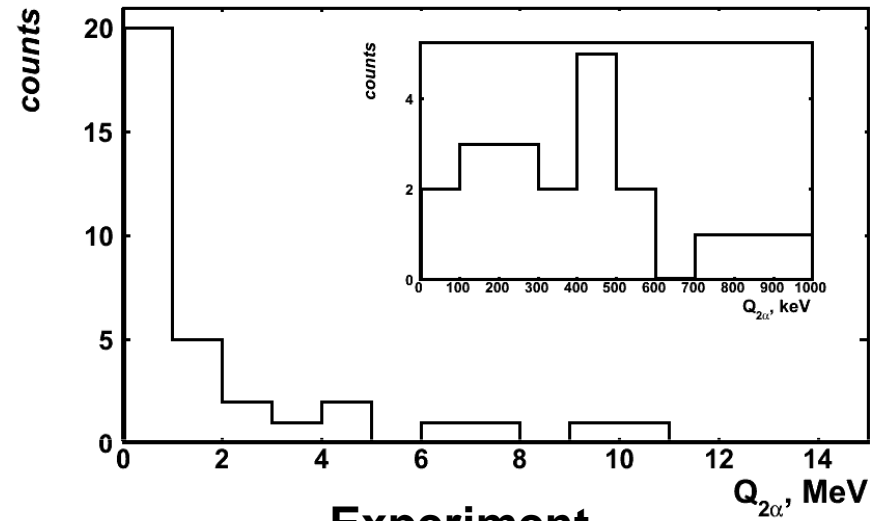
Fig. 6. Distributions of $^{10}\text{C} \rightarrow 2\alpha + 2p$ events with respect to the (a) energy $Q_{2\alpha}$ of alpha-particle pairs and (b) energy $Q_{2\alpha p}$ of the $2\alpha + p$ three-particle systems. The insets show enlarged distributions of $Q_{2\alpha}$ and $Q_{2\alpha p}$.

Modeling of ^{10}C fragmentation with Geant4

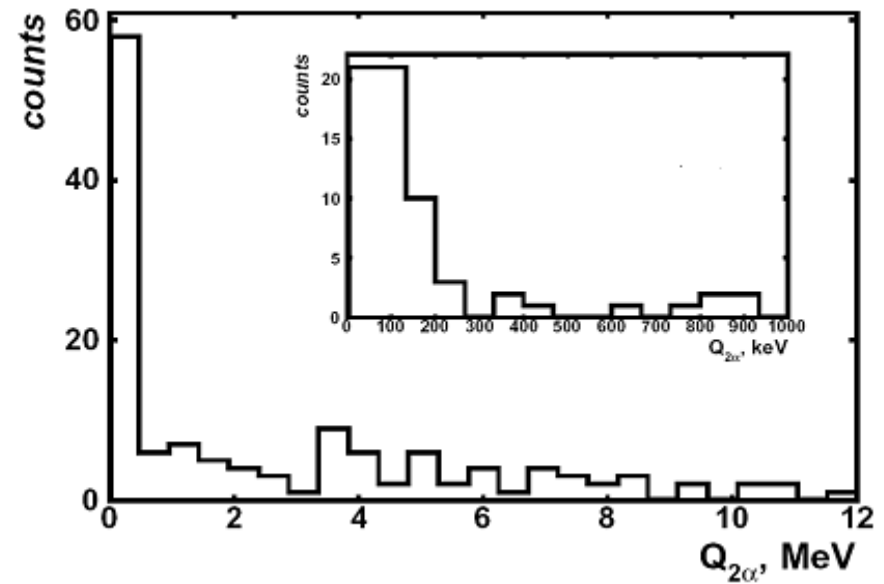


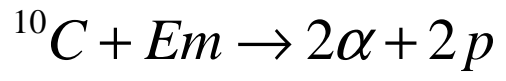
$$Q_{2\alpha} = M_{2\alpha} - 2 \cdot m_{\alpha}$$

Model

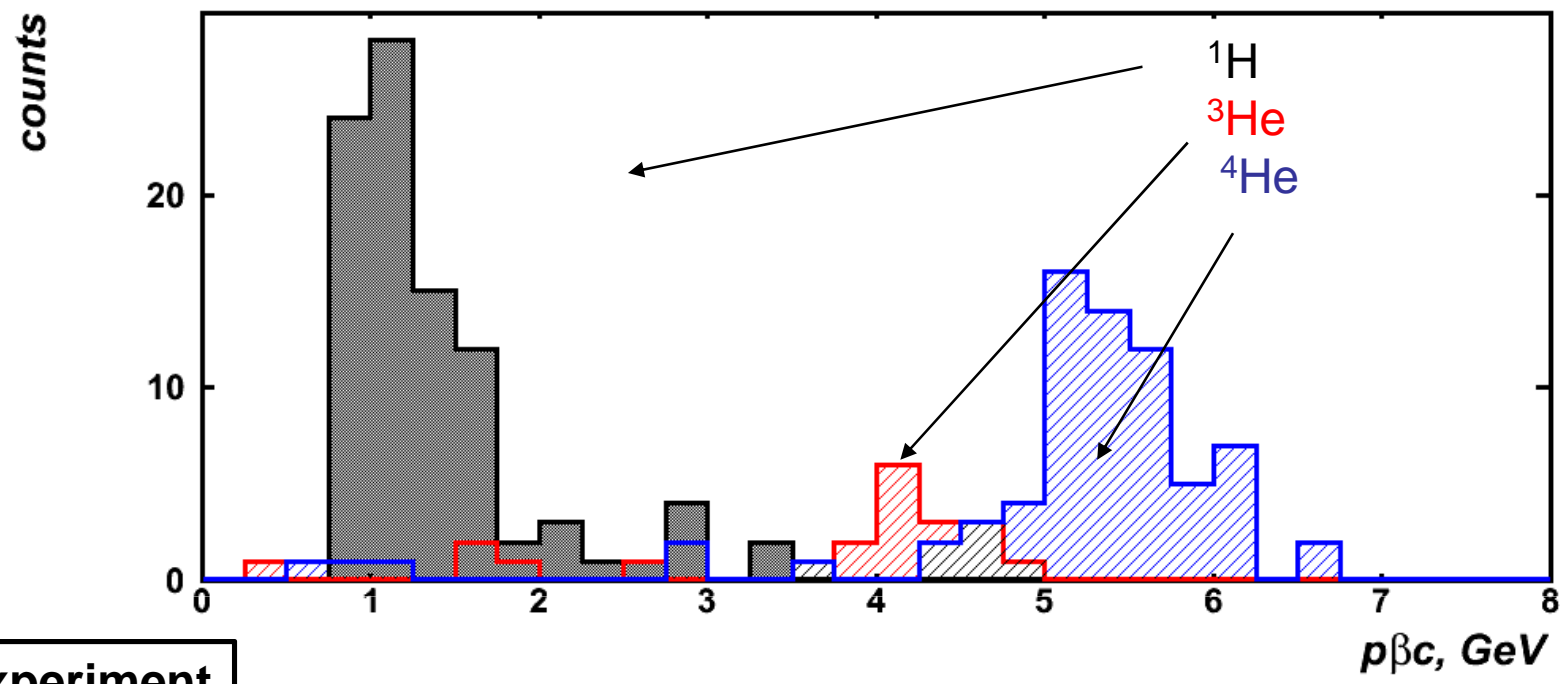


Experiment

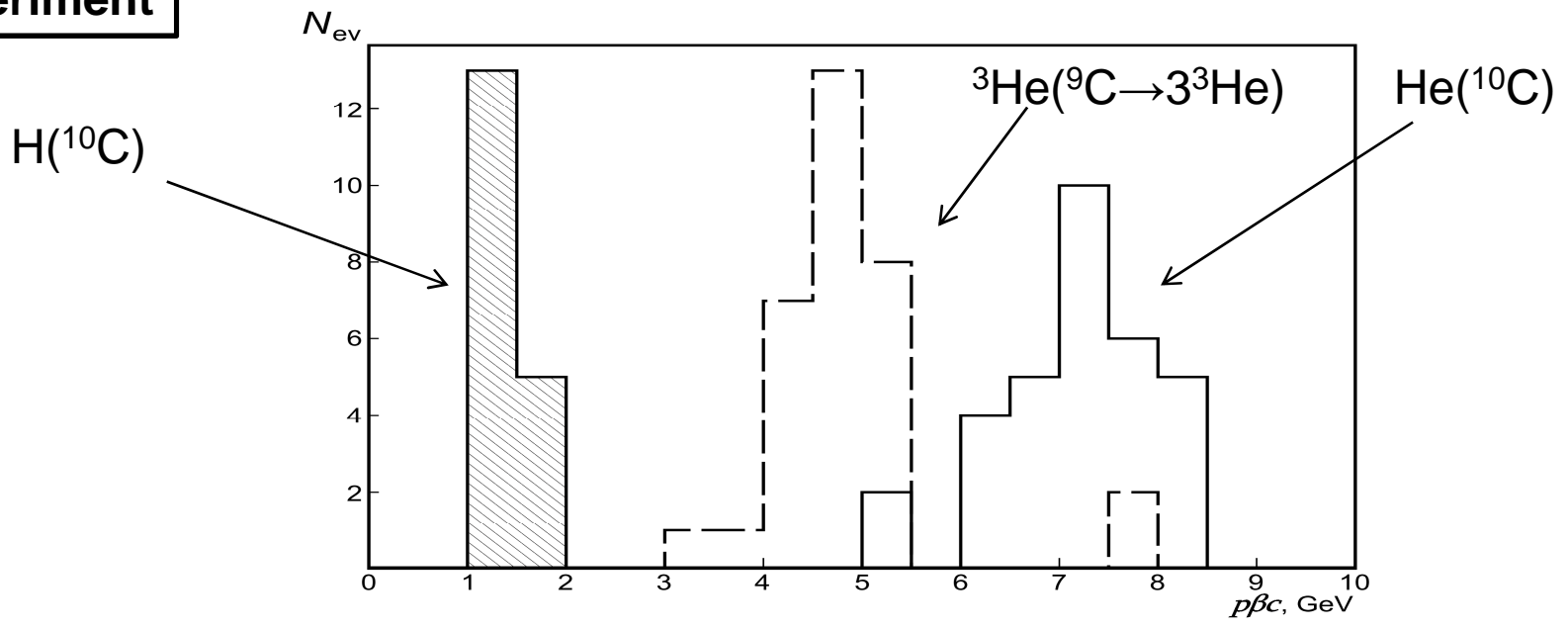




Model



Experiment



Fragmentation of relativistic ${}^9\text{C}$ (1.2 A GeV)

<http://arxiv.org/abs/1104.2439>

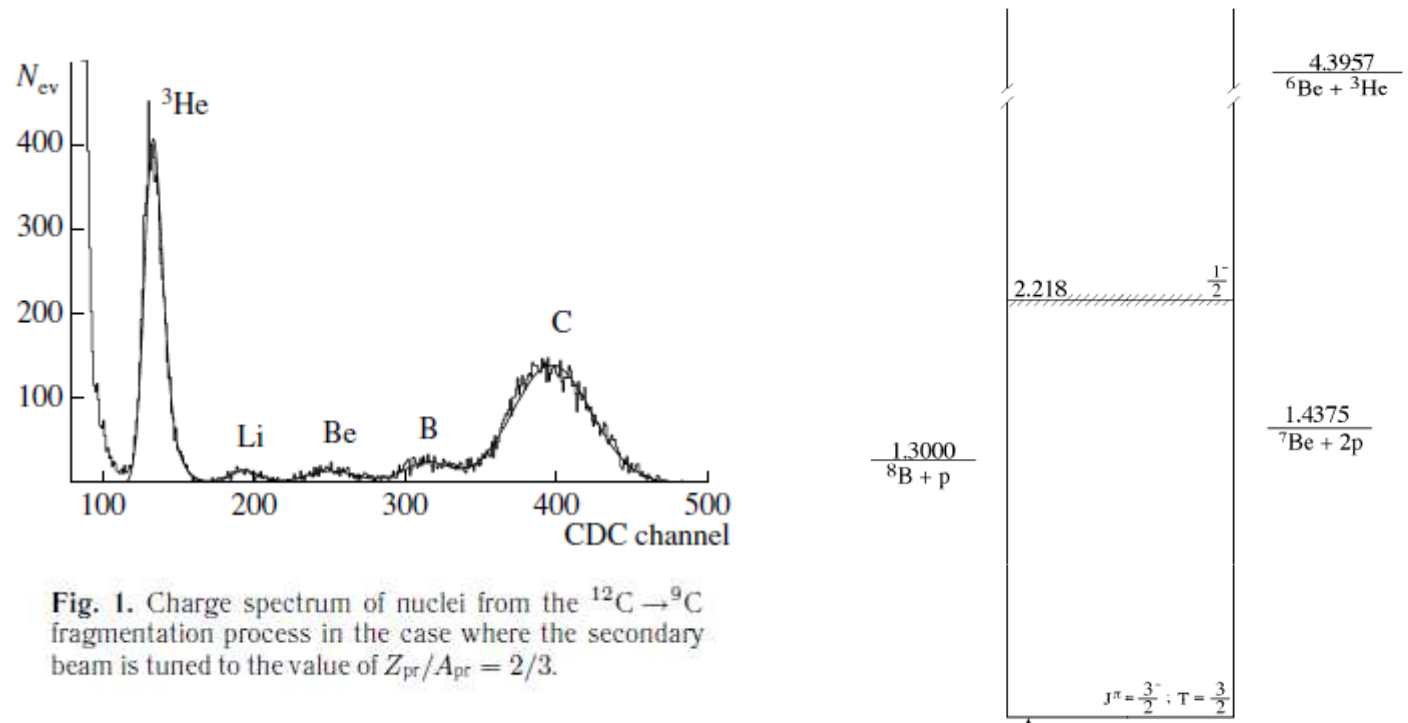
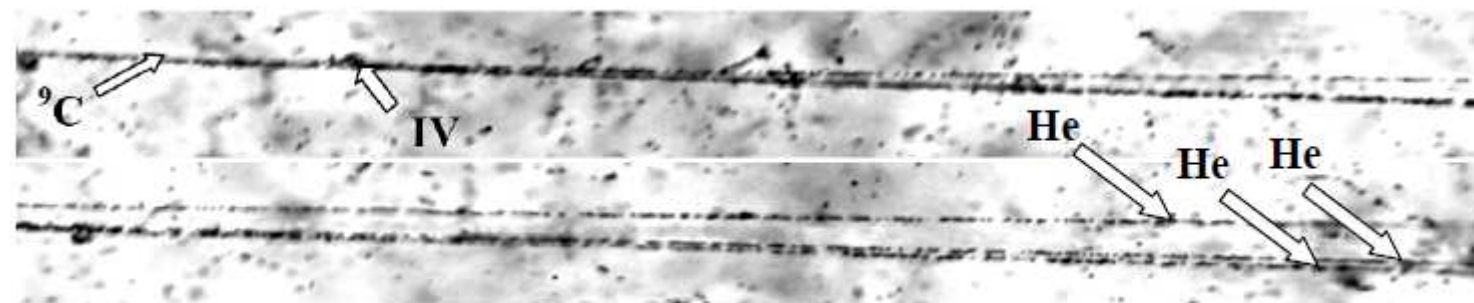
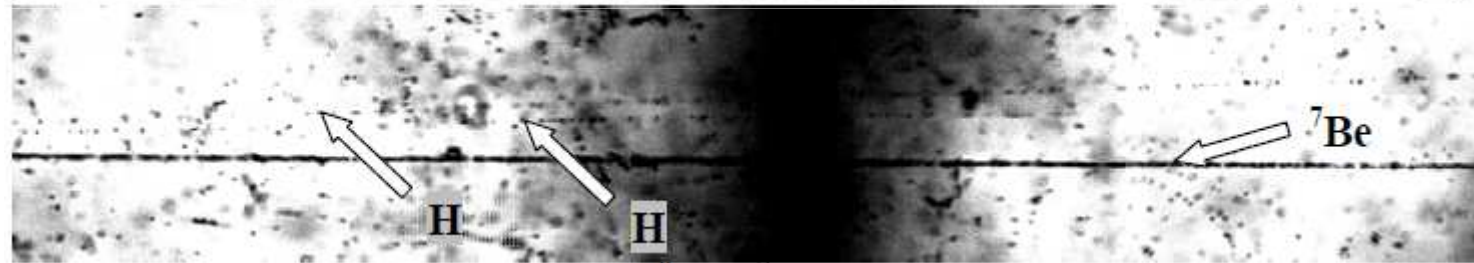
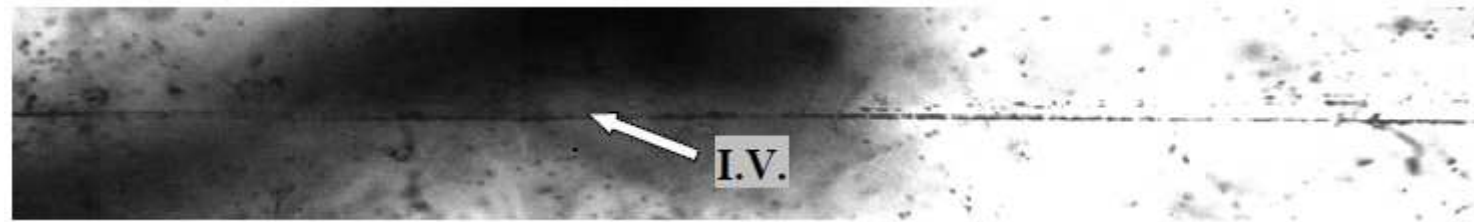
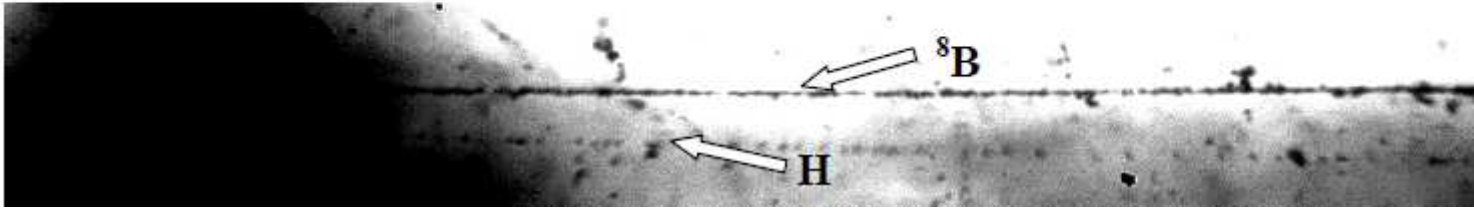


Fig. 1. Charge spectrum of nuclei from the ${}^{12}\text{C} \rightarrow {}^9\text{C}$ fragmentation process in the case where the secondary beam is tuned to the value of $Z_{pr}/A_{pr} = 2/3$.

Table 1. Distribution of the number of “white” stars, N_{ws} , and the number of events involving the production of target fragments, N_{fr} , with respect to $\sum Z_{fr} = 6$ channels

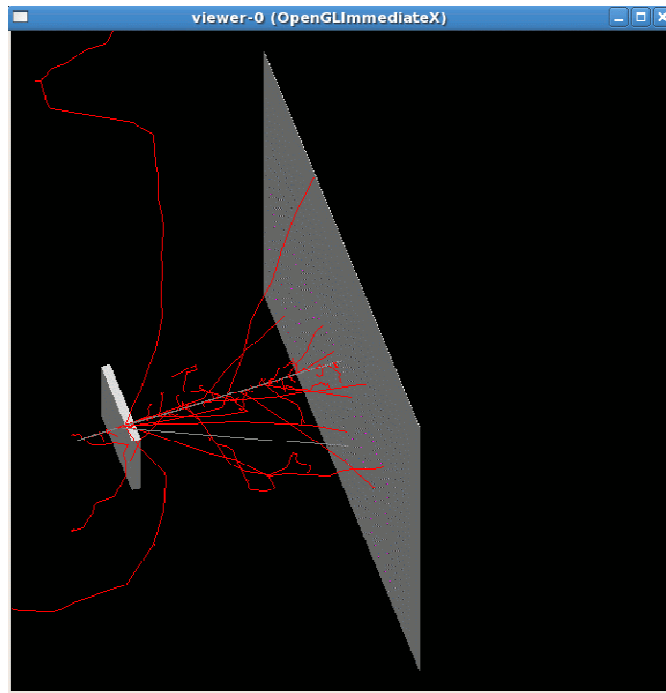
Channel	B + H	Be + 2H	3He	Be + He	Li + He + H	Li + 3H	2He + 2H	He + 4H	6H
N_{ws}	15	16	16	4	2	2	24	28	6
N_{fr}	51	47	9	7	11	8	54	80	16



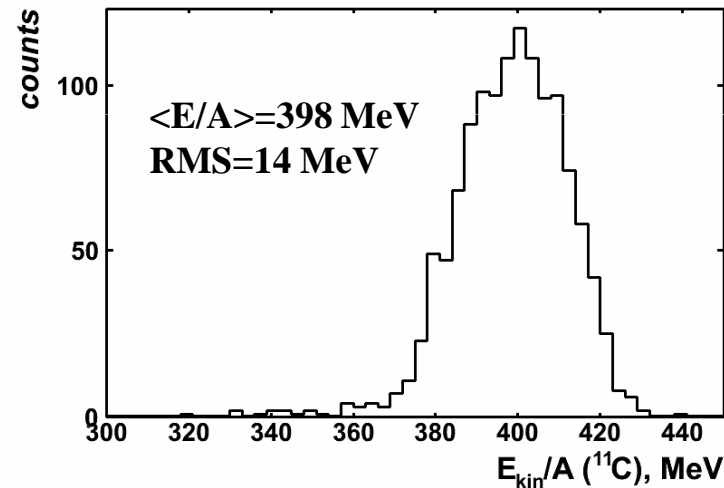
Proposal on exposures of NTE to beam of ^{11}C nuclei at 400 A MeV

based on:

- http://becquerel.jinr.ru/text/Papers/C12_U70_run_2012_1.pdf from Institute for High Energy Physics (IHEP) Protvino,
- P.A. Rukoyatkin et al., “Secondary nuclear fragment beams for investigations of relativistic fragmentation of light radioactive nuclei using nuclear photoemulsion at Nuclotron”, <http://arxiv.org/abs/1210.1540>



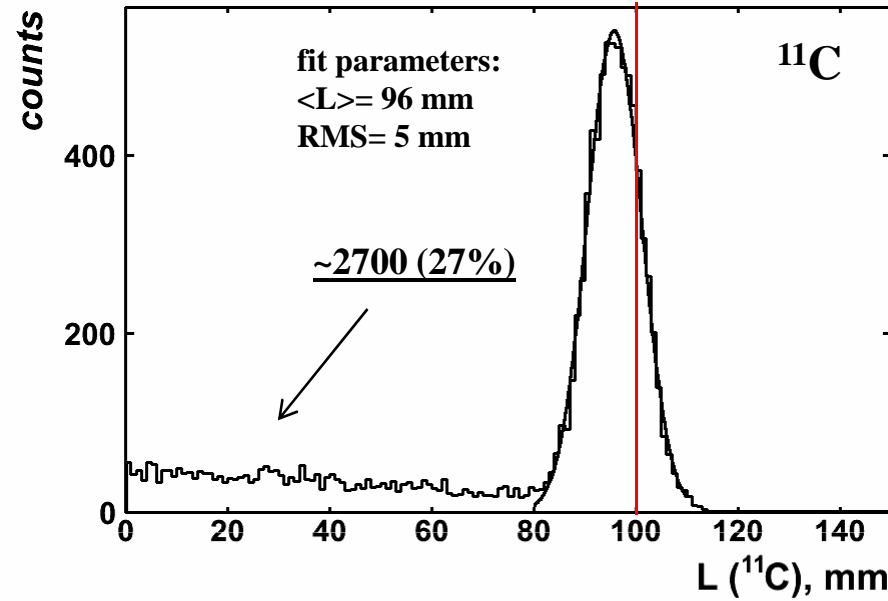
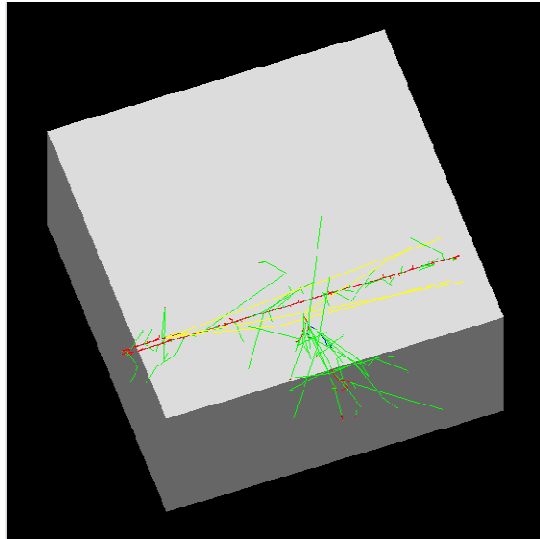
1272 nuclei of ^{11}C produced from 10^4 of ^{12}C



Polyethylene target (thickness - 1 cm) irradiated by ^{12}C nuclei with 420 A MeV. Used CHIPS physics list, and G4_POLYETHYLENE target (Geant4). All equipment located in air.

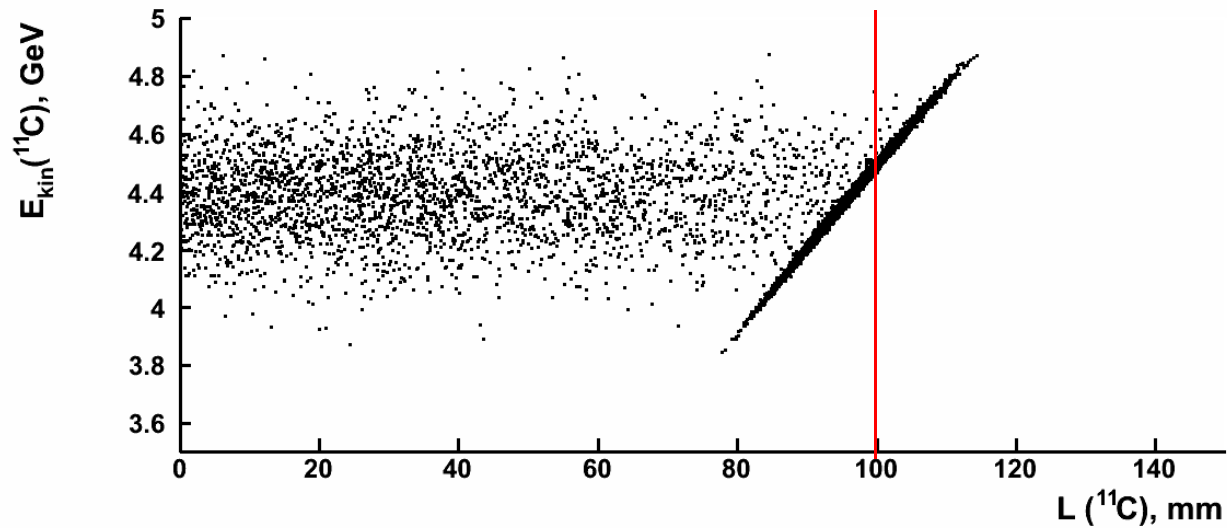
Break of NTE ($10 \times 10 \times 5 \text{ cm}^3$) irradiated by 10^4 of ^{11}C nuclei (400 A MeV, RMS = 14 A MeV)

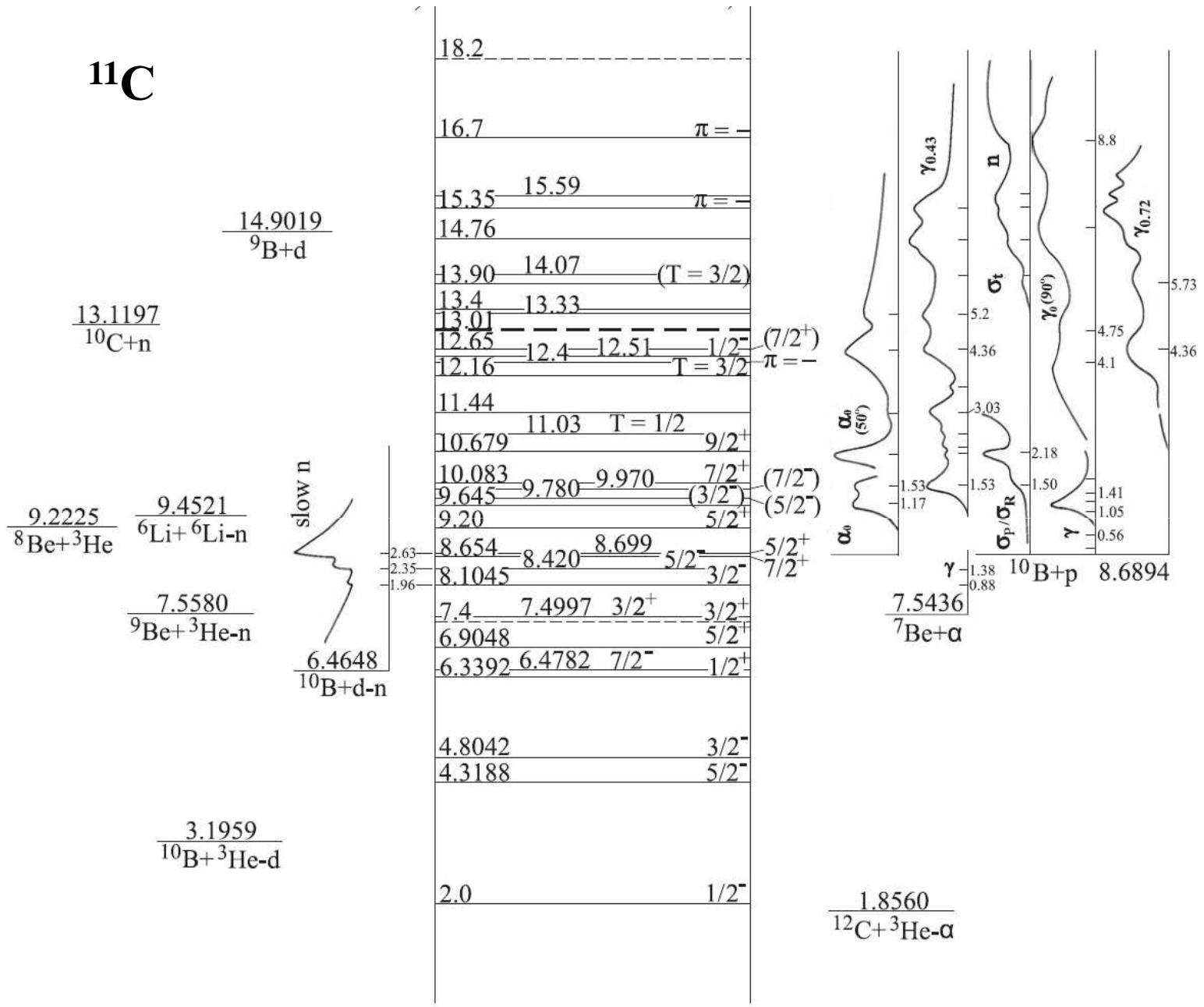
Track length of ^{11}C in NTE at 400 A MeV



G4_PHOTO_EMULSION

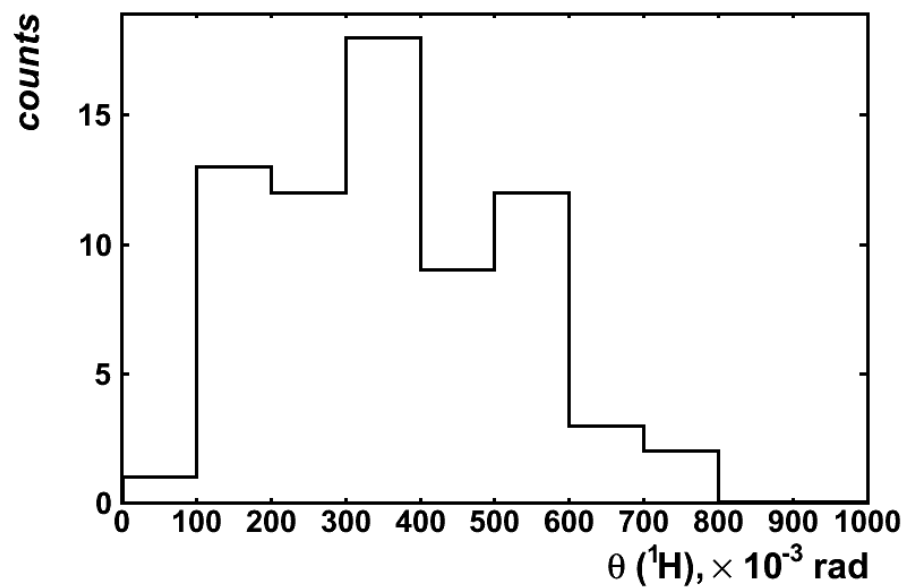
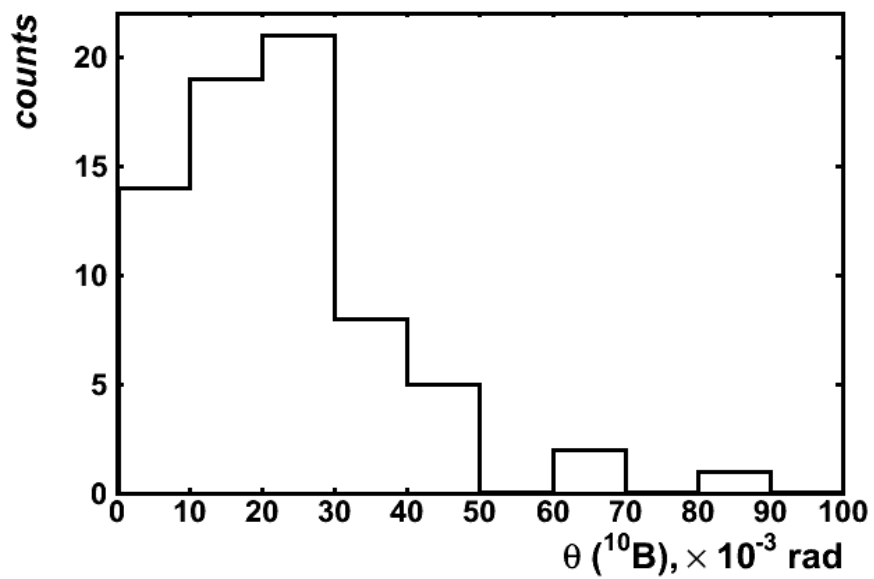
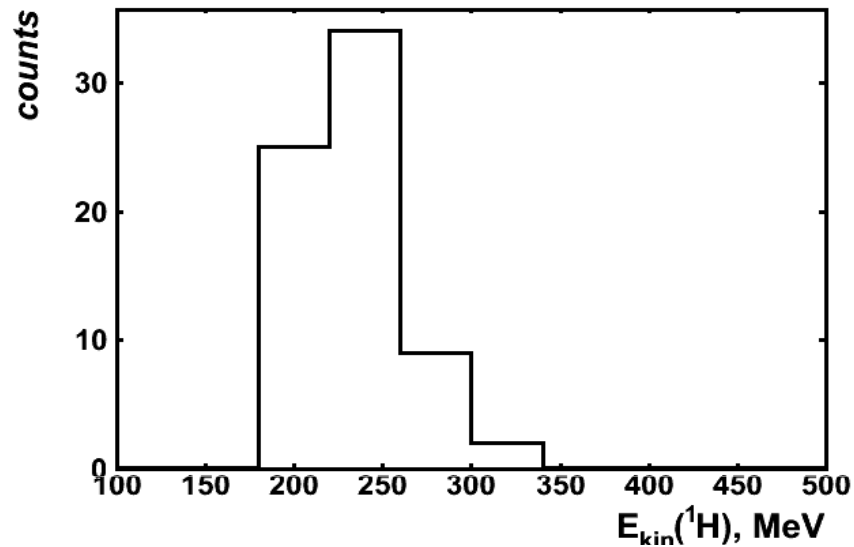
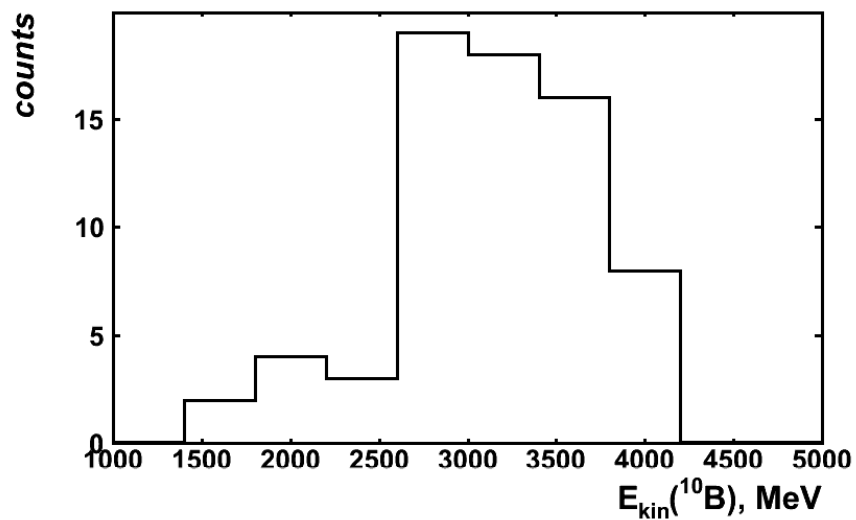
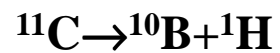
SRIM: E_{kin} (4.0, 4.4) GeV; L (90.3, 104.5) mm





Channel	Number	Energy threshold, MeV
$^{11}\text{C} \rightarrow ^8\text{Be} + ^3\text{He} \rightarrow 2^4\text{He} + ^3\text{He}$	16	9.23
$^{11}\text{C} \rightarrow 2^4\text{He} + ^3\text{He}$	4	9.13
$^{11}\text{C} \rightarrow ^{10}\text{B} + ^1\text{H}$	69	8.69
$^{11}\text{C} \rightarrow ^9\text{B} + ^2\text{H} \rightarrow 2^4\text{He} + ^1\text{H} + ^2\text{H}$	61	14.90
$^{11}\text{C} \rightarrow ^8\text{B} + ^3\text{H}$	14	27.22
$^{11}\text{C} \rightarrow ^9\text{Be} + 2^1\text{H}$	8	15.28
$^{11}\text{C} \rightarrow ^7\text{Be} + ^4\text{He}$	25	7.54
$^{11}\text{C} \rightarrow ^6\text{Li} + ^4\text{He} + ^1\text{H}$	10	13.15
$^{11}\text{C} \rightarrow ^{10}\text{C} + \text{n}$	3	13.12
$^{11}\text{C} \rightarrow 2^4\text{He} + ^2\text{H} + ^1\text{H}$	8	14.62
$^{11}\text{C} \rightarrow ^{11}\text{B}$	17	-1.98

Typical energy and angular scale for produced fragments from ^{11}C at 400 A MeV



Summary

The presented report serve as an illustration of possibilities of the NTE for study nuclear structure of carbon isotopes in wide energy range.

Proposal on exposures of NTE to beam of ^{11}C nuclei at 400 A MeV are overviewed.

All the results for ^{11}C are approximate and model dependent (physics list dependent). At the same time, they allow us to get an idea about the features of the study ^{11}C in with NTE.

Thank you for your attention!