



BECQUEREL
PROJECT

Проект
БЕККЕРЕЛЬ

Beryllium (Boron)

Clustering

Quest in

Relativistic Multifragmentation

<http://becquerel.jinr.ru>

Radioactive nuclei stopped in nuclear track emulsion

Denis Artemenkov,

VBLHEP, JINR (for the BECQUEREL collaboration)



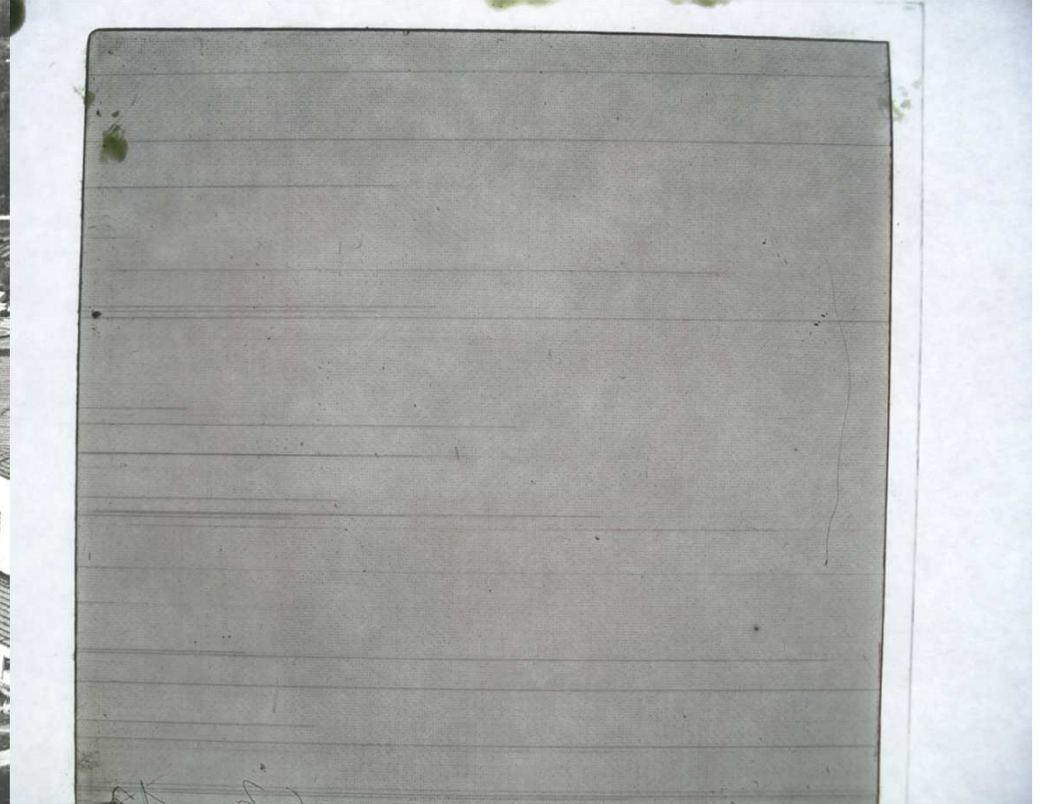
BECQUEREL
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Beryllium (Boron)
Clustering
Quest in
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<http://becquerel.jinr.ru>

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



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.

In the energy range of nuclei several MeV per nucleon, there is a possibility of implantation of radioactive nuclei into detector material. Of course, in this approach daughter nuclei are investigated rather than the nuclei themselves. In this respect it is worth mentioning the known, although somewhat forgotten, possibilities of **NTE** (**N**uclear **T**rack **E**mulsion) for the detection of slow radioactive nuclei. More than half a century ago, alpha tracks from the decay of ^8Be nuclei through the first excited state 2^+ of about 2.0 MeV were observed. They occurred in the alpha decays of stopped ^8Li .

PHYSICAL REVIEW

VOLUME 99, NUMBER 1

JULY 1, 1955

Alpha Spectrum in the Decay of $\text{Li}^{8\ddagger}$

R. T. FROST* AND S. S. HANNA

Department of Physics, The Johns Hopkins University, Baltimore, Maryland

(Received February 28, 1955)

The alpha-particle spectrum in the successive beta-alpha decay of Li^8 was observed with magnetic analysis from 1 to 6.5 Mev, corresponding to excitation energies in Be^8 from 2 to 13 Mev. The only definite structure in the spectrum corresponds to the well-known broad state at 2.9 Mev.

^8He

Atomic Mass: 8.0339218 ± 0.0000076 amu

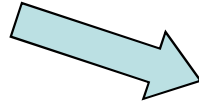
Excess Mass: 31597.983 ± 7.077 keV

Binding Energy: 31407.892 ± 7.077 keV

Half life: 119.0 ms

Mode of decay: β^- to ^8Li

Decay energy: 10.65 MeV



^8Li

Atomic Mass: 8.0224867 ± 0.0000005 amu

Excess Mass: 20946.195 ± 0.488 keV

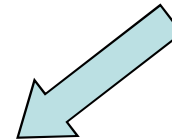
Binding Energy: 41277.328 ± 0.488 keV

Half life: 838 ms

Mode of decay: β^- to ^8Be

Decay energy: 16.004 MeV

Possible parent nuclides: β^- from ^8He



^8Be

Atomic Mass: 8.0053051 ± 0.0000000 amu

Excess Mass: 4941.662 ± 0.035 keV

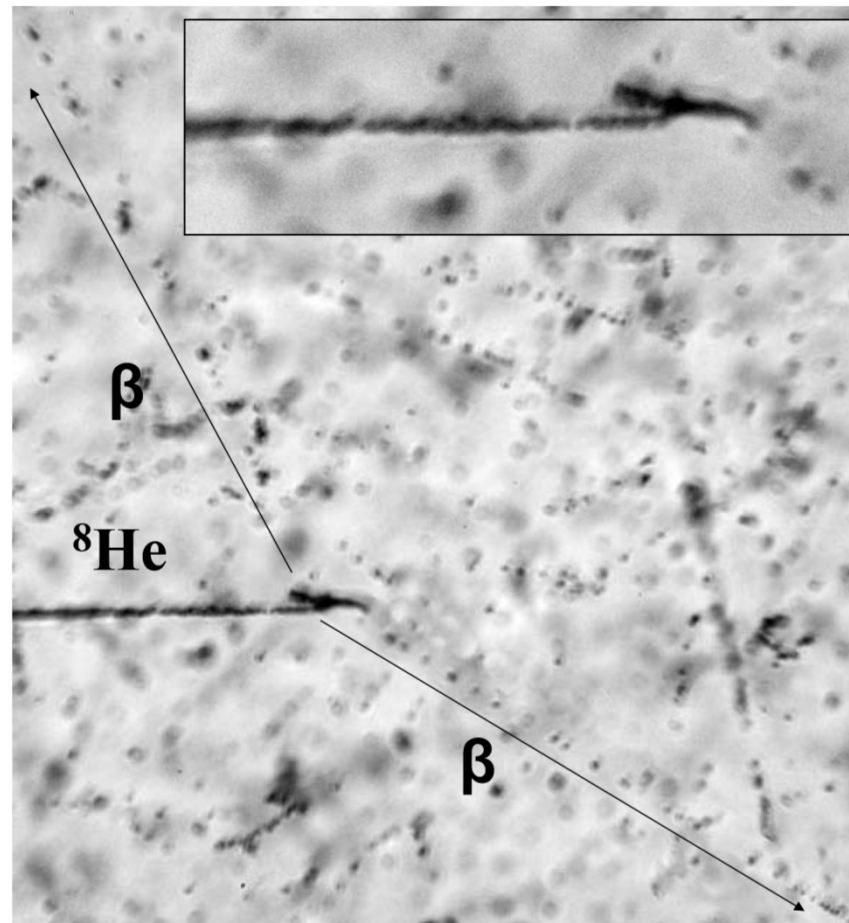
Binding Energy: 56499.506 ± 0.037 keV

Half life: 6.8 eV ($\approx 9.7 \cdot 10^{-17}$ c)

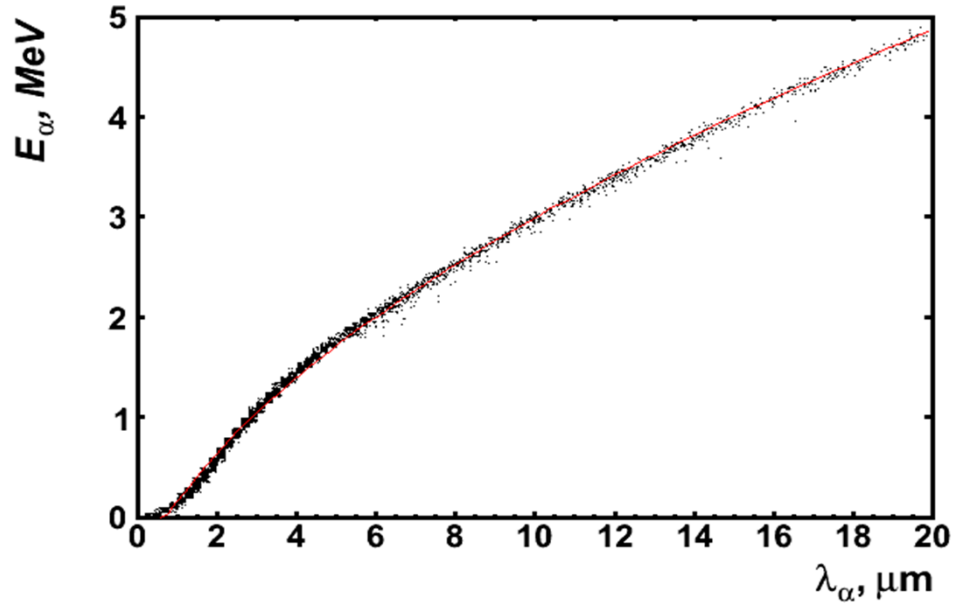
Mode of decay: 2 Alpha

Decay energy: 0.092 MeV

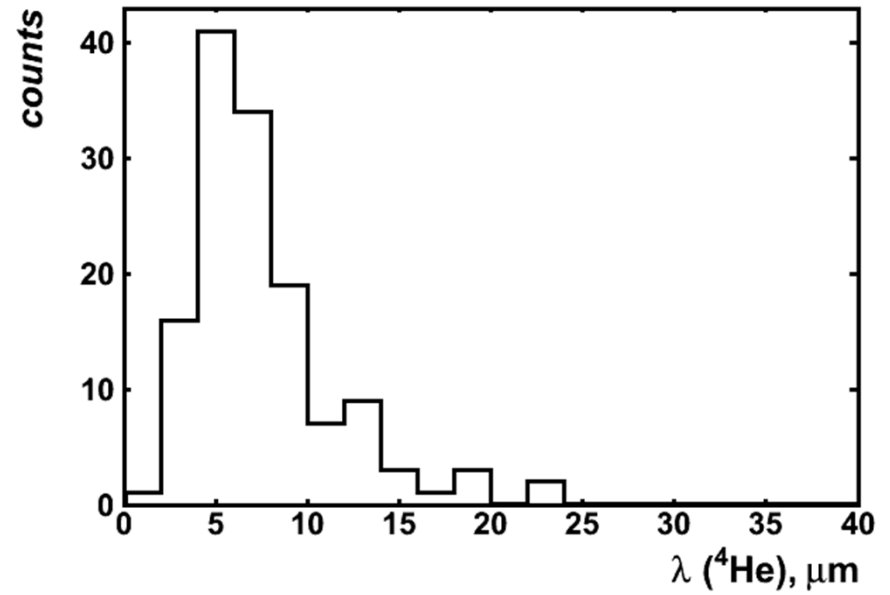
In March 2012 NTE was exposed at the Flerov Laboratory of Nuclear Reactions (JINR) at the ACCULINNA spectrometer (<http://aculina.jinr.ru/>). The beam in use was enriched by ≈ 7 A MeV ^8He nuclei. A 107 μm thick NTE pellicle was oriented at a 10° angle during irradiation, which provided approximately a five-fold effective thickness increase. For **10 minutes of irradiation**, statistics of about **2 thousand** of such decays was obtained. It is pleasant to note that the used NTE have been recently reproduced by the enterprises «Slavich» (Pereslavl-Zalessky, Russia).



Track length and kinetic energy of alpha particles

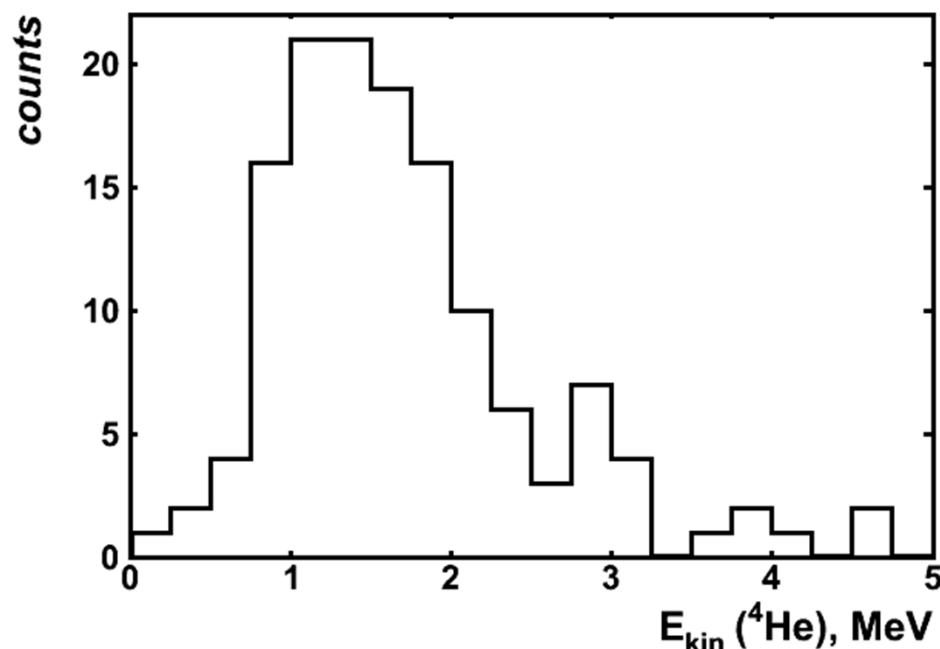


Track length / kinetic energy curve for alpha fragments (Geant4)



Track length of produced alpha particles

All data analysis based on free path and angular measurements for produced alpha fragments



Alpha spectrum from
(our experiment)

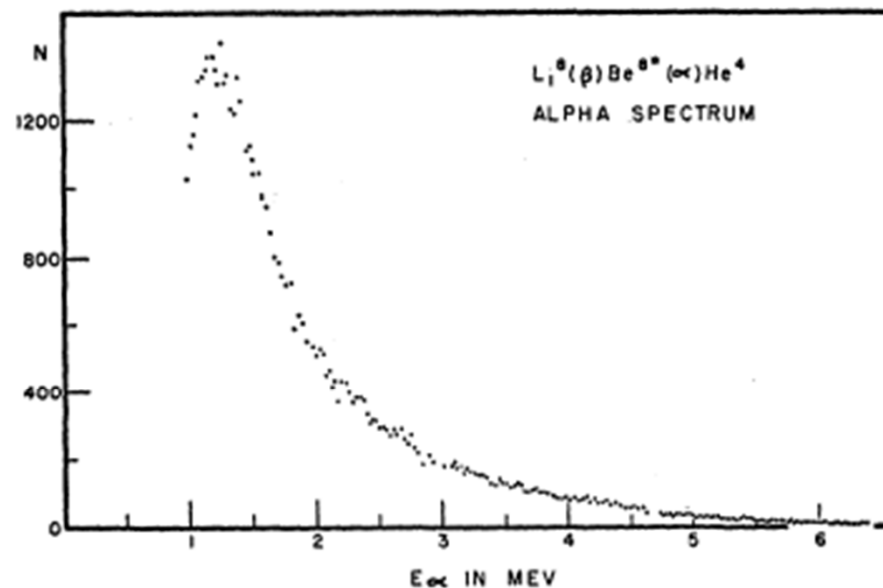
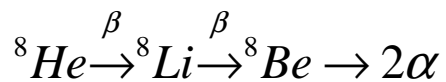


FIG. 1. Alpha spectrum from $\text{Li}^8(\beta)\text{Be}^{8*}(\alpha)\text{He}^4$. The vertical intensity scale is arbitrary. The numbers given indicate approximately the actual number of particles counted for the points below 3 Mev. Above 3 Mev the actual count is about twice that indicated by the numbers.

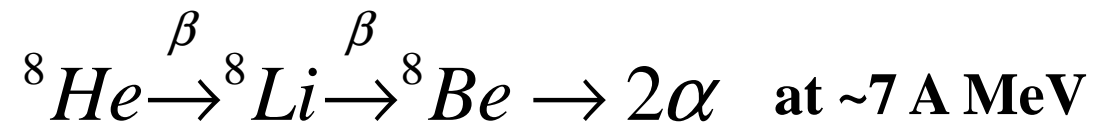
Alpha Spectrum in the Decay of $\text{Li}^{8\ddagger}$

R. T. FROST* AND S. S. HANNA

Department of Physics, The Johns Hopkins University, Baltimore, Maryland

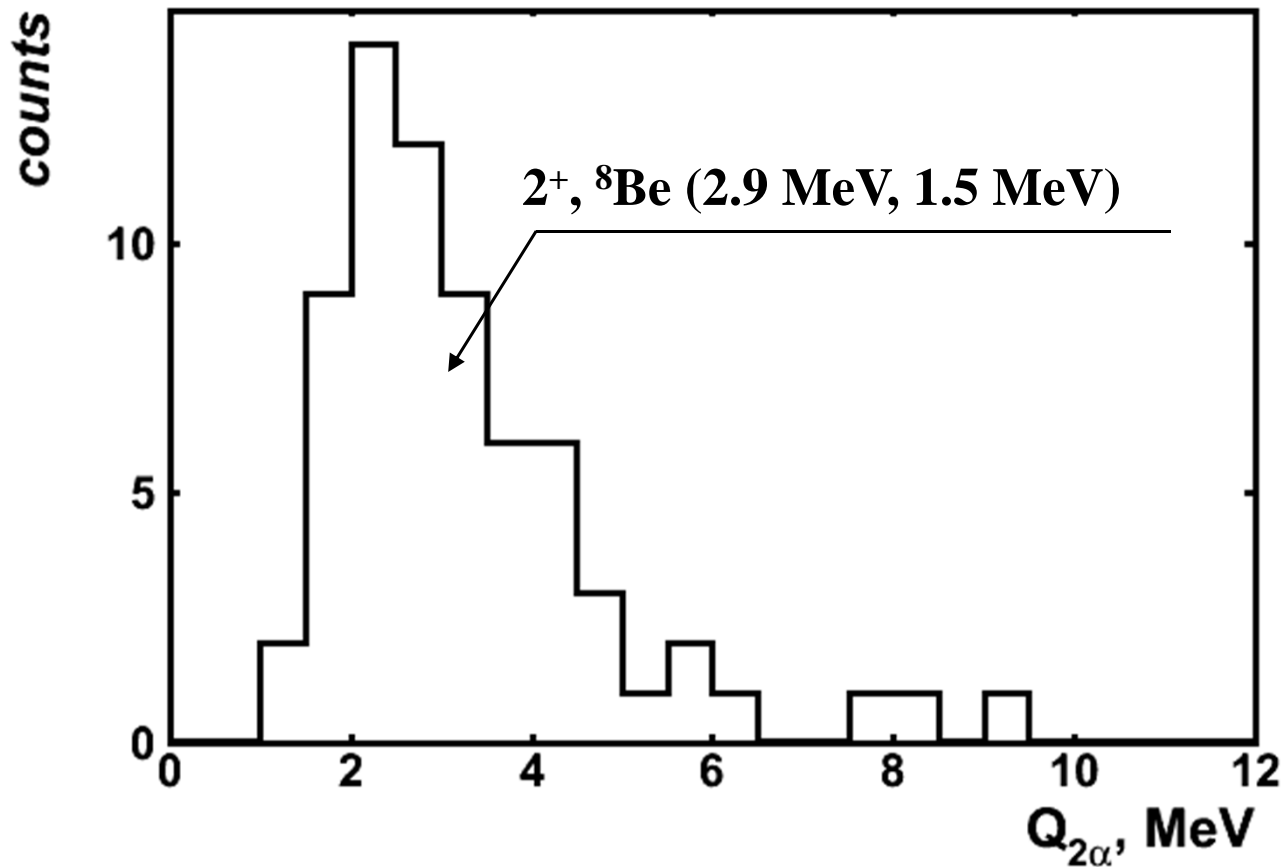
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$$M_{2\alpha} = \left[2(m_\alpha^2 + E_{\alpha 1} E_{\alpha 2} - p_{\alpha 1} p_{\alpha 2} \cos(\Theta_{12})) \right]^{\frac{1}{2}}$$

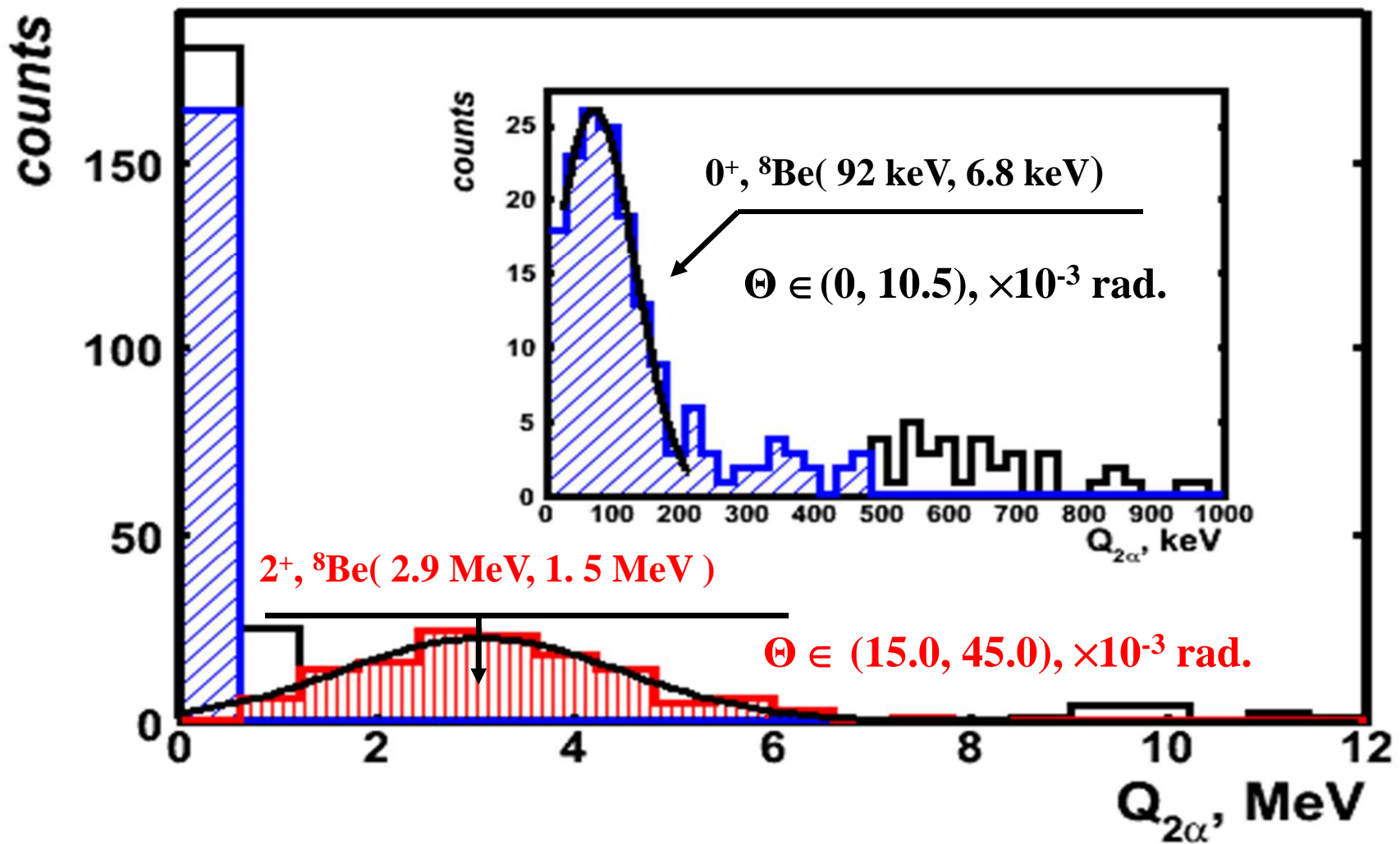
$$Q_{2\alpha} = M_{2\alpha} - 2 \cdot m_\alpha$$



${}^9\text{Be} \rightarrow 2\alpha$ at 1.2 A GeV

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

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

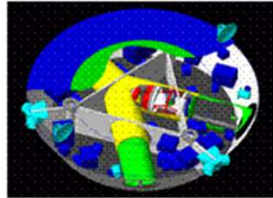


Geant4 is a toolkit for the simulation of the passage of particles through matter. Its areas of application include high energy, nuclear and accelerator physics, as well as studies in medical and space science. The two main reference papers for Geant4 are published in *Nuclear Instruments and Methods in Physics Research A* [506 \(2003\) 250-303](#), and *IEEE Transactions on Nuclear Science* [53 No. 1 \(2006\) 270-278](#).

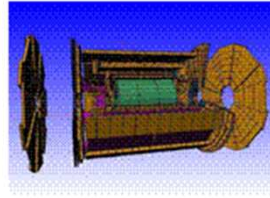
Applications



User Support



Results & Publications



Collaboration



News

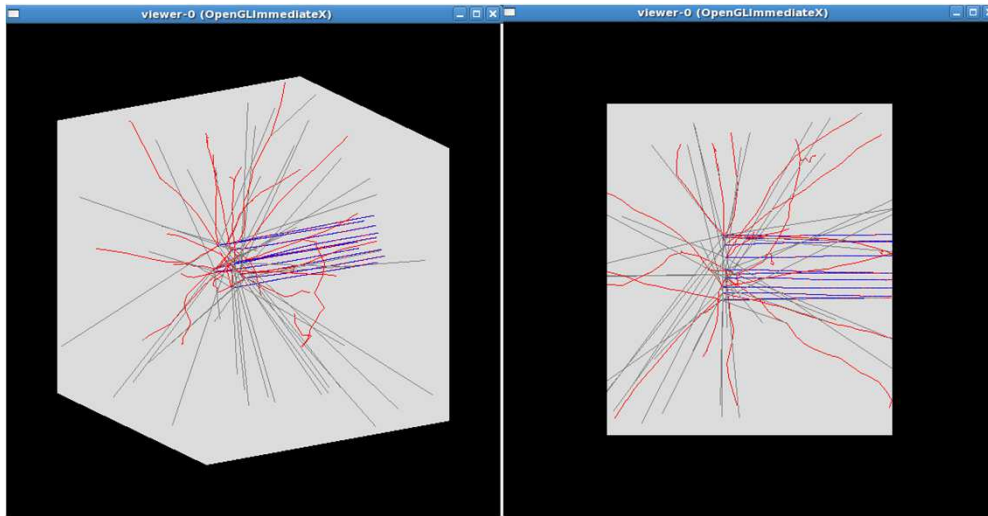
- 15 August 2012 - **Geant4-MT prototype 9.5.p01** is available from the [download](#) area.
- 29 June 2012 - **Release 9.6 BETA** is available from the [Beta download](#) area.
- 20 April 2012 - **Patch-04 to release 9.4** is available from the [archive download](#) area.

Ion Physics Radioactive Decay

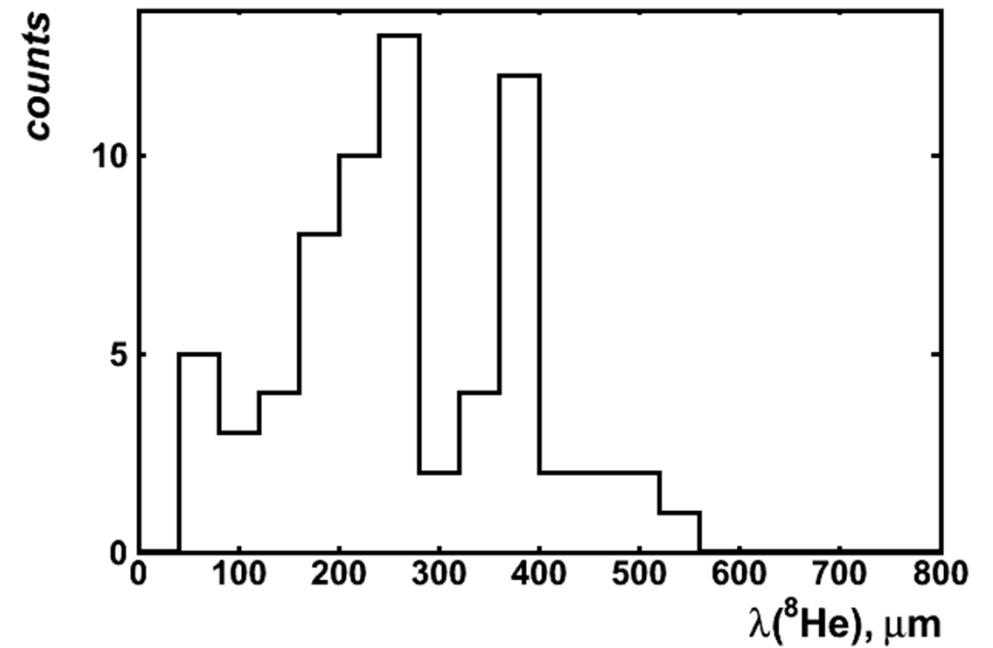
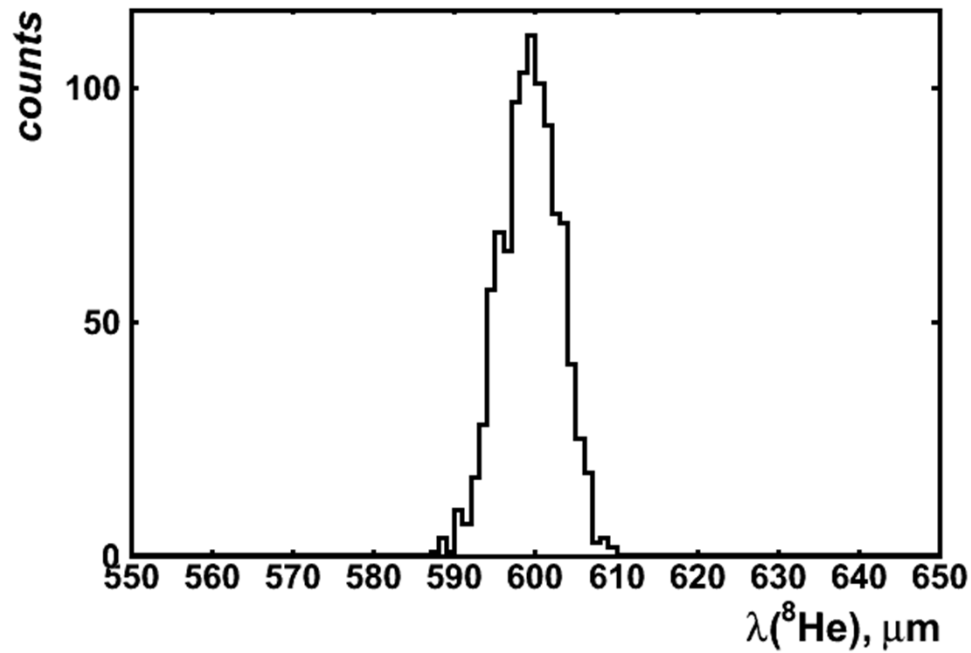
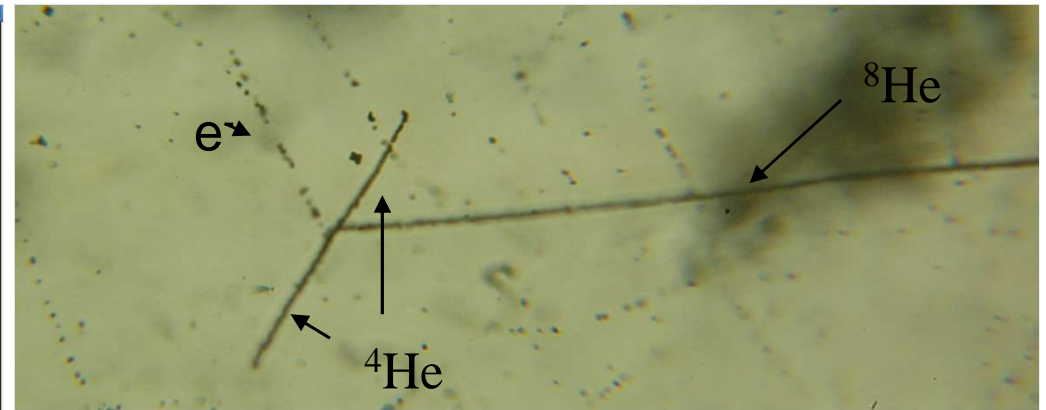
- To simulate the decay of radioactive nuclei
- Empirical and data-driven model
- α , β^+ , β^- decay electron capture (EC) are implemented
- Data (RadioactiveDecay) derived from Evaluated Nuclear Structure Data File (ENSDF)
 - nuclear half-lives
 - nuclear level structure for the parent or daughter nuclide
 - decay branching ratios
 - the energy of the decay process.
- If the daughter of a nuclear decay is an excited isomer, its prompt nuclear de-excitation is treated using the G4PhotonEvapolation

Data modeling and experiment (^8He at $\approx 7 \text{ A MeV}$)

Radioactive Decay (Geant4)

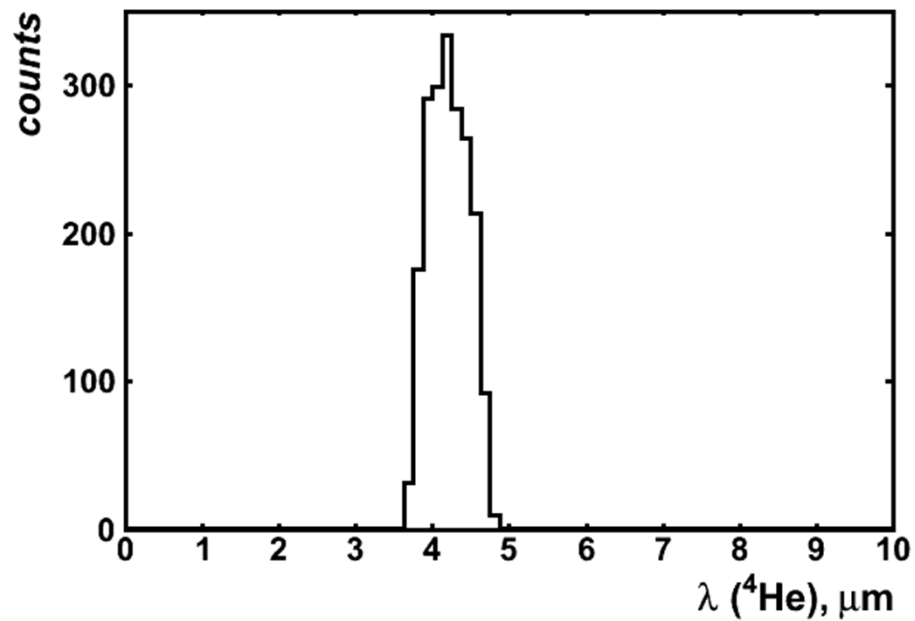


Experiment

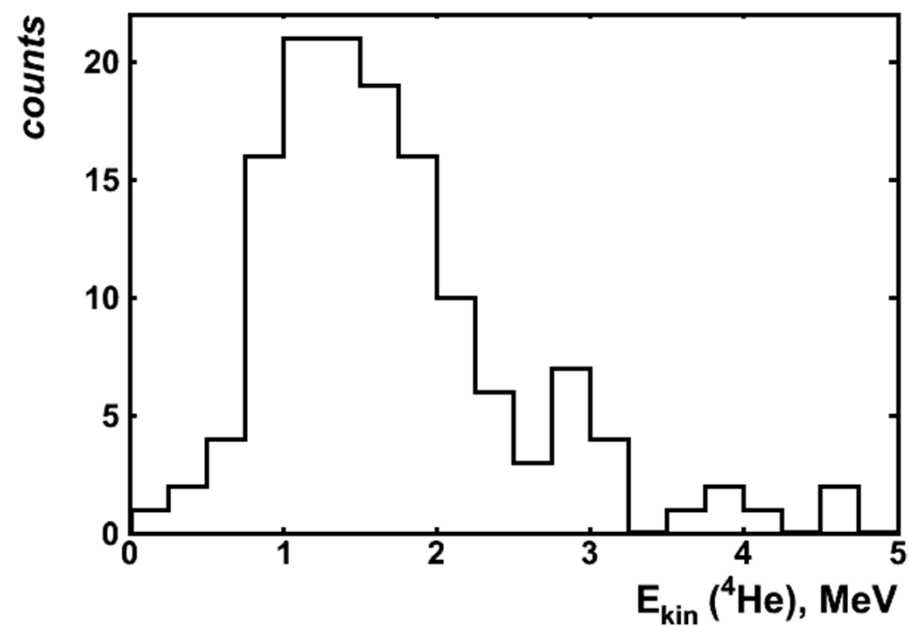
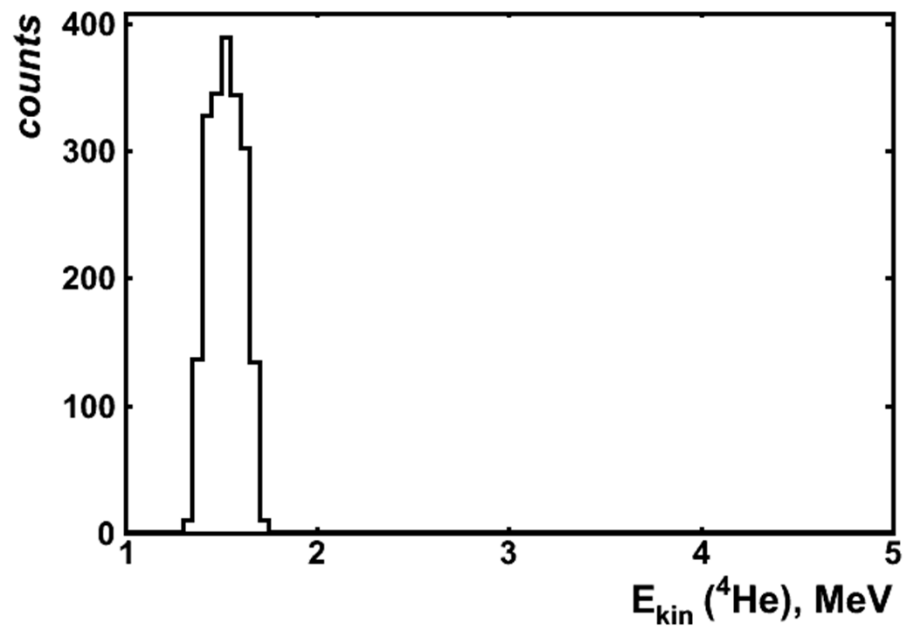
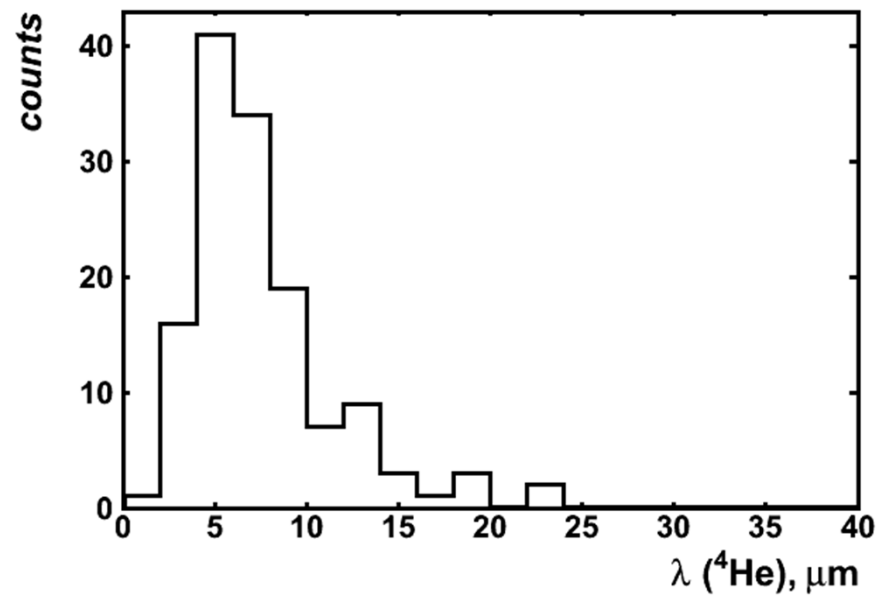


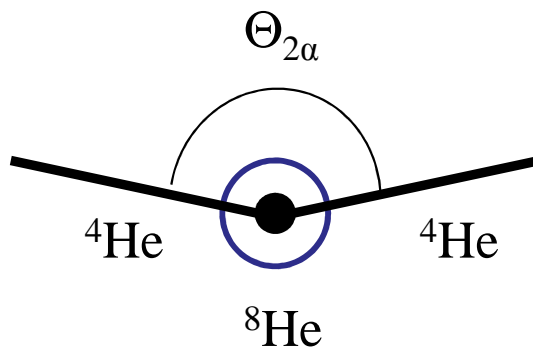
Track length and kinetic energy

Radioactive Decay (Geant4)

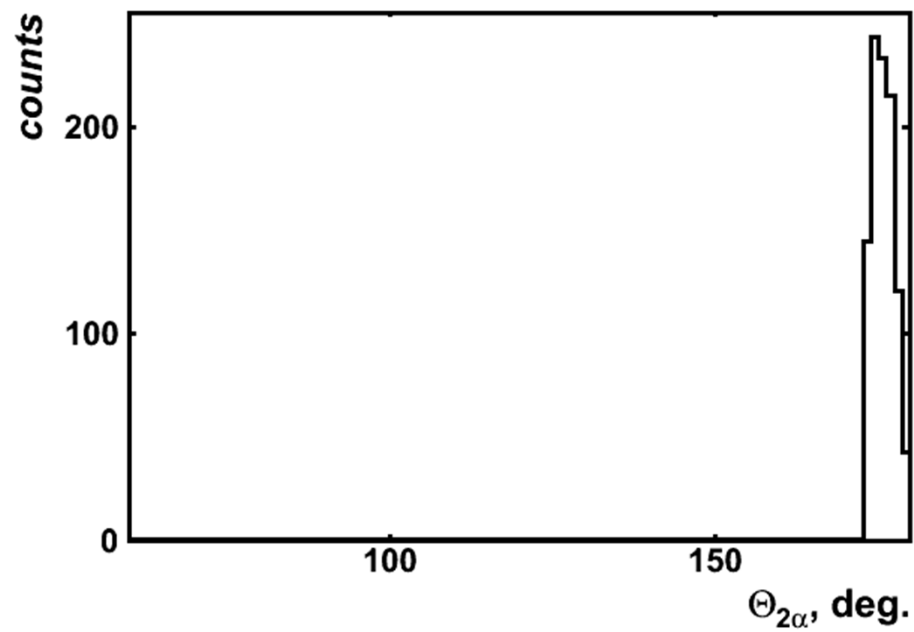


Experiment

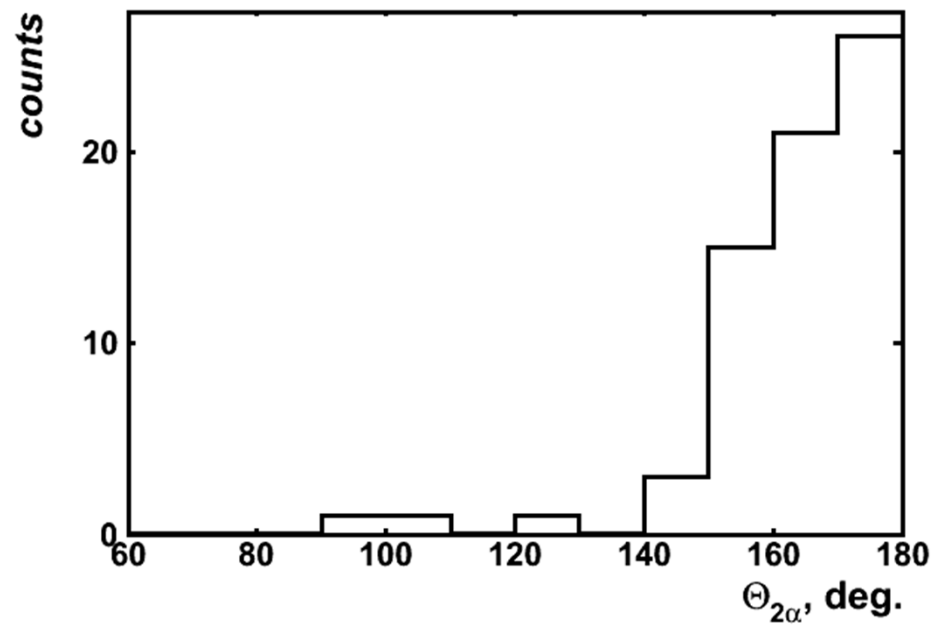




Radioactive Decay (Geant4)



Experiment



Summary

- **In the energy range of nuclei several MeV per nucleon, there is a possibility of implantation of radioactive nuclei into detector material.**
- **In the present talk the NTE usage for this kind of investigations is shown.**

Thank you for your attention!

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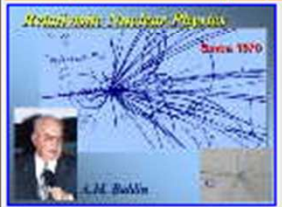
Address http://becquerel.lhe.jinr.ru/ Go



BECQUEREL PROJECT
 Проект БЕККЕРЕЛЬ

Beryllium (Boron) Clustering Quest in Relativistic Multifragmentation
<http://becquerel.lhe.jinr.ru>

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Relativistic Multifragmentation Since 1970
 A.M. Buzin



Light nucleus production in Fragmentation



Beryllium (Boron) Clustering Quest in Relativistic Multifragmentation




The BECQUEREL project is aimed to combine radiation of emulsions in combination of Nuclotron with the purpose of studying in detail processes of fragmentation of light nuclei near a source.



Clustering in light nuclei



Properties of nuclei and their fragmentation

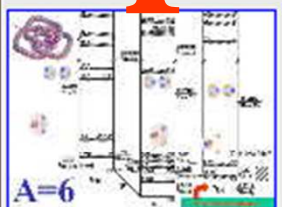


Clustering in Light Nuclei



Triplets Phenomena in Light Nuclei

http://becquerel.jinr.ru/



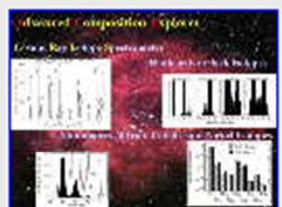
A=6



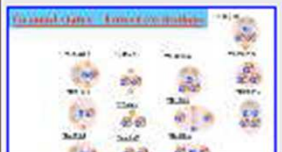
Mg-26 Dissociation into charge state 2+2=2=2=1



Fragmentation in emulsions



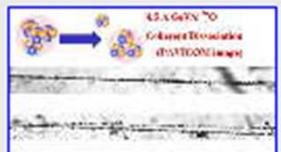
Fragmentation spectra



Advantages of relativistic fragmentation in emulsions



Advantages of relativistic fragmentation in emulsions



4.5 GeV/c²



4.5 GeV/c²