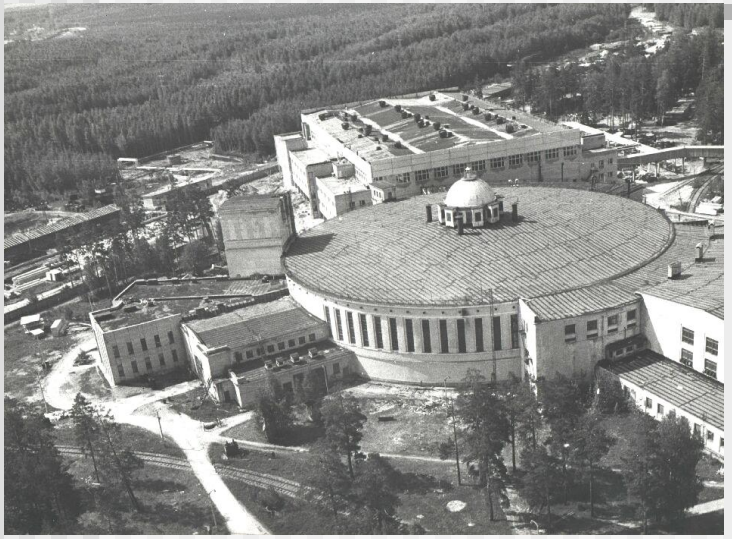
Detailed study of relativistic $^{9}Be \rightarrow 2\alpha$ fragmentation in peripheral collisions in nuclear track emulsion



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http://becquerel.jinr.ru/

The 3rd Light Ion Nuclear Collision Workshop
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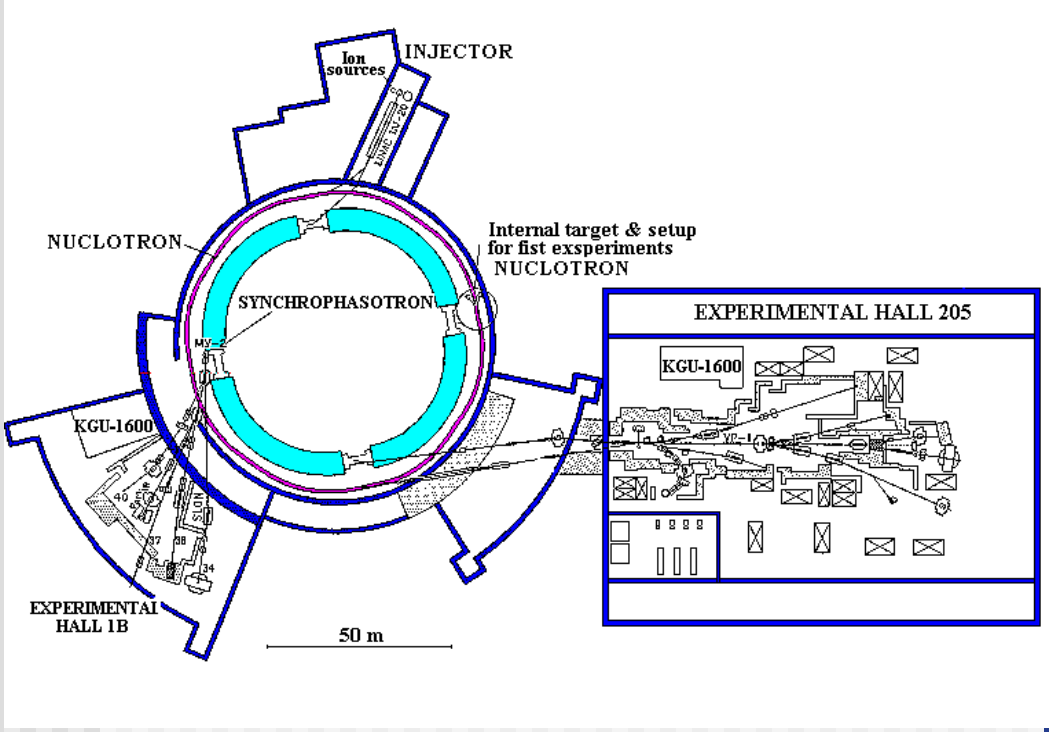
Introduction

Nuclear beams of energy higher than 1 A GeV are recognized as a modern tool used for the study of the structure of atomic nuclei*. Among the variety of nuclear interactions the peripheral dissociation beams a uniquely complete information about the excited states above particle decay thresholds. The peripheral dissociation is revealed as a narrow jet of relativistic fragments the summary charge of which is close to the charge of the primary nucleus. In spite of the relativistic velocity of motion the internal velocities in the jet are non-relativistic.

***T. Aumann, Eur. Phys. J. A, 26, 441(2005).**

BEryllium (Boron) Clustering QUEst in RELativistic Multifragmentation

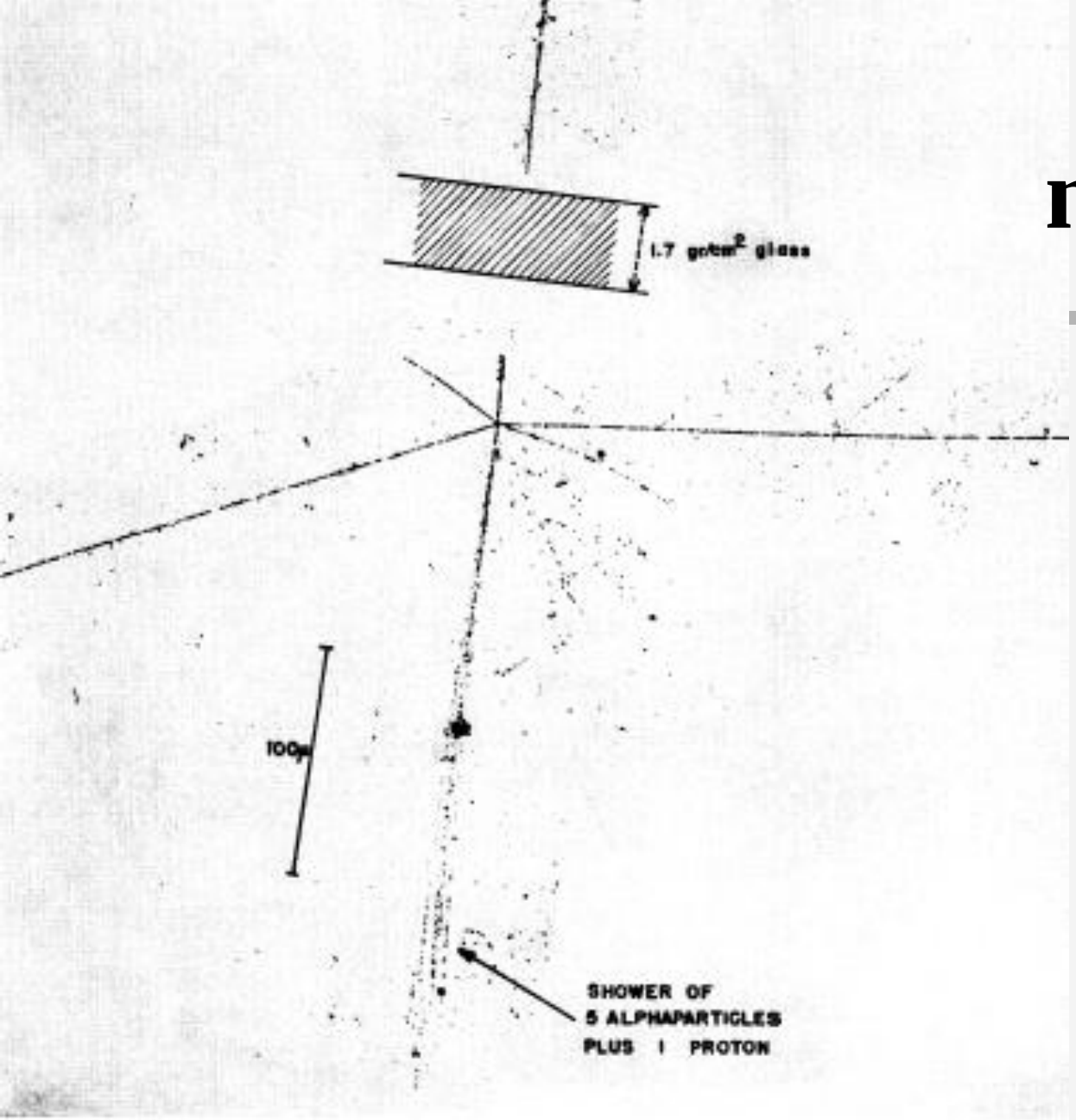
The fragmentation of a large variety of light nuclei was investigated using the emulsions exposed to few A GeV nuclear beams at JINR Nuclotron.



	INTENSITY (Particles per cycle)	
BEAM	**YEAR 2002**	**YEAR 2003**
p	$3 \cdot 10^{10}$	$1 \cdot 10^{11}$
d	$5 \cdot 10^{10}$	$5 \cdot 10^{10}$
^{4}He	$8 \cdot 10^{8}$	$3 \cdot 10^{9}$
^{7}Li	$8 \cdot 10^{8}$	$1 \cdot 10^{9}$
^{10}B	$2.3 \cdot 10^{7}$	$2 \cdot 10^{8}$
^{12}C	$1 \cdot 10^{9}$	$2 \cdot 10^{9}$
^{14}N	-	$1 \cdot 10^{7}$
^{16}O	$5 \cdot 10^{8}$	$7 \cdot 10^{8}$
^{24}Mg	$2 \cdot 10^{7}$	$1 \cdot 10^{8}$
^{40}Ar	$\sim 1 \cdot 10^{6}$	$3 \cdot 10^{7}$
^{56}Fe	-	$1.2 \cdot 10^{6}$
^{84}Kr	$\sim 1 \cdot 10^{3}$	-
^{131}Xe	-	-

http://nucloserv.jinr.ru

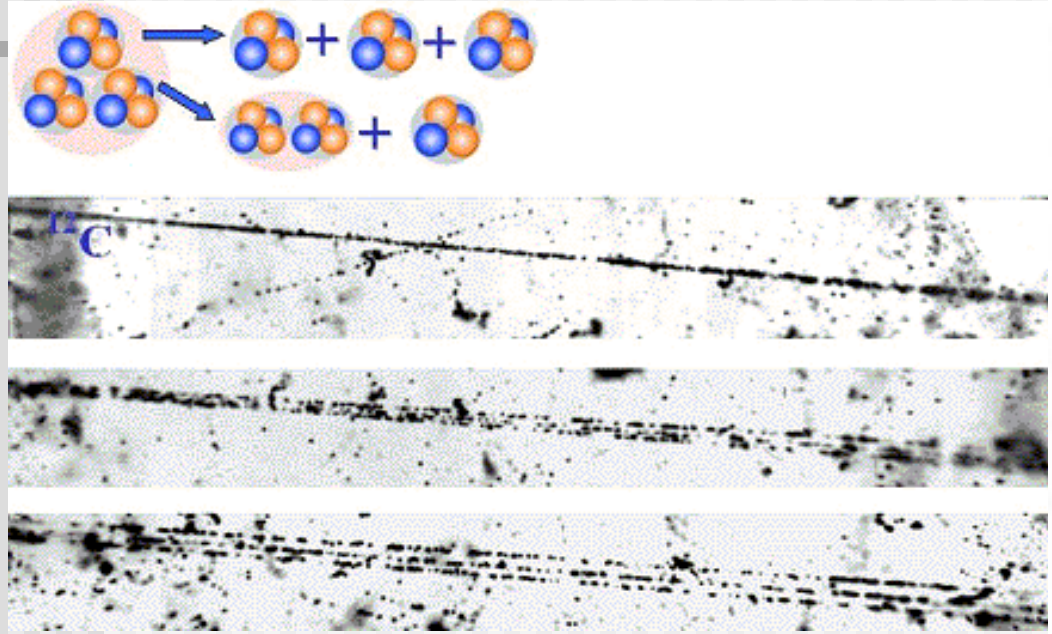
Collision of a nucleus of the Mg-Si group (Z~12-14)*

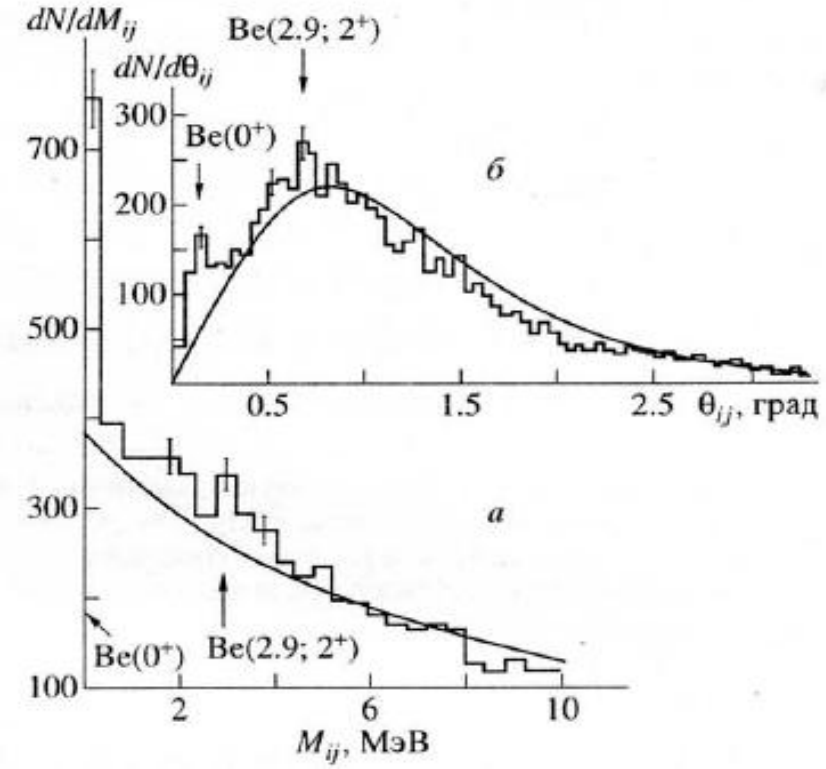


*H.L. Bradt and B. Peters, Phys. Rev. 77 (1950).

The $^{12}C \rightarrow 3\alpha$ and $^{16}O \rightarrow 4\alpha$ fragmentation at the energy of 3.65 A GeV was studied at JINR Synchrophasotron* .

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

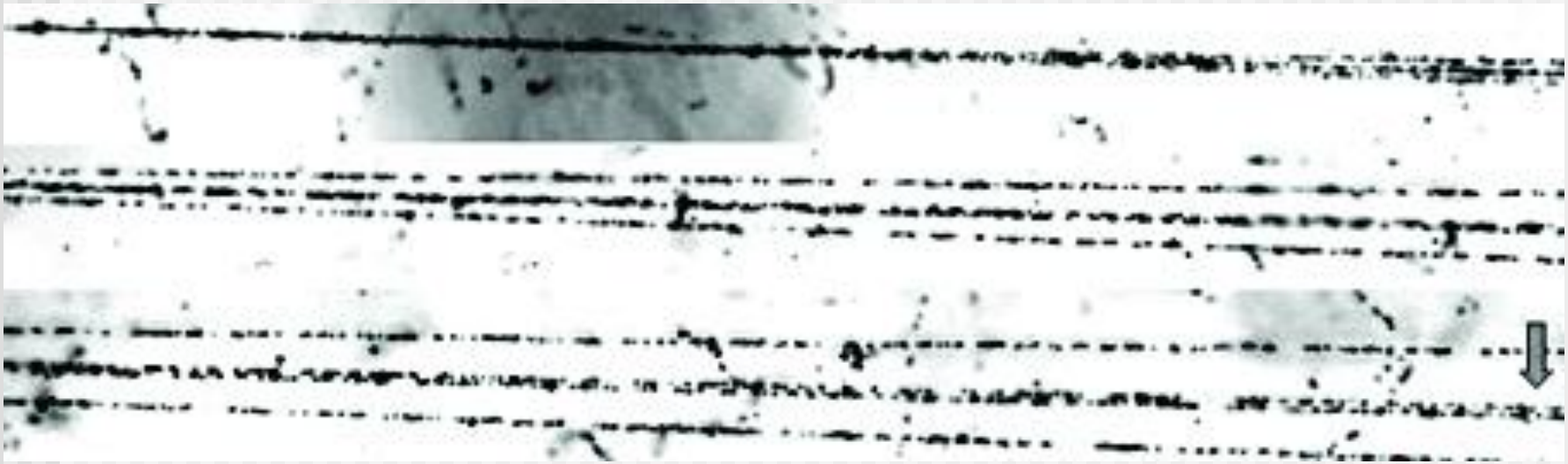




*V.V. Belaga et al., Phys. At. Nucl., vol. 58 (1995).

The $^{16}O \rightarrow 4\alpha$ fragmentation were investigated using a large amount of information (641 events). An analysis of the angular correlations gave evidence that the angular momentum was transferred to the systems of fragments and that the cascade decays via ^{8}Be and ^{12}C nuclei were nonessential*.

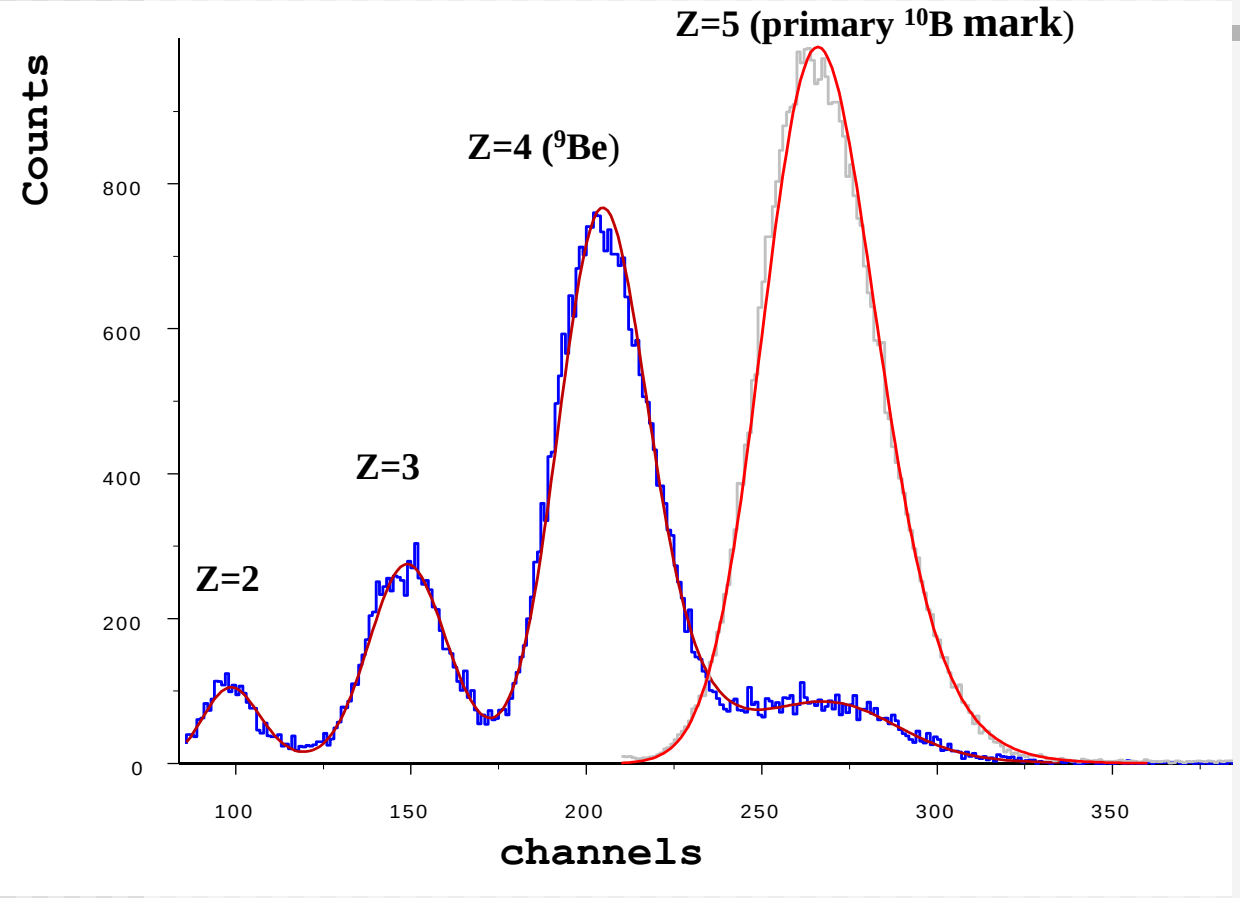
$^{16}O \rightarrow 4\alpha$, 3.65 A GeV (PAVICOM image)



*F.A. Avetyan et al., Phys. At. Nucl., vol. 59 (1996).

Fragmentation of relativistic ^{9}Be nuclei at 1.2 A GeV

The beam of relativistic ^{9}Be nuclei was obtained in the ^{10}B→^{9}Be fragmentation reaction with polyethylene target (JINR Nuclotron).

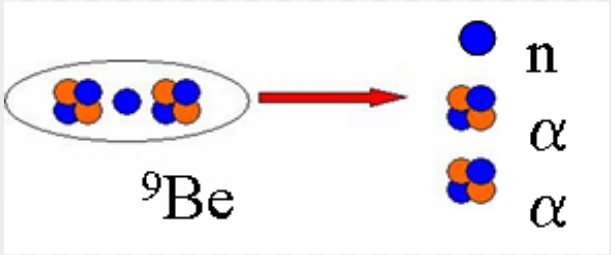


^{9}Be fraction in the beam:
67 2 %*

Found: 362 events of ^{9}Be →2α fragmentation

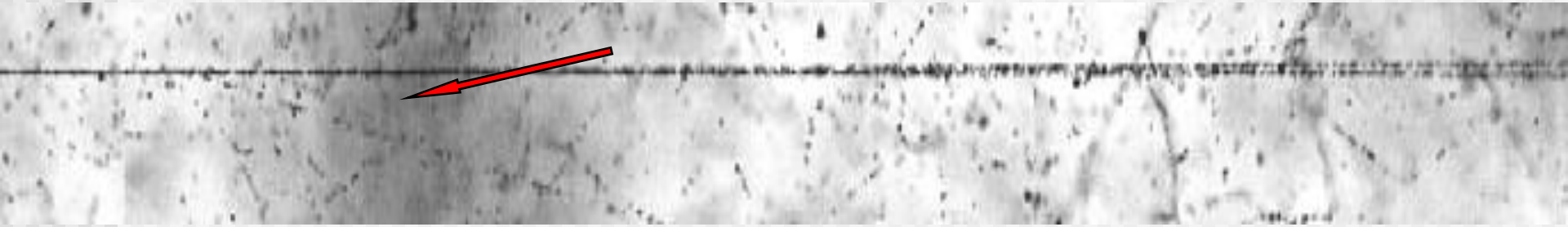
Angular measurements accuracy not worse then 4.4×10^{-3} rad.

***P. A. Rukoyatkin et al., Czech. J. Phys. 56, 379 (2006).**

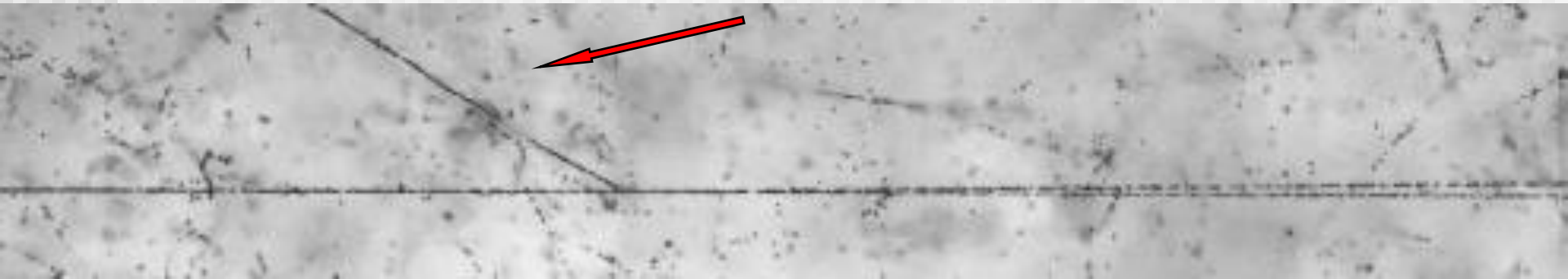


“white” stars

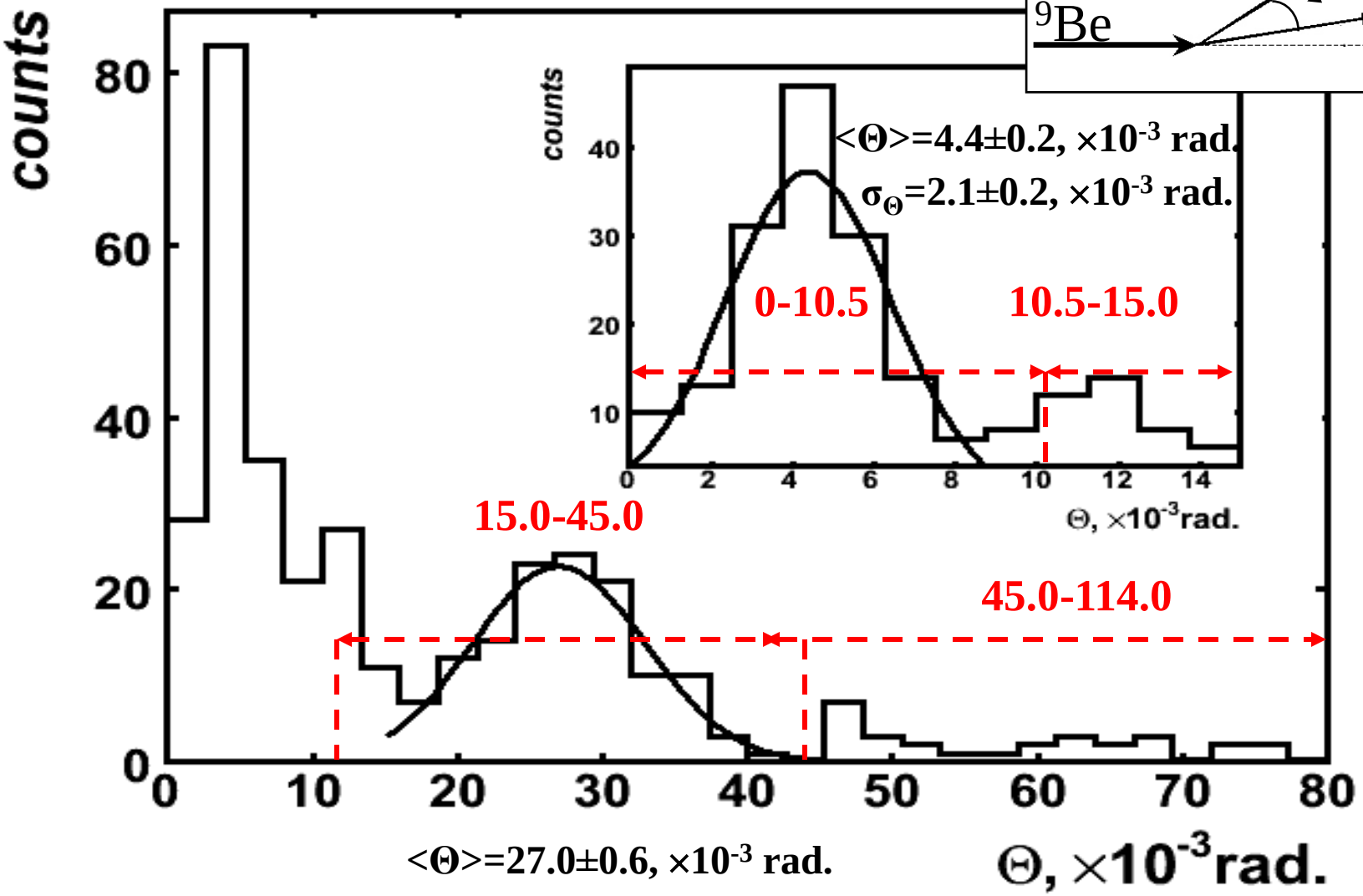
stars with target proton recoil (g-particle)



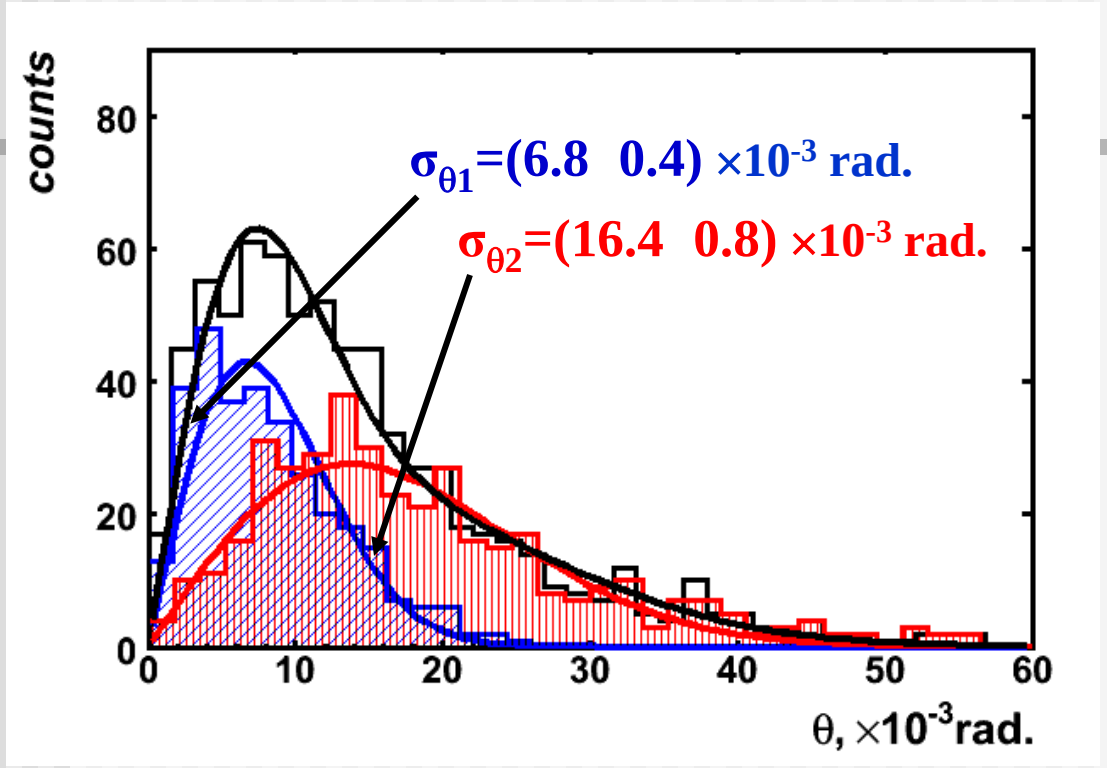
stars with heavy fragment of target nucleus (b-particle)

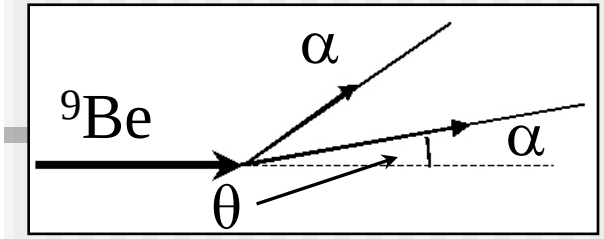


Opening angle Θ between two α fragments for $^{9}Be \rightarrow 2\alpha$



Polar angles θ of α fragments for $^{9}Be \rightarrow 2\alpha$



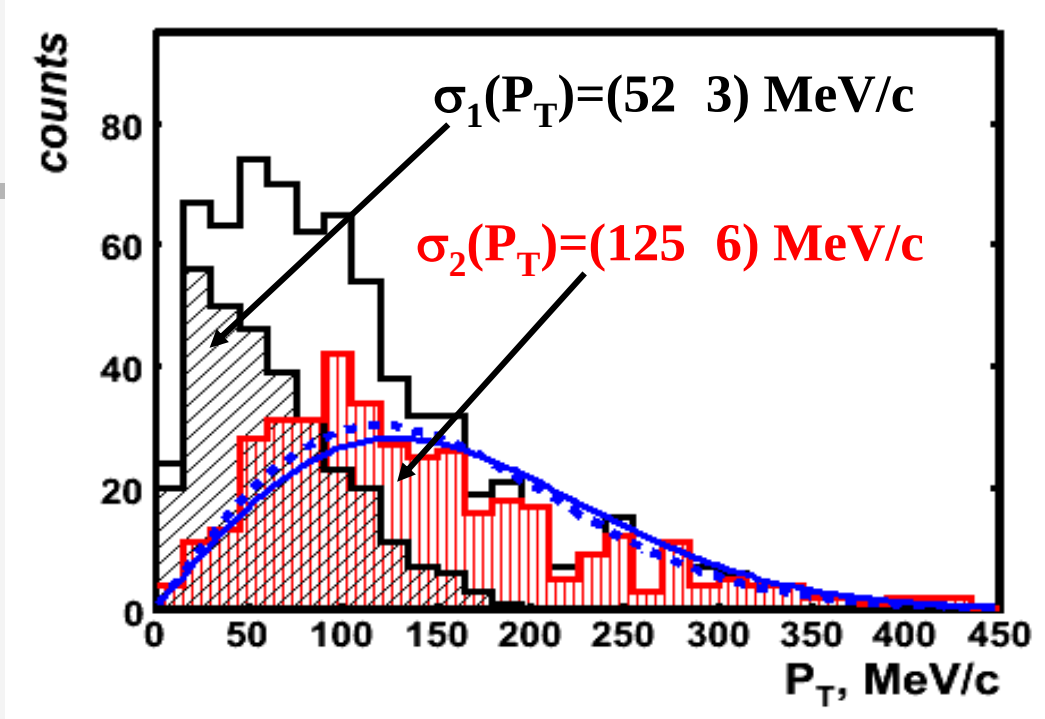


$$f(\theta) = \frac{\theta}{\sigma^2} \exp\left(\frac{-\theta^2}{2\sigma^2}\right)$$

$$\sigma^2 = \frac{\sum_{i=1}^{N} \theta_i^2}{2N}$$

events with opening angles Θ ∈ (0, 10.5) ×10^{-3} rad.;
events with opening angles Θ ∈ (10.5, 114.0) ×10^{-3} rad.

Transverse momentum P_T of α particles for $^9Be \rightarrow 2\alpha$



$$P_T = p_0 \cdot A \cdot \sin(\theta)$$

$$* \sigma_F^2 = \sigma_0^2 \frac{A_F (A_0 - A_F)}{A_0 - 1}$$

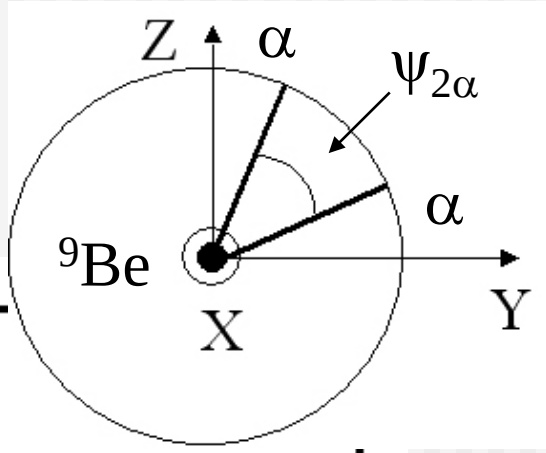
**for ^{9}Be σ_0=81.4 MeV/c

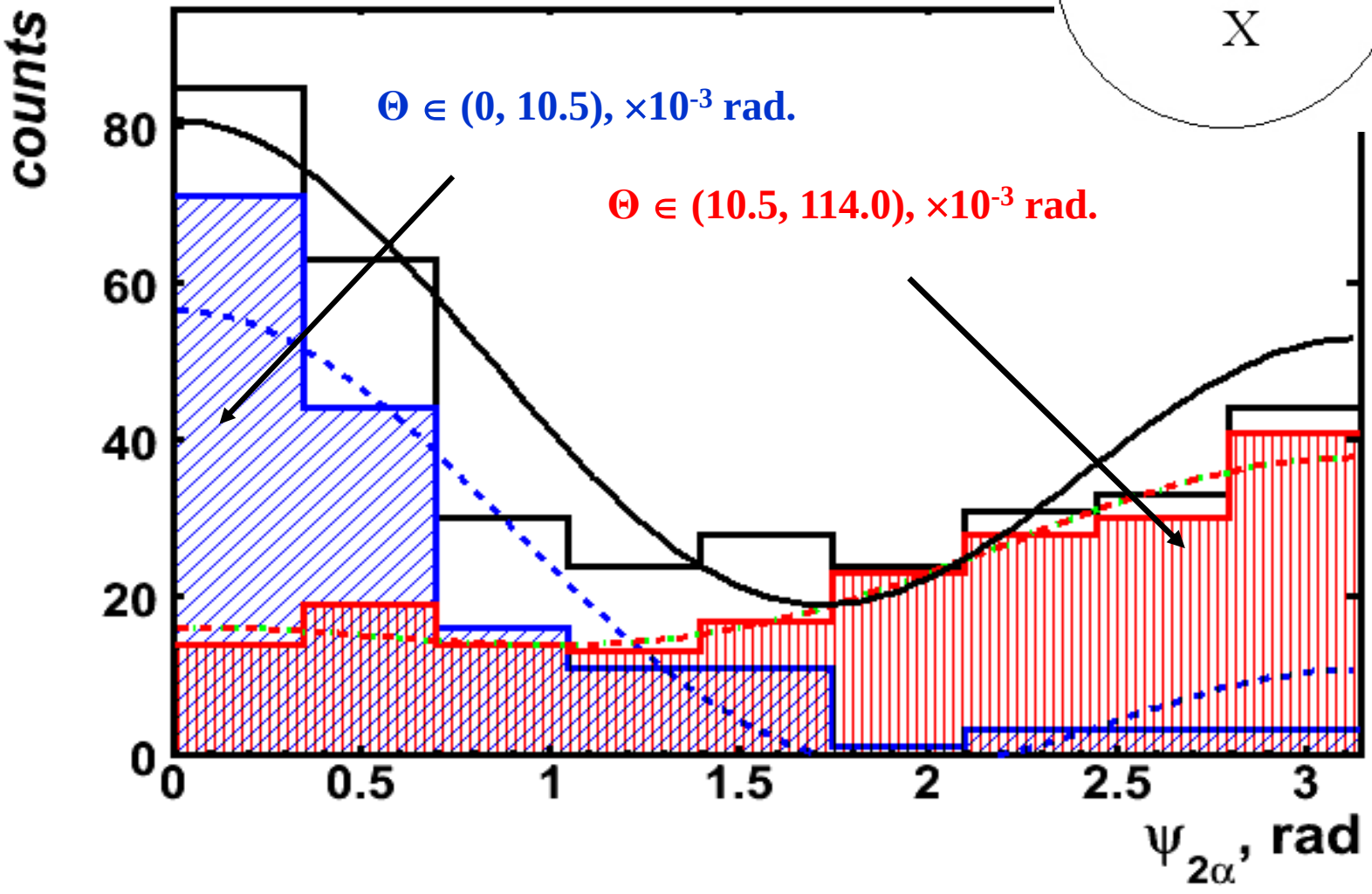
- solid curve - emitting α particles from ^{9}Be
- dash curve - emitting α particles from ^{8}Be in 2^+state

*A.S. Goldhaber, «Statistical models of fragmentation processes», Physics Letters 53B (1974)

**F.G. Lepekhin et al., Phys. At. Nucl., 68 (2005)

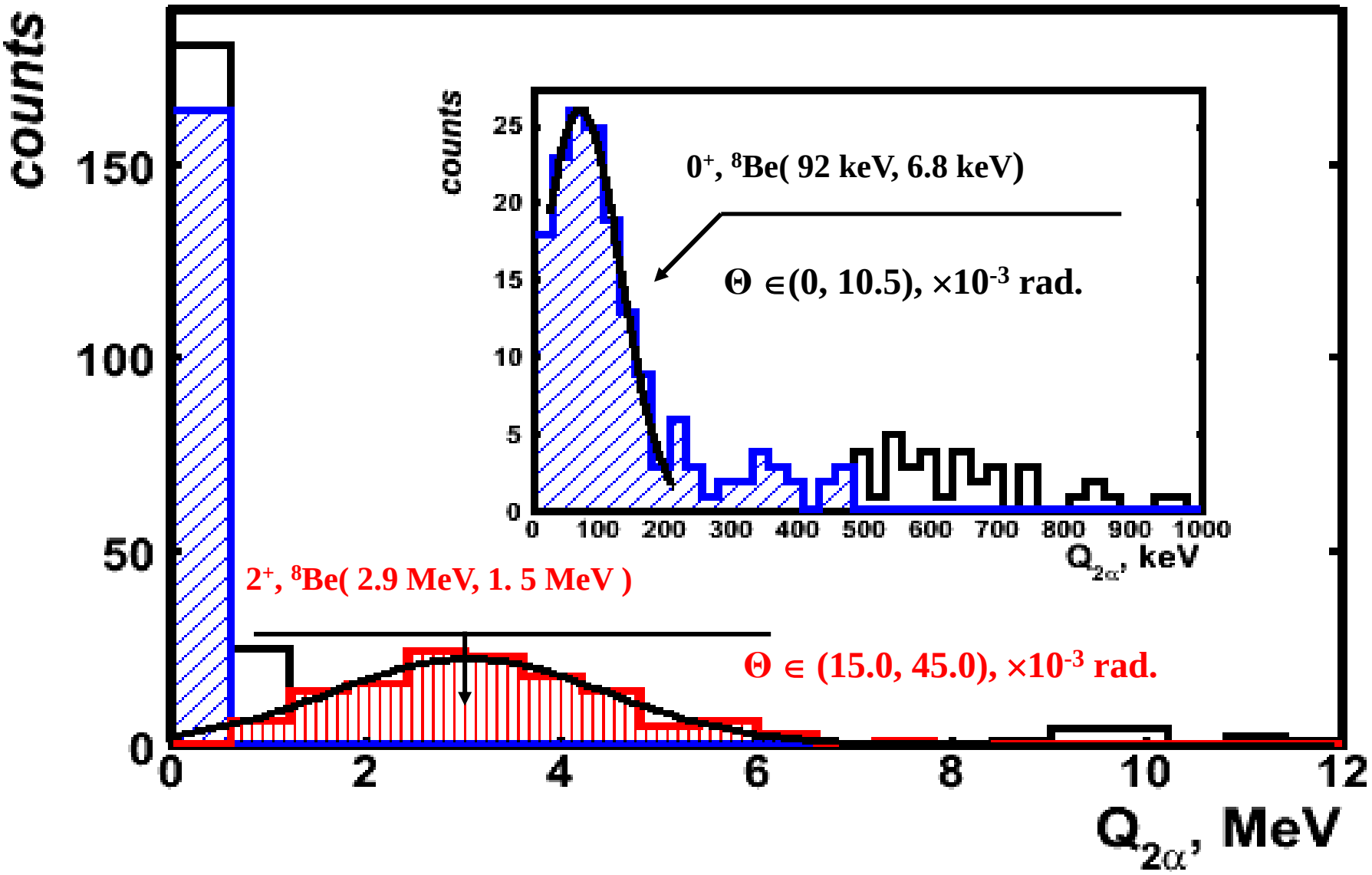
Azimuthal angle $\psi_{2\alpha}$ of α pairs for $^{9}Be \rightarrow 2\alpha$





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

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



The results comparison of $^{9}Be \rightarrow 2\alpha$, $^{12}C \rightarrow 3\alpha$, $^{16}O \rightarrow 4\alpha$ fragmentation in nuclear track emulsion

Parameter	^{9}Be (BR-2), $^{9}Be \rightarrow 2\alpha$	^{12}C (BR-2), $^{12}C \rightarrow 3\alpha$	^{12}C (BR-2+Pb), $^{12}C \rightarrow 3\alpha$	^{16}O (BR-2), $^{16}O \rightarrow 4\alpha$
number of events	362	44	72	641
$\left\langle P_T^2 \right\rangle^{1/2}$, MeVc	148 6 74 4, Θ∈(0,10.5) mrad., 156 9, Θ∈(15.0,45.0) mrad., 177 8, Θ∈(10.5, 114.0) mrad.	192 10	161 6	167 4
$\left\langle P^{*2}_T \right\rangle^{1/2}$, MeV/c	98 4 20 2, Θ∈(0,10.5) mrad., 105 9, Θ∈(15.0,45.0) mrad., 130 9, Θ∈(10.5, 114.0) mrad.	141 7	130 8	145 3
kT, MeV	2.6 ≈0.11, Θ∈(0,10.5) mrad., 3.0, Θ∈(15.0, 45.0) mrad., 4.5, Θ∈(10.5, 114.0) mrad.	4.0	3.4	3.7

$$^{*}kT = \frac{A \cdot \left\langle P_T^{*2} \right\rangle}{2 \cdot A_F \left(A - A_F\right) \cdot m_N}$$

*F.A. Avetyan, et al., Phys. At. Nucl. 59 (1996)

The target dependence of $^{9}Be \rightarrow 2\alpha$ fragmentation

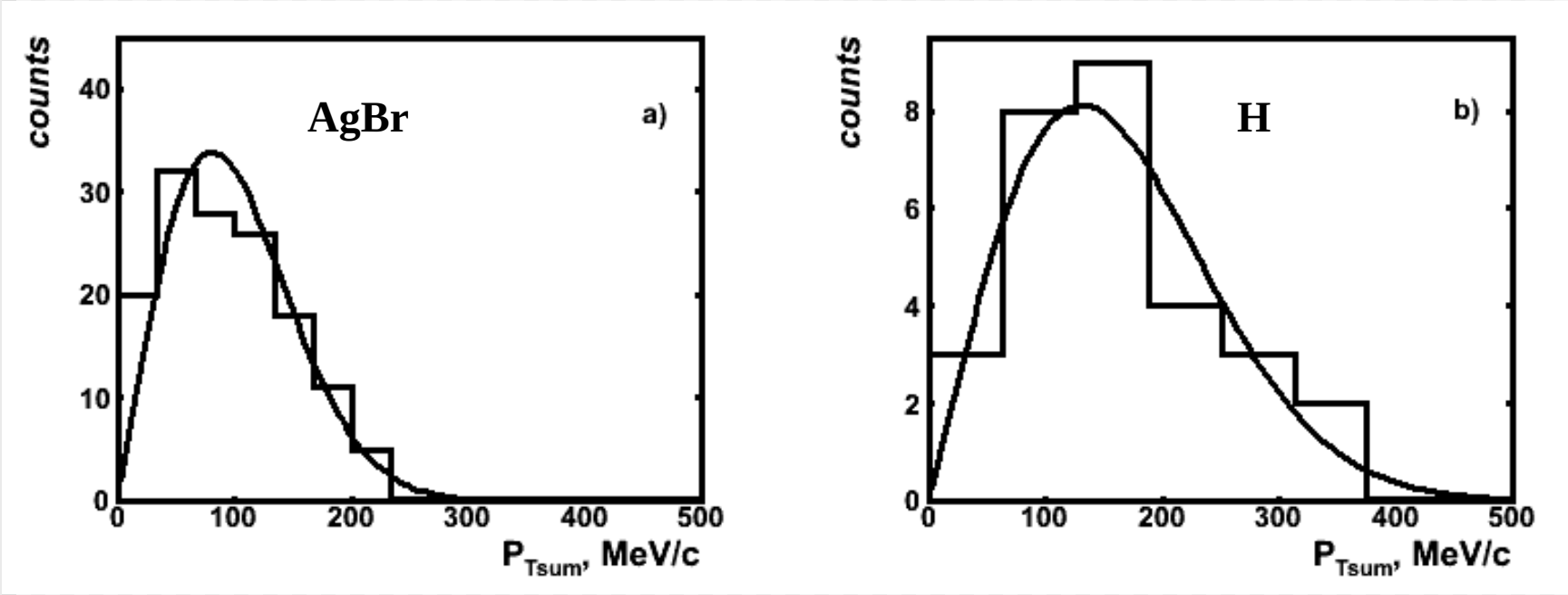
AgBr H CNO+AgBr

$n_g=0$ $n_b=0$	$n_g=1$ $n_b=0$	$n_g=0$ $n_b=3$	$n_g=0$ $n_b=4$	$n_g=0$ $n_b=5$	$n_g=0$ $n_b=6$	$n_h>2$ (ng≠0)	…	Number of events
176	33	9	9	2	1	43	…	362

$$W_{ti} = \pi \cdot R_0^2 \cdot \left(A_t^{\frac{1}{3}} + A_i^{\frac{1}{3}} - 1.17 \right)^2, \; R_0 = 1.45 \;\; fm$$

Target nucleus	P, %	W (^{9}Be-Em), (BR-2), %
H	9 2	10.4
CNO+AgBr	91±7	89.6

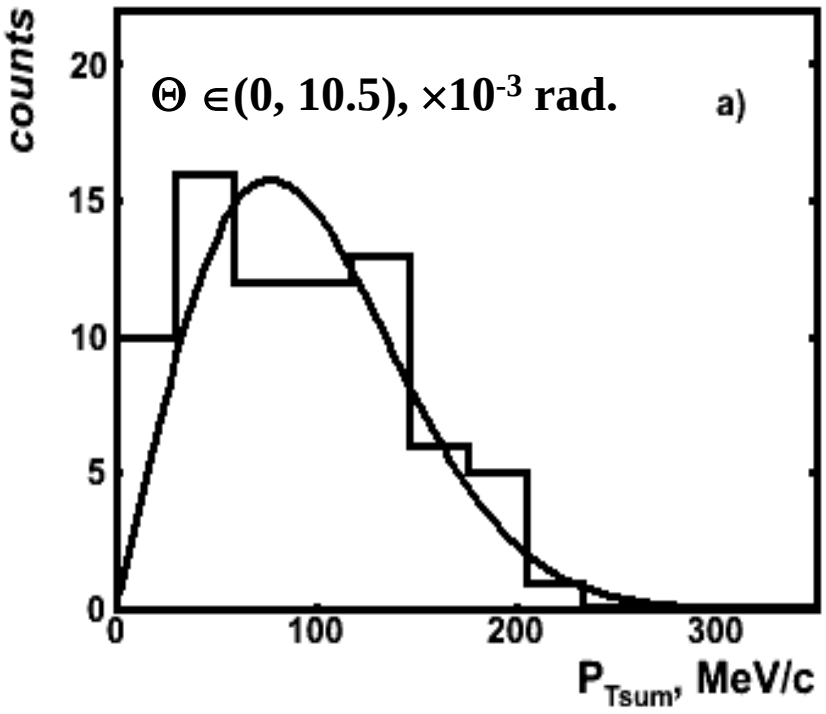
The total transverse momentum P_{Tsum} distribution of α pairs in $^{9}Be \rightarrow 2\alpha$, 1.2 A GeV for "white" stars - a), and interactions on protons -b)

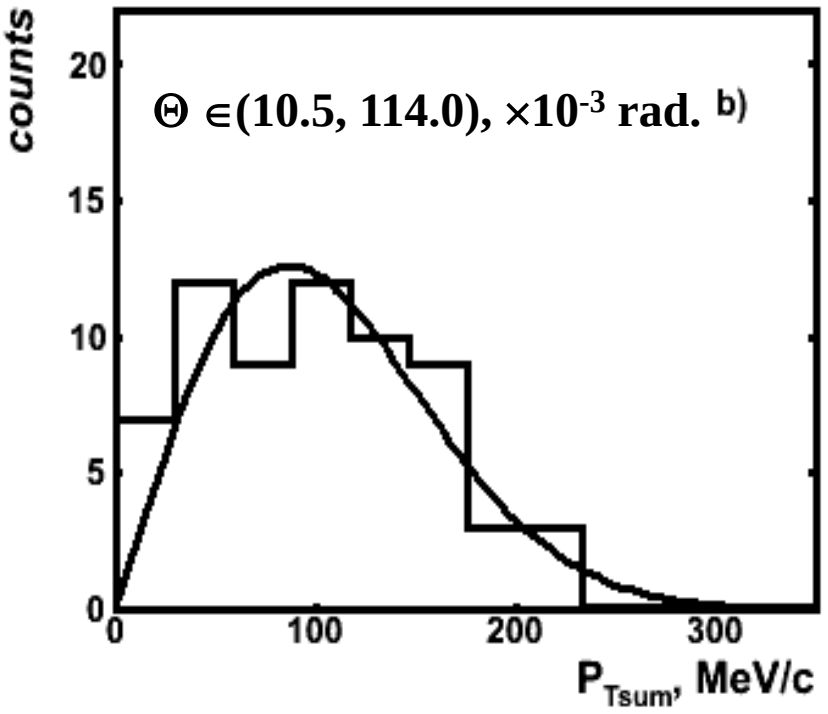


$\sigma_{AgBr}(P_{Tsum})=(77\pm7)$ MeV/c

$\sigma_{H}(P_{Tsum})=(126\pm23)$ MeV/c

The total transverse momentum P_{Tsum} distribution of α pairs for events on AgBr





$\sigma_{AgBr}(P_{Tsum})=(75\pm9)$ MeV/c

$\sigma_{AgBr}(P_{Tsum})=(80\pm10)$ MeV/c

Summary

1. In the first time the properties of ^{9}Be like 2α +n system is studied in peripheral fragmentation in nuclear track emulsion with relativistic energies, using the Nuclotron of JINR.
2. The results obtained in a large (for emulsion experiments) statistics – 362 events of ^{9}Be→2α peripheral fragmentation on H, CNO, AgBr. The achieved accuracy of angular measurements not worse then 4.4×10^{-3} rad.
3. In peripheral interactions the ^{9}Be nuclei are dissociated practically totally through the 0^{+} and 2^{+} states of the ^{8}Be nucleus.
4. For events from H and AgBr groups was found the tendency, when the target mass number A_t decrease the total transverse momentum P_{Tsum} of α pairs increase.
5. The data obtained from ^{9}Be investigation can be employed for the estimation of the ^{8}Be role in more complicated Nα systems.

BECQUEREL project.index The program of irradiation of emulsions in Nuclotron's beams. - Microsoft Internet Explorer

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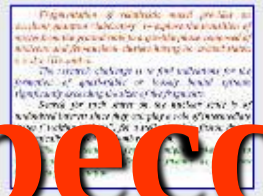



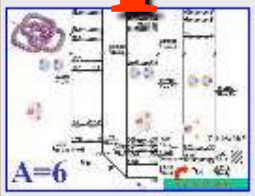



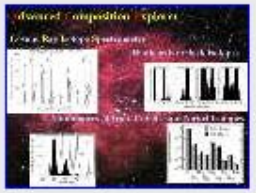
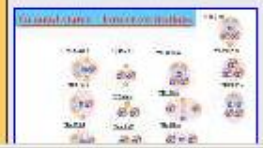



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