Coherent Bremsstrahlung Beam at MAX-lab Facility

The MAX-Tagg Collaboration

**.Fissum[1], J.Brudvik[3], D. Burdeinyi[2], V.Ganenko[2], K.Hanse
L.Isaksson[1], K.Livingston[4], M.Lundin[3], V.Morochovskiy[2],
B.Nilsson[3], D.Pugachev, B.Schr¨oder[1], G.Vashchenko[2]**

[1] Department of Physics, Lund University, SE-221 00 Lund, Sweden

[2] Kharkov Institute of Physics and Technology, Kharkov 61108, Ukraine

[3] MAX-lab, Lund University, SE-221 00 Lund, Sweden

[4] Department of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, Scotland, UK

e work was supported by:

the European Community – Research Infrastructu
Action under the FP6 "Structuring the Europe
Research Area" Programme (through the Integrat
Infrastructure Initiative "Hadron Physics")

**EUROTAG project – (*spokesperso*
K.Livingstone, Glasgow)**

the Swedish research organization and funds:

- **the Swedish Research Council,**
- **the Craaford Foundation,**
- **the Wennergren Foundation,**
- **the Royal Physiographic Society in Lund and the Kn
and Alice Wallenberg Foundation**

**STCU project 3239 (*spokesperson V.Ganenk*
Kharkov)**

Some History

rstly the Coherent Bremsstrahlung (CB) be
as produced in Frascati by Diambrini a
oworkers about **50 years ago (1960).**

nce that time the Coherent Bremsstrahlung bea
ere created practically on all electron accelerat
ith energies E_0~>1GeV (**SLAC, Erev**
harkov, Tomsk, Tokyo) and widely used
olarized photonuclear investigations.

t present the CB beams are successfully used
hotonuclear experiments at **Mainz, Bonn, Jlab.**

rincipal possibility to produce the CB beam
hotonuclear researches at MAX-lab was appea
ue to modernization of the MAX-lab facility
creasing maximal energy of the electron beam
E_0~200-250 MeV.

alculations of the **CB** beam expected parame
r MAX-lab conditions have been produced in
000-2001 years ***(J-O.Adler, V.Ganenko,***
Lindgren, Report 01/01 LUNF
NFFR-3086)1-31/2001, Lund 2001)

he proposition was supported by Prog
dvisory Committee of the MAX-lab in the **2**
OI-15 for NP-experiments at MAX-
B.Ganenko et al. A coherent bremsstrahl
am at the MAX-lab facility. Lund, May 30-
002).

hen it was required ***5 years*** in order that to prod
ecessary equipment and develop experimental meth
r the project realization.

007 of September - the first test experiment on
B beam production. It was performed:

-the goniometer placing on the beam line
reliminary adjustment;

-the crystals orientation;

-preliminary CB spectra measurements.

008 of April - the second test experiment:

-checking of the crystals orientation;

-the CB spectra measurements in more wide ene
nge and orientations;

-measurements of the channeling radiation;

-test measurements of the deuteron disintegration
olarized photon at E_γ~50-60MeV.

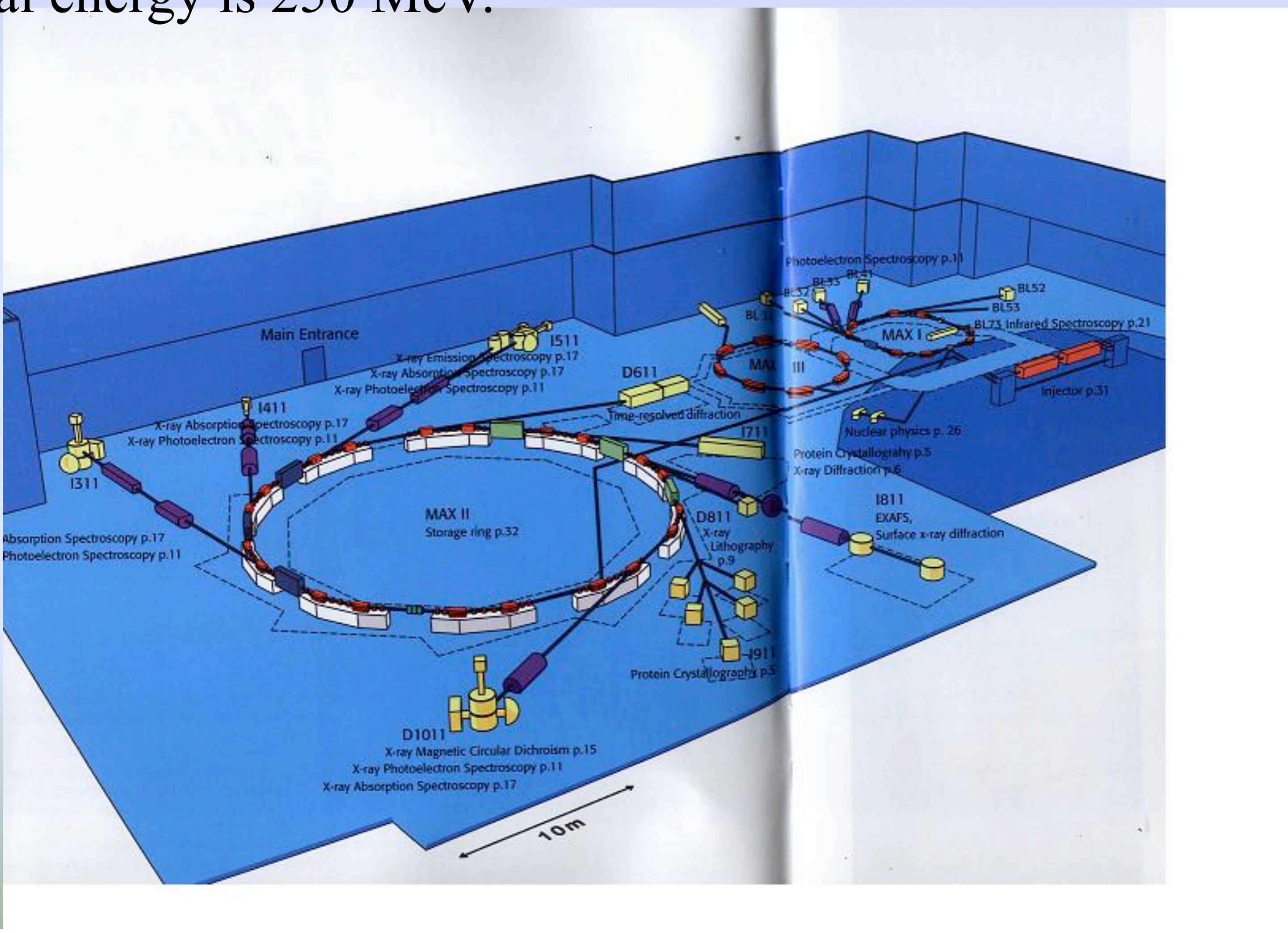
Production of the CB beam

The MAX-lab Facility

-lab is national laboratory of Sweden. It is center of synchro
tion investigations. There are three storage rings at present tim

- MAX-I - energy 550 MeV.
- MAX-II - energy 1.5 GeV.
- MAX-III - energy 700 MeV.

e is beam line for photonuclear researches. The beam comes
torage ring MAX-I, which in this case works as stretcher.
mal energy is 250 MeV.



xpected CB beam parameters at MAX-la

Calculations of the expected CB parameters have made for expected MAX-lab electron beam parameter

-in 2001 (old code);

-repeated in the 2004-2007 years using the developed by Peter Grabmayr.

J-O.Adler, V.Ganenko, L-J.Lindgren. *Report 01/01 LUN (NFFR-3086)1-31/2001, Lund 2001*

V.Ganenko, G.Vashchenko, D.Burdeinii. *The expected pola photon beam paramermeters at MAX_lab facility // MA Activity Report 2005-2006, p.454*

V.Ganenko, G.Vashchenko, D.Burdeinii. *The linearly pola photon beams for photonuclear investigatyions a low e faciliries // Journal of Kharkov University, No.781, 2007.Pl series "Nuclei, Particles, Fields", issue 3/35/, p.88-92.*

Calculations have shown that it is possible to get a bea the polarized photons in the range E_γ~20-100 MeV use:

-diamond crystal;

-electron beam with energy of E_0~200-250 MeV;

-collimation of the radiation in the angle θ_c~(1-0 ($\theta_\gamma = mc^2/E_0$)

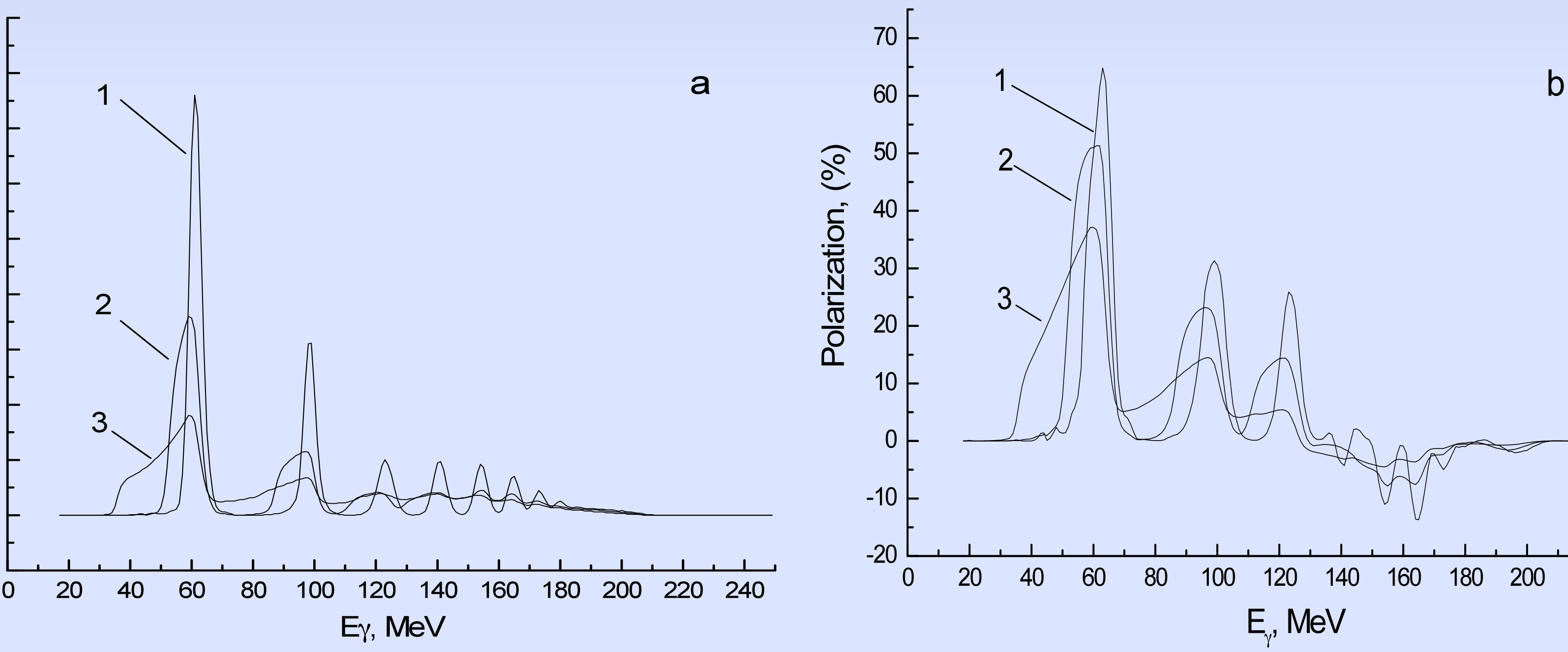
ere it is shown calculated spectra of the CB intensity larization for electron energy E_0=250 MeV and se llimation angles θ_c (in θ_γ units).

e intensity is presented as ratio

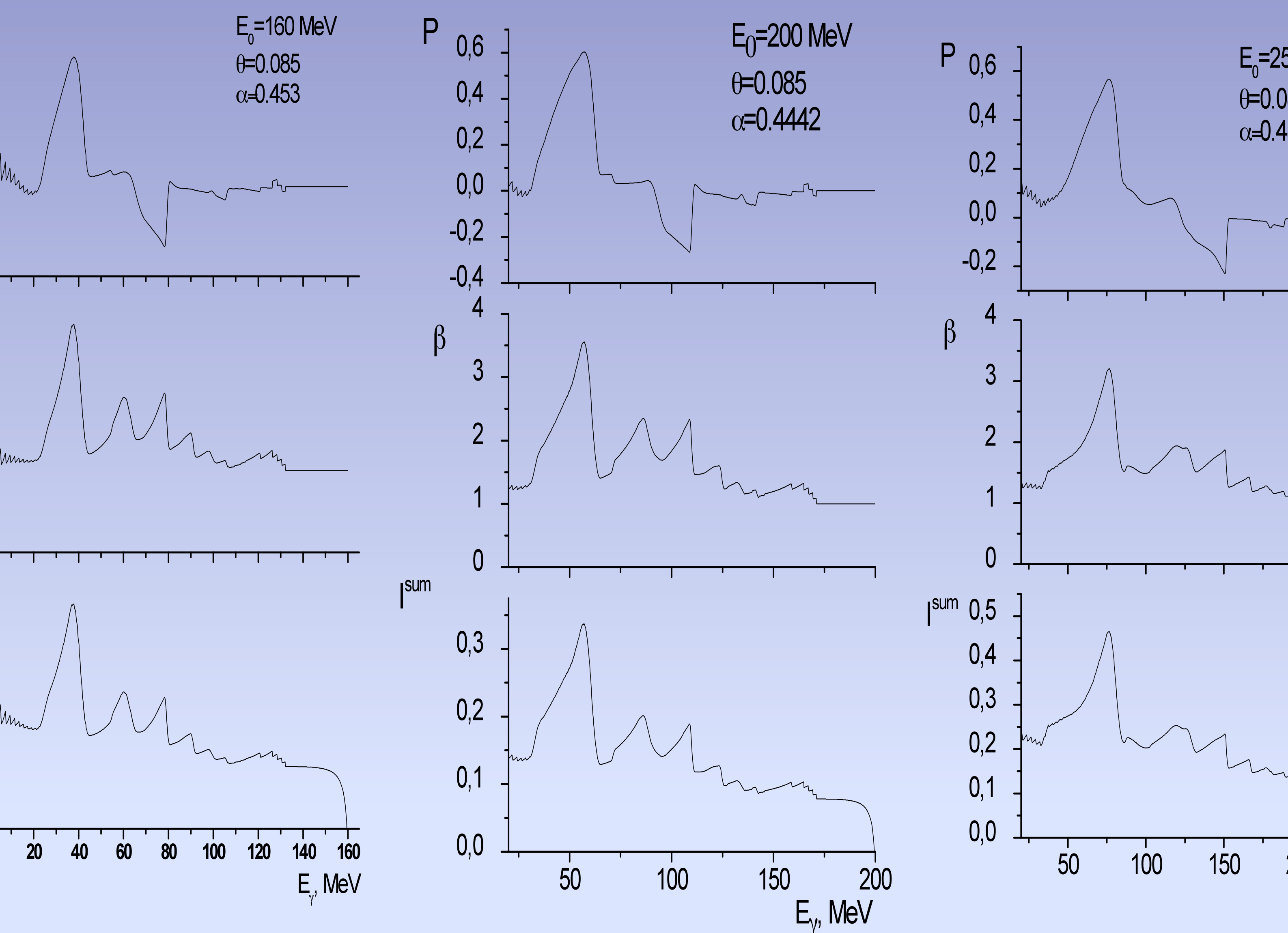
$$\beta=(I_{coh}+I_{in})/I_{in}$$

$_h(I_{in})$ is intensity of the coherent (incoherent) part of the C

ne can see, that intensity and polarization in the aximum are high enough (β_{max}~2…4.5 and $P_{\gamma,max}$~3 %) for the collimation angles in the interval 25-1)θ_γ.



. Intensity (a) and polarization (b) of the CB of electron ond crystal L=0.1mm thick. E_0=250 MeV, $E_{\gamma,p}$=60MeV, nation angles θ_c/θ_γ=0.25(1), 0.5(2), 1(3).



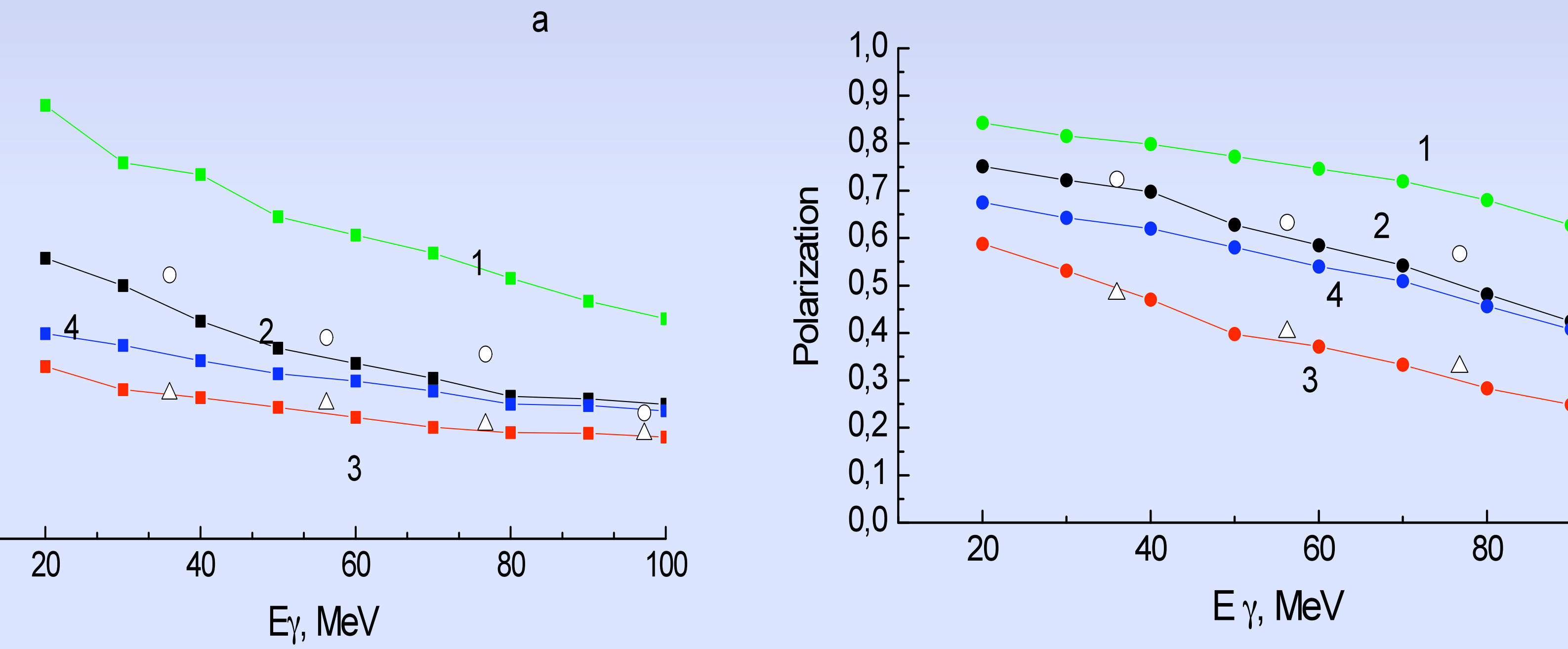
2. Polarization, coherent effect and intensity of the CB
tron energies E_0=160 MэB (collimation θ_c~0.310θ_γ), 200 M
0.360θ_γ) u 250 MэB (θ_c~0.450θ_γ). Diamond is 0.1 mm thick.

se calculations have been made with the code develo
P. Grabmayr with colleagues. In this code
erimental factors were taken into account m
urately. The calculations in a whole confirmed the res
ne previous calculations.

e values of the CB beam parameters at which the beam is su nuclear physics experiments are: $\beta_{max} \geq 1.4$ and $P_{\gamma,max} \geq 20\%$

lculations have shown the energy ranges available periments:

E_0	$\theta_c \sim \theta_\gamma$	$\theta_c \sim 0.5\theta_\gamma$
150 MeV	up to 40 MeV	up to 60 M
200 MeV	up to 60 MeV	up to 80 M
250 MeV	up to 80 MeV	up to 100 M



. Dependence of the coherent effect (a) and polarization (b) i aximum vs. the CB peak energy for E_0=250MeV, diamond ness L=0.1mm.

$0.25\theta_\gamma$; 2-$\theta_c=0.5\theta_\gamma$; 3-$\theta_c=\theta_\gamma$; 4-$\theta_c=0.5\theta_\gamma$ L=0.3mm.

y circles - $\theta_c=0.46\theta_\gamma$, triangles - $\theta_c=0.91\theta_\gamma$.

Experimental set up

e electron beam for photonuclear research is extracted fro
rage ring MAX-I, which in this case works in a stretcher mode

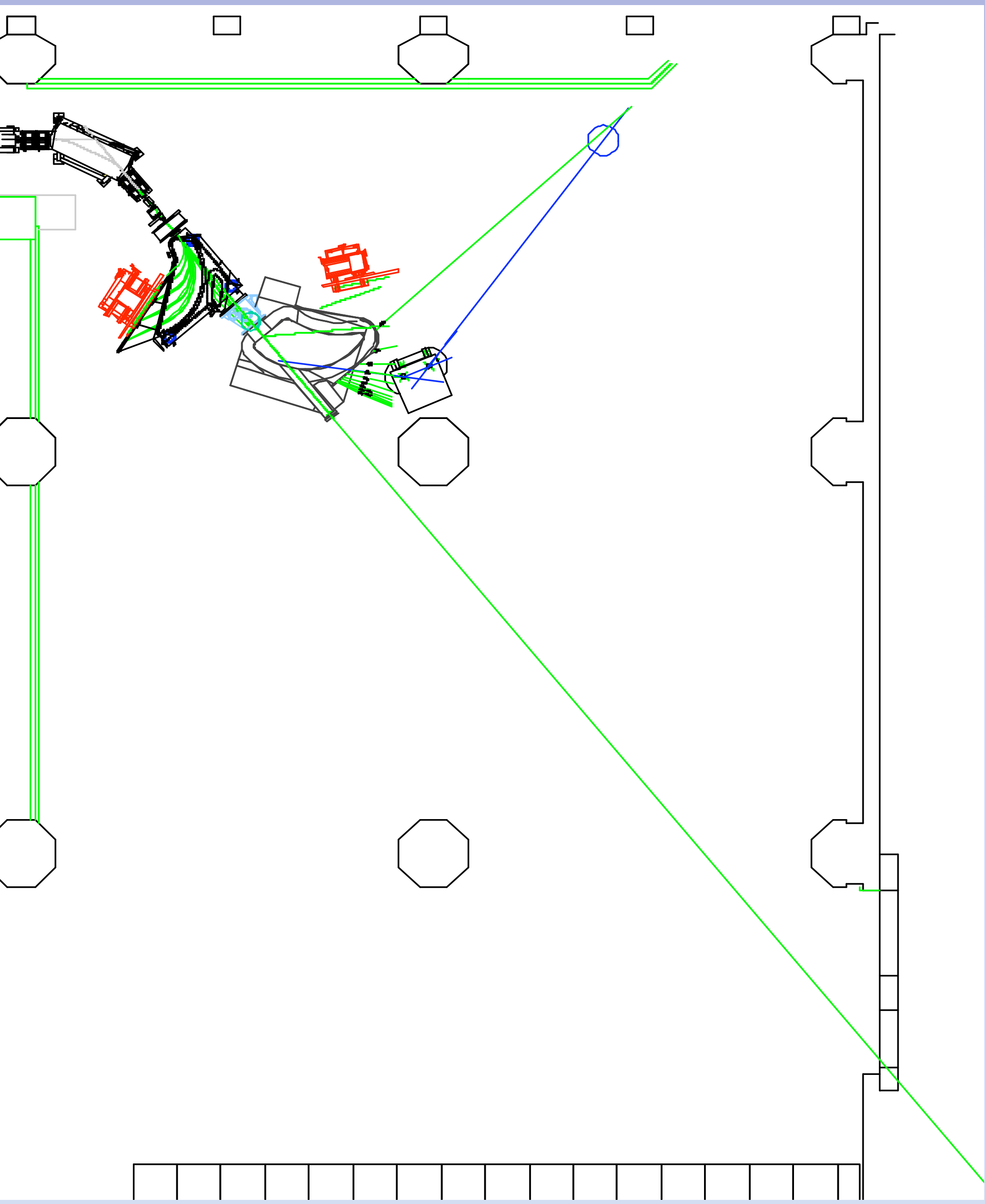


Fig.5. Scheme o
MAX-lab beam li
photonuclear
researhes.

The electron
comes into
experimental hal
directed to the c
fixed in the gonio
The goniometer
placed in a va
chamber betwee
magnets of the
(ET) and main
tagging systems.

passage of the photon radiators, the non-interacting part o
on beam is directed to the beam dump. The beam dump con
araday cup which measures the beam current.

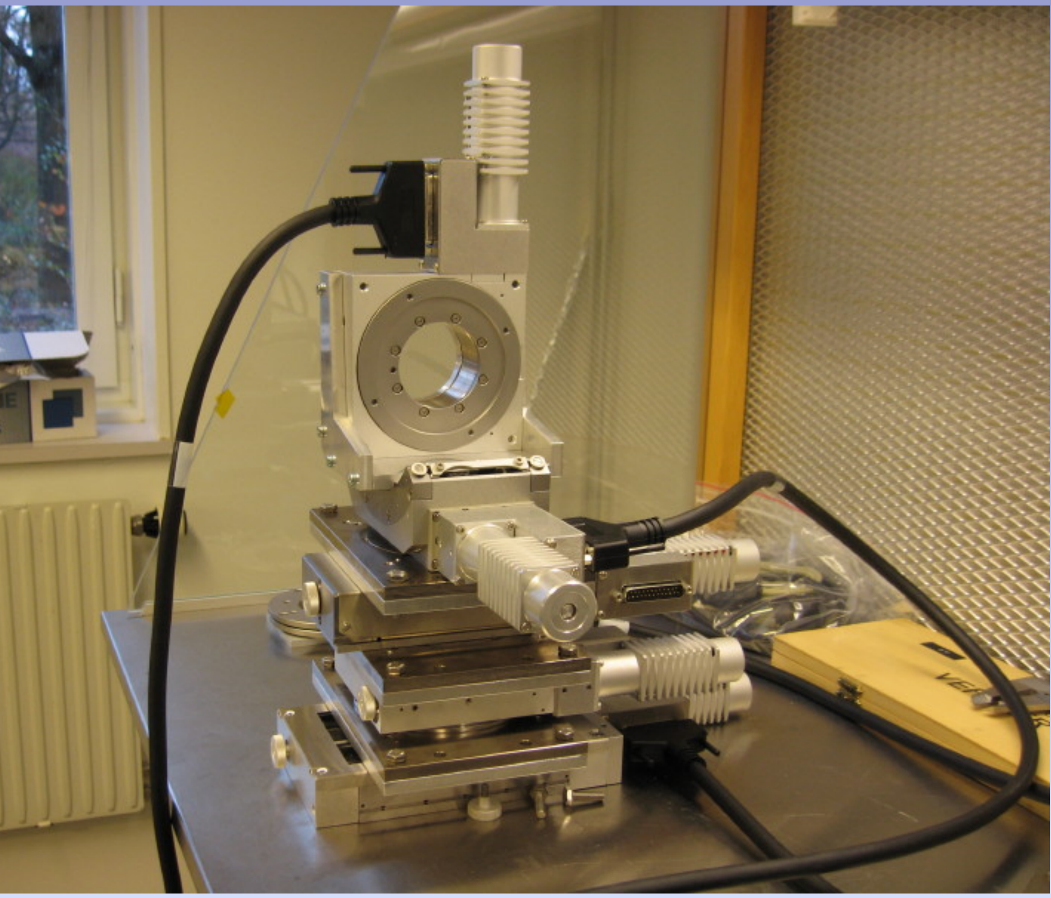
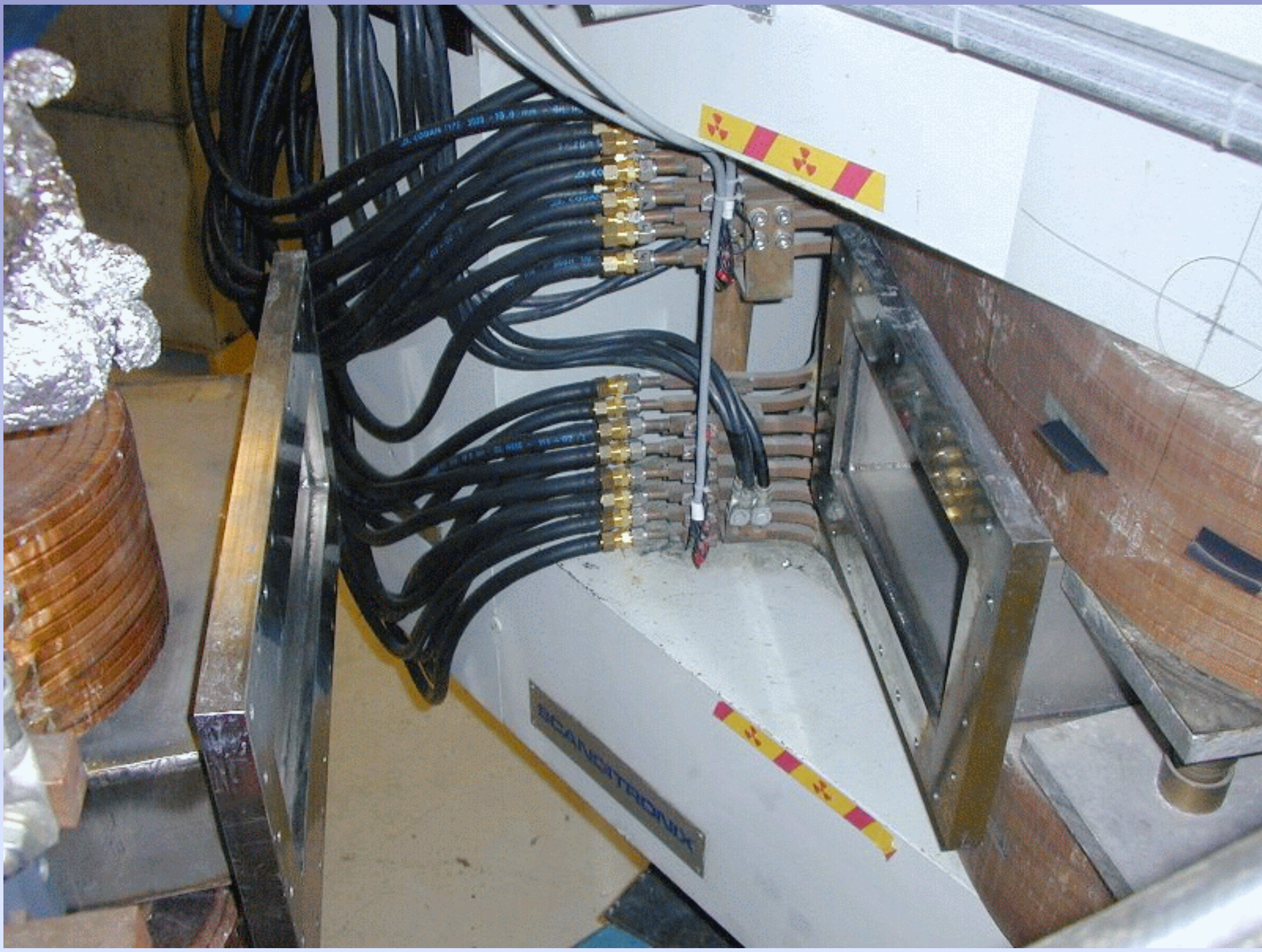


Fig.6. View of t
axes goniometer.
prototype the N
goniometer was us

goniometer consists of three rotation stages providing ntation of the crystal and two translation stages providin cal adjustment of the target and the movement perpendicular tron beam direction. Control of the goniometer is provide 4006 motion controller connected to RS-232 port of the PC.

e 2: Characteristics of the moving stages

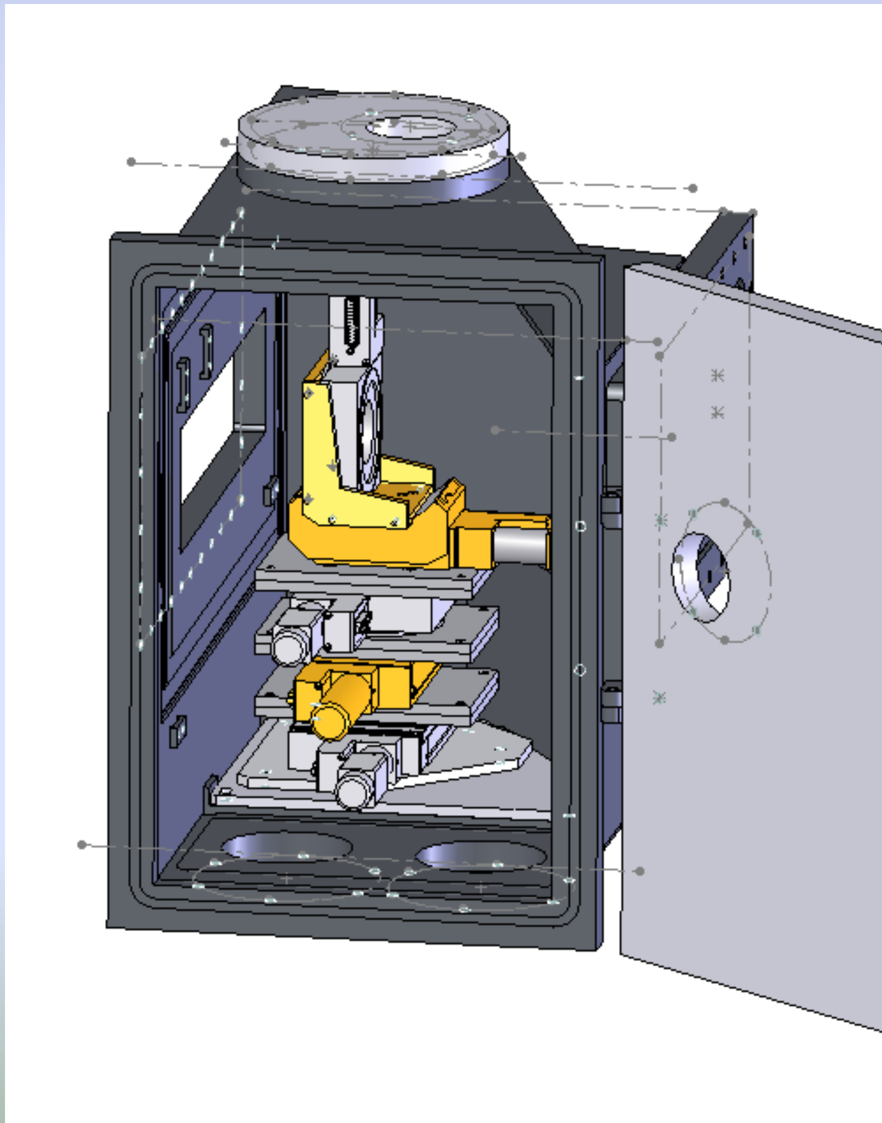
pe, M-	Travel Range	Unidirectional Repeatability	Hysteresis	Accuracy	Resolution
RM100APEV6	360°	0.003°	0.006°	0.023°(abs)	0.001°
GM80PEV6	±45°	0.004°	0.02°	0.05°	0.001°
ZM80PE.1V6	4 mm	0.2 µm	3 µm	4 µm	0.1 µm
TM50PE1V6	50 mm	1.5 µm	3 µm	5 µm	1 µm



. The goniometer was placed into vacuum chamber betwee
MT magnets. The place is not very suitable for this purpos
 the distance between flanges of these magnets is very s
m. Secondly, the yoke of the MT magnet hangs over the f
 magnetic chamber. These reasons result to complicate for
hamber, limit its sizes.

aft and working drawings were developed by Dm
achev (from MAX-lab) with participation the Kharkov gro
e chamber corps is made from (stainless) the not-magn
l. It is of itself an empty parallelepiped with two trunc
s that repeats lines of the MT magnet and has s
×526×677 mm.
e chamber was made in MAX-lab and placed on the beam l

. The model of the meter vacuum ber. It is shown the meter position in the ber.



Assembling of the goniometer on the beam line

otating goniometer target holder has five positions for radia

mond crystal (100 μm) was fixed at center of the hol

300 μm) crystal, Al radiator (50 μm), screen, empty slot

oned on the circumference of the target holder.

Crystal orientation

he procedure of the crystal initial orientation includes findin ngles of goniometer rotations, $\mathbf{\Phi_{v0}}$, $\mathbf{\Phi_{h0}}$, $\mathbf{\Phi_{a0}}$, along ve orizontal and azimuthal axes at which one of the crystal axes s directed along the axis of electron beam (along the impul lectrons $\mathbf{P_0}$), and the other two axes **b2** and **b3** are directed ne axes of goniometer rotations $\mathbf{f_v}$ and $\mathbf{f_h}$. The diamond was uch a way that axis <001> was perpendicular to the crystal pla

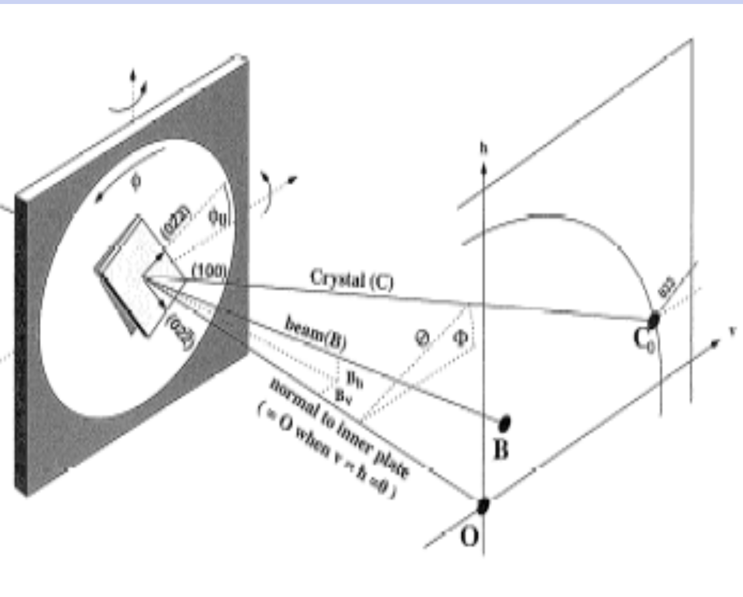
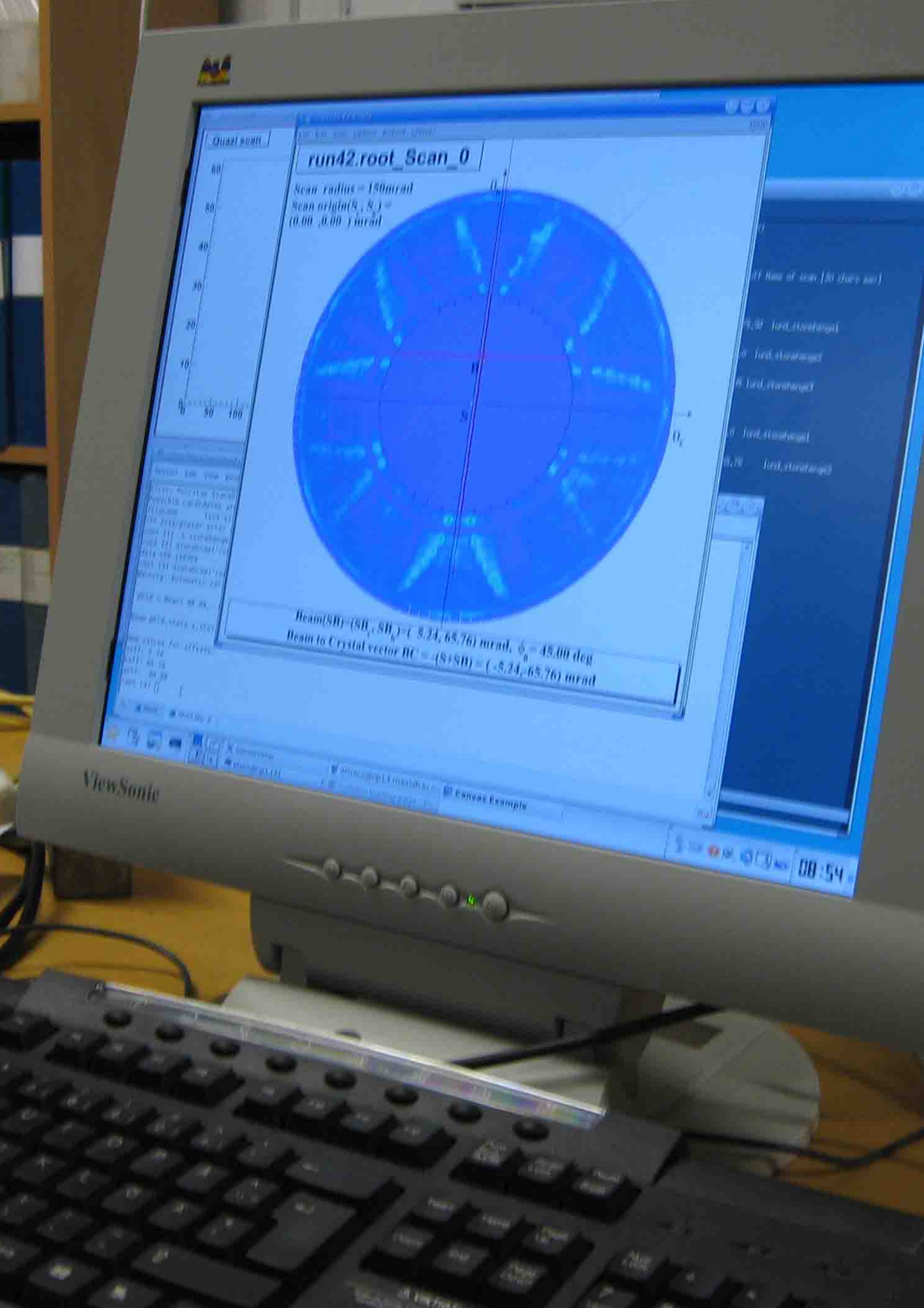


Fig. 9. Schematic of the goniometer and the definiti angles. Figure courtesy I Livingston (Summary of the period 04.14-04.30.2008.

wo methods were used at MAX-lab, based on measurements rientation dependence of gamma radiation intensity.

Stonehenge" technique (developed by Ken Livingst dapted for facilities with tagging systems. In this method it is ne orientation dependence of the gamma radiation intens zimuthal rotation which was registered with the tagger hodo n energy interval (~20…80 MeV).

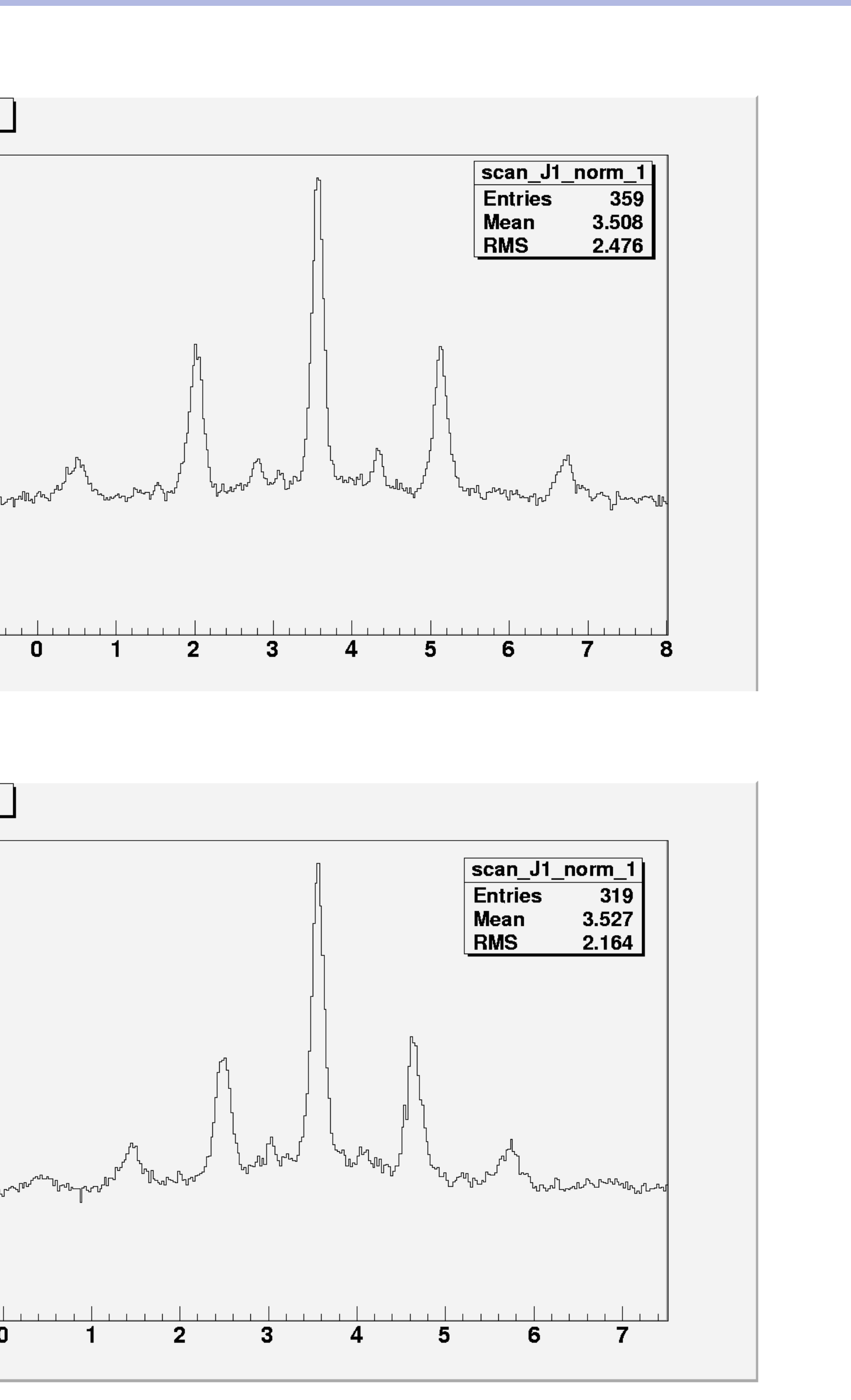

Quasi scan
run42.root_Scan_0
Scan radius = 150mrad
Canvas Example
08:54
ViewSonic

he second method was traditional. It imp
easurement of orientation dependence of
tal photon flux with any photon be
onitor (e.g. ionization chamber
uantometer).

n the MAX-lab experiments the scintillat
amma monitor was applied in front
hich a 2-6 mm thick metal converter
aced for increasing the secondary char
article yield.

he monitor worked in counting rate mo
he particle yield was normalized to
ectron beam current measured with
araday cup.

e measurements of gamma radiation intensity are ca
rotating the crystal round one of the axis (for exar
and for some fixed angles of horizontal rotation (**Φ_v**).



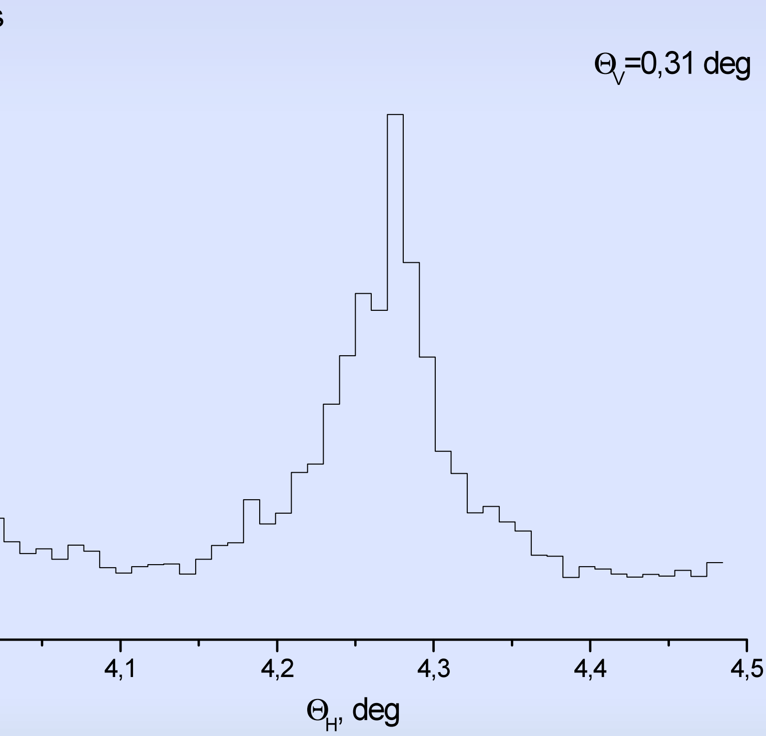
One can see the max central, correspondin strong plane (022), la peaks corresponding t planes (026), (062), ((040).

Fig.10. Orientation dependences
E_0=193.72 MeV
$\theta_V=-1.2^0$ and $\theta_V=-0.7^0$.

en the crystal axis <001> coincides with direction of
ron beam the large maximum is observed.

intensity of the maximum is ~3-5 times larger than
sity in disoriented crystal. Large intensity is resu
strong radiation of the electrons moving along
al axis.

channeling or above the barrier types of electron mo
is case are possible, as a result, the intensive pho
tion in low energies is produced.



The width of the maximum is
$\Delta\theta \sim 2(\psi_c + \theta_{msc})$
for diamond and silicon crysta

For diamond:
$\psi_c \sim 0.043^0$(0.75mrad) $\theta_{msc} \sim 0.0$

g.11. Orientation dependence of the intensity of the radiation
diamond crystal at the electron energy E_0=193.72 MeV .

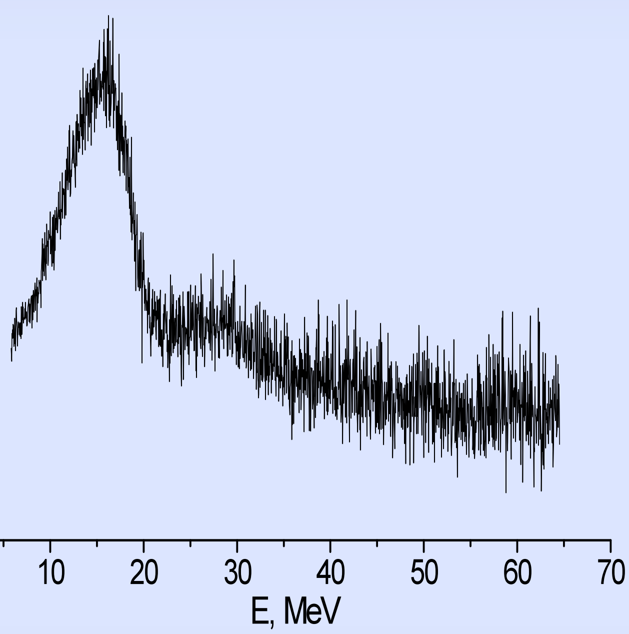
The CB spectra

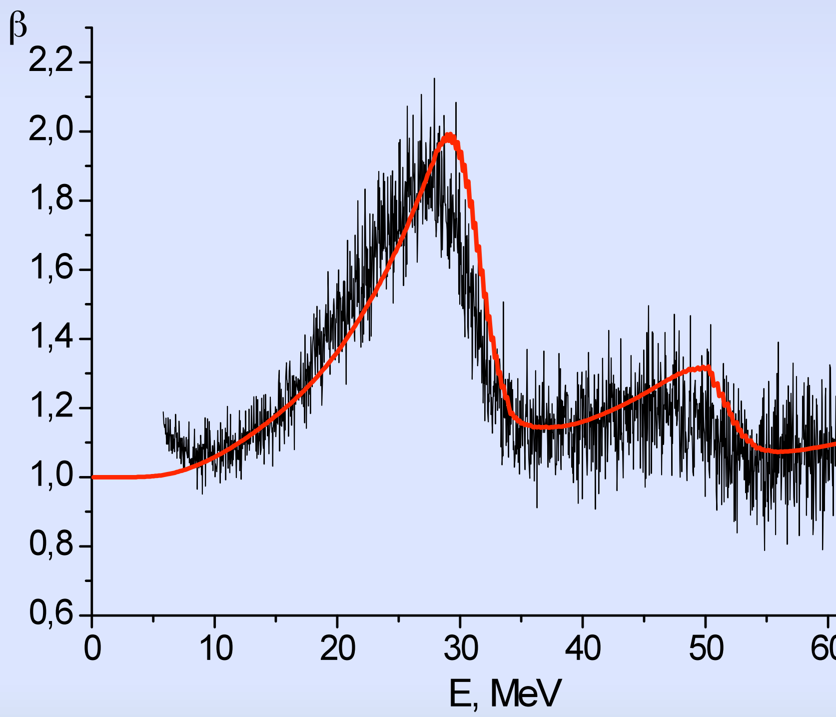
The gamma radiation spectra were measured with NaI de
25x25x25 cm^3) at electron energies:

E_0=143.87 MeV (first run)

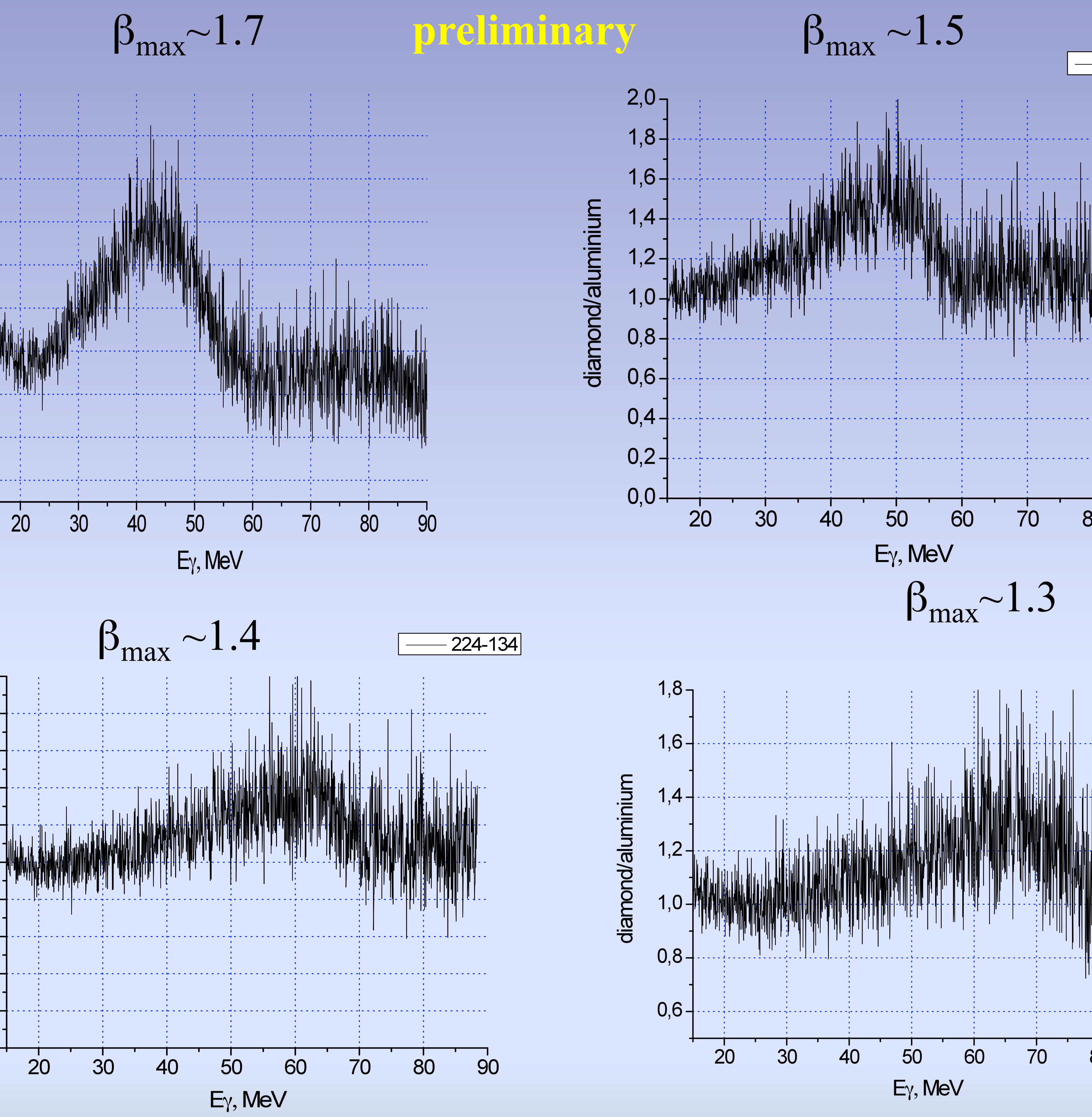
E_0=192.66 MeV (second run)

of the coherent effect is large enough β_{max}~2 at the CB
ies ***x_d<0.2*** even for E_0~150MeV. These values are in agree
results of previous calculations and corresponds to a polarizat
B maximum of ~40%. The calculation of the CB spectrum
agreement with experiment.





0. Spectra of the CB from diamond crystal 0.1 mm
alized to the bremsstrahlung spectrum from Al target. Ele
y is 143.9 MeV, θ_c~0.73θ_γ. The curve is CB calculation. First

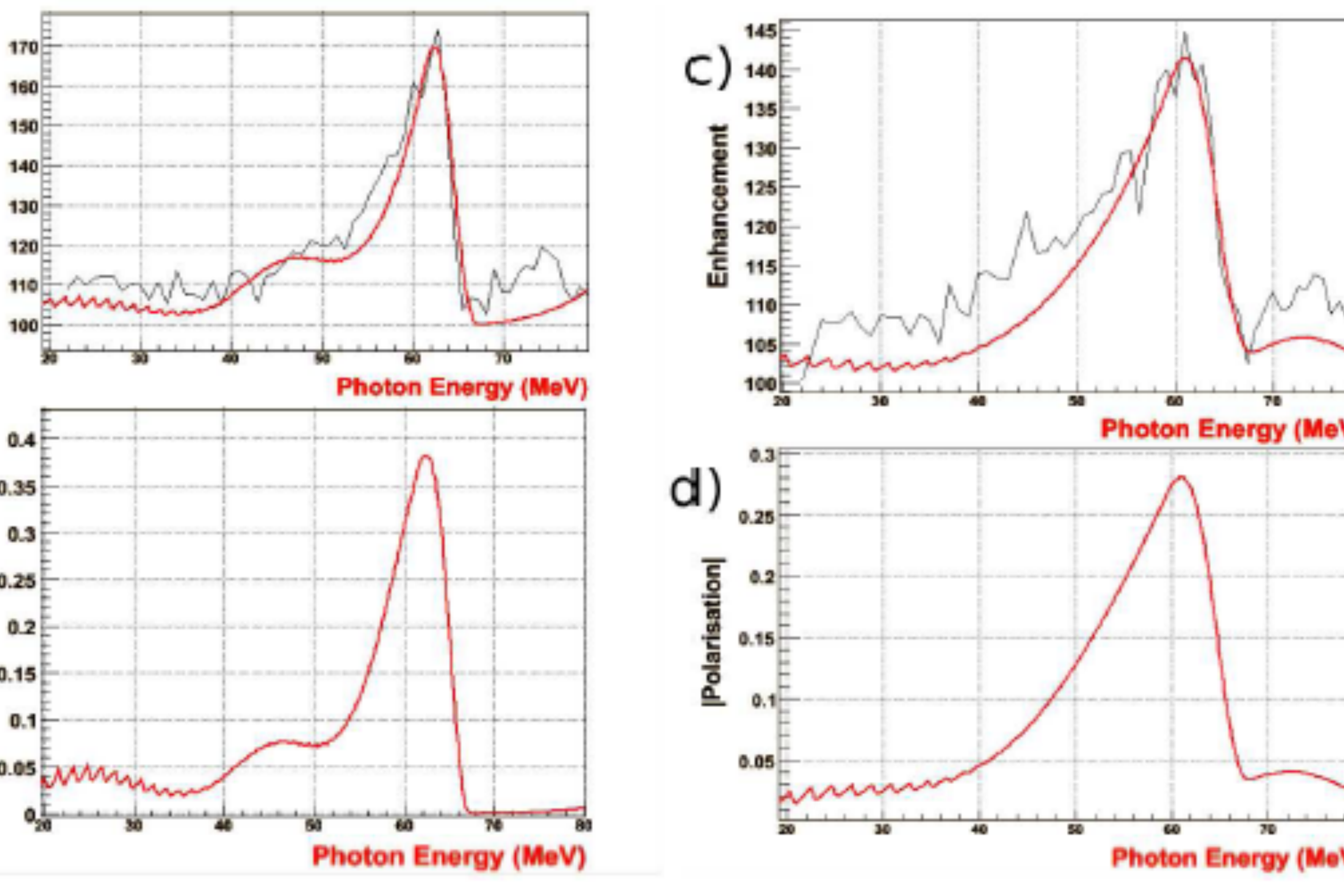


1. Spectra of the CB from a diamond crystal of thickness 0.1

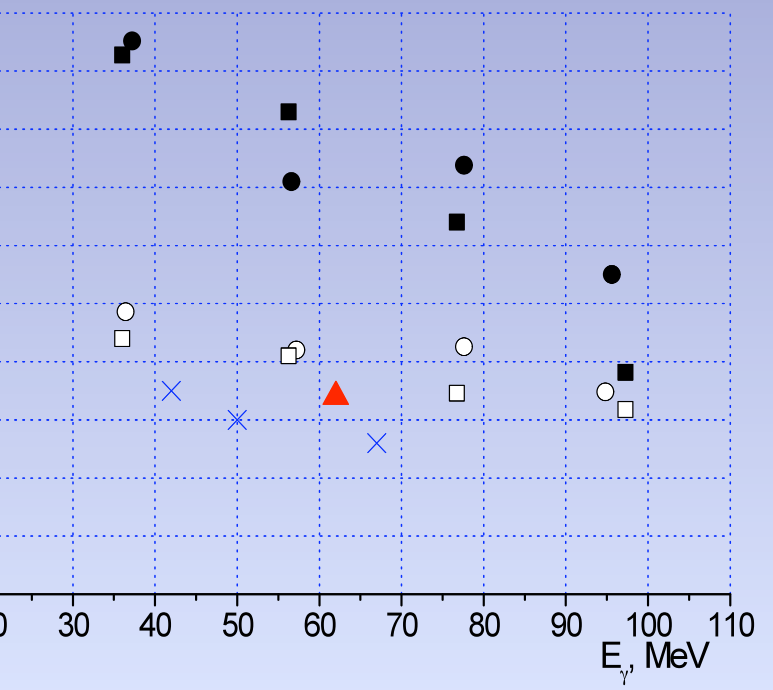
mation angle θ_c~1.7θ_γ, electron energy E_0= 192.66MeV.

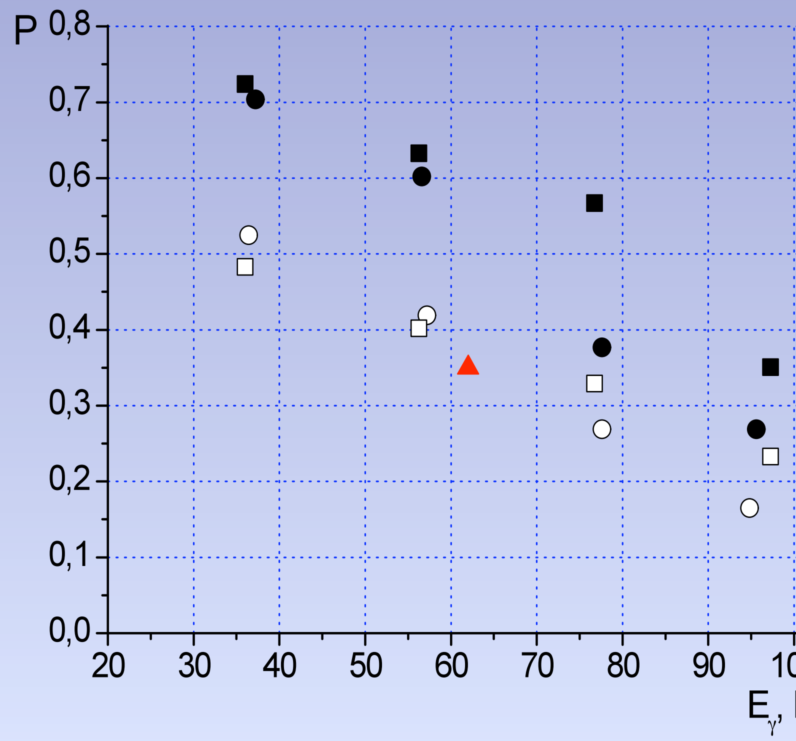
ere it is presented the measured CB spectra for collin les 12mm and 4 mm (corresponds to collimation a ~1.1θ_γ) and θ_c~0.37θ_γ) and results of the calculations. ergy is E_γ~62 MeV. Polarization ~37%.

rong collimation does not improve the CB rameters (due to multiple scattering and compa mensions of the electron beam sport on the crystal (~3 d the collimator hole).



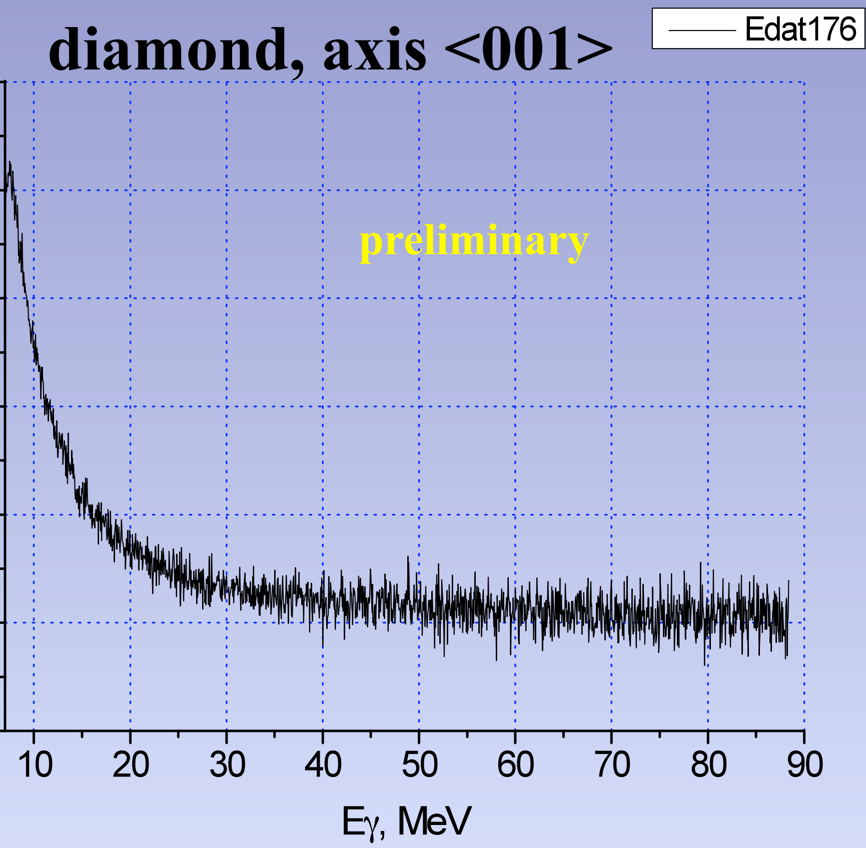
12. The spectra (a) and polarization (b) of the CB for 12 mator. The same plots for 4 mm collimator can be seen in (c





13. Dependencies of the coherent effect and polarization in
aximum as a function of the peak energy.
50 MeV (squares: filled - θ_c=0.46θγ, empty - θ_c=0.91θγ).
00 MeV (circles: filled - θ_c=0.36θγ, empty - θ_c=0.54
urements at E_0=192.66 MeV: crosses - $\theta_c \sim 1.7\theta_\gamma$, red triang
$1\theta_\gamma$

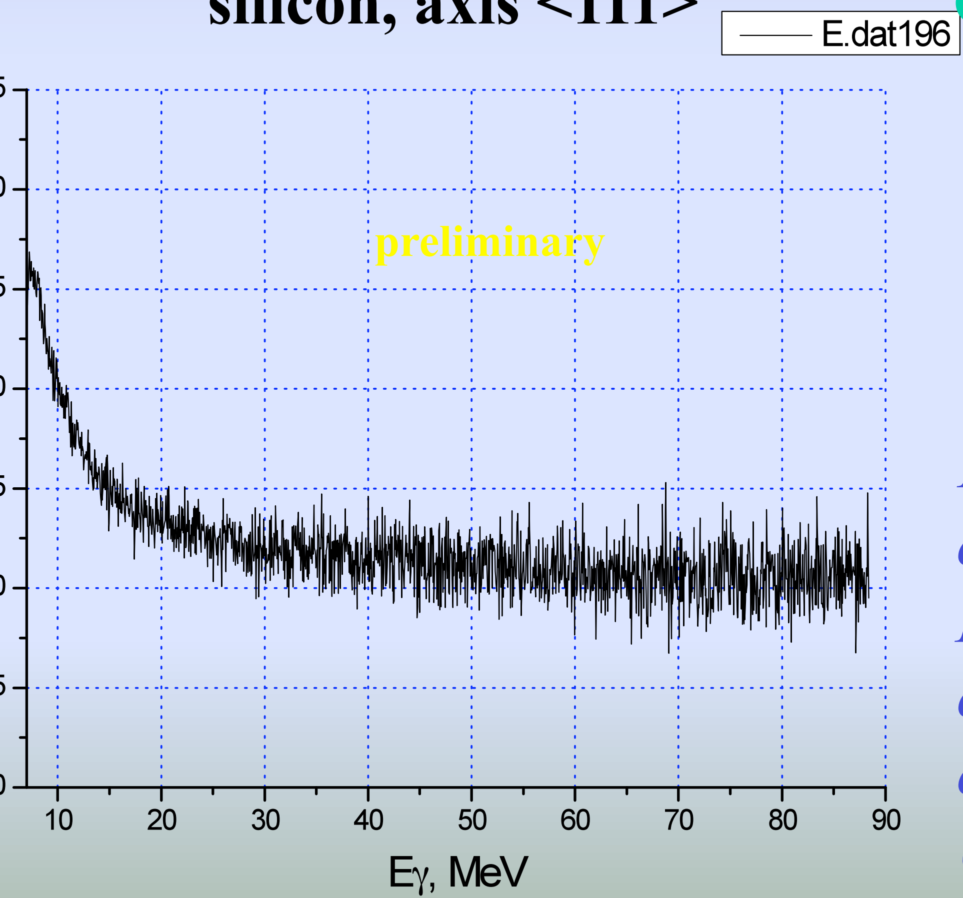
diamond, axis <001>



Channeling radiation

Strong increasing of radiation intensity at energies, at ~6-7Me almost 5 times (for diar exceeds intensity of ele radiation in the amor matter of the same thick

silicon, axis <111>



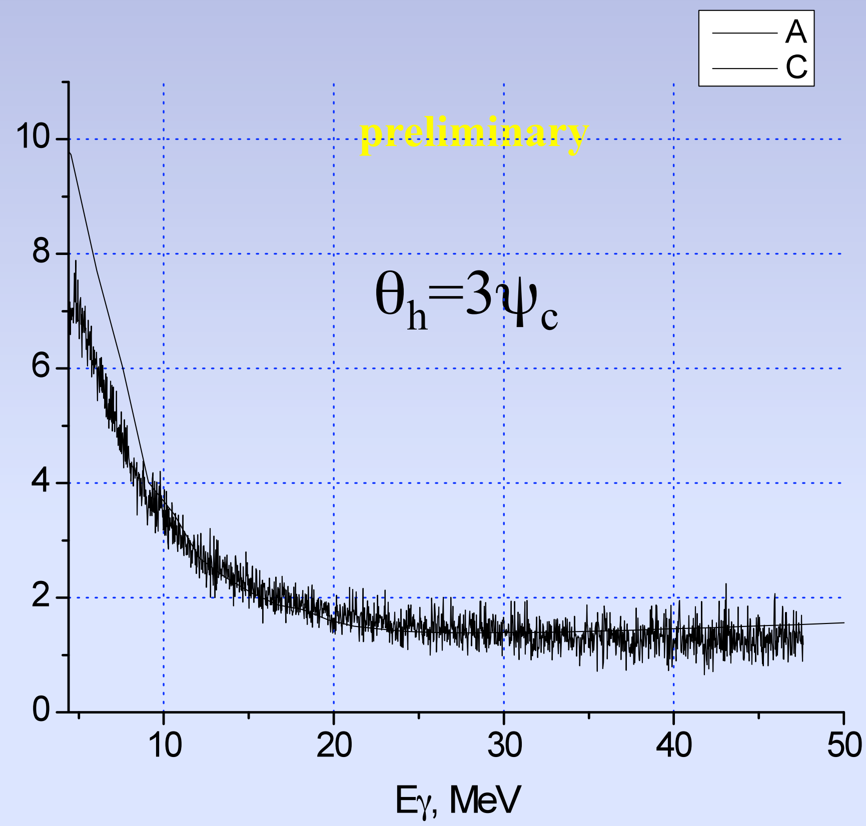
Critical angle of the ax channeling:

diamond ψ_c~0.75mrac

silicon ψ_c~0.91mrad

Fig.14. Spectra radia of electrons with ene E_0=192.66 MeV conditions of a channeling (θh=0,θv θc~1.7$\theta\gamma$.

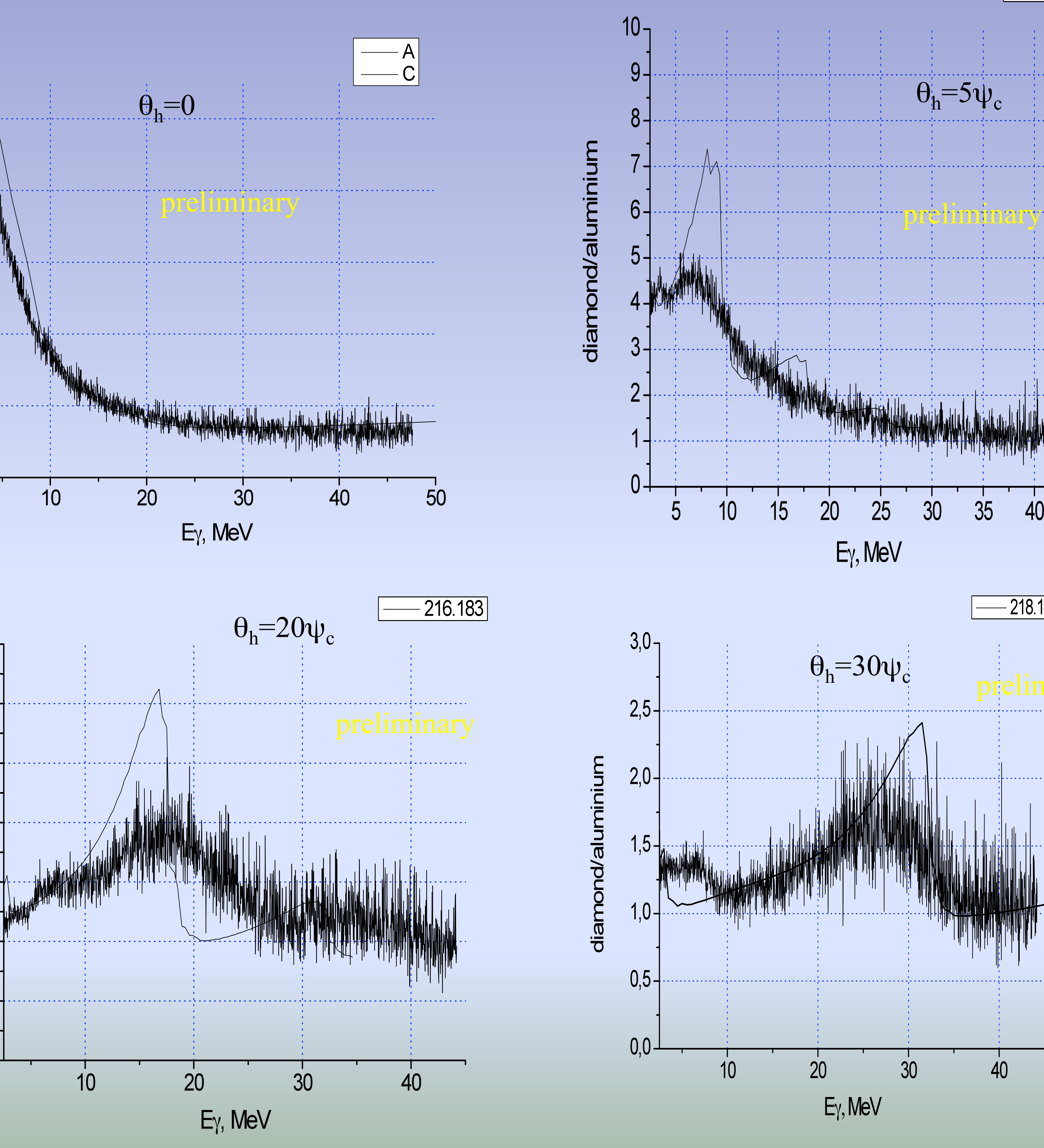
is shown the expected spectrum of electron radiation
ons move near axis <110> of diamond crystal 0.3 mm
ron energy is E_0=200MeV. At ~3MeV it almost 10 times ex
sity of electron radiation in the amorphous matter of the
ness.



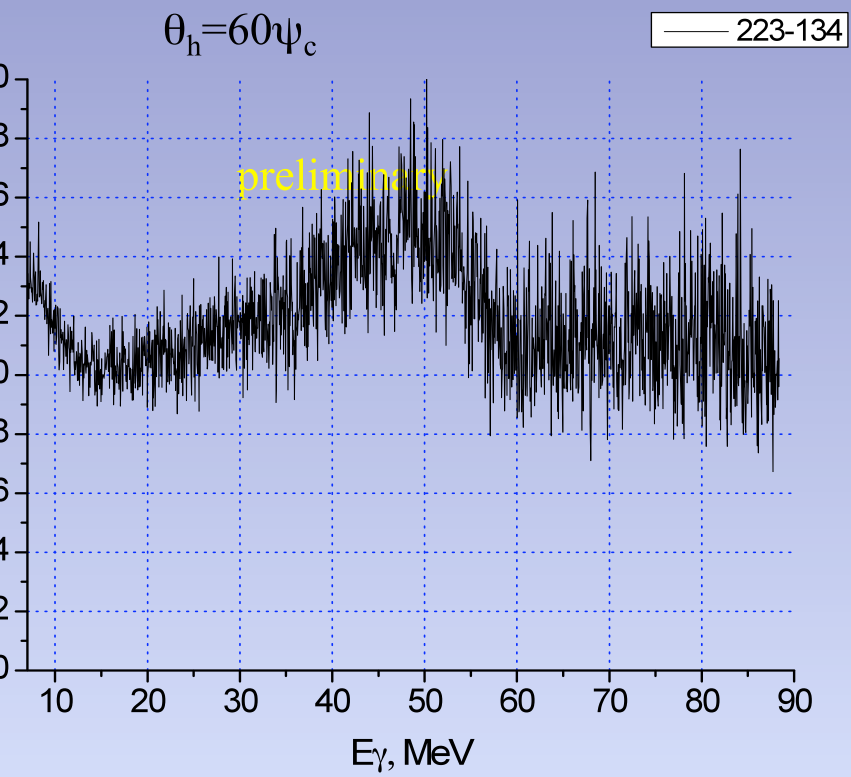
16. Radiation spectrum of electron with energy E0=193.72 ing under zero and three critical angle of axial channeling <001> along plane (220) of diamond crystal 0.1 mm imation angle θc~1.7θγ.

ve is the calculation in the model based on the semi-cla roximation developed by Kharkov group (*N.F. Shul'ga, V.I Tr Greenenko. Nucl.Instr.Meth. 1998, v. B145*)

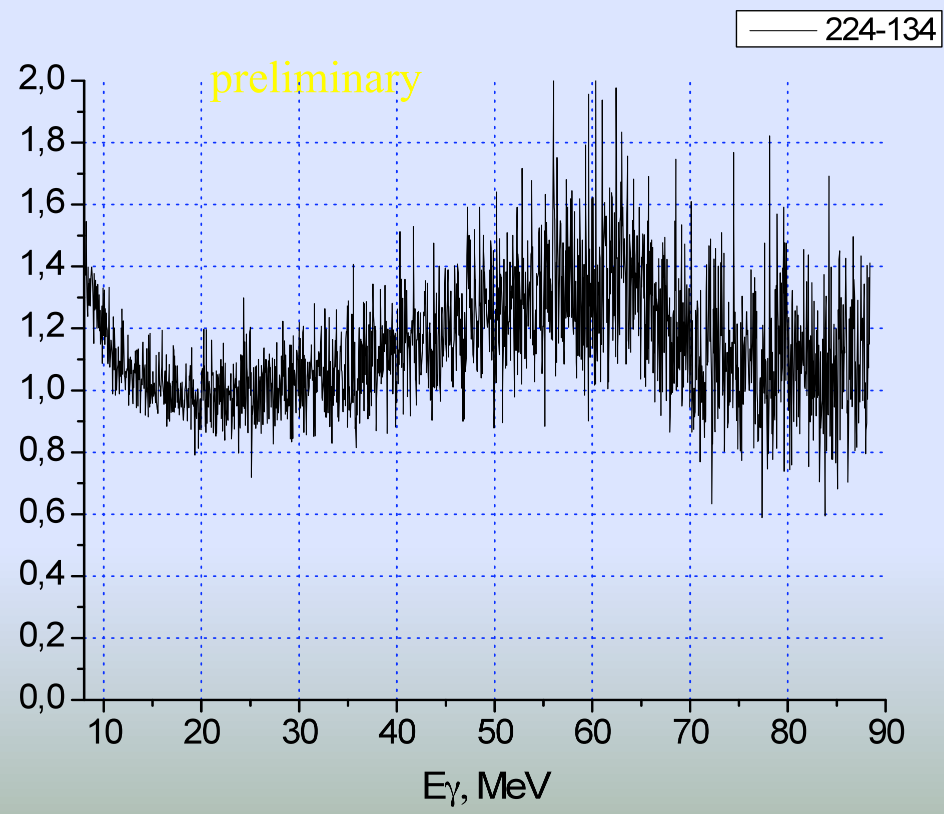
nder angle θ_h to <100> in the plane (220)



$\theta_h=60\psi_c$



$\theta_h=80\psi_c$



Preliminary results

he test measurements have shown that the
eam at MAX-lab was produced and the prev
omputations were confirmed.

he electron beam with energy E_0=200 M
ovides the photo-nuclear investigation in the ra
o to Eγ~60 MeV (with beam collimation $\theta_c \sim \theta_\gamma$)
e CB peak energies x_d~0.1-0.2, ($E_{\gamma,p}$~20-30 M
e polarization can achieve values $P_{\gamma,max} \approx 50\%$.

o increase the polarization and coherent effect
ectron beam energy increasing up to 250 Me
ost effective. It will allow us to get the CB b
rameters suitable for nuclear physics experim
energy range up to 100 MeV.

nother possibility to improve the CB paramete
use thinner crystal, ~50mkm.