

A 5 TO 20 MEV ELECTRON LINEAR ACCELERATOR FOR METROLOGY

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NATIONAL STANDARD* OF UNITS:

Electron radiation field	Bremsstrahlung field
Particle flux , c^{-1} Particle flux density , $c^{-1} \cdot cm^{-2}$ Particle fluence , cm^{-2}	
Energy flux , $J \cdot c^{-1}$ or W Energy flux density , $J \cdot c^{-1} \cdot cm^{-2}$ or W/cm^2 Energy fluence , $J \cdot cm^{-2}$	Energy flux , $J \cdot c^{-1}$ or W Energy flux density , $J \cdot c^{-1} \cdot cm^{-2}$ or W/cm^2 Energy fluence , $J \cdot cm^{-2}$

Metrological assurance of measurements in

- nuclear-physical instrumentation,
- ship and aircraft building,
- rocket production,
- radiation processing,
- accelerating equipment for industry and medicine

OLD ACCELERATOR SYSTEM:



NEW ACCELERATOR SYSTEM:



- ELECTRON SOURCE
- ACCELERATING STRUCTURE
- MAGNET - SEPARATOR
- RADIATION HEAD

/ WITH UNITS

TO FORM BREMSSTRAHLUNG
AND ELECTRON RADIATION FIELDS /

RADIATION HEAD INPUT:

W_B , MeV	5-20
$\Delta W/W_B$, %	5
I_0 , μA	0.1-10
D_B , mm (FWHM)	≤ 5

W_B - ENERGY OF ELECTRONS IN THE SPECTRUM MAXIMUM

ΔW - ENERGY SPREAD

I_0 - AVERAGE ELECTRON CURRENT

D_B - BEAM DIAMETER IN THE PLANE OF EXTRACTION WINDOW

Electron radiation field at the 100 cm SSD:

Area, cm²	10x10
Flatness, %	≤ 2
Particle flux density (aver.), c⁻¹·cm⁻²	$6 \cdot 10^{11} - 6 \cdot 10^{13}$

Bremsstrahlung field at the 100 cm SSD:

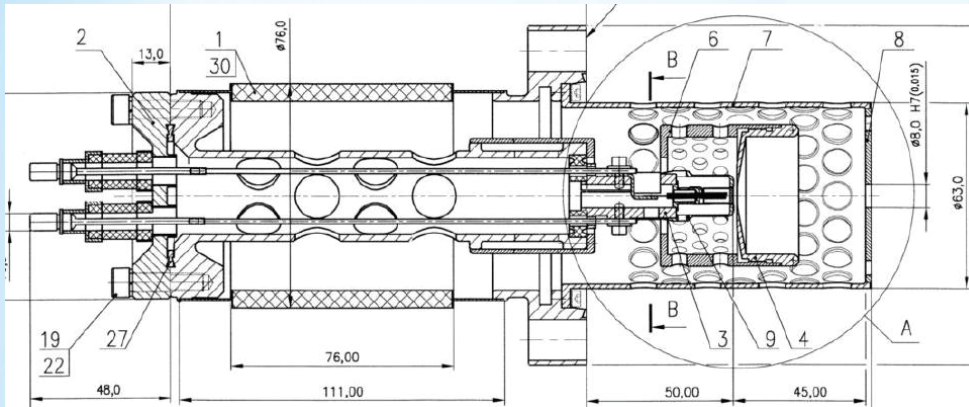
Area, cm²	10x10
Flatness, %	≤ 2
Energy flux density (aver.), W/cm²	0.5-200

SPATIAL STABILITY OF RADIATION FIELDS:

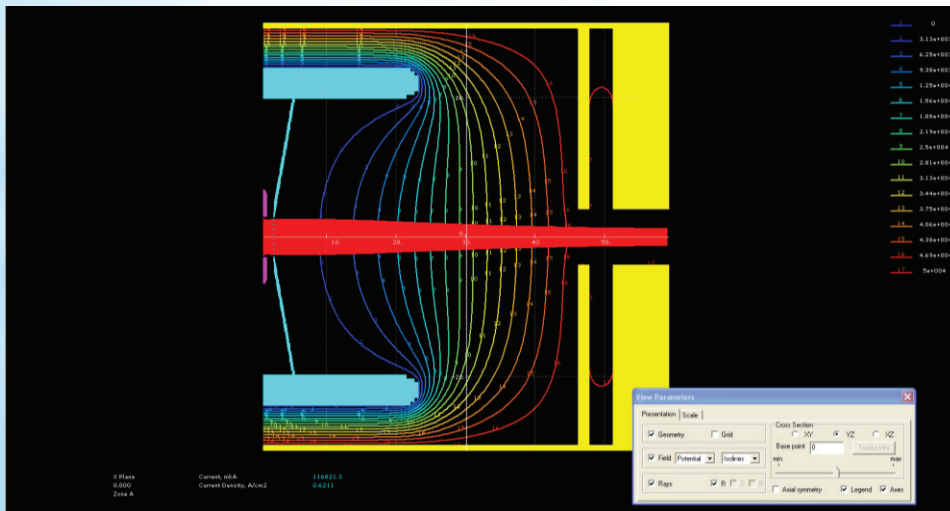
REQUIRED (CONTINUOUS, 2 ORDER) RANGE OF RADIANT FLUX IS OBTAINED BY

- CHANGING THE PULSE-REPETITION FREQUENCY**
- FINE ADJUSTMENT OF THE BEAM CURRENT IN A PULSE**

ELECTRON SOURCE

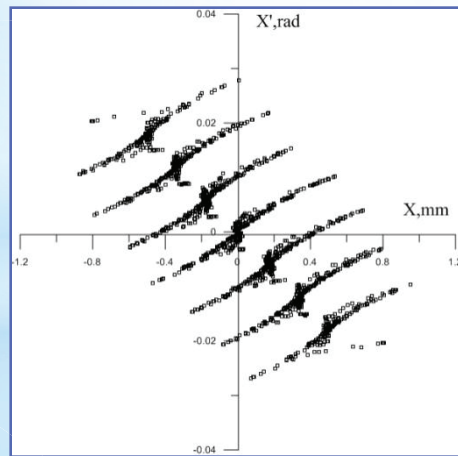
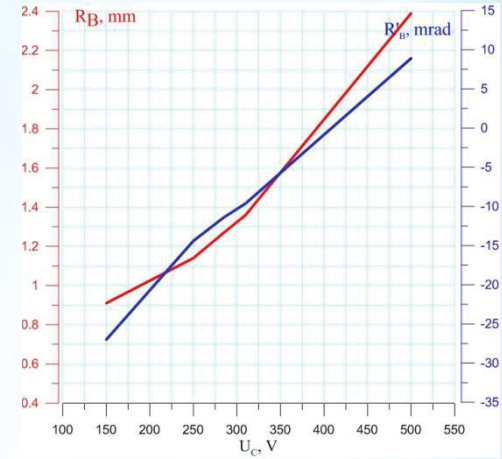
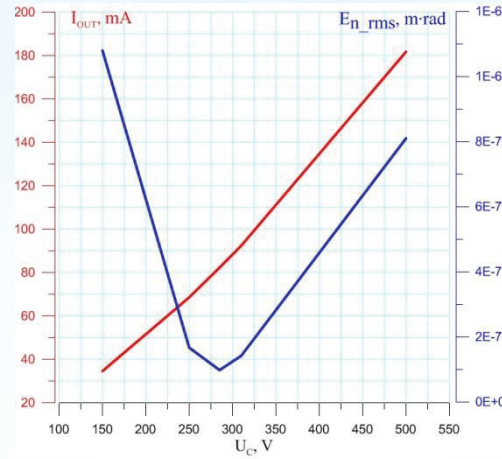
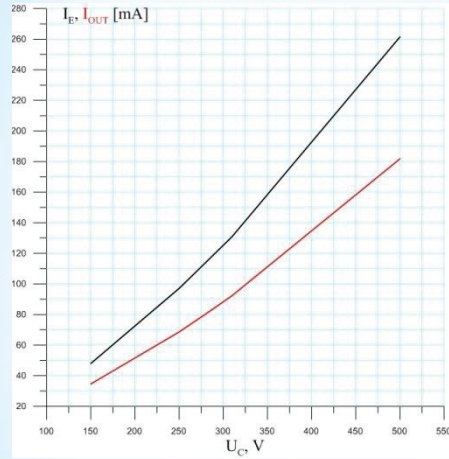


W_B	50 keV
$I_{CATHODE}$	95-140 mA
I_{OUT}	65-95 mA
U_{GRID}	200-350 V
T_{puls}	5 μs
F_{puls}	2-200 Hz
$D_{CATHODE}$	5mm
$L_{CATH-GR}$	1.45mm

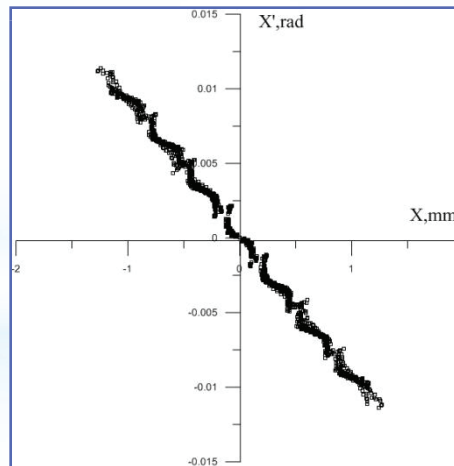




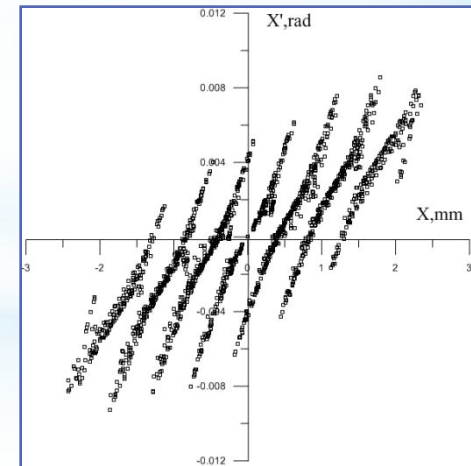
ELECTRON SOURCE



34mA

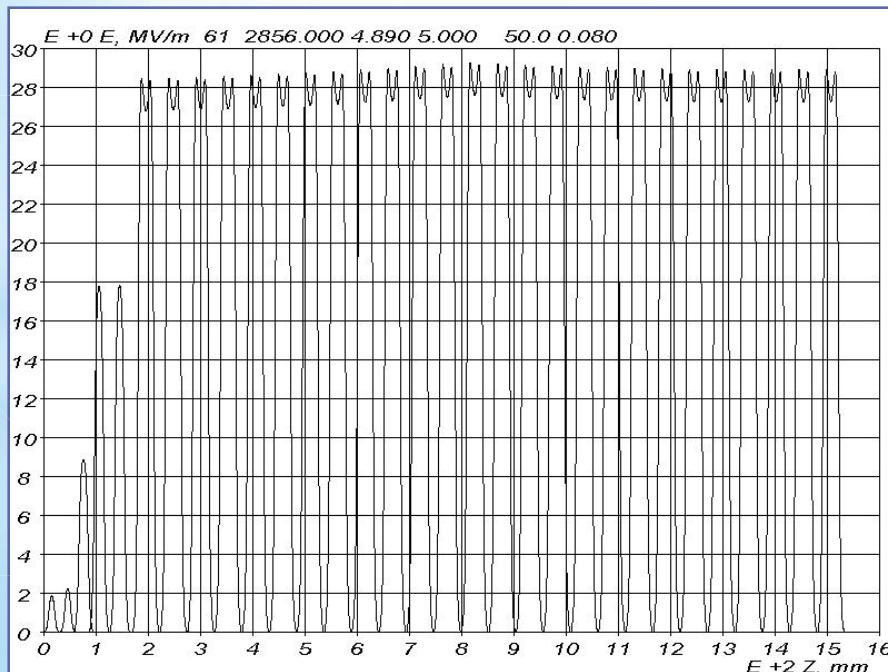
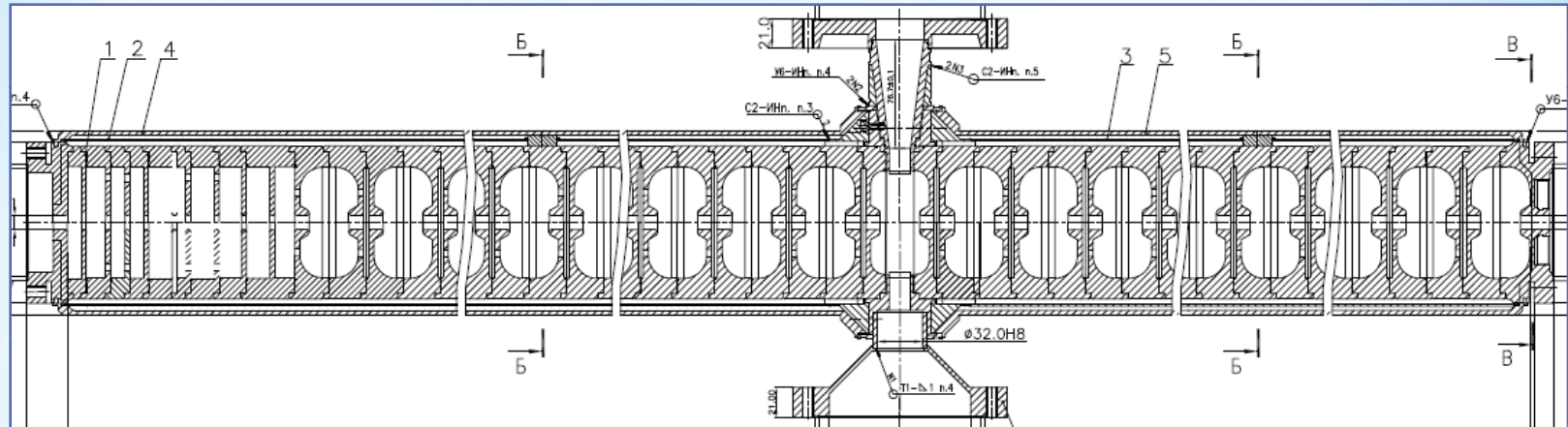


82mA



182mA

ACCELERATING STRUCTURE



Frequency	2856 MHz
Type of SW oscillation	$\pi/2$
N_{CELLS}	61 (10+51)
Length	1.5 m
RF pulse duration	6μs
Repetition rate	2..200 Hz
Electron energy	5..20 MeV
Injection energy	50 keV

ACCELERATING STRUCTURE



DESIGN PARAMETERS

W_B , MeV	P_{RF} , MW	E_M , MV/m	I_{INP} , mA	I_{OUT} / I_{INP}	I_W / I_{OUT}	I_W , mA	VSWR
5	1.59	17.7	86	0.65	0.36	20	1.50
8	1.86	18.7	80	0.69	0.65	36	1.38
11	2.31	20.4	80	0.73	0.71	41	1.28
14	2.95	22.7	80	0.78	0.77	48	1.18
17	3.95	26.2	80	0.84	0.84	57	1.08
20	5.00	29.8	80	0.88	0.87	61	1.01

P_{RF} - the pulsed RF power consumption;

E_M - the maximum field strength on the beam axis;

I_{INP} (I_{OUT}) - the pulsed beam current at the structure input (output);

I_W - the pulsed working current (current being in the energy interval $\pm 5\%$ relative to W and passing through the magnet-separator);

ACCELERATING STRUCTURE



Maximum average lost power in resonator walls - 1.3 kW

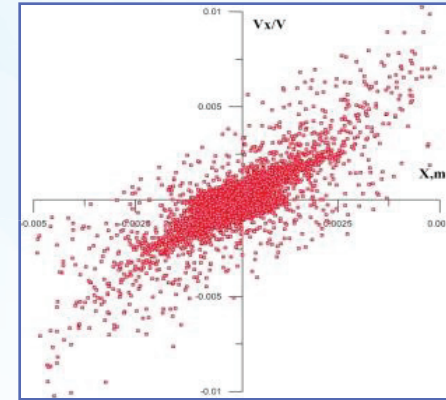
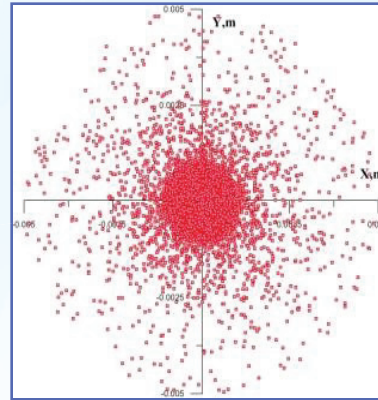
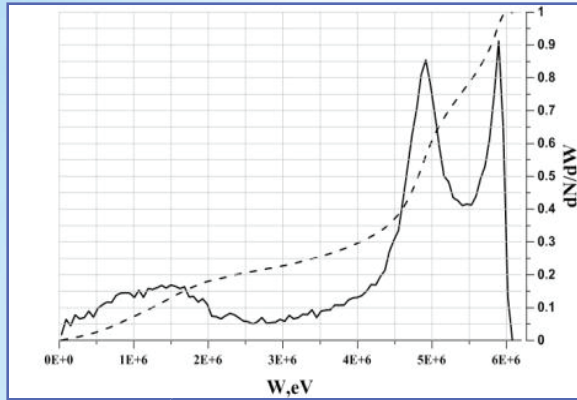
Maximum pulsed lost power in resonator walls - 3.7 MW

Maximum pulsed beam power – 1.3 MW

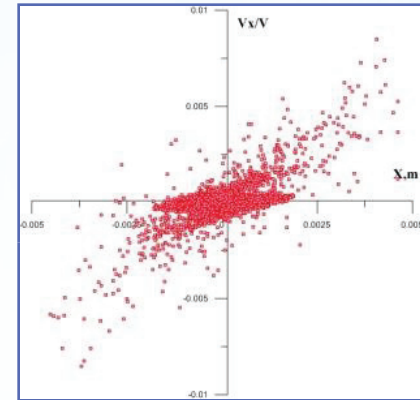
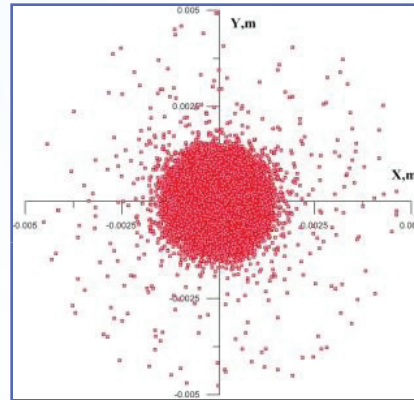
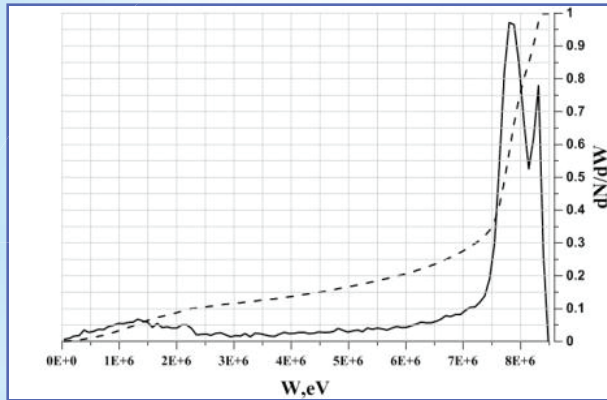
MULTY-BEAM KLYSTRON KIU-168

OPERATING FREQUENCY, MHz	2856±5
OUTPUT PULSED POWER, MW	6
AVERAGE OUTPUT POWER, kW	6
EFFICIENCY, %	45
AMPLIFICATION, dB	50
CATHODE VOLTAGE, kV	52
WEIGHT WITH PPMFS, kg	80

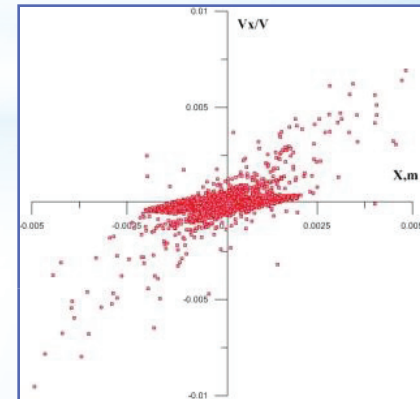
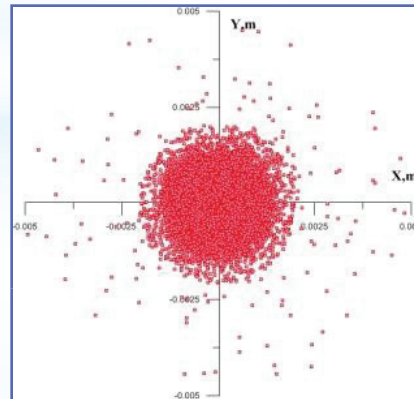
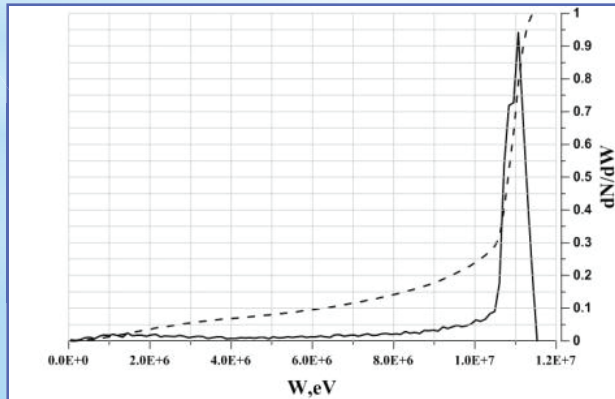
MAGNET – SEPARATOR INPUT



5 MeV

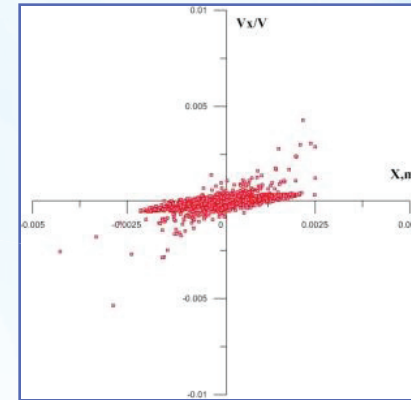
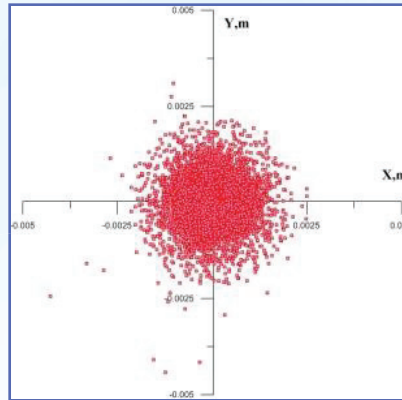
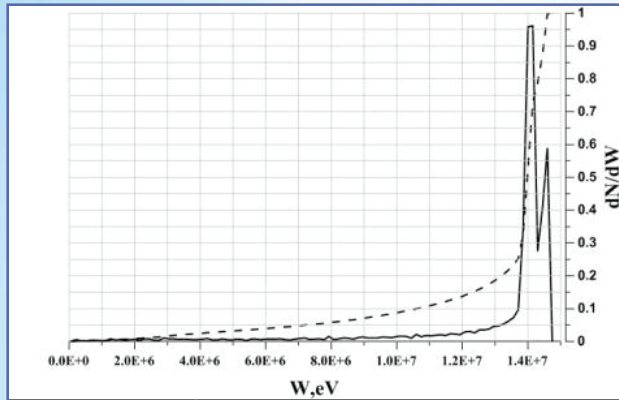


8 MeV

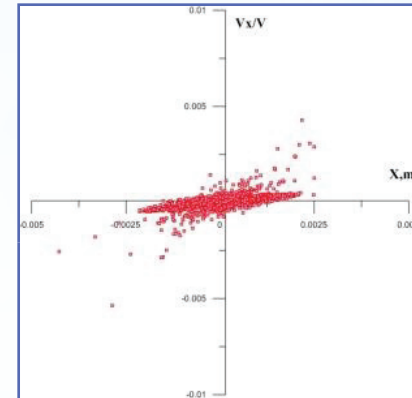
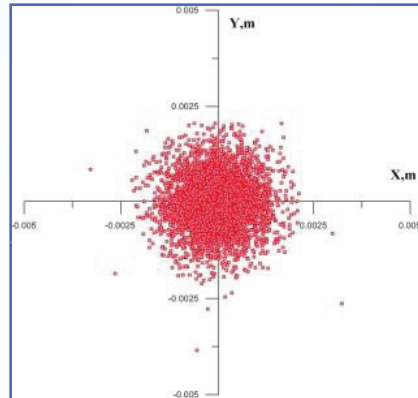
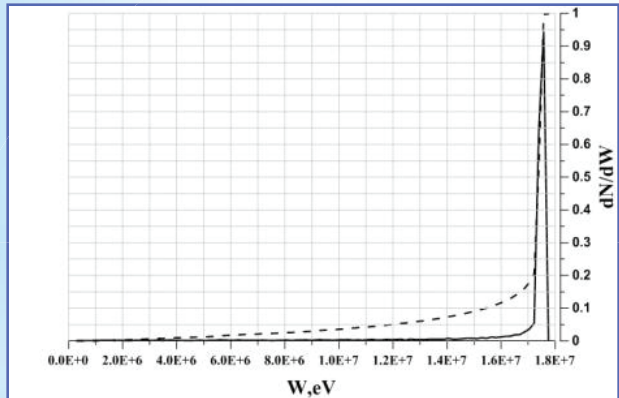


11 MeV

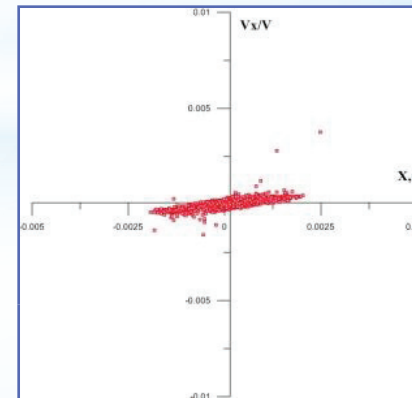
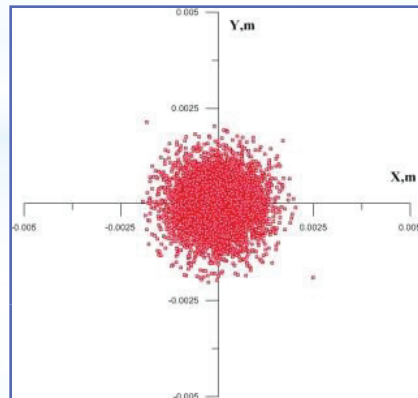
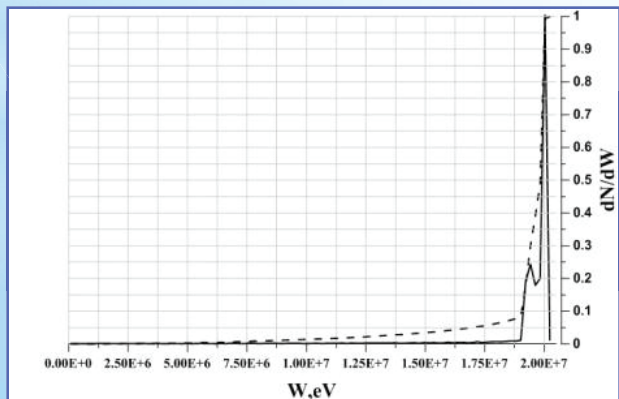
MAGNET – SEPARATOR INPUT



14 MeV



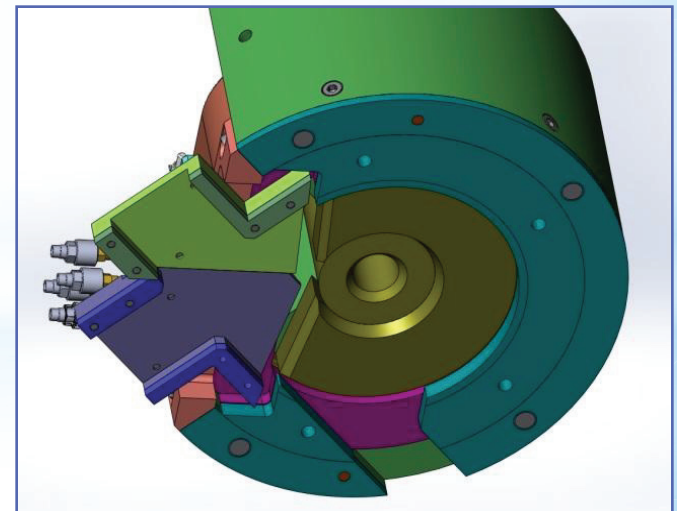
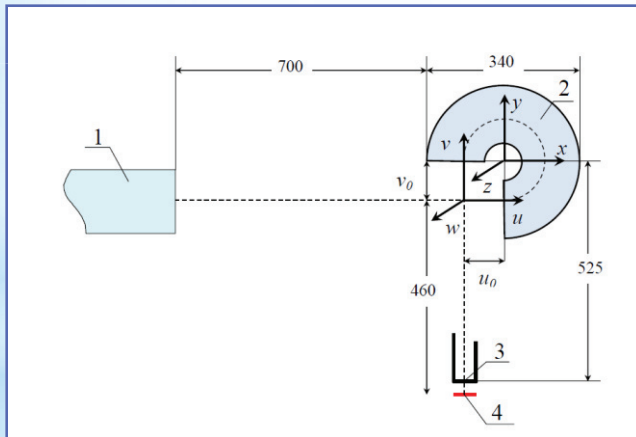
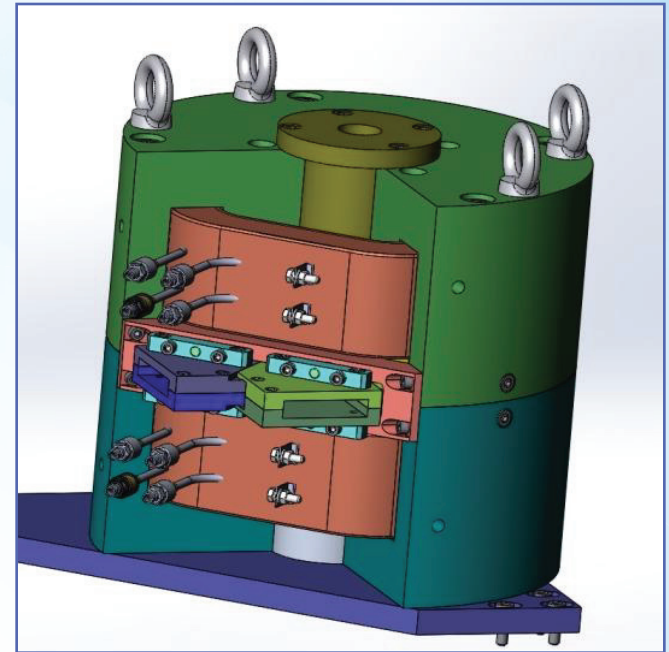
17 MeV



20 MeV

MAGNET - SEPARATOR

ELECTROMAGNET	1
ANGULAR LENGTH	270°
R_0	70 mm
B_0	0.26...0.97 T
POLE GAP	14 mm
POLE INDEX	0
POLE FACE ANGLES	
INPUT / OUTPUT	33.5 °/41°
POLE-CLAMP GAP	5..20 mm

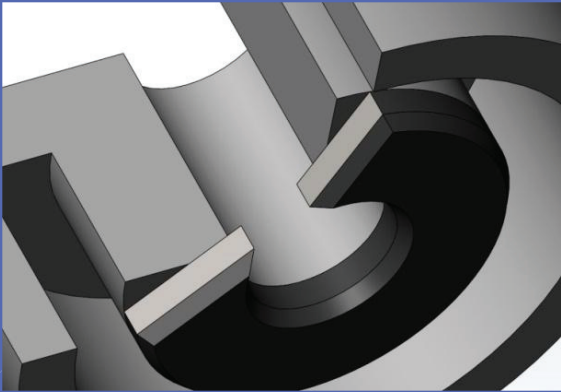


1- accelerating structure; 2 – magnet-separator;
3 – extraction window; 4 – bremsstrahlung target

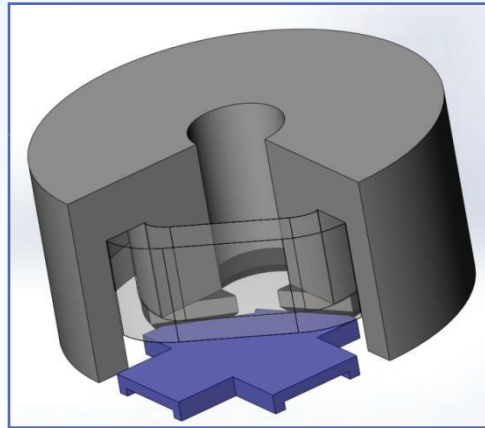


MAGNET – SEPARATOR

(SIMULATIONS)



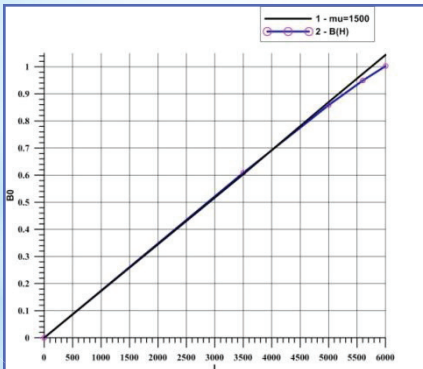
3D MODEL



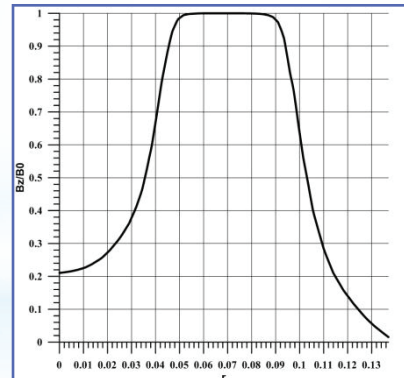
3D MODEL



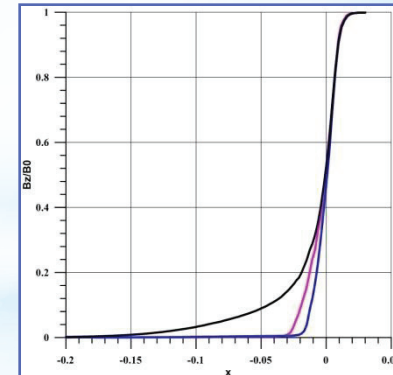
B-MAP



EXCITATION CURVE



RADIAL PROFILE



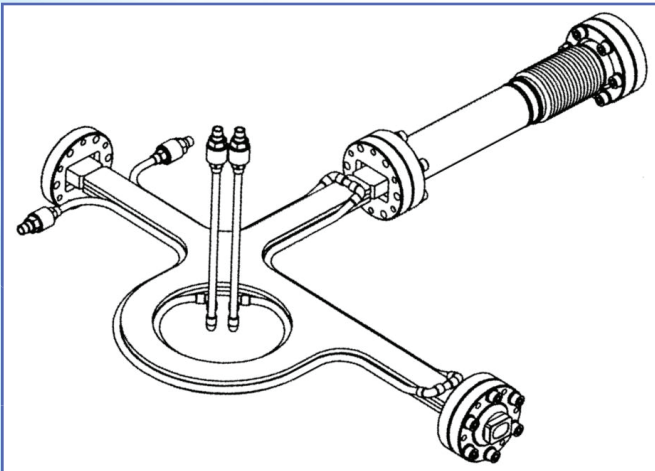
STRAY FIELD VS
CLAMP PARAMETERS

MAGNET - SEPARATOR



POWER SUPPLY	2 500 W
VOLTAGE	20 V
CURRENT	45-50 A
STABILITY	$1 \cdot 10^{-3} (\Delta I / I)$

VACUUM CHAMBER WITH COOLING CHANNELS

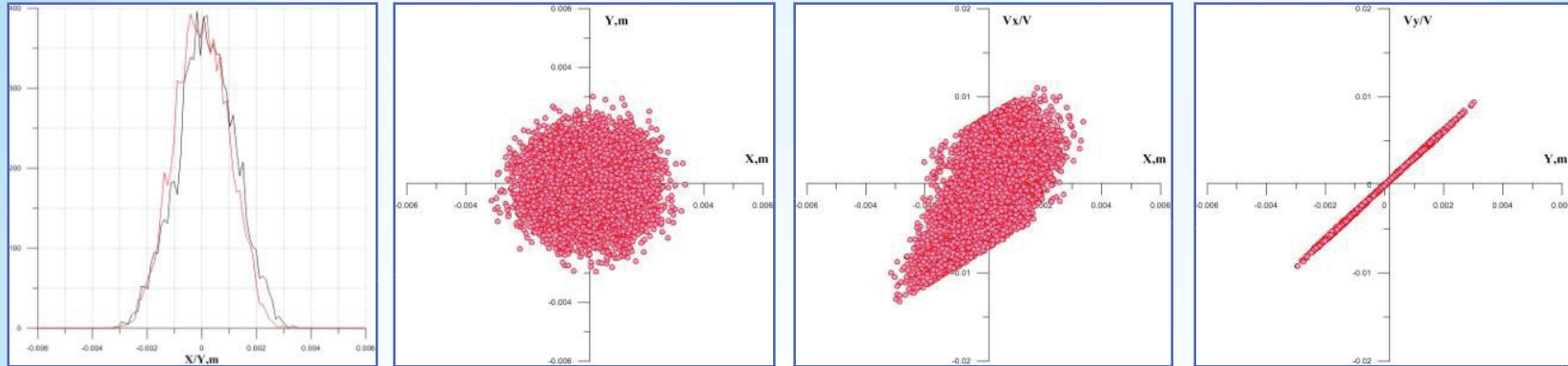


MOMENTUM ACCEPTANCE	$\pm 5\%$
DISTANCE BETWEEN WALLS	16MM
DUMP NON-WORKING PART OF BEAM	
P_{HEAT}	$< 140 \text{ W}$

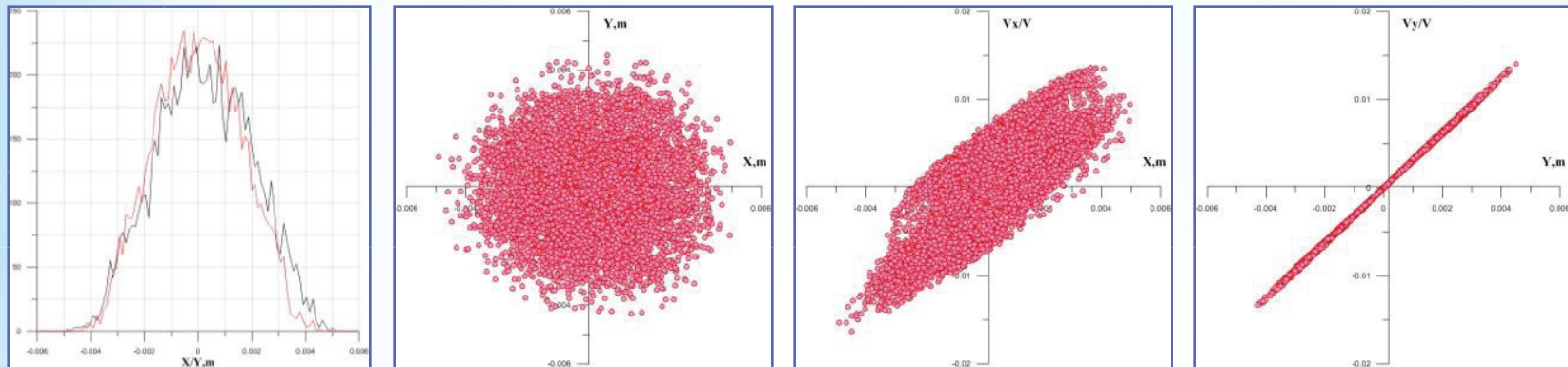
EXTRACTION WINDOW PLANE



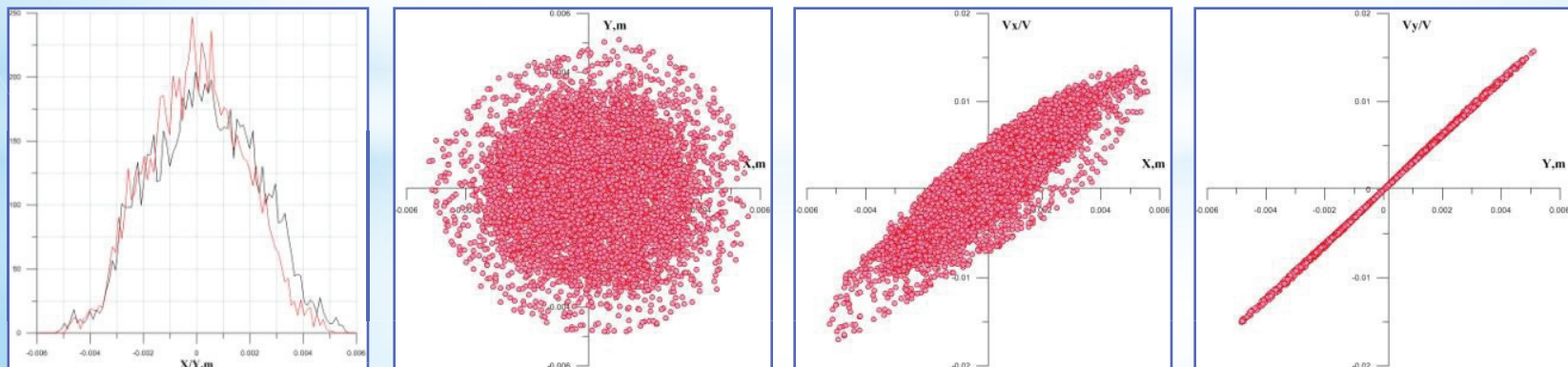
5 MeV



8 MeV



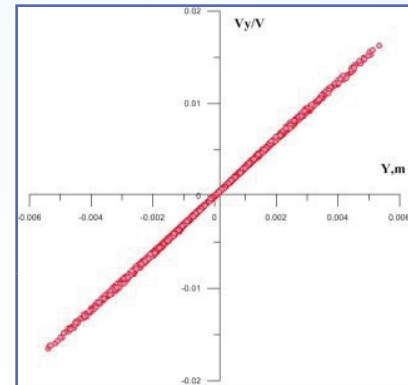
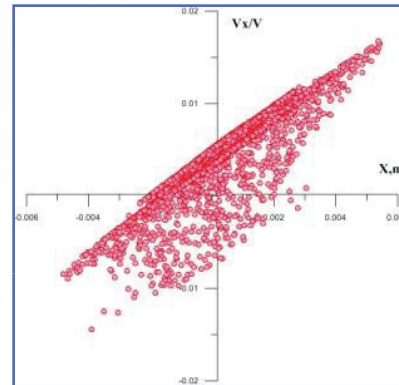
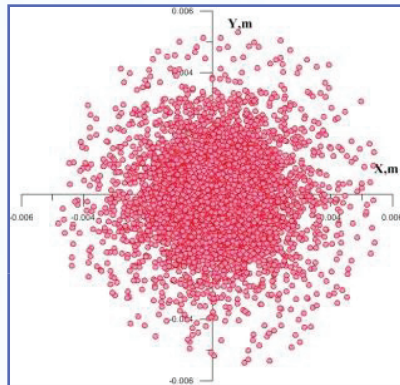
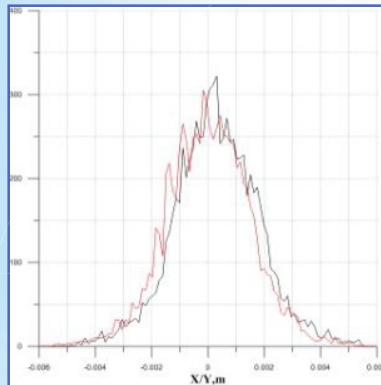
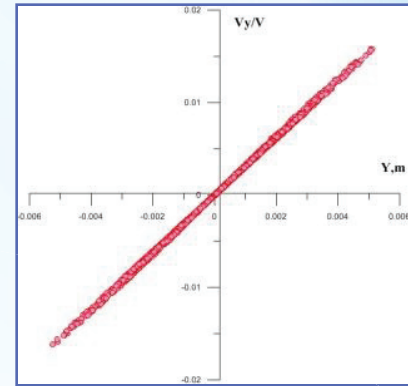
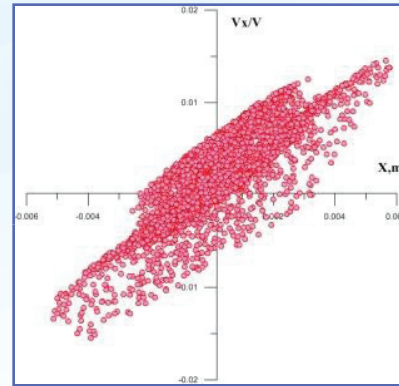
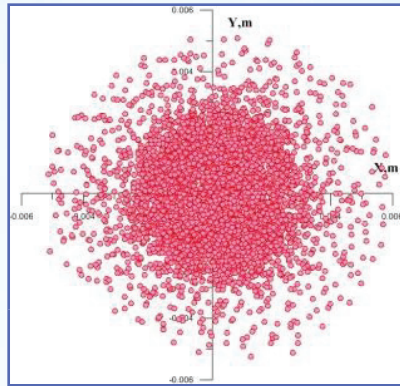
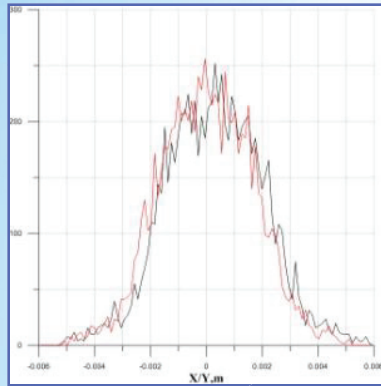
11 MeV



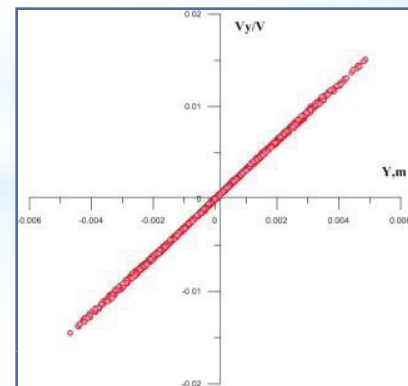
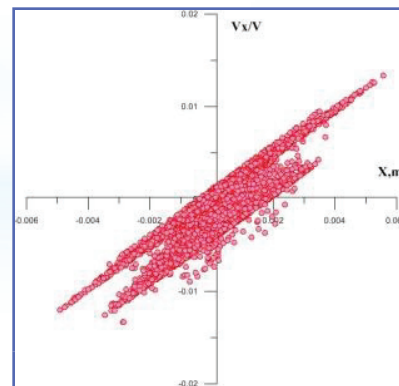
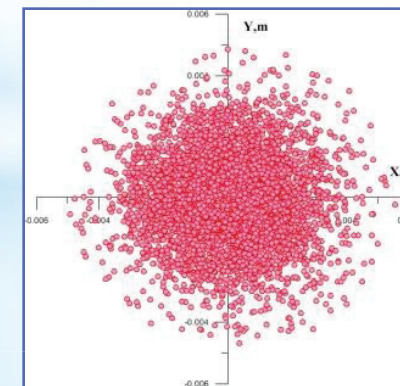
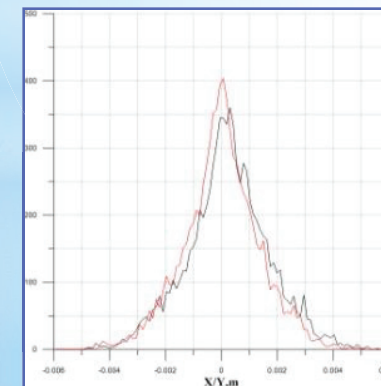
EXTRACTION WINDOW PLANE



14 MeV



17 MeV

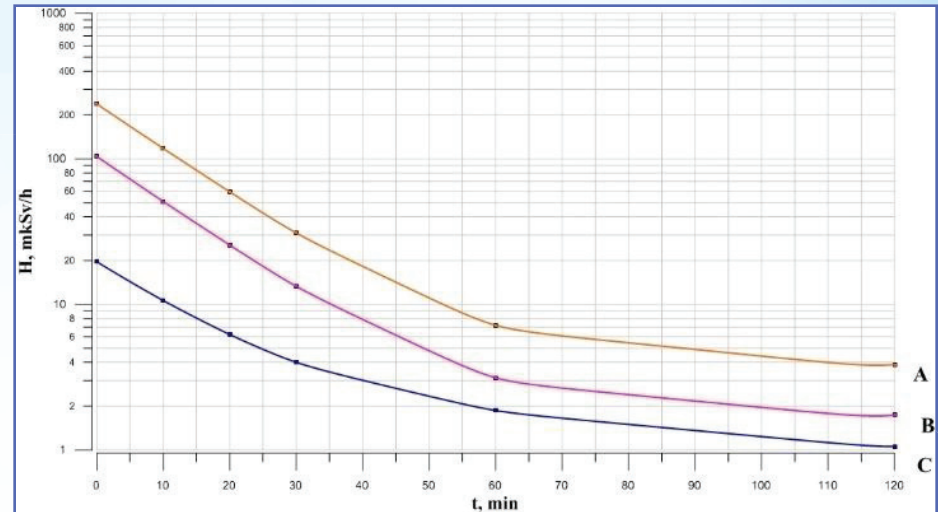


20 MeV

COMPONENTS OF LOCAL RADIATION SHIELDING



- **MAGNET YOKE**
- **EXCITATION COILS**
- **CLAMPS**
- **VACUUM CHAMBER**
- **SPECIAL NON-MAGNETIC ABSORBERS (red color)**

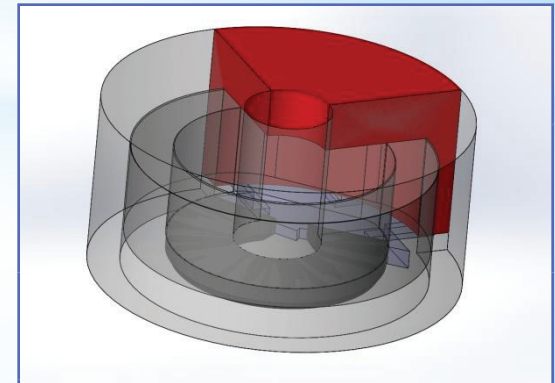
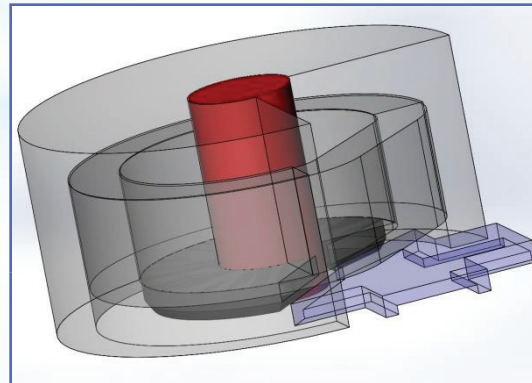
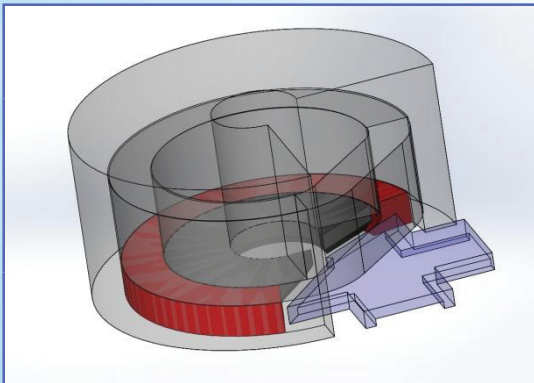


INDUCED ACTIVITY OF MAGNET-SEPARATOR:

A – without special radiation shielding

B – with added Al absorbers

C – with added Pb absorbers





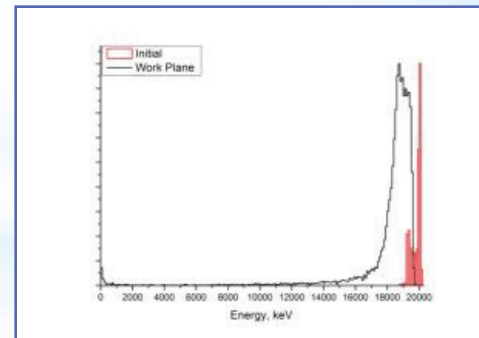
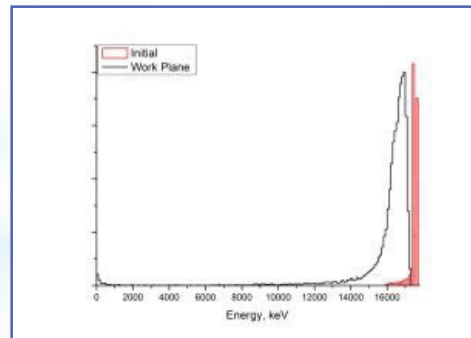
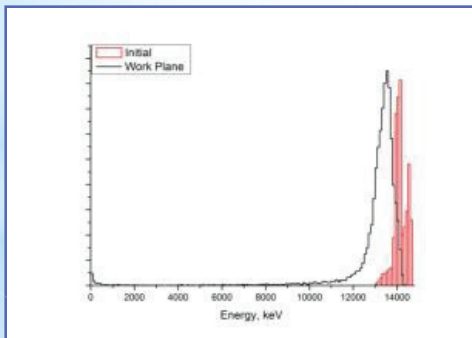
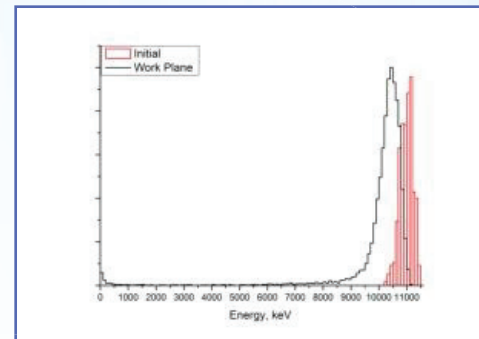
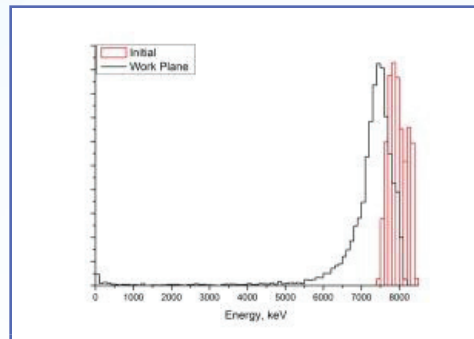
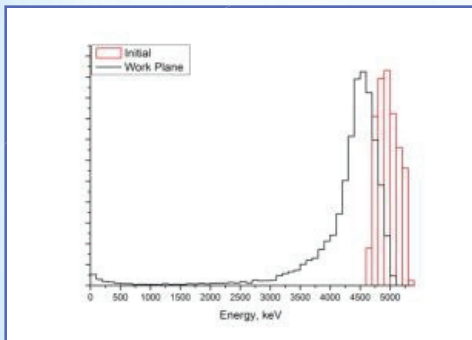
RADIATION HEAD

BREMSSTRAHLUNG FIELDS:	ELECTRON RADIATION FIELDS:
▪ TARGET (W-Rh)	▪ PRIMARY COLLIMATOR (Al)
▪ CONE COLLIMATOR (W-Ni-Cu)	▪ SCATTERING FOIL (Ta)
▪ FLATTENING FILTER (Cu)	▪ COMPENSATING FOIL (Al)
2 REPLACEABLE UNITS	4 REPLACEABLE UNITS
ELECTRICALLY-OPERATED MECHANISM FOR REPLACEMENT	



RADIATION HEAD

DATA ON ELECTRON SPECTRUM DEGRADATION IN DUAL-FOIL SYSTEM





STATUS OF THE PROJECT

- **ELECTRON SOURCE HAS PASSED TESTING,
DESIGN PARAMETERS WERE CONFIRMED**
- **ACCELERATING STRUCTURE
HAS BEEN MANUFACTURED AND RF-TUNED**
- **ALL THE MAIN SYSTEMS OF THE FACILITY
ARE READY FOR DELIVERY TO THE CUSTOMER**



ACCELERATING STRUCTURE WITH COOLING JACKET

THANK YOU FOR ATTENTION !