Monte-Carlo Simulations for estimation of the radiation environment around the modernized Nuclotron

Timoshenko G.N.

Paraipan M.

Florko B.V.

Zaitsev L.N.

Joint Institute for Nuclear Research

The most heavy radiation situation at the NICA exploitation will be acceleration of ^{238}U ions up to 3,5 (4,5) GeV/n energy (4000 h per year)

MAIN RADIATION SOURCES OF THE NICA:

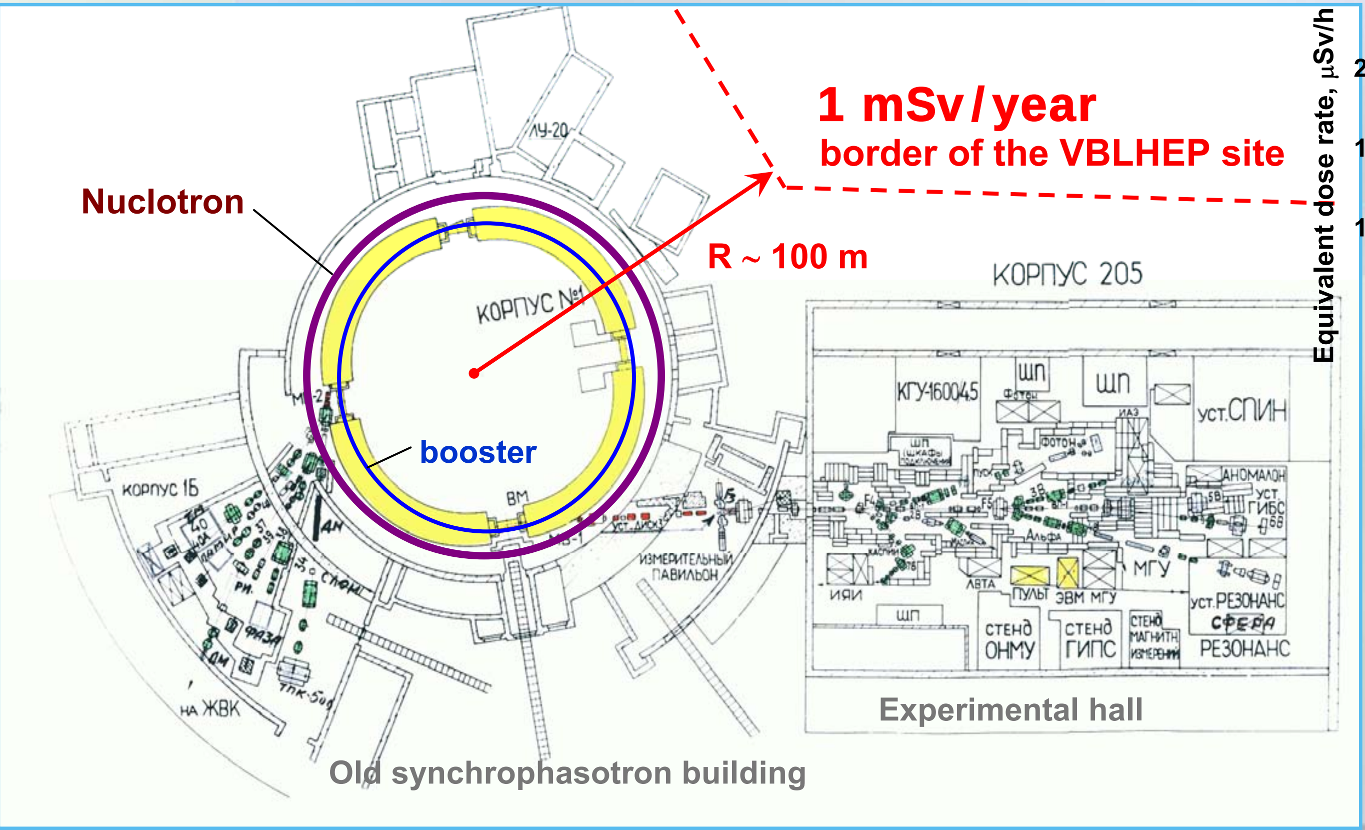
- **BOOSTER [0,44 GeV/n]**
- **NUCLOTRON [0,44 – 3,5(4,5) GeV/n]**
- **COLLIDER [3,5(4,5) Gev/n]**
- **BEAM TRANSPORT CHANNELS**
- **BEAM STOPPERS**

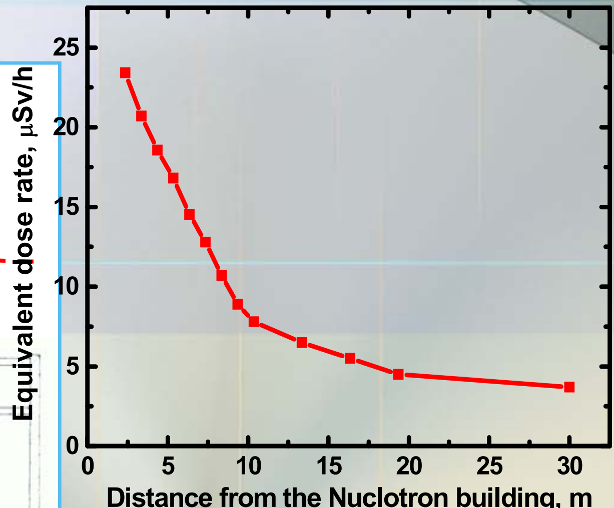
It is planned to arrange the booster inside the synchrophasotron ring. Thus the booster and Nuclotron are placed within the old synchrophasotron building.

The collider ring will be arranged or within the experimental hall (1st variant) or on the outside near the synchrophasotron building (2nd variant).

The crucial point determining the NICA shielding design is indispensable condition for keeping the yearly equivalent dose < 1 mSv on the border of the Lab site

(in accordance with "Main sanitary rules of radiation protection guarantee for workers and public OSPORB-99" < 0,5 mSv/year)



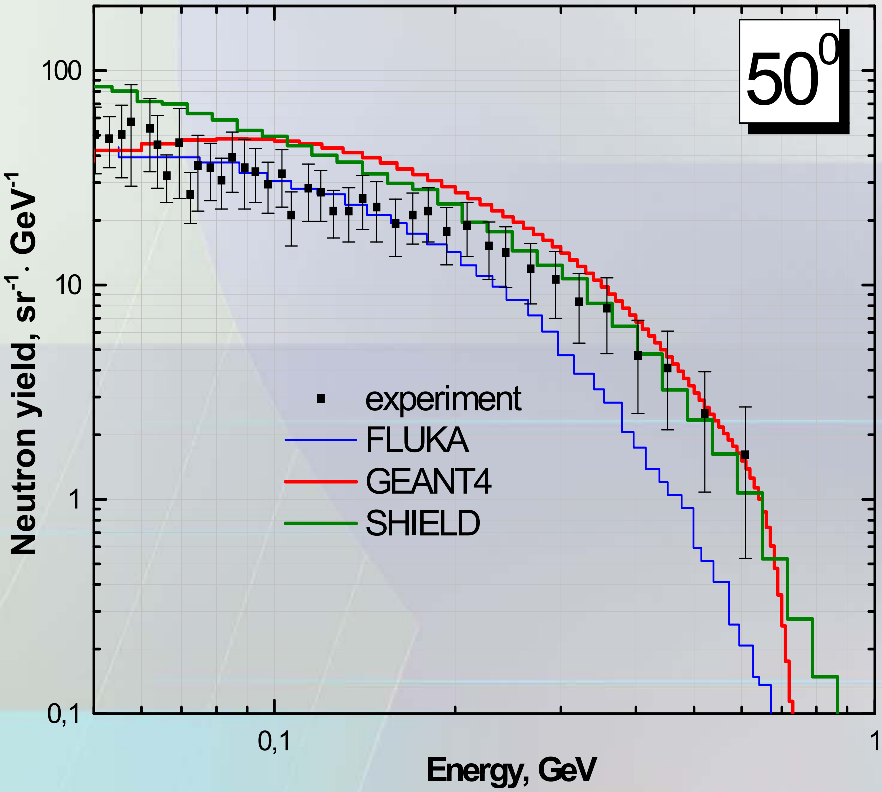


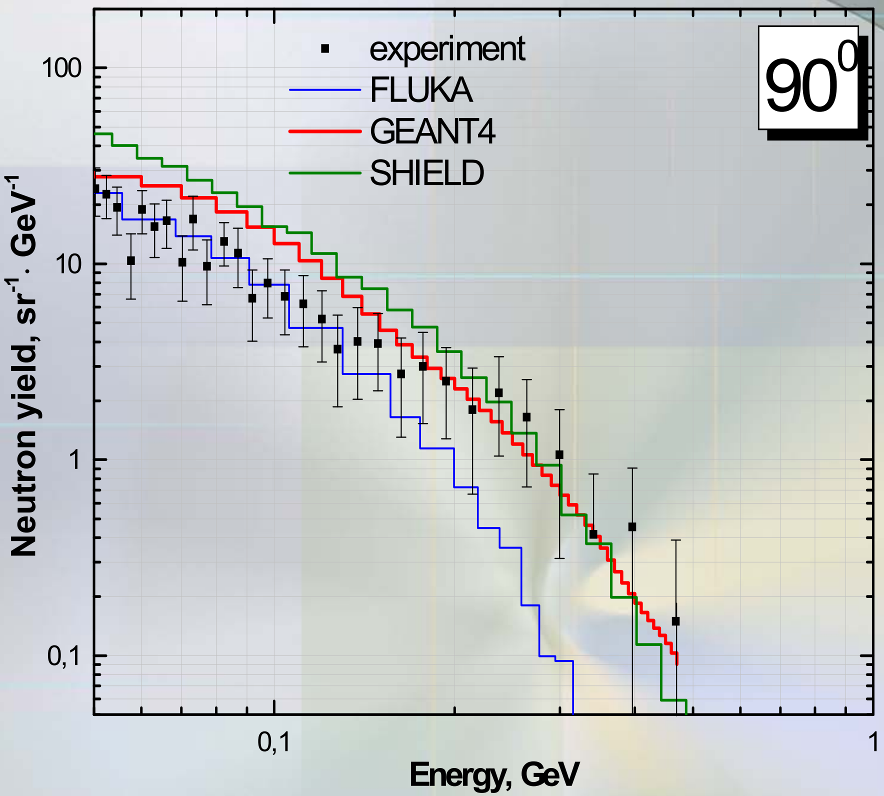
The radial distribution of the "skyshine" neutron equivalent dose at the deuteron acceleration (~ 10^9 d/s, 2,1 GeV/n)

The upper shielding of the Nuclotron tunnel is not assembled now !

The prognostication of radiation environment around the NICA complex was carried out by GEANT4 code

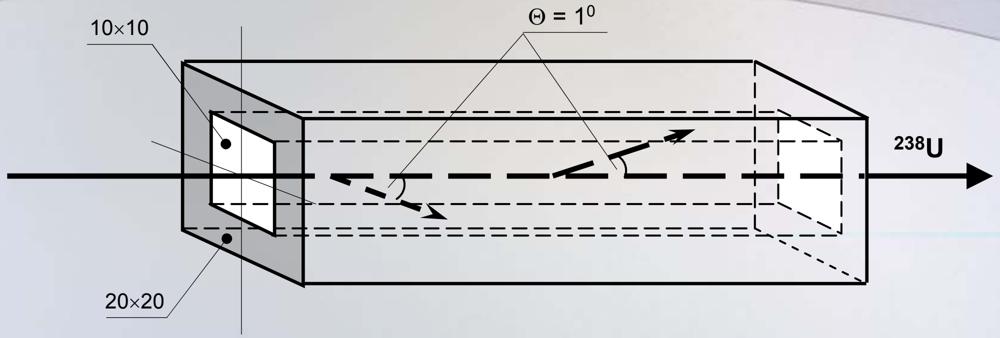
The verification of the various MC-codes (FLUKA, GEANT4, SHIELD) with available experimental data was done preliminary for selection of the most reliable code for our tasks [NIM B 266(2008) 4058-4060].





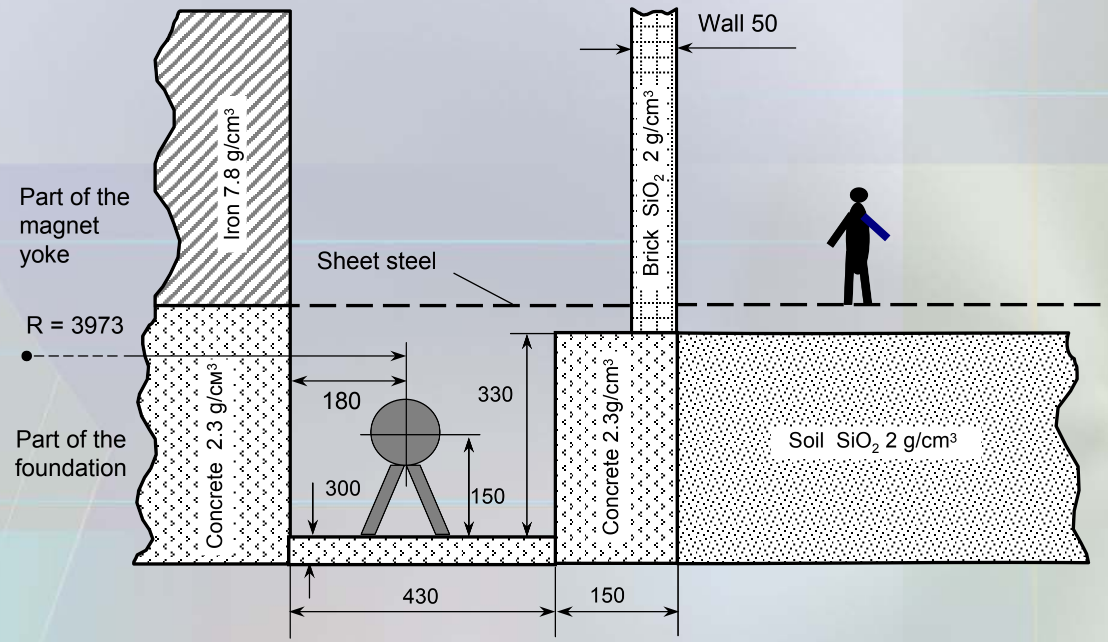
Double differential neutron yields at 50^0 and 90^0 from thick iron target induced by ^{238}U nucleus with energy 1 GeV/n simulated by the FLUKA, GEANT4 and SHIELD codes and measured at the GSI

GEOMETRY MODELLING OF THE NUCLOTRON



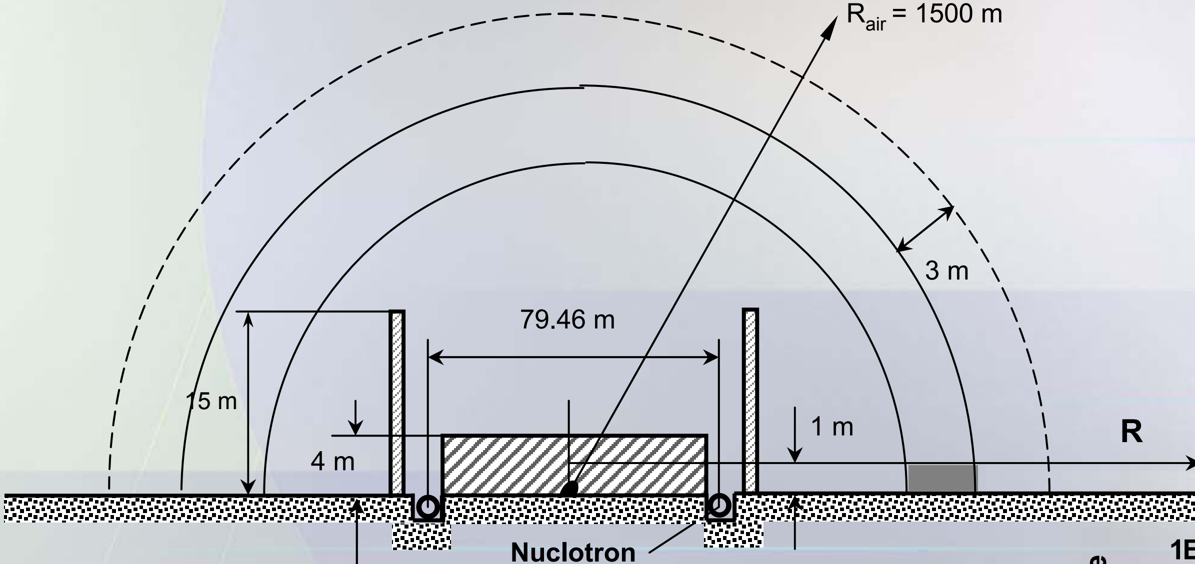
The incidence points are distributed uniformly over the vacuum chamber inner surface

The imitating element of the Nuclotron ring used at the Monte-Carlo simulations. All dimensions are in cm

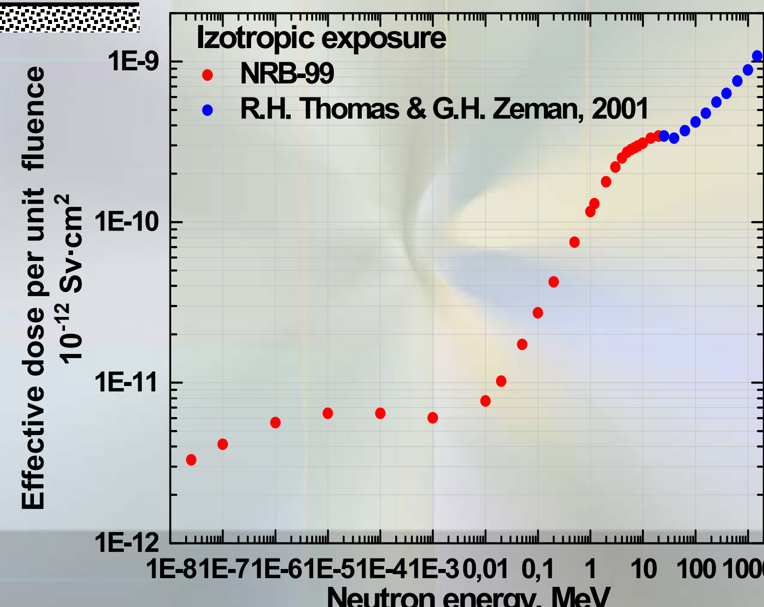


The Nuclotron simplified geometry employed at the simulations. All dimensions are in cm

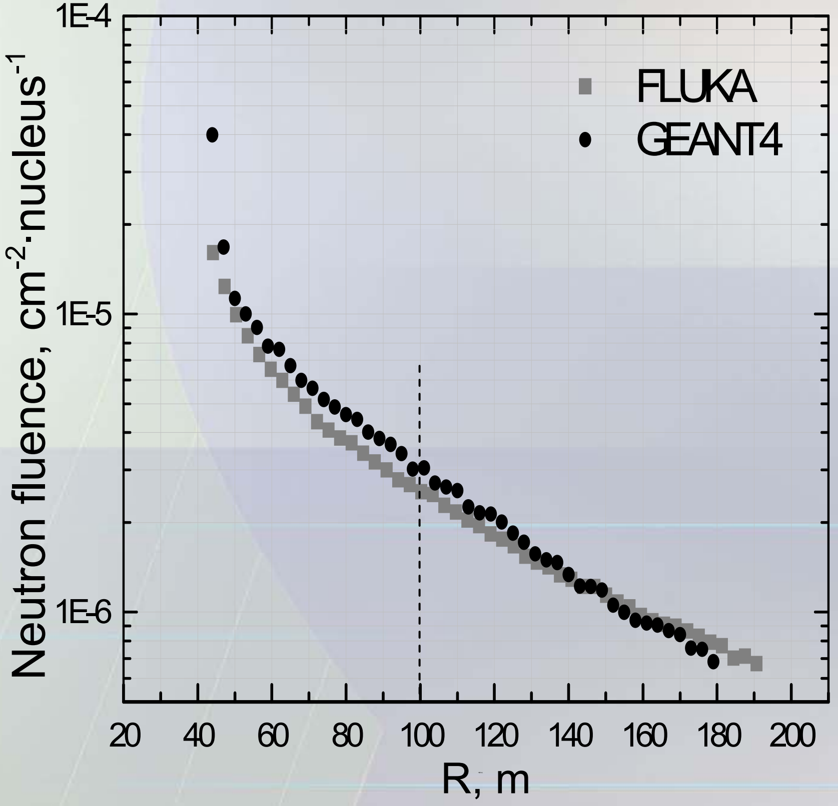
MODELLING OF THE NEUTRON "SKYSHINE" EFFECT



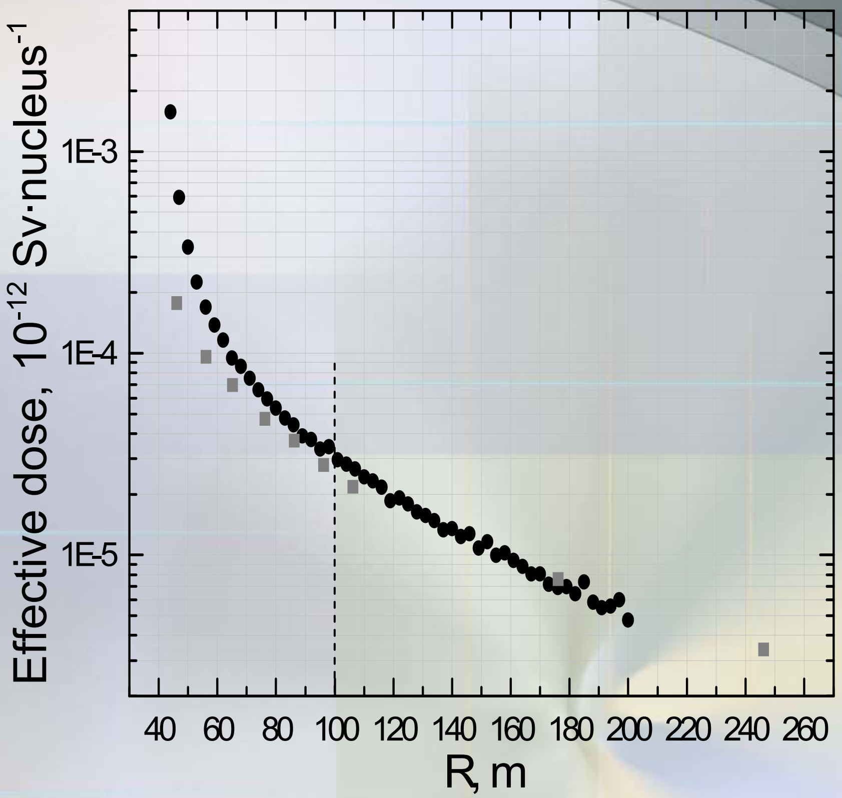
The geometry of the simulations of the "skyshine" neutron dose spatial distribution around the Nuclotron



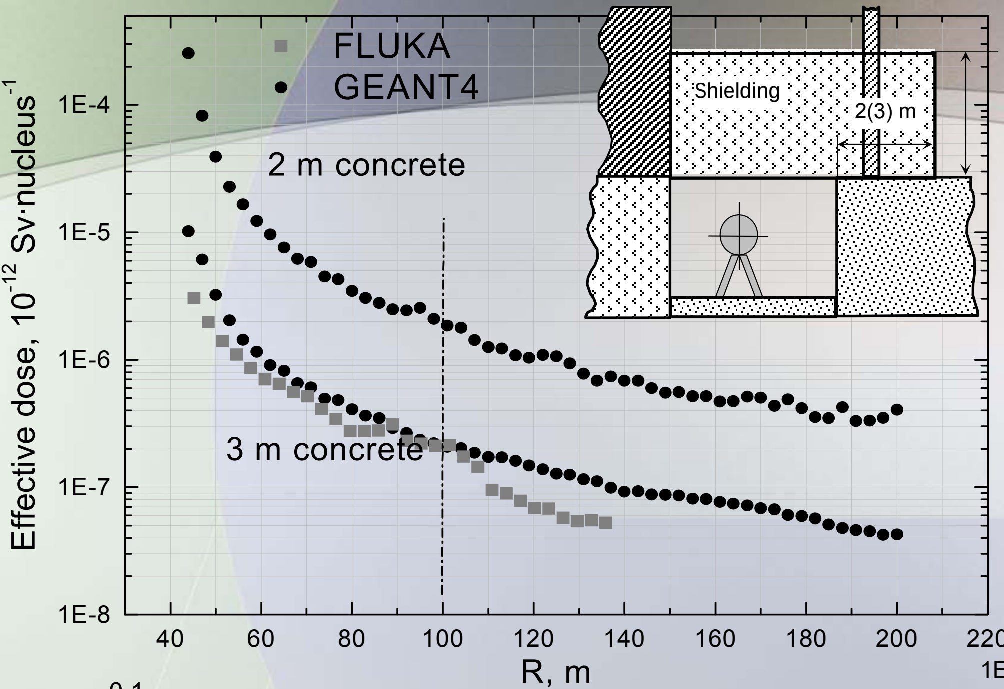
NUCLOTRON, ^{238}U, 3.5 GeV/n



The “skyshine” neutron fluence radial distribution at the absence of the upper shielding of the Nuclotron ring

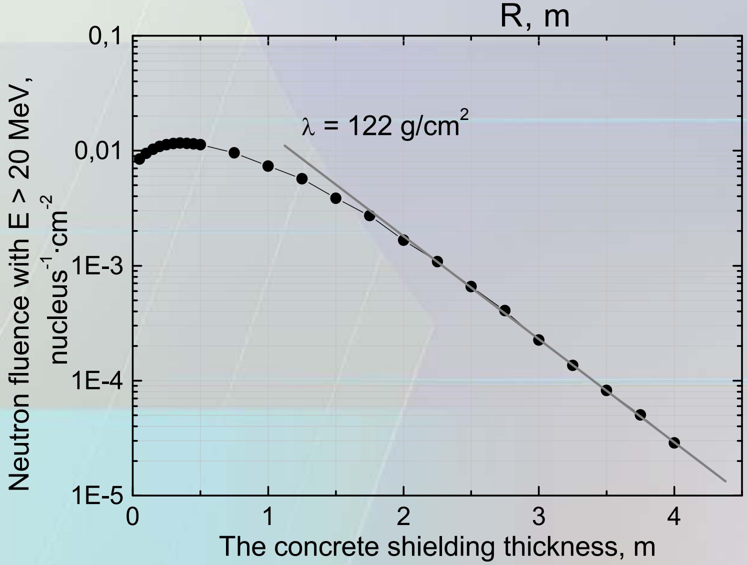


The “skyshine” neutron effective dose radial distribution at the absence of the upper shielding of the Nuclotron ring

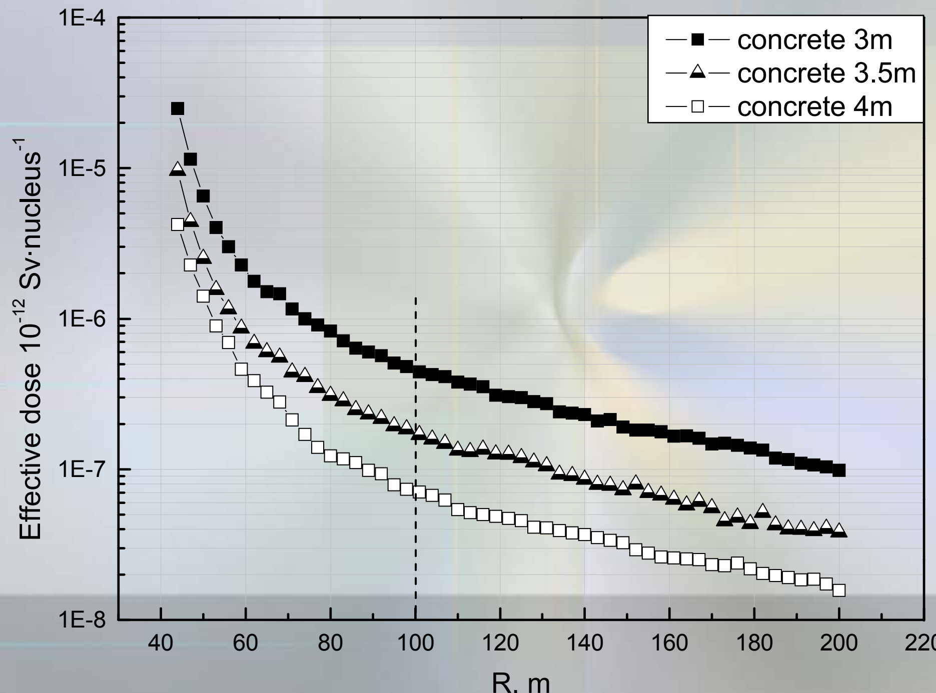


The "skyshine" neutron effective dose radial distributions at the presence of the upper concrete shielding of the Nuclotron ring with thickness 2 and 3 m **(^{238}U, E= 3,5 GeV/n)**

The "skyshine" neutron effective dose radial distributions at the presence of the upper concrete shielding of the Nuclotron ring with thickness 3; 3,5 and 4 m **(^{238}U, E=4,5 GeV/n)**



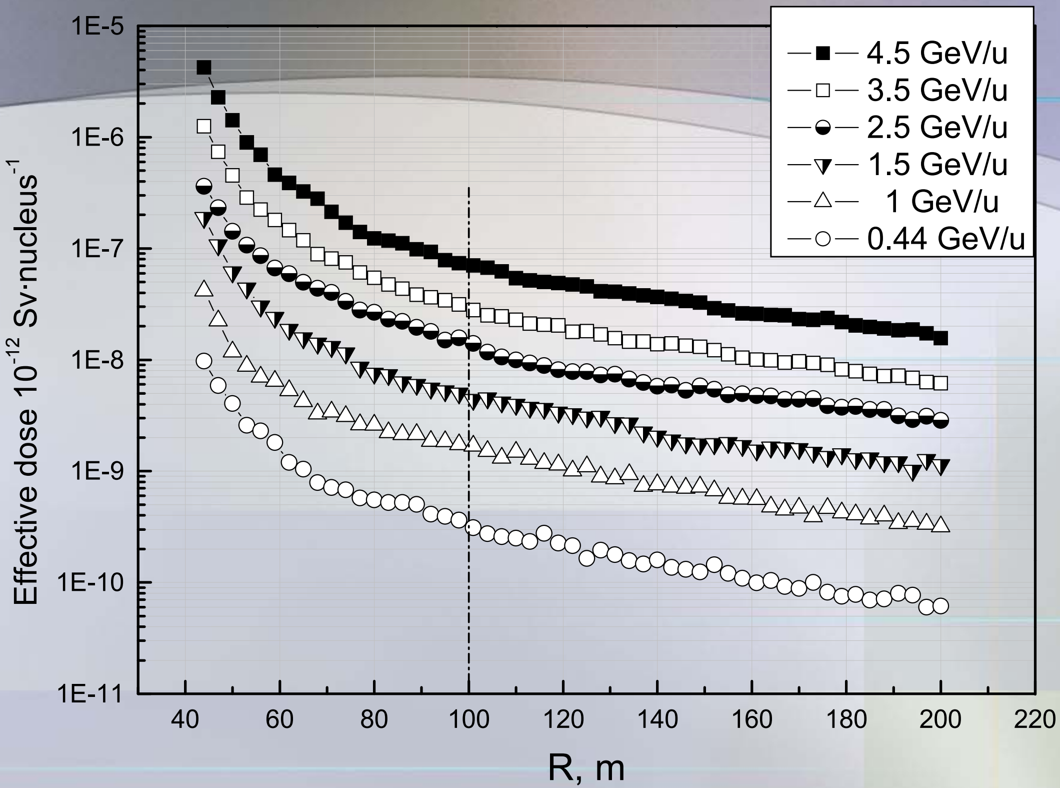
The relaxation of the neutron fluence within the concrete **(^{238}U, E= 3,5 GeV/n)**



The most uncertain problem at the new accelerator design is the problem of correct assignment of the particle losses. For the maximum estimation of the radiation situation around the Nuclotron the following energy distribution of the uranium beam losses within the Nuclotron ring was assumed:

1. Total beam losses - $5 \cdot 10^8$ nuclei/s ($I_{inj} = 1{,}5 \cdot 10^9$ nuclei/s, $I_{ext} = 1 \cdot 10^9$ nuclei/s)
2. Energy distribution:

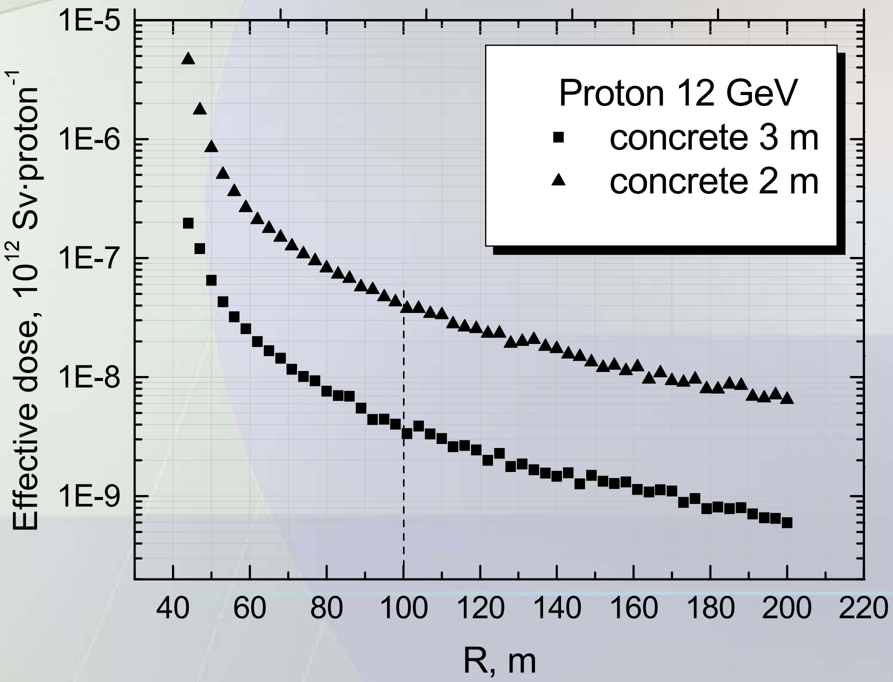
0,44 GeV/n	-	$1 \cdot 10^8$ nuclei/s
1,0 GeV/n	-	$5 \cdot 10^7$ nuclei/s
1.5 GeV/n	-	$5 \cdot 10^7$ nuclei/s
2.5 GeV/n	-	$5 \cdot 10^7$ nuclei/s
3.5 GeV/n	-	$5 \cdot 10^7$ nuclei/s
4.5 GeV/n	-	$2 \cdot 10^8$ nuclei/s
	Total:	$5 \cdot 10^8$ nuclei/s



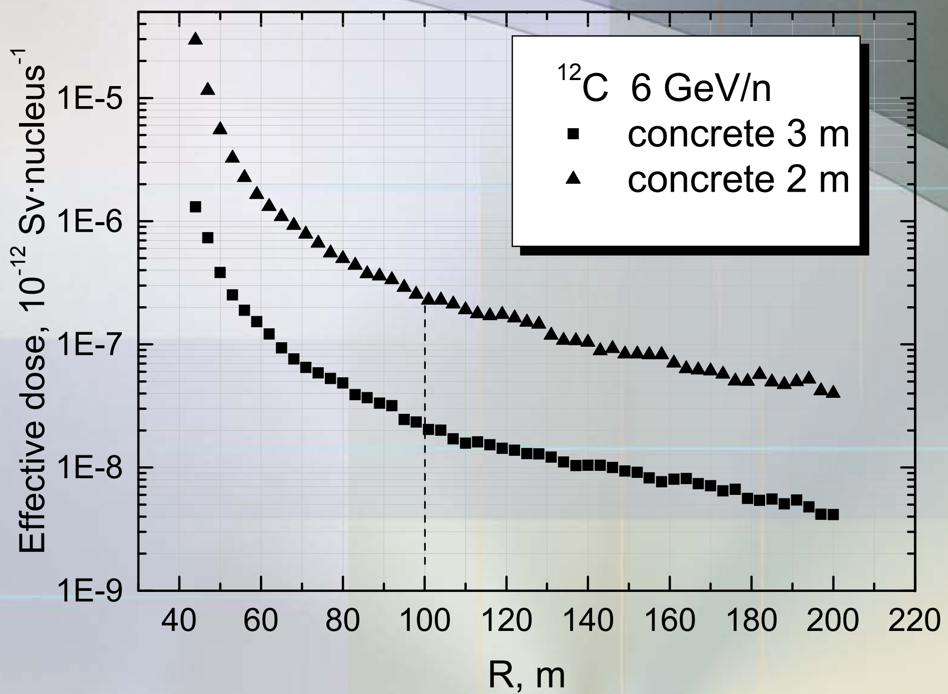
The radial distribution of the “skyshine” neutrons effective dose for different nuclei energies at the upper shielding from 4 m ordinary concrete

SUMMARY DOSE:

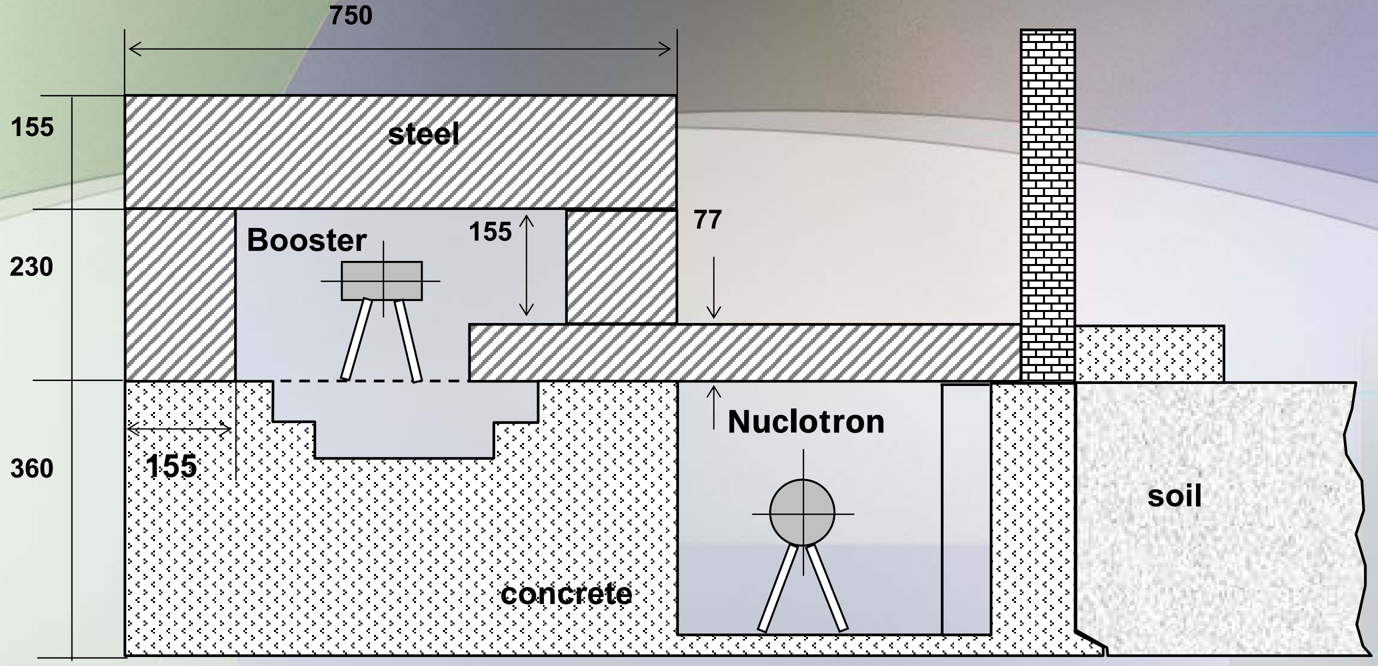
0,63 mSv/year with 3,5 m shielding thickness



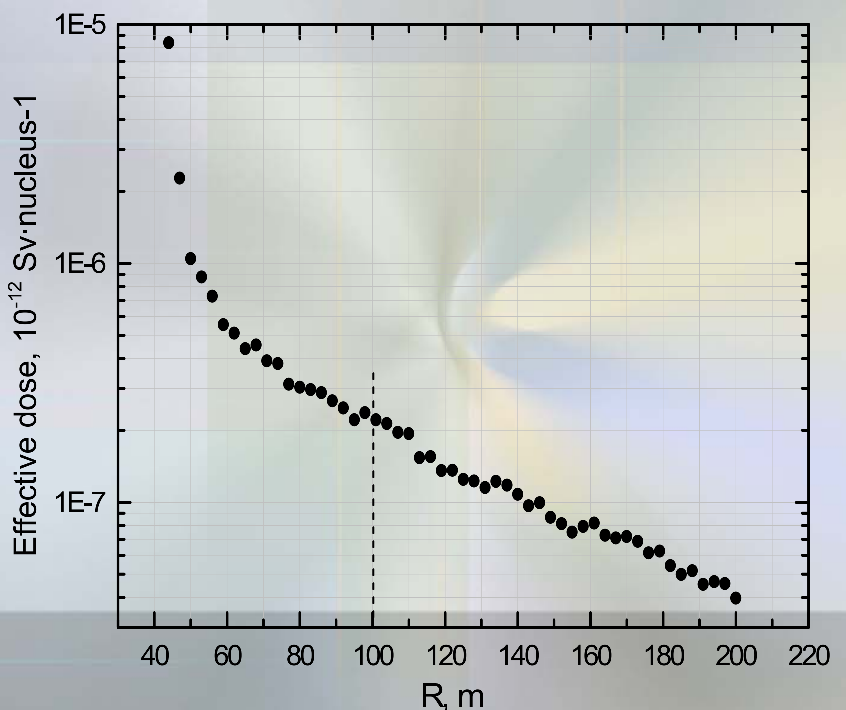
The “skyshine” neutron dose radial distribution for 12 GeV proton beam



The “skyshine” neutron dose radial distribution for 6 GeV/n carbon beam

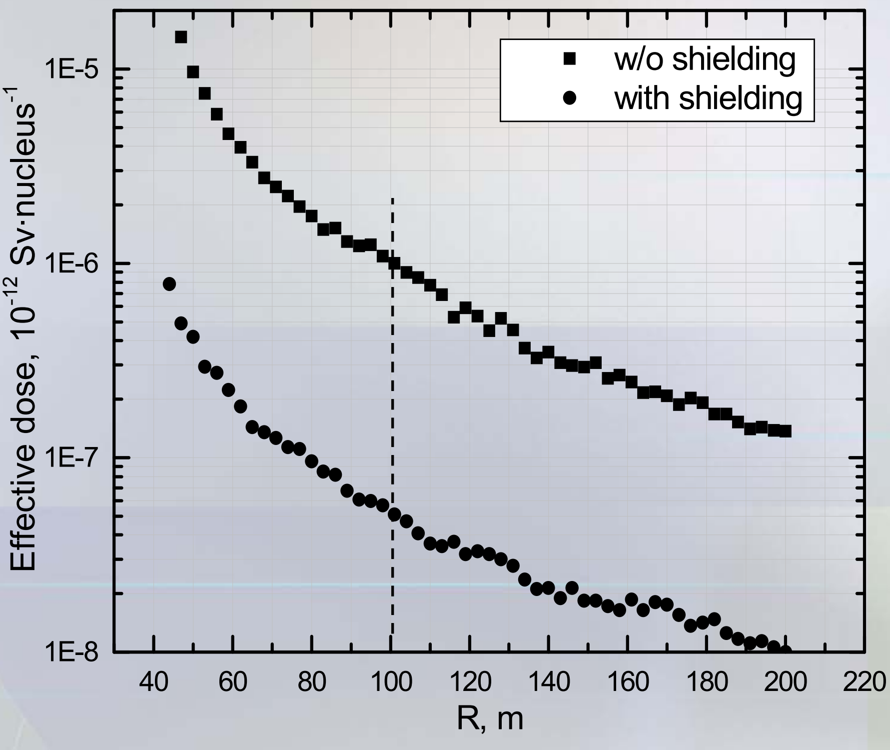


The design variant of the corbel back Nuclotron shielding with using of the lower steel beams of the synchrophasotron magnets. All dimensions are in cm



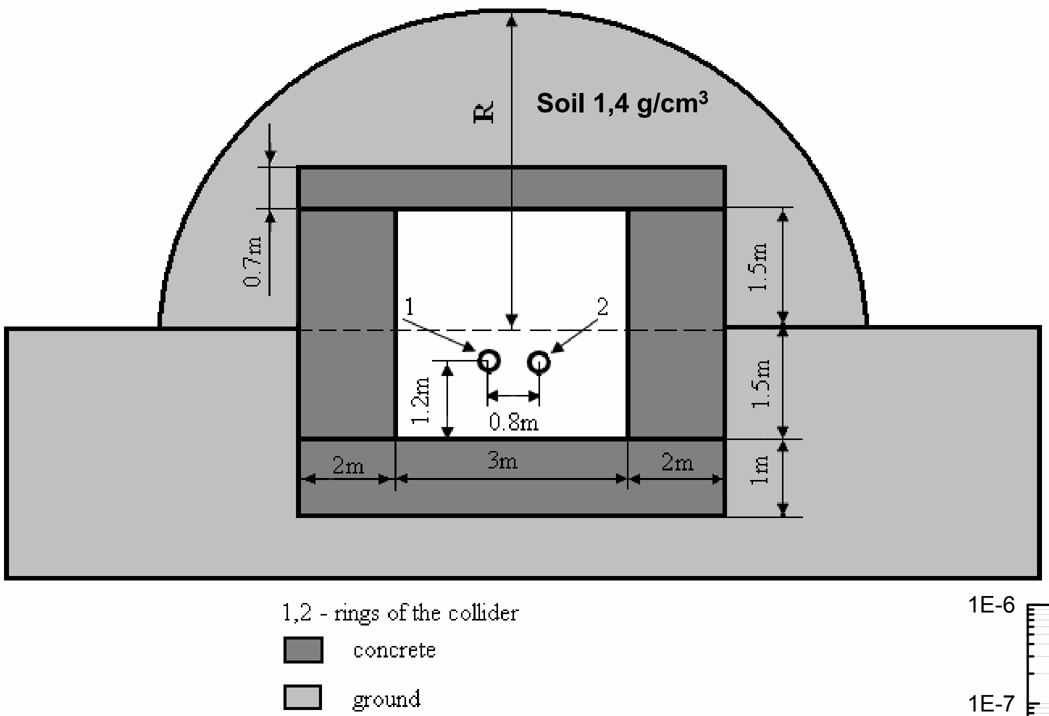
The “skyshine” neutron effective dose radial distribution for the design variant with the steel corbel back shielding of the Nuclotron **(^{238}U, E= 3,5 GeV/n)**

BOOSTER



The “skyshine” neutron effective dose radial distributions at the presence of the booster linear spaces shielding from 1 m concrete and without the shielding **(^{238}U, E= 0,44 GeV/n)**

COLLIDER (VARIANT 2)



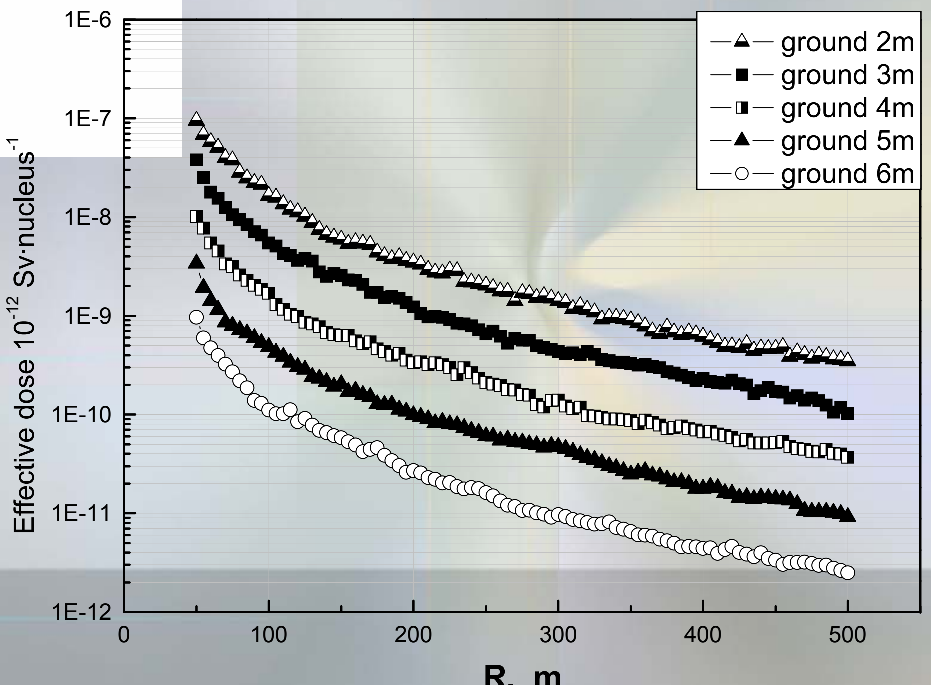
(^{238}U, E= 4,5 GeV/n)

Collider beam losses:

2 rings $\times$ $5 \cdot 10^7$ nuclei/s

Yearly “skyshine” neutron equivalent dose (mSv)

Thickness of the soil [m]	Distance from the collider center [m]				
	100	200	300	400	500
2	1.641	0.347	0.141	0.061	0.034
3	0.545	0.123	0.043	0.023	0.098
4	0.169	0.033	0.014	0.0066	0.0037
5	0.048	0.01	0.0047	0.0018	0.00092
6	0.011	0.0027	0.00097	0.00044	0.00025



The authors thank Prof. A.S. Sorin, Prof. I.N. Meshkov, V.G. Trubnikov and N.N. Agapov for the help in the work and useful discussions

THANK FOR ATTENTION