GEANT4 CODE APPLICATION FOR RADIATION ENVIONMENT PROGNOSTICATION AT THE NICA COMPLEX

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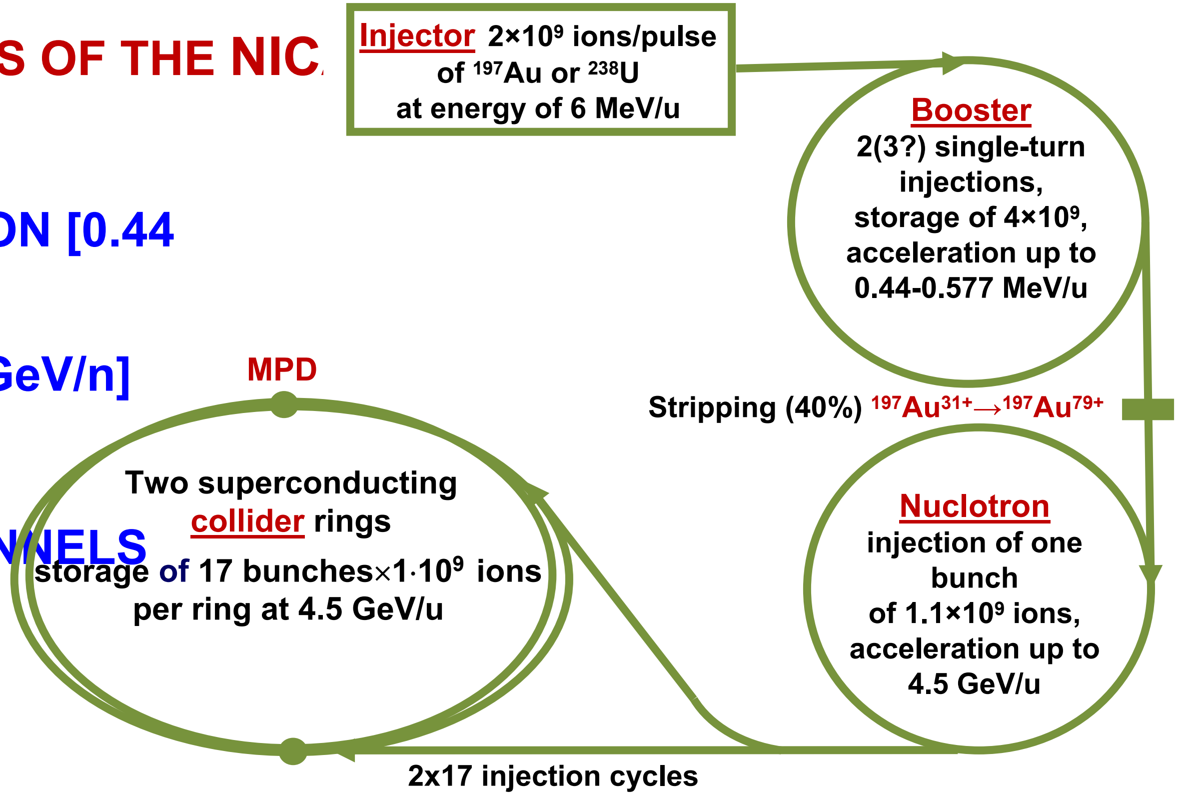
MAIN RADIATION SOURCES OF THE NIC

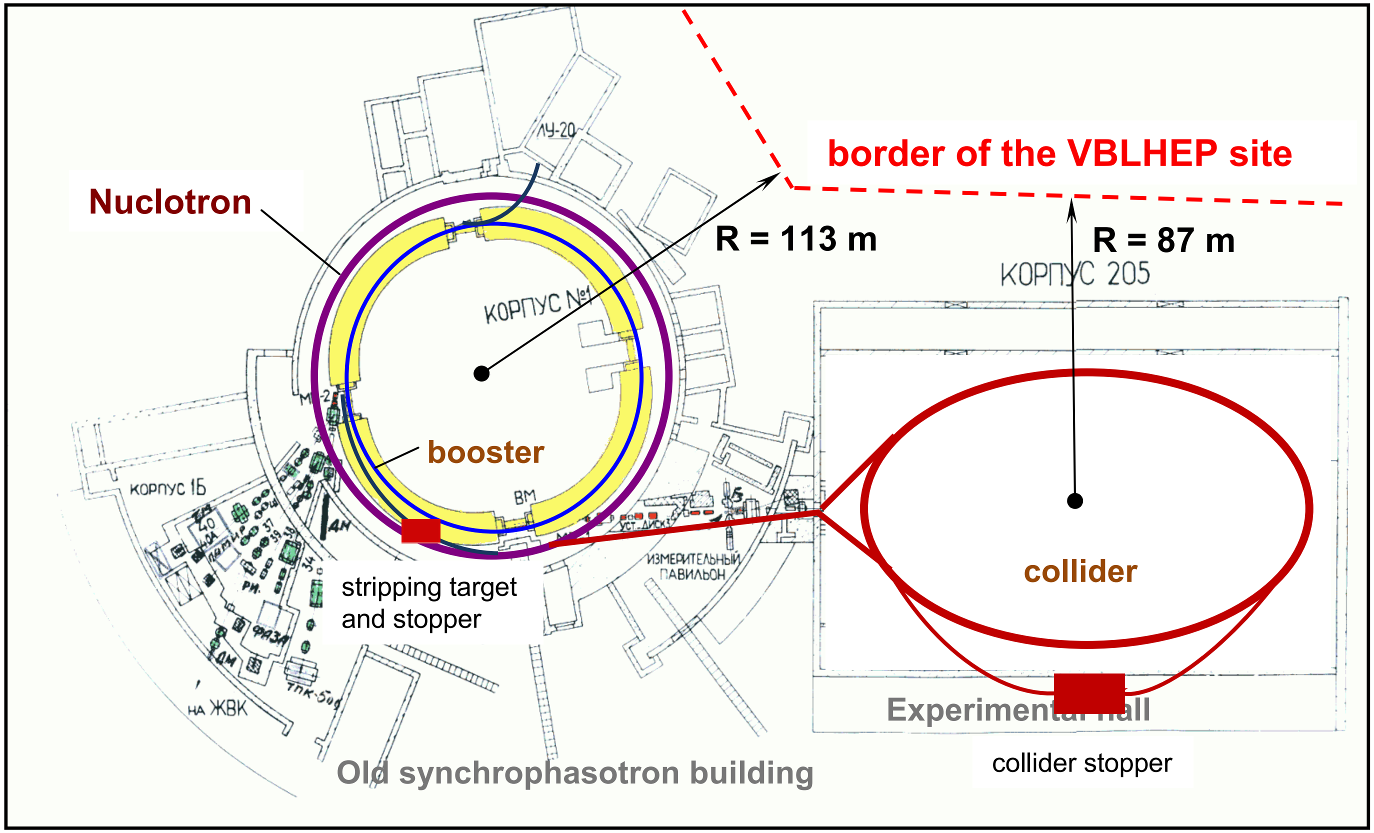
- ❑ BOOSTER [0.44 GeV/n]
- ❑ BEAM STRIPPING STATION [0.44 GeV/n]
- ❑ NUCLOTRON [0.44 – 4.5 GeV/n]
- ❑ COLLIDER [4.5 Gev/n]
- ❑ BEAM TRANSPORT CHANNELS
- ❑ BEAM STOPPERS



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

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

The most heavy radiation situation at the NICA exploitation will be at acceleration of ^{197}Au or ^{238}U ions up to 4.5 GeV/n energy (4500 h per year). The summary duration of all other runs at the Nuclotron (protons, deuterons, light ions) will not exceed 1000 h per year.



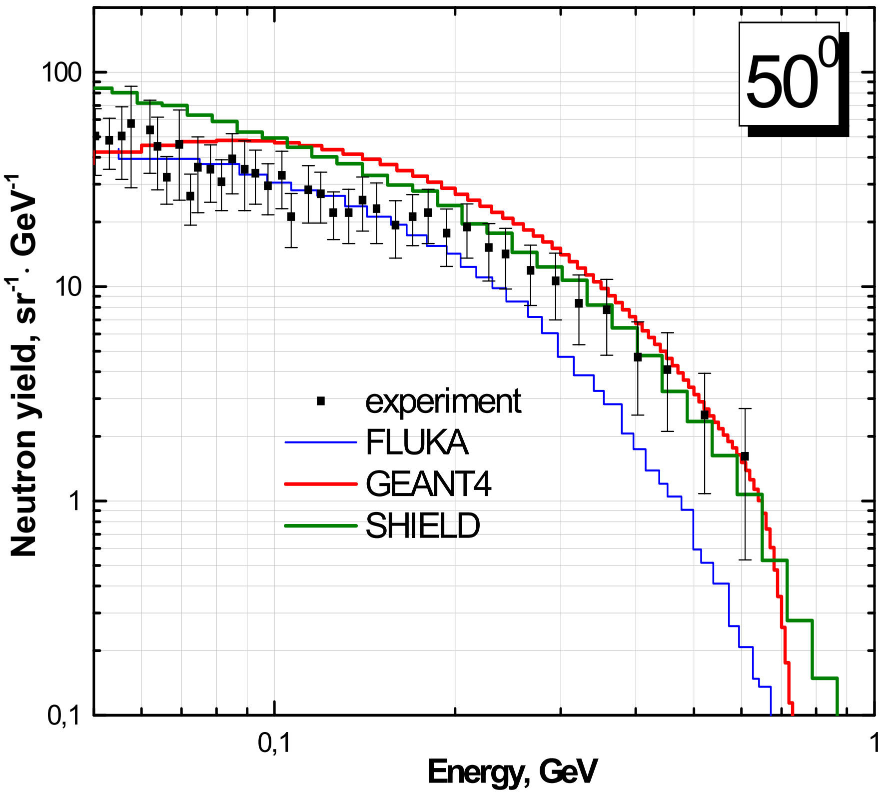
There are four crucial points at the NICA radiation shielding design:

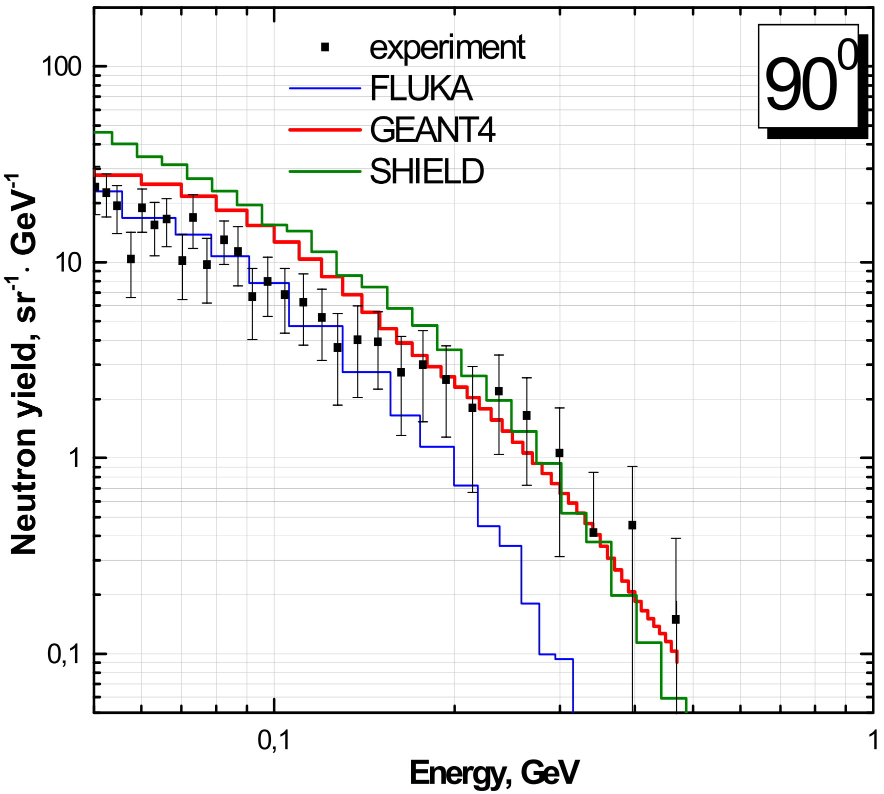
- ❑ the source term problem;
- ❑ neutron fluence and dose attenuation characteristics of the shielding;
- ❑ simulation of the spatial distributions of “skyshine” neutron doses around every radiation source;
- ❑ estimation of the beam loss for every element of NICA complex

In accordance with “Main sanitary rules of radiation protection guarantee for workers and public OSPORB-99” the equivalent dose of radiation from new nuclear facilities at the border of control area must be < 0.5 mSv/year

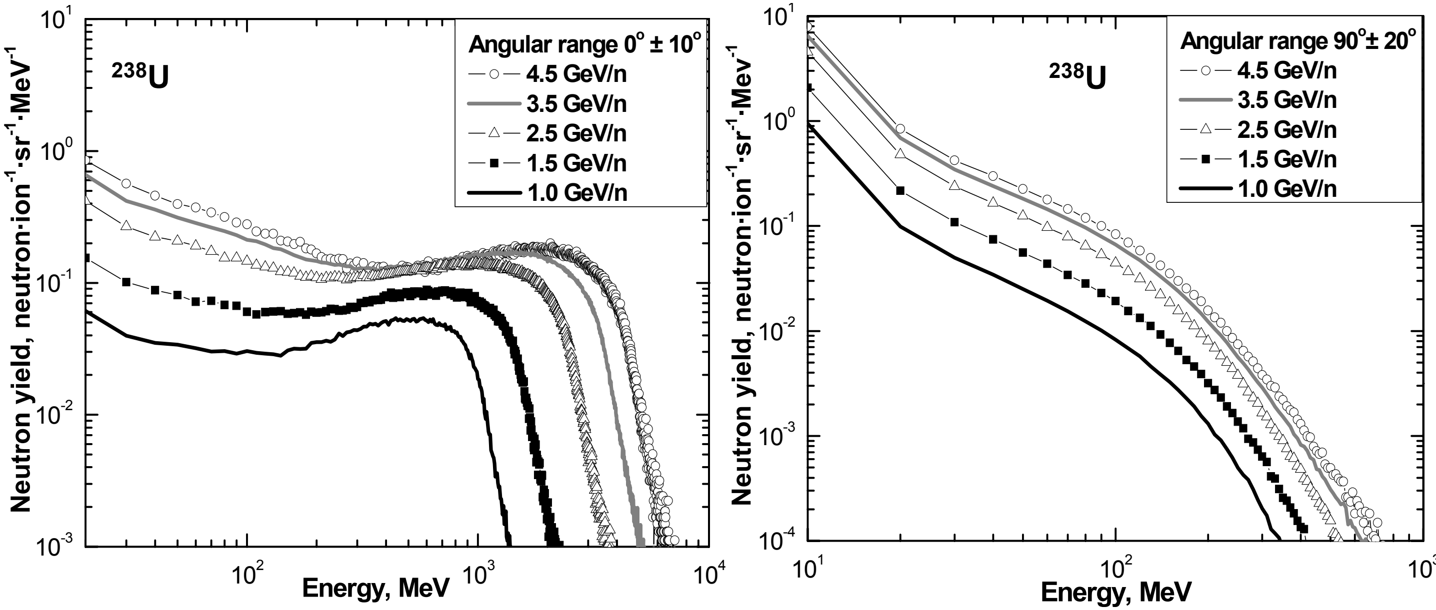
The prognostication of radiation environment around the NICA complex was carried out by GEANT4 code

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)

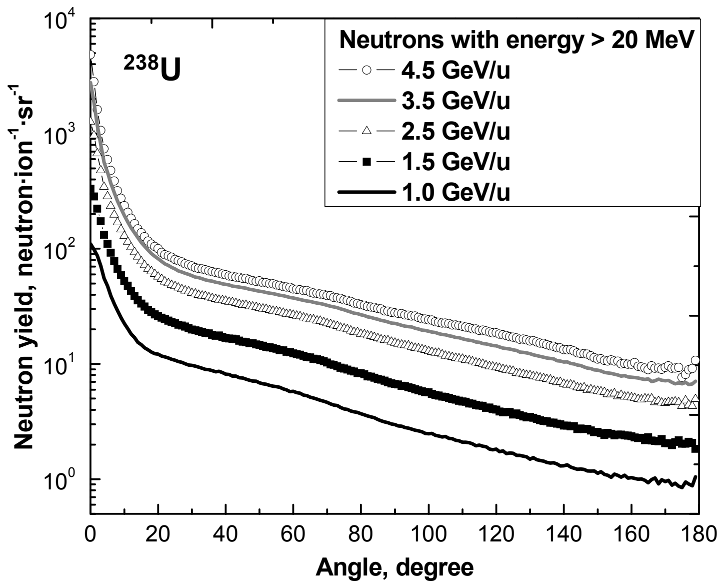




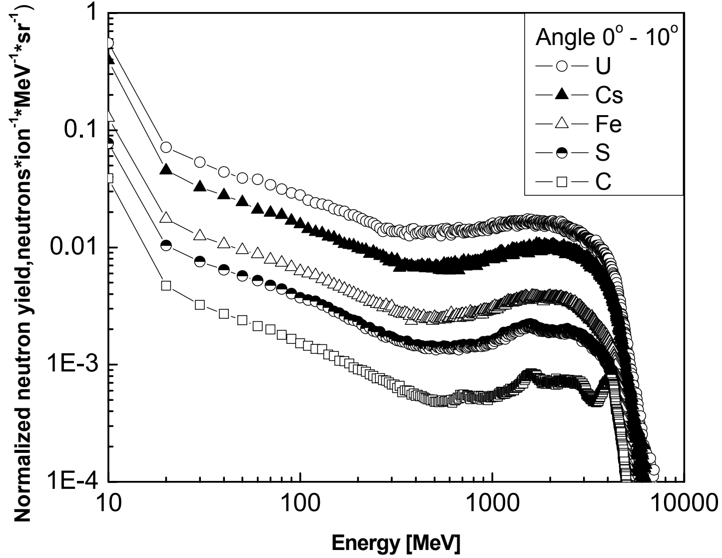
Double differential neutron yields at 50^0 and 90^0 from thick iron target induced by ^{238}U nucleus with energy 1 GeV/n simulated by the FLUKA, GEANT4 and SHIELD codes and measured at the GSI



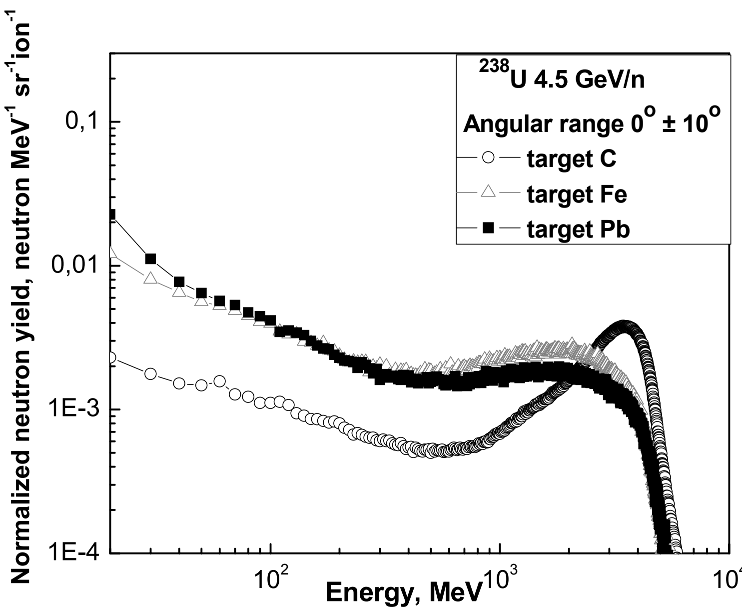
Dependences of the neutron spectra from the thick Fe target in the forward and lateral directions on the uranium projectile energy

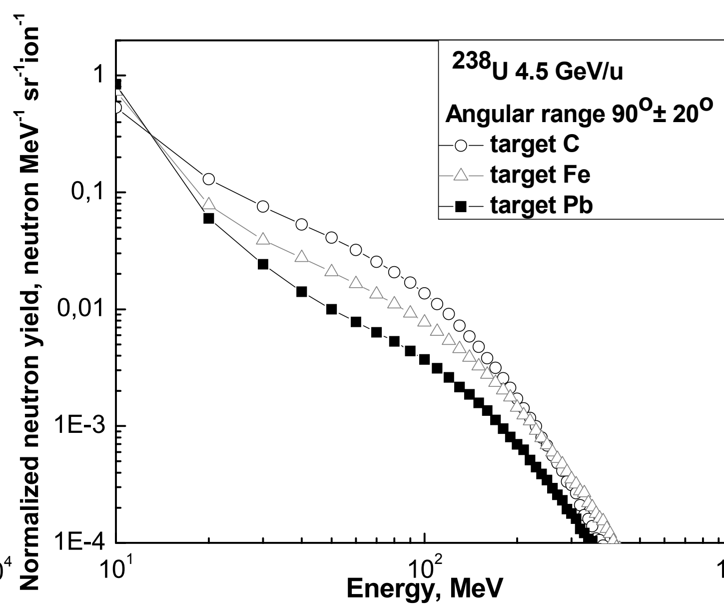


Angular dependences of the yield of neutrons with energies above 20 MeV from the thick Fe target on the uranium projectile energy

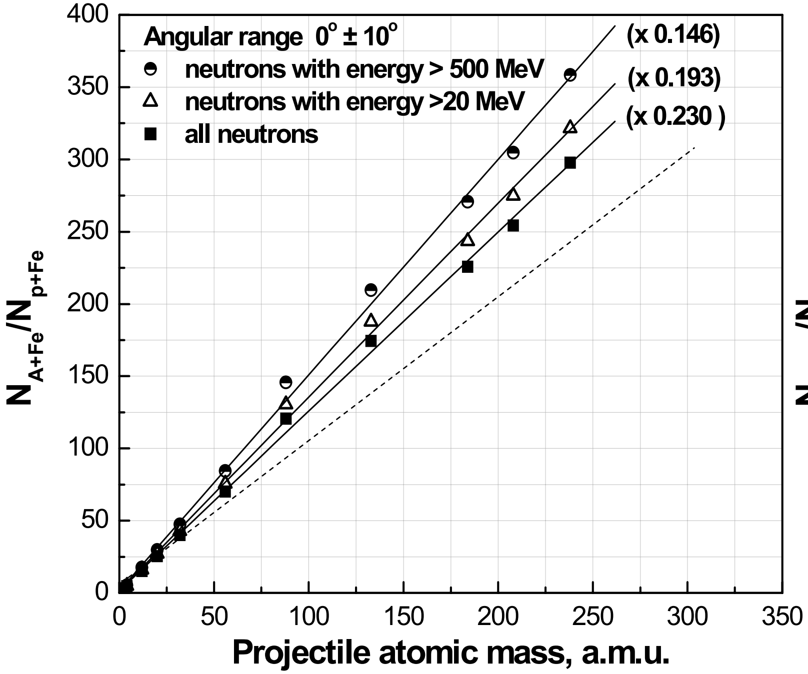


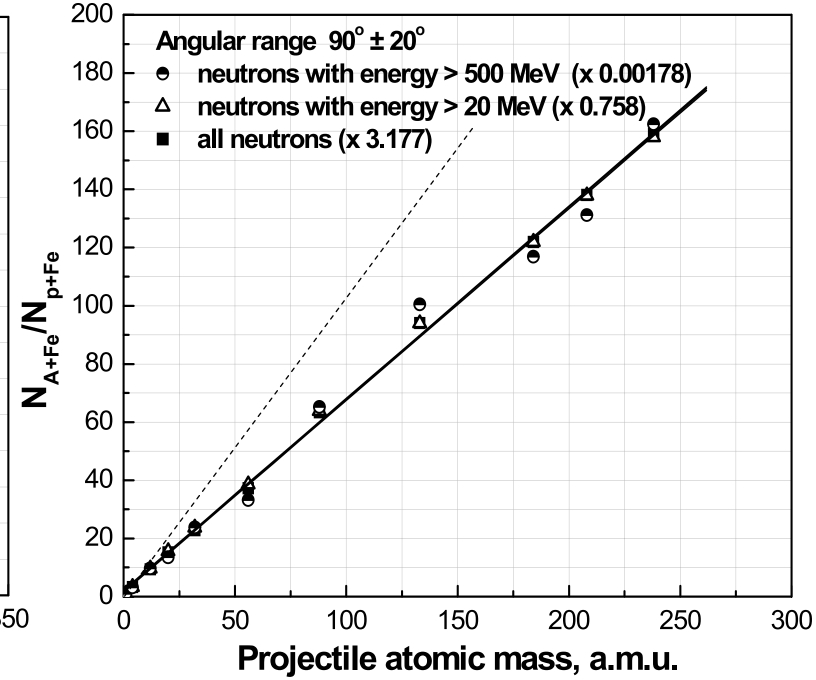
Dependences of the neutron spectra from the 4.5 GeV/n nuclei on the projectile mass n the forward directions

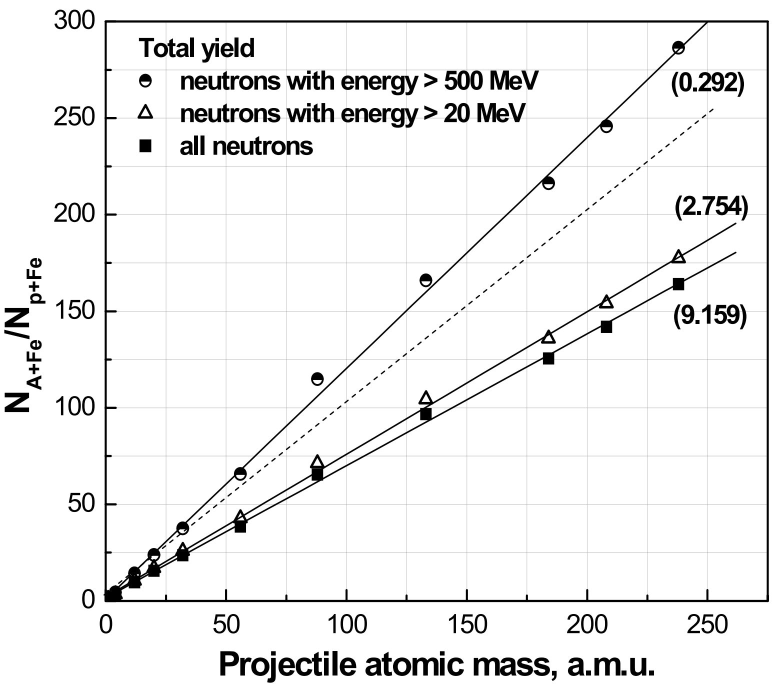




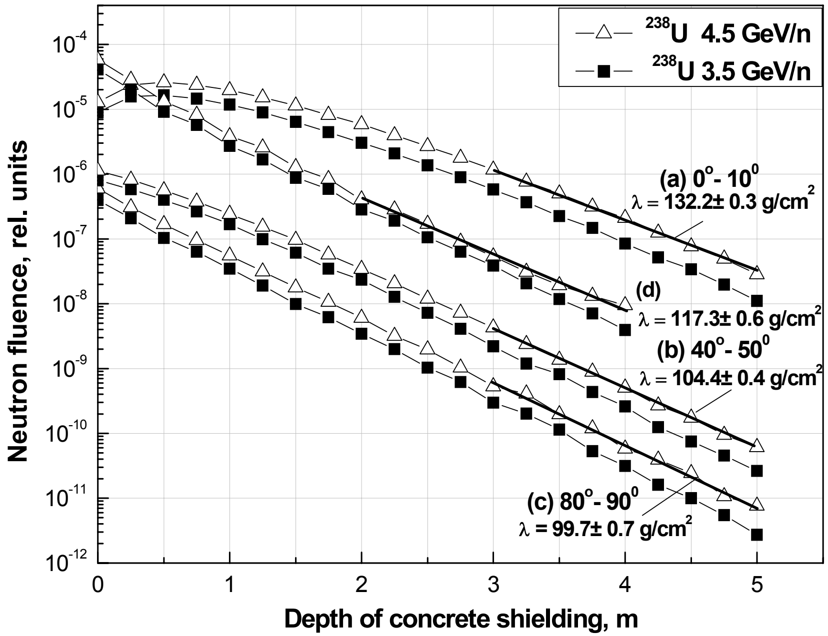
Dependences of the neutron spectra from the 4.5 GeV/n uranium nuclei on the target material in the forward and lateral directions



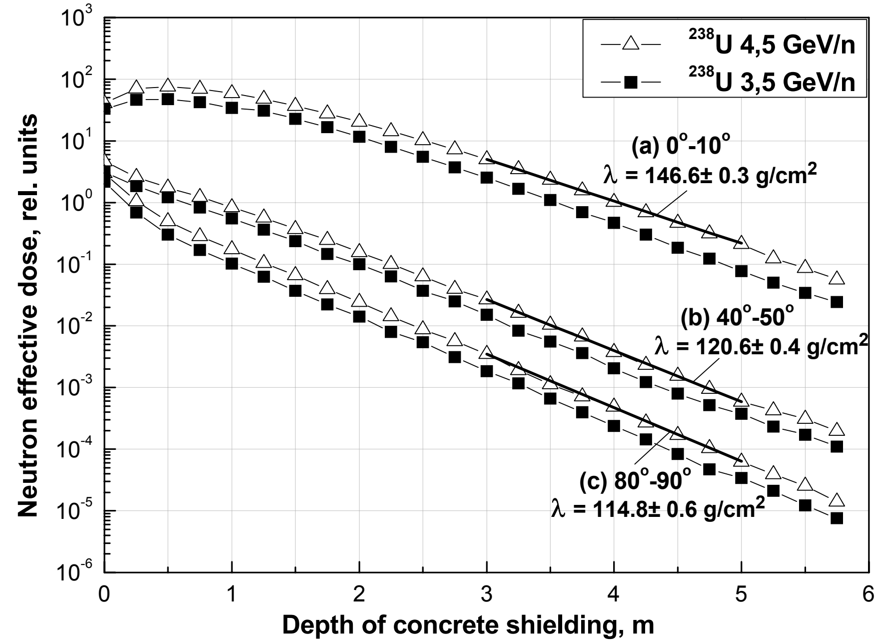




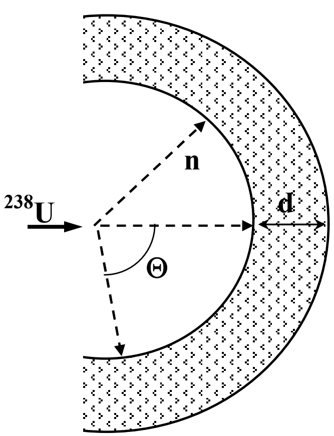
Relative secondary neutron yields from the thick Fe target bombarded by beam projectiles with different atomic masses and energies of 4.5 GeV/n. N_{A+Fe} is the neutron yield for the beam projectiles, N_{p+Fe} is the neutron yield for 4.5 GeV proton beam. The solid lines are linear approximations. The dashed lines show the A-equivalent proton approaches. The factors in round brackets are the neutron yields per proton required to obtain the absolute values of the neutron yields for projectiles.



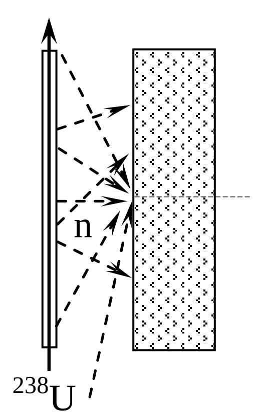
Total neutron fluence attenuation inside ordinary concrete shielding depending on the emission angle and uranium ion energy (a, b, c are the attenuation curves for the angular ranges 0°-10°, 40°-50° and 80°-90°, respectively, in the spherical shielding geometry). d is the attenuation curve for real lateral shielding of the accelerator ring



Neutron effective dose attenuation inside ordinary concrete shielding depending on the emission angle and uranium ion energy (a, b, c are the attenuation curves for the angular ranges 0°-10°, 40°-50° and 80°-90°, respectively, in the spherical shielding geometry)

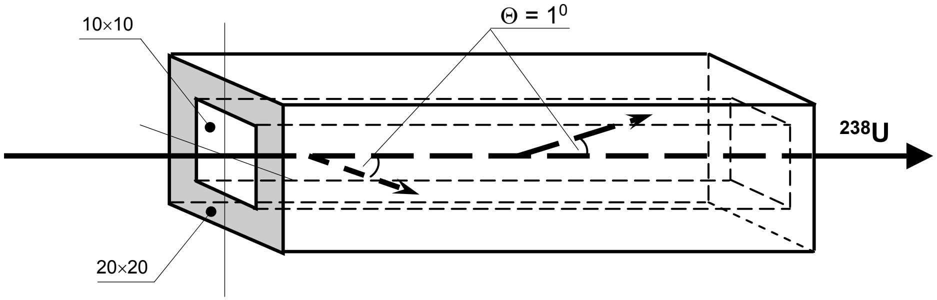


a,b,c
spherical
shielding
geometry



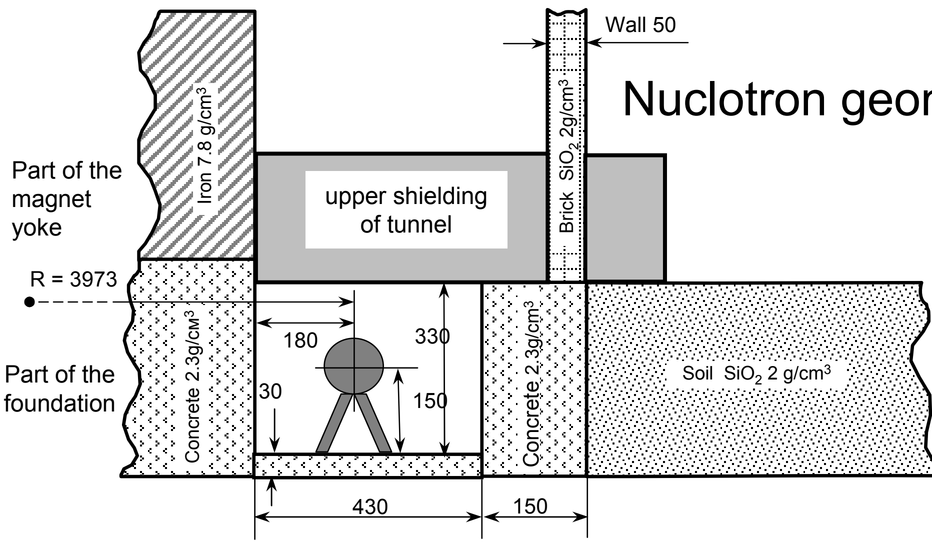
d
accelerator
lateral
shielding
geometry

GEOMETRY MODELLING OF THE NUCLOTRON

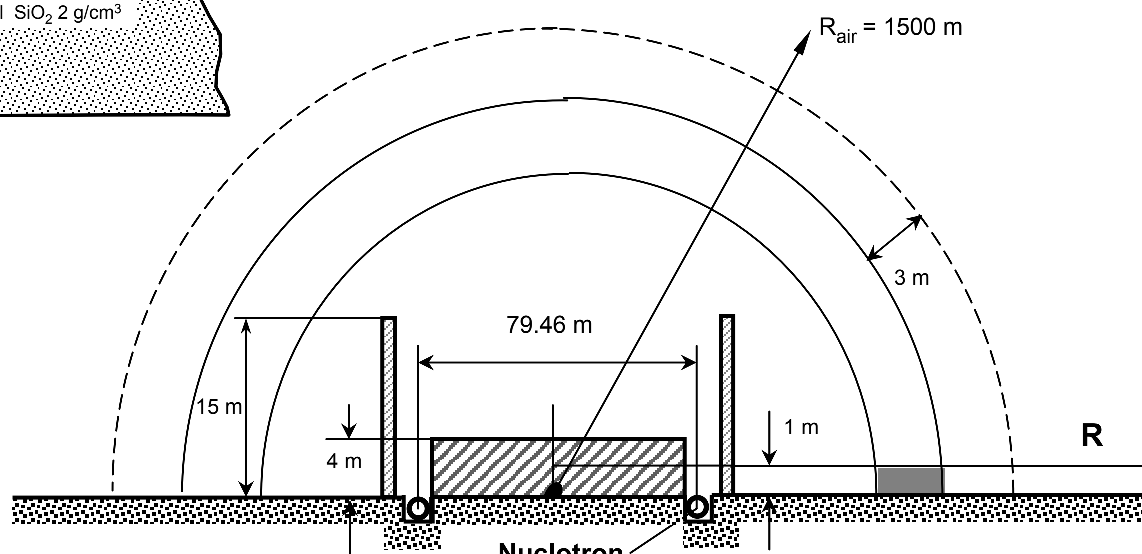


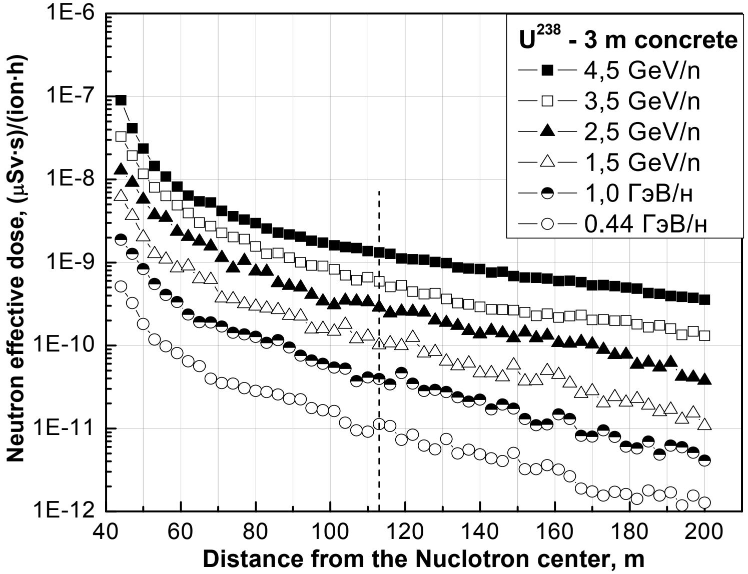
Nuclotron and colliler chambers;
ion transport channels

Nuclotron geometry



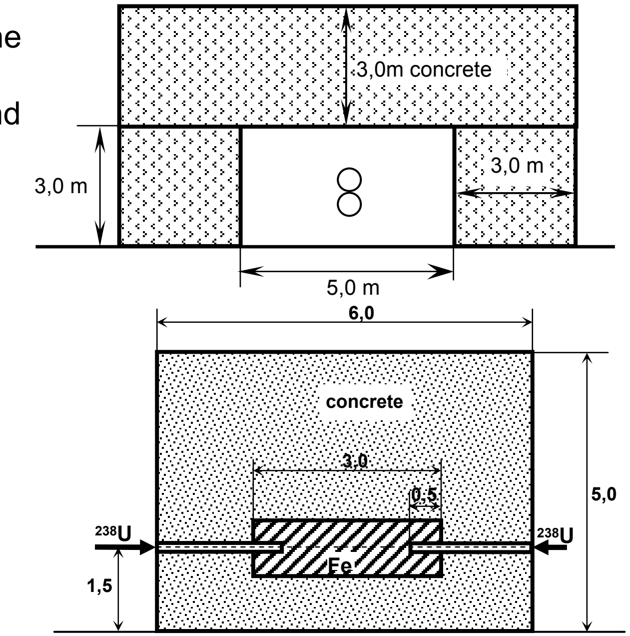
The geometry of the simulations of the "skyshine" neutron dose spatial distribution around the Nuclotron

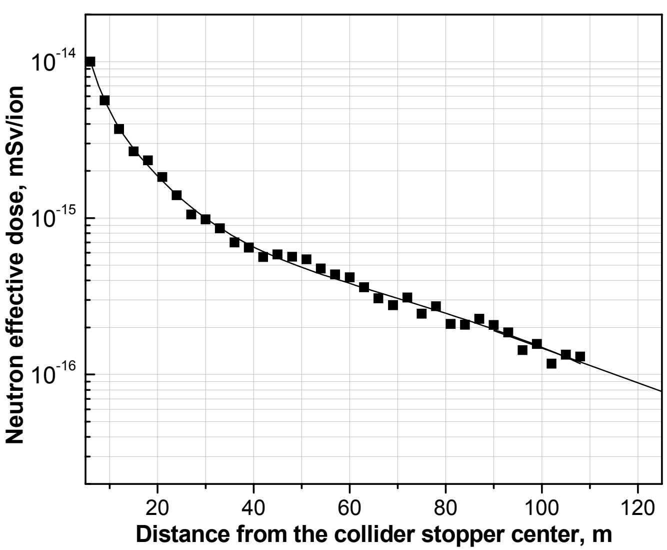




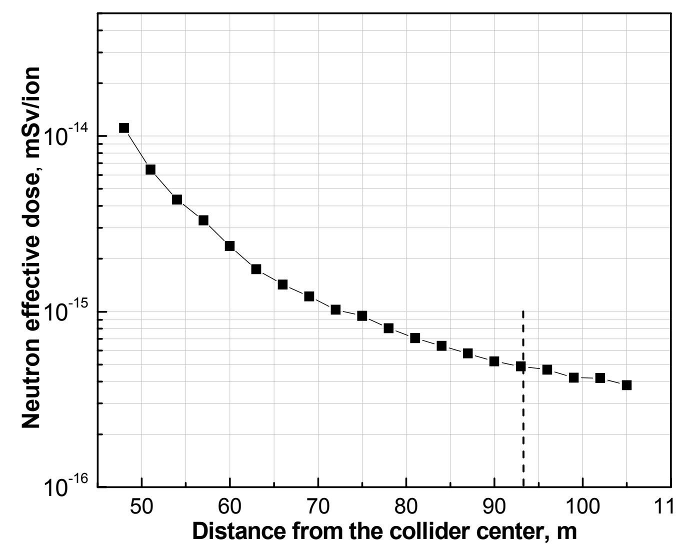
Radial distribution of the effective dose of “skyshine” neutrons from the Nuclotron ring

Design of the collider shielding and stopper





Radial distribution of the effective dose of “skyshine” neutrons from the collider stopper



Radial distribution of the effective dose of “skyshine” neutrons from the collider shielding

^{238}U

Radiation source	Booster	Stripping station stopper	Nuclotron	Beam transport channels	Collider	Collider stopper	All NICA complex
Annual neutron dose, mSv	0,0018 0,0018	0,0166 0,0166	0,0082 (3 m concrete) 0,0604 (2 m concrete)	0,0501 0,0501	0,0347 (3 m concrete) 0,0943 (2,5 m concrete)	0,0562 0,0562	0,1676 0,2794

^{197}Au

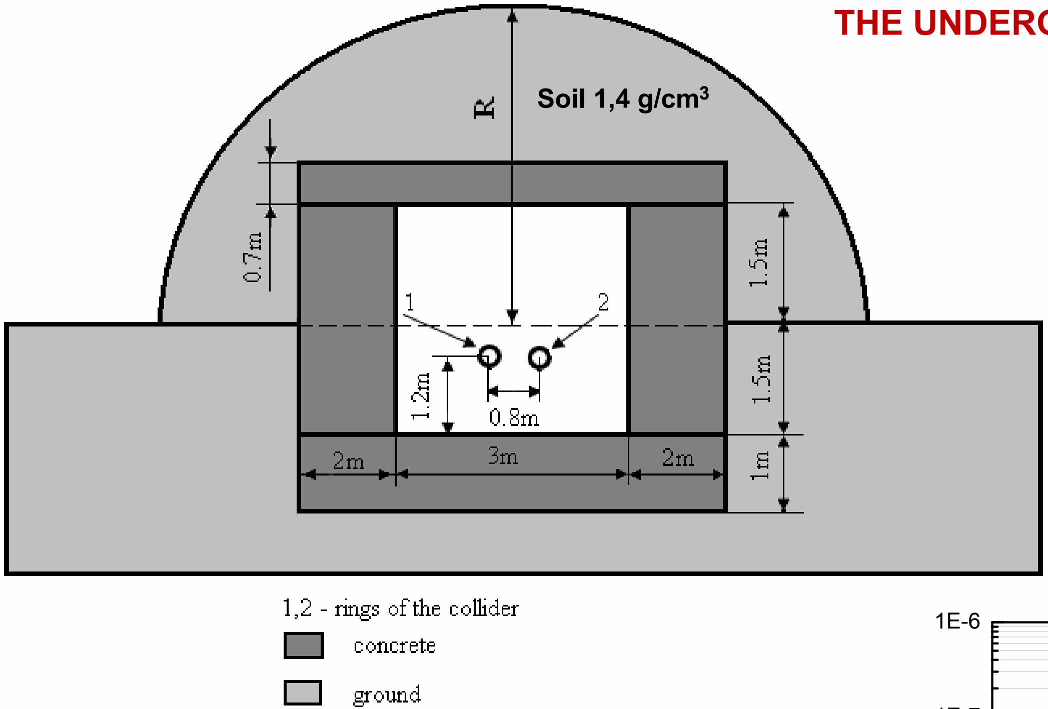
Radiation source	Booster	Stripping station stopper	Nuclotron	Beam transport channels	Collider	Collider stopper	All NICA complex
Annual neutron dose, mSv	0,0015 0,0015	0,0137 0,0137	0,0499 (2 m concrete) 0,0034 (77 см steel)	0,0414 0,0414	0,0779 (2,5 m concrete) 0,0779 (2,5 m concrete)	0,0465 0,0465	0,231 0,185

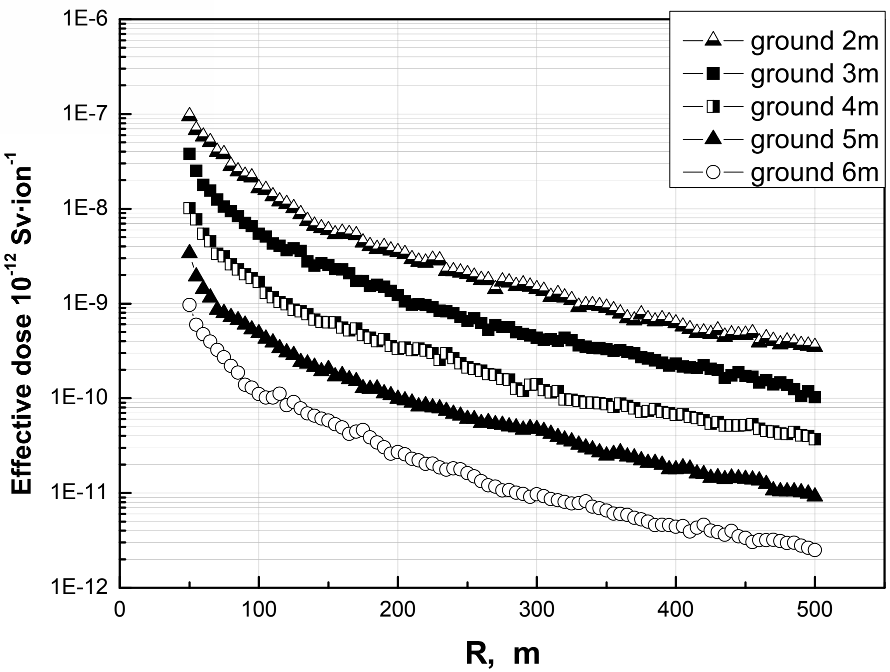
In the total, the proposed variants of NICA radiation sources shields will ensured the annual equivalent dose at the border of VBLHEP site less than 0,5 mSv (even taking into account 10%-contribution of gammas to the summary dose)

It permits the execution of additional proton runs at the Nuclotron with yearly duration 1500 h and intensity of the proton beam 10^{11} proton/cycle without exceeding of the prescribed dose limit of 0,5 mSv

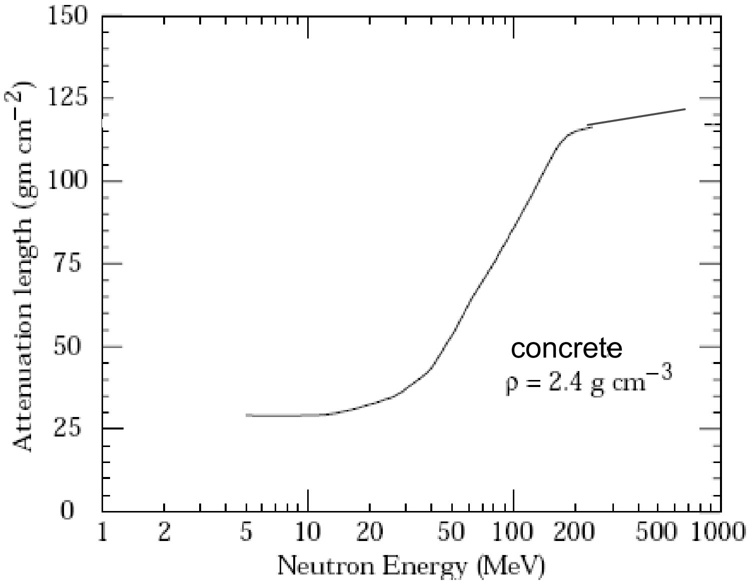
THE UNDERGROUND VARIANT OF THE COLLIDER DESIGN

^{238}U, 4.5 GeV/n

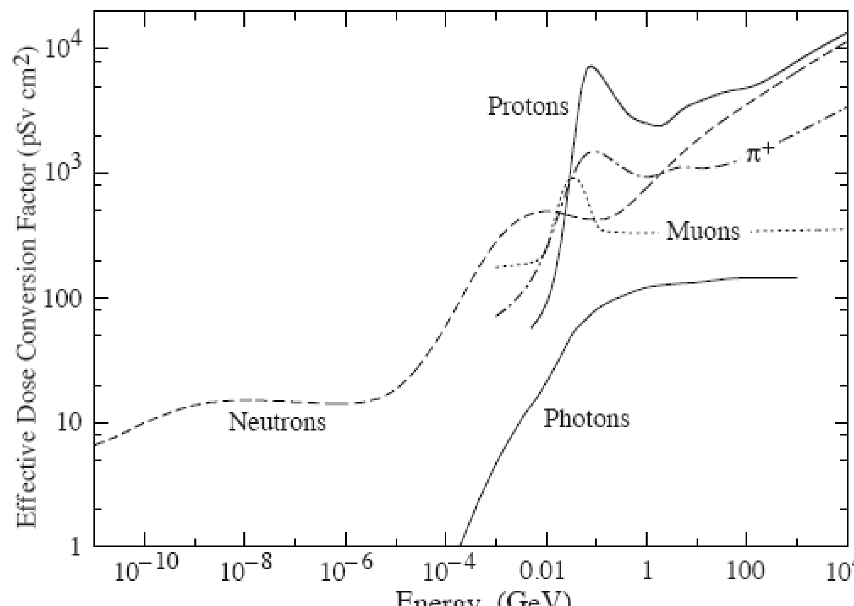




Thanks a lot!



Attenuation length (gm cm^{-2})
Neutron Energy (MeV)
concrete
ρ = 2.4 g cm^{-3}



Effective Dose Conversion Factor (pSv cm2)
Energy (GeV)
Protons
π^+
Muons
Neutrons
Photons

References

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