Suppression of neutrons from beam dump at photon colliders

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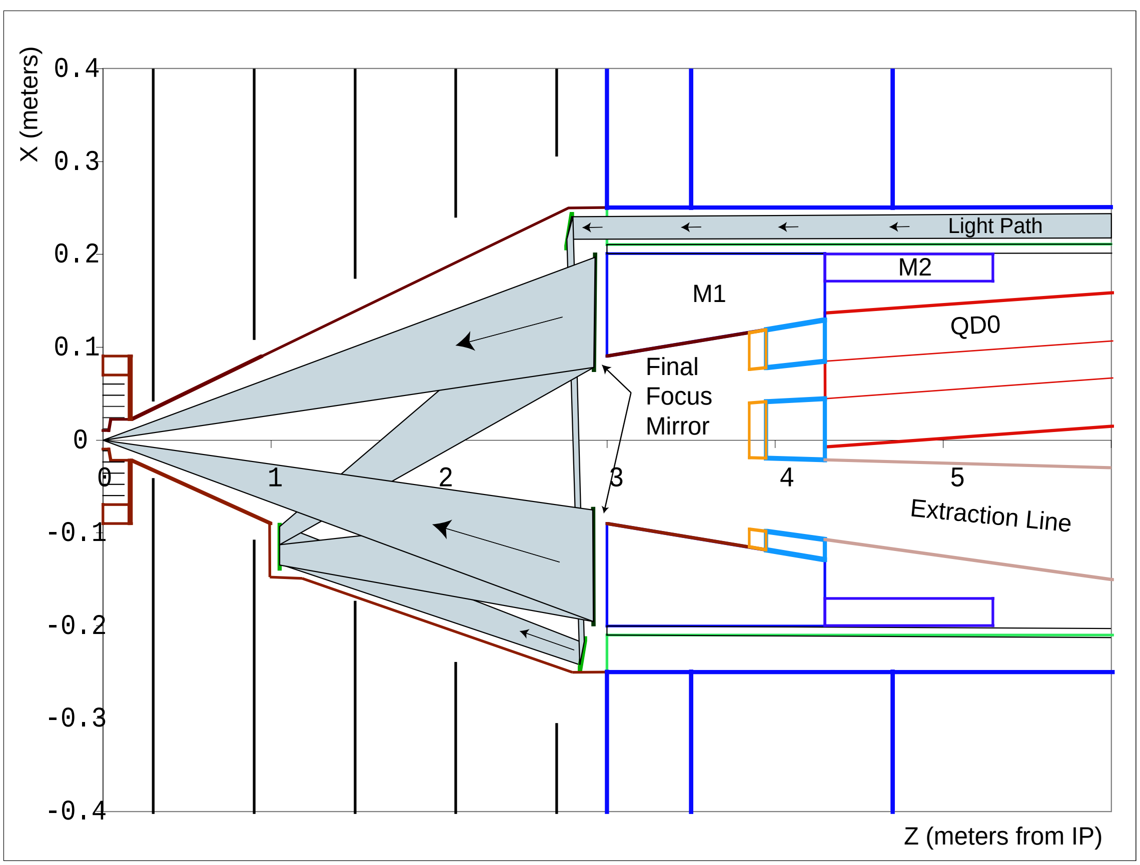
Neutrons from beam dump

The problem was emphasized at Snowmass2001: at photon colliders there is ± 12 mrad extraction line, which means the hole in the detector with a diameter of about 5-10 cm (at the distance 2-4 m from IP), neutrons from the beam dump (at 150 m distance) will illuminate the vertex detector, the fluence of about 10^{11} neutrons/year/cm^2 is expected that is too much for standard CCD, rad-hard CCD or pixel detector is required.



How one can suppress the neutron flux?

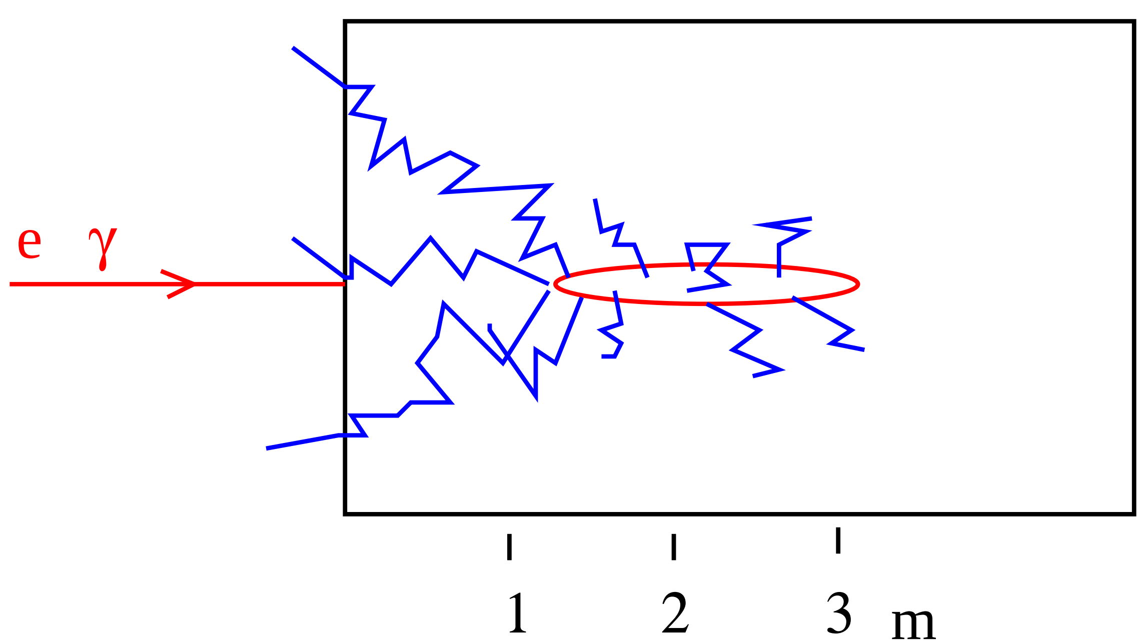
Physics picture:

neutrons are produced by photons in e-m. shower at the depth 5-10 X_0, that is 2-3.5 m in H_2O.

The attenuation length at $E < 30$ MeV is about 30 cm.

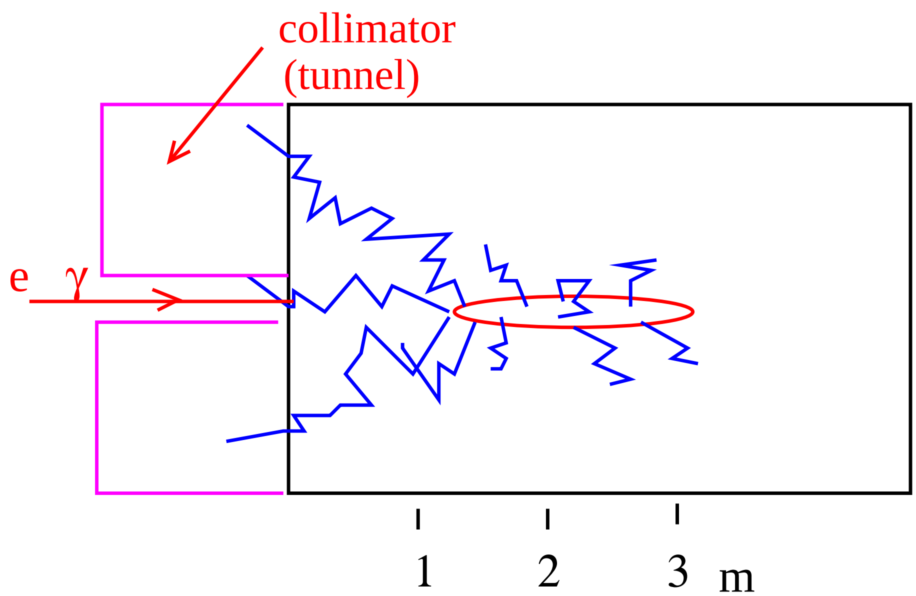
The scattering length even shorter: 2.7 cm for 1 MeV, 9.6 cm for 10 MeV, 14 cm for 30 MeV.

Most of neutrons reach surface after many scattering, though some of them can be generated near the surface and reach the detector without scattering. Background in the detector give neutrons with $\theta \approx \pi$. Area on the water dump of about 2×2 m^2 is a source of such neutrons.



Possible solutions

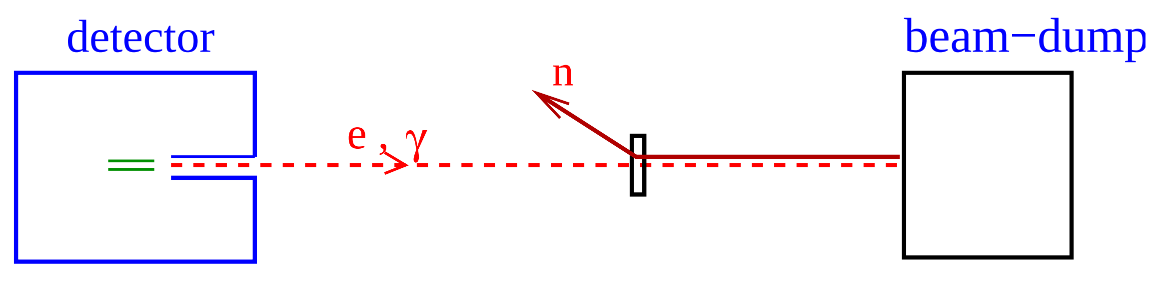
- A natural solution is to place collimator (narrow "tunnel") in front of absorber. A very narrow collimator would capture almost all neutrons.



Unfortunately the diameter of the hole should be large enough. The angular spread of initial electron beams and Compton photons is very narrow, $\sigma_\theta \sim 0.1$ mrad. However, due to beam repulsion the angular spread is up to 10 mrad for all disrupted particles and about 2 mrad for electrons with full energy at $E = 100$ GeV (20 cm at the distance 100 m). So, the diameter of the tunnel should be about 1 m; (checked: helps)

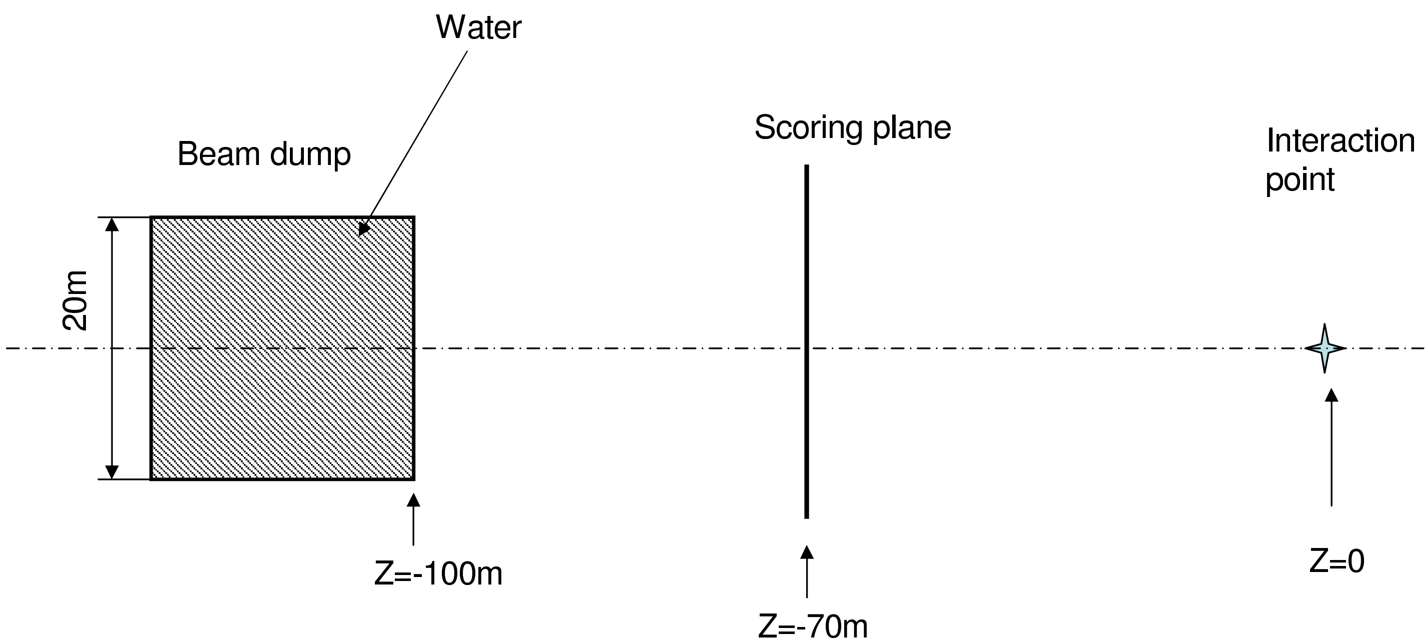
- to increase the diameter of the shower or allow neutrons go in transverse direction; (checked: helps)

- to put a thin plate between the dump and detector which is too thin for development of shower but thicker than the scattering length. Then neutrons with $\theta \approx \pi$ will change their direction to isotropical and will not hit the detector. (checked: did not help) careful study needs a lot of computer time.

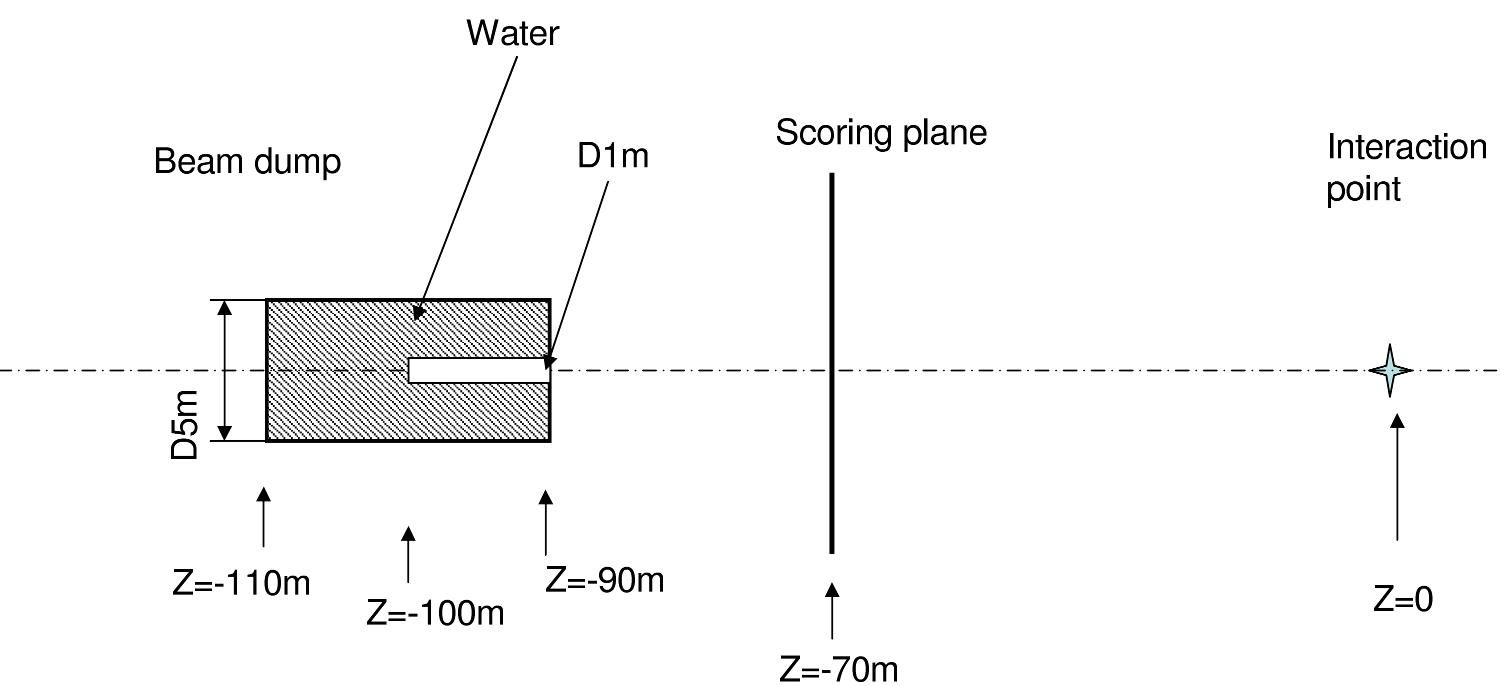


Considered options

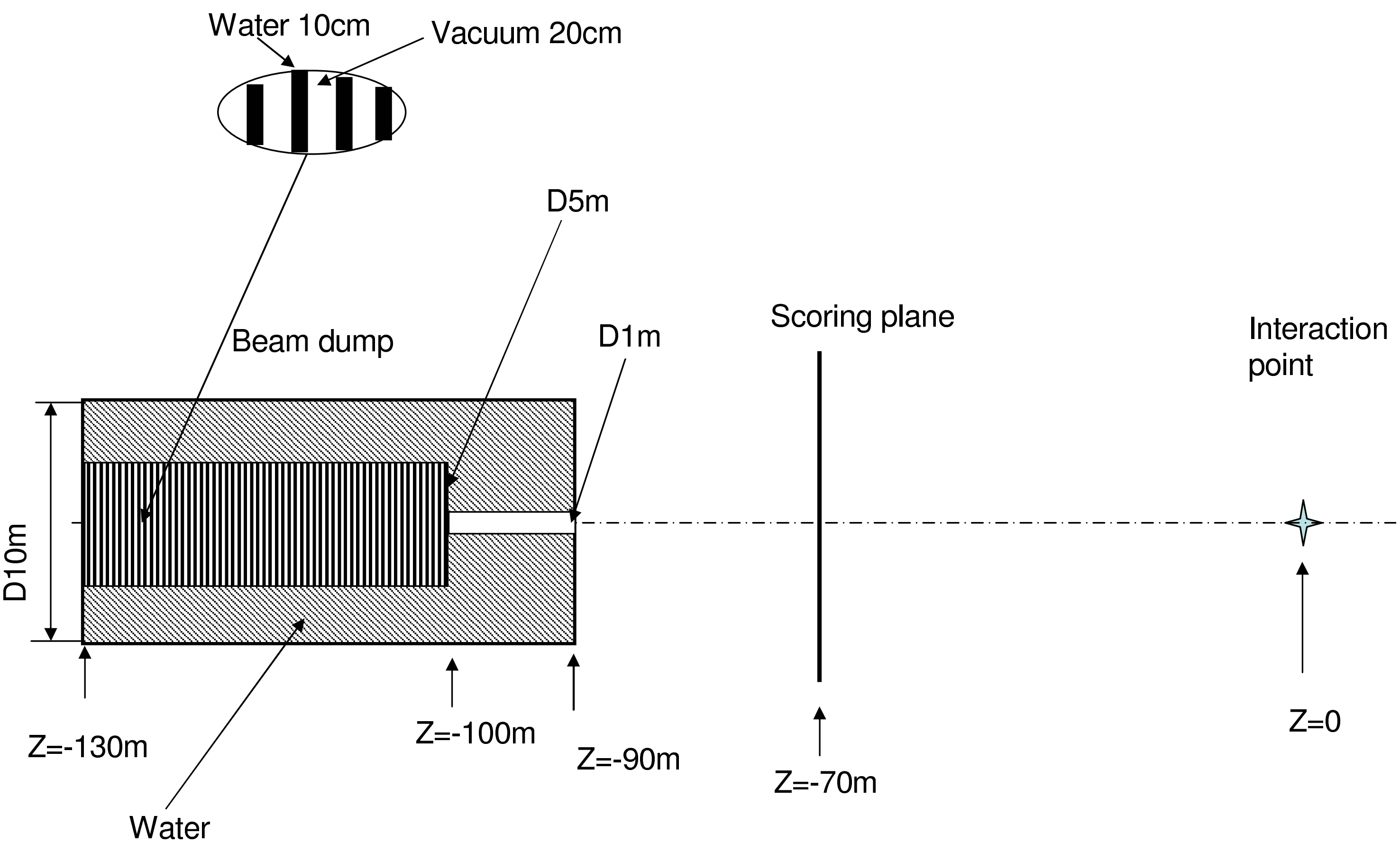
Option 1: “cube”



Option 2: “cylinder with tunnel”



Option 3: “hybrid” cylinder with tunnel and sandwich absorber”



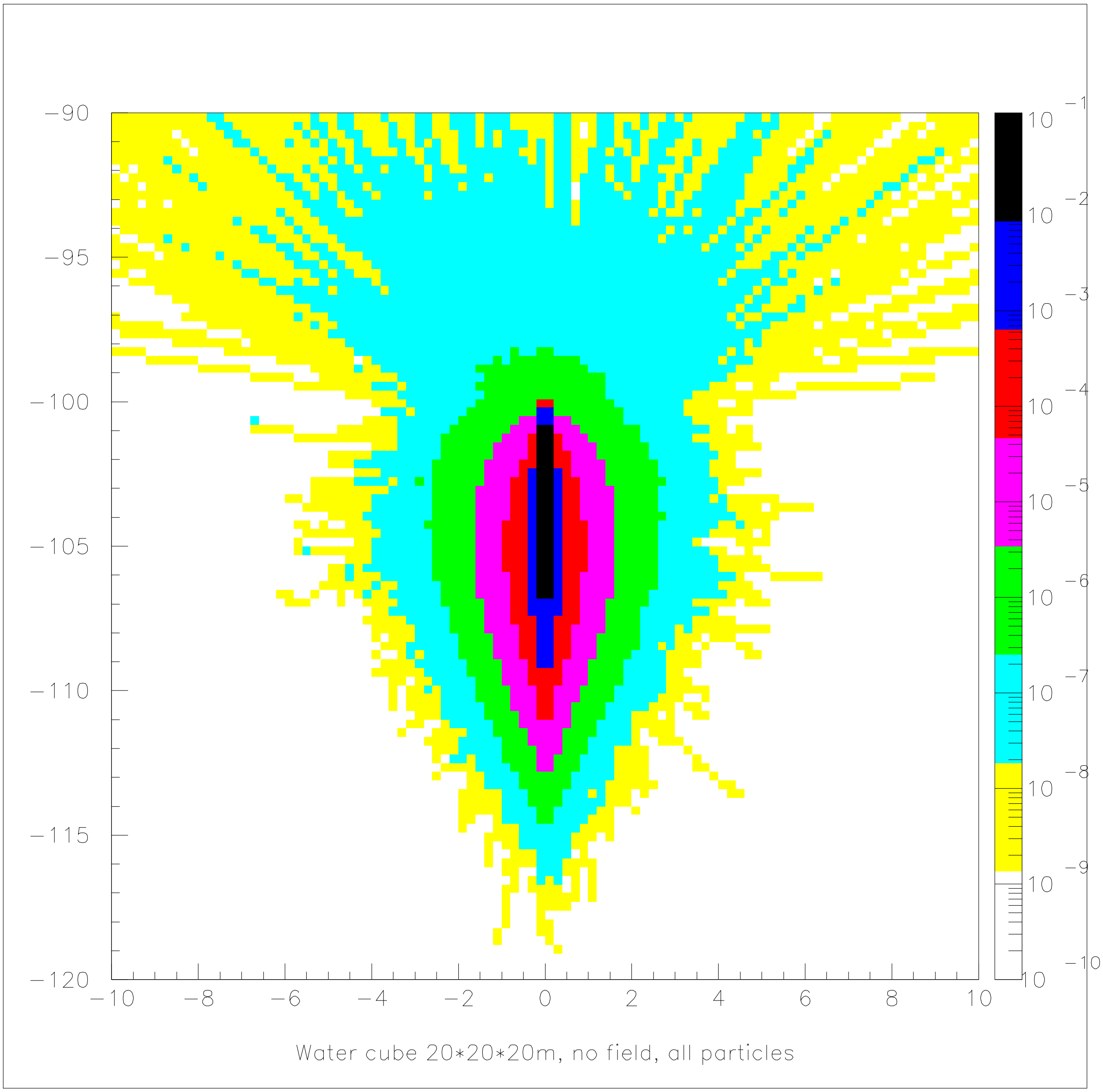
Figures for each of three options

1. Distributions of all particles in the dump (cut in along beam-line)

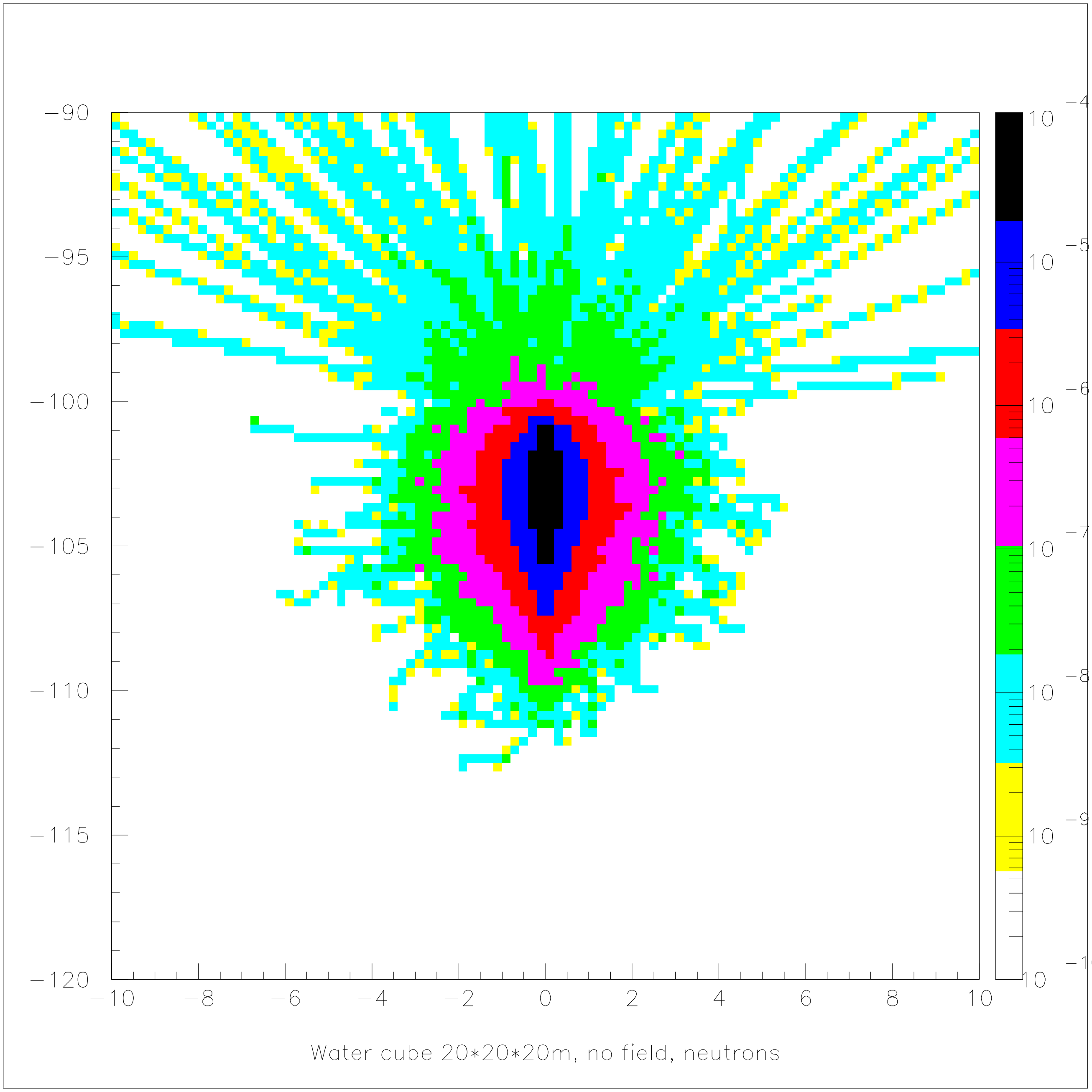
2. Distributions of neutrons in the dump (cut in along beam-line)

3. Distributions of neutrons in the plane transverse to the beam-line, at the distance minus 30 meters before beginning of the dump. Then we calculate the number of neutron going backward (passing a square 4×4 m^2 in this plane)

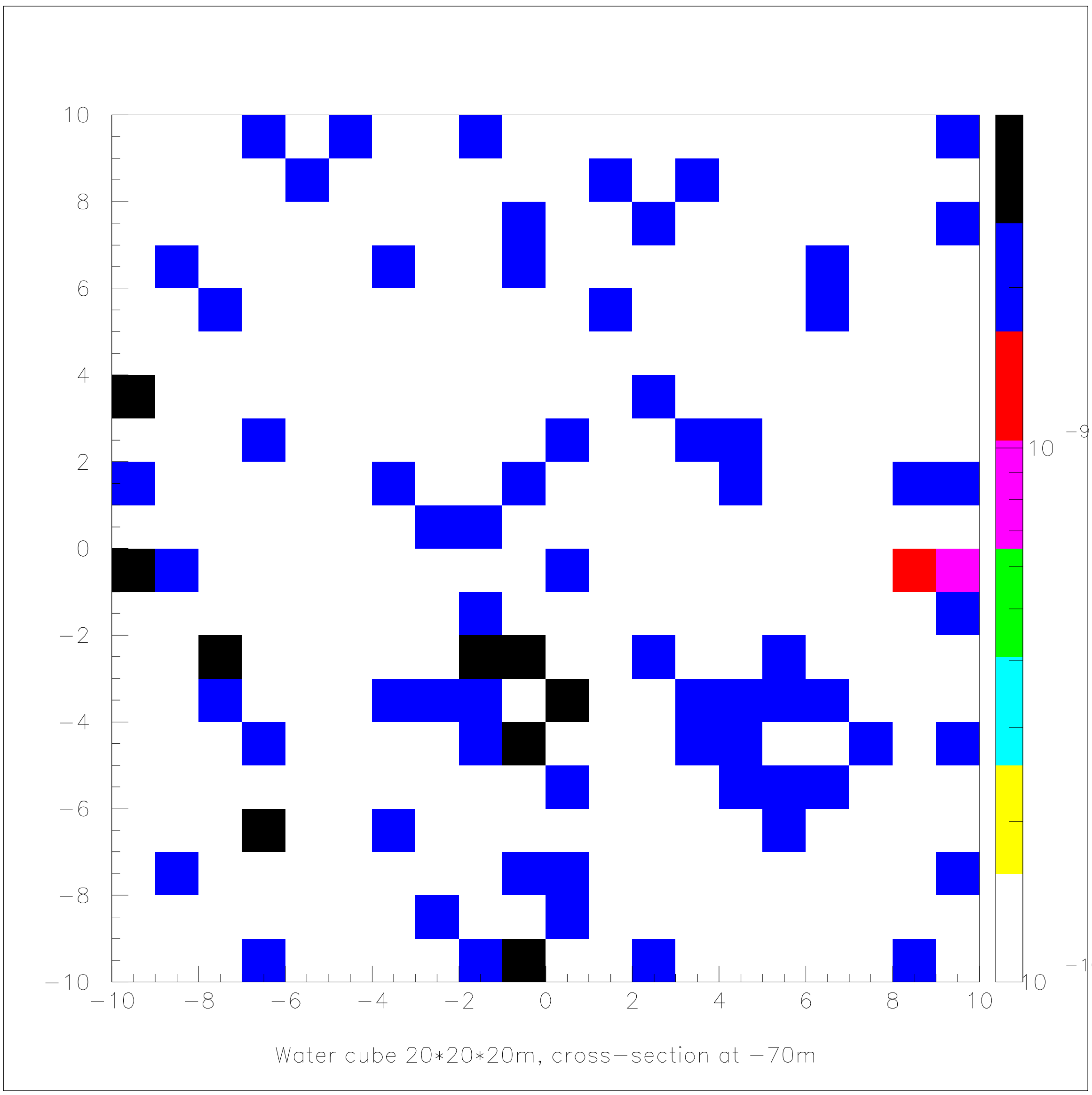
"Cube", all particles



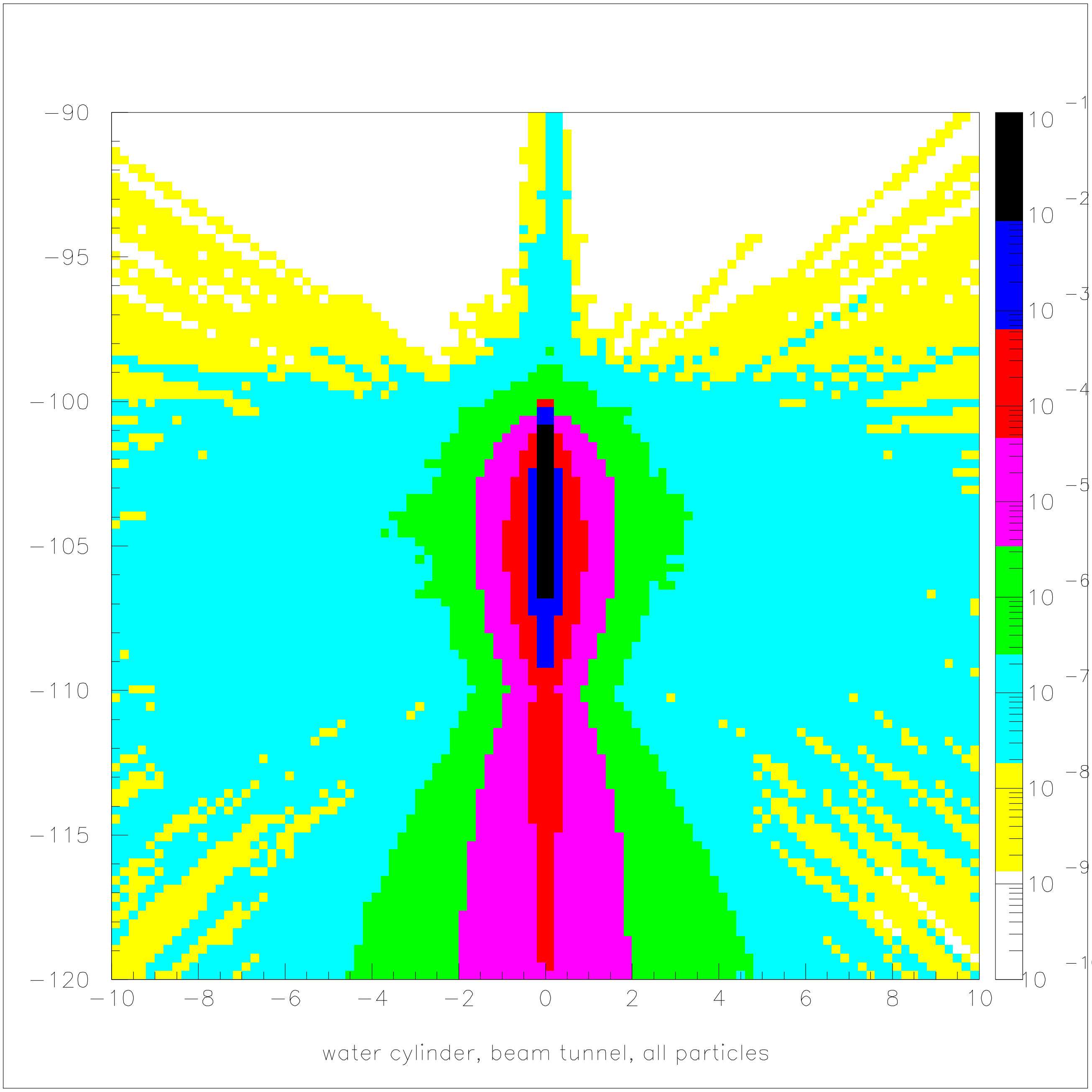
"Cube", neutrons



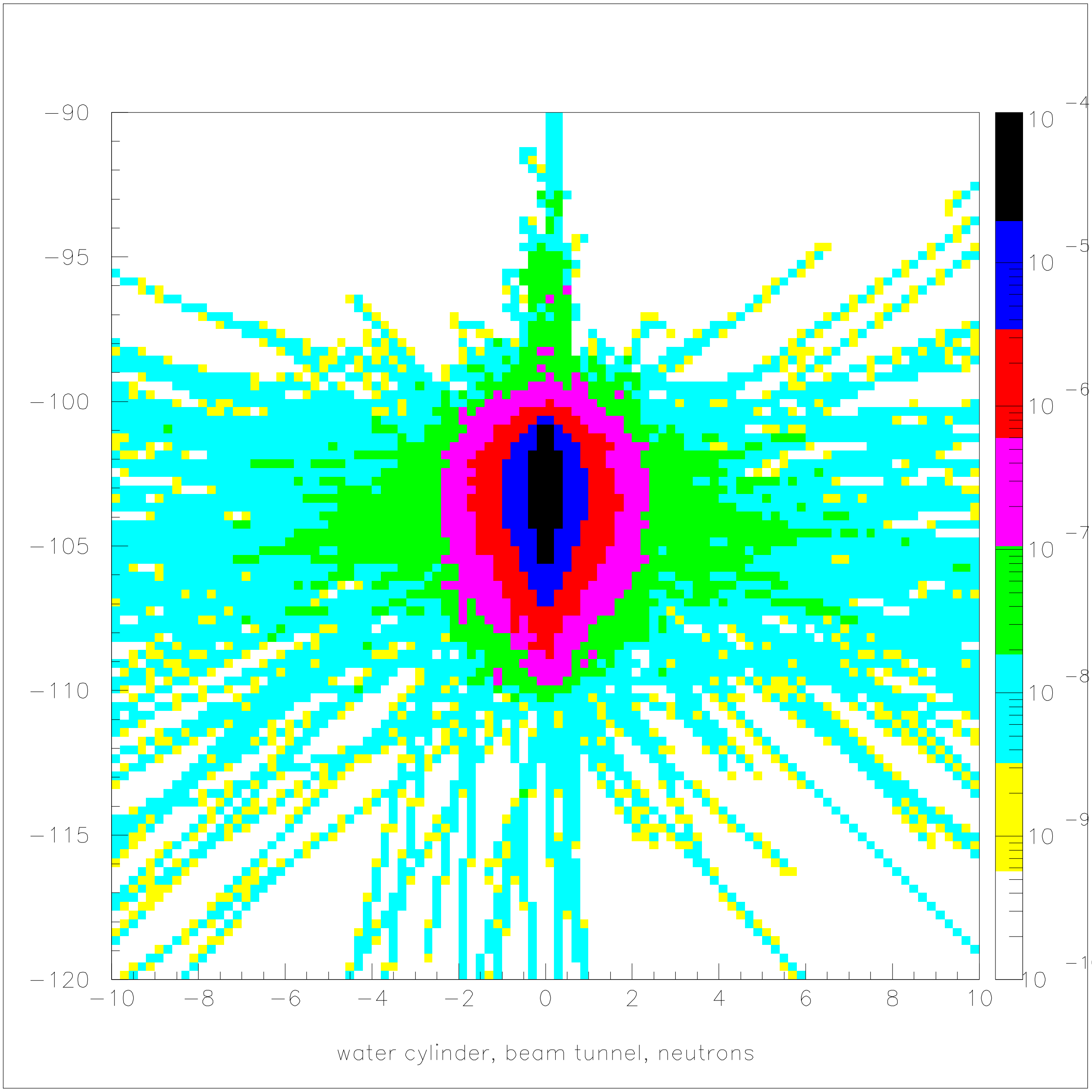
“Cube”, back moving neutrons for
50000 initial 250 GeV electrons



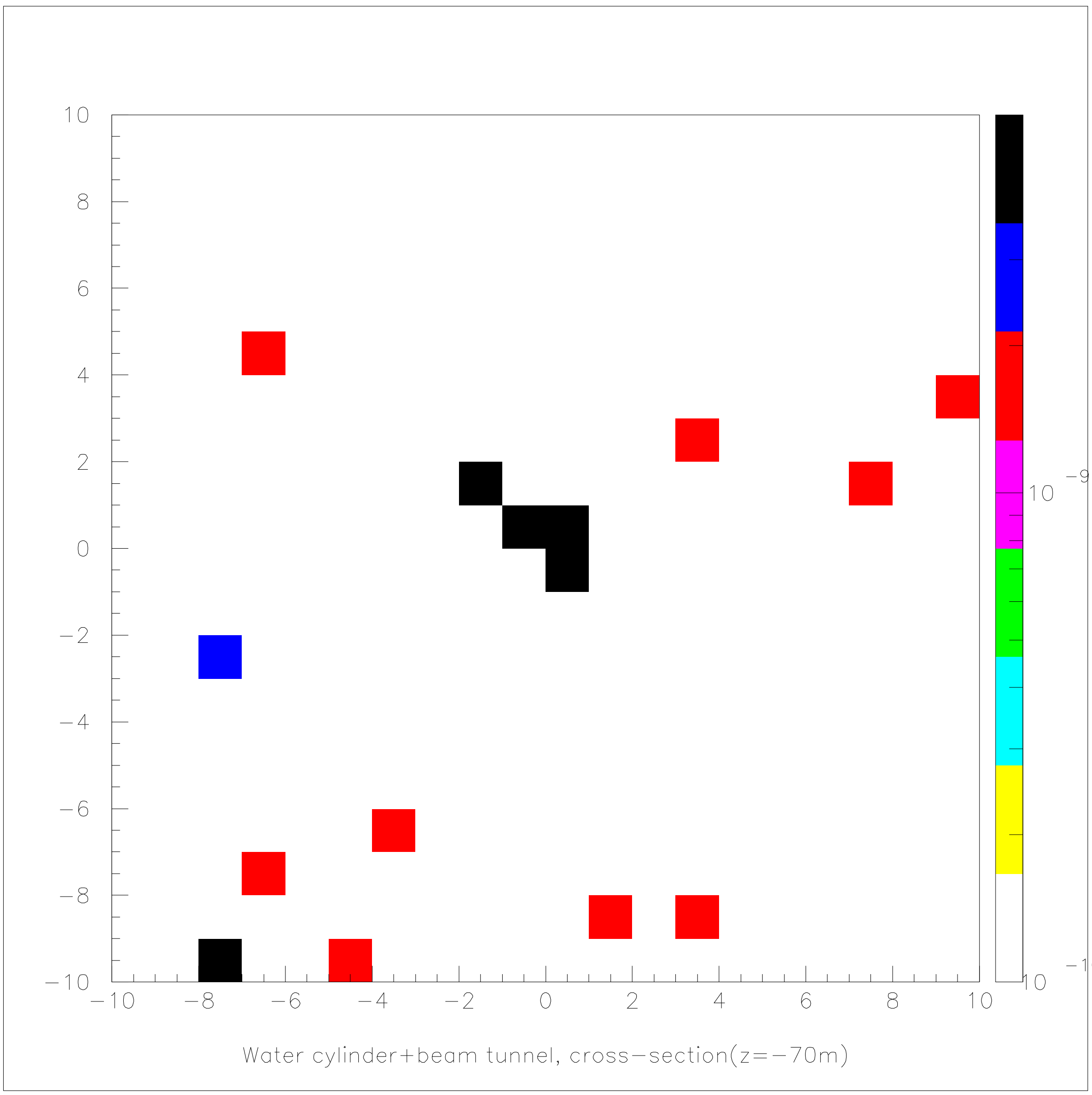
“Cylinder with tunnel”, all particles



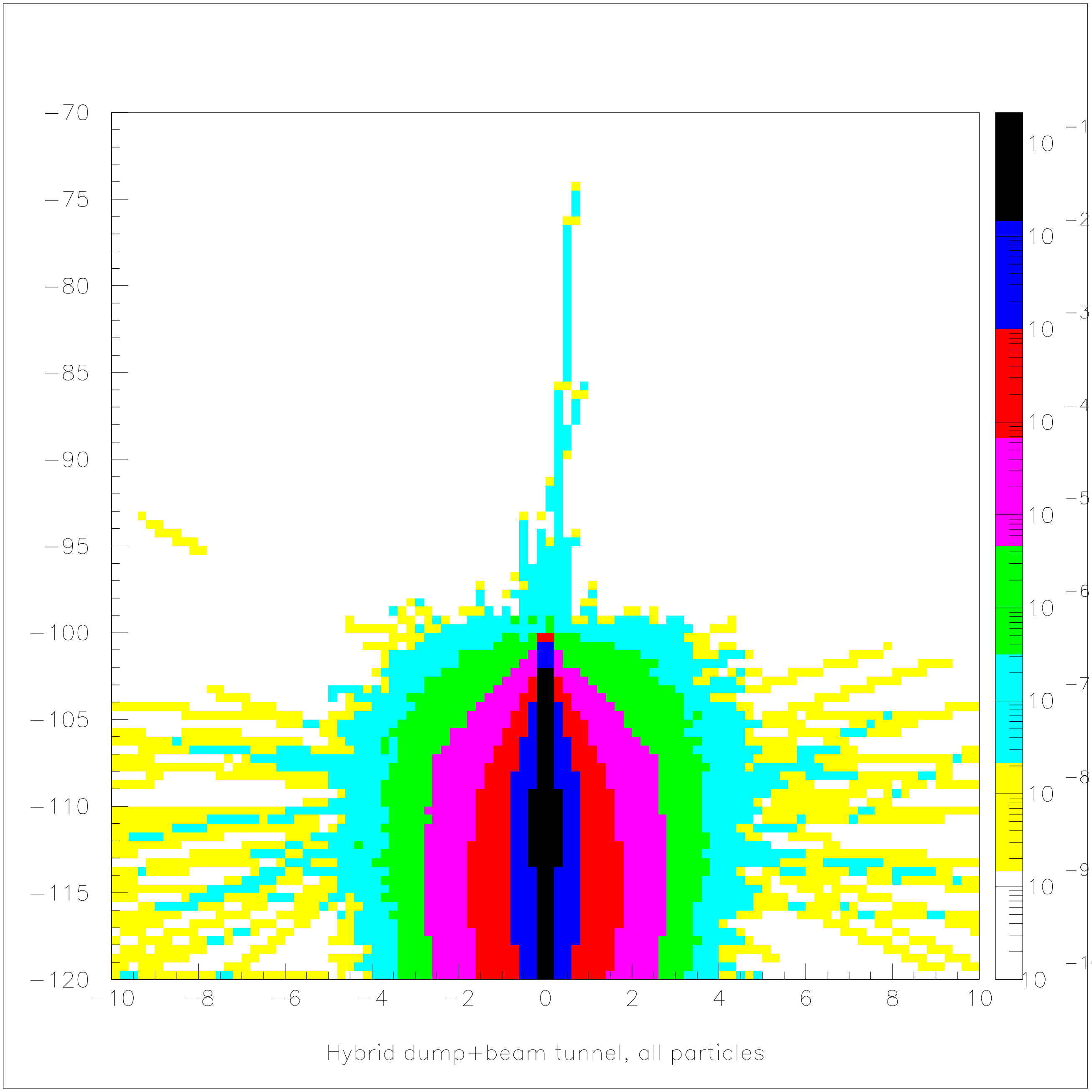
“Cylinder with tunnel”, neutrons



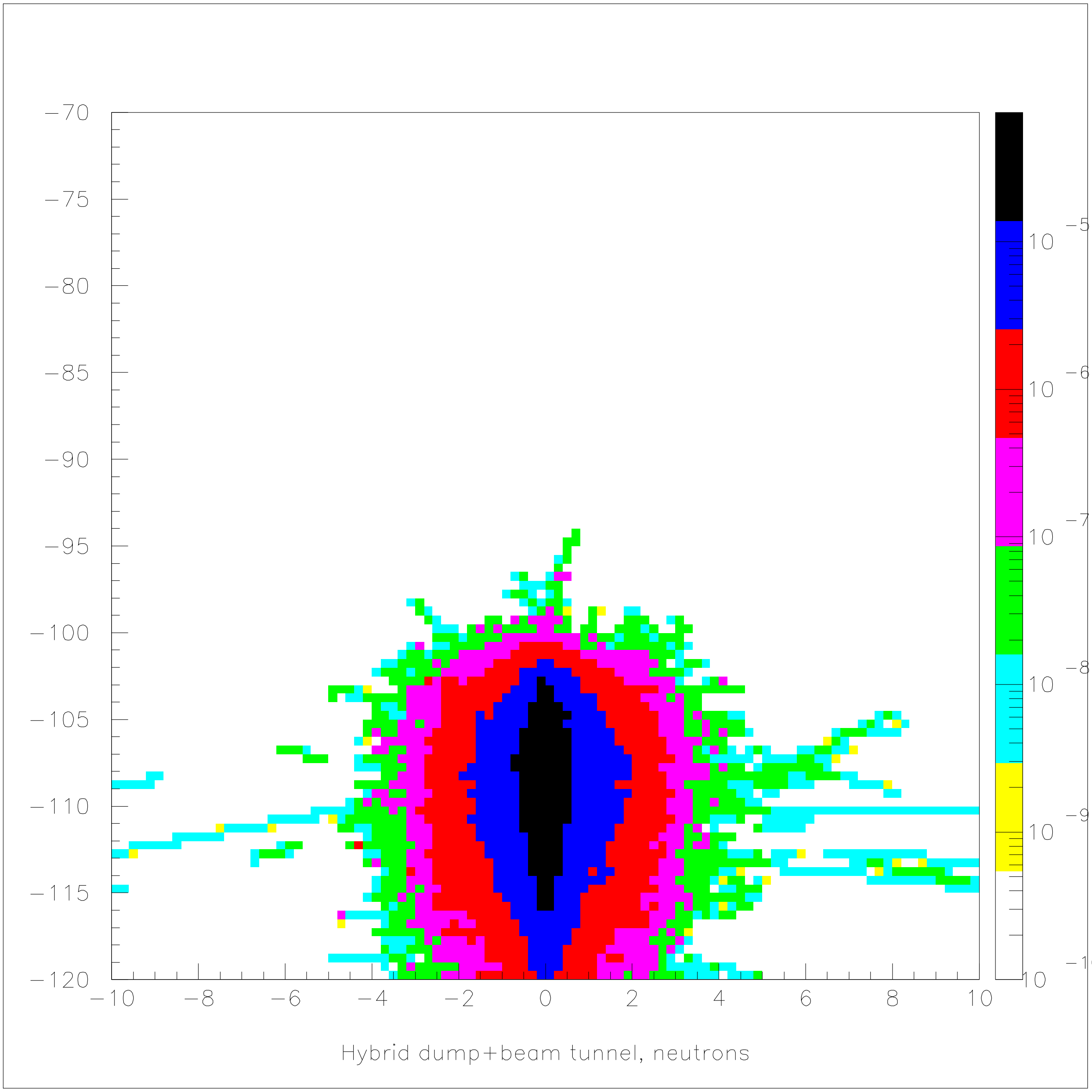
“Cylinder with tunnel”, back moving neutrons for 250000 initial 250 GeV electrons



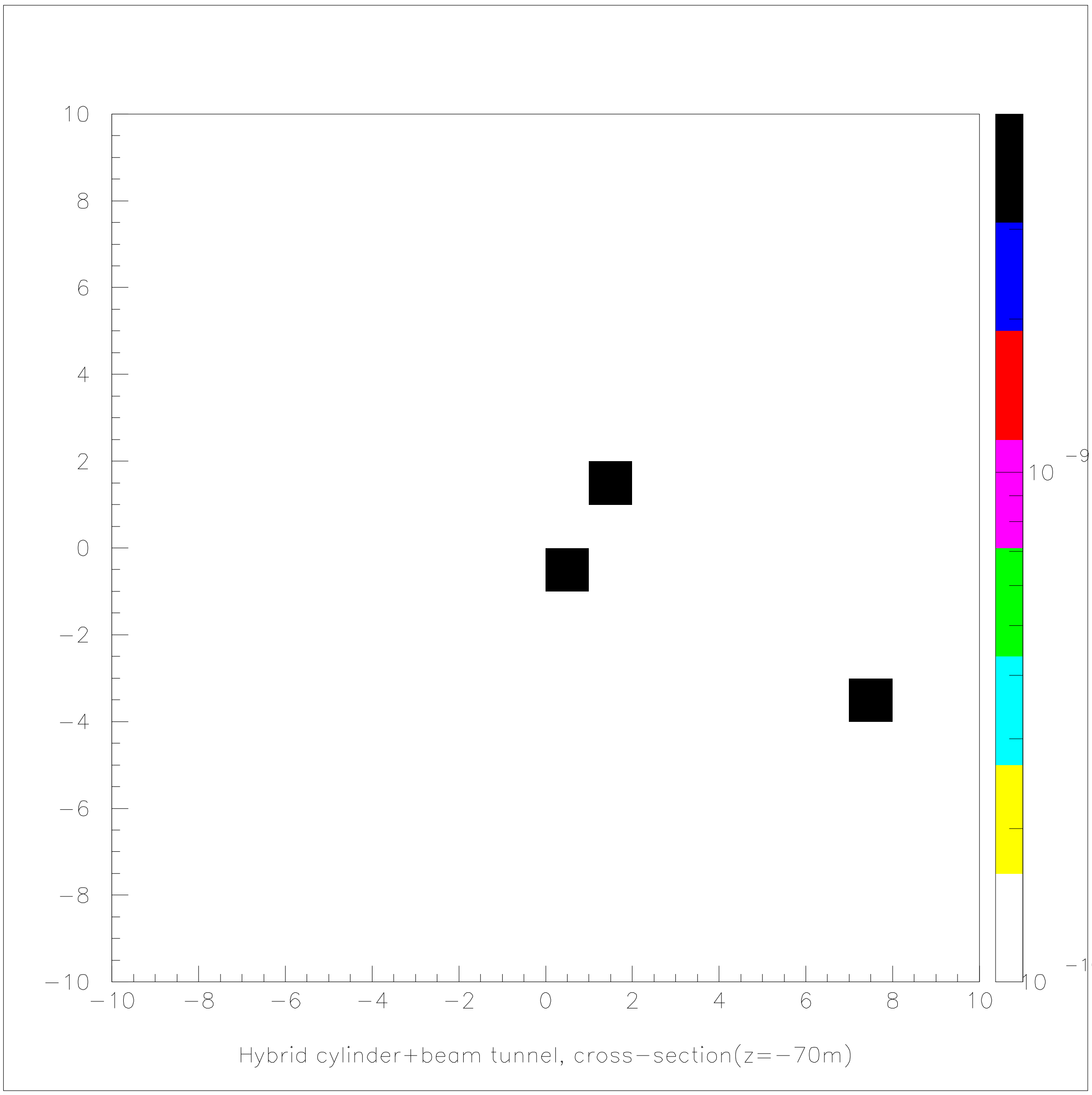
“Hybrid”, all particles



“Hybrid”, neutrons



“Hybrid”, back moving neutrons for 400000 initial 250 GeV electrons



Comparison

Option	# of e.	# neutrons in 2x2 m^2	# neutr. /10^6 e	suppression
Cube	50000	4	80	1
Cylinder	250000	4	16	0.2
Hybrid	400000	2	5	0.06

For the distance IP-beam-dump $L = 100$ m and $N = 2 \times 10^{10}$, $\nu = 14$ kHz,
the fluxes of neutrons/cm^2/10^{7}sec are
"Cube": 5×10^{11} (agrees with NLC after corr. to N,ν,L)
"Cylinder with tunnel": 10^{11}
"Hybrid": 3×10^{10}.

Conclusion

It has been demonstrated that using a proper design of beam-dump the neutron flux can be suppress by a factor of 16 (2 events statistics).

Further optimization (very time consuming) is possible, the limit is not reached.