A powerful UCN source at an external beam of thermal neutrons at the PIK reactor

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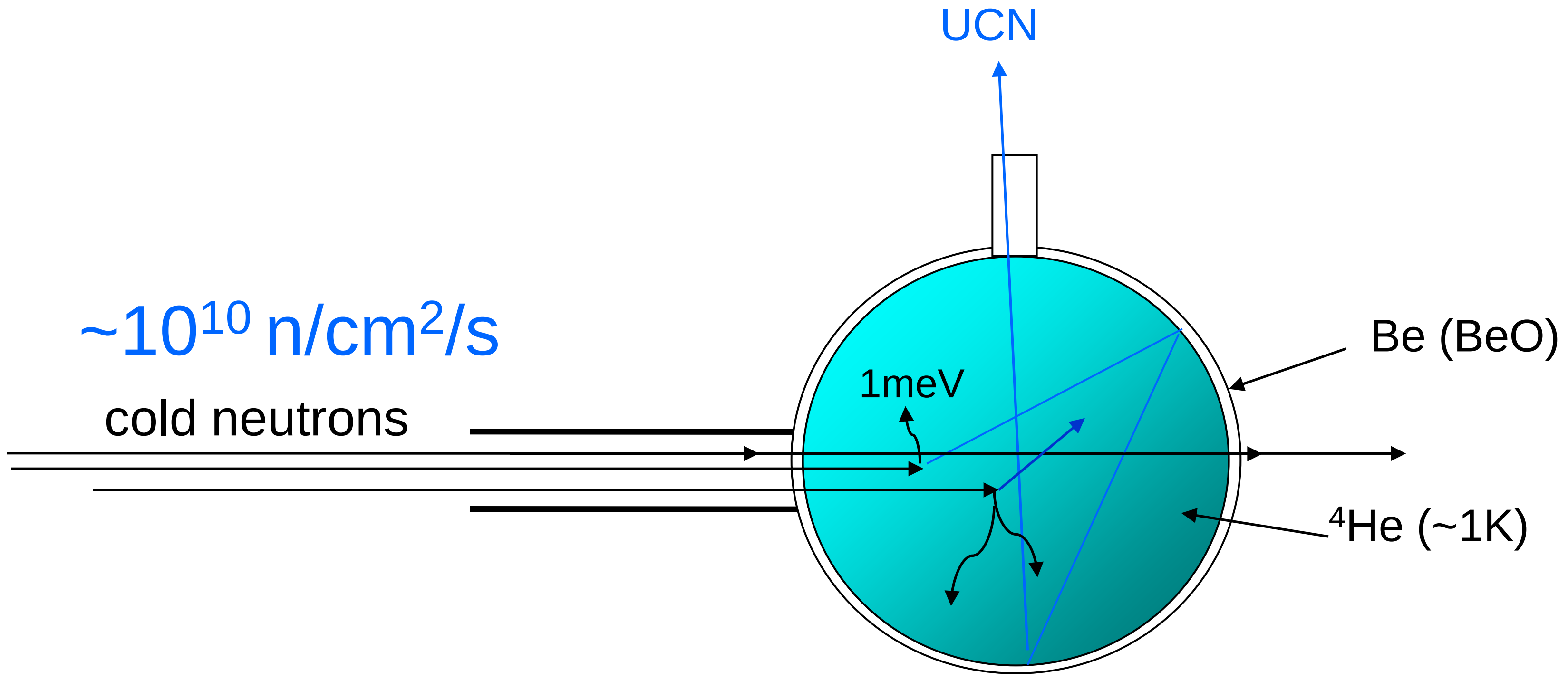
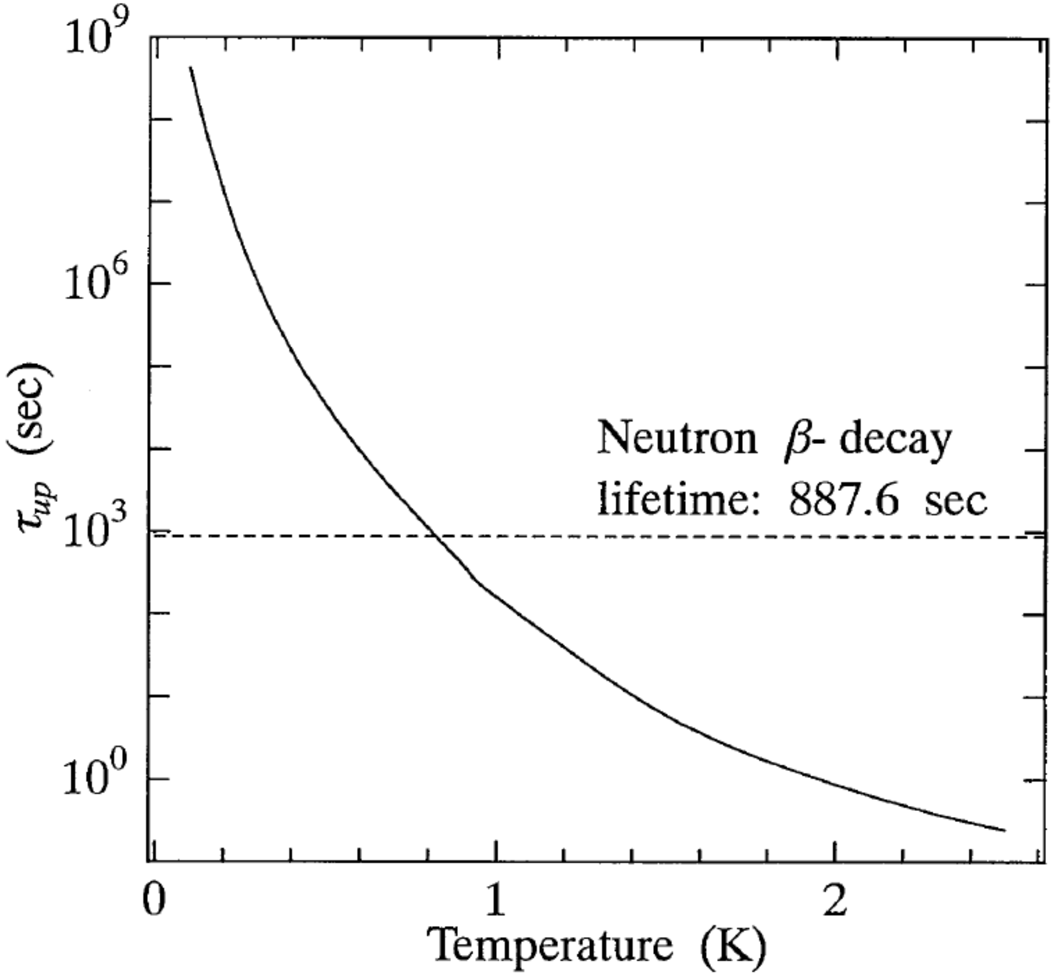
The idea of the source

1. **SUPER-TERMAL SOURSES OF ULTRACOLD NEUTRONS**
   R.Golub and J.M. Pendlebury. *PHYSIC LETTERS V53 A, 1975*.



The idea of the source



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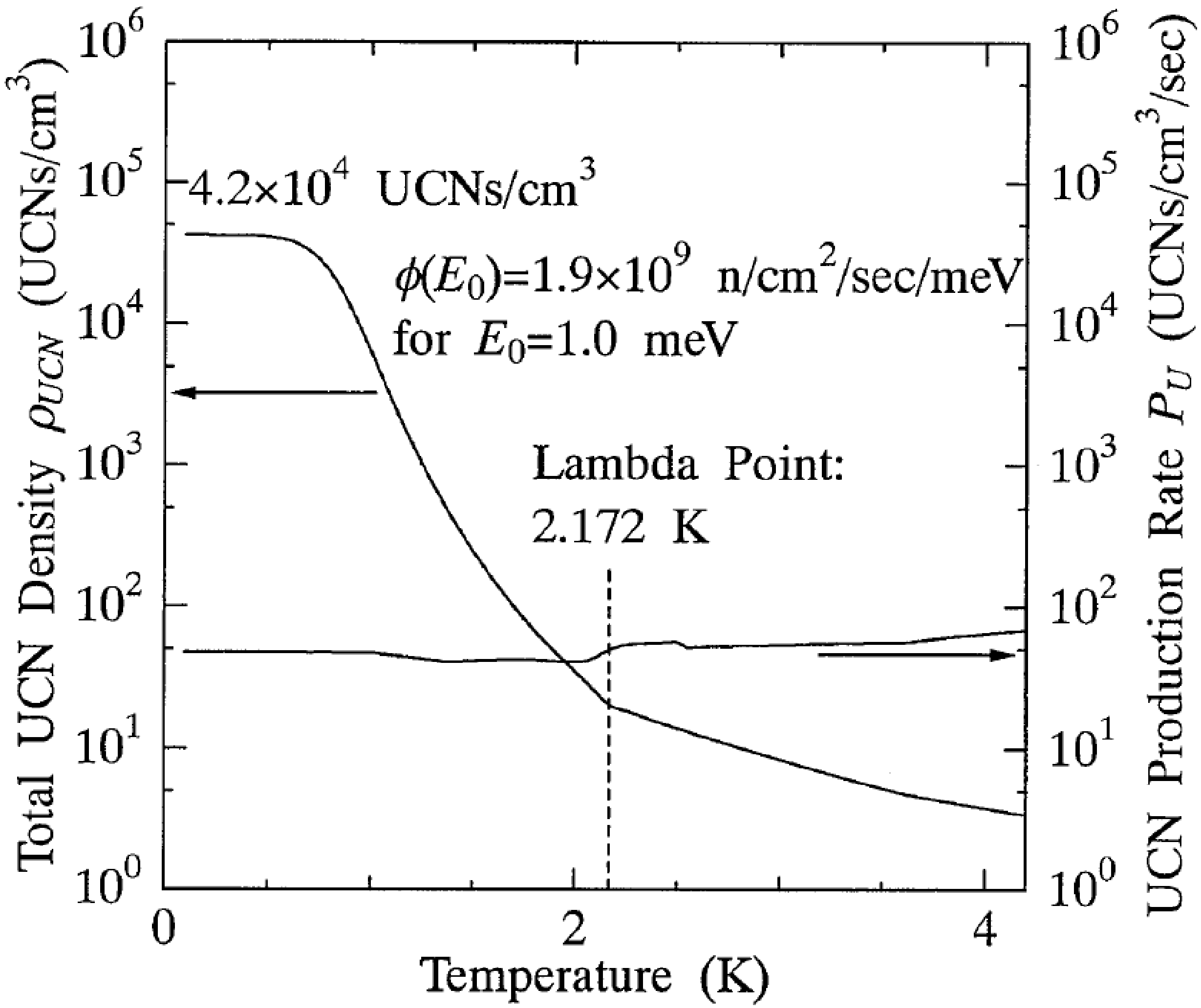

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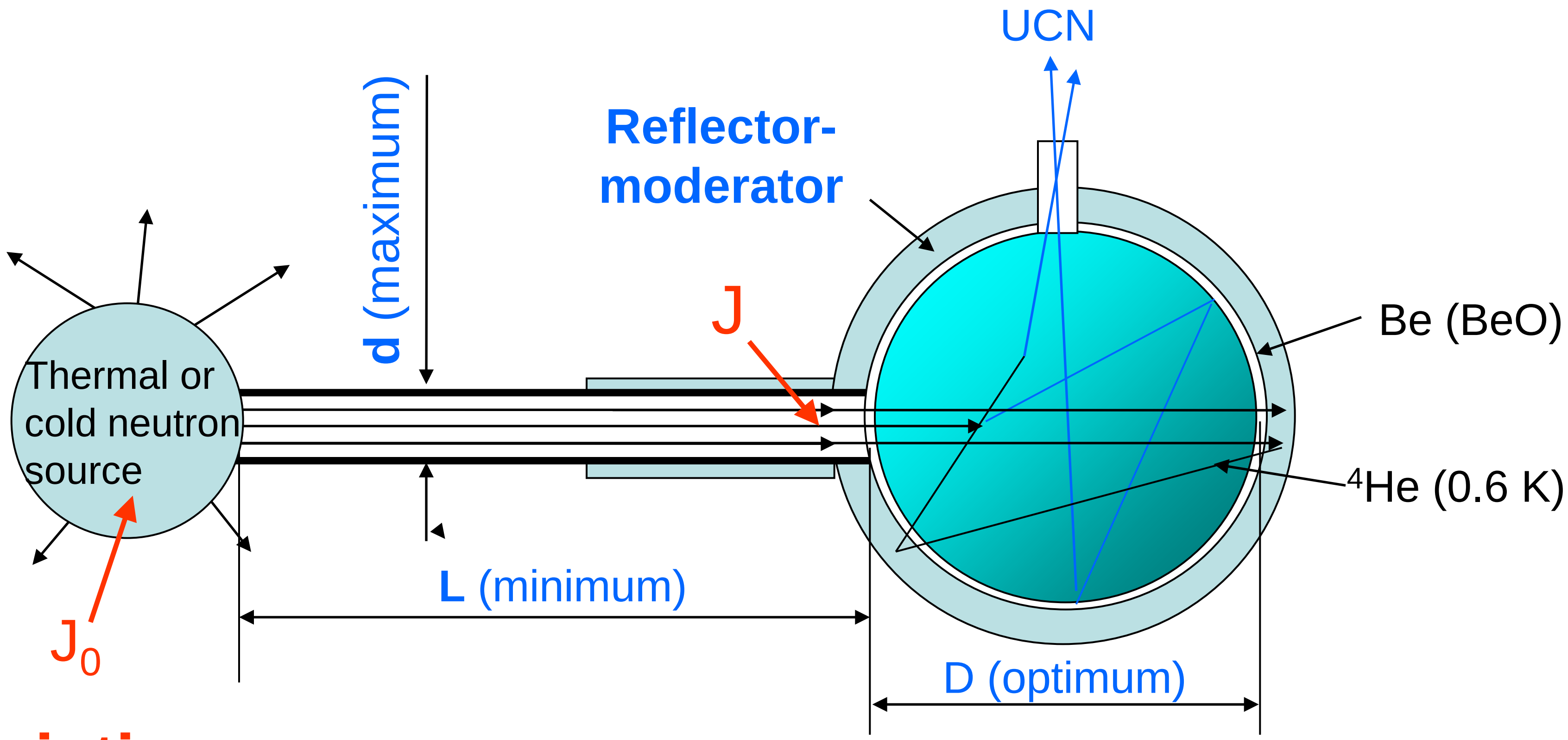
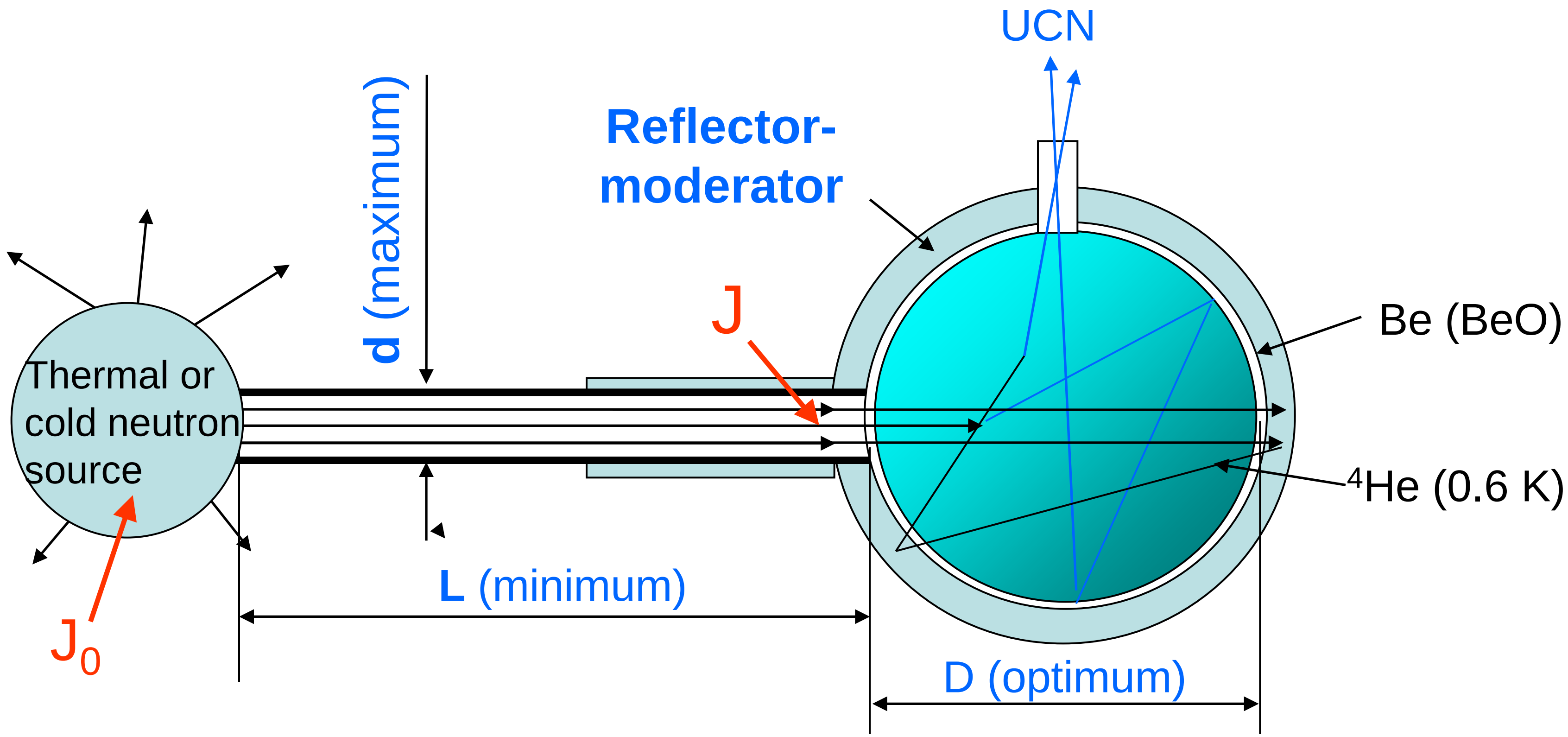


Optimistic:

ILL: **L_{min}** - 5m; **d** – up to 20 cm; **J_0**~10^{15}n/sm²/s; **J**~10^{11}n/cm²/s; **F**~$4{\cdot}10^{13}$ n/s

PIK: **L_{min}** - 3m; **d** – up to 30 cm; **J_0**~10^{15}n/sm²/s; **J**~$8{\cdot}10^{11}$n/cm²/s; **F**~$5{\cdot}10^{14}$n/s

The idea of the source

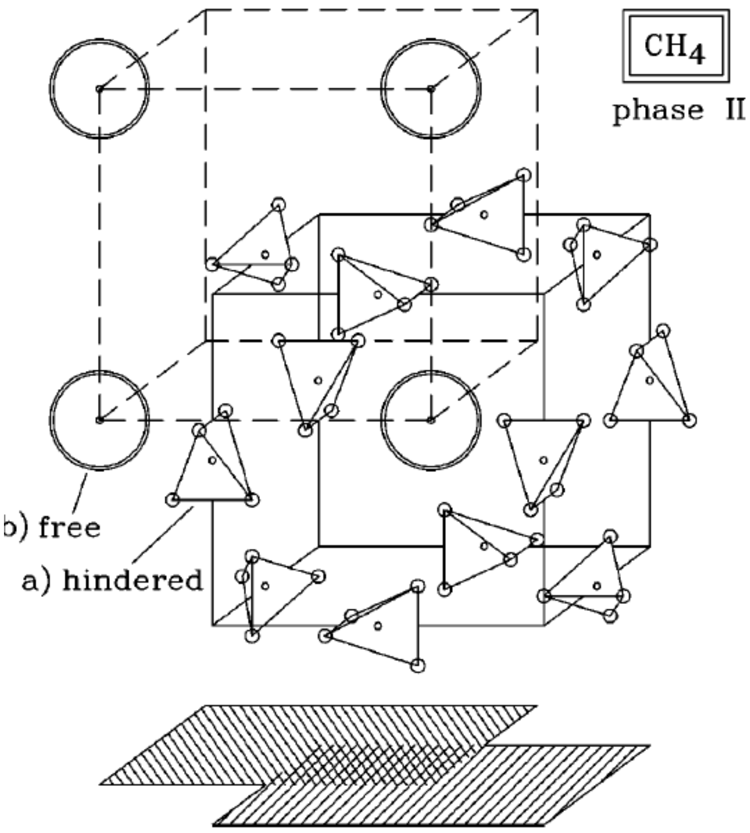


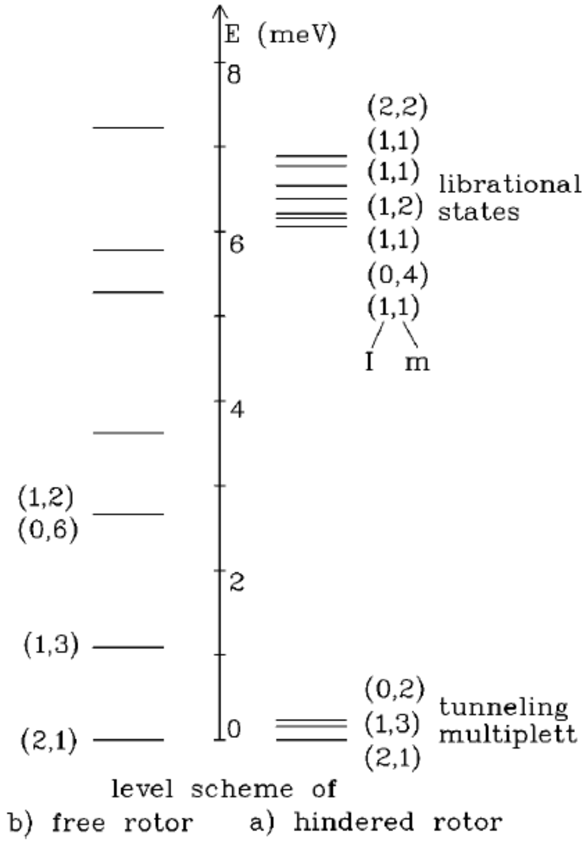
Realistic:

ILL: $\mathbf{L_{min}}$ - 5m; **d** –15 cm; $\mathbf{J_0}$~10^{15}n/sm^2/s; **J**~6·10^{10}n/cm^2/s; **F**~10^{13} n/s

PIK: $\mathbf{L_{min}}$ - 3m; **d** –20 cm; $\mathbf{J_0}$~10^{15}n/sm^2/s; **J**~4×10^{11}n/cm^2/s; **F**~10^{14} n/s

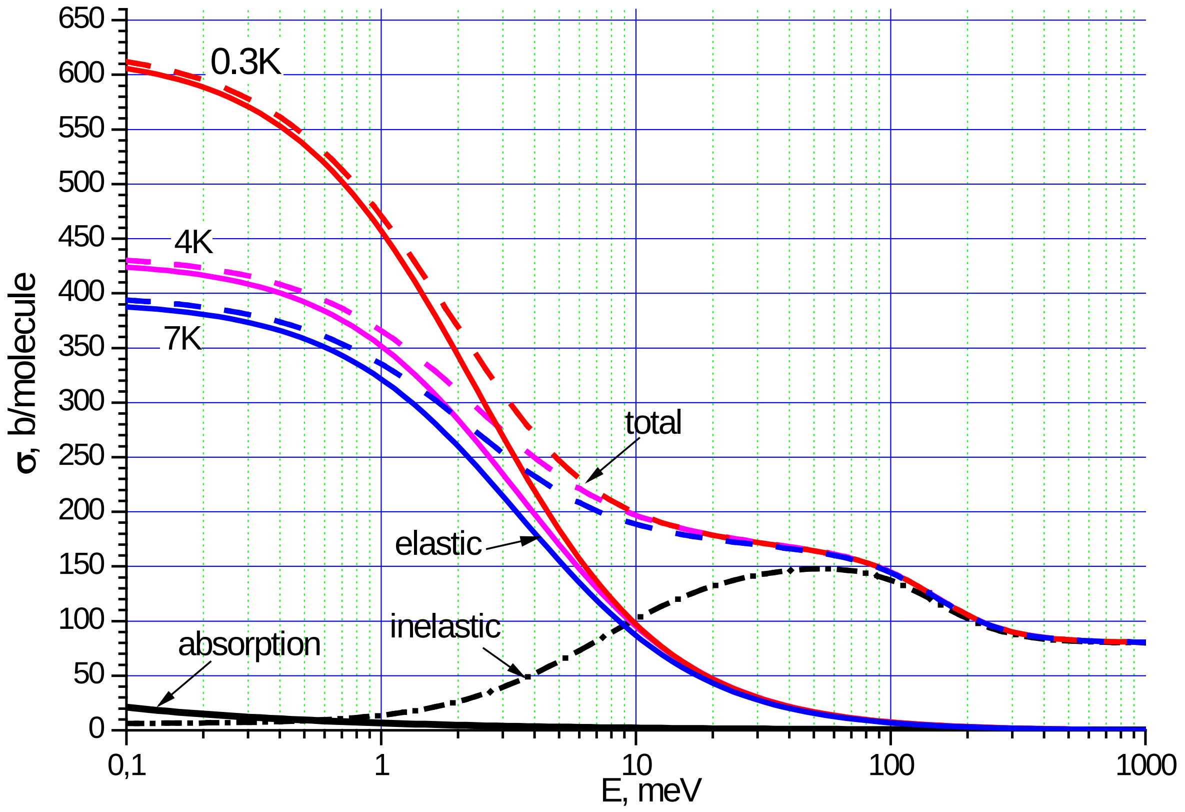
Methane





molecular crystal with a very round molecule

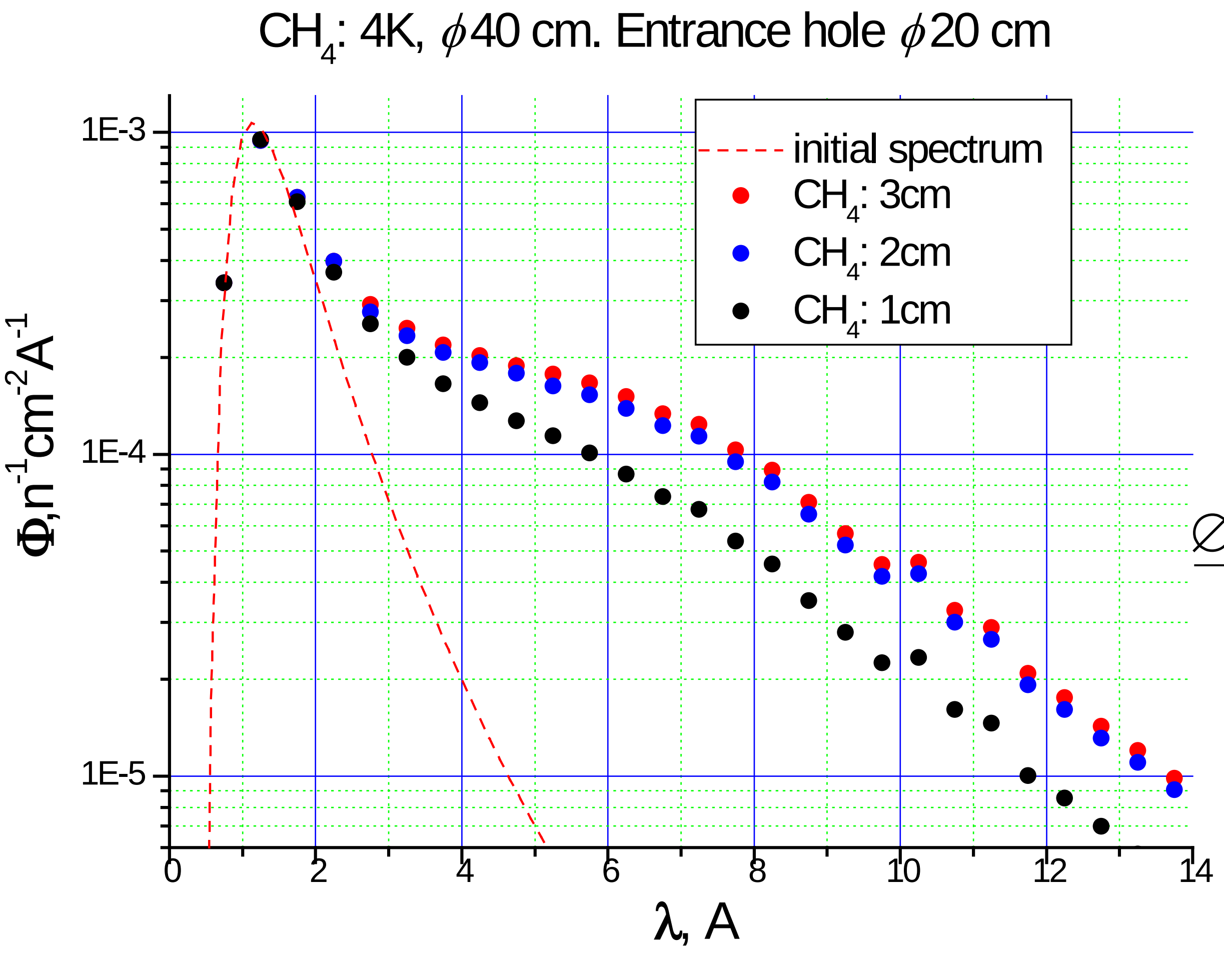
Methane

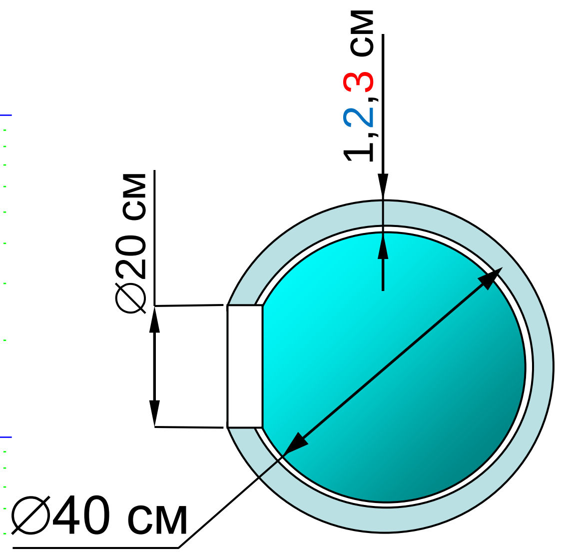


Solid CH_4: Coherent scattering in one molecule and incoherent scattering on different molecules.

Simulations

MCNP 4c with special kernel (solid CH_4)





Simulations

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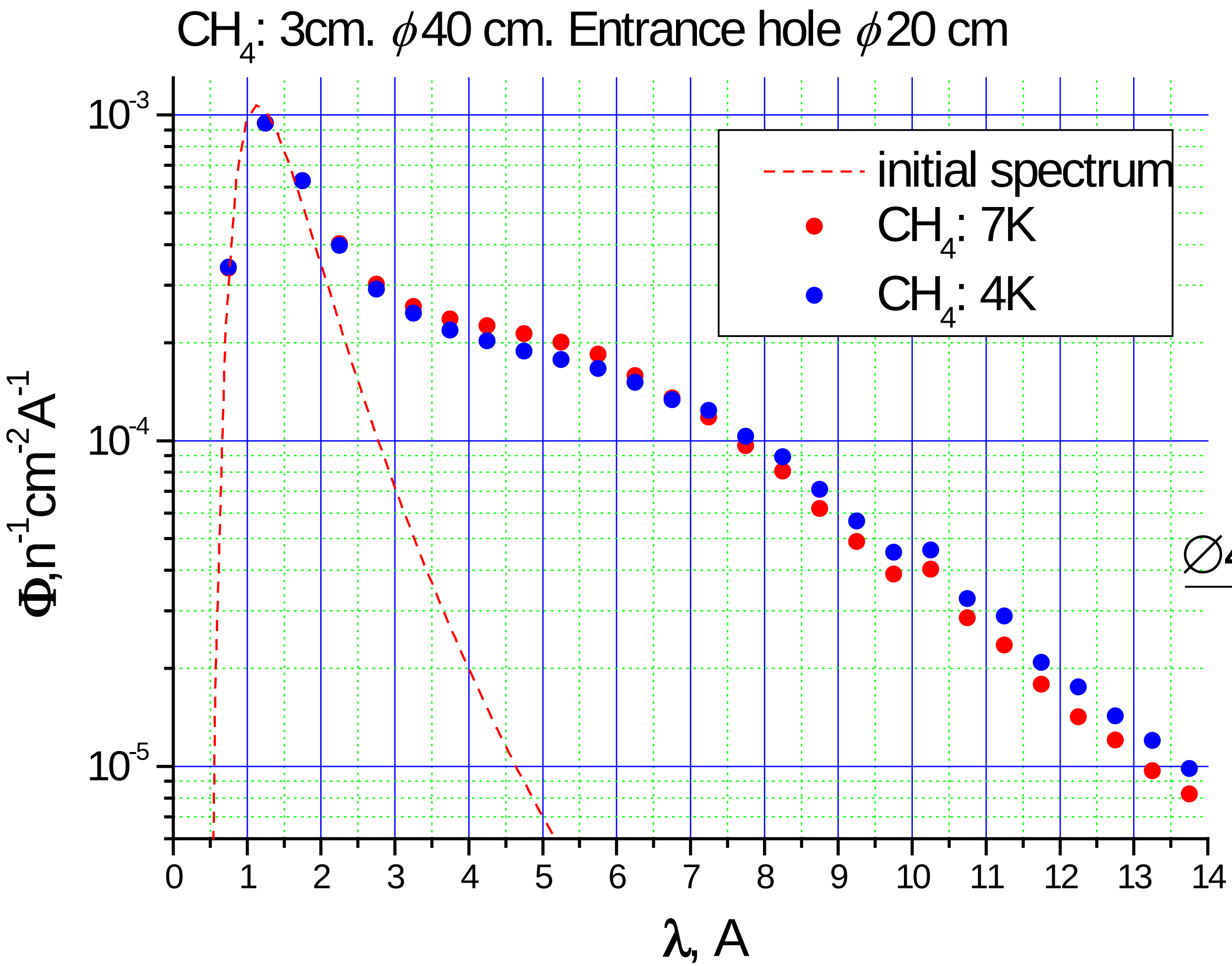

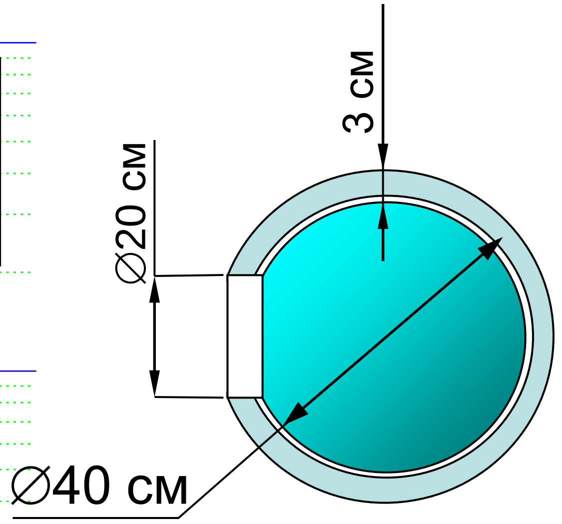

Simulations

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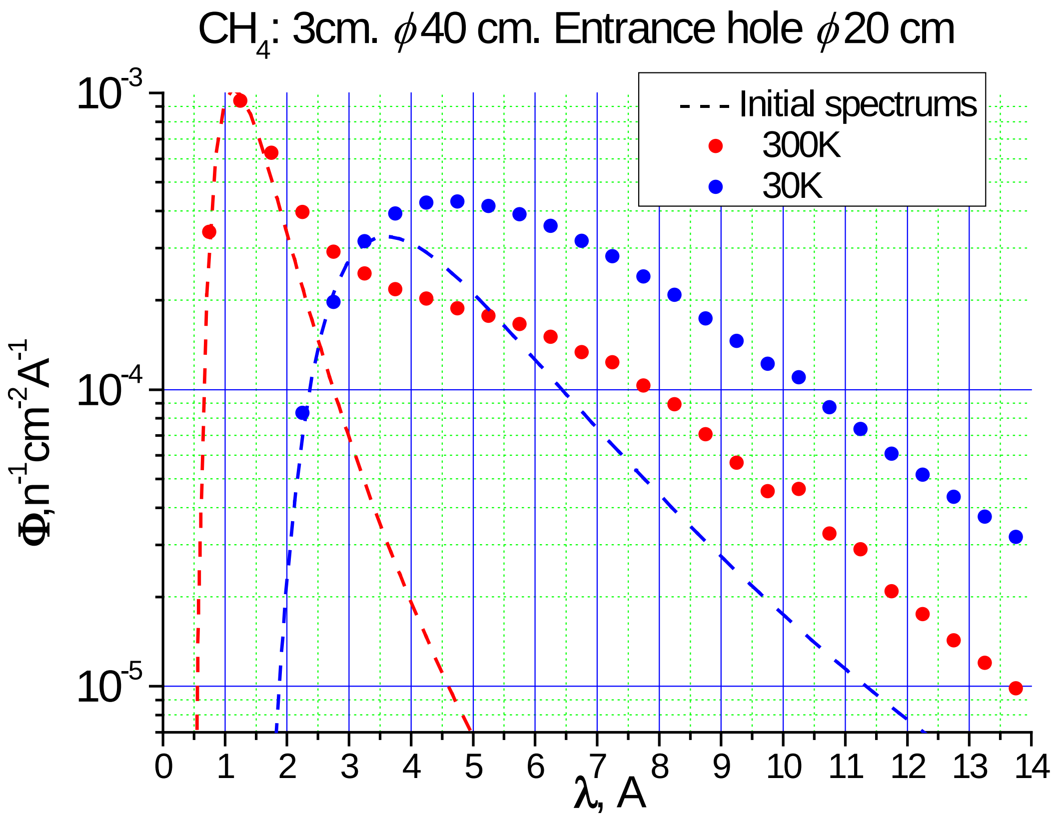
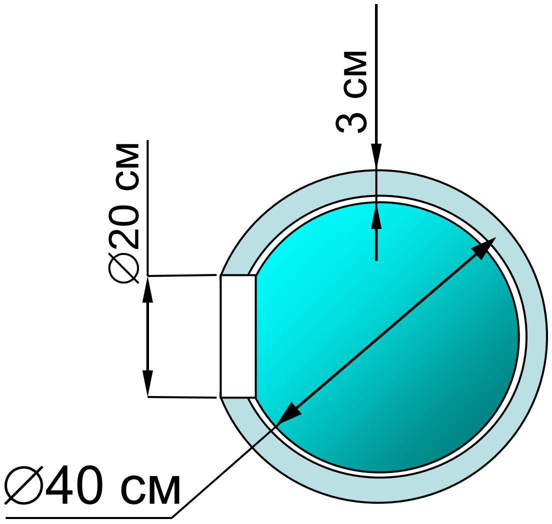
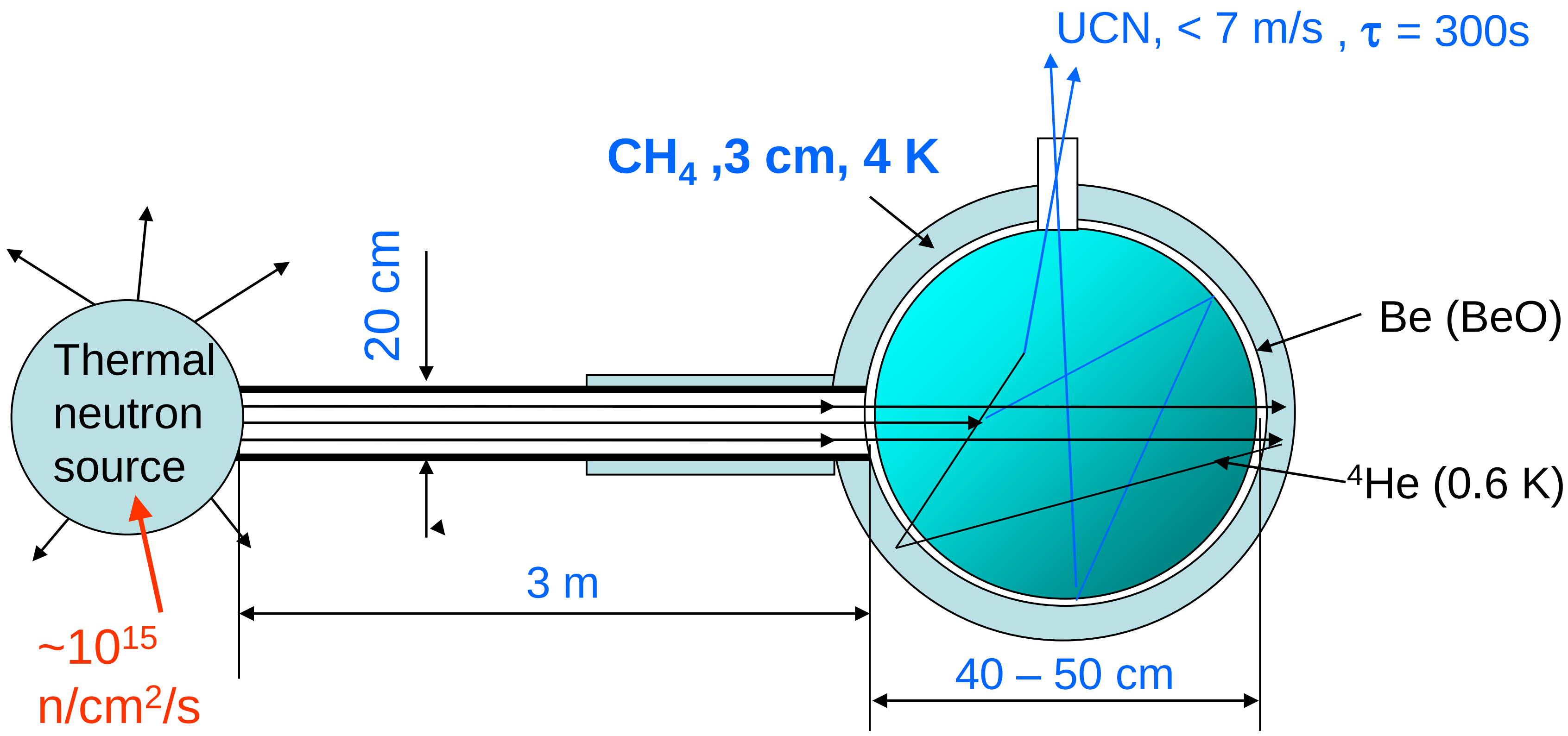




Evaluation parameters of the source



Density ~10^5 cm^{-3} Power ~10^7 UCN/s

Size is very important ! **Up to d^5**

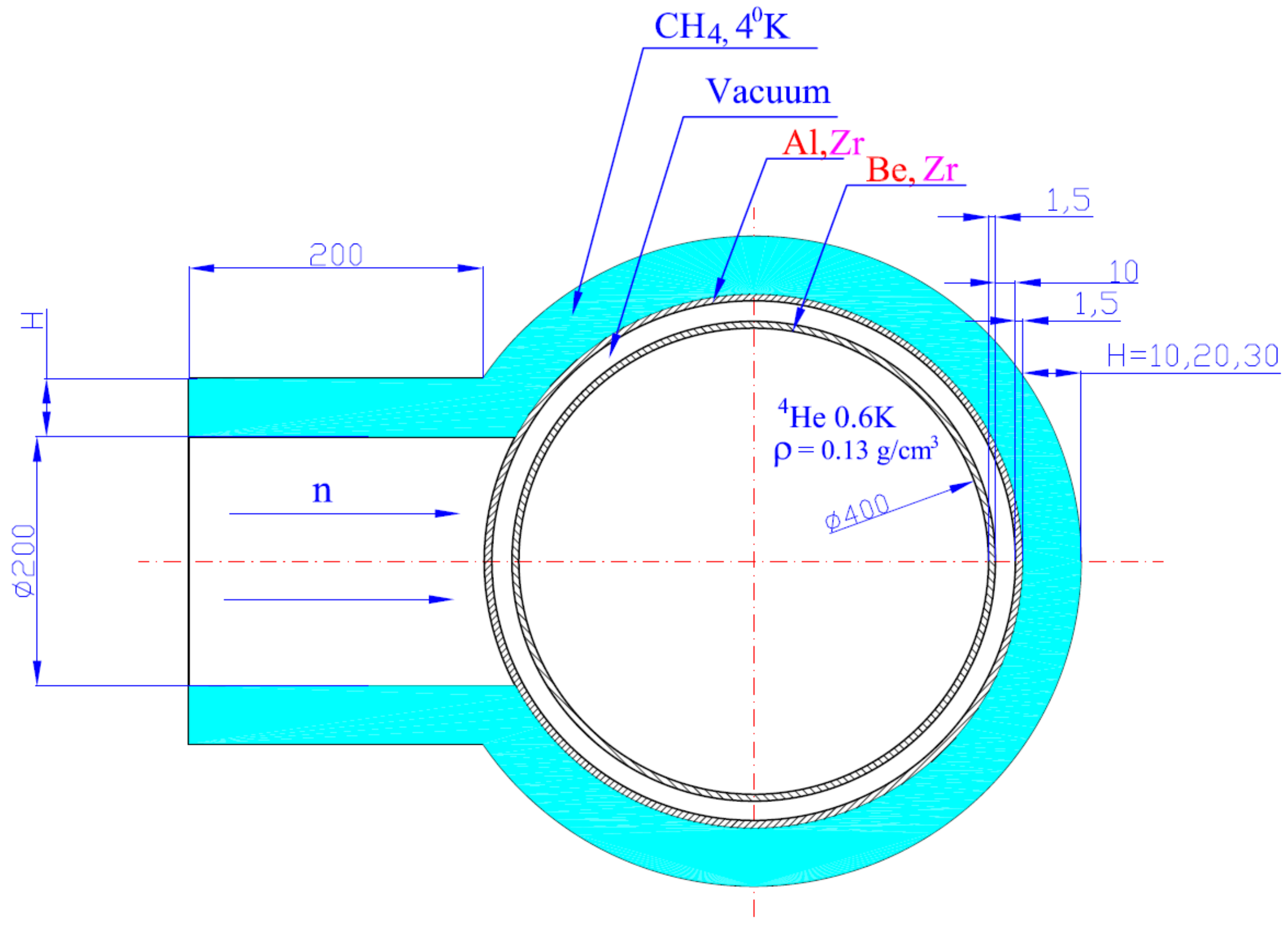
Radiative heating

1. External radiative heating:
   γ-rays+fast neutrons from the reactor
2. Internal radiative heating:
   capture of thermal neutrons in the source

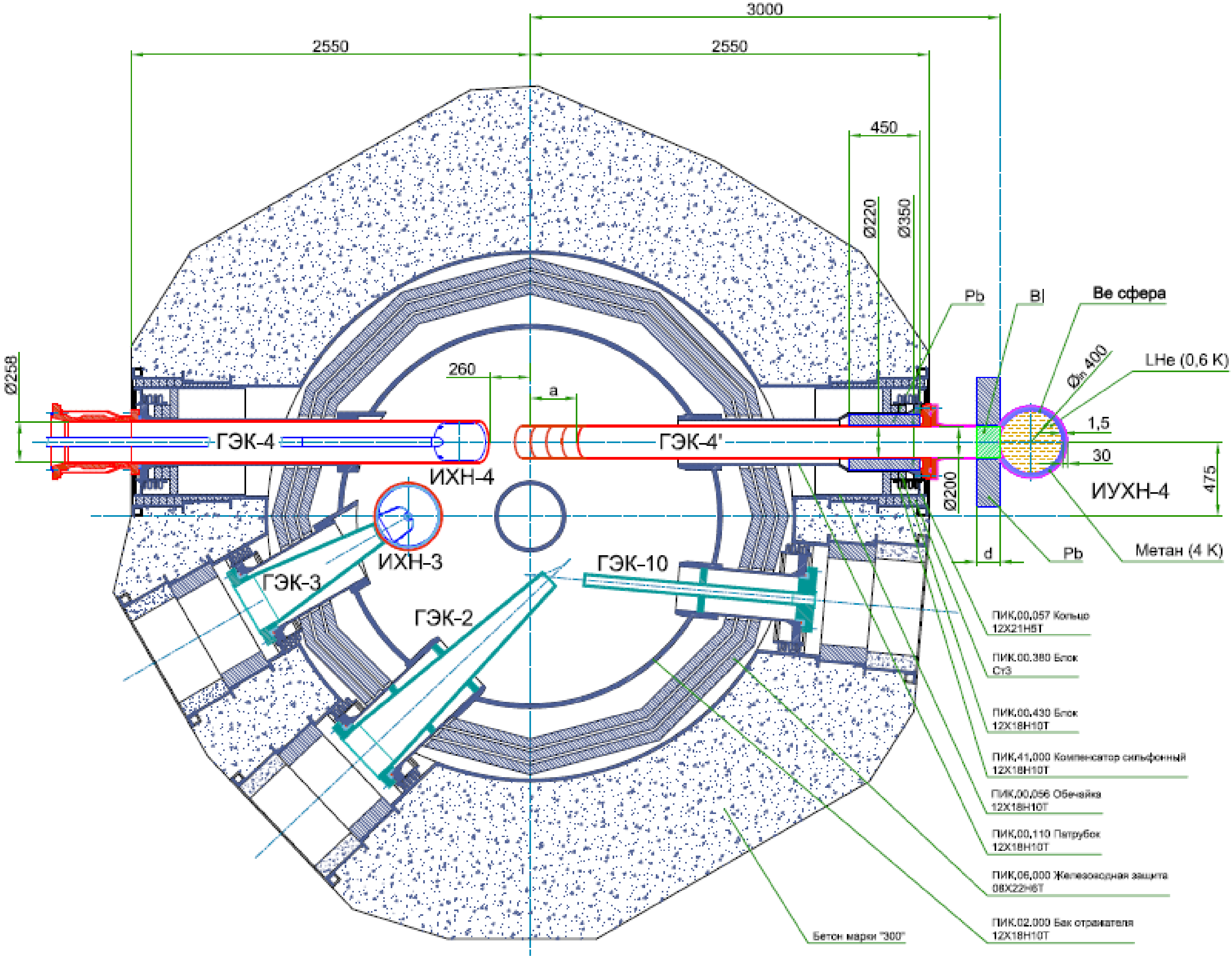
Limitations:

Q ~ 1 – 2 W

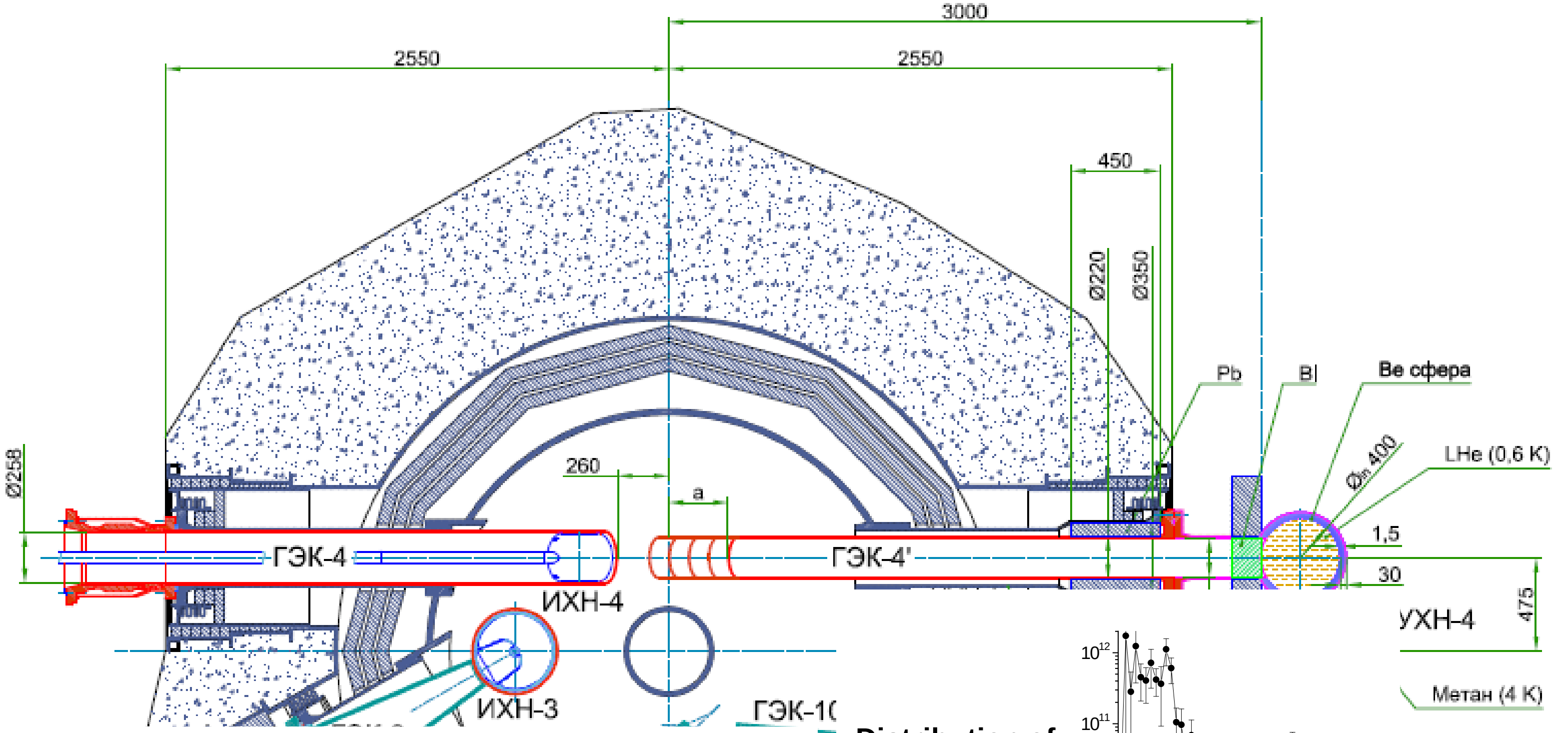
Geometry for simulations:

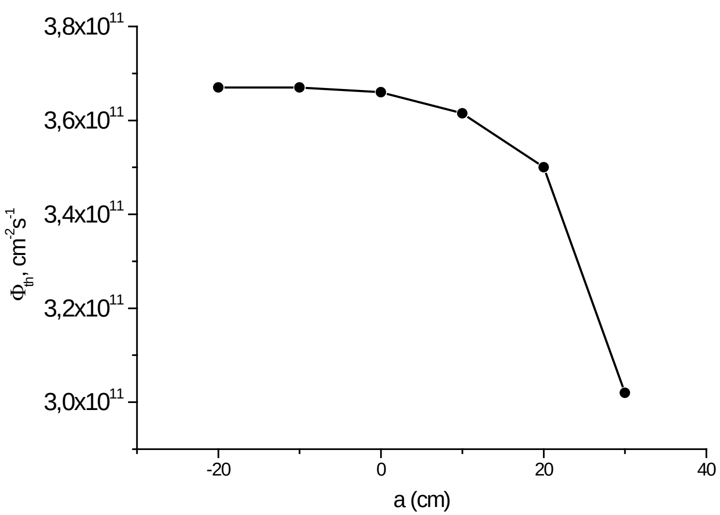


Geometry for simulations:

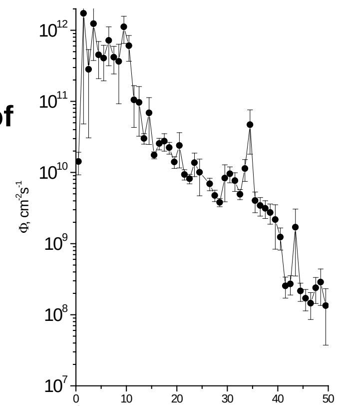


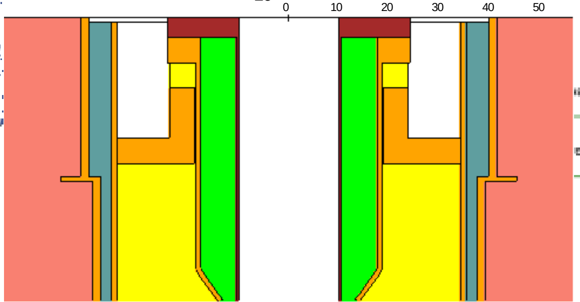
Geometry for simulations:



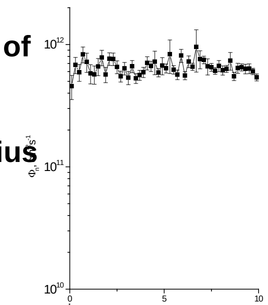


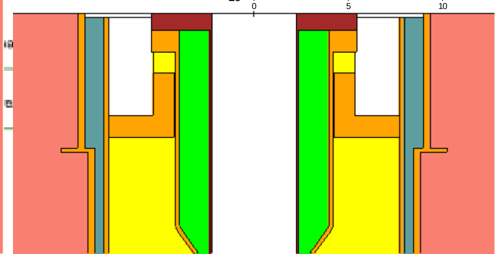
Distribution of gamma Flux along radius





Distribution of neutron Flux along channel radius





External radiative heating

Simulations d=20cm; D=40cm; J=3.66 n/sm^2/s;
Be vessel (h=1.5 mm):

Q = 3.67 W (He$_4$>90% γ-rays >90%)

$\Rightarrow$ γ-filter

10 cm Bi: Q<0.2W

Thermal neutron transmission:

Polycristal Bi ~ 10%

Perfect single crystal Bi (300K) ~ 50%

Perfect single crystal Bi (80K) ~ 80%

Real single crystal Bi (80K) ~ 60%

Internal radiative heating

Substances for the source: min σ_{abs} and max E_b

Al: σ_{abs}= 0.233b β-decay ~2 Mev/n

Zr: σ_{abs}= 0.185b

Be: σ_{abs}= 0.0076b

C: σ_{abs}= 0.0035b - pyrolytic graphite

Coatings: **Be: $E_b(v_b)$= 250 neV (6.9 m/s)**

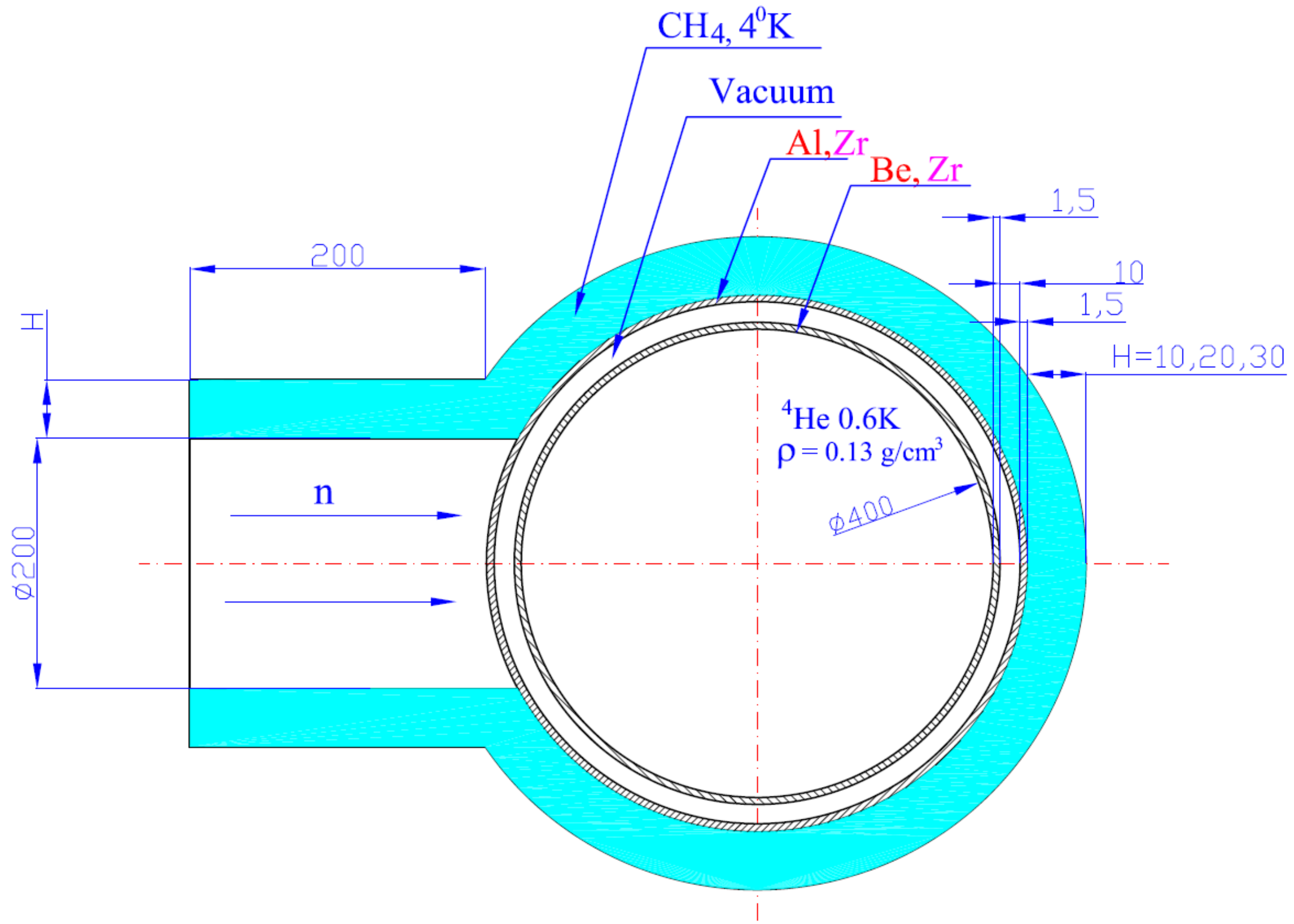
diamond: $E_b(v_b)$= 300 neV (7.6 m/s)

DLC (sp^3-70%): $E_b(v_b)$= 270 neV (7.2 m/s)

DLC (sp^3-45%): $E_b(v_b)$= 250 neV (6.9 m/s)

Internal radiative heating

Geometry for simulations:

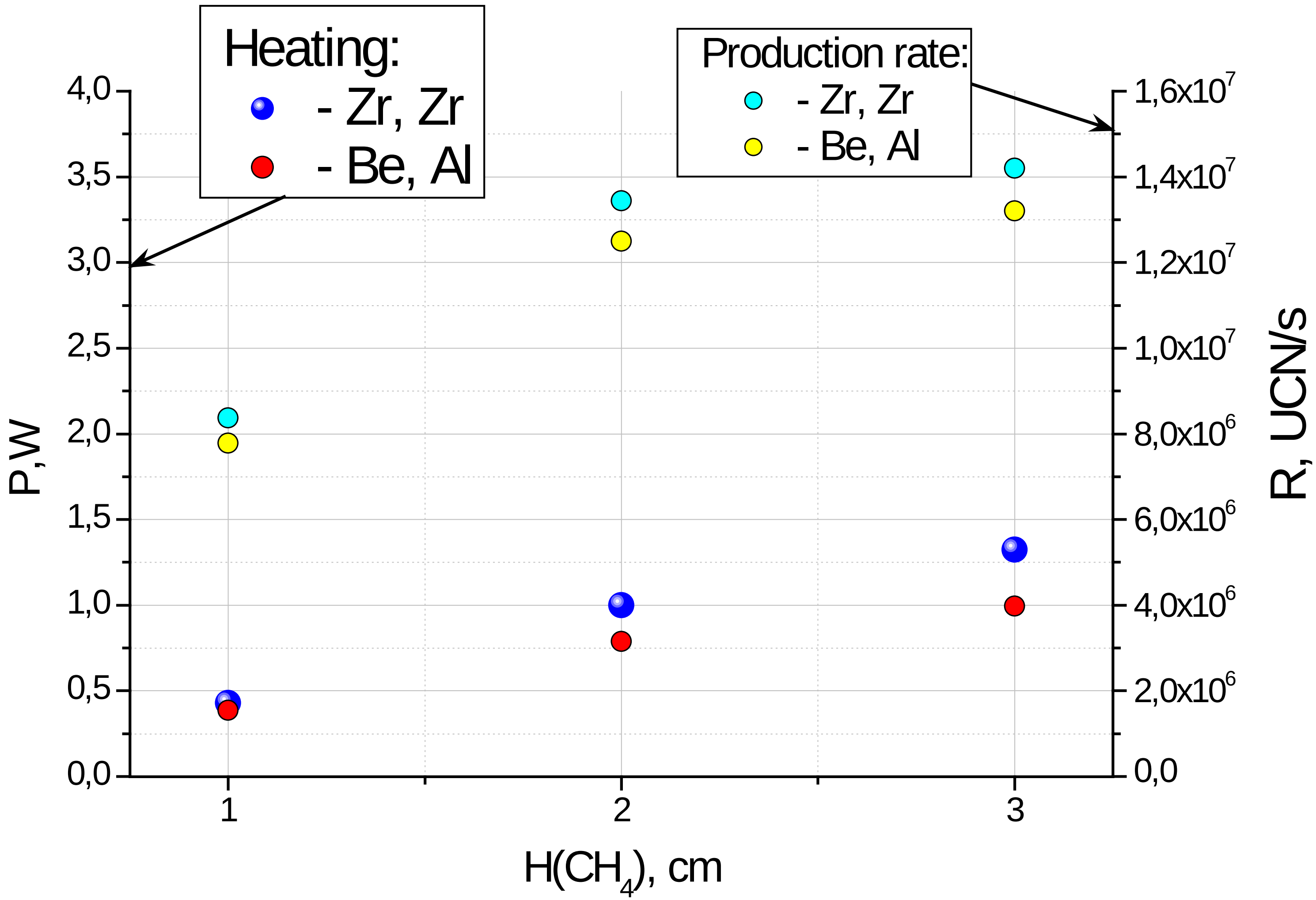


$J=3.66*10^{11}\ n/cm^2/sec$

Internal radiative heating

Simulations (Without Bi-filter)

UCN source ϕ40 cm; neutronguide ϕ20 cm; J=3.66*10^{11}n/cm^2/s



UCN source with solid CH_4 moderator
($h(CH_4) = 2$ cm)

d=20 cm; D=40cm, Be, Bi-filter:

Thermal neutrons:

power – $6\cdot10^6$ n/s; density - $6\cdot10^4$ n/cm^3; Q – 0.7 W

Cold neutrons:

power – $2\cdot10^7$ n/s ; density – $1.7\cdot10^5$ n/cm^3; Q – 1.2W

d=25 cm; D=50cm; Be, Bi-filter: :

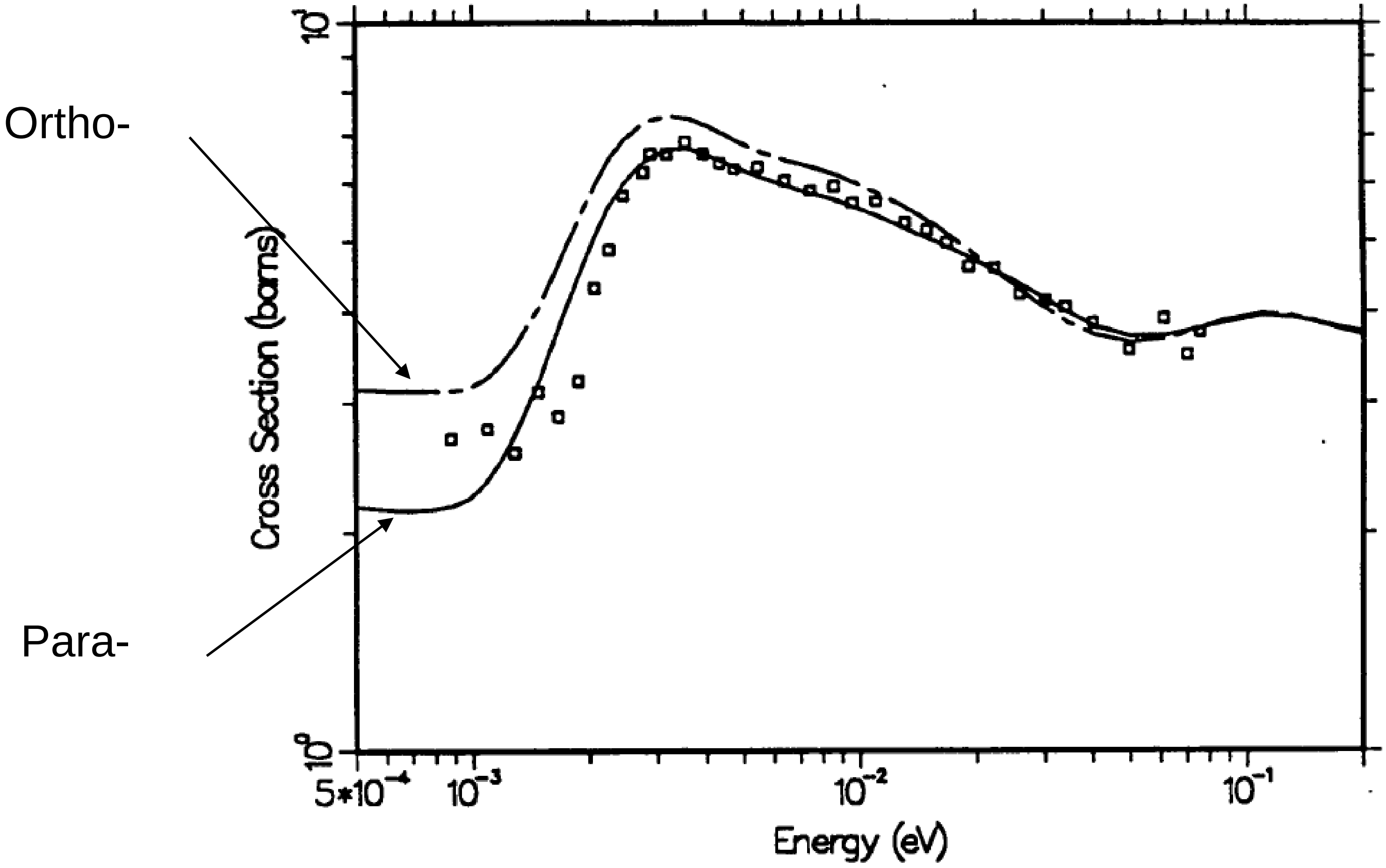
Thermal neutrons:

power – $1.8\cdot10^7$ n/s ; density – $1\cdot10^5$ n/cm^3; Q – 1.8 W

Cold neutrons:

power – $5\cdot10^7$ n/s ; density – $3\cdot10^5$ n/cm^3; Q – 3.1W

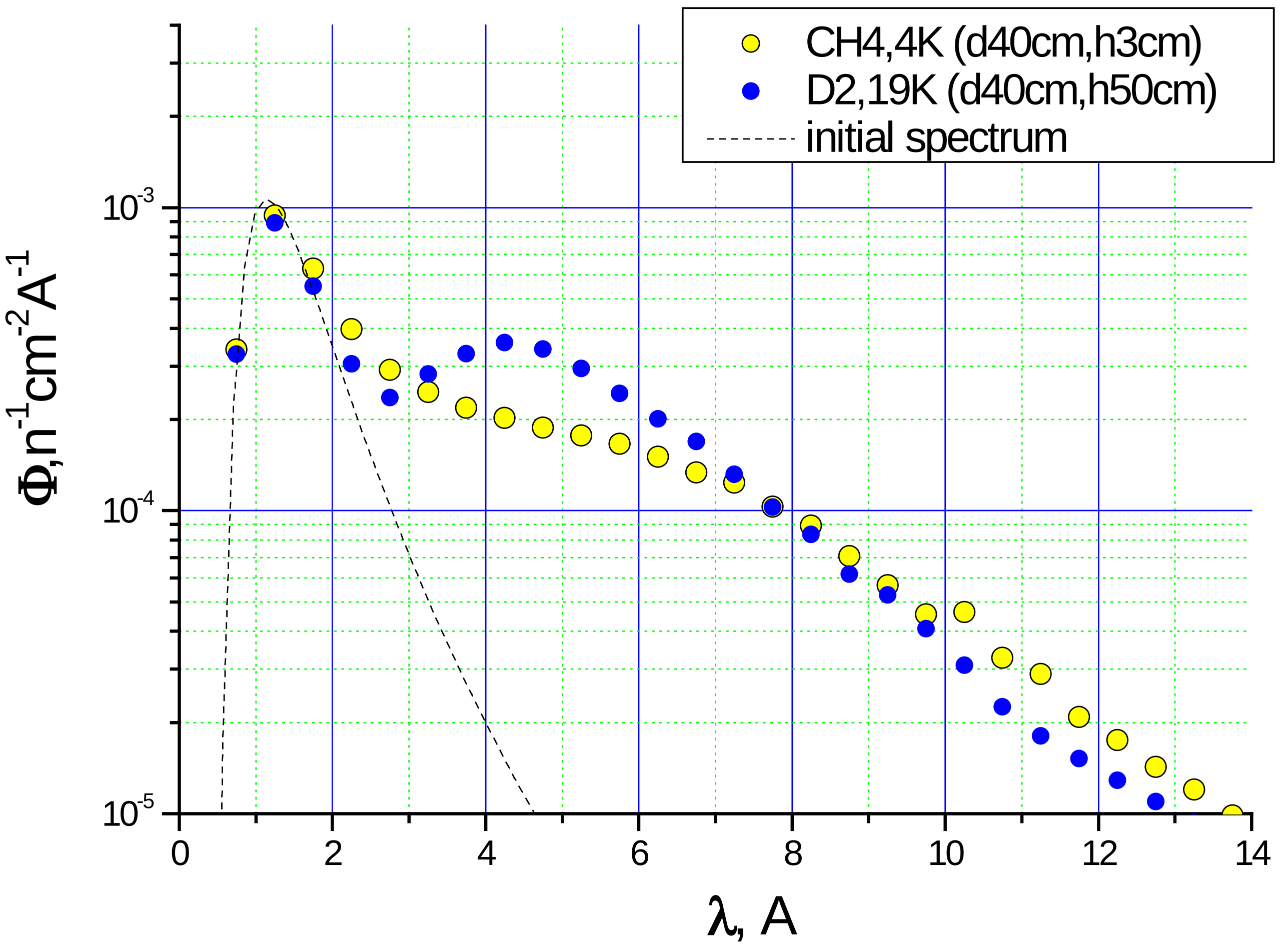
Liquid deuterium 19K

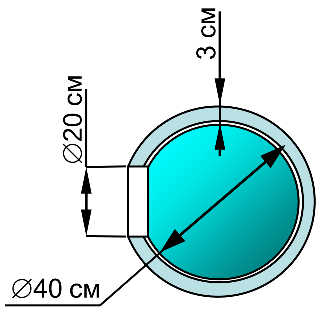


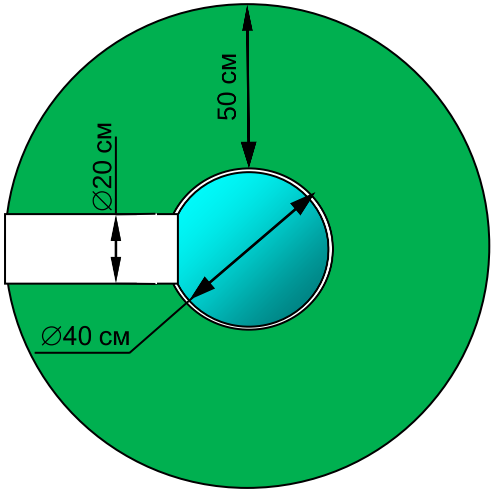
coherent scattering ⟶ optical potential

Simulations

MCNP 4c with special kernels (solid CH_4 and liquid D_2)

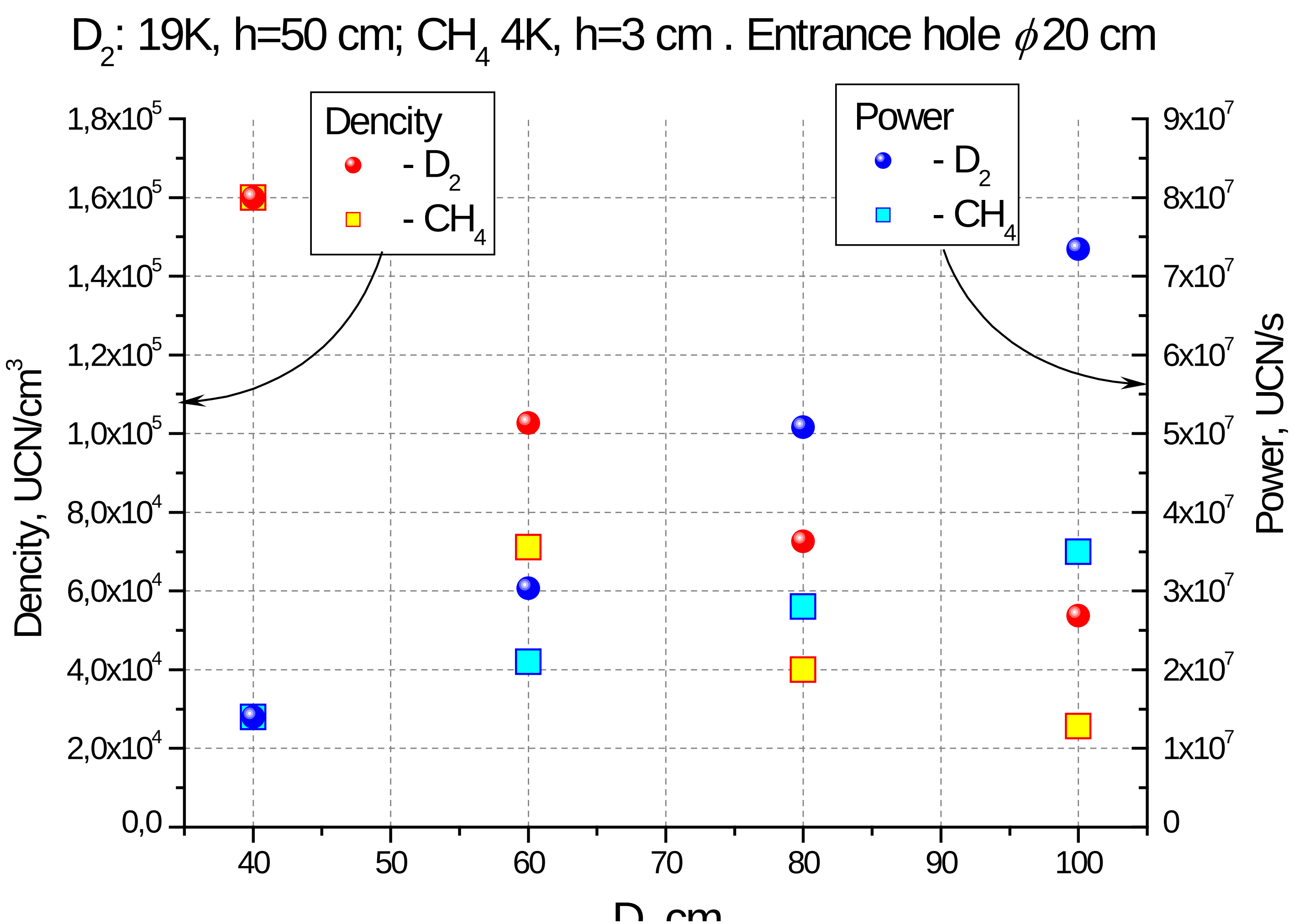


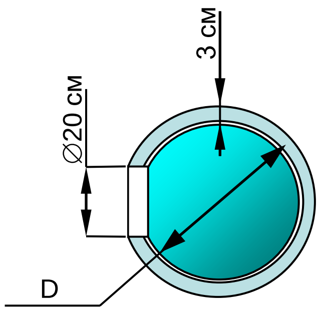


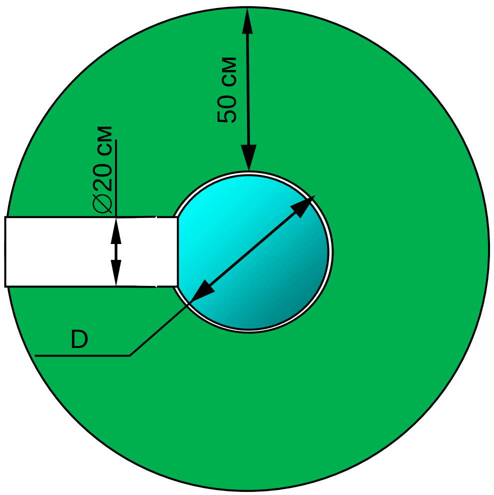


Simulations (Without Bi-filter)

MCNP 4c with special kernels (solid CH_4 and liquid D_2)





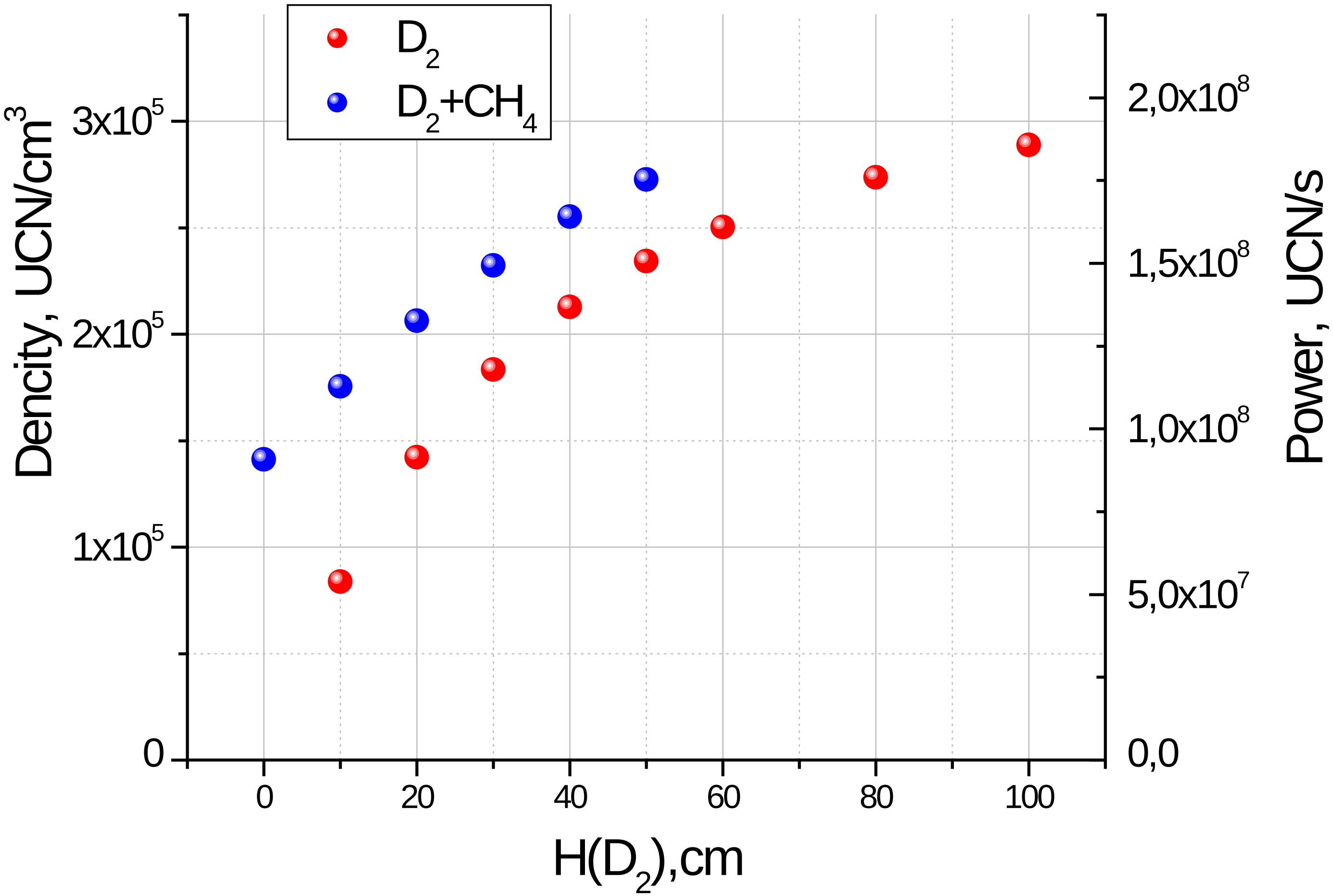


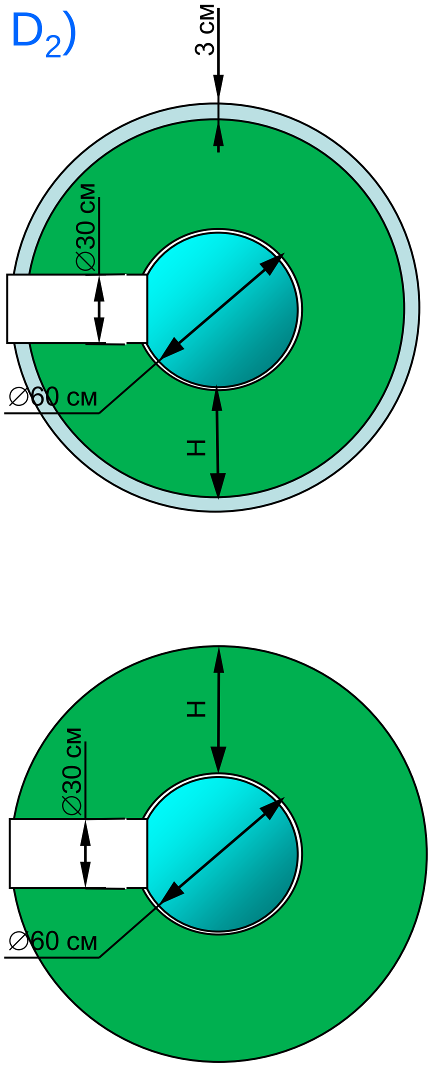
Simulations

MCNP 4c with special kernels (solid CH_4 and liquid D_2)

D = 60cm

D_2: 19K, CH_4 4K, h=3 cm . Entrance hole ϕ30 cm, J = $8*10^{11}$ n/sm^2/s





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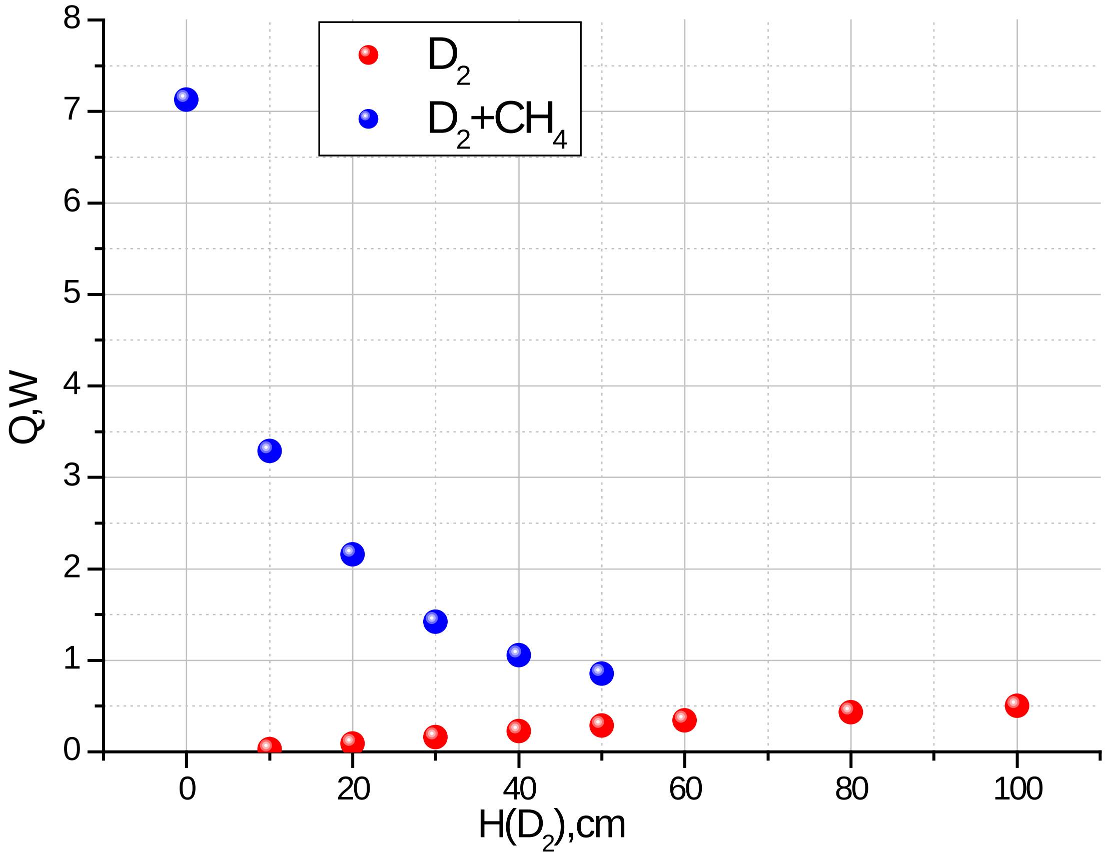
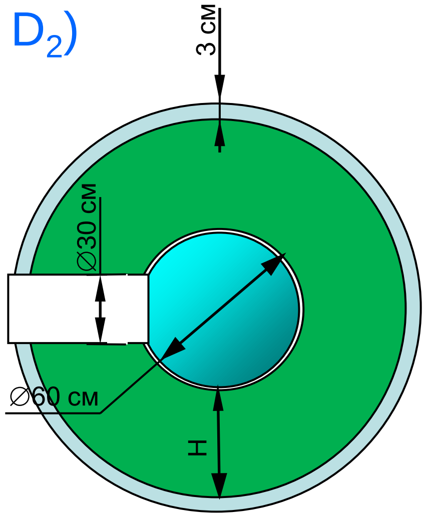
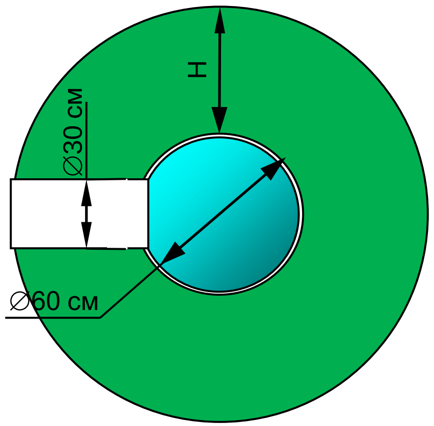






UCN source with solid D_2 moderator
($h(D_2)$ = 50 cm), Bi-filter.

d=30 cm; D=60cm:

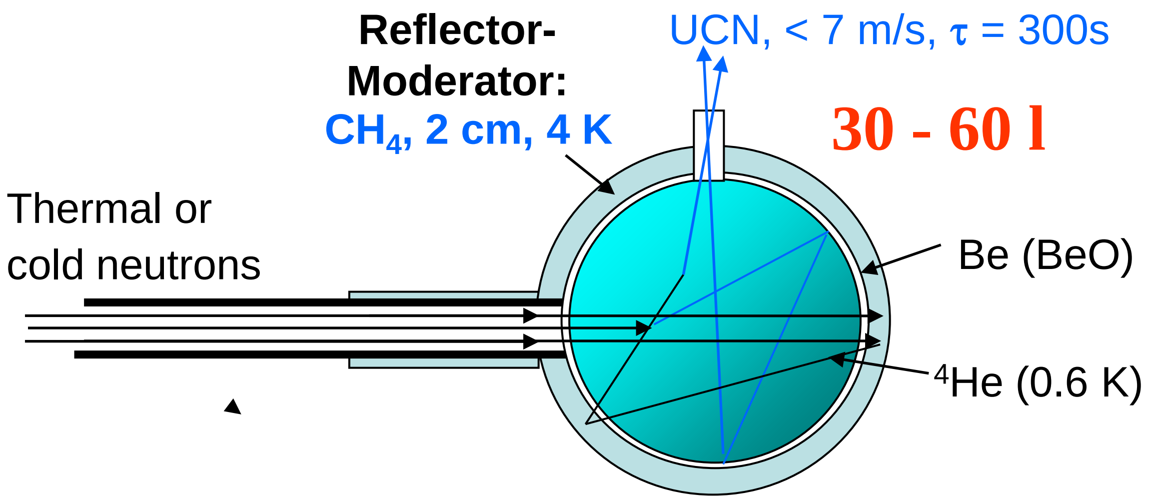
Thermal neutrons:

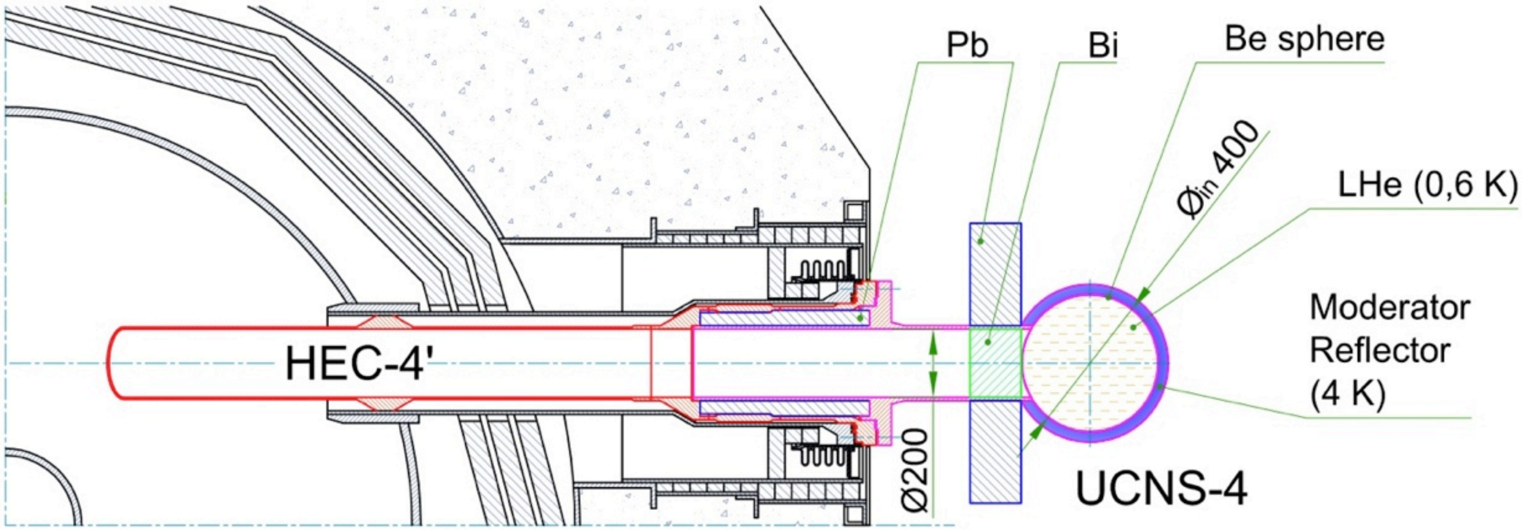
power – $7 \cdot 10^7$ n/s ; density – $1.5 \cdot 10^5$ n/cm^3; Q – 1.5 W

Cold neutrons:

power – $2 \cdot 10^8$ n/s ; density – $5 \cdot 10^5$ n/cm^3; Q – 2.1 W

UCNS on the extracted beam of the PIK reactor





UCN density ~10^5 cm^{-3} UCNS flux ~10^7 c^{-1}