Neutron spin filter based on spin-exchange interaction of ^3He nuclei with the atoms of saturated ferromagnetic

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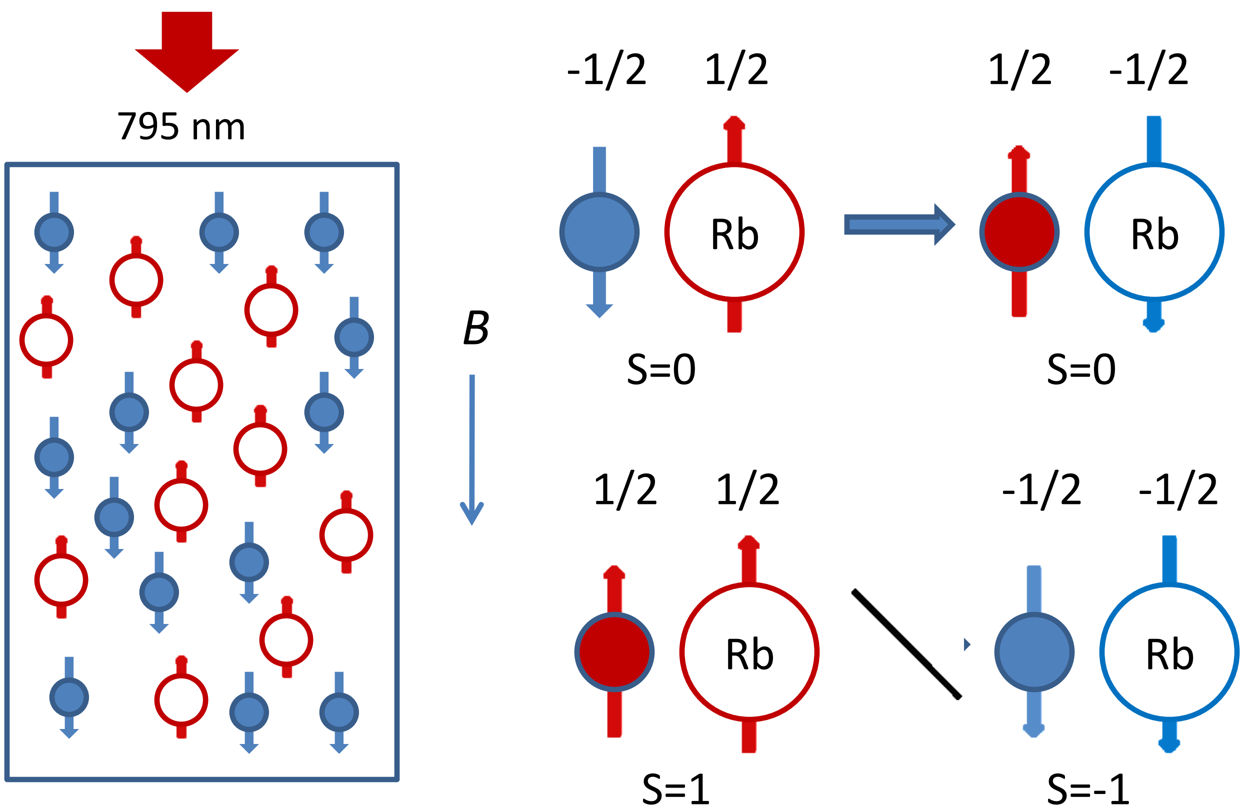
ISINN 29. Dubna 2023

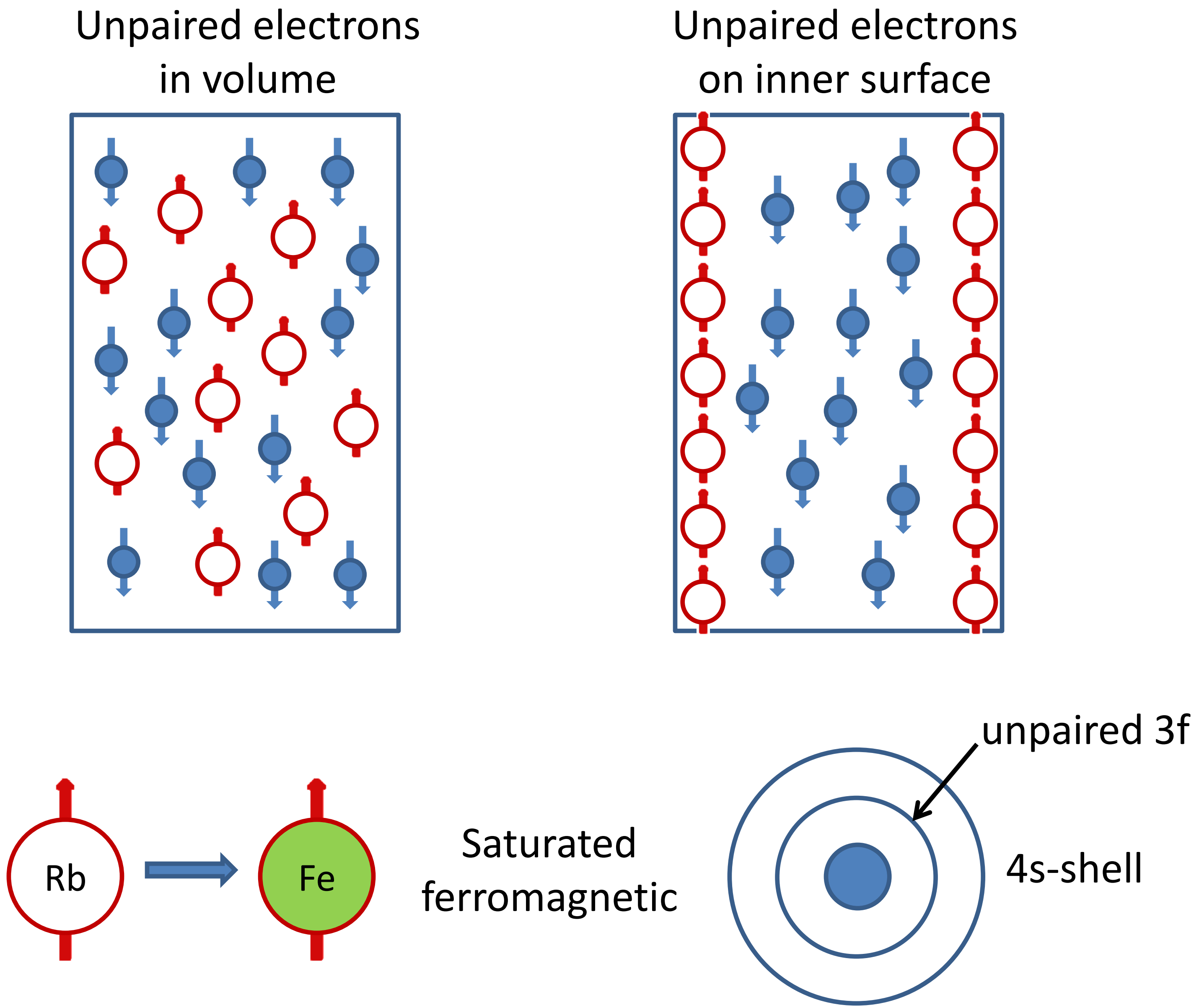
OPTICAL POLARIZATION OF ^{3}HE NUCLEI

Physical background of ^{3}He nuclear polarization is a hyperfine interaction of the nuclear magnetic moment with that of unpaired electron on the outer shell of alkali metal atom (Rb).

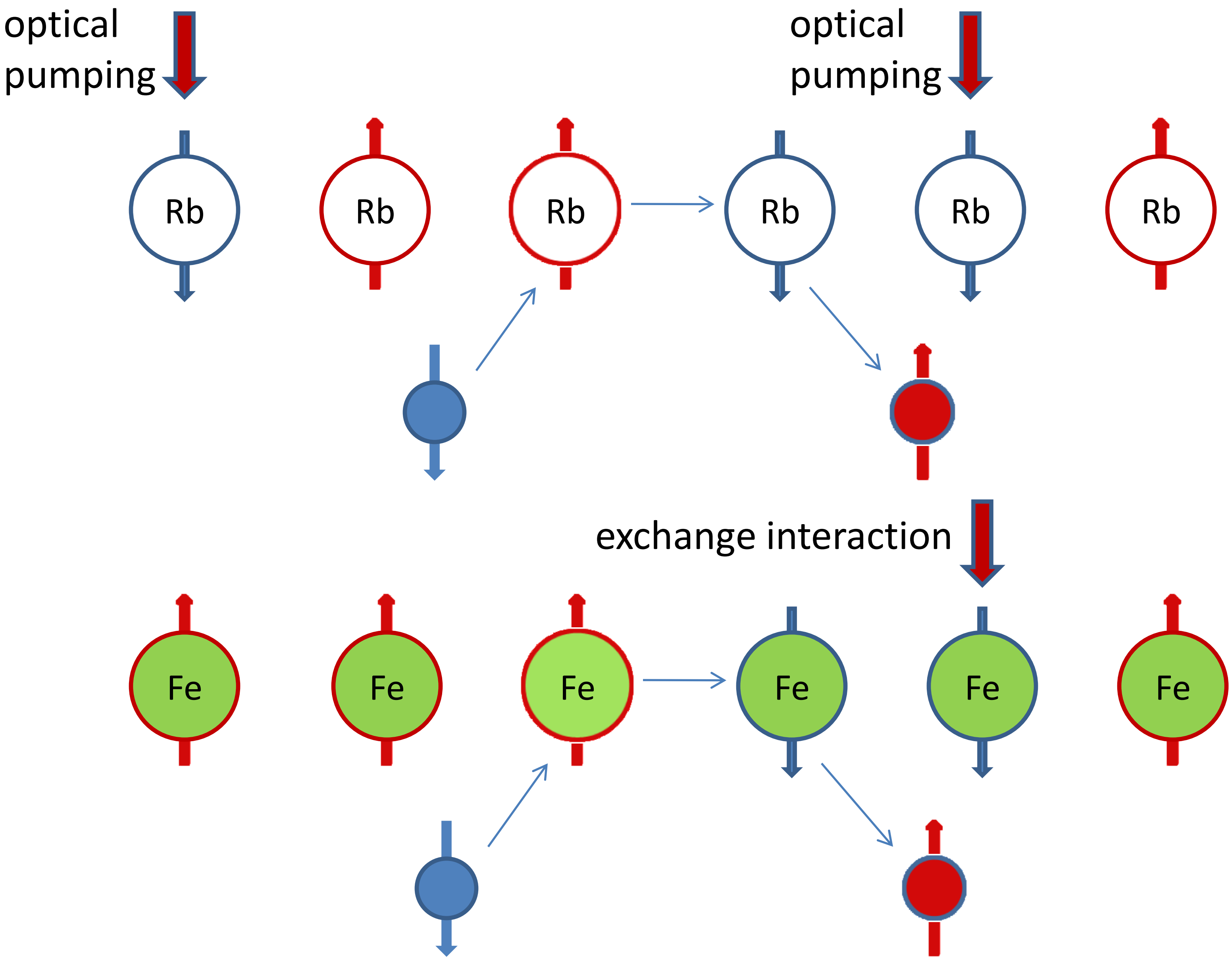
The outer Rb electrons are polarized by optical pumping of circular 795 nm laser light.



Gradual polarization of ^{3}He in +1/2 state


Unpaired electrons
in volume
Unpaired electrons
on inner surface
Rb
Fe
Saturated
ferromagnetic
unpaired 3f
4s-shell

ASSUMPTION ANALOGY

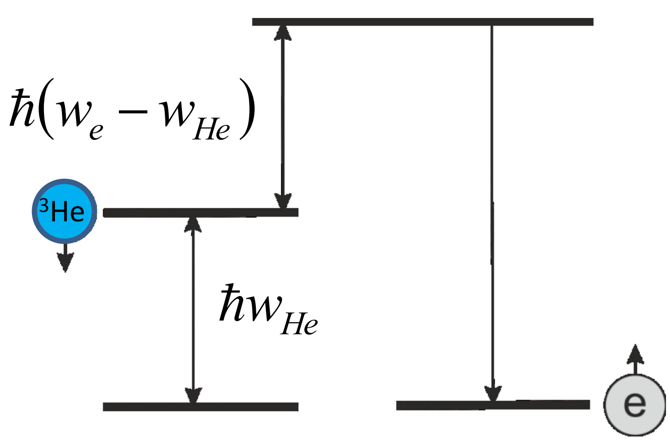


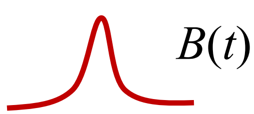
THE ANALOGY WITH KNOWN PROCESS HAS USED JUST FOR DEMONSTRATION OF IDEA.

Thus collisions of ^3He atoms with the ferromagnetic surface are not perfectly same like with individual Rb atoms in volume.

The ferromagnetic atoms in bulk sample share their 4s - electrons, but 3d – electrons keep their locations in atoms.

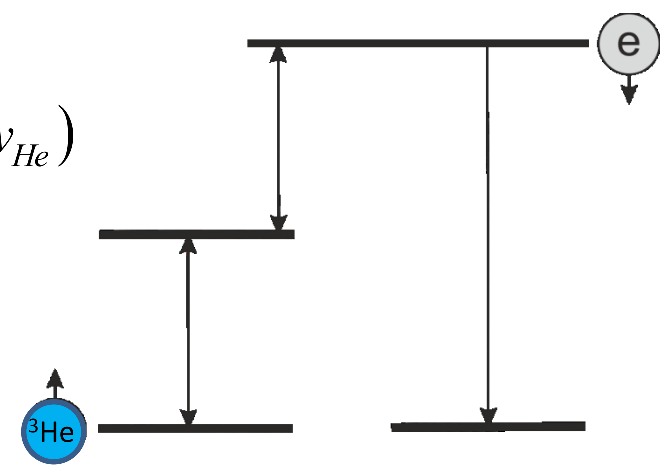
In ferromagnetic ^3He nuclear and electron spins interact thru fluctuated magnetic fields, which arise in the locations of the electron spins because of relative nuclear and electron spins movement (collisions).





$$\frac{1}{2\mu_0 c} B_w E_w = \hbar(w_e - w_{He})$$

$$\mu_e B_0 << kT$$



EVALUATION OF ^{3}HE POLARIZATION P_{HE}

Hamiltonian in case of hyperfine interaction:

$$H = g_I\left(\vec{I}\cdot\vec{B}\right) + \alpha\left(\vec{I}\cdot\vec{S}\right)$$

Solution for saturated ferromagnetic:

$$\frac{dI_z(t)}{dt} = -\Gamma_\alpha\left[I_z(t) - \langle S_z\rangle\right] - \Gamma\cdot I_z(t) \quad \Rightarrow \quad P_{He}(t) = P_e\cdot\frac{\Gamma_\alpha}{\Gamma_\alpha+\Gamma}\left[1-e^{-(\Gamma_\alpha+\Gamma)t}\right]$$

Exchange rate constant:

$$\Gamma_\alpha = n_S v\sigma_3 / d$$

Γ - polarization decay rate. Must be less than Γ_α

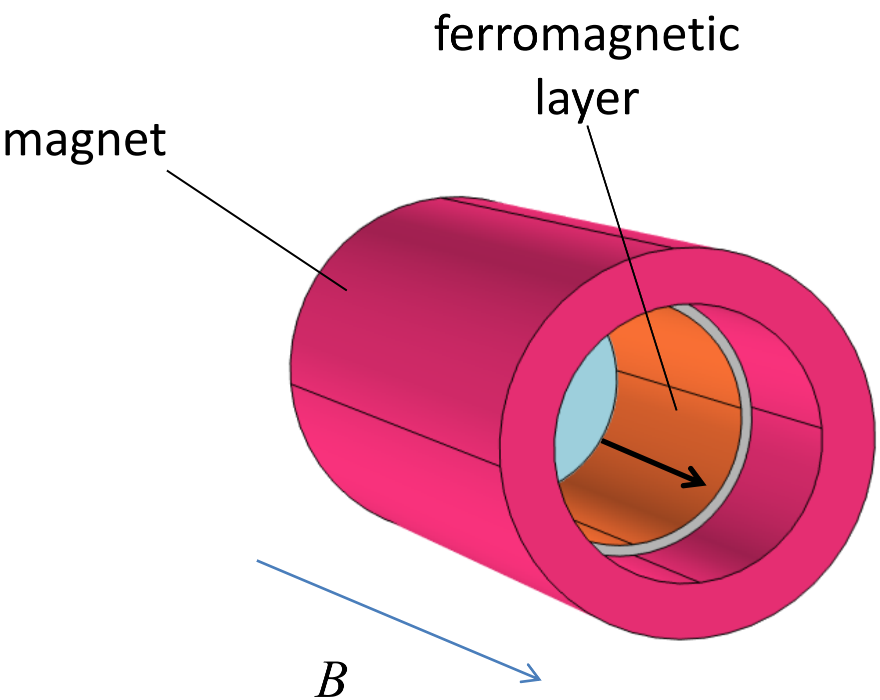
n_S – number of ferromagnetic atoms per cm^2,
v – speed of ^{3}He atoms,
σ_3 – spin flip scattering cross section,
d – cell wall distance.

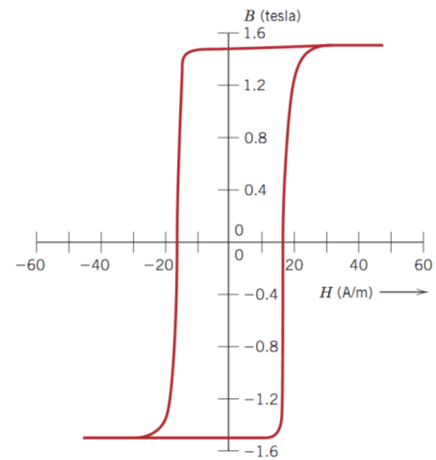
For iron and d = 5 cm:

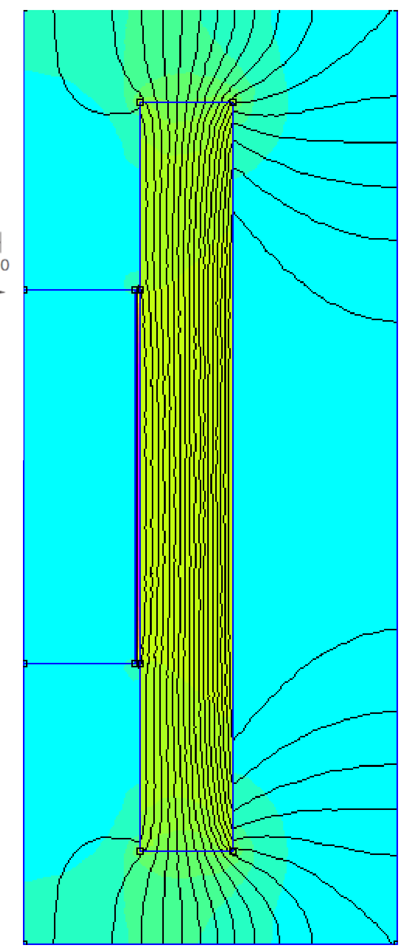
$$\Gamma_\alpha \approx 10^{15}\cdot\left(v\sigma_3\right) \geq 1/20\ hours$$

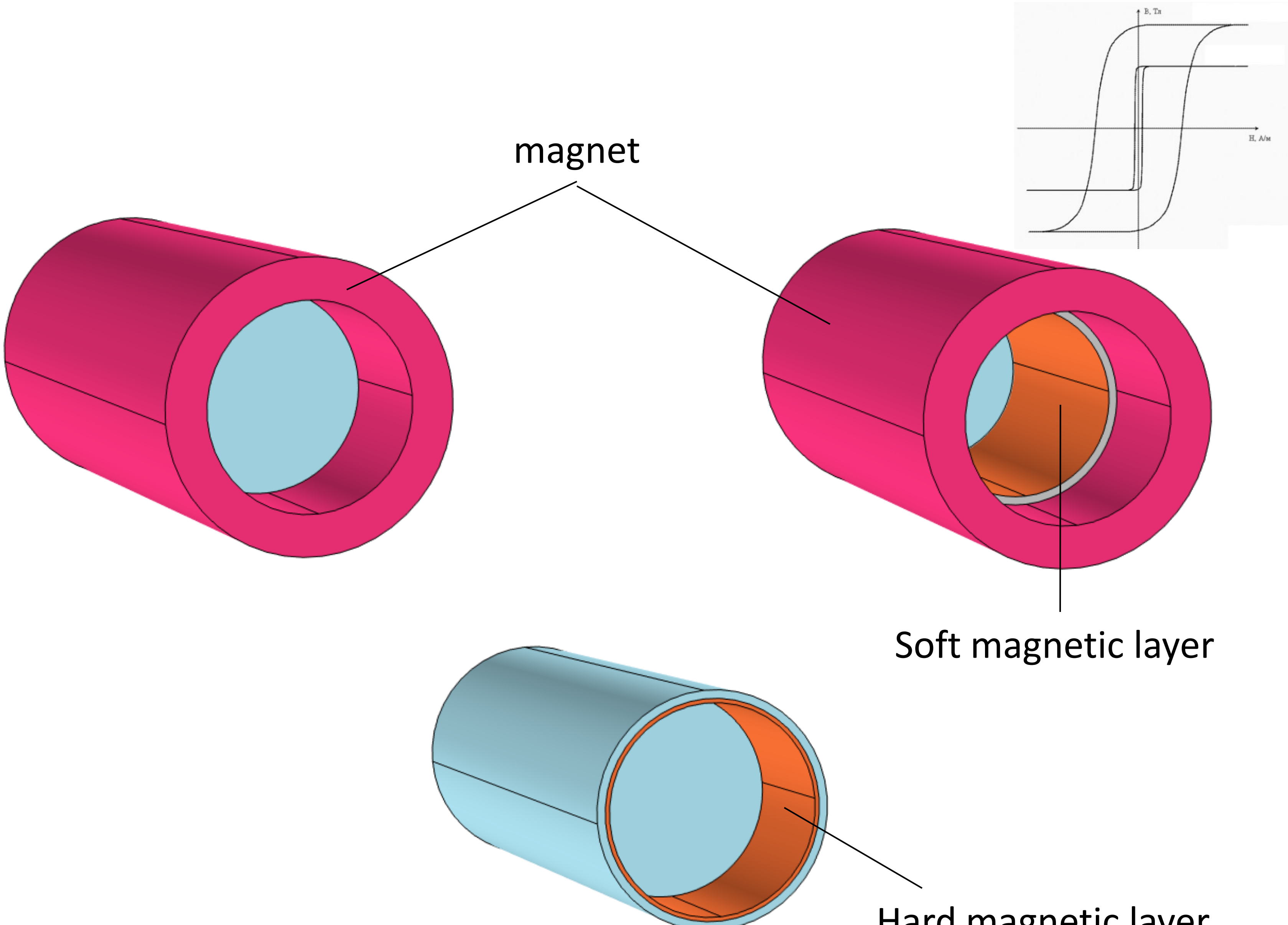
TECHNICAL DEMANDS FOR SPIN FILTER

1. ^{3}He must be free from paramagnetic atoms (getter).
2. Low roughness ferromagnetic surface (polishing, rolling).
3. High purity of all inner surfaces, free from fat and oxide layers (chemical and US-cleaning, heating and pump out)
4. High saturated ferromagnetic surface








B, Тл
H, А/м
magnet
Soft magnetic layer
Hard magnetic layer

CONCLUSIONS

1. The assumption about nuclear ^3He polarization as result of mutual spins flip during collisions with ferromagnetic atoms has been done.

2. The technical demands for neutron spin filter and its possible designs were proposed.

Thank for Your Attention