Measurement of the magnetic momentum of silver atoms

A heated crucible filled with silver it heated in vacuum chamber. Because of the heat the silver melts and some atoms are vaporized out of the crucible. The beam of vaporized atoms passes through collimators (screens with a hole in the center) and become a very thin beam of silver atoms.
Silver atoms have a total magnetic momentum which is randomly oriented. In that, silver atoms can be regarded as tiny current loops with an intrinsic magnetic momentum.

As we have seen in our lectures current loops in an external magnetic field experience a TORQUE which makes them rotate and align their magnetic momentum with the external magnetic field. Even if the SUM OF THE FORCES ON THE LOOP IS ZERO, there is a torque acting on the loop.

We can define a MAGNETIC POTENTIAL ENERGY which is equal to the work done by the external magnetic field to orient the loop magnetic momentum from its original direction towards the direction of the external magnetic field.

$$U_m = -\bar{\mu} \cdot \bar{B}_{ext}$$

SCALAR QUANTITY

$\bar{\mu}$: magnetic momentum of the current loop

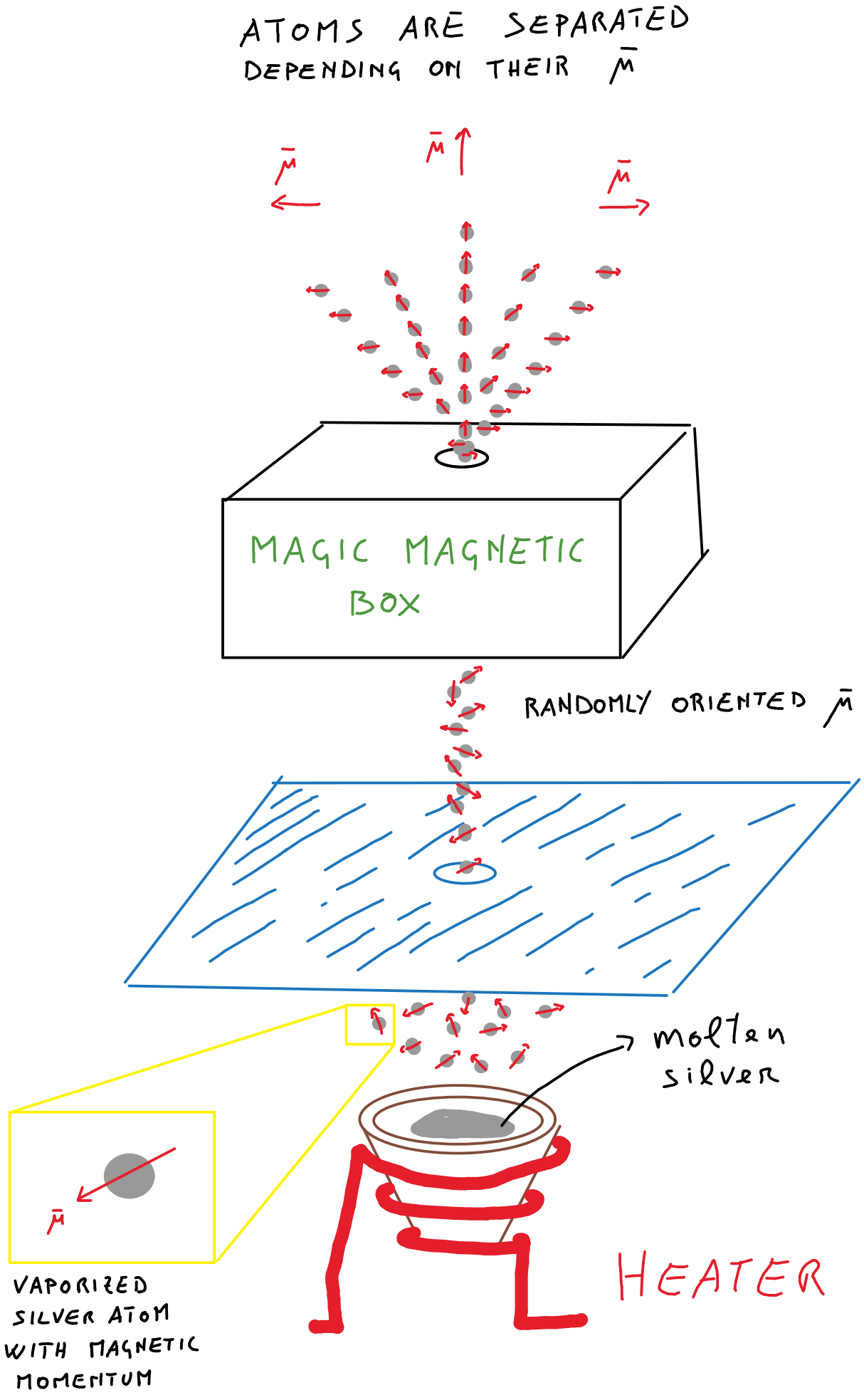
$\bar{B}_{ext}$: External magnetic field

The torque experienced by each single atom (current loop) is:

$$\bar{M} = \bar{\mu} \times \bar{B}_{ext}$$

VECTOR QUANTITY

The experimental setup



The Magnetic Magic Box creates a magnetic field such that atoms (current loops) are separated according to the orientation of their magnetic momentum.

To achieve this, the magnetic field has to EXERT A FORCE on the atoms, which depends on the projection of the magnetic momentum on the direction of the magic box magnetic field

HINTS :

- Uniform magnetic field apply a torque on the loops but NO force
- The superposition of uniform magnetic fields is still a uniform magnetic field.
- The magic box has been first realized in 1922.

ASSIGNMENT : Suggest how can the magic box separate the atoms depending on their magnetic momentum and explain why this "special" magnetic field can exert a force on the atoms.