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RAZPOUTYNE project towards compact cooling techniques

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RAZPOUTYNE project towards compact cooling techniques

Impact of dead time on the clock short term stability

When interrogating the clock transition the result is judged by two criteria :

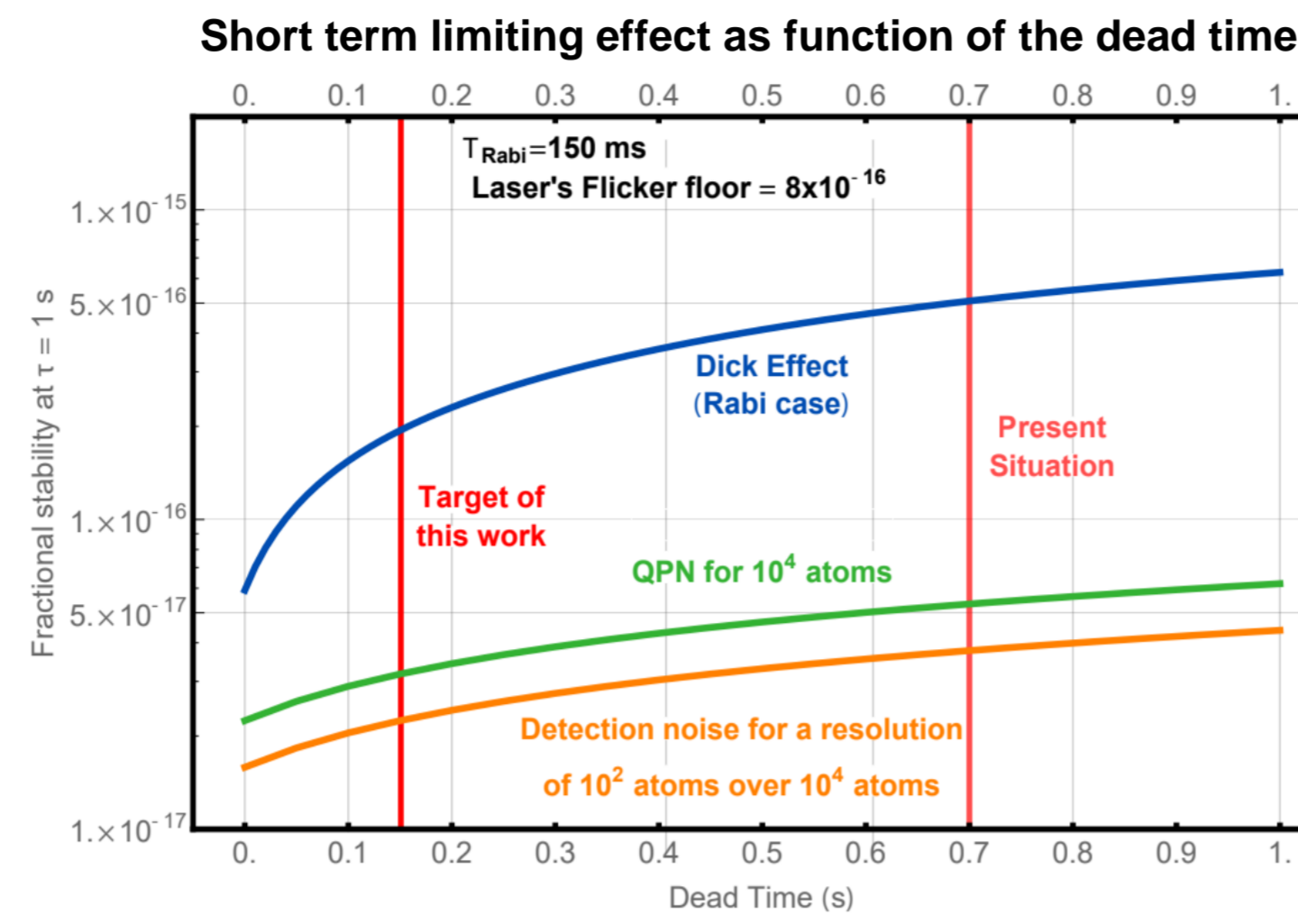
- **The uncertainty**, or how close we believe the corrected measured frequency is to the 'ideal' unperturbed value, and it will be reflected by how well are known the corrections made due to systematic effects shifting this frequency.
- **The stability**, when the values of repeated measurements are clustered close together and have minimal scatter over time.

The major limitation noise on the stability

Dick effect

Loading as fast as the coherence of the laser will reduce it

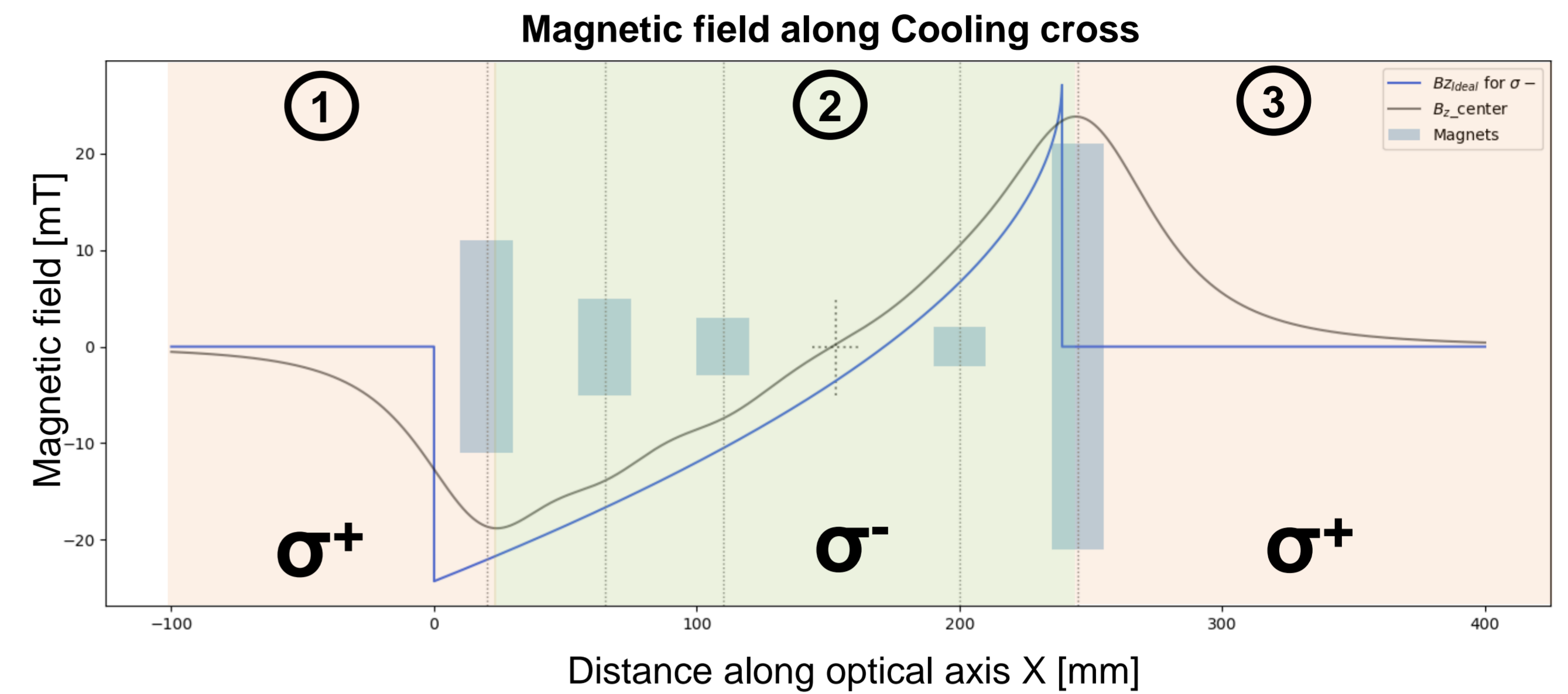
The project aims at loading **>10⁴ atoms into the optical trap in <150 ms.**



Simulation: Cooling cross

Cooling cross skeleton is based on the next three totally-related parameters:

- Velocity capture, being higher velocity the cross is able to cool down.
- Maximum (des)acceleration, defined by the cooling laser intensity.
- Length of the cross, defined as the minimum distance to stop atoms at $v=0$ m/s.



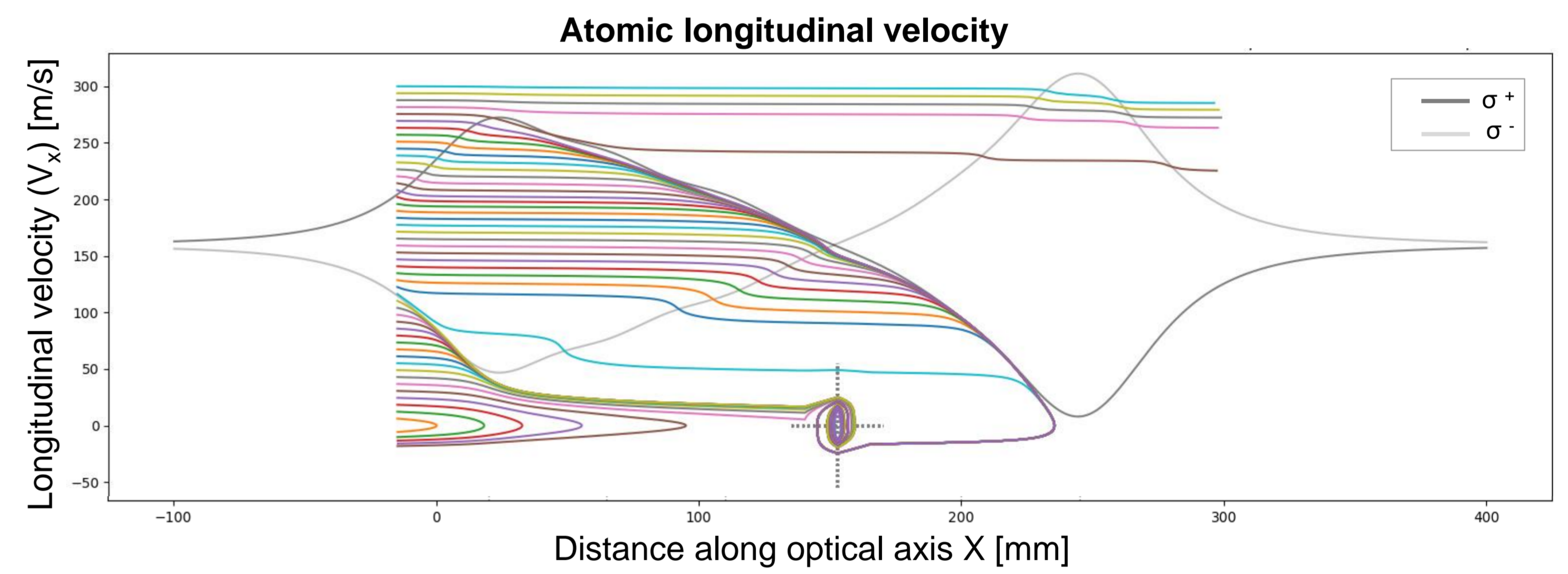
Region 1 and 2 can be use for deceleration (also region 3).

ZS beam contains of 50% σ^- and 50% σ^+ , since the polarization is perpendicular to B field.

Two different circular polarization play a roll:

- σ^+ light slow down atoms where $\nabla B > 0$, and they are capture in the 2D-MOT region.
- σ^- light slow down atoms where $\nabla B < 0$, and they are capture in the 2D-MOT region after the atomic beam "reflection".

The laser detuning (Δ_{laser}) able us to **select a velocity window**, being an offset.



Motivation: Ultrafast loading rates in a optical lattice

Initial Idea: Desing a compact cooling system by combining in space and time two known components:

- **Zeeman Slower with permanent magnets :**

Doppler cooling & Zeeman shift

1D

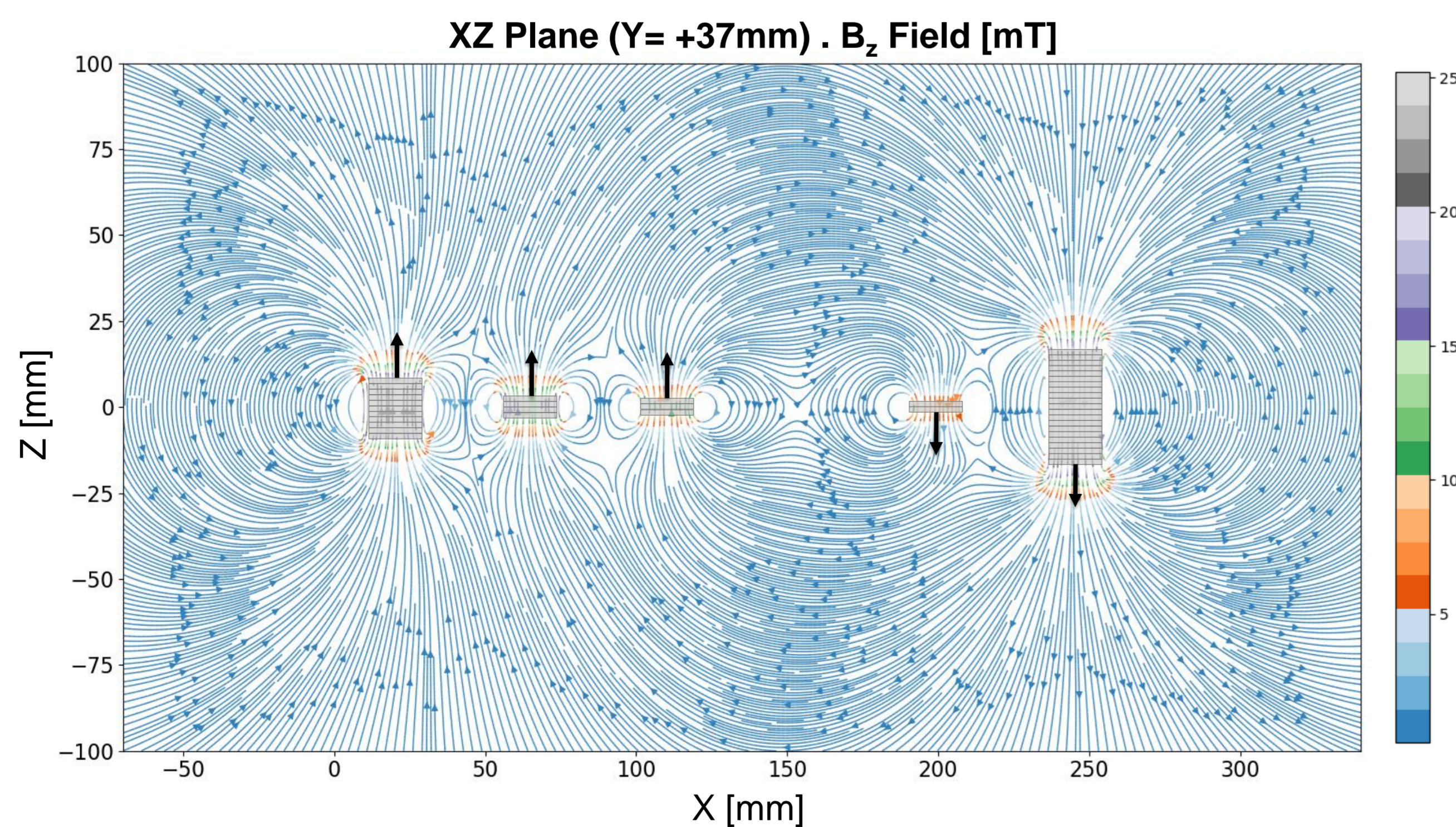
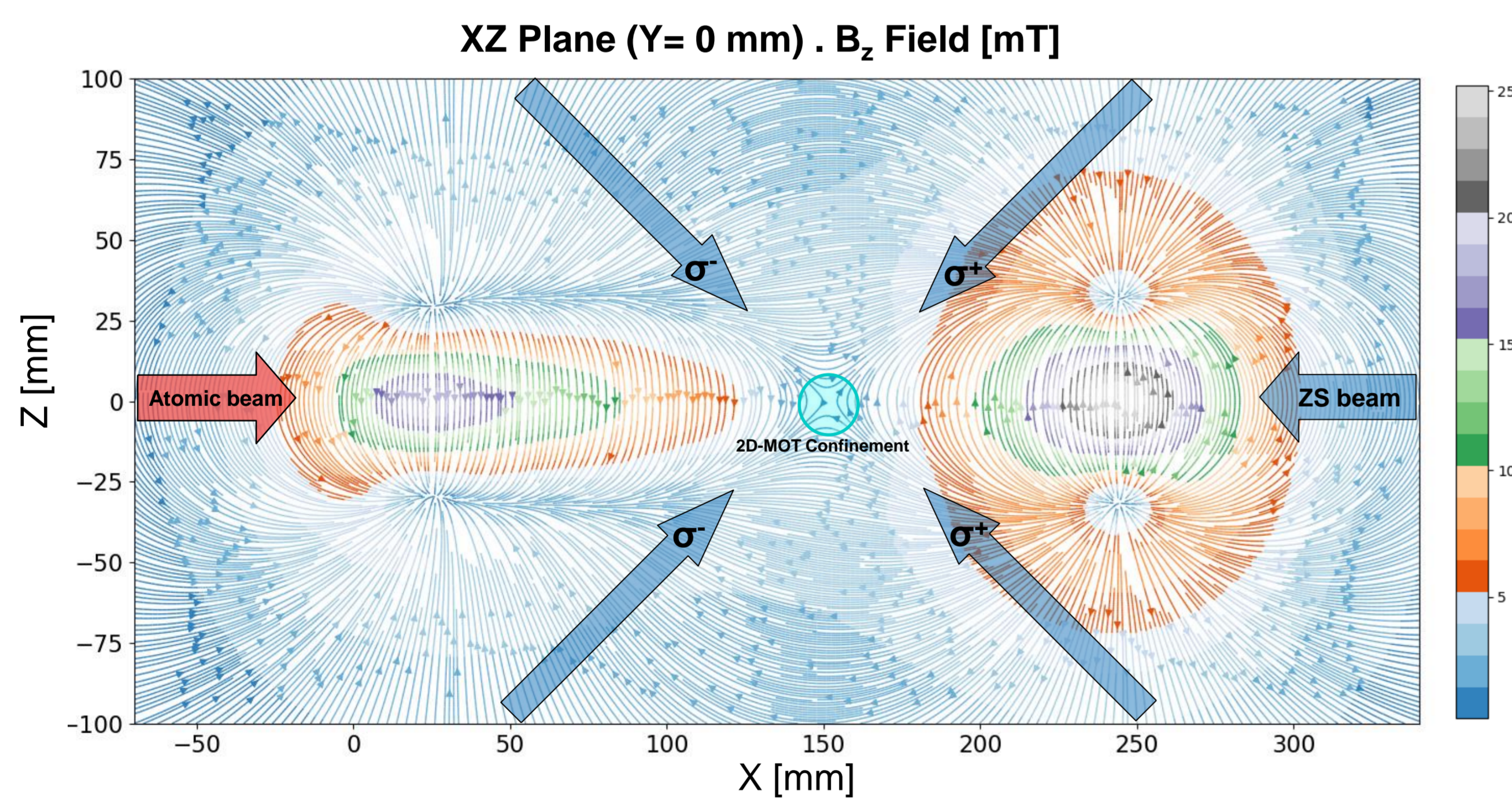
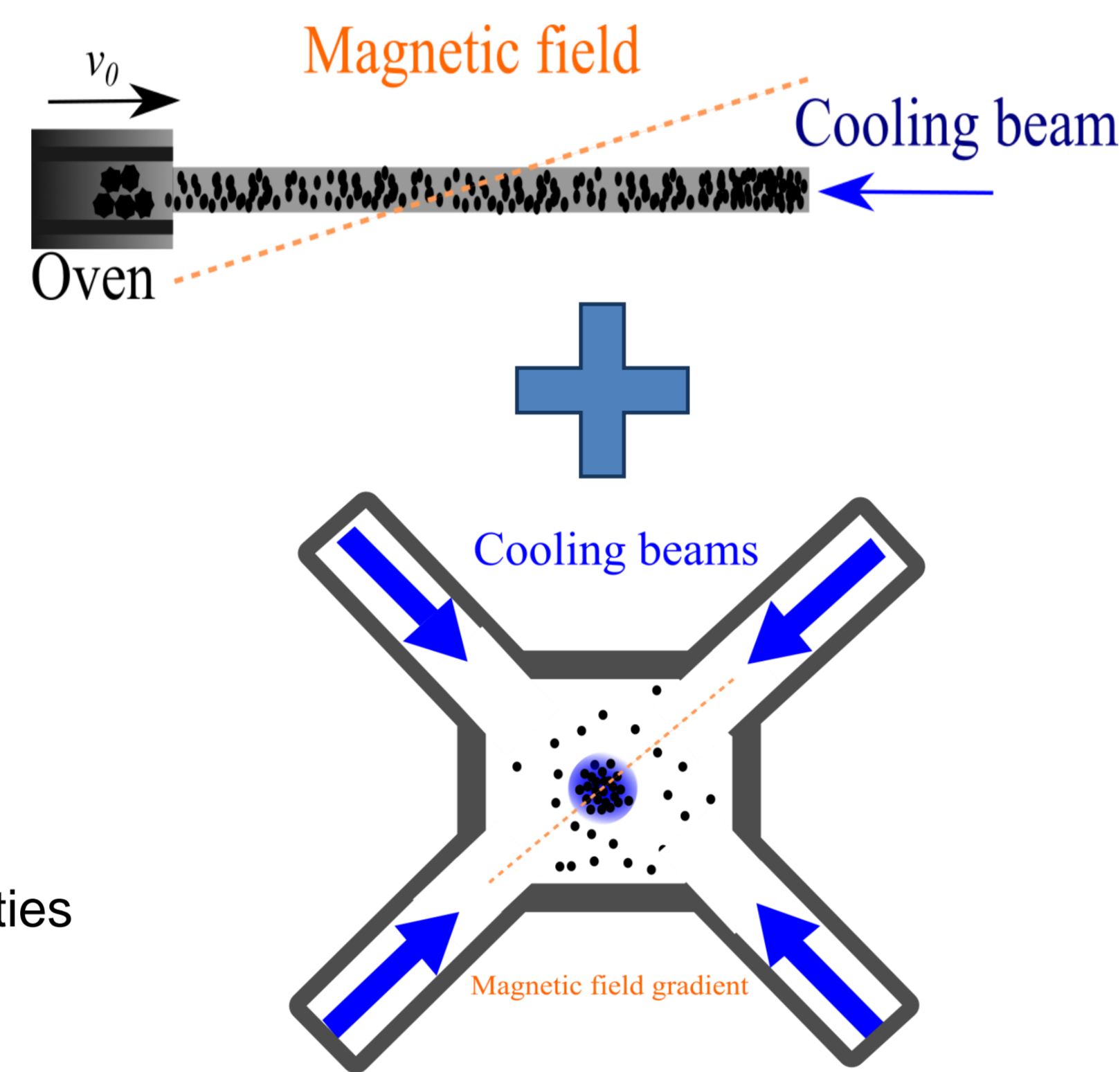
Cool down longitudinal velocity

- **2D-MOT :**

Doppler cooling & Zeeman shift

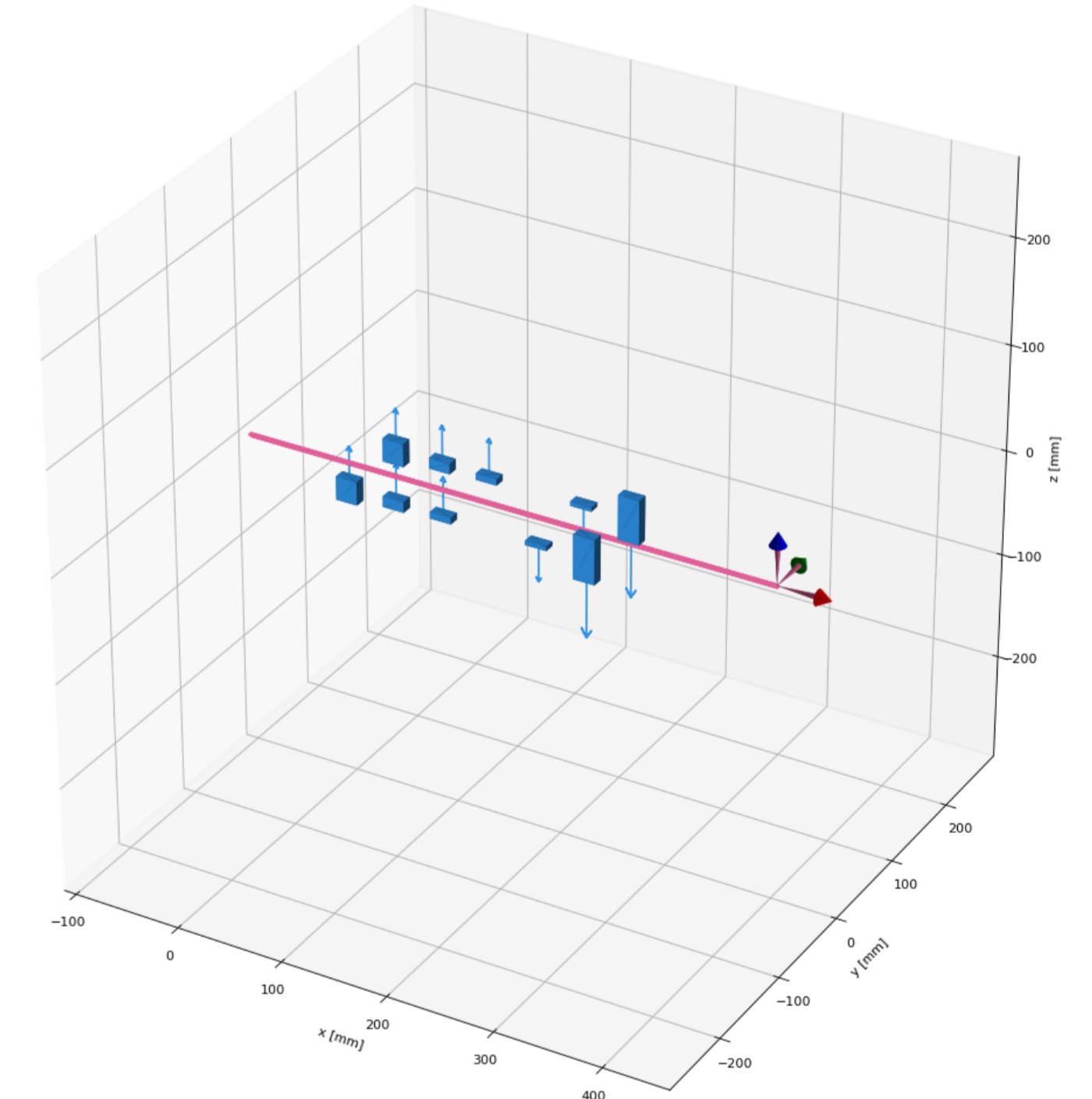
2D

Cool down the radial plane of velocities

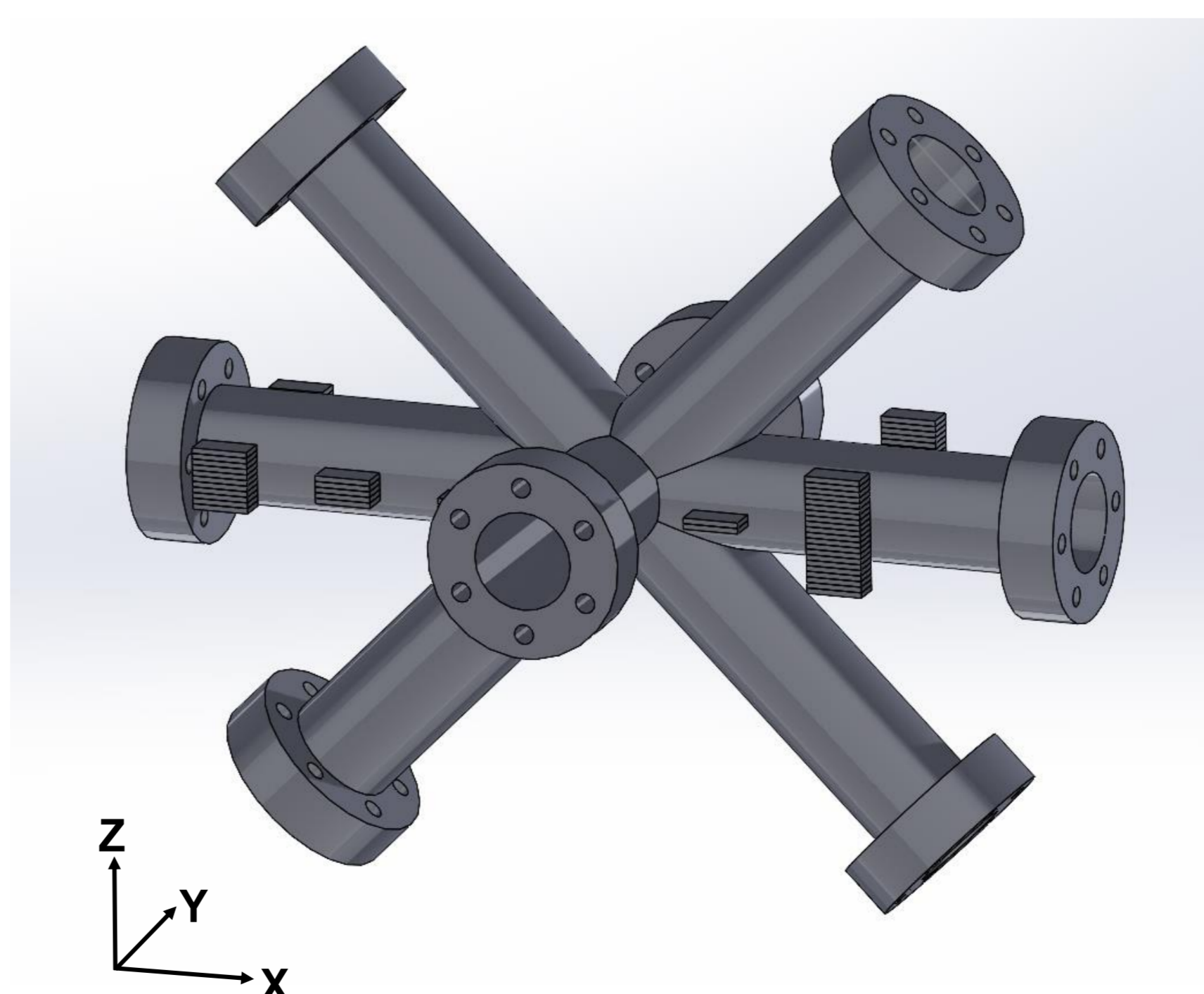


- Zeeman Slower**
- $P_{zs} = 80$ mW
 - $w_{zs} = 12.5$ mm
 - $\Delta_{laser} = -400$ MHz
 - $v_{cap} = 300$ m/s
- 2D-MOT**
- $P_{2D-MOT} = 60$ mW
 - $w_{2D-MOT} = 12.5$ mm
 - $\Delta_{2D-MOT} = 0.00$ MHz
 - $MOT_{pos} = 152.8$ mm

Arrangement of permanent magnets



Structure design in SolidWorks®.



X axis, Zeeman slower beam is counter-propagating to the Yb atoms, who are launched from from the oven.

ZX plane, 4 counter-propagating beam create the 2D-MOT.

Along the Y axis:

- The Yb atoms are confinement in a cigarette shape along the center of the MOT.
- A pushing beam will translate the Yb cigarette shape to the 3D-MOT.

Key aspect:

- The same array of magnets create the necessary magnetic field for the Zeeman Slower and the magnetic gradient for the 2D-MOT.

Fundings

Reference

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