A Superconducting Demonstrator Magnet for Magnetic Density Separation

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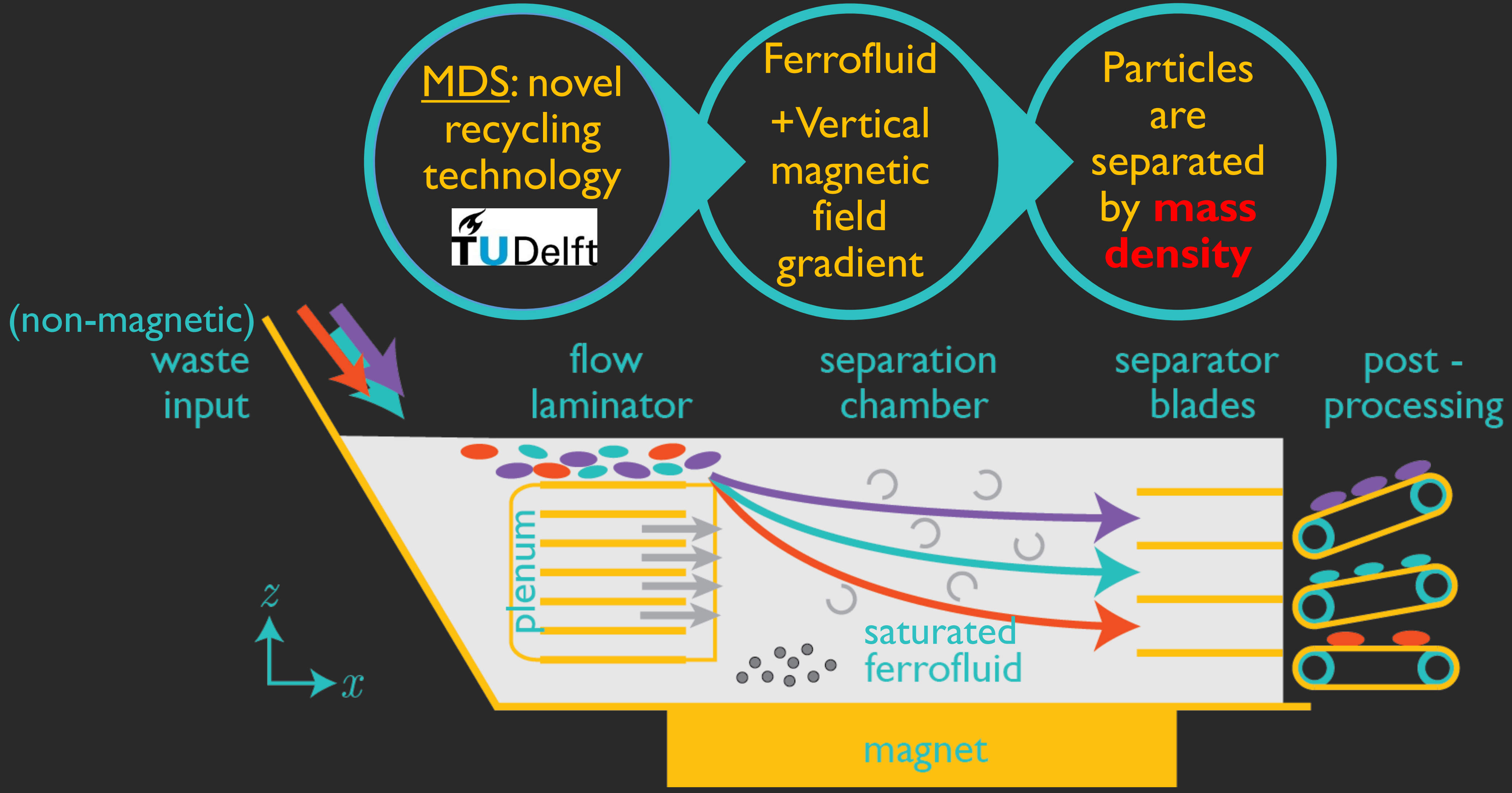
Magnetic Density Separation?



Basic MDS operating principle

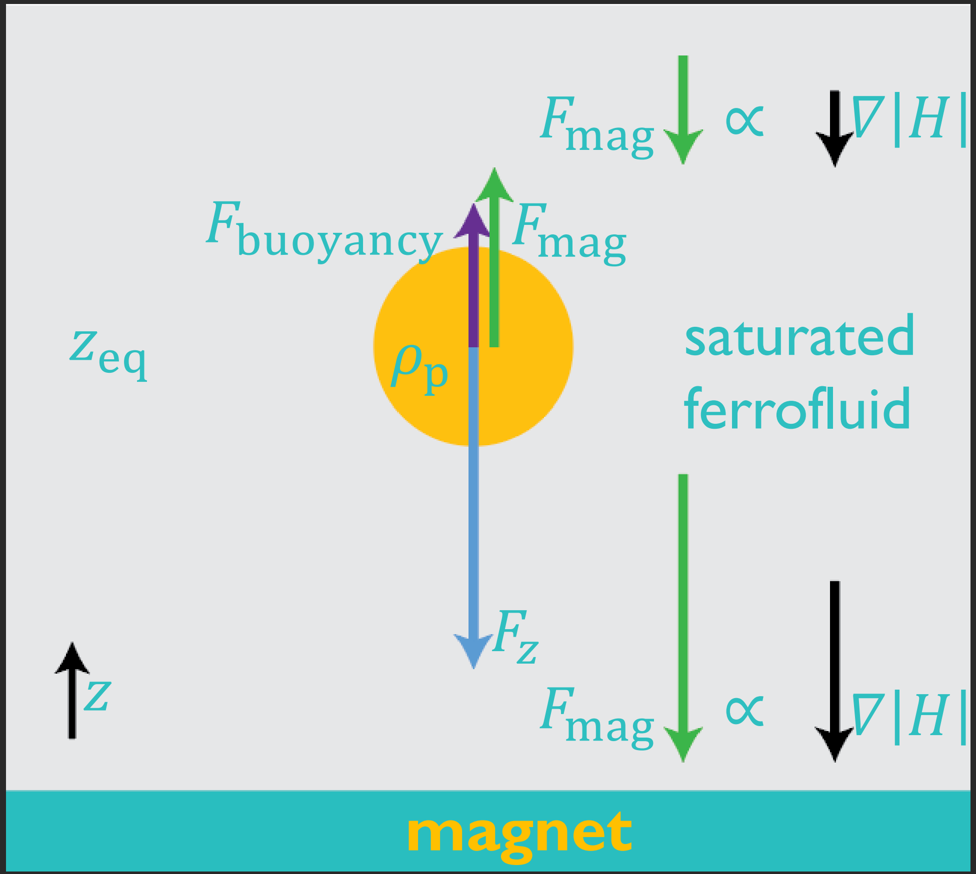
At a height z_{eq}, the net force on a (non-ferromagnetic) waste particle is zero:

$$F_z + F_{\mathrm{buoyancy}} + F_{\mathrm{mag}}(z) = 0$$

Vertical field gradient desired that:

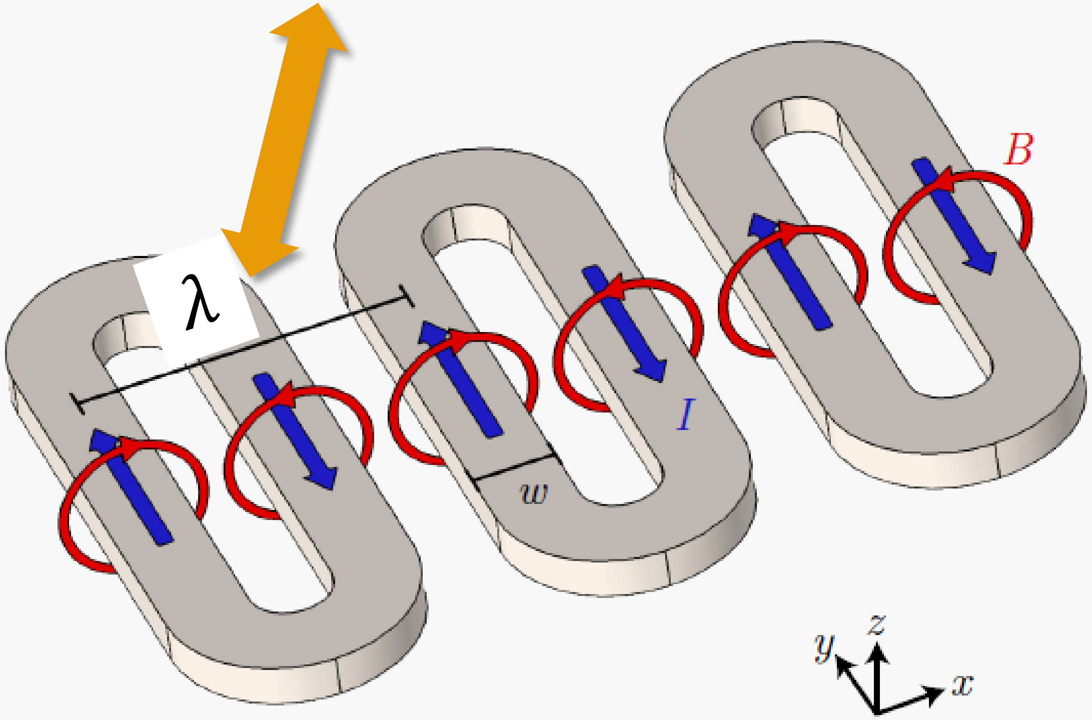
- varies with z
- is **constant** in horizontal directions

$|H|(z) = H_0 \exp\left(-\frac{2\pi}{\lambda} z\right)$ does the trick!



Why use superconductors in MDS?

$$|H|(z) \approx H_0 \exp\left(-\frac{2\pi}{\lambda} z\right)$$

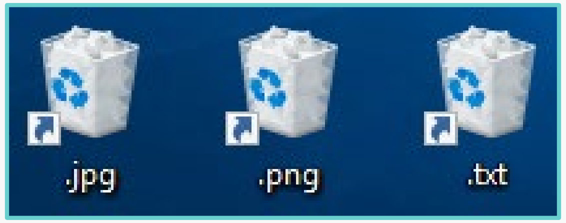


Higher **field strength** (H_0) & larger **periodicity** (λ):

- Enhanced separation **resolution**
- Wider density **range**
- Deeper usable fluid bed
- More **dilute** ferrofluid (lower OPEX)

Project goal: demonstrator magnet

- 3 NbTi racetrack coils
- 5 T peak field
- λ = 60 cm
- Targeted application: electronic waste



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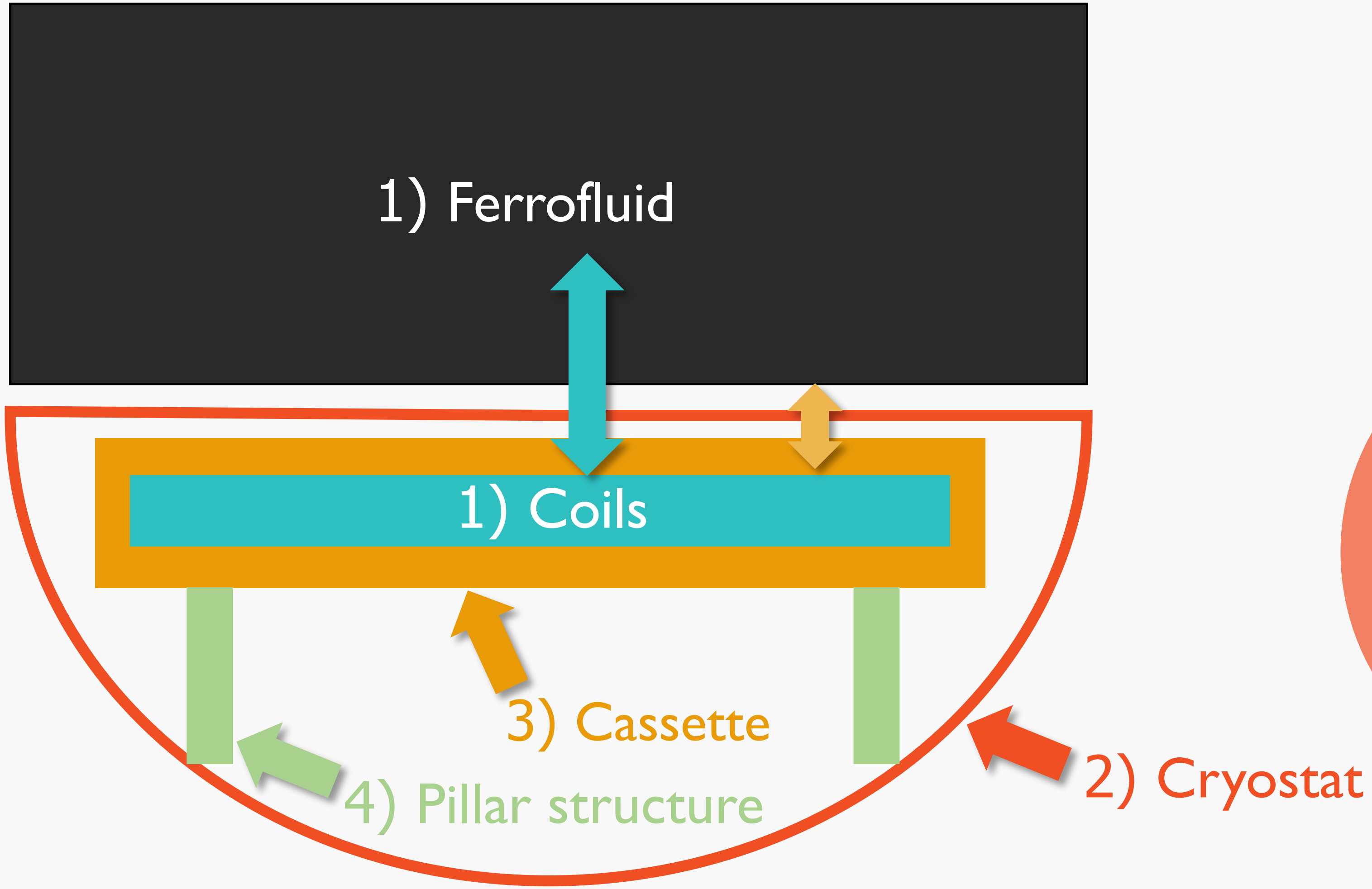
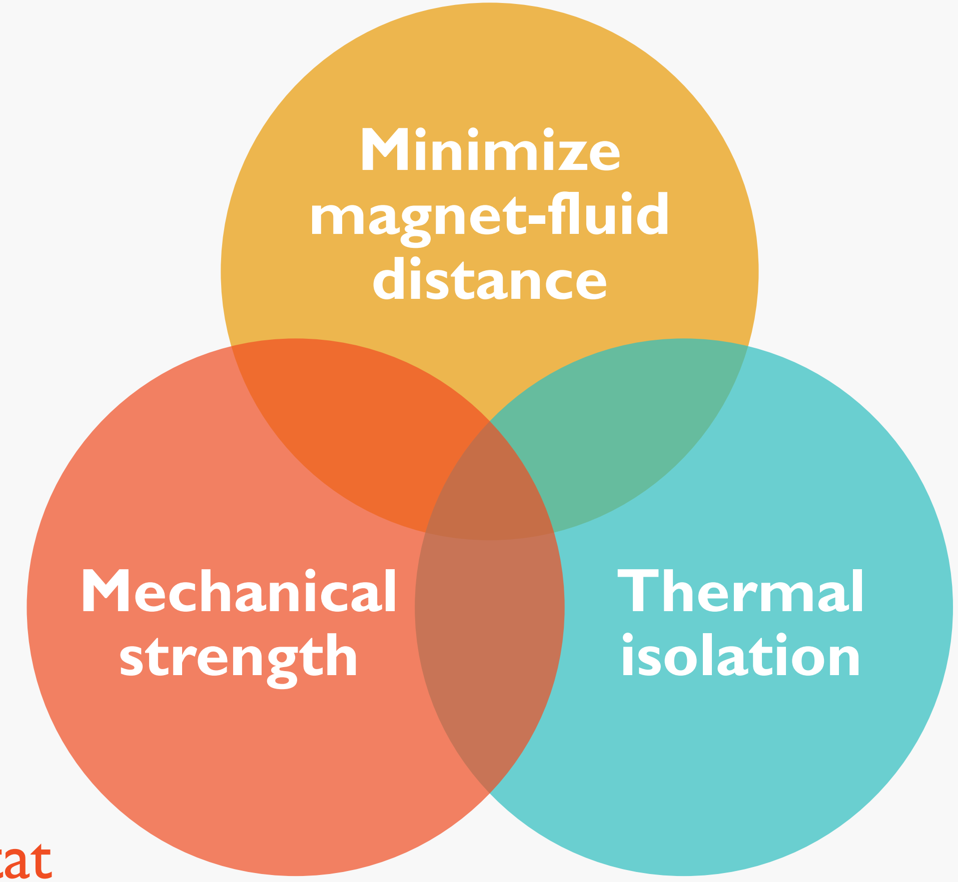


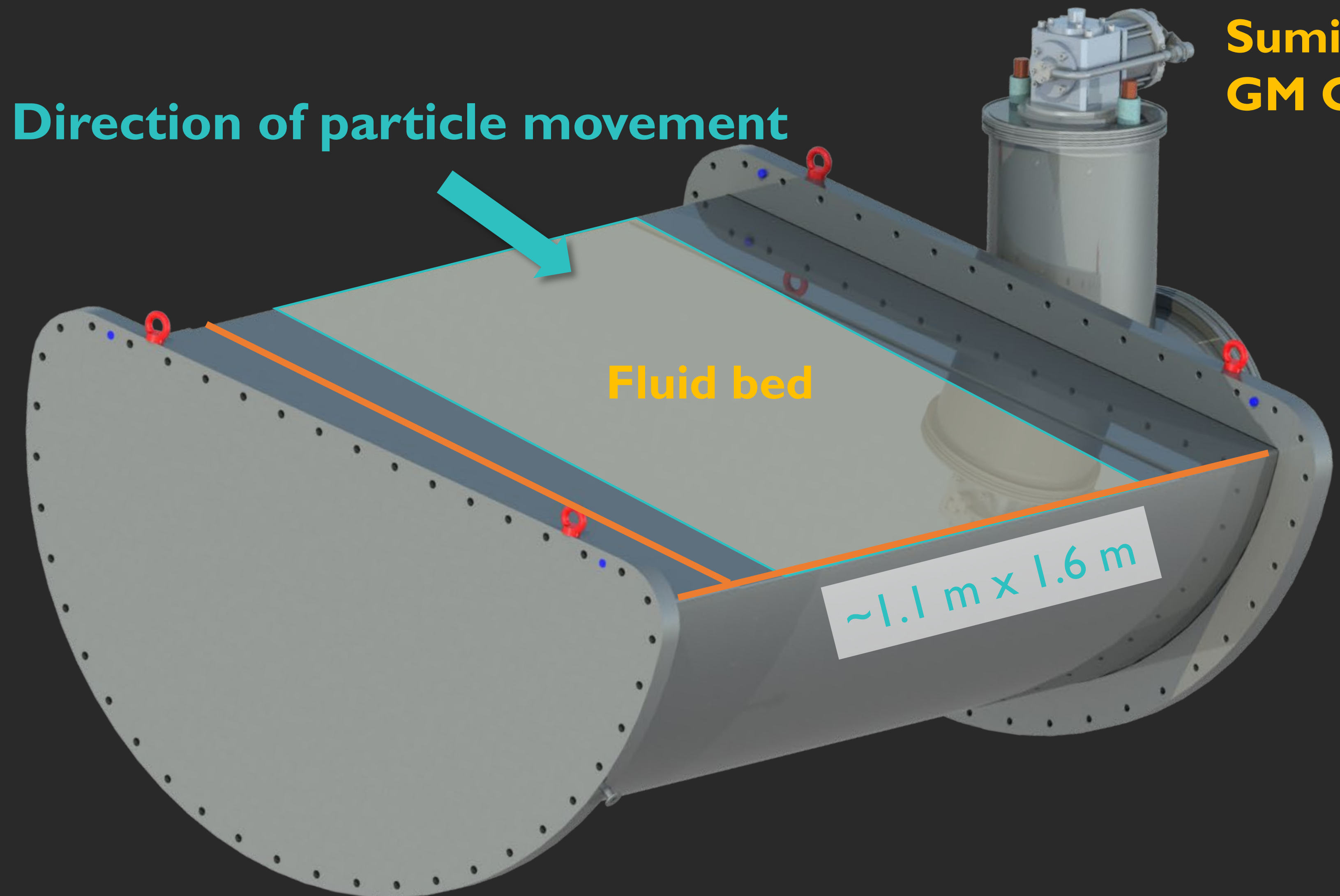
1) Ferrofluid
1) Coils
3) Cassette
4) Pillar structure
2) Cryostat



Minimize magnet-fluid distance
Mechanical strength
Thermal isolation

Single-walled cryostat

Sumitomo Cryogenics GM Cryocooler. 1.5 W at 4.2 K



Single-walled cryostat

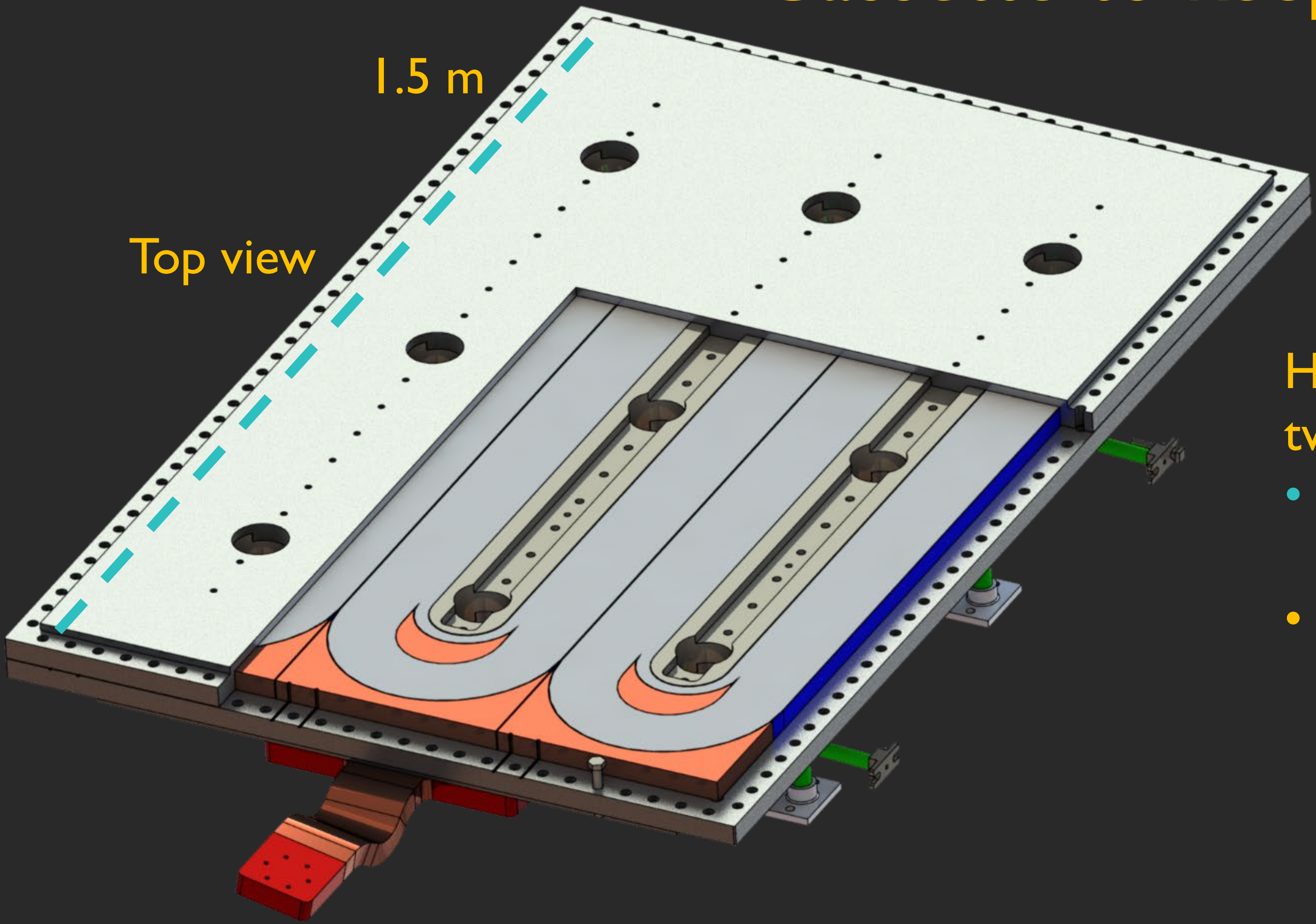
Magnet to be mounted on alu plate, plate

can slide into cryostat

Room-temperature steel pillars

support the top plate and
help minimize top-plate thickness

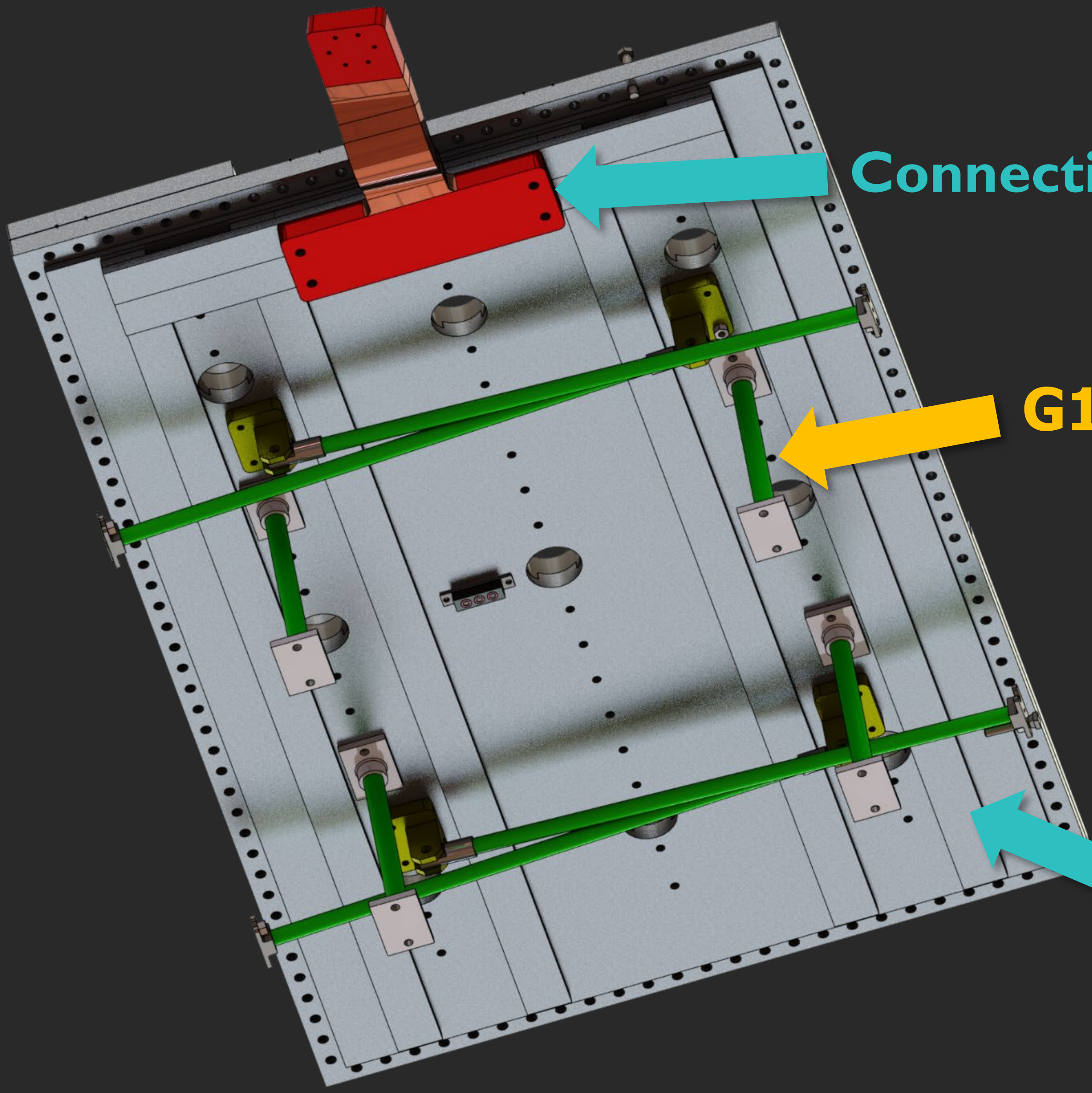
Cassette to keep coils in place



High-strength aluminum alloy two-part cassette

- Shrink fits around coils upon cool-down
- Holes for RT pillars

Cassette bottom view



Connection to cooler

G11 warm-cold pillars

Pure aluminum busbars to **reduce ΔT**

Pillars optimized to balance buckling strength and heat in-leak

Euler's buckling criterion

+

Fourier's law

$$Q_c = \frac{\bar{k}\Delta T}{L_2}\frac{\pi}{4}\left[\sqrt{\left(\frac{64L^2F}{C\pi^3E}+D_i^4\right)}-D_i^2\right]$$

Solid rod: $D_i = 0$

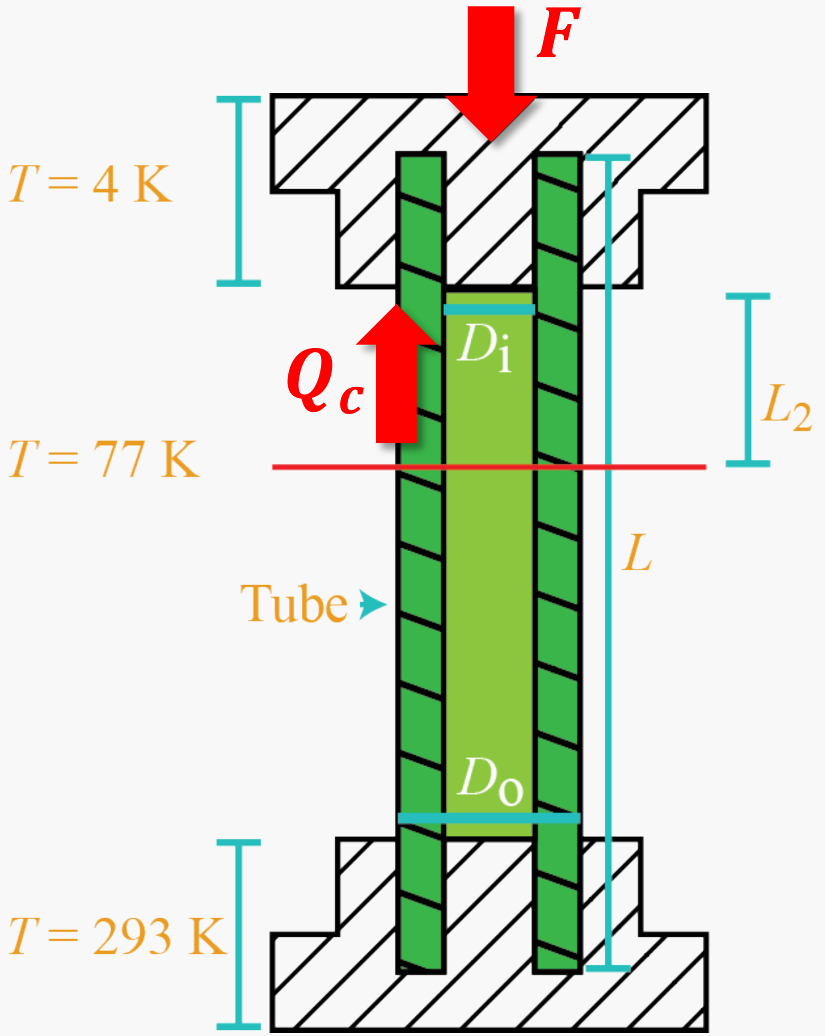
$$Q_c = 2\bar{k}\Delta T\frac{L}{L_2}\sqrt{\left(\frac{F}{C\pi E}\right)}$$

Minimize $\frac{\bar{k}}{\sqrt{E}}$

SS: $\frac{4.5}{\sqrt{195}} \approx 0.32$

77→ 4 K

G11: $\frac{0.21}{\sqrt{20}} \approx 0.047$



Conclusions

MDS

Recycling technology, allows **separation** on non-magnetic materials based on **mass density**

NbTi

Demonstrator magnet under construction at University of Twente

Conduction-cooled

To be installed at Delft University

Design

Balances **heat in-leak** vs **mechanical strength** vs **magnet-fluid distance**

Thank you for your attention

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