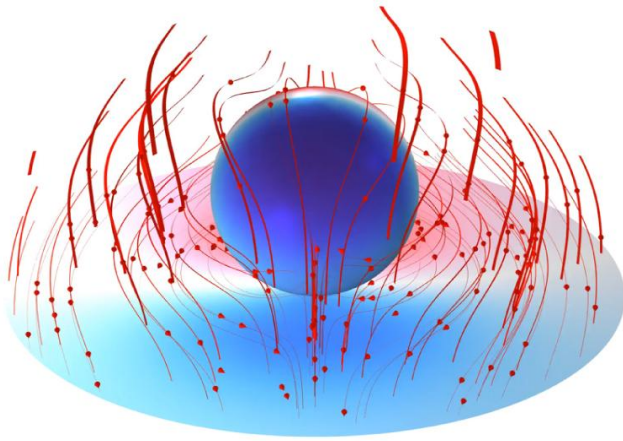


Capturing of Superparamagnetic Beads for Medical Diagnostics Device Iterations.



Resolvent

COMSOL Conference 2026 Cambridge

23–25 September 2026 · Churchill College, Cambridge

Kresten Juel Jensen · André Gugele Steckel

About Resolvent

A consultancy dedicated to transforming R&D through multiphysics simulation.

Core physics

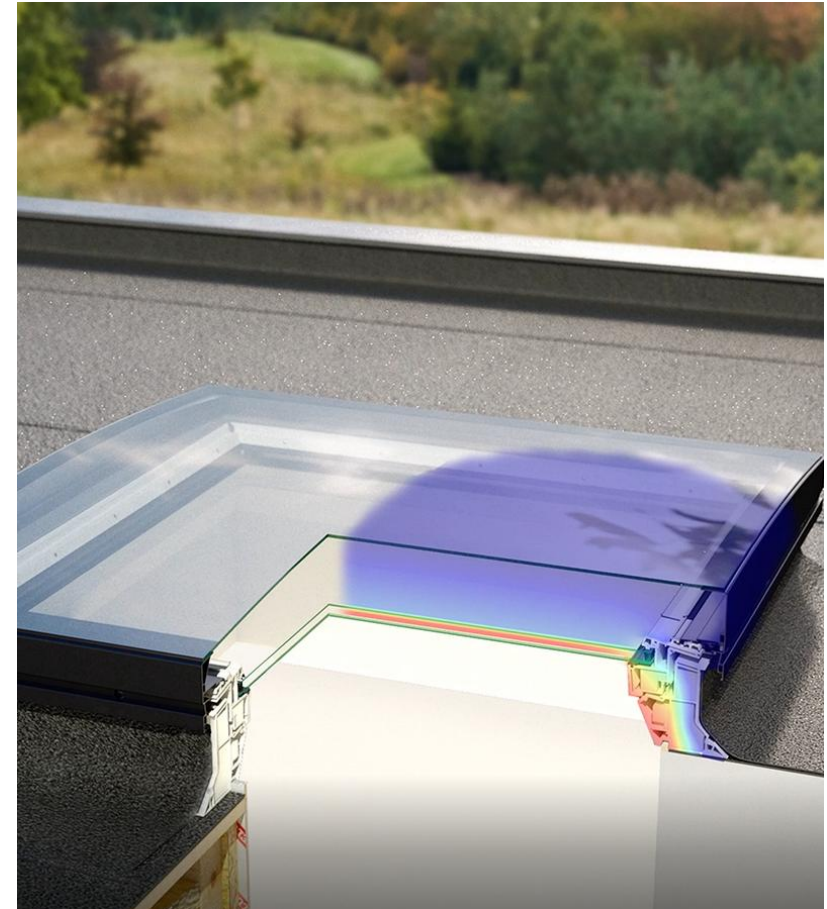
CFD · Heat transfer · Structural mechanics · (Electro)chemistry

Industry focus

Green tech · Pharma and medical · Process industries

Company profile

Copenhagen · Established 2014 · COMSOL Certified Consultant



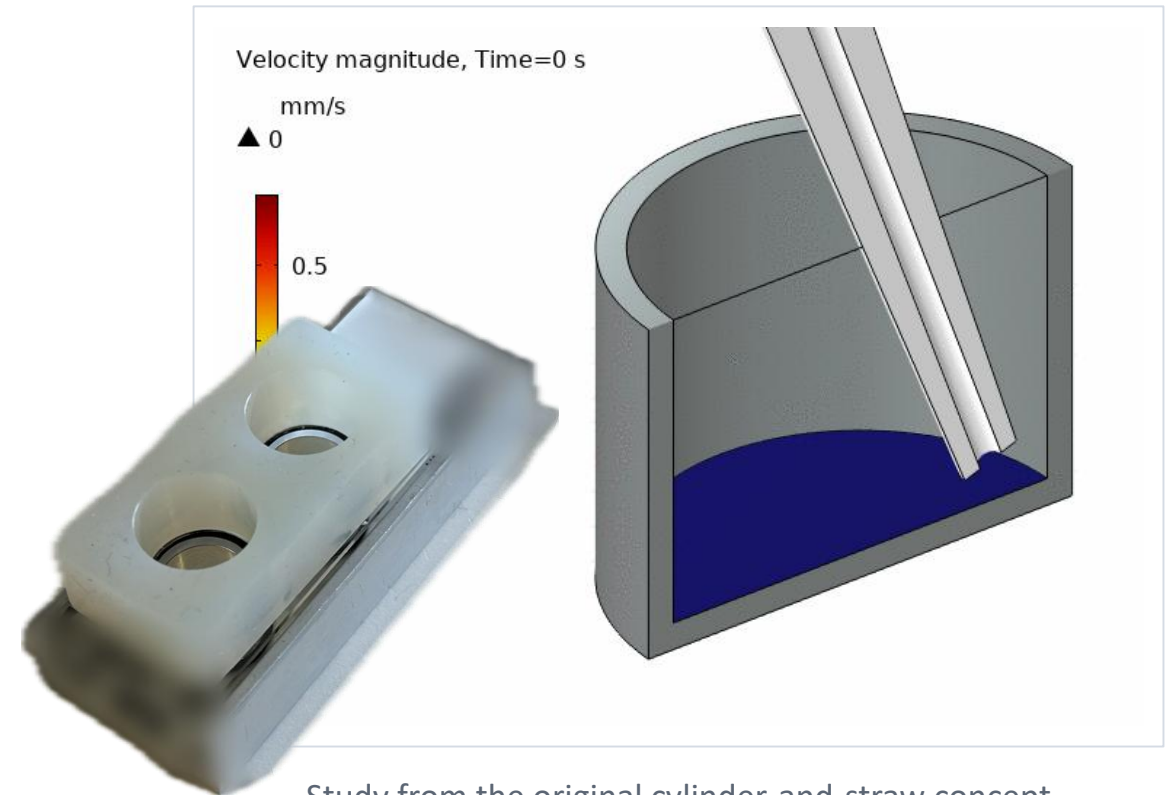
Selected customers



What is the technology for?

Capture and concentrate target (cell) material from a liquid sample

- 1 Bind**
Magnetic beads bind to bacteria, DNA or another target.
- 2 Capture**
A magnetic field pulls the beads out of the moving liquid.
- 3 Concentrate**
The retained target can then be analysed.

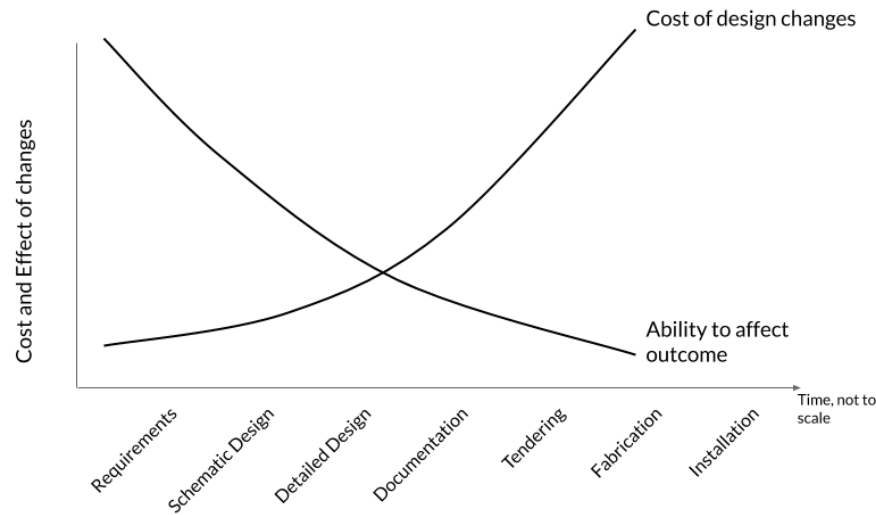


Study from the original cylinder-and-straw concept

Why optimize concepts early?

Simulation creates the greatest value before the concept is fixed.

A • Maximum impact at minimum cost



Early decisions retain high influence
— while concept changes are still inexpensive.

B • Optimize capture performance

MINIMIZE

Required capture area

→ Smaller equipment

MAXIMIZE

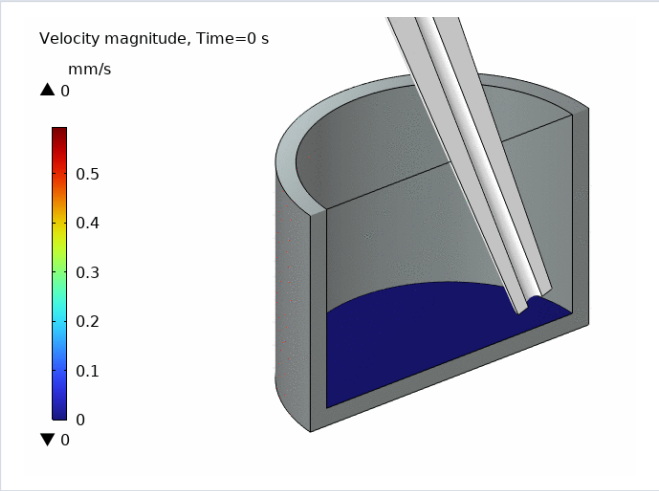
Bead concentration

→ Faster analysis

The best concept delivers both.

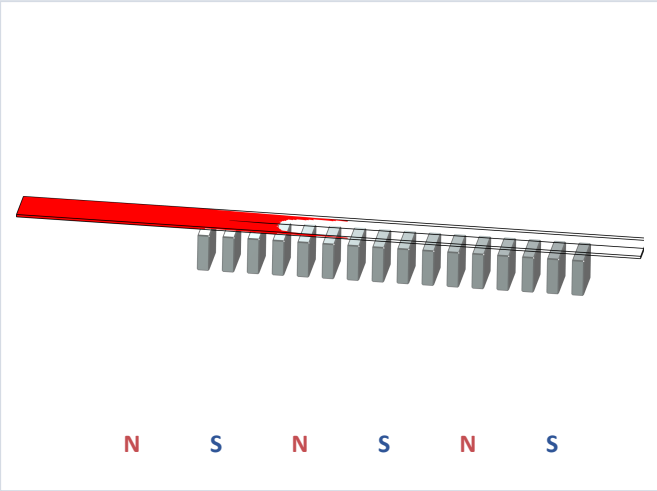
Which capture concept to develop?

Three plausible architectures — before optimizing magnet details



A · Container + straw

A magnet attracts beads while liquid is aspirated.



B · Flow channel + magnet (array)

A channel passes close to magnet(s)

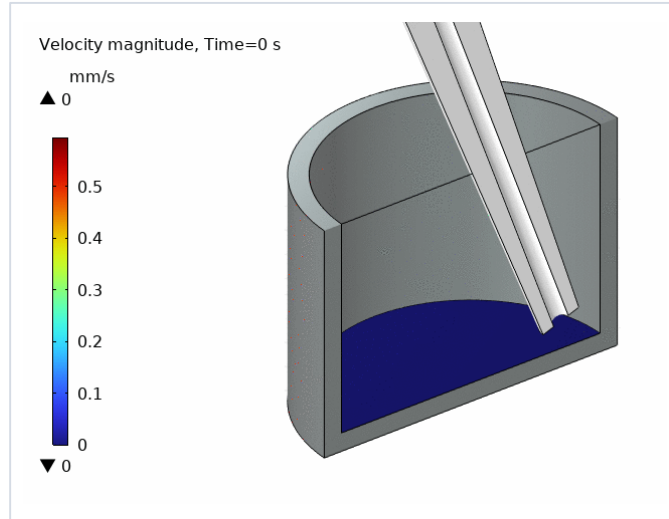


C · Unpublished concept

Evaluated, selected and kept confidential.

Simulation was used to decide which architecture deserved development. Testing requires 100s of prototypes.

Coupling flow, magnetic fields and particles



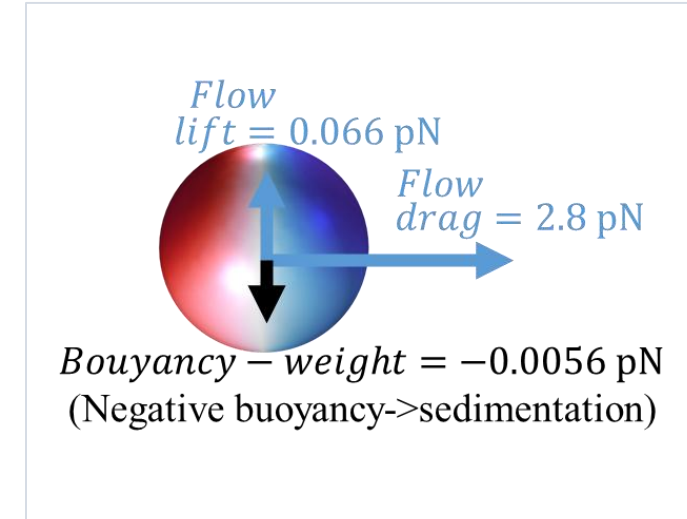
Laminar flow

Velocity through the capture geometry

$$\vec{F} = -\vec{\nabla} \left(\frac{1}{2} \chi_m V B^2 \right)$$

Magnetic field

Field strength and spatial gradient

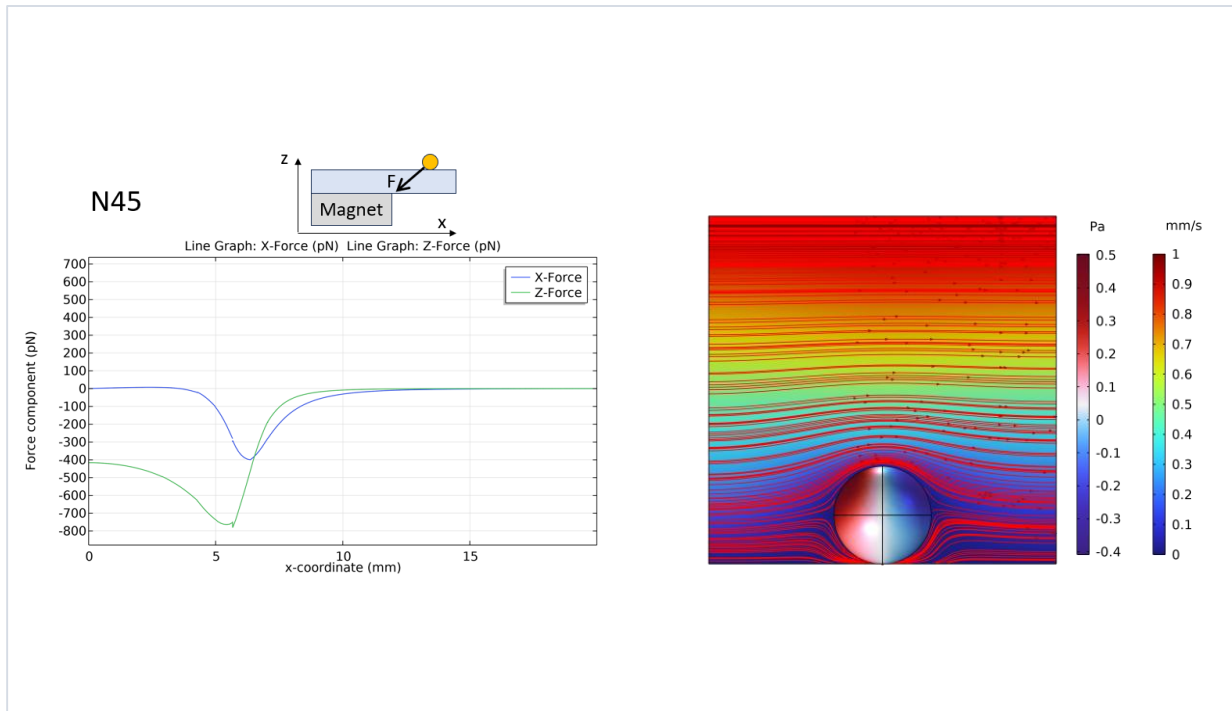


Particle tracing

Magnetic force, drag, lift and gravity

Beads stick when they reach a capture surface – but is the assumption correct?

Magnetic force dominates in this regime



Flow

drag 2.8 pN · lift 0.066 pN

Gravity

buoyancy – weight 0.0056 pN

Magnet

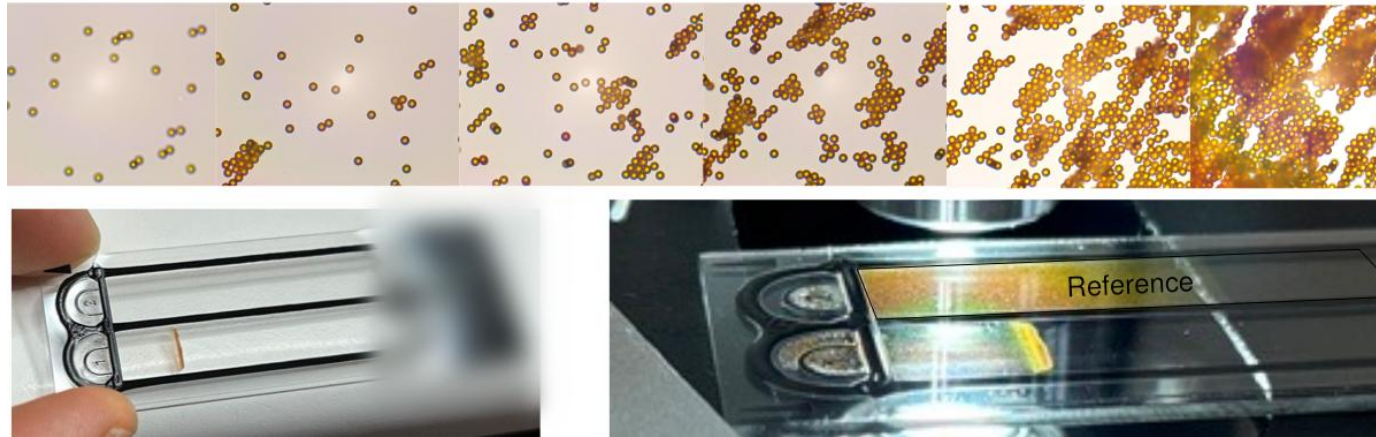
peak component $\approx 400\text{--}800$ pN

$$400\text{--}800 \text{ pN} \div 2.8 \text{ pN} = 140\text{--}285\times$$

$\approx$ two orders of magnitude above drag

Using the largest hydrodynamic term makes the comparison conservative.

Model validation experiments



Capture pattern

Beads accumulated around the magnetic region as predicted.

Retention

Captured beads remained fixed under the tested flow conditions.

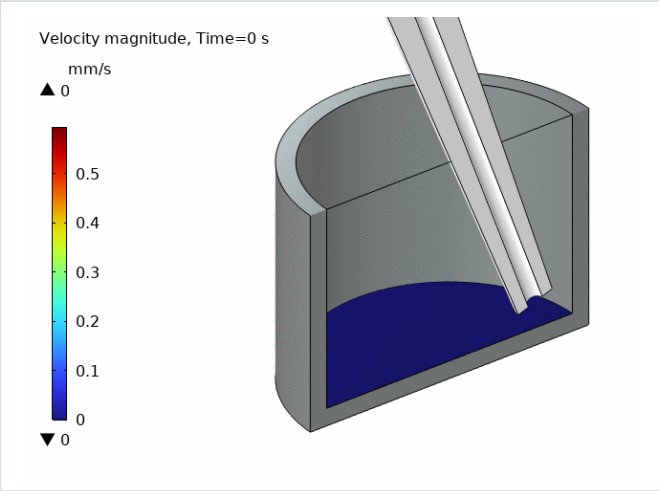
Downstream check

No beads were observed after the magnet in the flow test.

Validation was sufficient for comparative concept screening.

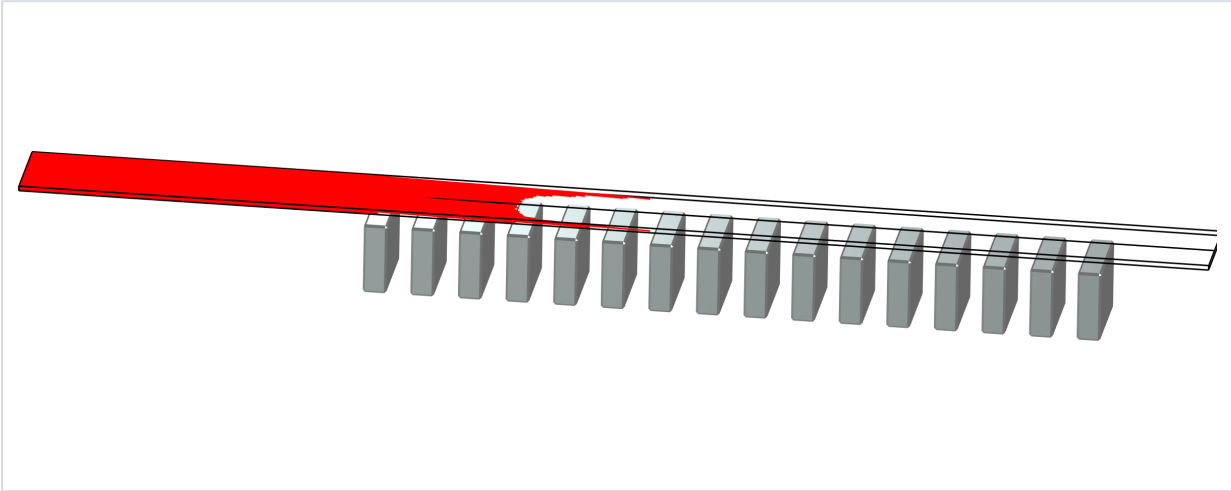
Focusing on the flow-channel concept

Container + straw



Not developed further in this section

Flow channel



Screened in detail

Size

Shape

Position

Polarity

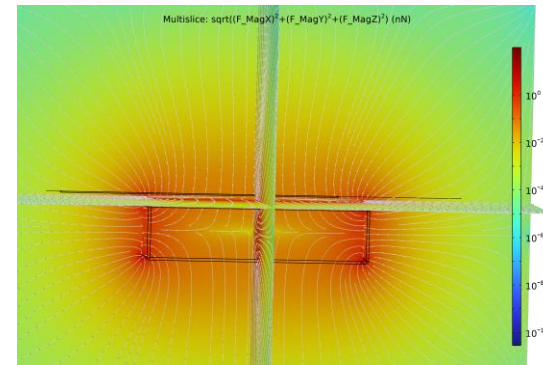
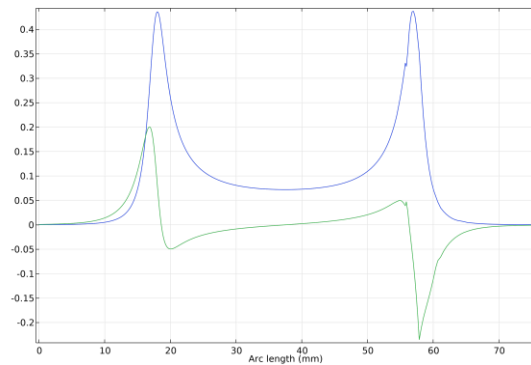
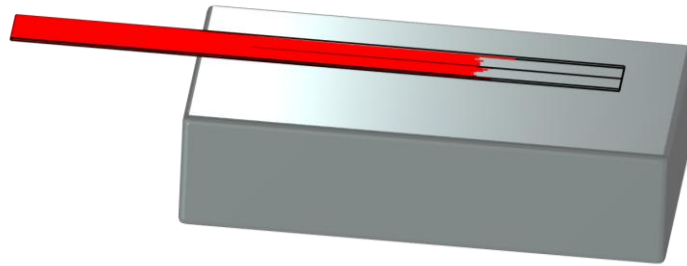
Spacing

Distance

Flow path

Flow channel — one large magnet

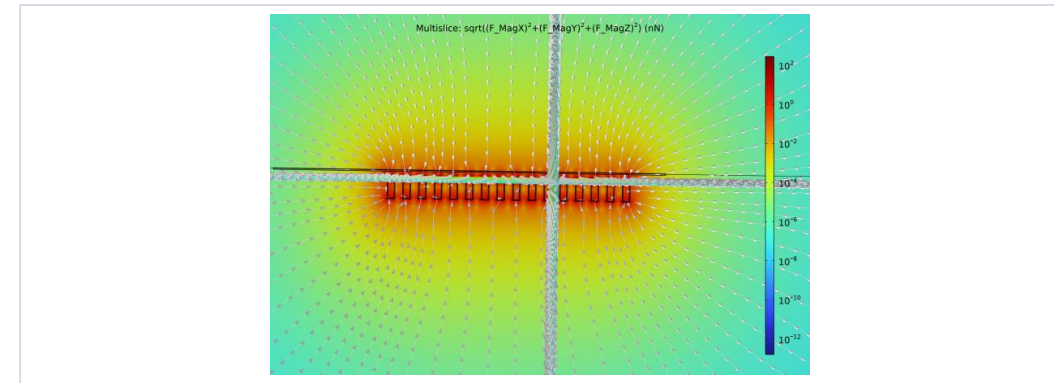
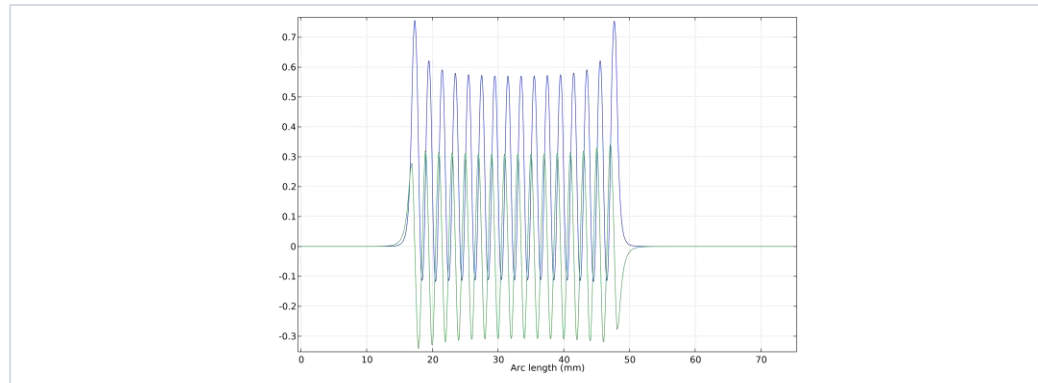
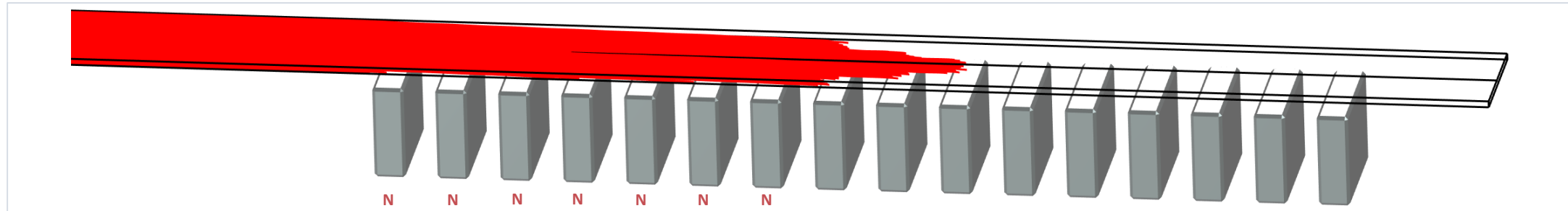
One large magnet



High field — but capture-driving gradients are concentrated at two magnet edges

Flow channel — multiple magnets

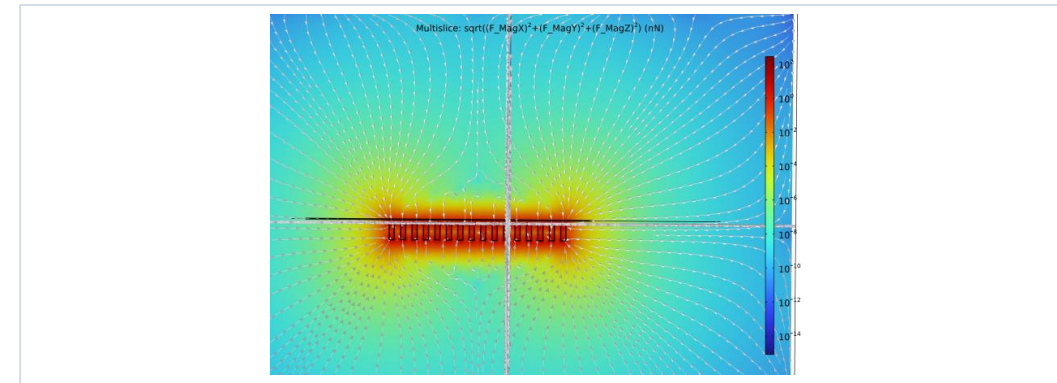
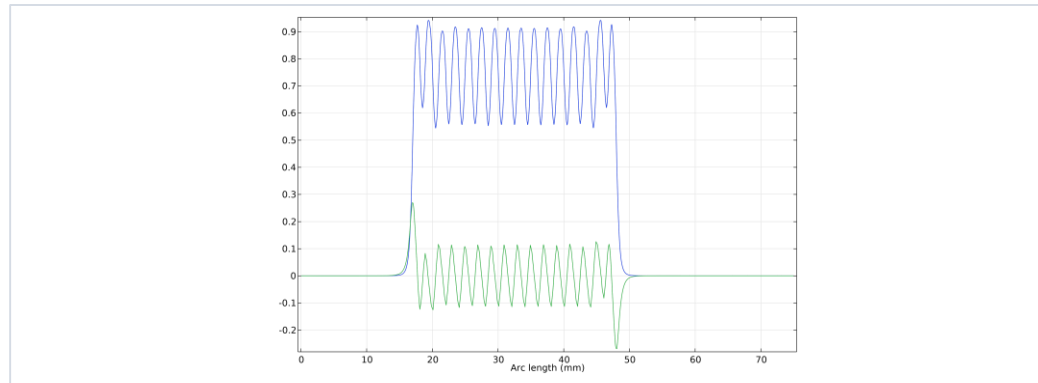
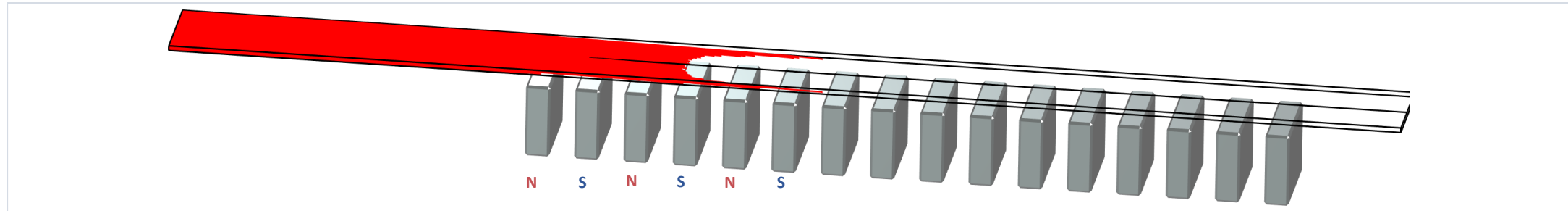
Same polarity



Repeated gradients — but a common-polarity field pattern

Flow channel — alternating magnets

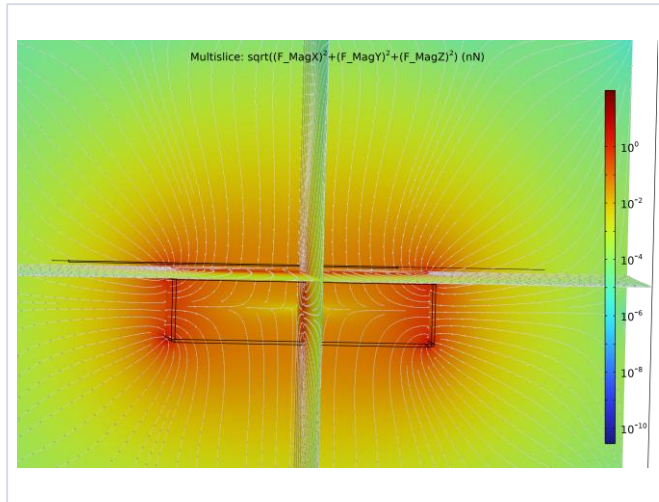
Alternating polarity



Opposing poles create repeated steep gradients along the channel
- Driving earlier and more efficient capture -> less channel length required

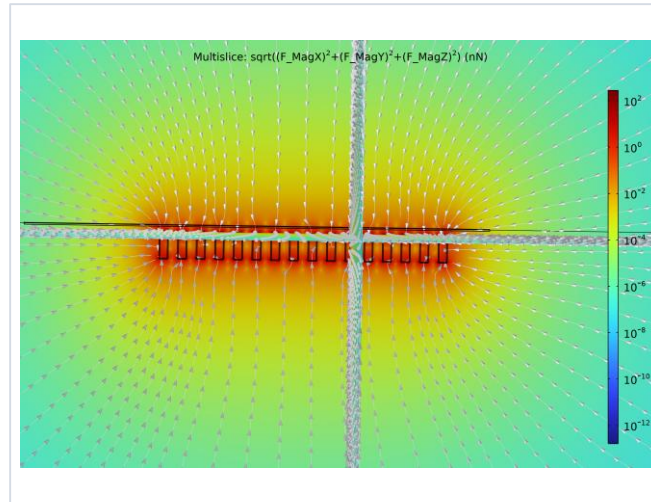
Comparing the three magnet configurations

One large



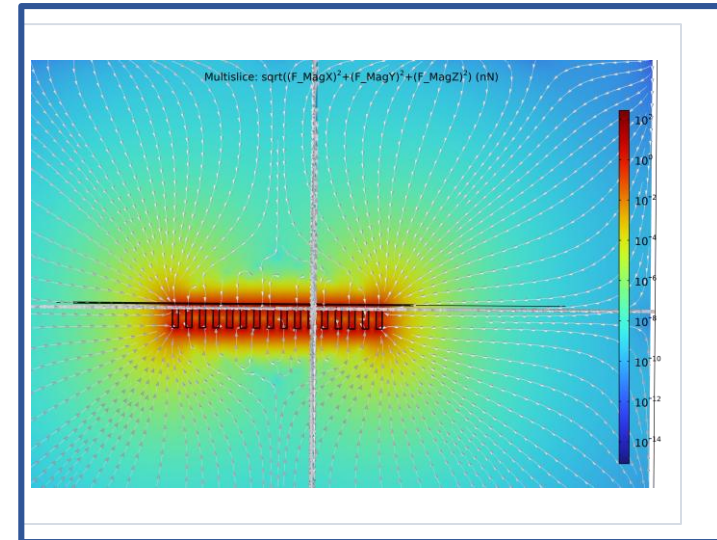
High field
Two dominant edge peaks

Multiple



Repeated gradients
Common polarity

Alternating

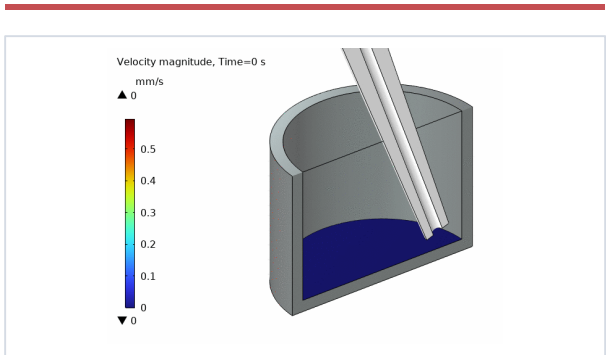


Repeated steep gradients
Opposing poles

The comparison pointed away from field strength alone and toward gradient placement.

The initially favored concepts were inferior

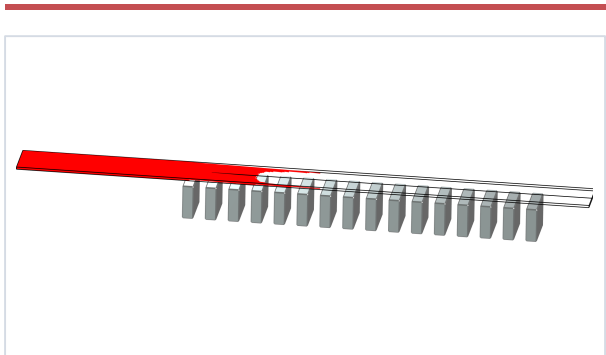
Simulation changed the preferred development direction before detailed engineering began.



A • Container + straw

Initially favoured standard solution

Inferior



B • Optimized flow channel

Promising after magnet optimization

Promising but inferior to C



C • Unpublished concept

Selected architecture remains confidential

Best-performing

Choosing the right concept early

1–2 years

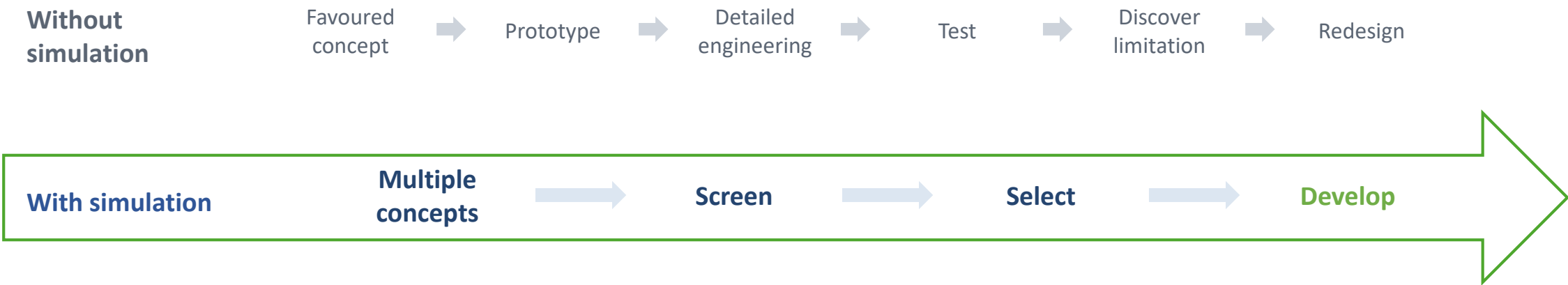
development time potentially avoided

€X m

development cost potentially avoided

€X m

lost revenue from delayed market entry



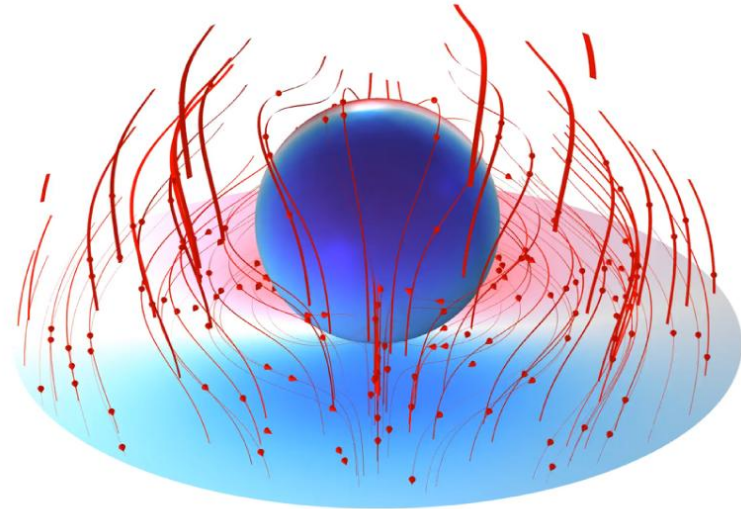
Understand the physics • Screen broadly • Commit to the right concept

Thank you

Questions & discussion

Kresten Juel Jensen

André Gugele Steckel



Capturing Of Superparamagnetic Beads For Medical Diagnostics Device Iterations.