
Matti at 80

However, we should be happy that Matti is indeed with us.

(Ours and also Matti's desire is that this does not turn into a memorial meeting).

Detecting, and measuring the mobility of, excitations at the boundary of the topological superfluid ^{3}He

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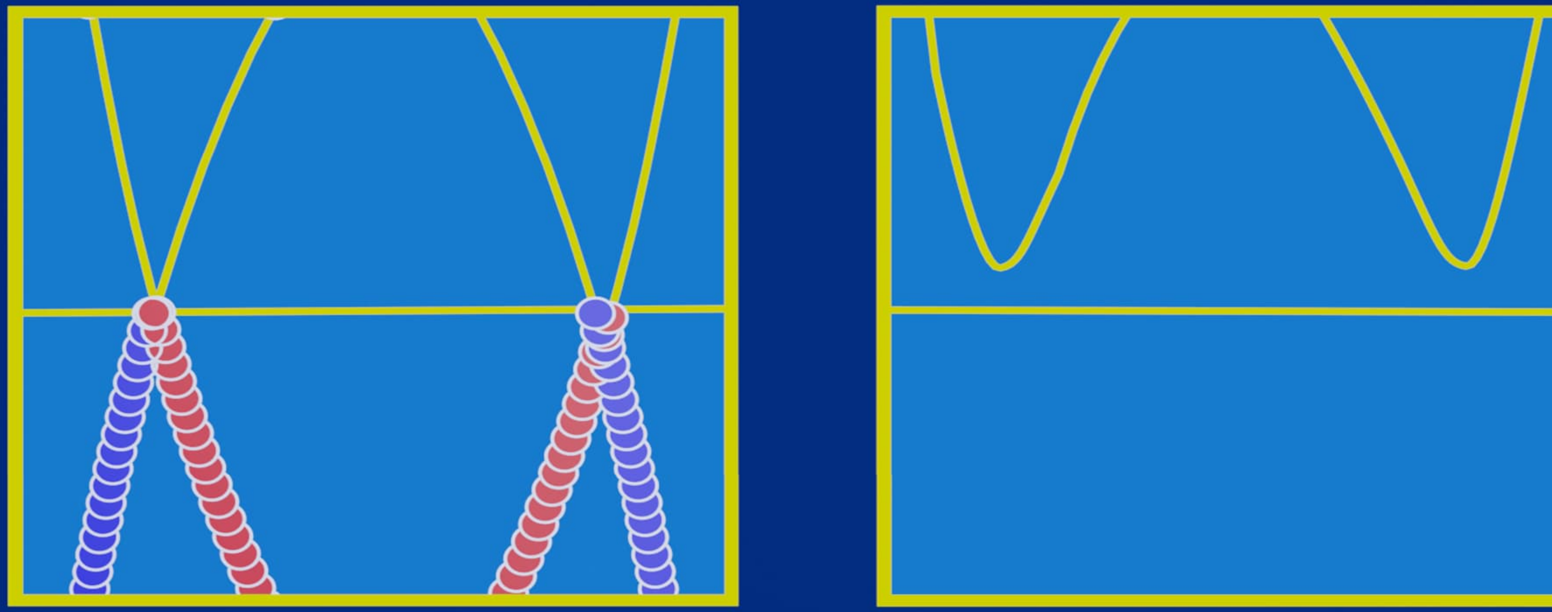

Matti Krusius anniversary symposium on superfluid ^{3}He and topological quantum materials

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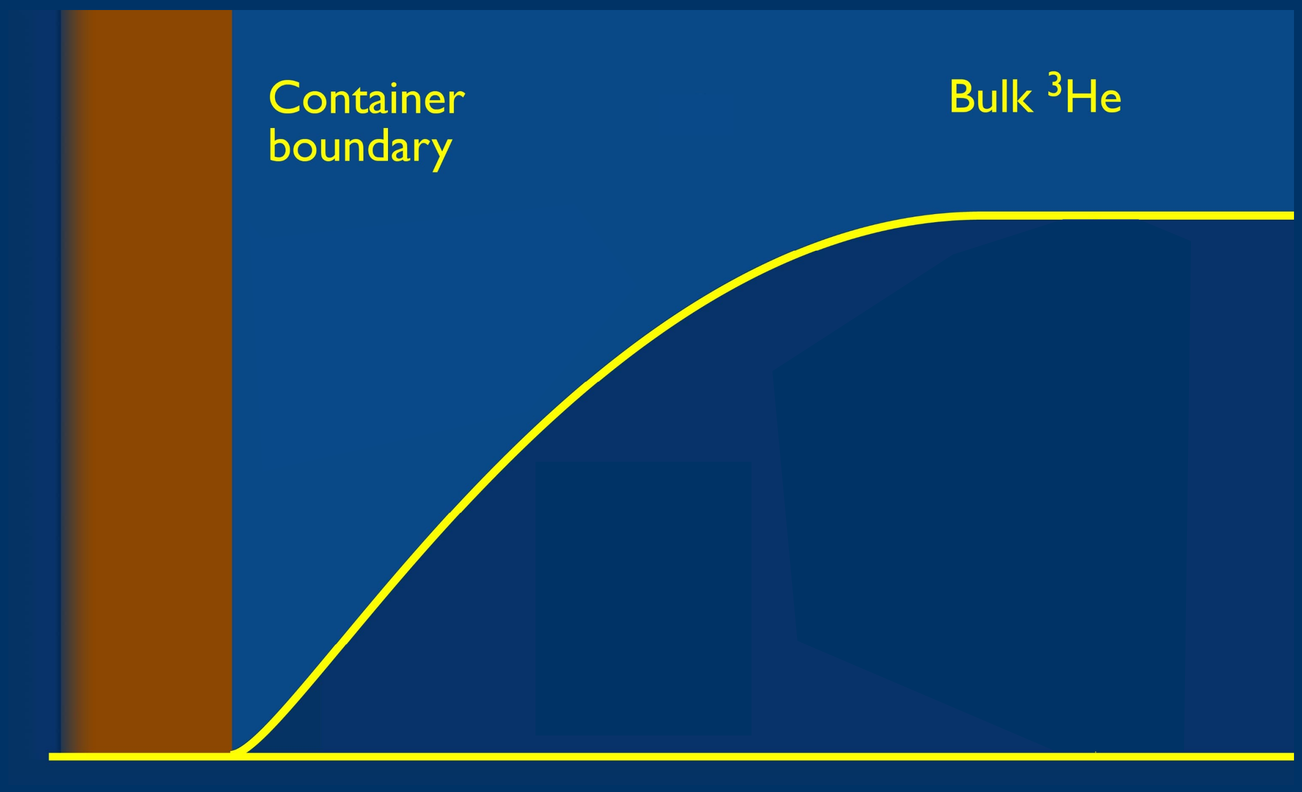
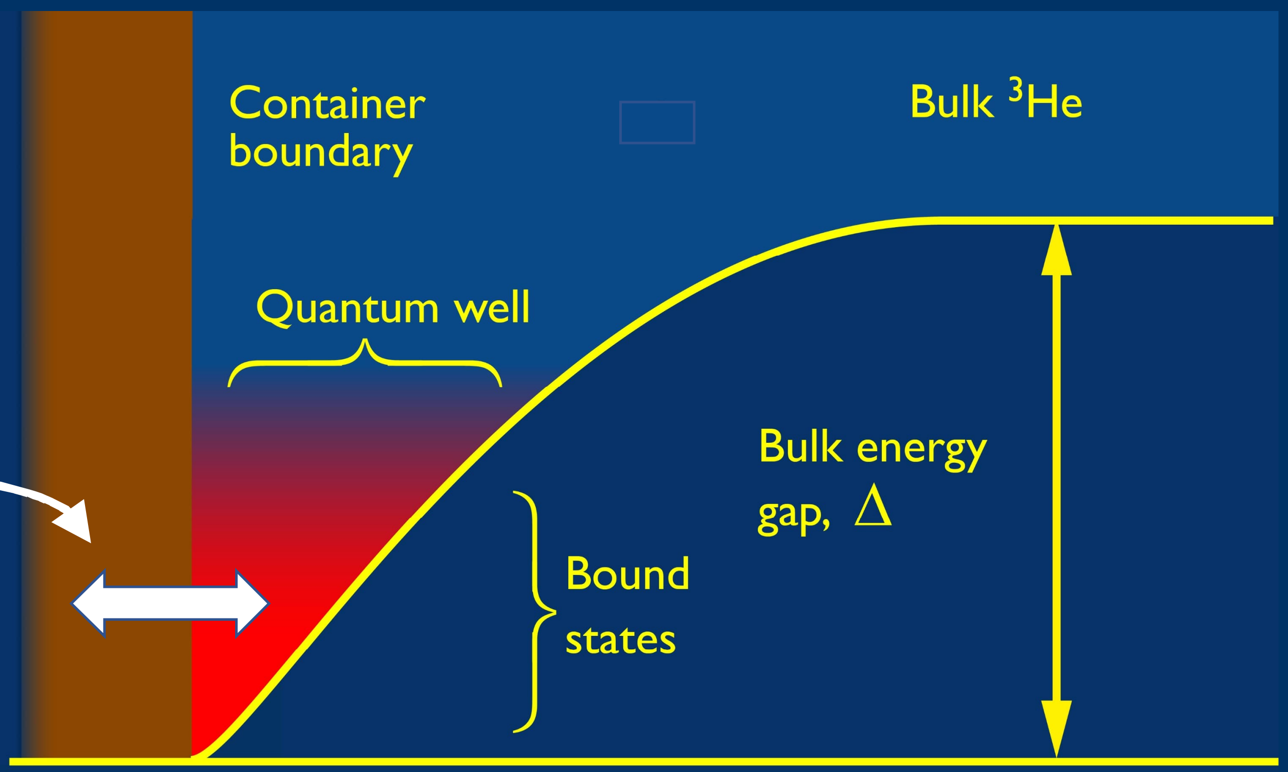
Today we are dealing with experiments the group has been doing on the dynamics of the excitations which live at the boundaries of superfluid ^3He.

So, let's look at ^3He boundary excitations:

So, let's look at ^{3}He boundary excitations: The battleground



Bound states thermally isolated from the bulk superfluid as essentially *no* excitations in the bulk.



Bound states thermally isolated from container by "infinite" Kapitza resistance.

Thus these bound excitations live in a completely isolated world of their own.

So, we have our excitations but how do we talk to them?

We can talk to them by inducing a superflow in the plane of the boundary.

As Lancaster does everything with vibrating devices, that's how we do it.

Most of the previous work using mechanical devices in the superfluid has been done with oscillating structures, of one sort or another, which can yield misleading results.

So we begin by using "vibrating wires" where we can set up a long trajectory of steady motion.

PG1

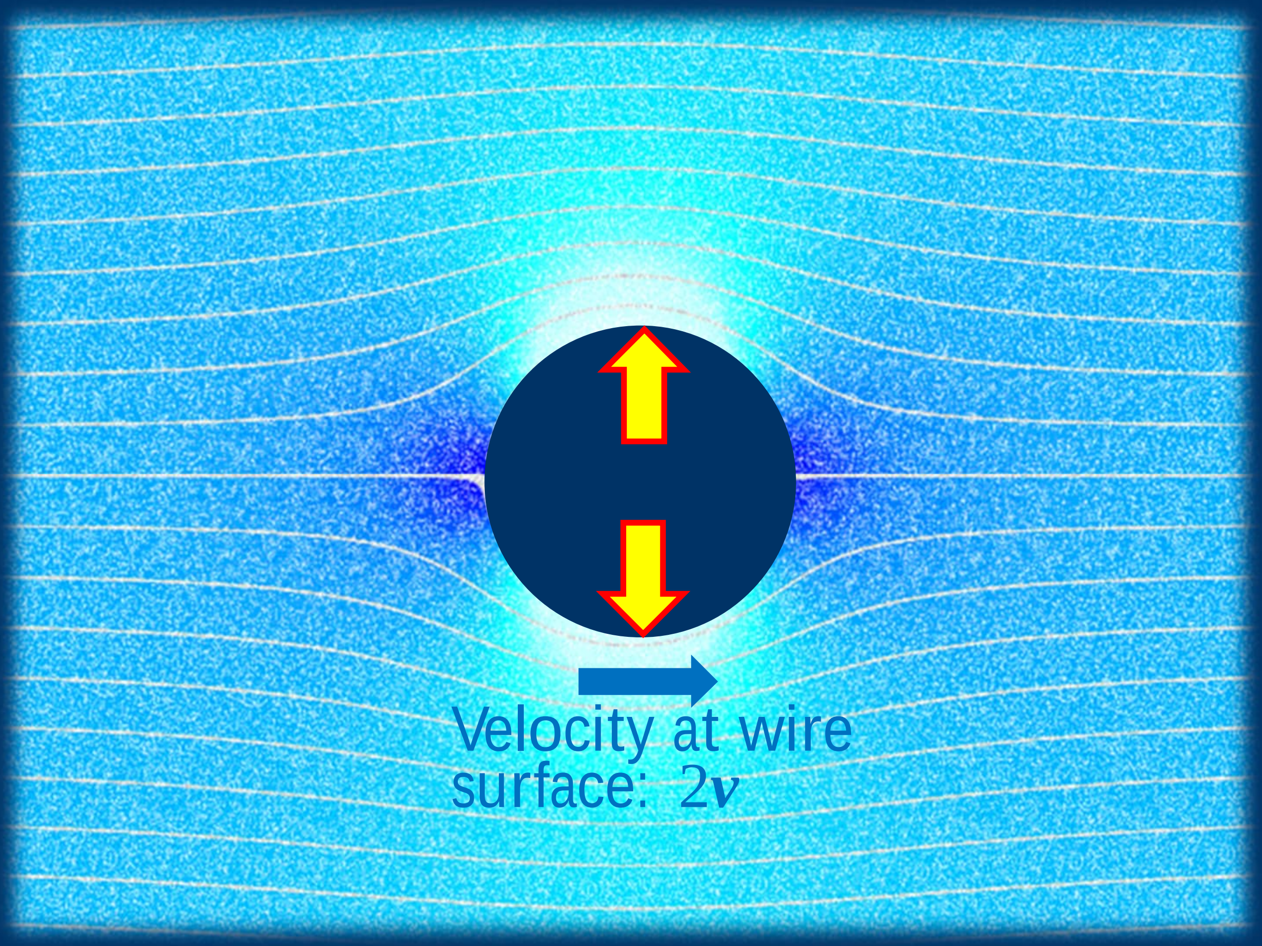
With such a device we need to contrive a carefully profiled drive current to ensure that the motion is accurately linear.

PG1

This motion forms the basis of the experiment, as it sets up a superflow around the periphery of the moving wire which allows us to manipulate the distribution of excitations in the potential well.

Pure potential flow around a moving cylinder, in the cylinder rest frame.

Velocity in the bulk: v



The wire sees the bulk liquid approaching at velocity v,

but at the wire surface, the pure potential flow profile gives the liquid a velocity of 2v along the “polar” lines.

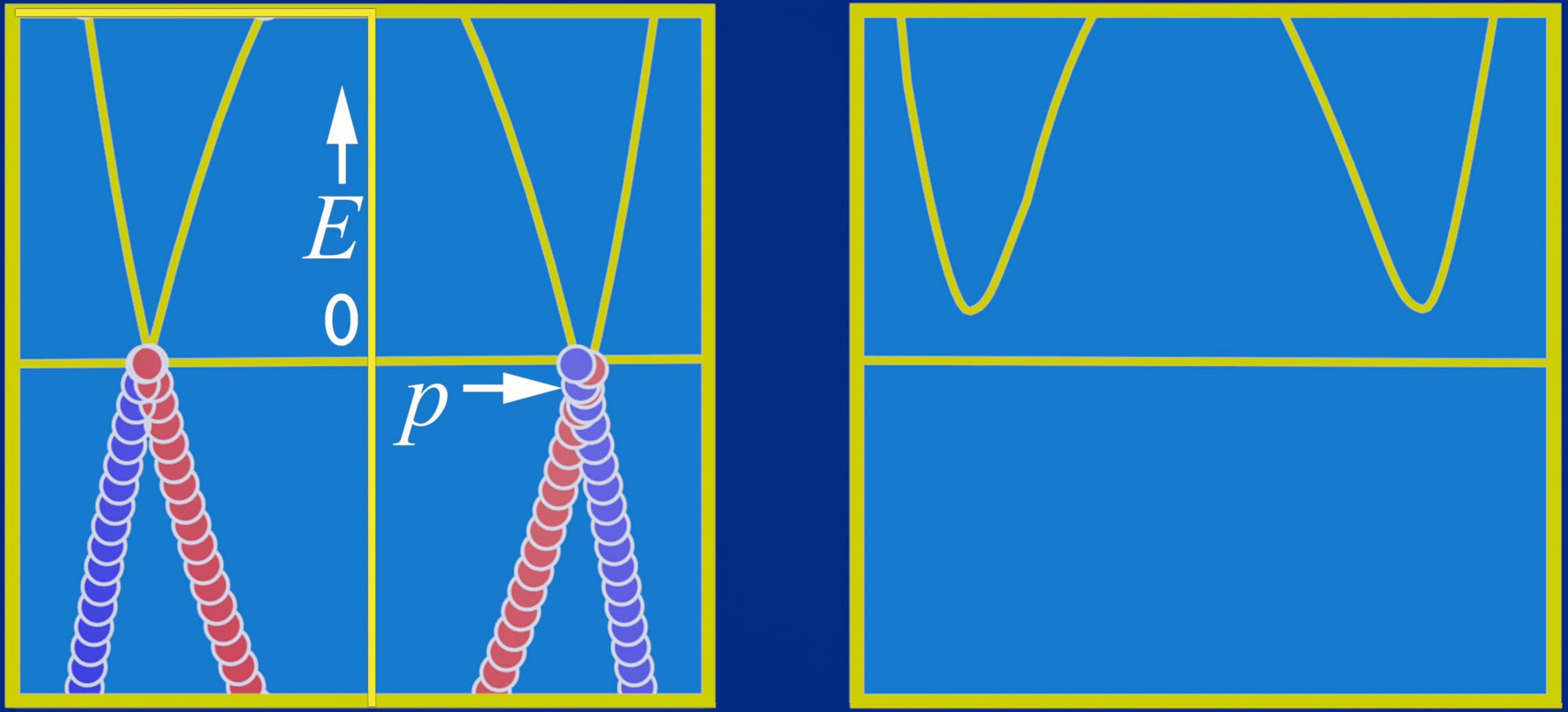
This is where the action takes place.

Toy model for the excitation dispersion curves

To keep the arguments straightforward we assume that the excitations in the surface potential well simply follow a gapless fermionic form in the two dimensions parallel to the surface.

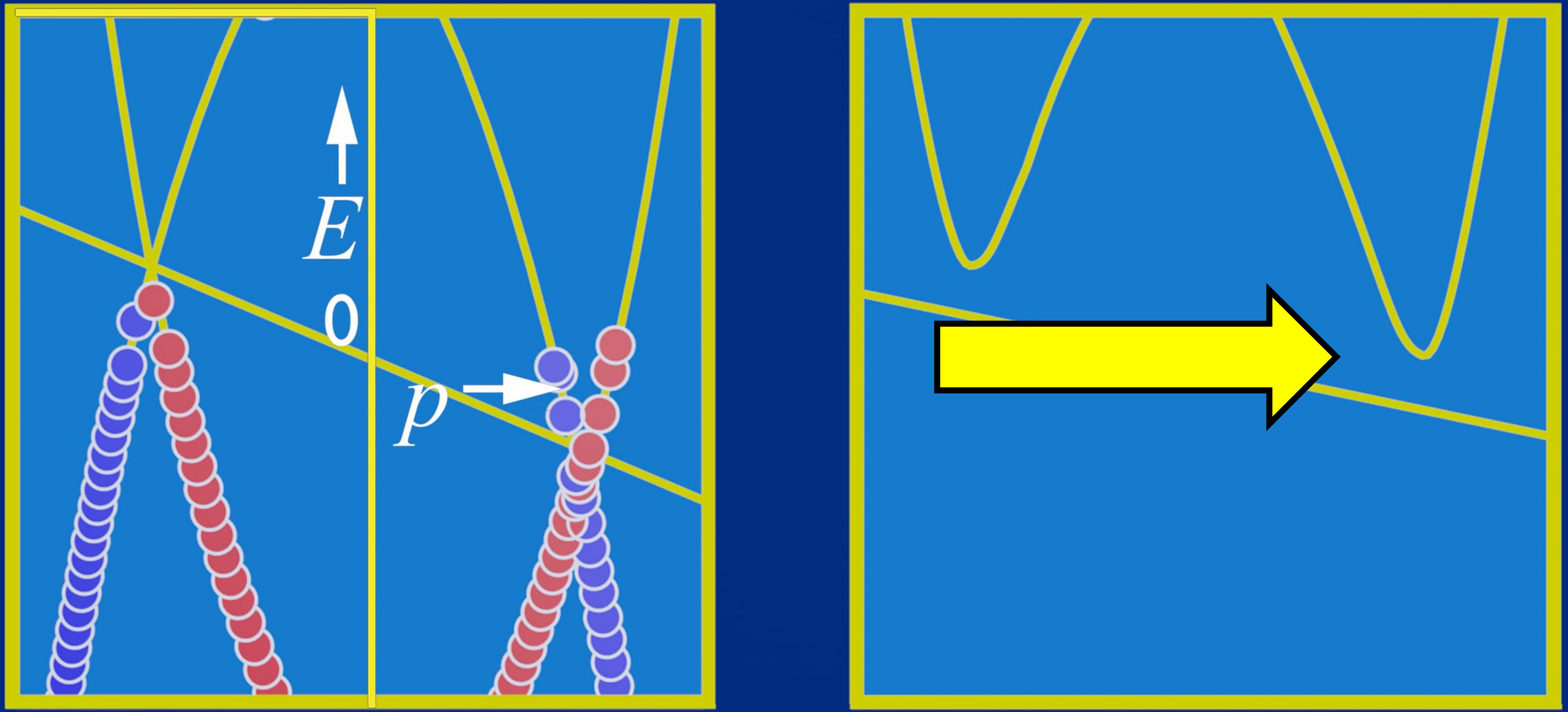
Toy model for the excitation dispersion curves

OK, let us start the wire moving.



This gives rearrangement of the excitations among the curves in the well but no change in the local excitation density.

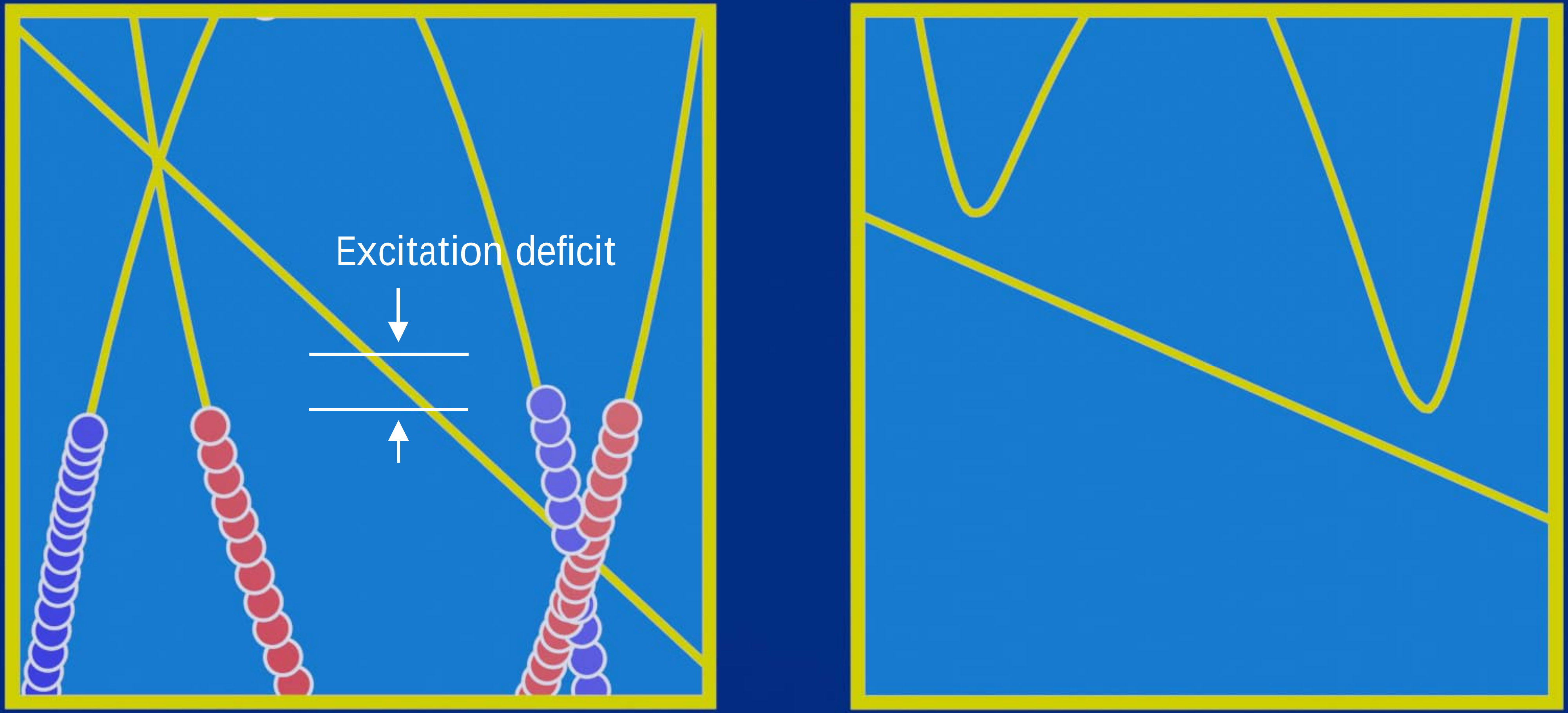
BUT, as soon as the minimum of the dispersion curve in the bulk falls below the “Fermi level” of the surface excitations,



So, now excitations can escape to the bulk, with haemorrhaging of excitations from the quantum well.

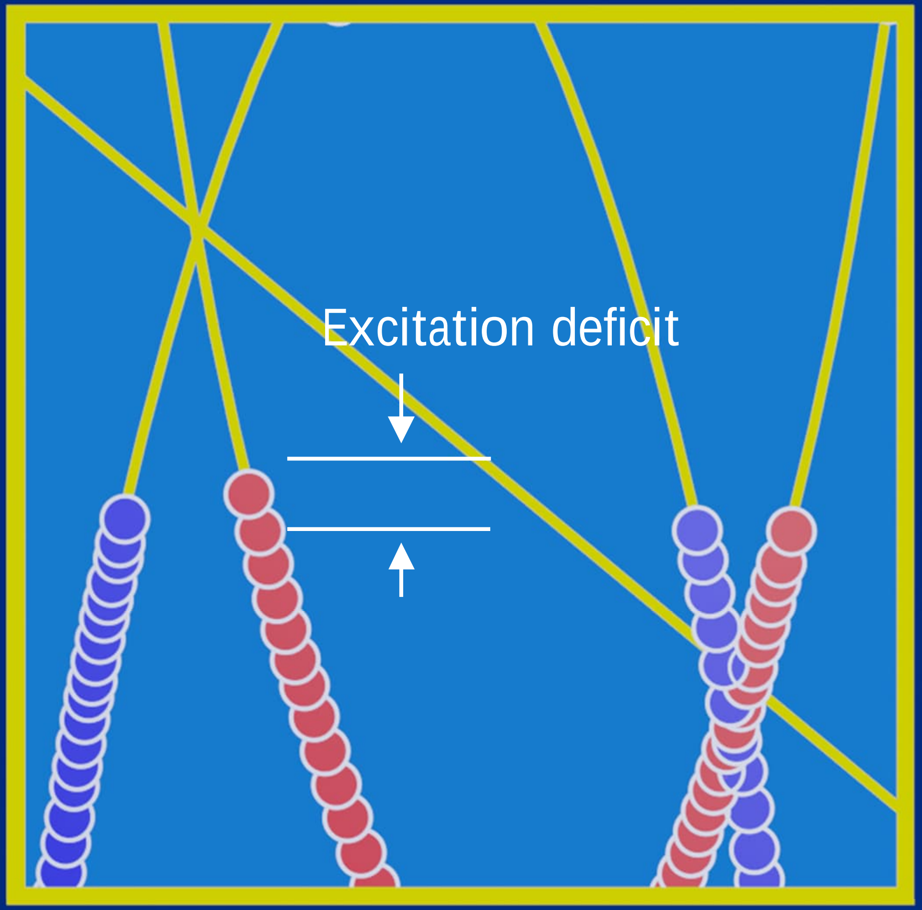
As long as the bands keep shearing, i.e. as long as the wire keeps accelerating, then more and more “bound” excitations will escape into the bulk.

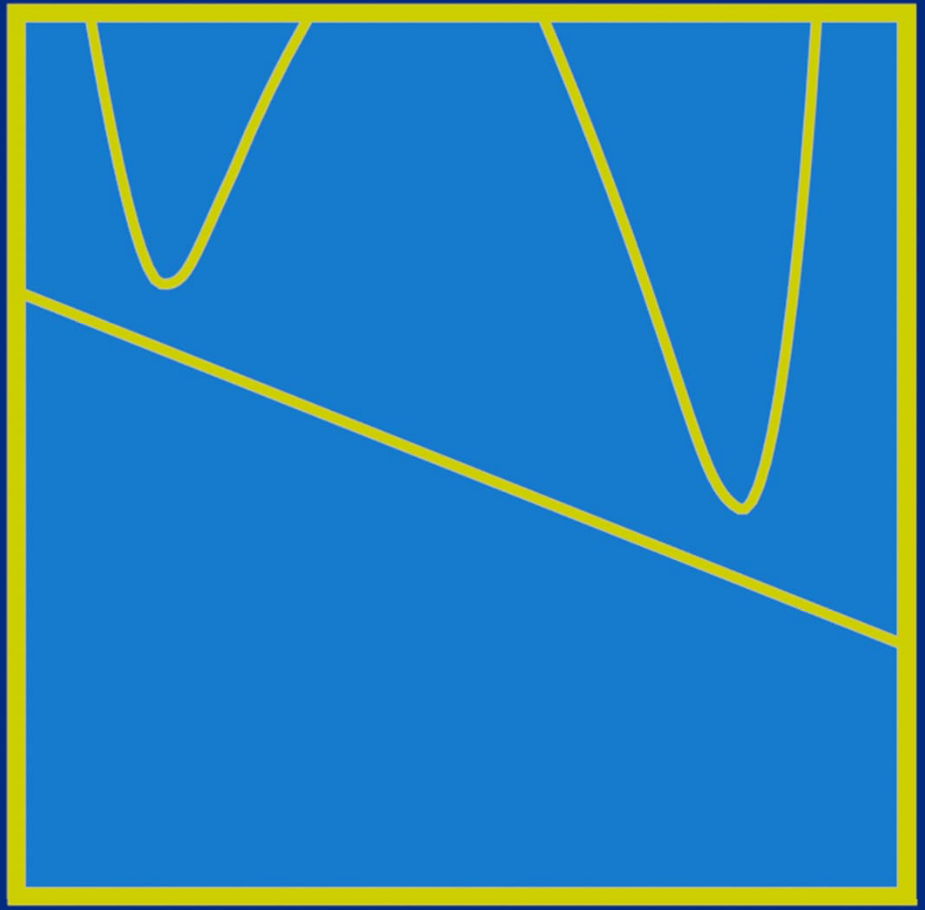
HOWEVER,



With the equilibrium distribution looking like this but with a large local deficit of excitations.

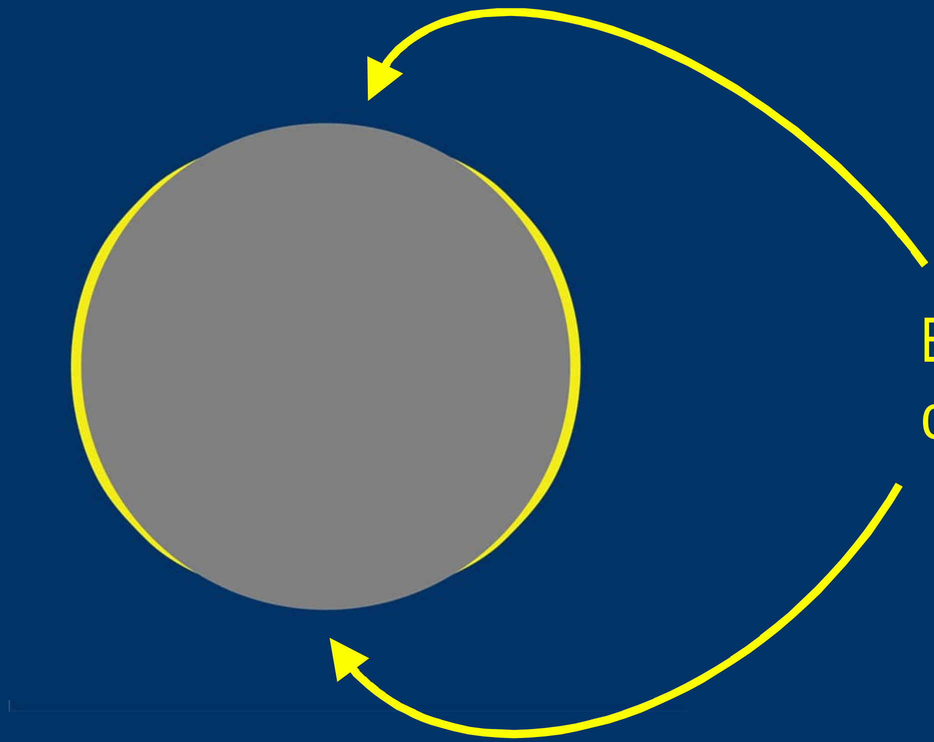
From this stable situation, if we now decelerate the wire back to zero velocity, the deficit remains as there is no rapid way that the excitations can be replenished.





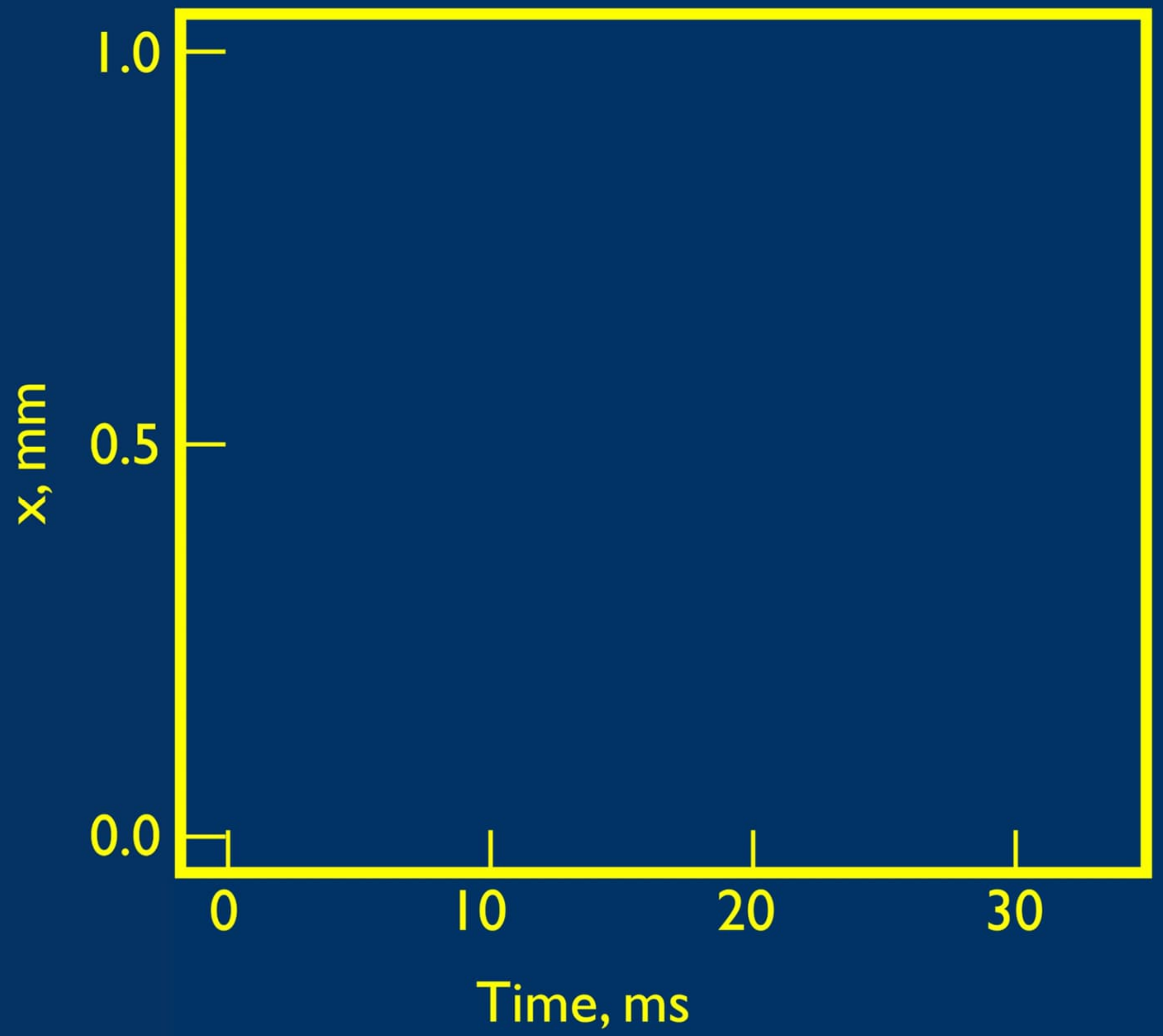
We have inter-curve scattering but this does not change the densities.

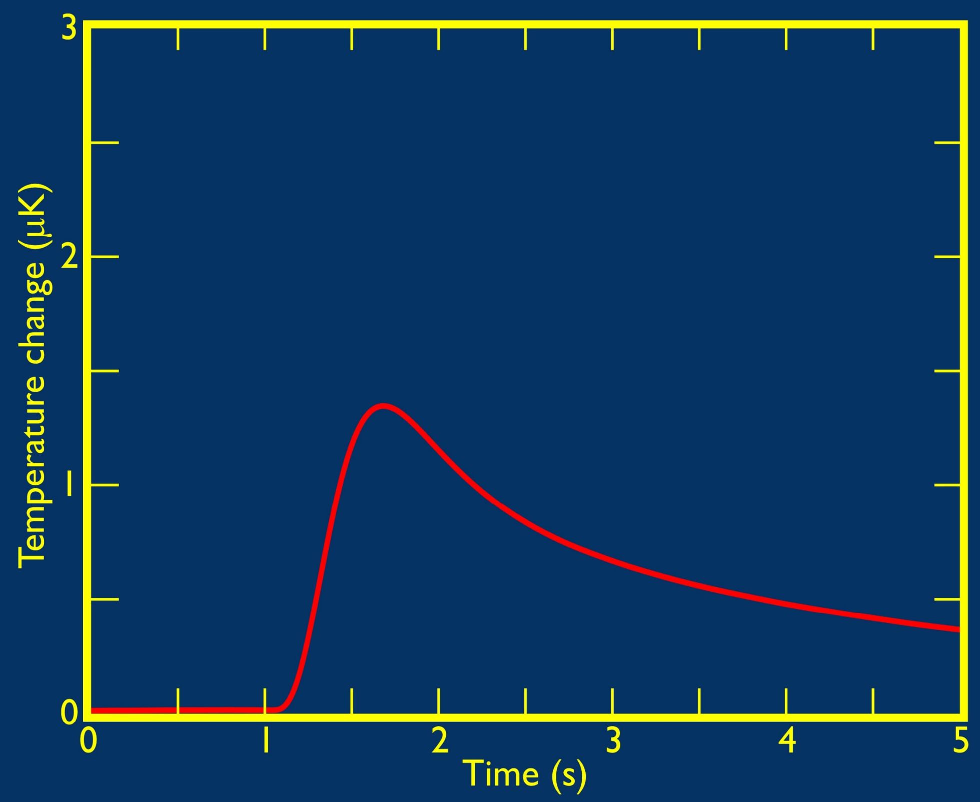
So,   by accelerating the wire up above the local Landau Velocity we can clear out a large fraction of the local bound excitations in the region of the wire cross-section extrema.



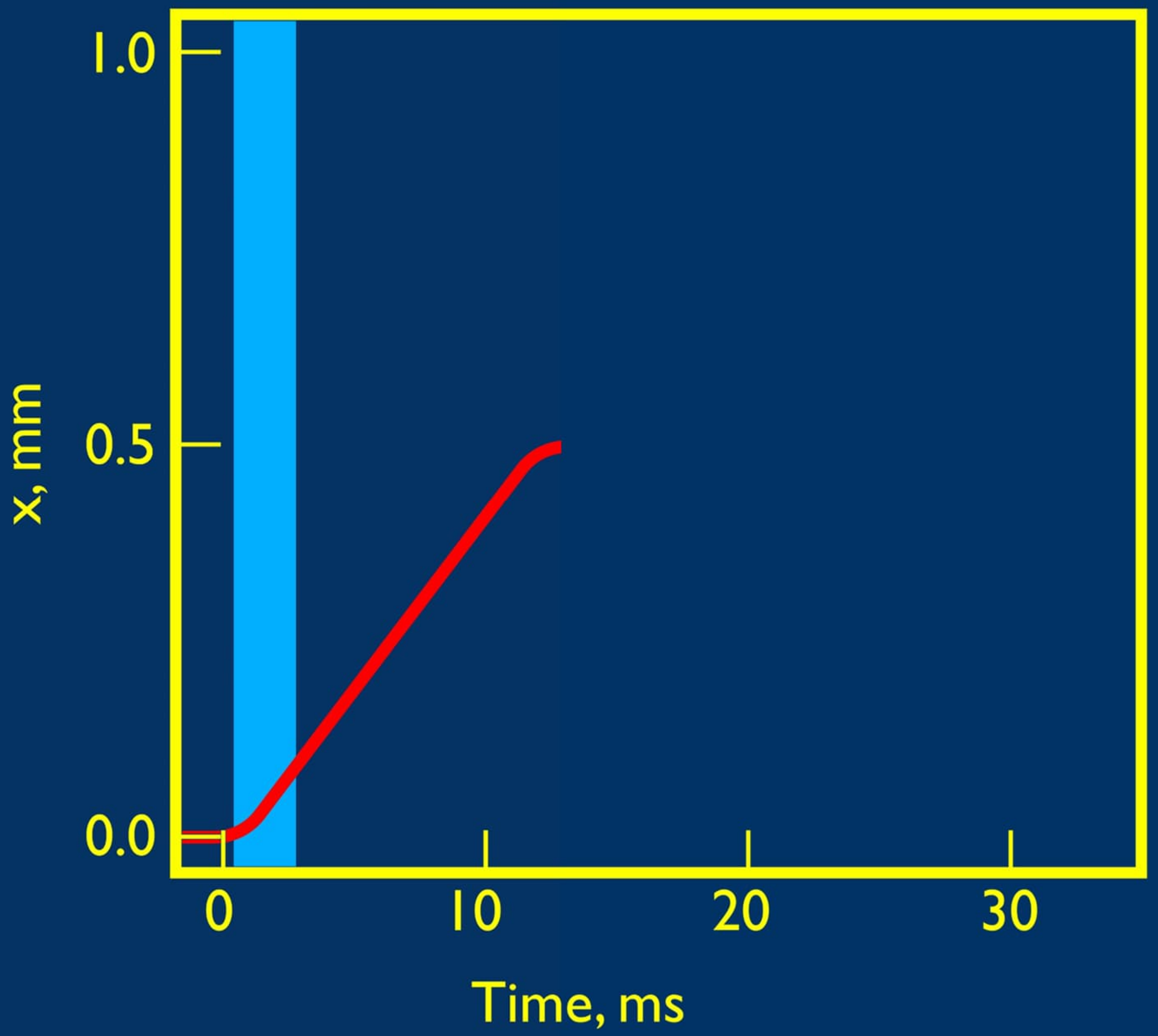
Excitations cleaned out!

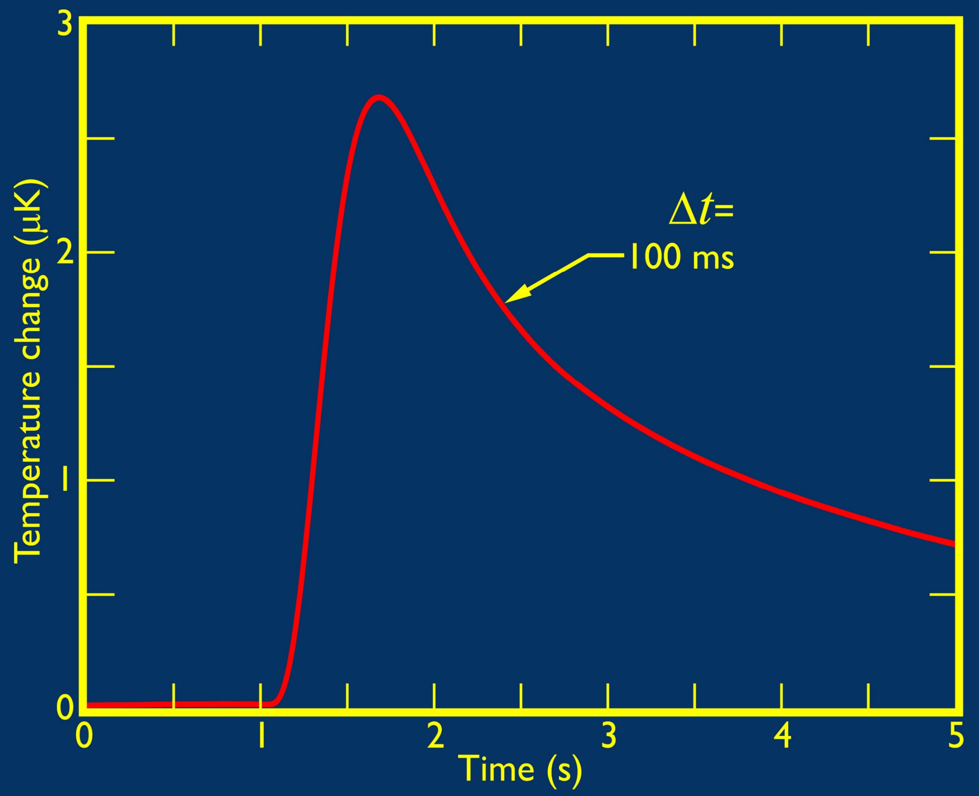
Also, what is amazing about this is that because we are at such low temperatures, just throwing these very few excitations off a very small area of the wire, increases the temperature of the whole ^{3}He liquid volume by a very measurable amount.


1.0
0.5
0.0
x, mm
0
10
20
30
Time, ms

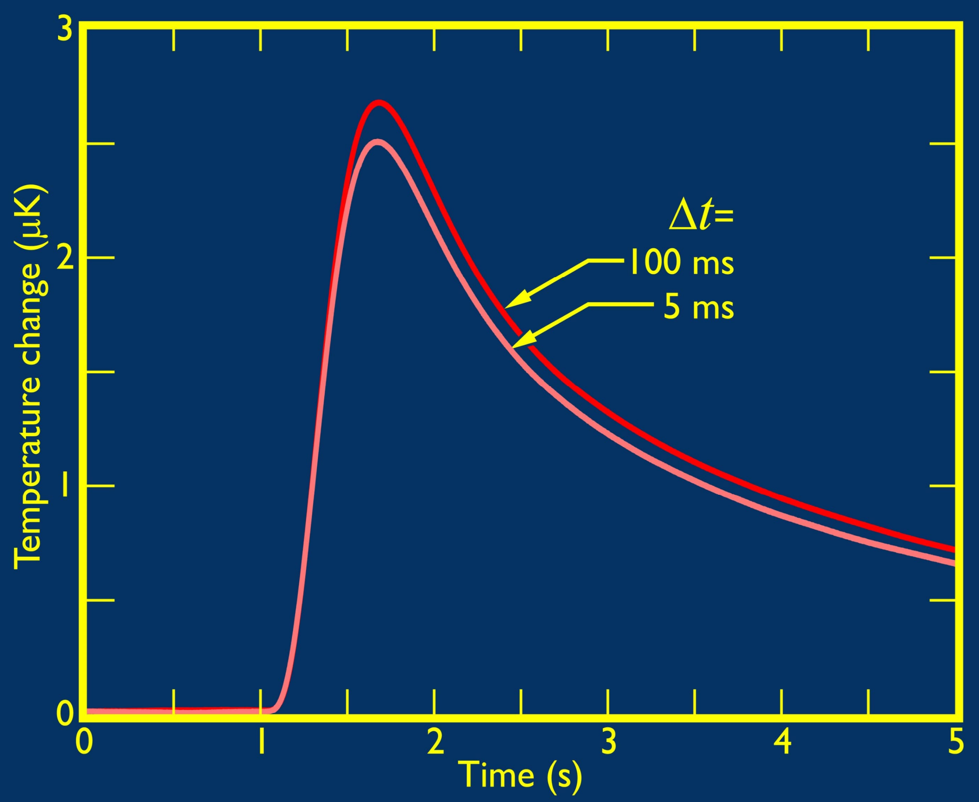


So, just emitting these very few excitations off a very small area of the wire increases the temperature of the whole ^{3}He liquid volume by ~1.5 μK.

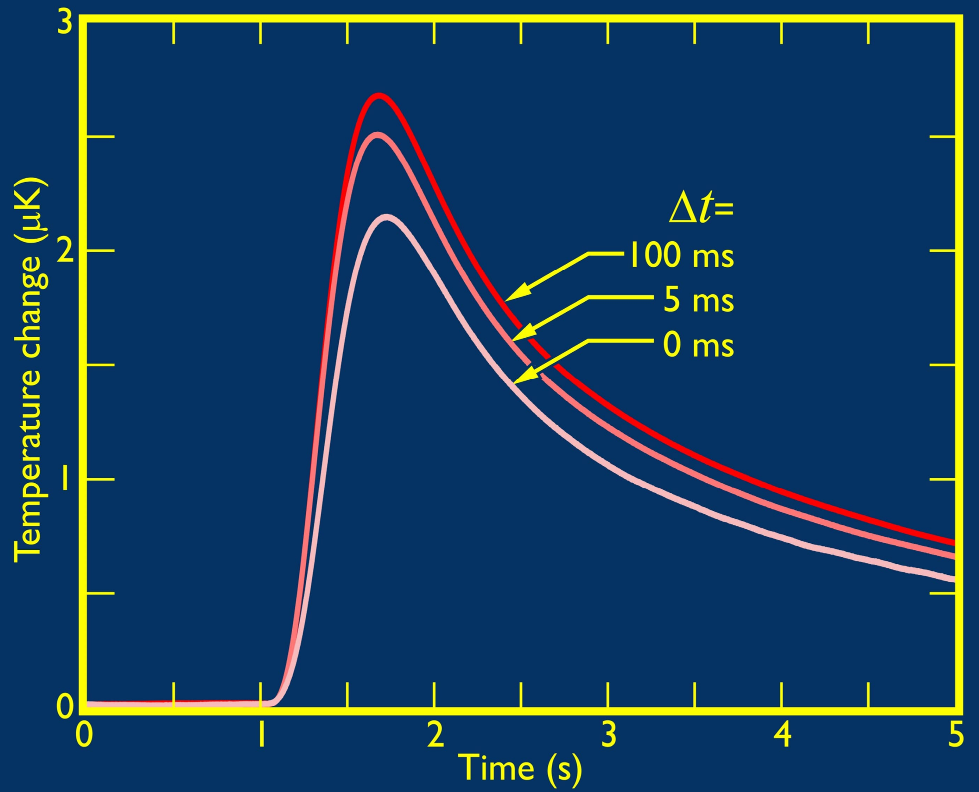

1.0
0.5
0.0
x, mm
0
10
20
30
Time, ms

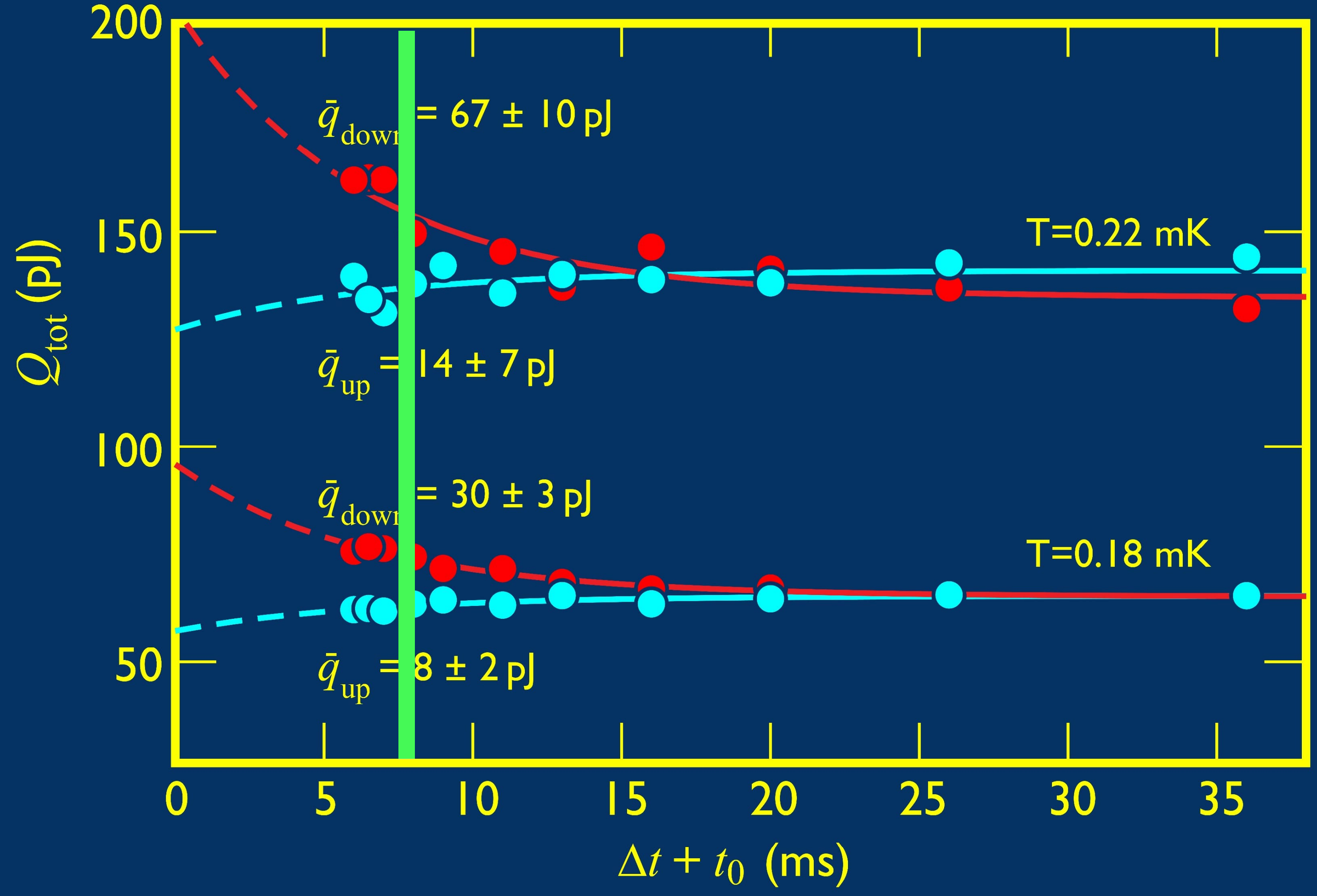


3
2
1
0
0
1
2
3
4
5
Temperature change (μK)
Time (s)
Δt=
100 ms



Temperature change (μK)
0
1
2
3
Δt=
100 ms
5 ms
0
1
2
3
4
5
Time (s)


Temperature change (µK)
Time (s)
Δt=
100 ms
5 ms
0 ms
0
1
2
3
4
5
0
1
2
3



Thus, the mobility of the bound excitations fills up the deficit region exponentially with a time constant of roughly 8 ms.

The thermal effect is higher at higher temperatures as there is a higher density of bound states in the well, but mobility is similar.

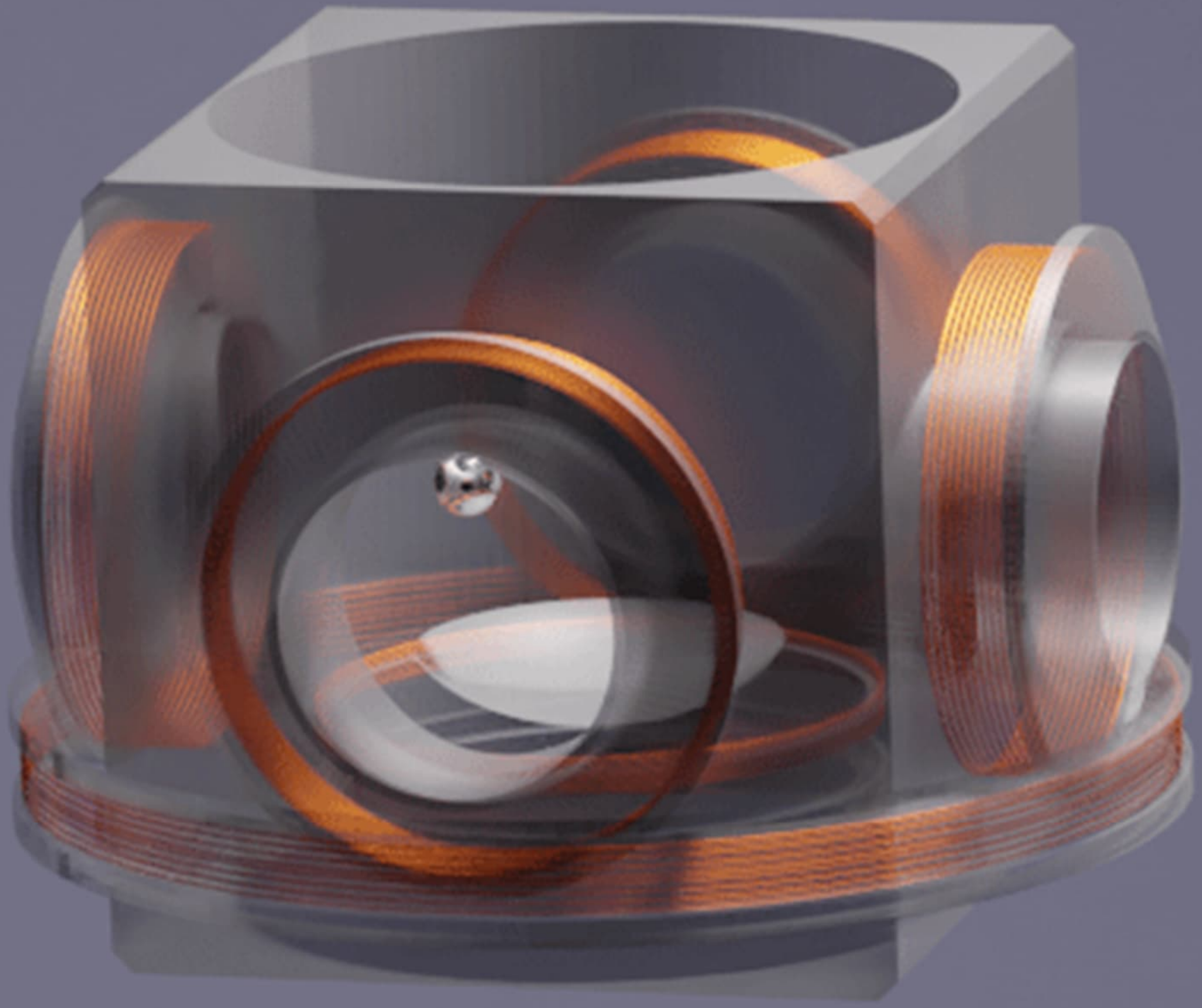
We are now having a debate about what all these time constants mean. There have been several statements in the past that the velocity of the bound states should the Landau critical velocity. But that seems unlikely, just from logic.

European Microkelvin Platform

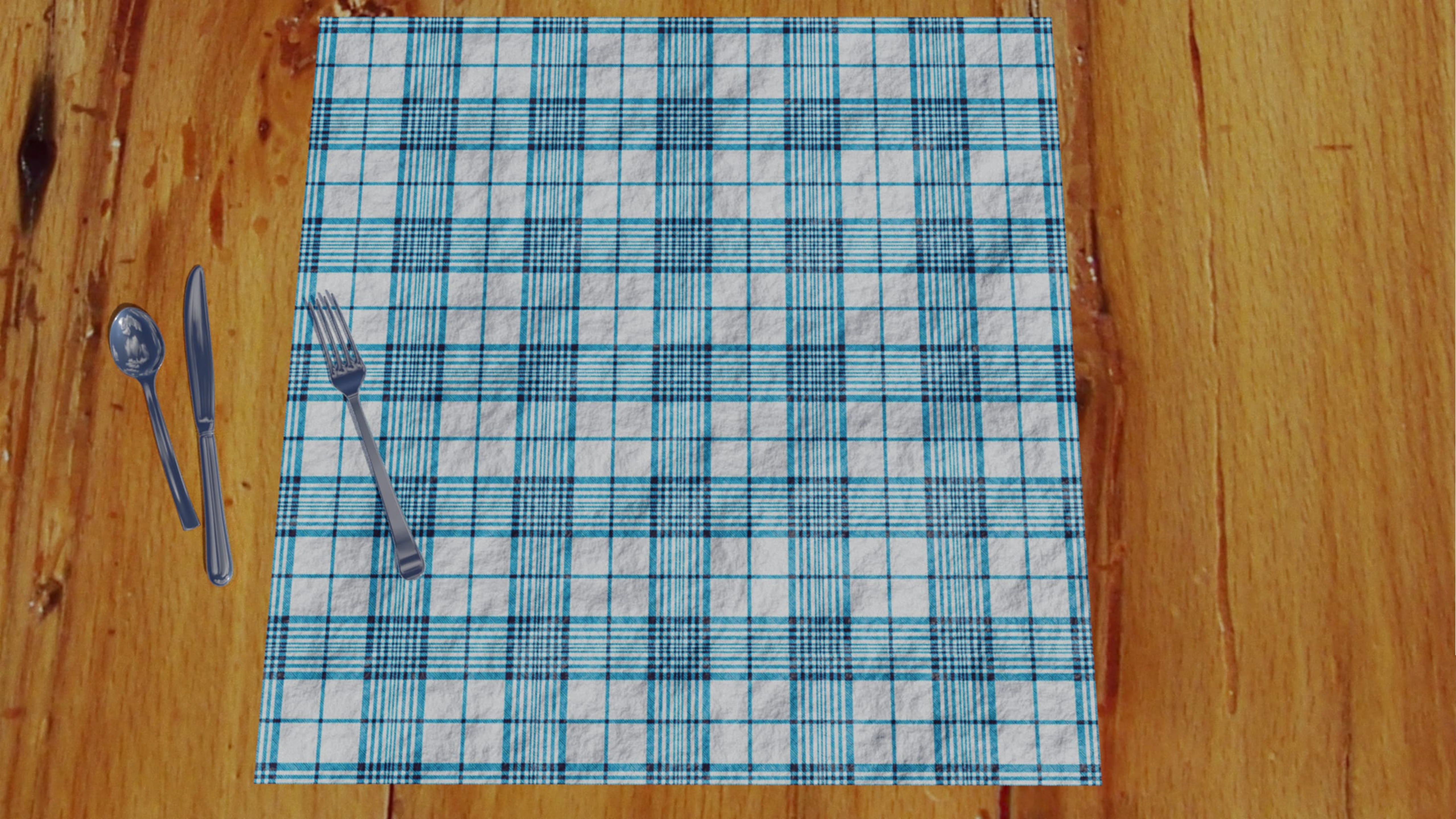
Where next??

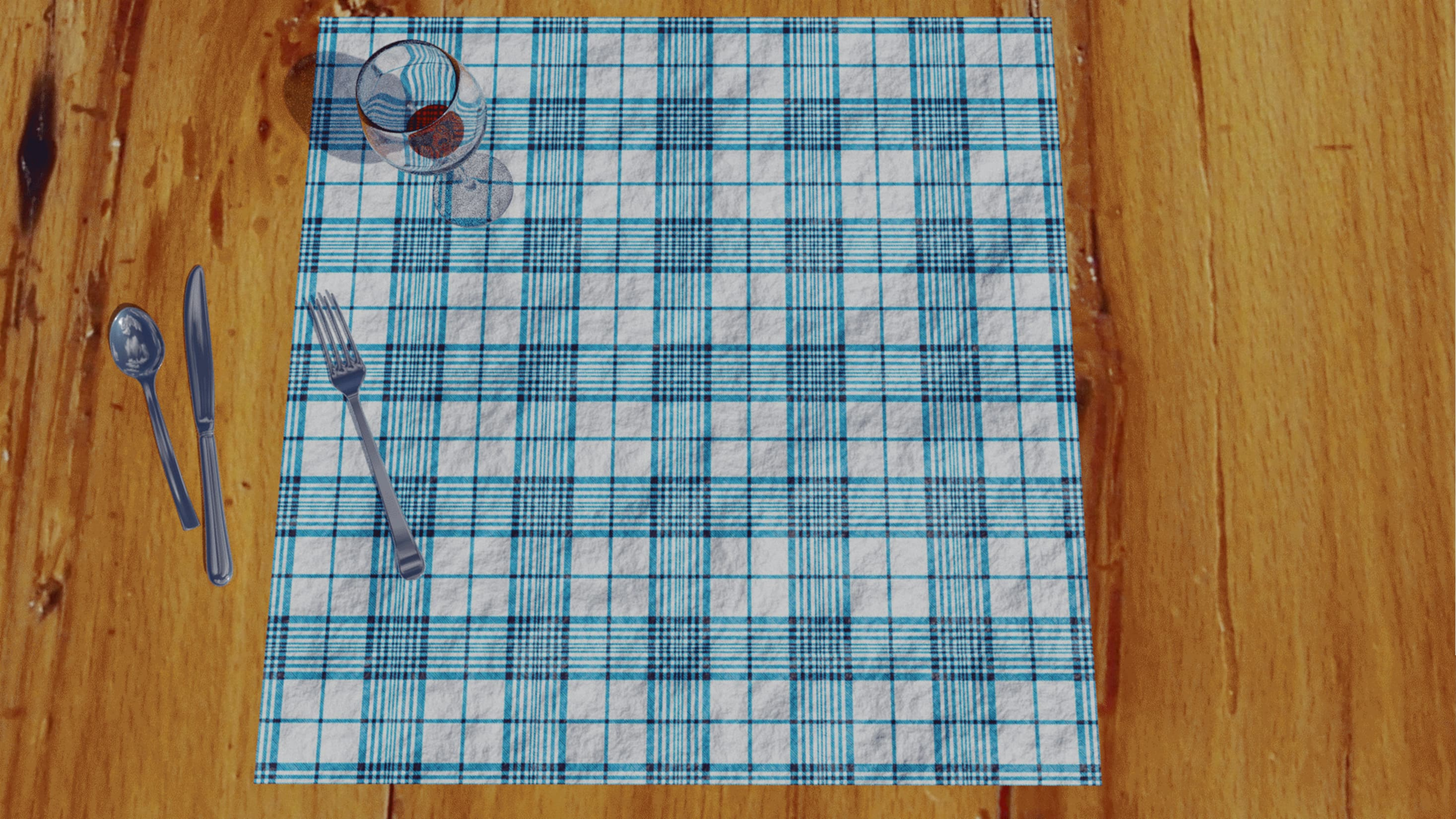
EMP

European Microkelvin Platform



But this meeting is about topological systems. Thus, I thought for Volodya's sake that there ought to be a topological conclusion.






The End