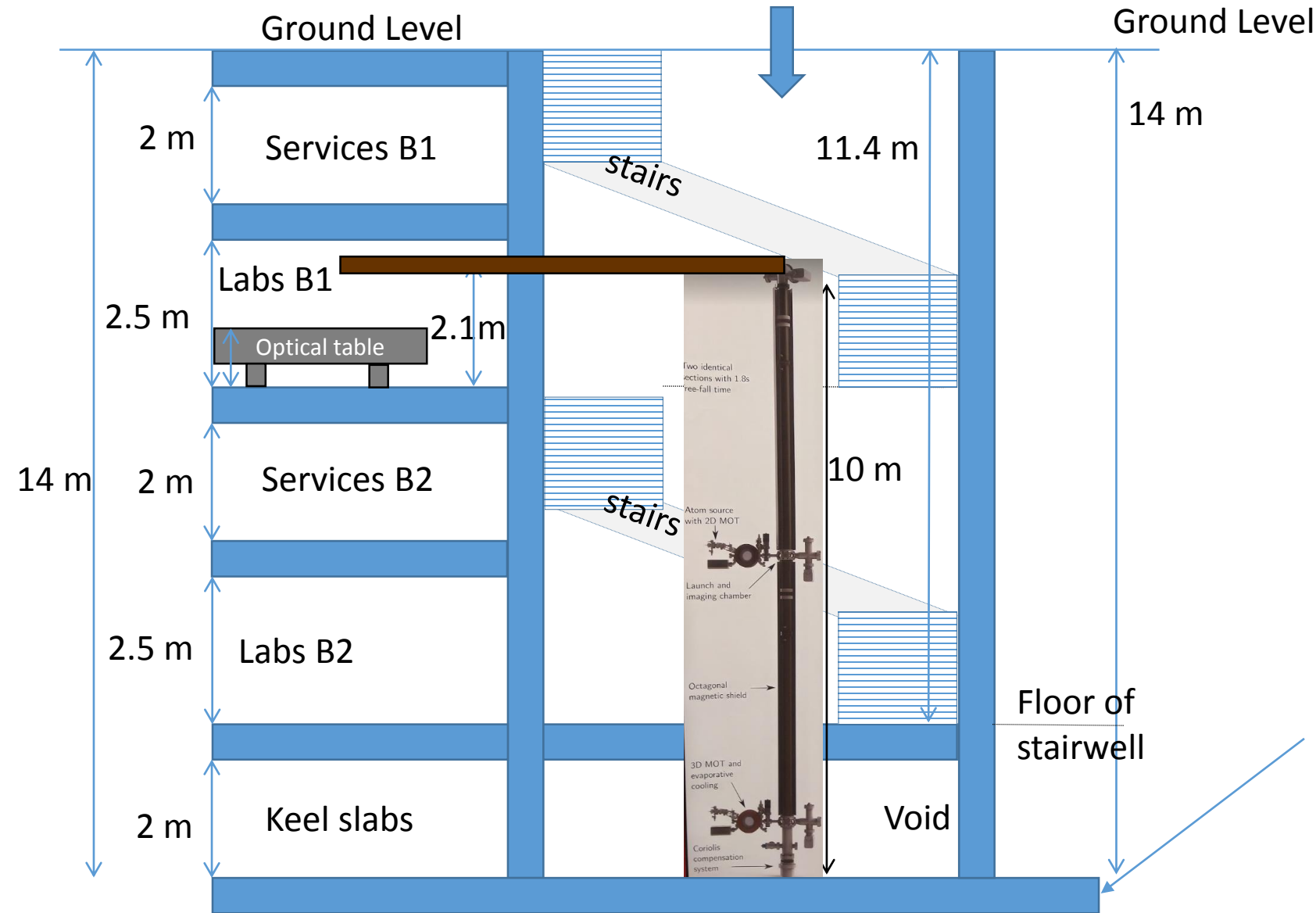


# Sketches for AION

Chris Foot, 21 Jan 2019

# Stairwell in Beecroft (ultralow vibration building): side view



Heights (approx.)

5 floors slabs:  $5 \times 0.6 = 3\text{ m}$

2 labs:  $2 \times 2.5 = 5\text{ m}$

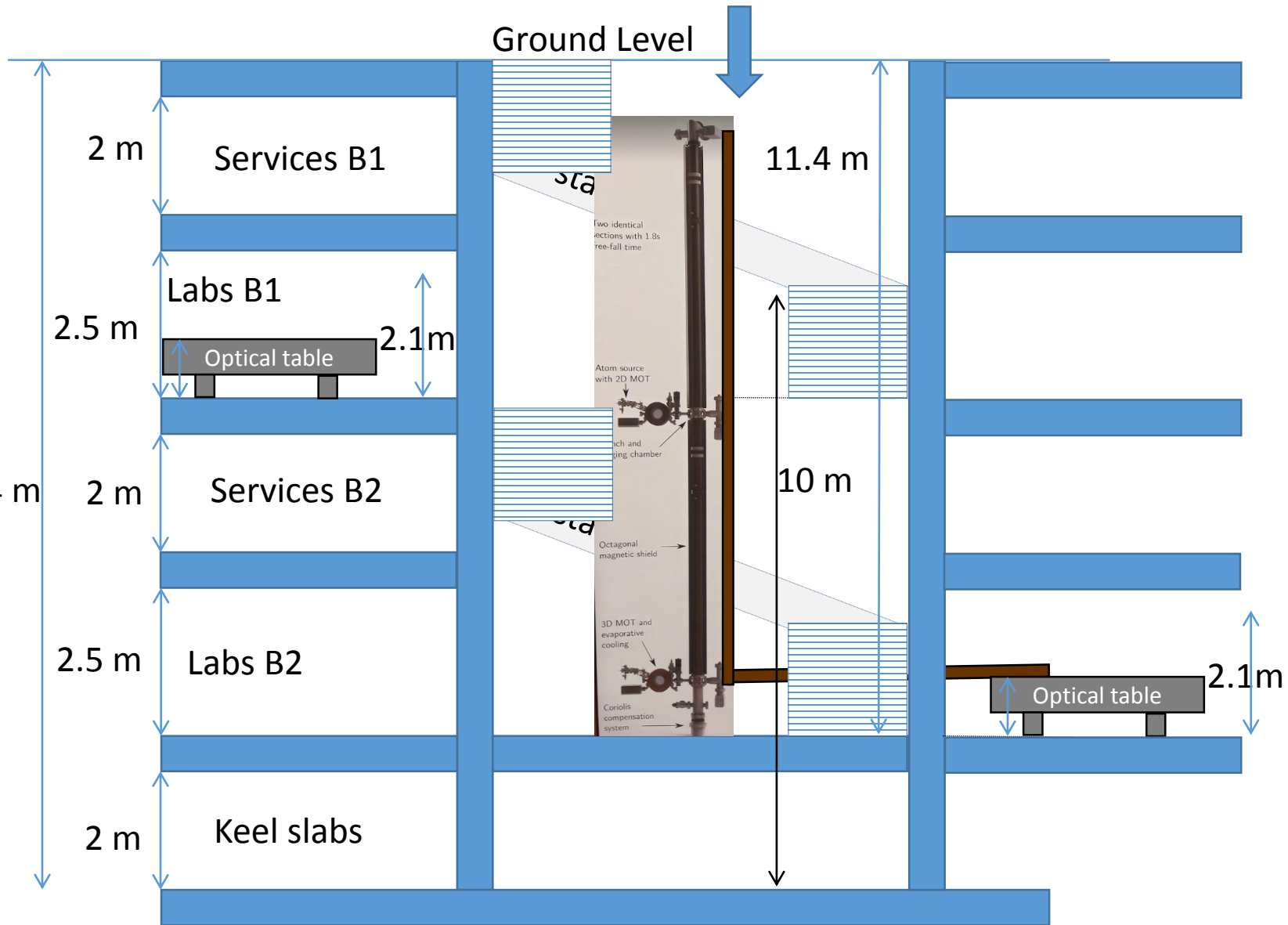
3 interstitial spaces:  $3 \times 2.0 = 6\text{ m}$

Void to ground =  $14\text{ m}$

[ 6 stair flights:  $11.4/6 = 1.9\text{ m}$  each ]

Scale: 1:100 in PowerPoint

# Stairwell in Beecroft (ultralow vibration building): side view



Heights (approx.)

5 floors slabs:  $5 \times 0.6 = 3\text{m}$

2 labs:  $2 \times 2.5 = 5\text{m}$

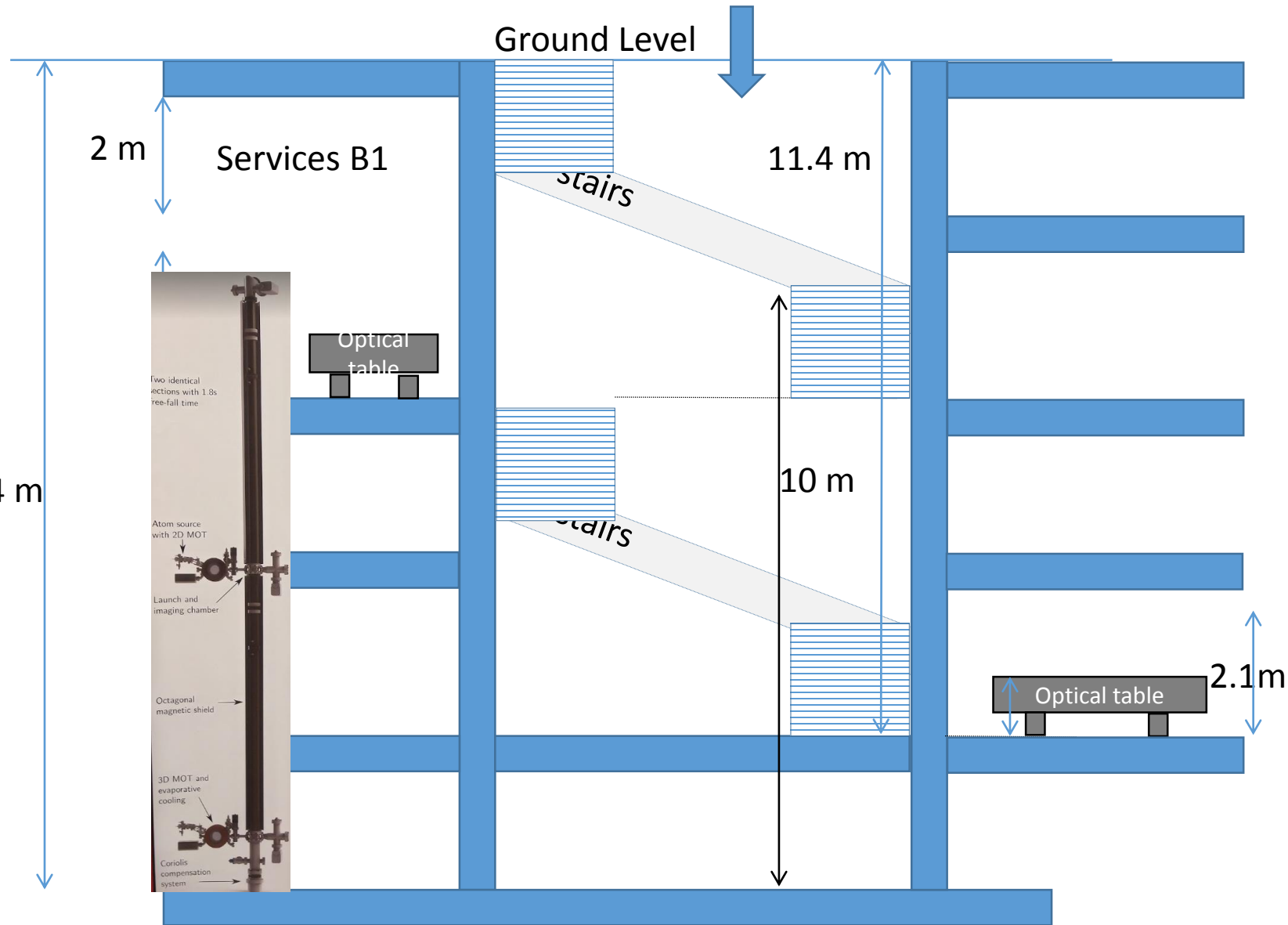
3 interstitial spaces:  $3 \times 2.0 = 6\text{m}$

Void to ground =  $14\text{m}$

[ 6 stair flights:  $11.4/6 = 1.9\text{m}$  each ]

Scale: 1:100 in PowerPoint

# Stairwell in Beecroft (ultralow vibration building): side view



Heights (approx.)

5 floors slabs:  $5 \times 0.6 = 3\text{ m}$

2 labs:  $2 \times 2.5 = 5\text{ m}$

3 interstitial spaces:  $3 \times 2.0 = 6\text{ m}$

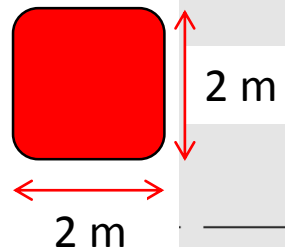
Void to ground =  $14\text{ m}$

[ 6 stair flights:  $11.4/6 = 1.9\text{ m}$  each ]

Scale: 1:100 in PowerPoint

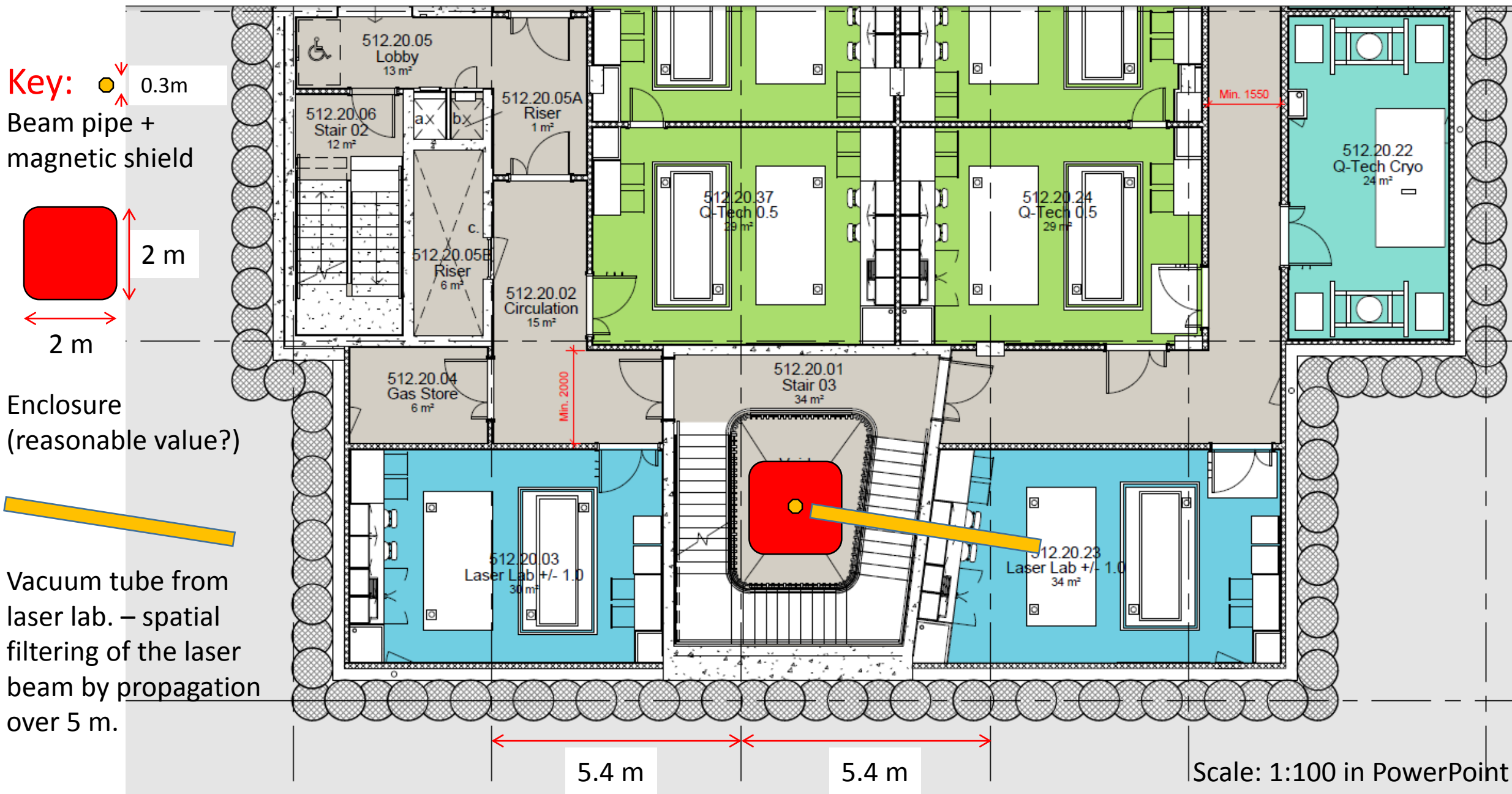
# Beecroft: upper basement labs. Plan view of AION apparatus

**Key:** ● 0.3m  
Beam pipe + magnetic shield



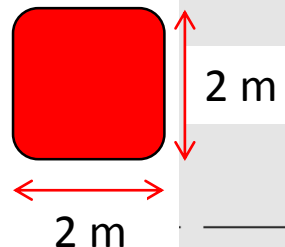
Enclosure (reasonable value?)

Vacuum tube from laser lab. – spatial filtering of the laser beam by propagation over 5 m.



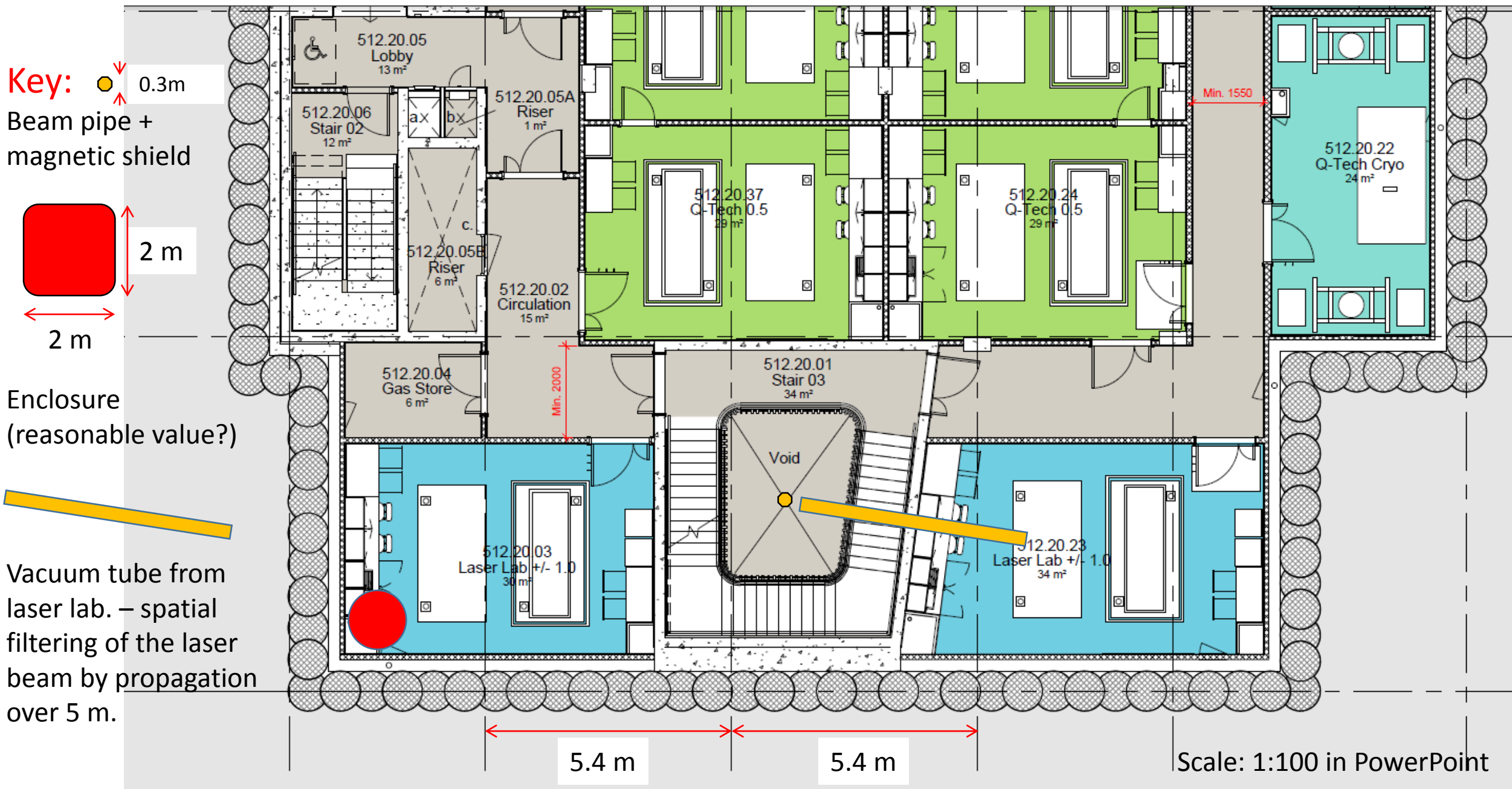
# Beecroft: upper basement labs. Plan view of AION apparatus

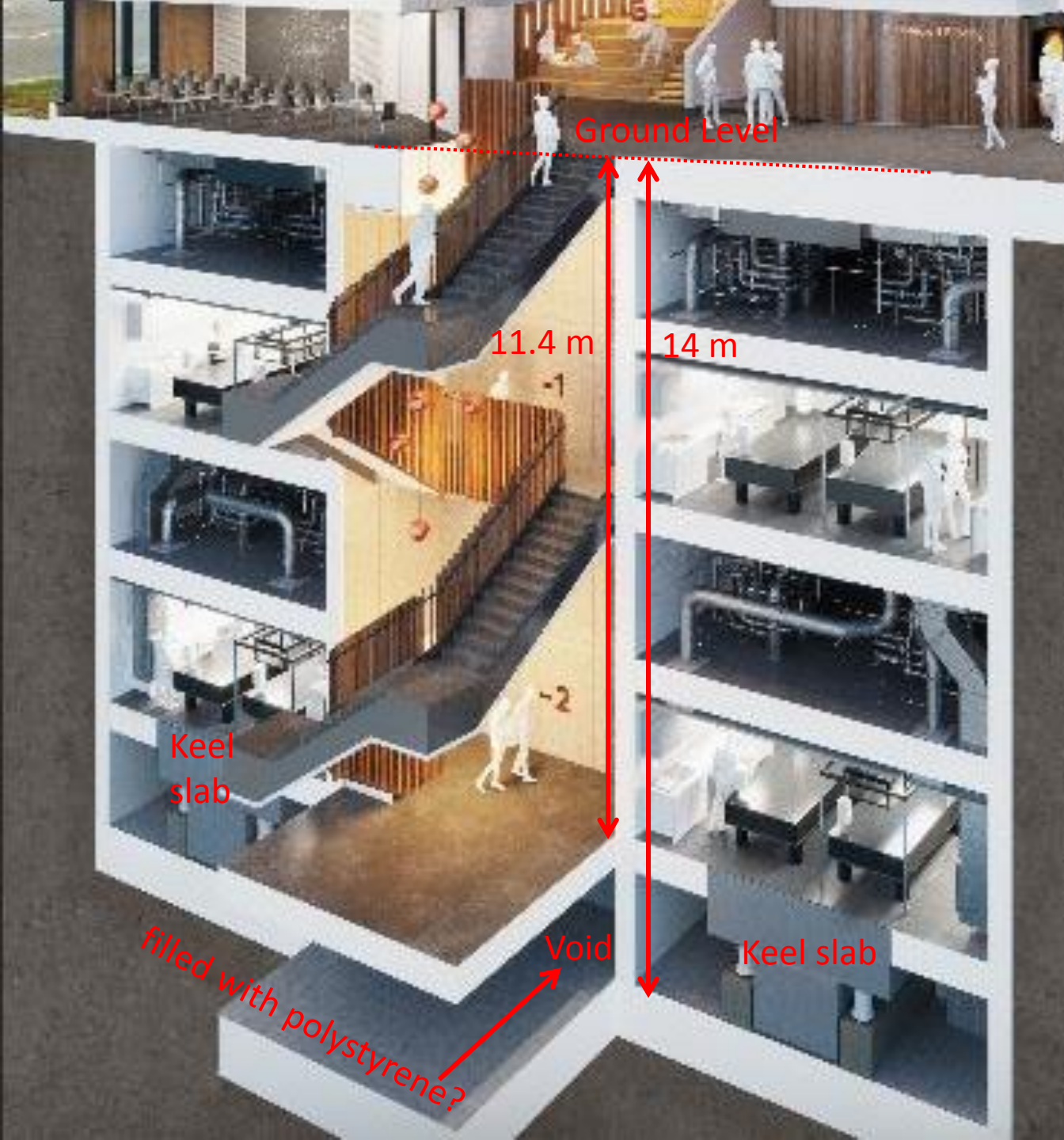
**Key:** ● 0.3m  
Beam pipe + magnetic shield



Enclosure (reasonable value?)

Vacuum tube from laser lab. – spatial filtering of the laser beam by propagation over 5 m.





Ultralow vibration

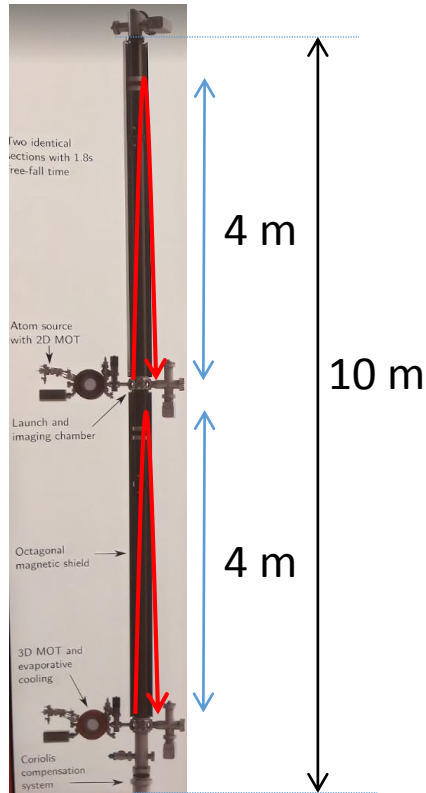
- All plant isolated
- Thick concrete walls



Determine scale of the Stanford poster:

Free-fall time = 0.9 s

Fountain height = 4 m



- Tower allows free-fall time of  $2T$ , where  $T = \sqrt{\frac{2l}{g}} = 0.9\text{s}$
- Two atomic clouds addressed by the same laser allows common-mode rejection
- Measure gravity gradient with phase  $\phi \propto T \Delta p = \sqrt{\frac{2l}{g}} N \hbar k$
- Long time-of-flight allows novel measurements of gravitational waves and ultralight dark matter

### Tower Vacuum and Magnetic Shielding

Atomic trapping lifetime limited by vacuum

- Hydrogen outgassing from strontium oven
- Getter pumps placed near imaging chambers
- Target vacuum  $10^{-11}$  mbar

#### Octagonal Mumetal shield with four bias coils

- 2D finite element simulation
- Earth field shielding factor > 100
- Target bias field  $\sim 1$  Gauss
- Optimal configuration achieves  $\sim 10^{-3}$  field inhomogeneity within 1 inch from the center
- 3D simulation in progress with Robert Wands at Fermilab

### Levitating Sequences

Repeated pulses can levitate atoms

- 698 nm light imparts a recoil velocity of 6.5 mm/s
- Velocity-selected light talks to each arm separately
- Levitation requires a pulse rate of  $f_{\text{pulse}} = \frac{mg}{\hbar k} = 1503 \text{ s}^{-1}$
- Rabi frequency requirement of approx. 3 kHz
- Allows longer sequences and higher spacetime area

### References

P. W. Graham, J. M. Hogan, M. A. Kasevich, and S. Rajendran, "New Method for Gravitational Wave Detection with Atomic Sensors", *Phys. Rev. Lett.* 110, 171102 (2013)

L. Ha, N. Poli, L. Salvi, and G. M. Tino, "Atom Interferometry with the Sr Optical Clock Transition", *Phys. Rev. Lett.* 119, 203601 (2017)

P. W. Graham, J. M. Hogan, M. A. Kasevich, S. Rajendran, and R. W. Romani, "Mid-band gravitational wave detection with precision atomic sensors", arXiv:1711.02225 (2017)

C. P. Bidzheci and J. W. Martin, "Passive Magnetic Shielding in Gradient Fields", arXiv:1310.8242 (2013)

K. J. Hughes, J. H. T. Burke, and C. A. Sackett, "Suppression of Atoms and Gravity Using a Pulsed Standing Wave", arXiv:0902.0169 (2009)

Two identical sections with 1.8s free-fall time

Atom source with 2D MOT

Launch and imaging chamber

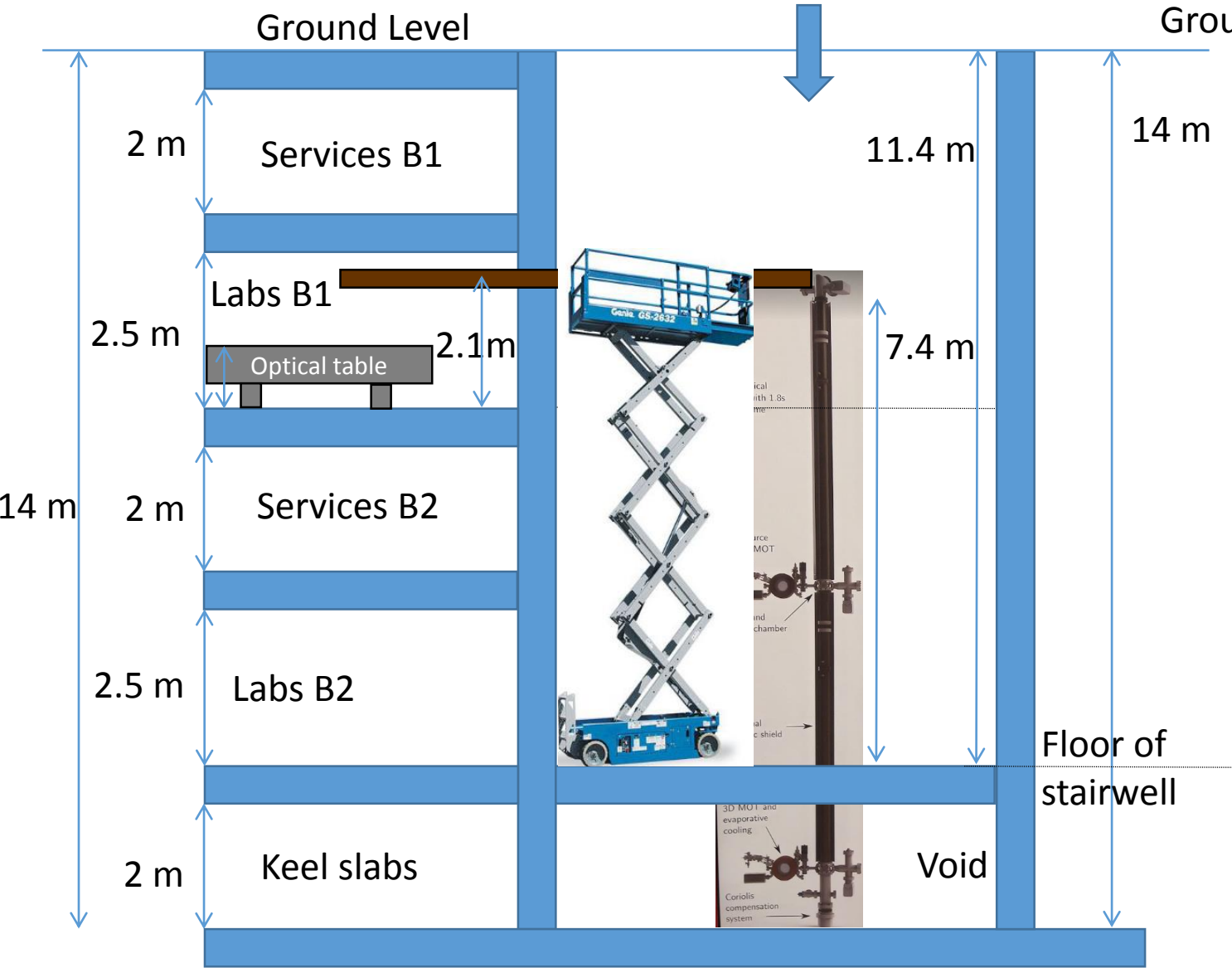
Octagonal magnetic shield

3D MOT and evaporative cooling

Coriolis compensation system



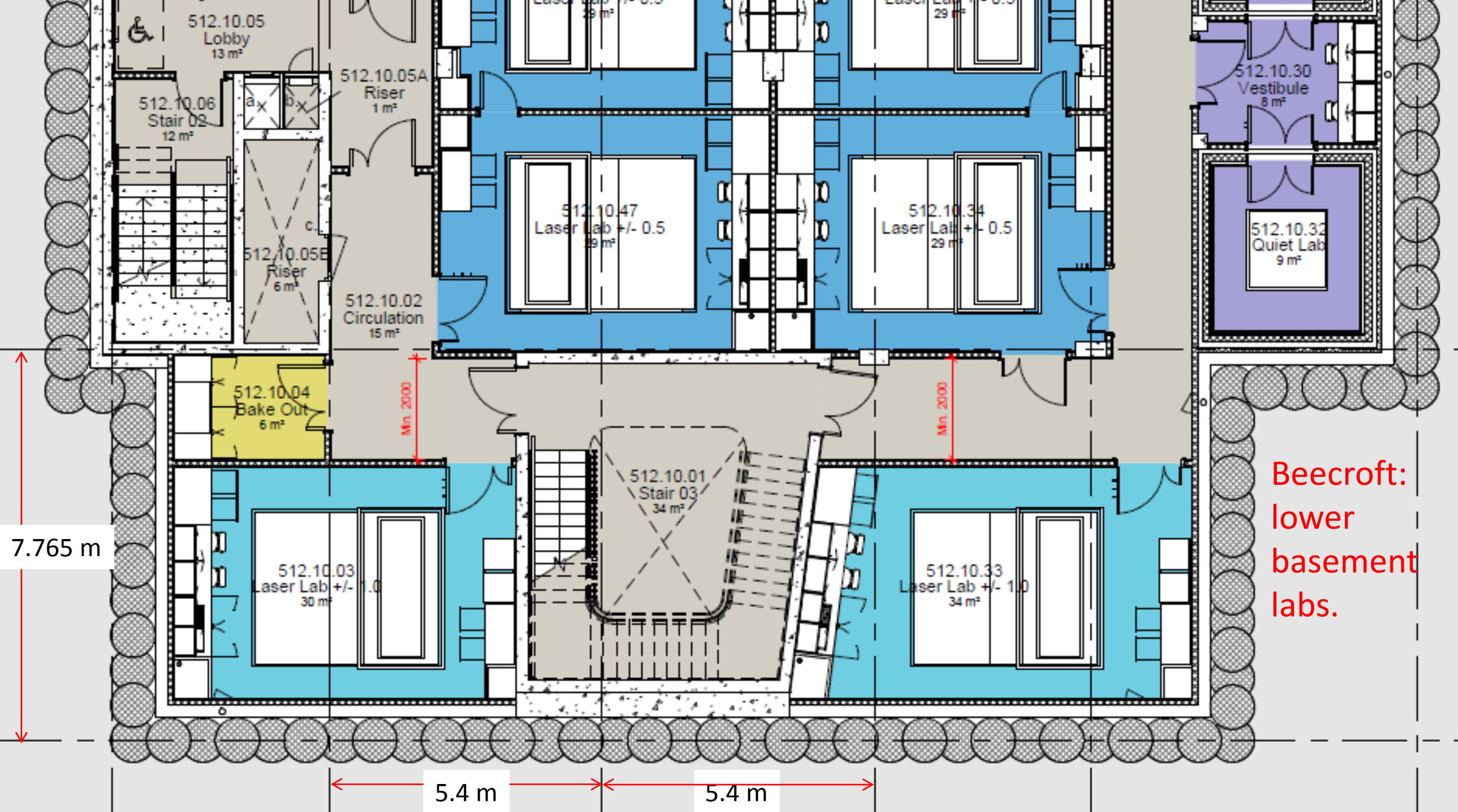
# Stairwell in Beecroft (ultralow vibration building)



Heights (estimated)

- 5 floors slabs:  $5 \times 0.6 = 3\text{m}$
- 2 labs:  $2 \times 2.5 = 5\text{m}$
- 3 spaces:  $3 \times 2.0 = 6\text{m}$
- Void to ground =  $14\text{m}$

6 stair flights:  $11.4/6 = 1.9\text{m}$  each



Beecroft:  
lower  
basement  
labs.