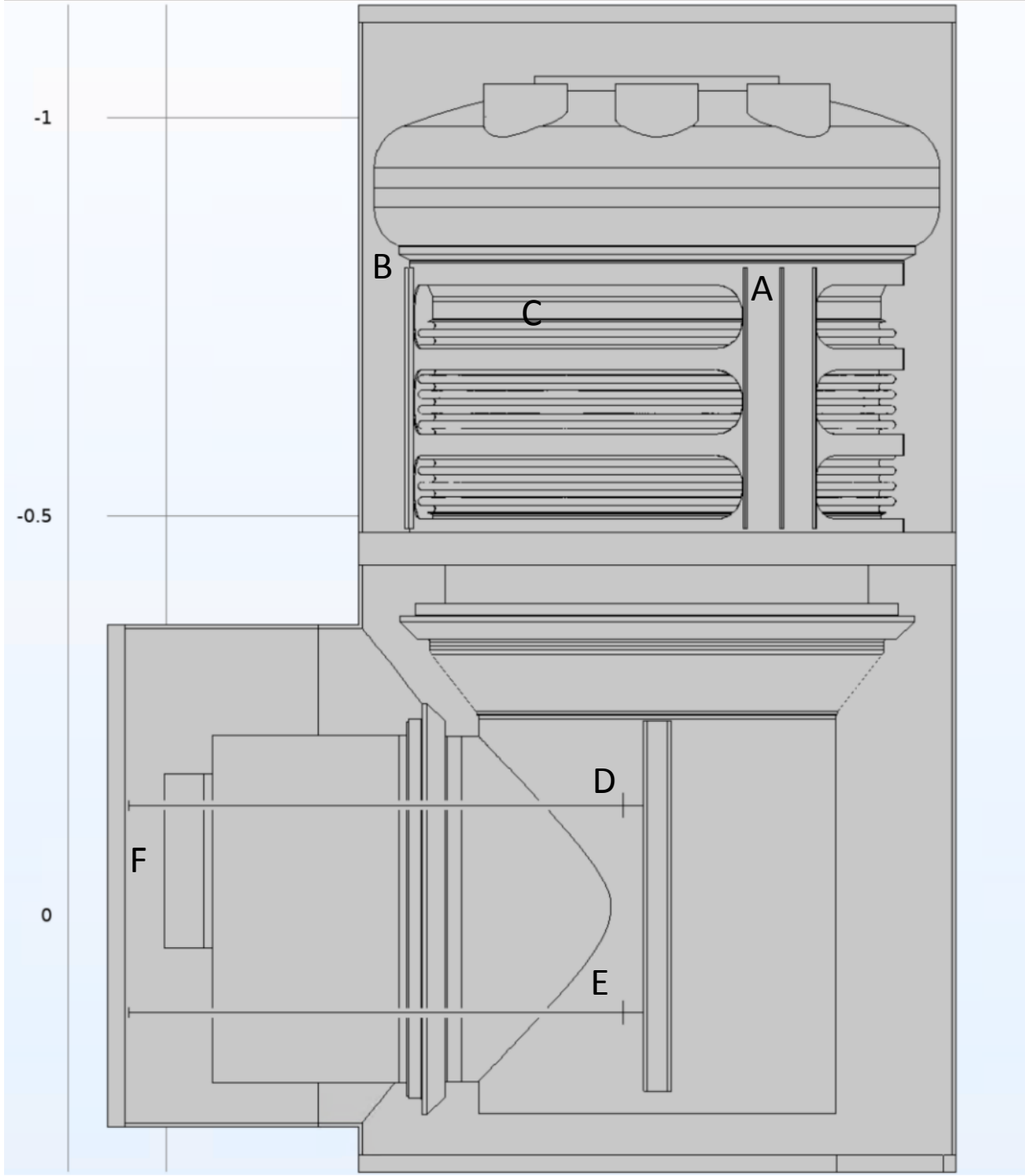
Force link points to the inner vertical vessel
OK

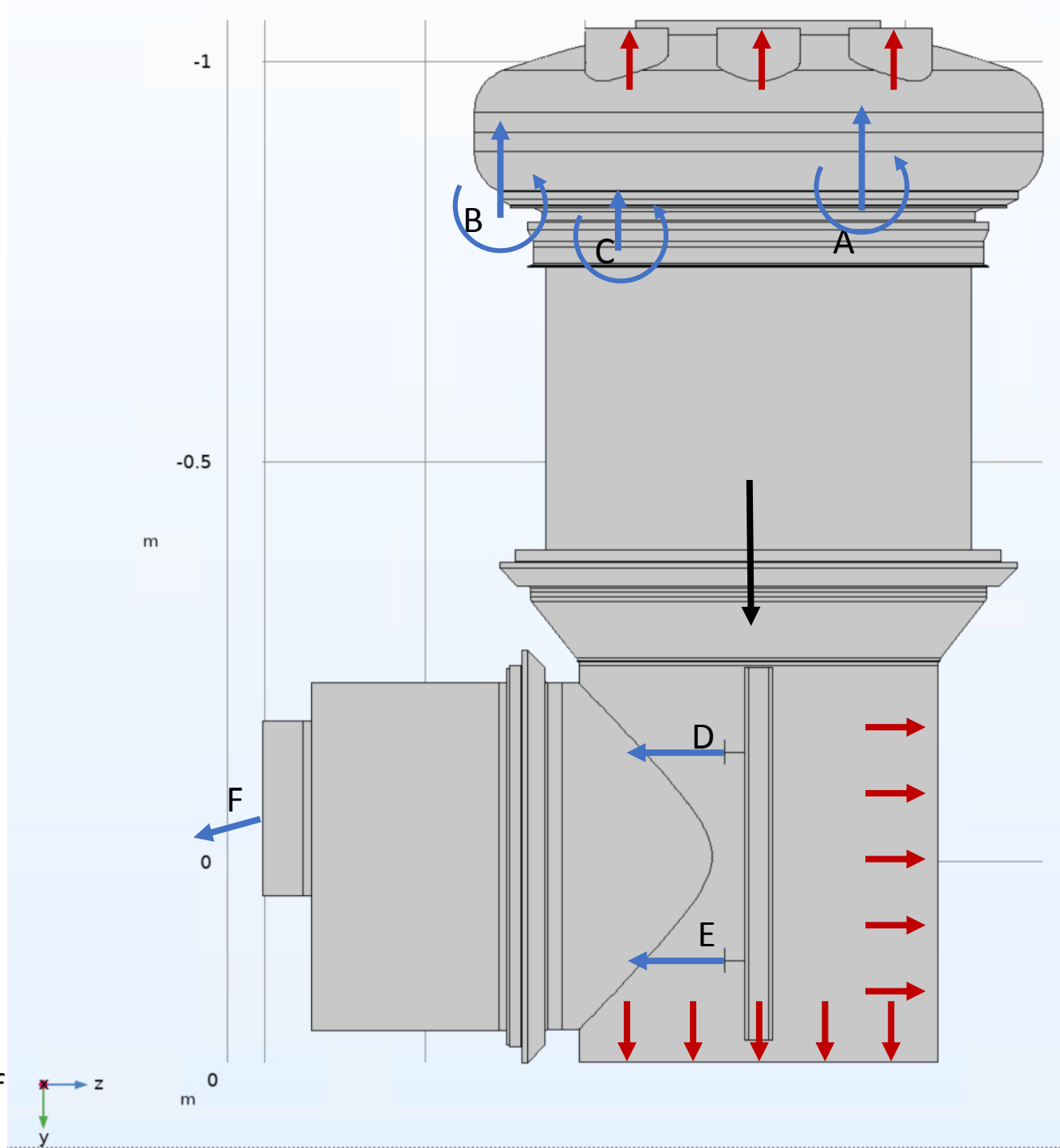
A: connection to the lateral supporting bars of the vacuum break
B: connection to the in-plane (yz) supporting bar of the vacuum break
C: effective load point by the vacuum membrane
D/E: connection to the invar bar
F: connection to the horizontal bellow



Free body force diagram of the inner vertical vessel

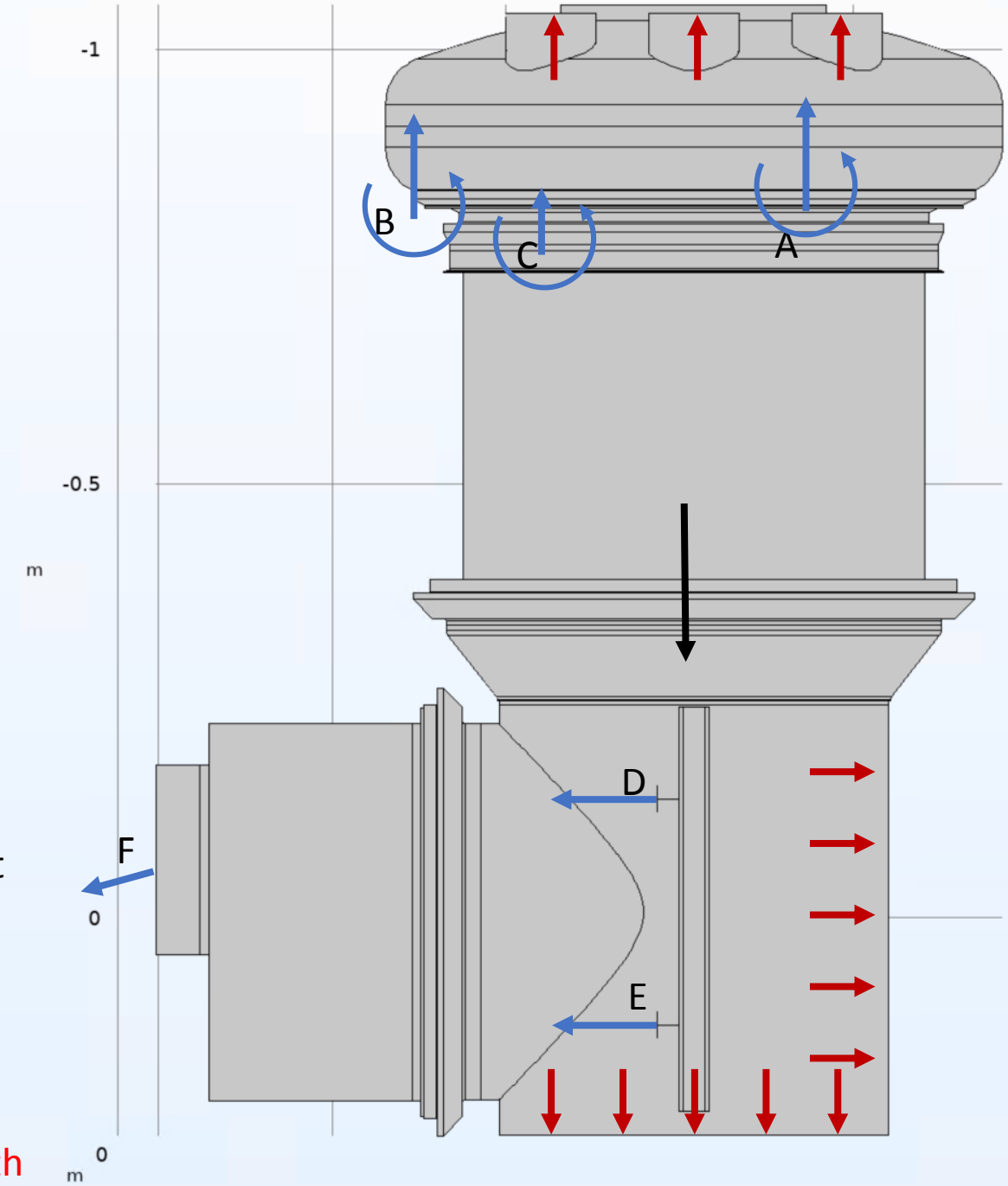
OK

1. Body forces:
    - Internal pressure (red) (combination of downwards along *y* and expanding along *z*
    - Weight (black) downwards
2. Link forces
    - A/B/C: mostly upwards to counter the downwards forces and differential thermal contraction between the inner cold vessel and the vacuum break fixed at room temperature
    - D/E: horizontal along *y* to counter the expansion force of the inner pressure
    - F: horizontal along *y* to accommodate the thermal contraction of the horizontal section
3. Toque
    - *Without the invar bars*, the (horizontal) inner pressure causes large bending moments at A/B/C. The bending of the vacuum break provides the balance force to the pressure.
    - The invar bars are used to reduce/eliminate the bending moment. The relative *z* displacement between the inner vessel and the fixed warm vessel is kept at minimum with the low thermal contract of the invar



Management of inner vessel thermal contraction

1. Horizontal
    - The invar bars fix the cylindrical axis of the vertical inner vessel relative to the fixed warm vacuum vessel.
    - The vertical vessel contracts symmetrically in the horizontal direction, leading to bending moments at A/B/C in the opposite to the inner pressure
2. Vertical
    - The contraction of the upper vessel is restricted by the vacuum break, which bear the loads
    - With invar bars *fixed* at the room temperature, the contraction of the lower vessel is restricted, but only modestly (2.1mm instead of 2.6mm free contraction) because of the bending flexibility of the long-and-thin invar bars See Paul's email about clarification of 2.1/2.6mm
    - With the invar bars *pivoted* at the room temperature, the restriction on the lower vessel contraction is moderated but results in the bending of the vertical vessel. The pivot also requires more space OK, how much is the displacement?
    - With invar bars *free to slide transversely in the xy plane* at the room temperature, the lower vessel is virtually free to contract vertically. It is also simpler to implement and to install as shown in the next slide. How can the bars slide with the friction ? (Note: PTFE is not allowed at CERN, see spec).



Sliding fixture of invar bars/rods at room temperature