SPT-SLIM Electronics Rack

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SPT Background

The South Pole Telescope (SPT) is located at Amundsen-Scott South Pole Station. It has been in operation since 2007 and primarily makes Cosmic Microwave Background (CMB) measurements at mm wavelengths. The telescope consists of a 10-meter diameter primary mirror which focuses light onto detectors inside the co-moving cabin. The current-generation CMB experiment, SPT-3G, utilizes a transition edge sensor (TES) detector array; upcoming experiments (SPT-4, SPT-SLIM) will transition to microwave kinetic inductance detectors (MKIDs).

Fig. 1: Photo of SPT

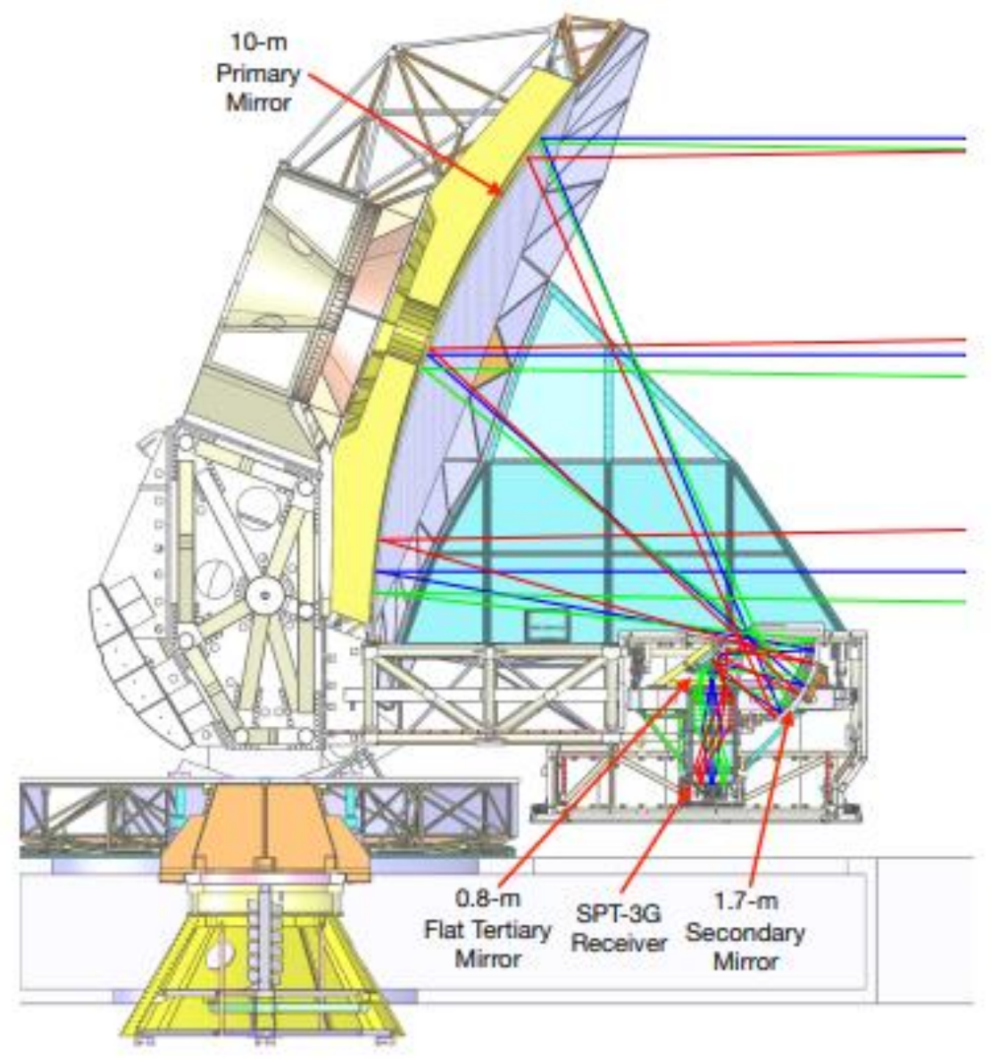

Fig. 2: Photons reflect off primary mirror and into SPT cabin

SPT-SLIM & Line Intensity Mapping

Line Intensity Mapping (LIM) involves measuring the redshift of a particular atomic or molecular emission line from numerous sources across the universe. This relatively new methodology can be applied to map large-scale structure (LSS) and subsequently improve constraints on various parameters (e.g., sum of neutrino mass states, expansion parameters, etc.) in the ΛCDM model of cosmology. SPT-SLIM (Summertime Line Intensity Mapper) is an upcoming LIM experiment on SPT planned for the austral summer of 2023-2024. It will target CO J→J-1 rotational transitions redshifted to between 120-180 GHz. These emission lines are commonly found in dense molecular clouds and therefore serve as useful tracers of matter. The choice of observation frequency range is convenient, as it is nearly identical to SPT-3G's 150 GHz observation band. SPT-SLIM aims to serve as a proof of concept for future LIM experiments—when technology will be better equipped to measure greater redshifts—along with investigating the pros and cons of using CO as a tracer.

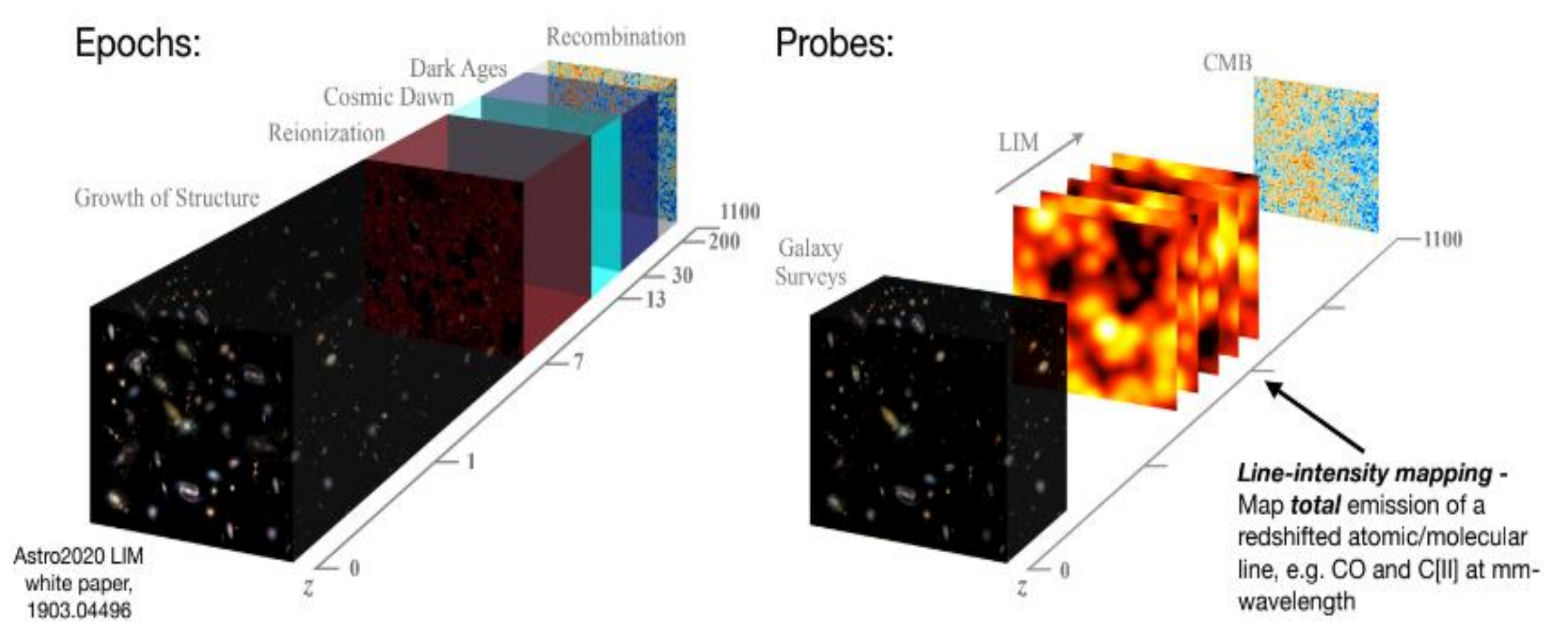

Fig. 3: LIM can be used to probe high-redshift sources more efficiently than current methods (e.g., galaxy surveys).

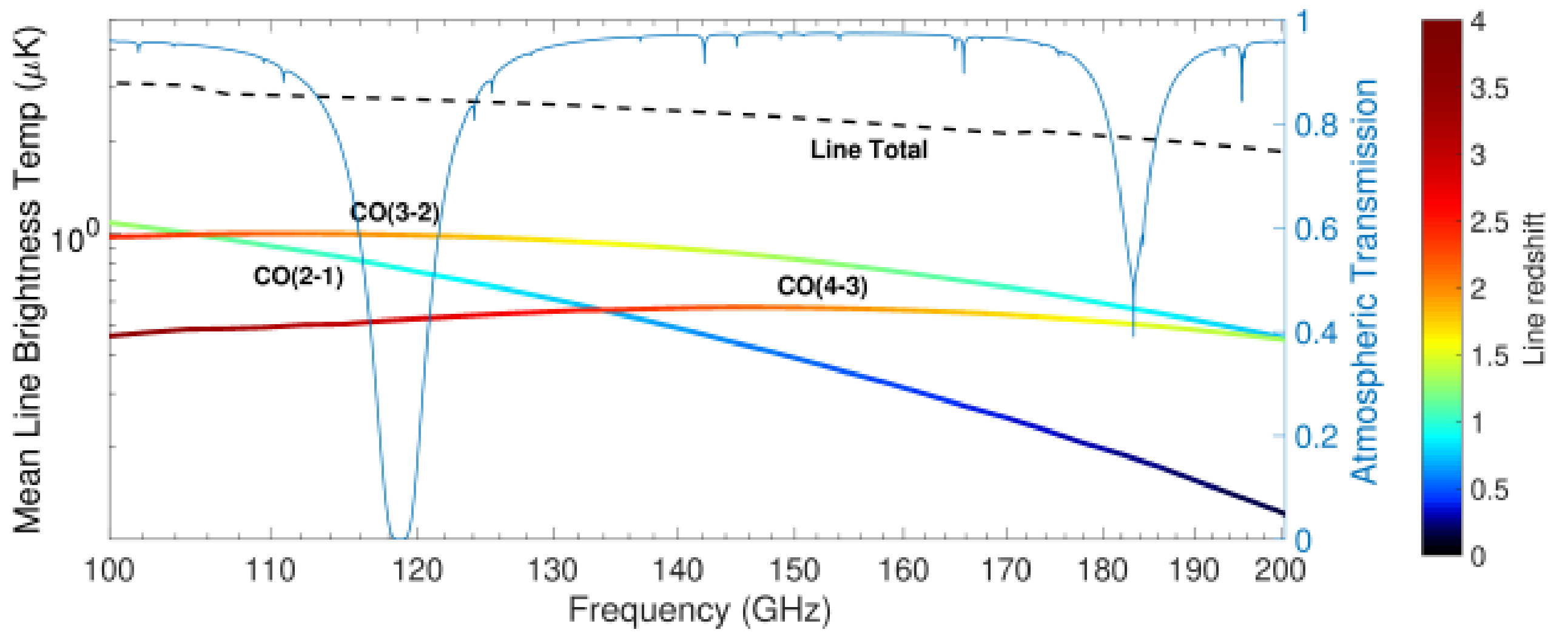

Fig. 4: Spectral lines targeted by SPT-SLIM, which will observe from 120-180 GHz. Shown are the model predictions for the brightness temperatures of CO(2-1), CO(3-2), and CO(4-3), their sum total (dashed black), and median atmospheric transmission during the South Pole summer (thin blue). The colors correspond to the observed redshifts of the lines.[3]

Electronics Rack

- **Purpose:** House electronic components necessary for SPT-SLIM
- **Location:** Mounted to SPT cabin's interior walls
- **Design Constraints:**
  - Be compact, since the cabin interior is cramped.
  - Support the combined mass (about 285 kg) from itself and all electronics.
  - Maintain a stable attachment to the cabin interior, since the cabin orientation is not fixed.

The rack's main body—sized at about 45.95" x 30.04" x 44.42"—contains 2 columns with widths specified by the EIA standard for 19-inch racks and heights of 24 rack units each. The main body is primarily composed of T-slotted profiles and has mounting structures (mounting rod and mounting bar) protruding from both ends. The choice of T-slotted profiles streamlines the assembly process by not requiring the drilling of holes for connecting adjacent members. For this same reason, the T-slotted profiles also allow for additional features to be added easily. The mounting structures attach the rack to the cabin walls as illustrated in Figure 7. The mounting bars require custom-machining, since their design was specified to be compatible with the pre-existing cabin dimensions.

Component Name	Rack Units	Weight [kg]
HPD 1510 CryoJunction	2	4
Rack Mount Control Computer	1	2
Moxa Nport 5650-8 Server	1	2.3
Lakeshore 372 Resistance Bridge	2	6.8
Lakeshore 218 Diode Thermometer Readout	2	3
3x Iceboard Mini-Crates	9	6
Power Supply for Iceboards (Keysight N5744A)	1	7
Fans for Iceboards	1	
Cisco CBS250-24T-4G-NA Ethernet Switch	1	2.6
Power Supply for LNAs	1	
Lakeshore 625 (ADR Magnet Power Supply)	4	27.2
PTC Linear Driver	3	6.3
Uninterruptable Power Supply (UPS)	4	61.4
APC AP7900B Network-Controlled Switch	1	2.3
Total	33	124.9

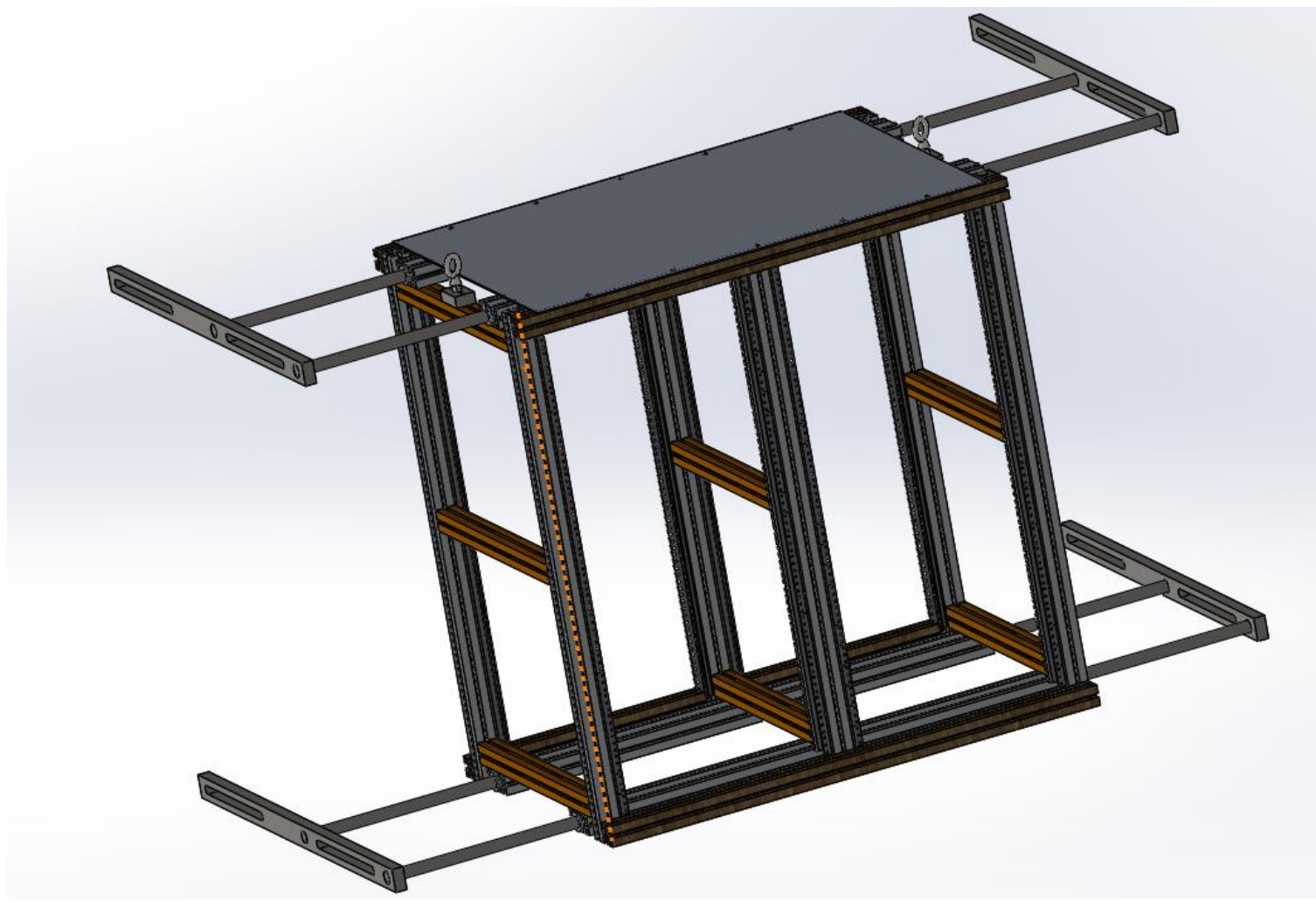

Fig. 5: SolidWorks model of rack

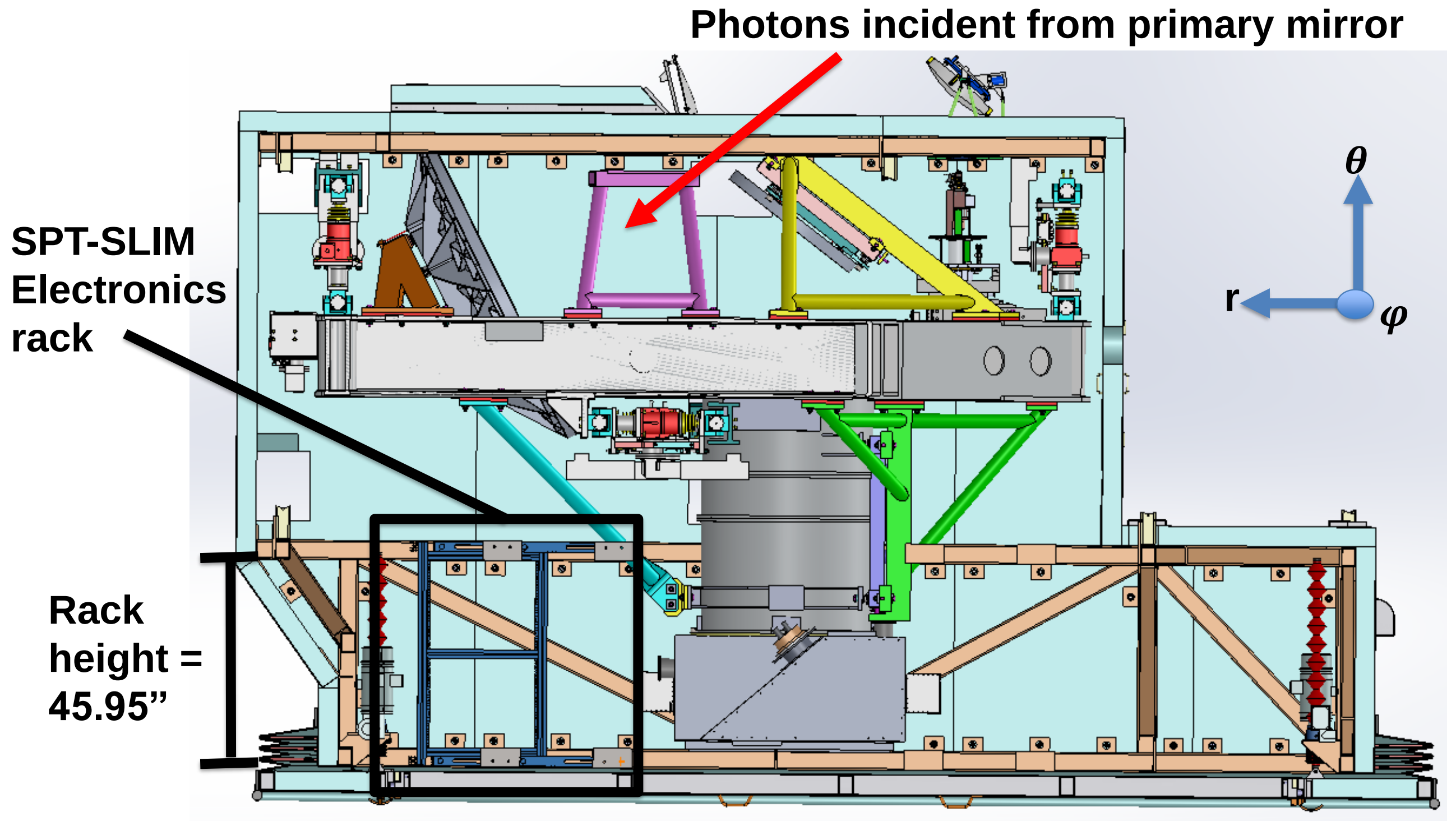

Fig. 6: Cross-section view of SPT cabin

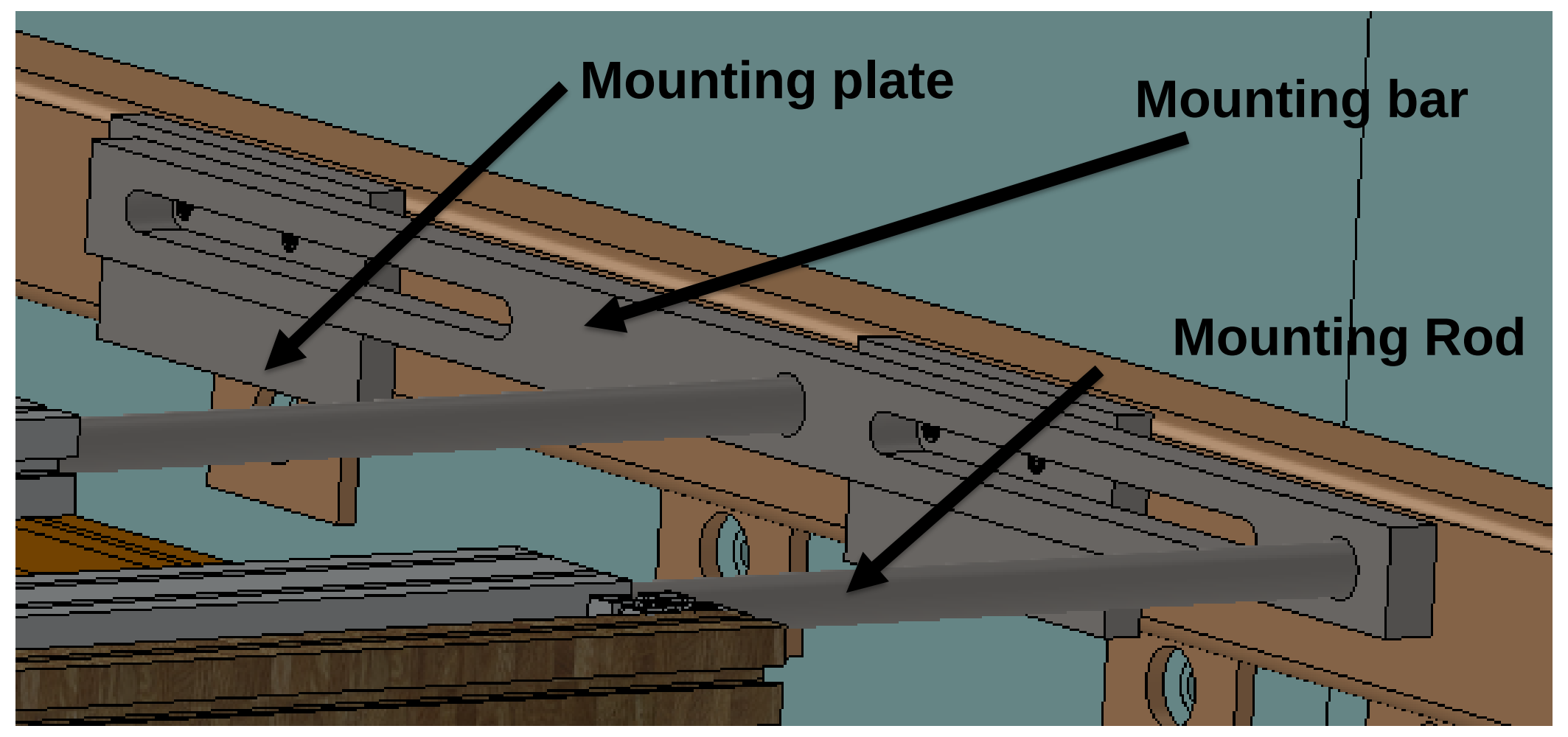

Fig. 7: Mounting Scheme: Custom-machined AISI 304 stainless steel mounting bars are bolted to mounting plates located on the SPT cabin's interior walls. The slots allow for variability in the positioning of the electronics rack within the cabin.

Figure 8 contains a simplified representation of the rack which approximates the rack body as a uniformly dense solid block. An FEA was performed using von Mises stress theory on said model. This was repeated for various orientations of the cabin and multiple positionings of the rack within the cabin. The simplified model always remained within the elastic deformation regime with a factor of safety (FOS) of at least 4.9.

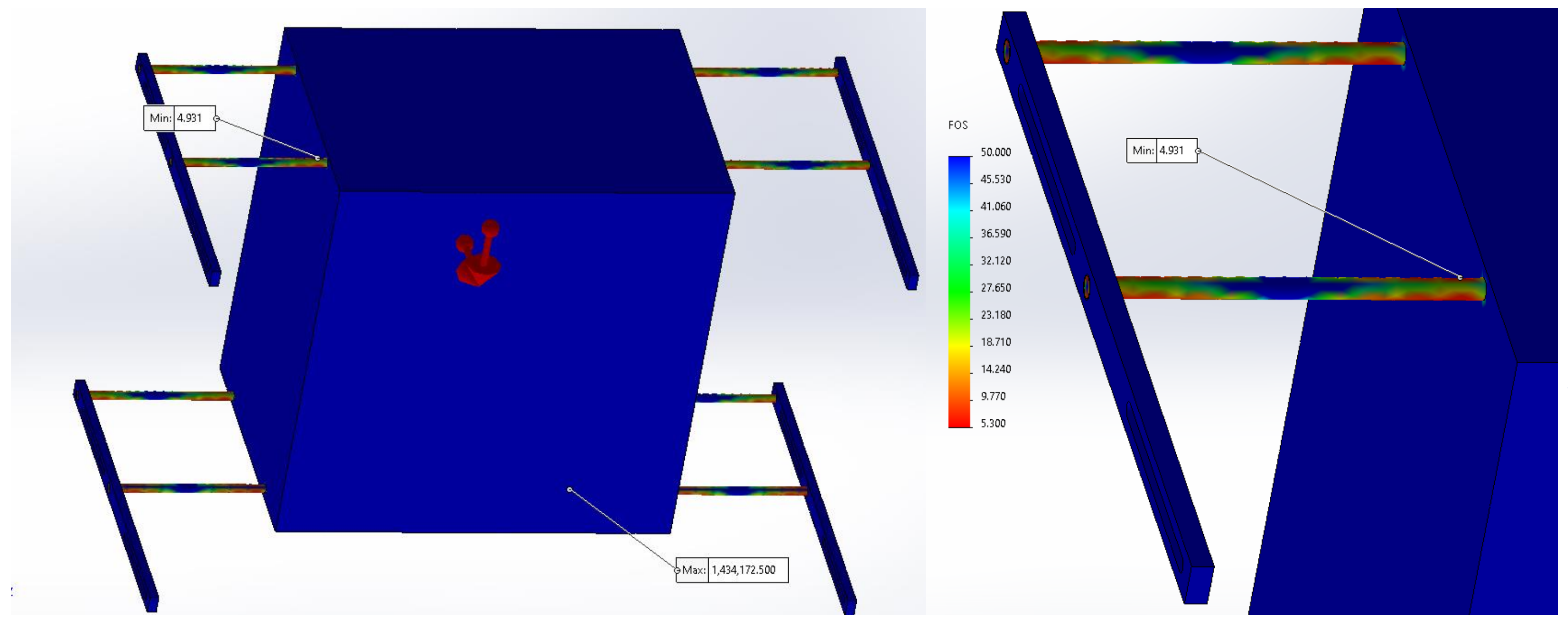

Fig. 8: An FOS plot for the simplified rack model in the minimum offset position. All dark blue points have an FOS of 50 or higher.

References

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4. Sobrin, J. A., Anderson, A. J., Bender, A. N., et al., arXiv e-prints, arXiv:2106.11202 (2022).

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