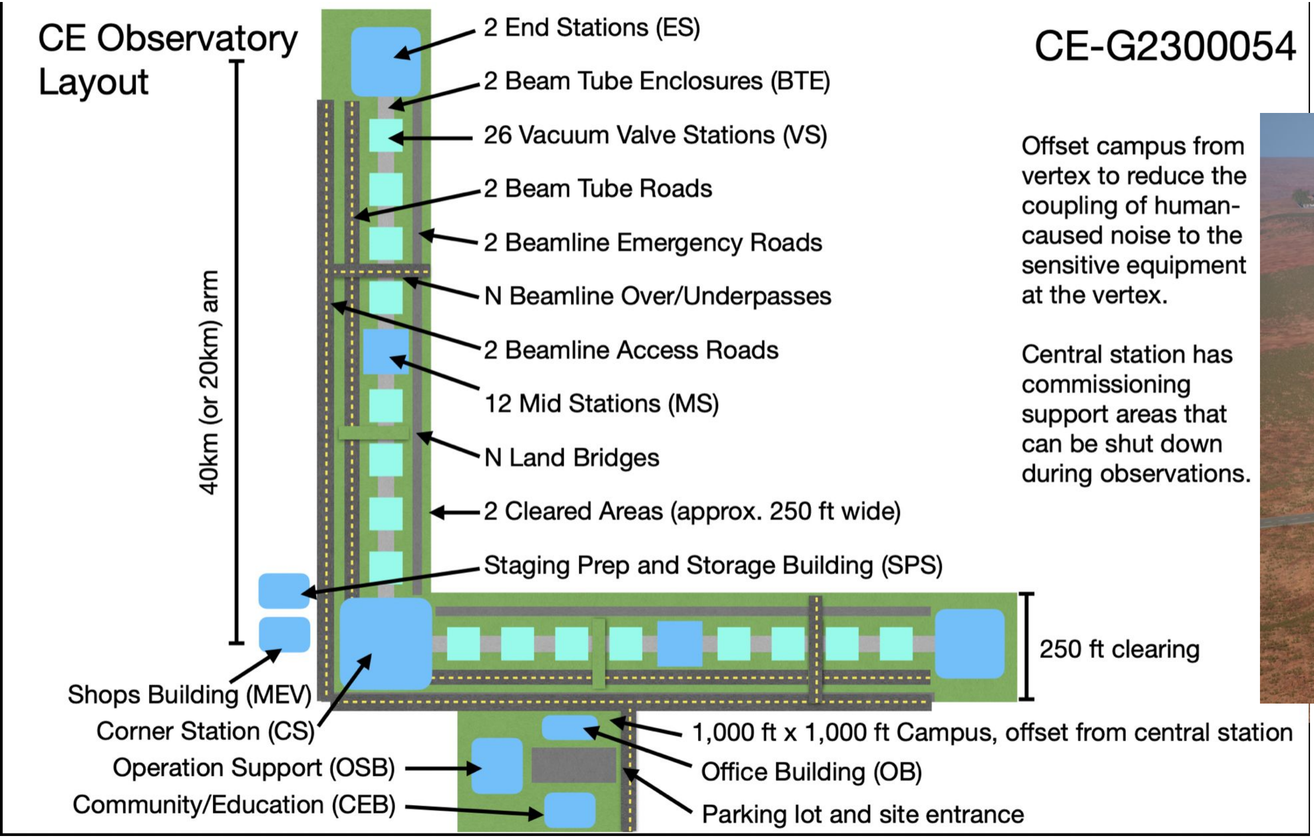
Round-table discussion on CE instrument open questions and future-proofing CE facilities

Organizers: Jenne Driggers and Josh Smith

CE/PAX 2025 Illinois

The CE Facility Components



The CE Central Station

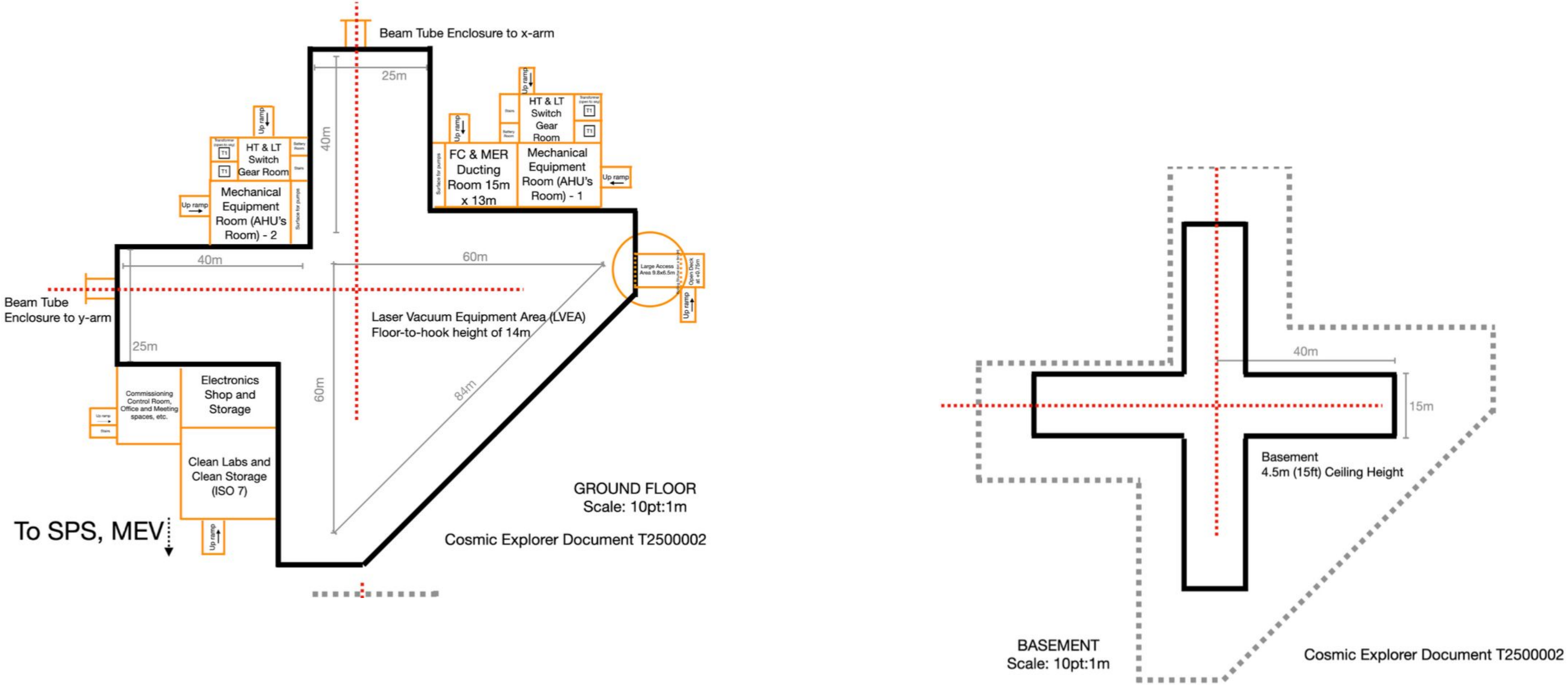


Figure 15: Sketch of the Central Station VEA Building. *Top:* Ground floor plans, based on the LIGO India Corner Station (figure 14) and the CE technical layout. *Bottom:* Basement plans. https://dcc.cosmicexplorer.org/T2500002

Some Facility Open Questions

We hope to have an architect under contract in the coming weeks/month. From the LIGO (India), other designs, what should be changed that we haven't changed yet?

Might anyone from LIGO Lab know of building occupancy information you could point us (Josh, Matt, Elio) to?

Are the tunnels/Newtonian hollows needed and reasonable? Limit loads, stiffness? Re second floor or basement, Robert S says everything in LIGO not on the floor or seismically isolated moves more.

For LVEA, end stations, and pump areas, are there specific vibration performance criteria required? Such as VC-E or similar measure of slab acceleration or limitation?

CE R&D (compared to A#)

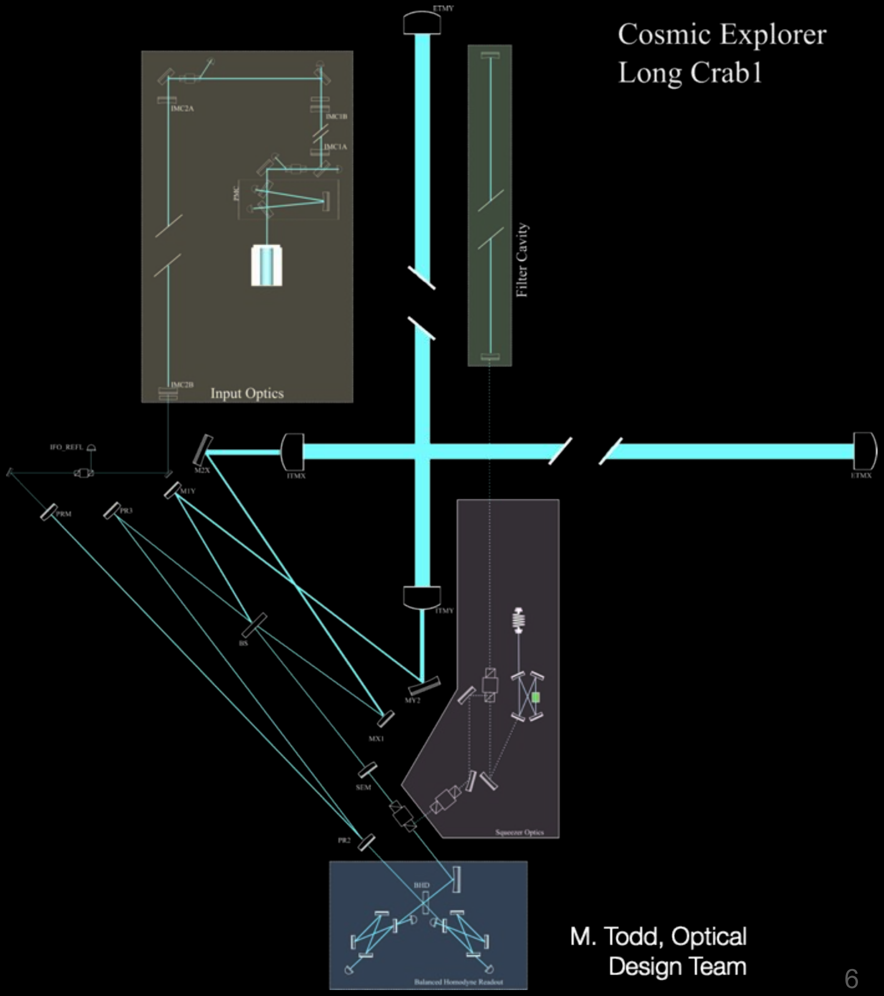
		A♯ R&D	CE R&D	Δ
Core Optics	Substrates (§4.1.1)	production and polishing of fused silica optics 45 cm ∅, 100 kg	further scaling, toroidal mirrors for corner, polishing of strong lens in ITMs	🟡
Core Optics	Coatings (§4.1.2)	amorphous coatings: materials better than A+ coatings and scaling	amorphous coatings: further scaling required	🟢
Core Optics	Coatings (§4.1.2)	crystalline coatings: birefringence tests and scaling	crystalline coatings for future upgrades: further size scaling required	🔴
Vibration Control	Suspensions (§4.2.1)	improved controllability, high stress fibers, test mass actuation, full scale prototype	design optimization, long high stress fibers, test mass actuation, full scale prototype	🟡
Vibration Control	Active Vibration Isolation (§4.2.2)	improved sensors and global control strategies	scaling up of A♯ design	🟢
Lasers & Input	Lasers (§4.3.1)	high power laser, beam quality	integration of A♯ design	🟢
Lasers & Input	Input Optics (§4.3.2)	mitigation of laser noise couplings (intensity, frequency, beam jitter)	mitigation of laser noise couplings with double mode-cleaners	🟡
Readout & Quantum	Readout (§4.4.1)	optimization of Balanced Homodyne	adaptation of A♯ design	🟢
Readout & Quantum	Squeezing (§4.4.2)	loss, mode mismatch and phase noise reduction, robustness	adaptation of A♯ design, reduction of SEC loss, study of HOM in band	🟡

		A♯ R&D	CE R&D	Δ
Sensing & Control	Length & Angle (§4.5.1)	control noise reduction, optimal hierarchical control	adaptation of A♯ design, lock acquisition for 40 km arms	🟡
Sensing & Control	Mode (§4.5.2)	improved sensors and actuators, evaluation of BS thermal lensing	adaptation of A♯ design elements, study of low AOI on BS	🟡
Sensing & Control	Parametric Instab. (§4.5.3)	improved modeling and dampers	adaptation of A♯ design	🟢
Facility & Interface	Vacuum system (§5.2)	maintenance of existing infrastructure	large scale sector test of new system	🔴
Facility & Interface	Newtonian Noise (§5.1.2)	modeling and demonstration of subtraction techniques	adaptation of A♯ design, facility design optimization	🟡
Facility & Interface	Stray Light (§5.3)	incremental improvements, material research	beam tube baffling strategy, analysis of corner layouts, detection strategy	🔴
Facility & Interface	Environment (§5.1.1)	incremental improvements	building isolation, beam tube isolation, HVAC redesign	🔴
Facility & Interface	Electronics (§4.5.4)	advanced prototypes	exploration of modern low-noise electronics designs	🟡
Computing & Data	Digital I/O (§4.6.1)	incremental improvements	architecture re-design with modern technology	🟡
Computing & Data	Calibration (§4.6.2)	incremental improvements	fast and accurate low latency calibration techniques	🟢
Computing & Data	Data Analysis, Transfer and Storage (§4.6.3)	incremental improvements	integrated architecture for low-latency analysis of ~ 1000 daily events	🟡

Cosmic Explorer
Long Crab1

- The CE baseline for the corner layout looks very different from LIGO

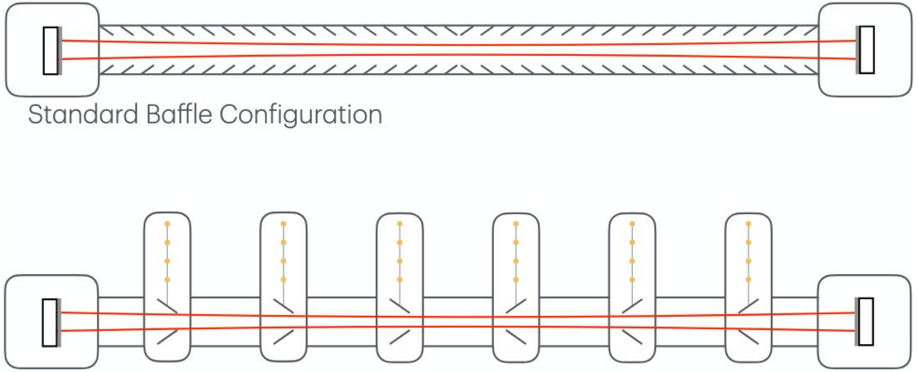
- What else, beside simulations, shall we do to validate the corner layout?



M. Todd, Optical Design Team

Straylight mitigation

- Straylight mitigation in the beam tube can not be wrong
- Modeling effort on-going, plus measurements on LIGO beam tube to validate model



- Is this enough?

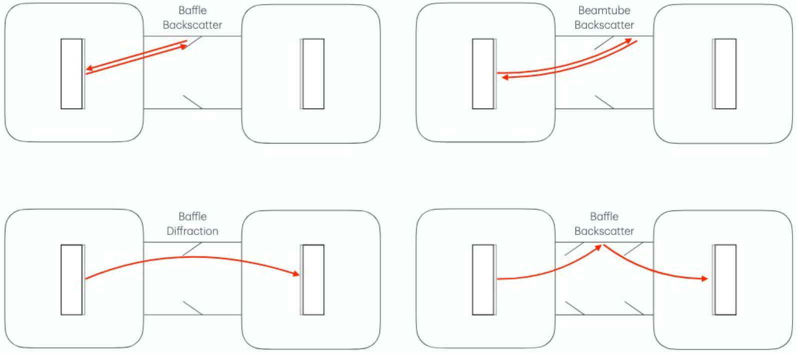


Figure 10: The four noise couplings from the beamtube that are modeled.

What are your top open questions?

What research should we do now, to quantitatively inform the design of CE?

What are the things we won’t know in time, and need to build in flexibility?