CDI sample and detection requirements

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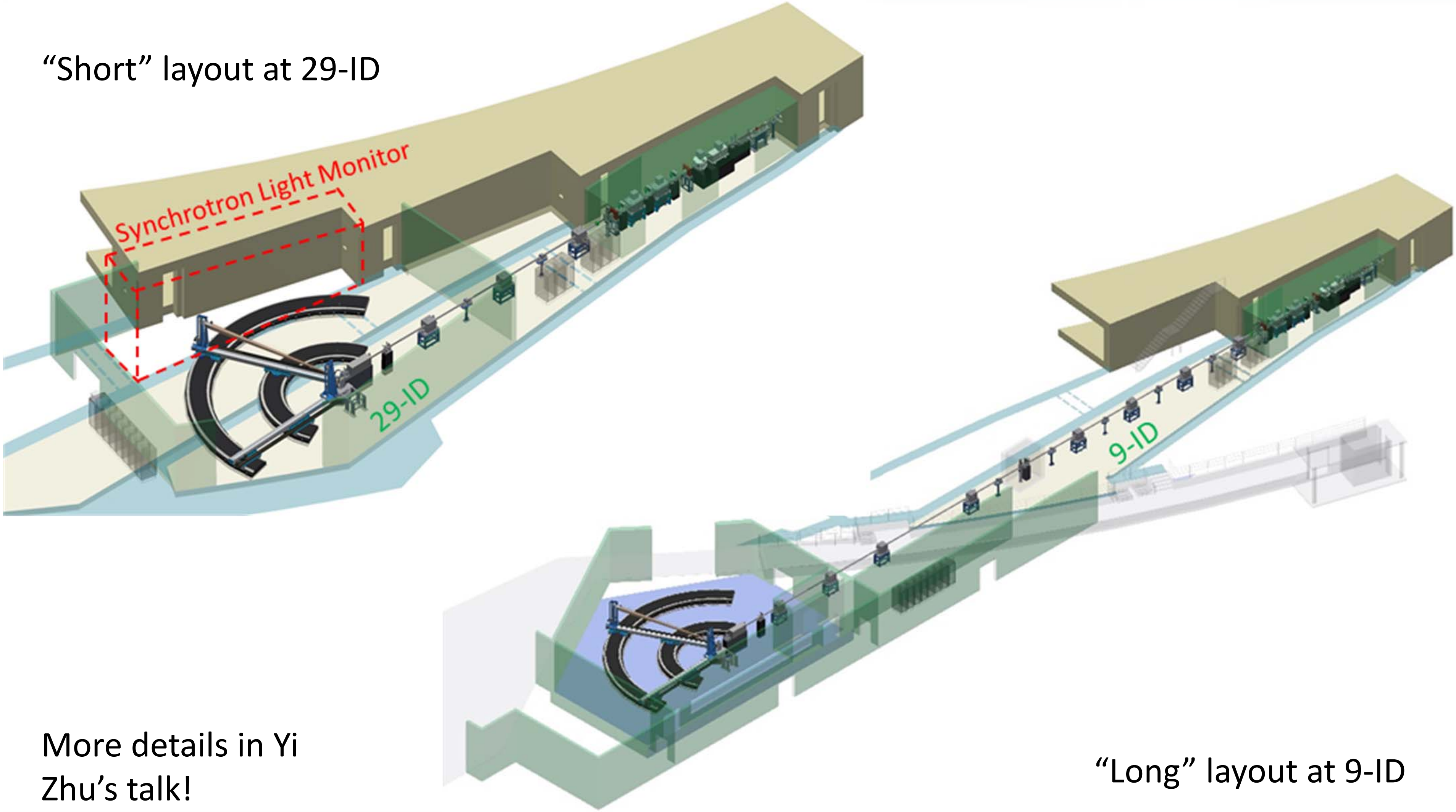
Design goals

- *Flexible illumination to provide best-in-class ability to tailor illumination to the sample (hopefully we achieved this)*
  - *Provide control of spot size and coherence properties to maximize signal*
  - *Allow for phase structures in the illumination*
- Provide a stable platform for multiple technique coherent scattering measurements
  - Provide a flexible detection geometry that embraces multiple detectors
  - Detection should permit the application of non-traditional phasing algorithms
- Facilitate the measurement of time-dependent phenomena
  - Provide fast detectors to target 1 ms and slower dynamics
  - Provision for pump-probe measurements: timing signals and triggering
  - Provision for sample environmental cells

Layout options

"Short" layout at 29-ID

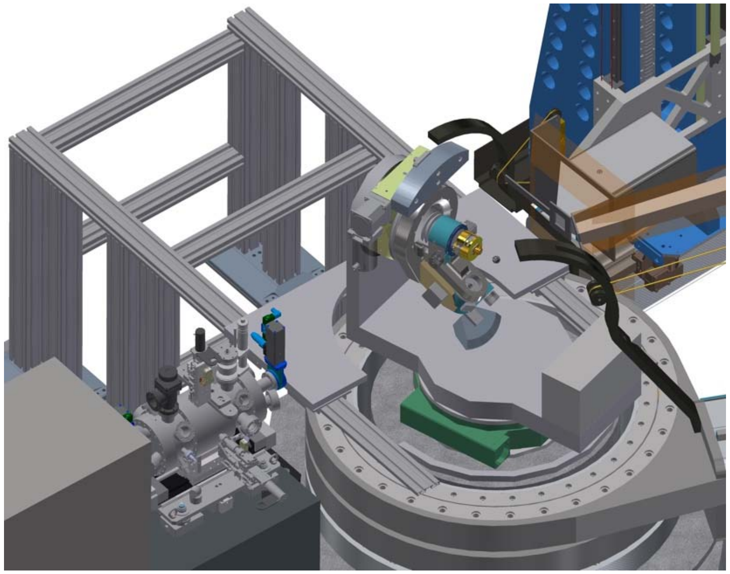


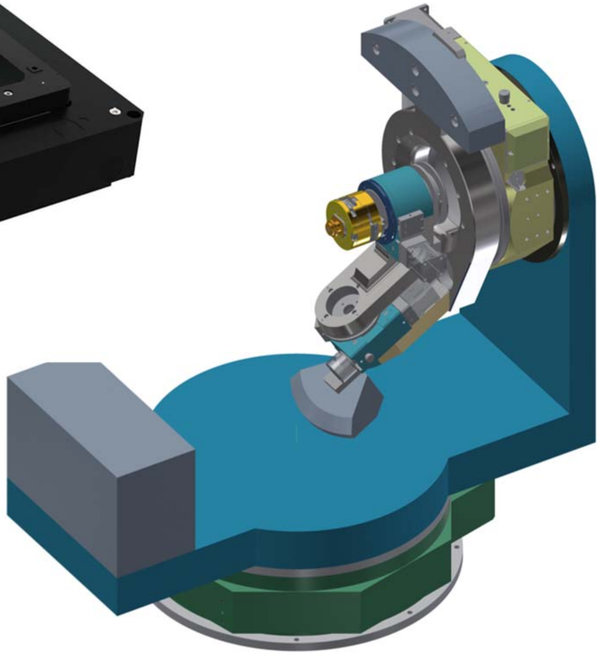
More details in Yi Zhu's talk!

"Long" layout at 9-ID

Sample positioning

- Positioning stability requirements for (Bragg) ptychography are approx. 50 nm RMS
- Current concept is a kappa goniometer
  - Maximizes flexibility in diffraction geometry
  - 2.5 kg load
    - reserve 1.0 kg for user payload
    - 1.5 kg for coarse and nanopositioning stages



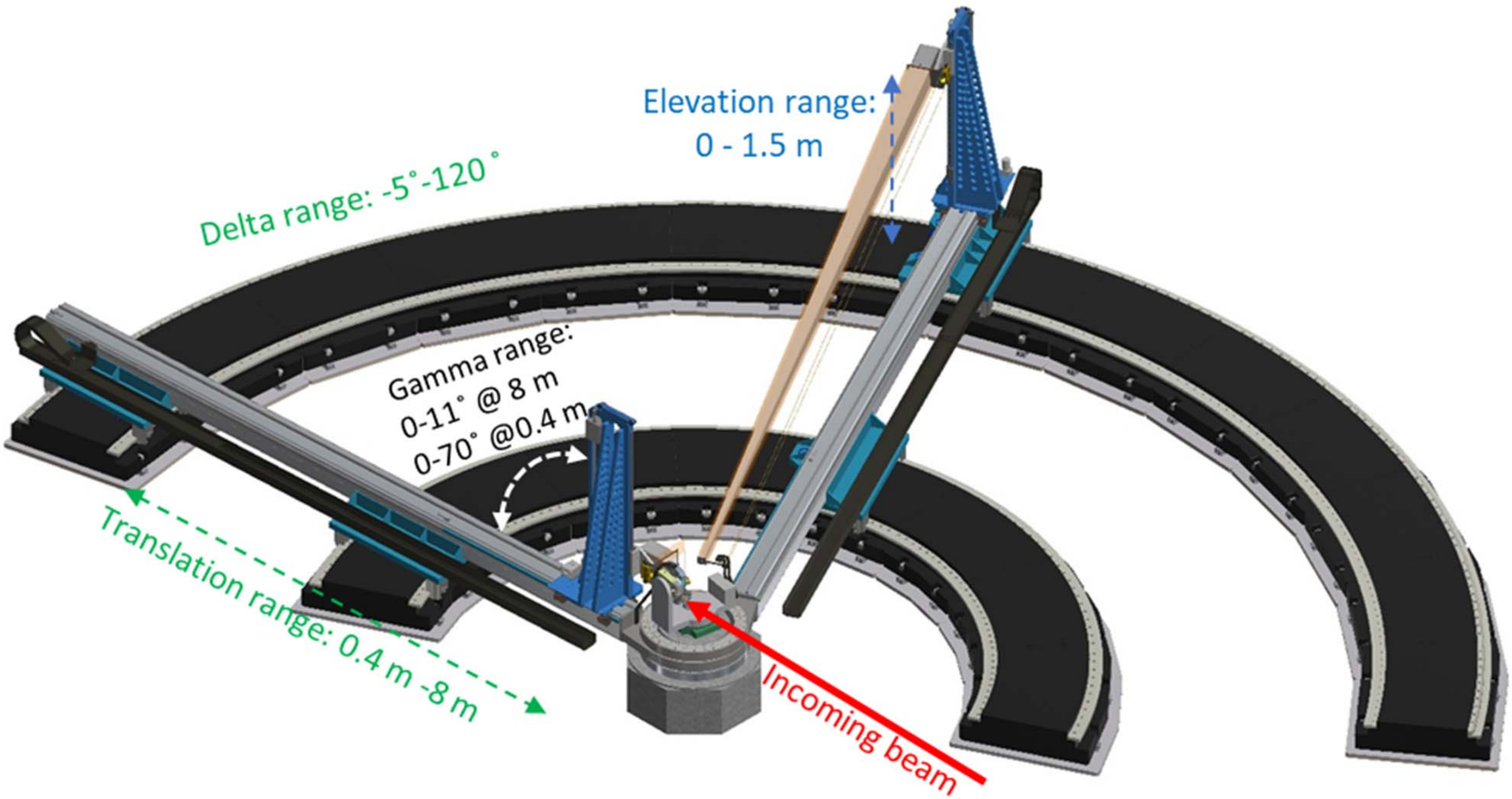


- Provide the capability to remove the kappa when more limited diffraction geometries are need, e.g., in conjunction with sample growth chambers.

Detection needs and detector specifications

- The center of each detector can be continuously positioned (See Yi Zhu's talk for a movie.):
  - at displacements of 0.5 to 8.0 m from the sample
  - in the horizontal, from -5 to 120^{o}
  - in the vertical, from 0-11^{o} at 8 m displacement and 0-70^{o} at 0.5 m displacement.
  - along a mutual vertical line
- The sampling rate of the diffraction signal is set by the detector's pixel pitch and this sets the size of the of the object that can imaged. **Small pitches are better.**
- The numerical aperture of the detector sets the highest resolution to which an image can be recovered. **Large numerical apertures are better.**
- A flight path concept will be developed to avoid the loss of signal.

Detector motion capabilities



See Yi Zhu's talk for a movie.

Detection needs for advanced CDI techniques

Energy [keV]	Detector pixel [micron]	Largest object size with critical sampling [micron]	Largest object size with typical sampling [micron]	Largest object size with polyCDI sampling [micron]	Largest object with half the transverse coherence [micron]
5	40	25	12	8.1	6.3
5	55	11	5.5	3.6	2.8
5	75	8.3	4.1	2.7	2.1
10	40	12	6	4	3
10	55	9	4.5	3	2.3
10	75	6.6	3.3	2.2	1.6
15	40	8.3	4.2	2.7	2.1
15	55	6	3	2	1.5
15	75	45	2.2	1.4	1.1

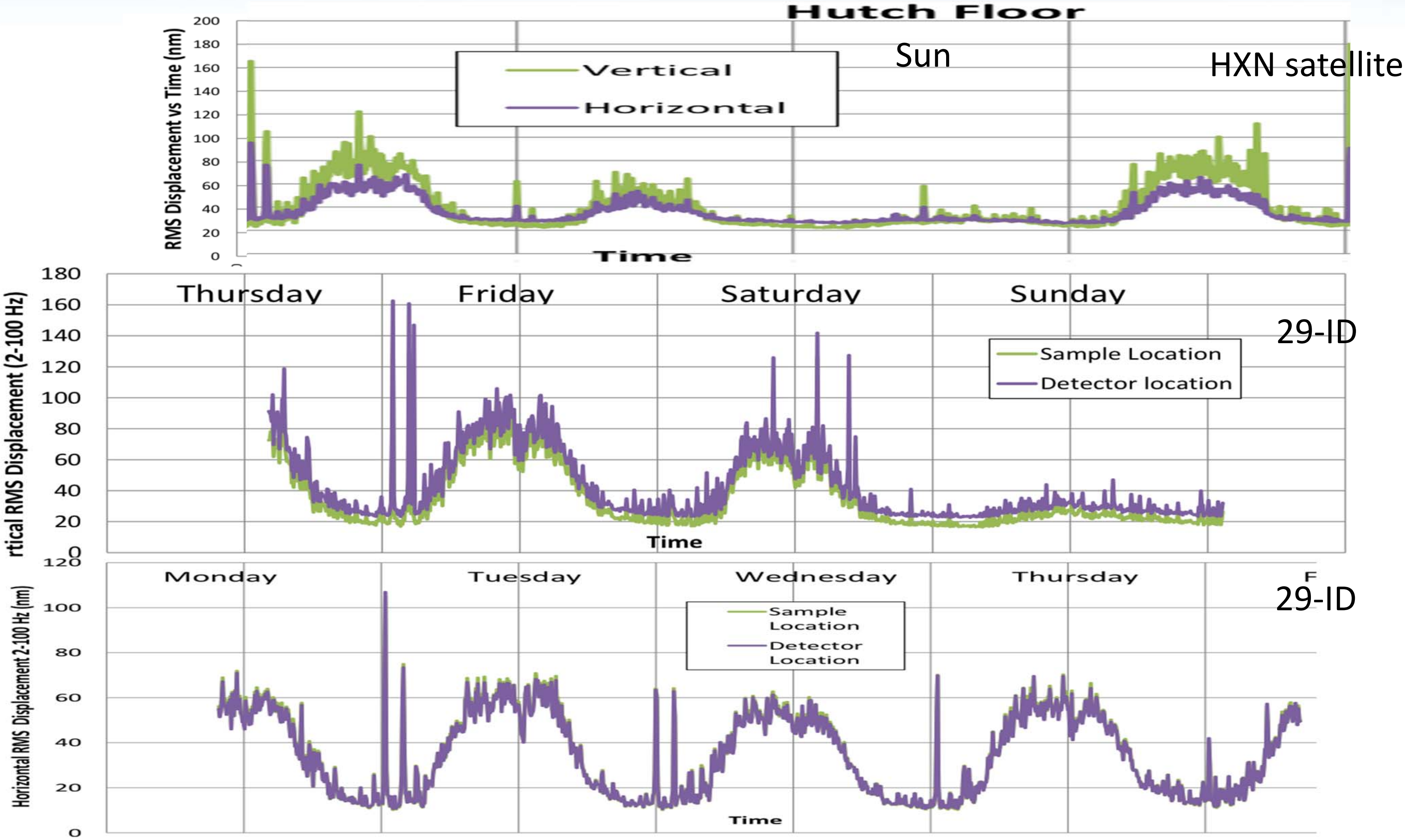
Table 5: A summary of the constraints on CDI experiments as a function of instrument photon energy, detector pixel size, and and sample-to-detector distance.

The sampling of the diffraction signal is an integral part of CDI experiment design. The sample size is normally known only approximately, so the sampling is chosen to be slightly better than the critical value. A reduction in coherence of the illuminating field increases the sampling requirement (Sizes calculated for reduced transverse coherence are conservative.). The highlighted values correspond to the use of an Eiger.

Stability needs

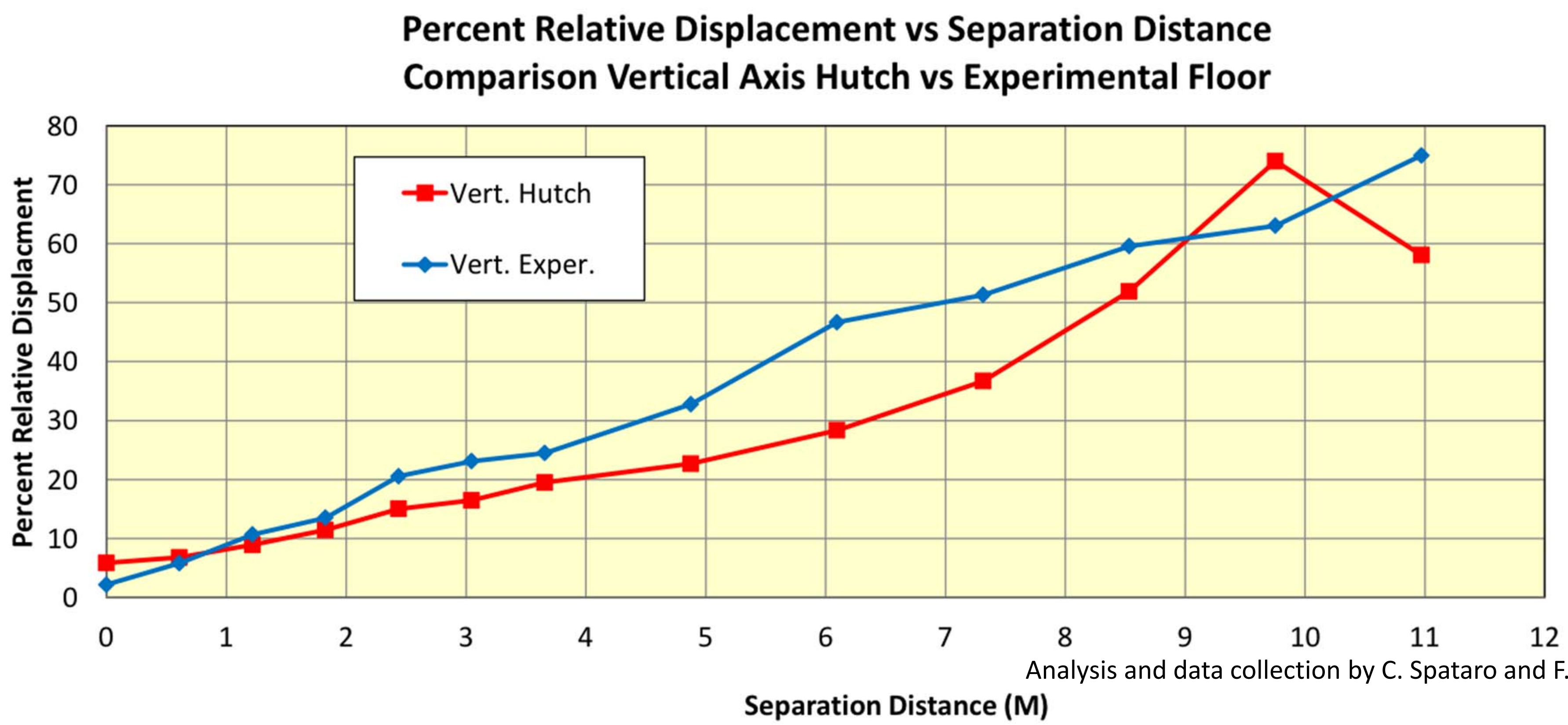
- In the endstation, the mutual alignment and stability of the **sample and the optical axis** is important, as is the alignment of the **detector and the sample**.
- The mechanics, especially for the sample positioning, are complex so **ambient vibrational energy should be minimized**.
- Better than **50 nm** for ptychography and angle/energy scanning (over a few hours)
- A **few tens of nanometers per hour** of long term drift (temp stability of 0.1C)
- Our target specifications are similar to HXN.

Stability measurements



Analysis and data collection by C. Spataro and F. Lincoln

Stability measurements



Analysis and data collection by C. Spataro and F. Lincoln

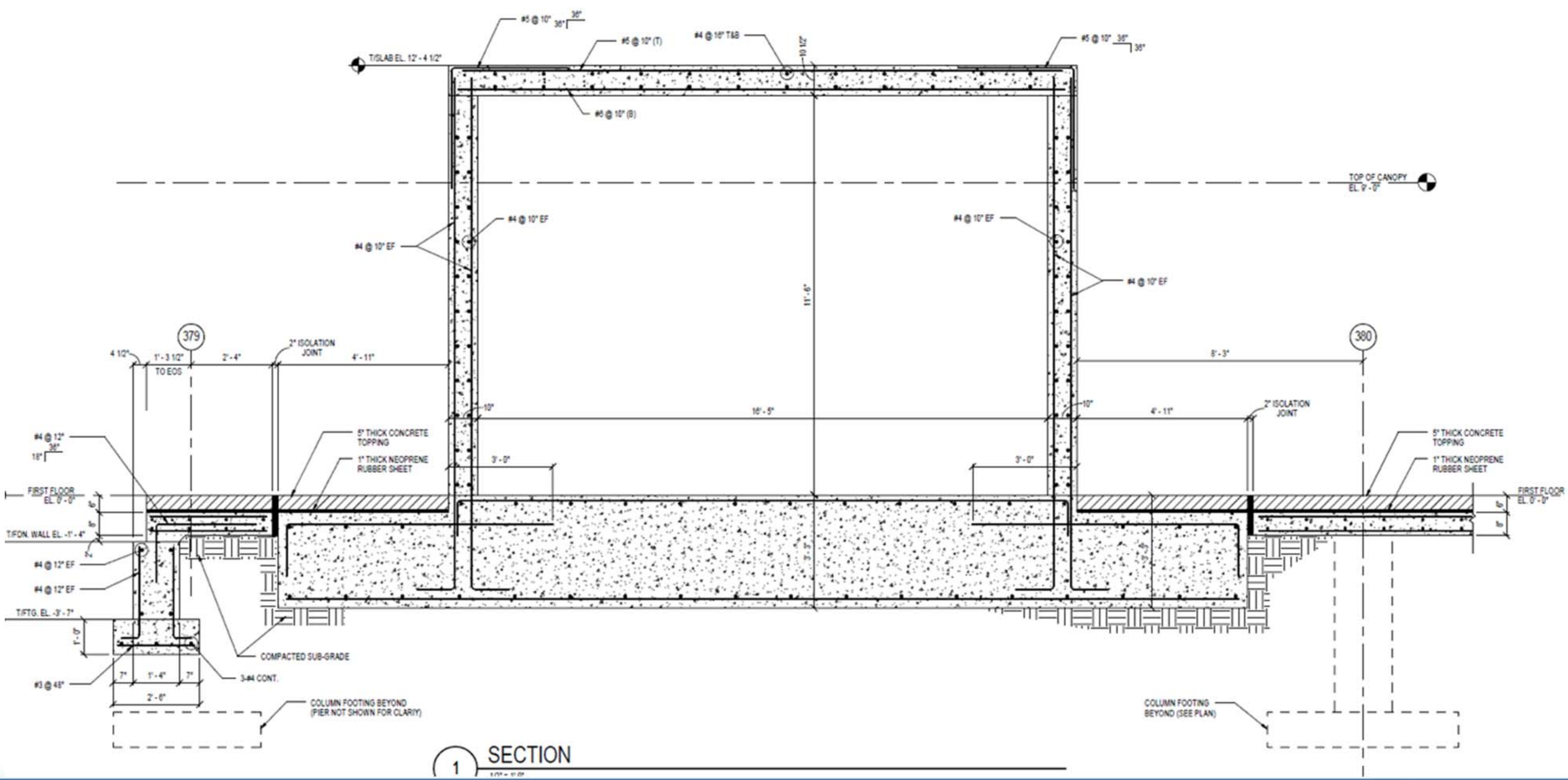
The correlation of the ambient motion of two points in the HXN hutch is better than the experimental floor. This is an important parameter since we need to minimize the motion of the sample and the detector, which can be located up to 8 m apart.

Time resolved measurements

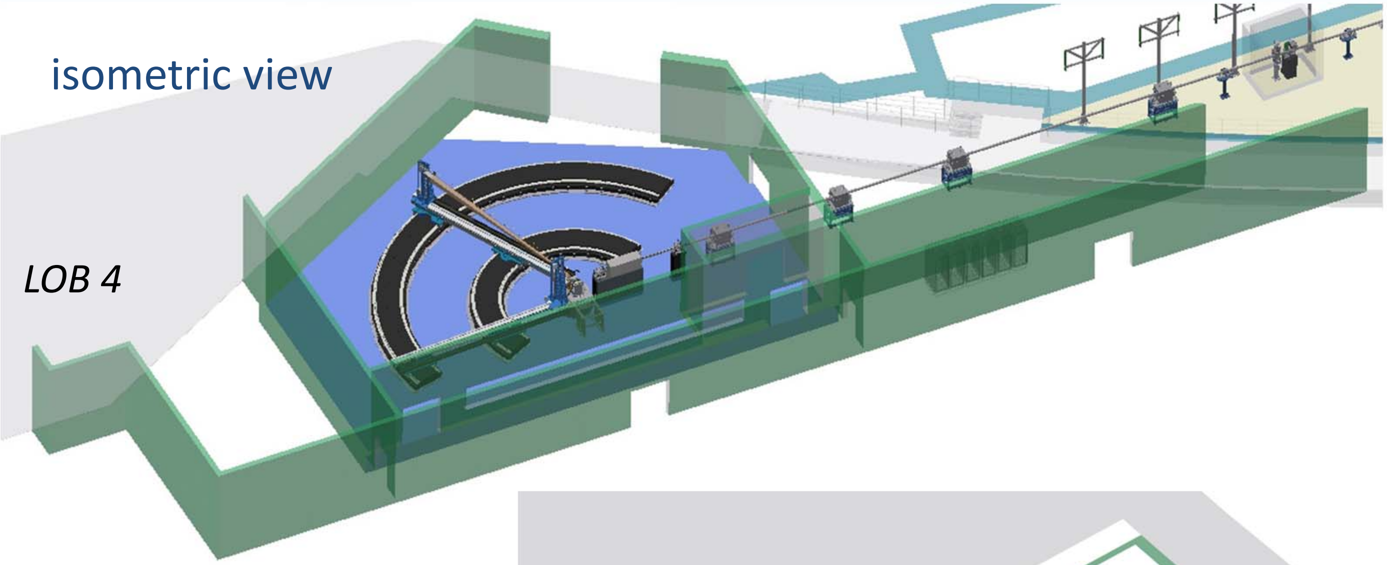
- Two timing regimes
  - Slower than few-millisecond sampling interval
    - Detectors operate at around 1 kHz with deadtimes of around 10 microseconds
    - Flux limited, expect to deliver a useable flux of more than 1E9 photons/ms
    - Can be improved by shortening coherence lengths in the x-ray beam
  - Sub-ms timing
    - Provision for this by including appropriate electronics, i.e., a fast timing event receiver to tie device triggering to the storage ring's RF system
    - Deliver a "laser-ready" hutch by reserving space and keep-clear areas for laser transport, as well as maintaining clear a area around the sample for optics and diagnostics.
    - Identify areas in the layout for the installation of a fast shutter/chopper
    - This mode depends on special fill patterns of the storage ring

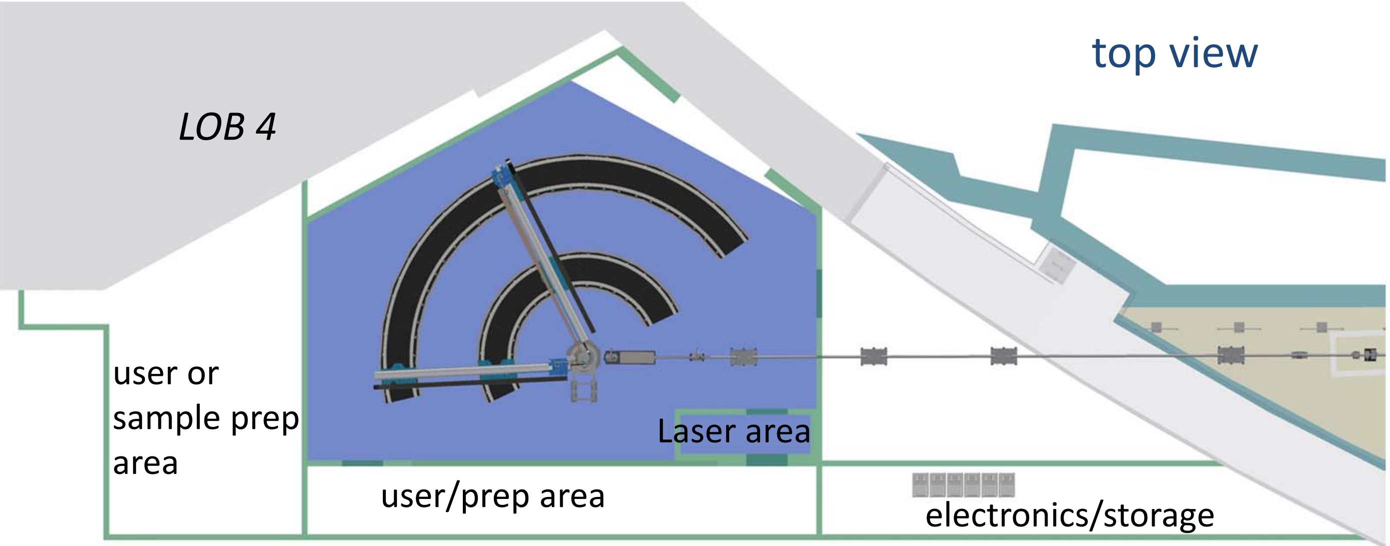
Hutch construction concept

We propose to modify the HXN concept, shown below, for the footprint and height of the hutch. The hutch floor thickness is 39” and the wall thickness is 8”. The enclosure is concrete. Note that the hutch slab is separated from the surrounding floor.



Tentative concept for satellite building





Wall locations are not final. A separation area between the hutch floor and the user floor must be determined.

Comments on the length of the beamline

Contributing factor	100-m concept	60-m concept
Endstation location	In a satellite building, 9-ID.	On the experimental floor, 29-ID.
Beam pointing stability	Feedback required, 50 nrad* rms	Feedback required , 90 nrad* rms
Feedback sensor	1-micron sensitivity gives ~16 nrad angular sensitivity	1-micron sensitivity gives ~40 nrad angular sensitivity
Feedback actuator	~10 nrad accuracy	~10 nrad accuracy
Free area in endstation	Ample free area in new building, detector arm could grow, new capabilities added.	Compromises needed: the detector arm might shrink by 1 m, the angular range of detection would reduced, minor redesign of optical system, SLM must be relocated
Vibrational Stability	High likelihood that requirements will be met. Correlated motion of distant points is good.	Likely that requirements would be met only at night and on weekends. Correlated motion of distant points poor.
Temperature Stability	0.1 degree at HXN.	Typically 0.5 degree or worse on floor.
Logistics	Satellite construction understood.	Detection system is heaviest system proposed on the floor; hutch design is large and needs additional review

This represents a beam motion of 10% of the final aperture size.