SLAC alignment techniques and results

FCC-ee optics tuning and alignment mini-workshop, May 2022

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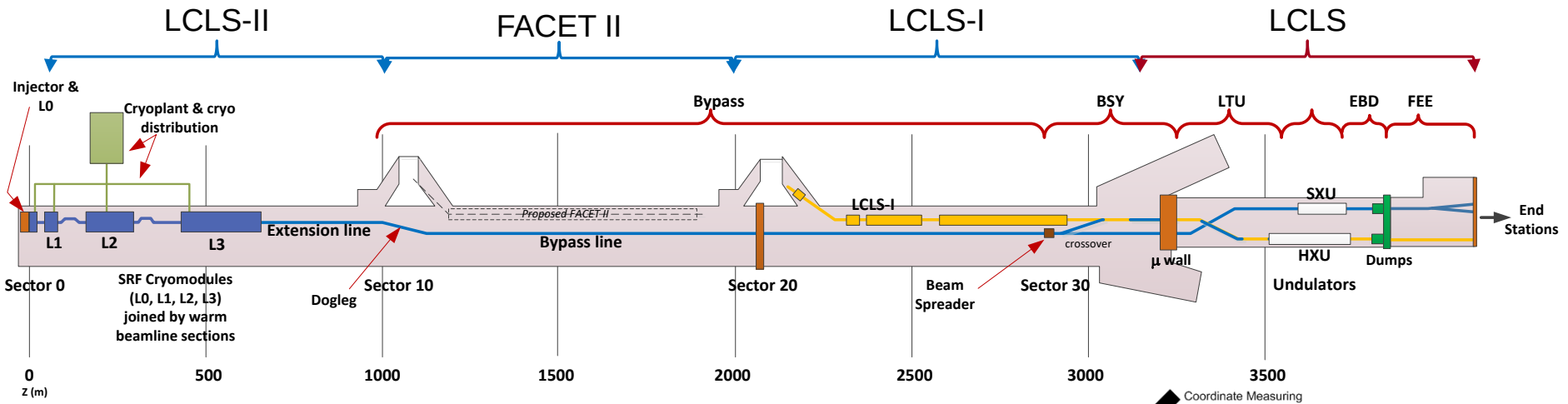
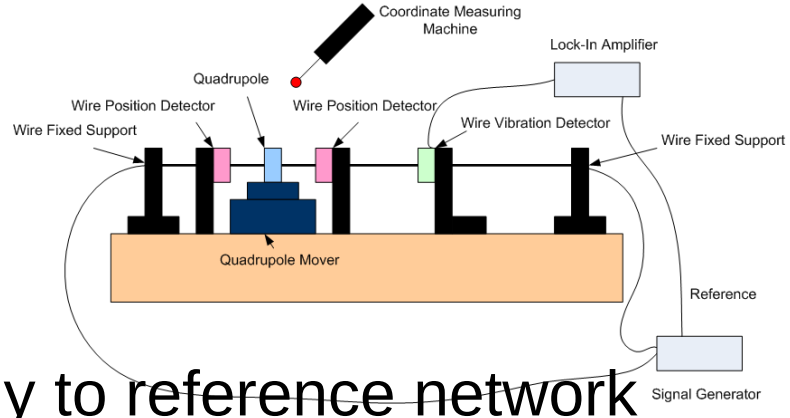
SLAC NATIONAL ACCELERATOR LABORATORY

SLAC – Alignment techniques

- Establish reference network



- Fiducialize components / rafts

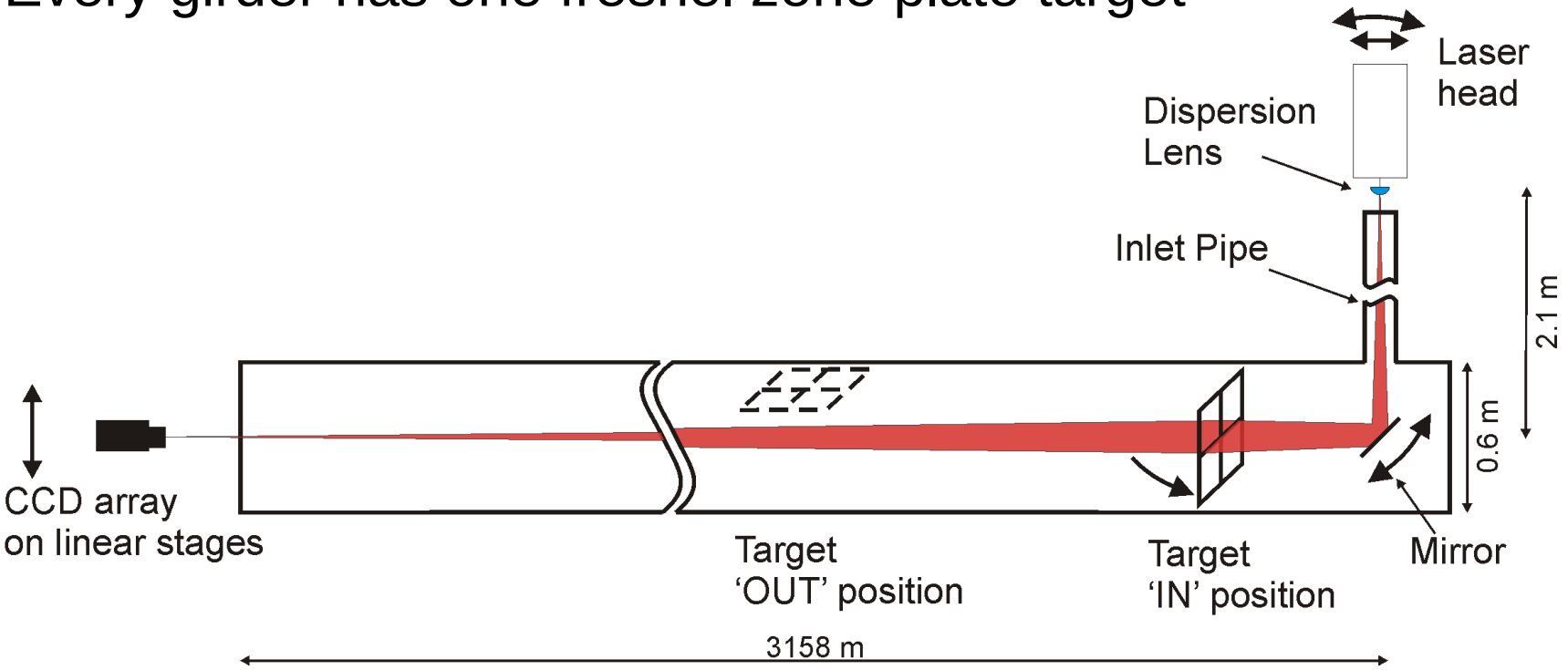


- Align components relative locally to reference network
- Smoothing to maintain

Reference Network – Linac Laser Alignment System (LLAS)

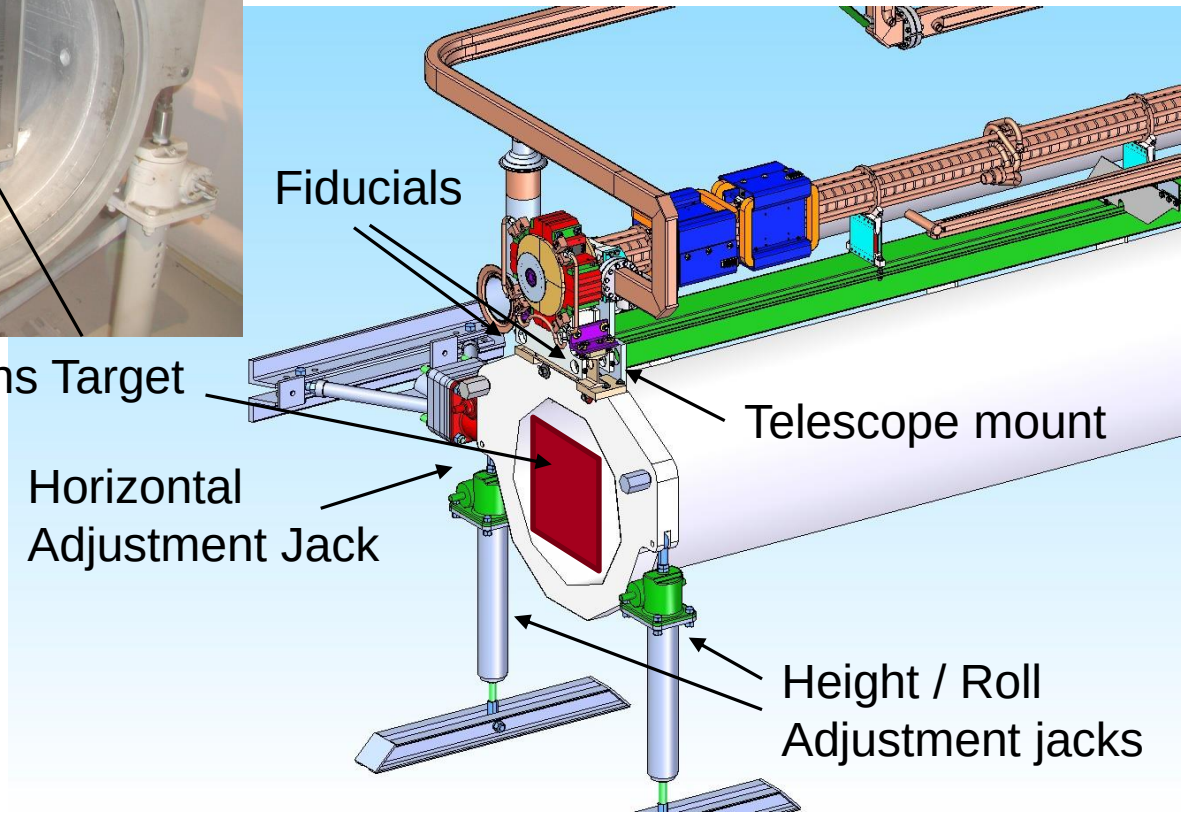
270 girders of 12m and 3m length

Every girder has one fresnel zone plate target

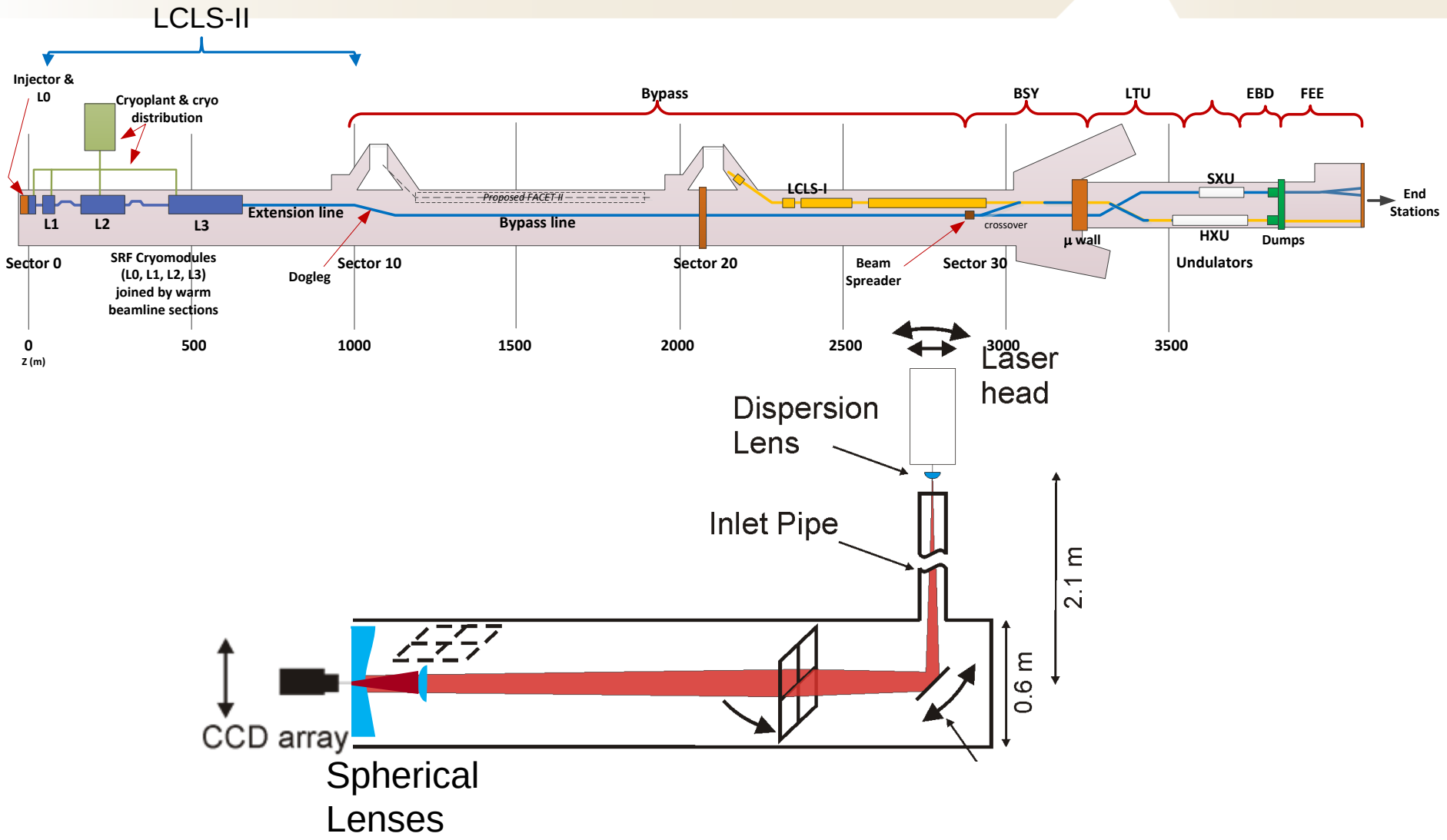


Linac Alignment System - Girder

Fresnel Lens Target



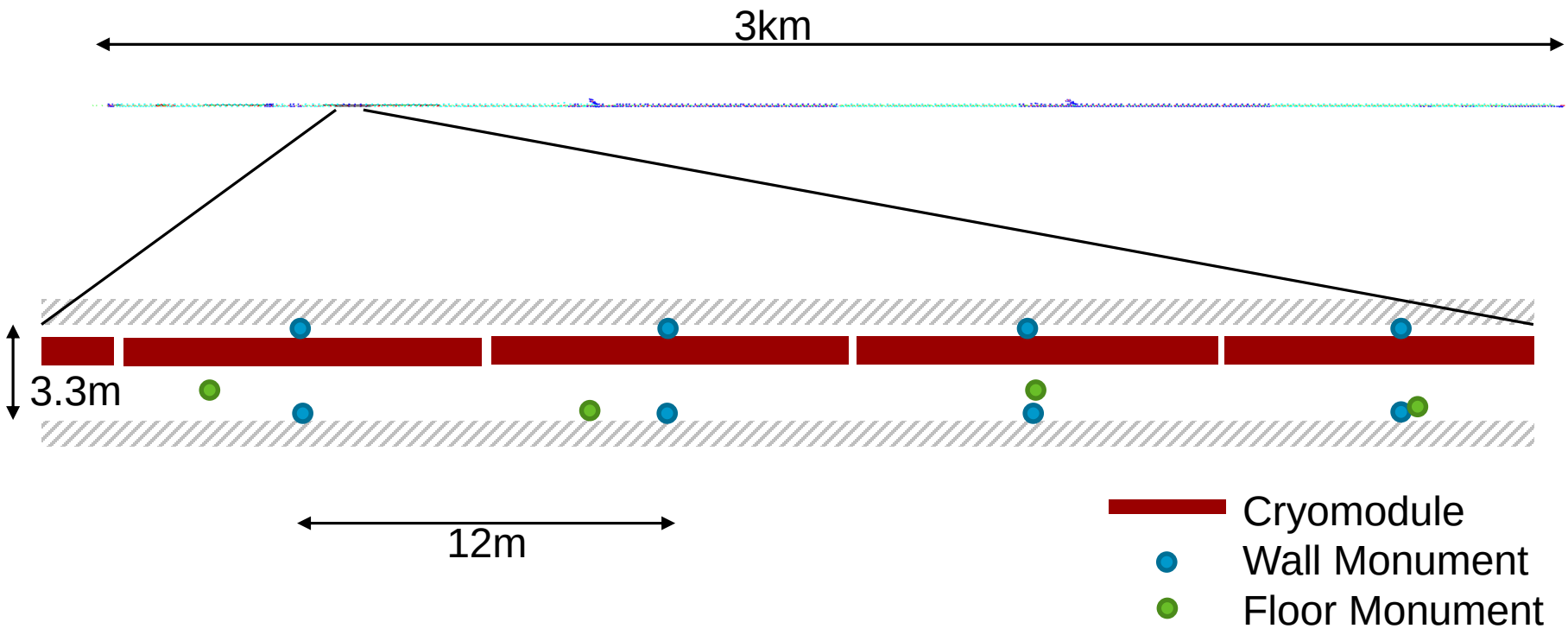
LCLSII – Cryomodule installation - Reconfigure LLAS



Conventional Alignment Network S0-S30 – Layout

S0-S10 does no longer have a light pipe and bypass lines are not tied to girders -> Monument based network

Opposing wall monuments to mitigate effect of refraction



Alignment Network S0-S30 - Measurements

311 Laser Tracker (Leica AT401/402) setups with 5082 measurements

577 Height differences (Leica DNA03)

200 Linac Light Pipe readings

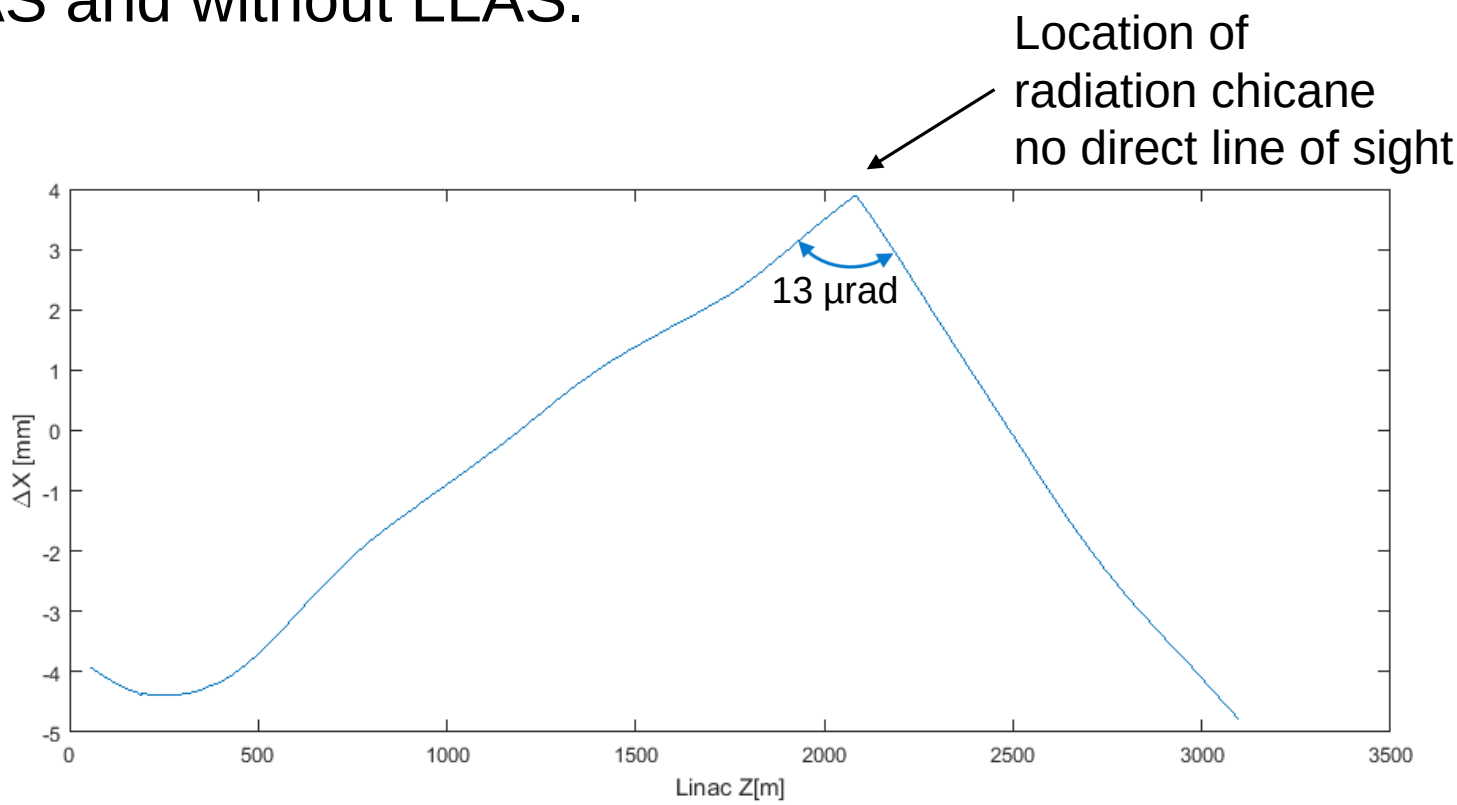
(3km - 6 weeks with 1 crew (2-person)

->100km –> 200 weeks 1 crew + above ground network)

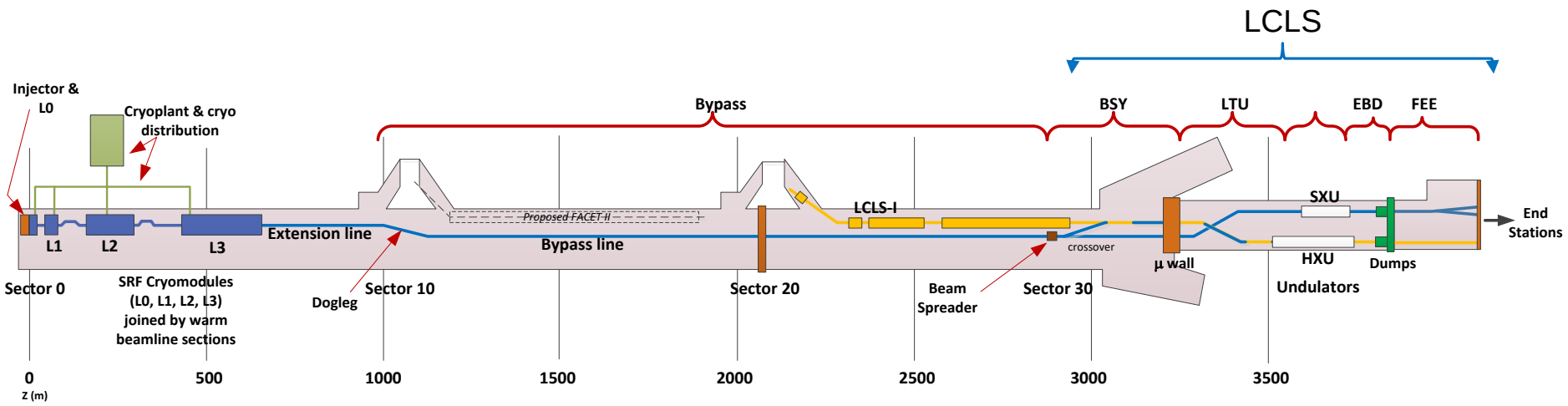
Least Squares Adjustment with GEONET which allows the Linac Light Pipe readings (σ=±0.5mm) to be included as deviations from a straight line

Alignment Network S0-S30 – Results (1)

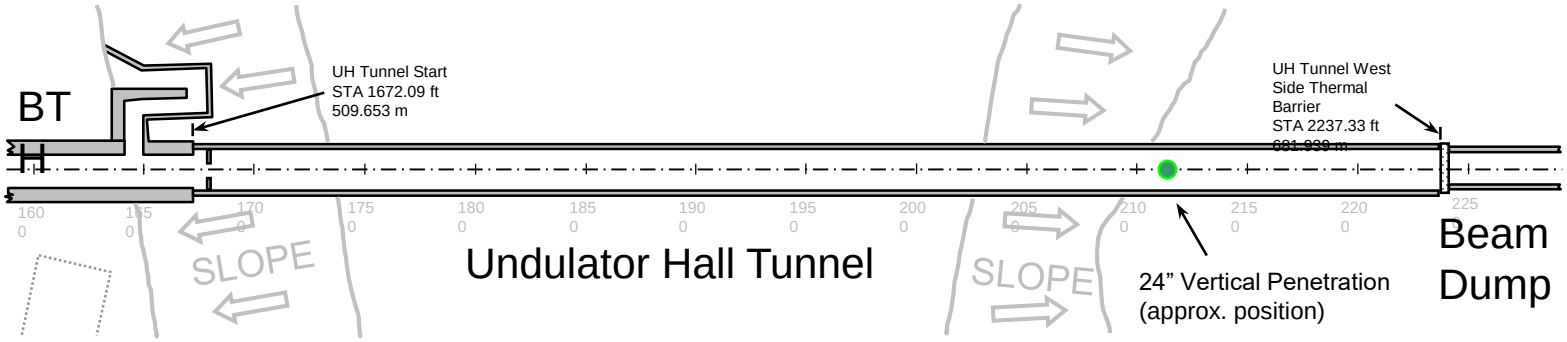
Comparison of coordinate results between adjustment with LLAS and without LLAS.

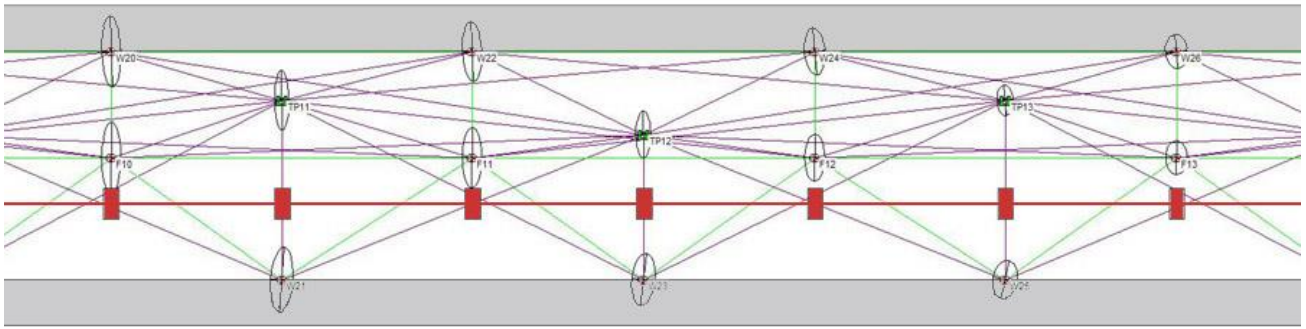


SLAC LCLS – 1km new construction



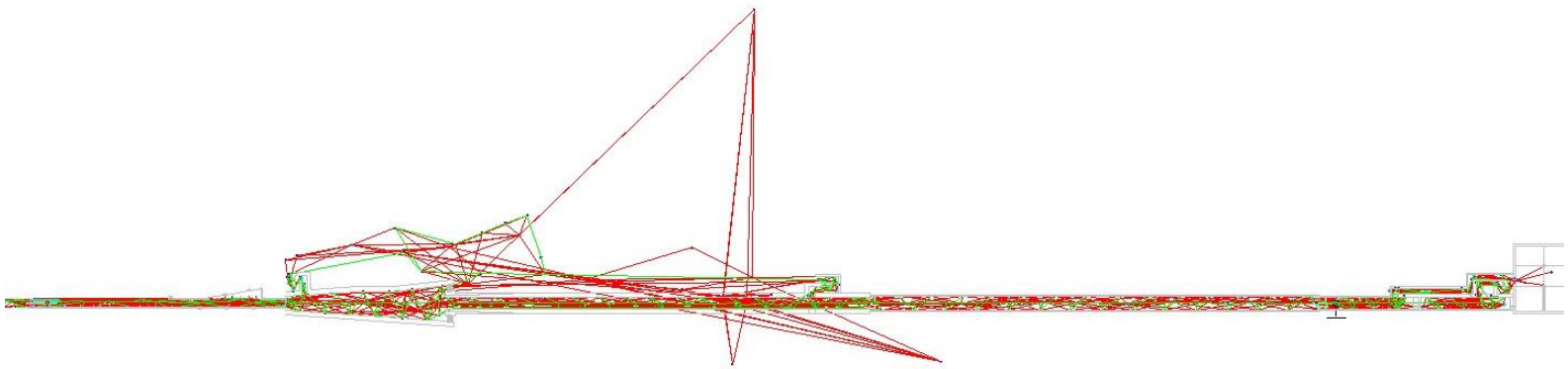
Network Design / Simulations





sD = 30 μm sh = 30 μm / D sv =50 μm /D sdh = 50 μm
sz = 22 μm sx = 47 μm sy =46 μm

LCLS Network

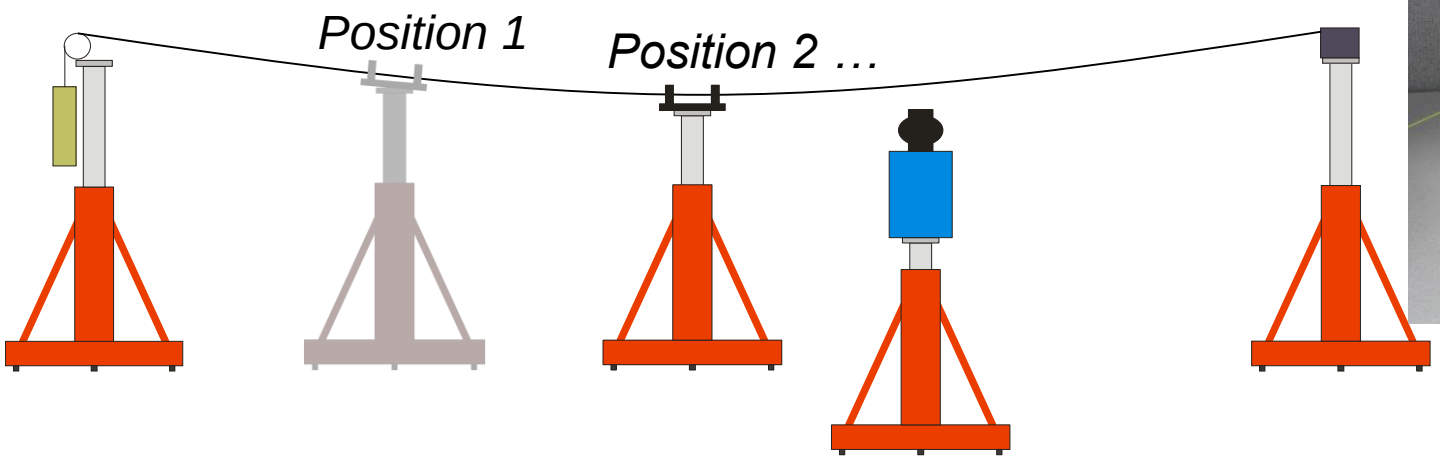


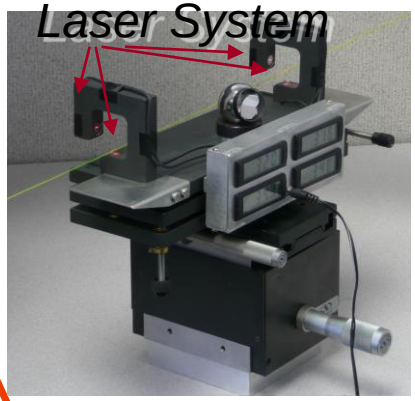
Points	451
Tracker	86
Total Station	11
Triplets	1475
Height Differences	473
Azimuth	14
Wire	3
Horizontal Offsets	79

Point Coordinates	1329
Instrument Coordinates	291
Instrument Rotations	269
Nuisance Parameters	7
Datum Parameters	4
Total Unknowns	**1900**

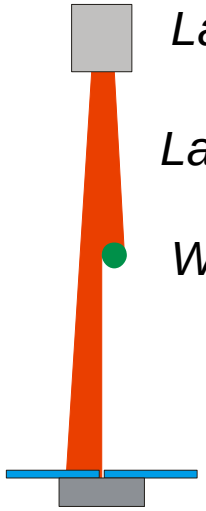
Network Measurements – Portable Wire Measurement System

In house development

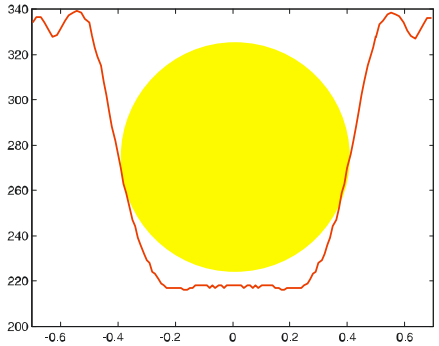




Laser system

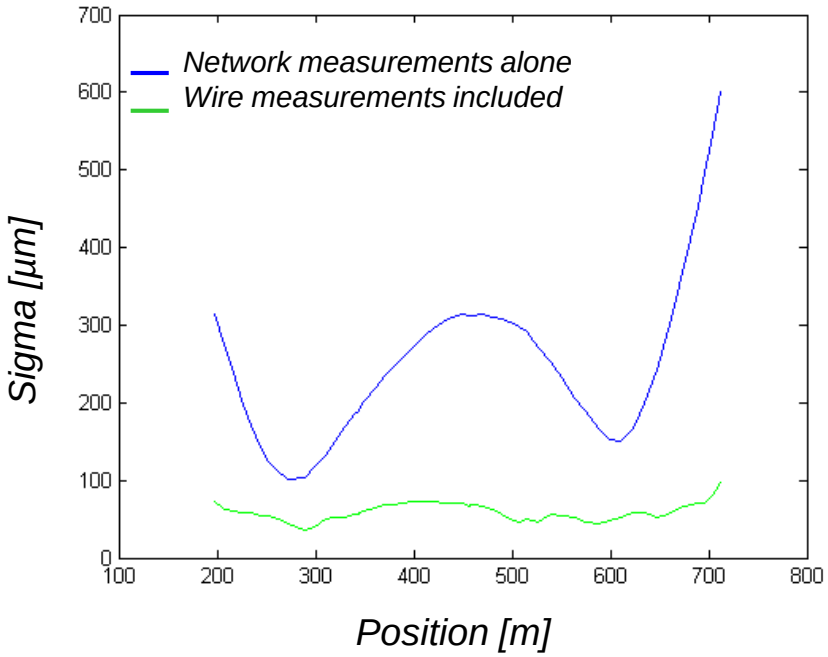


Scan of a wire with the laser system

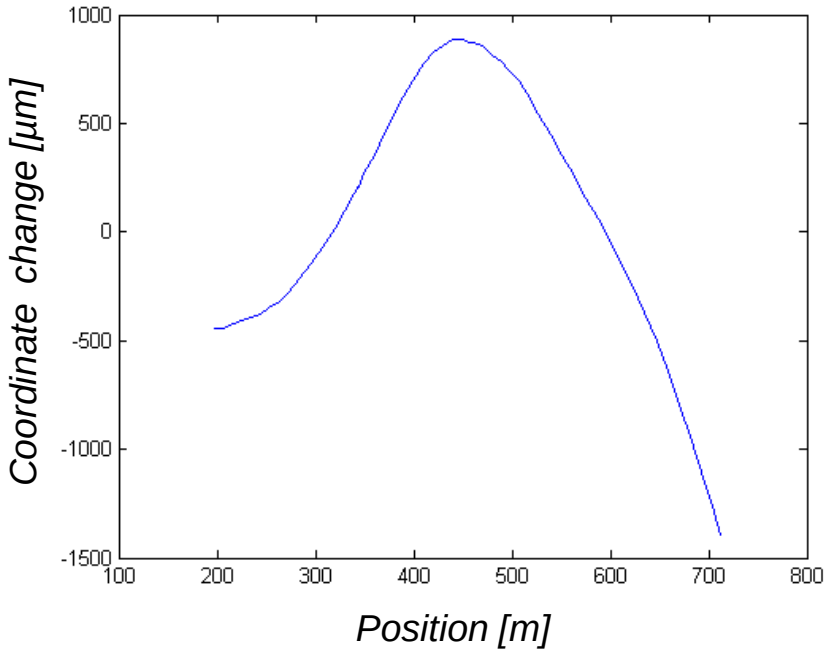


LCLS-I Portable Wire Results

Impact of wire on standard deviations



Impact of wire on coordinates



Network of 393 points with the following observation schema: triplets from 69 tracker setups, 465 height differences and 57 offset measurements to two overlapping wires (240m long and 370m long).
A-priori standard deviations:

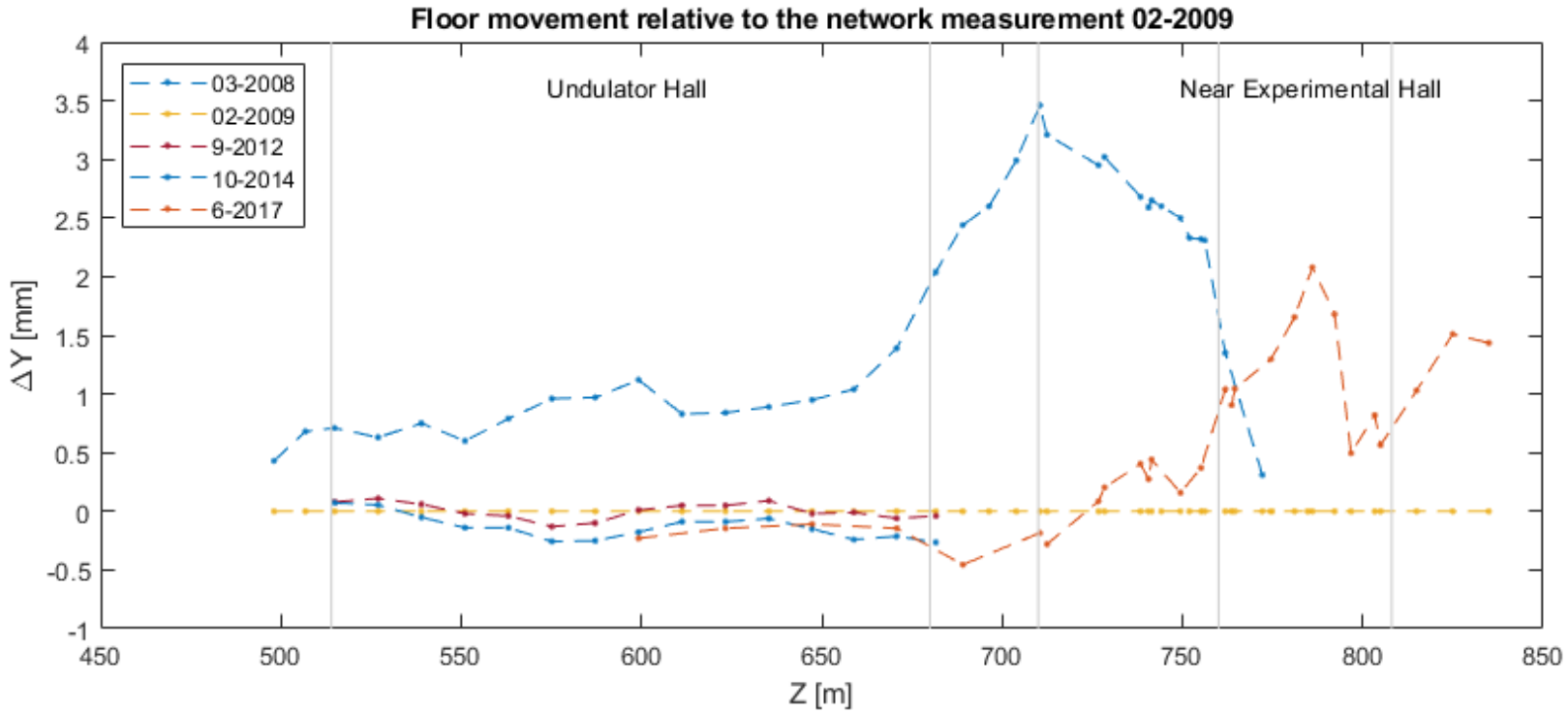
Laser Tracker: σ_D=50 µm, σ_{Hz}=70 µm/m, σ_V=100 µm/m
Level: $\sigma_{\Delta h}$=70 µm
Offset measurement: $\sigma_{\Delta o}$=30 µm

Alignment tolerances

- Fiducialization (4m)
  - Usually within 50µm
- Field alignment tolerances (20m):
  - Local alignment relative to the network 100µm
- Network
  - Mid range (200m) 0.3mm
  - Long range (1km) 2-3mm

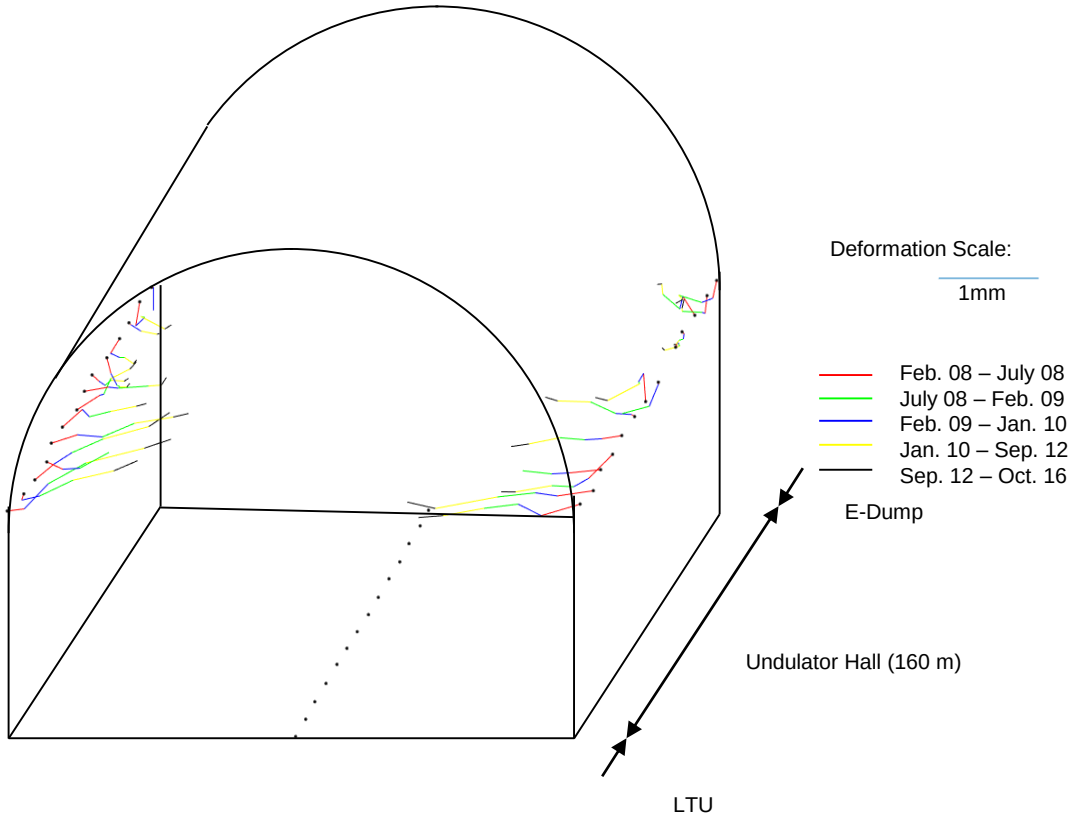
Alignment Network – Building stability

The floor in the undulator hall showed very little movement over the last 10 years, the only significant movement was in the FEE and NEH where another floor was installed.



Alignment Network – Building stability

The walls in the undulators are still moving inward, the rate has slowed down.



Summary

- Conventional alignment methods will either take a long time or a very large workforce.
- Tunnels are not stable, especially right after construction requiring re-establishing the alignment network depending on tolerances.