ALS-U Alignment Status

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2024-Oct

Outline

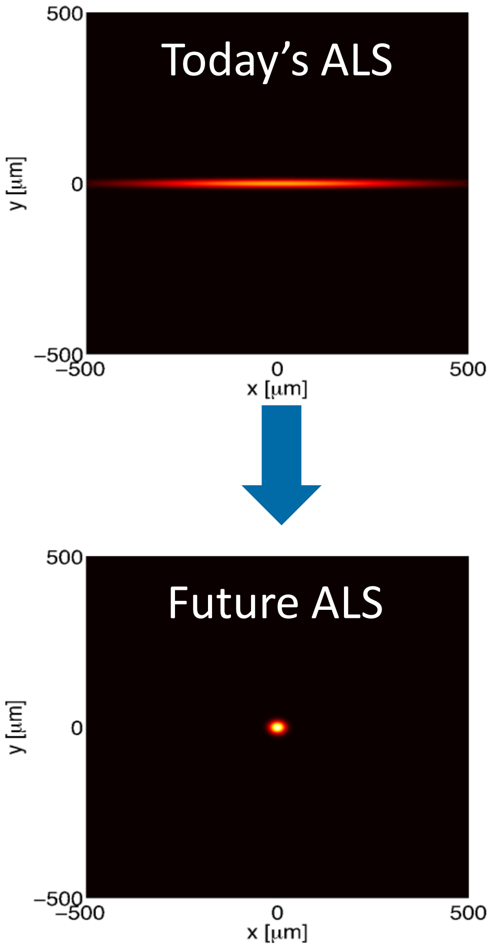
- ALS-U Project Introduction
- Accumulator Ring
  - Magnet to magnet Alignment tolerance breakdown
  - Stretch Wire magnetic measurement
  - Prestaging
  - AR Prestaging and Installation progress

ALS-U Project

High-level goals:

- Achieve an increase in brightness and coherent flux of soft x-rays (@1 keV) of at least 2 orders of magnitude beyond today's ALS capabilities
- Develop a set of world-class experimental capabilities that will push the frontiers in soft x-ray science and maintain ALS leadership in this area
- Provide infrared and hard x-ray capabilities comparable to present-day ALS

Electron Beam Profiles



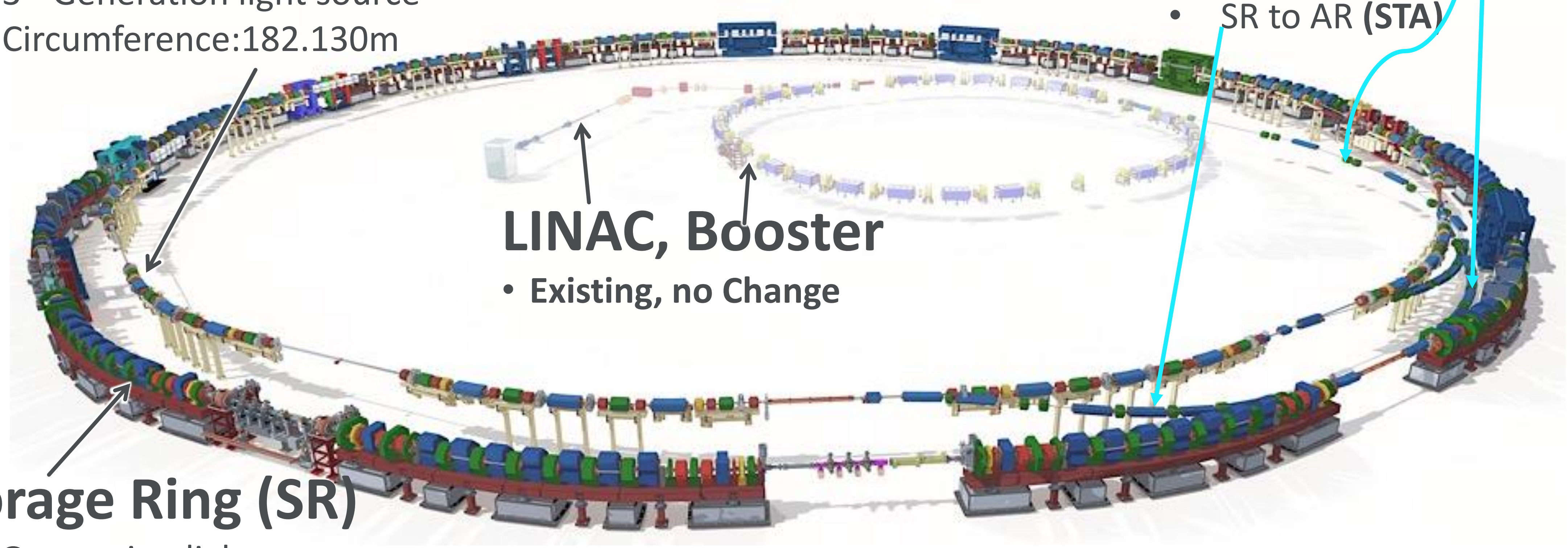
ALS-U Accelerators

Accumulator Ring(AR)

- 3rd Generation light source
- Circumference:182.130m

Three Transfer Lines:

- Booster to AR **(BTA)**
- AR to SR **(ATS)**
- SR to AR **(STA)**



LINAC, Booster

- **Existing, no Change**

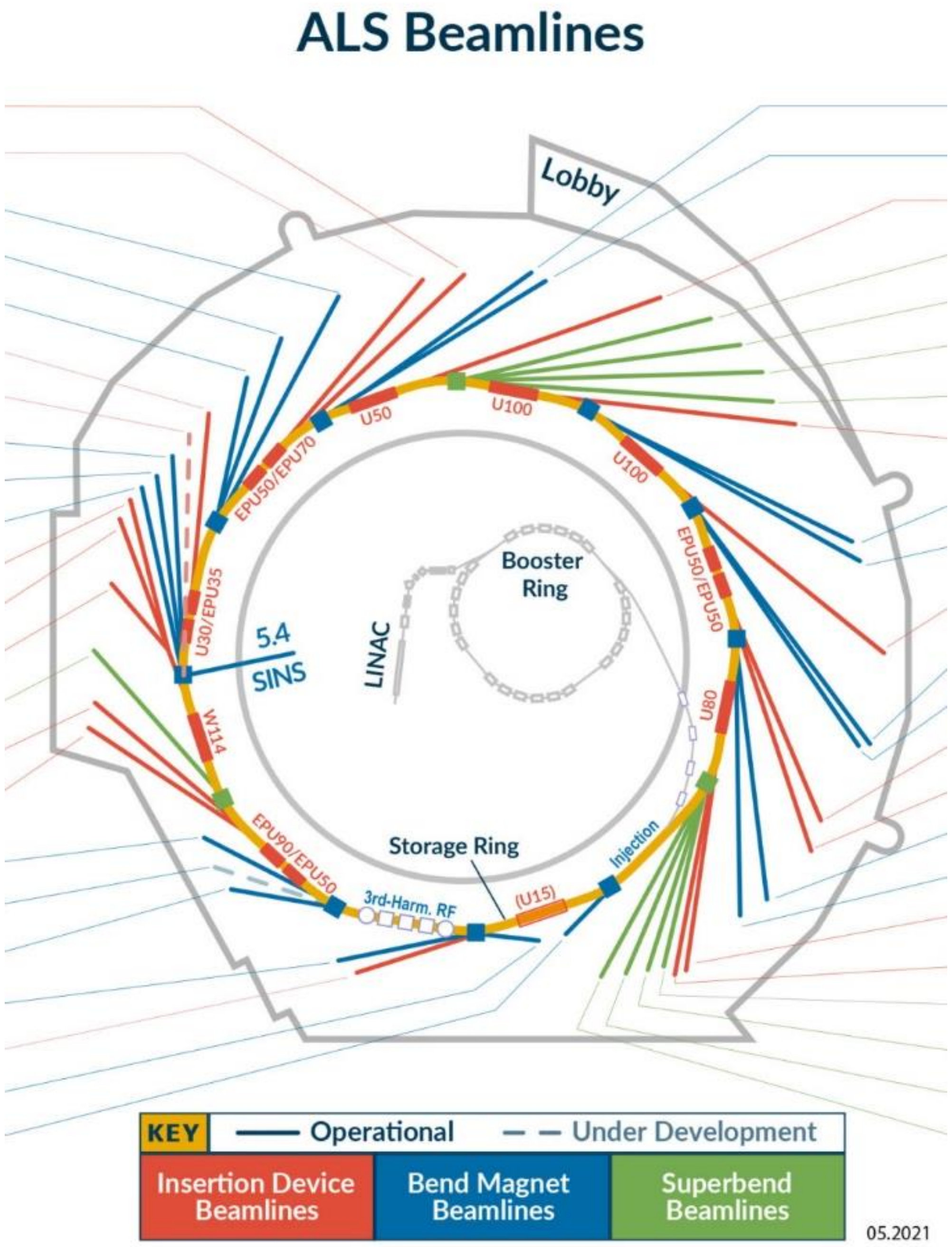
Storage Ring (SR)

- 4th Generation light source
- Circumference:196.5097m
- 9-bend achromat lattice

- All accelerators will be installed on a level plane.
- All magnets will be installed to nominal position without considering the existing beamlines position.

ALS-U Beamlines

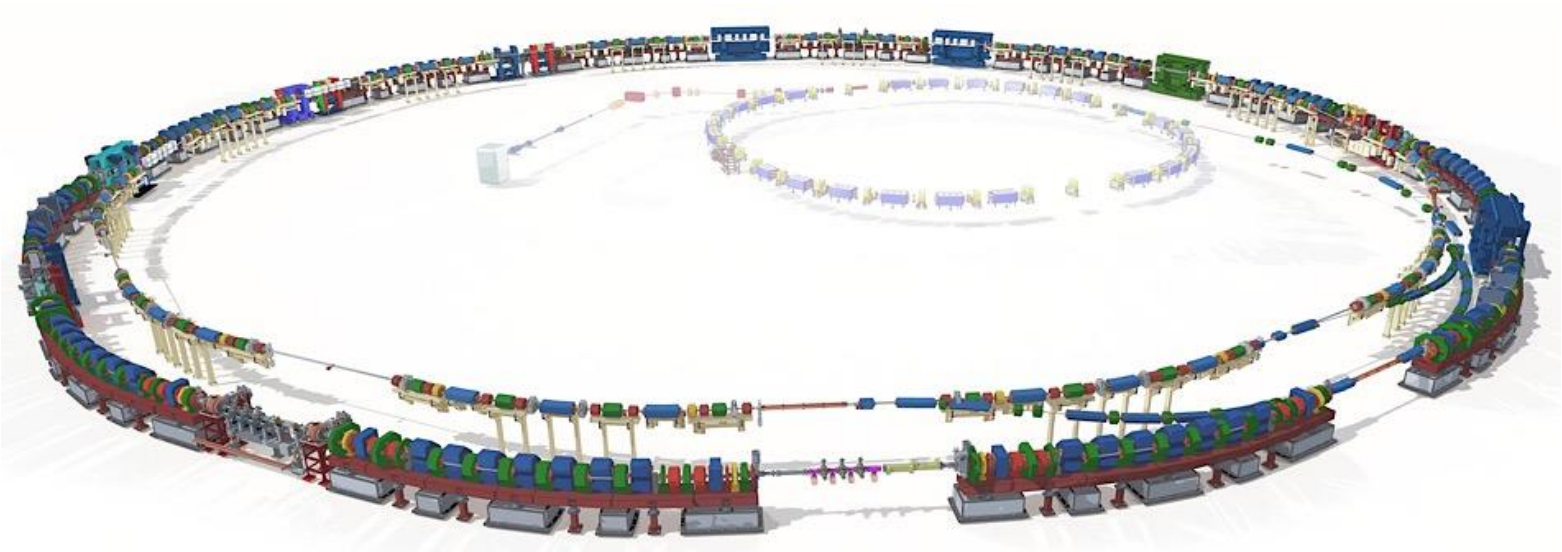
- **Insertion Device BLs Upgrade:**
  - 7.0.1 (COSMIC)
  - 7.0.2 (MAESTRO)
  - 8.0.1 (TENDER)
  - 10.0.1 (FLEXON)
- **No position change for the rest of IDBLs (Red BLs in the image)**
- **All Bend Magnet and Superbend BLs need to be moved to match the new Source centric: 25+ BLs. (All the dark blue and green BLs.)**



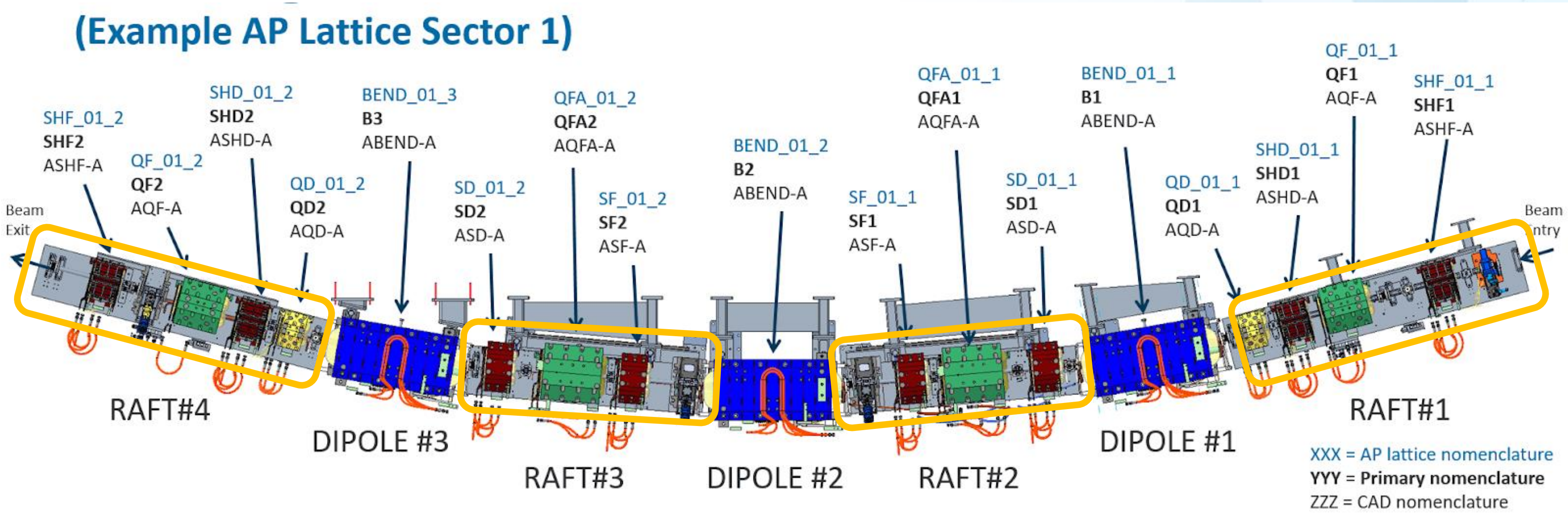
ALS-U Installation Plan

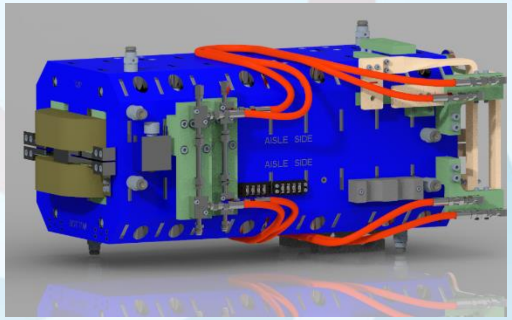
- Install AR and BTA during ALS summer and winter shutdowns, 3+ years.
- Start commissioning BTA and AR to minimize risk and duration of the main dark time.
- **Dark Time**
  - Remove ALS BTS and SR.
  - Install ALS-U SR.
  - Install ATS and STA.
  - The Beamline relocation happens in parallel with Accelerator installation.

We are here

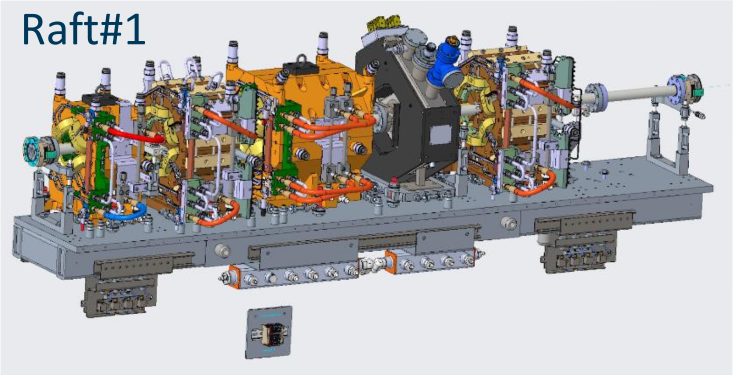


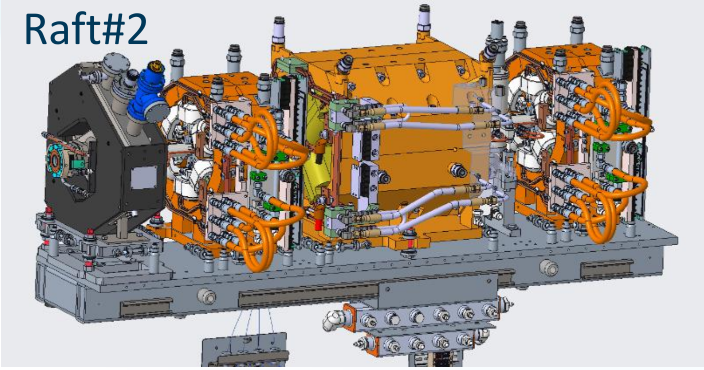
Accumulator Ring





- **12 Arc Sectors**
- **3 Dipoles and 4 Rafts**
  - The lattice of Raft#1 and Raft#4 is symmetrical.
  - The lattice of Raft#2 and Raft#3 is symmetrical.
  - Dipoles and Rafts are separately supported.





ALS-U Accelerator Alignment tolerance

		X(µm)	Y(µm)	Z(µm)	Rx(µrad)	Ry(µrad)	Rz(µrad)
AR & BTA	**Magnet to Magnet**	**± 100**	**± 100**	**± 400**	**± 1000**	**± 1000**	**± 1000**
	Raft to Raft	± 100	± 100	± 1000	± 200	± 200	± 200
	Sector to Sector	± 200	± 200	NA	NA	NA	NA
SR & ATS & STA	**Magnet to Magnet**	**± 60**	**± 60**	**± 200**	**± 400**	**± 400**	**± 400**
	Raft to Raft	± 60	± 60	± 200	± 35	± 35	± 200
	Sector to Sector	± 200	± 200	NA	NA	NA	NA

- The **Magnet-to-Magnet(M2M)** alignment tolerance for each magnet relates to its relative positioning with respect to its nearest neighboring (adjacent) magnets. A minimum of 4 fiducials per magnet should be used. For magnets at the edge of a raft, this needs to only be evaluated relative to the one neighbor on the same raft.
- The specified error interval corresponds to a 95%(≈2σ)confidence based on a Gaussian error distribution.

ALS-U Accelerator Alignment tolerance

		X(µm)	Y(µm)	Z(µm)	Rx(µrad)	Ry(µrad)	Rz(µrad)
AR & BTA	Magnet to Magnet	± 100	± 100	± 400	± 1000	± 1000	± 1000
	Raft to Raft	**± 100**	**± 100**	**± 1000**	**± 200**	**± 200**	**± 200**
	Sector to Sector	± 200	± 200	NA	NA	NA	NA
SR & ATS & STA	Magnet to Magnet	± 60	± 60	± 200	± 400	± 400	± 400
	Raft to Raft	**± 60**	**± 60**	**± 200**	**± 35**	**± 35**	**± 200**
	Sector to Sector	± 200	± 200	NA	NA	NA	NA

- The **raft-to-raft(R2R)** alignment tolerance for each raft relates to its relative positioning with respect to its nearest neighboring (adjacent) rafts. This is determined by least square fit of all magnets on either raft. A minimum of 3 fiducials per magnet should be used.
- The specified error interval corresponds to a 95% (≈2σ) confidence based on a Gaussian error distribution.

ALS-U Accelerator Alignment tolerance

		X(µm)	Y(µm)	Z(µm)	Rx(µrad)	Ry(µrad)	Rz(µrad)
AR & BTA	Magnet to Magnet	± 100	± 100	± 400	± 1000	± 1000	± 1000
	Raft to Raft	± 100	± 100	± 1000	± 200	± 200	± 200
	Sector to Sector	**± 200**	**± 200**	**NA**	**NA**	**NA**	**NA**
SR & ATS & STA	Magnet to Magnet	± 60	± 60	± 200	± 400	± 400	± 400
	Raft to Raft	± 60	± 60	± 200	± 35	± 35	± 200
	Sector to Sector	**± 200**	**± 200**	**NA**	**NA**	**NA**	**NA**

- The **sector-to-sector** alignment tolerance for each sector (i.e. set of rafts) relates to its relative positioning with respect to its nearest neighboring (adjacent) sectors. This is determined by least square fit of all magnets in either sector.
- The specified error interval corresponds to a 95%(≈2σ) confidence based on a Gaussian error distribution.

ALS-U Accelerator Alignment tolerance

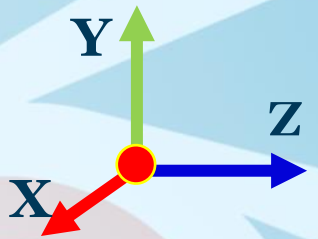
AR Magnet to magnet Alignment tolerance breakdown

	Baseline Process	Local X One Sigma Value		Local Y One Sigma Value		Local Z One Sigma Value	
Group Responsibility	**Uncertainty Attribute**	**Step Uncertainty [microns]**	**Cumulative Quadrature [microns]**	**Step Uncertainty [microns]**	**Cumulative Quadrature [microns]**	**Step Uncertainty [microns]**	**Cumulative Quadrature [microns]**
Mag.	Assembly Field Reproducibility (Splitting)	**5.0**	**5.0**	**1.5**	**1.5**	**15.0**	**15.0**
Mag Meas.	Sensitivity of the SW magnetic apparatus	**15.0**	**15.8**	**15.0**	**15.1**		**15.0**
Mag Meas.	Mechanical Fiducialization of CMM	**10.0**	**18.7**	**10.0**	**18.1**	**10.0**	**18.0**
Mag Meas.	CMM Fid of Mag Center to Tooling Nests	**6.0**	**19.6**	**6.0**	**19.1**	**6.0**	**19.0**
Prestaging	Magnet Position Error (effective sigma= SD) on AR Raft	**11.5**	**22.8**	**11.5**	**22.3**	**11.5**	**22.2**
Prestaging	Laser Tracker Position Meas.	**20.0**	**30.3**	**20.0**	**29.9**	**20.0**	**29.9**
R&I and Supports	Transport Stability on Raft	**10.0**	**31.9**	**5.0**	**30.4**	**10.0**	**31.5**
Nature	Cumulative Thermal Offsets on Raft	**0.0**	**31.9**	**2.1**	**30.4**	**7.3**	**32.4**

Summary Positioning Estimate	**<x>**	**<y>**	**<z>**	N/A
Cumulative Mechanical Sigmas [microns]	**31.9**	**30.4**	**32.4**	

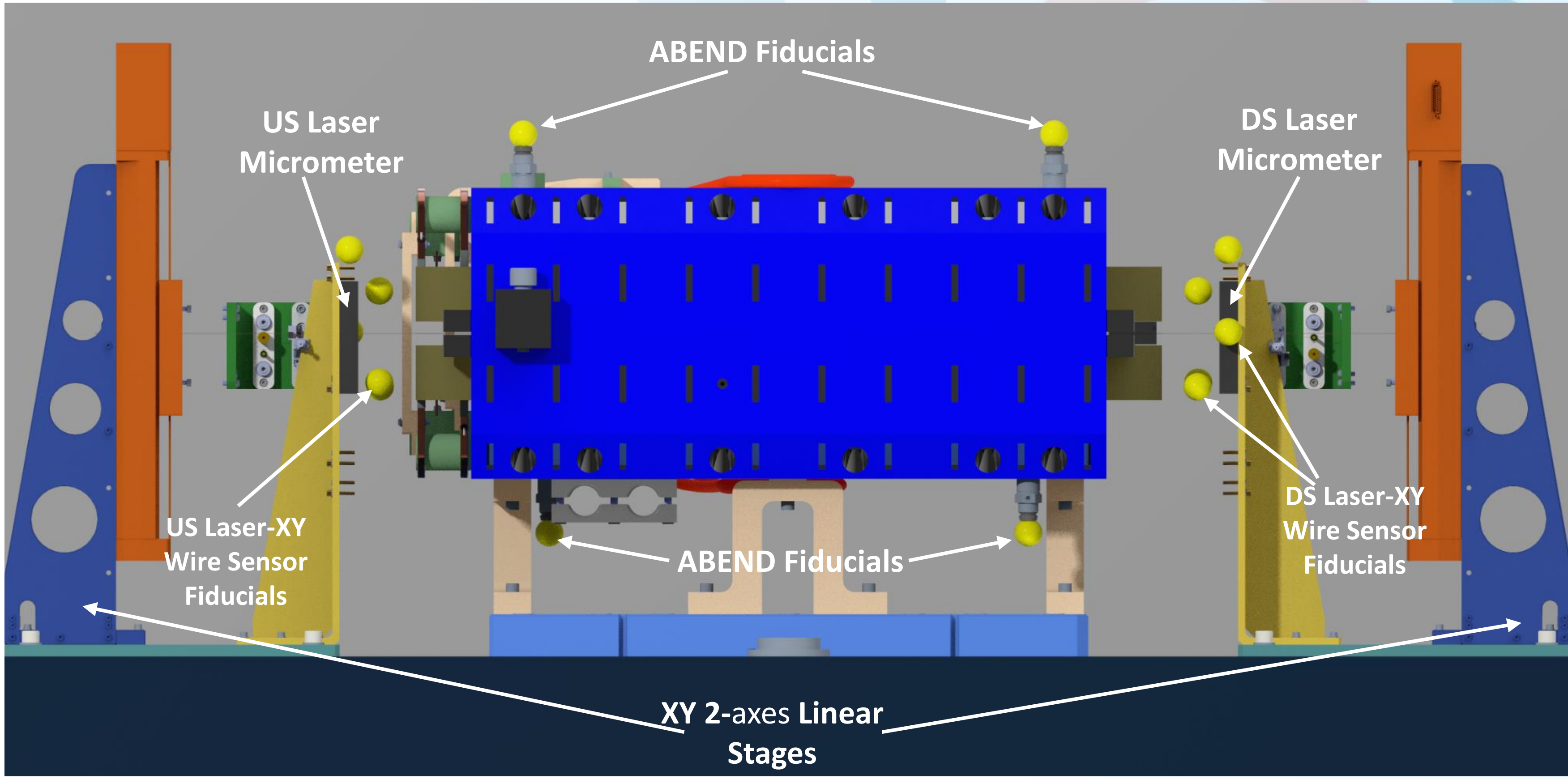
- Survey Alignment contributes to three attributes in the list, two will be covered in the following slides.
- The cumulative position error can meet the 95%(≈2σ) confidence level.
- The AR R2R and SR M2M,R2R Tolerance breakdown are in progress.

Stretch Wire Magnetic Measurement



SW System:

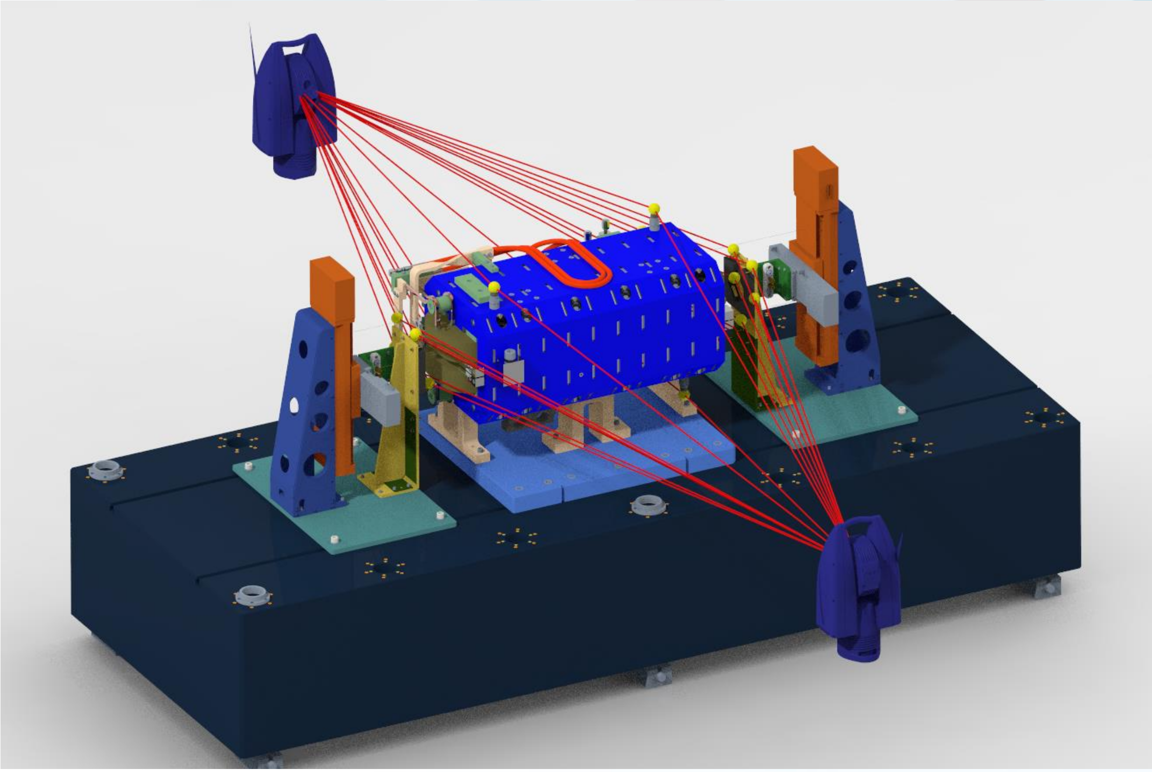
- The Perpendicularity of Upstream(US) and Downstream(DS) XY 2-axes stages are better than 100µrad.
- The Parallelism between US and DS stages are better than 100µrad
- Two Laser Micrometers:
  - Repeatability: 3
  - Non-Linearity: < 10µm
  - Fiducialized with CMM, Mapped with Laser tracker: 225 mapping points.



Stretch Wire Magnetic Measurement

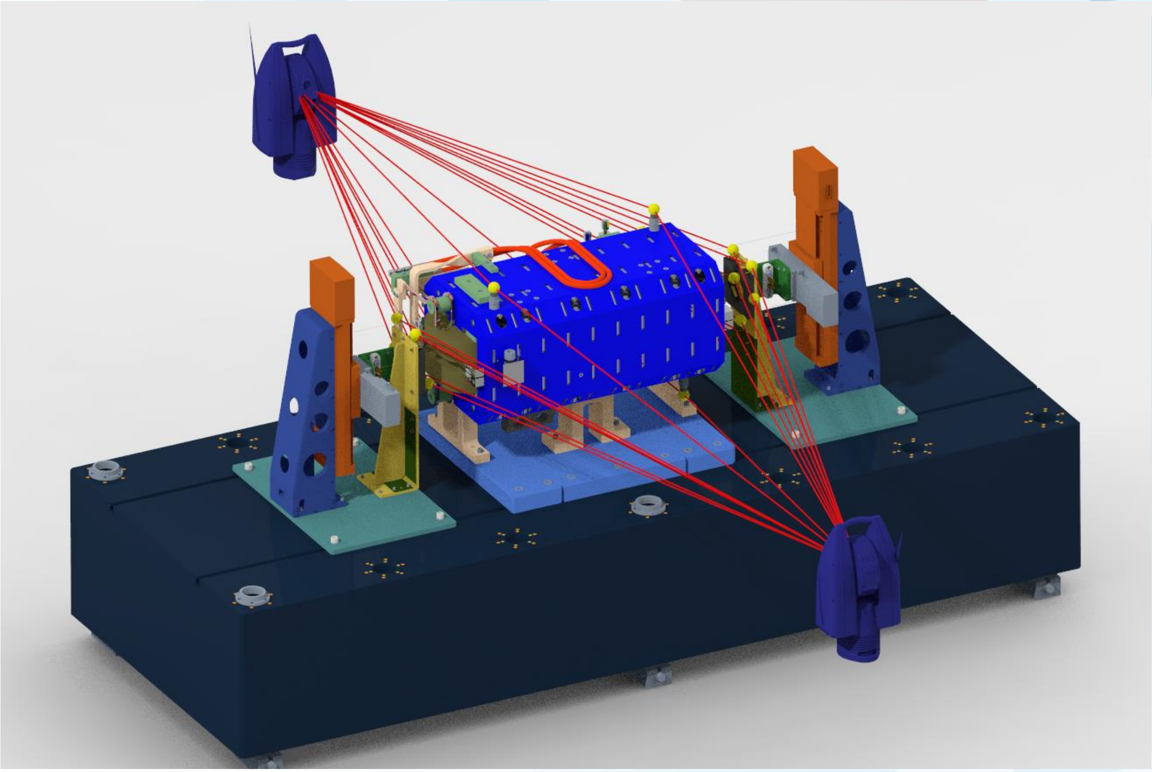
Procedures:

- Bisect the US and DS stage coordinate system(CS) to get the SW CS.
- Align the CMM fiducialized magnets to the SW CS within +/-5mm @X&Y and +/-3mrad @Rx,Ry &Rz.
- Use Two Laser tracker stations to measure all the Magnet’s fiducials and Laser Micrometers’ fiducials.
- Calculate the intersections between the Magnet’s mechanical axis and the Laser Micrometers’ laser curtain.
- Stages drive the wire to the intersections to start magnetic measurement.
- The offset between mechanical and magnetic center in X and Y direction can be measured and applied to the magnet fiducialization data.
- Data processing is integrated in one Spatial Analyzer measurement plan, increase efficiency.



Stretch Wire Magnetic Measurement

- **Uncertainty attribute: Sensitivity of SW magnetic apparatus.**
  - Utilizing the standard deviation of the differential errors determined by comparing the magnetic field fiducialization's positional estimate to the mechanical fiducialization estimate made with a CMM. And Including the Laser micrometer fiducialization error and mapping error.
  - The fiducialization uncertainties reported by magnetic measurements implicitly have underlying uncertainties introduced by the LT utilized to position the magnet, and apparatus on the bench. The reported magnetic measurement uncertainties may therefore be a bit optimistic.



	X(µm)	Y(µm)	Z(µm)	Rx(µrad)	Ry(µrad)	Rz(µrad)
Uncertainty(1σ)	± 15	± 15	NA	± 60	± 60	± 60

Estimated

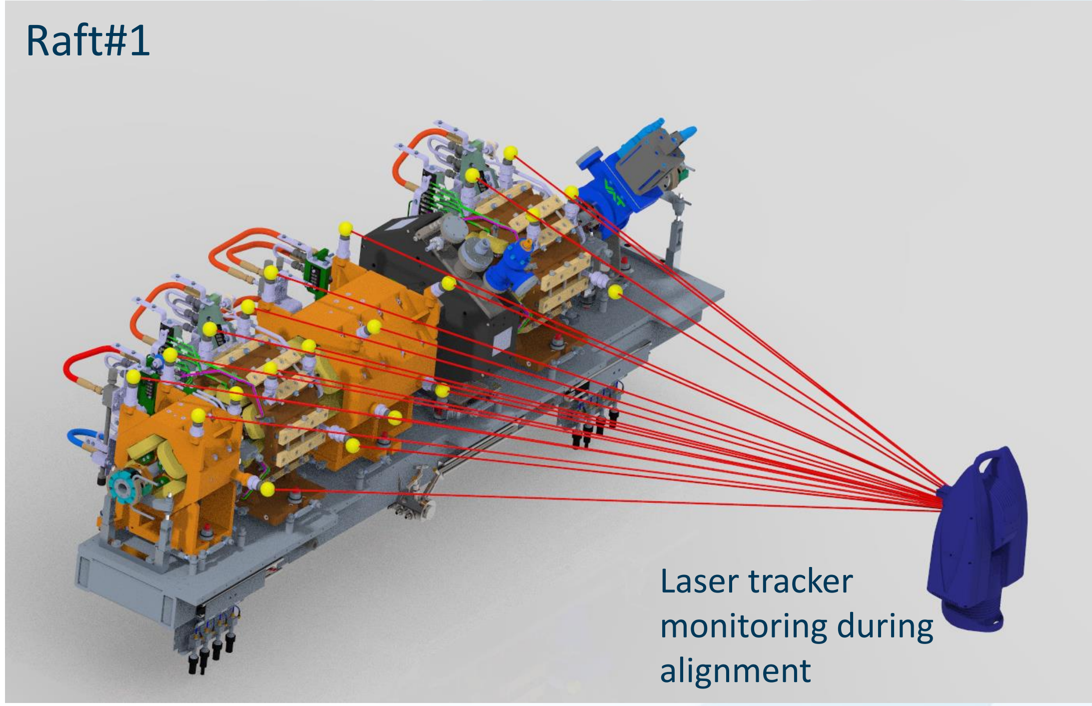
Stretch Wire Magnetic Measurement

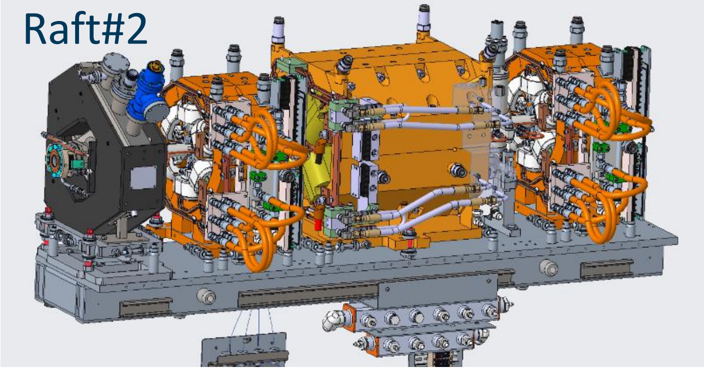
- AR 100% Dipole and 25% Non-Dipole are measured by SW.
- The magnetic and mechanical center offset are applied for all Dipoles, not for Non-dipole magnets.
- Completed all AR magnets SW measurements.

Prestaging

Procedures:

- Measure Raft weldment X,Y,Z datum to align laser tracker to the Model.
- Align the middle Quad relative to the Raft weldment.
- Align the two adjacent Sextupoles relative to the Quad.
- Align the end Quad to the adjacent Sextupole.
- Align the BPMs, vacuum pumps and chambers.
- Multiple laser tracker stations to record the magnet fiducials, BPM fiducials and critical features of Vacuum system.
- Data processing, report generating and alignment requirements checking are integrated in one measurement plan.



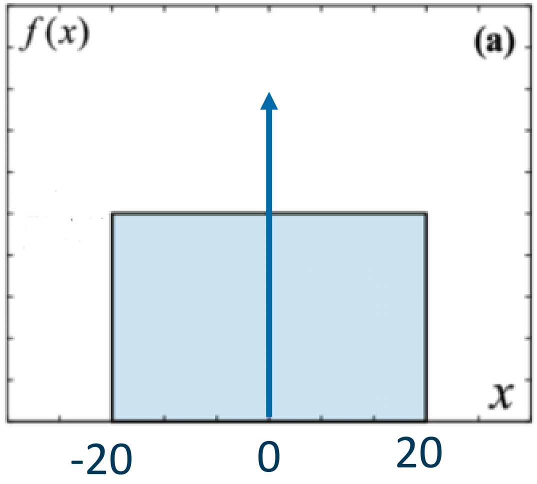


Prestaging

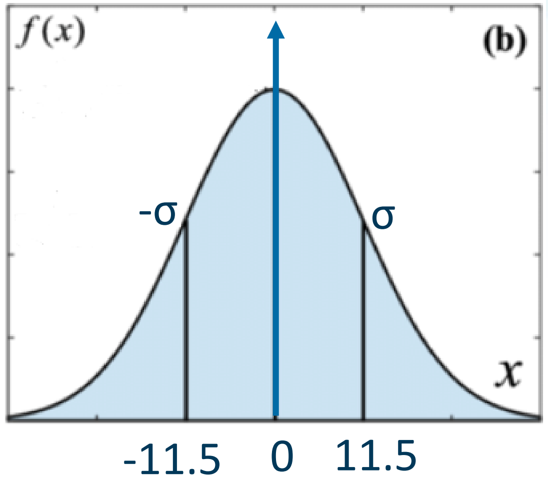
- **Uncertainty attribute: Magnet position error on AR Raft.**
  - **Magnet Position Error** is treated as Uniform distribution, +/-20 μm(the beam direction is updated to +/-40 μm) converted to Gaussian distribution 1sigma value by dividing by $\sqrt{3}$.

	X(μm)	Y(μm)	Z(μm)
Magnet position error on AR Raft(1σ)	± 11.5	± 11.5	± 23

Uniform distribution

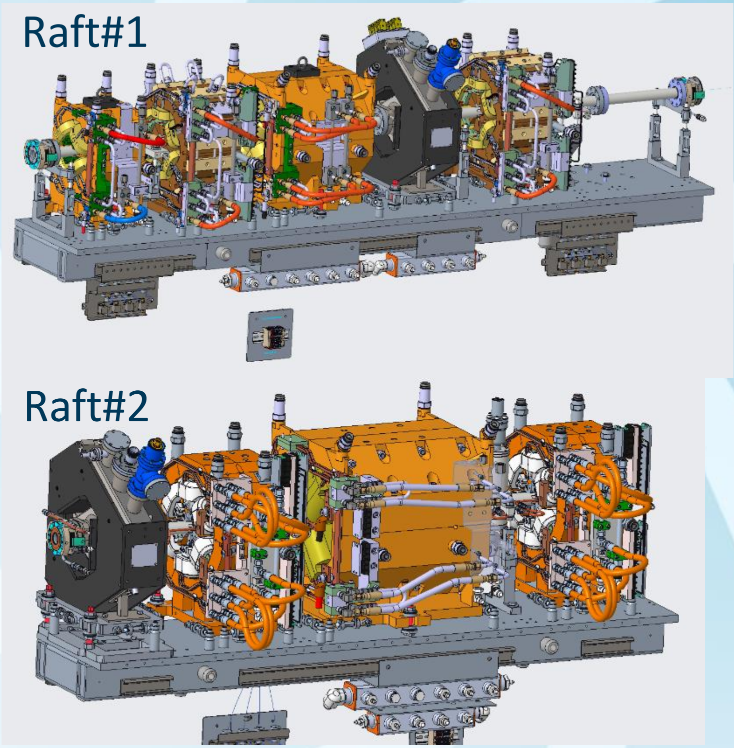


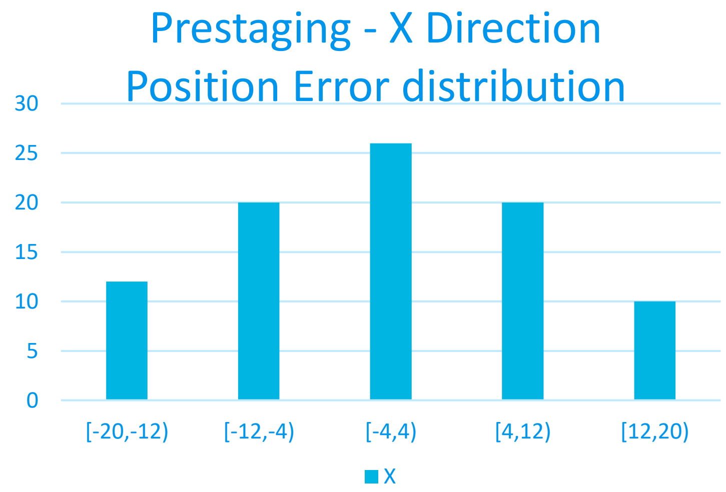
Gaussian distribution

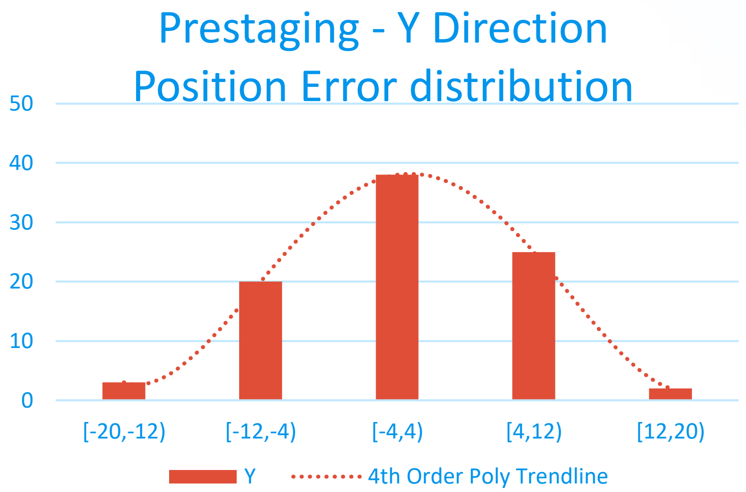


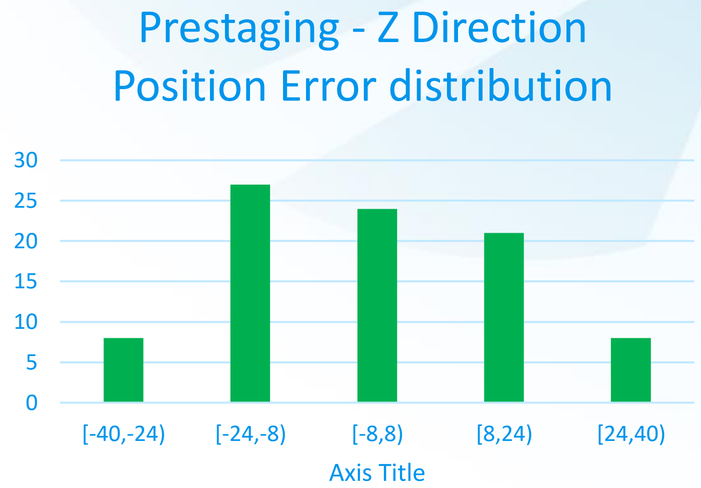
Prestaging

- **Uncertainty tribute: Magnet position error on AR Raft.**
  - Statistics of the finished 30 Rafts, there are 88 magnets pairs, the magnet to magnet position error distributions on three axes are different.
  - X and Z are slightly better than Uniform distribution. Y direction is close to Gaussian distribution.
  - Treating three directions position error as Uniform distribution is reasonable when allocating error budget in the designing phase.









AR Prestaging and Installation progress

- **75% Rafts prestaging.**
- **56% Rafts initial tunnel alignment.**
- **52% Dipoles initial tunnel alignment.**

In initial tunnel alignment phase, all Rafts and Dipoles are aligned to nominal position, then vacuum connection can be made. After the completion of initial tunnel alignment and vacuum connection, there will be fine alignment for the whole AR.

What has been presented is very much a Group Effort…

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Thanks for your attention!