ProtoDUNE – DSS Mechanical Design
DSS Review

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DSS Review

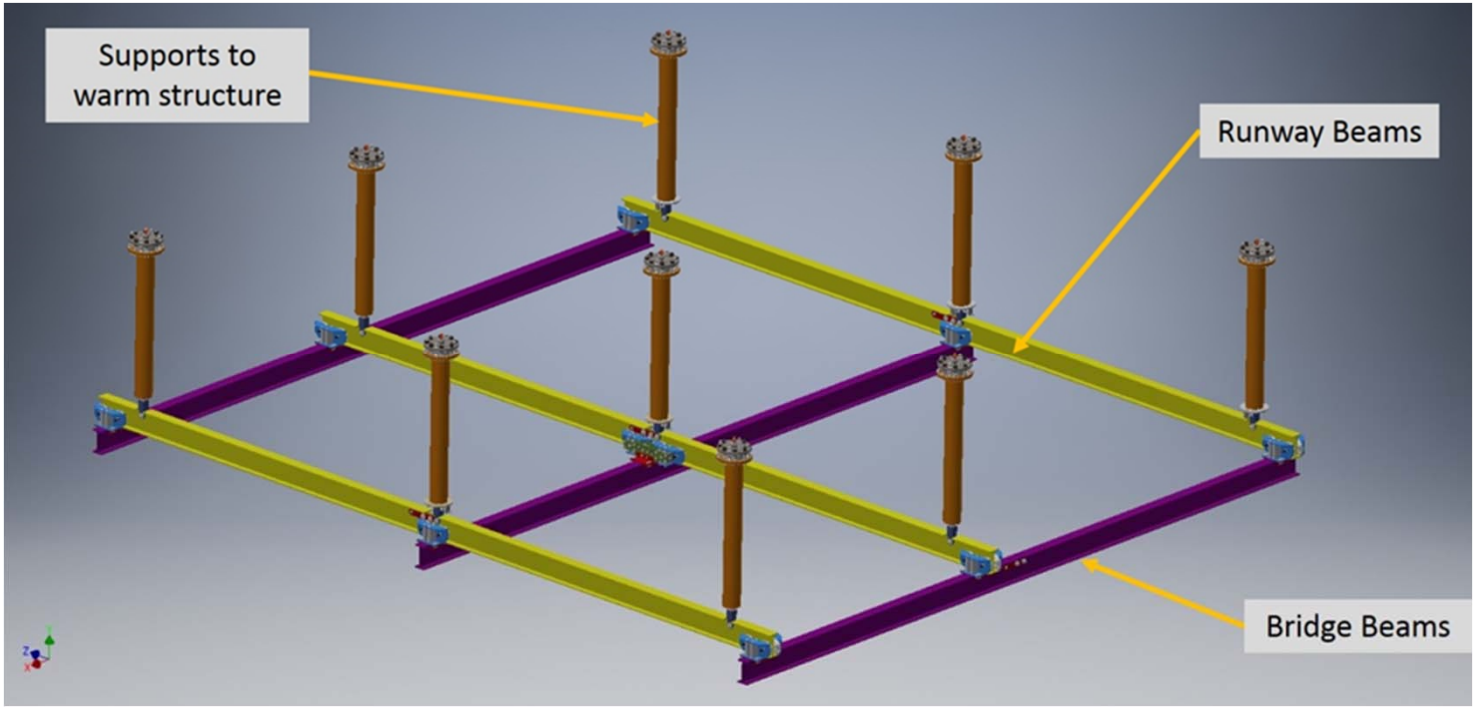
November 7, 2016

Outline

- General Description
- Connections and Interfaces
  - Interface to the cryostat warm structure
  - DSS hanger assembly
  - Beam pivots
  - Bridge beam trolleys
  - Bridge beam to TPC connections
  - Interface to cryogenic piping
- Materials
  - I-beams
  - Trolleys
  - Feed thru Flange connections
  - Fasteners
- Loads, load cases and analysis
  - Loads
  - Load cases
    - Bridge beam loads
    - Beam Trolley loads
    - Runway beam loads
    - Runway beam to Hanger points
    - Load transferred to the cryostat warm structure
- Analysis
- Drawings

General description

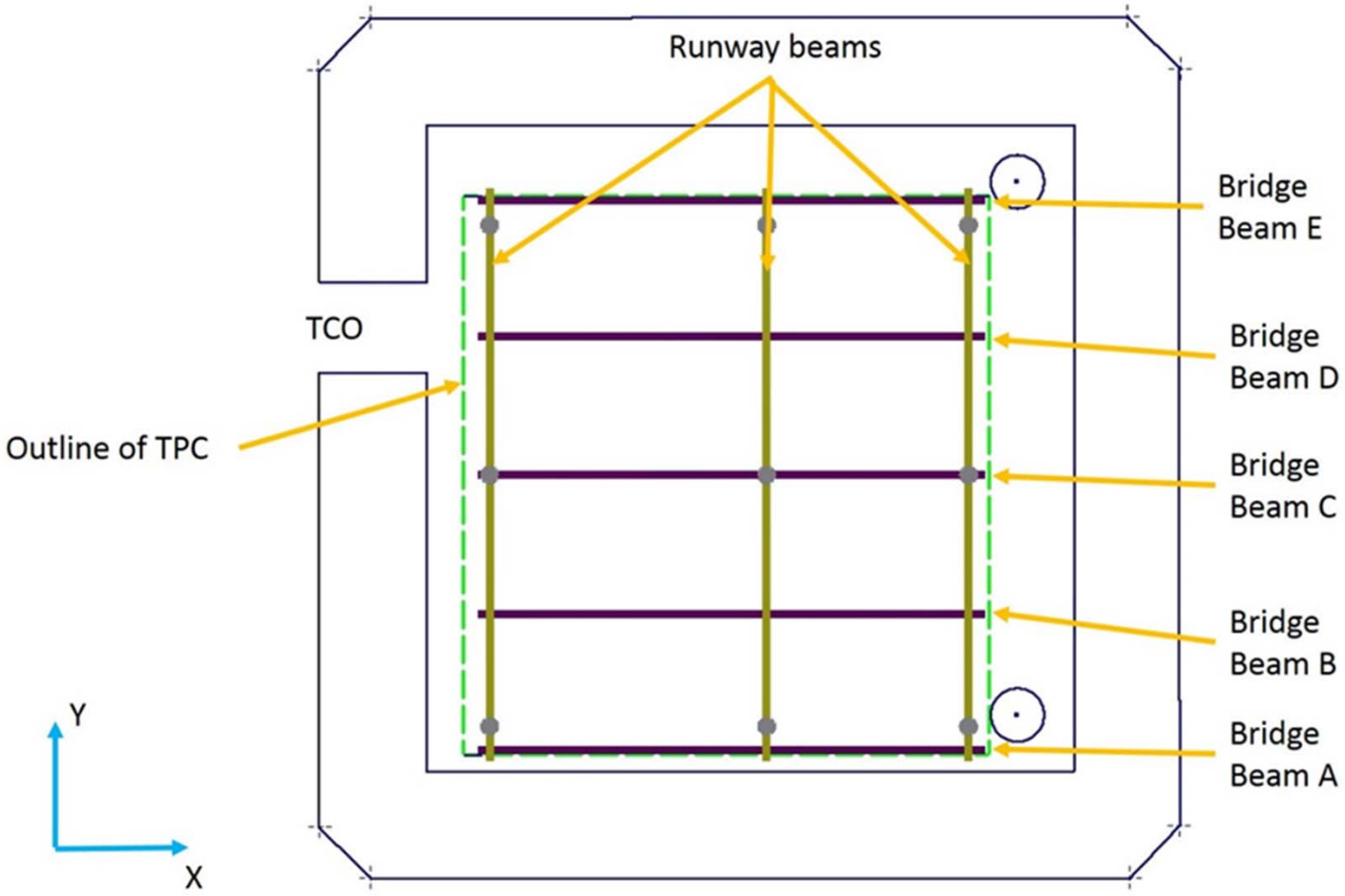
- The DSS delivers, supports, and positions modular TPC subassemblies
- The DSS beam system is similar to a bridge crane
- APAs, CPAs(with FCs), and EWs are moved on trolleys that run on the bridge beam
- The bridge beam translates to final position



Isoview of DSS

Duplicate

General description - continued

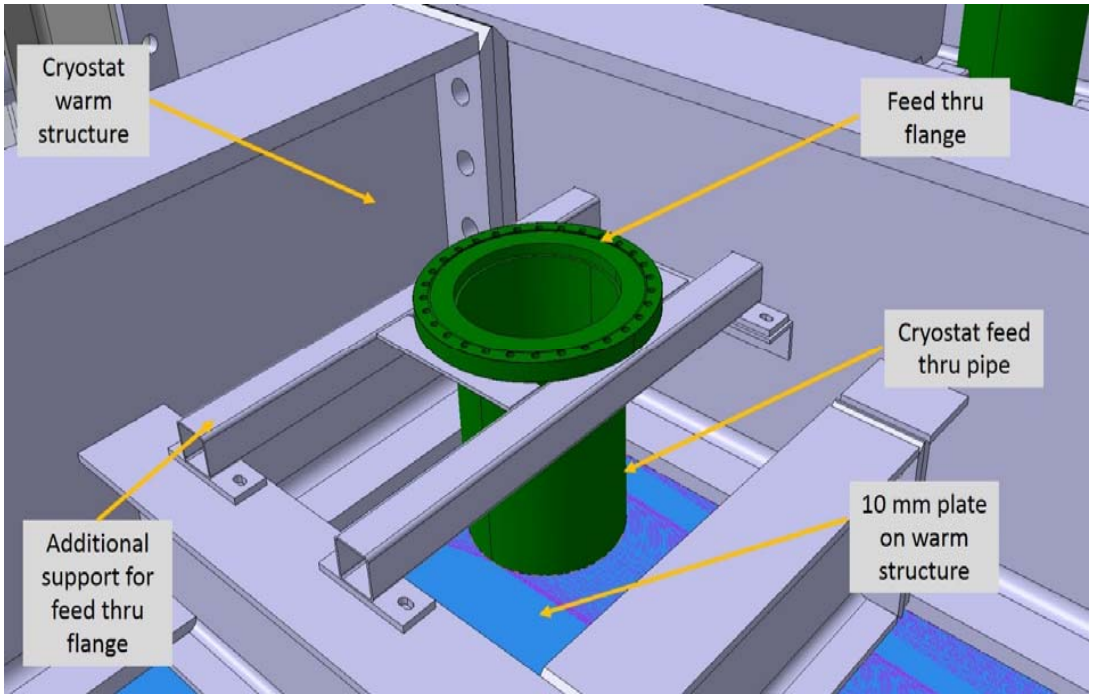


Top view of the DSS

Connections and Interfaces

Interface to the cryostat warm structure

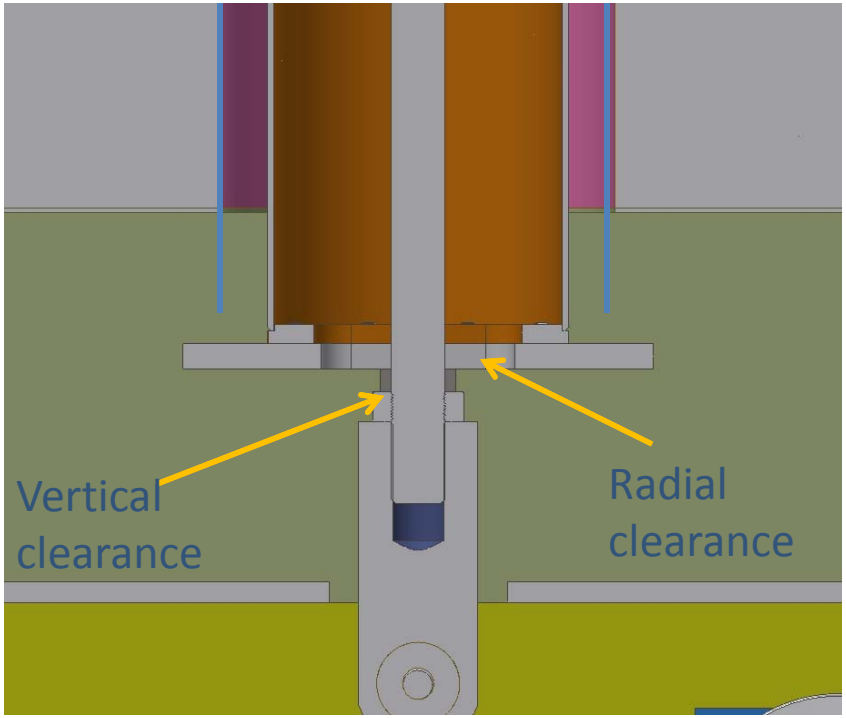
- DN250 CF blank flange custom machined to match a 200mm OD tube
- The x and y locations of the support feedthroughs are well defined.
- The height of the flange is not fixed, but should be shortly



ISO view of the feed thru support and cryo warm structure

Connections and Interfaces

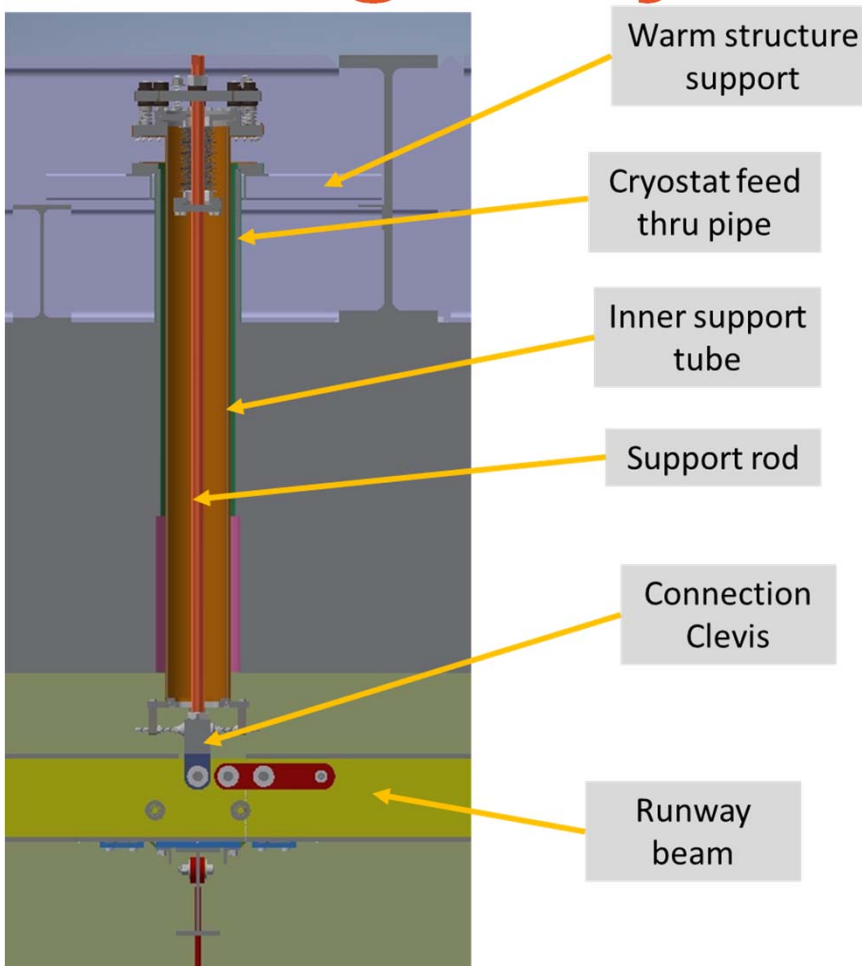
Interface to the cryostat



Section view of the feed thru support and internal membrane

- Membrane tube is ~196mm in ID and extends 50 mm below the membrane.
- Inner support tube has an OD of 152mm
- Radial clearance to membrane tube is ~22mm
- Vertical clearance is 10mm

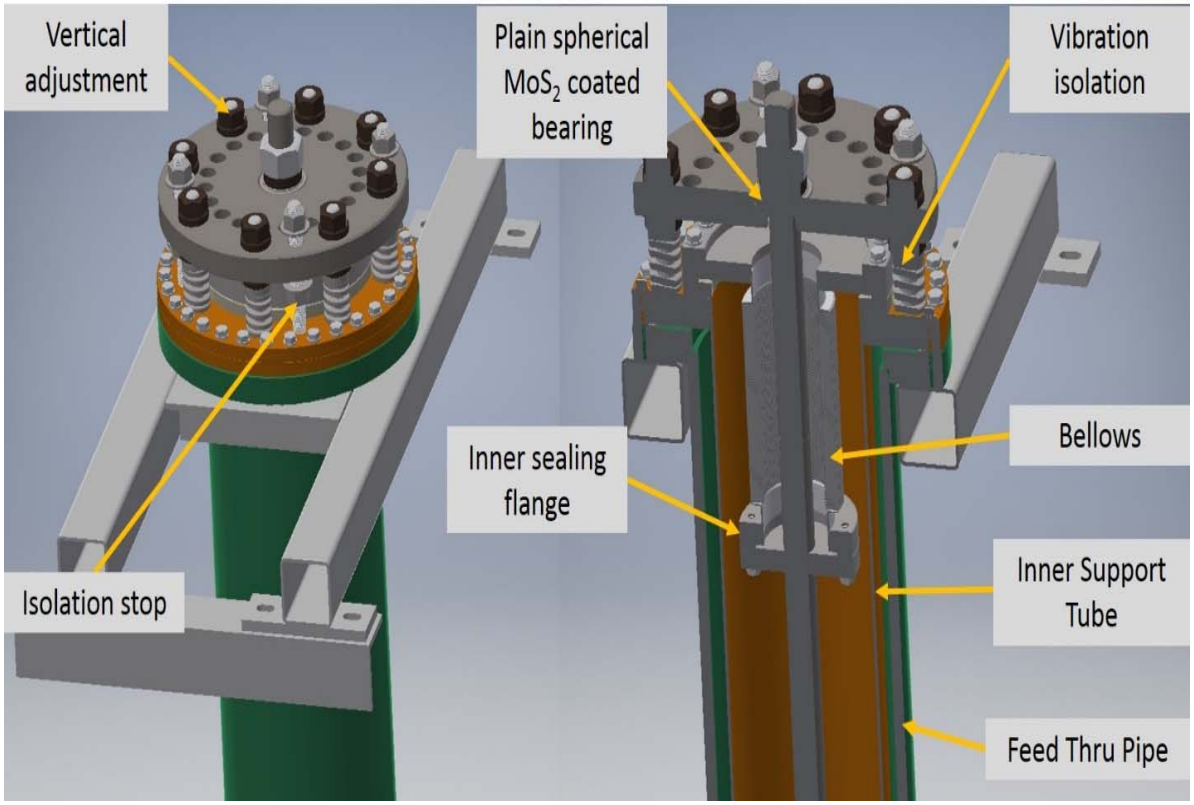
DSS Hanger System



Section through the DSS hanger assembly

- No side loads are allowed on the membrane
- Inner support tube positions and constrains the DSS beams laterally
- The support rod carries the vertical loads

DSS Hanger system



Upper Assembly Detail

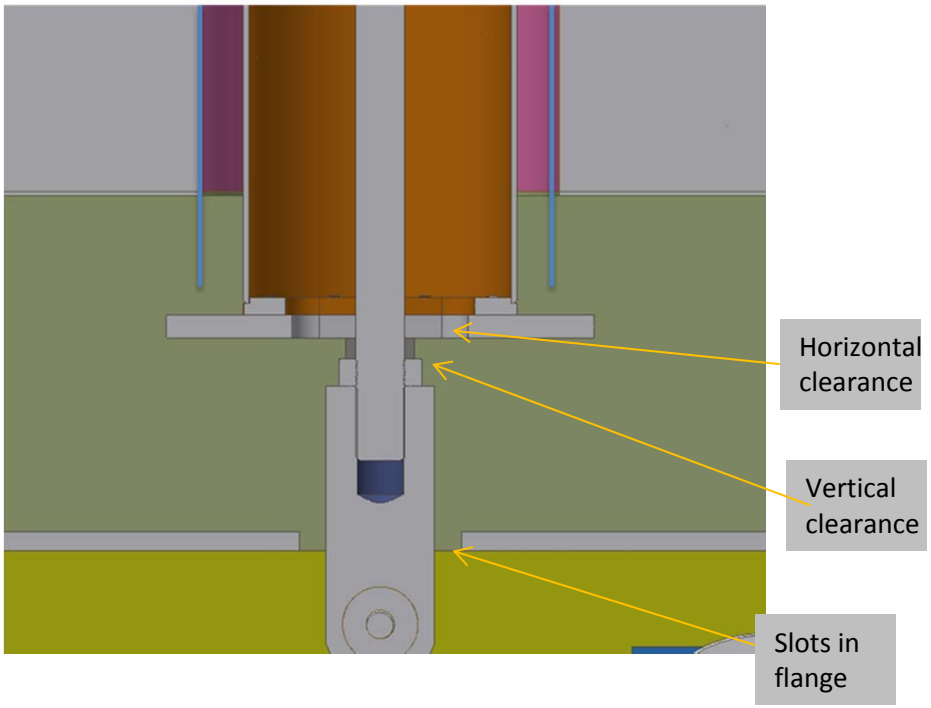
- The support rod is made from 30mm OD 304 Stainless steel
- It is fixed to a MoS2 coated plain spherical bearing
- The upper flange is supported on long life die springs for vertical vibration isolation.
- The lower flange/bellows/rod assembly maintains the gas seal while accommodating pivoting
- Vent holes near the top of the inner support tube will allow for purging

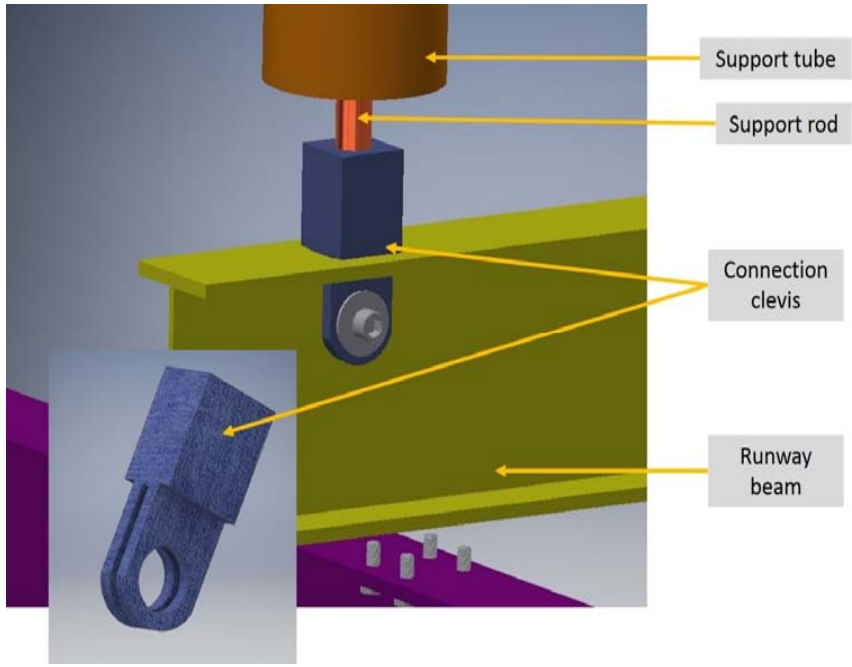
DSS Hanger system

Additional features and comments

- The length from the pin hole in the beam connection to the top of the support rod is set precisely. Survey of the top of the support rods will indicate the flatness of the DSS beam structure. (This assumes that the thermal gradient in the feedthrus are similar.)
- Estimated temperature gradients can be used to predict the effect on the TPC vertical position
- For height adjustment, the upper flange is mounted to the springs on threaded adjusters
- The vibration isolation can be locked out with the isolation stop.
  - For shipping and installation
  - For performance comparison
  - For spring repair
  - To swap springs for a different spring constants
- Due to its ~2 meter length, the inner support tube is effectively a spring providing lateral vibration isolation.

DSS Hanger system



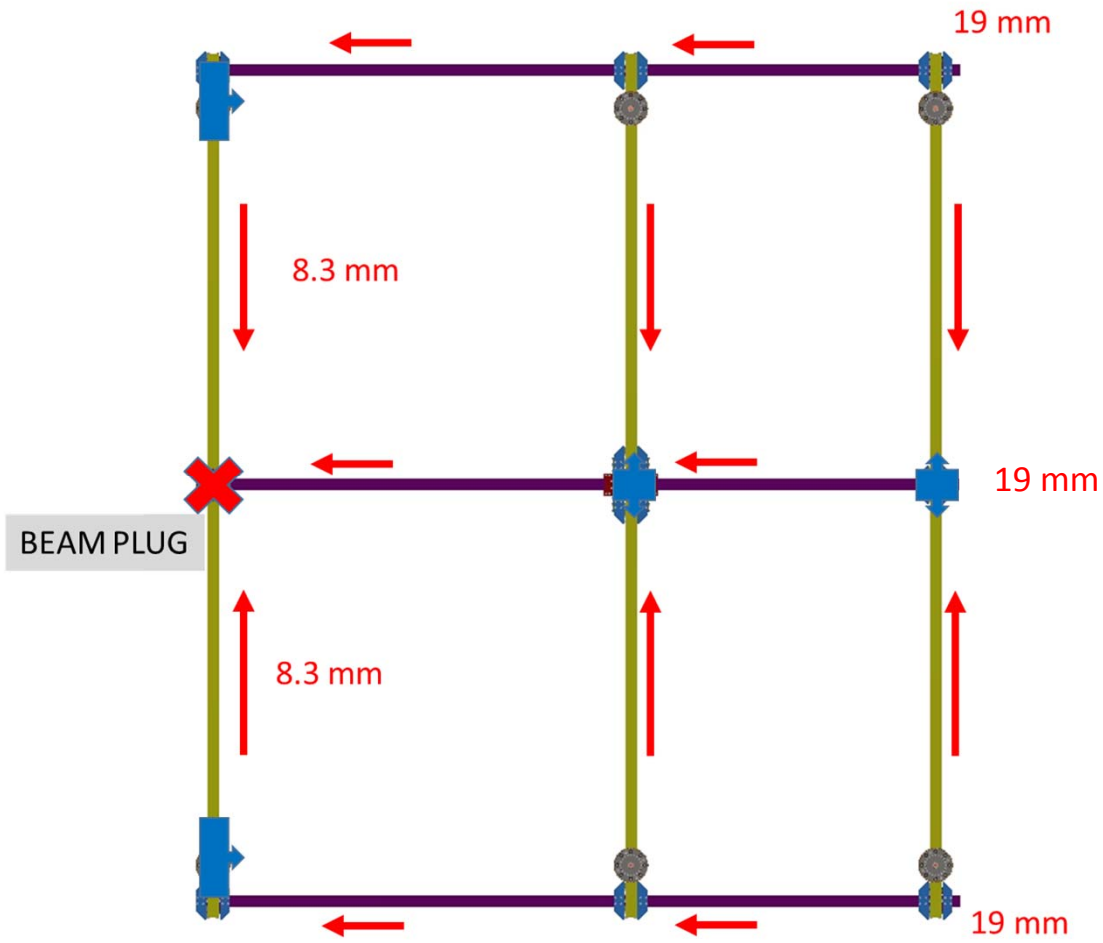


+/- 3cm of radial clearance allows +/- 1cm for CTE and +/- 2cm for positional tolerance

- Clevis is pinned directly to the web for strength
- Captured pin is copper for anti-galling and cryogenic properties

Lower Assembly Detail

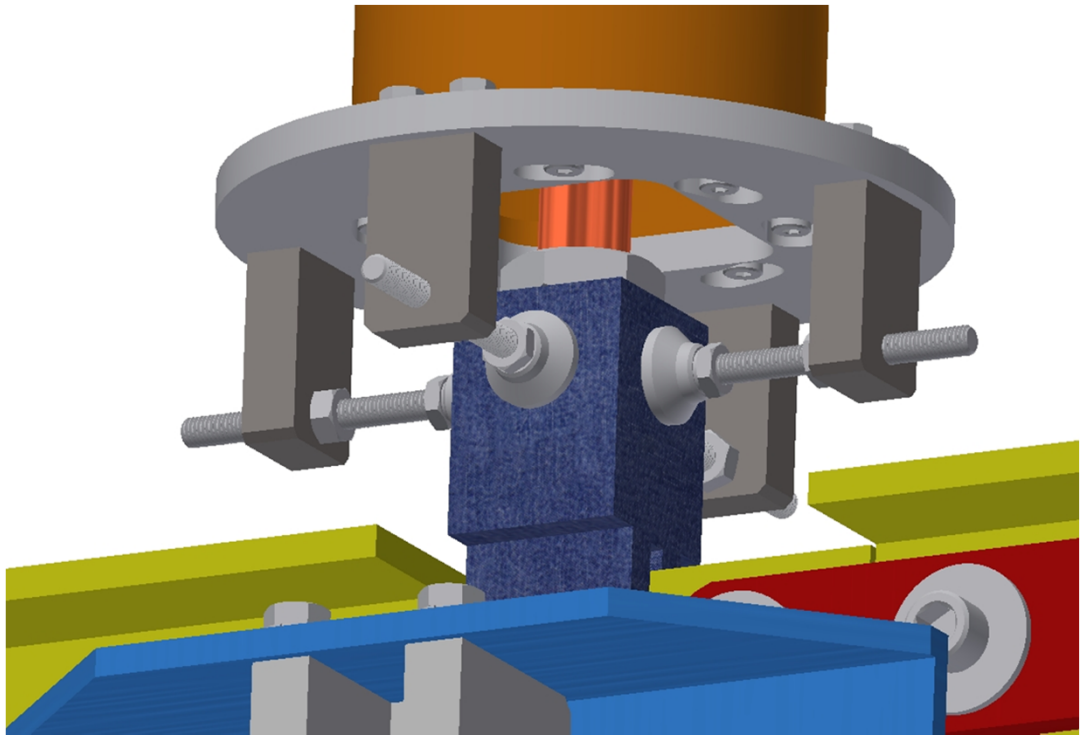
DSS Hanger system



Constraining system

The beam connection clevises are constrained to control the position of the TPC , but to allow for expansion and contraction

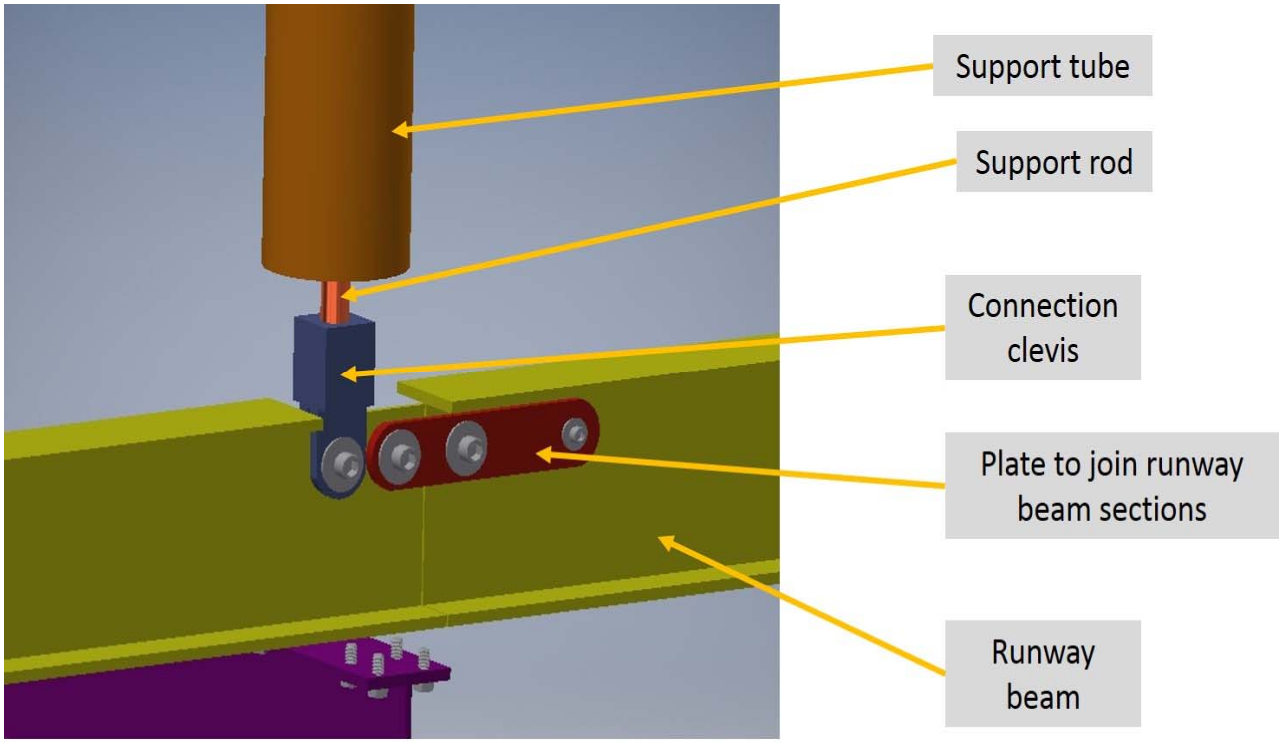
DSS Hanger system



Constraining system shown for the fixed point

- Adjustable swivel feet adjust the support location
- Mount block is tapped and nuts are on the inside for access
- Adjustment will be guided by survey
- Swivel feet are engaged or disengaged with the clevis depending on location
- Swivel feet may be engaged temporarily during installation to stiffen the DSS
- Seal for inner tube volume has been designed but is not shown.

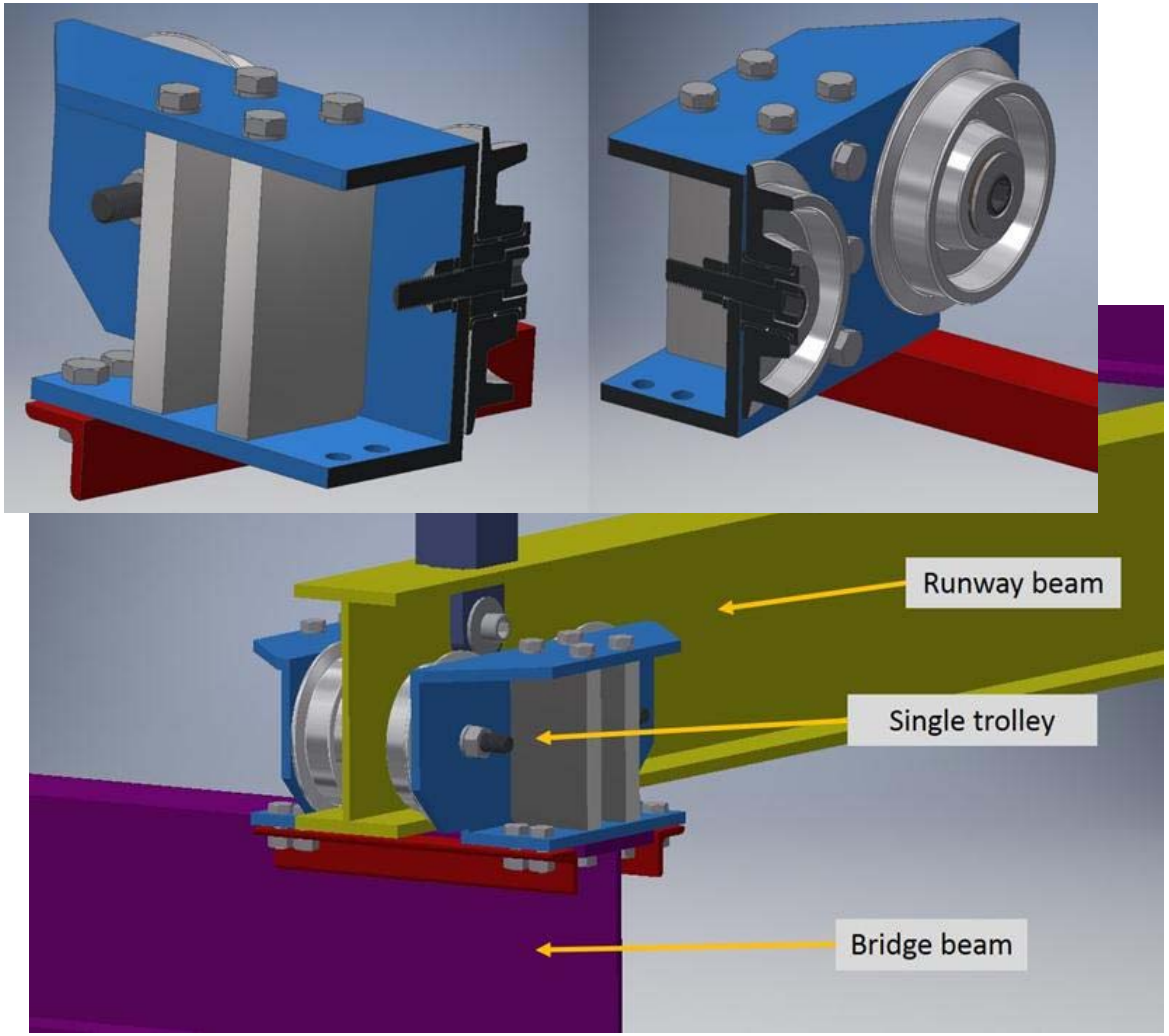
Beam Pivots



- Pivot points near the center of the beams accommodate roof flex without over stressing the DSS hangers
- The pivot point is connected directly to the web for strength and pivots on a captured copper pin.
- The two fixed points are also pinned in place . One pin has flats and fits in a slotted hole to accommodate hole position tolerances.

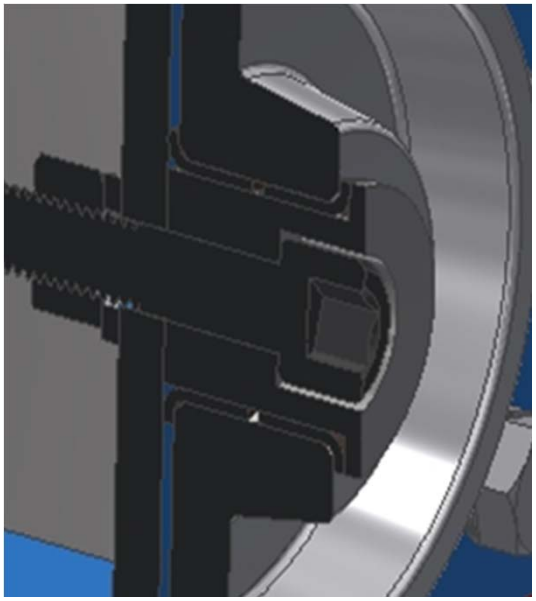
Runway to bridge - beam trolleys

- Bearings used in APA and CPA beams will be loaded when cold and will use a plain bearing that is rated for the cold.
- The other trolleys are not loaded in the cold and will use alloy steel rolling element bearings . This will minimize the friction and make installation easier.

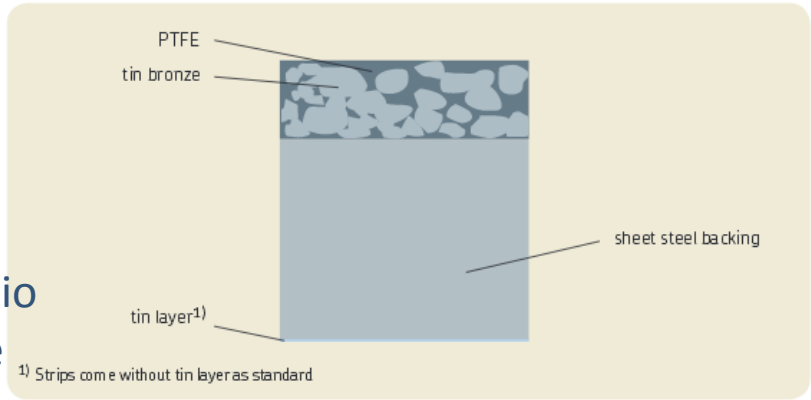


Runway to bridge beam trolleys

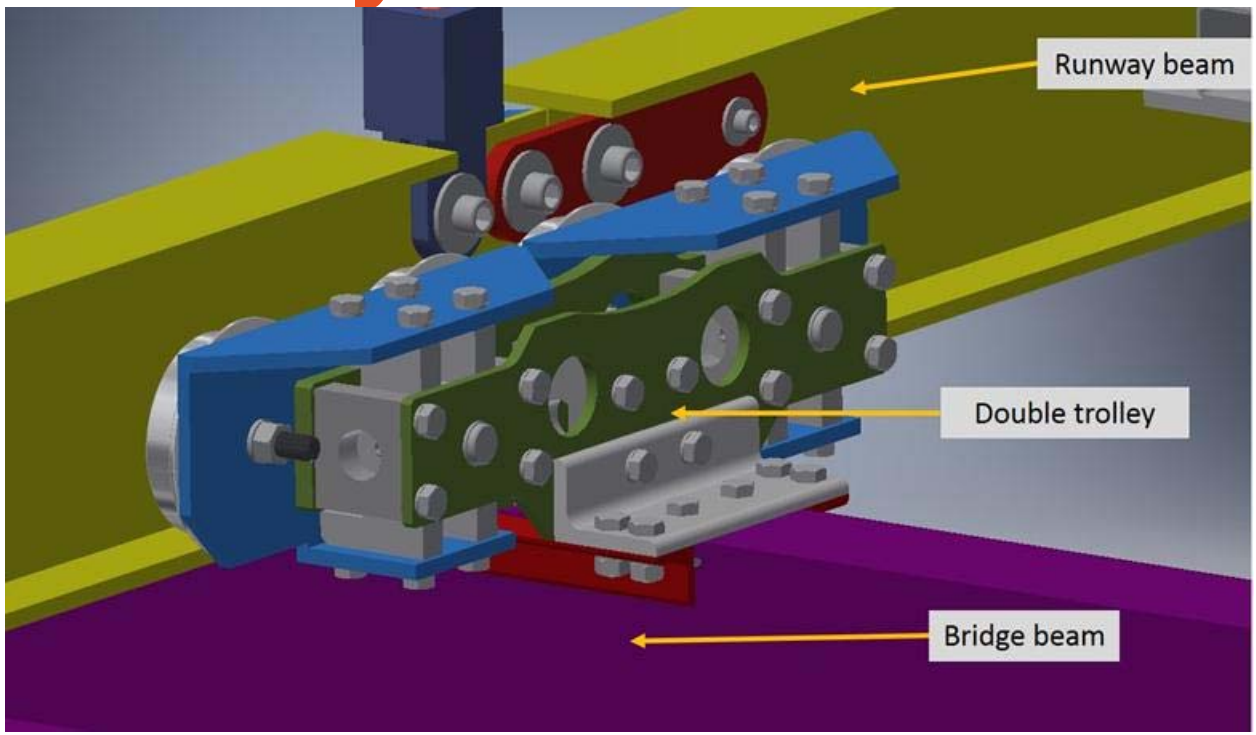
- It is extremely difficult to procure cryogenic bearings to react the loads necessary in the trolley system. Commercial bearings are produced from materials that loose their ductility and their load bearing capacity at cryogenic temperatures. They may also contain lubricants that may be detrimental to the LAr purity.
- The bearings in the trolley design are constructed from a composite bushing produced by SKF that is rated for 73°K.
- This bushing consists of a coated steel backing with a layer of sintered tin/ bronze.
- Lubrication is achieved by filling the pores of the sintered material with a layer of PTFE with MoS_2 additives.
- The COF is 3 to 25 % depending on the mating surface.
- The trolley wheel has a 4 to 1 wheel/bushing ratio and a smooth to reduce the rolling friction of the trolley on the beams.



Cross section of SKF PTFE composite plain bearings



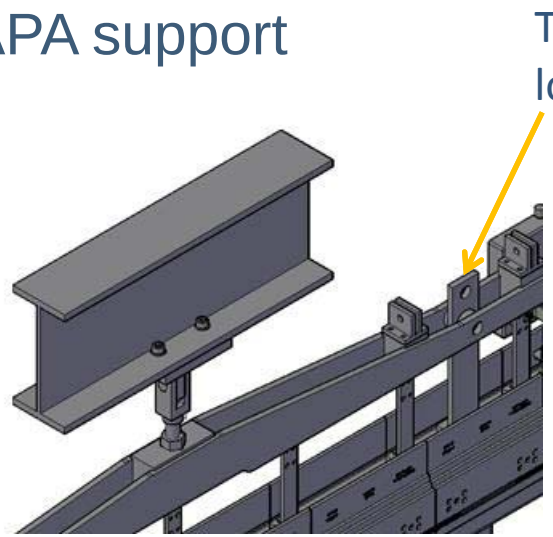
Double trolley

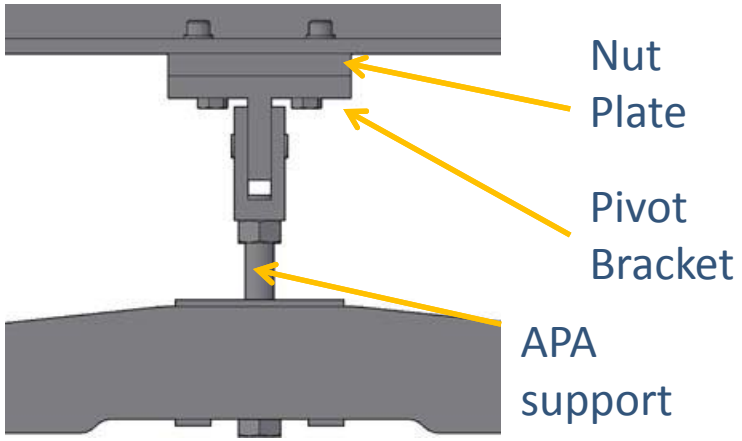


- A double trolley has been designed for locations with loading greater than 1920kg (4000lbs). It is anticipated that this will be needed to support the center of the CPA bridge beam, but will be determined after final load analysis for all configurations
- Assembly consists of the single trolleys connected to a beam on pivots. The pivots ensure that the load is shared between wheels.

Bridge Beam to TPC connections

- APA support

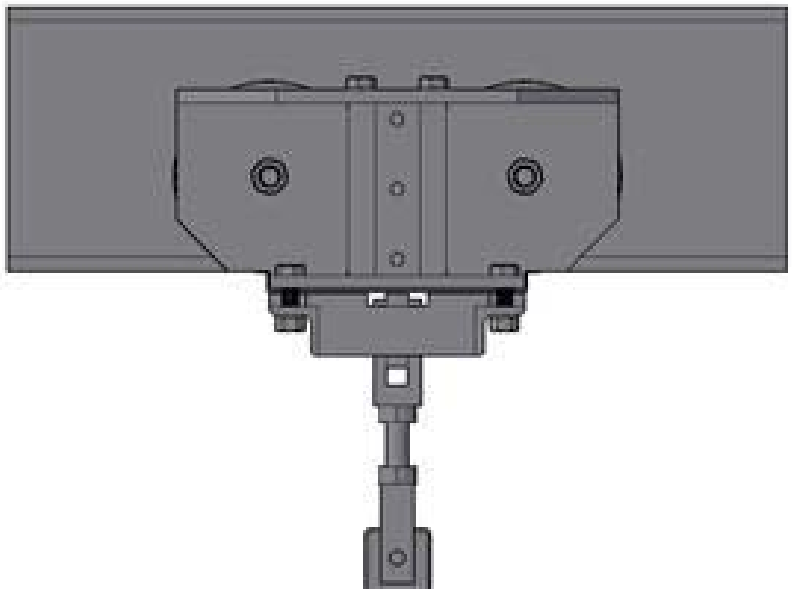




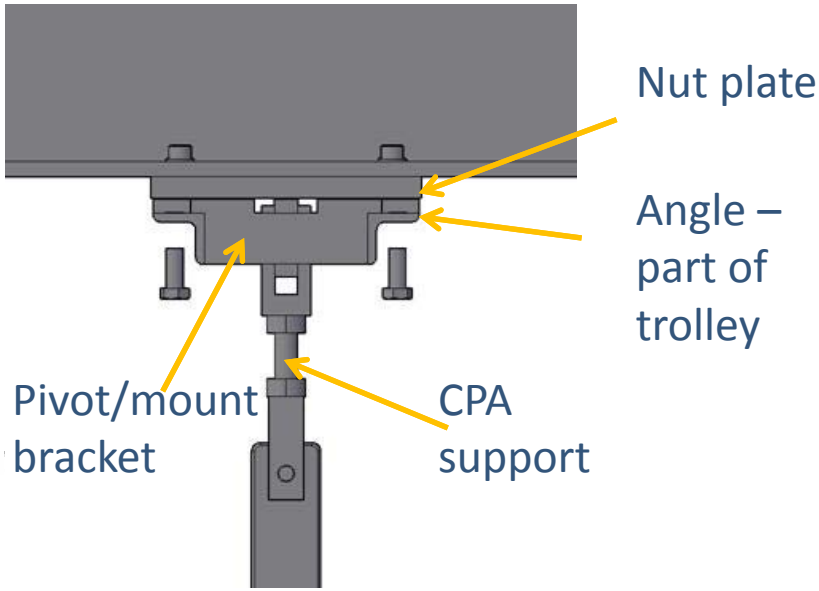
- The APA is delivered on two trolleys to its mount point
- The single permanent connection is made by connecting the mounting bracket to a nut plate
- The load is transferred by adjusting the APA support

Bridge Beam to TPC connections

- CPA support



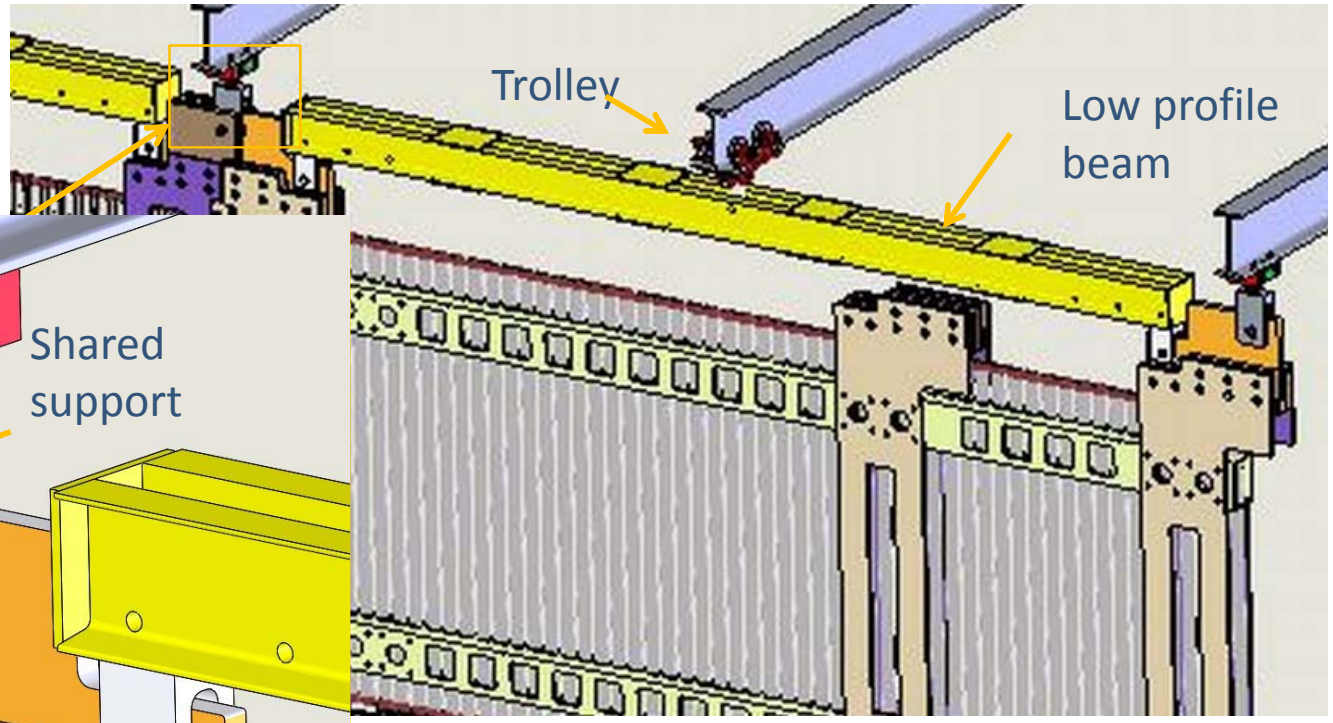
Trolley removed fro clarity

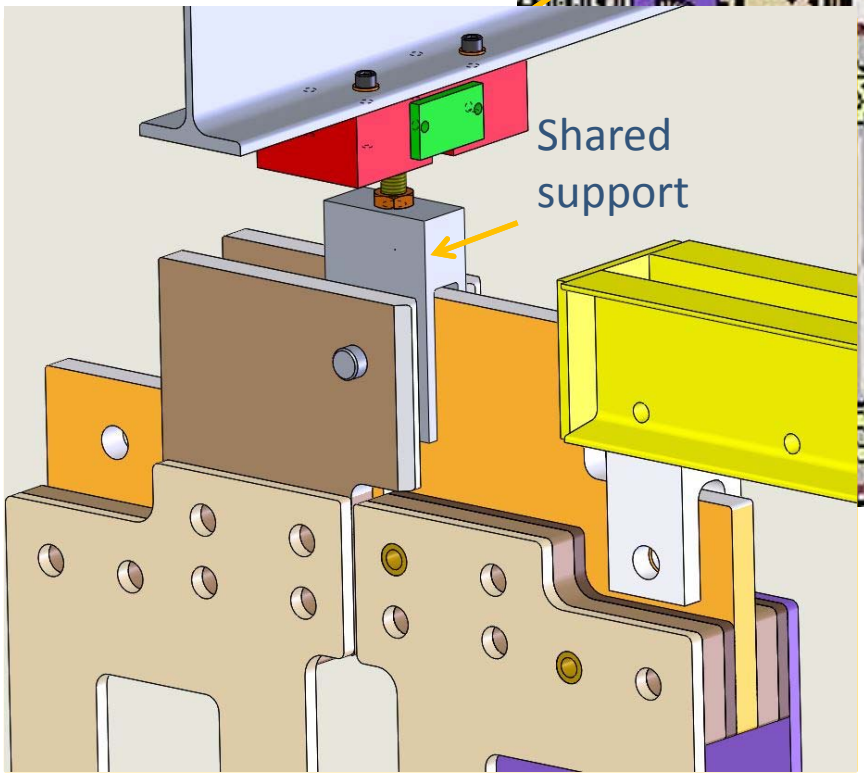


- The CPA is delivered on one trolley that is connected to the its single support point
- The pivot mount bracket is in the load path between the trolley and the CPA support.
- There is clearance between the nut plate and the pivot mount
- Bolting the pivot mount to the nut plate lifts the CPA and takes the load off the trolley.
- The trolley halves could be removed at this time if desired.

Bridge Beam to TPC connections

- EW support



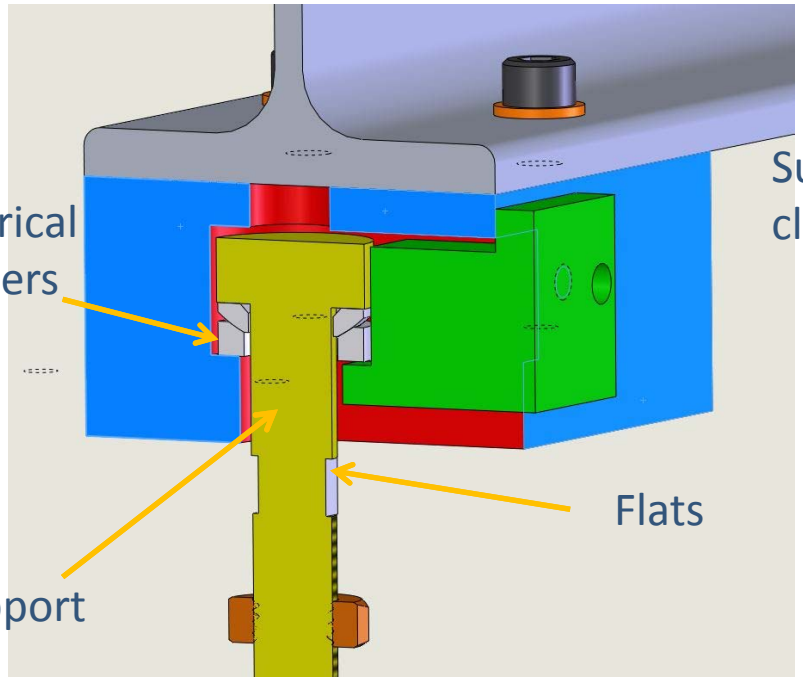


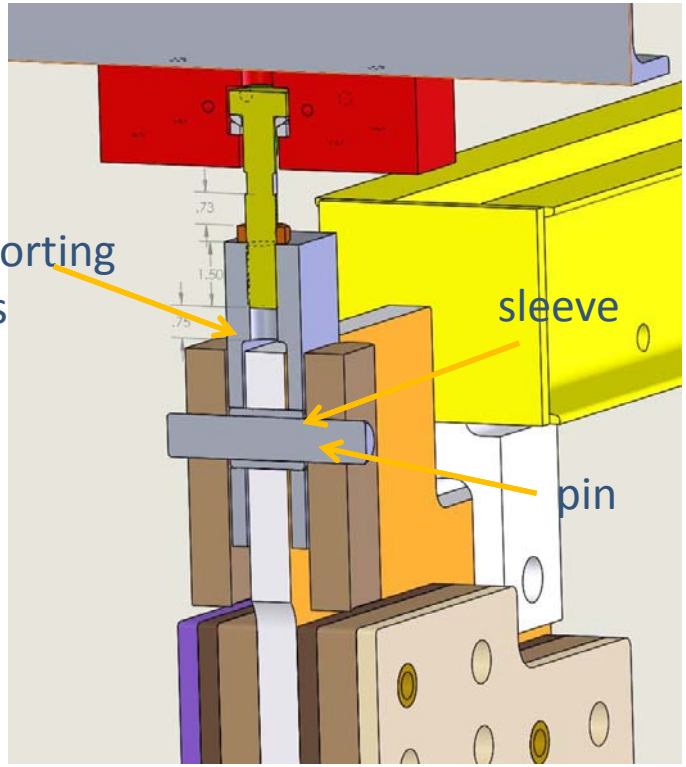
Final configuration

- The end wall is delivered on a low profile beam.
- Once in position its load is transferred to 2 permanent support points on each end.
- The north drift EW is shares the support point with the south drift.

Bridge Beam to TPC connections

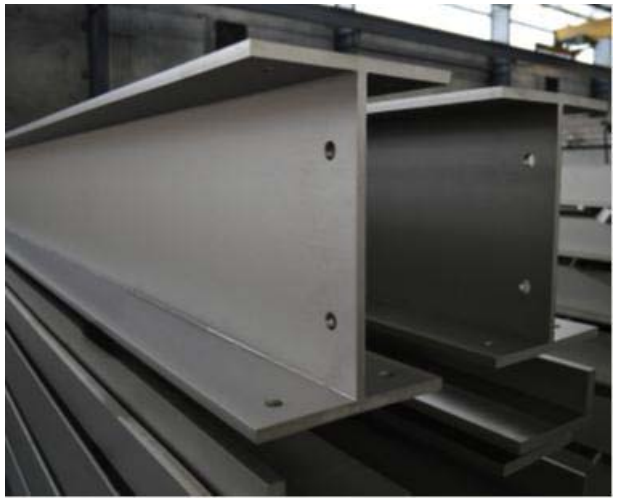
- EW support





- The south drift EW is connected to the supporting clevis using a sleeve
- The EW support is then adjusted to pickup the load.
- When the north drift EW is delivered it is connected to the same clevis with a pin

Materials – I beams



- The base material will be 304L grade stainless steel that conforms to ASTM A1069 (Standard Specification for Laser-Fused Stainless Steel Bars, Plates, and Shapes), ASTM A6 for dimensions and EN 1090, which is requirement for structural steels sold and used in Europe

Materials – I Beams

9004177

Stainless Structurals Works, LLC
575 Conroe Park West Drive
Conroe, Texas 77303

Product			MTR#
S8X18.4			400206
Bundles	PCS #	Weight (lbs)	Lenght (in)
400318	5	1832	240
400319	2	736	240

SHIP TO:
STAINLESS STRUCTURALS LLC
575 Conroe Park West Drive
Conroe, Texas 77303

Grade	PO Nr.	Certificate
304/304L	**3721**	EN 10204 3.1
Melting	Net Weight	Standard
EAF/AOD	**2568**	ASTM A1069

Heats	C	Si	Mn	P	S	Ni	Cr	Mo	Ti	Al	N	Cu
03035D	0.012	0.272	1.768	0.029	0.001	8.047	18.089	0.354	0.000	0.000	0.079	0.488
06047A	0.014	0.236	1.794	0.032	0.001	8.041	18.312	0.315	0.000	0.000	0.079	0.410

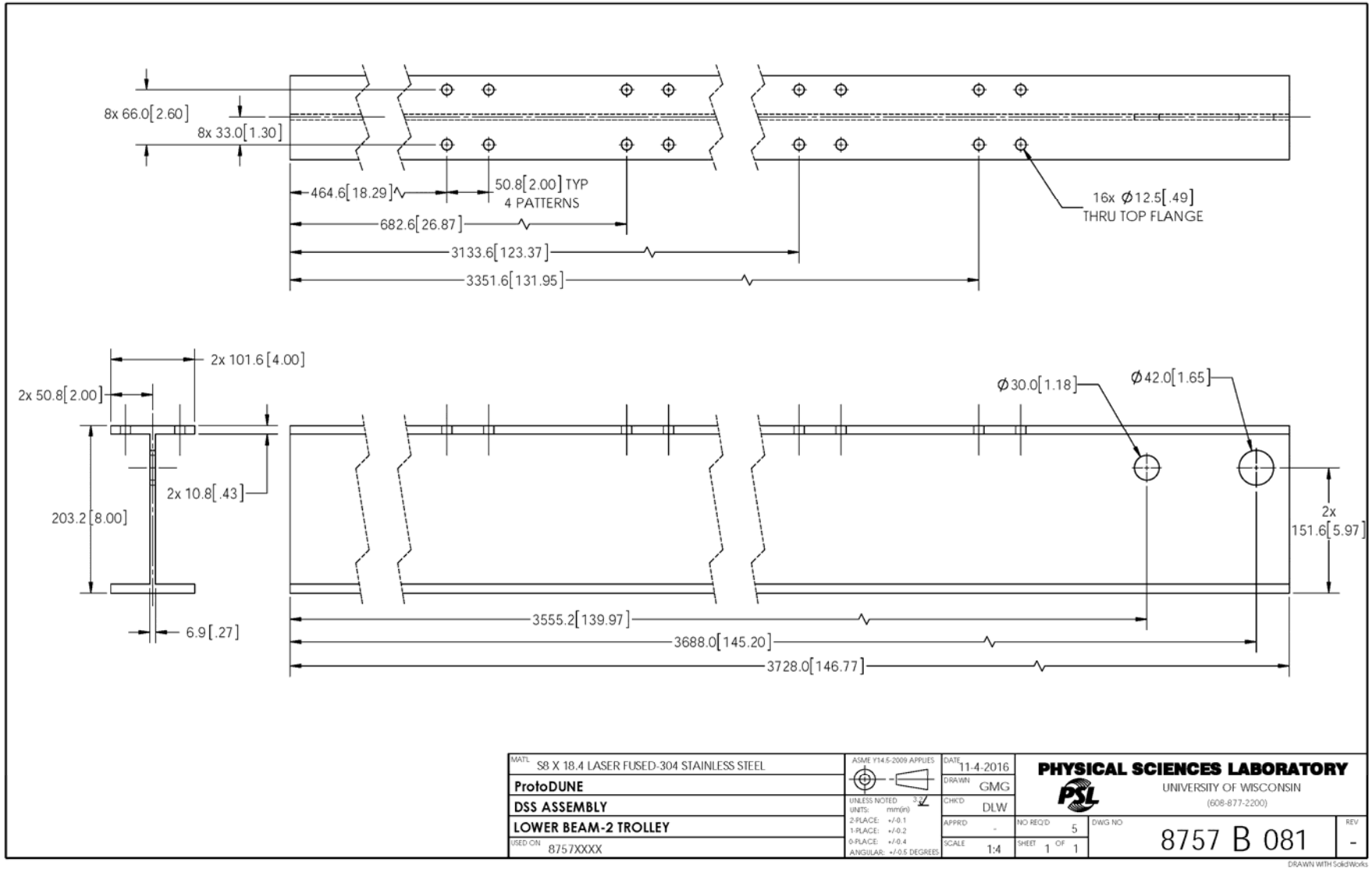
	Rm (KSI)	Rp (KSI)	Rp1% (KSI)	A2%	Z%	HB
03035D	91.76	54.23	0.00	50.52	65.33	160.00
06047A	92.04	52.60	0.00	53.09	65.01	158.00

- We hereby confirm that the material certified in this document is conform to enclosed data sheet
- Anti mixing checked
- No weld repair on base material
- Material free from Mercury and radioactive contamination
- Parent material solution annealed
- Material is produced in compliance with ROHS (2002/95/EC)
- Country of Melt WEB: USA FLANGE: USA
- Country of Manufacturing Origin: USA

MTR date of emission:	08/11/16
The Work's Inspector (signature)	Mike Scott
	Mike Scott

- The beams will be supplied with material compliance and test reports as per EN 10204 3.1

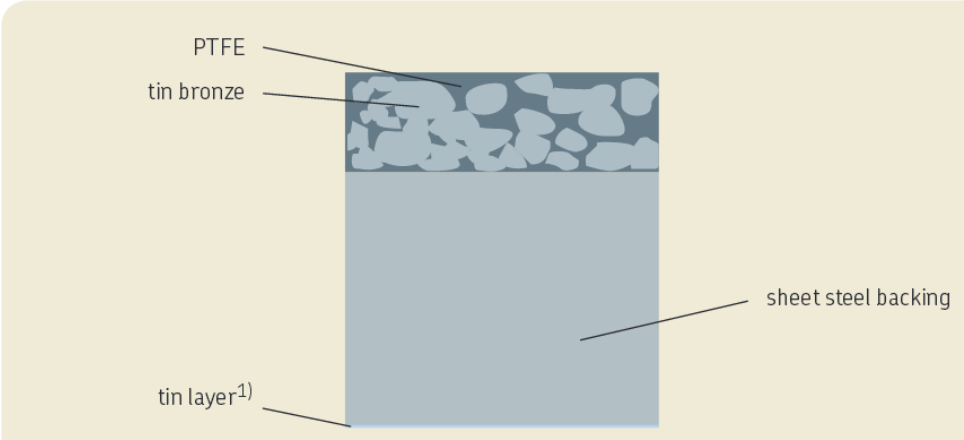
Materials – I Beams



Materials - Trolleys

- CPA and APA bridge trolleys will be all 304 stainless
- Solid bearings are rated for 73K (Many thanks to Giancarlo Spigo for finding these!)
- Will be purity tested

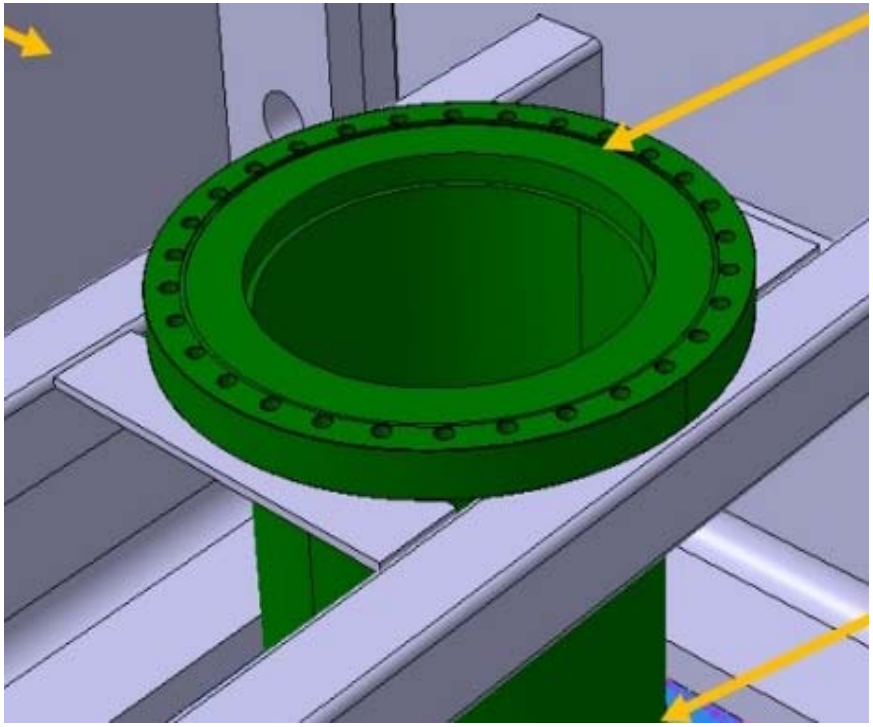
Cross section of SKF PTFE composite plain bearings



- All other trolleys will be steel and use low friction steel roller bearings
- Trolleys will be clean, possibly nickel plated, and bearings will not have lubricant
- Bill Miller has found a vendor who will make trolleys per our specification

Feed through flange connections

- DN250 CF blank flange custom machined to match a 200mm OD tube
- 304 stainless steel.
- Sealed with either standard copper or Viton gaskets.



Fasteners

Silver Plating Spec

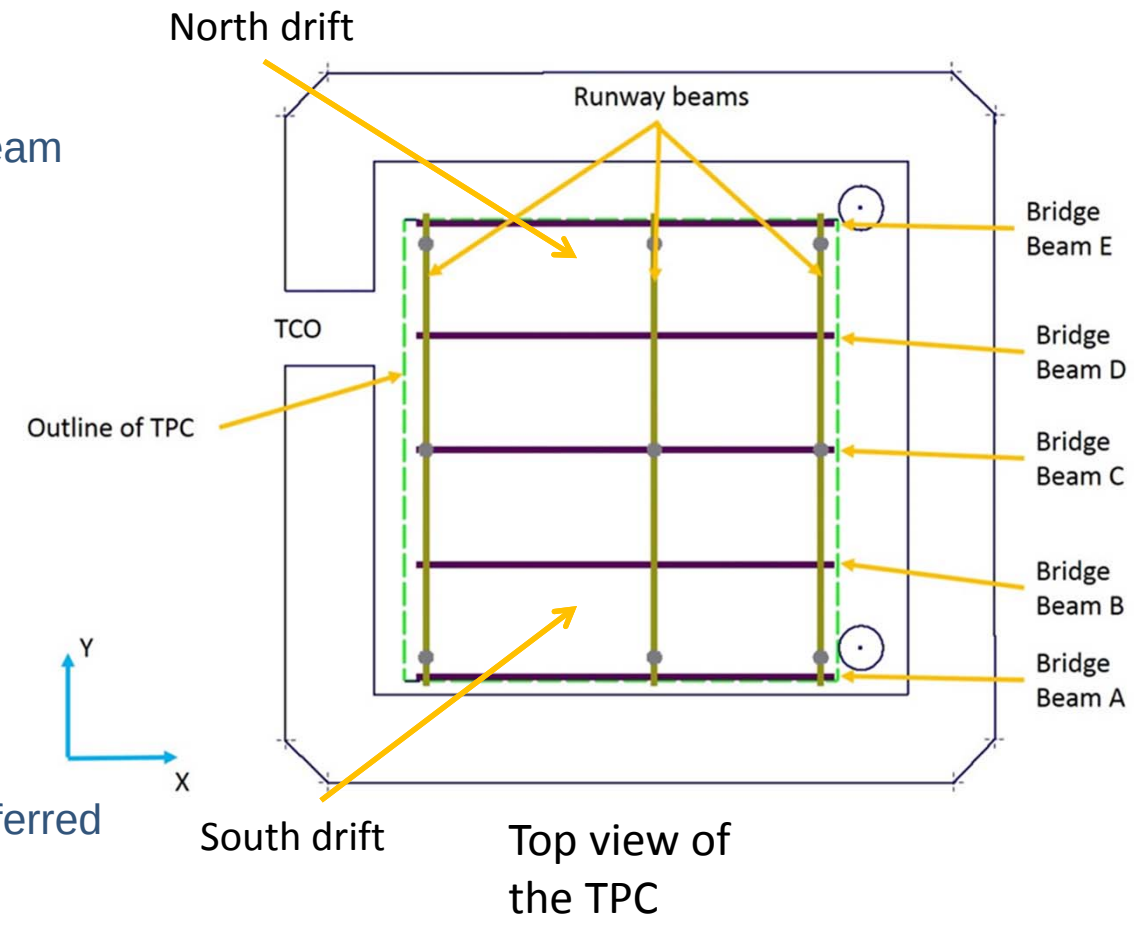
Reference ASTM B700:
Type 2 (99.0% Ag purity), Grade A (matte finish), Class N (no tarnish inhibitive coating), plating to be applied 100 to 300 µin thickness

Loads

Sub assembly	Qty	W -lbs(ea)	W-TOT (lbs)		W -kg(ea)	W-TOT (kg)
CPA panel	6	158	948		72	430
FC Top Panel	6	440	2640		200	1197
FC Bottom panel	6	440	2640		200	1197
FC End Wall panel	4	1400	5600		635	2540
Beam Plug	1	100	100		45	45
APA panel	6	791	4745		359	2152
Support structure	1	4397	4397		1995	1995
GRAND TOTAL			**21071**			**9557**

Summary of the installation process

- South Drift
  - APAs delivered on Beam A
  - EWs delivered on Beam B
  - CPAs with FCs delivered on Beam
  - EW load transfer
  - South Drift FCs are deployed
- North Drift
  - APAs stored on Beam E
  - EWs stored on Beam D
  - TCO is closed
  - EW (TCO) is delivered
  - APAs positioned
  - EW (TCO) load transfer
  - Last EW is delivered and transferred
  - North Drift FCs are deployed



Top view of the TPC

Load Cases

- Important to consider all the installation load cases
- It is sometimes clear that a configuration is not a worse case load, but there are other times when it is not so clear.
- Must also be aware of possible, but unplanned configurations.
- Load cases will be considered for each component starting at the TPC and working towards the support flange.

Trolley loads

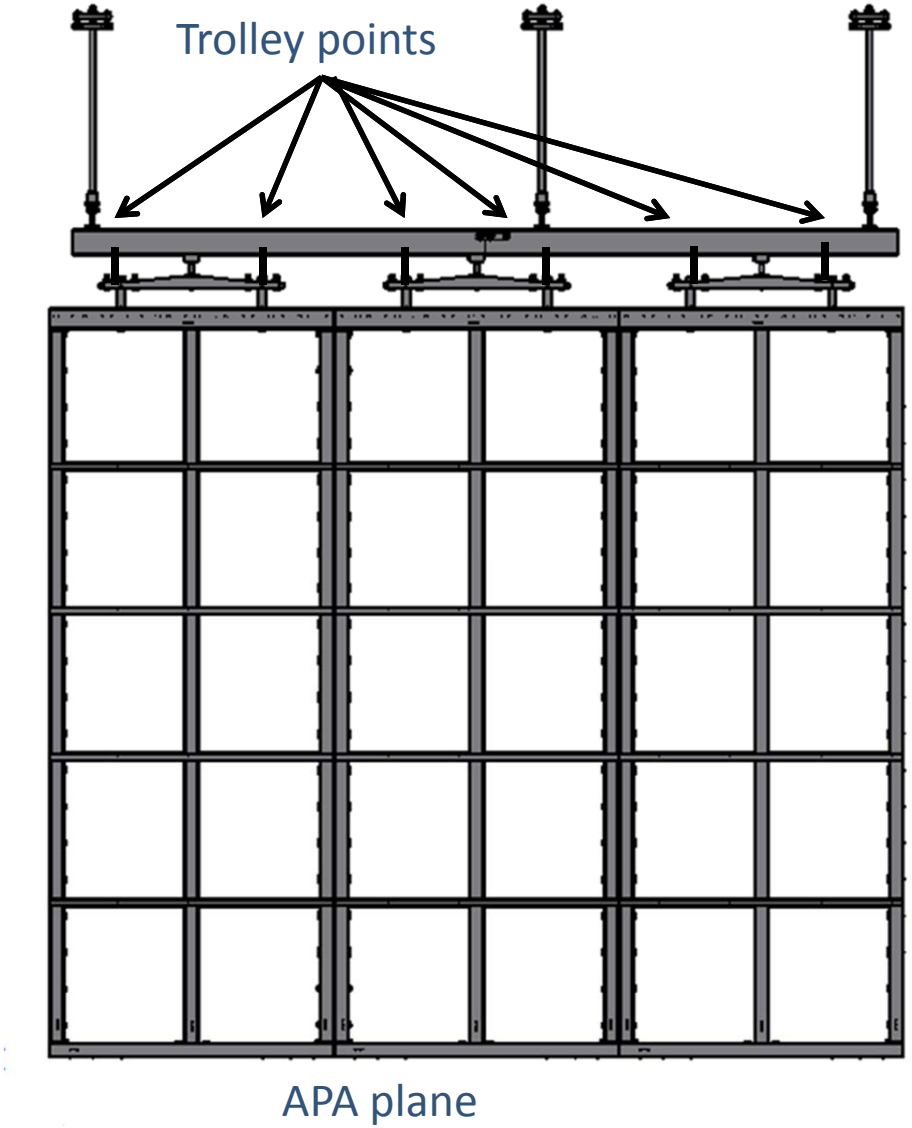
- APA, CPA and EW trolleys are directly loaded and easier to determine:
  - APA is 180kg (400lbs)
  - CPA wFC is 471kg (1038lbs)
  - EW is 636kg (1400lbs)
- 1 ton rated trolley

Bridge Beam Loads

- Five identical bridge beams
- Highest stresses are found on the longest spans and heaviest load.
- Three cases to check
  - EW cantilevered into position
  - EW on the longest span
  - Three CPA trolleys on the longest span
- Stresses and deflections for these two cases will be added to the design document.

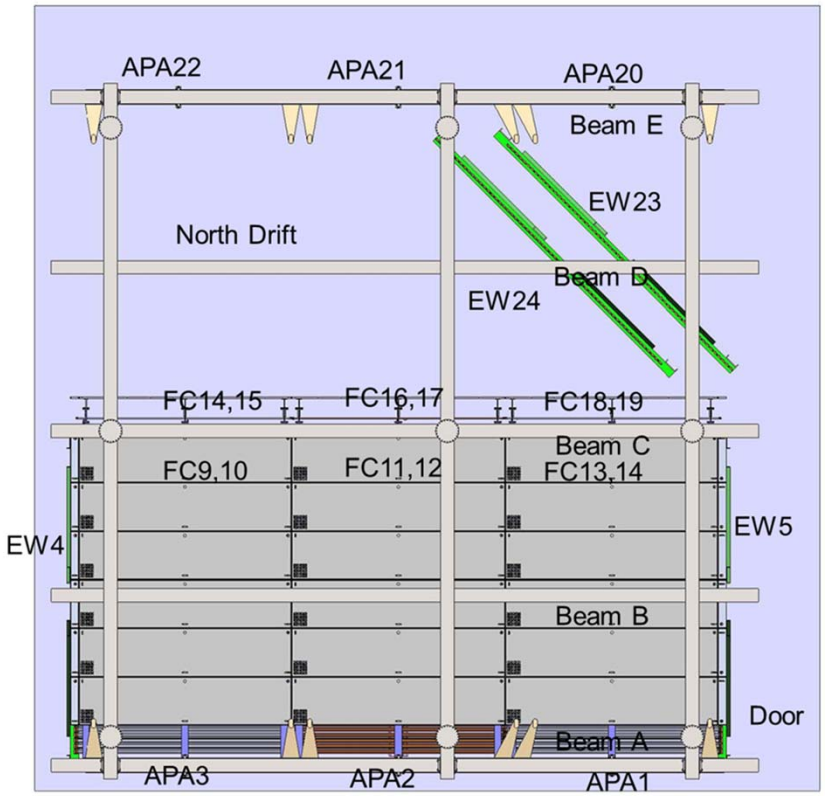
Bridge to Runway – Beam Trolleys

- APA beam is not a worst case
  - APA load points are the same as the CPA load points, but the loads are lighter



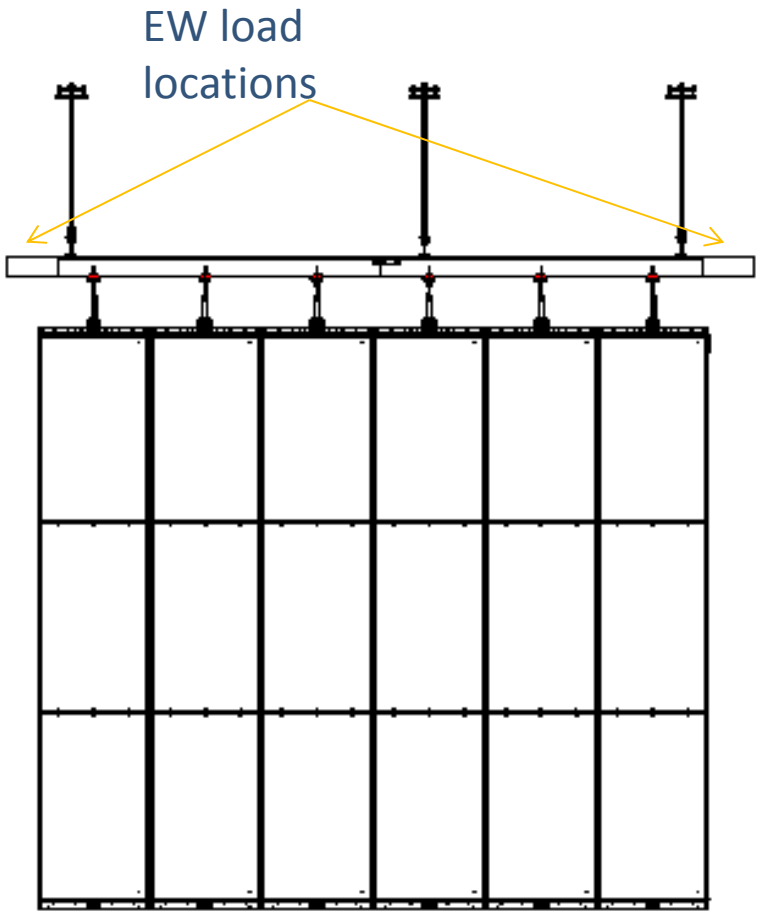
Bridge to Runway – Beam Trolleys

- The EW beam needs to be checked
  - It is possible to have both EW's near each under and under a single trolley.



Bridge to Runway – Beam Trolleys

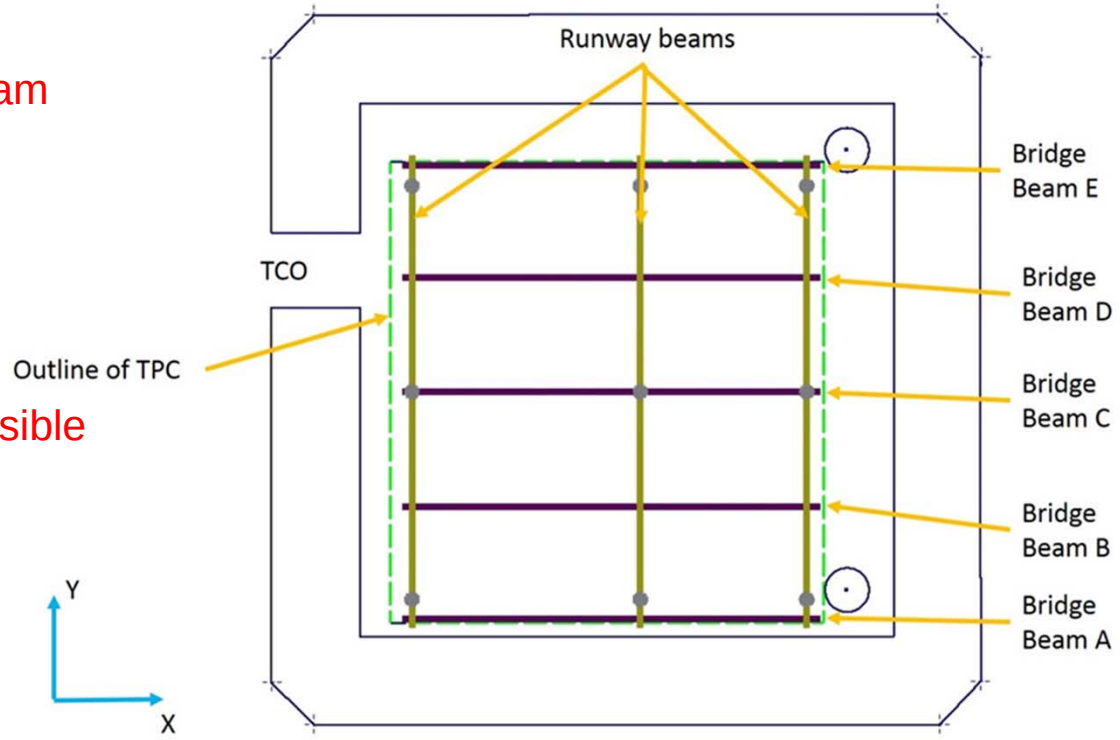
- The CPA load on the beam is the heaviest and needs to be checked
  - The load on the center trolley will be highest before the EW load is transferred
  - The load on the outer trolleys will be the highest after the EW load is transferred



CPA plane with out FC

Runway beam to hanger

- South Drift
  - APAs delivered on Beam A
  - EWs delivered on Beam B
  - CPAs with FCs delivered on Beam
  - EW load transfer
  - South Drift FCs are deployed
- North Drift
  - APAs stored on Beam E
  - EWs stored on Beam D (All possible locations)
  - TCO is closed
  - EW (TCO) is delivered
  - APAs positioned
  - EW (TCO) load transfer
  - Last EW is delivered and transferred
  - North Drift FCs are deployed



***Will analyze all load cases shown in red

Required Analysis

- Currently reviewing EN 1993 as a guide
- Define maximum loads on DSS components for all load cases.
- Stresses in bridge beam due to Trolleys hanging on the bottom flange
- Stresses in the bridge beam from bending
- Stresses in beams and trolleys at the beam to beam connections
- Stresses in the runway beam from bending
- Stresses at the connection of the support rod to the runway beam
- Stresses in the hanger assembly
- Deflections at the TPC subassembly support points.

Note: Some of this has been done already, but needs to be rerun because of design modifications and for final loads

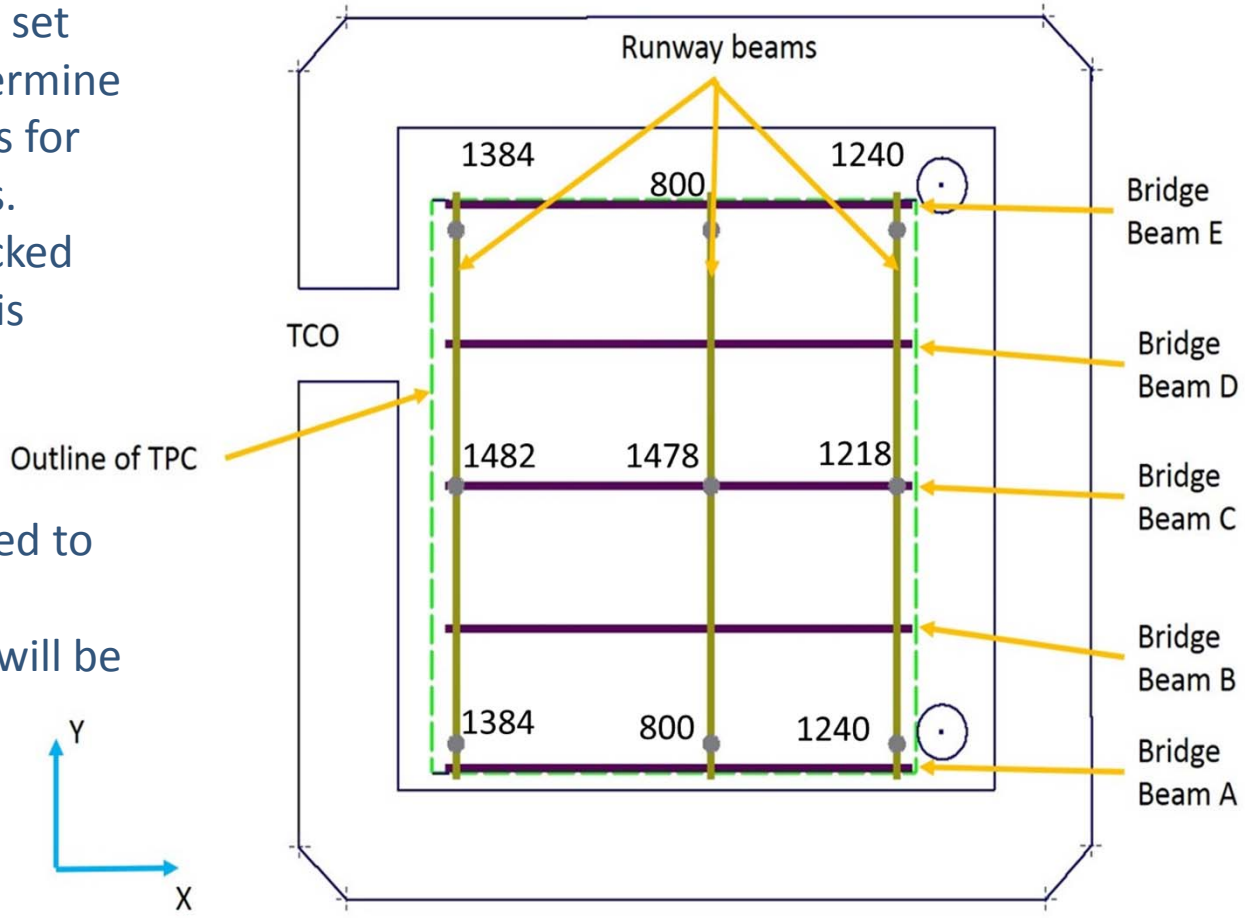
Load Analysis

Loads

- Math CAD file has been set up to evaluate and determine all the component loads for all important load cases.
- This output will be checked with a structural analysis package by Vic Guarino

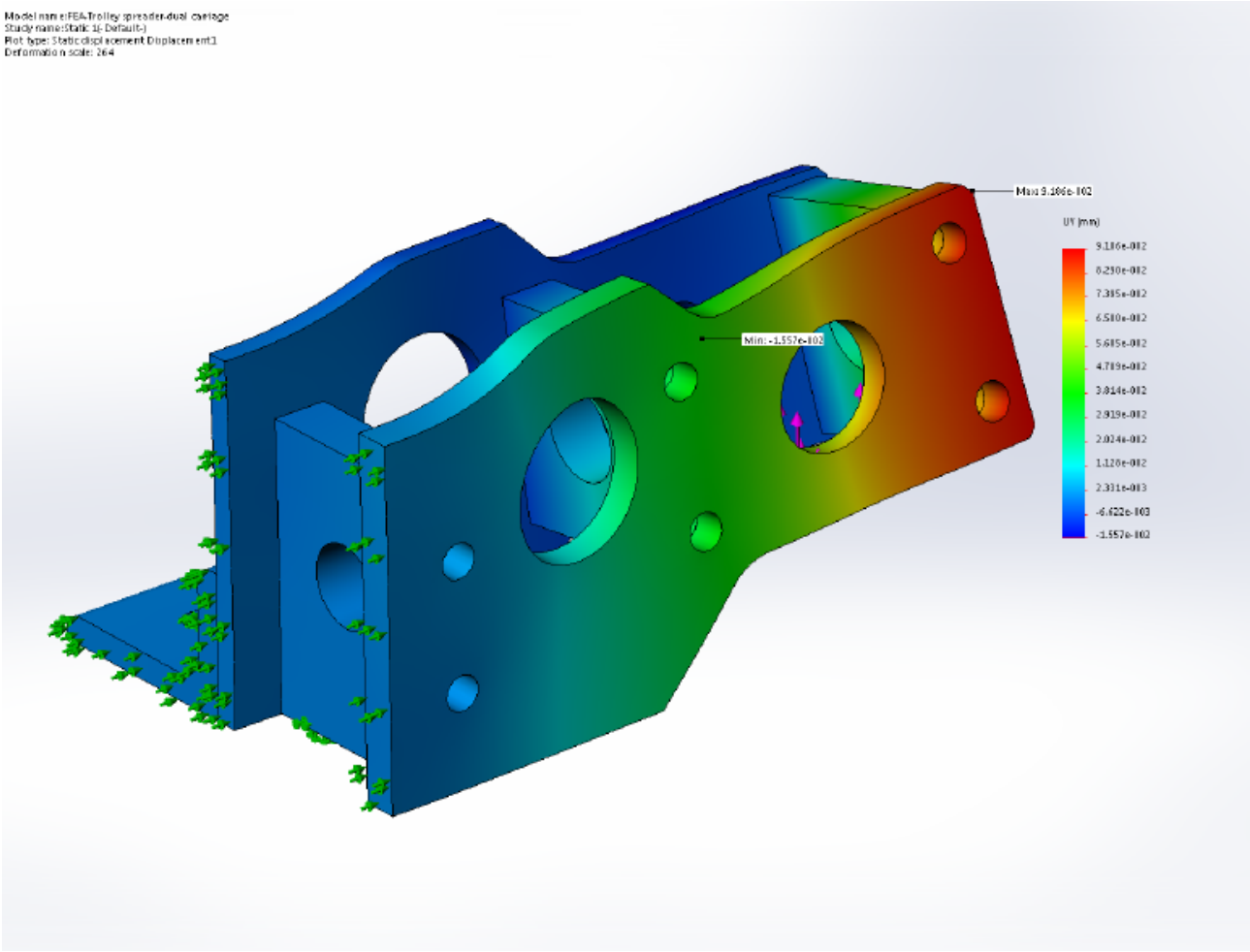
Deflections

- Vic's package will be used to calculate deflections. Deflection calculations will be checked by FEA



Loads (kgs) – Final configuration dry

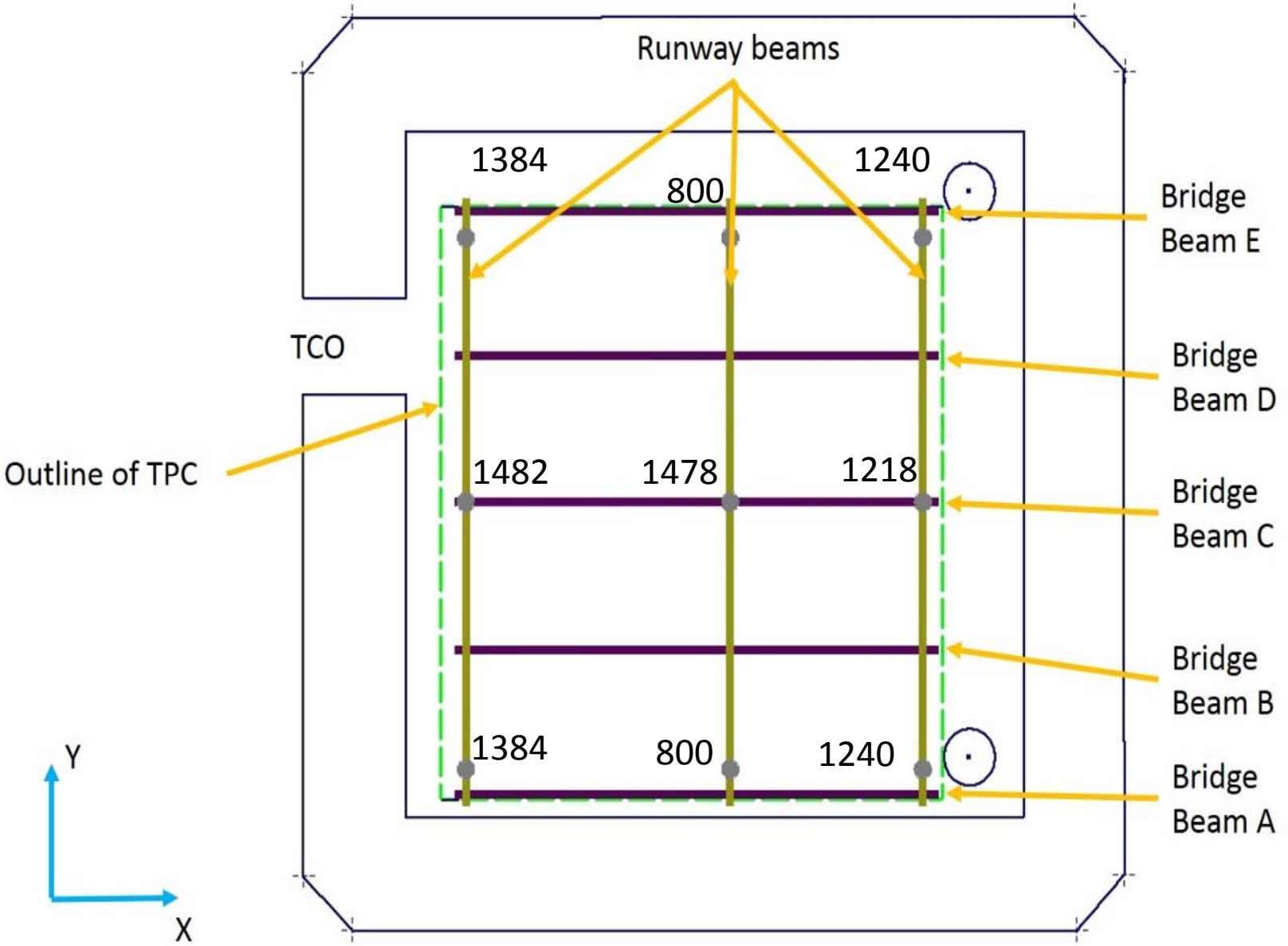
Example of stress analysis –
Double trolley beam



Max stress is 6.5 MPa

Back up slides

Load Analysis



Example of strain analysis