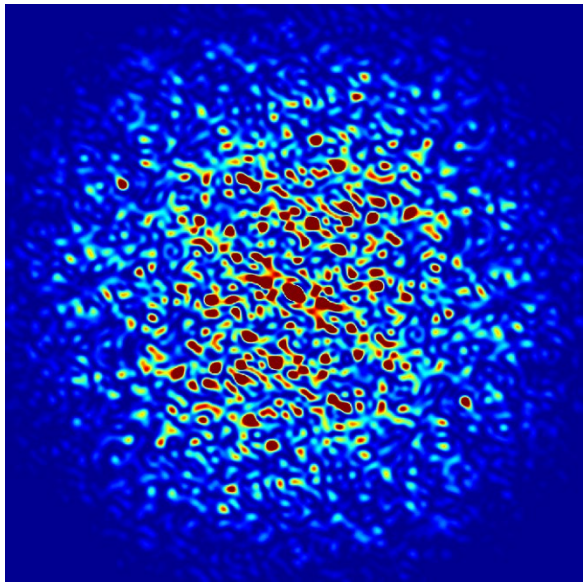
APS-U Horizontal Injection BTS Line Magnets



JIE LIU

Mechanical Engineer

Outline

- Mechanical Design of the BTS line
  - Layout
  - Magnets
  - Survey and Alignment
  - Vacuum systems
  - Diagnostics
  - Support tables
  - Modules
- Interfaces
- Documentation for production and procurement
- Safety and Quality
- Summary

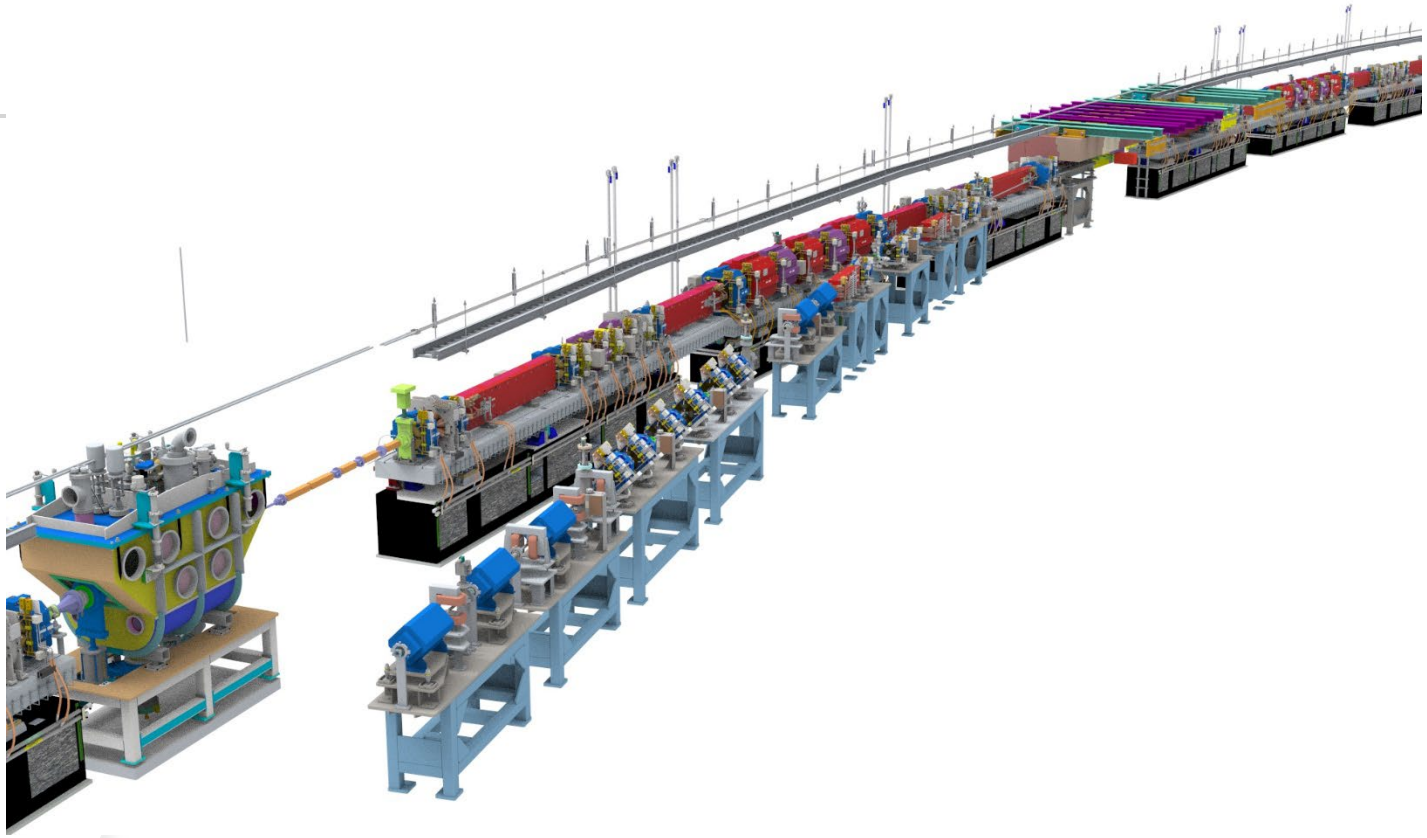
Horizontal Injection BTS – Design Process

Concept
- Feasibility study
- Lattice design
- Specifications

Functional Design
- Magnetic design
- Vacuum Design
- Diagnostics system design

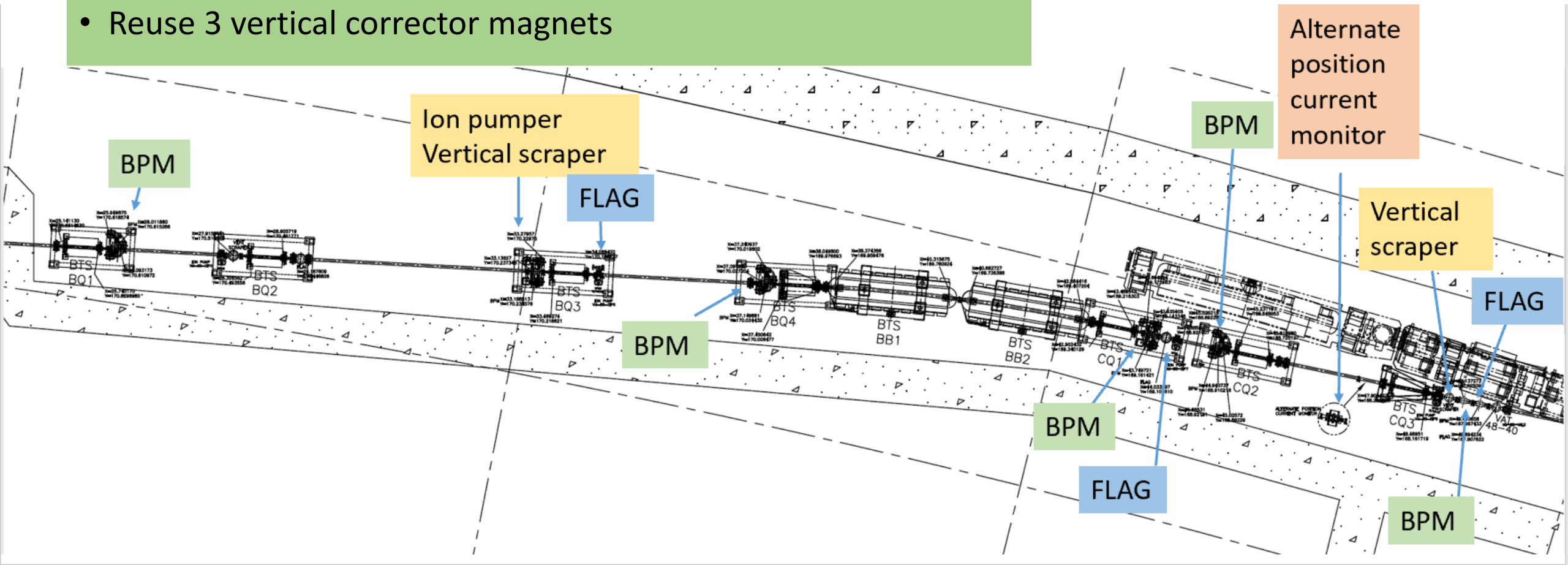
Mechanical design
- Magnet mechanical design
- Vacuum system component design
- Diagnostics components
- Support tables

Iterative



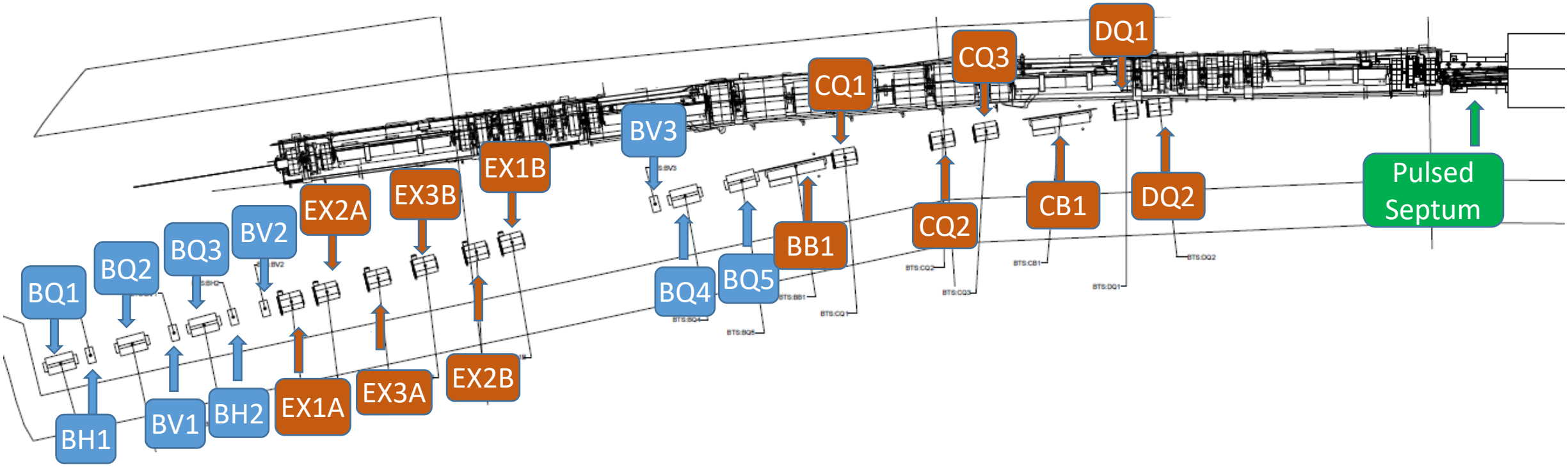
Current APS BTS Transfer line

- Complete removal
- Reuse 5 quadruple magnets BQ1, BQ2, BQ3, BQ4, CQ1
- Reuse 2 horizontal corrector magnets
- Reuse 3 vertical corrector magnets



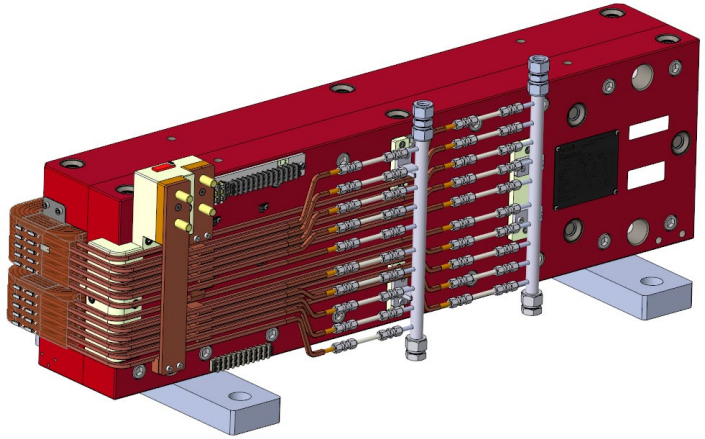
Horizontal Injection BTS – Layout (Magnets)

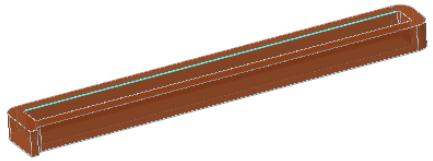
- **10 normal quadruples**
  - **BQ1 – BQ5 (reuse)**
  - **CQ1 – CQ3 (with corrector coils)**
  - **DQ1, DQ2 (with corrector coils)**
- **6 skew quadruples with corrector coils**
  - **EX1A-EX3A**
  - **EX3B-EX1B**
- **2 dipoles - new**
- **3 vertical correctors (reuse)**
- **2 horizontal correctors (reuse)**

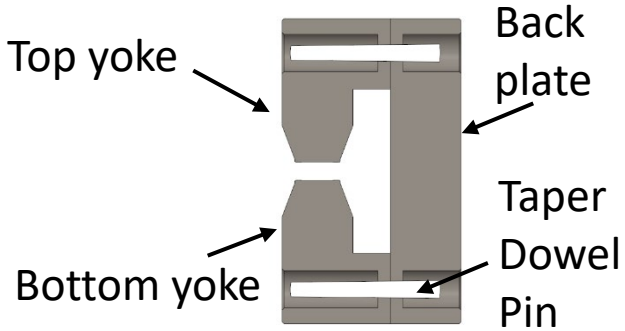


Horizontal Injection BTS Components – Dipole Magnets

- Design and interfaces are consistent with SR magnets
- Same design for BB1 and CB1
- Three-piece yoke design
- Each coils include 5 coil packs
  - Peek tubing for insulation
  - Standard Parker fittings
  - Input to inner and exit from outer turner
- Power connections
  - Bolted connections for easy separation
  - Thermo-switches for power interlock
  - One TC for temperature monitoring
- Survey and alignment







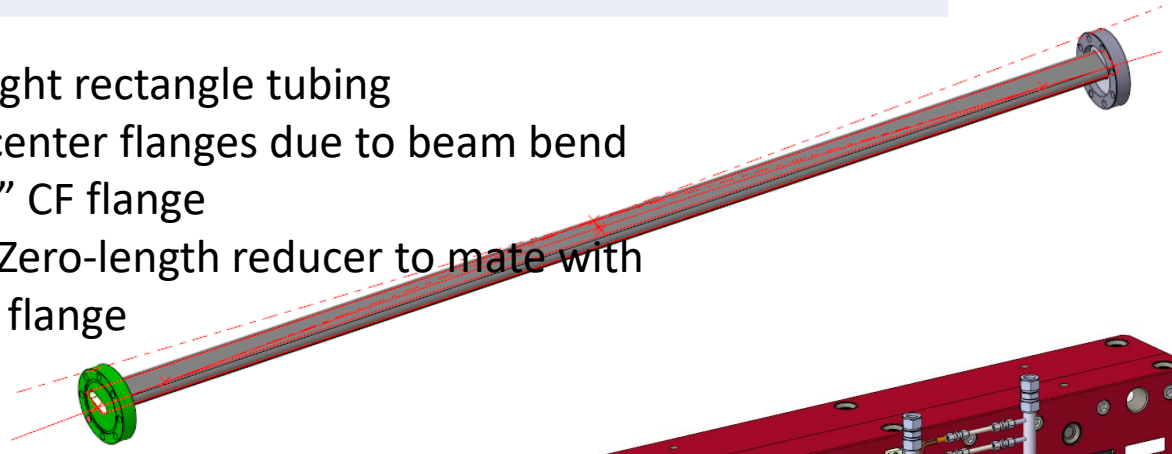
CB1 Selected Parameters

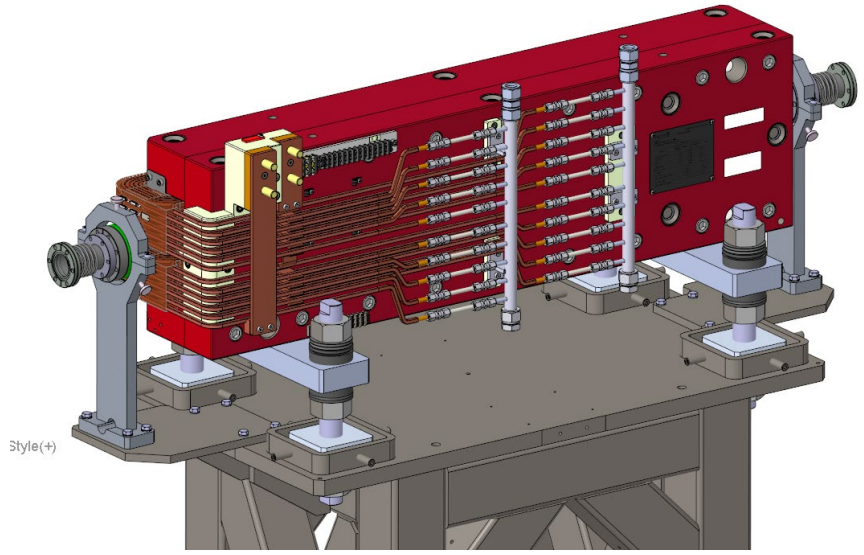
CB1 Dipole Parameters		
Effective arc length	1.112	m
Insertion length	1.18	
Dipole Field	1.41	T
integrated Dipole field	1.57	T-m
Beam Energy	6	GeV
Beam Stay Clear x	8.8	mm
Beam Stay Clear y	4.9	mm
Bend Angle	0.07846	radians
Sagitta	10.2	mm
Vertex	15.28	mm
Vertical vacuum chamber aperture min	9.8	mm
Horizontal vacuum chamber aperture min	27.8	mm
Gap	18	mm
Good Field Width (GFW)	16	mm
Allowed roll off at GFW edges	0.001	G-cm/G-cm
Core length	1.02	m
		From Physics
		Calculated
		Selected

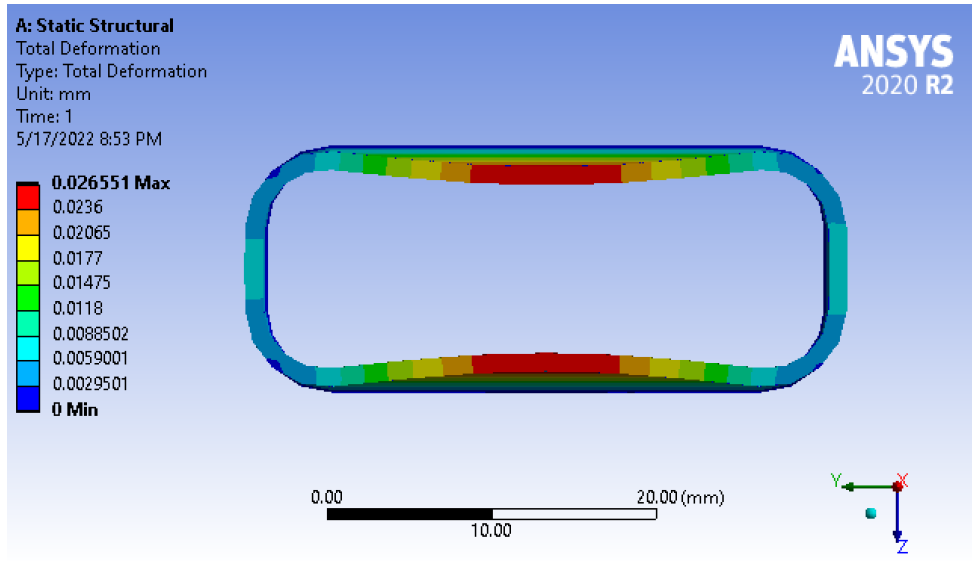
Horizontal Injection BTS Components – Dipole Vacuum Chamber

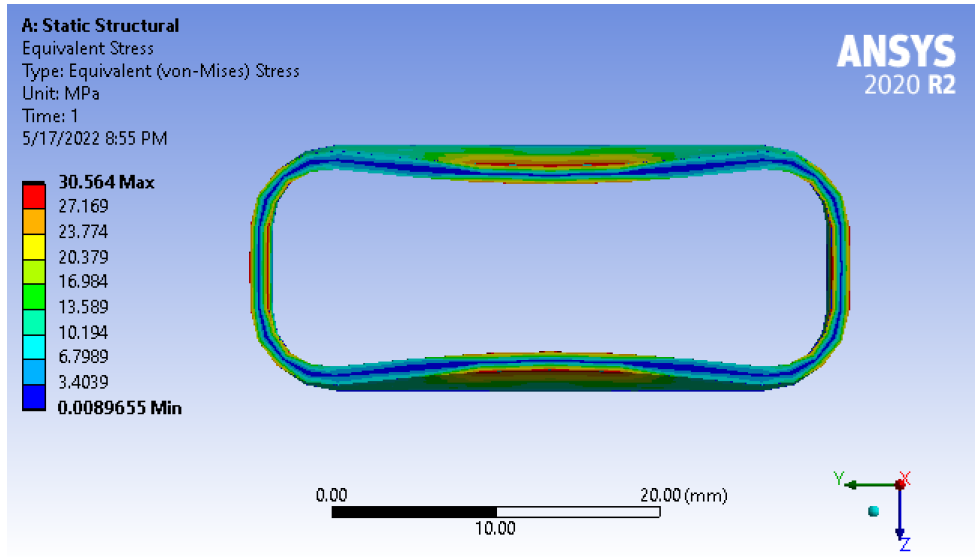
Inside height	12.78	mm	0.503	inches
Inside width	33.78	mm	1.33	inches
Wall thickness	1.11	mm	0.044	inches
Material: 316L Stainless Steel				

- Straight rectangle tubing
- Off center flanges due to beam bend
- 3.38” CF flange
- Use Zero-length reducer to mate with 2.75 flange



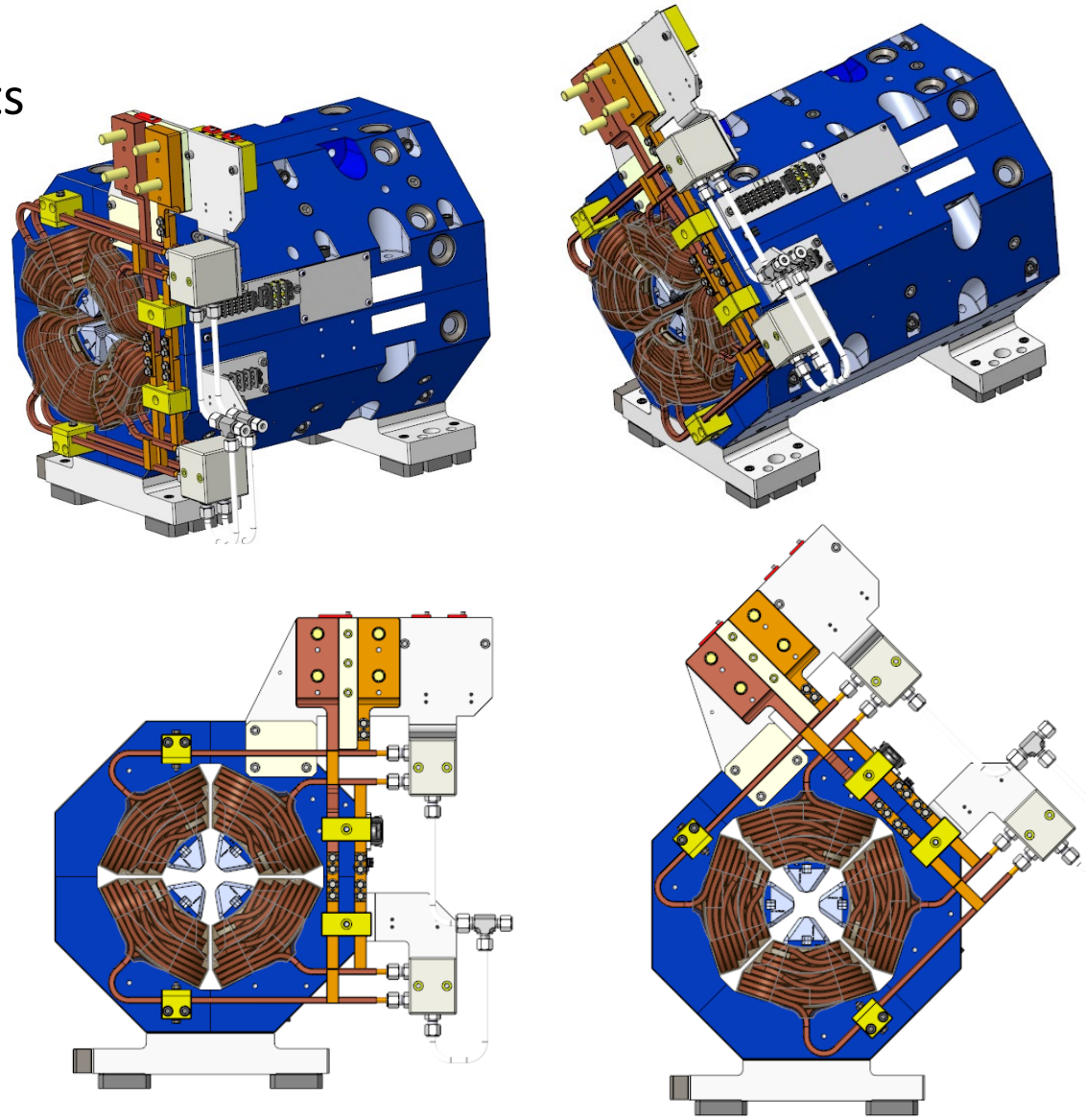






Horizontal Injection BTS Components – Normal and Skew Quadrupole Magnets

- Design and interfaces are consistent with SR magnets
- Same design for 3 CQs and 2 DQs
- Eight-piece yoke design
- All coils include corrector coils
  - Standard Parker fittings
  - Input to inner and exit from outer turn
- Power connections
  - Bolted connections for easy separation
  - Thermo-switches for power interlock
  - One TC for temperature monitoring
- Survey and alignment



HBTSU Quadrupole Magnet Specifications

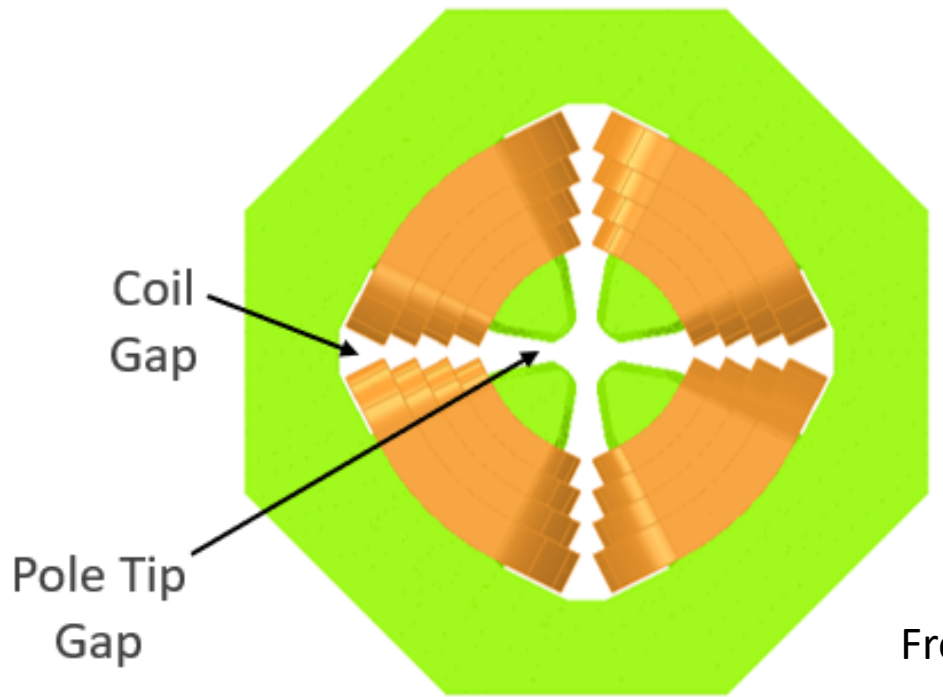
Table 2: Quadrupole parameters

Name	Type	Eff. Length m	K1 $1/m^2$	B1 T/m	B1L T
BTS:CQ1	NewQuad	0.429	1.106591	-22.147	-9.499
BTS:CQ2	NewQuad	0.429	-1.940519	38.837	16.658
BTS:CQ3	NewQuad	0.429	-0.788443	15.780	6.768
BTS:DQ1	NewQuad	0.429	2.502067	-50.076	-21.479
BTS:DQ2	NewQuad	0.429	-2.289819	45.828	19.657
EXQ1A	SkewQuad	0.429	-1.950012	39.027	16.746
EXQ1B	SkewQuad	0.429	-1.950012	39.027	16.746
EXQ2A	SkewQuad	0.429	2.830455	-56.648	-24.307
EXQ2B	SkewQuad	0.429	2.830455	-56.648	-24.307
EXQ3A	SkewQuad	0.429	-2.826161	56.562	24.271
EXQ3B	SkewQuad	0.429	-2.826161	56.562	24.271

Physics specifications		
Effective length	429	mm
Max integrated gradient	24.307	T
Min integrated gradient	6.768	T/m
gradient strength margin	+/-10	%
Max x and y corrector deflection	0.35	mrad
Electron beam energy	6	GeV
Max beam stay clear x	9.8	mm
Max beam stay clear y	7.3	mm
Magnet alignment	150	microns
Max allowed harmonics at 10 mm R	100	units

Magnet Specifications		
Insertion length	482	mm
Aperture	26.0	mm
Max required integrated gradient	26.7	T
Min required integrated gradient	6.1	T
Max integrated corrector	0.0077	T-m

+/-10% operating range



From Mark Jaski

Horizontal Injection BTS Components –Power Supply for Magnets

- New PS for all magnets
- Magnet Polarity identified with red tag
- Magnet has grounding point
- 7 different PS model with different quantities

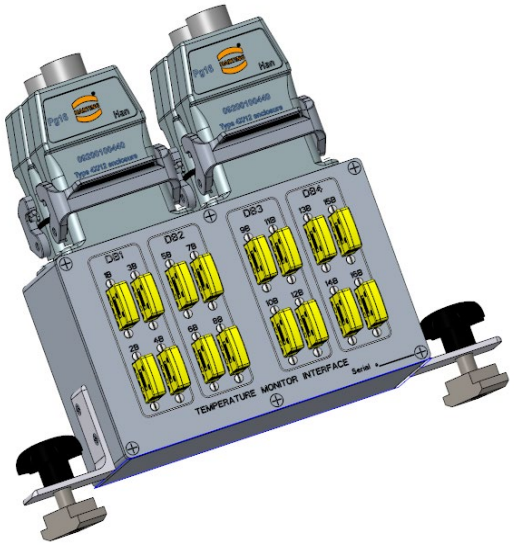
Qty.	MFR.	Model
2	TDK-Lambda	G20-50-U
2	TDK-Lambda	G20-85-1P208
7	TDK-Lambda	GEN30-56-3P208
3	TDK-Lambda	G30-170-3P208
1	TDK-Lambda	GEN40-68-3P208
6	TDK-Lambda	GSP40-250-3P208
2	TDK-Lambda	GSP60-170-3P480
2	TDK-Lambda	GSP80-390-3P480
13	APS-U	DCB-15

Tables from Byron Jordan

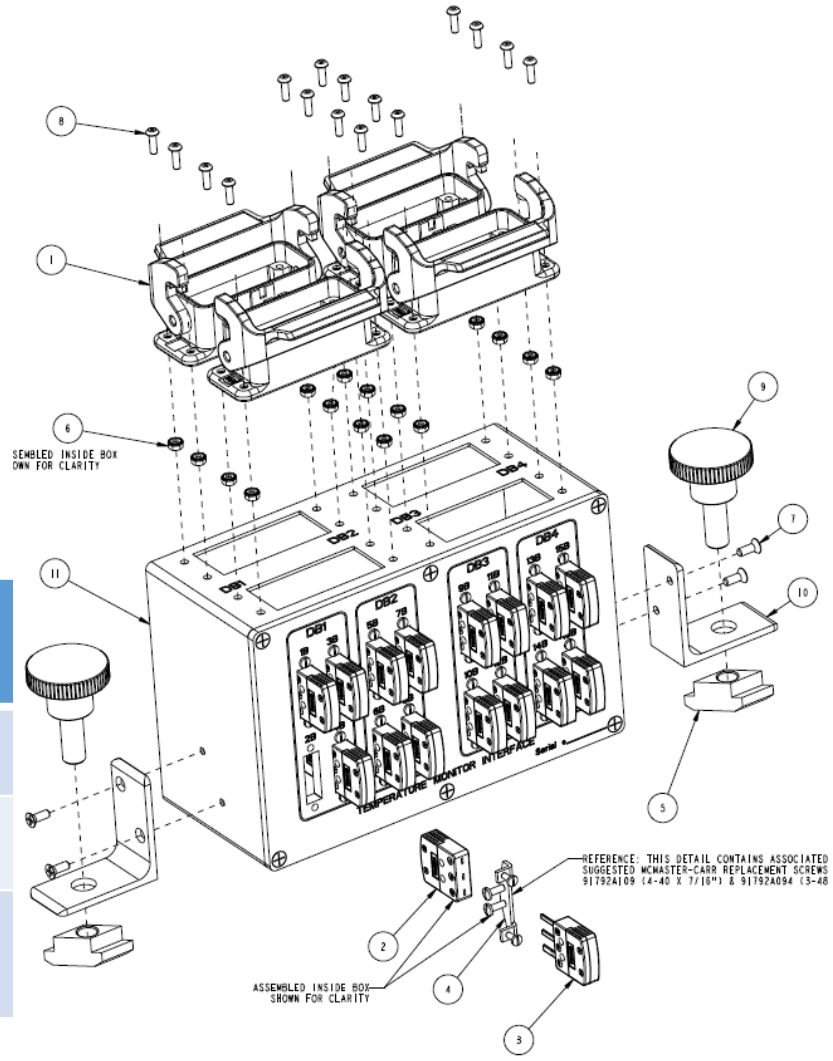
		Power Supply Ratings			AC Feed					
Magnet Name	Rack Location	Power Supply	Operational Power (W)	Rated Power	Panel Name	Circuit Number	...put Voltage (VAC)	...b. Phases	...Size (A)	...Trip Rating (A)
BTS:AQ1	HET RR6	GEN30-56-1P208	436	1.7E+3	TRP-R3	ckt.1,3	208	1	15	20
BTS:AQ2	HET RR6	GEN30-56-1P208	498	1.7E+3	TRP-R3	ckt.2,4	208	1	15	20
BTS:AQ3	HET RR6	GEN30-56-1P208	448	1.7E+3	TRP-R3	ckt.5,7	208	1	15	20
BTS:AQ4	HET RR6	GEN30-56-1P208	441	1.7E+3	TRP-R3	ckt.6,8	208	1	15	20
BTS:AQ5	HET RR6	G20-50-U	146	1.0E+3	TRP-R3	ckt.9,11	208	1	15	20
BTS:BQ1	HET RR6	G20-50-U	67	1.0E+3	TRP-R5	ckt.1,3	208	1	15	20
BTS:BQ2	HET RR1	GEN40-68-3P208	980	2.7E+3	TRP-R5	ckt.5,7,9	208	3	15	20
BTS:BQ3	HET RR1	GEN30-56-1P208	698	1.7E+3	TRP-R5	ckt.11,13	208	3	15	20
BTS:BQ4	HET RR1	GEN30-56-1P208	833	1.7E+3	TRP-R5	ckt.15,17	208	3	15	20
BTS:BQ5	HET RR1	GEN30-56-1P208	752	1.7E+3	TRP-R5	ckt.19,21	208	3	15	20
BTS:BB1	BTS:RBO	GSP-80-390-3P480	16.5E+3	31.2E+3	TDP-R2	ckt.1,3,5	480	3	100	110
BTS:CB1	BTS:RSR	GSP-80-390-3P480	16.5E+3	31.2E+3	TDP-R2	ckt.2,4,6	480	3	100	110
BTS:EXQ1A	HET RR2	G30-170-3P208	1.9E+3	5.1E+3	TRP-R5	ckt.14,16	208	3	20	25
BTS:EXQ1B	HET RR2	G30-170-3P208	1.9E+3	5.1E+3	TRP-R5	ckt.18,20	208	3	20	25
BTS:EXQ2A	HET RR2	GSP40-250-3P208	4.0E+3	10.0E+3	TRP-R5	ckt.22,24	208	3	40	45
BTS:EXQ2B	HET RR3	GSP40-250-3P208	4.0E+3	10.0E+3	TRP-R5	ckt.26,28	208	3	40	45
BTS:EXQ3A	HET RR3	GSP40-250-3P208	3.7E+3	10.0E+3	TRP-R5	ckt.30,32	208	3	40	45
BTS:EXQ3B	HET RR3	GSP40-250-3P208	3.7E+3	10.0E+3	TRP-R5	ckt.34,36	208	3	40	45
BTS:CQ1	HET RR1	G20-85-1P208	556	1.7E+3	TRP-R5	ckt.2,4	208	1	15	20
BTS:CQ2	HET RR2	G30-170-3P208	1.5E+3	5.1E+3	TRP-R5	ckt.6.8	208	3	20	25
BTS:CQ3	HET RR3	G20-85-1P208	386	1.7E+3	TRP-R5	ckt.10,12	208	1	15	20
BTS:DQ1	HET RR3	GSP40-250-3P208	3.0E+3	10.0E+3	TRP-R5	ckt.23,25	208	3	40	45
BTS:DQ2	HET RR3	GSP40-250-3P208	2.6E+3	10.0E+3	TRP-R5	ckt.27,29	208	3	40	45
BTS:RBO	HET RR4	GSP-60-170-3P480	5.7E+3	10.2E+3	TDP-R3	ckt.19,21,23	480	3	20	25
BTS:RSR	HET RR5	GSP-60-170-3P480	6.5E+3	10.2E+3	TDP-R3	ckt.25,27,29	480	3	20	25

Horizontal Injection BTS Components –Controls for magnet and PS

- 45 Power supplies
  - 16 for quadrupoles
  - 2 for dipoles
  - 27 for correctors and trim coils
- All new magnets has thermo-switch interlock with PS
- All new magnets has one thermocouple each, 13 total, interface with control system through one TMI



TMI from Ron Blake

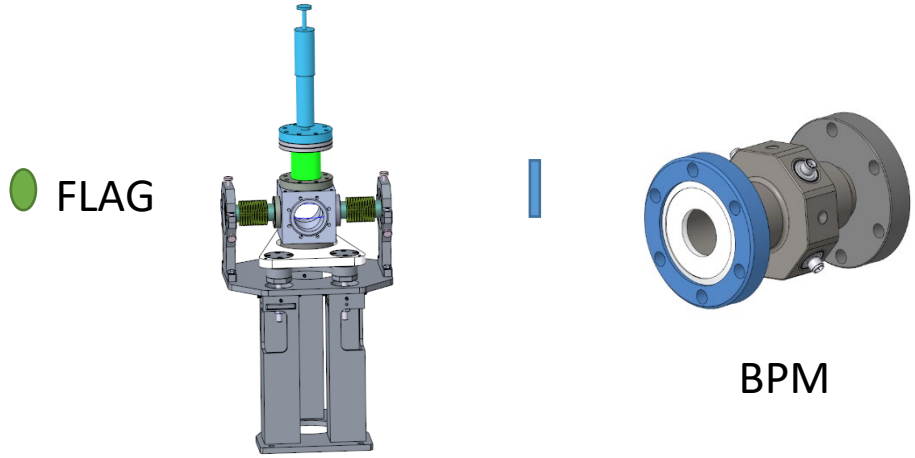


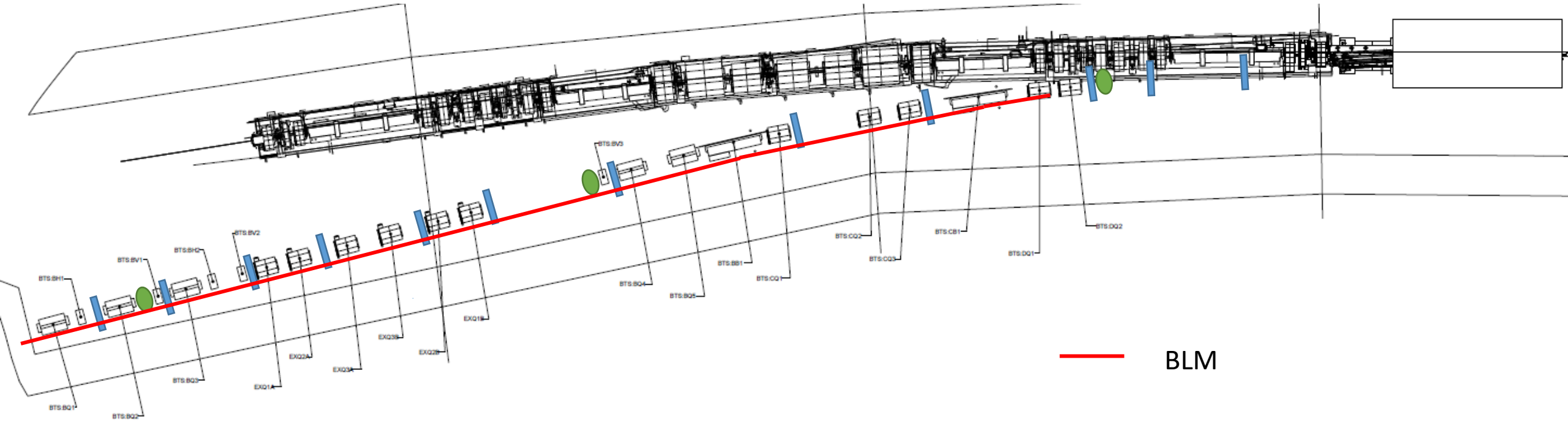
Device	Count	Interface	Communication Device
DC Power Supply	45	Ethernet	Ethernet
Thermo-switch	18	PLC	Ethernet
Temperature Monitor	13	PLC	Ethernet

Tables from Hong Ran

Horizontal Injection BTS Layout- Diagnostics

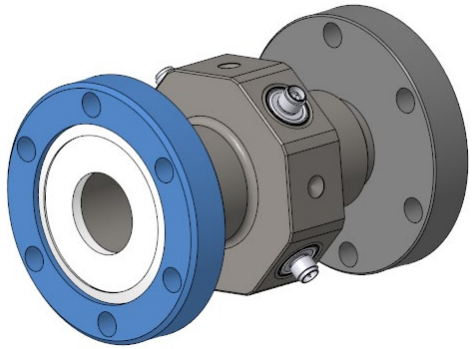
- 12 4-button beam position monitors (BPM)
- 3 Profile monitors (FLAG)
- 1 Beam loss monitor (BLM)

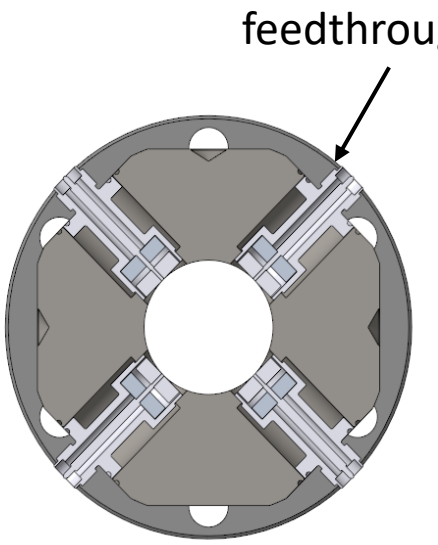


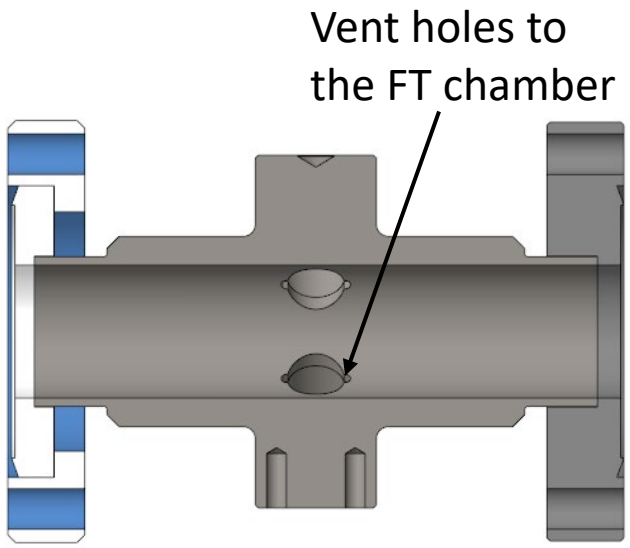


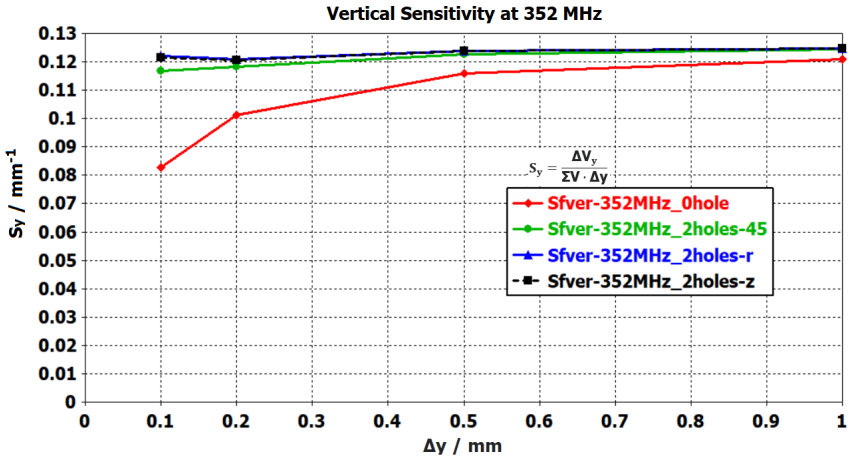
Horizontal Injection BTS Components - BPM

- 4-button design similar to the design of SR BPMs
- Use the same electronics system as SR BPMs
- Each BPM connected with 1 bellow
- Five orders:
  - Housing
  - Feedthrough
  - Electronics
  - Cables
  - Cable drop



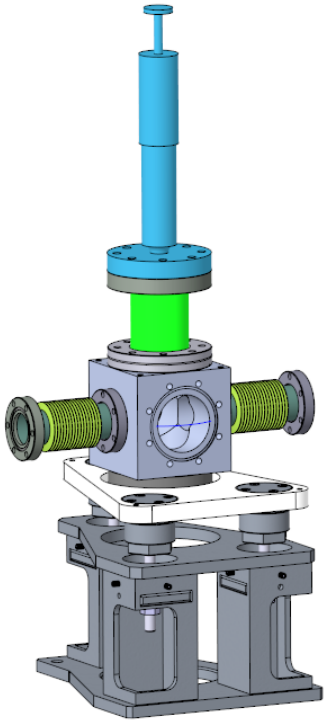






Horizontal Injection BTS Components - FLAG

- Different height for mounting on different tables
- Cubical chamber allow adding of horizontal actuator in the future



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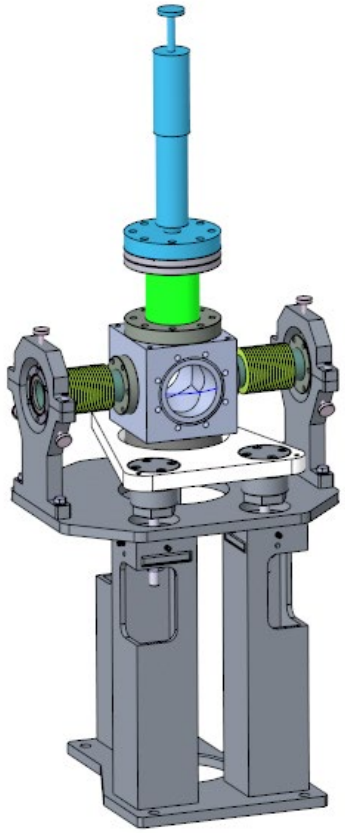

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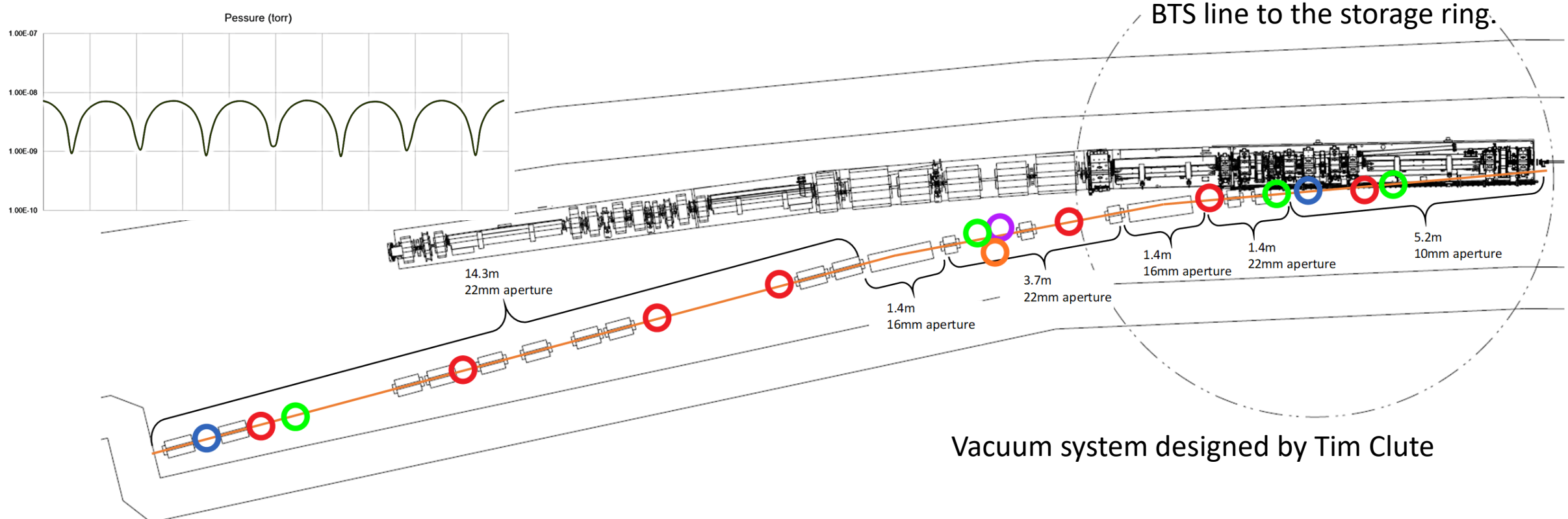
Horizontal Injection BTS Components - BLM

- Fast fiber-based BLM
- Run the length of BTS line end before BTS:DQ2
- Fiber bundle will be attached to the beam pipe
- Primary use of the fiber is in commissioning to assist in BTS steering and optimization
- Diagnose issues with poor transfer efficiency during operations.

Horizontal Injection BTS Layout– Vacuum System

Item	Qty	Company	Part Number	Color
45 L/s Ion Pump	7	Gamma Vacuum	45SDI2VSCNN	Red
2.75" Gate Valve	2	VAT Vacuum	48132-CE24	Blue
Manual Hand Valve	4	VAT Vacuum	54132-GE02	Green
Vacuum Gauge Set	1	Televac	2-2120-052 and 2-2416-053	Purple
RGA Head	1	MKS	835100-YG-1D	Orange

- With the reduction of aperture diameter, seven (7) pumps of 45 L/s speed be used to obtain desired pressure with the redundancy in case a pump fails during operation.
- A gate valve be installed at either end of the line and a gauge tree be present near the connection of the BTS line to the storage ring.



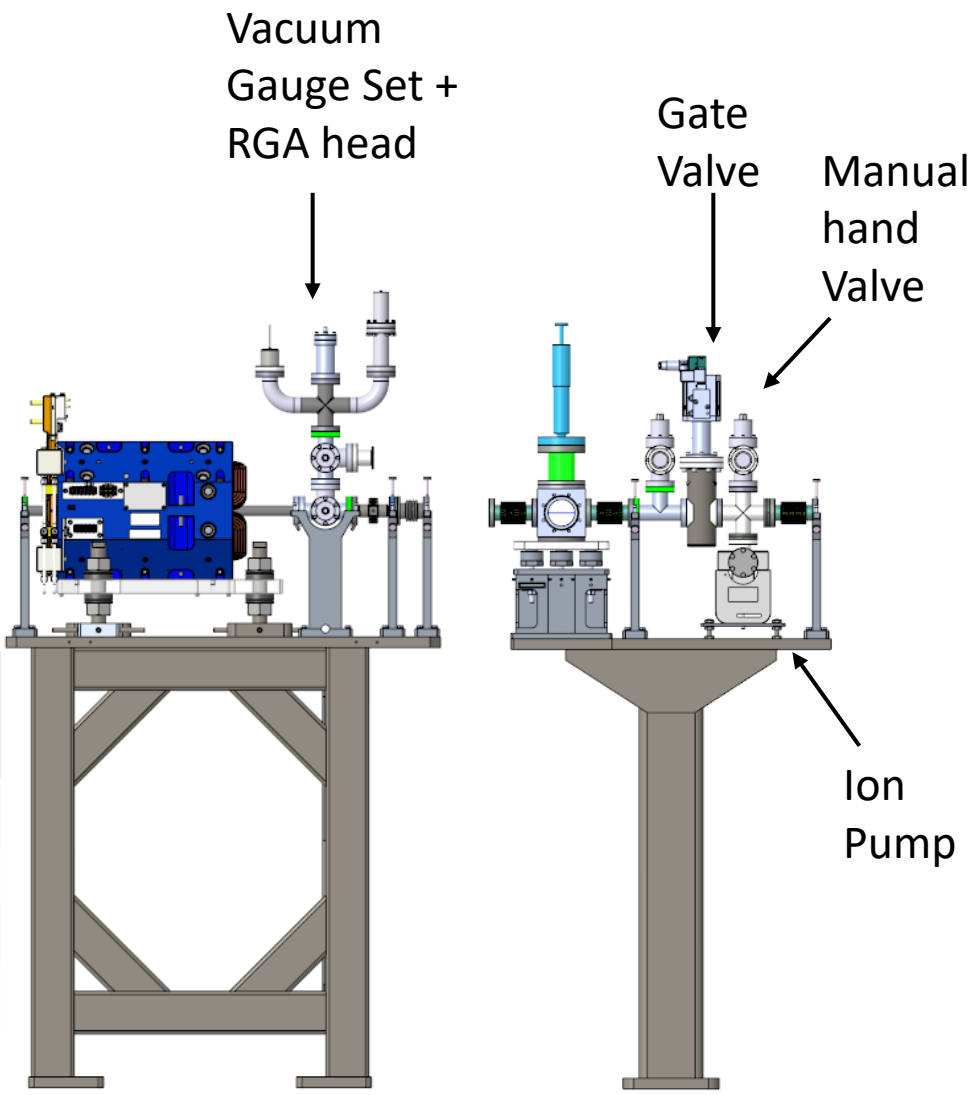
Vacuum system designed by Tim Clute

Horizontal Injection BTS component – Vacuum Components

- All vacuum components integrated into BTS modules
- 4 types of vacuum control interfaces
  - The 7 ion pumps are controlled by 2 ion pump controllers from Gamma Vacuum QPCe controller.
  - The vacuum gauge is controlled by the Televac MX200 controller.
  - The 2 gate valves and 4 manual valves will be integrated with the vacuum PLC.
  - RS232 interface to the controls network through MOXA NPORT serial device servers.

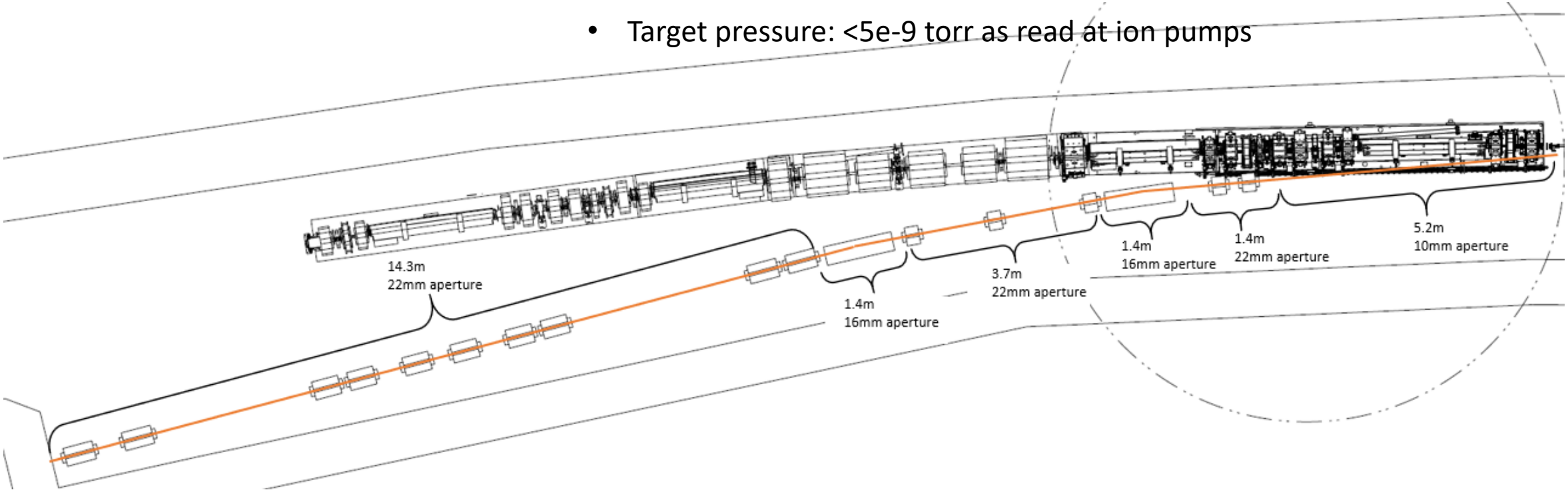
Device	Count	Interface	Communication Device	Controller
Ion Pump Controller	2	RS232	Moxa	QPCe
Vacuum Gauge	1	RS232	Moxa	MX200
Gate Valve	2	PLC	Moxa	
Manual Valve	4	PLC		

Table by Hong Ran



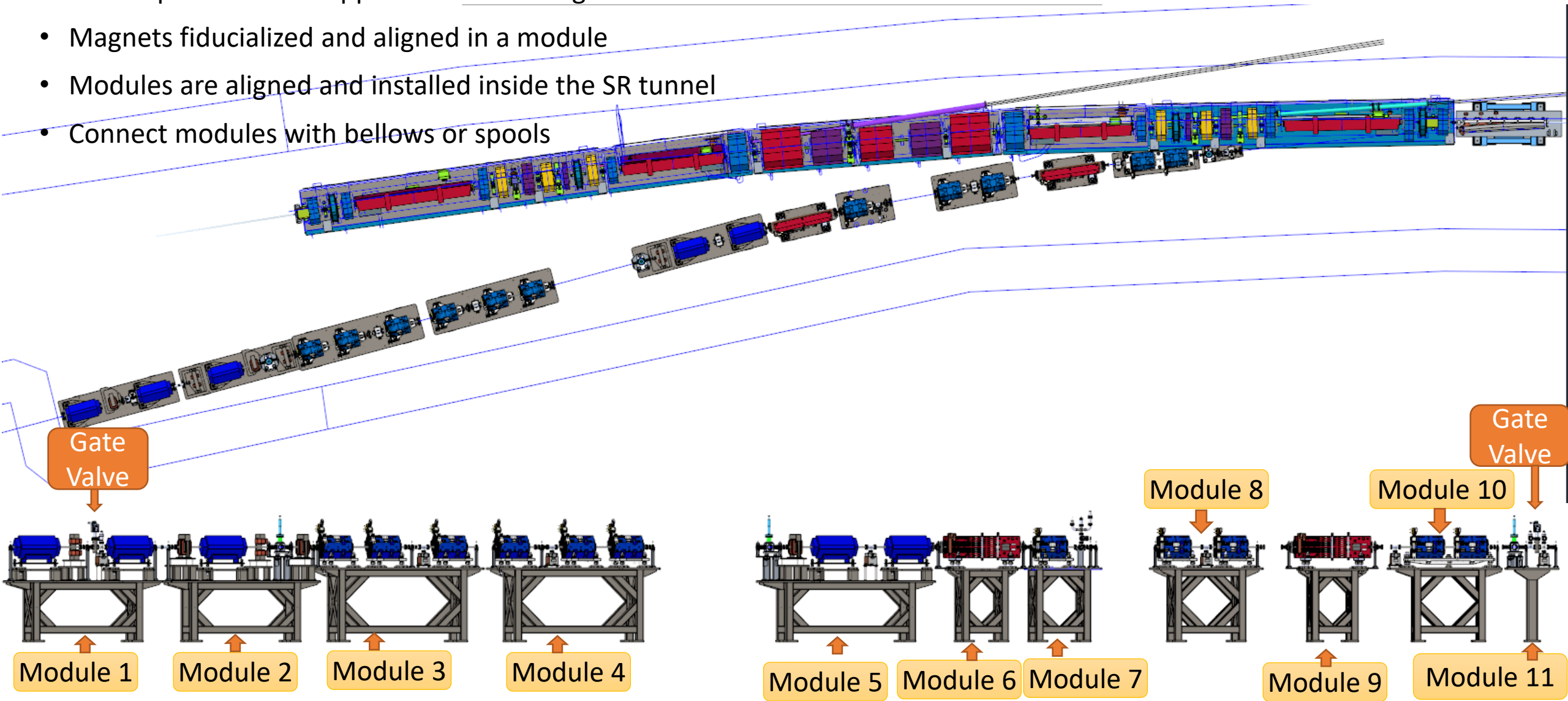
Horizontal Injection BTS components – Vacuum chambers

- Layout: Overall length of 27.4 meters
  - 14.3 m of 22 mm aperture
  - 1.4 m of 16 mm aperture
  - 3.7 m of 22 mm aperture
  - 1.4 m of 16 mm aperture
  - 1.4 m of 22 mm aperture
  - 1.4 m of 10 mm aperture
- Material: Vacuum cleaned and stainless steel
- System is assumed to be unbaked but under UHV condition for > 10 hours
- Target pressure: <5e-9 torr as read at ion pumps



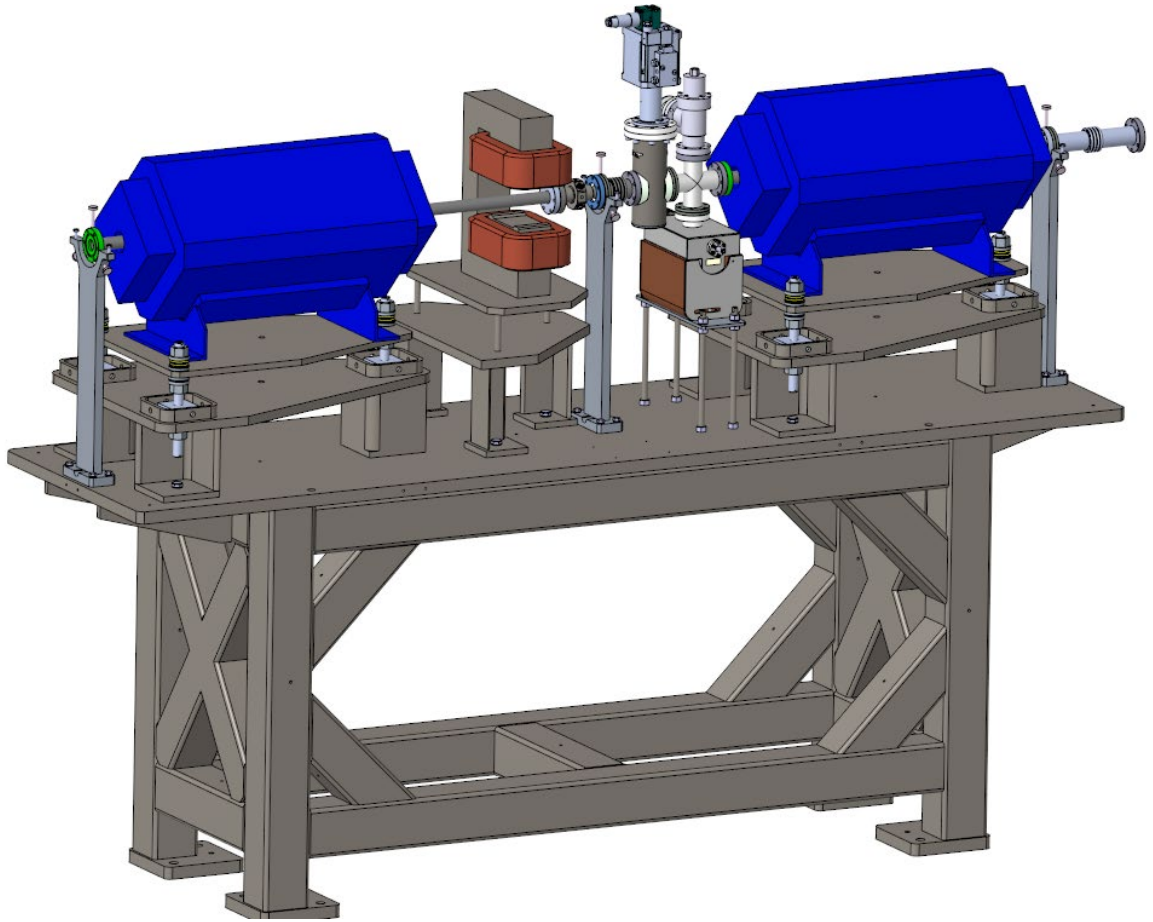
Horizontal Injection BTS – Module layout

- Modular design for easy pre-installation and installation
- All components and support table are integrated into 11 modules
- Magnets fiducialized and aligned in a module
- Modules are aligned and installed inside the SR tunnel
- Connect modules with bellows or spools

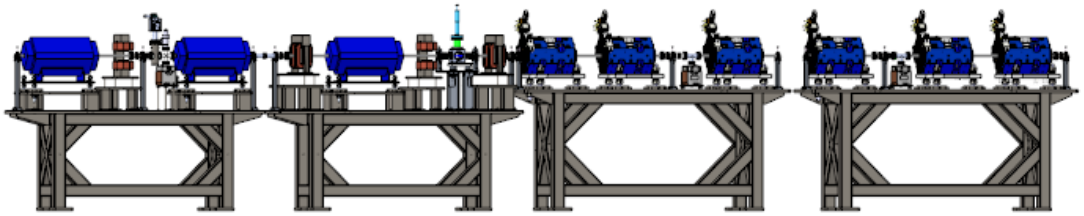


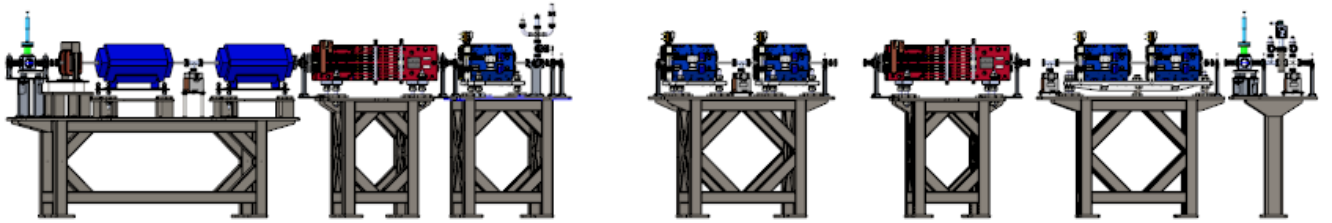
Horizontal Injection BTS –Modules Mechanical Design

- Module 1
  - BTS:BQ1
  - BTS:BH1
  - BTS:BQ2
  - Gate Valve
  - BPM1
  - Module assembled and magnet aligned by Module assembly group (MSG)
  - Harvest magnets and module installation by R&I
  - Back filled with Helium and connect to module 2 through a bellow



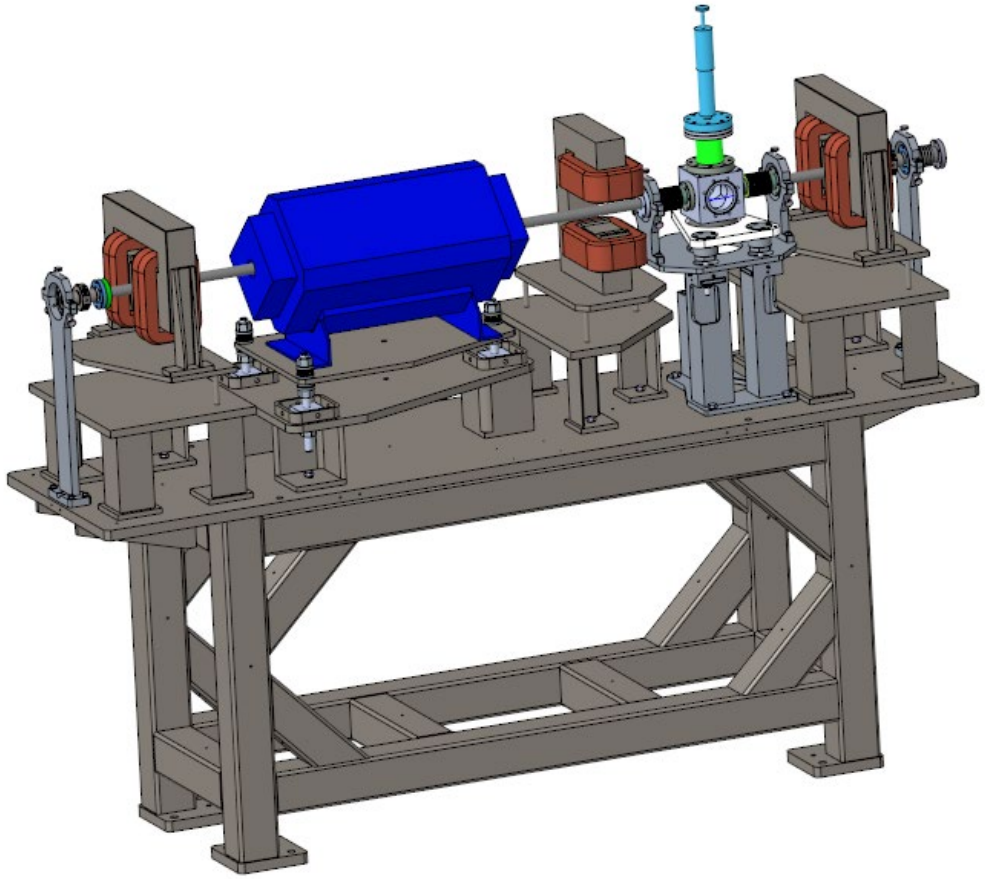
Module 1

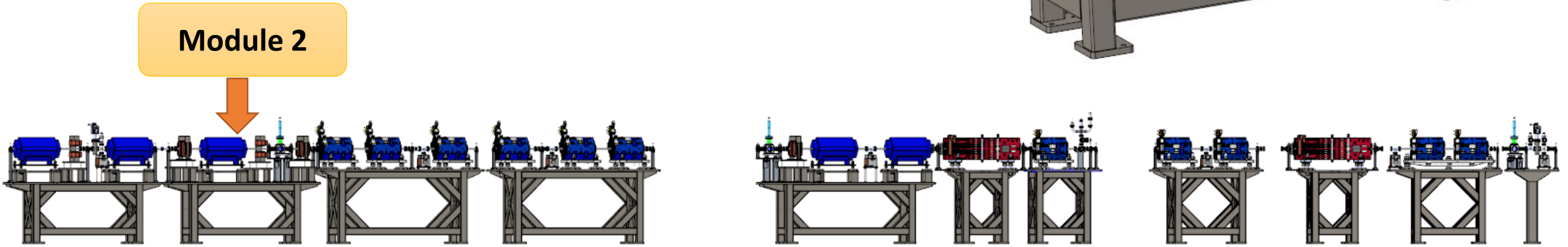




Horizontal Injection BTS –Modules Mechanical Design

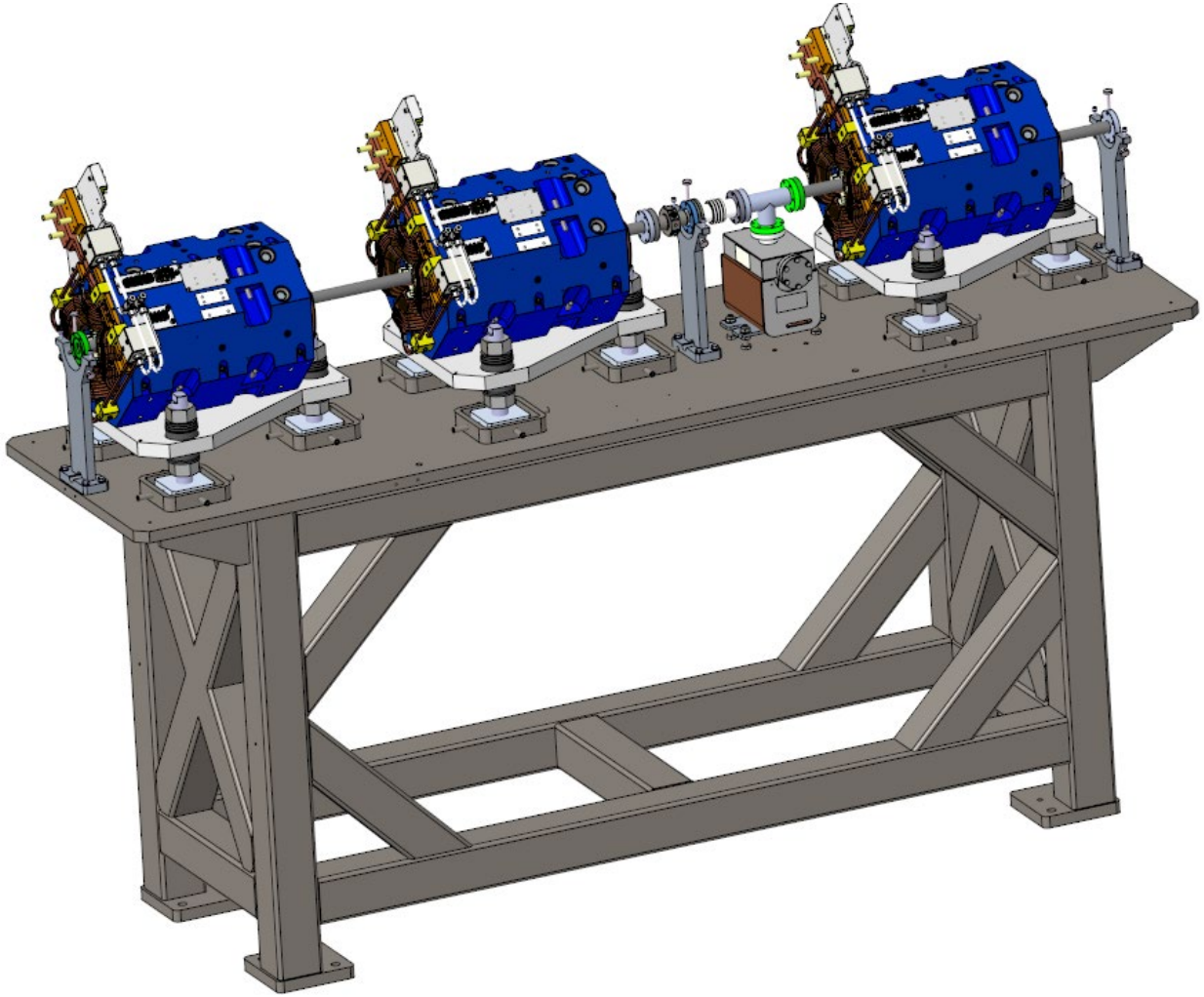
- Module 2
  - BTS:BQ3
  - BTS:BV1
  - BTS:BV2
  - BTS:BH2
  - Flag: FS3
  - BPM2 and BPM3
  - Ion pump
  - Connect to module 3 through a bellow

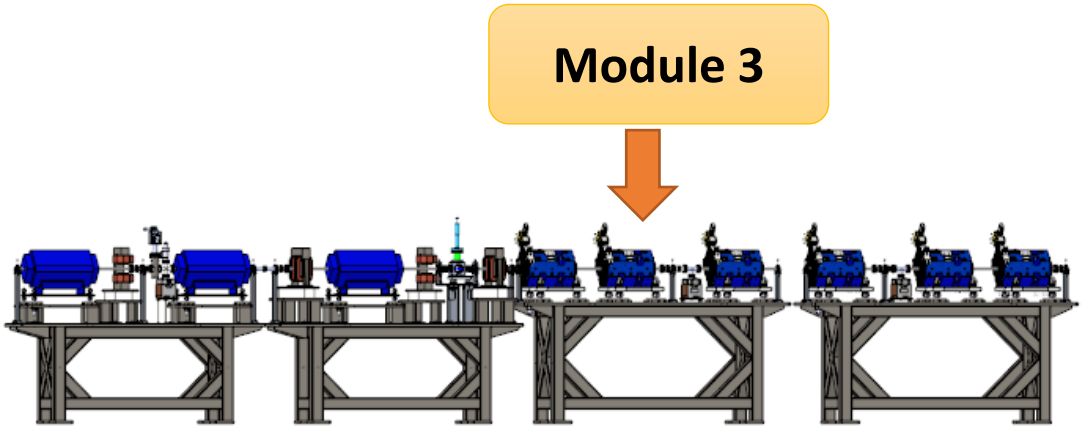


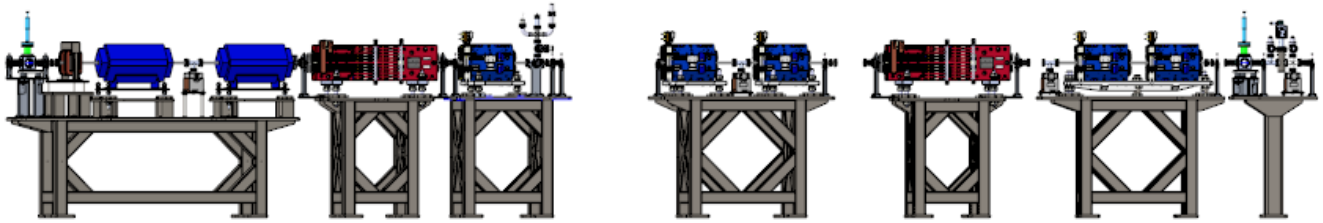


Horizontal Injection BTS –Modules Mechanical Design

- Module 3
  - BTS:EX1A
  - BTS:EX2A
  - BTS:EX3A
  - BPM4
  - 1 pump
  - Connect to module 4 through a bellow

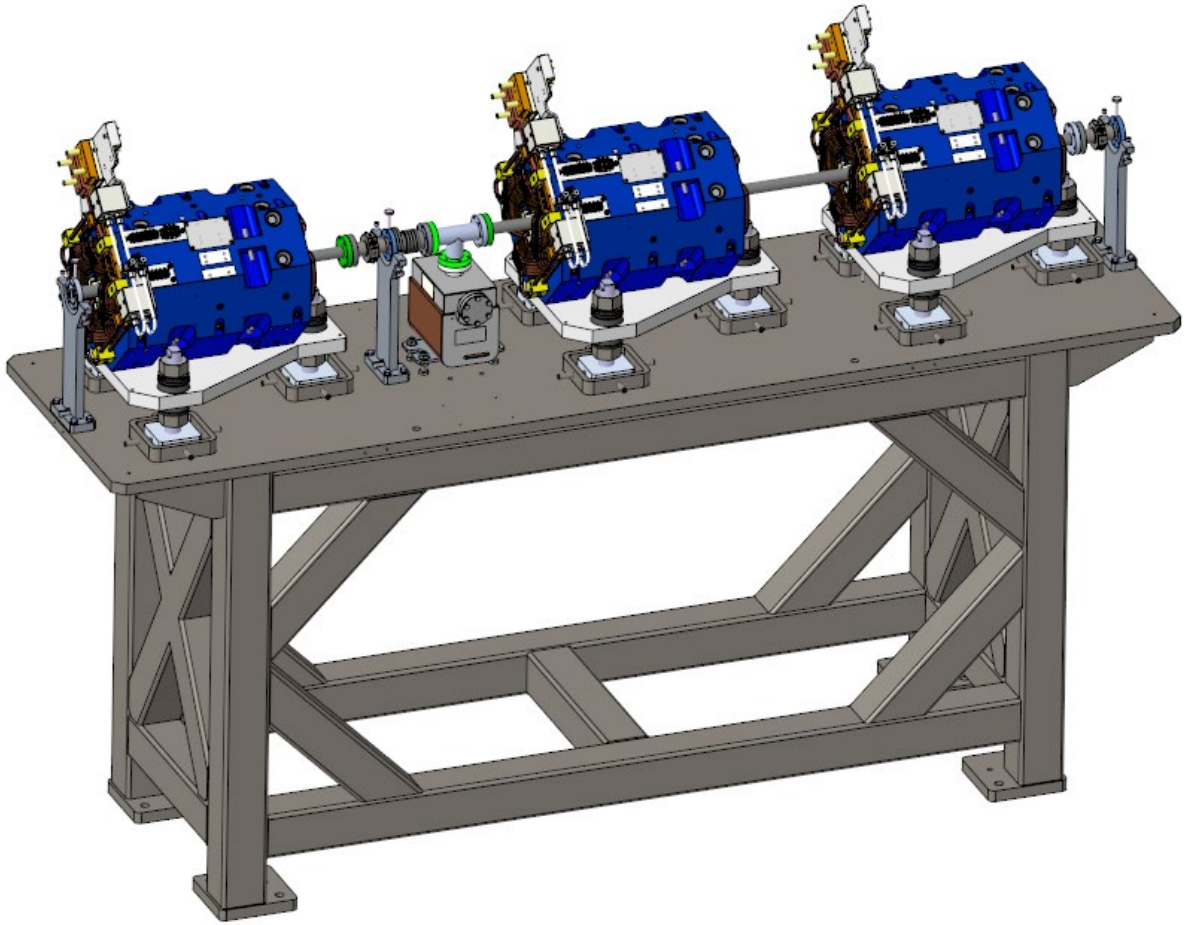


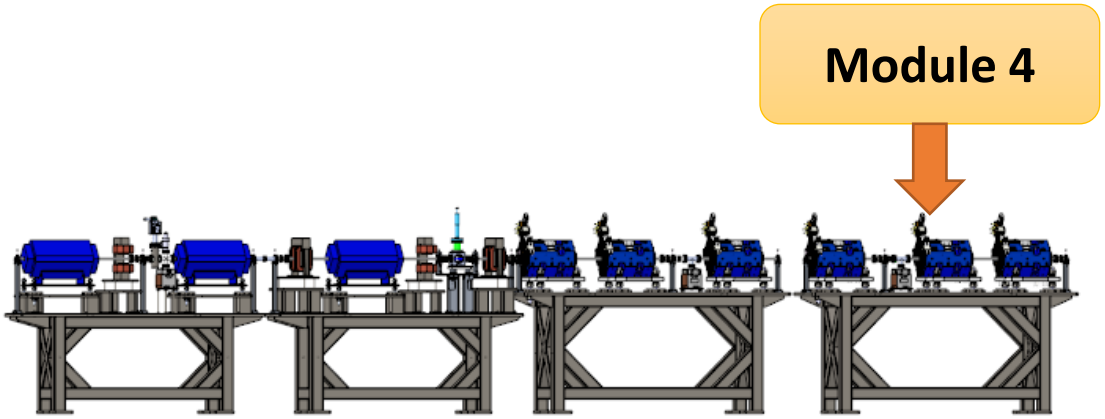


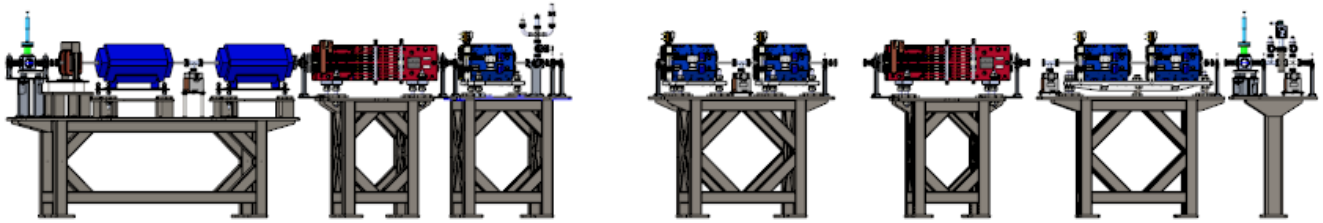


Horizontal Injection BTS –Modules Mechanical Design

- Module 4
  - BTS:EX3B
  - BTS:EX2B
  - BTS:EX1B
  - BPM5 and BPM6
  - 1 pump
  - Bellow to vacuum tube to module 5
  - Magnets symmetrical to module 3

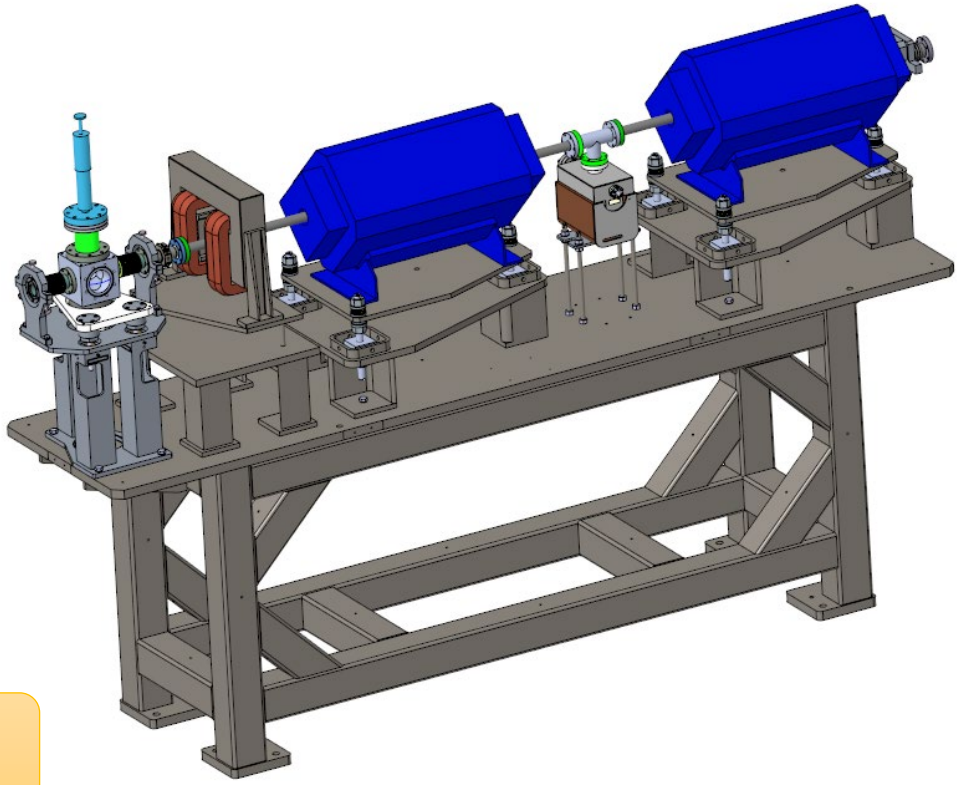


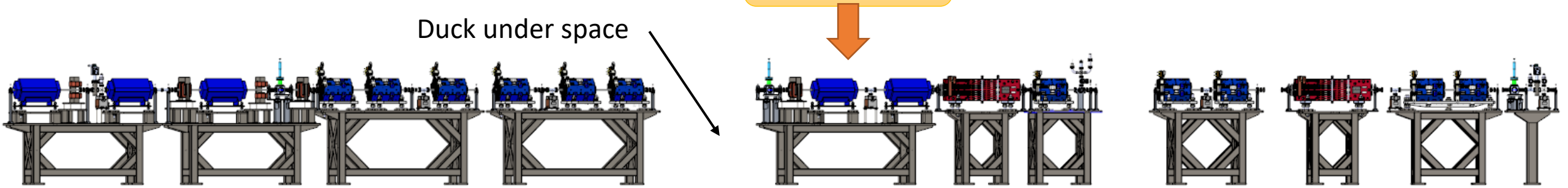




Horizontal Injection BTS –Modules Mechanical Design

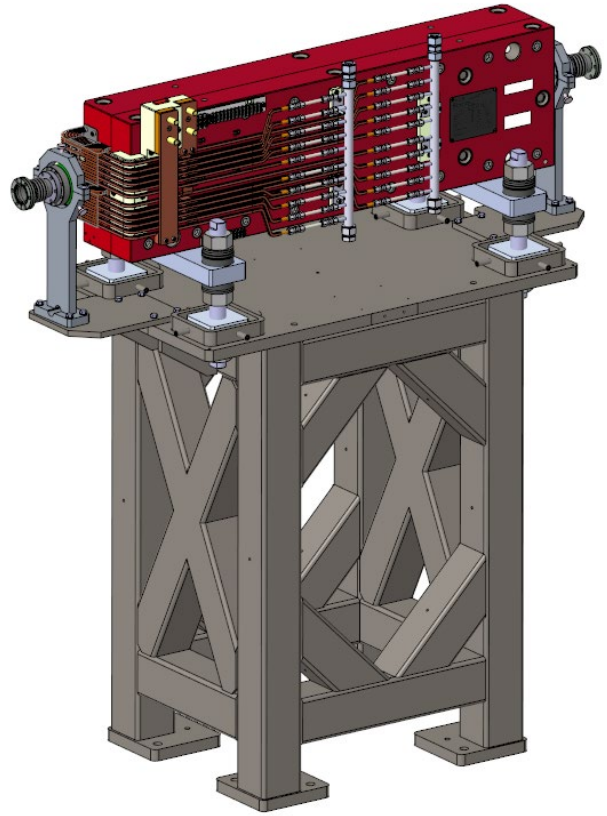
- Module 5
  - BTS:BQ4
  - BTS:BQ5
  - BTS:BV3
  - BPM7
  - FLAG: FS4
  - One Ion Pump
  - Connect to module 4 through a long spool
  - Connect to module 6 through a bellow
  - Duck under space between Module 4&5

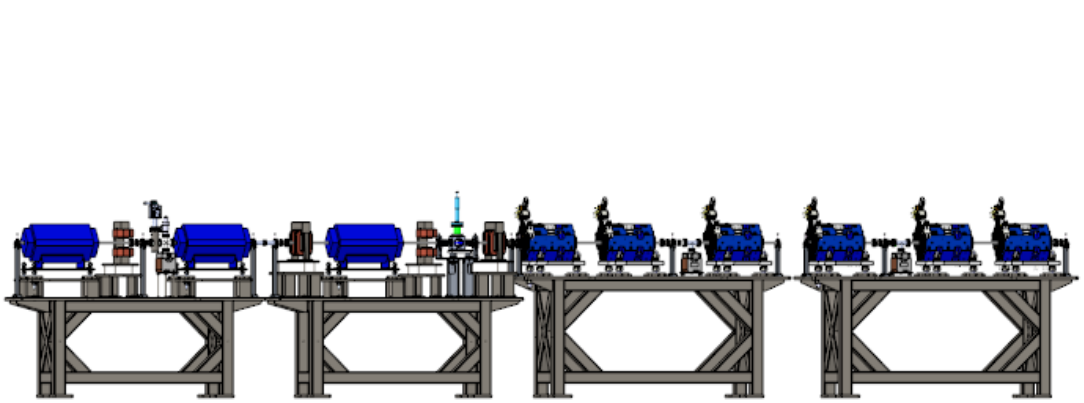


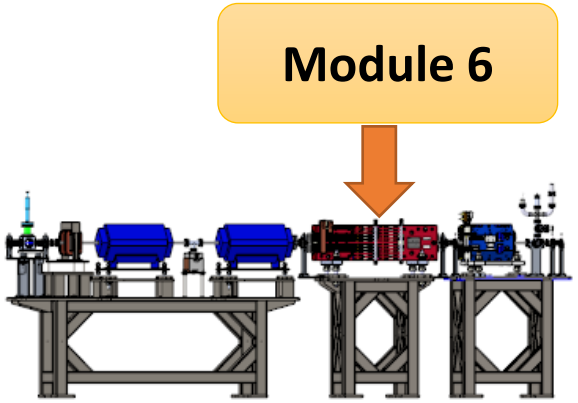


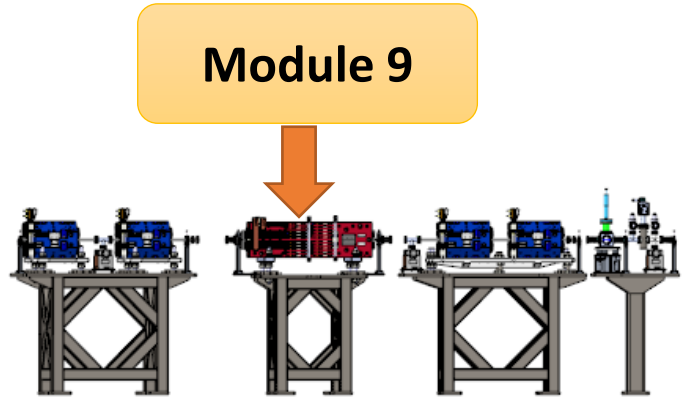
Horizontal Injection BTS –Modules Mechanical Design

- Module 6 and 9
  - BTS: BB1 (Module 6)
  - BTS: CB1 (Module 9)
  - Align vacuum chamber to the magnet through Vertex Points
  - Connect to neighboring modules through a bellows



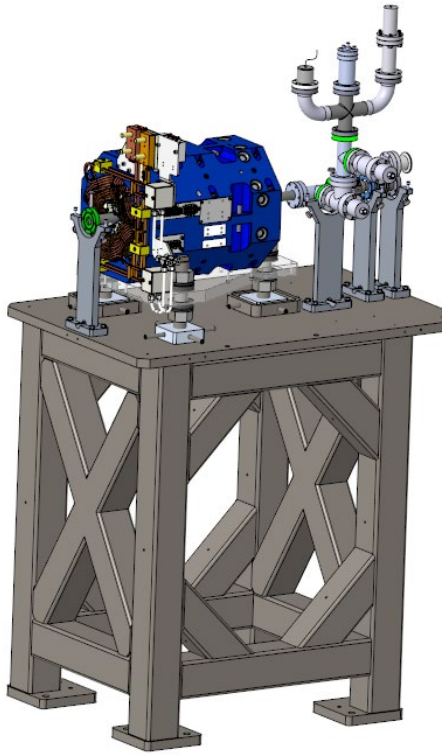


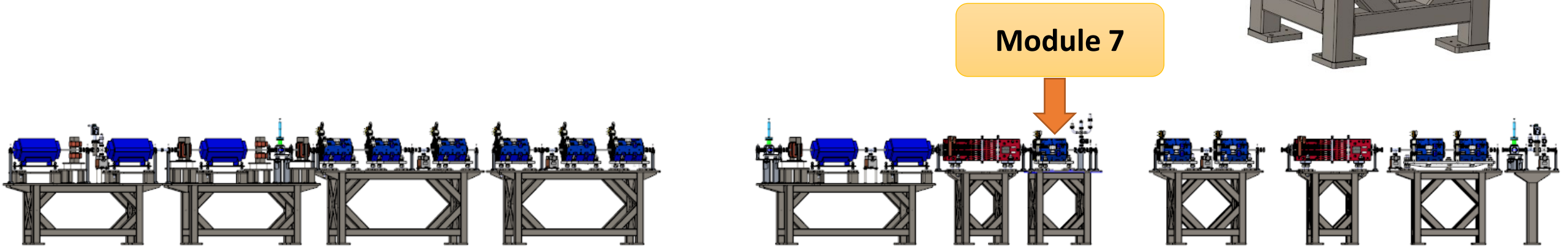




Horizontal Injection BTS –Modules Mechanical Design

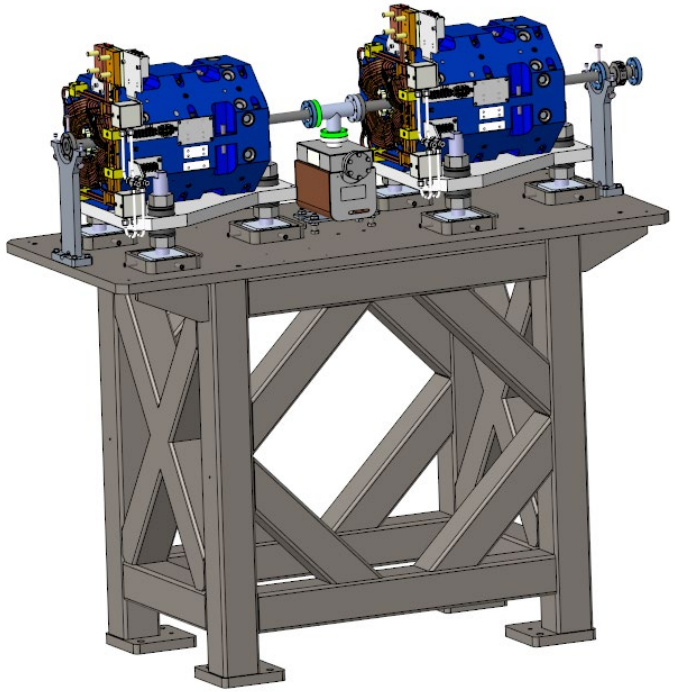
- Module 7
  - BTS: CQ1
  - BPM8
  - Vacuum Gauge Set
  - Connect to module 6 and 8 through a bellow

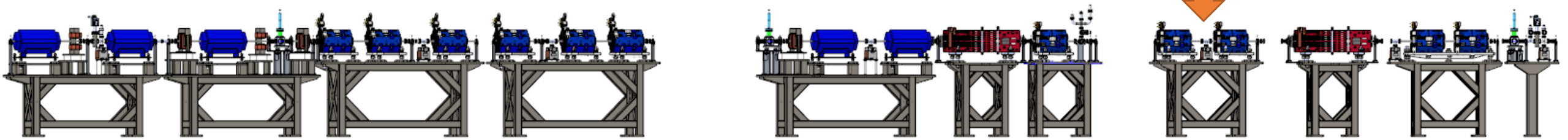




Horizontal Injection BTS –Modules Mechanical Design

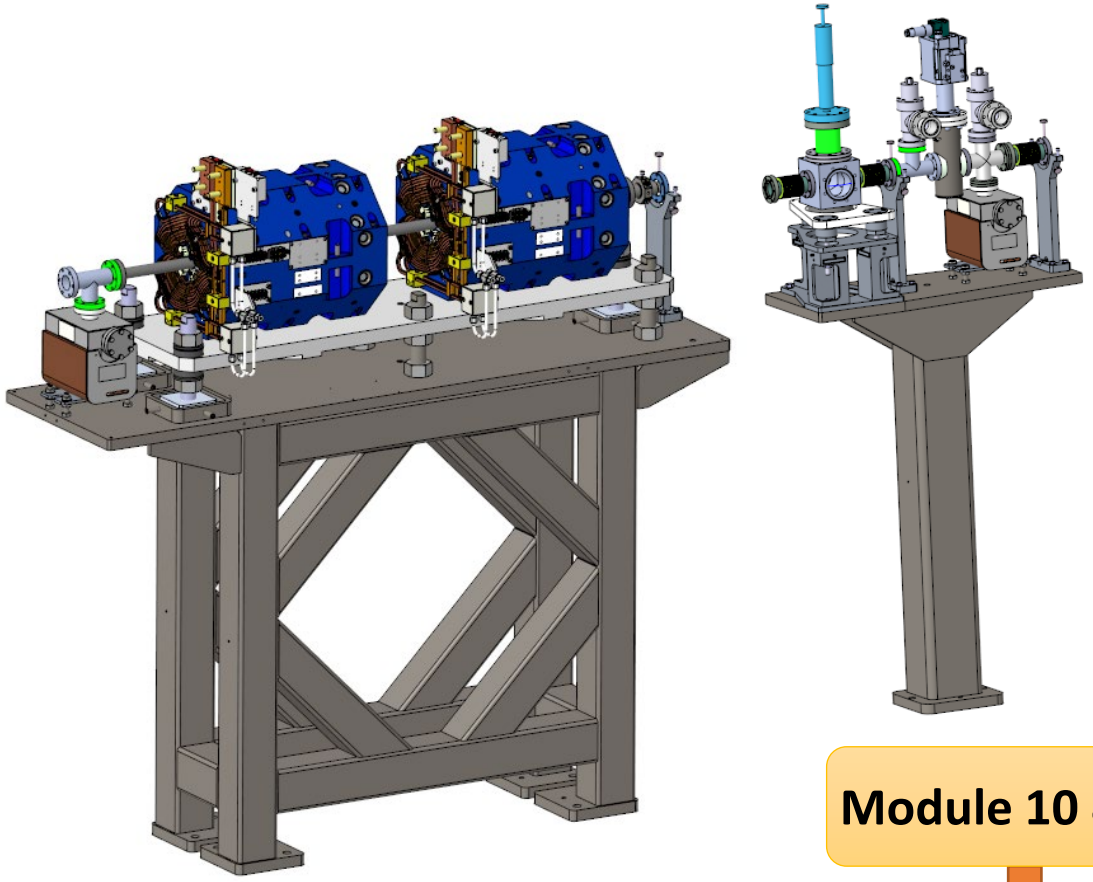
- Module 8
  - BTS:CQ2
  - BTS:CQ3
  - BPM9
  - One Ion Pump
  - Connect to module 7 and 9 through spools



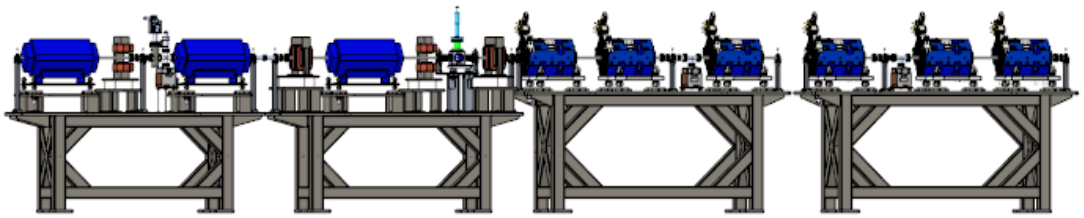


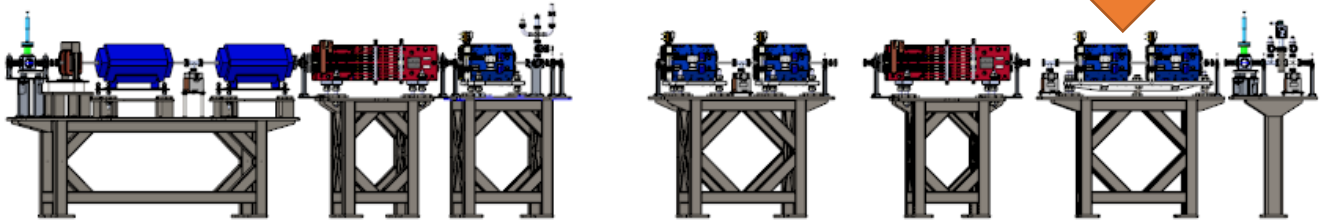
Horizontal Injection BTS –Modules Mechanical Design

- Module 10 and 11
  - BTS:DQ1
  - BTS:DQ2
  - BPM10
  - 2 Ion Pumps
  - FLAG: FS5
  - 1 Gate Valve
  - 2 manual hand valves



Module 10 & 11



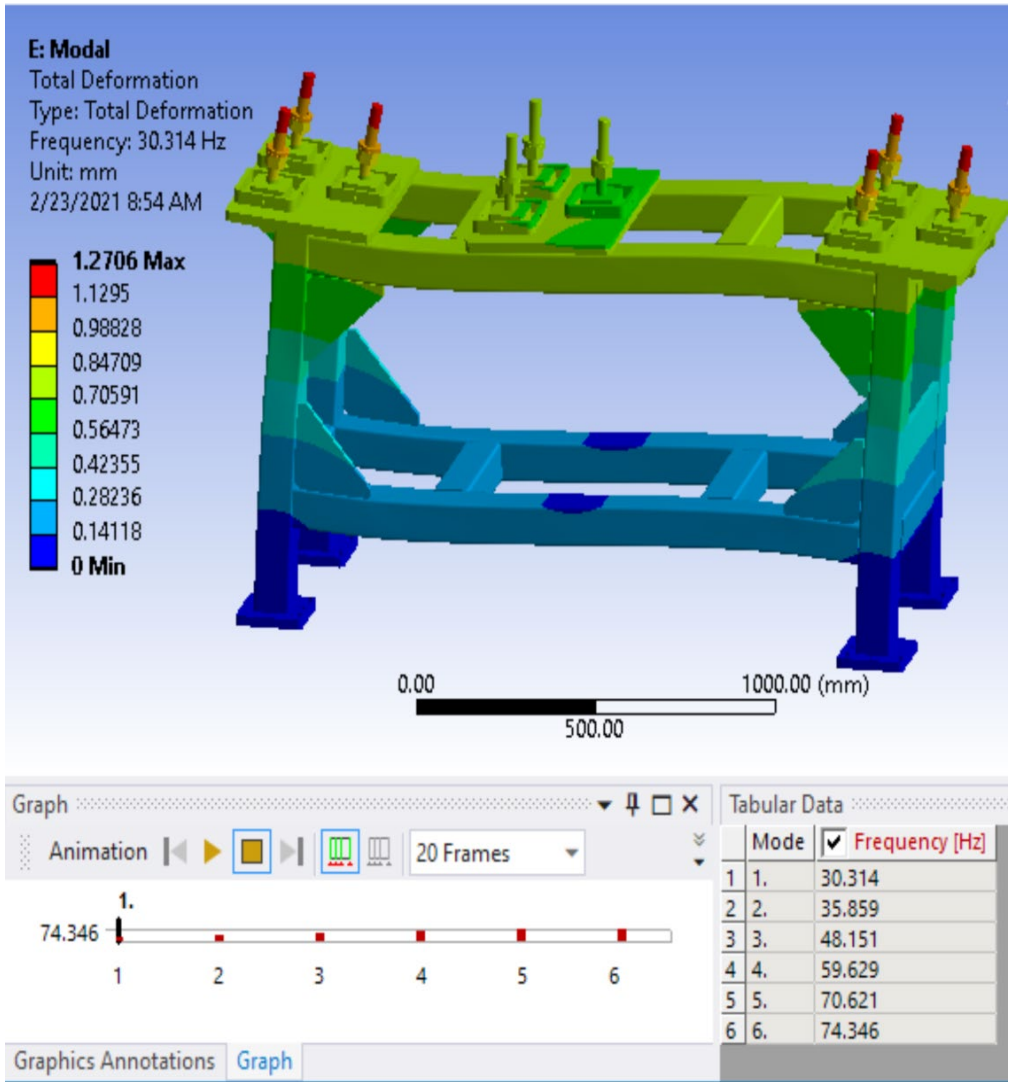


Horizontal Injection BTS – Support table Mechanical Design

- Module vibration
  - 1 µm rms motion integrated from 0.1 Hz to infinity
- Support table vibration
  - Table 1st mode > 50 Hz
- Alignment
  - Magnet to magnet in a modul: 50 µm rms
  - Module to modul in installation: 100 µm rms

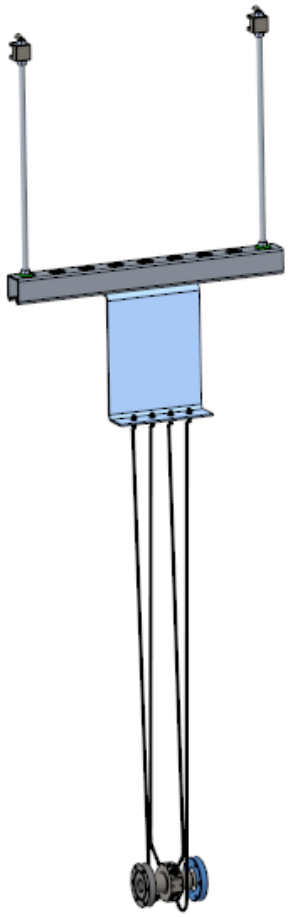
Module 3, 4		
X	**Y**	**Z**
0.0165 µm	0.0174 µm	0.0172 µm

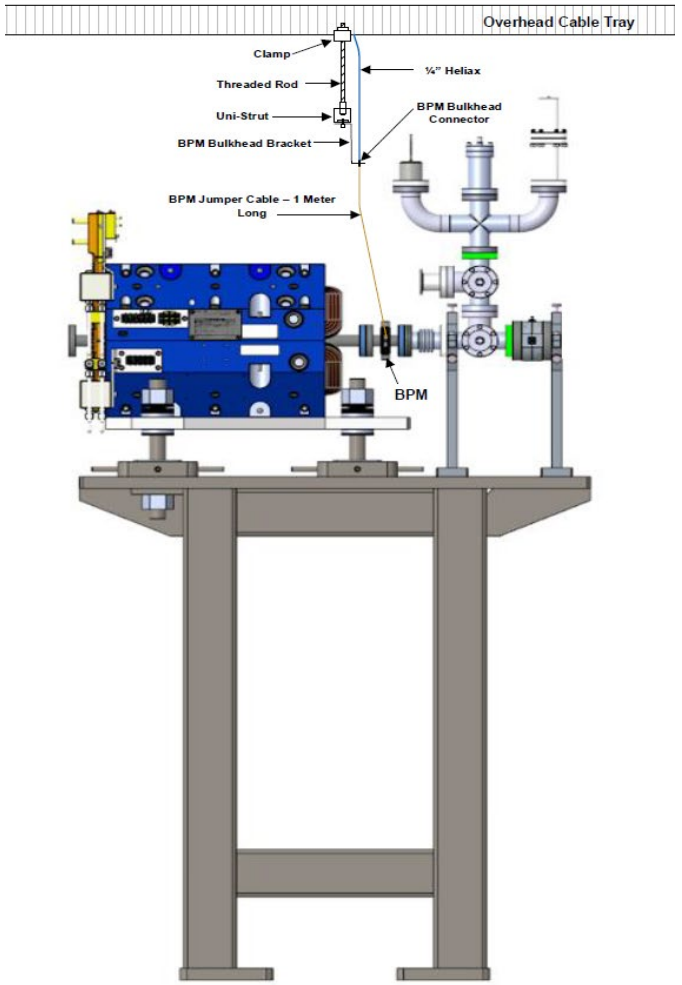
BB1, CB1 Module		
X	**Y**	**Z**
0.0116 µm	0.0003 µm	0.0071 µm



Horizontal Injection BTS – Utilities and Cables

- Magnet Power cables
- Magnet thermo-switch wires
- Magnet TC wires
- Magnet cooling water
- Diagnostics electronics wires

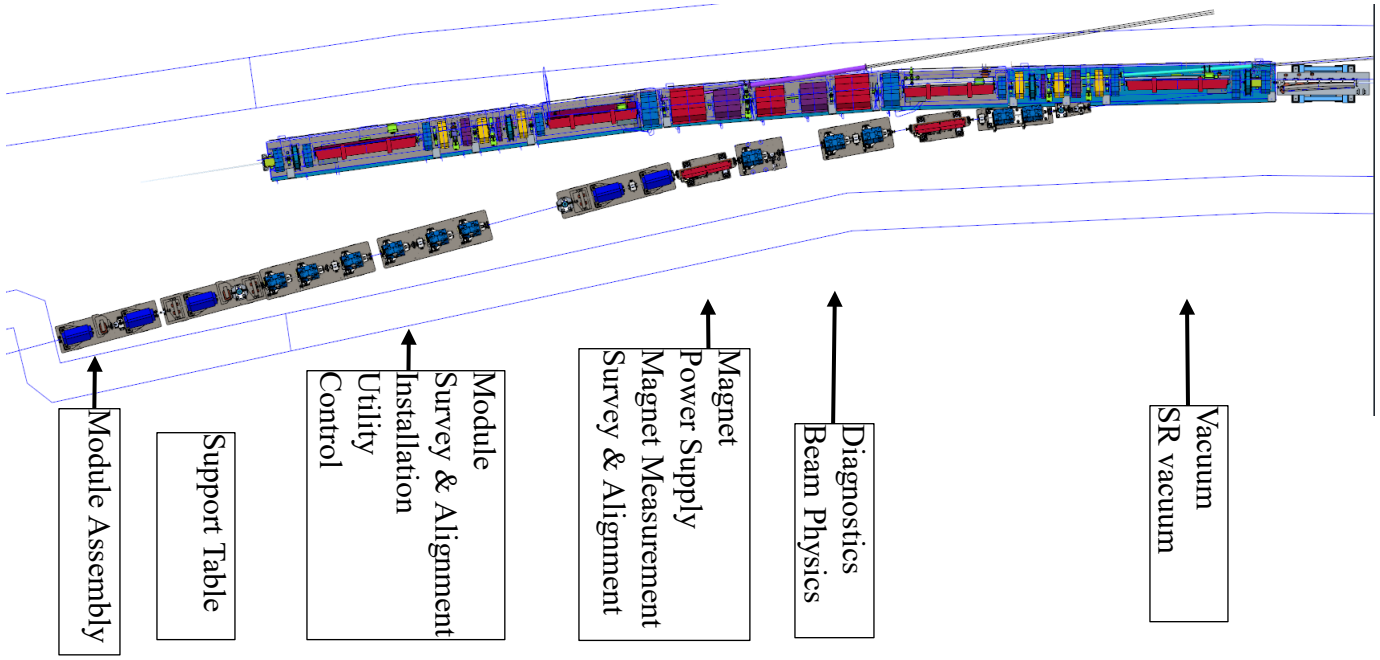




Sketch by Ron Blake

Horizontal Injection BTS – Interfaces

- Interface Control Document (ICD): APSU_2176353
  - Magnet
  - Magnet measurement
  - Vacuum
  - Power Supply
  - Cooling Water Systems
  - Survey and Alignment
  - Diagnostics
  - Beam Physics
  - Control
  - Preinstallation
  - Removal and Installation
  - ESH

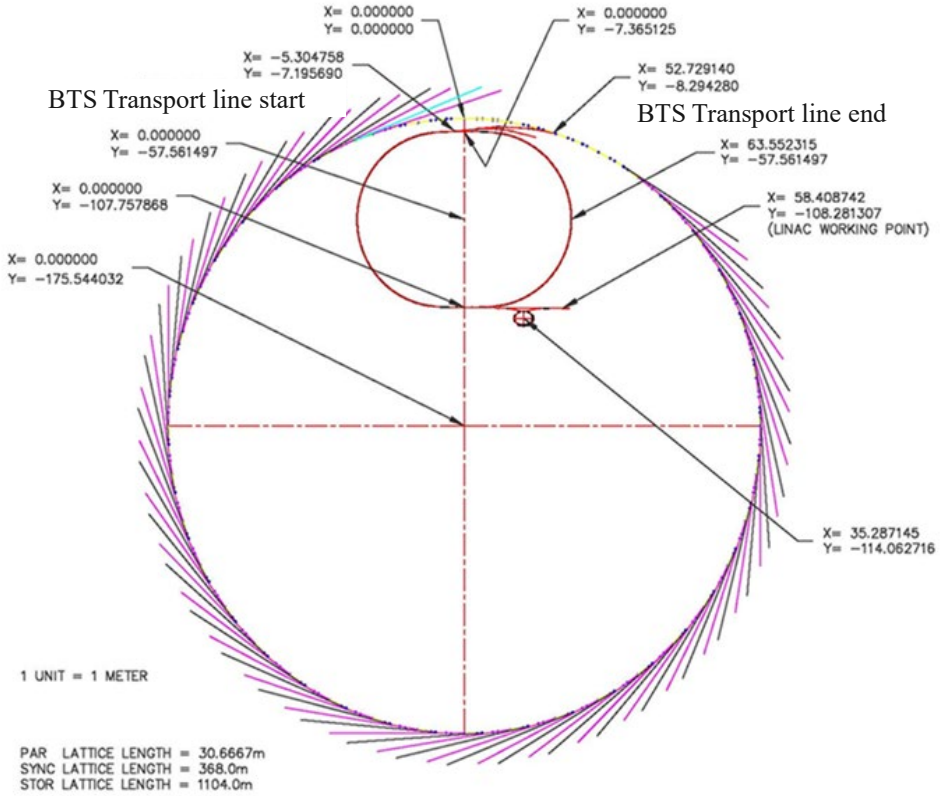


- Incorporate interfaces into design and fabrication

Horizontal Injection BTS – Survey and Alignment

- BTS line will be aligned to fit the SR lattice coordinate system
- Alignment requirements

Parameter	Value	Unit
Feudalization uncertainty for each magnet module, transverse	50 rms	µm
Align magnet-to-reference line within a module, transverse	100 rms	µm
Module fiducials to reference line, transverse	100 rms	µm
Module alignment to adjacent modules, transverse	100 rms	µm
Alignment magnet to magnet within a module, longitudinal	0.5 rms	mm
Alignment module to adjacent modules, longitudinal*	0.5 rms	mm



From Bill Jansma

Horizontal Injection BTS – Documentations

- **Production documentations**
  - Engineering Specifications
  - 3D models and Drawing packages
  - Travelers
  - Statement of Work
- **Make per Print**