CEPC mechanics issues

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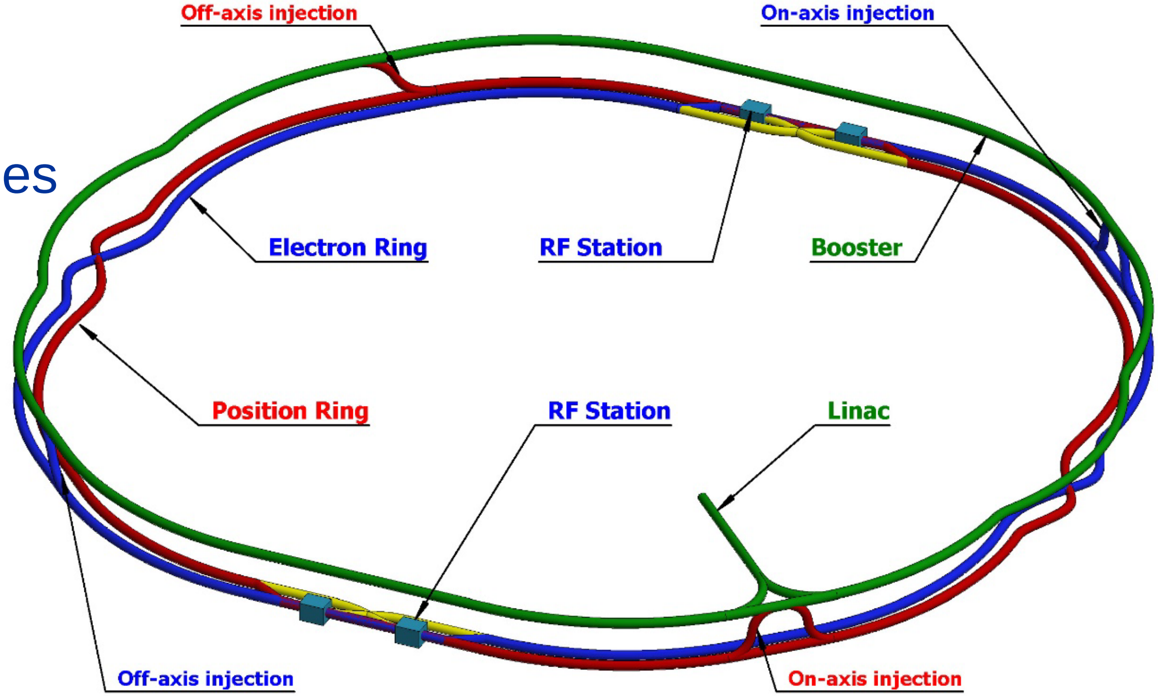
The Hong Kong University of Science and Technology

IAS conference

- CEPC is composed by the double ring Collider, the Booster, the Linac and Transport lines.
- Mainly mechanics issues:
  - Supports
    - Supports in Collider, Booster, Linac & Damping ring, Transport lines…
    - Tunnel mockup
    - Transport vehicles
  - Movable collimators
  - MDI mechanics

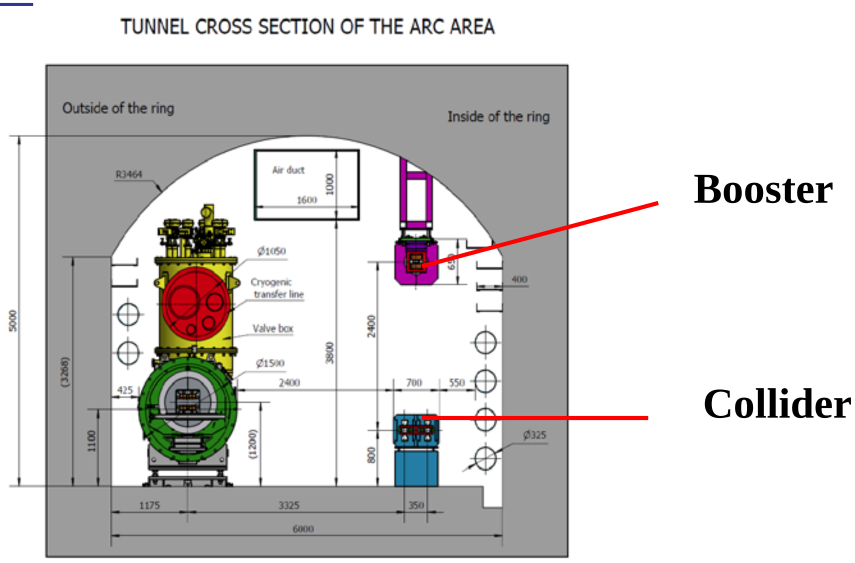


Supports

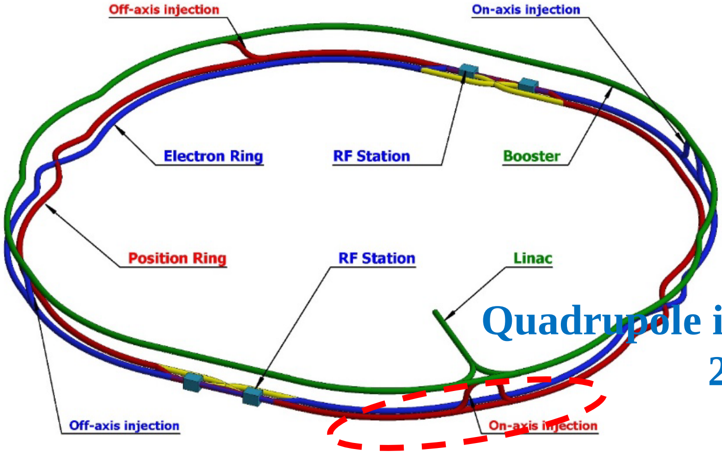
- Over 80% of the length is covered by magnets of about 138 types, each magnet needs to be supported.
- Accelerating tubes, vacuum tubes, instruments…, all need supports.
- Aims
  - Simple & flexible structure: plates or standard elements
  - Small deformation & good stability: multi-point support, optimization
  - Low cost: concrete or steel frames, adjusted manually

Adjustment Ranges of magnets			
X	≥±20 mm	Δθx	≥±10 mrad
Y	≥±30 mm	Δθy	≥±10 mrad
Z	≥±20 mm	Δθz	≥±10 mrad

- Support method
  - Supported to the ground by concrete or hanged on the wall of the tunnel by steel frame

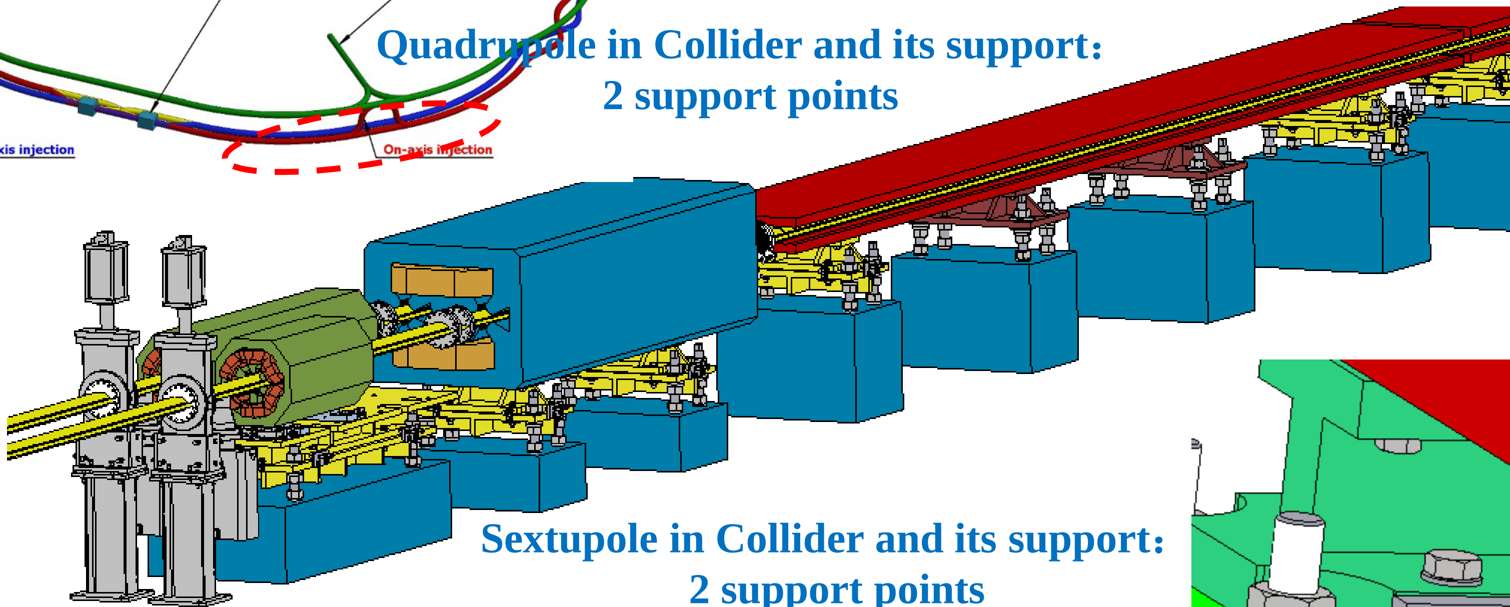


Supports in Collider



Dipole in Collider and its support: 4 support points

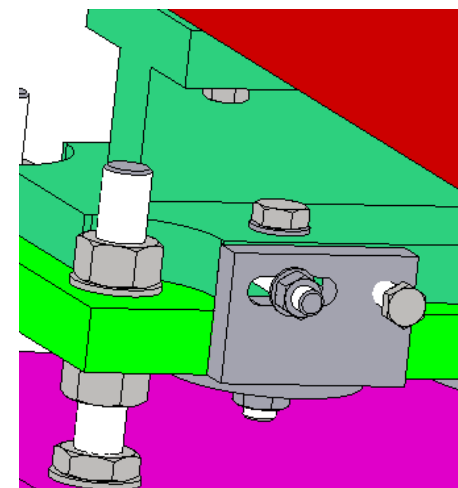
Quadrupole in Collider and its support: 2 support points



Sextupole in Collider and its support: 2 support points

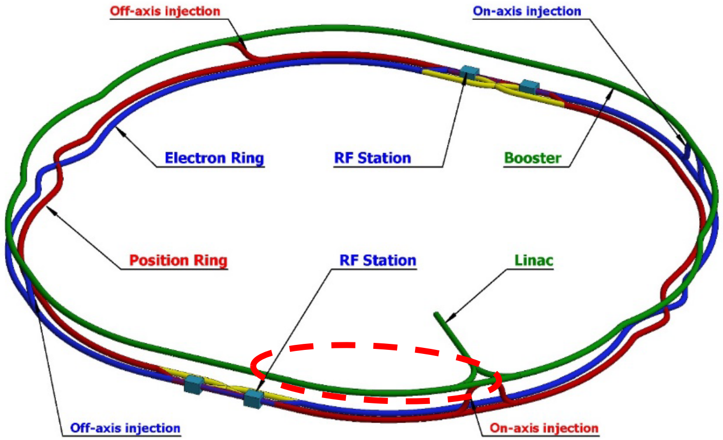
Common girders for quadrupoles and sextupoles are also in consideration

- **Pre-aligned units can save workload in tunnel and reduce the relative misalignment**
- **Long and thin, hard to design in stiffness**

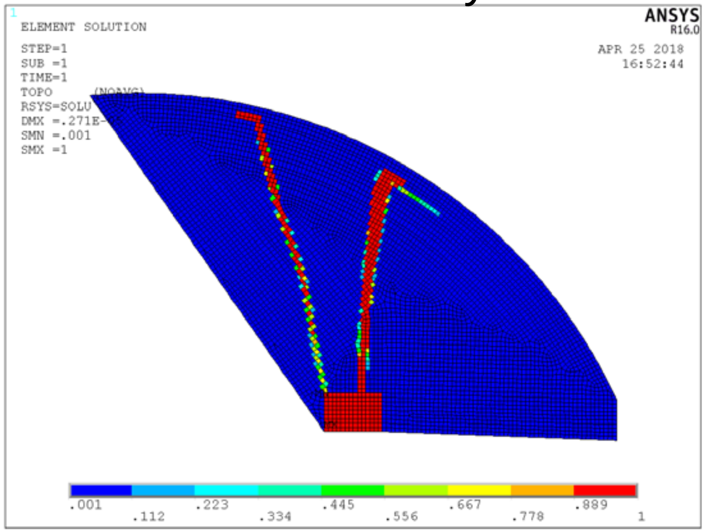


- Bolts & push-pull bolts for adjusting

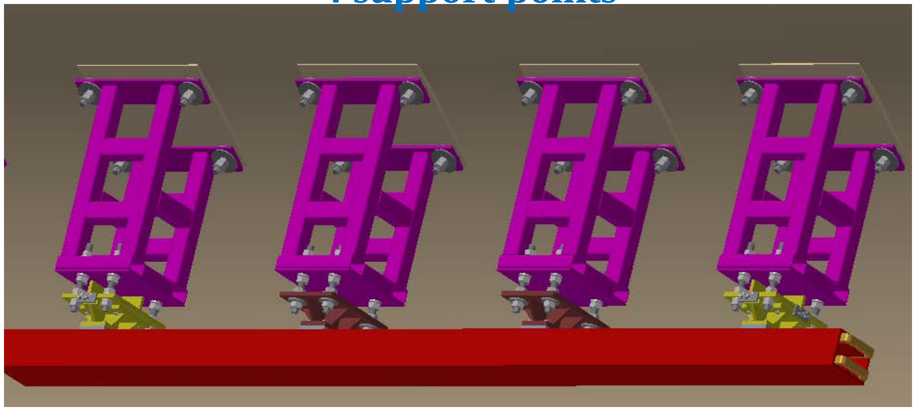
Supports in Booster



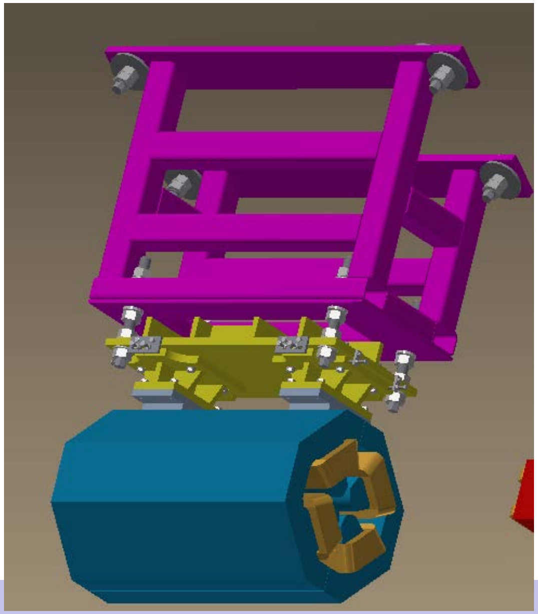
- Supports in Booster
  - Topology optimization is used: best static stability



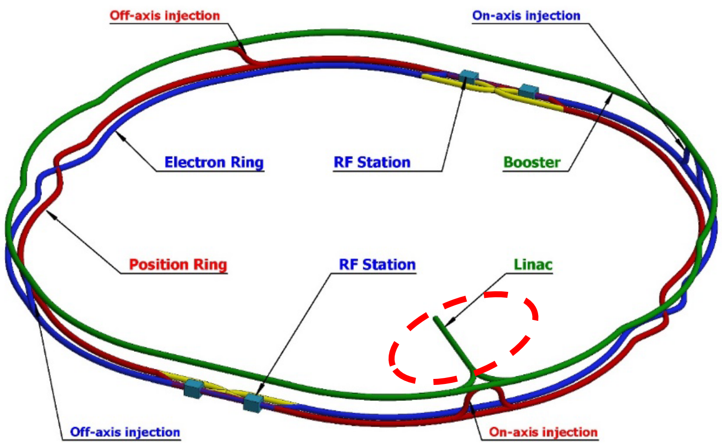
Dipole in Booster and its support: 4 support points

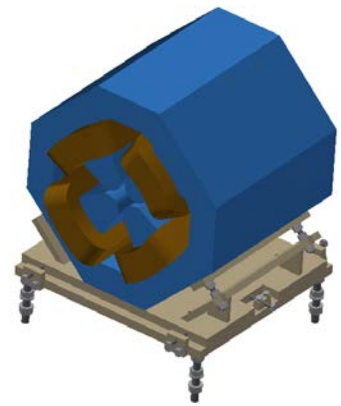


Quadrupole in Booster and its support: 2 support points

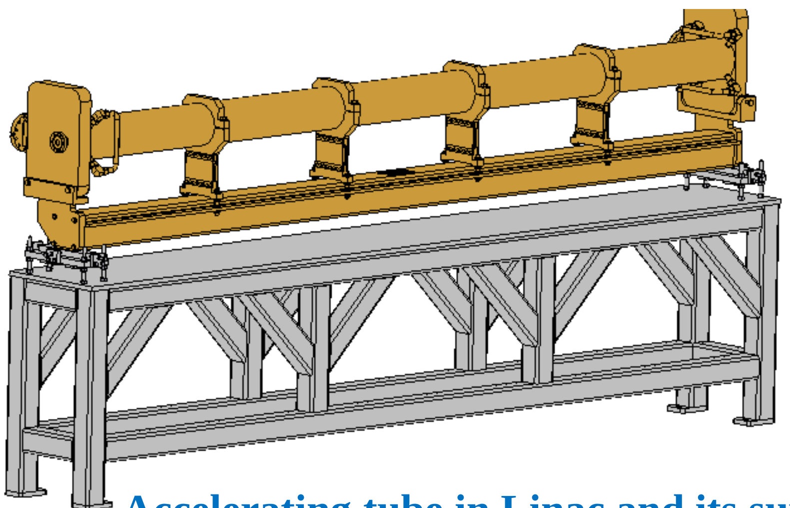


Supports in Linac

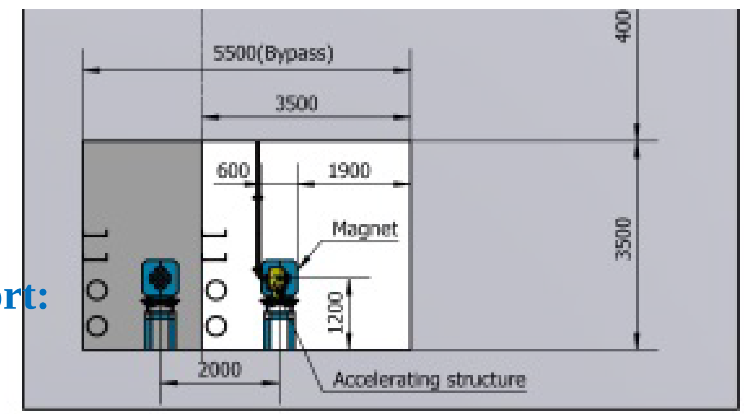




Typical magnets and their support



Accelerating tube in Linac and its support: 2 support points，3000 mm



Supports

- Plenty of supports to be designed.
- We has began the cooperation on design with members of CIPC

Table 4.3.9.1: Quantities of magnets and their supports in the Collider

Magnet type	Quantity	Magnet length (mm)	Core number per magnet	No. of supports per core
Dipole	2384	28686 (twin-aperture)	5	4
	162	9667~93378 (single-aperture)	2~17	4
Quadrupole	2384	2000 (twin-aperture)	1	2
	8	1000 (twin-aperture)	1	1
	1132	500~3500 (single-aperture)	1	1~3
	8	1480/2000 (superconducting)	1	1
Sextupole	996	700/1400	1	0.5
	72	300/1000	1	1
	32	300 (superconducting)	1	1
Corrector	5808	875	1	1

Table 5.3.8.1: Quantities of magnets and their supports in the Booster

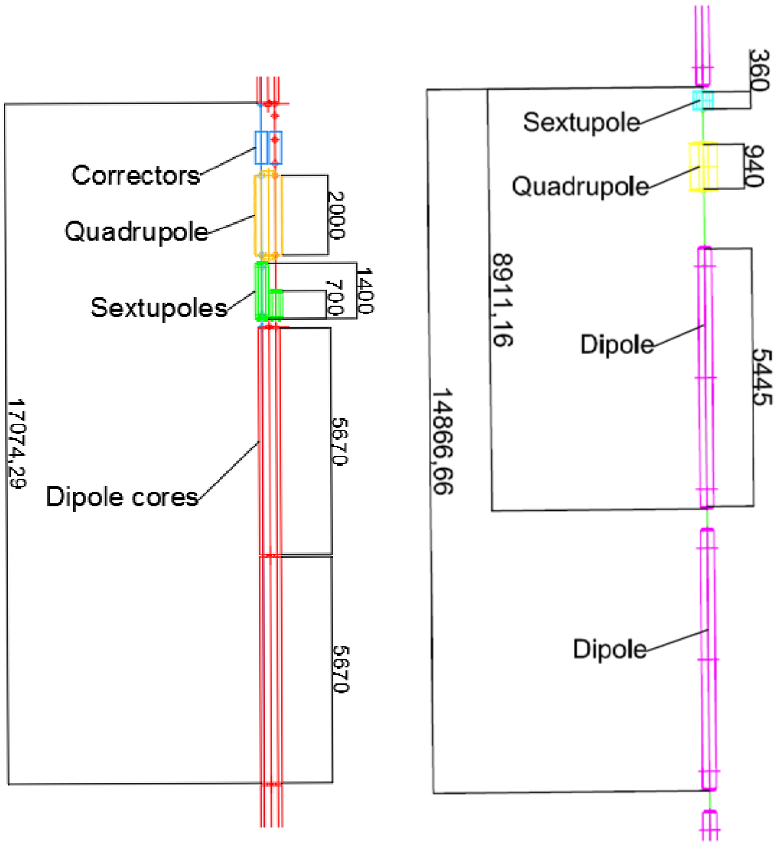
	Magnet type	Quantity	Magnet (core) length (mm)	No. of supports per magnet
Magnets in Booster	Dipole magnet	15360	5445	4
		640	2645	3
		320	2945	3
	Quadrupole magnet	1910	940	1
		8	1440	2
		118	2140	2
	Sextupole magnet	448	360	1
	Correctors	350	550	1
Magnets in Transport line BTC	Dipole magnet	68	5000	4
	Quadrupole magnet	40	1988	2
	Corrector	30	300	1
	Kicker	20	1000	1
	Septum	140	1000	1
Magnets in Transport line LTB	Dipole magnet	48	5000	4
		28	4000	4
	Quadrupole magnet	80	884	1
	Corrector	24	200	1
	Kicker	2	500	1
	Septum	4	1000	1

Table 6.5.8.1: Quantities of accelerator tubes, magnets and their supports in the Linac

Magnet type	Quantity	Device length (mm)	No. of supports per device
Accelerator tubes	277	3000	3
	6	2000	2
Dipole	4	2356	2
	6	262/279	1
	2	5236/5847	4
Quadrupole	54	300/400	1
	3	~600 (triplet)	1
	63	~1200/1800 (triplet)	2
Solenoids	1	80-1000	1
Corrector	85	100-250	1

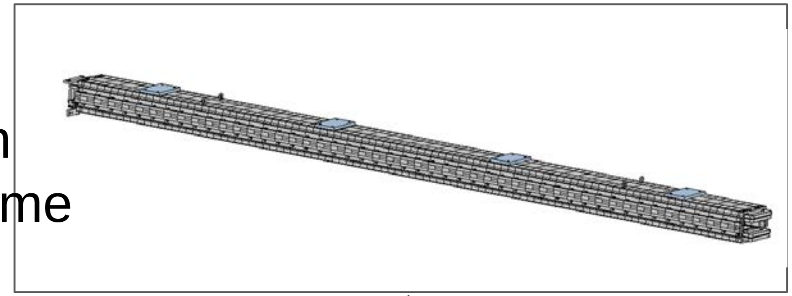
Tunnel mockup

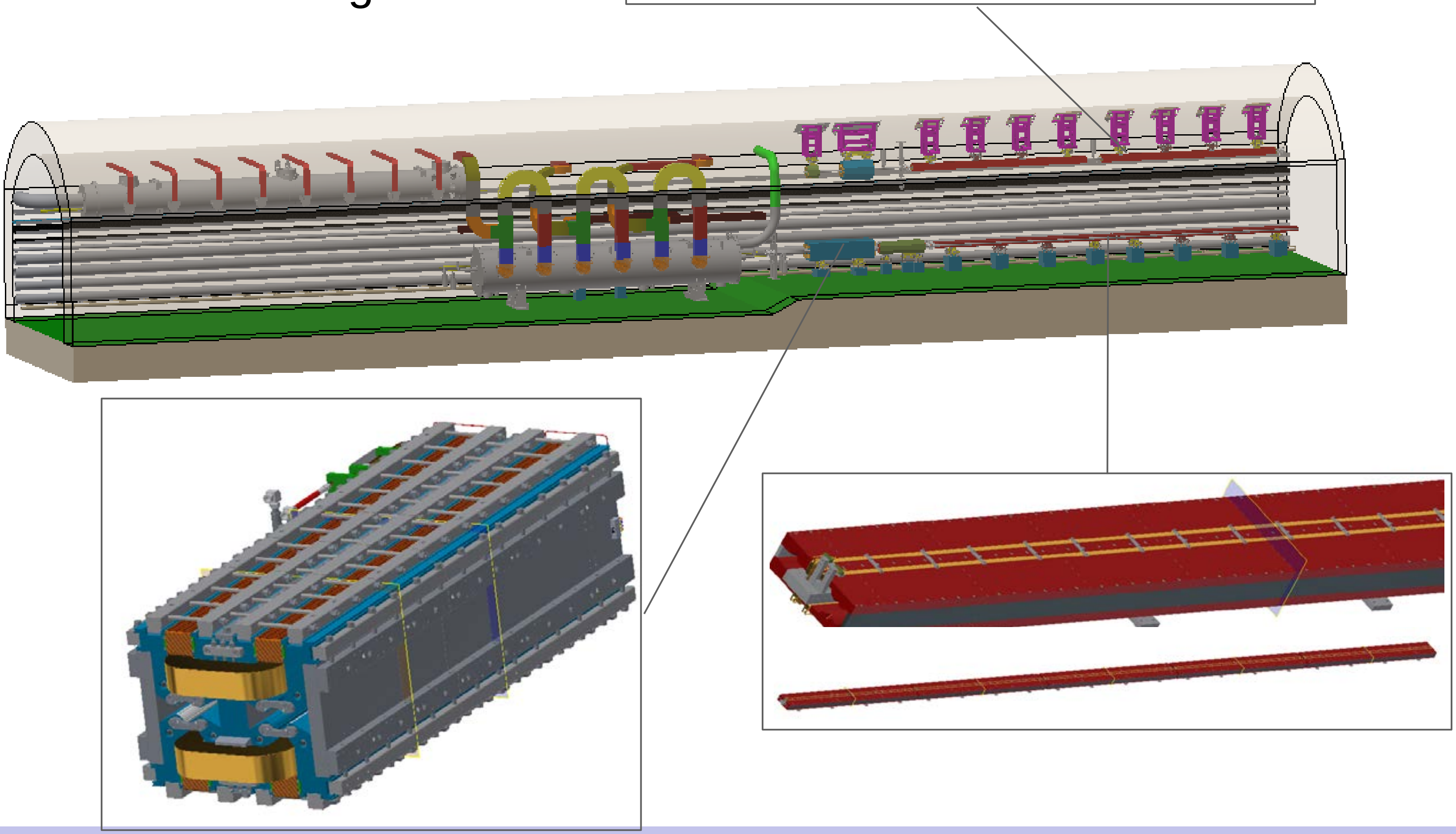
- A tunnel mockup is designed for the interface checking of the equipment locations, installation, alignment and transportation. It includes part of arc section and part of RF section.
- The arc section of Collider and Booster includes two dipole cores (or two dipoles), one quadrupole, one sextupole and one BPM.
- The RF section of Collider and Booster includes one cryomodule each.
- The total length is 40 meters.



Tunnel mockup

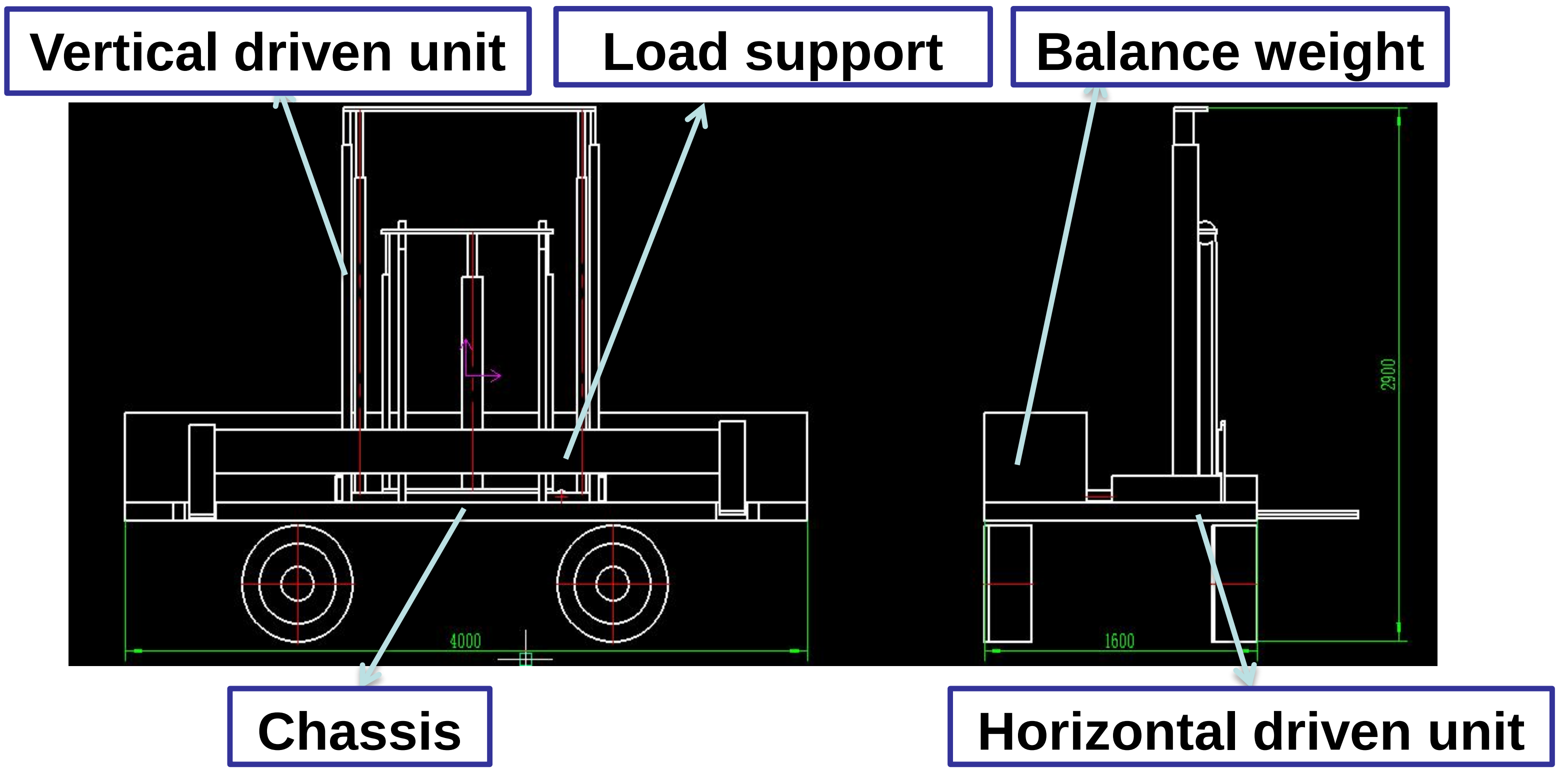
- The relative locations between magnets in each ring is the same as the lattice design.





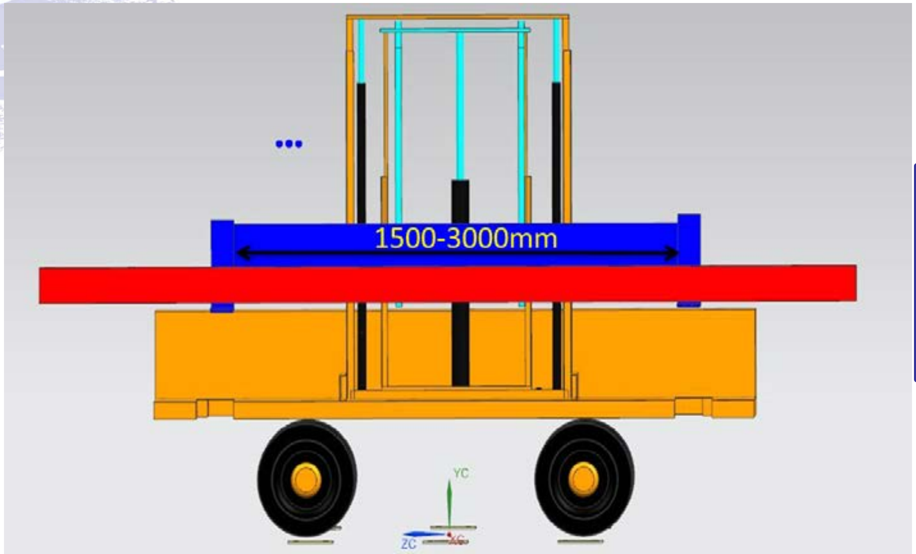
Transport vehicles

- Over 80% of the tunnel length is covered by magnets. Efficiency of transportation and installation must be considered.
- Transport vehicles are designed for the magnets transportation and coarse positioning.
- Accuracy of coarse positioning: better than 0.5 mm.



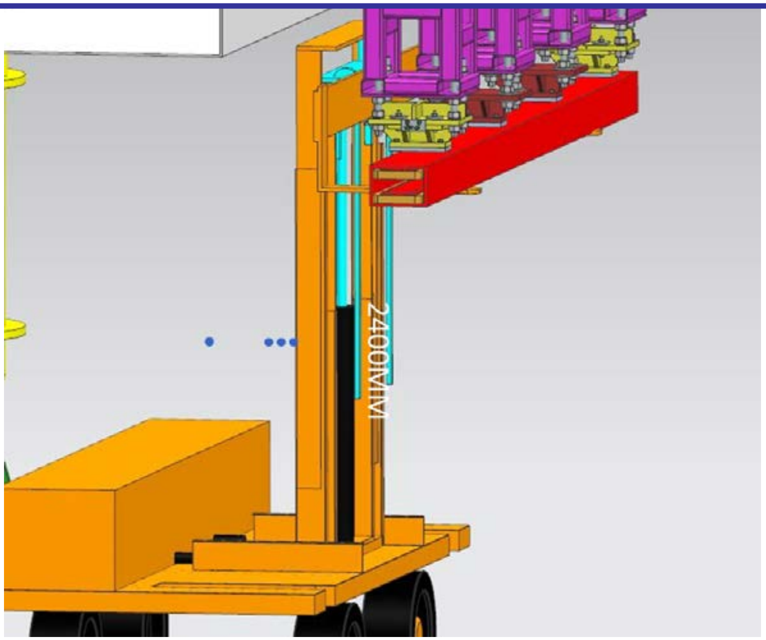
** Cooperate with Beijing North Vehicle Group Corporation.*

Transport vehicles

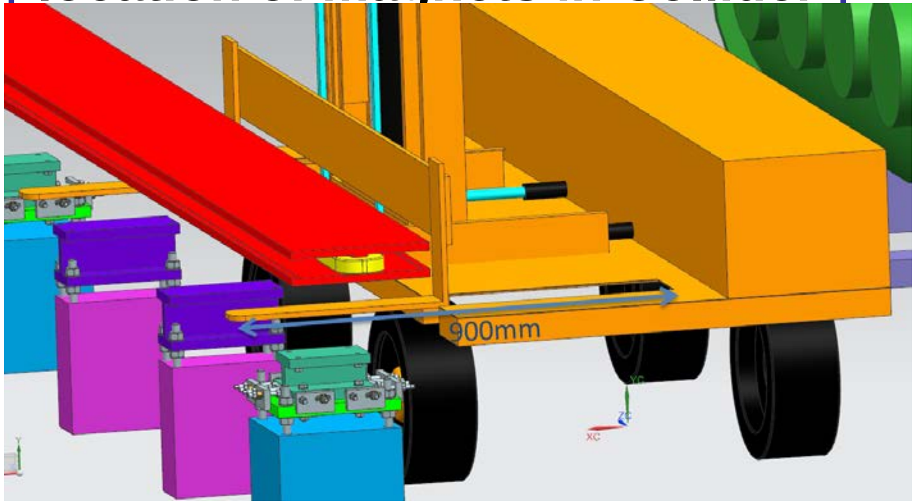


Flexible load support for "long" devices and "short" devices

Transportation and coarse location of magnets in Booster



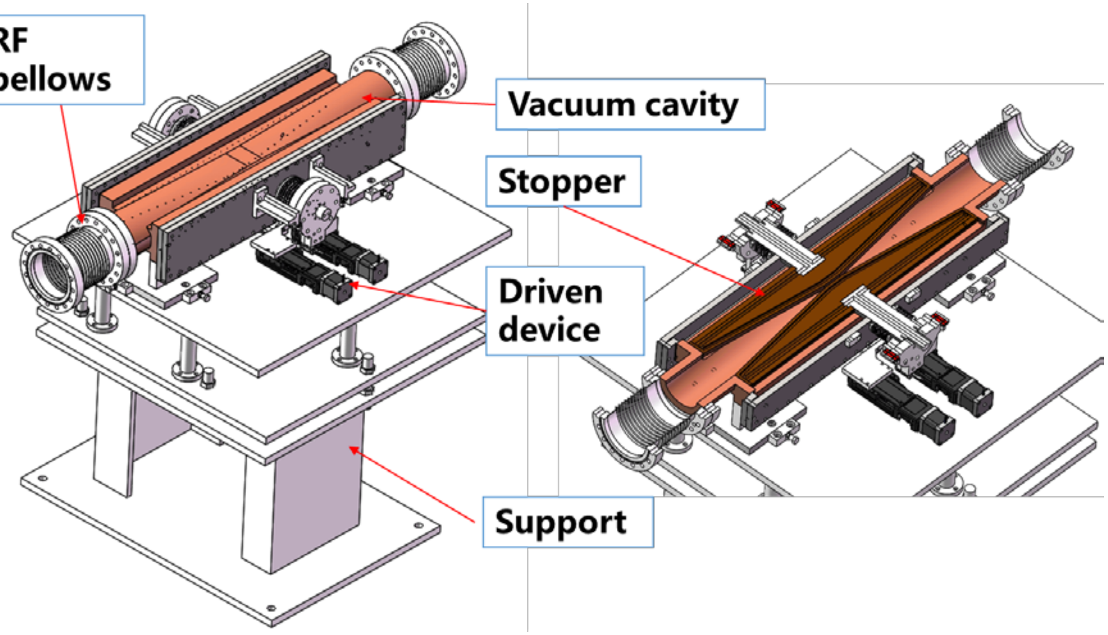
Transportation and coarse location of magnets in Collider



** Cooperate with Beijing North Vehicle Group Corporation.*

Movable collimators

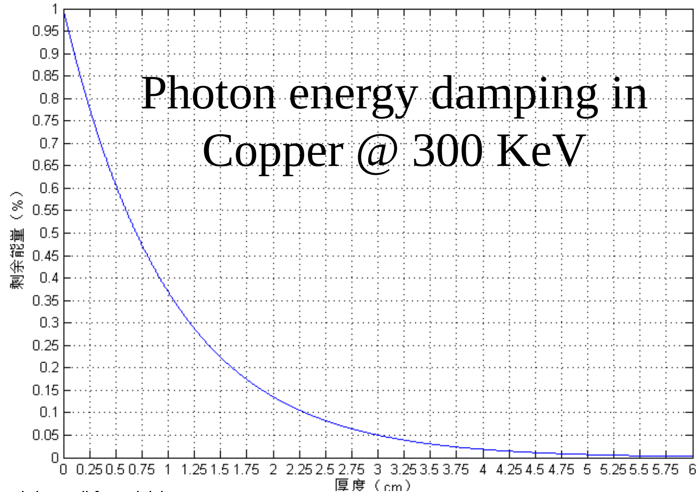
- Located in straight section between two dipoles, the length is 800 mm.
- Five horizontal collimators in each ring are designed in the TDR stage.

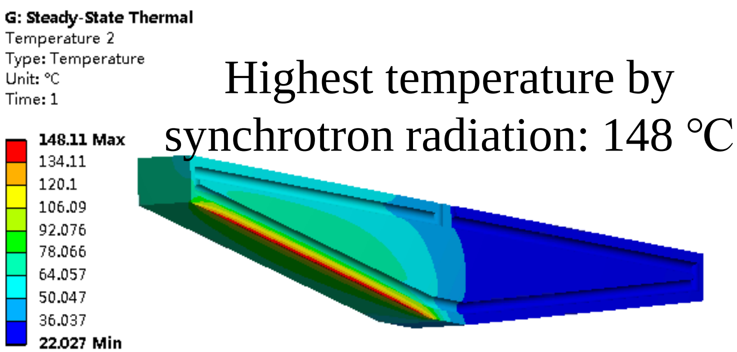


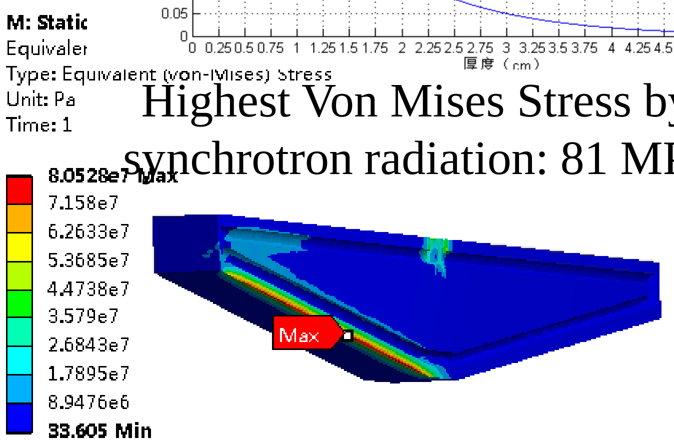
name	Position	Distance to IP/m	Beta function/m	Horizontal Dispersion/m	Phase	BSC/2/m	Range of half width allowed/mm
APTX1	D1I.1897	2139.06	113.83	0.24	356.87	0.00968	2.2~9.68
APTX2	D1I.1894	2207.63	113.83	0.24	356.62	0.00968	2.2~9.68
APTX3	D1O.10	1832.52	113.83	0.24	6.65	0.00968	2.2~9.68
APTX4	D1O.14	1901.09	113.83	0.24	6.90	0.00968	2.2~9.68
APTX5	DMBV01IRU0.492	31	196.59	0	362.86	0.01178	2.9~11.78

Movable collimators

- Synchrotron radiation: 7700W @120GeV, 30MW.
- Preliminary thermal-static analyses by synchrotron radiation have been done. Material: Glidcop-Al15.



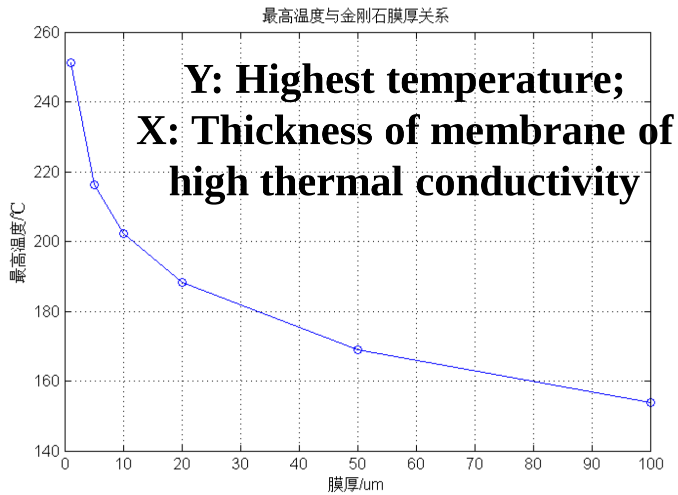




Cooling method	Loads	Highest temperature（℃）
Copper & water	Surface load	286
Copper & water	Volume load (Damping of X ray)	148
Laminated material & water	Surface load	146

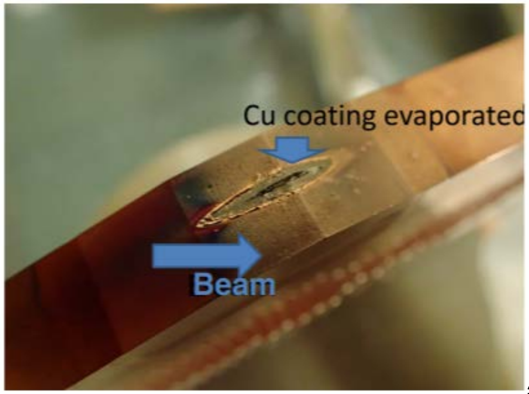
Movable collimators

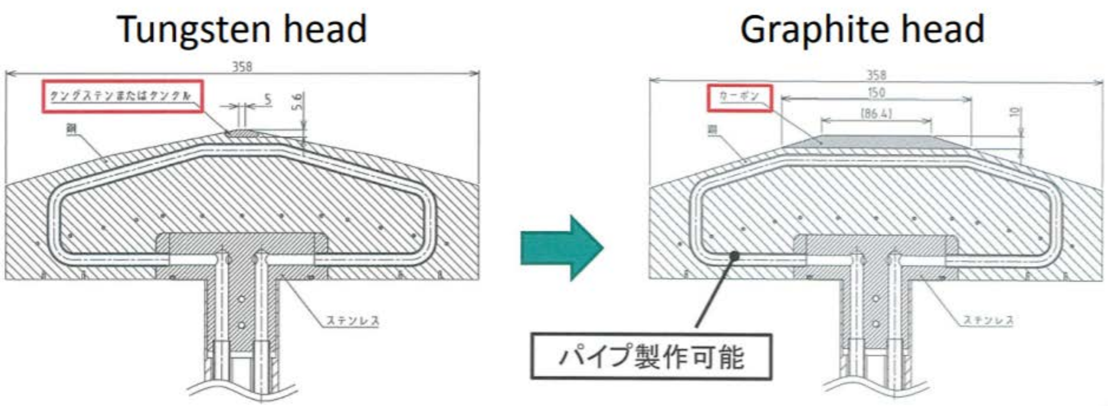
- Laminated materials with metal and high-thermal-conductivity membrane is considered for severe heat load.



Laminated material with copper and graphene film

Bottom

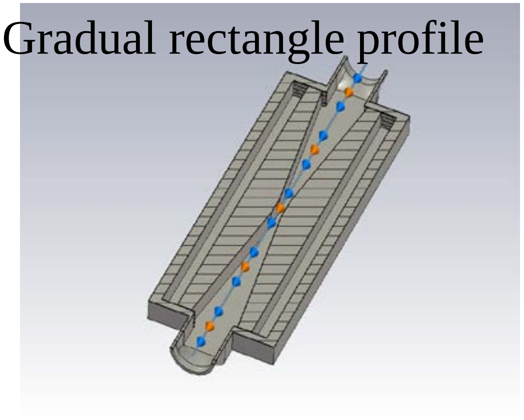


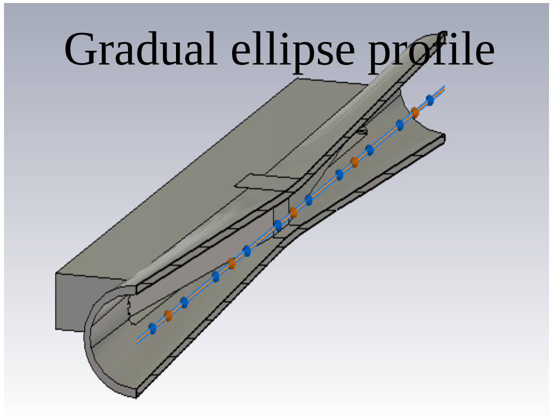


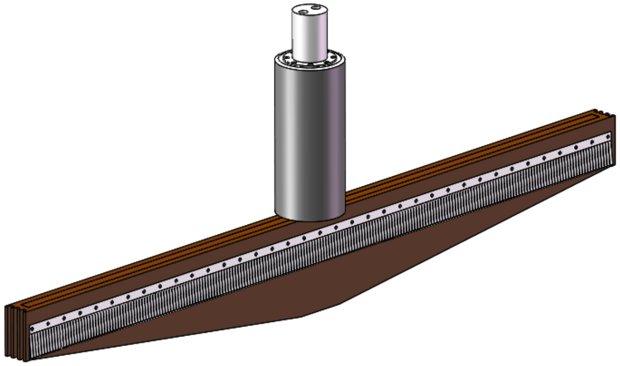
** From Carsten Niebuhr, IAS MDI Workshop, Hongkong, 16.-17.01.20*

Movable collimators

- Two inner profiles are designed, gradual rectangle and gradual ellipse with movable stoppers in them.
- RF fingers are at the edges of the stoppers to decrease impedance.



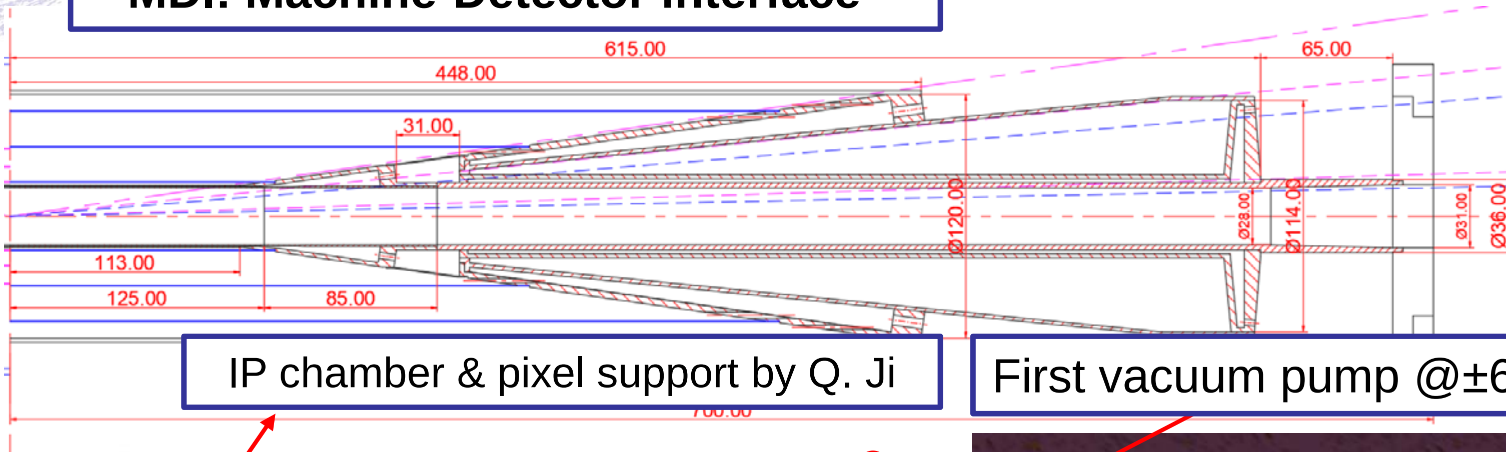




		Energy loss (no RF fingers) (W)		
		Higgs	W	Z
Gradual rectangle profile	Stopper open	66	267	933
	Stopper closed	39	160	560
Gradual ellipse profile	Stopper open	8	32	112
	Stopper closed	19	76	266

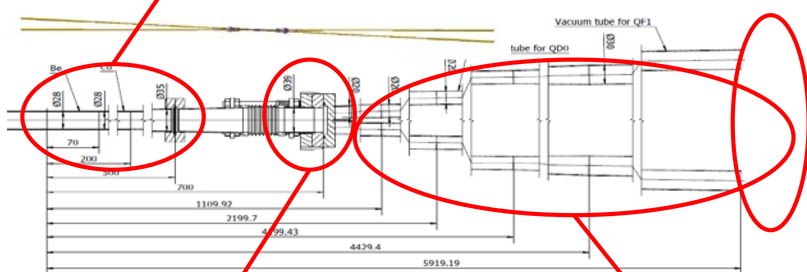
** From Y Liu et al., Impedance and Collective Instabilities for Collider, Booster and damping ring in CEPC, this workshop*

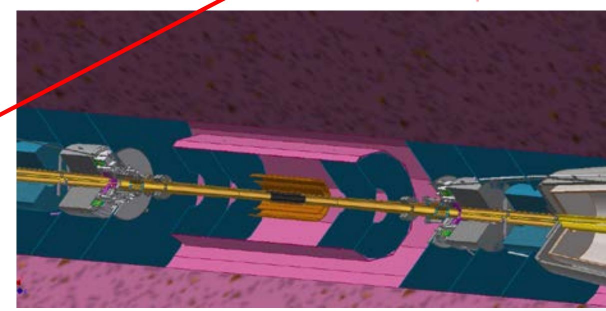
MDI: Machine-Detector interface

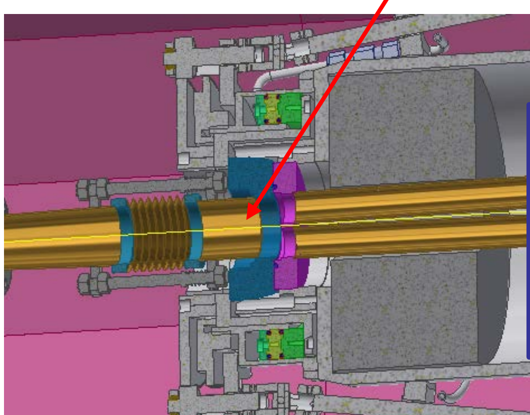


IP chamber & pixel support by Q. Ji

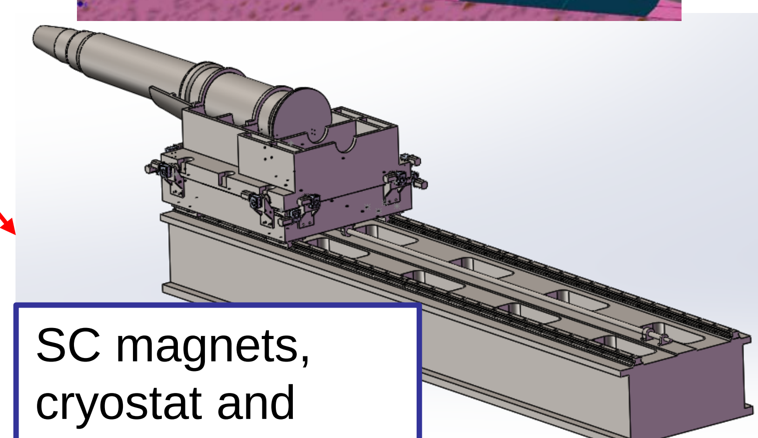
First vacuum pump @±6.5m







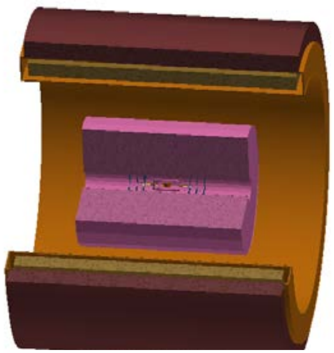
Connection interface of detector and accelerator

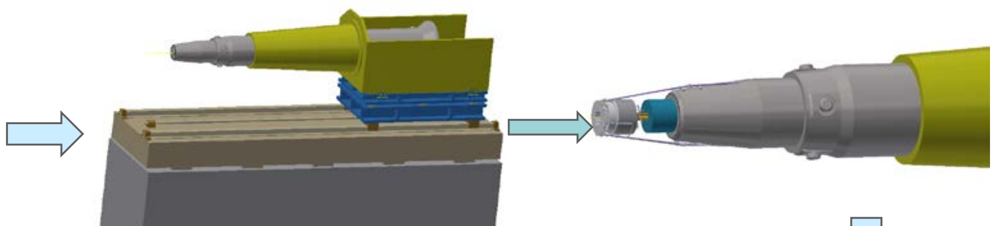


SC magnets, cryostat and their support

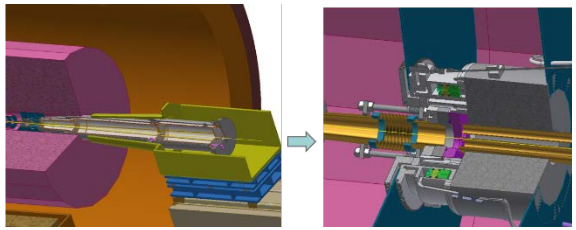
MDI mechanics

- Installation scenario of MDI
  - Assume the IP chamber and the detectors, the yoke have been installed.
  - The remoted vacuum connection methods will be used.
  - The support system of cryostat is under studying.
  - The idea of Lumical being moved to the detector part has been discussed.

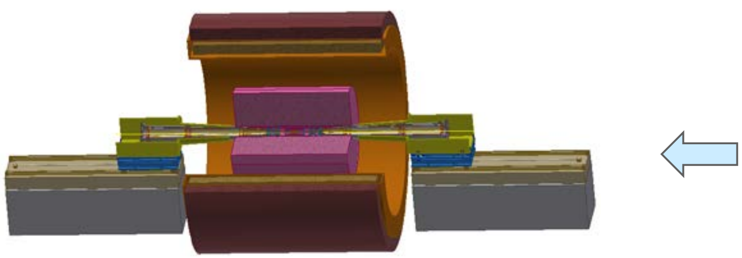




Pre-alignment of SC magnets and installation of accelerator components

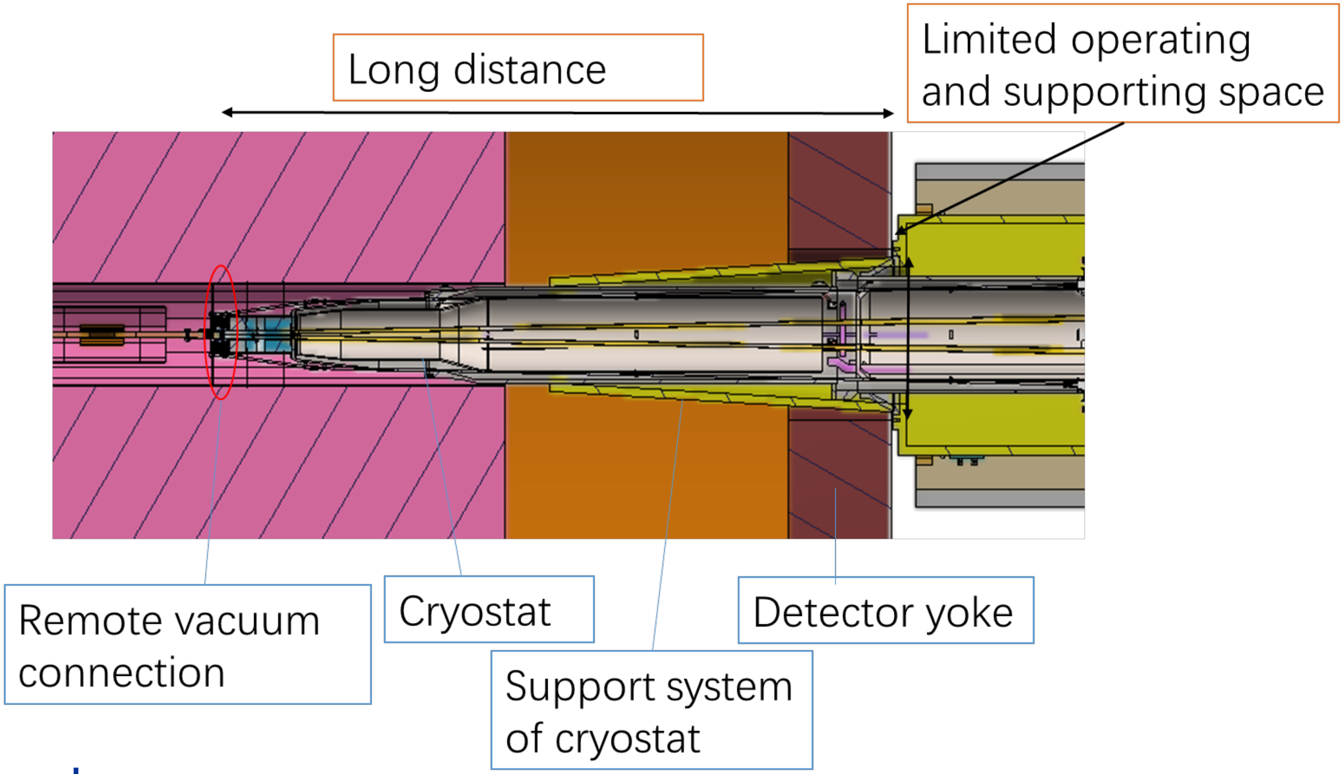


The connection and alignment of one side



The similar procedure at the other side

MDI mechanics

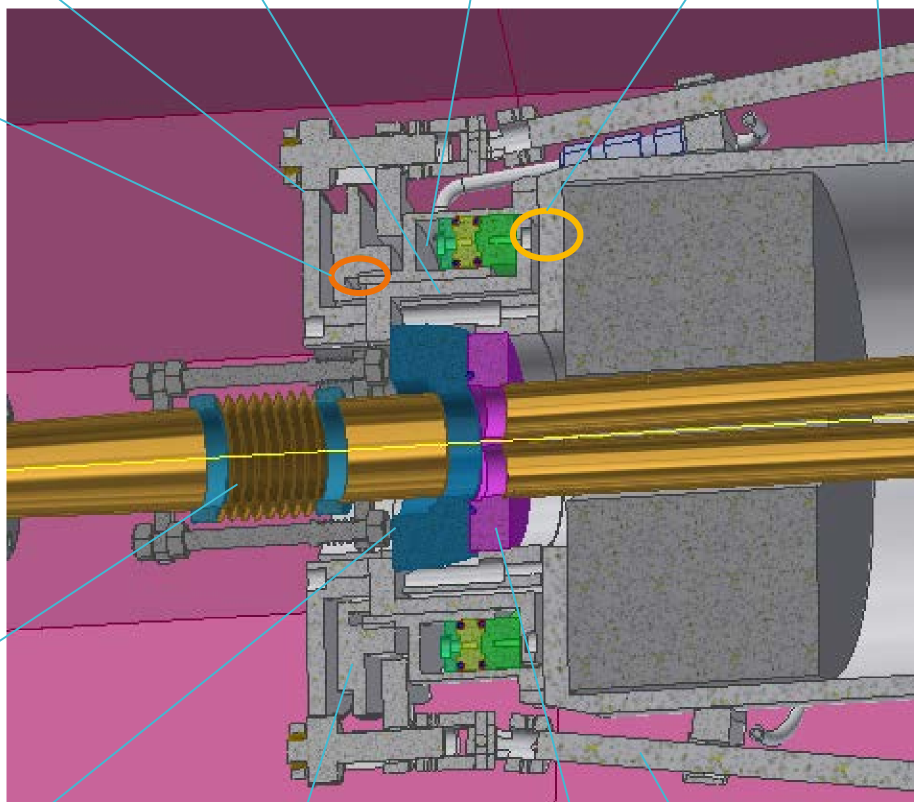


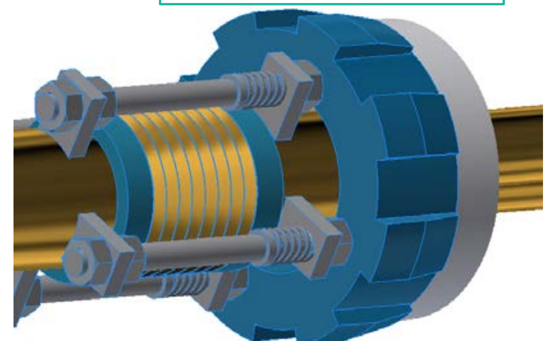
Lists to be done:

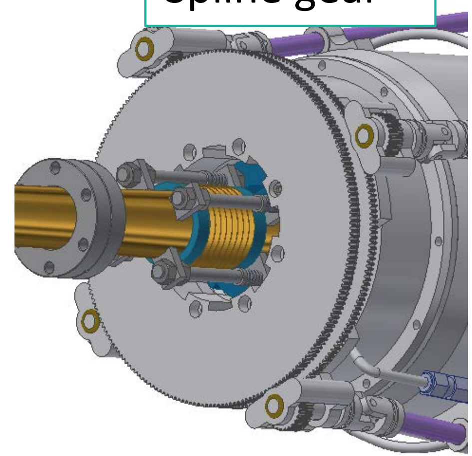
- Vacuum connection method. Leak rate requirement: ≤2.7e-11Pa.m3/s
- Support system. Alignment error requirement: ≤30 μm, at least ≤50 μm.
- 3D layout of all the components, find and solve the space problems.
- The vacuum tubes and cooling methods.
- Integration of accelerator and detector, and the installation and replacement scenarios.

MDI mechanics-Remote vacuum connection

RVC Design





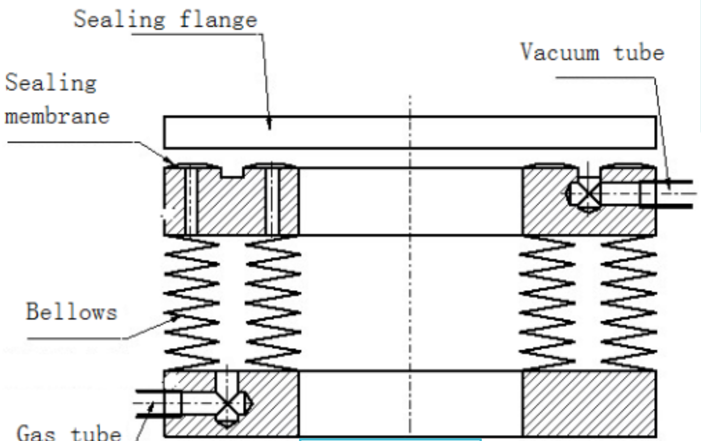


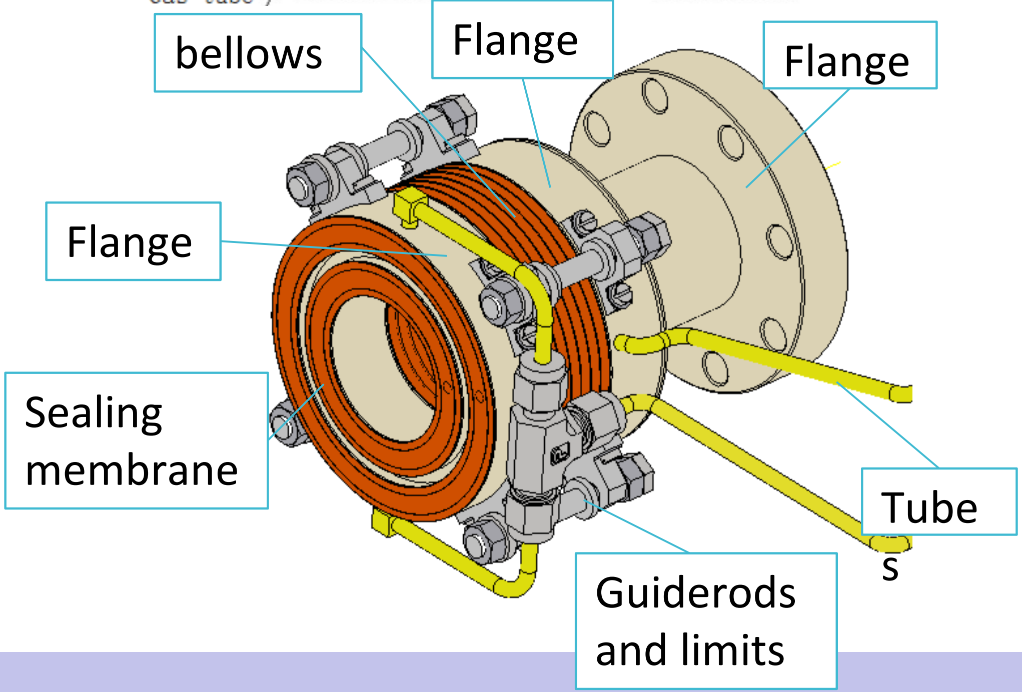
Dimensions:

- Transversal: Max. ϕ264mm
- Longitudinal: ~223mm

MDI mechanics-Remote vacuum connection

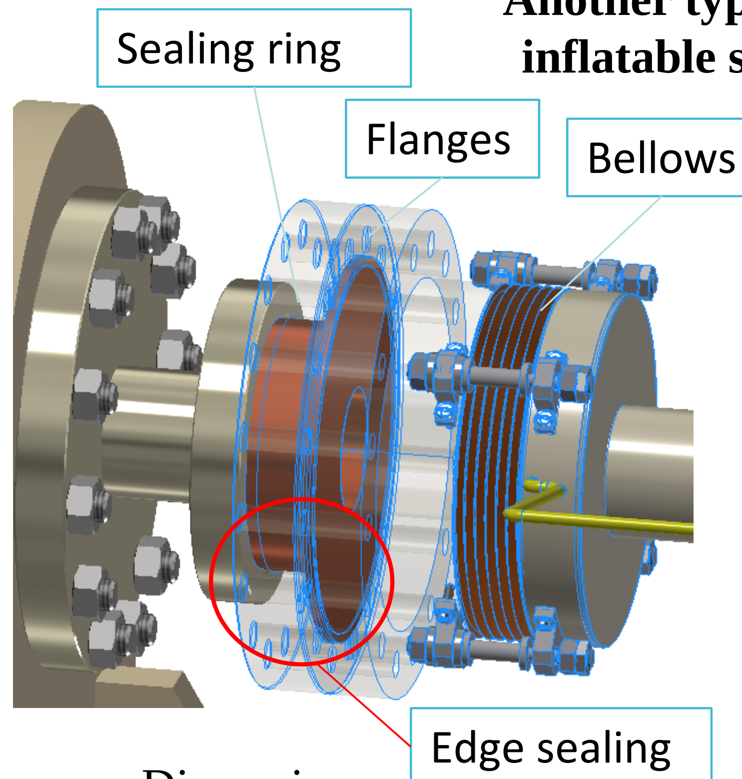
Inflatable seal design





- Experience from CSNS: leak rate ~10-7 Pa.m3/s level, four levels higher then CEPC requirement.

Another type of inflatable seal

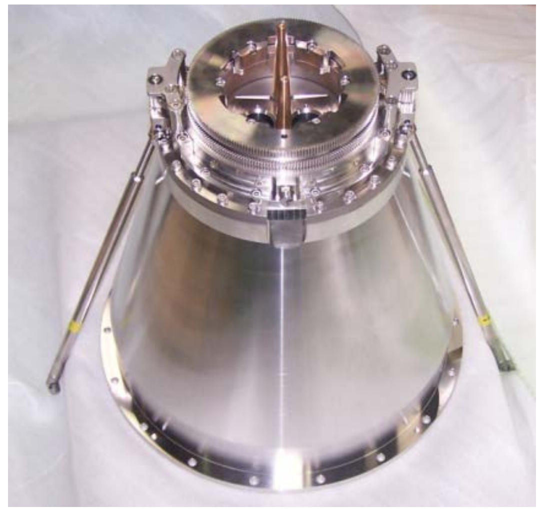


Dimensions:

- Transversal: Max. ϕ112mm
- Longitudinal: ~120mm

MDI mechanics-Remote vacuum connection

RVC similar to SuperKEKB as baseline, and studying other schemes at the same time.



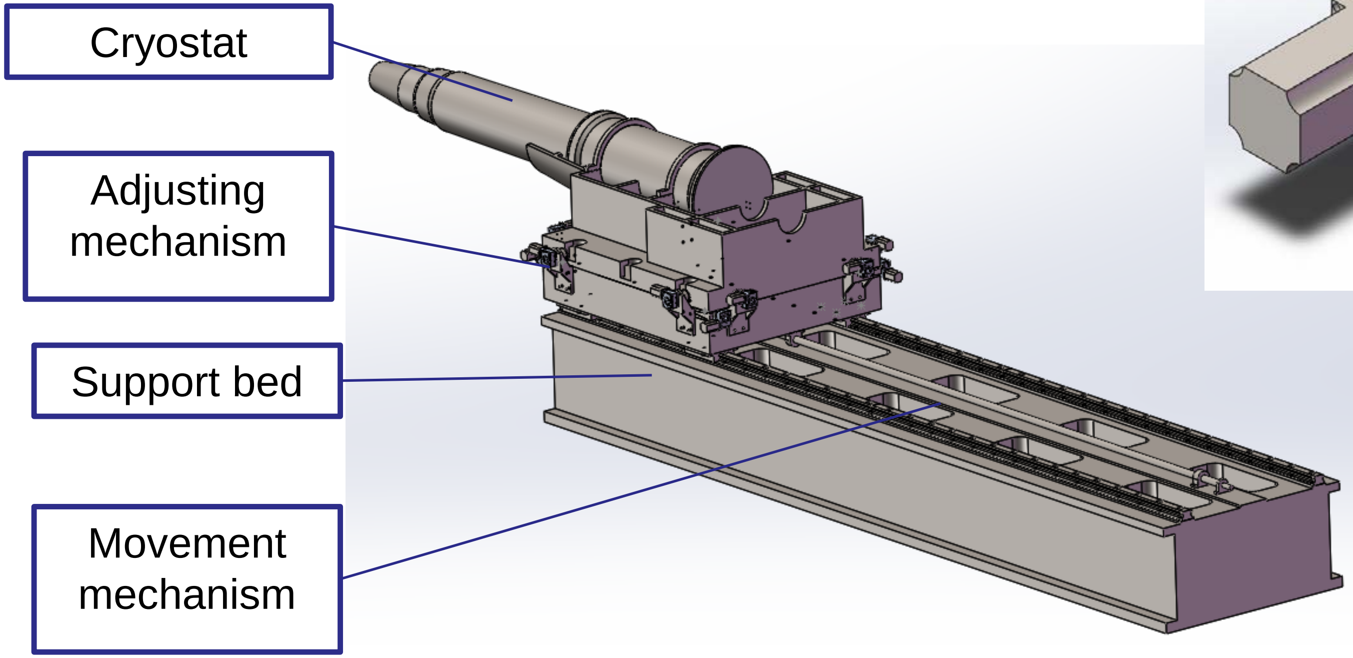
RVC of SuperKEKB

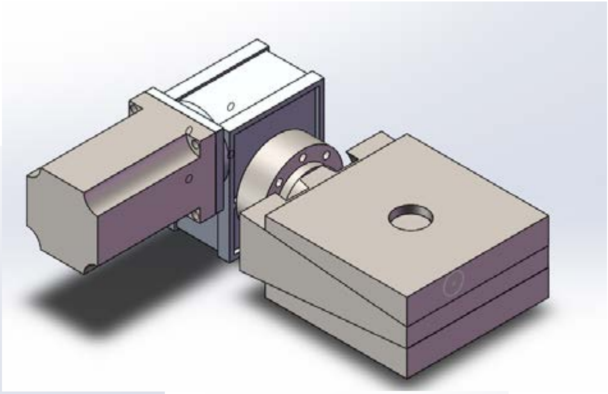
Ken-ichi Kanazawa, the 2019 international workshop on CEPC

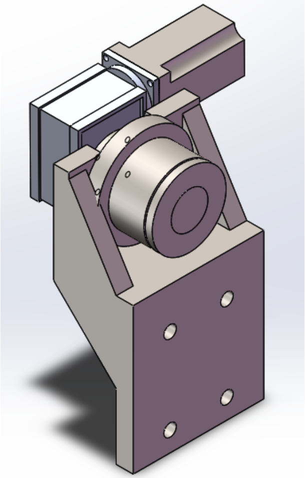
	RVC	Inflatable seal	Long tools
Sealing methods	Pneumatic clamping with auxiliary locking	Pneumatic clamping	Screws clamping using long tools
Advantages	Successful experience from SuperKEKB	Small and simple; Bellows at accelerator side. Independent on operating distance.	Simple and small
Disadvantages	Big and complex; Bellows at IP chamber side. Relay on operating distance.	Difficult for leak rate requirement	Difficult in operation. Relay on operating distance badly.

Support system of SC magnets

- Support system of SC magnets
  - The alignment accuracy of SC magnets: ≤30 μm, at least ≤50 μm.
  - Movement mechanism: high precision track & rack.
  - Adjusting mechanism: motor driven wedges jacks for vertical direction, motor driven screw jacks

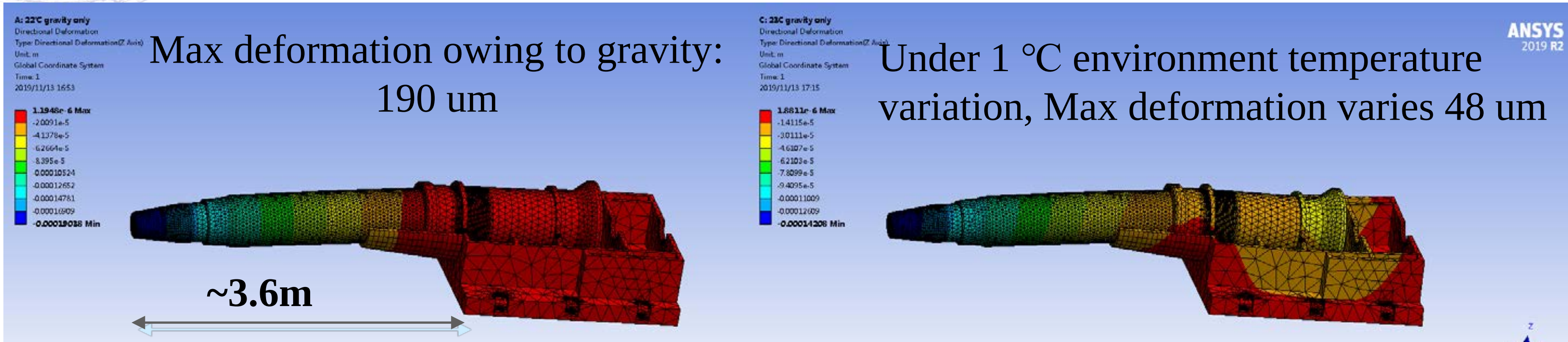






** Cooperate with Beijing Institute of Space Mechatronics*

Support system of SC magnets



Detailed analyses of the cryostat & support assembly should be done, including the deformation and vibration, considering gravity, temperature, magnetic field force.

- The current design of cryostat is 5 meters long with18 mm thick stainless walls. The weight of the cryostat is about 2 tons.
- Only the cryostat itself is considered in the calculation above.
- If the yoke length gets larger, the deformation will be even larger, which is proportional to the 4^{th} power of length.
- If the weight of components inside the cryostat and the magnetic field forces are considered, the deformation will be much larger.
- We are searching the solution. The design will be adjusted with detector design, dynamic design and alignment design.

MDI mechanics-Support system

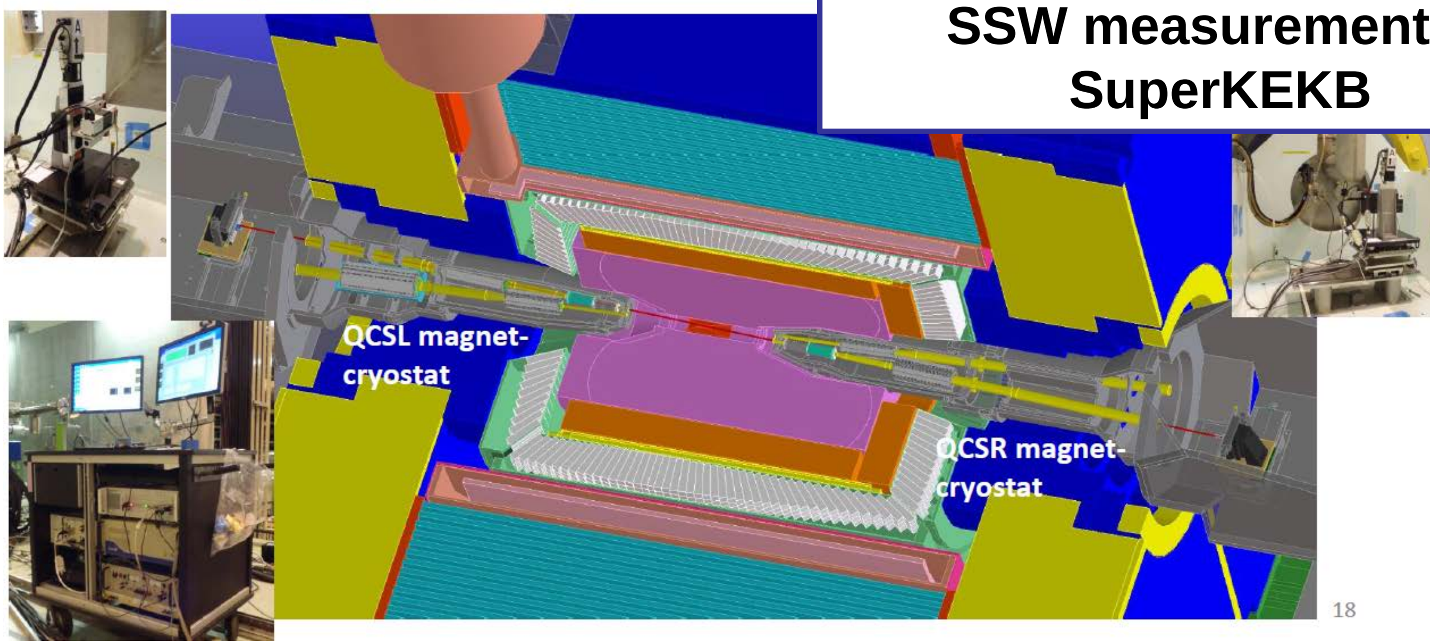
SSW measurement

SSW measurement system in the IR

N. Ohuchi, IPAC2018

- Two magnet-cryostats of QCSL/R were aligned to the beam lines with the targets of the cryostats.
- A BeCu single wire of ϕ0.1 mm, which was aligned to the design beam line, was stretched through QCSR and QCSL cryostat bores.
- The measurements were performed with operating the Belle SC solenoid at 1.5 T, and ESL and ESR1 solenoids.
  - The measured data include the displacement by the electro-magnetic forces between solenoids and magnetic components in the cryostats.

SSW measurement of SuperKEKB



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- **Max. center misalignment is 0.69 mm**
- **“Every alignment errors are able to corrected by the corrector magnets.**

Summary

- Preliminary magnet supports has been done for typical magnets.
- A 40 meters mockup of arc-section has been designed for interface checking, installation, alignment and transportation.
- Transport vehicles for the magnets transportation and coarse positioning has been designed.
- Preliminary structure design, FEA and impedance calculation has been done for the movable collimators.
- For the MDI region, the design of the remote vacuum connection methods have done, and the support system of SC magnets is under design.

Thanks for your attention!