IAS2021: highlights

M. Koratzinos

FCC-ee Optics Design Meeting

22/1/2021

introduction

- A very eclectic and biased review of the IAS conference
- I have only things that:
  - I noticed
  - That I was interested in
  - That show a deviation from my preconceptions

Final focus quadrupoles

- Two main units on each side of the IP and for each beam, e^+ (P)and e^-(E): QC1LE, QC2LE, QC1RE,QC2RE, QC1LP, QC2LP, QC1RP,QC2RP
- QC1 is inside the detector and itself comprises three units per side per beam: QC1L1P, QC1L2P,QC1L3P, QC1L1P, QC1L2P,QC1L3P, QC1L1E, QC1L2E,QC1L3E, QC1L1E, QC1L2E,QC1L3E
- There are 5X2X2=20 single aperture units in total

From the FCC CDR update 13/12/2019, Katsunobu Oide

	Start position (m)	Length (m)	B' @Z (T/m)	B' @W (T/m)	B' @ H (T/m)	B' @ tt (T/m)
QC2L2	-8.44	1.25	25.05	43.82	61.30	69.50
QC2L1	-7.11	1.25	-0.18	0.00	7.32	56.85
QC1L3	-5.56	1.25	-19.35	-34.38	-53.08	-99.98
QC1L2	-4.23	1.25	-18.57	-32.94	-53.07	-99.98
QC1L1.1	-2.9	0.7	-40.95	-70.00	-99.71	-95.39
QC1L1.2	2.2	0.7	-40.95	-70.00	-99.71	-95.39
QC1R2	2.98	1.25	-25.44	-37.25	-51.94	-100.00
QC1R3	4.31	1.25	-19.54	-39.51	-53.65	-91.87
QC2R1	5.86	1.25	14.64	16.85	-2.65	37.19
QC2R2	7.19	1.25	19.50	44.32	67.52	94.43

- Optics design is such that E and P quads have the same strength
- Maximum strength is 100T/m
- The most difficult element is QC1L1, the closest to the beam and where the E and P quads are closer together

The updated parameters are rather different for QC1L1: its length is now 70cm from 120cm

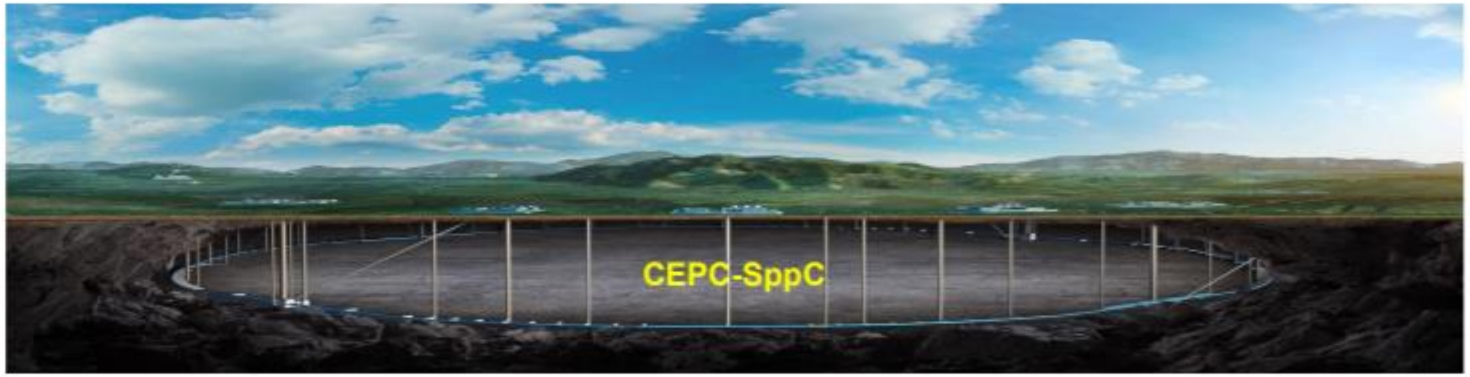
My impression regarding the CEPC

- A lot of hardware
- Very aggressive design – more aggressive than FCC-ee!
  - L* less than FCC-ee: 1.9m
  - B field of detector higher than FCC-ee: 3T
  - Beam pipe diameter @FF quads smaller than FCC-ee: 17mm
  - FF quad strength higher than FCC-ee ~140T/m
  - (beam pipe diameter @ the IP: 28mm)
- Still some errors

CEPC Accelerator Status and TDR Progress

J. Gao

IHEP
On behalf of CEPC Group



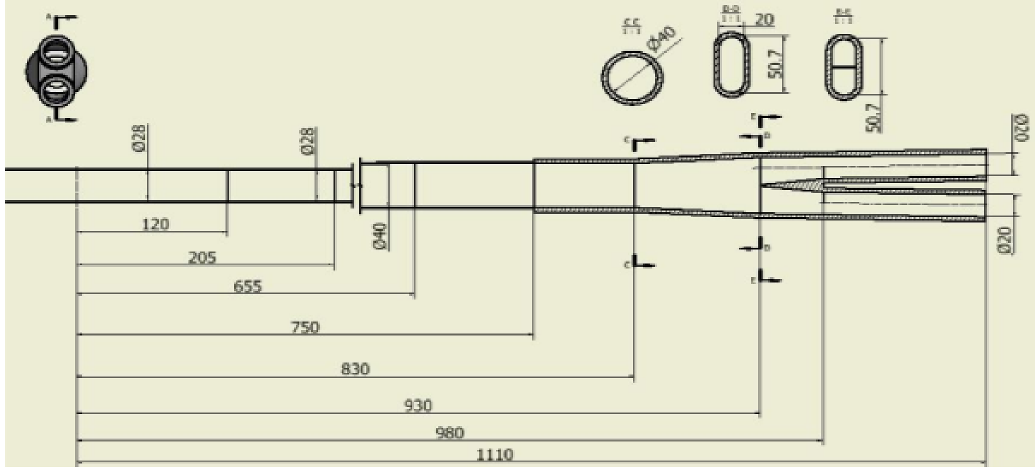
HKIAS HEP Conference, Jan. 18, 2021

High Luminosity Scheme at Higgs energy

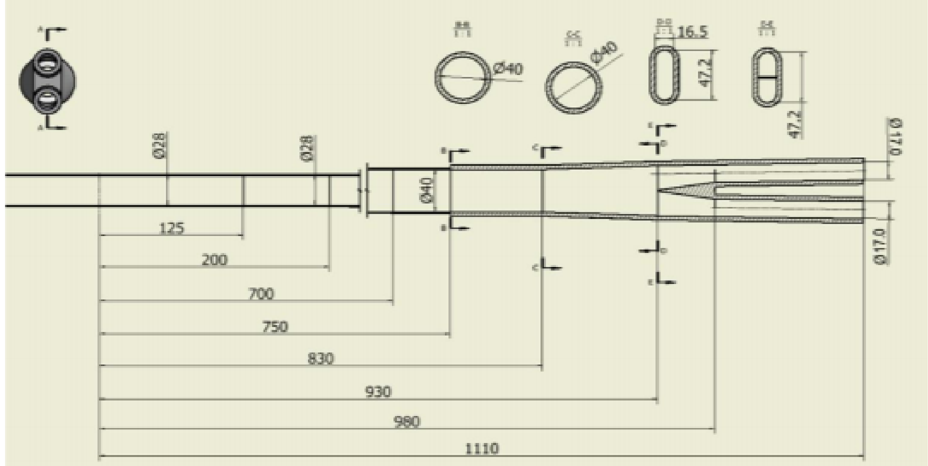
Change of IP chamber

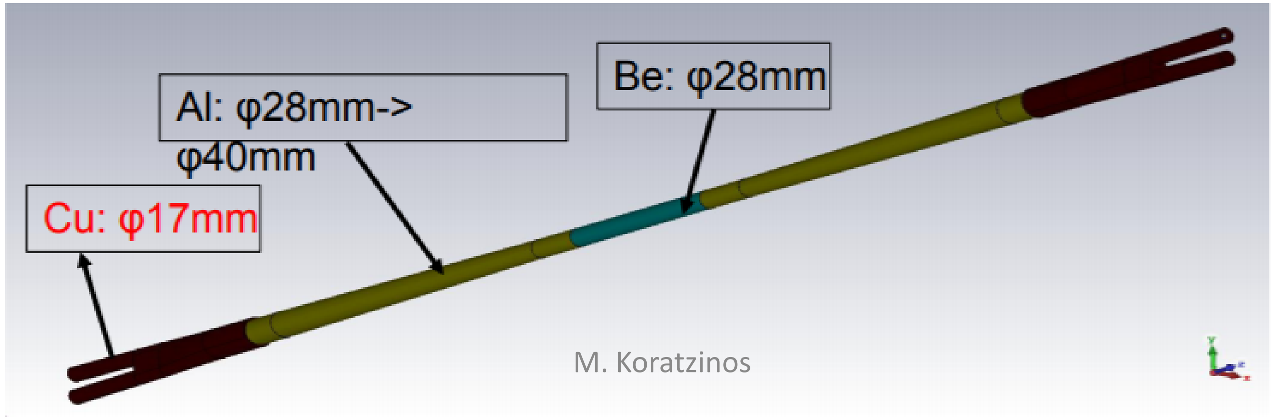
CDR | High luminosity

Be pipe: 28mm, SCQ Beam pipe:20mm



Be pipe: 28mm, Beam pipe:17mm





M. Koratzinos

Imperfection and correction for CEPC

Bin Wang (on the behalf of the CEPC error correction team)
Institute of High Energy Physics

01.19
2021

THE IAS PROGRAM ON HIGH ENERGY PHYSICS (HEP 2021)

Similar assumptions to ours?

Errors definition and challenges

IR=50μm

Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)	Field error
Dipole	0.10	0.10	0.1	0.01%
Arc Quadrupole	0.10	0.10	0.1	0.02%
IR Quadrupole	**0.05**	**0.05**	**0.05**	
Sextupole	0.10	0.10	0.1	

IR=100μm

Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)	Field error
Dipole	0.10	0.10	0.1	0.01%
Arc Quadrupole	0.10	0.10	0.1	0.02%
IR Quadrupole	**0.10**	**0.10**	**0.10**	
Sextupole	0.10	0.10	0.1	

- The lattice with small beta functions is very sensitive to FF misalignments.
- Small vertical dispersion and the coupling correction.
- 1000 lattice seeds are generated for further correction.

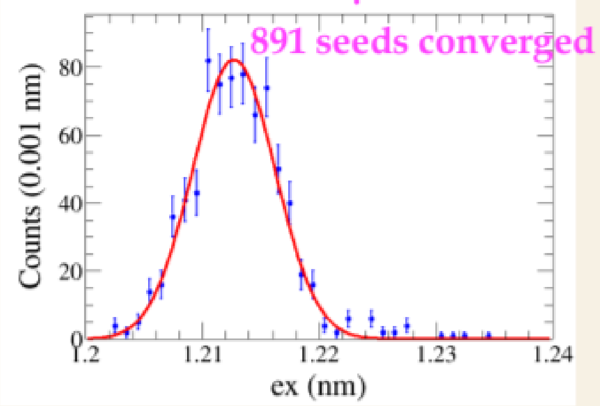
IAS 2021

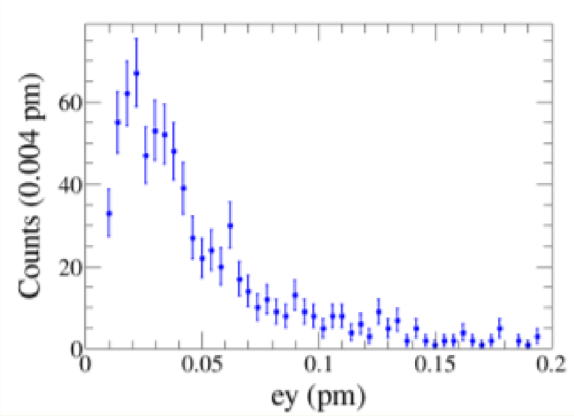
E = 120GeV

Results of emittance tuning

IR=50µm

891 seeds converged

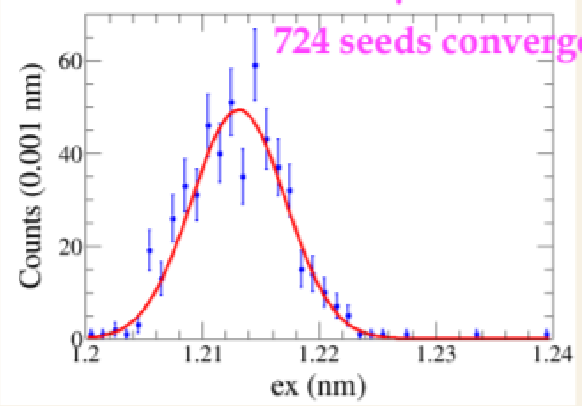


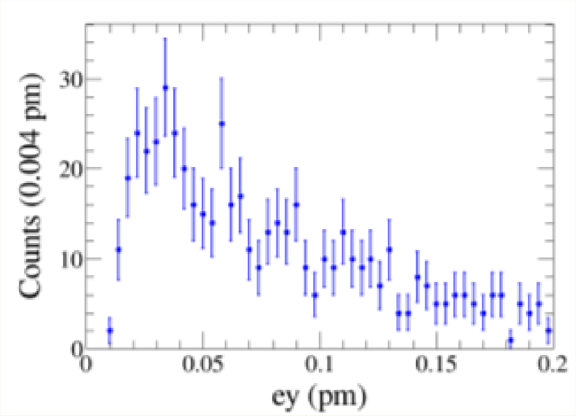


ex = 1.2127±0.0035 nm,
ey = 0.050± 0.0015 pm
ey/ex = (0.0041± 0.0001)%

IR=100µm

724 seeds converged





ex = 1.2131±0.0040 nm,
ey = 0.0777± 0.0023 pm
ey/ex = (0.0064± 0.0002)%

香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Institute of High Energy Physics
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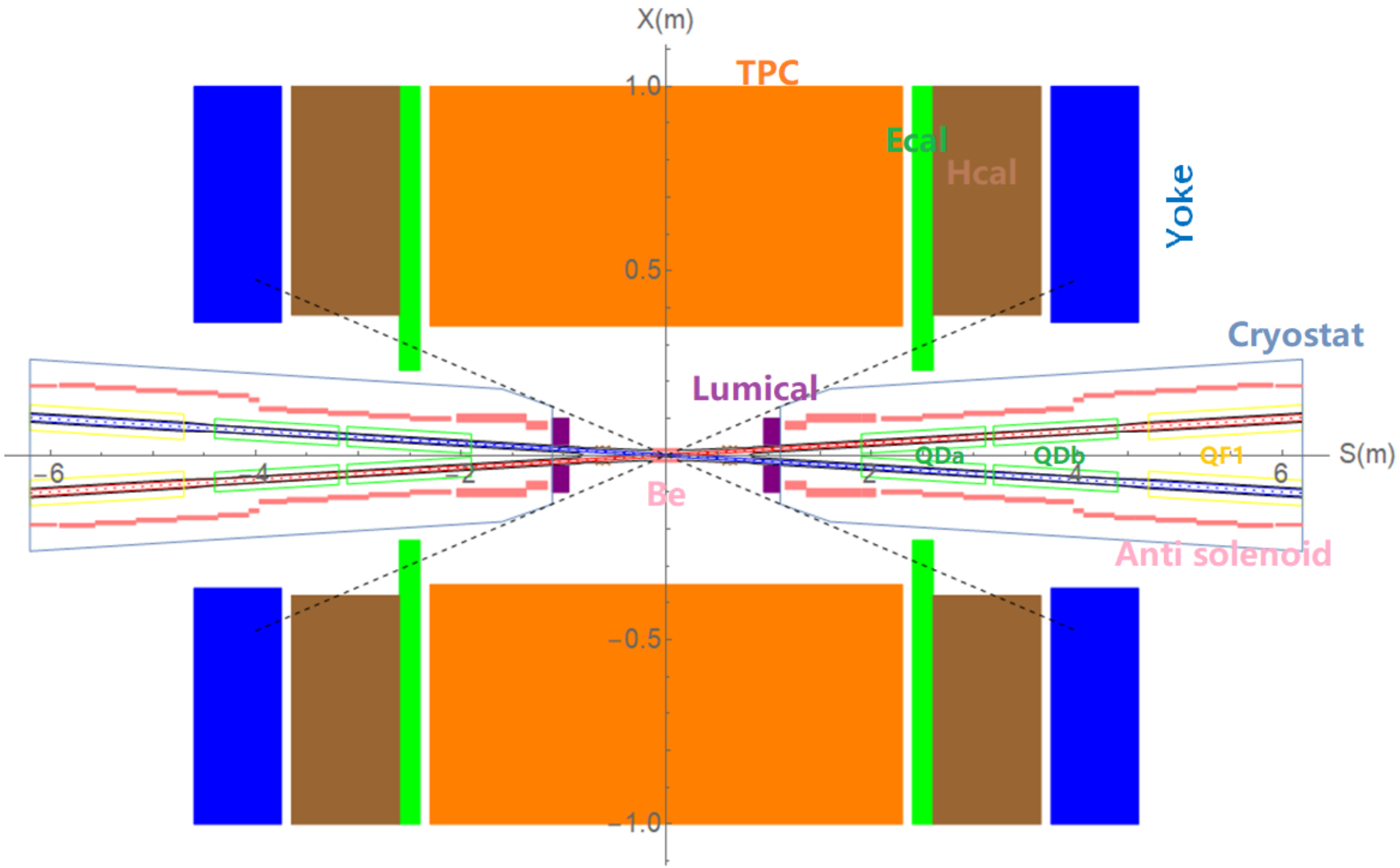
HKUST JOCKEY CLUB INSTITUTE FOR ADVANCED STUDY

CEPC MDI Issues

Sha Bai
for CEPC MDI group

IAS Program on High Energy Physics,
Hong Kong, Jan 19-21, 2021.
2021-01-21

MDI layout and IR design



- The Machine Detector Interface (MDI) of CEPC double ring scheme is about ±7m long from the IP.
- The CEPC detector superconducting solenoid with 3T magnetic field and the length of 7.6m.
- The accelerator components inside the detector without shielding are within a conical space with an opening angle of cosθ=0.993.
- The e+e- beams collide at the IP with a horizontal angle of 33mrad and the final focusing length is 1.9m.

Chances since their CDR

- Now L* is 1.9m, strength of FF quad ~150T/m
- Design is more aggressive than ours!
- B-s-c is ~15mm, but beam pipe (from Jie Gao's talk) is only 17 mm diameter

MDI parameters

	range	Peak filed in coil	Central filed gradient	Bending angle	length	Beam stay clear region	Minimal distance between two aperture	Inner diameter	Outer diameter	Critical energy (Horizontal)	Critical energy (Vertical)	SR power (Horizontal)	SR power (Vertical)
L*	0~1.9m				1.9m								
Crossing angle	33mrad												
MDI length	±7m												
Detector requirement of accelerator components in opening angle	8.11°												
QDa/QDb		3.2/2.8T	141/84.7 T/m		1.21m	15.2/17.9mm	62.71/105.28mm	48mm	59mm	724.7/663.1 keV	396.3/263keV	212.2/239.23W	99.9/42.8W
QF1		3.3T	94.8T/m		1.5m	24.1 mm	155.11mm	56mm	69mm	675.2keV	499.4keV	472.9W	135.1W
Lumical	0.95~1.11m				0.16m			57mm	200mm				
Anti-solenoid before QD0		8.2T			1.1m			120mm	390mm				
Anti-solenoid QD0		3T			2.5m			120mm	390mm				
Anti-solenoid QF1		3T			1.5m			120mm	390mm				
Beryllium pipe					±120mm			28mm					
Last B upstream	64.97~153.5m			0.77mrad	88.5m					33.3keV			
First B downstream	44.4~102m			1.17mrad	57.6m					77.9keV			
Beampipe within QDa/QDb					1.21m							1.19/1.31W	
Beampipe within QF1					1.5m							2.39W	
Beampipe between QD0/QF1					0.3m							26.5W	

QDa/QDb, QF1 physics design parameters

β_y^*=1mm, β_x^*=0.33m

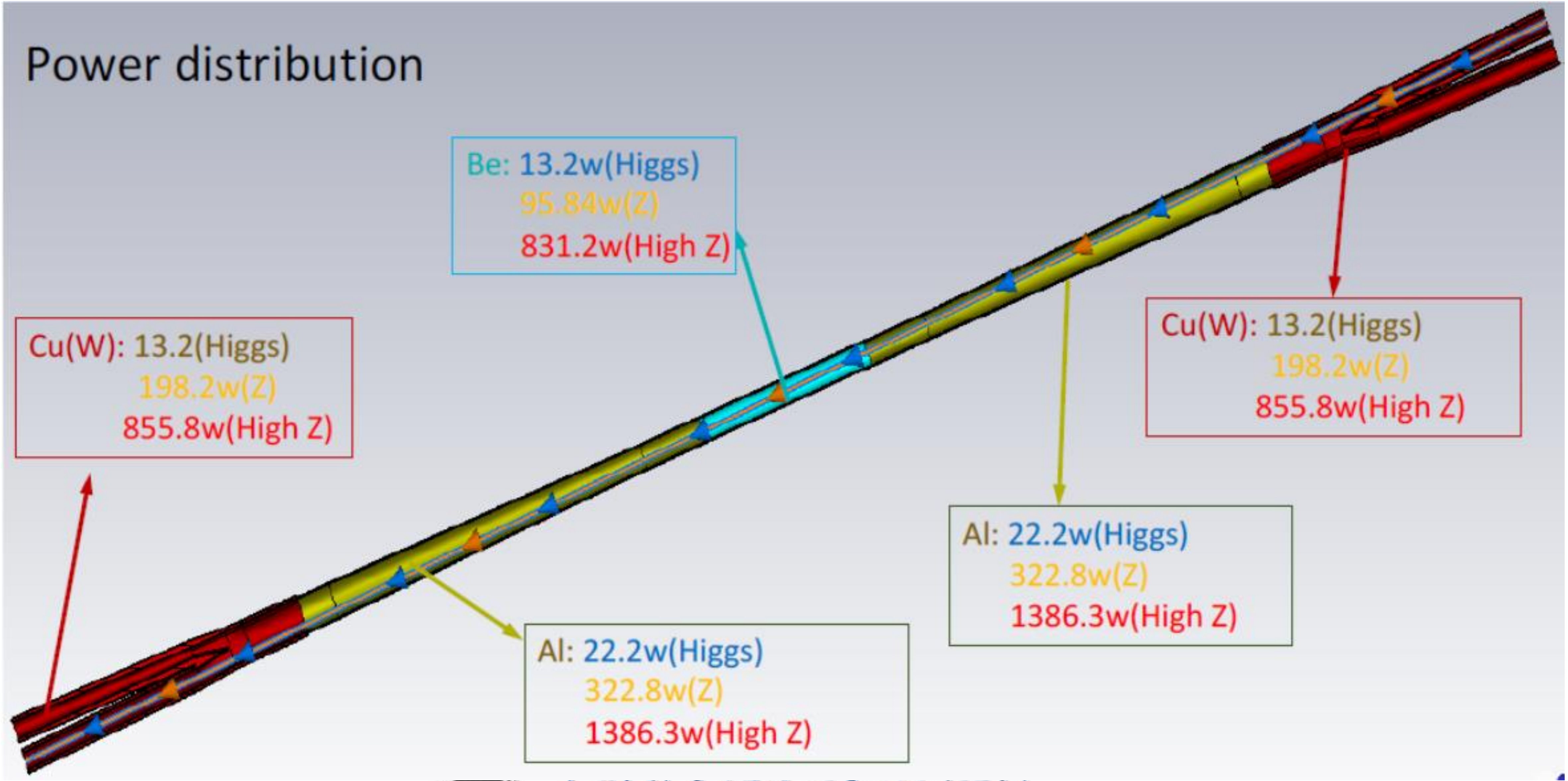
QDa/QDb	Horizontal BSC 2（$18\sigma_x$+3）	Vertical BSC 2（$22\sigma_y$+3）	e+e- beam center distance
Entrance	12.41/19.66 mm	12.89/15.22 mm	62.71/105.28mm
Middle	14.84/23.02 mm	14.61/14.88 mm	82.84/125.41mm
Exit	17.92/24.14 mm	15.21/13.87 mm	102.64/145.21mm
Good field region	Horizontal 12.13/17.92 mm; Vertical 15.21/15.22 mm		
Effective length	1.21 m		
Distance from IP	1.9/3.19 m		
Gradient	141/84.7 T/m		

QF1	Horizontal BSC 2（$18\sigma_x$+3）	Vertical BSC 2（$22\sigma_y$+3）	e+e- beam center distance
Entrance	19.66 mm	13.21 mm	155.11 mm
Middle	23.02 mm	12.00 mm	179.87 mm
Exit	24.14 mm	11.60 mm	204.62 mm
Good field region	Horizontal 24.14 mm; Vertical 13.21 mm		
Effective length	1.5 m		
Distance from IP	4.7 m		
Gradient	94.8 T/m		

Heating load on beam pipe

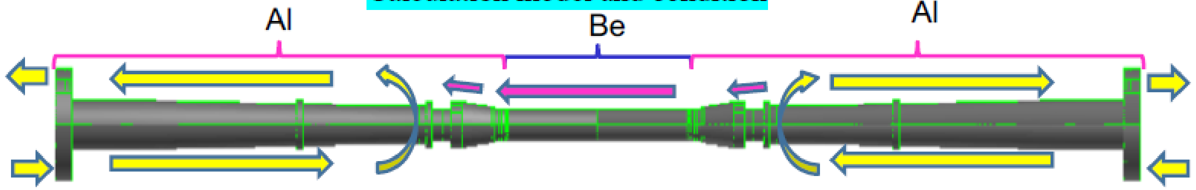
- Big discussion on SR heating and collision debris heating, but no mention of resistive heating…
- Huge amount of HM heating (4kW around +-2m from the IP)
- Paraffin cooling does not work, use water instead.

HOM power distribution



Beam pipe thermal analysis

Calculation model and condition



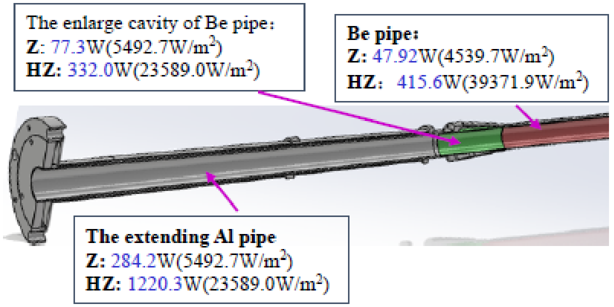
- Coolant: water
- Inlet temperature: 23°C
- Flow rate: 3.4L/min

- Coolant: paraffin
- Inlet temperature: 23°C
- Flow rate: 2.2L/min

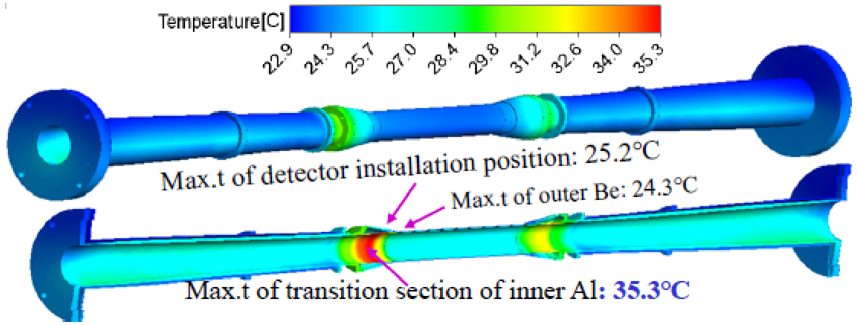
- Coolant: water
- Inlet temperature: 23°C
- Flow rate: 3.4L/min

Viscous model: Laminar

Heat in each part of calculation model



Temperature distribution in Z model



paraffin: Δp=19.8kPa, Δt=3.1°C
water: Δp=14.8kPa, Δt= 1.2°C

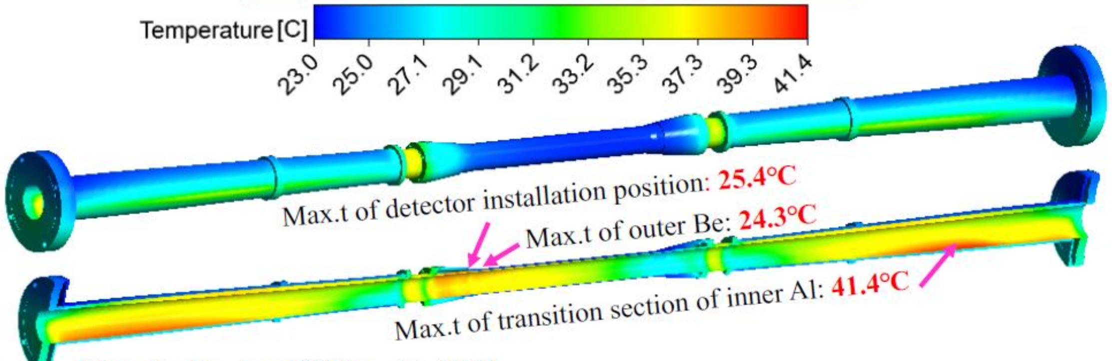
CDR Z parameters

High Lumi Z parameters

With the heat deposition in High Luminosity Z mode, it becomes impossible to cool the Be beam pipe with oil. Water is chosen as the coolant for the demonstration purpose.

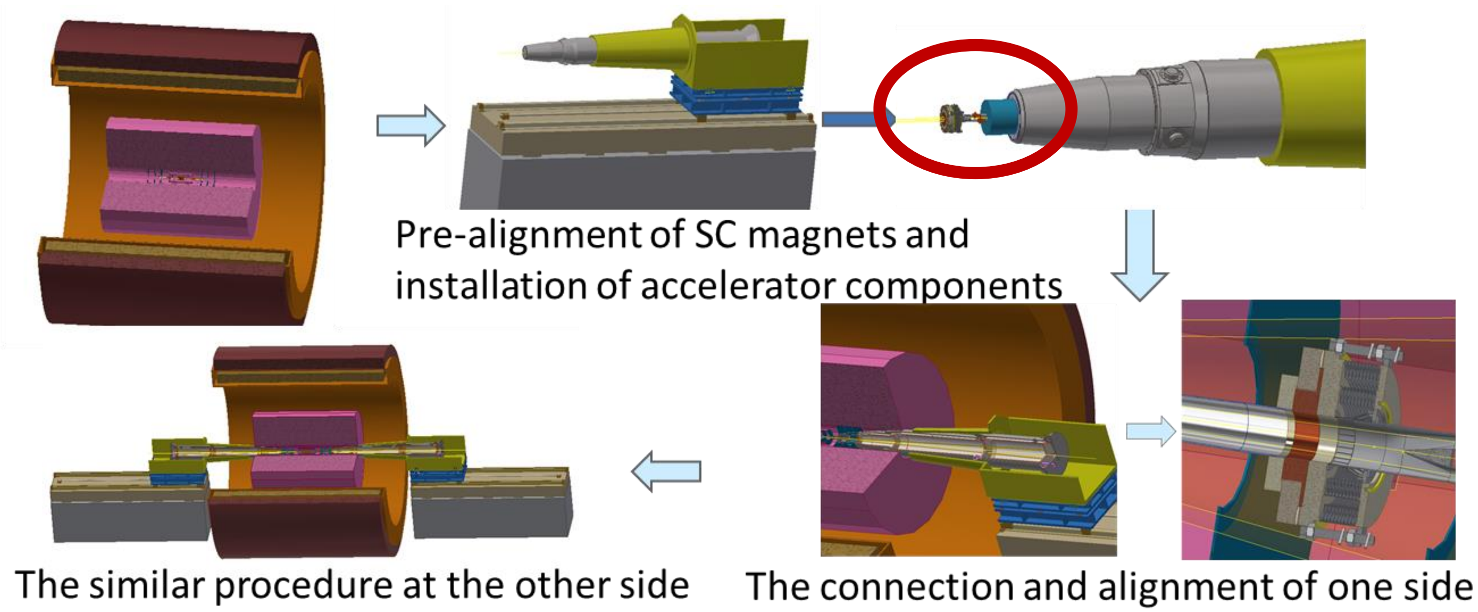
- Water flow rate for Be: 3.4L/min
- Water inlet temperature: 23^{0}C
- Other calculation condition is the same as before

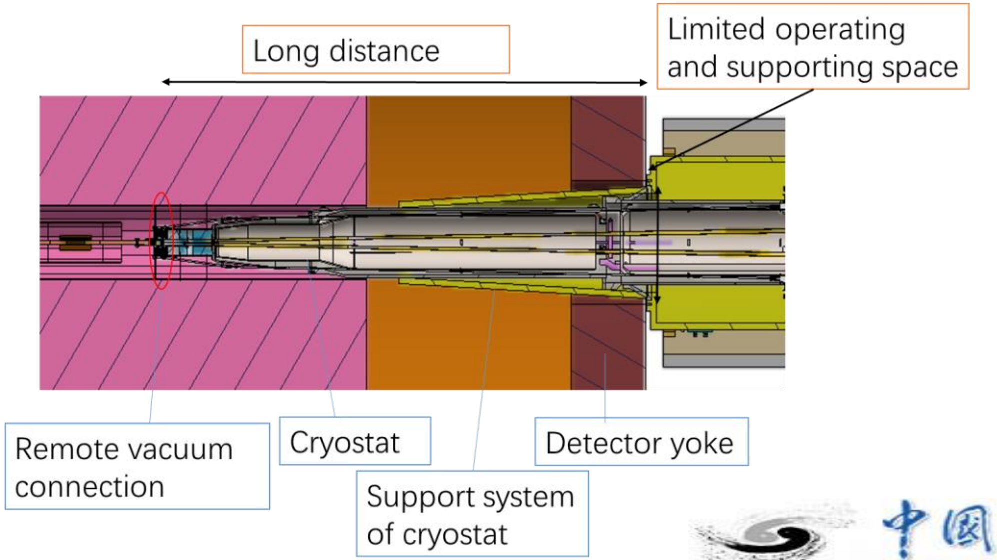
Temperature distribution in High Luminosity Z model



Water for Be: Δp=19.8kPa, Δt=5.0°C
Water for extending Al pipe: Δp=14.9kPa, Δt= 5.1°C

MDI integration and alignment

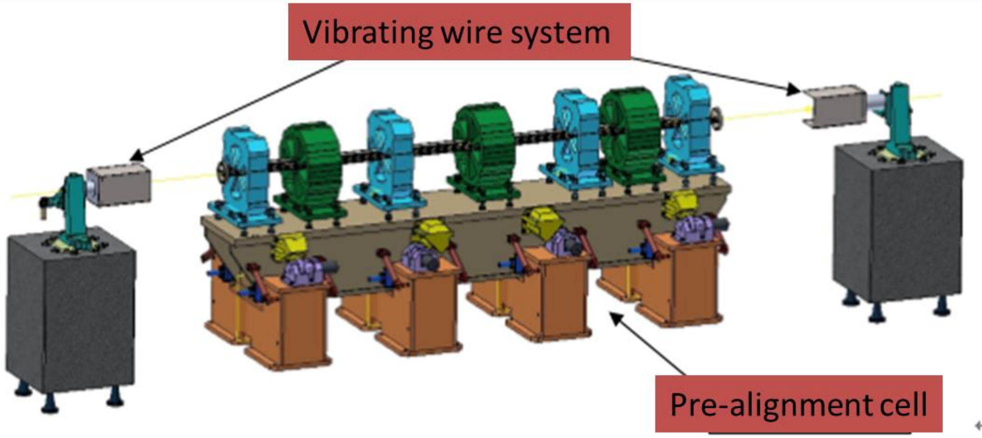




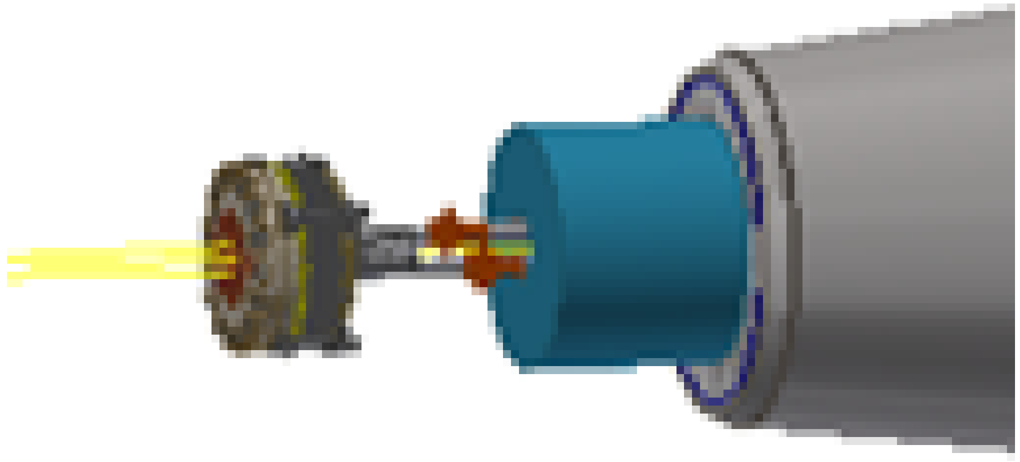
Alignment scenario:

- Pre-align the SC magnets using vibrating wire system to “certain location” to compensate the effect of loads.
- Align the SC magnets in two cryostats using optical system.
- Measure misalignment using SSW and adjust by corrector magnets meet the alignment requirements.

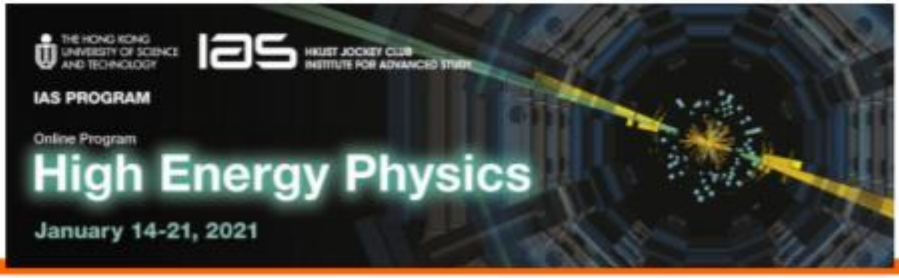
VWS is a candidate pre-alignment method, accuracy of magnet centers: ≤10 μm



Still lumical behind flange



Also Lumical not centred on outgoing beam pipe



CEPC Superconducting Quadrupole in Interaction Region

Yingshun Zhu, Xiangchen Yang, Ran Liang, Chuang Shen

Institute of High Energy Physics, Chinese Academy of Sciences

Jan. 21, 2021

中国科学院高能物理研究所
Institute of High Energy Physics
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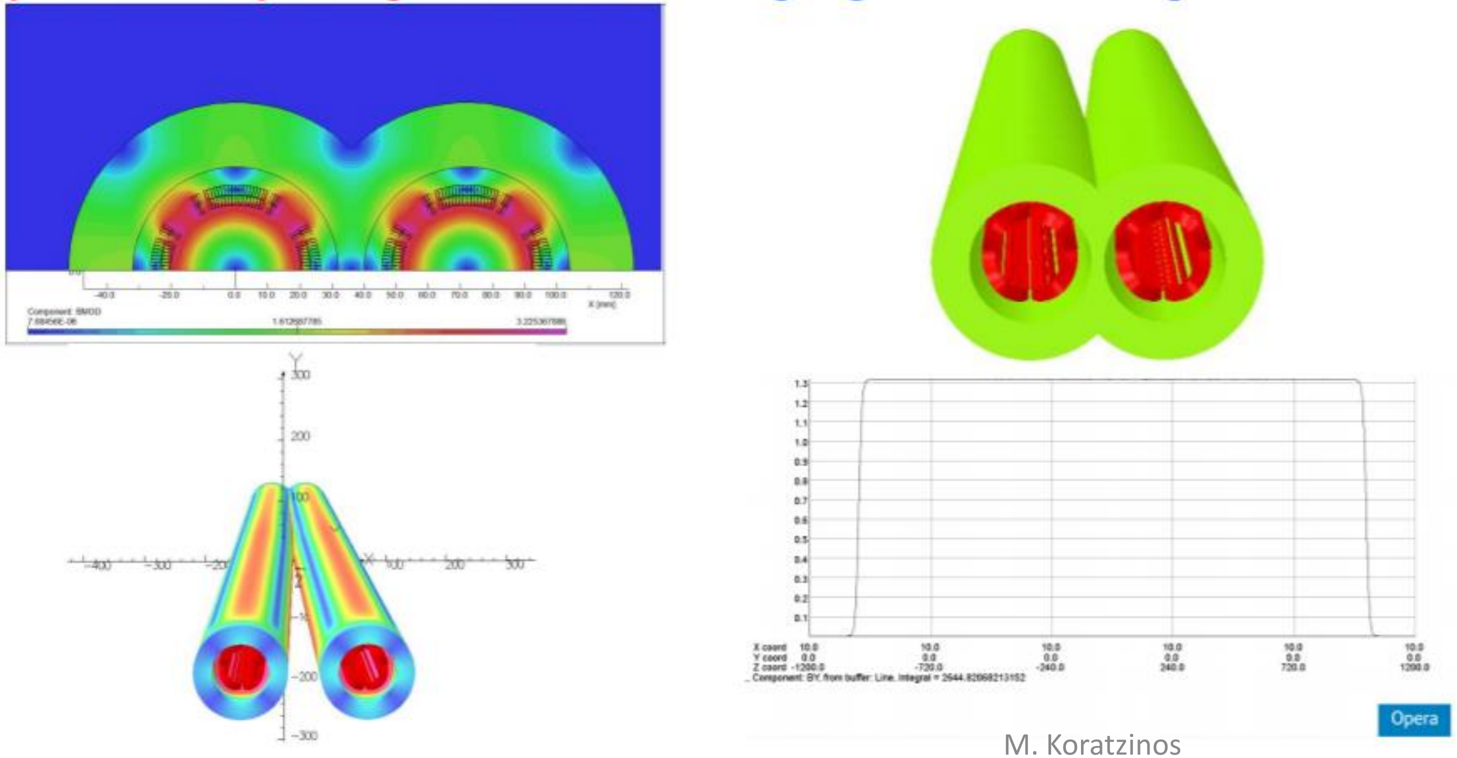
Old design

Option2: QD0 design with iron

- The excitation current is 2080A @4.2K.
- The field harmonics as a result of field crosstalk is smaller than 0.5×10^{-4}. Compared with the iron-free design, the excitation current can be reduced.
- Novel design: Double aperture quadrupole magnet using cos2θ coil with iron yoke shared by two apertures, with crossing angle between two apertures.



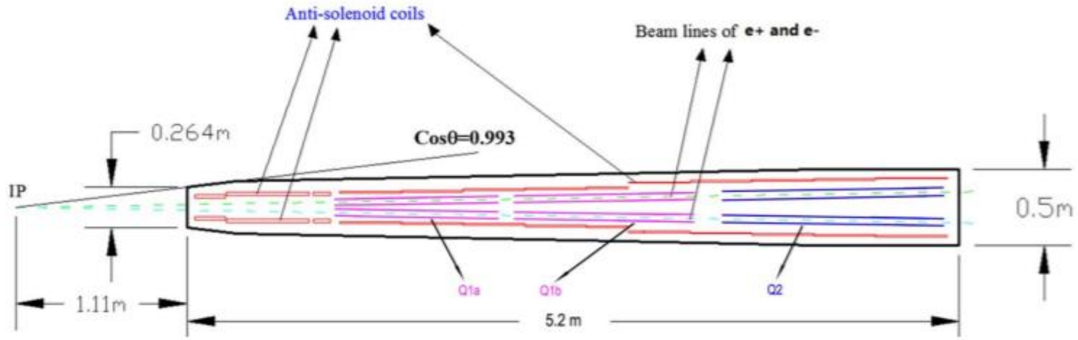
New “high luminosity” design

Conceptual design of HTS final focus quadrupole coils in CEPC IR

- The requirement of the CEPC double aperture Final Focus quadrupoles is recently updated for high luminosity with L*=1.9m.

Table 3: Updated Requirements of final focus quadrupole magnets for Higgs

Magnet	Central field gradient (T/m)	Magnetic length (m)	Width of GFR (mm)	Minimal distance between two aperture beam lines (mm)
Q1a	141	1.21	15.21	**62.71**
Q1b	84.7	1.21	17.92	105.28
Q2	94.8	1.5	24.14	155.11



Conceptual design of HTS final focus quadrupole coils in CEPC IR

Design considerations

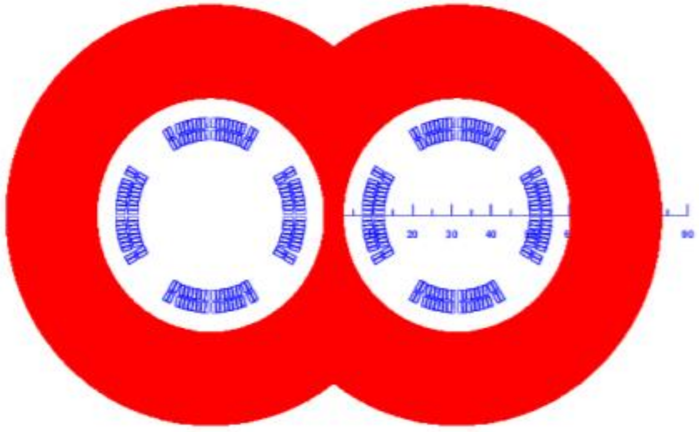
- The field gradient of quadrupoles is stronger compared to that in CDR, and the available bore space for the coil is smaller.
- The development of Q1a is the most challenging.
- Design of quadrupoles and anti-solenoid is similar to that in CDR.
- Corrector coils will be inside the bore of Q1b and Q2 quadrupole coil.
- Iron yoke is used to eliminate the field crosstalk between the two apertures.
- Inside quadrupole, beam pipe diameter is around 17mm or 18 mm.

Miraculously, crosstalk is still at 0.5 units

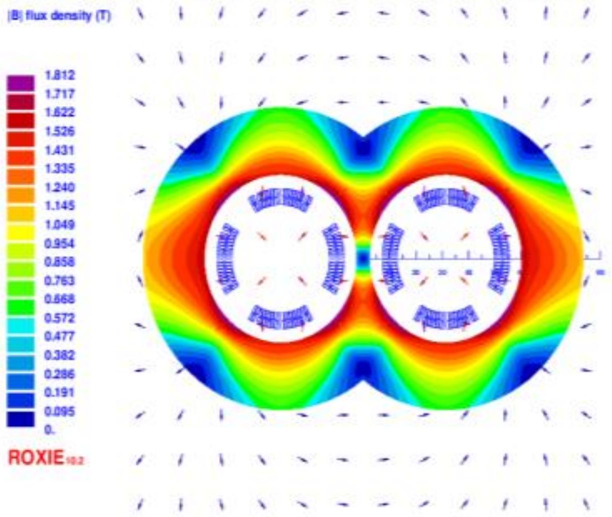
Cos2θ option of Q1a

Field cross talk of the two apertures

- 2D field cross talk of Q1a two apertures near the IP side, where the distance between two aperture centerlines is minimum.
- Iron yoke width in the middle is very limited; the field harmonics as a result of field crosstalk is smaller than 0.5×10^{-4}.
- The dipole field in each single aperture as a result of field crosstalk is smaller than 5 Gs. Magnetic field cross talk between two apertures is negligible.



Double aperture model



2D Flux lines

Progress of CEPC Magnet R&D

Wen Kang, Mei Yang

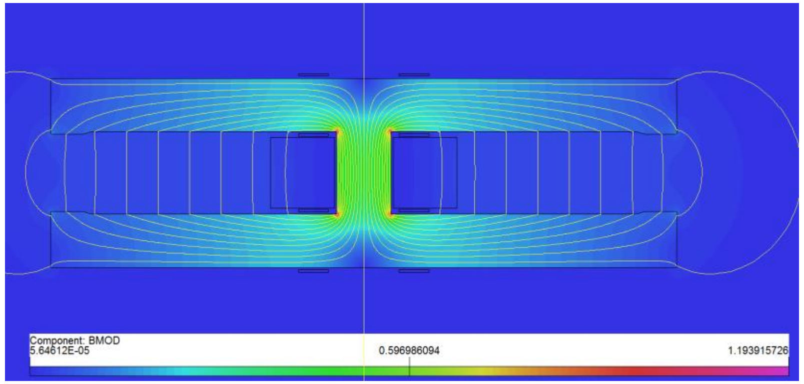
IAS 2021
Beijing, Jan. 21, 2021

Design of long DAD magnet

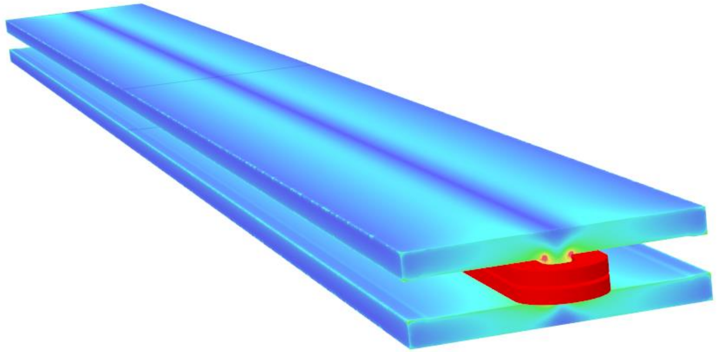
- As the magnetic length is up to 28.7m, the 5.7m pure dipole model will be built to check the field quality, mechanical strength and deformation.
- Basic parameters and design considerations

	Item
Center field (Gs)	141.6@45.5GeV，373@120GeV，568@182.5GeV
Gap (mm)	66
Magnetic Length (m)	5.737
Good field region (mm)	±13.5
Field harmonics	<0.05%
Field adjustability	±1.5%
Field difference between two apertures	<0.5%

  - Beam center separation is 350mm;
  - Solid iron with DT4;
  - Two turns of aluminum busbars with cooling hole;
  - Anodizing treated insulation coil;
  - Silvered contact face to reduce contact resistance.

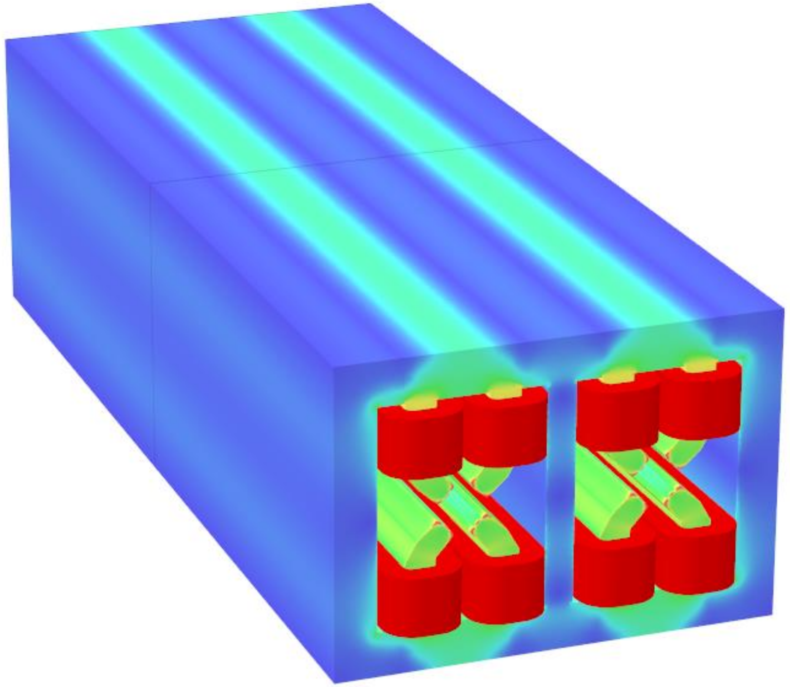


Cross section of long DAD

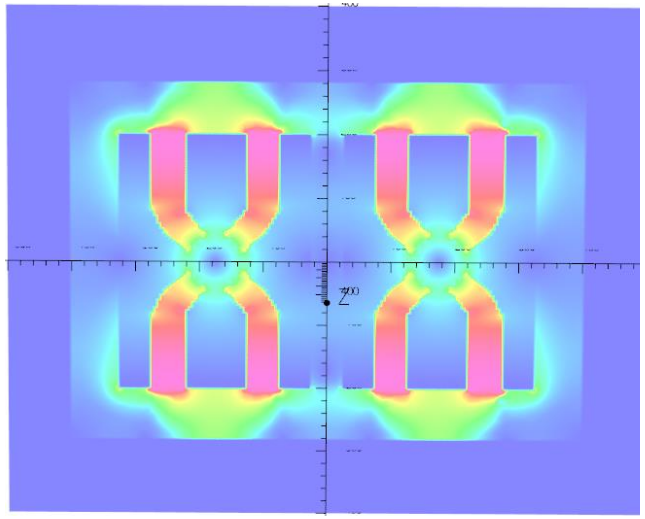


A new design of DAQ magnet

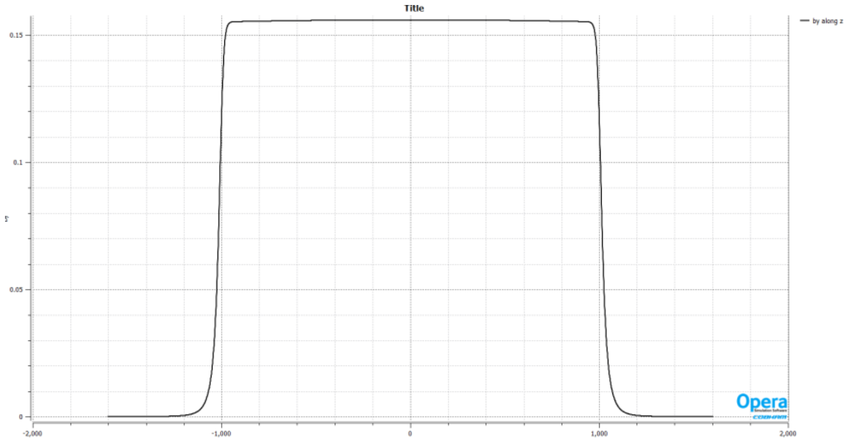
- 3D simulation (2m long iron)
  - The iron weight is about 4 ton, the coils’ weight is about 270kg .
  - The power consumption 9kW @120GeV.



Bmod@182.5GeV



Bmod@182.5GeV, @center plane

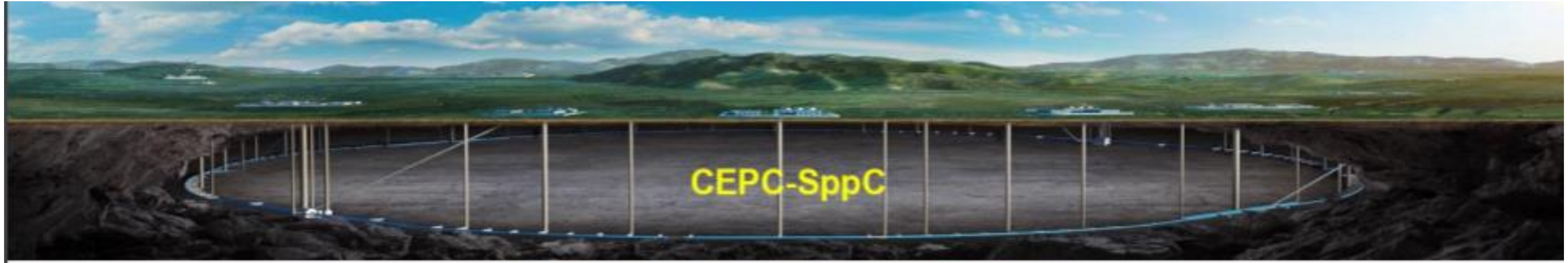


By along z @r=12.2mm in Ap2

Arc quad

	Dipole	Quad.	Sext.	Corrector	Total
Dual aperture	2384	2392	-	-	13742
Single aperture	80*2+2	480*2+172	932*2	2904*2	
Total length [km]	71.5	5.9	1.0	2.5	80.8
Power [MW]	7.0	20.2	4.6	2.2	34

- CEPC moved to a double aperture design. Power consumption: 9kW@120GeV
- @top energies: 21kW
- Number of quads: 2400
- Total power of quads: 50MW!! (compared to 60MW SR power!!)



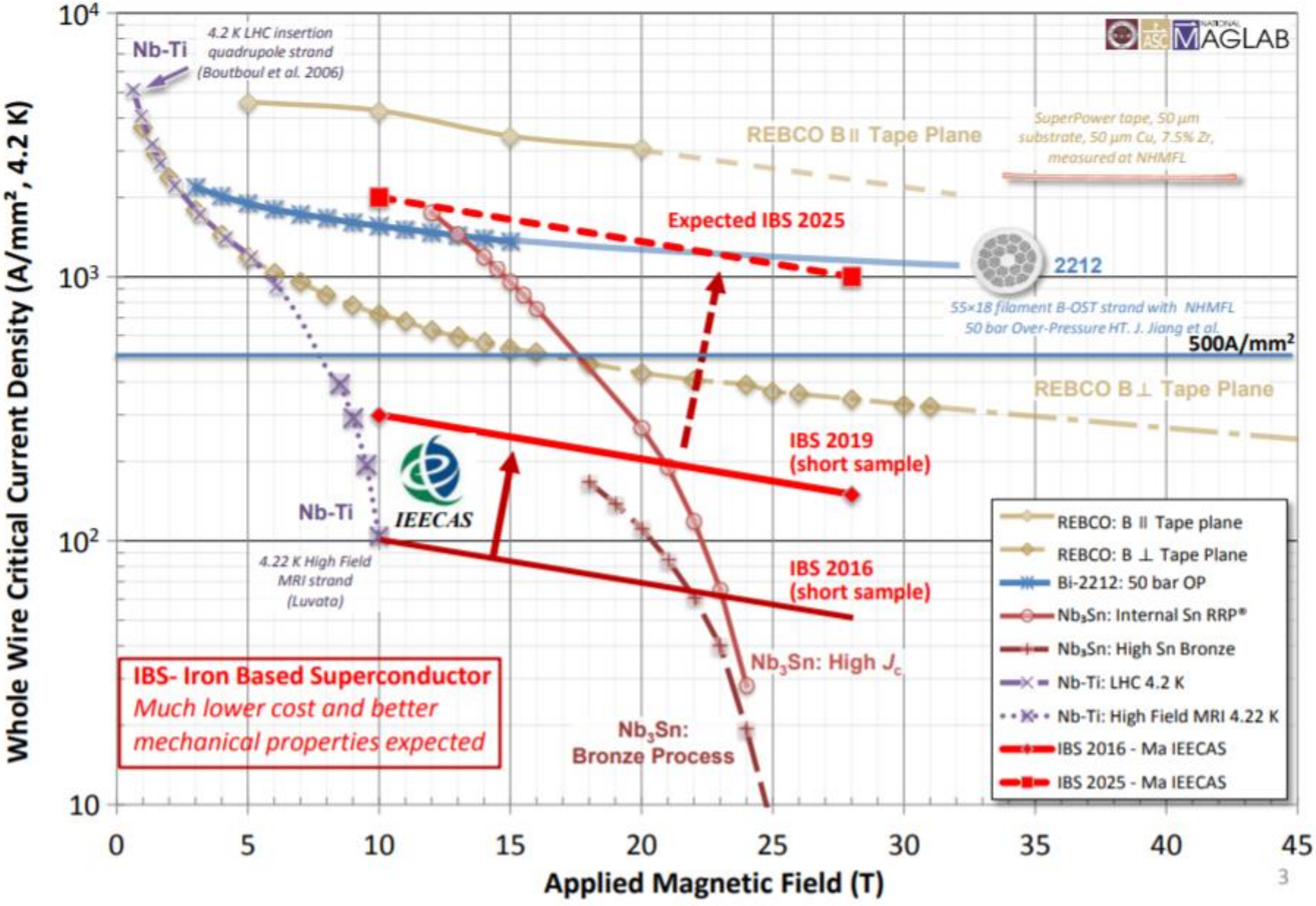
Progress of the High Field Superconducting Magnets for Particle Accelerators

Qingjin XU

Institute of High Energy Physics,
Chinese Academy of Sciences

IAS Program on High Energy Physics (HEP 2021), January 2021

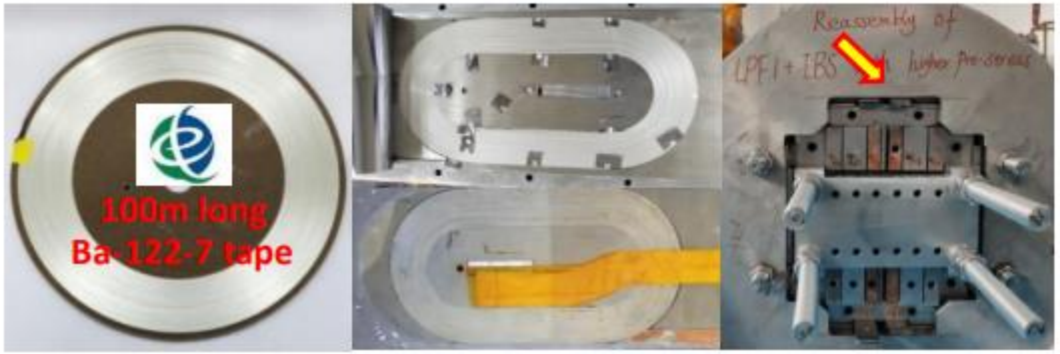
Practical Superconductors Presently

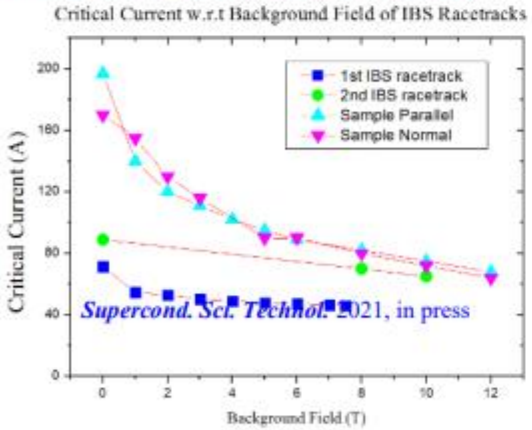


Performance of the 1st IBS racetrack coil

Fabrication of racetrack coil with 100m IBS tape and test at 10T

- *Two racerack coils with 100m long IBS tapes have been fabricated and tested at 10T background field.*
- *The Ic in the coil reached 86.7% of the short sample at 10T.*





Comments from SUST reviewers :

a) ...the new results that can have a strong impact on the conductor and magnet community.

b) ...demonstrated the great potential of Iron-Based Superconductor in the development of next-generation accelerators.

It seems reality is different... we are down from 500A/mm2 to ~50A/mm2