Status of Magnet Systems and RF System for 4GSR

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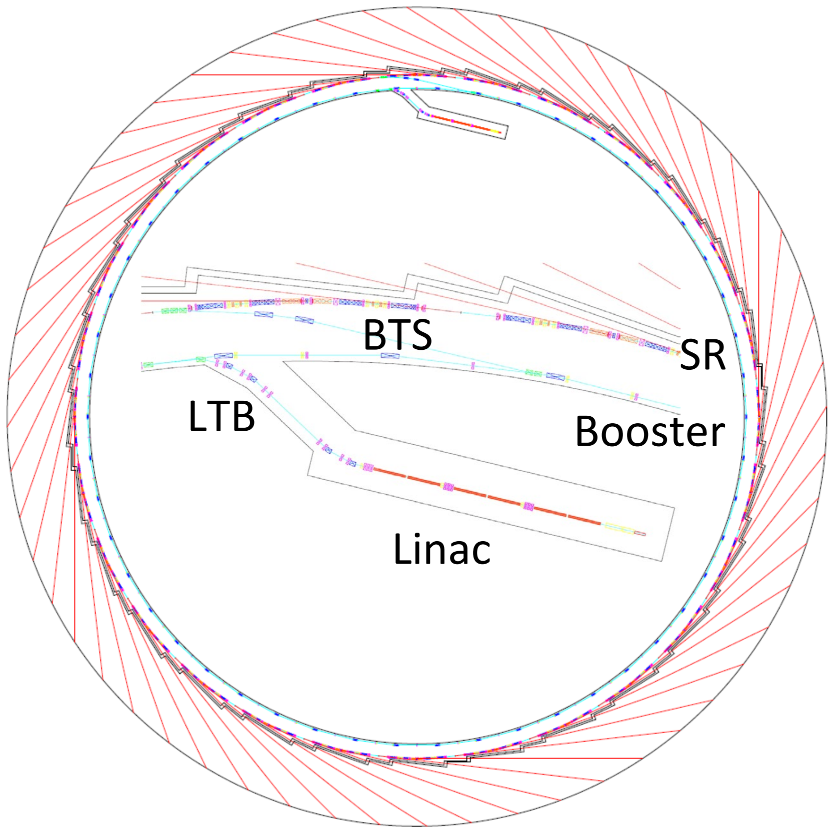
- Brief status of 4GSR RF system
- Short term RF tasks
- Brief status of 4GSR magnet system
- Short term magnet activities
- Summary

Introduction

- Korea is trying to develop 4th Generation SR based light source starting construction on 2022.
- It features 4 GeV, 7BA, 800 m circumference, 58 pm emittance, 28 superperiods, full energy booster injection, 2 T center bends for harder X-ray source.
- The project is now on CDR v0 phase, and TDR efforts will continue to 2022. After 18month of full technical design, the actual construction will start on 2024 lasting 3 years for the completion.
- In this report, 0.5th version of the magnet system, and high power RF efforts are summarized.



Total # of BL: 52 (60)

4GSR Ring		Value	Unit
Design Parameters	Cell Number	28	-
	Circumference	**798.84**	**[m]**
	Electron Energy	**4**	**[GeV]**
	Natural Emittance	**58**	**[pm rad]**
Tune and Chromaticiy	Horizontal Tune	67.395	-
	Vertical Tune	24.275	-
	Natural Horizontal Chromaticity	-115.344	-
	Natural Vertical Chromaticity	-84.693	-
	Horizontal Chromaticity	3.5	(target)
	Vertical Chromaticity	3.5	(target)
Radiation related quantities	**Energy Loss per Turn**	**1009**	**[keV]**
	Energy Spread	0.1197	[%]
	Horizontal Damping Time	11.075	[ms]
	Vertical Damping Time	21.127	[ms]
	Longitudinal Damping Time	19.342	[ms]
Twiss functions at the ID	Horizontal beta function at the ID center	8.564	[m]
	Vertical beta function at the ID center	2.459	[m]
	Dispersion function at the ID center	1.3	[mm]

Injector: Booster

Overview of Storage Ring RF system

- Parameters, related to RF system

Parameter	Unit	Values	Remark
Beam current	mA	400	
Revolution frequency	MHz	0.37528	
Harmonic number	-	1332	
RF frequency	MHz	499.8773	
Electron energy loss /turn by bending magnet	keV	1010.01	
Electron energy loss /turn by IDs	keV	790.00	
Electron energy loss /turn by Others (estimated)	keV	50.00	loss by vacuum chamber
Total beam energy loss /turn by turn	keV	1850.01	

RF Gr.

RF System for 4th Gen. Synchrotron Light Sources

Cavity type	Light source	Energy (GeV)	Circumference	Emittance (nm*rad)	Current (mA)	Operation year	Cavity type	Status	Frequency (MHz)	# of Cavity	Gap V (kV)	RF Source
NC	ESRF-EBS	**6**	844.4	0.15	**200**	2020	EU type cavity	Upgrade	352	13	500	3 of 150kW SSPA 2 of 1.2MW Klystron 1 of 0.4MW Klystron
	APS-U	**6**	1104	0.065	**200**	Planning	NC	Upgrade	352	12	535	2 of 650kW Klystron
	PETRA-IV	**6**	2304	0.03	**200**	Construction	EU cavity	Upgrade	500	24	333	20 of 60kW SSPA
	Diamond-II	3	561.6	0.12	300	Concept	EU cavity	Upgrade	500	8	338	8 of 80kW SSPA
	SLS-II	2.7	290.4	0.126	400	Upgrade	NC	Upgrade	500		450	4 of 180kW Klystron
	MAX-IV	3	528	0.3	500	2015	MAX-lab	Upgrade	100	6	300	12 of 60kW SSPA
SC	HEPS	**6**	1295	0.059	**200**	Construction	HEPS	New	166	5	1200	4 of 200kW SSPA
	NSLS-II	3	780	0.6	400	2014	CESR-B	Upgrade	500	2	1400	2 of 300kW Klystron (기존)
	SIRIUS	3	518.4	0.15	350	2018	CESR-B	New	500	2	1500	8 of 60kW SSPA

Overview, Selection of RF System

- Cavity

  Normal conducting

  (to avoid long downtime by superconducting RF system)

- High power RF source

  Klystron amp. ≤ Solid state power amp.
  Coaxial power transmission ≤ waveguide transmission

  (lower cost for installation and operation)

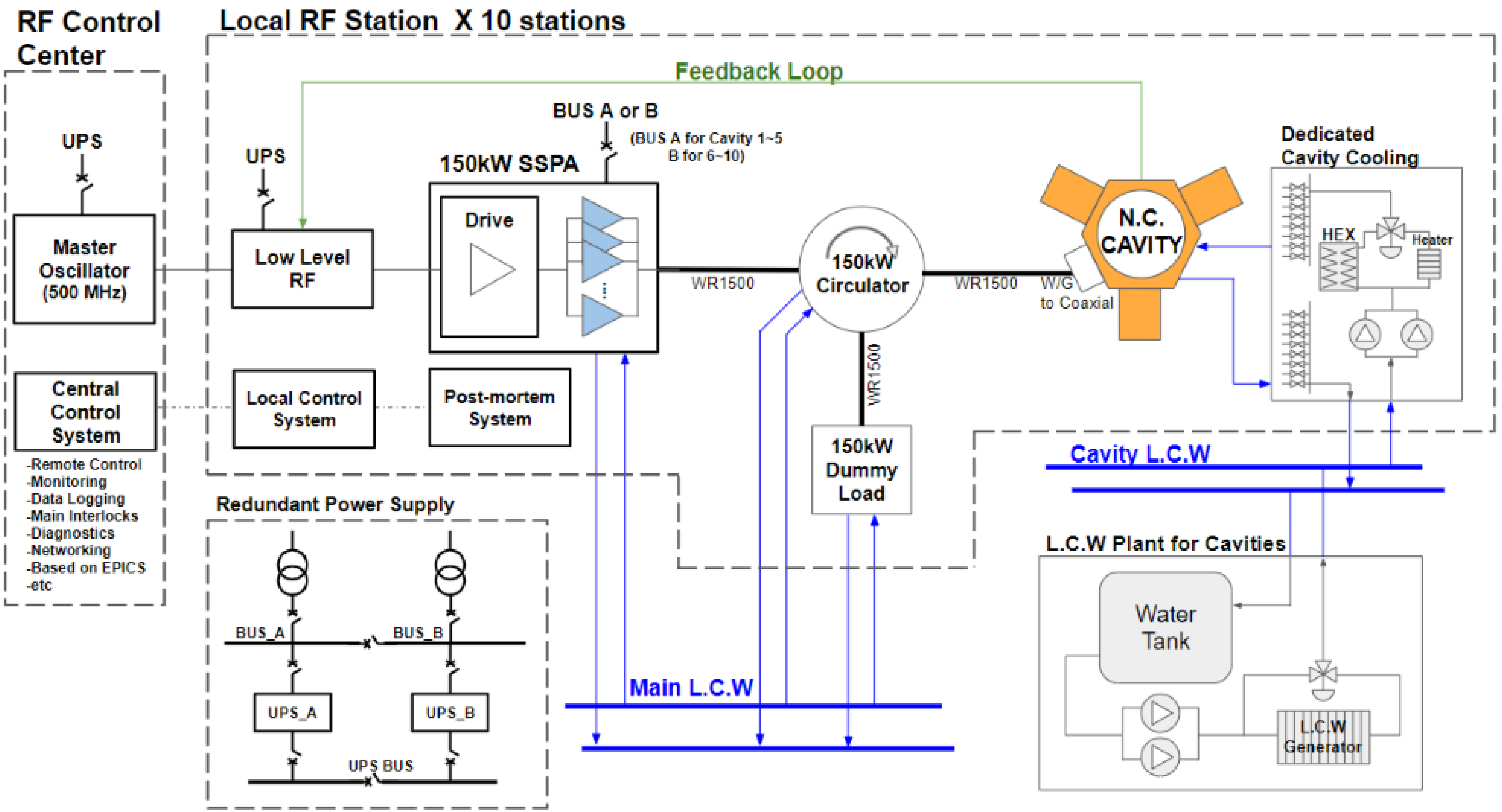
- Low-level RF

  Crate-based systems (μTCA) ≤ Pizza box (module, PLS-II Experience)

  (more flexible management and experience through PLS-II)

RF Gr.

Schematic Diagram of RF system – main ring (10 RF stations)



Overview of Storage Ring RF system

Parameter	Unit	Values	Remark
Accelerating voltage	MV	3.5	
Number of cavity	-	10	
Coupling beta	-	~5.5	for minimum reflect power @ 400 mA
Required accelerating voltage per cavity	MV/unit	0.35	
Wall loss power per cavity	kW/unit	18	
Beam loading power per cavity	kW/unit	74	
Power loss at HOM absorber	kW/unit	5	
Required power to coupler per cavity	kW/unit	97	
Transmission line loss per cavity	kW/unit	10	circulator, waveguide, etc.
Required output power of HPRF	kW/unit	107	
Rated power of HPRF /unit	kW/unit	150	power linearity 구간 고려 (Max. power의 60~70%)
Total AC power for RF source (klystron case)	kW	3750	operation efficiency : 40 %
Total AC power for RF source (SSPA case)	kW	3333	operation efficiency : 45 %

Available manpower on October, 2022

Affiliation	Specialty	Job share rate (%)	Remark
PAL - 1	RF physics	30	main ring
PAL - 2	Physics - LLRF	30	main ring
PAL - 3	Computer - Control	30	main ring
PAL - 4	Mechanics – design, system integration	30	main ring
PAL - 5	Electricity - HPRF	30	main ring
PAL - 6	Chemistry – cooling, system integration	30	main ring
Retiree -1	Mechanics & Physics - cavity	50	main ring & booster
Retiree -2	Electricity - HPRF	50	booster
Retiree -3	Electricity - LLRF	50	booster
New comer	Physics - cavity	100	main ring & booster

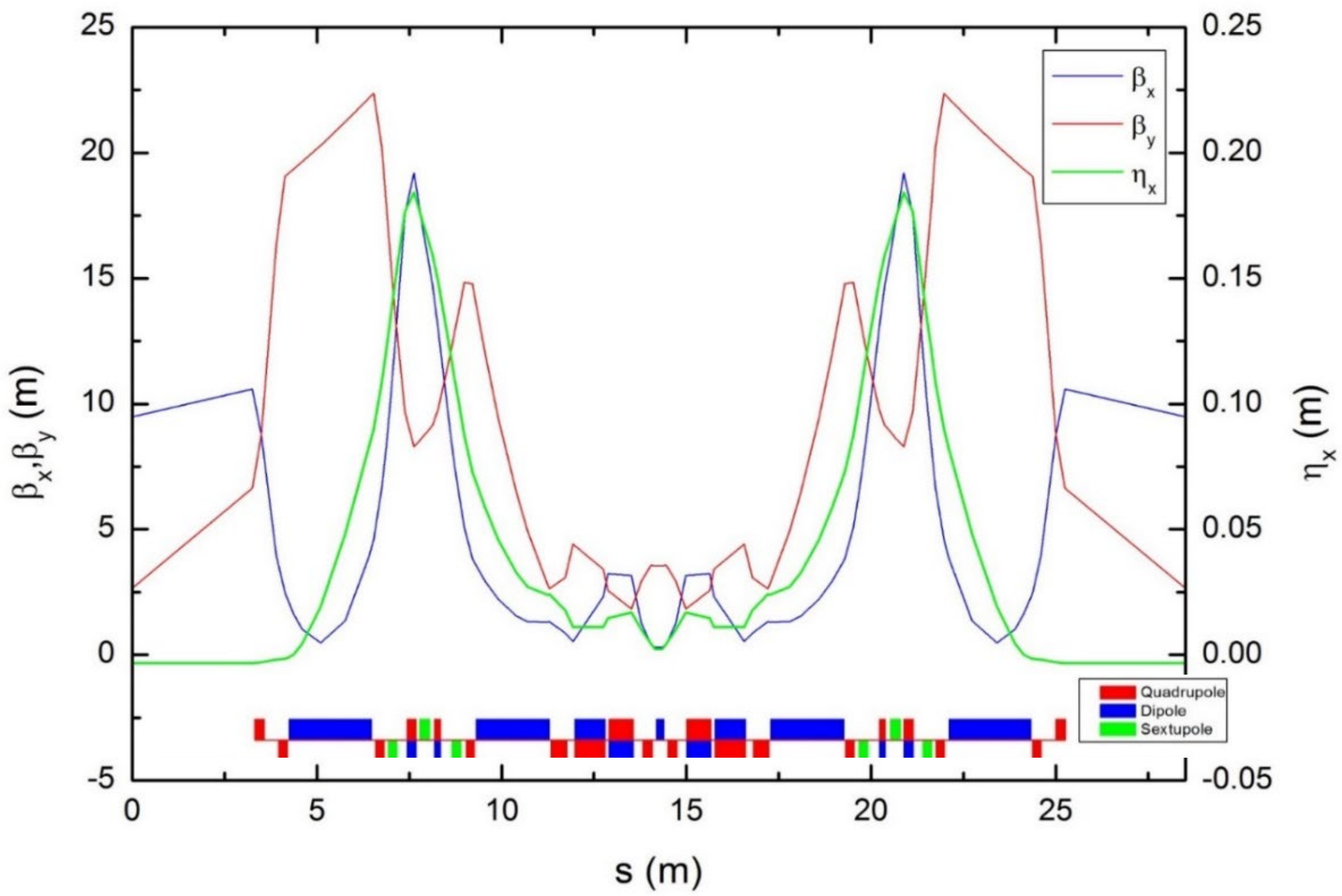
- Manpower on October, 2022: 4.3 full time equivalent
- Another 4 full-time staffs will be hired until 2026.
- Big portion of work should be done by industry.

Expected Activities for RF in 2022-2023

- Technical design for main/booster ring RF system
- To construct a RF test facility in PAL site
- Prototype R&D for major components (cavity, RF amplifier, LLRF) and integrated system
- To specify major components
- To support the design of building, utility and facility

Lattice design

- ESRF-EBS type
  - Dispersion bump w/sextupoles.
  - Longitudinal gradient dipoles.
  - Phase advance of $\Delta\varphi_x = 3\pi$ and $\Delta\varphi_y = \pi$ between corresponding sextupole.
- APS-U type: Reverse bends in Q4, Q5, and Q8.



1. Achieving 58 pm with 800 m circumference at 4.0 GeV beam energy.
2. Natural evolution of ESRF-EBS, and APS-U.
3. Massive use of combined function magnet for quad focusing and bending using “Offsetted” quadrupole.
4. Application of reverse bend with strong quad focusing (DQ51)
5. 6.5 m straight section and 2 T Center-bend as bending source (ec=21 keV).

Magnet Summary for Booster and SR

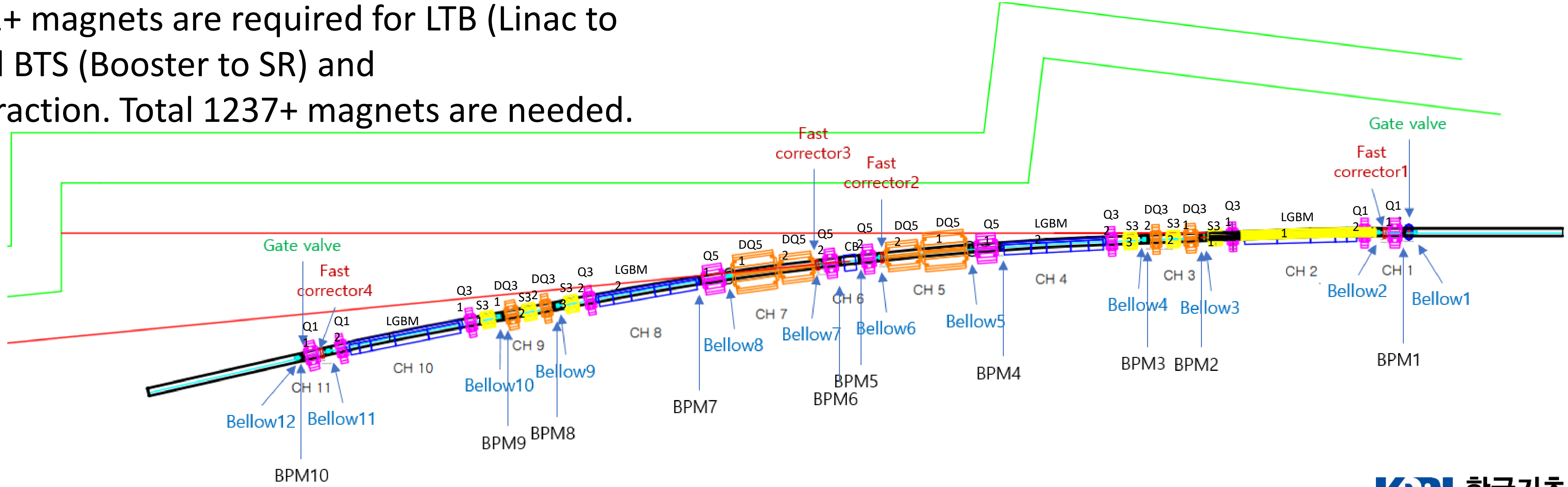
Magnet	Required Number	Remark
Combined Dipole	72	2*36 cell
Quadrupole	72	2*36 cell
Sextupoles	72	2*36 cell
Corr.	?	TBD
Total	216+	Total number of magnets

Booster Magnet Summary

Magnet	Required Number	Remark
Central BM	28	1*28
Long. BM	112	4*28
Reverse Bend	168	2*3*28 (should have B, B')
Quad Bend	56	2*28 (should have B, B')
Quadrupoles	336	6*2*28
Sextupoles	168	6*28 (should have B", H/V Corr, Skew Quad)
Fast Corr.	112	4*28 (H/V combined corrector)
Magnets/Sec	35	31+4 (fast Corr.)
Total	980	Total number of magnets

SR Magnet Summary

Additional 41+ magnets are required for LTB (Linac to Booster), and BTS (Booster to SR) and injection/extraction. Total 1237+ magnets are needed.



General Design Requirements

- LGBMs mirror symmetric in longitudinal direction with respect to center bend.
- Dipole Quadrupole (DQ) series operational range is 95% to 105% of the nominal value.
- Quadrupole operational range is 75% to 110% of the nominal value.
- Sextupole magnets operational range is 50 to 120% of the nominal value.
- More than 98% magnetic efficiency for sextupole for min cross-talk btw the H/V/SQ coils.
- DQ, RB, Quads should have 90% min efficiency.
- Coolant pressure drop is 6bar (or 90 psi) with inlet temperature of 25C.
- Coolant temperature rise is limited to less than 20 K.
- Min H/V apertures are decided based on BD simulation and vacuum requirements.
- Typical Quad aperture radius is 15 mm with good field radius of 10.0 mm except DQ51, DQ32.
- DQ51 ro/rc=15mm/30mm, DQ32 ro/rc=10mm/20mm.
- For Quadrupoles, multipole requirements are < 1.0E-3 at good field radius.
- For Sextupoles ro/rc=10mm/20mm with multipole < 1.0E-3 at good field radius.
- For Dipoles, the uniformity requirement is DB/B < 1.0E-3 for +-13.0 mm.
- Vertical half gap for center bend, LGBM1, LGBM2 are 7.0/13.9/12.2 mm, respectively.
- Fast correctors need about 1.0 mrad kick but detailed requirements are not fixed yet. Therefore it's not treated here

Additional Magnet

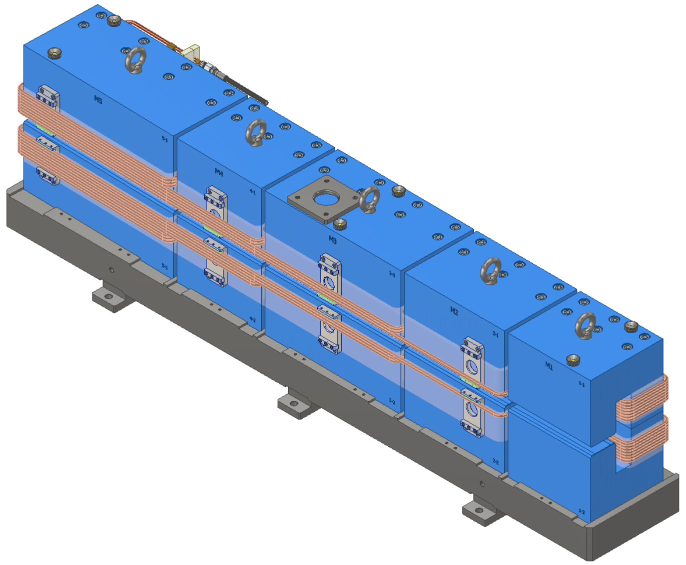
- In addition to SR magnets, we need 341+ magnets for the booster and LTB (Linac to Booster), BTS (Booster to SR) line.
- Parameters of the magnets are being optimized for BD, and manufacturing aspects. (For example, the field strength, and length of the dipole magnets in the booster).
- Physical parameters (eg, miminum pole gap, required uniformity) are being summarized to start actual design.
- No technical difficulties are expected for these magnets since the magnets are more easily realizeable compared to SR magnets except thick, thin current septum (good benchmark needed!)

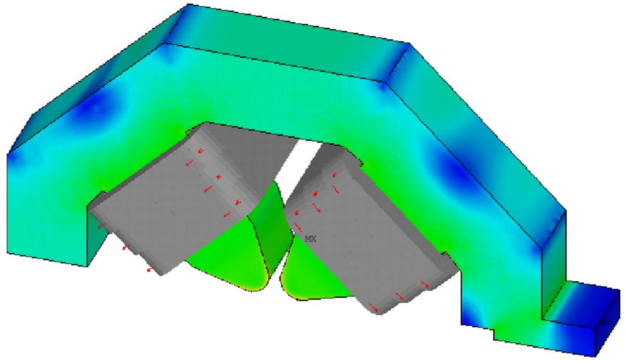
	Magnet	Required Number	Remark
LTB Magnets	BM	4	0.5m, 0.35 T
	Septum	1	0.8 m, 0.30 T
	Kicker	1	0.8m, 0.0125 T
	Quad	10	0.2 m, 5.7 T/m
	Correctors (H/V)	4	0.1 m, 0.01 T
BTS Magnets	BM	2	1.6 m, 0.73 T
	Septum	5	0.6 m, -1.17 T
	Quad	10	0.5 m, 21 T/m
	Correctors (H/V)	4	0.3 m, 0.08 T

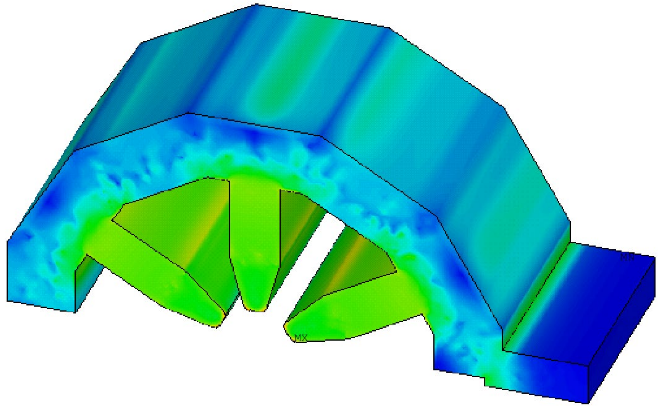
LTB, BTS Magnets (41+ Magnets)

Features of 4GSR magnet system

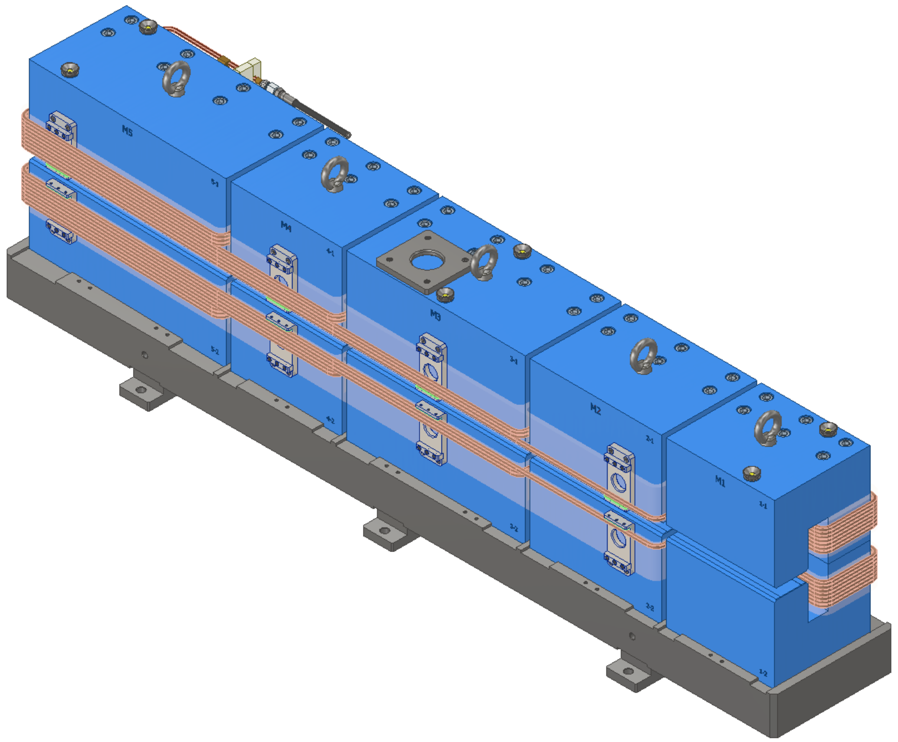
-Some Preliminary Concepts.
-Center bend is short (0.186m), but strong 2.0 T with electromagnetic excitation.
-EM version is being considered for LGB, and CB to cope a long term radiation damage.
-Quadrupole, DQ quadrupole pole tip field is about 0.883T which is acceptable.
-Max pole tip field for sextupole is 0.425 T with 120% nominal excitation which is achievable.
-Quad, DQ aperture ranges from 15 mm, 20 mm (DQ32), 30 mm (DQ51).
-For quad bends (DQ family), offsetted quadrupole concept is used following APSU.
-Long DQs have curved pole, while shorter DQs have a straight pole.
-Sextupole magnet has H/V corrector, skew Quad windings.
-To speed up design process, 3D analysis are parameterized for speedy analysis. (eg. Core length, chamfer, chamfer angle)
-Booster dipole is a combined dipole with quadrupole components.
-Usual 4 kicker injection is being considered with optional study for nonlinear kick injection.
-Thick, thin current septum magnet for extraction/injection are needed.

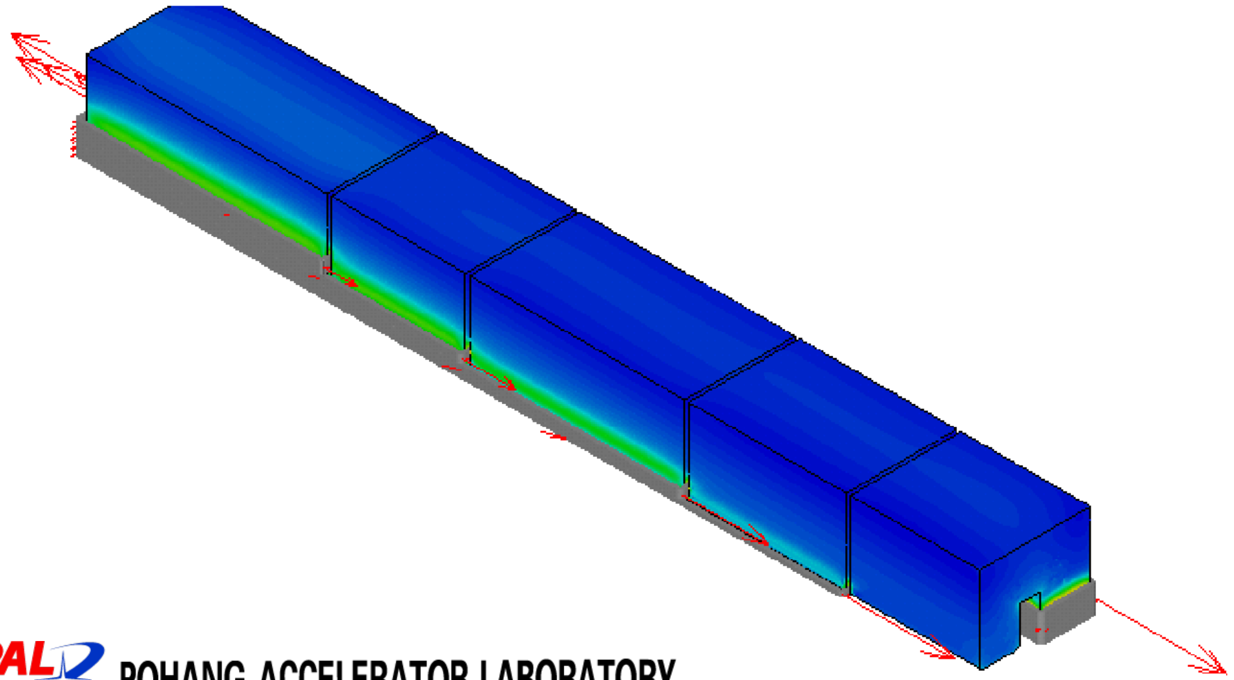




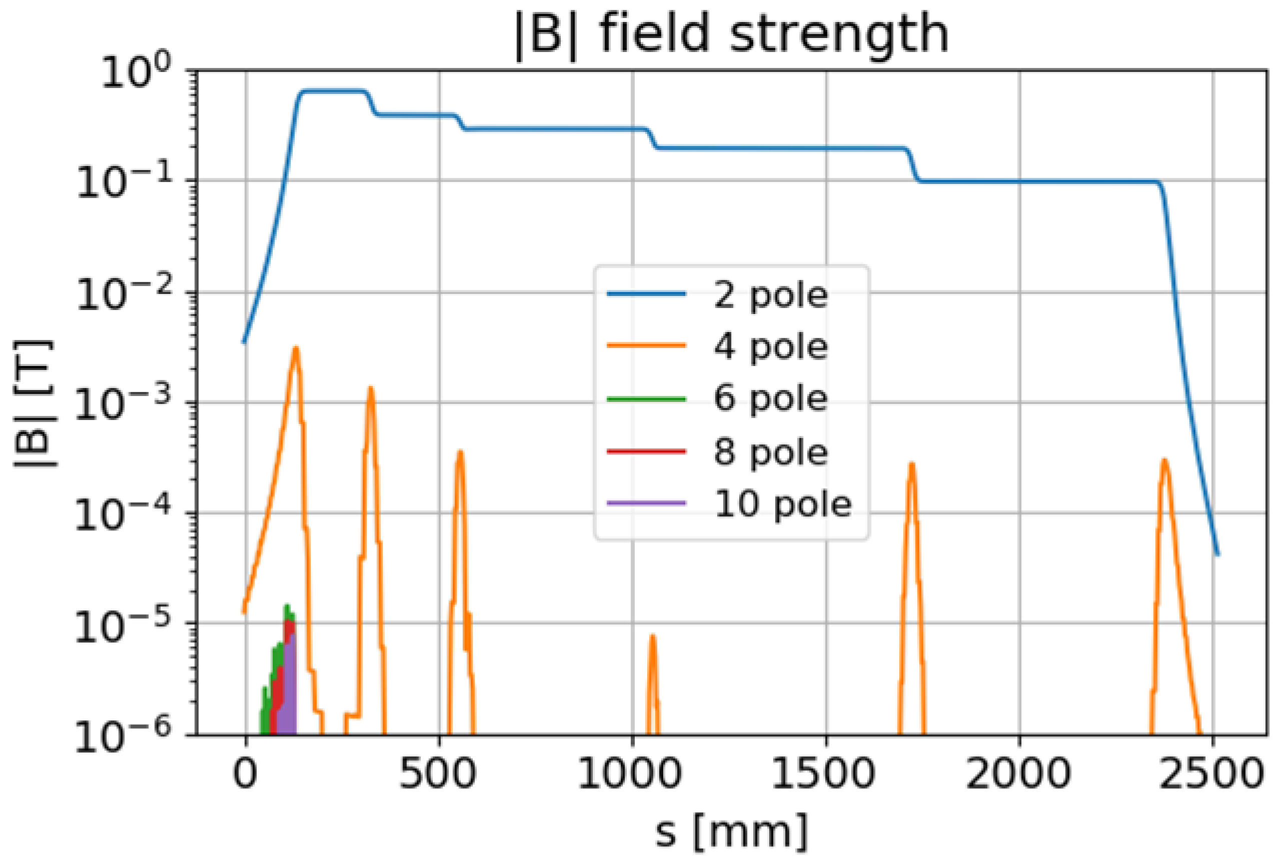


Longitudinal Gradient Dipole (LGBM2) : 3D



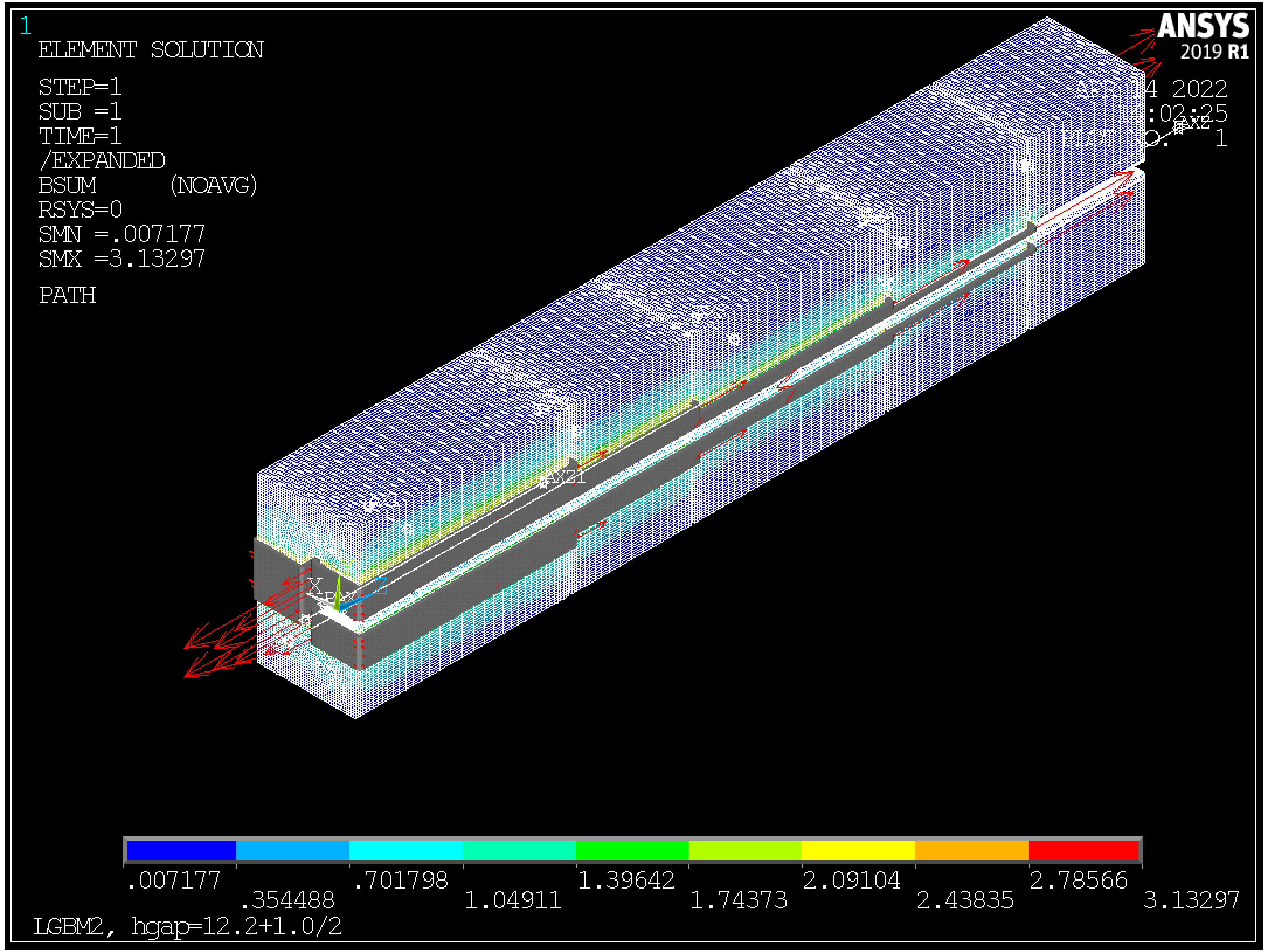


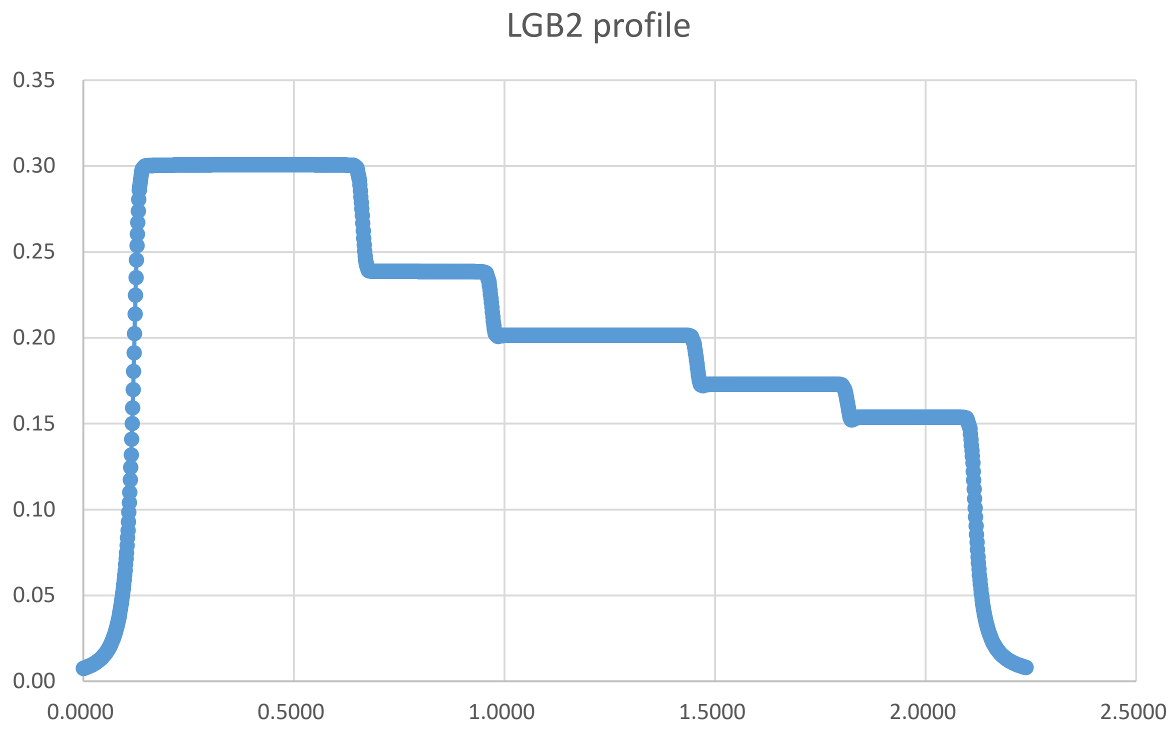
Dipole and higher order multipole along the orbit.



- EM version is selected for construction costs and total cost of operation during the lifetime.
- 3D field map with 1mm step size is calculated, and the multipole along the orbit is calculated.
- Except the quadrupole component which comes from the edge focusing, higher order was negligible.
- To match the design field, reluctance gap at the return yoke is implemented for each magnet section
- Prototype manufacturing in progress.

Example of LGB2 Analysis

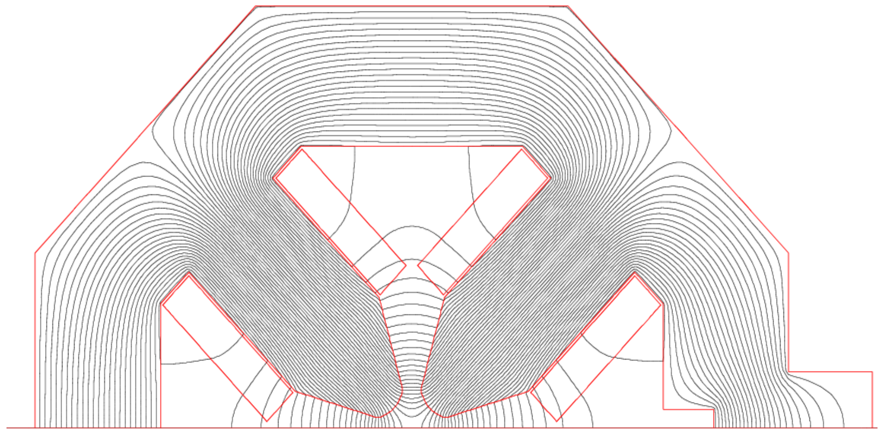




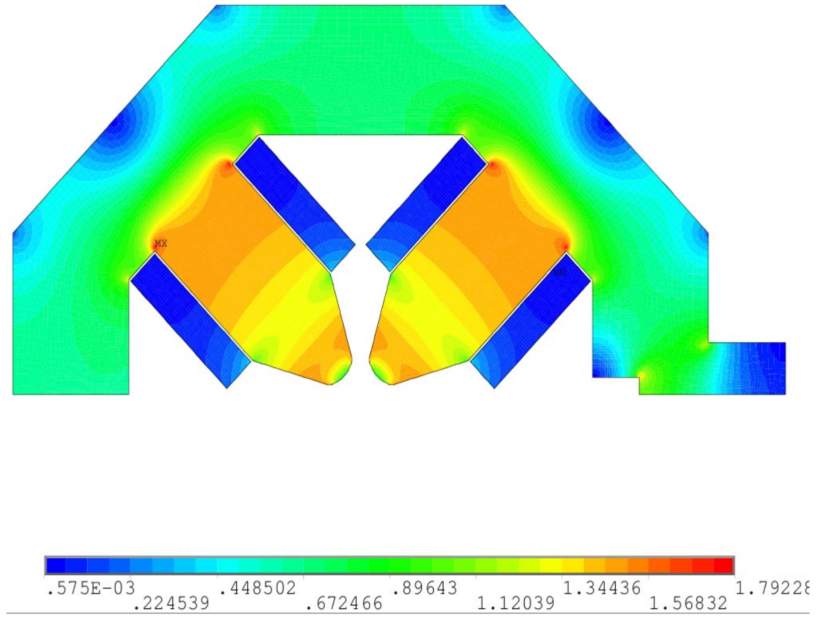
3D FEM model and results (left), and the calculated field profile (above) of LGB2 magnet.

Dipole Quadrupole (DQ), Reverse Bends Quadrupoles, Quad

- Dipole Quadrupoles, Reverse Bend Quadrupoles are basically offsetted quadrupoles for design simplicity.
- The offset for dipole component reaches from 20.1 mm to 2.74 mm.
- DQ51 which has the largest offset has an aperture radius of 30 mm, DQ32 has an aperture radius of 20 mm to avoid mechanical interference. The max B'=30 T/m (DQ51), 23 T/m (DQ32) which is achievable without any difficulty using standard low carbon steel.
- Other types DQ52, DQ31 has an aperture radius of 15 mm which is same with regular quadrupoles with Max B'=58.9 T/m.
- The poles are optimized for min harmonic content and maximum B' with tapering (See next quad page)
- All DQ should have trim windings for dipole component that will be used to keep the dipole component while quad component changes.
- Each type may have a slot for photon extraction depending on the lattice position.
- All DQ use solid core.
- Quad max B'=58.7 T/m at 110% excitation

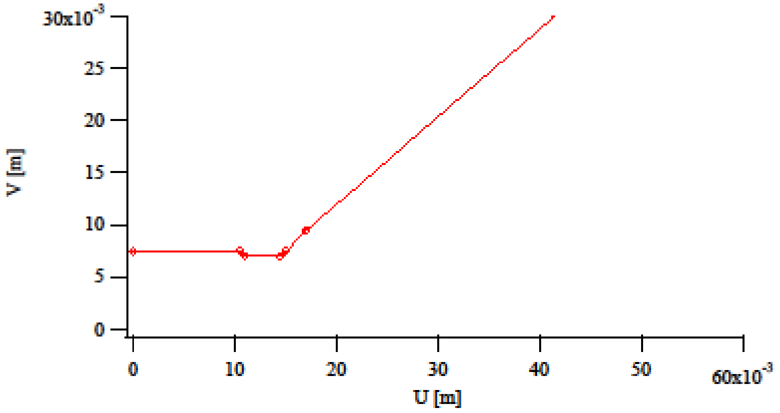


Flux distribution

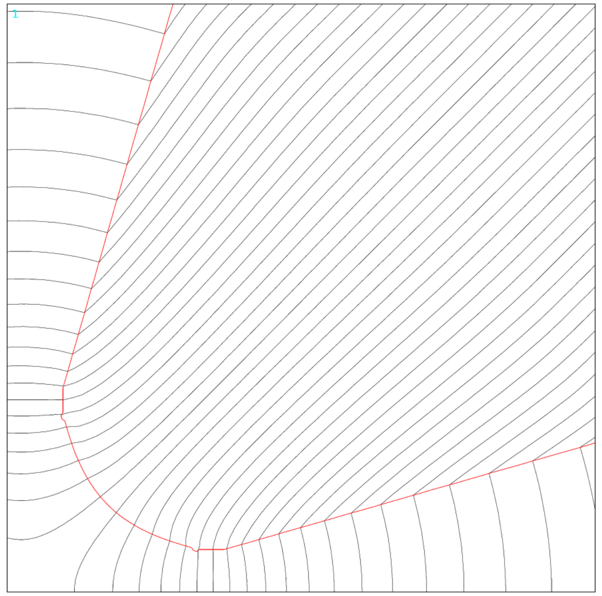


|B| distribution

DQ and Quadrupole Magnet



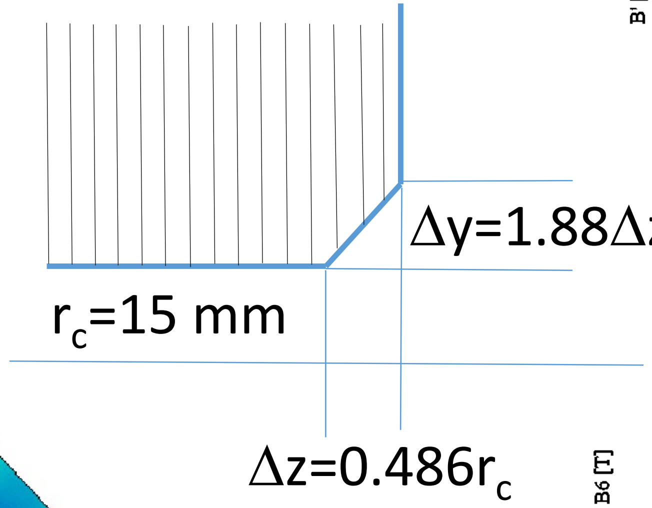
U plane

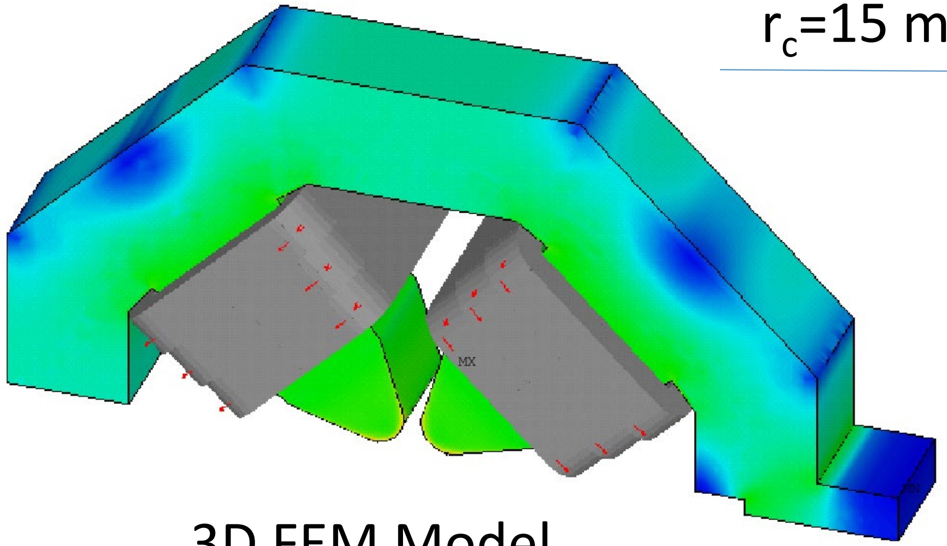


z plane

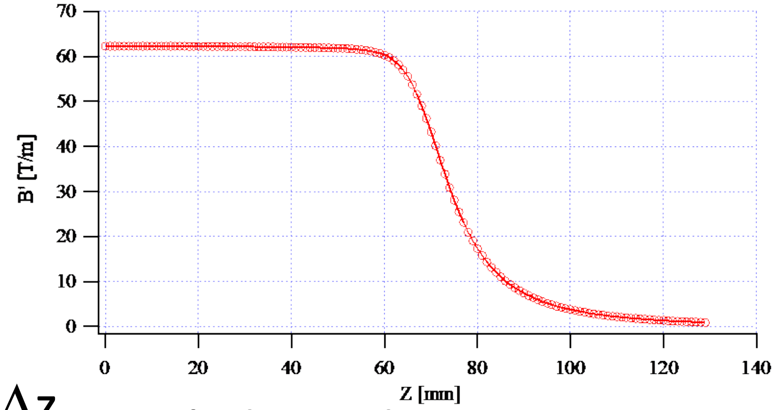
Conformal map

$$w = u + iv = \frac{z^2}{2r_c} = \frac{(x+iy)^2}{2r_c}$$

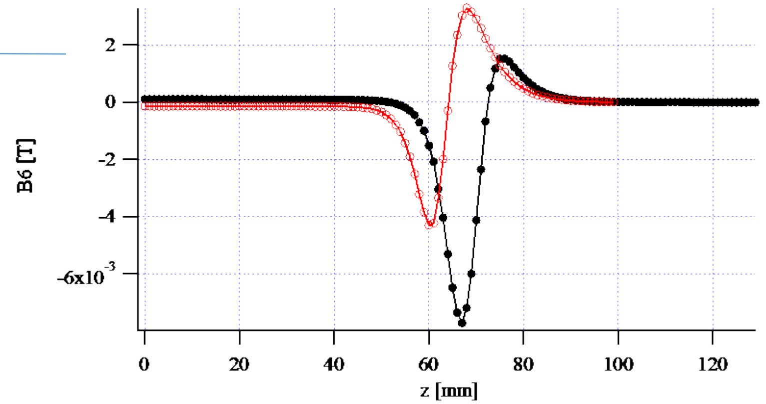




3D FEM Model



B' along the magnet

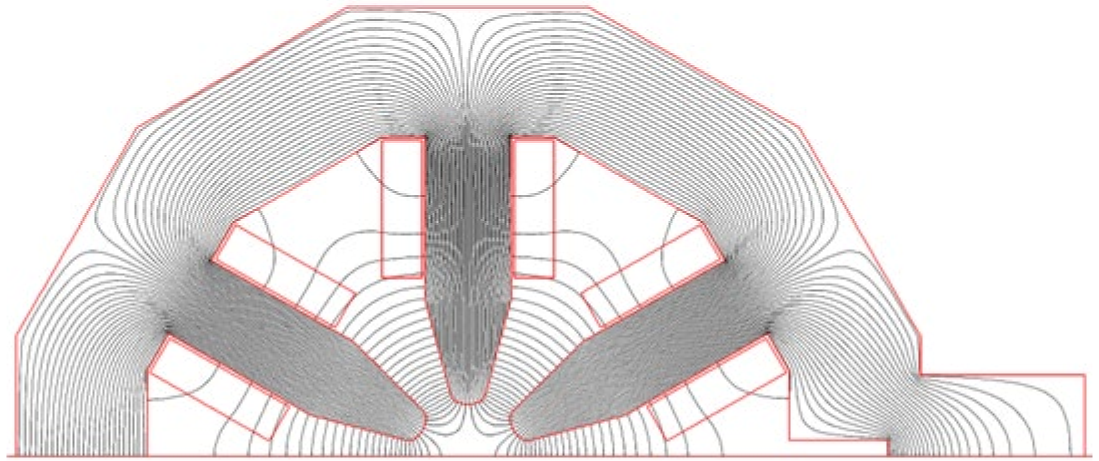


B6, Before (black), Red (after) end chamfering

- Quad, and DQ magnets are similar design. Two DQ types have longer effective length and decided to be arc shape. Other quad, DQs have straight core shape.
- Apertures are all 15 mm for quad, and 15, 20, 30 mm for DQ magnets.
- Shims are introduced in w plane, and transformed to z plane and the geometry is analyzed in 2D, and 3D with real permeability.
- The fundamental component, and two first allowed harmonics b6, b10 along the magnet is calculated for each 1mm slices which were well within requirements.
- Pole shape is optimized in 2D, end chamfering is optimized for 3D effects.
- Each quadrupole and DQ types have different photon exit slot size.

Sextupole Magnets

- Sextupole magnet has a strength (2nd derivative) B”=2166 T/m2 with aperture radius of 20 mm, and effective length 250 mm.
- Pole tip field is about 0.433 T which is well acceptable.
- All sextupoles should have H-corr/V-corr/Skew Quad windings.
- To minimize the interference between the coils, the magnetic efficiency should be kept high (about 98%) which is achievable due to low pole tip field.
- For extraction of photons, there is minimum vertical clearance between the poles at 30 degree and -30 degree. This limits the maximum possible pole width which affects the allowed multipole. (±7 mm)
- Sextupole may need very wide photon extraction slot. This will be confirmed soon.
- Following figure shows 2D flux distribution, and right table shows the key parameters of the sextupole magnet.

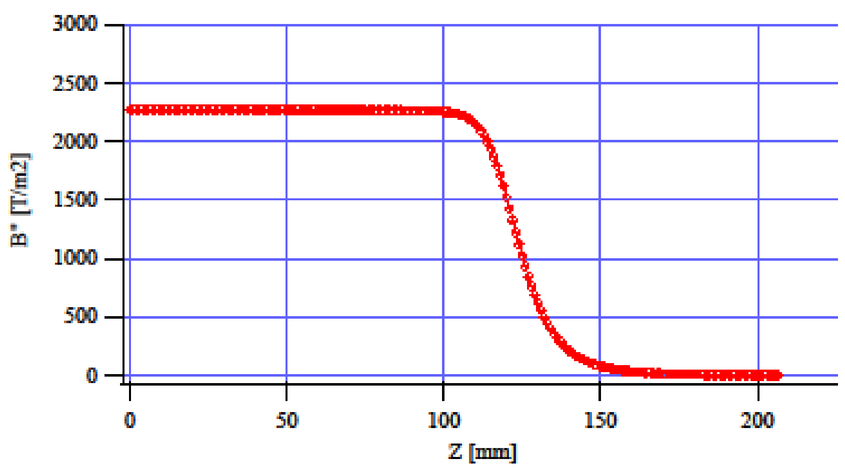


Parameter	S1	Units/Remark
B''_{max}=	2166	
Rc/Ro=	20/12	mm Aperture/GFR
Req. Number=	6*28	
Leff=	0.250	m
Efficiency=	0.94	
Ampere Turns=	2.44	kA
Conductor=	6.5X6.5-3.5Φ	mm
N/pole=	21	
Current=	116.4	A
Voltage/Mag=	6.11	V
Power/Magnet=	0.711	kW
# Cooling Cha=	2	
Coolant v=	1.60	m/sec
Flow rate=	1.85	liters/min
DT=	5.5	K
dP=	6.0	Kg/cm^2
Trim Windings	Yes	H/V/SQ

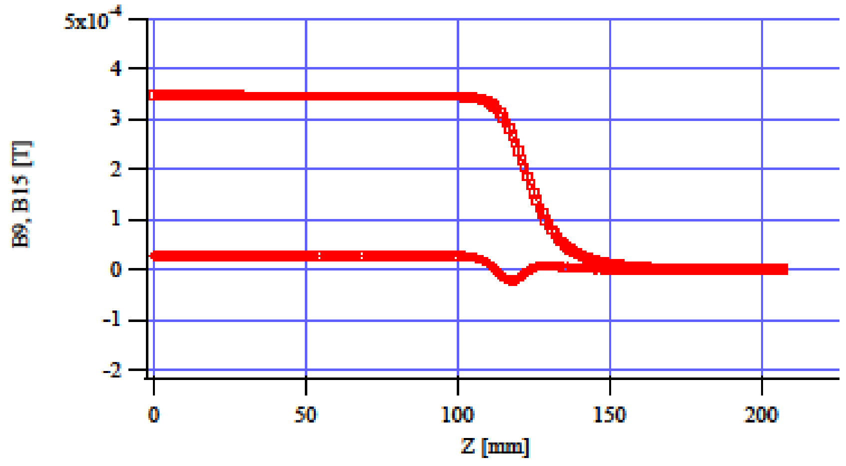
Sextupole Magnets

Conformal map

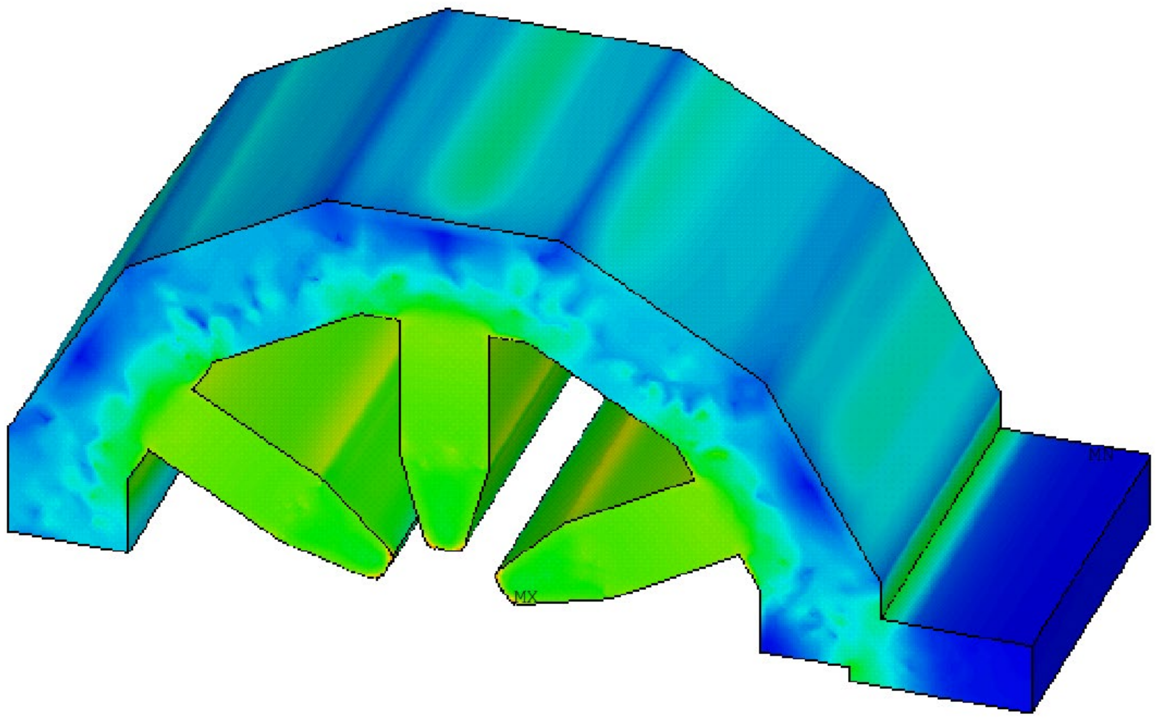
$$w = u + iv = \frac{z^3}{3r_c^2} = \frac{(x+iy)^3}{3r_c^2}$$



B" along the magnet



b9, b15 along the magnet



- Like quadrupole, shims are introduced in w plane, and transformed to z plane and the geometry is analyzed in 2D, and 3D with real permeability.
- Max B"=2166 T/m2, with effective length 250 mm.
- Apertures are all 20 mm to meet the minimum vertical photon slot size requirements.
- The fundamental component, and two first allowed harmonics b9, b15 along the magnet is calculated for each 1mm slices which were well within requirements.
- All sextupoles should have H-corr/V-corr/Skew Quad windings.
- To minimize the interference between the coils, the magnetic efficiency should be kept high (about 98%) which is achievable due to low pole tip field.

Magnet Status and short term targets

- SR needs 35*28(cell #)=980 magnets, and 300+ booster magnets with additional correctors and LTB, BTS, injection/extraction magnets.
- Currently 2*physicists, 0.5*engineers are working in the design/prototyping. More man power is needed as the project progresses.
- Requirements for magnets are relatively mild compared to APS-U, ESRF in terms of pole tip field.
- All magnets are in electromagnetic excitation to avoid any long term radiation damage issue, supply chain issue, and lower construction costs. (with slightly larger operating costs)
- LGBM2 prototype contracted awarded (Expected delivery Jun. 2023)
- Center Bend (2T), and a DQ prototypes contracts are expected within 1 month.
- Quadrupole design is going on with 2D, 3D optimization of the multipoles. Prototyping expected in 2m.
- Other magnets including center bends, correctors, quad DQs with different parameters are also being carried out.
- Prototyping of one DQ, center bend magnet is planned in this year.
- Prototyping all other magnets is expected to finish within next year.
- TDR report for magnet system is expected to finish in 2023 Sep.
- Special magnet like thick, thin current septum needs more attention after elaboration of extraction/injection scheme.
- Series production magnet contracts are expected during 2024.

Thank you for your attention!

Backup OLD Slides from here

Major Parameters of (DQ), and Reverse Bends

Parameter	DQ32	DQ31	DQ51	DQ52	Units/Remark
B'=	23	60	30	60	
Rc=	20	15	30	15	mm
Req. Number	56	56	56	56	
Leff=	0.145	0.200	0.820	0.626	m
Efficiency=	0.97	0.94	0.97	0.94	
Ampere Turns=	3.78	5.71	11.43	5.71	kA
Conductor=	6.5X6.5-4.0Φ	6.5X6.5-4.0Φ	9.0X9.0-5.0Φ	6.5X6.5-4.0Φ	mm
N/pole=	56	56	56	56	
Current=	67.4	102.0	204.1	102.0	A
Voltage/Mag=	5.08	9.31	26.34	21.91	V
Power/Magnet=	0.17	0.95	5.38	2.24	kW
# Cooling Cha=	2	2	4	4	
Coolant V=	1.53	1.37	1.26	1.24	m/sec
Flow rate=	2.31	2.07	5.94	3.74	Liters/min
DT=	2.1	6.6	13.0	8.6	K
dP=	6.0	6.0	6.0	6.0	Kg/cm^2
Reynolds #=	9300	8400	9600	7600	

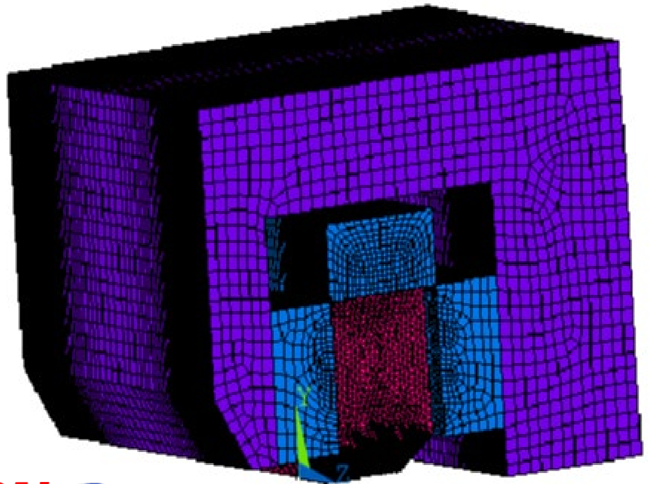
Major Parameters Quadrupole Magnets

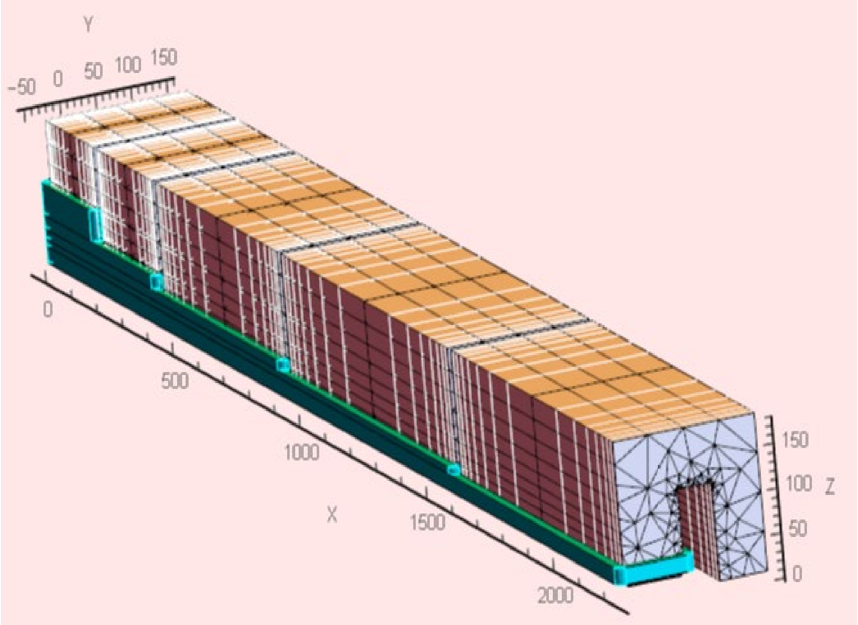
Parameter	Q12/Q31/Q32	Q11/Q52	Q51	Units/Remark
B'=	60	60	60	
Rc/Ro=	15/10	15/10	15/10	mm Aperture/GFR
Req. Number=	56+56+56	56+56	56	
Leff=	0.145	0.200	0.384	m
Efficiency=	0.94	0.94	0.94	
Ampere Turns=	5.71	5.71	5.71	kA
Conductor=	6.5X6.5-4.0Φ	6.5X6.5-4.0Φ	6.5X6.5-4.0Φ	mm
N/pole=	56	56	56	
Current=	102.0	102.0	204.1	A
Voltage/Mag=	7.70	9.31	14.76	V
Power/Magnet=	0.78	0.95	1.51	kW
# Cooling Cha=	2	2	4	
Coolant v=	1.51	1.40	1.53	m/sec
Flow rate=	2.28	2.11	4.61	Liters/min
DT=	4.9	6.5	4.7	K
dP=	6.0	6.0	6.0	Kg/cm^2
Reynolds #=	9250	8570	9670	

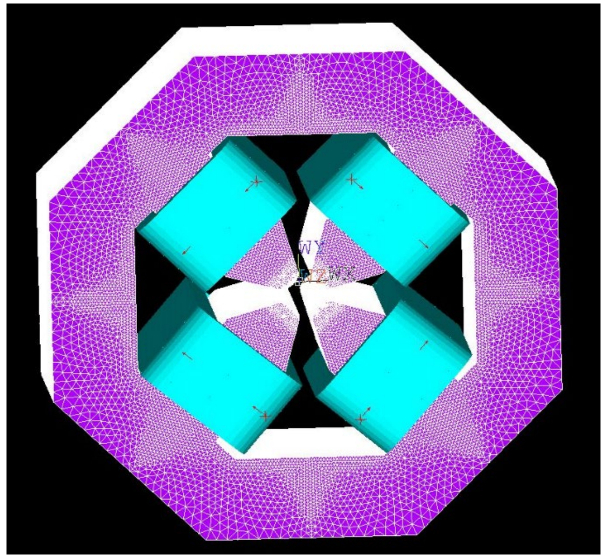
Magnet Summary 1

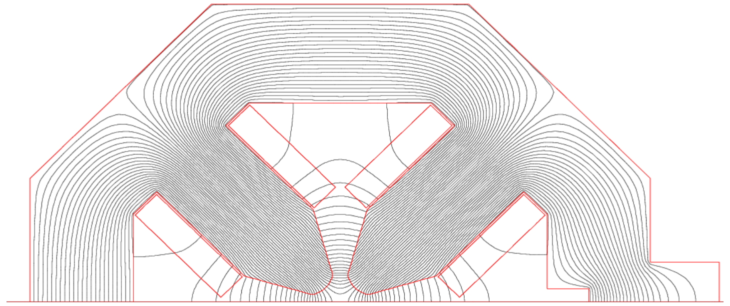
- Korea-4GSR needs 980 demanding magnets.
- Center bend features 2T field, and Permendur is adopted for the pole.
- Longitudinal Dipole used staggered independent coils, and reluctance gap in the return yoke to follow the design field.
- Quadrupole, Dipole Quad magnet achieved 60 T/m gradient using tapered pole, without using expensive Permendur.
- Sextupole is not so demanding but requires non-interfering H/V/SQ windings.

Magnet	Required Number	Remark
Central BM	28	1*28
Long. BM	112	4*28
Reverse Bend	336	2*3*28 (should have B, B')
Quad Bend	56	2*28 (should have B, B')
Quadrupoles	336	6*2*28
Sextupoles	168	6*28 (should have B", H/V Corr, Skew Quad)
Fast Corr.	112	4*28 (H/V combined corrector)
Magnets/Sec	35	31+4 (fast Corr.)
Total	980	Total number of magnets



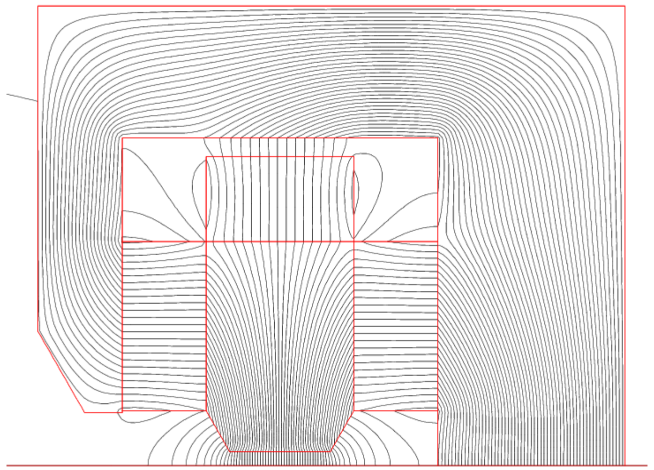


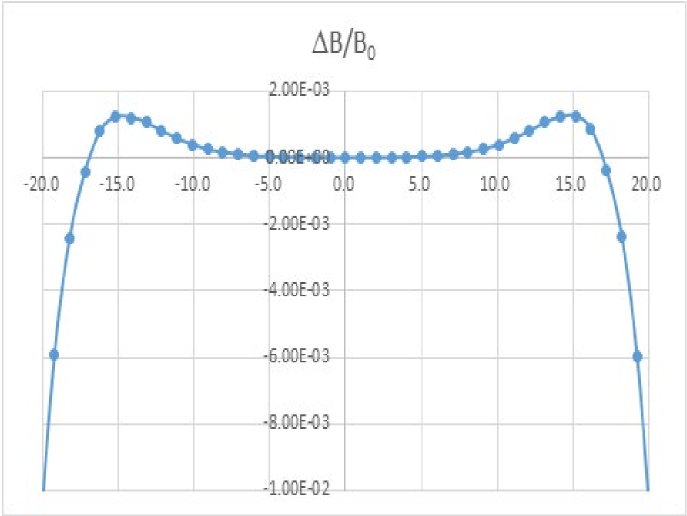


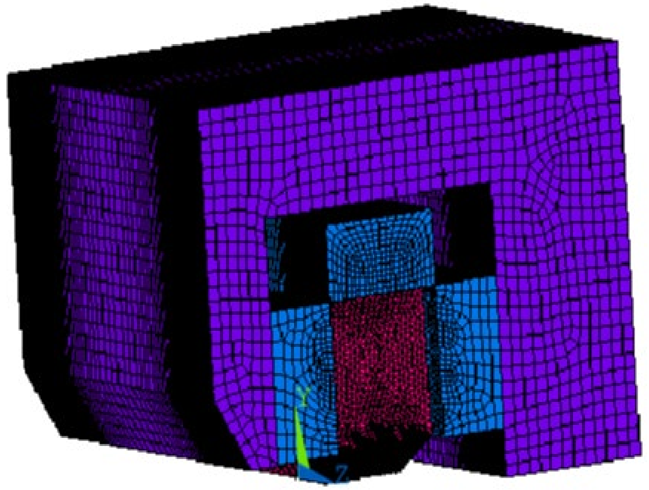


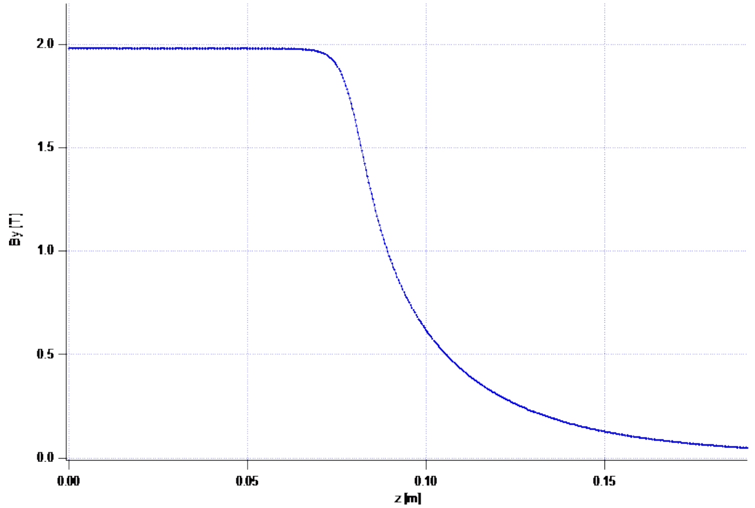
Central Bends (CB)

- Half gap at the magnet center is 7.5 mm, 0.5 mm is space for shims to optimize the uniformity.
- Max field strength is 2 Tesla, with effective length 0.190 m.
- Permanent magnet version, and EM excitation version is studied.
- Due to higher field, Iron-Cobalt is used for part of the pole, and chamfering in transverse direction and longitudinal direction is applied to alleviate the magnetic saturation issue.
- For PM version, overhang in longitudinal direction is applied to achieve the required field.
- Sm2Co17 is assumed for PM material to resist radiation damage.
- Vertical spacing in the magnet will be used to tune the magnet within 1-2%.
- 2D flux shape, 2D uniformity, FEM model, and longitudinal profile of PM version CB is shown below.



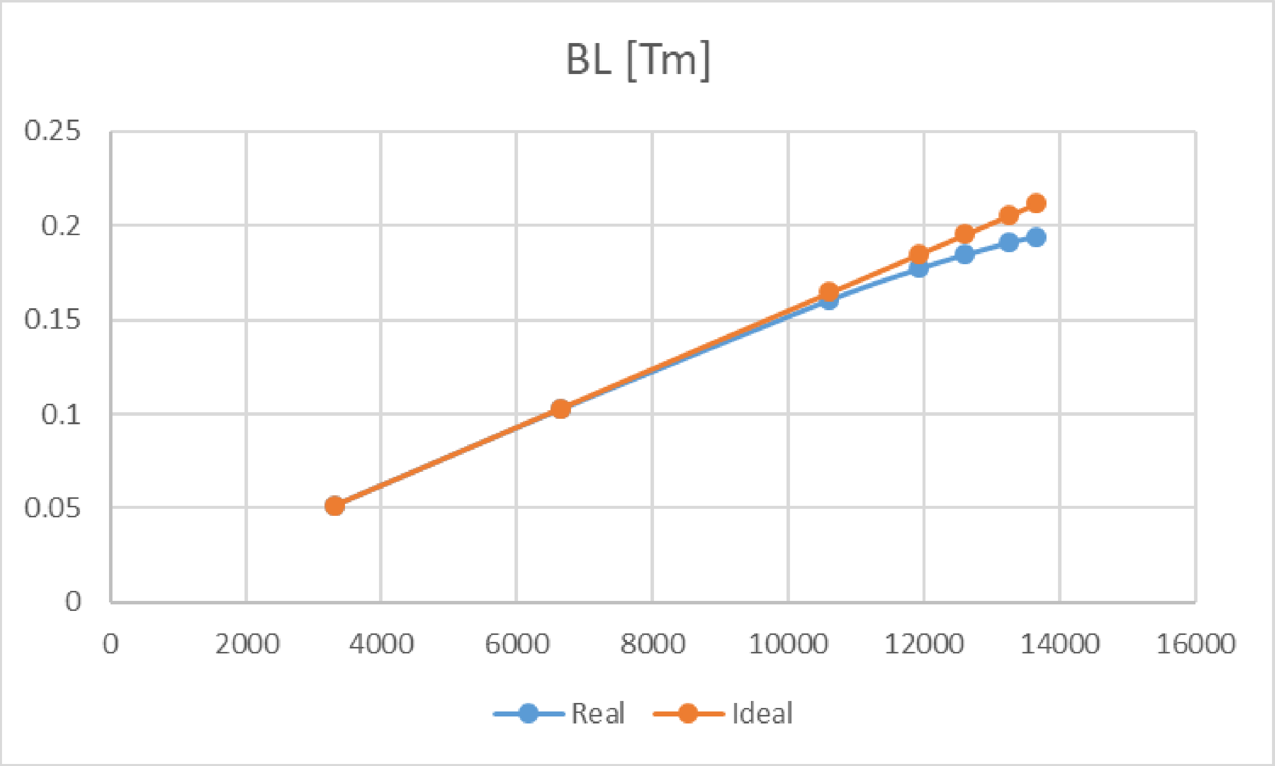




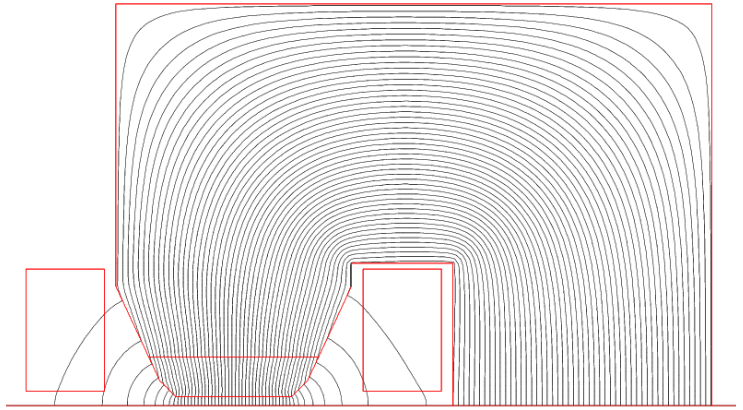


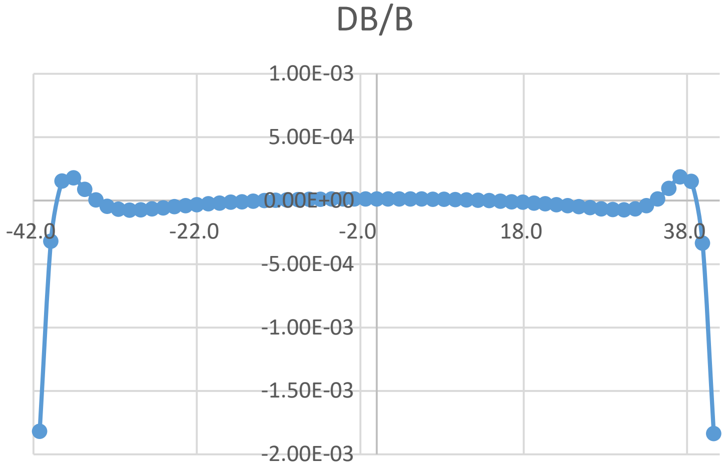
Central Bends (CB)-EM version

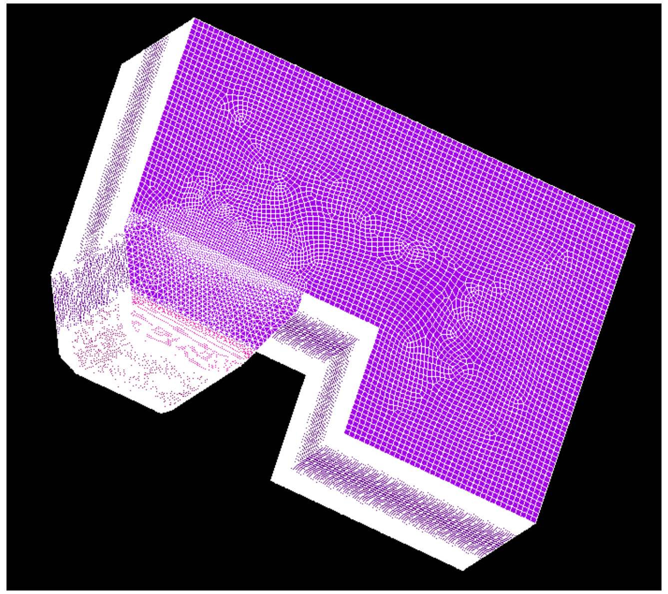
- PM excitation has some concern on the long tem stability.
- Alternative EM excitation version is studied.
- Pole is tapered in transverse/longitudinal for less magnetic saturation.
- Iron-Cobalt is used for part of the pole..
- 2D flux shape, 2D uniformity, FEM model, and longitudinal profile of EM version CB is shown below.
- Graph on the right shows the excitation curve of the magnet for real/ideal case. Magnetic efficiency is about 90% at operating point

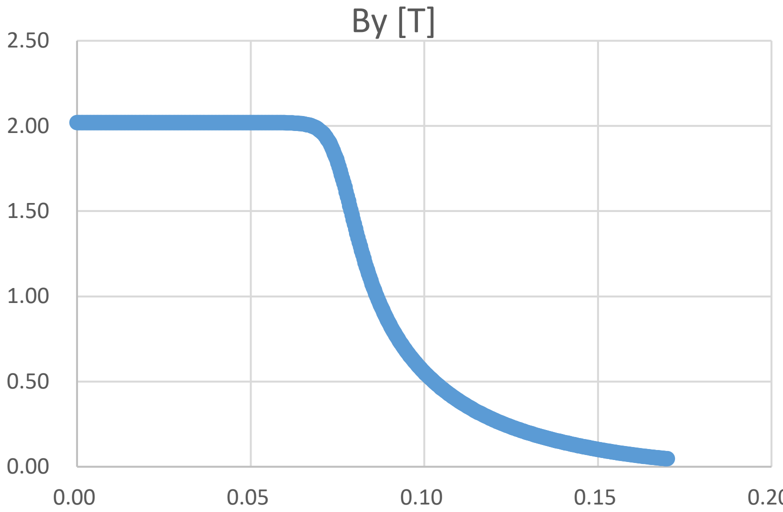


Excitation Curve of EM CB magnet





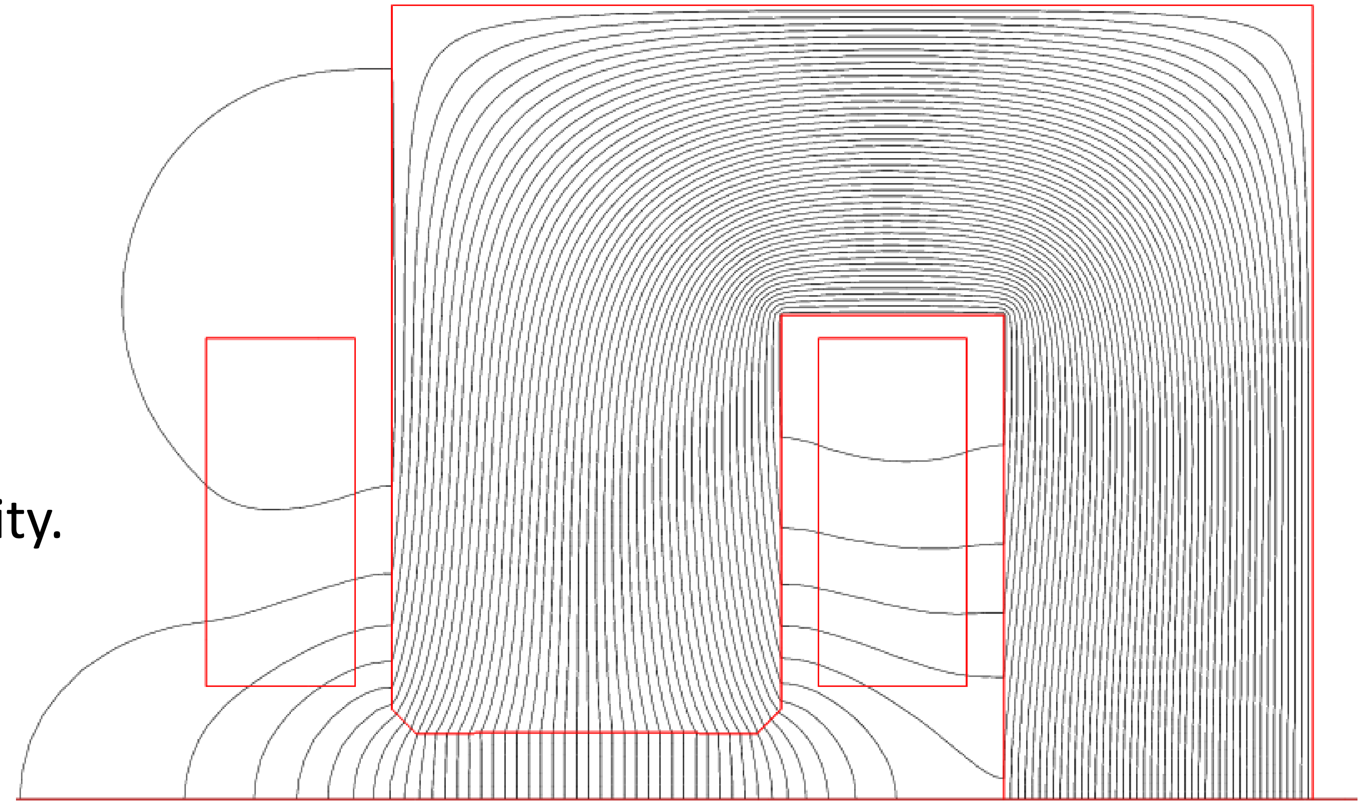


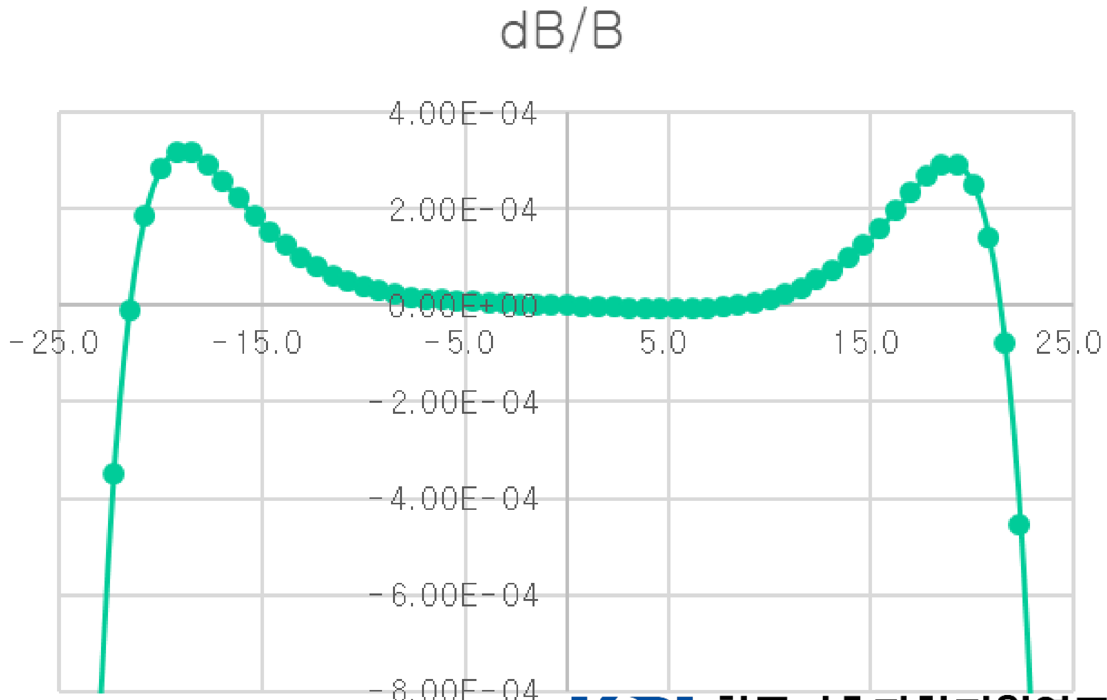


Longitudinal Gradient Dipole (LGBM)

- There are two types of LGBMs field ranging from 0.15T to 0.63 T.
- EM excitation is chosen with staggered coils to achieve stepped field profile. (See model in the next page)
- Due to quantized nature of the coil turns, reluctant air gap is introduced in the return yoke to achieve the design field.
- Following show the key parameters, 2D flux shapes, and 2D uniformity.

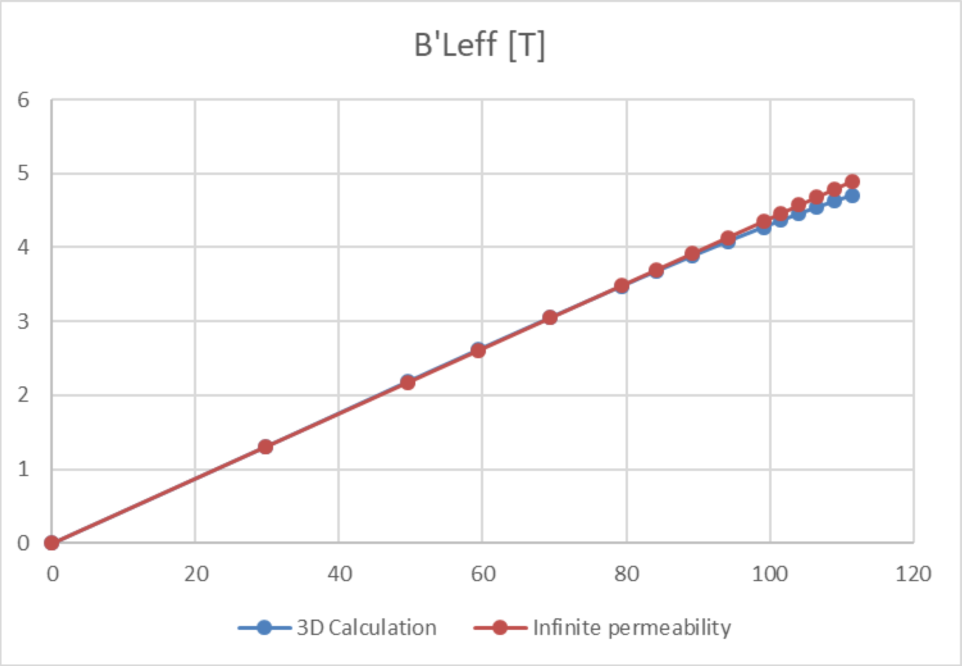
Parameter	Value	Remarks
Num of Types	4	2 types are mirror symm.
Req. Num/type	28	Total 112 EA
Bmax (LGBM1)	0.6314-0.1324	T
Bmax (LGBM2)	0.3051-0.1535	T
Uniformity dB/B	1.0E-3	<±13mm
Type	EM-type	
Max half gap. (BM1/BM2)	13.9/12.2	mm
Trim Windings	Yes	For 2nd field integral tuning.
NI=	7.27/3.08	kA (BM1/BM2)
Conductor	11.5x11.5x7.5Φ 9.0x9.5x5.0Φ	BM1, 24 turns BM2, 16 turns
I=	303.1/192.8	A (26/16 Turns)
V=	15.8/8.7	V (per Mag)
DT=	8.3/6.5	K (for DP=6bar)



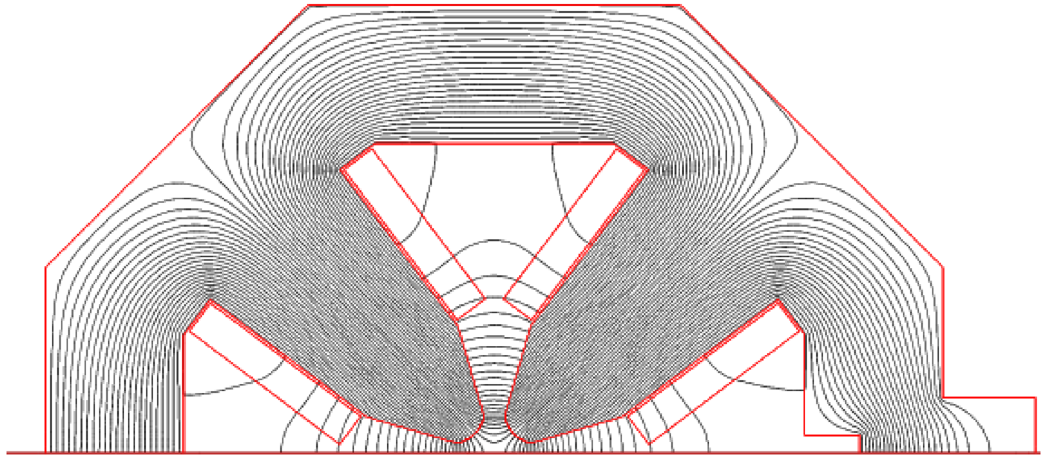


Quadrupoles

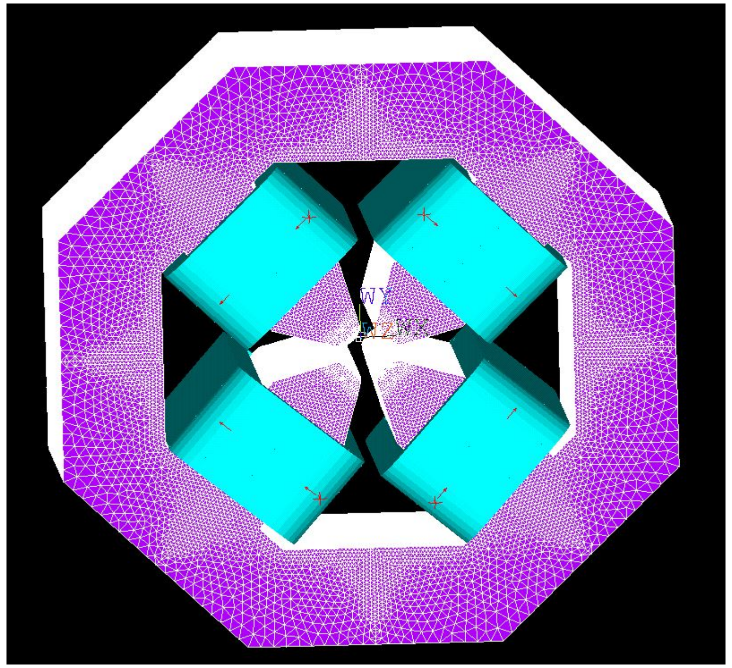
- Normal Quad and DQ31, DQ52 has aperture radius of 15 mm, with maximum B'= 60 T/m. This gradient is achievable with low carbon steel with slightly tapered pole which alleviates the pole root saturation issue.
- excitation to achieve stepped field profile.
- Due to quantized nature of the coil turns, reluctant air gap is introduced in the return yoke to achieve the design field.
- Following show the key parameters, 2D flux shapes, and 2D uniformity.
- Saturation due to fringe field is most severe for the shortest quadrupole with effective length 145 mm. And this model is intensively simulated to assess the 3D effects. The excitation characteristics is shown in the right graph.



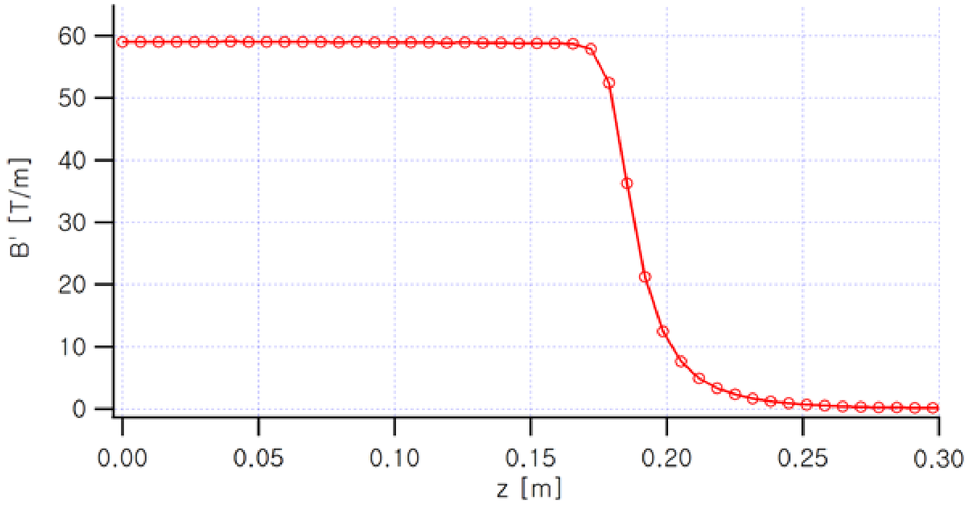
B'Leff vs current for 3D, ideal case



2D model with photon slot



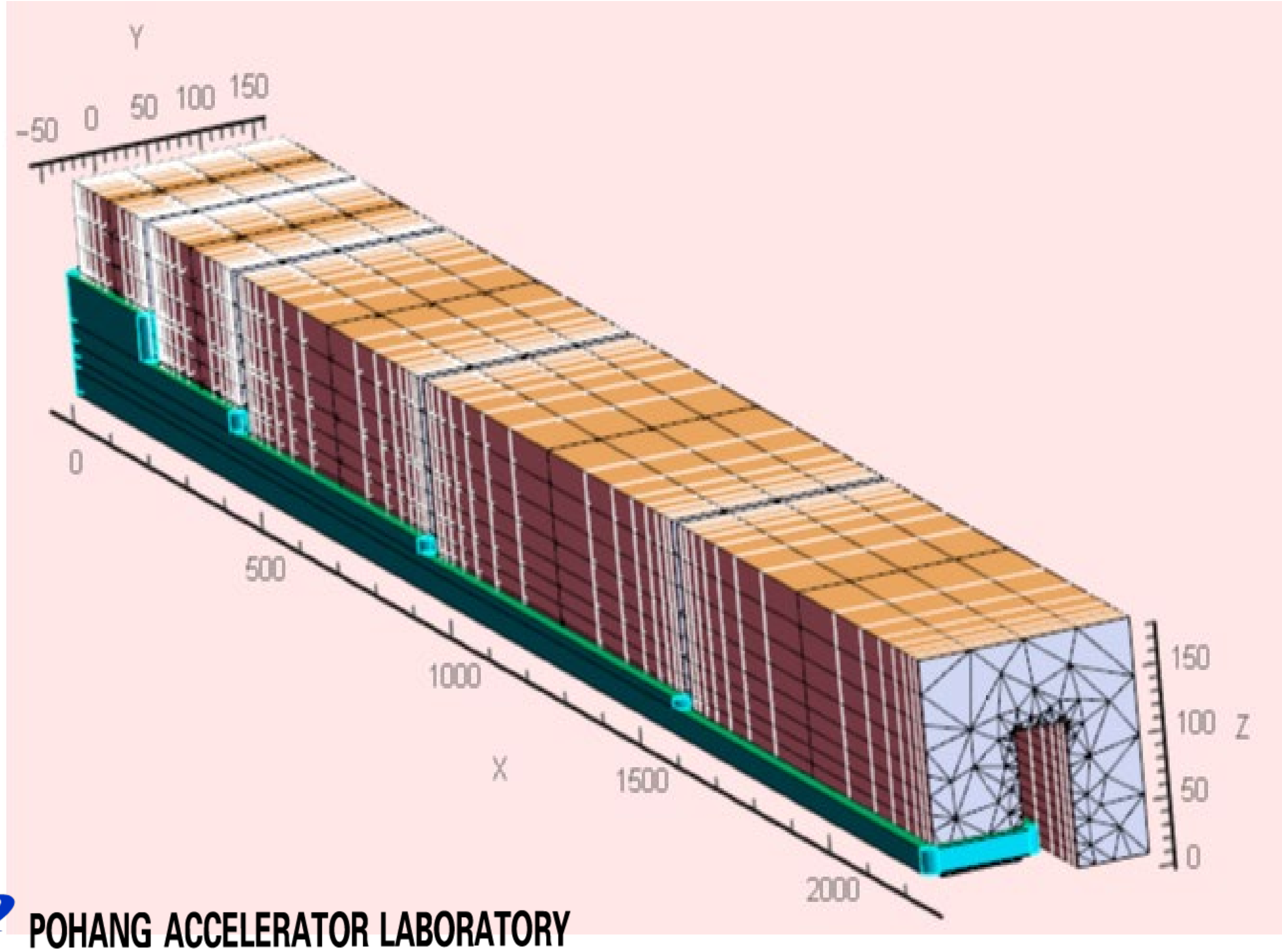
3D model without photon slot

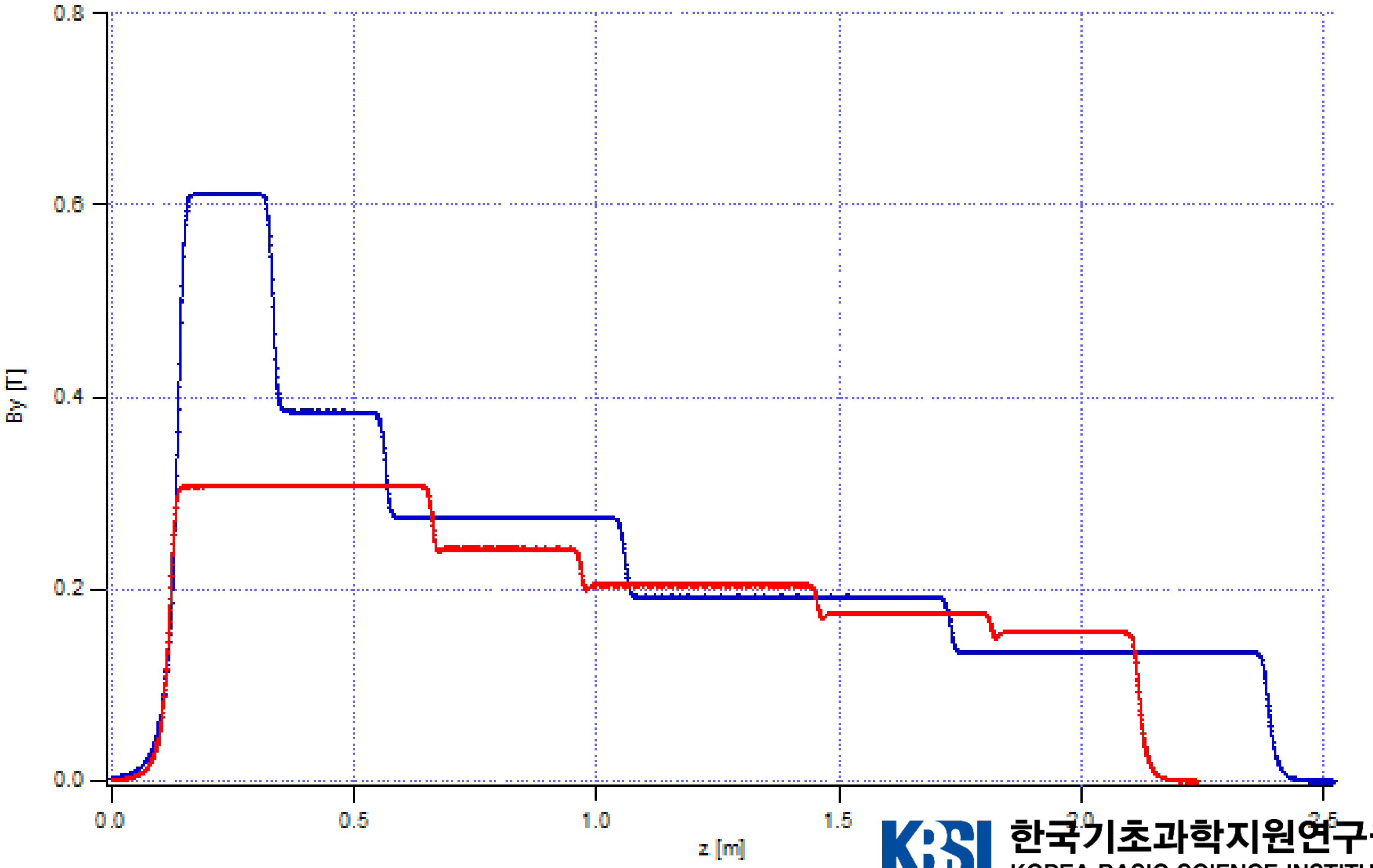


B' profile for Leff=384 mm case.

Longitudinal Gradient Dipole (LGBM) : 3D

- The spacing between the section is compromised for current density and profile accuracy. The spacing is 14mm for LGBM1, and 12mm for LBGM2.
- Due to quantized nature of the coil turns, reluctant air gap is introduced in the return yoke to achieve the design field.
- Following show the 3D Raida model, and longitudinal field profiles of BM1, BM2.
- It's also simulated using ANSYS 3D.





Work Scope of RF Group, 4GSR TFT

(for storage ring and booster)

- To design RF system, for TDR (Main & booster rings)
- To study each prototyping component and integrated system
- To fabricate/purchase RF components
- To construct a RF test facility in PAL site (The facility construction in O'Chang site is beyond scope of PAL)
- To test RF components (SAT) in the test facility
- To hire required man powers for RF system of 4GSR (limited number)
- Training new commers for RF system

Un-defined Works of RF Group, 4GSR TFT

(The discussion & decision between PAL and 4GSR Headquarter)

- To construct a RF test facility in O'Chang site
- To install RF components in the accelerator, O'Chang
- To commission an integrated RF system, with & without beam
- To develop and install a harmonic RF system in the main ring
- To study and devise required systems for suppressing coupled-bunch instability in the storage ring

Plan and Budget Distribution

Year	Works	Budget (rate)	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Y '2022	Technical design (TDR)	30%				
	Prototyping R&D					
	Preparing RF system test facility @PAL					
Y '2023	Completion, TDR	11%				
	Completion, RF test facility					
	Specification of component through prototyping R&D					
Y '2024	Design improvement	20%				
	Components purchase & fabrication					
Y '2025	Components fabrication	27%				
	Preparing cooling facility					
Y '2026	Components delivery and SAT	12%				
	Preparing RF system test facility @O'chang					
	Completion cooling facility @O'chang					
Y '2027	Component installation in the accelerator	-				
	Commissioning single components					
	RF commissioning (without/with beam)					Target
Y '2028	Beam commissioning & RF optimization					
Total budget, assigned in plan		**100%**	*※It should be revised after TDR completion*			

RF Layout: RF Sections over the Accelerator Building