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ORNL PUP-II STS QH10 Quadrupole

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ORNL-FNAL STS PDR Narrow Quadrupole Review

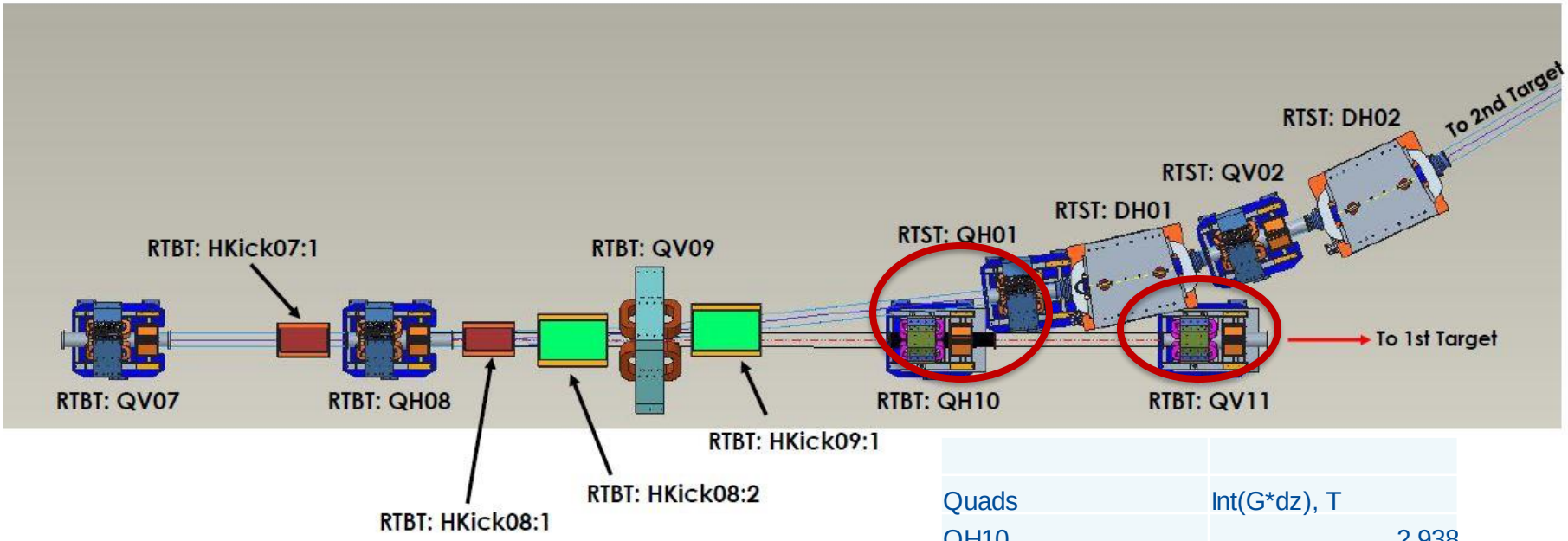
April 16, 2024

Outline

- Beam lines layout
- Specification QH10
- Quadrupole magnetic design
- Quadrupole engineering parameters
- Summary

Beamline Magnets

RTST Extraction Region Design Concept



Quads	Int(G*dz), T
QH10	2.938
QH01	2.1306
QV02	-2.9954
QV07,QV09,QV11	2.8065

- RTBT transports proton beam to first target
- RTBT optics to remain unchanged
- RTST proton beam to intersect truck entrance wall at prescribed position and angle

OAK RIDGE National Laboratory

Need narrow quadrupoles to provide some clearance between: QH10-STS Beamline and DH01-QV11.

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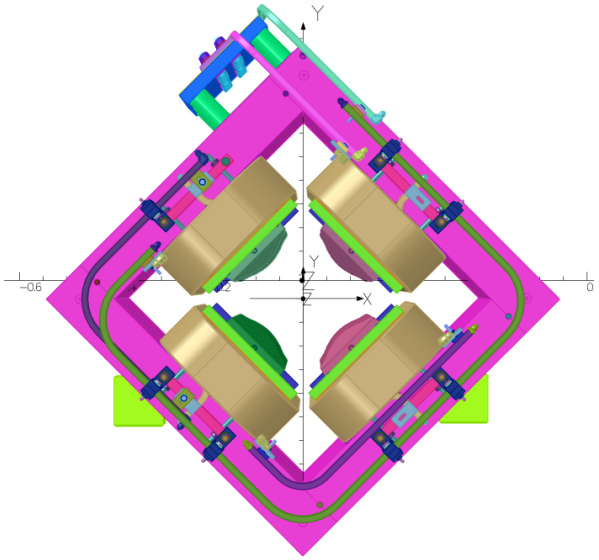
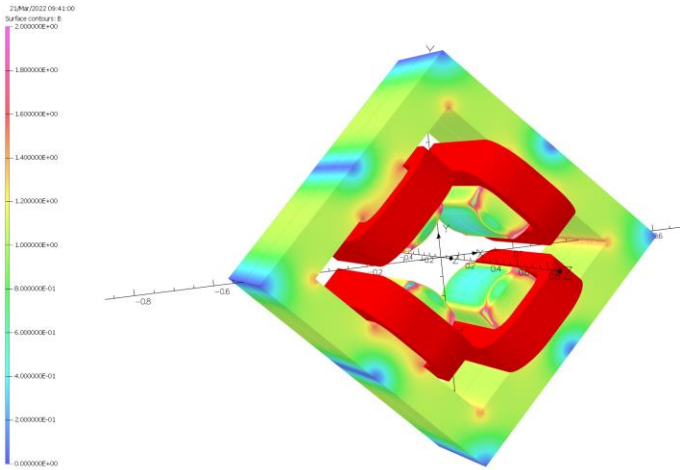
Quadrupole Specifications

RTBT Beam Line Magnet Parameters						
		Parameter Value				
Name	Unit	QV07	QH08	QV09	**QH10***	QV11*
Magnet New/Old		Old	Old	New	**New**	New
Magnet center Z-coordinate	m	0	3.8608	7.7216	**11.5824**	15.4432
Magnet center X-coordinate	m	0	0	0	**0**	0
Angle of magnet rotation	Deg.	0	0	0	**0**	0
Gradient	T/m	-5.613	5.876	-5.613	**5.876**	-5.613
Integrated field/gradient	T-m/T	-2.8065	2.938	-2.8065	**2.938**	-2.8065
Effective length	m	0.5	0.5	0.5	**0.5**	0.5
Magnet Gap/Aperture diameter	m	0.209	0.209	0.4	**0.209**	0.209
Good field area diameter**	m	0.147	0.147		**0.147**	0.147
Good field area horizontal	m	0.147	0.147	-0.0735 < x < 0.2003	**0.147**	0.147
Good field area vertical	m	0.147	0.147	0.147	**0.147**	0.147
Field homogeneity/non-linearity	%	0.1	0.1	0.1 target	**0.1**	0.1
Number of coils		4	4	4	**4**	4
Coil current	A					
Coil number of turns		28	28	28	**28**	28
Magnet yoke length	m	0.4	0.4	0.4	**0.4**	0.4
Magnet maximum physical length	m	0.67	0.67	TBD. 0.67 assumed	**0.67**	0.67
Magnet maximum physical width	m	1.05	1.05	TBD.***	**TBD. 0.668 assumed**	TBD. 0.668 assumed
Abbreviaitions:	*QH10, QV11 are the same as QV07, QH08 but with narrow yoke					
TBC - To Be Confirmed	** Spec is given in as horizontal x vertical					
TBD - To Be Determined	*** Beam axis is 0.99 m from floor					

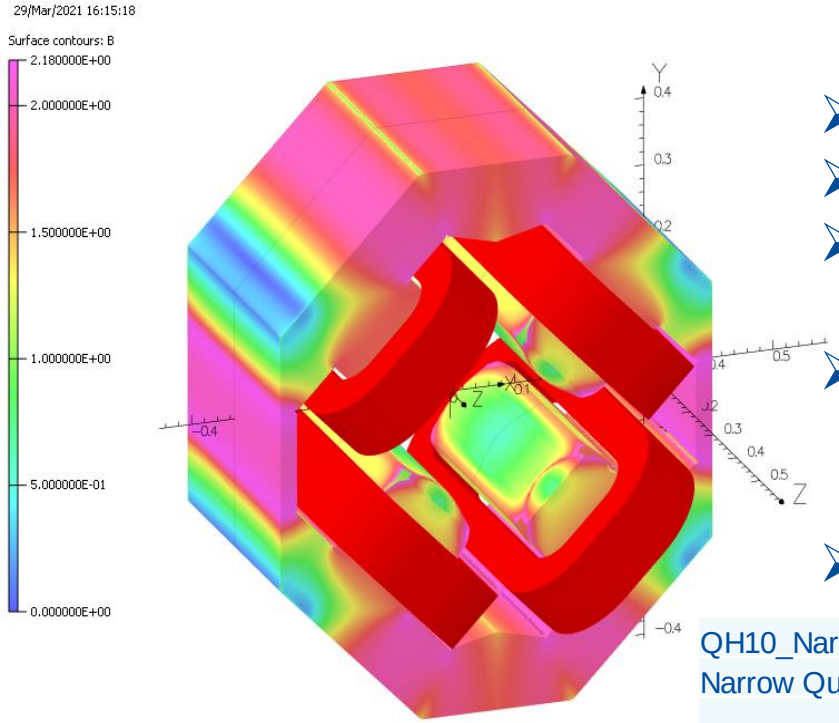
Old Quadrupole 21Q40

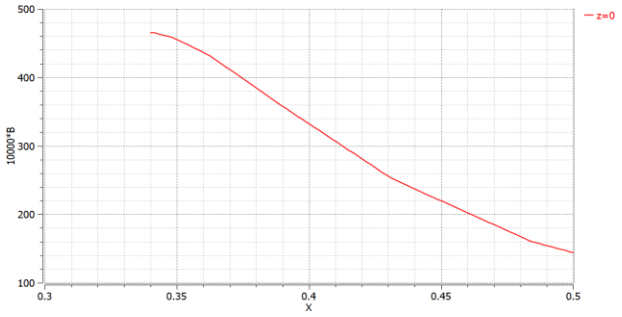




- Quadrupole too wide and overlaps with other magnets.
- Should be decreased magnet yoke width.
- Coils and quadrupole poles are not modified.
- Power and cooling parameters are the same as in the old magnet.
- Figure-8 quadrupole configuration might be a preferable choice.

STS Narrow Quadrupole QH10, V1

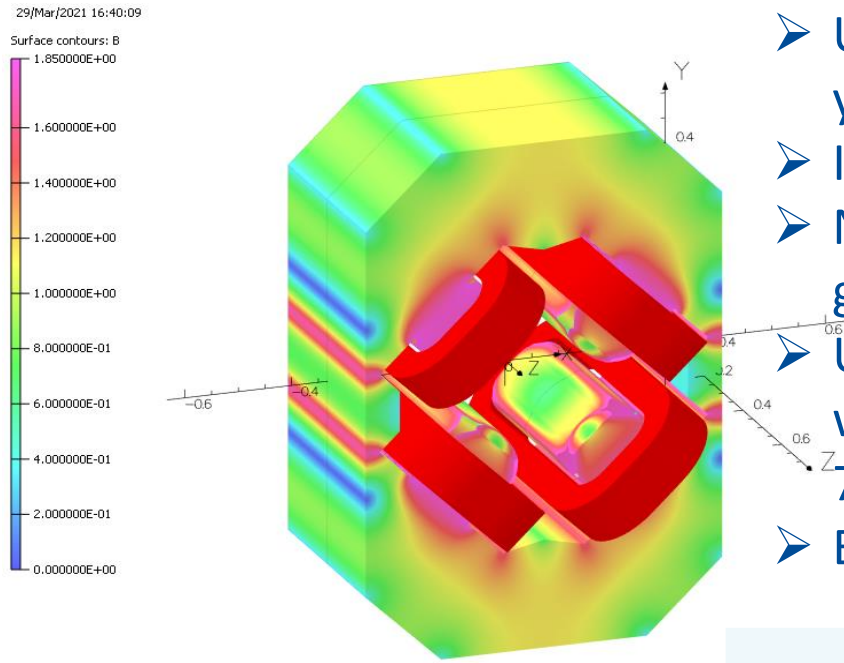


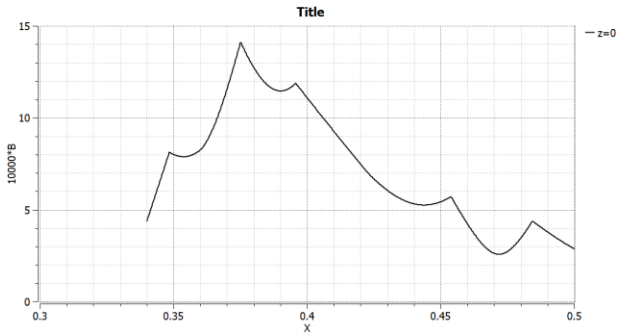


- Simulated stp file geometry.
- Iron yoke highly saturated to 2.18 T.
- Needed 31.2 kA/coil to generate an integrated gradient 2.895 T (Spec. 2.938 T).
- Pole profile and end chamfers are good providing 1 unit field quality at 75 mm reference radius.
- Effective length is stable within 1 mm.

QH10_Narow_26kA_50_800_100_115_120%_032421a						
Narrow Quadrupole from stp file						
		Coil Ampere-turns in % to 26kA				
Parameter	Unit	50	80	100	115	120
Coil ampere-turns	kA	13	20.8	26	29.9	31.2
Center gradient	T/m	2.955	4.551	5.336	5.825	5.973
Integrated gradient (Spec. 2.938T)	T	1.440	2.215	2.591	2.825	2.895
Effective length	m	0.487	0.487	0.486	0.485	0.485
Maximum flux density (narrow wall)	T	1.450	1.850	2.100	2.170	2.180
Harmonics for Rref	m	0.075	0.075	0.075	0.075	0.075
Integrated field at Rref (from Harm)	T-m	0.108	0.166	0.194	0.212	0.217
Integrated gradient (from Harmonics)	T	1.440	2.215	2.592	2.825	2.895

STS Narrow Quadrupole QH10, V3 (increased yoke)





Peak fringe field 14 Gauss.

- Updated geometry: increased top/bottom yoke thickness and added side wall thickness.
- Iron yoke is less saturated < 1.85 T.
- Needed 27.4 kA/coil to generate an integrated gradient 2.956 T (Spec. 2.938 T).
- Used an old pole profile and end chamfers which are good providing 1 unit field quality at 75 mm reference radius.
- Effective length is stable within 1 mm.

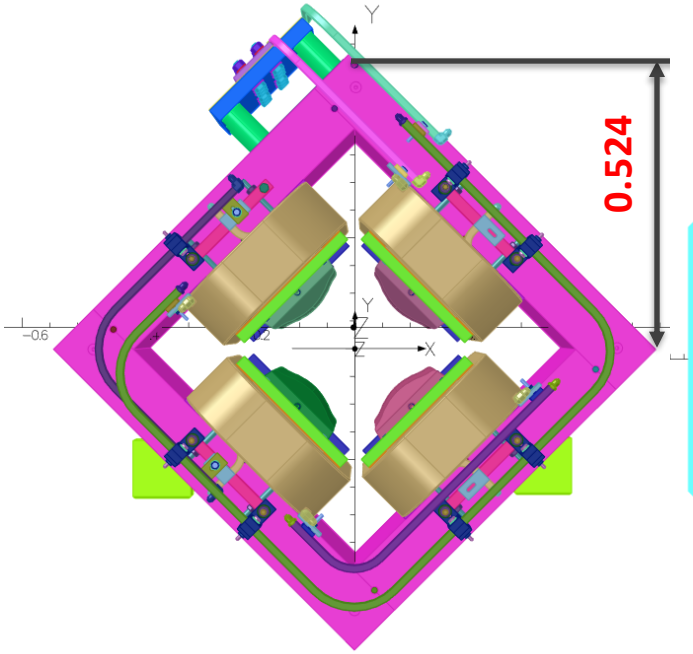
	Updated Yoke V3 032521b			
	Coil Ampere-turns in % to 26kA			
Parameter	Unit	100	110	105.385
Coil ampere-turns	kA	26	28.6	27.4
Center gradient	T/m	5.787	6.277	6.07
Integrated gradient (Spec. 2.938T)	T	2.816	3.057	2.956
Effective length	m	0.487	0.487	0.487
Maximum flux density (narrow wall)	T	1.800	1.900	1.900
Harmonics for Rref	m	0.075	0.075	0.075
Integrated field at Rref (from Harm)	T-m	0.213	0.229	0.222
Integrated gradient (from Harmonics)	T	2.834	3.059	2.958

Quadrupole Harmonics Old vs. New

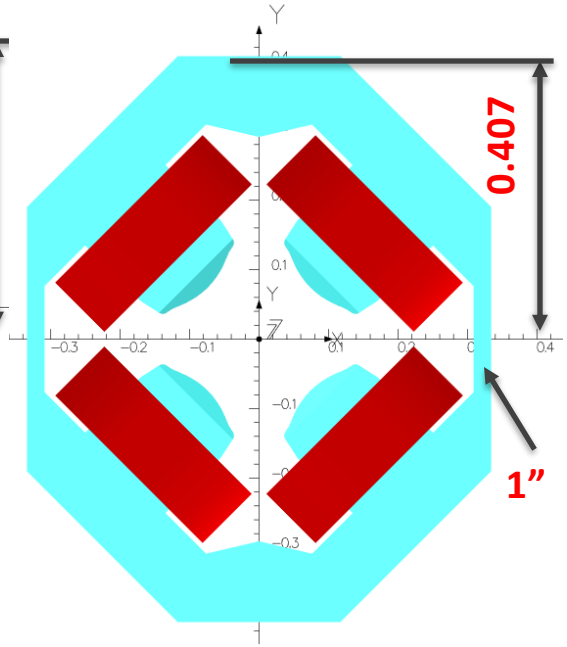
21Q40_19kA_V1_012221a													
Old 21Q40 quadrupole, Iw=19 kA/coil				Red-might be because of iron saturation									
Rref=0.075													
m	0.075												
Zmx	ai2	ai1		ai2	ai3	ai4	ai5	ai6	ai7	ai8	ai9	ai10	
1	0.1585	0		10000	0	-1.79	0	10.77	0	-0.26	0	-0.35	
Int.gradient	2.113												
QH10_Narrow_26kA_V3_032521b													
Quadrupole QH10 with 27.4 kA/coil													
Rref=0.075													
m	0.075												
Zmx	ai2	ai1		ai2	ai3	ai4	ai5	ai6	ai7	ai8	ai9	ai10	
1	0.2218	0		10000	0	-0.29	0	0.064	0	-0.022	0	-0.805	
Int. Gradient	2.957333												
Spec	2.938												

- All harmonics calculated for the reference radius 75 mm.
- For the new quadrupole all harmonics are less than 1 unit.

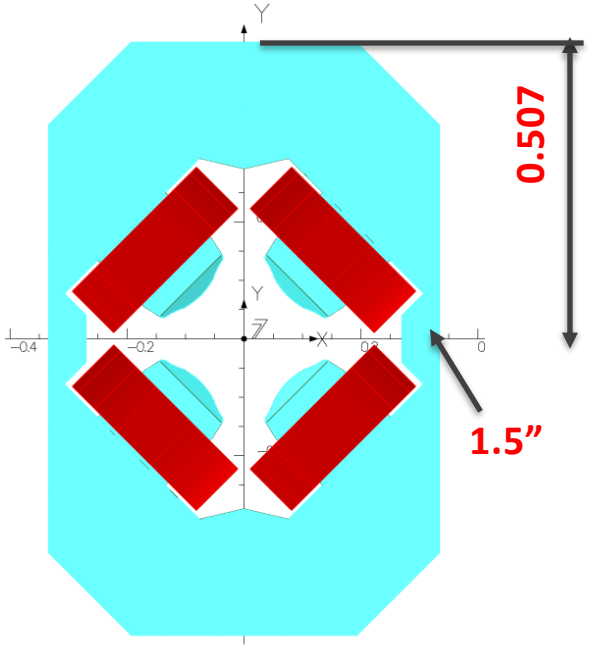
STS Quadrupole Geometries



21Q40
Old quadrupole



QH10, ORNL stp
Initial design



QH10
Updated design

- Updated geometry: increased 100 mm top/bottom yoke thickness and added 25 mm (0.5”) side wall thickness.

Summary

- Simulated an old quadrupole geometry at 19 kA/coil.
- Simulated the first version of narrow quadrupole which has the iron yoke over saturated above 2 T.
- Proposed for the further consideration the narrow Figure-8 quadrupole with increased vertical yoke height.
- The quadrupole has integrated harmonics less than 1 unit.
- This quadrupole fit the magnet specification and geometry limits.