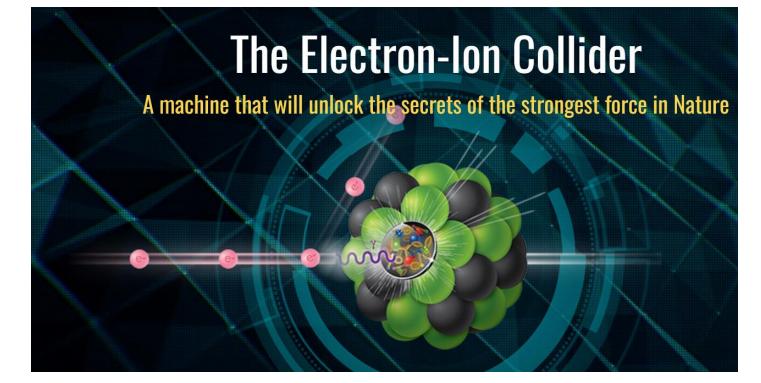




MT-28 International Conference on Magnet Technology

Aix-en-Provence, France, 10-15 September 2023

Brookhaven® National Laboratory



Magnetic design of the interaction region quadrupole Q2pF for EIC*

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Abstract

(EIC) planned Electron-Ion Collider for The İS construction at Brookhaven National Laboratory. The design of the Interaction Region (IR)quadrupole Q2pF of EIC is based on a 2-layer coil with an inner diameter of 280 mm. This is a challenging magnet with a computed (with EIC "Q" cable) peak field of 6.4 T at design in a relatively large coil aperture. With little time for R&D, the desired operating is >30% over the design. Another key margin requirement is the low field and low field errors in the electron beam which is traversing within the same iron yoke and is in a proximity to the main coils with separation between the two beams changing from one end to another end. The paper presents the status of the Magnet Division current design.

Cross-section Optimization

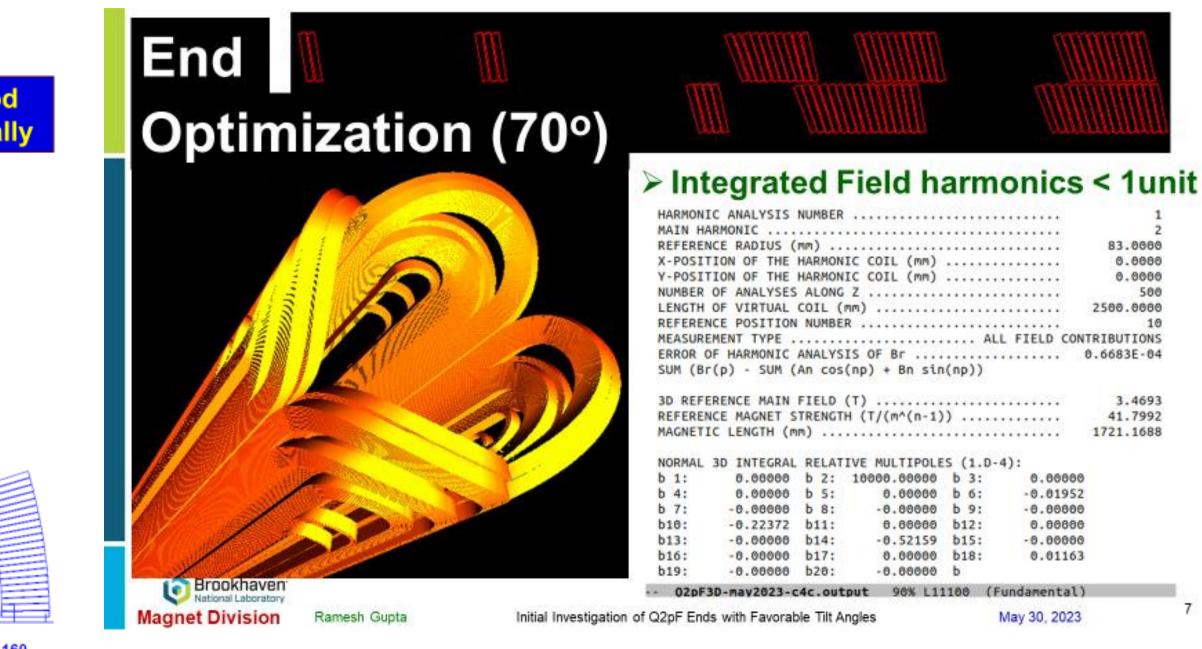
Design with Wedges Forced Symmetric

Looks good nechanically

0 20 40 60 50 100 127

June 20, 2023

End Optimization

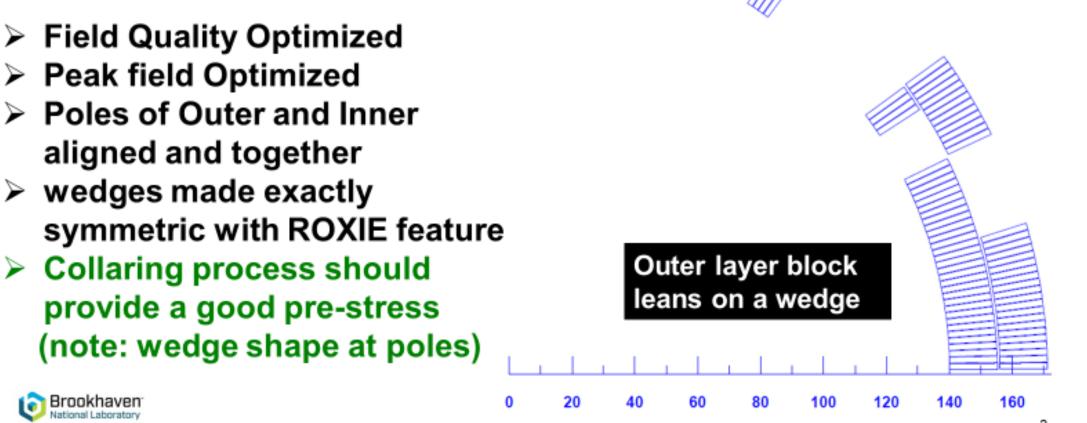




LHC Style Cable used in Quad & Dipole (based on full keystone for Q2pF and B1ApF)

		No Nane	heigh	t wid	thi	width_o	ns	transp.	degrd Connent	8					
-10		1 EICLHCB	15.		.816	1,984	28	115	5 LHC IN KEYSTOE FOR EIC DIPOLE						
		1 EICLHCQ	15,	1	1.79	2,01	28	115	5 LHC IN KEYSTONE FOR EICIR QUAD	Keystor	ne angle for cab	le width << o	oil readi		
4		1 EICLHC01	15.	1 1	.786	2.014	28	115	5 LHC CABLE KEYSTOR FOR EIC 4,2K	Pro youor	ne angle for cab				
		2 EIC3642	19.	4 1	.773	2.027	36	115	3 EIC 36 STRAND 04.2K			Q2pF	B1Ap		
		3 EIC3618	19,	4 1	.773	2,027	36	115	3 EIC 36 STRAND 01,8K	Cable h	eight	15.1	15.1		
		4 EIC3642A	19.	4 1	.788	2.012	36	115	3 EIC 36 STRAND 04.2K 2 Layers		Cable mid-thickness		1.9		
но		5 CABLEO1	15.	1 1	,736	2,064	28	115	5 MB INNER LAYER,STR01 5 MB OUTER LAYER,STR01	Insul (one side)		1.9	0.12		
		6 CABLE02	15,	1 1	.362	1,598	36	100				0.12			
		7 SINGLE	0.9	4	0.94	0.94	1	0	O SINGLE STRAND	Coil i.r.		140	185		
		8 GSI1CAB	9.7	4 1	.061	1.271	30	74	0 GSI001 (RHIC) CABLE						
		9 GSI001	9,7	3 1	,111	1,321	30	74	0 GSI001 following Wanderer						
		10 20MMCABLE	2	0 1	,736	2,172	37	0	0 20mm cable				100.00		
		11 20MMCBNOK	2	0	13,8	13,8	290	0	0 7x20mm cable, no keystone	Avg Rad		147.55	192.55		
		12 20MMCAB2	82 20 1.8 2 37 0 0 20 mm cable 2		0 20 mm cable 2	dt		0.2190	0.167						
											Width_i		1.816		
	围	Cable Definiti	lon									1.790	1.984		
		No Nane	Cable Geom.	Strend	Filament	Terrul	Trans	Quench Mat.	T_o Connent	width_c	2	2.010	1.304		
		1 EICLHCB2K	provide state of the state of t	STREIC1	NBTII	ALLPOLYTE	2.	NONE	2 LHC INNER FOR EIC IR QUA	0.825	Mater Ke				
	\rightarrow		2 EICLHCQ2K EICLHCQ STREICI NBTII ALLPOLYIL TRANSI NONE 3 LHCIN42K EICLHCO1 STREICI NBTII ALLPOLYIL TRANSI NONE						2 LHC INNER FOR EIC IR DIP	NOLE, NEVALUIIEA			s are		
					4.2 LHC INNER FOR EIC 04.2K	Contra to	reduced for EIC								
2⊒				STR01	NBTII	ALLPOLYIL		NONE	1.9 V6-1 DESIGN DIPOLE INNER		reauc				
	odac	TELLONOU		STR02	NBTIO	ALLPOL YOU		NONE	1,9 V6-1 DESIGN DIPOLE OUTER						
			OTHER DESIGN	C DECORE	LINT TO	PROFILE OF THE	The second second	in section.							

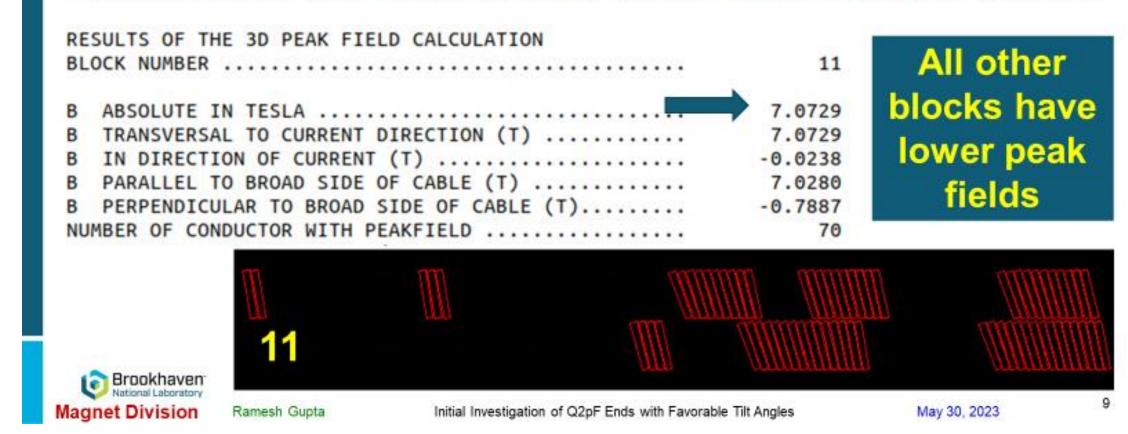
Similar to LHC inner: "YELLONIN" (CABLE01)



Peak Field in the Ends (Linear Iron)

- Peak field in the body (including self field) : 7.05 T
- Peak field in the ends (including self field): 7.07 T

Peak field in the Ends is close to the field in cross-section



Calculation of Peak Field with OPERA3d (non-linear iron)

2-d Field Quality and Quench Margin

roaress in Q2pF Desi

F							Margin to quer	ch (%)
MAIN HA REFEREN X-POSIT Y-POSIT MEASURE ERROR O	RMONIC ICE RADIUS (TION OF THE TION OF THE MENT TYPE . OF HARMONIC	mm) HARMON HARMON ANALYS	IC COIL (mm) IC COIL (mm) IS OF Br (np) + Bn sin	AL	L FIELD CONT	0.0000 0.0000 RIBUTIONS	94.15 91.24 88.32 85.41 82.49 79.57 76.66 73.74 73.74	
		/ (m^ (n	-1))			3.147502 37.9217	70.83 67.91 64.99 62.08 59.16	
b 1: b 4: b 7: b10:	-0.14254 -0.01577 -0.00201 -0.40774 -0.00002 -0.00000	b 2: b 5: b 8: b11:	10000.00000 0.02641 -0.00094 -0.00011 -0.46484 -0.00000	b 6: b 9: b12: b15:	0.00250 -0.10295 0.00065 0.00000 0.00000 0.00550		56.25 53.33 50.41 47.50 44.58 41.66 38.75 ROXIE 10.2	

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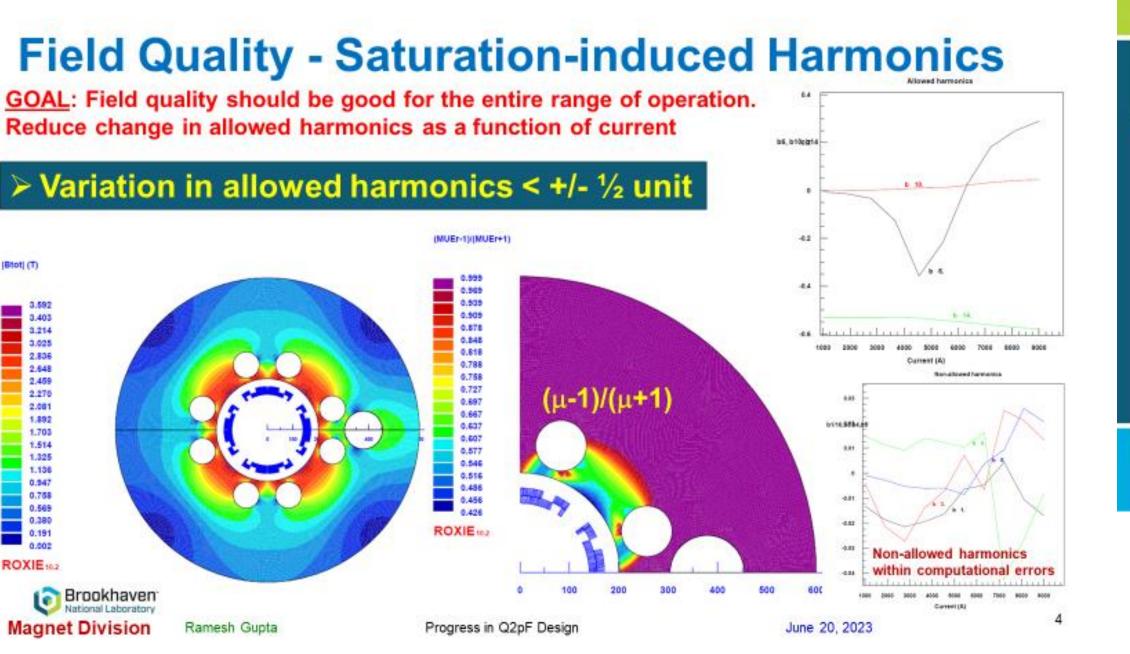
agnet Division

Ramesh Gupta Cable Parameters of the EIC IR Cable Magnets March 22, 2022 Magnet Division

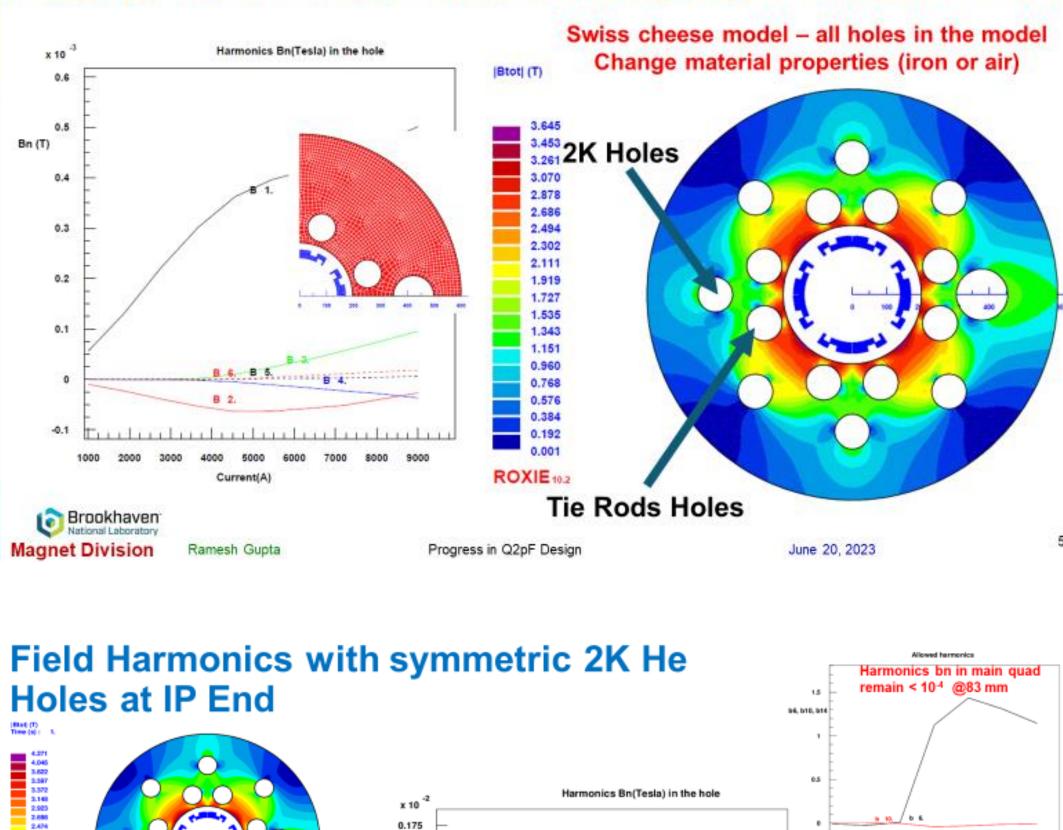
() Brookhaven

Magnet Design Parameters

Coil inner diameter	280	mm
Coil outer diameter	342.8	mm
Number of layers	Two	
Integrated gradient @design	133.55	Т
Design gradient (@center of magnet)	38.22	T/m
Operating current @ design gradient	8500	Α
Magnetic length	3.494	meter
Coil length (last turn to last turn)	3.64	meter
Yoke length	3.72	meter
Total number of turns per coil	70	per octant
Number of turns in inner layer	34	per octant
Number of turns in outer layer	36	per octant
Cable required (whole magnet)	2	km
Superconductor	NbTi	
Cu/Sc Ratio (nominal)	1.6	
strand diameter (mm)	1.065	
Number of strands in cable	28	
Cable width, bare (mm)	15.1	mm
Cable mid-thickness, bare (mm)	1.9	mm
Cable insulation radial	0.15	mm
Cable insulation azimuthal	0.12	mm
Cable width insulated	15.4	mm
Cable mid-thickness, insulated	2.14	mm
Operating temperature (nominal)	2	Κ
Stored energy @design gradient	2.7	MJ
Inductance	75	mH
Quech current	13700	Α
Quench gradient	5.54	T/m
Peak field @design	6.4	Τ



Placement of Tie Rods Holes to Reduce field in electron Hole



Harmonics B_n, n=3-5, in electron hole remain ~10⁻⁴ T @50 mm

B 4.

Progress in Q2pF Design

June 20, 2023

0.15 Bn (T)

Field in hole with optimiz

Ramesh Gupta

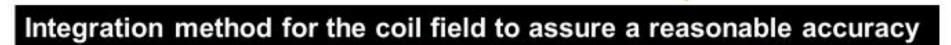
Field a 0 kA

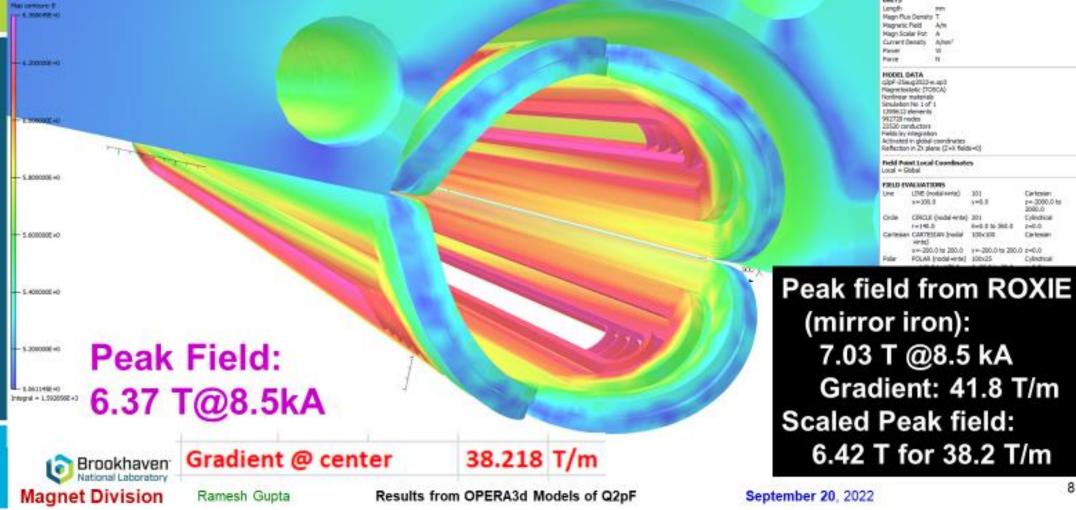
design ~8.5 kA)

National Lab

Magnet Division

B(T) 0.18





Field Quality Tuning After Construction

Optimization of Coil Geometry – ROXIE Input

										Edit	Cable D	ata [/home/g	upta/EIC/Q	2p#/2022/rox	ie-eic.cadata]
Input to coil geometry							File Display								
					STATISTICS STATISTICS			No Nene	Redial	Reimut, C					Cable
Xroxie [/home/gupta/EIC/Q2pF/2022/elc-Q2pF-600-7_7kA-NO-tie1							A-NO-tieti	1 3965	0	0.12 POLYIMID MB INNER				Cable	
							2 ALLPOLYTL 3 ALLPOLYOL	0.15			MB OUTER	- 110	100	Includent and the second second	
Eile Edit Display Run								4 ALLPOLNOV	0,08		And in case of the local division of the loc	MOY_MON			barameters
Connert : ID: USpF ISee cable, 2K - orm600 wa, NO tie rodz 7,5kA, hole#366,8ws							5 ALLPOLMO	0.13		POLYIMID			5	and annotion o	
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E SD Opt.)	lone							No Nane	dian.	cu/sc	RER	Iref	Bref	Jc88-Tr	dJc/dB Consent
Block I	Date 2D							1 STREDC1	1.065	1,6		1,91	10	1591	500,34 EDC BRUKER-DERN SCRLED.7XDB
- 10.000 M		61				Constant Path for some		2 (STR01	1.065	1.6	70	1.9	10	1433.3	500,34 MB DWER
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2 Co		3	140	31,179	25,196	-7717 E ICLHCH2K •		5 GSI1STRA	0,648	2,21	187	4,2]	5,5	2495,24	583,898 (CSI001 (RHIC) STRANDS
3 Co	e : : : :	19	155,5	0.8	0	-7717 E IOLHCIEK -									
		11 111	and the second	1.00		and a second second a second s	and see in	TE Transient							

* This work was supported by DOE Grant No. DE-SC0021578 and by Brookhaven Science Associates, LLC under contract No. DE-SC0012704, with the U.S. Department of Energy.

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		and the state of		(h - H- 1-	100 M	I Quench Material F	Properties						
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	U Bro	onal Laboratory											
	Magnet D		Ramesh Gupta		Initial Invest	tigation of Q2pF	Ends with F	avorable Tilt	Angles		May 30, 2023	14	
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in quad	Slot	for tu	ning s	hime	start	ting at	270				4	1×7	
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eids	Slot With Slot	NORMAL b 12 b 14 b 1 b 4 b 7 b 10 b 13 b 10 b 13 b 10 b 13 b 10 b 13 b 10 b 13 b 10 b 12 b 10 b 12 b 14 b 12 b 14 b 12 b 14 b 12 b 14 b 12 b 16 c 11 b 12 b 16 c 12 b 12 b 12 c	-0.4135 -0.0000 0.0000 -0.008 0.020 0.020 0.020 -0.3120 -0.000 0.000	4 b11: 0 b14: 0 b17: MULTIPO 11 b 2: 12 b 8: 03 b11: 00 b14: 01 b17: n b6 8: 01 b17: 01 b17: 03 b11: 04 b14: 05 b17: 05 b17: 05 b17: 05 b17: 05 b17: 05 b17: 05 b17: 05 b17: 0 b11: 0 b14: 0 b	0.0 -0.4 0.0 -0.4 0.0 -0.4 0.0 -0.0 -0.0	0025 b 9 0000 b12 3059 b19 0000 b18 00000 b18 000193 b 000429 b 000429 b 000429 b 000429 b 00000 b18 00000 b18 0000000 b18 000000 b18 0000000 b18 0000000 b18 0000000 b18 00000000 b18 0000000 b18 000000000000000000000000000000000000	3: 92: 12: 15: 18: its, n	-0.00004 -0.00001 0.00000 0.00491 -0.022(0.051(-0.000) 0.0000 0.0000	08 01 10 07 00 39 nore			Tuning Shims	250
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