Q_ext Puzzles

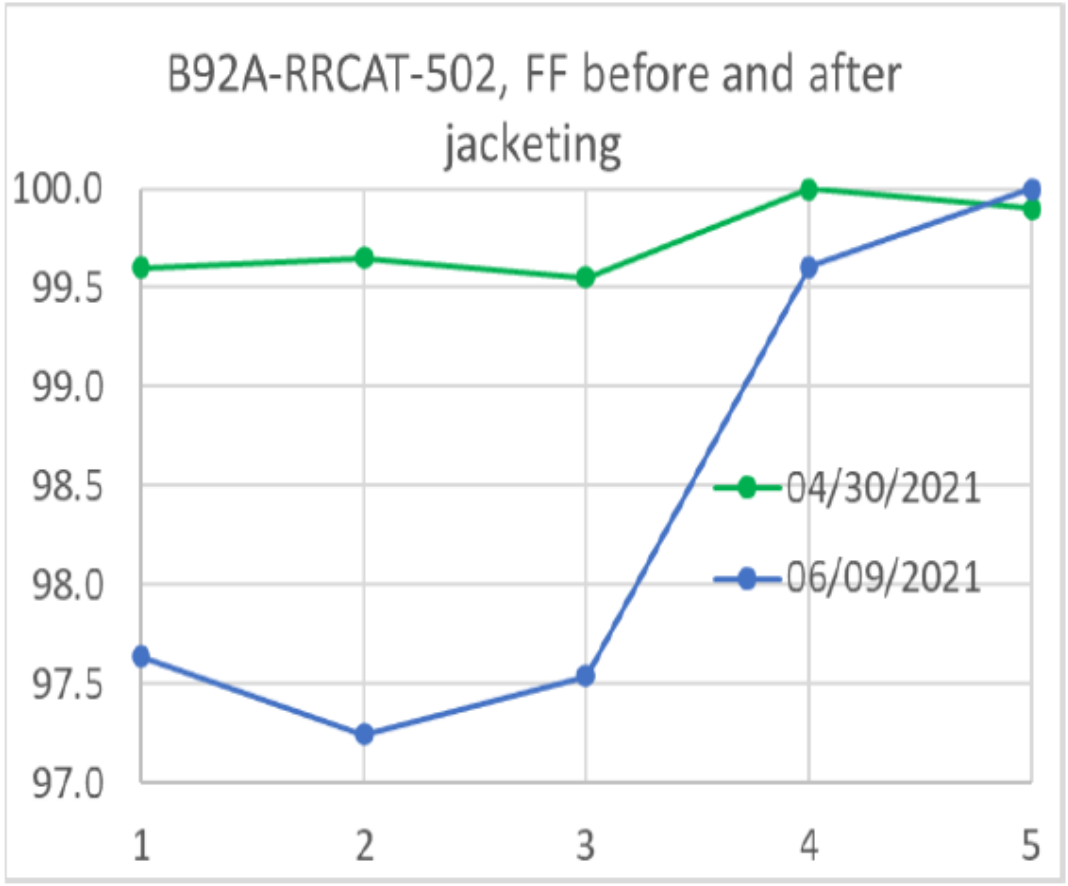
Based on material from S. Kazakov, G. Romanov, T. Khabiboulline, J. Helsper, V. Bocean

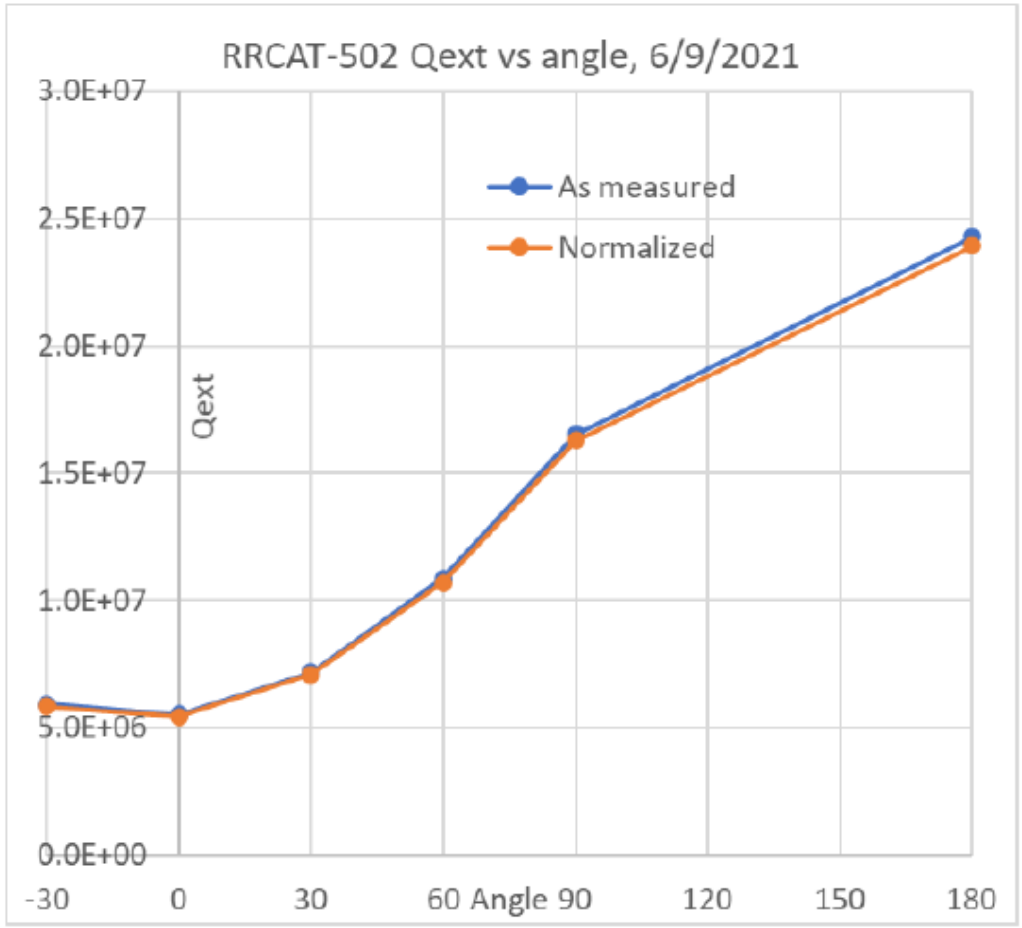
Chapter One: up to B92D-RRCAT-502 STC test

Summary

- **Spec is Qext = 9.9e6 (x1.2/÷1.2) (8.25 e6 < Qext < 1.19 e7)**
- 'Old' coupler prototype is used on B92D-RRCAT-502 for STC
- Qext ≈ 1e7 is believed to be reached at about 50° angle, from early RF measurements with dummy coupler on B92D-RRCAT-502, B92D-RRCAT-504 and B92E-RRCAT-506.
- STC measurement gives Qext = 6.8e6
- At disassembly, the angle is found to be 60°, which makes the disagreement even worse.

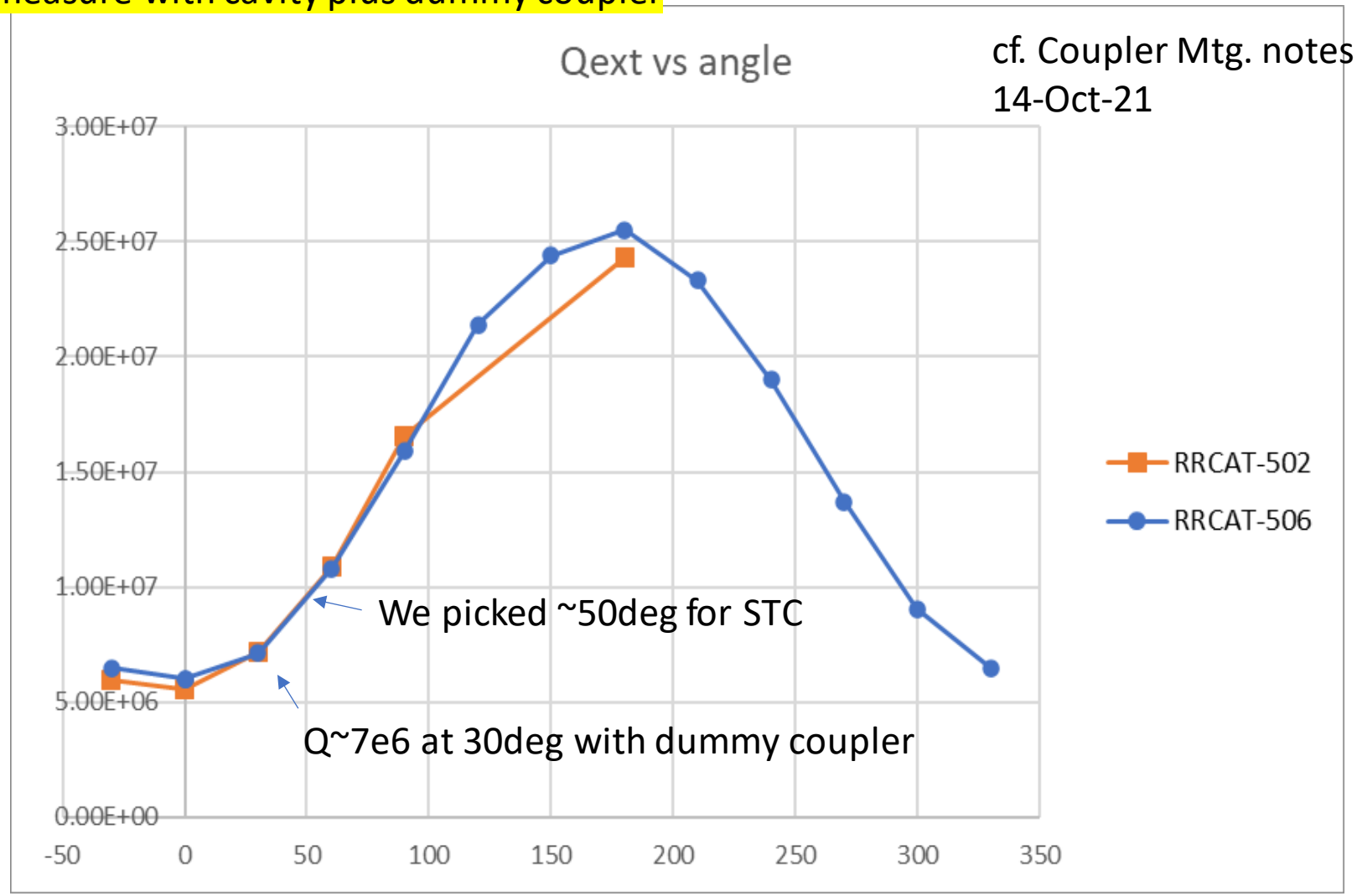
RF Measurement by Timergali on B92D-RRCAT-502 after jacketing





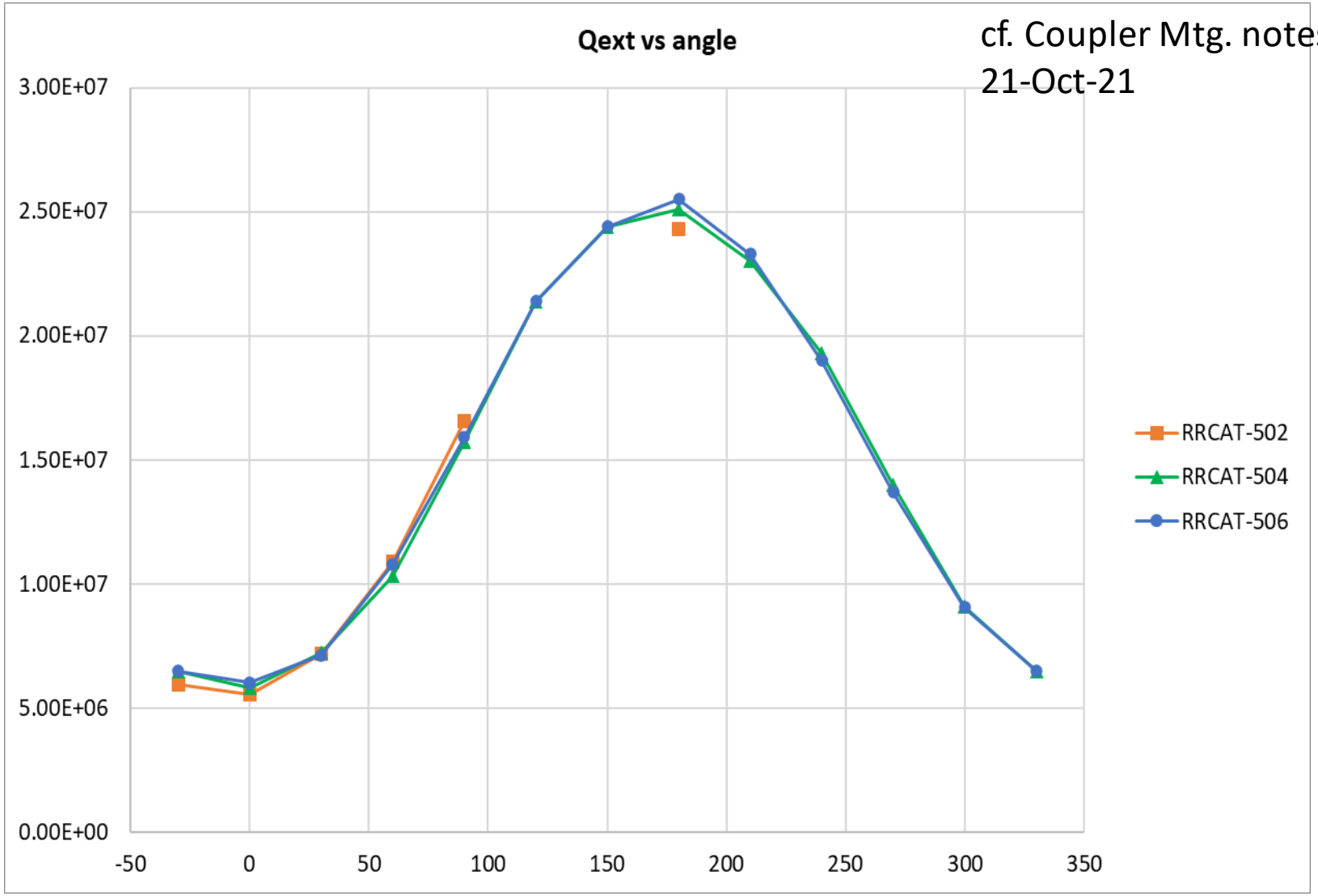
RF Measurement by Timergali on B92D-RRCAT-506 after jacketing (11-Oct-22)

Coupling measure with cavity plus dummy coupler



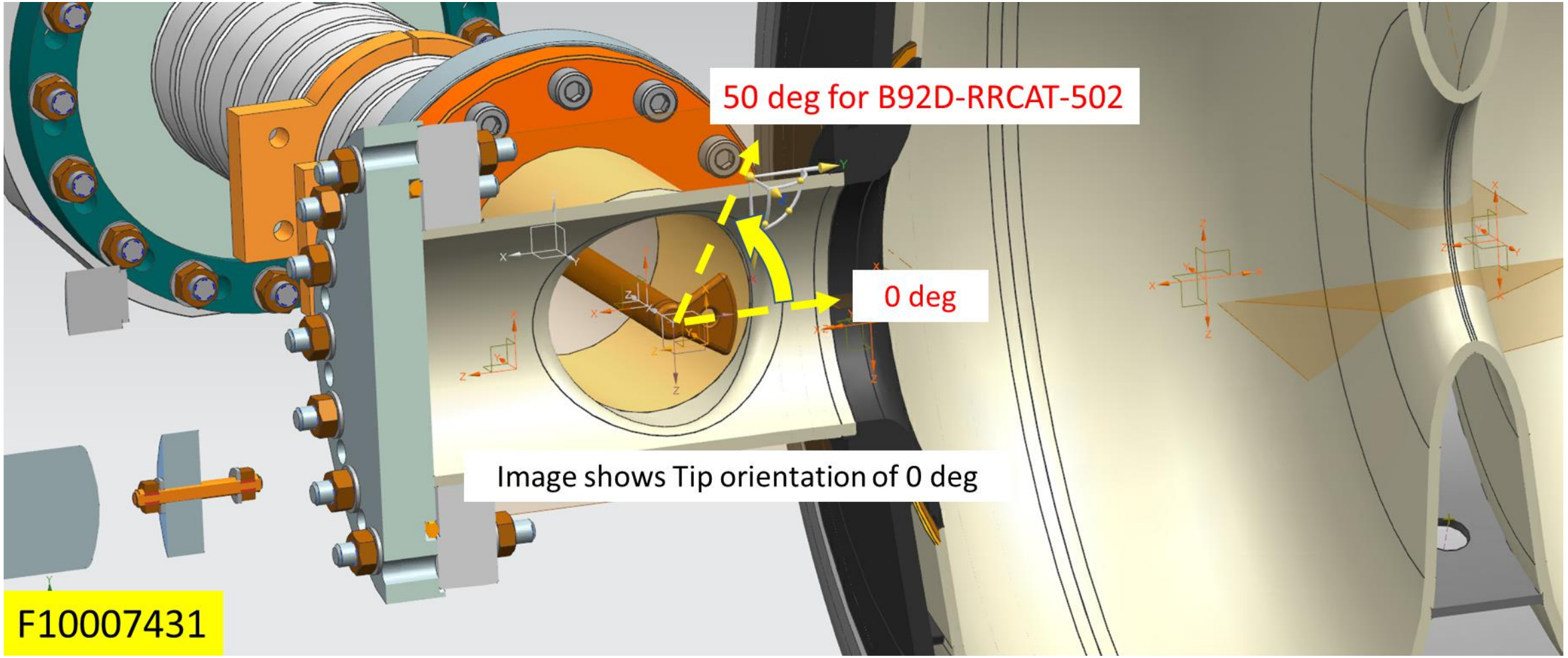
Measured coupling in STC (~6.7e6) suggests the angle would be below 30deg .

RF Measurement by Timergali on B92D-RRCAT-504 before jacketing



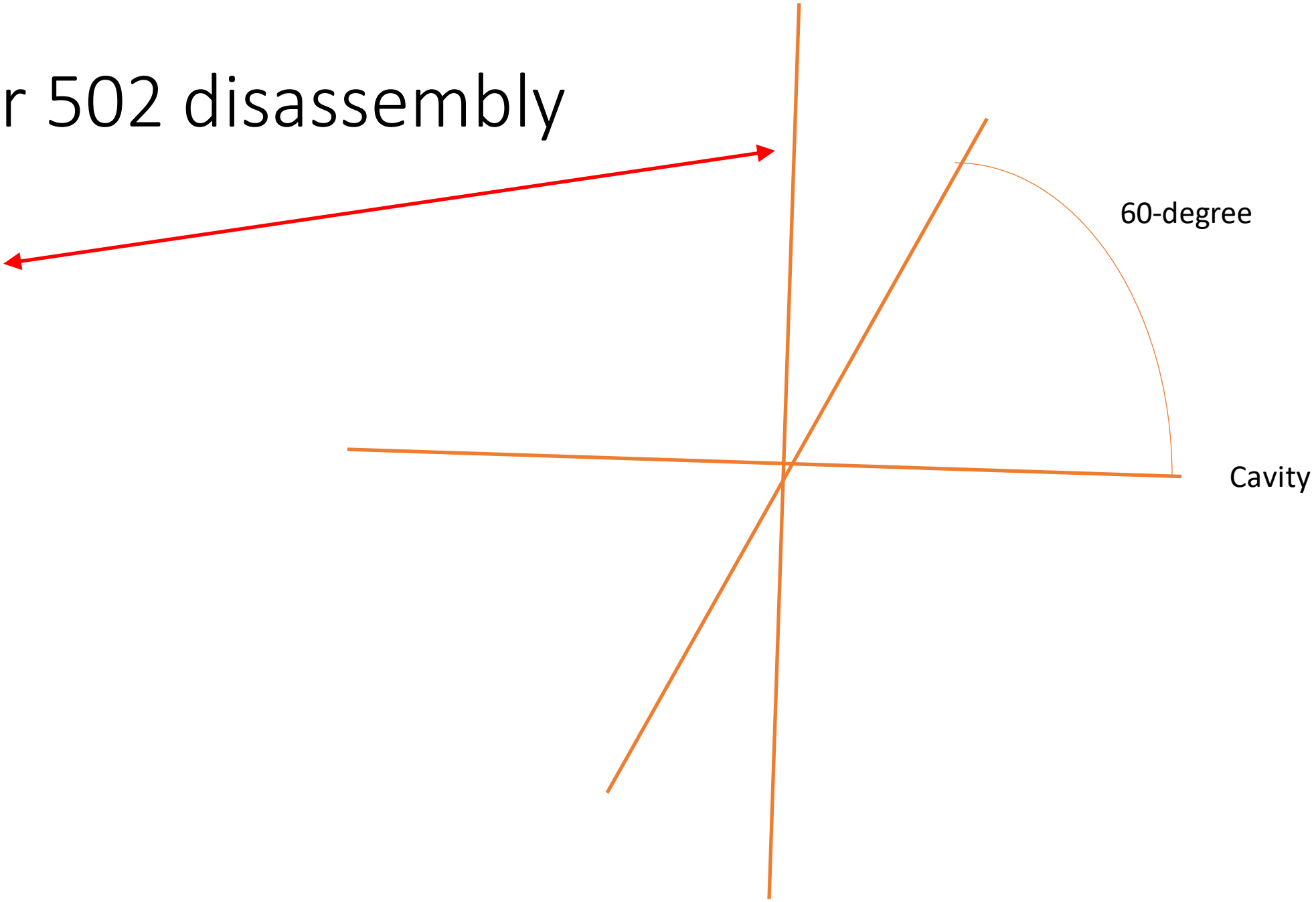
cf. Coupler Mtg. notes 21-Oct-21

Support image of orientation



Images can suggest the tip angle would be more than 50deg.

Photos after 502 disassembly

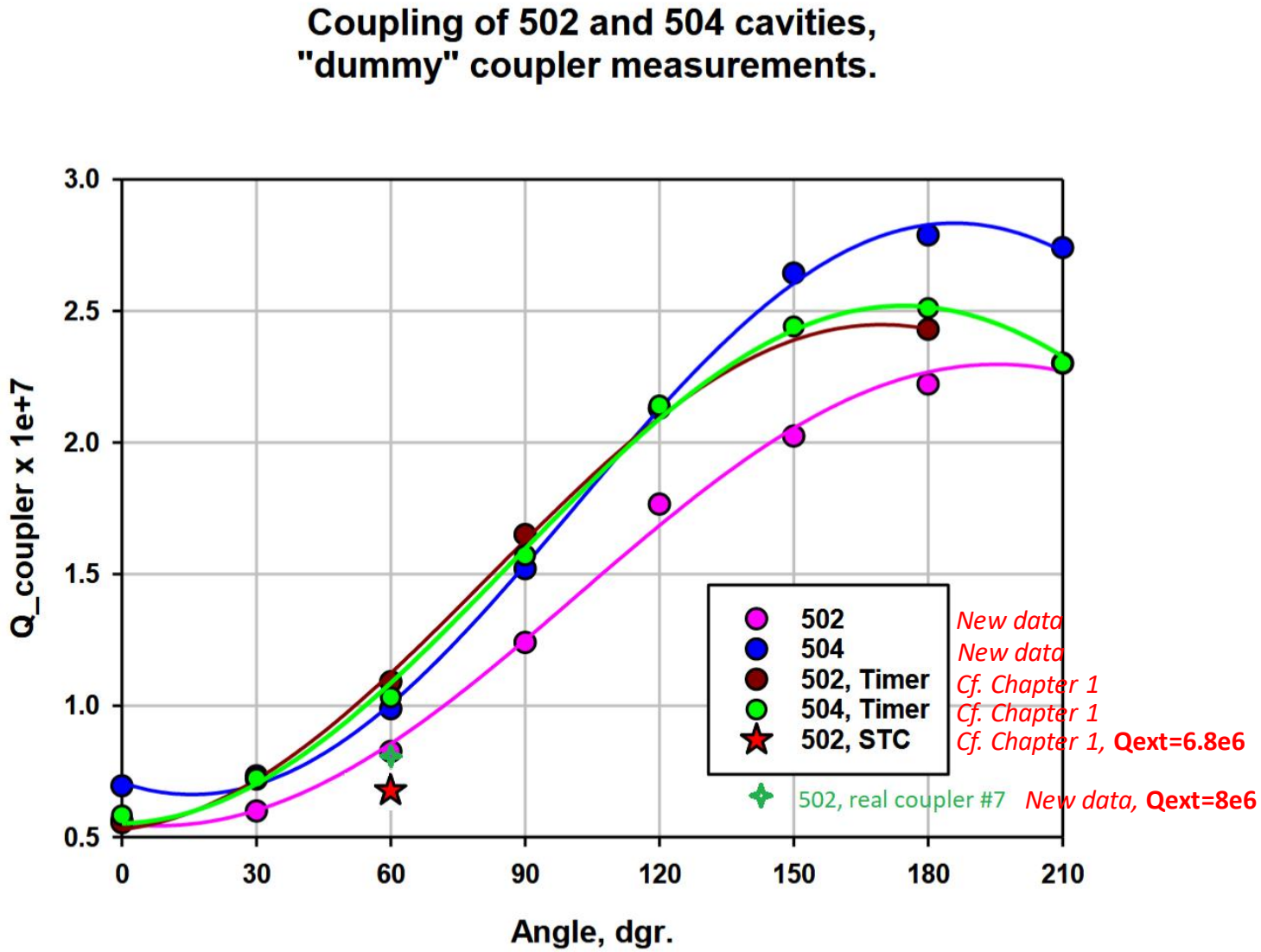


Chapter Two: new measurements at MP9 and RF Lab

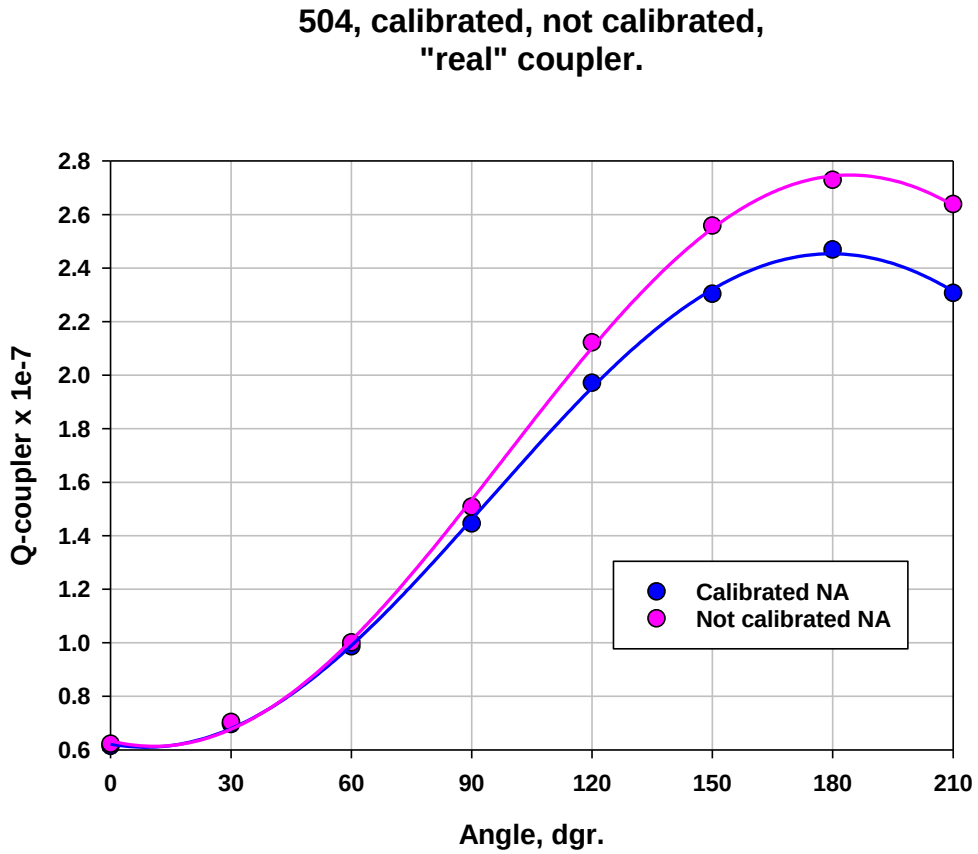
Summary

- Spec is Qext = **9.9e6 (x1.2/÷1.2)** (8.25 e6 < Qext < 1.19 e7)
- For string assembly, the outer conductor orientation is fixed for the electron pick-up, thermal intercepts etc. to be on pre-defined positions
- Antenna orientation is a multiple of $2\pi/16$ = 22.5°: 0°, 22.5°, 45°, 67.5°, 90°, 112.5°, 135°, 157.5°, 180°, corresponding to the angular period of the ceramics-antenna flange.
- On paper, Qext is symmetric w.r.t. 180°

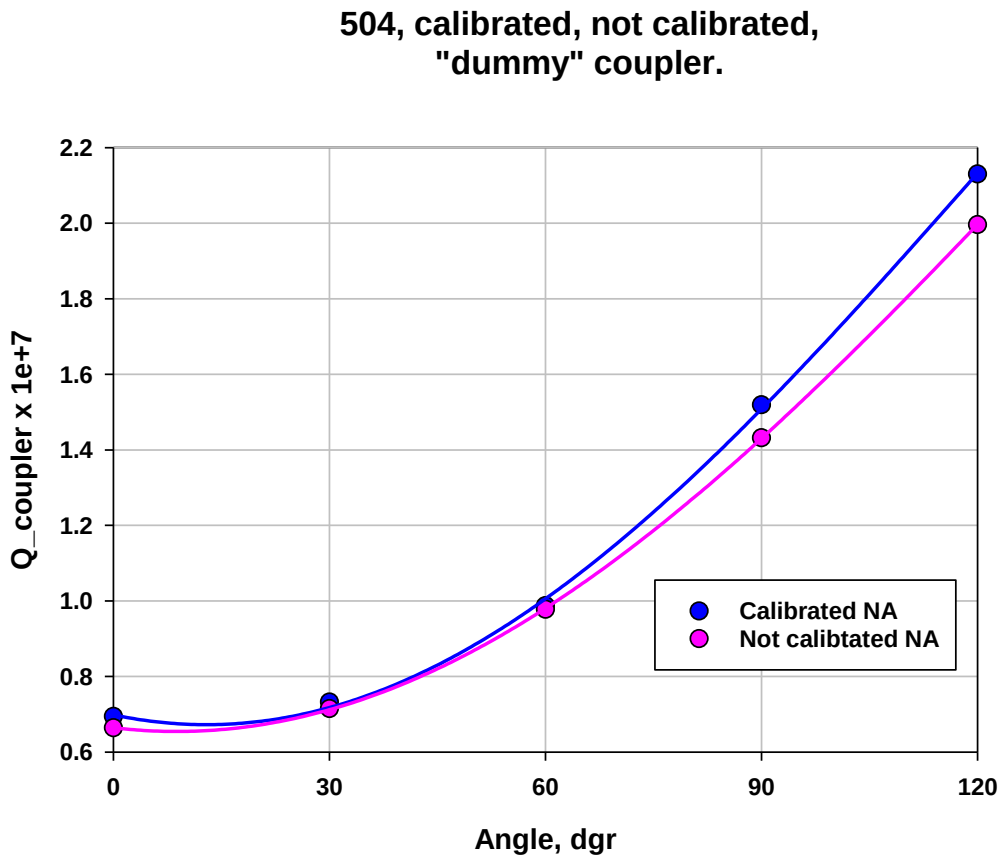
RF Measurements: 502 and 504 at MP9, xx-Jan-22



RF Measurements: 504 at MP9, 21-Jan-22

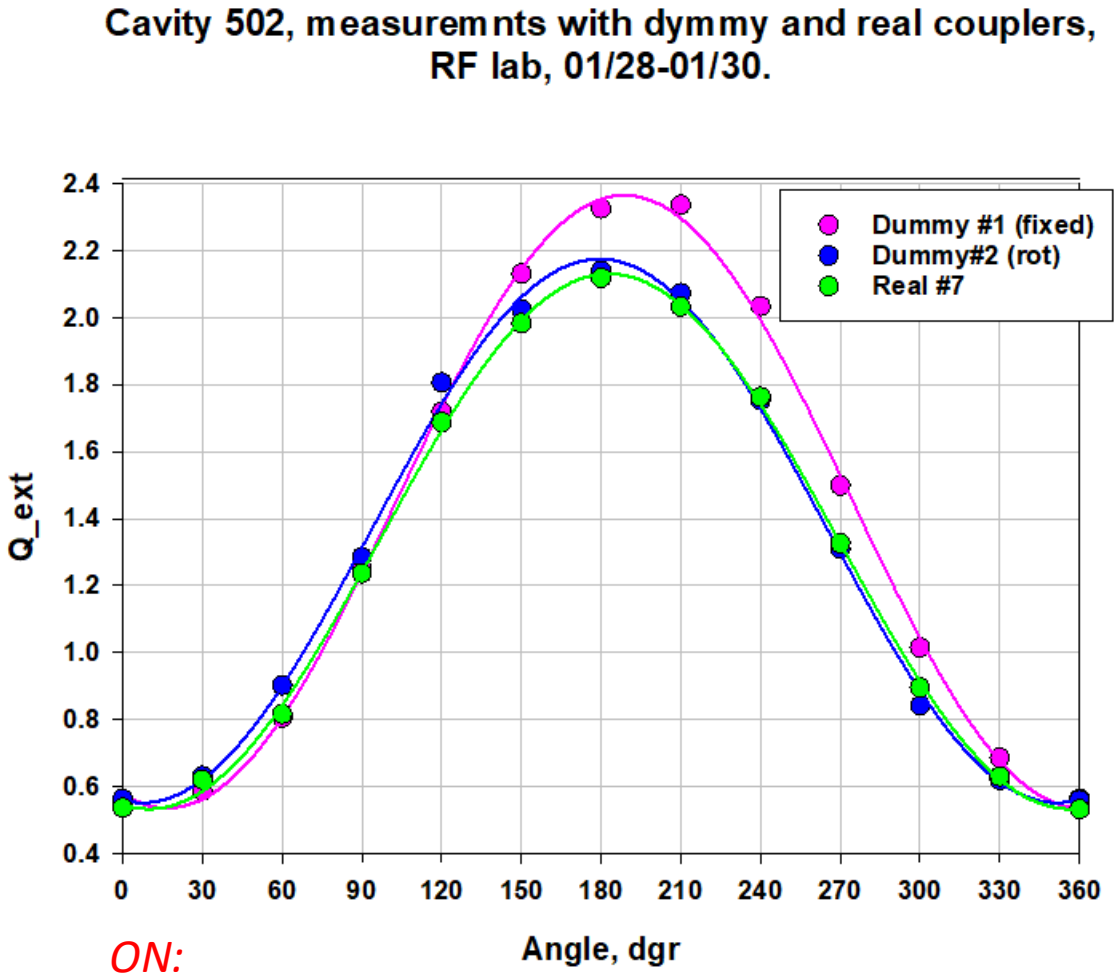


The pink curve is presumably the blue curve of the preceding page.



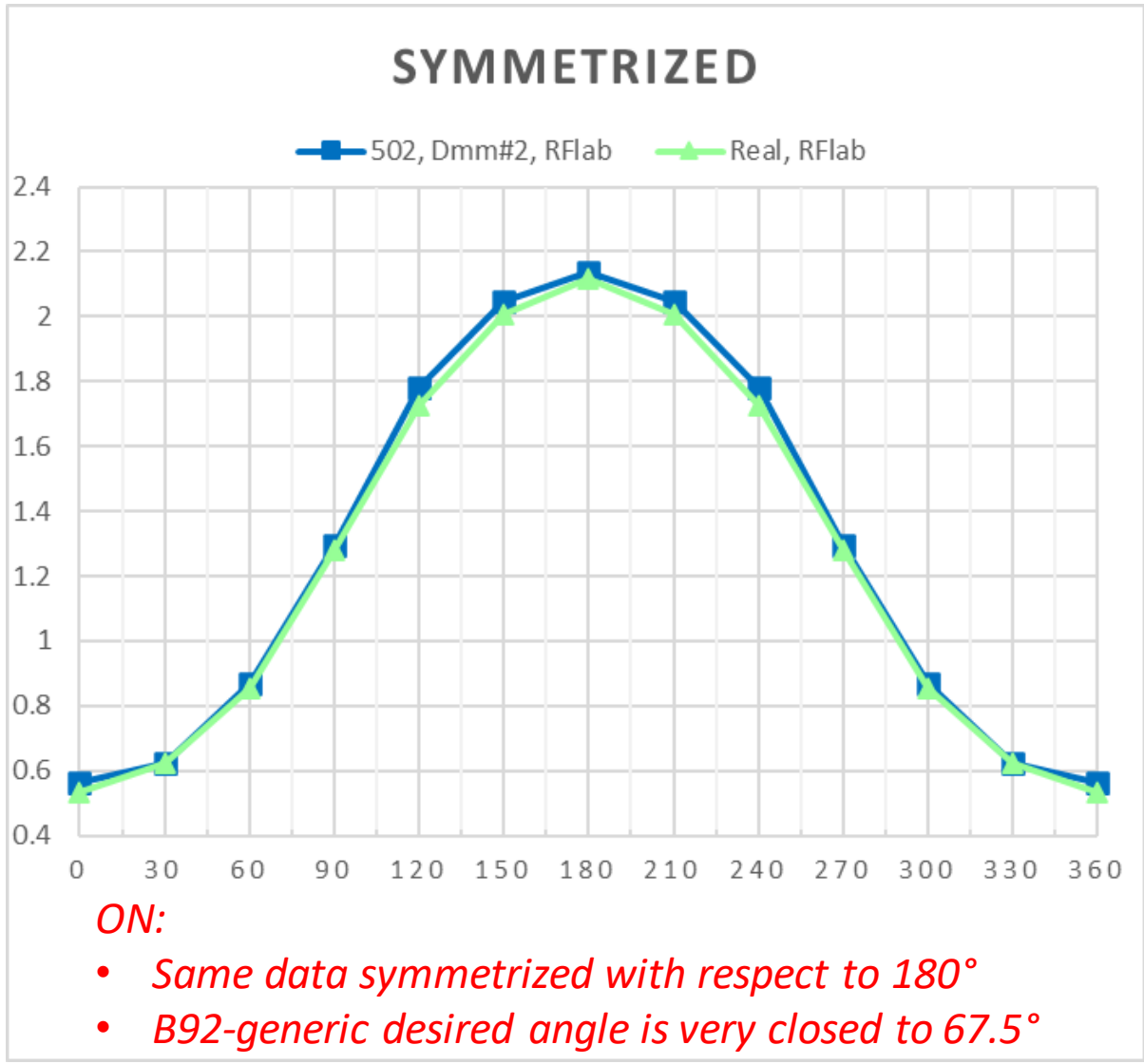
Same data, zoomed in [0°,120°]

RF Measurement: B92D-RRCAT-502 at ICB, 28/30-Jan-22



ON:

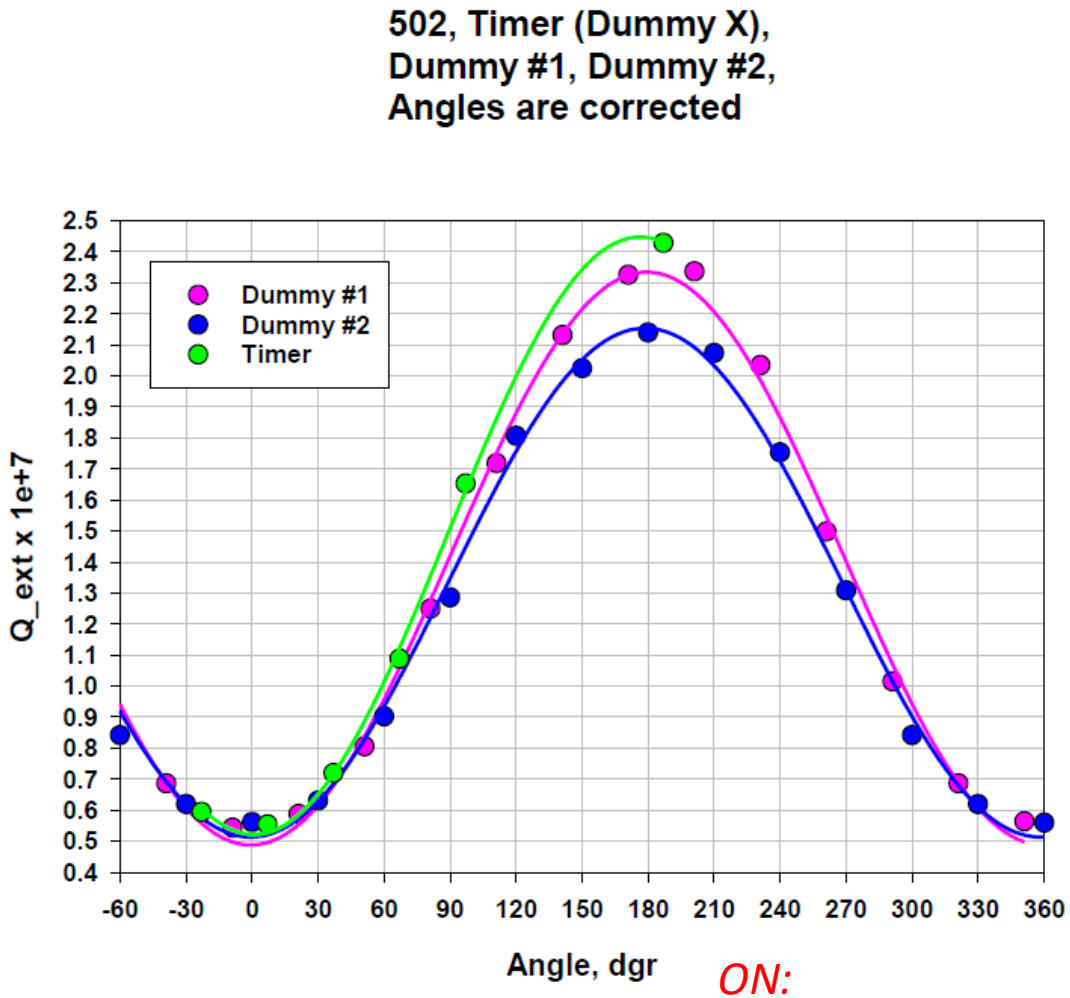
- ***Dummy coupler #2 (rot)*** *looks more reliable*
- ***Dummy coupler #1 (fixed)*** *curve is offset by 15°*

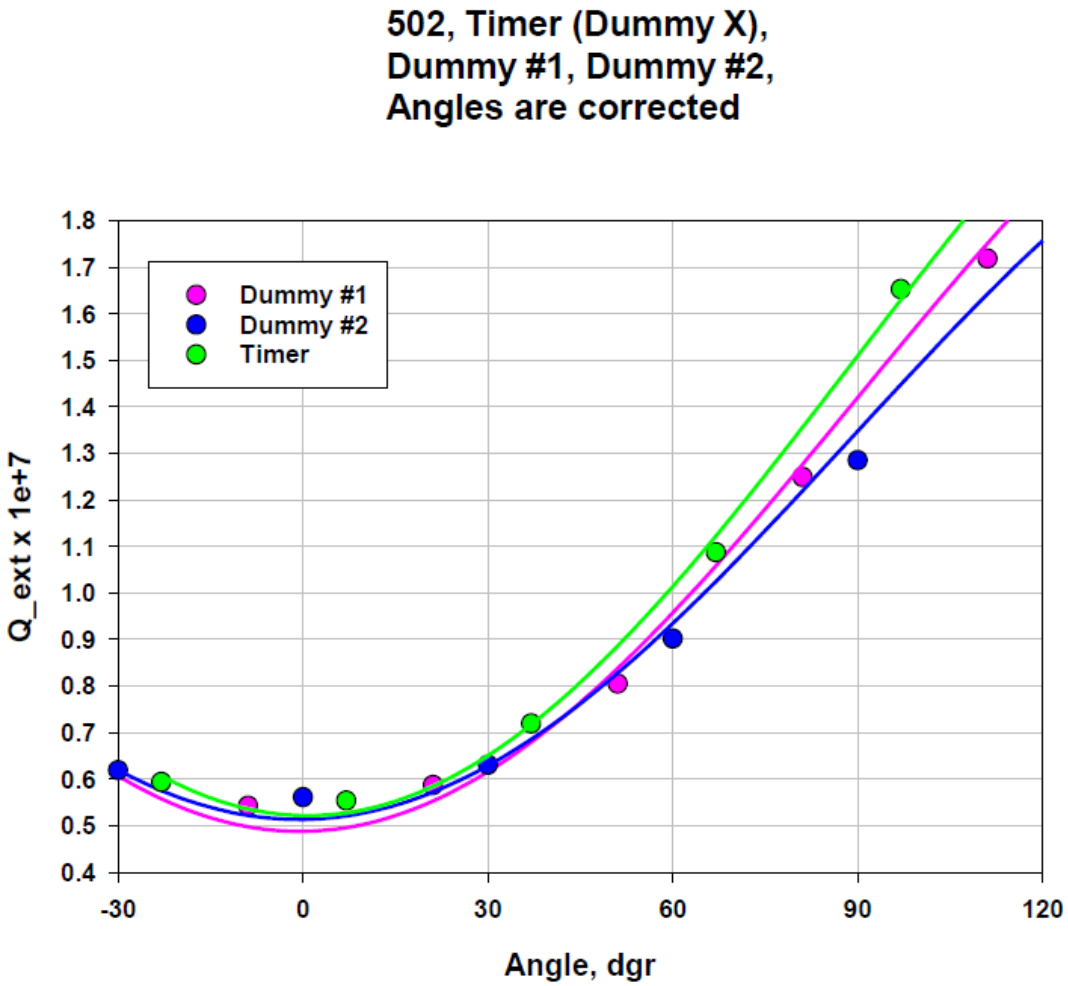


ON:

- *Same data symmetrized with respect to 180°*
- *B92-generic desired angle is very closed to 67.5°*

RF Measurement: B92D-RRCAT-502 at ICB, 28/30-Jan-22

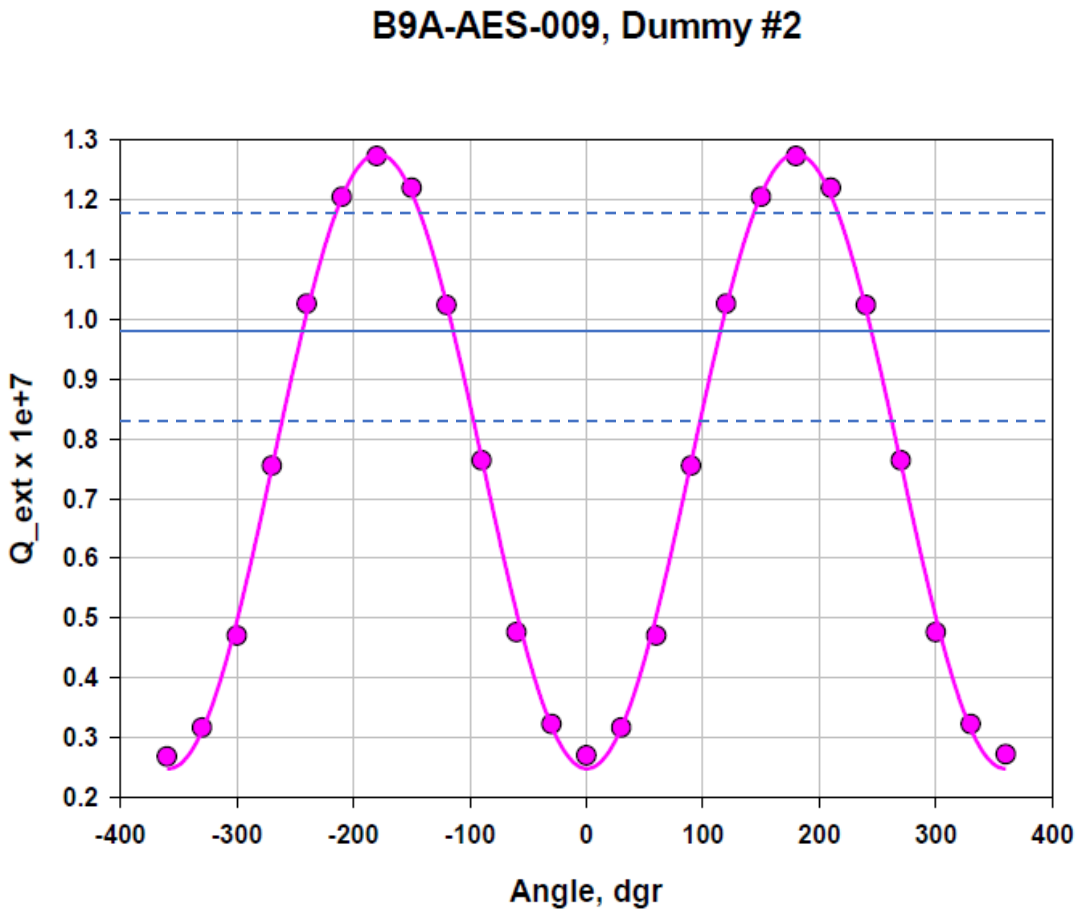


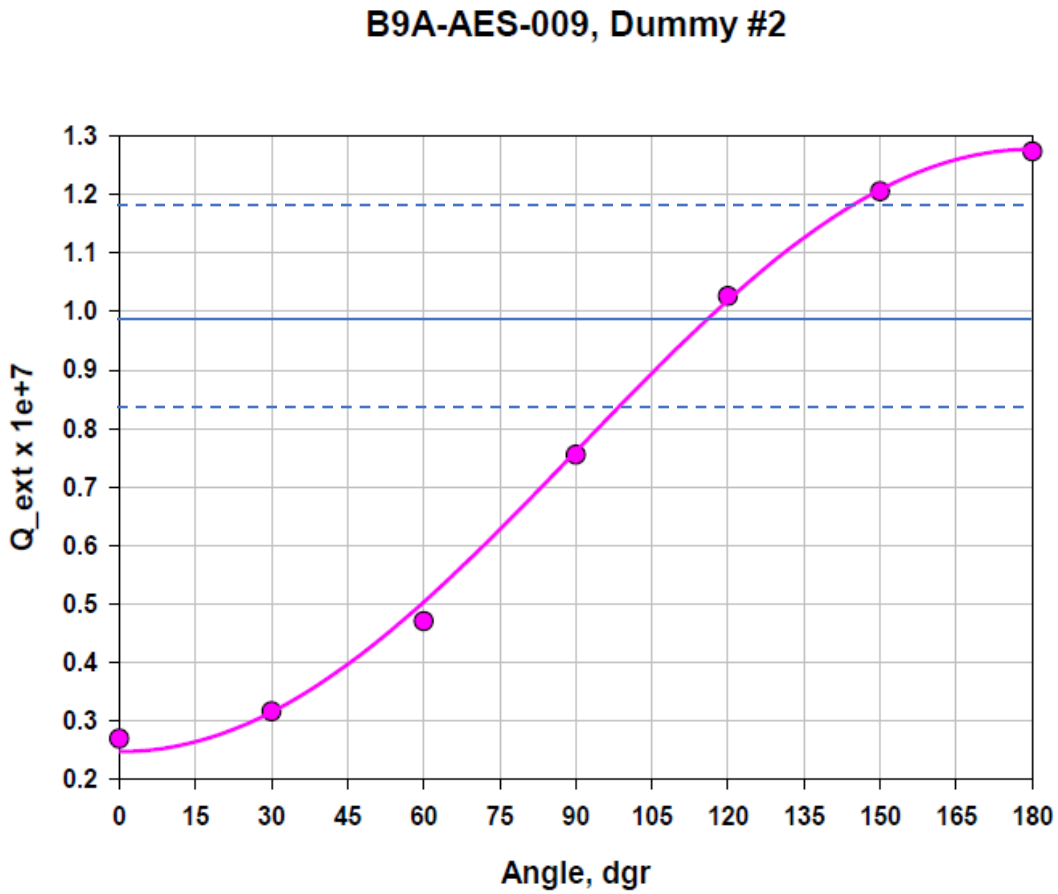


ON:

- ***Dummy coupler #1 (fixed)*** *curve is shifted by -15°*

RF Measurement: B9A-AES-009 at ICB, 1-Feb-22

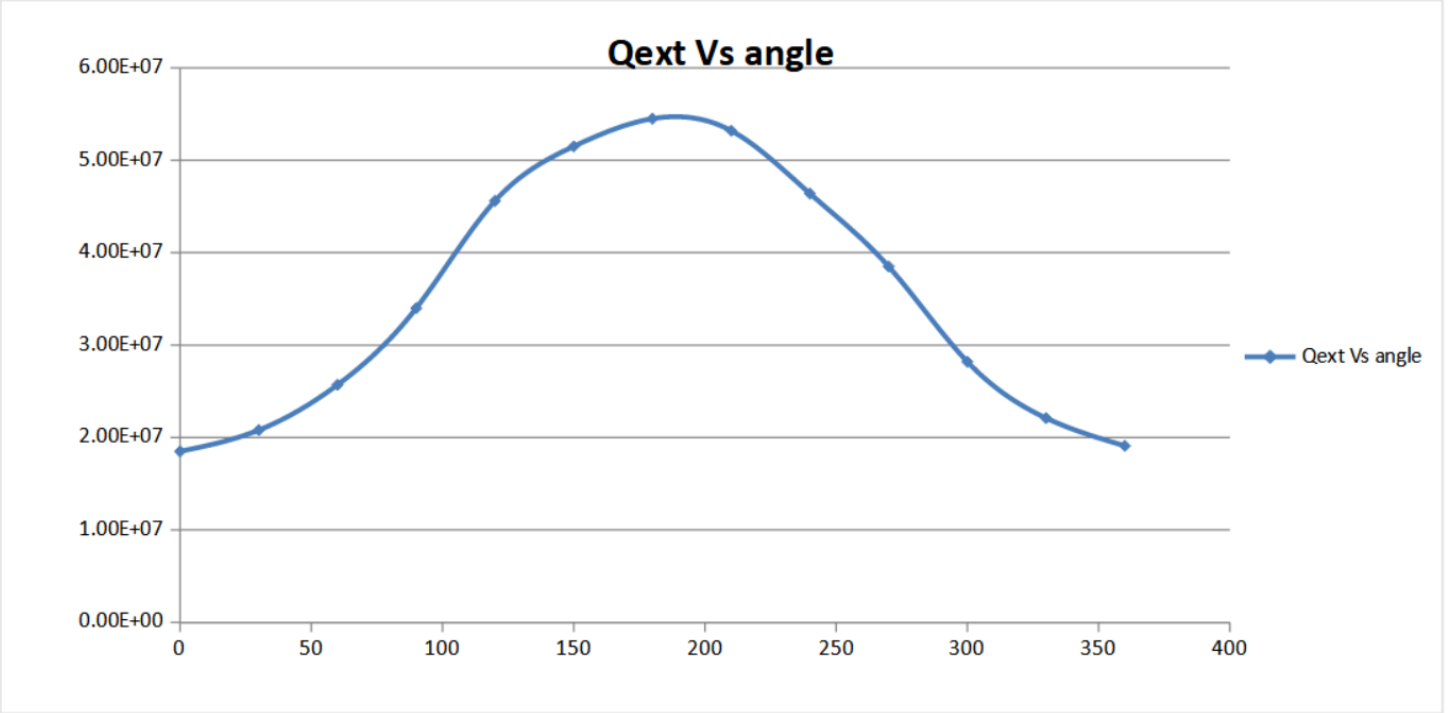




- *Desired angle is very closed to 112.5°*
- *Acceptable angles: 112.5°, 135°, 225°, 247.5°*

Measurement made at RRCAT on 5-cell 650MHz cavity

Quality factor of High power coupler(Cold part) Vs angle



Minimum value of Qext measured by FNAL was ~6E+6.
But we measured minimum value ~2E+7.

This might be due to adopter(Impedance mismatch).
Clarification on this is required from Expert (FNAL).

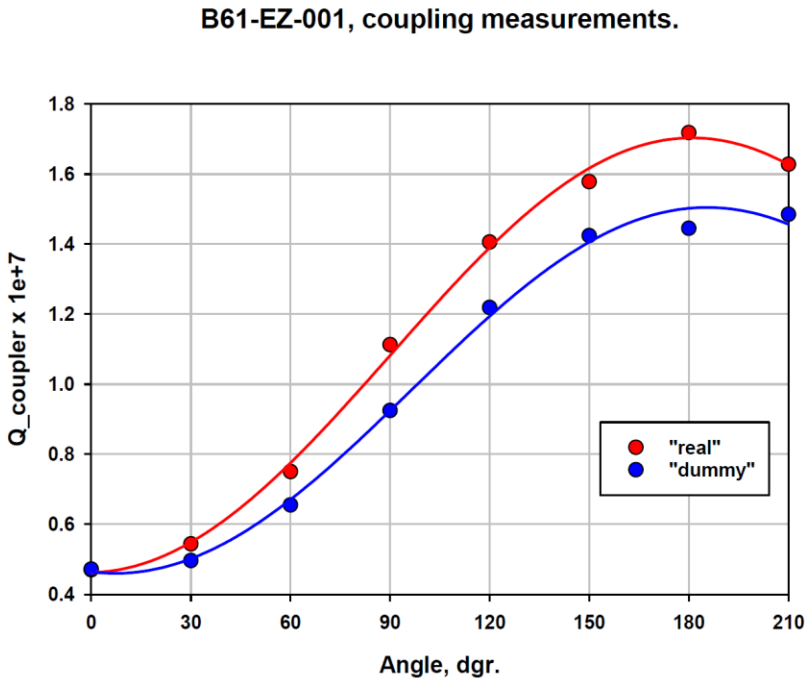
4 February 2022

Chapter Three: B61-EZ001 for LB650 STC test

Summary

- Spec is Qext = 1.04 e7 (x1.2/÷1.2) (0.87 e7 < Qext < 1.25 e7)

Antenna orientation B61-EZ-001 (27-Jan-2022)



Coupling measurements of B61-EZ-001,

S. Kazakov, G. Romanov, 01/27/2022

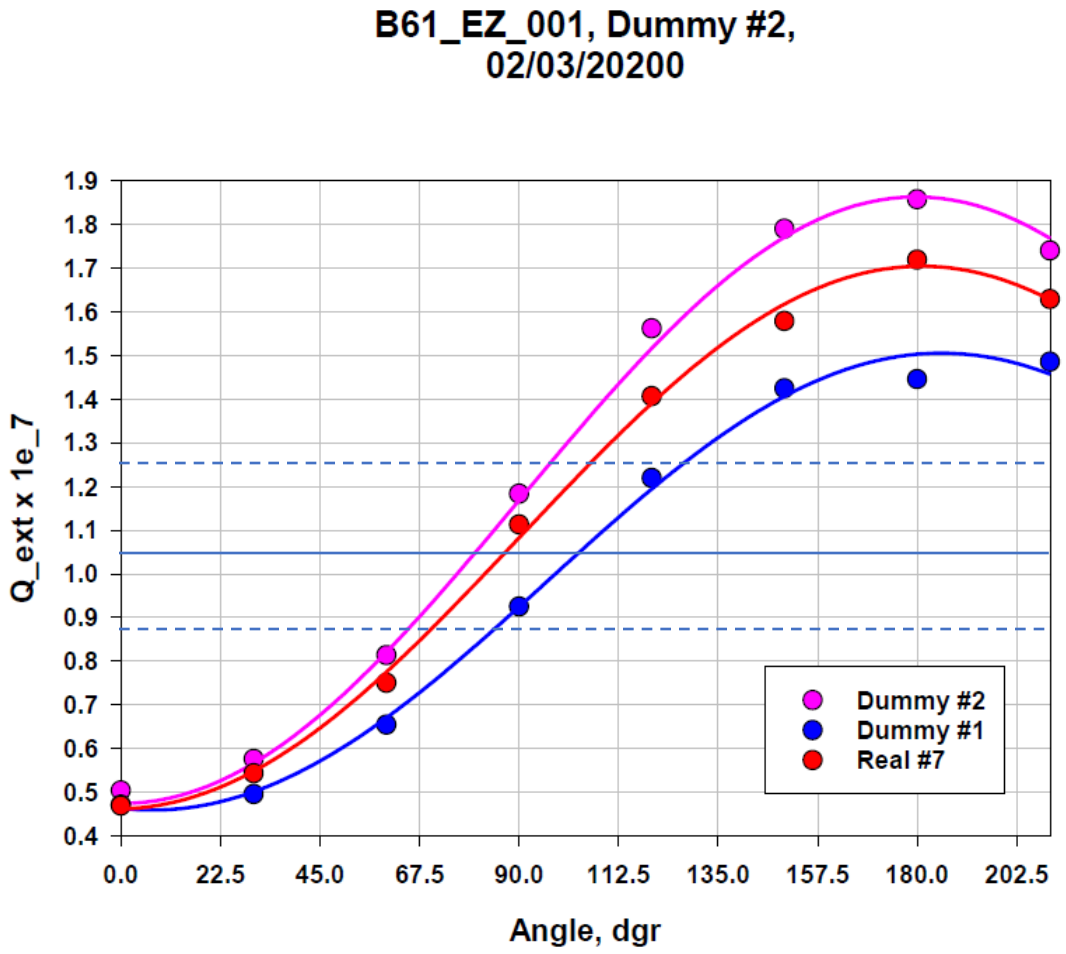
Comments: Difference between “real” and “dummy” can be explained by accuracy of measurements. “Quality” (shape) of signals is not too good, especially in case of dummy and big angle – difficult to establish “the base” of signal to estimate “the depth of signals”.

Recommendation: to buy good quality cables for this kind “low level, sensitive” measurements.

Antenna orientation B61-EZ-001 (4-Feb-2022)

B61_EZ_001, Q_external measurements.

S. Kazakov. G. Romanov, T. Khabiboulline
02/042022



- *Desired angle is about 90°*

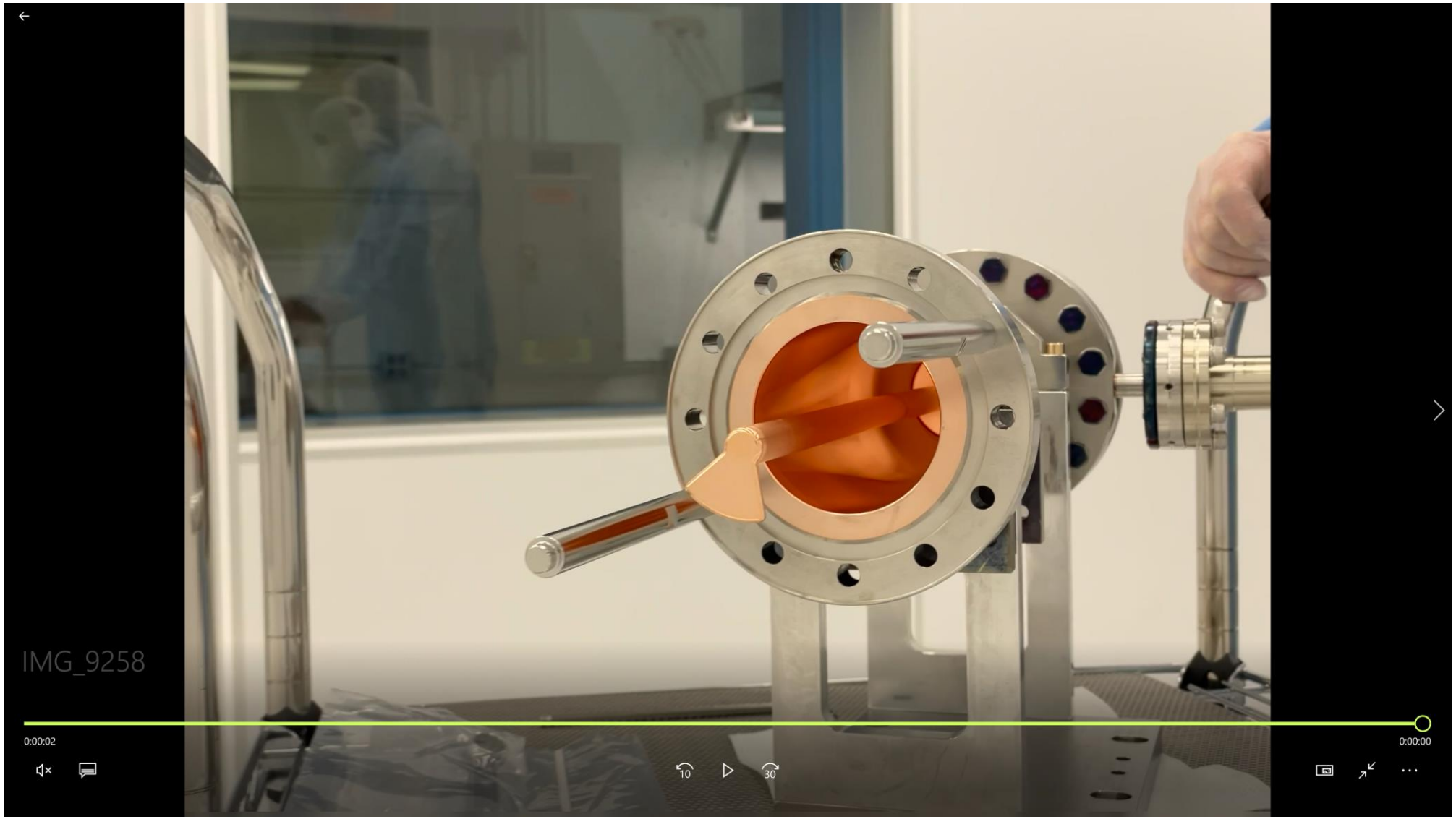
Dummy #2 acceptable angles:
67.5°, 90.0°, 270.0°, 292.5°

Real #7 acceptable angles:
90.0°, 270.0°

Coupler antenna orientations

Coupler #	1	2	3	4	5	6
Installed on	B92E-RRCAT-506	B9A-AES-007	B9A-AES-008	B9A-AES-009	B92E-RRCAT-504	B92E-RRCAT-502
Antenna angle	45°	112.5°	112.5°	112.5°	67.5°	67.5°
Qext on HB650 string (28-Apr-22)	9.0×10^6	7.1×10^6	7.1×10^6	1.4×10^7	1.0×10^7	1.0×10^7
Qext (3-May-22)	8.6×10^6	6.7×10^6	6.9×10^6	1.4×10^7	1.0×10^7	1.0×10^7
Qext/9.9×10^6	0.87	0.68	0.70	1.41	1.01	1.01
Coupler #	**7**	**8**	**9**	**10**	**11**	
Installed on	Spare of spare	B61-EZ001	Spare B92	Spare B90		
Antenna angle	?	90°	*67.5°*	*112.5°*		
Qext (21-Apr-22)		$10.6.x10^6$ @STC, vacuum part	*proposal*	*proposal*		
Qext (15-Jun-22)		$9.1.x10^6$ 2K@STC, vacuum part				
Qext/1.04×10^7		1.02/0.88				

AES009 coupler antenna at 112.5°

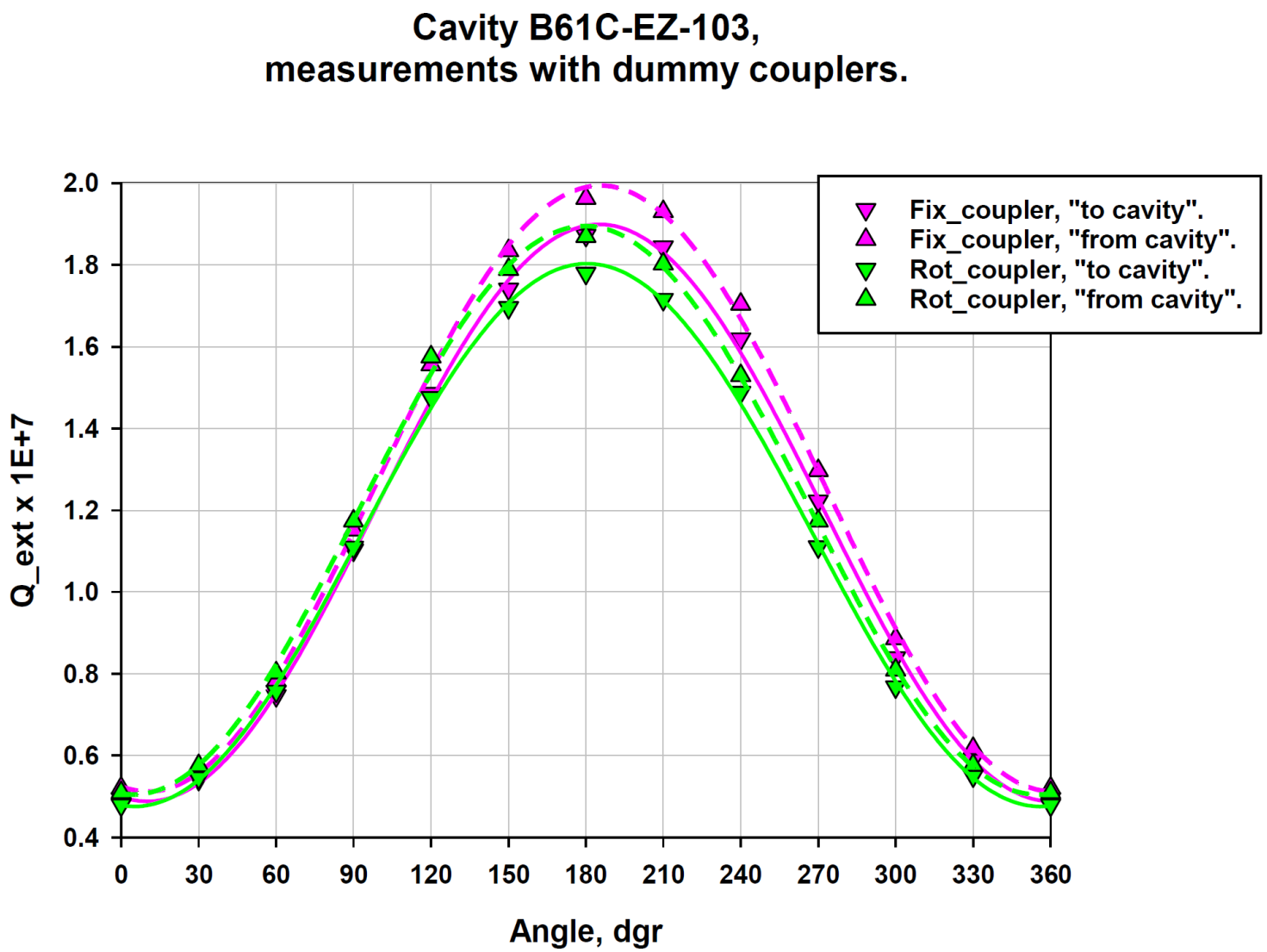


Chapter Four: June 2022 investigations

- B61C-EZ-103 (3-Jun-22)
- B61C-EZ-101 (7-Jun-22)

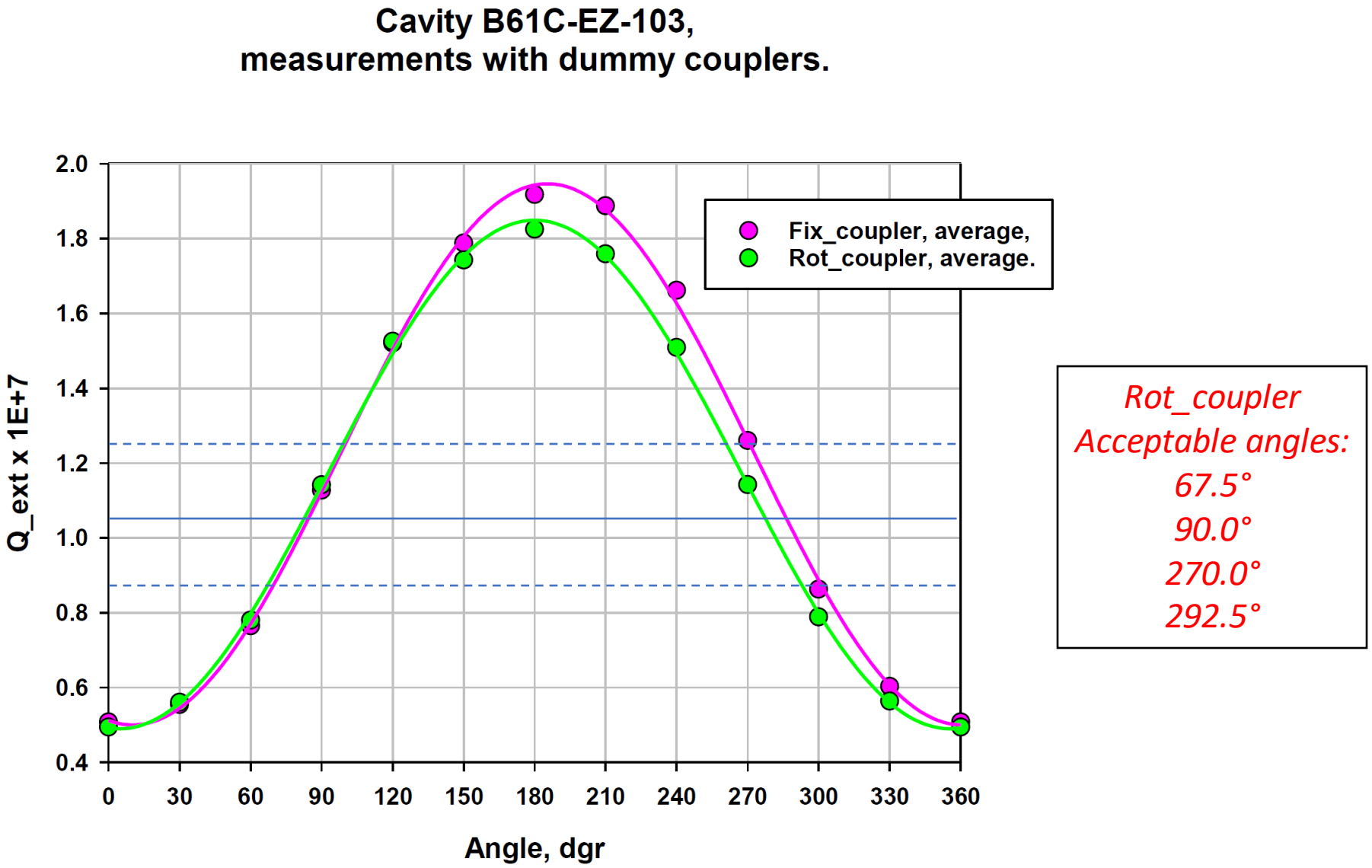
- B92-RI-202 (10-Jun-22)
- B92-RI-201 (22-Jun-22)

Dummy couplers on B61C-EZ-103 (SK, 3-Jun-22)



Dummy couplers on B61C-EZ-103 (SK, 3-Jun-22)

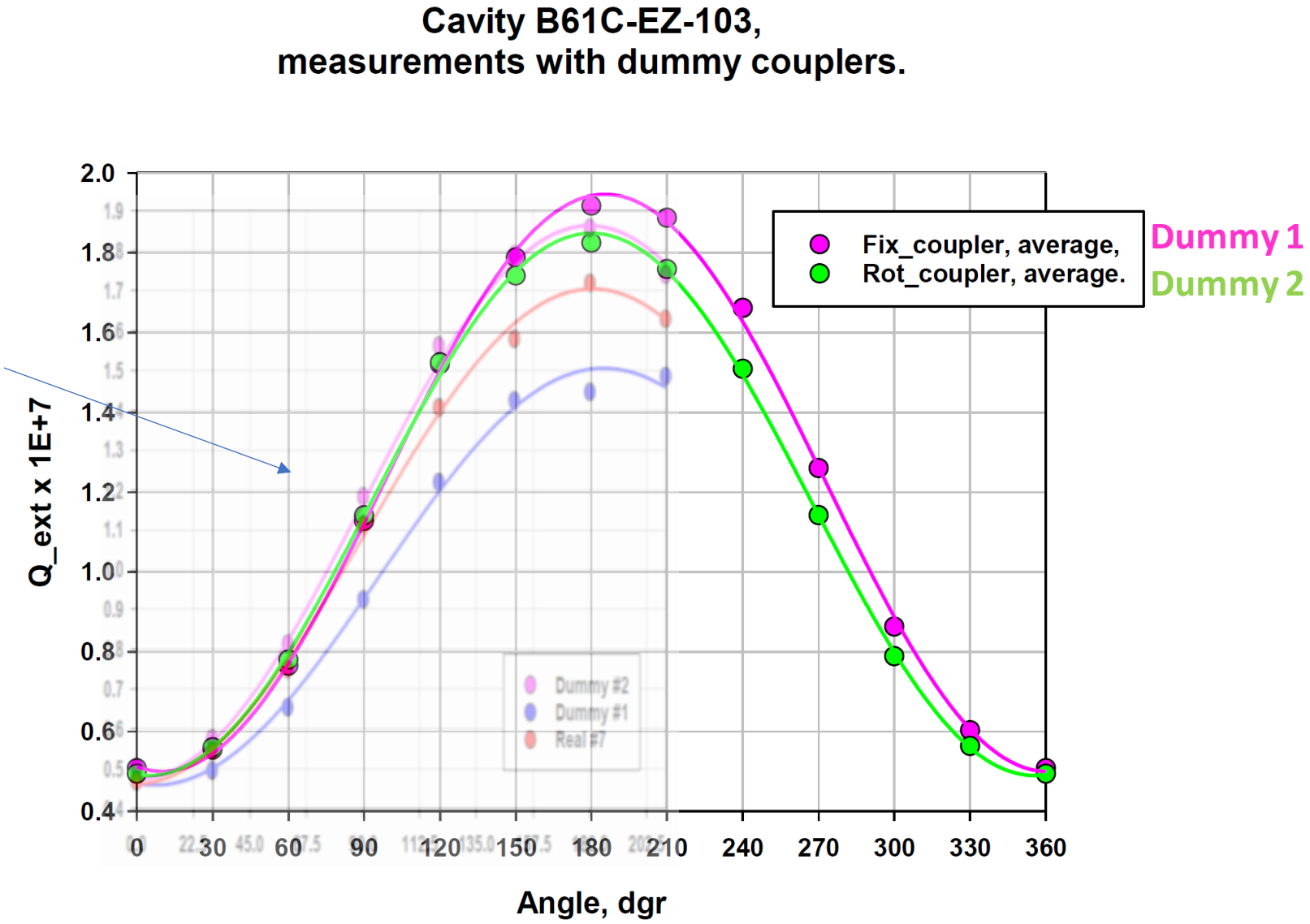
Spec is Qext = 1.04 e7 (x1.2/÷1.2) (0.87 e7 < Qext < 1.25 e7)



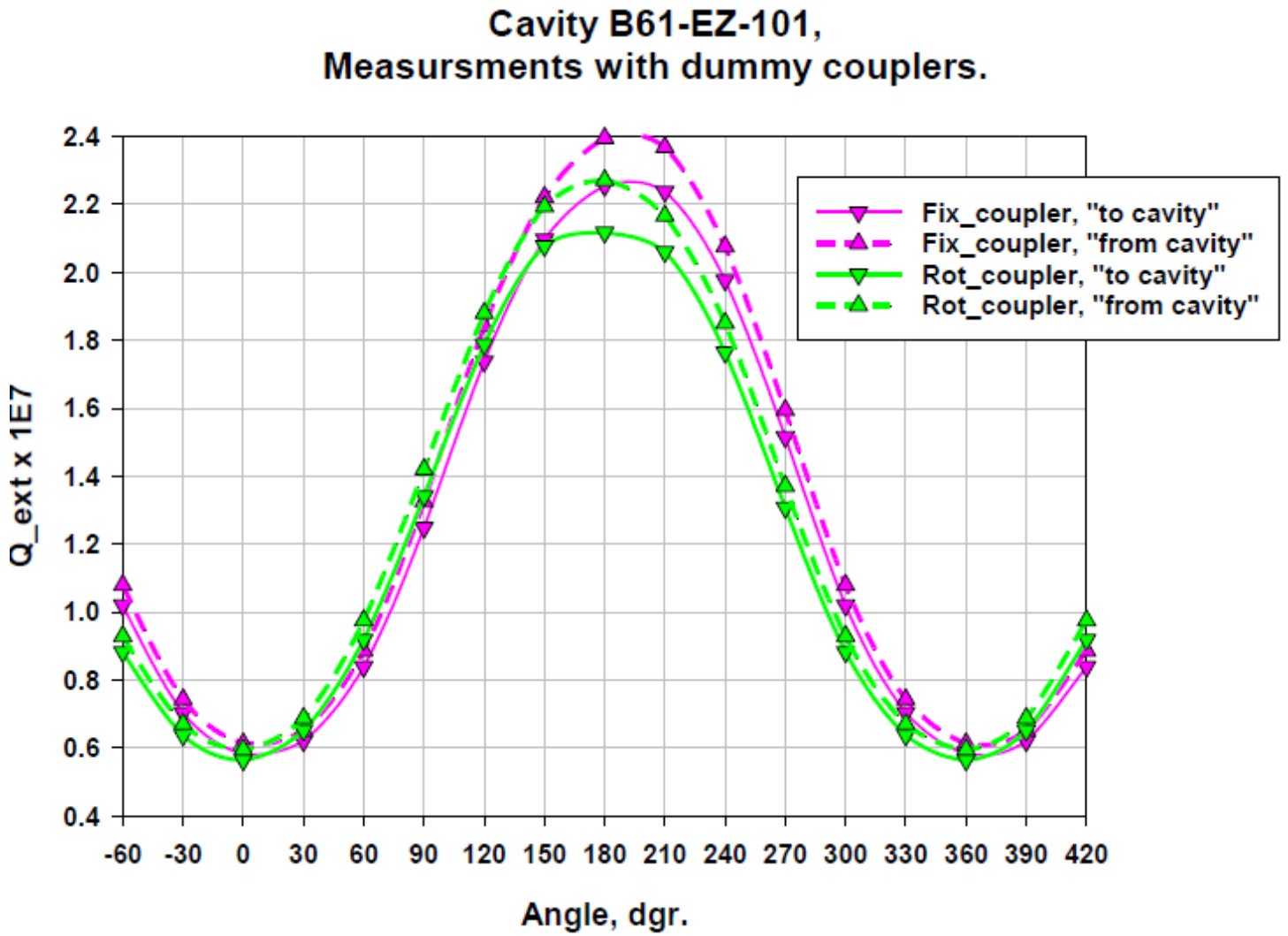
Rot_coupler
Acceptable angles:
67.5°
90.0°
270.0°
292.5°

Dummy couplers on B61C-EZ-103 (SK, 3-Jun-22)

Comparison with preceding EZ001 measurement

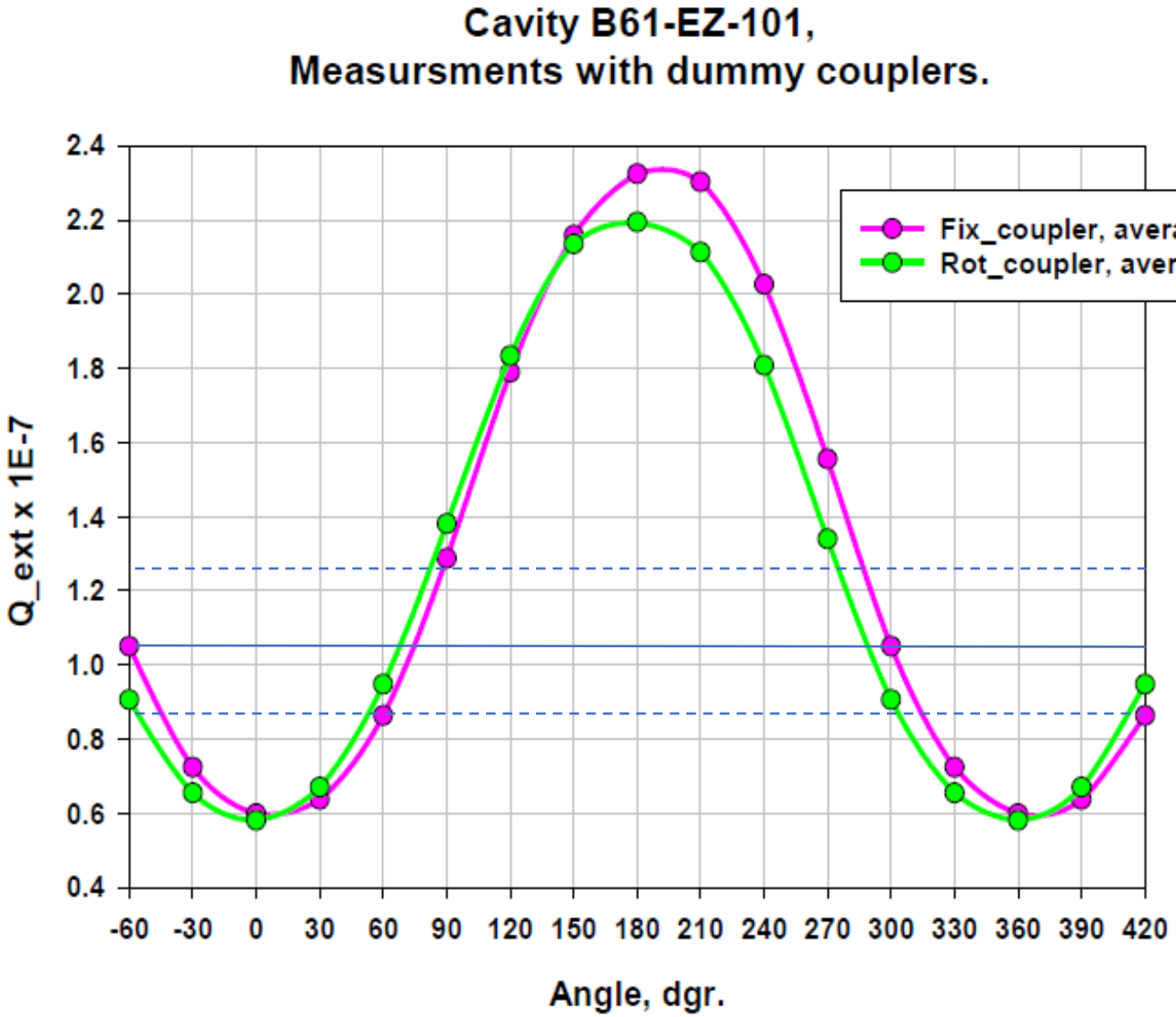


Dummy couplers on B61C-EZ-101 (SK, 7-Jun-22)



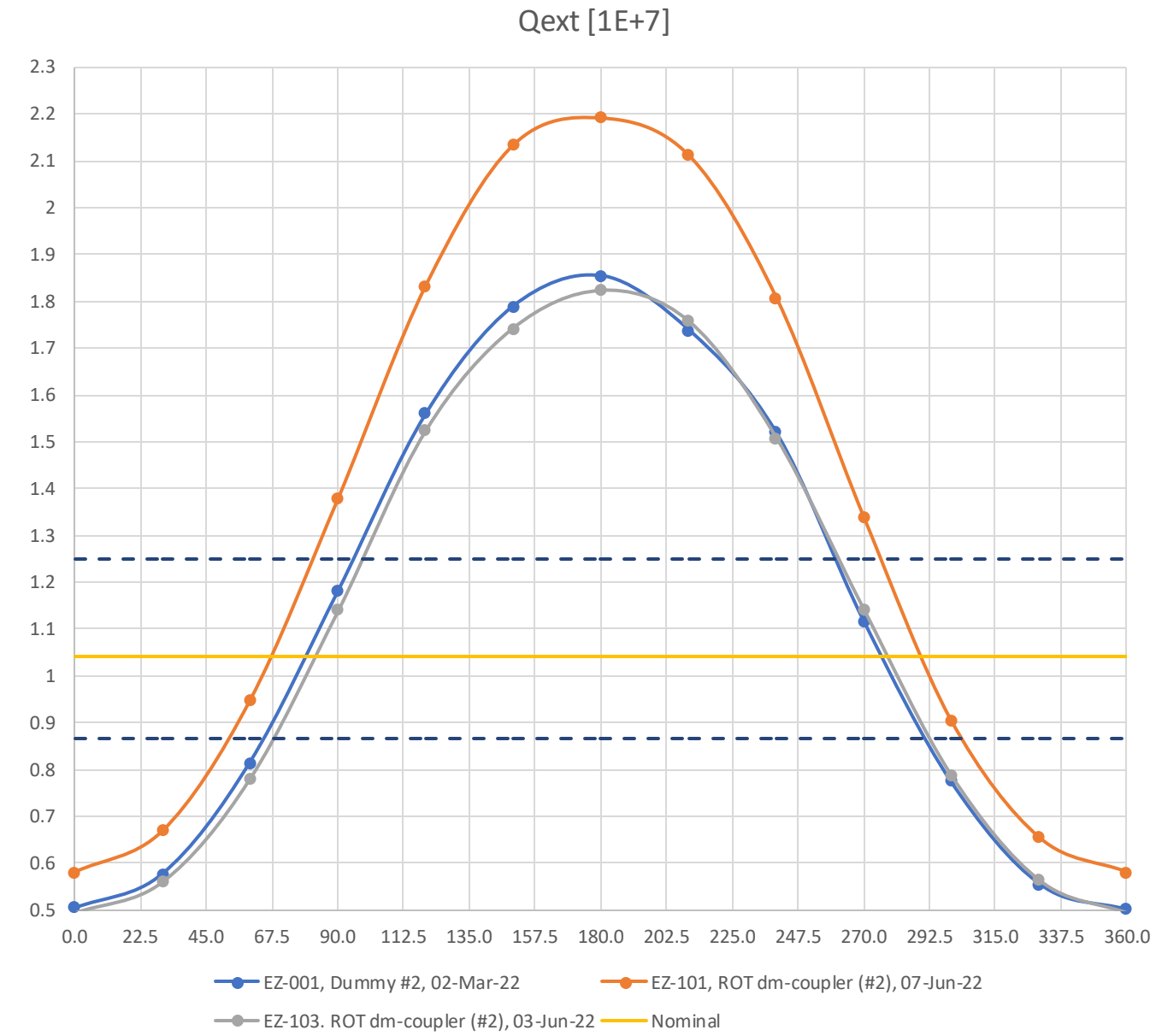
Dummy couplers on B61C-EZ-101 (SK, 7-Jun-22)

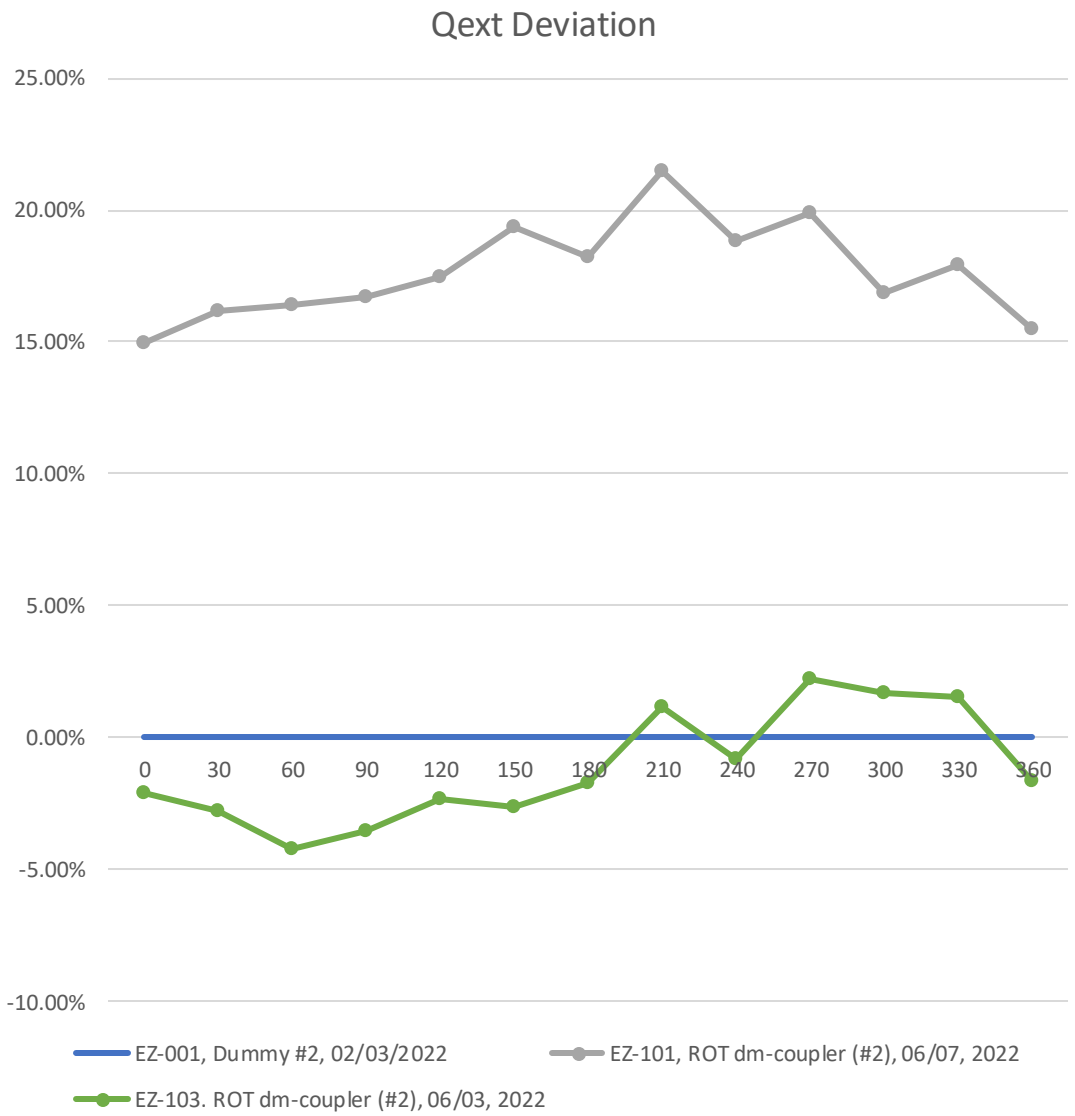
Spec is Qext = 1.04 e7 (x1.2/÷1.2) (0.87 e7 < Qext < 1.25 e7)



Rot_coupler
Acceptable angles:
67.5°
292.5°

Comparisons EZ001/EZ101/EZ103





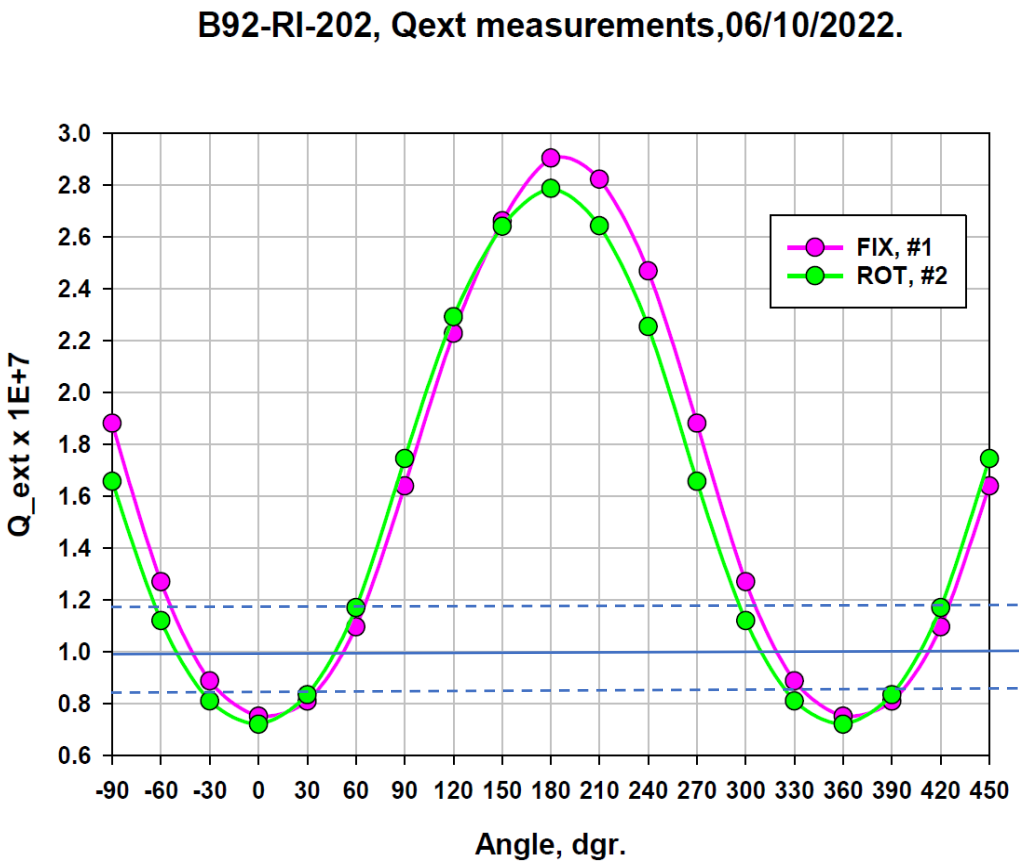
Q_ext measurements of B92-RI-202

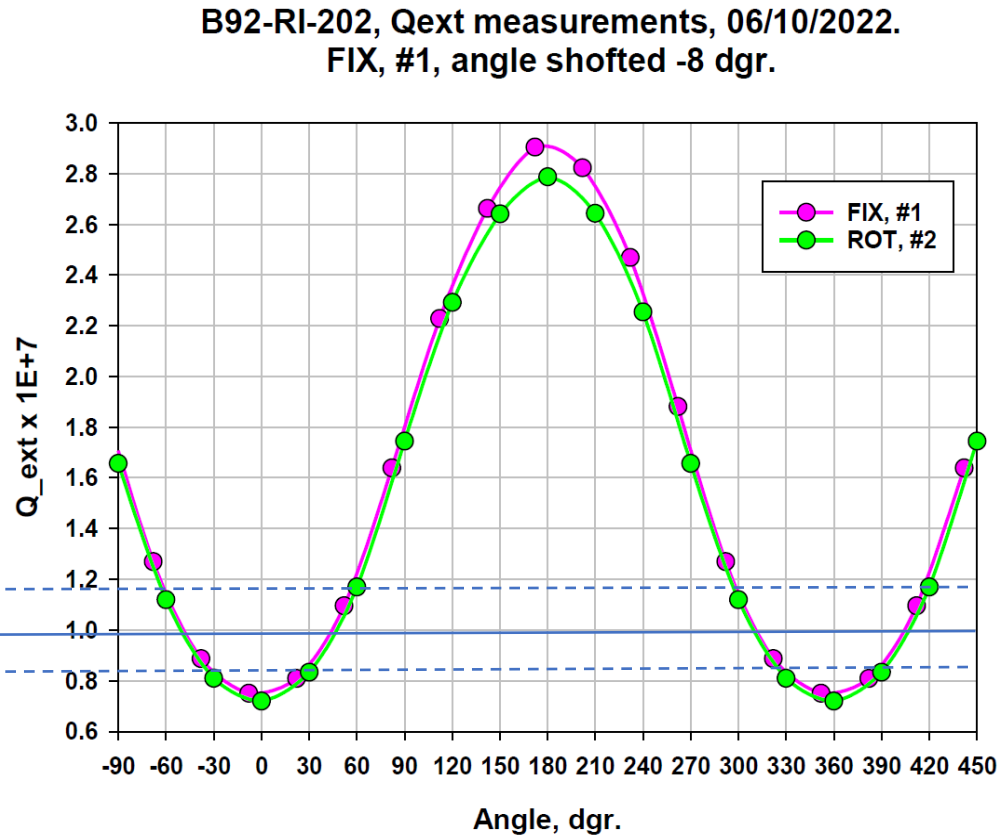
S. Kazakov, 06/10/2022

10-Jun-22

Q_ext x 1E+6, Q0=13300.21

Angle	0	30	60	90	120	150	180	210	240	270	300	330
FIX, #1	7.50	8.08	10.95	16.39	22.28	26.62	29.04	28.23	24.69	18.81	12.69	8.86
ROT, #2	7.19	8.33	11.69	17.45	22.92	26.41	27.87	26.43	22.54	16.57	11.19	8.09





Spec is Qext = 9.9e6 (x1.2/÷1.2) (8.25 e6 < Qext < 1.19 e7) → *Acceptable angles: 45°, 315°*

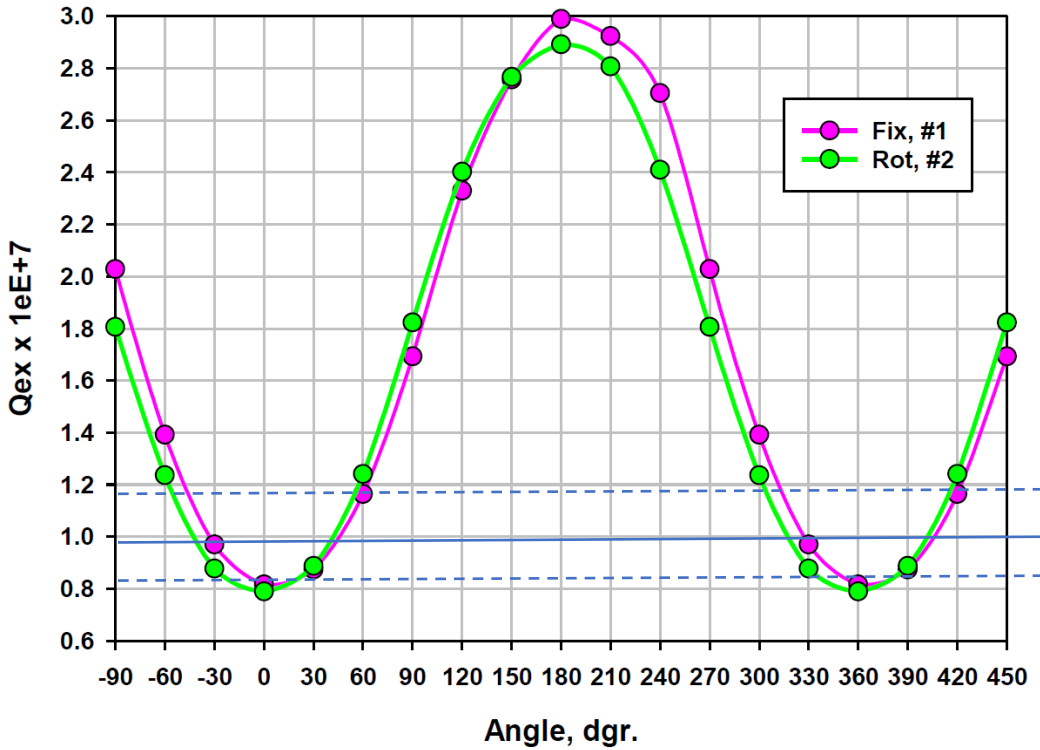
Field flatness coefficient C = 1.018 (Qext = C*Qext_ideal)

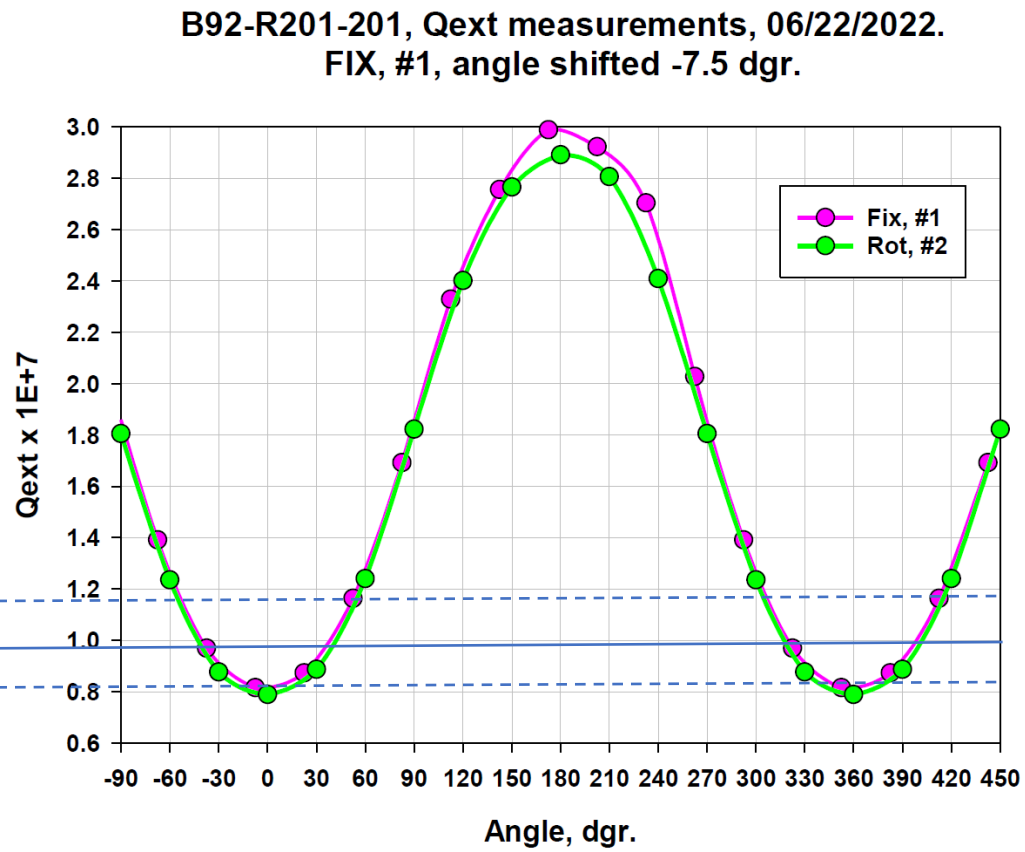
Q_ext measurements of B92-RI-201

S. Kazakov, 06/22/2022

22-Jun-22

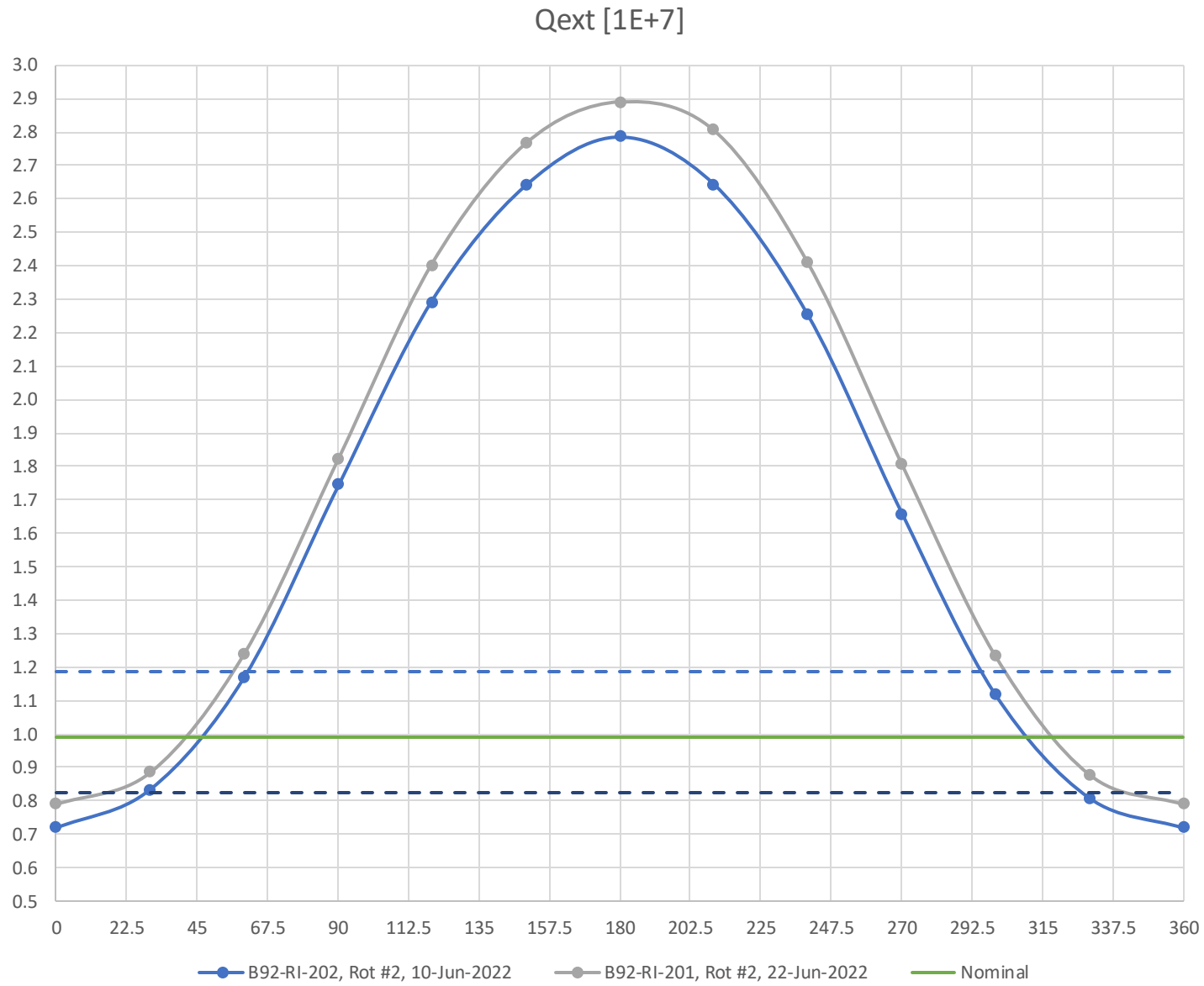
Angle	0	30	60	90	120	150	180	210	240	270	300	330
FIX, #1	8.16	8.73	11.63	16.93	23.29	27.56	29.89	29.23	27.04	20.28	13.91	9.69
ROT, #2	7.89	8.87	12.40	18.23	24.02	27.66	28.91	28.06	24.09	18.06	12.35	8.77



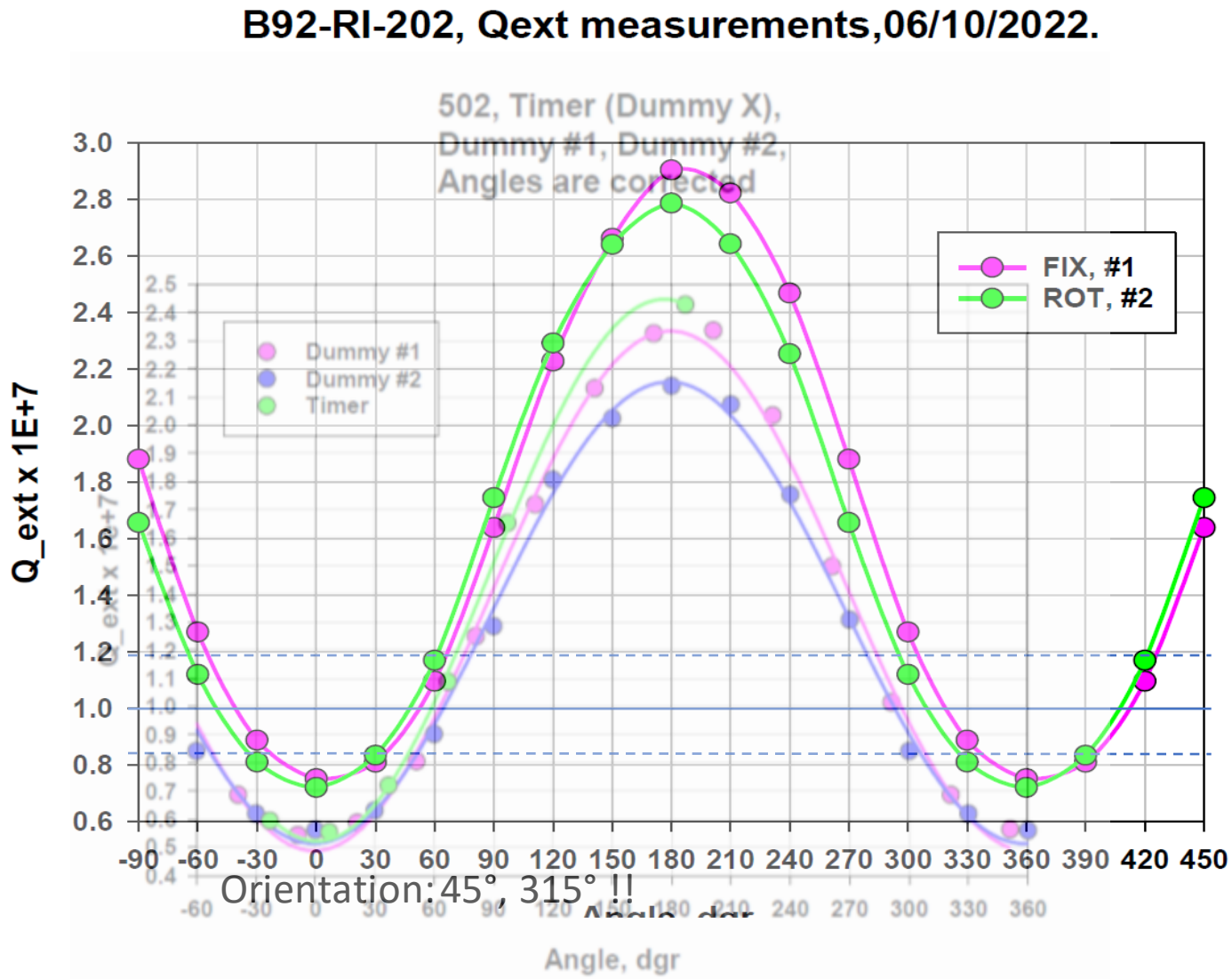


Spec is Qext = 9.9e6 (x1.2/÷1.2) (8.25 e6 < Qext < 1.19 e7) → Acceptable angles: 22.5°, 45°, 315°, 337.5°

Comparison B92-RI-202 vs B92-RI-201

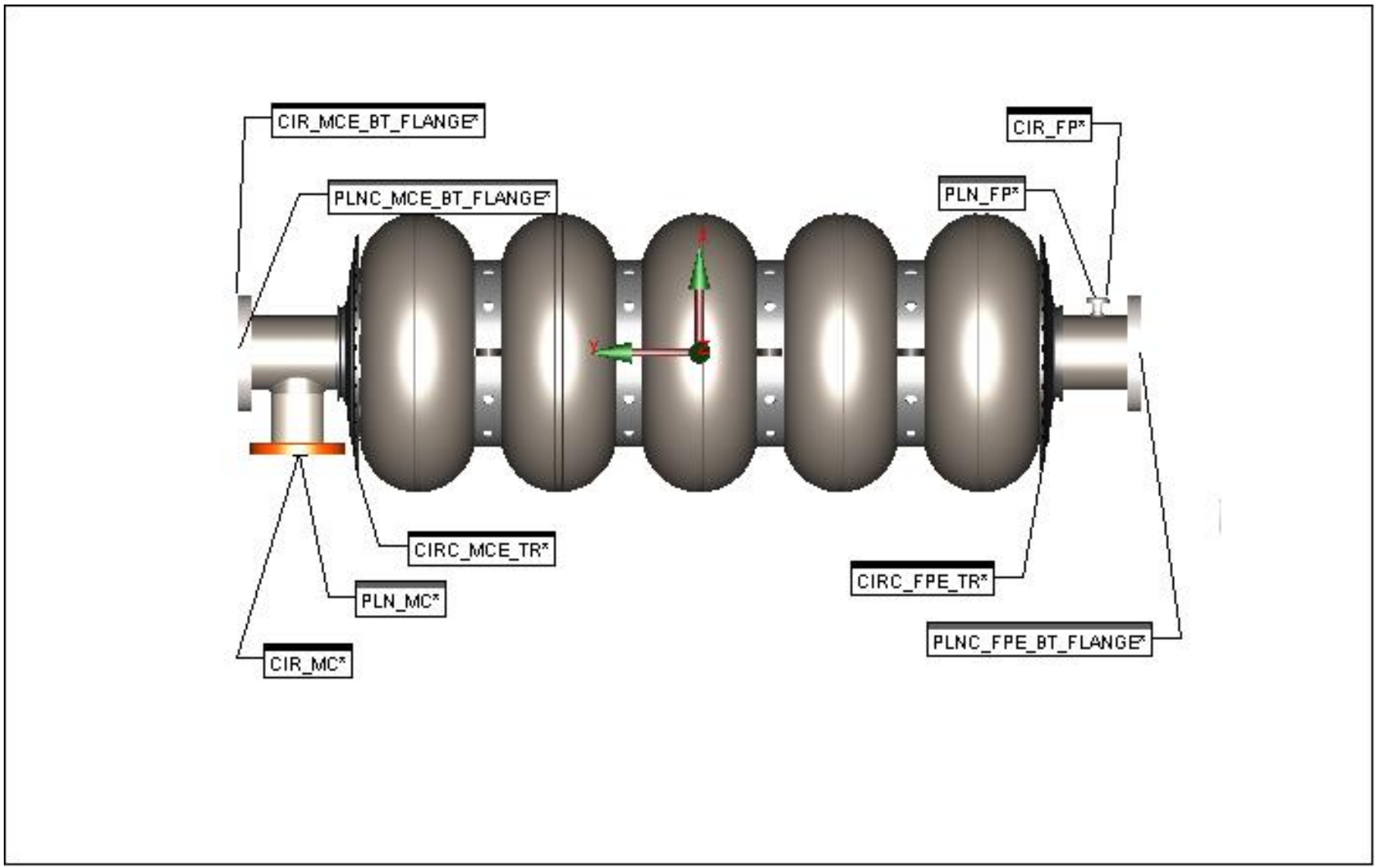


Comparison B92-RRCAT-502 vs B92-RI-202



Dimensional controls of pCM cavities and string

CMM data for B90 cavities



CMM data B90: unit MC-flange normal vector N

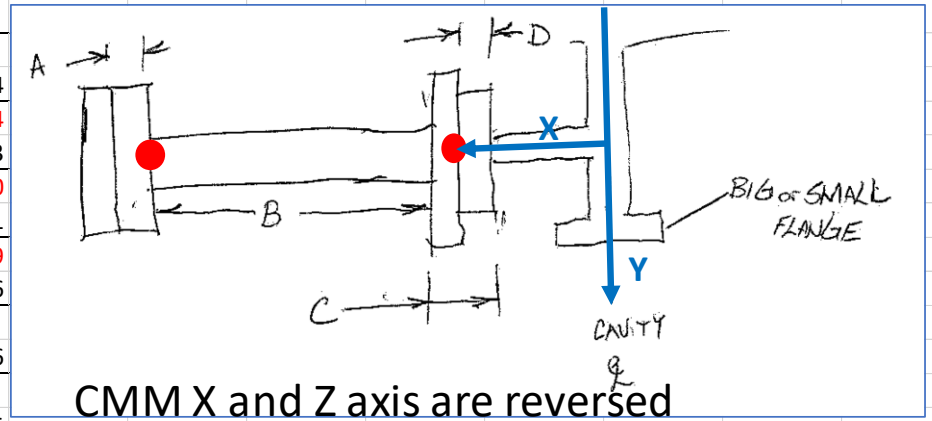
⌗	MM	LOC30 - PLN_MC

AX		Nx	MEAS	Ny	Nz
AX		I		J	K
V	AES007	-0.99996		0.00804	0.00438
AX		I		J	K
V	AES008	-0.99998		0.00390	-0.00395
AX		I		J	K
V	AES009	-0.99995		-0.00960	0.00093

pCM couplers survey (Virgil, 26 May 2022) vs. CMM

The local Cavity coordinate system has the following axes orientation:
Origin = Projection point of Inner Coupler Center on Line from UPST/DNST Flange Centers
X = positive right when looking downstream Cavity
Y (stationing) = positive downstream Cavity
Z = positive upward when looking downstream Cavity (and orthogonal to Y axis)

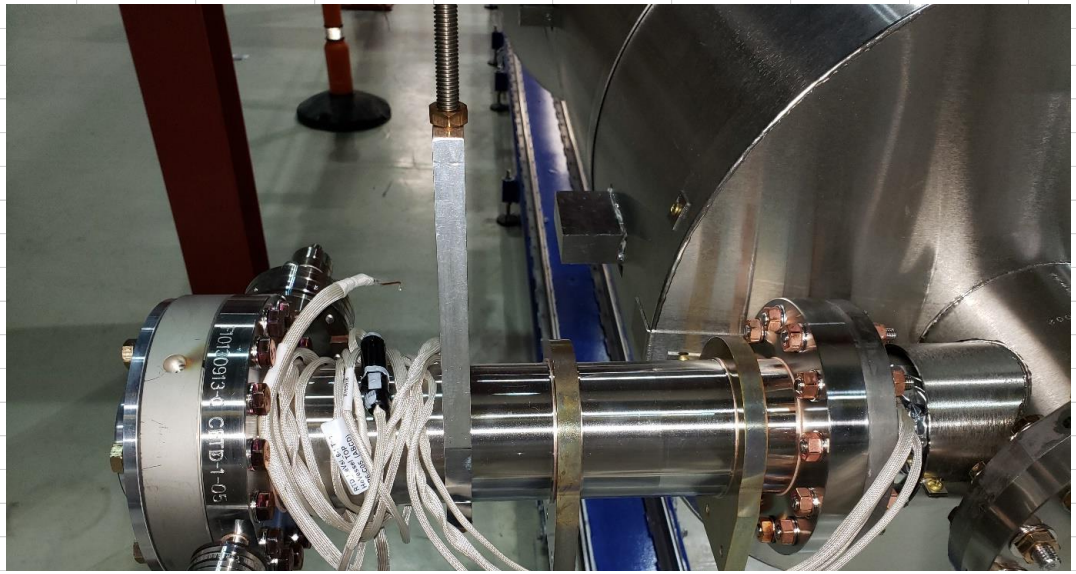
NAME	X [mm]	Y [mm]	Z [mm]	DX [mm]	Y' [mrad]	Z' [mrad]
Cav 1 Inner Coupler-Center	140.021	0	0			
Cav 1 Outer Coupler-Center	447.516	2.667	0.728	307.5	8.7	2.4
Cav 2 Inner Couple-Center	127.383	0	0	CMM 007	8.0	-4.4
Cav 2 Outer Couple-Center	434.926	0.206	-1.938	307.5	0.7	-6.3
Cav 3 Inner Coupler-Center	128.367	0	0	CMM 008	3.9	4.0
Cav 3 Outer Coupler-Center	435.831	-1.223	1.251	307.5	-4.0	4.1
Cav 4 Inner Coupler-Center	129.14	0	0	CMM 009	-9.6	-0.9
Cav 4 Outer Coupler-Center	436.593	-5.523	-0.192	307.5	-18.0	-0.6
Cav 5 Inner Coupler-Center	139.925	0	0			
Cav 5 Outer Coupler-Center	447.439	-0.443	-0.495	307.5	-1.4	-1.6
Cav 6 Inner Coupler-Center	137.944	0	0			
Cav 6 Outer Coupler-Center	445.494	1.586	-1.397	307.6	5.2	-4.5



CMM X and Z axis are reversed

Parallelism of the two coupler flanges (plane to plane angle between normals)

NAME	Angle [mrad]
Cavity 1 Coupler Outer Plane to Coupler Inner Plane	0.3311
Cavity 2 Coupler Outer Plane to Coupler Inner Plane	0.3375
Cavity 3 Coupler Outer Plane to Coupler Inner Plane	1.0912
Cavity 4 Coupler Outer Plane to Coupler Inner Plane	0.6568
Cavity 5 Coupler Outer Plane to Coupler Inner Plane	0.1351
Cavity 6 Coupler Outer Plane to Coupler Inner Plane	0.9008



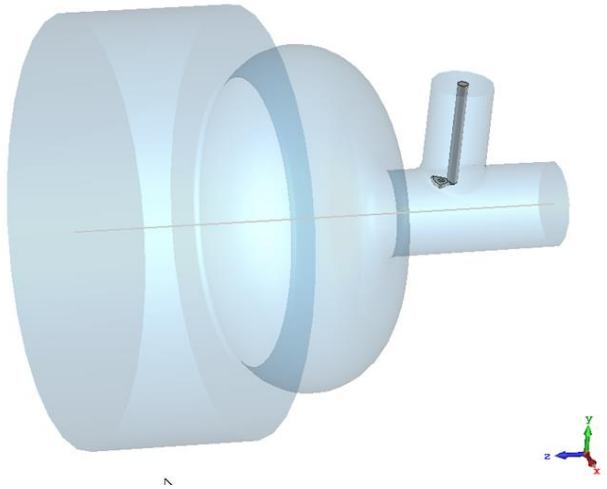
pCM couplers survey (Virgil, 26 May 2022) vs. CMM

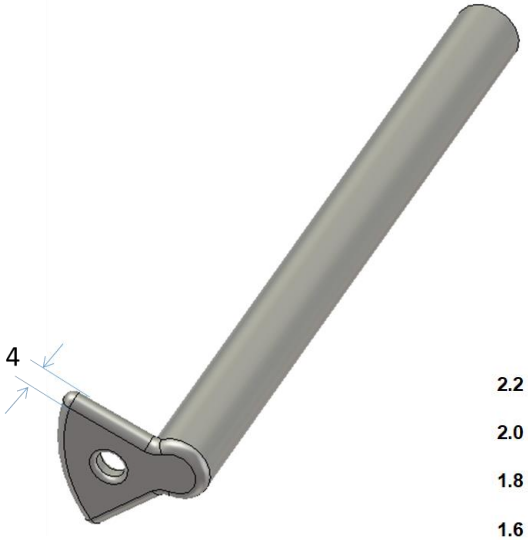
- Length DX of outer conductor is very uniform (< 0.1 mm) $\Rightarrow$ antenna penetration is presumably uniform
- Parallelism of inner and outer coupler flanges is good (=< 1 mrad).
- CMM vs. Survey in good agreement for the coupler pitch angle Z'
- Yaw angle $Y'_{survey} \approx Y'_{CMM}$ - 8 mrad. Why is that ???
  - Both survey and CMM use the same reference axis given by the beamline flange centers.
  - If the flanges 'moved' since CMM measurements of AES cavities, why only is Y', and by the same amount. Unlikely.
- CMM data for RRCAT cavity does not give the vector N in a straightforward manner.

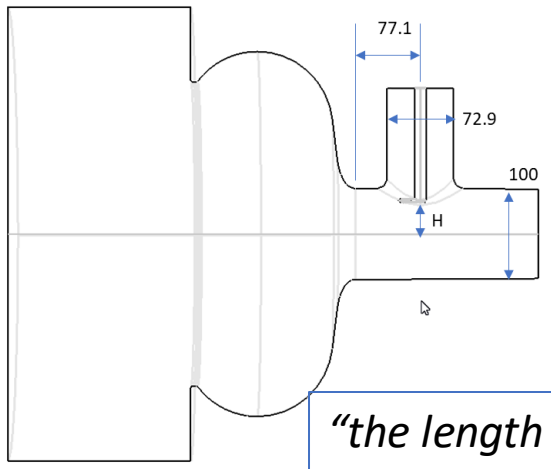
Back-up Material

Saddlejoint Shape

Coupling can be adjusted by rotation of antenna.
Magnitude of coupling can be change ~5 times.

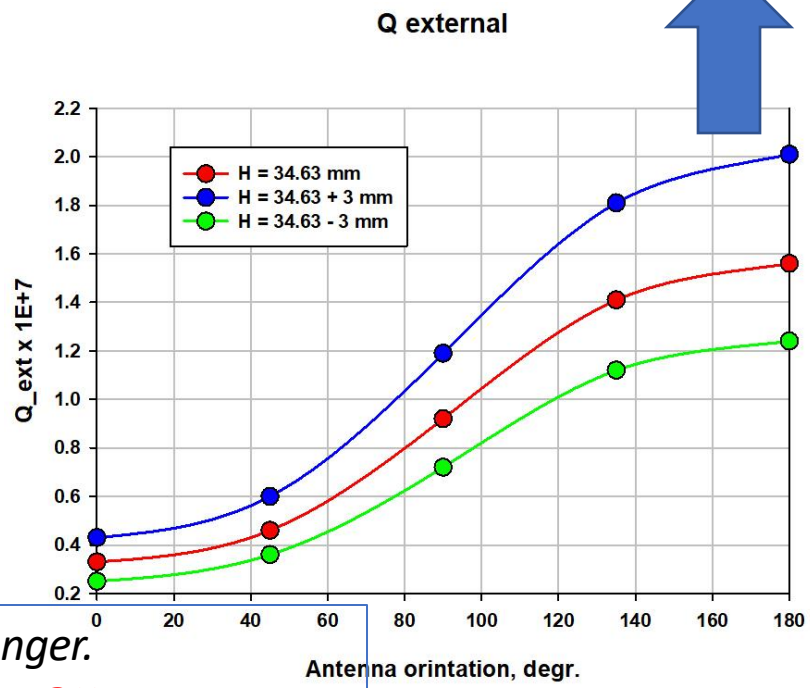






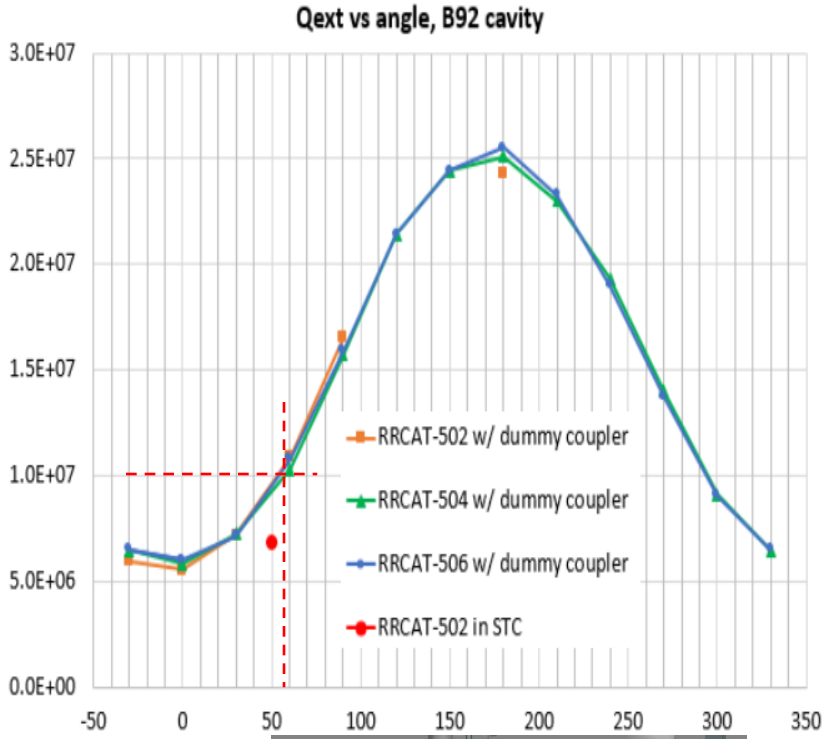
Qext x 1.08/mm longer
Qext ÷ 1.08/mm shorter

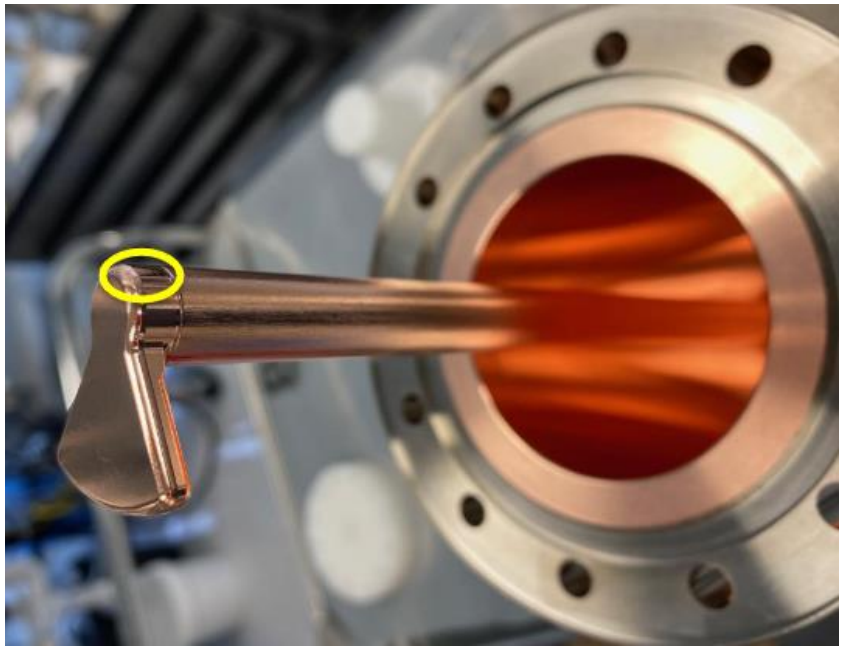
→ 8% per mm

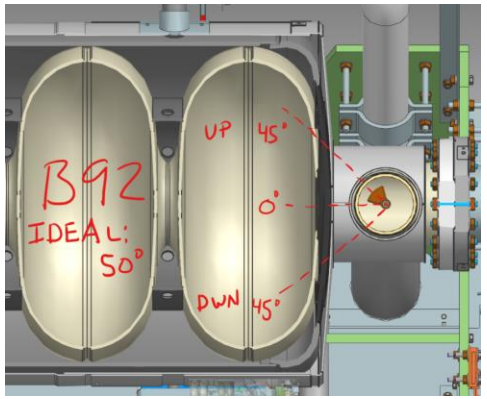


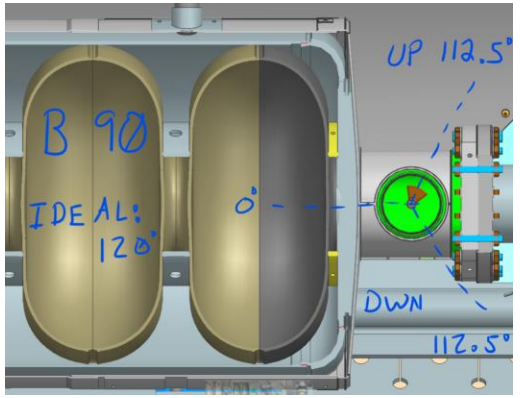
"the length of Rot coupler is about 0.35 mm longer.
It gives ~ 2.5% larger coupling." (SK, 7-Jun-22). *OK*

Coupler to cavity coupling, QL









From Timegali, 28-Apr-2022

HB650 string at MP9 Phase1A. Coupler Qext measurements						
pos.	Cavity	F, MHz	Q	Qext1	Qext2	P2, W
1	RRCAT506	648.96	13350	9.02E+06	3.63E+13	0.02
2	AES007	648.88	13060	7.08E+06	1.21E+12	0.40
3	AES008	648.64	12970	7.06E+06	1.75E+12	0.28
4	AES009	648.99	13200	1.43E+07	2.08E+12	0.24
5	RRCAT504	648.99	13300	1.01E+07	7.02E+12	0.09
6	RRCAT502	648.93	13300	1.02E+07	1.30E+12	0.50