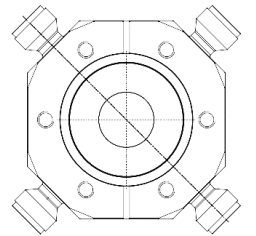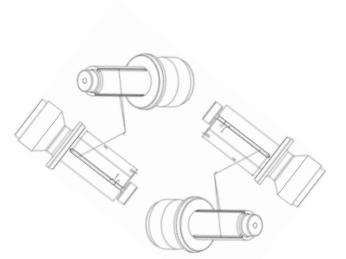# Advancements in BPM Development for PETRA IV

Evaluating individual feedthroughs and fully assembled BPMs

M. Holz, G. Kube, D. Lipka, Sergey Strokov, S. Vilcins-Czvitkovits
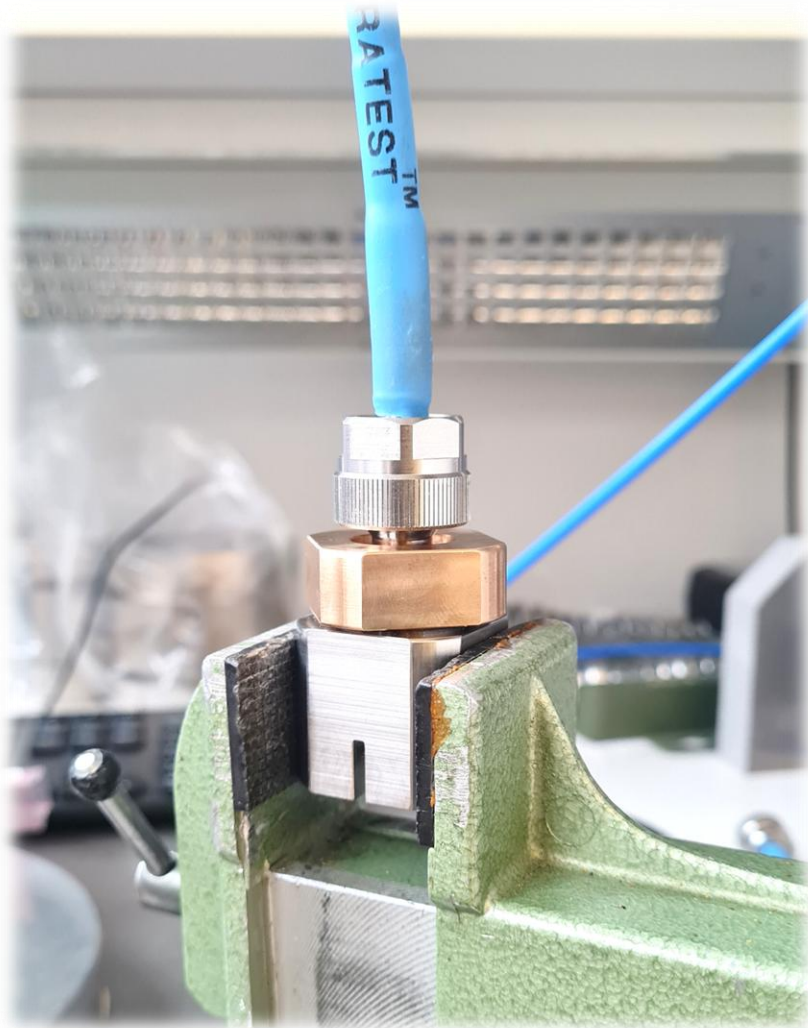ALBA Synchrotron, 11.12.2024

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Outline

1. Setup for measurement of TDR traces

Using VNA and feedthrough holder

VNA – R&S®ZNB8,
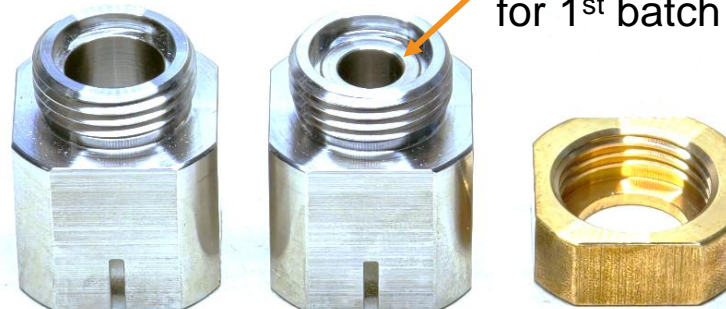4 ports, 8.5 GHz

first and second batches
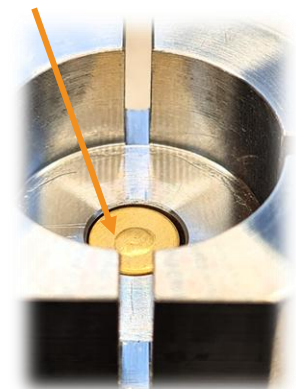of feedthrough prototypes
(30 feedthroughs in each batch)

1st   2nd

holders for feedthroughs

cylindrical adaptor
for 1st batch

button of installed
feedthrough

Electrical center offset estimation from TDR traces

Rise time → capacitance calculation

- Electrical center offset can be estimated through V_n using Δ/Σ method

- Voltage is inversely proportional to capacitance ($V \sim 1/C$)

- Feedthrough capacitance C can be found from TDR trace ($C = \tau/50\ Ohm$)

- Monitor constant $K_{x,y} = 7.2$ mm

- No fitting

$$Horizontal = K_x \frac{(V1 + V2) - (V3 + V4)}{V1 + V4 + V2 + V3}$$

$$Vertical = K_y \frac{(V1 + V4) - (V2 + V3)}{V1 + V4 + V2 + V3}$$
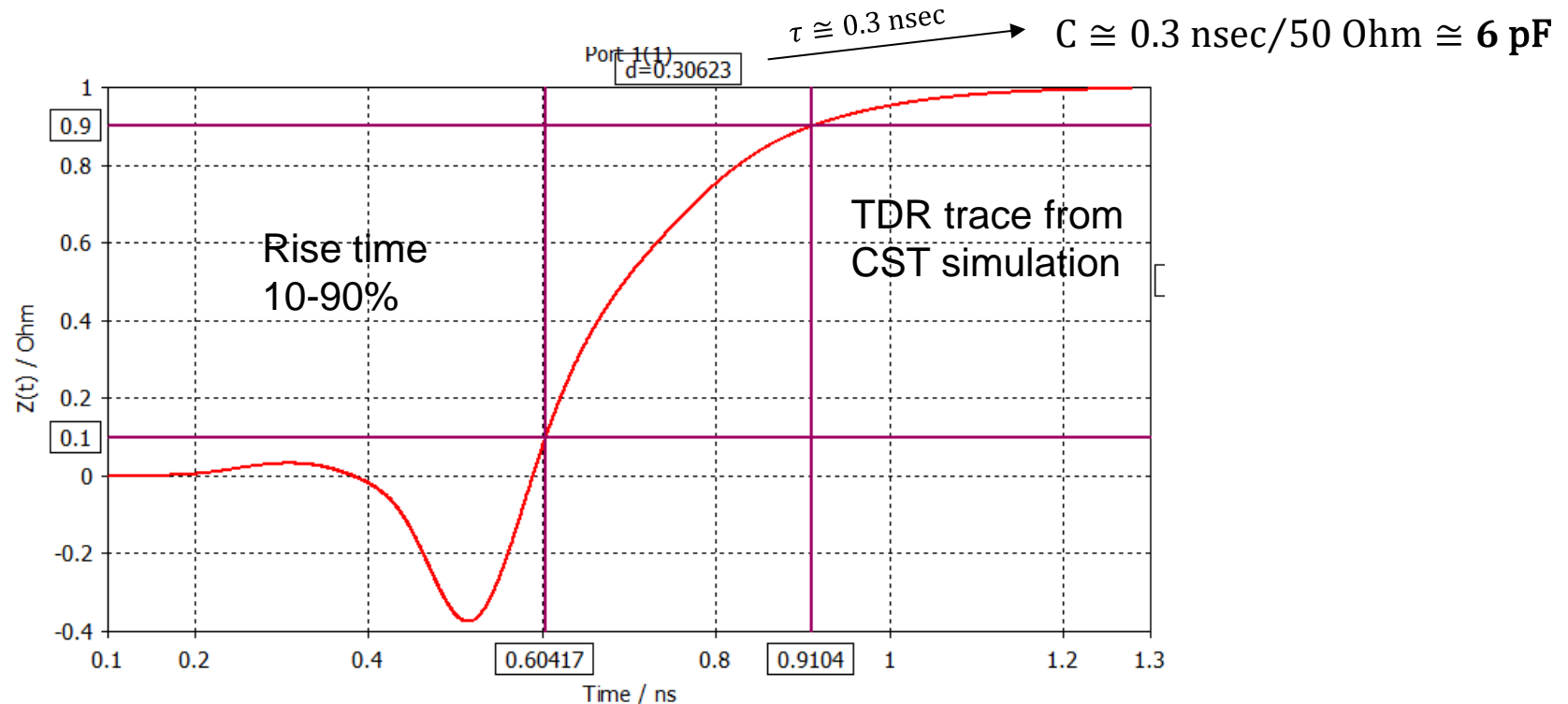
$\tau \cong 0.3$ nsec $\longrightarrow$ $C \cong 0.3$ nsec/50 Ohm $\cong$ **6 pF**

Port 1(1)
d=0.30623

Rise time 10-90%

TDR trace from CST simulation

0.60417   0.9104

Time / ns

Z(t) / Ohm

2. Measurements of single feedthrough using VNA

Steps to understand influence of measurement conditions

Fixed in a holder feedthrough – to understand influence of VNA and measurement condition

- fixed cable and holder with installed feedthrough

- TDR traces were measured and averaged over 1, 10, and 50 consecutive traces

- 10 measurements at each averaging set

1	10	50
x = ± 4.223 um y = ± 4.313 um	x = ± 1.165 um y = ± 1.177 um	x = ± 0.506 um y = ± 0.730 um
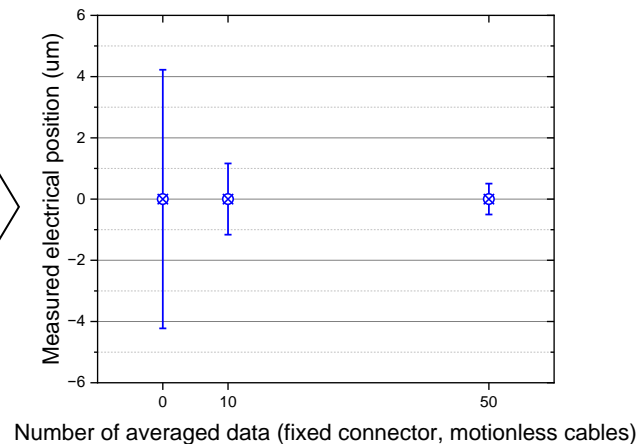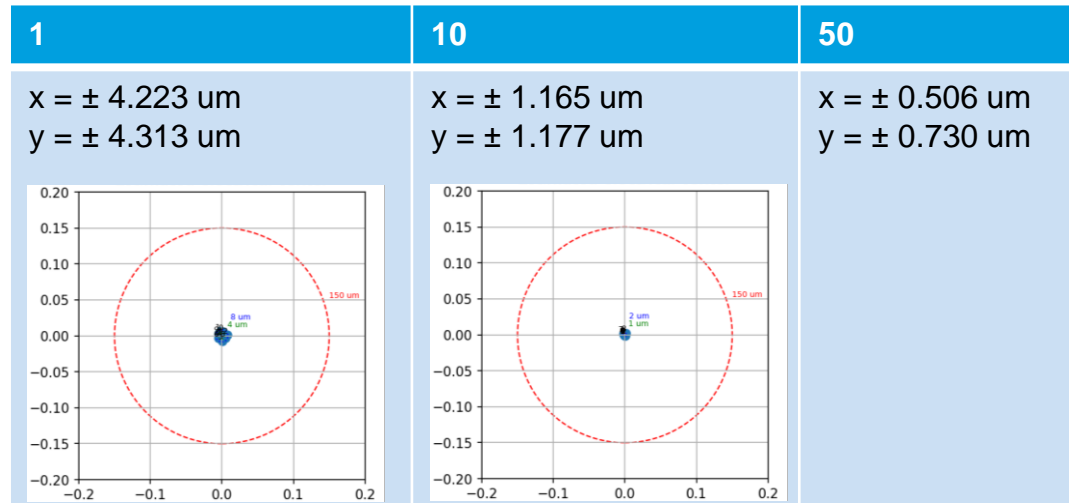
- Averaging over 50 traces is sufficient!

- Influence of VNA is negligible

2. Measurements of single feedthrough using VNA

Steps to understand influence of measurement conditions

Fully assembled-disassembled holder with feedthrough – to understand influence of manufacturing tolerances

- assembling-disassembling holder with feedthrough before each measurement to reproduce real-life situations

- 10 TDR measurements, each averaged over 50 consecutive traces

x = ± 27.7 um   Mechanical tolerances restrict magnitude of minimum
y = ± 33.7 um   achievable center offset deviation to ± 30 um

3. Results of measurements of 30 feedthroughs

How mechanical tolerances affects center deviation

1st batch of 30 feedthroughs in holder **without** adaptor
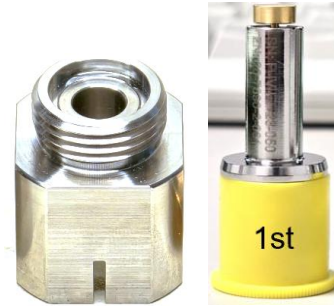
1st batch of 30 feedthroughs in holder **with** adaptor

2nd batch of 30 feedthroughs

x = ± 231 um
y = ± 217 um

x = ± 134 um
y = ± 132 um

x = ± 80 um
y = ± 70 um

2nd batch of 30 feedthroughs (№№ 23-079 to 23-108)

- least squares method was used to find similar traces
- from 30 feedthroughs, 7 groups of 4 feedthroughs with similar TDR traces can be formed

- Table of "distances" which is used to form groups of 4 closest to each other

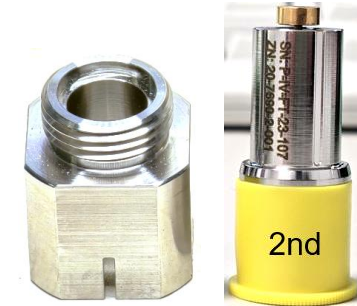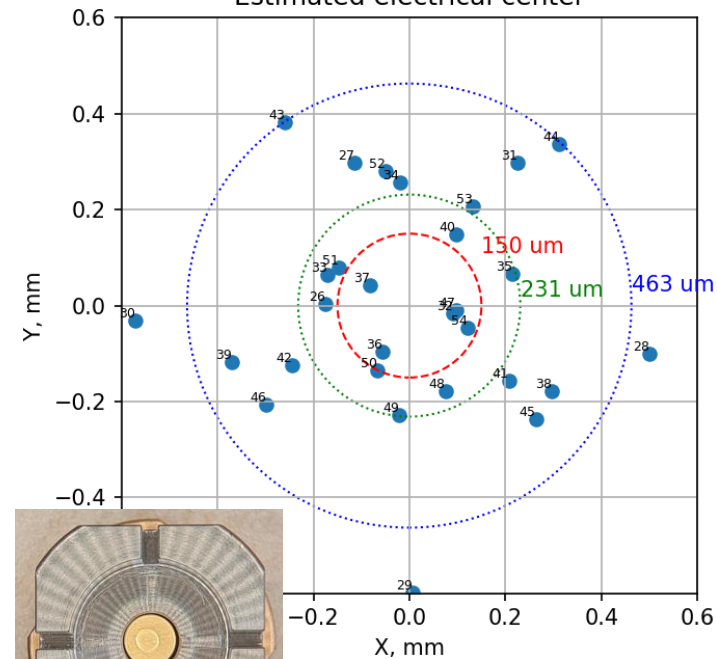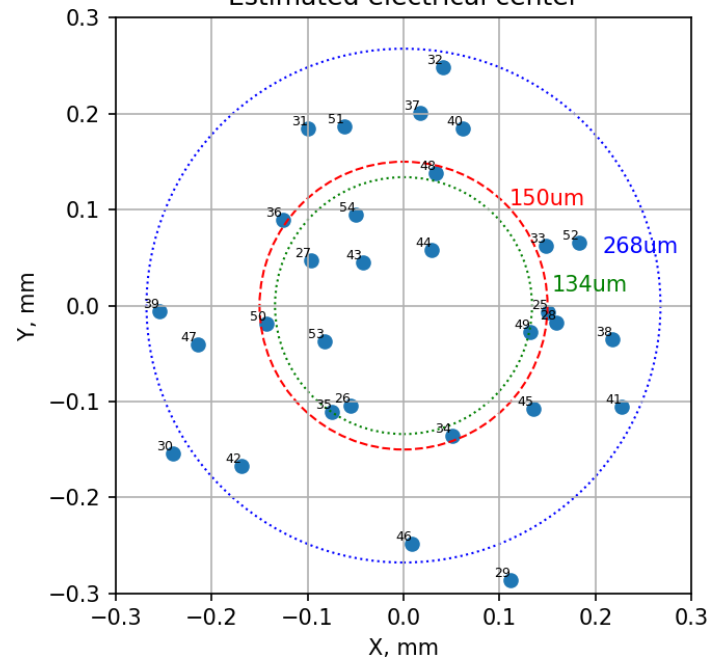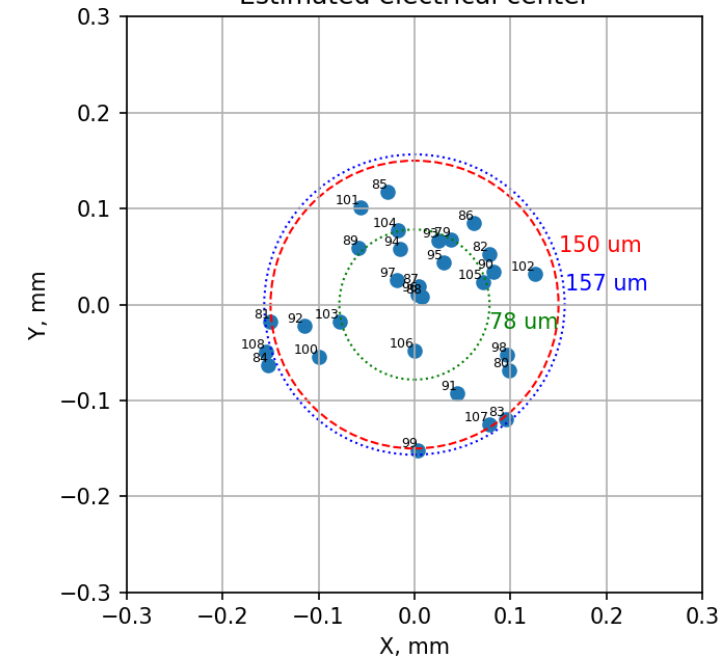|	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
1.	0																													
2.	133	0																												
3.	80	171	0																											
4.	54	21	99	0																										
5.	93	7	164	13	0																									
6.	215	663	258	455	582	0																								
7.	126	468	248	316	386	103	0																							
8.	62	115	230	70	73	425	233	0																						
9.	72	54	56	20	56	412	320	119	0																					
10.	11	125	34	49	97	215	156	101	44	0																				
11.	4	163	60	72	122	172	113	95	77	7	0																			
12.	44	170	16	82	151	198	181	161	44	15	29	0																		
13.	4	150	56	63	112	184	123	89	66	4	1	25	0																	
14.	312	746	240	534	686	45	215	583	437	270	251	207	258	0																
15.	10	91	86	26	61	281	179	45	39	17	20	44	15	371	0															
16.	14	125	39	46	99	218	166	99	36	3	11	12	6	270	13	0														
17.	37	152	11	71	133	211	185	157	42	9	24	3	20	227	41	10	0													
18.	75	202	10	112	189	207	214	222	59	34	53	6	48	190	77	32	10	0												
19.	152	440	77	289	402	78	169	375	217	110	109	67	112	46	191	113	76	53	0											
20.	96	313	40	187	285	117	165	269	123	59	65	22	64	99	113	56	32	16	15	0										
21.	229	480	94	334	457	158	278	471	230	163	178	92	176	74	250	158	108	63	24	33	0									
22.	222	652	224	449	582	6	127	451	389	208	174	176	185	20	284	210	190	176	49	90	111	0								
23.	7	85	69	24	56	278	178	58	39	9	14	40	10	363	4	10	32	70	178	108	240	279	0							
24.	62	37	95	7	32	437	318	76	10	50	78	69	66	499	26	41	65	98	270	166	301	426	30	0						
25.	77	87	24	42	90	364	307	164	8	38	72	26	62	364	54	34	24	31	161	85	169	333	49	32	0					
26.	167	481	104	317	439	59	162	386	241	128	122	81	125	30	204	127	93	71	4	21	30	33	196	291	186	0				
27.	46	306	174	188	235	136	44	117	208	78	45	116	52	260	86	89	114	153	162	134	271	159	85	198	207	165	0			
28.	389	807	254	599	760	108	308	700	476	327	318	241	324	16	447	326	263	205	59	119	57	66	434	561	389	50	354	0		
29.	37	254	68	131	211	105	105	154	105	29	21	24	21	150	51	24	30	39	58	26	106	100	52	116	91	58	64	208	0	
30.	232	511	105	355	483	130	255	473	251	169	181	99	179	51	260	165	114	74	17	33	6	87	249	320	188	18	256	42	103	0

Example of four TDR traces before grouping

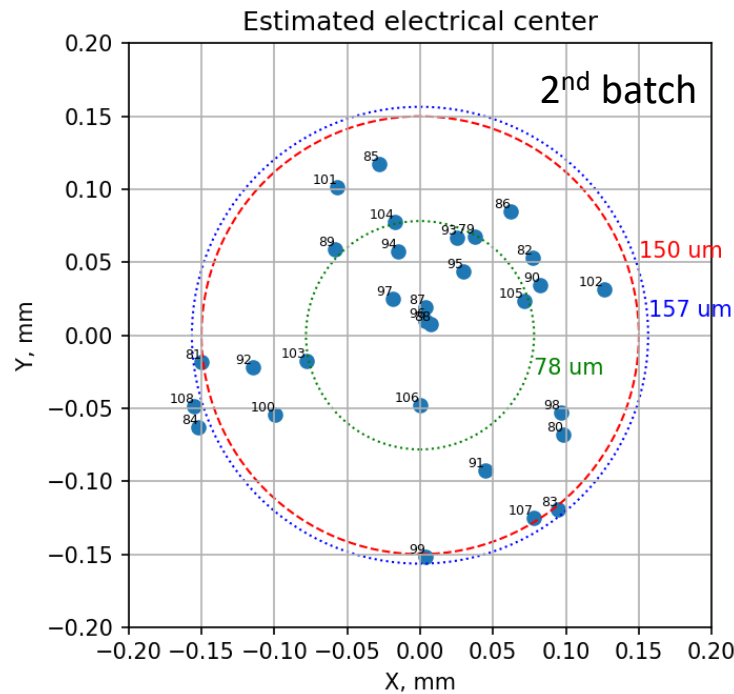After grouping

Before and after grouping

- 7 sets by 4 feedthroughs were formed out of 30 initial feedthroughs
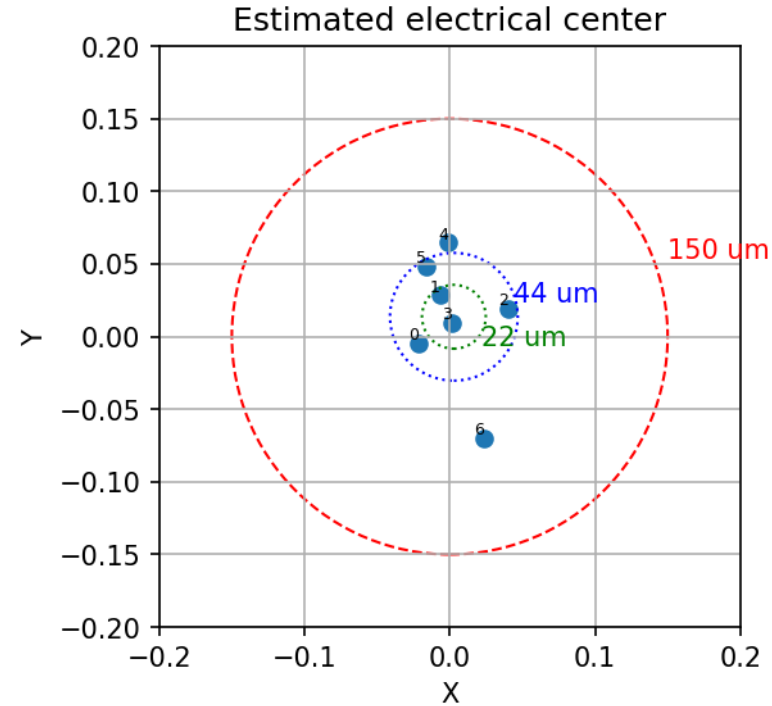- Traces with longer distances (wavy traces) are used last
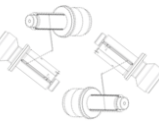
Main result

selecting feedthroughs with identical TDR traces

x = ± 80 um
y = ± 70 um

x = ± 22 um
y = ± 44 um

- through group formations, deviation in coordinates X and Y is reduced by factors of approximately 3.5 and 1.5, respectively

- more feedthroughs → higher probability to find identical feedthroughs → smaller spread

- procedure and algorithm of forming groups can still be improved

5. Measurements of 6 fully assembled BPMs

S-parameters (trasmission) measurements for Lambertson method

R&S®ZNB8,
4 ports used, 8.5 GHz
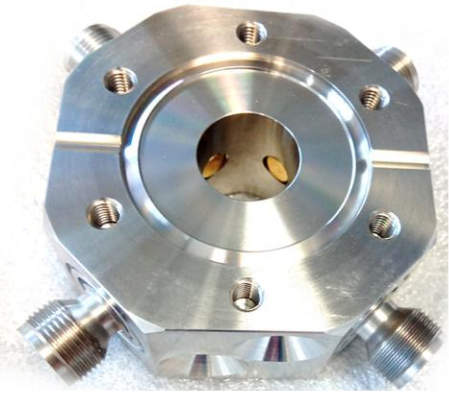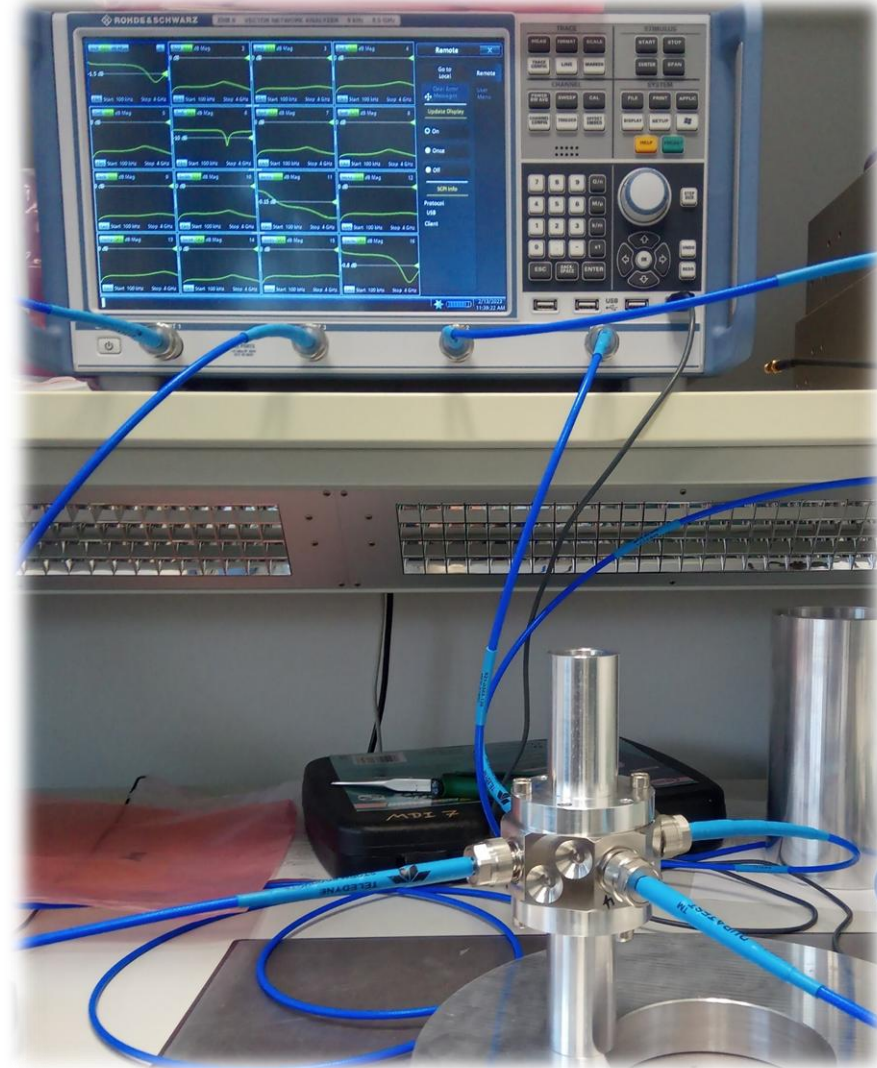
6 fully assembled BPMs

Welded-in feedthroughs were
not preliminary checked and
grouped in sets of 4

Result of mechanical measurements of buttons' displacements

BPM #23-011

Beam pipe radius = 10 mm
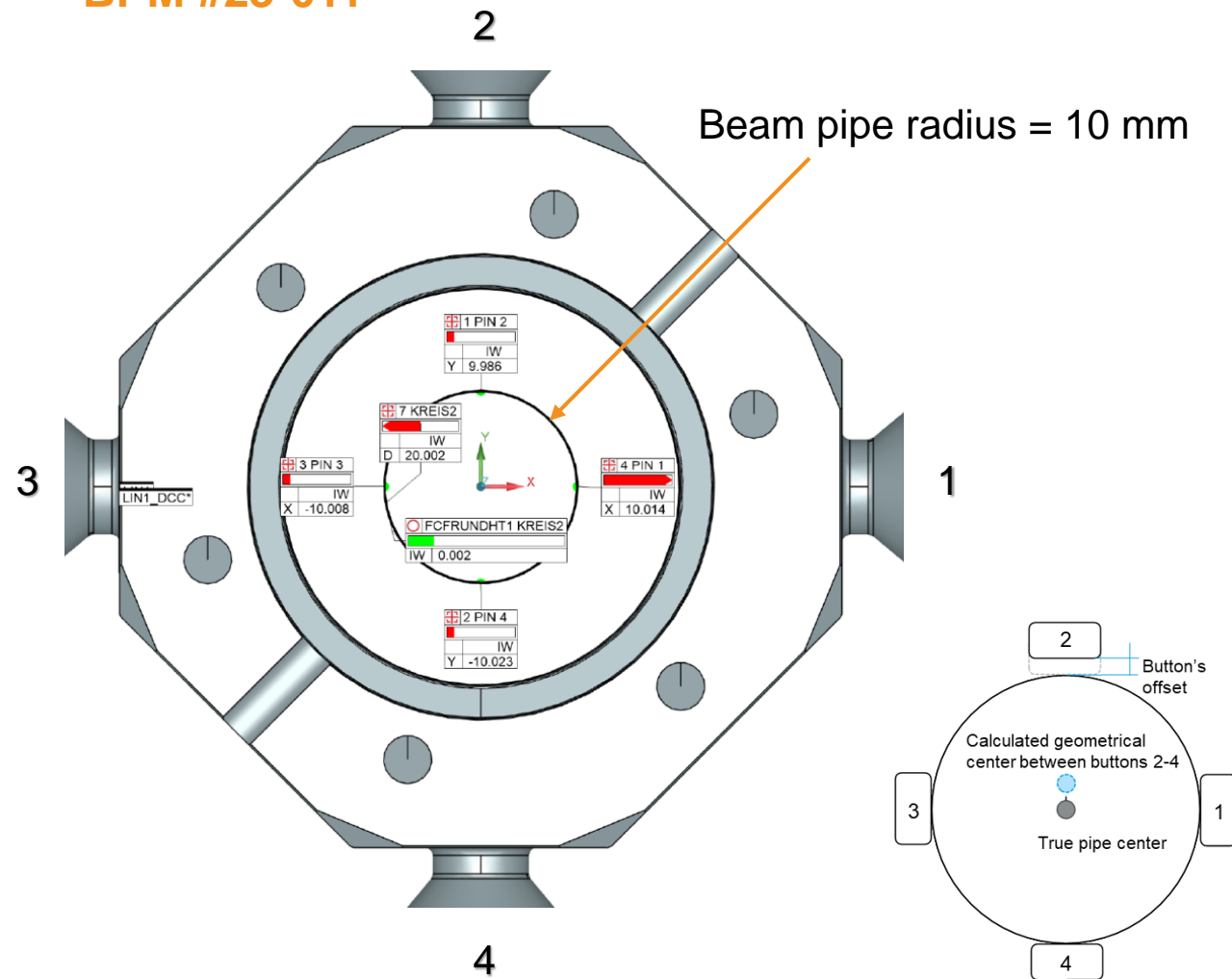
	23-007	23-008	23-009	23-010	23-011	23-012
Measured position of buttons (mm)						
1	10.021	10.001	10.008	9.984	10.014	10.023
2	10.014	9.996	9.985	10.026	9.986	10.018
3	-10.055	-9.979	-10.007	-9.995	-10.008	-10.012
4	-10.032	-10.013	-9.968	-10.043	-10.023	-10.012
Calculated geometrical center offset (mm) (0 deg rotated)						
Center X	-0.017	0.011	0.0005	-0.0055	0.003	0.0055
Center Y	-0.009	-0.0085	0.0085	-0.0085	-0.0185	0.003

Averaged position of 24 feedthrough buttons
10.00929 ± 0.020361 mm   **± 20 um**

Relation between geometrically and electrically measured centers
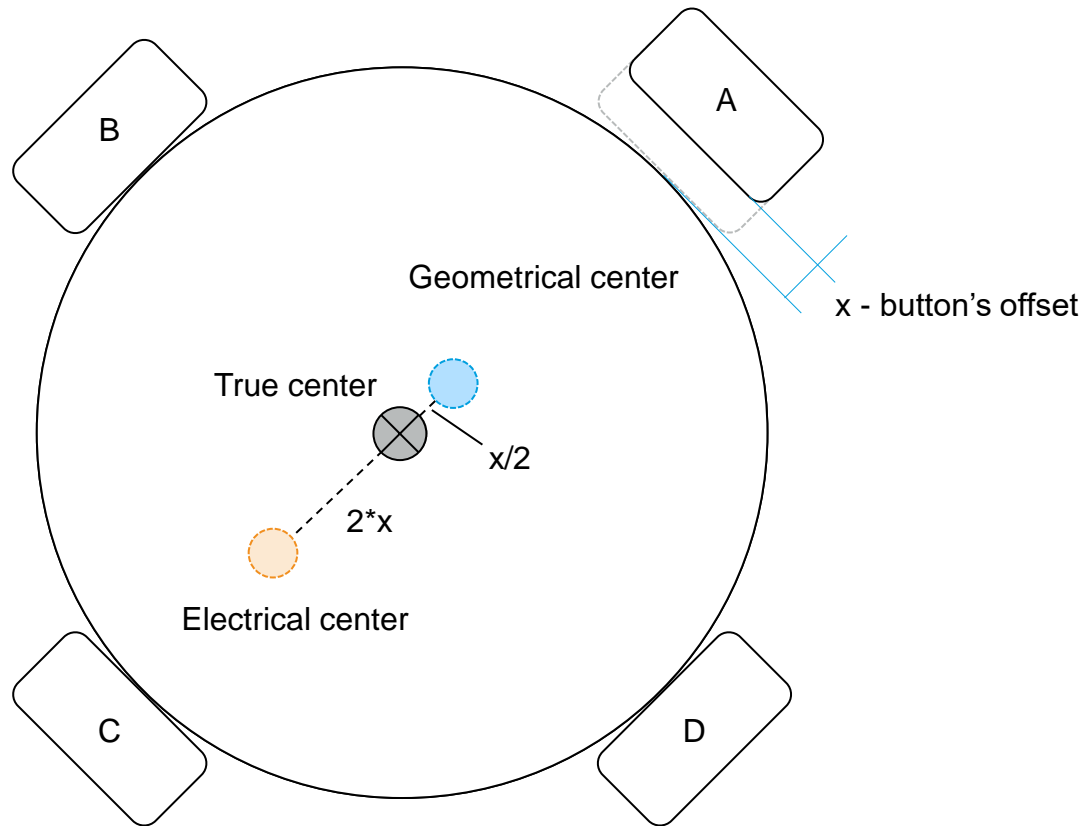
- Lambertson and Δ/Σ methods reflects electrical offset which is opposite to geometrical center offset

- To compare electrical and geometrical center offsets, geometrical should be rotated and adjusted by a multiplication factor x4

Center offsets from CST simulations, mechanical and RF measurement data

## CST – Lambertson method (HF solver), Δ/Σ method (WF solver)
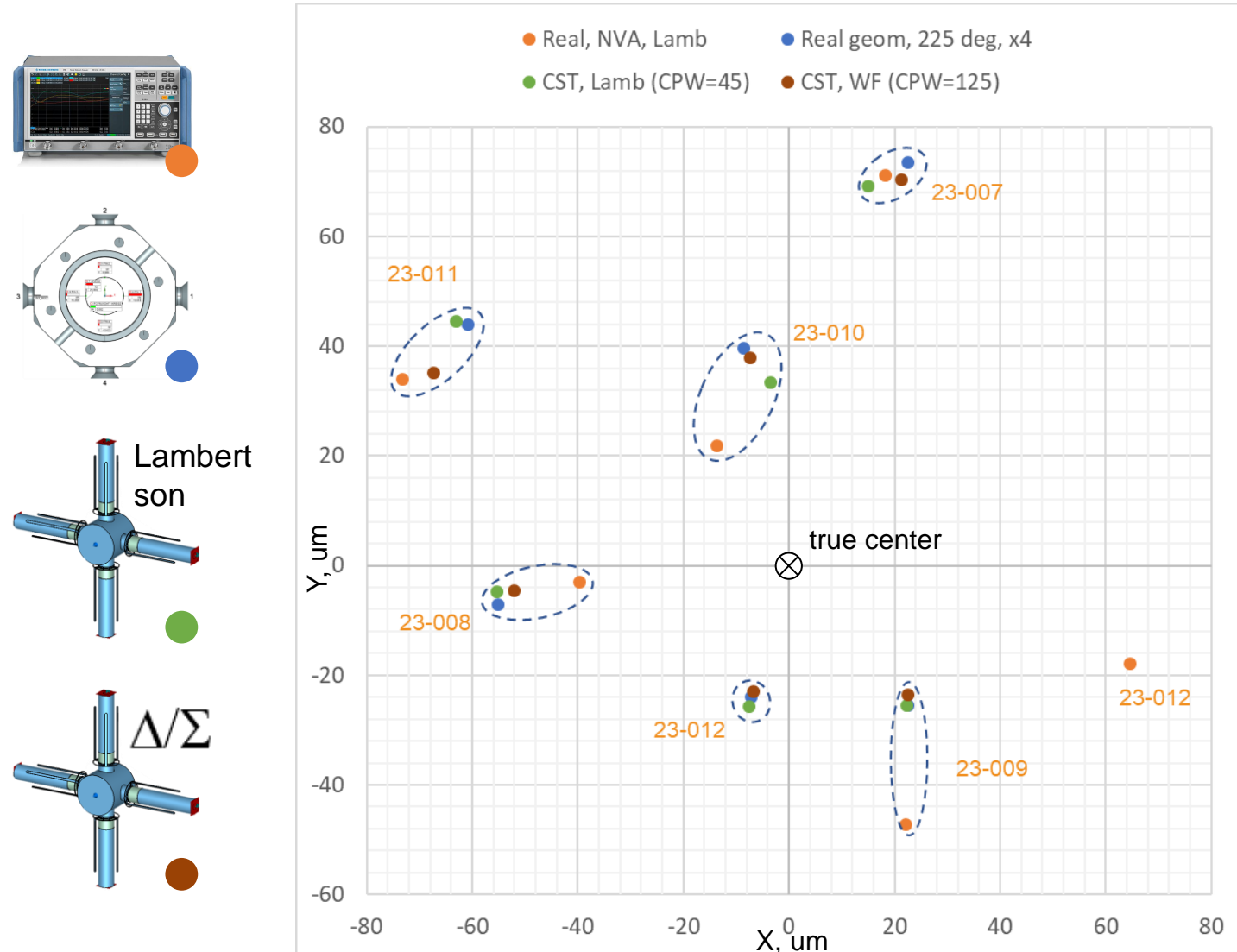
- Measured mechanical button displacements were used to set buttons positions in CST simulations

- CST simulations were performed using HF and WF solvers to calculate electrical center offset, applying Lambertson and Δ/Σ methods, respectively

- There is good agreement between mechanically measured offsets, offset measured by VNA (and calculated with Lambertson method) and offsets obtained from CST simulations

Summary

- 6 prototype BPMs manufactured without preliminary feedthrough selection process show electrical offset of less than 80 um < required 150 um

- accuracy of BPMs can be further improved by preliminary grouping feedthroughs in sets of 4 with similar TDR traces

- next step will be development of BPM test stand where we can use preselected feedthroughs to further reduce center offset of assembled BPM

randomly chosen feedthroughs
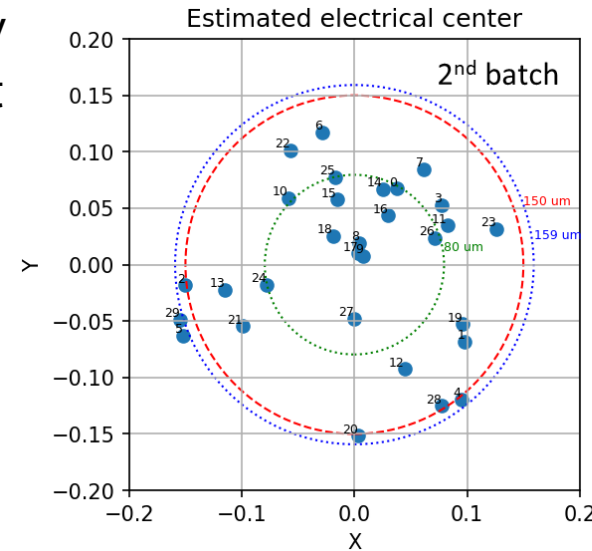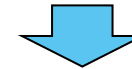
after forming groups of similar feedthroughs
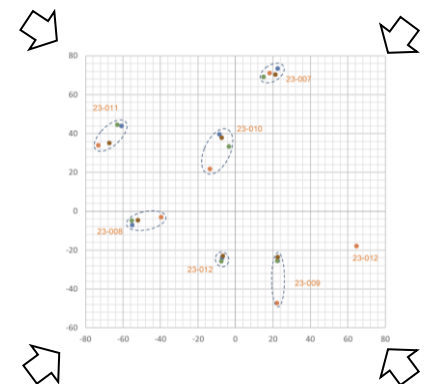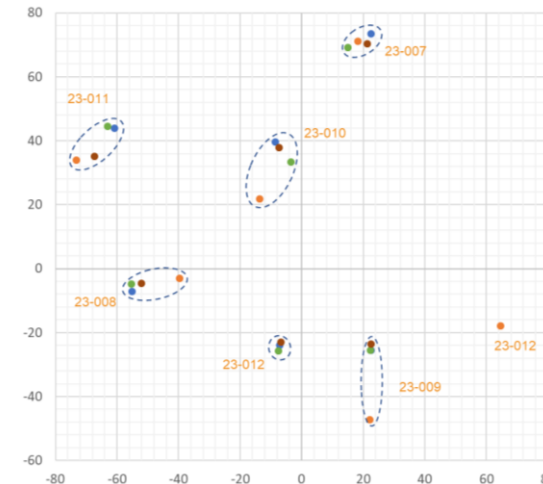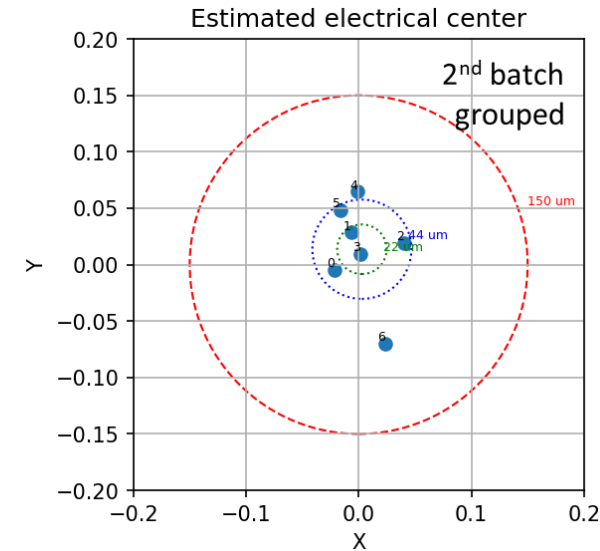
next step is to further reduce center offset
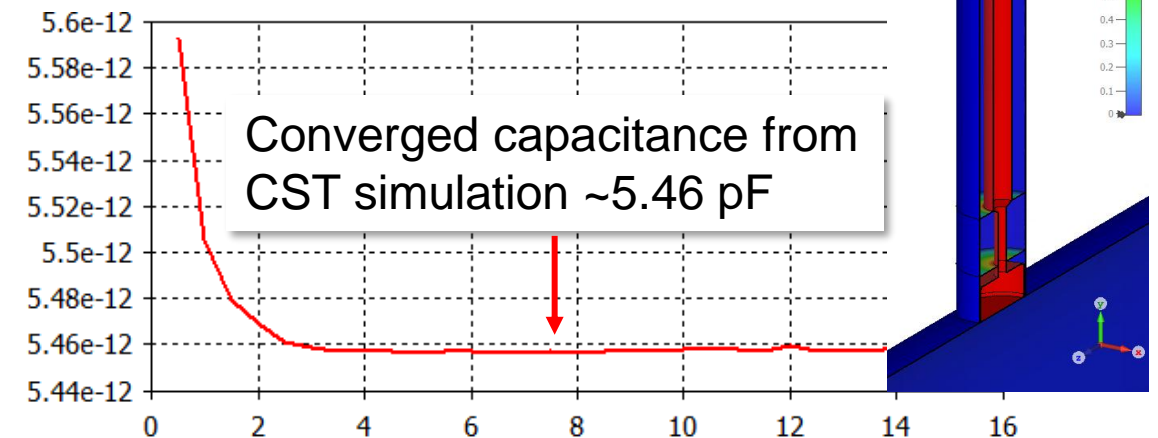
Capacitance measurement

comparison of real measurement with simulation

- Feedthrough #203-085

- Capacitance measured by Capacitance Meter is 5.6 pF

- Taking into account capacitance of wires measured separately – 0.1 pF – capacitance of feedthrough is ~**5.5 pF**

Good agreement with simulation

Converged capacitance from CST simulation ~5.46 pF

Thank you