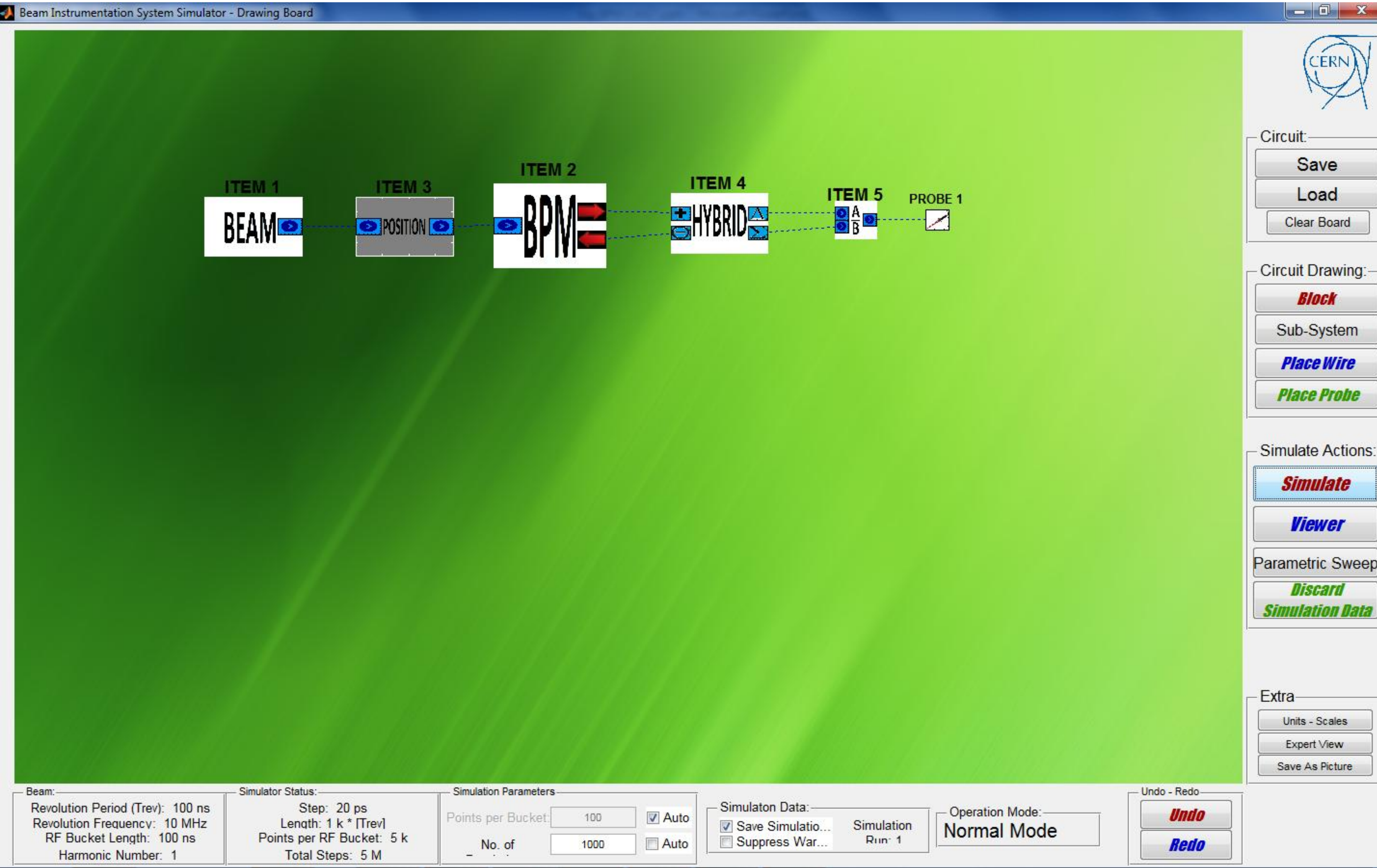
Calibration of
Button Type Beam Position Monitors

Yellow: Your Tasks T1 – T4

Simulation



Beam Instrumentation System Simulator - Drawing Board
ITEM 1
BEAM
ITEM 3
POSITION
ITEM 2
BPM
ITEM 4
HYBRID
ITEM 5
PROBE 1
Circuit:
Save
Load
Clear Board
Circuit Drawing:
Block
Sub-System
Place Wire
Place Probe
Simulate Actions:
Simulate
Viewer
Parametric Sweep
Discard Simulation Data
Extra
Units - Scales
Expert View
Save As Picture
Beam:
Revolution Period (Trev): 100 ns
Revolution Frequency: 10 MHz
RF Bucket Length: 100 ns
Harmonic Number: 1
Simulator Status:
Step: 20 ps
Length: 1 k * [Trev]
Points per RF Bucket: 5 k
Total Steps: 5 M
Simulation Parameters
Points per Bucket: 100
Auto
No. of 1000
Auto
Simulaton Data:
Save Simulatio...
Suppress War...
Simulation Run: 1
Operation Mode:
Normal Mode
Undo - Redo
Undo
Redo

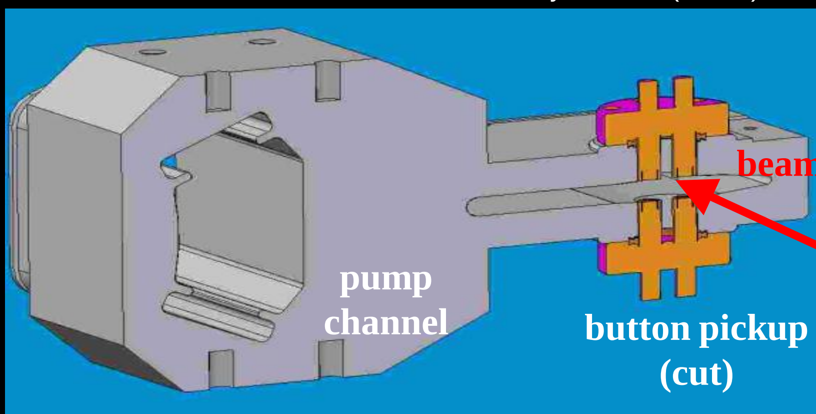
Electrostatic Pick-up – Button

Non-linear

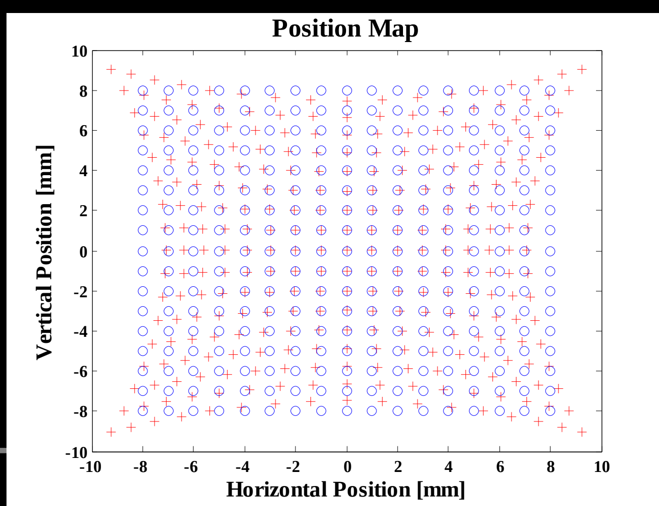
– requires correction algorithm when beam is off-centre

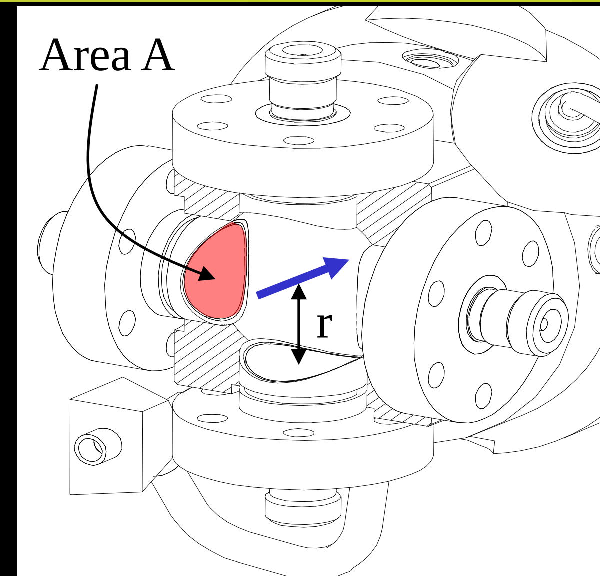
– vacuum chamber not rotational symmetric (SR-source)

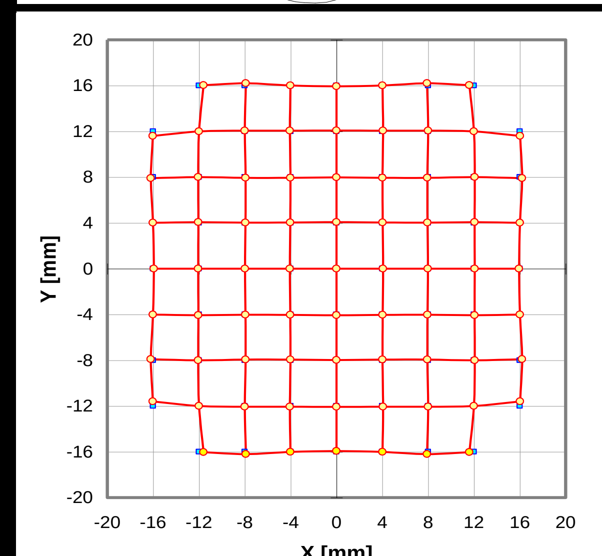
courtesy: A.Delfs (DESY)



PETRA-III BPM close to ID

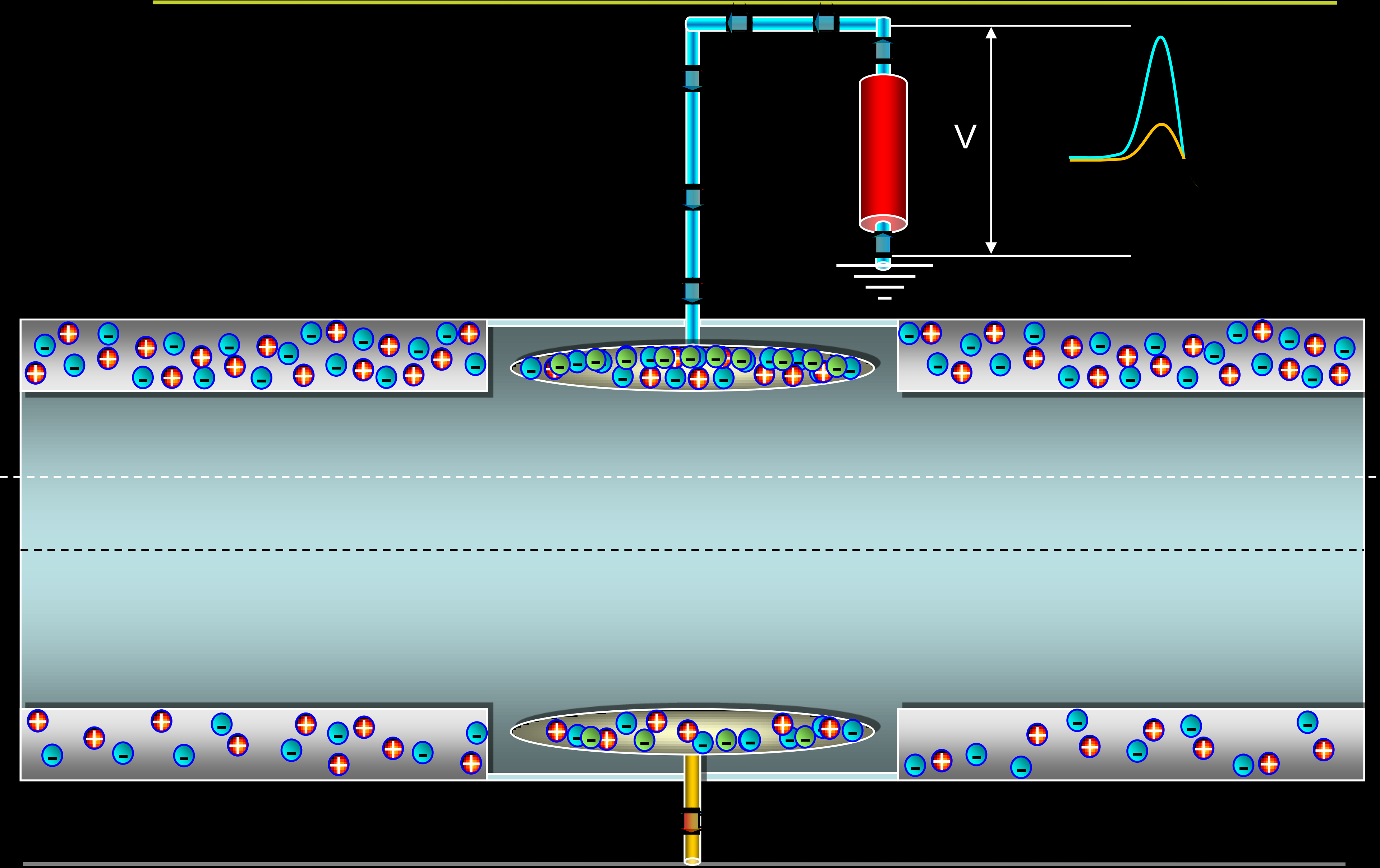


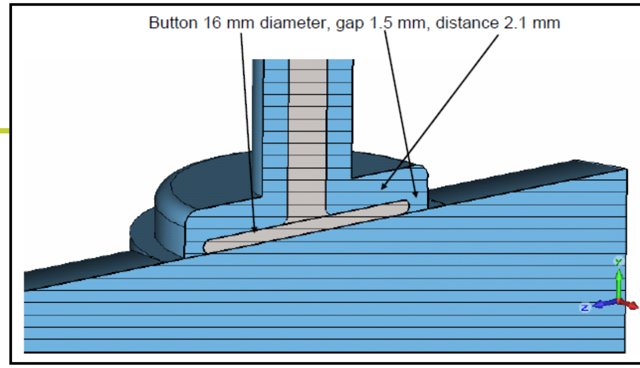


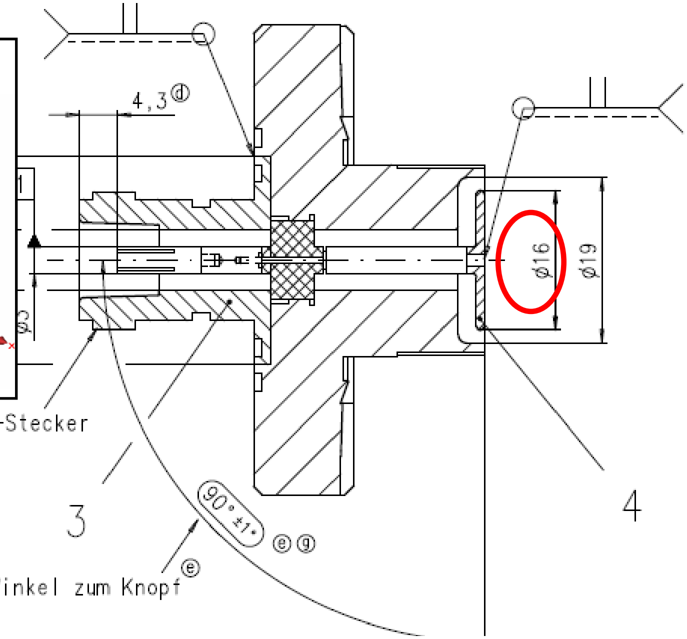


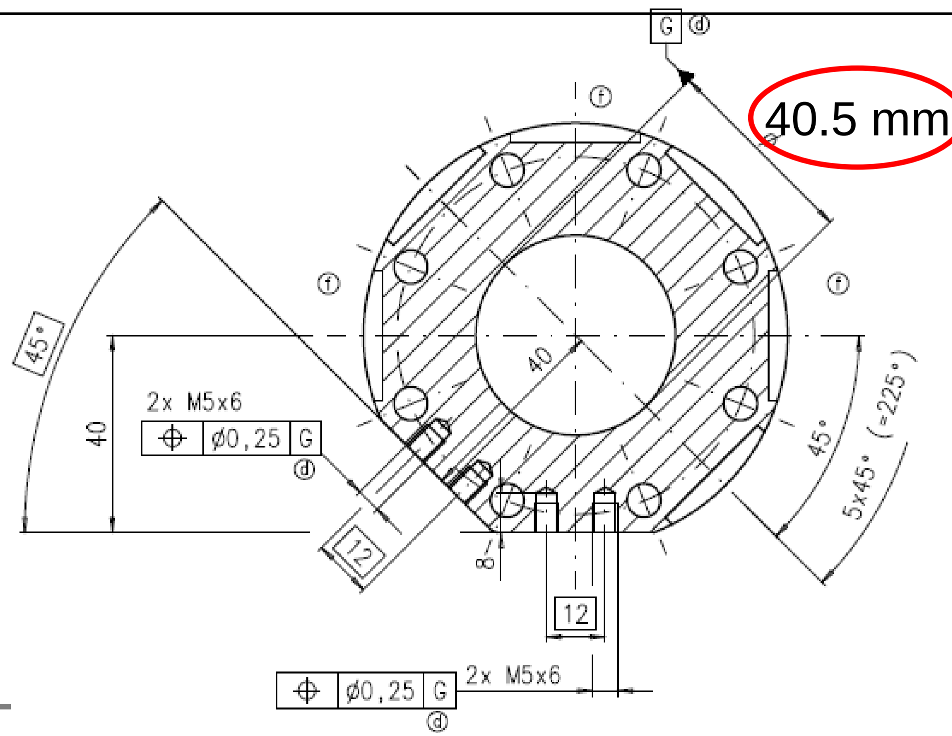
$$X = 2.30\cdot 10^{-5} X_1^{\,5} + 3.70\cdot 10^{-5} X_1^{\,3} + 1.035\,X_1 + 7.53\cdot 10^{-6} X_1^{\,3} Y_1^{\,2} + 1.53\cdot 10^{-5} X_1 Y_1^{\,4}$$

Electrostatic Beam Position Monitor




Button 16 mm diameter, gap 1.5 mm, distance 2.1 mm

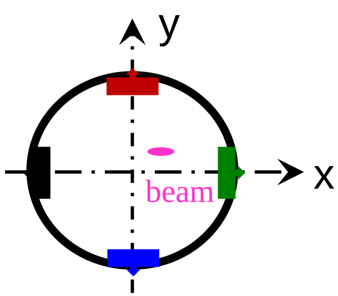

4,3 ⓓ
ø16
ø19
N-Stecker
3
4
90° ±1°
ⓔ ⓖ
Winkel zum Knopf ⓔ


G ⓓ
40.5 mm
ⓕ
45°
40
2x M5x6
⌖ ø0,25 G
ⓓ
12
8
45°
5x45° (=225°)
⌖ ø0,25 G
2x M5x6
ⓓ

Position Reconstruction

- Two common monitor geometries
  - difference in position reconstruction

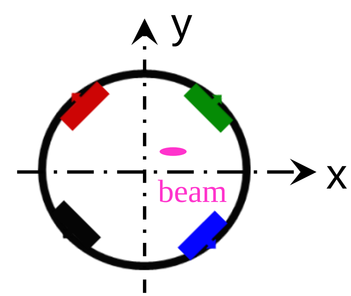
linac-type



$$x = K_x \frac{P_1 - P_3}{P_1 + P_3}$$

$$y = K_y \frac{P_2 - P_4}{P_2 + P_4}$$

storage ring-type



$$x = K_x \frac{(P_1+P_4)-(P_2+P_3)}{P_1+P_2+P_3+P_4}$$

$$y = K_y \frac{(P_1+P_2)-(P_3+P_4)}{P_1+P_2+P_3+P_4}$$

⇒ difference-over-sum or $Position = K \cdot \frac{\Delta}{\Sigma}$

Beampipe: round: r = 20.25 mm
Button Diameter: d =16.0 mm

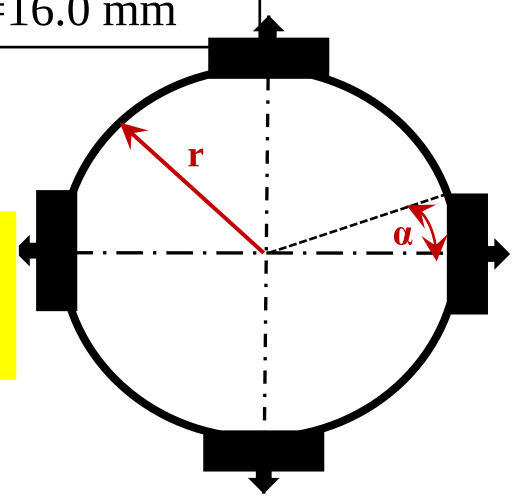
- Position Information
  - **requires knowledge of monitor constant K_x, K_y**
    → rule of thumb (circular duct)

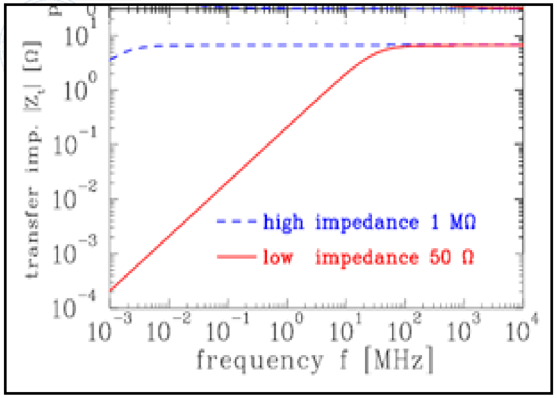
$$K_{x,y} = \frac{r}{2} \frac{\alpha}{\sin\alpha}$$ **linac-type**

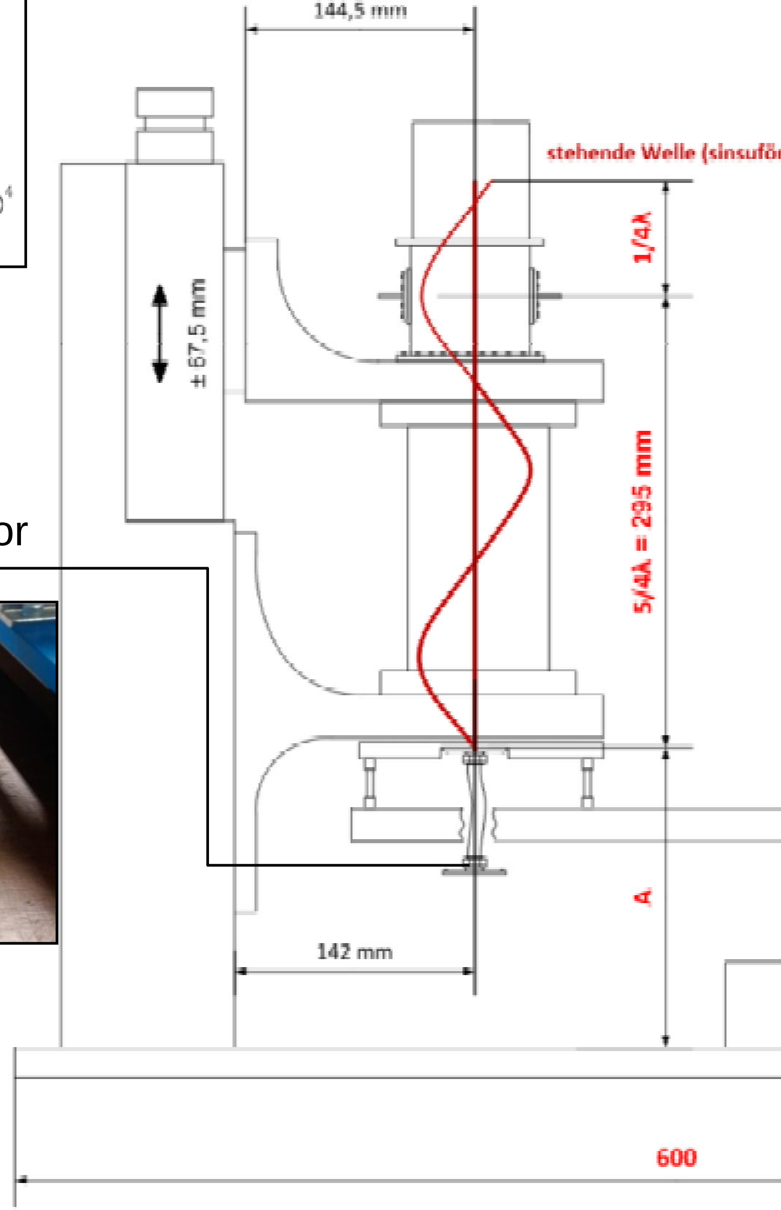
$$K_{x,y} = \frac{r}{\sqrt{2}} \frac{\alpha}{\sin\alpha}$$ **storage ring-type**

T1) Calculate K_{x}, for Linac type

sin(α) =
α =
K_x =







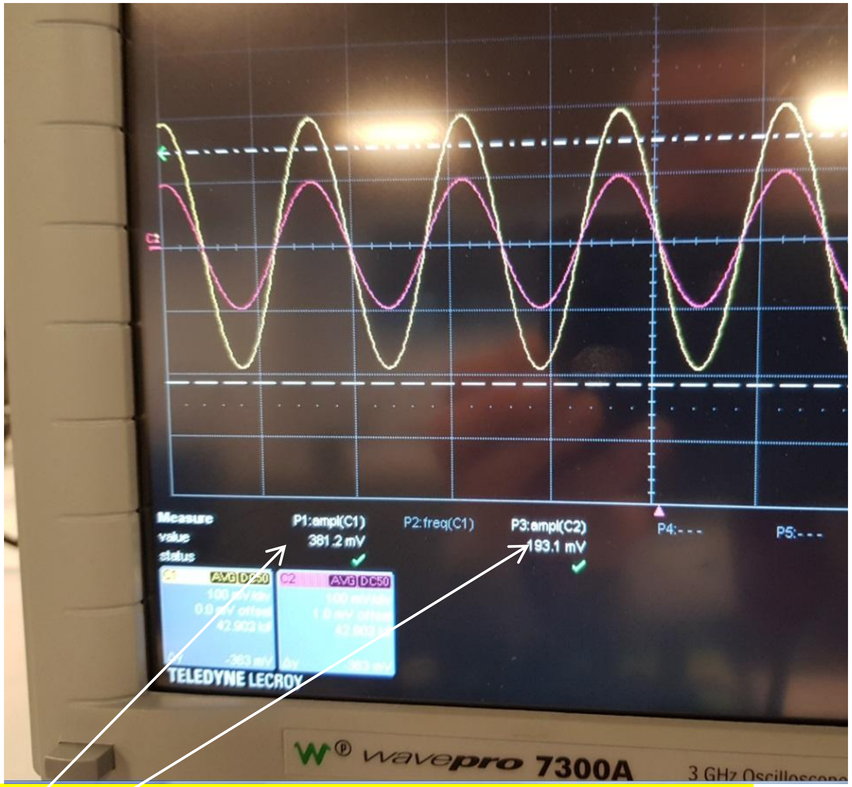
1.3 GHz sine wave generator

Tasks: BPMs

Signal generation by button BPM

- calculate monitor constants for BPMs
  - use rule-of-thumb formulae

- measure XFEL BPM monitor constants



- T2) define electrical center of both planes and calibrate movers
- T3) perform 1-dim. scan along one axis → max. wire position: ± 15 mm (!!!)

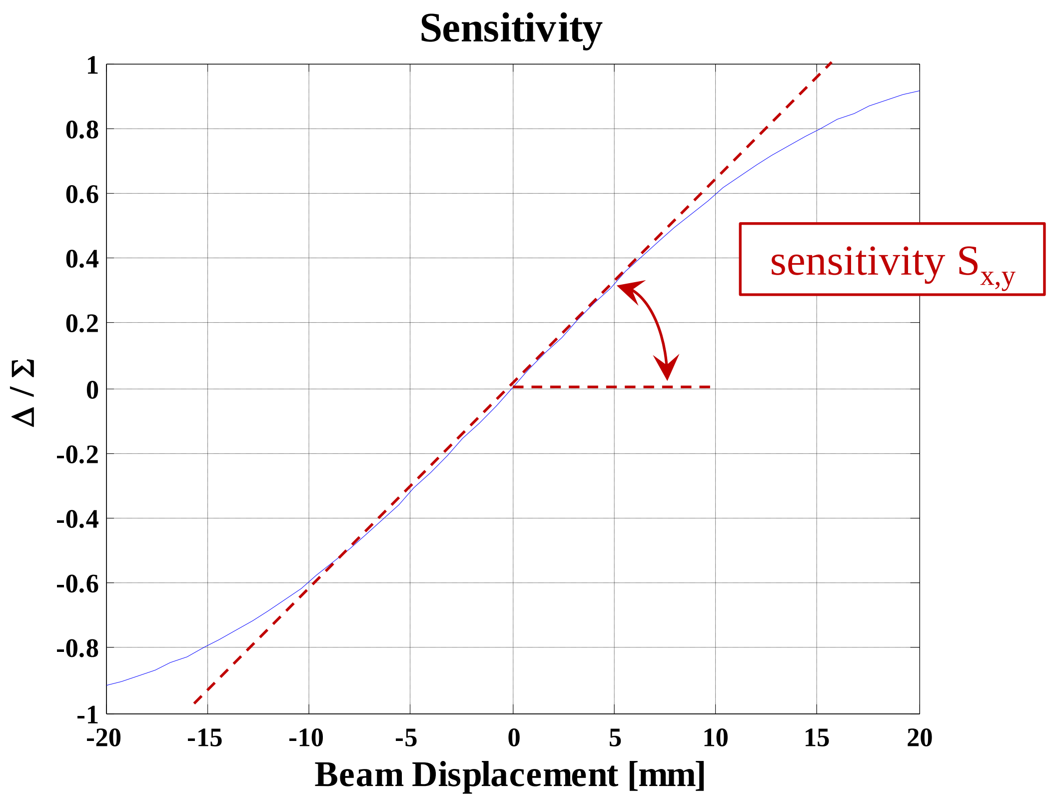
→ 3a) measure signal amplitudes from each button (x-plane only)
→ 3b) calculate Δ/Σ from measured signals
→ 3c) plot Δ/Σ versus wire position

- T4) determine monitor constant from slope at origin and compare with rule-of-thumb

Monitor Constant Calculation

$$x = K_x \frac{P_1 - P_3}{P_1 + P_3} = K_x * \Delta/\Sigma$$

- sensitivity: slope at origin



Please stay in the middle of Chamber!!!!-

Maximum ± 15 mm

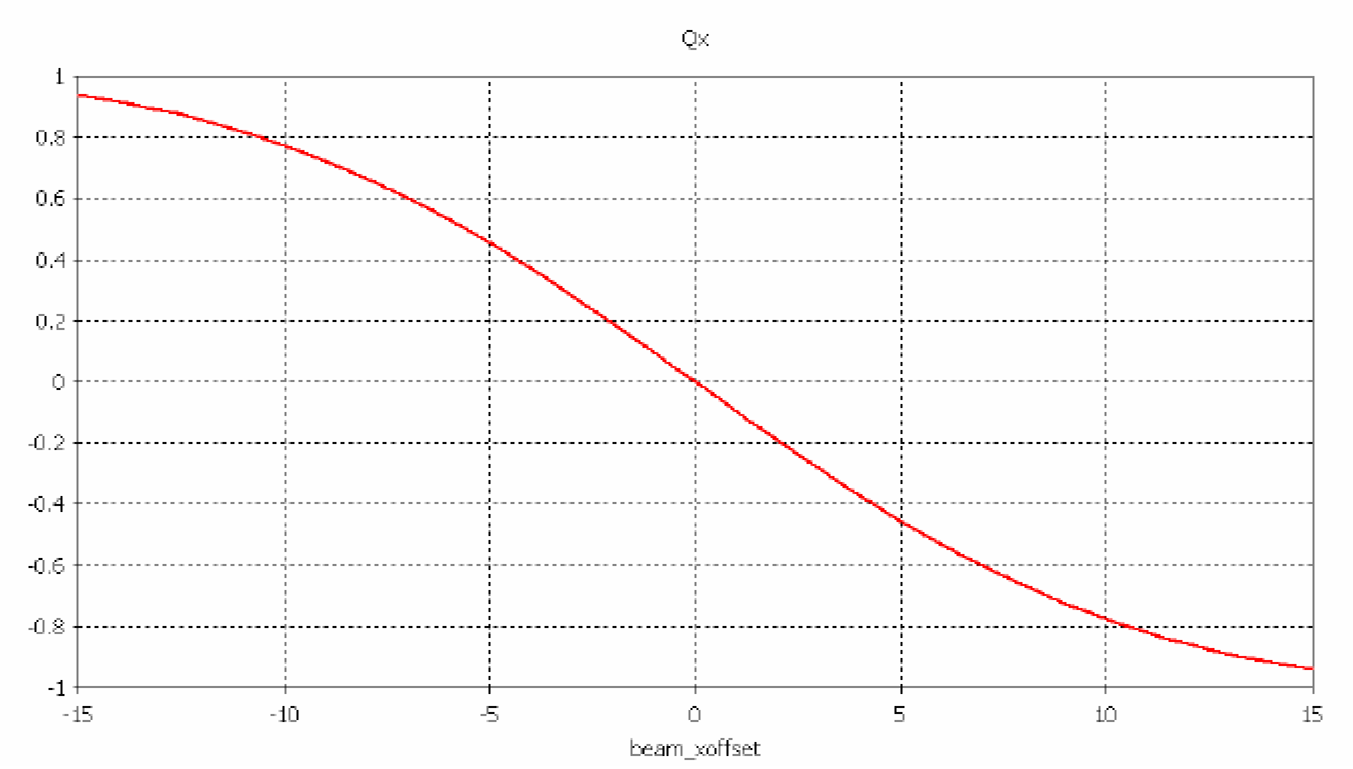
(more might damage the antenna)

- monitor constant: $K_{x,y} = S_{x,y}^{-1}$

- End

From CST Simulation

Delta over Sum



Scan in x, Sensitivity=0.0942/mm, monitor constant=10.61 mm

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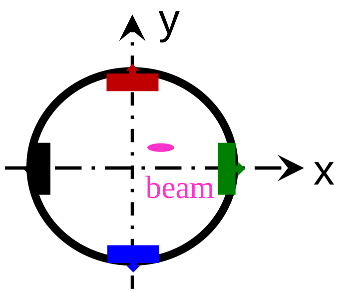

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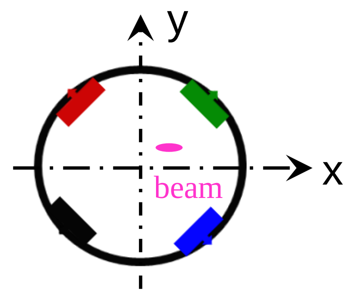
storage ring-type



$$x = K_x \frac{(P_1+P_4) - (P_2+P_3)}{P_1+P_2+P_3+P_4}$$

$$y = K_y \frac{(P_1+P_2) - (P_3+P_4)}{P_1+P_2+P_3+P_4}$$

$\Rightarrow$ difference-over-sum or $Position = K \cdot \frac{\Delta}{\Sigma}$

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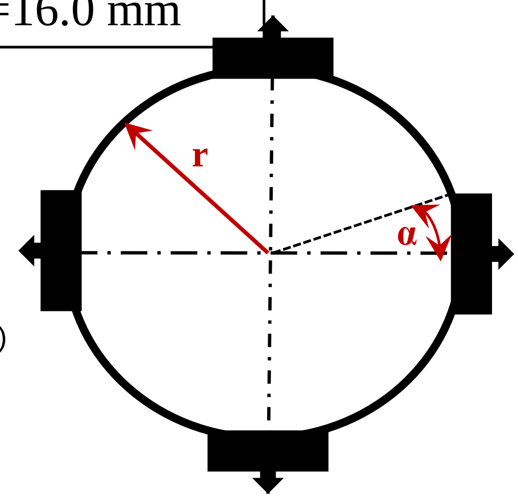
$$K_{x,y} = \frac{r}{\sqrt{2}} \frac{\alpha}{\sin\alpha} \quad \text{storage ring-type}$$

T1) Calculate K_x, for Linac type

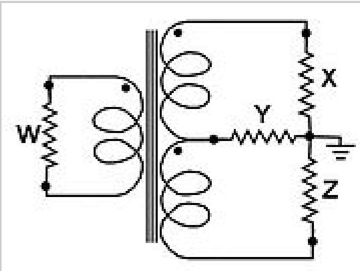
$\sin(\alpha)$ = 0.367
α = 0.376
K_x = 10.367 mm (linac)



180 deg Hybrids

Input at x and z
out W = x+z, out Y = x-z

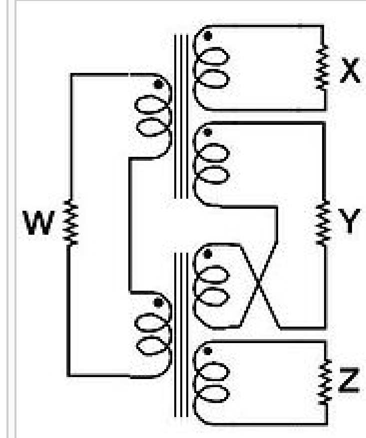
Single transformer hybrid [edit]



Wiring diagram of a single transformer hybrid

For use in 2-wire repeaters, the single transformer version suffices, since amplifiers in the repeaters have grounded inputs and outputs. X, Y, and Z share a common ground. As shown at left, signal into W, the 2-wire port, will appear at X and Z. But since Y is bridged from center of coil to center of X and Z, no signal appears. Signal into X will appear at W and Y. But signal at Z is the difference of what appears at Y and, through the transformer coil, at W, which is zero. Similar reasoning proves both pairs, W & Y, X & Z, are conjugates.

Double transformer hybrid [edit]



Wiring diagram of a double transformer hybrid

When both the 2-wire and the 4-wire circuits must be balanced, double transformer hybrids are used, as shown at right. Signal into port W splits between X and Z, but due to reversed connection to the windings, cancel at port Y. Signal into port X goes to W and Y. But due to reversed connection to ports W and Y, Z gets no signal. Thus the pairs, W & Y, X & Z, are conjugates.

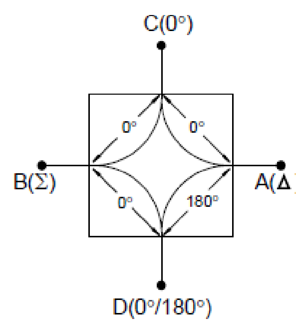
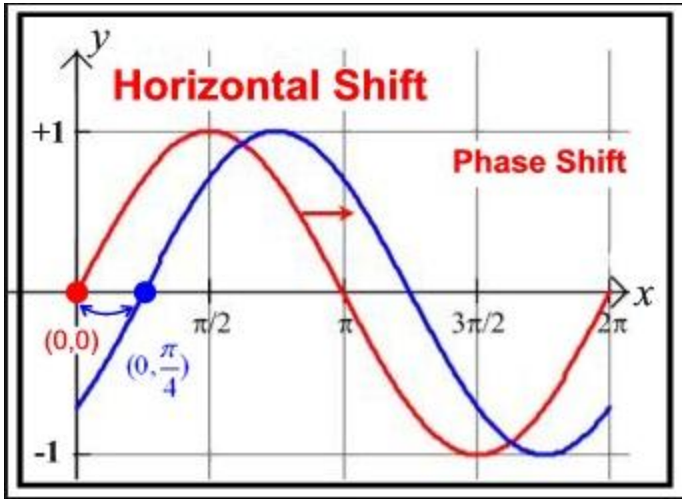


Figure 1a: RF Frequencies
(Up to 2000 MHz)

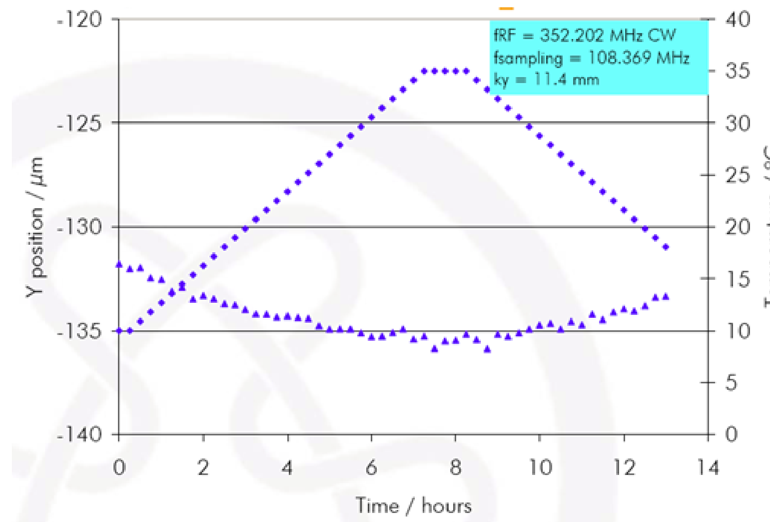
180° Hybrids Functional Description

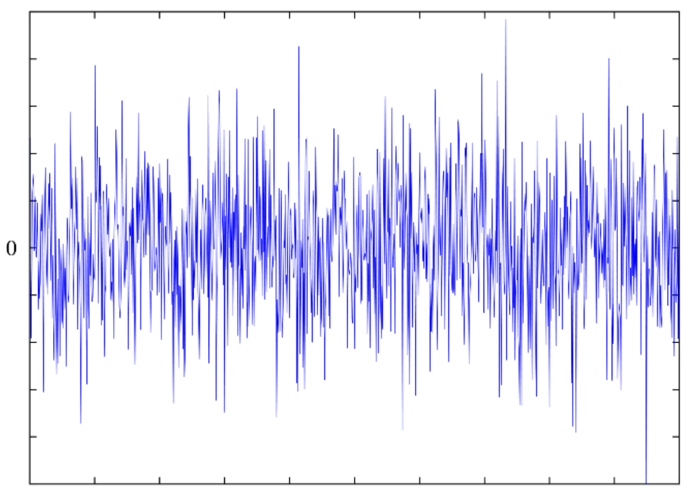
A 180° hybrid is a reciprocal four-port device which provides two equal amplitude in-phase signals when fed from its sum port (Σ) and two equal amplitude 180° out-of-phase signals when fed from its difference port (Δ). Conversely, signals input into ports C and D will add at the sum port (B) and the difference of the two signals will appear at the difference port (A). **Figure 1** is a functional diagram which will be used in this article to represent the 180° hybrid. Port B can be considered the sum port and port A is the difference port. Ports A and B and ports C and D are isolated pairs of ports.

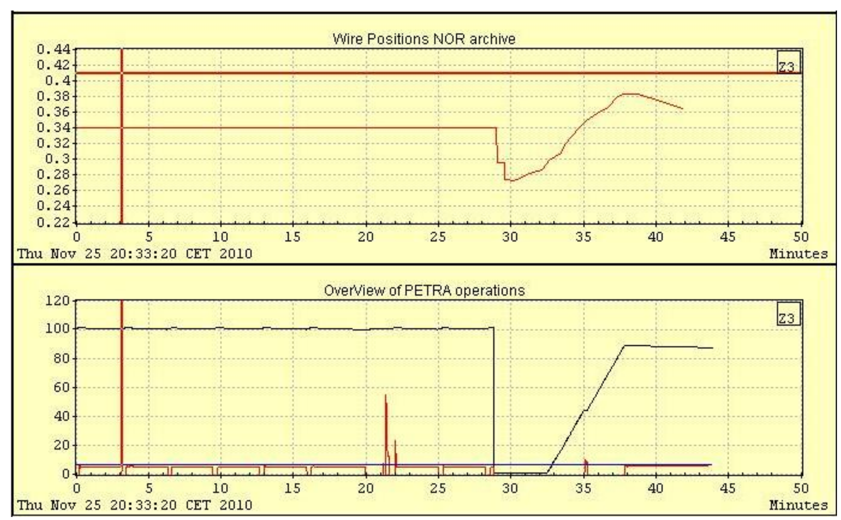
Phase, Noise, and Drifts (Stability)



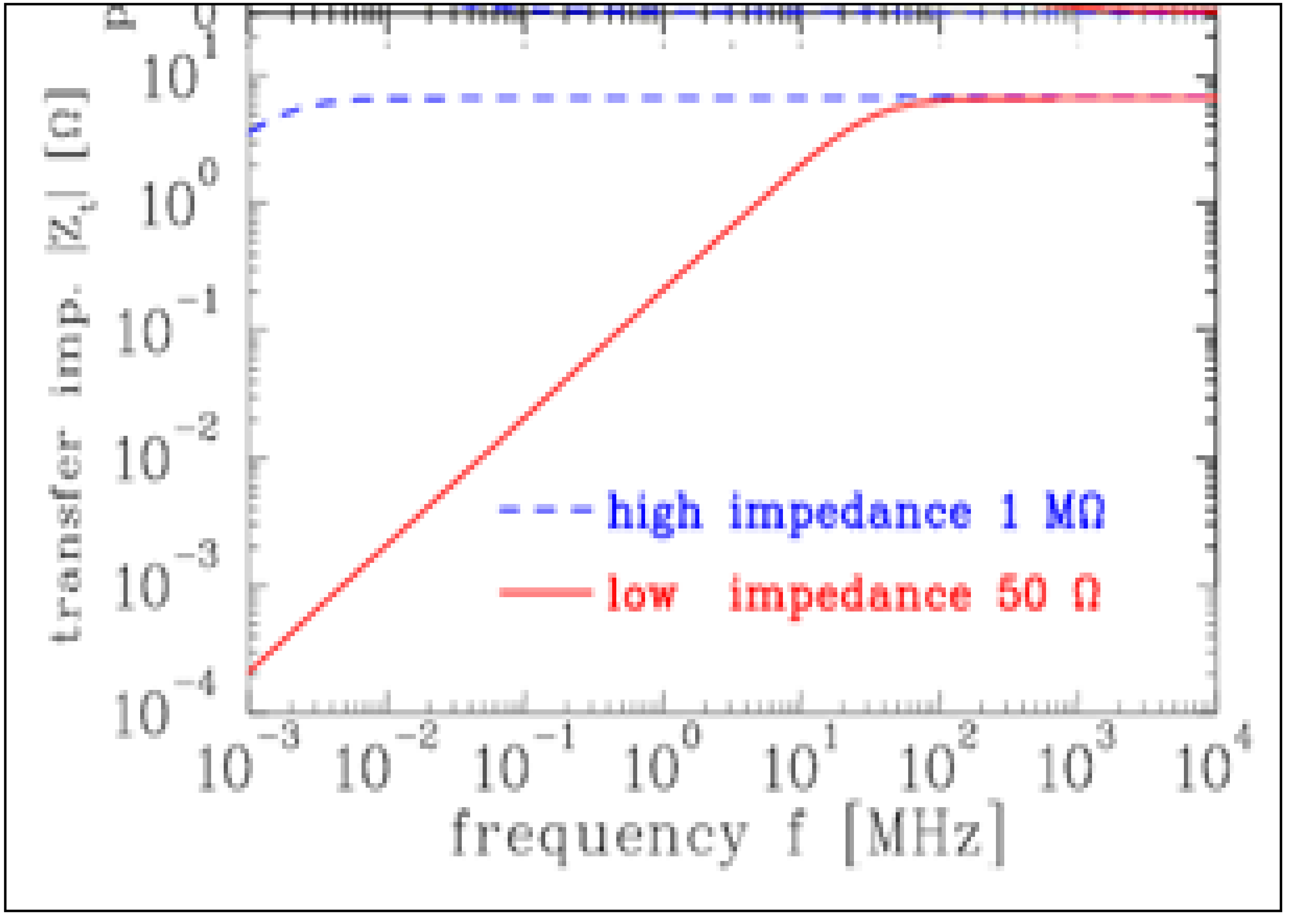
Problem: Electronic drift: 0.2 μm/^{0}C



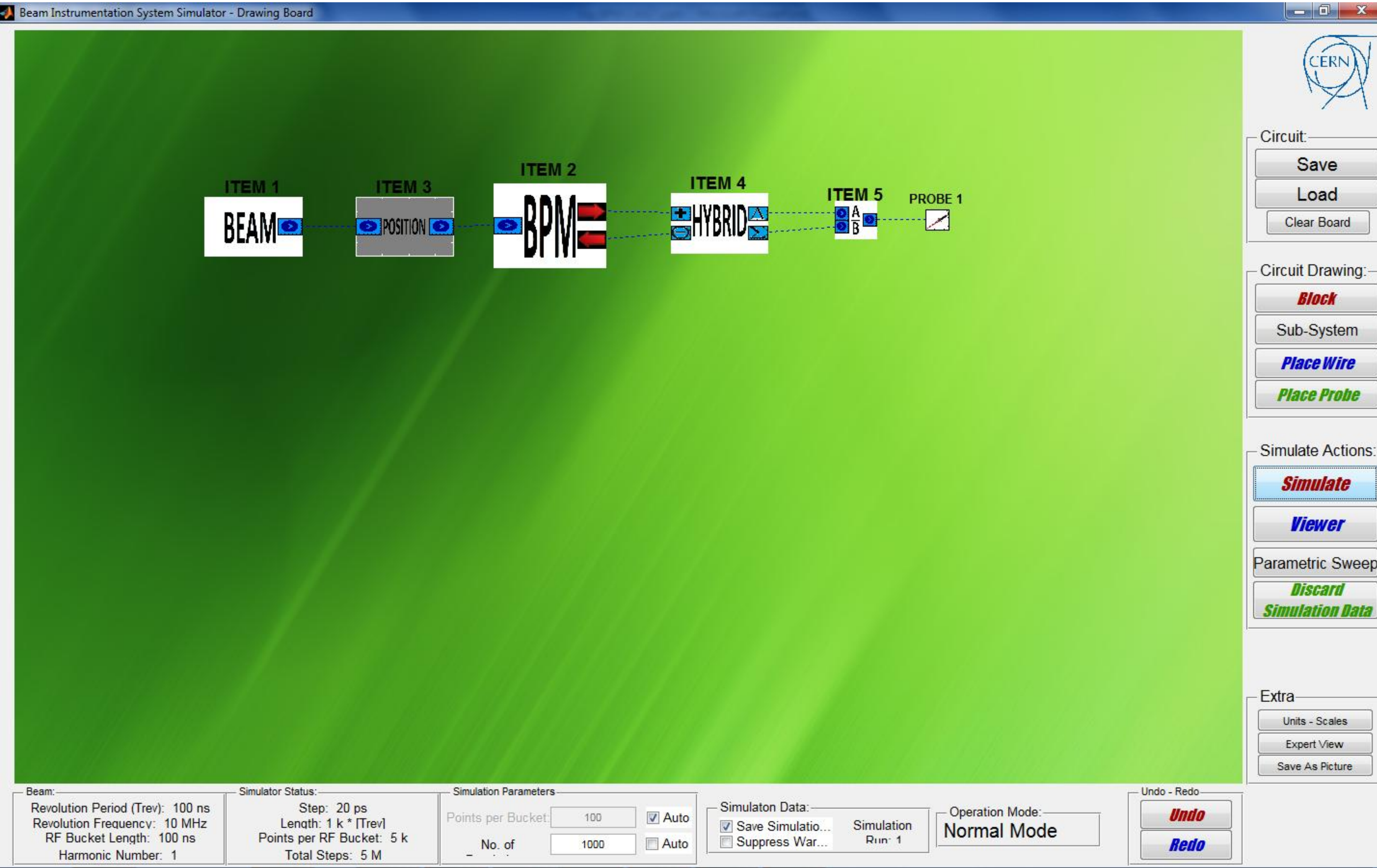




Sensitivity



Simulation



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Simulaton Data:
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Simulation Run: 1
Operation Mode:
Normal Mode
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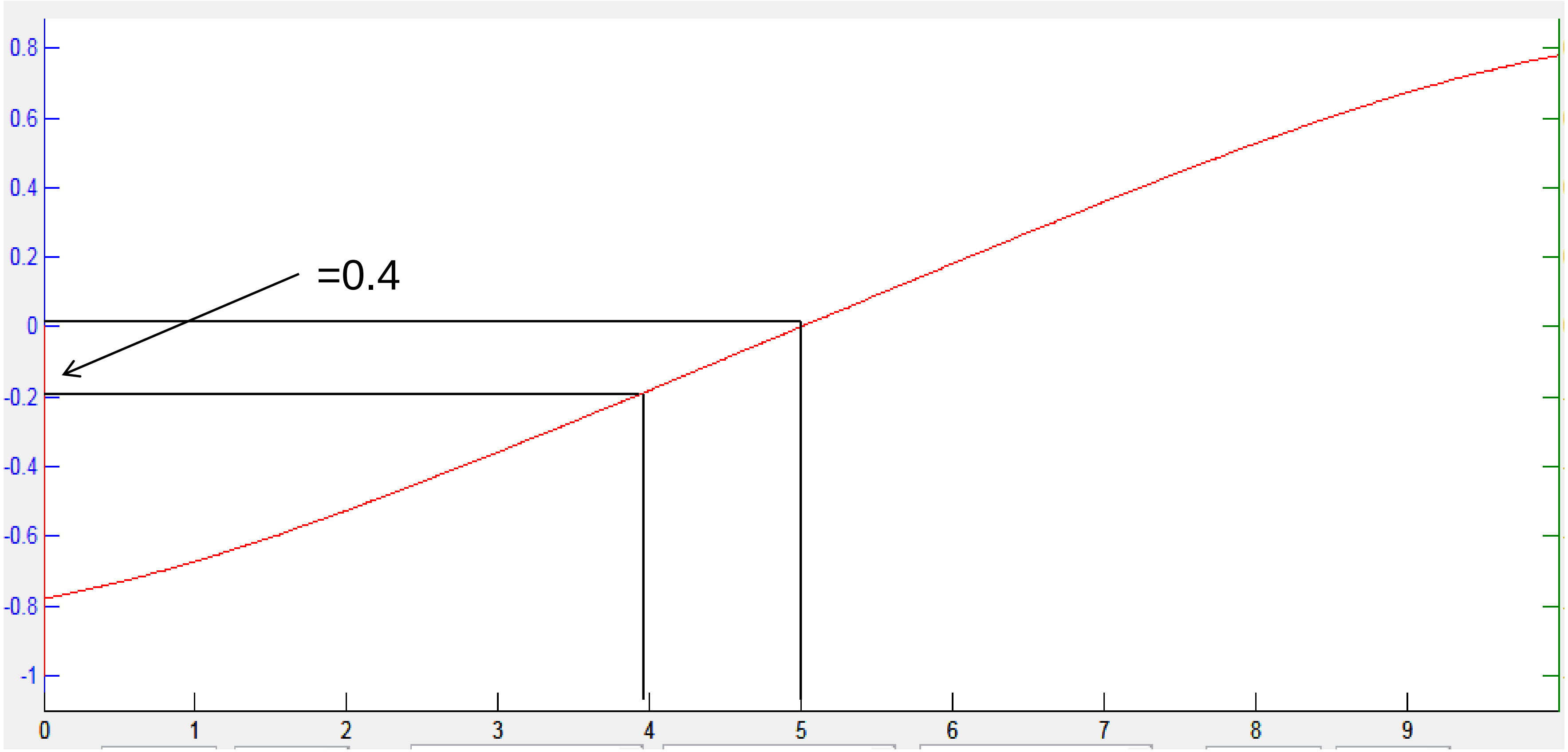
Undo
Redo

Multiply to the Scale a factor 2!



y=S*x, $x_{\text{full scale}}$ = position variation, S=y/x

-100% to 100% means the ± radius => x=10 => x= 40.5 mm

K_x = 1/S = 4.05 / 0.40 = 10.15