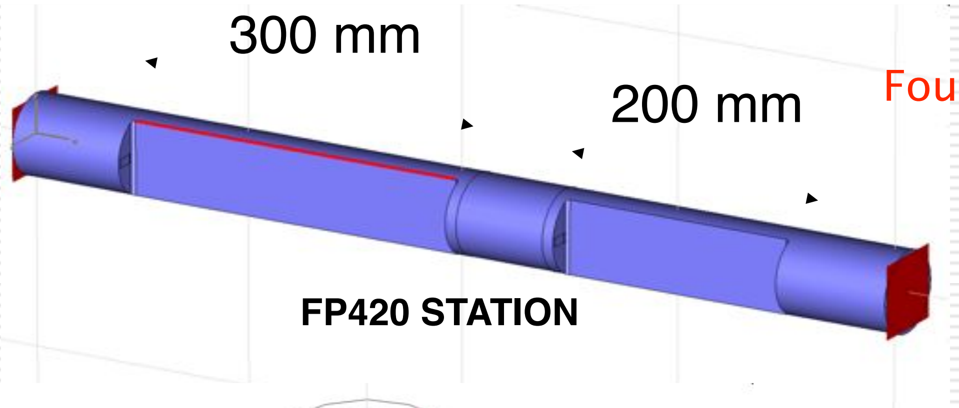
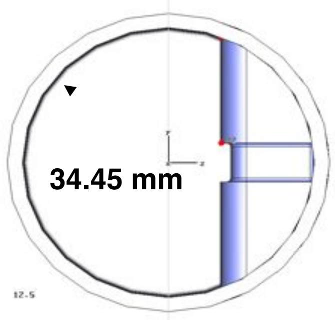
# FP420 detectors

Mechanical design based on **movable "Hamburg Pipe"**

Four detectors proposed (IP1, IP5, beam1 + beam2)

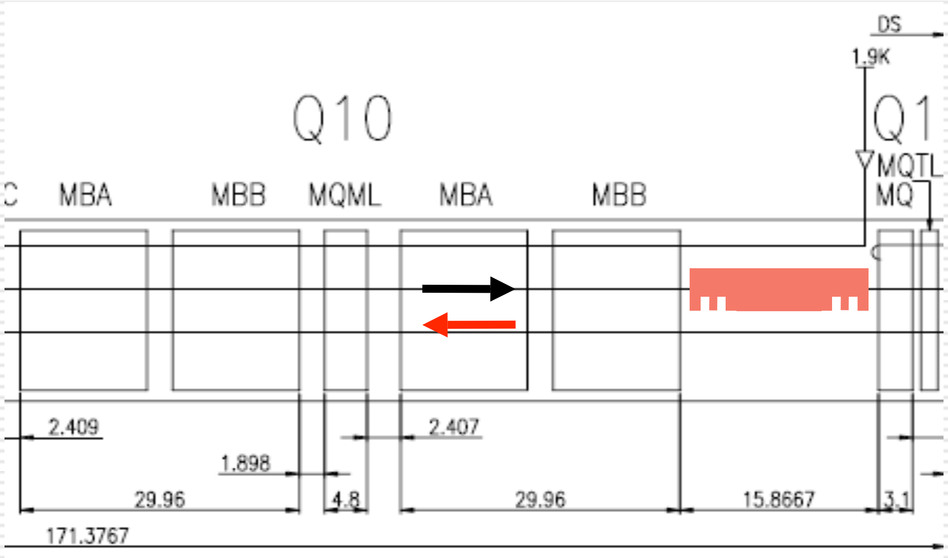
- Two (or three) stations for each detector
  - Two pockets for each station with (20cm + 30 cm)



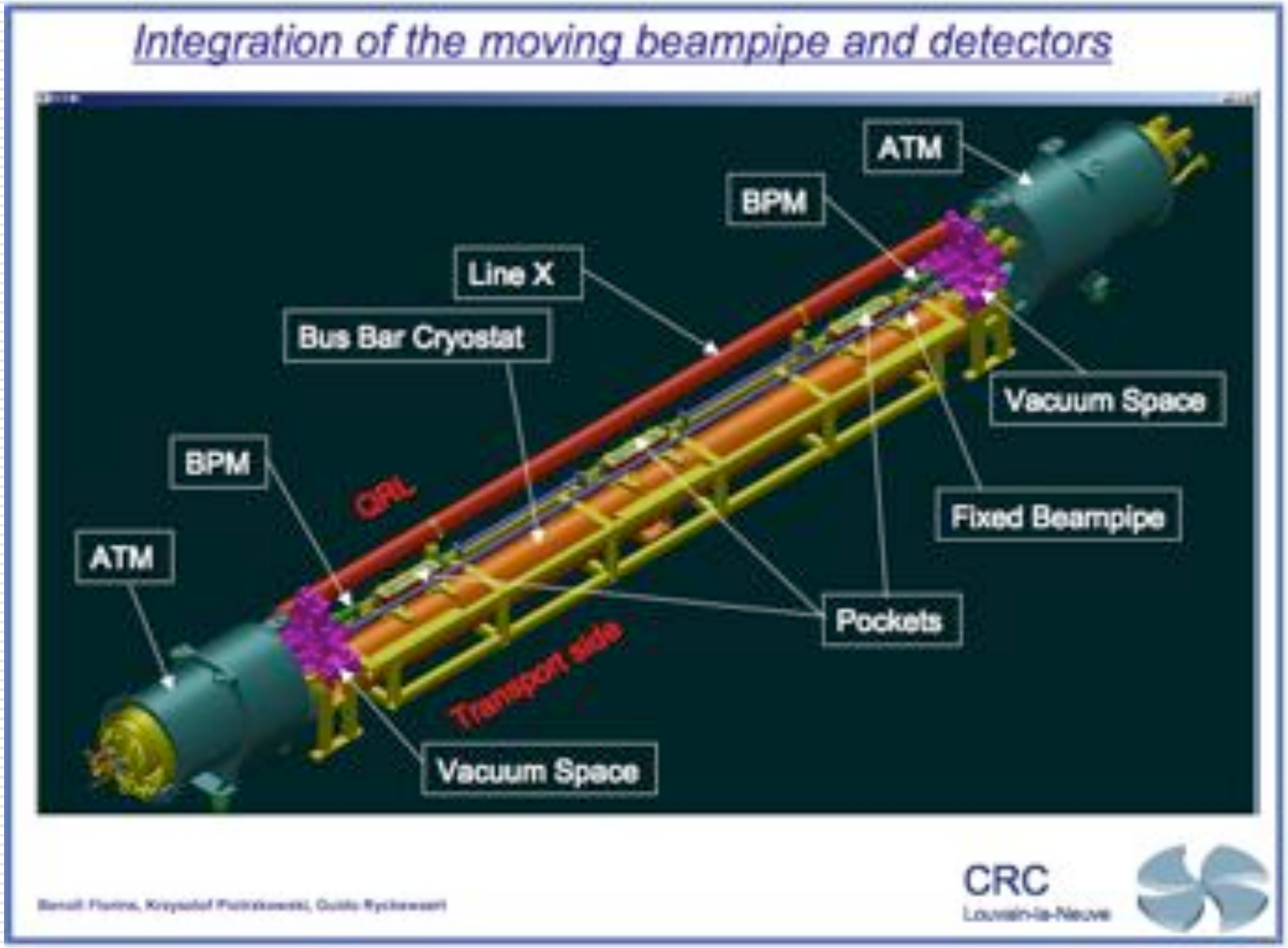




BEAM 1

BEAM 2



# FP420 integration



# How to measure the impedance

## Stretched wire method

The wire is used to simulate the EM fields induced by the beam. The structure becomes a coaxial wave guide structure with TEM modes. The set up consists in some alignment system and a Vector Network Analyzer as RF source.

The longitudinal impedance can be inferred from scattering parameters analysis. In particular: the signal S21 transmitted through the wire along the Device Under Test (DUT) has to be compared to the one measured along a smooth reference beam pipe with the same length of the DUT.

Longitudinal impedance

$$Z_{||}(f) = -2Z_c ln \frac{S_{21}^{DUT}(f)}{S_{21}^{REF}(f)}$$

with: $Z_c$ = Line impedance

$d$ = Wire diameter

$D$ = Inner pipe diameter (or distance between plates)

Transverse impedance from longitudinal impedance variation

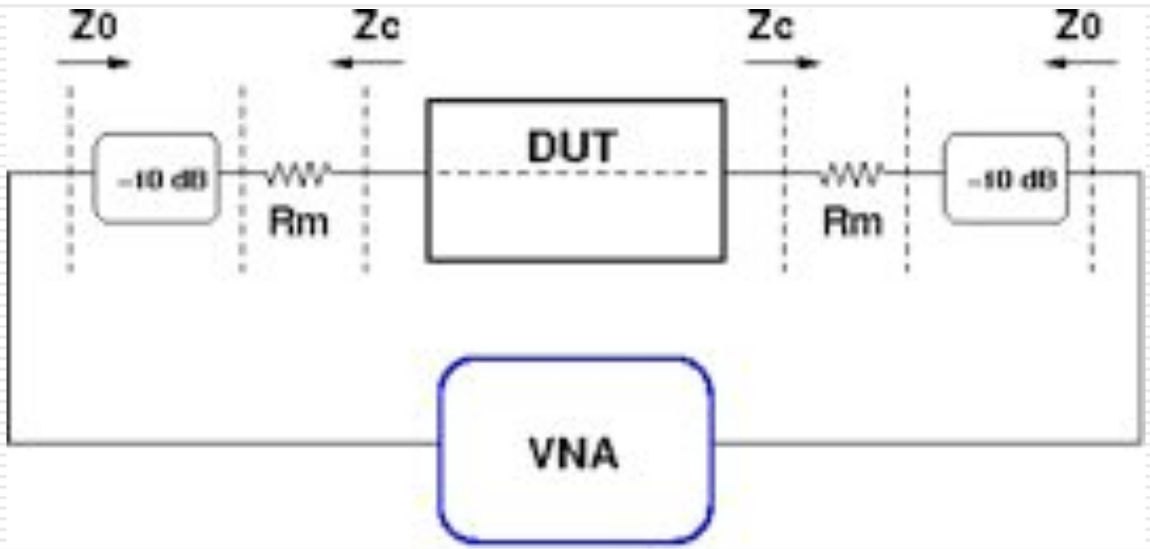
$$Z_{\perp}(x,\omega) \simeq \frac{c}{\omega} \frac{Z_{||}(x) - Z_{||}(x=0)}{x^2}$$

# Stretched wire measurements - Matching

We saw with numerical simulations that tapering cones were not very helpful at low frequencies

→ resistors to match the line impedance/cables

→ The residual mismatch is calibrated out (measuring only cables + resistors)



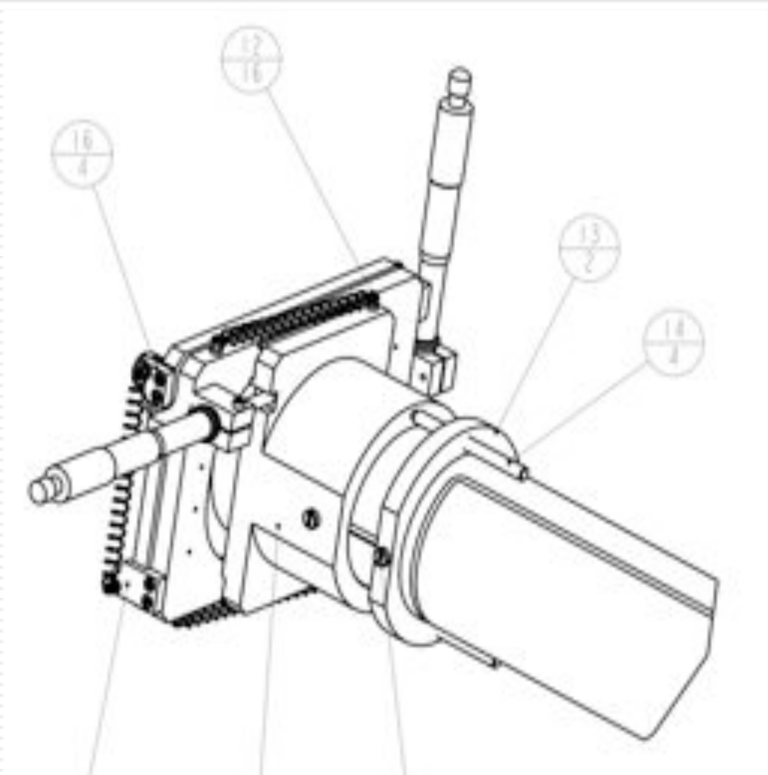

$$
\begin{aligned}
R_m &= Z_c - Z_0 \\
Z_0 &= 50\,\Omega \\
Z_c &= \text{From analytical models, i.e. } 60 \cdot ln\left(\frac{d}{D}\right) \text{ for cyl. coax} \\
& \quad \text{Moving the wire } Z_c \text{ changes, unavoidable missmatch}
\end{aligned}
$$

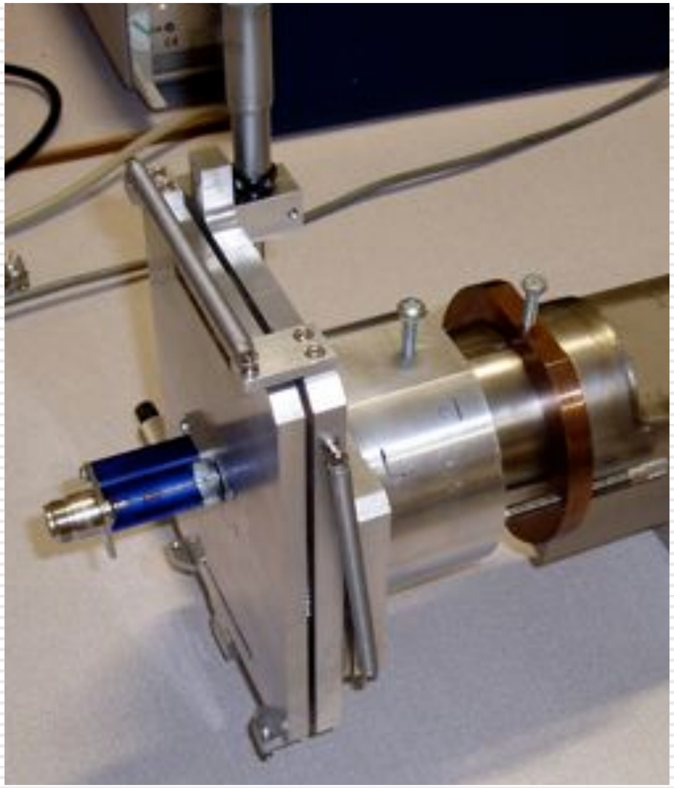
# Laboratory measurements

Laboratory setup at Cockcroft Institute

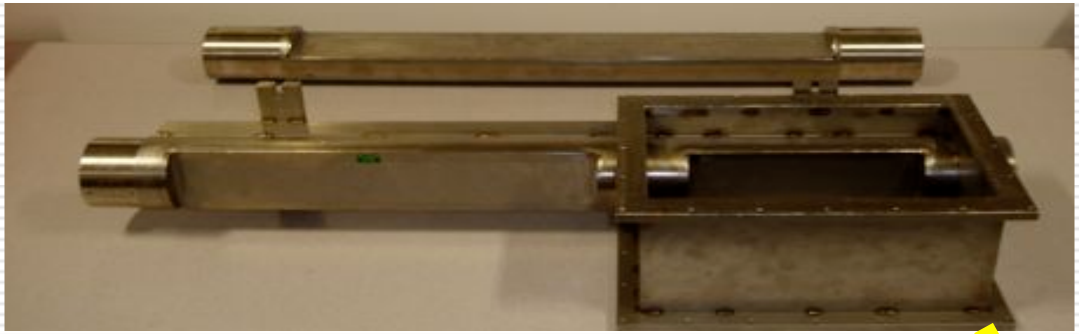
Sophisticated system to position and stretch the wire

High precision micrometer screws to monitor the wire position





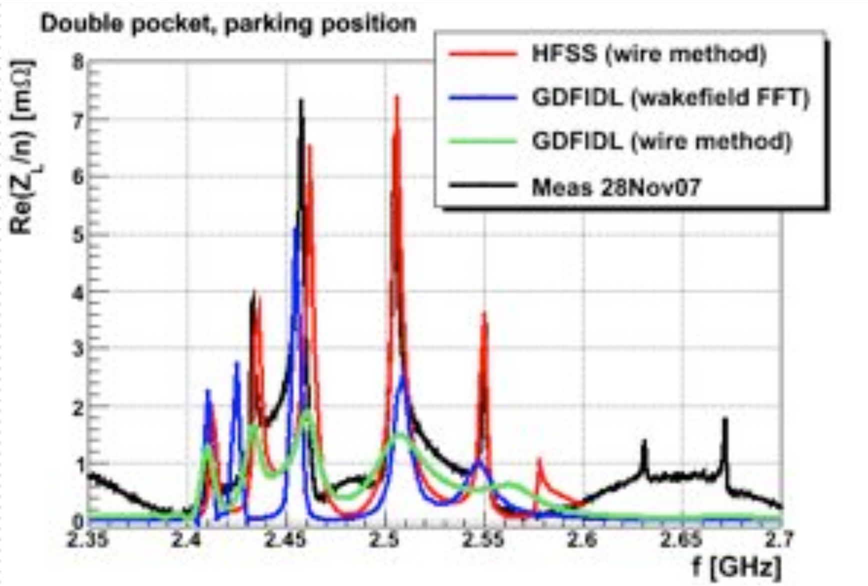
# Beam pipe with pockets prototypes

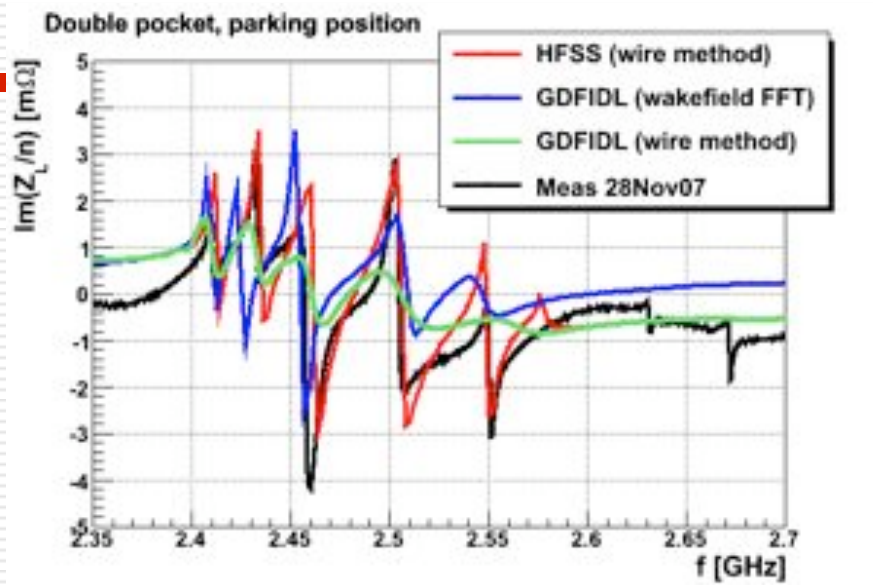


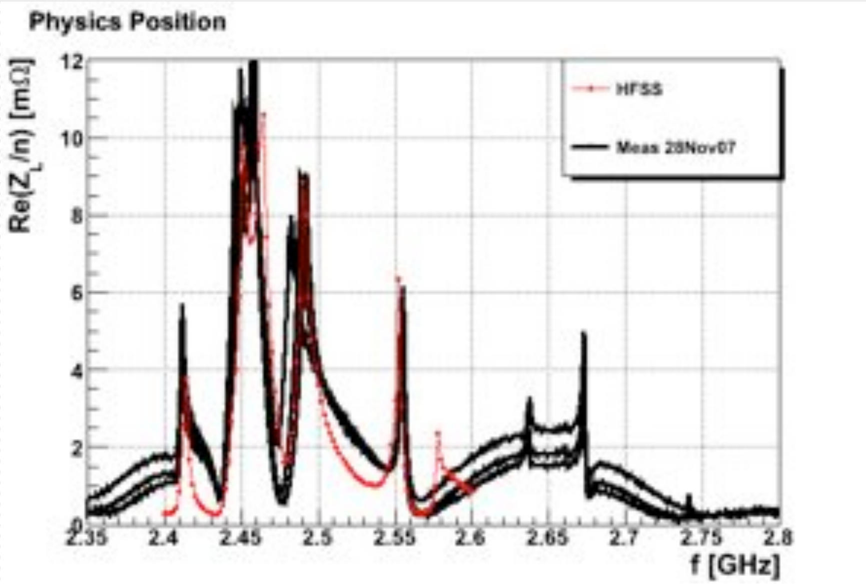
- Single and double pocket prototypes are here at CI and have been measured

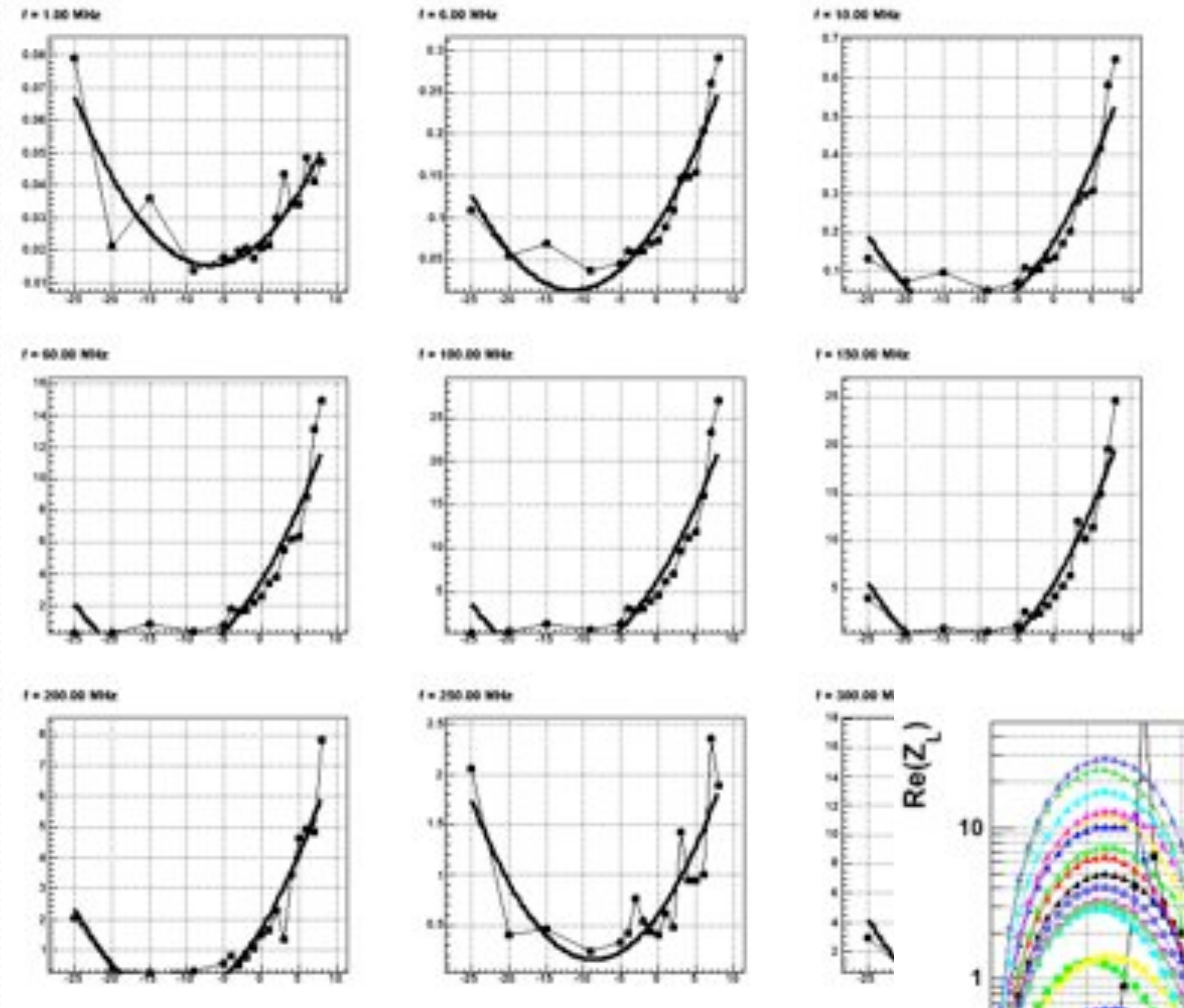
- Box designed for hosting tracking detectors
- prototype used for CERN test beam in Oct 2007

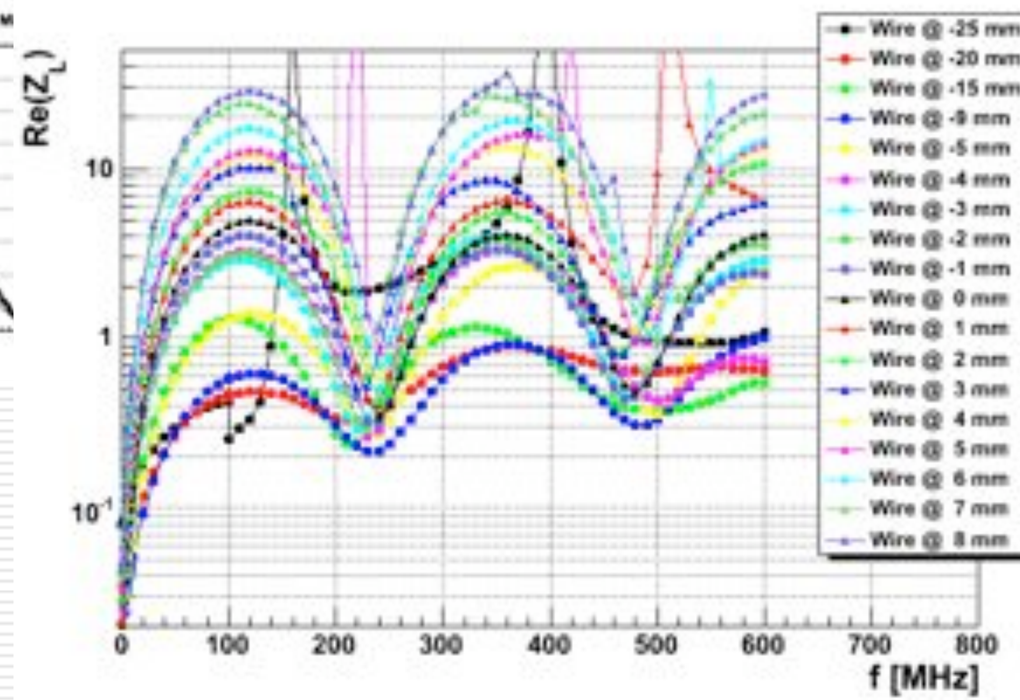
TEXT


Double pocket, parking position
HFSS (wire method)
GDFIDL (wakefield FFT)
GDFIDL (wire method)
Meas 28Nov07
Re(Z_L/n) [mΩ]
f [GHz]


Double pocket, parking position
HFSS (wire method)
GDFIDL (wakefield FFT)
GDFIDL (wire method)
Meas 28Nov07
Im(Z_L/n) [mΩ]
f [GHz]

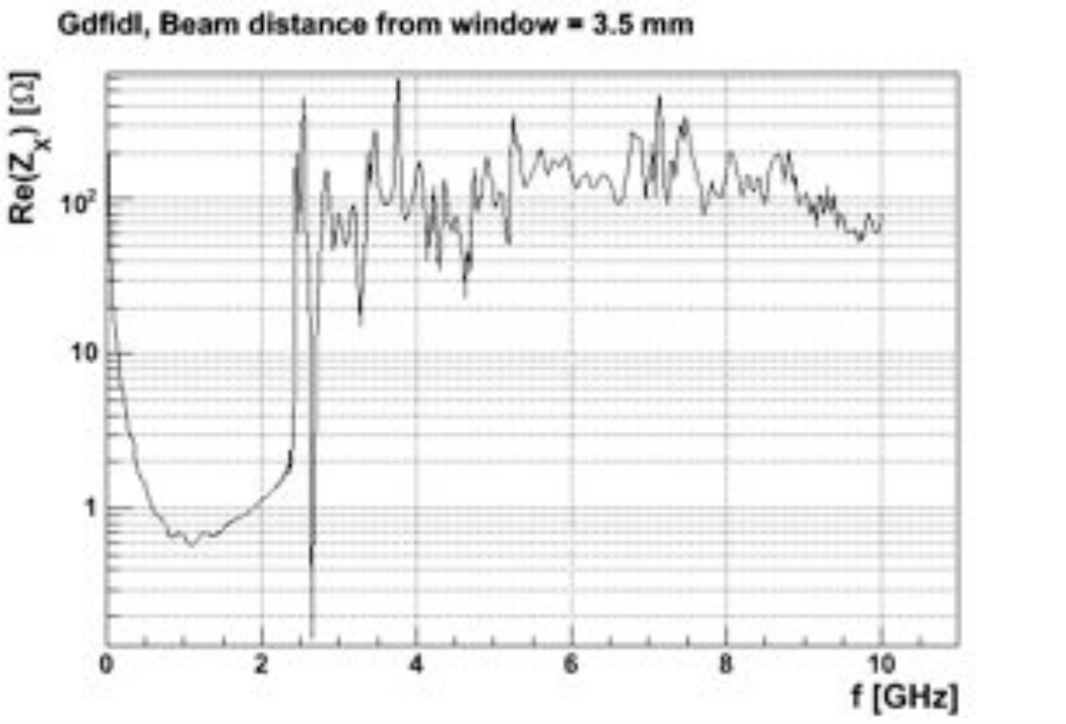

Physics Position
HFSS
Meas 28Nov07
Re(Z_L/n) [mΩ]
f [GHz]

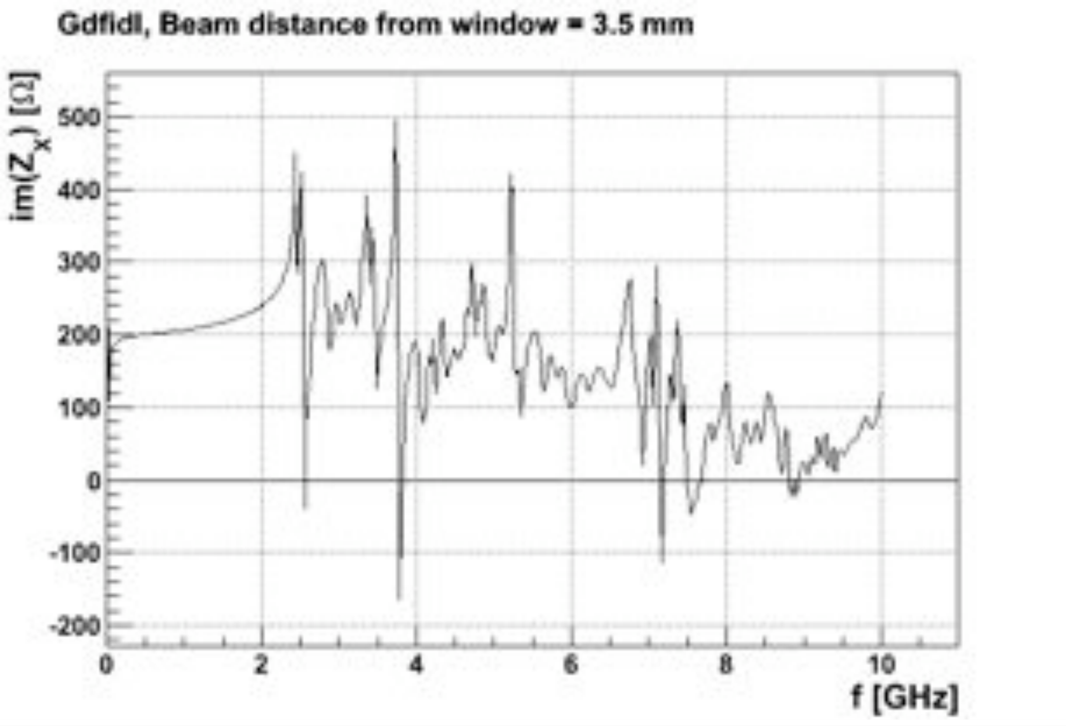




Re(Z_L)
10
1
10^-1
0
100
200
300
400
500
600
700
800
f [MHz]
Wire @ -25 mm
Wire @ -20 mm
Wire @ -15 mm
Wire @ -9 mm
Wire @ -5 mm
Wire @ -4 mm
Wire @ -3 mm
Wire @ -2 mm
Wire @ -1 mm
Wire @ 0 mm
Wire @ 1 mm
Wire @ 2 mm
Wire @ 3 mm
Wire @ 4 mm
Wire @ 5 mm
Wire @ 6 mm
Wire @ 7 mm
Wire @ 8 mm

TEXT


Gdfidl, Beam distance from window = 3.5 mm
Re(Z_x) [Ω]
10²
10
1
0
2
4
6
8
10
f [GHz]

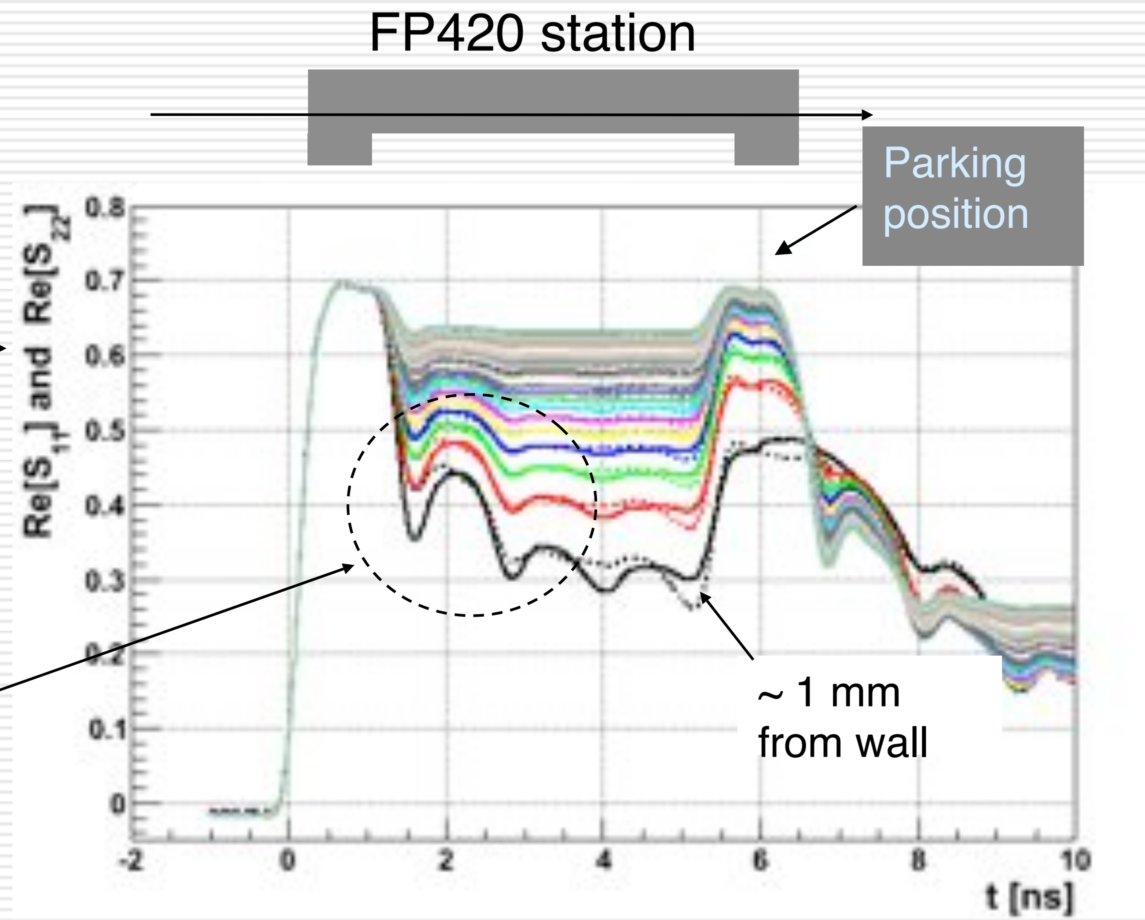

Gdfidl, Beam distance from window = 3.5 mm
Im(Z_x) [Ω]
500
400
300
200
100
0
-100
-200
0
2
4
6
8
10
f [GHz]

# Measurements in reflection mode

**REFLECTED POWER**

**S11 (solid) and S22 (dashed)**

**In TIME DOMAIN for different wire positions w.r.t pipe wall**




Multiple reflections to be averaged out by offline analysis

This signals can be used to estimate line impedance to be used in the “log formula”

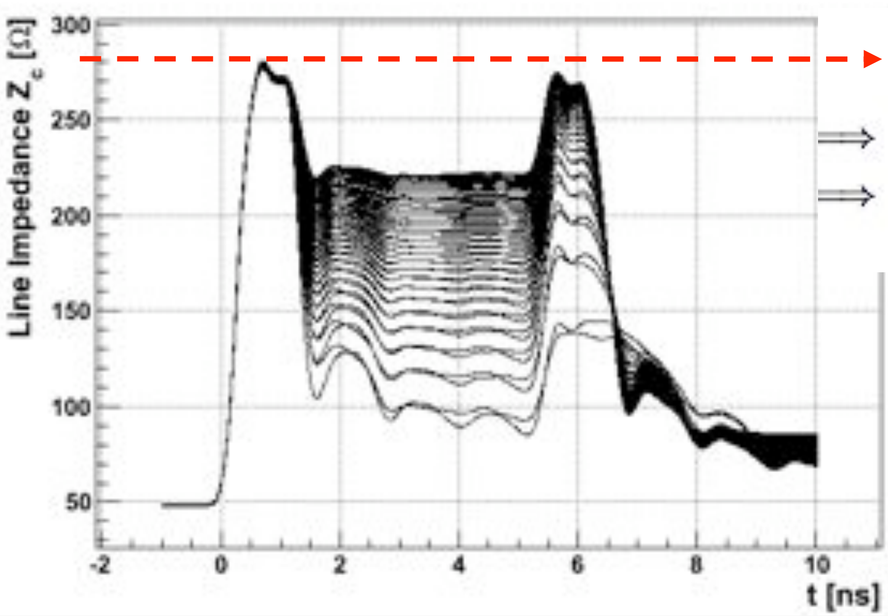
–as function of long position

–as function of wire transverse position

**RELEVANT FOR OUR ASYMMETRIC STRUCTURE**

# Meas. in reflection - Line impedance

$$Z_c = Z_0 \frac{1+S_{11}}{1-S_{11}}$$ line impedance from reflection signal , $Z_0 = 50\,\Omega$




Line impedance

$Z_c \approx 270\,\Omega$

$\Longrightarrow$ 10 % smaller than analytical value for symmetric structure

$\Longrightarrow$ Real part of longitudinal impedance 10 % smaller than what quoted in previous plots

# Meas. in reflection - Wire position (I)

**Reflected signal in time domain.** We can use it to do this:

$$Z_c^1 = Z_0 \frac{1+S_{11}}{1-S_{11}}, \quad Z_0 = 50\,\Omega$$

Line impedance from reflection signal

$$Z_c^2 = 60\ acosh\left(\frac{2\,b}{d}\right)$$

Line impedance of a wire with diameter d at distance b from a plate

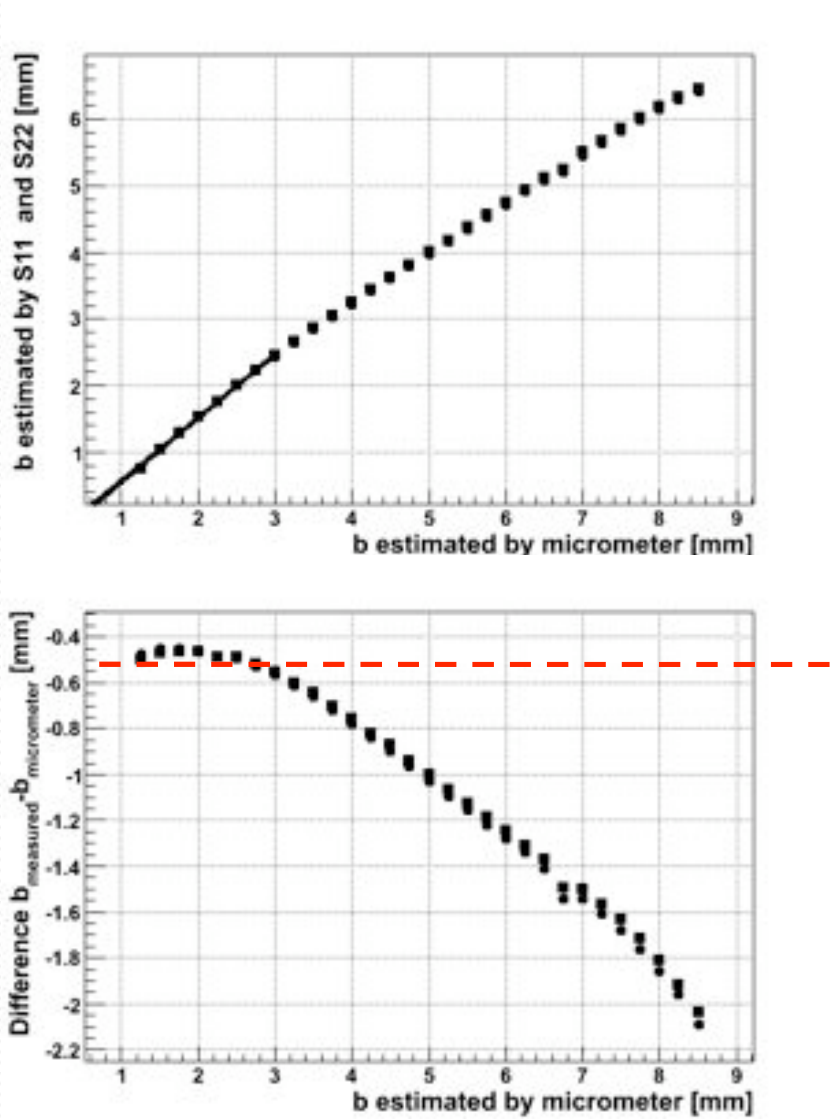
$$Z_c^1 \equiv Z_c^2 \quad \Longrightarrow b$$

So: for different mechanical positions:

-invert this last equation using $Z_c$ from $S_{11}$ $\rightarrow$ get distance from windows b

-plot mechanical position (based on "touch point" ) .vs. this calculated b

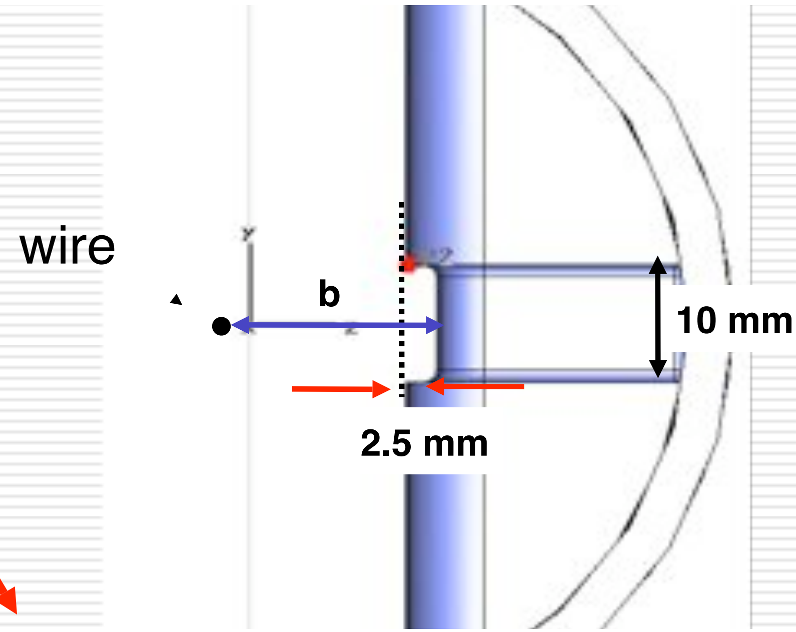
# Meas. In reflection - Wire position (II)




**Mechanical vs measured position:**

-linear only when wire is < 2 mm from wall

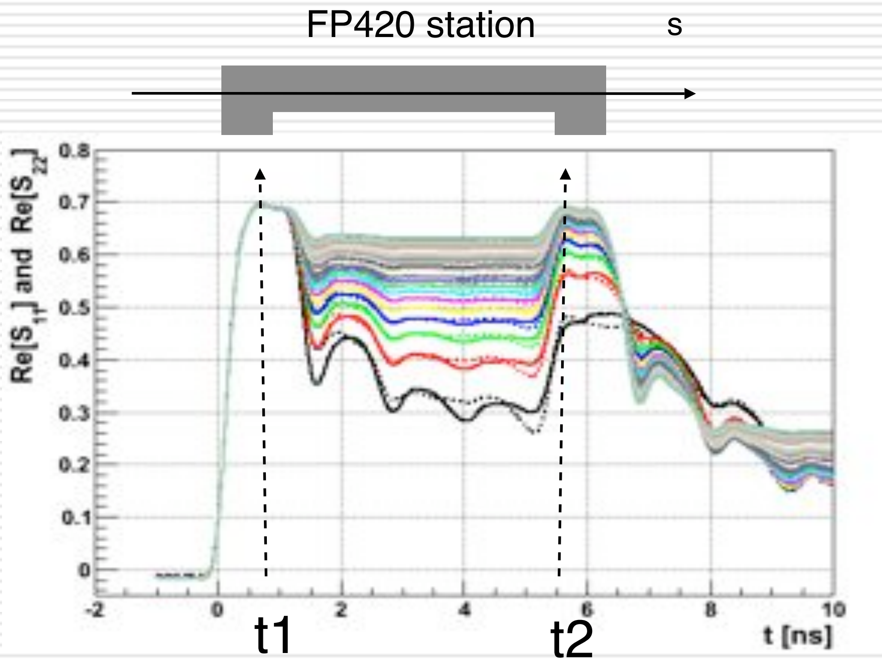
-for b > 2 mm approximation of wire close to a plate is not valid anymore




~ **0.5 mm** = correction to apply to mechanical position measurement

**N.B.** : we were only worried about absolute wire position not about the relative displacement (very well know with micrometer screws)

# Meas. in reflection-Resistive wall (I)




The difference between the two maxima at t1 and t2 is only due to resistive wall effect integrated over the chosen frequency range.

**From measurements**

$$S_{11}(t_1) - S_{11}(t_2) \equiv S_{22}(t_1) - S_{22}(t_2) = \frac{S_{21}}{S_{21}^{ref}}$$

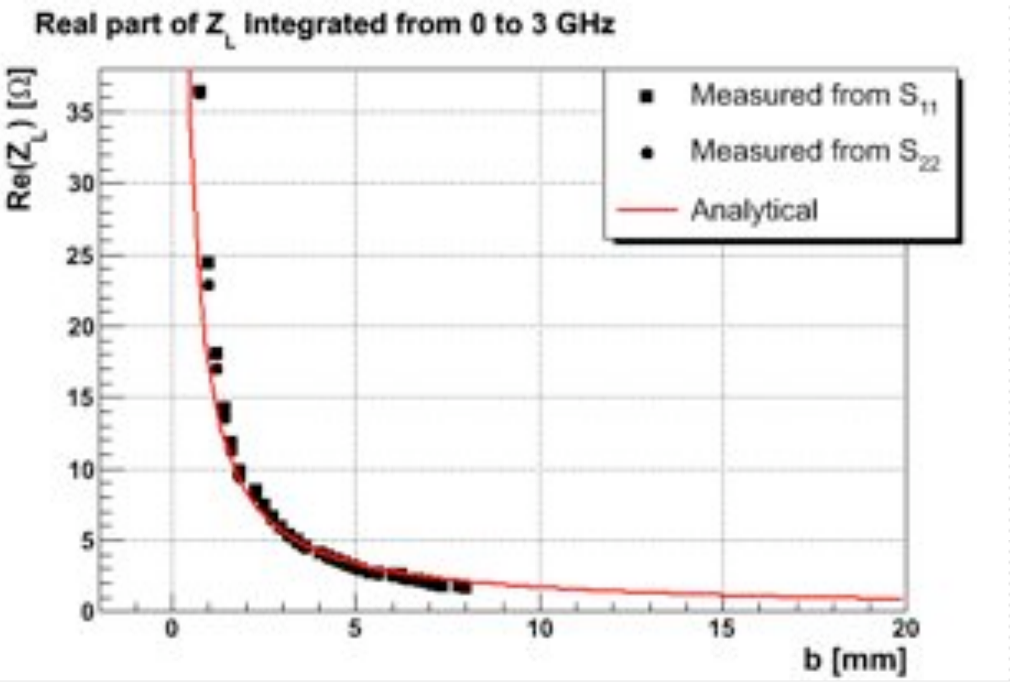
$$\int_{f_1=0}^{f_2=3\,GHz} Z_L(f)df = -2Z_C ln\frac{S_{21}}{S_{21}^{ref}}$$

**Analytical prediction:**

Wire close to a plate:

$$Z_L(f) = \frac{L}{2\pi b}\sqrt{\frac{\omega Z_0}{2c\sigma_c}} \cdot \frac{\pi}{12}$$

# Meas. in reflection - Resistive wall (II)




**Maximum discrepancy** between measurement and theory:

$$\Delta Z_L < 5\,\Omega \quad \text{or} \quad \Delta x < 0.1\,mm$$

**To be verified:**

Windowing in frequency domain of Network Analyzer not included in analytical prediction yet