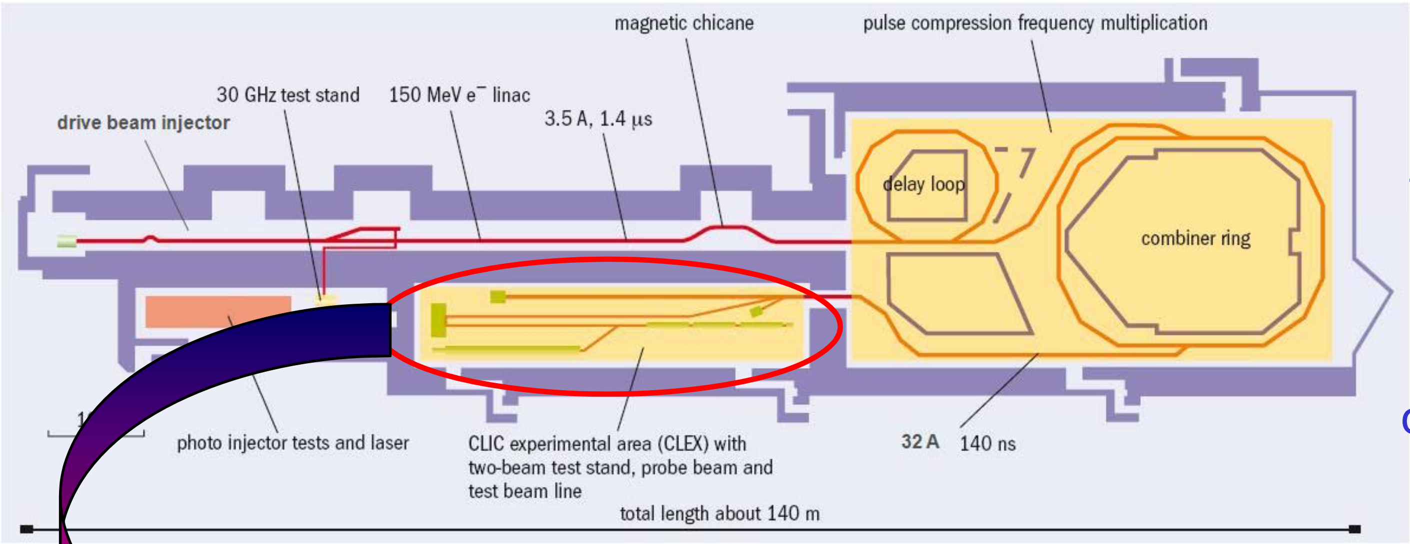
Status on the construction of the BPSs for the Test Beam Line of the CTF3

A. Faus-Golfe, J.V. Civera, C. Blanch and J.J. García-Garrigós
whit the help of the CTF3 Collaboration

Contents

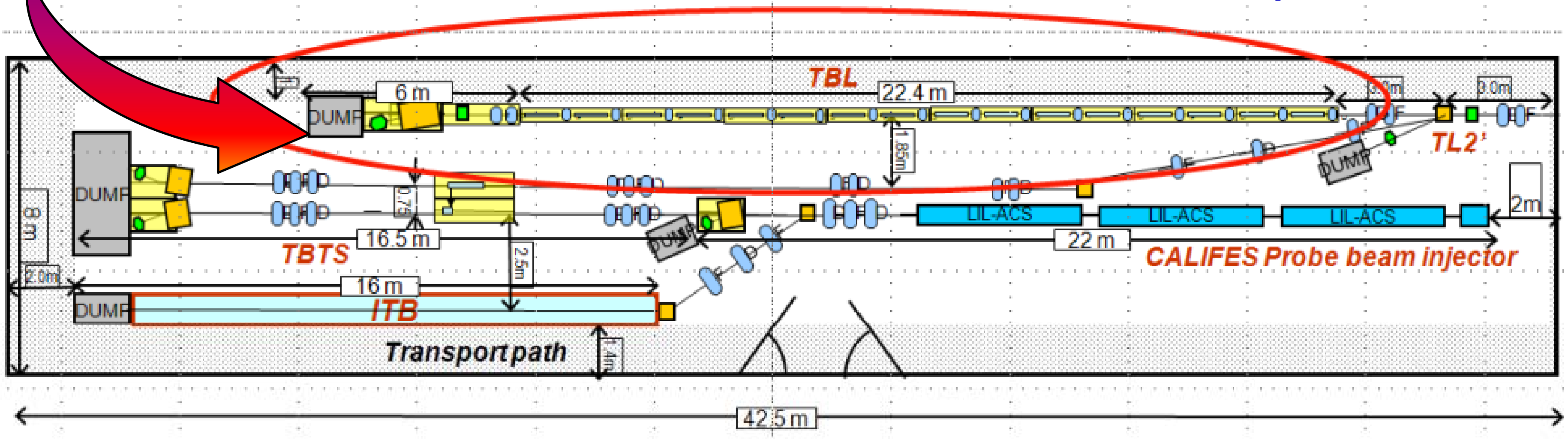
- The CLIC and CTF3
- The BPS monitor prototype in theTest Beam Line
- BPS mechanical design
- BPS sensing mechanism and general description
- BPS electronic design
- BPS wire test results and analysis
- Conclusions and Future work

CTF3: The CLIC Test Facility 3



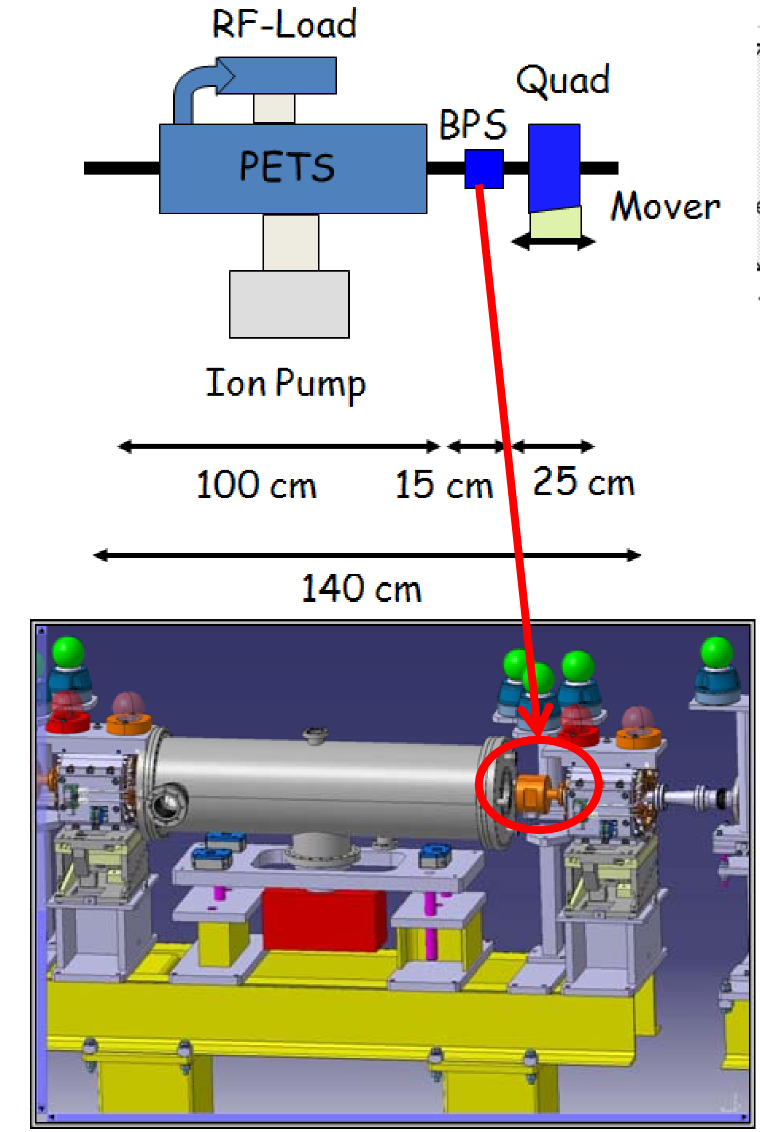
- To demonstrate the two-beam acceleration scheme

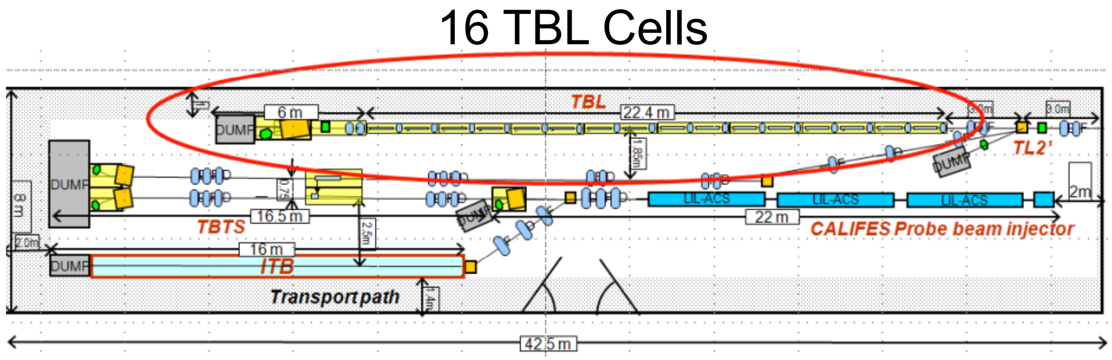
- A scaled facility for one branch of the Drive Beam Generation System of CLIC



Layout of the CLIC EXperimental area (CLEX) building with TBL

TBL: The Test Beam Line





The main aims of the TBL:

- Study and demonstrate the technical feasibility and the operability a drive beam decelerator (including beam losses), with the extraction of as much beam energy as possible. Producing the technology of power generation needed for the two-beam acceleration scheme.

- Demonstrate the stability of the decelerated beam and the produced RF power by the PETS.

- Benchmark the simulation tools in order to validate the corresponding systems in the CLIC nominal scheme.

TBL + BPM specifications

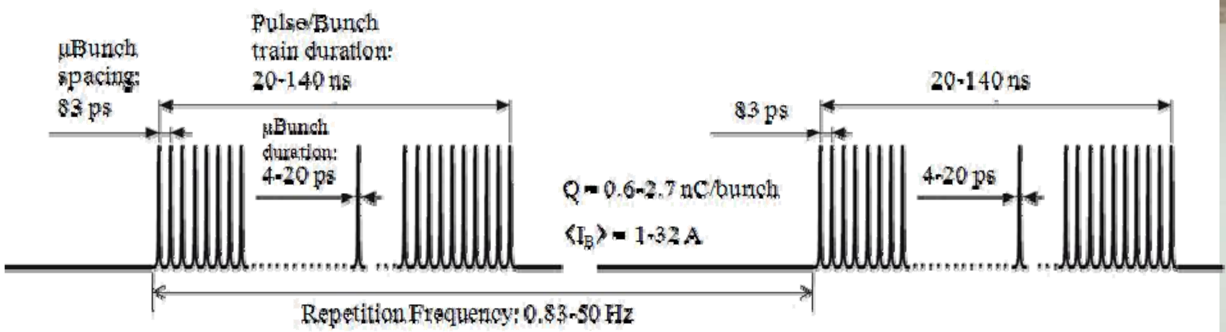
TBL Beam Parameters	
Beam current range	1-32 A
Bunch train duration	20-140 ns
Injection beam energy	150 MeV
Microbunch spacing	83 ps(12 GHz)
Microbunch duration	4-20 ps
Microbunch charge	0.6-2.7 nC
Repetition frequency	0.83-50 Hz
Radiation level	$\leq$1000 Gray/year
Emittance	150 μm
BPM Parameters	
Analog bandwidth	10 kHz-100 MHz
Beam position range	$\pm$5 mm (H/V)
Beam aperture diameter	24 mm
Overall mechanical length	126 mm
Number of BPM's in TBL	16
Resolution at maximum current	$\leq$5 μm
Overall precision	$\leq$50 μm

Main features of the Inductive Pick-Up (IPU) type of BPM:

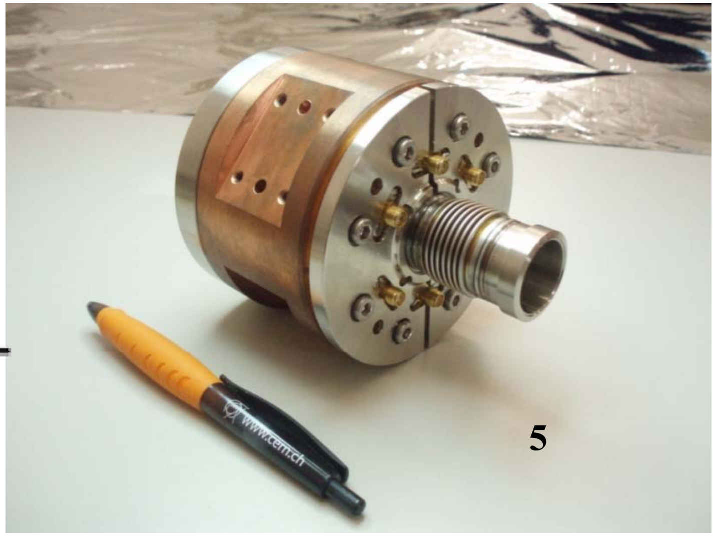
- less perturbed by the high losses experienced in linacs;
- the total length can be short;
- it generates high output voltages for typical beam currents in the range of amperes;
- calibration wire inputs allow testing with current once installed
- broadband, but better for bunched beams with short bunch duration or pulse

IPU type of BPM suitable for TBL

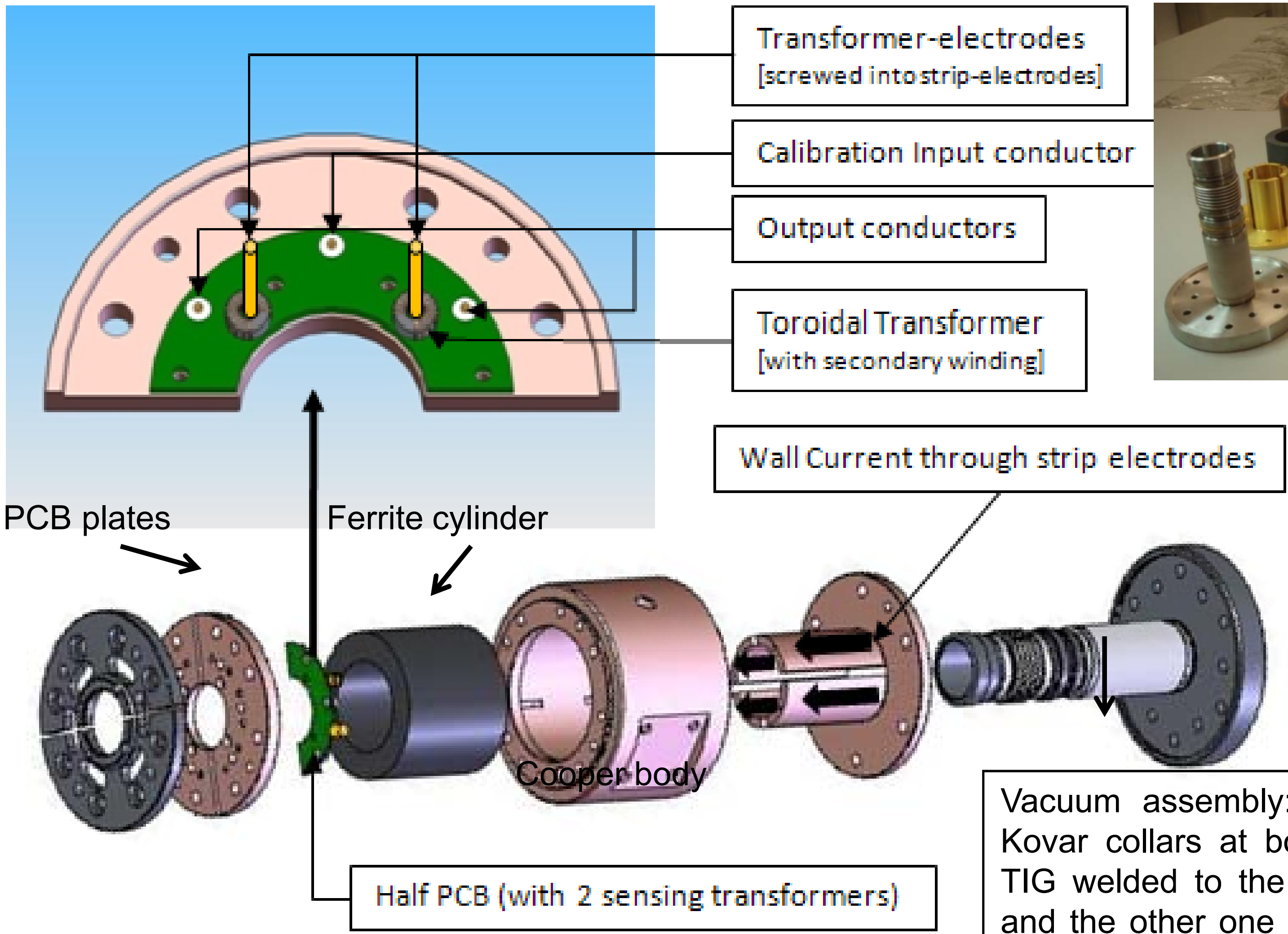
2 BPS prototypes design and constructed at IFIC (scaled version of IPU DBL of CTF3)

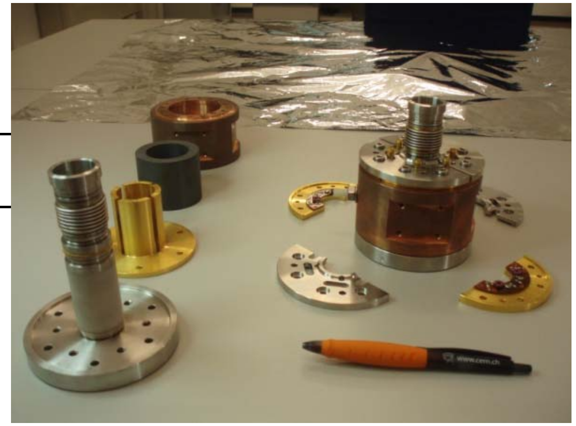


TBL beam time structure



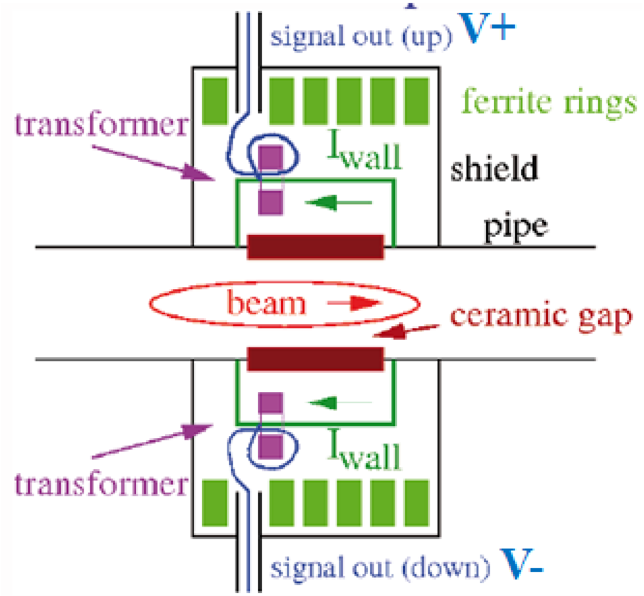
BPS Mechanical Assembly



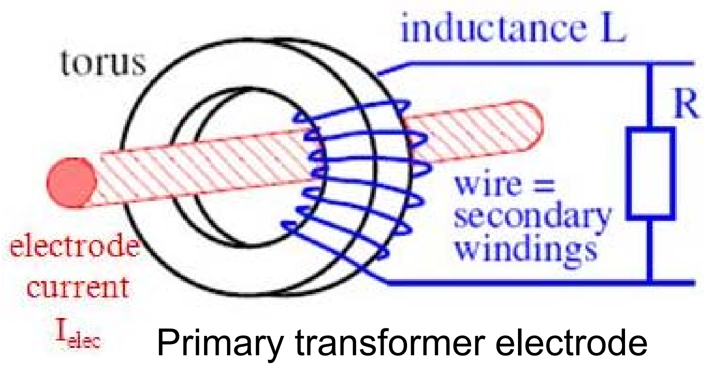


Vacuum assembly: ceramic tube with Kovar collars at both ends, one collar TIG welded to the downstream flange, and the other one electron welded to a bellow and a rotatable flange (~10^{-10} mbar l/s High Vacuum)

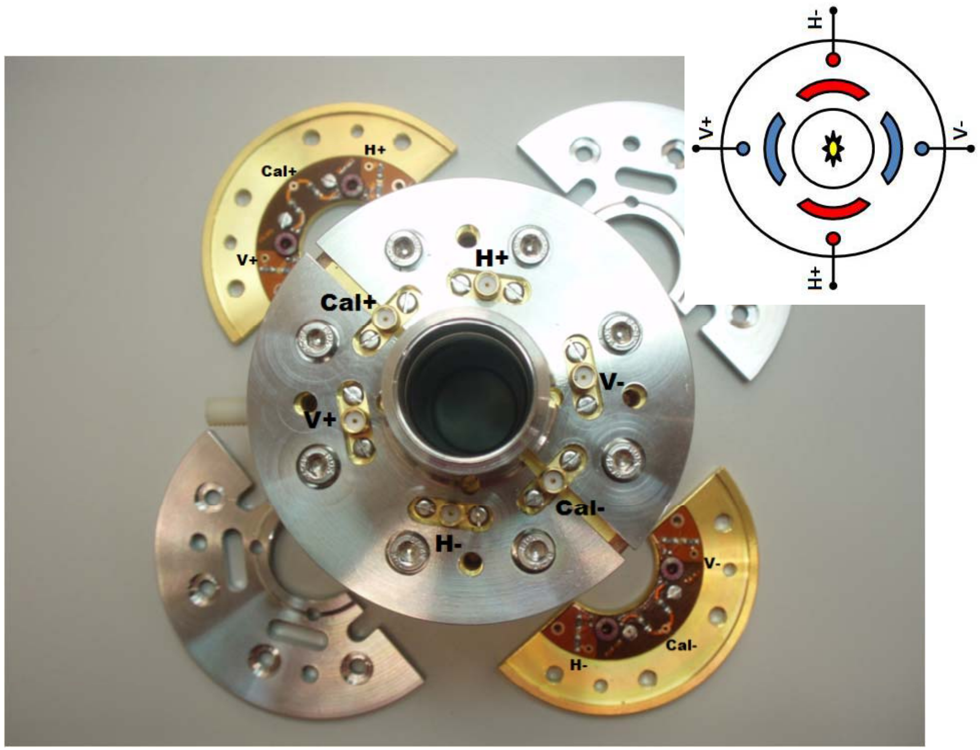
BPS Basic Sensing Mechanism



Longitudinal cross-section view



Primary transformer electrode



- Four Outputs (V+,V-, H+,H-) with two Calibration inputs (Cal+, Cal-)
- Difference signals (Δ) normalized to sum signal (Σ) (proportional to beam position coordinate)

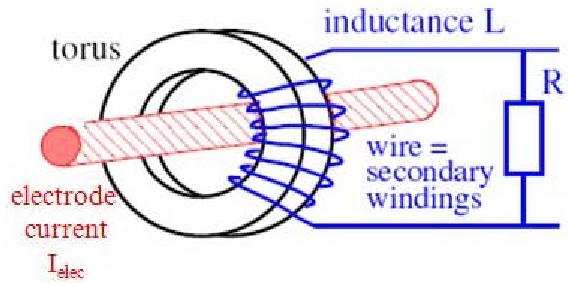
$x_V \; \alpha \; \Delta V / \Sigma$ Vertical plane

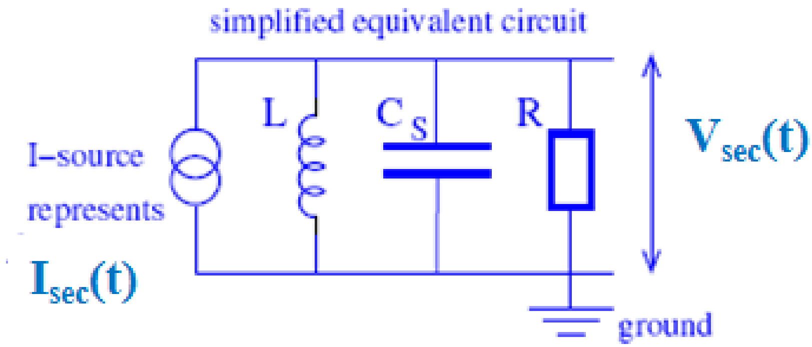
$x_H \; \alpha \; \Delta H / \Sigma$ Horizontal plane

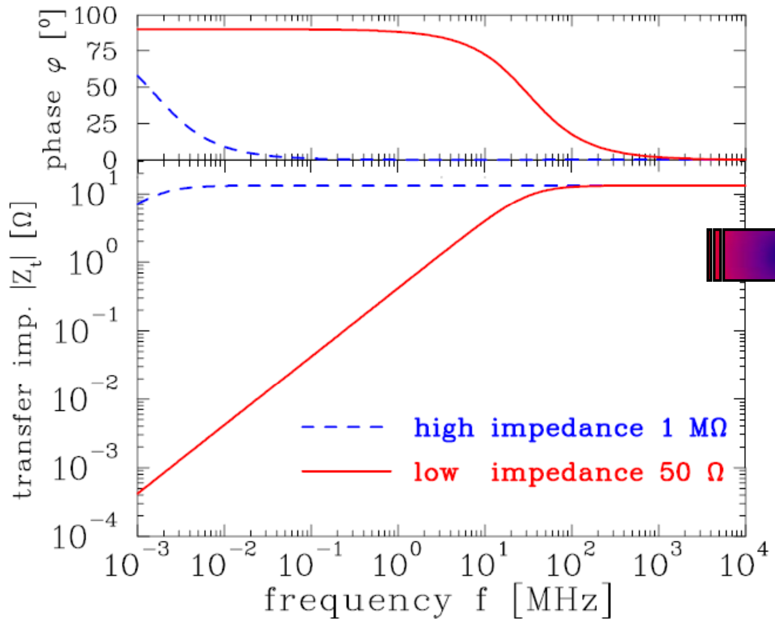
where: $\Delta V \equiv (V+ - V-)$; $\Delta H \equiv (H+ - H-)$;

$\Sigma \equiv (V+ + H+ + V- + H-)$

BPS Frequency Response

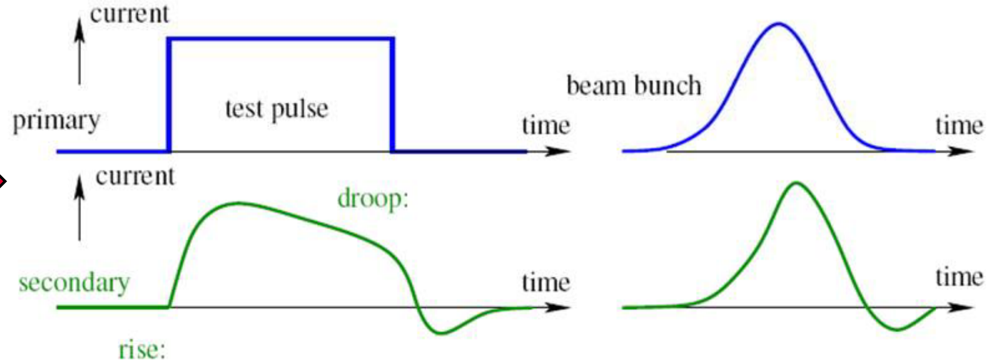






Induced current/signal

Pulse deformation



$\tau_{droop} = 1/\omega_{low}$ and $\tau_{rise} = 1/\omega_{high}$

to let pass the pulse without deformation

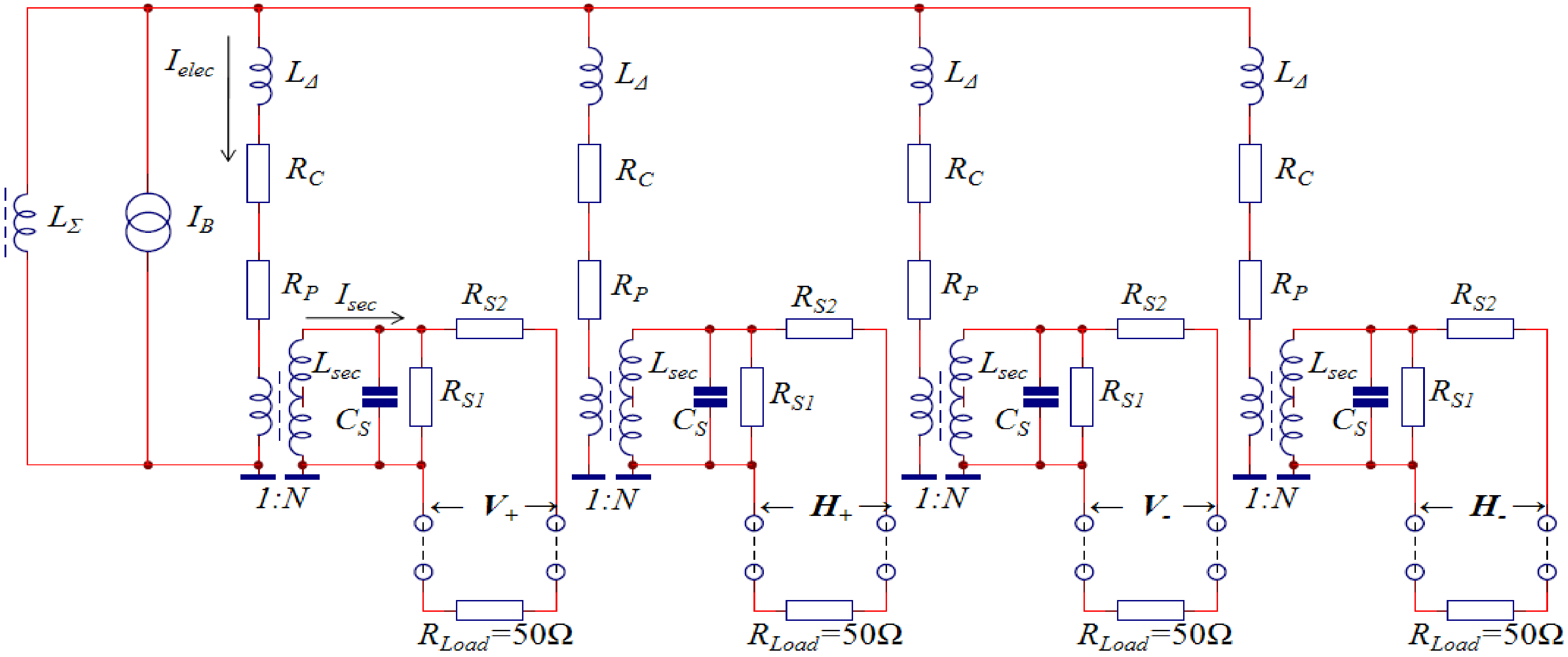
(droop time very important for ADC sampling)

$\omega_{low} = R/L$ or $f_{low} = R/2\pi L$

$\omega_{high} = 1/RC_S$ or $f_{high} = 1/2\pi RC_S$

$\tau_{droop} \sim 10^{2}\, t_{pulse}$ $\tau_{rise} \sim 10^{-2}\, t_{pulse}$

BPS Electric Model



Cut-off Frequencies:

$$f_{high} = 1/2\pi R_e C_S$$

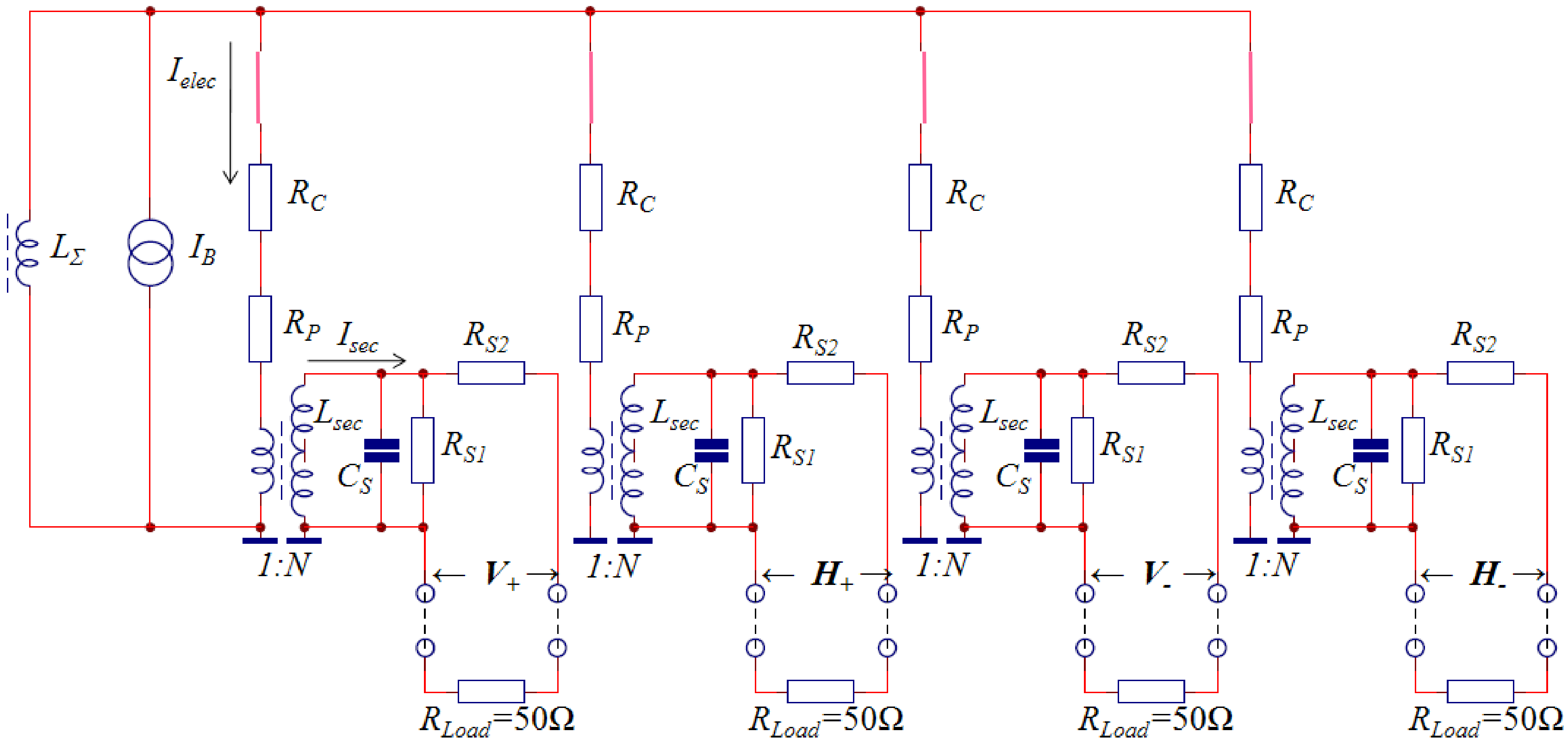
$$f_{L\Sigma} = (R_P+R_C)/2\pi L_\Sigma$$
$$f_{L\Delta} = (R_P+R_C)/2\pi L_\Delta$$

- High cut-off frequency: Fixed by secondary C_s for all cases
- Low cut-off frequencies:

I) Centered wire: Balanced wall image curent

II) Displaced wire: Unbalanced wall image current (low frequency coupling)

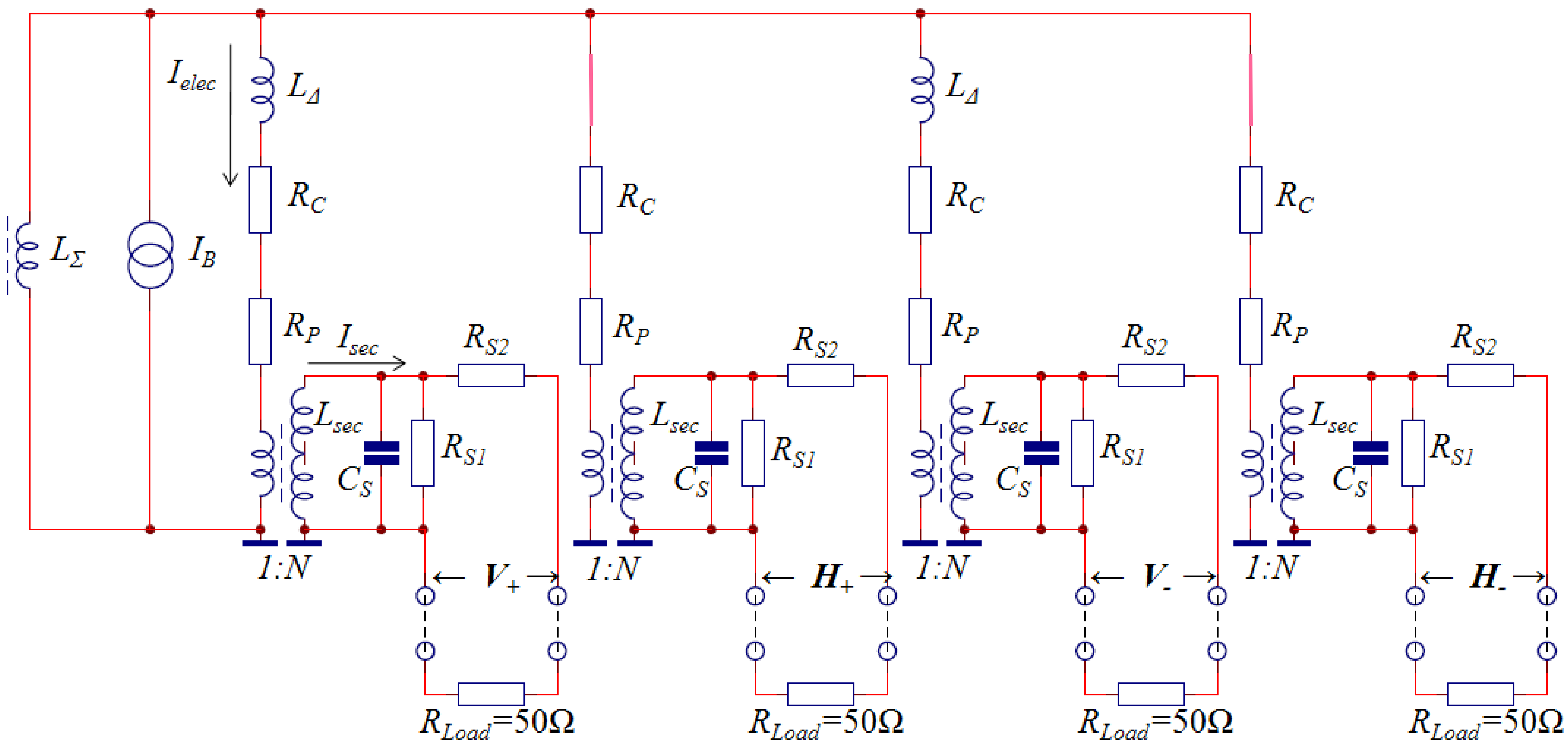
BPS Electric Model



I) Centered wire: Balanced wall image current:

- $\Delta \sim 0 \rightarrow L_\Delta = 0$ because reflects a coupling in the other case
- Low cut-off fixed by $L_\Sigma >> L_\Delta \rightarrow f_\Sigma << f_\Delta$

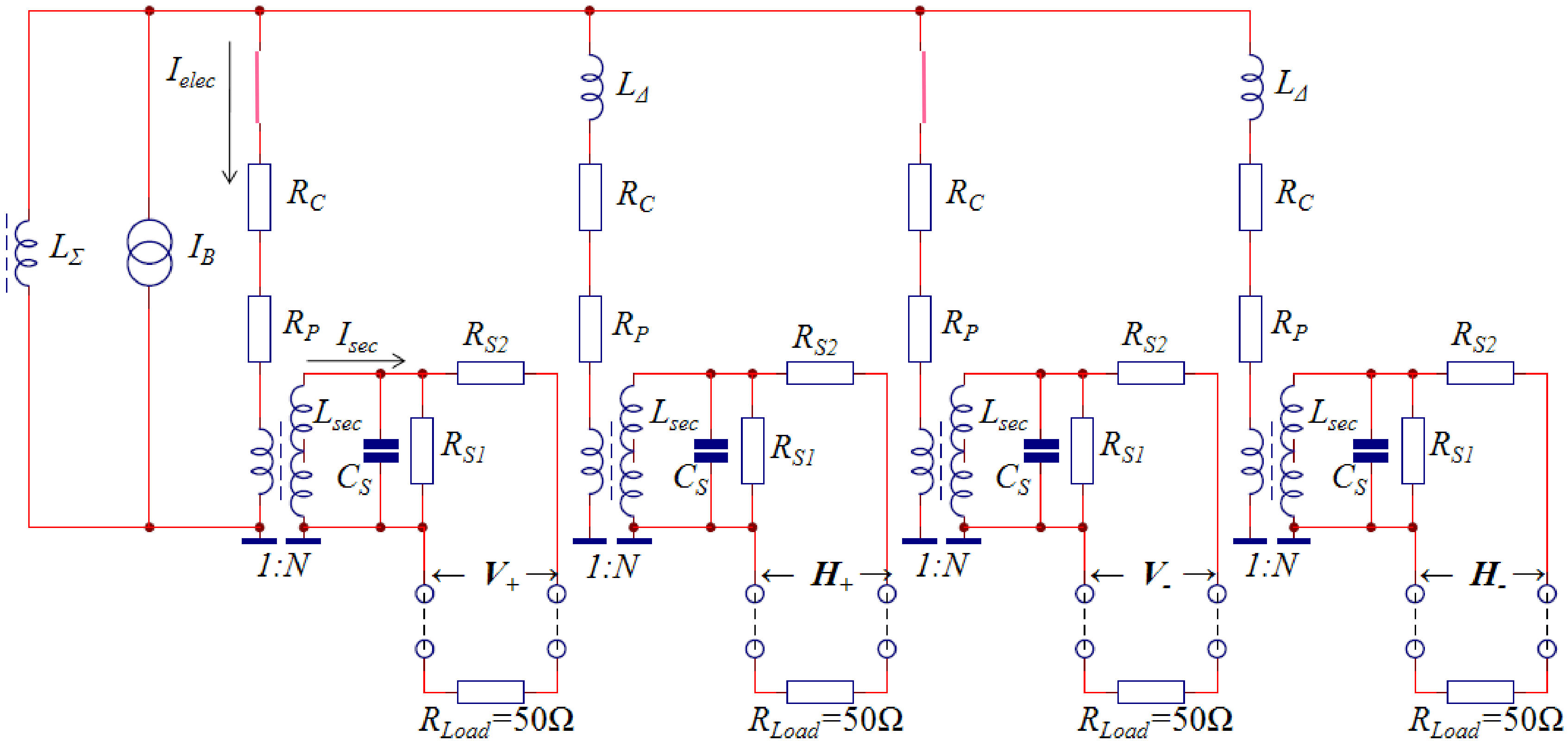
BPS Electric Model



II) Displaced wire V plane: Unbalanced wall image current (low freq. coupling)

- $\Delta \neq 0$ → $L_\Delta \neq 0$ appears on the pair of V electrodes
- Low cut-off fixed by $L_\Delta >> L_\Sigma$ → f_Δ general case and must be compensated by External Amplifier

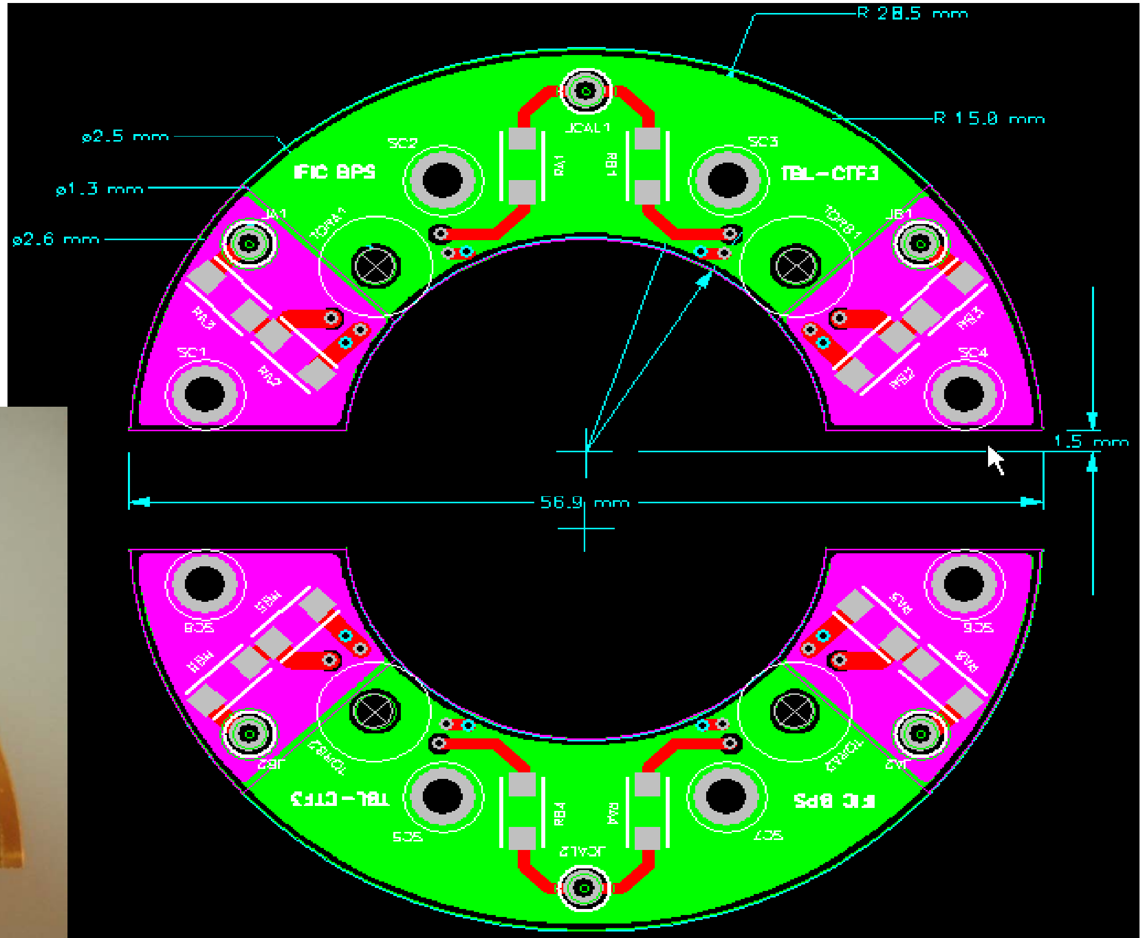
BPS Electric Model



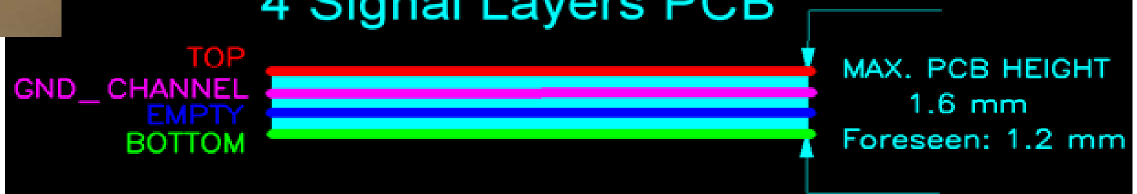
II) Displaced wire H plane: Unbalanced wall image current (low freq. coupling)

- $\Delta \neq 0$ → $L_{\Delta} \neq 0$ appears on the pair of H electrodes
- Low cut-off fixed by $L_{\Delta} >> L_{\Sigma}$ → f_{Δ} general case and must be compensated by External Amplifier

BPS Electronic design

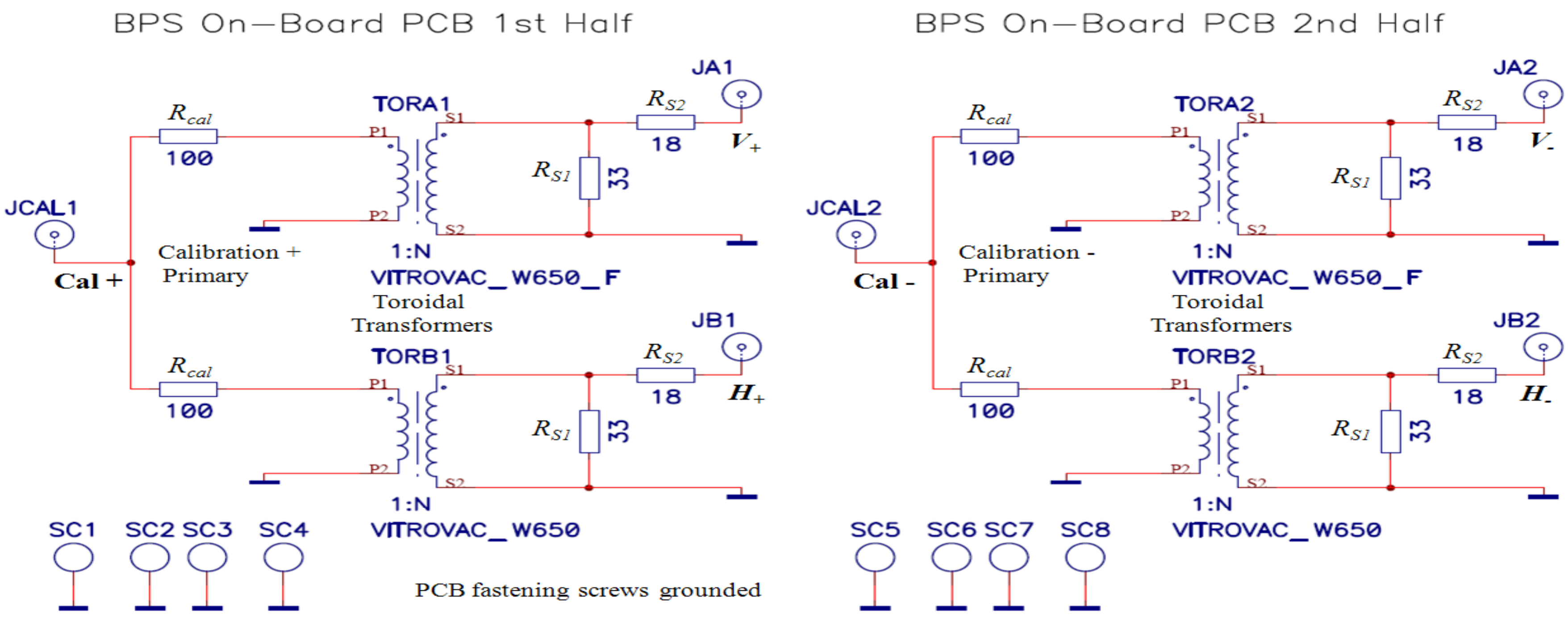


4 Signal Layers PCB



Drill Table			
Hole Dia (mm)	Symbol	Quantity	Plated
0.600	+	24	Yes
1.300	X	6	Yes
2.500	Y	4	No
2.600	┬	8	Yes

BPS Electronic design



PCBs Schematics and Output relation

$$V_{sec} = (\Sigma/I_B)\ I_{elec}$$

with: $(\Sigma / I_B) = (R_{Load} R_{S1} / (R_{S1} + R_{S2} + R_{S1}) N)$

$= 0.55\Omega$ for design values:

$R_{Load} = 50\ \Omega$,

$R_{S1} = 33\ (13)\ \Omega$, $R_{S2} = 18\ (0)\ \Omega$ (Ver. 2)

$N = 30$ turns

Characteristic Output Signal Levels:

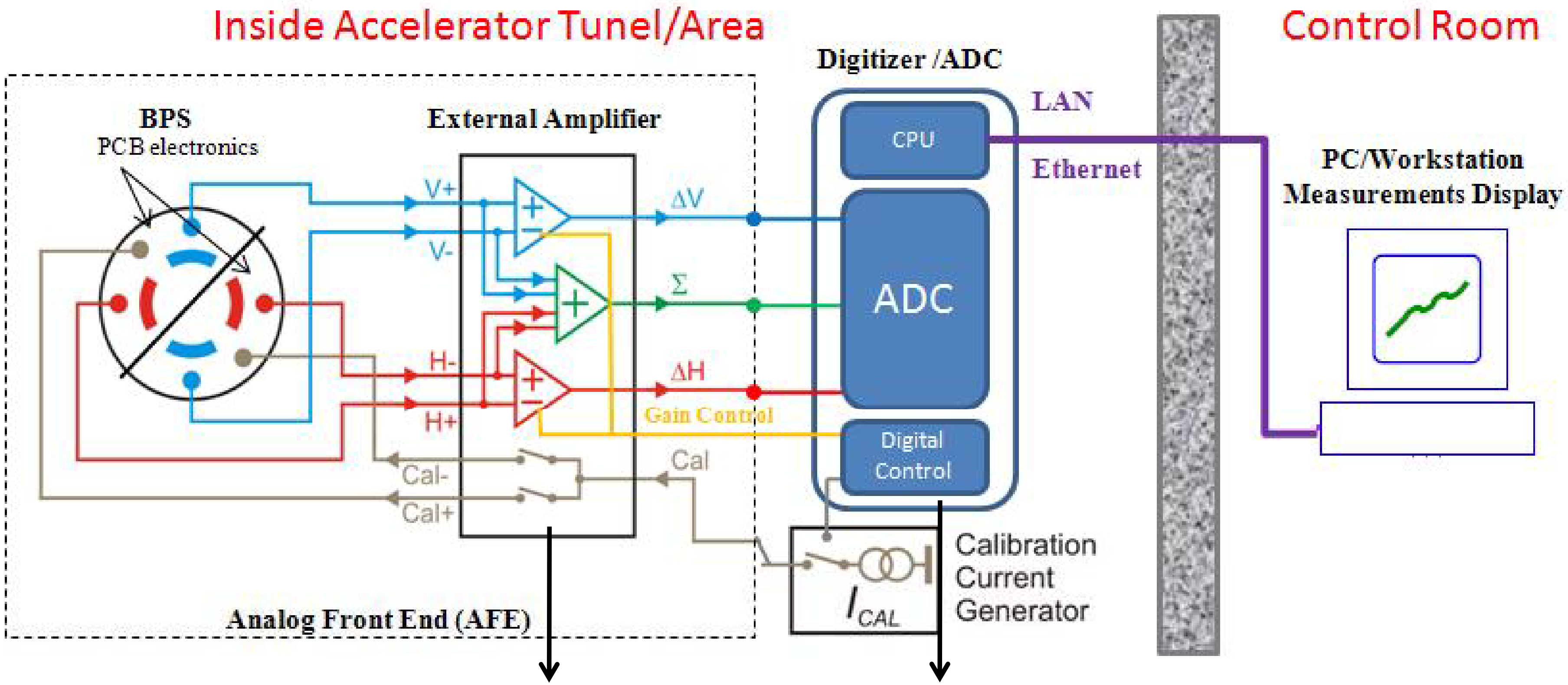
For a beam current of: $I_B = 30A$

$\Sigma = 16.5$ V outputs sum

$V_{sec} = \Sigma / 4 = 4.125V$ centered beam

$\|\Delta V\|_{max} = \|\Delta H\|_{max} = \Sigma / 2 = 8.25V$ beam at electrodes

BPS Readout chain



Amplifier developed at UPC

Digitizer/ADC developed at LAPP(Annecy)

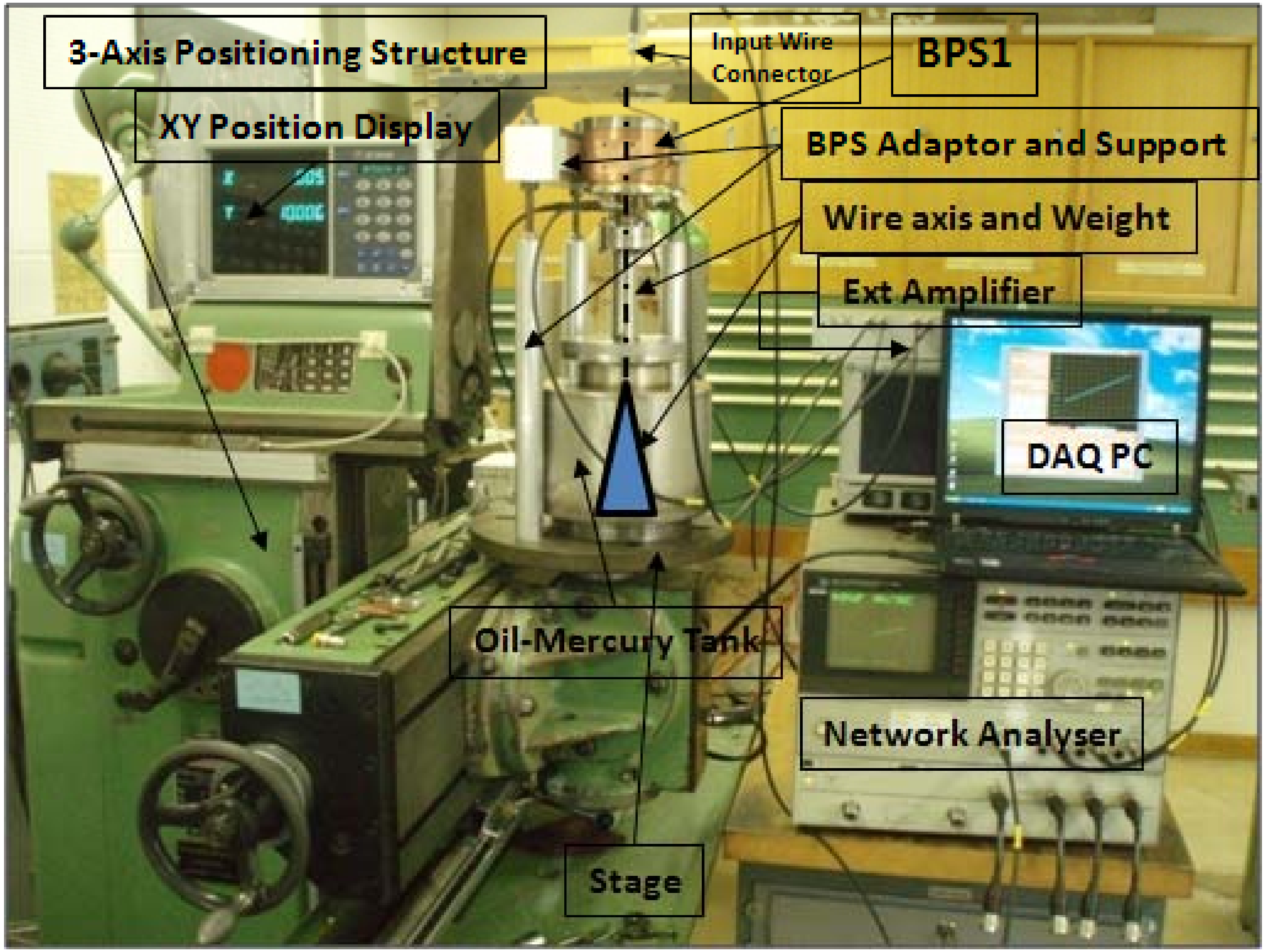
Both designs must be rad-hard

BPS Characterization Tests (Wire-Test)

Sensitivity, Linearity and Frequency response

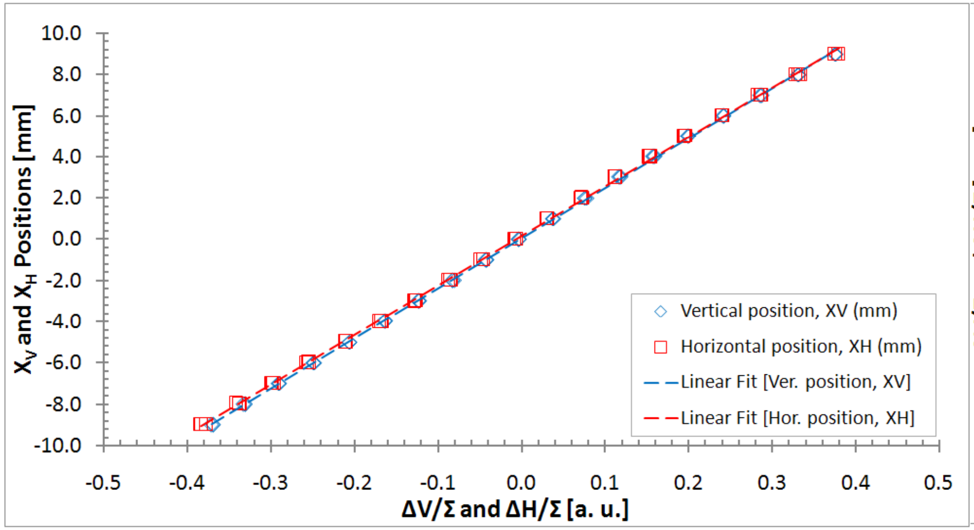
Tests carried out during several short stays at CERN, in the AB/BI-PI* Labs.

Testbench used to characterize the BPMs for the Drive Beam Linac (DBL) of the CTF3

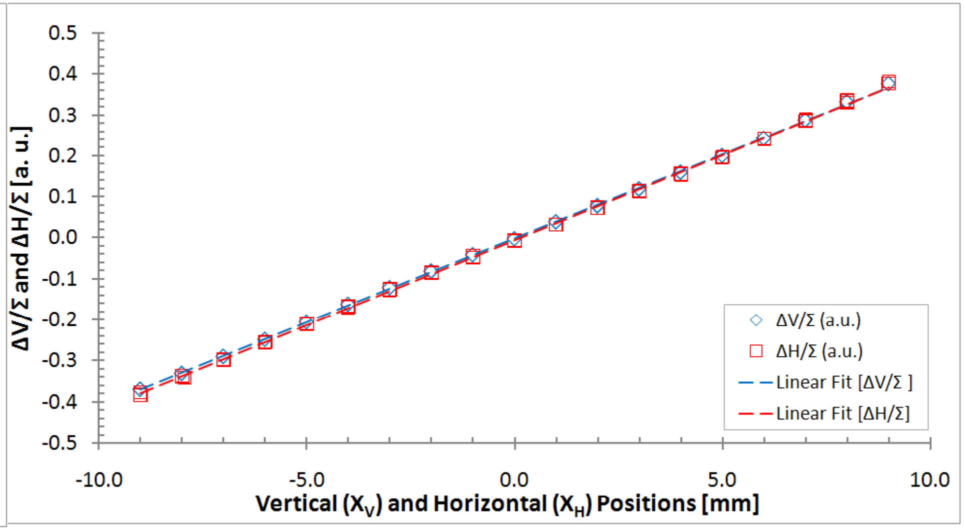


BPS: Sensitivity test (Ver. 1)

Sensitivity



Electric Offset



Linear fit equations

Sensitivity for V,H planes

$$\left(\frac{\Delta V}{\Sigma}\right)[a.u.] = n_V + S_V x_V$$

$$\left(\frac{\Delta H}{\Sigma}\right)[a.u.] = n_H + S_H x_H$$

$$S_V = (41.09 \pm 0.08)10^{-3}\ \mathrm{mm}^{-1}$$

$$S_H = (41.53 \pm 0.17)10^{-3}\ \mathrm{mm}^{-1}$$

Electric Offset for V,H planes

$$x_V[mm] = EOS_V + k_V\left(\frac{\Delta V}{\Sigma}\right)$$

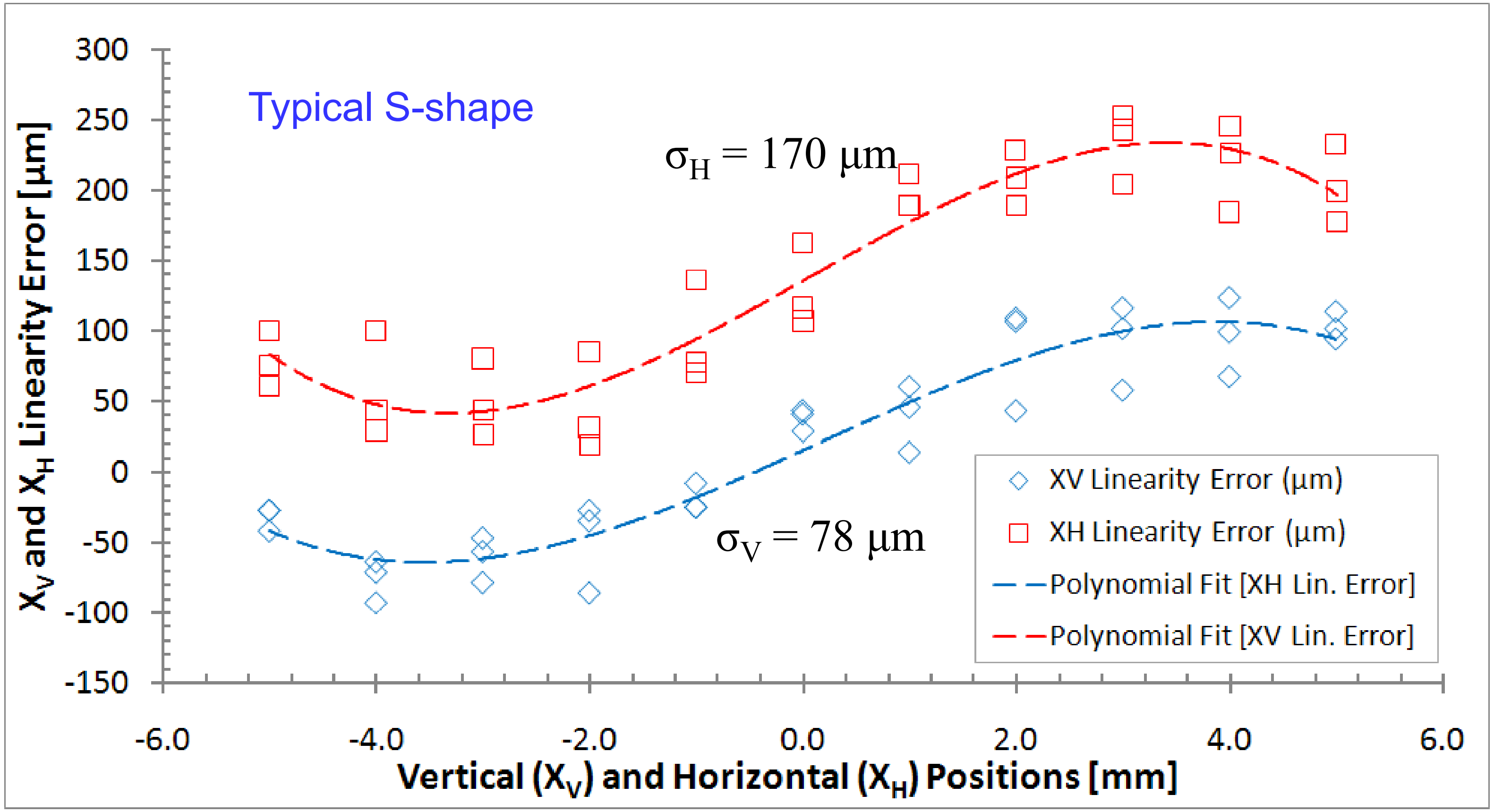
$$x_H[mm] = EOS_H + k_H\left(\frac{\Delta H}{\Sigma}\right)$$

$$EOS_V = (0.03 \pm 0.01)\ \mathrm{mm}$$

$$EOS_H = (0.15 \pm 0.02)\ \mathrm{mm}$$

BPS: Linearity test (Ver.1)

Linearity error→Overall Precision/Accuracy



$\sigma_{TBL} < 50\mu m$

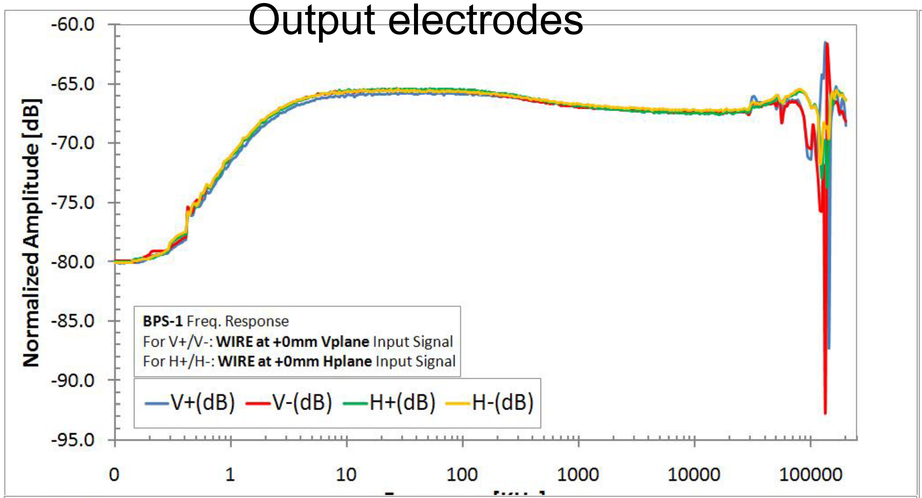
BPS above specs:

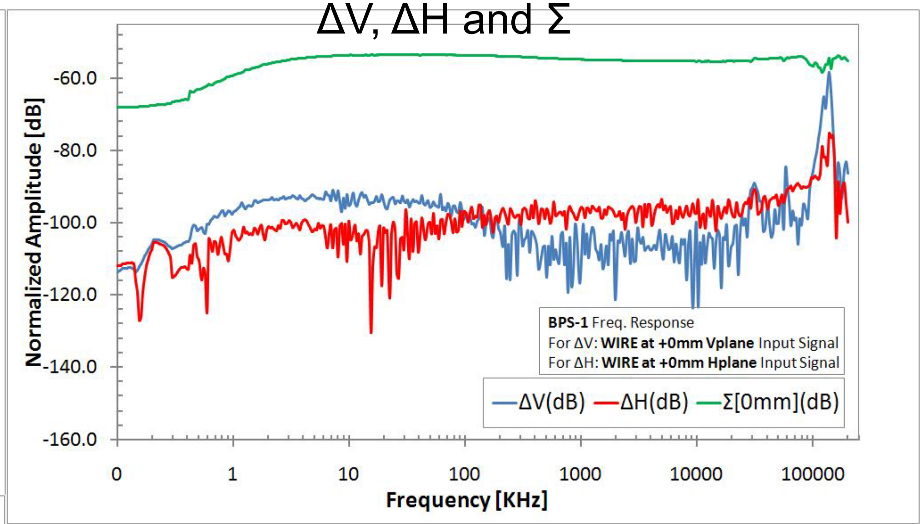
i) Low current in the wire (13 mA) vs beam 32 A

ii) Misalignment in the horizontal electrodes

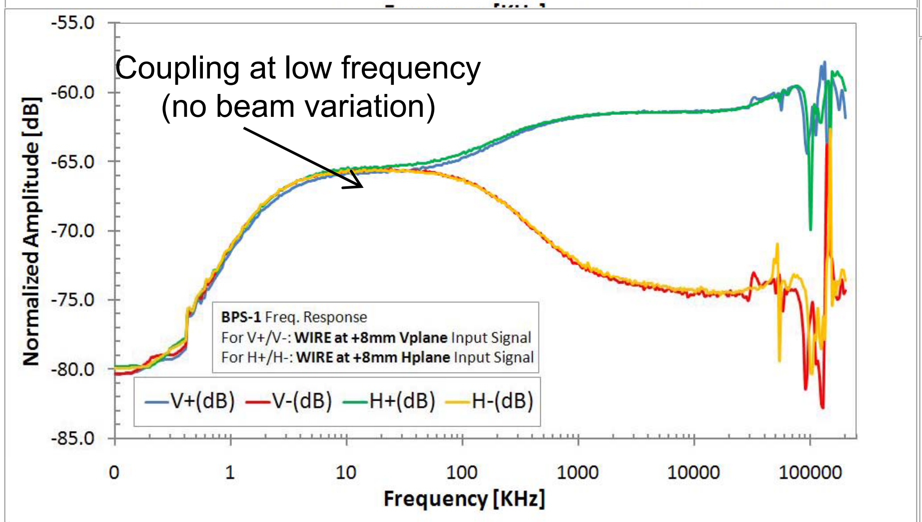
BPS: Frequency Response test (Ver.1)

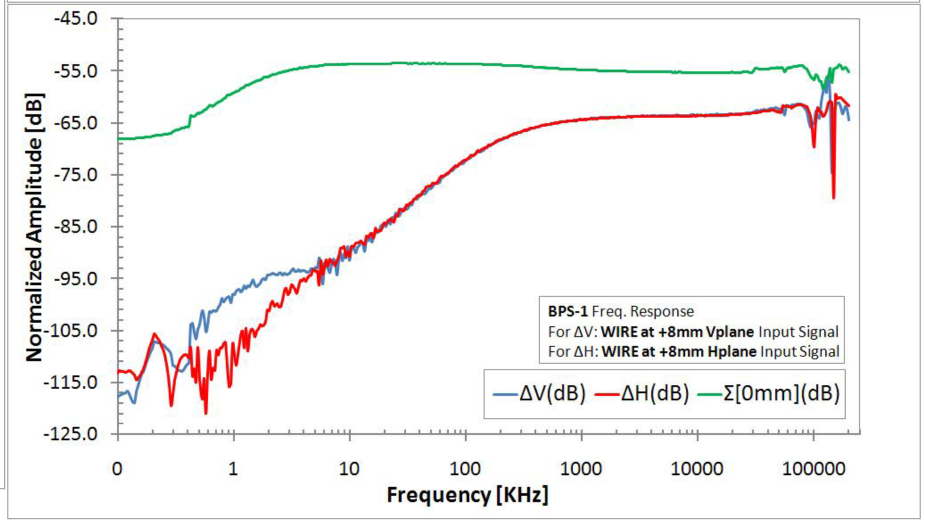
Wire Pos: Center





Wire Pos:+8mm V,H





Bandwidth specs:
10KHz-100MH
t_{pulse}=140ns

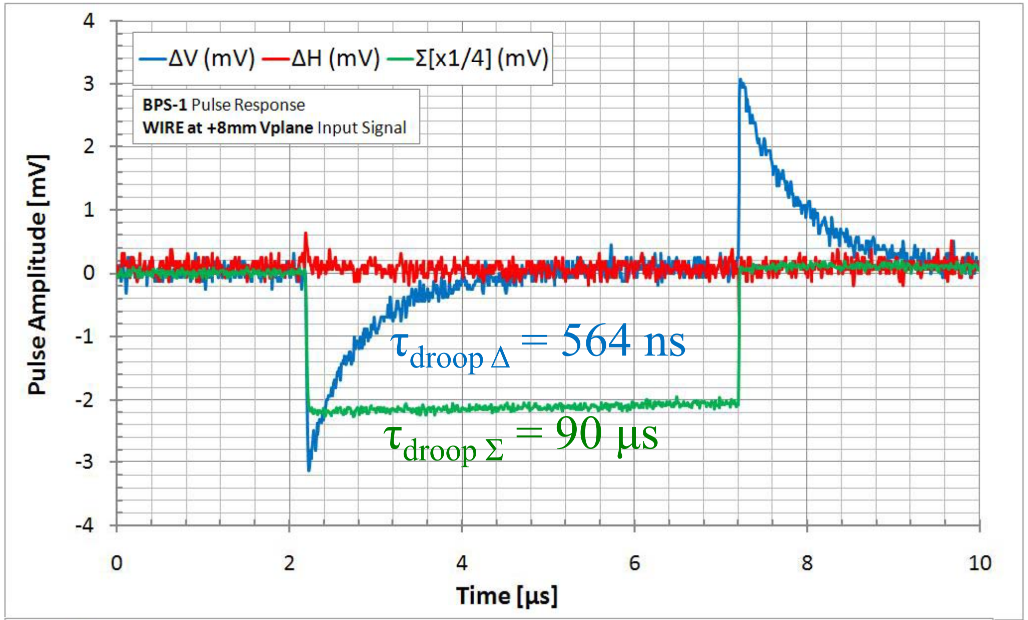
Cut-off frequencies: $f_{high} > 100$ MHz $\tau_{rise} < 1.6$ ns
$f_{L\Sigma} = 1.76$ KHz $\tau_{droop\ \Sigma} = 90\mu s$
$f_{L\Delta} \equiv f_{L\Delta H} = f_{L\Delta V} = 282$KHz $\tau_{droop\ \Delta} = 564$ns

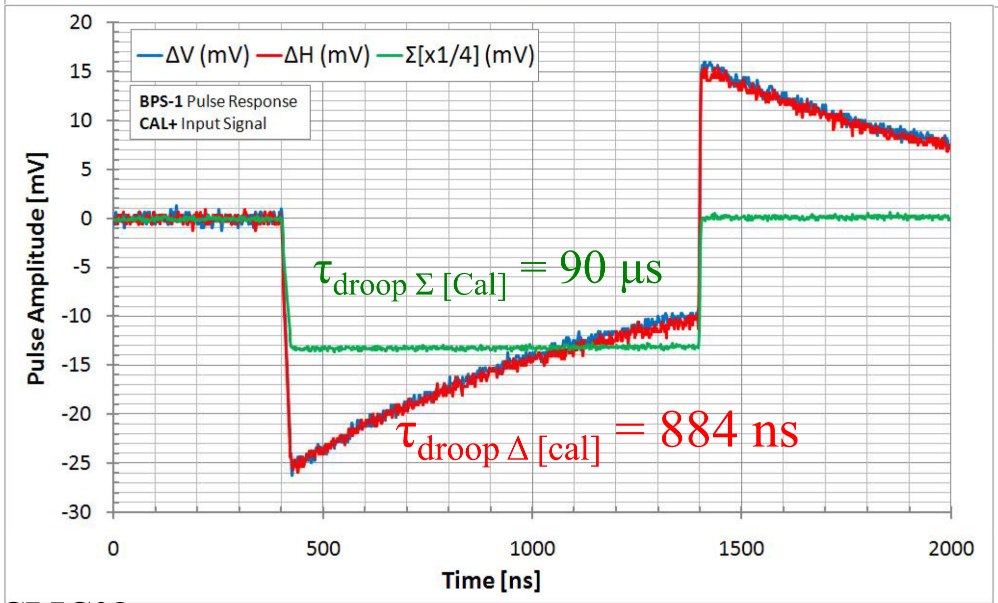
BPS: Pulse Response and Calibration (Ver.1)

$f_{L\Delta[\mathrm{cal}]}$ =180 KHz < $f_{L\Delta}$ =282 KHz
(difference is about 100 KHz)

Represents a problem for the amplifier compensation in the Δ channels (lower $f_{L\Delta}$), because the same compensation designed for the $f_{L\Delta}$ will be applied when exciting the calibration inputs to $f_{L\Delta[\mathrm{Cal}]}$ (bad pulse for calibration ,overcompensation)

Compensation frequency at the lower one $f_{L\Delta[\mathrm{Cal}]}$ gives a calibration pulse good flatness and wire-beam pulse flat enough for TBL pulse duration



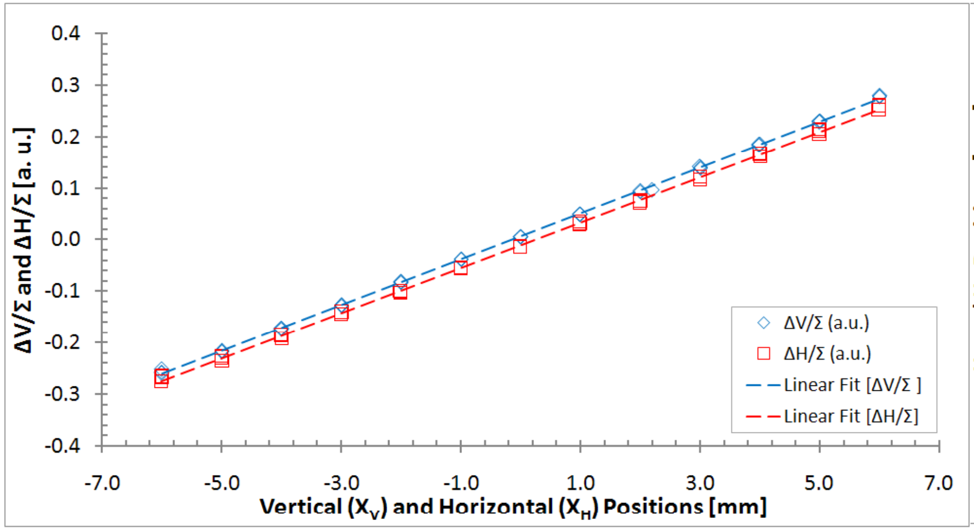


BPS: Characterization Table (Ver.1)

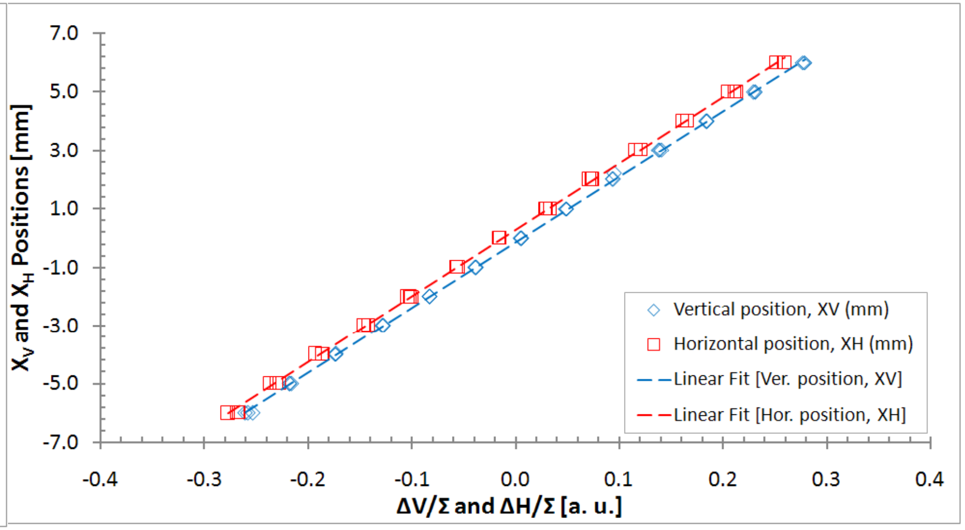
BPS1 Sensitivity and Linearity Parameters	
Vertical Sensitivity, S_V	41.09 mm^{-1}
Horizontal Sensitivity, S_H	41.43 mm^{-1}
Vertical Electric Offset, EOS_V	0.03 mm
Horizontal Electric Offset, EOS_H	0.15 mm
Vertical overall precision (accuracy), σ_V	78 μm
Horizontal overall precision (accuracy), σ_H	170 μm
BPS1 Characteristic Output Levels	
Sum signal level, Σ	16.5 V
Difference signals max. levels, $\|\Delta V\|_{max}$, $\|\Delta H\|_{max}$	8.25 V
Centered beam level, $V_{sec}(x_V = 0, x_H = 0)$	4.125 V
BPS1 Frequency Response (Bandwidth) Parameters	
Σ low cut-off frequency, $f_{L\Sigma}$	1.76 KHz
Δ low cut-off frequency, $f_{L\Delta}$	282 KHz
Σ low cut-off frequency calibration, $f_{L\Sigma\,[Cal]}$	1.76 Hz
Δ low cut-off frequency calibration, $f_{L\Delta\,[Cal]}$	180 KHz
High cut-off frequency, f_{high}	> 100 MHz
High cut-off frequency calibration, $f_{high\,[Cal]}$	> 100 MHz
BPS1 Pulse-Time Response Parameters	
Σ droop time constant, $\tau_{droop\Sigma}$	90 μs
Δ droop time constant, $\tau_{droop\Delta}$	564 ns
Σ droop time constant calibration, $\tau_{droop\Sigma\,[Cal]}$	90 μs
Δ droop time constant calibration, $\tau_{droop\Delta\,[Cal]}$	884 μs
Rise time constant calibration, τ_{rise}	< 1.6 ns
Rise time constant calibration, $\tau_{rise\,[Cal]}$	< 1.6 ns

BPS: Sensitivity test (Ver. 2)

Sensitivity



Electric Offset



Linear fit equations

Sensitivity for V,H planes

$$\left(\frac{\Delta V}{\Sigma}\right)[a.u.] = n_V + S_V x_V$$

$$\left(\frac{\Delta H}{\Sigma}\right)[a.u.] = n_H + S_H x_H$$

$S_V = (44.57\pm0.16)10^{-3}\ \mathrm{mm}^{-1}$

$S_H = (50.0\pm0.8)10^{-3}\ \mathrm{mm}^{-1}$

Electric Offset for V,H planes

$$x_V[mm] = EOS_V + k_V\left(\frac{\Delta V}{\Sigma}\right)$$

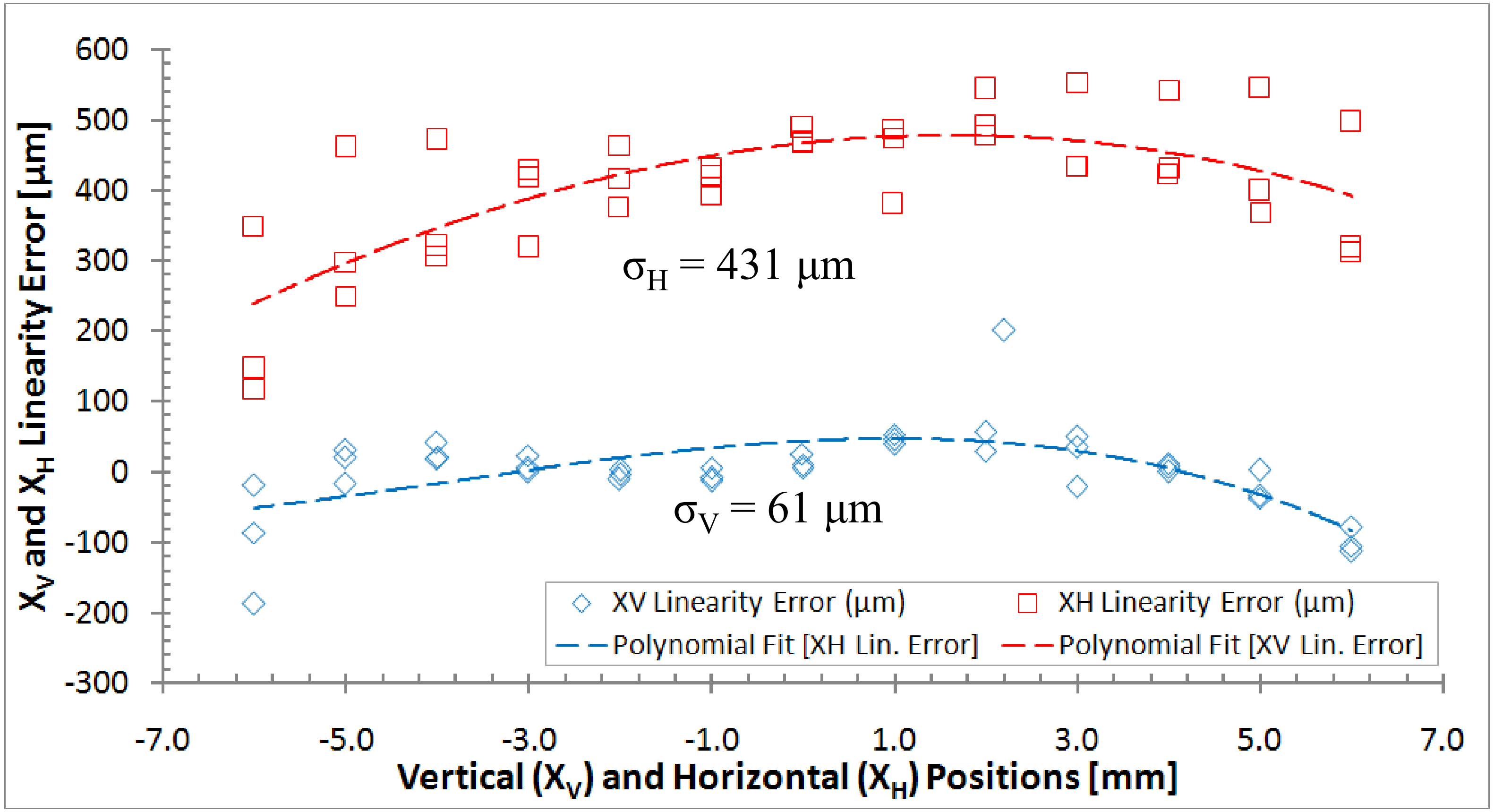
$$x_H[mm] = EOS_H + k_H\left(\frac{\Delta H}{\Sigma}\right)$$

$EOS_V = (-0.14\pm0.01)$ mm

$EOS_H = (0.27\pm0.07)$ mm

BPS: Linearity test (Ver. 2)

Linearity error→Overall Precision/Accuracy



$\sigma_{TBL} < 50\mu m$

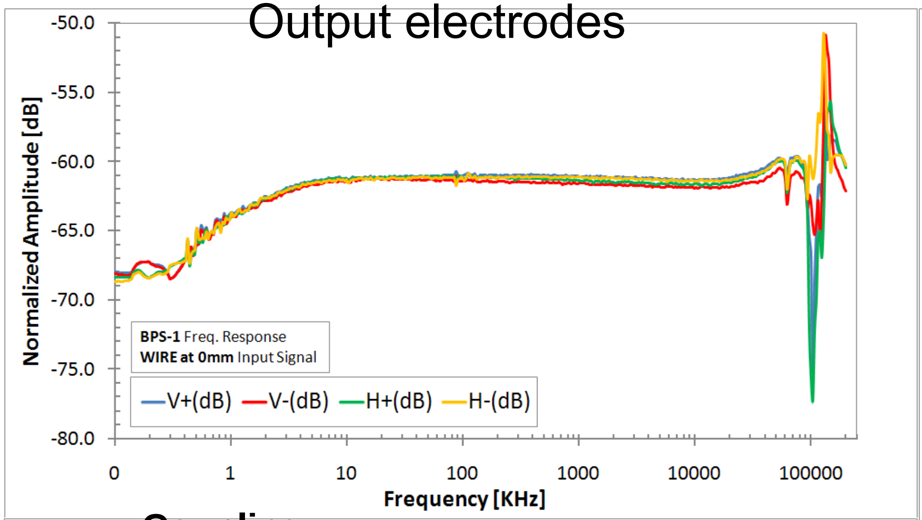
BPS above specs:

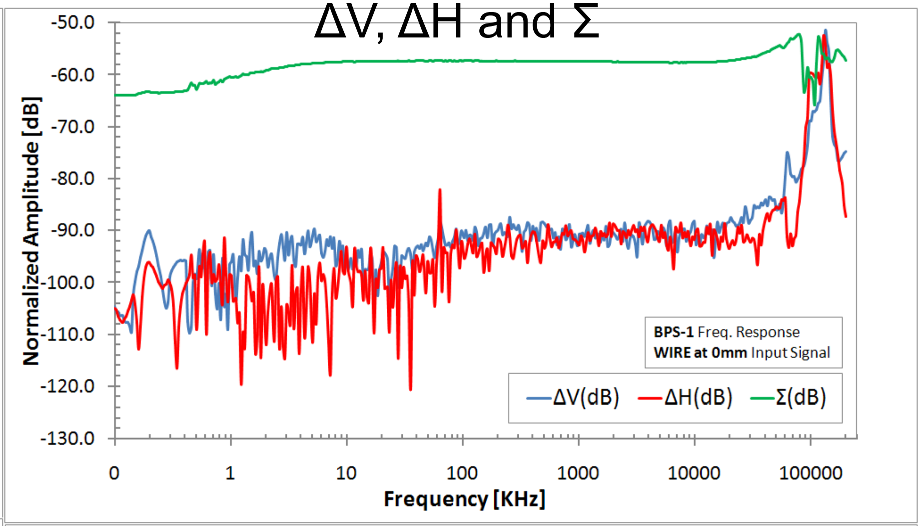
i) Low current in the wire (13 mA) vs beam 32 A

ii) ii) Misalignment in the horizontal electrodes

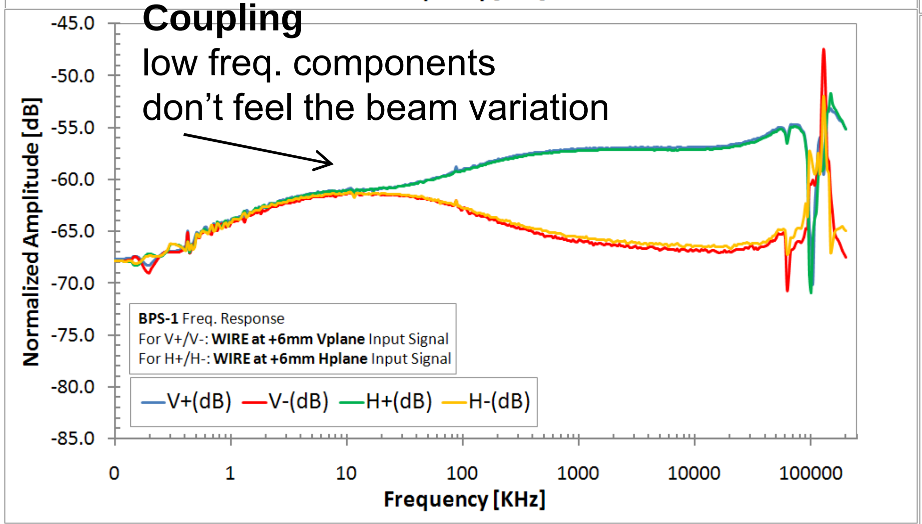
BPS: Frequency Response test (Ver. 2)

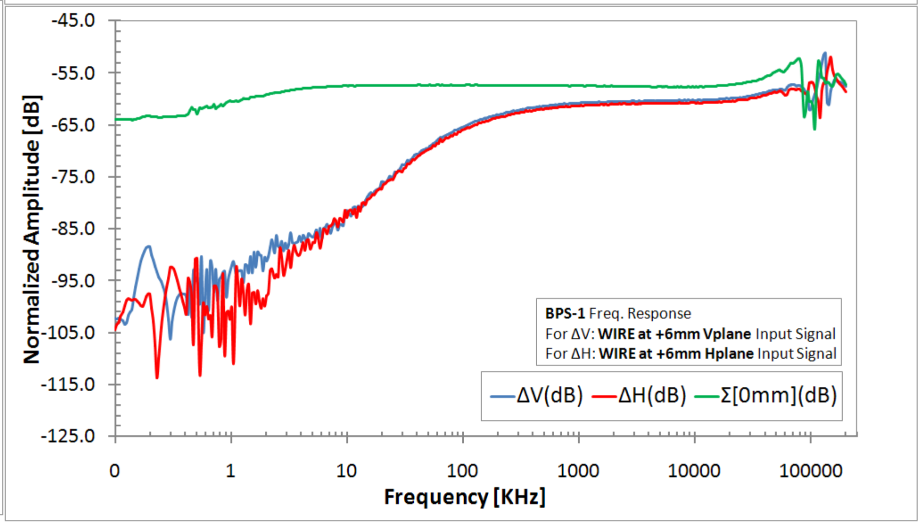
Wire Pos: Center





Wire Pos:+6mm V,H





Bandwidth specs:
10KHz -100MHz
t_{pulse}=140ns

Cut-off Frequencies:

$f_{high} > 100$ MHz

$f_{L\Sigma} = 1$ KHz

$f_{L\Delta} \equiv f_{L\Delta H} = f_{L\Delta V} = 175$ KHz

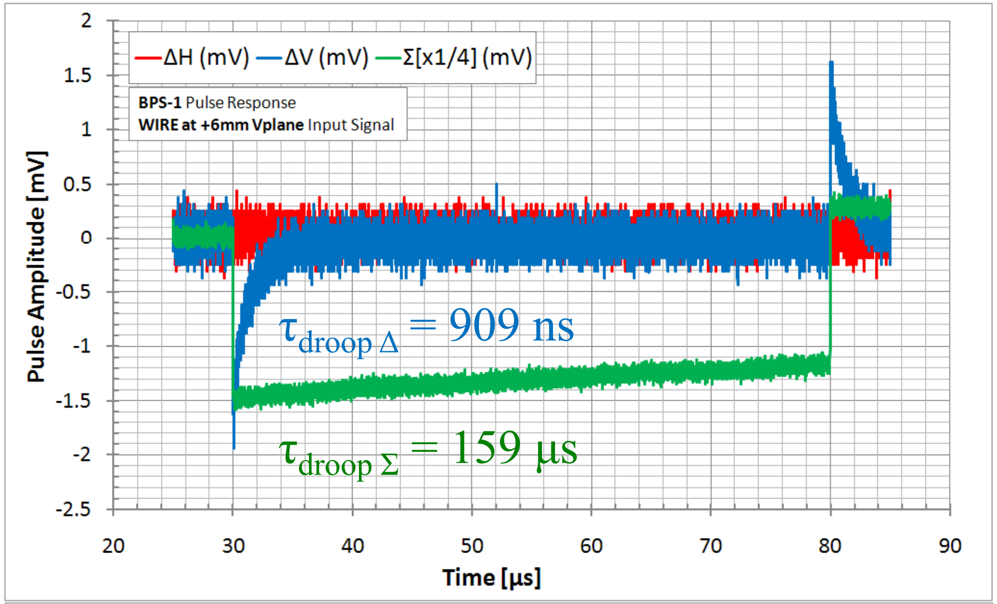
$\tau_{rise} < 1.6$ ns

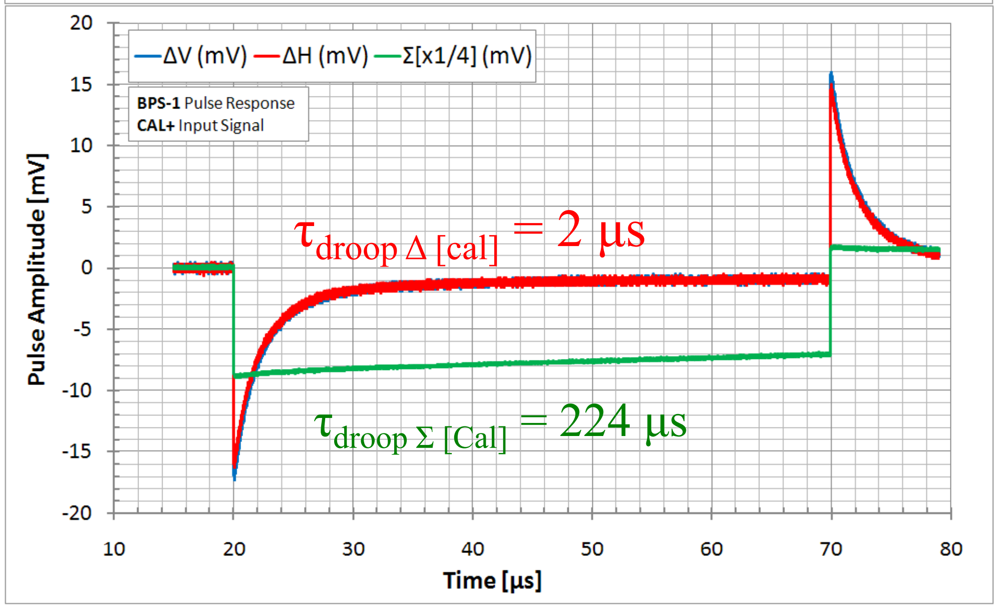
$\tau_{droop\ \Sigma} = 159$ µs

$\tau_{droop\ \Delta} = 909$ ns

BPS: Pulse Response and Calibration (Ver. 2)

$f_{L\Delta[cal]}$ =79 KHz < $f_{L\Delta}$ =175 KHz
(difference after the last modifications, about 100 KHz)





BPS: Characterization Table (Ver. 2)

BPS1 Sensitivity and Linearity Parameters	
Vertical Sensitivity, S_V	44.57 mm^{-1}
Horizontal Sensitivity, S_H	50.0 mm^{-1}
Vertical Electric Offset, EOS_V	-0.14 mm
Horizontal Electric Offset, EOS_H	0.27 mm
Vertical overall precision (accuracy), σ_V	61 µm
Horizontal overall precision (accuracy), σ_H	431 µm
BPS1 Characteristic Output Levels	
Sum signal level, Σ	10.5 V
Difference signals max. levels, $\|\|\Delta V\|\|_{max}$, $\|\|\Delta H\|\|_{max}$	5.25 V
Centered beam level, V_{sec} $(x_V = 0, x_H = 0)$	2.625 V
BPS1 Frequency Response (Bandwidth) Parameters	
Σ low cut-off frequency, $f_{L\Sigma}$	1 KHz
Δ low cut-off frequency, $f_{L\Delta}$	175 KHz
Σ low cut-off frequency calibration, $f_{L\Sigma\ [Cal]}$	709 Hz
Δ low cut-off frequency calibration, $f_{L\Delta\ [Cal]}$	79 KHz
High cut-off frequency, f_{high}	> 100 MHz
High cut-off frequency calibration, $f_{high\ [Cal]}$	> 100 MHz
BPS1 Pulse-Time Response Parameters	
Σ droop time constant, $\tau_{droop\Sigma}$	159 µs
Δ droop time constant, $\tau_{droop\Delta}$	909 ns
Σ droop time constant calibration, $\tau_{droop\Sigma\ [Cal]}$	224 µs
Δ droop time constant calibration, $\tau_{droop\Delta\ [Cal]}$	2 µs
Rise time constant calibration, τ_{rise}	< 1.6 ns
Rise time constant calibration, $\tau_{rise\ [Cal]}$	< 1.6 ns

BPS: Schedule

Jul-Dec 06	Jan-Mar 07	Apr-Jun 07	Jul-Sep 07	Oct-Dec 07

- Jul-Dec 06: Define module, Diagnostics, 30 GHz Pets
- Jan-Mar 07 to Oct-Dec 07: 12 GHz PETS
- Jan-Mar 07 to Oct-Dec 07: Fabrication of Prototypes: T1, T2, T3, T4, T5
- Jan-Mar 07 to Oct-Dec 07: Test of Prototypes

Jan-Mar 08	Apr-Jun 08	Jul-Sep 08	Oct-Dec 08

- Jan-Mar 08: Test of Prototypes
- Apr-Jun 08 to Oct-Dec 08: Fabrication of Series
- Install TBL with 2PETS: T6, T7
- Commissioning of the line and run with 2 PETS

Jan-Mar 09	Apr-Sep 09	Oct-Dec 09	Jan-Mar 10	Apr-Jun 10

- Jan-Mar 09: Install up to 8 PETS, 1.4 GW
- Apr-Sep 09: Run with 8 PETS, 1.4 GW
- Oct-Dec 09 to Jan-Mar 10: Install remaining 8 PETS
- Apr-Jun 10: Run with 16 PETS, 2.8 GW

Conclusions

• A set of two BPS prototypes with the associated electronics were designed and constructed.

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•The performed tests yield:

- o Good linearity results and reasonably low electrical offsets from the mechanical center.
- o Good overall-precision/accuracy in the vertical plane considering the low test current; and, a misalignement in the horizontal plane was detected by accuracy offset and sensitivity shift.
- o Low frequency cut-off for Σ/electrodes signals, $f_{L\Sigma}$, and high cut-off frequency, f_{high}, under specifications.
- o Low frequency cut-off for Δ signals, $f_{L\Delta}$, determined to perform the compensation of droop time constant, $\tau_{droop\Delta}$, with the external amplifier.

Future Work

• Open issues for improvement in the BPS2 monitor prototype:

  o correct the possible misalignments of the horizontal plane electrodes suggested in the linearity error analysis

  o check if overall-precision below 50µm (under TBL specs), with enough wire current → New wire testbench at IFIC

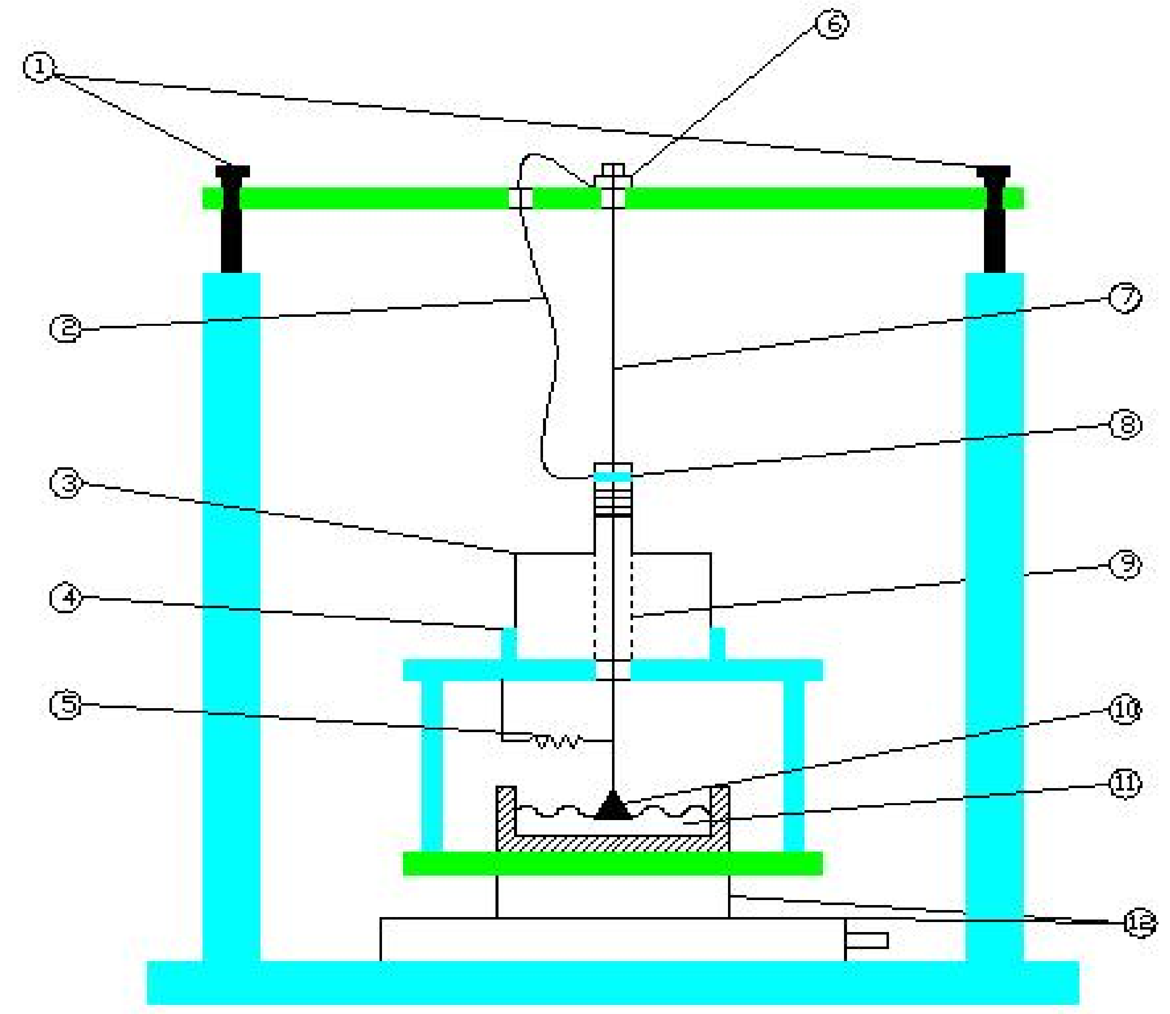
  o study the different low cut-off frequencies in the calibration, $f_{L\Delta[Cal]}$, and wire excitation cases, $f_{L\Delta}$

• Test Beam of the BPS1 in the TBL→Resolution at maximum current.

• BPS series production and characterization (15 more units). The new wire testbench will allow higher currents, accurate (anti-vibration and micro-movement system) and automatized measurements.

Future Work

Sketch of New IFIC
Wire Testbench
(under construction)



Thanks for your Attention