Status of the Stripline Beam Position Monitor Development for the CLIC Drive Beam* TUPC12

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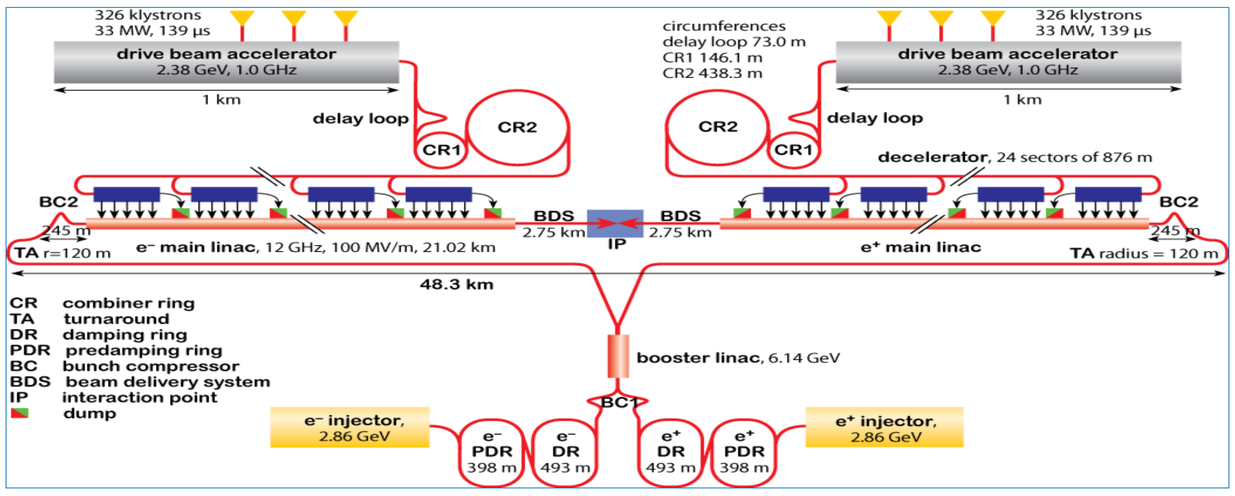
ABSTRACT

In collaboration with SLAC, LAPP and IFIC, a first prototype of a stripline Beam Position Monitor (BPM) for the CLIC Drive Beam and its associated readout electronics has been successfully tested in the CLIC Test Facility linac (CTF3) at CERN. In addition, a modified prototype with downstream terminated striplines is under development to improve the suppression of unwanted RF signal interference. This paper presents the results of the beam tests, the most relevant aspects for the modified stripline BPM design and its expected improvements.

THE COMPACT LINEAR COLLIDER (CLIC)



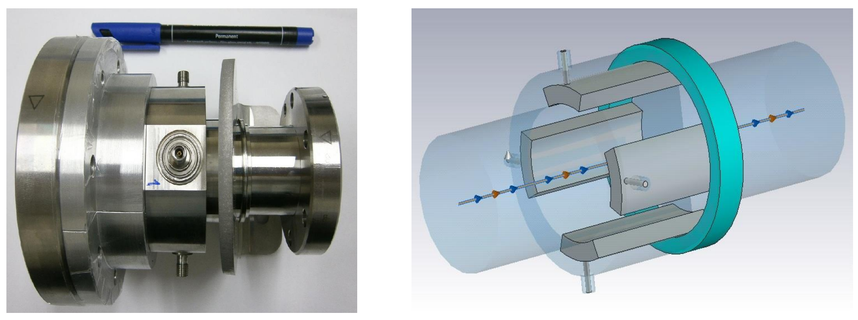
CLIC Layout

CLIC Drive Beam BPM Parameters		
Beam Current	101 A	
Bunch Spacing	83 ps (12 GHz)	
Bunch Length	10 ps	
Train Length	242 ns	
BPM quantity	> 40000	Total Drive Beam BPM
Duct Aperture	23 mm	In decelerator
Resolution	2 µm	Multi-bunch train
Accuracy	20 µm	
Temporal resolution	< 10 ns	BW > 20 MHz

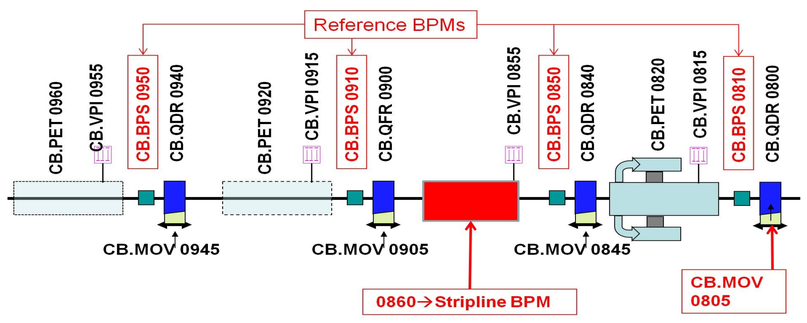
- About **40000 BPMs** are needed for the Drive Beam decelerator → Compact and inexpensive solutions preferred.
- Power Extraction and Transfer Structures (PETS) close to the BPMs → **High power RF EMI at 12GHz** propagating in the beam duct (fc_{TE11} = 7.6GHz).

BEAM TESTS OF A STRIPLINE PROTOTYPE (SHORTENED ELECTRODES)

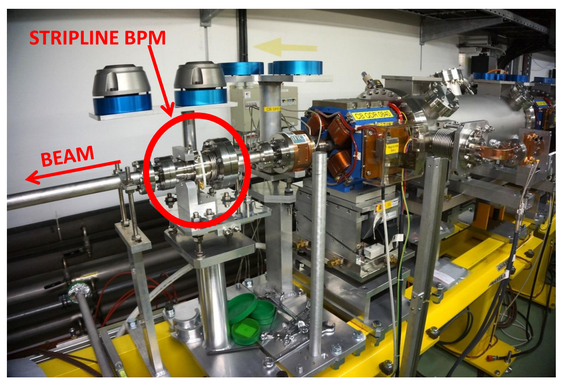
- **Compact model**, fits into the quadrupole vacuum chamber.
- Length L chosen for the transfer function to have a **zero at 12GHz** (bunch cancellation in the central part of the train).
- **SiC damping ring** added to absorb trapped modes at 12GHz.



CLIC Drive Beam Stripline BPM Prototype with shortened electrodes

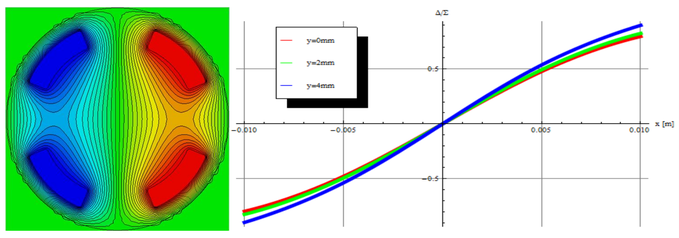


Layout of TBL girders n° 8 and 9 showing the test setup

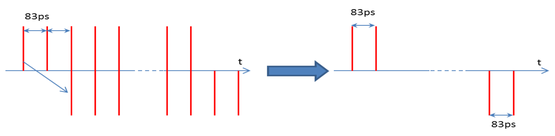


Stripline BPM installed in TBL girder n° 8, at position 0860

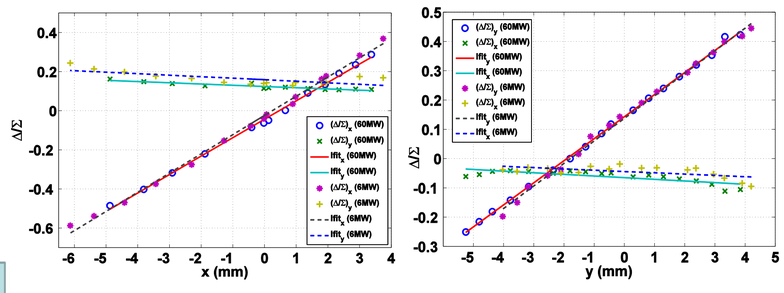
- Position estimates as **x=kΔ/Σ**, being k the linear calibration coefficient and Δ the difference, Σ the sum of opposite electrode signals.
- **Analog signal shaping** required for correct acquisition of short and intense BPM electrode signals → Integration / Low-Pass (LP) filtering before ADC.



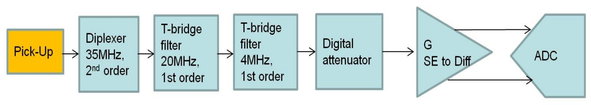
2D electromagnetic analysis of the BPM (45°)



Multi-bunch train response of the first stripline BPM prototype

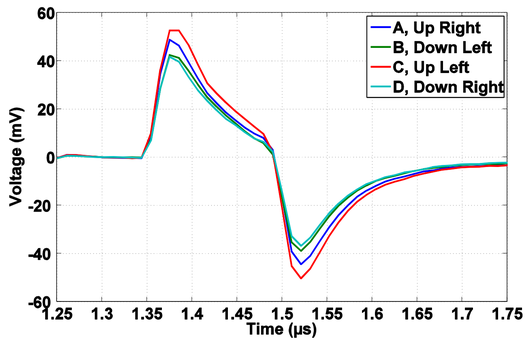


Dependency of the Δ/Σ position signal on the beam displacement (both planes)



Analog readout electronics

- Pick-up installed in **Test Beam Line (TBL)**, at position 0860, with 45° rotation.
- Two test scenarios: **low (6MW) and high power (60MW) RF interference** from the decelerating structures (PETS).
- Beam steered in ~ **±5mm range** in horizontal and vertical plane for **sensitivity test** by moving quadrupole QDR0800. BPS0850 and BPS0910 acted as reference BPMs.
- **Reduced vertical sensitivity** than theoretically expected (100m^{-1}).
- The effect of a 10 times **higher RF PETS power** is a ~190µm **offset** in both planes.

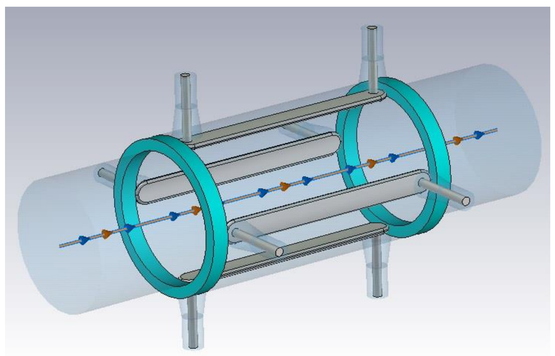


BPM output signals for a centred beam under high power RF interference

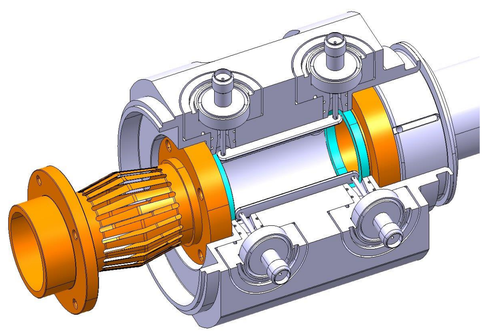
$x_{H,V} = (S_{H,V}^{-1})\Delta/\Sigma + EOS_{H,V}$		
Parameter	6 MW PETS RF power (Beam current: 10 A)	60 MW PETS RF power (Beam current: 22 A)
V sensitivity S_V (m^{-1})	72.4±1.8	75.3±0.6
H sensitivity S_H (m^{-1})	98.1±1.7	94.2±1.4
V offset EOS_V (mm)	-1.76±0.07	-1.91±0.02
H offset EOS_H (mm)	0.24±0.05	0.46±0.04
V RMS lin. error (µm)	250.42	92.73
H RMS lin. error (µm)	182.87	120.00

Linearity and sensitivity parameters

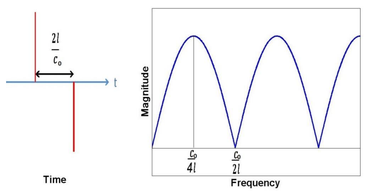
DESIGN OF A 50Ω-TERMINATED STRIPLINE PROTOTYPE



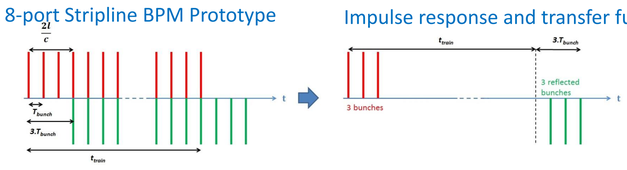
- First prototype provides **insufficient suppression of the 12GHz CLIC RF power signal.**
- Longitudinal dimensions are very close to transverse ones (25 vs 23mm) → **non-ideal transfer response**.
- New design intends to tune the **third notch** of the frequency response to 12GHz → electrode length ***l*=37.5mm**.
- Option of a **loop-thru calibration** via the downstream ports.



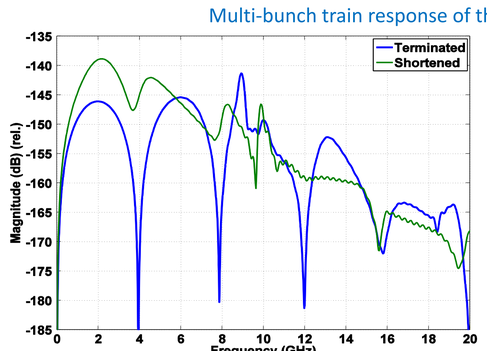
50Ω-Terminated, 8-port Stripline BPM Prototype



Impulse response and transfer function of an ideal stripline BPM



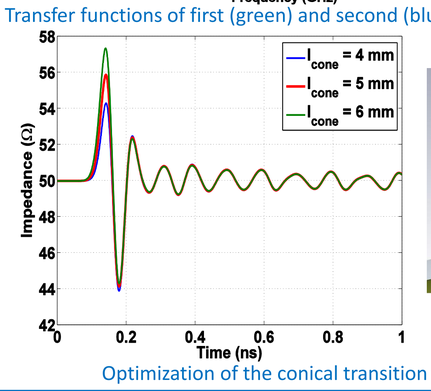
Multi-bunch train response of the modified stripline BPM prototype



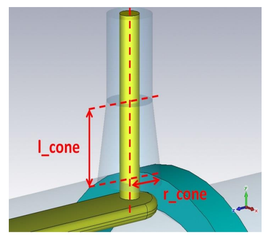
Transfer functions of first (green) and second (blue) prototype

Parameter	Shortened BPM	Terminated BPM
Stripline length	25 mm	37.5 mm
Angular coverage	12.5% (45°)	5.55% (20°)
Electrode thickness	3.1 mm	1 mm
Outer radius	17 mm	13.54 mm
Ch. Impedance	37 Ω	50 Ω
Duct aperture	23 mm	23 mm
Resolution	2 µm	2 µm
Accuracy	20 µm	20 µm
Temporal Resolution	10 ns	10 ns

CLIC DB Stripline BPM Prototype Parameters



Optimization of the conical transition for impedance matching



- **35dB suppression of 12GHz** frequency components.
- Conical transition included from electrode to coaxial feedthrough to **minimize reflection** and improve the **impedance matching**.

CONCLUSIONS

- **Expected performance** of the first stripline BPM prototype and its acquisition electronics during CTF3 beam tests: expected signals, levels and radiation-hardness.
- **The presence of high power RF** interferences from the PETS has an influence in the offset, which seems to be caused by **insufficient suppression of 12GHz CLIC RF fields**.
- The problem is addressed by the **development of a new stripline prototype with improved notch filter effect at 12GHz**, providing also the possibility of loop-thru calibration via the downstream ports.
- Prototypes under **test at CTF3** and will be compared to a simulated **coaxial BPM.**