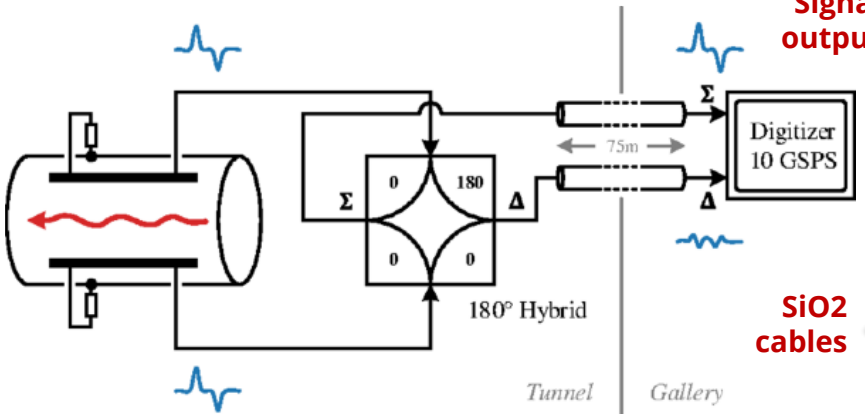
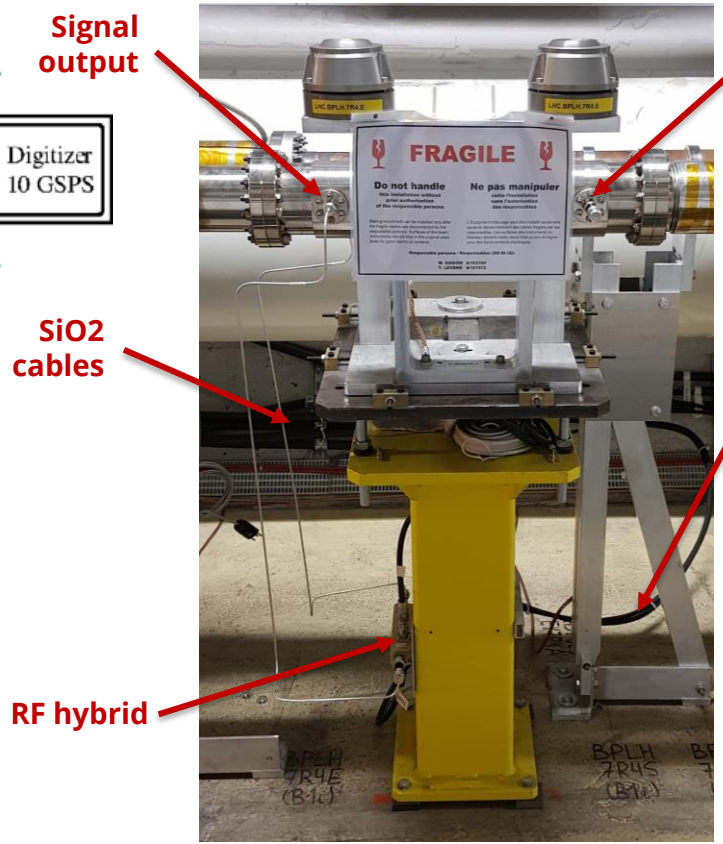
EM stripline developments status and plans

Michal Krupa SY-BI-BP / WP13

HF BPM review, 15/01/2025

Stripline BPMs

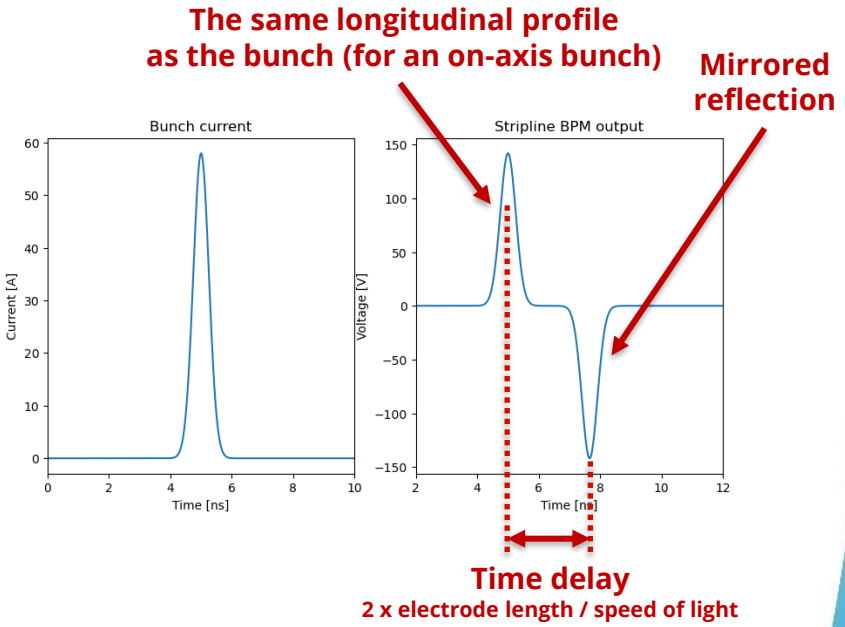




- Long electrodes with a connector on each end
  - For head-tail (HT): one end for signal generation, the other end loaded with 50 Ω
- Current HT – elongated version of the standard LHC stripline BPM

Stripline BPM for intra-bunch measurements

- Perfect stripline generates an electric signal which is a replica of the bunch current (+ reflection) which is modulated by the intra-bunch position
  - Commonly used at CERN and other facilities as an HT monitor
  - Gating on the positive signal only for HT measurements
  - “Standard” electrode length to resolve LHC bunches – 400 mm
- In real (imperfect) world the signal is distorted due to the electrode impedance variations, and other reflections and BW limitations in cables and electronics

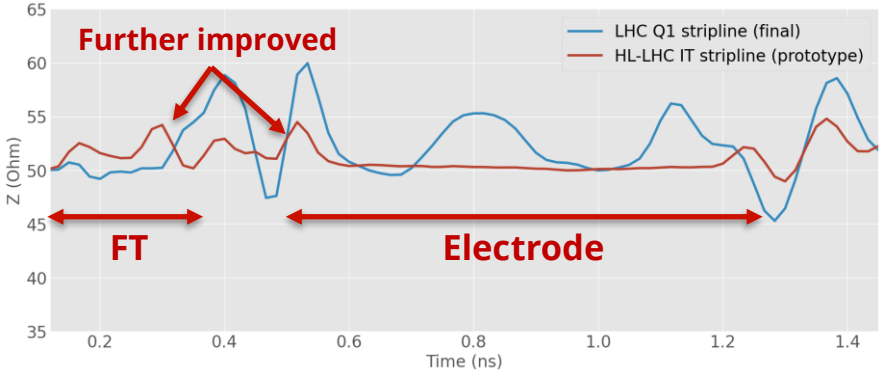


Can we reuse the existing LHC HT BPM design?

- End flanges, aperture, body length, electrode length are appropriate for the HL-LHC BPW
- Three issues:
  - Currently used LHC HT BPMs are single plane only – design update would be needed to accommodate the request for a double-plane BPW
  - Non-optimal electrode design: very complex mechanical connection to the BPM body and poor impedance control
  - Limited availability of spare FTs

LHC stripline

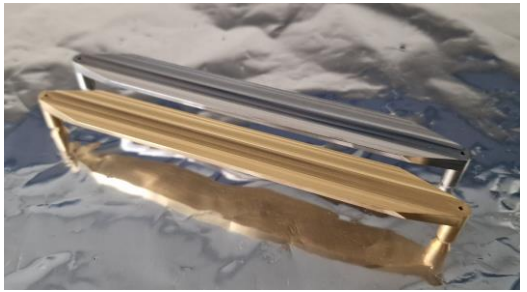
HL-LHC stripline

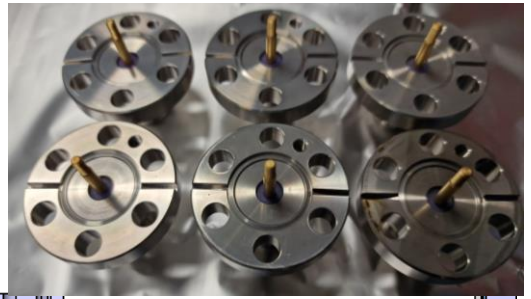


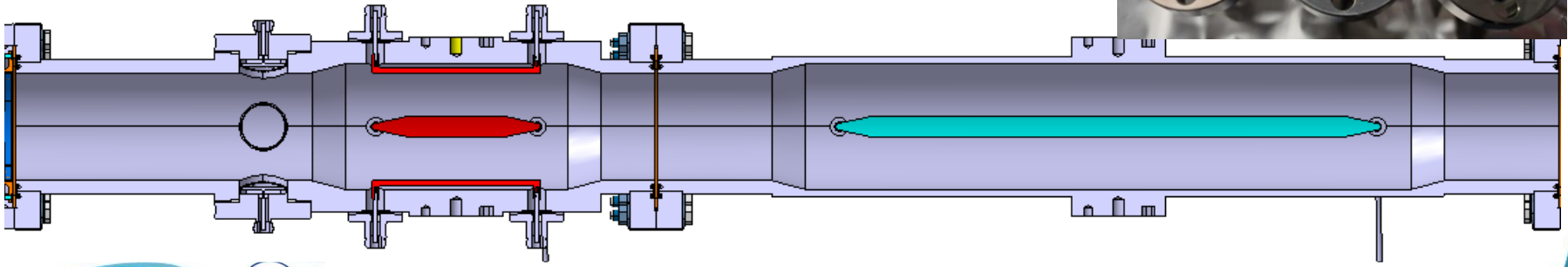
TDR up to 20 GHz
Change of N connector grade and pin dimensions to compensate for decrease of ε during thermal treatment

Elongated HL-like stripline

- Same approach as the LHC HT pick-ups: use the latest stripline BPM design but make the electrode longer (400 mm)
  - Electrode and feedthroughs already optimized for 6 GHz BW, measured up to 20 - 26.5 GHz
  - Machining techniques already developed and demonstrated
  - Good reproducibility achieved after a few design iterations
  - The same approach is used for the BPTQR

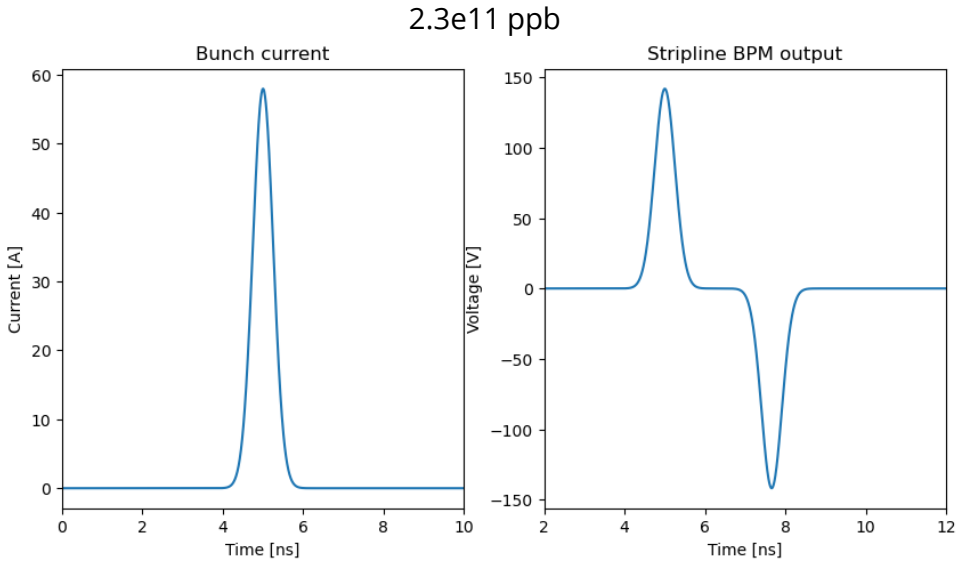






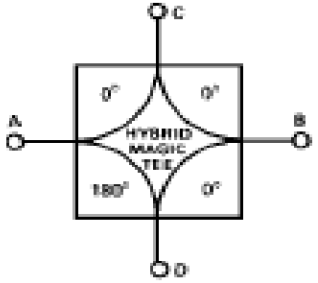
Signal levels

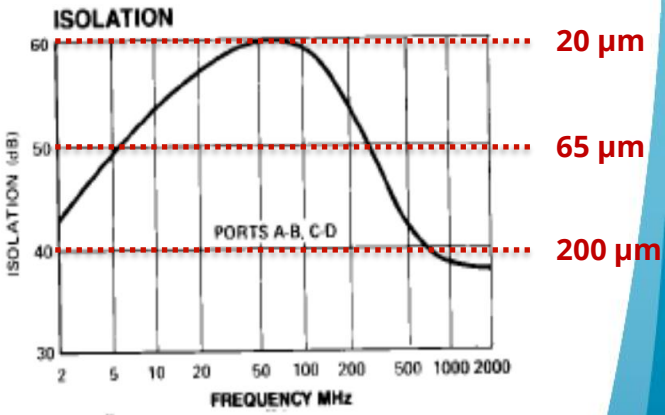
- Stripline BPMs generate high-amplitude signals exceeding 100 Vpp in the LHC
- ~ 15 W per BPM output with full beam
  - Can get much worse for off-centred beams
- This power must be taken by the front-end electronics (e.g. hybrid, attenuators)



Expected performance

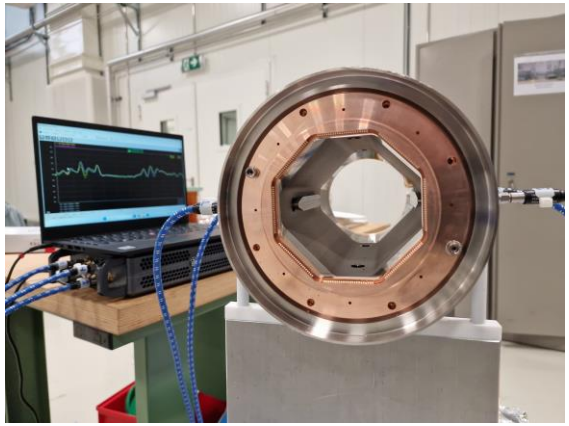
- BPM thermal noise (10 GHz BW) with a pilot bunch: ~ 1 µm
  - Resolution will be (most likely) limited by the front-end (e.g. hybrid) and acquisition electronics (e.g. scope)
- H-9 hybrid, used in the existing LHC HT, is the best available on the market
  - BW: 2 GHz; Power: 25 W; Isolation: min. 30 dB
  - Collaboration with Oxford University to develop a better hybrid – many prototypes not exceeding the H-9 performance
  - Most likely candidate for “classical” stripline BPW – no performance improvement
    - Alternative solution in the next talk
- Better digitizers might be available in 5 years to improve on the existing HT resolution / sampling

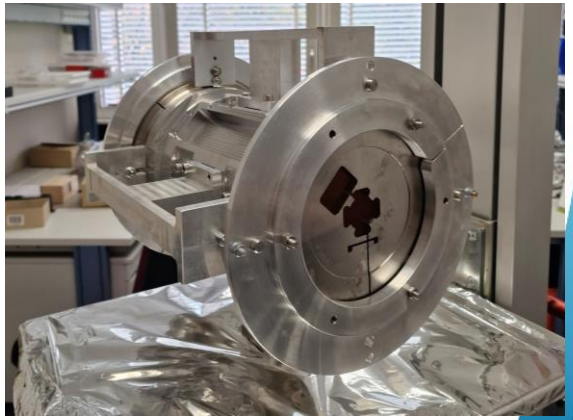




Lab RF measurements

- RF measurements performed for the cryogenic HL-LHC striplines:
  - Electrode impedance
  - Electrode symmetry
  - Electrode cross-coupling
  - Electrical center w.r.t. the mechanical fiducials
  - Beam position sensitivity
  - Beam position nonlinearity
- The same measurements are possible for a stripline BPW – all measurement equipment and tooling already exists or can be easily adapted





Compatibility with environmental constraints

- Mechanics:
  - Preliminary design compatible with the available space done
  - No known alignment constraints
- Bakeout:
  - BPM, feedthroughs and SiO2 cables compatible with the LHC bakeout requirements
  - 50 Ω loads will need to be removed before and reinstalled after each bakeout (5 min per BPM)
- Radiation:
  - BPM, feedthroughs and SiO2 cables are rad-hard up to 10's MGy (needed for the IP1/IP5 IT)
  - 50 Ω loads and hybrids might eventually suffer from radiation damage – replacement parts must be available
- Accessibility:
  - Preliminary design giving access to all BPM connectors done

Proposed strategy and milestones

- **Study:**
  - RF measurements of the existing LHC HT BPMs, hybrids and cables [Q1'25]
  - Estimation of performance limitation due to each component [Q2'25]

  } **Giusy Passarelli [DOCT]**
- **Design:**
  - Decision on the necessity of the intermediate flange [Q2'25]
  - Final BPTQR design + stripline BPW design [Q2-Q4'25]
  - Final alignment and support system design [Q3-Q4'25]

  } **Loann Havart [TECH]**
  - Production of manufacturing drawings [Q1'26] ← **EN-MME job already opened**
- **Production:**
  - Procurement of RF FTs and SiO2 cables [done]
  - Procurement of raw material for BPTQR and stripline BPW [Q1'25]
  - Production of two prototype elongated HL-like electrodes [Q2-Q3'25]
  - Production of a pre-series alignment platform [Q2'26]
  - Production of two pre-series BPTQR + BPW assemblies [Q2'26-Q4'26]
  - Series production of alignment platforms, BPTQR's and BPW's [Q2'27-Q4'27]

  } **EN-MME or external, TBC**
- **Testing:**
  - Metrology and lab RF measurements of prototype electrodes [Q3-Q4'25]
  - Alignment tests with the pre-series alignment platform and pick-ups [Q4'26-Q1'27]
  - Lab RF measurements (and at CLEAR?) of pre-series BPTQR's and BPW's [Q1'27]

  } **SY-BI**

Thank you for your attention