CC pick-up (BPTQR) status and plans

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With inputs and a lot of help from:
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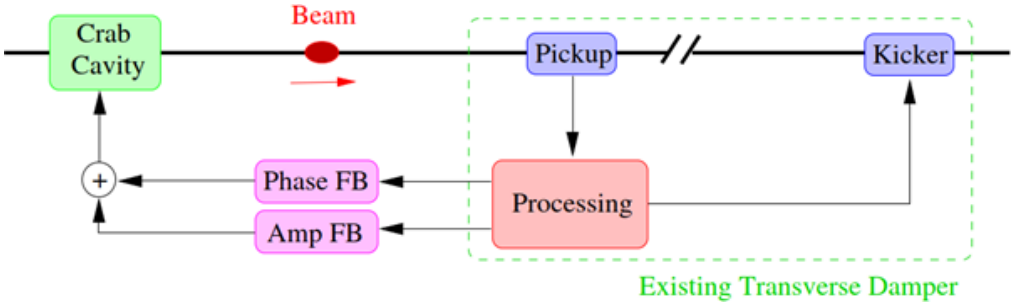
WP12: E. Page, J. Hansen
WP4: P. Baudrenghien, W. Hofle
WP15: G. Aparicio, S. Chemli, M. Noir, M. Sosin

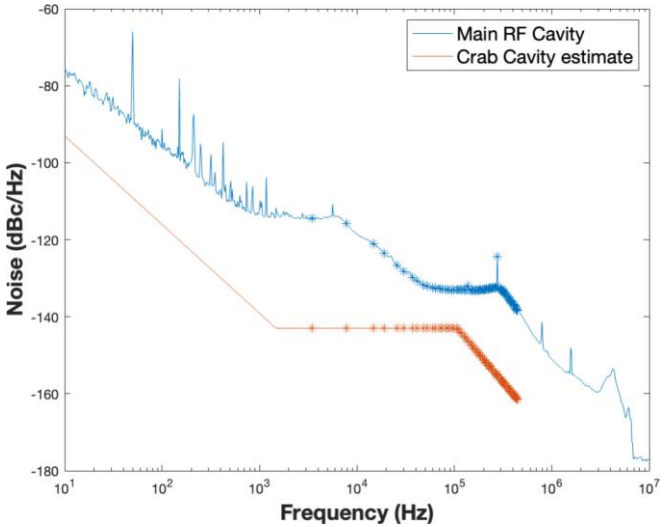
13th HL-LHC Collaboration Meeting, 28/09/2023 Vancouver

Motivation for a CC pick-up

- Without a feedback system, transverse emittance growth due to the CC noise significantly exceeds the target value of ≤ 2%/h

	With ADT off	With ADT on
Amplitude noise	11.2%/h	4.2%/h
Phase noise	4.2%/h	1.1%/h
TOTAL	**15.4%/h**	**5.3%/h**





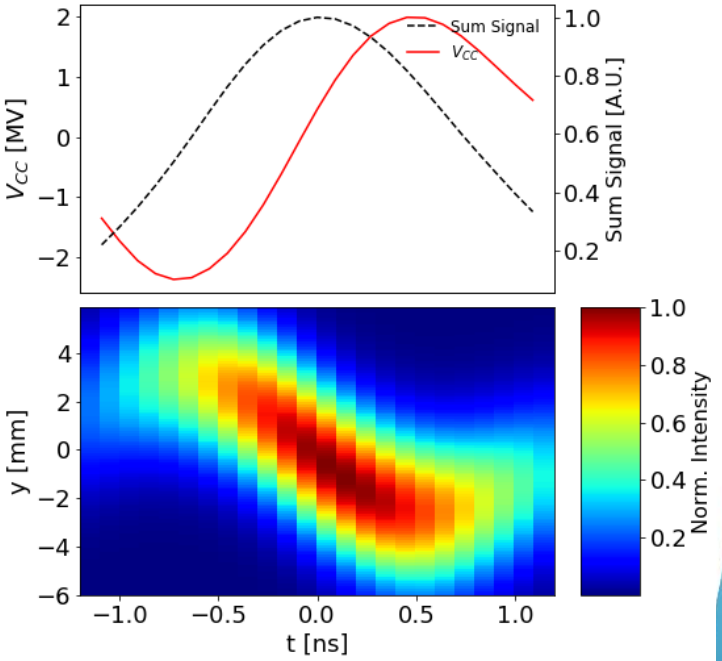
More details:
P. Baudrenghien et al.
CC feedback and BPM HW options

From APWL to BPTQR

- Originally, APWL (wall current monitor) chosen as the CC pick-ups managed by WP4
  - Complex mechanics
  - Optimized for longitudinal measurements
- WP13 proposed to take over the responsibility for those pick-ups and design them using standard BPM technologies
  - Clear responsibility split: pick-up by WP13, electronics by WP4
  - Baseline change documented in the ECR 2499201
  - Preliminary conceptual design proposed in the ECR: 4 button electrodes + 2 stripline electrodes per pick-up
  - 400 kCHF transferred from WP4 to WP13 for production of 10 pick-ups (8 installed + 2 spares)

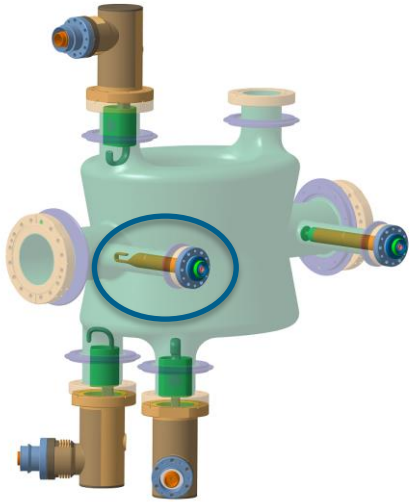
Functionality A: CC-beam phasing

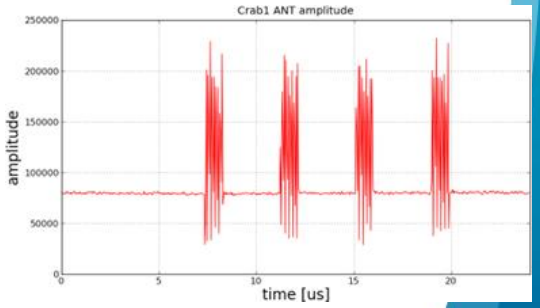
- Longitudinal beam position defined by the 400 MHz system in SR4 / UX45
- CCs controlled by electronics installed in 4 Faraday cages in IP1/5
- WP requirement: monitoring of the phase of the 400 MHz beam current component close to the CC location to correct the crabbing phase
- ECR proposal: 2 button electrodes for narrowband longitudinal measurements, next to the CC



Functionality B: Filtering of beam interference on the CC antenna signal

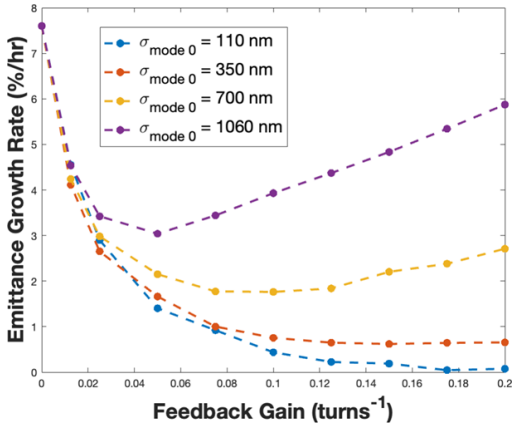
- An antenna installed outside the CC generates a signal used to regulated the CC field
- Undesired coupling to the beam field to be removed through Adaptive Noise Cancelling techniques
- WP4 requirement: Monitoring of the beam current in the 360–440 MHz band close to the CC location. Sensitivity from a single pilot bunch to a full nominal beam
- ECR proposal: 2 button electrodes for longitudinal measurements, next to the CC

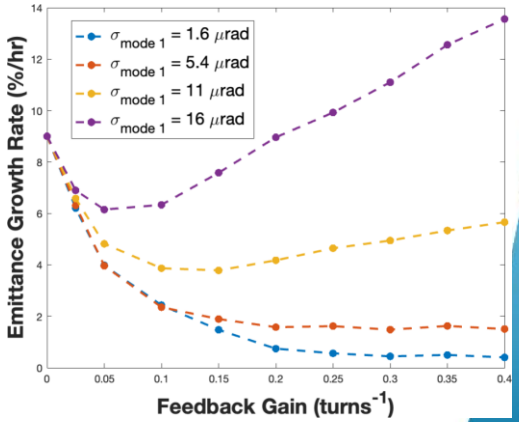




Functionality C: CC noise FB

- Excessive CC noise results in an additional bunch tilt outside of the crabbing region
- WP4 requirement: Monitoring of bunch tilt in a high β location with a suitable phase advance from the CC
- Noise floor of 5.3 μm for rigid bunch displacement, 55 μrad for bunch tilt
  - Assumes β=2000 at the BPTQR location
  - Assumes FB regulation BW of 136 kHz (~ 150 bunches)
- ECR proposal: 2 stripline electrodes for transverse HT measurements





BPW: instability monitoring

- Existing wideband HT pick-ups for instability monitoring installed in IP4
  - Limited performance
  - Bad location for CC monitoring
- New design needed for HL era
  - Better performance – open spec
  - More suitable location – the same constraints as for the BPTQR
- Two technologies under consideration:
  - Electro-optical BPMs – HL baseline
  - Long stripline BPMs (min. electrode length of 400 mm to resolve the full longitudinal bunch profile)

More details:
T. Levens (previous talk)
HT measurements & outlook for HL-LHC

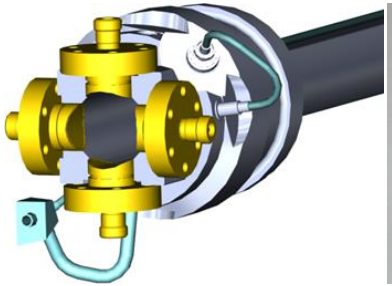
Electrode choice

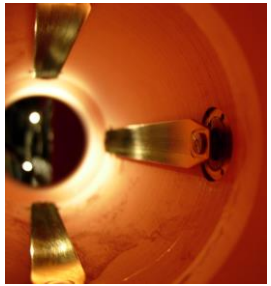
Button

- “Default” choice for most BPMs
- Simple mechanics
- Lower cost
- Limited low-frequency sensitivity
- Low cutoff frequency defined by the capacitance and the load
- Commercially procured component
- Easy to pair

Stripline

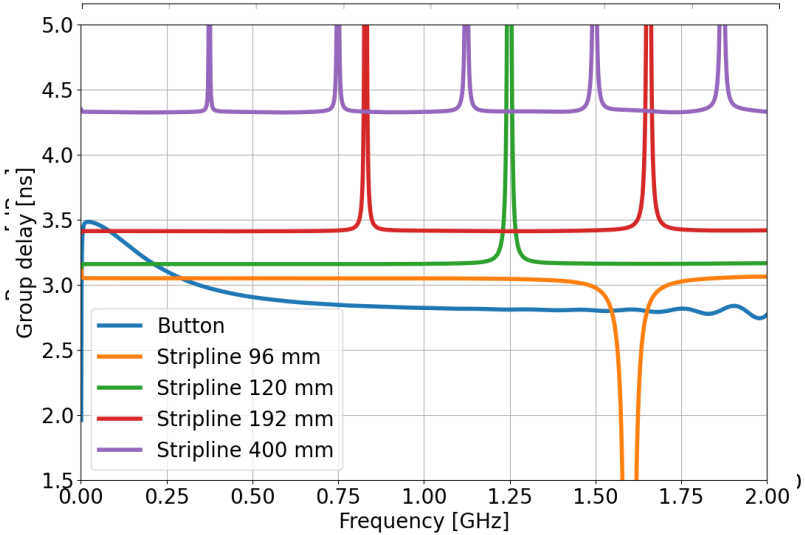
- “Special” BPMs – directivity, BW
- Complex mechanics
- Higher cost
- Good wideband response possible with perfect matching
- Frequency response defined by the electrode length
- Custom made
- Very difficult to pair





Stripline and button signals

- Stripline BPMs are approx. 6 times (16 dB) more sensitive to the bunch current
- LHC HT stripline BPMs use 20 dB / 20 W attenuators at the pick-up output to protect the tunnel electronics from high power signals and additional 6–20 dB attenuators in front of the oscilloscopes in the galleries



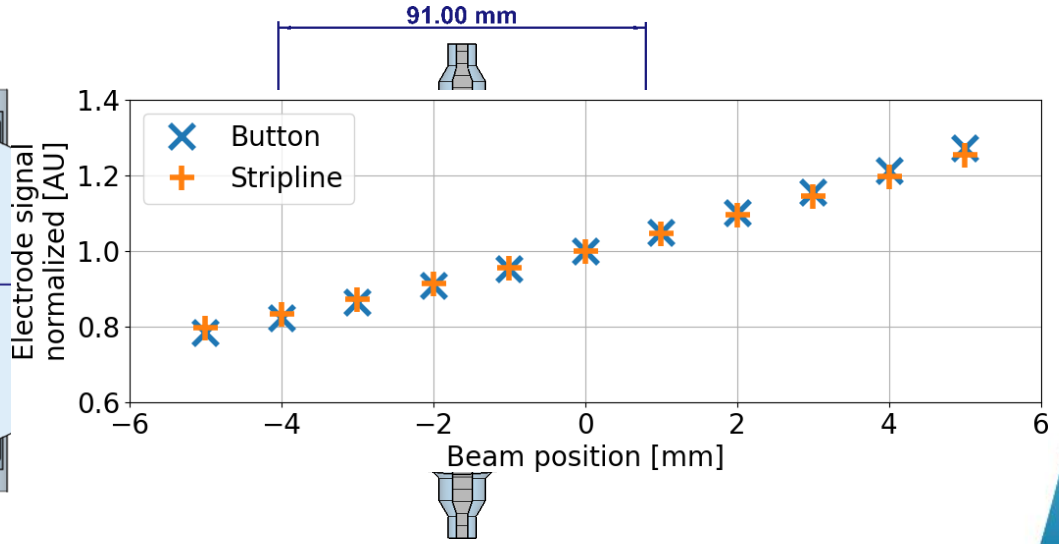
Button	Phase flatness @ 400 MHz ± 68 kHz
Button	0.145 deg (2.5 mrad)
Strip 96 mm	0.149 deg (2.6 mrad)
Strip 120 mm	0.155 deg (2.7 mrad)
Strip 192 mm	0.167 deg (2.9 mrad)
Strip 400 mm	0.212 deg (3.7 mrad)

1e11 ppb, 1.2 ns, Gaussian bunch, centred

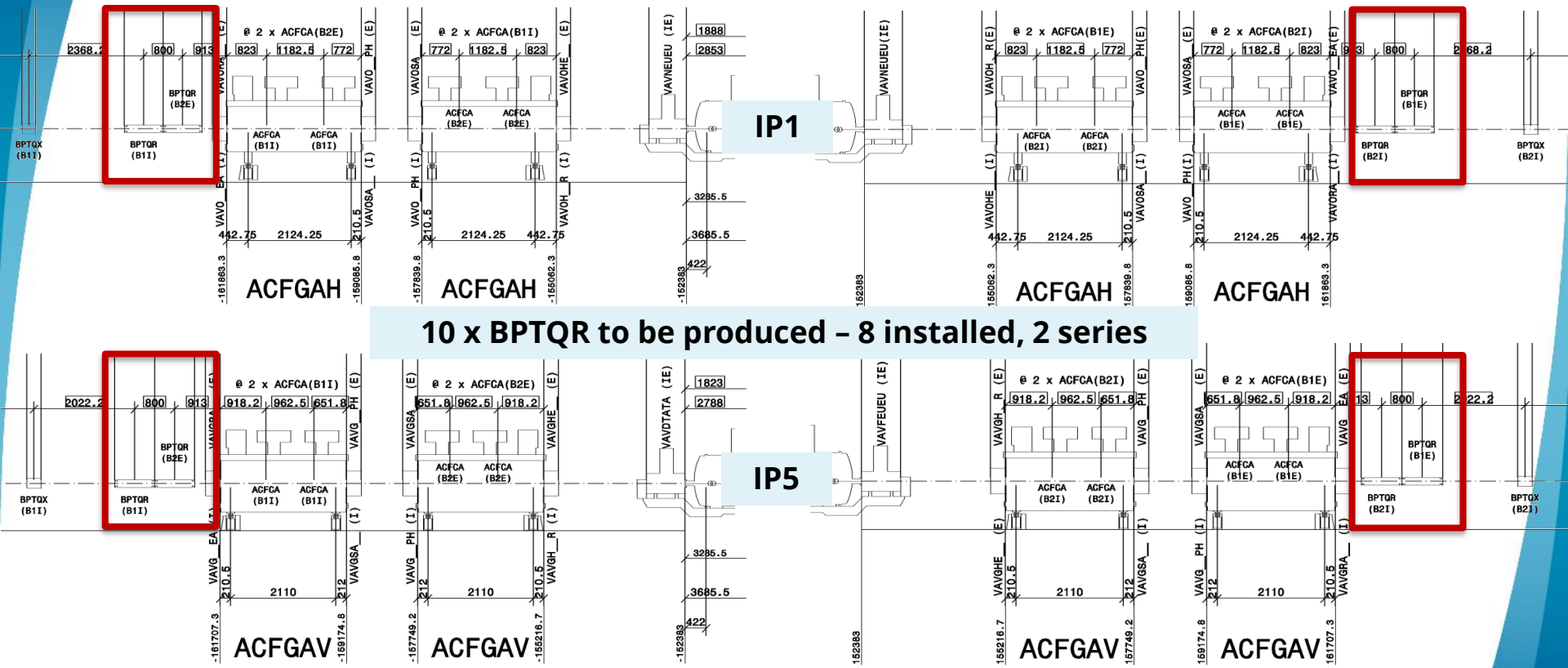
Beam position sensitivity

- Sensitivity to the beam position is defined by the BPM aperture
  - For small displacements close to the center: $k_{PU} = 2 / r_{PU}$
  - Ø81 mm needed at the BPW location
  - Effective aperture of the stripline is larger than the button

	k_{PU}
Button	0.0494 mm^{-1}
Stripline	0.0462 mm^{-1}



Installation location

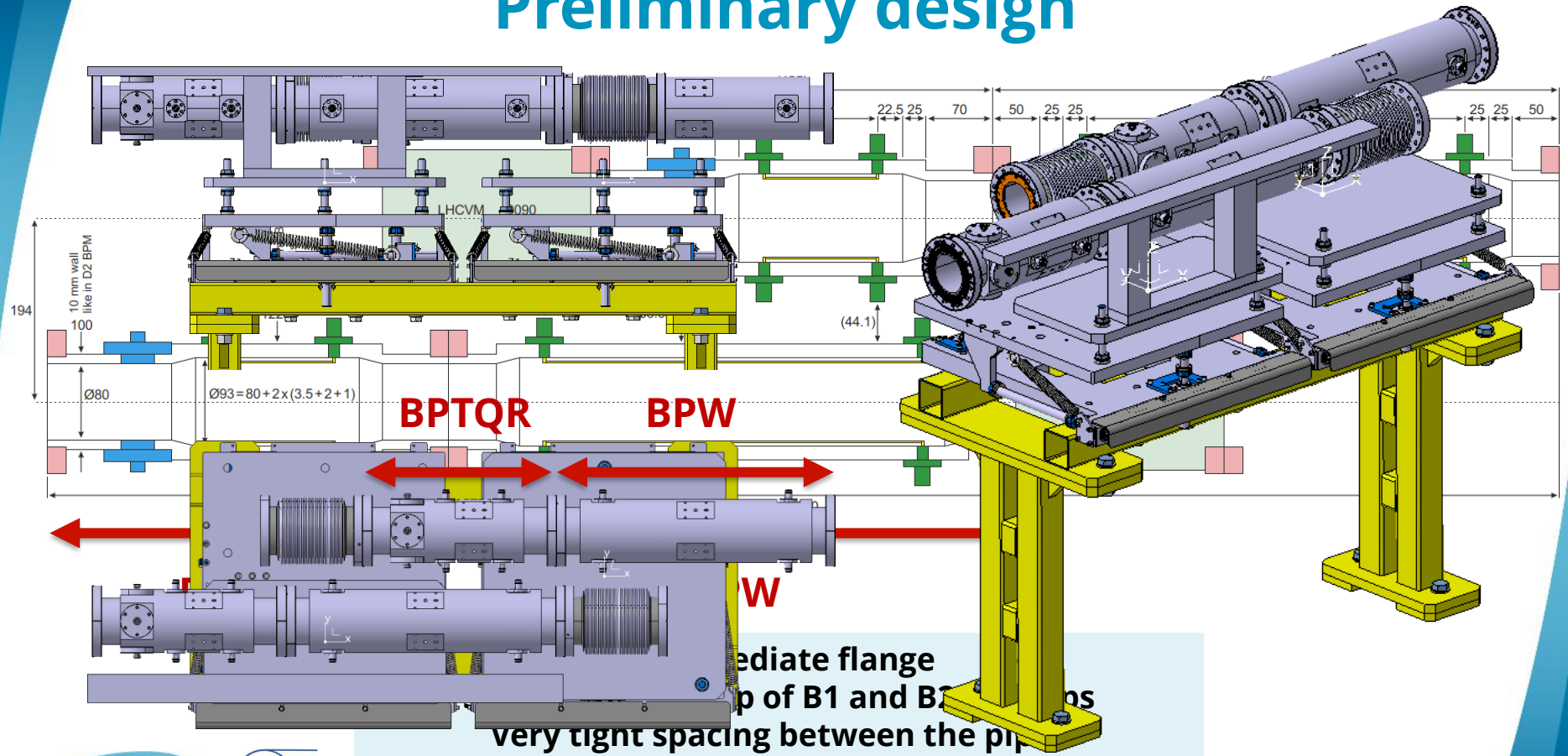


10 x BPTQR to be produced – 8 installed, 2 series

CC pick-up design consideration

- BPTQR and BPW as a combined pick-up
- Beam measurements only in the relevant plane - “rotatable” design
- Reuse RF components designed for the “standard” HL-LHC BPMs:
  - Button electrode, RF feedthroughs, SiO2 cables, striplines
- Inner body coatings: gold flash, 100 µm Cu, NEG (TBC)
- No FRAS integration – installation on a manual UAP for semi-manual realignment in YETS and LS
- BPTQR part (as in the ECR):
  - 4 x button electrodes for functionalities A and B
  - 2 x 120 mm stripline electrodes for functionality C
- BPW part:
  - Plan B: 400 mm stripline electrode – can be substituted by a short EO BPM + drift chamber without impact on the surrounding WP12 equipment

Preliminary design



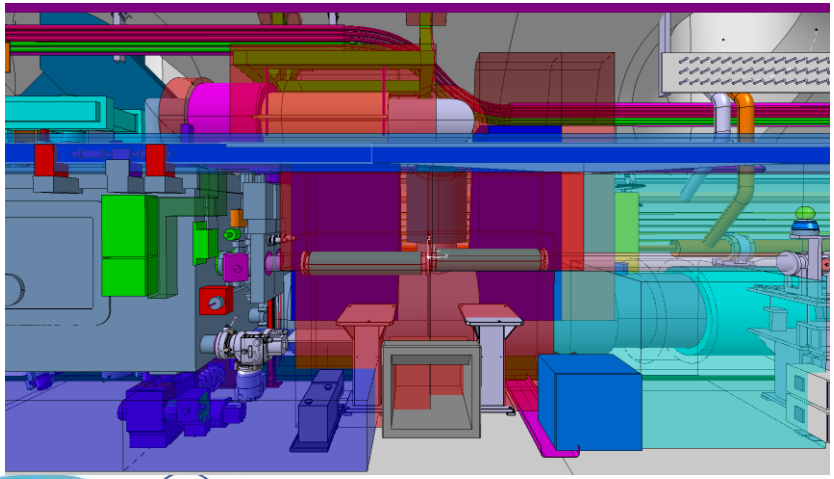
ediate flange

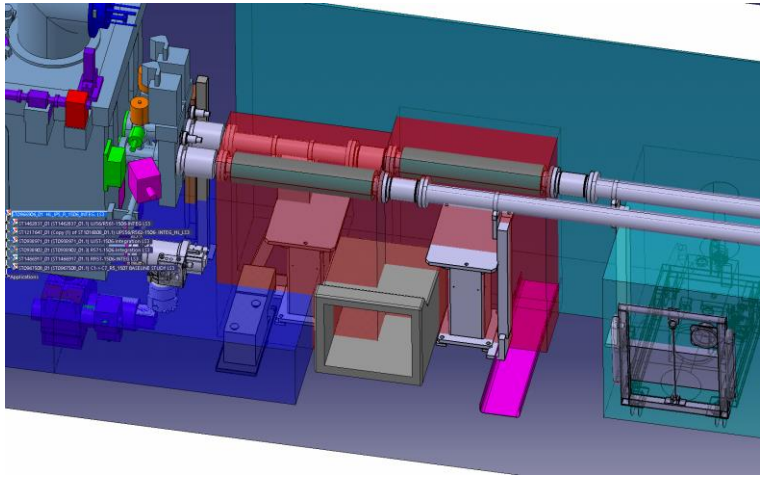
p of B1 and B2 ns

very tight spacing between the pi

Integration

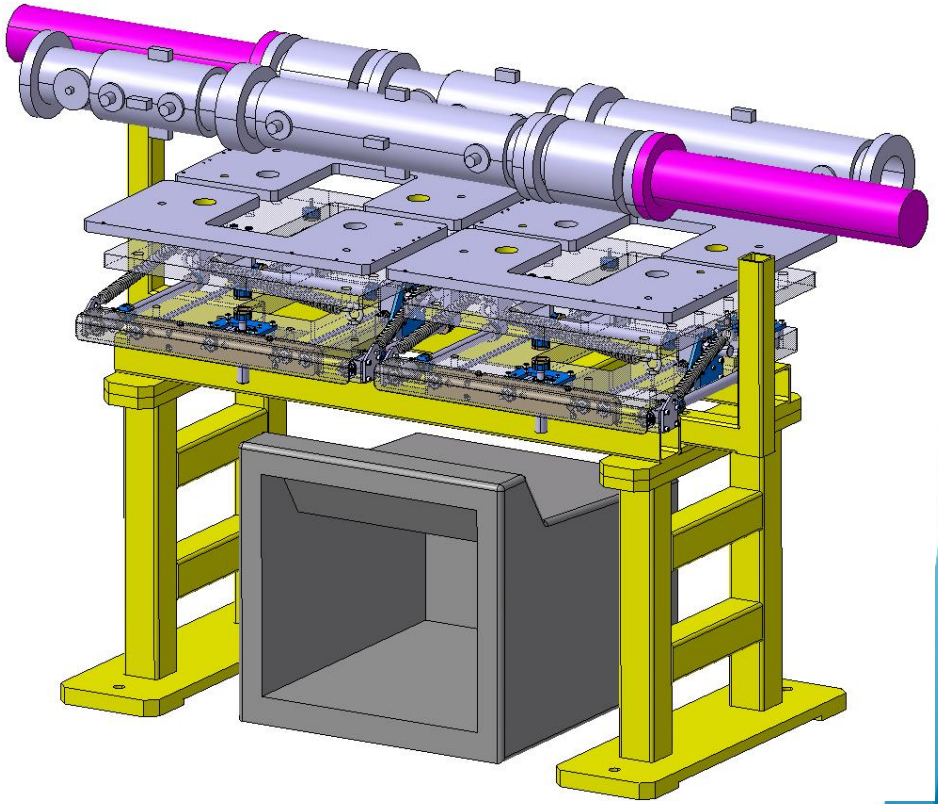
- Relatively difficult area for integration – personnel access constraints, many reserved volumes, auxiliary VSC and EL equipment, limited tunnel floor
- Initial space reservation of 2 x 800 mm of beam line
  - Pick-up length increased to 1025 mm, significant overlap
- Current goal: an updated BPTQR+BPW model to WP15 for layout 2.0





Integration

- Integration of supports for the adjacent drift chambers under discussion
- Requests for long cables done by WP4 in 2020:
  - 1 x 7/8” cable to the Faraday Cage per APWL (now BPTQR)
  - This is not enough for the 4 buttons + 2 striplines
  - Cabling request to be updated after the final pick-up configuration is confirmed



Alignment

- FRAS specification: APWL (i.e. BPTQR) on a “Manual standardized adjustment platform” for realignment during LS and YETS
  - Alignment strategy: Universal Alignment Platform (UAP) developed based on a WP12 design, following BE-GM guidelines
- After FRAS activation, the beam can be several mm away from the BPTQR center until LS / YETS realignment is possible
  - The resulting “residual” beam position signal several orders of magnitude larger than the signal of interest
  - Significant reduction of the available dynamic range
  - Impact on performance will be quantified by WP2 / WP4

Potential performance

- Functionality C (noise FB) noise floor specification reminder, assuming β=2000 and BW=136 kHz
  - 5.3 μm for rigid bunch displacement
  - 55 μrad for bunch tilt
- Noise floor will be dominated by the processing electronics
  - Intrinsic pick-up noise: < 0.1 μm in (400 MHz ± 68 kHz) BW
- (Very) Preliminary performance assessment done by WP4
  - The specification probably achievable with the existing LHC ADT electronics (further analysis to be done by WP4)
  - Assuming the beam at the center of the BPTQR

Upgraded LHC ADT electronics:
D. Valuch, V. Stopjakova New generation of very low noise BPM system for the LHC transverse feedback

Schedule

- BPTQR + support design to be completed by April 2024
  - The final choice for the BPTQR electrodes must be confirmed by the end of October 2023
- Decision on the BPW technology expected after EO BPM beam tests
  - Preliminary stripline-BPW design done in parallel with the BPTQR
- Procurement of components shared with the “standard” BPMs ongoing (SiO2 cables) or about to start (button electrodes, RF feedthroughs)
  - 58 SiO2 cables, 40 buttons, 40 feedthroughs
  - Buying more components in the future might be challenging
- Design Review with WP2, WP4, WP12 and WP15 in 2024
- Production of 10 pick-ups in 2025-26 for installation in 2028

Summary

- Dedicated pick-up for CC diagnostics and feedback needed for setting up and reducing the transverse emittance growth
- Original APWL owned by WP4 replaced with BPTQR owned by WP13 installed on the Q4 side of the CCs
  - BPW for instability monitoring installed at the same location
- BPTQR is a large and complicated pick-up with multiple electrodes providing the three required functionalities without signal splitting
  - The final configuration of the electrodes must be soon confirmed to …
- BPTQR is not included in the FRAS
  - (Semi-)manual UAP for realignment during YETS / LS
  - Performance reduction due to a beam offset remains to be quantified
- Noise floor will be dominated by the processing electronics (WP4 scope)
  - Preliminary analysis of the LHC ADT electronics hints that the performance goal is achievable with a centered beam

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Thank you for your attention

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