Aperture, impedance and thermal considerations and electrode design for IP1/IP5 LSS BPMs

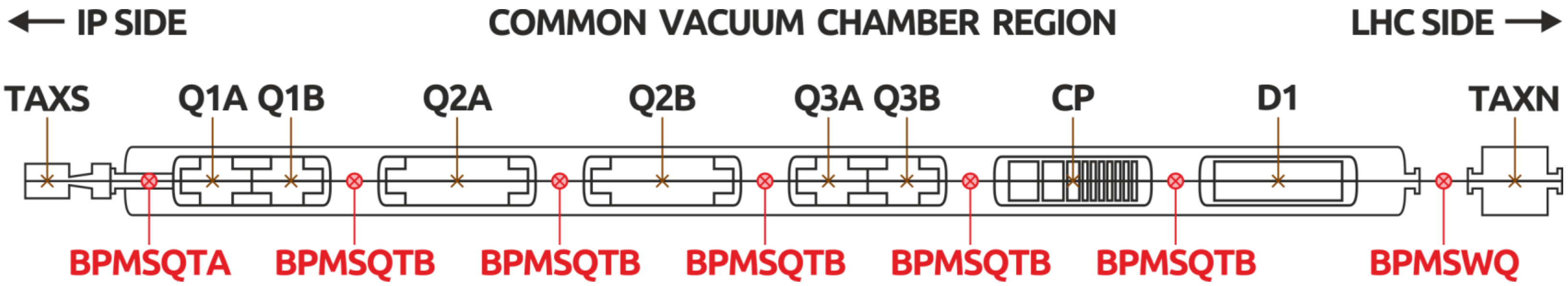
Michal Krupa BE/BI/BP

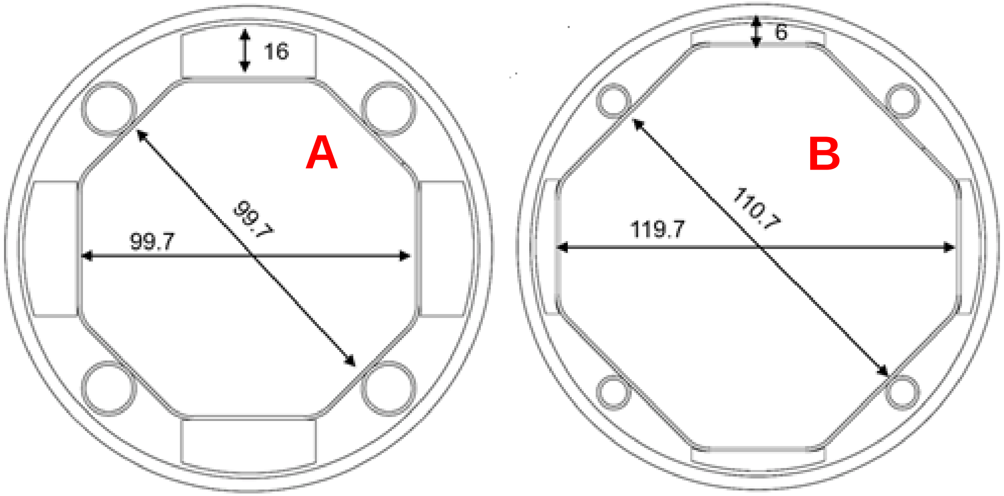
HL-LHC IT BPM conceptual design review – 17/05/2018

Outline

- Vacuum aperture
- Impedance
- Heat-load sources and estimation
- Cooling approach
- Electrode design

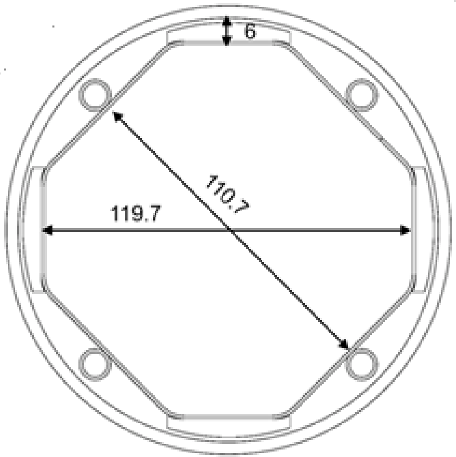
Stripline BPMs per HL-LHC IP side

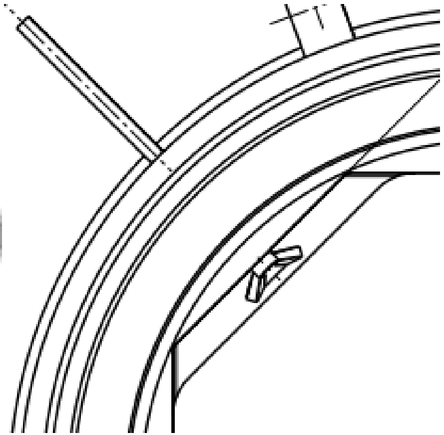


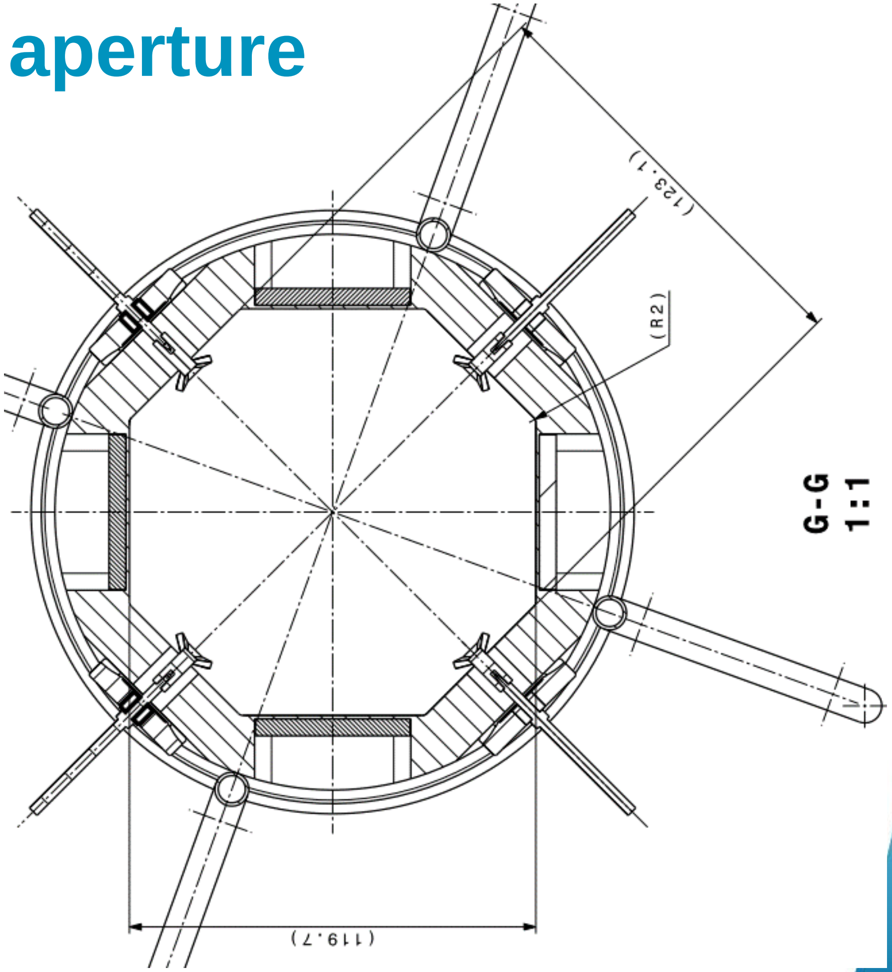


Vacuum aperture

- Maintain beam screen aperture in H and V
- Increase aperture at 45º to hide the electrodes from the beam by 1 mm



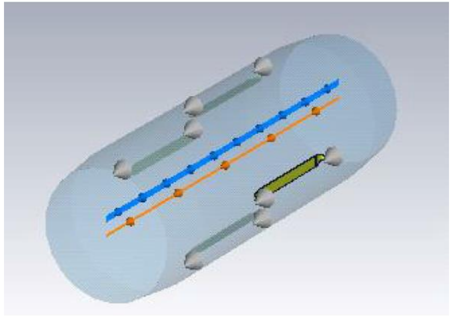




Impedance

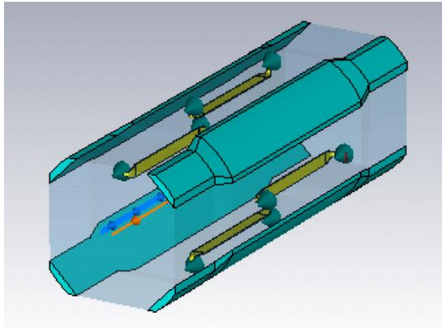
- 2016 BPM models simulated by N. Biancacci, R. De Maria, B. Salvant (BE/ABP)
- **Conclusions:** “The IT stripline BPMs impedance looks negligible in both configurations, octagonal and circular, with respect to the full HL-LHC impedance model”
- **Details:** 76th HL WP2 Meeting 02/09/2016
- Final models, when available, to be simulated again by BE/ABP

Circular – no tungsten



Strip to strip = 123mm

Octagonal- with tungsten



Strip to strip = 112mm

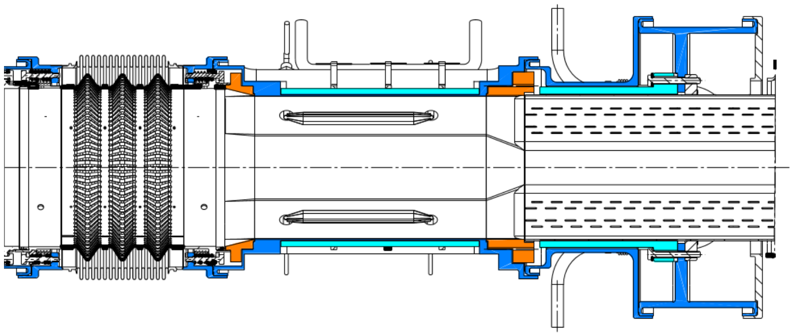
Heat load estimations

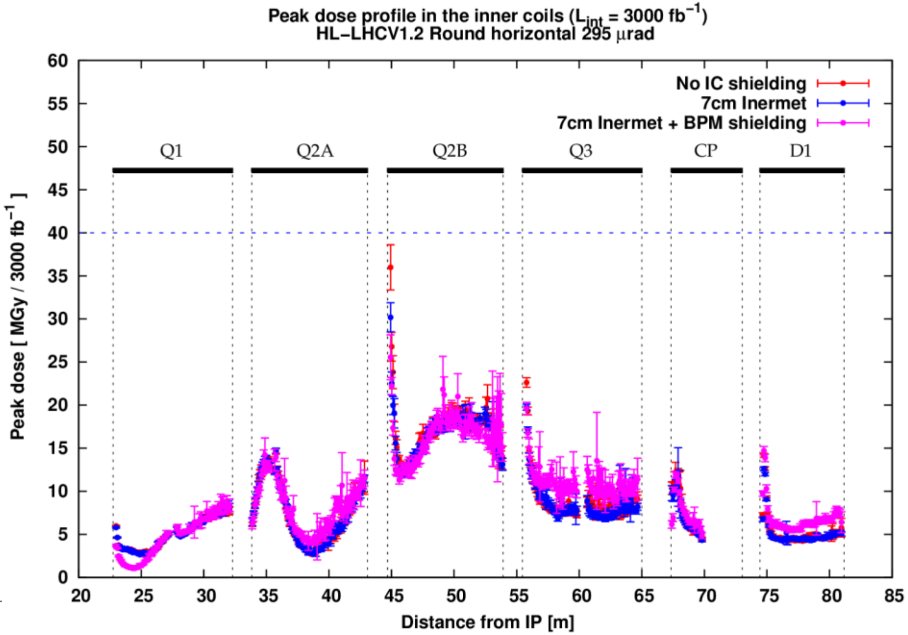
- Collision debris absorbed by Tungsten: 1.5 W
- Collision debris absorbed by BPM: 1 W
- Electron cloud: 2 W (20 W uncoated)
- Impedance: 0.5 W
- Beam: 2 W
- Cables: 0.5 W

Total per BPM: **~ 7.5 W** (coated), **~ 25.5 W** (uncoated)

Collision absorption

- Tungsten absorbers on the H and V planes of the Q2B BPM lower the peak dose to the magnet by further **15%**
- With VSC equipment dose lower by a total of **30%**

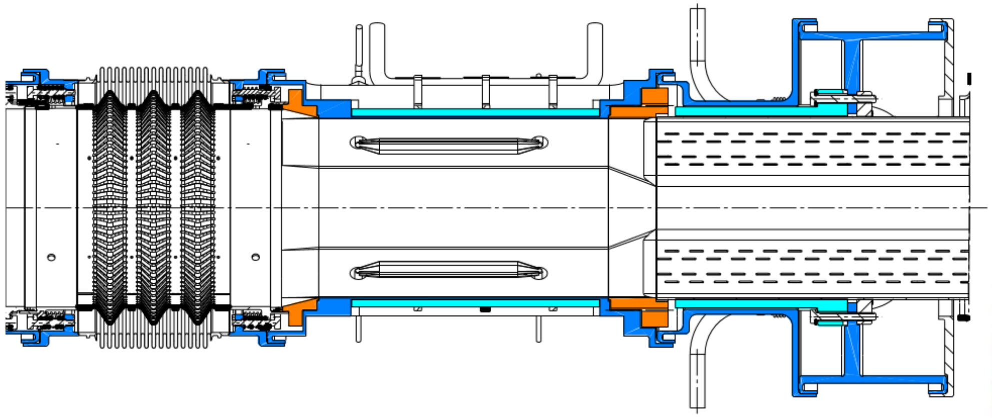




Details: 14th TCC, 01/09/2016
A. Tsinganis, F. Cerutti (EN/STI)

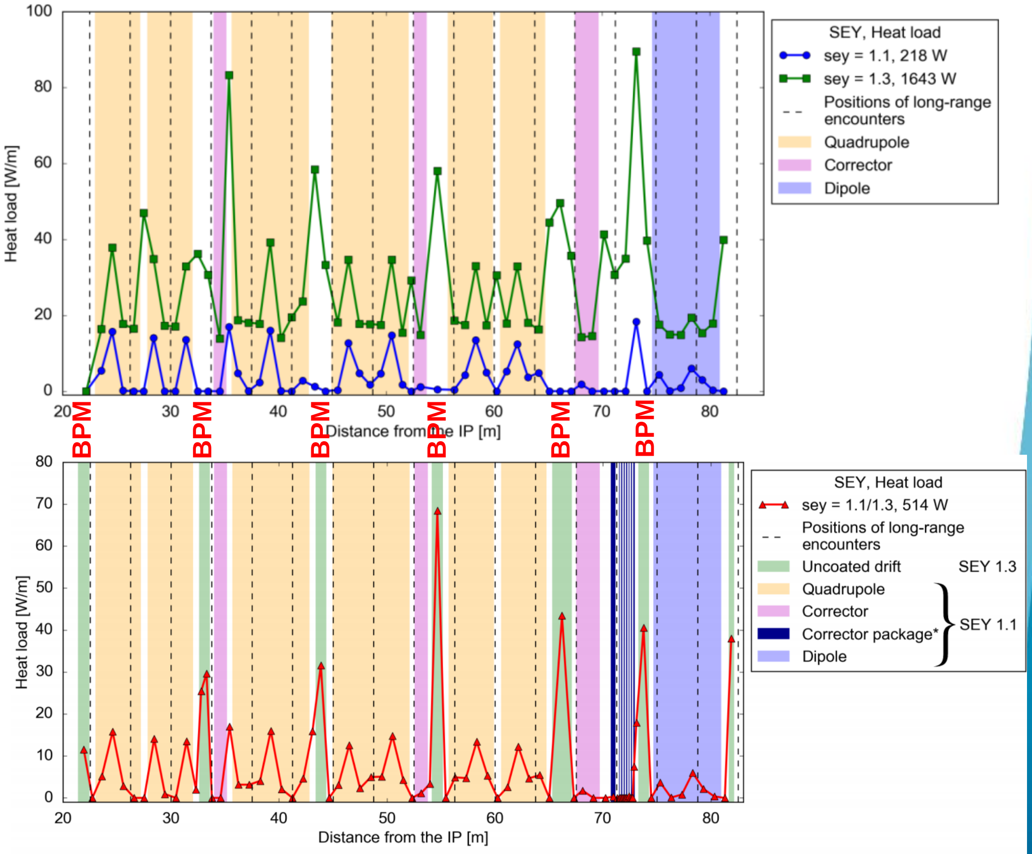
Tungsten block alignment

- Debris shielding efficiency calculations assume perfect continuity (i.e. alignment) of the tungsten absorbers among different equipment
- More realistic estimations (i.e. tungsten misalignment) under discussion with EN/STI (F. Cerutti, A. Tsinganis)
- Dedicated simulations to come



Electron cloud

- Uncoated BPMs (SEY 1.3)
  - Total **~ 80 W**
  - Worst BPM **~ 20 W**
- Coated BPMs (SEY 1.1)
  - Total less than **2 W**
- **Details:** CERN-ACC-2018-0009 by G. Skripka and G. Iadarola (BE/ABP)



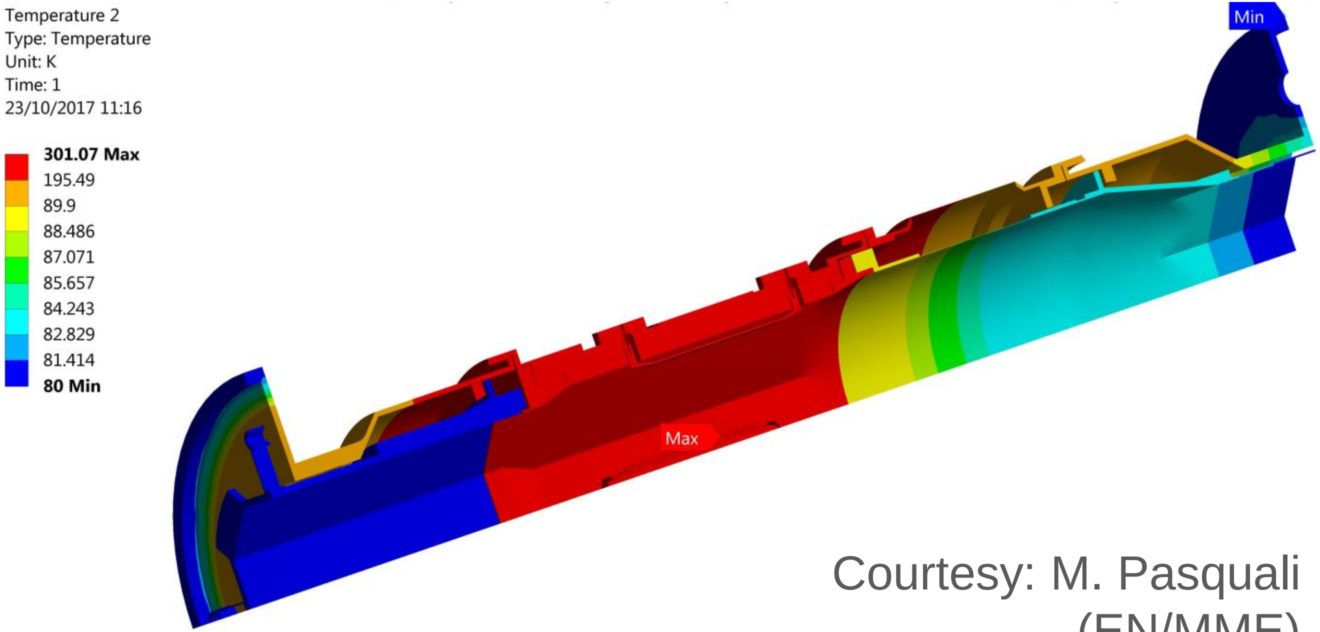
* dodecapole, skew dodecapole, decapole, skew decapole, octupole, skew octupole, sextupole, skew sextupole

IP5 simulations
BPMs located in drifts (green)

Cryogenic overhead

- Collision debris for all BPMs: **~ 10 W** out of **~ 600 W** for a single Q1-D1 string: **< 2%**
- Electron cloud for all BPMs:
  - Uncoated BPMs: **~ 80 W** out of **~ 500 W** for a single string: **~ 15%**
  - Coated BPMs: **~ 2 W** out of **~ 200 W** (coated drifts) for a single string: **~ 1%**
- **Details:** 34th TCC, 31/08/2017 by A. Tsinganis, F. Cerutti (EN/STI)

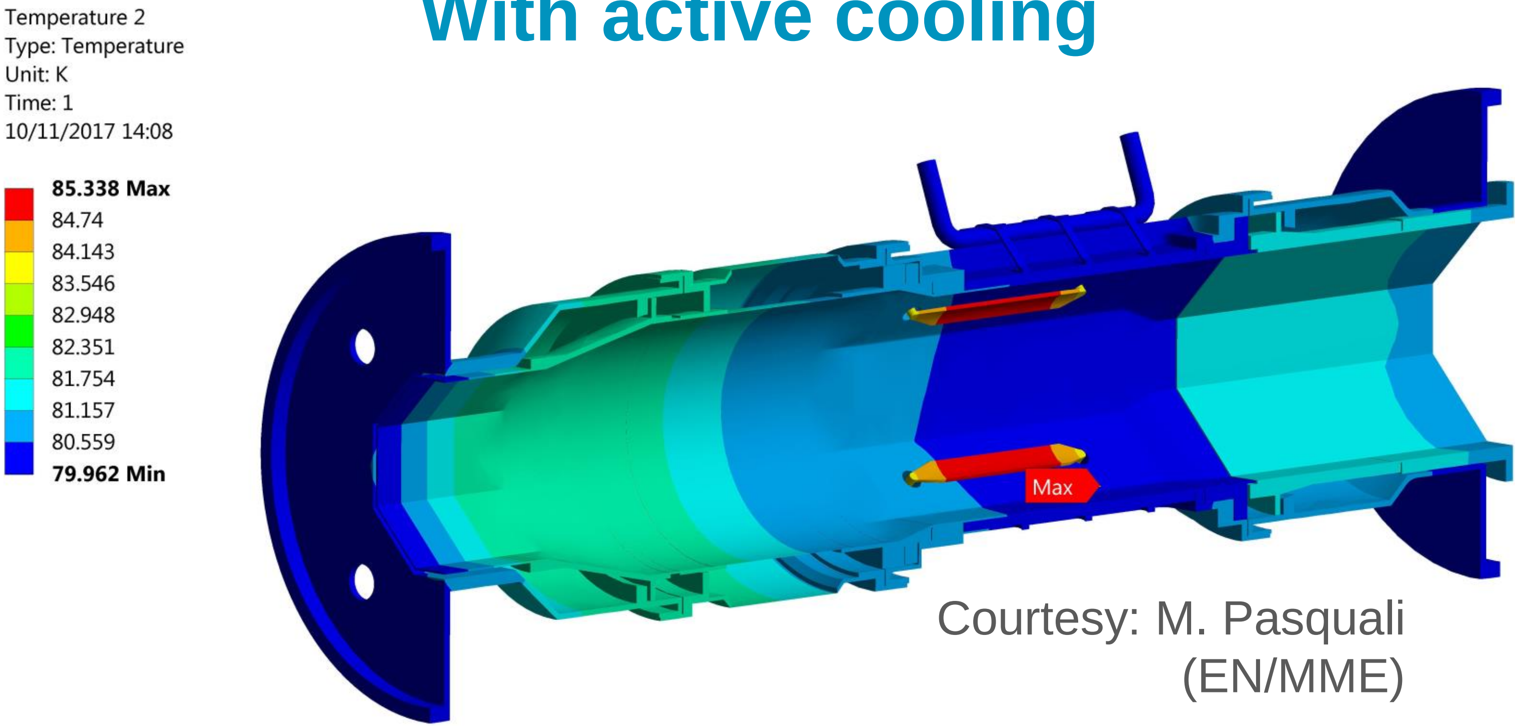
Lack of active cooling



Courtesy: M. Pasquali (EN/MME)

BPM **220 K above** beam screen temperature

With active cooling



Courtesy: M. Pasquali (EN/MME)

Cooling inspired by the beam screen solution

Electrodes **5 K above** beam screen's temperature

Other thermomechanical considerations

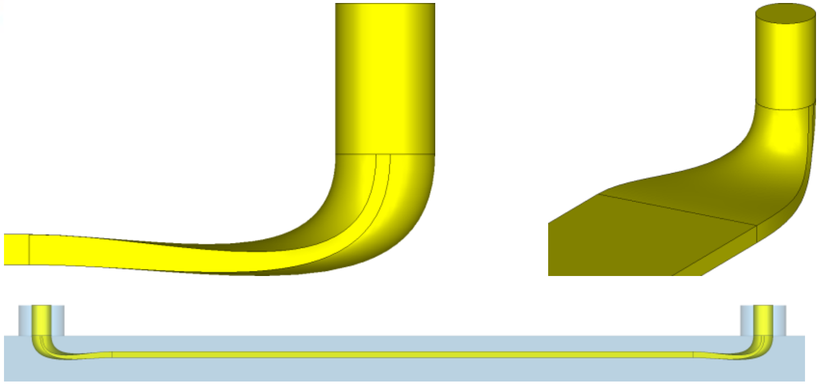
- Thin skin BPM body deformation due to pressure difference – 60 µm
- Electrode-body thermal expansion differential – 100 µm (steady state)
- Electrode thermal deformation (sag) – ~10 µm

Electrode design

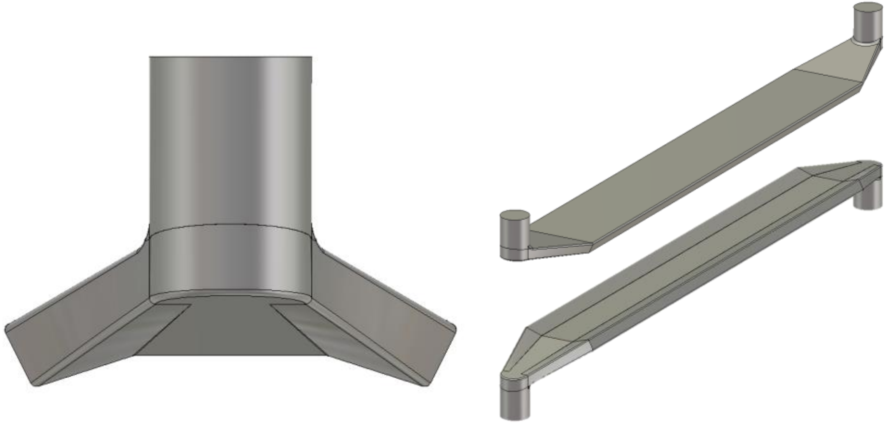
- Critical part for performance of the BPM
- Requires careful optimisation through electromagnetic simulations
- Design philosophy:
  - Decouple electrode design and BPM body design
  - Common interface: DN16CF flanges
  - Possibility of independent manufacturing and tests

Electrode redesign

2016

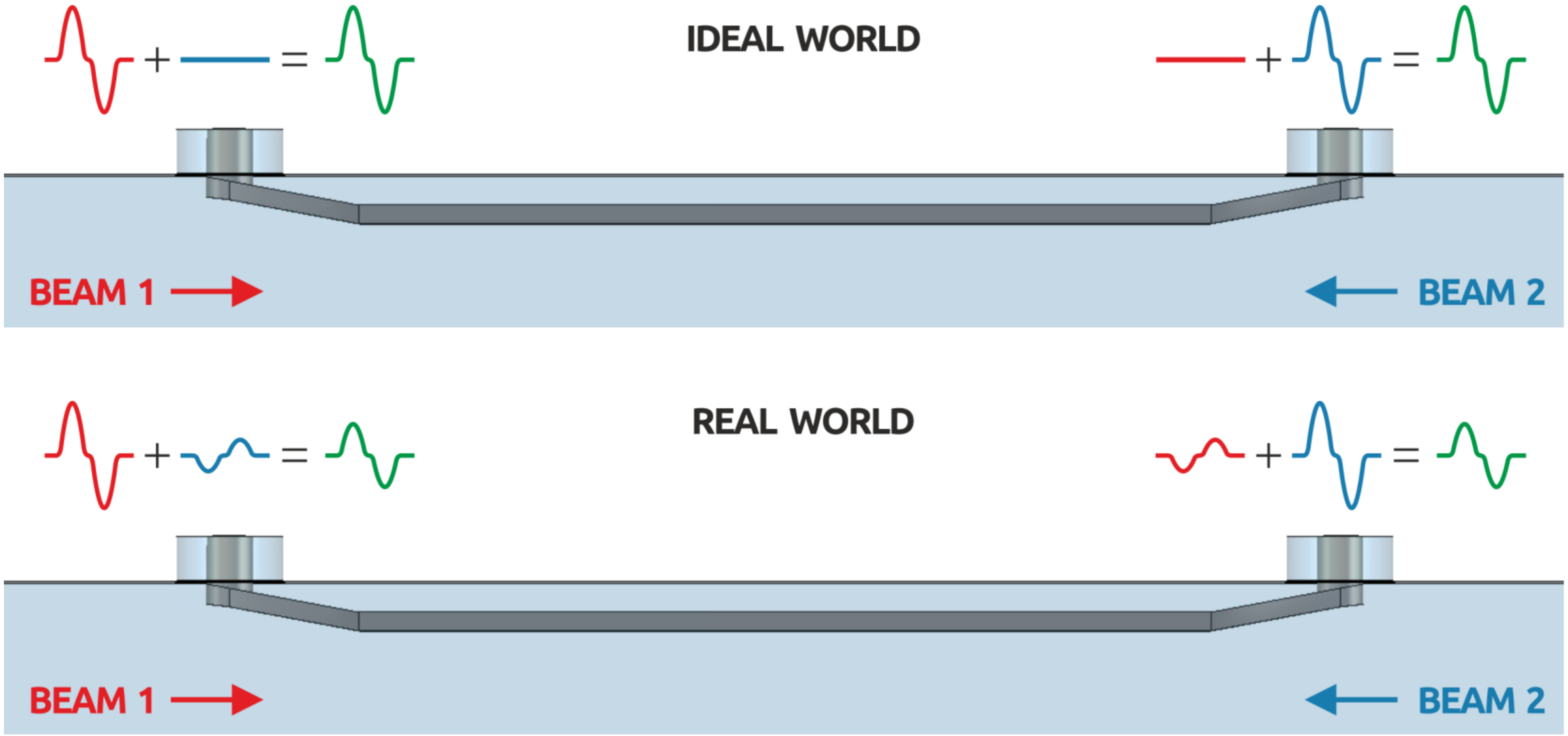


2017

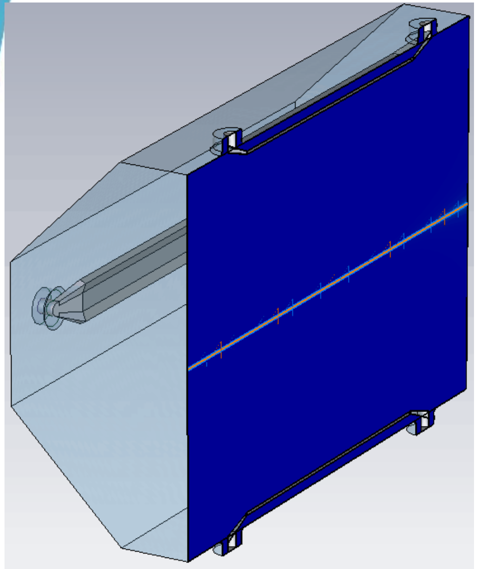


3D printing of the 2016 electrode very challenging
Major effort made to simplify the electrode's shape in 2017
Additional performance improvements achieved

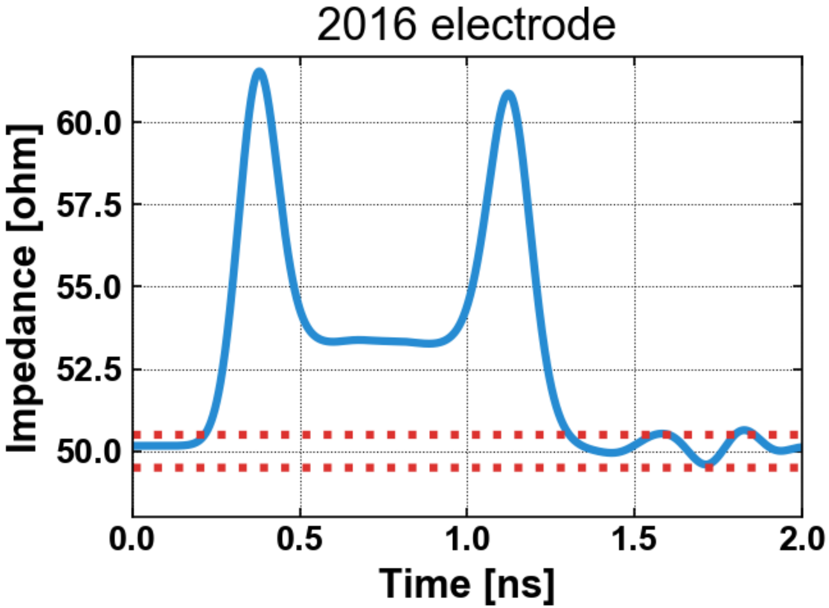
BPM directivity

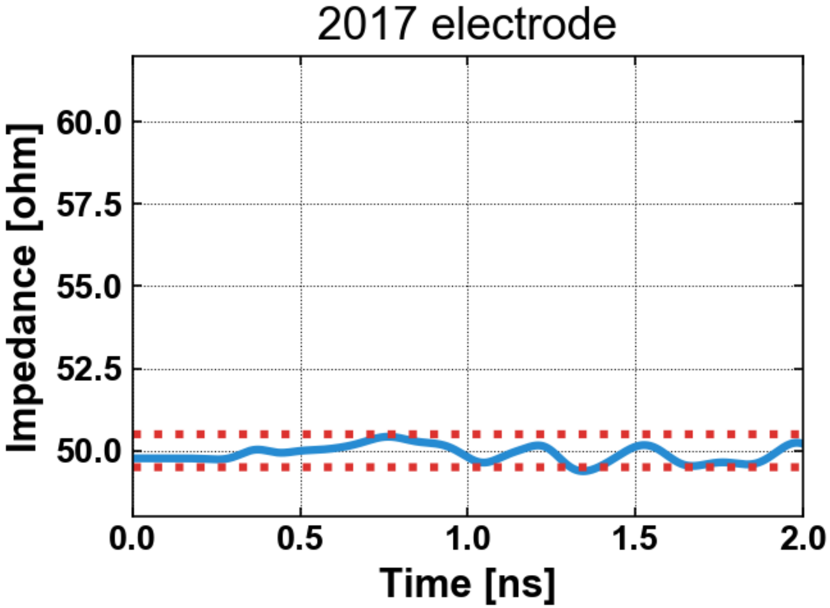


BPM directivity



Electrode simulations - TDR





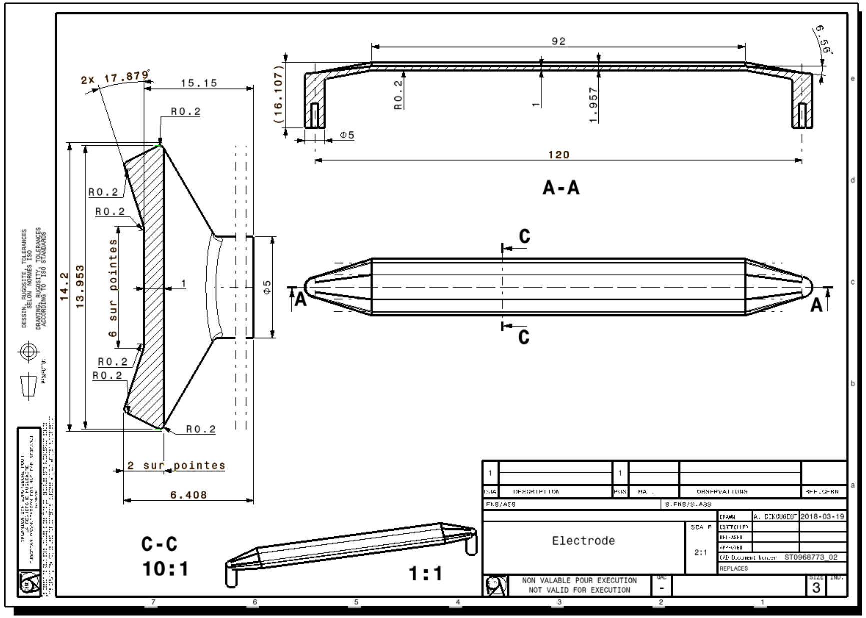
Goal: electrode impedance stable at **50 ± 0.5 Ω**

Bunch temporal separation

Number	1	2	3	4	5	6	7
Type	BPMSTQA	BPMSTQB	BPMSTQB	BPMSTQB	BPMSTQB	BPMSTQB	BPMSQW
Distance from IP [mm]	21853	33073	43858	54643	65743	73697	86846
Location comments	Between TAXS and Q1A	Between Q1B and Q2A	Between Q2A and Q2B	Between Q2B and Q3A	Between Q3B and CP	Between CP and D1	After D1, WARM
Preceding ideal position [mm]	20,570	31,790	43,010	54,230	65,450	72,930	84,150
Succeeding ideal position [mm]	24,310	35,530	46,750	57,970	69,190	76,670	87,890
Distance from ideal position [mm] Towards the IP. Negative number means it's too far from the IP	-1,283	-1,283	-848	-413	-293	-767	1,044
TOF from ideal position [ns] Towards the IP. Negative number means it's too far from the IP	-4.28	-4.28	-2.83	-1.38	-0.98	-2.56	3.48
Bunch arrival time difference [ns] Negative numbers mean the bunch going towards the IP arrives first	**3.92**	**3.92**	**6.82**	**9.72**	**10.52**	**7.36**	**-5.51**

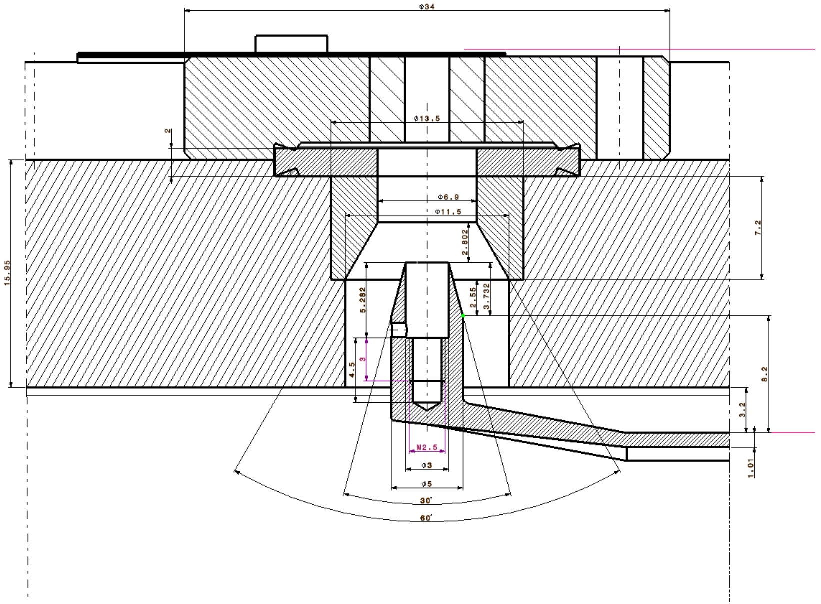
Electrode manufacturing

- Preliminary drawings prepared by A. Demougeot and N. Chritin (EN/MME)
- Manufacturing discussed with the main workshop – possibility of in-house machining with 50 μm tolerances, surface quality via electro-polishing
- Exact coatings to be discussed with TE/VS, min. flash of gold



Feedthroughs

- Critical part for BPM performance
- 16 potential suppliers identified (10 from member states)
- Gathered feedback from the BPM community
  - Promising supplier: BC-tech (CH)
- Electrode – feedthrough interface under design with EN/MME: decouple feedthrough and electrode designs



HL-LHC IP1/5 LSS BPMs - summary

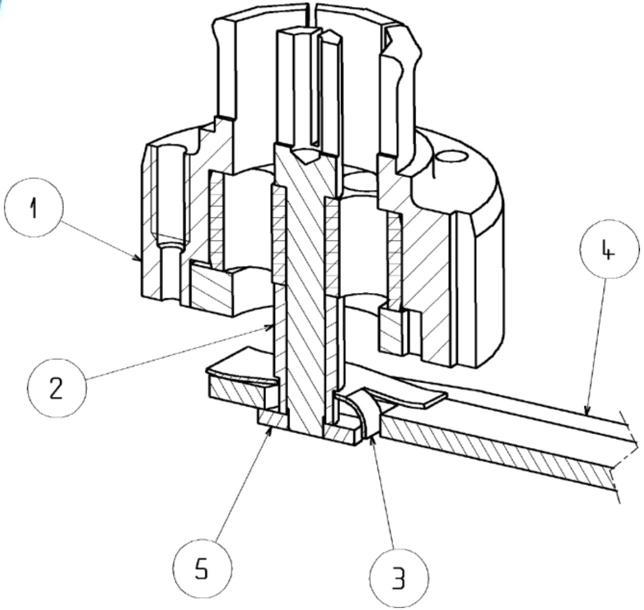
- Two designs are needed due to different apertures – maximize the number of common solutions between the designs
- The vacuum aperture will not be restricted by the BPMs – H and V plane as the beam screen, 45º plane larger by ~ 12 mm
- Impedance is foreseen to be negligible in the HL-LHC context
- Sources of heat load are identified and the levels are estimated – less than 10 W per BPM (assuming coating)
- Electron cloud effect can be mitigated by coating
- Need for tungsten absorbers alignment requirements identified and being addressed with EN/STI
- Cryogenic overhead due to the BPMs looks minor
- Active cooling at the beam screen temperature keeps the BPMs at constant temperature

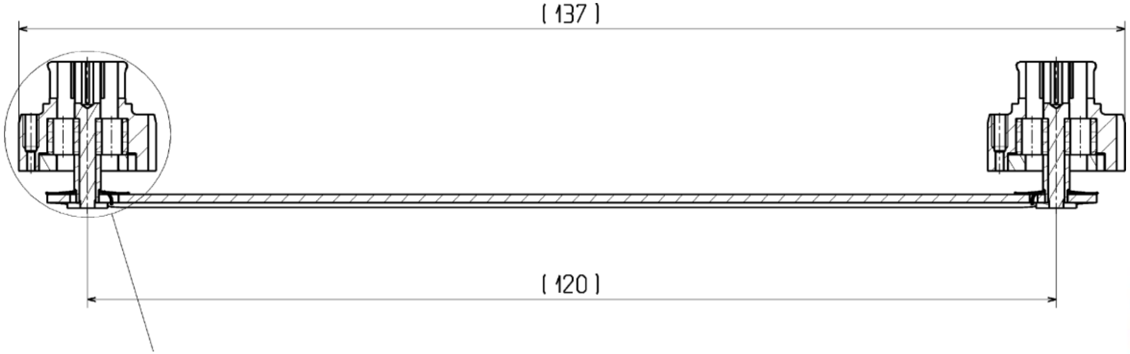
HL-LHC IP1/5 LSS BPMs - summary

- Electrode and feedthrough identified as critical parts for BPM performance
- Design split into three “independent” branches: BPM body, electrode, feedthrough with defined interfaces
- Electrode redesigned in 2017 to improve performance and simplify manufacturing
- New electrode viable for manufacturing with desired tolerances
- Feedthrough suppliers identified and preliminarily evaluated

Thank you for your attention!

Back up: LHC electrodes





Courtesy: C. Boccard, P. Clergue