Status of the tungsten shielded BPM design for the inner triplets

HL-LHC WP13

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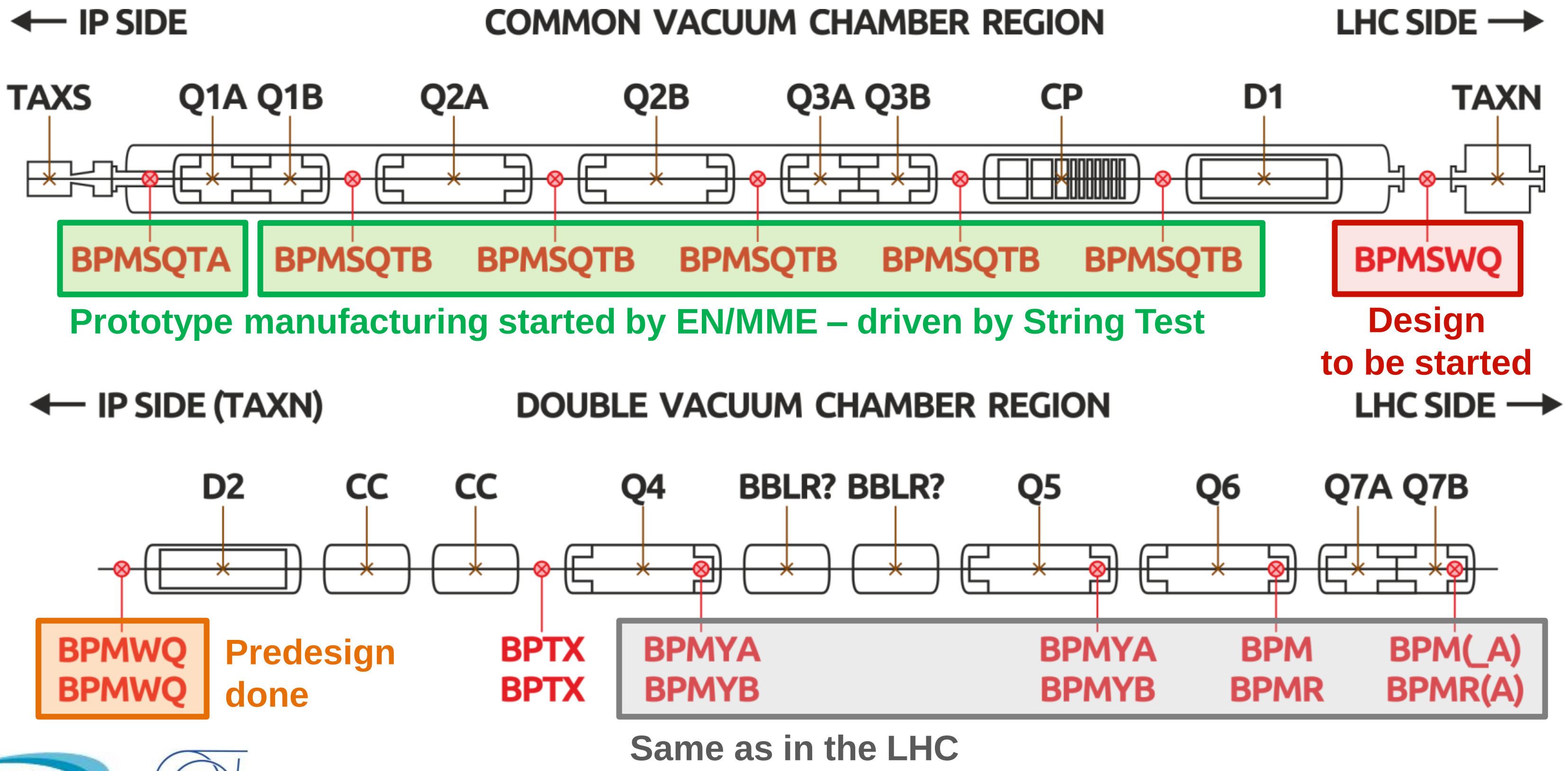
8th HL-LHC Collaboration Meeting – CERN – 18/10/2018

BPMs per HL-LHC IP side



New BPMs per HL-LHC IP side

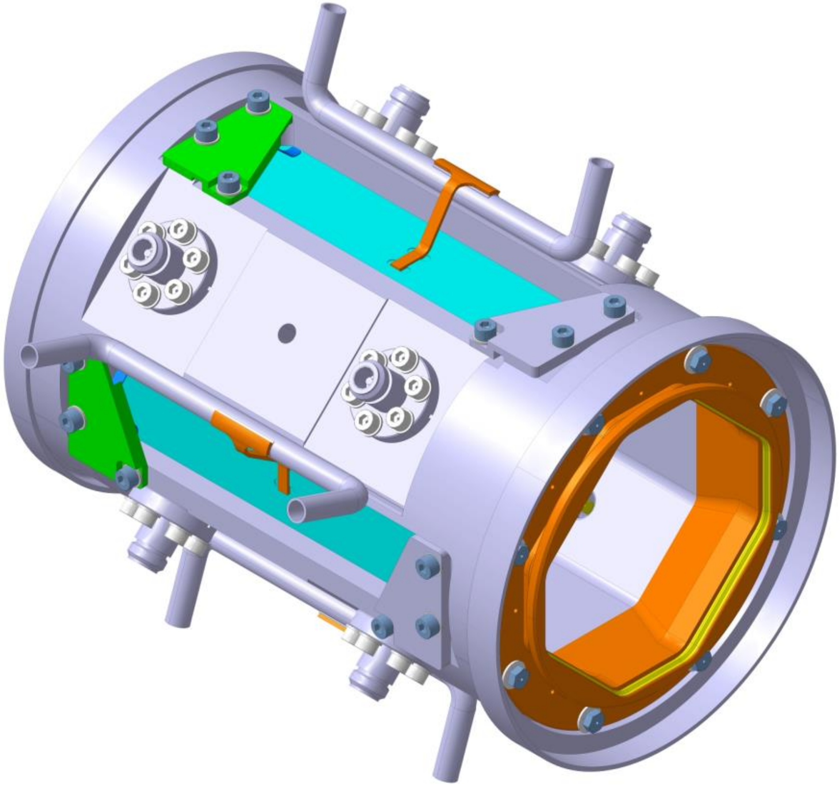
1x **BPMSQTA**	cryogenic directional coupler, aperture A (small)
5x **BPMSQTB**	cryogenic tungsten-shielded directional coupler, aperture B (large)
1x **BPMSWQ**	warm directional coupler
2x **BPMWQ**	warm or cold (non-directional) button

In total:

9 BPMs x 2 IPs x 2 sides = 36 new BPMs to be installed

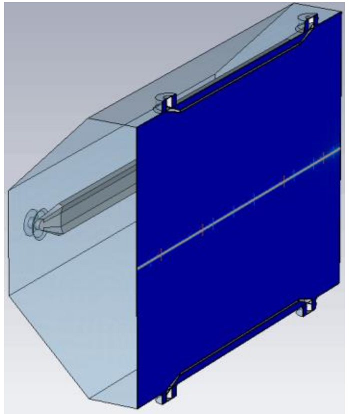
Cryogenic directional coupler challenges

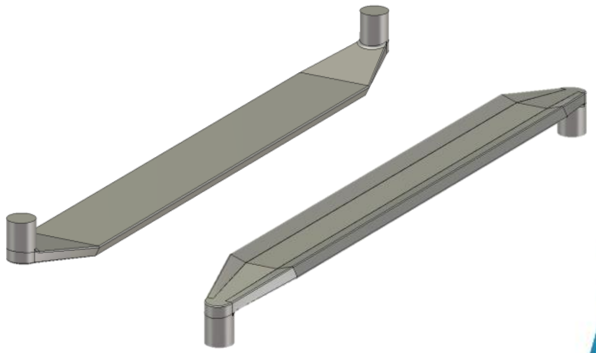
- Both beams in a single vacuum chamber
- Octagonal vacuum chamber
- Cryogenic BPMs installed in vacuum
- Heat load due to electron cloud
- Tungsten blocks at H and V planes to absorb collision debris
- Very complicated integration



Directional coupler – RF design

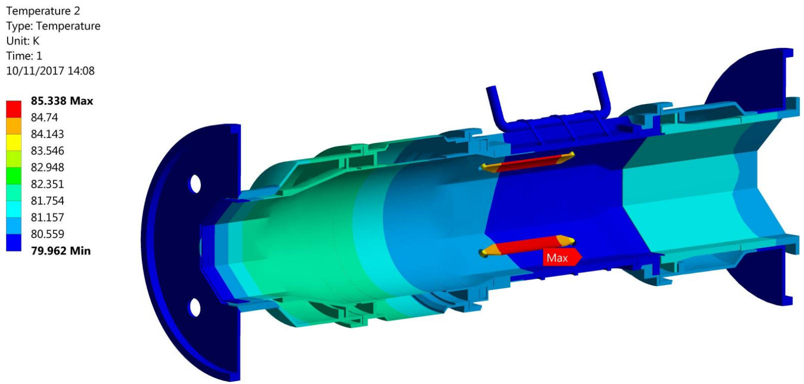
- RF design optimised with 3D EM simulations
  - Achieved very good directivity
- Electrode **prototyping started** with EN/MME
- Purchasing of 400 RF coaxial feedthroughs to be started soon
  - Technical specification ready
- Impedance being validated by WP2





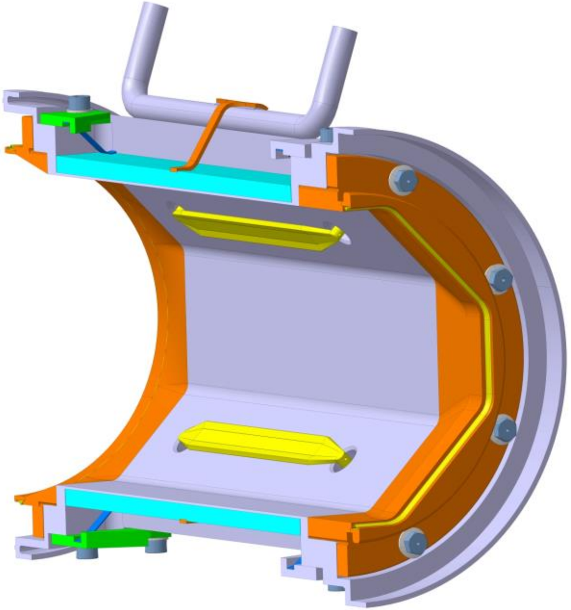
Cryogenics - heat load and cooling

- Heat load contributions:
  - **2.5 W (45%)** – collision debris
  - **2 W (35%)** – electron cloud
  - **1 W (20%)** – beam and cabling
- Amorphous carbon coating
  - Electron cloud effects lower by **a factor of 40**
- Active cooling with liquid helium required
  - Same technical solution as designed for the beam screen
  - Simulations performed by M. Pasquali (EN/MME)



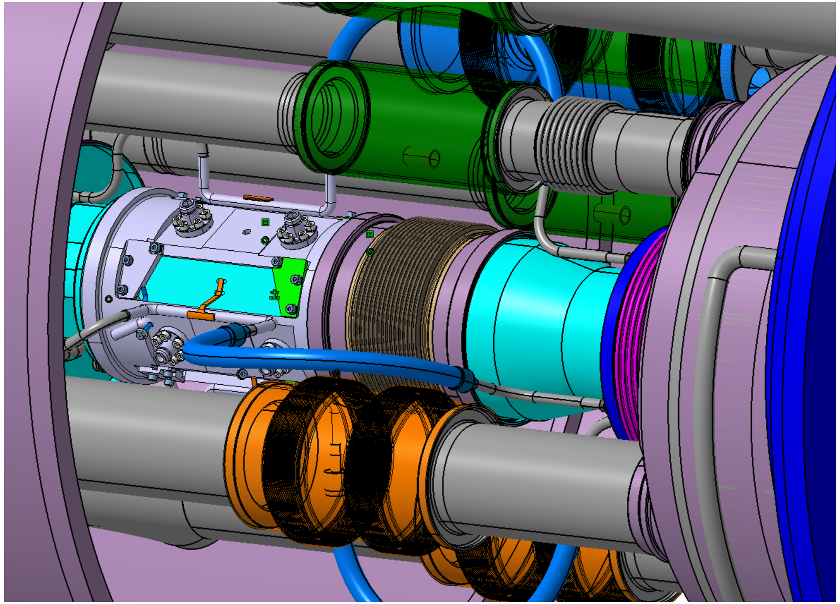
Collision debris – tungsten absorbers

- Tungsten absorbers installed at H and V plane
  - **15% lower dose** on the Q2B magnet
  - BPM electrodes installed at 45º
- Tungsten block alignment specification discussed with WP10
  - Manufacturing tolerances seem adequate
  - Simulations performed by F. Cerutti, M. Sabate Gilarte, A. Tsinganis (EN/STI)
- Procurement of 100 absorbers in collaboration with WP12
  - Same contract handled by TE/VSC

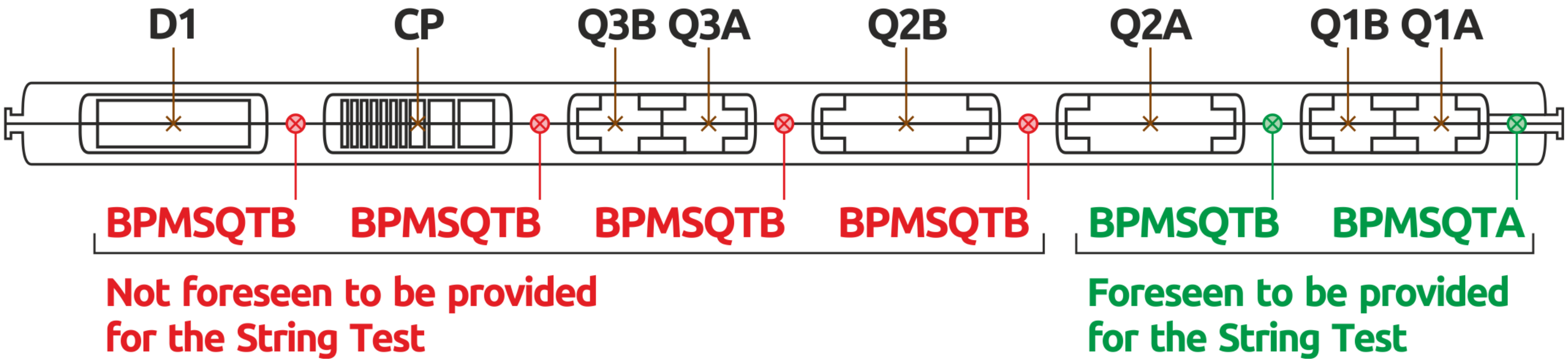


Integration in the interconnect

- Major collaboration of multiple WPs to advance integration of the IT interconnect regions
  - Work coordinated by D. Duarte Ramos (TE/MSC)
- **Extremely busy region** with multiple important stakeholders
  - Alignment
  - Welding and cutting machines
  - Cable routing
- Mock-ups planned
  - Details under discussion



String Test preparation



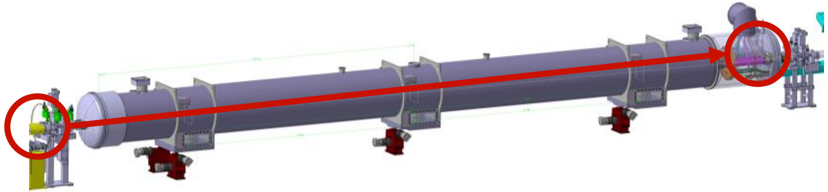
- IP5L configuration
- **2 BPMs needed by 2021** – prototype manufacturing launched with EN/MME
- BPM test program presented at the HL-LHC Inner Triplet String Test Day (05/10/2018)

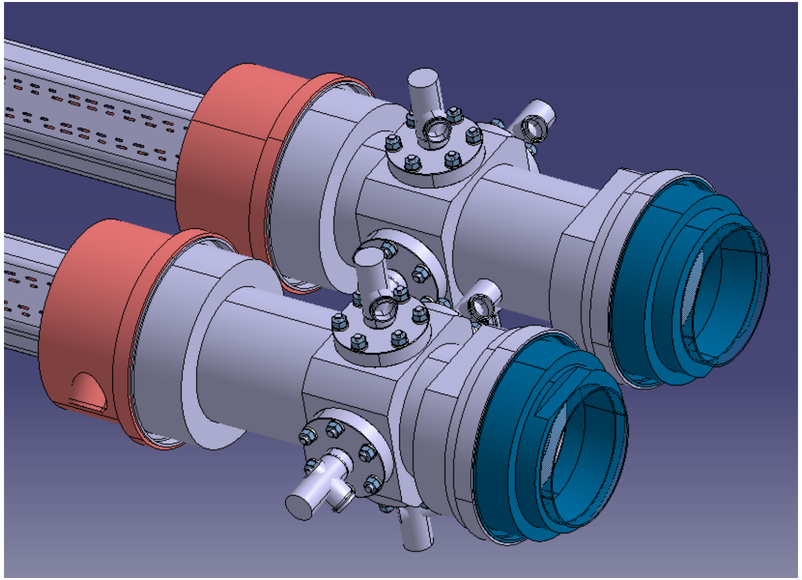
HL-LHC IT BPM conceptual design review

- Organised by WP13 and held on 17 May 2018
- With input from HL-PO, WP3, WP10, WP12, WP16, EN/MME
- Identified **4 recommendations** and **20 actions**
  - 4 recommendations followed
  - 13 actions completed
  - 3 actions being addressed
  - 4 actions to be addressed
- Summary to be presented at the TCC

D2 BPM – from warm to cold

- Recent request to study moving the D2 BPM into the cryostat
  - Motivated by full remote alignment
- **Preliminary design done**
  - No showstoppers identified
  - Huge thanks to N. Chritin and A. Demougeot (EN/MME)
- Detailed design and integration study to follow





Conclusions and outlook

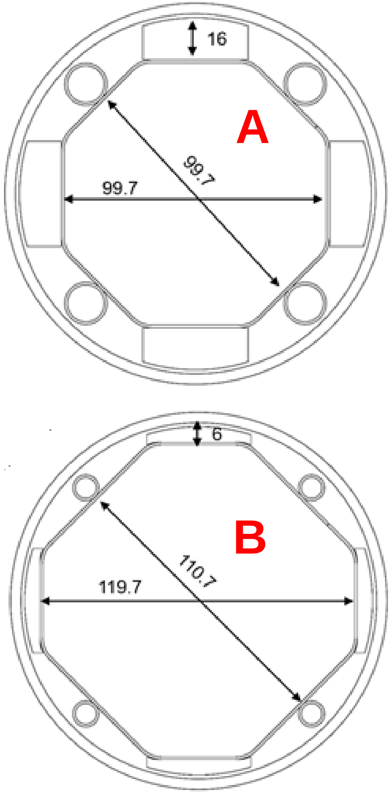
- Development of new HL-LHC BPMs on track
  - Collaboration and common designs with other WPs
- Project priorities driven by the String Test
  - Prototype manufacturing started by EN/MME
  - Tests on mock-ups planned before the String Test
- Purchasing planned and on schedule
  - Tungsten absorbers with TE/VSC
  - RF coaxial feedthroughs ready to start
- Conceptual design review held in May
  - All recommendations followed
  - Most actions already completed or being addressed
  - Remaining actions to be addressed soon

Thank you for your attention!

Acknowledgements: F. Cerutti, N. Chritin, A. Demougeot, D. Duarte Ramos, G. Iadarola,
R. Jones, M. Pasquali, A. Tsinganis

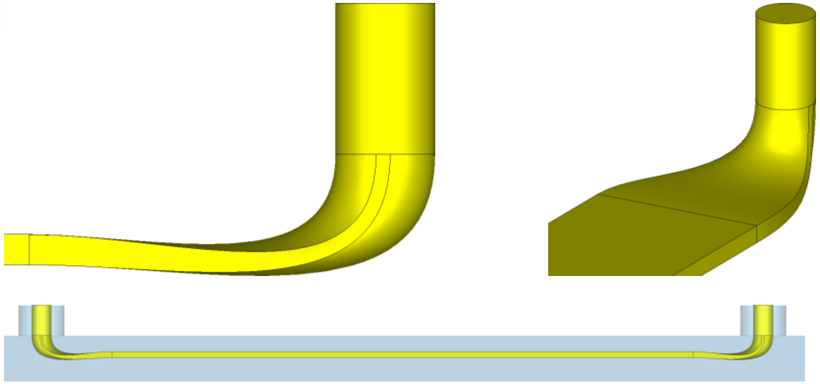
Back up: design priorities

- Main focus on the cryogenic directional couplers **BPMSQTA** and **BPMSQTB** which are required for string test in 2020
- Minimising differences between the two designs
- Studying possibilities of reusing parts of the design for the non-cryogenic **BPMSWQ**

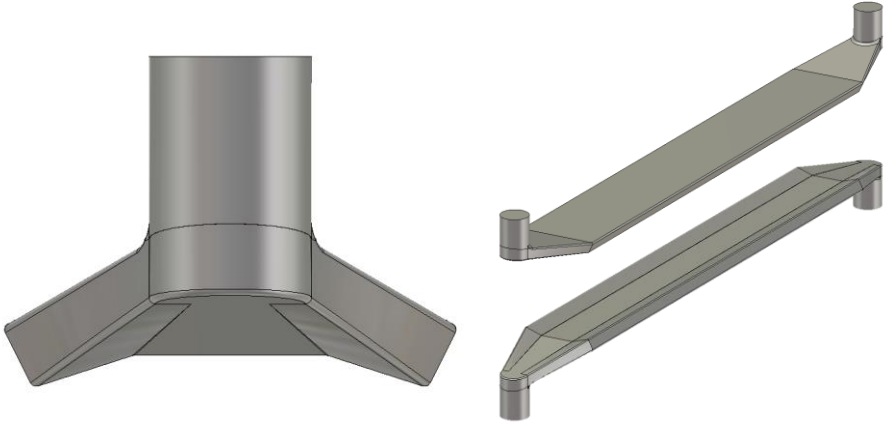


Back up: electrode design

2016

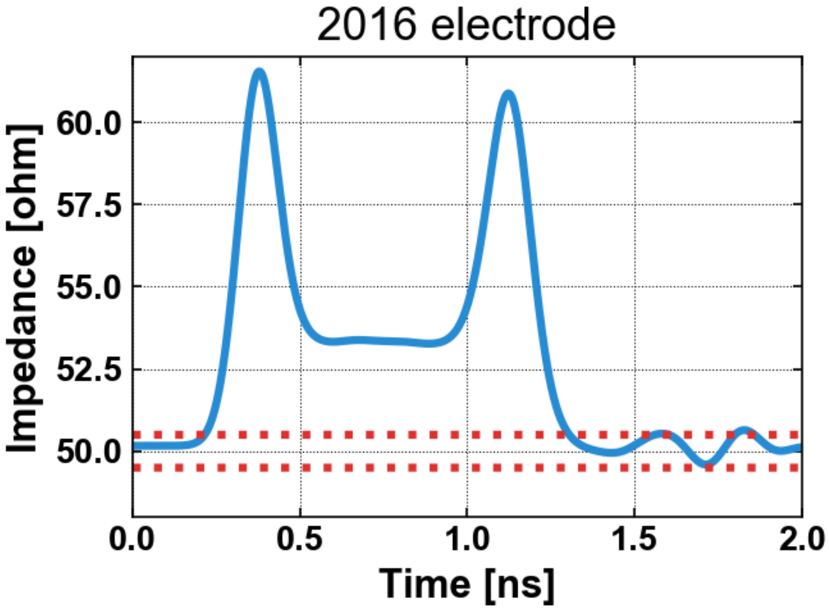


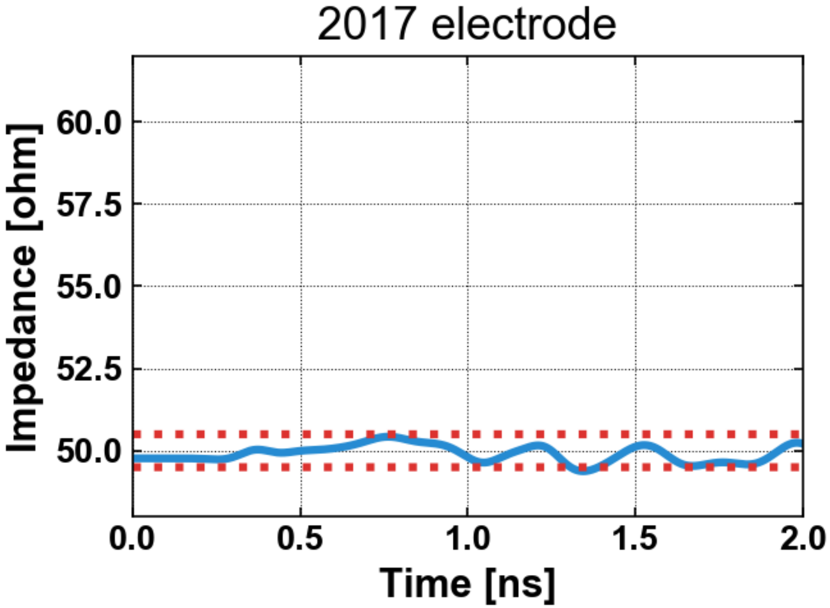
2017



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

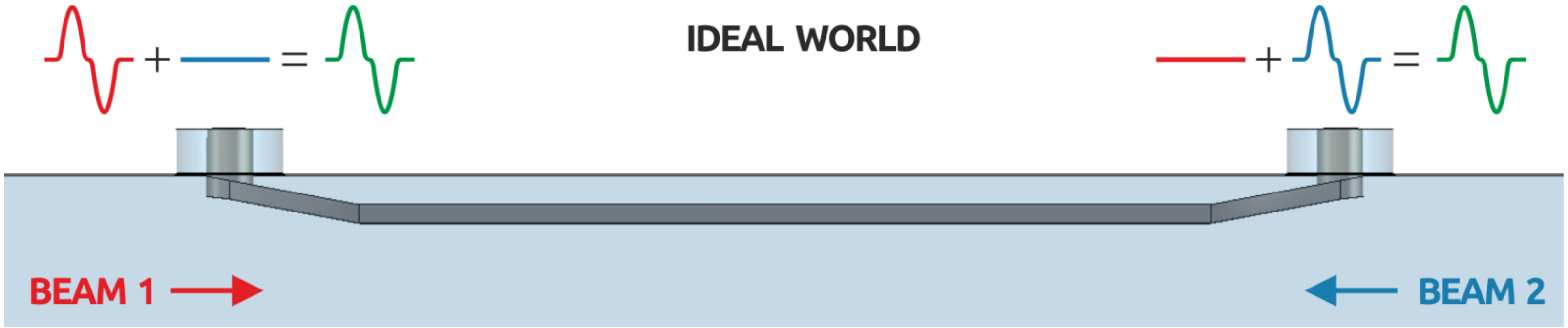
Back up: TDR simulations



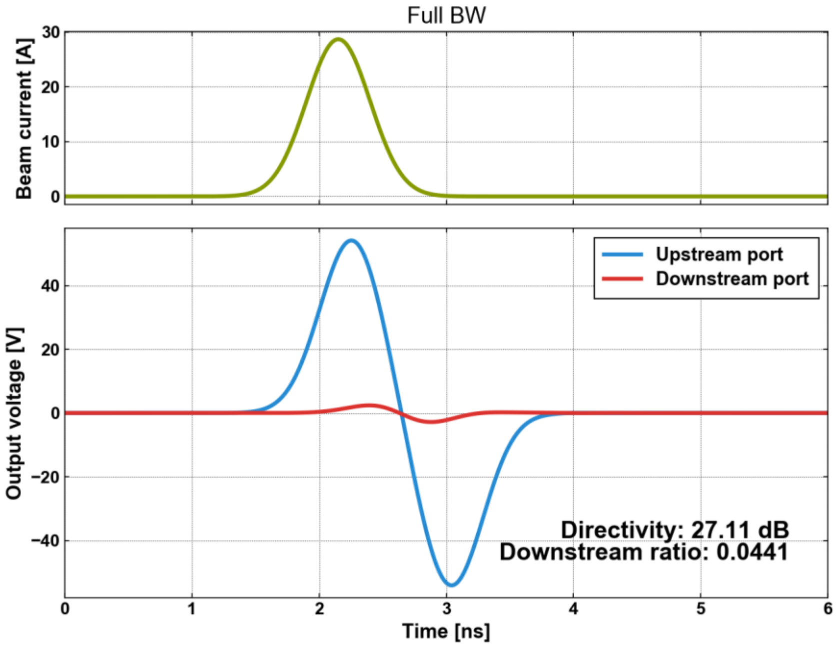


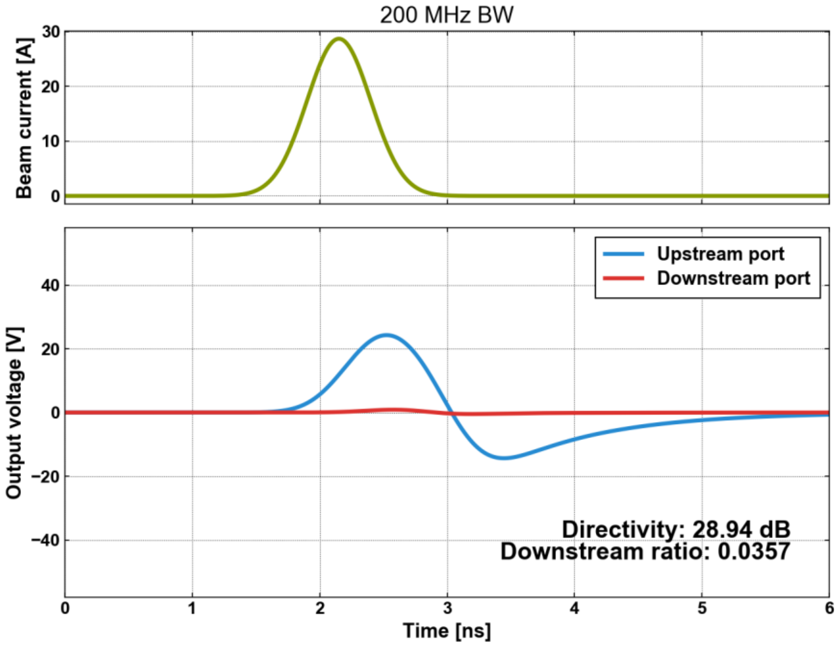
Goal: electrode impedance stable at **50 ± 0.5 Ω**

Back up: directivity



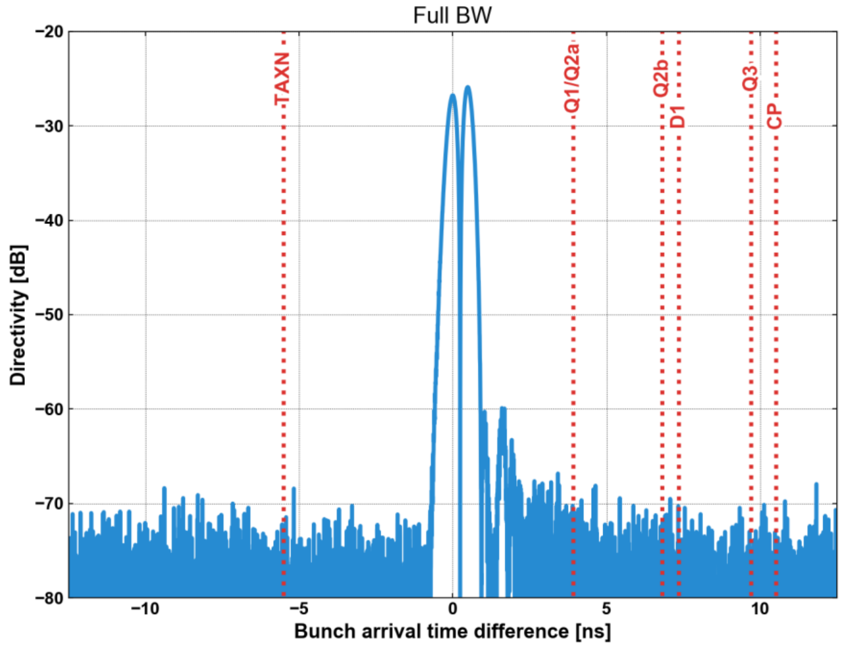
Back up: directivity

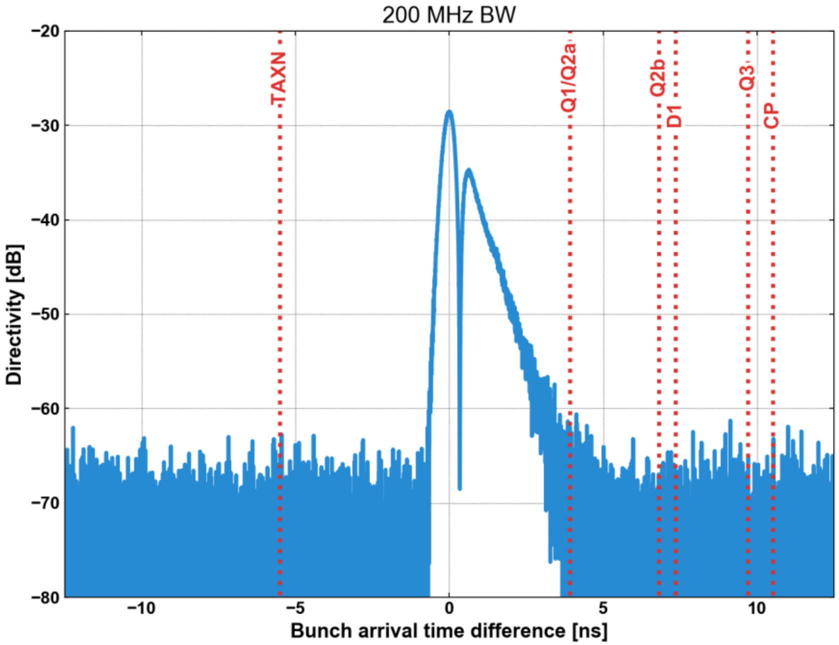




Dream: **30+ dB** directivity → 0.0316 downstream ratio

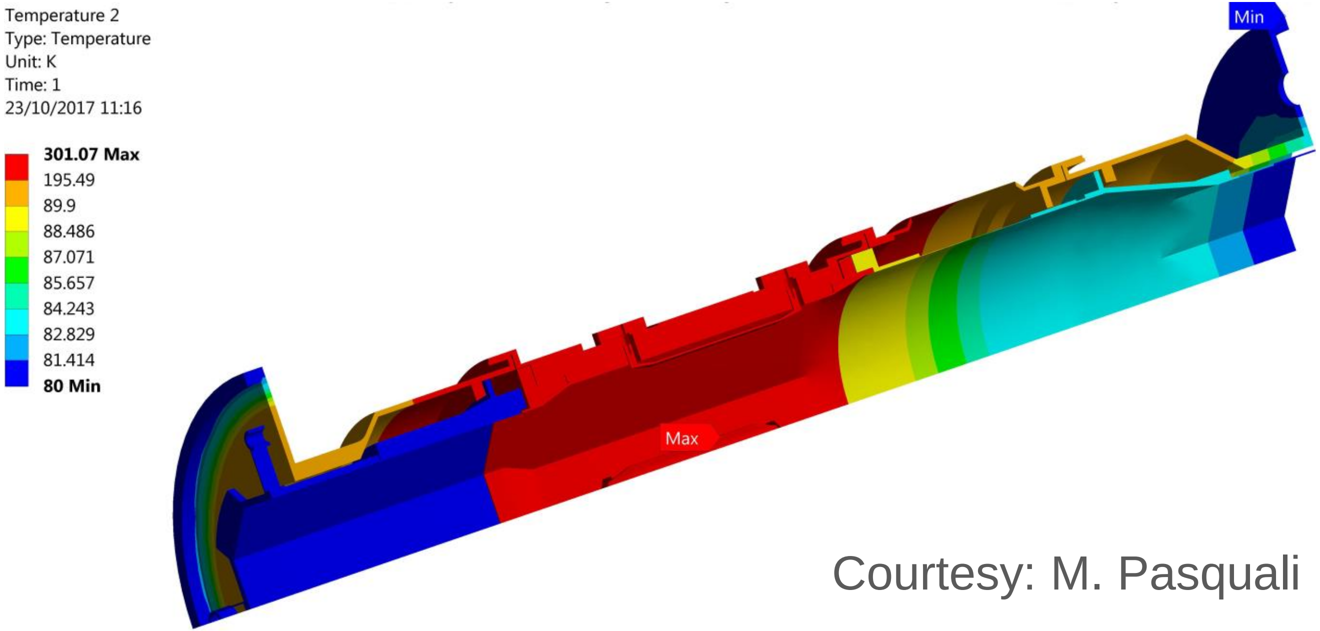
Back up: temporal separation





Optimisation: temporal bunch separation at **BPM locations**

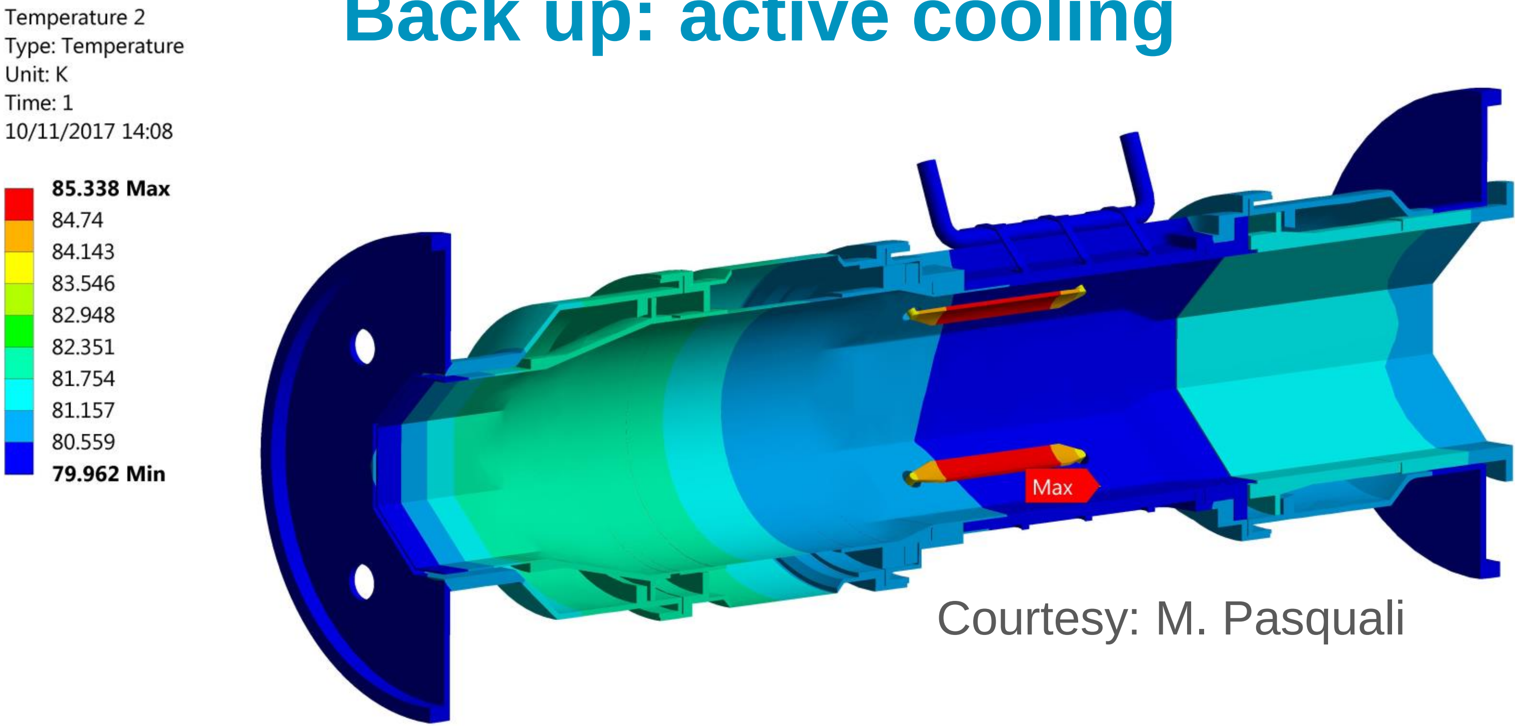
Back up: passive cooling



Courtesy: M. Pasquali

BPM **220 K above** beam screen's temperature

Back up: active cooling

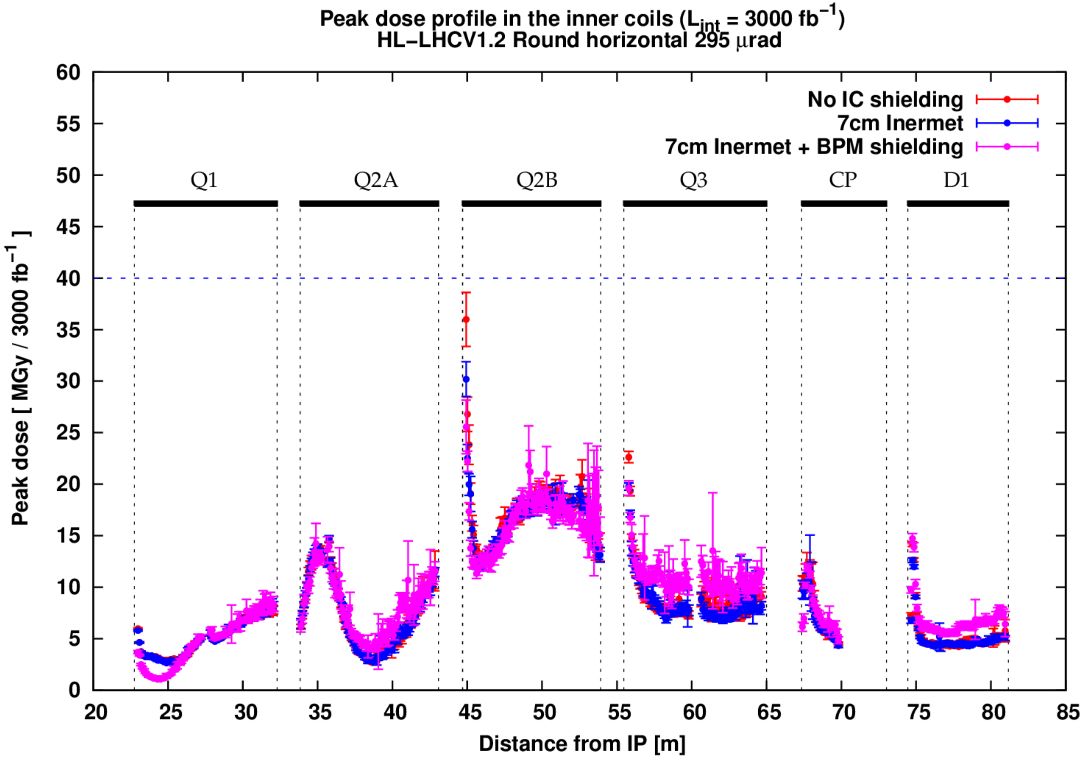


Courtesy: M. Pasquali

Cooling inspired by the beam screen solution

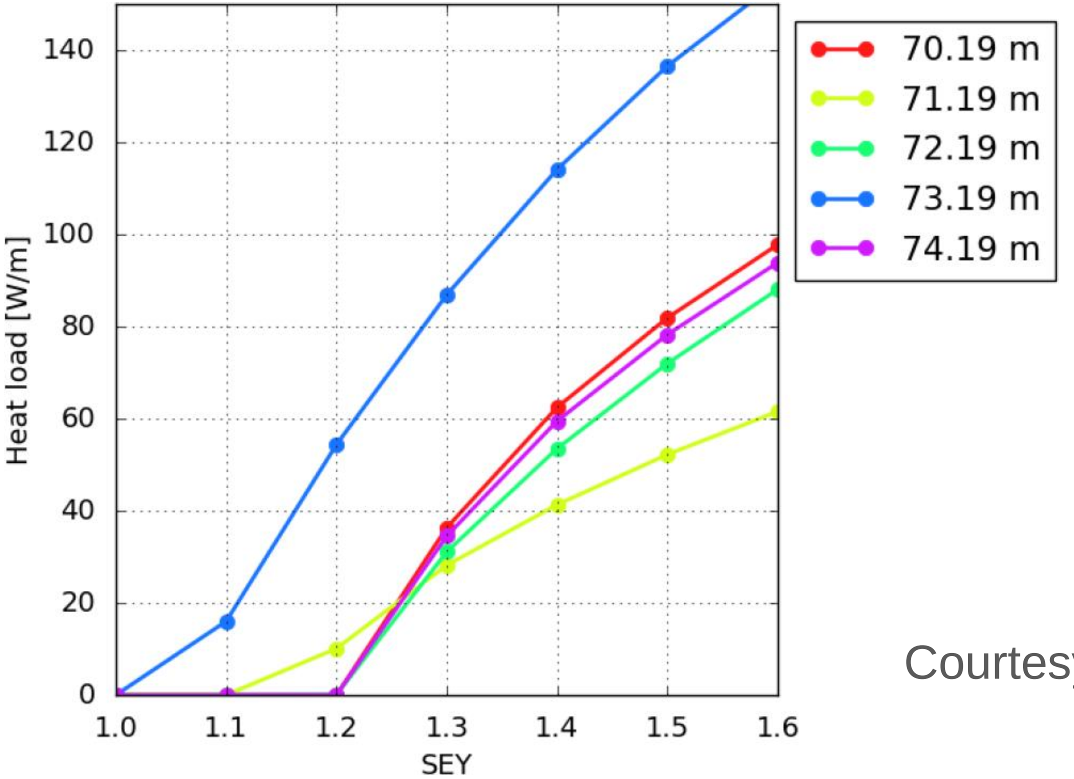
Electrodes **5 K above** beam screen's temperature

Back up: Tungsten shielding



Courtesy:
A. Tsinganis
F. Cerutti

Back up: Heat load

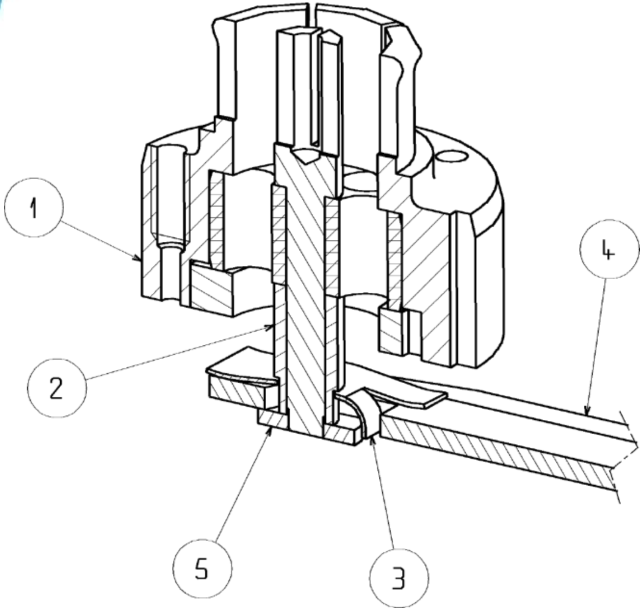


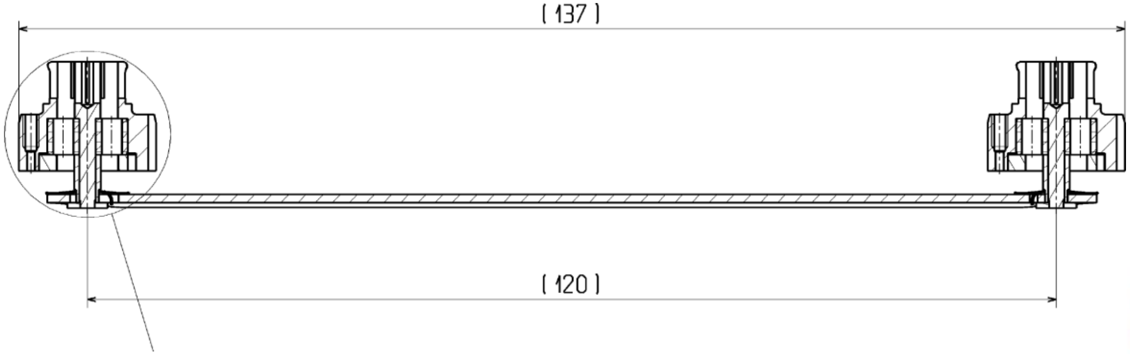
Courtesy: G. Iadarola

Back up: Locations

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
N Periodicity number	5.34	8.34	11.23	14.11	17.08	19.21	22.72
Preceding ideal position [mm] N = floor(N)	20,570	31,790	43,010	54,230	65,450	72,930	84,150
Succeeding ideal position [mm] N = ceil(N)	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

Back up: LHC electrodes





Courtesy: C. Boccard, P. Clergue