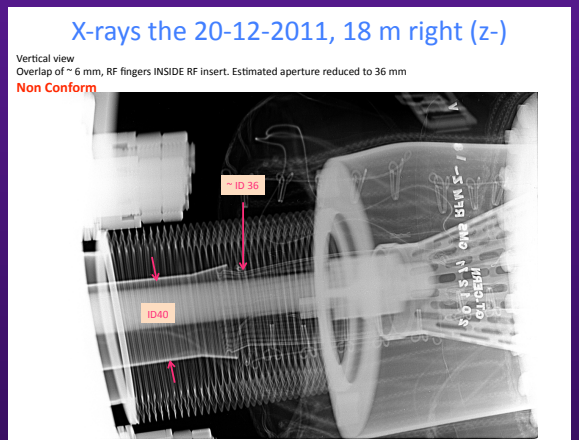
Past work on the PIMs, PIMs' crisis and PIMs Working Group

Elias Métral

- **Discussion with Pierre Strubin yesterday afternoon => Pierre should come on 17/04/2012 to have more detailed information etc.**
- **Technical Specification for the Components for the LHC Arc Beam Vacuum Interconnects: https://edms.cern.ch/file/308337/1.0/lhc-lvi-ca-0001.pdf**
- **PIMs' crisis (linked to buckling or "flambage") and PIMs Working Group**
- **Conclusion**

PIMs' crisis and PIMs' Working Group (1/10)

- There are ~ 1200 dipoles + ~ 500 quads => There are ~ 1700 PIMs (= Plug-In Modules) in total per turn => Detailed analysis ongoing...
- One should not mix 2 different things:
  - Incident 3-4 in September 2008 (where the PIMs were re-discussed etc.) => But it had nothing to do with the electrical and mechanical quality of the PIMs
  - The PIMs' crisis => Linked to buckling (which is not due to RF fingers falling inside due to a too long elongation etc. as could be observed for instance at 18 m right of CMS: http://emetral.web.cern.ch/emetral/ICEsection/2011/2011-12-21/X-rays_CMS_20-12-11.ppt)

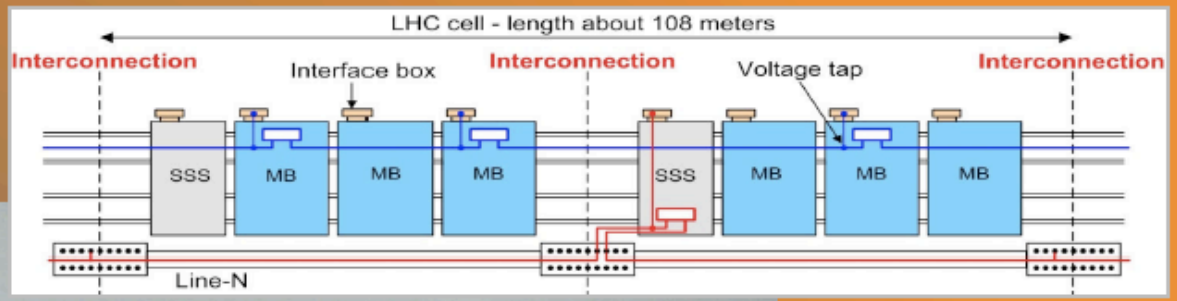


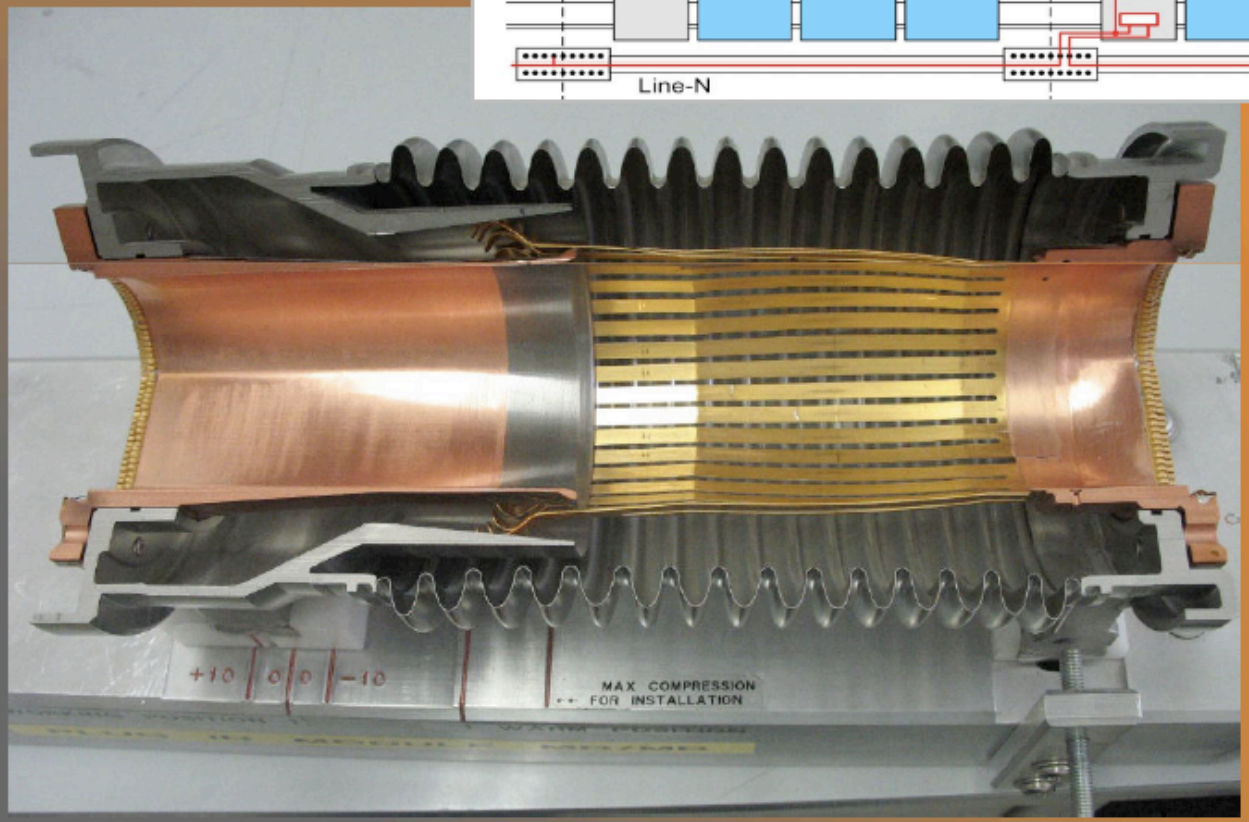
V. Baglin

PIMs' crisis and PIMs' Working Group (2/10)

- The 1st damaged PIM was found (by chance) around August 20th, 2007, in the sector 7-8 => Buckling
- 1st meeting of the Working Group on August 23rd, 2007
- First part devoted to try and understand the exact cause(s) and to evaluate the probability of other damages
- In Spring 2008 the meetings resumed after the warm-up of the sector 4-5 where some damaged PIMs were also found
- During this period, the Working Group also worked on potential solutions to exchange a PIM without having to warm all the sector, with some tests performed at SM18
- The Working Group met again after the incident of the sector 3-4 in September 2008 to check if the increase of pressure in the vacuum pipe could have damaged the PIMs

The crisis of the PIM's





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PIMs' crisis and PIMs' Working Group (4/10)

- **The RF fingers have a certain number of foldings: From Modeling of the RF-shield Sliding Contact Fingers for the LHC Cryogenic Beam Vacuum Interconnects Using Implicit and Explicit Finite Element Formulations (D. Ramos, CERN-TS-2008-007, 2008)**

D. Ramos

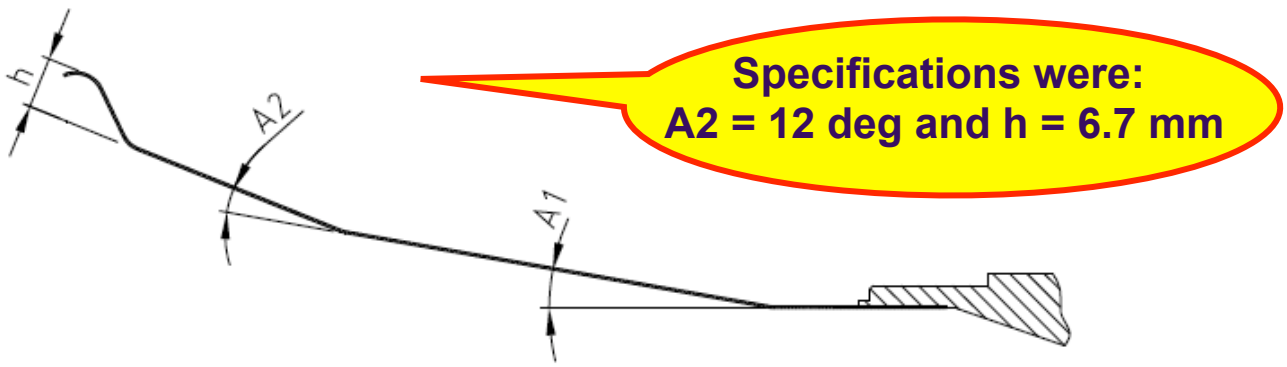


Figure 2 – Main geometrical parameters of the contact finger characterising its shape before assembly.

- **The materials have been also studied in details (see next week's talk by SergioC) to avoid cold welding: gold plated CuBe RF fingers on Rhodium**

PIMs' crisis and PIMs' Working Group (5/10)

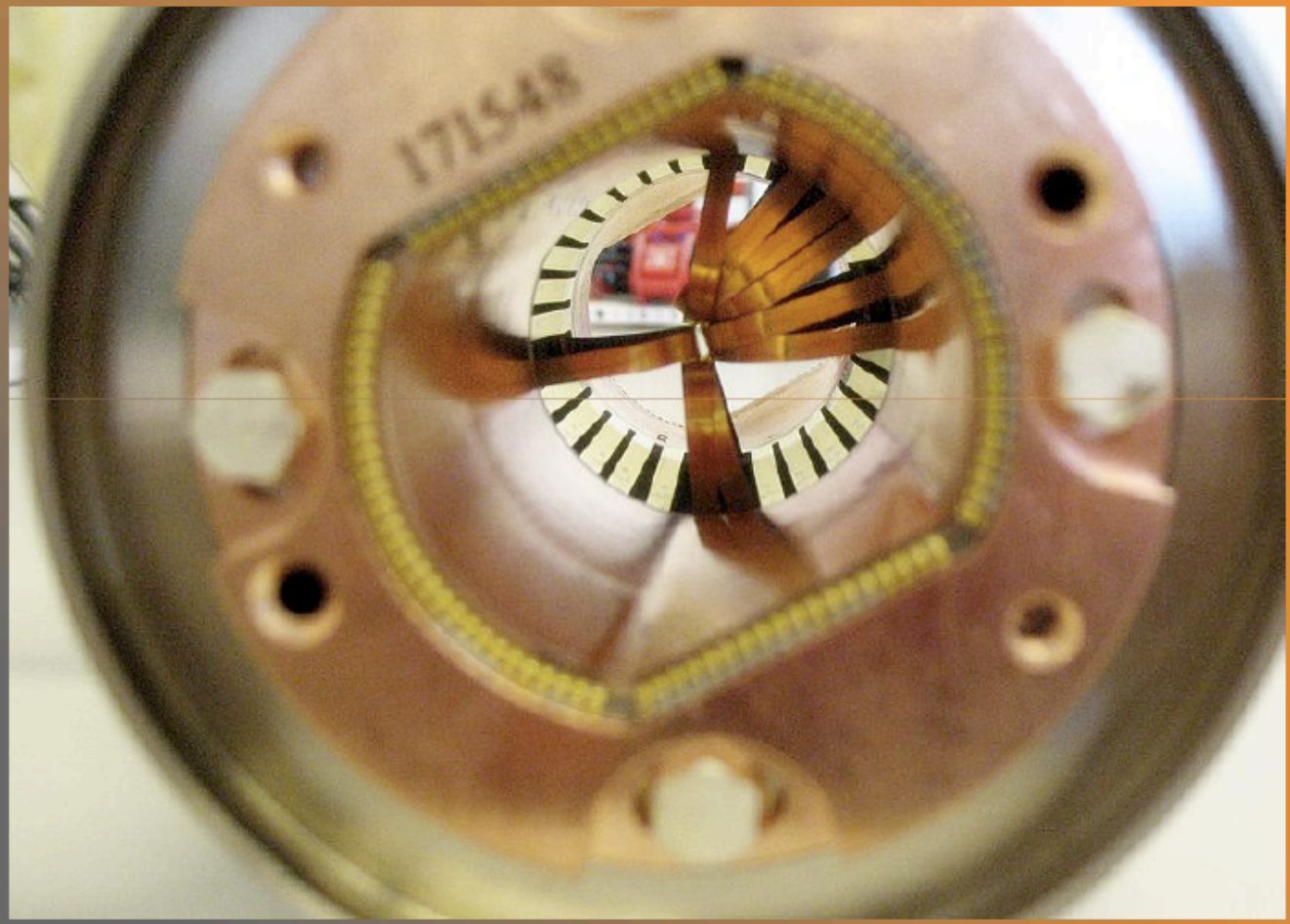
- To reach the specified electrical conductivity (based on DC measurements by FritzC) the angle A2 has been increased during the fabrication process at Novossibirsk (without documenting it and corrections have been done manually => different for all the RF fingers!)
- Conclusions:
  - Specified DC electrical conductivity was reached for all RF fingers
  - BUT this was indentified as the cause of the buckling => Delio Ramos studied this in detail (see previous slide)
- This issue has been fully understood: when built within specifications the RF fingers are good but they were not built within specs… => Manufacturing issue
- Initially the idea was to change all of them, but then it was found that the most realistic/rational solutions was stay like this and change the most critical ones (~ 200 have be changed, tbc) and to test the others with the "RF or ping-pong ball" (see next slides)

PIMs' crisis and PIMs' Working Group (6/10)

- It was found that below a certain temperature (~ 100 K, tbc) there is no problem. But at any warm-up, buckling can be observed (even if no buckling at the previous warm-up!)
- Reminder:
  - The problem may appear during the warm-up of the adjacent magnets as in this case there is dilatation of the magnets => Contraction of the PIMs (which are between the magnets) and risk of buckling
  - At low temperature, the PIMs are elongated and there is no risk of buckling

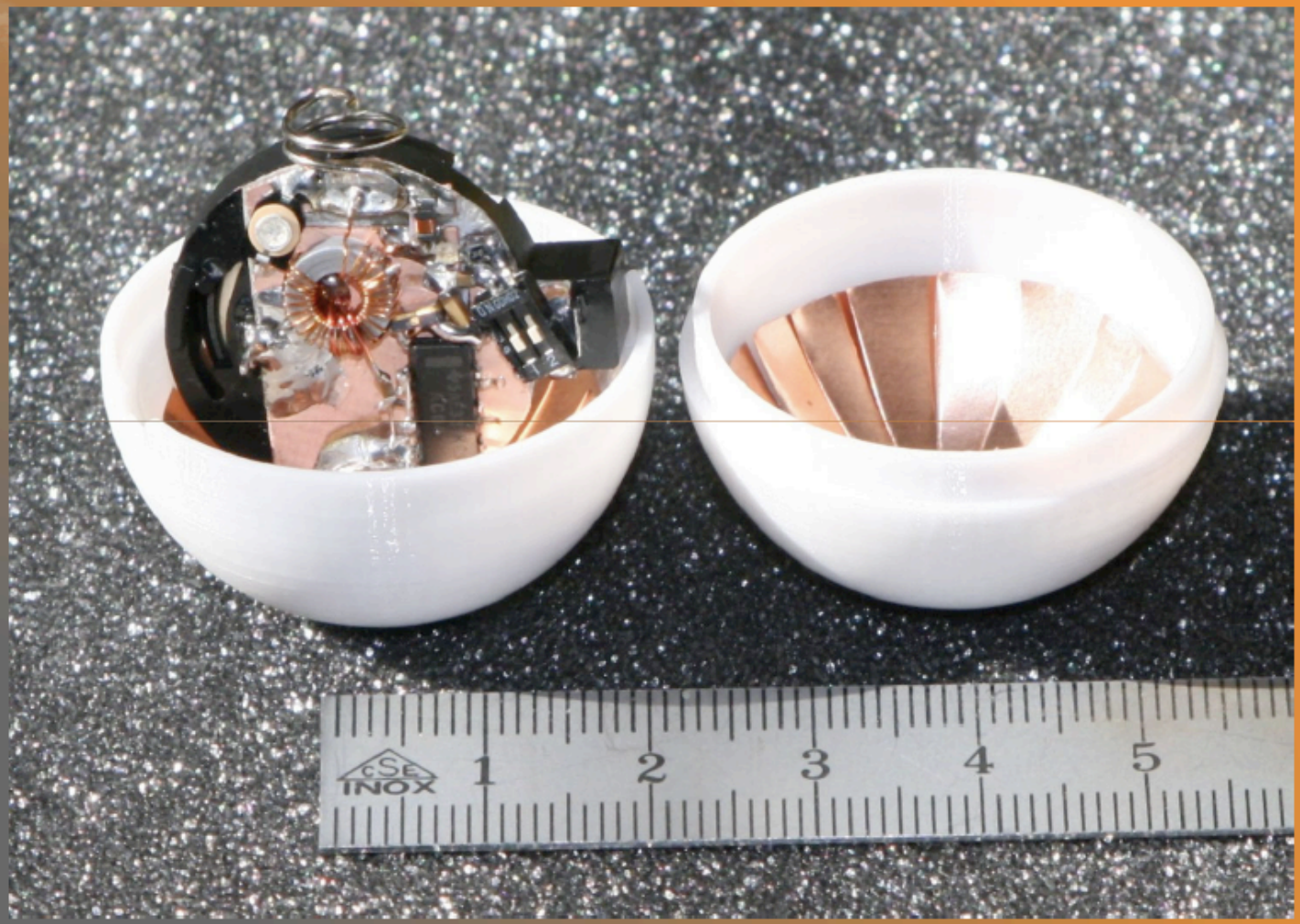
PIMs' crisis and PIMs' Working Group (7/10)

Arc plug-in module with damaged fingers



PIMs' crisis and PIMs' Working Group (8/10)

Transmitter ball



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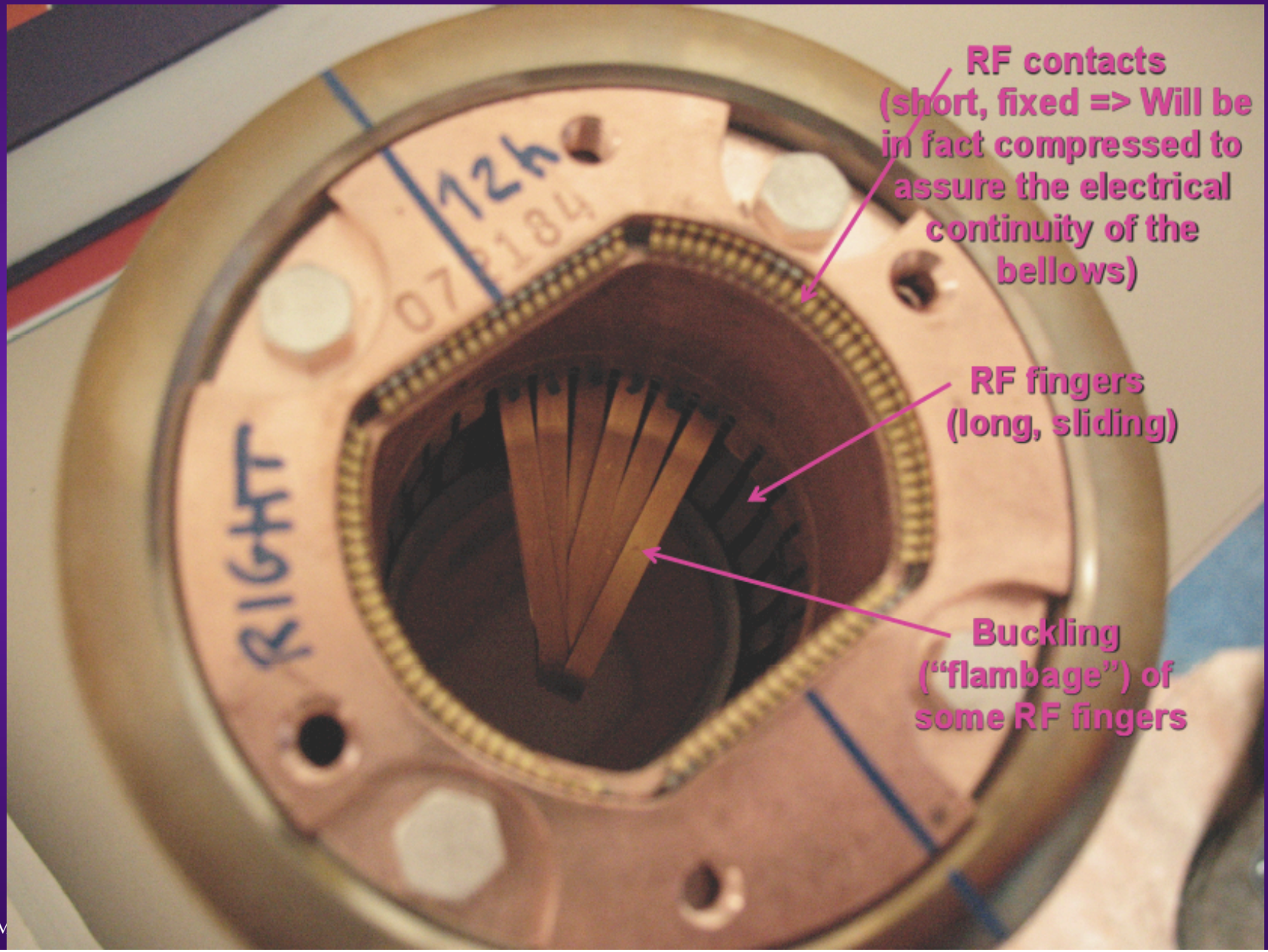
PIMs' crisis and PIMs' Working Group (9/10)

- **Reminder of discussion with Francesco Bertinelli (22/09/2010) => See https://impedance.web.cern.ch/impedance/LHC/PIM/DiscussionOnLHCPIMs_FrancescoBertinelli_22-09-10.pdf :**
  - **This buckling was discovered in the past by chance, always at the same places (revealing a type of PIM) and it was understood that this issue came from a manufacturing problem**
  - **Solution proposed => Displace all the SSS by 2 mm. This was done and it reduced considerably the number of bucklings of RF fingers**
  - **Now, if we warm up a sector, the latter is then tested with the RF ball (ping-pong ball) => This is an additional constraint for the cryo: it needs to remain below ~ 80-100 K (above these temperatures we introduce some plastic deformations)**

PIMs' crisis and PIMs' Working Group (10/10)



Conclusion

- No design issue (and no impedance issue) revealed in the past but a manufacturing problem responsible for the observed buckling of RF fingers
- There were some specifications made in the past and it was confirmed that everything is / should be fine if within specs
- Nevertheless, the impedances (and associated effects) should / will be re-evaluated to check the compatibility with high beam intensities contemplated for the future
- More info / discussions etc. when Pierre will come on 17/04/2012