Follow-up of the LHC RF Heating Issues

Elias Métral
with impedance team and equipment colleagues

- **BS's table at Evian2011:** https://indico.cern.ch/getFile.py/access?contribId=33&sessionId=7&resId=1&materialId=slides&confId=155520
- **VMTSA (double bellows)**
- **CMS RF fingers**
- **ALFA detector**
- **MKI**
- **TDI, TCP and TCTVB**

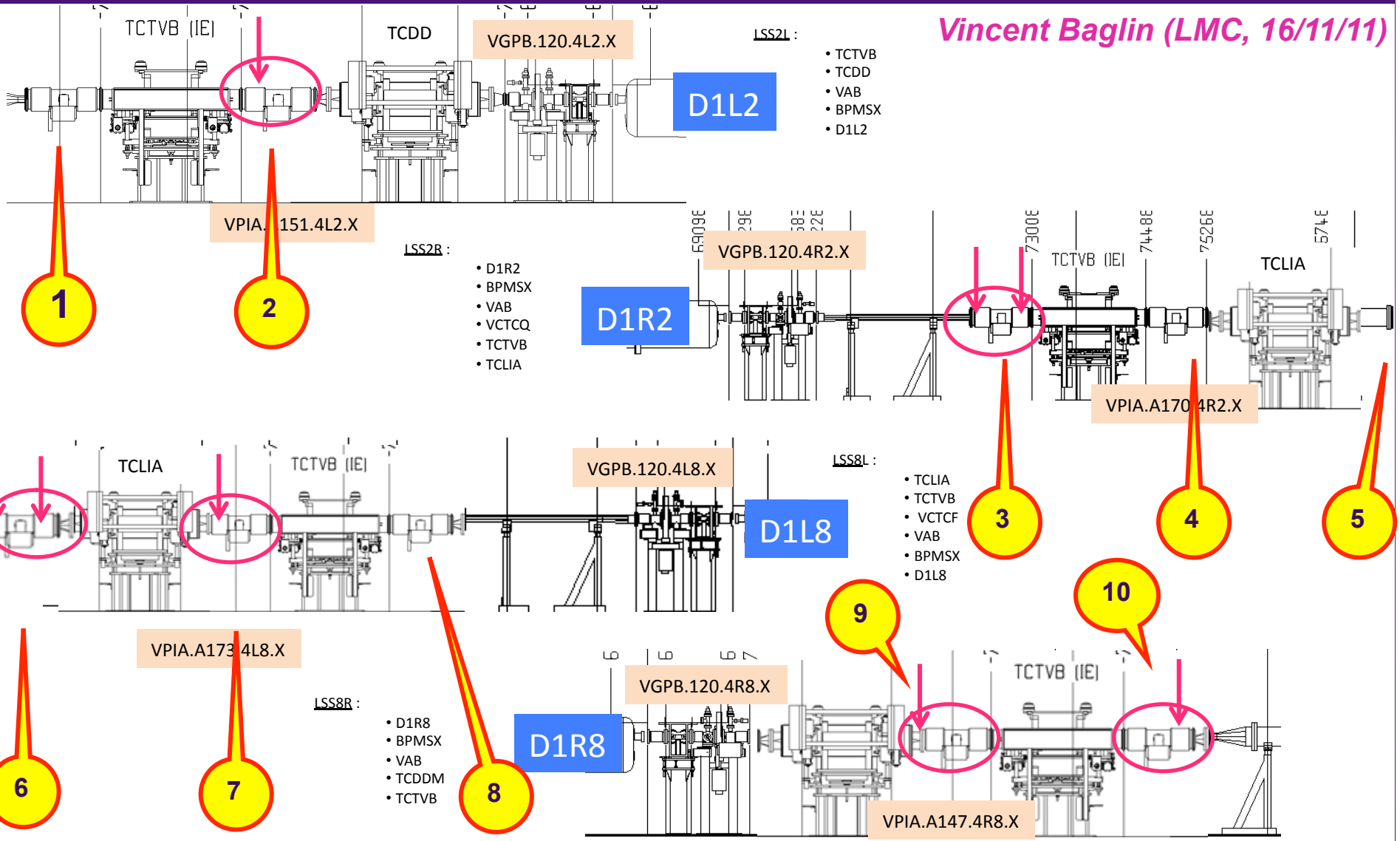
BS's table at Evian2011: https://indico.cern.ch/getFile.py/access?contribId=33&sessionId=7&resId=1&materialId=slides&confId=155520

	observable	Cooling?	Limits operation?	better if bunch length increased	improves with time?	Is it happening to all similar devices
TCP_B6L7_B1	temperature	water	Yes, dump in Sept 17th interlock increase from 55 to 70 degrees	yes	no	No (1/6)
TCTVB.4R2	temperature	water	Yes, dump in October 9th interlock increase from 50 to 70 degrees	Yes	Not obvious	No (1/4)
TDI	Vacuum Temperature (outside tank)	no	Not anymore, should be put in parking position	?	no	Yes (2/2)
MKI	Temperature and Rise time and delay (soon)	no	Yes (kick strength), and temp interlock increased from 50 deg to 62 deg. Needed to wait 4h in Oct 2011	Yes	no	All are heating but MKI-8D seems to be heating more No (1/8)
Beam screen	Heat load computed from regulation response	yes	No, except in one cell Q6R5	Yes	no	No (only one)
ALFA	Temperature on the roman pots	no	Not yet (18deg increase in temperature in 2011, with margin of 40 degrees)		?	Cooling was needed in TOTEM
VMTSA	Vacuum Spring broken after May	no	Yes (spring broken and dangling fingers)		?	Yes
BSRT Mirror	Jitter in BSRT measurement		mirror is deforming and RF heating is suspected			N/A
BGI	Vacuum		Probably not a heating issue		No data	N/A

VMTSA (1/18)

- 10 modules (each of 2 bellows) in total in 2011. 8 bellows were found with defaults (see arrows below). 2 modules will be removed for 2012

Vincent Baglin (LMC, 16/11/11)



Typical default, DCUM 3259.3524

Left side

Vincent Baglin (LMC, 16/11/11)

Side view (xray from corridor to QRL)

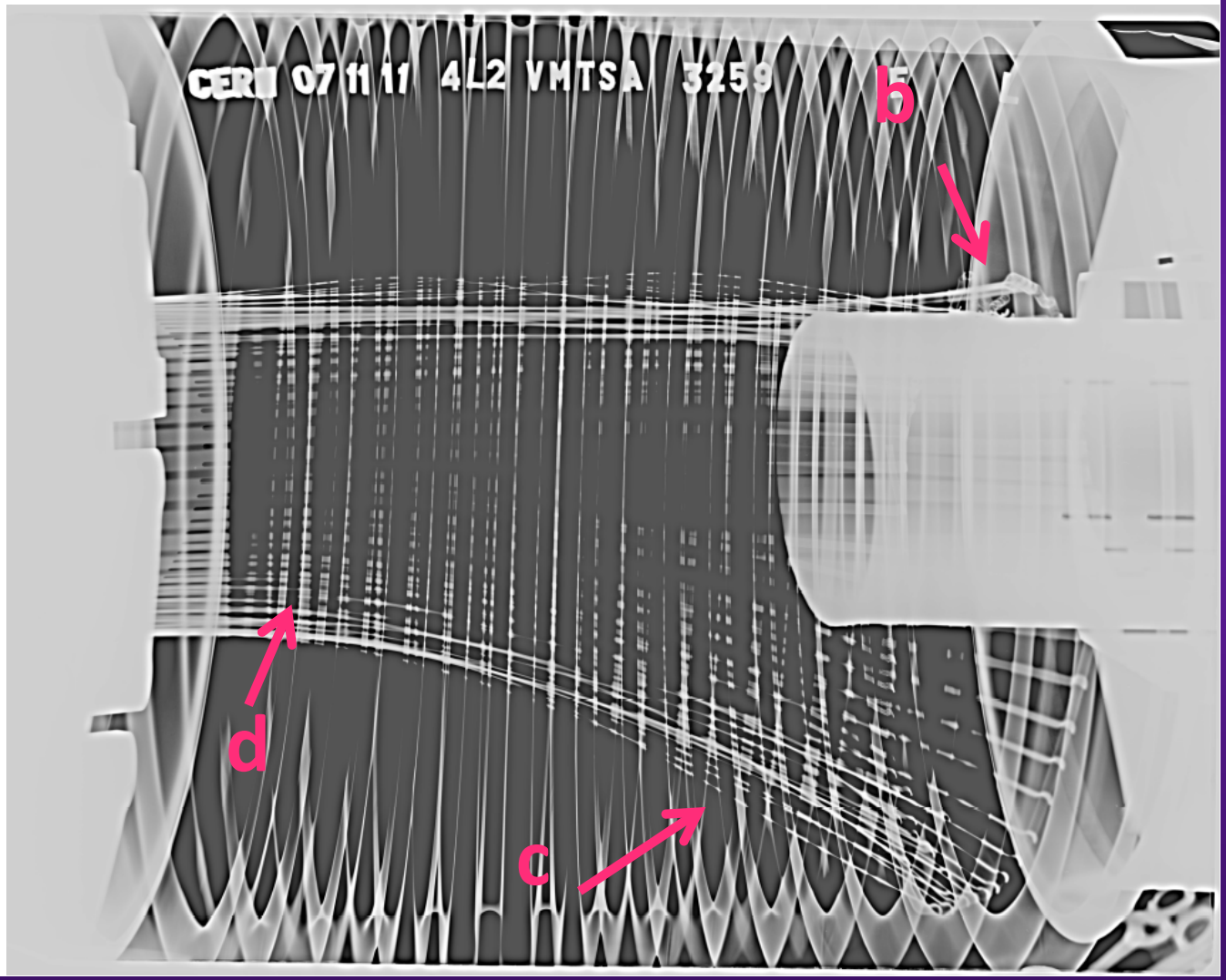
b) Metallic noise due to loose spring when hitting vacuum chamber

c) RF fingers falling due to broken spring

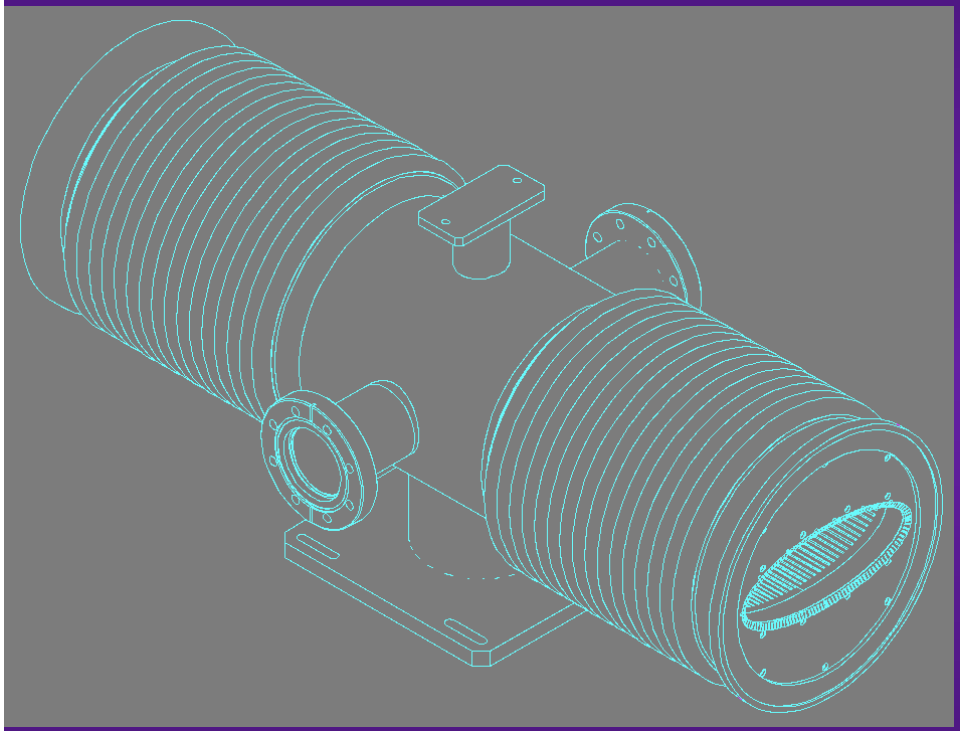
d) aperture reduced ?

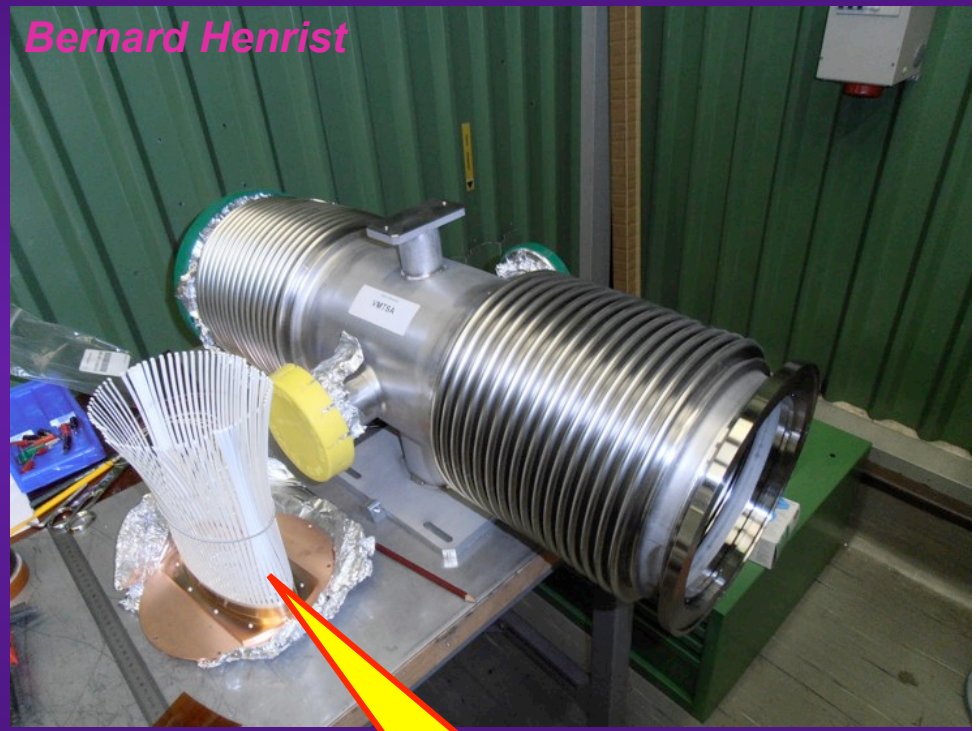
Non Conform

Spring was broken between May and November 2011



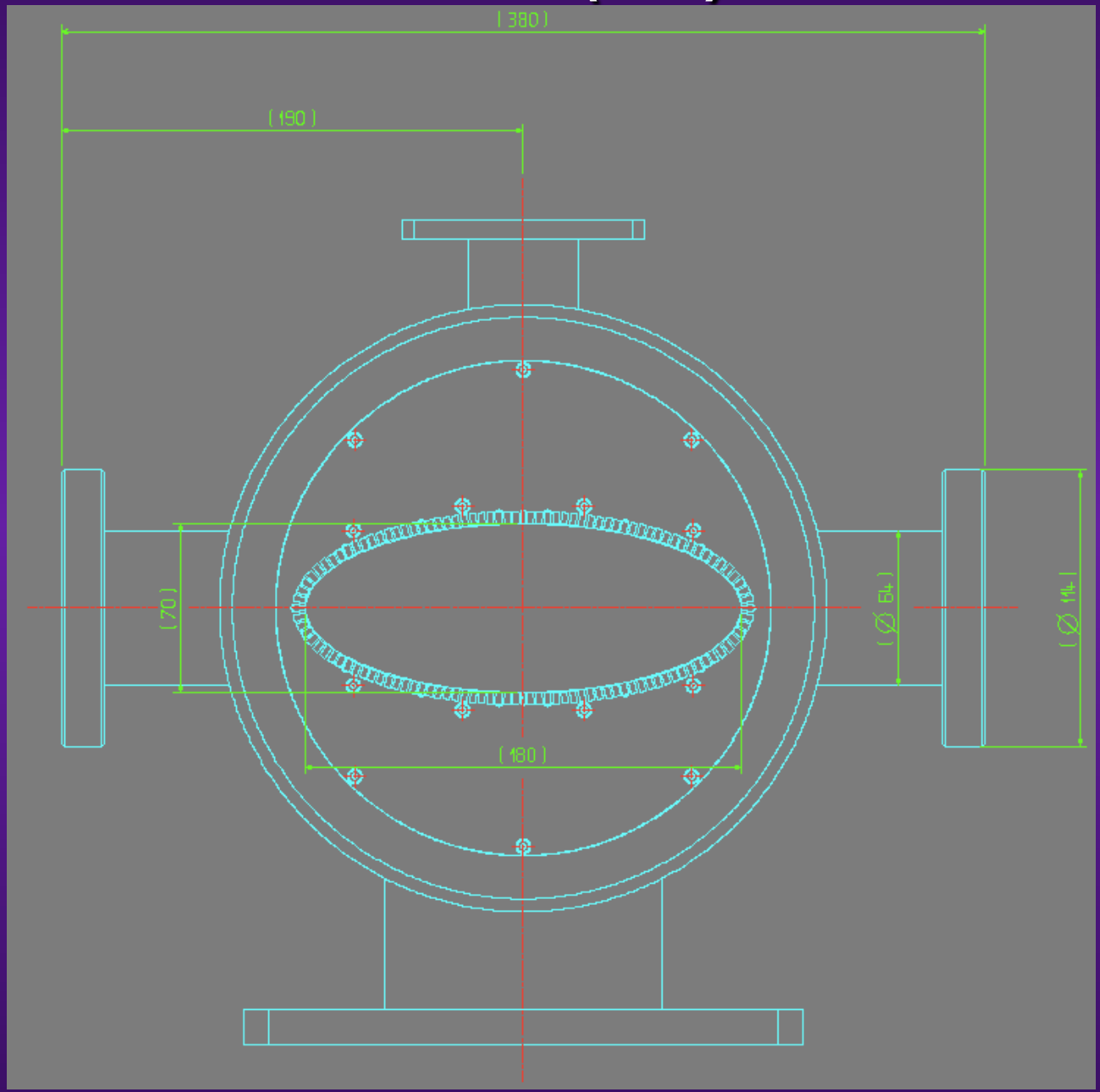
VMTSA (3/18)



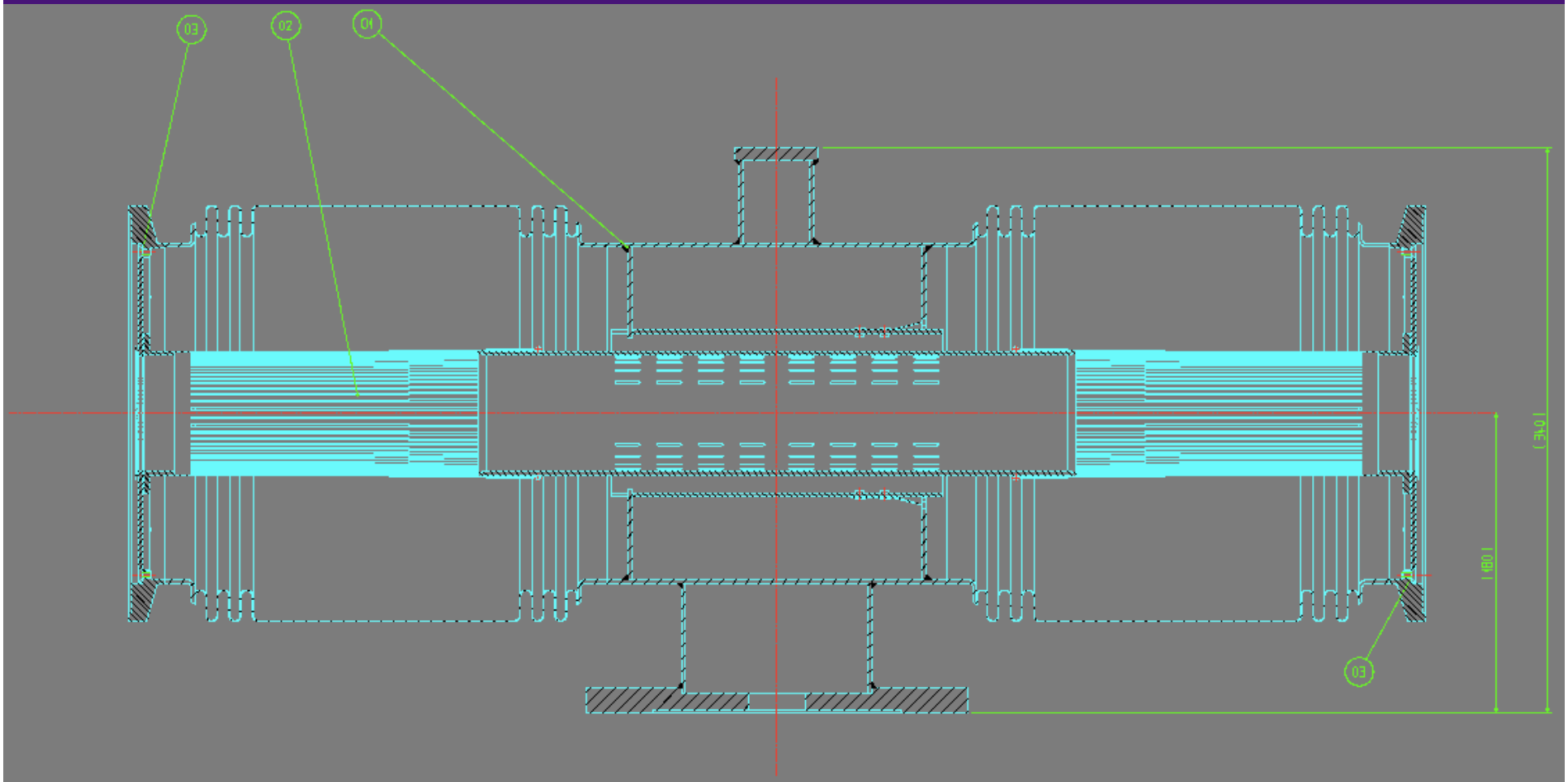


Very long RF fingers:
28 cm instead of 17 cm

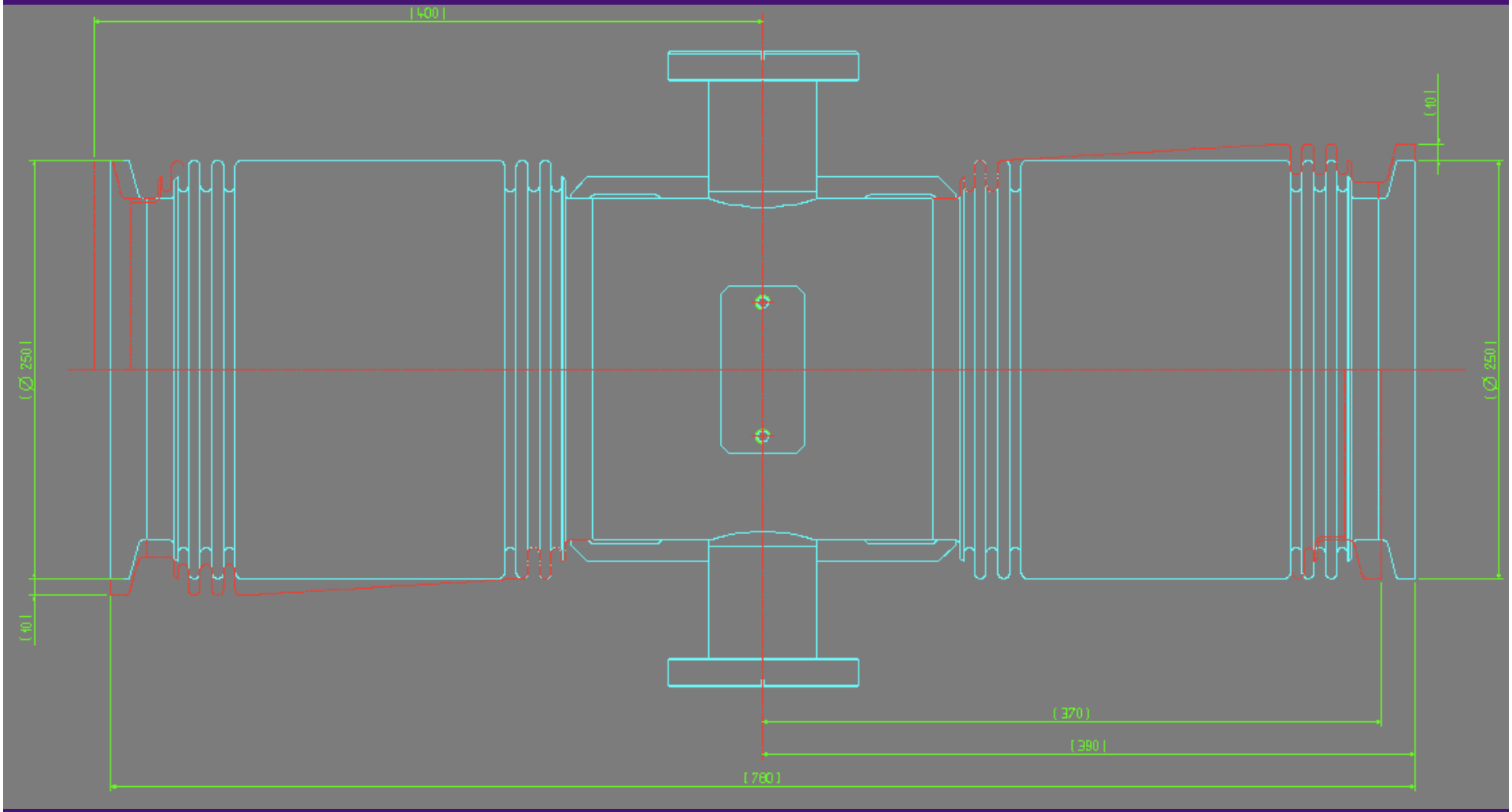
VMTSA (4/18)



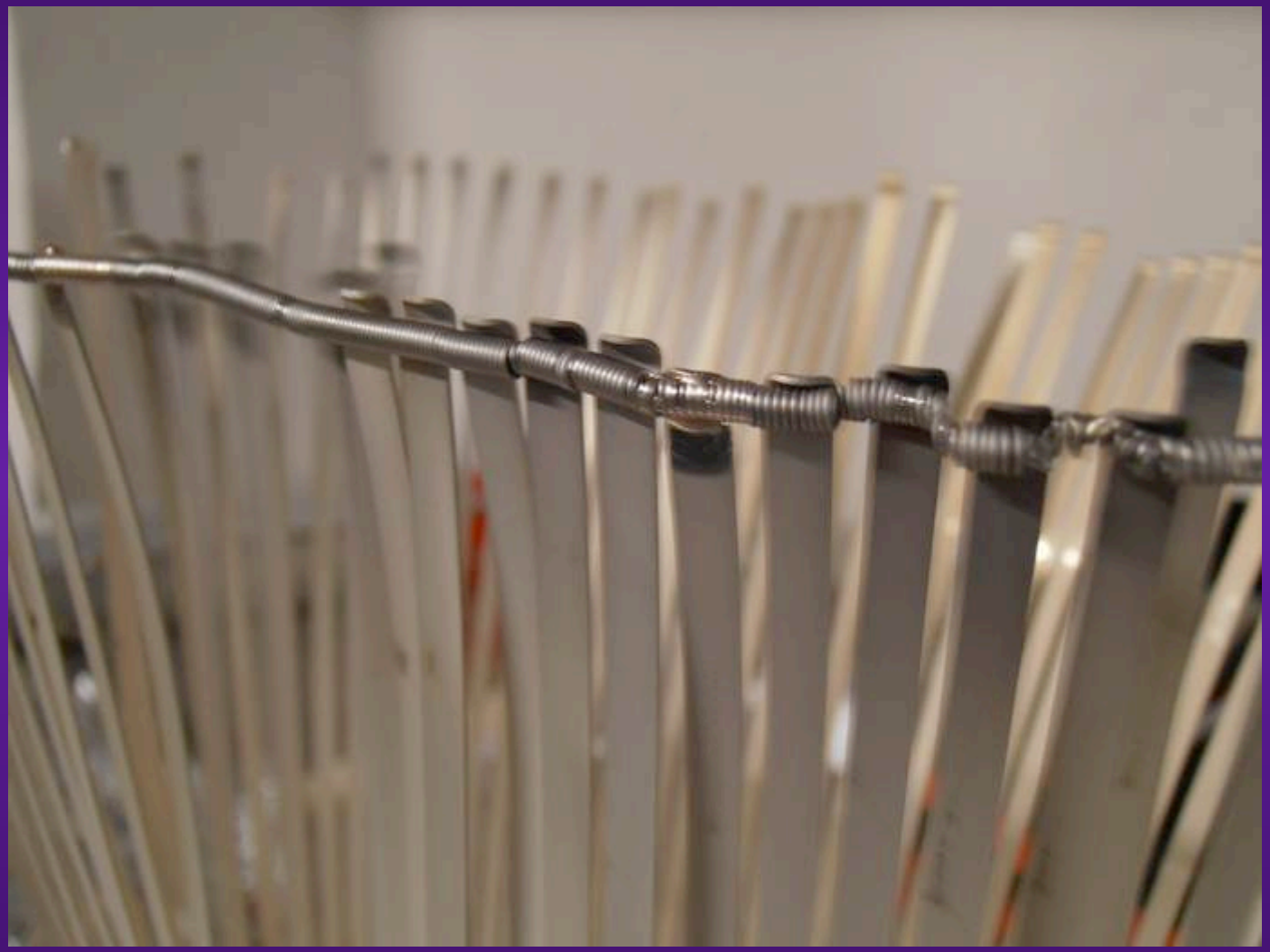
VMTSA (5/18)



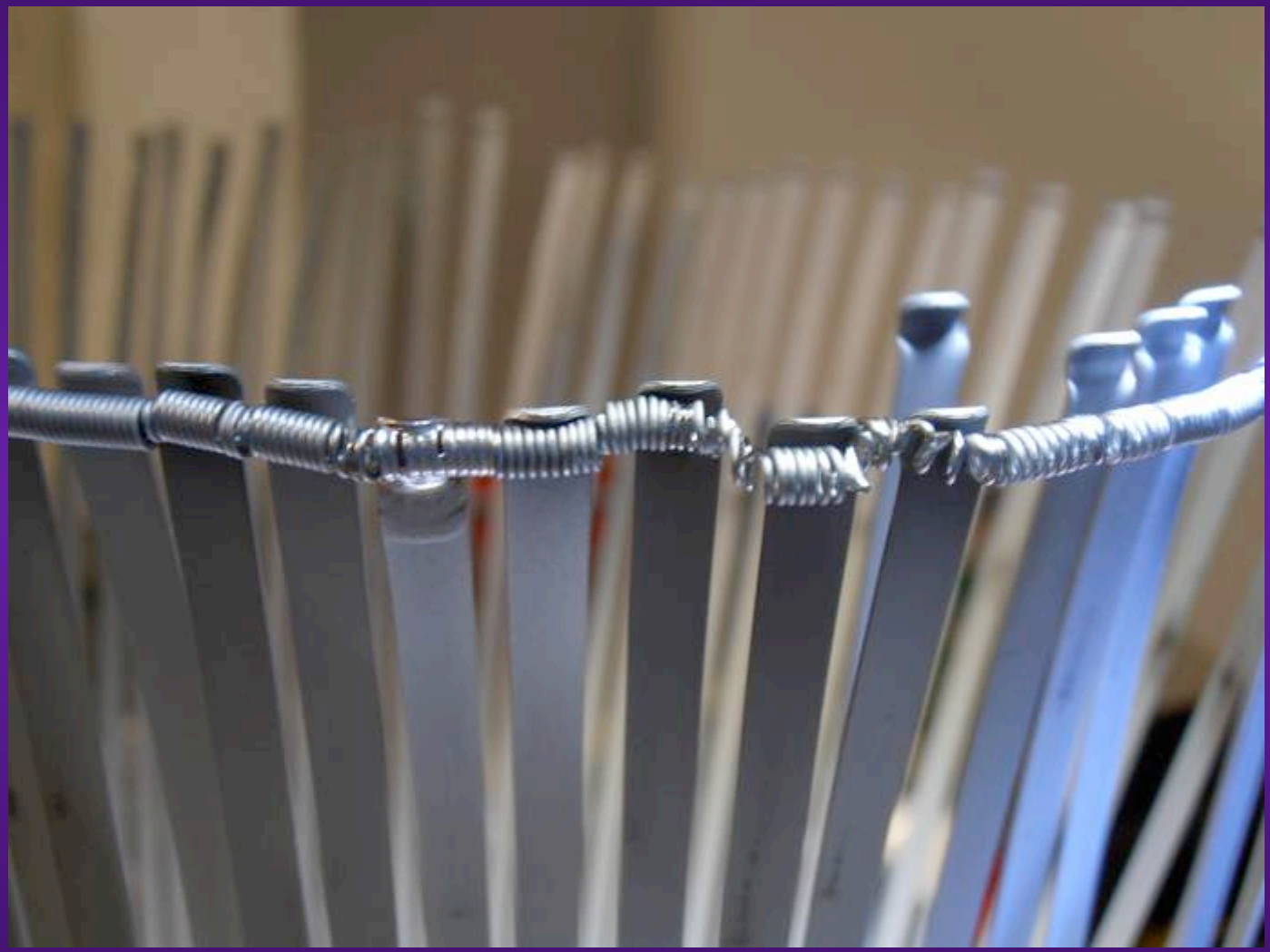
VMTSA (6/18)



VMTSA (7/18)



VMTSA (8/18)



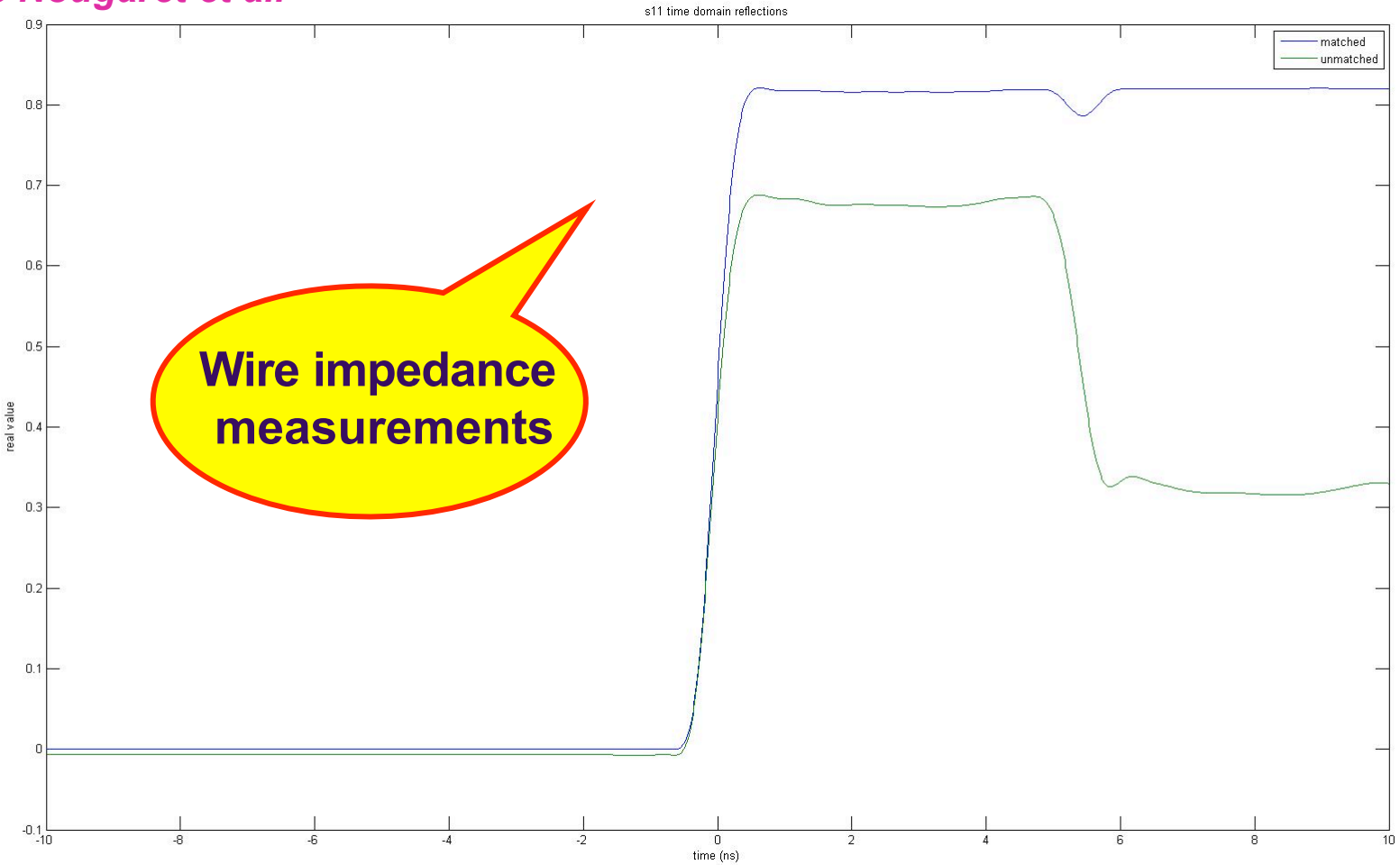
VMTSA (9/18)

VMTSA (10/18)

VMTSA (11/18)

VMTSA (12/18)

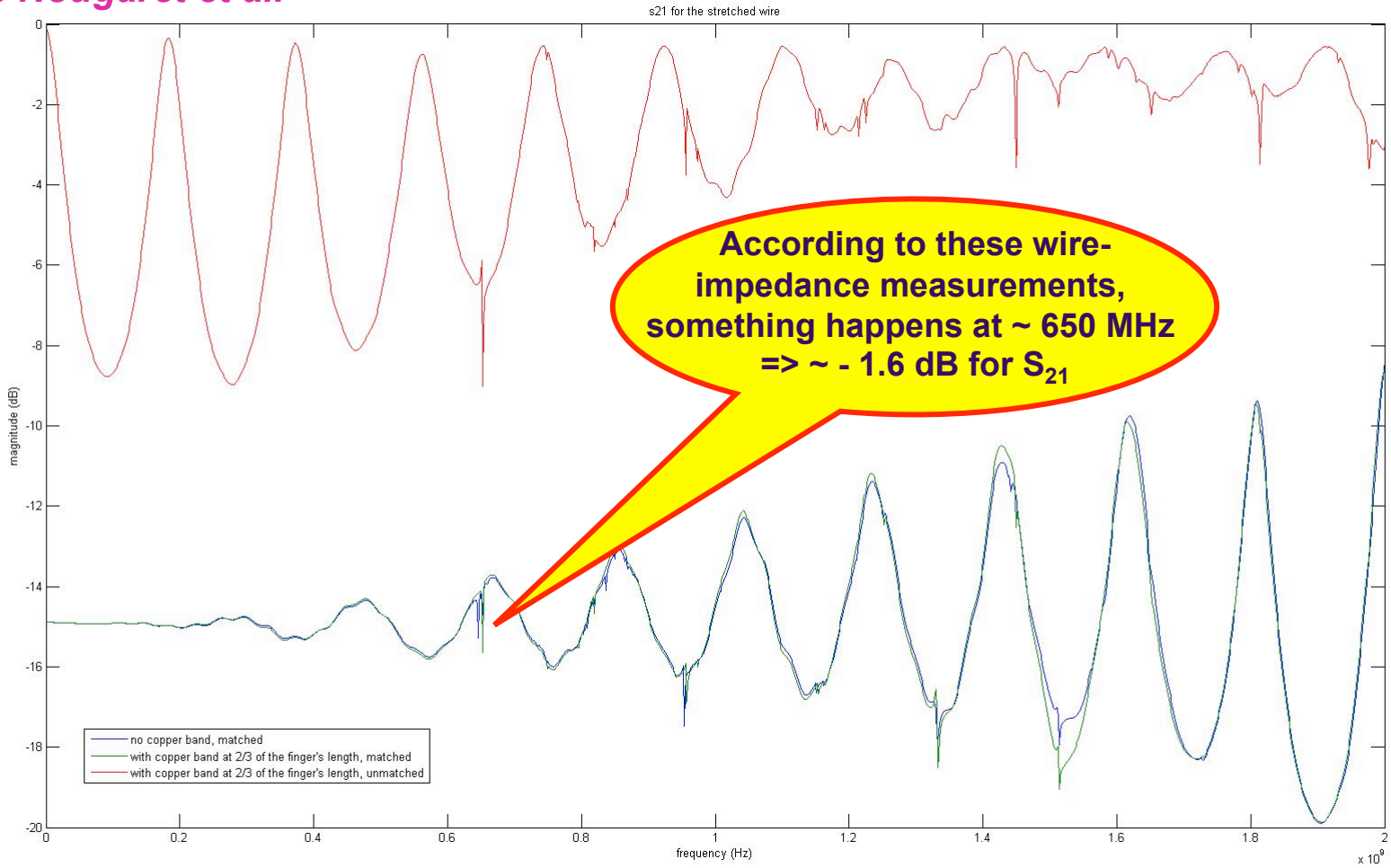
Jean-Luc Nougaret et al.



Wire impedance measurements

VMTSA (13/18)

Jean-Luc Nougaret et al.



VMTSA (14/18)

- The oscillations (frequency dependent residual reflections related to end effects and / or matching resistor) still need to be understood
- Applying the usual formula, the longitudinal impedance can be deduced

$$Z_l = -2\,Z_{ch}\,\ln\left(\frac{S_{21}}{S_{REF}}\right)$$

$$S_{REF} = e^{-j\omega\frac{L}{c}}$$

=> Numerical application for the real part of the impedance

- Z_{ch} was measured and found to be ~ 270 Ω
- We use $S_{REF} = 1$

=> $$Z_l = -2\,Z_{ch}\,\ln\left(\frac{S_{21}}{S_{REF}}\right) = -2\,Z_{ch}\,\ln\left(10^{\frac{S_{21}[\,\mathrm{dB}\,]}{20}}\right) \approx 2\times 270\times\ln\left(10^{\frac{1.6}{20}}\right) \approx 100\ \Omega$$

VMTSA (15/18)

- **This would give a power loss (if the Q of this resonance is very high, i.e. > few hundreds)**

$$P_{loss} = \left(M\, I_b \right)^2 \times R_l \times 10^{\frac{P_{dB}\left(f_r \right)}{10}}$$

=> Numerical application for the case of the 50 ns beam at the end of the 2011 run

- $M \times I_b$ = 1380 × *1.5E11 × 1.6E-19 × 11245 ~ 0.37*
- R_l = 100 Ω
- P_{dB} *(650 MHz) ~ - 10 dB (see* http://emetral.web.cern.ch/emetral/ICEsection/2011/2011-11-23/TheoreticalPowerSpectraComparison_LHCbunch_v6.pdf*)*

=> P_{loss} ~ 1.4 W

VMTSA (16/18)

Available ferrite from FritzC:

1) Dimensions: ~ 12 cm × 3 cm × 1 cm

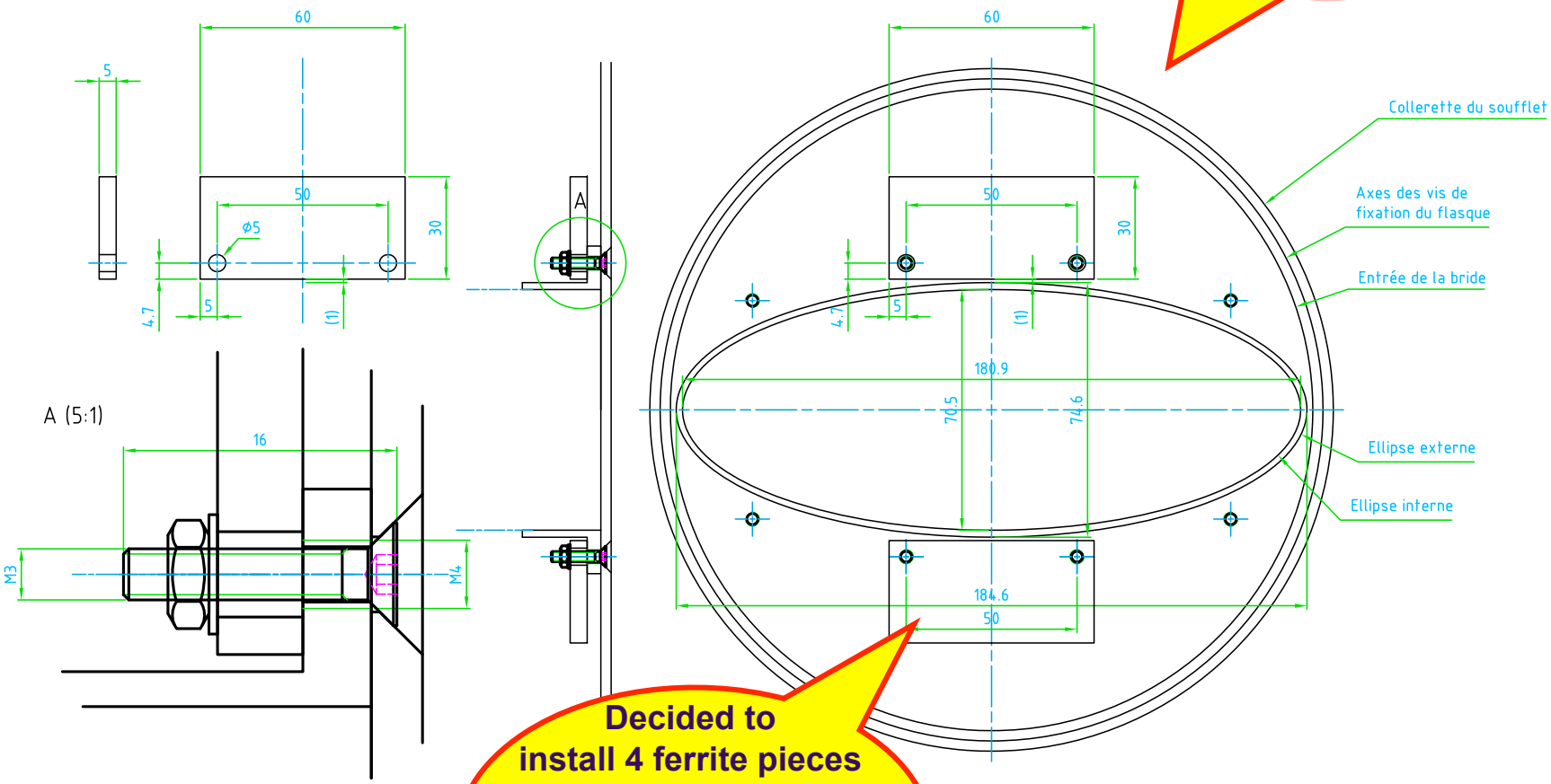
2) Should be excellent vacuum-wise as they were used in the past in the AA

3) Total: 79 (+ 6 broken)

VMTSA (17/18)

Bernard Henrist

2 recommendations from FritzC: 1) Water jet cutter to cut the ferrite; 2) Flexible clamping washer



Decided to install 4 ferrite pieces per module (i.e. 2 per bellow: up and down => On the inside of the entry and exit plates)

=> 8 × 4 = 32 ferrite pieces needed

VMTSA (18/18)

- **Next steps:**
  - New modules with shorter RF fingers (~ 2 times shorter) are being prepared. The counter effect is that we will no longer allow a lateral displacement of the collimator (needed in case the jaws are damaged by a huge beam impact)
  - Check of the ferrite vacuum-wise (from FritzC from the AA, which seem to by 8C11 from Philips) => Should be known by today (good signs were observed by VincentB on Monday)…
  - In case of problem with these ferrite blocks, William Andreazza found also 50 other ferrite blocks: 6 cm x 6 cm x 5 mm with 2 holes (6 mm diameter). Seem to be TT2111R from Transtech / Skyworks, which should be very good for UHV
  - Impedance measurements should be performed on the new module (with the shorter RF fingers) as soon as it is easy (next week), without and with ferrite => JLN. May be do also the ferrite measurement with old (long RF fingers) module => This week?
  - On a “longer term” => Impedance simulations to benchmark

CMS (1/4)

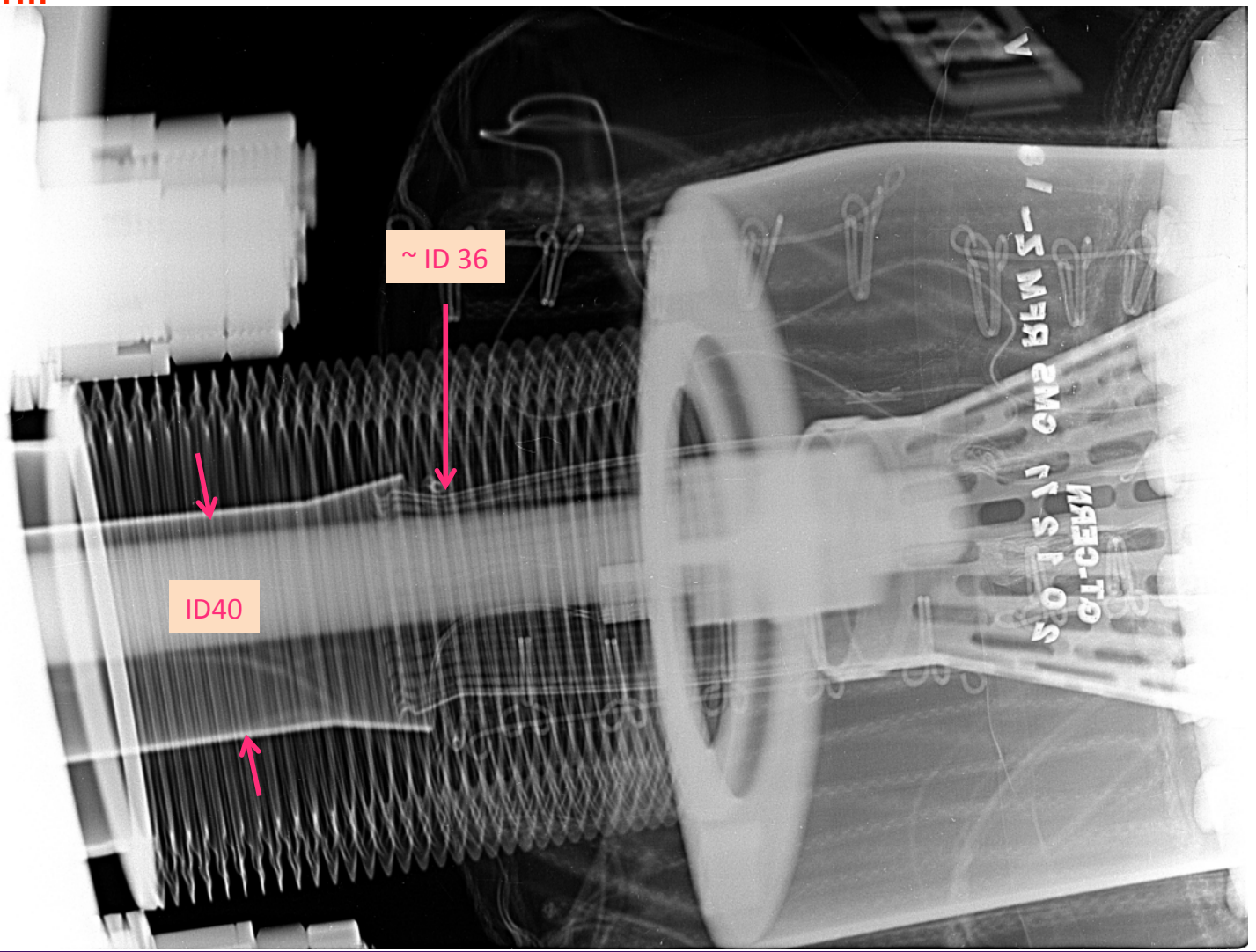
- **Only 1 pb with RF fingers at 18 m right (z-)**

Vertical view

Vincent Baglin (20/12/11)

Overlap of ~ 6 mm, RF fingers INSIDE RF insert. Estimated aperture reduced to 36 mm

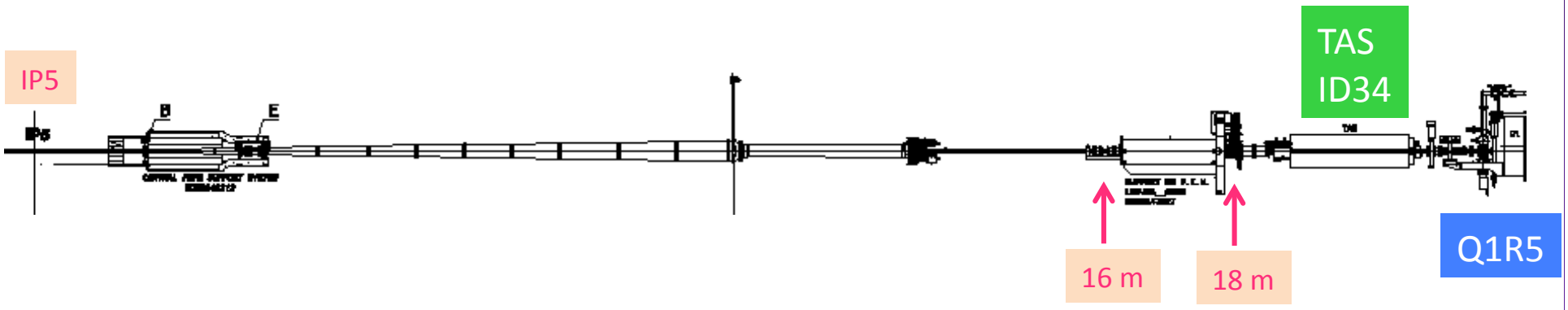
Non Conform

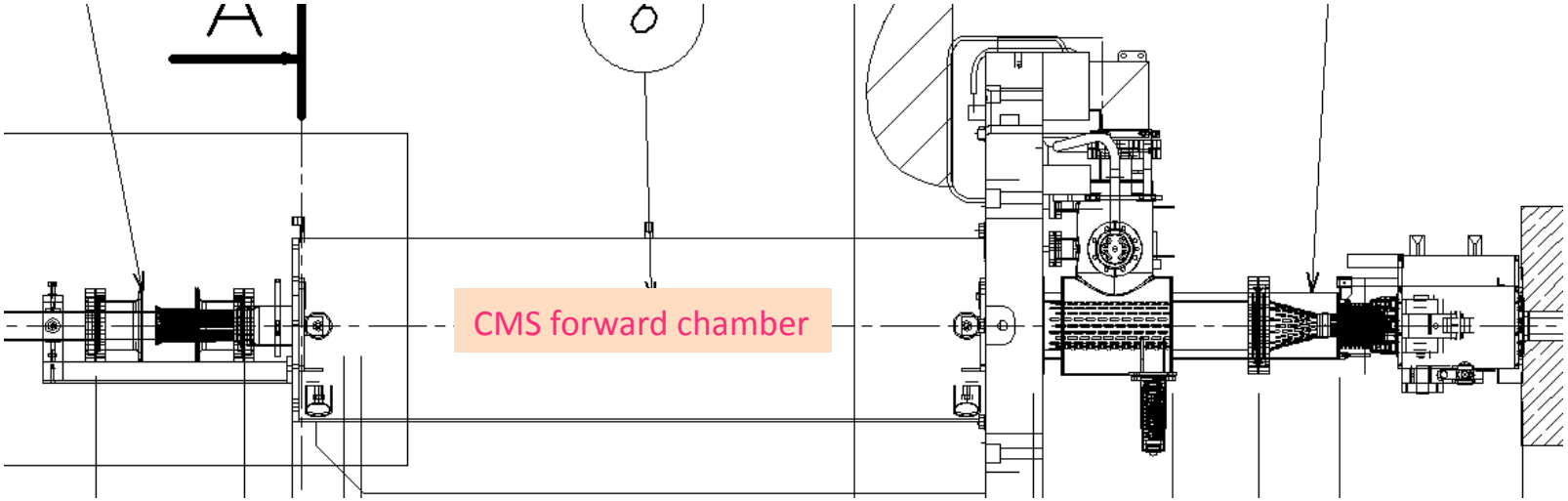


CMS (2/4)

The layout is symmetric wrt to the IP

Vincent Baglin (20/12/11)



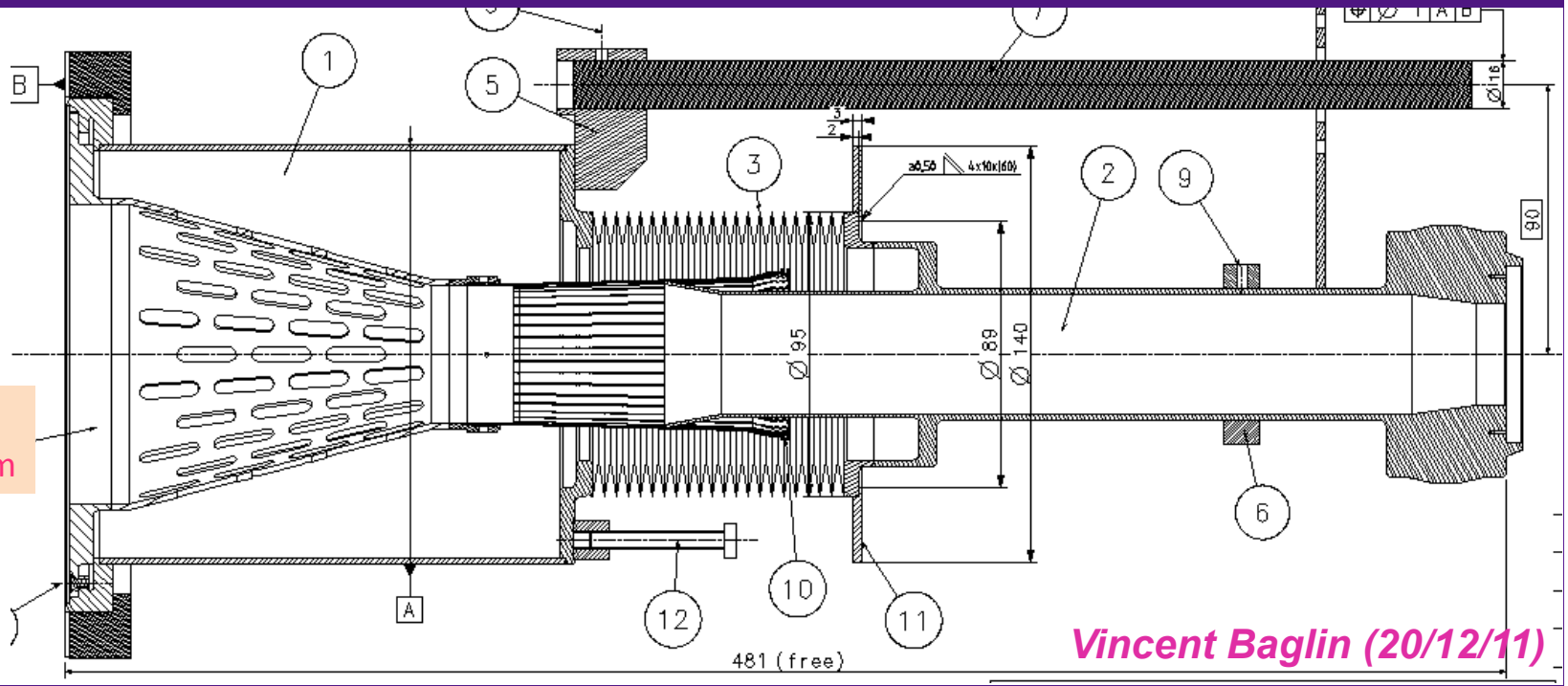


RF fingers at 16 m

RF fingers at 18 m

CMS (3/4)

Module with
RF fingers at 18 m



Vincent Baglin (20/12/11)

CMS (4/4)

- **Next step:**
  - The faulty module will be replaced by a new module (with RF fingers outside) in situ using some Ne gas (very inert noble gas, which has therefore no interaction with the NEG)
  - They will check also the length and add a small piece in case the space is too big in order not to end with the same situation in some time
  - => No action from the impedance team

ALFA (1/7)

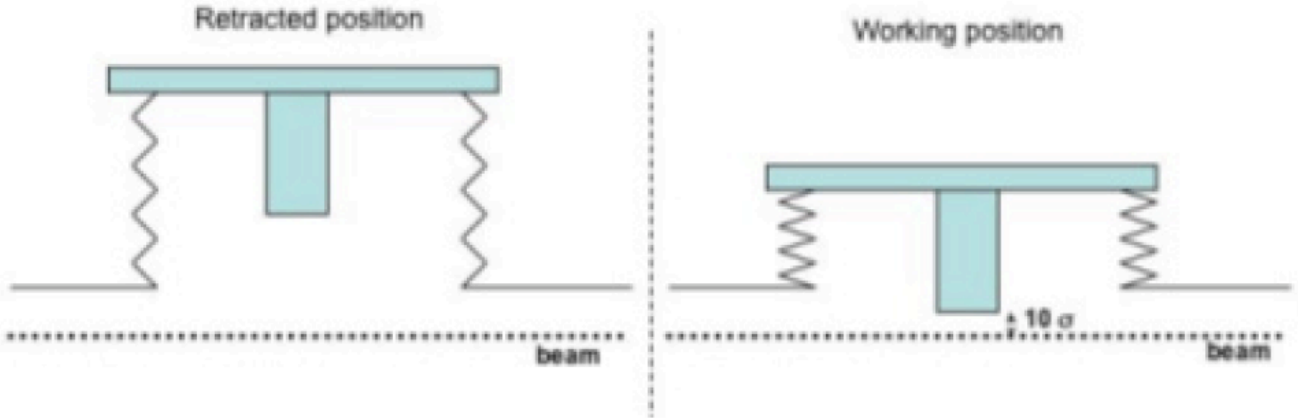


Figure 1: Roman pot detector concept.

Figure 2: 3D view of a RP unit, side seen from the beam.

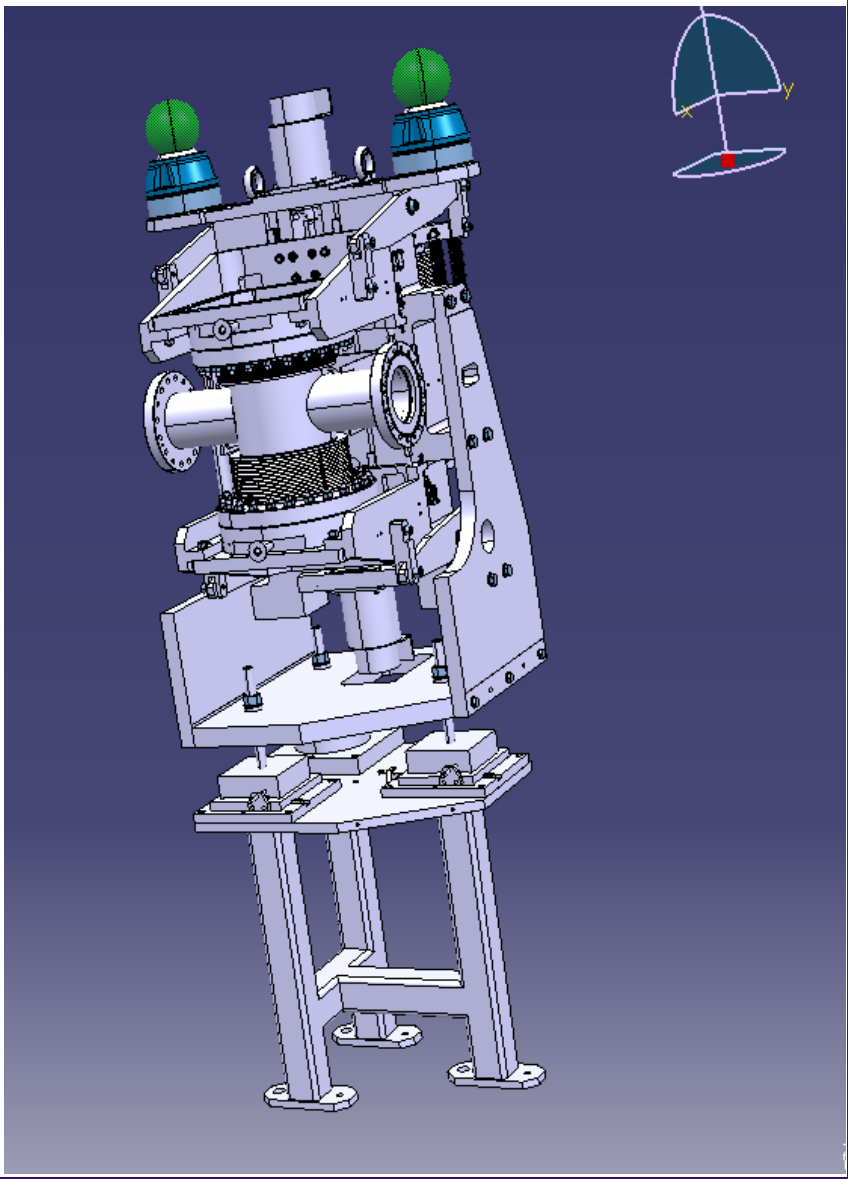
Paper by F. Roncarolo et al.:
http://accelconf.web.cern.ch/AccelConf/e08/papers/tupp063.pdf

ALFA (2/7)

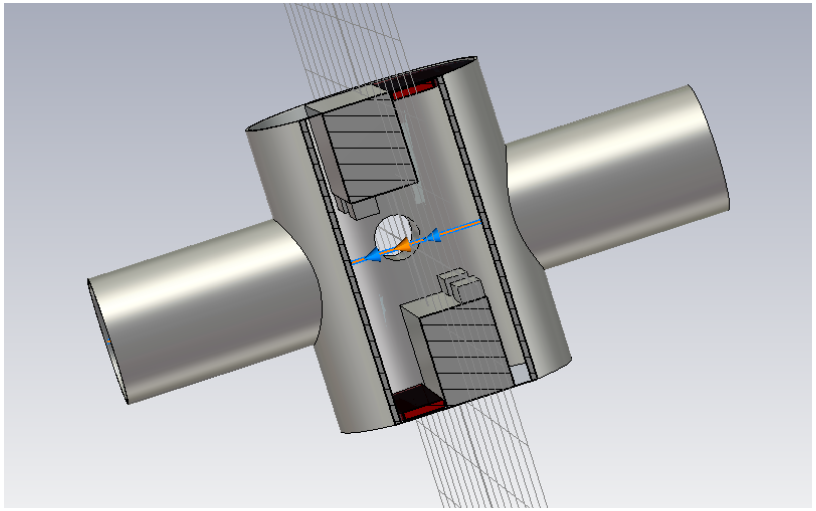
SMARTEAM references for the relevant CATIA drawings:

Benoit Salvant

- ST0243713_01
- ST0040591_02



CST model



ALFA (3/7)

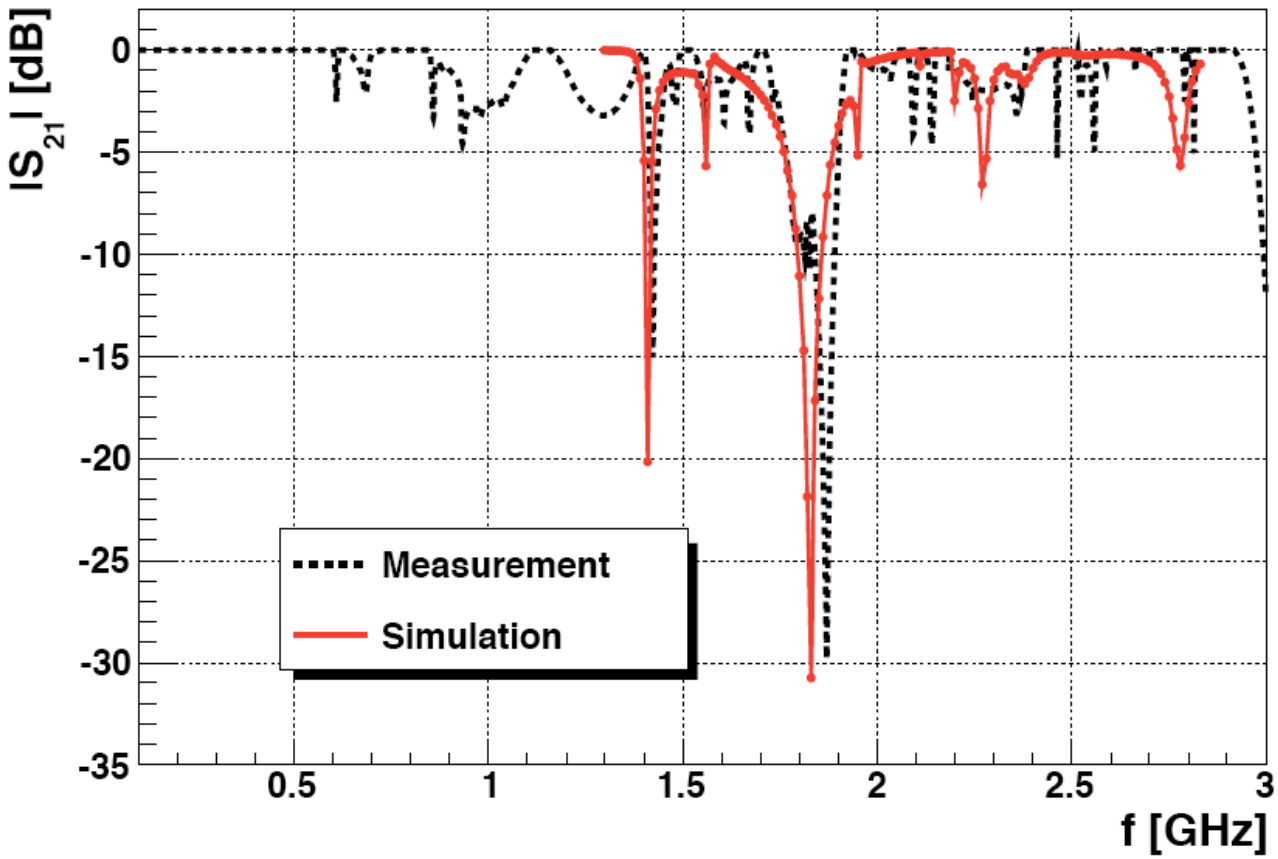


Figure 3: Modulus of the transmission scattering parameter S_21 as measured and simulated with HFSS, for a RP retracted position at 36 mm from the wire (i.e. form the beam)

ALFA (4/7)

Federico Roncarolo et al.

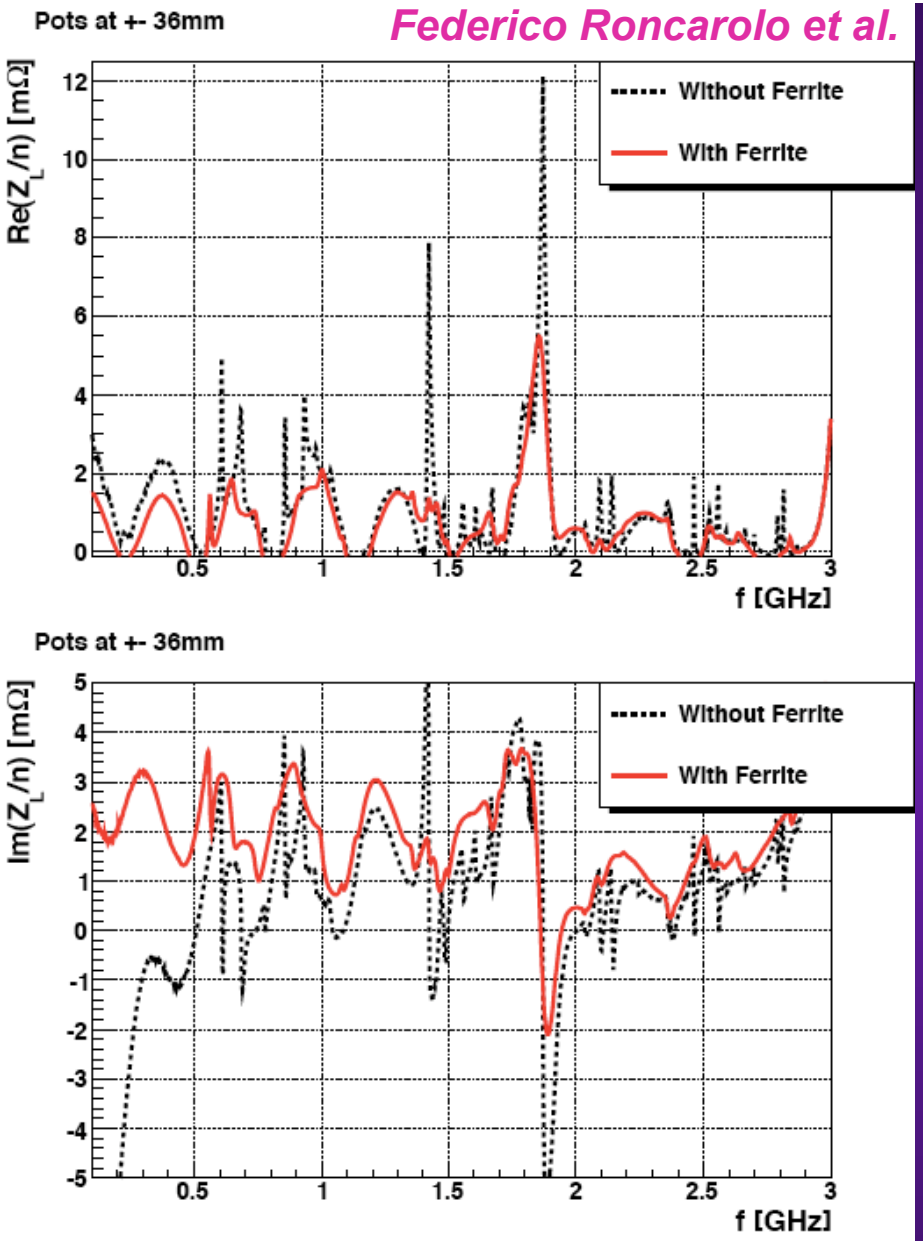


Figure 4: Real and imaginary part of the longitudinal impedance as measured for RP unit in retracted position before and after mounting ferrite tiles.

ALFA (5/7)

- **Meeting before Christmas (on 20/12/2011) with BS, FritzC, Per Grafstrom, Christian Joram and Patrick Fassnacht:**
  - **BS showed some simulation results in time domain and frequency domain**
  - **FC reminded us the role of the ferrite:**
    - **It can be not totally intuitive but by adding a material with (magnetic) losses (ferrite) we decrease the Q factor and therefore the (R/Q)*Q = R and therefore we decrease the power loss proportional to R!**
    - **The ferrite will decrease the total power by a factor of few tens, maybe 50**
    - **But, then the ferrite will absorb the remaining power**
    - **Note also that adding ferrite should decrease (slightly) the resonance frequency (as seen also by BS' simulations)**
  - **If the pot is welded then the shielding is more than 100dB**
  - **BS's most critical mode with simultion is ~ 960 MHz => With this most critical mode, Ploss ~ 8 W with the ferrite there. Without the ferrite it would be kW**

ALFA (6/7)

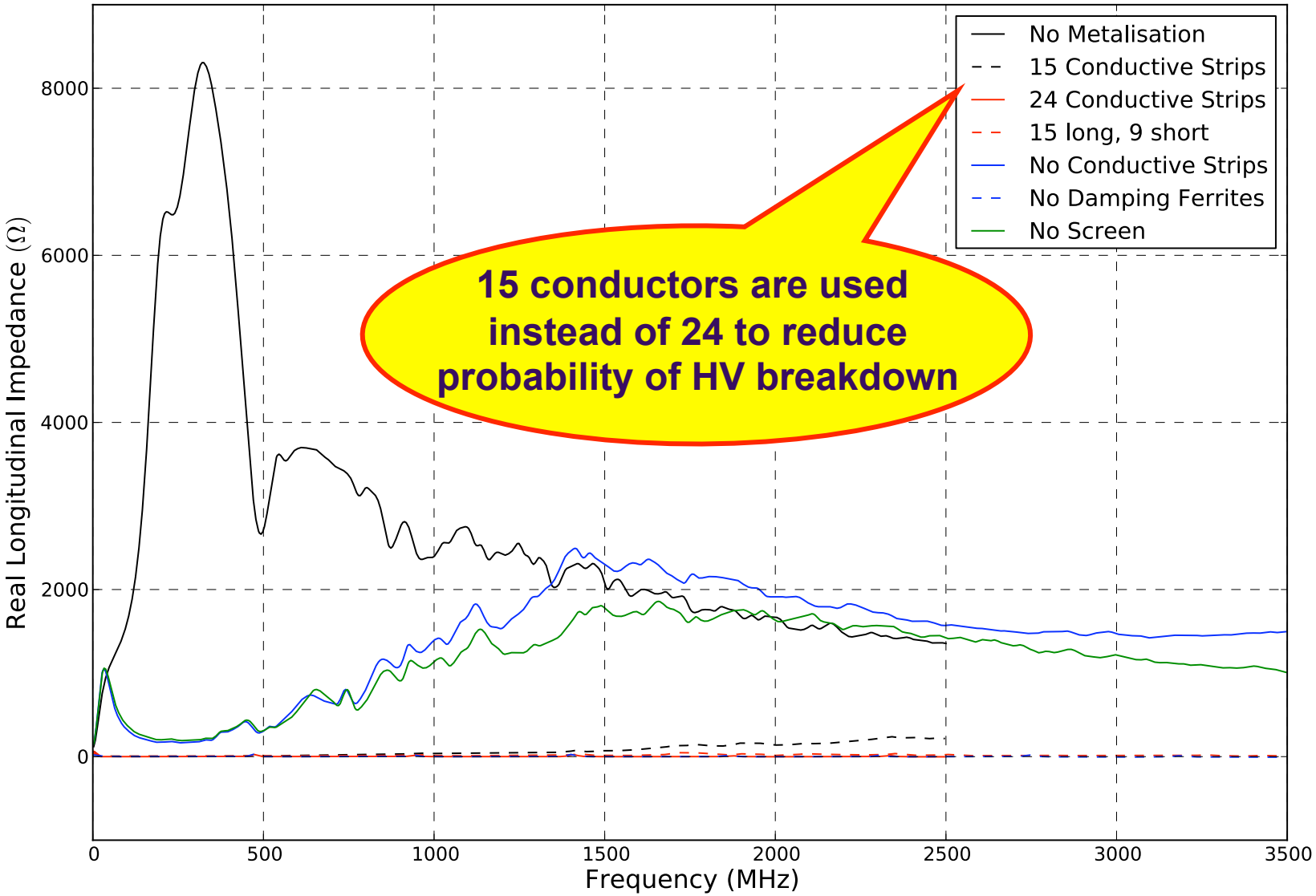
- Their observation is a temperature increase by ~ 30 deg (to reach ~ 50 deg)
- They made a test by putting ~ 10 W (with a heating tape at the outside, in the air, but with vacuum in the pot) and saw this ~ 50 deg inside the pot => Seems consistent
- But we need to understand how the heating goes from the outside to the inside (this is very important for them to know how the heat exchange happens as it will define the cooling system!). FritzC proposed to make a coating of the outside of the pot
- Reminder: Convection is very small in vacuum and for the radiation we should not assume a black body => The first observations they made seem to go in the direction of radiation as the only possibility for the heat exchange. To be followed up

ALFA (7/7)

- The current ferrites do not seem in the good positions => Adding ferrites at the optimized position we could reduce the power loss by a factor ~ 5
- Reminder: For 2012, we will have not time to prepare and install the ferrites, so we should not rely on that for 2012 => We will have to deal with this power loss but we need to find a solution otherwise they will have to stop their physics programme
- Reminder from Per: In the Design Report, it was mentioned that the roman pot should be removed for high intensity beams => Could be a solution but then they think they need a stop of ~ 1 week to re-install it and it cannot be done during a technical stop of 4 days!!!
- Best solution maybe to explore: Put the roman pot not in parking position (~ 40 mm) but at ~ 20 mm => The cavity would be smaller and maybe the resonance frequency would shift to a higher frequency leading to a smaller power loss => To be checked

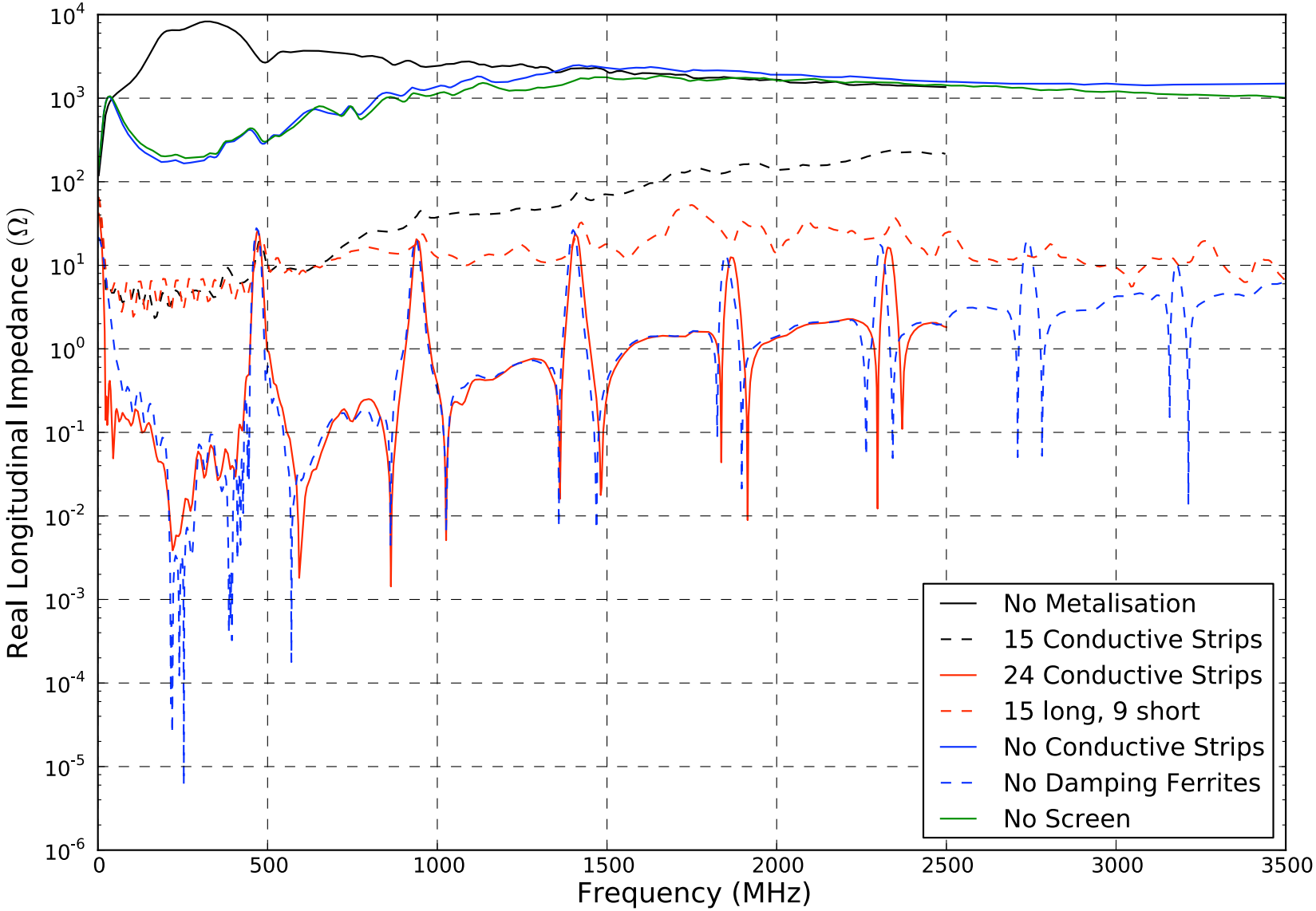
MKI (1/6)

Hugo Day



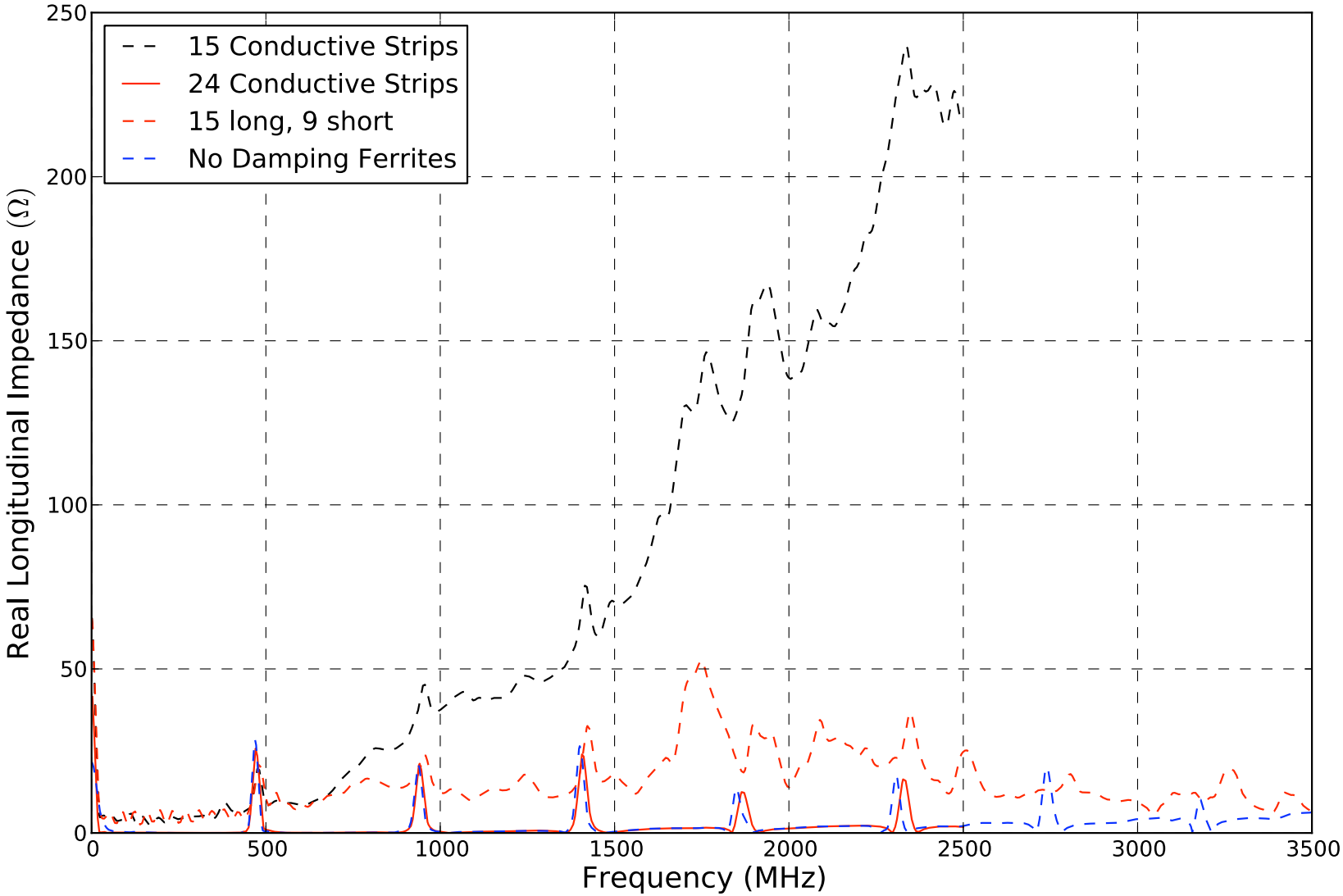
MKI (2/6)

Hugo Day



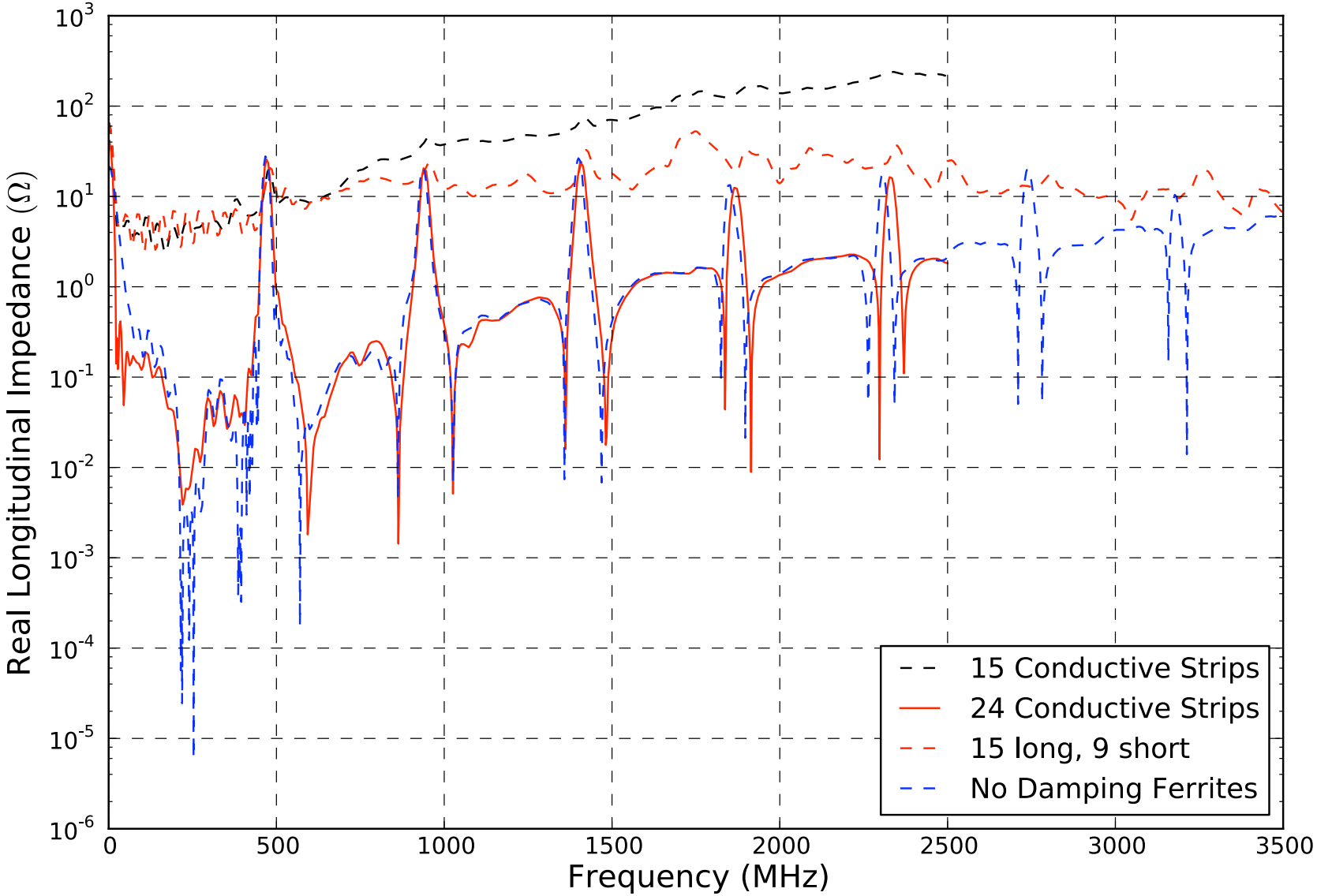
MKI (3/6)

Hugo Day



MKI (4/6)

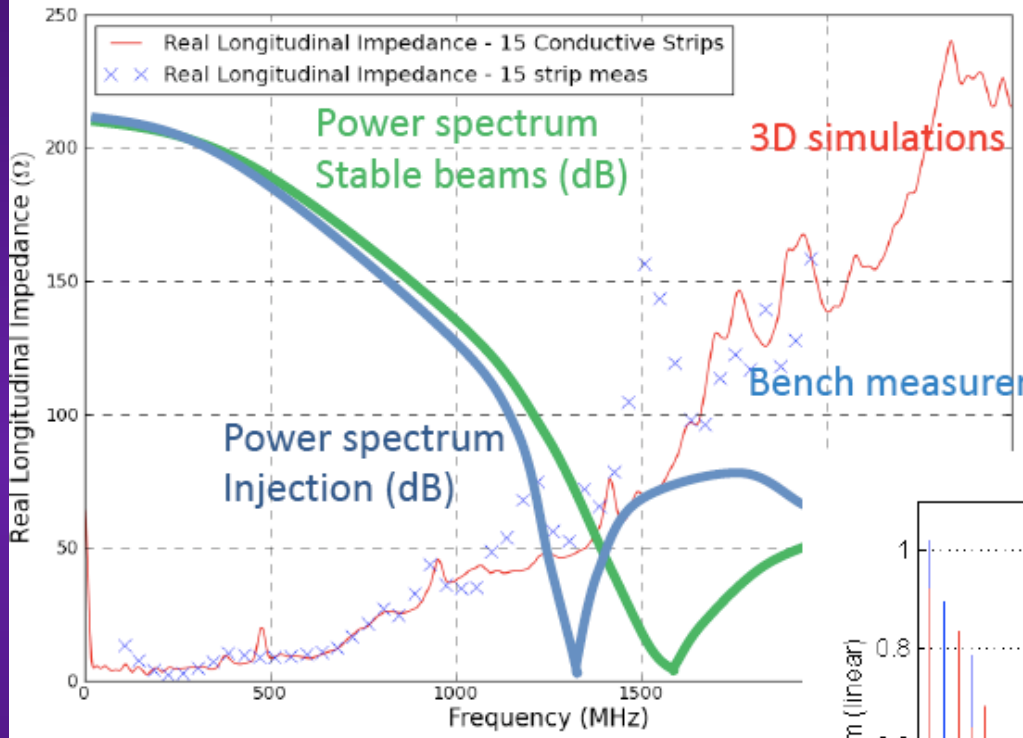
Hugo Day

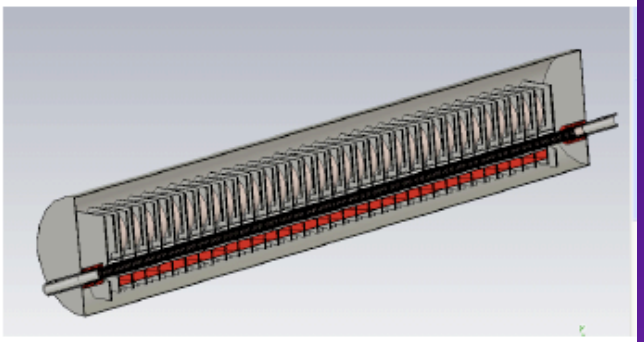


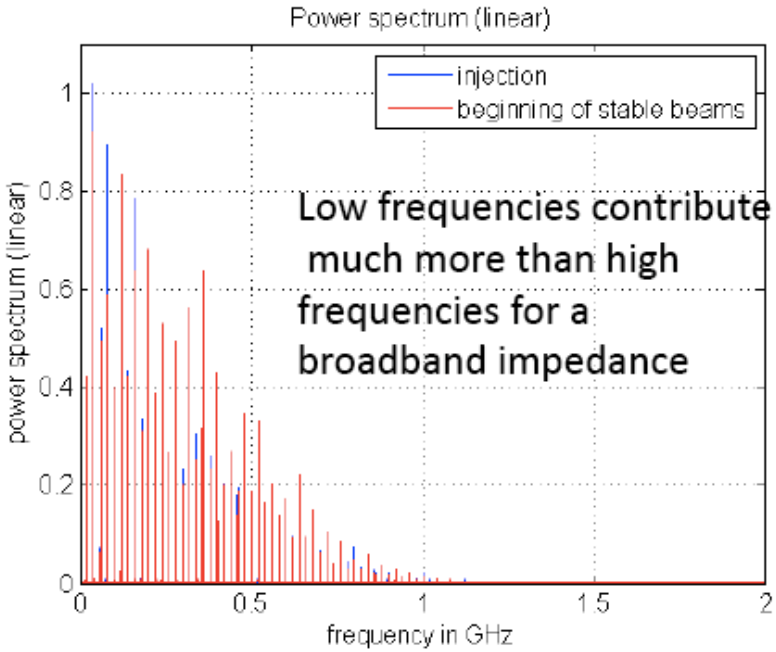
MKI (5/6)

Simulations and bench measurements of MKI

BS' Evian11 talk





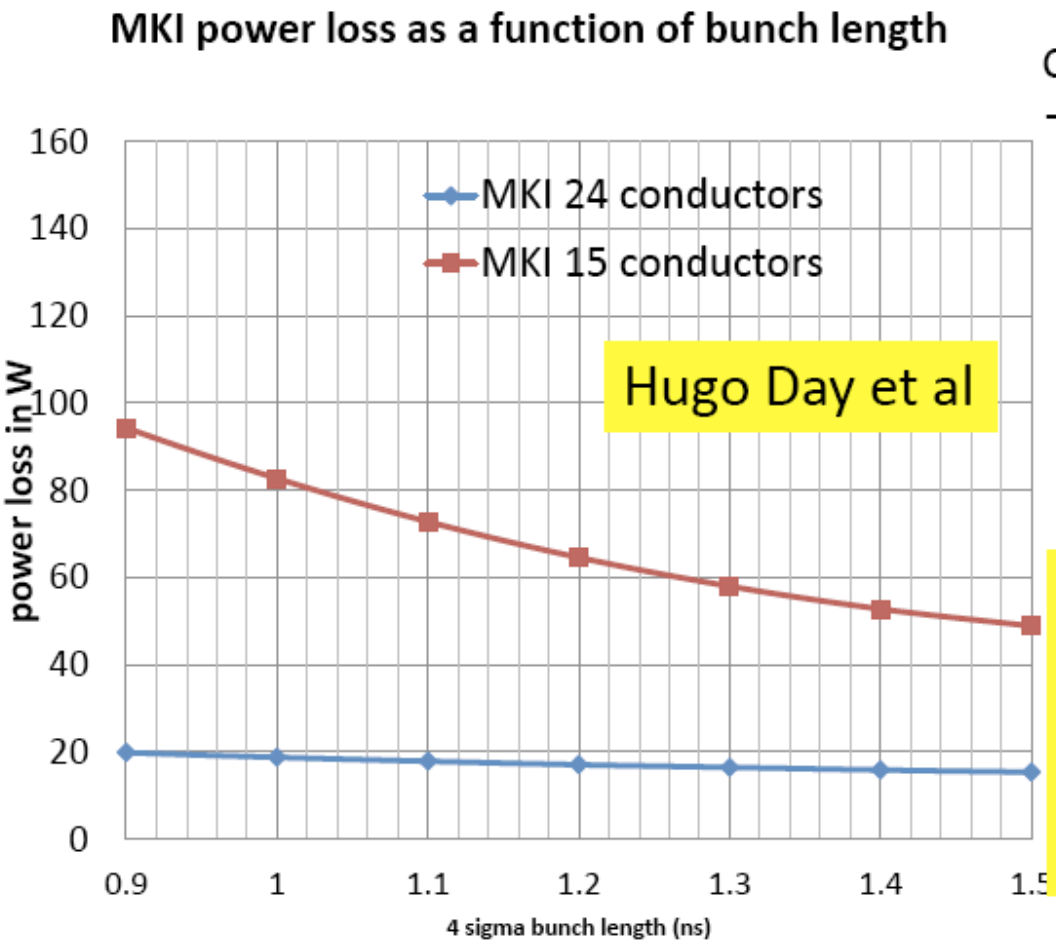


- Very complicated 3D model!!!
- Simulations seem to grasp the physics

Hugo Day et al

MKI (6/6)

Effect of bunch length on simulated power loss (50 ns) very preliminary… more at Chamonix!



Cos^2 distribution
→ To be checked with measurements

BS' Evian11 talk

Increasing bunch length could help!
But using 1.4 ns instead of 1.2 ns gives a 12 W reduction
→ not drastic

Nice to try in the beginning in 2012!

Without conductors, the power loss shoots to 20 kW

News for TDI, TCP, MKI and TCTVB

- **TDI:** Inspection foreseen next week (with Bernard Henrist): metallization + sheilding foil
- **TCP:** Oliver Aberle will contact Stefano Sgobba to take pictures of the heating collimator
- **MKI:** Mike Barnes made a request to check the RF fingers of MKI8D
- **TCTVB:** Plan to remove some => See ECR - Class I (2011-10-12): https://edms.cern.ch/file/1153295/1.0/LHC-LJ-EC-0025-10-00.pdf => Modification IR2 to solve the ALICE ZDC TCTVB interference problem: It is proposed to modify IR2 on both sides in order to get the same collimation layout as in IR1/IR5 to solve the interference problem between the ALICE ZDC and TCTVB during beam operation. The modification consists in moving the recombination chamber by 1.36 m towards IP2 to install a TCTVA between the recombination chamber and D2, in shortening the VCDGA chamber by 1.36 m and finally removing the TCTVB. In the LSS2R, the TCTVB slot will be taken by the existing TCLIA collimator

  => If TCTVB.4R2 is removed, then the observed heating is not a pb anymore: was it due to it or to the adjacent VMTSA faulty module (see Slide 3)