# RF window conditioning

**Materials from Denis Kostin, Michael Bousonville**

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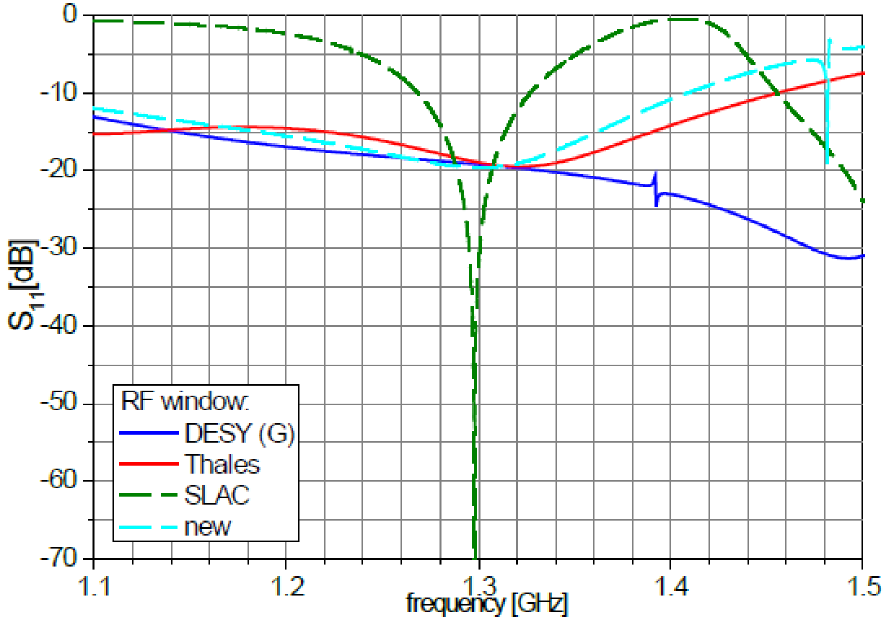
# 4 RF windows

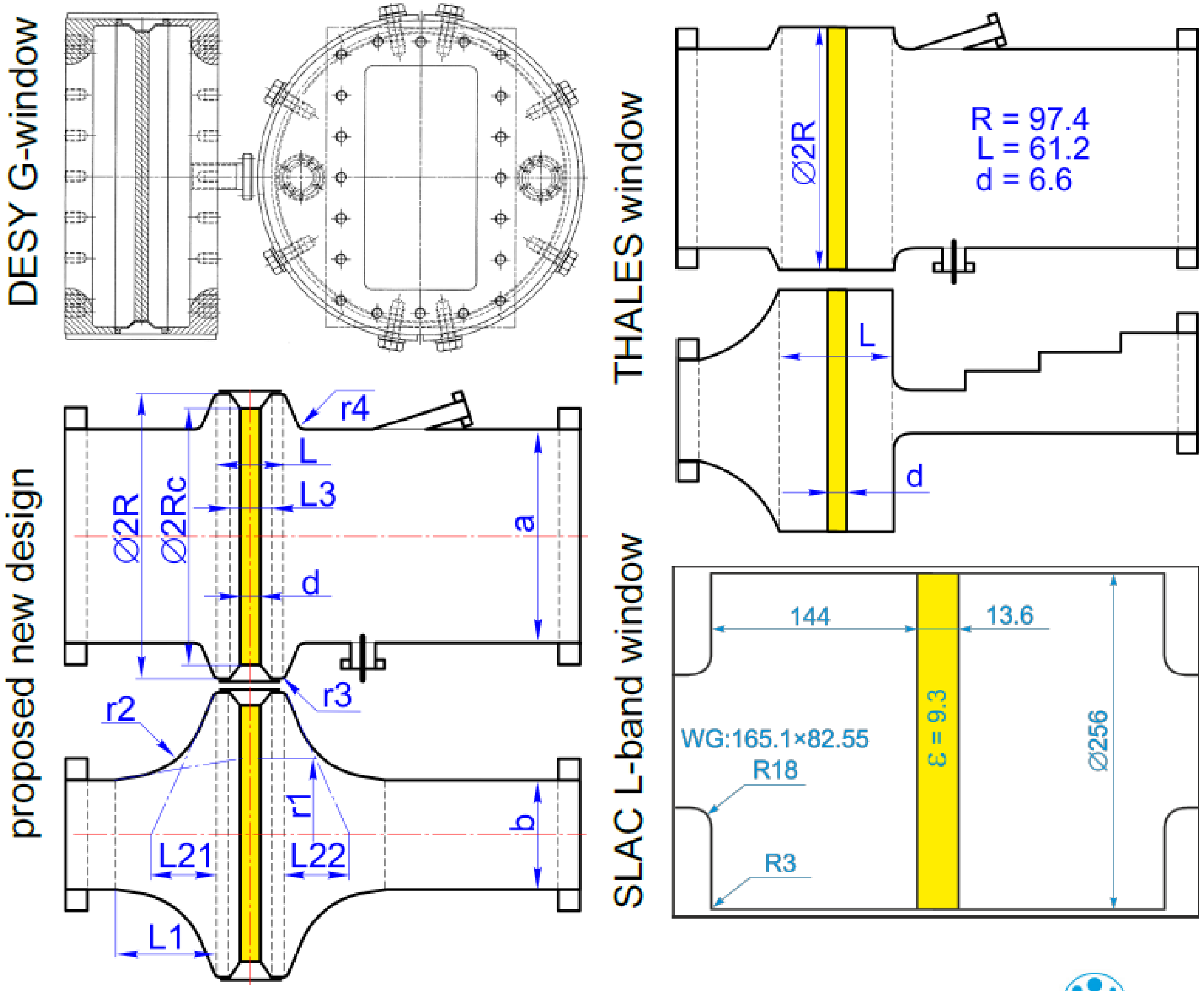
## L-band

### RF Windows

some problems with the RF-Gun window - ideas

- Several designs exist – new one is proposed.
- There seems to be no ideal solution (next slide).
- Limiting factors – surface overvoltages and multipacting (RF discharge) must be addressed.



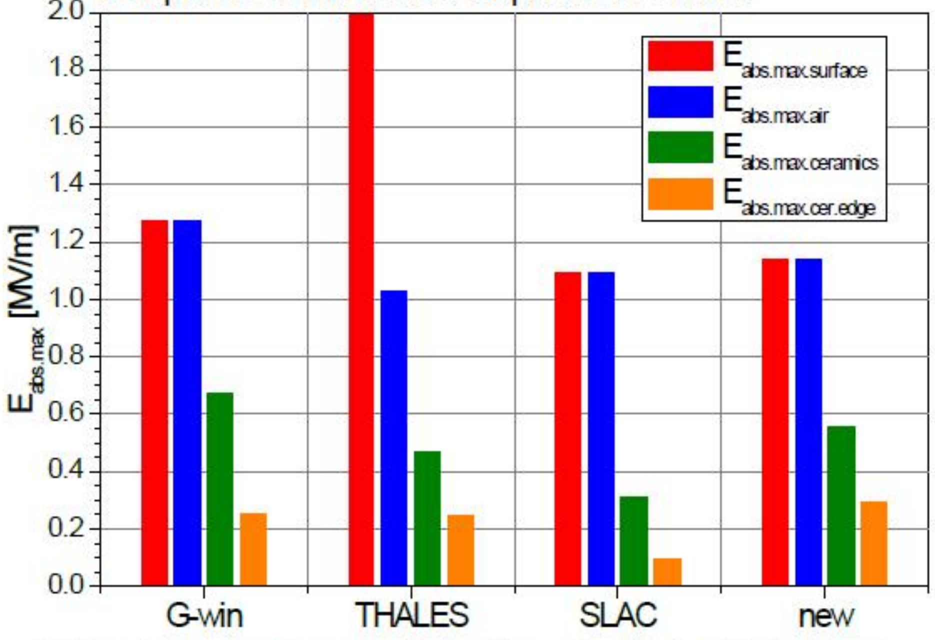
# 4 RF windows

## L-band

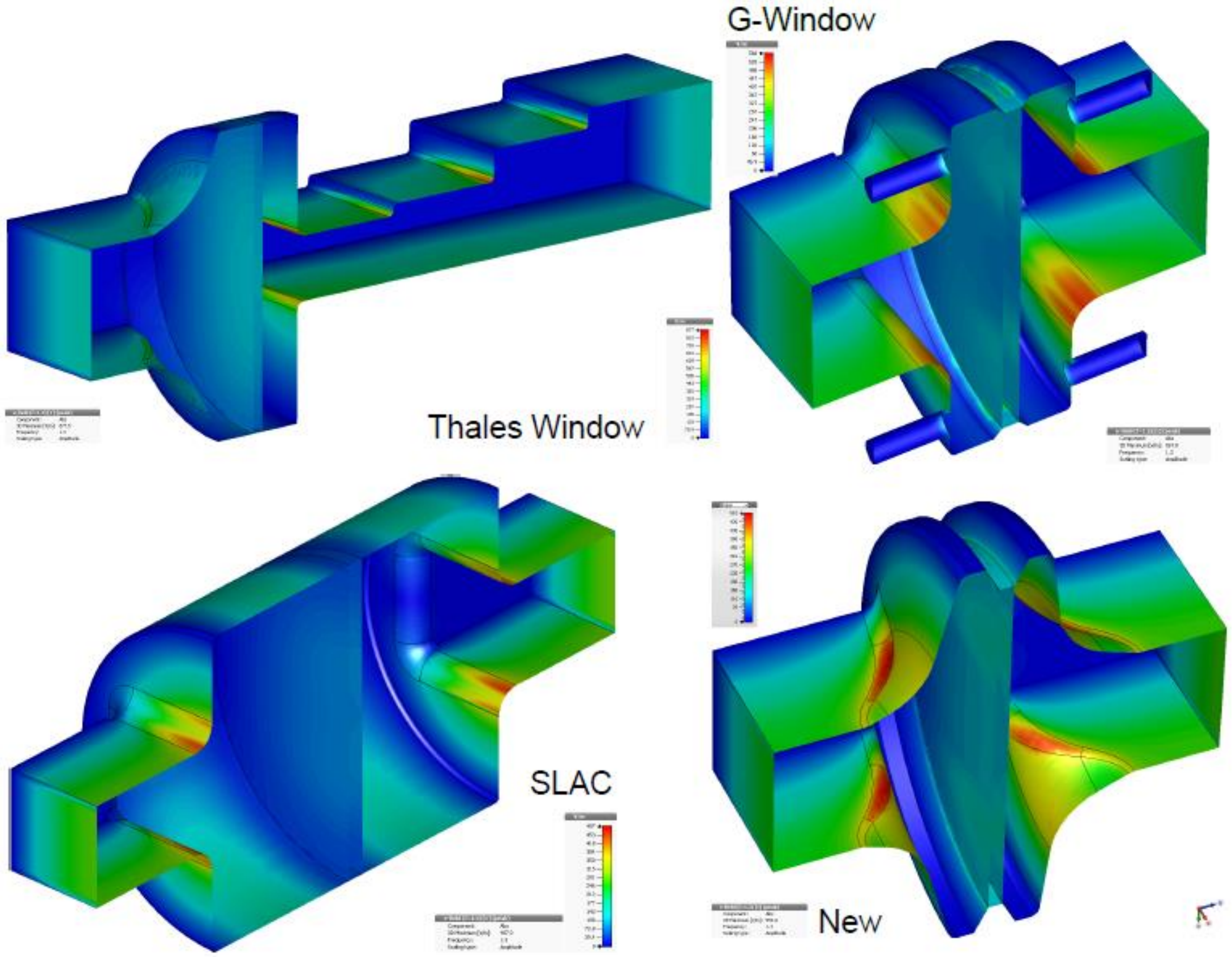
### RF Windows

some problems with the RF-Gun window - comparison

Compared electrical field amplitudes at 5MW

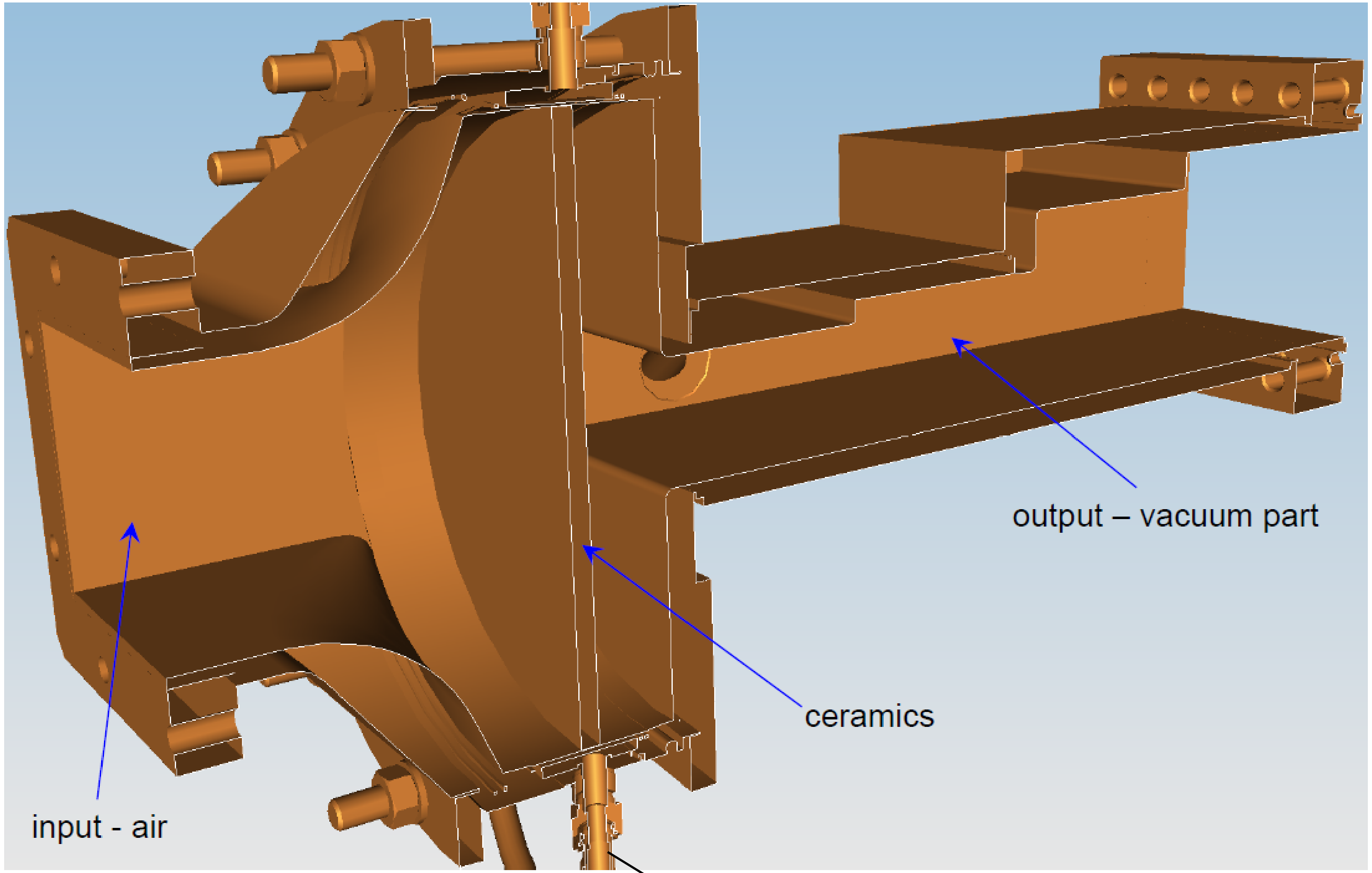



- Surface overvoltage must be addressed – Thales window has a problem with a half-height waveguide adapter;
- DESY G-window has a multipacting problem – geometry;
- New design should compromise surface overvoltage and a geometry less prone to the multipacting (RF discharge).



# THALES window design

## Modified from THALES klystron window, a step transformer on the vacuum side

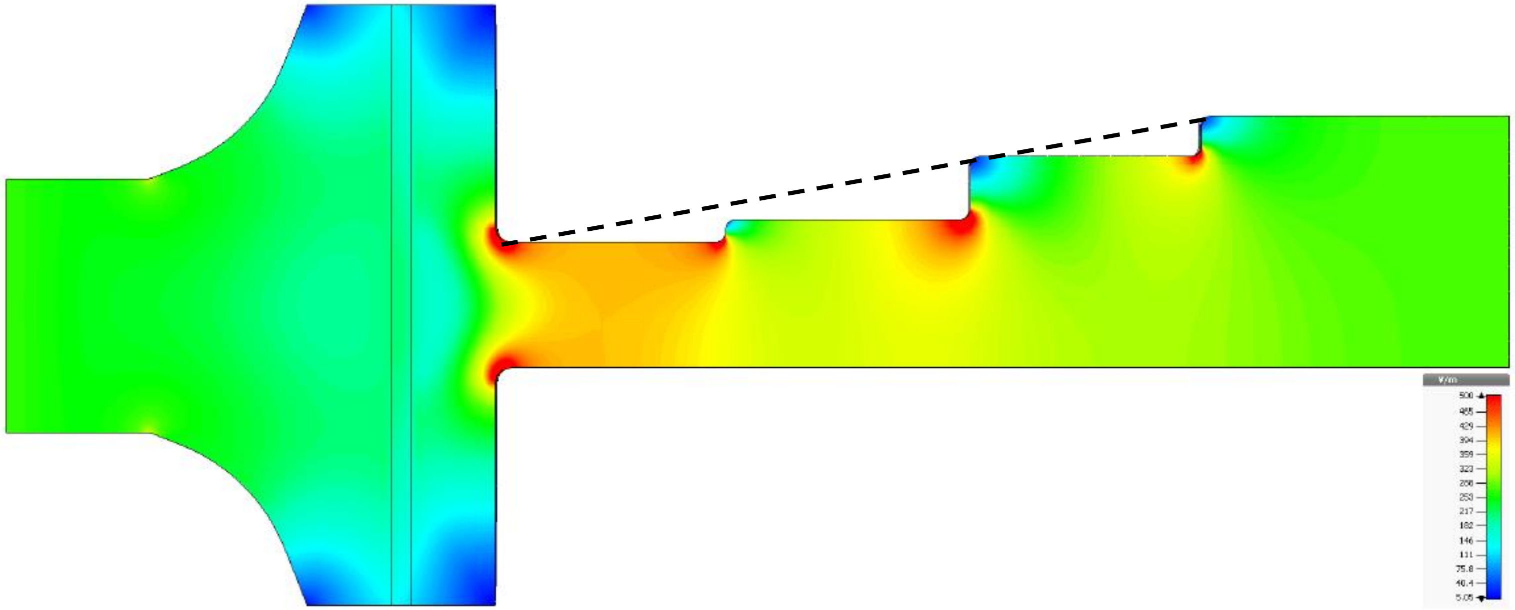


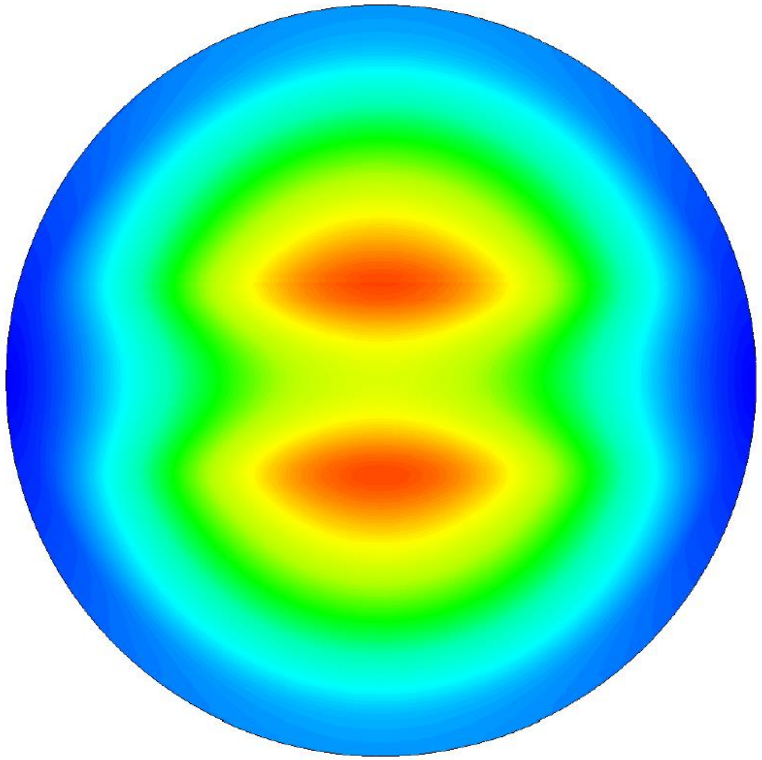

Water cooling

Water cooled RF window maximum outside surface temperature was 55°C (6 MW x 10 Hz)

# Max E field

Why not a smooth transition instead of step transition?



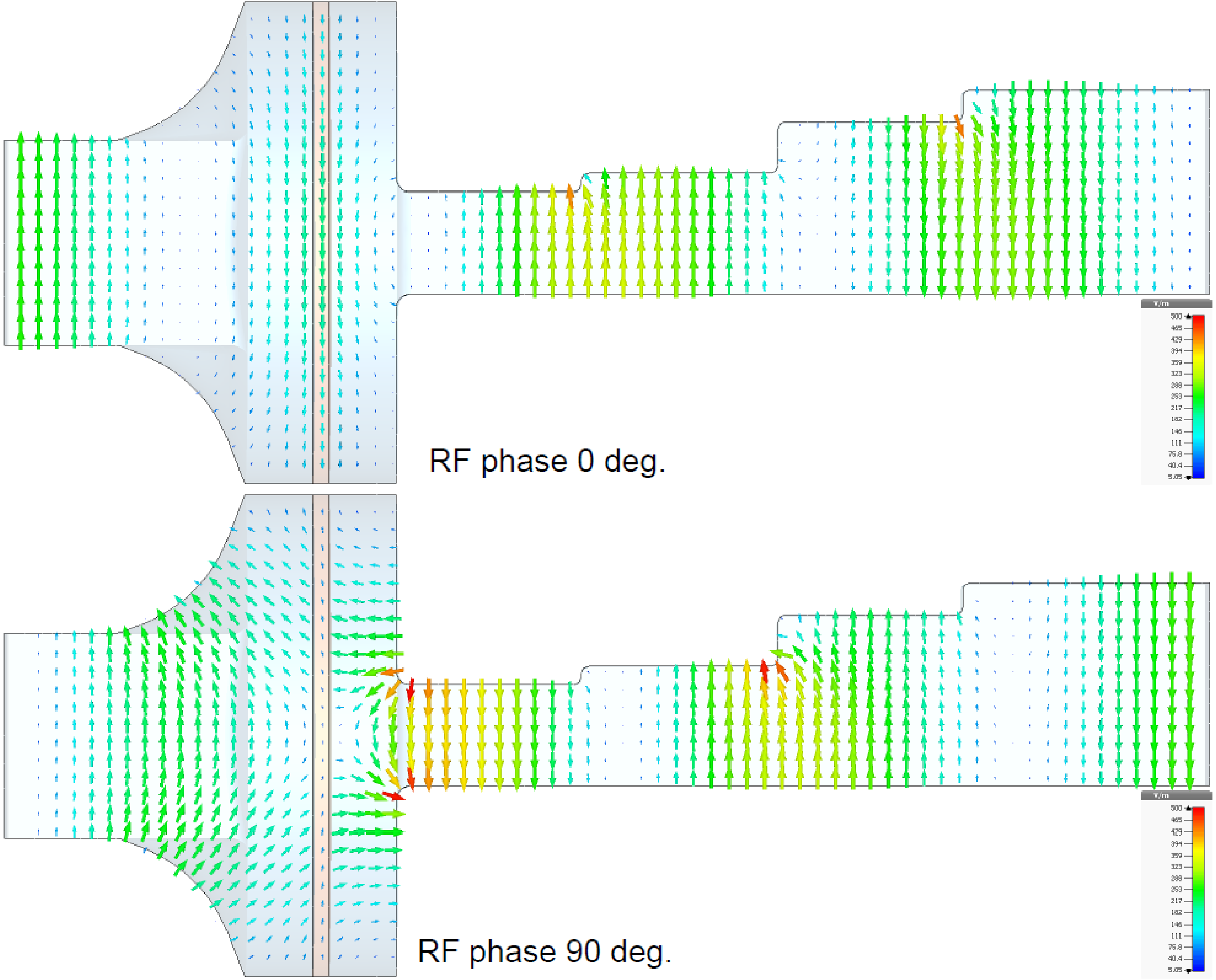
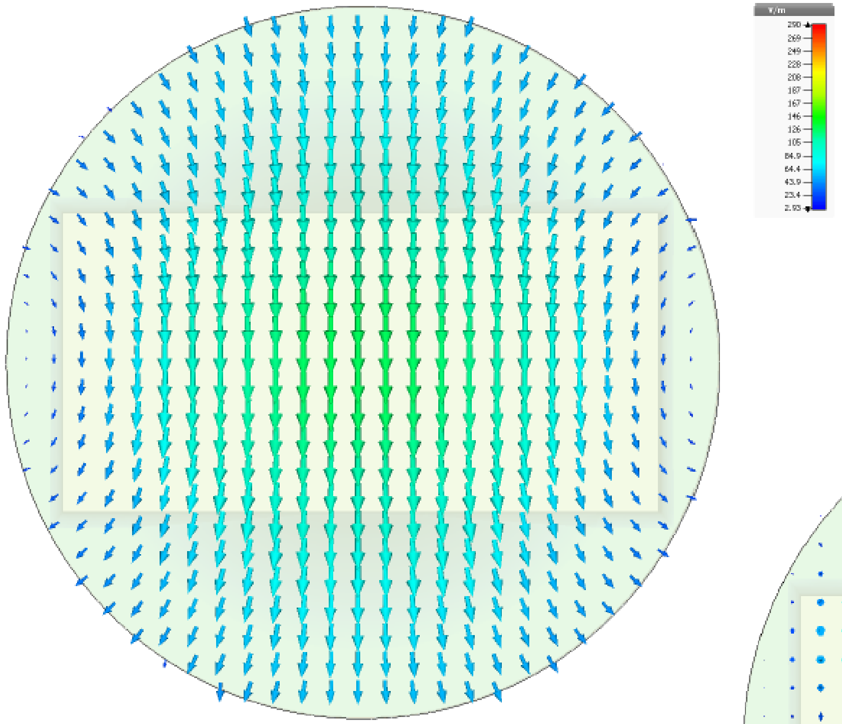
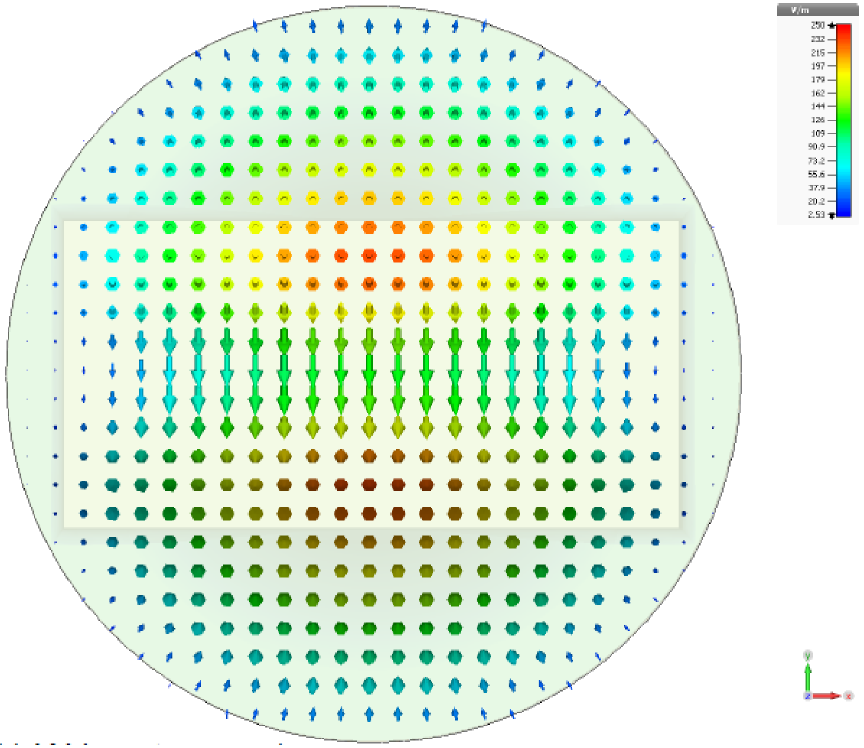


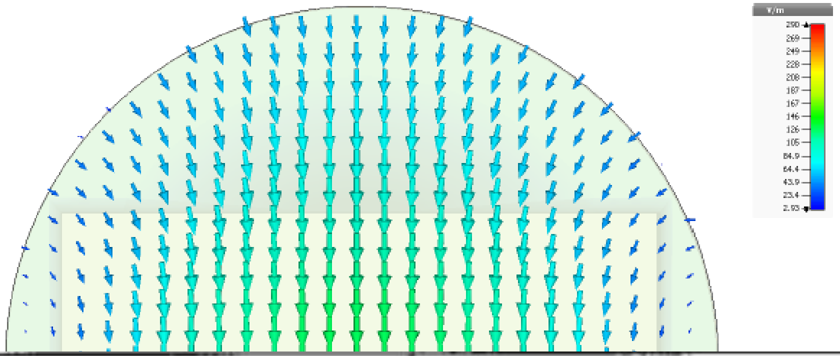

Figure 7: Electrical field (YZ) at 1.3 GHz (1 W input power).



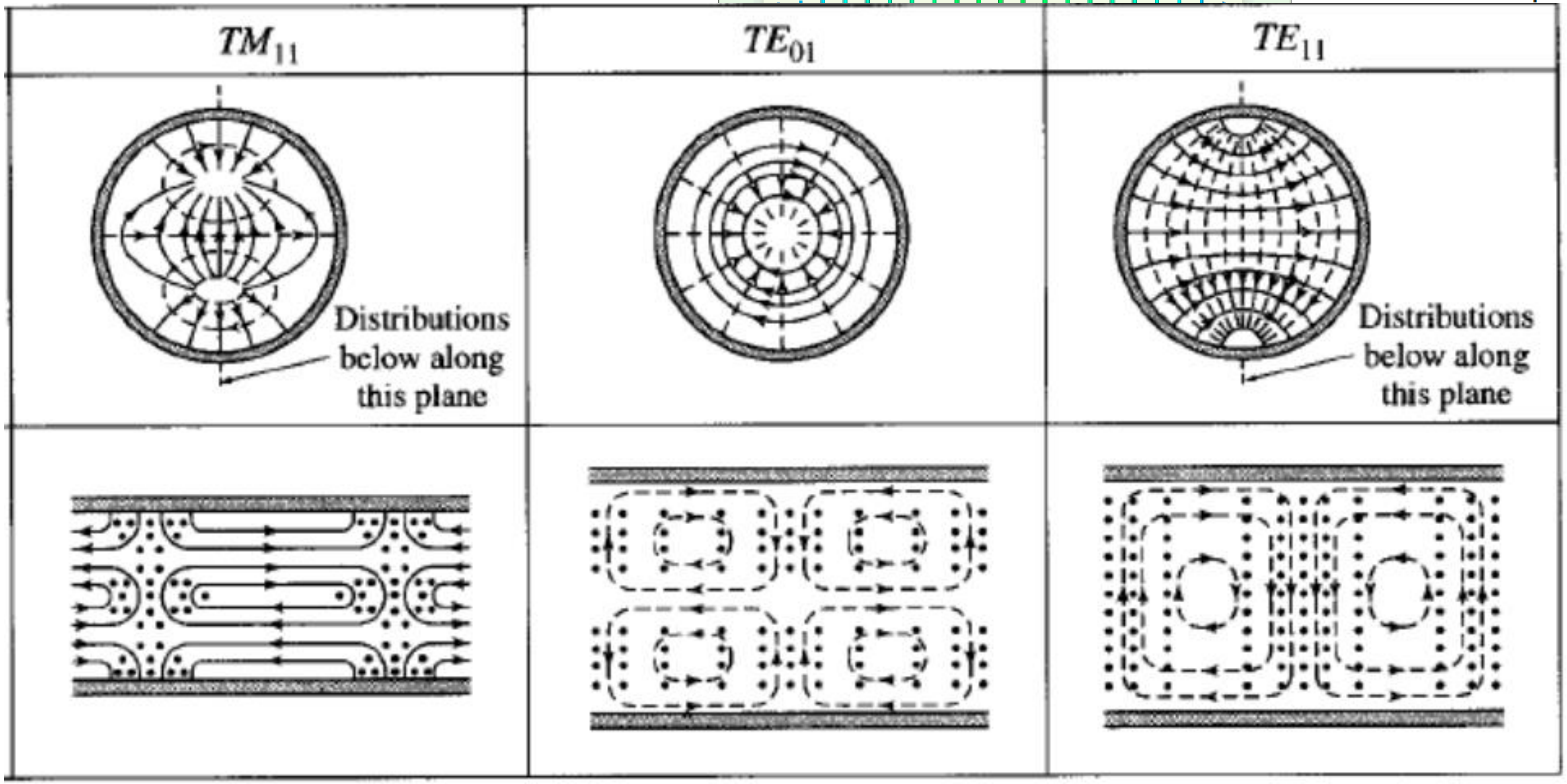
RF phase 0 deg.

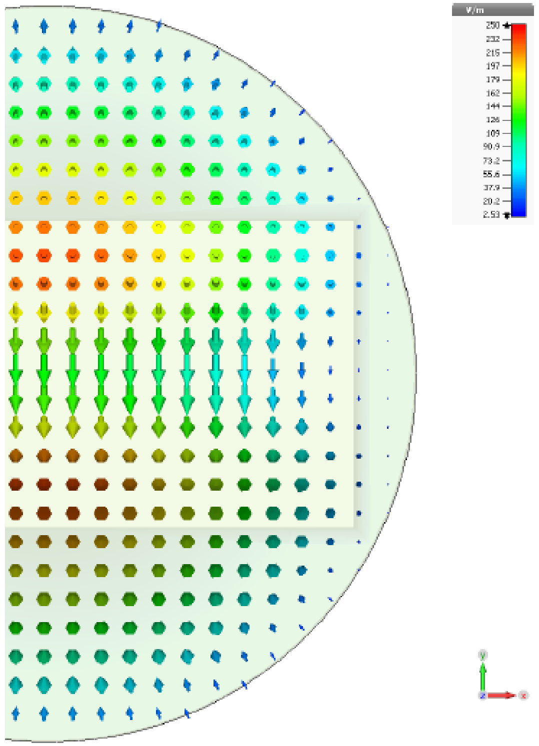
RF phase 90 deg.

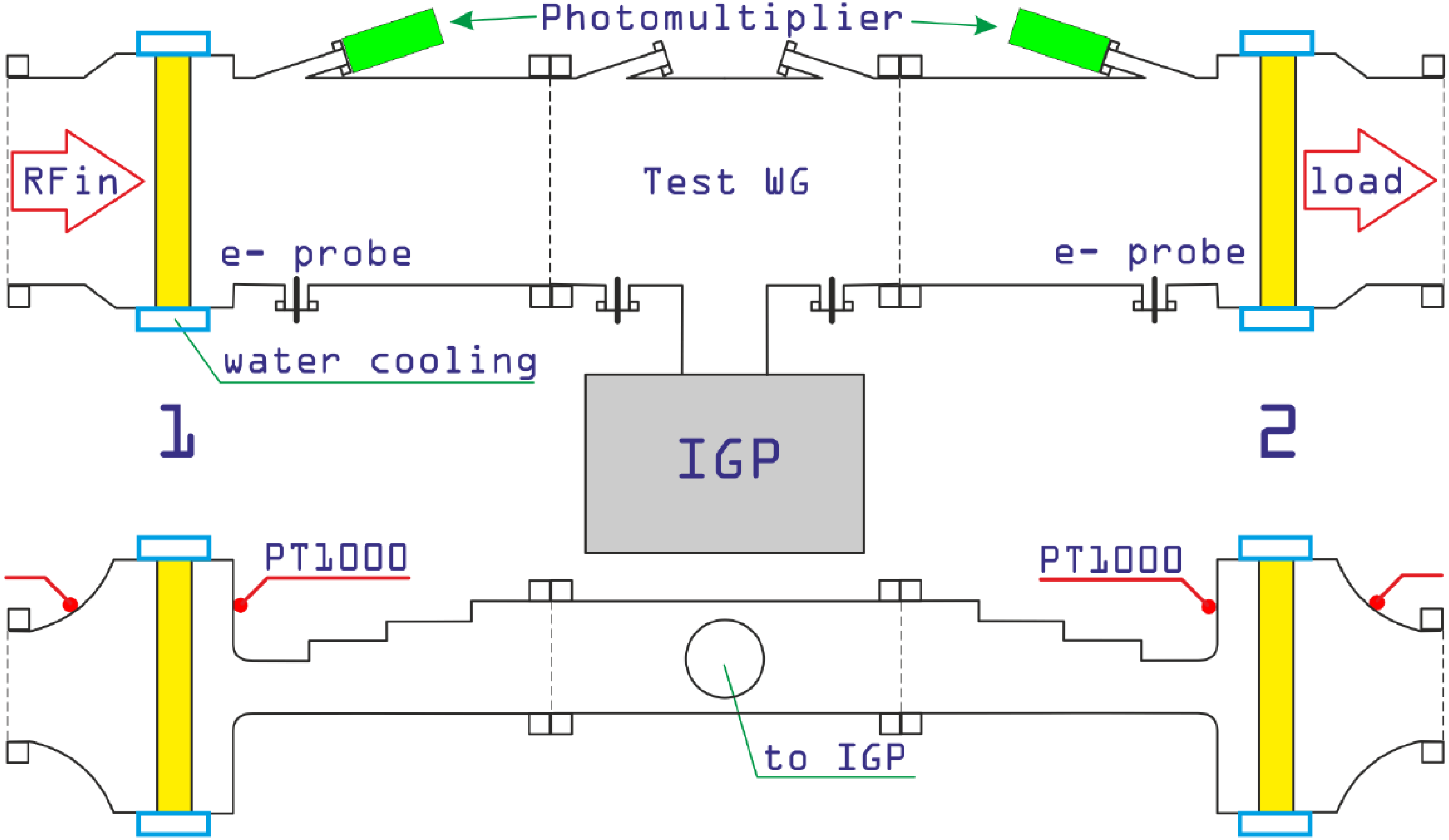




RF phase 90 deg.



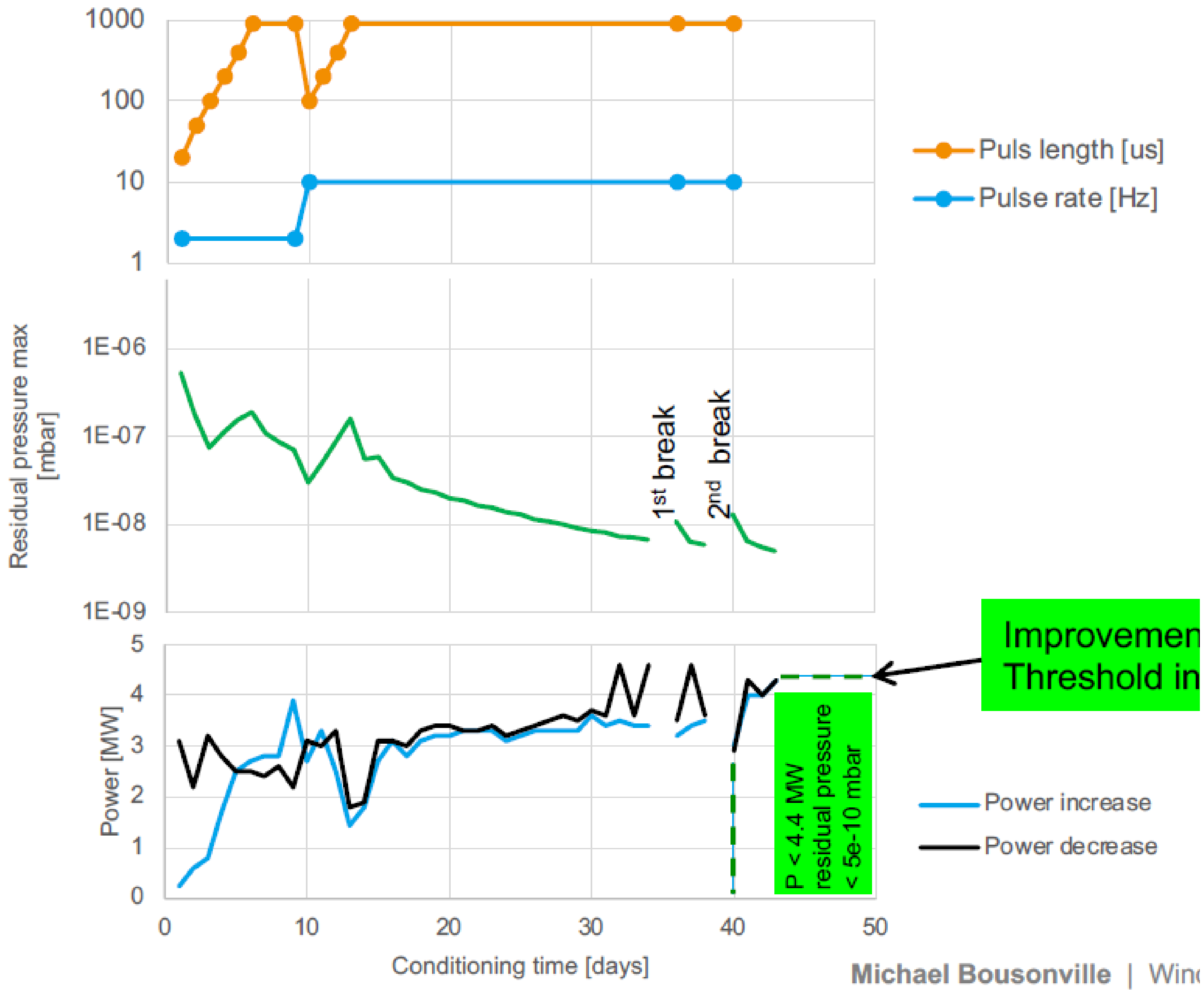




Photomultiplier
RFin
Test WG
load
e- probe
e- probe
water cooling
1
IGP
2
PT1000
PT1000
to IGP

RF conditioning of the vacuum RF-components, like an RF-gun, a cavity or a coupler, is a surface cleaning process using a low density plasma in RF fields. Electrical fields making the field emission possible and, hence, residual gases ionization, as well as secondary emission. Such a combined process, usually enhanced by the multipacting, changes the surface properties, in effect cleans the surface. Conditioning is only possible in vacuum system, the will be no conditioning effect in the air, just further burning and deterioration. Conditioning effect and progress is judged by indirect and direct plasma density measurements. Indirect means biased e- probes and photomultipliers, direct is a vacuum chamber pressure measurement. First said plasma density increases, the goal is on that stage to find the balance, not falling into avalanche-like event increasing the pressure exponentially, nor extinguishing the activity at all. After certain time activity drops down and conditioning can be judged as completed.

Normally the conditioning with RF power is done starting with a short RF pulses, like 10..20 µs and power is increased controlling the said plasma density (thus limiting the RF power rise) until maximum available (or planned) RF power value (like n * 1 MW) is reached and is kept for some hours. One of the most important limiting parameters is a vacuum pressure, normally the pressure is $10^{-9}$ .. $10^{-8}$ mbar before the start, then it reaches $10^{-7}$ .. $10^{-6}$ mbar during the conditioning and the goal for the conditioning is $10^{-8}$ .. $10^{-7}$ mbar. Then the pulse length is doubled and RF power is increased again from Pmin to Pmax. This is done until needed operating pulse length (like 1.3 ms) or CW mode (if this is the goal) is reached. At the end of the RF conditioning RF power sweep (going up/down between Pmin and Pmax) is done to check for the multipacting resonances, in case there are some.

# 6 weeks conditioning for our windows (S/N 21/20)




Michael Bousonville | Win

> Two breaks
- 1st break due to technical problems
- 2nd break full reflexion test or extra conditioning
- After 43 days the windows are clean above 4.4 MW (average forward RF power measurement of directional coupler at in and output)

## > Thales Window
- SN 6980-21 → Positive, below 4.3 MW
- SN 6980-20 → Positive, below 4.3 MW

## > Test Conditions
- Travelling wave max 6 MW / 10 Hz / 900 $\mu s$

  power ramped up and down from 2 to 6 MW
- With full reflection 6 MW / 10 Hz / 20 $\mu s$

  2 different reflection distances, power ramped up and down from 2 to 6 MW

## > Involved
- Denis Kostin (MHF-sl) – conditioning
- Ingo Sandvoss (MHF-p) – waveguides
- Carsten Müller (MHF-sl) – sensors
- Alexander Urban – organization transport

DESY.

# An example of THALES window conditioning

## ~500 hours of conditioning (~3 weeks)

THALES1/THALES2

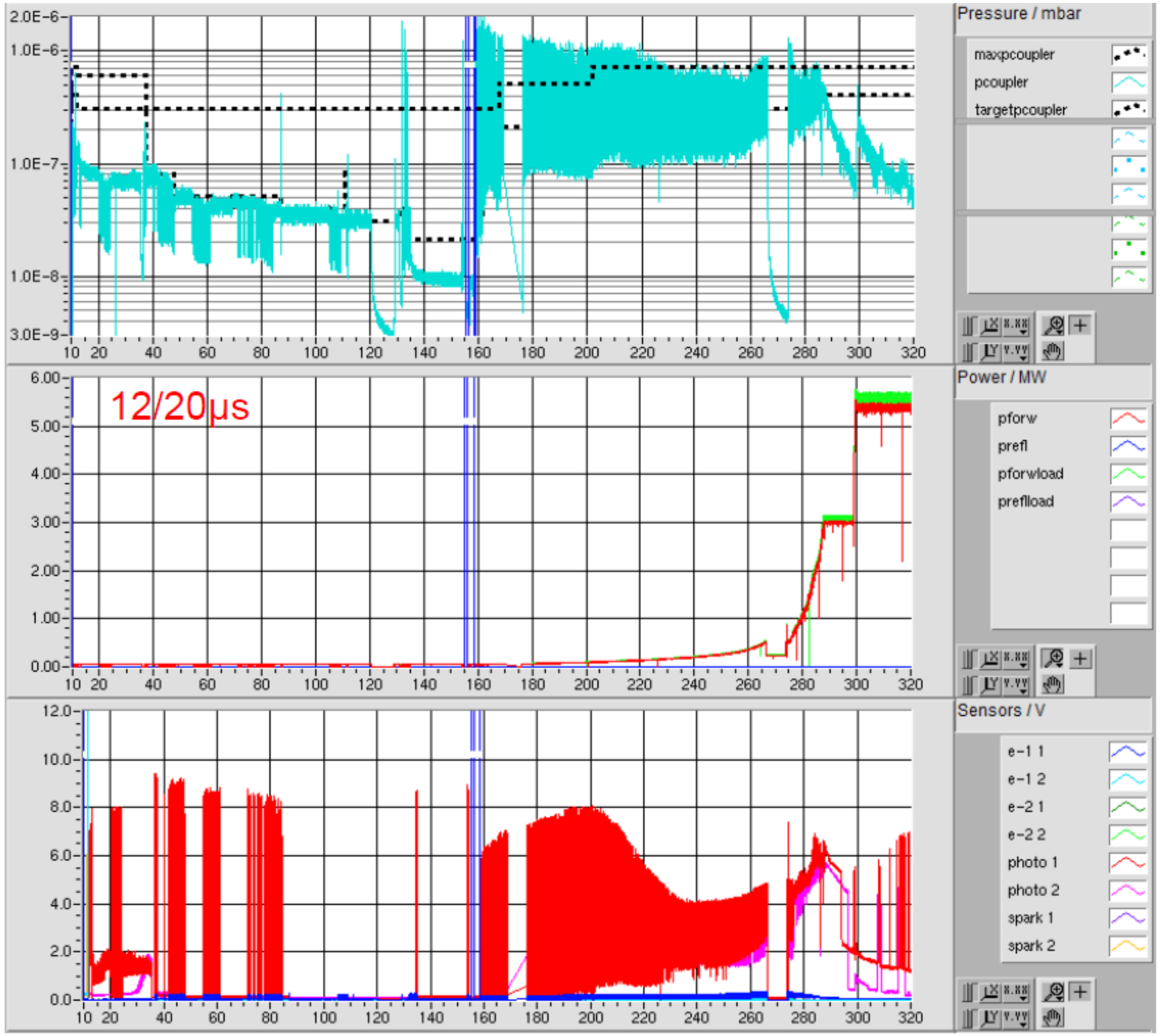
12/20 µs / 2 Hz

up to 5.5 MW
time: 320 hr

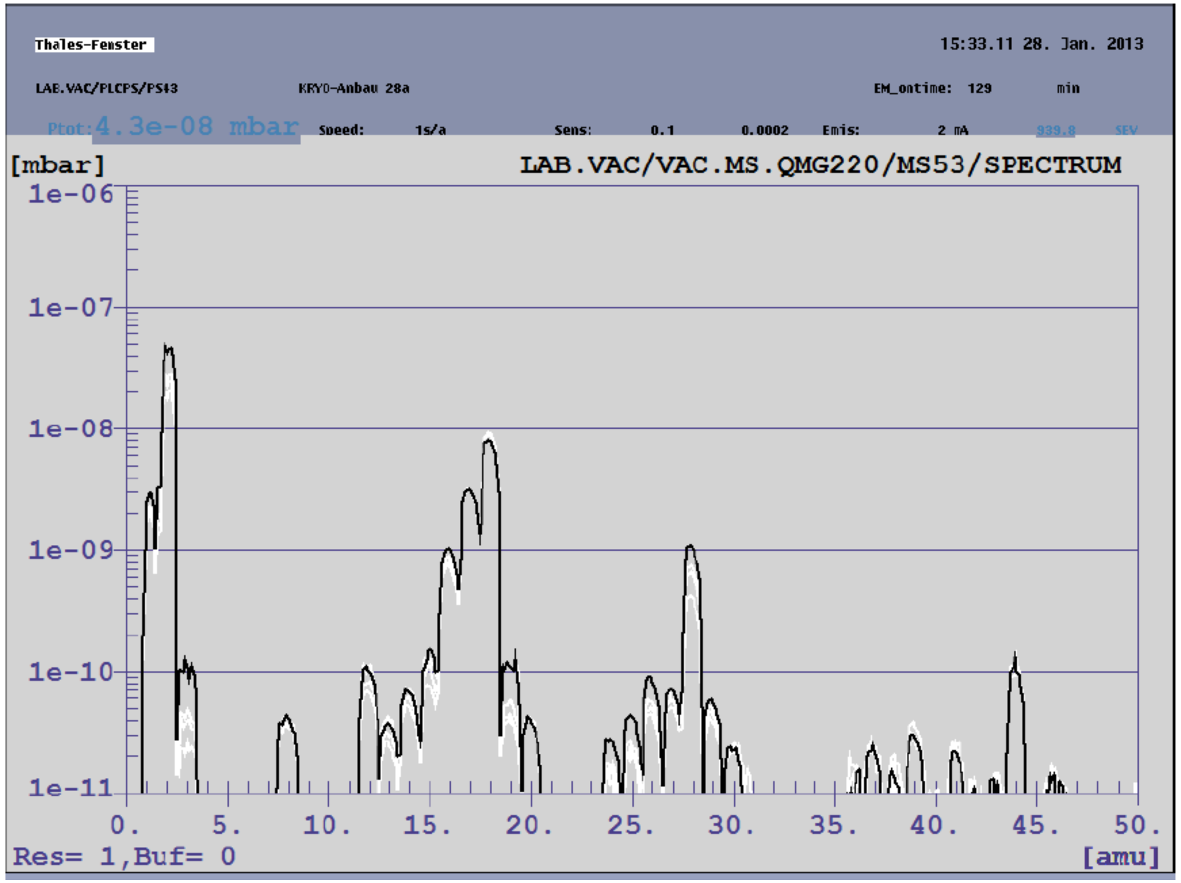
50..900 µs / 5.5 MW
took +100 hr.

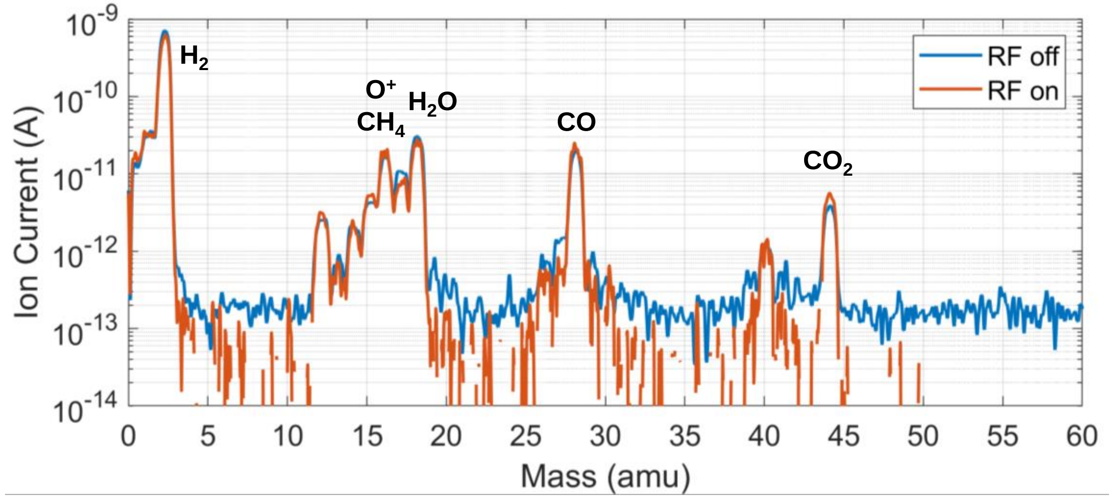
limited by
- vacuum
- PM (light)

in the test
up to 8MW
THALES1 did
have a discharge
problem.



# RGA


Thales-Fenster
15:33.11 28. Jan. 2013
LAB.VAC/PLCPS/PS43
KRYO-Anbau 28a
EM_ontime: 129 min
Ptot:4.3e-08 mbar
Speed: 1s/a
Sens: 0.1
0.0002
Emis: 2 mA
939.8
SEV
[mbar]
LAB.VAC/VAC.MS.QMG220/MS53/SPECTRUM
1e-06
1e-07
1e-08
1e-09
1e-10
1e-11
0. 5. 10. 15. 20. 25. 30. 35. 40. 45. 50.
Res= 1,Buf= 0
[amu]


$10^{-9}$
$10^{-10}$
$10^{-11}$
$10^{-12}$
$10^{-13}$
$10^{-14}$
Ion Current (A)
0 5 10 15 20 25 30 35 40 45 50 55 60
Mass (amu)
$H_2$
$O^+$
$CH_4$
$H_2O$
CO
$CO_2$
RF off
RF on

# Thales RF windows TH 20698C

| DESY # | S/N | MHF-sl Name | status | date | comment |
|---|---|---|---|---|---|
| **1** | 698-014 | **THALES1** | NOT OK | 16.05.2014 | Tested 2 times, both times broken: burned on air side with burn marks around ceramics (was cleaned after first test). Test 1 on input, test 2 output (load). Window was repaired by Thales, is in test. |
| **2** | 698-010 | **THALES2** | OK | 24.07.2013 | Tested 3 times, 2 times with THALES1 and 1 time with THALES5. No problems from this window. |
| **3** | 698-013 | **THALES5** | NOT OK | 16.05.2014 | Was previously installed at PITZ. In the test was on output (load), have a lot of light signal, was also at PITZ like this. Light is not conditionable. Window was repaired by Thales, is in test. |
| **4** | 698-012 | **THALES3** | ? | 07.02.2013 | Very long conditioning time (475hr). Conditioned together with THALES4. Periodic vacuum pressure jump effect was observed after conditioning with RF on. Not clear whether MP is only on other window. |
| **5** | 698-011 | **THALES4** | ? (MP) | 07.02.2013 | Very long conditioning time (475hr). Window shows multipacting effects, mostly pronounced near to 1.5 and 2.9 MW. Periodic vacuum pressure jump effect was observed after conditioning with RF on. |



RF Test procedure: 20, 50, 100, 200, 400 and 900µs pulse at 2/10Hz up to 6.5MW

# Multipacting

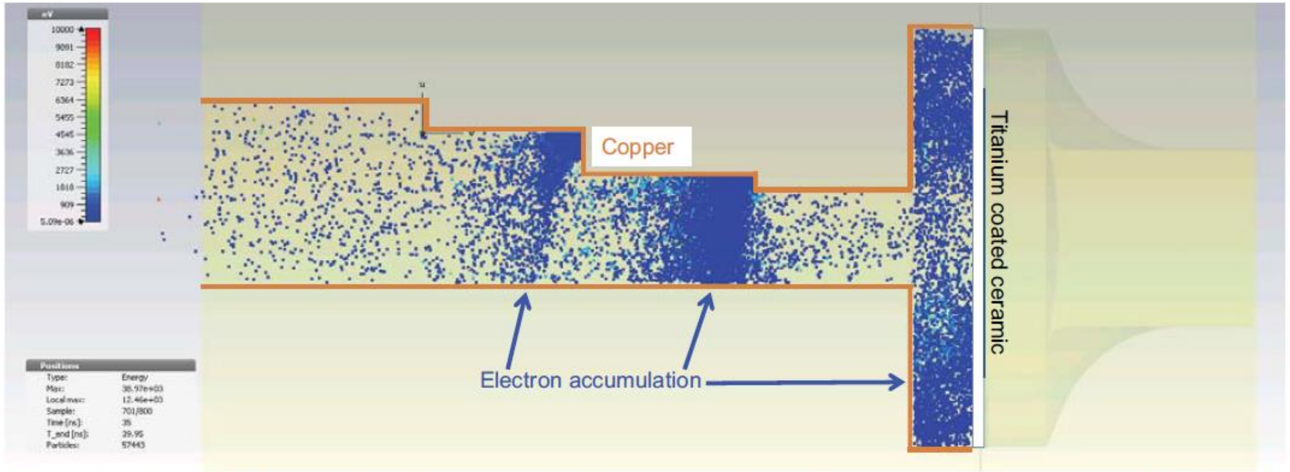
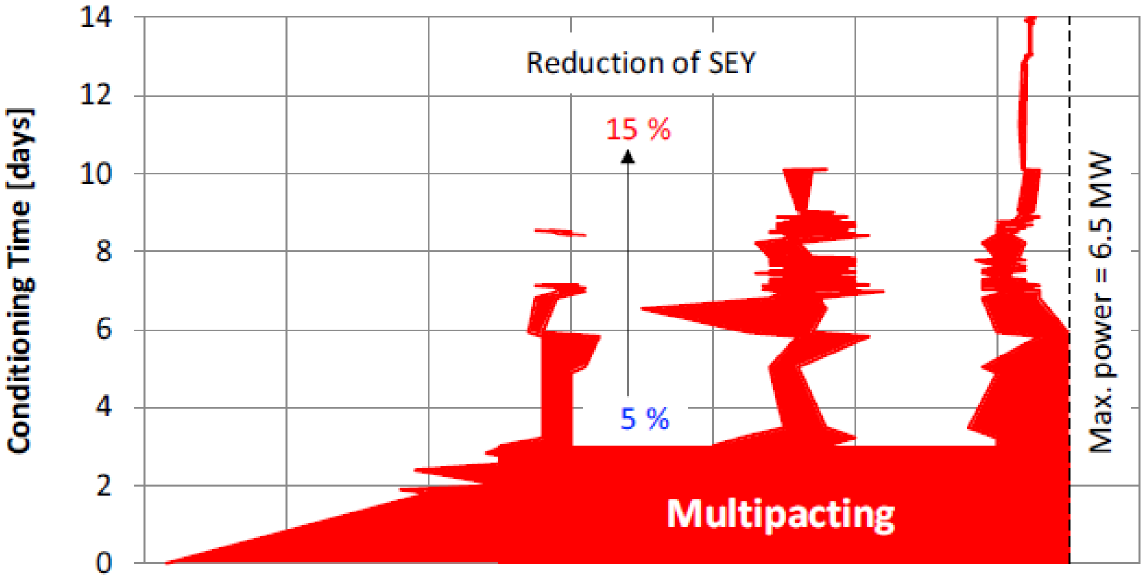
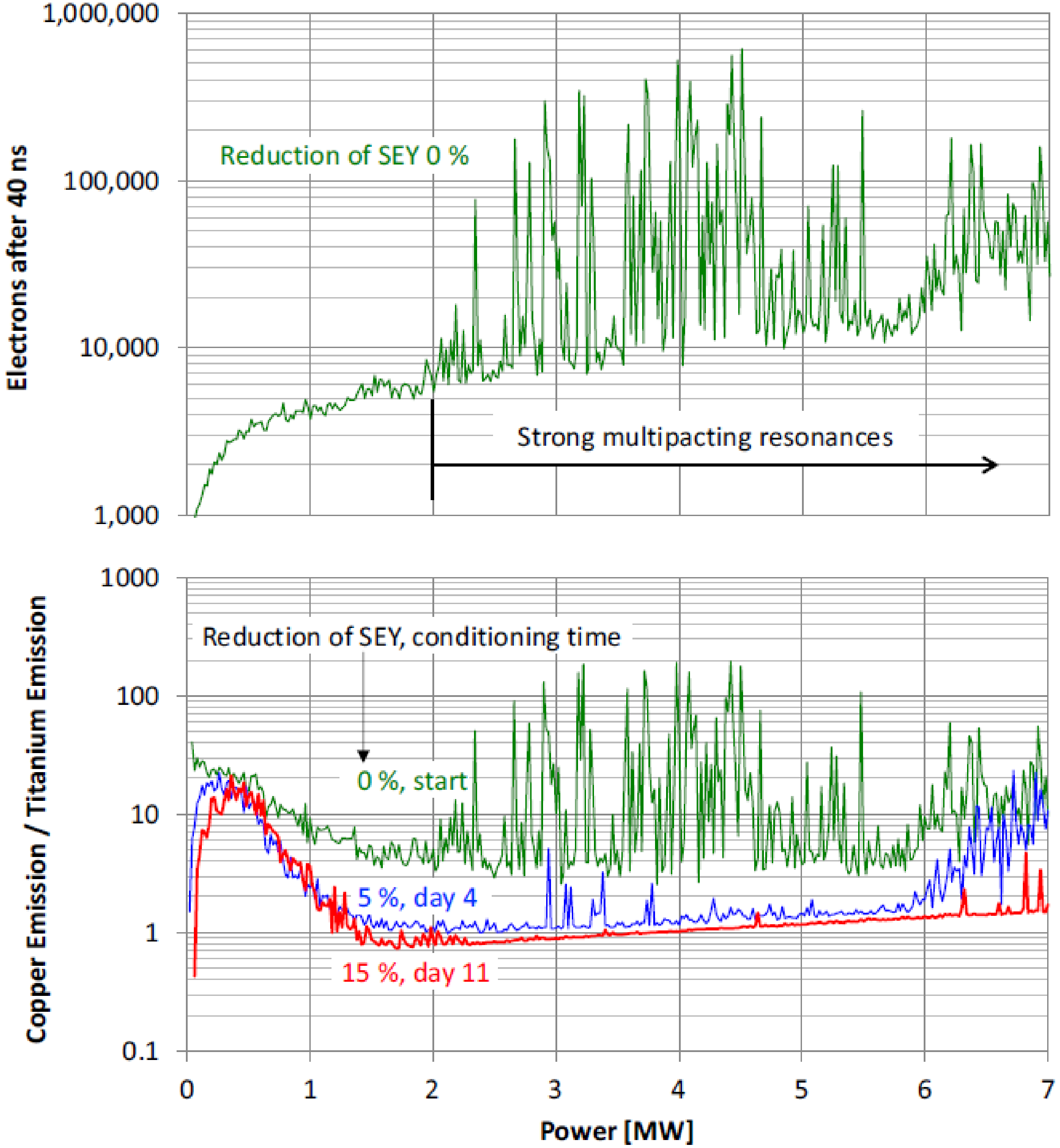



**Figure 7.** Typical electron distribution at the beginning of conditioning here at a power of 6.36 MW after 35 ns.

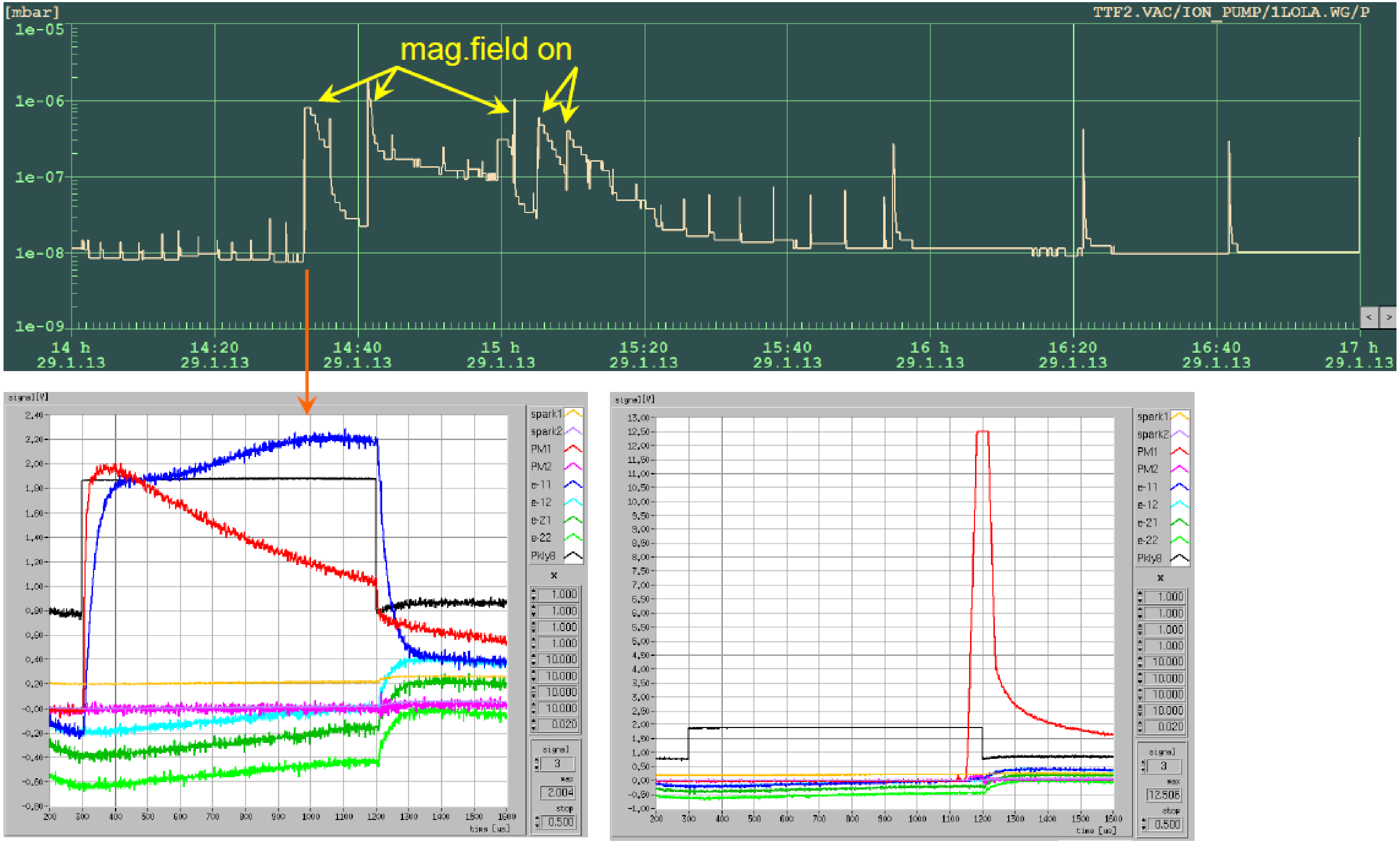



b)



## RF Window at 6 MW / 10 Hz: Magnetic field effect (THALES3/THALES4)

applying DC magnetic field on the window vac.side → strong effect / vacuum pressure jumps.



- > 1) Why do the THALES window use a step transition to normal WR650 waveguide? A smooth transition, i.e. a straight slope, can avoid the field enhancement and multipacting near the steps. A connecting question: can we use the step transformer side for the gas side, and the other side for vacuum connection to the gun?

  This was Thales design, I do not know why they did it.
  We asked for a window, they took a standard Thales klystron RF-window with 1/2 WG height and adapted it in this way, with a step-transformer. I'd also do it differently. But probably they did it like this because it was most simple solution for Thales - or already existing solution.

  We can not modify this window. This is a Thales design under contract and warranty, the RF-window like it is. We can not add any flanges or vacuum connections to it. This could be done on the design stage and introduced into manufacturing process in proper time/step, but Thales will not do it now.

- 2) Another Multipacting is between the ceramics and the copper, can the distance between the two be adjusted to avoid the multipacting? For example, the SLAC window has a long distance between the ceramics and the copper surface. Do you know the power capability of the SLAC window?

  Yes, this is usual. There are many ways to optimize the RF-window design, I also did mine.
  SLAC widow is too resonant to be usefull and too big. In my opinion. I'm not sure about power capability.

- 3) Since the PM detector are looking towards the ceramics, does it mean the light are from the multipacting between ceramics and copper, not from the multipacting from the steps of the transformer?

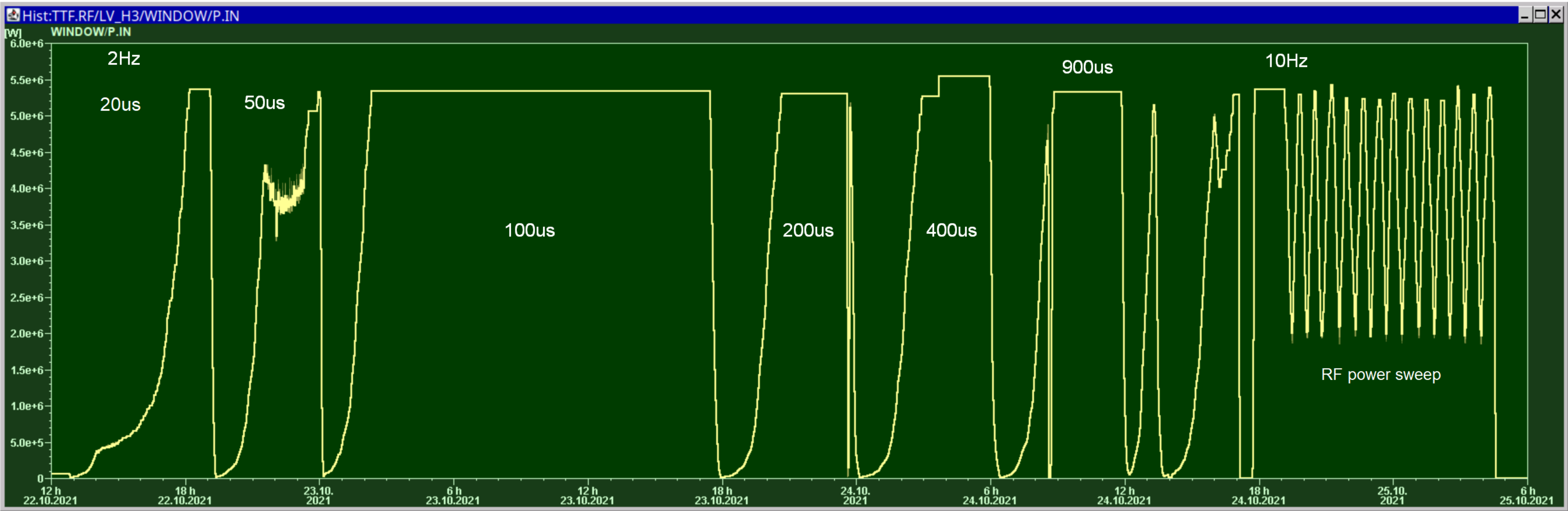
  Mostly yes, but light is reflected from different surfaces, so it also comes from the transformer.

- 4) For those windows with ~500 hours' conditioning, it takes roughly 280 hours to condition up to 1 MW (e.g. THLES1/THALES2), after that, the conditioning is much faster towards 6 MW, why? Is it because in the low power region, multipacting is dominated by the step regions?

  Initial conditioning, with 20us/2Hz pulse up to 1MW takes usually most of the time.
  Outgassing (mostly humidity) takes place, some desorption processes on surfaces.
  MP is only (small) part in it, later MP is most what You see thou.

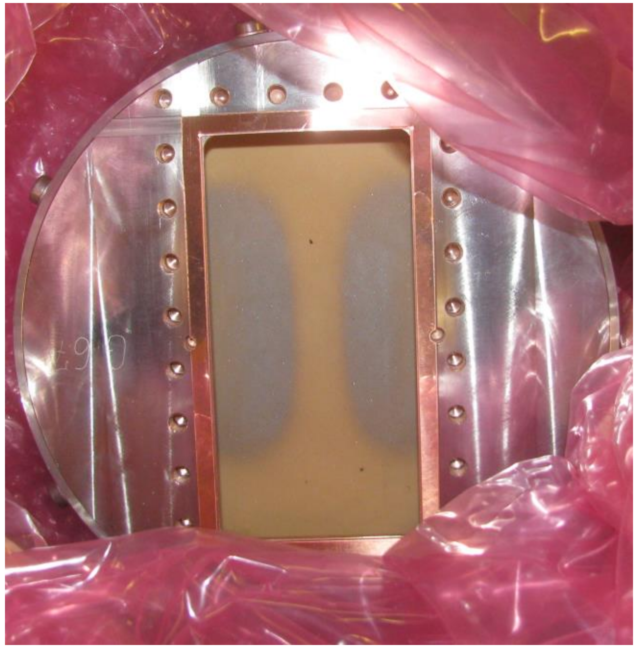
- 5) Last time, you mentioned some windows are much cleaner, and takes a couple of days only to condition to 6 MW? I didn't see those examples in the files you sent me. For the new THALES windows sent to PITZ for gun5.1, S/N 21/22, they even took ~40 days to condition. Does it mean SN 21/21 pair are not as clean as other windows when they arrive from the vendor?

  Yes, RF-windows are different. For some of them it takes 2..3 days to condition, like in the attached example.
  Last test took me ~60hr - up to 900us/10Hz/6MW. I even let it run longer at 100us/2Hz, as a precaution.
  It was really fast this time. Some windows are not as clean, but with RF conditioning finished succsessfully it doesn't matter - short or long - the result is conditioned RF-window.



- 6) You mentioned about magnetron like cross fields near the ceramics to form electron cloud near the ceramics. I looked at your simulations of E field near the ceramics. There are two types of E field pattern for 0 phase and 90 degree phase. Zero phase pattern is more like TE11 mode, 90 degree phase pattern is more like TM11 mode. With the diameter of the window, looks like cut off freq for TE11 and TM11 is 0.9 GHz and 1.8 GHz. So TE11 should be the dominating mode for 1.3 GHz?

  I attached hier a picture with damaged G-window from FLASH at DESY.
  In my opinion this deterioration was mostly caused by plasma clouds near ceramics.
  Overheating could also be it, with near fields also, but we did not see a very high temperatures.
  G-Window is symmetric, so that crossed EM-fields of a resonator (magnetron effect) should be the case.
  I did some EM-simulations which shows that field configuration with a dipole mode near ceramics.



- 7) Another question is about magnetic field to disturb multipacting, you showed one slide with such experiment, which induced a big vacuum event and large e-detector signal, but reduced PM-detector signal.

  Is it good for window conditioning, or is it more useful during the operation (like European XFEL gun)?

  When you apply B field near the window, what's the direction? Is it parallel to the ceramic surface?

- I think the field direction isn't important, any strong magnetic field would
  disrupt the MP effect changing the electron trajectories. We applied a (piece of) strong permanent magnet.
  We did this in test, and also with Injector RF-Window. Sometimes it helps.
  But we did not observe or measure the B-field vector.