- News from HL-LHC organization and deadlines => https://espace.cern.ch/HiLumi/WP2/task4/SiteAssets/SitePages/Home/ImpedanceStudiesPlan_HL-LHC_v2.docx

- Highlights from the mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures", Diamond Light Source, 30/01/2013 => http://www.diamond.ac.uk/Home/Events/Past_events/Simulation-of-Power-Dissipation---Heating-from-Wake-Losses.html

GOAL: Have an initial estimate of the HL-LHC machine impedance for 01/11/2013.

Item	Coordination	Computations
Collimators (many, with several types): TCP, TCS, TCDQ, TCSG, TCT, DS collimators, TCL	Nicolas Mounet [1]	Resistive-wall => Nicolas Mounet
		Geometric (broad-band + trapped modes) => Mikhail Zobov (INFN) + Andrea Mostacci (La Sapienza) [2]
TDI	Alexej Grudiev	Resistive-wall => Nicolas Mounet
		Geometric (broad-band + trapped modes) => Alexej Grudiev
MKI	Benoit Salvant	Benoit Salvant, Uwe Niedermayer (TUD) [3] and possible fellow with Mike Barnes
Experimental beam pipes (ATLAS, CMS, LHCb, ALICE)	Benoit Salvant	CMS and ATLAS => Rainer Wanzenberg and Olga Zagorodnova
		LHCb and ALICE => Benoit Salvant
Crab cavities	Nicolas Mounet	Crab cavities designers (see with Rama Calaga)
Arc beam screens vs. ATS optics and new beam screens	Nicolas Mounet	Resistive-wall => Nicolas Mounet
		Other studies (holes, longitudinal weld etc.) => Andrea Mostacci (La Sapienza) + Carlo Zannini's past studies
RF fingers	Elias Metral	Elias Metral => Summary of the 2012 LHC RF Fingers (LRFF) Task Force
Instrumentation (BSRT, etc.)	Federico Roncarolo?	Federico Roncarolo and Andriy Nosych?
800 MHz	Elena Shaposhnikova [4] and Mikhail Zobov (INFN)	Elena Shaposhnikova and Mikhail Zobov (INFN)
Others: Beam-beam compensation (BBC) wires [5], Electron lenses [6], Crystal collimators [7]	Benoit Salvant	

HL-LHC

[1] As responsible for the LHC and HL-LHC impedances, Nicolas Mounet will also collect all the impedances & wake fields of all the equipments to compute the total impedances and wake fields of the HL-LHC.

[2] Uwe Niedermayer (TUD) will come at CERN for 1 month, from 07/04/13 to 05/05/13.

[3] Andrea Mostacci (La Sapienza) will come at CERN for 1 month, from 10/06/13 to 05/07/13.

[4] The complete design of the 800 MHz RF system should include all parameters of HOMs and achievable damping. At the moment we have only some preliminary reference designs. The final design of one resonator as well as their number strongly depend on the purpose of it => Elena Shaposhnikova started to organize reviews/discussions on the potential uses of a higher harmonic RF system in different HL-LHC scenarios (1st meeting took place on 01/02/13: https://indico.cern.ch/conferenceDisplay.py?confId=231528). This should help to finalize the parameters of the system.

[5] The design hasn't been finalized yet but to first order what concerns RF, the BBC will be identical to the new TCT with the embedded BPM buttons and long TCL (info from Ralph Steinhagen) => Once the design is finalized, it should be nevertheless carefully simulated.

[6] Might be studied by the electron lenses designers.

[7] A student should join next year (applying to the TSC committee in Spring).

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (1/14)

Programme

9.00-9.45	**T. Guenzel** *Heatload distribution in the ALBA stripline kicker on the basis of eigen mode simulations*
9.45-10.30	**R. Nagaoka** *Some experiences at SOLEIL regarding the beam-induced heating of the vacuum components*
10.30-11.00	**Coffee break**
11.00-11.45	**D. Lipka** *Heating of a DCCT and a FCT due to wake losses in PETRAIII, simulations and solutions*
11.45-12.30	**A. Morgan** *Analysis of time domain wake potential and port signals for calculation of radiated and dissipated power due to wake losses*
12.30-13.30	**Lunch**
13.30-14.15	**A. Novokhatski** *Analysis of wake field effects in the PEP-II SLAC B-factory*
14.15-15.00	**E. Metral & F. Caspers** *Beam induced RF heating in the LHC*
15.00-15.30	**Coffee break**
15.30-16.15	**S. Casalbuoni** *Beam heat load due to geometrical and resistive wall impedance in COLDDIAG*
16.15-17.00	**A. Blednykh** *Wake loss simulations at NSLS-II*

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (2/14)

- **Several machines discussed**
  - ALBA (Barcelona) synchrotron light source => 3 GeV, top-up injection, 268 m circumference, 4.6 nm rad (4.3 design), maximum design current = 400 mA, 4.6 mm rms bunch length, 448 bunches, bunch rep freq = 2 ns
  - SOLEIL (Paris) synchrotron light source => 2.5 GeV, 355 m, single- and multi-bunch operation, 440 mA, 416 bunches and same bunch length as before, i.e. ~ 20 ps. Low alpha operation to have very short bunches

Beam-induced heating of the machine may well impose more stringent requirements on the vacuum chamber structures than those for beam instabilities

Ryutaro Nagaoka

The fast beam-ion instability encountered at 500 mA at SOLEIL is considered to originate in the beam-induced vacuum components heating

  - Petra III (DESY, Hamburg) => 6 GeV, 2304 m, 1 nm rad, 100 (200) mA, 40/960 bunches, supplement to X-FEL
  - PEP II SLAC B-factory => 1700 bunches of 3.0 A of 3 GeV positrons on 1.75 A of 9 GeV electrons (closed in 2008)
  - LHC

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (3/14)

- **DLS (Diamond Light Source, RAL)** => 3 GeV, 561.6 m, h = 936, 300 mA design (upgrade foreseen to 500 mA), 2.74 nm rad in H and 0.0274 nm rad in V, bunch length similar to the other light sources. Aim of COLDDIAG = COLD vacuum chamber for DIAGnostics is to measure the beam heat load on a cold bore simulating the liner of superconducting IDs with different operating conditions, etc.
- **NSLS II (National Synchrotron Light Source, BNL)** => 3 GeV, 791.5 m, 7.8E9 p/b, 1.25 nC, 0.5 mA single bunch current, 1080 bunches, average current = 500 mA, 15 ps rms.

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (4/14)

- **Several simulation codes used**
  - GdFidL (1st 2 talks and 8th one)
  - CST (3rd, 4th, 6th, 7th , 8th talks) => Thermal studies also (input power and field distribution to get temperature distribution)
  - MAFIA, NOVO and Omega3P (5th talk)
  - ECHO (8th talk)
  - Temperature distribution => ANSYS
- **Review of some basic computations**
  - Power loss (incoherent and coherent)
  - Quality factor and loss factor for the different parts of a device
  - Loss factor for an off-resonance line
  - Loss factor for single-bunch and multi-bunch operations

• Q_{ext} = [energy· ω]/[Powerflow in T-domain] is not precise enough.

When the Q_{ext} s were computed (2009), eigen mode computation with absorbing boundary conditions was still not implemented in GdfidL.

Thomas Gunzel

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (5/14)

- **Design of HOM absorbers for PEP II**
  - Ceramic tiles: AlN-SiC Ceralloy 13740Y
  - SashaN proposed to give some of them to CERN if we want to use them => I told him that it would be indeed quite interesting => To be followed up
- **Some discussions / questions raised**
  - It seems we can either // the code (e.g. GdFidL) or we can treat the lossy materials => Why? It seems the only code which can do both is the US one called T3P / Omega3P

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (6/14)

Simulation of Eigenmodes to get loss distribution

Optional: thermal simulation to get temperature (thermal boundary condition)

When power >~10 W (my private suggestion):

– Change geometry or
– Add cooling: P between 10 and 100 W air cooling, above water cooling

Dirk Lipka

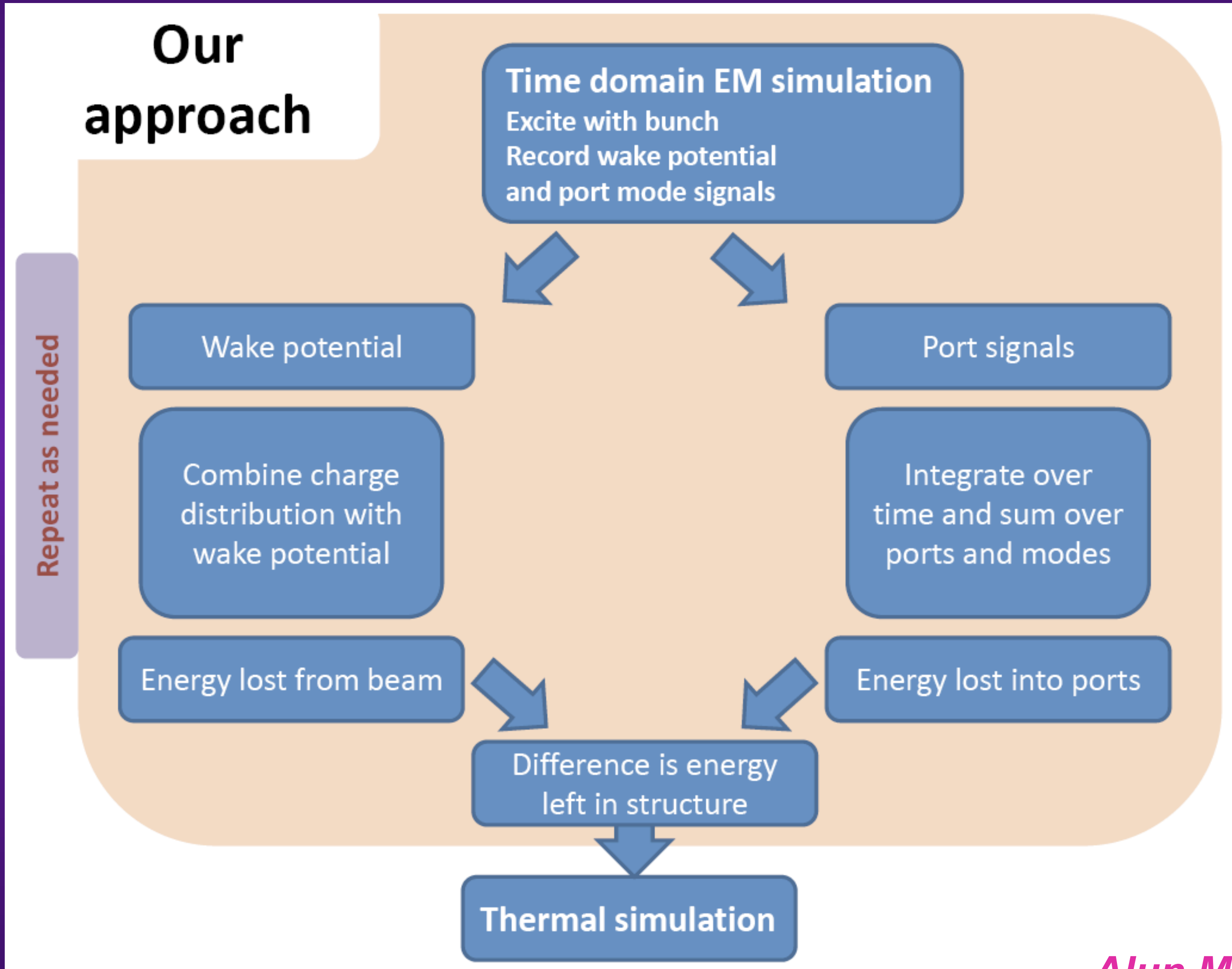
Why are we worried?

- Diagnostics systems are *designed* to couple to the beam.
- Wake loss factor is large enough to give uncomfortably large amounts of energy being lost from the beam.
- We plan to go to higher currents and shorter bunches.

- Current settings imply 189W lost in striplines
- Planned settings imply 313W lost in striplines

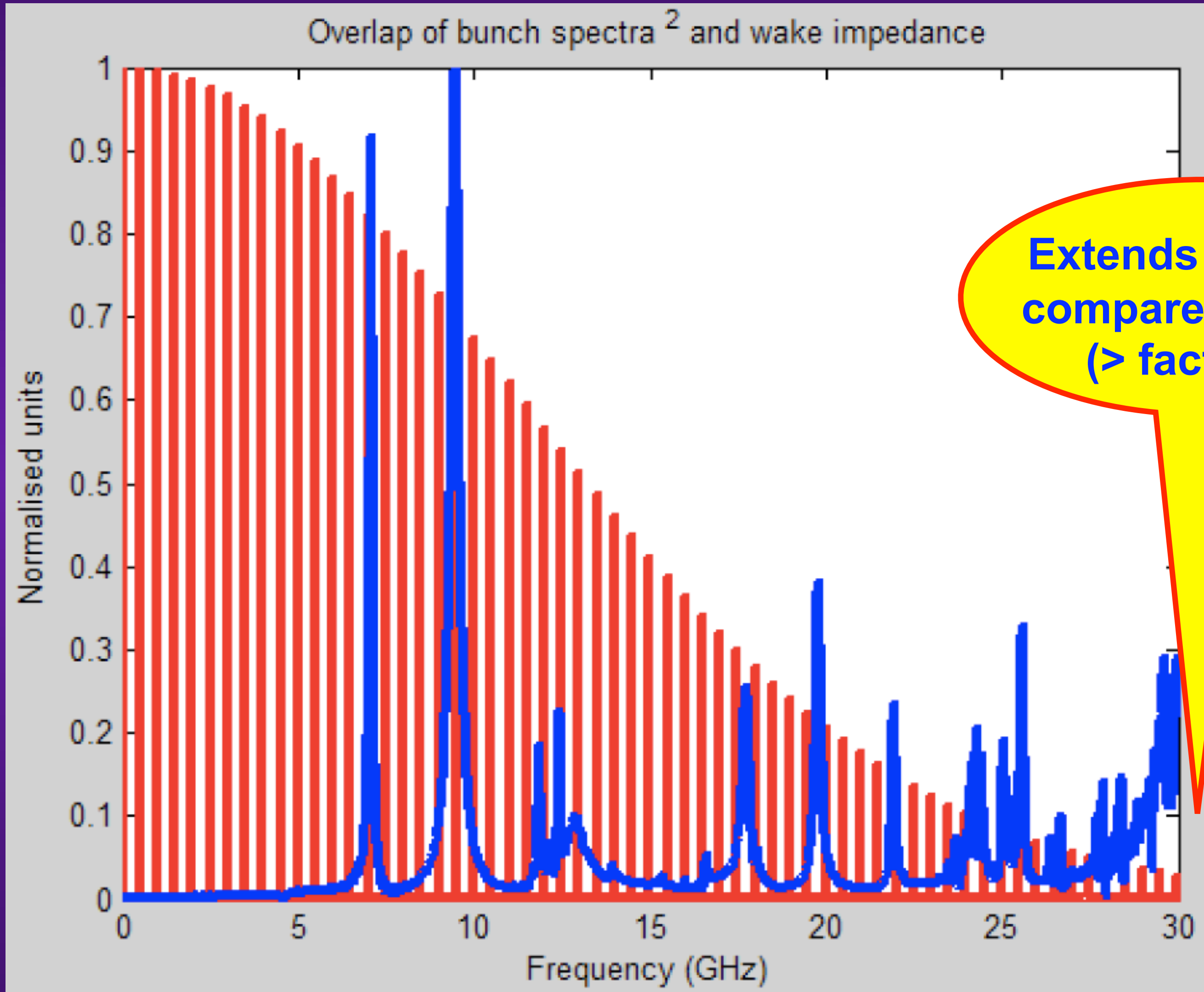
Alun Morgan

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (7/14)



Alun Morgan

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (8/14)



Extends to very f compared to LHC (> factor 10)

Alun Morgan

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (9/14)

Final thoughts

- For all the structures tested so far, a large fraction of the power is sent down the beam pipe. This will act as an additional heat load on nearby structures. Does this mean we should model adjacent models together?

Alun Morgan

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (10/14)

Wake fields generated inside a beam chamber may propagate long distances but sooner or later be absorbed by the resistive walls of the chamber.

Sometimes, because of forward and back reflections, these fields may stay in one place or in one vacuum element.

In this case the wake field power will be concentrated and dissipated in a small region.

Without a proper cooling the temperature of this vacuum element can be very high.

Temperature can be high enough to mechanically deform the element, to melt thin shielded fingers or to destroy the vacuum sealing.

Sasha Novokhatski

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (11/14)

- heating and damage of vacuum beam chamber elements
  - RF seals: breakdowns, sparks
  - vacuum valves: melted fingers
  - shielded bellows: melted fingers
  - BPM buttons falling down
  - ceramic tiles: sparks
- vacuum rise, spikes and vacuum instabilities
  - NEGs stop pumping
  - high detector background
- beam instabilities
  - longitudinal, transverse and ion instability
- RF background
  - wake fields outside the beam chamber

Sasha Novokhatski

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (12/14)

Recommendations

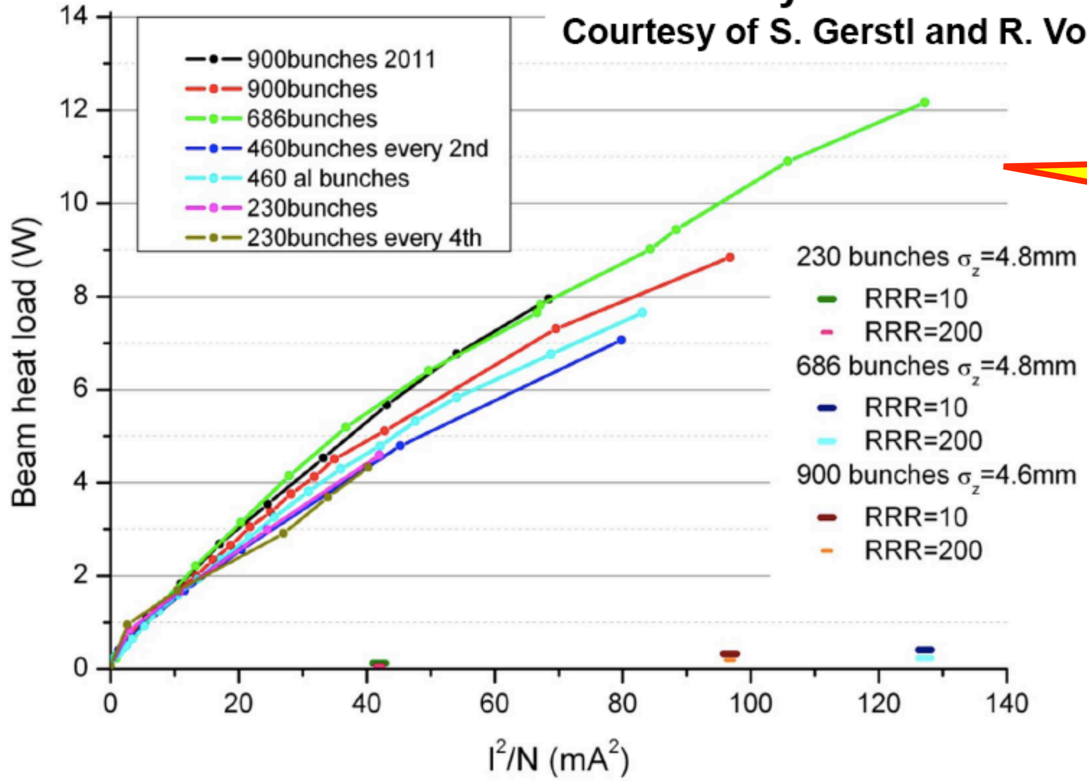
* Electron and positron bunches generate electromagnetic fields at any discontinuity of the vacuum chamber
* These fields can travel long distance and penetrate inside bellows, pumps and vacuum valves.
* Vacuum chamber must be very smooth.
* HOM absorbers must be installed in every region that has unavoidable discontinuity of the vacuum chamber
* Maximum attention to the RF seal designs
* Better design of a BPM button
* No open (to the beam) ceramic or ferrite tiles

Sasha Novokhatski

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (13/14)

Outlook

Preliminary data !
Courtesy of S. Gerstl and R. Voutta



Can we understand this scaling?

- From these preliminary data, we would conclude that the beam heating due to geometrical and resistive wall impedances is not the main mechanism responsible for the beam heat load.

Sara Casalbuoni

Mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures" (14/14)

RF shielding of the NSLS-II Bellows has been well adapted for the octagonal shape of the NSLS-II vacuum chamber.

NSLS-II Bellows passed beam-test in the APS storage ring at high current without damages and deteriorations. The next step is temperature measurements in the NSLS-II storage ring under beam condition.

Successful Implementation of RF Shielding for Large Aperture BPM Assemblies.

Stripline Heating Concern. Close monitoring of temperature rise using outside-body thermocouples. Designed water-cooled feedthrough.

Alexei Blednykh

HOMEWORK

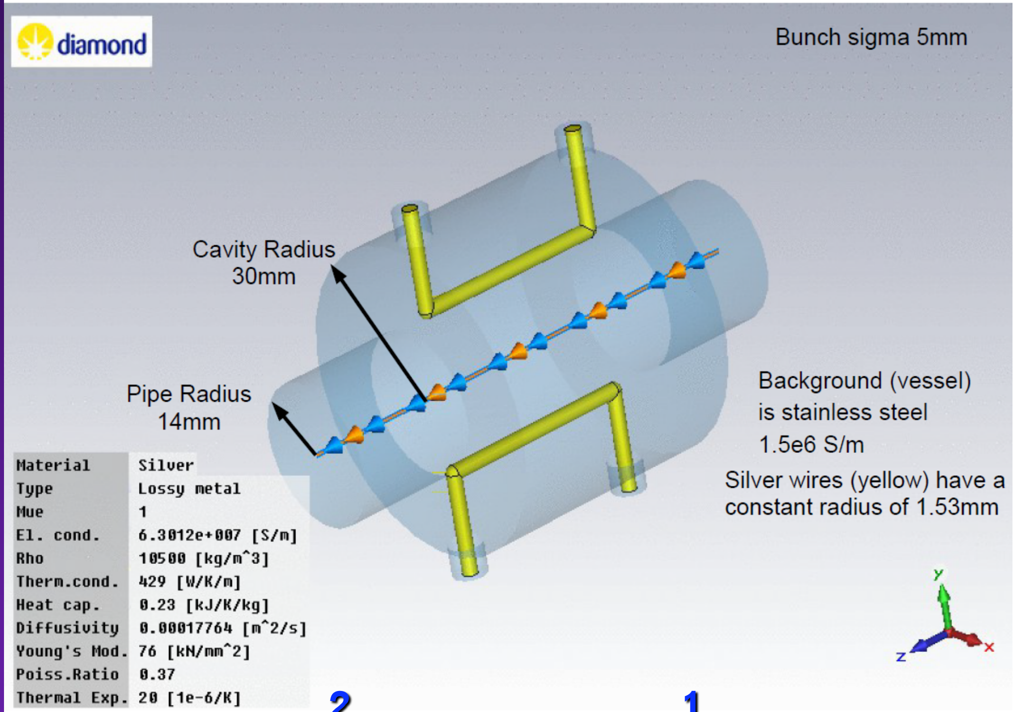
=> For the mini-workshop on "Simulation of Power Dissipation and Heating from Wake Losses in Accelerator Structures”

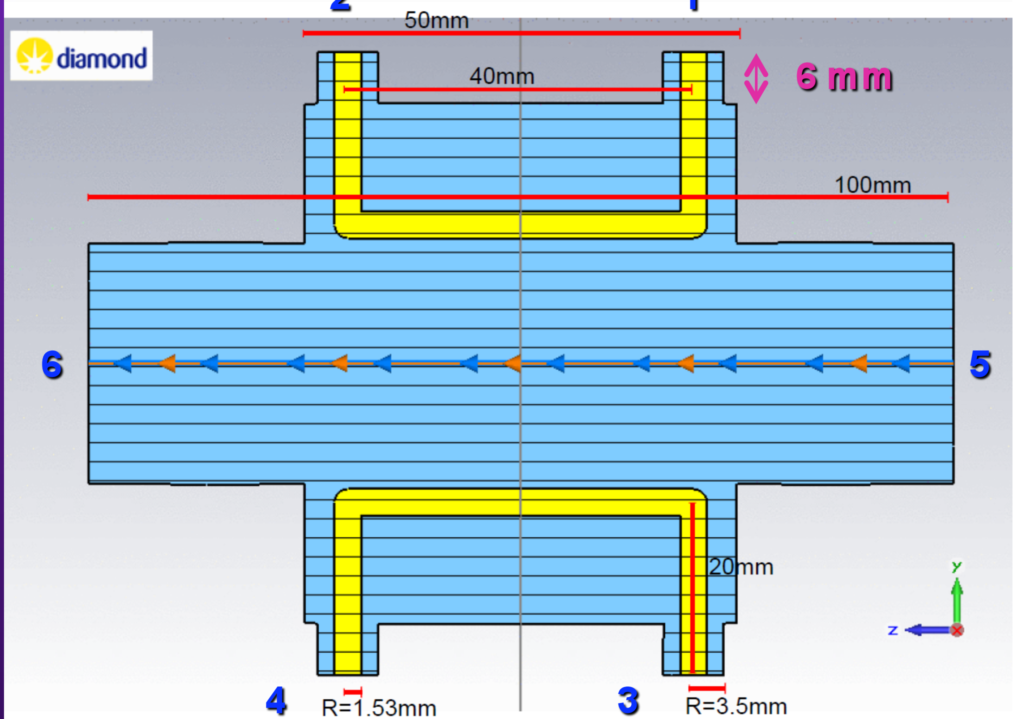
(ongoing with the different participants)

GEOMETRY OF THE STRUCTURE

Simplified strip line with the coax ports terminated (waveguide boundary)

- **Beam condition: 1 bunch of 1 nC with 5 mm rms bunch length**





RESULTS (1/9)

Olav Berrig and Benoit Salvant

1) Wake loss factor, energy lost by beam

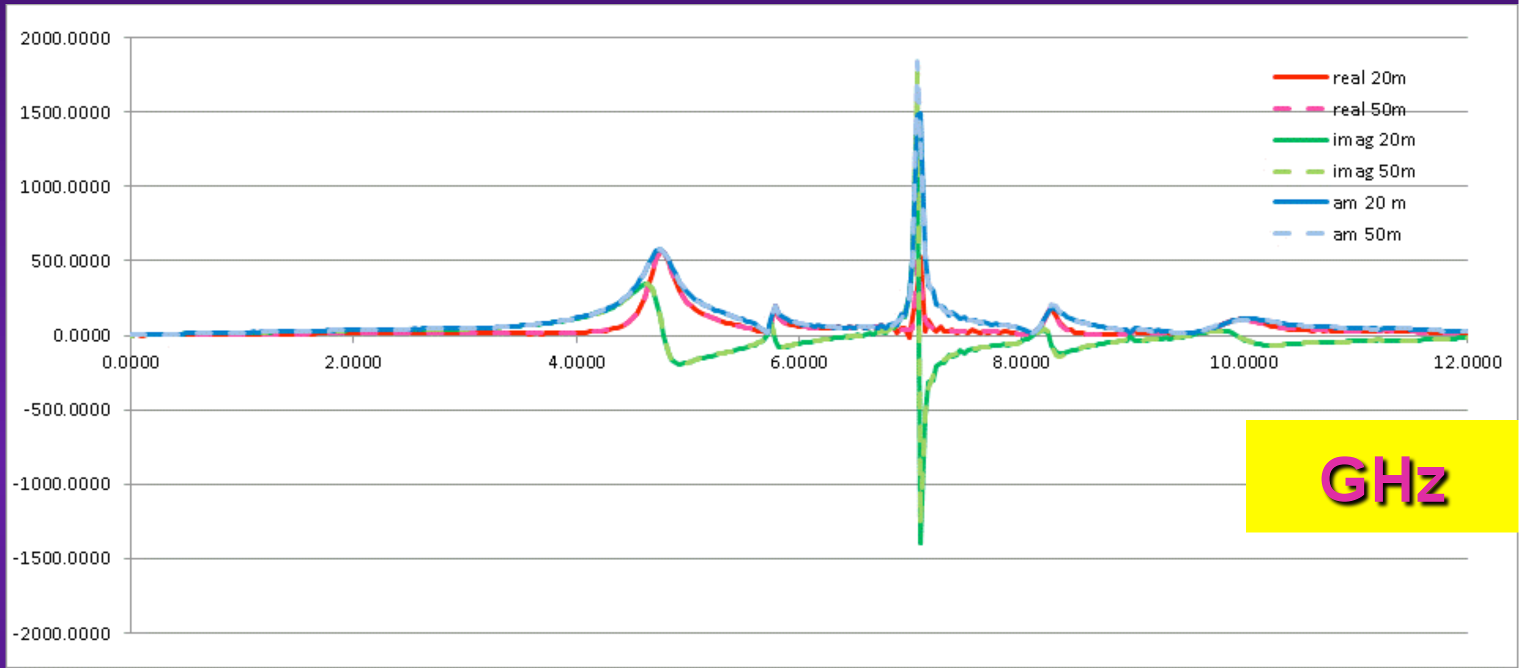
- Wake loss factor => k_{loss} ≈ 0.86 V / pC

- Energy loss by the bunch => E_{loss} ≈ 0.86 V / pC × $(1\ nC)^2$ ≈ 860 nJ

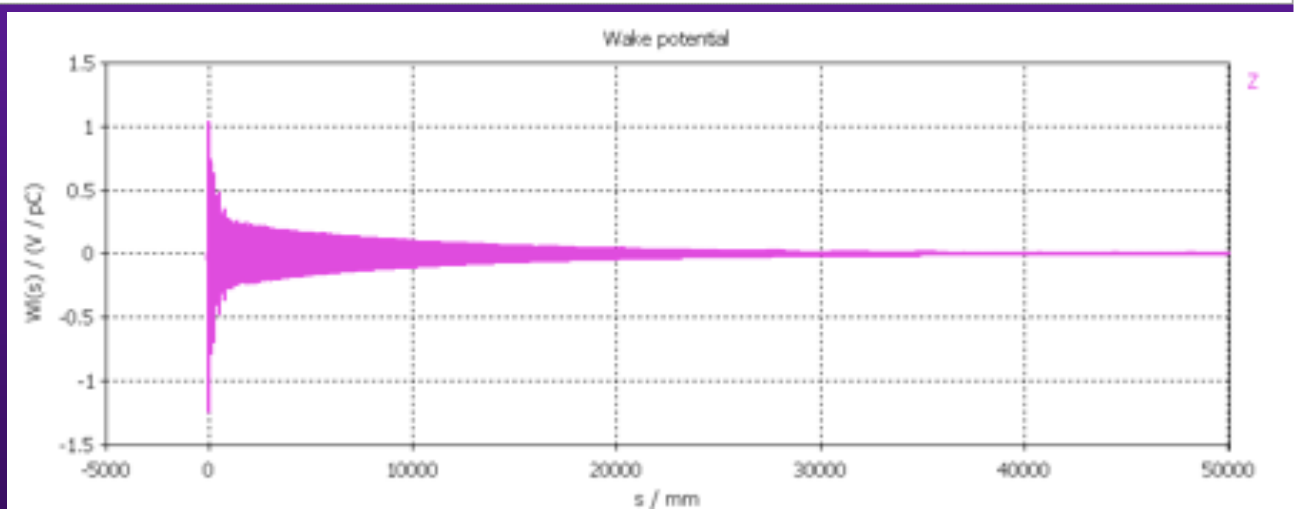
RESULTS (2/9)

2) Wake impedance

Ω



Wake potential



RESULTS (3/9)

3) Frequencies and Q factors of the 3 strongest resonances

fr => 4.8 GHz, 5.8 GHz, 7.1 GHz

Q (deduced from half width at half maximum) => 5, 15, 40

$$Q = \frac{f_r}{2\,\Delta f_{\mathrm{HWHM}}}$$

RESULTS (4/9)

4 and 5) Energy radiated into beam pipe ports upstream and downstream and into coax ports 1-4

=> 119 × 2 + 246 × 2 + (44 + 1.3) + (51 + 4) ≈ 830 nJ

Port 1 = Port 3 => 119 nJ

Port 2 = Port 4 => 246 nJ

Port 5 => 44 + 1.3 (2 modes) = 45.3 nJ (discussion about first ns)

Port 6 => 51 + 4 (2 modes) = 55 nJ

$$\text{Energy} = \int dt \, (\text{port signal})^2$$

$$\text{port signal} = \frac{V}{\sqrt{Z}}$$

RESULTS (5/9)

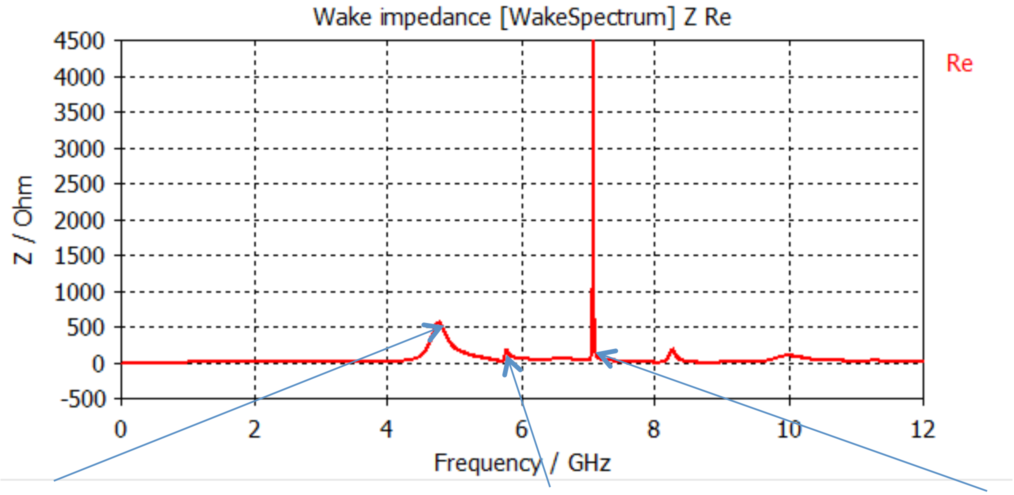
6) Energy deposited into structure, if possible separate for strip line and vessel

=> ~ 860 – ~ 830 ≈ 30 nJ on both strip line and vessel

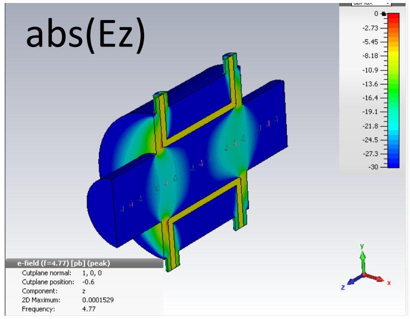
=> ~ 94 % of remaining energy loss in vessel (i.e. ~ 28 nJ) and ~ 6 % in stripline (i.e. ~ 2 nJ) => See next slide

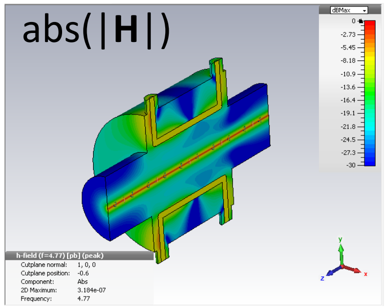
Ongoing

RESULTS (6/9)

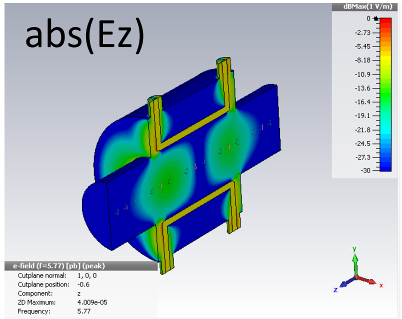


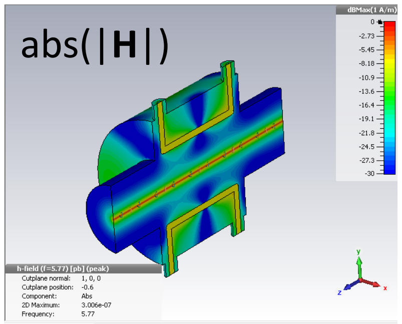
f=4.77 GHz (2 10^{-25} J)
(90 % in vessel, 10% in stripline)



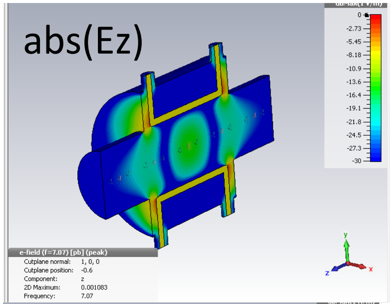


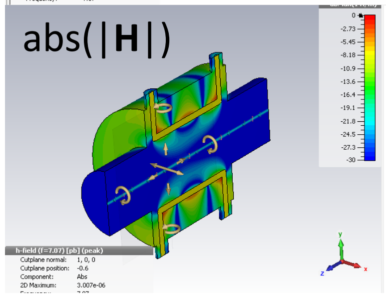
f=5.77 GHz (2 10^{-25} J)
(94 % in vessel, 6% in stripline)





f=7.07 GHz ***(3 10^{-23} J)***
(94 % in vessel, 6% in stripline)





RESULTS (7/9)

1) What software you used for simulation, including version number and module

=> CST Particle Studio (TD) and CST Microwave Studo (FD)

Build version: 2012.6 Release from 2012-09-29 (change 226220)

2) What hardware you have been simulating on, and how long the simulation took (roughly)

=> TD: 12 CPU, RAM of 128 GB, # mesh cells = 1324800 (without use of symmetry), ~ 1h30 for 20 m wake length

3) If you did a time domain simulation, how much time did you simulate (what length of wake potential) and what time steps

=> 20 m wake length. Also 50 m (linear in time)

RESULTS (8/9)

4) If you did an Eigen mode simulation, what frequency range you searched and how many modes you found

=> 2 solvers: AKS (Tetrahedral or Hexahedral) and JDM (uses in simulation losses in the material, whereas in AKS uses it as perturbation, and JDM is very slow)

=> Don’t have much experience in simulating ports in eigenmode… To be continued…

RESULTS (9/9)

OS Name	Microsoft Windows Server 2008 R2 Enterprise
Version	6.1.7601 Service Pack 1 Build 7601
Other OS Description	Not Available
OS Manufacturer	Microsoft Corporation
System Name	CAEVMSRV48
System Manufacturer	Dell Inc.
System Model	PowerEdge R710
System Type	x64-based PC
Processor	Intel(R) Xeon(R) CPU X5650 @ 2.67GHz, 2660 Mhz, 6 Core(s), 6 Logical Processor(s)
Processor	Intel(R) Xeon(R) CPU X5650 @ 2.67GHz, 2660 Mhz, 6 Core(s), 6 Logical Processor(s)
BIOS Version/Date	Dell Inc. 2.0.13 [1.1.22], 4/20/2010
SMBIOS Version	2.6
Windows Directory	C:\Windows
System Directory	C:\Windows\system32
Boot Device	\Device\HarddiskVolume1
Locale	United States
Hardware Abstraction Layer	Version = "6.1.7601.17514"
User Name	Not Available
Time Zone	W. Europe Standard Time
Installed Physical Memory (RAM)	128 GB
Total Physical Memory	128 GB
Available Physical Memory	108 GB
Total Virtual Memory	224 GB
Available Virtual Memory	204 GB
Page File Space	96.0 GB
Page File	C:\pagefile.sys