Update on simulation of new RF "fingers" using ACE3P

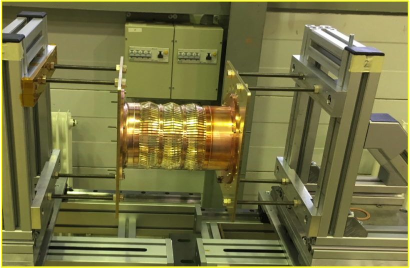
Kyrre Sjobak

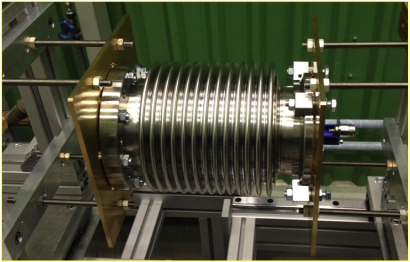
WP2 meeting, August 16^{th} 2016

Outline

New LHC RF shielding

- New RF contacts geometry being considered for HL-LHC
- Design with fixed extremities
- Trapped modes when not completely extended
- Possibility of resonances in the outer volume coupling to the beam





Photos by C. Vollinger

Measurements

- Wire measurements by C. Vollinger et. al., presented at:
  - WP2 meeting no. 69, Jun 2016
    `https://indico.cern.ch/event/525677/`
  - Impedance meeting Dec. 2014
    `http://indico.cern.ch/event/358583/`
- For 2-convolution bellows, observe that high-Q resonances show up when the outer bellow is mounted.
- For 3-convolution bellows, coupling of resonances to inner volume disappear when bellow is mounted.

Earlier simulations

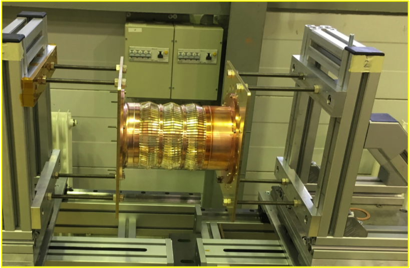
- Presentations:
  - O. Berrig & B. Salvant: "Beam impedance of 63 mm VM with unshielded bellows", 6/11-2012
  - Na Wang & B. Salvant: "Impedance calculations for the new LHC triplet shielded bellows and the changes linked to 5th axis in the LHC", Impedance meeting 18/06-2015 `http://indico.cern.ch/event/403089/`
  - K. Sjobak & B. Salvant: "ACE3P for RF finger simulation", Impedance meeting 10/08-2015 `http://indico.cern.ch/event/437858/`
  - B. Salvant & E. Metral: "HL-LHC Triplet "RF fingers", WP2 meeting 29/03-2015 `https://indico.cern.ch/event/512380/`
- Using CST, HFSS, ACE3P, ABCI
- All have problems with the complex geometry

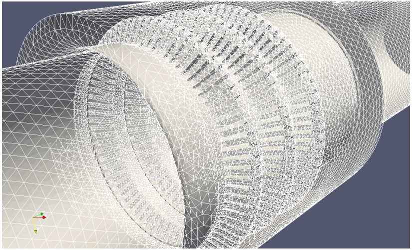
Why ACE3P

- Unstructured conformal tetrahedal mesh
- Scalable to huge problems (especially in time domain)
- Can do time domain, eigenmodes, S-parameters and more with the same tools (and the same mesh)
- Developed for accelerator physics by SLAC
- Requires external CAD program & mesh generator ~~Cubit~~ **Trellis** by ~~Sandia~~ **CSimsoft**
  - CERN has 2 floating Trellis licenses, users in ABP and RF
- Uses external pre- and postprocessing tool `acdtool`

Geometry

- Modeling the 3 convolution bellow, 111 mm inner diameter
- Partially successful import of CAD model from CATIA via SAT
    - Could not modify the resulting ACIS geometry
- Redrafted geometry in Trellis, compared (overlay) with imported
    - Parameterized geometry
- Method:
    1. Draw convolutions and sweep
    2. Remove "material" from holes
       Finger thickness is constant – not constant-angle sector!
    3. Add flanges, bellow, beampipes
- Simplifications:
  Inner bellow (d=0.1 mm) approximated as 0 mm, no outer corrugations





Resonant modes

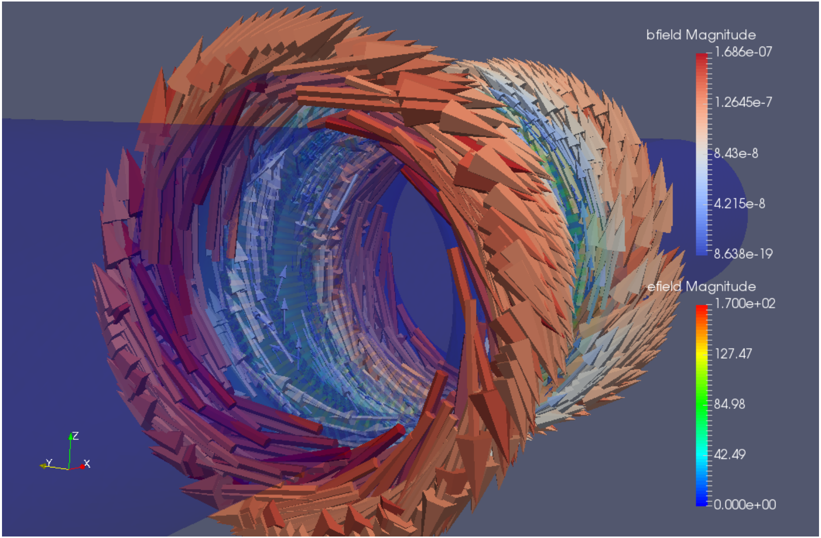
- Find a “double” set of modes
  - Inner volume TE- and TM-like modes
  - Outer volume TEM-like modes
- Outer modes couple weakly to the beam
  - Offset R/Q $<$ 1e-5 ($\Delta x = 5\ \mathrm{mm}$)
- Frequency varies slightly between coupled- and uncoupled case
- Also some dependency on LBP
- Lots of “beampipe modes” ($\mathrm{TM/TE}_{m,n,p}$, $p > 0/1$)

Mode	f_1	f_2	f_3	$(R/Q)_2$
TEM_{010}		0.732	0.742	6.4-05
TEM_{110}		1.008	0.917	1e-10
TEM_{210}		1.568	1.278	2e-10
TE_{111}	1.600	1.585	1.572	2e-8
TM_{010}	2.011	2.013	2.011	0.625

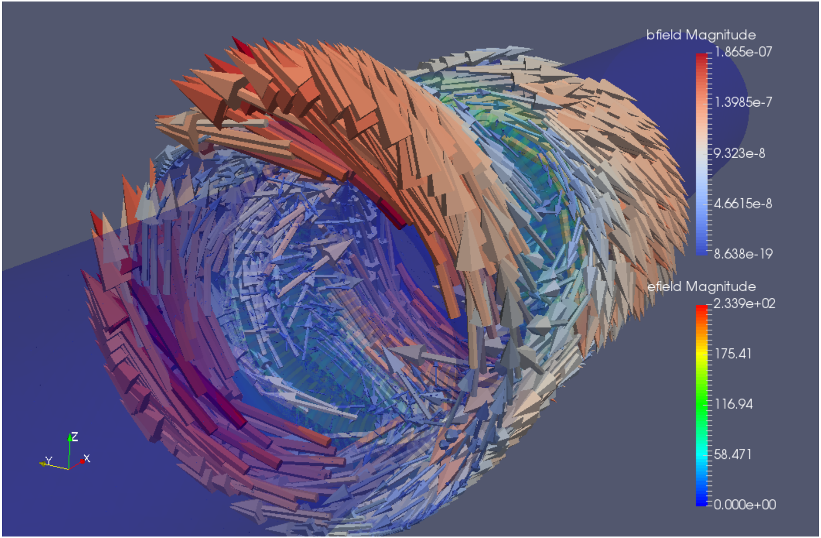
Frequencies in GHz, $R/Q = V^2/(\omega U)$ [Ω]
Subscript key:

1. Separated, LBP=150 mm
2. Separated, LBP=300 mm
3. Combined inner and outer, LBP=300 mm

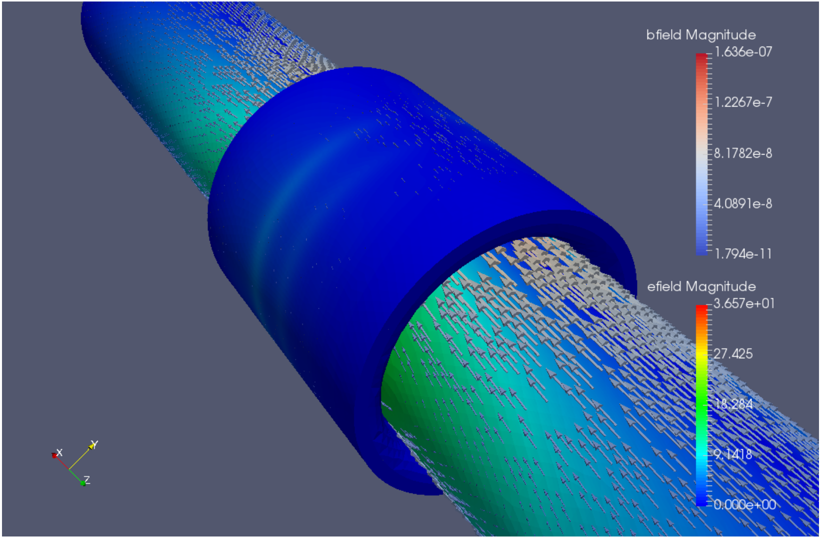
Mode Gallery – TEM_{010}



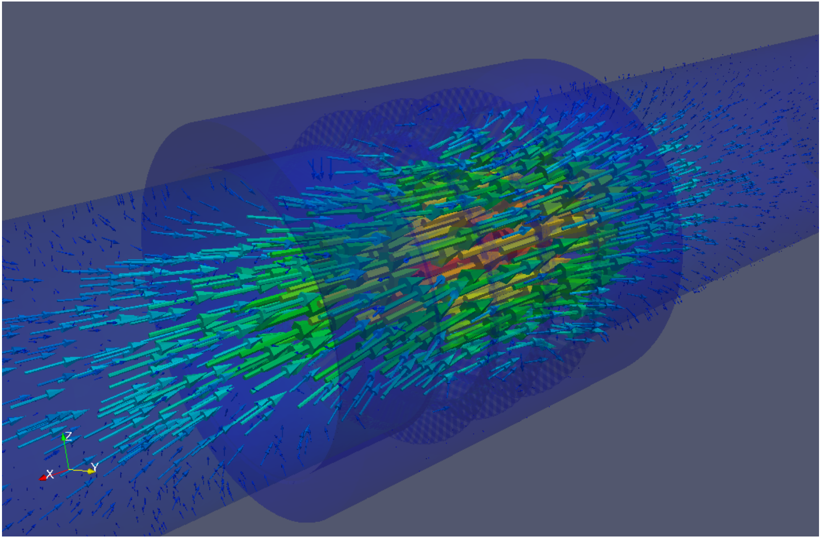
Mode Gallery – TEM_{110}



Mode Gallery – TE_{111}

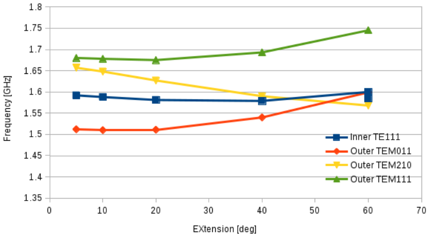


Mode Gallery – TM_{010}

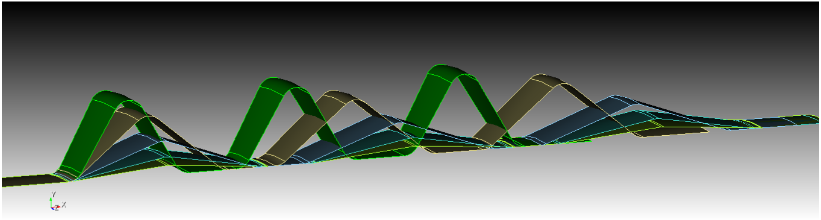


Effect of stretching the structure

- Use geometry parametrization
- Would expect more coupling if inner- and outer resonances cross
- They do for large angles; but mode symmetry is different
- Dependency on vacuum bellow radius and corrugations not studied



deg	5	10	20	40	60
mm	39.3	38.3	34.1	19.6	0.0



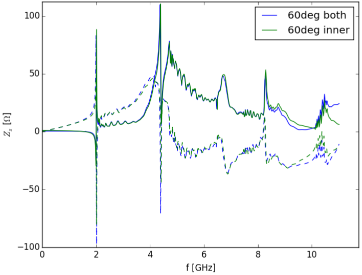
Longitudinal wake

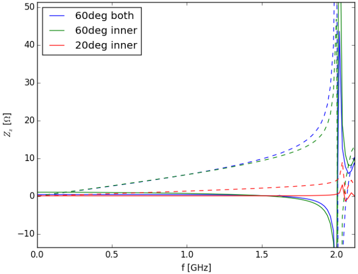
- Longitudinal wake
  - Complete structure vs. only inner part: Very similar
  - TM_{010}-like mode found at expected frequency
  - Stretching out $\Rightarrow$ amplitude drops
  - Analytical model ($\lim \beta\gamma^2 \to 1$):

$$Z_L \propto \mathrm{i} * f * L * \ln\left(\frac{b'}{b}\right)$$

From "Selection of formulae concerning proton storage rings" by Guignard, Gilbert (1977)

- Transverse wake: Some technical difficulties, next time. . .





Conclusions

- Built a very useful parameterized geometry model
- Did not observe any significant coupling
- Frequencies of modes not very stretch-dependent
- Lowest relevant longitudinal mode at ≈ 2 GHz.
- $\Im(Z_L(f))$ behaves as expected

Outlook

- Sideways deflection
  - ACE3P Can in principle solve mechanical system
  - Difficult to deform vacuum mesh correctly
  - Maybe just shift parts of the mesh?
- Fix transverse wake calculation
- 2-convolution bellows
- Direct simulation of wire measurements

Thanks to Benoit Salvant, Christine Vollinger, Oleksiy Kononenko, Thomas Kaltenbacher, and HSS section.

Conclusions

- Built a very useful parameterized geometry model
- Did not observe any significant coupling
- Frequencies of modes not very stretch-dependent
- Lowest relevant longitudinal mode at ≈ 2 GHz.
- $\Im(Z_L(f))$ behaves as expected

Outlook

- Sideways deflection
  - ACE3P Can in principle solve mechanical system
  - Difficult to deform vacuum mesh correctly
  - Maybe just shift parts of the mesh?
- Fix transverse wake calculation
- 2-convolution bellows
- Direct simulation of wire measurements

Thanks to Benoit Salvant, Christine Vollinger, Oleksiy Kononenko, Thomas Kaltenbacher, and HSS section.

Conclusions

- Built a very useful parameterized geometry model
- Did not observe any significant coupling
- Frequencies of modes not very stretch-dependent
- Lowest relevant longitudinal mode at $\approx$ 2 GHz.
- $\Im(Z_L(f))$ behaves as expected

Outlook

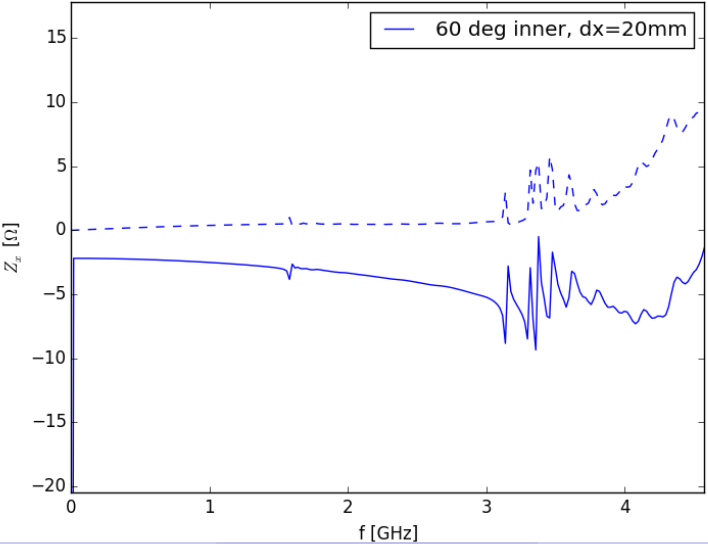
- Sideways deflection
  - ACE3P Can in principle solve mechanical system
  - Difficult to deform vacuum mesh correctly
  - Maybe just shift parts of the mesh?
- Fix transverse wake calculation
- 2-convolution bellows
- Direct simulation of wire measurements

Thanks to Benoit Salvant, Christine Vollinger, Oleksiy Kononenko, Thomas Kaltenbacher, and HSS section.

Mech. drawing numbers

- LHCVSMPA0026 – sheet with holes
- LHCVSMPA0025 – separation rings
- LHCVSMPA0018 – general "exploded view" and overview
- LHCVSMP0021 – Middle piece
- LHCVSMPA0020 – Curved flange
- LHCVSMPA0022 – Body contact RF
- LHCVSMPA0023 & LHCVSMPA0024 – Half flanges
- LHCVSMPA0017 & LHCVBU___0038 – Vacuum bellow

Transverse impedance spectrum (not trusted)



More modes and stretch dependence