Wakefield Monitors Development

BI Workshop – 2-3 June 2009

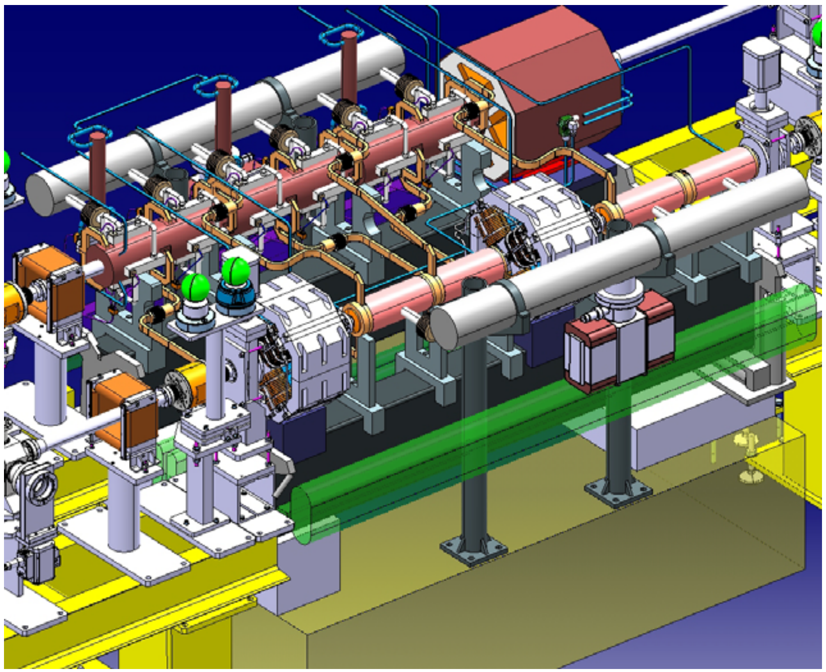
F. Peauger

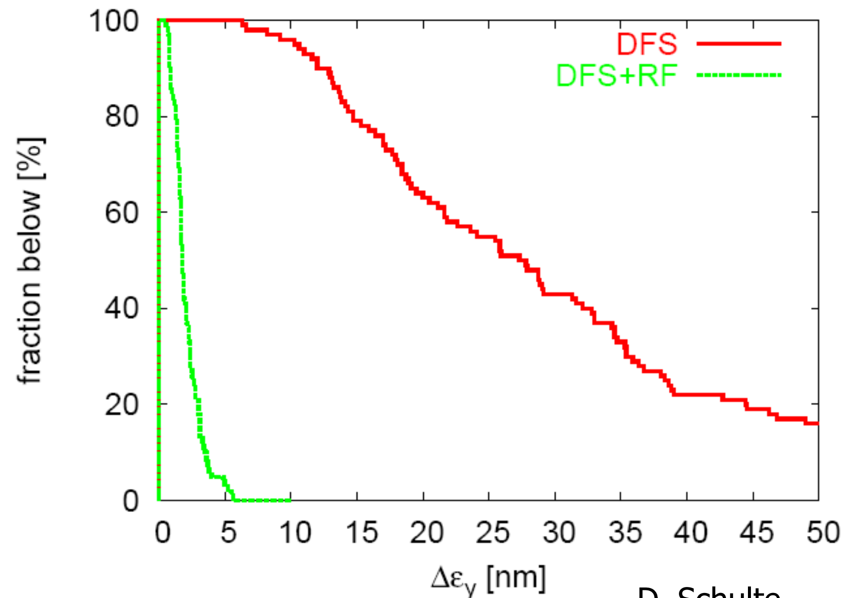
Outline

- Context
- Program Goals
- Basic Design Approach
- Wakefield sensitivity to beam offset
- First WFM design
- Test layout in CTF3

Context

CLIC module components mounted on a girder equipped with micro-movers
→ active alignment + stabilization
One girder = up to eight accelerating structures



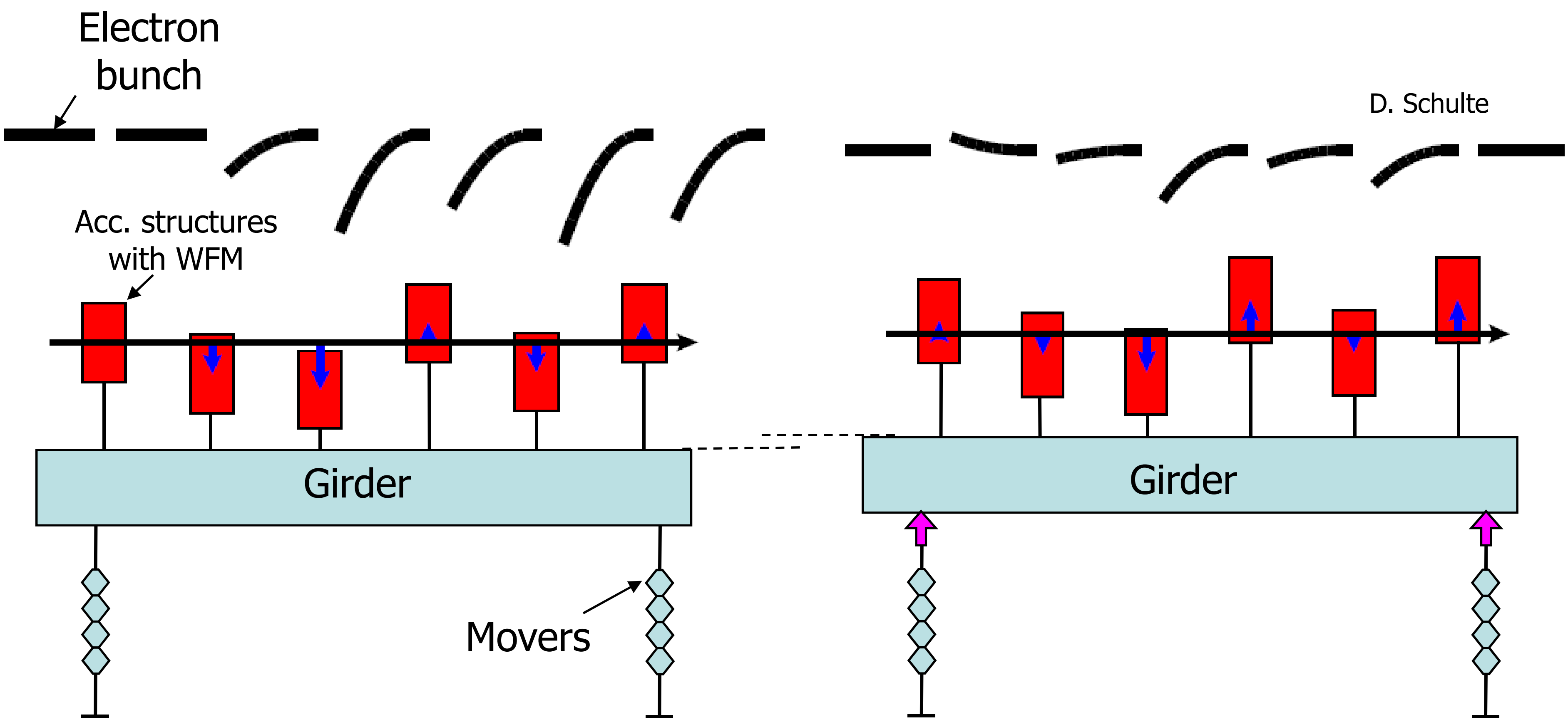


D. Schulte

Horizontal emittance growth $\Delta\varepsilon_y$ well improved by aligning the accelerating structures to an RMS accuracy of 5 µm to the beam

Context

Wakefield kicks from misalignment structure can be cancelled by another structure.
Mean offset is important and scatter around the mean does not matter



WFM requirements

Two extreme cases:
- commissioning with one low intensity bunch
- maximal luminosity with nominal bunch charge and train length

Parameters	CLIC Commissioning	CLIC Operation	CTF3 (CALIFES+TBTS)
Charges per bunch	3.7×10^8	3.7×10^9	0.6 nC
Number of bunches	1 - 312	312	1 – 32 - 226
Bunch length	45 – 70 µm	45 – 70 µm	500 µm
Train length	156 ns max	156 ns	150 ns max
Bunch Spacing	0.5 ns	0.5 ns	0.66 ns
Accuracy	5 µm	5 µm	
Resolution	5 µm	< 5 µm	
Stability	5 µm		
Range	± 2 mm	± 100 µm	
Bandwidth	35 MHz	35 MHz	
Beam Aperture	~ 5.5 mm	~ 5.5 mm	
Available length	-	-	
Intercepting device	No	No	
Quantity	142812	142812	3
Used in RT Feedback	Yes	Yes	
Machine protection Item	No	No	

WFM development plan

- CALIFES probe beam linac and TBTS commissioned and fully characterized

  ☞ mid/end of 2009

- Single WFM experiment where a WFM prototype will be implemented in the 12WDSDVG1.8T structure fabricated by CERN. The beam offset with and without RF will be measured and compared to the beam position given by the BPMs of the TBTS.

  ☞ beginning of 2010

- Two or three dedicated structures equipped with WFM will be fabricated and tested on the CLIC Module in order to reproduce the previous measurement and measure the tilt.

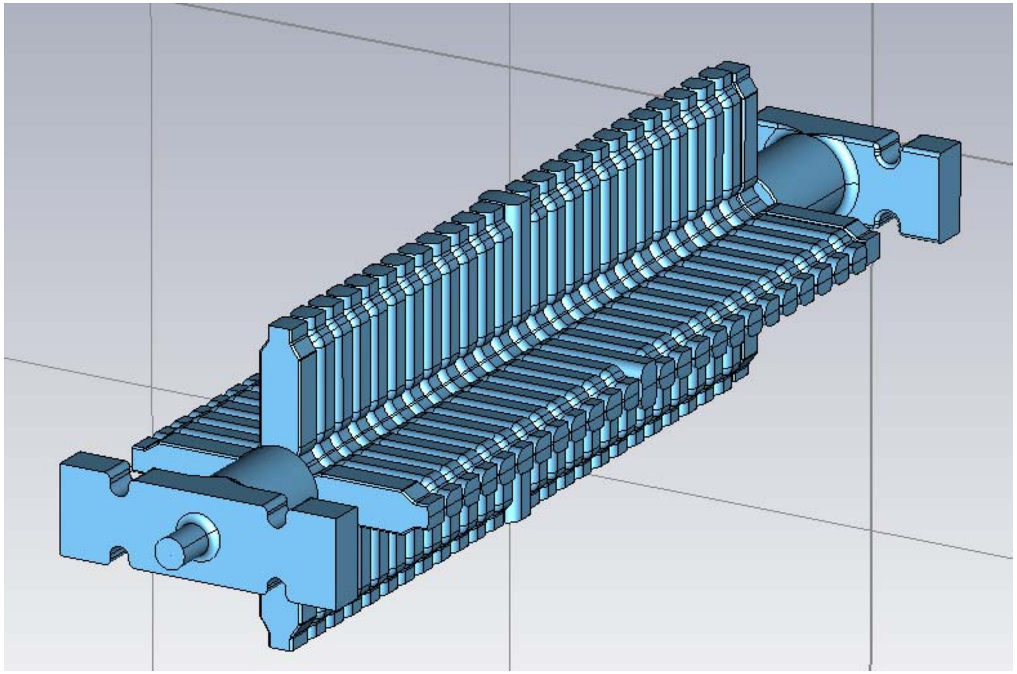
  ☞ 2010 – 2011

WFM design approach

- No length available in the main linac →WFM integrated to the structure
- WFM located at the middle cell → measure the mean offset of the structure.
- WFM basic feature ≈ single resonant cavity BPM
  - The electromagnetic fields processed to evaluate the beam offset are generated and measured in one cell. The only difference is that this cell (or cavity) works in a travelling wave regime so propagation and dispersive effects must be taken into account
- Four WFM couplers (or RF pickups) positioned at 90° for XY detection.
- Pickups coupled to the damped rectangular waveguide and terminated by 50Ω coaxial waveguide for post processing
  - The coupling will be done as far as possible to let the fundamental accelerating mode attenuate sufficiently. If not, this would affect directly the resolution of the WFM
- WFM should not affect the accelerating properties of the structure
  - Small modification of resonant frequency, R/Q, Q0, HOM damping …

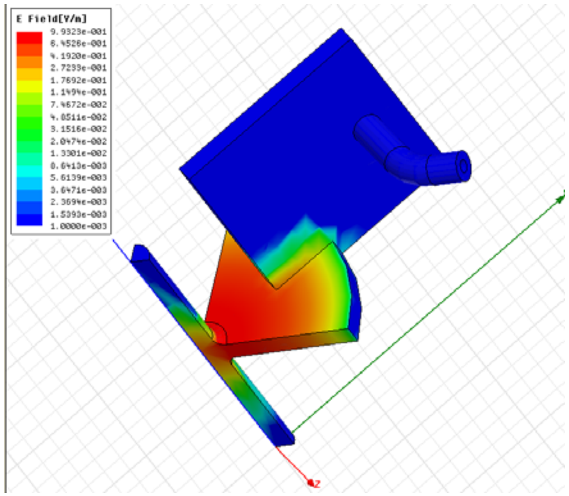
Accelerating structure

- Ref.: 12WDSDVG1.8T
- Tapered heavily damped structure of 24 cells (+ 2 matching cells)
- Copper structure



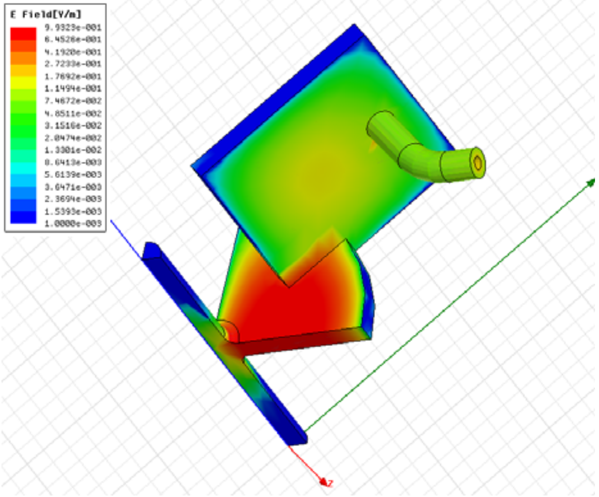
Example of CCBPM

- Circular cavity BPM at X-band



Monopole mode TM_{01}

F=7.3 GHz, Q=2300



Dipole mode TM_{11}

F=11.23 GHz, Q=370

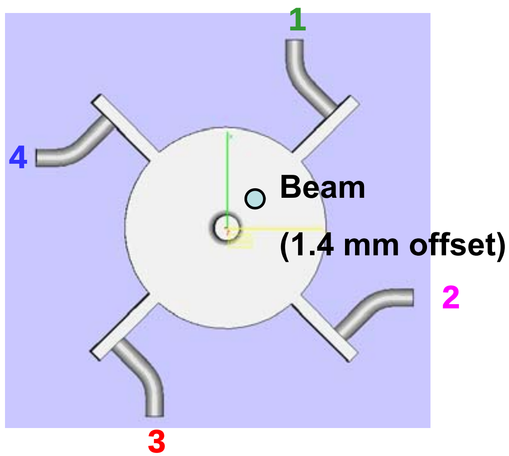
- Internal resolution:

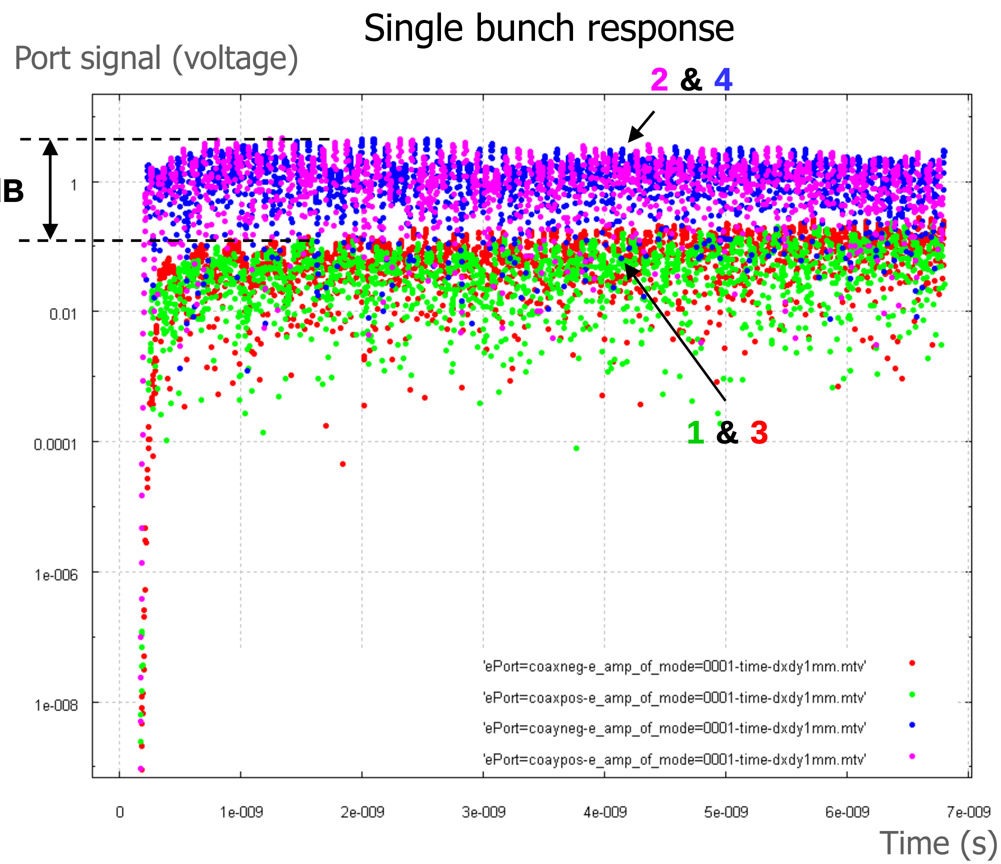
$$R(x) = x \cdot \frac{S_1(x=0)}{S_1(x)}$$

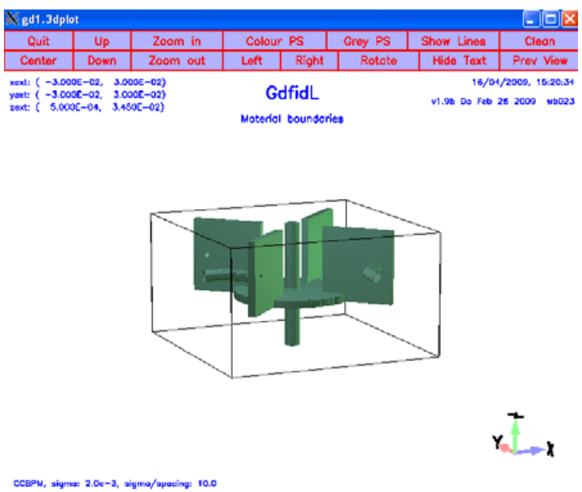
x = beam offset, S1(x) = amplitude of the signal (voltage) generated by the passage of the beam at the abscise x, collected at the output of the coupler. S1 is proportional to beam offset

Example: X-band circular cavity BPM

- GdfidL simulations of the circular cavity BPM (CCBPM)



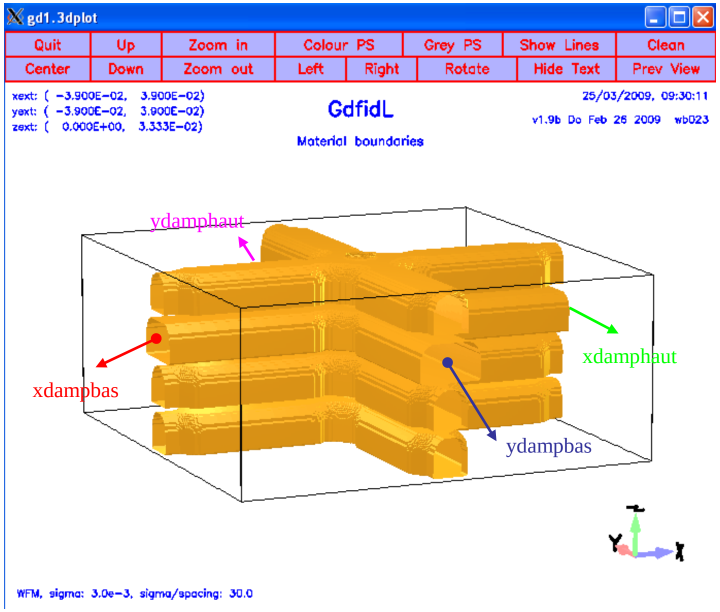


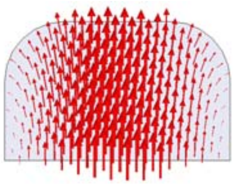


Internal resolution = 50 µm
With 20 dB hybrid, resolution = 500 nm (100 nm achieved with post processing in 2006)

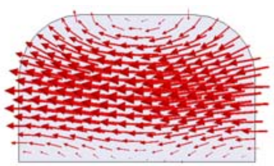
Wakefield sensitivity to beam offset

- Four cells meshed (no symmetry) with a mesh step of 0.3 mm
- PML set at the waveguide extremities (Xmin, Xmax, Ymin, Ymax)
- Beam: 1 bunch of 0.6 nC, σ_z=3 mm, offset Δx = 1 mm
- Simulation stopped at 6.66 ns.
- Rectangular ports at the end of the damped waveguides of the middle cell. The two first modes are selected in GdfidL so that longitudinal (TM) and transverse (TE) modes can be recorded



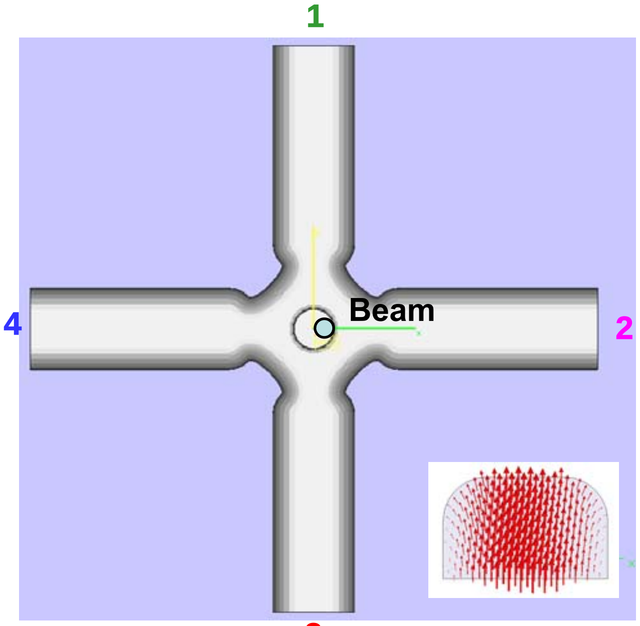


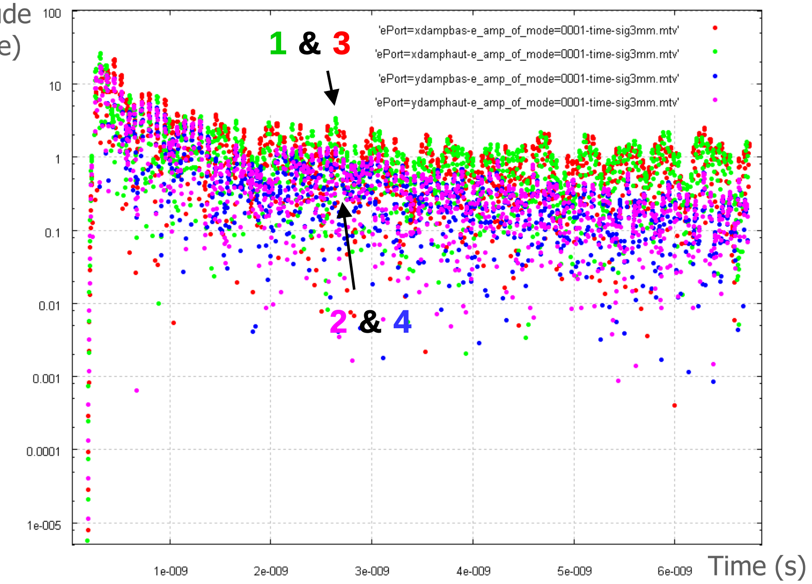
(TM)

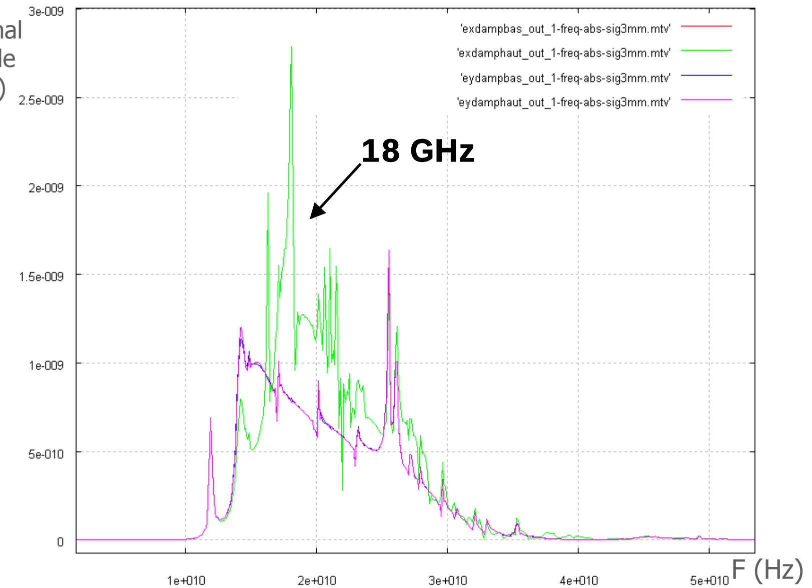


(TE)

Longitudinal TM modes



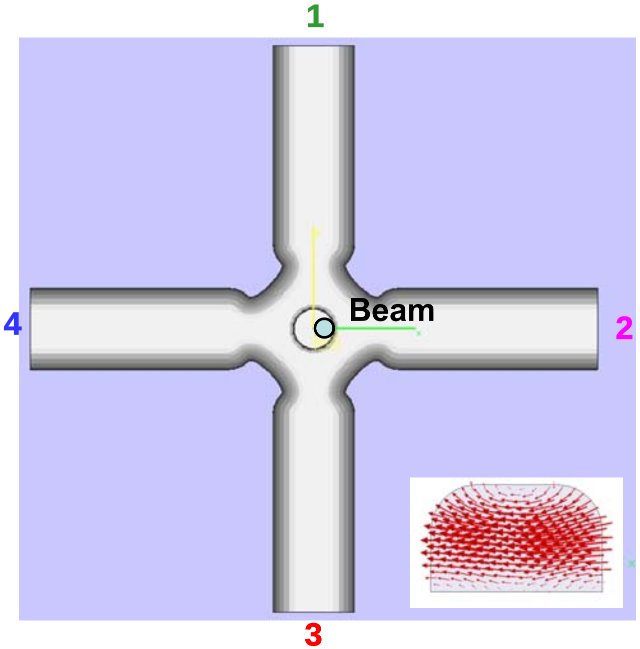


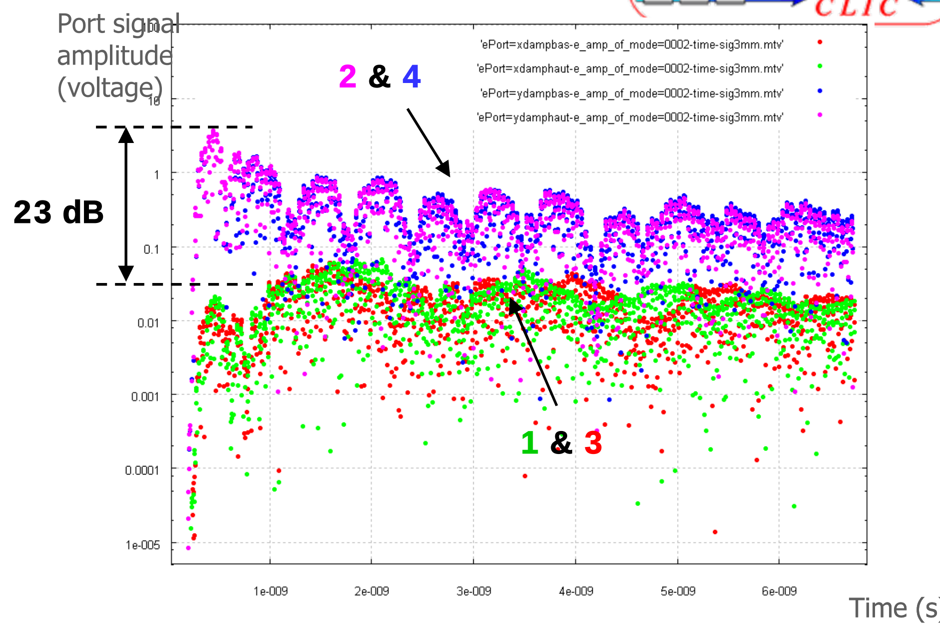


Max. theoretical internal resolution =

$$1mm \times \left(\frac{0.9 \cdot 10^{-9}}{2.7 \cdot 10^{-9}} \right) = 333 \mu m$$

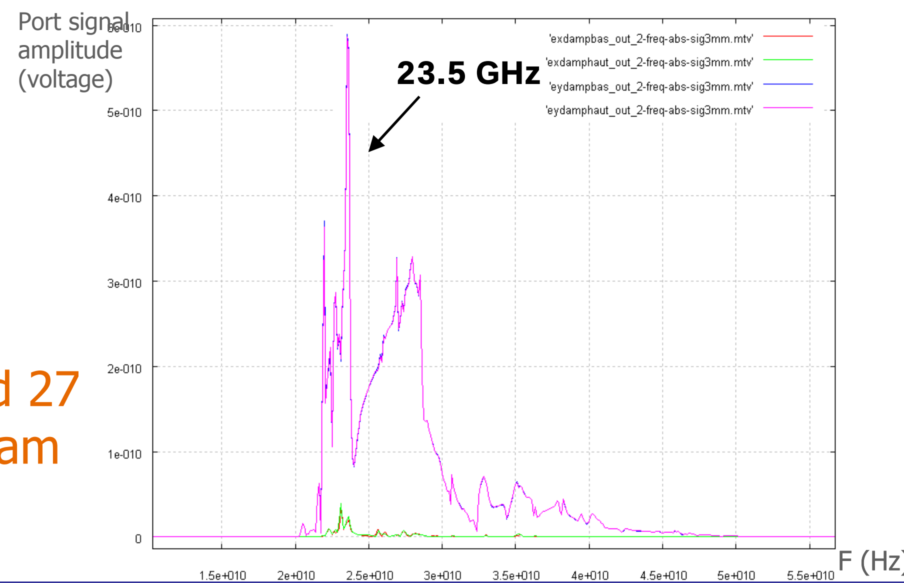
Transverse TE modes





Max. theoretical internal resolution =

$$1mm \times \left(\frac{0.022}{4}\right) = 5.5\mu m$$



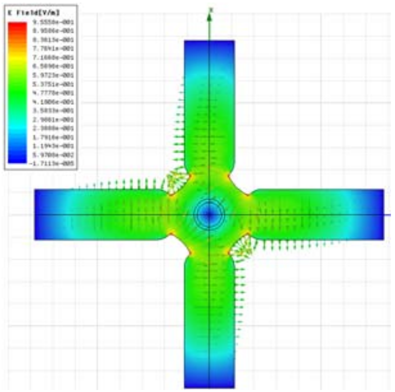
➡ GdfidL simulations showed that the transverse TE modes between 22 and 27 GHz are much more sensitive to a beam offset than longitudinal TM modes

Frequency domain analysis

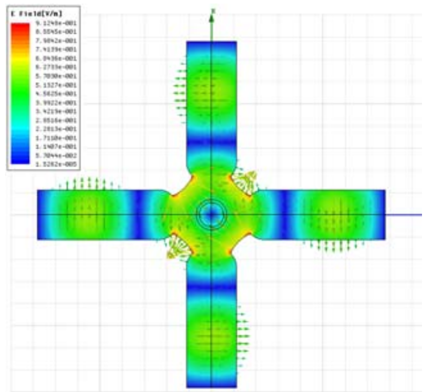
- Simulations using HFSS to study the TE modes involved in the WFM → try to correlate them to the spectra found in time domain

- In a first step, only one cell is simulated and no PML is included at the damped waveguide boundary. This first analyze is <u>qualitative</u> view of the modes.

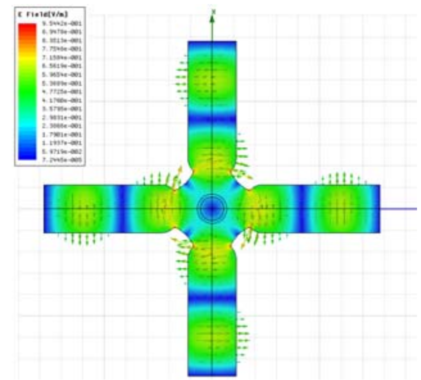
E Field



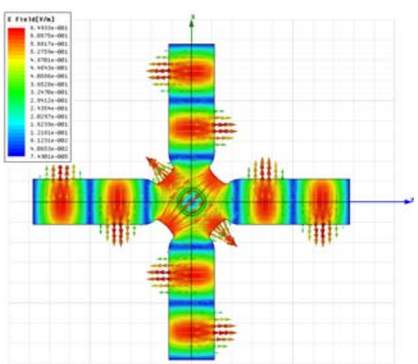
TE_{210}-Quadruple
22.2 GHz



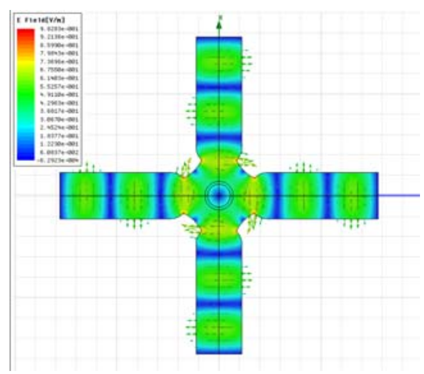
TE_{211}-Quadruple
23.0 GHz



TE_{211}-Quadruple
23.5 GHz



TE_{212}-Quadruple
24.5 GHz



TE_{212}-Quadruple
25.1 GHz

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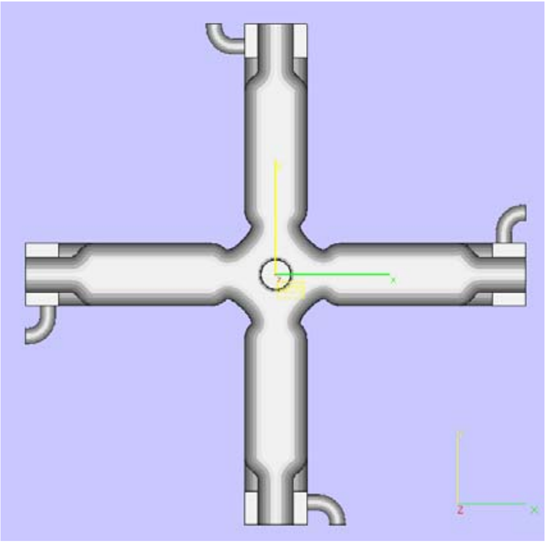
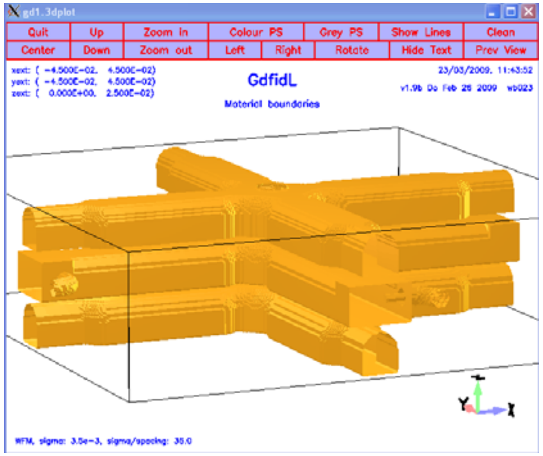
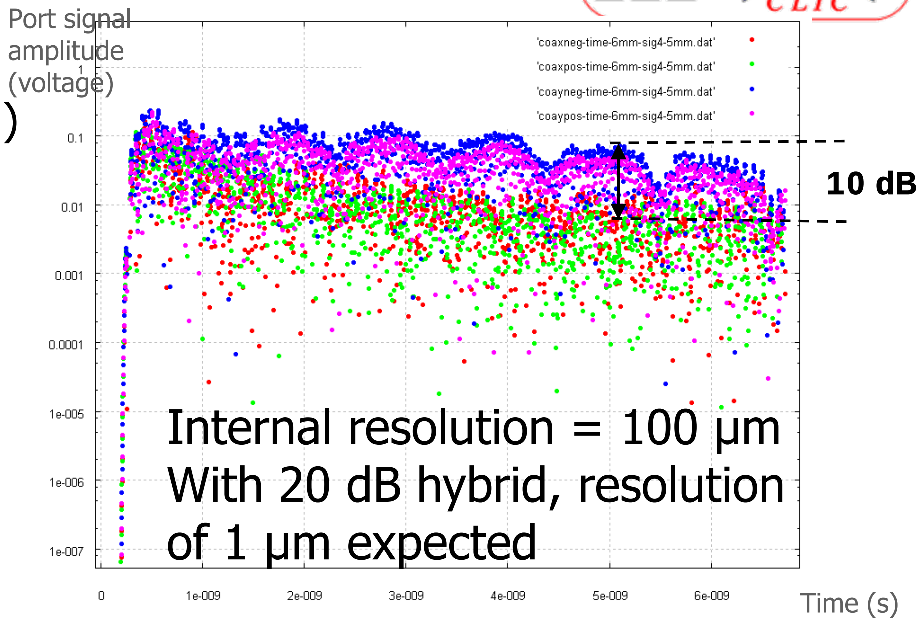
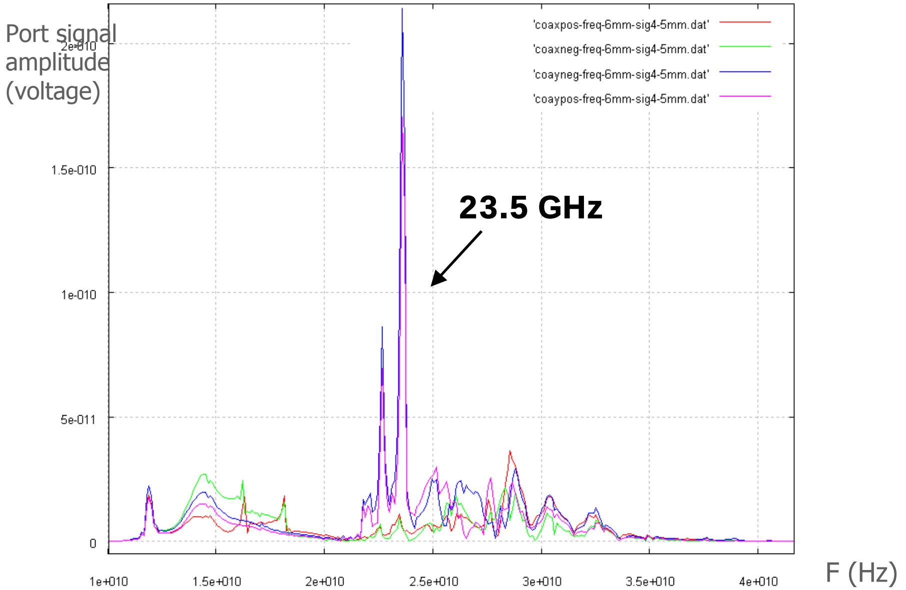
WFM RF transition design

- Very simple approach: 50 Ω coaxial waveguide + antenna (3 to 6 mm depth)



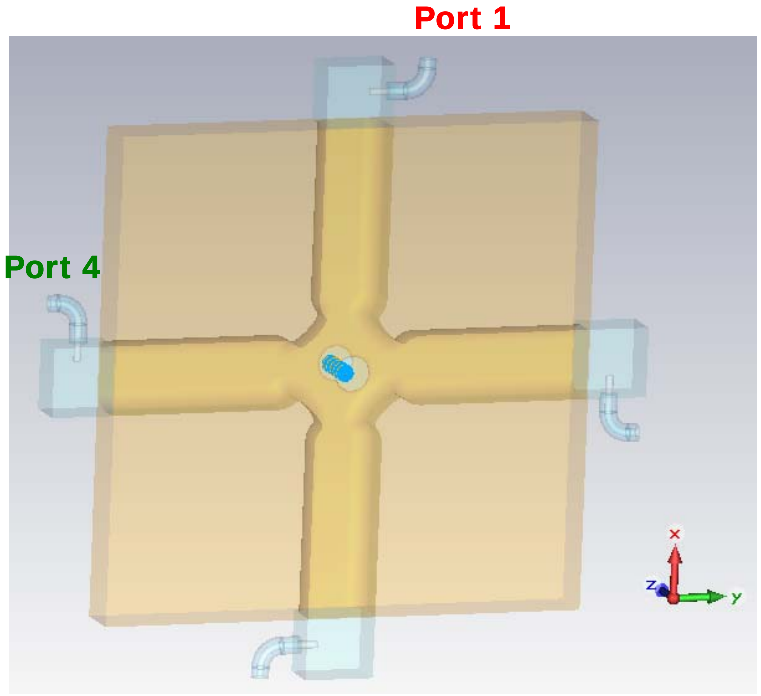


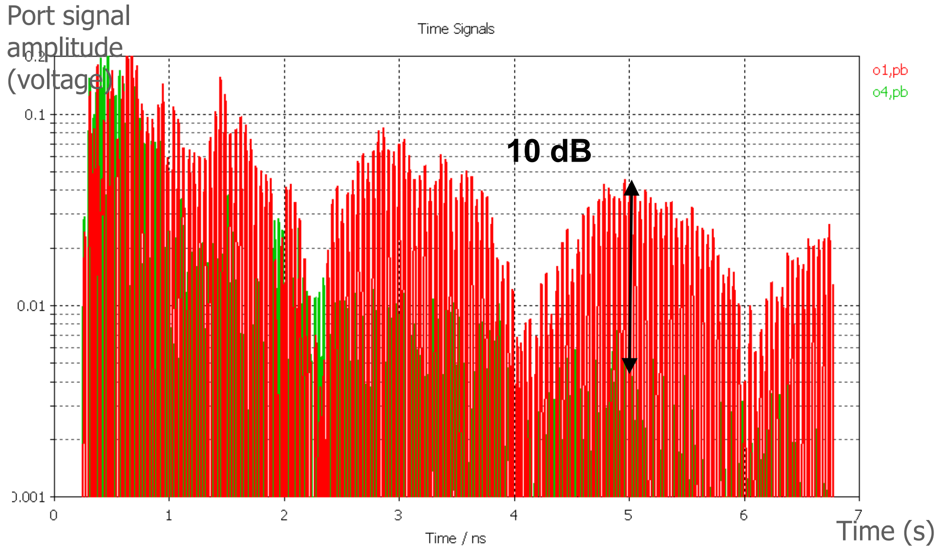


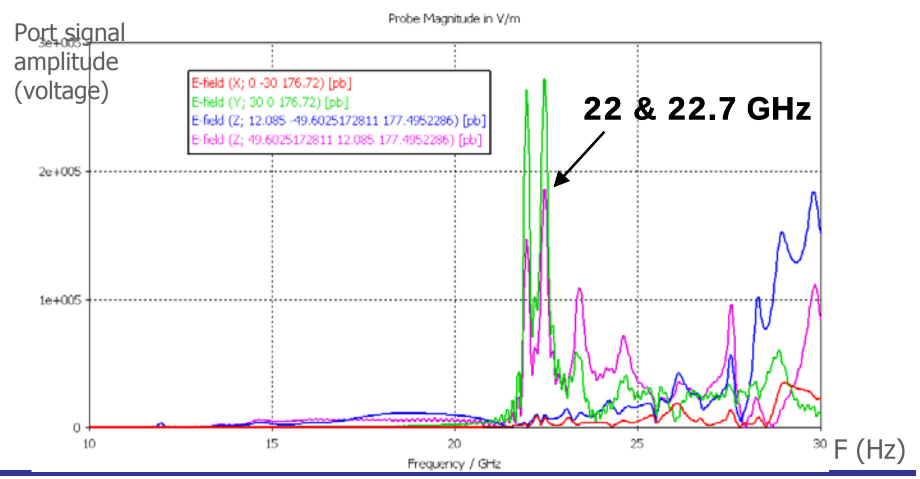


WFM RF transition

- Check by CST – Particle Studio simulations (Wakefield solver)







Layout of the WFM prototype test

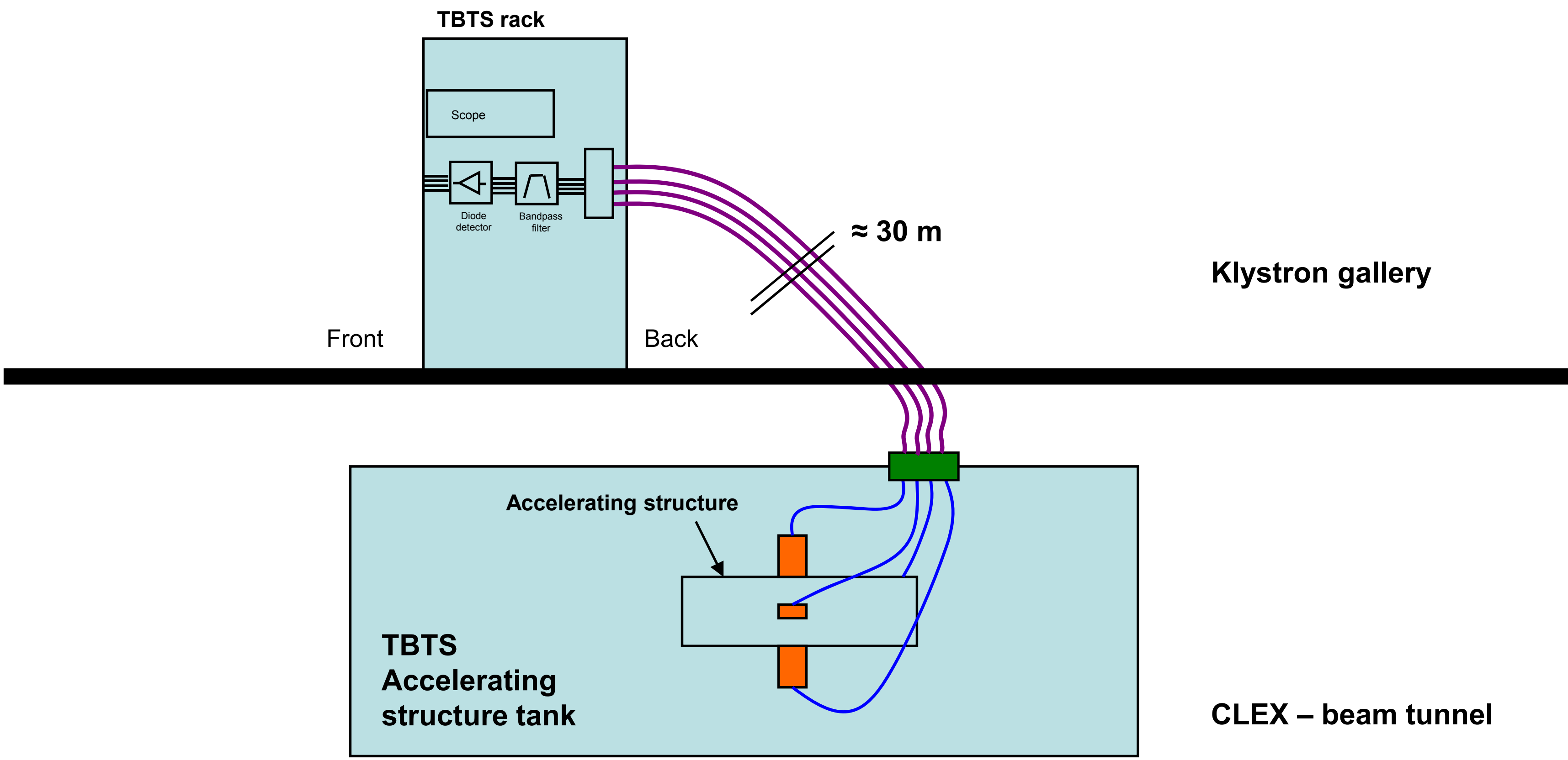
: « WFM – transition », qty 4, output connector = K female, UHV compatible

: semi rigide cable, Type?, qty 4, length ≈ 400 mm , input connector = K male, output connector = K female, UHV compatible

: CF flange feedthrough, qty 1, 4 connectors, input connector = K male (vacuum side), output connector = K female, UHV compatible

: Flexible cable, qty 4, length ≈ 30 m , input connector = K male, output connector = K female,

- with type 10 (Spectrum): ext. dia.=7 mm, loss=1.5 dB/m at 22GHz -> 45dB



Conclusion

- WFM Context and requirement well defined now
  - resolution = 5 µm
- Wakefield sensitivity study using GdfidL showed that transverse modes around 23 GHz are much more sensitive than longitudinal modes, with a max. theoretical resolution of 5 µm
- First design: 100 µm resolution without post processing (1 µm with 20 dB Hybrid)
- Need to go on with simulations (power evaluation, fundamental mode coupling…)
- First layout for the WFM prototype testing

Thank you for your attention