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Wake field monitors in the PSI X Band Structure

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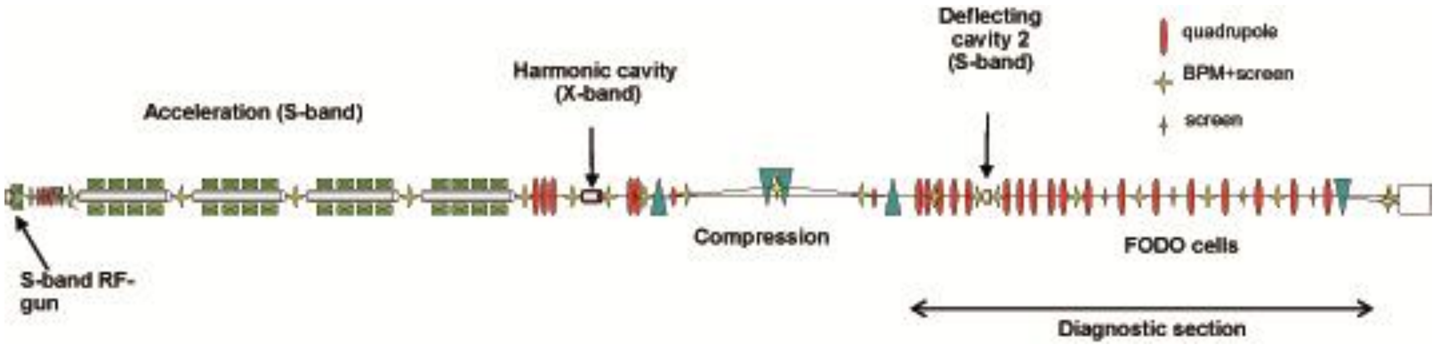
Introduction

PSI Injector: a prototype installation for the SwissFEL



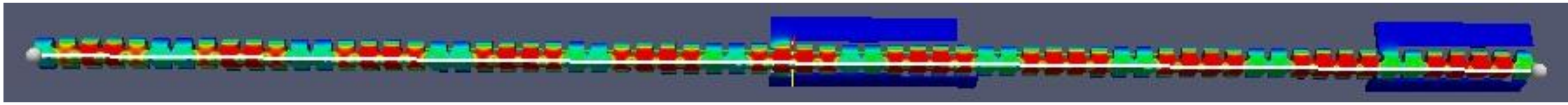
•X band structure (commono development of PSI, CERN, ELETTRA) to linearize the longitudinal phase space for high efficiency bunch compression – current state of the system:

•Klystron run in diode mode

•X Band structure was installed in August, problems with mover system, was removed beginning October to put in stronger stepper motors, is now reinstalled, expect first high power tests beginning of March

•Nonetheless were able to do preliminary tests with the alignment monitors

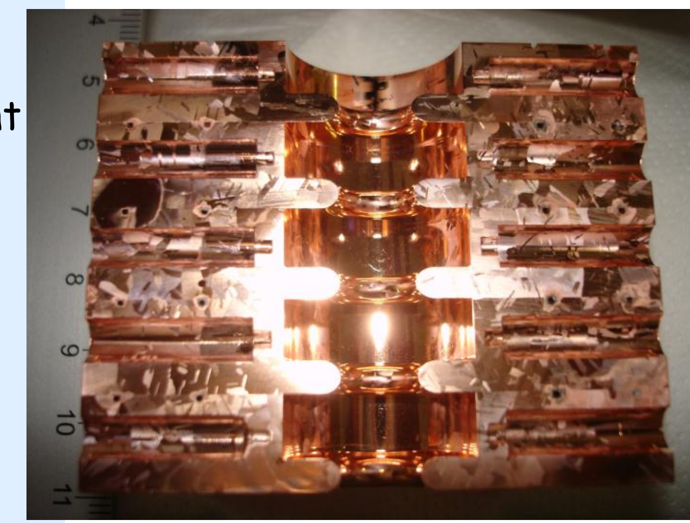
Main features



- Long constant gradient design: 72 cells, active length 750 mm
- No HOM damping
- Cooling design for 1 usec/100 Hz RF pulse
- Use 5π/6 phase advance:
  - Long cells with large mean aperture of 9.1 mm: small transverse wake
  - Intrinsically lower group velocity: Good gradient even for open design with large iris
- Wake field monitors to ensure optimum structure alignment
- Average gradient 40 MV/m (30 MeV voltage) with 29 MW input power
- Group velocity variation: 1.6-3.7%
- Fill time: 100 nsec
- Average Q: 7150

Above: field distribution as calculated with ACE3P

Prototype stack



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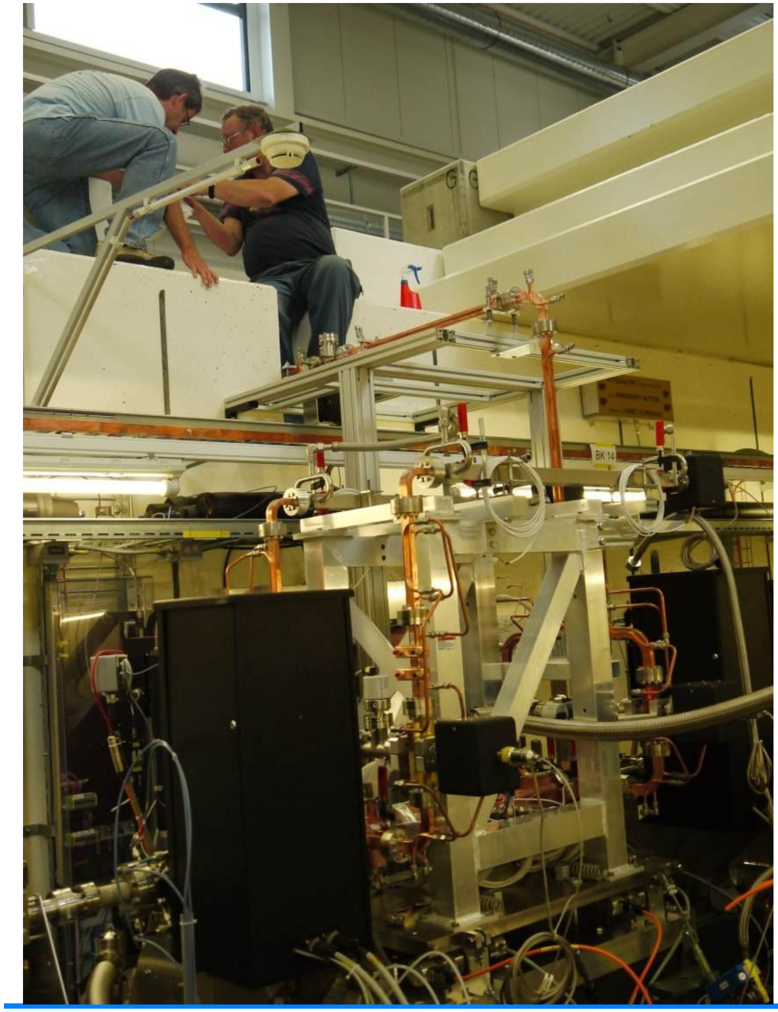
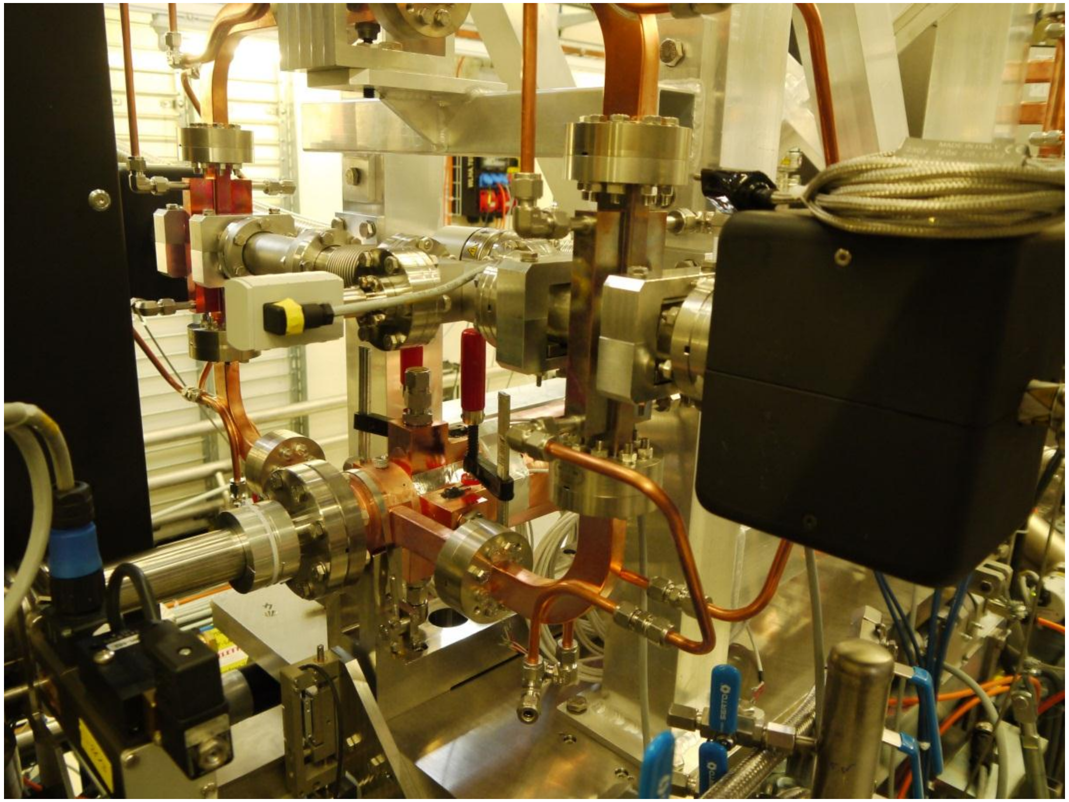
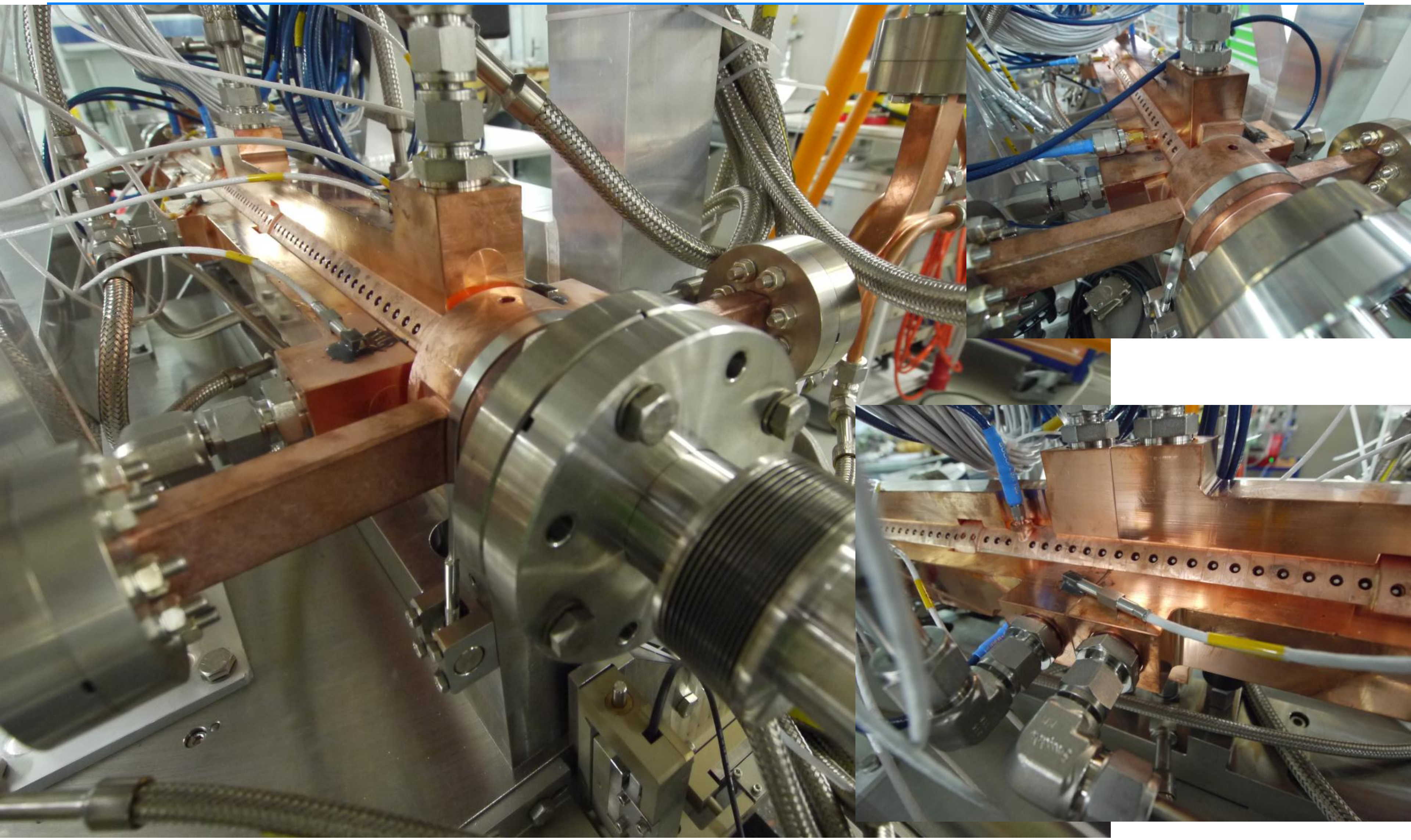
Impressions from the installation





Close view of the structure



Design of wake field monitors

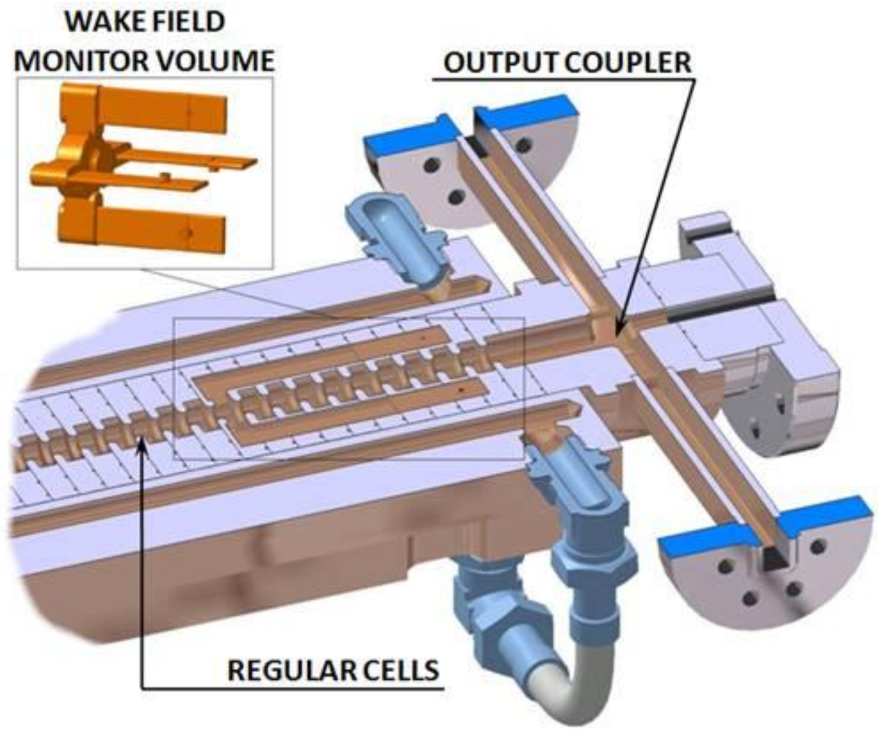
TE type coupling minimizes spurious signals from fundamental mode and longitudinal wakes

Need only small coupling (Qext<1000) for sufficient signal

Minor loss in fundamental per- formance: 10% in Q, <2% in R/Q

Output wave guides with coaxial transition connecting to measurement electronics

Big advantage: Even accounting for mechanical tolerances, extremely strong suppression of longitudinal signals – precondition for ultra high sensitivity measurements!!



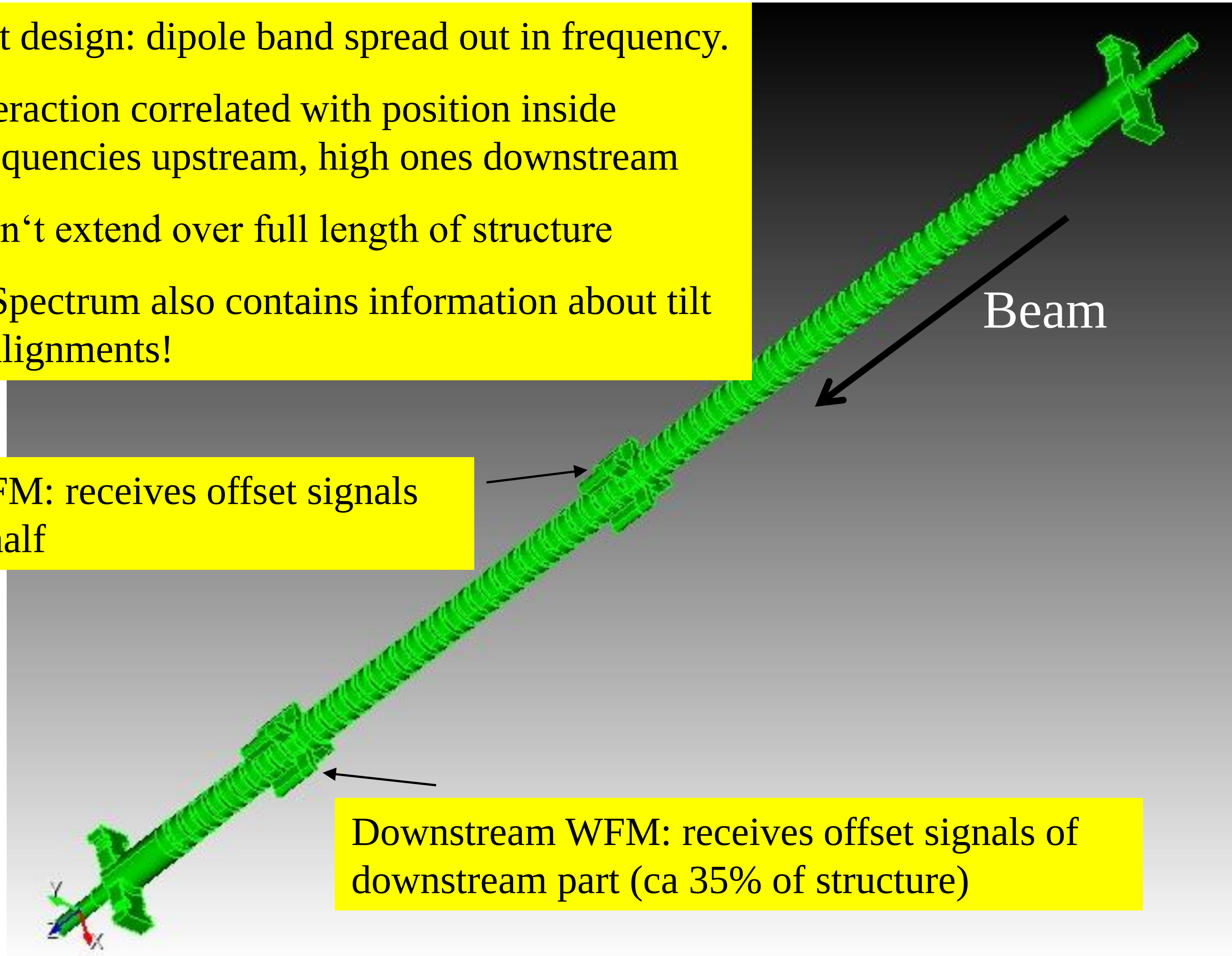
Two sets of monitors

Constant gradient design: dipole band spread out in frequency.

Frequency of interaction correlated with position inside structure, low frequencies upstream, high ones downstream

Dipole modes don‘t extend over full length of structure

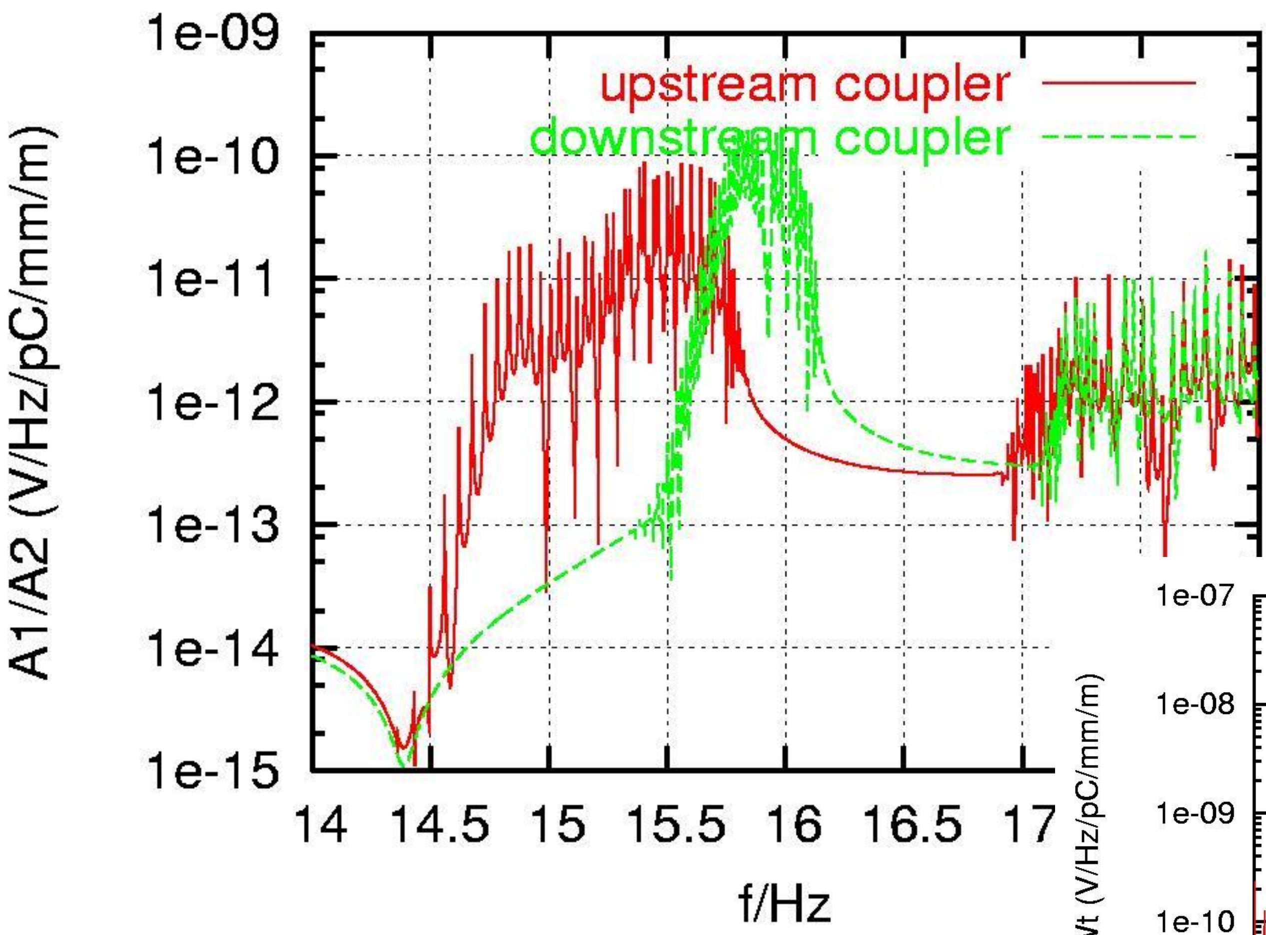
Big Advantage: Spectrum also contains information about tilt and internal misalignments!



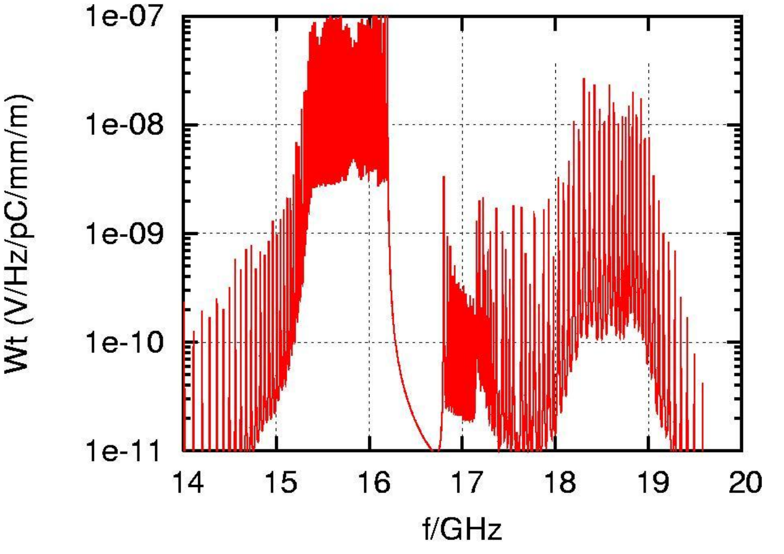
Upstream WFM: receives offset signals of upstream half

Downstream WFM: receives offset signals of downstream part (ca 35% of structure)

Output signal spectra

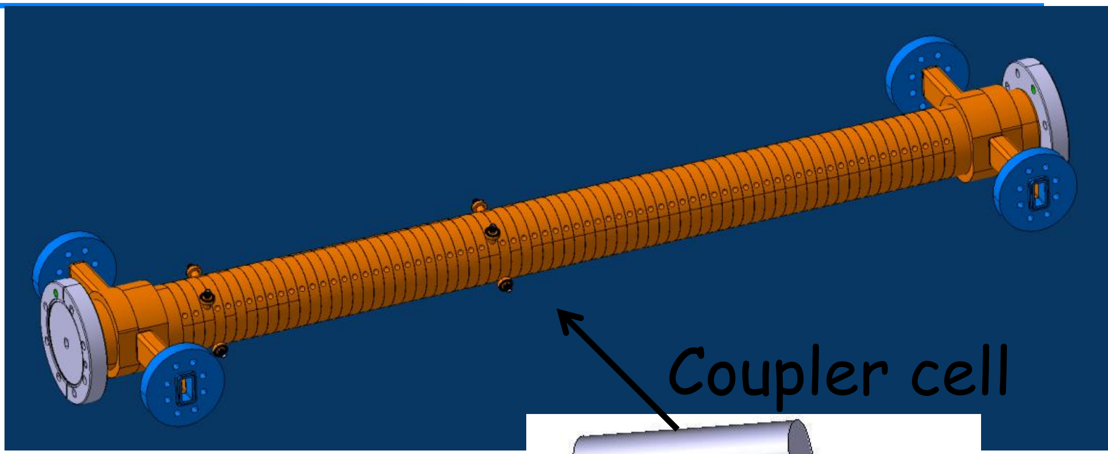


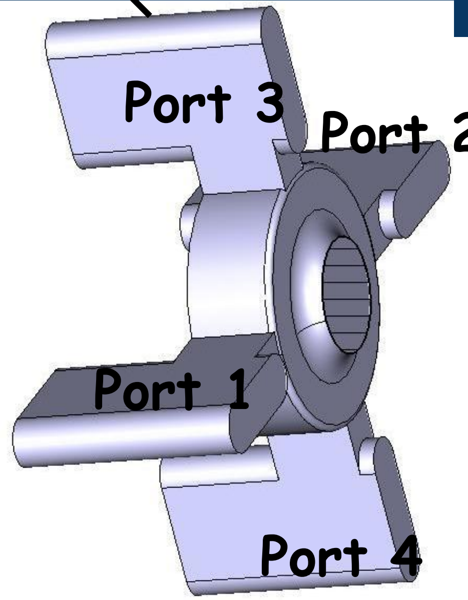
Dipole wake spectrum



Lab Characterisation of WFM

Characterisation of WFMs using a network analyzer

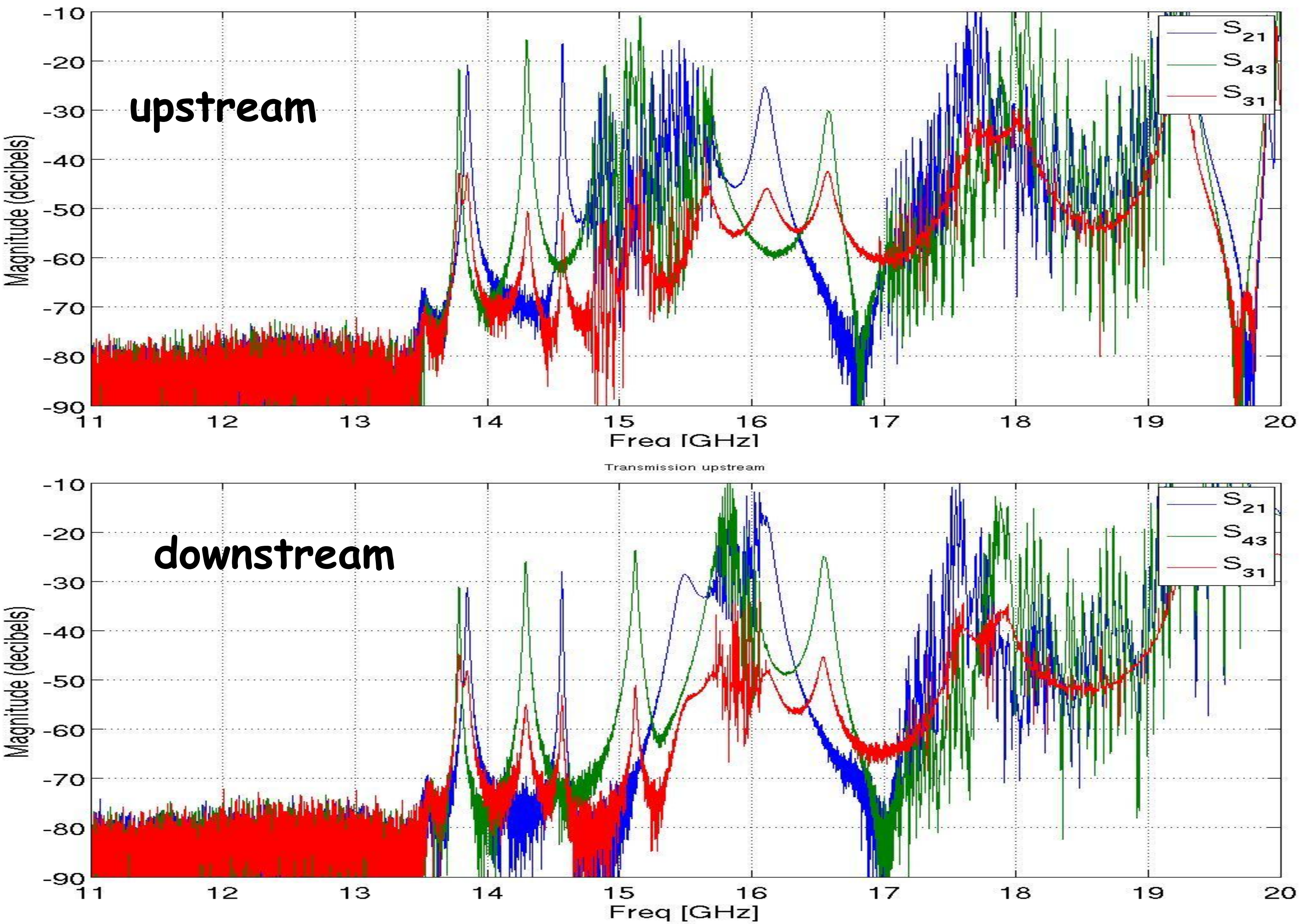




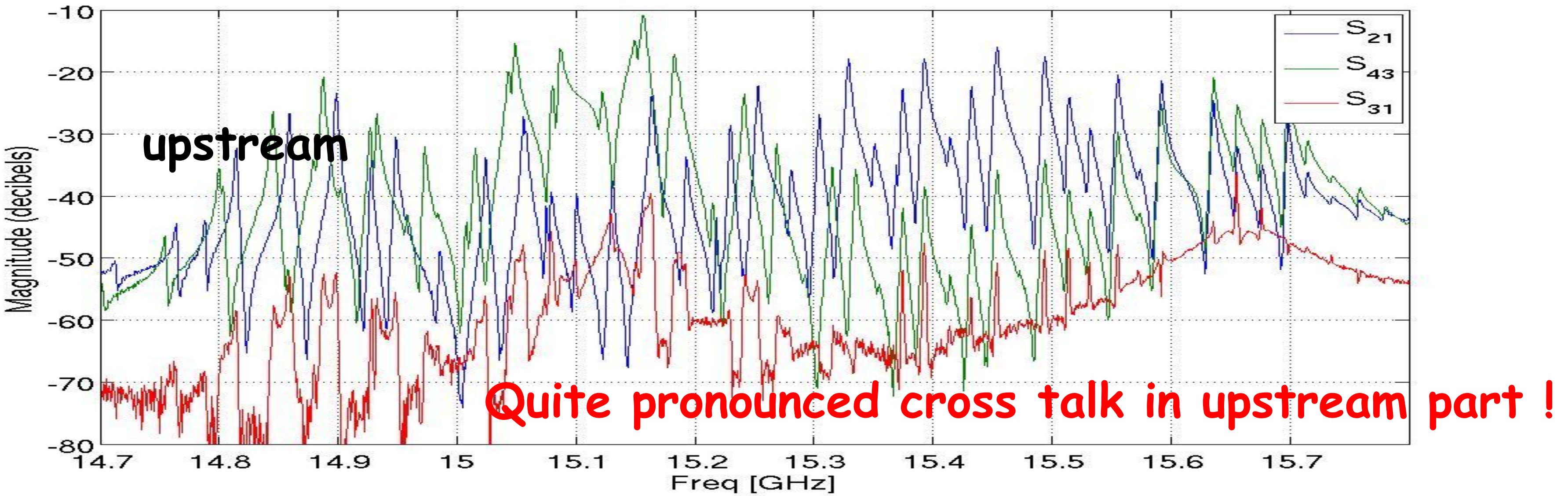
- Fundamental mode
- Horizontal dipoles: Transmission Port 1 → 2
- Vertical dipole: Transmission Port 3 → 4
- Cross talk horizontal/vertical (Mechanical alignment!!): Transmission Port 1 → 3

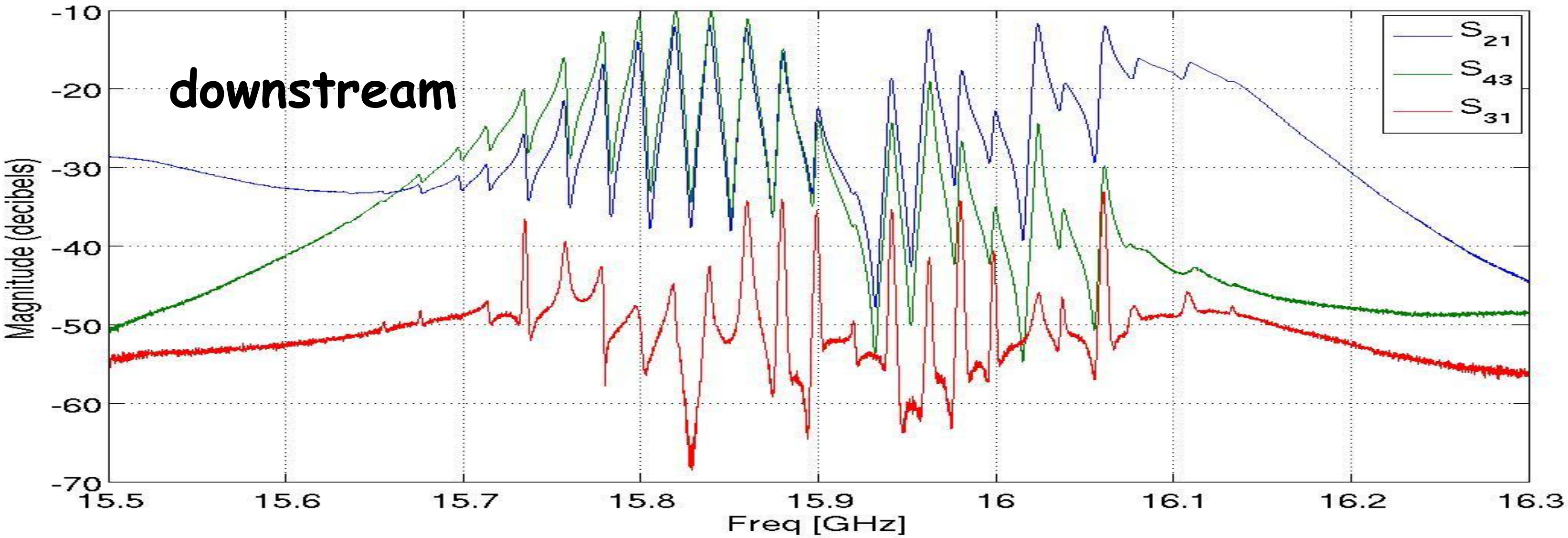
Spectra not weighted with kick factor, so don‘t compare to wake/WFM spectra.

Transmission wide frequency
- No coupling at all to fundamental mode!

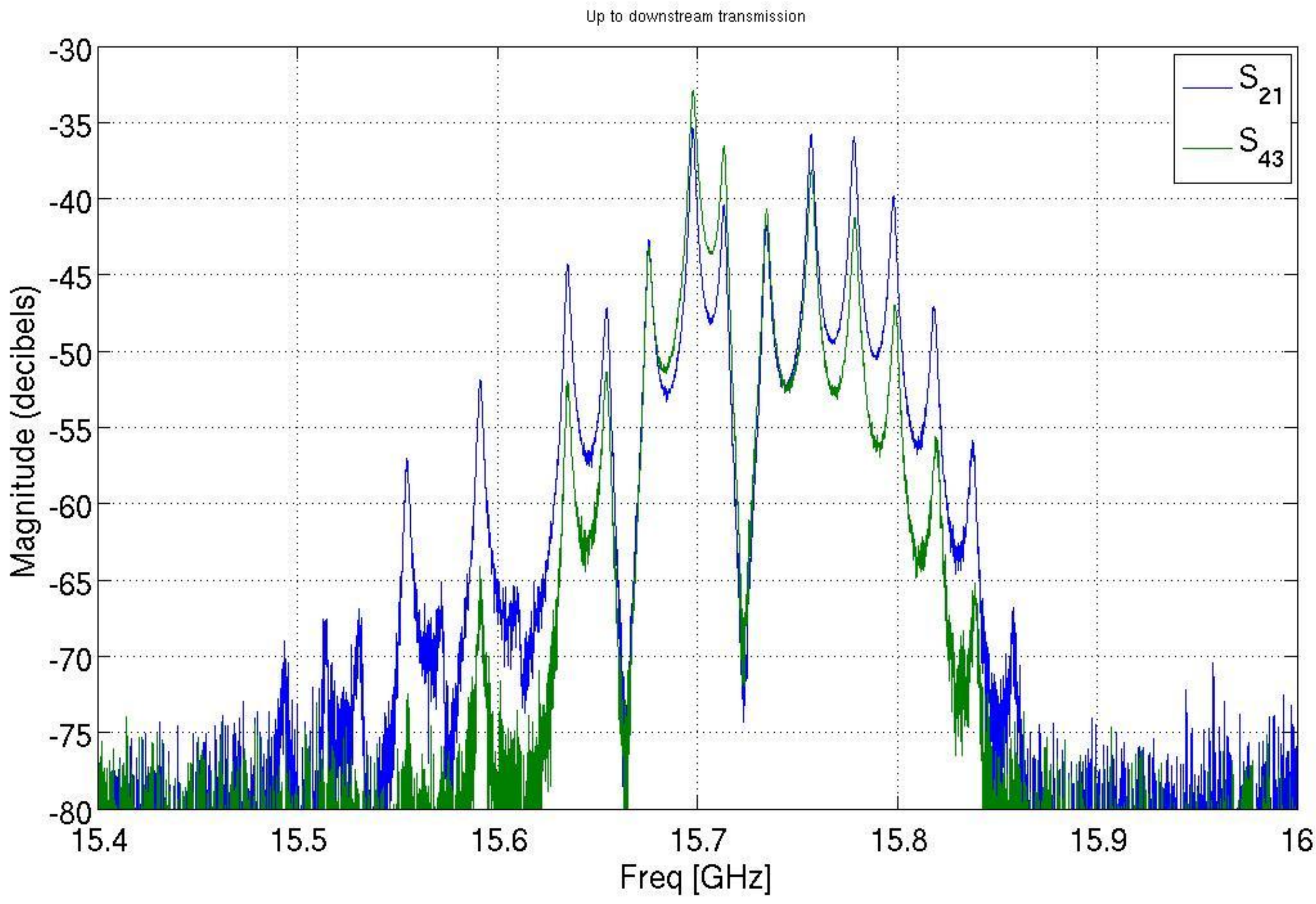


Transmission first dipole band





Transmission up-/downstream



Characterisation with beam

Measurements of transverse effects

- Mechanical movers were not working, so had to run an orbit bump through the structure. Also, structure was not centered on golden orbit (offset ~ 500um)
- Similar to ELETTRA, structure had slightly bent and twisted waveguides of the power couplers. For minimum strain on all components, structure was mounted slightly rotated (~ 10 degrees)
- Measurements were done with a very provisorical mix of cables and adapters with high (and unknown) reflection and attenuation
- Measuring with fast scope: 20 GHz BW, 40 GS/sec.

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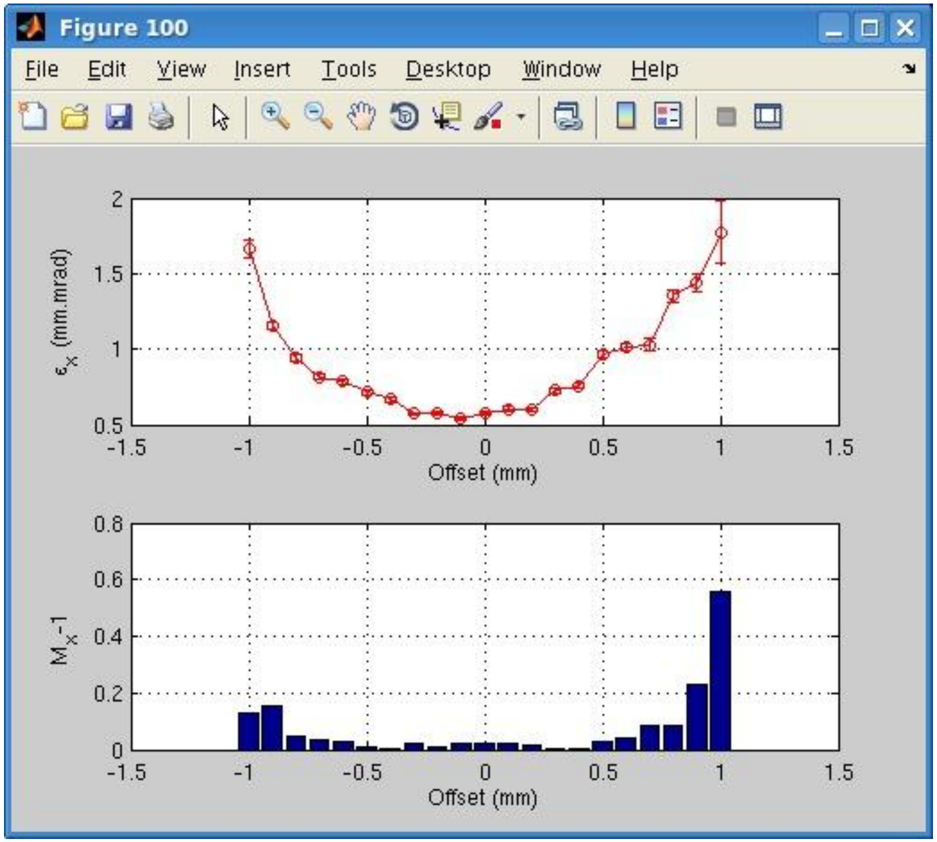
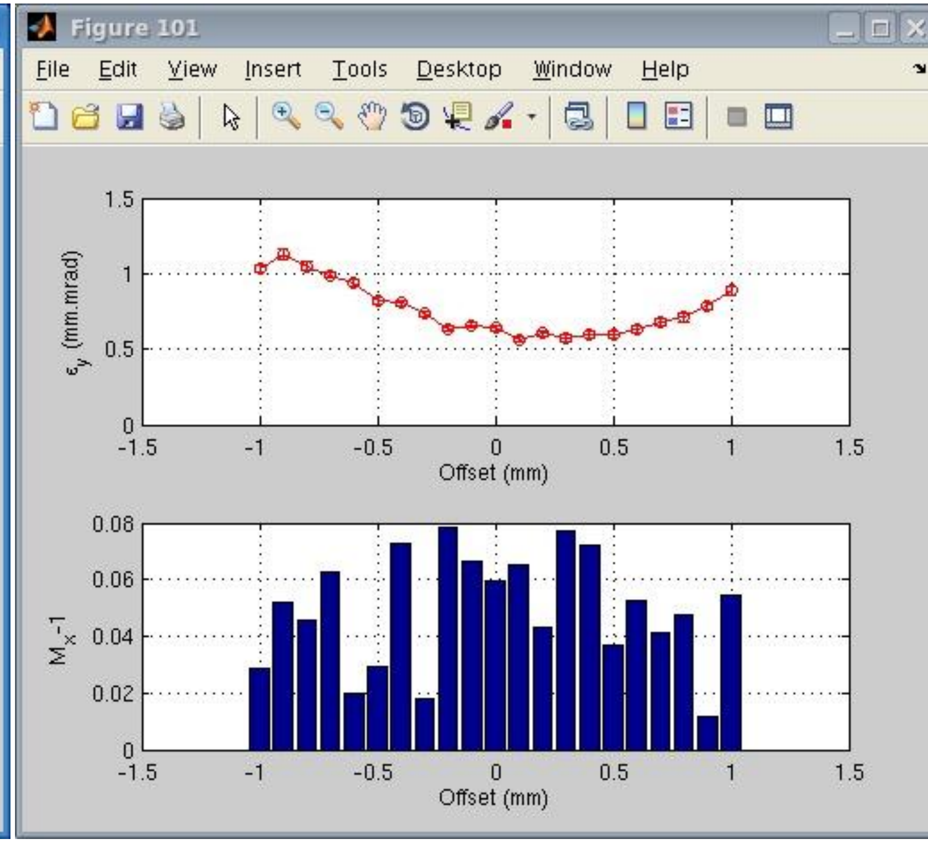
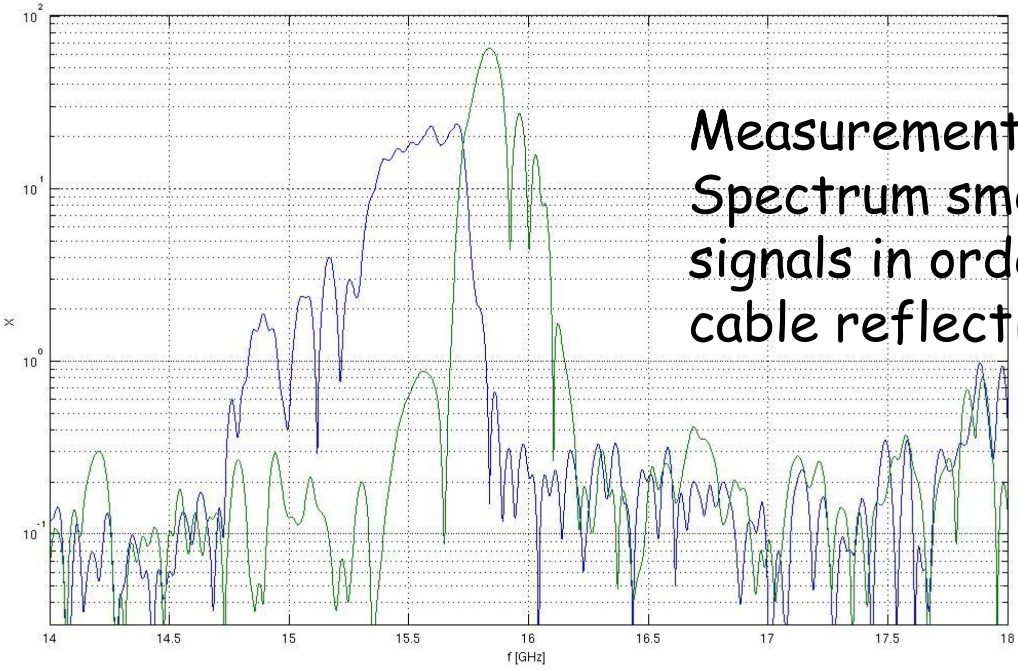
Emittance dilution vs. offset (S. Bettoni)





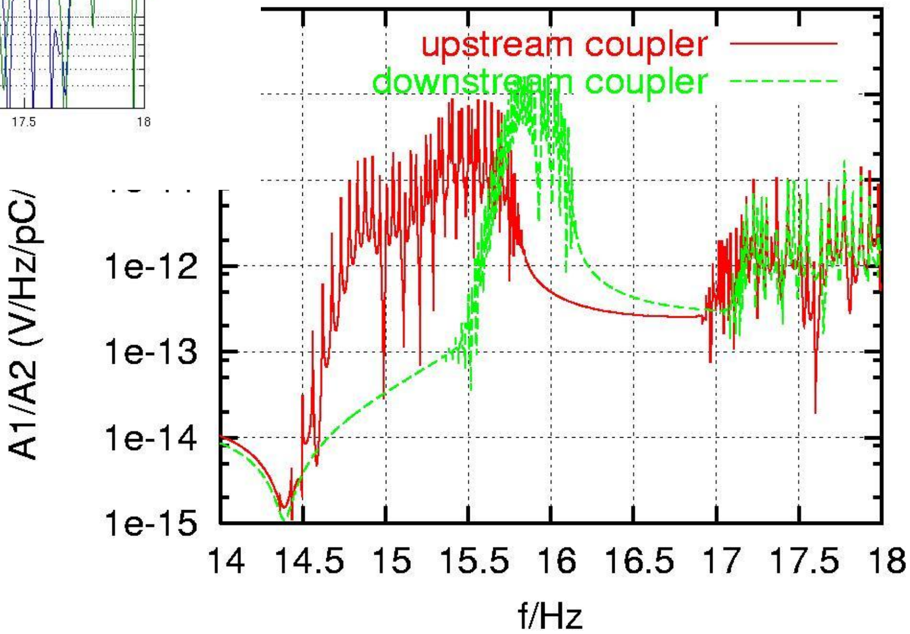
- Att: Structure not aligned on golden orbit
- Asymmetry between x and y?

Output spectrum of WFM monitors

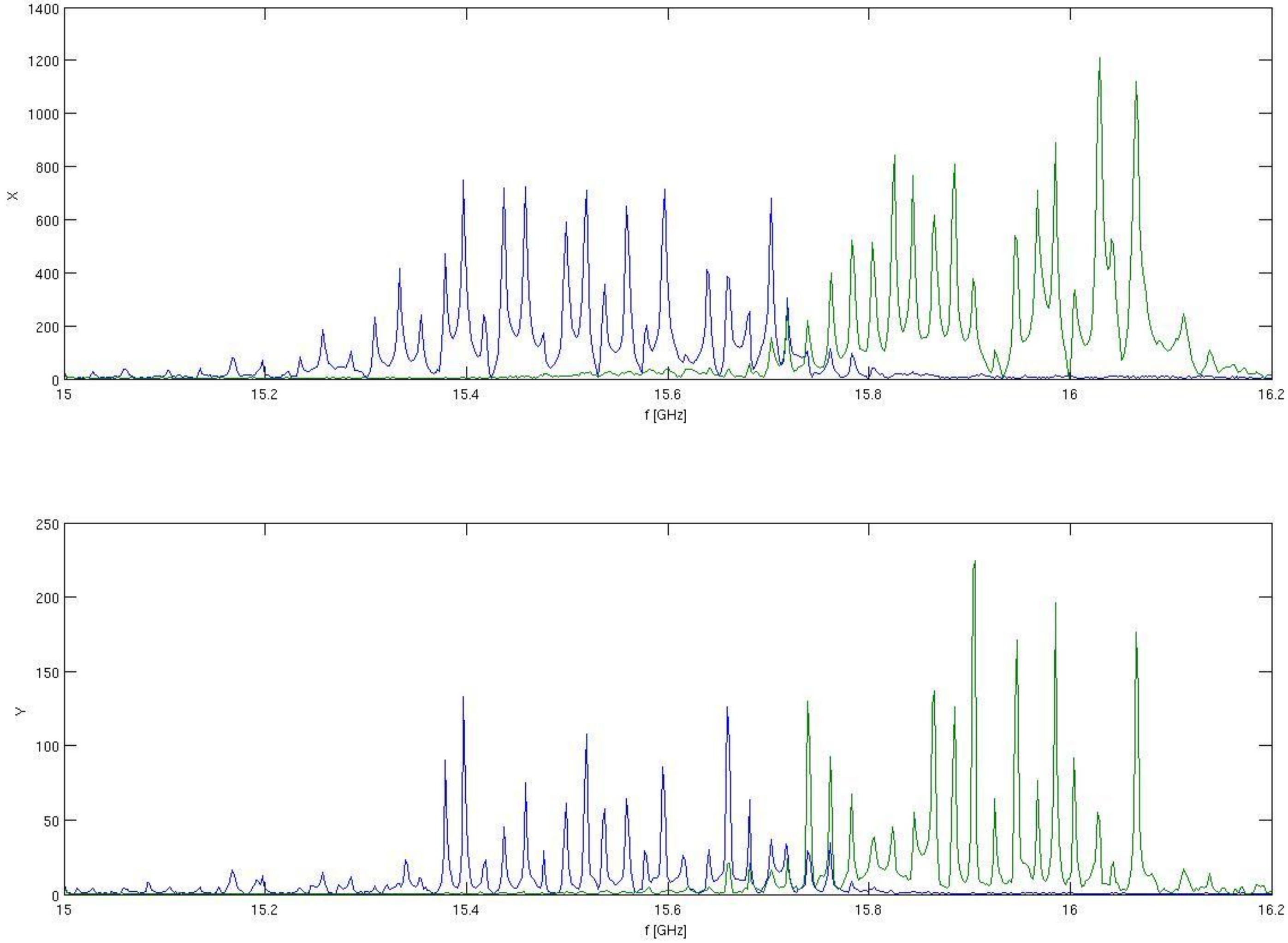


Measurement:
Spectrum smeared out by truncating signals in order to eliminate effect of cable reflections

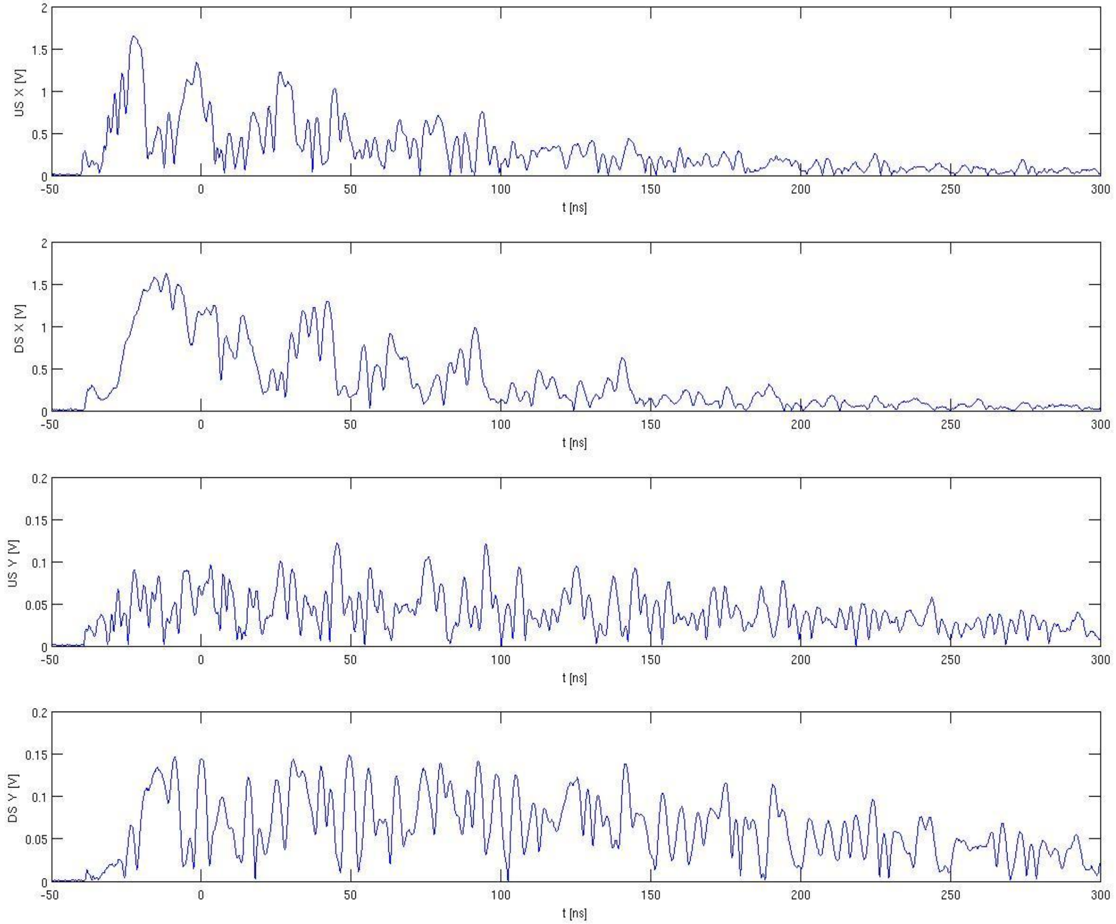
Theory



All channels for offset with 1 mm hor. offset



Time domain signals (Hilbert transformed envelopes), Q=200pC, 1mm offset



- Levels of 1.5 V roughly OK (lots of unknown attenuation & reflection!)
  - CST wake solver gives 4V (full spectrum using relatively long bunch)
  - Eqv. Circuit model 6 V

Cannot do reasonable comparison to signal shape (too much reflections)

Open question: cross talk between X and Y:

- Structure is rotated, so should expect signal in both planes, **but**
- Signal shapes should be very similar between upstream X and Y, downstream X and Y
- **?? Something perturbing the quarter symmetry of the structure, that way coupling X and Y dipole spectra??**
- **Effect already also seen in measurements with NWA**
- **No apparent effect on resolution**

Outlook

- Structure now reinstalled with working movers
- Able to align structure to golden orbit and to move the structure, better evaluation of effects on beam emittance
- New high quality cables should allow cleaner evaluation (but still without any filtering/RF front end electronics → task in EuCARD2) – internal misalignments?
- Operation with high power in March/April – effect of RF fields on beam emittance?

- …. **Plus another structure for fabrication in the queue!!!**