Subharmonic buncher at 1.5 GHz for CTF3

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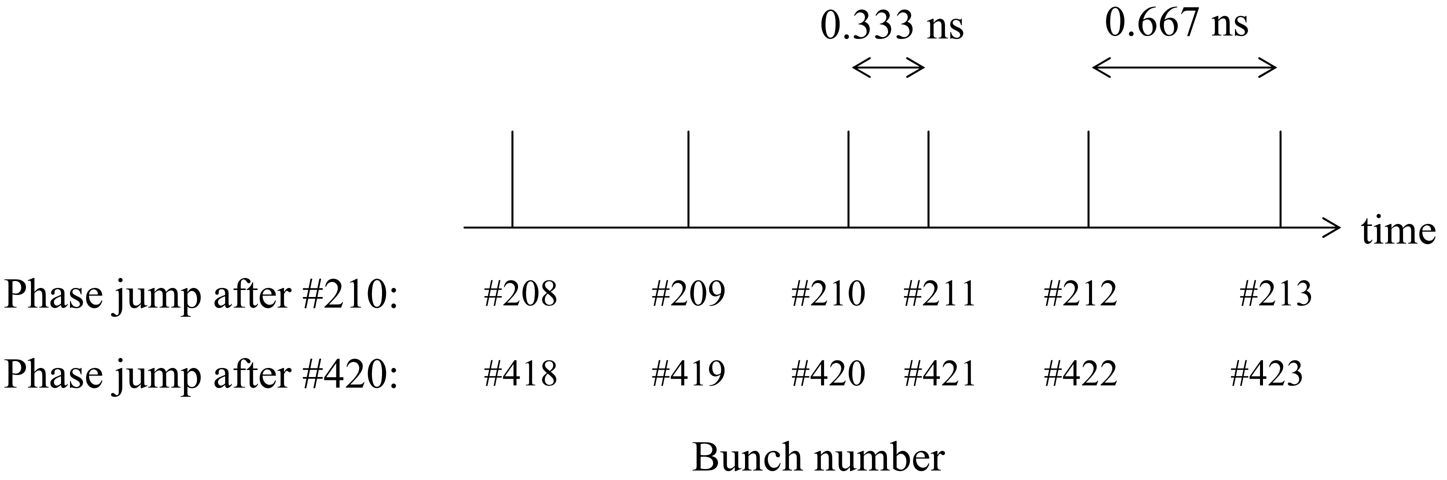
Purpose: a) bunch the beam from the injector with essentially 0.667 ns spacing.

b) using 180 deg. phase jumps all 210 bunches, to halve the spacing to the following bunch, as needed for the CTF3 stacking scheme.

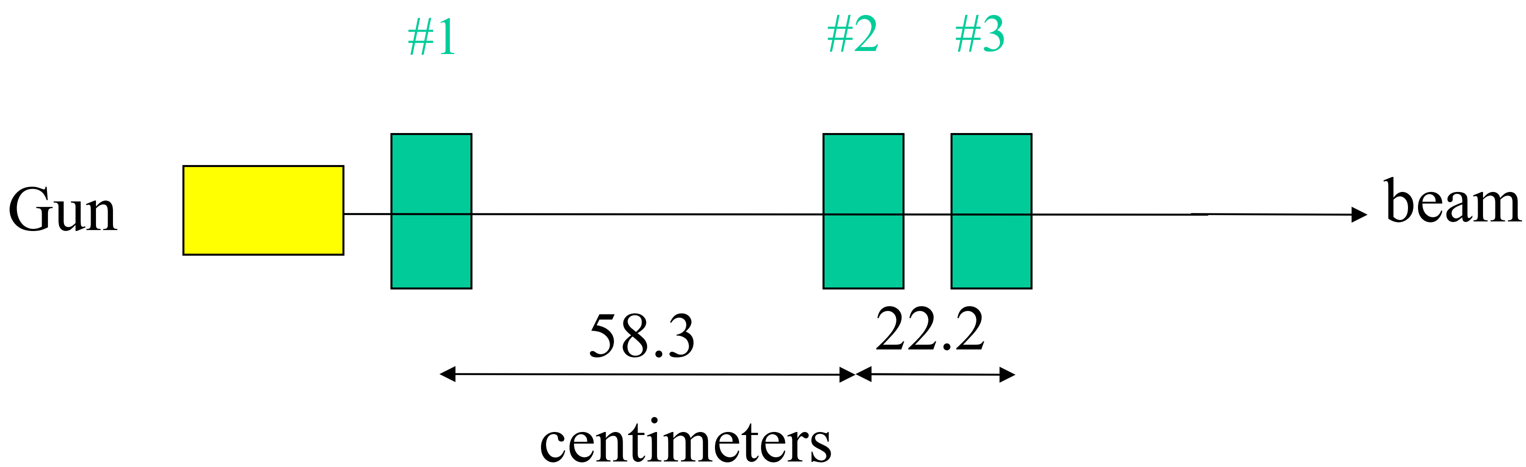


Specification:

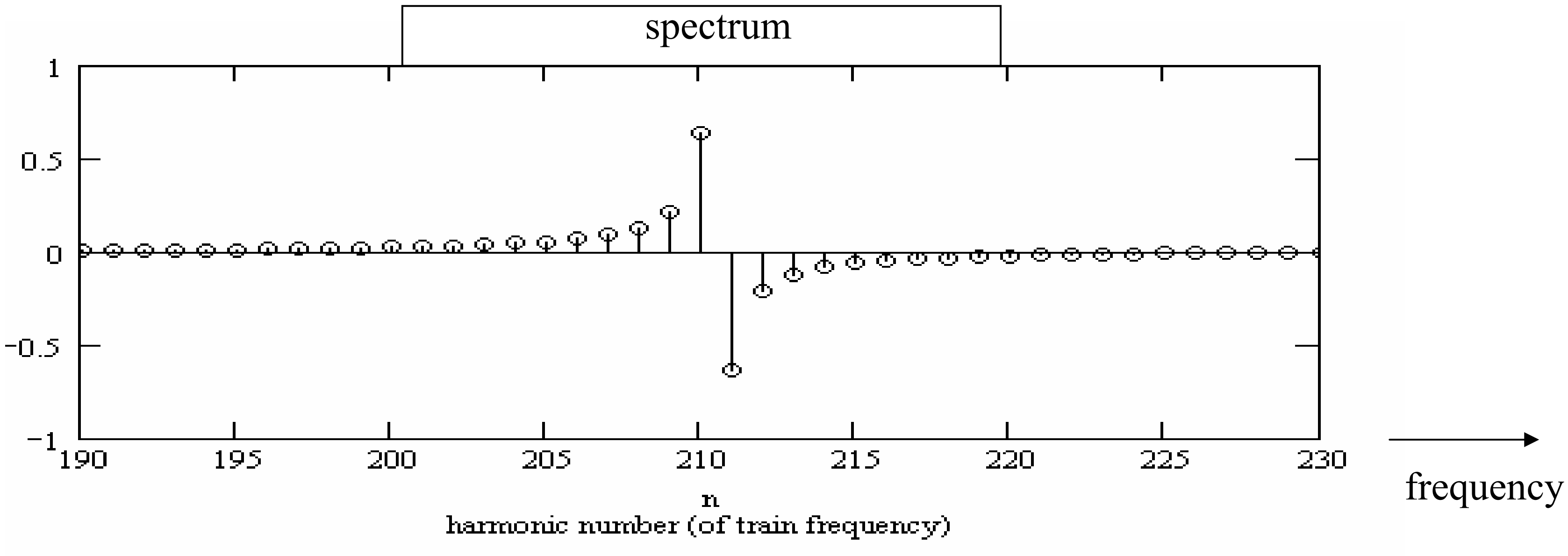
-3 identical structures, 20 keV/structure peak accel.

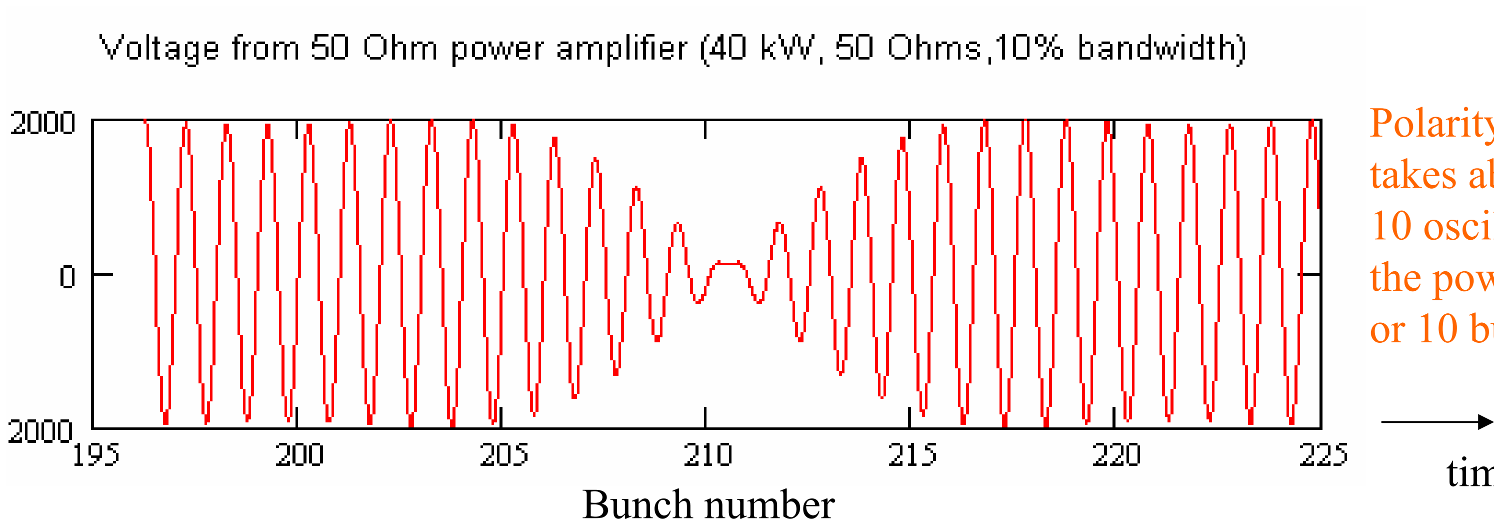
-150 MHz bandwidth for fast phase switching

For large bandwidth short structures with high group velocity are needed (short fill/drain times).



Spectrum and pulse shape

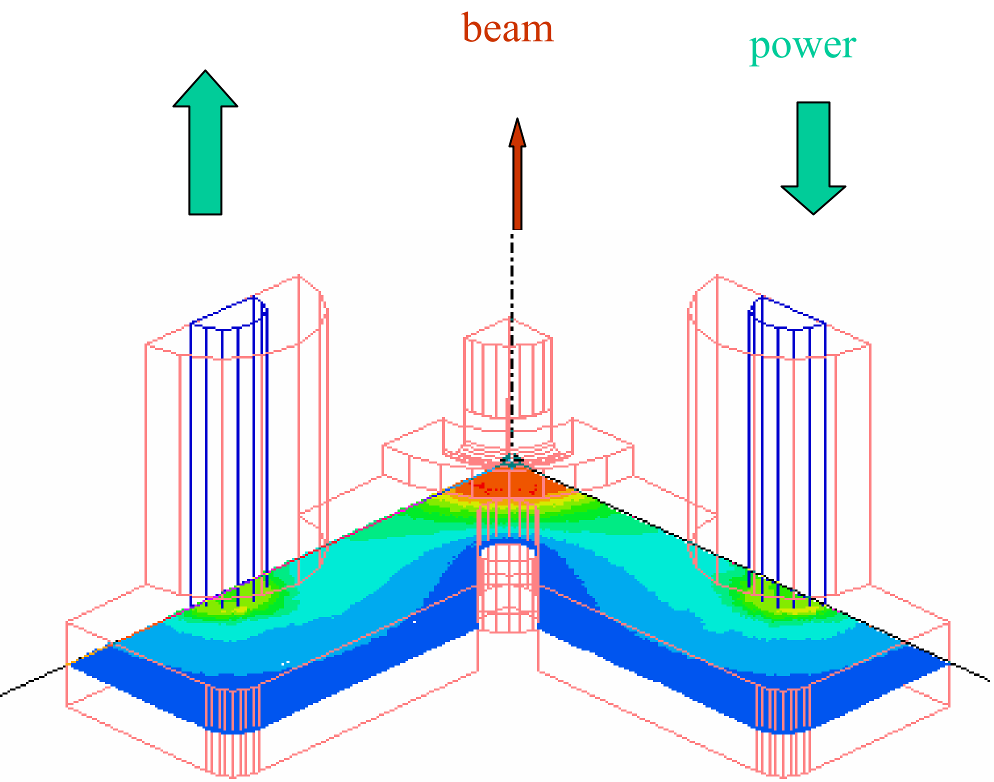




Polarity change takes about 10 oscillations after the power amplifier, or 10 bunches!

A) Short waveguide-type structure, low drain time

A. Millich G. Carron



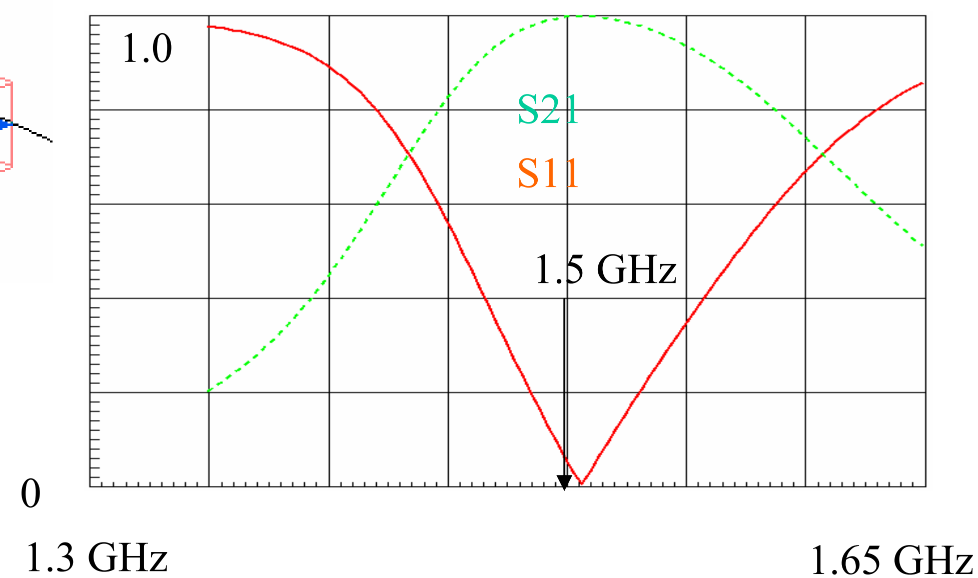
Total of 6 structures foreseen, (pairwise back to back)

10 keV/structure.

37 kW/structure

Total power 222 kW

Total 24 vacuum feedthroughs

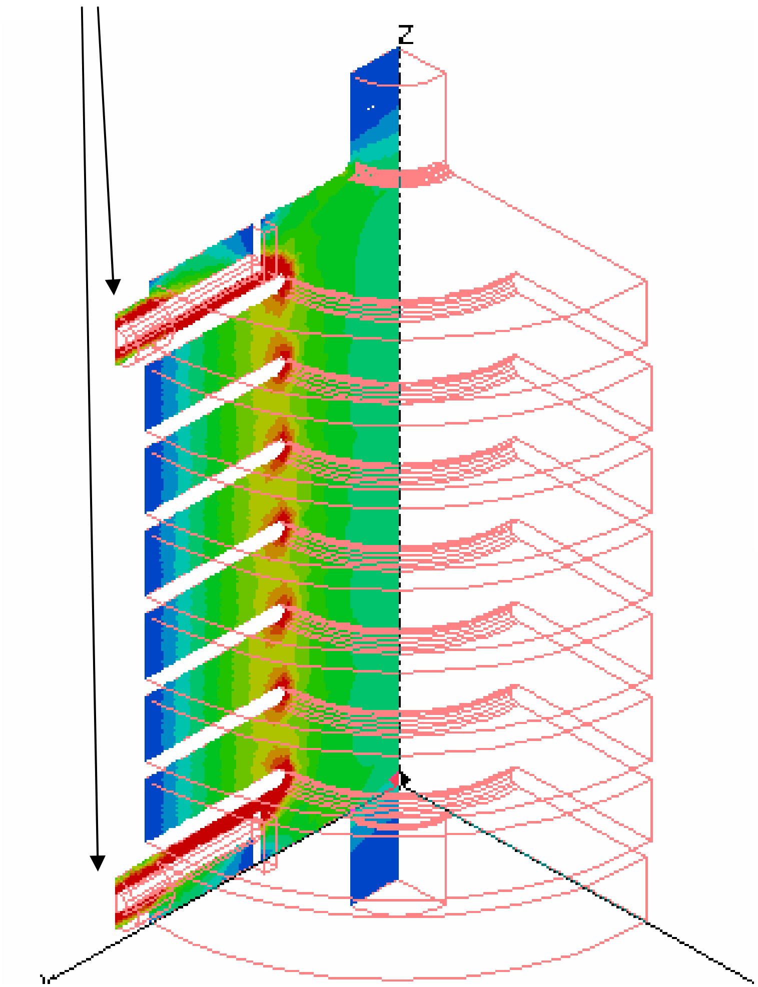


A quarter structure is shown. The power is fed onto the waveguide through coax.line to the right capacitively and exits through coax.. to the left.

Design being analysed

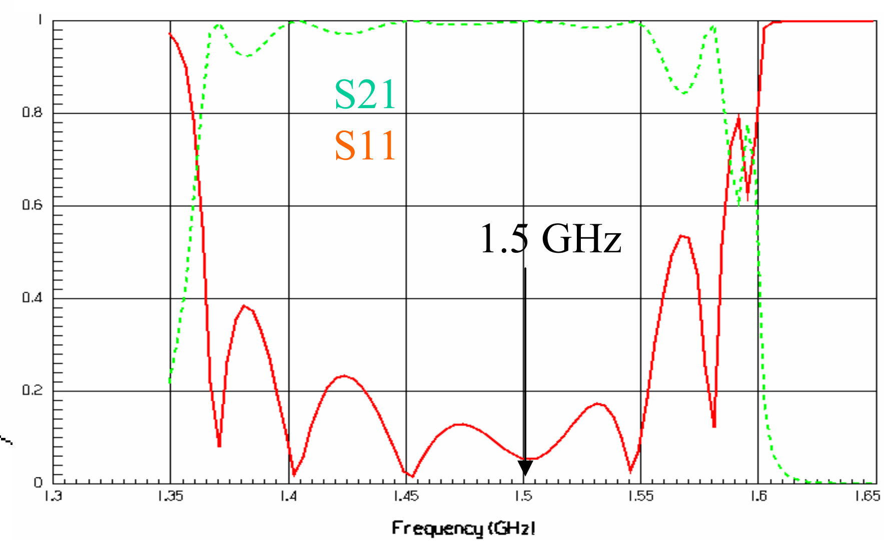
B) Conventional iris-loaded 8 cell structure

coaxial feeds to coupler loops

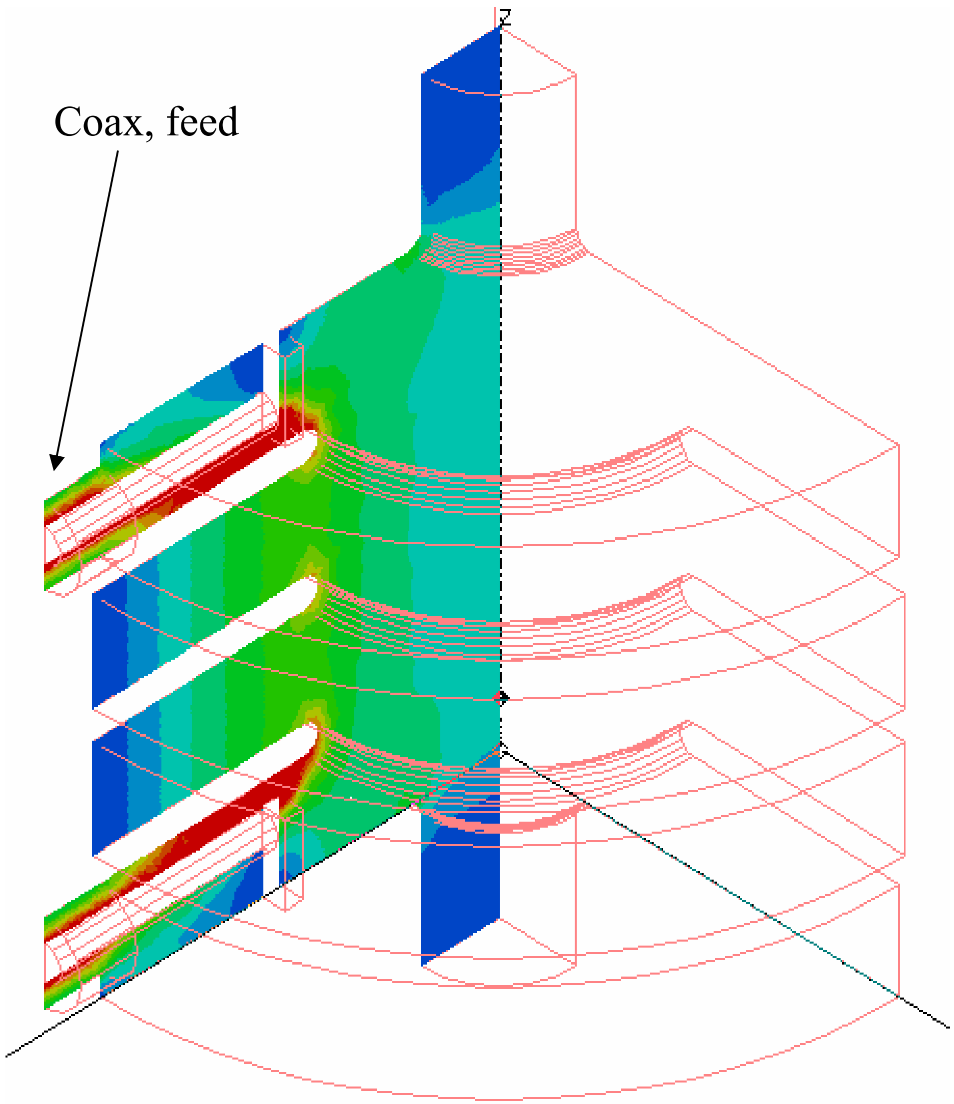


length = 26 mm/cell
R/Q = 56 Ohms/structure (circuit)
betagroup = 0.068
fill time = 9.8 ns
drain time = 8.8 ns (or time for passage of ~12 bunches)
power needed for 20 keV = 40 kW
iris diam. a = 79 mm
disk thickness = 6 mm
outer cell diam. b = 159 mm

Large bandwidth obtained with 75.5 deg./cell:



C) Short 4-cell conventional structure



length = 26 mm/cell

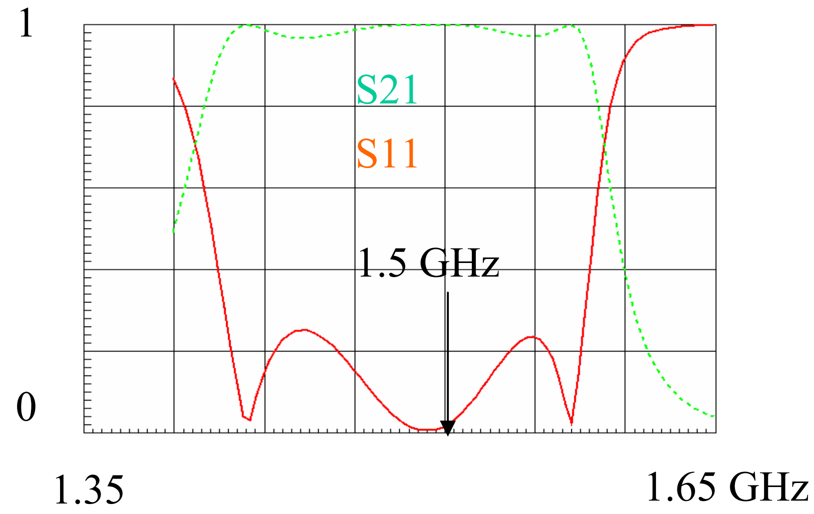
R/Q = 28 Ohms/structure (circuit)

betagroup = 0.068

fill time = 4.9 ns

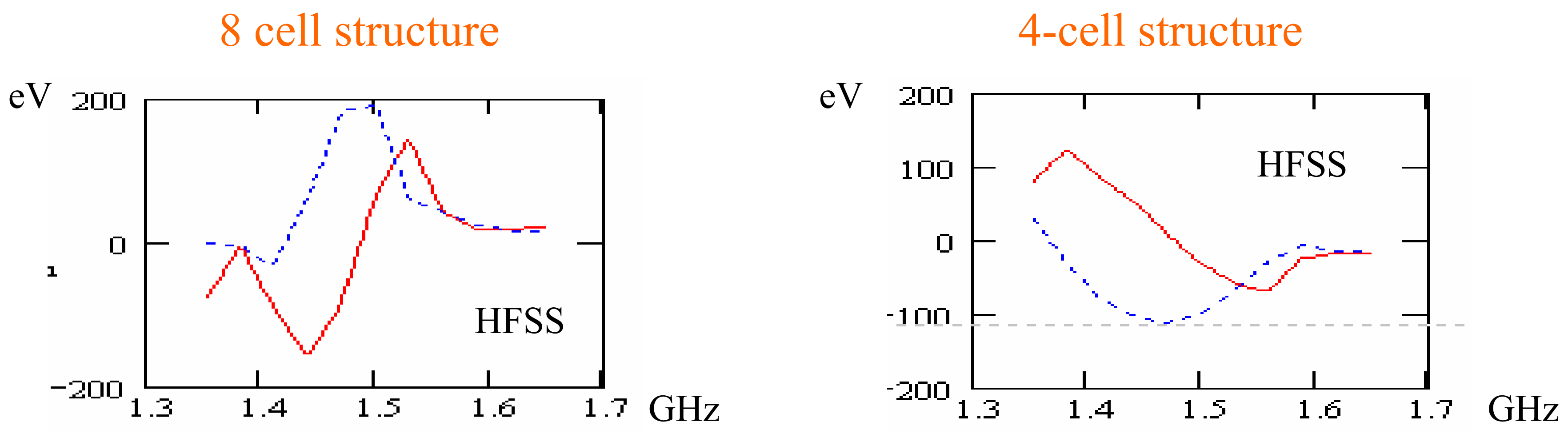
drain time = 4.4 ns (or time for passage of ~6 bunches)

power needed for 20 keV = 160 kW

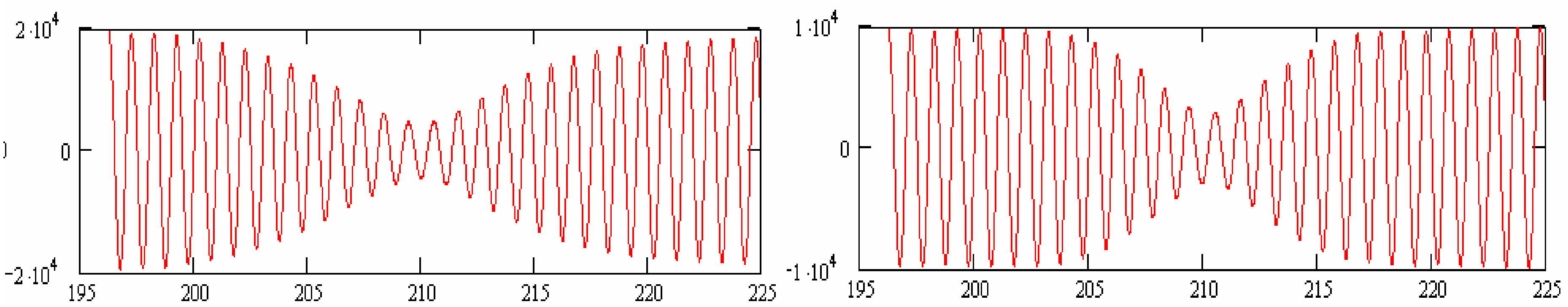


Structure performances

Acceleration for 4 W input versus frequency, complex values, HFSS results:



After multiplication: amplifier output spectrum (40 kW) X structure cheracteristics (as above)



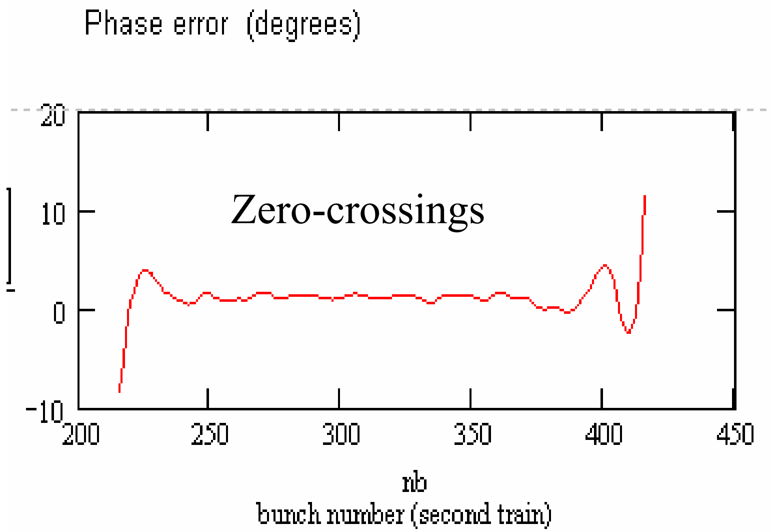
Structure fill and drain time delays are included (beamloading neglected)

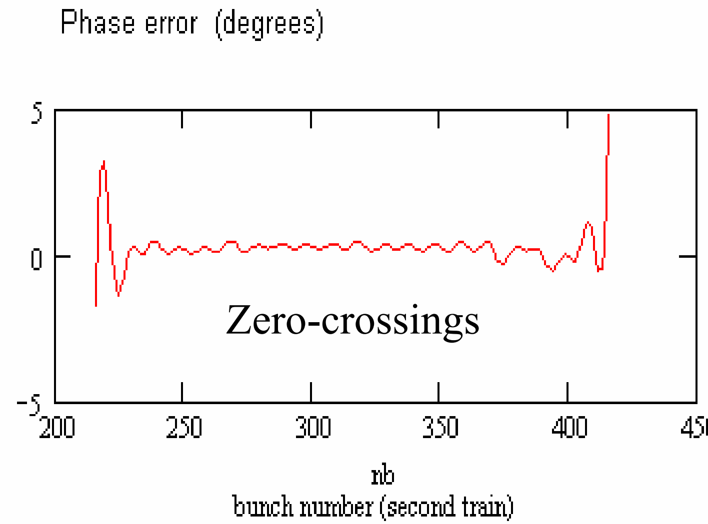
Power needed: 40 kW/structure, 120 kW total 160 kW/structure, 480 kW total

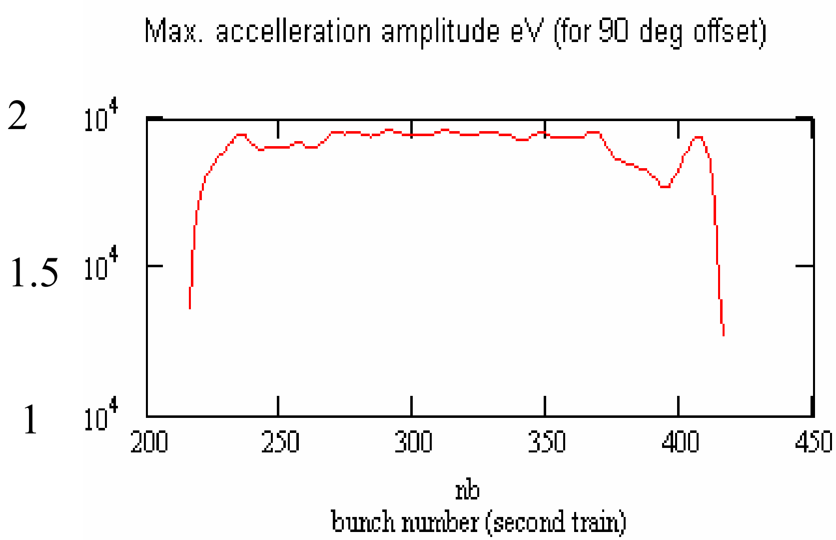
Structure performance (continued)

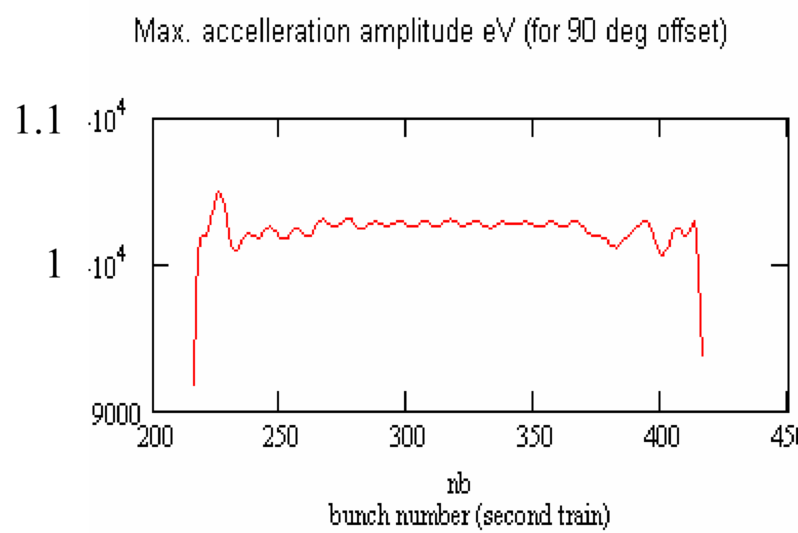
8-cell structure | 4-cell structure

Results for first 5 and last 5 train oscillations are not shown



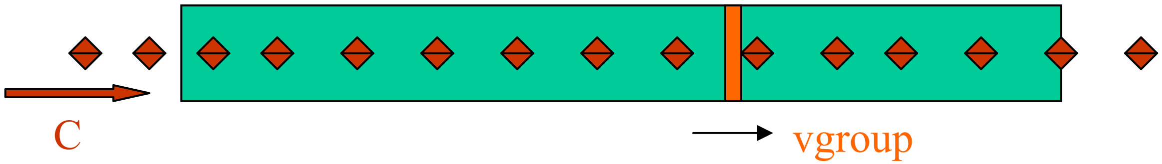






Beamloading compensation

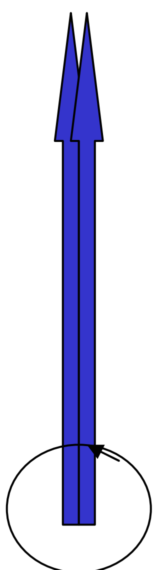
We follow an “rf-energy sample” as it moves with the group velocity in the structure:



For bunching the bunches traverse the sample when the wave is at zero crossings.
Zero crossings correspond to the wave phasor being positive and purely imaginary.

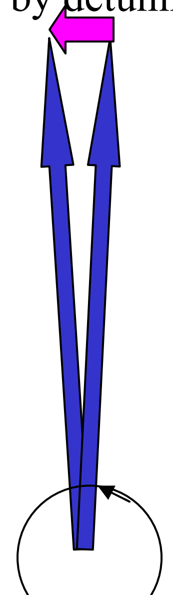
Phasor analysis shows that the set-up is correct for bunching when between passages of bunches through the moving sample, the phasor turns by an integral number of turns.

With beamloading a negative real phasor = $-q\omega R'/Q$ x (bunch formfactor) (q = bunch charge) is added at each traversal; it can be compensated by detuning:



Tuned structure with Ez phasors turning 360 deg. between bunch passages yielding correct bunching phasor.

n-1



Detuned structure with Ez phasors turning less than 360 deg. between bunch passages yield correct imaginary bunching phasor in presence of beam loading.

How to use a fixed detuning for a range of intensities and bunch form factors:

- A) The intensity is too high or the bunch too short: the phasors will turn too fast between passages through the sample.
- Cure 1: Phase the input negatively (blue phasors to the right for the first sample crossings), such that in the structure middle the phasors are upright and at the structure end they are angled to the left.
- Cure 2: Increase the power to the structure.
- B) Intensity low or bunches too long (the phasors do not turn enough): do the opposite phase adjustment

Power amplifier tubes

Most likely the choice will be between:

In case of 4-cell structures or waveguide-type structures

a) Single 750 kW broadband klystron (spare unlikely), estimated: 1MCHF
modulator available at Cern.

In case of 8-cell structures

b) Four 40 kW PITOV TWTs (one spare) offer: 114 000 $
power supplies estimated at 100 000 to 200 000 $

Time table

November 2003: Choice of structure and power amplifier(s) for ordering of amplifier(s) with finance committee agreement in december.

Both types of amplifiers need about 1 year lead time.

December 2003: Call for tenders for machined structure components.

(In-house brazing)

December 2004: Subharmonic bunchers built, tuned, installed and ready for beam tests (as well as power amplifiers).

tight !

Conclusions

- 1 The economic 8-cell structures with a total power need of 120 kW are able to satisfy the specs.
- 2 With preadjusted detuning they will also work for a nominal beam current and bunch form factor.
- 3 For a range of currents and form factors reasonable performance can possibly be obtained by phase offsets or input power changes (this remains to be shown with Parmela).