TE Wave Measurements at Cesr-TA

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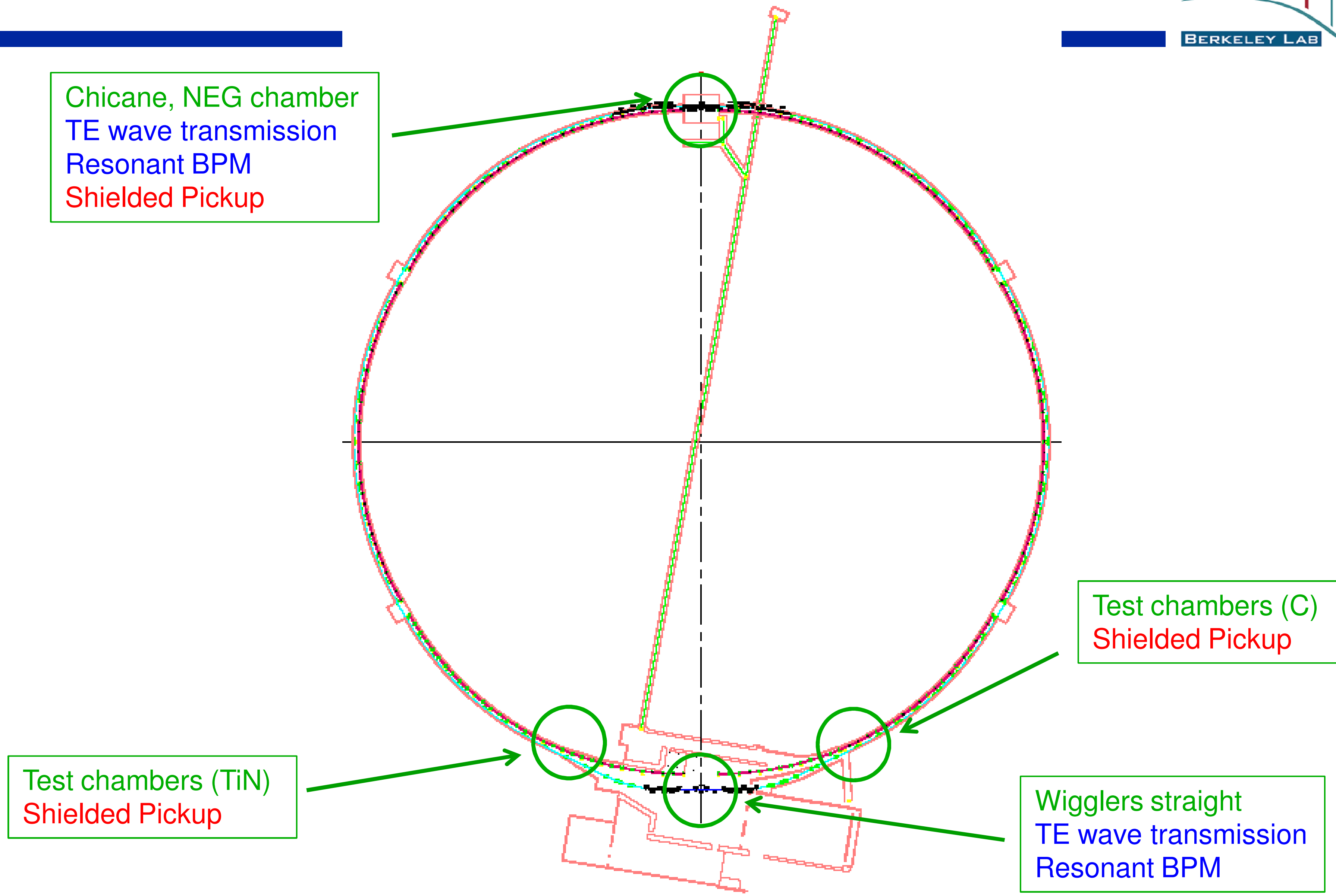
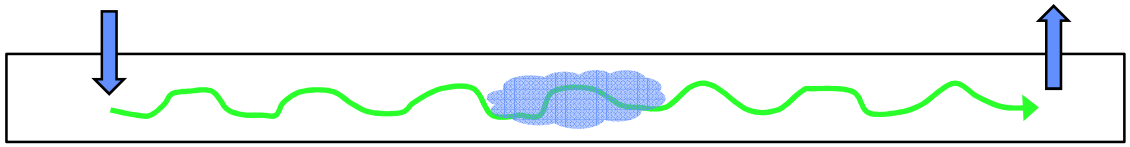
Outline

- TE wave transmission method.
- Quantitative evaluation of ECD from TE Wave, SPU data.
- Clearing solenoid NEG chamber (TE wave and SPU).
- TE wave resonance in a dipole magnet.
- Reflections and standing waves in the beampipe.
- TE wave resonant method.

TE Wave/SPU Setup on CESR

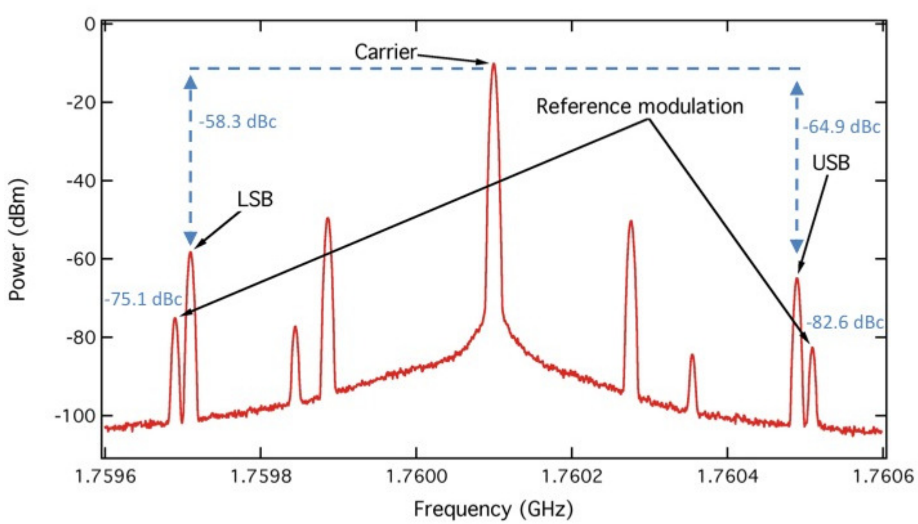


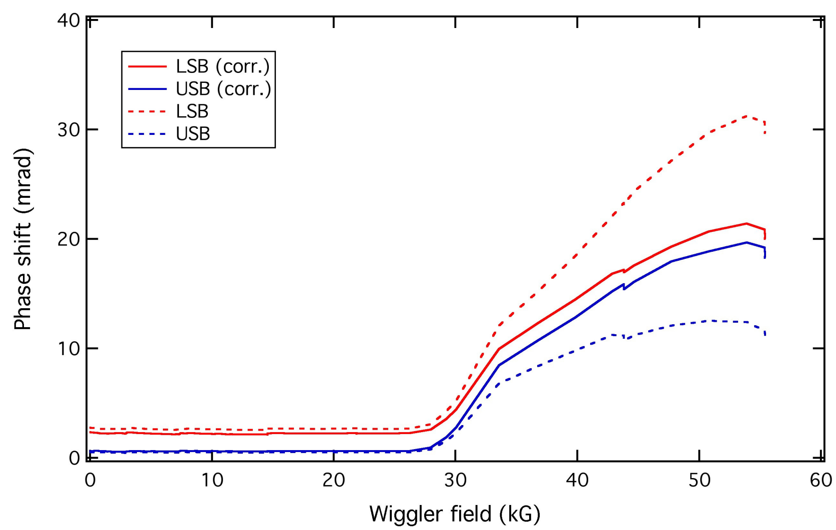
TE Wave Transmission Method



Conceptually a simple method: Changes in the wave propagation caused by the electron cloud appear as a phase modulation (requires gap). Modulation depth proportional to ECD. The devil is in the details…

For example: Reference sidebands for dynamic correction of dispersion





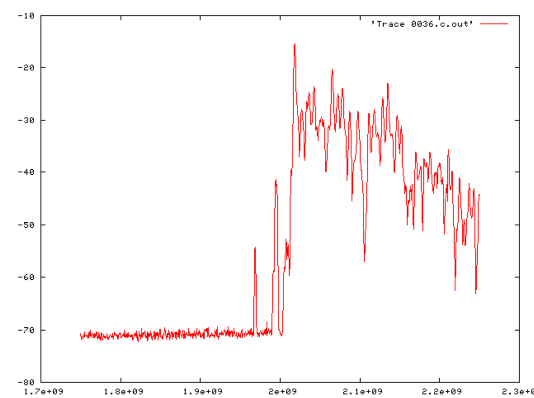
From Sidebands Amplitude to ECD

We carefully measure the relative amplitude of the modulation sidebands and estimate the modulation depth:

fill "form factor"

$$\Delta\varphi = \frac{1}{2} \cdot SB_c \frac{\pi}{\sin\left(\pi \cdot t_b \cdot f_{rev}\right)}$$

we measure this



Then we calculate the plasma frequency:

$$\omega_p = k_z c \sqrt{1 - \left(1 - \frac{\Delta\varphi}{k_z L}\right)^2}$$

Source of error: where is the cutoff ?

…and the ECD is approximately $\boxed{n_e \approx \frac{f_p^2}{80} \quad \left[e^- / m^3\right]}$

From SPU Voltage to ECD

We have shielded pickups in the machine and there are formulas for estimating the ECD from those devices too:

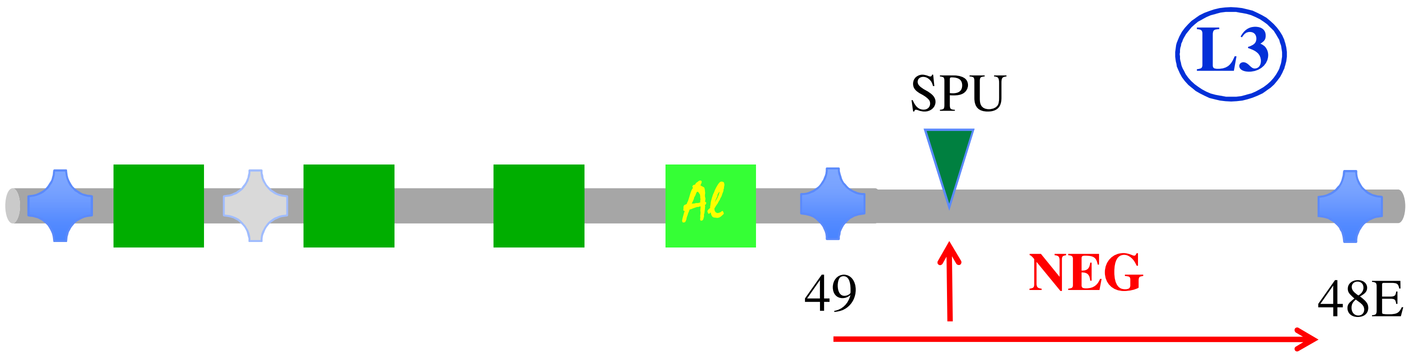
we measure this

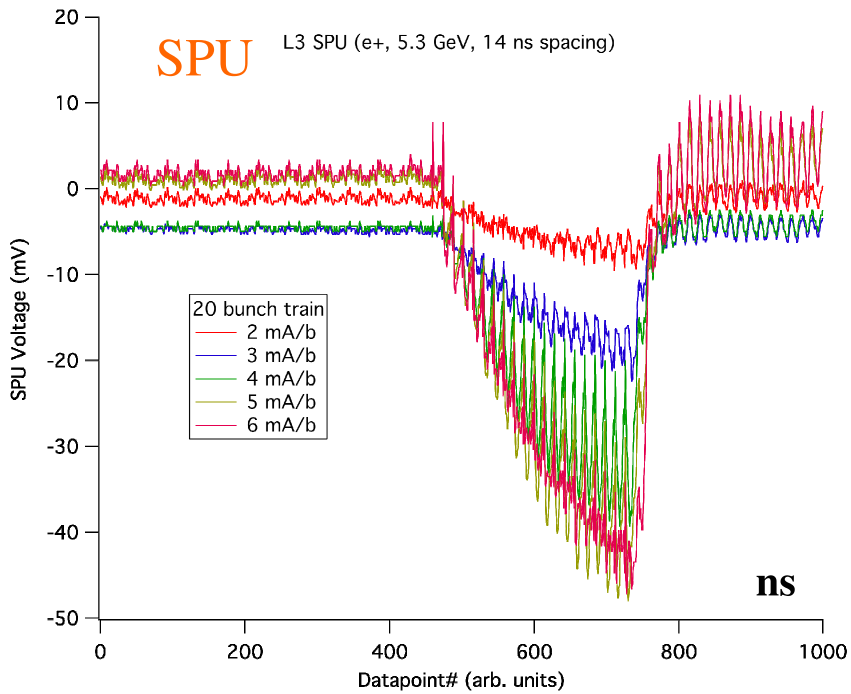
$$n_e \approx \frac{V_{SPU}}{f_b F_g t \cdot Z_{SPU} G_{tot} \pi r_p^2 q_e} \quad [e^- / m^3]$$

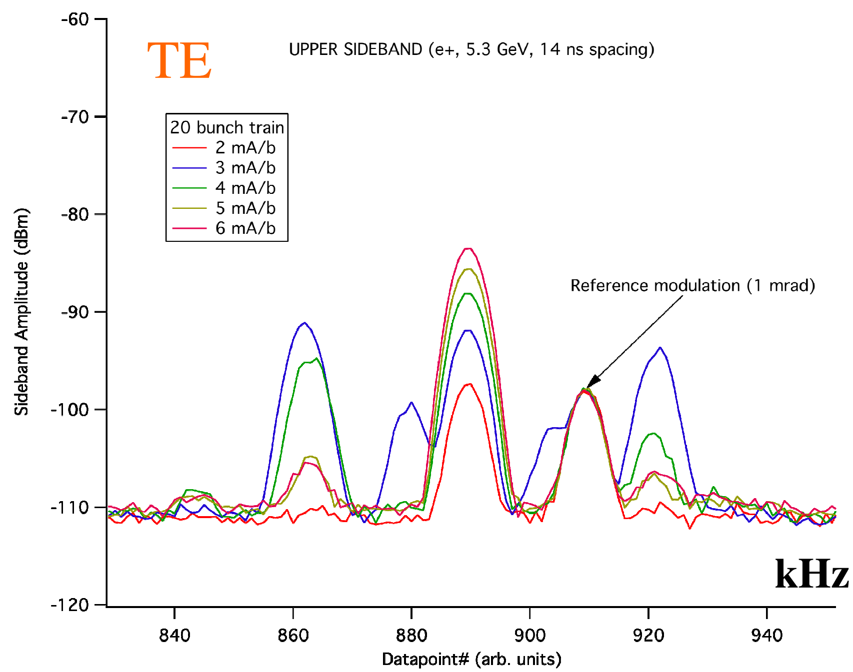
geometric factor "how much SPU area per beampipe unit length"

Notable approximation: at passage of each bunch all electrons collide with the pipe. Also, it assumes infinitely thin RF shield (i.e. does not depend on the electrons angle of incidence)

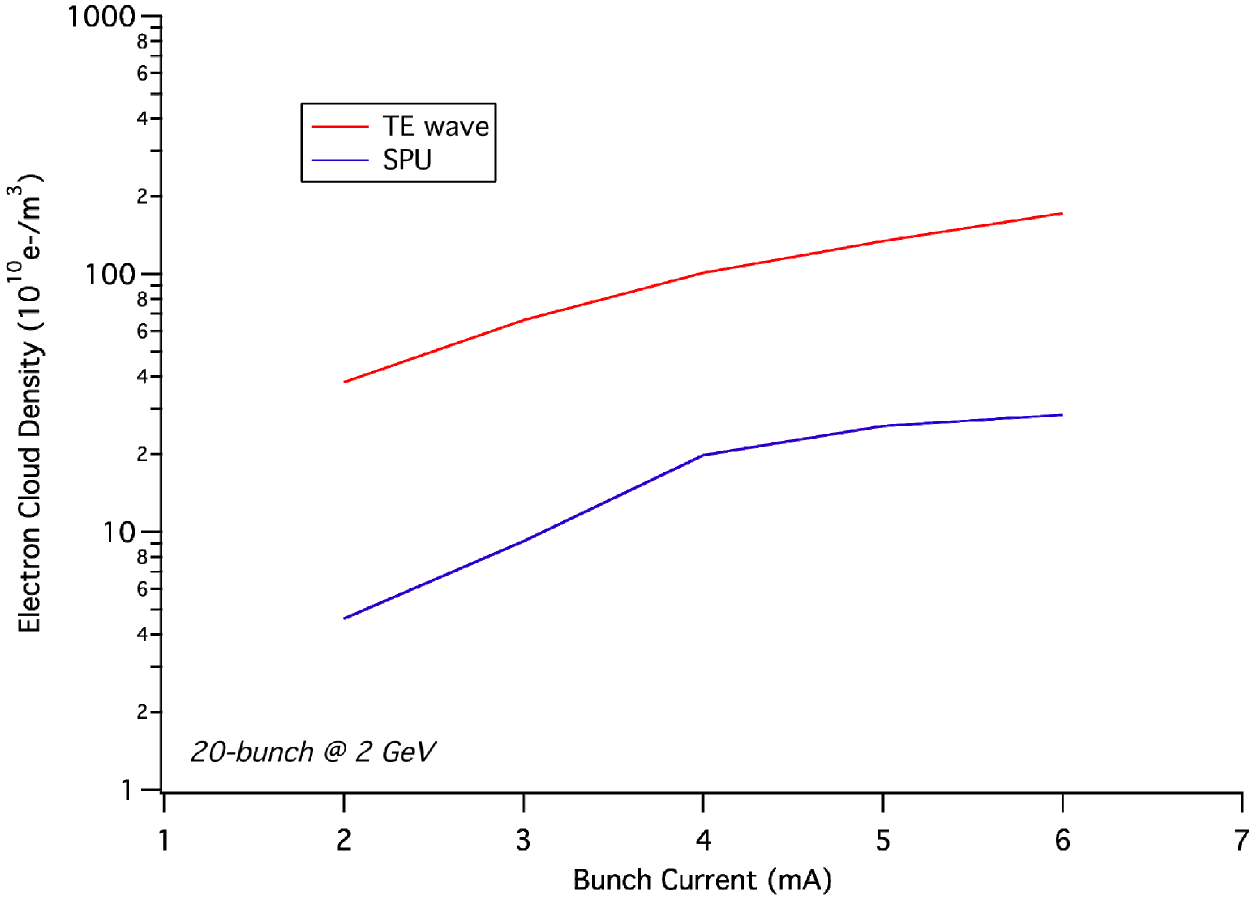
TE wave and SPU Measurements in L3







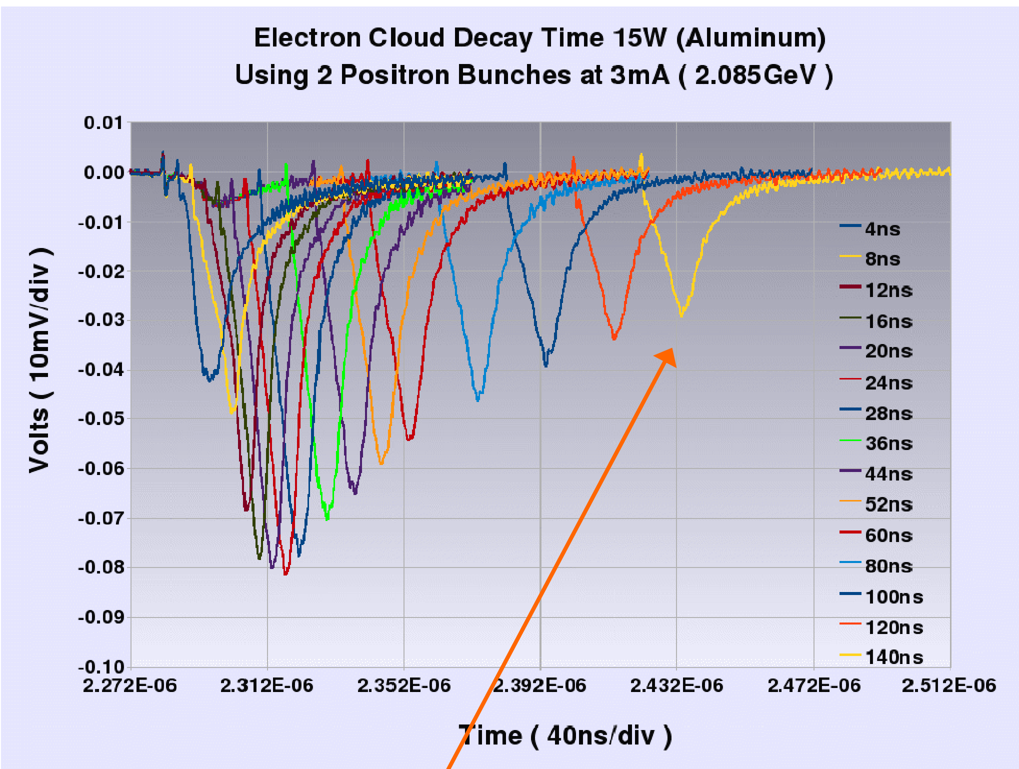
Comparison of ECD Estimates

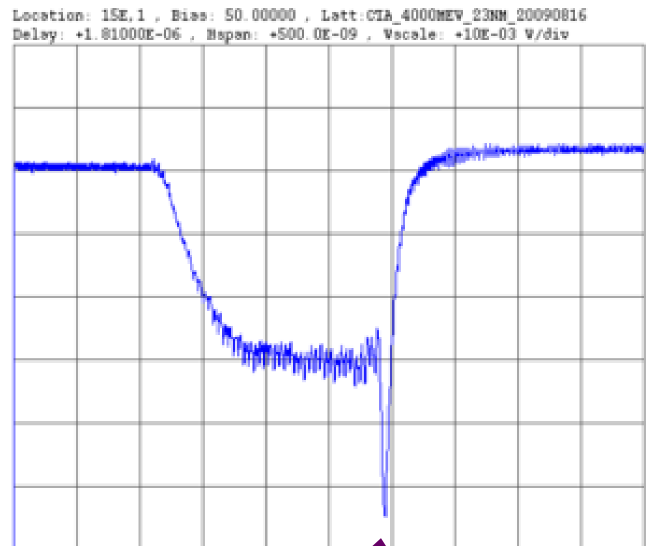


The estimate based on SPU data is about ten times lower

A Possible Reason for SPU/TE Difference

We know that electrons remain in the pipe after the bunch passage (SPU data). This effect should become smaller with longer trains.



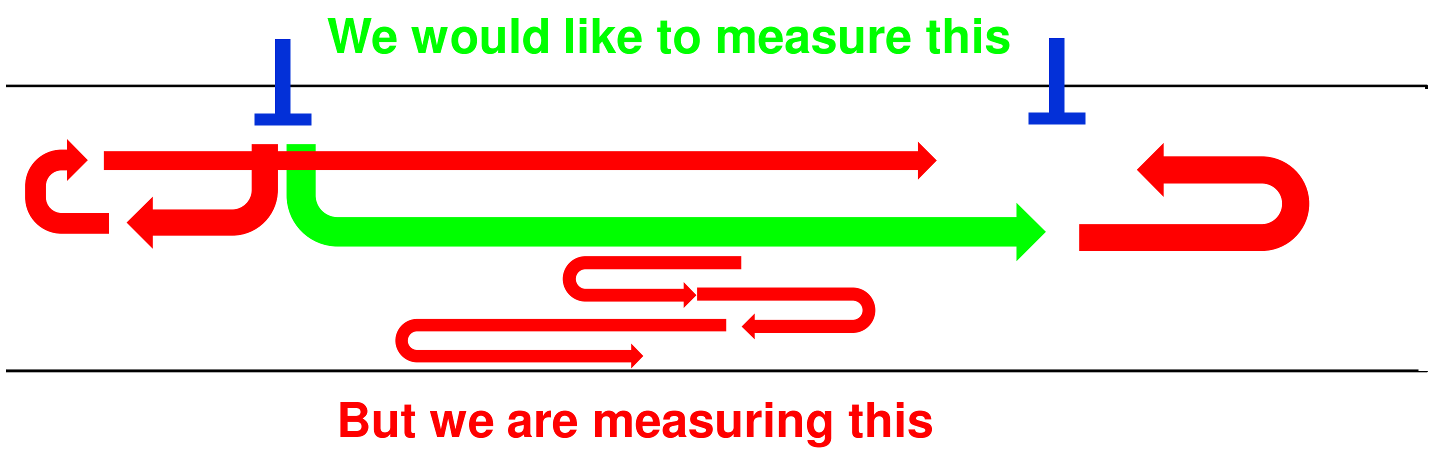


Electrons released from beampipe centre after train ends

“Uncaptured” electrons still there after >140 ns, and plenty of them!

…Another One

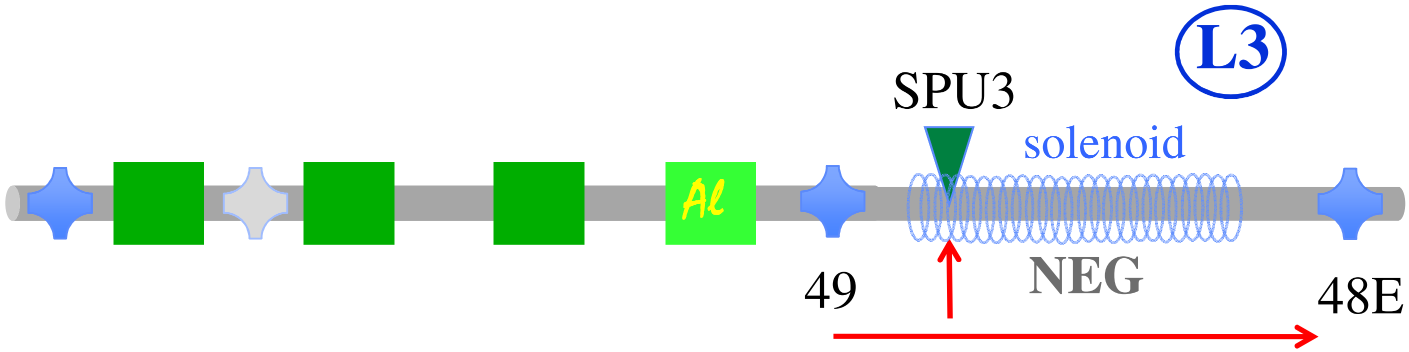
Which portion of the beampipe are we really measuring with the TE wave ?



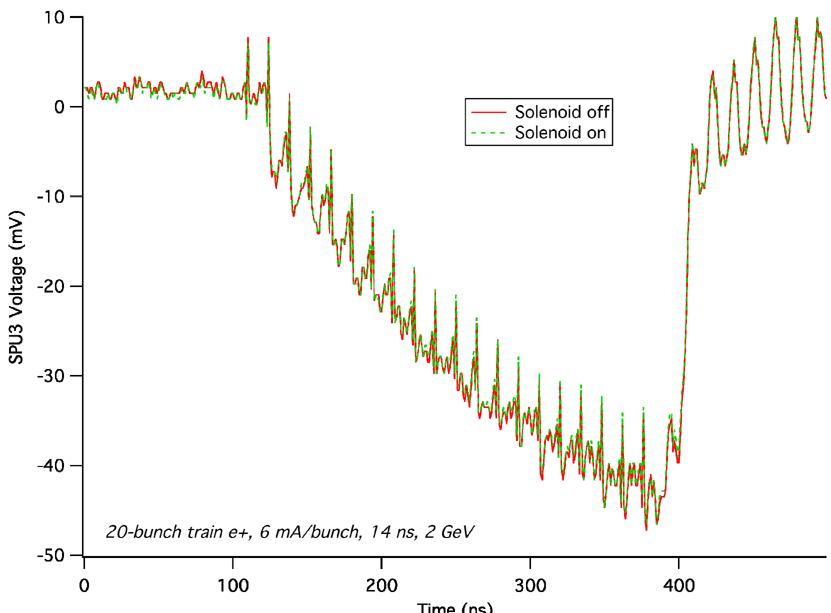
- The BPMs used to transmit and receive the wave are non-directional.
- The beampipe is not a circular waveguide: Lots of junk, multiple riflections.

More about this later

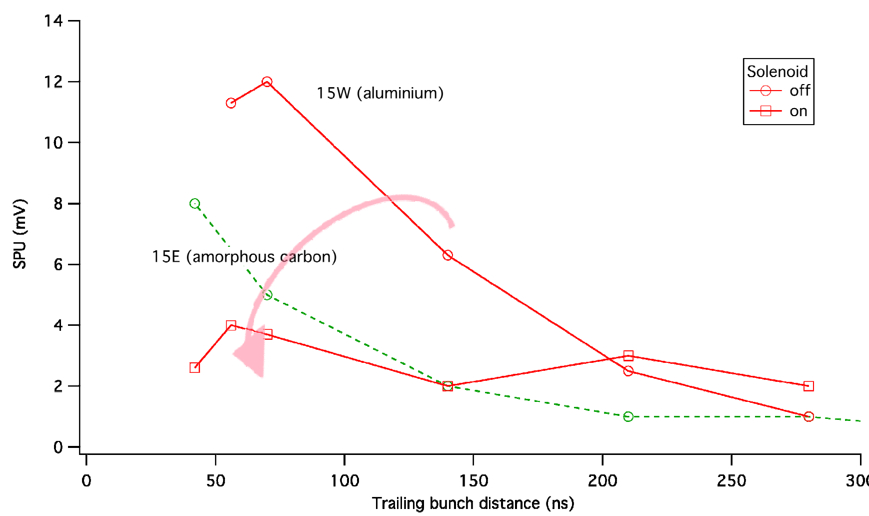
Effect of Clearing Solenoid



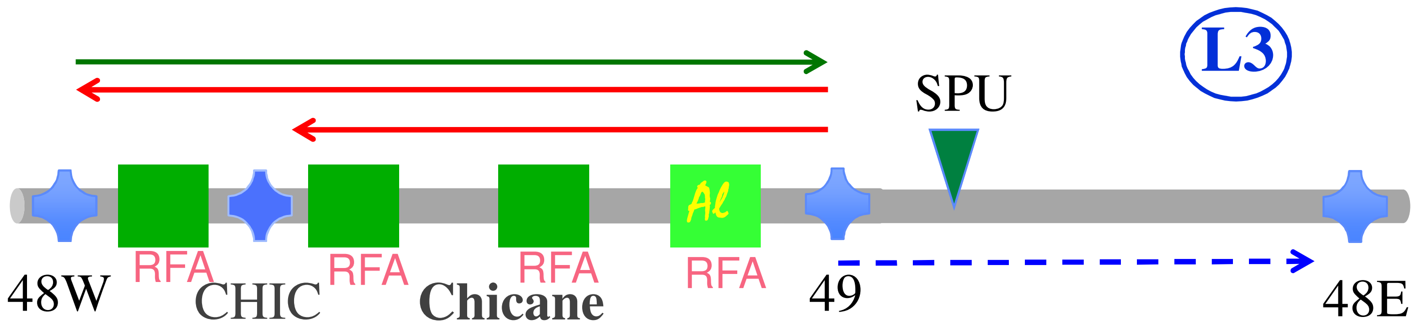
No effect on either TE wave and SPU signal ! Is NEG coating working so well that secondary electrons are virtually eliminated ?



As a reference, solenoid works well in the Al chamber



TE Wave Resonance in a Dipole B Field

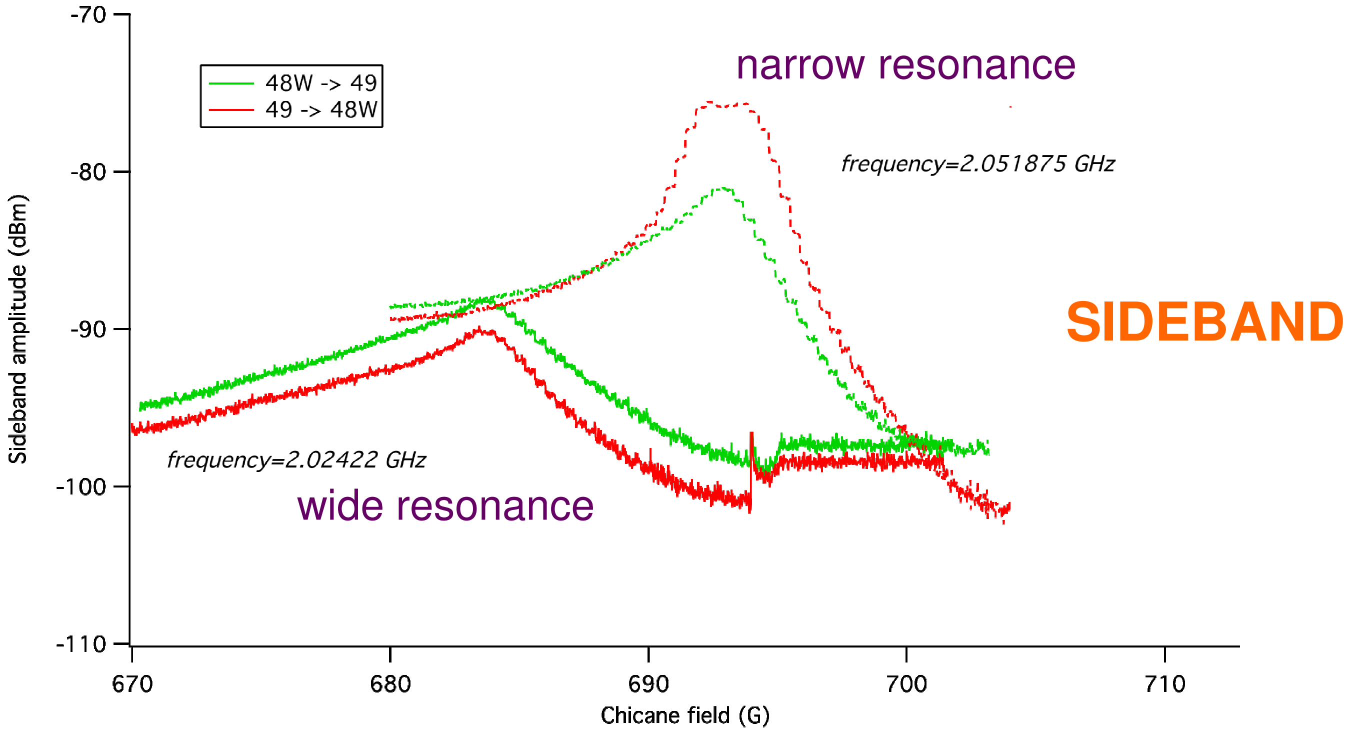


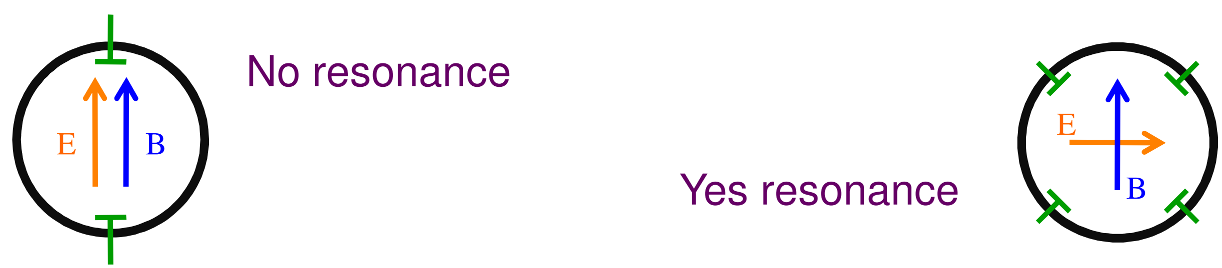
- Betatron resonance is a resonance between the beam's EM field and the magnetic field by means of the electron cloud. This is not it !

- The TE wave resonance is between the TE wave EM field and the magnetic field by means of the electron cloud. <u>Does not depend on the beam parameters</u>

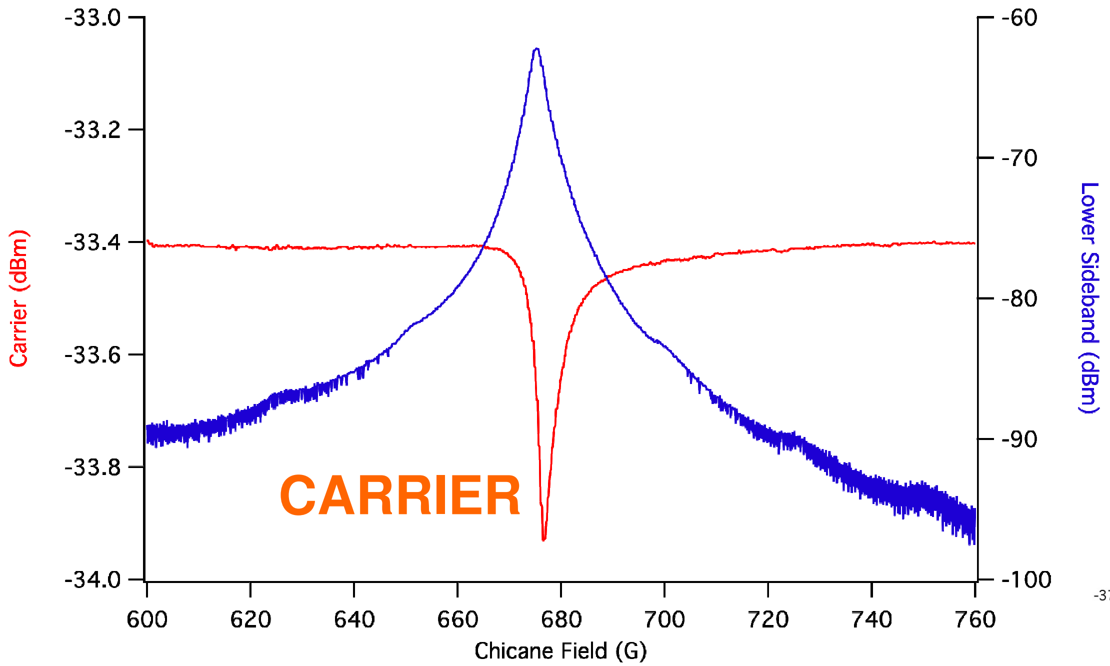
The many Faces of the TE Resonance

Dependence from frequency, polarization, direction of propagation (?)



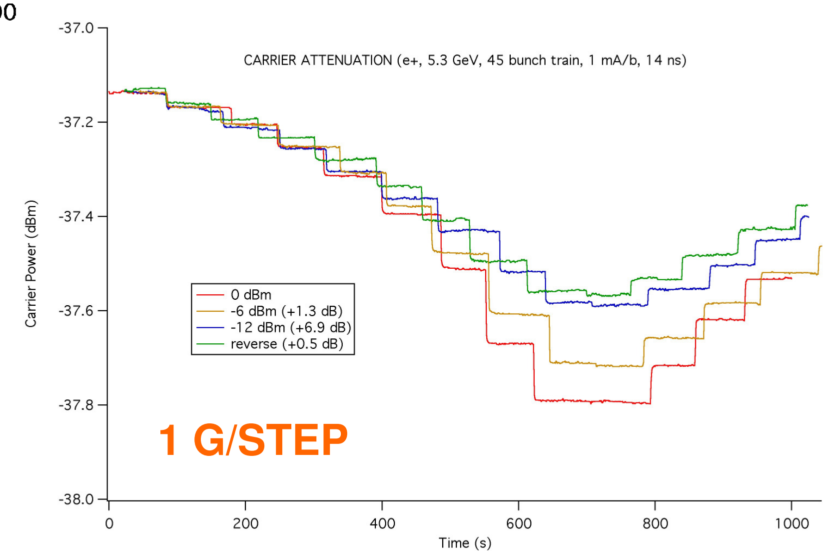


TE Resonance (cont.)



What we are observing is not phase, but amplitude modulation !

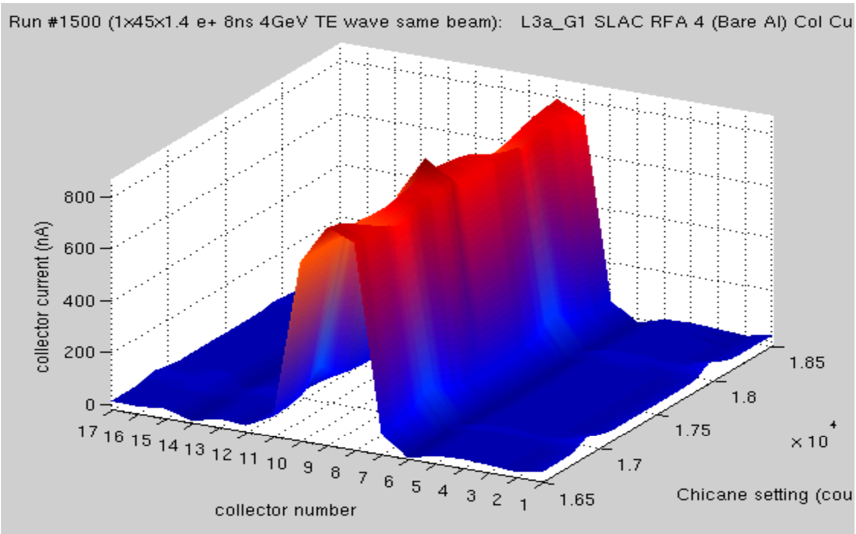
…which depends on the carrier power and direction of propagation of the wave



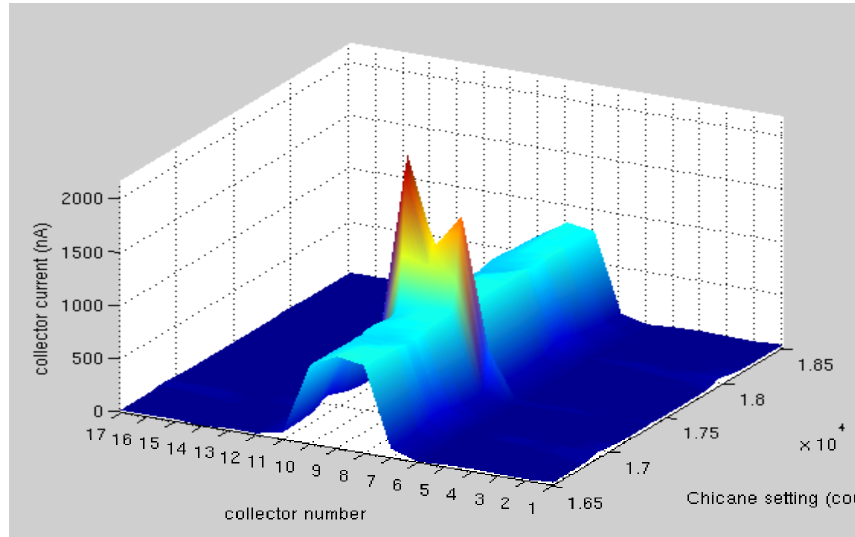
TE Resonance As Seen By Joe's RFA

(Data courtesy of J. Calvey)

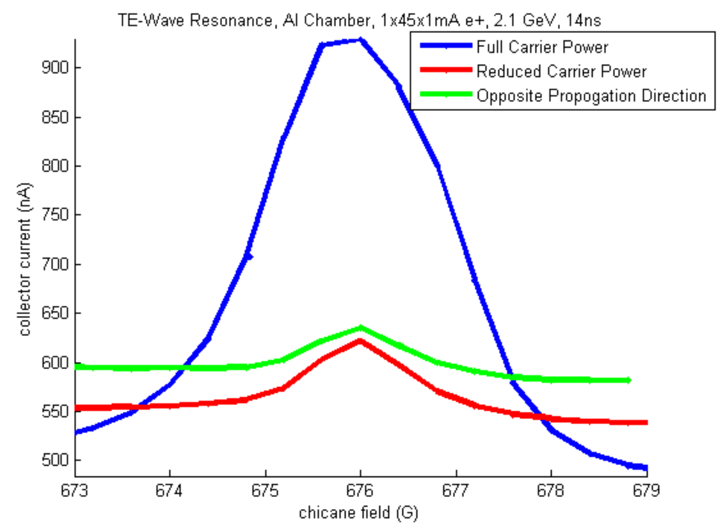
wide resonance



narrow resonance



Only the Al chamber RFA shows this effect: the TE resonance is localized in that element.



The narrow resonance, but not the wide one, can change the EC distribution with 1 W of power.

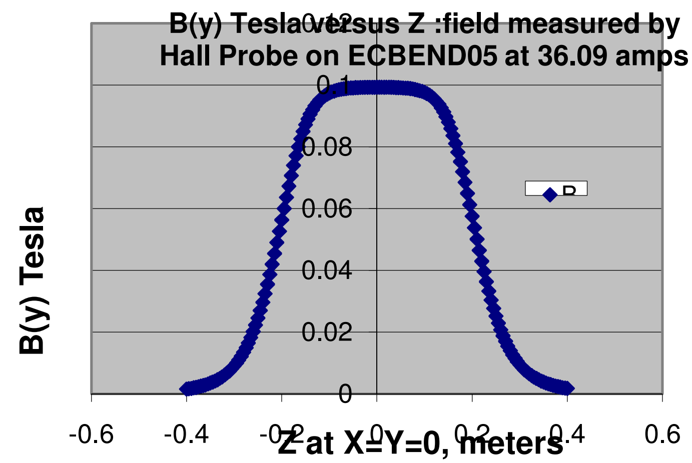
More TE Resonance Properties

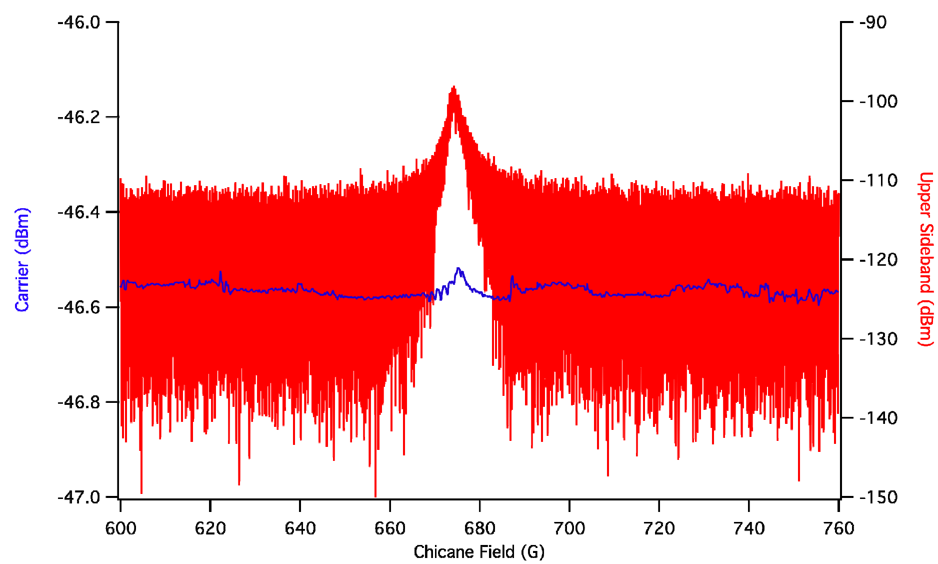
- Why is the narrow resonance so narrow ? There are plenty of magnetic field values.

- Propagating the wave from 49 to CHIC, or to 48W does not make any difference.

- We can still see the resonance when propagating the way to 48E, even if nominally the wave is not going through the chicane anymore !

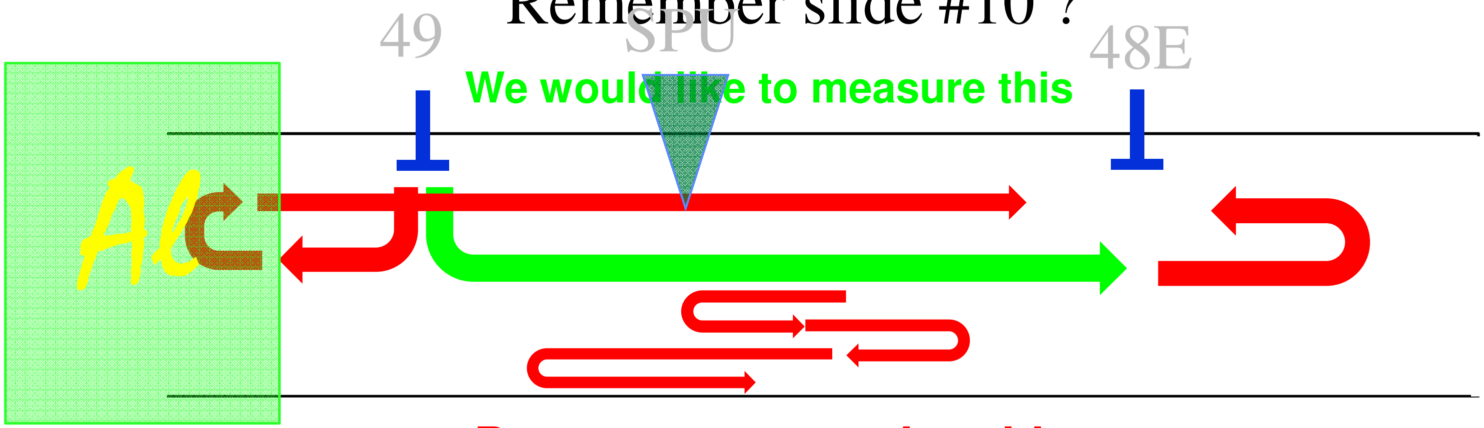
Chicane dipole measurements (M. Pivi)





Effects of Reflections in the Beampipe

Remember slide #10 ?

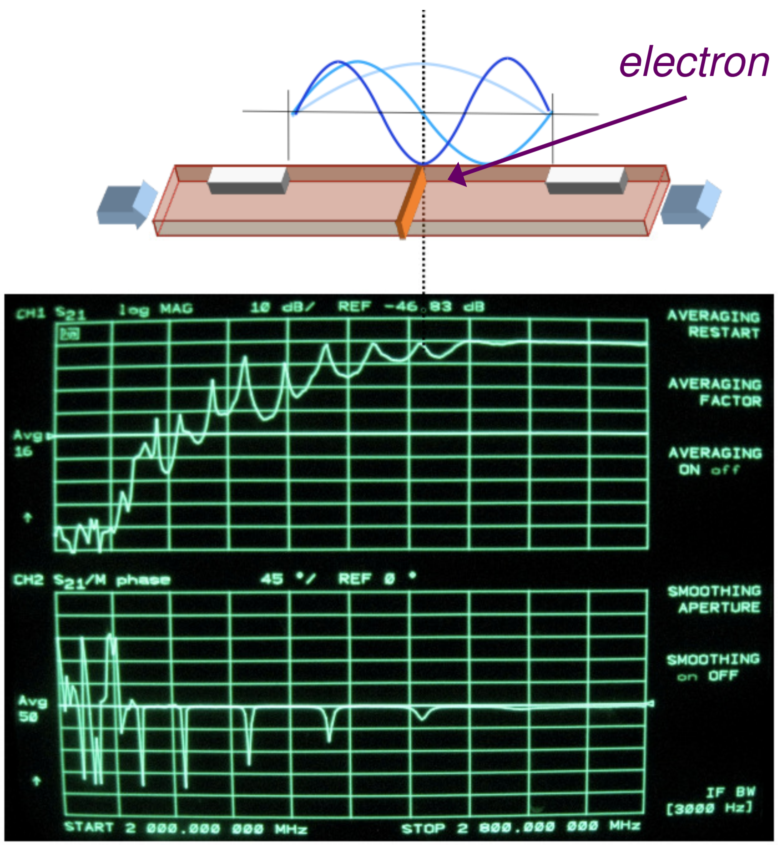


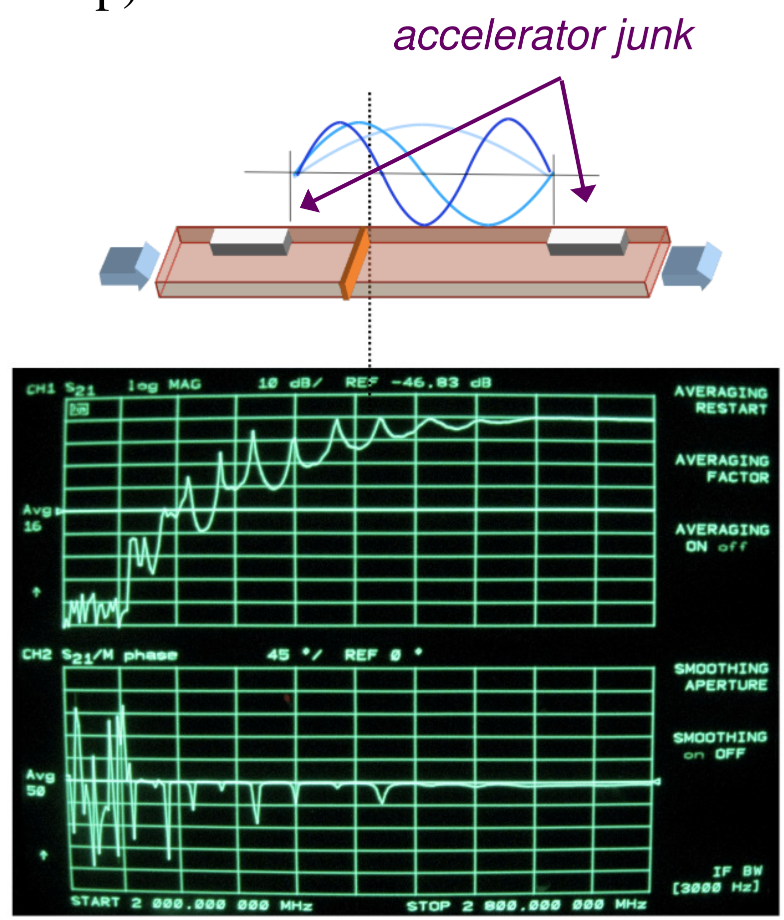
The complex EM environment of the Cesr-TA vacuum chamber has created a stationary wave at certain frequencies, with its maximum inside the Al-chambered dipole.

In general, these complicated wave patterns can affect TE wave propagation measurements. What can we do about that ?

The K. Hammond's Report

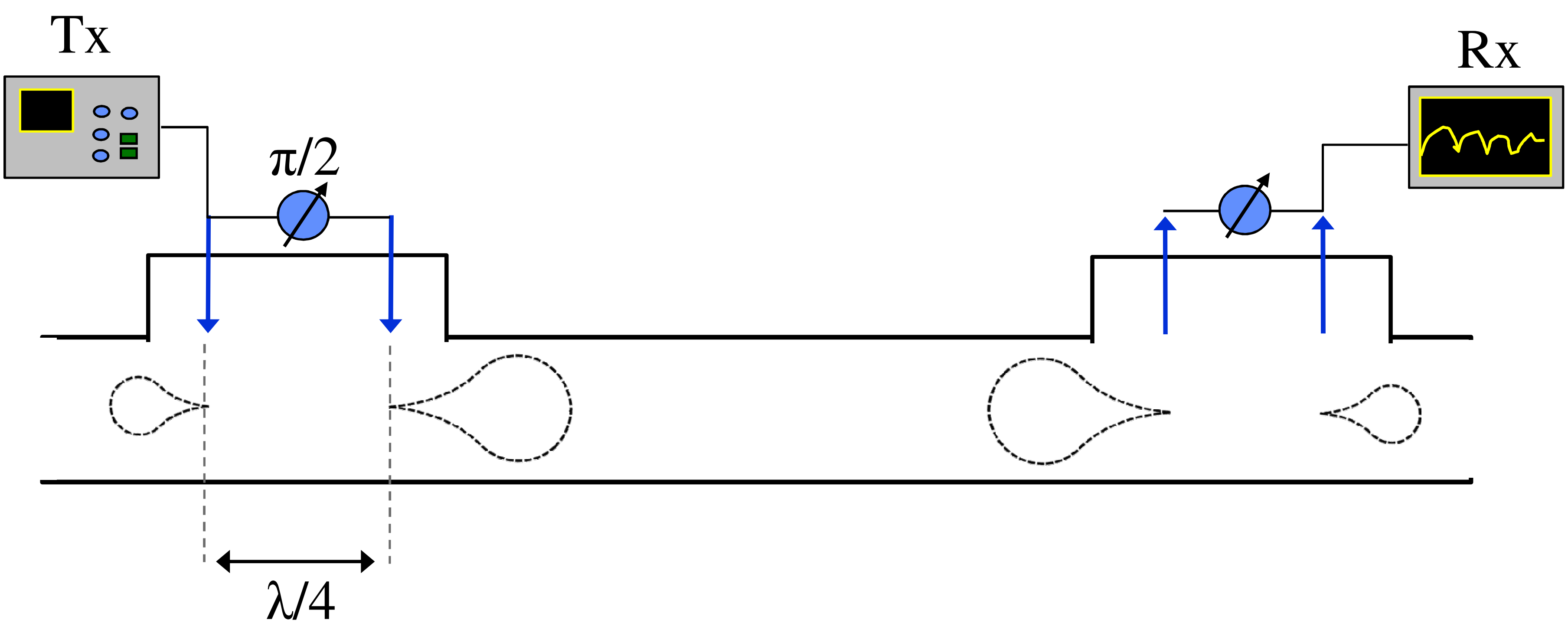
This Summer, K. Hammond, J. Sikora, K. Sonnad and S. Veitzer have studied the problem: Knowledge of the actual EM field inside the beampipe would allow to correct the measurements (posters, this workshop).



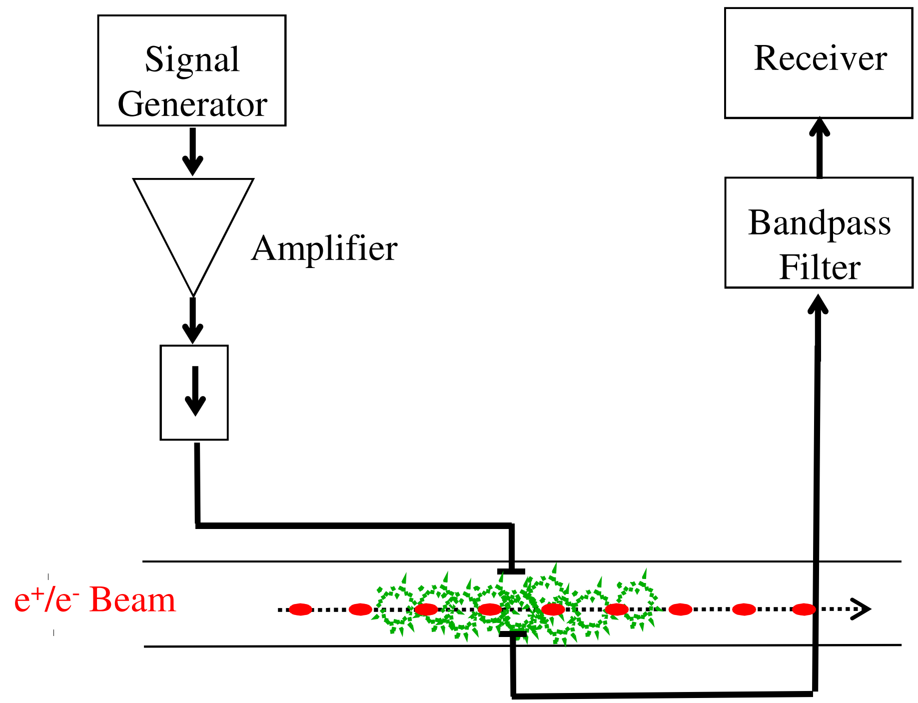


Directional Coupling of the TE Wave

Mini phased array can provide directionality in transmission and reception of the TE wave. At typical cuoff frequencies 1.5÷2 GHz even multiple antennas would require a foot, or less.

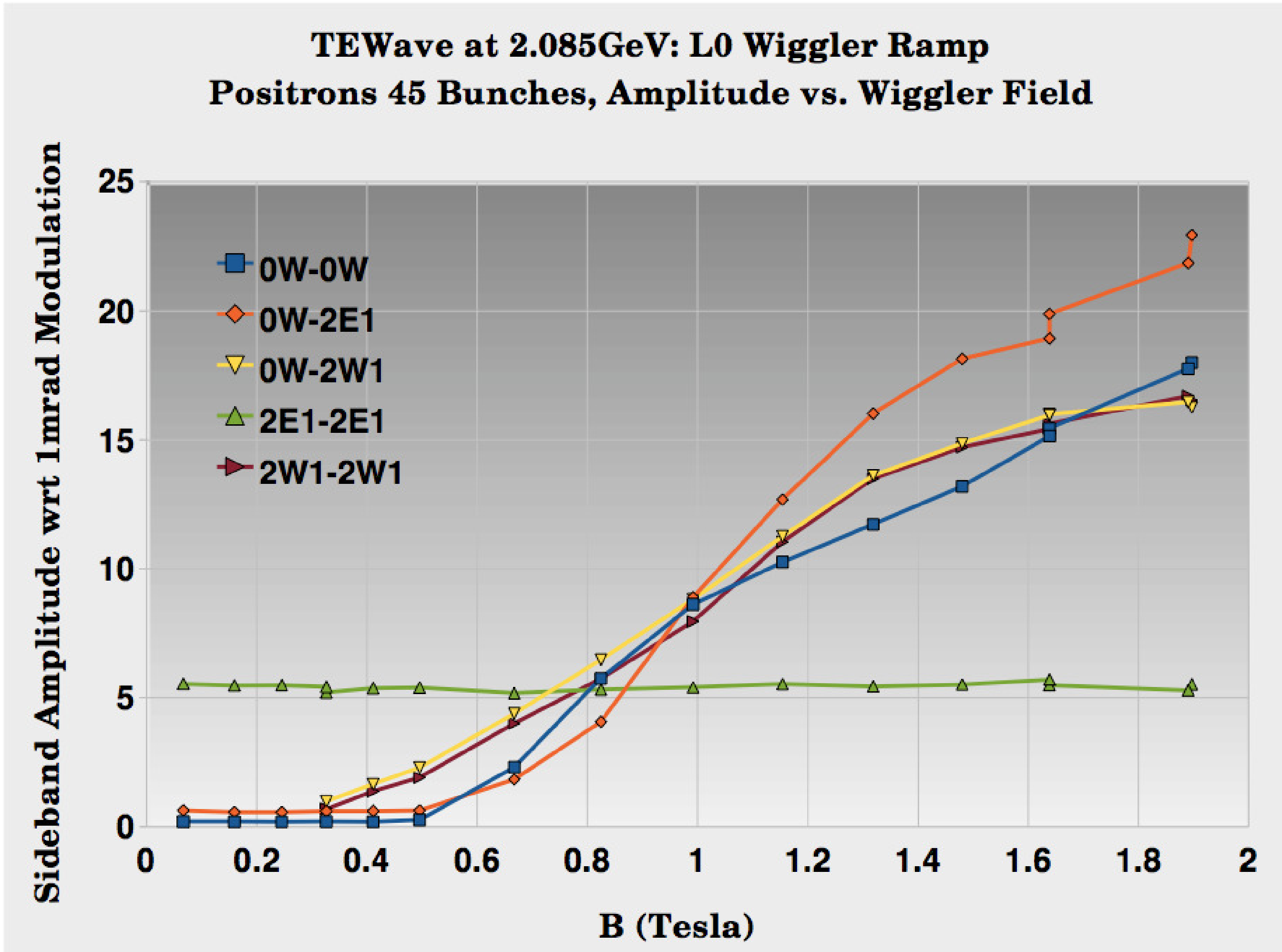


Do Not Transmit the Wave: the TE Resonant Method



The wave is excited slightly below cutoff so that there is no propagation, but only exponential attenuation, effectively obtaining a resonator. Selecting the frequency changes the resonator dimensions. Distant and unwanted parts of the accelerator do not affect the measurement.

Example: Wiggler Ramp



Resonant detectors can shed light on where the electron cloud is with higher precision

Conclusions

- Although having a simple formulation, the practical application of the TE Wave method is not straightforward.
- Comparisons with other quantitative methods can help in validating assumptions and "fudge factors".
- Reflections and standing waves can greatly affect measurements in a number of cases.
- Several strategies are possible for improving the method robustness in such cases.