Measurements of the Electron Cloud Density by TE wave propagation in Cesr-TA

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Summary

- Types of measurements performed.
- Locations of measurements in the CESR ring.
- Measurement results.
- TE wave resonance.
- Future developments.

EC induced additional phase delay

By measuring the additional phase shift per unit length introduced by the presence of the electron cloud one can calculate the "average" ECD in that portion of beampipe

$$\rho_e \propto \omega_p^2 = k_{z0}^2 c^2 \left[1 - \left(1 - \frac{\Delta\varphi}{k_{z0} L} \right)^2 \right]$$

Sidebands relative amplitude

⇩

Mod. depth/Max. phaseshift

⇩

Plasma frequency

⇩

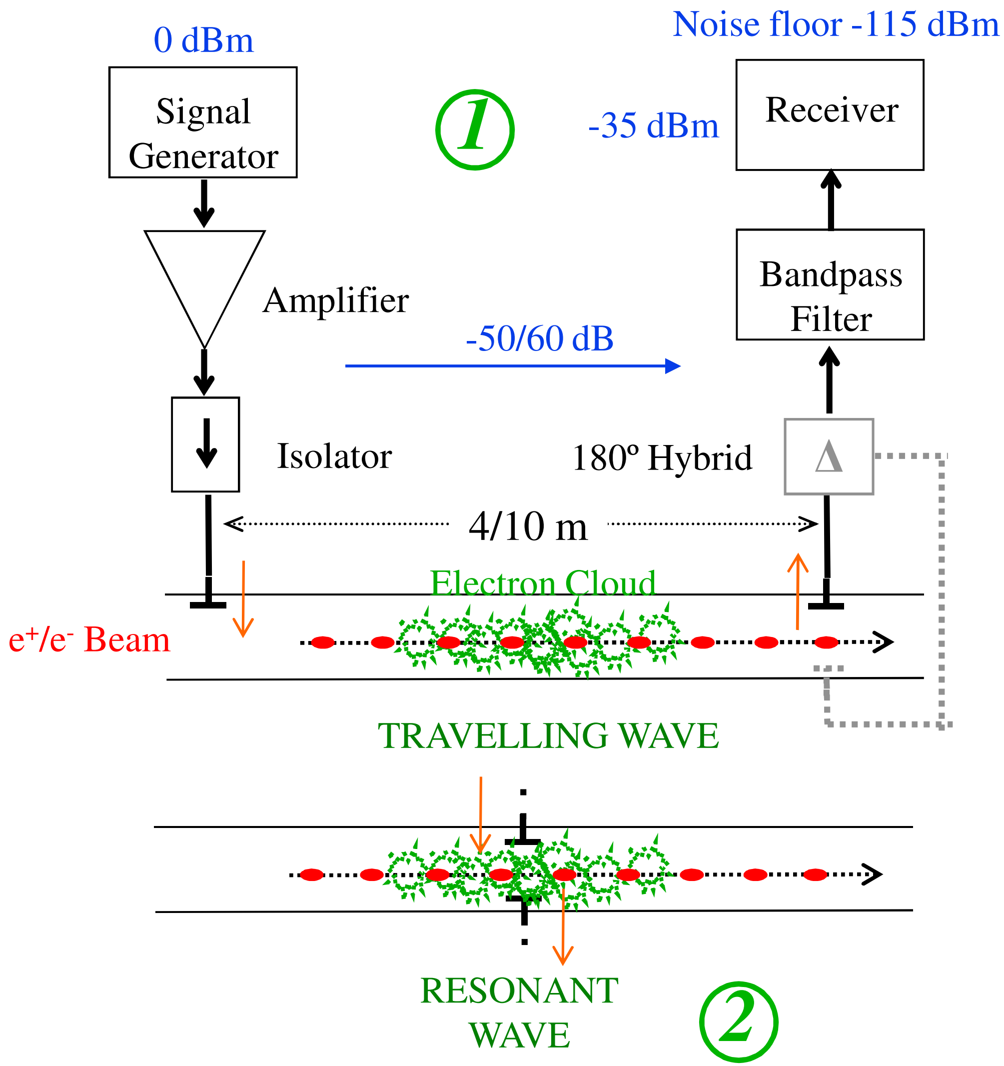
ECD

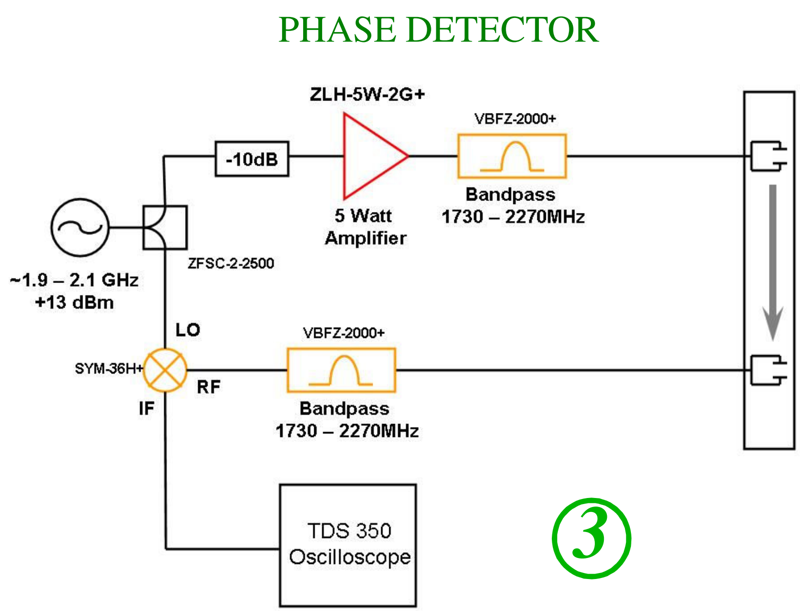
$$k_{z0} = \frac{\sqrt{\omega^2 - \omega_c^2}}{c}$$

practical formula

$$\rho_e \approx \frac{f_p^2}{80} \quad (e^- / m^3)$$

Phase shift detection methods

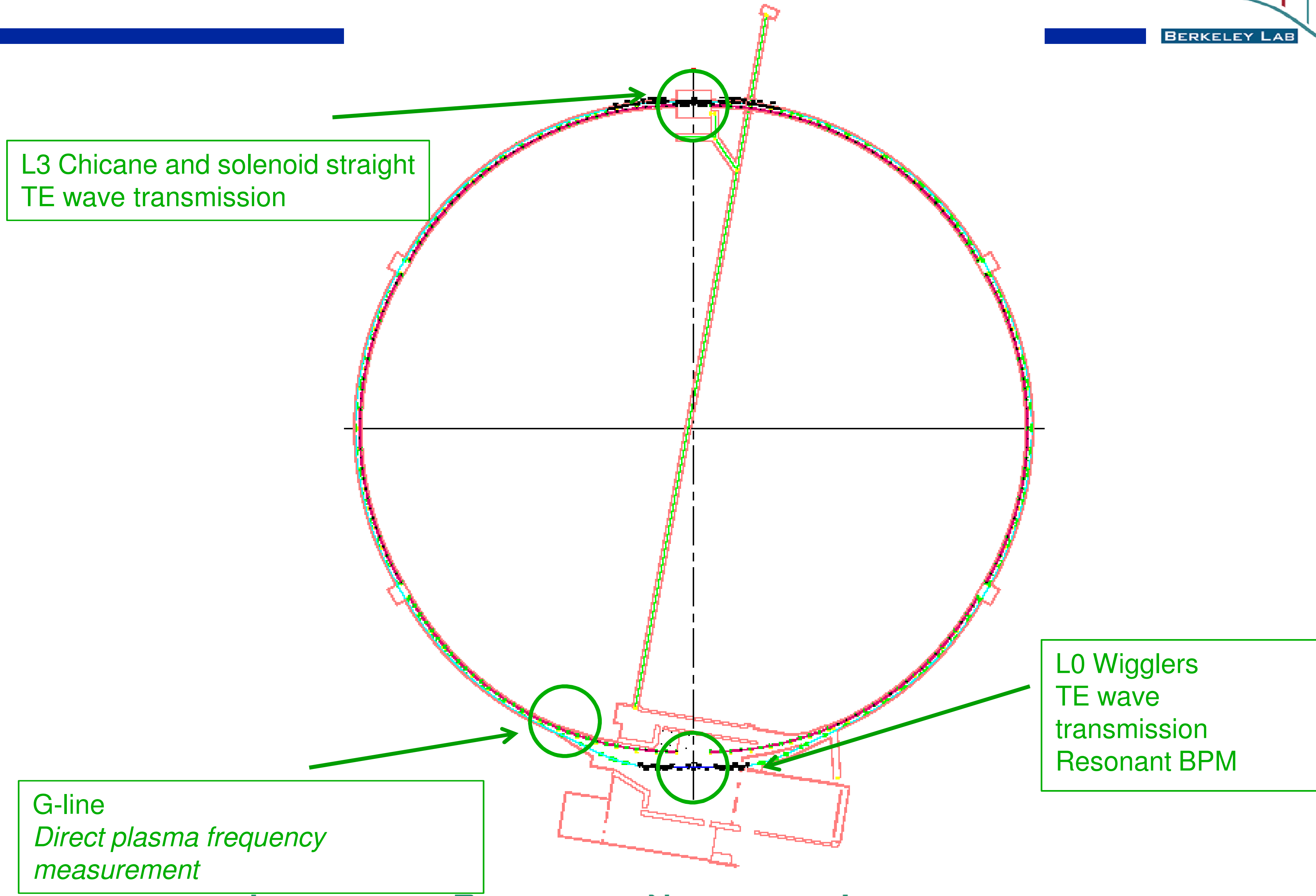




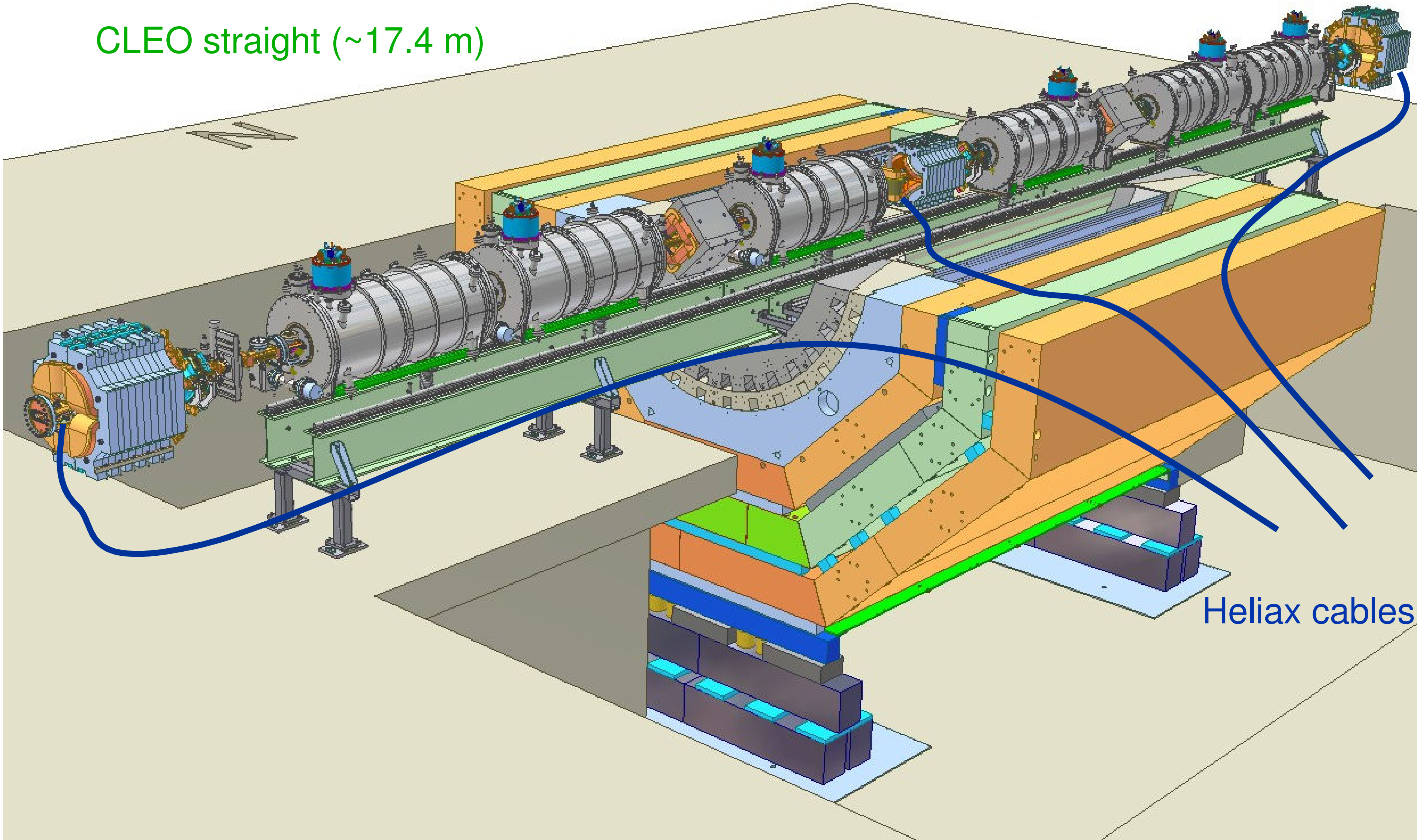
"State of the art"

- **Travelling wave**
  - Method has been successfully applied anywhere we tried. Effects of bunch train length, beampipe attenuation, etc. are accounted for. We can produce quantitative measurements with a certain level of confidence of the average ECD over the propagation length.
- **Resonant BPM**
  - This method can be intrinsically be applied to any BPM (no attenuation limits). A detailed quantitative understanding is under study. We can produce relative localized measurements of the ECD
- **Direct phase detection**
  - Hardware has been successfully tested. Not the main effort up to now.

Current Cesr-TA Setup



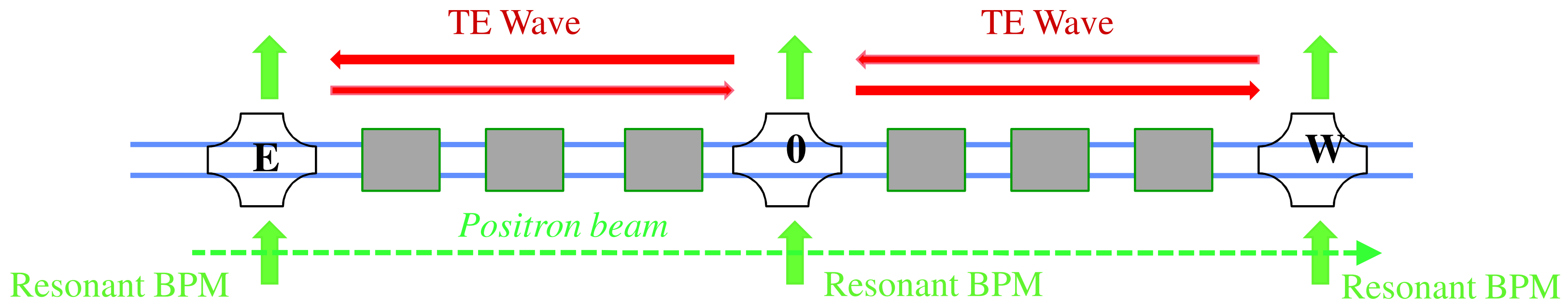
CesrTA – Wiggler straight (L0)



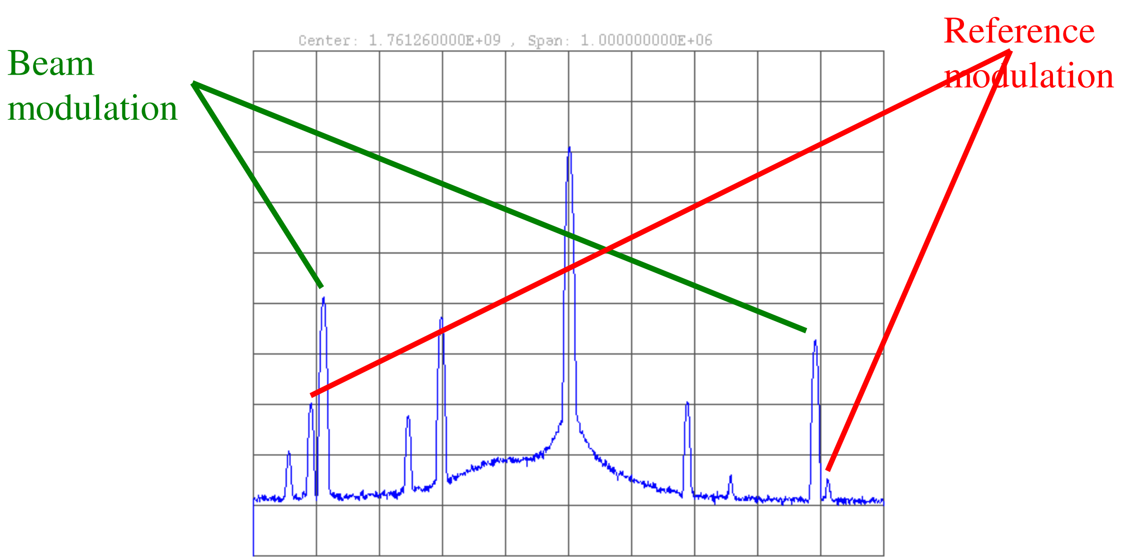
L0 Measurements

Improvements: automated measurement, reference modulation

Transmission through L0 and resonant BPM continuously monitored; multiple data taken at every change in current and wiggler field. Added phase modulation at 410 kHz to signal source for continuous calibration of transfer function.

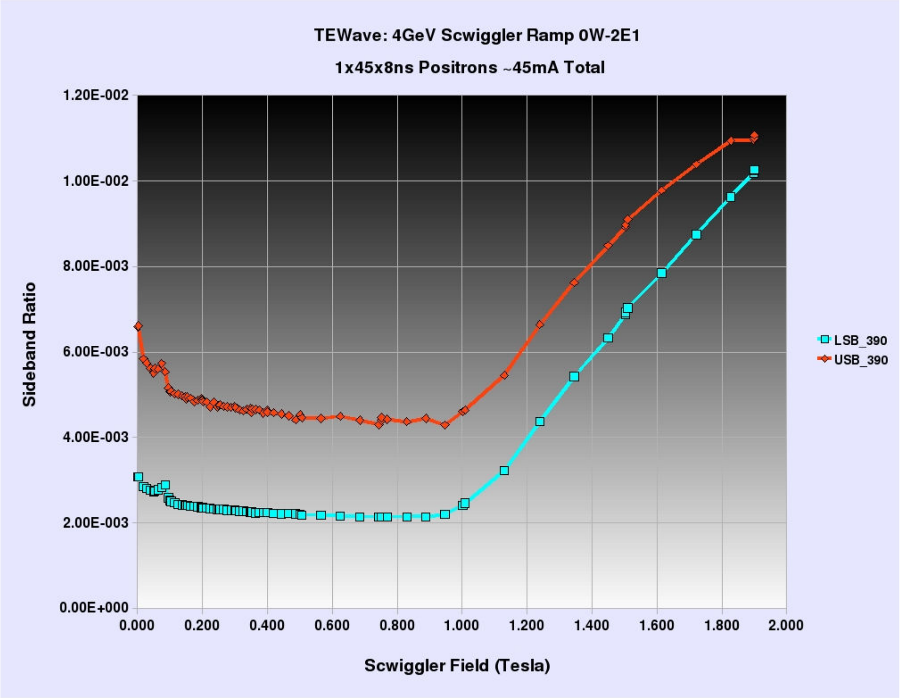


3 resonant BP and 2 transmission measurements are continuously performed and stored whenever beam conditions, or wiggler field change.

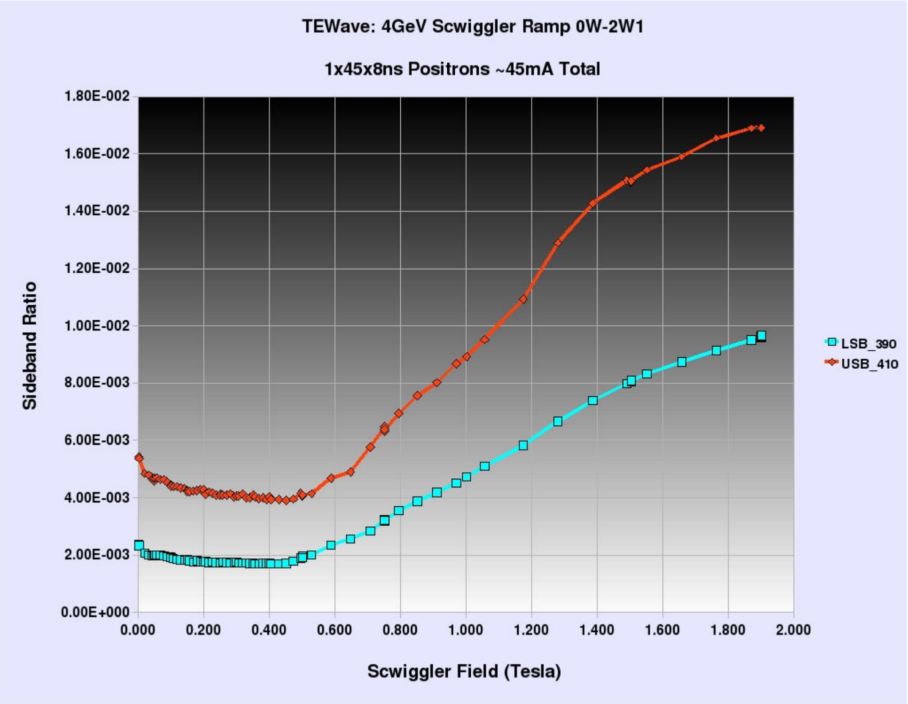


L0 Data (SC wiggler ramp)

TE wave



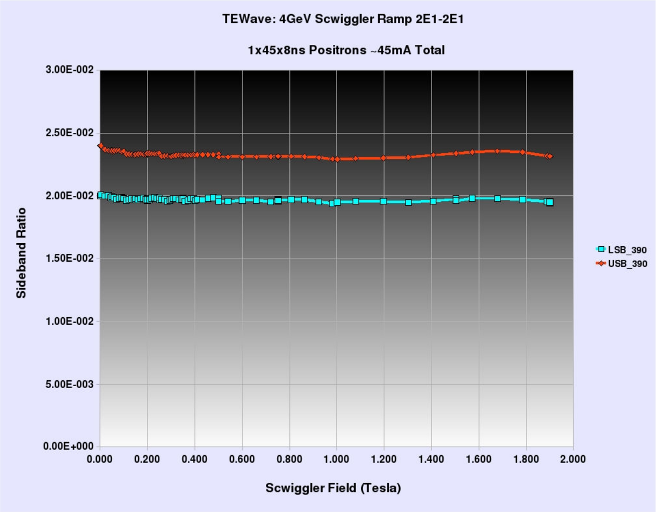
0 -> East



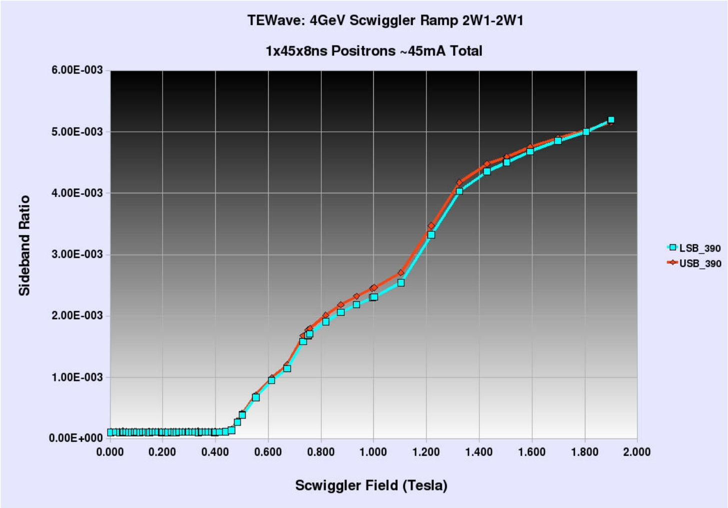
0 -> West

L0 Data (SC wiggler ramp)

Resonant BPM

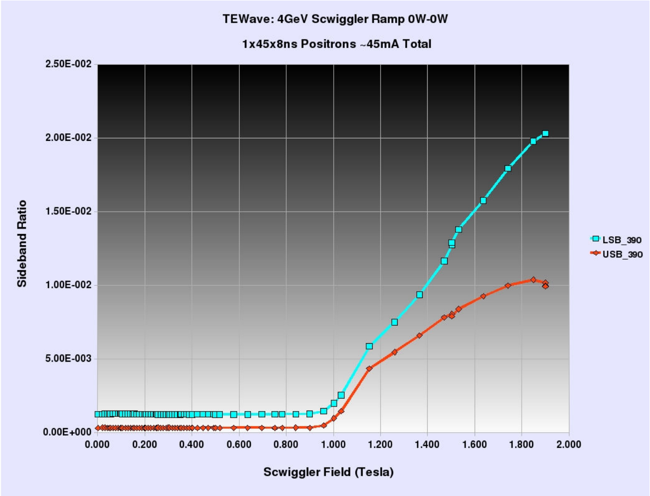


East



West

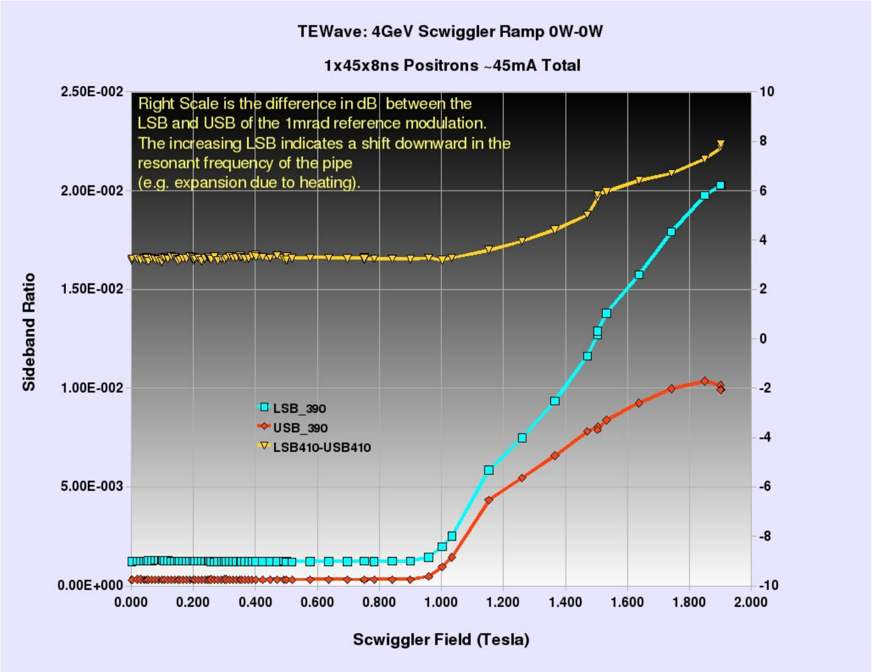
Centre



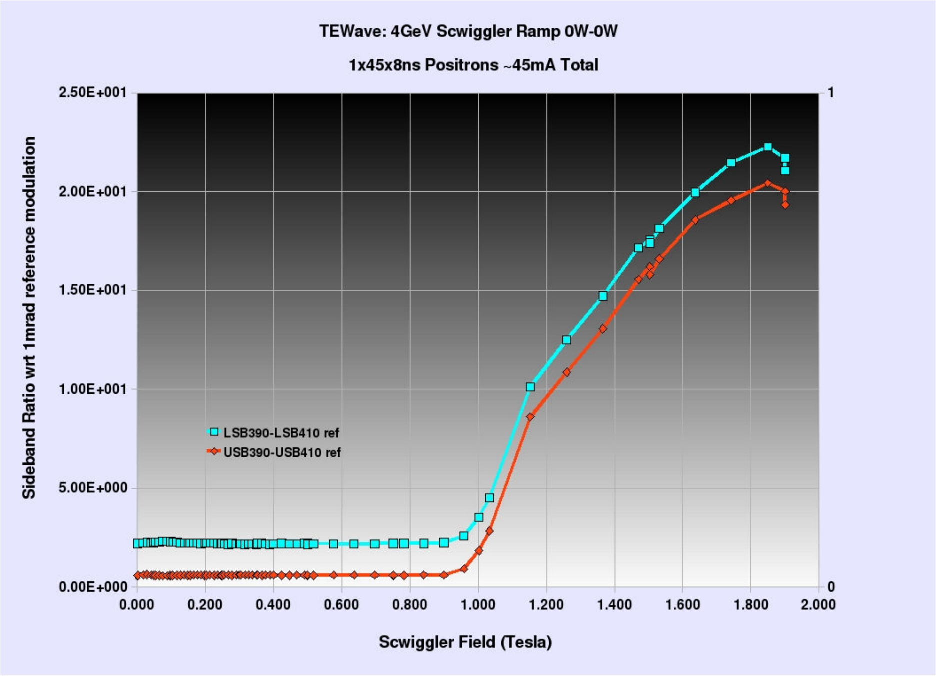
L0 Data (SC wiggler ramp)

Reference modulation

Difference between upper and lower sideband increases with wiggler field (beampipe expansion due to heating ?). Compensation with reference sidebands cancels the effect, which is caused by changes in the transfer function).

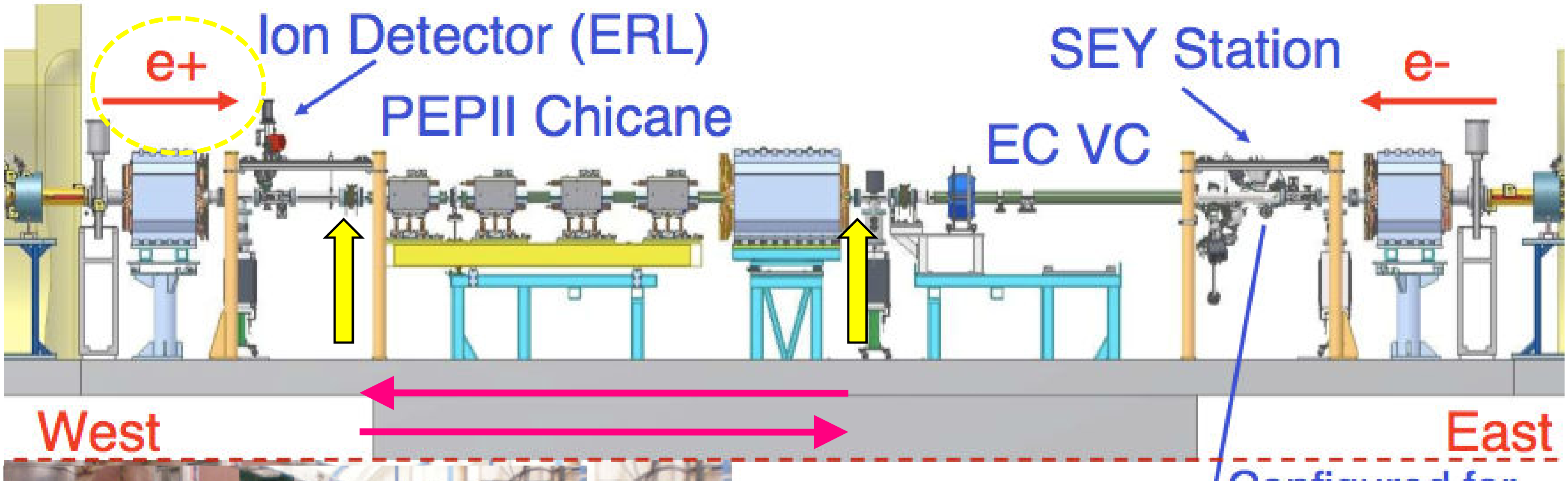


Uncorrected

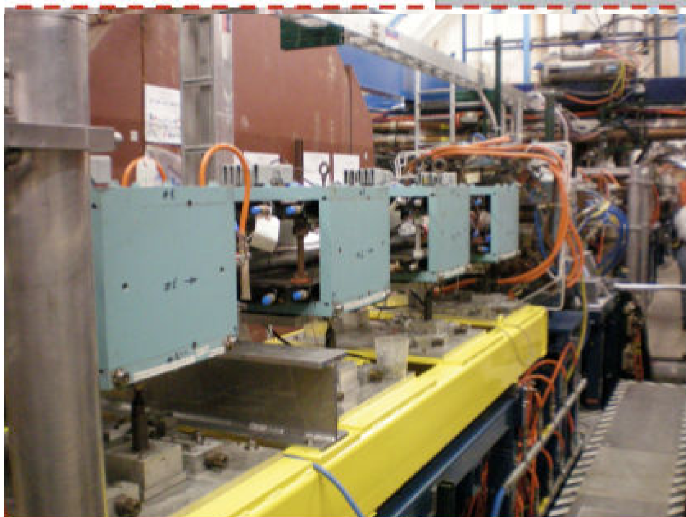


Corrected

L3 Chicane



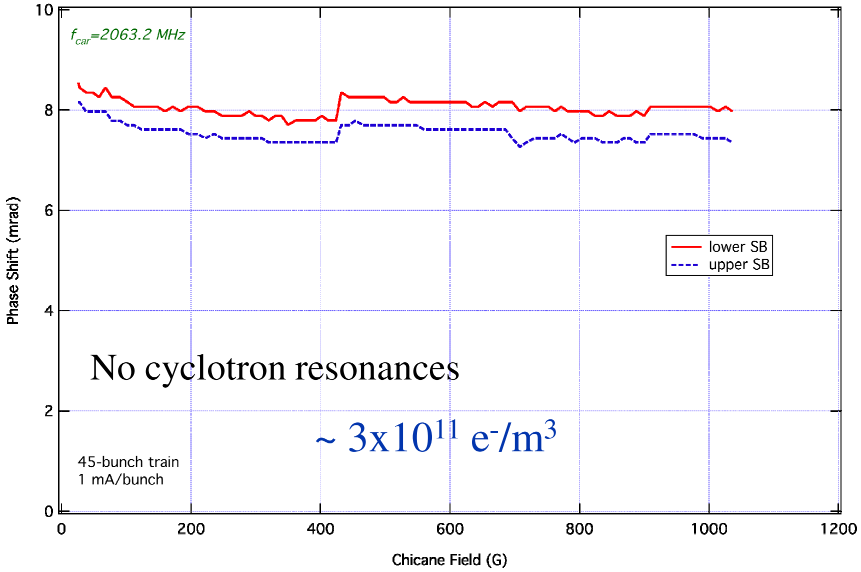
e+
Ion Detector (ERL)
PEPII Chicane
SEY Station
e-
EC VC
West
East

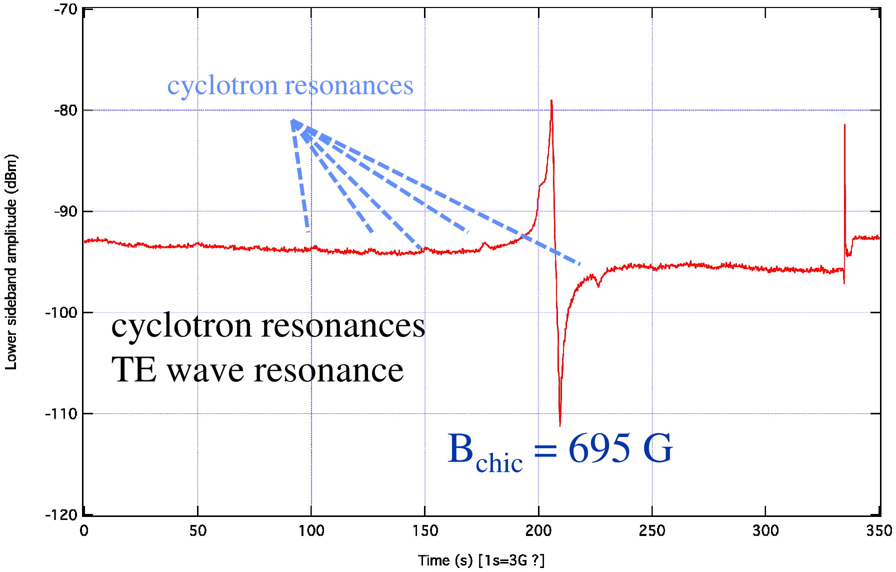


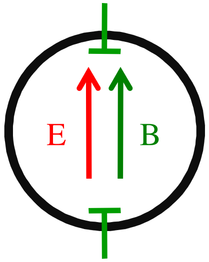
L3 Chicane – TE wave resonance

Chicane scan – Effect of wave polarization

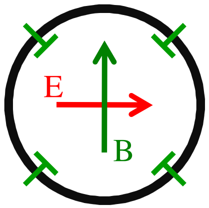
Changing the TE wave polarization to horizontal revealed a strong resonance near $f_{cycl}=f_{TE}$. This resonance is different from the classical cyclotron resonances, which are wider and only change the wave phase delay marginally. TE wave resonance: $f_{TE}=f_{cycl}$







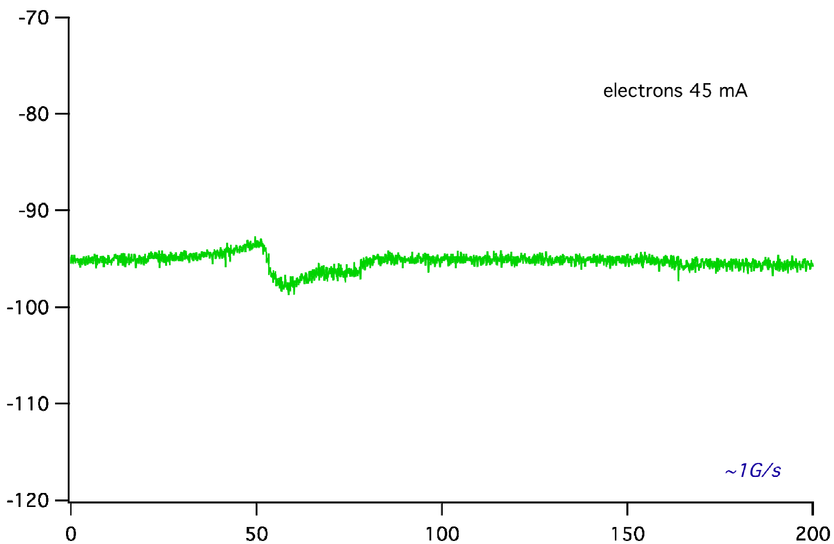
E TE wave electric field
B Chicane magnetic field

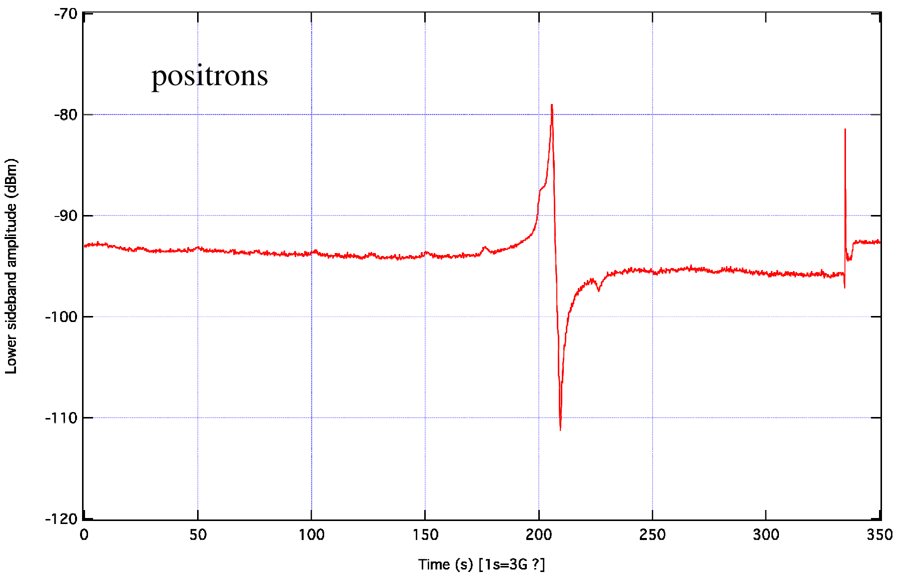


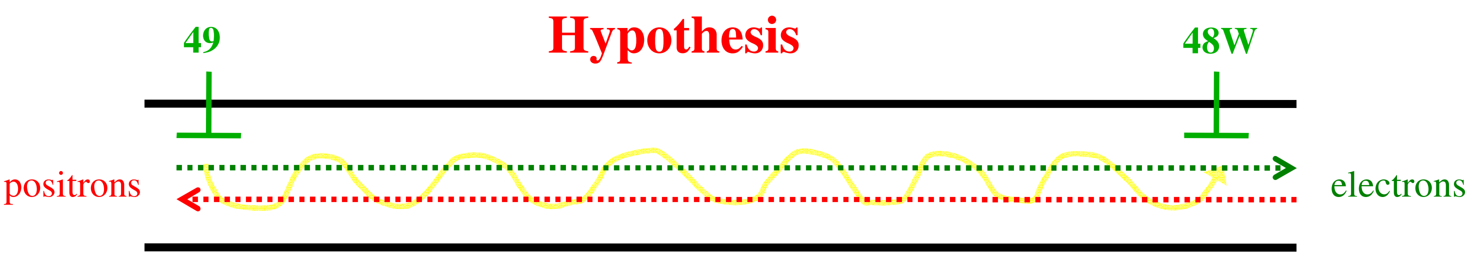
L3 Chicane – TE wave resonance

Effect of the direction of propagation, beam species ?

Measurements with electron and positron beam unexpectedly yielded grossly different results at the TE wave resonance, although the ECD are comparable off-resonance.

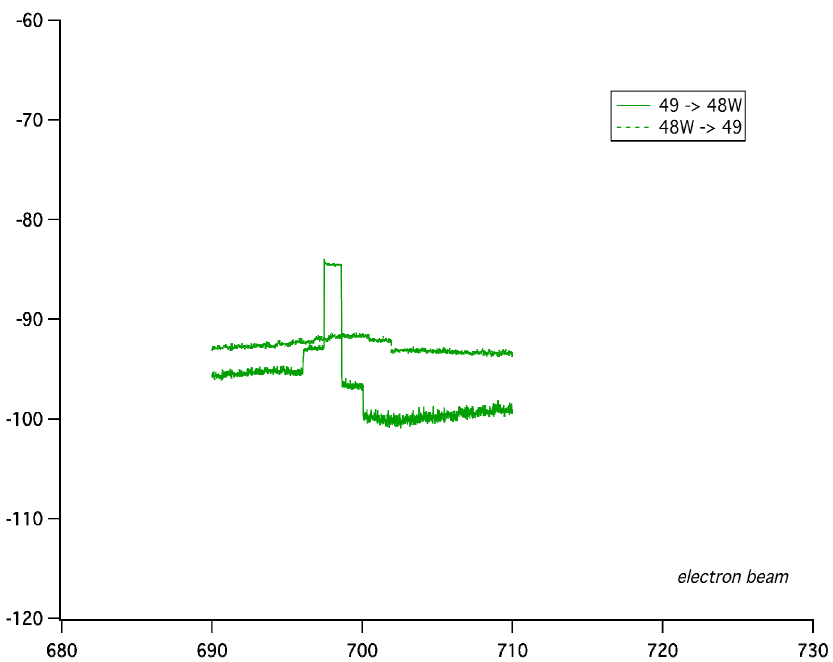


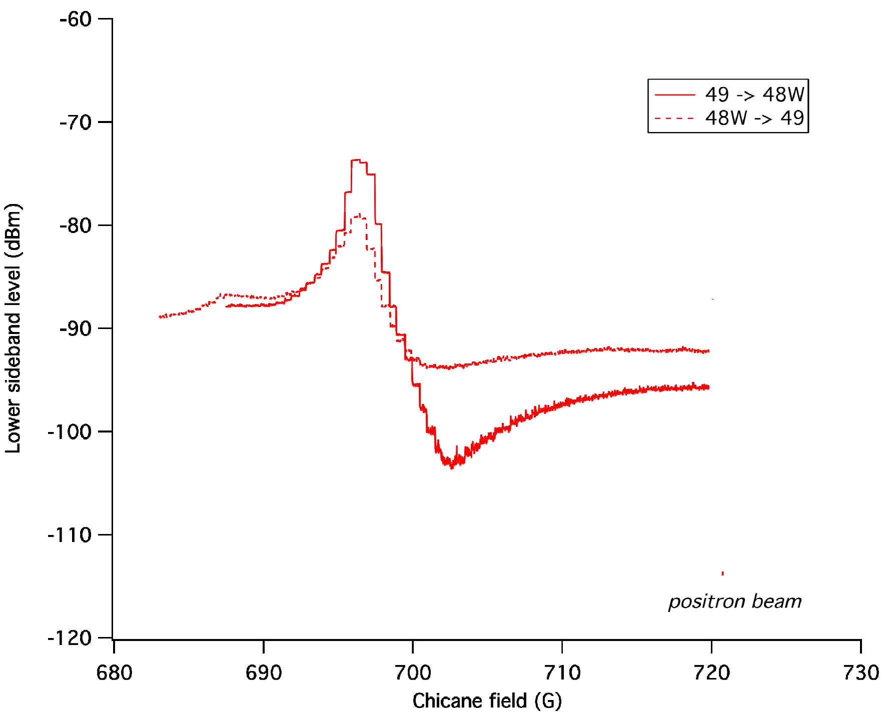




Effects of the direction of propagation.

Results point out to an effect due to the wave direction, independently of the beam's direction of propagation. These look somewhat different than what measured at 5 GeV, though.

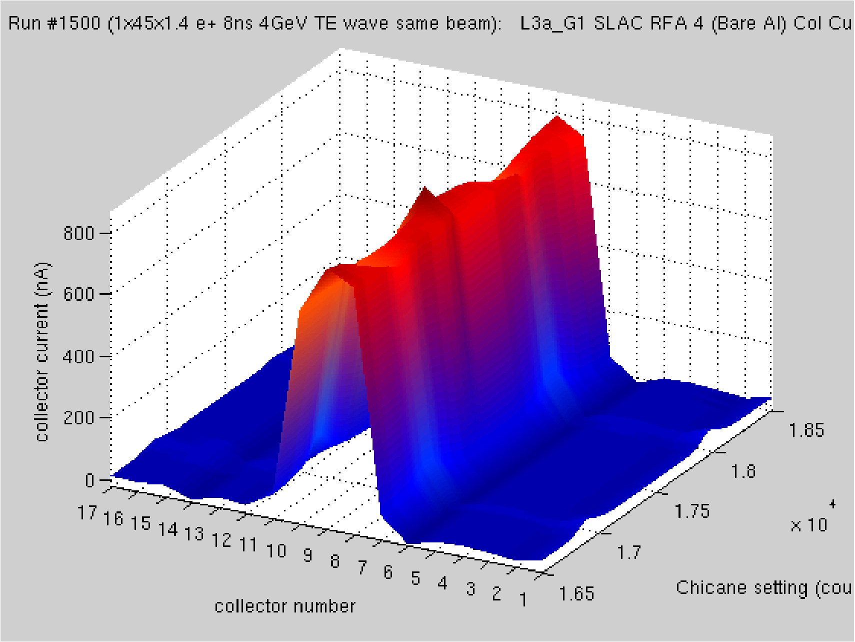




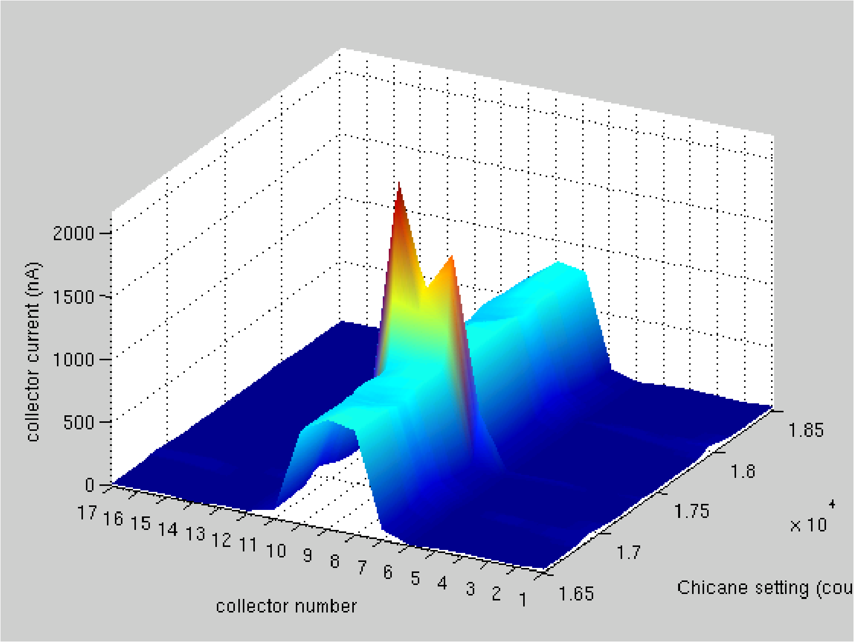
What the RFA sees…

The RFA data (Al chamber) show a more dramatic effect than what observed from the modulation sidebands for positron beam. With electron beam data is below noise treshold.

"Reverse"



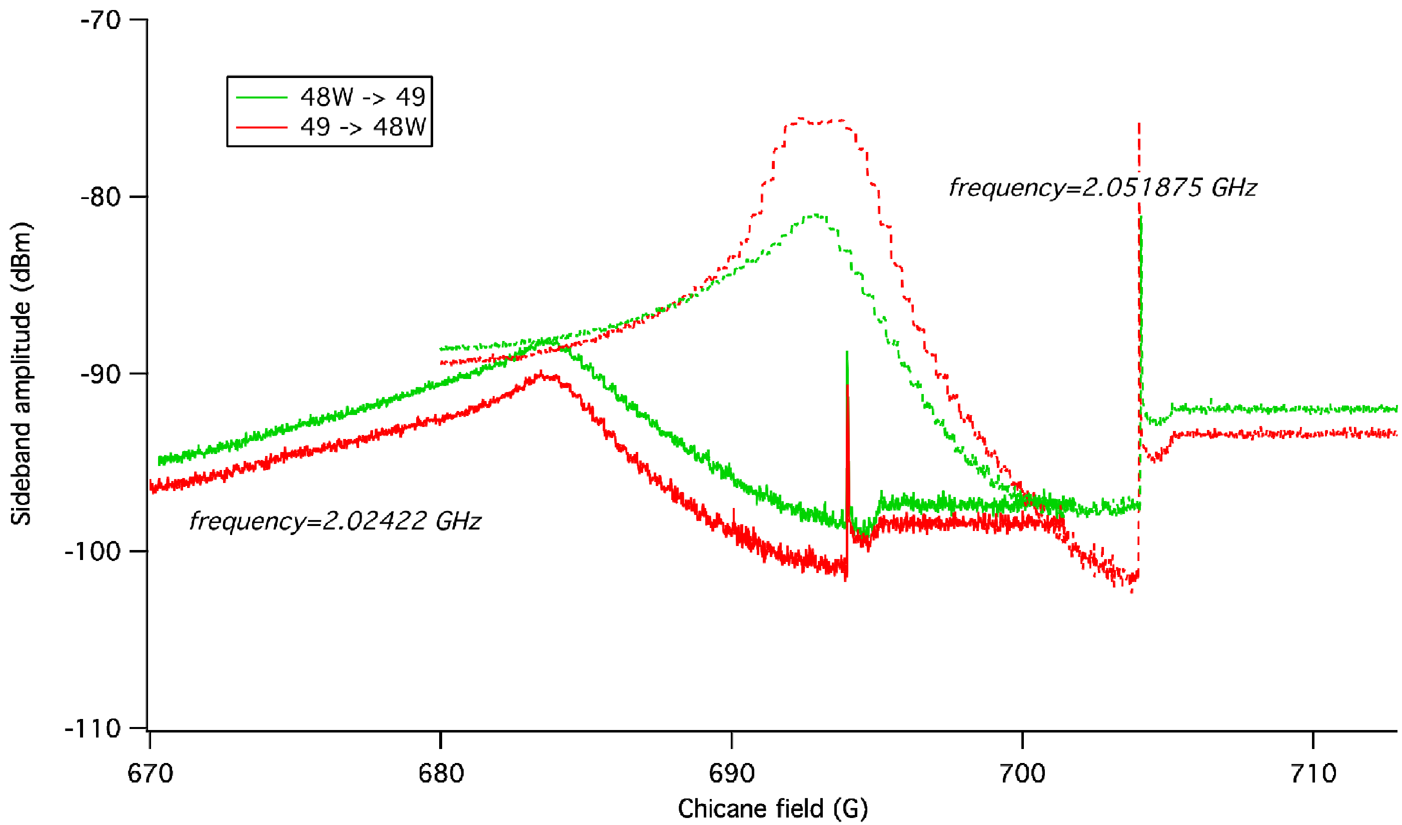
"Direct"



The TE wave does not affect the RFA readout; it radically changes the EC distribution !!

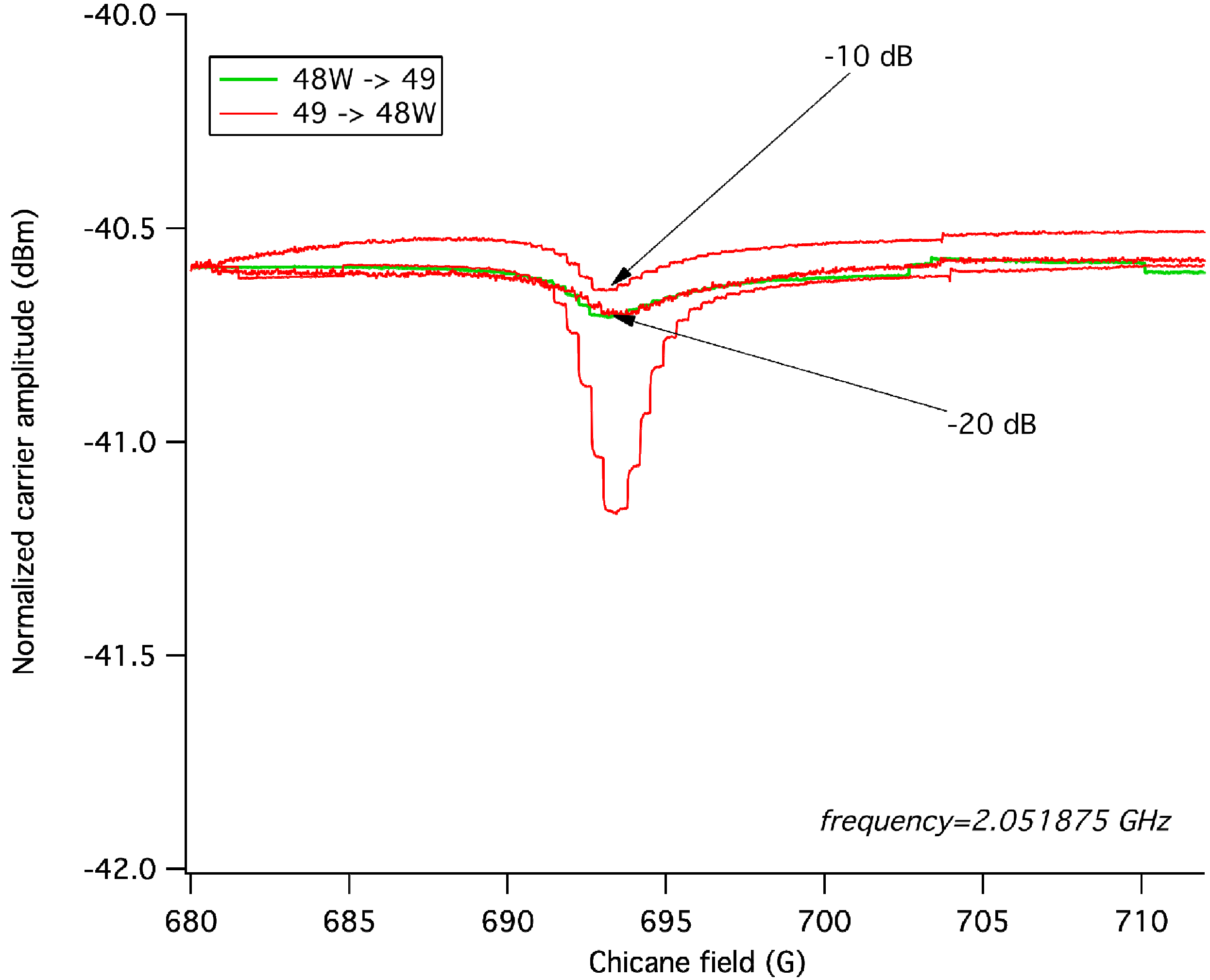
L3 Chicane – TE wave resonance

Changing the TE wave frequency, shifts the resonance as expected: ~ 2.799 MHz/Gauss. We see a qualitative change: at the lower frequency the (weaker) resonance is not affected by changing the wave's direction of propagation.



L3 Chicane – Carrier attenuation

We also observed that, by reducing the carrier power, the absorption peak is reduced and essentially becomes identical to the full power "reverse" wave (green). This would point out to a power dependent (i.e. non-linear) effect.

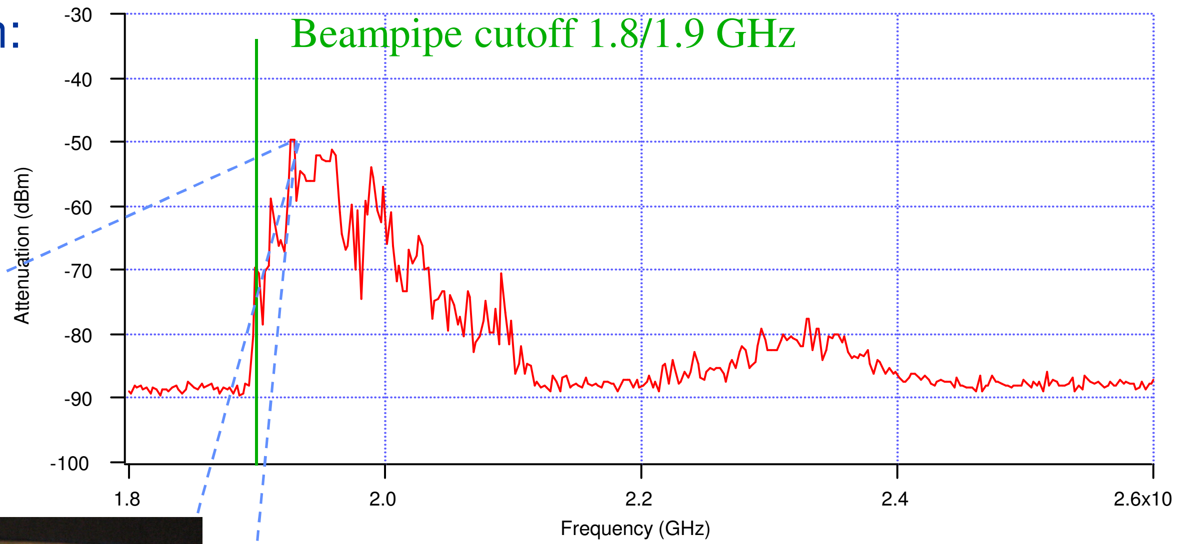


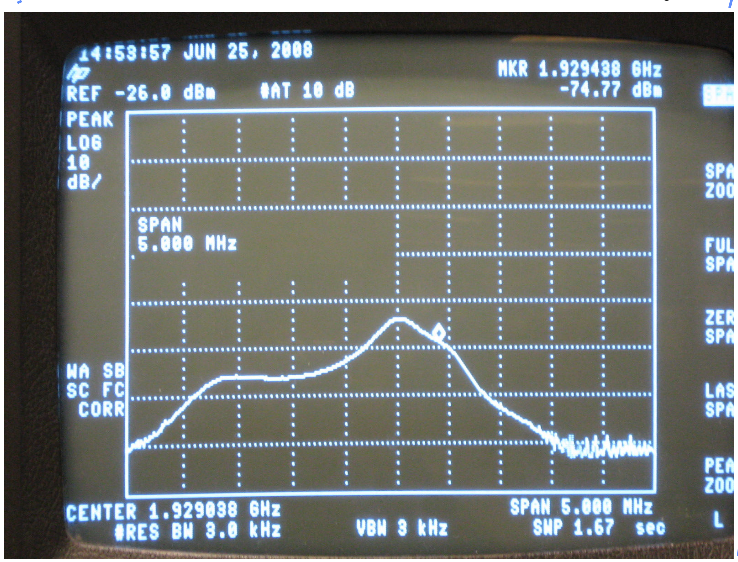
Conclusions

- **The TE wave method can be easily implemented on any machine (no installation required) and it requires only standard RF equipment.**
- **The integrated phase shift along the beam pipe is weighted so to enhance the effect of those electrons near the pipe axis (i.e. on the beam path). For the $TE_{1,1}$ mode the maximum E field on the pipe wall is 1.6 times lower than in the pipe center**
- **Alternative procedures are being studied (resonant BPM, etc.).**
- **Presence of magnetic fields may affect the measurement, but it is easy to change frequency and/or polarization (TE wave resonance)**

Beampipe Transfer Function

Choice of measurement region:
- Close to cutoff
- Low attenuation
- Reasonably “flat”





Search for origin of reflections and/or resonances in the beampipe did not turn out conclusive results (gate valves, pumping holes, RF cavity)