Traveling Waves Resonant Ring for Electron Cloud Studies

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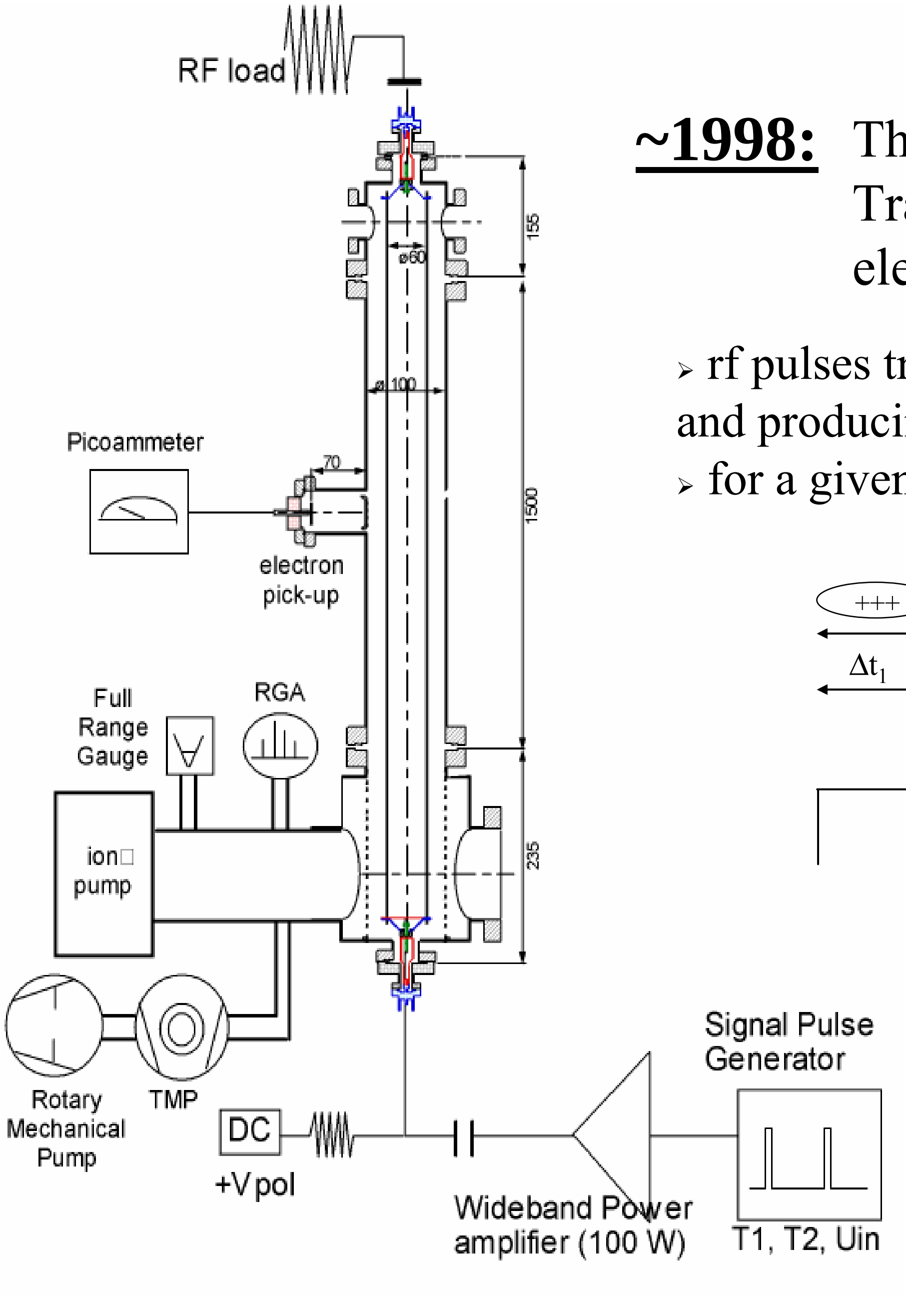
Contents

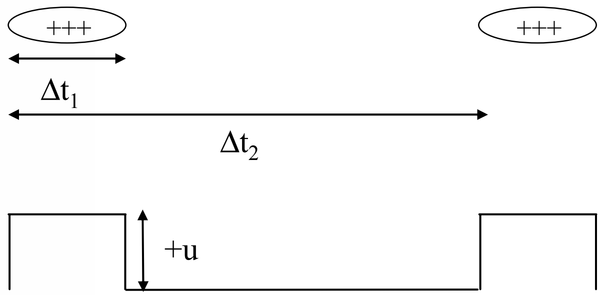
1. Introduction: a Traveling Waves Chamber
2. Design of the Resonant Ring:
    a) Decreasing the system attenuation
    b) Building-up the Coupler
3. Results
4. Conclusions

1. Introduction



~1998: The LHC/VAC Group at CERN installs a Traveling Wave (TW) chamber in its lab for electron cloud studies*

- rf pulses travel along 6 wires acting as a bunched beam and producing multipacting inside the vacuum chamber.
- for a given pulse voltage threshold, multipacting occurs.



bunched beam:

rf pulses:

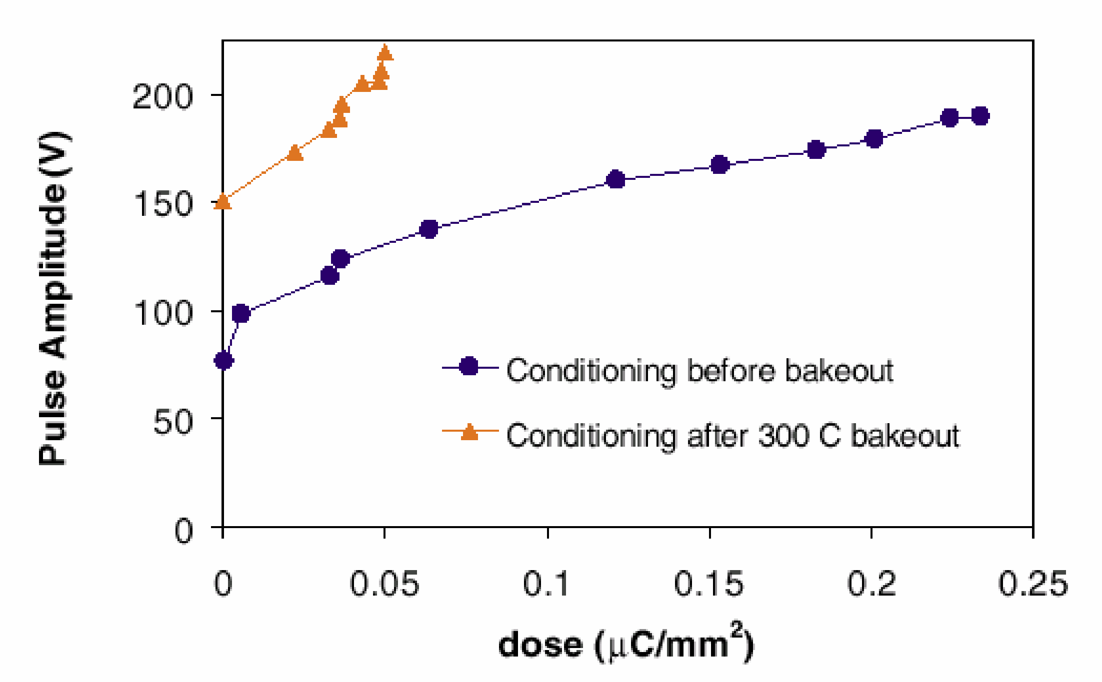
NOTE: the pulses are dumped into a load placed at the end of the vacuum chamber.

*See M. Pivi PhD Thesis -- CERN-THESIS-2000-018

1. Introduction

Limitation: the max voltage is limited by the wideband 100W power amplifier:

Max. pulse voltage, $V_{p\text{-}p} \sim 150$ V ➔ $E_{electron} \sim 75$eV (for stainless steel)



After a certain surface treatment (bake out or e- bombardment), the minimum pulse amplitude to trigger the multipacting is not achievable using the normal pulse amplifier.

➔**Need a new setup to increase the pulse amplitude through the wires** (and thus, produce multpacting)

➔The voltage should be increased by around a factor ~3, 4.

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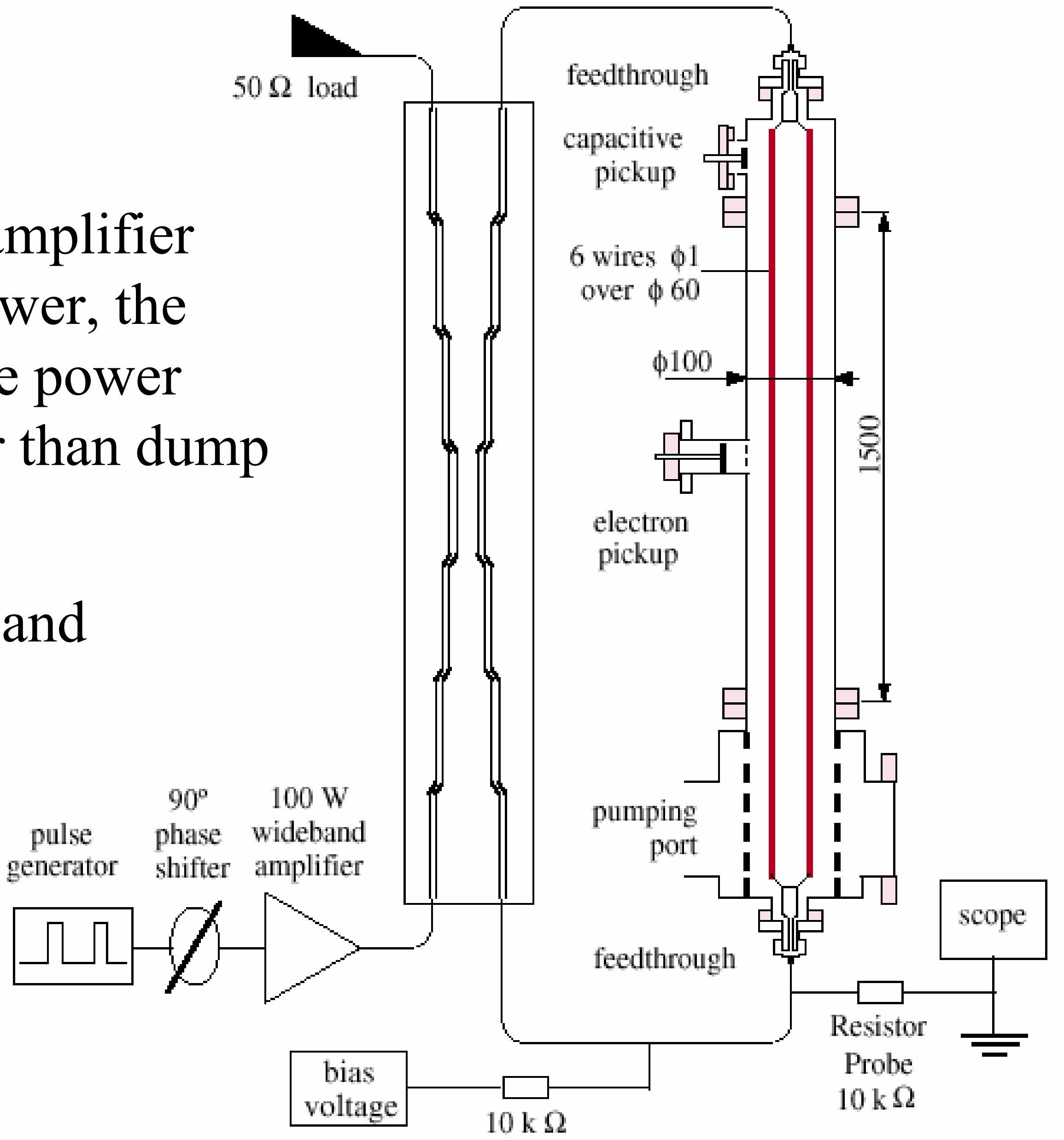
2. Design of the Resonant Ring

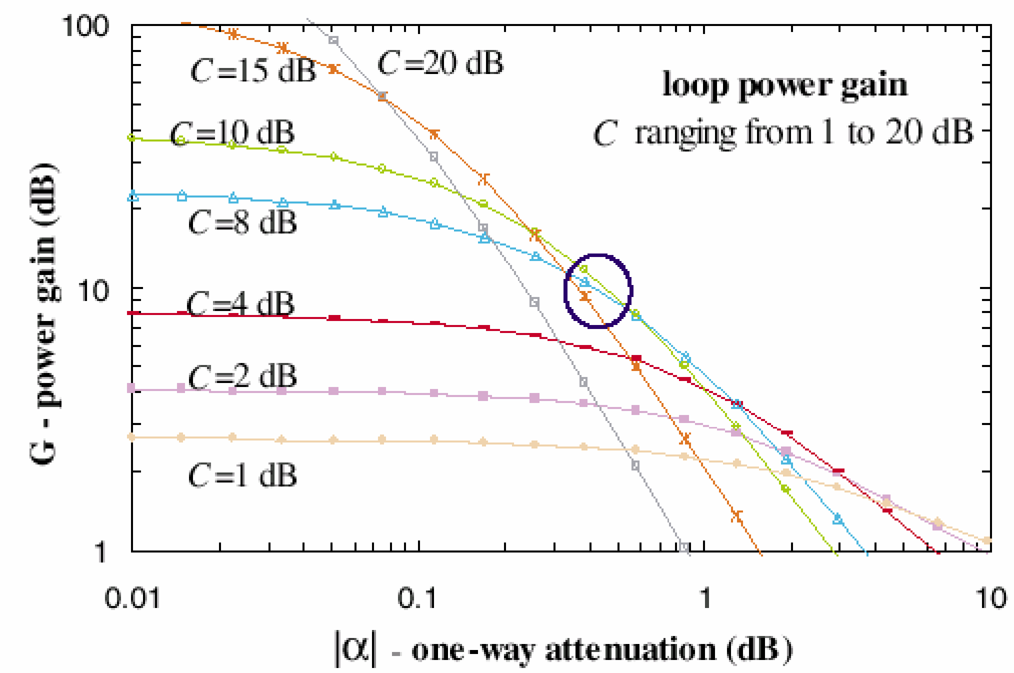
→ Instead of buying an amplifier with more than 1kW power, the idea is to re-circulate the power into the chamber (rather than dump it into the 50Ω load)

→ Need to build a wideband coupler "ad-hoc"



2. Design of the Resonant Ring

→ Such a device will allow a gain G ~ 9dB



$$G = \left[\frac{C}{1 - 10^{-\alpha/20}\sqrt{1 - C^2}} \right]^2$$

C = coupling factor (dB)
α = system attenuation
G = total power Gain

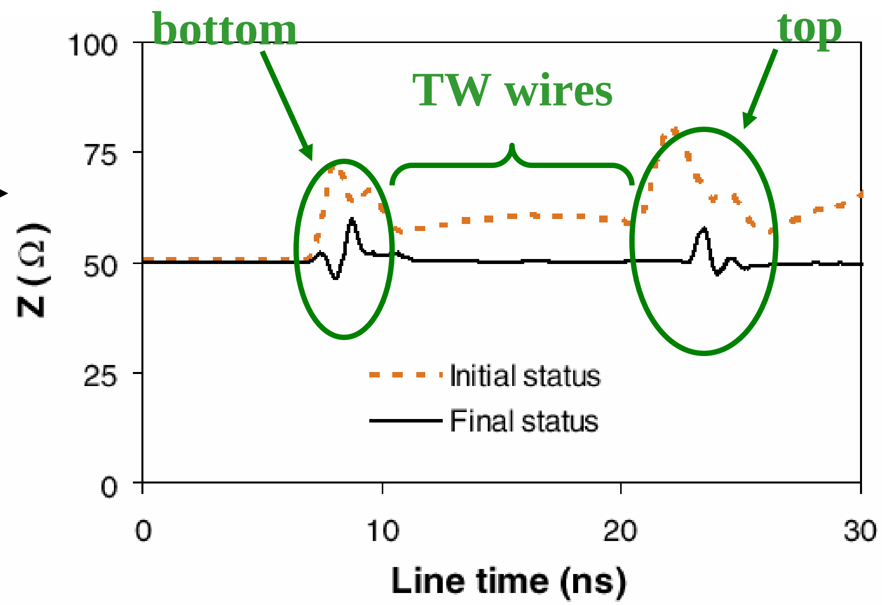
REFERENCE:
Microwave filters, impedance-matching networks, and coupling structures.
G.L.Matthaei, L.Young, E.M.T.Jones

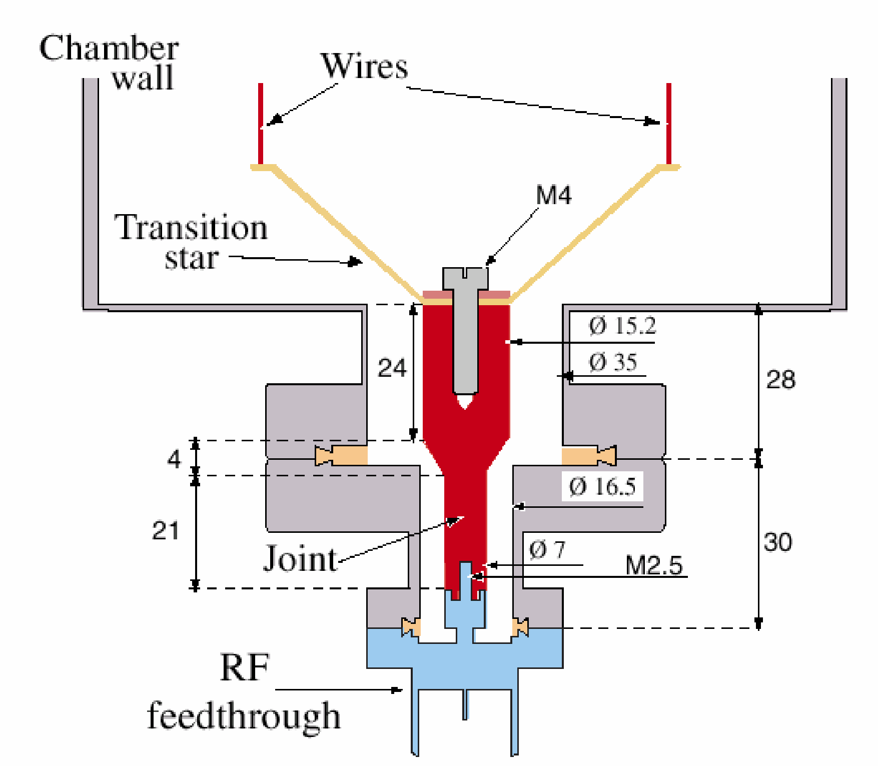
Steps: a. Decrease system attenunation |***α*** | < ***0.5dB***
b. Build a wideband coupler of ***C ~ 9dB***

2.a. Decreasing the system attenuation

Measures to improve attenuation:

- Locate possible mismatches using the VNA
- Example: analysis of the TW chamber →
  - Losses are due to mismatches at top and bottom of the chamber
  - Wires diameter/material





- Careful redesign of adaptors between feedthroughs and wires
- Use of materials like Cu-Be
- Use of new RF feedthroughs
- …

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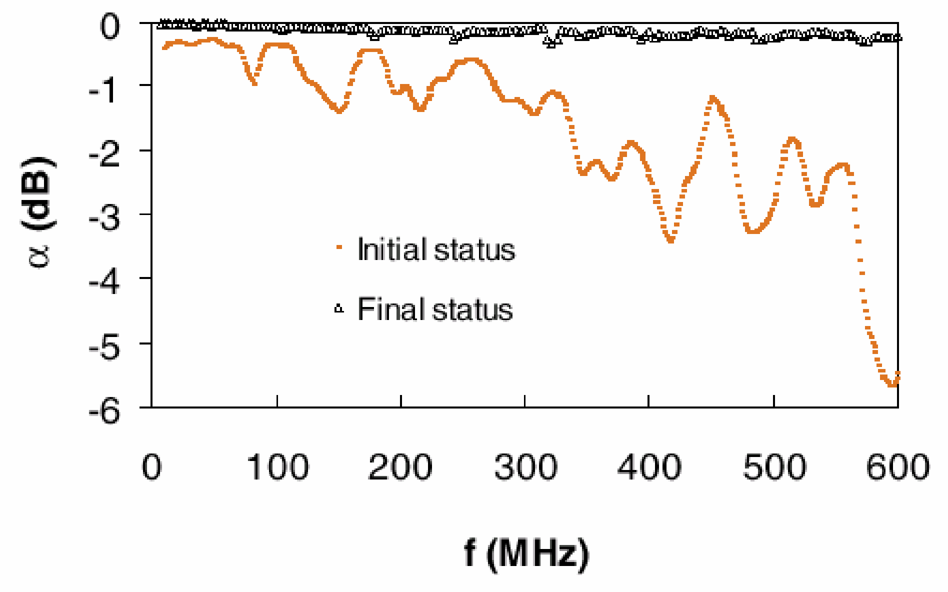
2.a. Decreasing the system attenuation



- $|\alpha| \sim$ **0.3 dB** up to 600 MHz after improvements!!
- Losses before improvements were mainly due to mismatch, not from resistive dissipation

So, **a. Decrease system attenunation** $\boldsymbol{\alpha < 0.5dB}$ ✓

b. Build a wideband coupler of $C \sim 9dB$

2.b. Building-up the Coupler

Requirements:

- G_{power} ~ 9 dB
- Bandwidth: 20-600 MHz
- Coupling factor ***C=10 dB***
- DC isolation up to 1 KV
- Very low transmission losses ~0.3 dB each arm

Solution*:

- **strip-line λ/4, symmetric 9 sections coupler**
- Since f_{center}=300 MHz ➔ λ/4 = 25 cm ➔ total coupler length = 2.25 m!
- Shielding box not bigger than ~10x10 cm in cross section: limit due to propagation of wave-guide modes (cut-off around 1 GHz)

→ Since it is not easy to find on the market a coupler with such a characteristics, we decided to build it up ourselves.

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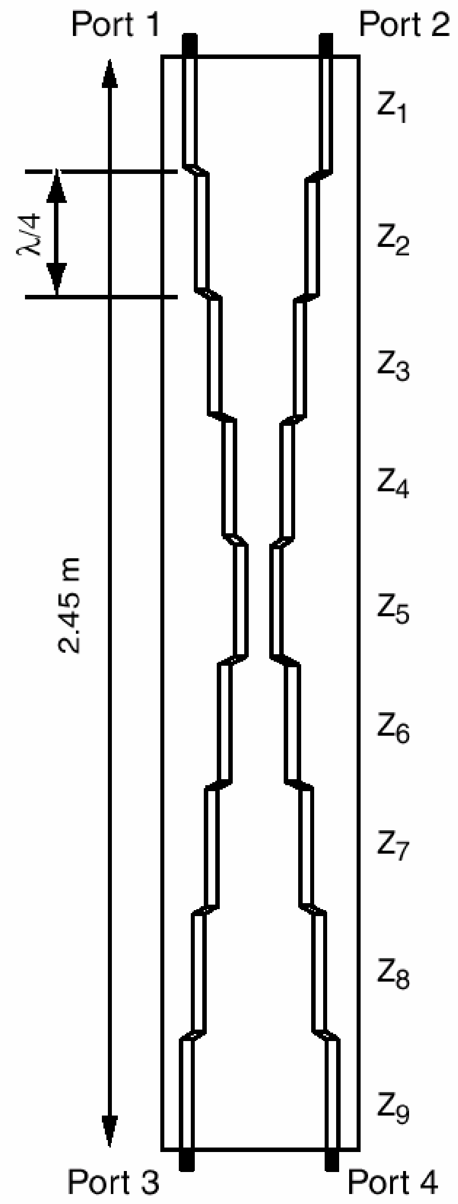
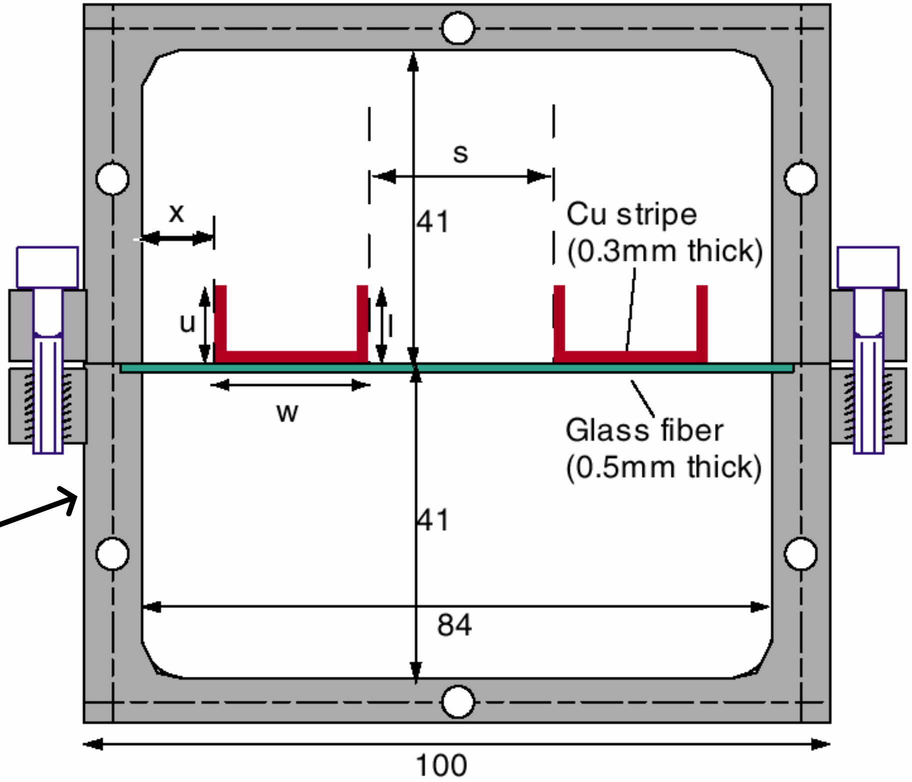
***Strip-line circuit design**, Harlan Howe, JR

2.b. Building-up the Coupler



Longitudinal view of the coupler

Transverse view of a general section



Dimensions for each section must be designed to match the tabulated* impedance values in Odd and Even mode:

	Z1 (=Z9)	Z2 (=Z8)	Z3 (=Z7)	Z4 (=Z6)	Z5
Zeven(Ω)	53.06	55.63	59.90	68.38	103.80
Zodd(Ω)	47.11	44.93	41.73	36.55	24.08

***IEEE Transactions on microwave theory**, Cristal and Young. 1965

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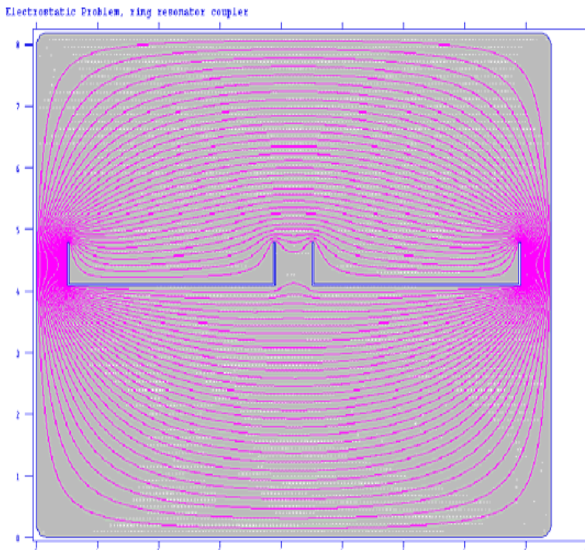
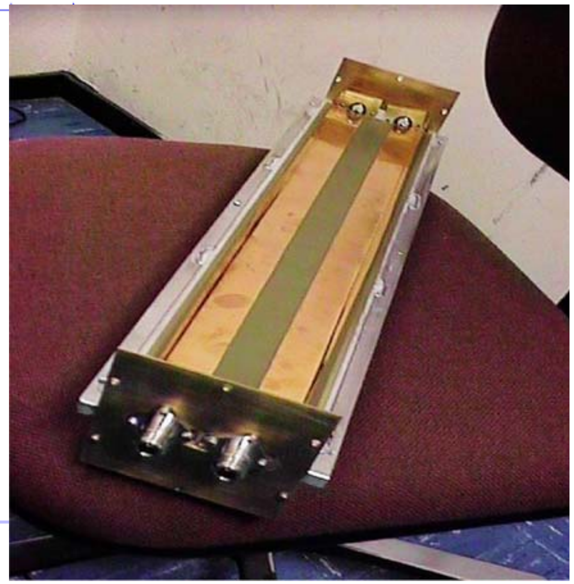
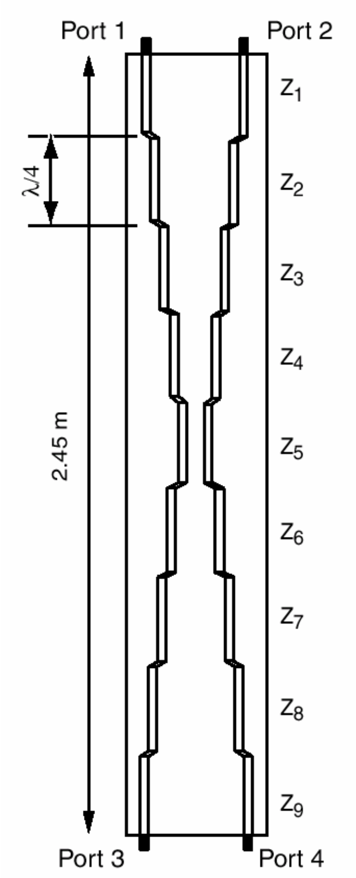
2.b. Building-up the Coupler

Prior to its welding inside the coupler,
→ Each coupler section is designed using SuperFish (odd & even modes)

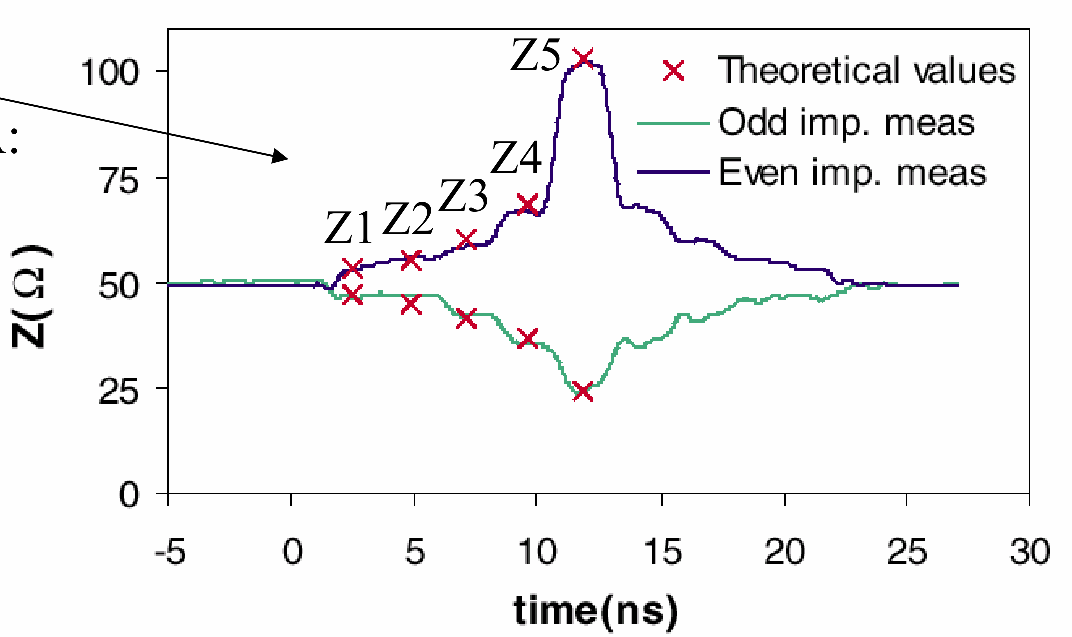
→ Each coupler section is measured separately in a test stand





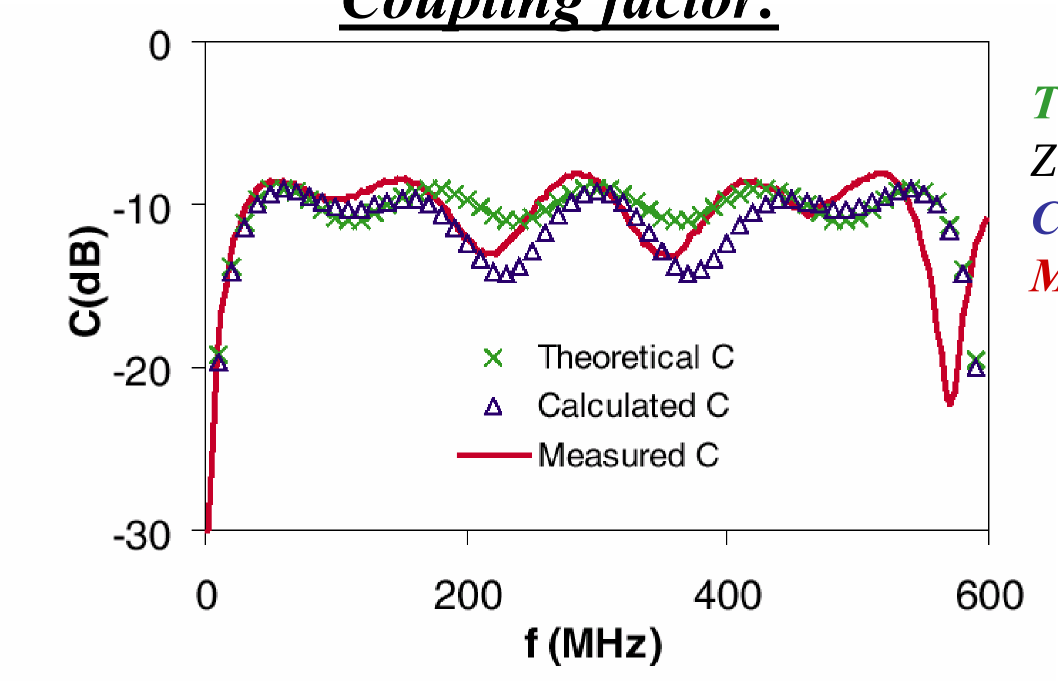


Measurement using the VNA:



2.b. Building-up the Coupler

Coupling factor:



Theoretical C: according to the tabulated Zi values
Calculated C: using Serenade simulations
Measured C: using the VNA

- Final coupling factor: **C~10dB**
- Reasonable ripple, reasonable agreement with theoretical behavior

So, **1. Decrease system attenunation |α| < *0.5dB*** ✓
2. Build a wideband coupler of *C ~ 9dB* ✓

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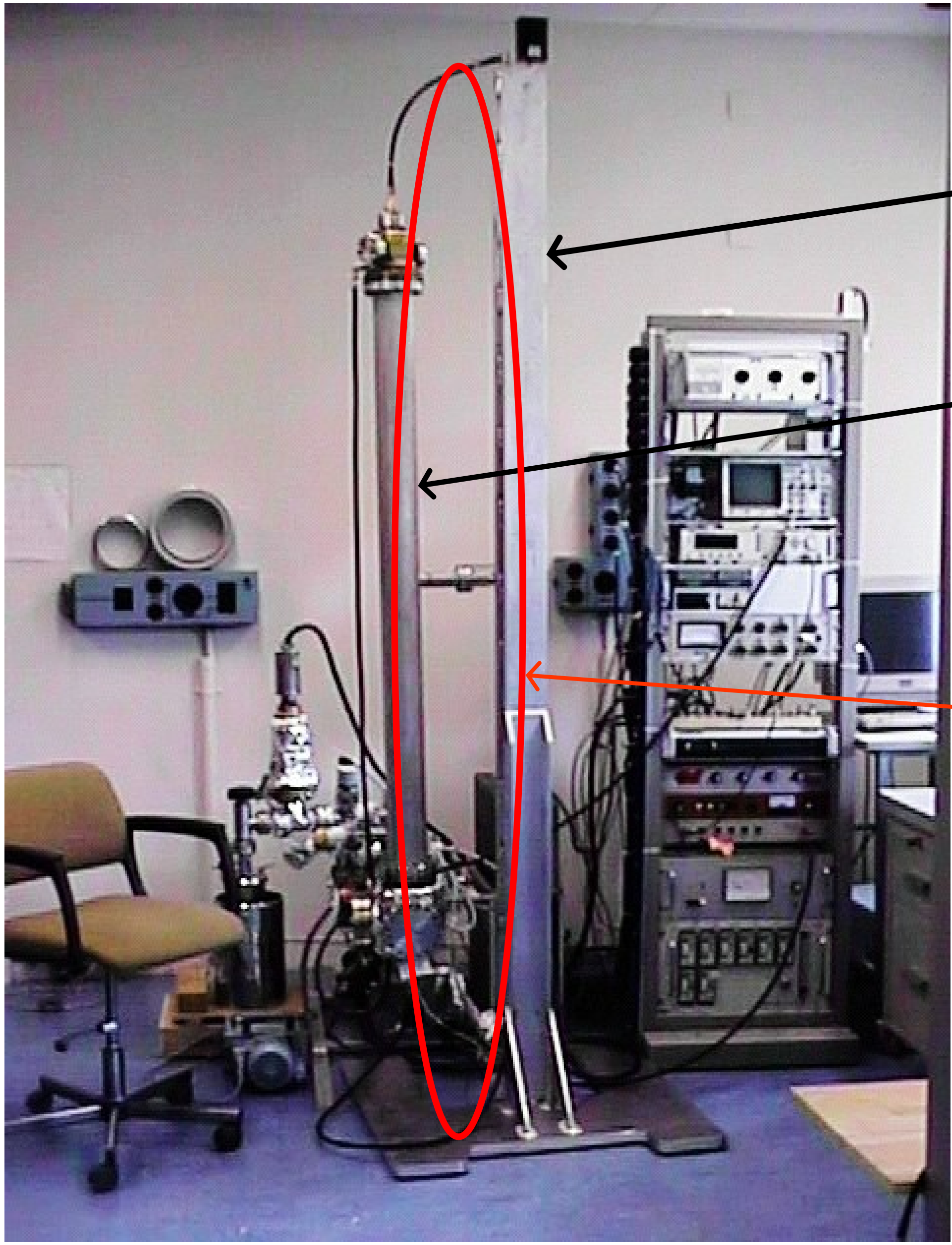
3. **Results**
4. Conclusions

3. Results using the Resonant Ring

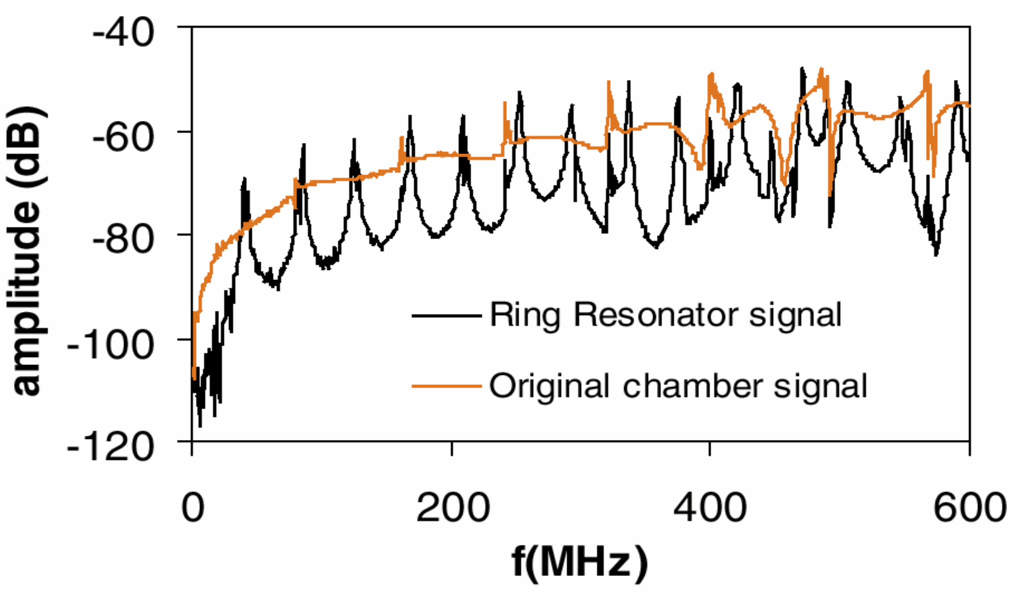


coupler

multiwire chamber

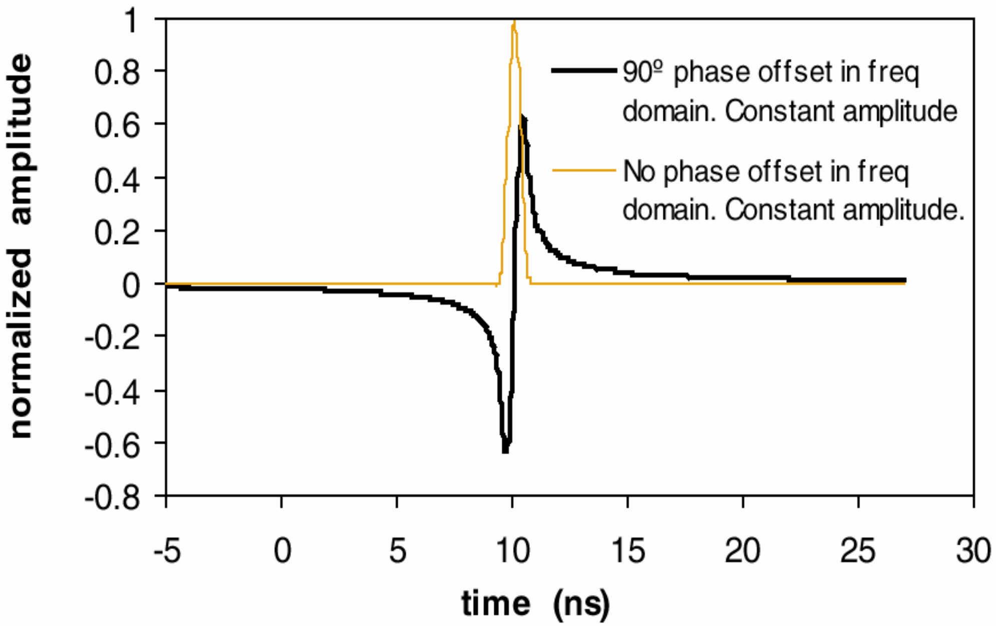
Resonant Ring

3. Results using the Resonant Ring



Power enhancement:

- Every 40 MHz (LHC beams), the minimum increase is 6 dB



Phase offset:

- Better use of the amplifier power limiting characteristics by applying a 90º phase shifter: bipolar to polar Gaussian pulse gives a gain of ~ 3 dB

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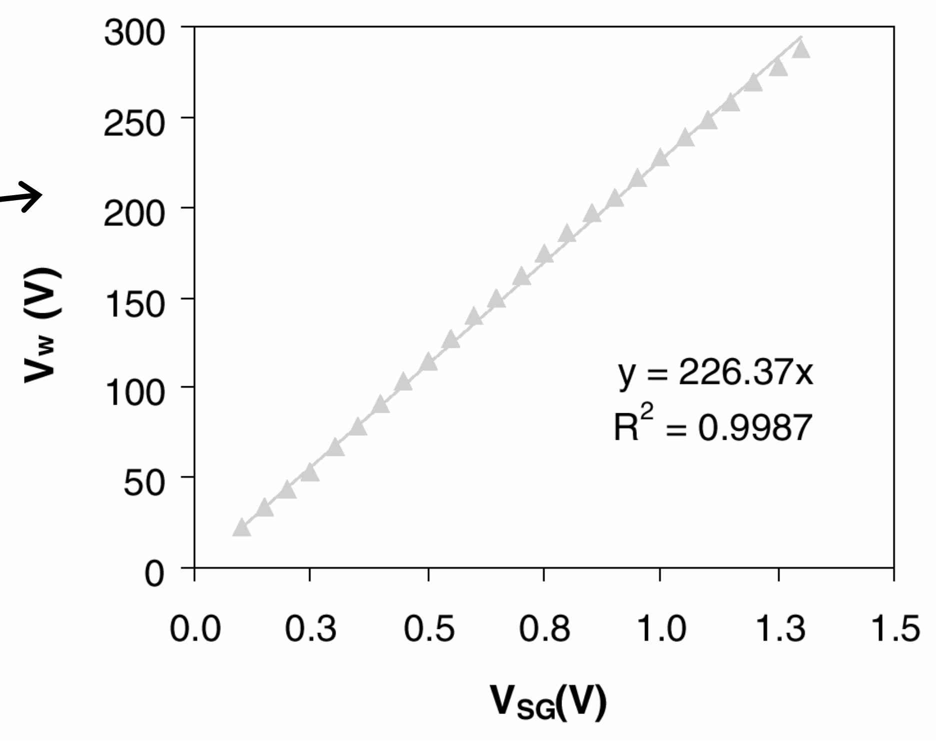
3. Results using the Resonant Ring

• Measurement of the wire voltage as a function of the signal generator:



• After ~300V, multipacting is triggered and the wire voltage decreases (and it is no longer linear)

9dB power ➔ factor ~3 in voltage ✓

Larger electron energies are readily attainable using the new setup, and multipacting can be characterized more deeply.

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- A wideband Resonant Ring has been made by:
  - decreasing system attenuation $|\alpha|$~***0.3dB***
  - build-up a 9 section coupler of ***C~10dB***
- The Traveling Wave voltage is increased by a factor ~3
- The difference in electron energy (Ee):

original set-up: E_e~75 eV

current set-up: E_e~200 eV

↓

- Multipacting can be produced for surfaces with low SEY
- Characterize of scrubbing effect, test surface coatings, evaluate the impact of microwave on the e-cloud, etc