EUROTeV Diagnostics WP5

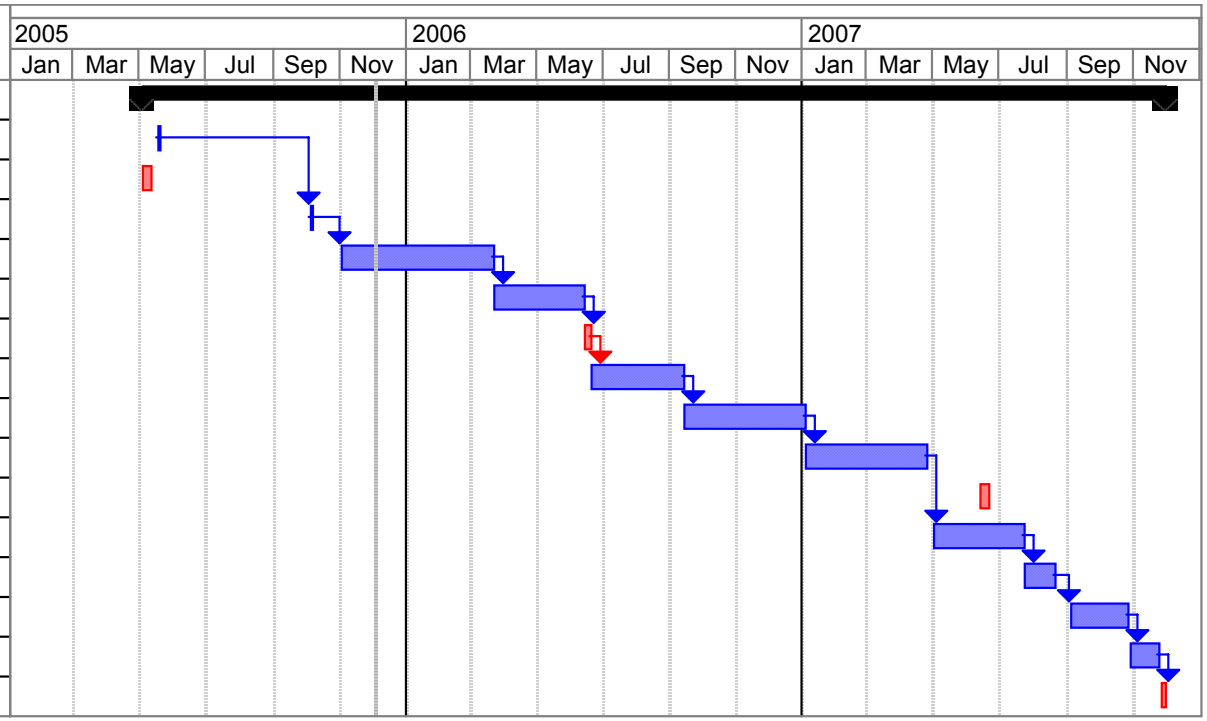
PBPM:
Precision Beam Position Monitor.

WBCM:
Wide Band Current Monitor.

https://cern-eurotev-wp5.web.cern.ch/CERN-EUROTeV-WP5/

PBPM

ID	Task Name
1	**PBPM**
2	Publish fellow post
3	Present work plan for EUROTeV
4	Hire fellow
5	Design PBPM
6	Simulate PBPM
7	Present design for EUROTeV
8	Fabrication drawings
9	Fabrication of 1BPM
10	Tests on bench
11	Present Results for EUROTeV
12	Manufacture 3 PBPMs
13	Tests on bench
14	Tests in CTF3
15	Write report
16	Send report to EUROTeV



Ivan Podadera hired from November 2005 for 2.2y, 75% of his time.

L. Søby working 5% in 2005 and 25% in 2006 and 2007

PBPM- deliverables

- **Prototype PBPM (100nm resolution):**
  - Design and build prototype.
- **Report on bench tests:**
  - Design and build high resolution (100nm), mechanical stable test bench.
  - Develop front end electronics.
  - Measure PBPM.
- **Report on beam tests:**
  - Build 3 PBPMs test with CTF3 or ATF-2 beam.

PBPM-Requirements

EUROTeV ⇒

- Aperture: 4mm
- Resolution: 100nm
- Absolute precision: 10µm
- Rise time: <15ns

ME ⇒

Dynamic range:	±1.5mm (15 bits)
Linearity error:	< 1%
24H stability:	1µm
Vibrations	<10nm
Low frequency cutoff:	100kHz (CLIC 58ns pulse)
High frequency cutoff:	30MHz
CMRR:	>90dB
Bake out temperature:	150°C
Operating temperature:	~20°C
Vacuum:	10^{-9} Torr

PBPM-beam parameters

	ILC	CLIC
Repetition rate	5Hz	150Hz
Beam pulse length	950μs	58ns
Bunch spacing	337ns	267ps
Bunch length	1ps	0.1ps
Charges per bunch	2E10	2.5E9
Nb of bunches	2820	220
Peak current (LP 10MHz)	3220A (0.1A, 60ns)	4023A
Mean current per pulse	9.5mA	1.5A

For CLIC the BPM's are foreseen for the main Linac, with minimum one BPM per quadrupole i.e. 2600 BPM's.

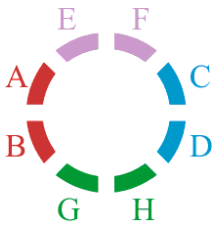
We need additional BPM's for the accelerating structures which could bring the number up to 20000.

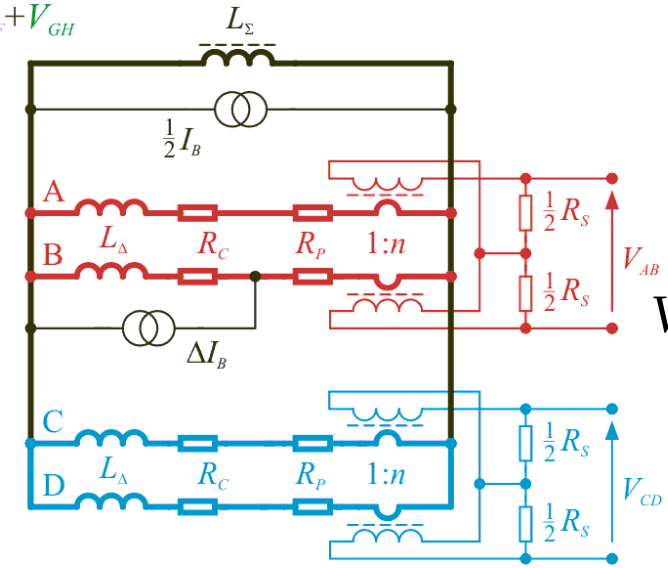
CERN/PS (e^-) BPM history

- This type of PU, based on a WCM, was first developed and used in LPI (UMA), S Battisti, M. Le Gras, D. J. Williams.
- A circular version was developed for CTF3 (BPM), M. Gasior.
- A third version for rectangular vacuum chamber in the CTF3 DL (BPI), A. Stella and al, Frascati.
- CLIC……..CPM!!

Transformer Pick-Up

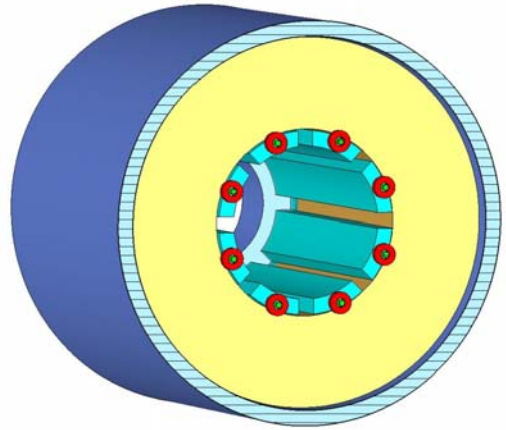
$$V_{\Sigma} = V_{AB} + V_{CD} + V_{EF} + V_{GH}$$
$$V_{\Delta H} = V_{AB} - V_{CD}$$
$$V_{\Delta V} = V_{EF} - V_{GH}$$





$$R_P = \frac{R_S}{2n^2}$$

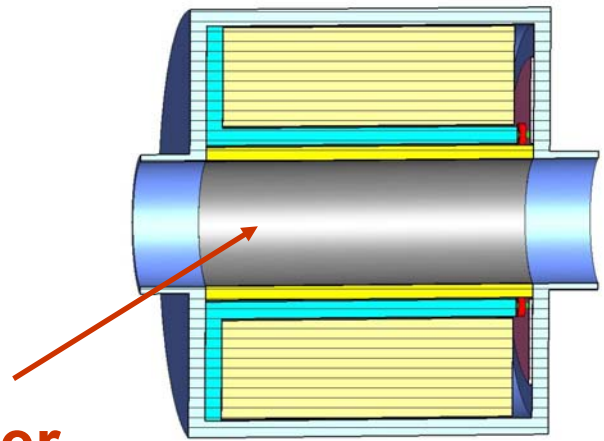
$$V_{Out} = \frac{I_{Beam} * R_{Load}}{n}$$



Dipole mode:

$$f_{Low-Delta} = \frac{R_s}{n^2 \cdot 2 \cdot \pi \cdot L_{Electrodes}}$$

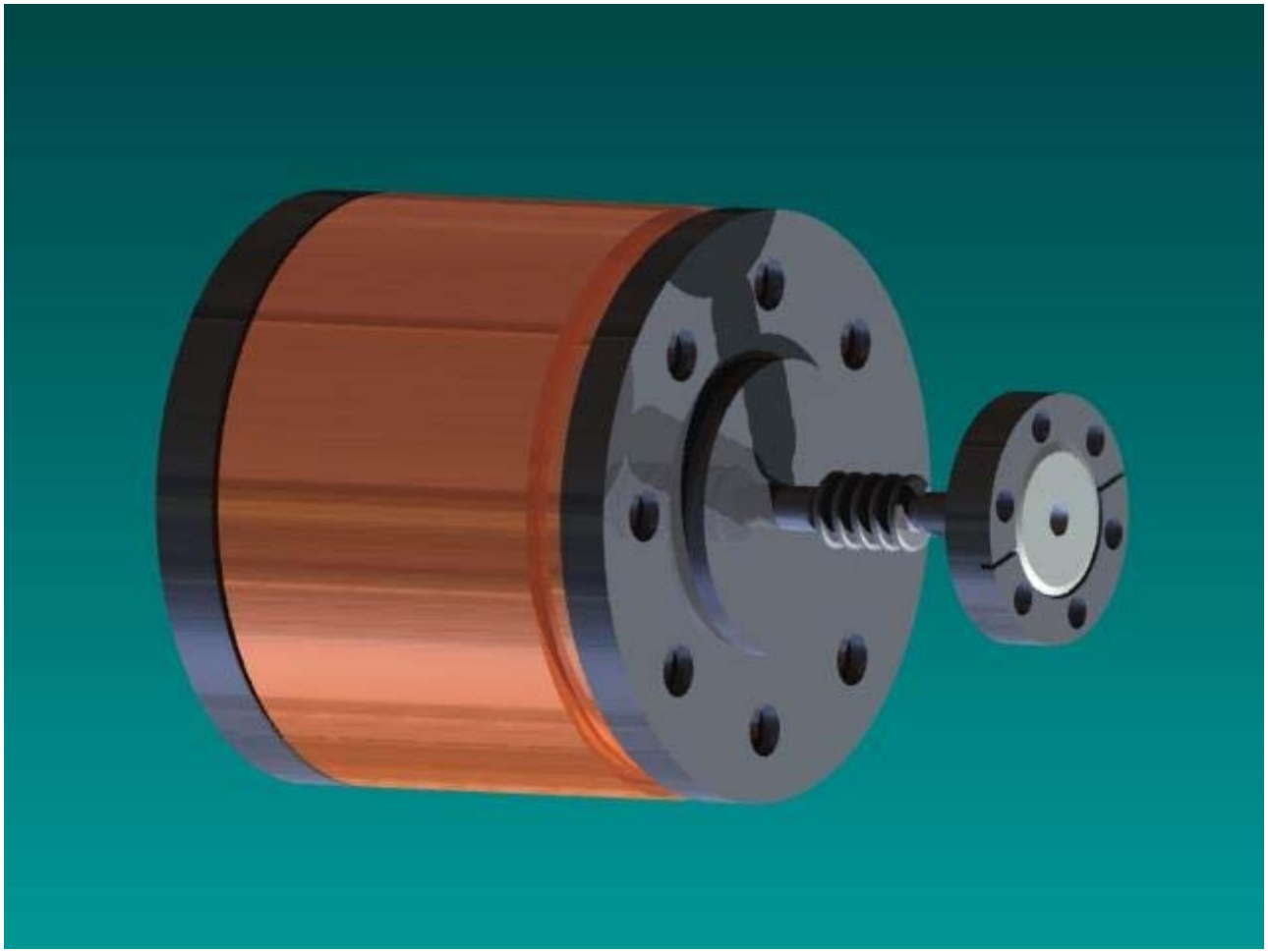
- **Electrodes are combined in pairs so that each transformer sees half of the load**
- **Frequency low cut-offs are limited by connection parasitic resistances and primary electrode inductance.**



Design: M. Gasior

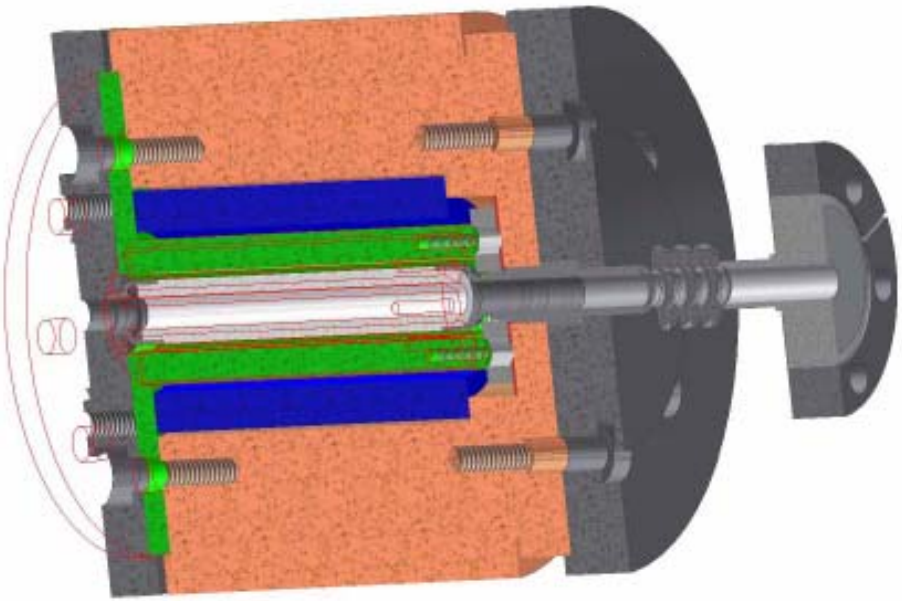
Resistive layer

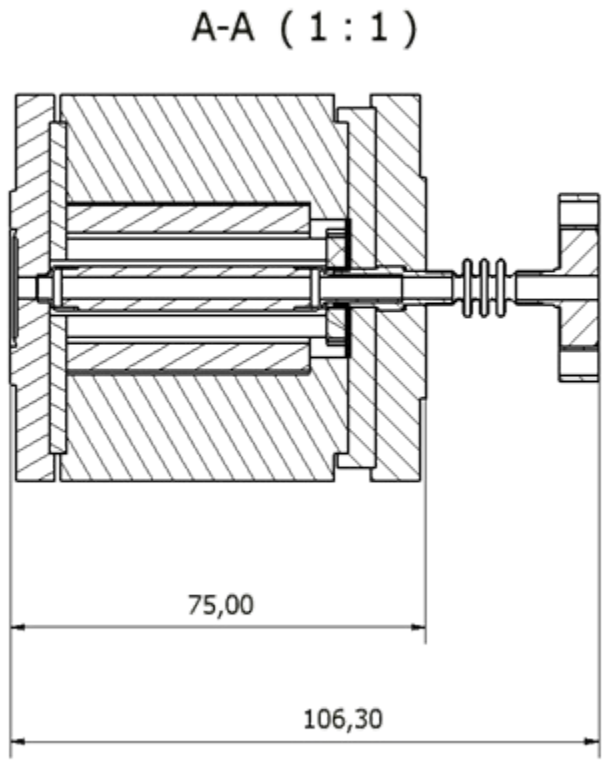
PBPM preliminary design



- Circular 4mm vacuum tube.
- Length ~100mm.
- DN 16 flanges (CF)?.
- External reference plane for alignment (WPS?).
- Mounted on damped quadrupole support.
- Fixed to quadrupole?

PBPM preliminary design



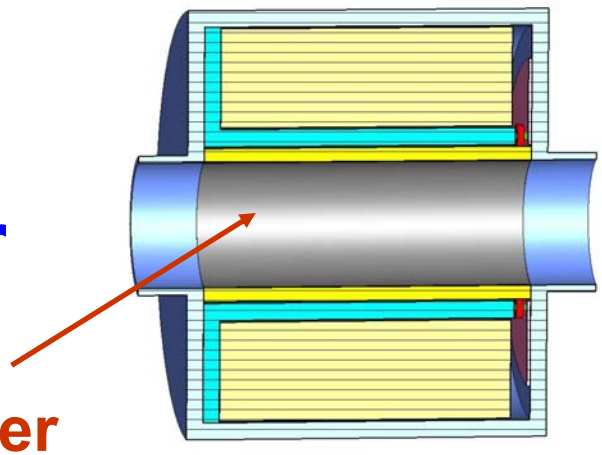


PBPM Preliminary design

- External reference machined to 10um absolute precision.
- Surface relative error ~1um. Metrology to determine mechanical center to within ~1um.
- Test bench determines electrical offset to a precision of ~1um.
- WPS should enable preliminary alignment of ± 10um.
- Balistic beam alignment

PBPM simulations

- **Wakefield's, How much is OK?**
  - Optimize design
  - Resistive layer in ceramic tube
  - Include bypass capacitor for very high frequencies
- **Electrical response**
- **Mechanical stability**
- **Dissipation in resistive layer**

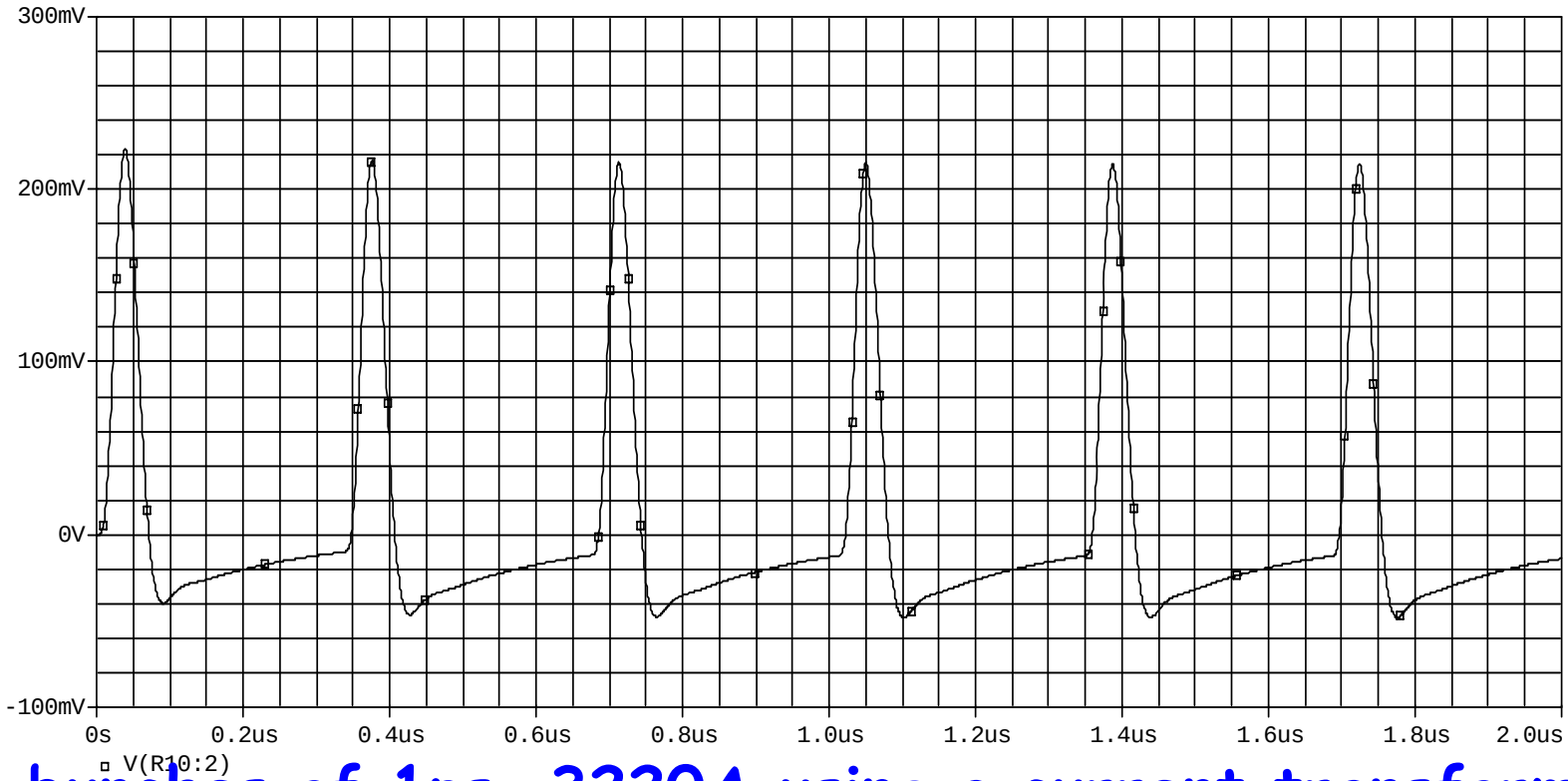


Resistive layer

PBPM electronics

- Front-end hybrid to generate difference and sum signals. BW=100kHz-30MHz.
- Difference must have ~90dB CMRR to obtain 100nm resolution over ± 2mm.
- ILC version must include 10MHz Bessel filter to dilute 1ps bunch to ~60ns.
- Fast 200MS ADC.

Simulations



ILC bunches of 1ps, 3220A using a current transformer with 20 turns. Sigma is 200mV giving 10uV per 100nm.

⇒ S/N=2 for nominal beam with en=1nV/sqrt(Hz).

For CLIC we get 15 times more signal.

PBPM test bench

- Resolution with CLIC and ILC type beams.
- Sensitivity and Linearity.
- Electrical offset.
- Temperature stability 15-25°C
- 24H stability
- Long term stability

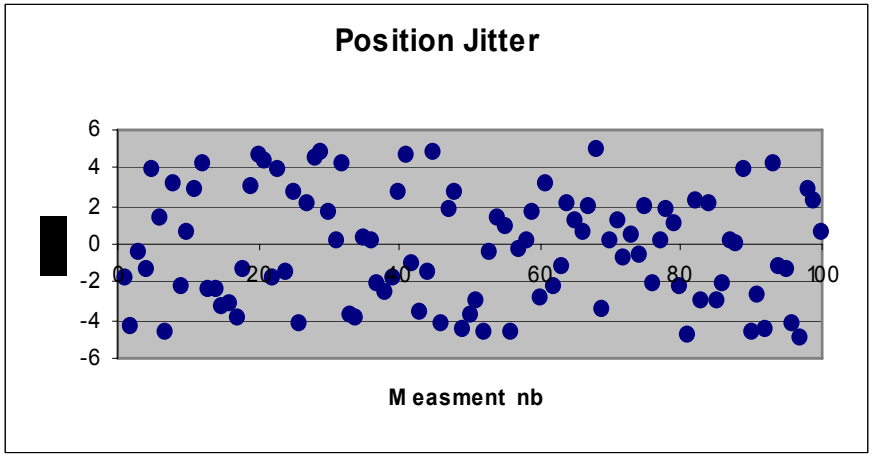
PBPM test bench

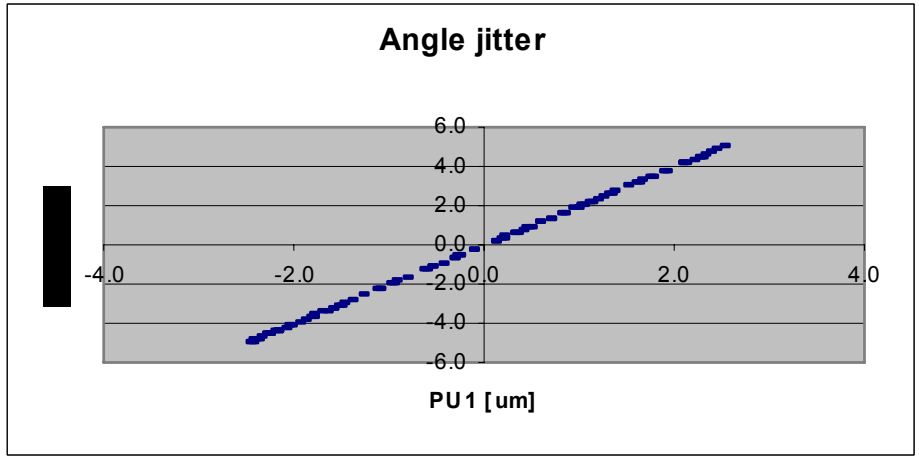
- **Antenna**:
  - Connection electrical
  - signals.
  - Part of a 50 Ω system, terminated in 50 Ω.
- **Vibrations**
  - Total vibrations <100 nm.
  - With damping table :
    - **<10 nm (>4 Hz).**
    - **<10nm (<4 Hz).**
- **Environment**
  - Stabilized around room temperature (20 ºC).
  - Wind shield
- **Linear motion**
  - X-Y table or only X?
  - Displacement: ±2 mm.
  - Resolution: <100 nm.
  - Repeatability: ≤100 nm.
  - Deviation: 0.1%.
  - Accuracy ~1 μm.
- **Rotary motion.**
  - 180º (steps of 90º).
  - Eccentricity: <1μm.
  - Accuracy: 0.1mrad.

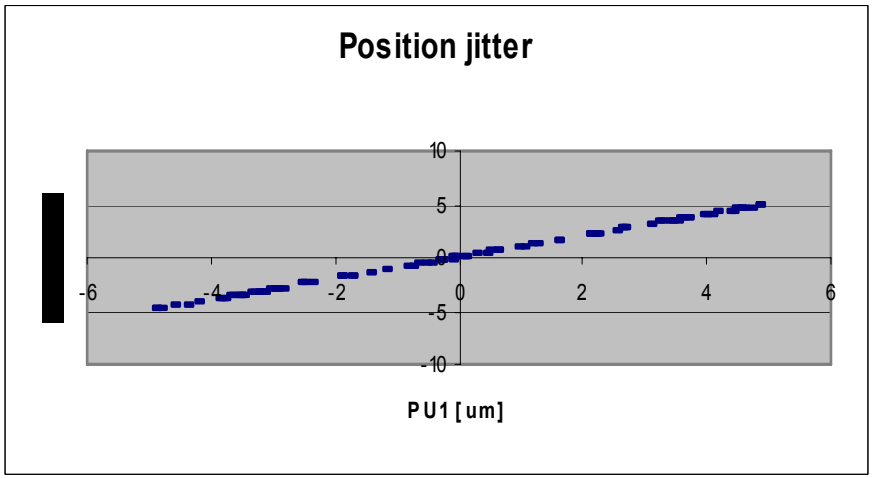
Beam tests

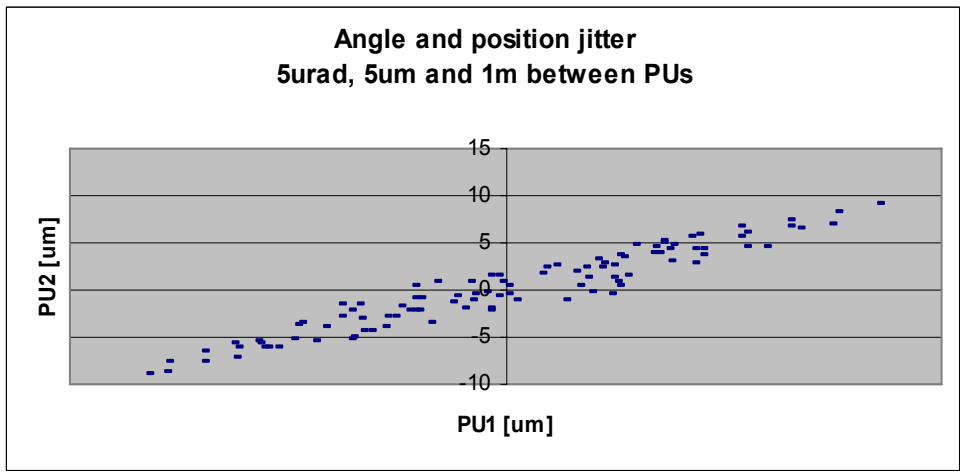
- Autumn 2007
- ATF-2 or CTF3. If ATF-2 the aperture must be 6mm.
- Beam jitter of tens of um could make it difficult.
- 3 PBPM to build in order to disentangle angle and position jitter.
- PBPM's installed on separate micro-movers

Beam tests


Position Jitter
6
4
2
0
-2
-4
-6
0
20
40
60
80
100
Measment nb


Angle jitter
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-4.0
-2.0
0.0
2.0
4.0
PU1 [um]


Position jitter
10
5
0
-5
-10
-6
-4
-2
0
2
4
6
PU1 [um]


Angle and position jitter
5urad, 5um and 1m between PUs
15
10
5
0
-5
-10
PU2 [um]
PU1 [um]

EUROTeV Diagnostics WP5

WBCM: Wide band current monitor.

WBCM

ID	Task Name	2005 Qtr 1	2005 Qtr 2	2005 Qtr 3	2005 Qtr 4	2006 Qtr 1	2006 Qtr 2	2006 Qtr 3	2006 Qtr 4	2007 Qtr 1	2007 Qtr 2	2007 Qtr 3	2007 Qtr 4
1	**WBCM**												
2	Present work plan for EUROTeV												
3	Hire scientific associate												
4	Simulate existing WCM												
5	Simulate new design												
6	Present design for EUROTeV												
7	Fabrication drawings												
8	Fabrication of 1 WCM												
9	Tests on bench												
10	Modify design												
11	Present Results for EUROTeV												
12	Tests on bench												
13	Tests in CTF3												
14	Write report												
15	Send report to EUROTeV												

Hope to hire scientific associate from June 2006.

R. Fandos will help with HFSS simulations, starting from early next year.

I. Podadera will work 25%.

L. Søby working 5% in 2005, 25% in 2006 and 2007.

WBCM- deliverables

- **Report on BW limits:**
  - 3D EM simulations to identify high frequency limits of existing WCM.
- **Improved prototype system:**
  - Modify design and simulate.
  - Build new WCM and test on bench.
- **Report on beam tests:**
  - Tests with CTF3 beam

WBCM-Requirements

EUROTeV ⇒

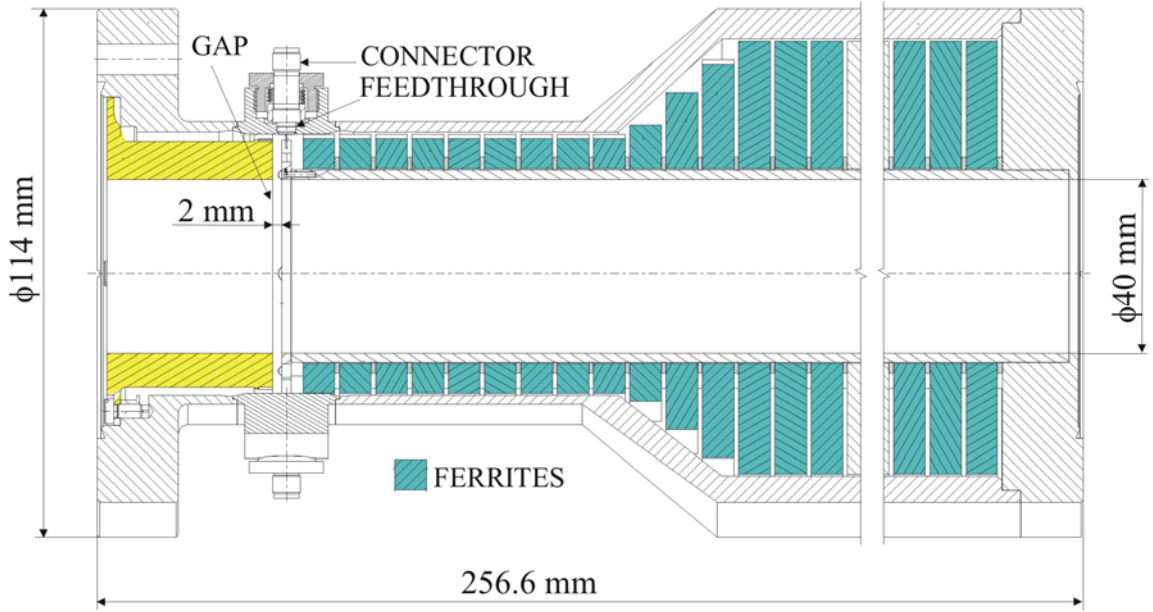
- **Beam current monitor with > 20GHz band width for measurement of intensity and bunch to bunch longitudinal position.**
- **Main beams, drive beams and damping rings.**

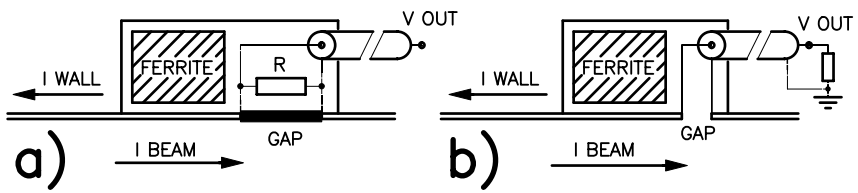
ME ⇒

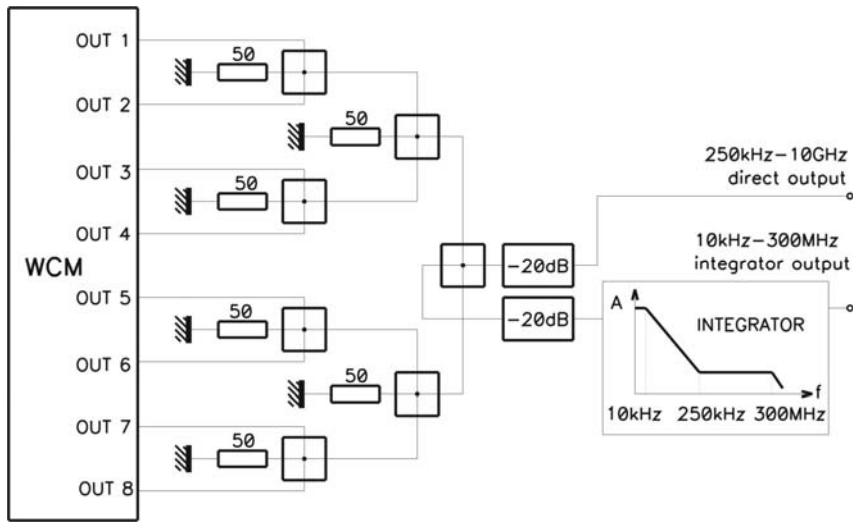
Low frequency cutoff:	**100kHz**
Bake out temperature:	**150°C**
Operating temperature:	**20°C**
Vacuum:	**10^{-9} Torr**

100kHz-20GHz WB signal transmission over 10-20m.

Existing WCM

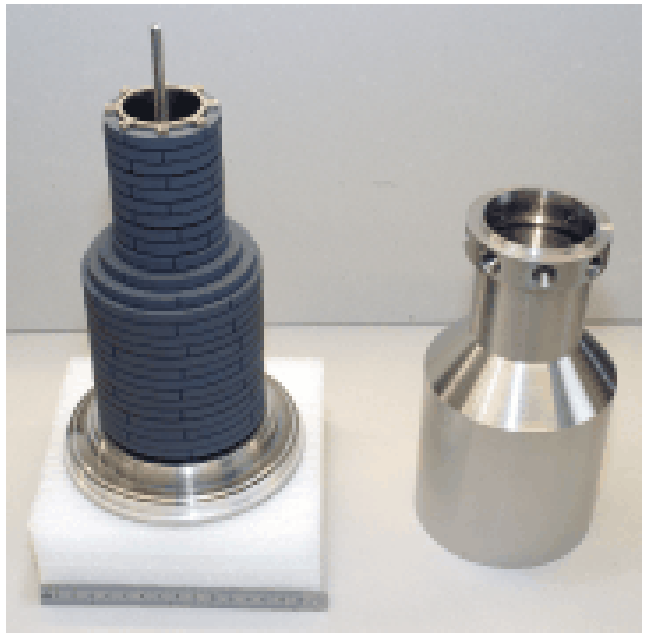


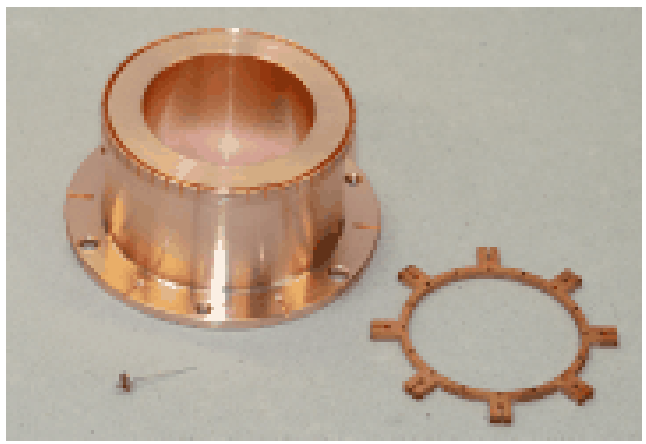




Design: J. Durand, P. Odier

Existing WCM





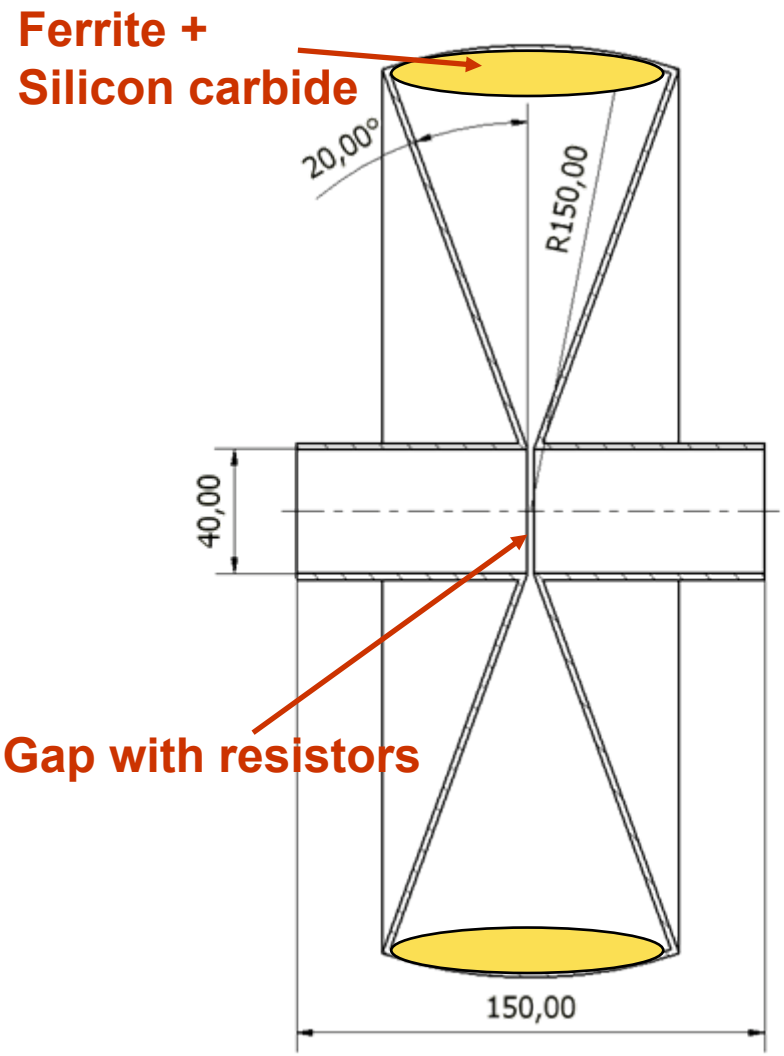
Existing WCM

Impedance	4 Ω
Lf cut-off, direct output	250 kHz
Lf cut-off, integrator output	10 kHz
Hf cut-off	7 GHz
Number of feed thru	8
Gap length	2 mm
Beam aperture diameter	40 mm?
Length	256 mm
Flange type	DN63CF
Max temp. bake-out	150 °C

A "biconical" WCM

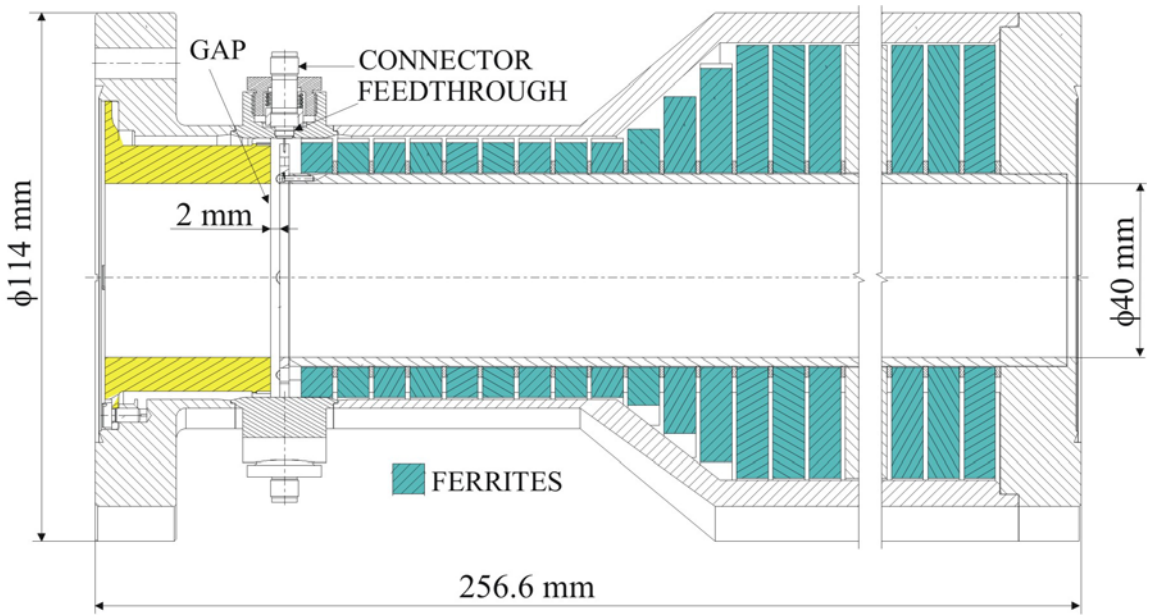
- An idea (Biconical antennas or radial transmission line) by F. Caspers.
- Guides radial spherical TEM wave which is absorbed by Silicon carbide and ferrite.
- No corners to avoid HOM conversions.
- Should have higher bandwidth than traditional tank shapes .
- Optimize angle to gap impedance.

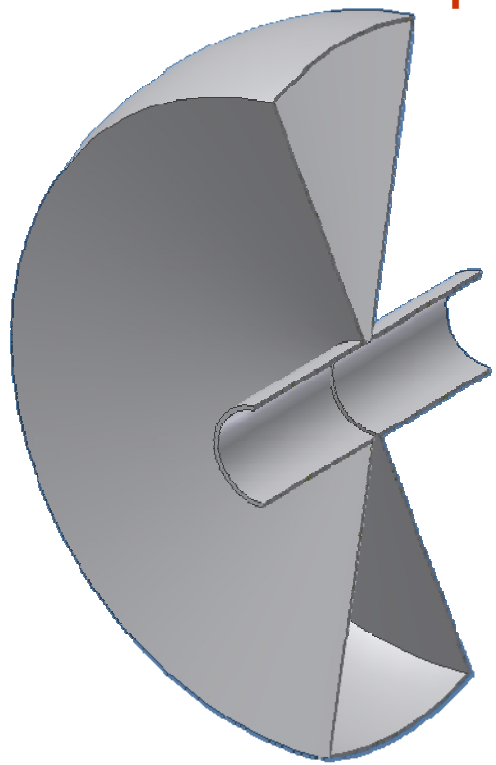
$$Z_{Cone} = \frac{377}{\pi} \ln(\cot\frac{\varphi}{2})$$



WCM

A WCM with biconical shape!!



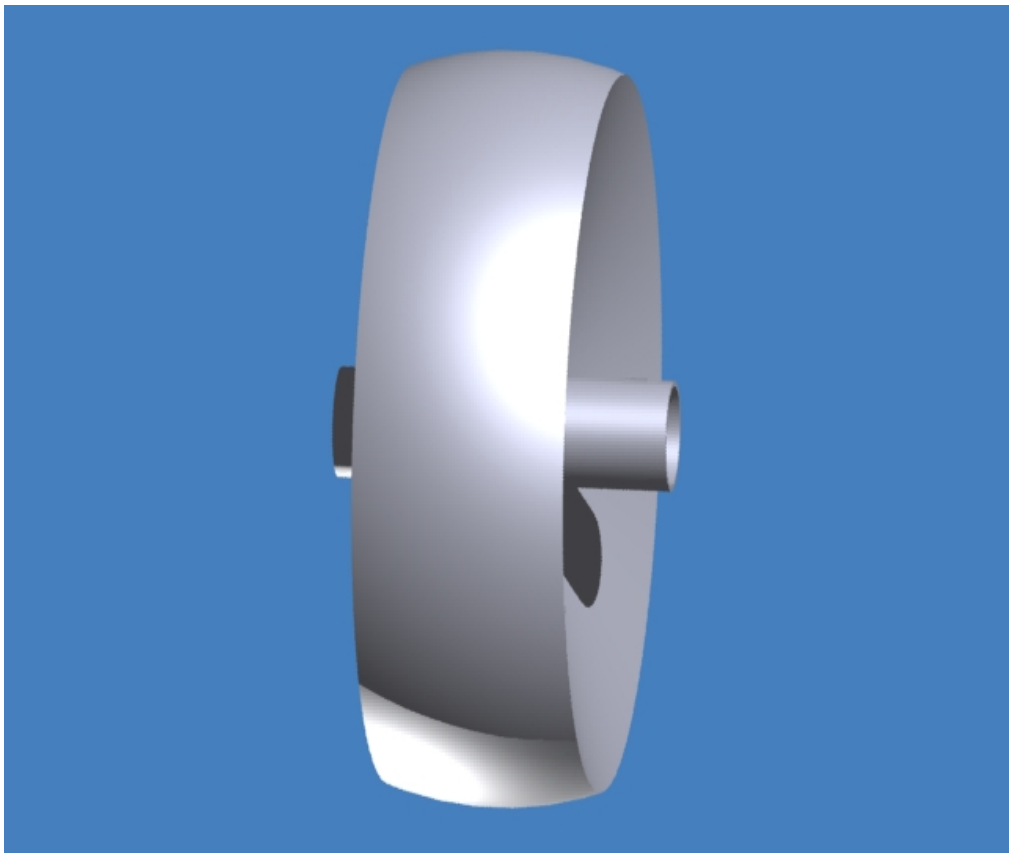


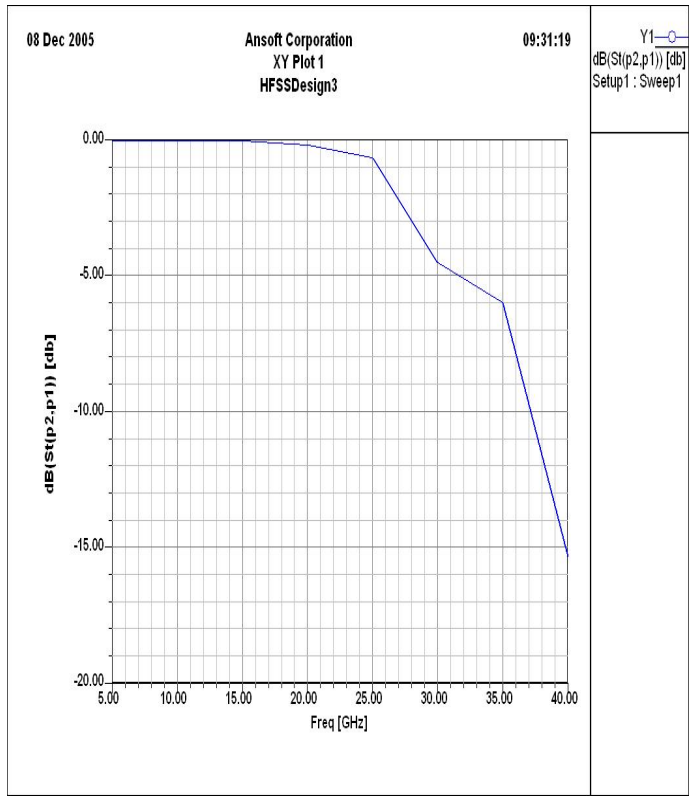
Complicated tank with corners excite HOM.

Lots of volume for ferrites is good for low frequency response.

Simulate both structures and compare.

"Biconical" WCM

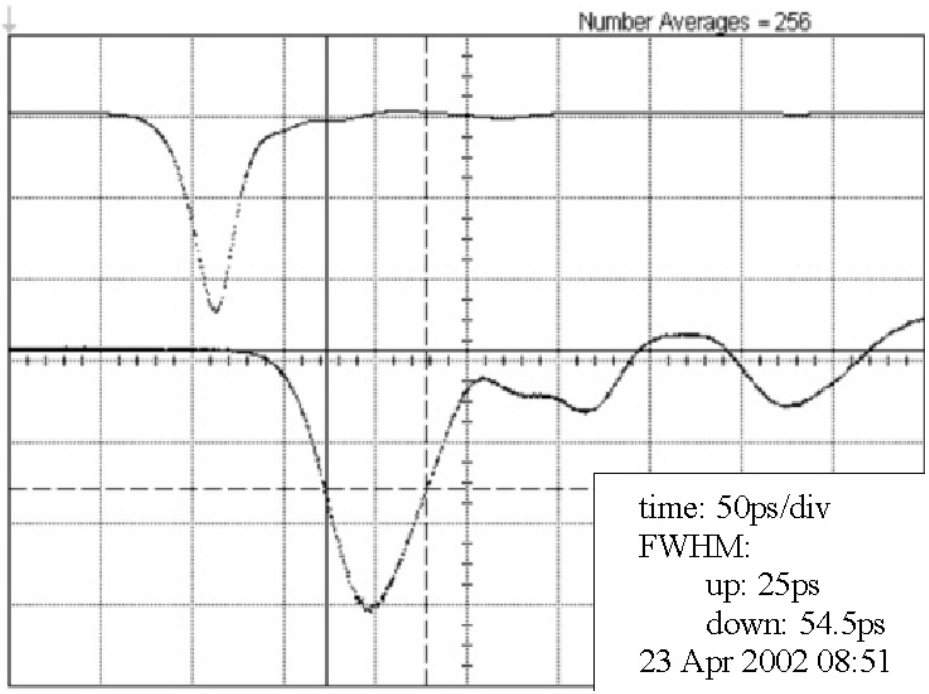




Transmission (S21) simulation of 50ohm setup, but done without absorbing boundary.

WCM bench tests

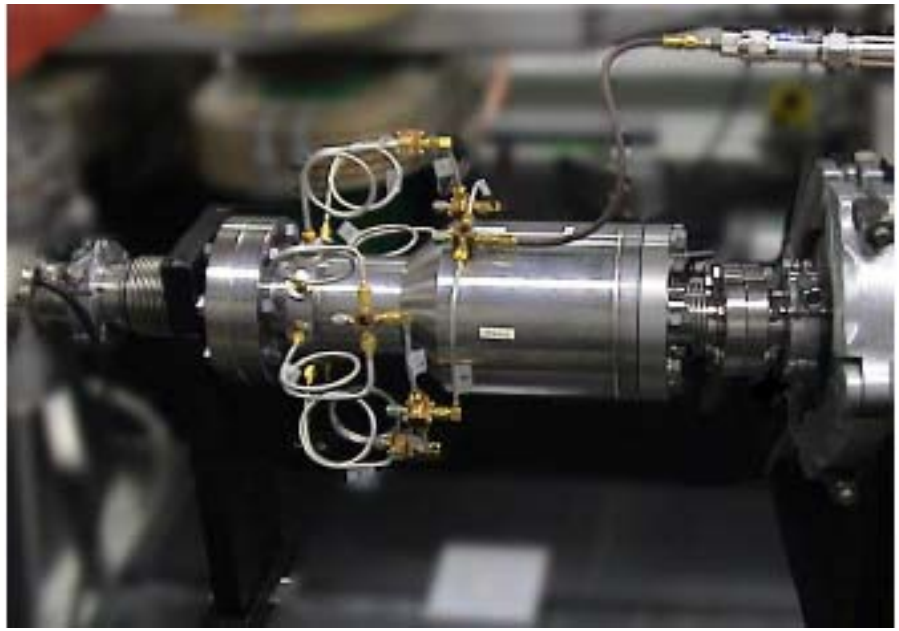
- 50 ohm test set using pulse of 25ps FWHM.
- Thin wire using time domain gating to eliminate reflections.
- HP86100 50GHz sampling oscilloscope



WCM beam tests in CTF3

Signal transmission over 10-20 m.
Low frequency part on coax and high frequency on optical fiber?

Using a sampling oscilloscope requires very stable beam and trigger. Not easy.



Real time oscilloscopes are limited by bandwidth and price.

DSO81304A

12 - 13 GHz BW

20 GSa/s per channel
40 GSa/s on two channels
From US$ 115,000

Thank you for your attention