High Precision Beam Position Monitor for the TESLA Spectrometer

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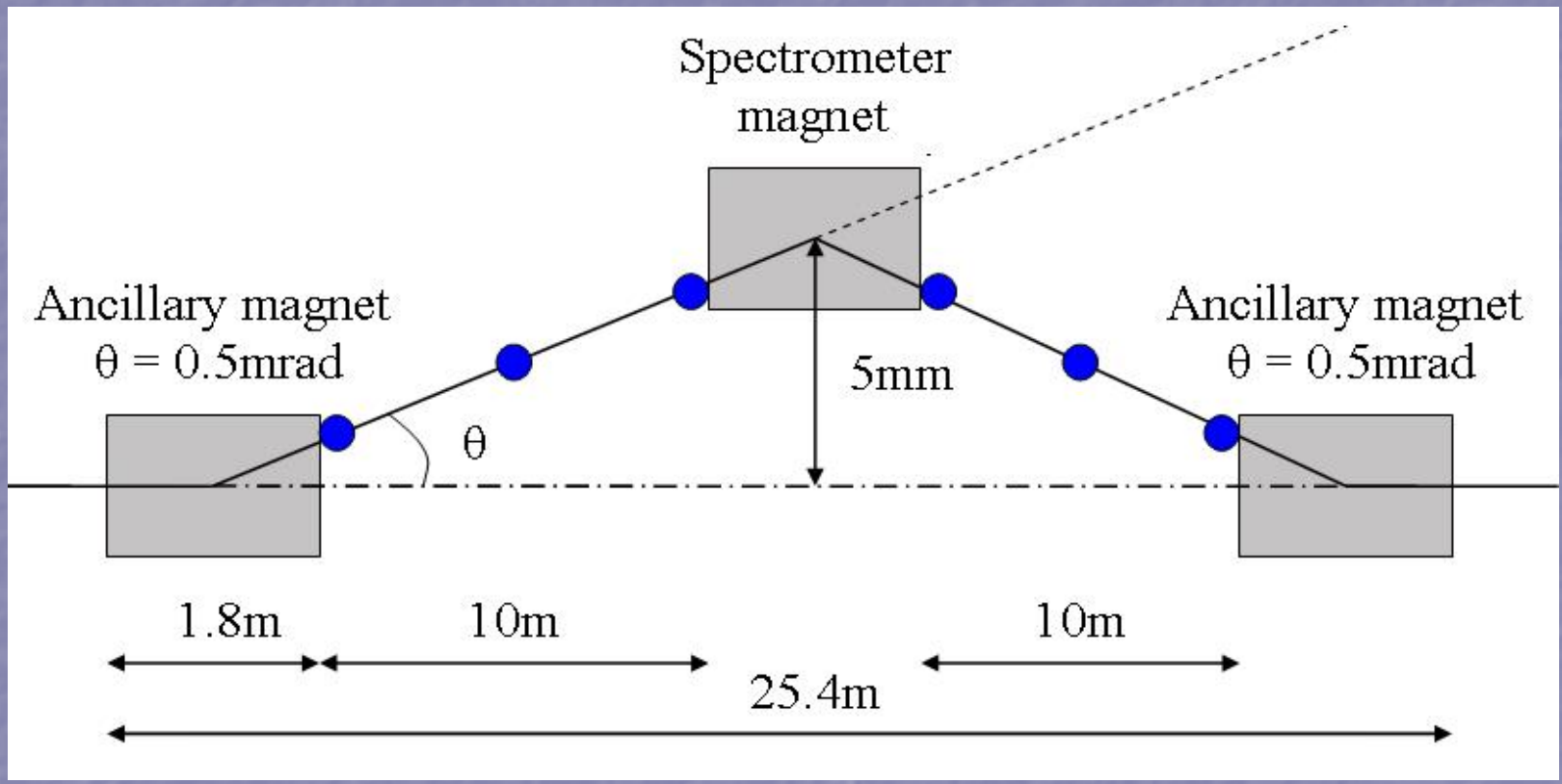
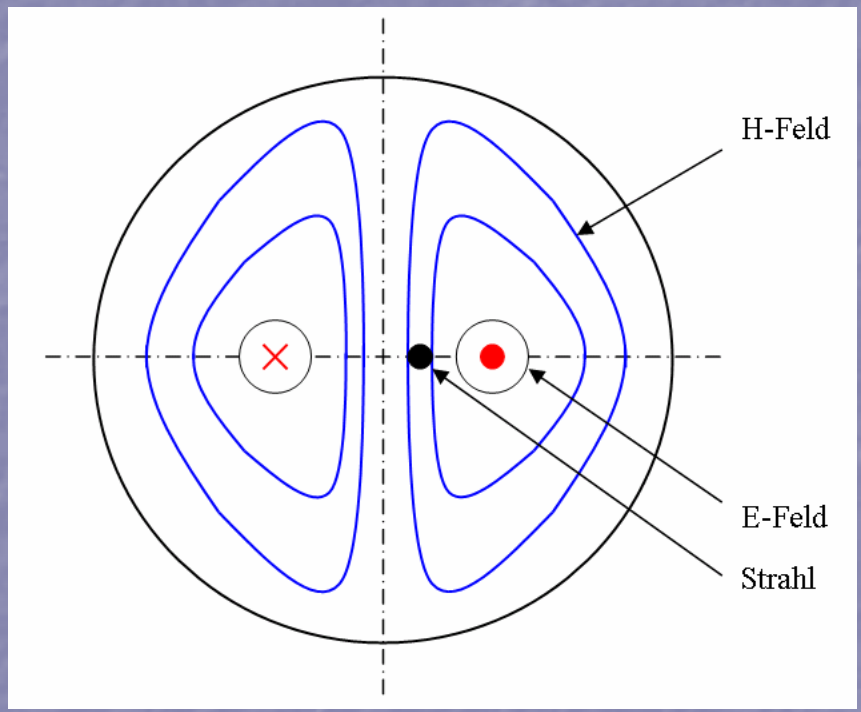
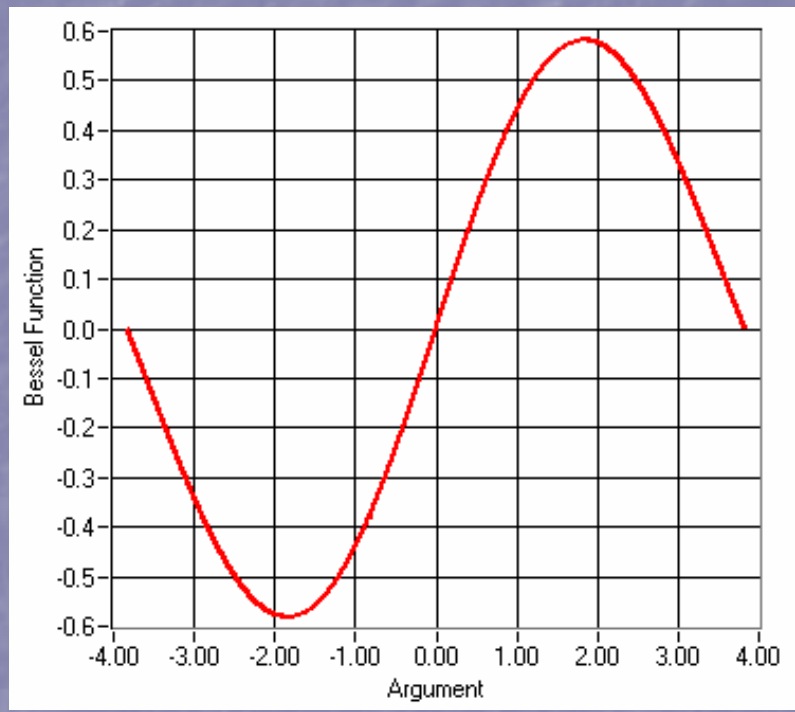
BPM in the Spectrometer



- the resolution of BPMs has to be higher than 1μm (100nm preferred)
- the dynamic range has to be possibly wide to avoid mecanical movement
- BPMs must work with a beam, which is not parallel to z-axis

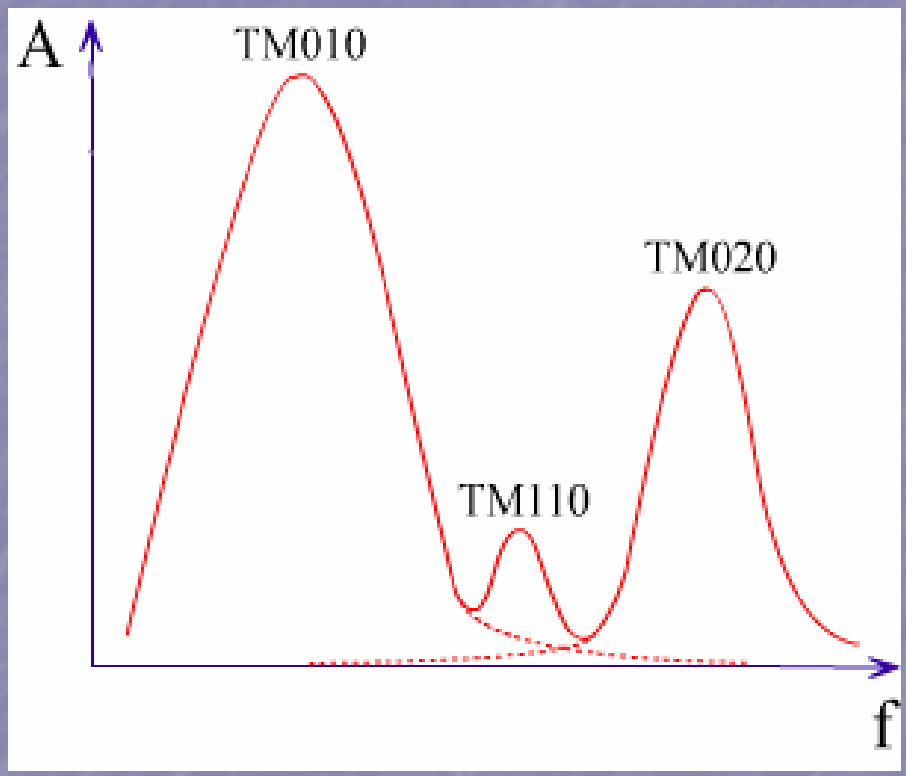
BPM Proposal

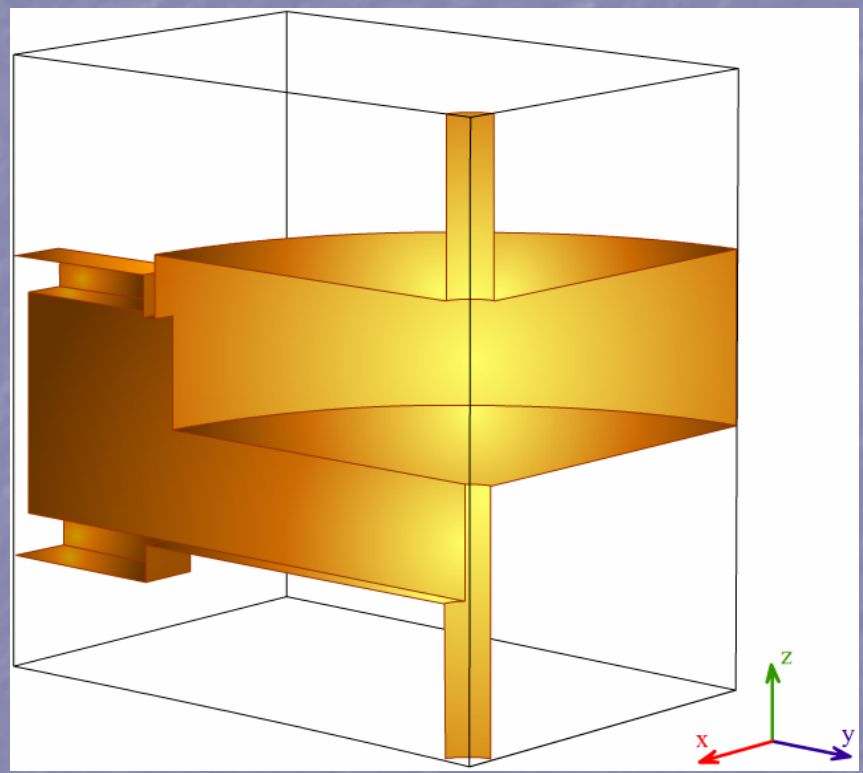




The exitation of the dipole mode in a cylindrical cavity is proportional to the beam offset from the cavity center: $E_{110} = CJ_1(j_{11}r/R)\cos\phi$

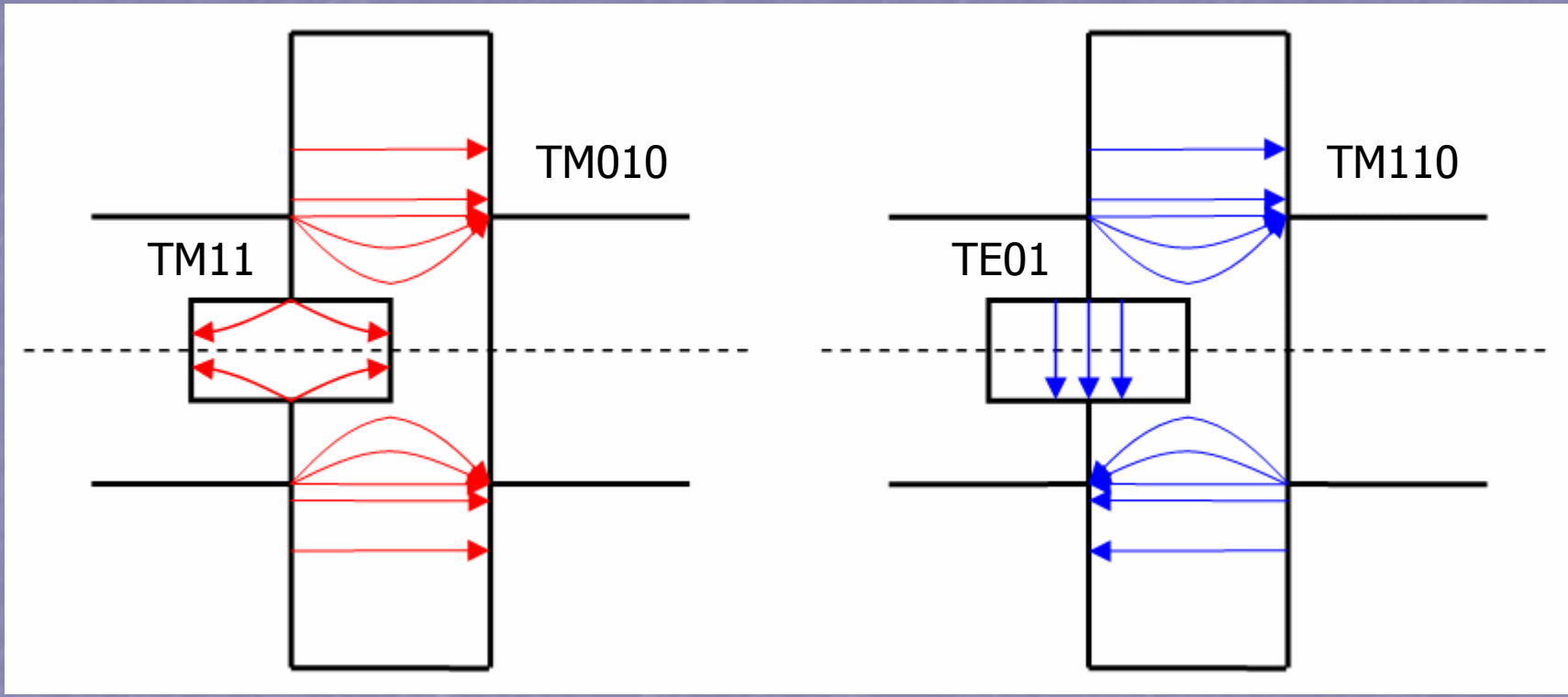
BPM Proposal





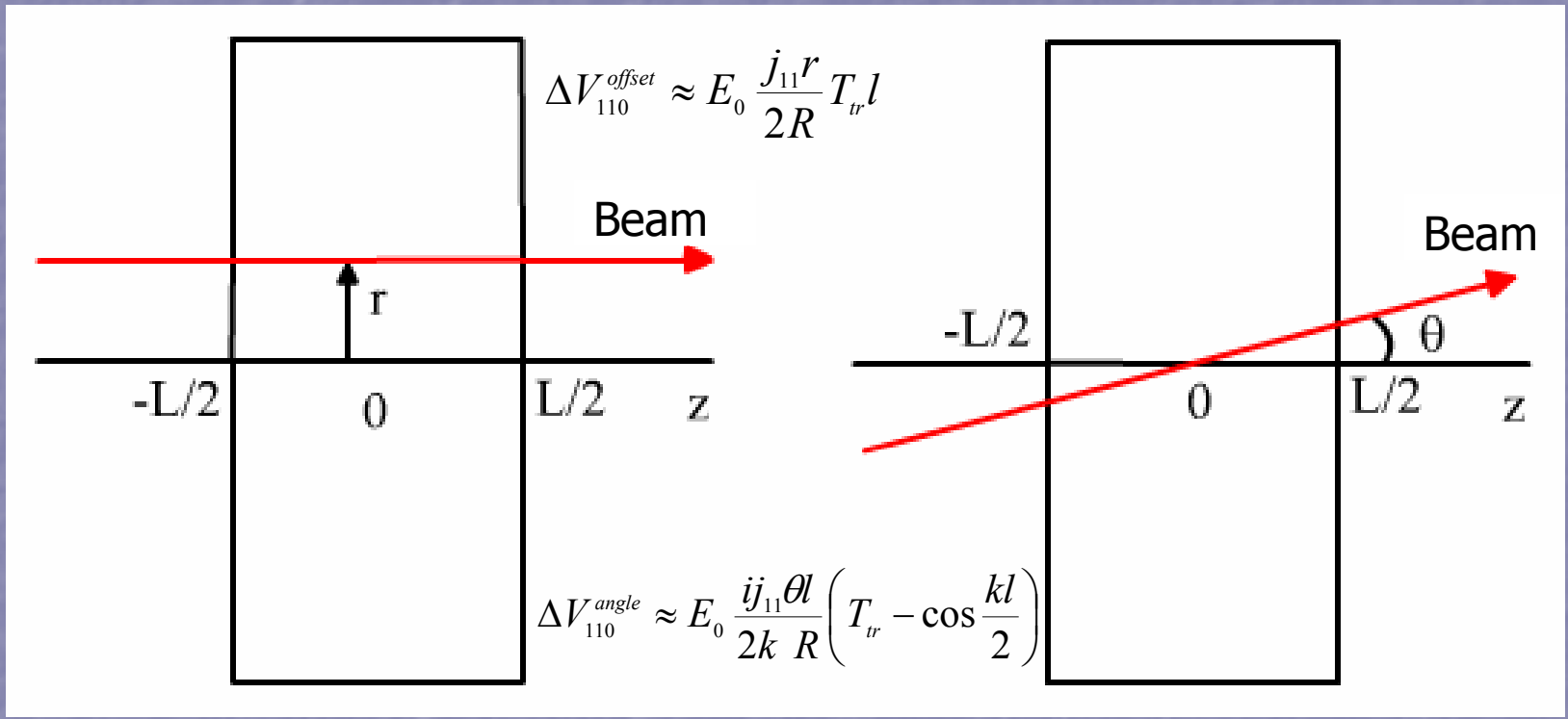
In order to avoid the modes which are stronger than the dipole mode a mode-selective structure of the cavity is proposed.

BPM Proposal



The dipole mode TM110 couples to the lowest wave of the waveguide - TE01, while the monopole modes couple to the higher wave – TM11, which has a higher cut-off frequency. Therefore the monopole modes don't propagate in the waveguide.

Angle-dependence



The dipole mode is also exited if the beam is not parallel to z-axis

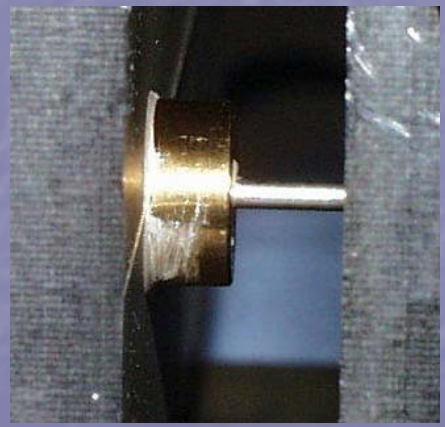
The ratio of two components: $\frac{\Delta V_{110}^{angle}}{\Delta V_{110}^{offset}} \approx i \frac{\theta}{kr} \left(1 - \frac{kl}{2} ctg \frac{kl}{2} \right)$

1.5 GHz - Prototype

Closed monitor with the waveguides

Opened cavity

Antenna



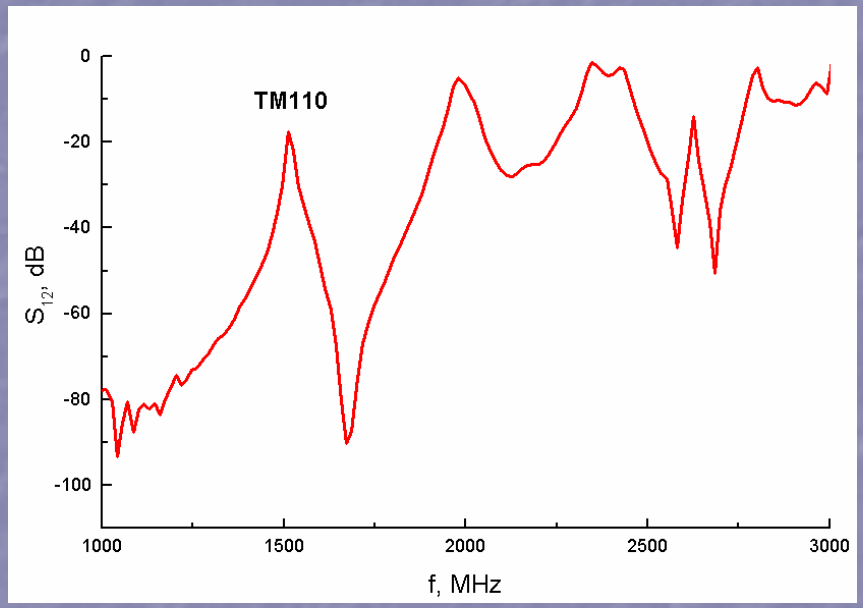
Contact inside the waveguide

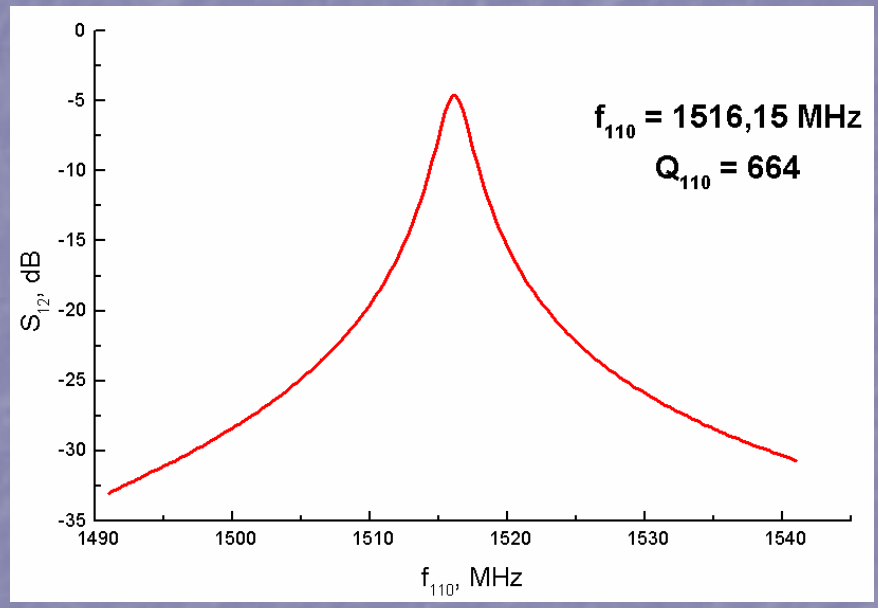
Waveguide

1.5 GHz - Prototype

Parameter	TM010	TM110
f, MHz	1010	1518
Q_0	2110	1620
Q_{ext}	$\rightarrow\infty$	820
Damping time, ns	660	115
V_{in}, V	1450	4.0/mm
V_{out}, mV	9.3(0.005)/100μm of slot offset	0.06/100nm of beam offset
V_{noise}, μV	---	1.6
V_{angle}/V_{offset}	---	34 (0.5mrad, 100nm)

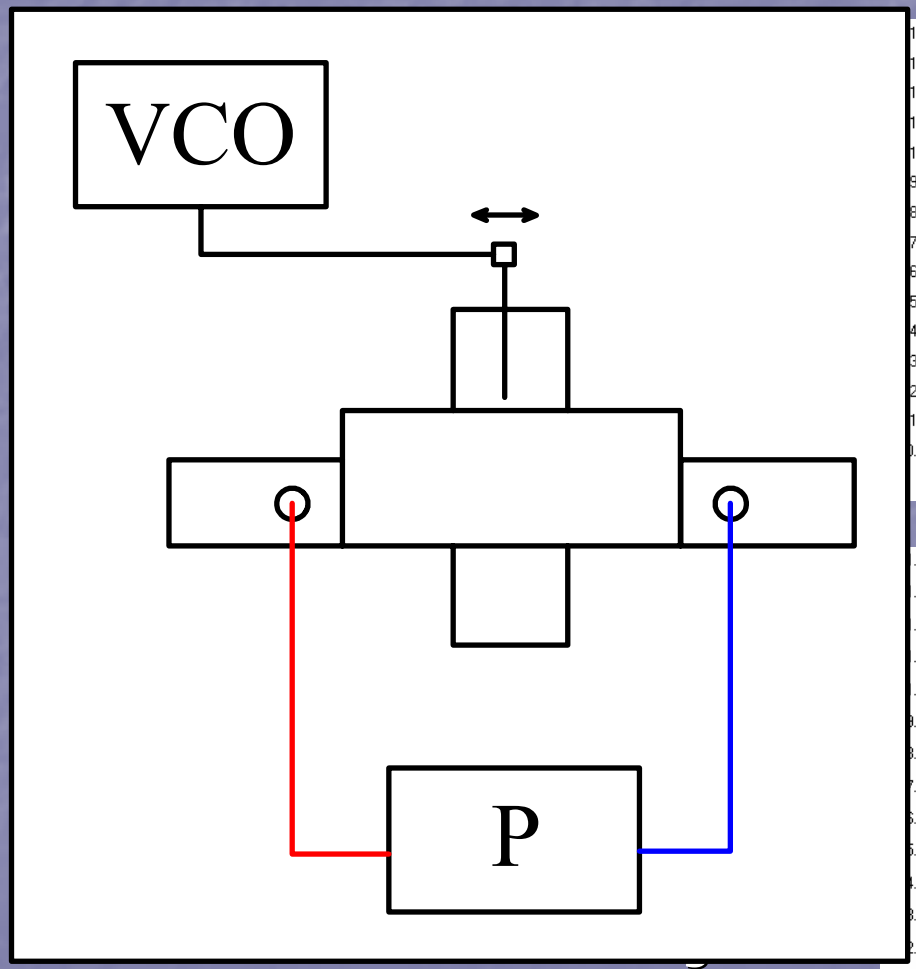
1.5 GHz - Prototype

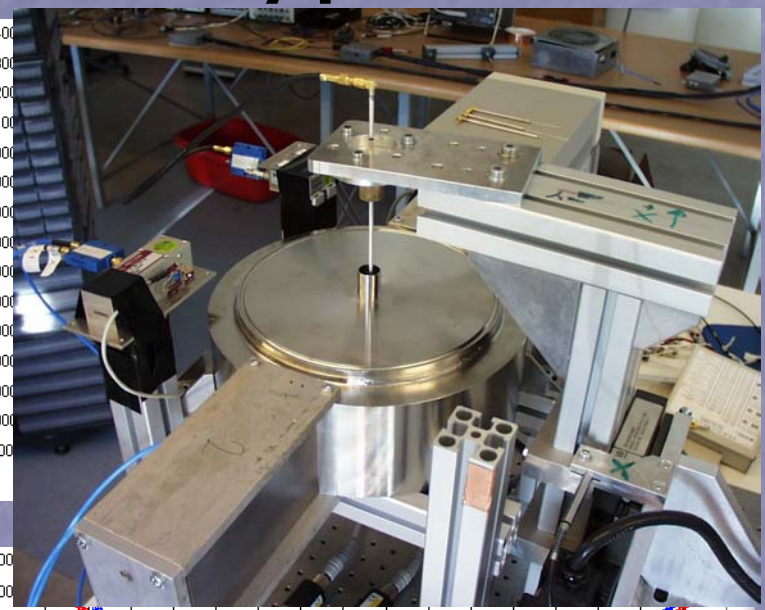


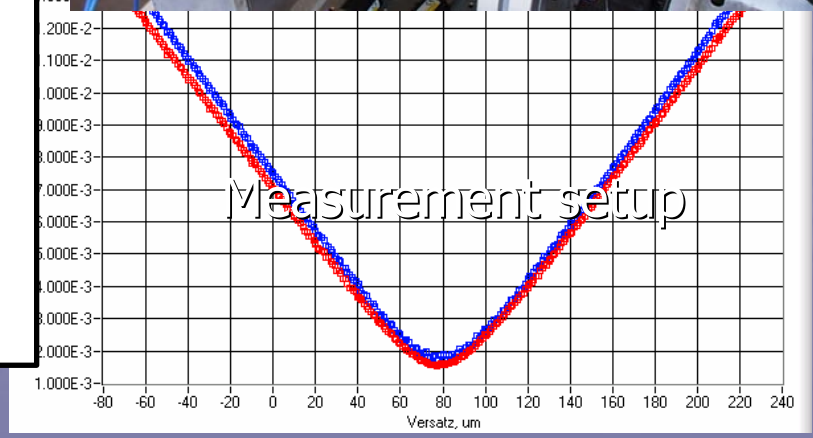


The cavity was tested with a network analyser
in order to check its resonant frequency
and the quality factor

1.5 GHz - Prototype



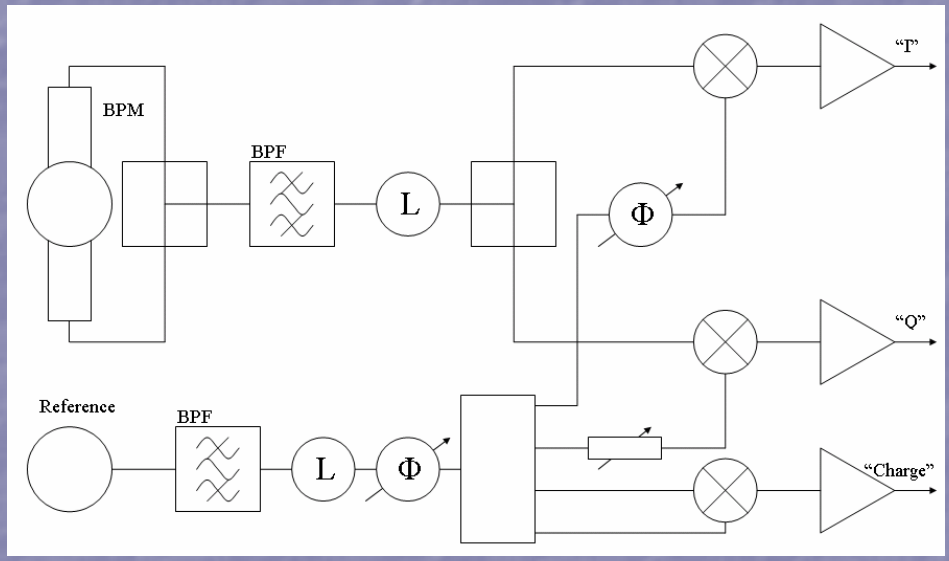




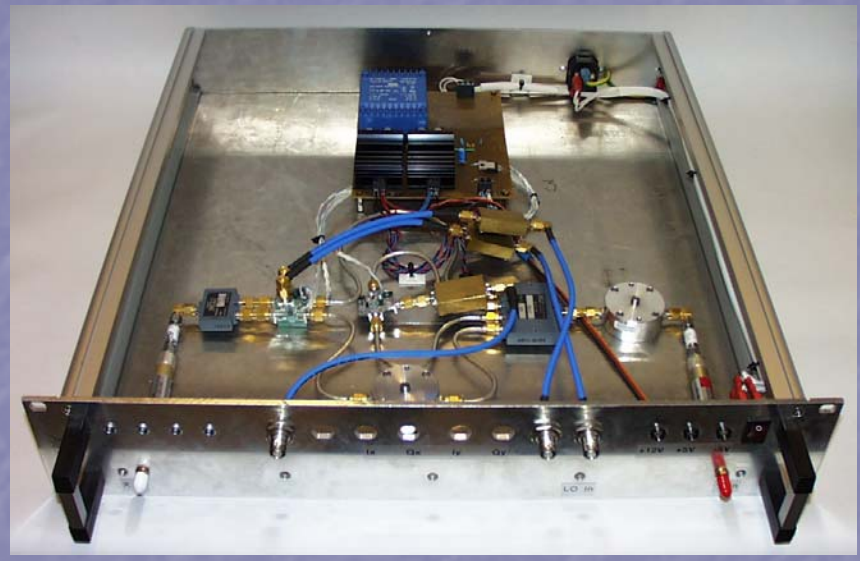
Measurement setup

σ=400nm, V_{out}=8.5μV/100nm

Electronics

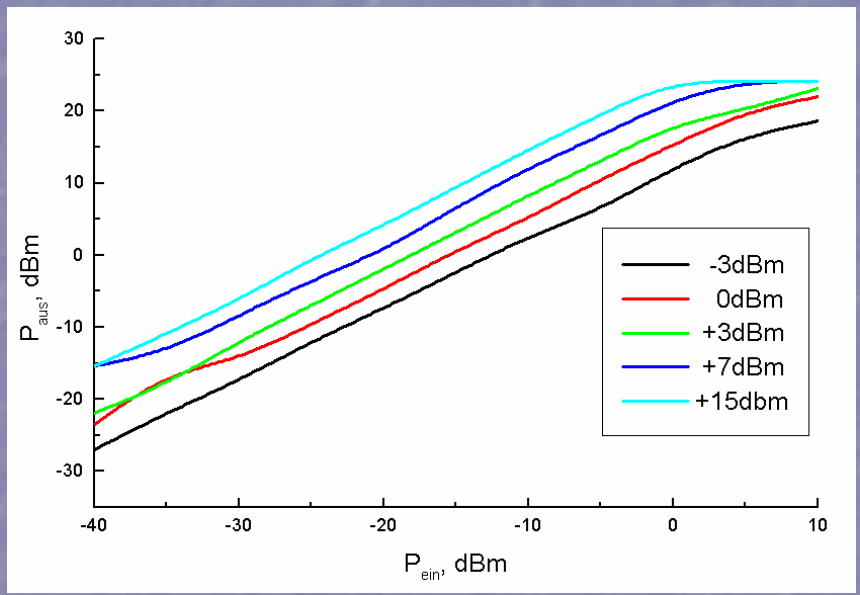


The electronics for the monitor is designed using the homodyne principle

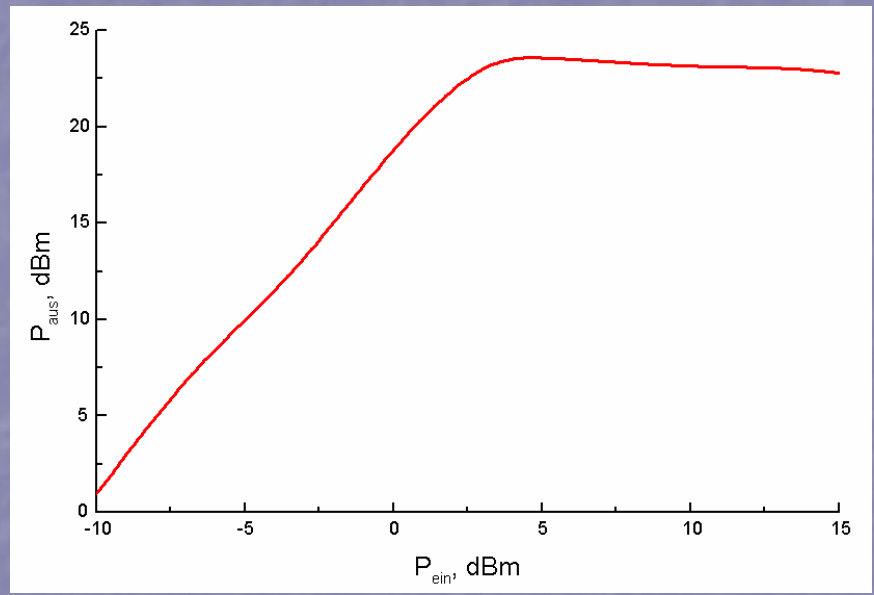


The apperance of the electronics

Electronics

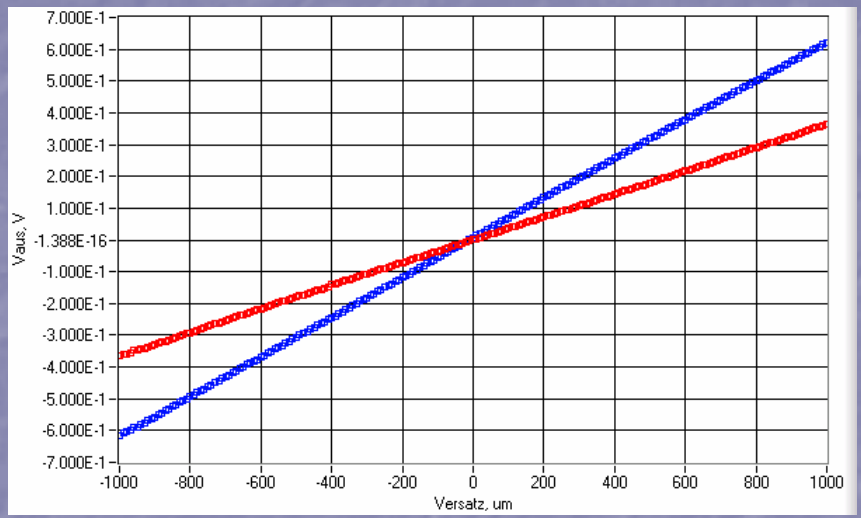


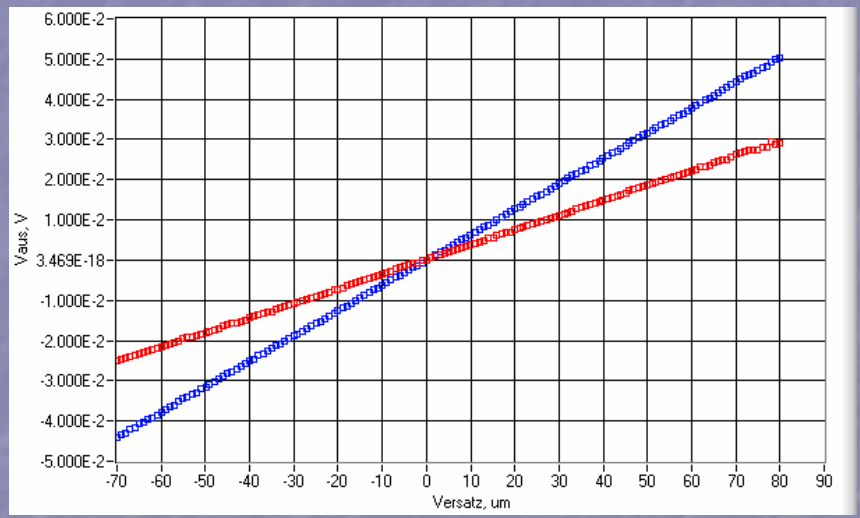
Characteristic of the position channel



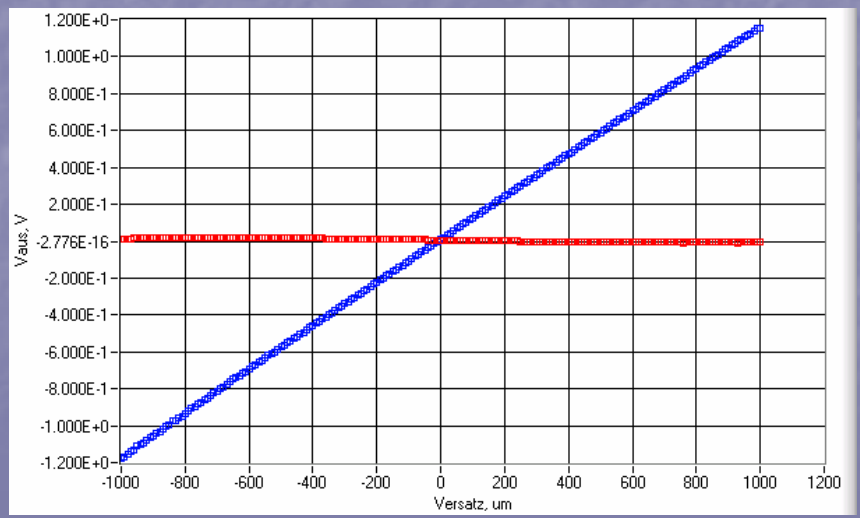
Characteristic of the charge channel

Measurements with Electronics





1. Linescan in wide range σ=180nm
2. Linescan in narrow range σ=20nm
3. Linescan after tuning σ=200nm in -1..+1mm

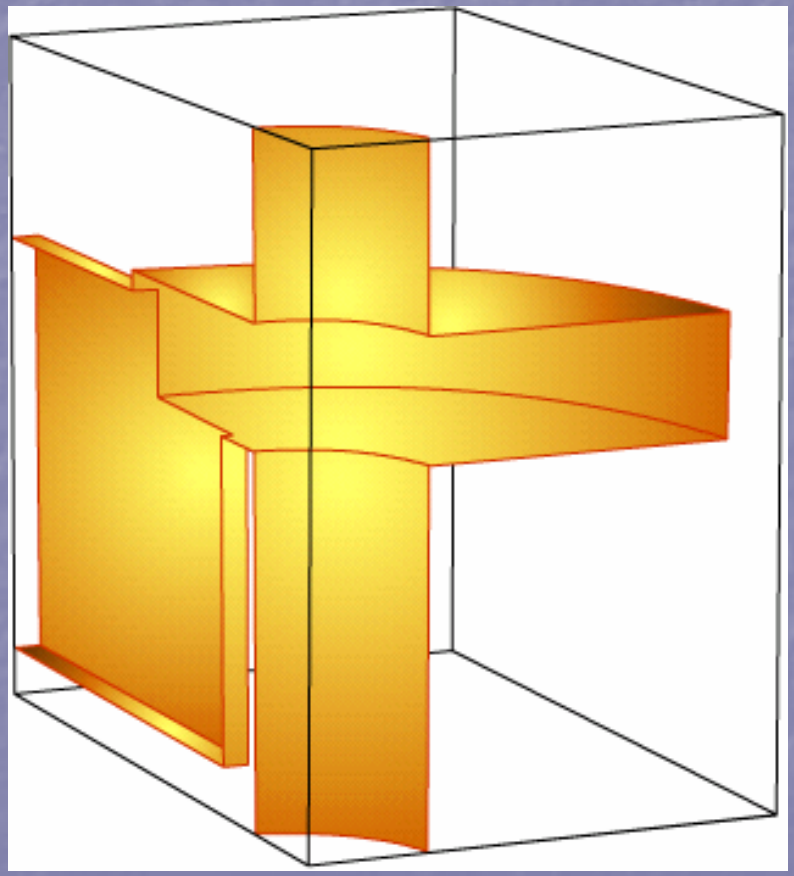


Conclusions

- relative resolution is about 200nm

+ linear range is -1mm…+1mm
+ moderate mechanical tolerances
+ relative simple and cheap electronics
- strong angle-dependent component
- large and heavy
- hard to provide high vacuum

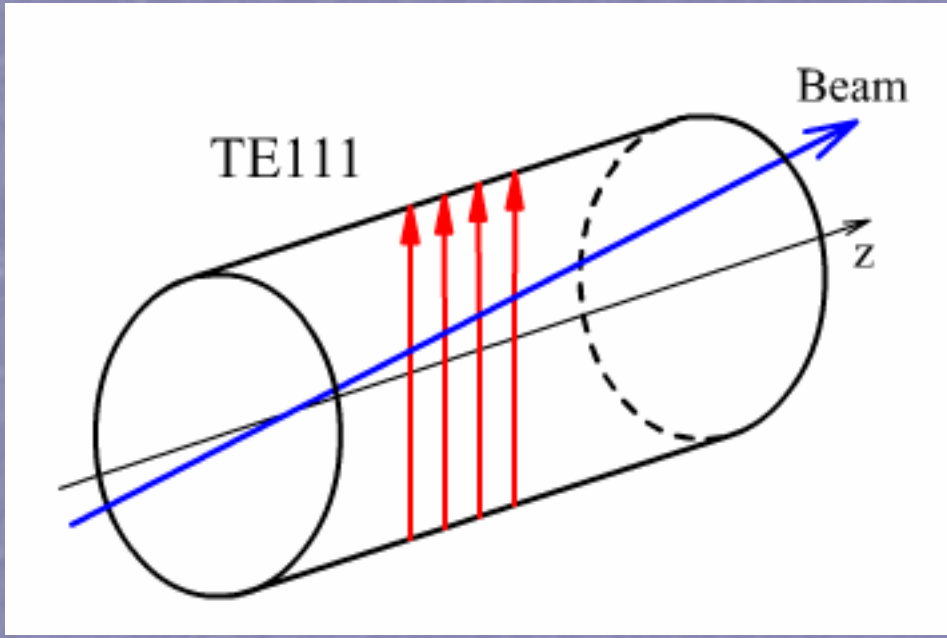
Alternatives



5.5 GHz cavity

+ smaller, easier to handle
+ weak angle-dependent component
+ stronger dipole mode signal
+ better time resolution
- critical production tolerances
- smaller linear range (250μm)
- more complicated electronics

Alternatives



We want to measure not the offset, but the angle
Probably TE111-cavity is the right one for that purpose