Status of IP-BPM R&D

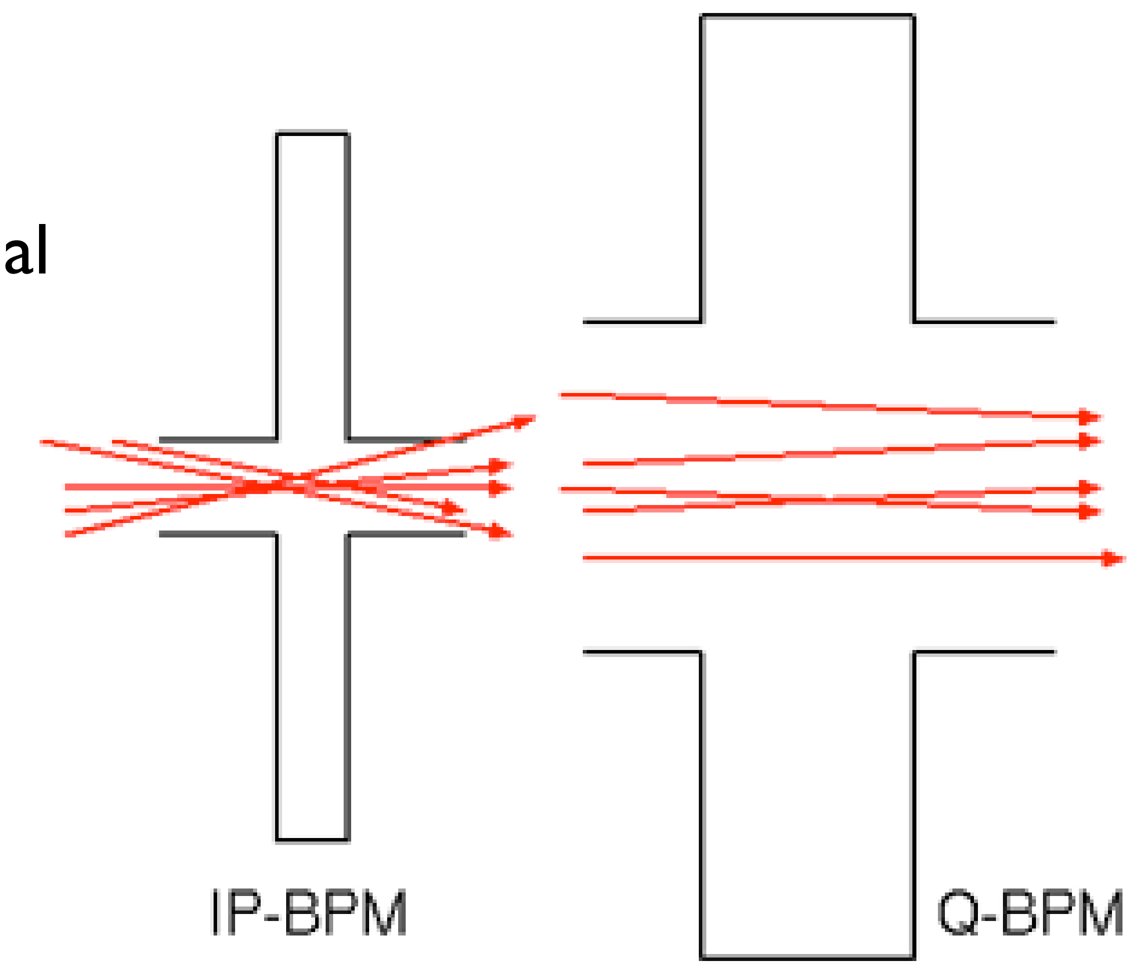
by T.Tauchi

ATF2 Meeting, Annecy, 9 -11 October 2006

IP-BPM (2nm) R&D

Starting point of the design work

- Challenges
  - ultimate y-direction resolution
    - 1 nm signal > thermal/amplifier noise
  - under angle jitter condition
    - 100 urad angle signal < 1 nm position signal
  - under large x jitter
- Basic idea
  - thin gap to be insensitive to the beam angle
  - small aperture to keep the sensitivity
- Additional idea
  - separation of x and y signal
  - higher coupling to have stronger signal



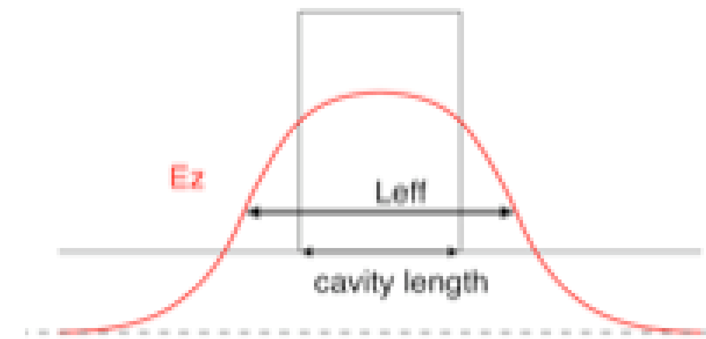
position/angle =f L^2

4 : 1

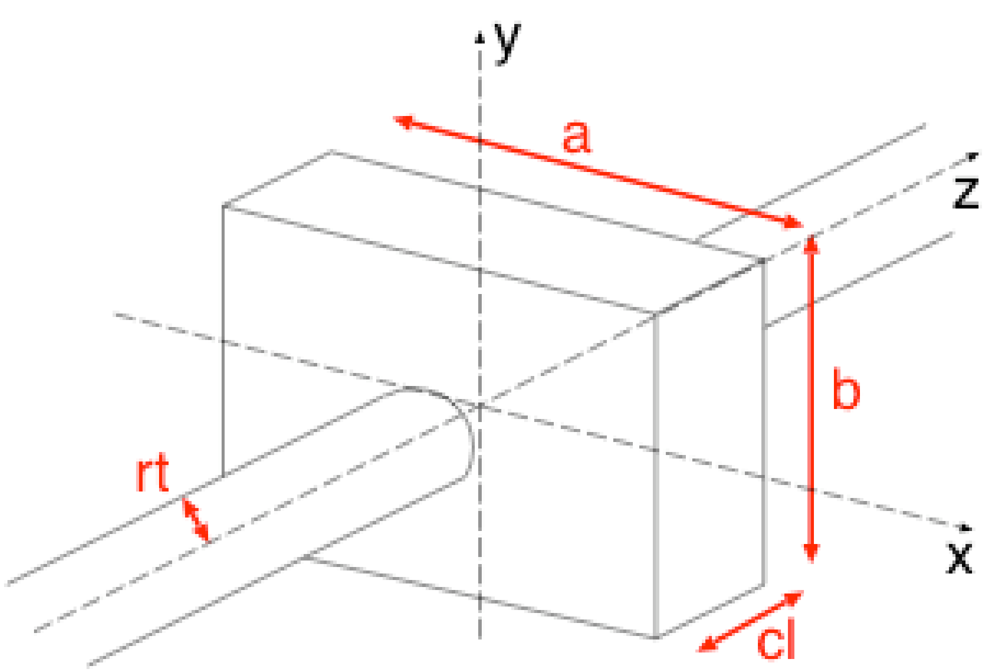
Gap and aperture

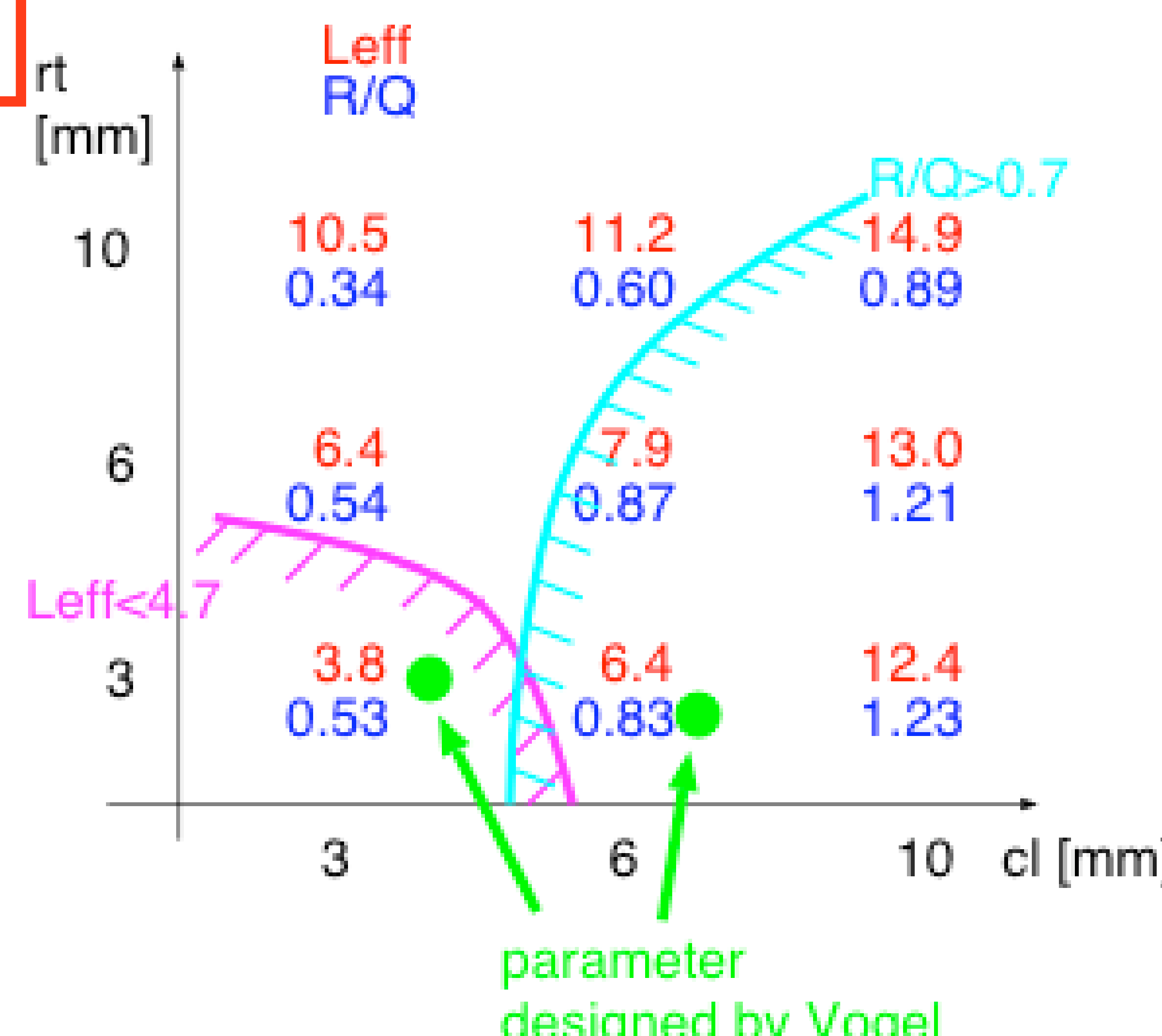
f = 6.426GHz (y) and 5.712GHz (x)

- Guide line
  - keep the existing cavity's position sensitivity
  - reduce angle sensitivity
- Position signal
  - noise: sqrt(4kTBZ) = 1.6 uV (T=300k, B=3MHz)
  - existing cavity (cl=12,rt=10): 2.5uV for 1nm
  - R/Q > 0.7ohm to be able to detect 1nm
- Angle sensitivity
  - existing: Leff=15mm
  - Leff<5mm to reduce the sensitivity by factor 10
- cl=6mm, rt=3 is the compromise.
  - 1nm (R/Q, beta, noise figure, cable att.)
  - 10 urad ~ 1nm (100 urad ~ 1 nm with phase detection)
- for X-port larger aperture is preferable
  - rt=6 for X → rectangular

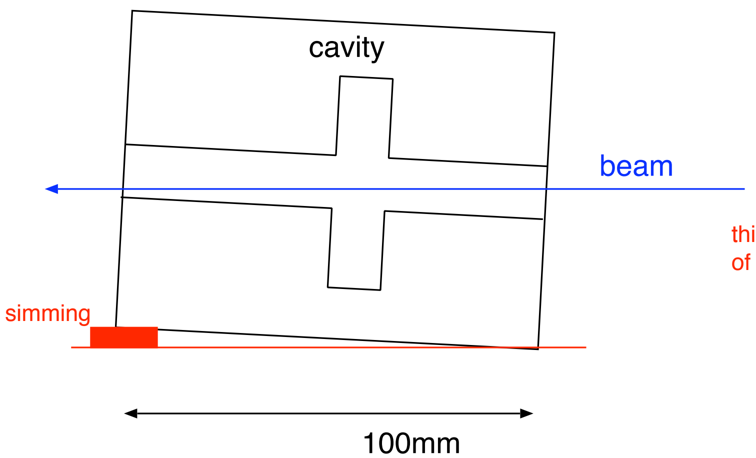


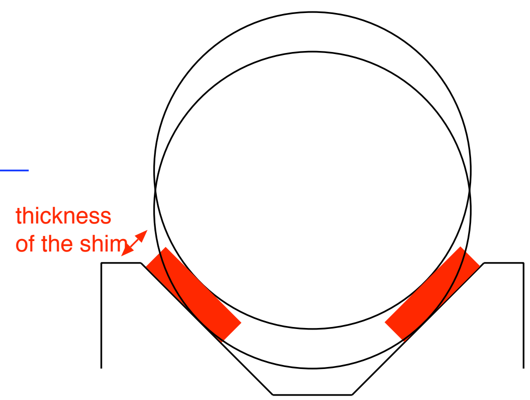
$$\frac{\text{Angle sensitivity}(\mu rad)}{\text{Position sensitivity}(\mu m)} = \frac{\omega L^2}{8\sqrt{2}c}$$





Measurement of Inclined signals at QBPM





Results

y : 1µm/100µrad

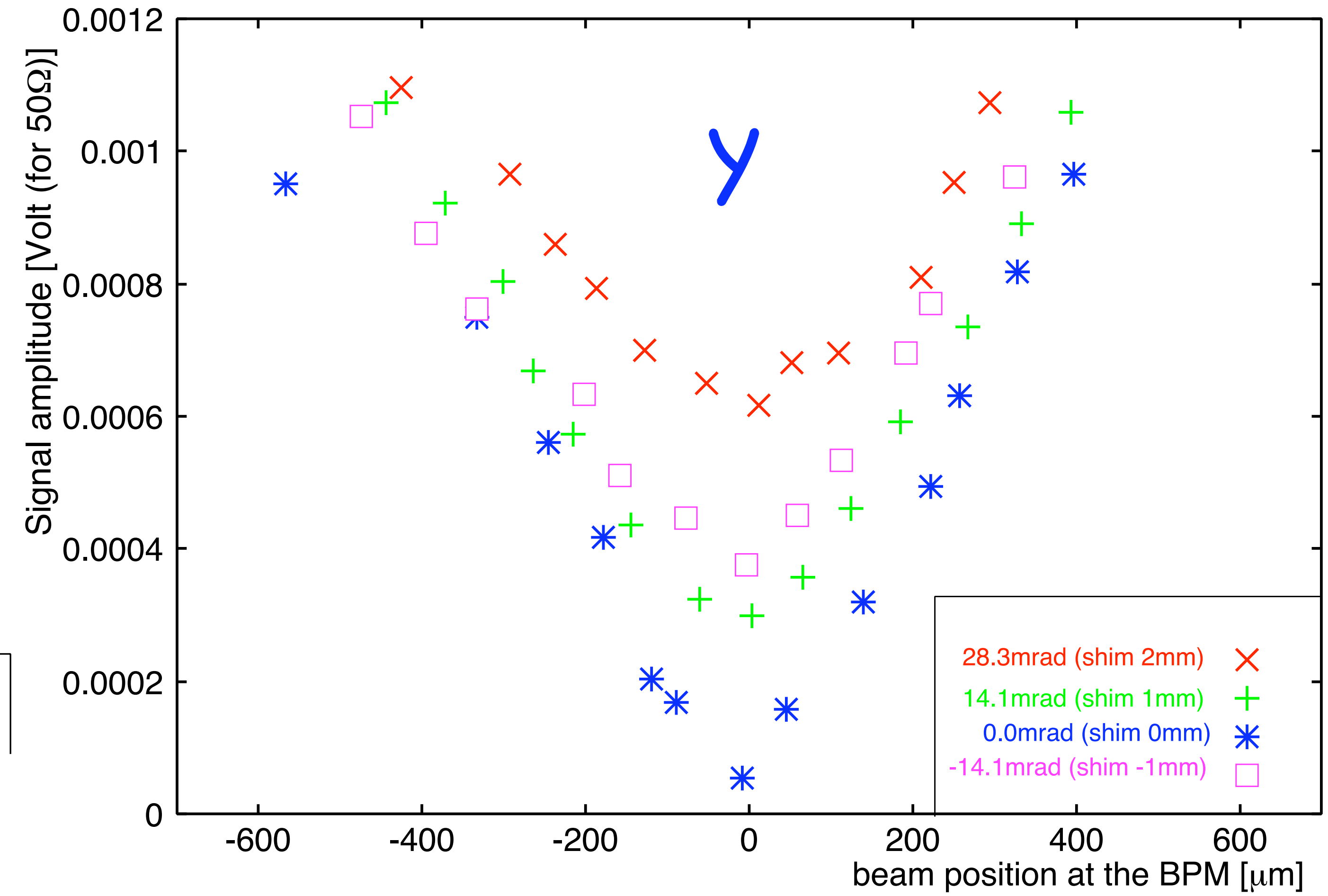
(cal : 1µm/450µrad)

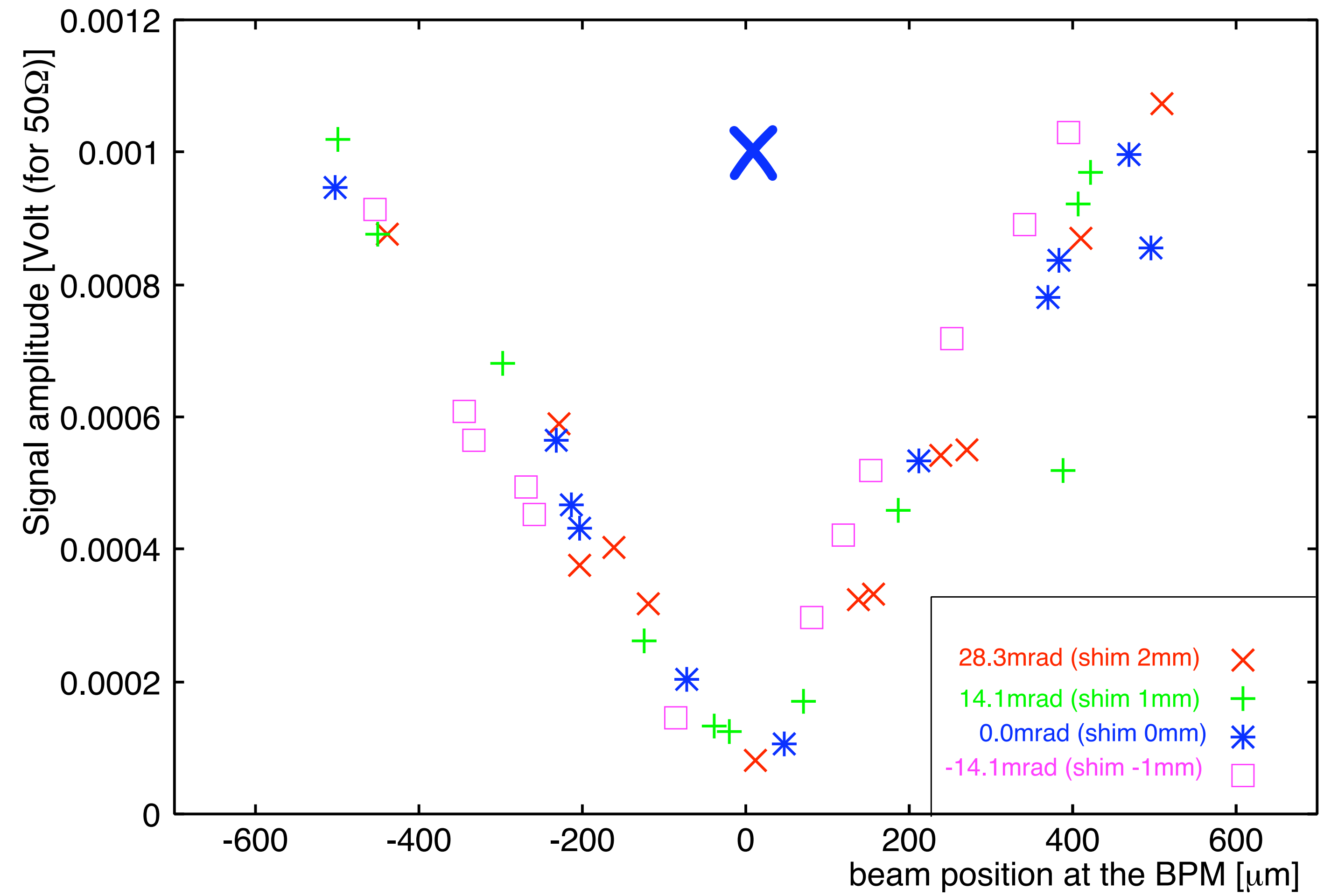
X : no dependence

1/5

y : 200nm/100µrad at IP-BPM

i.e. > 40dB phase separation from 0° to 90°





Philippe Doublet

Phase Isolation Measurement

Electronics of IP-BPM

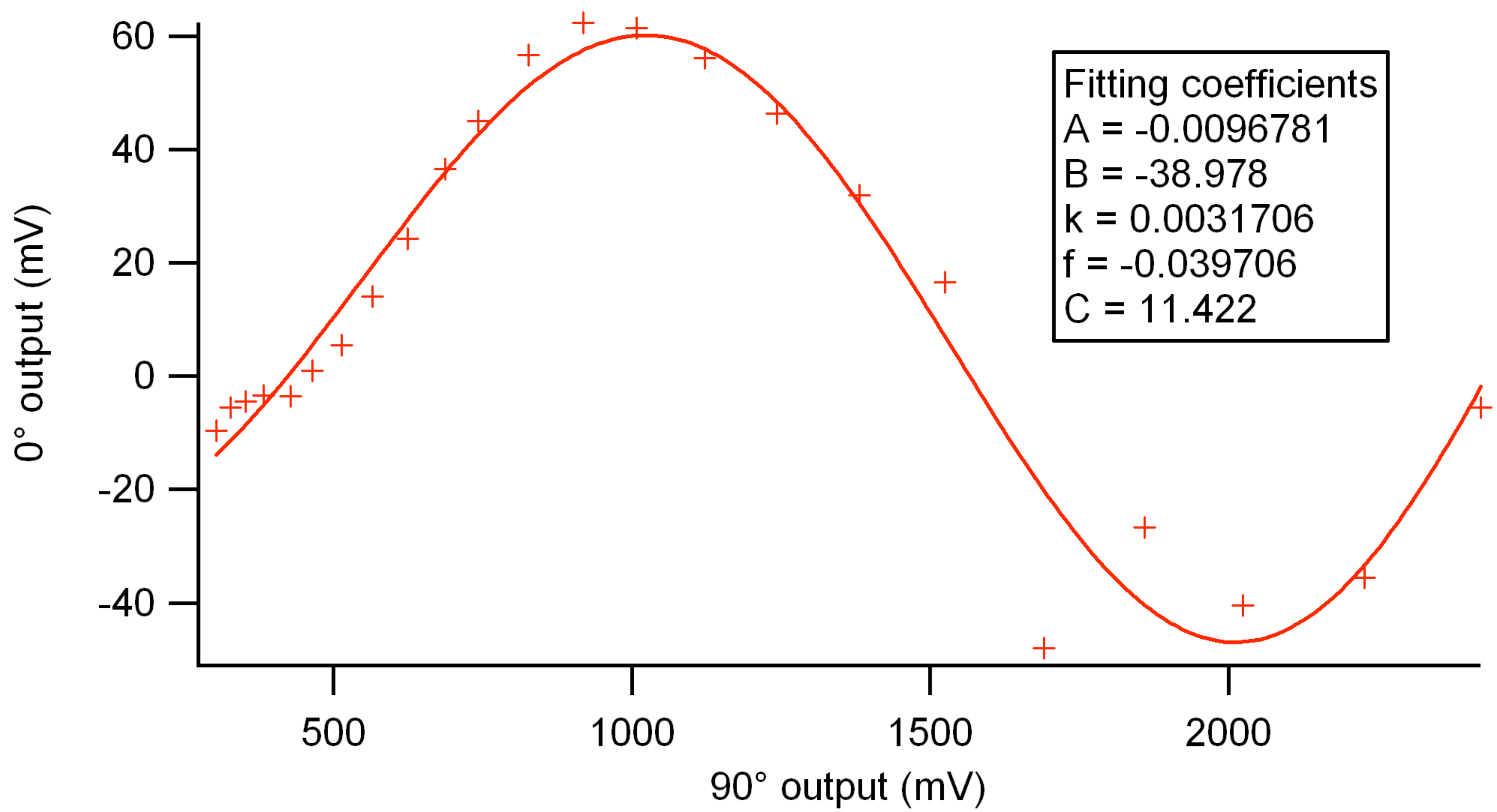


Figure 13: 0° output against 90° output

$$\text{"}0^\circ\text{ output"} = (A \times \text{"}90^\circ\text{ output"} + B) \times \cos(k \times \text{"}90^\circ\text{ output"} + f) + C \quad (3)$$

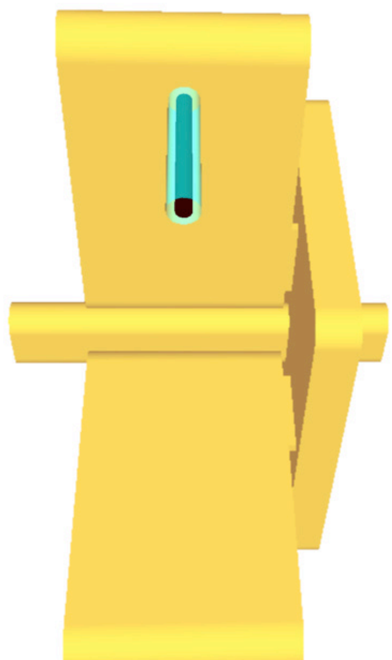
Then A is the isolation factor in V/V. And we deduce $A = 87.45\ dB$.
Note : One has to remark that the scale for 90° output is 20 times higher than for 0° output.

IPBPM R&D

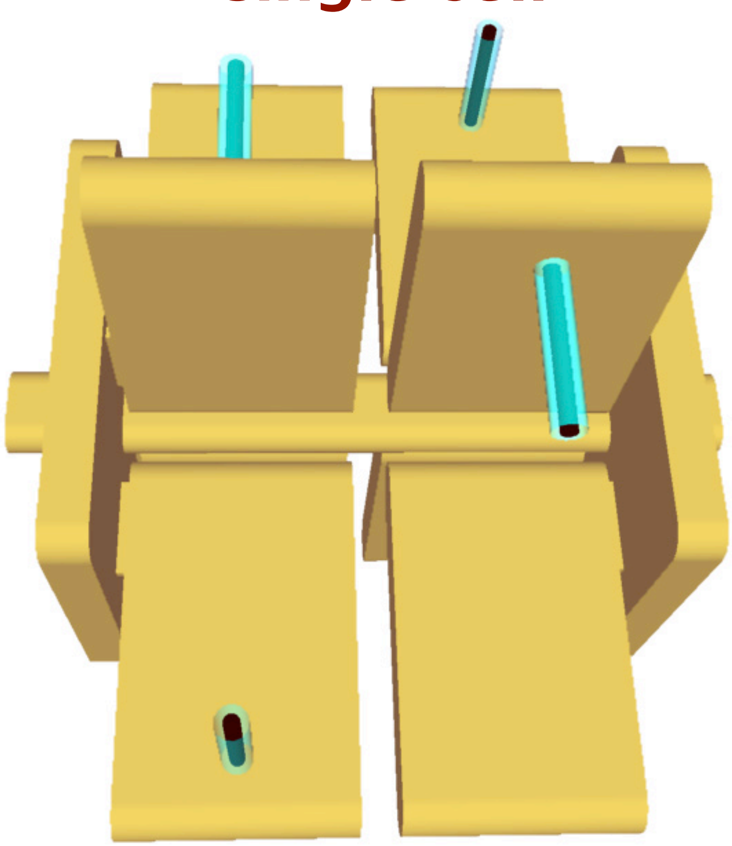
Cold model : Check the electric design

- coupling, frequencies, cross talks etc.

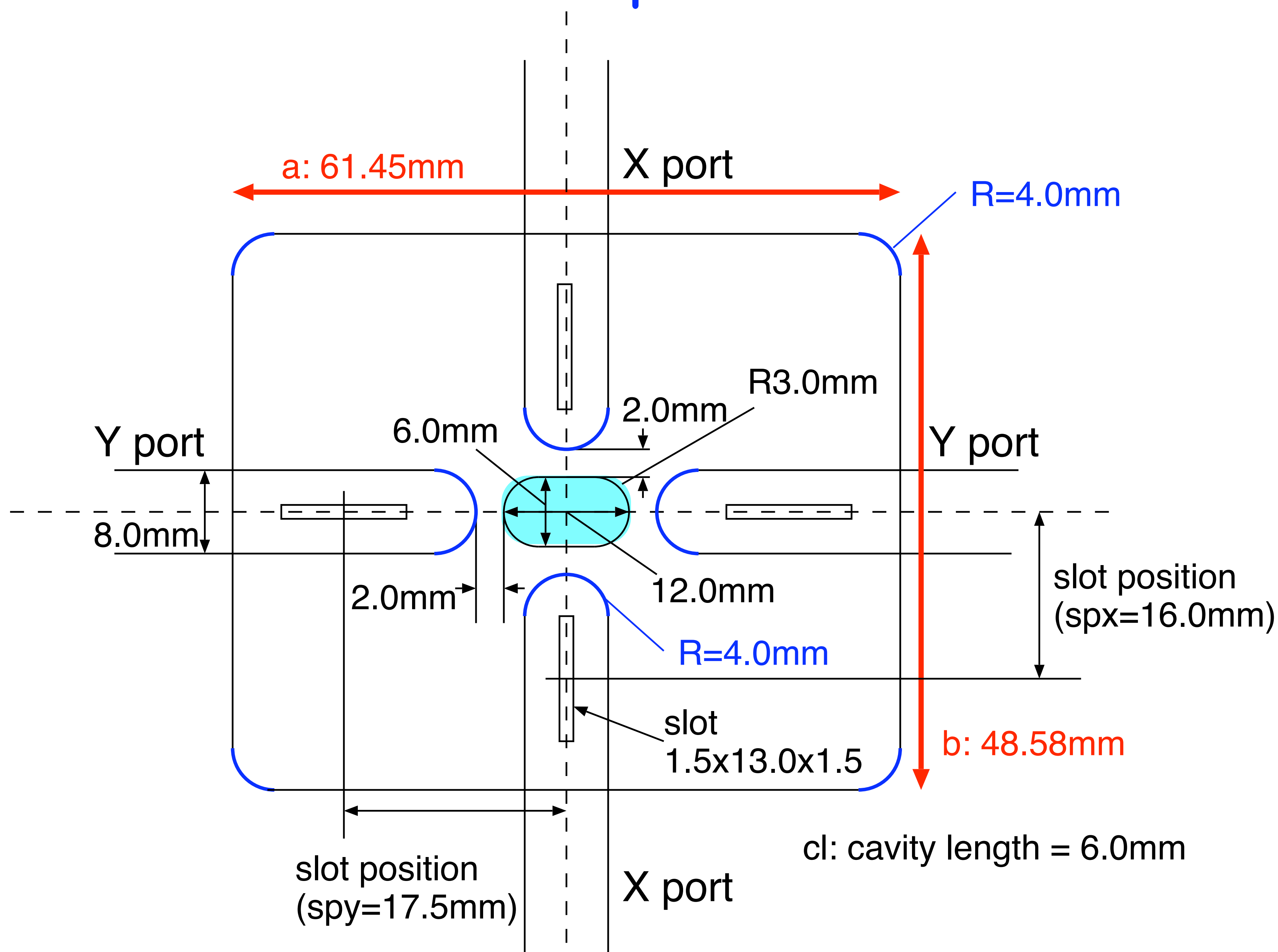
Check the fabrication precision



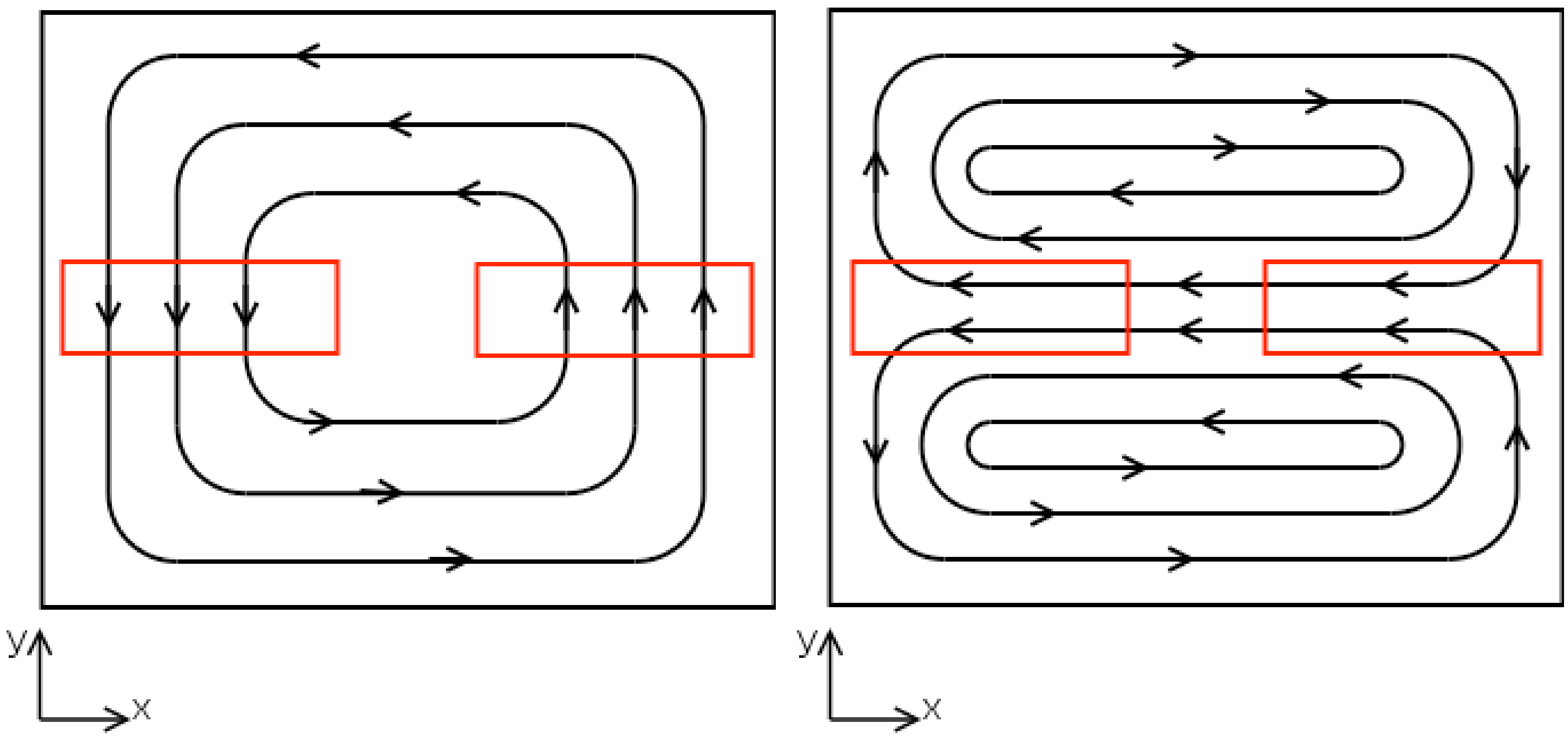
single cell



double cell



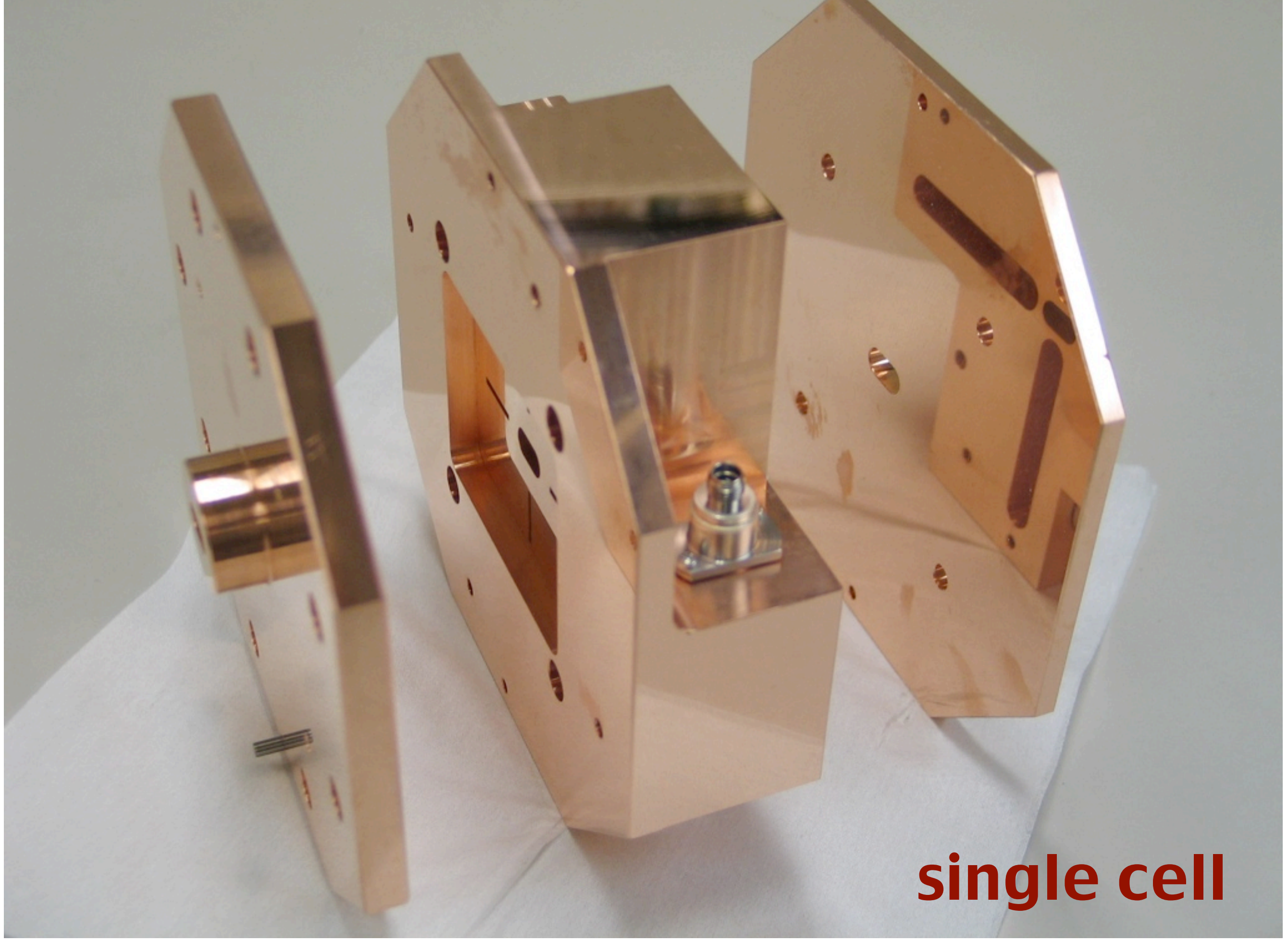
6mm depth, along the beam line

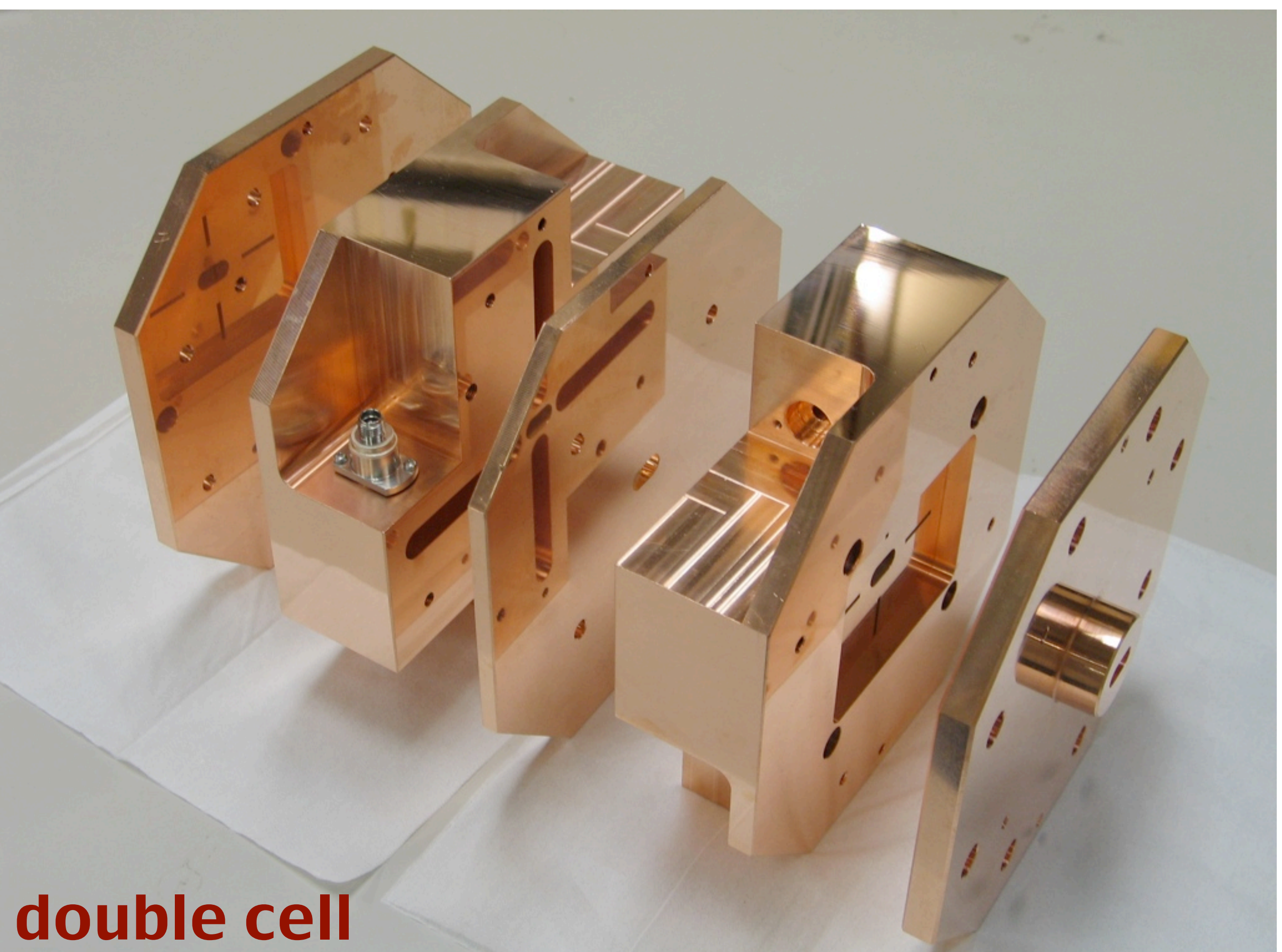


(a) TM_{00} mode : small coupling (b) TM_{01} mode : high coupling

Figure 3: Coupling of the magnetic field with slots – Intensity

IP-BPM : Cold Model



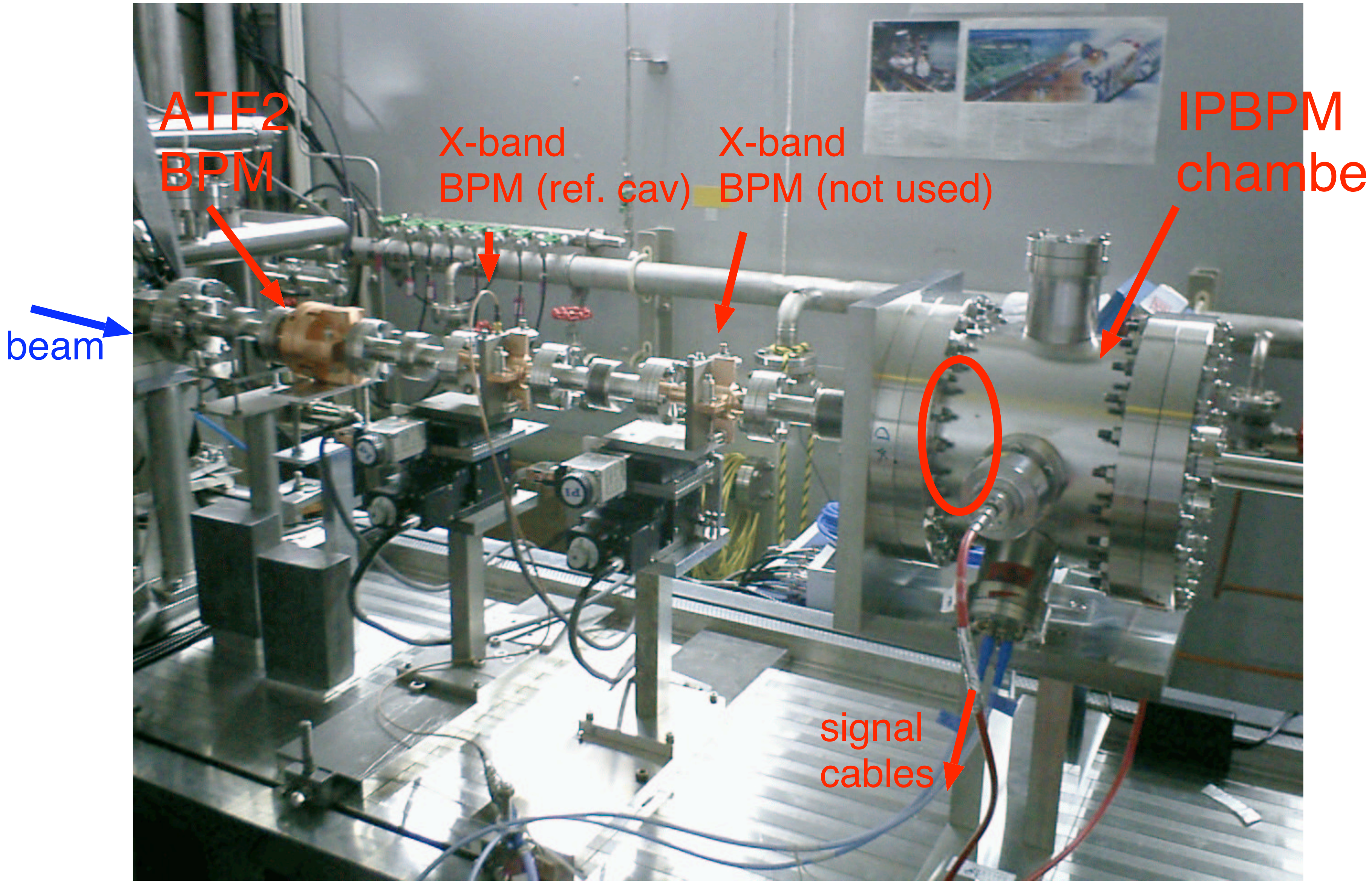


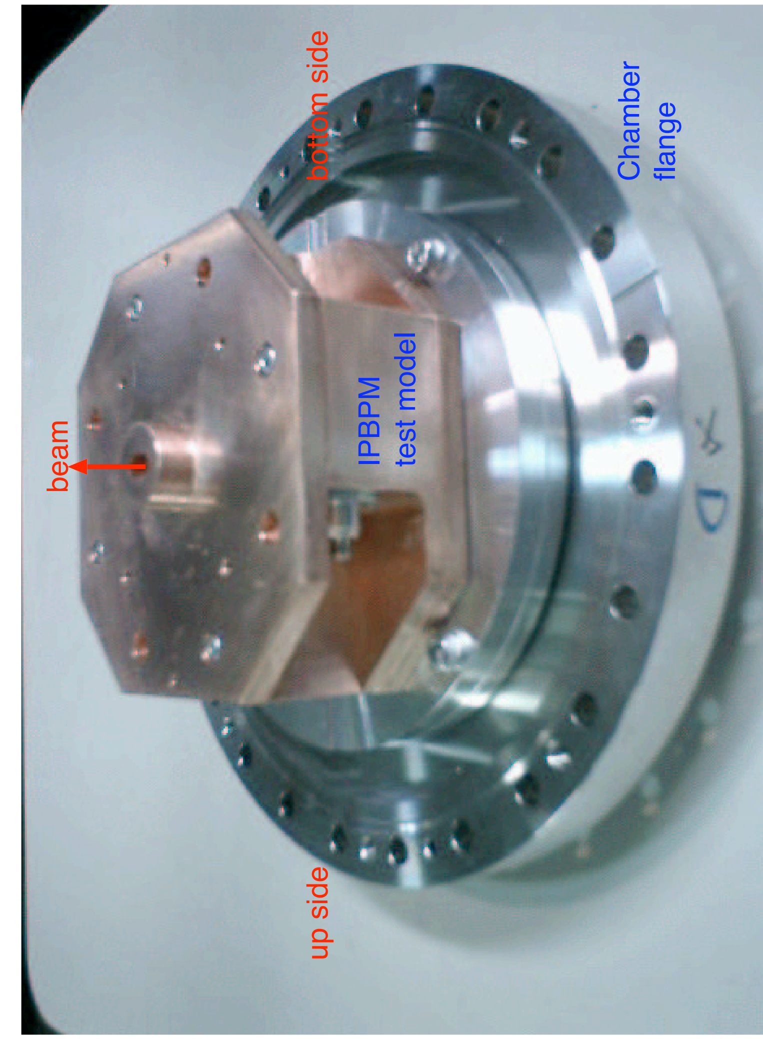
Quick measurements :

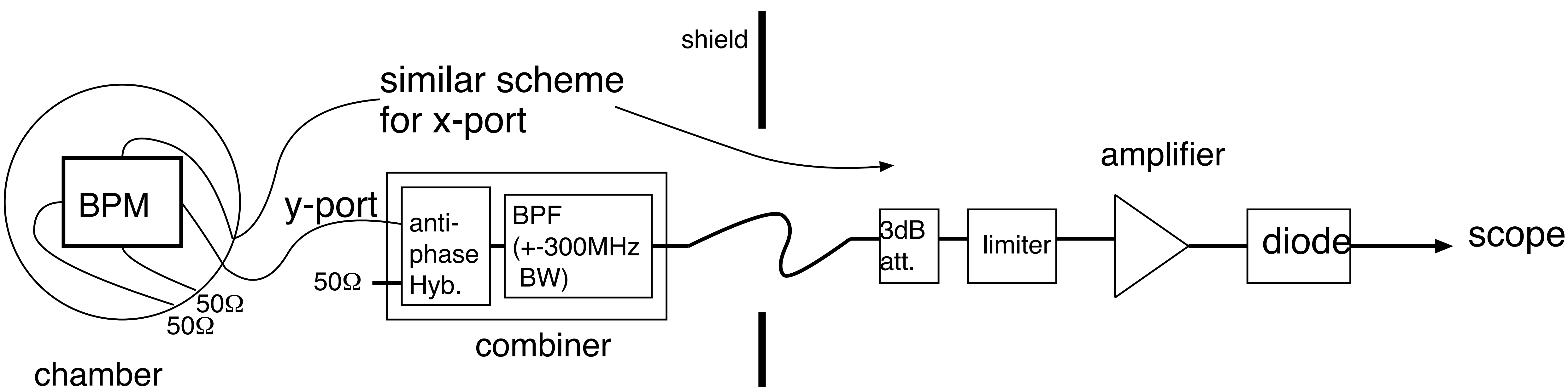
Frequency in x = 5703 MHz
(5712 MHz designed)

Frequency in y = 6420 MHz
(6426 MHz designed)

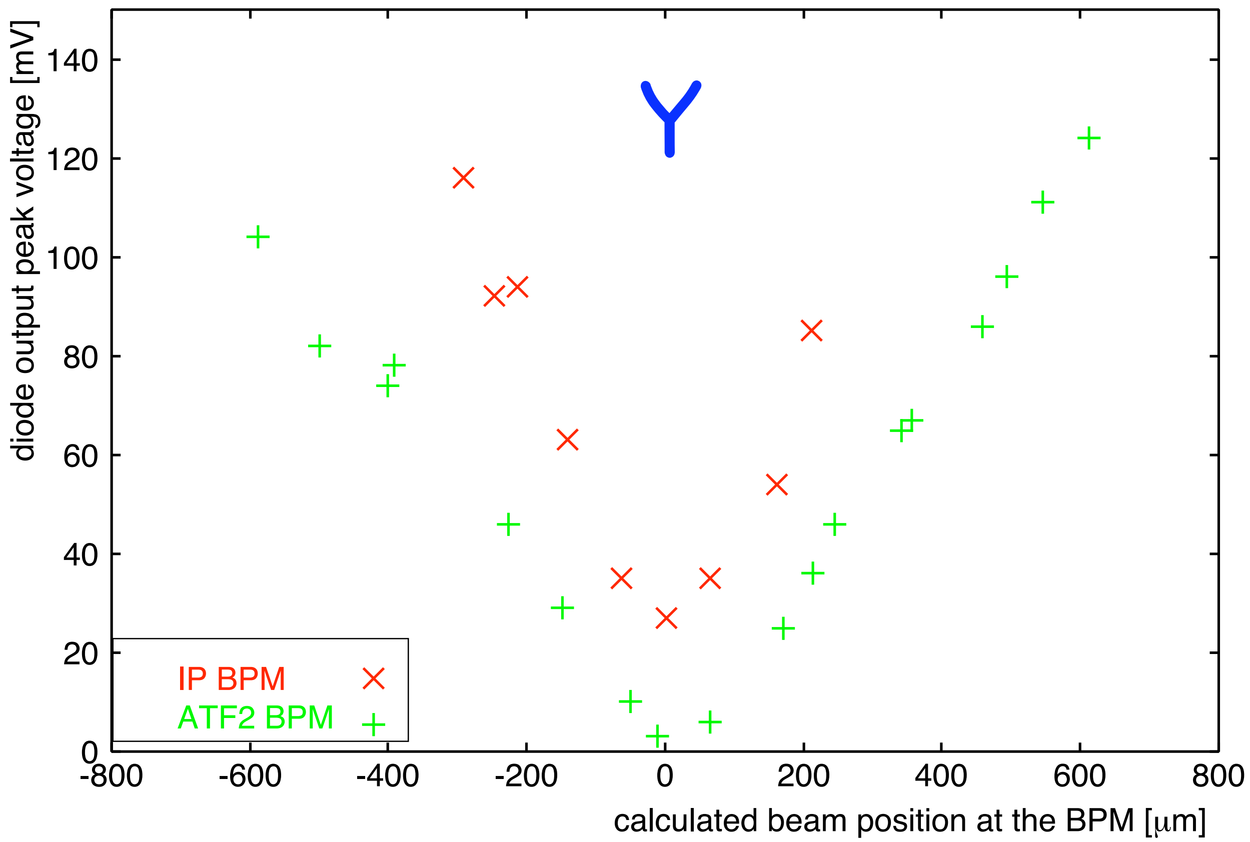
First Beam Test at the LINAC-end, June 2006

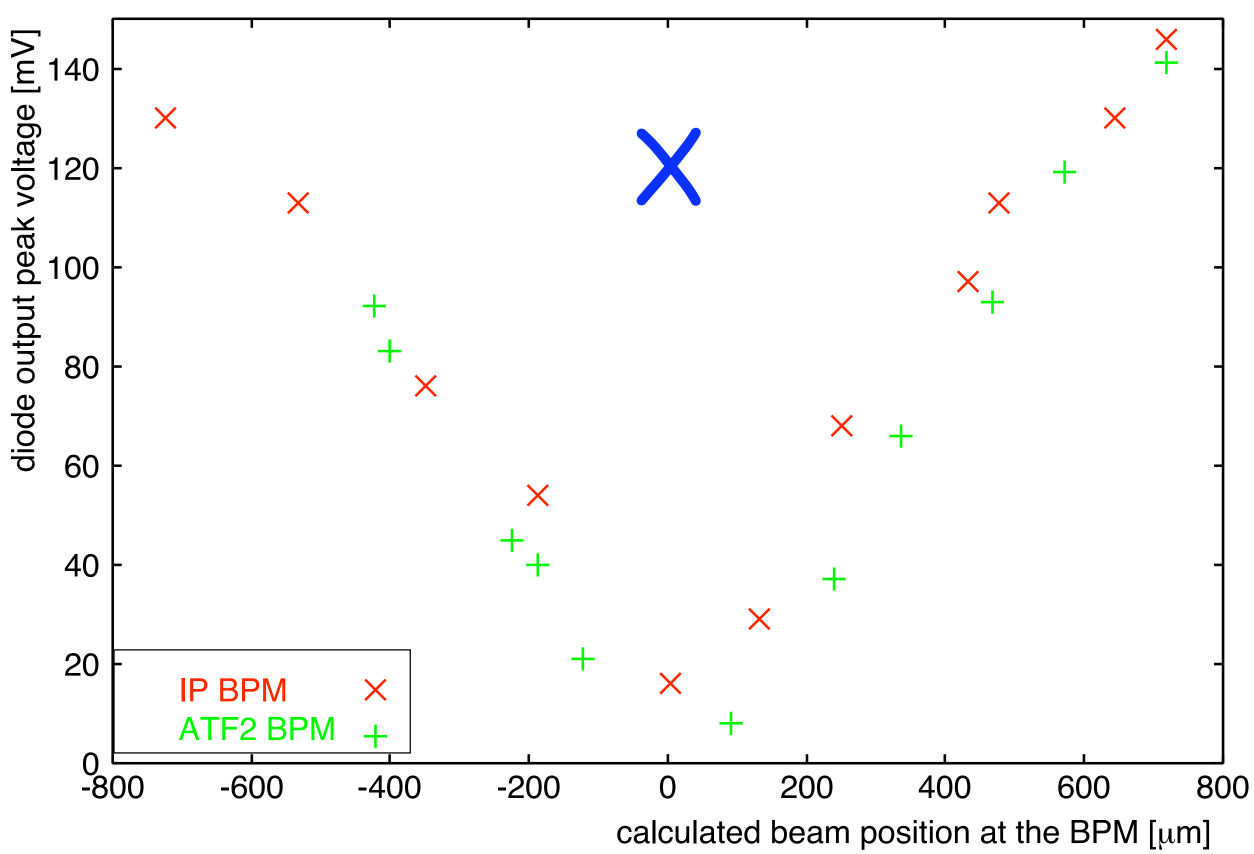






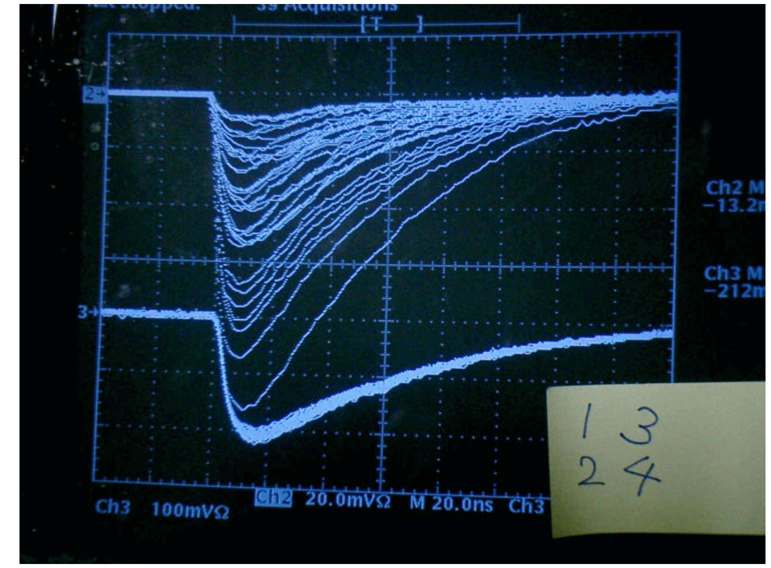
First Beam Test Results





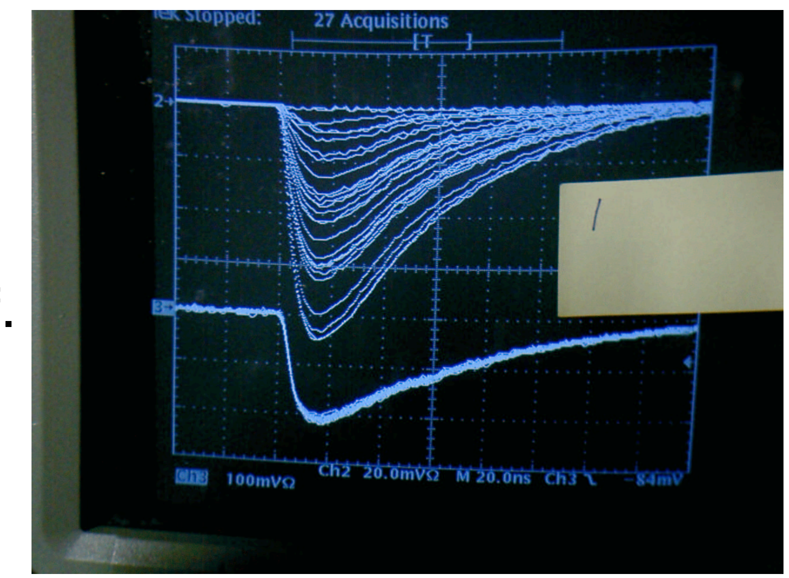
without BPF
1-port
(att. 6dB)

Y
Ref.



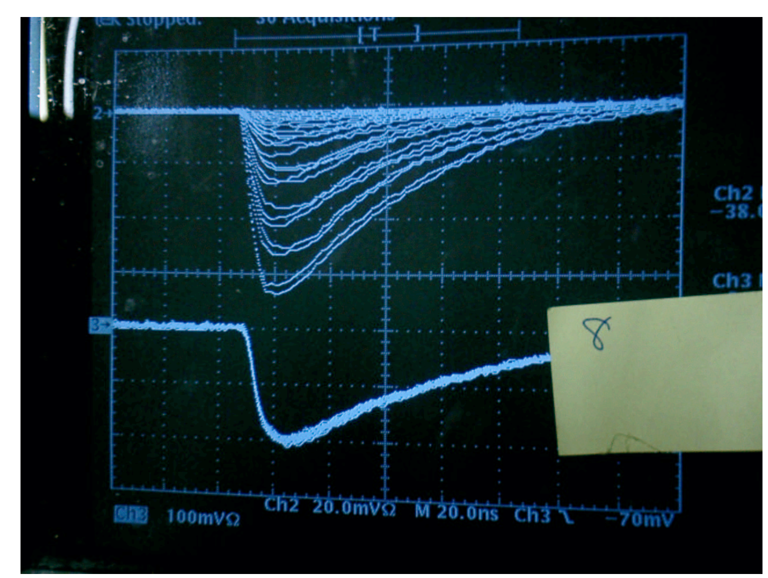
Combiner
1-port
(att. 3dB)

Y
Ref.



Combiner
2-port
(att. 9dB)

Y
Ref.



"cold model"

表 1: Expected sensitivity

cavity	f(GHz)	Q_{ext}	R/Q (1mm offset)	relative sensitivity
ATF2 Q-BPM	6.422	25000	1.00 Ω	1.0
IP-BPM Y	6.422	2300	1.51 Ω	4.1
IP-BPM X	5.705	2400	0.48 Ω	2.0

beam test

2

1

shorter decay as expected

ATF2 BPM signal (50nsec/Div.)

X

Y

Ref.

trig.

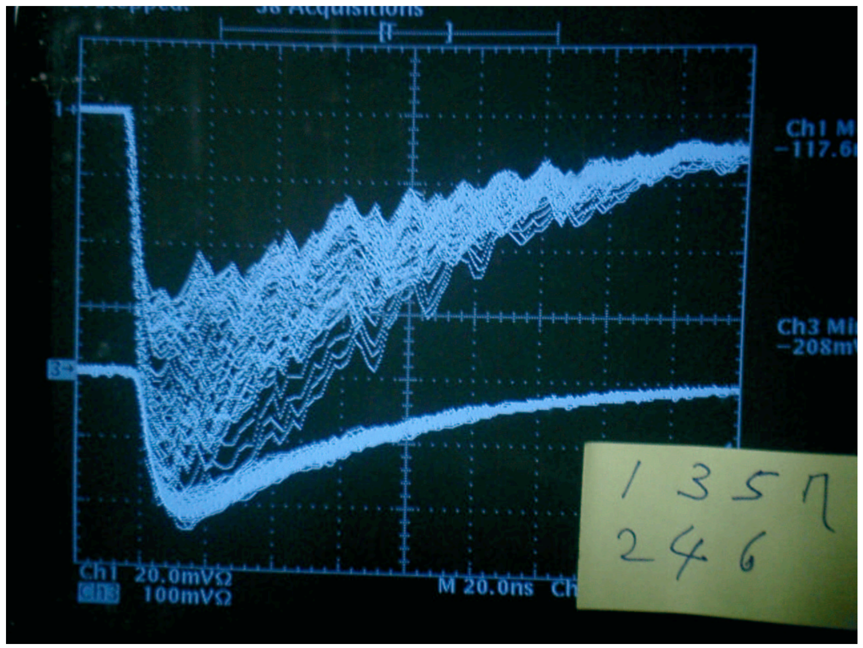
IPBPM signal (50nsec/Div.)

Beat wave problem in X-direction

due to accidental "coincidence" between resonant frequencies of cavity and wave guide

Without BPF
1-port
(att. 6dB)

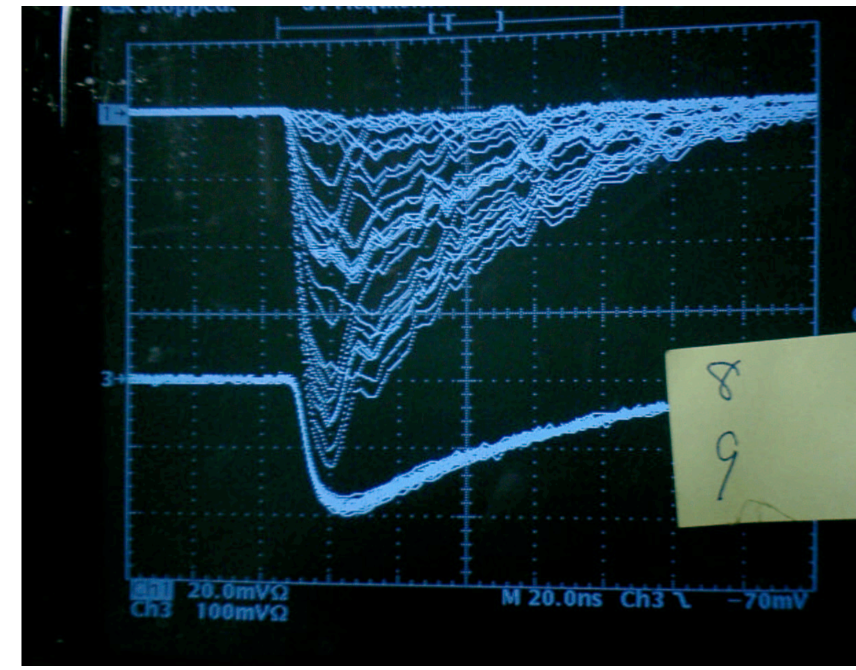
X



Ref.

Combiner
2-port
(att. 9dB)

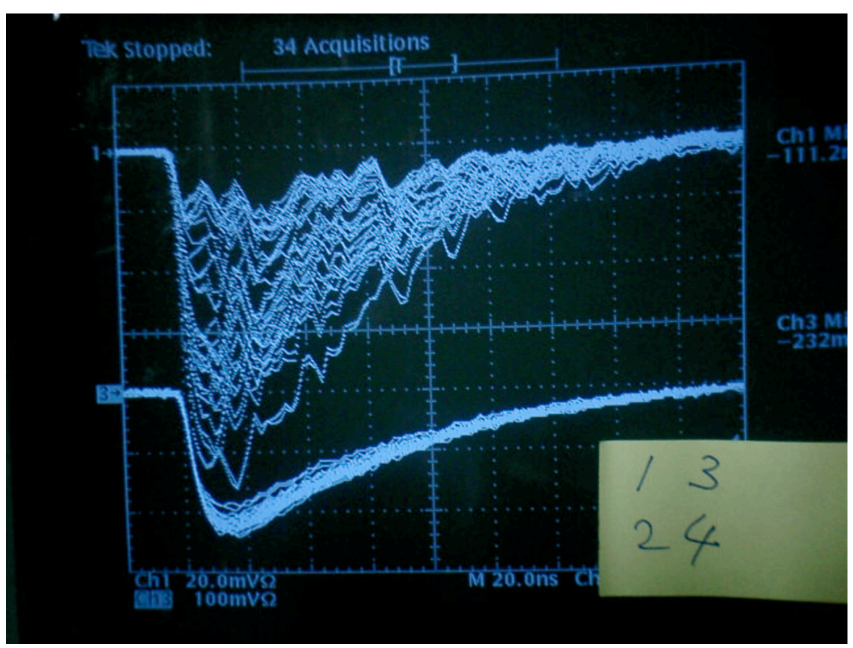
X



Ref.

Combiner
1-port
(att. 3dB)

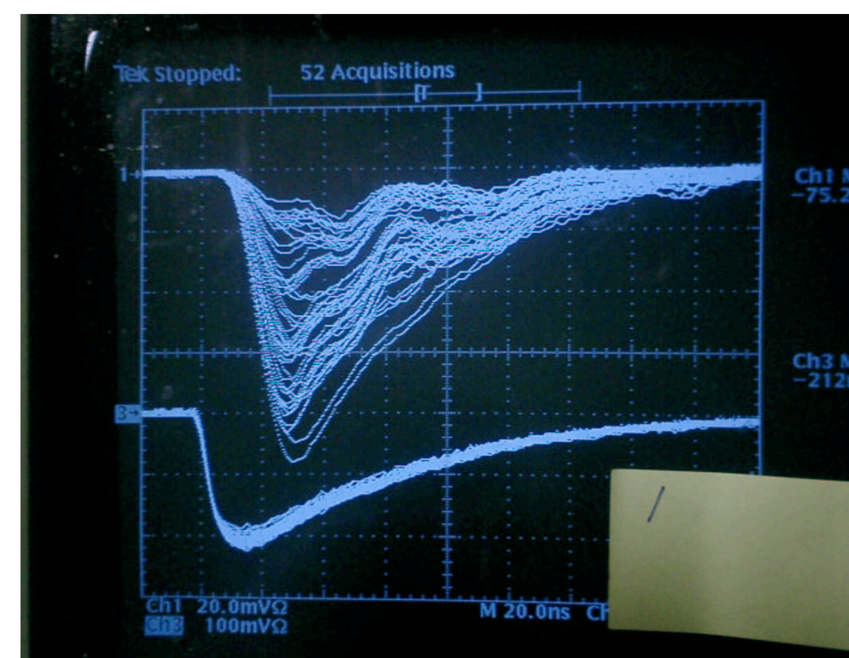
X



Ref.

nallow band BPF
1-port
(att. 6dB)

X

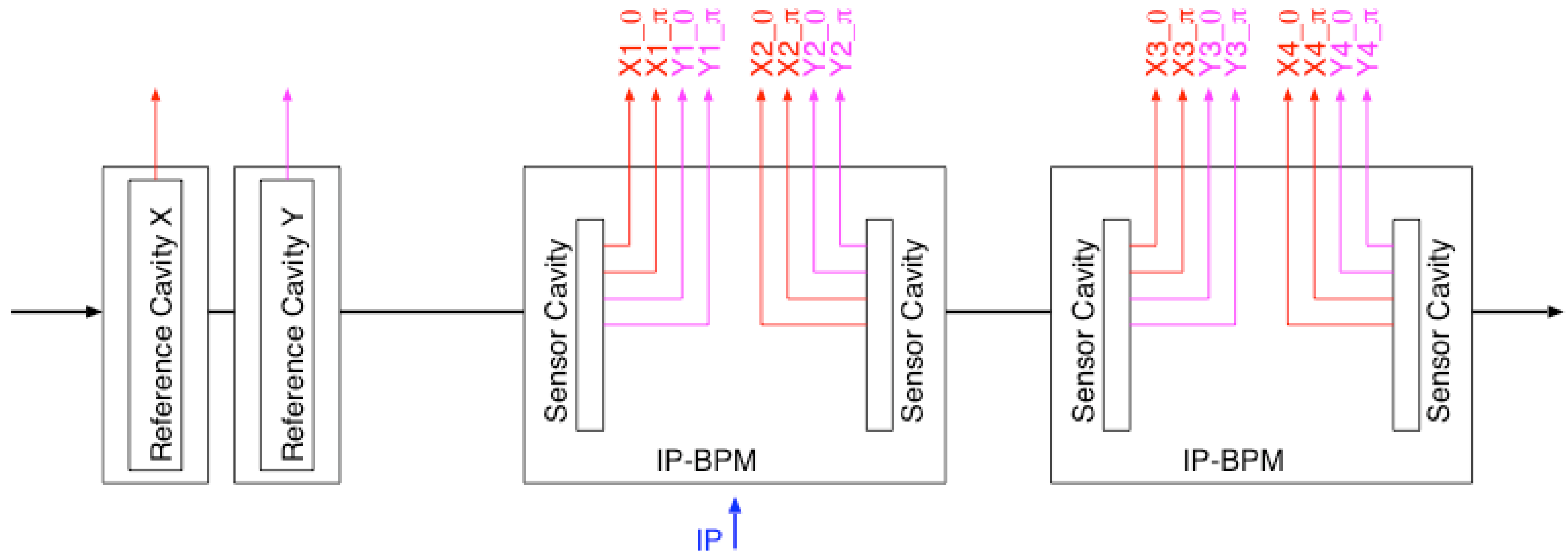


Ref.

Mode	S_{11} or S_{21}	Q_L	β	Q_0	Q_{ext}
X Reflexion – Port1	0.559	653	0.788	1167	1481
X Reflexion – Port2	0.532	700	0.881	1316	1495
X-X Transmission	0.437	875	0.778	1555	2000
Designed value		2247	1.4	5300	3901
Y Reflexion – Port1	0.283	918	2.534	3244	1280
Y Reflexion – Port2	0.343	976	1.915	2844	1486
Y-Y Transmission	0.251	1044	0.335	1393	4163
Designed value		1630	2.0	4900	2442

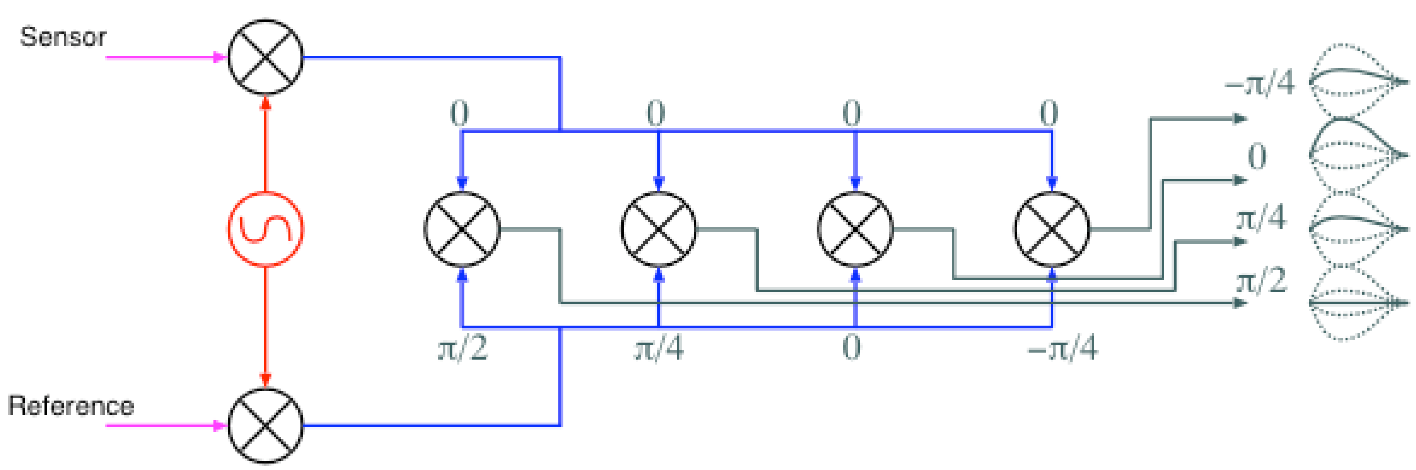
As one can see, the X dipole mode is very different from what was expected whereas the Y dipole mode matches the designed values (apart from transmission what is certainly due to an erroneous measure). This may come from the fact that in this first model, *the frequency of the the waveguides' modes* were really close to the one of the X dipole mode which *implies another interfering resonant mode* in the waveguide. Further models of the cavity will take this problem into account and change the waveguides' dimensions to avoid it.

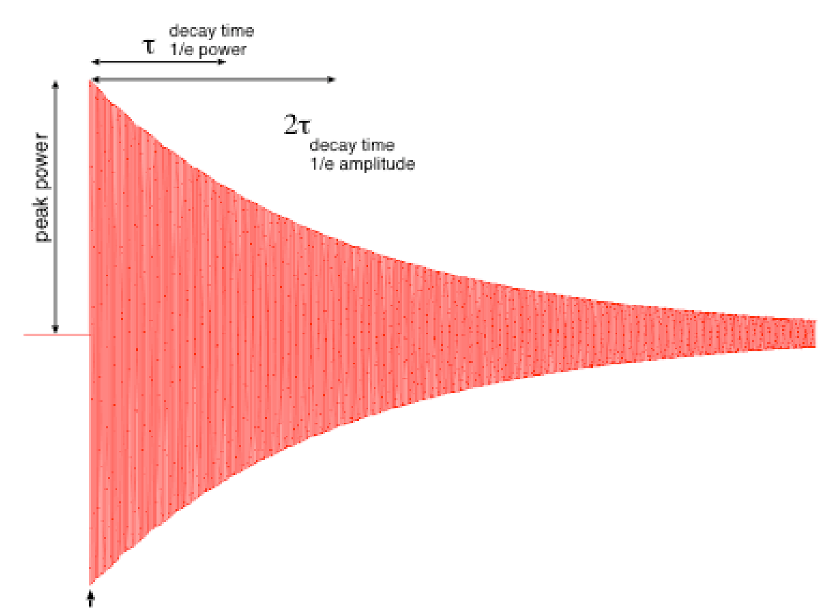
Electronics



- Faster decaying time than Q-BPM
- Detection scheme
    - upgrade version of KEK nano-bpm type
        - octant phase detection to reconstract the position and angle information
        - charge sensitive adc
    - easily changeable to SLAC type scheme

Cavity	f(GHz)	Q_L	τ (nsec)	signal power for 1 nm
Sensor X	5.712	3900	109	-101.6 dBm
Sensor Y	6.426	2400	59	-100.0 dBm
Reference X	5.712	8000	223	
Reference Y	6.426	8000	198	





Noise Measurement

Philippe Doublet

As it can be seen on the following graph, the expectations wer quite correct and the noise level found is about -98.2 dBm, which is consistent with the calculated noise above.

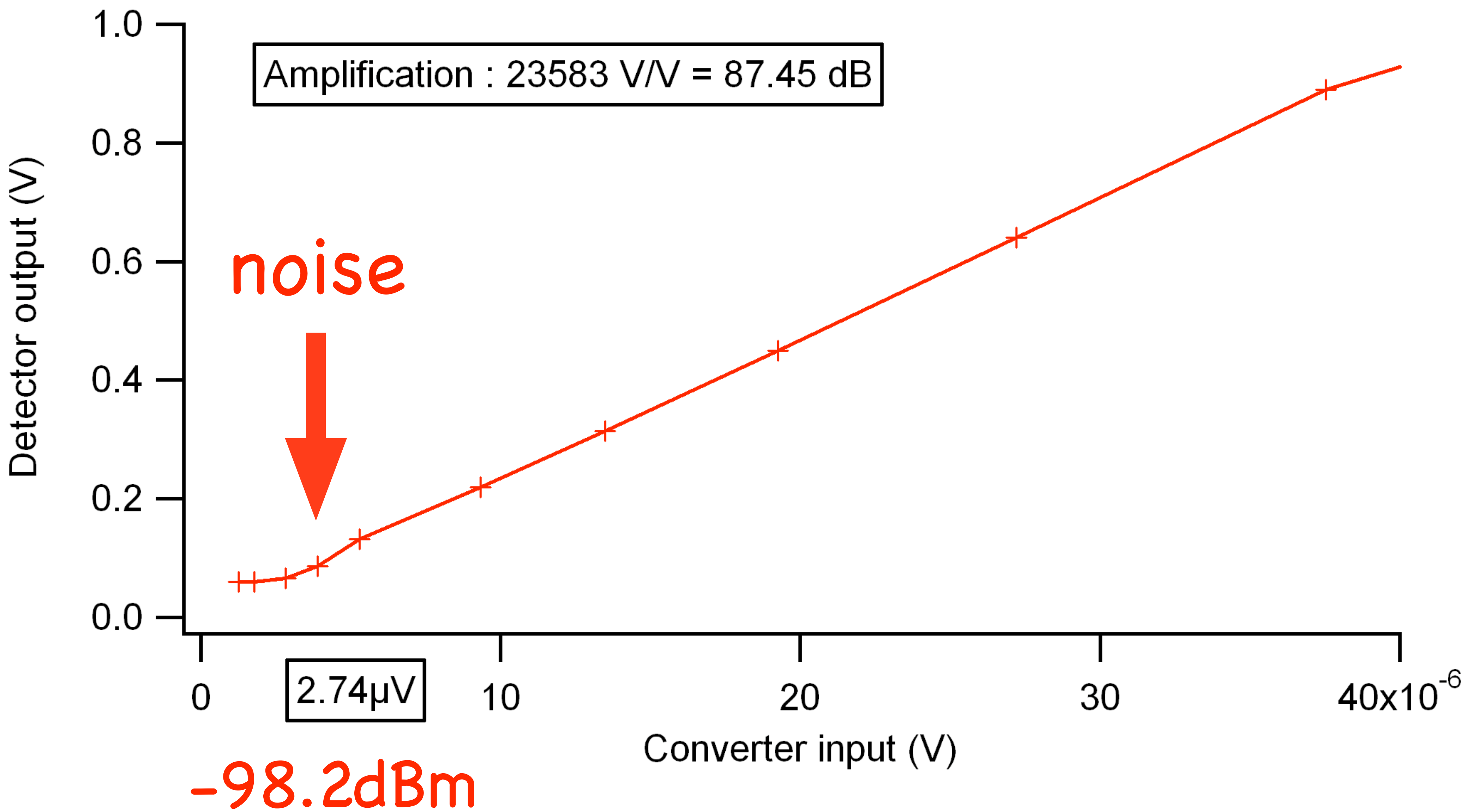


Figure 12: Noise measurement with all the electronics

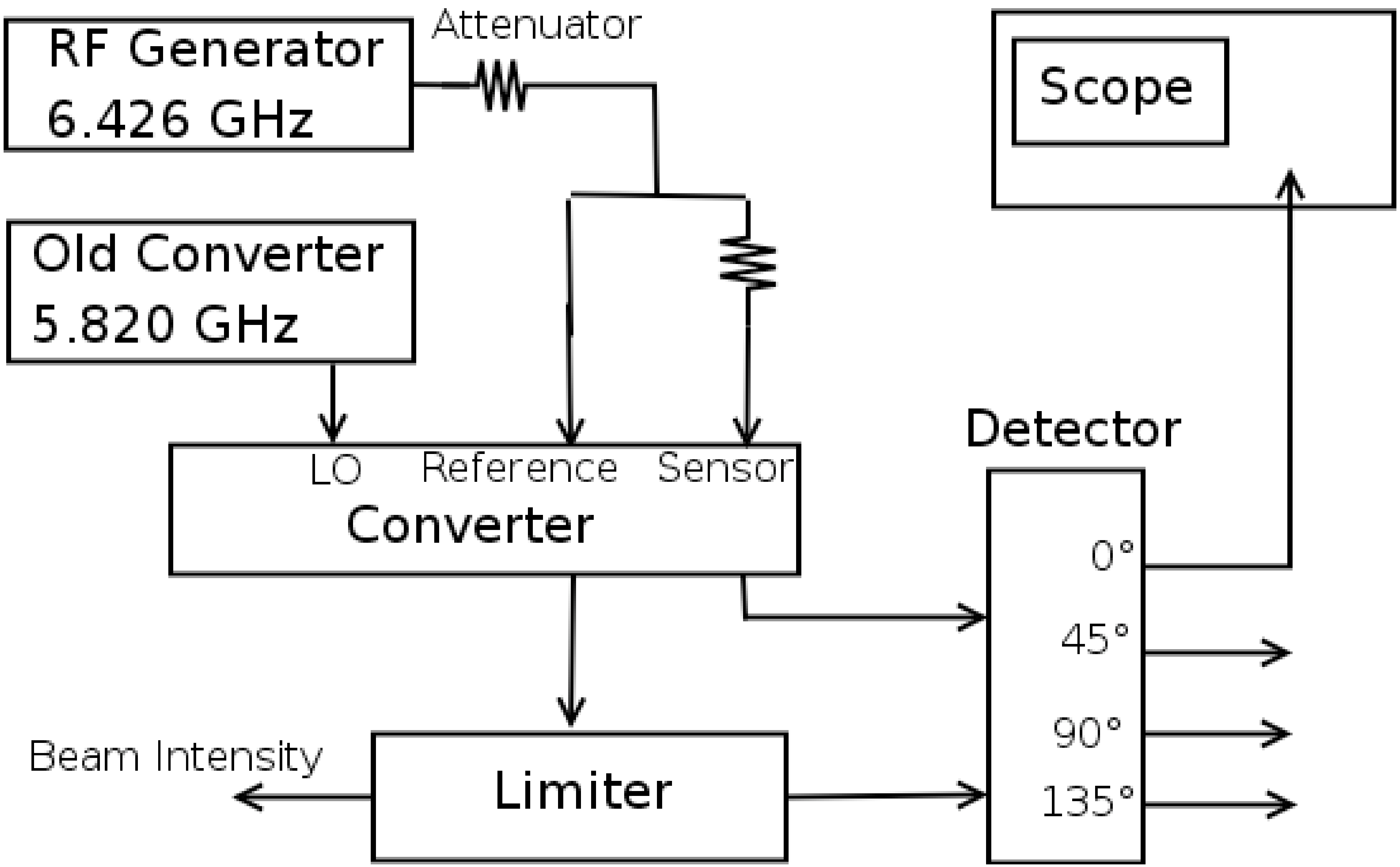


Figure 11: Setup of all the electronics

Present Status, October 2006

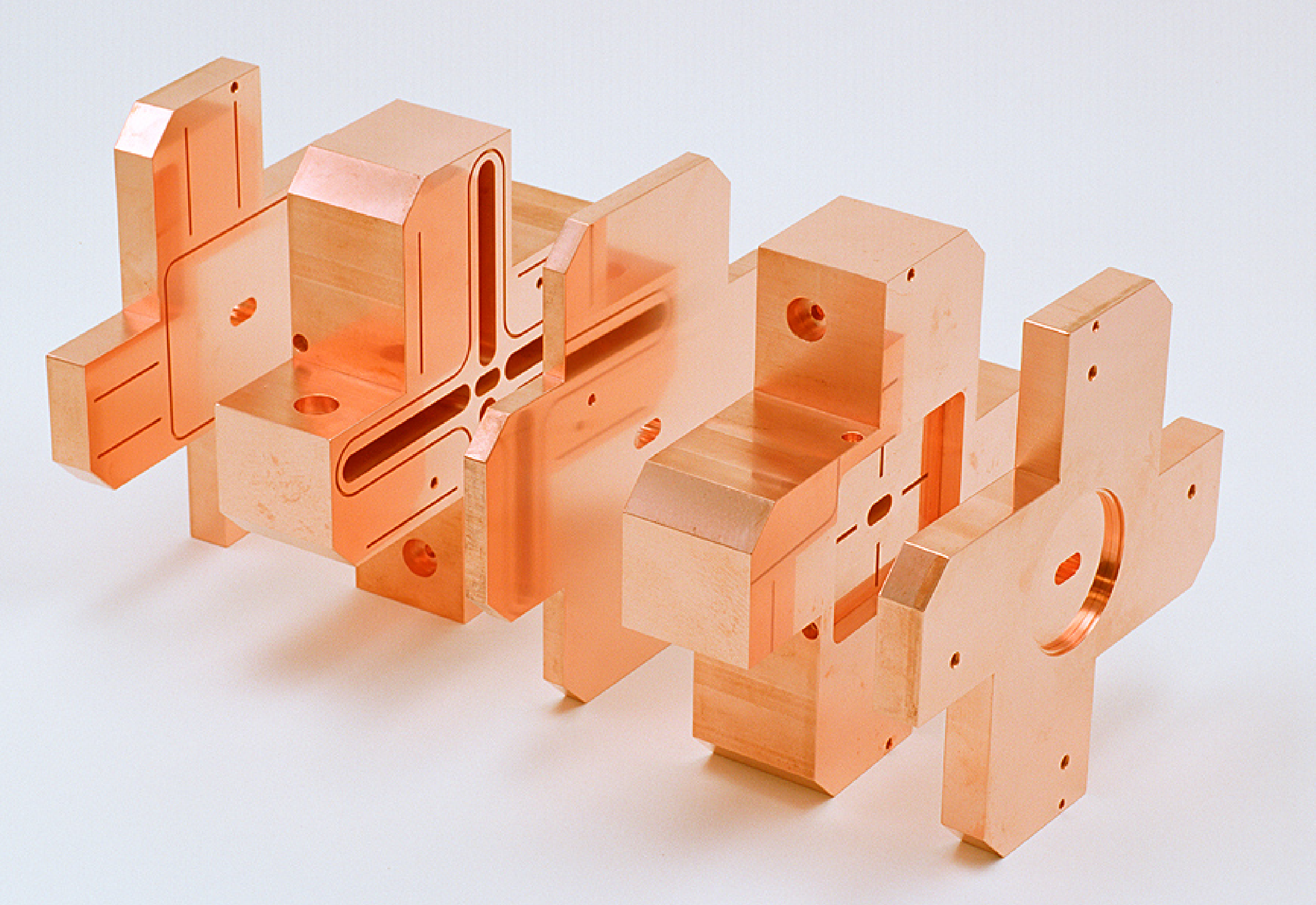
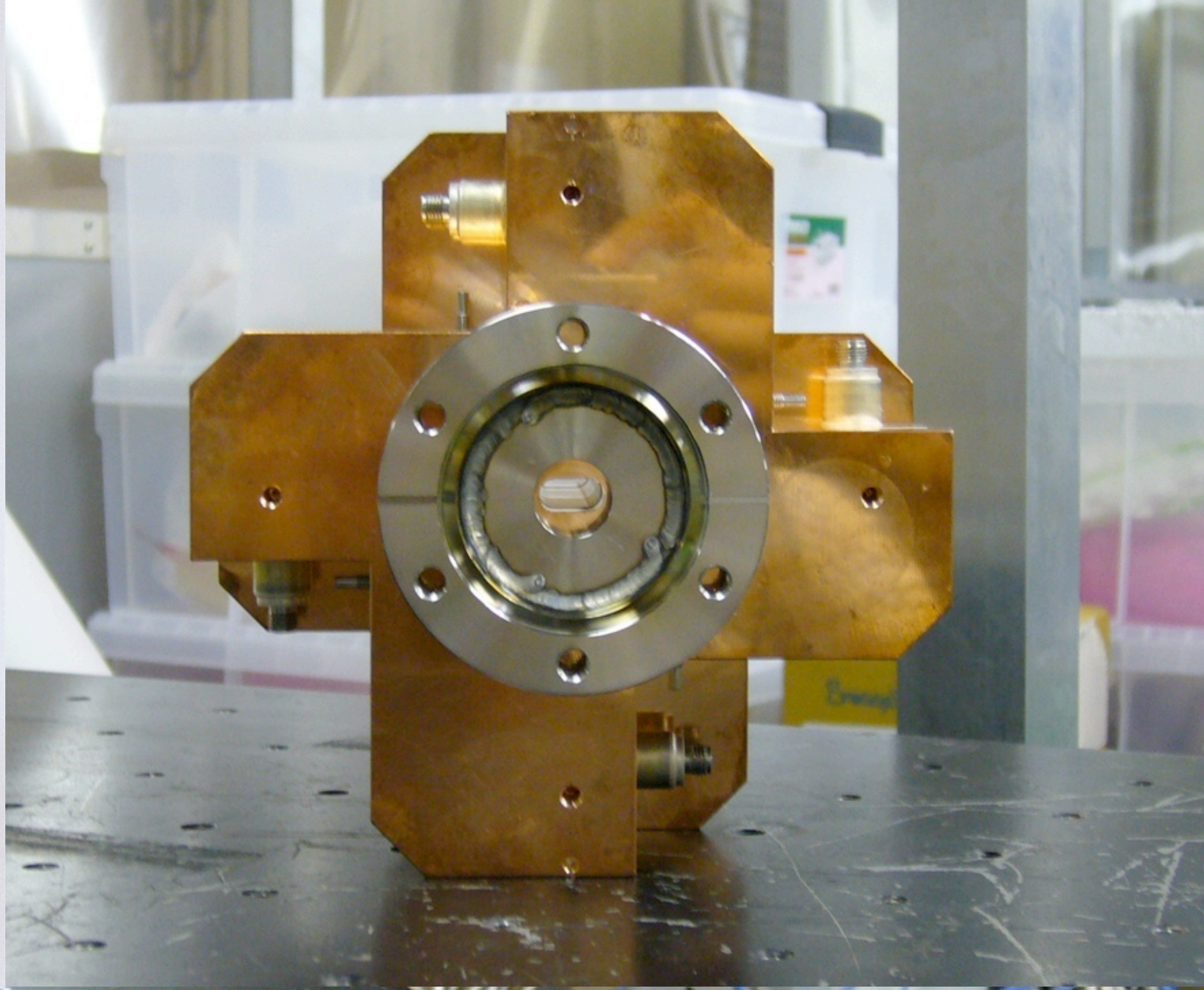
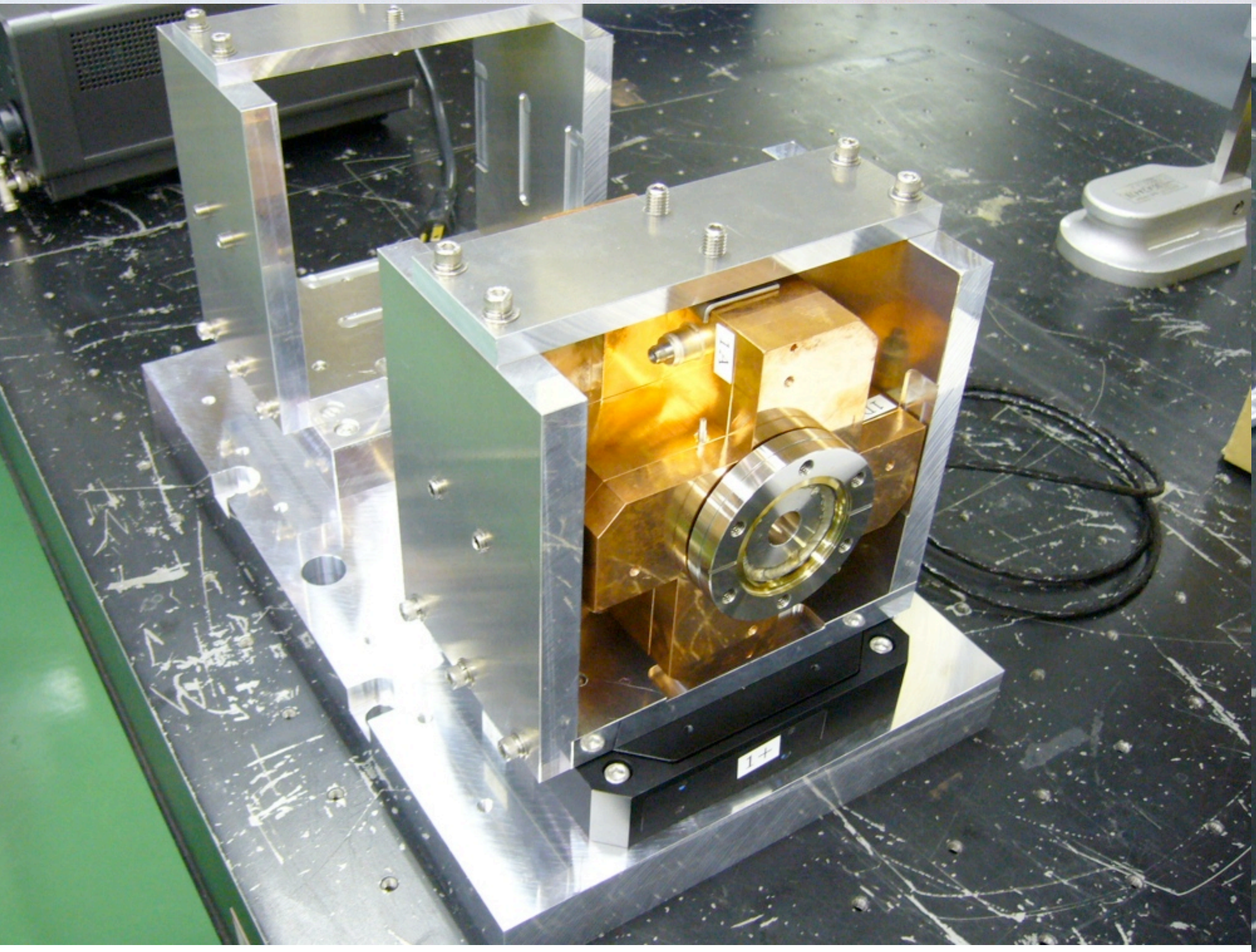
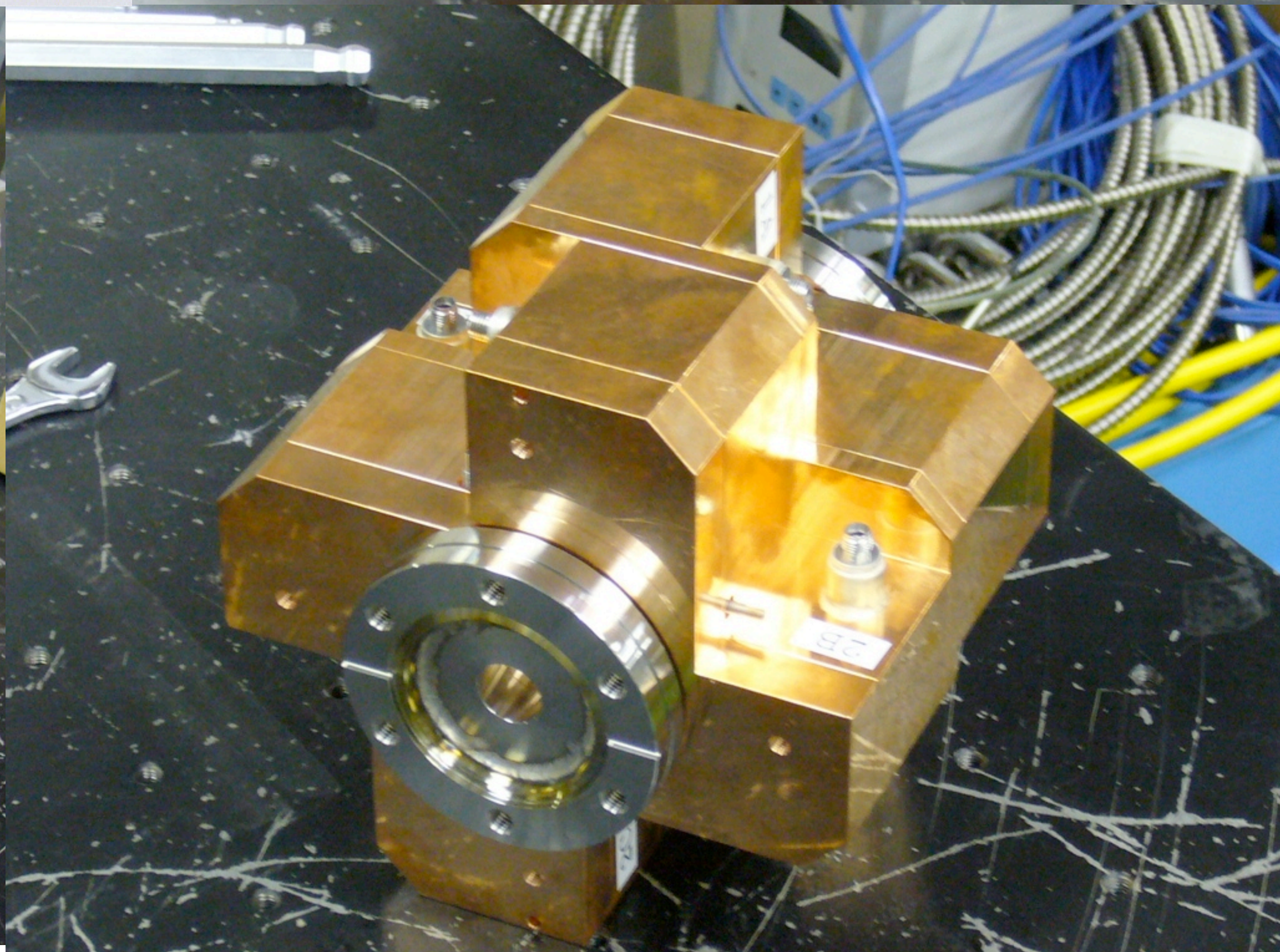
Two hot models, i.e. brazed ones, are fabricated;
- One was just completed, and
- the second is ready for brazing feed-through connectors.

A new reference BPM has been installed at the beam line where there was the FEATHER-BPM.

Also, new precision movers were made. The FFTB movers will be used for alignment of IP-BPMs.

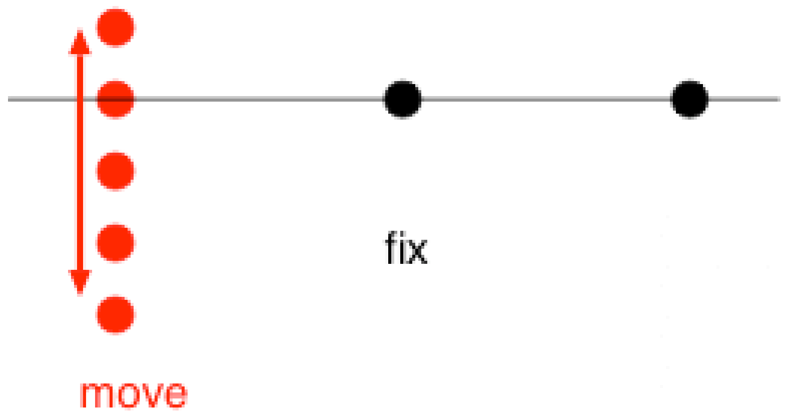
There is one set of electronics which has been made in last year. The electronics is under test, while it has been studied by Philippe.

To be test by beam in coming ATF machine time

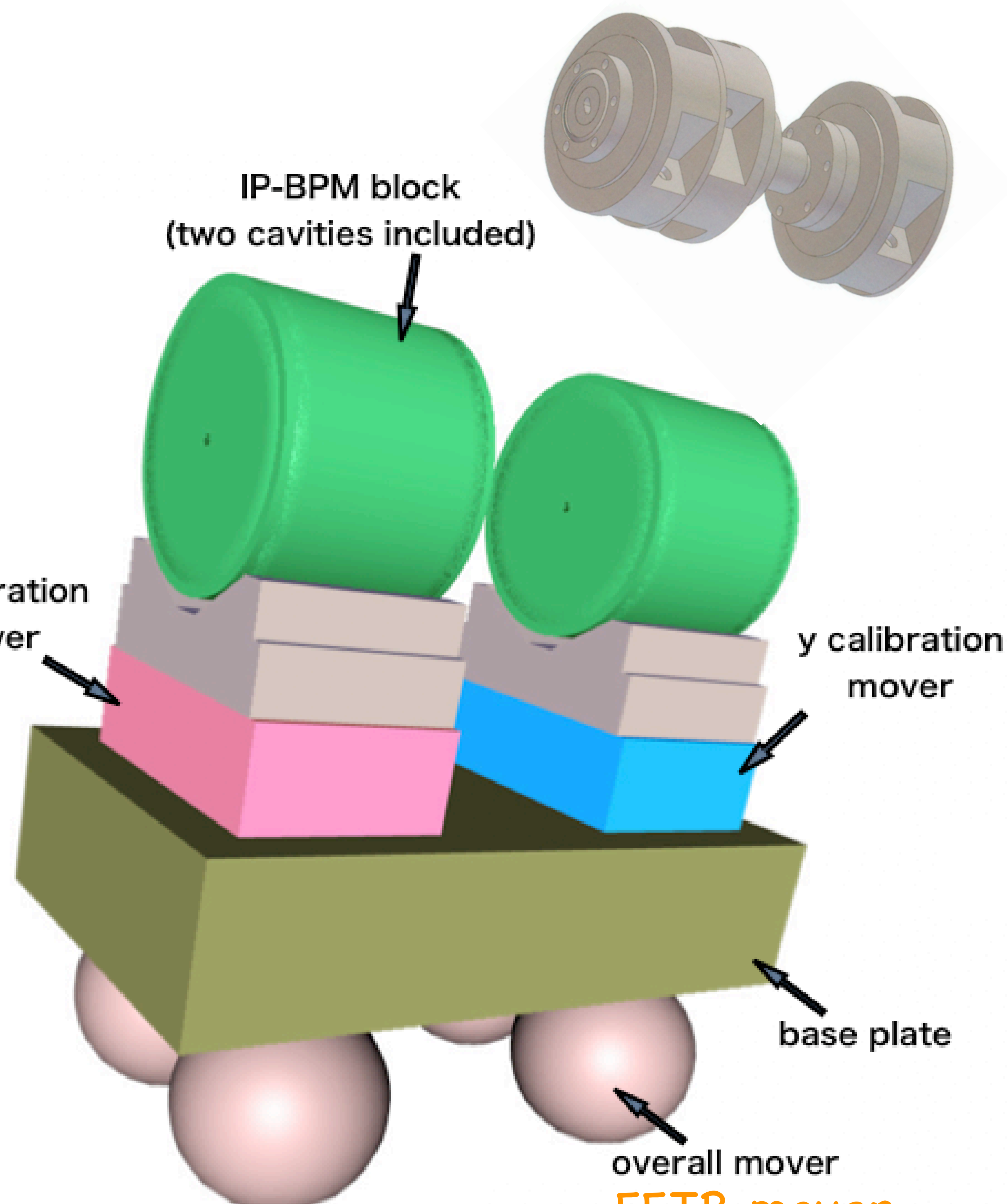





by Y.Honda, Feb. 2006

Mover



- precise mover 1 axis (X or Y)
  - for calibrating the BPM
  - <500nm step, 2um range
  - piezo based
  - closed loop
  - similar as KEK nano-bpm active mover
- overall mover
  - align the system on the beam
  - many axes (4?)
  - mm range, um precision
  - not yet determined
    - hexapod?, LW table like? etc.



FFTB mover