Overview of IPBPM objectives

by T.Tauchi

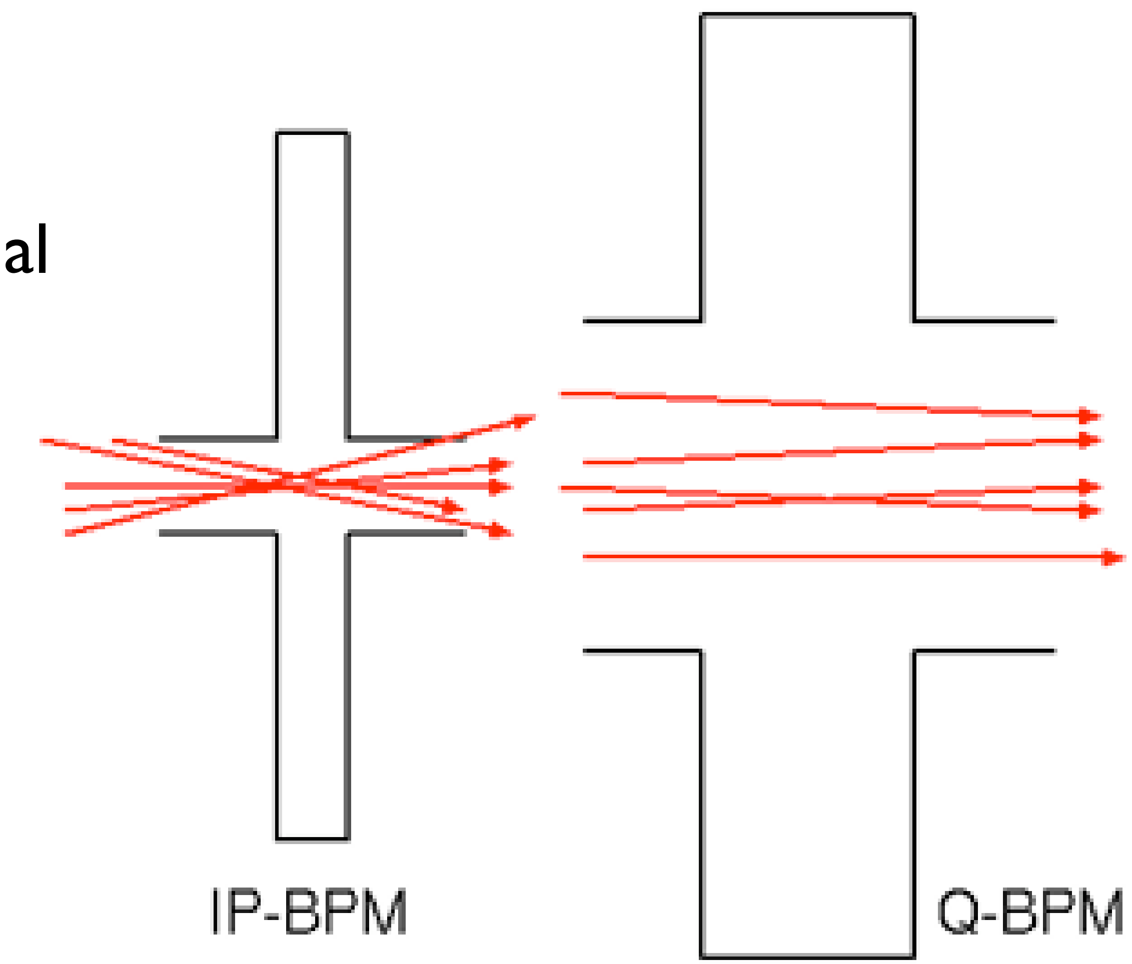
ATF2 Meeting, LAL, 19 -20 March 2012

1. Resolution :IPBPM (2nm)

Starting point of the design work

Y.Honda, 1st ATF2 project meeting

- 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

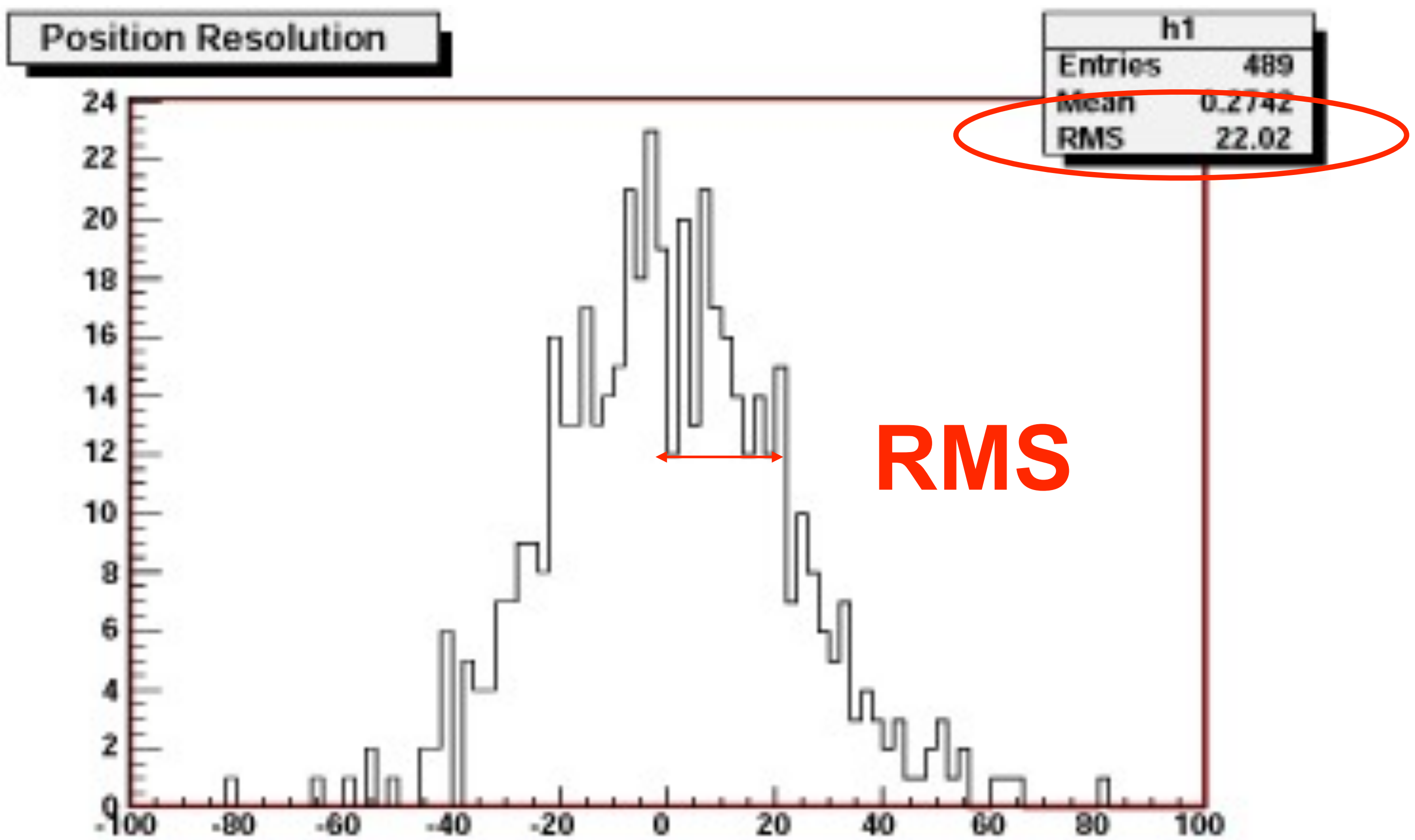


position/angle =f L^2

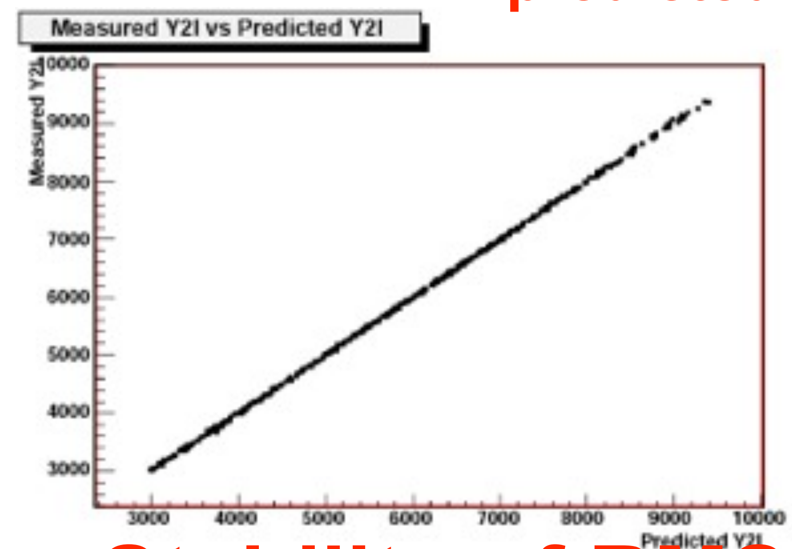
4 : 1

3, Resolution Run

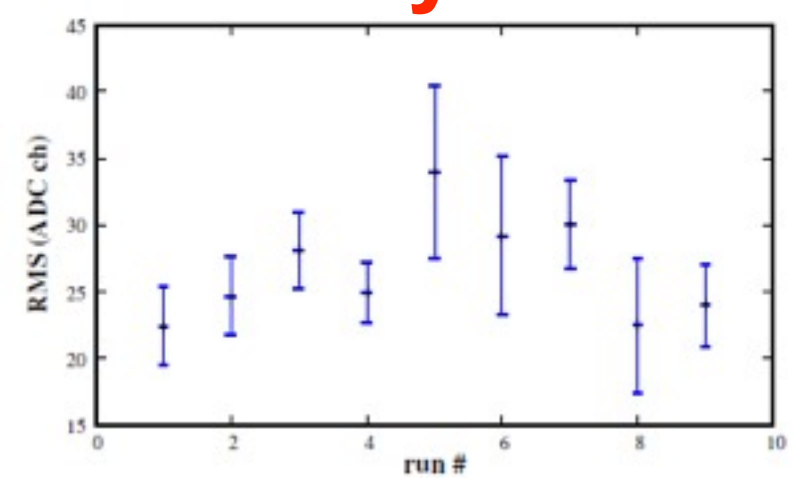
Residual of (Y2I – $Y2I_{predicted}$)



Y2I vs $Y2I_{predicted}$



Stability of RMS



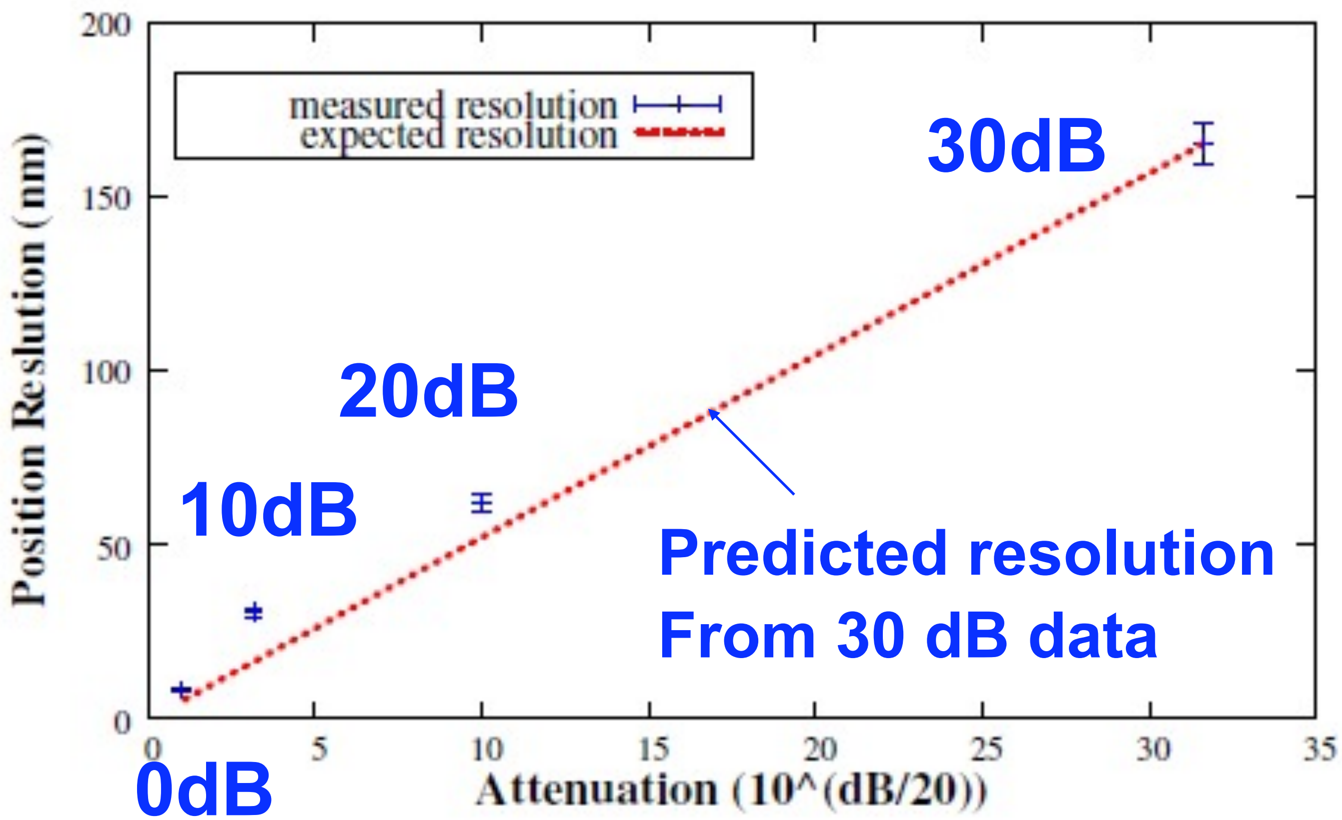
Data Cut

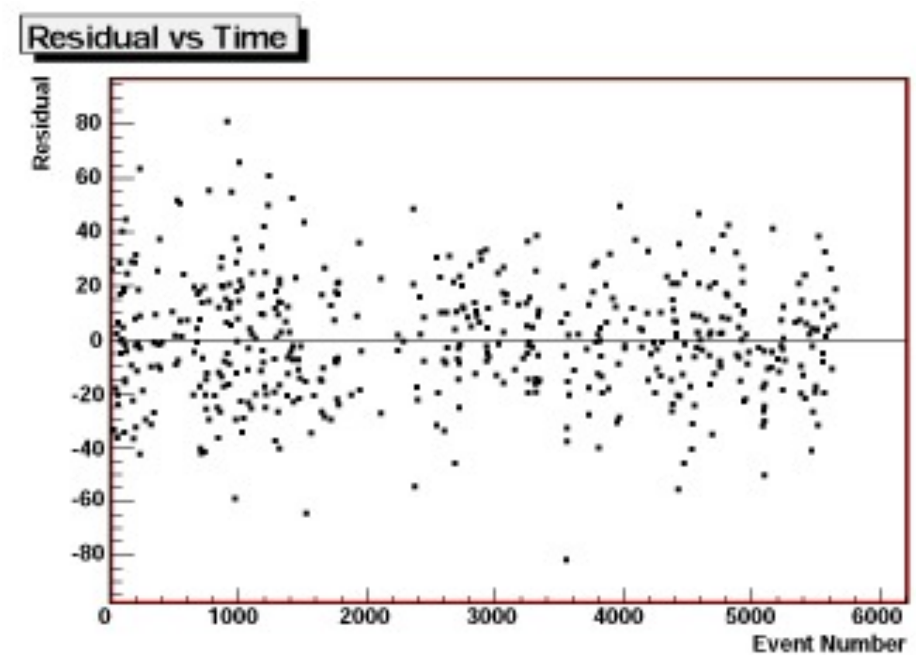
- 0.640 < ICT < 0.755 (*1.6nC)
- 3000 < Y1I,Y2I,Y3I < 13000 (ch) ⟷ 4.96 um dynamic range

Linear Regression Analysis

$$
\begin{aligned}
Y2I_{predicted} = \alpha_0 + \alpha_{Y1I} * Y1I + \alpha_{Y1Q} * Y1Q + \alpha_{Y3I} * Y3I \\
+ \alpha_{Y3Q} * Y3Q + \alpha_{Yref} * YREF + \alpha_{X1I} * X1I + \alpha_{X1Q} * X1Q \\
+ \alpha_{X3I} * X3I + \alpha_{X3Q} * X3Q + \alpha_{Xref} * XREF
\end{aligned}
$$

4, Position Resolution





Residual vs Time

Resolution = geo_factor x (RMS of residual (ADC ch) / calibration slope (ADC ch/nm))

Position resolution for 1 hour run: **8.72 +- 0.28 (stat.) +- 0.35 (sys.) nm**

(ICT = 0.68 x 10^{10} e^-/bunch, dynamic range = 4.96 um)

→ at the ATF2 condition (1~2 x10^{10} e^-/bunch), **5.94 ~ 2.97nm**

Stable enough for 1 hour

Y. Inoue et al, Phys. Rev. ST Accel. Beams 11, 062801 (2008)

Resolution - Homodyne

Vertical

Charge : 0.5 ~0.6 x 10^{10} , Unit [nm]

	40 dB	30 dB	20 dB
One point	10.0	15.0	16.0
Filter	6.90	8.12	9.05
Integration	6.73	7.55	10.09

Horizontal

	40 dB	30 dB	20 dB
One point	20.0	39.0	72.0
Filter	14.52	26.14	50.08
Integration	16.50	23.91	35.00

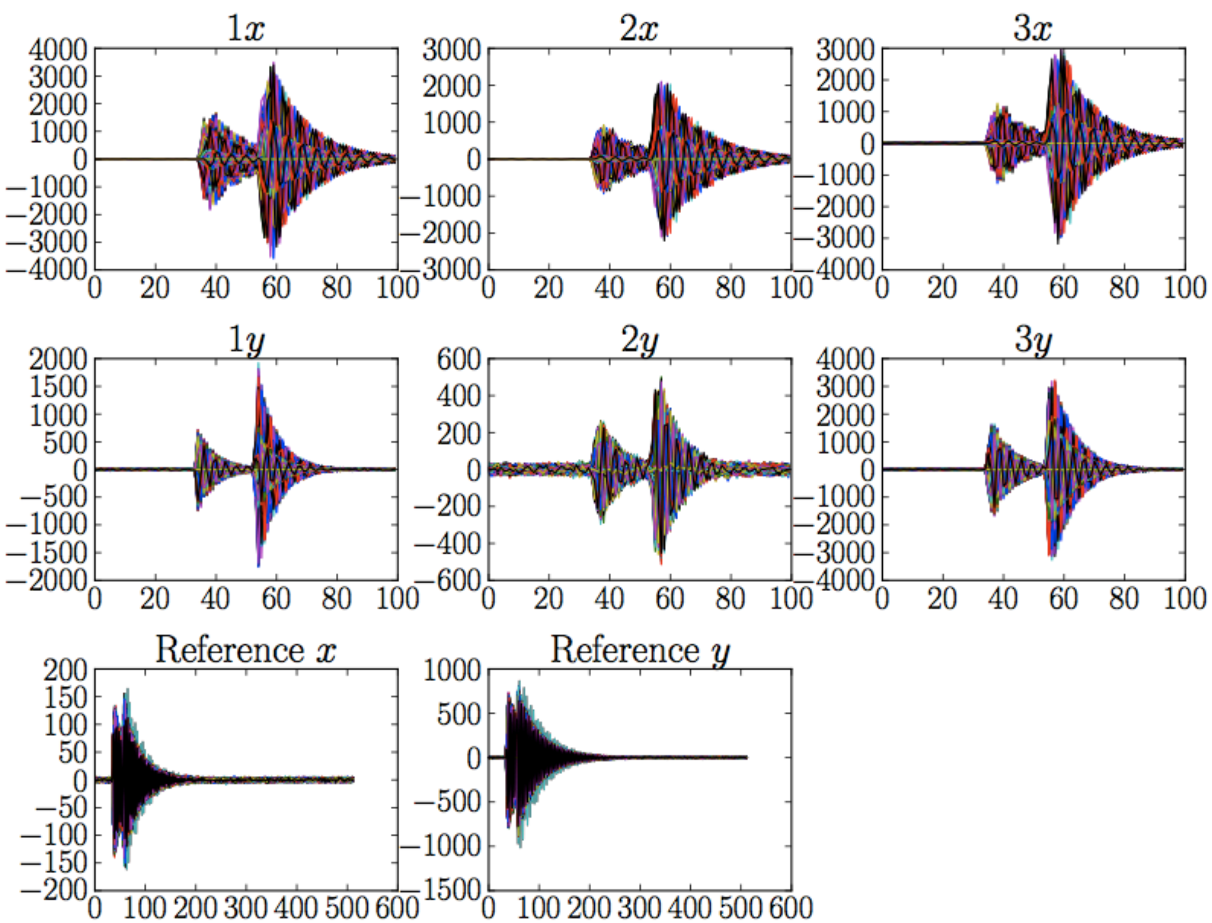
- SVD Residual
- Charge normalized
- Working on heterodyne data

- One point
  - Choose one sample point
- Filter
  - Use gaussian filter for removing noise on the homodyne signal
  - Choose one sample point
- Integration
  - Integrated few sample point
  - Same as charge ADC

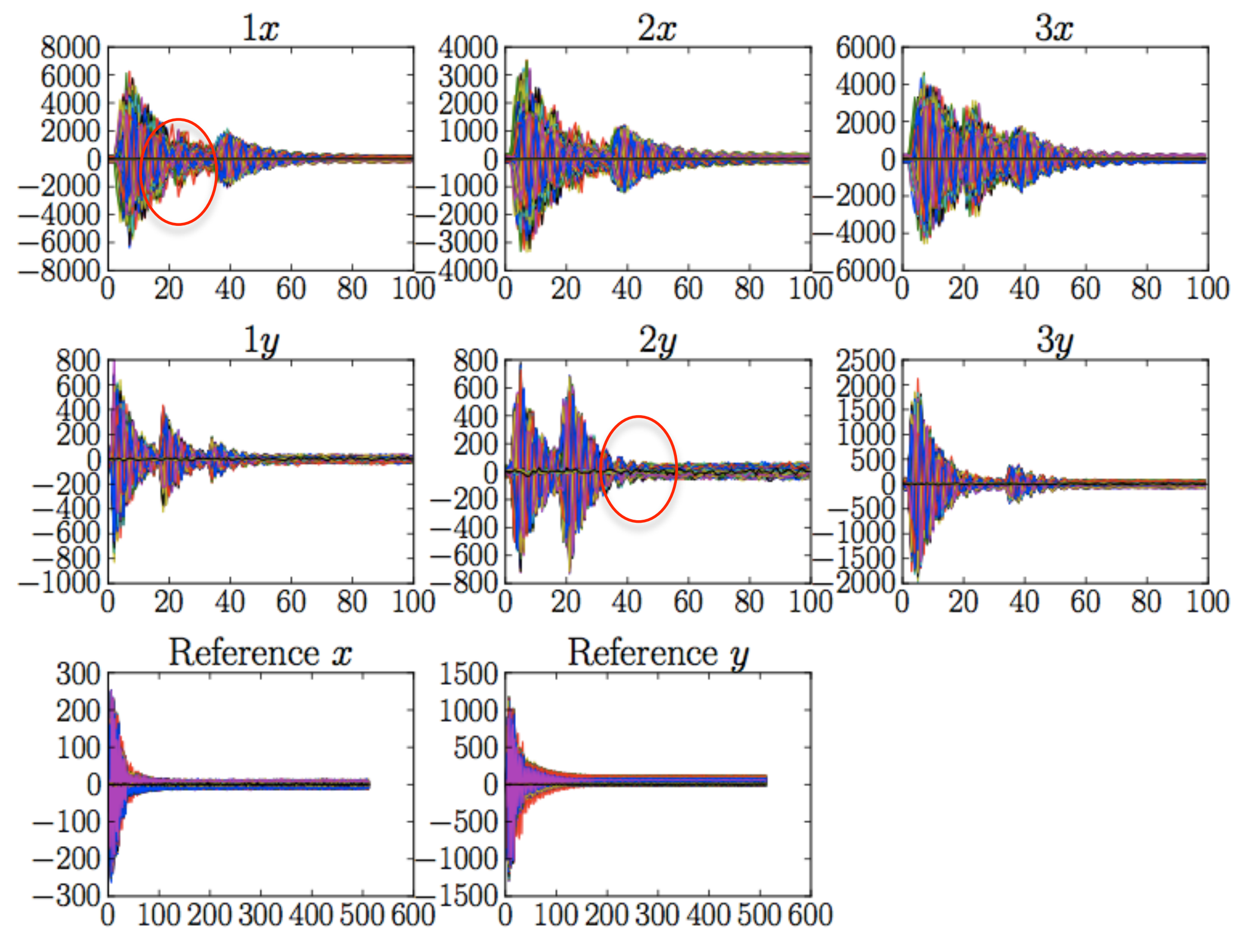
- Did few scans for finding filter width, sample point and integration width

Waveform – heterodyne (multi bunch)

Two bunch waveform (187.6 ns bunch spacing)



Three bunch waveform (150 ns bunch spacing)

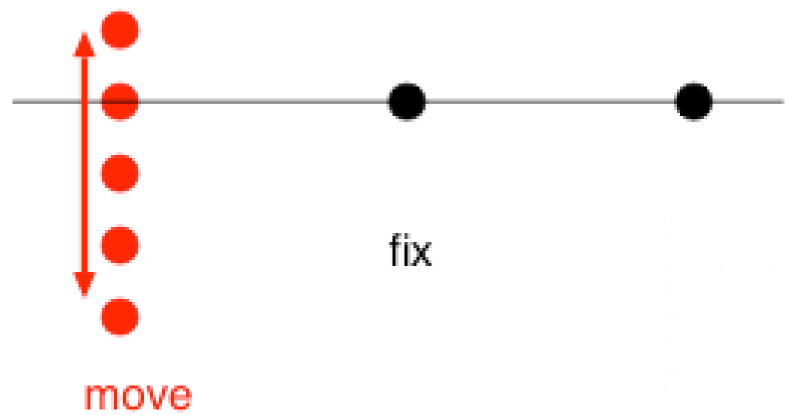


We can see clearly the bunch separation.

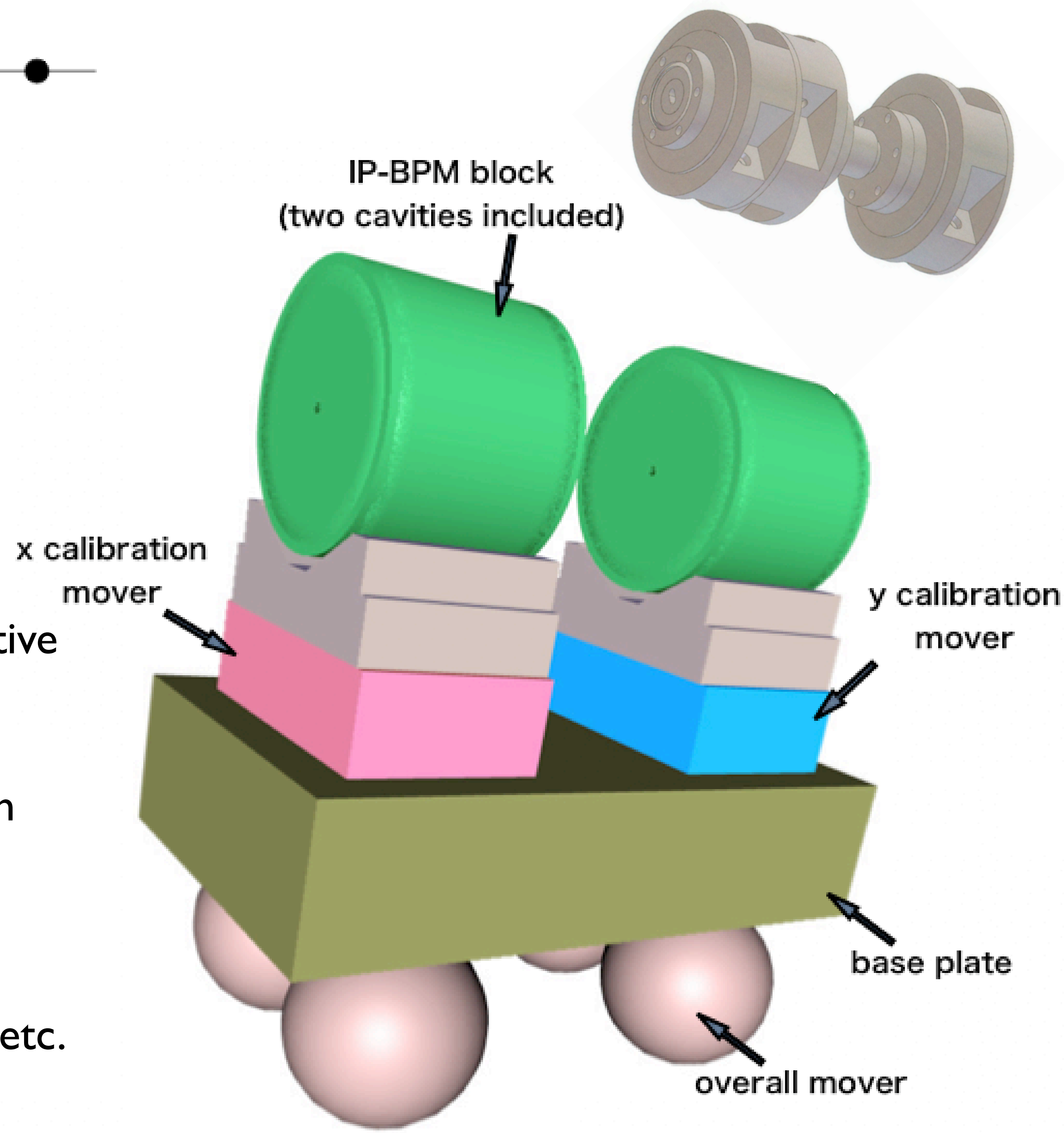
But, how can we use reference information for charge normalization??

2. Calibration Mover

by Y.Honda, Feb. 2006



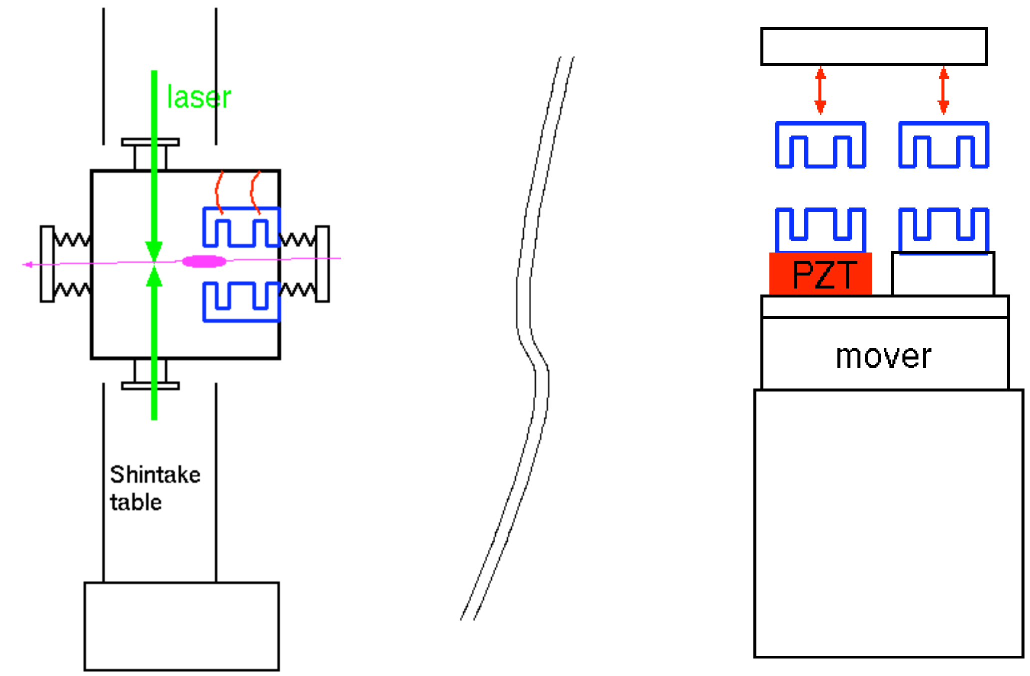
- precise mover 1 axis (X or Y)
  - for calibrating the BPM
  - <500nm step, 2um range
  - piezo based
  - closed loop
  - similar as KEK nano-bpm active mover
- overall mover
  - align the system on the beam
  - many axes (4?)
  - mm range, um precision
  - not yet determined
    - hexapod?, LW table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

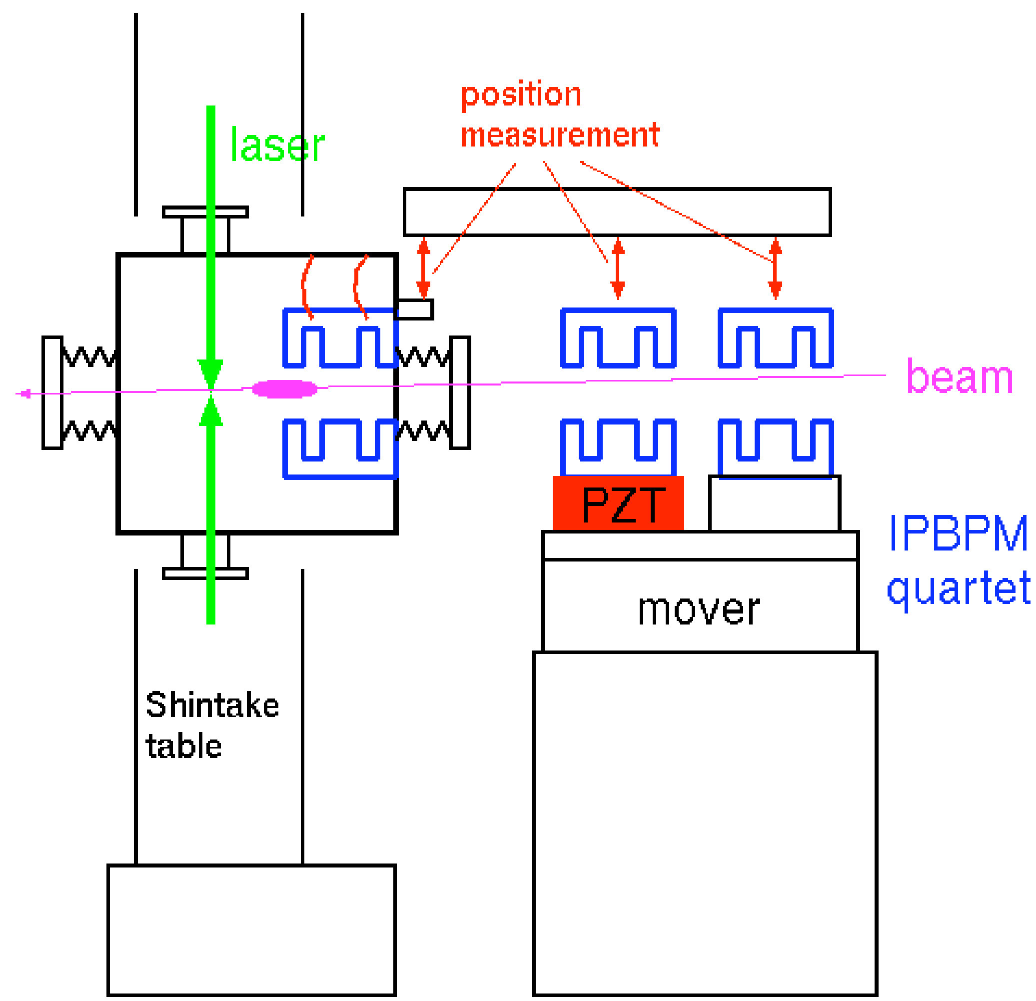


by Y.Honda, Feb. 2006

installation schedule

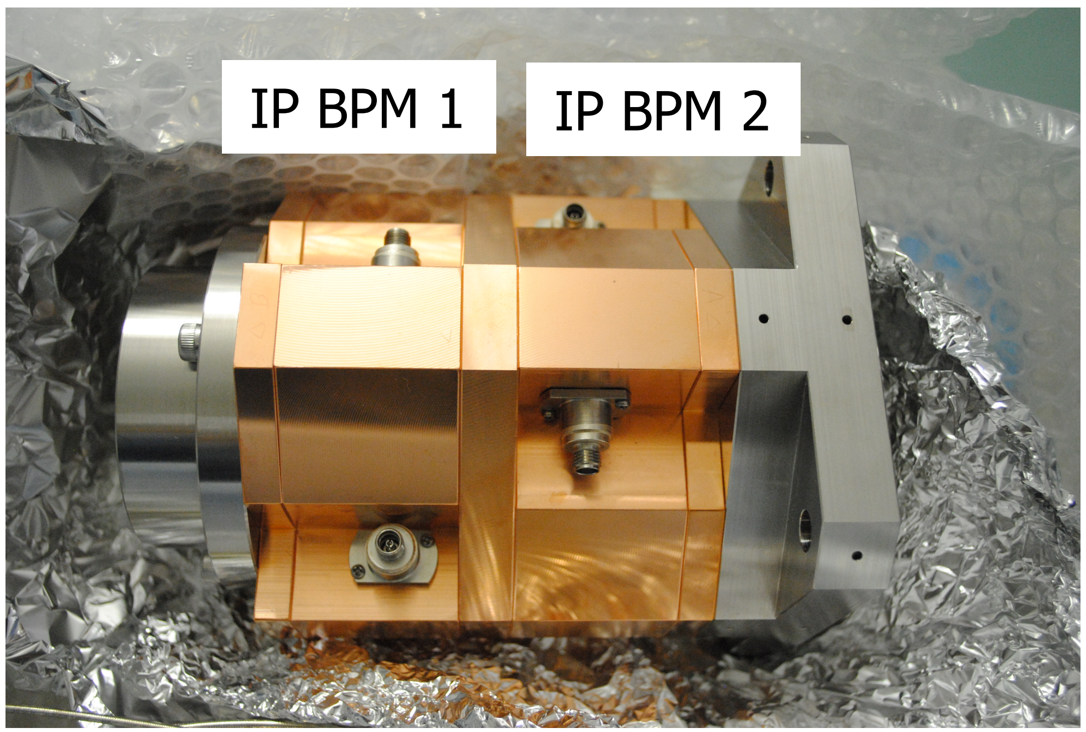
- Oct. 2008 ~ Mar. 2009
  - beam line comissioning
  - Shintake monitor comissioning
  - continue IP-BPM development at the device test section
- Apr. 2009 ~
  - move to IP area
    - a new alignment mover is needed because the FFTB mover will be used for a magnet
  - IP-BPM mode
    - shift the IP at the center of IPBPM quartet
  - Shintake mode
    - calibrate (check resolution) BPM inside the collision chamber using the IPBPM

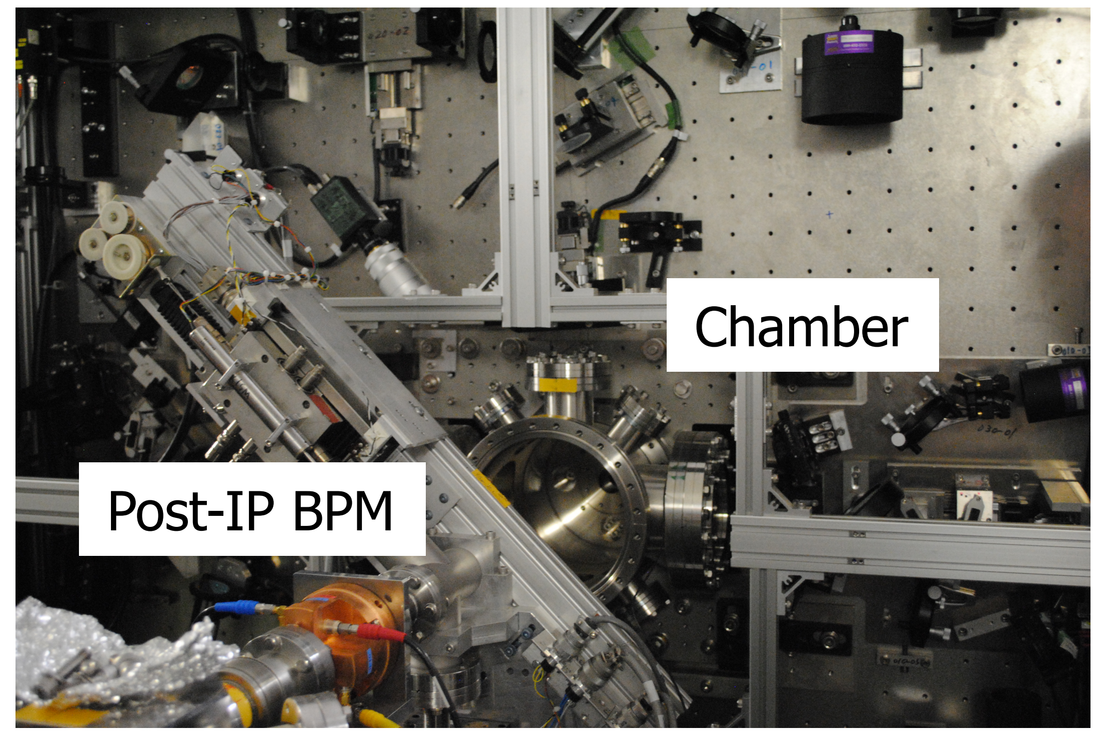


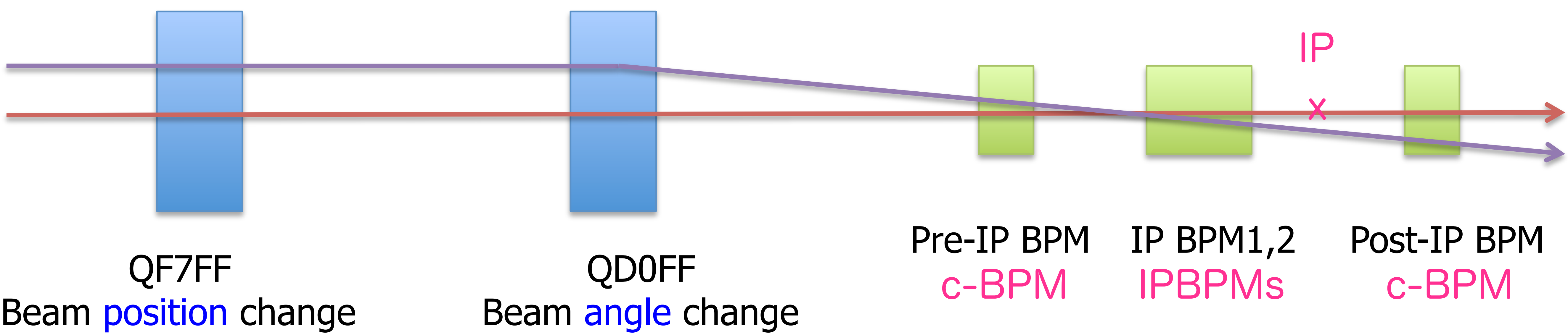


Orbit Monitor at IP

- IP BPM installed : September, 2010

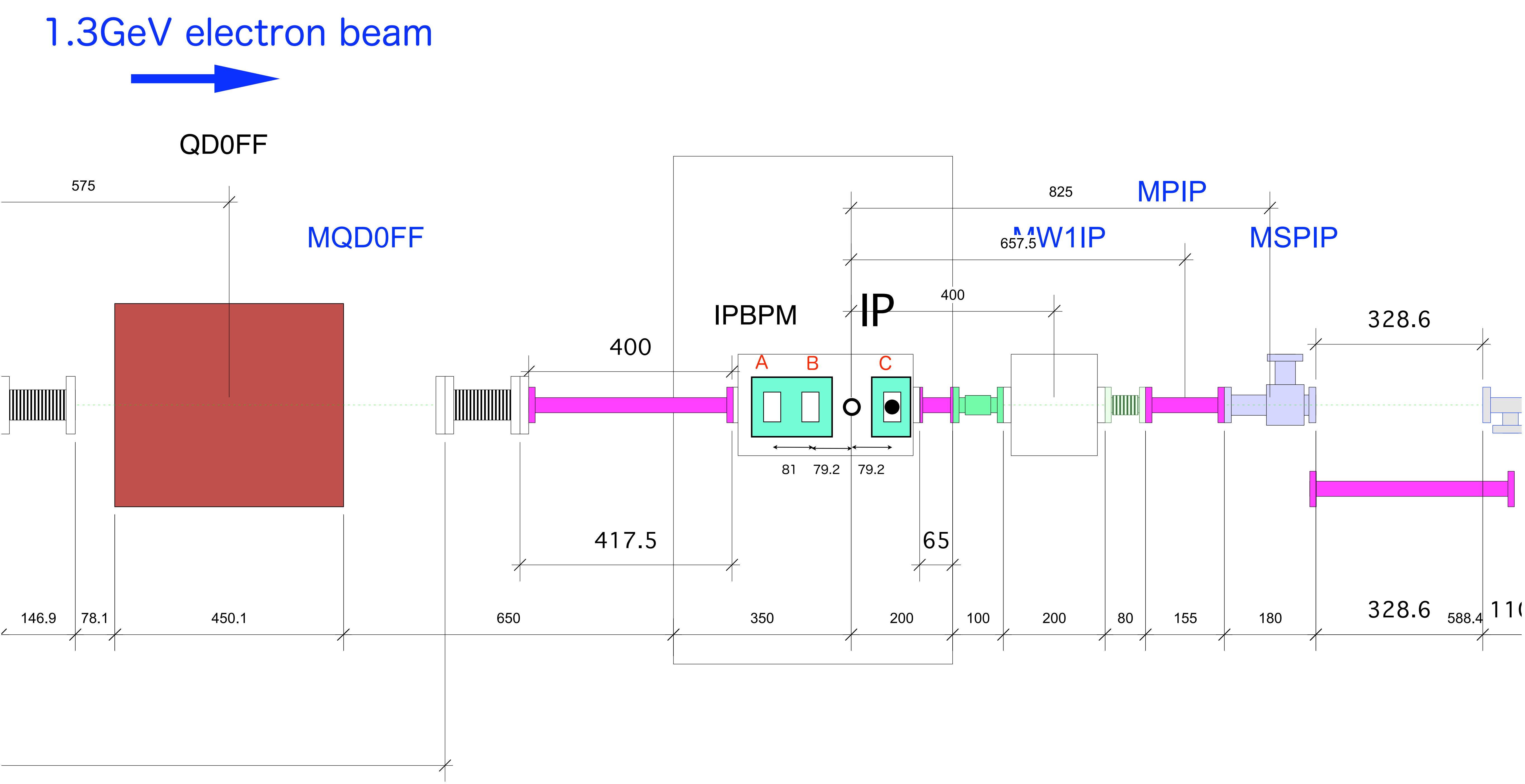






3. Layout

IPBPM Triplet with movers in the IP chamber



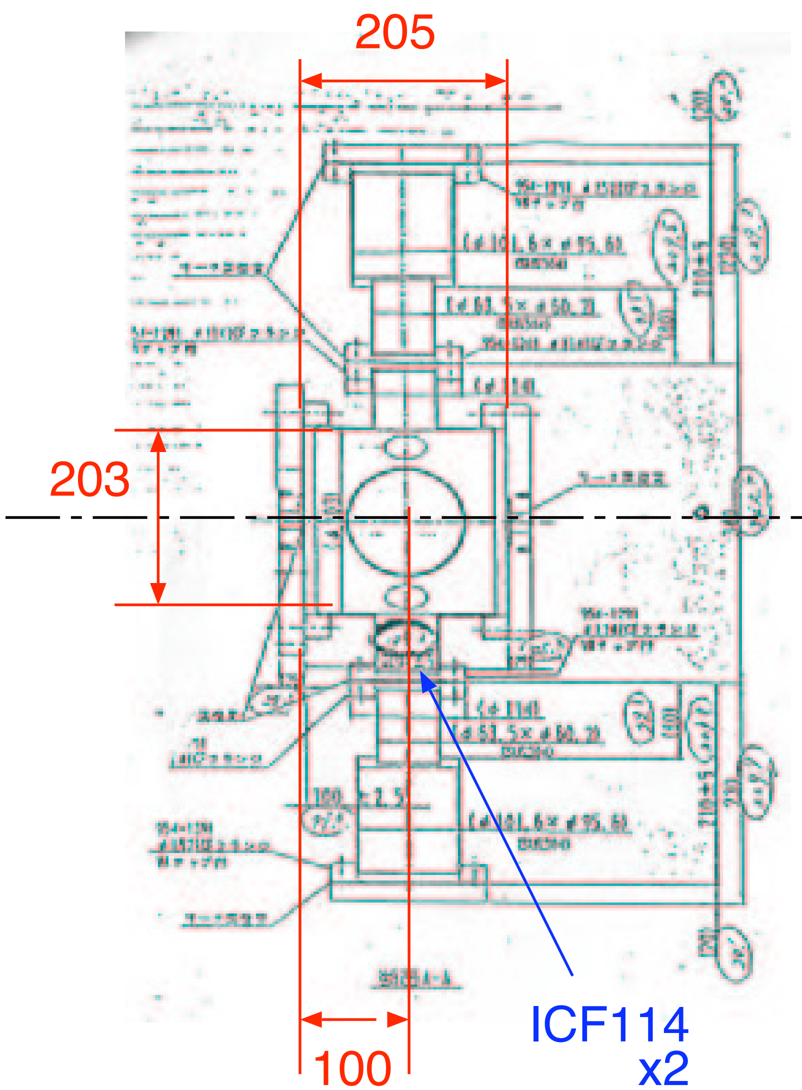
4. Waist (IP) shift to the IPBPM-C

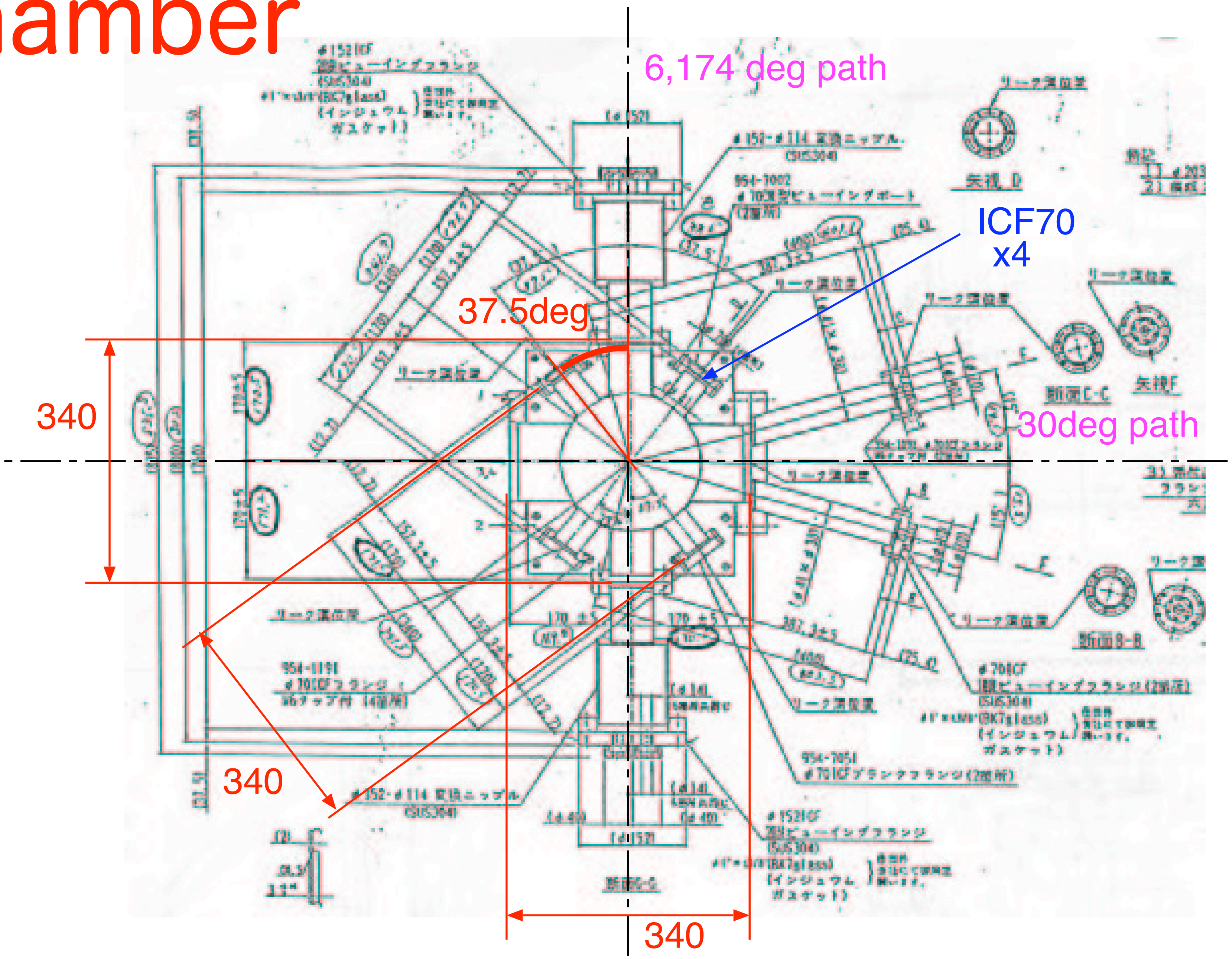
by SAD fitting

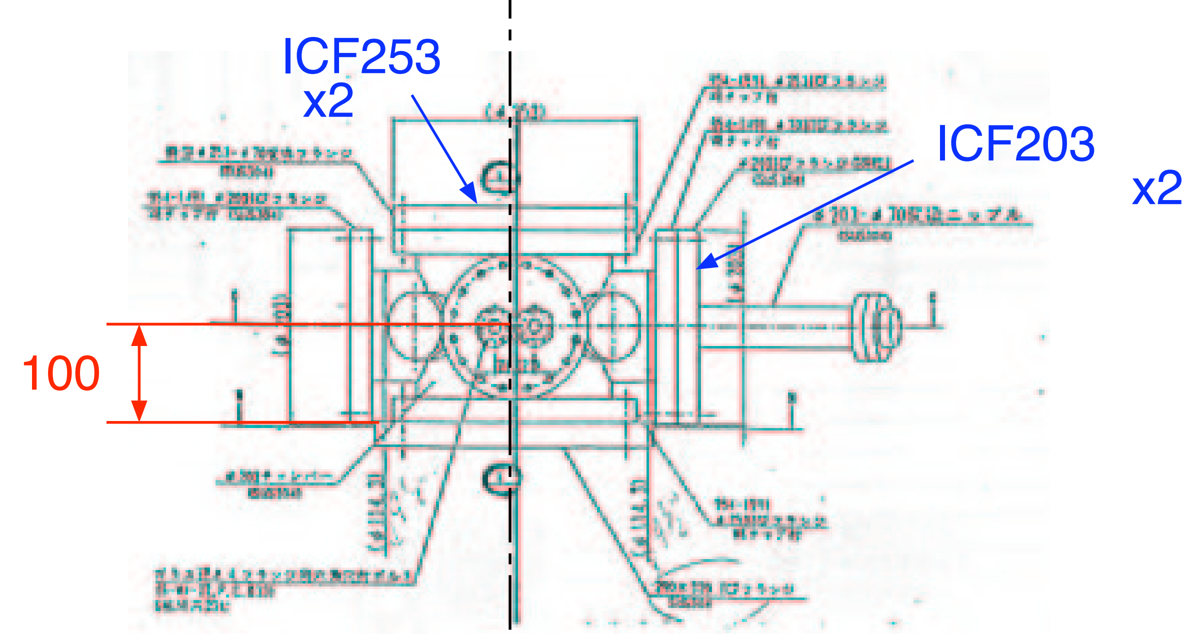
```
fit  MIPC
bx 4e-3 by 1e-4 ax 0 ay 0 ex 0 ey 0
free QD0FF QF1FF
go
---
mea MIPC ;  results of fitting by tracking
 Statistics at MIPC:   particles = 1000
 RAD: F, RFSW: T, GAUSS: T, DP = 8.0000E-4, DP0 =  .000000, GCUT = 1.0000E35
                   x      px/p0         y      py/p0         z      dp/p0
   C of M : -1.108E-06 3.320E-05 5.097E-10 2.666E-05-1.089E-05 5.308E-05
        x :  1.120E-11
    px/p0 :  2.655E-11 5.221E-07
        y : -3.692E-15 1.196E-13 1.734E-15
    py/p0 :  1.168E-11-1.828E-09 2.810E-13 1.045E-07
        z : -5.749E-11-1.643E-08-4.425E-13 4.280E-10 2.179E-08
    dp/p0 :  2.950E-10 8.629E-08 2.318E-12-2.194E-09-1.136E-07 5.925E-07
 x-y projected(coupled) parameters:
 emitx: 2.3730E-09 bx: 4.6574E-03 ax: 6.9157E-03 ex: 4.9785E-04 epx: 0.1456
 emity: 1.3421E-11 by: 1.2855E-04 ay:-2.1576E-02 ey: 3.9126E-06 epy:-3.7024E-03
 x-y decoupled parameters:
 emitu: 2.3730E-09 bu: 4.6574E-03 au: 6.9157E-03 eu: 4.9784E-04 epu: 0.1456
 emitv: 1.3411E-11 bv: 1.2848E-04 av:-2.1961E-02 ev: 4.1964E-06 epv:-3.8387E-03
    r1: 4.3964E-04 r2: 4.4624E-07 r3: -1.155     r4: 3.0136E-03detr: 1.8405E-06
   sigx: 3.3465E-06  sigy: 4.1646E-08   tilt: 3.2977E-04
  sigpx: 7.2257E-04 sigpy: 3.2320E-04
 sigp/p: 7.6972E-04  sigz: 1.4761E-04 dp/p/z:-7.6971E-04/sigz
```

42nm can be achieved
just by QD0 and QF1.

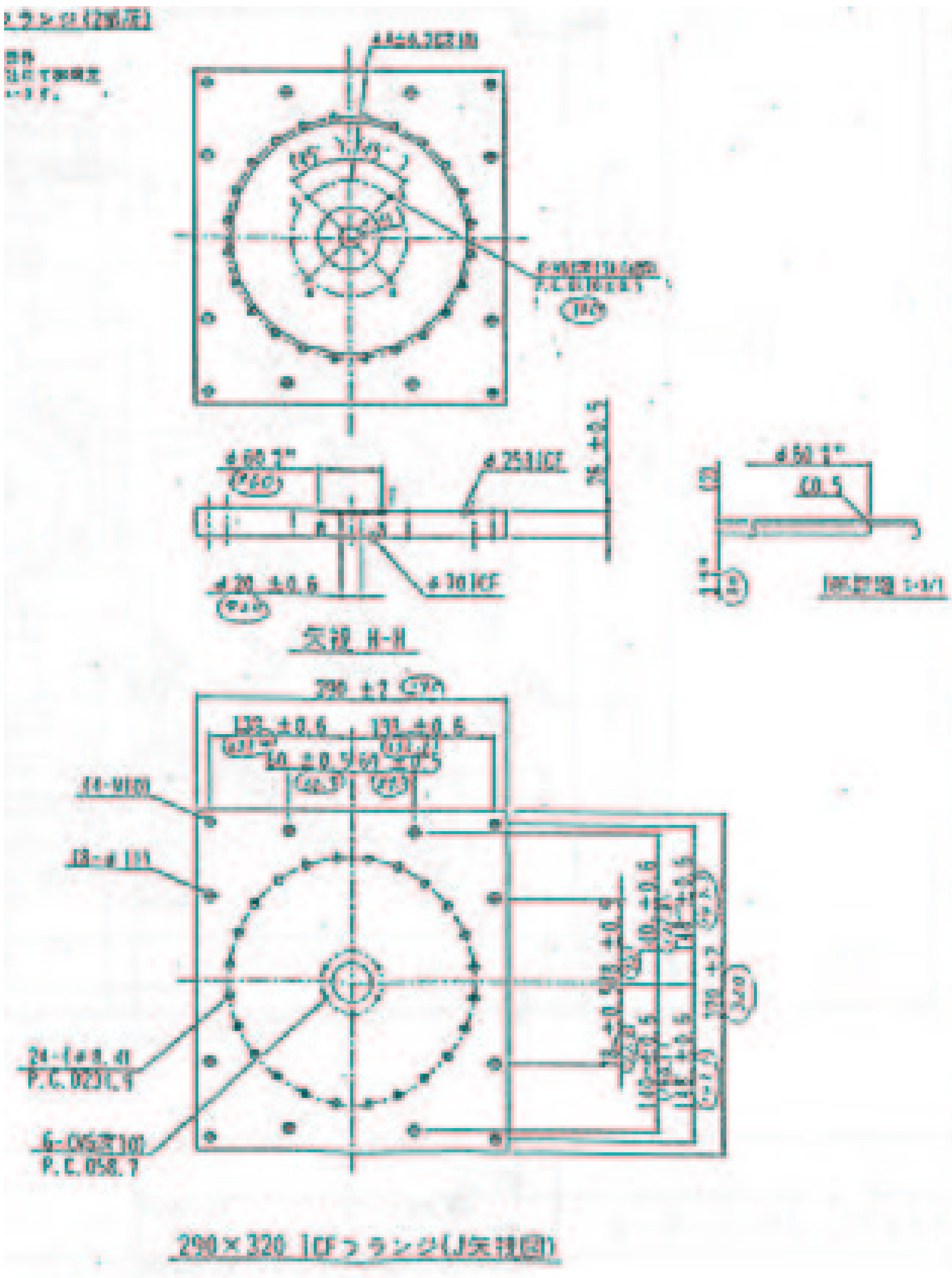
5. IP chamber

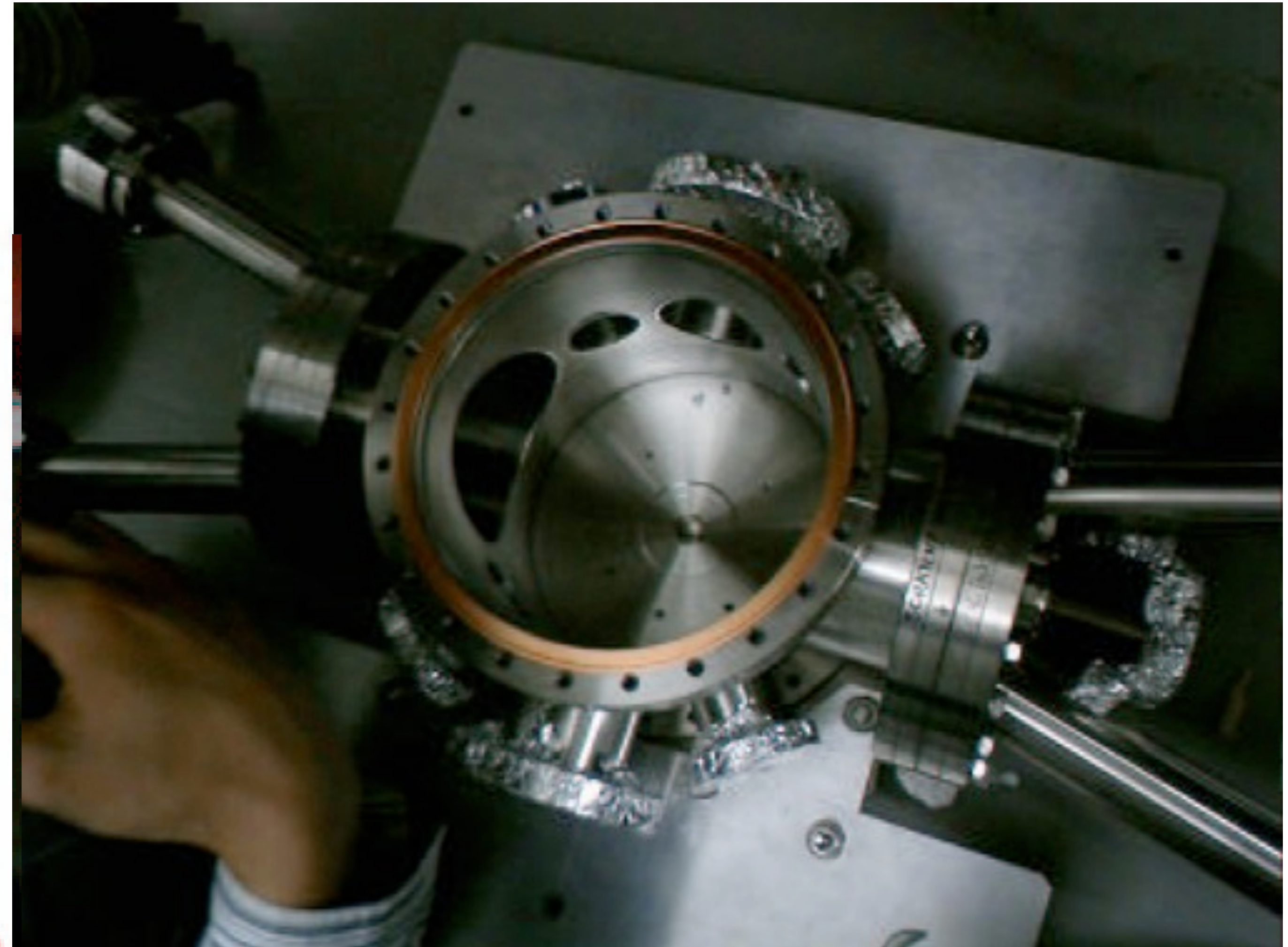


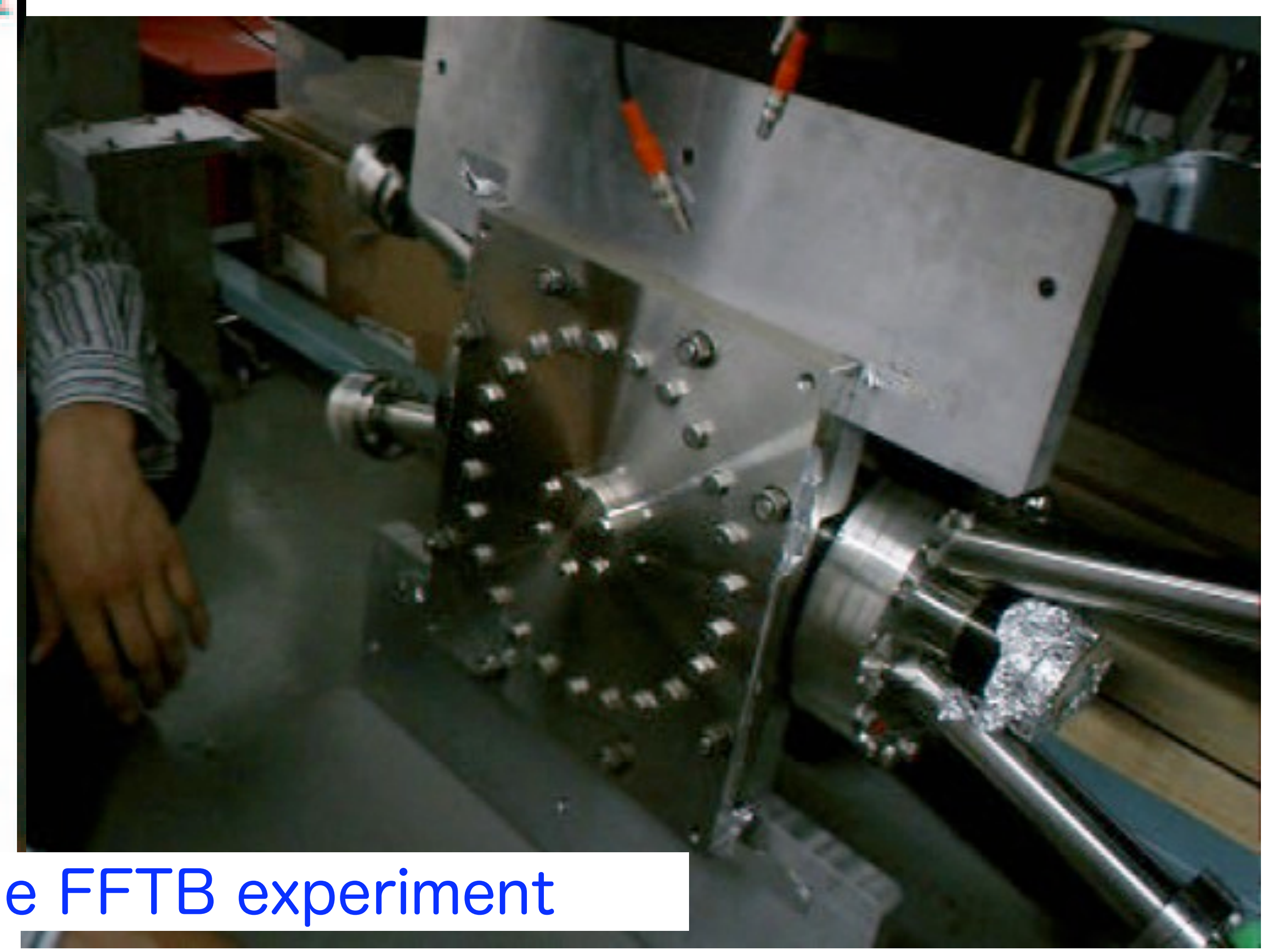




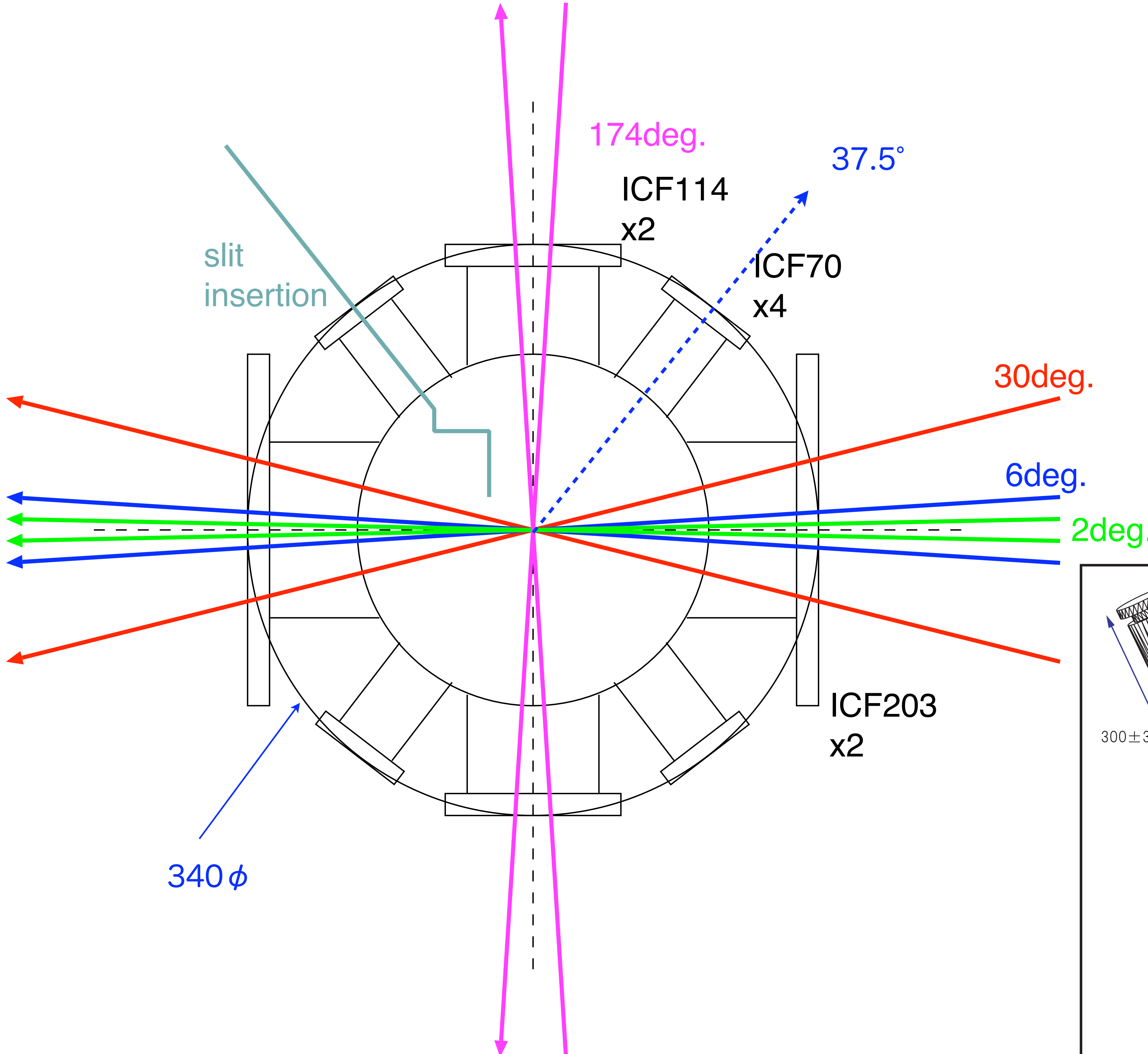
Drawing of the IP chamber at FFTB, which is re-used at ATF2.



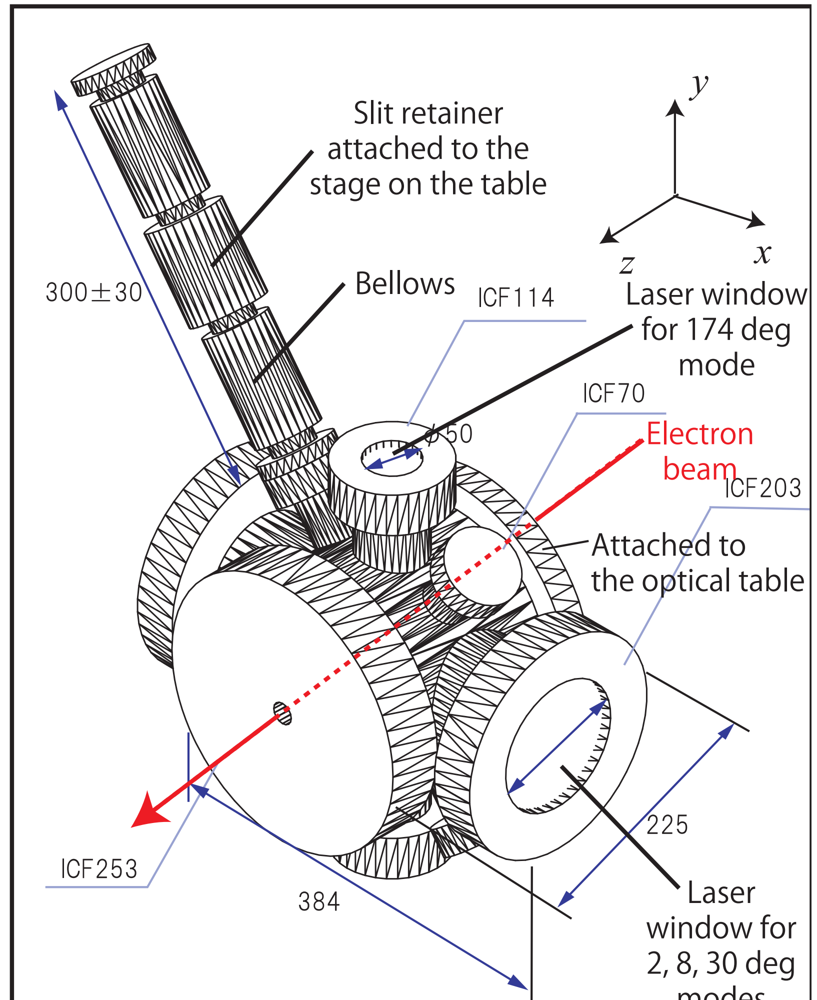




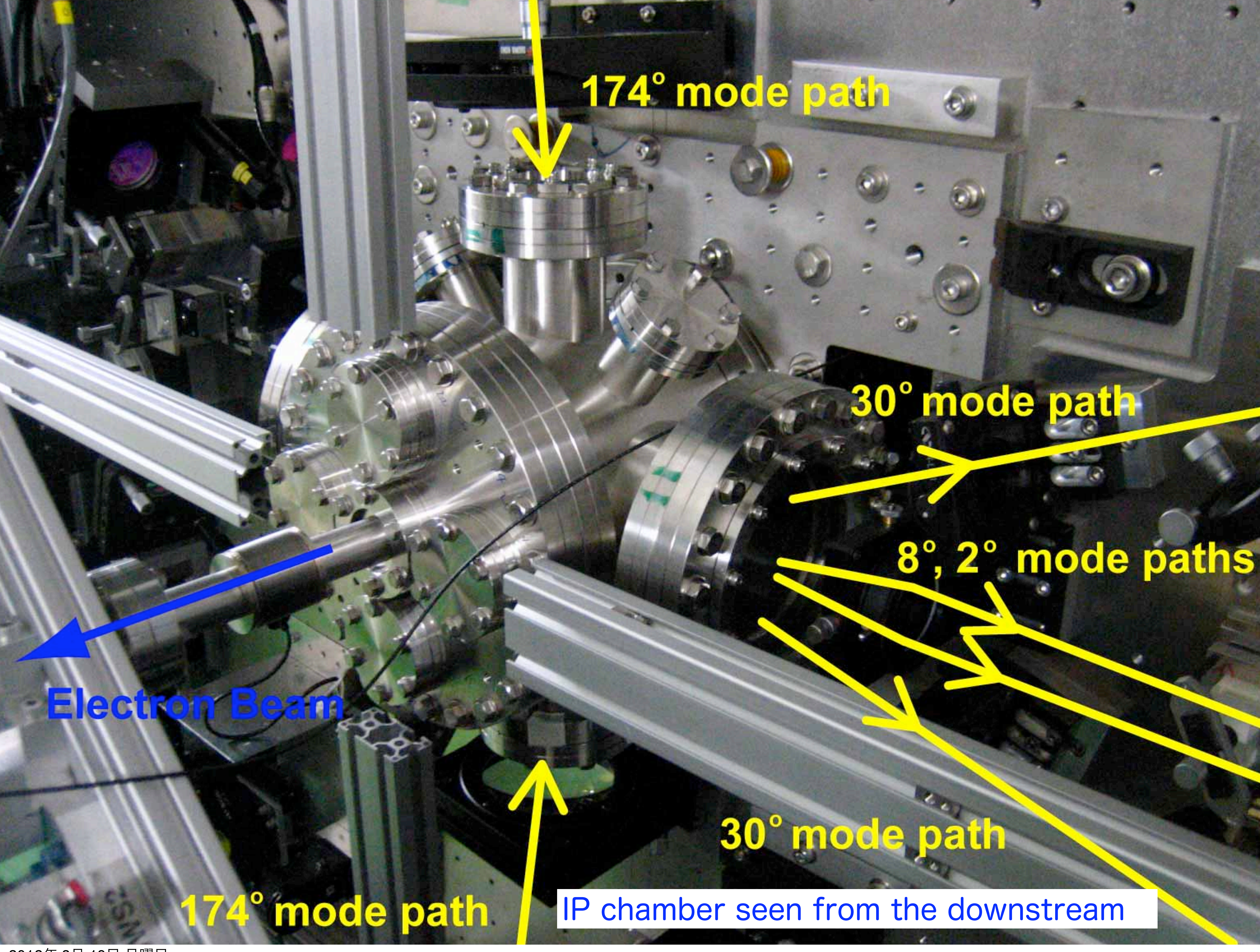
IP chamber at the FFTB experiment



Laser paths at the IP chamber



Vacuum Chamber Drawings


174° mode path
30° mode path
8°, 2° mode paths
Electron Beam
30° mode path
174° mode path
IP chamber seen from the downstream

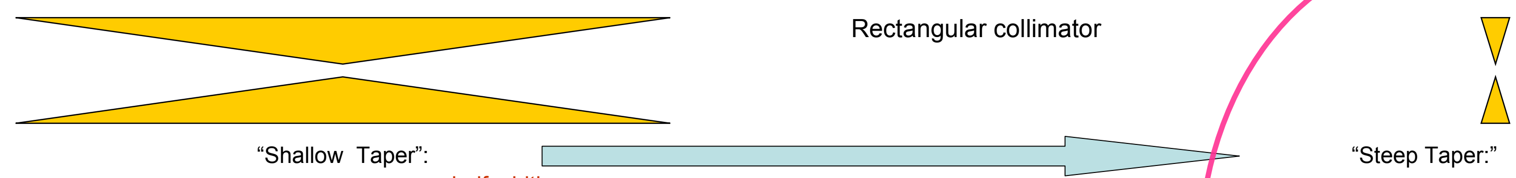
6. Wakefield

Geometric Wakefields: P.Tenenbaum, LCC-0101, August 2002

IPBPM

Depend on gap height, gap width, taper angle, bunch length
θ_T σ_z

Complex theory with 3 regimes



half-width

$$A = \frac{\sqrt{\pi}}{2} \frac{N r_e}{\gamma} \frac{\theta_T h}{\sigma_z r^2}$$

half-gap

$$\sqrt{\frac{\theta_T r}{\sigma_z}} << \frac{r}{h}$$

$$A = 2.7 \frac{N r_e}{\gamma} \sqrt{\frac{\theta_T}{\sigma_z r^3}}$$

$$A = \frac{N r_e}{\gamma} \frac{1}{r^2}$$

$$\sqrt{\frac{\theta_T r}{\sigma_z}} > 0.37$$

y' = 1.25 ur / mm for I= 1 x 10^{10}/bunch, where y' = A Δy

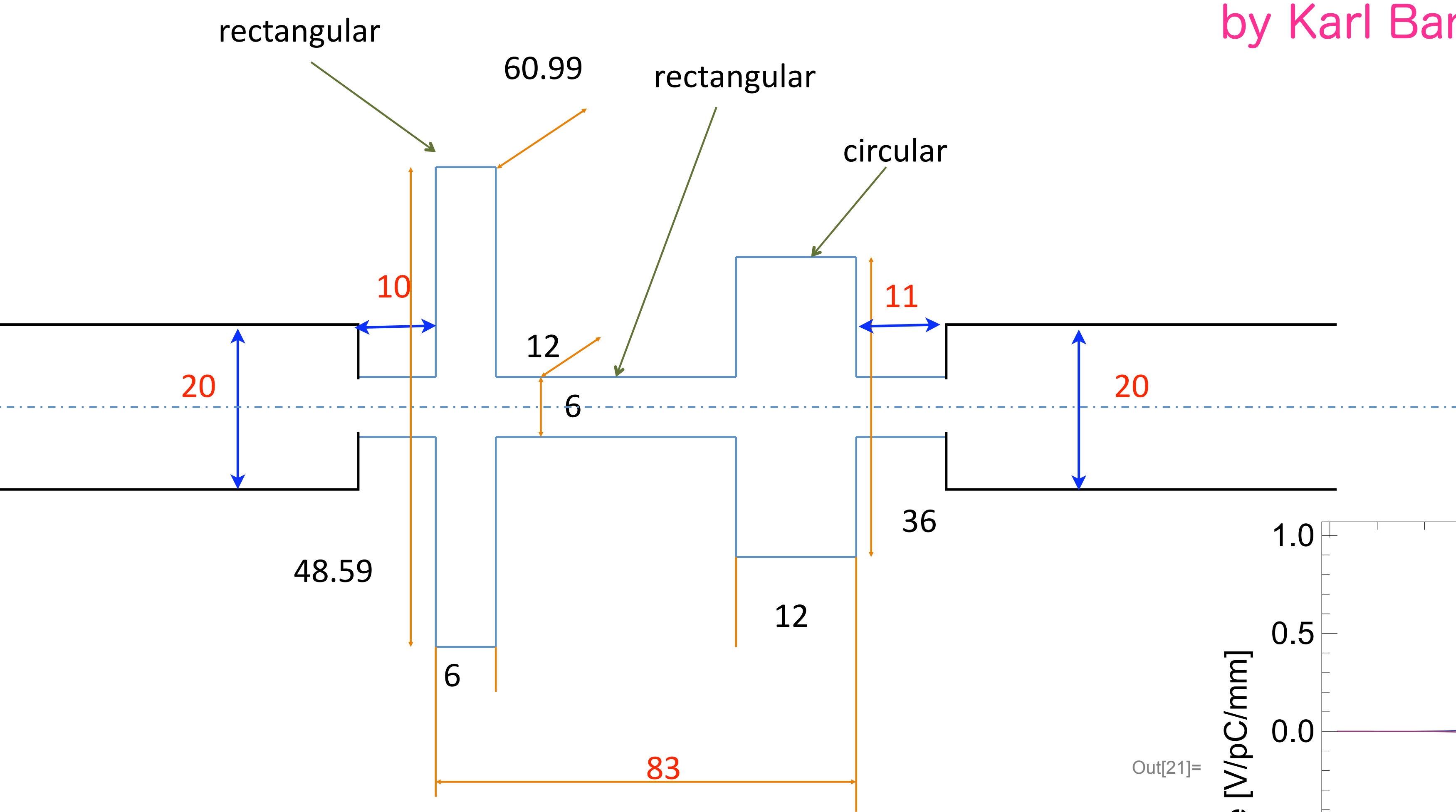
IPBPM	S_{IPBPM} : distance from IP(C), cm	vertical beam size, um	y' nr for 30% y jitter	y' x S_{IPBPM} nm
B	15.8	54.9	20.5	3.3
A	23.9	82.9	31.0	7.4

IPBPM	S_{IPBPM} : distance from IP(B), cm	vertical beam size, um	y' nr for 30% y jitter	y' x S_{IPBPM} nm
A	7.92	27.4	10.2	0.8
C	15.8	54.9	20.5	3.3

y' = 1.13 ur / mm for I= 1 x 10^{10}/bunch by Karl's calculation (Mafia, KNU-IPBPM) in next slide

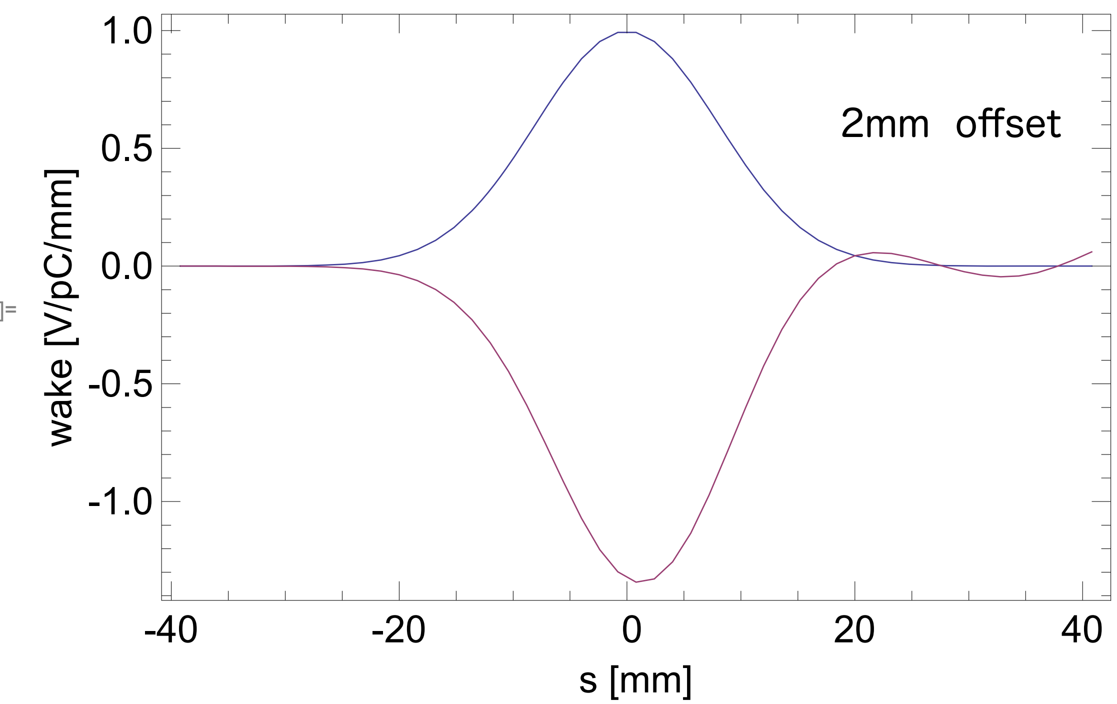
Geometry for wake-field calculations

for KNU-IPBPM with a reference cavity
by Karl Bane (SLAC)



y’ = 1.13 ur / mm for I= 1 x 10^{10}/bunch

Out[21]=



In[22]:= avewake = - Total[λd[[All, 2]] waked[[All, 2]]] / Total[λd[[All, 2]]]   average wakefield

Out[22]= 9.16363×10^{14} wakefield V/C

In[23]:= $8\ 10^{9}\ 1.6\ 10^{-19}$ beam intensity C

Out[23]= 1.28×10^{-9}

In[24]:= $\Delta yp = \frac{eN\ avewake\ xoff}{enrgy}$ /. {eN → $8\ 10^{9}\ 1.6\ 10^{-19}$, xoff → $2.\ 10^{-3}$, enrgy → $1.3\ 10^{9}$}

beam intensity   2mm offset,   1.3GeV energy

Out[24]= 1.80453×10^{-6} deflection angle   radian

Summary

1. Resolution : preliminary results based on the SVD analysis
   6.7nm at 0.6×10^{10}/bunch -> 4.02/ 2.01 at 1/2 $\times 10^{10}$/bunch
   Multi-bunch capability should be estimated

2. Calibration needs movers in both direction
   Orbit monitor at IP w/o movers

3. Layout for the IP feedback
   Triplet : upstream 2 IPBPMs (A,B) and downstream an IPBPM(C)
   New IP is the center of the IPBPM-C.

4. Waist shift to a new IP is OK by SAD calculation

5. IP chamber geometry
   Detailed evaluation of the geometry is needed with present optical components and necessary modifications if needed.

6. Wakefield
   IPBPM would produce vertical jitter of 7.4 (15) and 3.3 (6.6)nm at the beam intensity of 1 x (2) 10^{10} in cases of IP(C) and IP(B), respectively, assuming 30% jitter of vertical position at the IPBPMs. So, the upstream feedback may be needed especially for 2×10^{10}/bunch. Dedicated beam test at the upstream is needed to verify the calculation.