Overview of IPBPM objectives

by T.Tauchi

ATF2 Meeting, LAL, 19 -20 March 2012

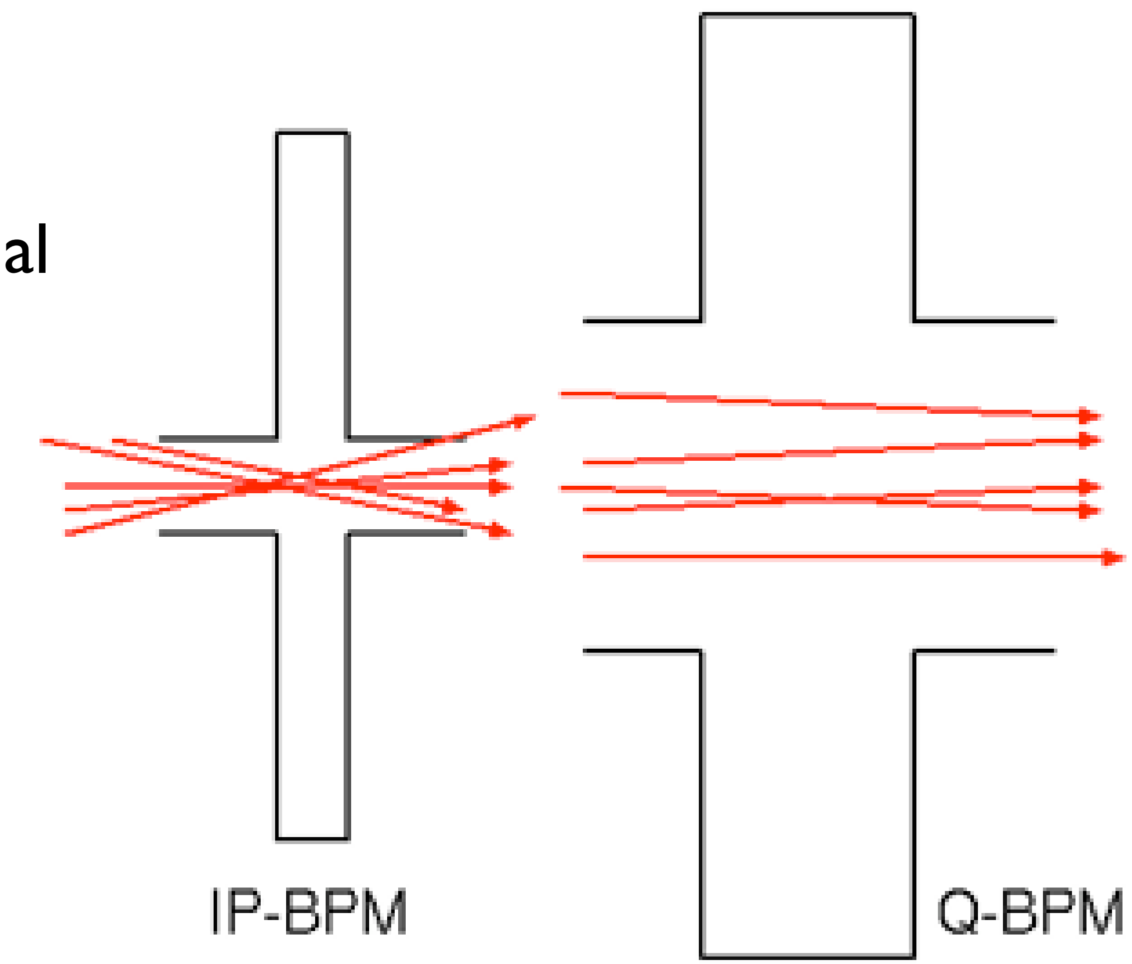
and 11-12 February 2013

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

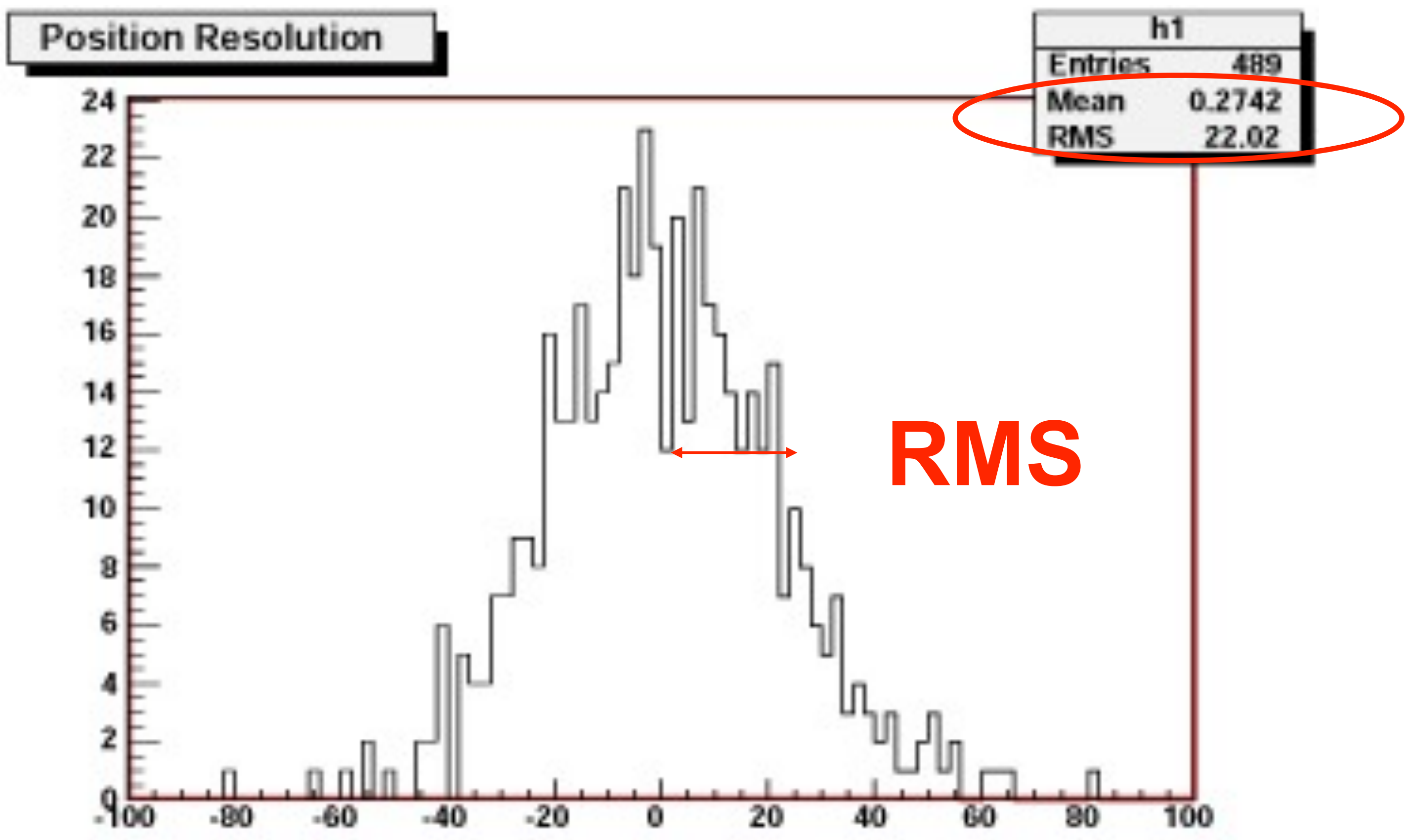


position/angle =f L^2

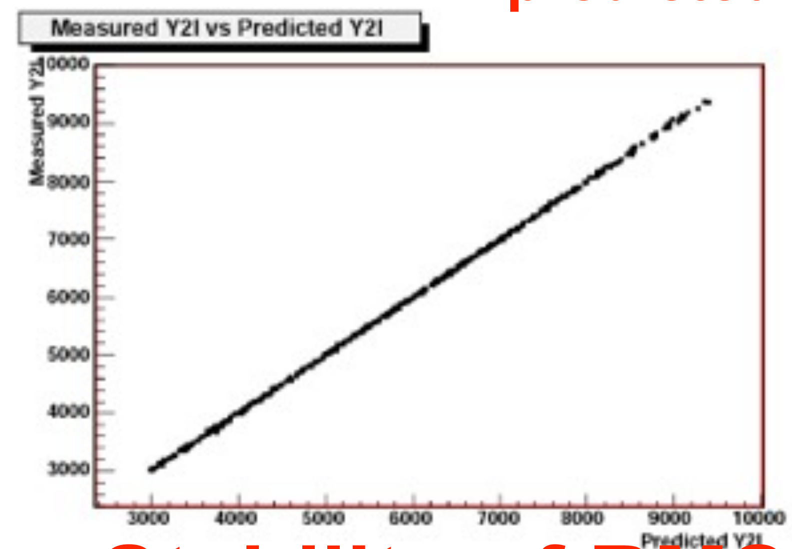
4 : 1

3, Resolution Run

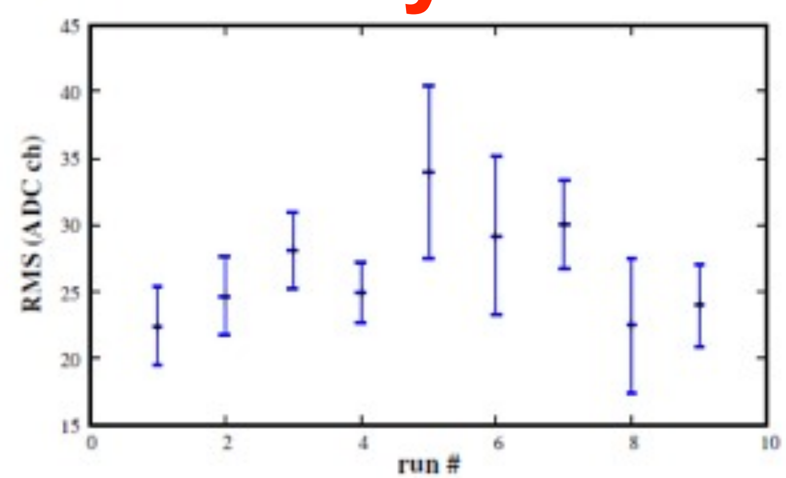
Residual of (Y2I – Y2I$_{predicted}$)



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

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

Result of 2008 and rough estimation of the online resolution

$$Y2I_{Predicted} = \frac{z_{23}}{z_{12}+z_{23}} Y1I + \frac{z_{12}}{z_{12}+z_{23}} Y3I$$
$$= 0.317 * Y1I + 0.683 * Y3I,$$

$$\text{Residual} = Y2I_{measured} - Y2I_{predicted}.$$

- To prove the intrinsic resolution, we used correlations of all available information of the three BPMs.
- RMS of Residual improves as number of parameters used in the analysis.
    - ideal model: 28nm
    - with x information: 15nm
    - all information: 8.7nm
- This result is almost same as Shintake's 25nm result at FFTB. (They used only y information.)

Parameter	A	B	C	D	E	F
Y1I	0.275	0.279	0.294	0.298	0.274	0.282
Y1Q	0.039	-	-0.016	-	0.035	0.027
Y3I	0.726	0.748	0.732	0.731	0.724	0.723
Y3Q	-0.009	-	0.022	-	0.001	-
YREF	0.012	-0.055	-0.053	-0.055	-0.046	-0.070
X1I	-0.063	-	-	-0.134	-0.324	0.0367
X1Q	-0.020	-	-	-	-	-0.021
X3I	0.089	-	-	0.170	0.365	-
X3Q	-0.012	-	-	-	-	-
XREF	-0.076	-	-	-	-	-
RMS (Count)	22.02	70.11	69.08	39.15	25.63	24.32

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

Result of 2008 and rough estimation of the online resolution

- Summary and Discussion
  - Intrinsic resolution 8.7nm has been measured.
  - Y information of single cavity can predict 28nm beam position.
  - With X information this can be improved
    - Roll misalignment of 1mrad between cavities can produce ~10nm residual if x beam jitter is 10um.
    - At IP, x jitter must be smaller. This situation might be improved.
  - Phase error (Q) contributed ~10nm .
    - Beam orbit angle signal can contaminate.
      - At IP angle jitter will be much bigger.
      - At FFTB, 25nm resolution has never achieved at the IP. They suspect beam angular divergence (jitter?).
  - Situation at strongly focused point. Bunch length stabilization becomes important.
    - Bunch tilt can produce position signal
    - Bunch length or tilt change look like a beam position jitter.

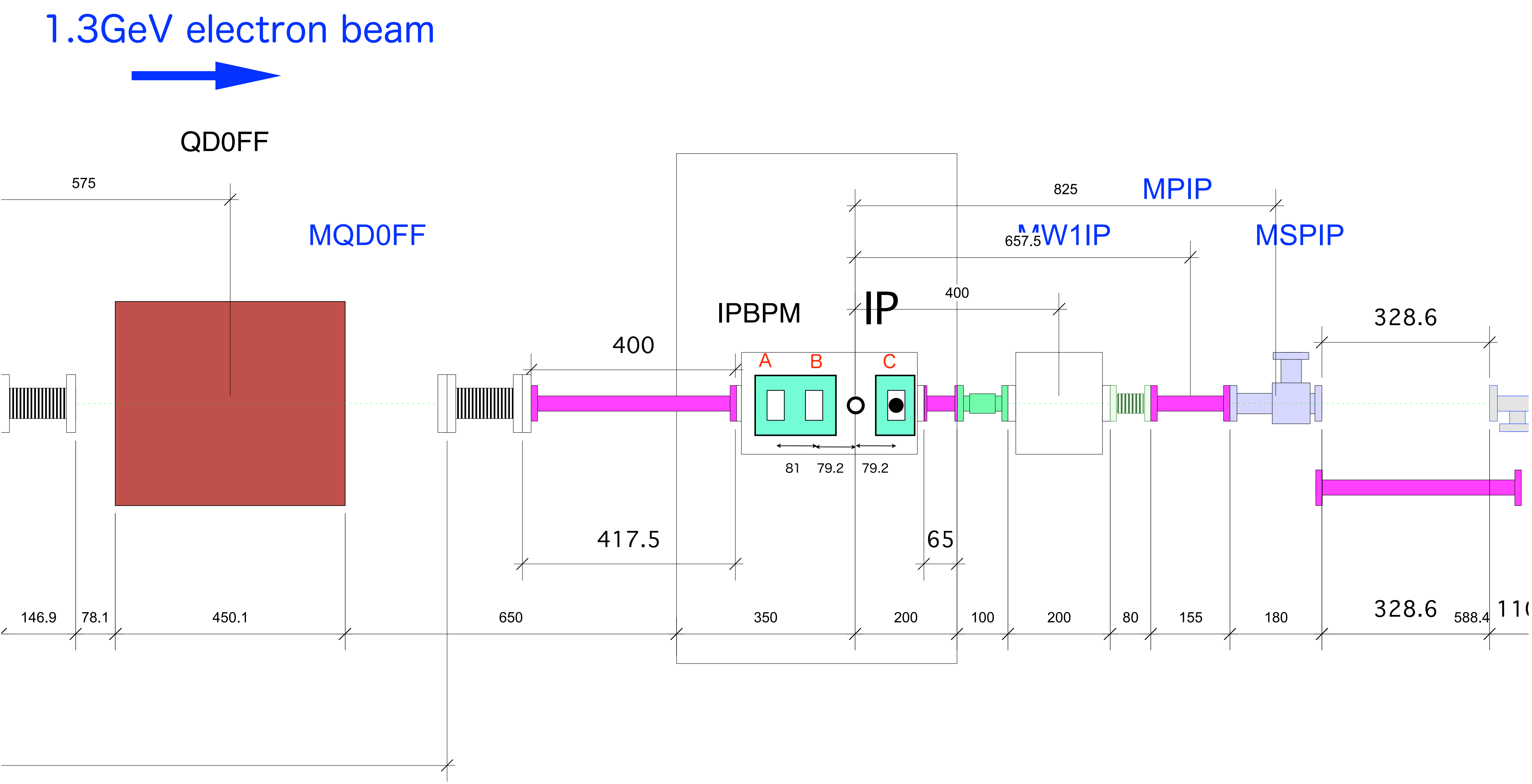
from FFTB paper

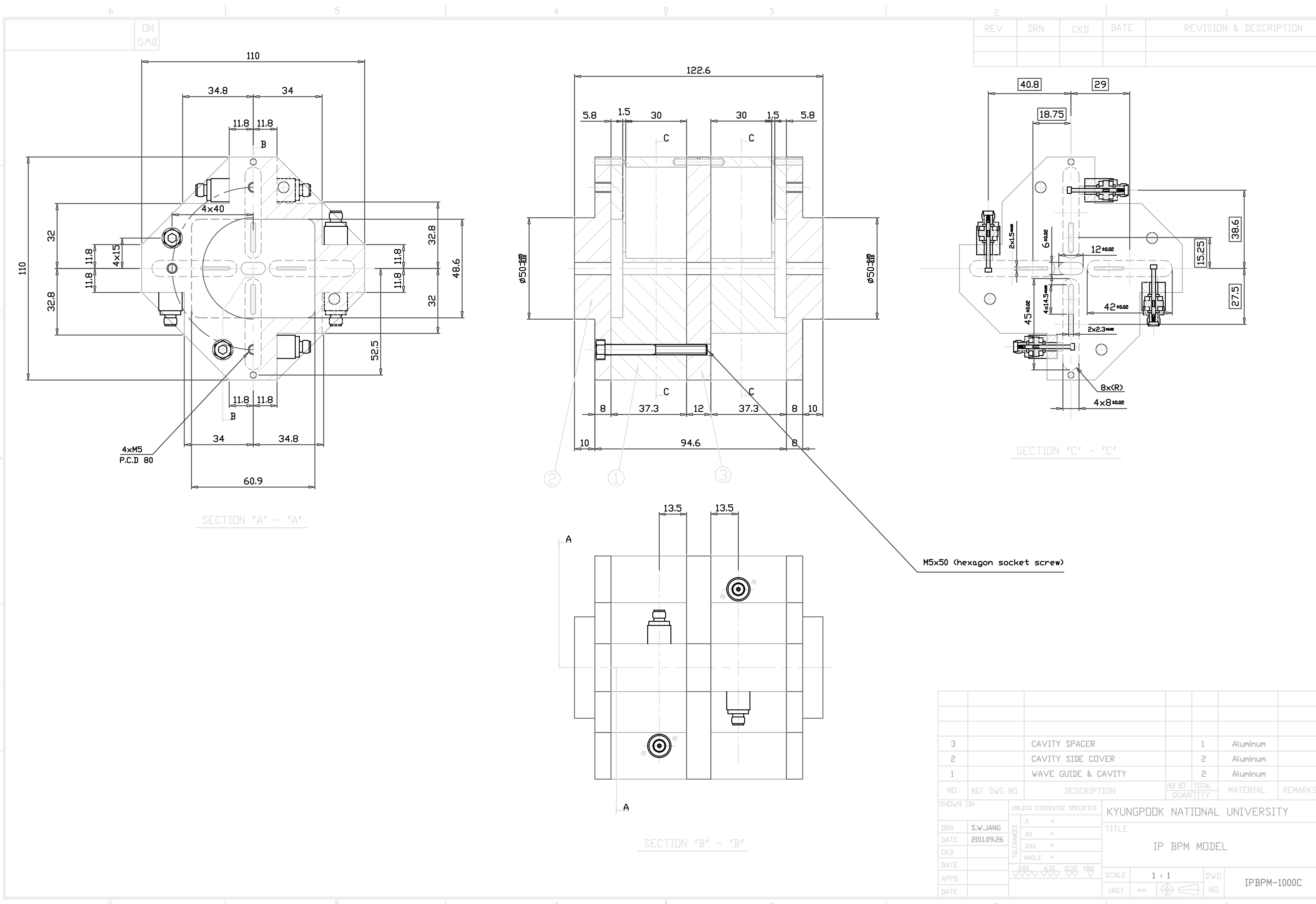
5 DISCUSSION AND CONCLUSION

Although the resolution of approximately 25 nm was measured for the RF-BPMs from the triplet set, the measured resolution of the RF-BPM at the FFP was around 80 nm. This is attributed to the beam's large angular divergence (460 μrad) and is not completely understood. Even though the FFP BPM was not able to measure beam motion below 80 nm, it was very efficient in minimizing beam aberrations before using the KEK BSM.

3. Layout

IPBPM Triplet with movers in the IP chamber





2013年 2月 16日 土曜日

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

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

by SAD fitting

42nm can be achieved just by QD0 and QF1.

6. Wakefield

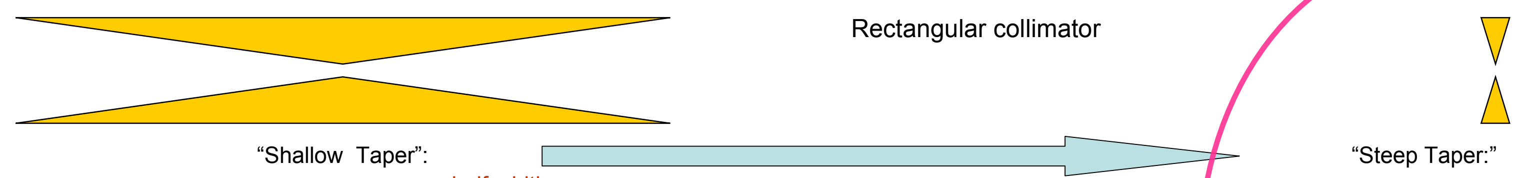
Geometric Wakefields: P.Tenenbaum, LCC-0101, August 2002

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

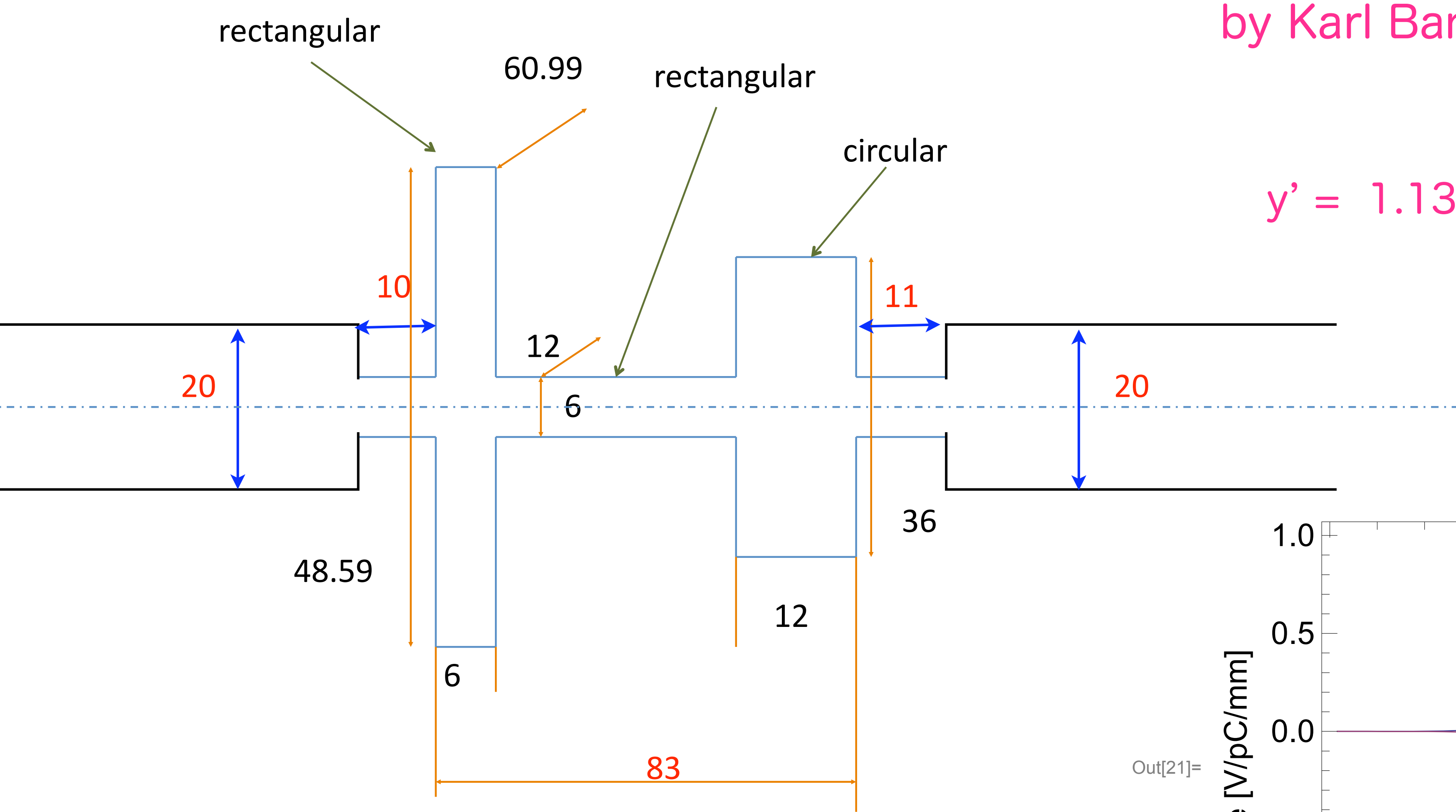
IPBPM	S_{IPBPM} : distance from IP(B), cm	vertical beam size, um	y' nr for 30% y jitter	y' x S_{IPBPM} nm
A	7.92	27.4	10.2	0.8
C	15.8	54.9	20.5	3.3

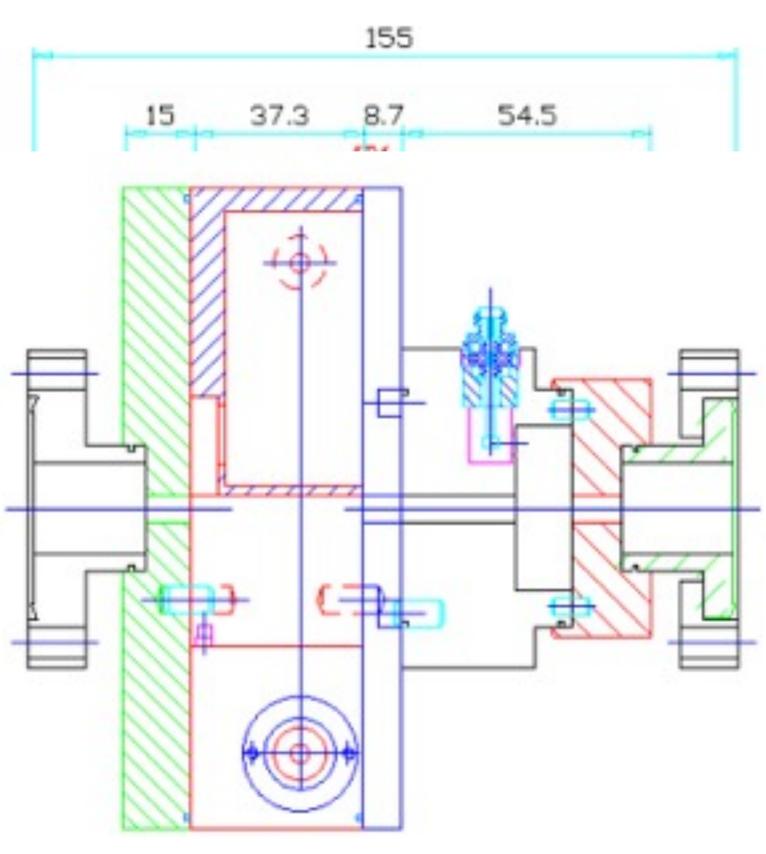
y' = 1.13 ur / mm for I= 1 x 10^{10}/bunch by Karl's calculation (Mafia, KNU-IPBPM) in next slide

Geometry for wake-field calculations

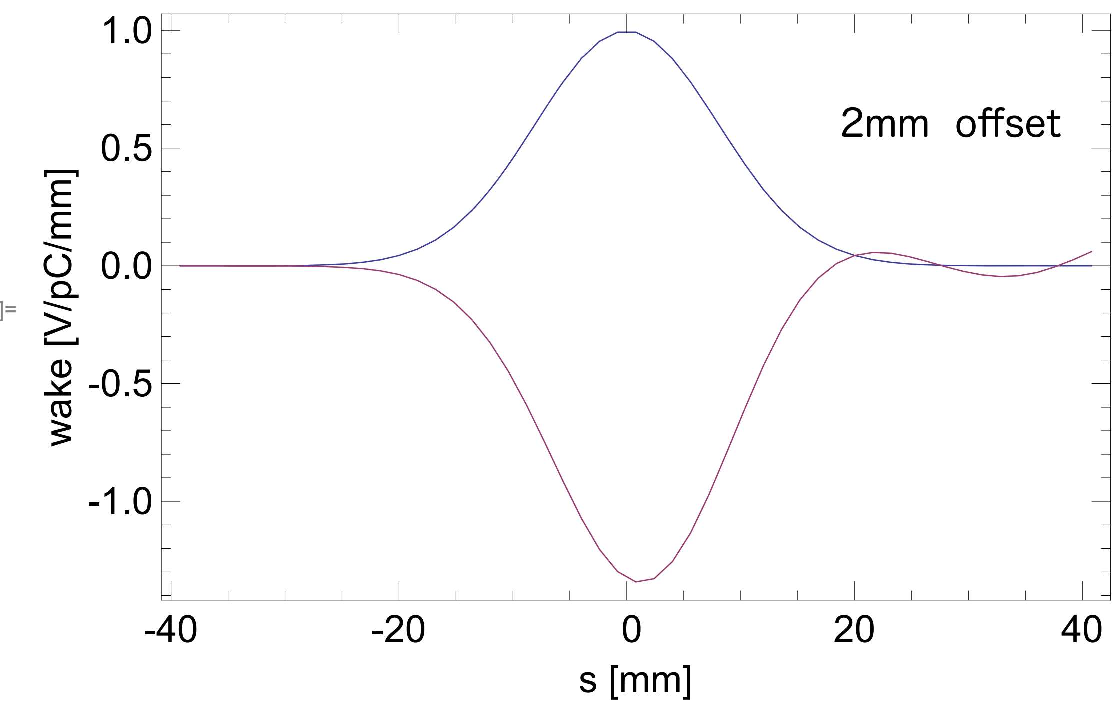
for KNU-IPBPM with a reference cavity
by Karl Bane (SLAC)

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





Out[21]=



In[22]:= $\text{avewake} = -\frac{\text{Total}[\lambda d[[\text{All}, 2]]\ \text{waked}[[\text{All}, 2]]]}{\text{Total}[\lambda d[[\text{All}, 2]]]}$ 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]:= $\Delta yp = \frac{\text{eN avewake xoff}}{\text{enrgy}}$ /. {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

2013年 2月 16日 土曜日

Summary

1. Resolution : preliminary results based on the SVD analysis
   6.7nm at $0.6x10^{10}$/bunch -> 4.02/ 2.01 at 1/2 $x10^{10}$/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 or IPBPM-B.

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 0.8 (1.6)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 $2x10^{10}$/bunch. Dedicated beam test at the upstream is needed to verify the calculation. Taper structure is needed too.