Recent work about crab cavity

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Thanks to Rama Calaga

AB/ABP Group

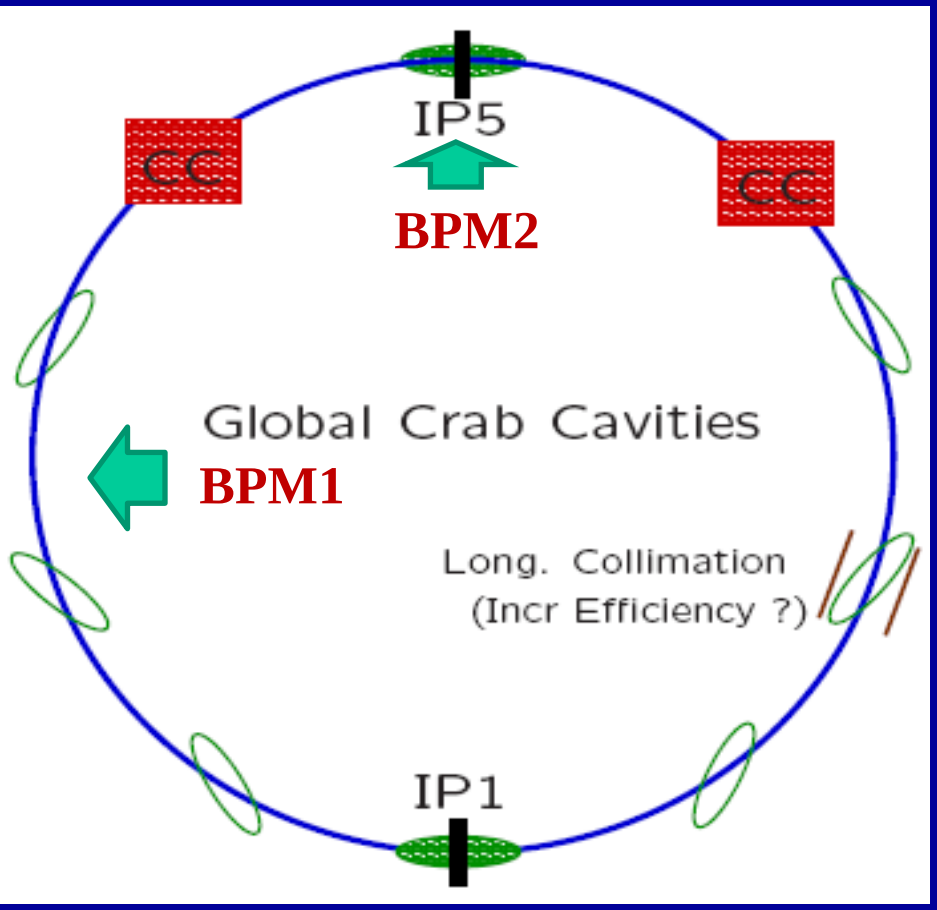
European Organization for Nuclear Research (CERN)

23 January 2008

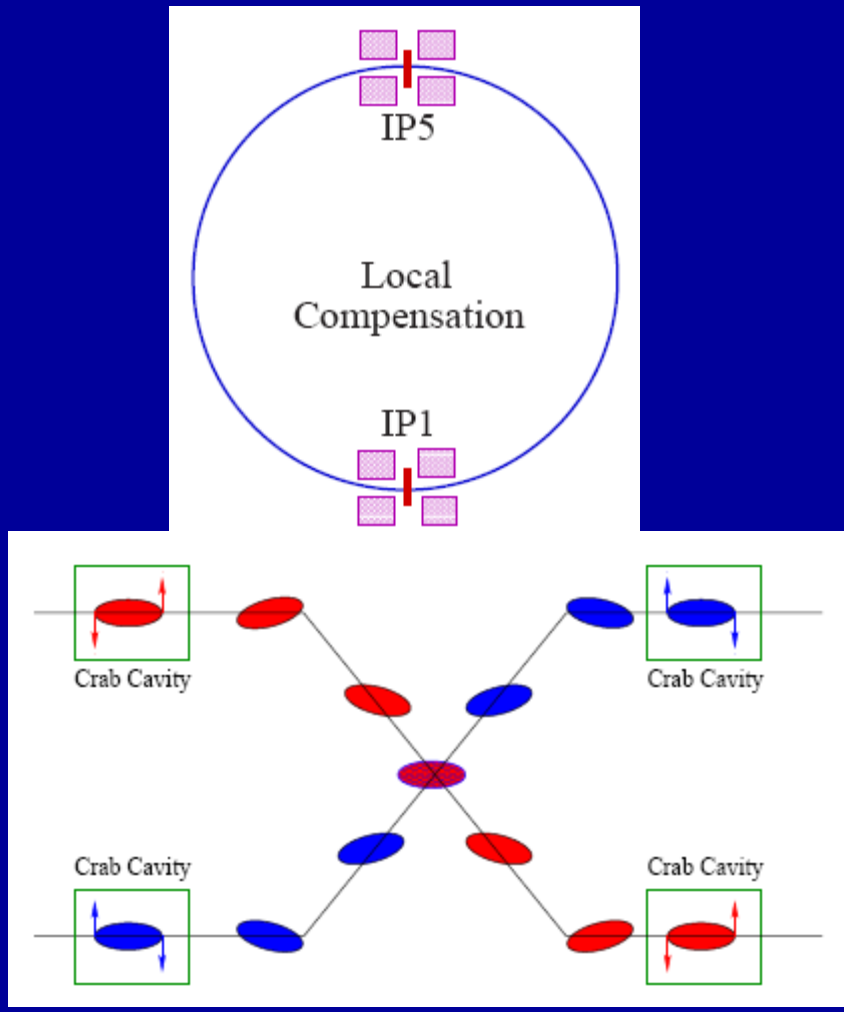
Outline

- Check of the SixTrack code: crab cavity part.
- One Global crab cavity, located near IP5, to get required crossing angle at IP5.
  - –**Horizontal crossing**.
  - –Two optics, lowbetamax and nominal LHC.
- Local crab cavity, located at both sides of IP5, to get required crossing angle at IP5.
  - –**Horizontal crossing**.
  - –Two optics, lowbetamax and nominal LHC.
- Comparison of dynamic aperture, also some analysis on peak to peak orbit and side bands.

Global Crab Cavity and Local Crab Cavity, pics from Rama's talk



Global



Local

Check the CC part in SixTrack code with formulae

Hamitonian for the cavity:

From Ulrich

$$H_{crab} = \frac{q\hat{V}}{p_s}\sin(\Phi_s + \omega\frac{x_3}{c}) \cdot x_1$$

The equation of motion in the code:

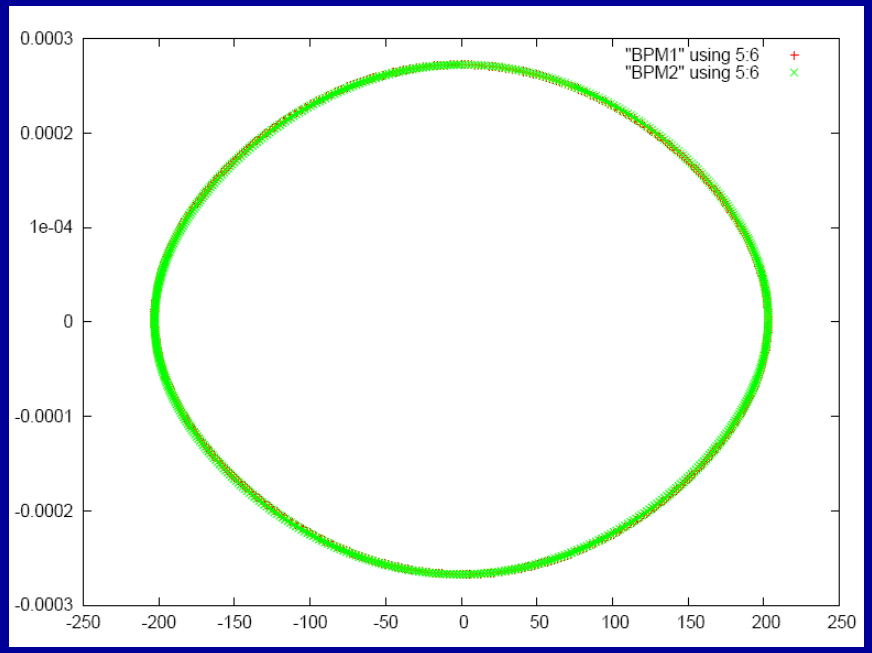
$$\dot{p_1} = -\frac{\partial H_{crab}}{\partial x_1} = -\frac{q\hat{V}}{p_s}\sin(\Phi_s + \omega\frac{x_3}{c})$$

$$\dot{p_3} = -\frac{\partial H_{crab}}{\partial x_3} = -\frac{q\hat{V}}{p_s}\cos(\Phi_s + \omega\frac{x_3}{c})(\frac{\omega}{c}) \cdot x_1$$

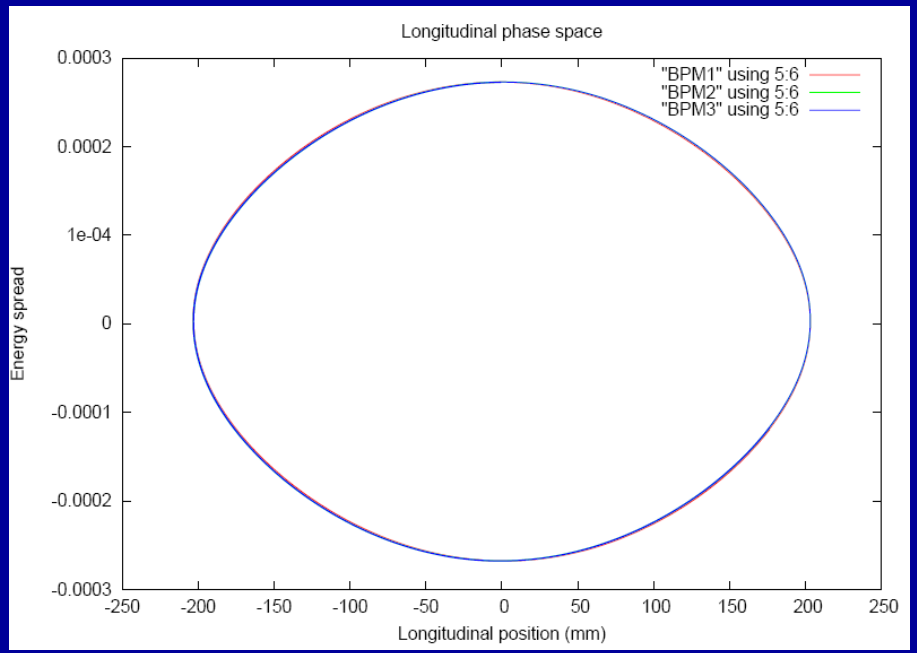
Use the horizontal and longitudinal position of particle, the CC voltage and frequency to calculate the energy kick from CC to the single particle.

Check the CC part in SixTrack code with formulae

	Energy kick from formulae	Energy kick from SixTrack (E)	Energy kick from SixTrack (delta p)
First turn	**-1.23737 MeV**	**-1.238 MeV**	**-1.2385 MeV**
Second turn	**-1.42168 MeV**	**-1.422 MeV**	**-1.42179 MeV**



No crab cavity



With crab cavity

Outline

- Check of the SixTrack code: crab cavity part.
- **One Global crab cavity, located near IP5, to get required crossing angle at IP5.**
  - **–Horizontal crossing.**
  - **–Two optics, lowbetamax and nominal LHC.**
- Local crab cavity, located at both sides of IP5, to get required crossing angle at IP5.
  - –Horizontal crossing.
  - –Two optics, lowbetamax and nominal LHC.
- Comparison of dynamic aperture.
- Maybe side bands?

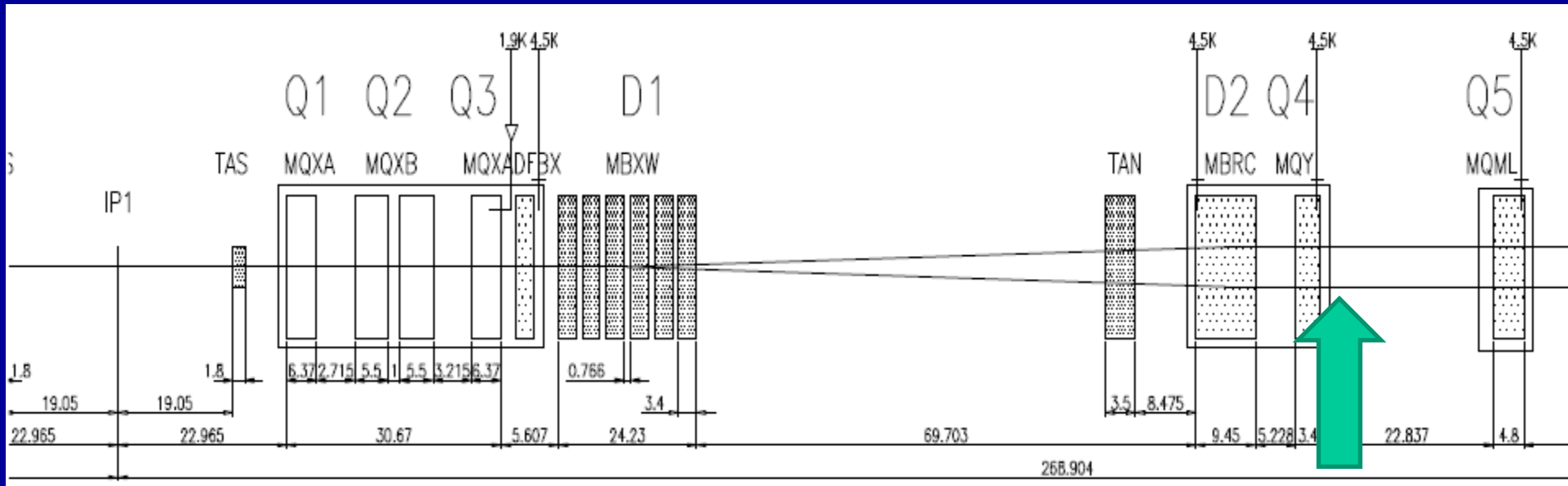
Lowbetamax optics, 381 urad Horizontal crossing at IP5

	S(m)	Beta_x(m)	Beta_y(m)	Phase_x	Phase_y
IP5	6664.568	0.253	0.2467	15.6213	14.367
Crab Cav	6835.7	1023.9	2685.6	15.86	14.5988

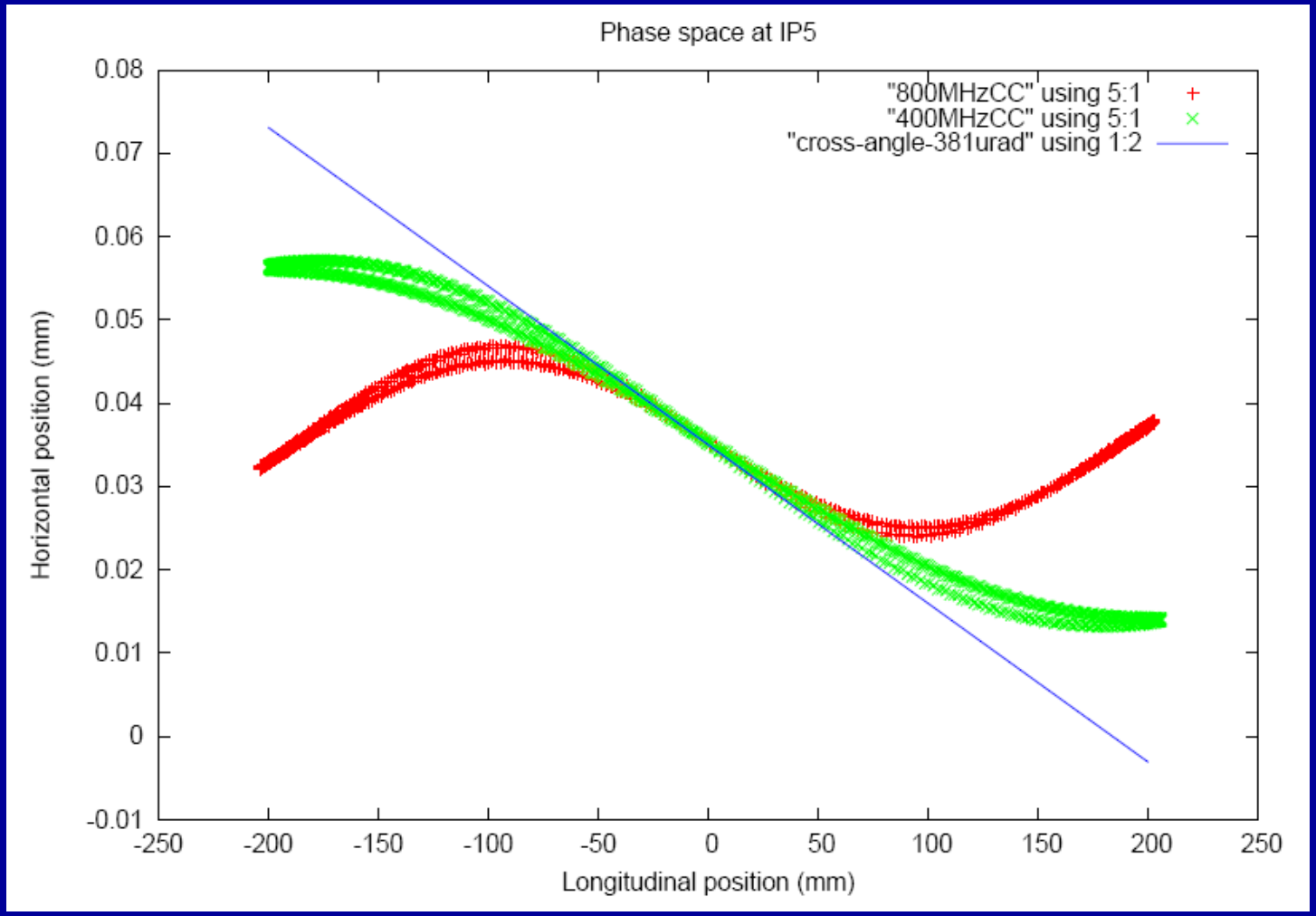
Horizontal phase advance from CC to IP5 is **0.239**, S is **171.1 m**.

$$V = \frac{c \cdot E \cdot tan(\theta/2)}{\omega \cdot \sqrt{\beta\beta}} \cdot \left| \frac{2sin(\pi Q)}{cos(\Delta\emptyset - \pi Q)} \right|$$

For **800 MHz CC**, the voltage is calculated to be **9.468 MV**.



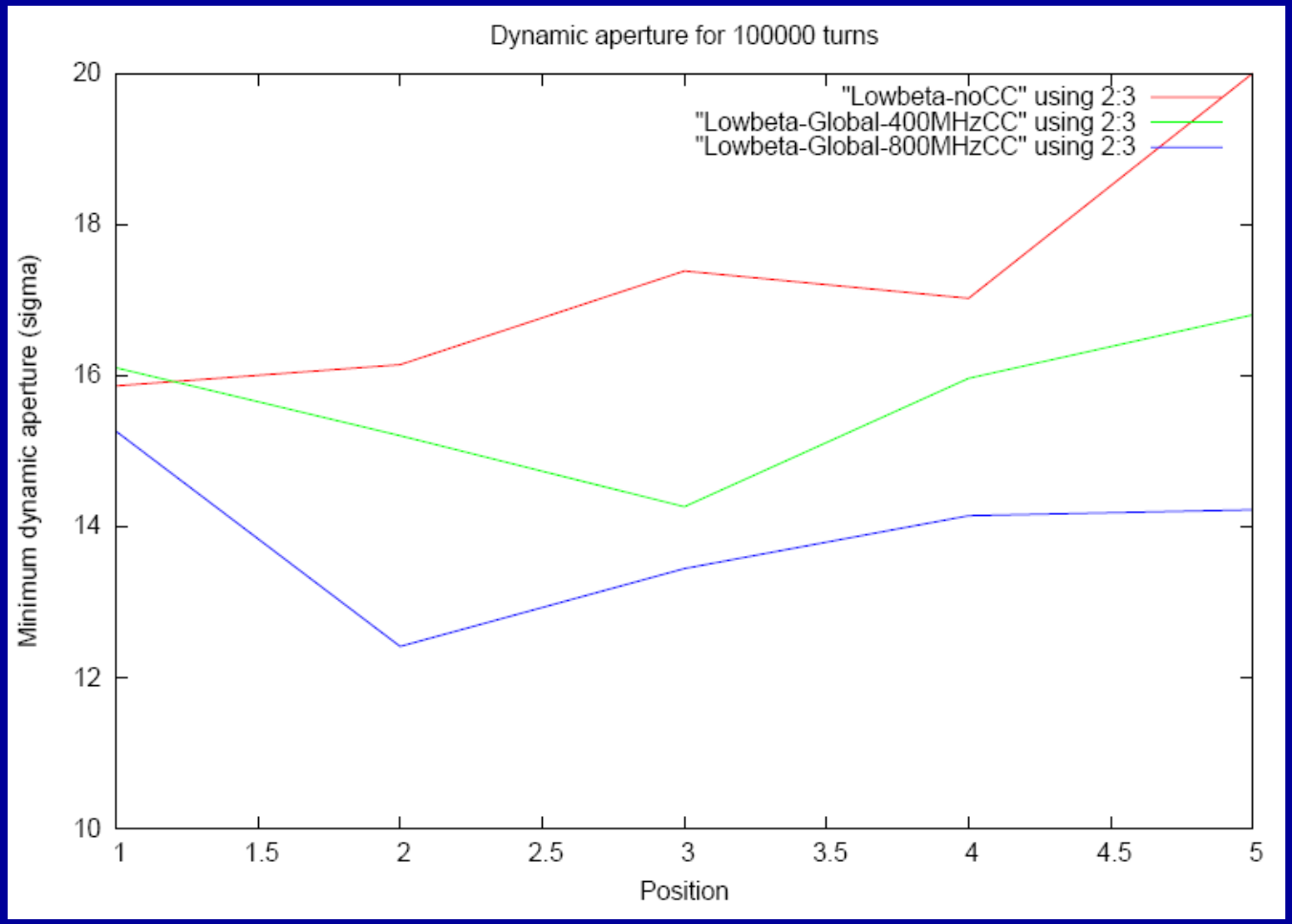
The horizontal crossing angle at IP5



800 MHz CC: 9.468 MV; 400 MHz CC: 18.936 MV.

One particle with 0 initial transverse offset, and 0.00027 longitudinal offset.

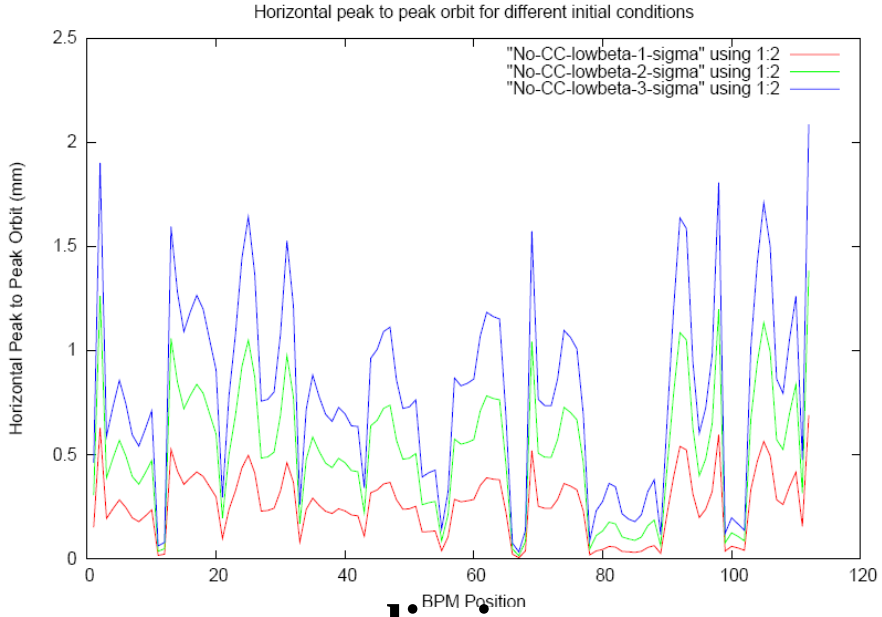
DA of lowbetamax optics, by SixTrack



Using 2 seeds, plot the minimum dynamic aperture for 100,000 turns

The horizontal peak to peak orbit under different initial conditions, lowbeta optics

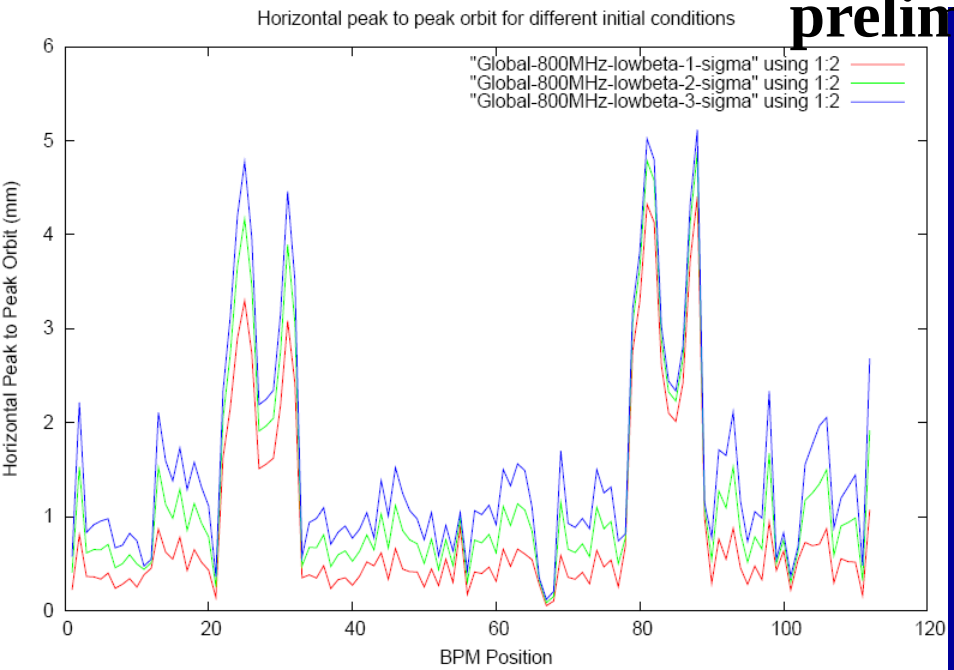
No CC

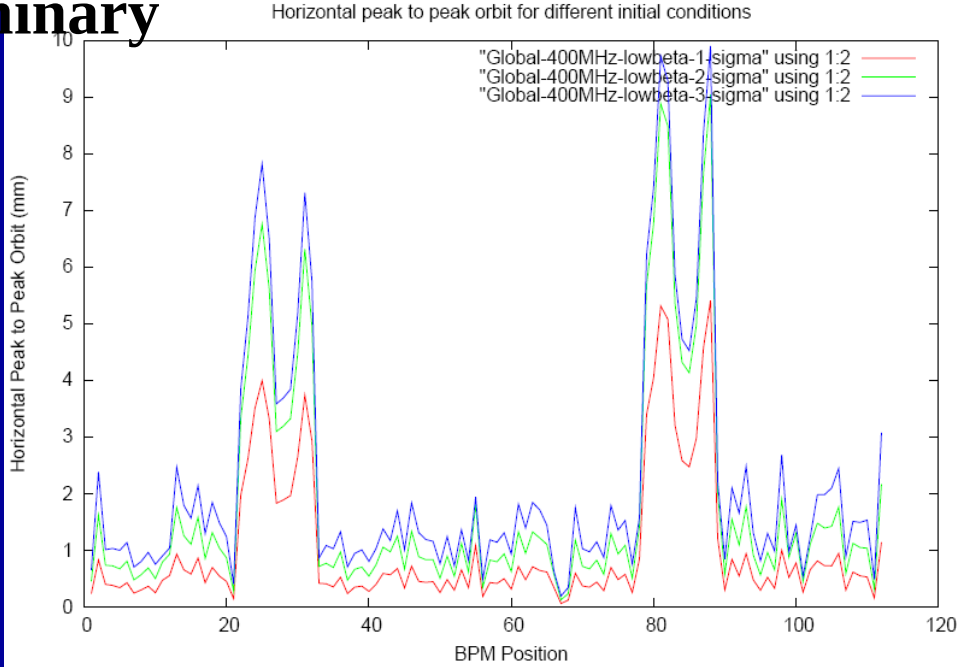


800 MHz CC

400 MHz CC

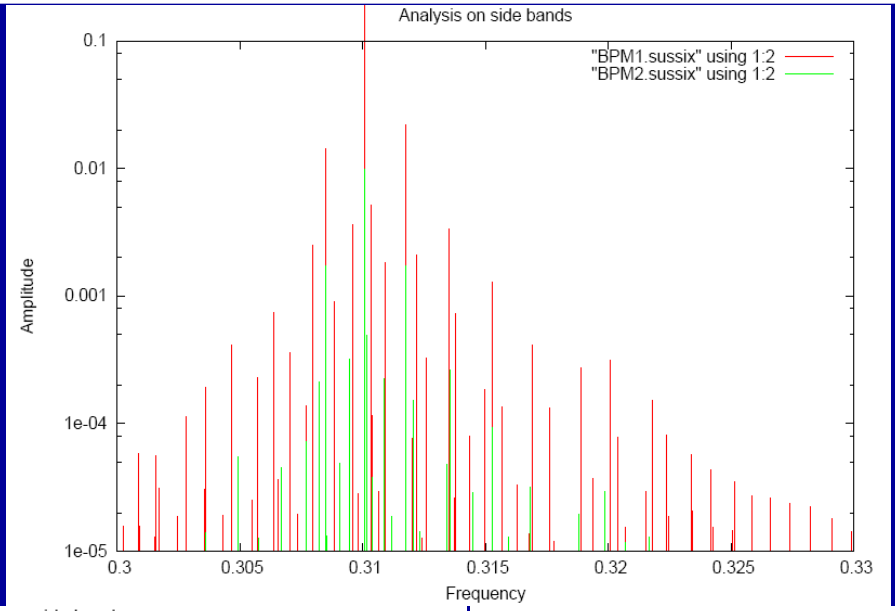
preliminary



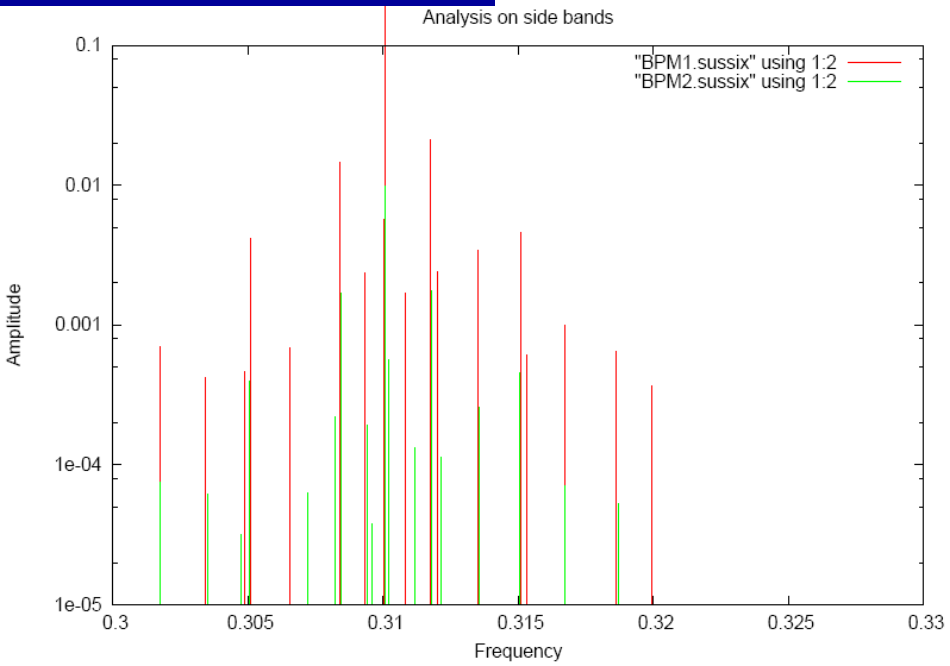


Longitudinal side bands by SUSSIX, lowbetamax optics

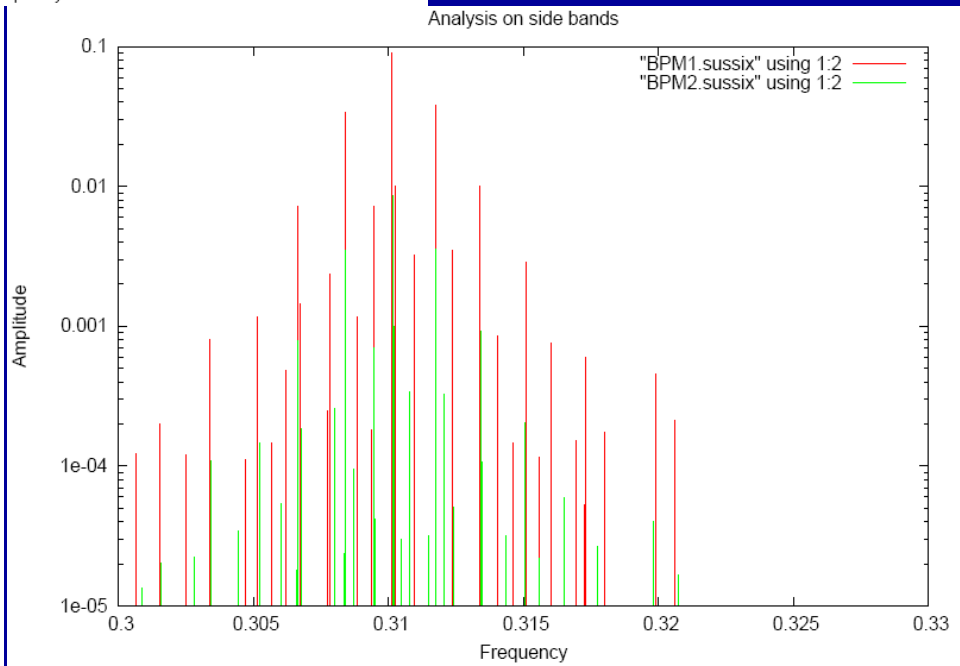
No CC



800 MHz CC



400 MHz CC



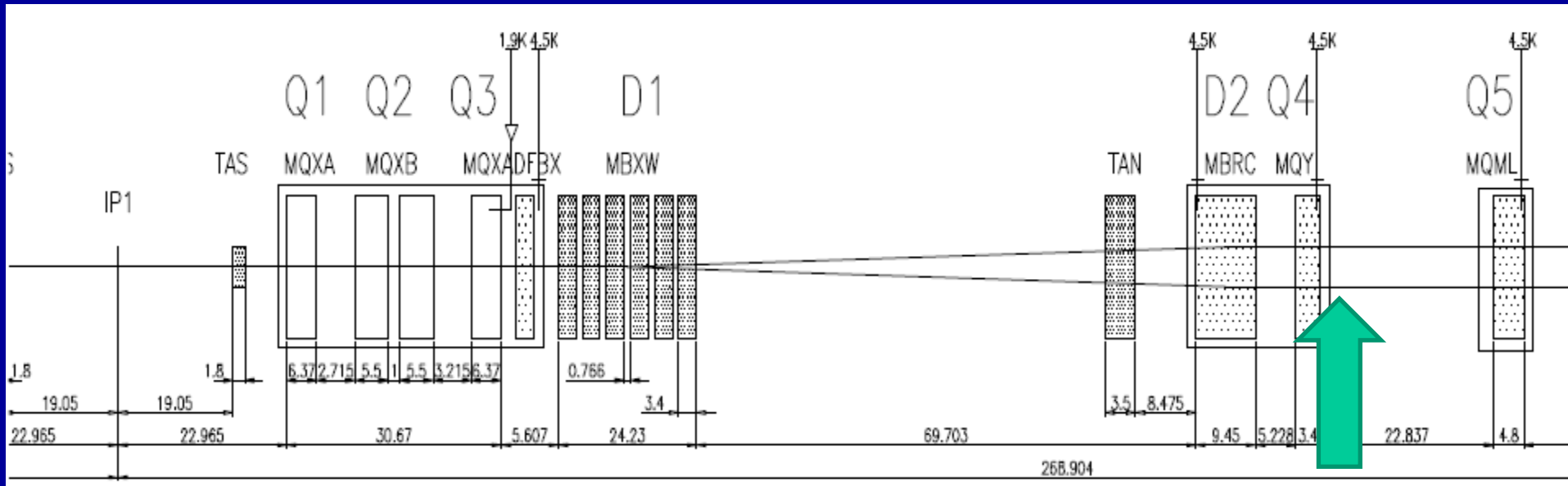
Nominal LHC optics , 285 urad Horizontal crossing at IP5

	S(m)	Beta_x(m)	Beta_y(m)	Tune_x	Tune_y
IP5	6664.568	0.544	0.539	15.4716	14.5941
Crab Cav	6835.2	257.87	1546	15.7496	14.8553

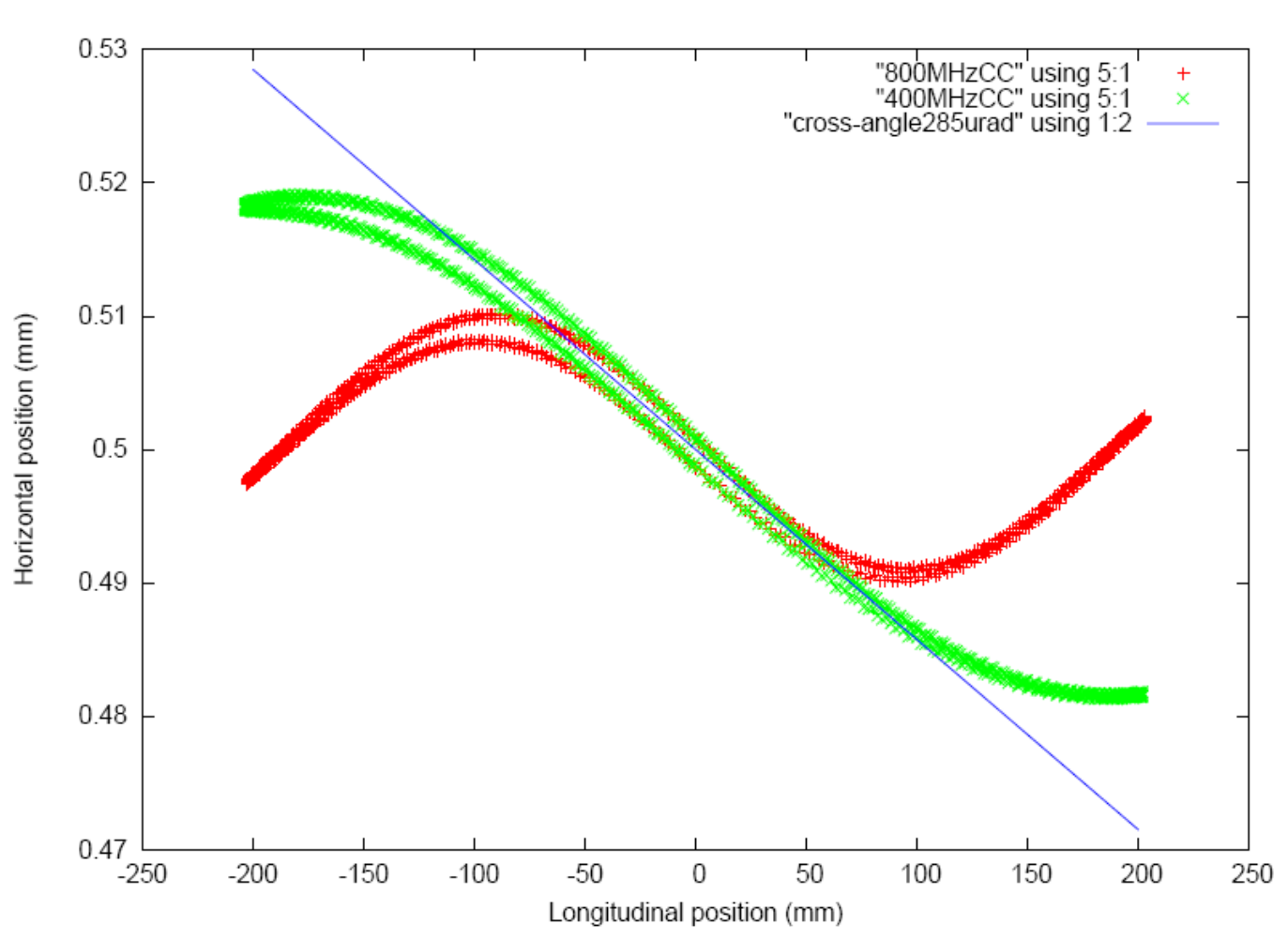
Horizontal phase advance from CC to IP5 is **0.278**, S is **170.6 m**.

$$V = \frac{c \cdot E \cdot tan(\theta/2)}{\omega \cdot \sqrt{\beta\beta}} \cdot \left| \frac{2sin(\pi Q)}{cos(\Delta\emptyset - \pi Q)} \right|$$

For **800 MHz CC**, the voltage is calculated to be **11.9087 MV**.



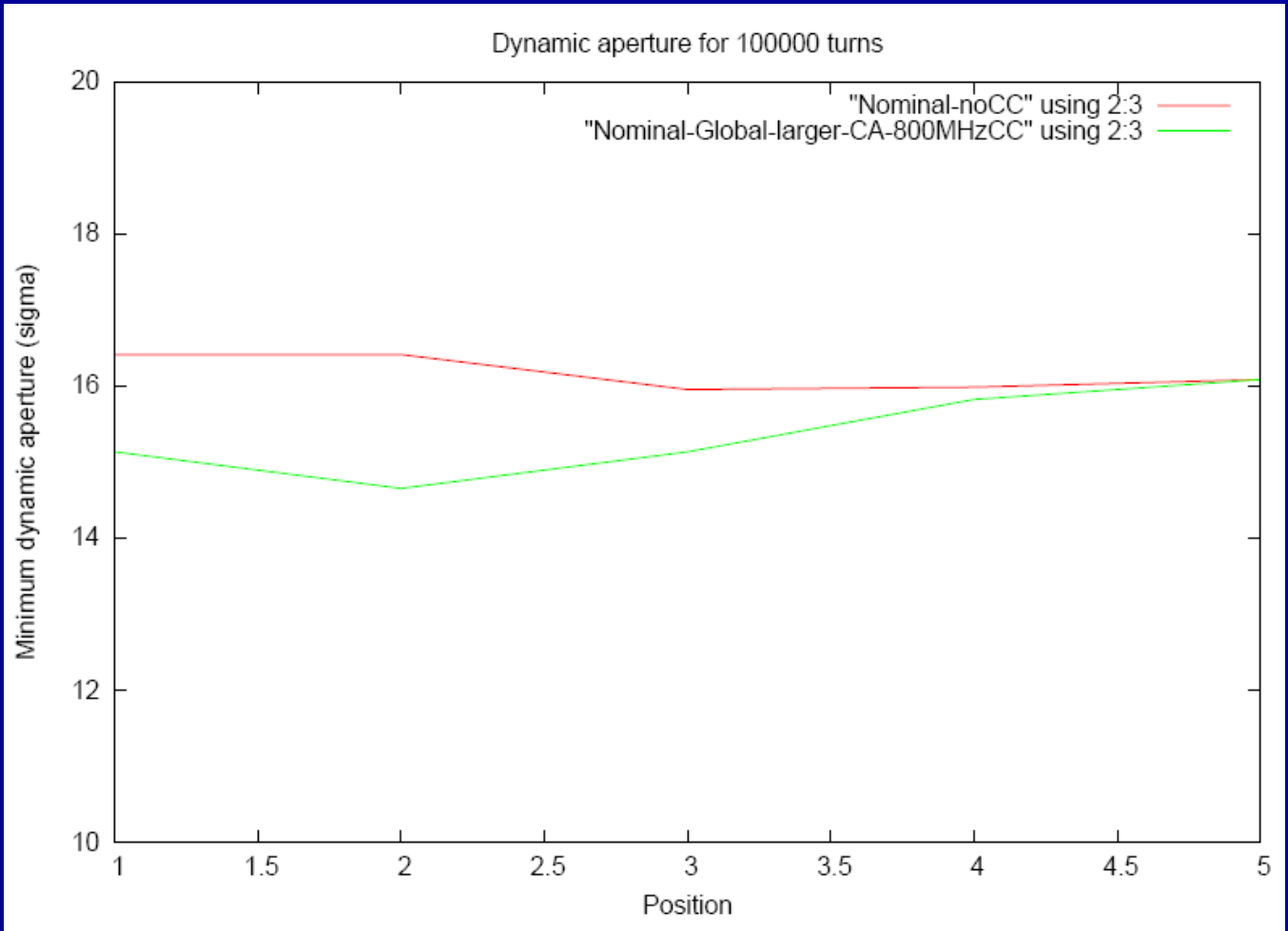
The horizontal crossing angle at IP5



800 MHz CC: 11.9087 MV; 400 MHz CC: 23.8174 MV.

One particle with 0 initial transverse offset, and 0.00027 longitudinal offset.

DA of Nominal LHC optics , by SixTrack



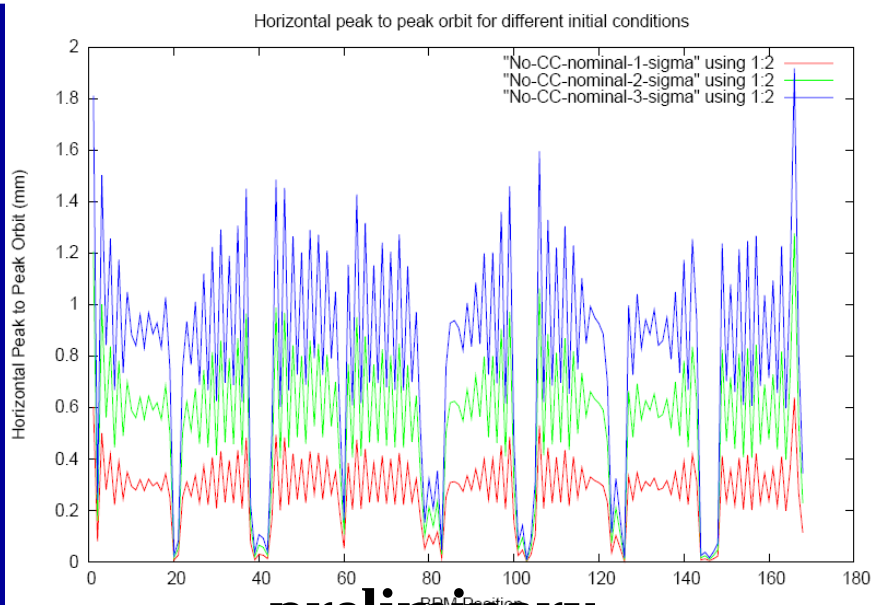
Using 2 seeds, plot the minimum dynamic aperture for 100,000 turns. The new DA is still in tracking, this figure shows results with larger crossing angle: ~**510 urad**.

The horizontal peak to peak orbit under different initial conditions, nominal LHC optics

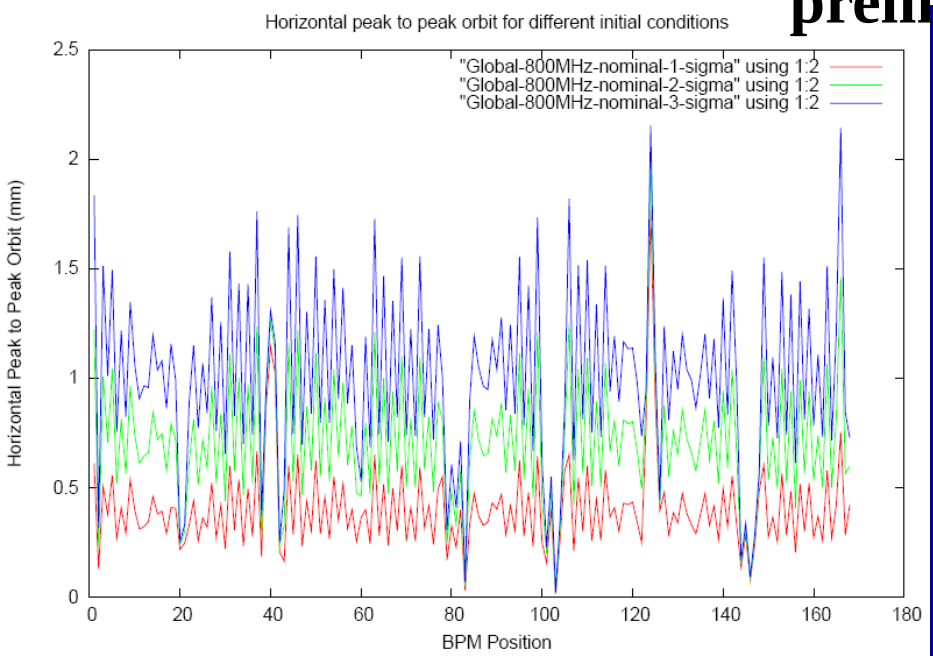
No CC

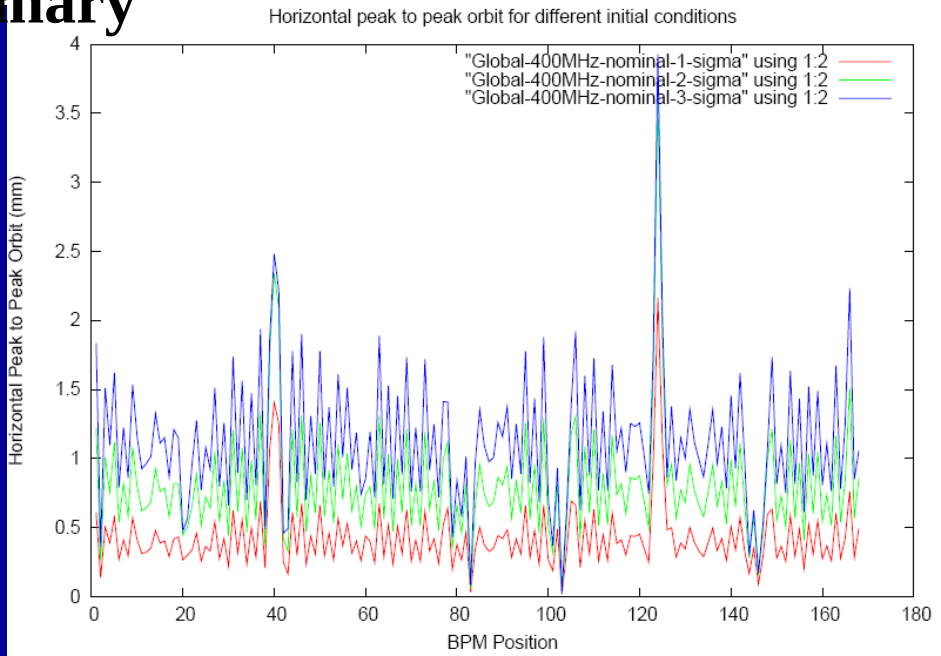
800 MHz CC

400 MHz CC



preliminary

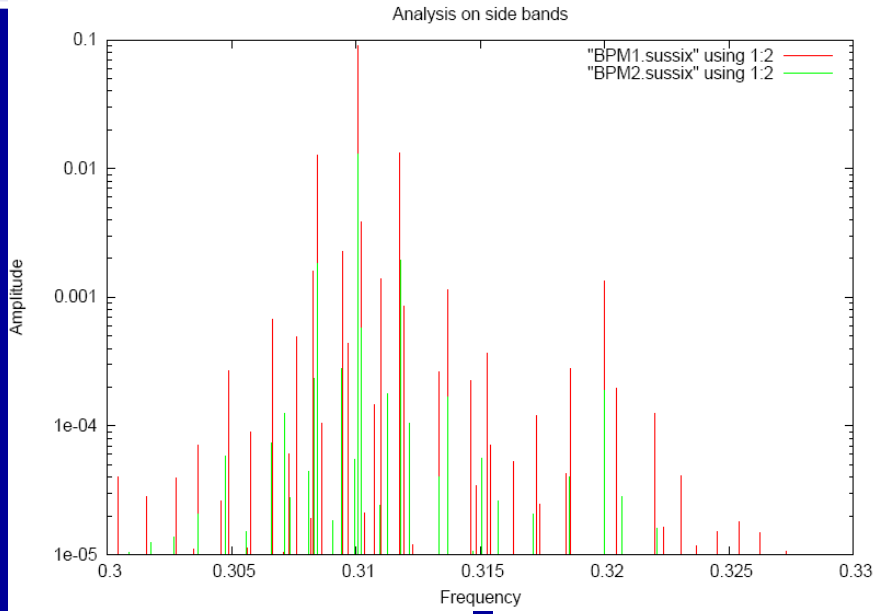




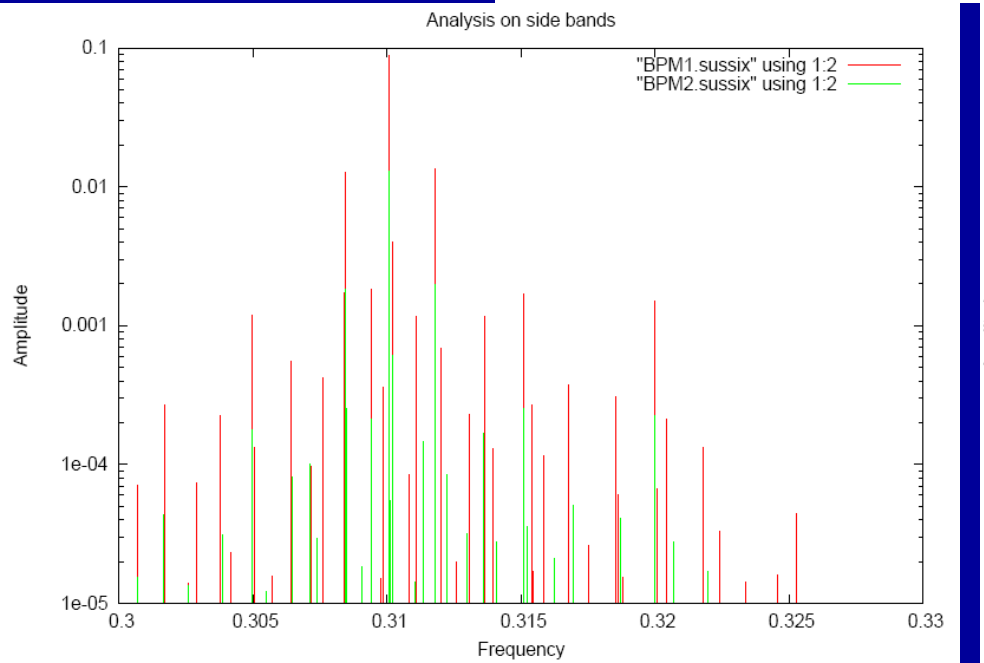
Longitudinal side bands by SUSSIX, Nominal LHC optics

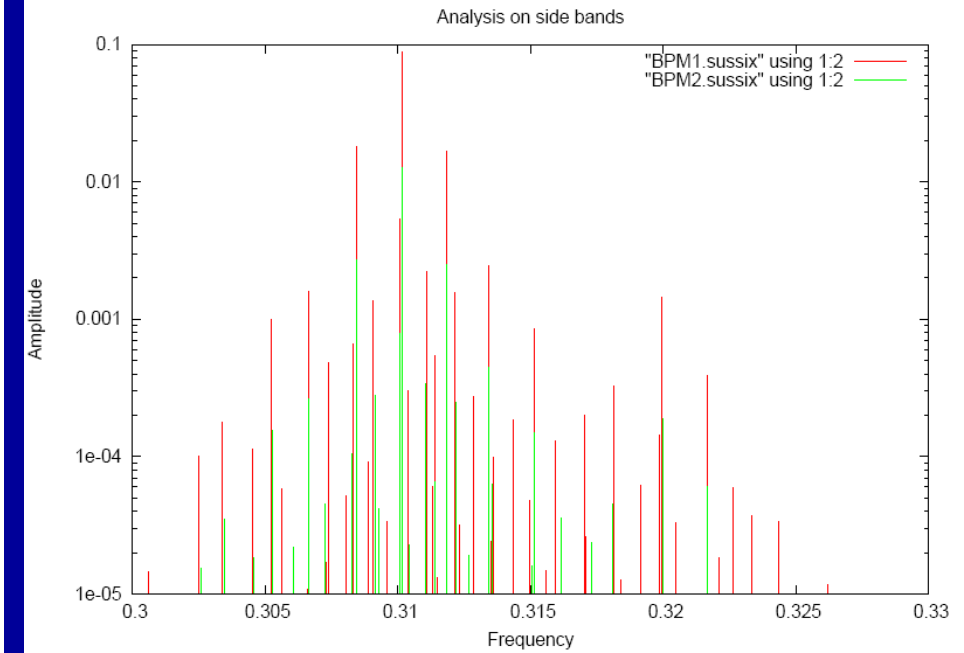
No CC

800 MHz CC



400 MHz CC





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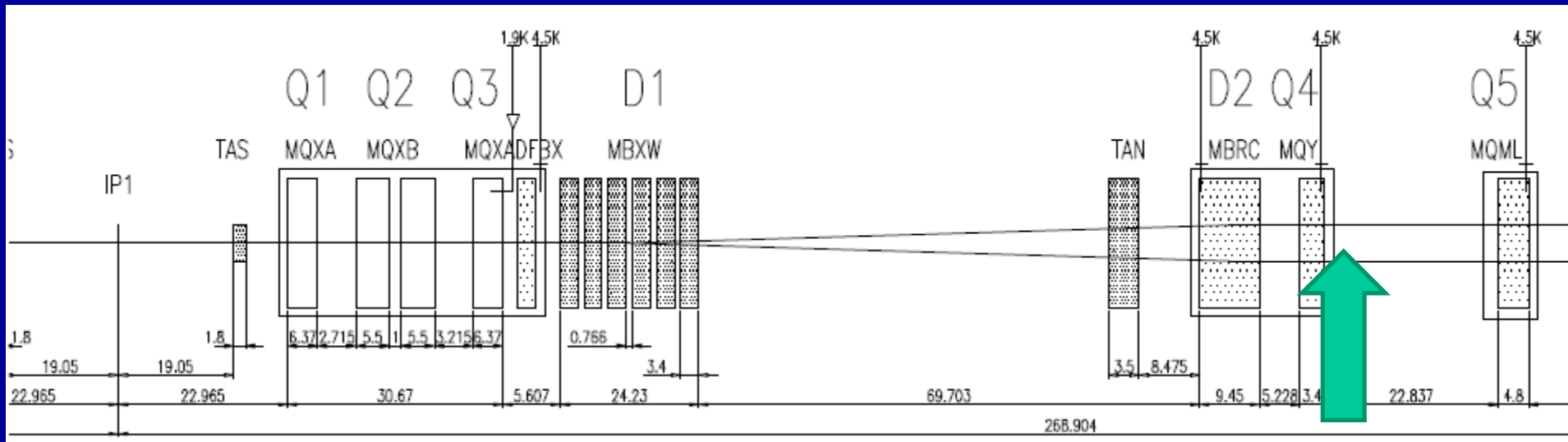
IP5	6664.568	0.253	0.2467	15.6213	14.367	
Crab Cav 1	6835.7	1023.9	2685.6	15.86	14.5988	4.95677MV
Crab Cav 2	6493.42	2616.8	1079.578	15.3511	14.0901	3.10058MV

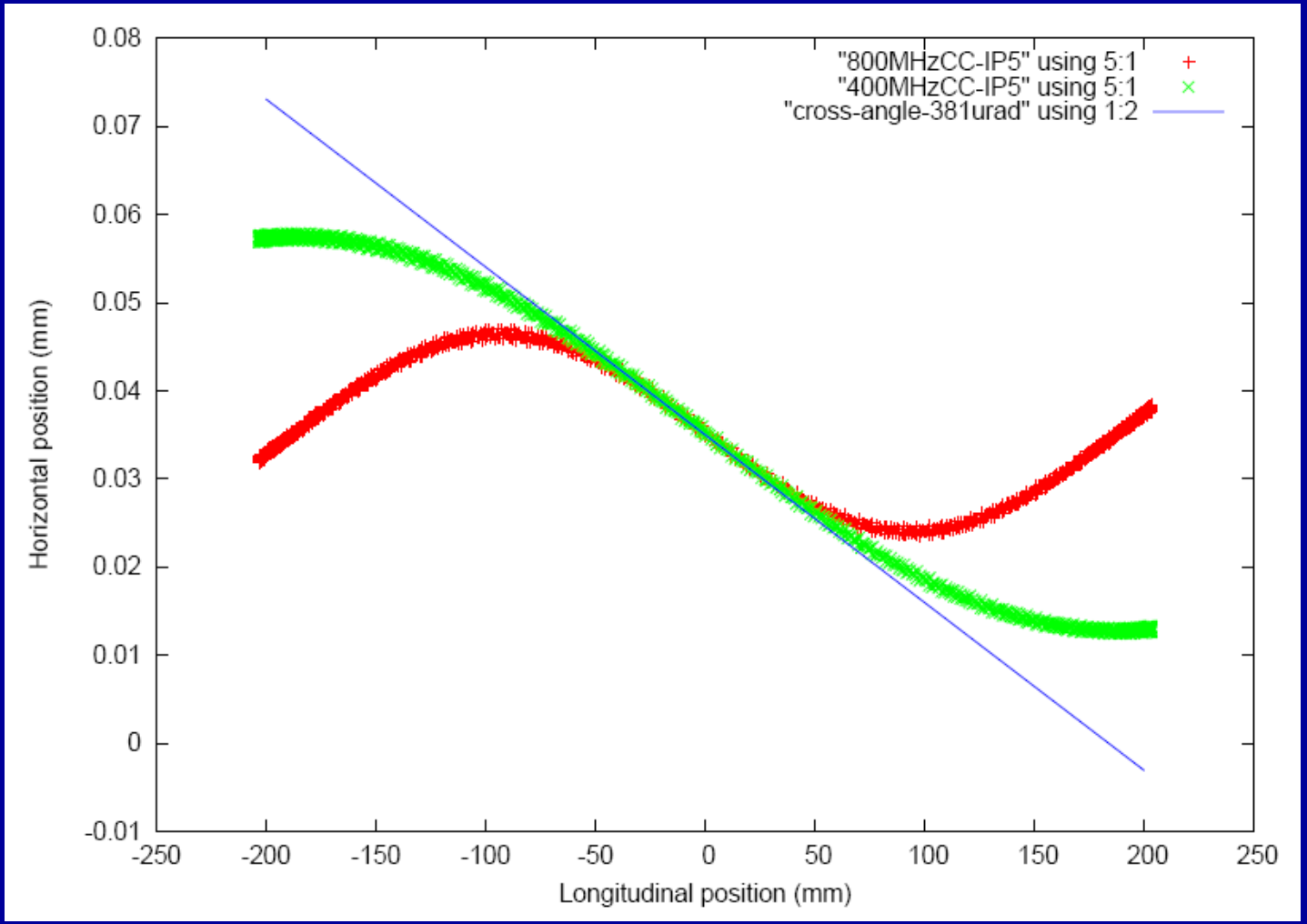
$$V1 = \frac{c \cdot E \cdot tan(\theta/2)}{\omega \cdot \sqrt{\beta\beta} \cdot sin(\Delta\emptyset)}$$

$$V2 = -R22 \cdot V1$$

Horizontal phase advance from 800 MHz CC1 to IP5 is **0.239**, S is **171.1 m**.
Horizontal phase advance from 800 MHz CC2 to IP5 is **0.2702**, S is **-171.148 m**.

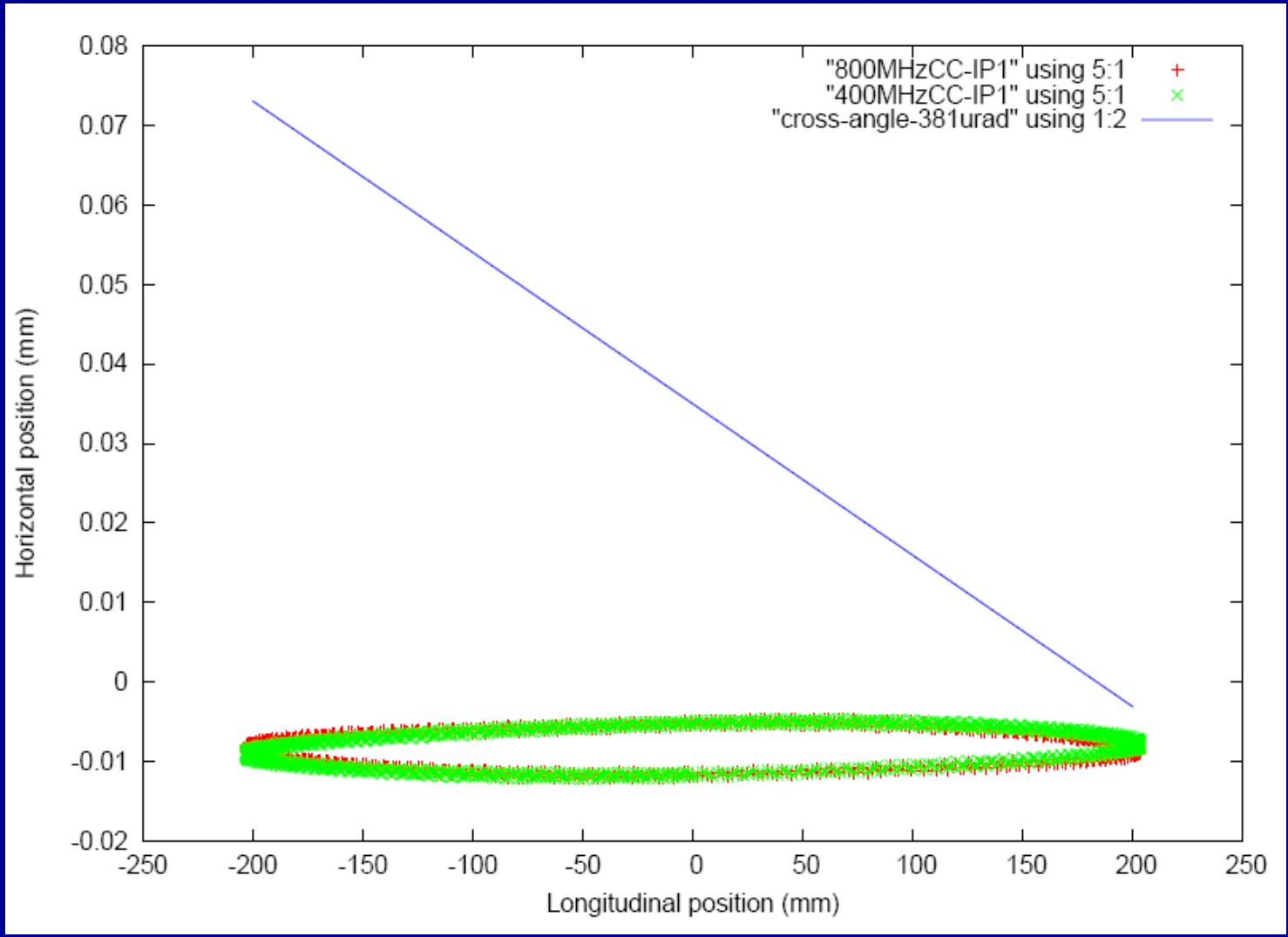


The horizontal crossing angle at IP5



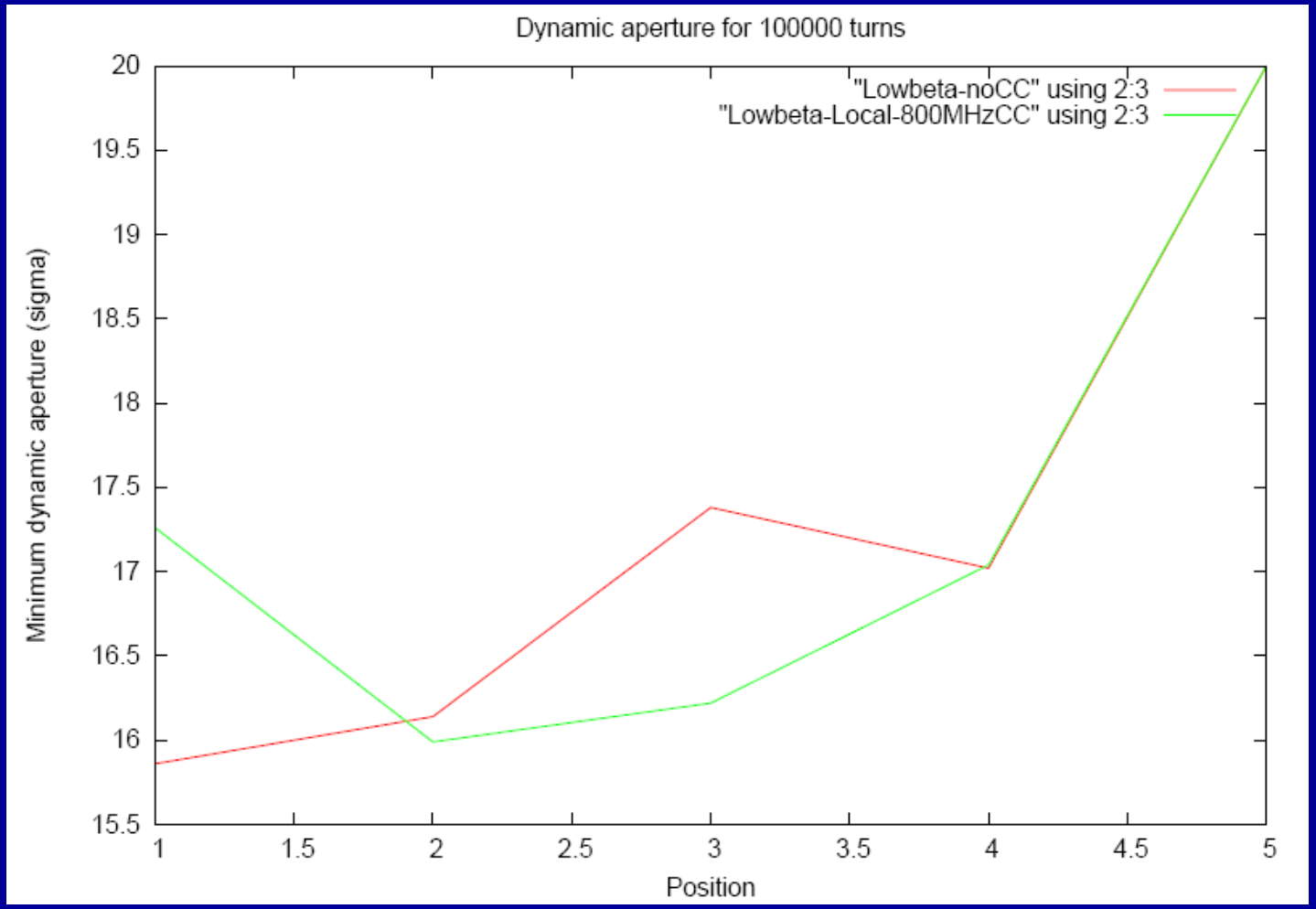
One particle with 0 initial transverse offset, and 0.00027 longitudinal offset.

The horizontal crossing angle at IP1



One particle with 0 initial transverse offset, and 0.00027 longitudinal offset.

DA of lowbetamax optics, by SixTrack



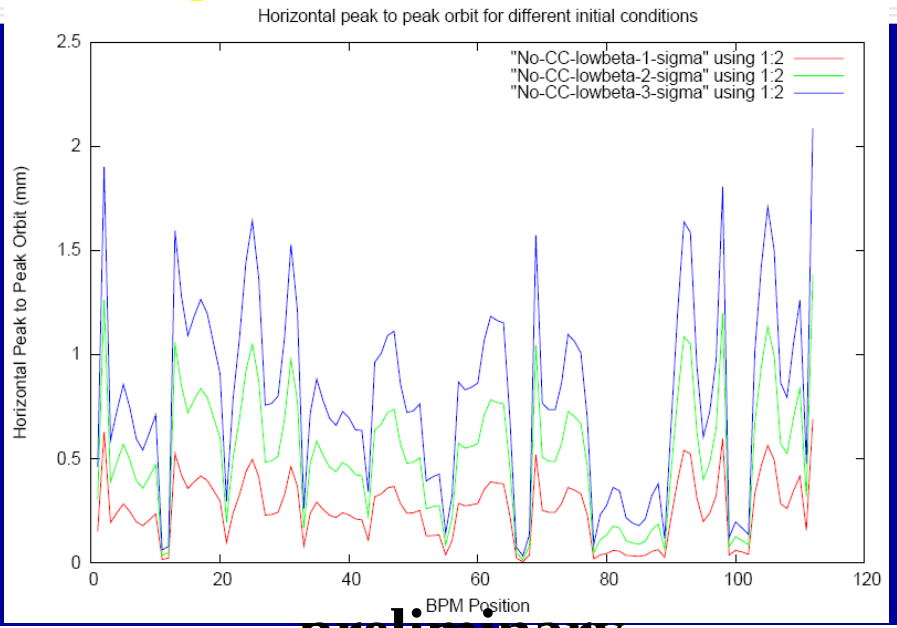
Using 2 seeds, plot the minimum dynamic aperture for 100,000 turns

The horizontal peak to peak orbit under different initial conditions, lowbeta optics

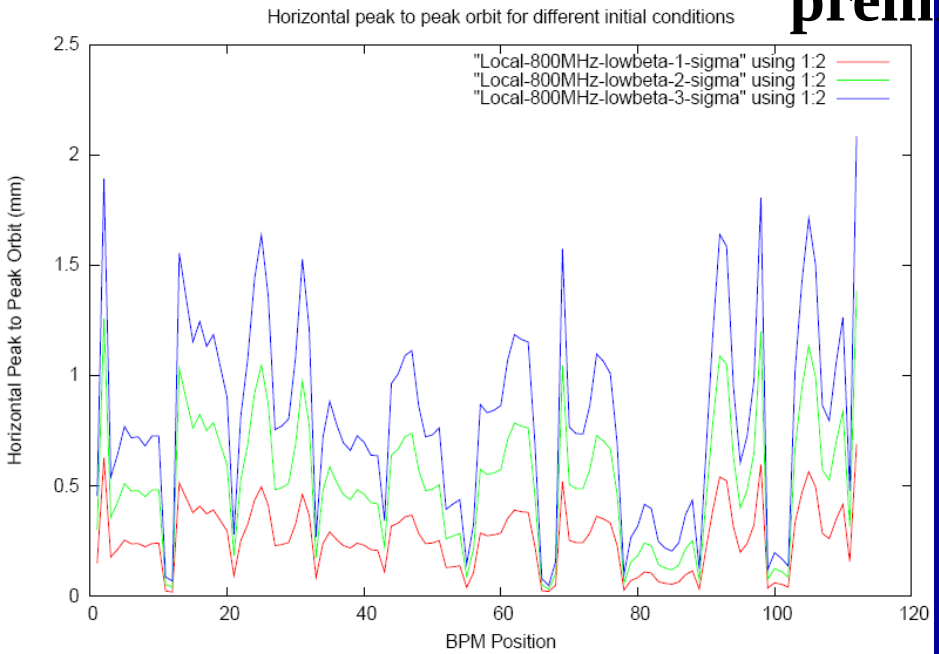
No CC

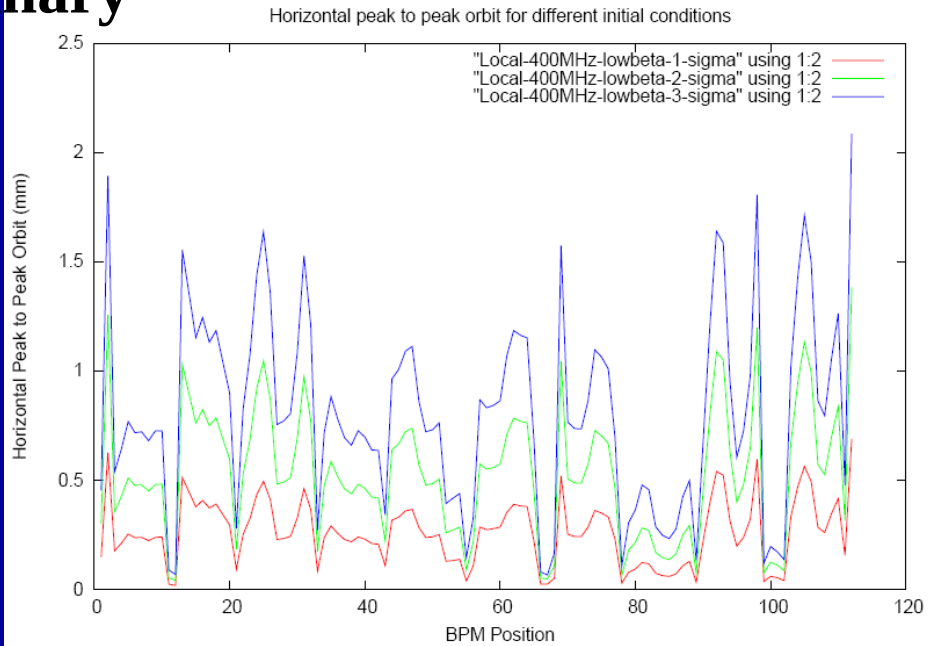
800 MHz CC

400 MHz CC

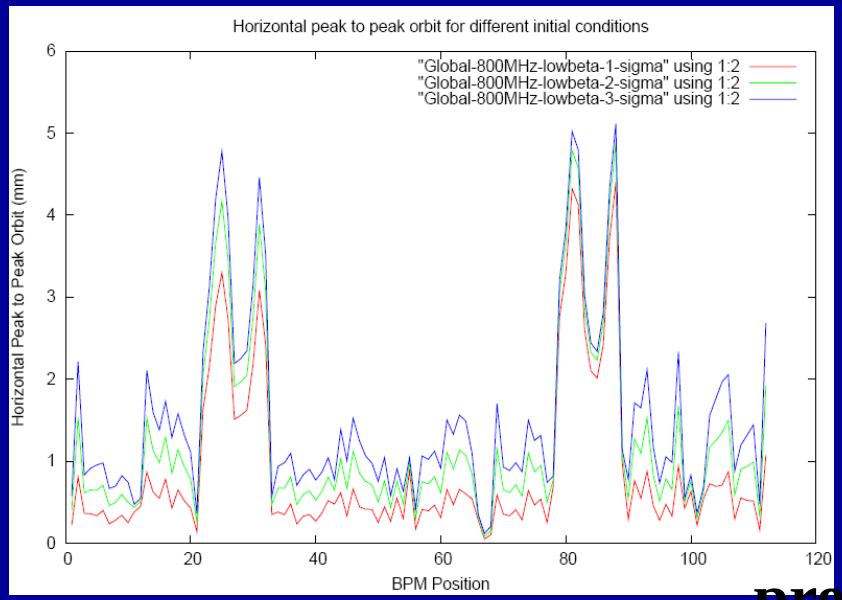


preliminary



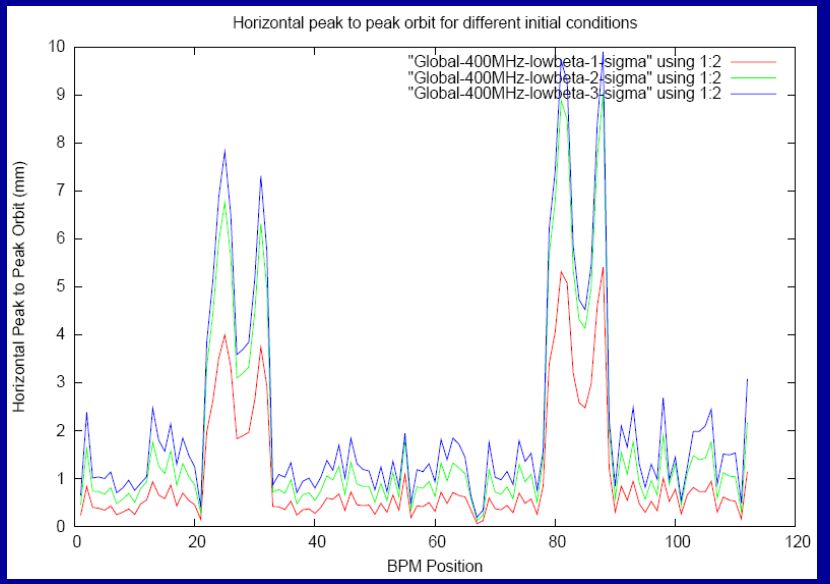


Comparison between Global CC (up) and Local CC (down)

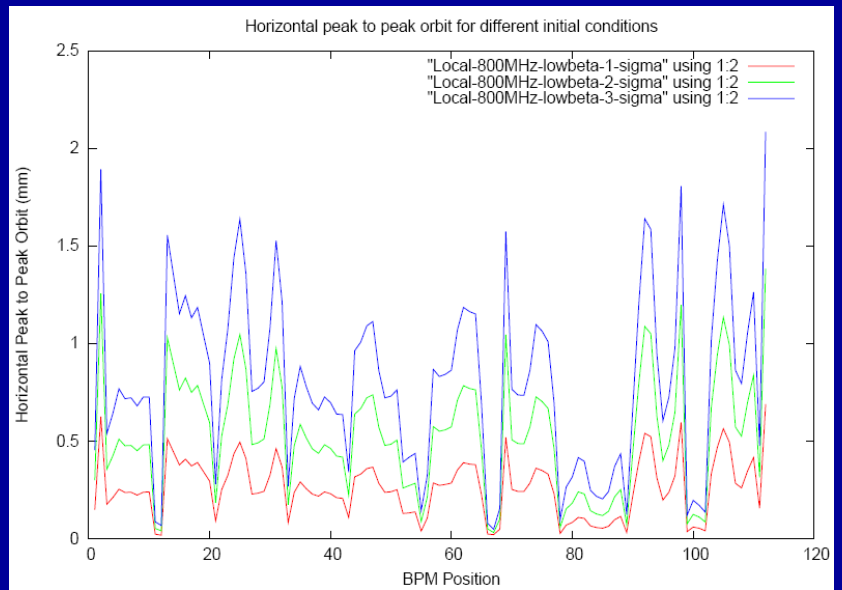


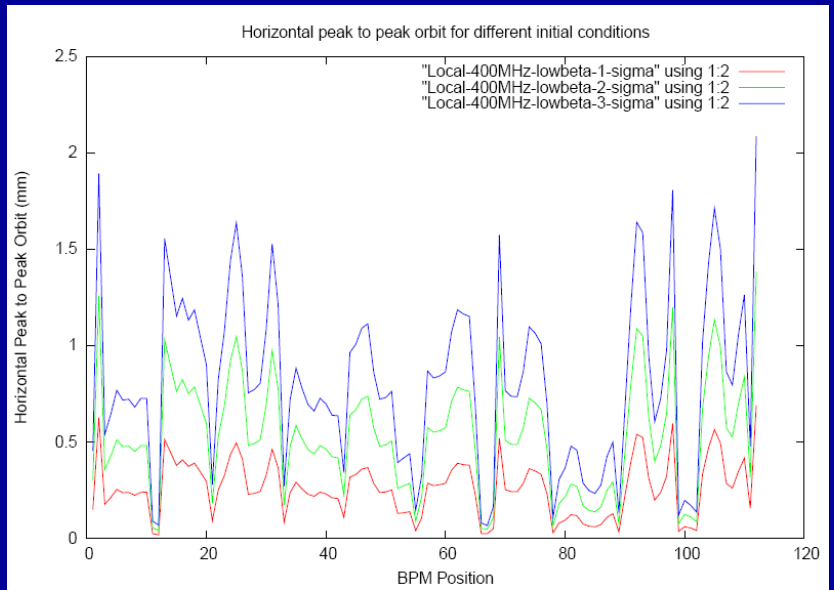
800 MHz CC

preliminary



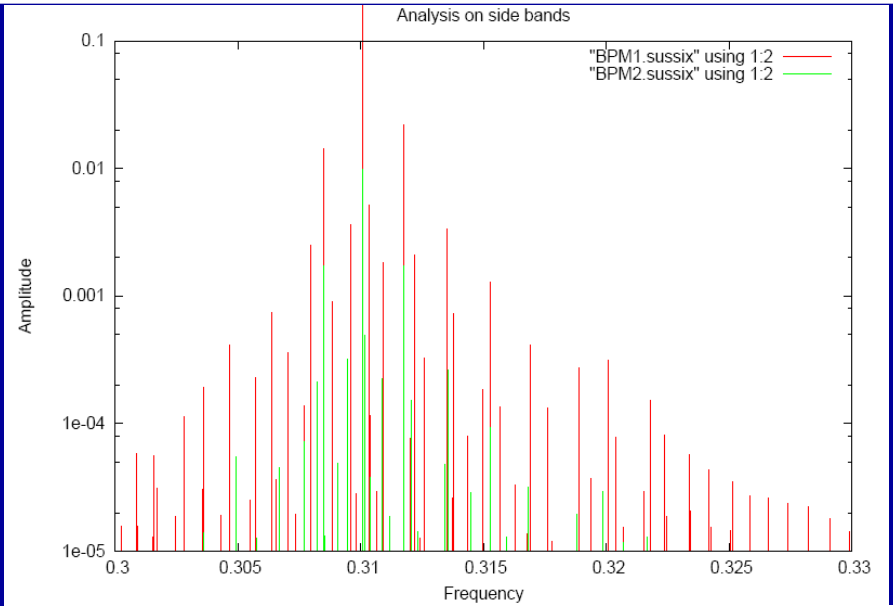
400 MHz CC



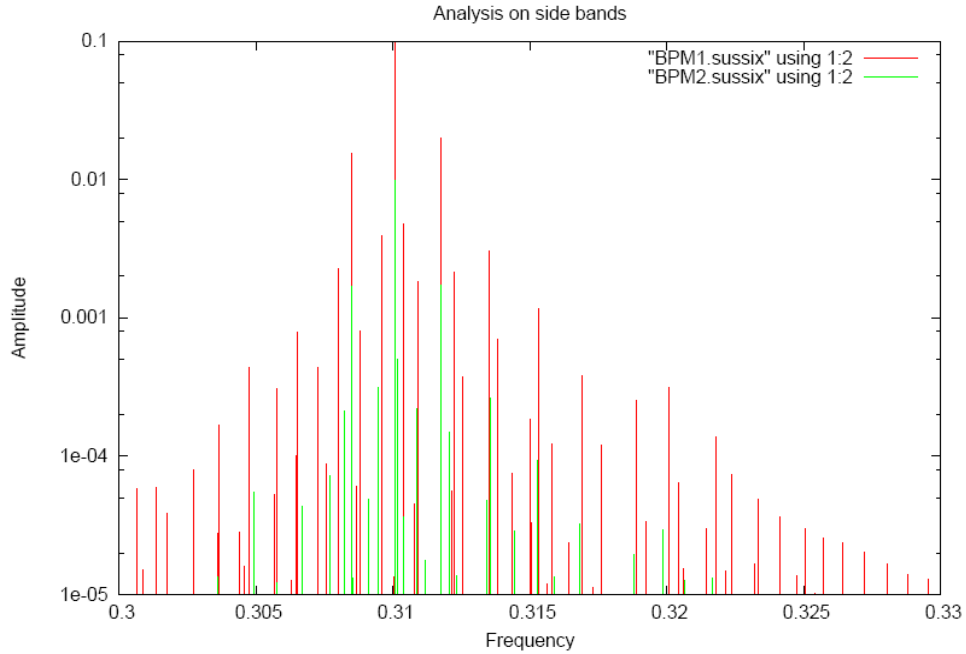


Longitudinal side bands by SUSSIX, lowbetamax optics

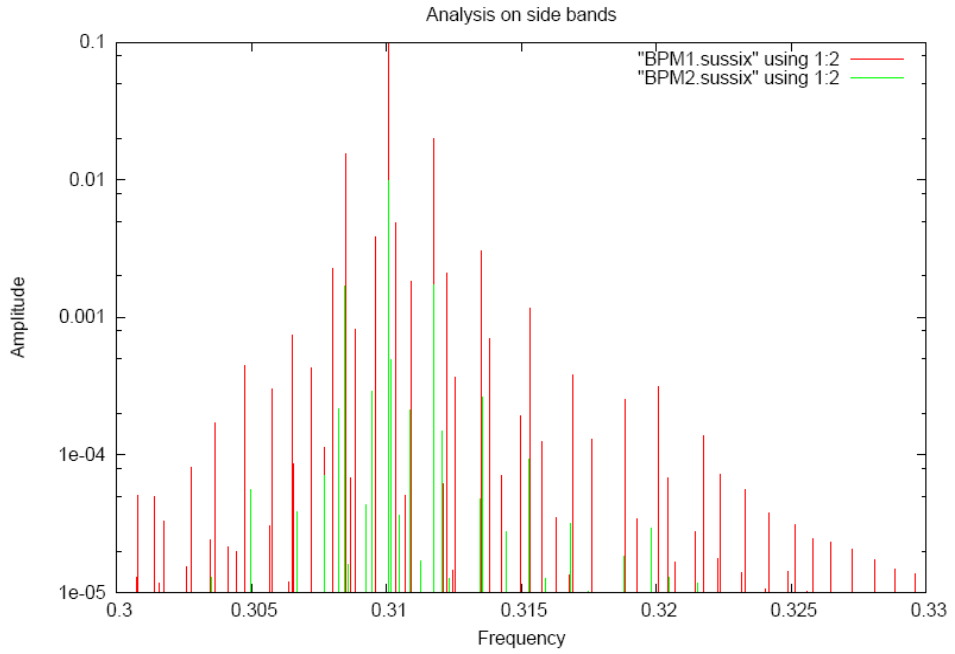
No CC



800 MHz CC



400 MHz CC



Nominal LHC optics , 285 urad Horizontal crossing at IP5

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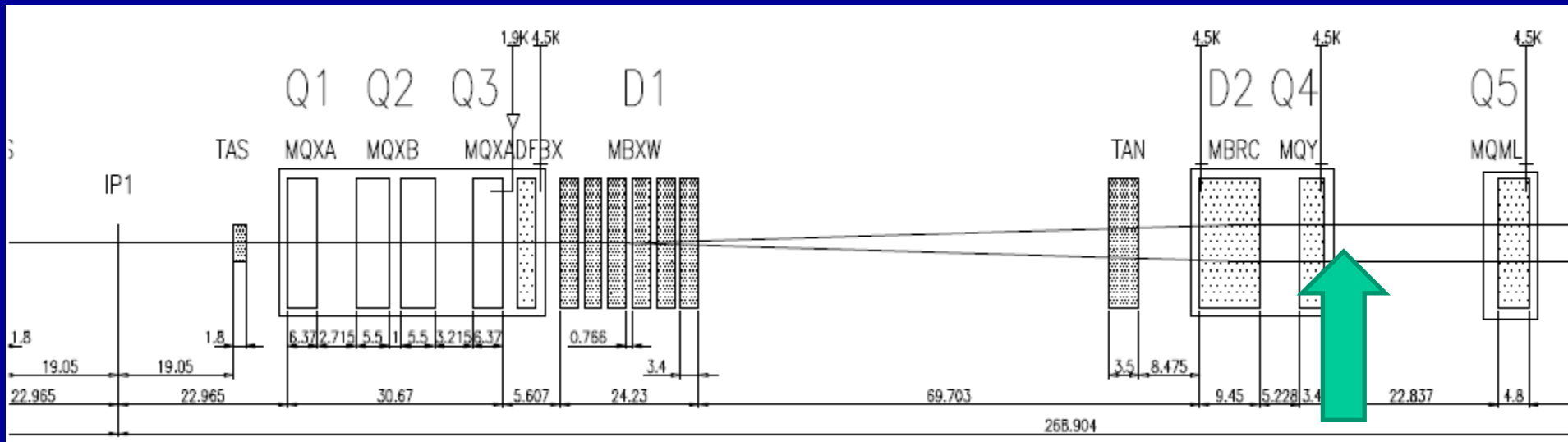
Crab Cav 1	6835.255	257.87	1546	15.7496	14.8553	5.1051MV
Crab Cav 2	6493.882	1523.244	255.171	15.2225	14.3283	MV

$$V1 = \frac{c \cdot E \cdot tan(\theta/2)}{\omega \cdot \sqrt{\beta\beta} \cdot sin(\Delta\emptyset)}$$

$$V2 = -R22 \cdot V1$$

Horizontal phase advance from 800 MHz CC1 to IP5 is **0.278**, S is **171.1 m**.
Horizontal phase advance from 800 MHz CC2 to IP5 is **0.2491**, S is **-171.148 m**.



Work for next steps

- complete and document ongoing studies
- luminosity from tracked distribution with different crab frequencies (using Guinea-Pig?)
- tracking of crab cavity + beam-beam with crossing angle ; effect on dynamic aperture and synchro-betatron sidebands
- impact on collimation; first simple estimates for both global and local schemes, followed by detailed study with help from Ralph Assmann & Collimation Team

Back up slide

- system, "ln -fns /afs/cern.ch/eng/lhc/optics/V6.500 ds";
- system, "ln -fns /afs/cern.ch/user/r/rtomas/w1/sixjobs/mask db";

- call, file="ds/V6.5.thin.seq";
- call, file="ds/V6.5.thin.coll.str";

- call, file="db/lhc_lowbeta.seq";