JHF Project and its Lattice

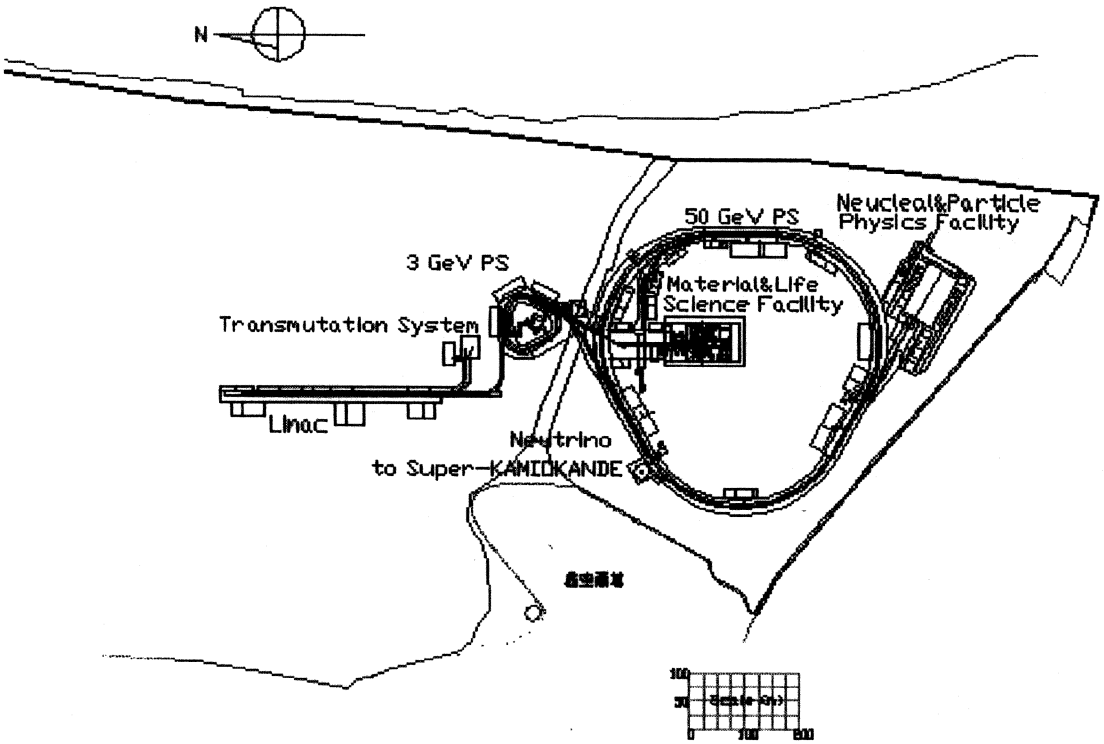
Shinji Machida

July 4, 2001

About this project

The high-intensity proton accelerator facility project in Japan was formed by joining together the Neutron Science Project (NSP) of Japan Atomic Energy Research Institute (JAERI) and the Japan Hadron Facility (JHF) Project of High Energy Accelerator Research Organization (KEK).

The facility will be constructed at the JAERI/Tokai site, as shown in Fig. 1.



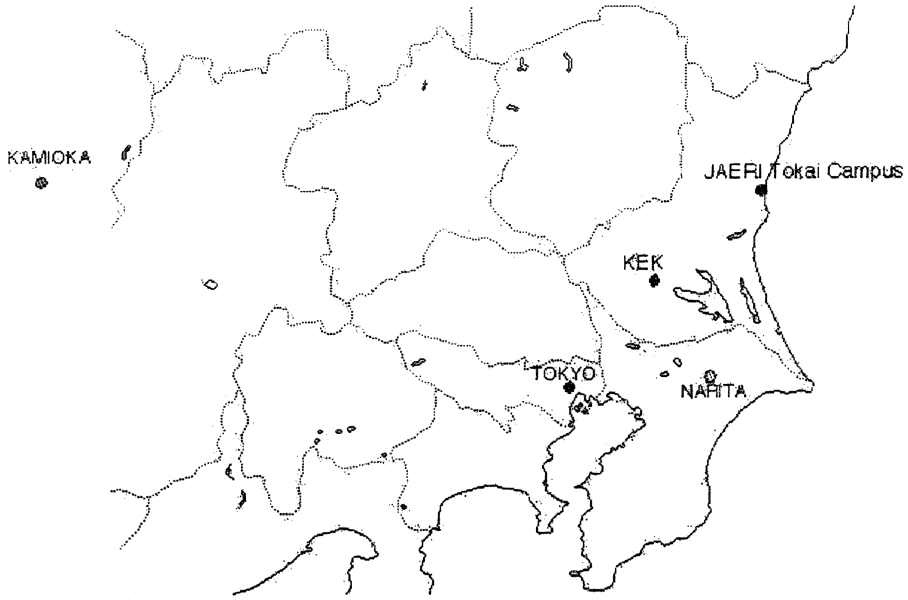
http://jkj.tokai.jaeri.go.jp/
Acc/all/english/about.html

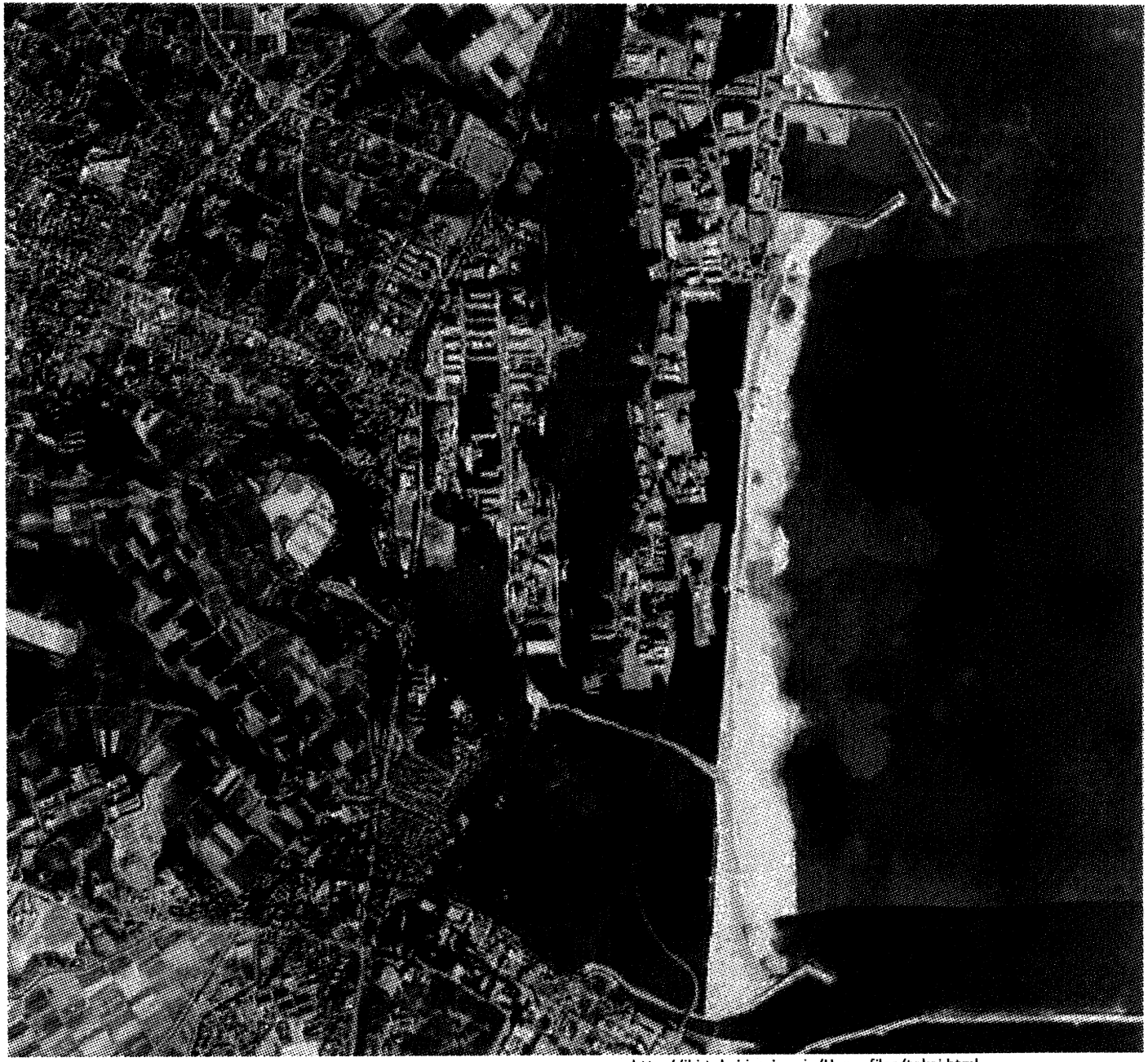
Phase-I of the project comprises a 600-MeV linac, a 3-GeV, 1-MW rapid-cycling synchrotron (RCS) and a 50-GeV main synchrotron. One half of the 400-MeV beam from the linac is injected to the RCS, while the other half is further accelerated up to 600 MeV by a superconducting (SC) linac. The 3-GeV beam from the RCS is injected to the 50-GeV synchrotron.

The 600-MeV beam accelerated by the SC linac is transported to the experimental area for an accelerator-driven nuclear waste transmutation system (ADS). The 3-GeV beam from the RCS is mainly used to produce pulsed spallation neutrons and muons. The muon-production target and the neutron-production target are, respectively, located in series in the Materials and Life Science Experimental Area. Ten percent of the beam is used for muon production. The 50-GeV beam is slowly extracted to the Particle and Nuclear Physics Experimental Area. It is also fast extracted for neutrino experiments, which are conducted at the SUPERKAMIOKANDE detector located 300-km from the Tokai site.

In this way, a wide variety of science and engineering fields will be intensively and efficiently promoted by the high-power proton accelerators. The Phase-I facility includes upgradability to a 5-MW neutron source, which is allocated to Phase II of the project.

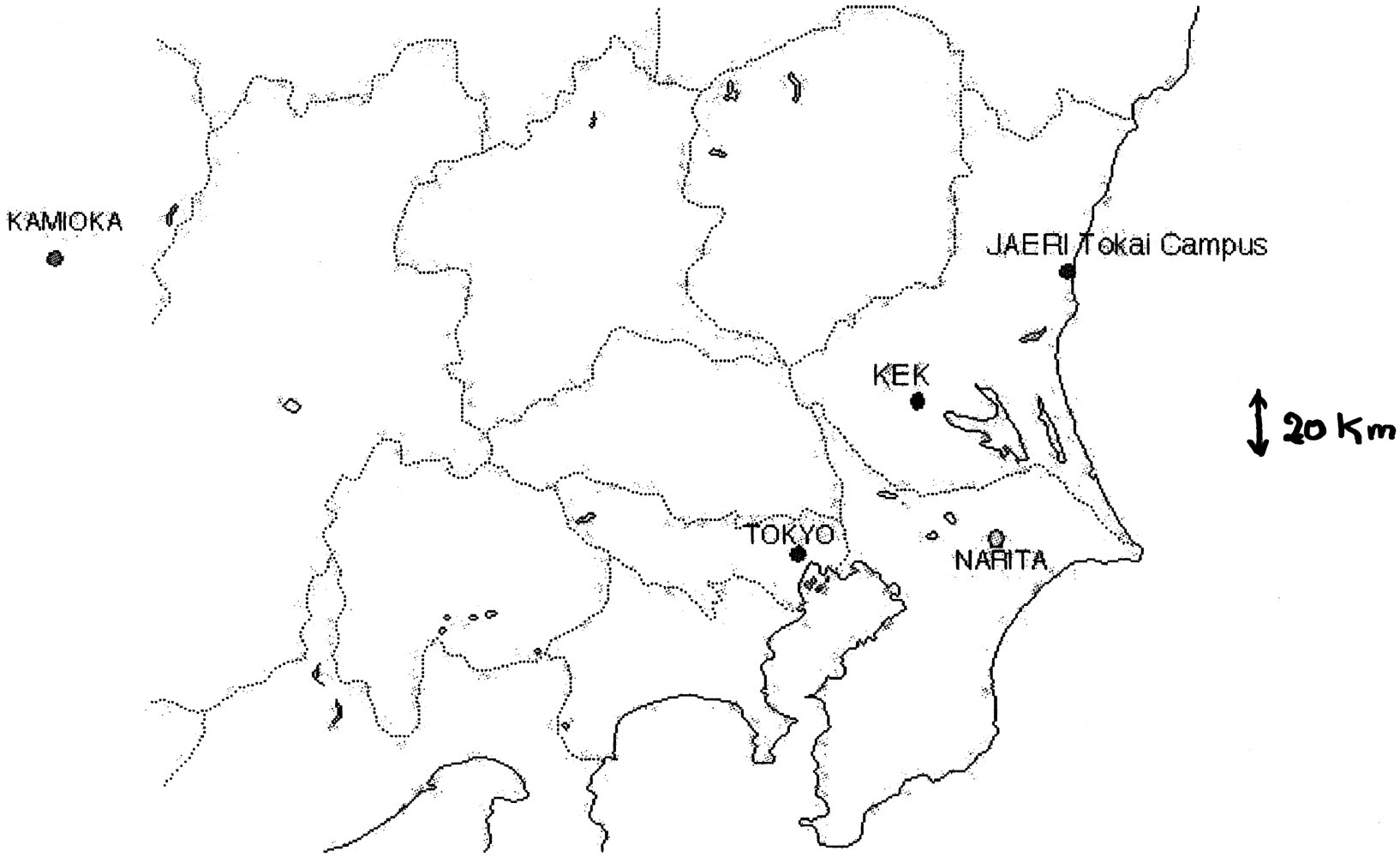
Back

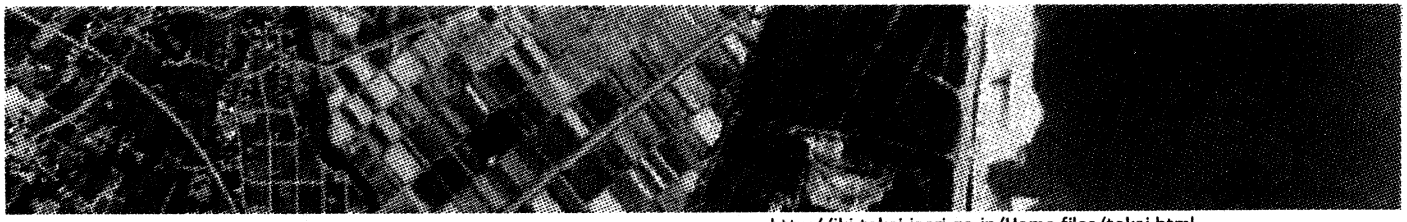

KAMIOKA
JAERI Tokai Campus
KEK
TOKYO
NARITA



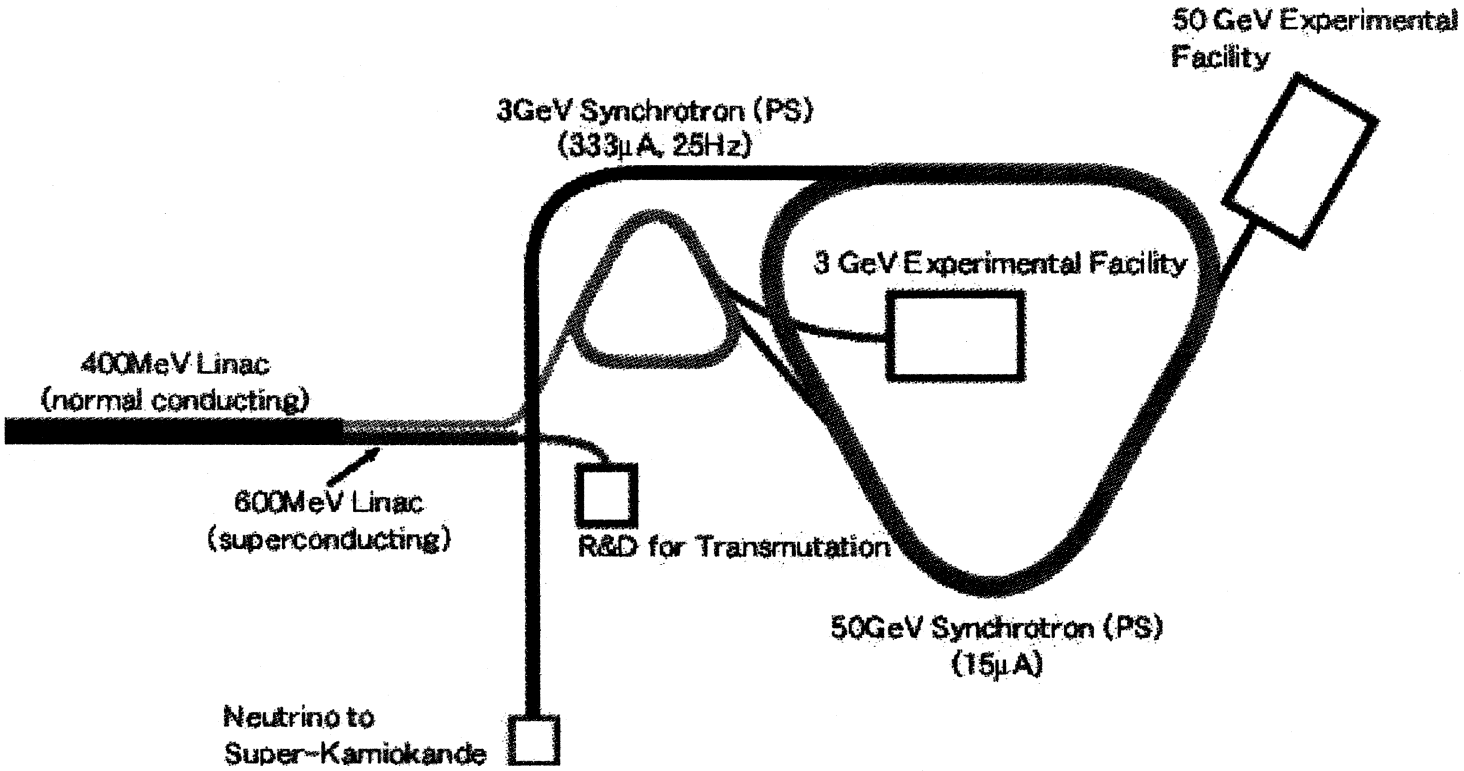
200 m

http://jkj.tokai.jaeri.go.jp/Home.files/tokai.html

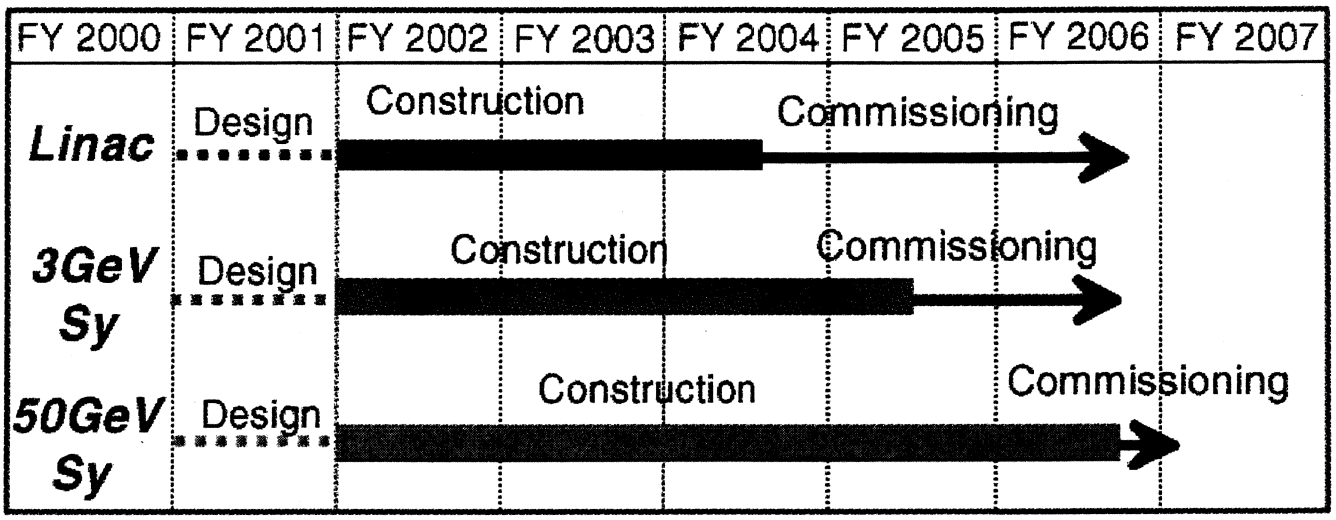




http://jkj.tokai.jaeri.go.jp/Home.files/tokai.html


50 GeV Experimental Facility
3GeV Synchrotron (PS)
(333μA, 25Hz)
3 GeV Experimental Facility
400MeV Linac
(normal conducting)
600MeV Linac
(superconducting)
R&D for Transmutation
50GeV Synchrotron (PS)
(15μA)
Neutrino to
Super-Kamiokande

Accelerators Baseline Schedule



Back

3 GeV Proton Synchrotron

8.3×10^{13} ppp

25 Hz repetition

1 MW

144π mm-mrad @ painting

216π " scraper aperture

312π " magnet aperture

incoherent tune shift ~ -0.38

50 GeV Proton Synchrotron

3.3×10^{14} ppp

0.3 Hz repetition for slow extraction → 0.75 MW

0.4 Hz " for fast extraction → 1 MW

54π mm-mrad @ injection

81π " magnet aperture

(54 – 81π " scraper aperture)

10π " @ 30 GeV extraction

6π " @ 50 GeV extraction

incoherent tune shift ~ −0.15

3 GeV PS Lattice

- arc : 2 × 3 cell DOFO with missing dipole

  ins : 3 cell normal FODO

  with 2 split Quad for charge exchange foil.

- $\gamma_t = 8.9$ (high γ_t lattice)

  we need high γ_t for longitudinal matching to 50 GeV PS

- 3 fold symmetry to separate

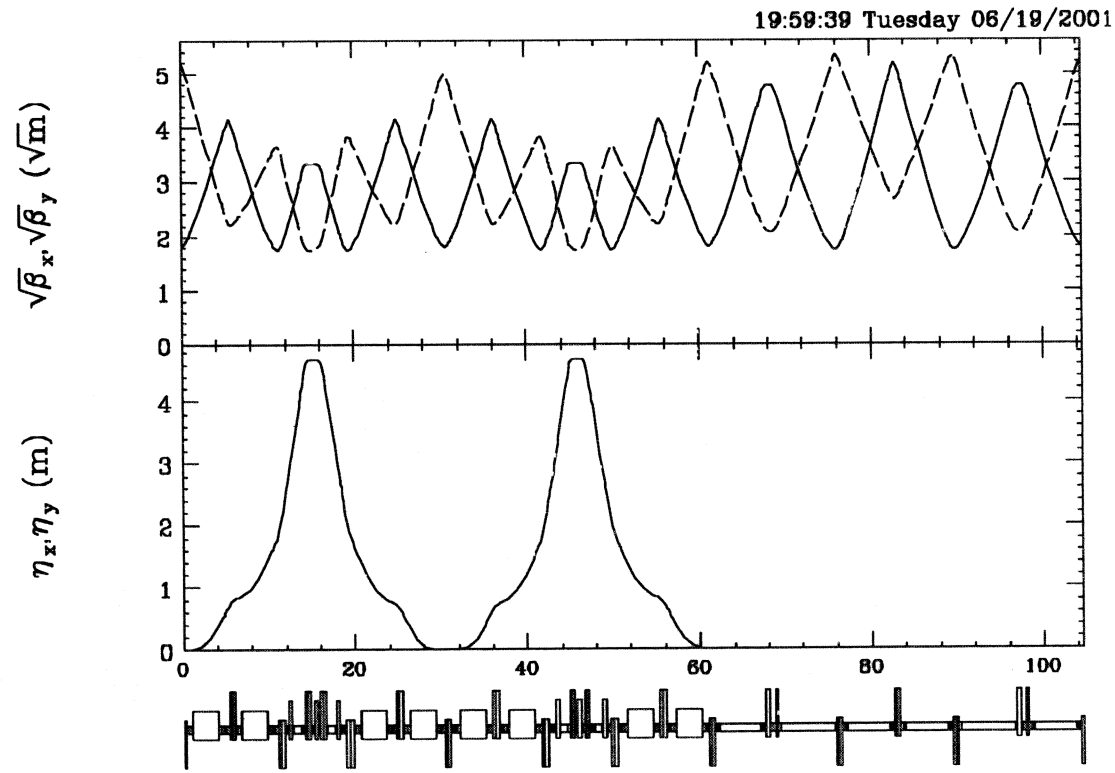
  RF, injection & collimator, extraction

  Still we have a debate if injection and collimator should be in a different insertion.

- 7 family of Quads

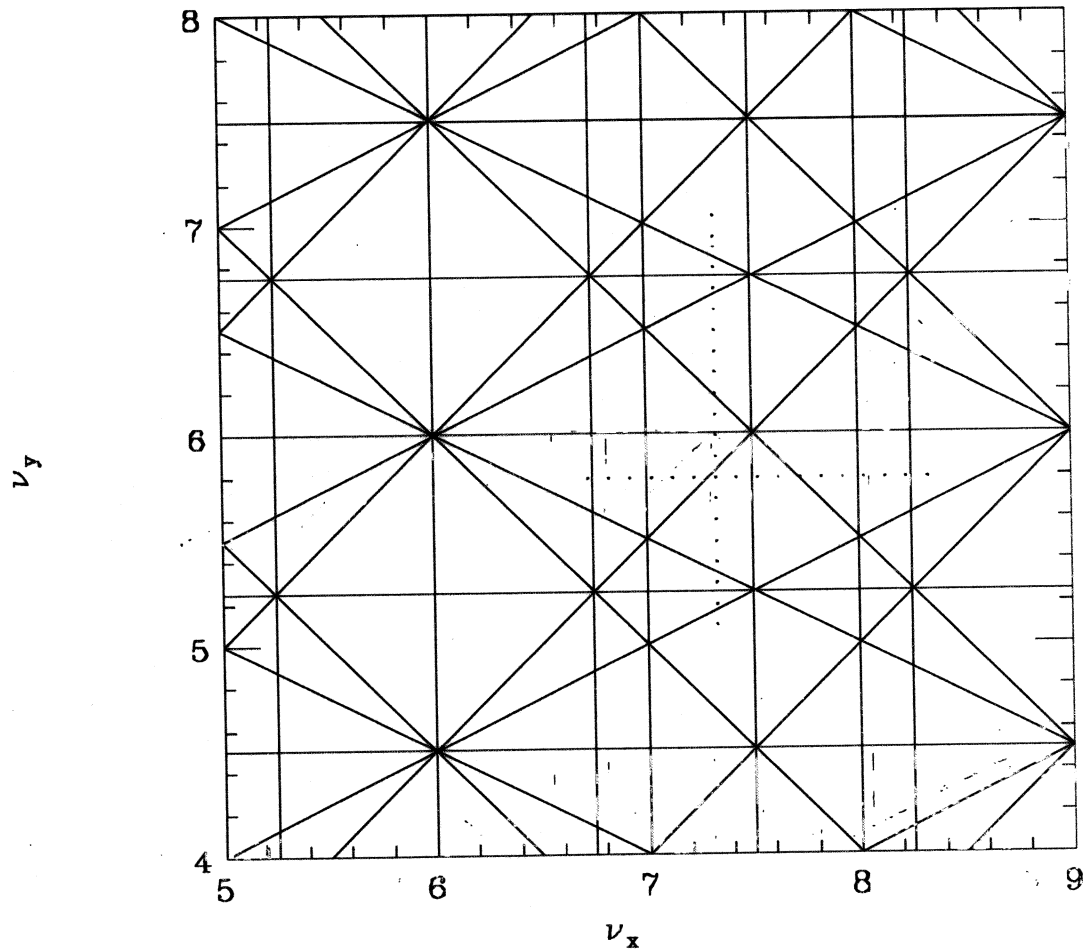
  We consider 7 is not a problem for a rapid cycling.

High Gamma-t Lattice for 3GeV PS



Possible operating points

Nominal bare tune is chosen at (7.35, 5.80). Small dots on the right figure show the bare tune we explored, together with structure resonances of up to 4th order.



Simulation model

code	Simpsons 2D
number of macro particles	10,000
number of turns	1,030
time step	5 ns
CPU time	~2.5 hours/run on 21264A

RMS emittance at 1000 turns after injection along horizontal tune

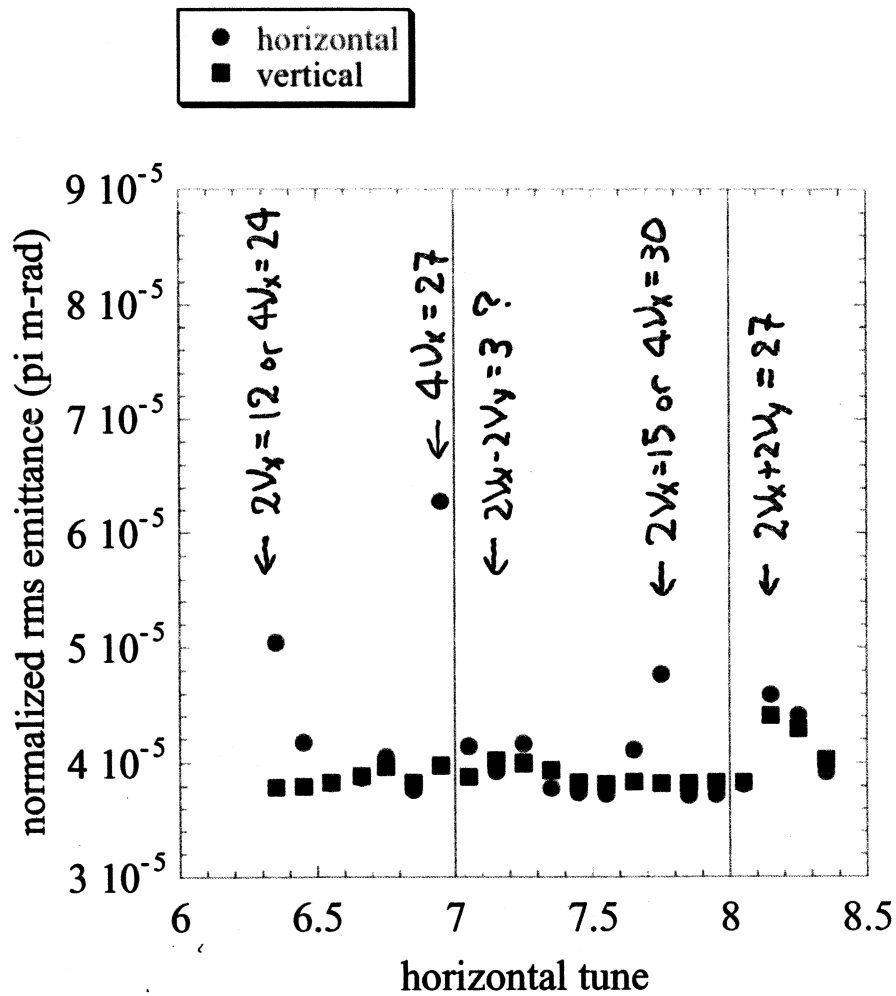
Some peaks on the right figure can be attributed to nearby resonances.

large peaks

- **one at νx=6.95 : 4νx=27**
- **one at νx=7.75 : 2νx=15 or 4νx=30**
- **one at νx=8.15 : 2νx+2νy=27**

small peaks

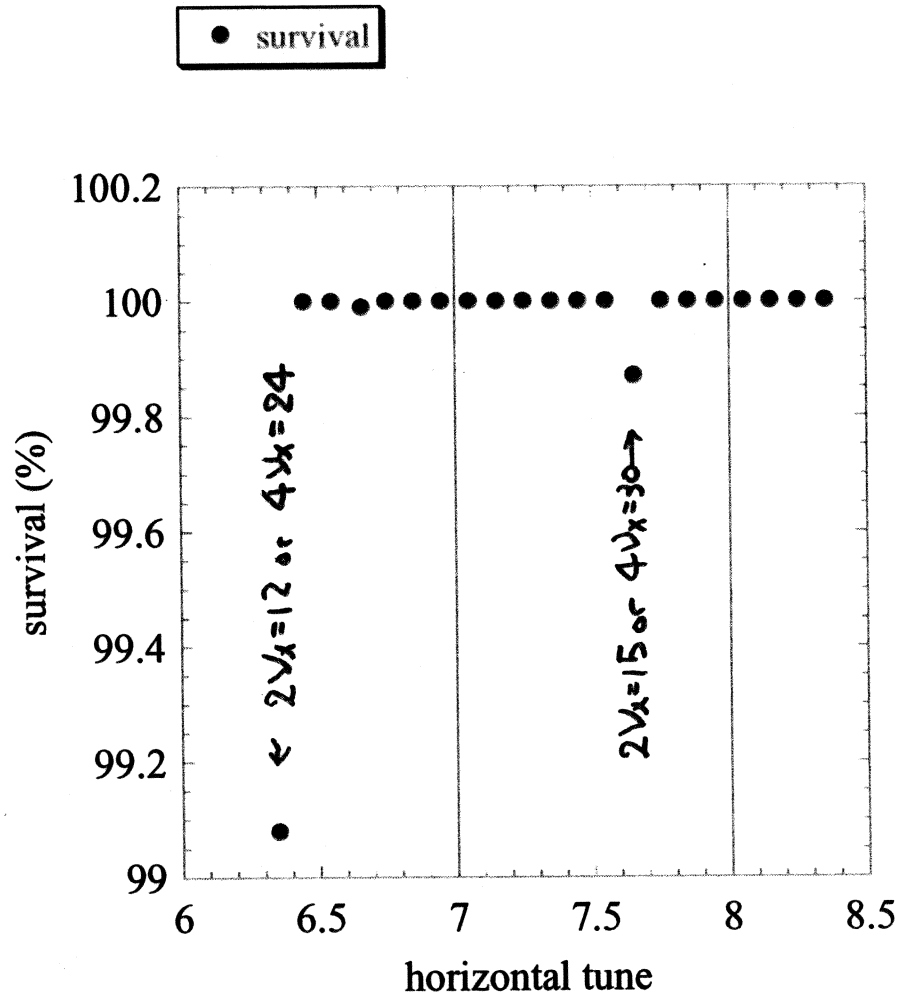
- **one at νx=7.25 : 2νx-2νy=3 ?**



Beam loss at 1000 turns after injection along horizontal tune

Beam loss occurs correspondingly.

one at νx=7.65 : 2νx=15 or 4νx=30



RMS emittance at 1000 turns after injection along vertical tune

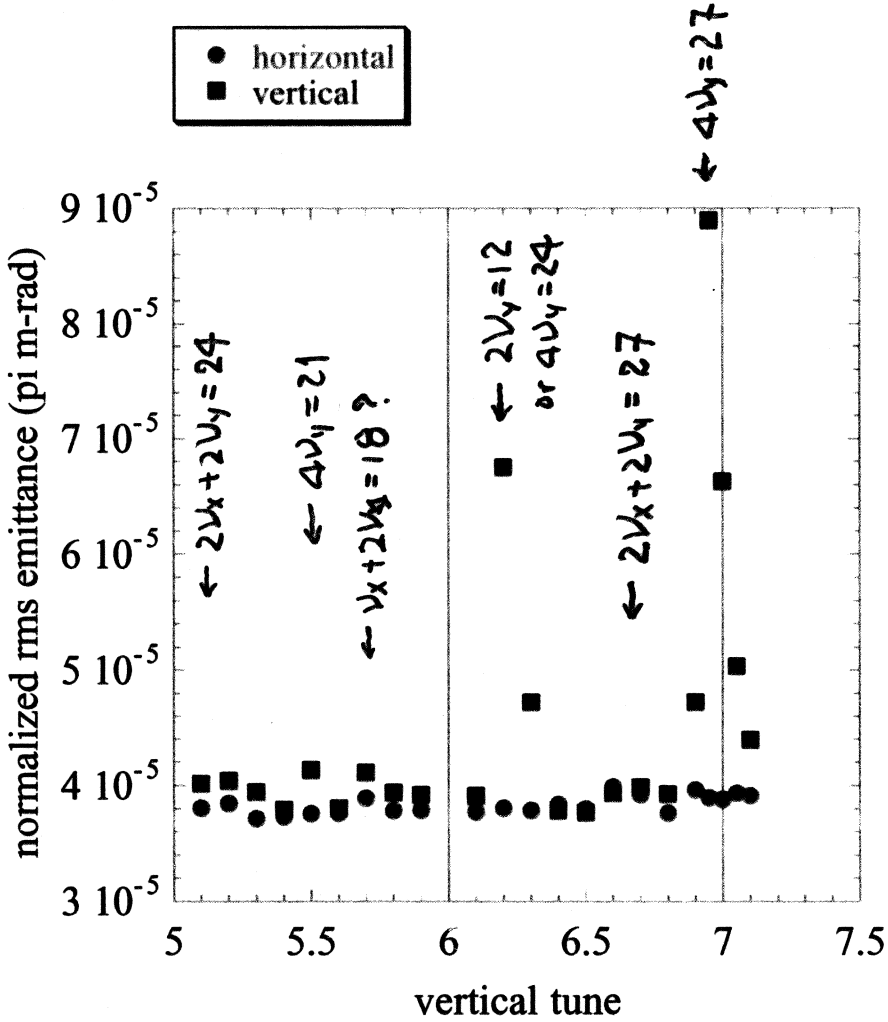
Some peaks on the right figure can be attributed to nearby resonances.

large peaks

- **one at νy=6.20 : 4νy=24**
- **one at νy=6.95 : 4νy=27**

small peaks

- **one at νy=6.60 : 2νx+2νy=27**
- **one at νy=5.50 : 4νy=21**
- **one at νx=5.70 : 2νx-2νy=3 ?**

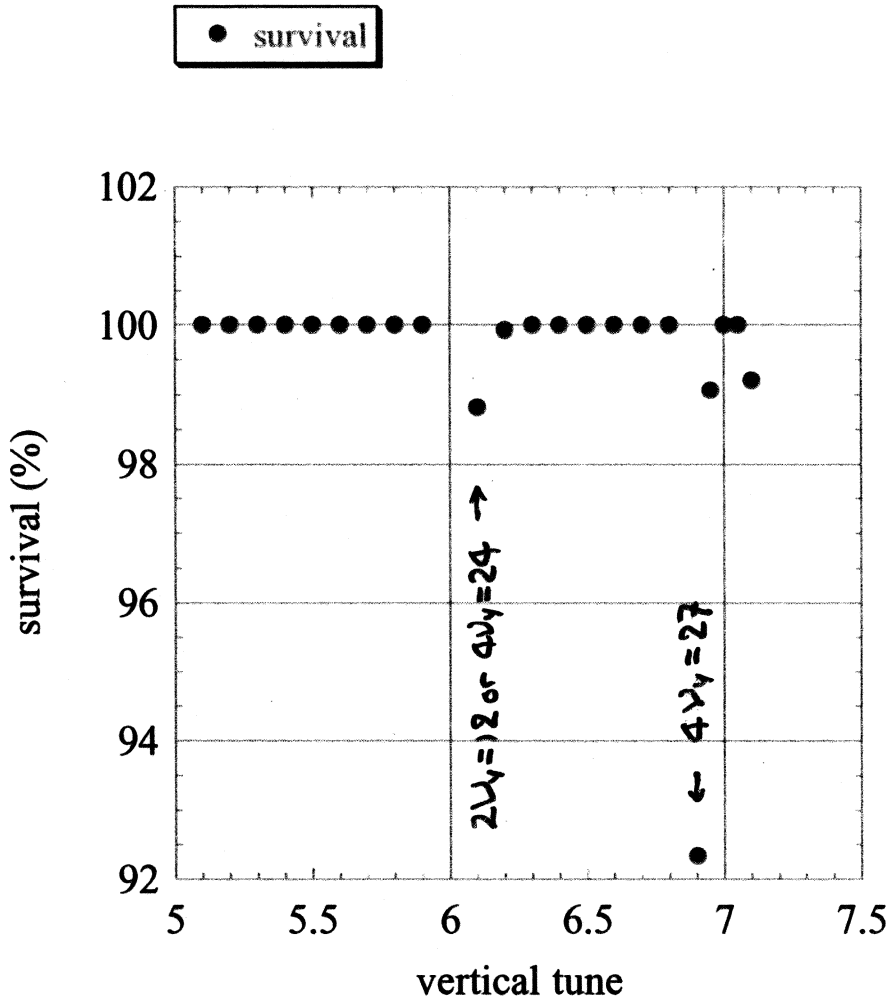


Beam loss at 1000 turns after injection along vertical tune

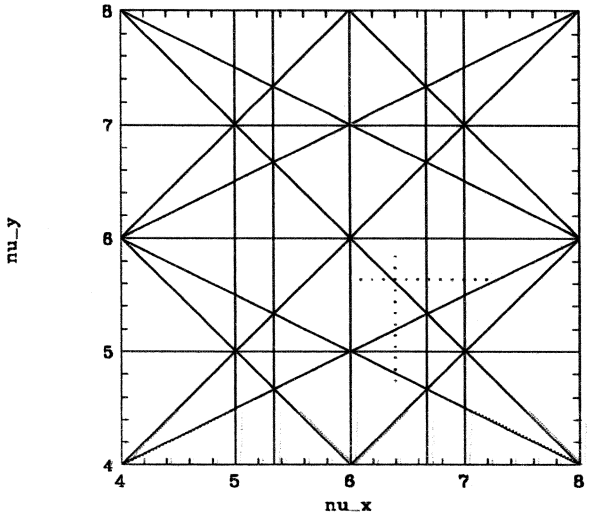
Beam loss occurs correspondingly.

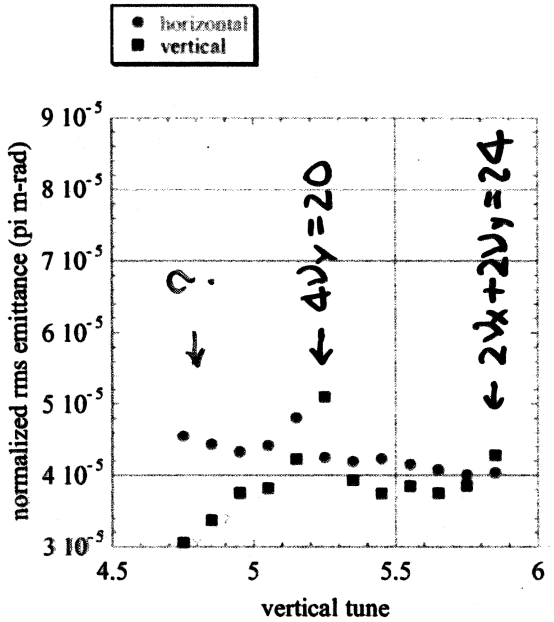
one at νy=6.10 : 4νy=24

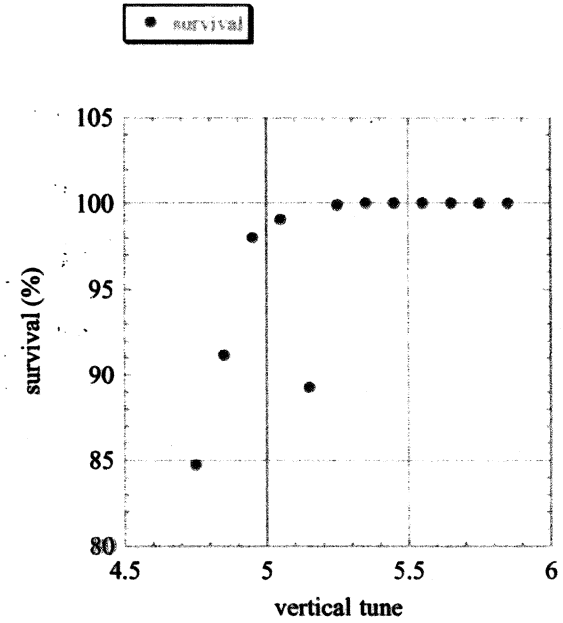
one at νy=6.95 : 4νy=27



Tune Survey in Vertical Direction (4-fold sym)







50 GeV PS Lattice

- arc : 8 × 3 cell DOFO with missing bend

  ins : phase shifter at the center

  matching section at the both end with high β and zero α for slow ext.

- $\gamma_t = 31i$ (imaginary γ_t lattice)

  no transition crossing

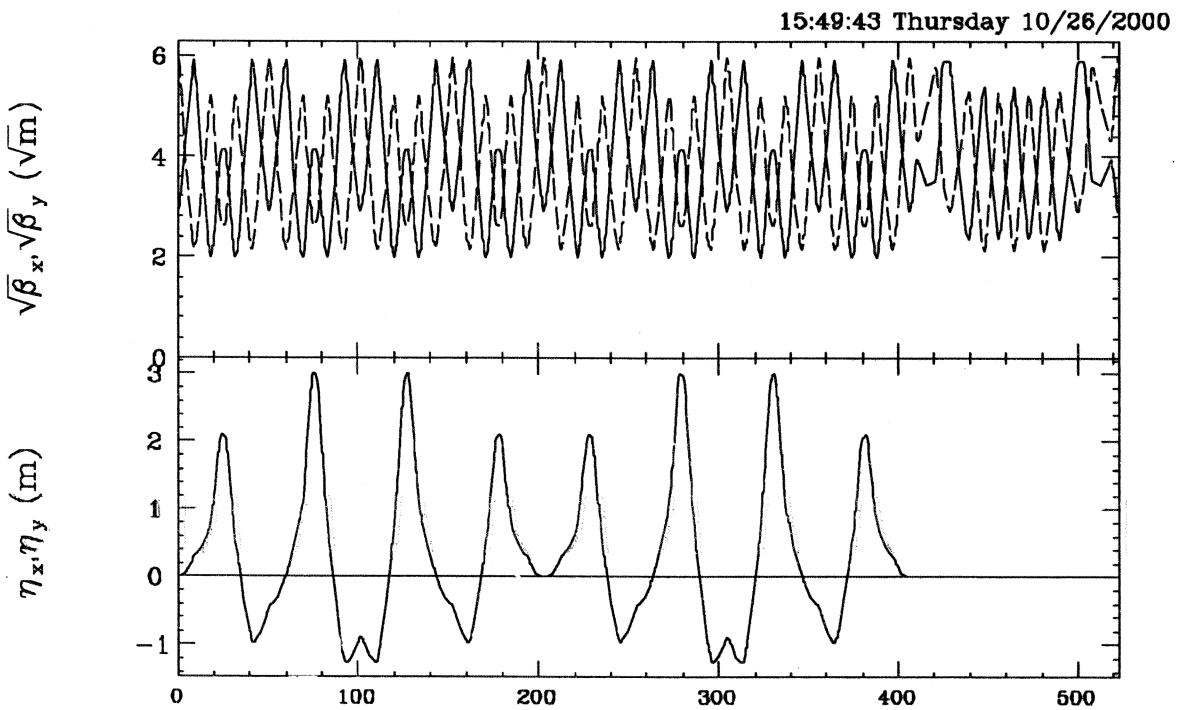
- 3 fold symmetry to separate

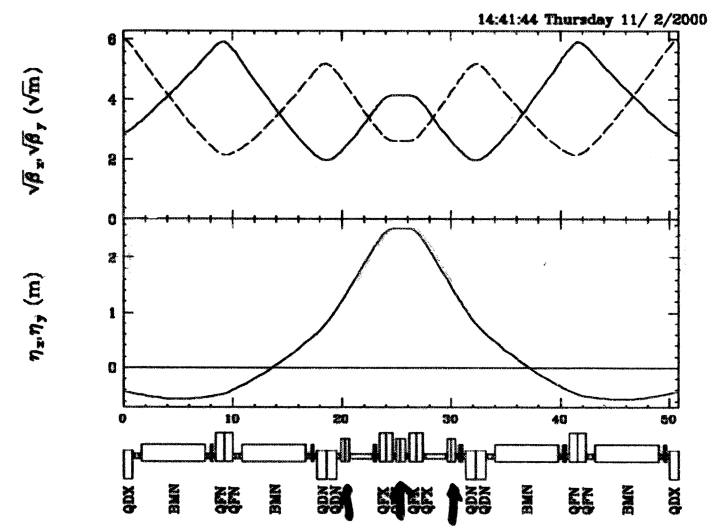
  fast ext & RF, injection & collimator, slow ext.

- 11 family of Quad

- 2 ~ 12 family of Sext.

50 GeV PS Lattice





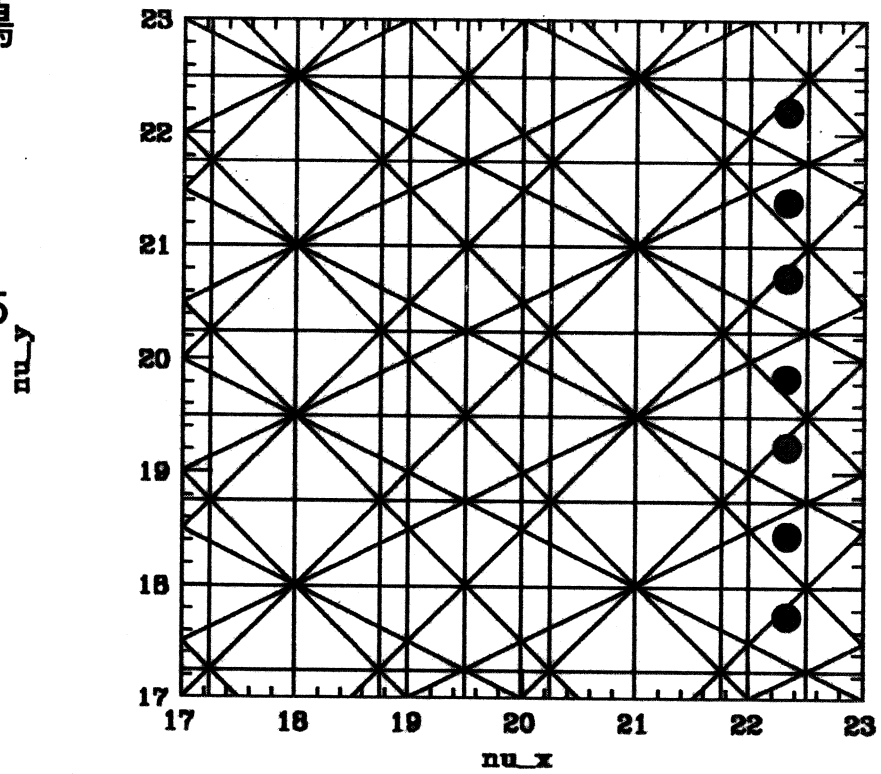
03:11:30 Wednesday 02\25\2001
(mV) v_y v_x
(mm) y_m x_m
0.10
0.05
0.00
-0.05
-0.10
0
4
8
0
20
40
60
80
100
XQ0
SQ0
TQ0
SQ1
TQ1
SQ2
TQ2
SQ3
TQ3
SQ4
TQ4
SQ5
TQ5
SQ6
TQ6
SQ7
TQ7
SQ8
TQ8
SQ9
TQ9
SQ10
TQ10
SQ11
TQ11
SQ12
TQ12
SQ13
TQ13
SQ14
TQ14
SQ15
TQ15
SQX
TQX

チューンダイアグラム

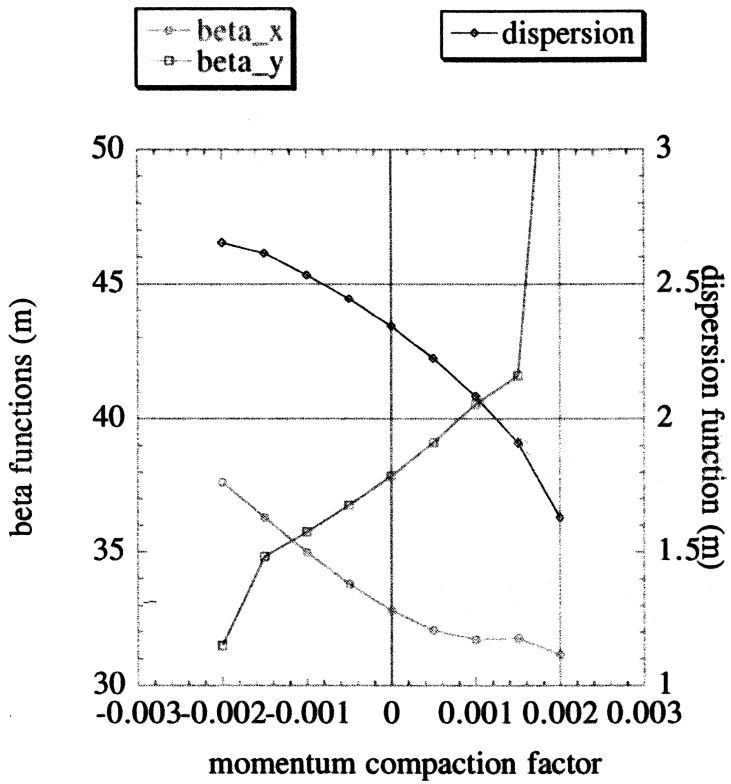
- 空間電荷共鳴による構造共鳴
  - 2nx＋2ny＝integer
  - 2nx－2ny＝integer
  - nx=22. 5
  - ny＝18, 19. 5, 21, 22. 5

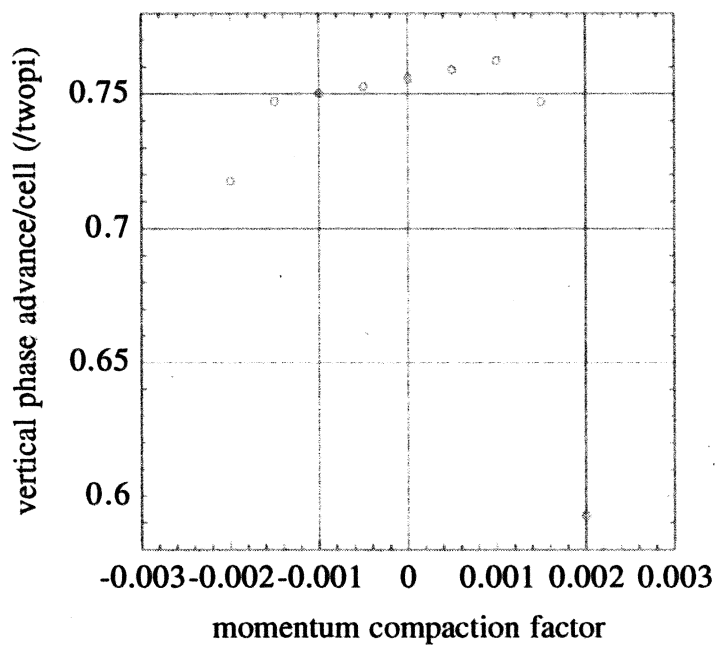
  を避ける。

- 空間電荷共鳴による3次の構造共鳴も避ける。

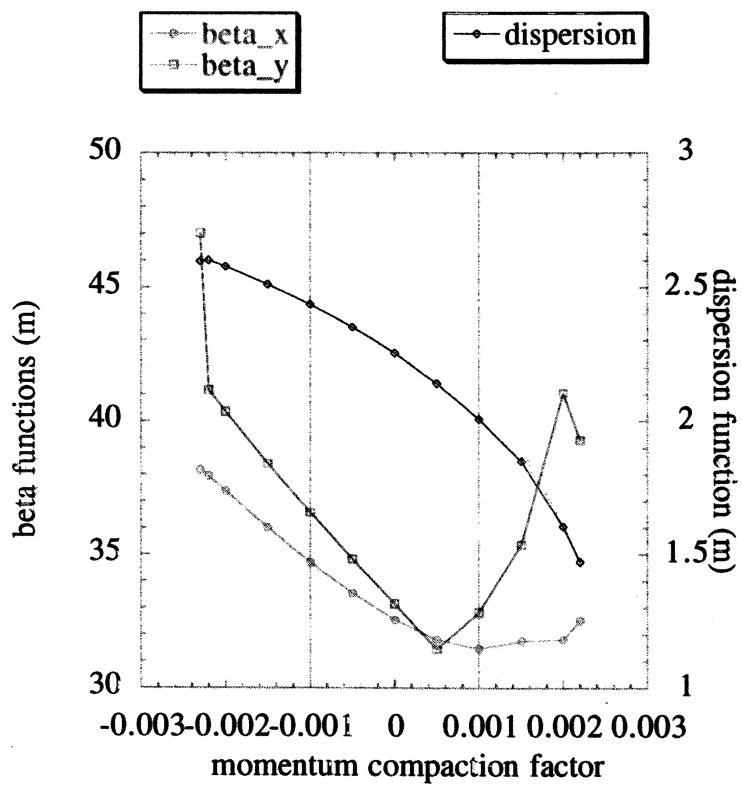


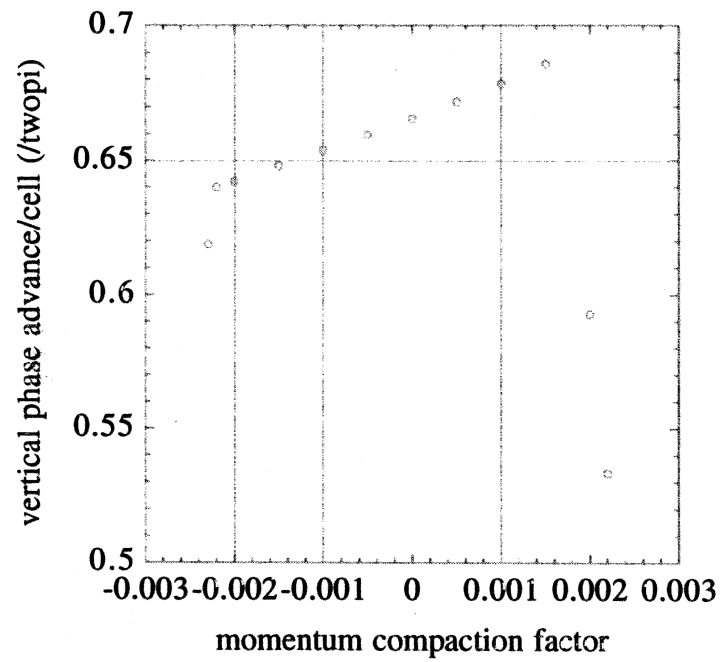
Variable Range of Momentum Compaction (high)



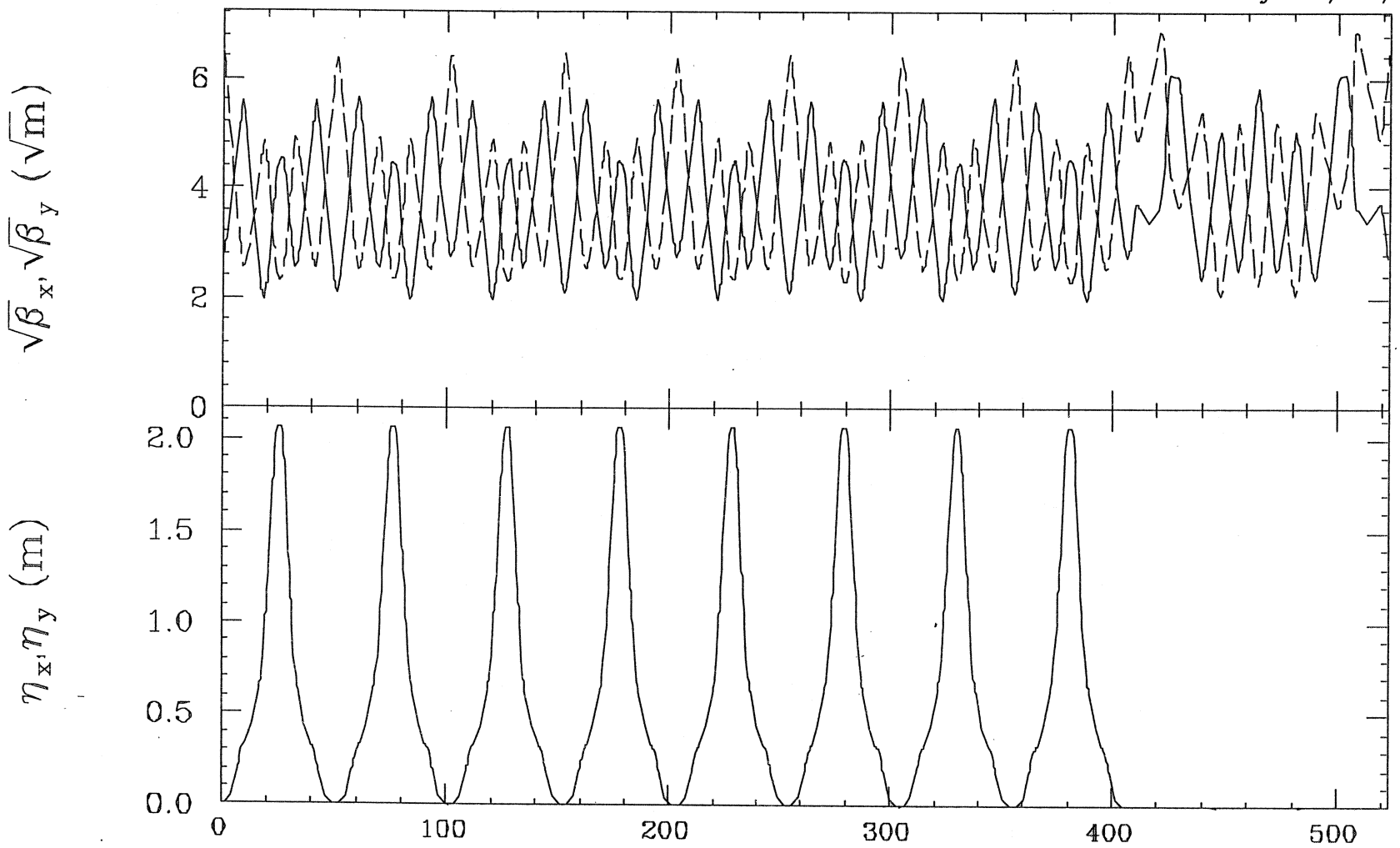


Variable Range of Momentum Compaction (low)





02:33:01 Wednesday 05/ 2/2001



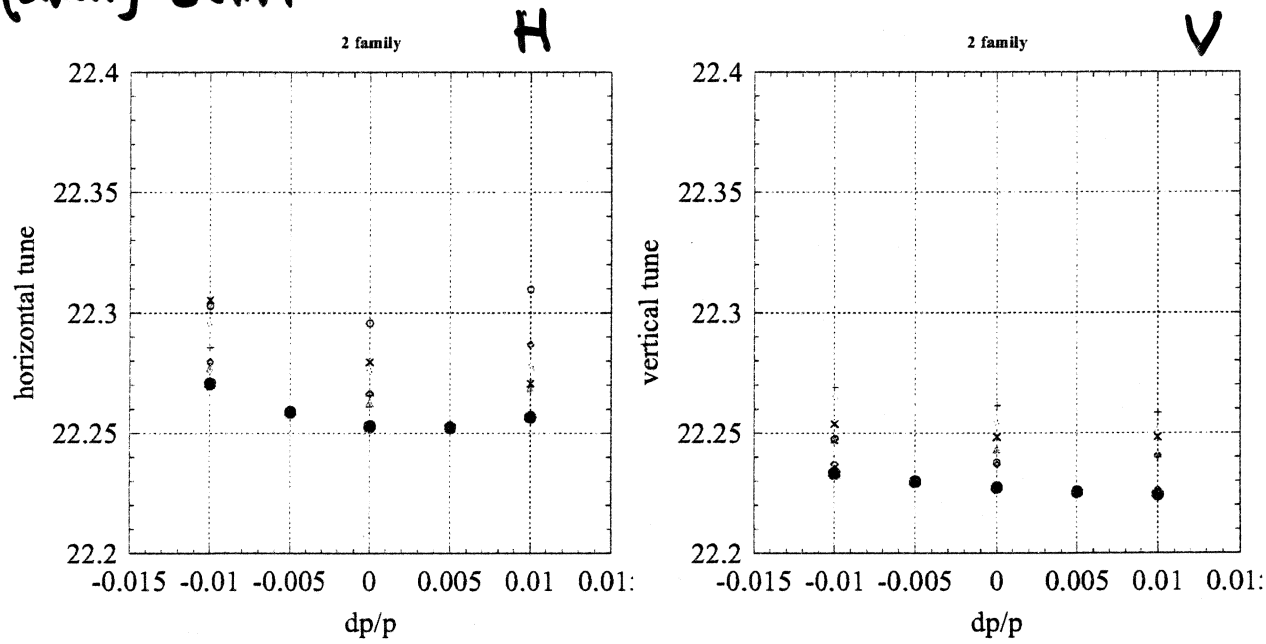
$\alpha_p = 0.001$ ($\gamma_t = 31.6$)

$\nu_x = 22.34$, $\nu_y = 20.30$

geometrical & chromatic aberration (tune)

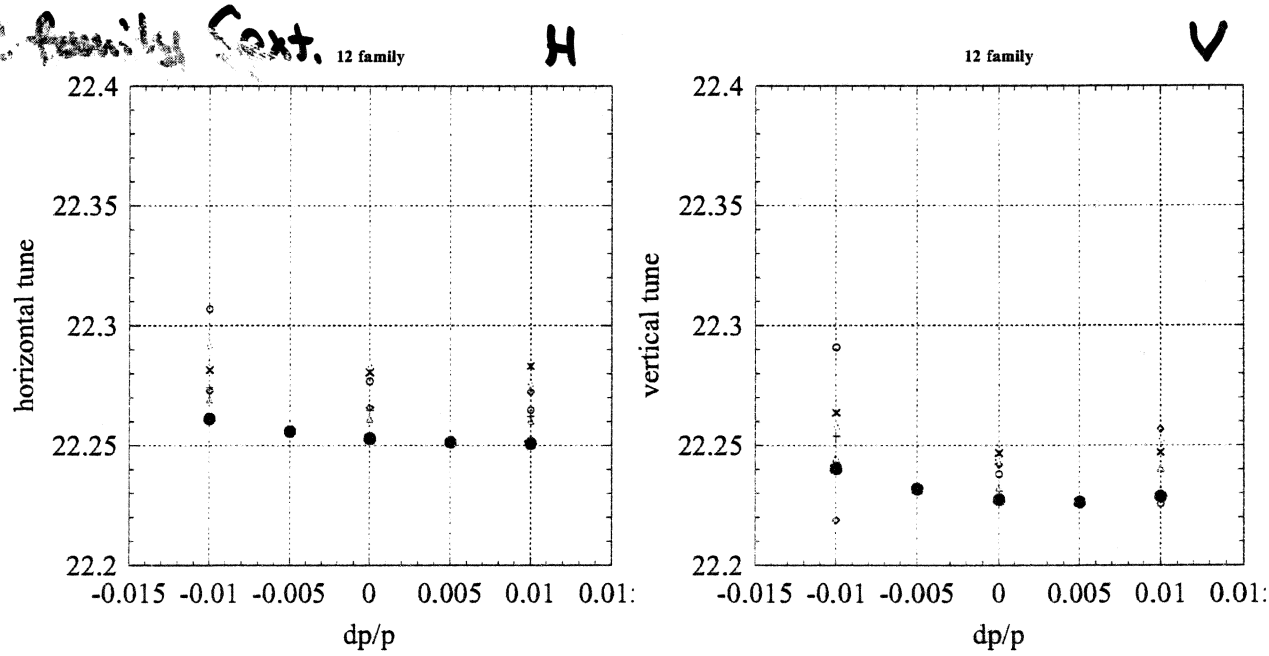
チューンの振幅依存性（2family）

2family Sext.



チューンの振幅依存性（12family）

12 family Sext.



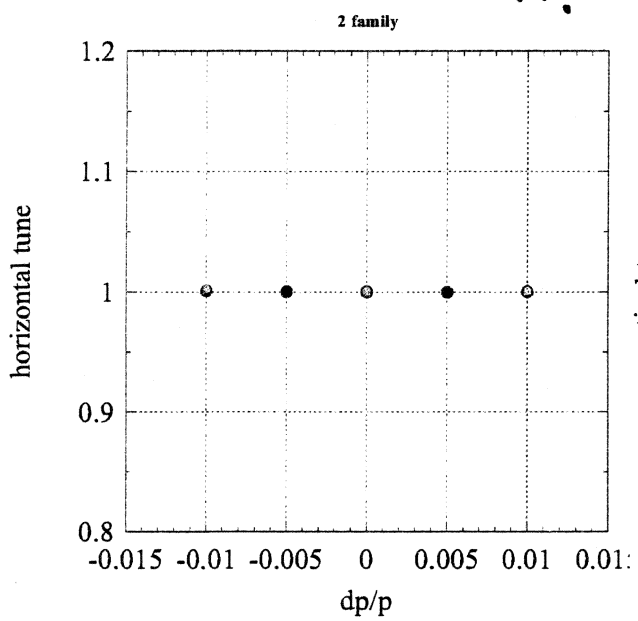
geometrical & chromatic aberration

ベーター関数の振幅依存性（2family）

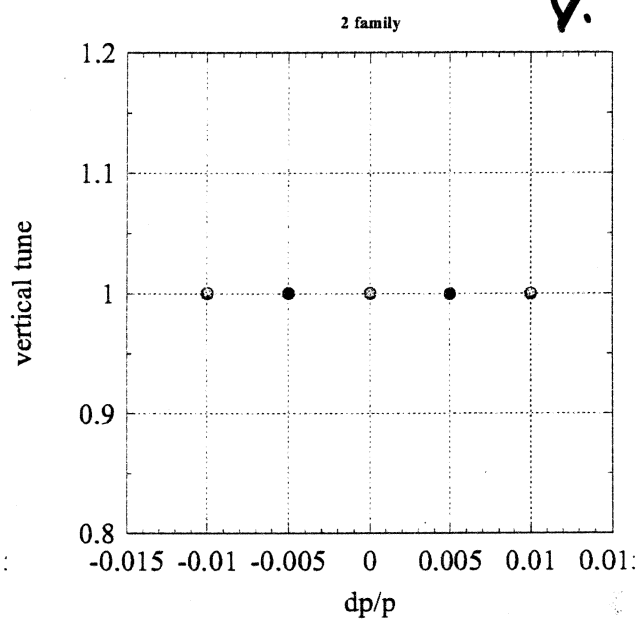
(β-function)

2 family Sext.

H.



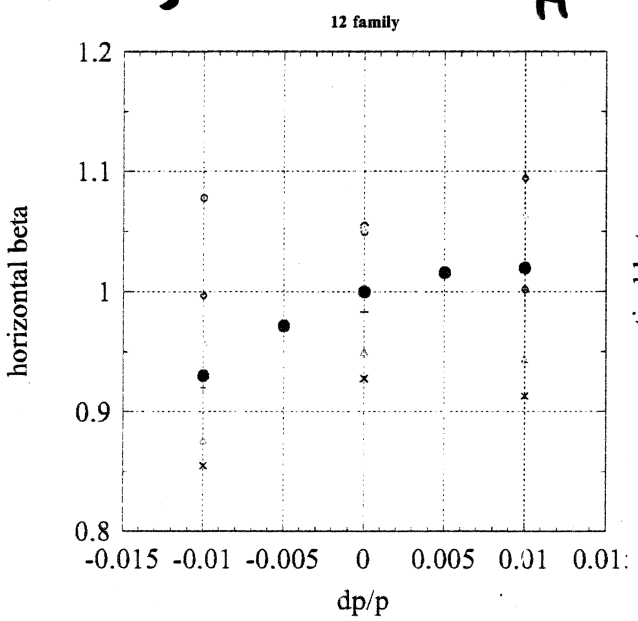
V.



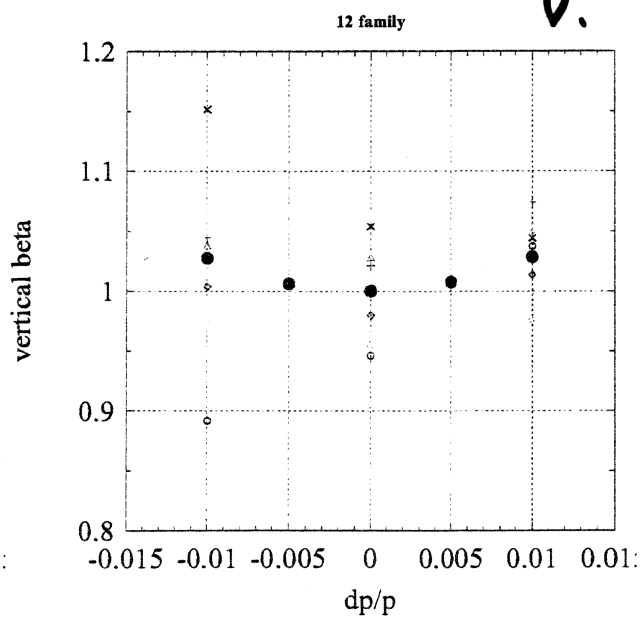
ベーター関数の振幅依存性（12family）

12 family Sext.

H



V.



dynamic aperture with 2 family Sext.

```
SEXT   SD1A    =(L =.4   K2 =-.231018822861 )
       SF1A    =(L =.4   K2 =.2631732775162 )
Display:   100 turns/character
     NZ      0----!----1----!----2----!----3----!----4----!----5
   -2.00 20 *************AAAAAAA7000000000000000000000000000000   -1%
   -1.00 21 **************AAAAAAA1000000000000000000000000000000
    0.00 21 **************AAAAAAA0000000000000000000000000000000   0%
    1.00 20 *************AAAAAAA1000000000000000000000000000000
    2.00 21 **************AAAAAAA1000000000000000000000000000000   +1%
     NZ      0----!----1----!----2----!----3----!----4----!----5
   Score:    103
```

色収差の補正のみの場合

```
Display:   100 turns/character
     NZ      0----!----1----!----2----!----3----!----4----!----5
   -2.00 20 *************AAAAAAA0000000000000000000000000000000   -1%
   -1.00 21 **************AAAAAAA0000000000000000000000000000000
    0.00 21 **************AAAAAAA0000000000000000000000000000000   0%
    1.00 20 *************AAAAAAA1000000000000000000000000000000
    2.00 20 *************AAAAAAA6000100000000000000000000000000   +1%
     NZ      0----!----1----!----2----!----3----!----4----!----5
   Score:    102
```

about 2 times magnet aperture is obtained.

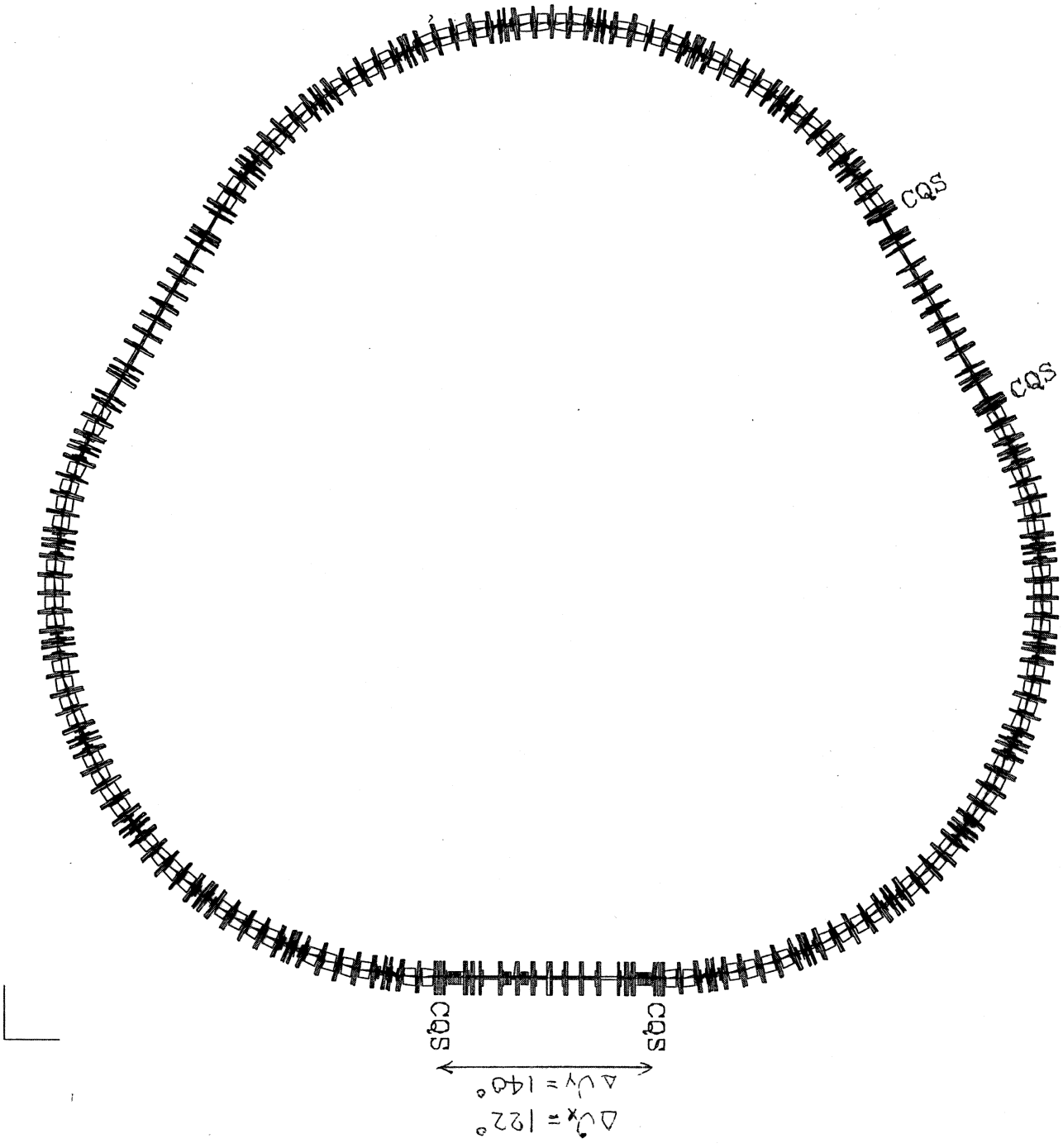
```
SEXT   SD1A    =(L =.4   K2 =-.2162694621286 )
       SF1A    =(L =.4   K2 =.3331988075587 )
       SD1B    =(L =.4   K2 =-.1370051908811 )
       SD2A    =(L =.4   K2 =-.3606174025981 )
       SF2A    =(L =.4   K2 =.1908925326879 )
       SD2B    =(L =.4   K2 =-.2619513493877 )
       SD3A    =(L =.4   K2 =-.2072844466999 )
       SF3A    =(L =.4   K2 =.3417901391306 )
       SD3B    =(L =.4   K2 =-.0951885733611 )
       SD4A    =(L =.4   K2 =-.3405172776304 )
       SF4A    =(L =.4   K2 =.189756288441 )
       SD4B    =(L =.4   K2 =-.2272518263433 )
       SD5B    =(L =.4   K2 =-.3405172776304 )
       SF5A    =(L =.4   K2 =.189756288441 )
       SD5A    =(L =.4   K2 =-.2272518263433 )
       SD6B    =(L =.4   K2 =-.2072844466999 )
       SF6A    =(L =.4   K2 =.3417901391306 )
       SD6A    =(L =.4   K2 =-.0951885733611 )
       SD7B    =(L =.4   K2 =-.3606174025981 )
       SF7A    =(L =.4   K2 =.1908925326879 )
       SD7A    =(L =.4   K2 =-.2619513493877 )
       SD8B    =(L =.4   K2 =-.2162694621286 )
       SF8A    =(L =.4   K2 =.3331988075587 )
       SD8A    =(L =.4   K2 =-.1370051908811 )
Display:   100 turns/character
     NZ      0----!----1----!----2----!----3----!----4----!----5
   -2.00 19 ************AAAAAAA17000000000000000000000000000000   -1%
   -1.00 20 *************AAAAAAA4A00000000000000000000000000000
    0.00 21 **************AAAAAAA10200000000000000000000000000000   0%
    1.00 20 *************AAAAAAA6A01000000000000100000000000000
    2.00 20 *************AAAAAAA92000000000000000000000000000000   +1%
     NZ      0----!----1----!----2----!----3----!----4----!----5
   Score:    100
```

色収差の補正のみの場合

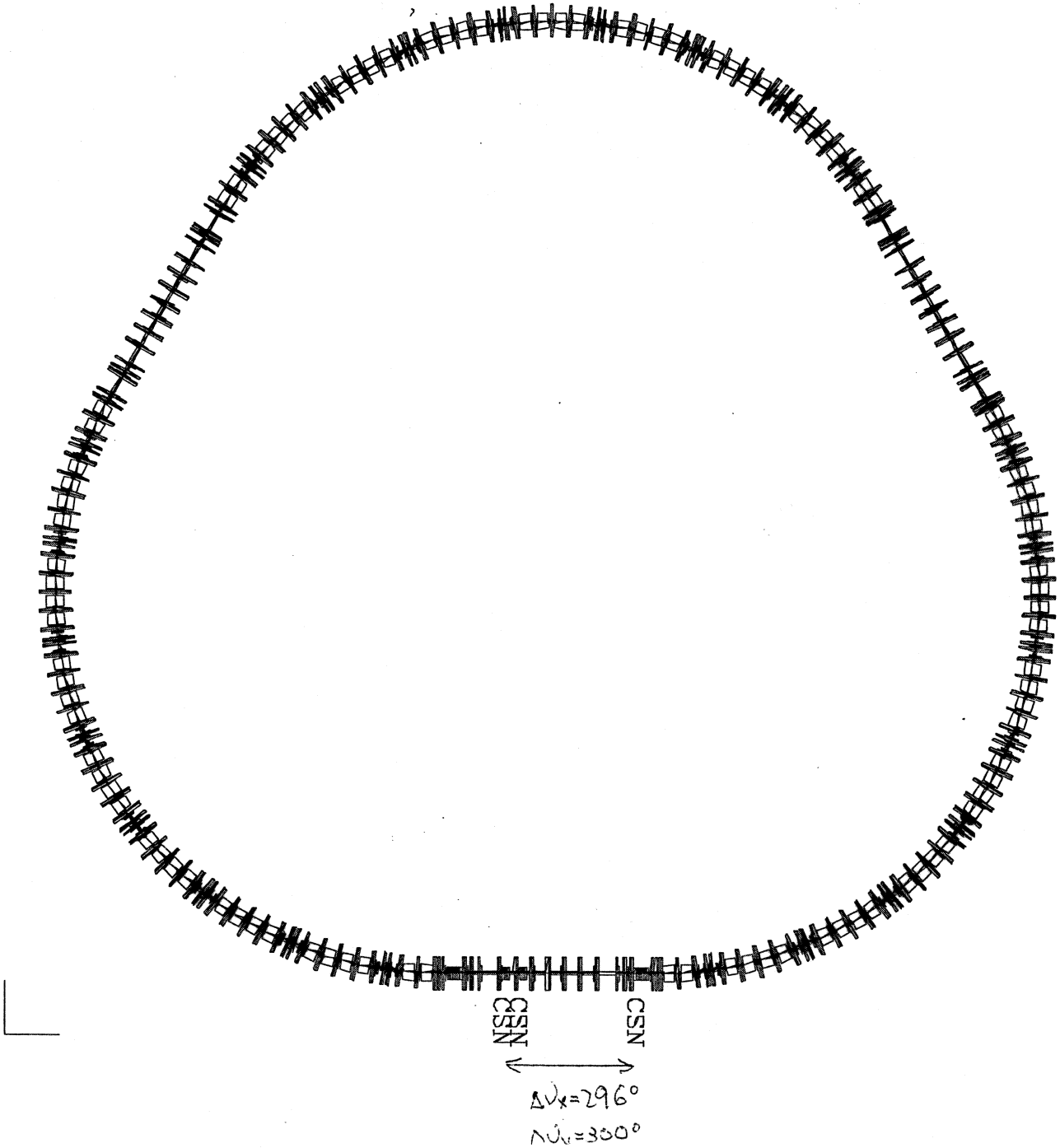
```
Display:   100 turns/character
     NZ      0----!----1----!----2----!----3----!----4----!----5
   -2.00 17 **********AAAAAAA72000000000000000000000000000000   -1%
   -1.00 19 ************AAAAAAA08000000000000000000000000000000
    0.00 19 ************AAAAAAA00000000000000000000000000000000   0%
    1.00 17 **********AAAAAAA10000000000000000000000000000000
    2.00 18 ***********AAAAAAA00000000000000000000000000000000   +1%
     NZ      0----!----1----!----2----!----3----!----4----!----5
   Score:    90
```

dynamic aperture with 12 family Sext.

02:40:58 Wednesday 05/ 2/2001



00:16:45 Sunday 04/29/2001



RPAH031

Optimization of an Operating Point in High Intensity Synchrotrons

Shinji Machida
KEK

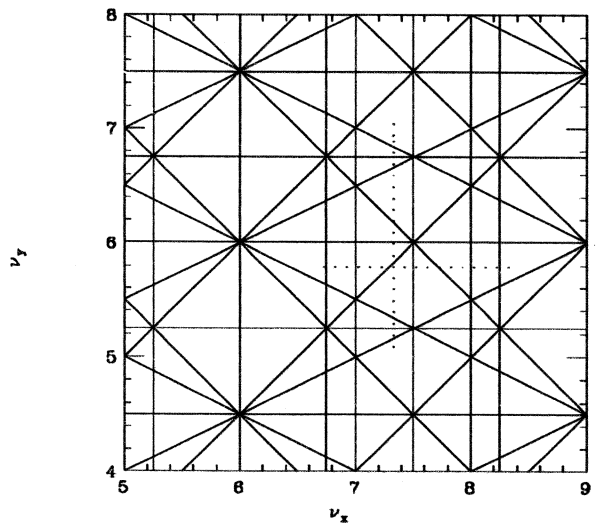
PAC2001, June 21

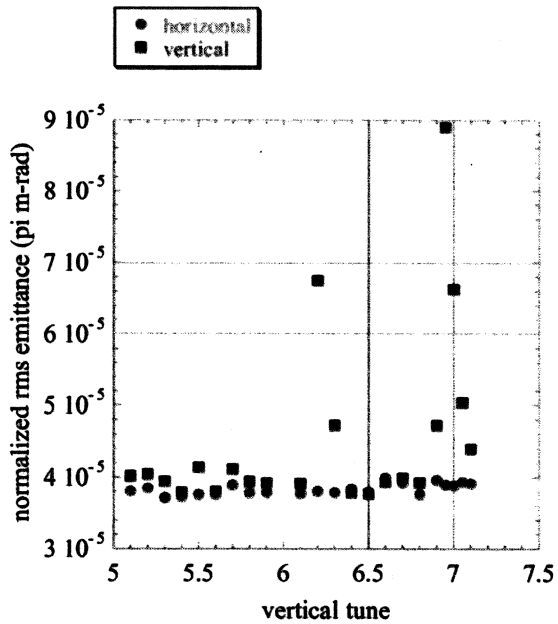
Abstract

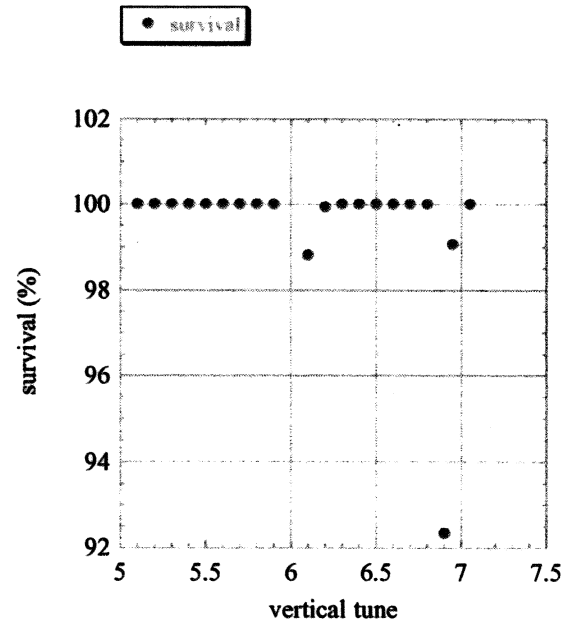
In a synchrotron such as JHF 3GeVPS and 50GeVPS, choice of an operating point in tune space depends mostly high intensity behavior of a proton beam, not by error fields of magnet manufacturing. Taking that into account, we have started a dry run of optimization of an operating point, namely, simulation of tune survey with space charge.

The idea is to simulate the early stage of commissioning process so that obviously fatal area in tune space is excluded from the beginning in the real commissioning and unnecessary radioactivation due to beam loss is minimized.

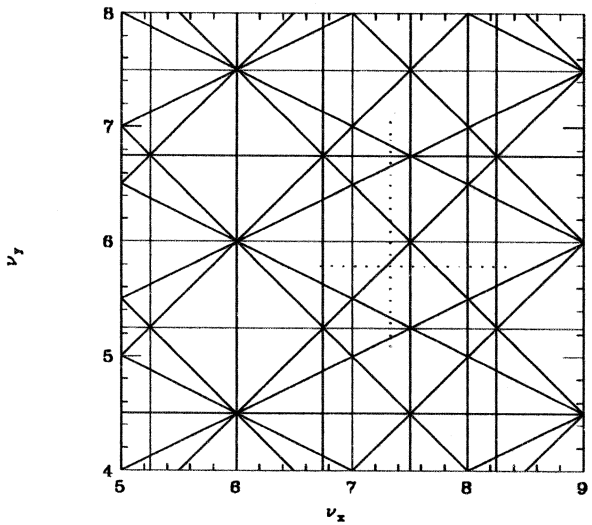
Tune Survey in Vertical Direction (3-fold hgt)

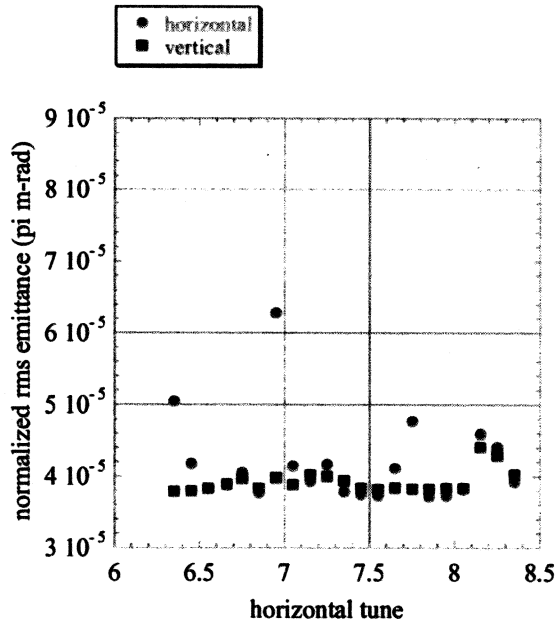


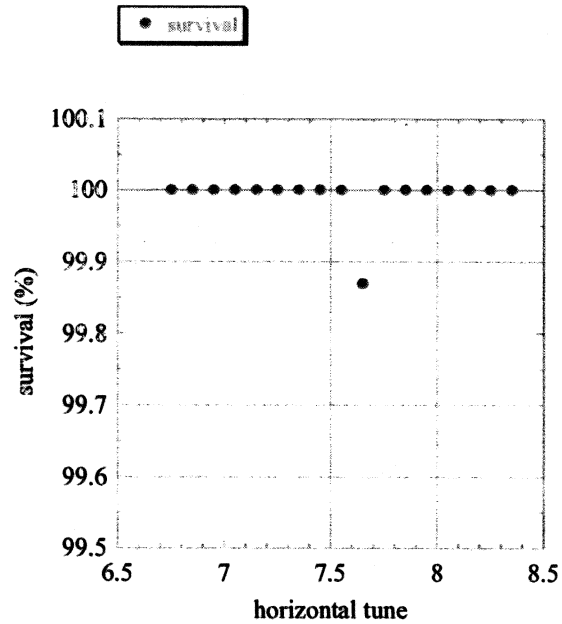




Tune Survey in Horizontal Direction (3-fold hgt)

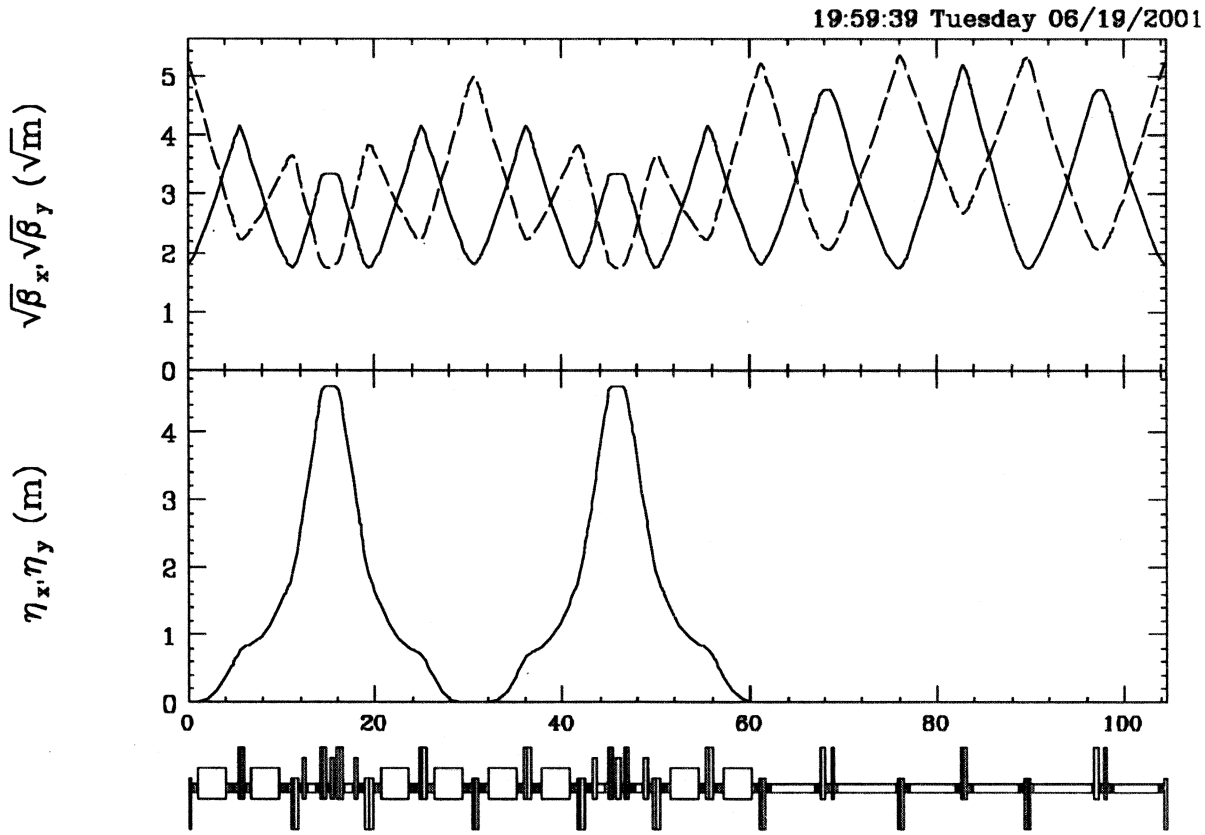






Lattice structure

As an example, JHF 3GeVPS lattice is considered. It has three-fold symmetry. Each superperiod consists of two 3-DOFO modules with missing bends in arc and 3-FODO in insertion. The right figure shows lattice functions in one superperiod.



Beam parameters

intensity	4.2×10^{13} ppb
harmonic number	2
energy	400 MeV to 3 GeV
un-normalized emittance (100%)	
at injection	144 π mm-mrad
momentum spread (rms)	+-0.2%
incoherent tune shift	
at injection	-0.32