- Part I, Status of CEPC Accelerator (Physics) Study
- Part II, Multi-Objective Optimization with possible application in SuperKEKB

Status of CEPC Accelerator (Physics) Study

Yuan Zhang for CEPC Accelerator Team

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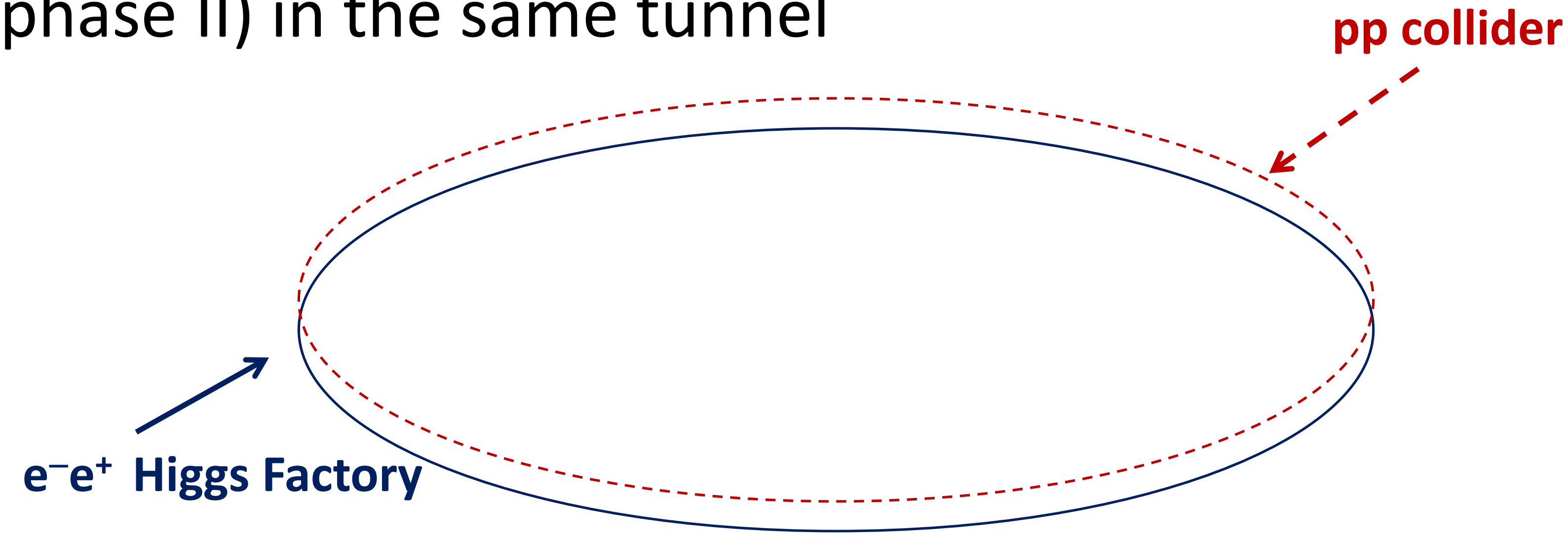
KEK Mar, 2016

What is a (CEPC + SppC) (Q. Qin)

- Circular Higgs factory (phase I) + super pp collider (phase II) in the same tunnel



CEPC-SPPC

Preliminary Conceptual Design Report

March 2015

300 authors from 57 institutions in 9 countries

The CEPC-SPPC Study Group

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International Review (Feb 14-16, 2015)

International Review Committee Members:

Ralph Assmann, DESY (Germany)
Ilan Ben-Zvi, BNL (USA)
Marica Biagini, INFN (Italy)
Mike Koratzinos, CERN/U. Geneva (Switzerland)
Eugene Levichev, BINP (Russia)
Katsunobu Oide (Chair), KEK (Japan)
Bob Rimmer, JLab (USA)
John Seeman, SLAC (USA)
Zhentang Zhao, SSRC (China)

Committee wrote a 17-page detailed report.

Committee's response to the charges:

1. The Committee considers the CEPC-SPPC to be well aligned with the future of China's HEP program, and in fact the future of the global HEP program.
2. The design goals are well defined and comprehensive. We provided remarks and recommendations to improve the design, but **we definitely consider this design to be credible and with sufficiently conservative assumptions.**
3. The great majority of the accelerator physics issues are adequately addressed, and after addressing our recommendations, we expect that all the accelerator physics issues would be adequately addressed.
4. The designs of the technical systems and conventional facilities are effective for achieving the performance goals.
5. We find the CEPC design compatible with the future upgrade to the SPPC.
6. Technical risks and their potential impact were presented together with mitigation measures, while in some cases more study and R&D are needed.
7. **The R&D program is clearly defined**, and while we recommended a few additional R&D items, the program is adequate. We further believe that this R&D program will be highly beneficial to the science and technology infrastructure in China and will contribute to its economy.
8. We made a few suggestions for improvements of the design.

CEPC-SPPC Timeline (preliminary)

2nd Milestone: 13th Five Year Plan R&D

CEPC

2015 | 2020 | 2025 | 2030 | 2035

Pre-studies (2013-2015)	R&D Engineering Design (2016-2020)	Construction (2021-2027)	Data taking (2028-2035)

1st Milestone: Pre-CDR (by the end of 2014) → R&D funding request to Chinese government in 2015 (China's 13th Five-Year Plan 2016-2020)

SPPC

2020 | 2030 | 2040

R&D (2014-2030)	Engineering Design (2030-2035)	Construction (2035-2042)	Data taking (2042-2055)

CEPC Design – Top Level Parameters

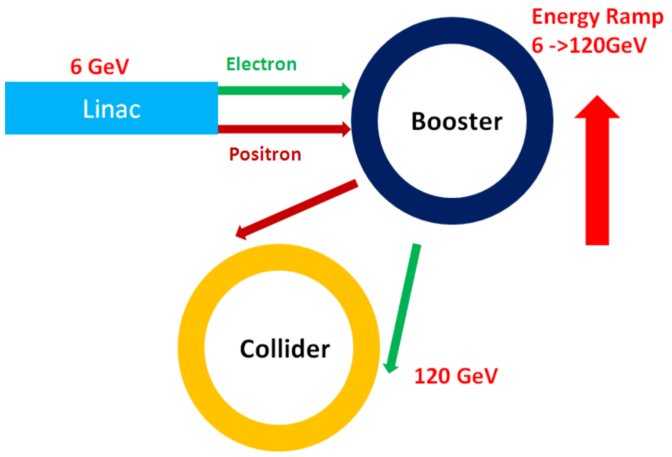
Parameter	Design Goal
Particles	e+, e-
Center of mass energy	240 GeV
Integrated luminosity (per IP per year)	250 fb^{-1}
No. of IPs	2

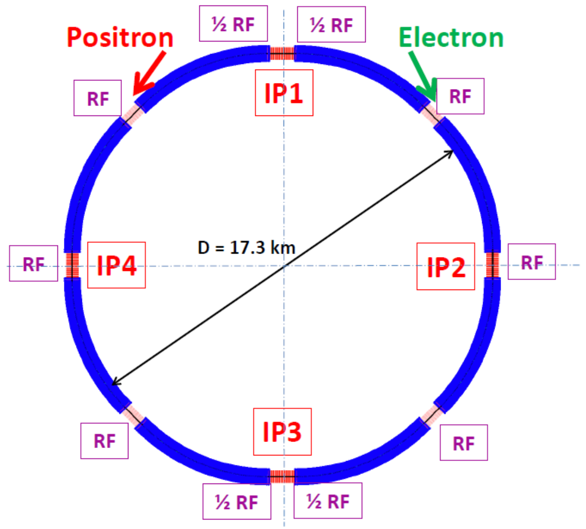
⇒ one million Higgs from 2 IPs in 10 years

CEPC Design – Z-pole Parameters

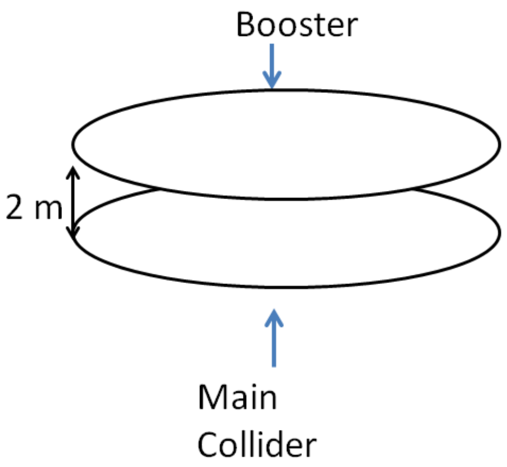
Parameter	Design Goal
Particles	e+, e-
Center of mass energy	45.5 GeV
Integrated luminosity (peak)	>1*10^34/cm^2s
No. of IPs	2

Injectors

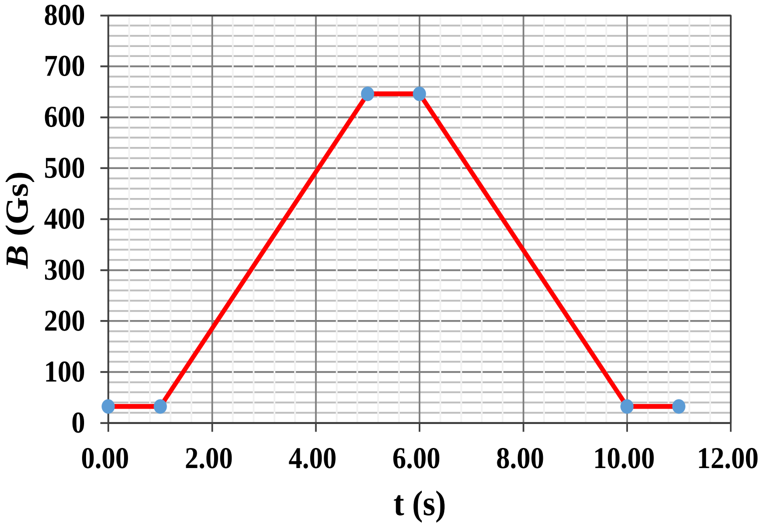




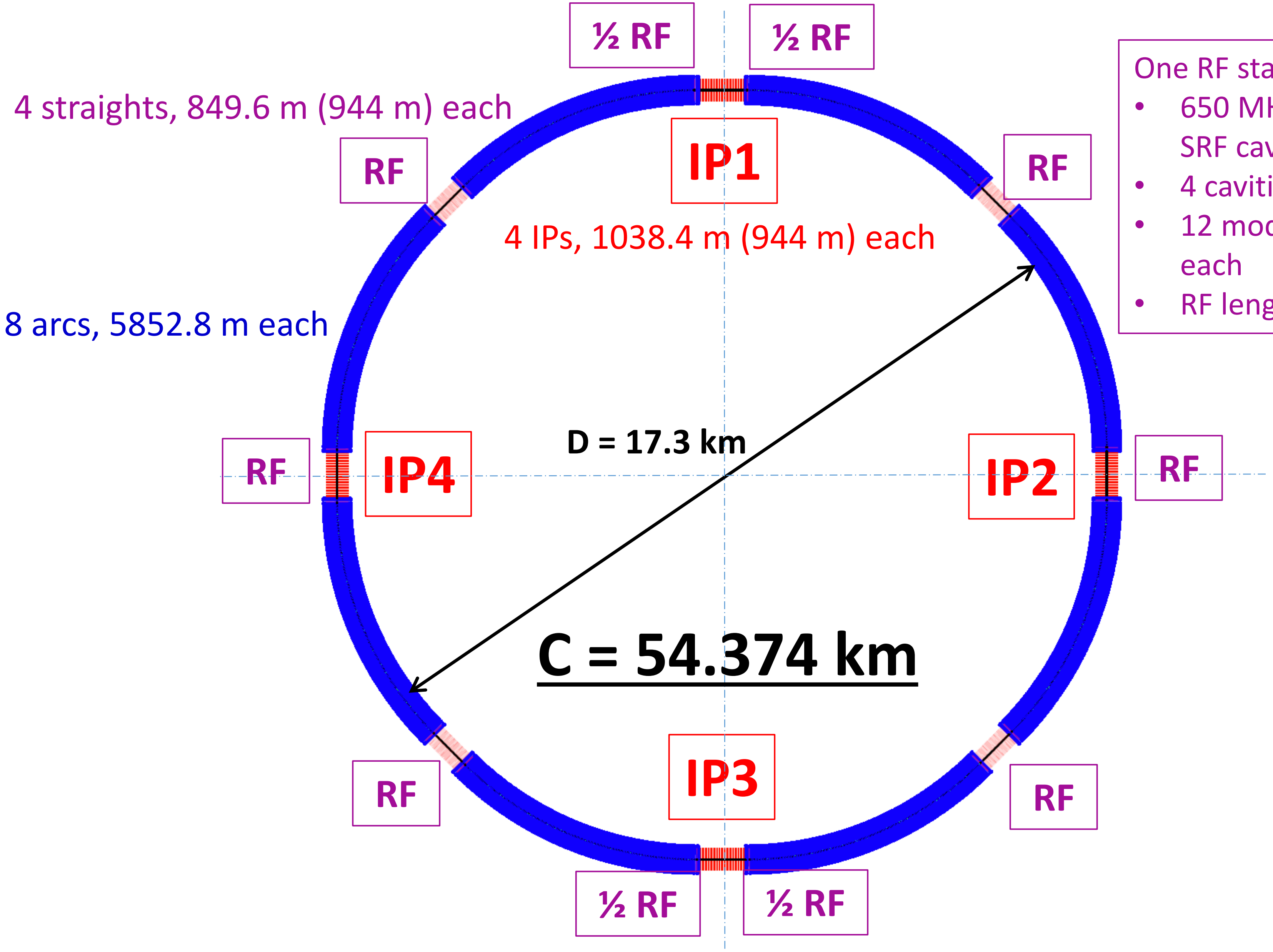
Top-up Full-energy Injection



Booster Cycle (0.1 Hz)



CEPC Lattice Layout (September 24, 2014)



One RF station:

- 650 MHz five-cell SRF cavities;
- 4 cavities/module
- 12 modules, 10 m each
- RF length 120 m

CEPC Design – Main Parameters

Parameter	Unit	Value	Parameter	Unit	Value
Beam energy [E]	GeV	120	**Circumference [C]**	m	54752
Number of IP[N_{IP}]		2	**SR loss/turn [U_0]**	GeV	3.11
Bunch number/beam[n_B]		50 (48)	**Bunch population [Ne]**		3.79E+11
SR power/beam [P]	MW	51.7	**Beam current [I]**	mA	16.6
Bending radius [ρ]	m	6094	**momentum compaction factor [α_p]**		3.36E-05
Revolution period [T_0]	s	1.83E-04	**Revolution frequency [f_0]**	Hz	5475.46
emittance (x/y)	nm	6.12/0.018	**β_{IP}(x/y)**	mm	800/1.2 (3)
Transverse size (x/y)	μm	69.97/0.15	**$\xi_{x,y}$/IP**		0.118/0.083
Bunch length SR [$\sigma_{s.SR}$]	mm	2.14	**Bunch length total [$\sigma_{s.tot}$]**	mm	2.65
Lifetime due to Beamstrahlung	min	47	**lifetime due to radiative Bhabha scattering [τ_L]**	min	51
RF voltage [V_{rf}]	GV	6.87	**RF frequency [f_{rf}]**	MHz	650
Harmonic number [h]		118800	**Synchrotron oscillation tune [ν_s]**		0.18
Energy acceptance RF [h]	%	5.99	**Damping partition number [J_ε]**		2
Energy spread SR [$\sigma_{\delta.SR}$]	%	0.132	**Energy spread BS [$\sigma_{\delta.BS}$]**	%	0.096
Energy spread total [$\sigma_{\delta.tot}$]	%	0.163	**n_γ**		0.23
Transverse damping time [n_x]	turns	78	**Longitudinal damping time [n_ε]**	turns	39
Hourglass factor	Fh	0.68	**Luminosity /IP[L]**	$cm^{-2}s^{-1}$	2.04E+34

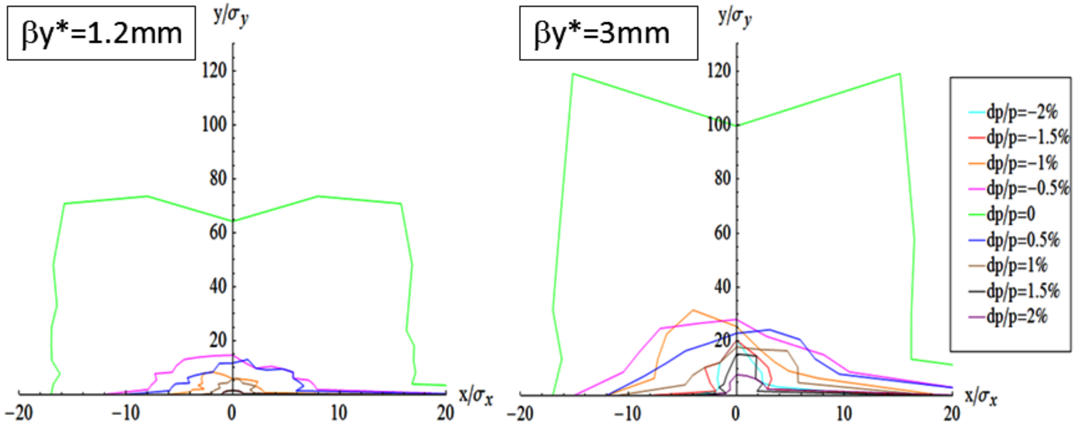
CDR Worklist (0)

General Comment:

- Pre-CDR is easy
- CDR is hard
- Why? Because we leave all hard things to CDR!
- But still, the Pre-CDR was a success:
  - made it possible to propose this project to the government in the 13th five-year plan
  - formed a CEPC-SPPC team
  - provided a baseline design
  - gave China the needed credit in the world HEP community that it is capable to carry out this project

CDR Worklist (3)

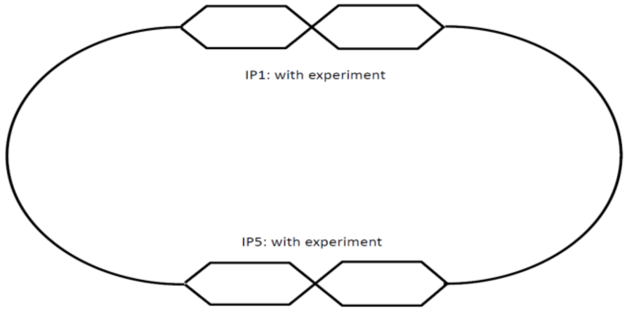
5. Dynamic aperture for L*= 1.5m, β_y^*= 3mm



6. Pretzel scheme:

to complete a consistent design including beam orbit/optics in the arcs and IRs, dynamic aperture, beam-beam, beam injection, etc.

7. Investigating alternative designs:



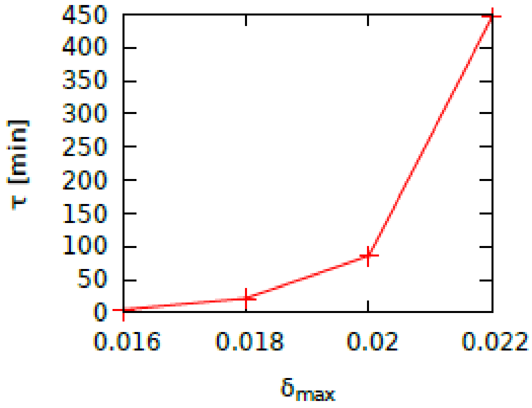
CDR Worklist (4)

8. **Saw-tooth orbit**
   - 0.3% energy error within an arc
   - for single-pipe design, there is no way to correct it
   - various effects on the beam
9. **To start machine errors analysis**
10. **To start corrector design**
11. **Arc lattice optimization, e.g.,**
    - working point
    - horizontal emittance
    - phase advance
    - momentum compaction
    - bunch length and RF voltage
12. **IR optics**
    - optimize β_y at the sextupoles
    - including fringe field, solenoid and compensation, errors and tolerances

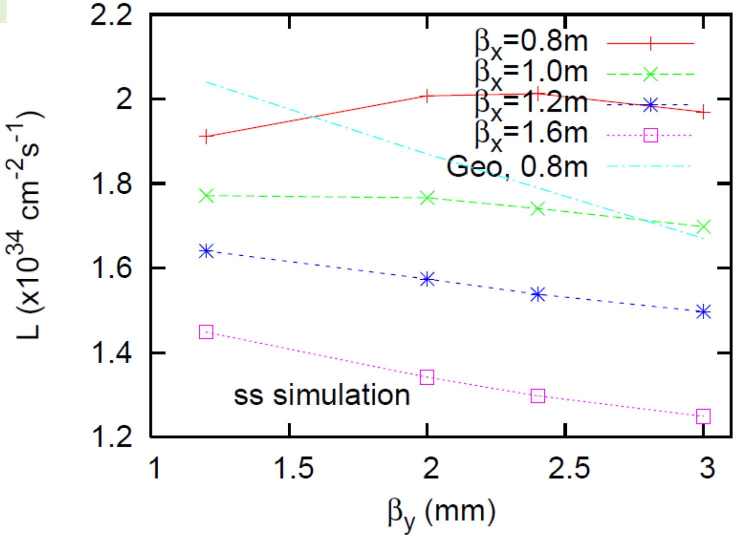
CDR Worklist (5)

13. Beam-beam effect:

Momentum acceptance *vs.* Beam lifetime



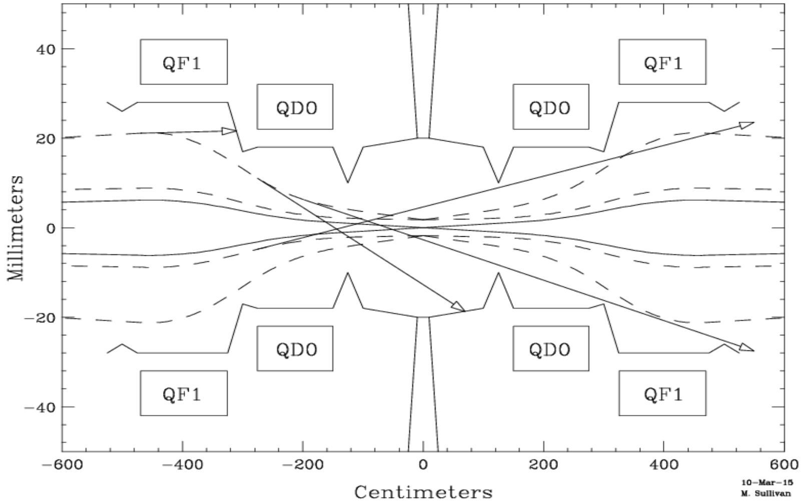
Luminosity *vs.* Beta*



- to study beam-beam from parasitic crossing
- this is especially important in Z operation due to large number of crossings
- compensation method

CDR Worklist (6)

14. **To establish an emittance budget**
    - from source to linac to Booster to collider
    - including machine imperfection and allowance, optics mismatch and energy errors
15. **To establish a geometric aperture model for the collider**
    - including the injection region, beam dump region, doublet, maximum beta area
16. **Machine-detector interface (MDI)**
    - radiation shielding design
    - simulation using Sullivan's code
    - collimator design



CDR Worklist (7)

17. **Beam instability**
    - to establish a realistic impedance model instead of scaling from KEKB or LEP, including separators, collimators, ferrite damper in RF, etc.
    - Banana effect due to transverse wake from off-center orbit
    - to study instabilities at Z-pole, which has lower energy and higher beam current
    - feedback system design
18. **Orbit stability**
    - not covered in the Pre-CDR but should be in the CDR
19. **Polarization**
    - not included for Higgs operation
    - but may be needed for Z operation
    - even for Higgs, we may need it for energy calibration
    - to investigate the options (e.g., Gai Wei's scheme)

CDR Worklist (8)

20. Source and linac

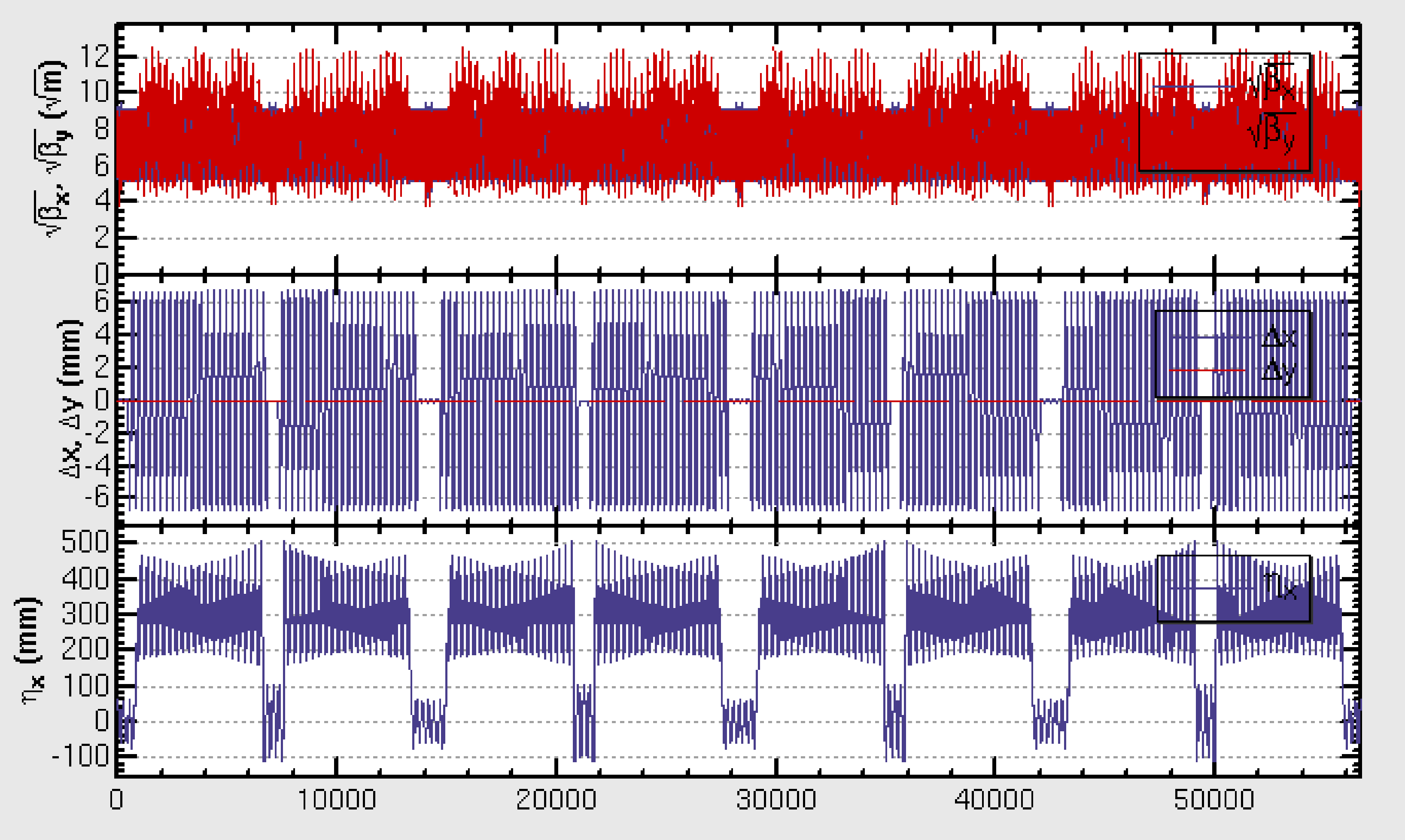
- a complete simulation for e+ beam: from the e- beam to target to capture to transport line to re-injection into the linac to acceleration to injection into the Booster
- If the requirement of 3 nC, 0.3 mm-mrad cannot be met, then a damping ring is needed in the CDR
- e+ beam return line design
- SLAC has offered us a 15 GeV linac including klystrons as well as two damping rings. We need a decision about whether we will take the offer. If yes, when and how.
- to include the study for Z operation, which needs higher beam current

21. Booster

- to mitigate low field injection problem: earth field shielding, to add SLAC's linac, to add a pre-Booster
- To study saw-tooth effect, vacuum pipe, eddy current, machine imperfection, correctors, etc.

Pretzel Scheme

After adding pretzel orbit (with correction) :



Solution need to be improved….

GENG Huiping

Main output parameters:

```
Design momentum        P0 = 120.00000 GeV  F                     f0 = 5292.9459 Hz
Energy loss per turn U0 = 3117.5564 MV     Effective voltage     Vc = 6870.0000 MV
Equilibrium position dz = 34.554035 mm     Momentum compact. alpha = 3.2353E-5
Orbit dilation          dl =   .0000000 mm  Effective harmonic #   h = 122880.00
Bucket height      dV/P0 =   .0599503

  Imag.tune:-0.0000000          0.0000000          -0.0000000
  Real tune: 0.0852147          0.1789284          -0.1796644

    Damping per one revolution:
          X : -2.226889E-02    Y : -1.290562E-02    Z : -1.626322E-02
    Damping time (sec):
          X :  8.484064E-03    Y :  1.463941E-02    Z :  1.161705E-02
    Tu                    ation:
                         5    Y : -3.278430E-08    Z :  2.805327E-05
    Damping partition number:
          X :     1.7317       Y :     1.0036       Z :     1.2647

Emittance X            = 3.77813E-9 m                         =  .00000000 m
Emittance Z            = 4.39763E-6 m   Energy spread         =  .00164455
Bunch Length           = 2.67407981 mm  Beam tilt             =  .00000000 rad
Beam size xi           =  .58021456 mm  Beam size eta         =  .00000000 mm
```

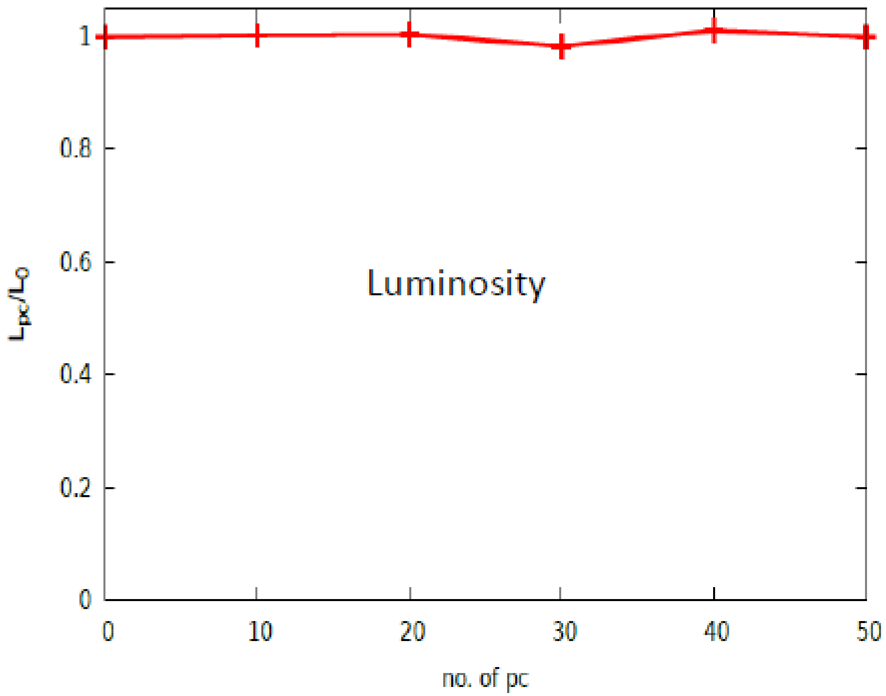
Was 3012MV

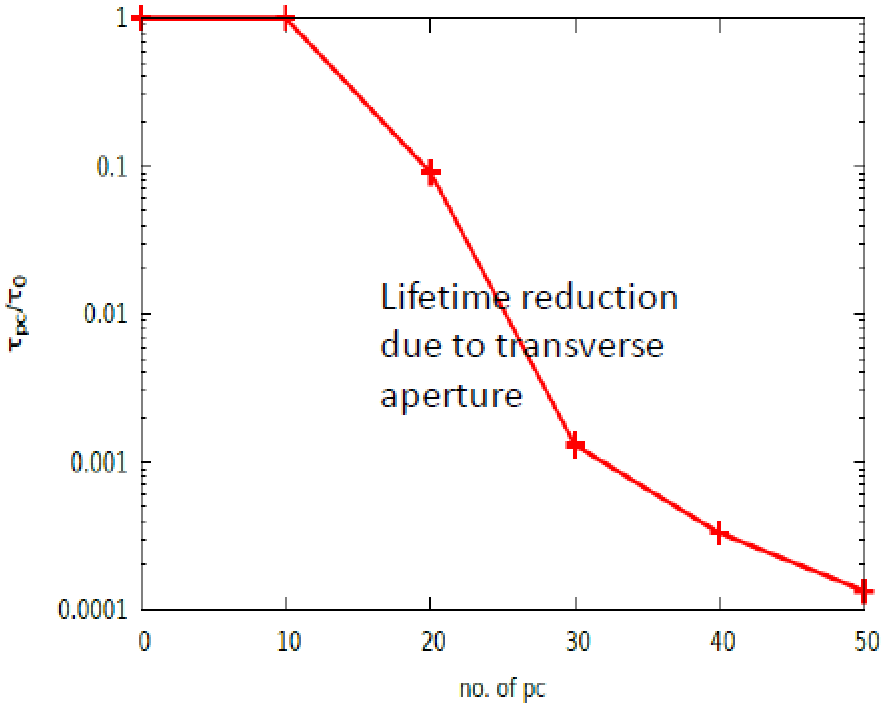
Was 1.0

Was 6.28nm

GENG Huiping

Number of PC (with lifetrac)

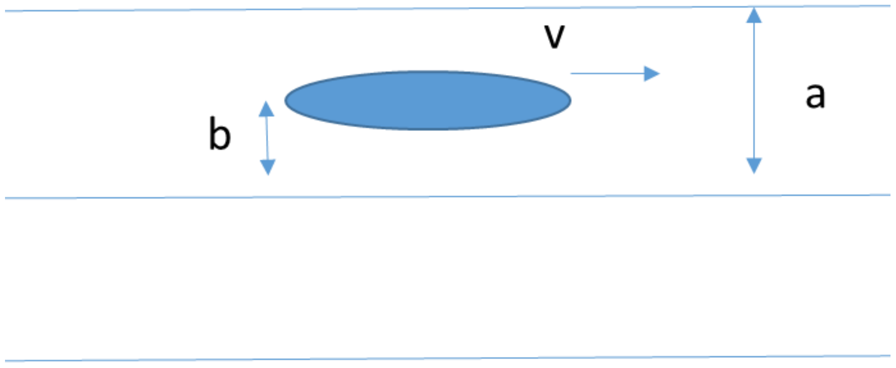


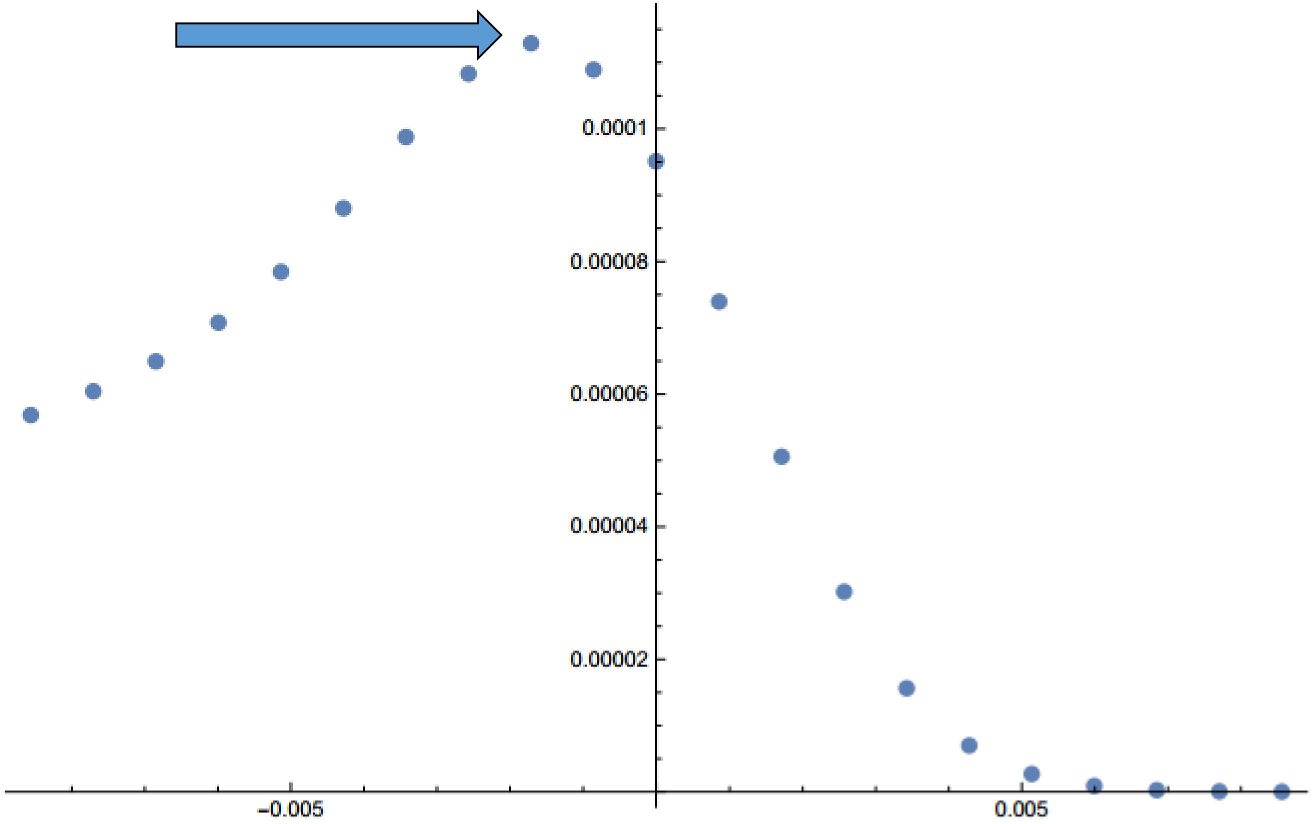


Beam Tilt Estimation

$$\sigma_x = 69.97(\mu m) \approx 0.7 * 10^{-4}(m)$$

$$\Delta X_{\max} \approx 1.16 * 10^{-4}(m)$$



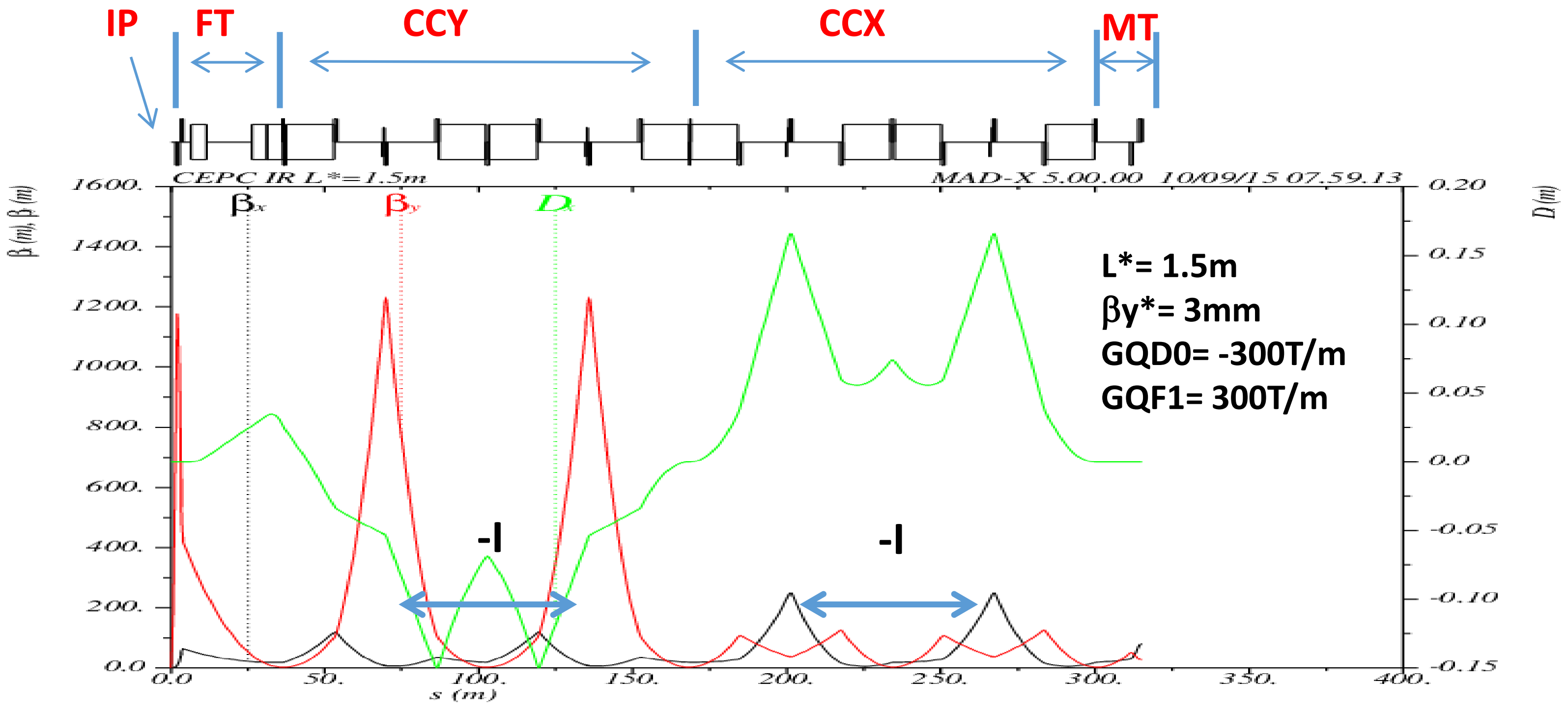


SUN Yuansheng

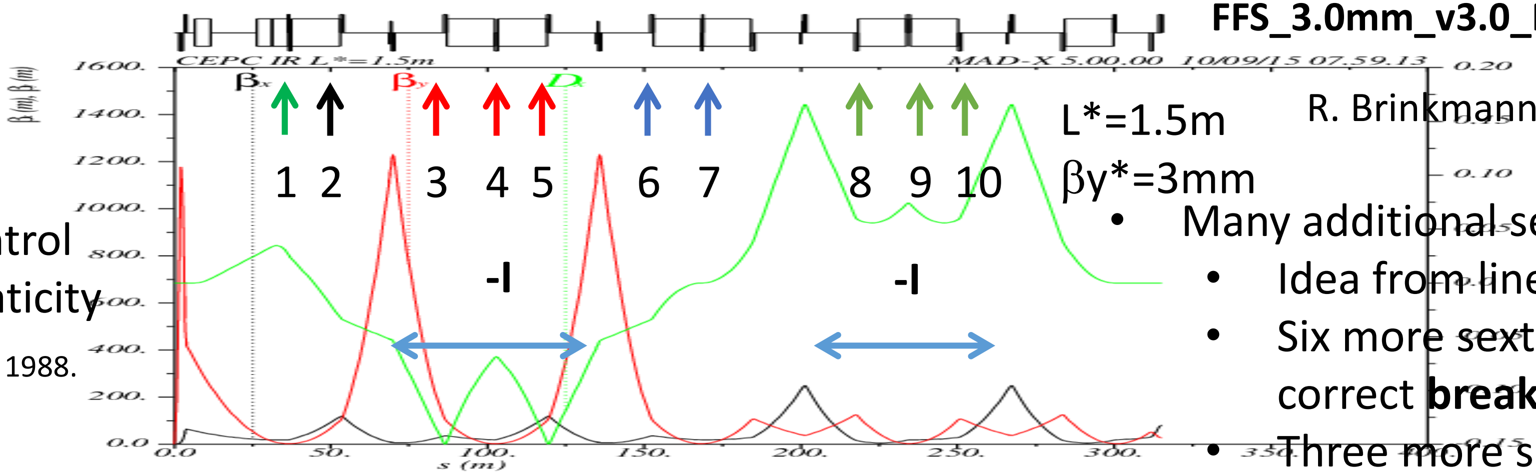
Interaction Region

Lattice of interaction region

- IR lattice design with local chromaticity correction with
  - βx*=0.8m, βy*=3mm, εx=6.12nm, κ=0.3%, L*=1.5m, 2IPs
  - latest lattice for head-on collision: **FFS_3.0mm_v3.0_Nov_2015**



-I break down and high order dispersion



FFS_3.0mm_v3.0_Nov_2015

L*=1.5m

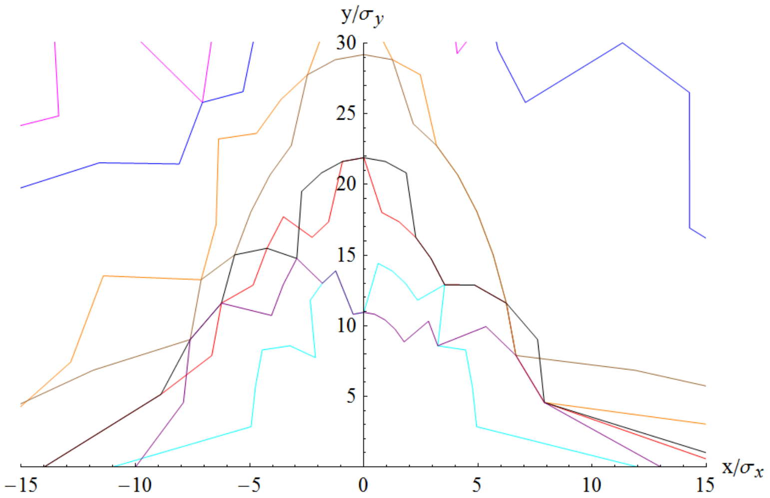
βy*=3mm

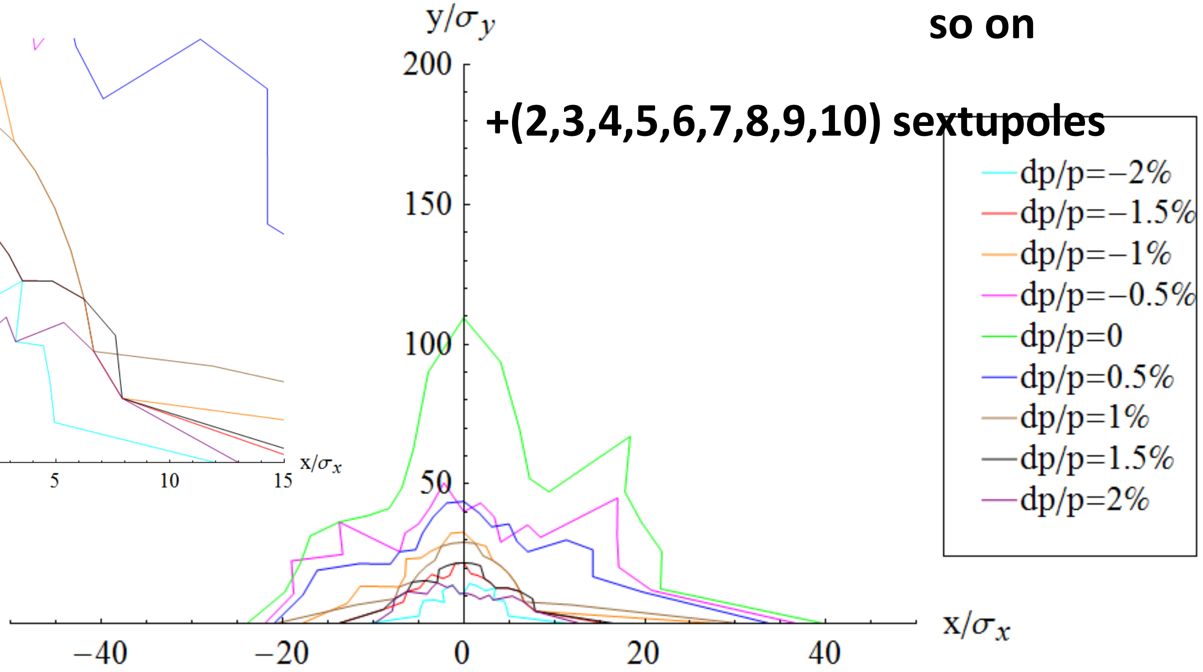
R. Brinkmann, DESY M-90-14, Nov 1990.

additional sext at 1st image point* to control higher order chromaticity

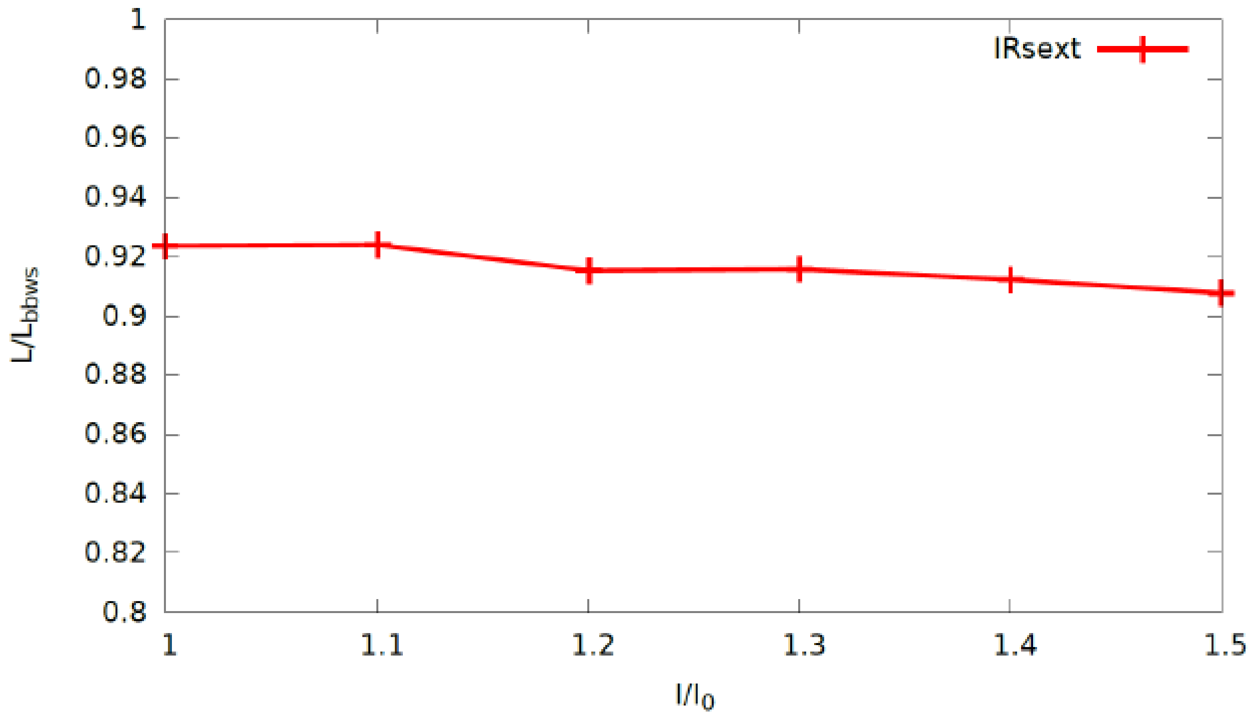
*K. Oide, SLAC-PUB-4806, Nov 1988.

- Many additional sextupoles in IR
  - Idea from linear collider final focus*
  - Six more sextupoles (3,4,5,8,9,10) to correct **break down of –I transformation**
  - Three more sextupoles (2,6,7) help to correct the **second order dispersion and so on**

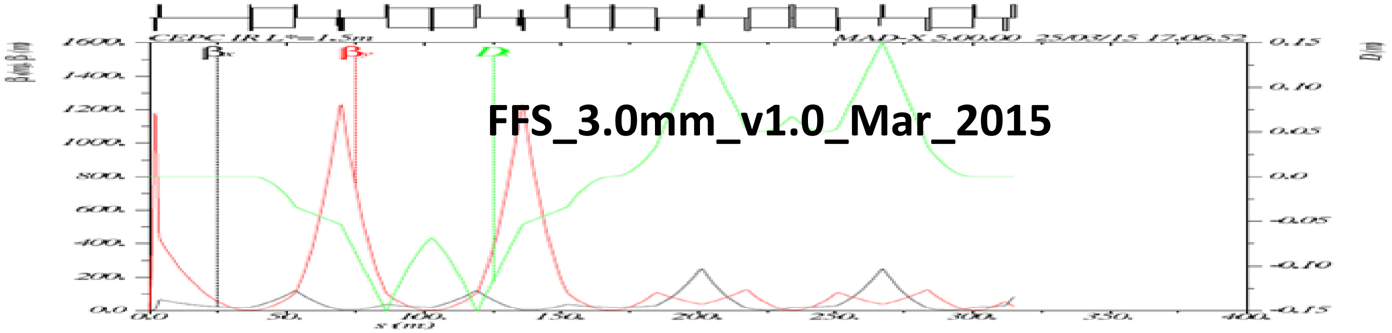


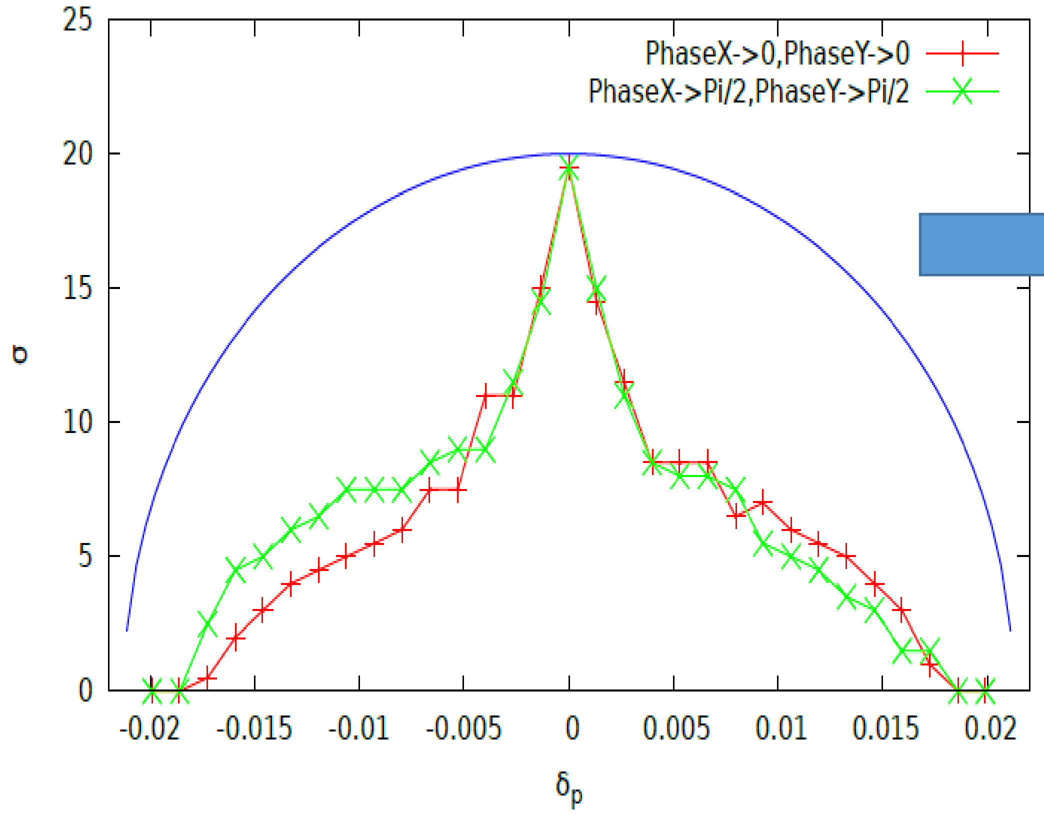


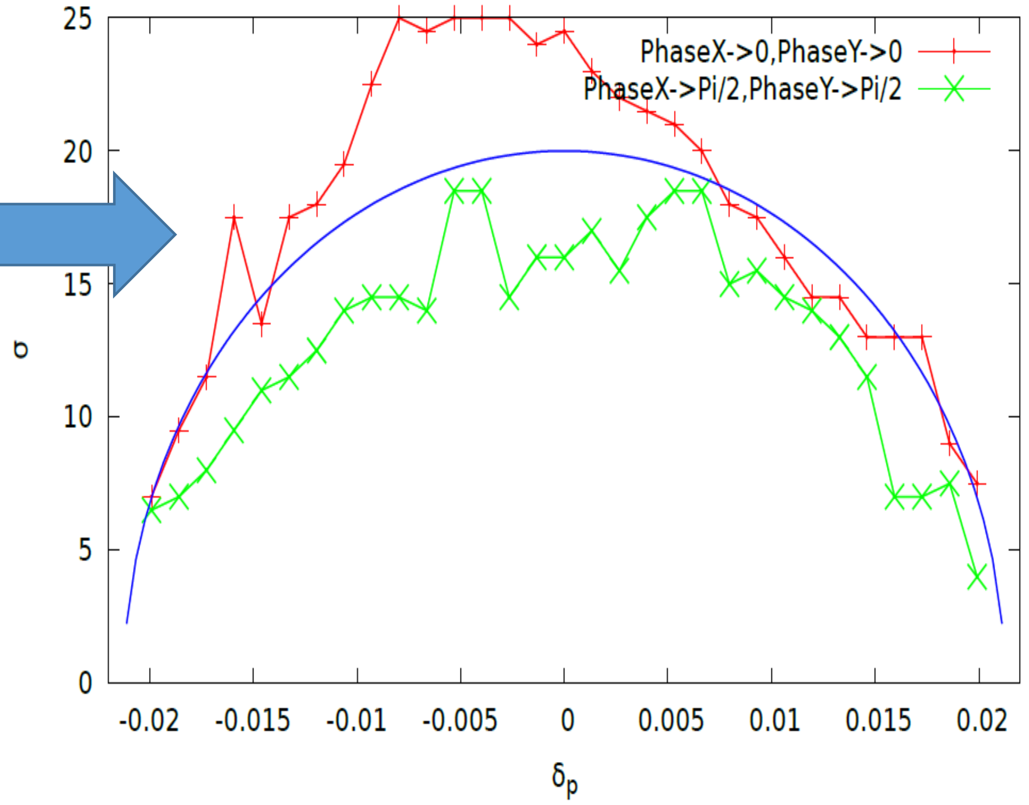
Weak-Strong Simulation with Lattice (IRsext)



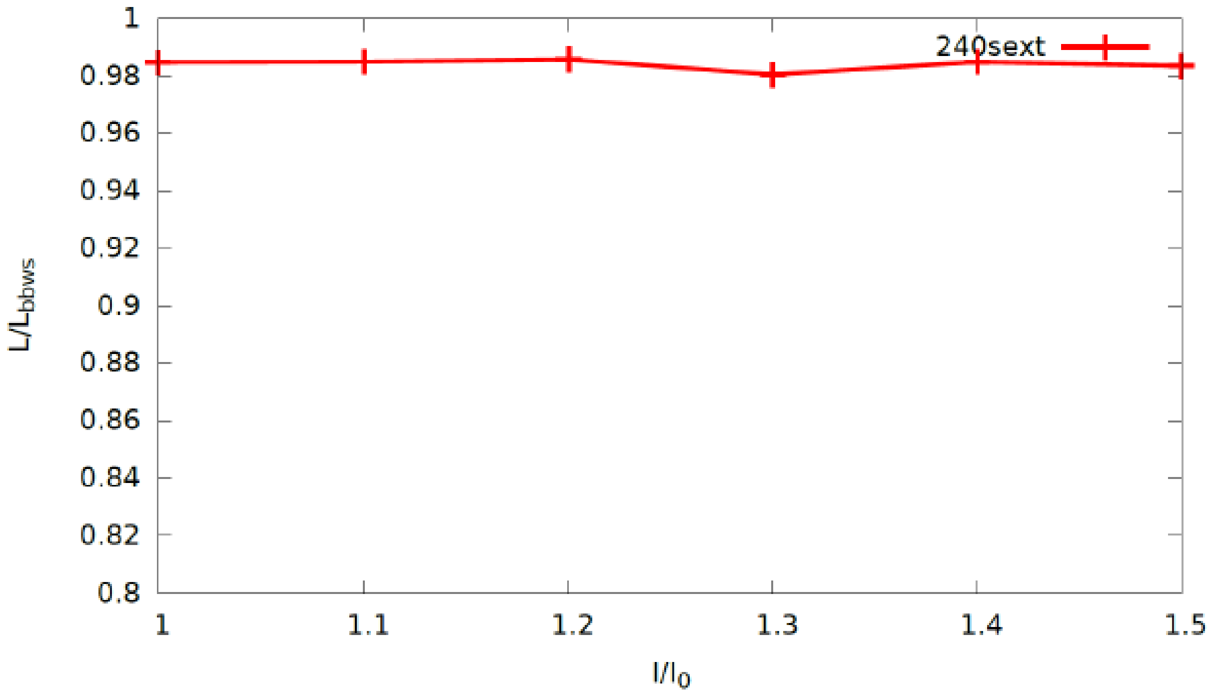
DA with 240 sextupole families in Arc with DAPWIDTH=15







Weak-Strong Simulation with Lattice (240sext)



Partial Double Ring

THE 'BOWTIE' DESIGN
by Michael Koratzinos (University of Geneva)

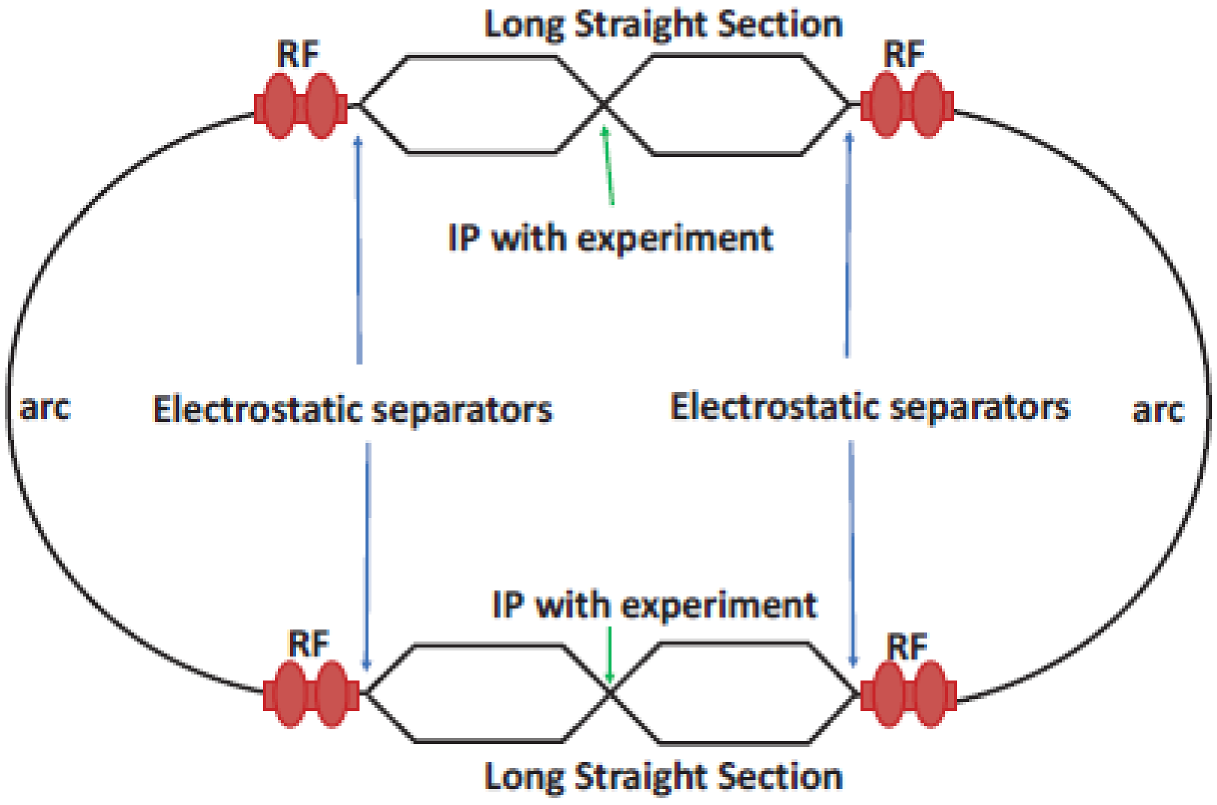


Figure 1: Schematic of the 'bowtie' idea (not to scale).

A solution that can accommodate O(1000) bunches while keeping more than 90% of the ring with a single beam pipe.

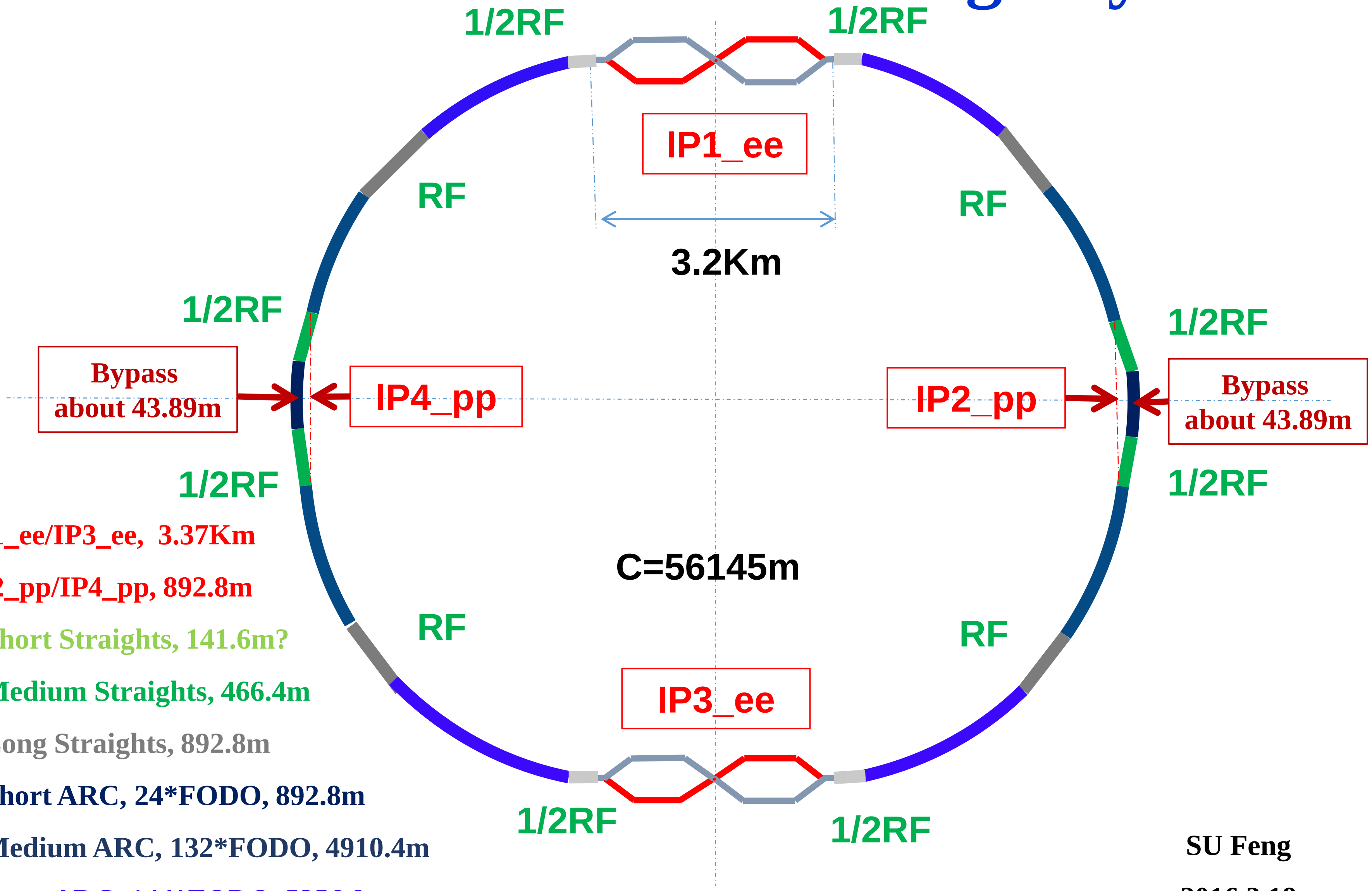
IPAC'15, **MITIGATING PERFORMANCE LIMITATIONS OF SINGLE BEAM-PIPE CIRCULAR e+e- COLLIDERS**

Primary parameter for CEPC double ring

（wangdou20160219）

	Pre-CDR	H-high lumi.		H-low power		Z
Number of IPs	2	2		2		2
Energy (GeV)	120	120		120		45.5
Circumference (km)	54	54		54		54
SR loss/turn (GeV)	3.1	2.96		2.96		0.062
Half crossing angle (mrad)	0	14.5	15	11.5	15	15
Piwinski angle	0	2	2.5	2	2.6	8.5
N_e/bunch (10^{11})	3.79	3.79	2.85	2.81	2.67	0.46
Bunch number	50	50	67	40	44	1100
Beam current (mA)	16.6	16.9	16.9	10.1	10.5	45.4
SR power /beam (MW)	51.7	50	50	30	31.2	2.8
Bending radius (km)	6.1	6.2	6.2	6.2	6.2	6.1
Momentum compaction (10^{-5})	3.4	3.0	2.5	2.6	2.2	3.5
β_{IP} x/y (m)	0.8/0.0012	0.306/0.0012	0.25/0.00136	0.22/0.001	0.268 /0.00124	0.08/0.001
Emittance x/y (nm)	6.12/0.018	3.34/0.01	2.45/0.0074	2.67/0.008	2.06 /0.0062	0.62/0.002
Transverse σ_{IP} (um)	69.97/0.15	32/0.11	24.8/0.1	24.3/0.09	23.5/0.088	7/0.046
ξ_x/IP	0.118	0.04	0.03	0.04	0.032	0.005
ξ_y/IP	0.083	0.11	0.11	0.11	0.11	0.084
V_{RF} (GV)	6.87	**3.7**	**3.62**	**3.6**	**3.53**	**0.12**
f_{RF} (MHz)	650	650	650	650	650	650
Nature σ_z (mm)	2.14	**3.3**	**3.1**	**3.2**	**3.0**	**3.9**
Total σ_z (mm)	2.65	4.4	4.1	4.2	4.0	4.0
HOM power/cavity (kw)	3.6	3.3	2.2	1.5	1.3	0.99
Energy spread (%)	0.13	0.13	0.13	0.13	0.13	0.05
Energy acceptance (%)	2	2	2	2	2	
Energy acceptance by RF (%)	6	**2.2**	**2.2**	**2.2**	**2.1**	**1.1**
n_γ	0.23	0.49	0.47	0.47	0.47	0.27
Life time due to beamstrahlung_cal (minute)	47	53	36	41	32	
F (hour glass)	0.68	0.73	0.82	0.69	0.81	0.95
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	2.04	2.97	2.96	2.03	2.01	3.61

CEPC Partial Double Ring Layout



IP1_ee/IP3_ee, 3.37Km

IP2_pp/IP4_pp, 892.8m

4 Short Straights, 141.6m?

4 Medium Straights, 466.4m

4 Long Straights, 892.8m

2 Short ARC, 24*FODO, 892.8m

4 Medium ARC, 132*FODO, 4910.4m

4 Long ARC, 144*FODO, 5356.8m

SU Feng

2016.2.18

Arc redesign-ultra low emittance

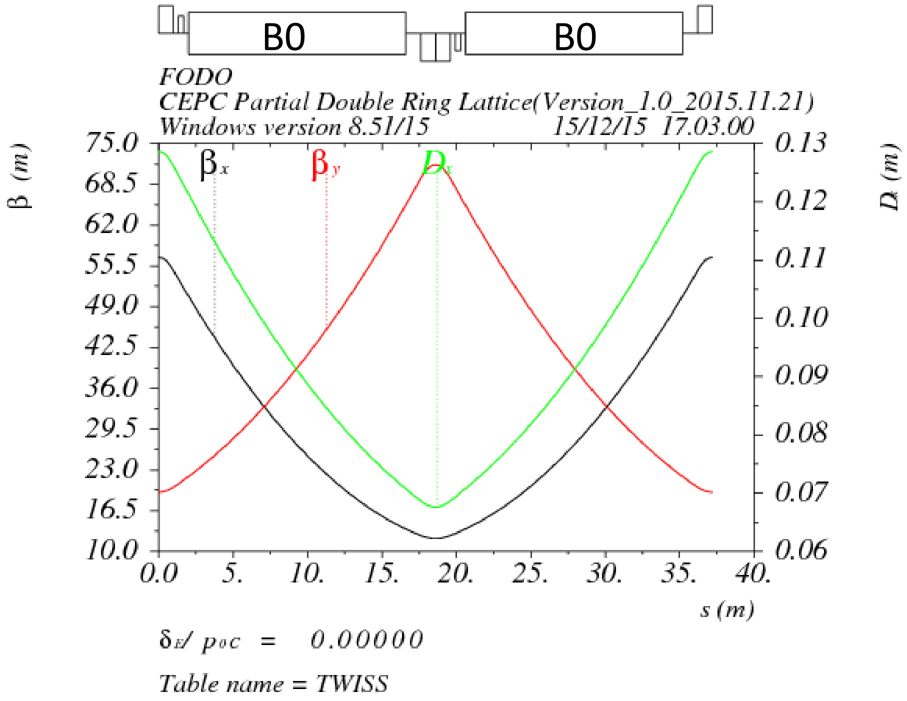
- ➢ Length of FODO cell: 37.2m
- ➢ Phase advance of FODO cells: 90/60 degrees
- ➢ Emittance: 2.52nm, αp=1.05E-5
- ➢ Bunch length: 1.5168mm

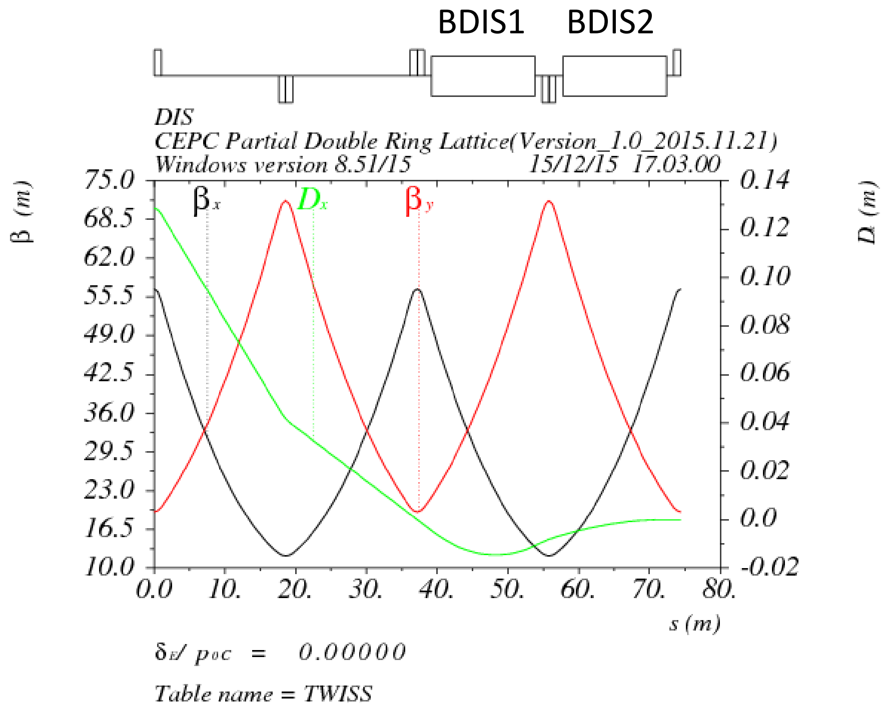
- ➢ Dispersion supressor:

Angle(BDIS1)=3.5816546264E-3

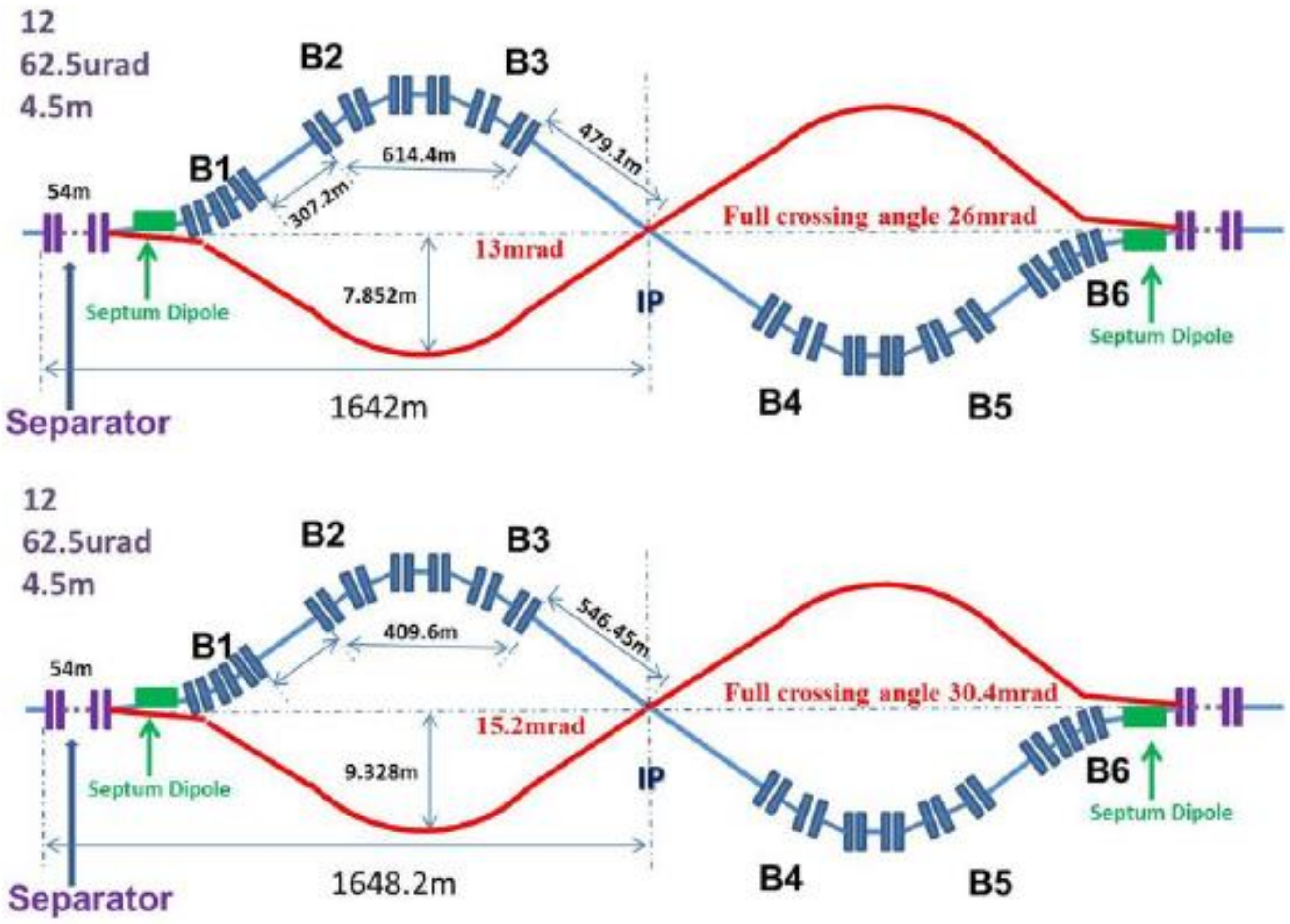
Angle(BDIS2)=-8.59314326219E-4

Angle(B0)=2.72235074352E-3





CEPC Local Double Ring Lattice (F. Su et al)



For CEPC 120GeV beam:

➢Max. deflection per separator is **66μrad**.

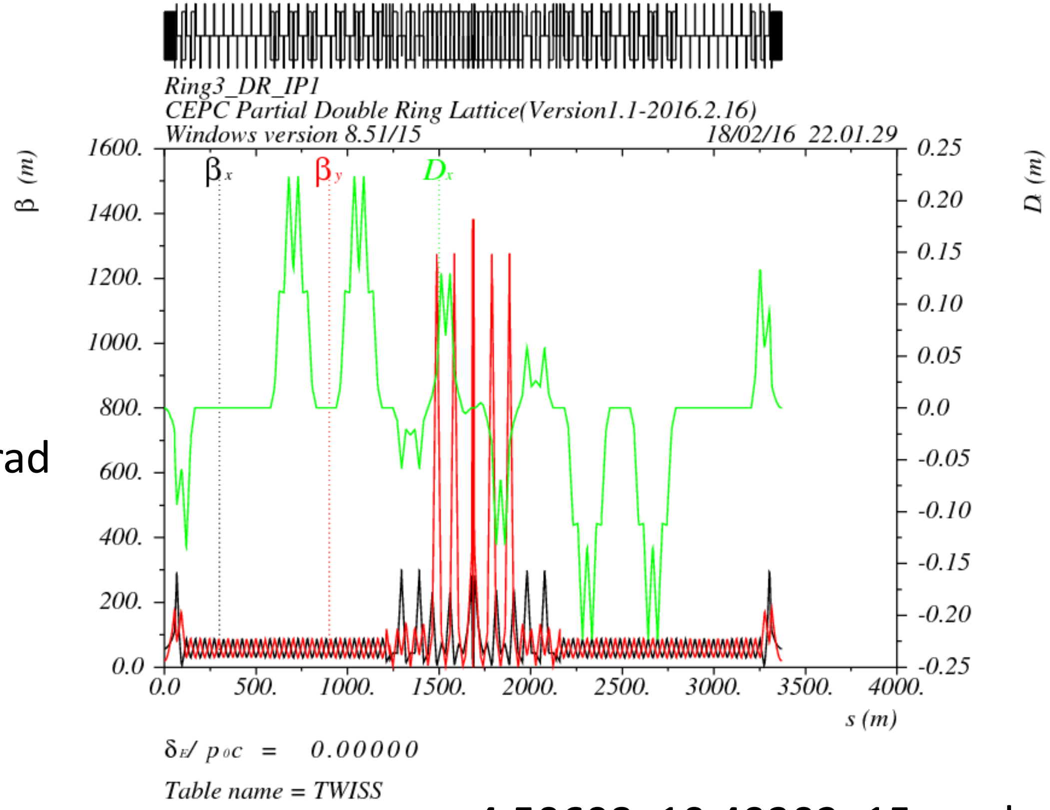
Using Septum Dipole after separator to acquire 13 mrad

Version 1.0

sufeng

2015.12.24-new

Orbit (RING3_DR_IP1) Version 1.1 + FFS(test20160115-2-Wangdou)



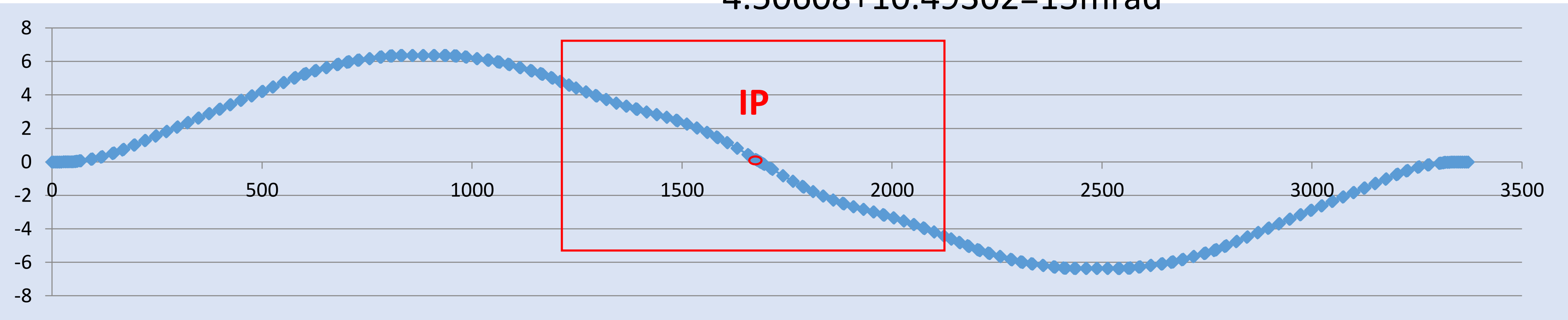
0.0625*12=0.75mrad

+4.25mrad

+5.49302mrad

=10.49302mrad

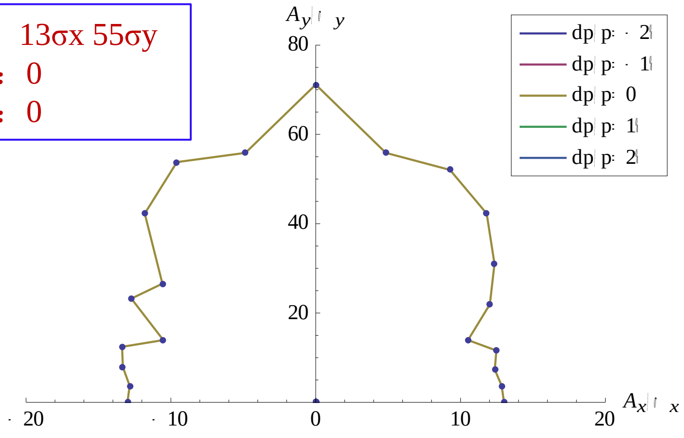
4.50608+10.49302=15mrad



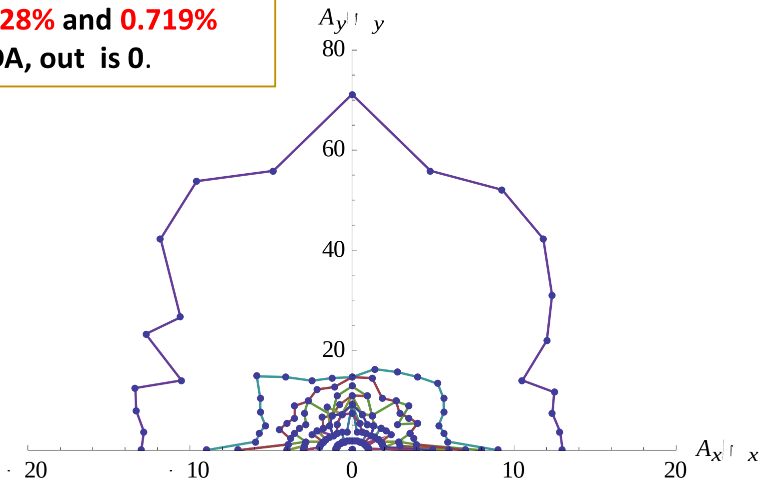
Dynamic Aperture

Version1.0-20160105

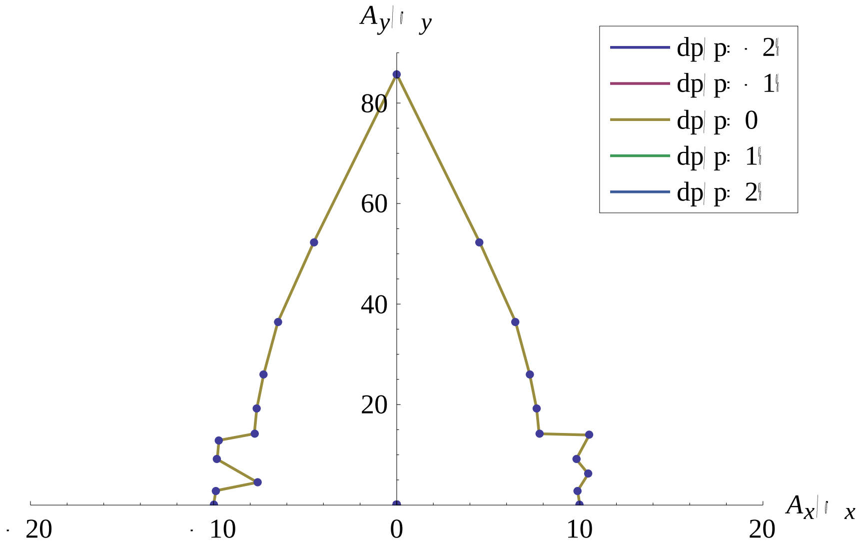
0:    13σx 55σy
0.01：0
0.02：0

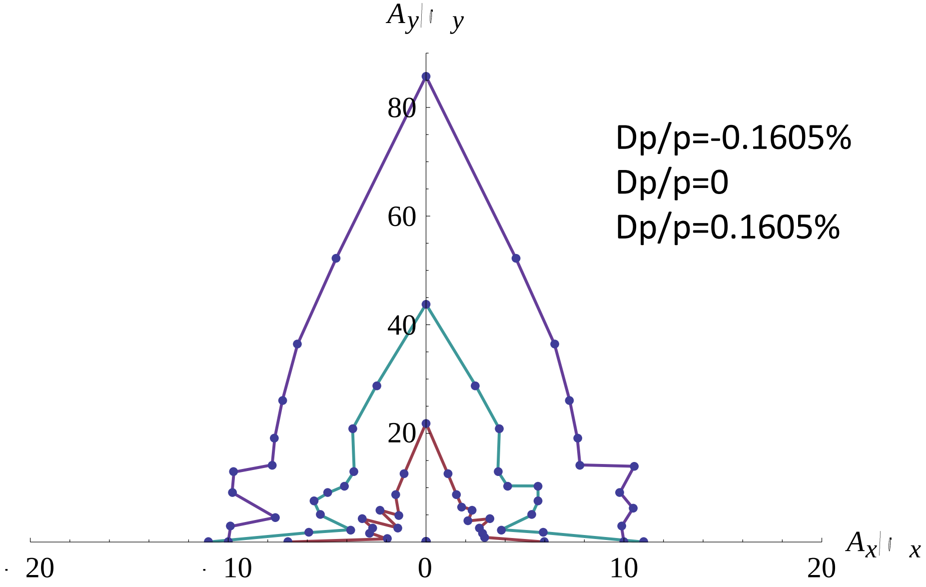


-0.8628% and **0.719%** has DA, out is 0.



Version1.1-20160216





Dp/p=-0.1605%
Dp/p=0
Dp/p=0.1605%

Booster

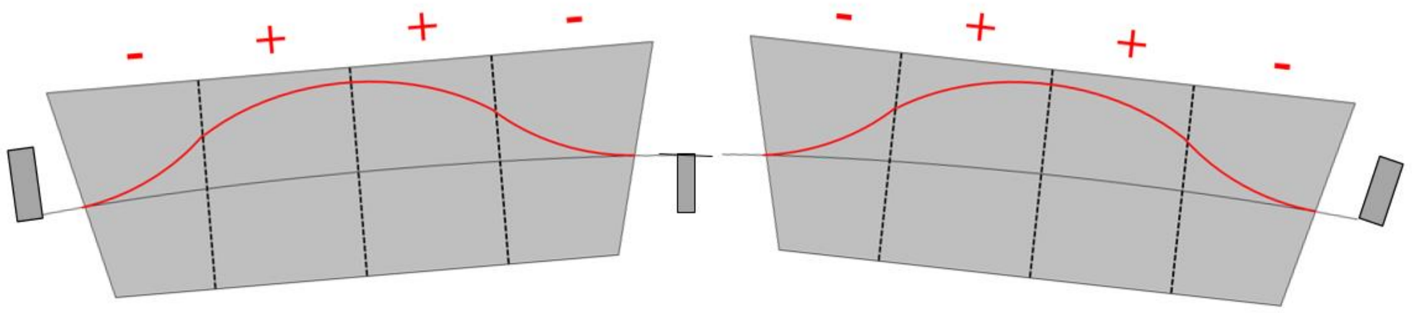
CEPC booster lattice

- 47.2 meter FODO structure.
- Non-interleaved sextupole scheme.
- 10 FODOs make up a cell to cancell off-momentum particle's beta beat effect.
- 8 folds symmetry
- 16 families sextupole are used to cancell second order chromaticity.
- DA of on-mumentum and off-mumentum are good enough for booster.
- 94.4 meter FODO structure is also trying

Tianjian Bian, Xiaohao Cui

Wiggling Bend Scheme

- The inject energy is 6GeV.
- If all the dipoles have the same sign, 33Gs@6GeV may cause problem.
- In wiggling bend scheme, adjoining dipoles have different sign to avoid the low field problem.
- Shorten the Damping times greatly.
- The picture below shows the FODO structure.



Booster Parameters (T.J. Bian et al)

- Main difference in parameters between Pre-CDR booster (old) and the alternating field booster (new)

	Old@6GeV	New@6GeV
Parameter		
U0 [MeV/turn]	0.019	0.70
Damping times(x/y) [s]	115.61	3.12
Emittances(x) [pi nm]	0.015	0.11
Strength of dipole [Gs]	33	-164.3/+229.9
Beam offset in dipole[cm]	0	2.3
Length of dipole [m]	19.6*1	4.9*4
Length of FODO [m]	47.2	47.2

Error

CEPC field error

- The multipole errors in the main ring seems to have a large effect on the 2% off-momentum DA.
- The field errors in the FFS seems to have a large effect on the vertical on-momentum DA.
- With all B,Q,S multipole errors in CEPC whole ring including FFS, the 2% off-momentum DA reduced to about 1/3~1/2.
- With correctors and BPMs adding in the beam line, SAD hash table has no space. SAD can not deal with large ring.

Cure DA

Method 1： Optimization of DA (precondition: best DA without error）

- orbit correction （for misalignment errors）
- tune correction （for quad B*L error）
- FMA analysis , add octupole, decapole, dodecapole.......

Although could be corrected in simulation, may not the case in real situation……

Method 2： Reduce errors (maybe high level requirement in magnet manufature）

reduce the errors to the DA that we can accept

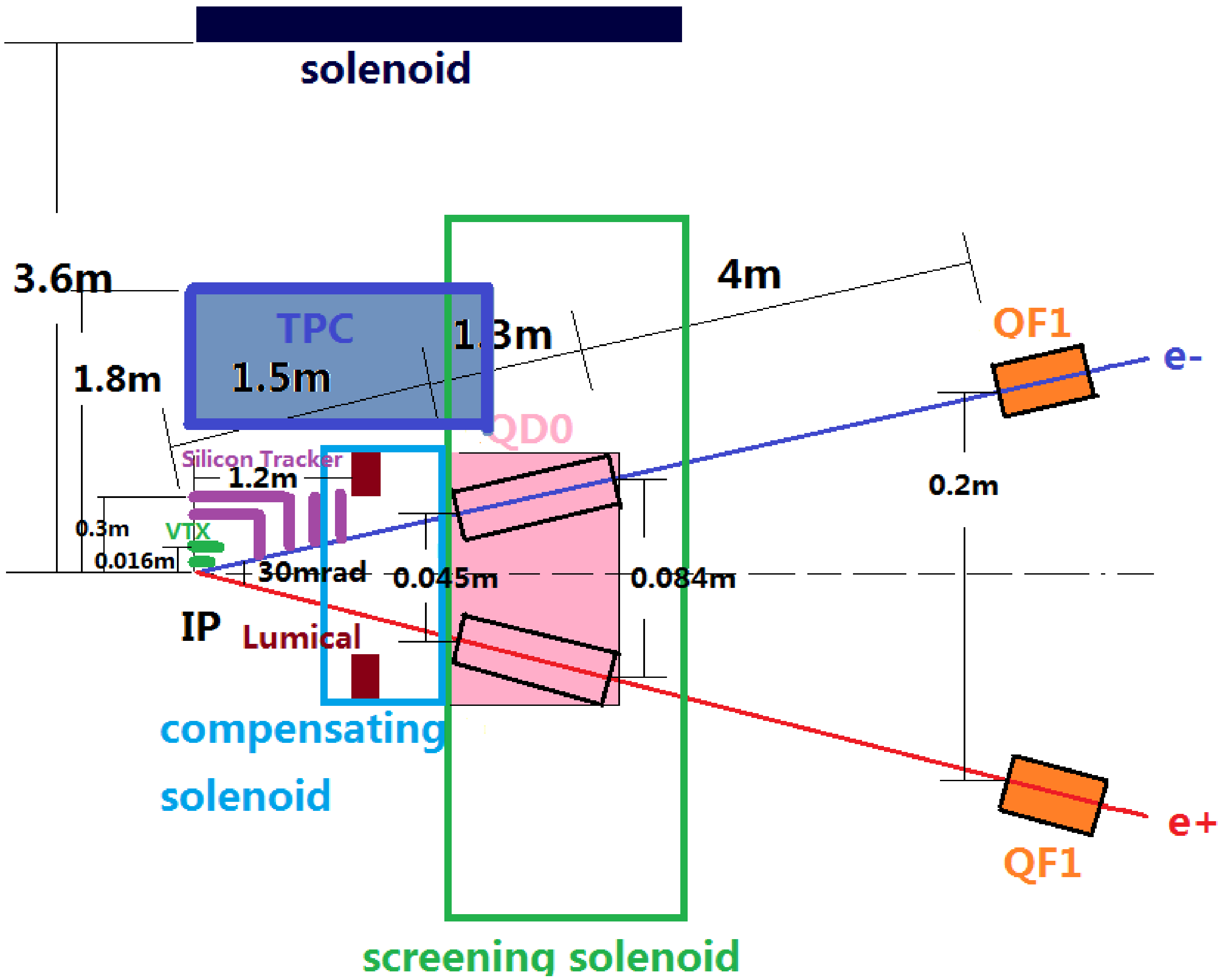
Sha Bai

MDI

MDI Status

- Develop MDIToolkit –uniform computing platform to established the environment for MDI study on IHEP computing cluster
- Background study: SR, Radiative Bhabha scattering, Beamstrahlung
- With 2cm aperture collimator, lost particles of radiative Bhabha and beamstrahlung in IR after several machine turns can be effectively prevented, but need to be optimized.
- SC magnets are designed preliminarily. Conceptual design and magnetic field calculation.
- Anti-solenoid design is optimizing, set up solenoid model in accelerator software.

Local double ring MDI layout



Detectors (including silicon tracker, vertex detector, TPC etc on….) which are "far" from this region, should be same as in the single ring.

Summary

- We’ve made much progress after pre-CDR.
- Many problems have been “touched”.
- All work should converge to a self-consistent design.
- It is urgent to finish the CDR in the end of 2016.

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Multi-Objective Optimization with possible application in SuperKEKB

Y. Zhang and D. Zhou

Mar. 9th, 2016

Introduction

- This work was firstly excited by Oide's talk.

  K. Oide, "A design of beam optics for FCC-ee", 2015-09

  "255 sextupole pairs per half ring"
- Downhill Simplex is a local optimization algorithm
- We use a global optimization algorithm: Diffential Evolution (Suggested by Ji Qiang@LBNL)
- Other popular algorithm: Genetic Algorithm, Particle Swarm

Differential Evolution

- The “DE community” has been growing since the early DE years of 1994 – 1996 （new）
- DE is a very simple population based, stochastic function minimizer which is very powerful at the same time.
- There are a few strategies, we choose ‘rand-to-best’. Attempts a balance between robustness and fast convergence.

$$\mathrm{v}(\mathrm{i},\mathrm{j}) = \begin{cases} x(i,j) + F \times [x(b,j) - x(i,j)] + F \times [x(r1,j) - x(r2,j)], & If\ rand(j) < CR \\ x(i,j), & Otherwise \end{cases}$$

- Different problems often require different settings for NP, F and CR
- F is usually (0.5,1) but according to our experience, maybe (0.1~0.5) better

Optimization with Algorithm
- Objective function

- $\frac{x^2}{20^2} + \frac{z^2}{16^2} = 1$
- z for energy deviation in unit of σ_p
- x for transverse amplitude in unit of σ

- For z =Range[-15,15,3],

$$\text{objective function} = \begin{cases} 0, & \text{if aperture boundary is outside the ellipse} \\ \text{distance between the boundary and the ellipse}, & \text{otherwise} \end{cases}$$

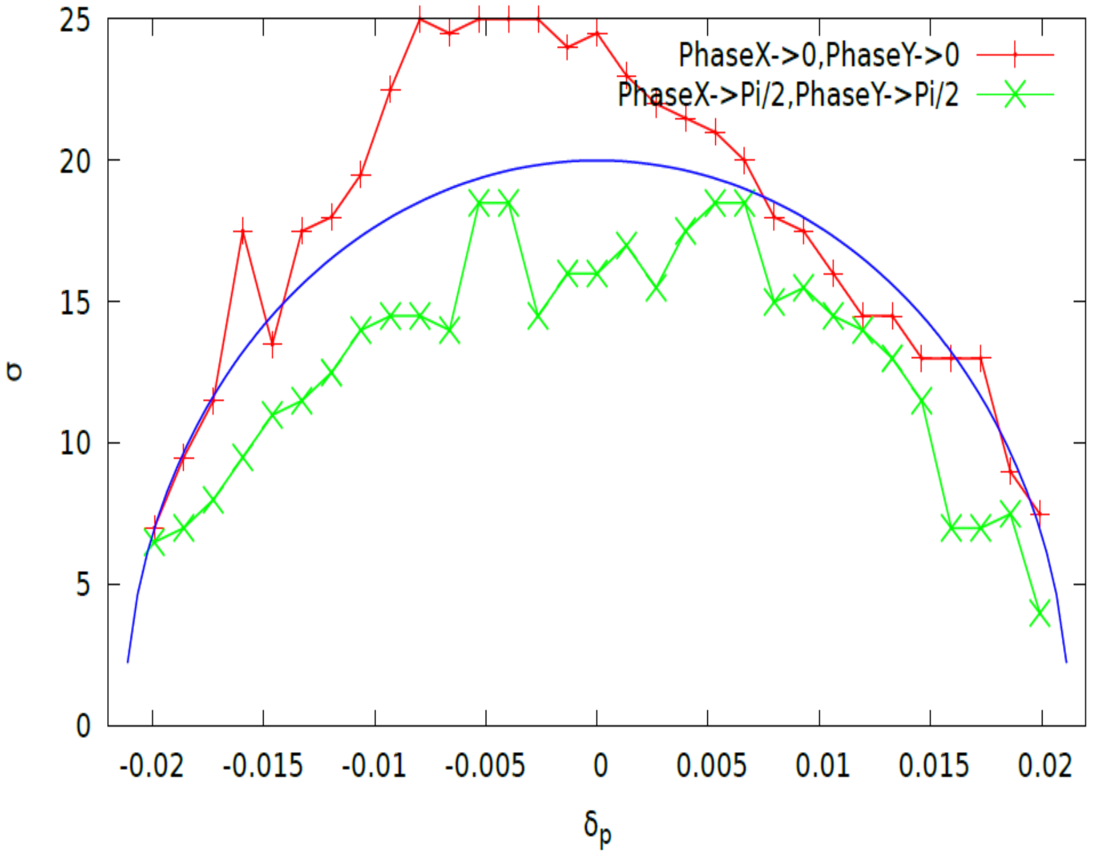
The first test, with 240 sextupoles, 100turns

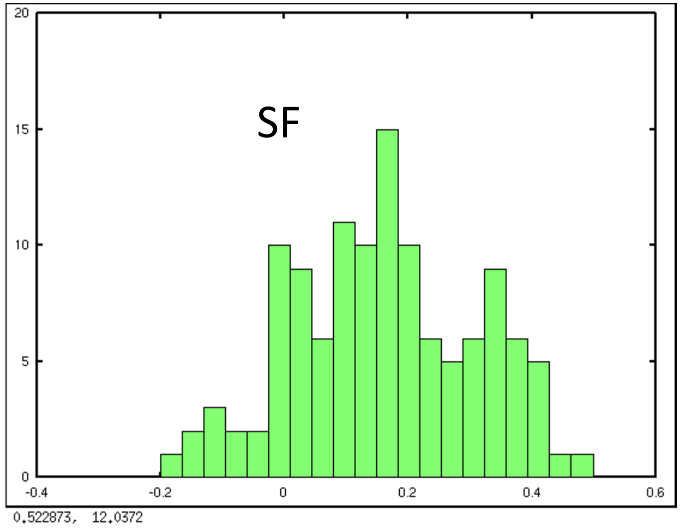
V1, 100 turns

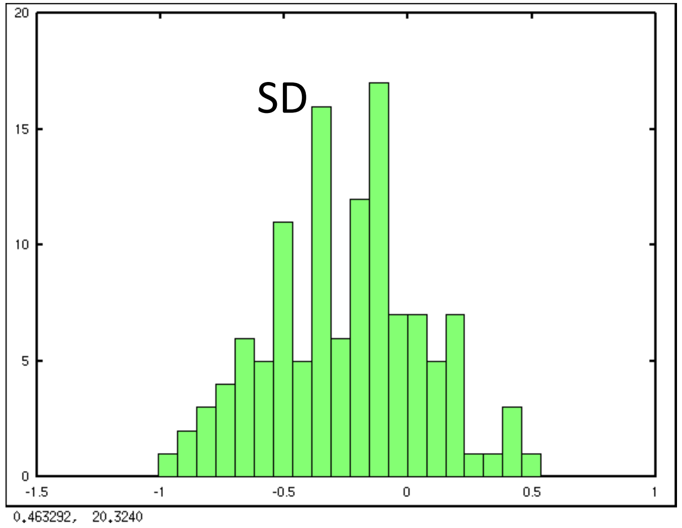
```
da=DynamicApertureSurvey[{{0,25},{0,1.369},Range[-15,15,3]},100,Output->6]
 Turns =100 Maximum number of particles =330
 Range    Xmin:   0.000 Xmax:  25.000
         (Ymin:   0.000 Ymax:   1.369)
          Zmin: -15.000 Zmax:  15.000
 Display:     10 turns/character
      NZ      0----!----1----!----2----!----3----!----4----!----5
   -15.00  1 A110000000000000000001000000000000000000000000000000
   -12.00  3 AAA98322111000000001000000000000000000000000000000000
    -9.00  7 AAAAAAA54563111111000000111000000000000000000000000
    -6.00 12 AAAAAAAAAAAA864321111110001001100000000000000000000
    -3.00 15 AAAAAAAAAAAAAAA342211311111122222262111111111853221
     0.00 51 ************************************AAAAAAAAAAAAAAA
     3.00 12 AAAAAAAAAAAA9AA439358222222231113533111011110000000
     6.00 15 AAAAAAAAAAAAAAA55222110000100000000000000000000000
     9.00  9 AAAAAAAAA664811000000000000000000000000000000000000
    12.00  3 AAA322111111000000000000000000000000000000000000000
    15.00  1 A11000000000000000000000000000000000000000000000000
      NZ      0----!----1----!----2----!----3----!----4----!----5
    Score:    129
```

```
DynamicApertureSurvey[{{0,25},{0,1.369},z},100,Output->6]
 Turns =100 Maximum number of particles =330
 Range    Xmin:   0.000 Xmax:  25.000
         (Ymin:   0.000 Ymax:   1.369)
          Zmin: -15.000 Zmax:  15.000
 Display:     10 turns/character
      NZ      0----!----1----!----2----!----3----!----4----!----5
   -15.00  4 AAAA3211000000000000000000000000000000000000000000000
   -12.00  8 AAAAAAAA9A6211000000000000000000000000000000000000000
    -9.00 13 AAAAAAAAAAAAA326131000000000000100000000000000000000
    -6.00 17 **AAAAAAAAAAAAAAA322211000000000100000000000000000000
    -3.00 20 *****AAAAAAAAAAAAAAA633AA11110000000001000110000000
     0.00 51 ************************************AAAAAAAAAAAAAAA
     3.00 22 *******AAAAAAAAAAAAAAA24A273111000010000000000000000
     6.00 18 ***AAAAAAAAAAAAAAA21111111000000100000000000000000000
     9.00 12 AAAAAAAAAAAA732111221000000000000000000000000000000
    12.00 12 AAAAAAAAAAAA531000000000000000000000000000000000000
    15.00  5 AAAAA211000000000000000000000000000000000000000000000
      NZ      0----!----1----!----2----!----3----!----4----!----5
    Score:    182
```

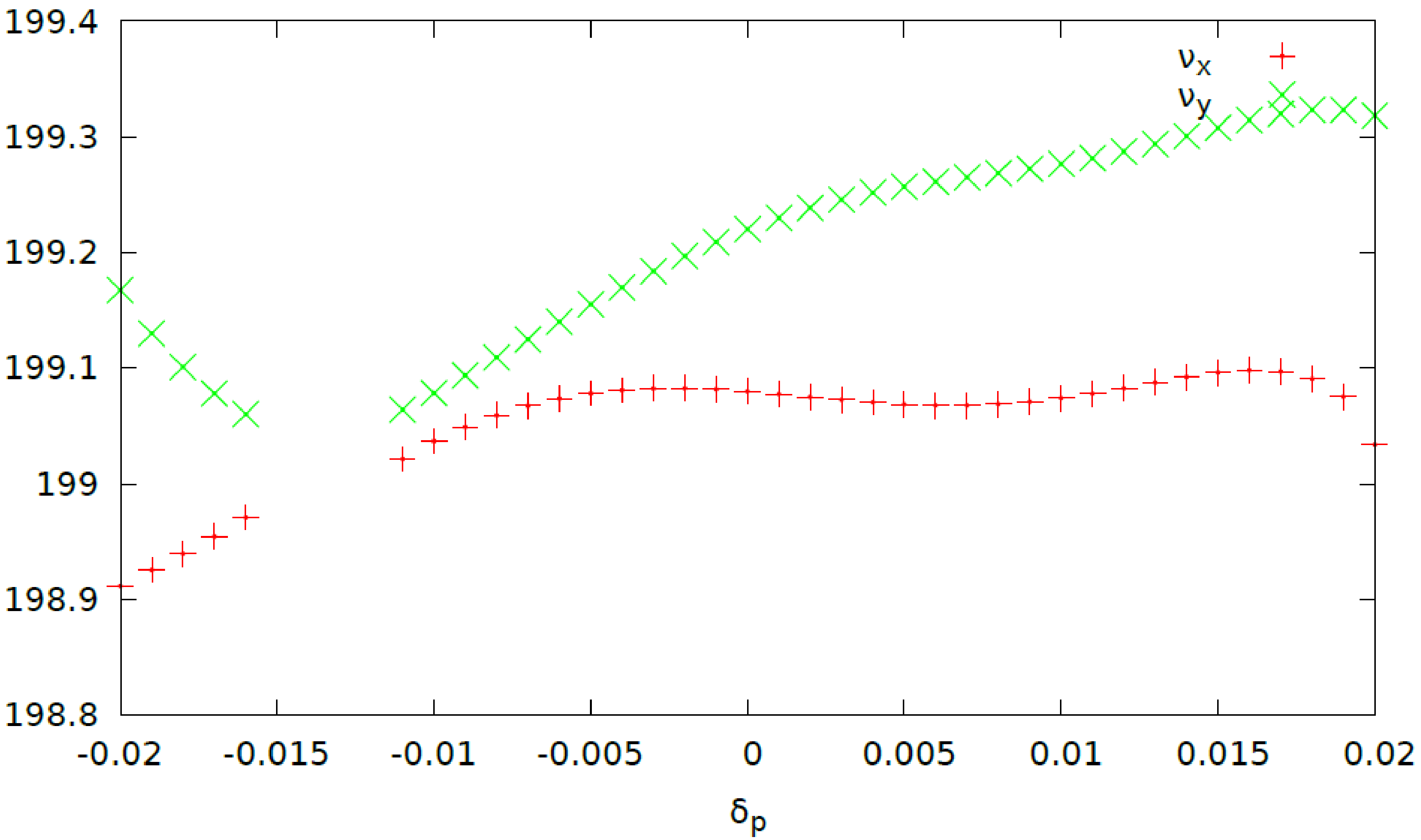
CEPC: Dynamic Aperture Optimization with 240 sextupoles in ARC (v1-IR)



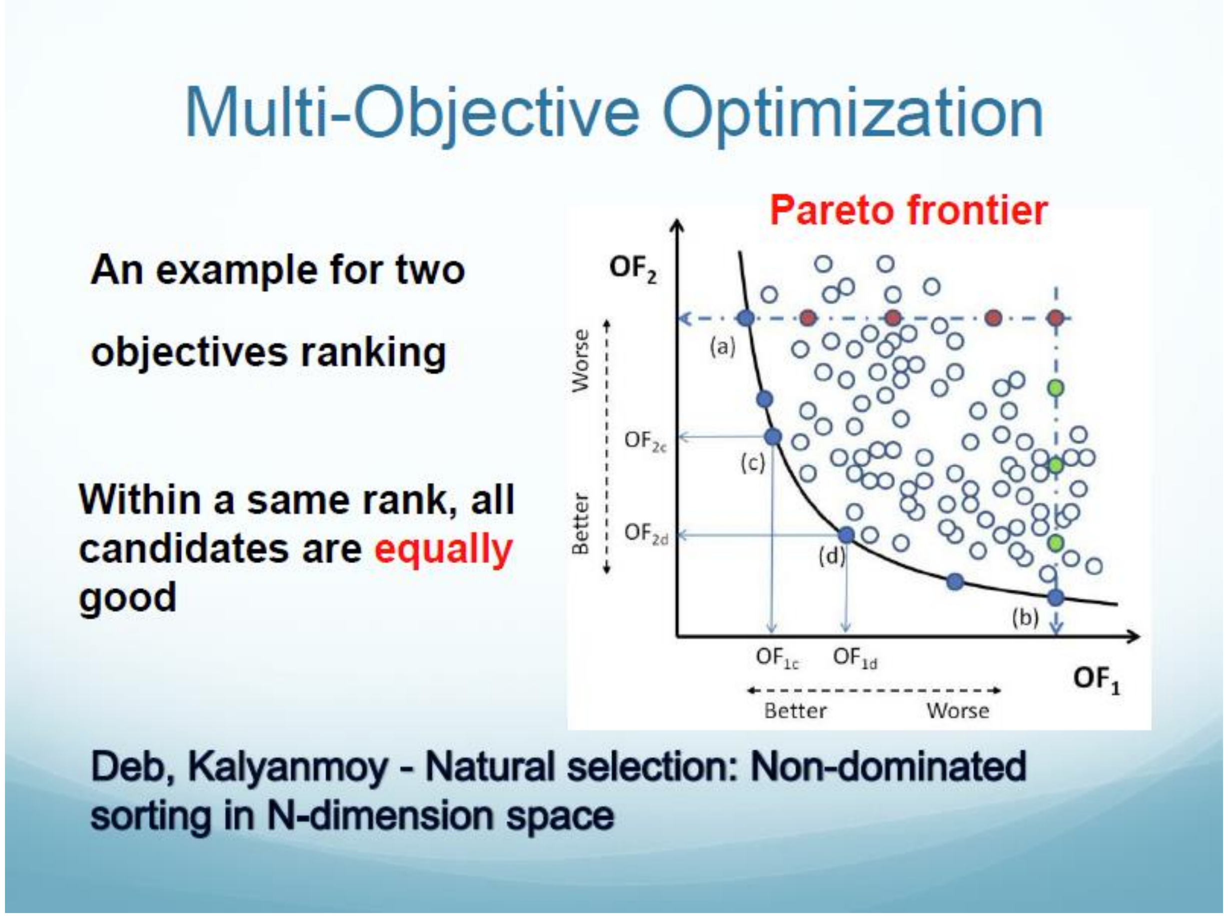




Tune



199.4
199.3
199.2
199.1
199
198.9
198.8
-0.02
-0.015
-0.01
-0.005
0
0.005
0.01
0.015
0.02
δ_p
ν_x
ν_y



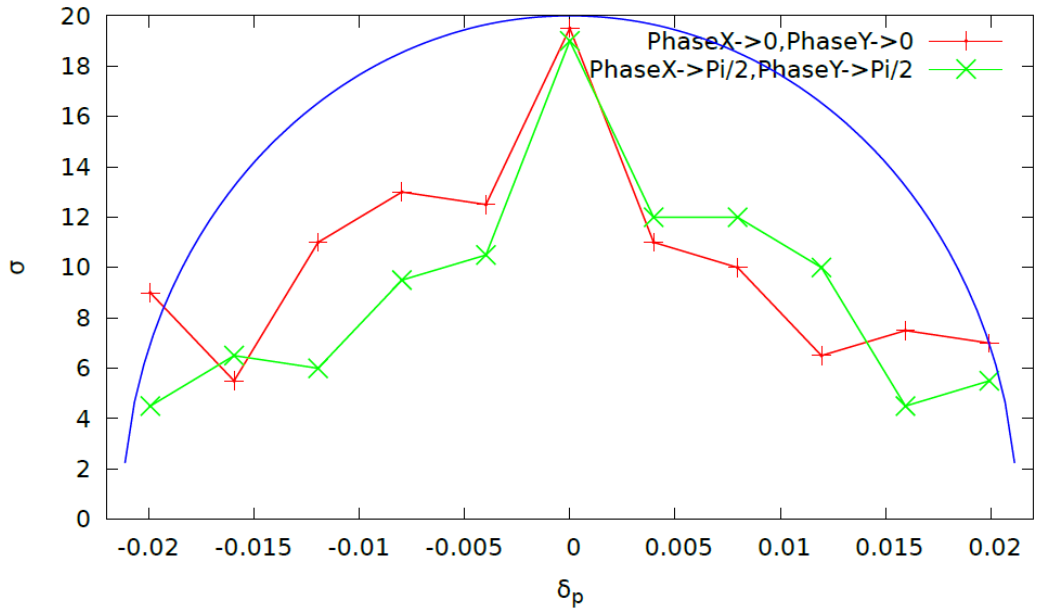
Yongjun Li, IAS Program on HEP Conference, 2016

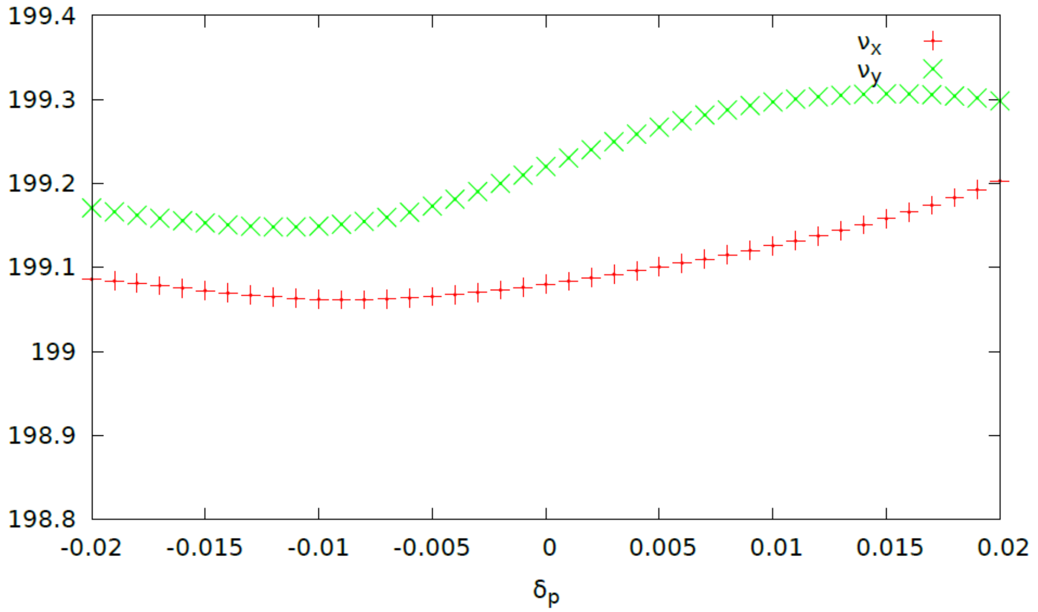
The multiple objective algorithm based on differential evolution is implemented referencing J. Qiang, IPAC'13.

More Objective in CEPC test

- DA with PhaseX->0,PhaseY->0
- DA with PhaseY->Pi/2, PhaseY->Pi/2
- Qx in [0, 0.5]
- Qy in [0, 0.5]
- ChromaticityX in [0, 5]
- ChromaticityY in [0, 5]
- DA: $\frac{x^2}{20^2}+\frac{y^2}{50^2}+\frac{z^2}{16^2}=1, for\ z=0$
- DA: $\frac{x^2}{20^2}+\frac{y^2}{50^2}+\frac{z^2}{16^2}=1, for\ z=-5$
- DA: $\frac{x^2}{20^2}+\frac{y^2}{50^2}+\frac{z^2}{16^2}=1, for\ z=+5$

A solution (not good enough, just a test)





2. Lattice nonlin.: LER: DA and lifetime

- Test by inserting a map of $H=K^*x^2y$ into the LER lattice
- Skew-sext. map:
  - cause loss in DA and lifetime (to be understood)

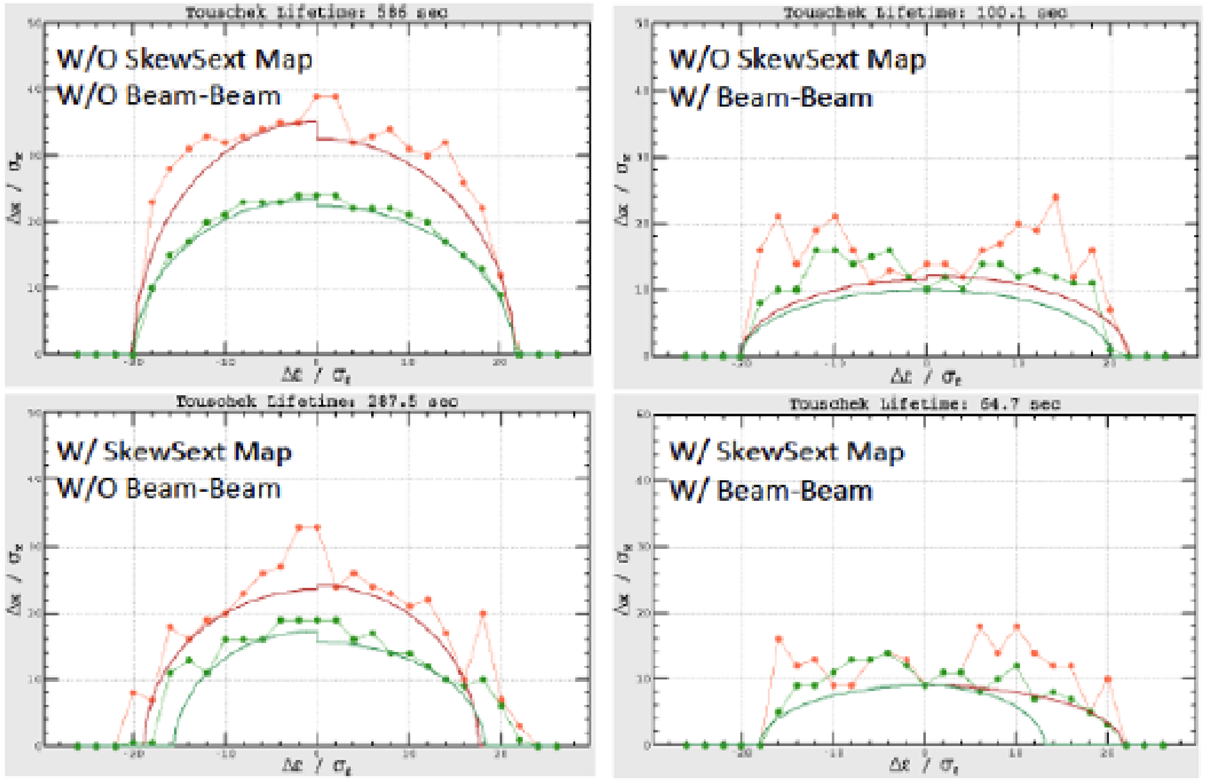
sler_1689

We have to suppress the skew sextupole resonance, and enlarge the DA in the mean time

This is a multiple objective task.

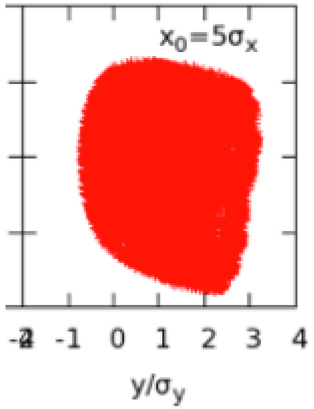
DA and Lifetime

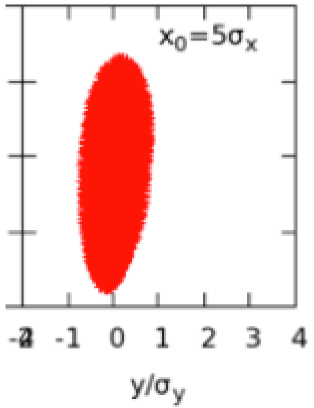
From H. Sugimoto



Objective

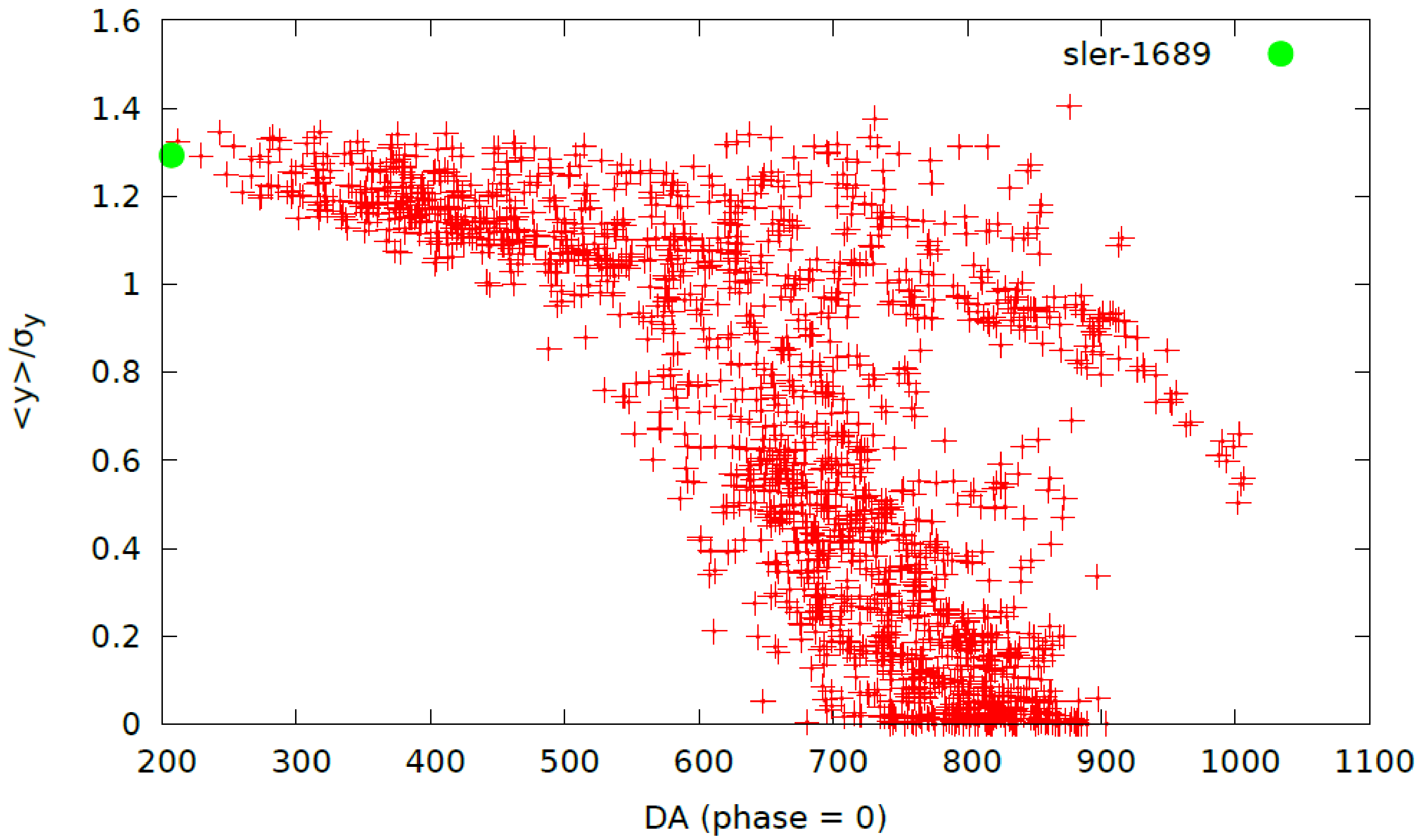
- DA: $\frac{x^2}{50^2} + \frac{z^2}{26^2} = 1$ with PhaseX->0,PhaseY->0, for z=-26:2:26
- DA: $\frac{x^2}{50^2} + \frac{z^2}{26^2} = 1$ with PhaseX->pi/2,PhaseY->pi/2, for z=-26:2:26
- $\frac{\langle y\rangle}{\sigma_y}$ for a particle with initial coordinate ($5\sigma_x$,0,0,0,0,0)
- $\frac{|y-\langle y\rangle|}{\sigma_y}$ for a particle with initial coordinate ($5\sigma_x$,0,0,0,0,0)
- Coupling Chromaticity: $\sum|R_1R_4 - R_2R_3|$, for $\delta = (-0.018, +0.018)$



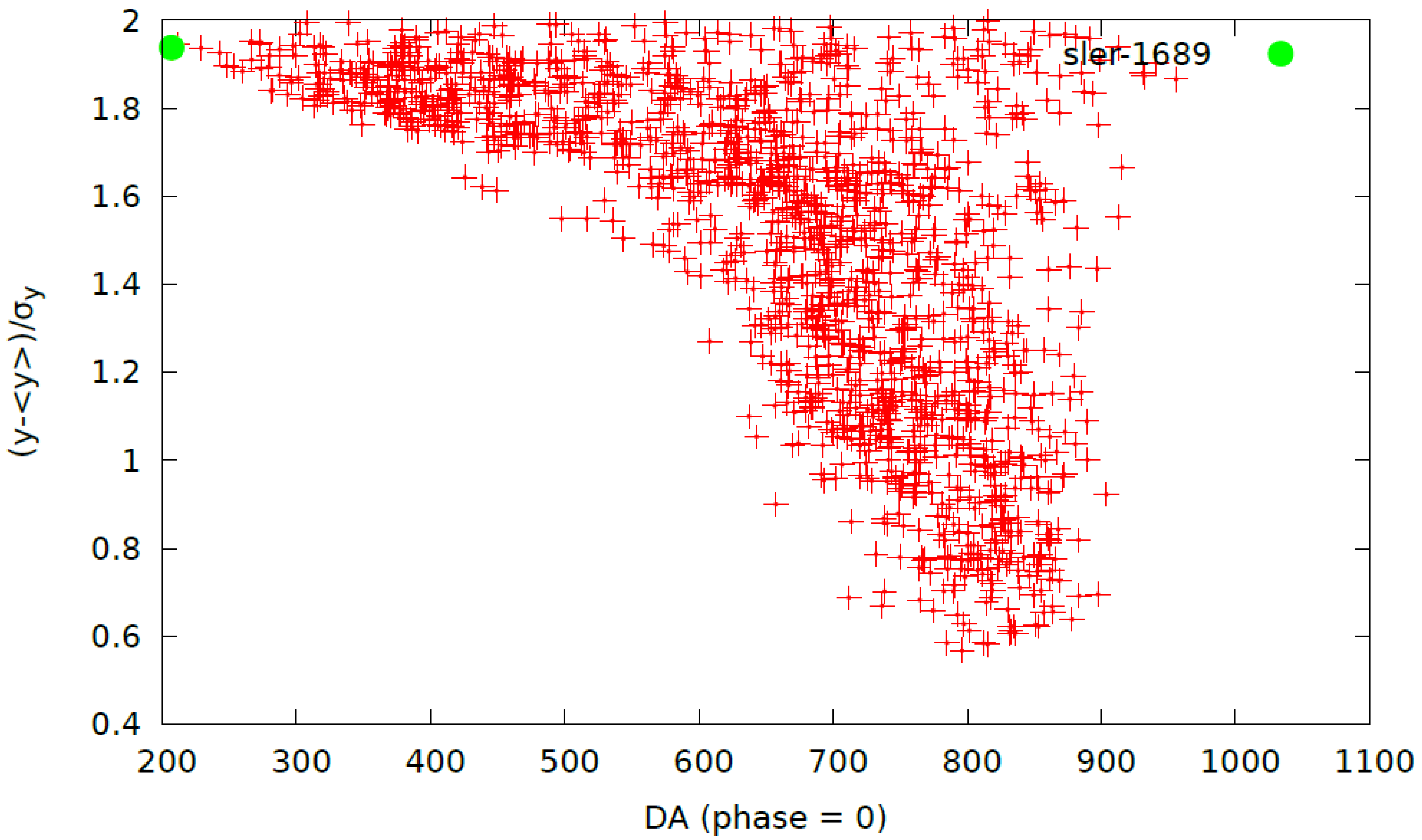


To correct the skew sextupole nonlinear terms, the skew sextupole strength symmetry in one pair is broken. Totally we use 24 skew sextupole.

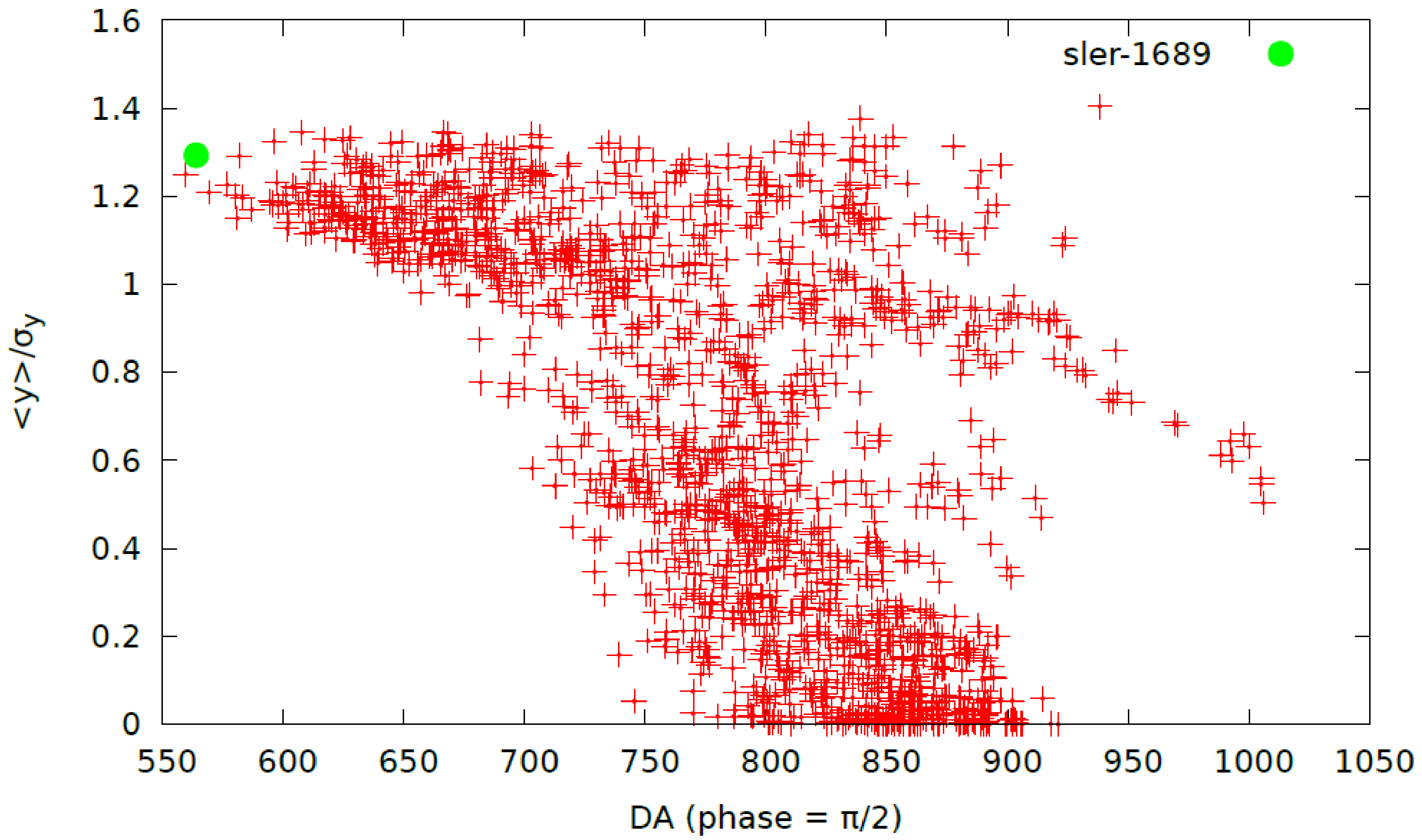
Status of Optimization (1)



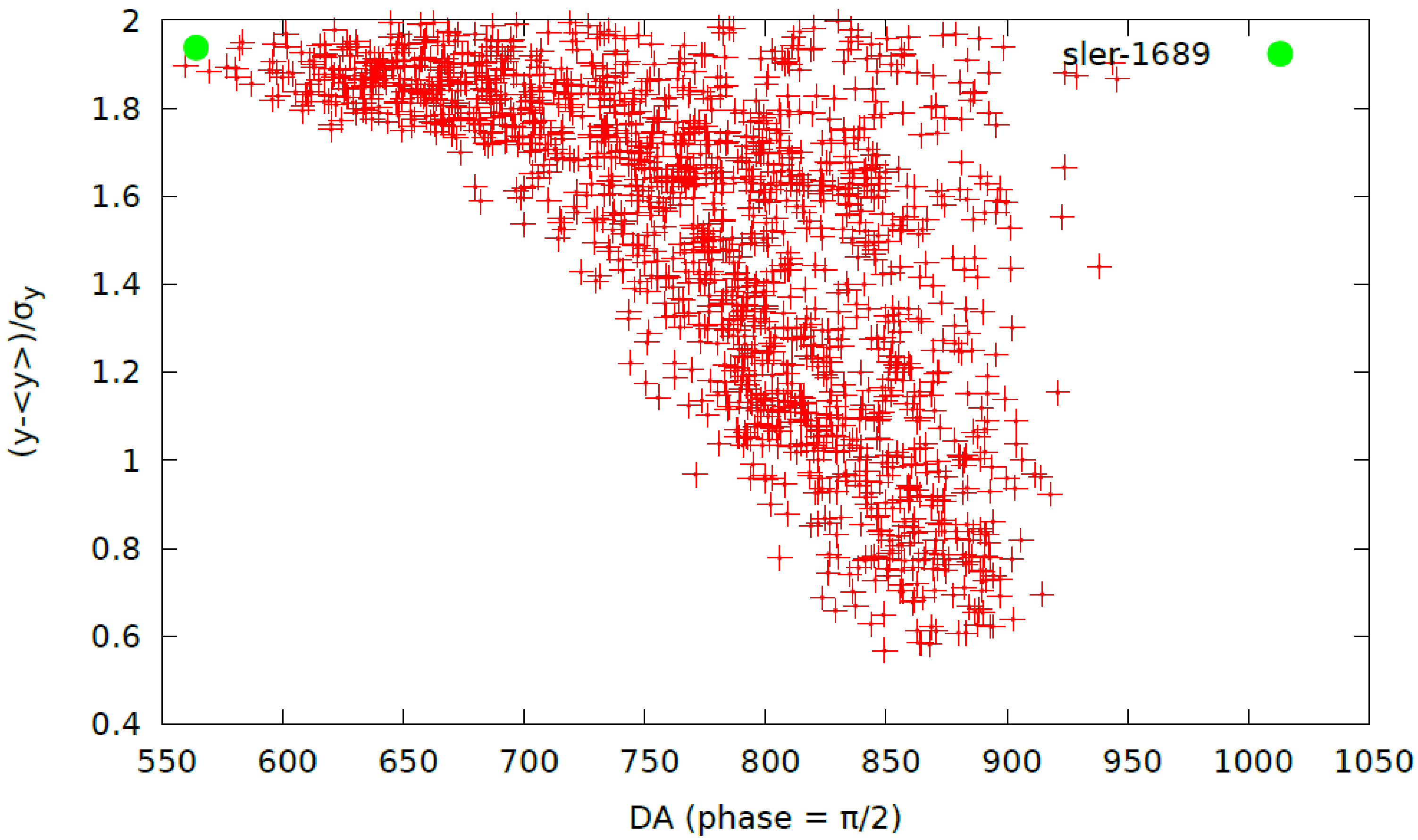
Status of Optimization (2)



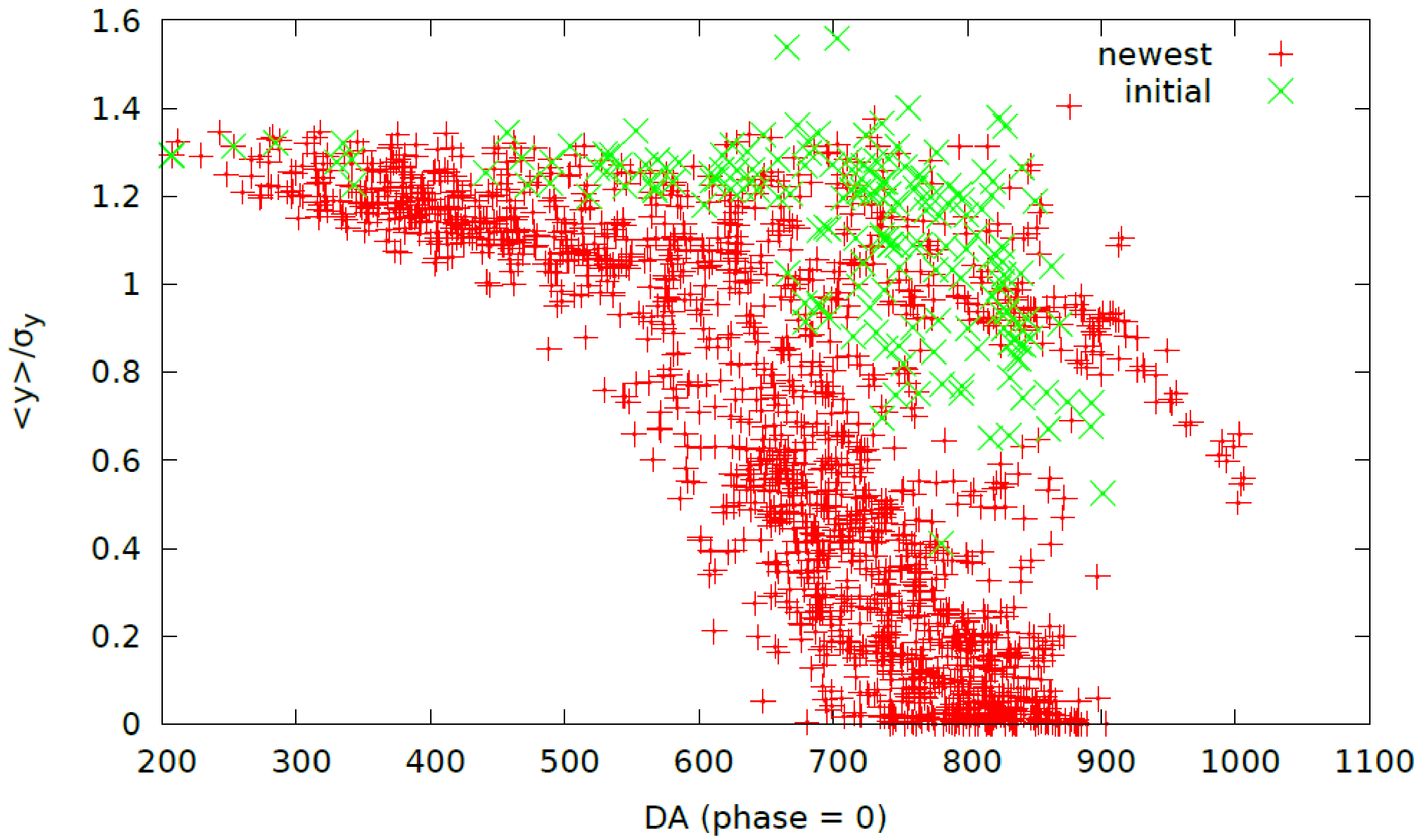
Status of Optimization (3)



Status of Optimization (4)



It’s evolving



Other way to be tried

- Insert a skew sextupole pair before/after IP, the pair could cancel each other and help compensate the nonlinear resonance at IP. It is like the crab-waist scheme. This may need to change the linear optics.☹
- If the DA with suppressed skew sextupole resonance is not good enough, we may need to optimize the sextupole strength further.

Summary

- DA optimization is a complicated problem
- DA is not the only objective. Chromaticity, coupling and even nonlinearity should also be well controlled. We have a multiple objective task.
- The multi-objective optimization has been used in light source machine (not only storage ring based) for a few years
- SuperKEKB team has developed powerful optimization tool.
- We wish the Multi-Objective-Differential-Evolution could also help the optimization of SuperKEKB
- The MODE is just a tool, no physics. Physics exist in the definition of objective function.
- The tool could only help us find the 'ceiling' of a design. But the 'ceiling' is determined by the design itself.