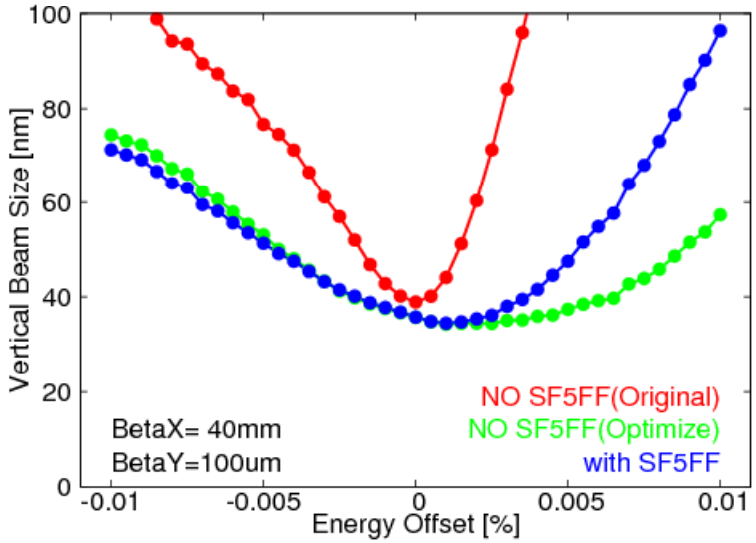
IP Beam Size Tuning Simulation

Toshiyuki OKUGI, KEK
2015/ 2/ 24
ATF2 Project Meeting
LAPP (Annecy, France)

Beam Tuning Simulation for ATF2 10x1 Optics

Energy bandwidth for ATF2 10x1 optics

Momentum Offset



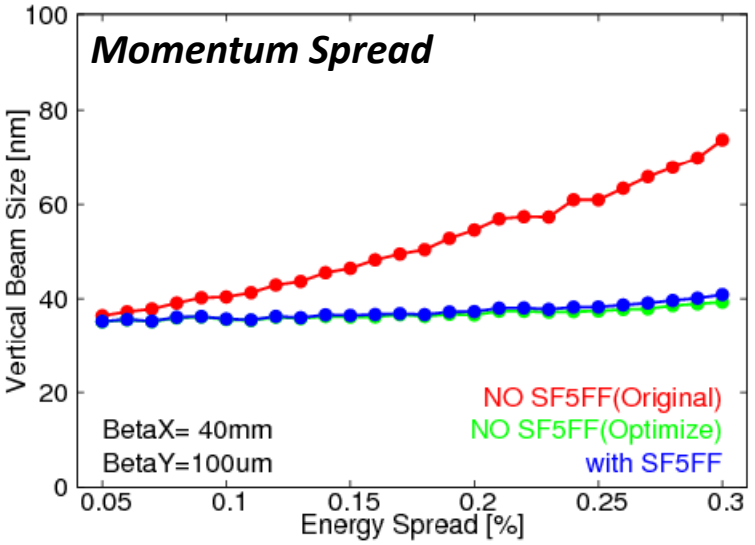
All magnets errors were OFF.

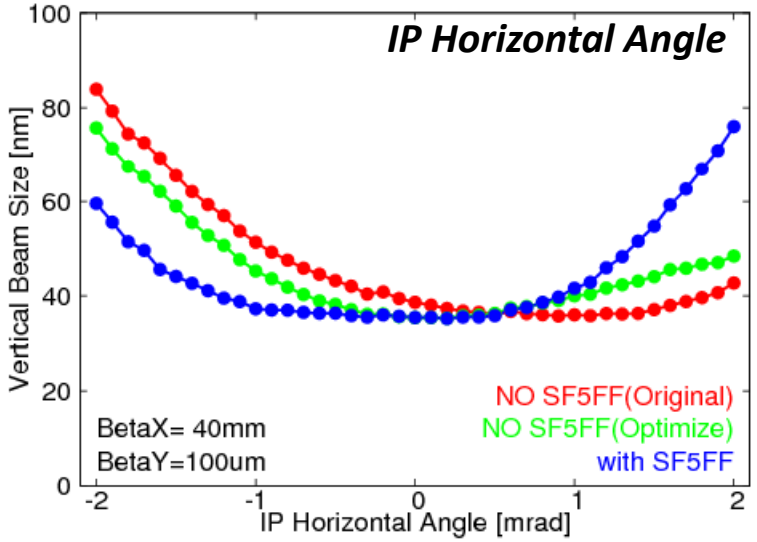
No SF5FF (Present sextupole setting)

No SF5FF (Optimized to make large bandwidth)

with SF5FF (Optimized to make large bandwidth)

Emittances ($\varepsilon_x/\varepsilon_y$)	2nm /12pm
Beta Functions (β_x^*/β_y^*)	40mm / 0.100mm
Momentum Spread (σ_p/p)	0.08%





The bandwidth for present sextupole setting was very narrow.

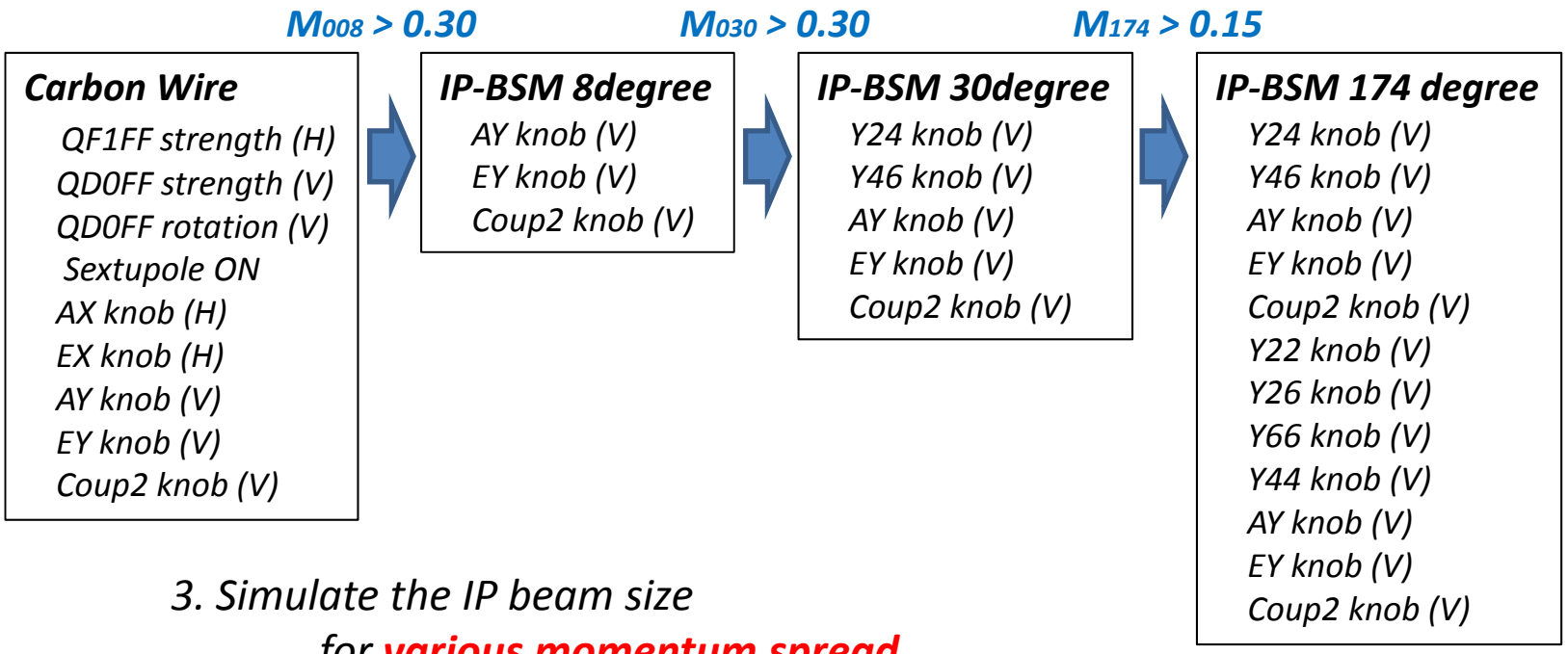
When we use SF5FF, the acceptance of horizontal IP angle makes wide for X66 correction.

Procedures of IP beam tuning simulation

1. Put the following errors in Magnets as follows.

	Quadrupole	Sextupole
Quadrupole error	0.001	N.A.
Sextpole error	0.001 at R=1cm	0.001
Rotation Error	0.1mrad	0.1mrad
BBA offset	N.A.	50um

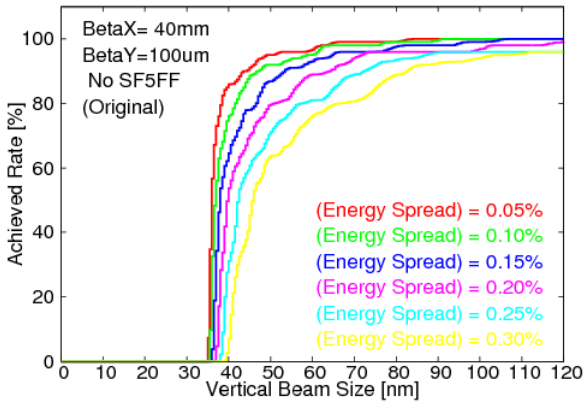
2. Tune the beam by the following steps

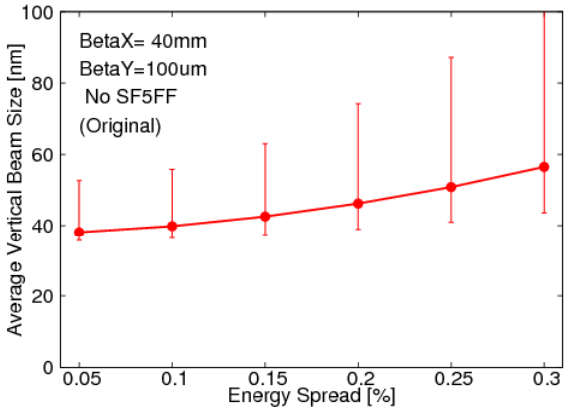


3. Simulate the IP beam size
*for **various momentum spread**.*

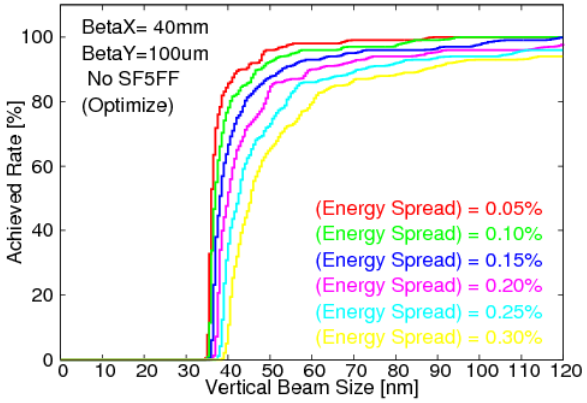
Results of beam tuning simulation for ATF2 10x1 optics

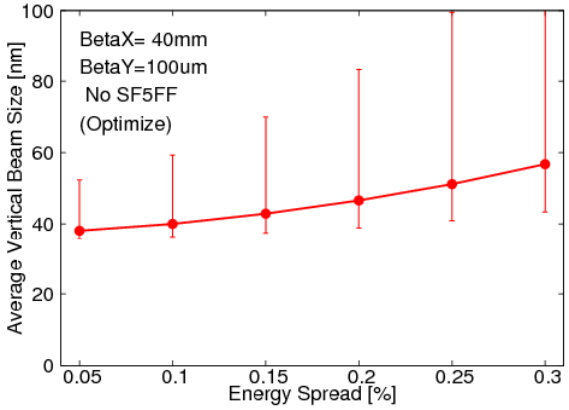
No SF5FF
(Present sextupole setting)



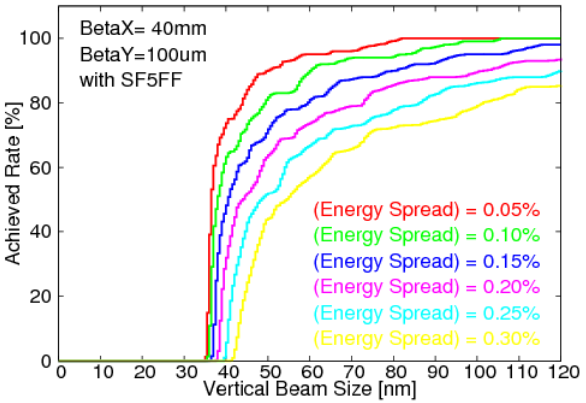


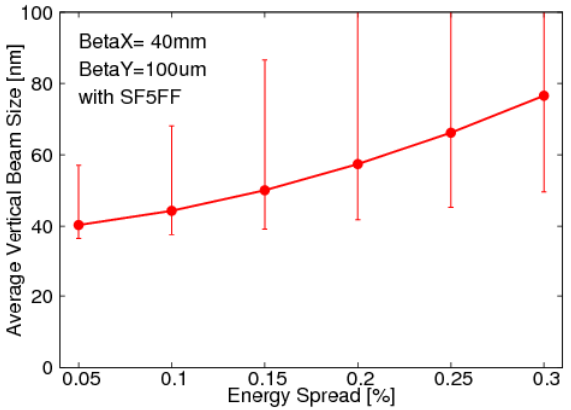
No SF5FF
(Optimize to large bandwidth)





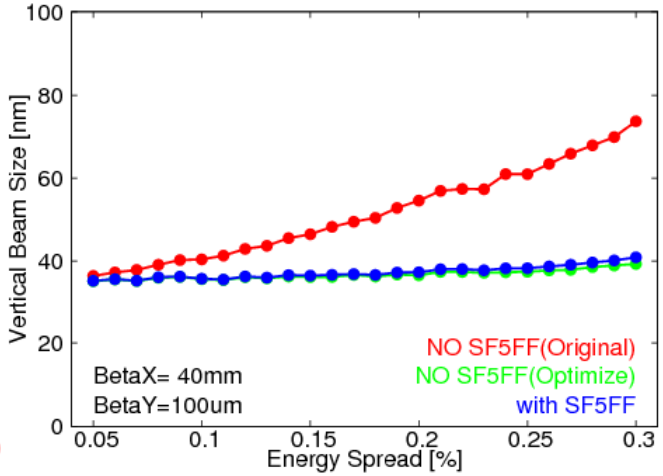
with SF5FF
(Optimize to large bandwidth)



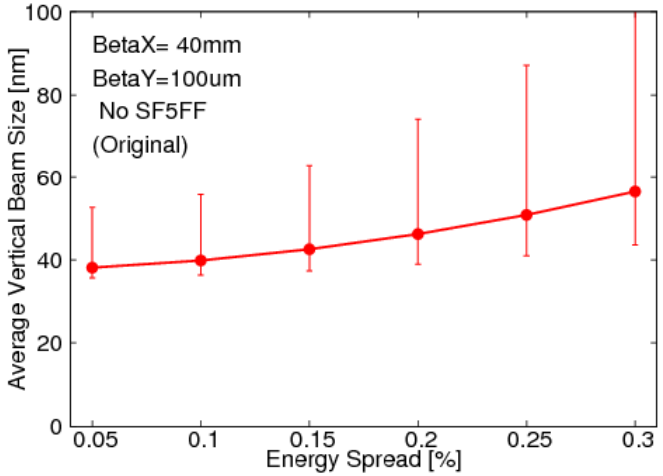


Momentum spread dependence for “NO” SF5FF

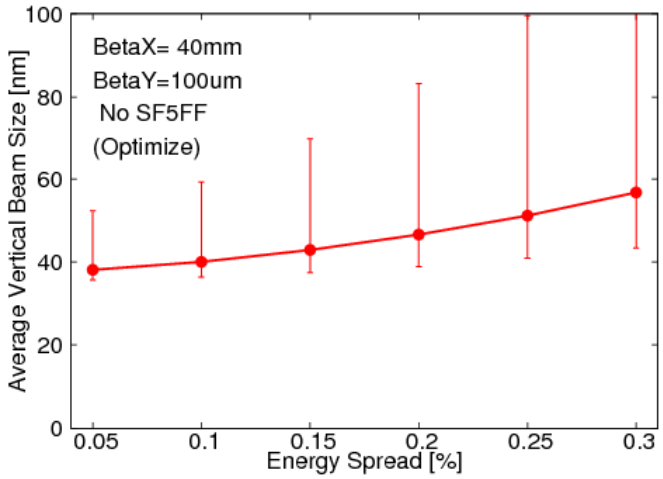
Model calculation, when no multipole errors



No SF5FF
(Present sextupole setting)



No SF5FF
(Optimize to large bandwidth)



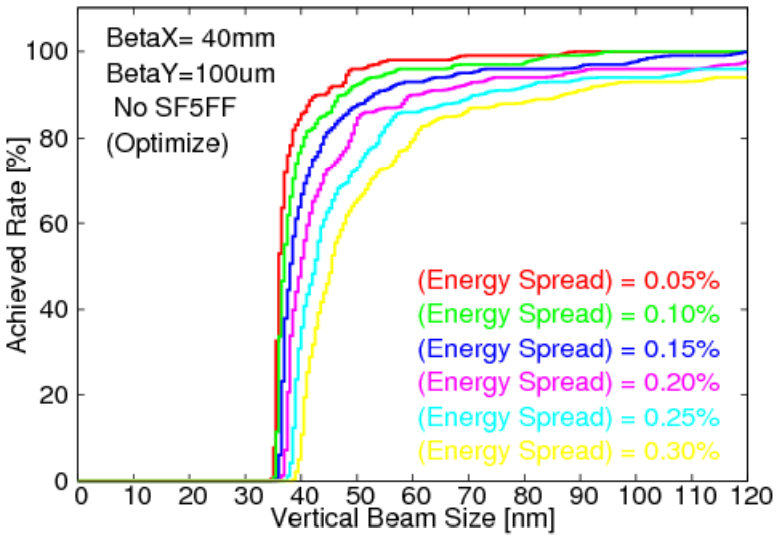
When momentum spread was increased after IP beam tuning with small momentum spread,

- momentum spread dependence are almost same for present and optimized optics without SF5FF.

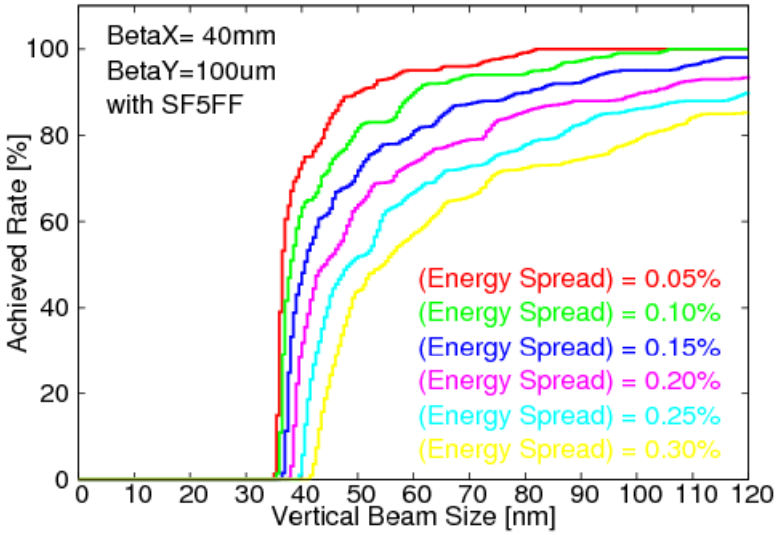
- momentum spread dependence was in between model calculation for present and optimized optics.

Momentum spread dependence "with" and "without" SF5FF

without SF5FF



with SF5FF



When momentum spread was increased after IP beam tuning with small momentum spread,

- momentum spread dependence of the optics with SF5FF was larger than that without SF5FF.

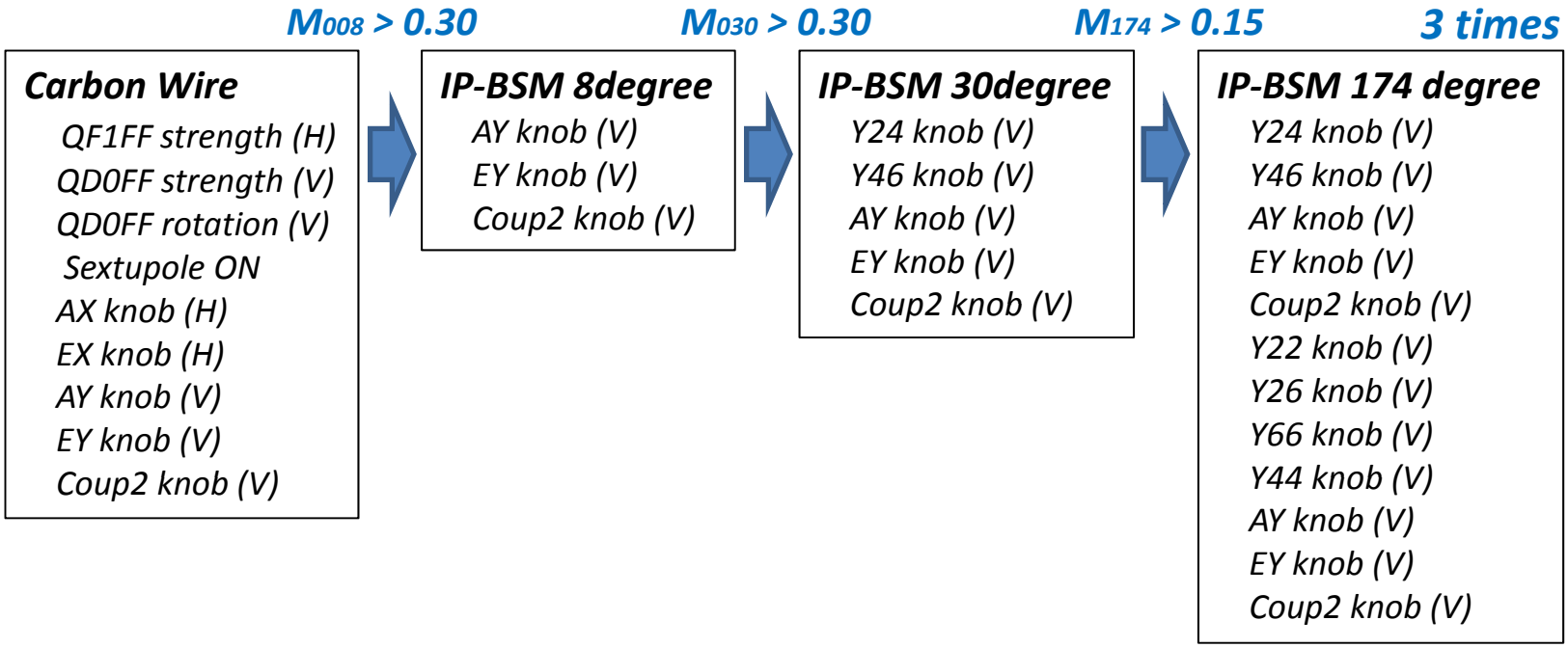
Procedures of IP beam tuning simulation

1. Put the following errors in Magnets as follows.

	Quadrupole	Sextupole
Quadrupole error	0.001	N.A.
Sextpole error	0.001 at R=1cm	0.001
Rotation Error	0.1mrad	0.1mrad
BBA offset	N.A.	50um

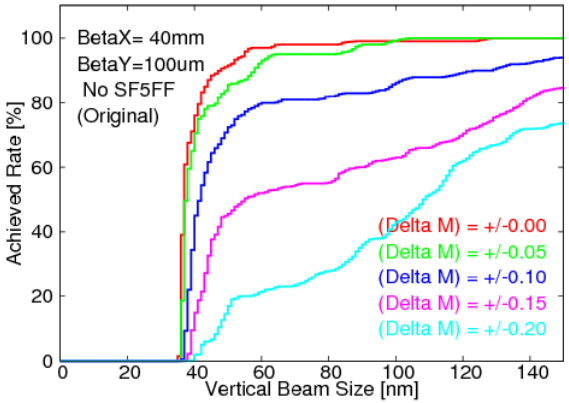
2. Set the **various IP-BSM monitor resolution**.

3. Tune the beam by the following steps

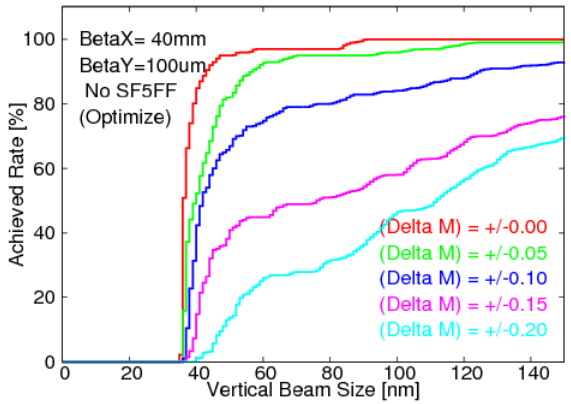


IP tuning performance of 10x1 optics for different IP-BPM monitor resolution

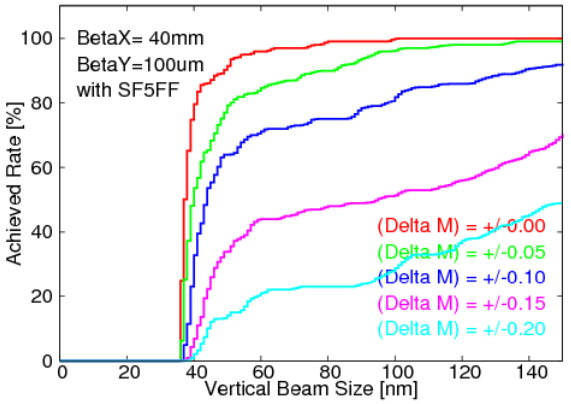
No SF5FF
(Present sextupole setting)



No SF5FF
(Optimize to large bandwidth)



with SF5FF
(Optimize to large bandwidth)



There are no clear difference for 3 beam optics.

The IP-BSM resolution is sensitive to the final IP beam size.

We should use the IP beam size monitor less than 5% modulation errors.

Beam Tuning Simulation for ATF2 10x0.25 Optics

Comment for low beta optics evaluation

The IP vertical beam size at ATF2 low beta optics is sensitive to the fringe field of final doublet.

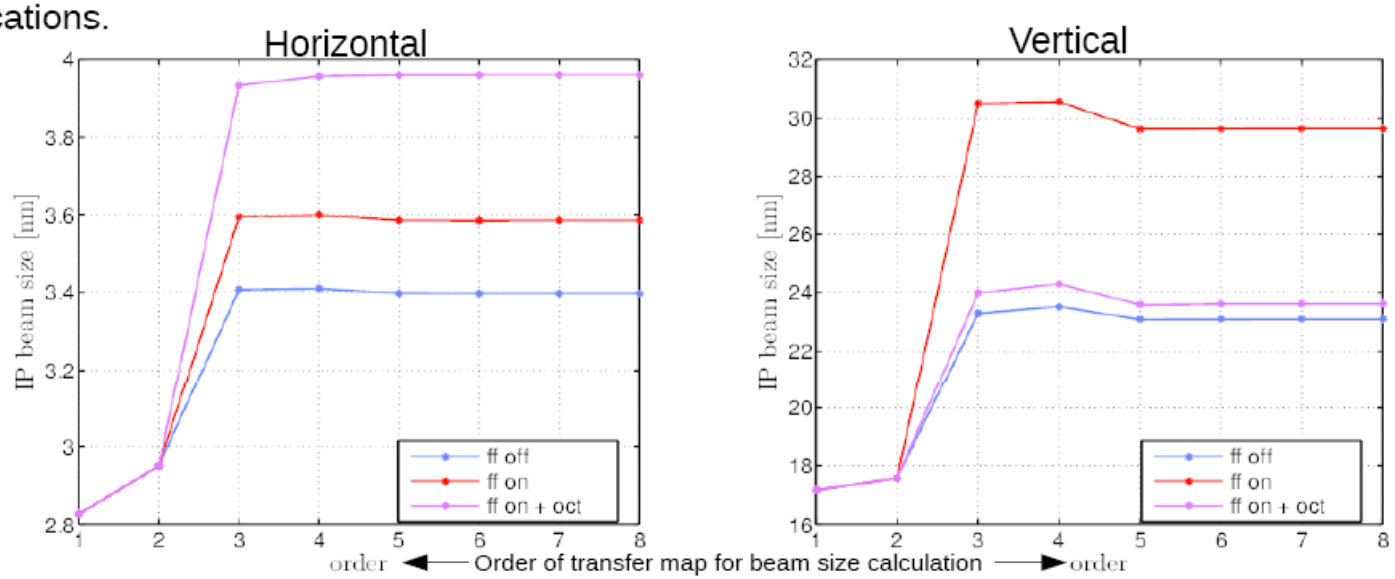
The fringe field may be corrected by using octupole magnets.

But, the following simulation, I will not use fringe field of FD and octupoles.

Octupole magnets for ATF2

FD fringe fields effect cancellation

FD fringe fields are responsible for the IP beam size growth. Both multipolar components and fringe fields can be mitigated with the use of the octupole magnets installed in proposed locations.



presented by M. Patecki et al., 2015 CLIC workshop

Energy bandwidth for ATF2 10x0.25 optics

All magnets errors were OFF.

No SF5FF (Matched only with QM magnets)

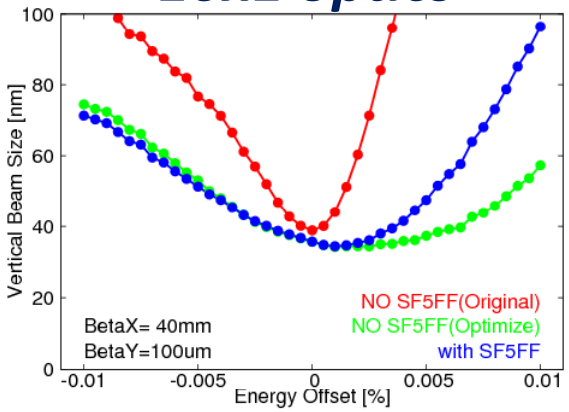
No SF5FF (Optimized to make large bandwidth)

with SF5FF (Optimized to make large bandwidth)

Emittances ($\varepsilon_x/\varepsilon_y$)	2nm /12pm
Beta Functions (β_x^*/β_y^*)	40mm / 0.100mm
Momentum Spread (σ_p/p)	0.08%

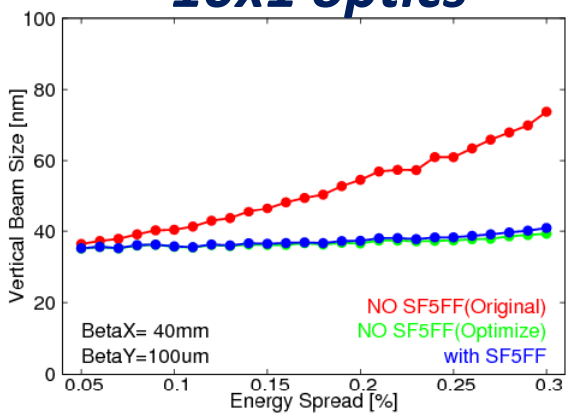
Momentum Offset

10x1 optics



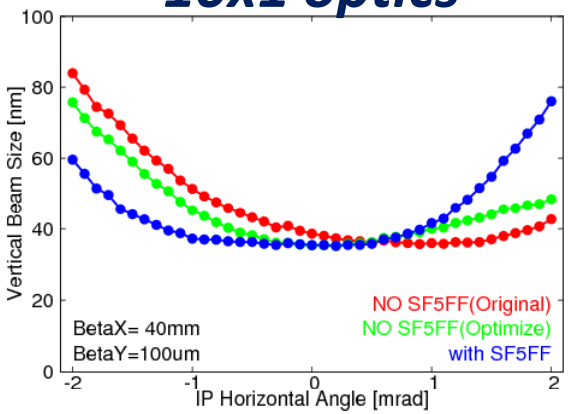
Momentum Spread

10x1 optics

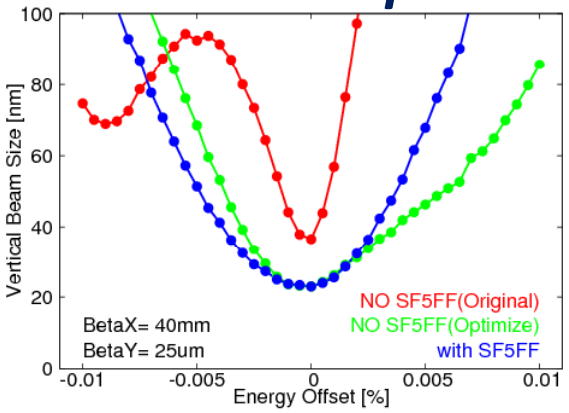


IP Horizontal Angle

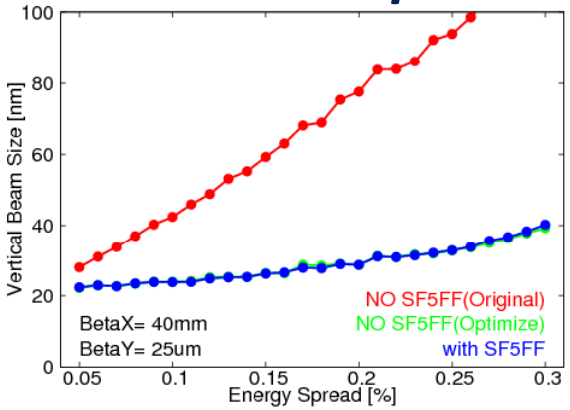
10x1 optics



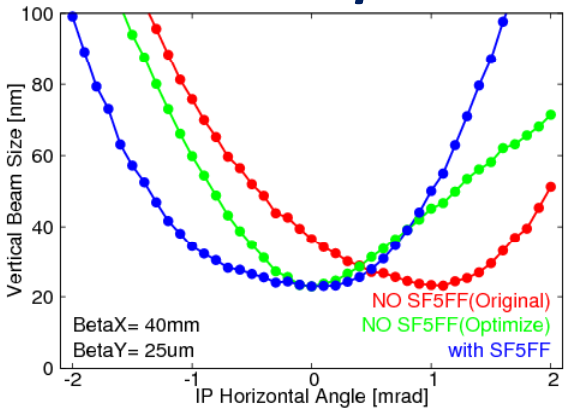
10x0.25 optics



10x0.25 optics



10x0.25 optics



Procedures of IP beam tuning simulation

1. Put the following errors in Magnets as follows.

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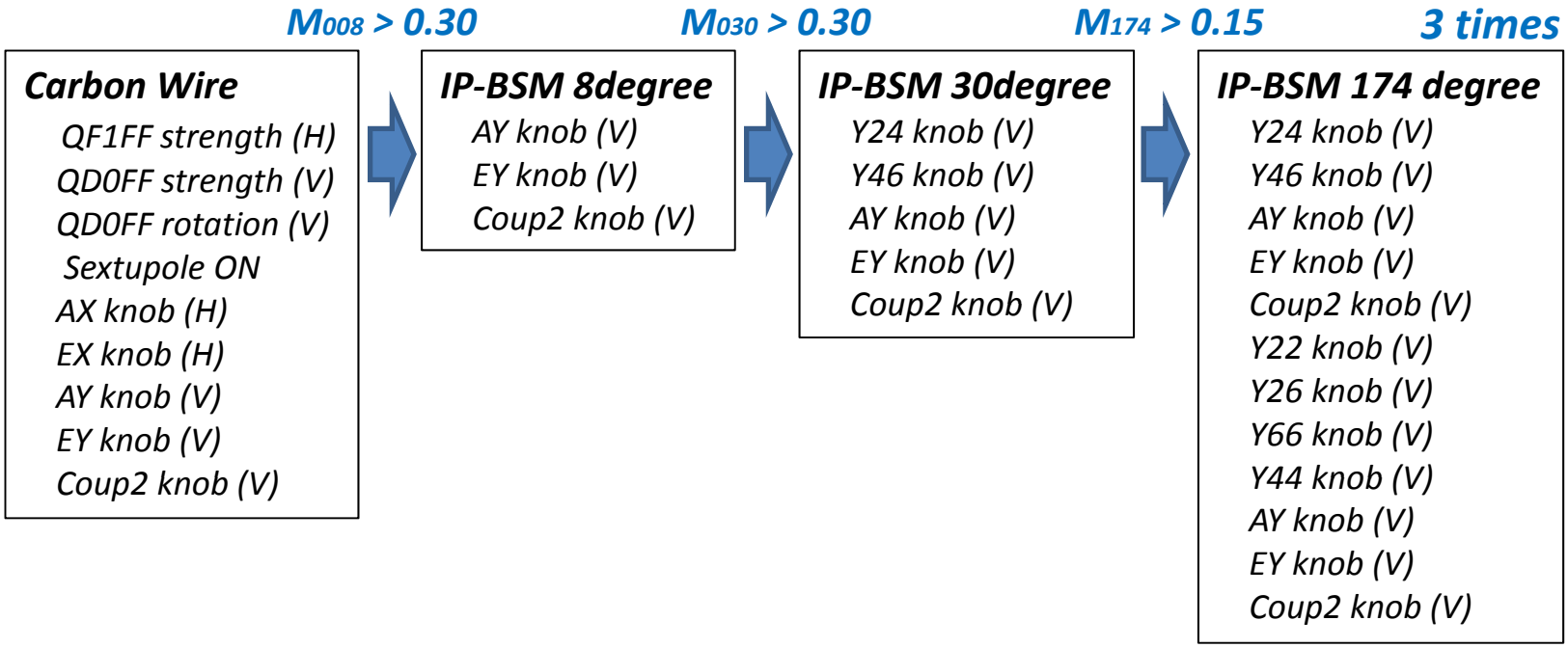
Quadrupole error	0.001	N.A.
Sextpole error	0.001 at R=1cm	0.001
Rotation Error	0.1mrad	0.1mrad
BBA offset	N.A.	50um

2. Set the **various IP-BSM monitor resolution**.

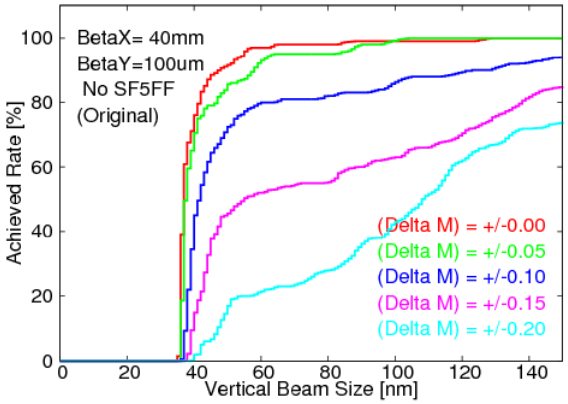
3. Tune the beam by the following steps



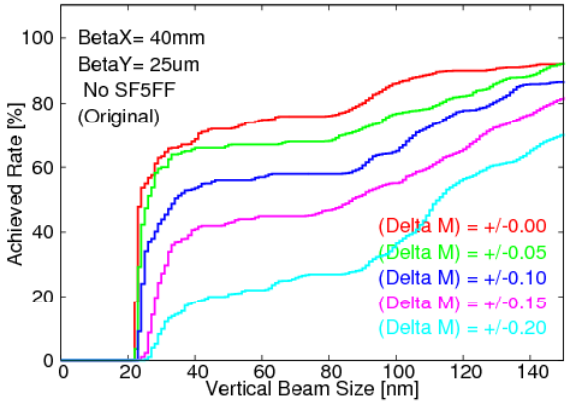
IP tuning performance for different IP-BPM resolution

No SF5FF
(Matched only with QM magnets)

10x1 optics

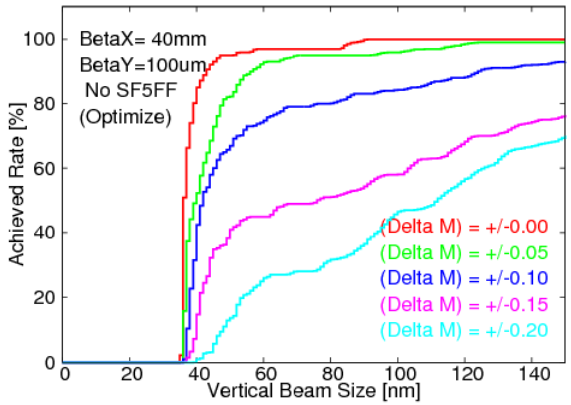


10x0.25 optics

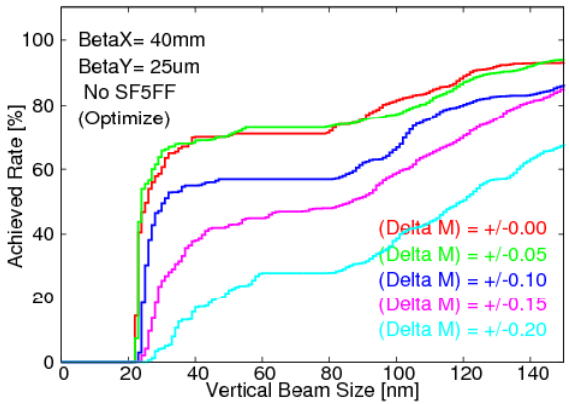


No SF5FF
(Optimize to large bandwidth)

10x1 optics

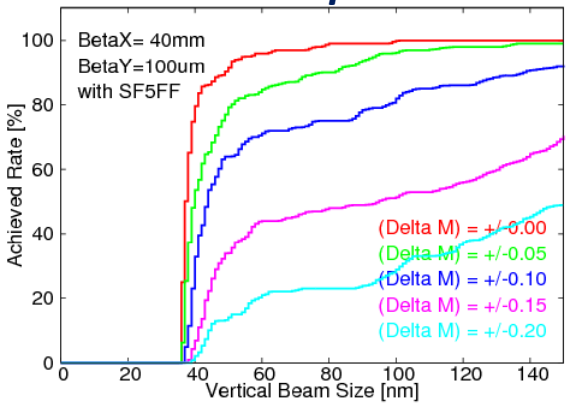


10x0.25 optics

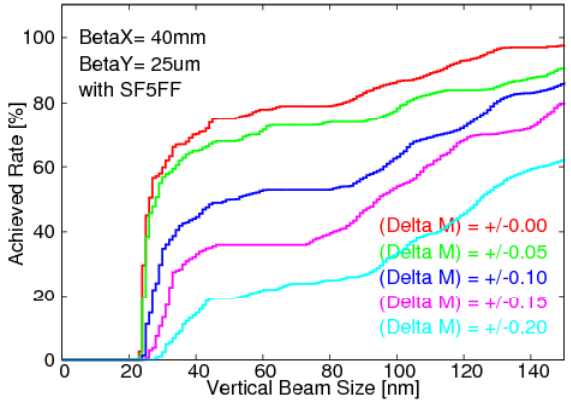


with SF5FF
(Optimize to large bandwidth)

10x1 optics



10x0.25 optics



10x0.25 optics sometimes cannot go to 174 degree mode (dynamic range of Y44).

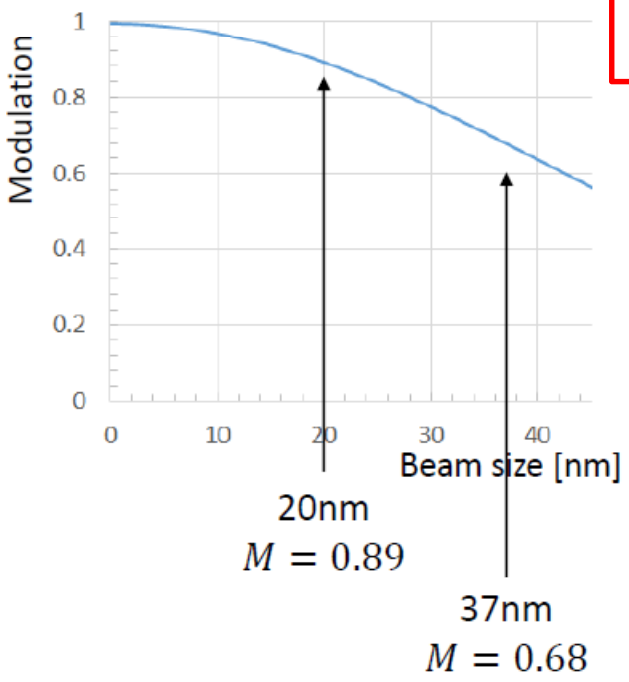
There are no clear difference for 3 beam optics.

Tuning result of 10x0.25 optics is also sensitive to monitor resolution.

Comment of IP-BSM for low beta optics

The IP-BSM resolution is not only sensitive to beam size tuning,
but also sensitive to the final beam size evaluation for low beta optics.

Sensitivity to 20 nm beam size



- $\sigma_y = 20\text{nm} \Rightarrow M = 0.89$

- 5nm precision:
  - To measure $\sigma_y = 37 \pm 5\text{nm}$, $M_{error} \lesssim 10\%$ is needed
  - To measure $\sigma_y = 20 \pm 5\text{nm}$, $M_{error} \lesssim 5\%$ is needed

- Observed error: $M_{error} \sim 10\%$

- Modulation reduction factor has to be considerably larger than $C > 0.89$

- Assumed experimentally last spring as $C \lesssim 0.83$

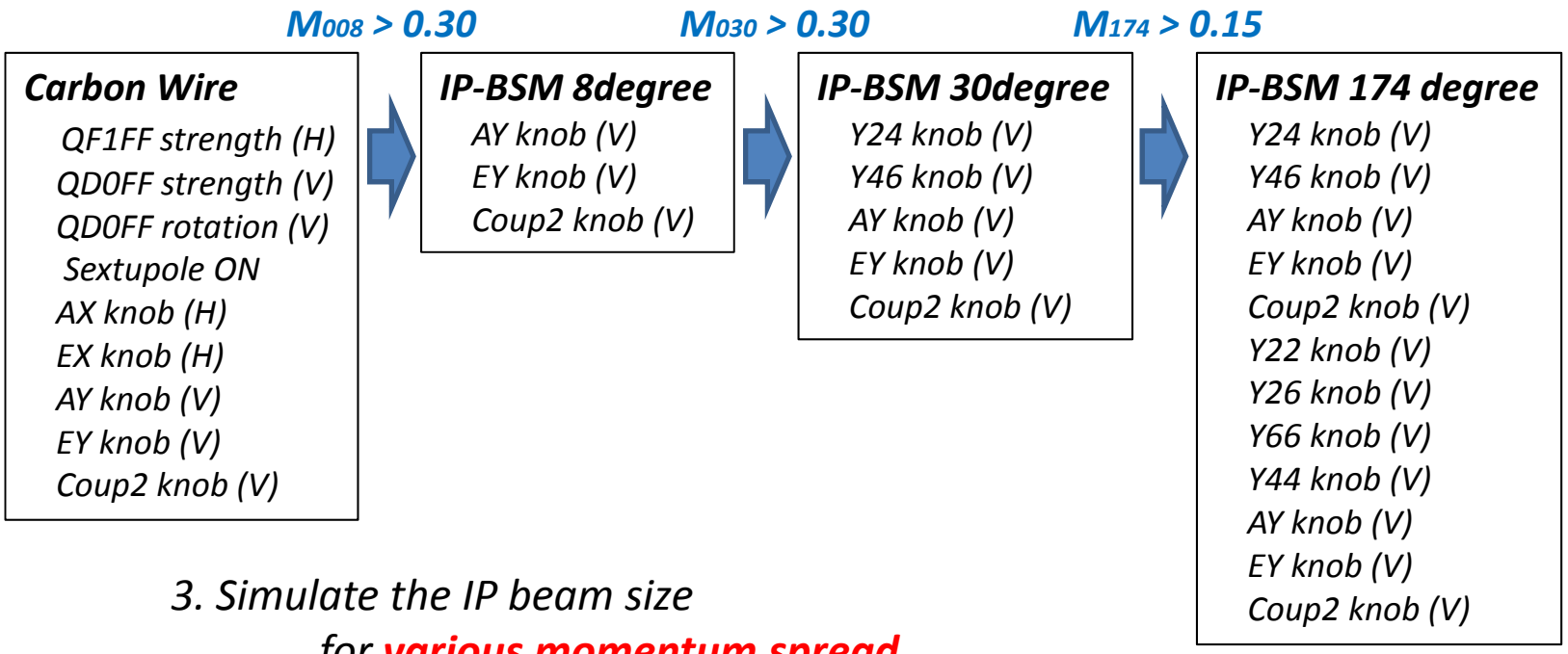
presented by Y. Kano, 2015 CLIC workshop

Procedures of IP beam tuning simulation

1. Put the following errors in Magnets as follows.

	Quadrupole	Sextupole
Quadrupole error	0.001	N.A.
Sextpole error	0.001 at R=1cm	0.001
Rotation Error	0.1mrad	0.1mrad
BBA offset	N.A.	50um

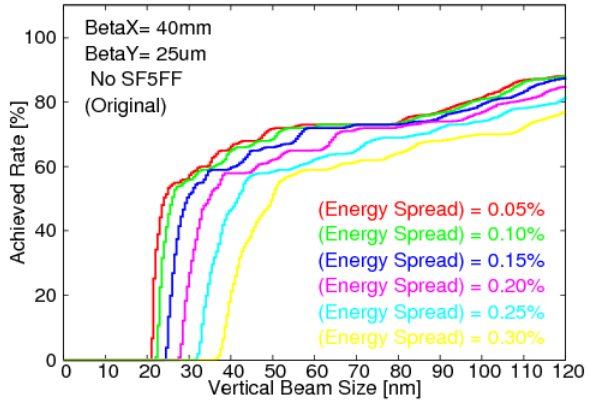
2. Tune the beam by the following steps

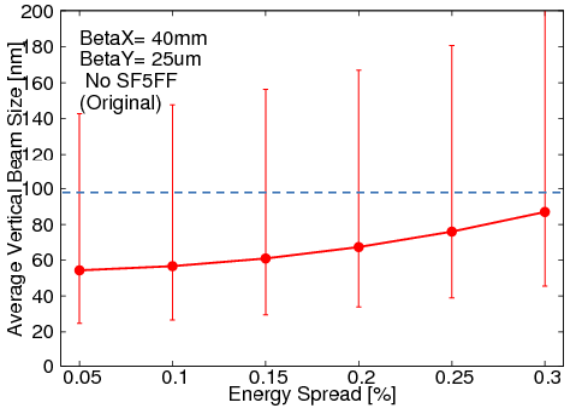


3. Simulate the IP beam size
*for **various momentum spread**.*

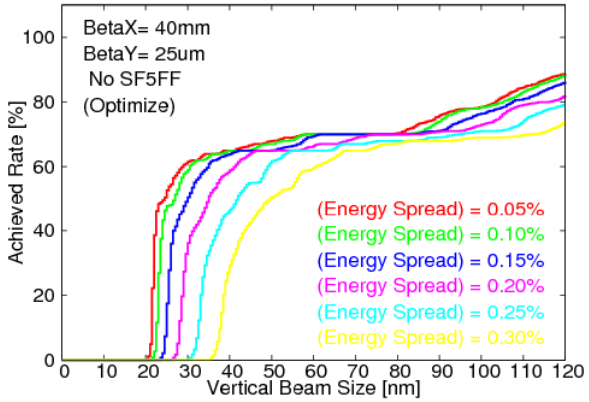
Results of beam tuning simulation for ATF2 10x0.25 optics

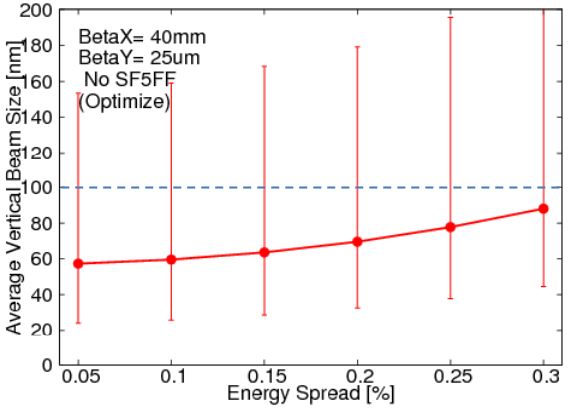
No SF5FF
(Matched only with QM magnets)



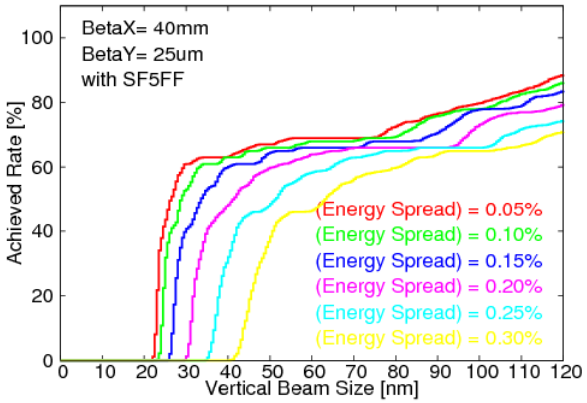


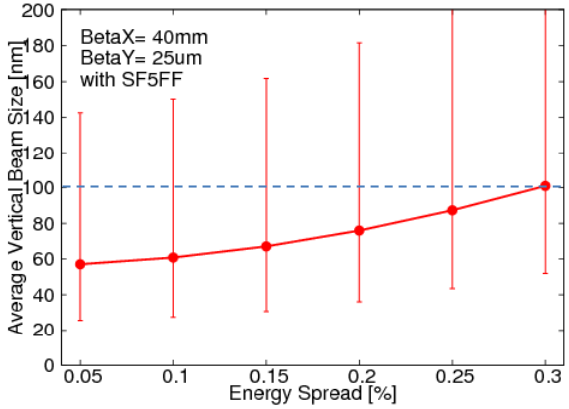
No SF5FF
(Optimize to large bandwidth)





with SF5FF
(Optimize to large bandwidth)





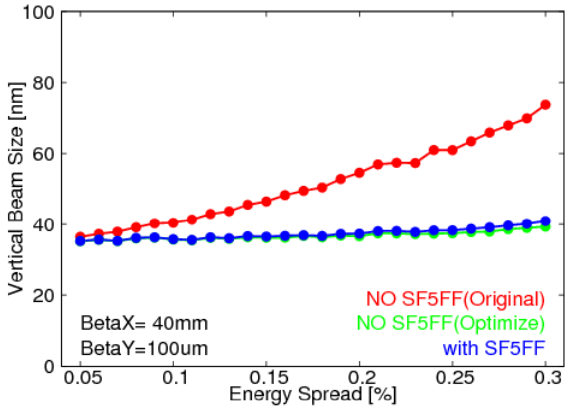
When momentum spread was increased after IP beam tuning with small momentum spread,
- momentum spread dependence are almost same for present and optimized optics without SF5FF.
- momentum spread dependence of optics with SF5FF was larger than that without SF5FF.

Momentum spread dependence

All of the results shows "NO SF5FF (Original)" as typical example.

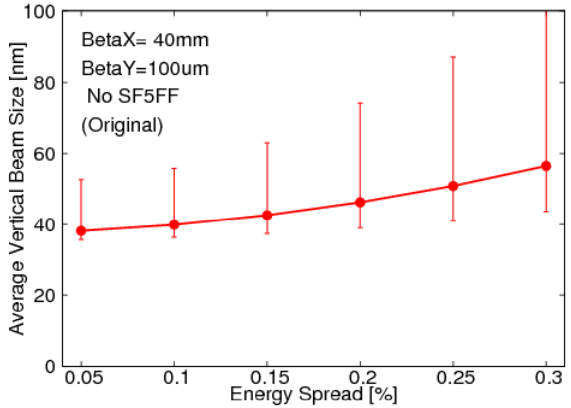
Model calculation

10x1 optics

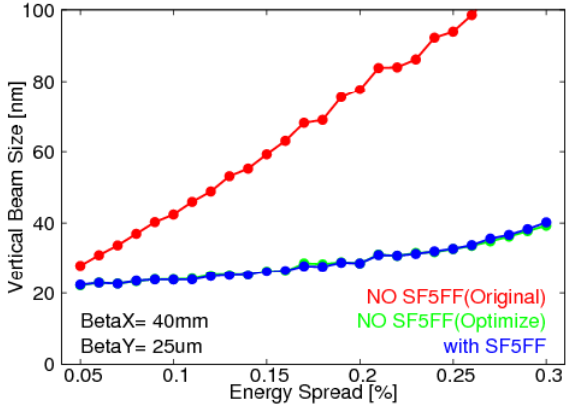


Simulation Result

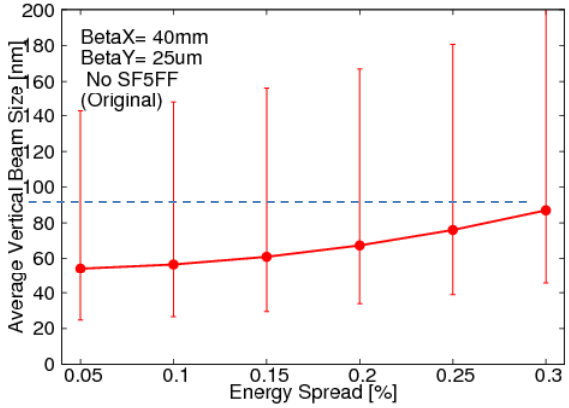
10x1 optics



10x0.25 optics



10x0.25 optics



When momentum spread was increased after IP beam tuning with small momentum spread,

- momentum spread dependence of 10x0.25 optics
was also in between model calculation for present and optimized optics.

Summary

When we apply the enough number of the iteration of knob tuning, the final sextupole setting after the beam size tuning is automatically optimized for the momentum spread of the beam.

Therefore, it is small impact for the initial sextupole setting.

The final sextupole setting of 10x1 optics for $\Delta p/p$=0.08% has small momentum bandwidth, and small IP horizontal angle acceptance.

The simulation said the momentum spread after tuning with 4 sextupoles were larger than that with 5 sextupoles for 10x1 optics.
(maybe the optics with smaller IP horizontal beta functions were different situations)

We need less than 5% of modulation accuracies for IP-BSM in order to achieve optimum IP beam size.

The multipole tolerances for 10x0.25 optics is tighter than 10x1 optics, especially for T344.

The momentum bandwidth and the IP horizontal angle acceptance for 10x0.25 optics is tighter than those for 10x1 optics.

The requirement of IP-BSM resolution for 10x0.25 optics was almost same to 10x1 optics.