Beam Delivery Systems at ILC and CLIC

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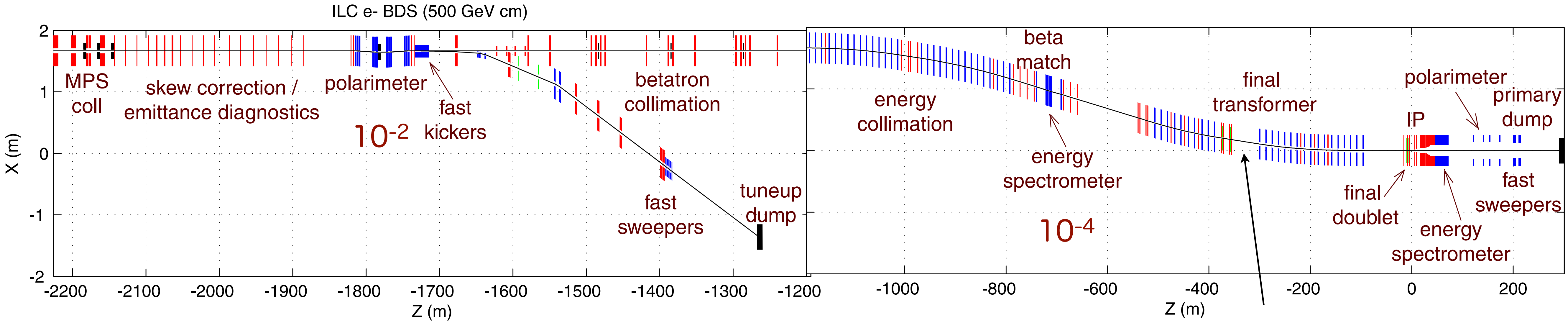
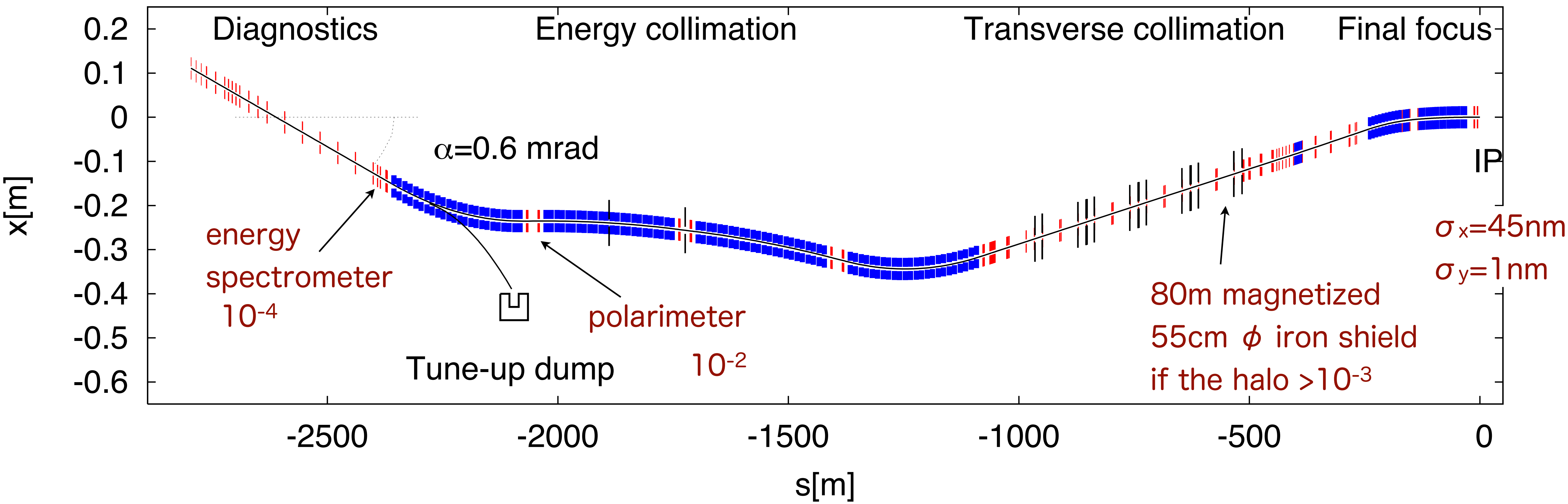
Acknowledgement

D. Angal-Kalinin, O. Blanco, H. Garcia, B. List, L. Malysheva, N. Phinney, A. Seryi, N. Walker, F. Zimmermann and more

ILC BDS, E_{cm} =500GeV



CLIC BDS, E_{cm} =3TeV



Both assume that beam halo of 10^{-5} hit the collimators -> 1 μ / bunch at IP

Luminosity degradation due to the collimators

1. Collimation depth, wakefield and emittance growth

	ILC-TDR	
$C_{dep\_y} = \theta_y^{max} / \sigma^{*\prime}_y$/safety_factor	→ 34.6(y), 6.6(x)@Eb=100GeV	
$A_y = 0.0482\ \gamma^{-1}\ C_{dep\_y}^{-1.5}\ \varepsilon_y^{-0.75}$	→ 4.4	55(y), 15(x)@CLIC
Emittance growth in y = $(0.4 * Jitter_{train} * A_y)^2$	→ 0.12	

Values in ILC-TDR (CLIC-CDR) ;

θ_y^{max} = 1 mrad, e.g. no syn.rad hit 20mmϕ beam pipe for ±10m around IP

safety_factor = 1.5

$Jitter_{train}$ = 0.2 (0.2), scaled by beam size with "FONT" feedback

note: emittance growth ∝ Jitter**2

$Jitter_{b\_b}$ = 0.1 (0.05), scaled by beam size

2. Bunch-to-bunch jitter effect on the luminosity

$\sigma_{b\_b} = Jitter_{b\_b} * (1 + A_y^2)^{0.5}$, jitter amplification	→ 0.45	
$L_{b\_b} - \Delta L_{b\_b} = EXP(-(\sigma_{b\_b}^2)/4)$	→ 0.95	~0.95

ILC

TDR : Assume gamepsX,Y incoming already include emittance growth due to wakefields etc. and no effect of b-b jitter

	Nominal 200	Nominal 250	Nominal 350	Nominal 500	HL 500	Nominal 1000
Ecms [GeV]	200	250	350	500	500	1000
gamma	1.96E+05	2.45E+05	3.42E+05	4.89E+05	4.89E+05	9.78E+05
N e-	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	1.74E+10
N e+	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	1.74E+10
nb	1312	1312	1312	1312	2625	2450
Tsep [ns]	554.0	554.0	554.0	554.0	366.0	366.0
Iave in train [A] e-	0.0058	0.0058	0.0058	0.0058	0.0087	0.0076
f	5	5	5	5	5	4
Pb [W] e-	2.10E+06	2.63E+06	3.68E+06	5.25E+06	1.05E+07	1.37E+07
Electron polarization, %	80	80	80	80	80	80
Positron polarization, %	31	31	29	22	22	30
Electron E-spread, %	0.220	0.190	0.158	0.125	0.125	0.083
Positron E-spread, %	0.170	0.150	0.100	0.065	0.065	0.043
IP Parameters						
gamepsX incoming	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05
gamepsY incoming	3.50E-08	3.50E-08	3.50E-08	3.50E-08	3.50E-08	3.00E-08
bx	1.60E-02	1.30E-02	1.60E-02	1.10E-02	1.10E-02	1.10E-02
by	3.40E-04	4.10E-04	3.40E-04	4.80E-04	4.80E-04	2.30E-04
sigx_geom	9.04E-07	7.29E-07	6.84E-07	4.74E-07	4.74E-07	3.35E-07
sigy_geom	7.8E-09	7.7E-09	5.9E-09	5.9E-09	5.9E-09	2.7E-09
sigx_effective	9.04E-07	7.29E-07	6.84E-07	4.74E-07	4.74E-07	3.35E-07
sigy_effective	7.8E-09	7.7E-09	5.9E-09	5.9E-09	5.9E-09	2.7E-09
sigxp	5.65E-05	5.61E-05	4.27E-05	4.31E-05	4.31E-05	3.05E-05
sigyp	2.29E-05	1.87E-05	1.73E-05	1.22E-05	1.22E-05	1.15E-05
gamepsX effective	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05
gamepsY effective	3.50E-08	3.50E-08	3.50E-08	3.50E-08	3.50E-08	3.00E-08
L* [m]	3.50	3.50	3.50	3.50	3.50	3.50
Max divergence X	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00E-04	4.00E-04
Max divergence Y	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
Collim safety factor	1.5	1.5	1.5	1.5	1.5	1.5
Coll depth X	6.6	6.6	6.2	6.2	6.2	8.7
Coll depth Y	34.6	42.5	38.5	54.6	54.6	57.7
BDS Inc. t-t jitter, sigma	0.2	0.2	0.2	0.2	0.2	0.2
BDS Inc. b-b jitter, sigma	0.1	0.1	0.1	0.1	0.1	0.1
Coll wake kick power xi, K~1/r^xi/ga	1.5	1.5	1.5	1.5	1.5	1.5
Coll wake Ay	4.4	3.1	3.3	1.8	1.8	1.5
Coll wake Y-emit growth	**0.124**	**0.060**	**0.068**	**0.020**	**0.020**	**0.015**
Increased b-b jitter, sigma	0.451	0.322	0.341	0.203	0.203	0.183
Lum reduct due to b-b jitter	**0.950**	**0.974**	**0.971**	**0.990**	**0.990**	**0.992**
sigz	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04
Dx e+	0.2	0.3	0.2	0.3	0.3	0.3
Dy e+	24.6	24.8	24.6	24.9	24.9	33.9
Theta0	6.39E-04	6.33E-04	4.83E-04	4.86E-04	4.86E-04	3.00E-04
xp_max_out	4.89E-04	4.84E-04	3.70E-04	3.71E-04	3.71E-04	2.30E-04
yp_max_out	1.09E-04	1.07E-04	8.21E-05	8.18E-05	8.18E-05	3.90E-05
Uave e+	0.013	0.021	0.031	0.063	0.063	0.156
Umax e+						
delta_B	0.0055	0.0100	0.0151	0.0389	0.0389	0.0910

Split FD at E_{cm}=200 and 250GeV

CLIC
15 (x)
55 (y)

Collimation depth

emittance growth

Lum loss
5%

Lum degradation

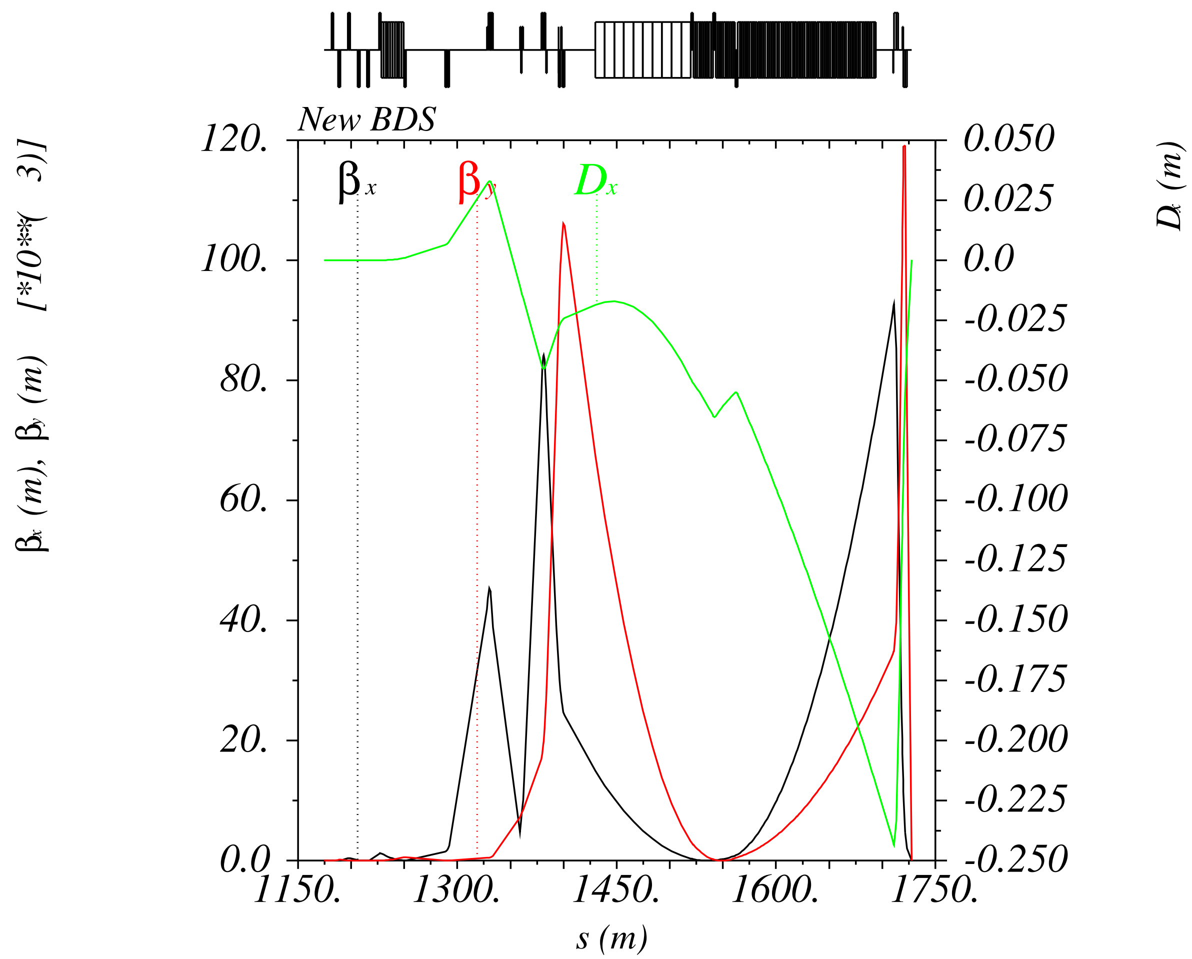
P_Beamstrahlung [W]	1.15E+04	2.62E+04	5.55E+04	2.04E+05	4.09E+05	1.24E+06
ngamma e+	0.94	1.15	1.22	1.71	1.71	2.00
Hdx	1.1	1.1	1.1	1.2	1.2	1.1
Hdy	4.5	5.4	4.5	6.1	6.1	3.3
Hd	1.7	1.8	1.7	2.0	2.0	1.6
Geo Lum (cm-2 s-1)	2.96E+33	3.74E+33	5.18E+33	7.51E+33	1.50E+34	2.65E+34
Lum. dil.	***0.950***	***0.974***	***0.971***	***0.990***	***0.990***	***0.992***
Lum. (cm-2 s-1)	**5.02E+33**	**6.85E+33**	**8.79E+33**	**1.47E+34**	**2.95E+34**	**4.13E+34**
Lum/bc	*7.66E+29*	*1.04E+30*	*1.34E+30*	*2.25E+30*	*2.25E+30*	*4.21E+30*
Coherent pairs/bc	5.36E-167	4.31E-105	1.15E-67	1.00E-28	1.00E-28	9.82E-07
Inc. pairs/bc (LL)	1.39E+04	2.00E+04	2.80E+04	5.12E+04	5.12E+04	1.13E+05
Inc. pairs/bc (BW)	1.63E+03	2.23E+03	2.05E+03	3.55E+03	3.55E+03	3.69E+03
Inc. pairs/bc (BH)	1.22E+05	1.81E+05	2.23E+05	4.33E+05	4.33E+05	7.80E+05
Inc. Pairs/bc (tot)	1.38E+05	2.04E+05	2.53E+05	4.88E+05	4.88E+05	8.97E+05
Caliculations by CAIN						
Lum. (cm-2 s-1)	5.08E+33	7.11E+33	8.90E+33	1.55E+34	3.10.E+34	3.54E+34
Lum. (cm-2 s-1) w/ waist shift	5.71E+33	7.85E+33	1.00E+34	1.68E+34	3.37.E+34	4.19E+34
Lum top 1% : L(0.01)/L	0.914	0.841	0.790	0.613	0.613	0.476
Lum top 1% w/ waist shift	0.911	0.840	0.784	0.612	0.612	0.463
Lum 1nm offsetY : L(1nm)/L	0.969	0.959	0.949	0.927	0.927	0.854
Lum 1nm offsetY w/ waist shift	0.959	0.952	0.937	0.916	0.916	0.828
energy loss	0.034	0.046	0.044	0.072	0.072	0.084
energy loss w/ waist shift	0.034	0.045	0.044	0.072	0.072	0.083
Inc. Pairs/bc (tot)	2.54E+04	4.17E+04	5.50E+04	1.23E+05	1.23.E+05	2.13E+05
Inc. Pairs/bc (tot) w/ waist shift	2.84E+04	4.45E+04	6.11E+04	1.30E+05	1.30.E+05	2.44E+05
Caliculations by GP						
Lum -ratio : analytic/GP	0.85	0.86	0.84	0.87	0.87	0.92
Date of run	25.Sep.12	25.Sep.12	25.Sep.12	25.Sep.12	25.Sep.12	25.Sep.12
Lum GP-beam-beam (cm-2 s-1)	5.89E+33	7.96E+33	1.04E+34	1.70E+34	3.40E+34	4.47E+34
Lum top 1% : L(0.01)/L	0.922	0.846	0.790	0.615	0.615	0.460
Lum(Ecms) /Lum (500GeV)	0.35	0.47	0.61	1.00	2.00	2.63
Ecms/500	0.4	0.5	0.7	1	1	2
relative to the scaled Lum	0.87	0.94	0.88	1.00	2.00	1.31
Inc. pairs/bc (LL)	18,811	25,793	34,409	111,658	223,316	101,258
Inc. pairs/bc (BW)	1,481	2,270	2,256	4,242	8,485	4,648
Inc. pairs/bc (BH)	20,974	35,687	49,000	111,658	223,316	218,083
Inc. Pairs/bc (tot)	41,266	63,751	85,666	227,558	455,117	323,989
energy loss	0.0060	0.0113	0.0165	0.0422	0.0422	0.0896
	Nominal 200	**Nominal 250**	**Nominal 350**	**Nominal 500**	**HL 500**	**Nominal 1000**

CLIC and ILC Final Focus System E_{cm} =500GeV

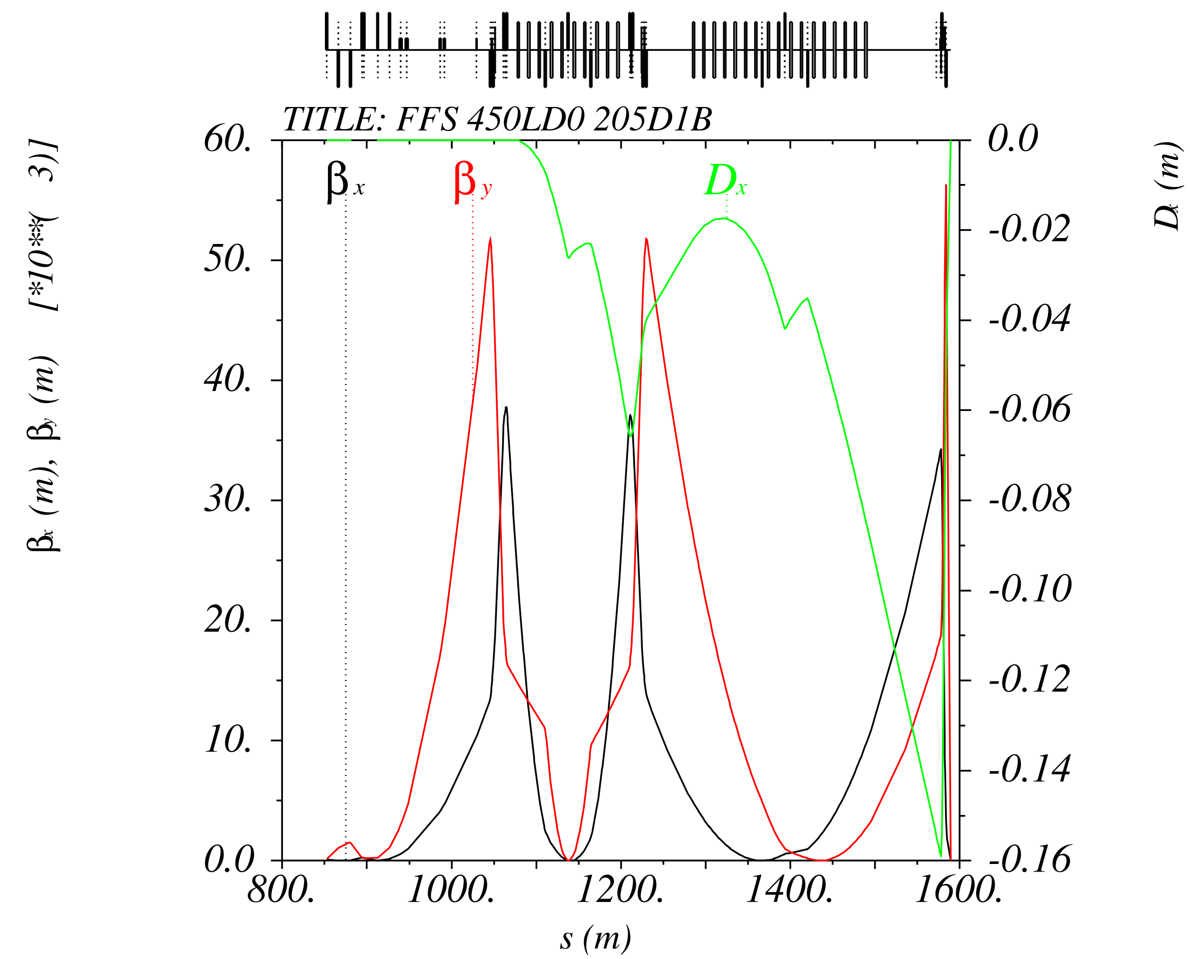
Both FFS follow the local chromaticity correction scheme proposed by P.Raimondi and A.Seryi.

Parameter [Units]	**CLIC500**	**ILC500**
FFS length/side [m]	553.1 constrained	735.4
Maximum energy/beam [TeV]	0.25 by 3TeV	0.25
Distance from IP to first quad, l^* [m]	4.30	3.51/4.50
Crossing angle at IP [mrad]	18.6	14.0
Core beam size at IP, $\sigma^*, x/y$ [nm]	202/2.3	474/5.9
Beam divergence at IP, $\theta^*, x/y$ [μrad]	25/23	43/12
Beta-function at IP, $\beta^*, x/y$ [mm]	8/0.1	11/0.48
Bunch length, σ_z [μm]	72 pushed β^*_y	300
Disruption parameters, $D, x/y$	0.1/12	0.3/24.6
Bunch population, N	$6.8 \cdot 10^9$	$2 \cdot 10^{10}$

CLIC $\sqrt{s} = 500$ GeV



ILC $\sqrt{s} = 500$ GeV



Both use the local chromaticity correction scheme.

a common FFS ?

Talks(optics optimisaton) by H. Garcia, Thursday morning, BDS+Beam dynamics

CLIC and ILC comparison

- CLIC β−functions are much smaller than ILC.
- The nonlinear correction is in both cases effective.

$\sigma_x^{\mathrm{ILC}} = 490$ nm, $\sigma_x^{\mathrm{CLIC}} = 222$ nm

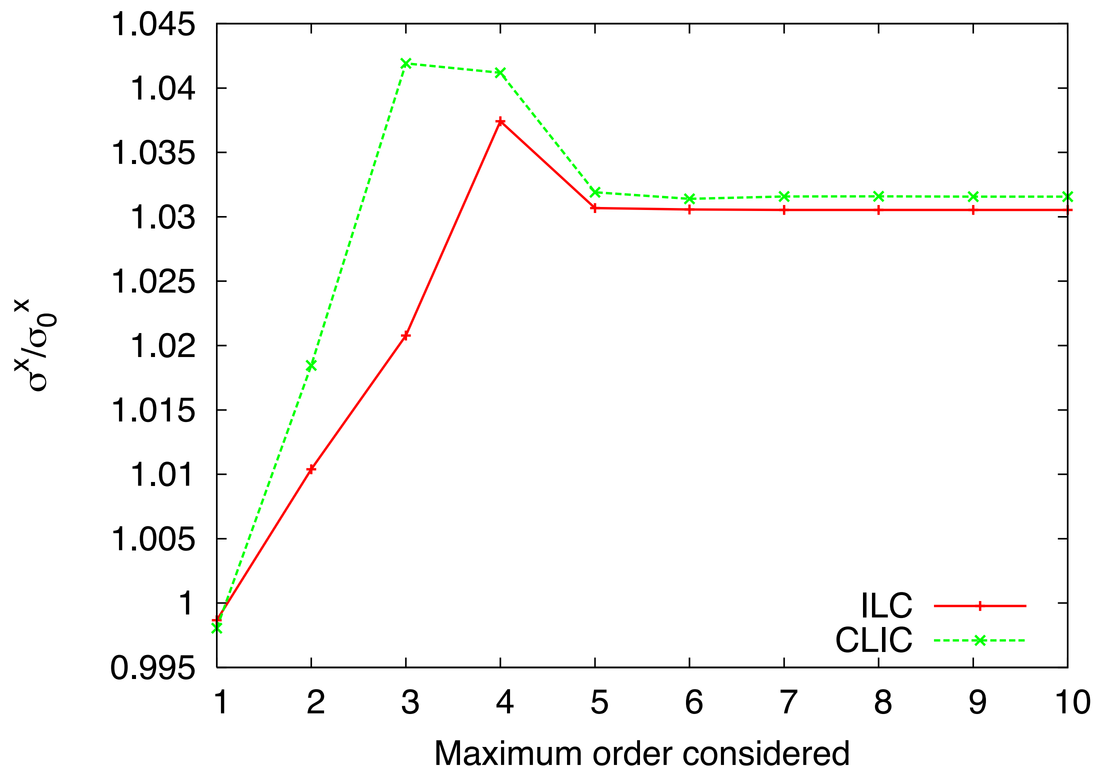


Figure: Nonlinear optimization for σ_x

$\sigma_y^{\mathrm{ILC}} = 6.6$ nm, $\sigma_y^{\mathrm{CLIC}} = 2.4$ nm

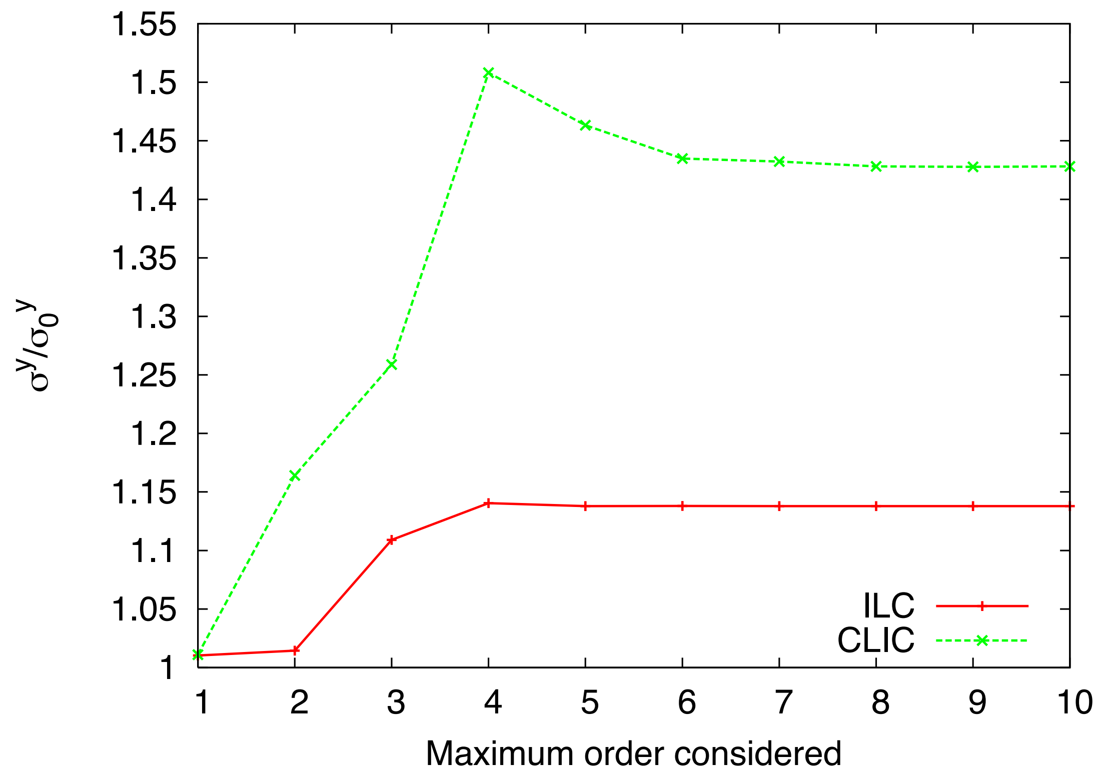
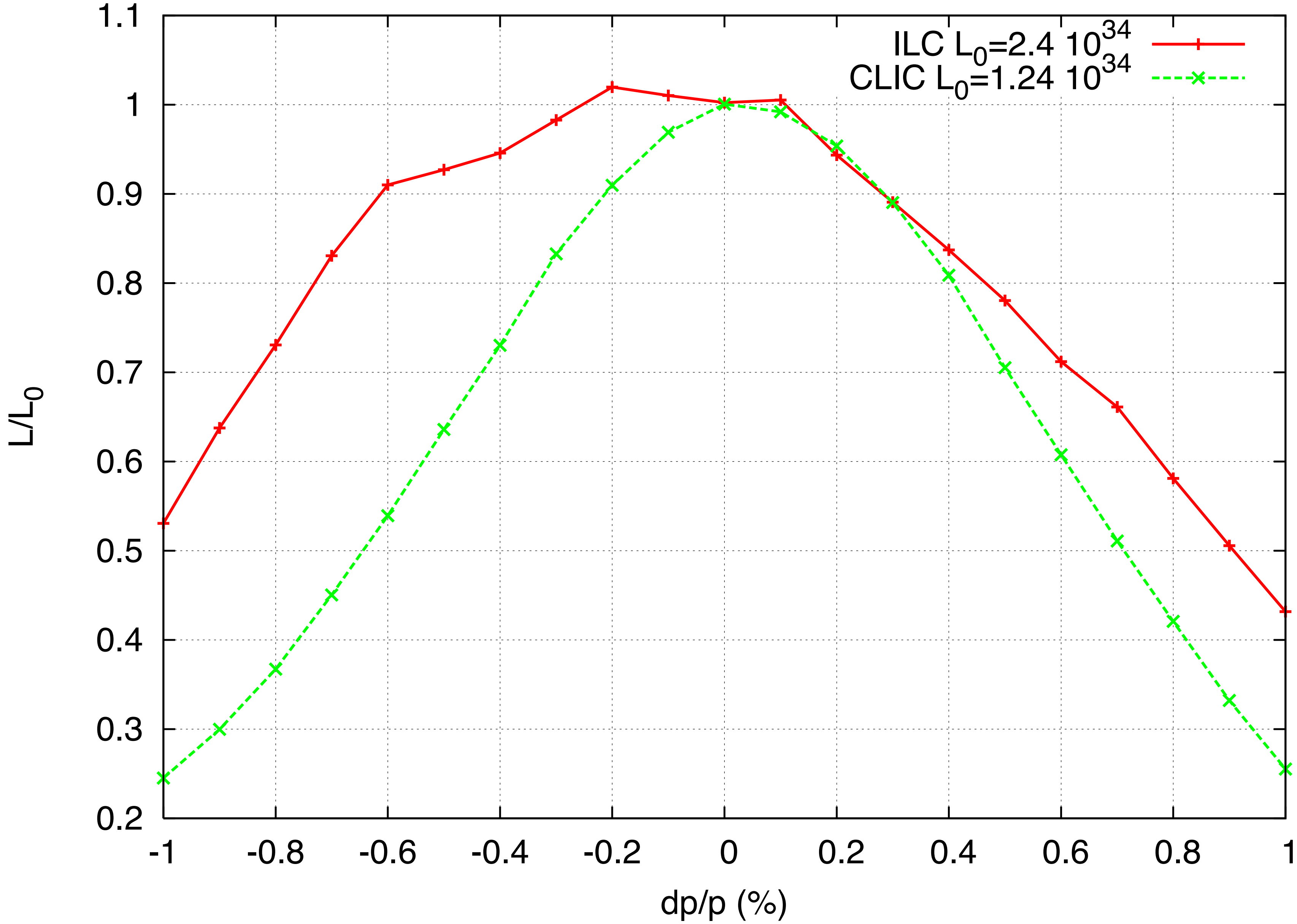


Figure: Nonlinear optimization for σ_y

CLIC and ILC Luminosity bandwidth



CLIC QD0 : Hybrid magnet

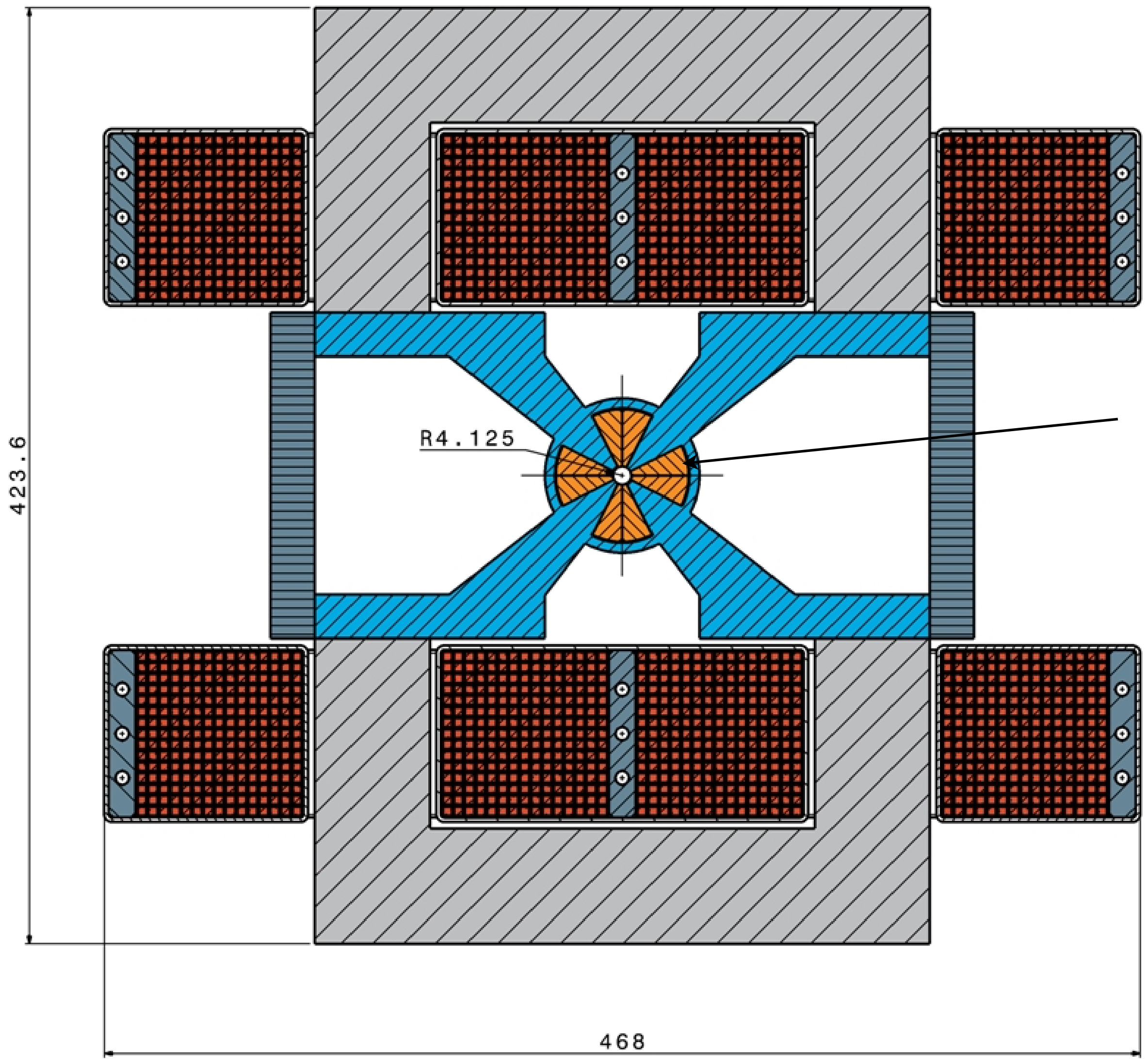


Table 4: Specifications of the FD QD0 quadrupole for the different L* cases.

L*	m	3.5	4.3	6.0	8.0
Gradient	T/m	575	382	200	211
Length	m	2.7	3.3	4.7	4.2
Beam aperture	mm	3.8	6.7	8	8.5
Jitter tolerance	nm	0.15	0.15	0.2	0.18
Gradient tol	10^{-6}	5	5	-	3
Octupolar error	10^{-4}@1mm	7	7	-	3
Prealignment	μm	10	10	8	2

permanent magnets

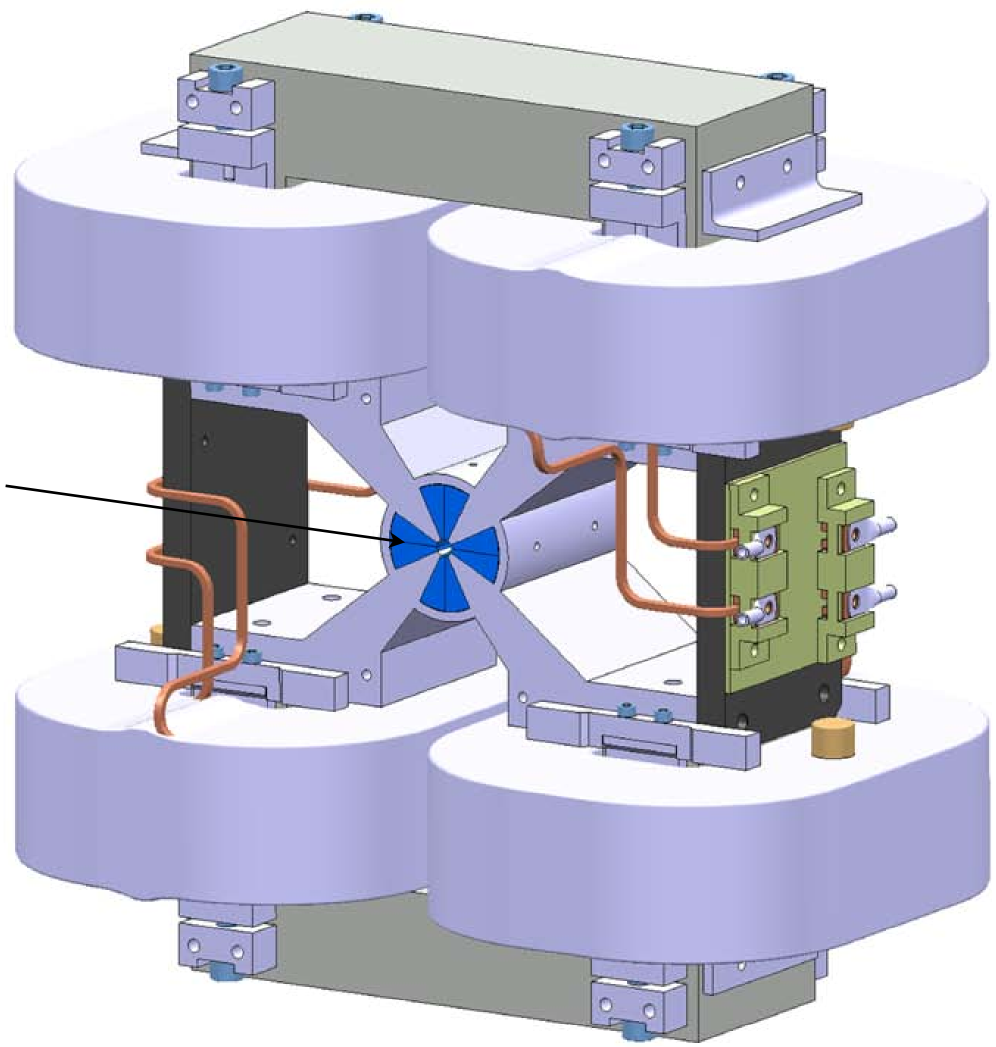
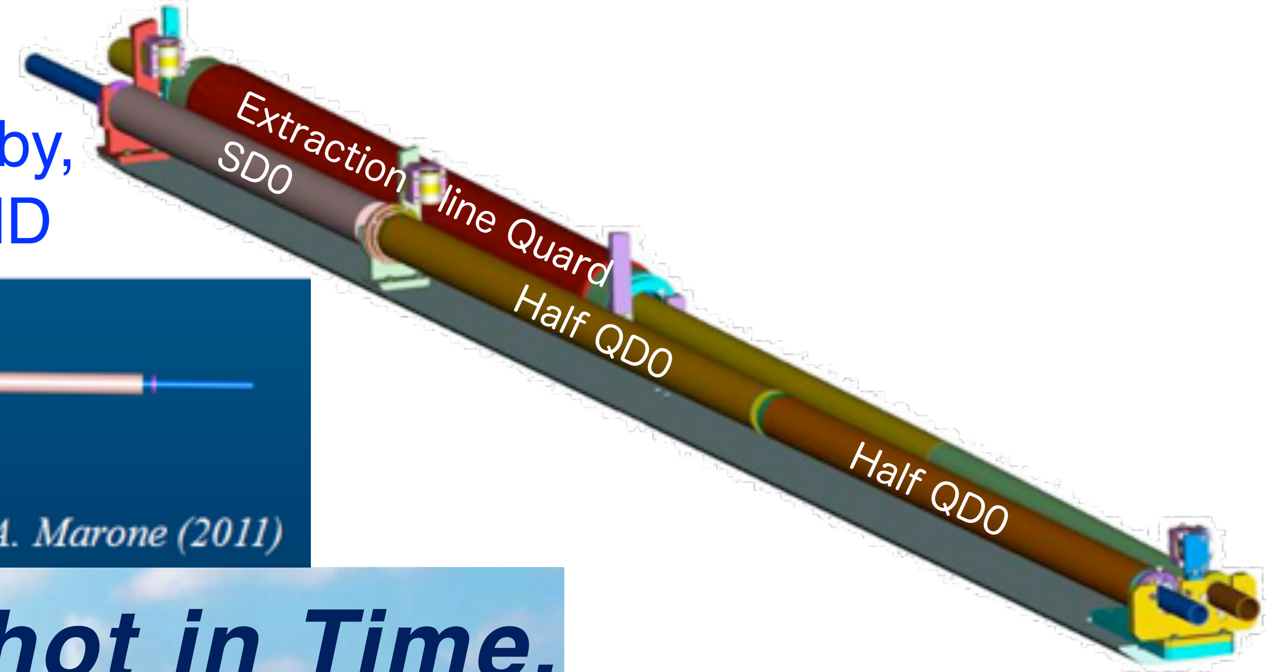


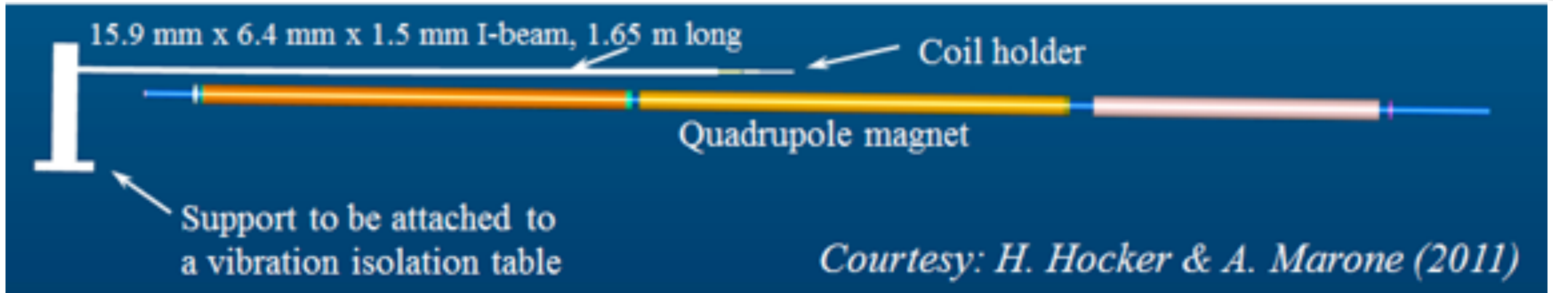
Fig. 5.289: Hybrid QD0 short prototype

with the same cross section but shorter length, which performs close to the specifications

ILC QD0 : SCQ

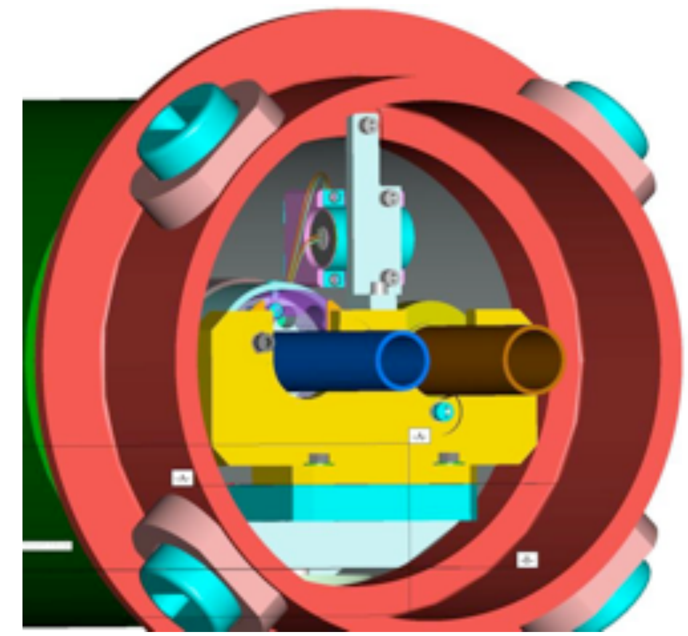
presented at KILC12 by,
Brett Parker, BNL-SMD





Daegu QD0 Status Snapshot in Time.

- *We have learned what is needed to wind long, slender ILC QD0 coils.*
- *We have new mechanical scenario for how to install and support QD0 in SiD; ILD is also developing their solution.*
- *We expect to have an ILC style QD0 IR magnet system for warm vibration tests; funding is needed for cold tests.*
- *Look to make the most of synergy with SuperKEKB and CLIC stability studies.*
- *We also have ATF2 FF upgrade coils.*



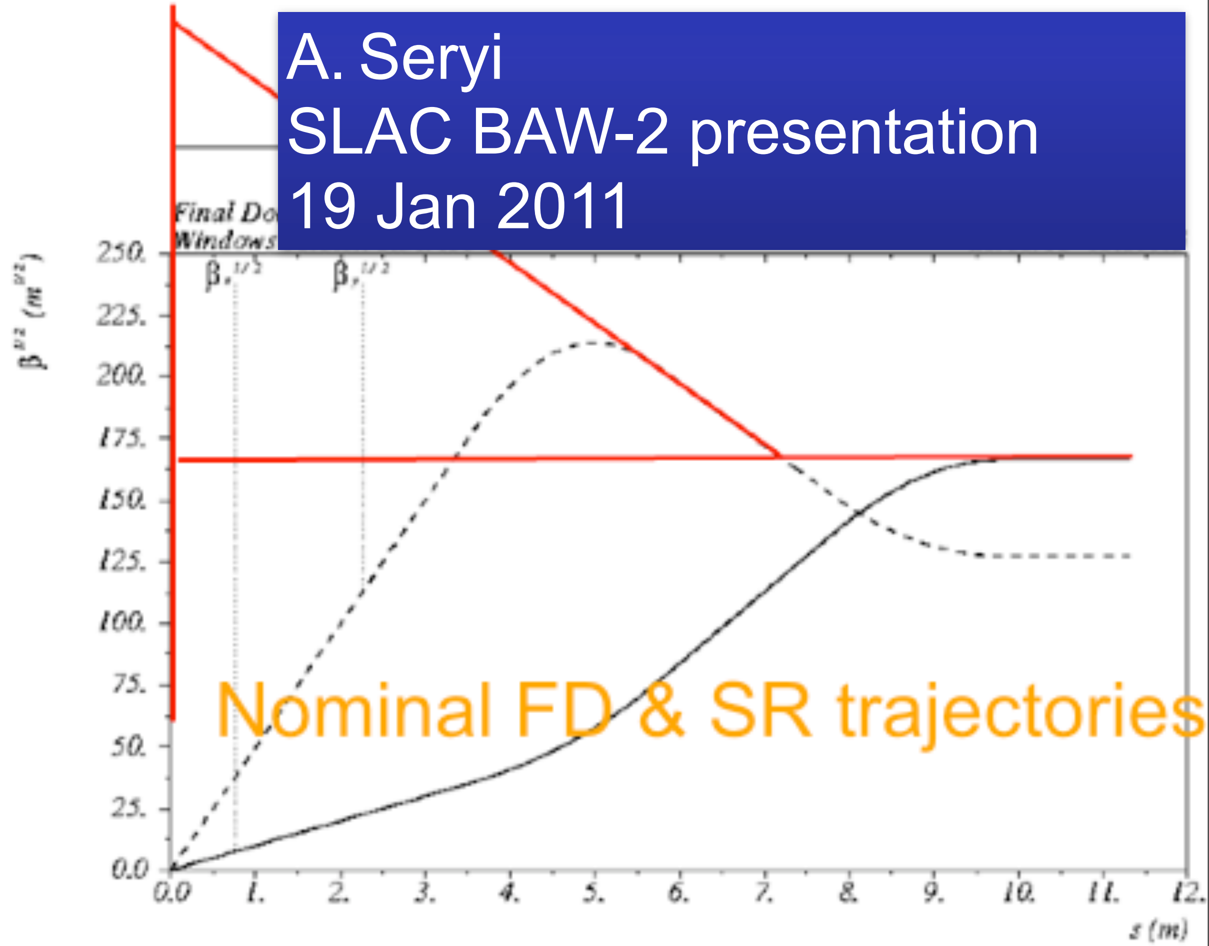
FD for low E

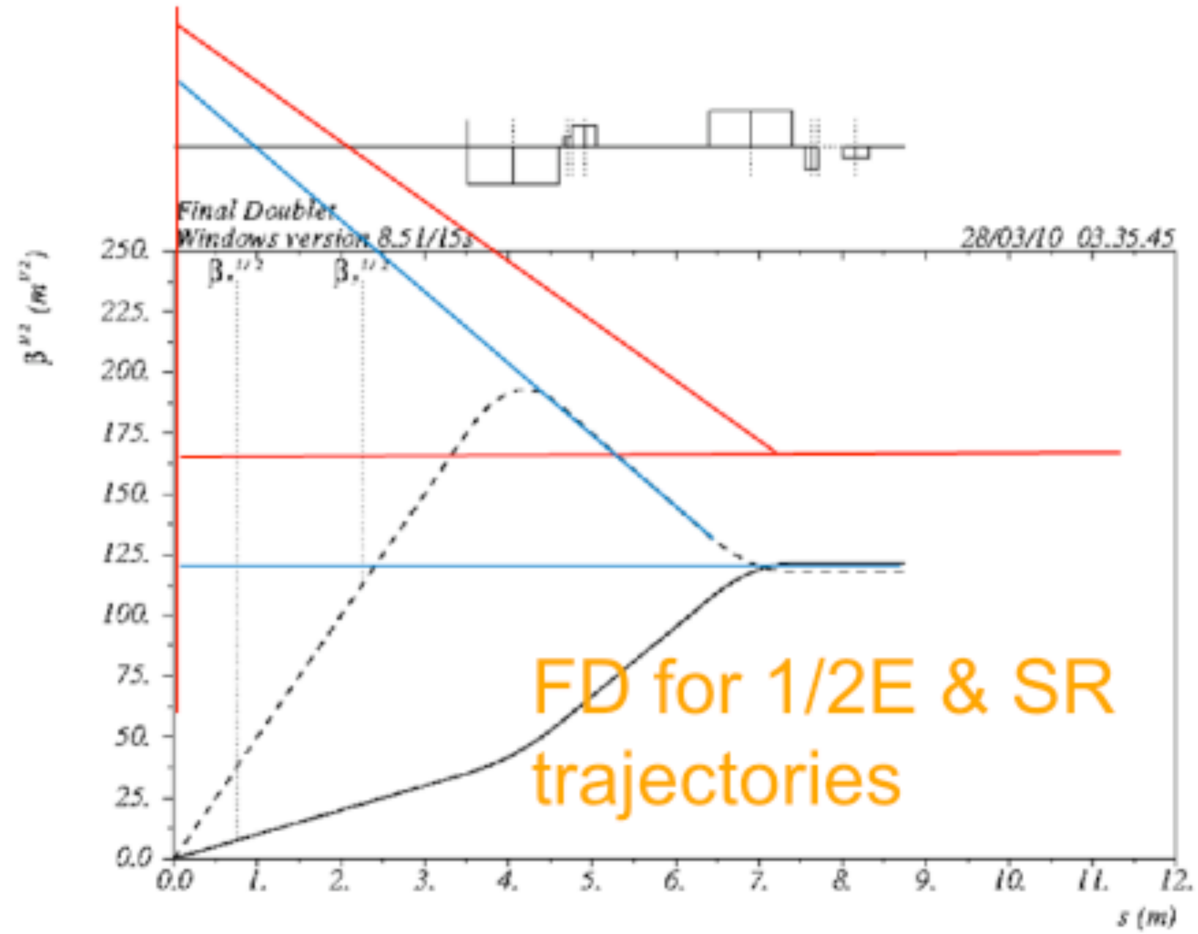
A. Seryi
SLAC BAW-2 presentation
19 Jan 2011

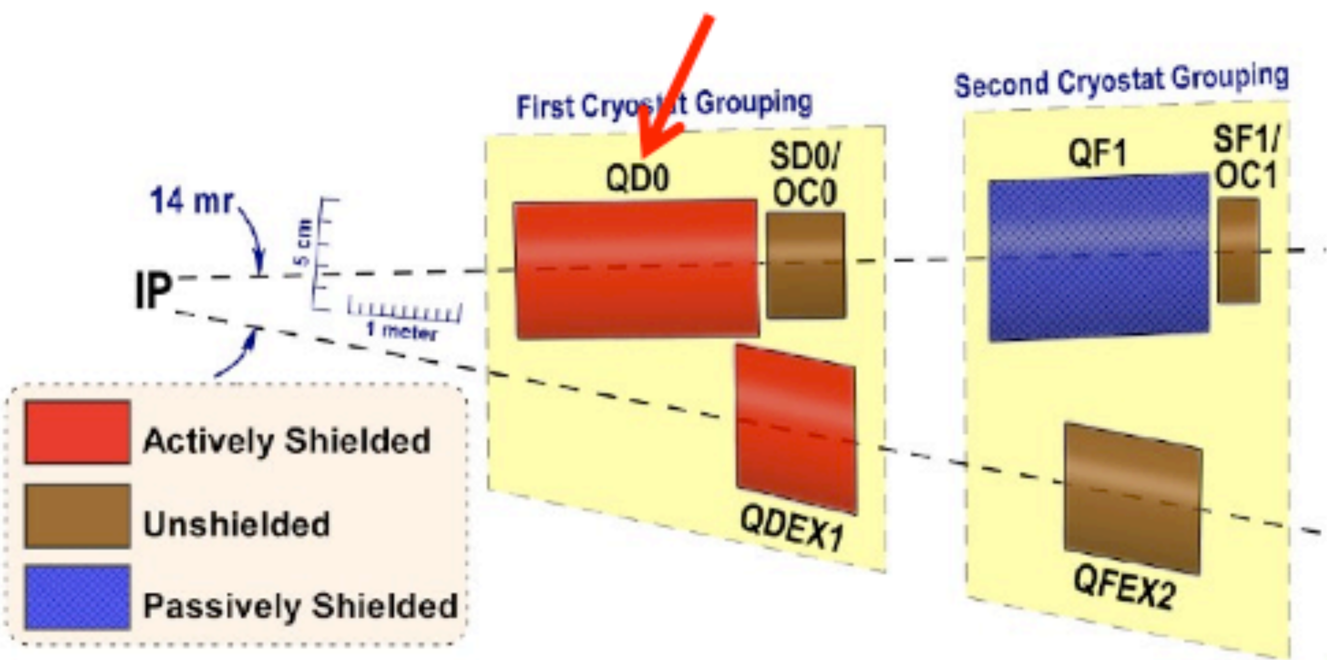
FD optimized for lower energy will allow increasing the collimation depth by ~10% in Y and by ~30% in X (Very tentative!)

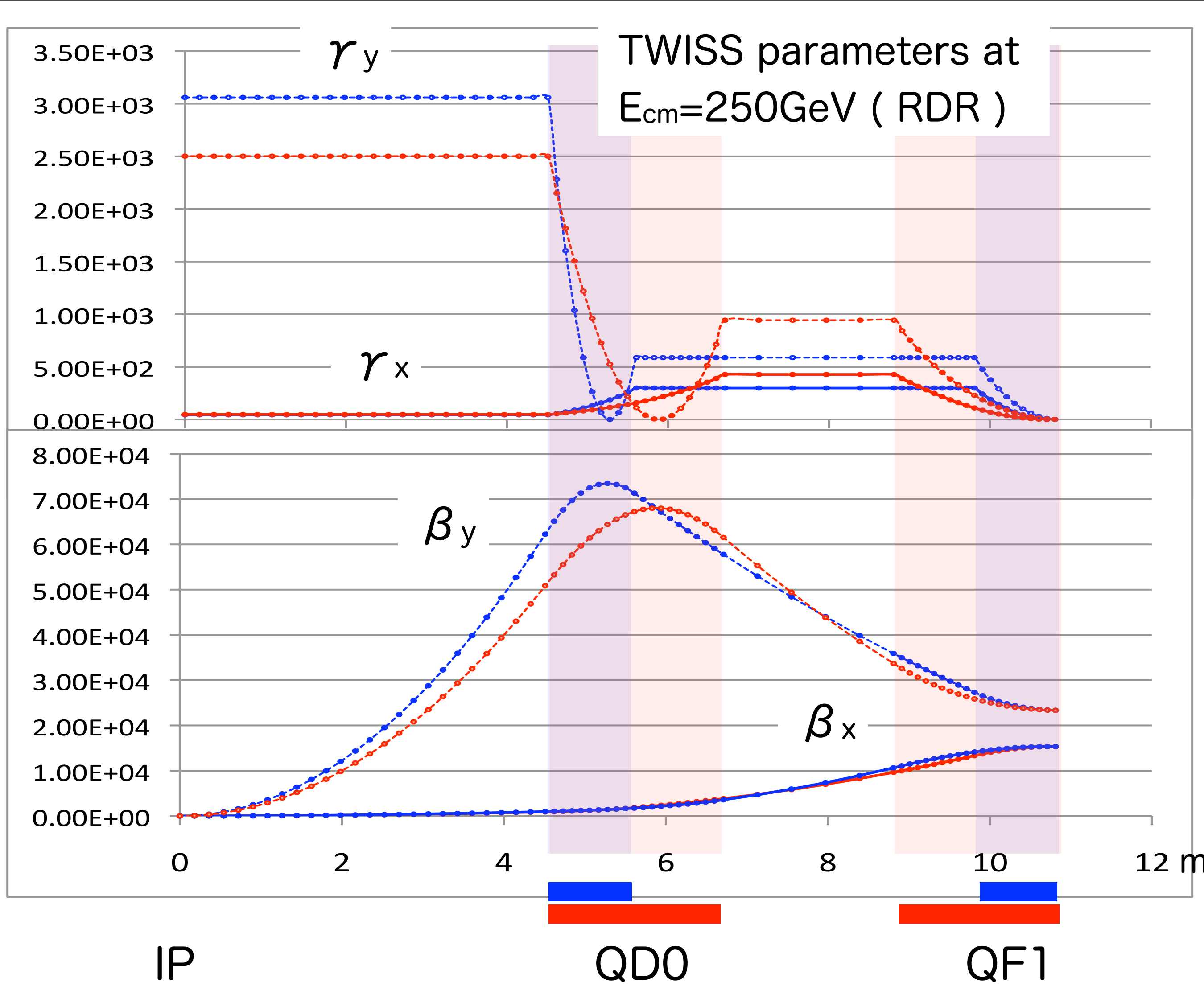
• One option would be to have a separate FD optimized for lower E, and then exchange it before going to nominal E

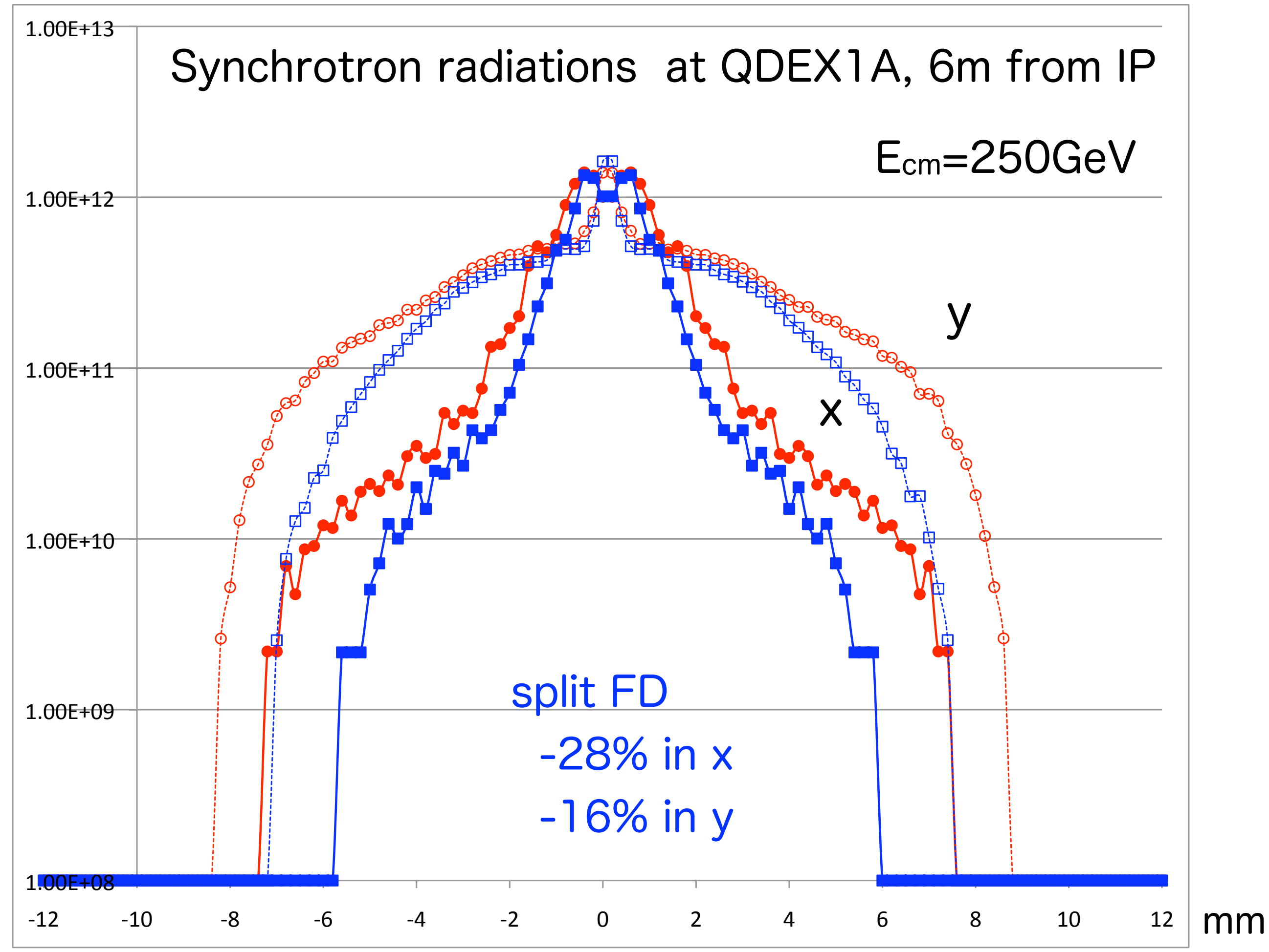
• Other option to be studied is to build a universal FD, that can be reconfigured for lower E configuration (may require splitting QD0 coil and placing sextupoles in the middle)

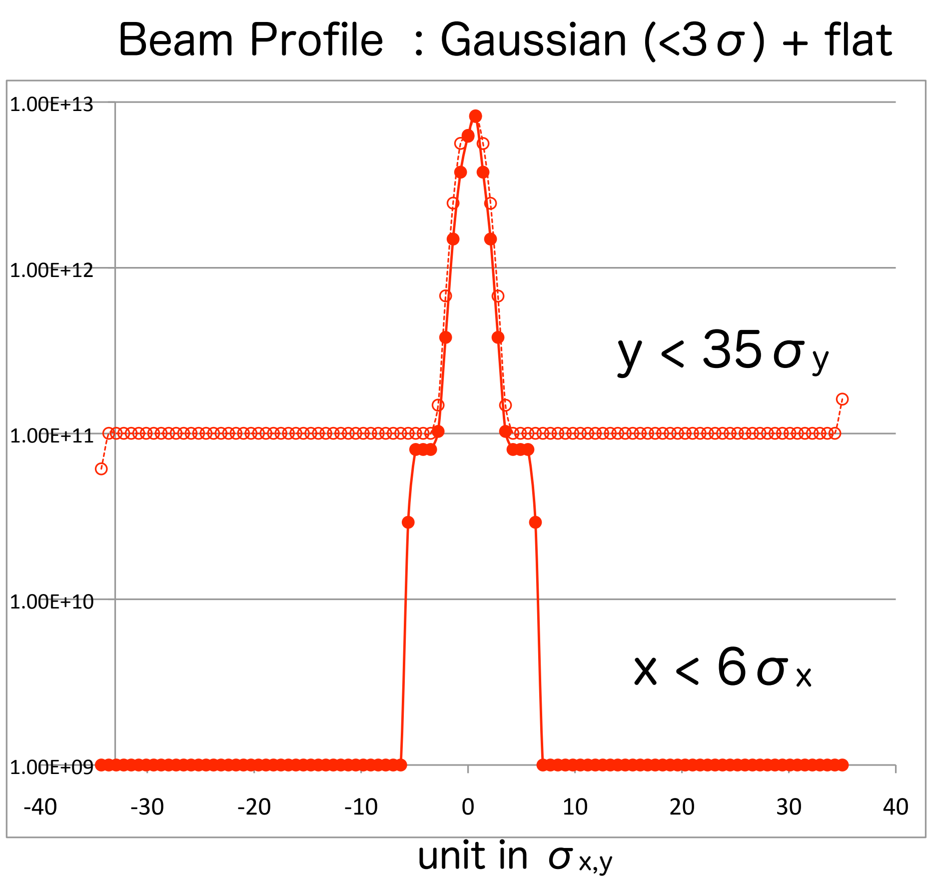


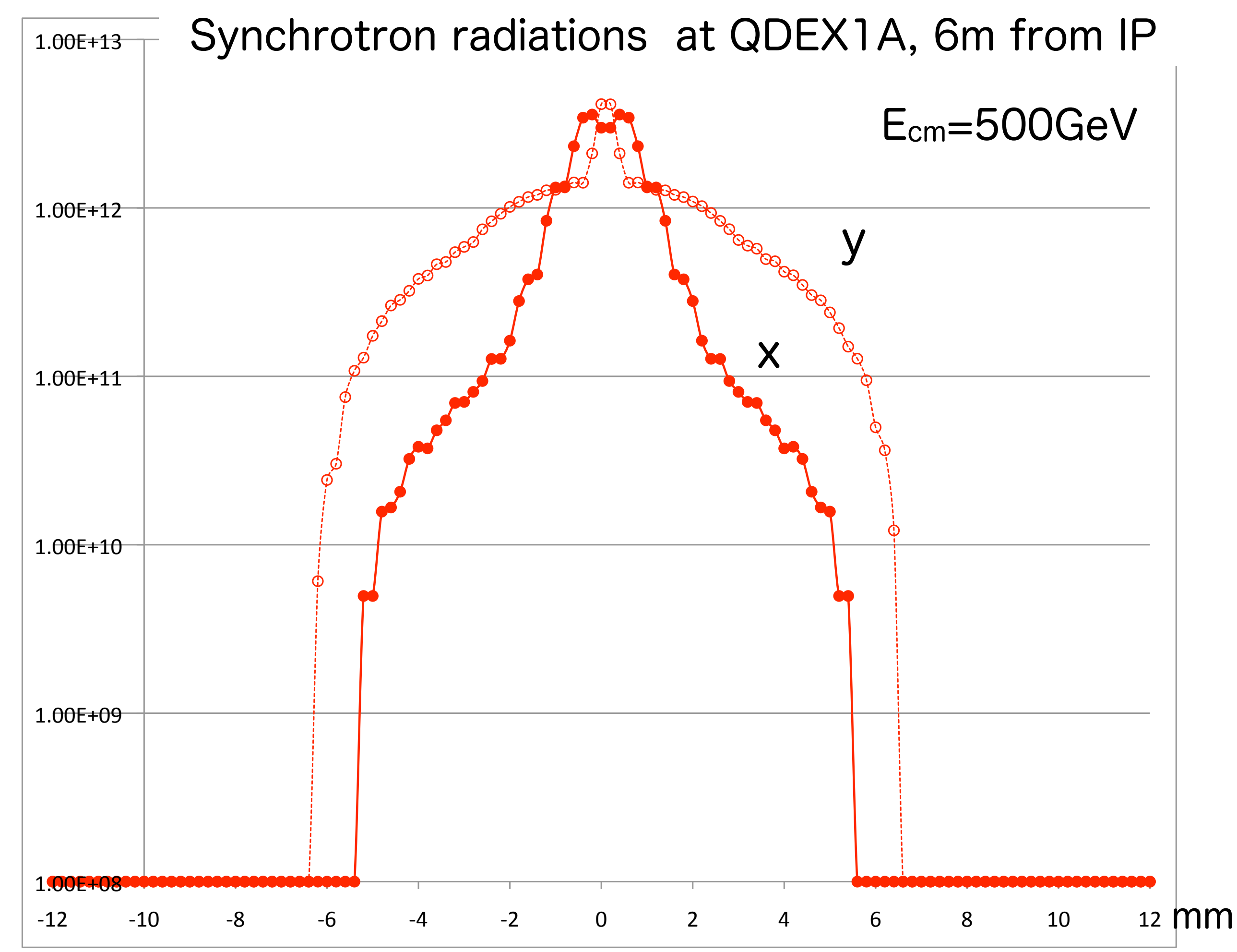





TWISS parameters at
Ecm=250GeV (RDR)
γy
γx
βy
βx
3.50E+03
3.00E+03
2.50E+03
2.00E+03
1.50E+03
1.00E+03
5.00E+02
0.00E+00
8.00E+04
7.00E+04
6.00E+04
5.00E+04
4.00E+04
3.00E+04
2.00E+04
1.00E+04
0.00E+00
0
2
4
6
8
10
12 m
IP
QD0
QF1

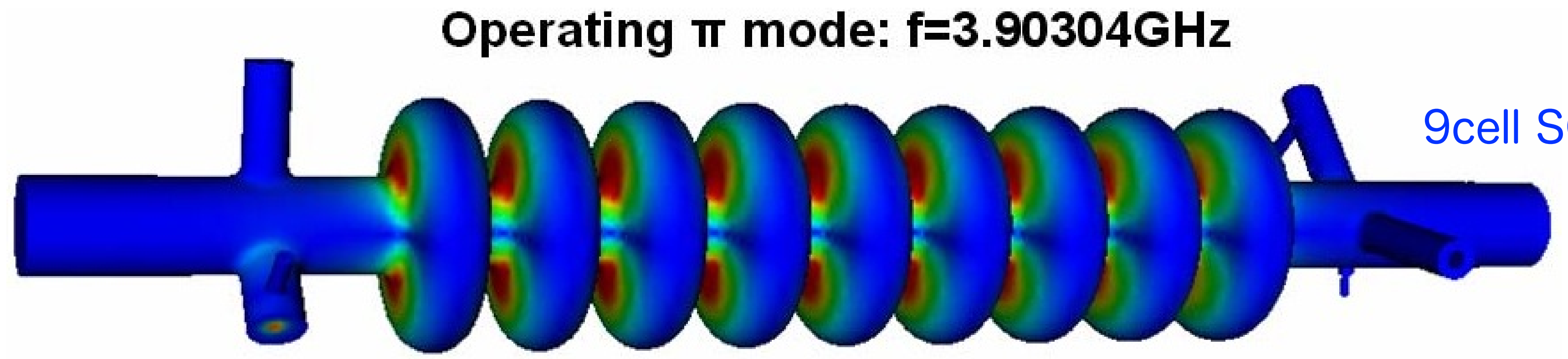

Synchrotron radiations at QDEX1A, 6m from IP
Ecm=250GeV
y
x
split FD
-28% in x
-16% in y
1.00E+13
1.00E+12
1.00E+11
1.00E+10
1.00E+09
1.00E+08
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
mm


Beam Profile : Gaussian (<3σ) + flat
y < 35σy
x < 6σx
1.00E+13
1.00E+12
1.00E+11
1.00E+10
1.00E+09
-40
-30
-20
-10
0
10
20
30
40
unit in σx,y


Synchrotron radiations at QDEX1A, 6m from IP
Ecm=500GeV
y
x
1.00E+13
1.00E+12
1.00E+11
1.00E+10
1.00E+09
1.00E+08
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
mm

Crab Cavities

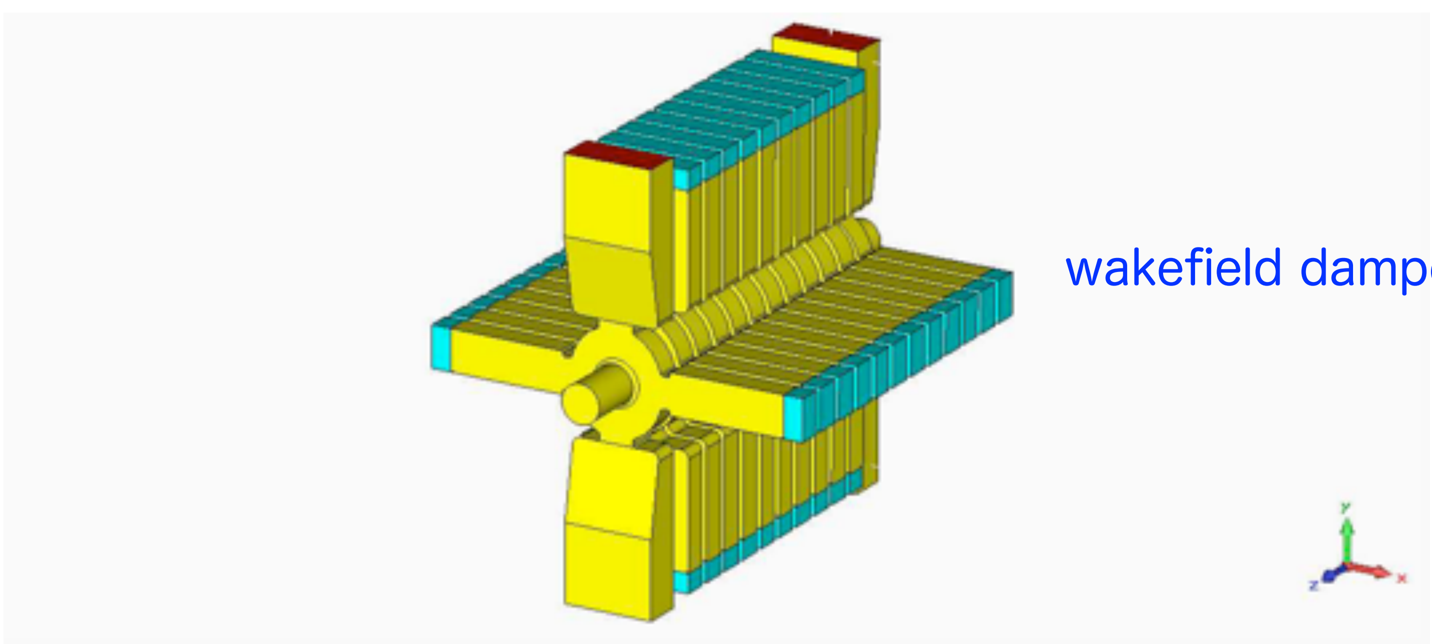
ILC : 2 cavities at 13.4m from IP, 2~3m long, the phase jitter < 61fsec



9cell SC cavities

Figure 10.18. Field distribution for the operating mode of the 3.9 GHz crab cavity

CLIC : ~3m long, the phase jitter < 0.02^{o}(4.6fsec) and amplitude<2% at 12GHz
2% luminosity loss



wakefield dampers

Effect of Synchrotron radiations (SR) on the beam size at IP

Effects in the horizontal sizes from the bending magnets

CLIC 3TeV : $\Delta\sigma_{SRbends}^2$=0.49(analytic)=0.55(tracking)

CLIC 0.5TeV: $\Delta\sigma_{SRbends}^2$=0.2(analytic)=0.24(tracking)

ILC 0.5TeV: $\Delta\sigma_{SRbends}^2$=0.31(analytic)=0.35(tracking)

in unit of $10^{-15}m^2$, where $\sigma^2 = \sigma_{norad}^2 + \Delta\sigma_{SRbends}^2$

Oide limit in the vertical sizes at the final doublet

CLIC 3TeV $\Delta\sigma$oide = 0.6386[nm]

ILC $\Delta\sigma$oide = 0.0207[nm]

CLIC 500 GeV $\Delta\sigma$oide = 0.0256[nm]

a common FFS ?

Suggestions

1. The current CLIC 500 has been design keeping layout constraints from the 3TeV design. In the new phase, we will aim at re-designing and optimizing CLIC at 500 GeV (or 370GeV) and the higher energies will have to adapt to the tunnel layout.

2. Necessity of 2 beam tuning simulations (meaning tuning the e^+ e^- in a global frame of ground motion in the same simulated physical time and computing luminosity from their collisions). So, it is a major subject for a demonstration of feasibility.

Learns from SLC experiences

SLC has never achieved the design luminosity, e.g. finally half of design luminosity after 10 years operations

with smaller beam sizes,

i.e. 1.5(x), 0.65(y) μm v.s. 1.65(x), 1.65(y) μm of the design

by careful emittance preservation and improvements in the final focus optics

with less beam intensities,

i.e. 4 - 4.5 x10^{10}/bunch v.s. 7.2 x 10^{10}/bunch of the design

and the repetition rate of 120Hz instead of 180Hz.

ILC and CLIC have been designed with these SLC experiences.

1. Less beam intensity and smaller beam sizes, control of emittance growth
2. Final focus systems are based on the local chromaticity correction scheme which has better performance than the separated function chromaticity correction scheme at SLC.
3. ATF2 is very important to verify the expected performances as a ILC/CLIC FF test facility
4. Additional skew sextupoles, octupoles and decapoles should be included in the baseline designs to minimize the residual higher-order aberrations.

Conclusions

1. CLIC could be lengthened to gain luminosity
   or that ILC can be shortened
   (maybe its bandwidth is unnecessarily large?).

2. Could we use a single FFS lattice for both projects?
   so the community focuses in one FFS?

3. Commissioning strategy should be made
   with and without detectors.