IP Parameters in TDR from RDR

T. Tauchi, KEK

Proposal / rationale

- **Adopt uniformly high D_y for all E_{cm} (~25)**
- **Include 10-15% (20%!?) gain from coherent vertical waist shift at IP (~0.8σ_z)**
- ***Assume* a 30% increase in collimation depth for $E_{cm} \lesssim 250$ GeV**
  - split FD approach
  - factor 1.7 reduction in β^*_x (over ~1/γ scaling)
- **Assume intra-train fast feedback at linac exit will constrain vertical beam jitter ≲ 1.5 μm RMS at SP2/SP4**
  - ~0.2 σ_y at 250 GeV beam energy
- **Keep "effective" IP $\gamma\varepsilon_y$ ~ 35 nm**
  - average emittance from LET emittance tuning simulations +10%
- **Drop TF because**
  - Difficultly in implementing the crabbed waist
  - Very high disruption parameter too challenging (incl. collimator wakes)

IP and General Parameters

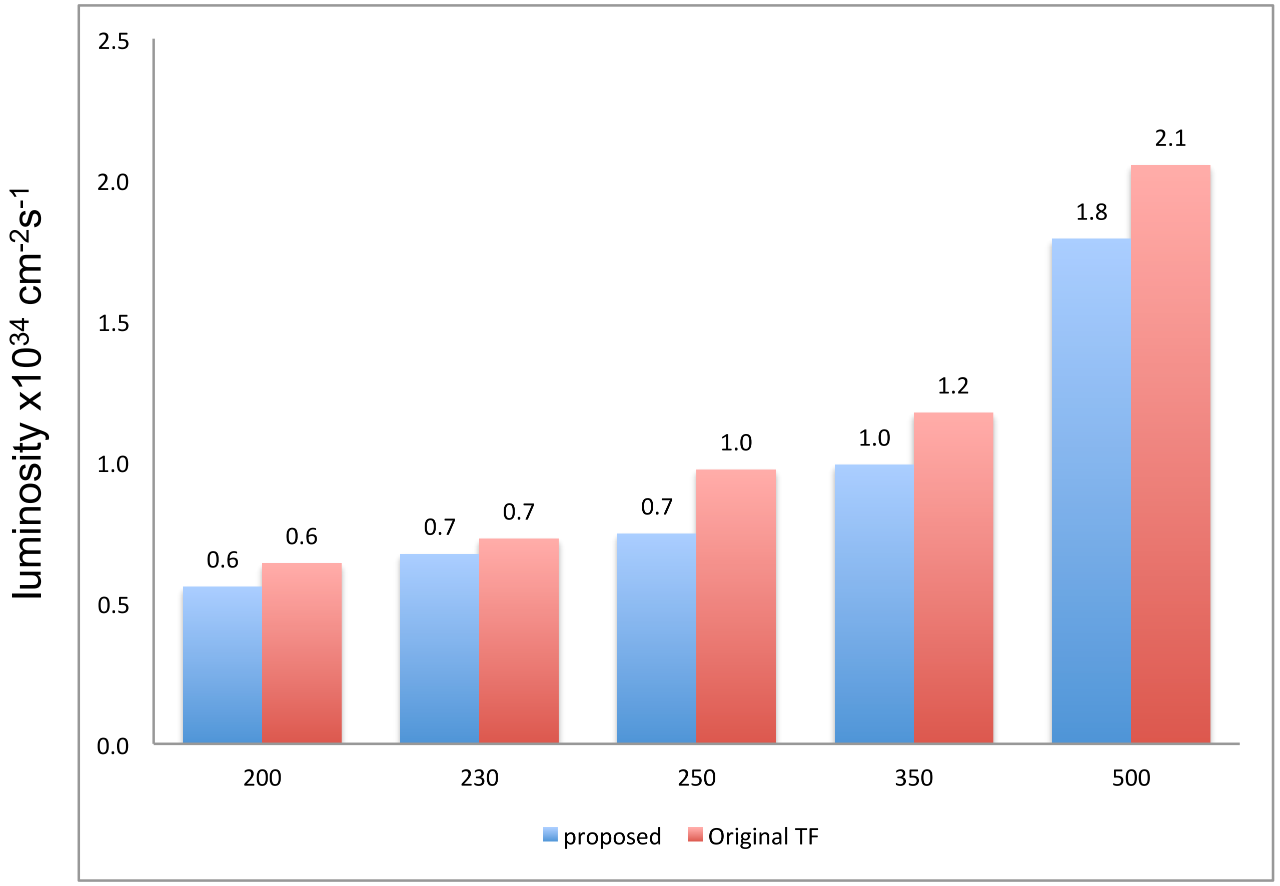
	Parameter	Symbol	Unit	200	230	250	350	500	L Upgrade 500	E_{cm} Upgrade 1000	1000	comment
				TF = Traveling Focus					L Upgrade	E_{cm} Upgrade		
	Centre-of-mass energy	E_{cm}	**GeV**	**200**	**230**	**250**	**350**	**500**	**500**	**1000**	**1000**	**comment**
										A1	B1b	
	Beam energy	E_{beam}	GeV	100	115	125	175	250	500	500	500	
	Lorentz factor			#######	#######	#######	#######	#######	#######	9,78E+05	9,78E+05	
	Collision rate	f_{rep}	Hz	5	5	5	5	5	5	4	4	
	Electron linac rate	f_{linac}	Hz	10	10	10	5	5	5	4	4	
	Number of bunches	n_b		1312	1312	1312	1312	1312	2625	2450	2450	
	Electron bunch population	N_-	$\times10^{10}$	2,0	2,0	2,0	2,0	2,0	2,0	1,74	1,74	
	Positron bunch population	N_+	$\times10^{10}$	2,0	2,0	2,0	2,0	2,0	2,0	1,74	1,74	
	Bunch separation	t_b	ns	554	554	554	554	554	366	366	366	
	Bunch separation $\times f_{RF}$	$t_b\ f_{RF}$		720	720	720	720	720	476	476	476	
	Pulse current	I_{beam}	mA	5,8	5,8	5,8	5,8	5,79	8,75	7,6	7,6	
	RMS bunch length	$_z$	mm	0,3	0,3	0,3	0,3	0,3	0,3	0,250	0,225	
	Electron RMS energy spread	p/p	%	0,206	0,194	0,190	0,158	0,125	0,125	0,083	0,085	See EDMS D*971945
	Positron RMS energy spread	p/p	%	0,187	0,163	0,150	0,100	0,070	0,070	0,043	0,047	See EDMS D*971945
	Electron polarisation	P_-	%	80	80	80	80	80	80	80	80	
	Positron polarisation	P_+	%	31	31	30	30	30	30	20	20	Approximate numbers (Wanming Liu)
	Horizontal emittance	$_x$	m	10	10	10	10	10	10	10	10	TeV numbers are potentially too optimistic. Check with K.Kubo.
	Vertical emittance	$_y$	nm	35	35	35	35	35	35	30	30	TeV numbers are potentially too optimistic. Check with K.Kubo.
	IP horizontal beta function	$_x^*$	mm	16,0	14,0	13,0	16,0	11,0	11,0	22,6	11,0	
	IP vertical beta function (no TF)	$_y^*$	mm	0,34	0,38	0,41	0,34	0,48	0,48	0,25	0,23	
	IP RMS horizontal beam size	$_x^*$	nm	904	789	729	684	474	474	481	335	
	IP RMS veritcal beam size (no TF)	$_y^*$	nm	7,8	7,7	7,7	5,9	5,9	5,9	2,8	2,7	
analytical estimates	Horizontal distruption parameter	D_x		0,2	0,2	0,3	0,2	0,3	0,3	0,1	0,2	
analytical estimates	Vertical disruption parameter	D_y		24,3	24,5	24,5	24,3	24,6	24,6	18,7	25,1	
analytical estimates	Horizontal enhancement factor	H_{Dx}		1,0	1,1	1,1	1,0	1,1	1,1	1,0	1,0	
analytical estimates	Vertical enhancement factor	H_{Dy}		4,5	5,0	5,4	4,5	6,1	6,1	3,5	4,1	
analytical estimates	Total enhancement factor	H_D		1,7	1,8	1,8	1,7	2,0	2,0	1,5	1,6	
analytical estimates	Geometric luminosity	L_{geom}	$\times10^{34}$ cm^{-2}s^{-1}	0,30	0,34	0,37	0,52	0,75	1,50	1,77	2,64	
analytical estimates												
analytical estimates	**Luminosity**	**L**	**$\times10^{34}$ cm^{-2}s^{-1}**	**0,50**	**0,61**	**0,68**	**0,88**	**1,47**	**2,94**	**2,71**	**4,32**	
analytical estimates	Average beamstrahlung parameter	$_{av}$		0,013	0,017	0,020	0,030	0,062	0,062	0,127	0,203	
analytical estimates	Maximum beamstrahlung paramete	$_{max}$		0,031	0,041	0,048	0,072	0,146	0,146	0,305	0,483	
analytical estimates	Average number of photons / partic	n		0,95	1,08	1,16	1,23	1,72	1,72	1,43	1,97	
analytical estimates	Average energy loss	E_{BS}	%	0,51	0,75	0,93	1,42	3,65	3,65	5,33	10,20	
simulation	Luminosity	L	$\times10^{34}$ cm^{-2}s^{-1}	0,498	0,607	0,681	0,878	1,50	3,00	3,23	4,31	
simulation	Coherent waist shift	W_y	m	250	250	250	250	250	250	190	190	~0.8* z.
simulation	**Luminosity (inc. waist shift)**	**L**	**$\times10^{34}$ cm^{-2}s^{-1}**	**0,56**	**0,67**	**0,75**	**1,0**	**1,8**	**3,6**	**3,6**	**4,9**	
simulation	Fraction of luminosity in top 1%	$L_{0.01}/L$		91,3%	88,6%	87,1%	77,4%	58,3%	58,3%	59,2%	44,5%	
simulation	Average energy loss	E_{BS}		0,65%	0,83%	0,97%	1,9%	4,5%	4,5%	5,6%	10,5%	
simulation	Number of pairs per bunch crossing	N_{pairs}	$\times10^3$	44,7	55,6	62,4	93,6	139,0	139,0	200,5	382,6	*≥ 1 MeV*
	Total pair energy per bunch crossin	E_{pairs}	TeV	25,5	37,5	46,5	115,0	344,1	344,1	1338,0	3441,0	

With TF	Parameter	Symbol	Unit	200	230	250	350	500
With TF	**Luminosity**	**L**	**$\times10^{34}$ cm^{-2}s^{-1}**	**0,64**	**0,73**	**0,97**	**1,17**	**2,05**
simulation	Fraction of luminosity in top 1%	$L_{0.01}/L$		91,6%	89,0%	83,0%	77,9%	60,8%
simulation	Average energy loss	E_{BS}		0,61%	0,79%	1,26%	1,78%	4,33%
simulation	Number of pairs per bunch crossing	N_{pairs}	$\times10^3$	46,9	55,7	81,0	101,1	211,1
simulation	Total pair energy per bunch crossin	E_{pairs}	TeV	29,4	40,0	68,8	136,5	567,7

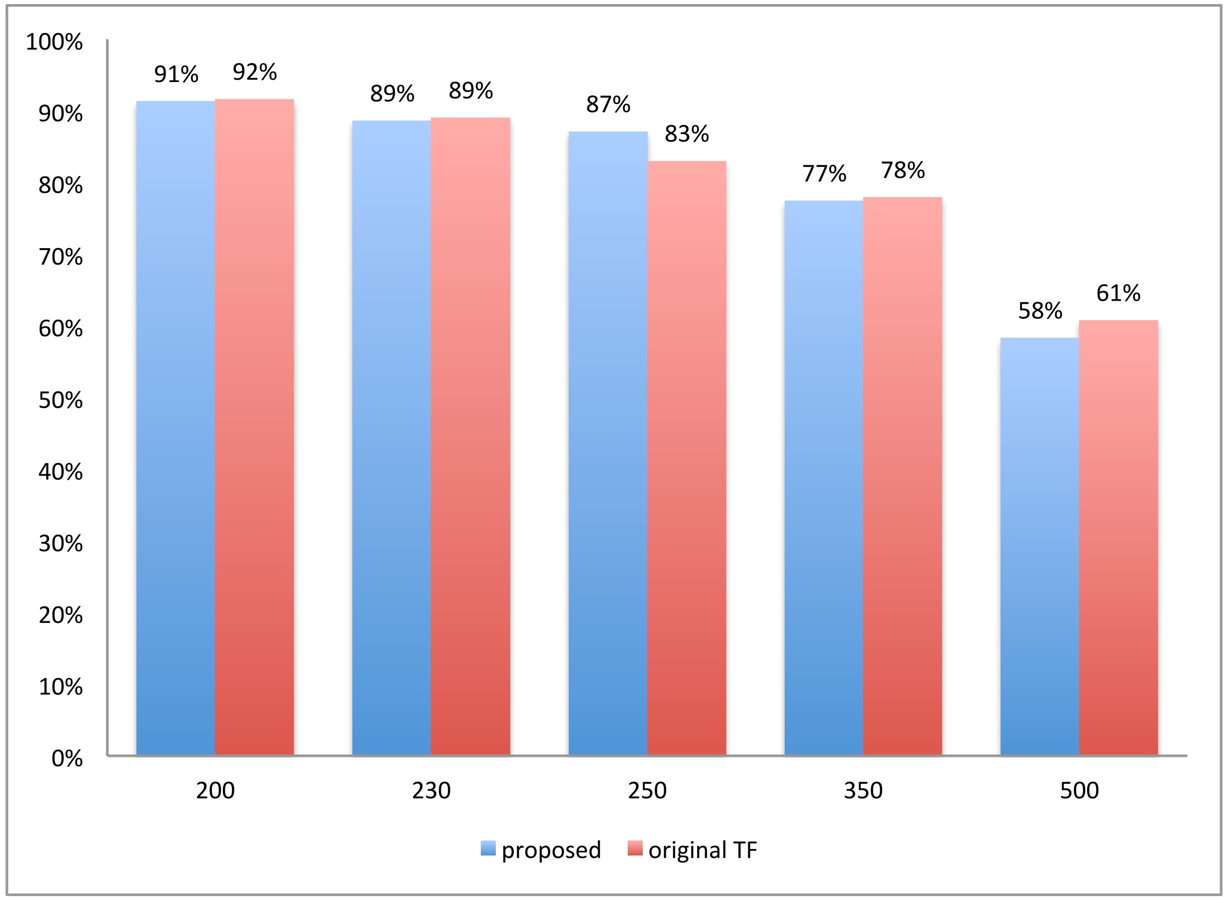
The TF number are retained as reference. Note however that so far a practicle scheme for generating the required correlation has not been found. The preferred values and therefore those quoted above with the coherent waist shift.

N. Walker, AD/I meeting,
29 February 2012

Comparison to TF numbers



Fractional L in top 1% E_{cm}



N. Walker, AD/I meeting, 29 February 2012

2012年 3月 9日 金曜日

Issues

- Optics solution still needs verification
  - **smaller (in general) β functions**
  - **short (split) FD solutions for low E_{cm}**
  - **Including re-evaluation of collimator depth**
- Luminosity stability (high D_y)
  - **should we include some degradation in *L* for this effect? If so how much?**
- Fast trajectory correction implementation
  - **should be feasible, but clearly needs a realistic design concept**
    - location of BPMs, kickers, performance analysis etc.
- …?

- Optics solutions will be looked at by R. Tomas starting April.
  - **Solutions probably May/June**
  - **Plan for success in the meantime.**
- Complicated problem which really requires “start-to-end” like simulations
  - **including fast feedback correction etc.**
  - **legacy simulations exist but for for different lattice (RDR), but results were very positive**
- Need to look at lattice and see how this might fit
  - **Should not be a real problem**
  - **Performance evaluation requires more design work**
  - **May need adjustment of early BDS lattice to accommodate hardware**

Issues

- Optics solution still needs verification
  - **smaller (in general) β functions**
  - **short (split) FD solutions for low E_{cm}**
  - **Including re-evaluation of collimator depth**

  by SAD and MQRAD
- Luminosity stability (high D_y)
  - **should we include some degradation in *L* for this effect? If so how much?**
- Fast trajectory correction implementation
  - **should be feasible, but clearly needs a realistic design concept**
    - location of BPMs, kickers, performance analysis etc.
- …?

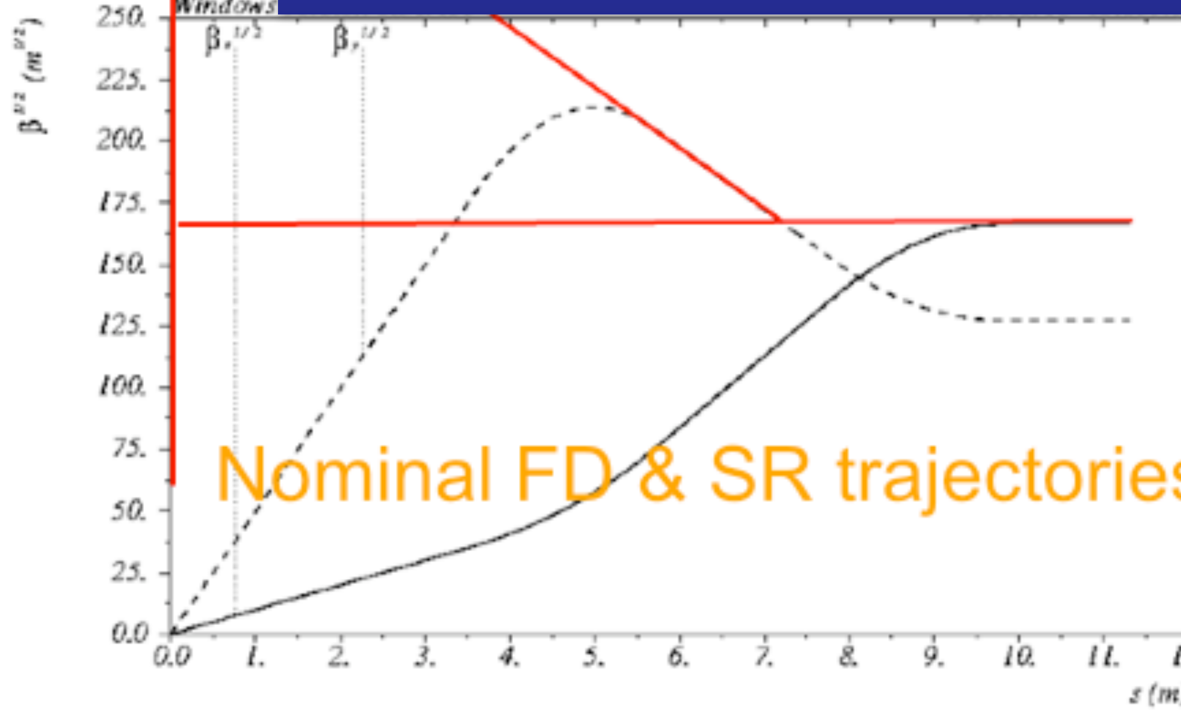
- Optics solutions will be looked at by R. Tomas starting April.
  - **Solutions probably May/June**
  - **Plan for success in the meantime.**
- Complicated problem which really requires "start-to-end" like simulations
  - **including fast feedback correction etc.**
  - **legacy simulations exist but for for different lattice (RDR), but results were very positive**
- Need to look at lattice and see how this might fit
  - **Should not be a real problem**
  - **Performance evaluation requires more design work**
  - **May need adjustment of early BDS lattice to accommodate hardware**

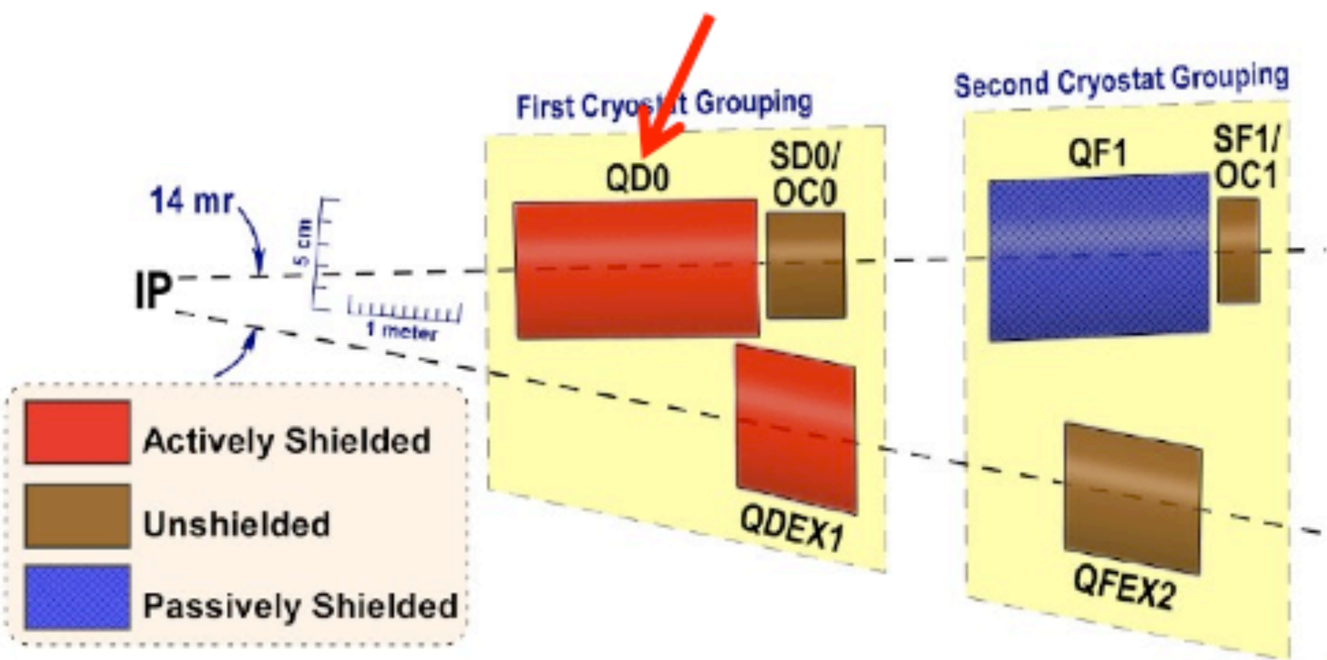
FD for low E

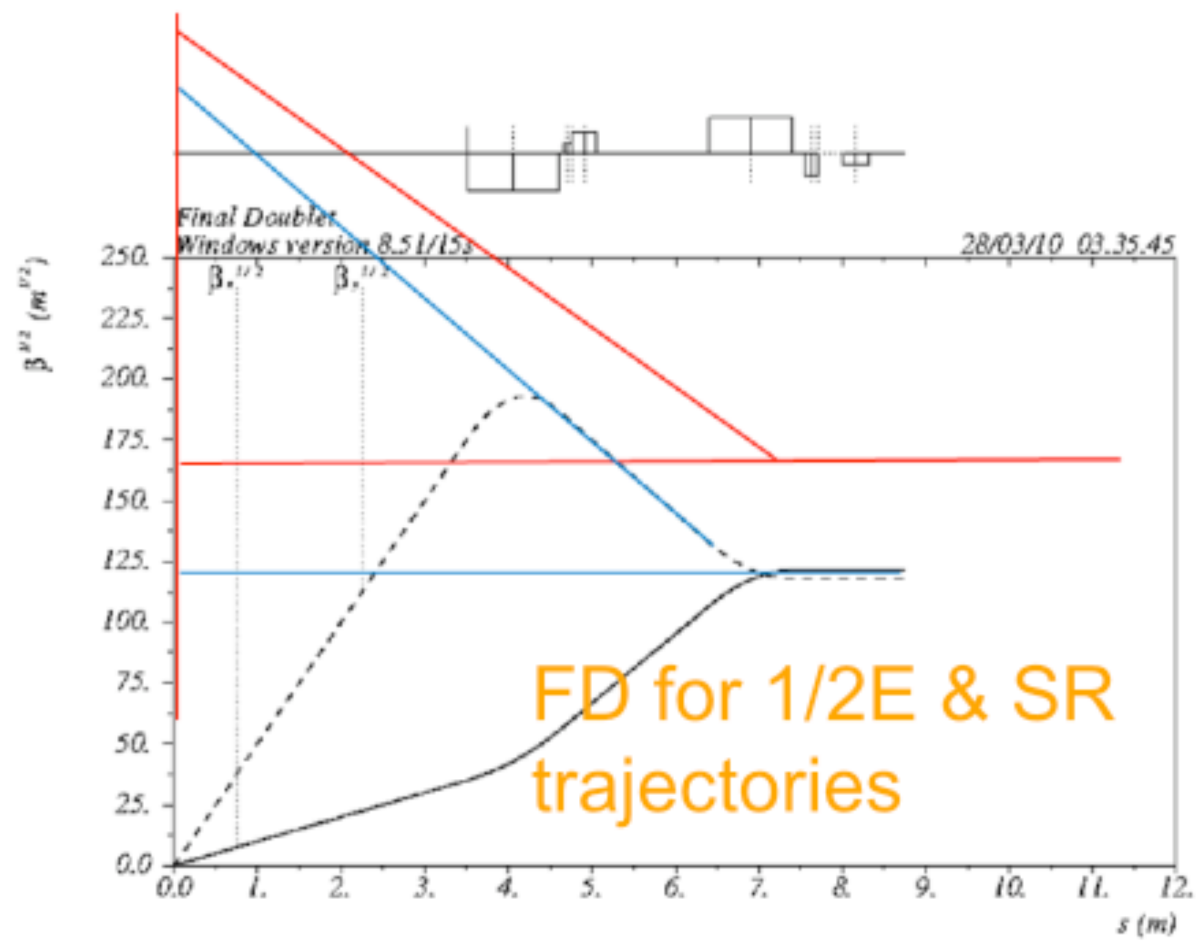
FD optimized for lower energy will allow increasing the collimation depth by ~10% in Y and by ~30% in X (Very tentative!)

- 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)

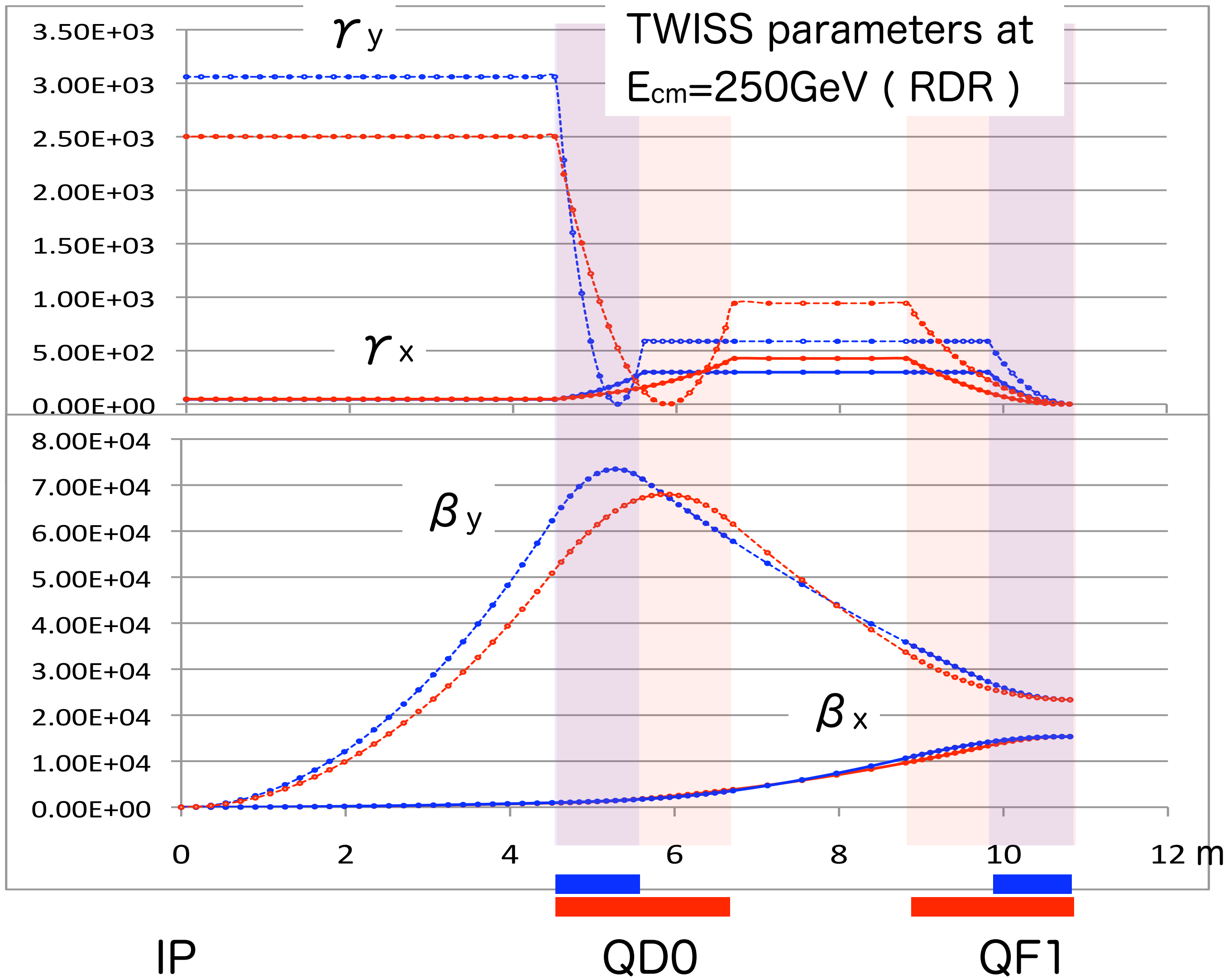
A. Seryi
SLAC BAW-2 presentation
19 Jan 2011

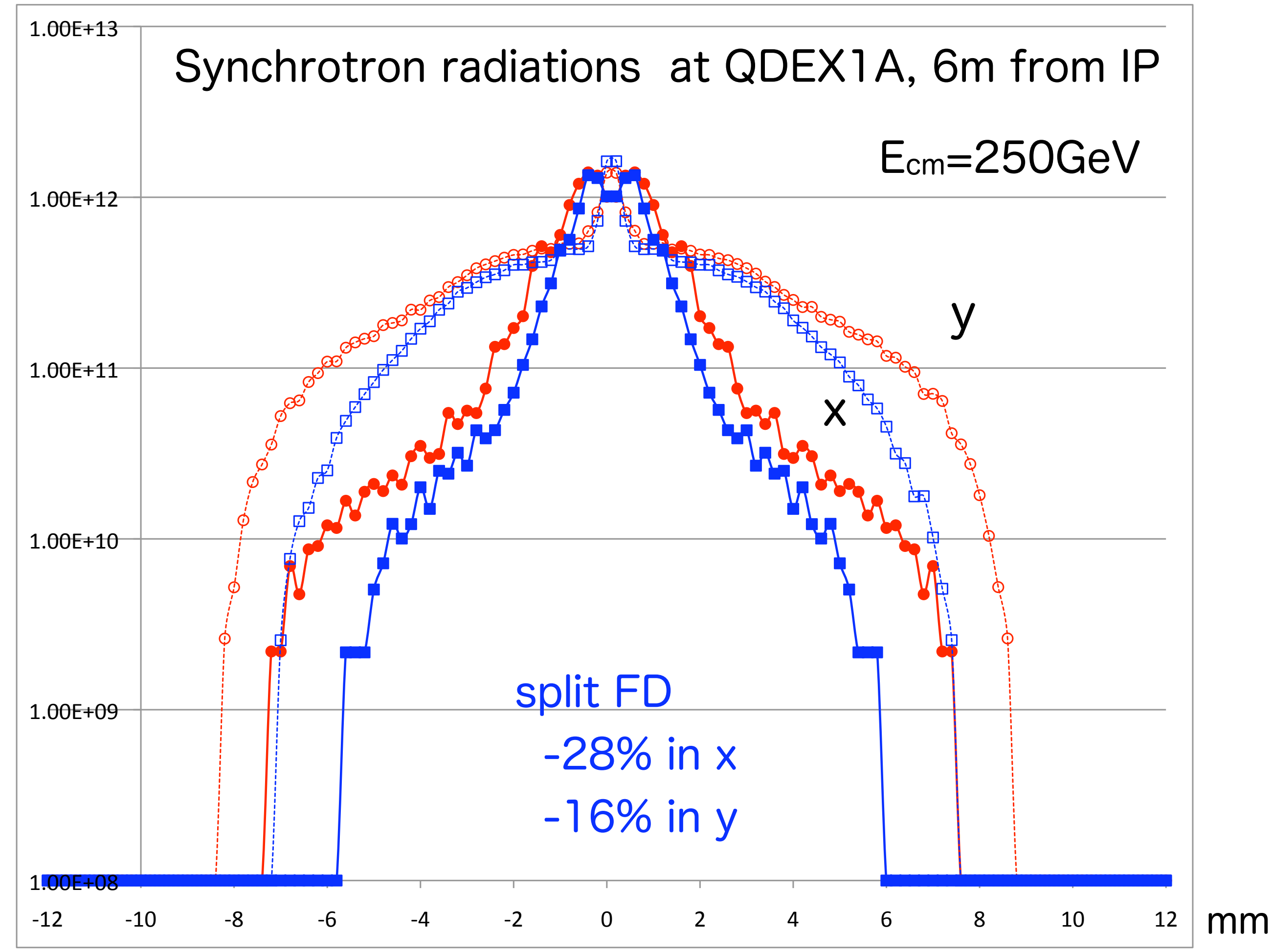




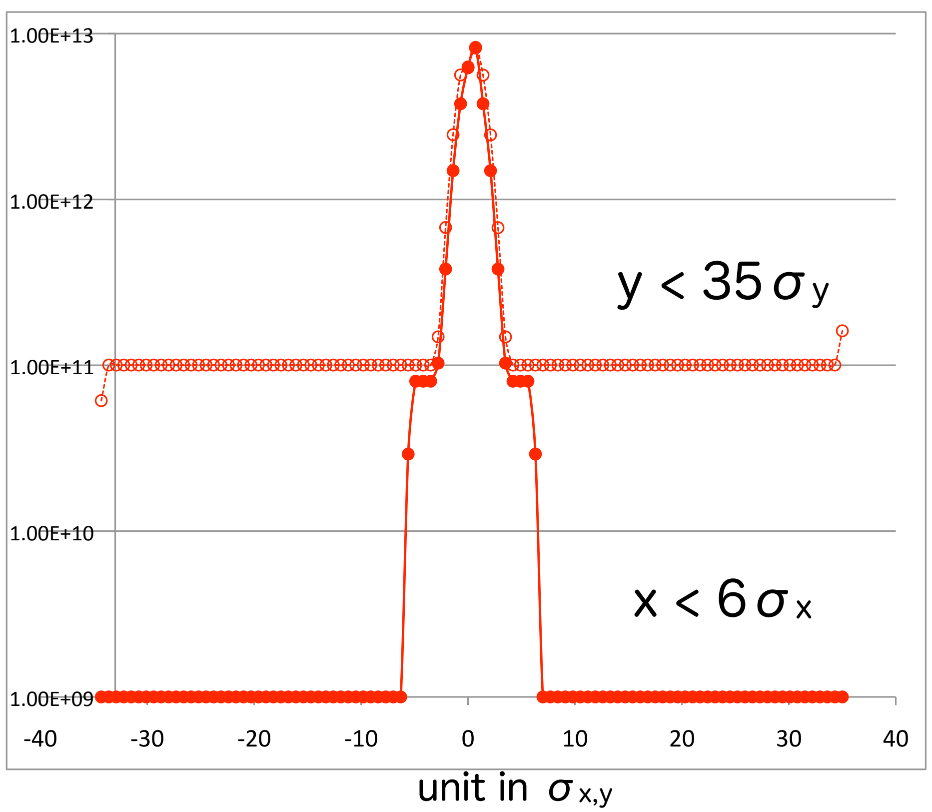


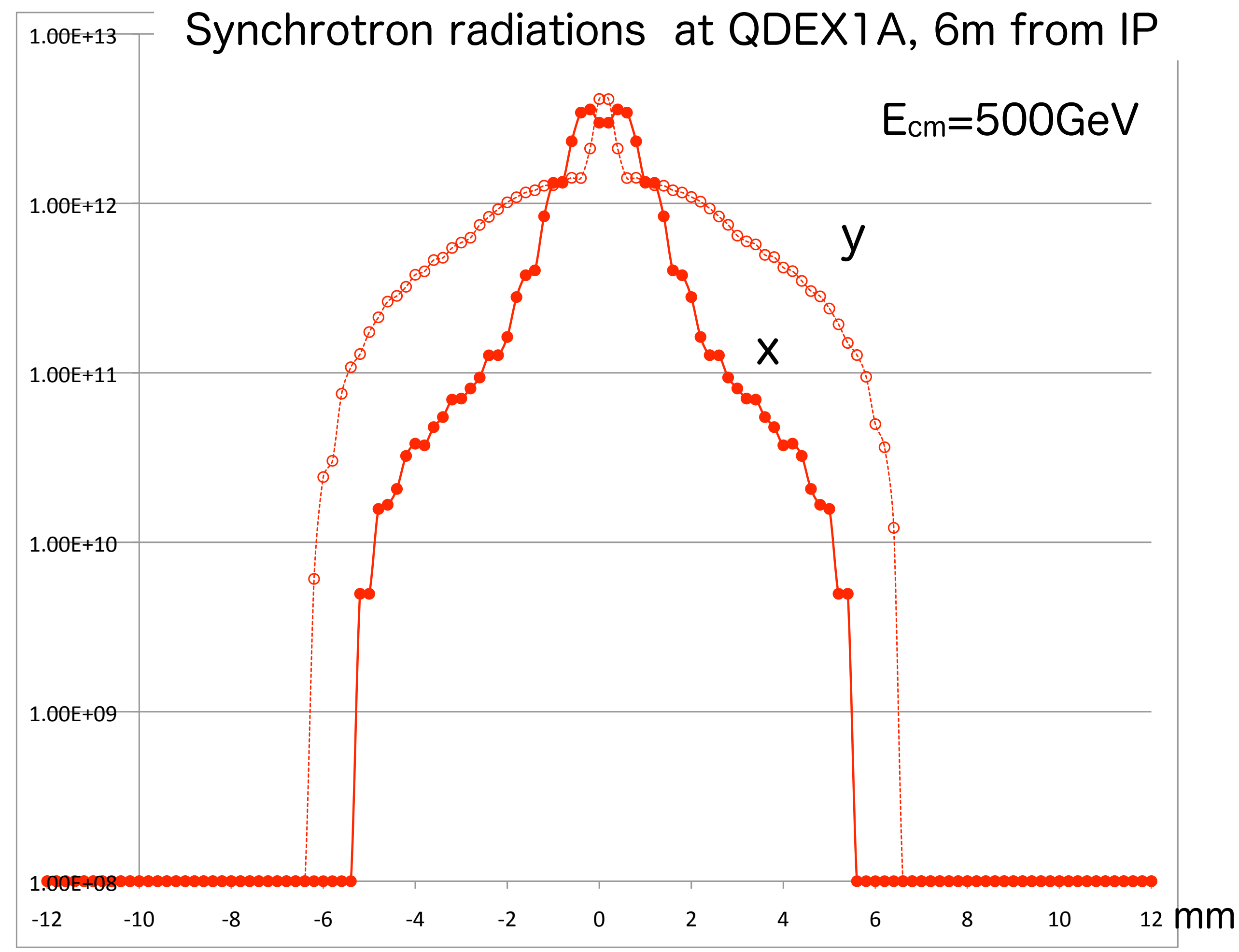
2012年 3月 9日 金曜日





Beam Profile : Gaussian (<3σ) + flat





Luminosity degradation due to the collimators

1. Collimation depth, wakefield and emittance growth

TDR

$C_{dep\_y} = \theta_y^{max} / \sigma^{*'}_y / safety\_factor$ → 28.6 @Eb=100GeV

$A_y = 0.0482\ \gamma^{-1}\ C_{dep\_y}^{-1.5}\ \varepsilon_y^{-0.75}$ → 5.8

Emittance growth in y = $(0.4 * Jitter_{train} * A_y)^2$ → 1.37 → 0 (< 0.2)

Values in RDR ;

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

safety_factor = 1.5

$Jitter_{train}$ = 0.5 (scaled by beam size) → 0.2 with “FONT” feedback

i.e. emittance growth to 1/6.25

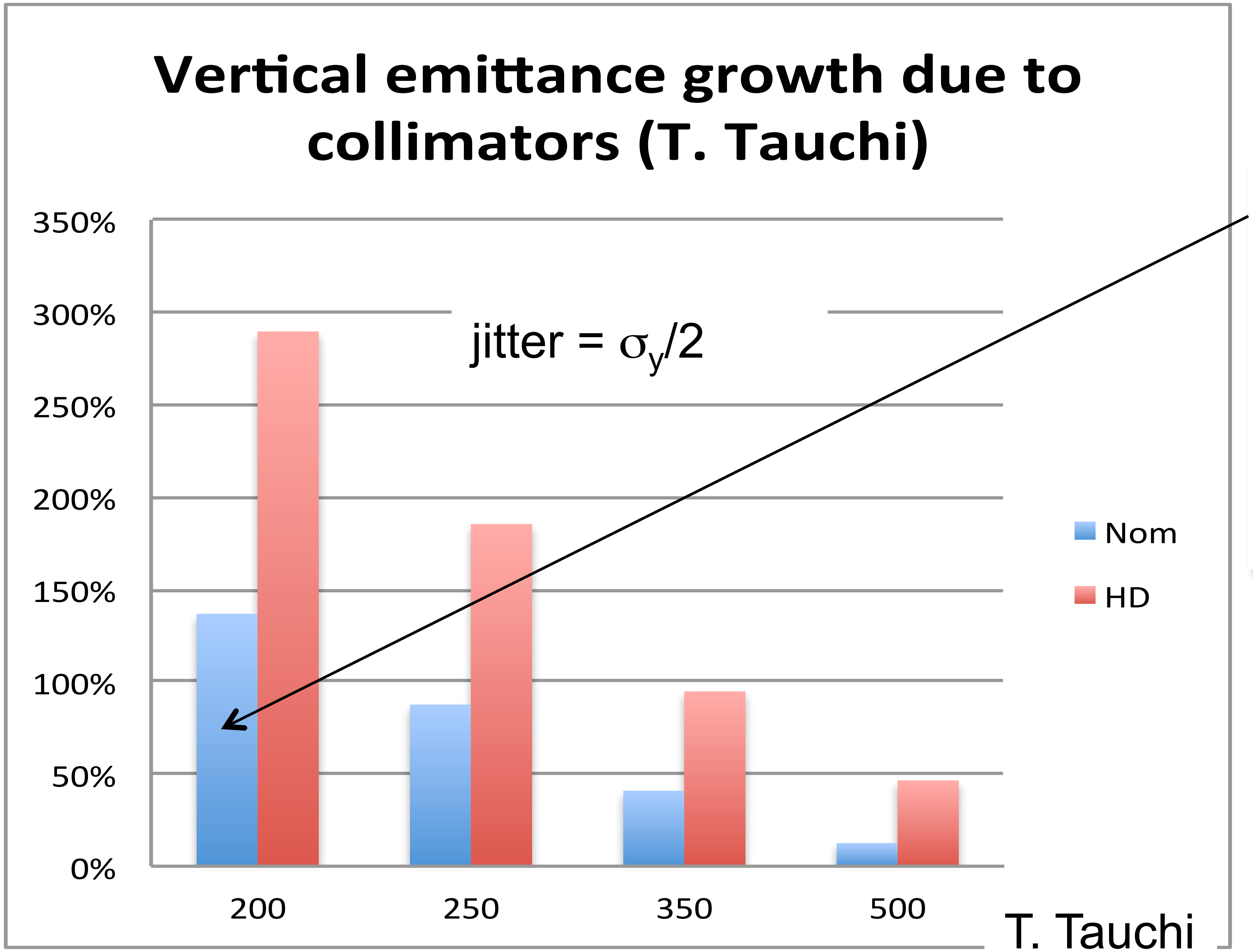
$Jitter_{b\_b}$ = 0.1 (scaled by beam size)

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

$\sigma_{b\_b} = Jitter_{b\_b} * (1 + A_y^2)^{0.5}$ → 0.59

$L_{b\_b} - \Delta L_{b\_b} = EXP(-(\sigma_{b\_b}^2)/4)$ → 0.92 → 1

Collimator Wakefields



140% @ $0.5\sigma_y$

Assume $0.2\sigma_y$ @ 250GeV
⇒ $0.13\sigma_y$ @ 100 GeV

⇒ ~10% emittance growth

But does the collimator gap change?

(β^*_y *is* changing)

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

	Nominal 200	HD 200	Nominal 250	HD 250	Nominal 350	HD 350	Nominal 500	HD 500	Nominal 1000	HD 1000
Ecms [GeV]	200	200	250	250	350	350	500	500	1000	1000
gamma	1.96E+05	1.96E+05	2.45E+05	2.45E+05	3.42E+05	3.42E+05	4.89E+05	4.89E+05	9.78E+05	9.78E+05
N e-	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	1.74E+10	1.74E+10
N e+	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	2.00E+10	1.74E+10	1.74E+10
nb	1312	1312	1312	1312	1312	1312	1312	1312	2425	2425
Tsep [ns]	554.0	554.0	554.0	554.0	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	0.0058	0.0058	0.0058	0.0058	0.0076	0.0076
f	5	5	5	5	5	5	5	5	4	4
Pb [W] e-	2.10E+06	2.10E+06	2.63E+06	2.63E+06	3.68E+06	3.68E+06	5.25E+06	5.25E+06	1.35E+07	1.35E+07
Electron polarization, %	80	80	80	80	80	80	80	80	80	80
Positron polarization, %	31	31	31	31	29	29	22	22	30	30
Electron E-spread, %	0.220	0.220	0.190	0.190	0.158	0.158	0.125	0.125	0.083	0.083
Positron E-spread, %	0.170	0.170	0.150	0.150	0.100	0.100	0.065	0.065	0.043	0.043
IP Parameters										
gamepsX incoming	1.00E-05	1.00E-05	1.00E-05	1.00E-05	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	3.50E-08	3.50E-08	3.50E-08	3.00E-08	3.00E-08
bx	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.50E-02	1.50E-02	1.10E-02	1.10E-02	2.26E-02	1.10E-02
by	3.30E-04	2.00E-04	3.30E-04	2.00E-04	3.50E-04	2.00E-04	4.80E-04	2.00E-04	2.50E-04	2.30E-04
sigx_geom	9.04E-07	9.04E-07	8.09E-07	8.09E-07	6.62E-07	6.62E-07	4.74E-07	4.74E-07	4.81E-07	3.35E-07
sigy_geom	7.7E-09	6.0E-09	6.9E-09	5.3E-09	6.0E-09	4.5E-09	5.9E-09	3.8E-09	2.8E-09	2.7E-09
sigx_effective	9.04E-07	9.04E-07	8.09E-07	8.09E-07	6.62E-07	6.62E-07	4.74E-07	4.74E-07	4.81E-07	3.35E-07
sigy_effective	7.7E-09	6.0E-09	6.9E-09	5.3E-09	6.0E-09	4.5E-09	5.9E-09	3.8E-09	2.8E-09	2.7E-09
sigxp	5.65E-05	5.65E-05	5.05E-05	5.05E-05	4.41E-05	4.41E-05	4.31E-05	4.31E-05	2.13E-05	3.05E-05
sigyp	2.33E-05	2.99E-05	2.08E-05	2.67E-05	1.71E-05	2.26E-05	1.22E-05	1.89E-05	1.11E-05	1.15E-05
gamepsX effective	1.00E-05	1.00E-05	1.00E-05	1.00E-05	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	3.50E-08	3.50E-08	3.50E-08	3.00E-08	3.00E-08
L* [m]	3.50	3.50	3.50	3.50	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	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	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	1.5	1.5	1.5	1.5
Coll depth X	4.7	4.7	5.3	5.3	6.0	6.0	6.2	6.2	12.5	8.7
Coll depth Y	28.6	22.3	32.0	24.9	39.0	29.5	54.6	35.2	60.2	57.7
BDS Inc. t-t jitter, sigma	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BDS Inc. b-b jitter, sigma	0.1	0.1	0.1	0.1	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	1.5	1.5	1.5	1.5
Coll wake Ay	5.8	8.5	4.7	6.8	3.2	4.9	1.8	3.4	1.4	1.5
Coll wake Y-emit growth	**1.365**	**2.894**	**0.874**	**1.852**	**0.408**	**0.945**	**0.125**	**0.463**	**0.083**	**0.094**
Increased b-b jitter, sigma	0.593	0.856	0.478	0.688	0.335	0.496	0.203	0.355	0.175	0.183
Lum reduct due to b-b jitter	**0.916**	**0.832**	**0.944**	**0.888**	**0.972**	**0.940**	**0.990**	**0.969**	**0.992**	**0.992**
sigz	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	2.50E-04	2.55E-04
Dx e+	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.1	0.2
Dy e+	25.0	32.1	25.0	32.1	25.0	33.2	24.9	38.7	18.9	28.8
Theta0	6.39E-04	6.40E-04	5.72E-04	5.73E-04	4.99E-04	5.00E-04	4.86E-04	4.88E-04	2.10E-04	3.00E-04
xp_max_out	4.89E-04	4.90E-04	4.37E-04	4.38E-04	3.81E-04	3.82E-04	3.71E-04	3.73E-04	1.60E-04	2.30E-04
yp_max_out	1.07E-04	8.71E-05	9.59E-05	7.79E-05	8.35E-05	6.62E-05	8.18E-05	5.68E-05	4.43E-05	4.47E-05
Uave e+	0.013	0.013	0.019	0.019	0.032	0.032	0.063	0.063	0.131	0.183
Umax e+										
delta_B	0.0055	0.0055	0.0082	0.0083	0.0160	0.0161	0.0389	0.0392	0.0568	0.1006
P_Beamstrahlung [W]	1.15E+04	1.15E+04	2.16E+04	2.17E+04	5.89E+04	5.92E+04	2.04E+05	2.06E+05	7.67E+05	1.36E+06
ngamma e+	0.94	0.94	1.05	1.05	1.26	1.26	1.71	1.71	1.42	1.97
Hdx	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.0	1.1
Hdy	4.4	2.5	4.4	2.5	4.7	2.6	6.1	2.8	3.6	3.8
Hd	1.7	1.4	1.7	1.4	1.7	1.4	2.0	1.5	1.5	1.6
Geo Lum (cm-2 s-1)	3.01E+33	3.86E+33	3.76E+33	4.83E+33	5.28E+33	6.98E+33	7.51E+33	1.16E+34	1.76E+34	2.62E+34
Lum. dil.	***0.916***	***0.832***	***0.944***	***0.888***	***0.972***	***0.940***	***0.990***	***0.969***	***0.992***	***0.992***
Lum. (cm-2 s-1)	**5.06E+33**	**5.39E+33**	**6.33E+33**	**6.74E+33**	**9.10E+33**	**9.85E+33**	**1.47E+34**	**1.76E+34**	**2.69E+34**	**4.21E+34**
Lum/bc	*7.71E+29*	*8.21E+29*	*9.64E+29*	*1.03E+30*	*1.39E+30*	*1.50E+30*	*2.25E+30*	*2.68E+30*	*2.78E+30*	*4.34E+30*
Coherent pairs/bc	5.64E-167	1.20E-166	2.90E-117	4.98E-117	2.83E-65	4.11E-65	1.00E-28	1.46E-28	6.75E-10	1.66E-04
Inc. pairs/bc (LL)	1.40E+04	1.49E+04	1.85E+04	1.97E+04	2.90E+04	3.13E+04	5.12E+04	6.12E+04	7.44E+04	1.16E+05
Inc. pairs/bc (BW)	1.64E+03	1.75E+03	1.80E+03	1.92E+03	2.21E+03	2.40E+03	3.55E+03	4.27E+03	1.34E+03	3.41E+03
Inc. pairs/bc (BH)	1.23E+05	1.31E+05	1.56E+05	1.67E+05	2.36E+05	2.55E+05	4.33E+05	5.20E+05	3.81E+05	7.62E+05
Inc. Pairs/bc (tot)	1.39E+05	1.48E+05	1.77E+05	1.88E+05	2.67E+05	2.89E+05	4.88E+05	5.85E+05	4.57E+05	8.81E+05
Caliculations by CAIN										
Lum. (cm-2 s-1)	5.09E+33	6.04.E+33	6.36E+33	7.55.E+33	9.25E+33	1.10.E+34	1.55E+34	1.94.E+34	2.66E+34	4.85.E+34
Lum. (cm-2 s-1) w/ waist shift	5.74E+33	5.95.E+33	7.18E+33	7.44.E+33	1.04E+34	1.08.E+34	1.68E+34	1.91.E+34	2.98E+34	4.79.E+34
Lum top 1% : L(0.01)/L	0.913	0.908	0.870	0.862	0.867	0.769	0.613	0.597	0.606	0.452
Lum top 1% w/ waist shift	0.911	0.908	0.866	0.863	0.774	0.770	0.612	0.601	0.599	0.457
Lum 1nm offsetY : L(1nm)/L	0.968	0.952	0.961	0.942	0.947	0.922	0.927	0.871	0.920	0.828
Lum 1nm offsetY w/ waist shift	0.958	0.942	0.950	0.932	0.934	0.910	0.916	0.847	0.905	0.814
energy loss	0.034	0.035	0.038	0.039	0.047	0.049	0.072	0.078	0.043	0.074
energy loss w/ waist shift	0.034	0.035	0.038	3.90.E-02	0.046	0.049	0.072	0.079	0.043	0.076
Inc. Pairs/bc (tot)	2.55E+04	2.92.E+04	3.50E+04	4.00.E+04	5.91E+04	6.75.E+04	1.23E+05	1.46.E+05	1.31E+05	2.77.E+05
Inc. Pairs/bc (tot) w/ waist shift	2.80E+04	2.88.E+04	3.84E+04	3.91.E+04	6.37E+04	6.59.E+04	1.30E+05	1.43.E+05	1.43E+05	2.73.E+05

wakefield effect @collimator

← coll. depth

← t-t jitter

← b-b jitter

CAIN simulation

waist scan by 0.6 σ_z