Optimization of L(E) with SB2009

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Reduced beam-power parameters

- The proposed reduction in the beam power (number of bunches per pulse) requires us to squeeze the beam-beam parameters to compensate the nominal factor-of-two reduction in luminosity.
- SB2009 explores two possibilities:
  - Pushing the beam-beam parameters into a high-disruption regime close to the single-beam kink-instability limits, at the expense of higher beamstrahlung and tighter collision tolerances. The proposed parameters could in principle recover the nominal RDR luminosity to within 25% (1.5×10^{34} cm^{-2}s^{-1}).
  - Making use of the so-called Travelling Focus [V.Balakin, LC91] effect, which can recover the remaining 25% luminosity without a further increase in the beamstrahlung. This approach comes at the cost of a very high disruption parameter, and the need for additional hardware

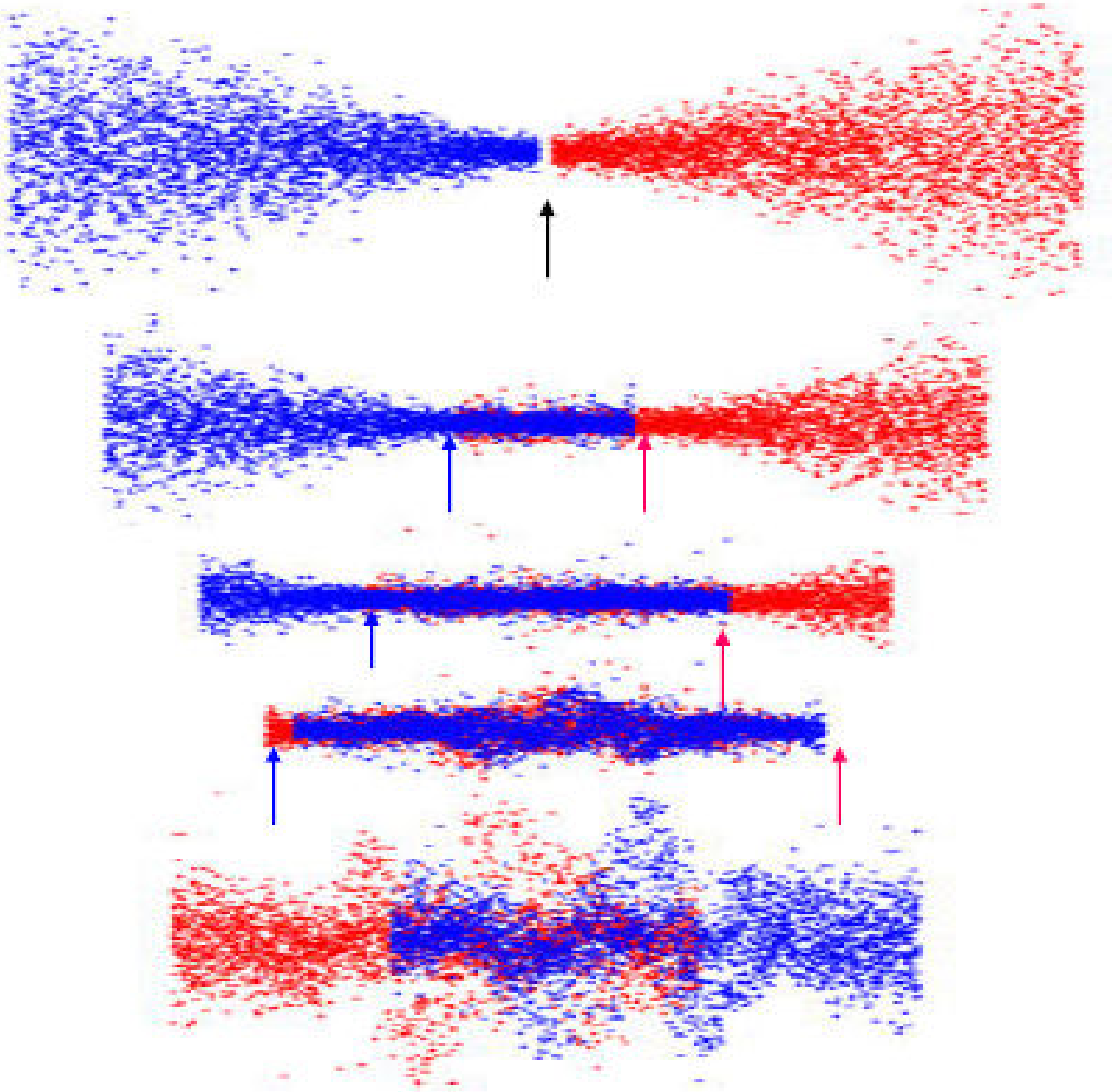
RDR parameter plane ranges compared to SB2009

		RDR			SB2009	
		min	nominal	max	no TF	with TF
Bunch population	x 10^{10}	1	2	2	2	2
Number of bunches		1260	2625	5340	1312	1312
Linac bunch interval	ns	180	369	500	530	530
RM bunch length	mm	200	300	500	300	300
Normalized horizontal emittance at IP	mm-mr	10	10	12	10	10
Normalized vertical emittance at IP	mm-mr	0.02	0.04	0.08	0.035	0.035
Horizontal beta function at IP	mm	10	20	20	11	11
Vertical beta function at IP	mm	0.2	0.4	0.6	0.48	0.2
RMS horizontal beam size at IP	nm	474	640	640	470	470
RMS vertical beam size at IP	nm	3.5	5.7	9.9	5.8	3.8
Vertical disruption parameter		14	19.4	26.1	25	38
Fractional RMS energy loss to beamstrahlung	%	1.7	2.4	5.5	4	3.6
Luminosity	x 10^{34}cm^{-2}s^{-1}		2		1.5	2

Travelling Focus Scheme

- The travelling focus is a technique in which the focussing of opposing bunches is longitudinally controlled so as to defeat the hourglass effect and to restore the luminosity.
  - The matched focusing condition is provided by a dynamic shift of the focal point to coincide with the head of the opposing bunch.
  - The longer bunch helps to reduce the beamstrahlung effect and improvement of background conditions is expected.
- TF can be created in two ways
  - Method 1 is to have small (uncompensated) chromaticity and coherent E-z energy shift dE/dz along the bunch. The required energy shift in this case is a fraction of a percent.
  - Method 2 is to use a transverse deflecting cavity giving a z-x correlation in one of the Final Focus sextupoles and thus a z-correlated focusing. The needed strength of the travelling focus transverse cavity was estimated to be about 20% of the nominal crab cavity

Travelling Focus $\beta^* < \sigma_z$

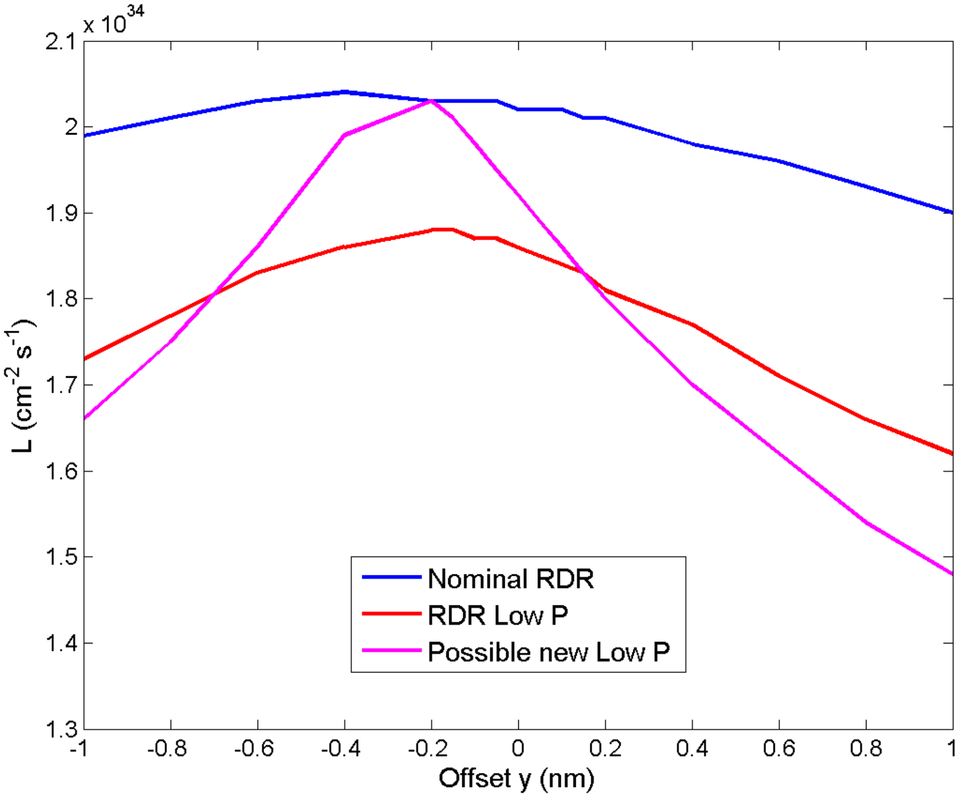


R&D and Design Work for TDP2

- The more demanding beam-beam parameters associated with SB2009 force us to be in a regime of higher disruption. Although there appears to be no fundamental show stoppers, a comprehensive study involving simulations is still required in an attempt to quantify the performance. Specifically:
  - The higher disruption results in a higher sensitivity to any beam-beam offset. Thus, operation of the intra-train feedback and intra-train luminosity optimisation becomes more important and more challenging than in the case of RDR. Early estimates suggest that in order to contain the luminosity loss within 5%, a bunch-to-bunch jitter in the train needs to be less than 0.2nm at the IP (~5% of a nominal beam sigma).
  - The parameter sets also have twice as small vertical betatron functions at the IP, which imply either tighter collimation, with gaps 40% closer to the beam core. This has implications for wakefields (emittance preservation) and fast feedback systems.
  - Enhanced beam-halo loss in the tighter collimation could potentially increase the number of generated muons and hence the muon shielding requirements.

Low P Parameter Set with Traveling Focus

- Higher Disruption
  - Higher sensitivity to Δy
  - Intratrain Feedback more challenging
  - Vertical bunch-bunch jitter to be <200pm for <5% lumi loss
  - However, twice longer bunch separation will help to improve bunch-bunch uniformity & jitter
- βx(LP)~50% βx(RDR) βy(LP-TF)~50% βy(RDR)
  - Collimation depth 1.4x deeper (smaller apertures)
  - May have more muons
  - however, have space to lengthen muon walls if needed

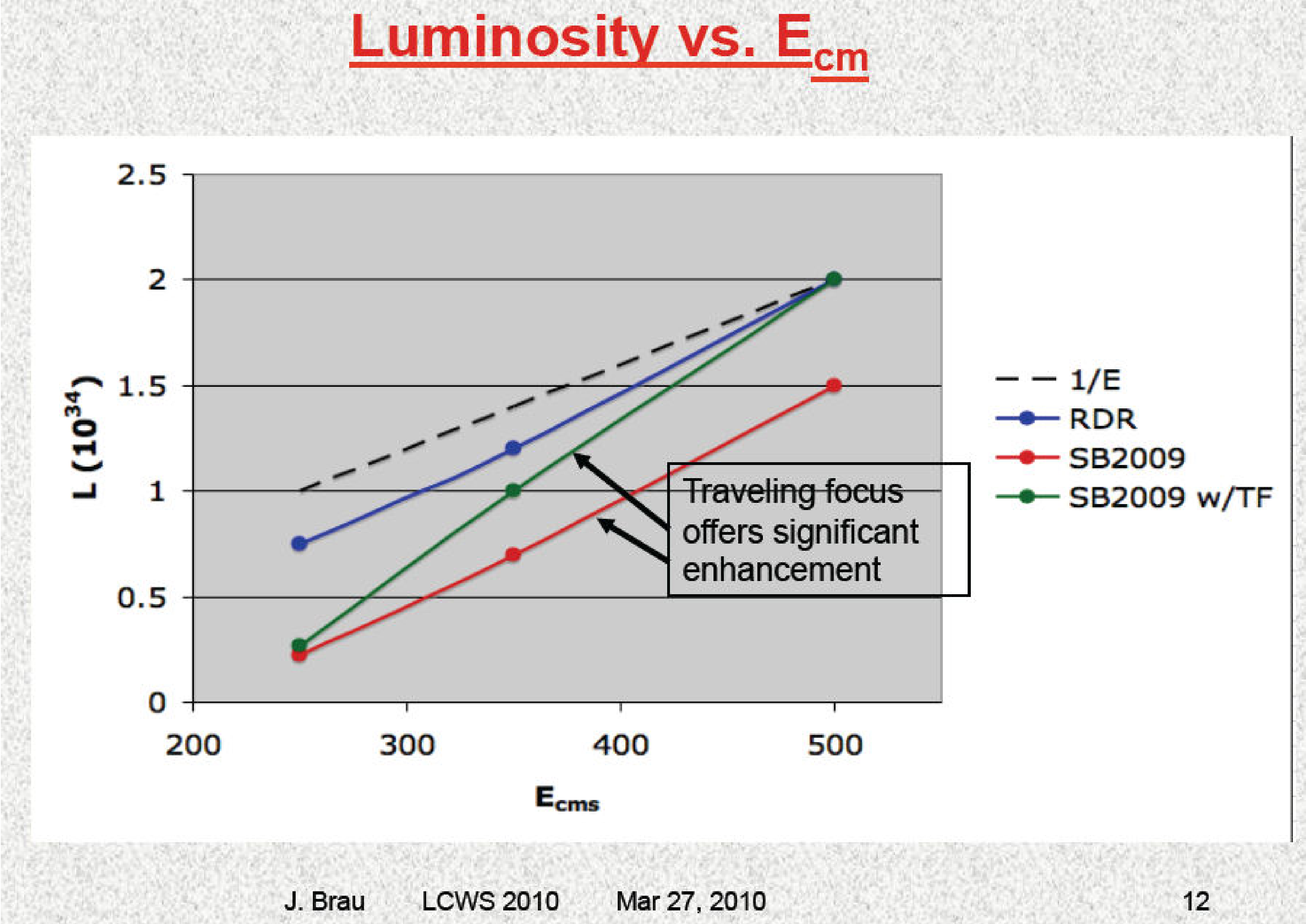


Beam Parameters

	RDR			**SB2009 w/o TF**				**SB2009 w TF**			
CM Energy (GeV)	250	350	500	250.a	250.b	350	500	250.a	250.b	350	500
Ne- (*10^{10})	2.05	2.05	2.05	2	2	2	2.05	2	2	2	2.05
Ne+ (*10^{10})	2.05	2.05	2.05	1	2	2	2.05	1	2	2	2.05
nb	2625	2625	2625	1312	1312	1312	1312	1312	1312	1312	1312
Tsep (nsecs)	370	370	370	740	740	740	740	740	740	740	740
F (Hz)	5	5	5	5	2.5	5	5	5	2.5	5	5
γex (*10^{-6})	10	10	10	10	10	10	10	10	10	10	10
γey (*10^{-6})	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
βx	22	22	20	21	21	15	11	21	21	15	11
βy	0.5	0.5	0.4	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
σz (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
σx eff (*10^{-9} m)	948	802	639	927	927	662	474	927	927	662	474
σy eff (*10^{-9} m)	10	8.1	5.7	9.5	9.5	7.4	5.8	6.4	6.4	5.0	3.8
L (10^{34} cm^{-2}s^{-1})	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.25	0.27	1.0	2.0

L(E) dependence in SB2009

- Factor determine shape of L(E) in SB2009
  - Lower rep (/2) rate below ~125GeV/beam
  - Tighter focusing at IP => reduced collimation depth at lower E => increased beam degradation due to collimation wakes and due to limit (in X) on collimation depth

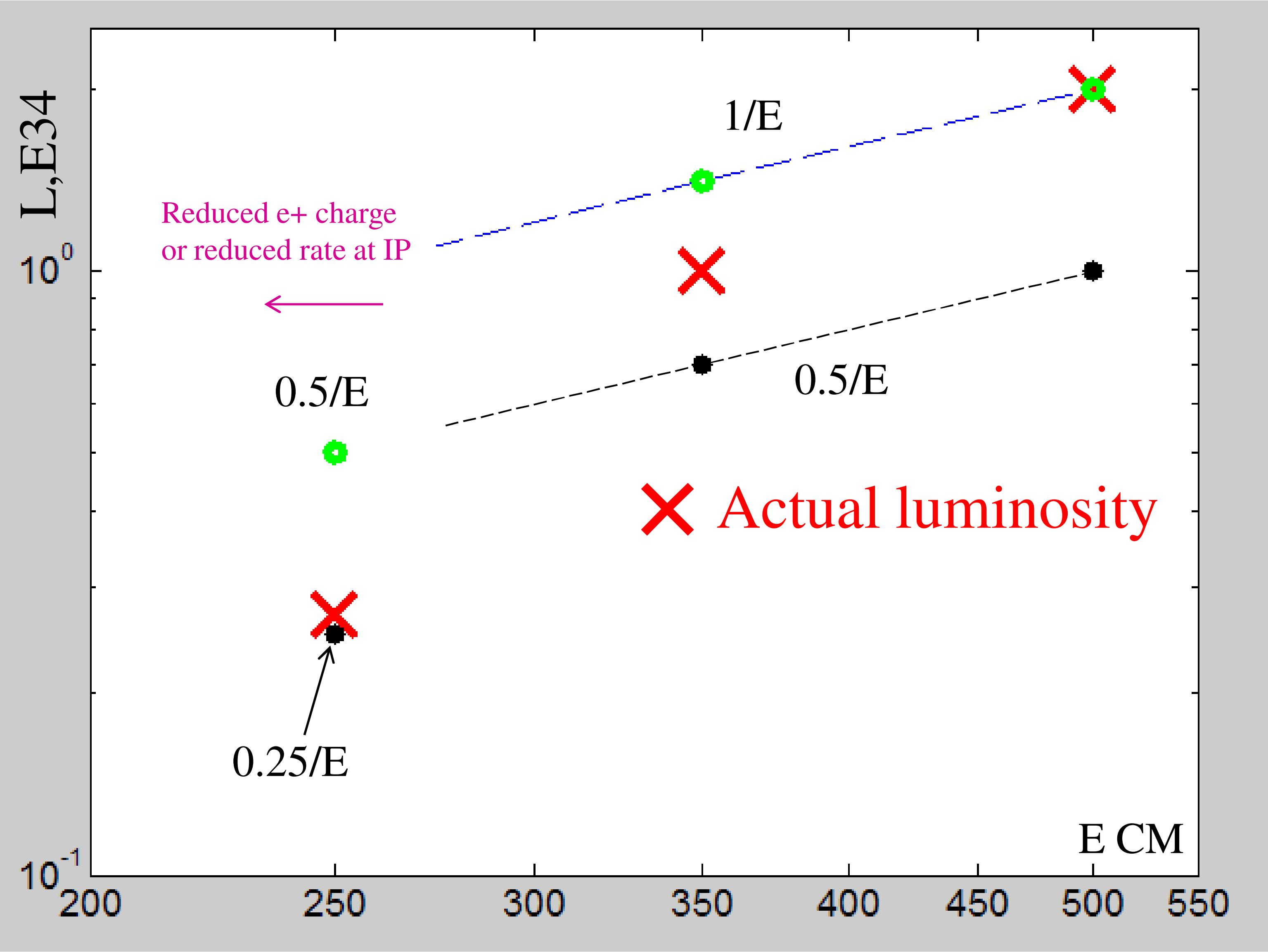


Luminosity vs. E_{cm}

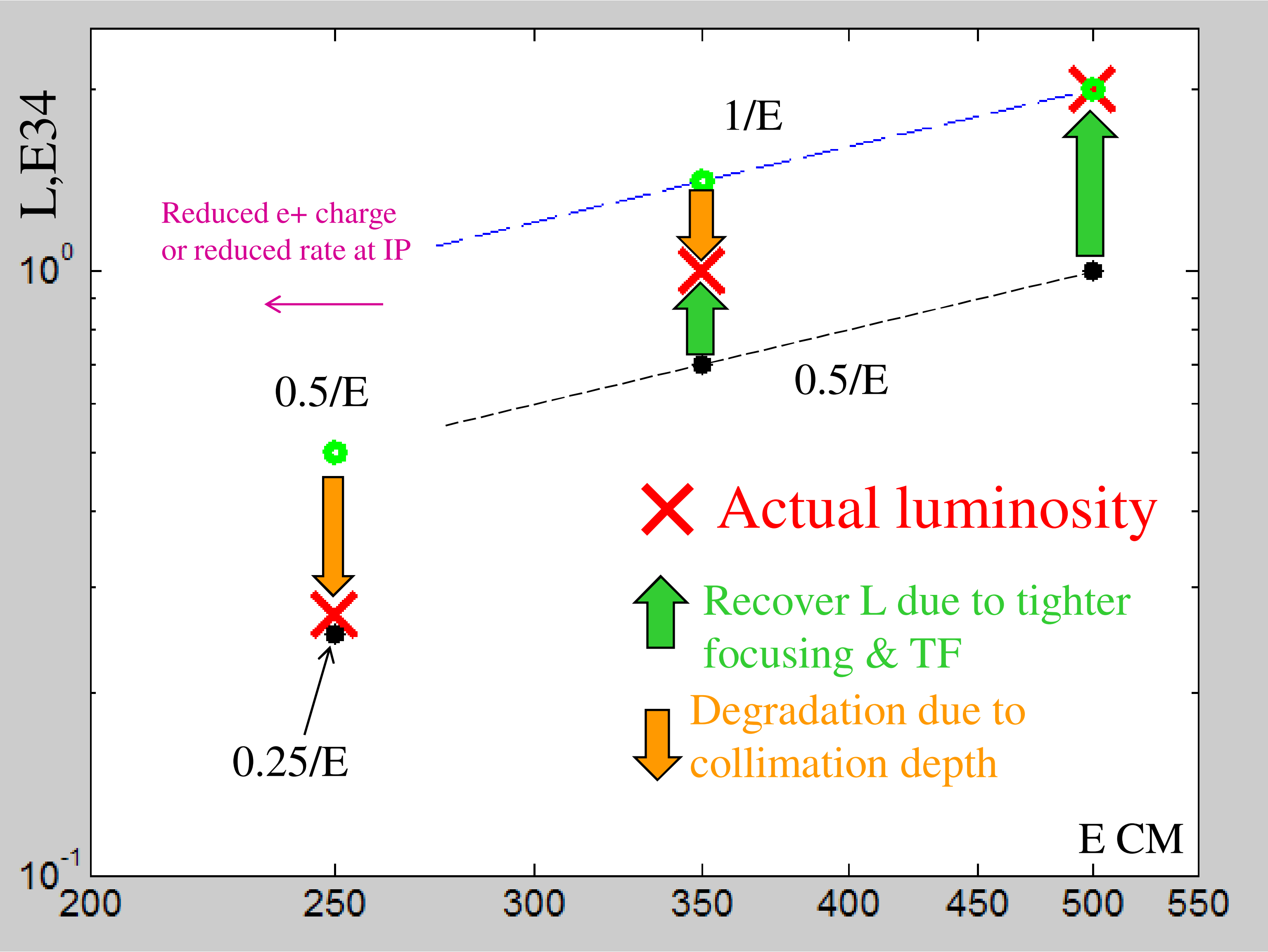
Traveling focus offers significant enhancement

J. Brau LCWS 2010 Mar 27, 2010 12

SB2009 Lumi


L,E34
10^0
10^-1
1/E
Reduced e+ charge
or reduced rate at IP
0.5/E
0.5/E
0.25/E
Actual luminosity
E CM
200
250
300
350
400
450
500
550

SB2009 Lumi


L,E34
10^0
10^-1
1/E
Reduced e+ charge
or reduced rate at IP
0.5/E
0.5/E
0.25/E
Actual luminosity
Recover L due to tighter
focusing & TF
Degradation due to
collimation depth
E CM
200
250
300
350
400
450
500
550

Possible mitigations of L(E) with SB2009

- Consider doubling the rep rate at lower energy (say below ~125GeV/beam)
  - Need to study implications for
    - DR
    - Sources
    - Linac, HLRF, Cryogenics
- Consider FD optimized for ~250GeV CM
  - May require change of FD to go to nominal 500GeV CM
    - Or a more universal FD? (New design. Feasibility?)
  - Shorter FD reduce beam size in FD and increase collimation depth, reducing collimation related beam degradation

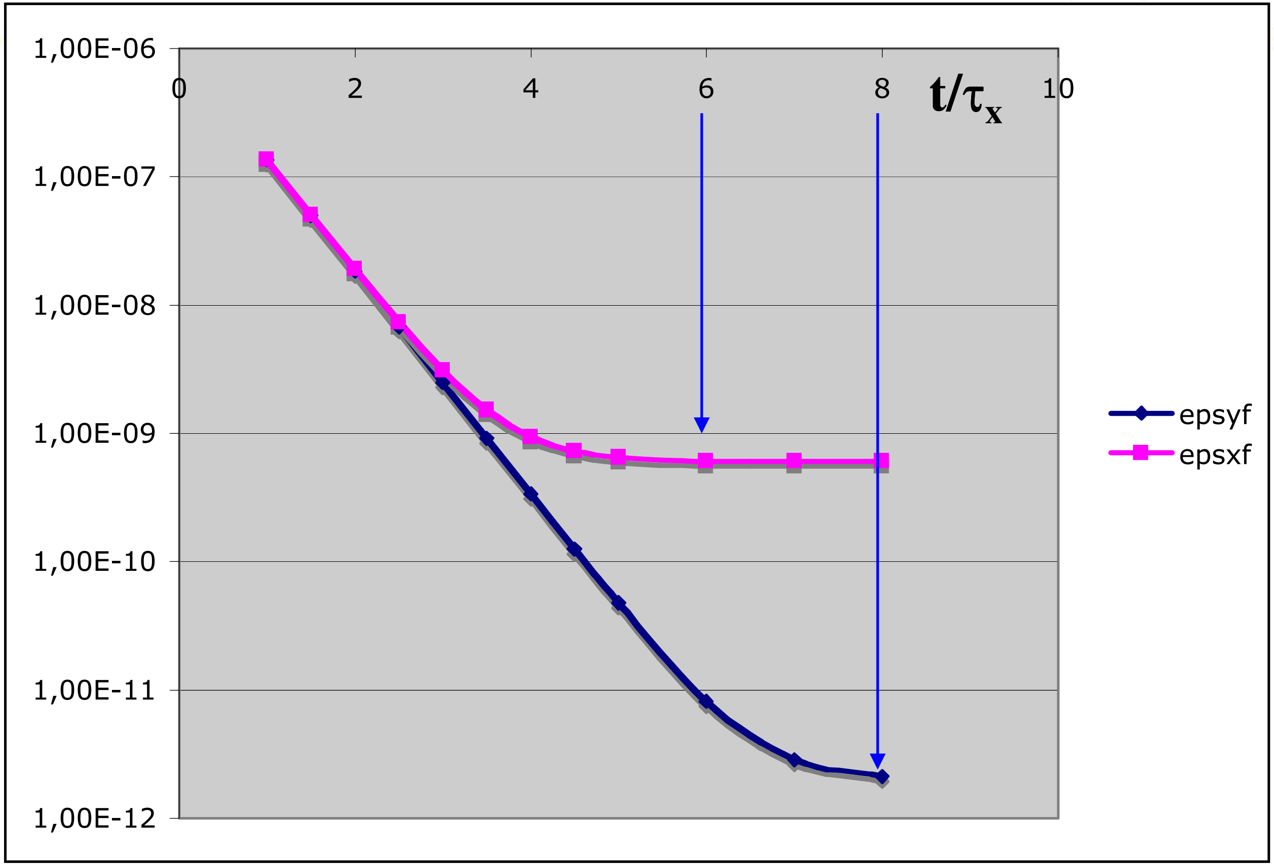
DR High Repetition Rate

- *S. Guiducci (LNF)*

- ILC10, Beijing
- 27 March 2010

Emittance damping

S. Guiducci (LNF)



8 damping times are needed for the vertical emittance

5 Hz ⇒ τ_x = 26 ms

10 Hz ⇒ τ_x = 13 ms

DR Parameters for 10 Hz Operation

S. Guiducci (LNF)

	RDR	**TILC08**	**SB2009**	**High Rep**
Circumference (m)	6695	6476	3238	3238
Damping time τ_x (ms)	25.7	21	24	13
Emittance ε_x (nm)	0.51	0.48	0.53	0.57
Emittance ε_y (pm)	2	2	2	2
Energy loss/turn (MeV)	8.7	10.3	4.4	8.4
Energy spread	1.3×10^{-3}	1.3×10^{-3}	1.2×10^{-3}	1.5×10^{-3}
Bunch length (mm)	9	6	6	6
RF Voltage (MV)	24	21	7.5	13.4
Average current (A)	0.40	0.43	0.43	0.43
Beam Power (MW)	3.5	4.4	1.9	3.6
N. of RF cavities	18	16	8	16
B wiggler (T)	1.67	1.6	1.6	2.4
Wiggler period (m)	0.4	0.4	0.4	0.28
Wiggler length (m)	2.45	2.45	2.45	1.72
Total wiggler length (m)	200	216	78	75
Number of wigglers	80	88	32	44

Energy = 5 GeV

Cost related modifications

S. Guiducci (LNF)

N. of RF cavities	8 ⇒ 16
Wiggler field	1.6 ⇒ 2.4 T
Wiggler period	0.4 ⇒ 0.28 m

Sources implications

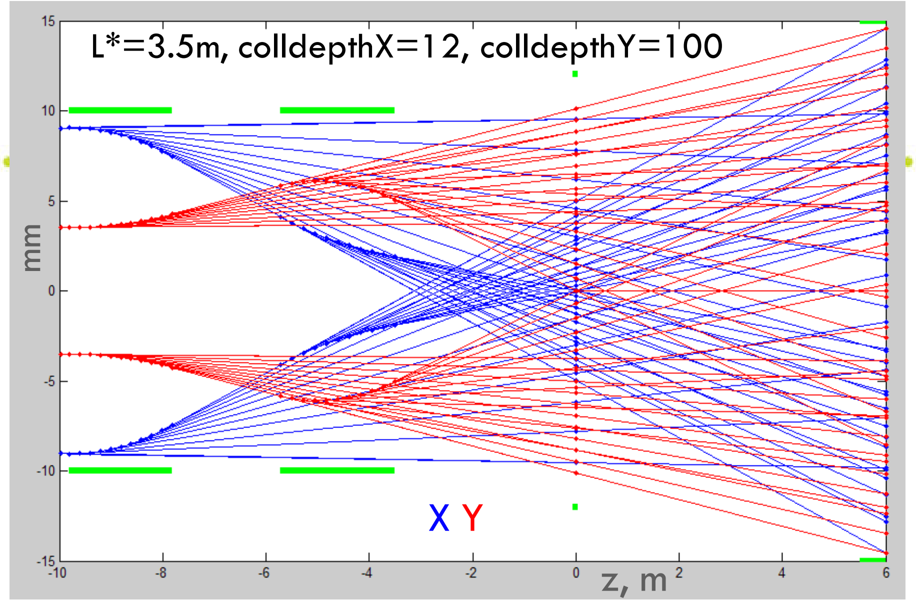
- Electron Source:
  - doubling rep rate is not critical
    [Axel Brachmann, Tsunehiko Omori]
- Positron Source:
  - The most important consequence of the increased rep rate will be the increased average power on the positron target
  - There is a hope that it can be managed, but need more detailed studies
    [Jim Clarke, Wei Gai]

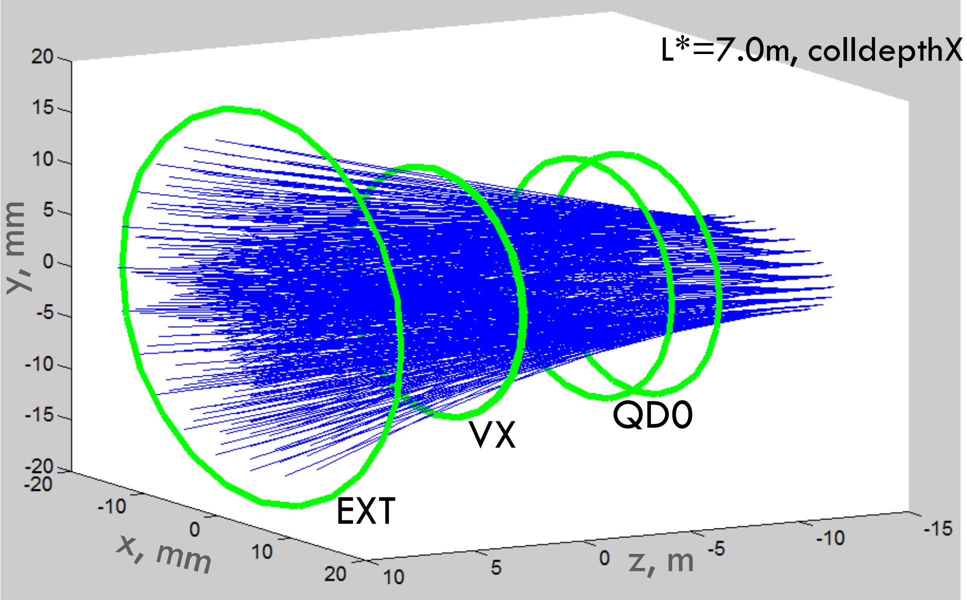
Linac and double rep rate

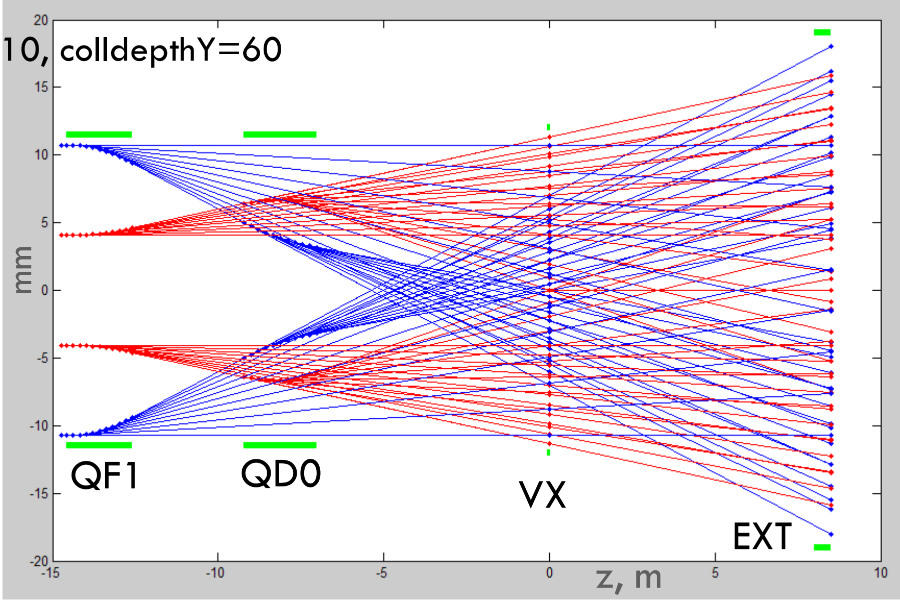
- Will have joint session with Linac colleagues this afternoon
- Will discuss
  - Linac, HLRF, Cryogenics
  - (and also
  - Injector 5 GeV linac
  - Warm e+ capture linac)

FD & collimation

- Reduced Collimation depth at lower E is responsible for large fraction of reduction of luminosity (w.r.to 1/E ideal curve)
- Shorter, matched to lower E, final doublet, will give some reduction of beam size at IP, thus increase the collimation depth

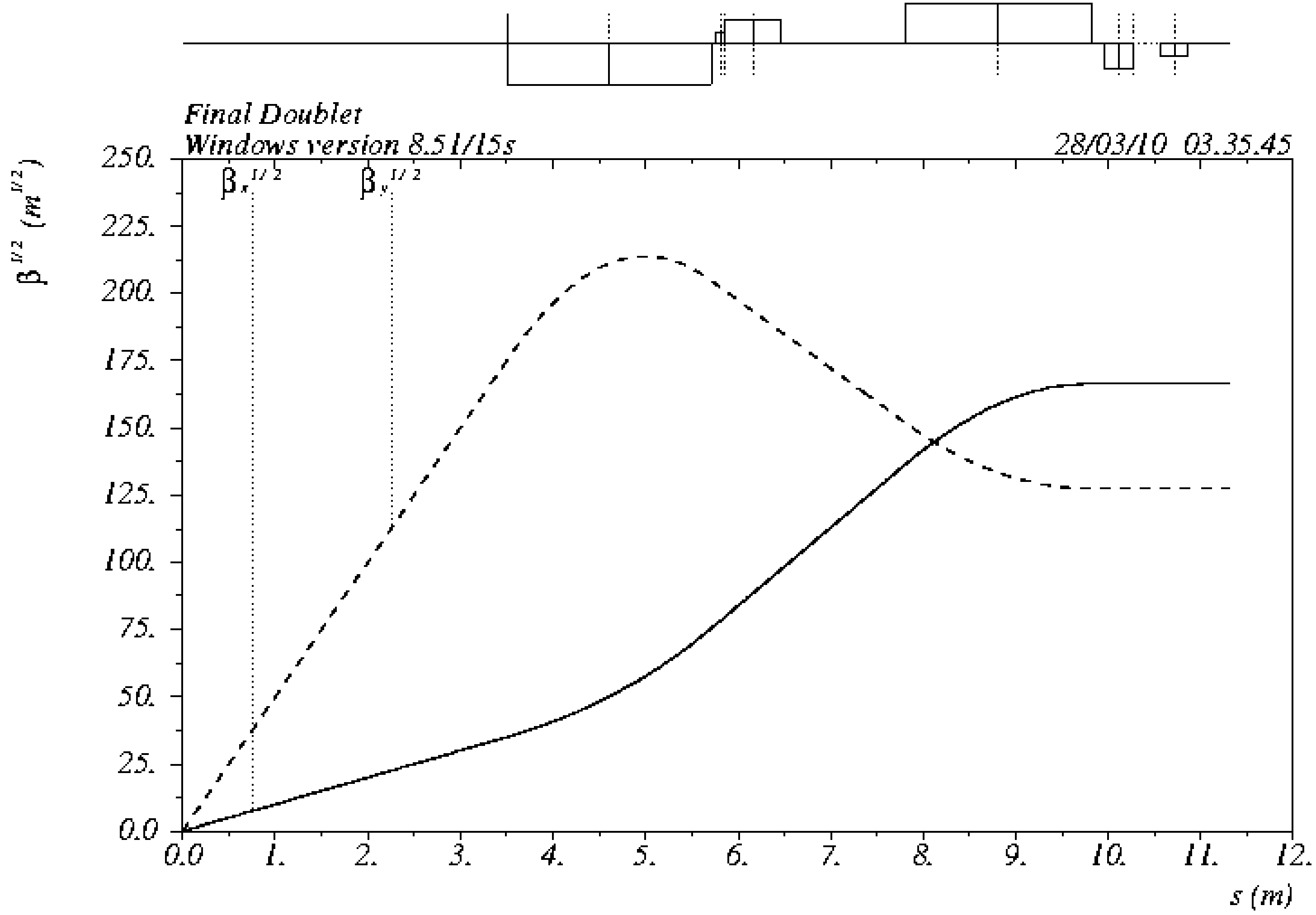




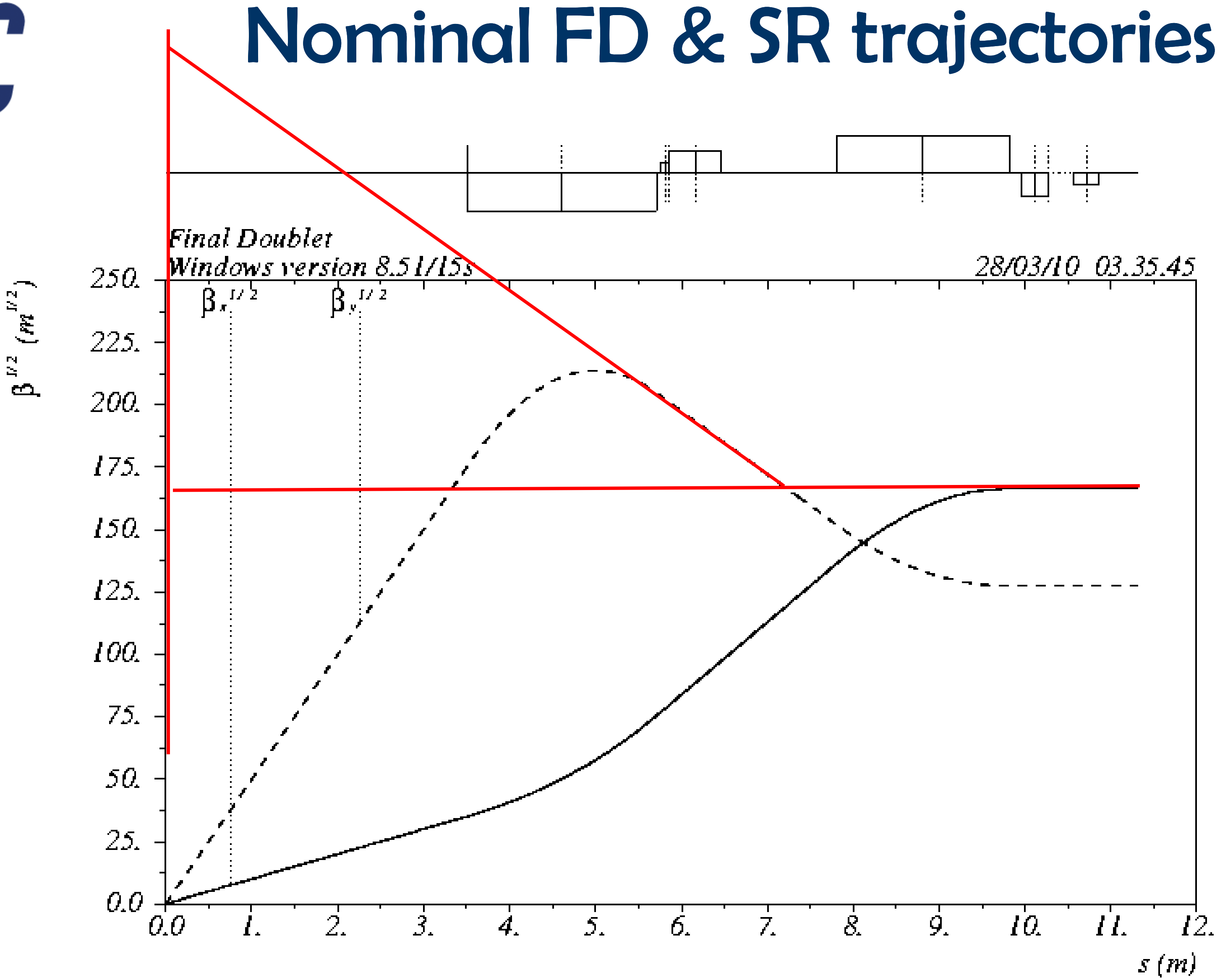


Rays show trajectories of possible SR photons. Amount of rays is not quantitative.

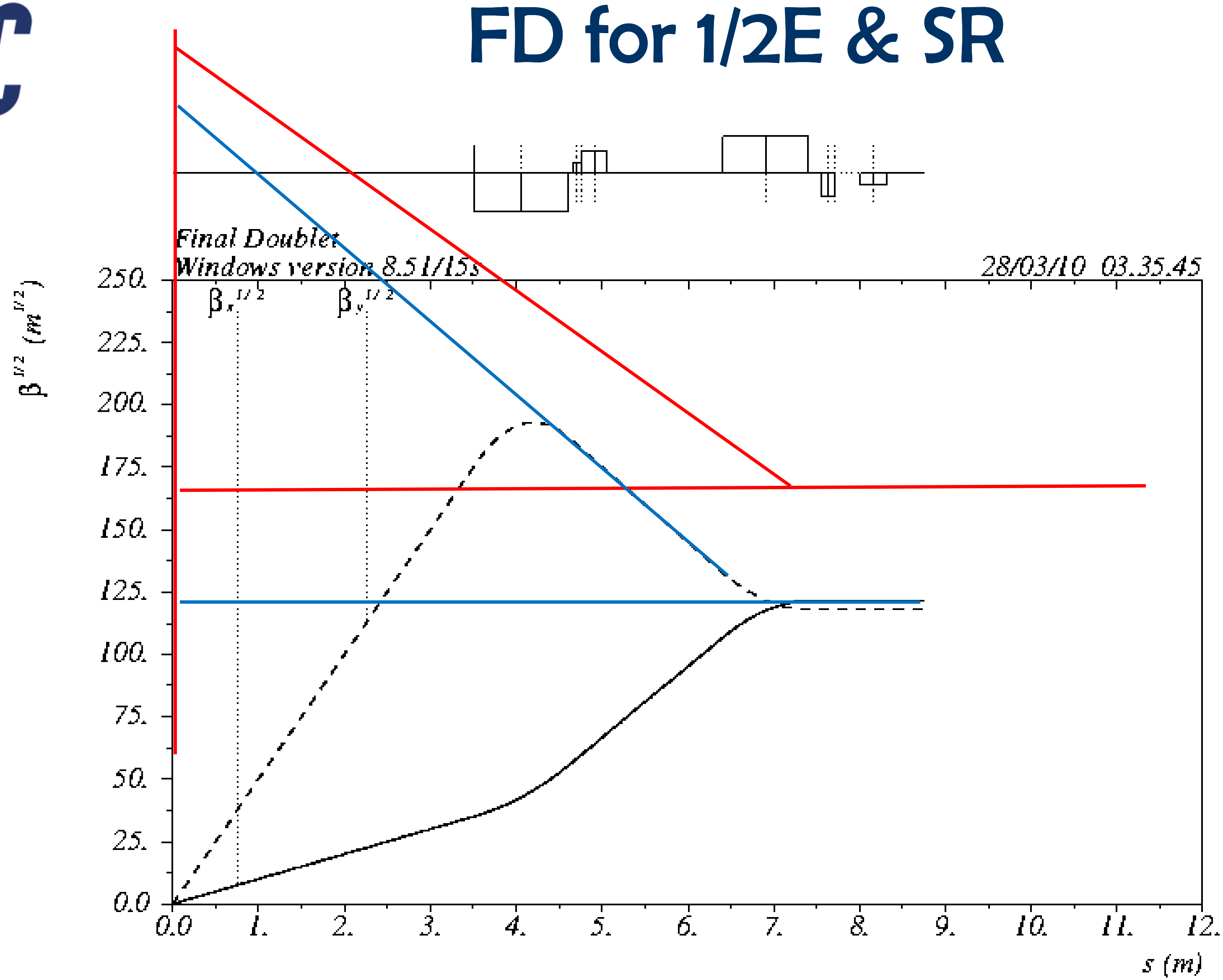
Nominal FD


Final Doublet
Windows version 8.51/15s
28/03/10 03.35.45
$\beta^{1/2}$ $(m^{1/2})$
$\beta_x^{1/2}$
$\beta_y^{1/2}$
250.
225.
200.
175.
150.
125.
100.
75.
50.
25.
0.0
0.0
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
s (m)

Nominal FD & SR trajectories

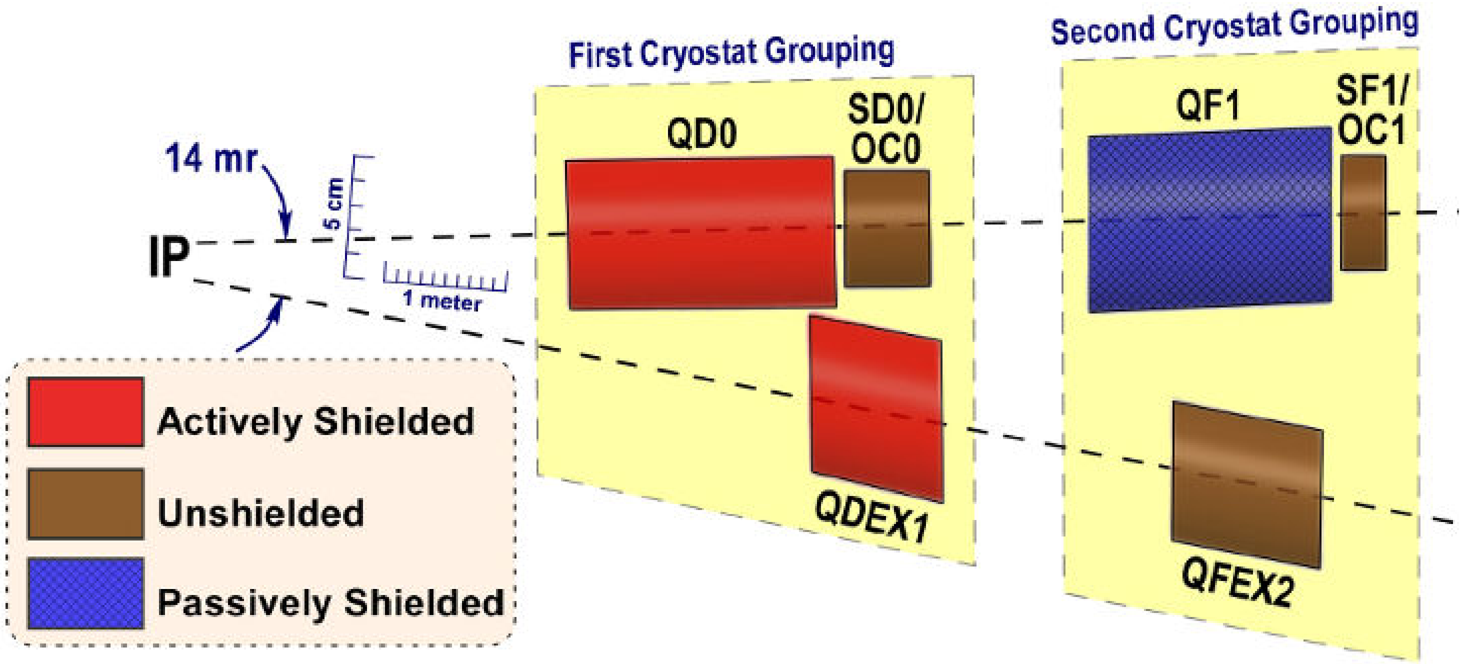


FD for 1/2E & SR



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

ILC Final Doublet layout



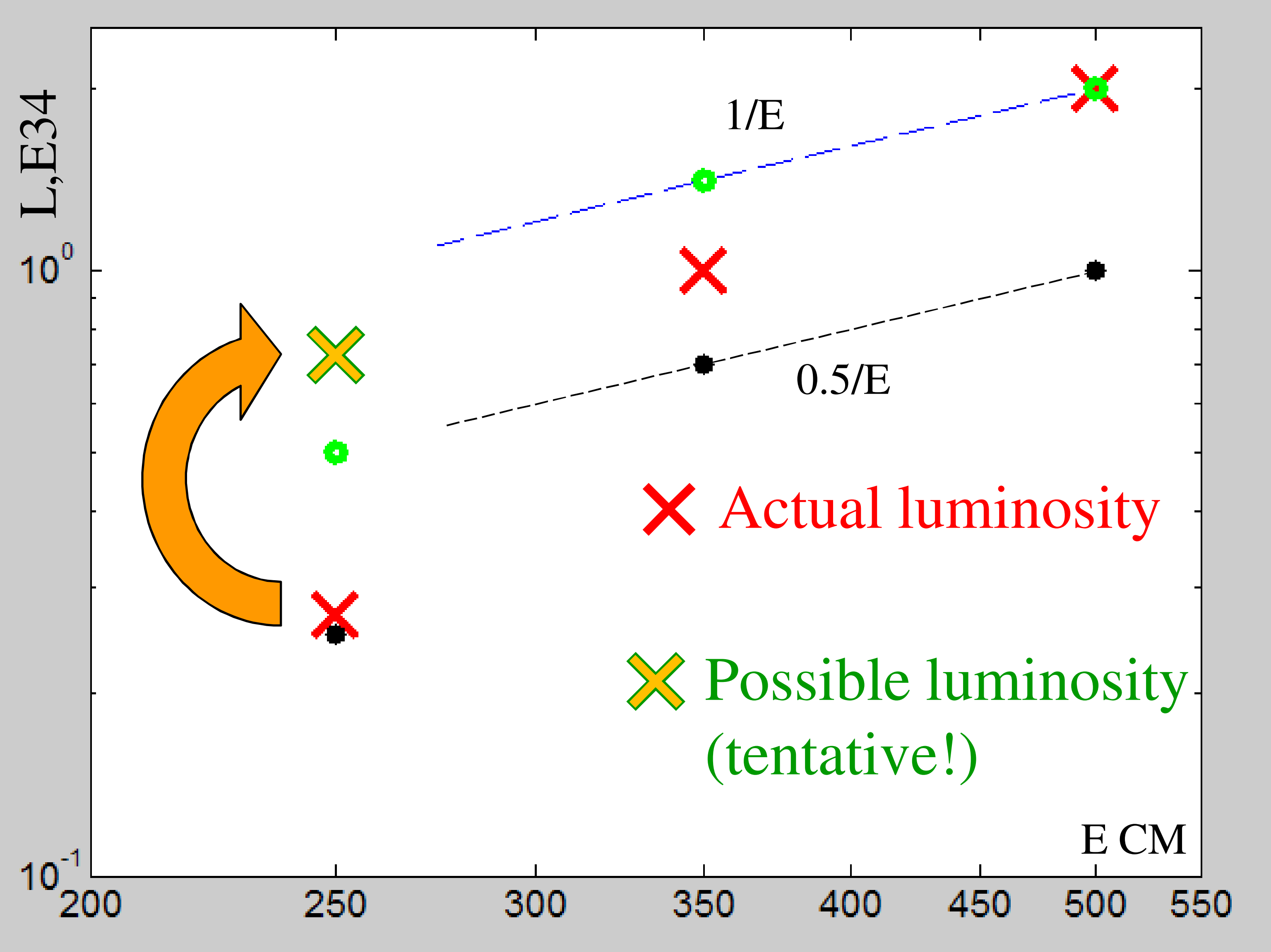
- Should we have a separate FD optimized for lower E, and then exchange it?
- Or, can we build a universal FD, that can be reconfigured for lower E config?
- To be studied

Beam Parameters & mitigation

	RDR			SB2009 w/o TF				SB2009 w TF			
CM Energy (GeV)	250	350	500	250.a	250.b	350	500	250.a	250.b	350	500
Ne- (*10^{10})	2.05	2.05	2.05	2	2	2	2.05	2	2	2	2.05
Ne+ (*10^{10})	2.05	2.05	2.05	1	2	2	2.05	1	2	2	2.05
nb	2625	2625	2625	1312	1312	1312	1312	1312	1312	1312	1312
Tsep (nsecs)	370	370	370	740	740	740	740	740	740	740	740
F (Hz)	5	5	5	5	2.5	5	5	5	2.5	5	5
γex (*10^{-6})	10	10	10	10	10	10	10	10	10	10	10
γey (*10^{-6})	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
βx	22	22	20	21	21	15	11	21	21	15	11
βy	0.5	0.5	0.4	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
σz (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
σx eff (*10^{-9} m)	948	802	639	927	927	662	474	927	927	662	474
σy eff (*10^{-9} m)	10	8.1	5.7	9.5	9.5	7.4	5.8	6.4	6.4	5.0	3.8
L (10^{34} cm^{-2}s^{-1})	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.25	0.27	1.0	2.0

- Tentative! At 250 GeV CM the mitigations may give
  - * 2 L due to double rep rate
  - * about 1.4 L due to FD optimized for low E

SB2009 Lumi


L,E34
10^0
10^-1
200
250
300
350
400
450
500
550
E CM
1/E
0.5/E
✕ Actual luminosity
✕ Possible luminosity (tentative!)

Summary

- There are ways to increase L at low E which look promising and can be studied further