Proposed machine parameters

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Assumptions:

- Starting point: parameters developed by the Physics Questions Committee (B. Foster, A. Seryi, J. Clarke, M. Harrison, D. Schulte, T. Tauchi) in December 2009.
- Take into account progress on 10Hz rep rate for low E achieved after LCWS10
  - There are issues with DR duty cycle that are being studied, however assume that they will be solved
- Assume that we will develop and use new universal FD that gives additional luminosity improvement (only) for 200 and 250 GeV energies
- Consider the following energies: 200, 250, 350, 500 GeV CM
- Assume single stage bunch compressor (min sigma_z=230um – will use 300um and consider 230 as an overhead or safety margin)
- Assume 10Hz and 1300 bunches
- Consider separately the cases with and without Travelling Focus
- Energy and rep rate:

E=	200	250	350	500	GeV CM
IP rep rate	5	5	5	5	Hz
Linac rate	10	10	5	5	Hz
	(double pulsing)				
		(gray area)			

Proposed new parameters

	w/o TF				with TF			
CM Energy (GeV)	200	250	350	500	200	250	350	500
Linac F (Hz)	**10**	**10**	5	5	**10**	**10**	5	5
IP F (Hz)	5	5	5	5	5	5	5	5
Ne- ($*10^{10}$)	2	2	2	2	2	2	2	2
Ne+ ($*10^{10}$)	2	2	2	2	2	2	2	2
nb	1312	1312	1312	1312	1312	1312	1312	1312
Tsep (nsecs)	740	740	740	740	740	740	740	740
σz (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Linac γex ($*10^{-6}$)	10	10	10	10	10	10	10	10
Linac γey ($*10^{-8}$)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
IP βx (mm)	16	12	15	11	16	12	15	11
IP βy (mm)	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
IP σx eff ($*10^{-9}$ m)	904	700	662	474	904	700	662	474
IP σy eff ($*10^{-9}$ m)	9.9	8.7	7.2	6.0	7.4	6.2	5.0	4.0
L (10^{34} $cm^{-2}s^{-1}$)	0.4	0.6	0.7	1.5	0.5	0.8	1.0	2.0

Parameters ~January 2010

	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

Comparison with Jan-2010

	w/o TF				with TF			
CM Energy (GeV)	200	250	350	500	200	250	350	500
Linac F (Hz)	**10**	**10**	5	5	**10**	**10**	5	5
IP F (Hz)	5	5	5	5	5	5	5	5
Ne- (*10^{10})	2	2	2	2	2	2	2	2
Ne+ (*10^{10})	2	2	2	2	2	2	2	2
nb	1312	1312	1312	1312	1312	1312	1312	1312
Tsep (nsecs)	740	740	740	740	740	740	740	740
σz (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Linac γex (*10^{-6})	10	10	10	10	10	10	10	10
Linac γey (*10^{-8})	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
IP βx (mm)	16	12	15	11	16	12	15	11
IP βy (mm)	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
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January 2010: 0.22 0.7 1.5 0.27 1.0 2.0

Further studies

- Design of the universal final doublet
- Collimation depth optimization
- Study of FF tuning with needed beta*
- Detailed beam-beam studies
- …

Backup info:
slides from LCWS 2010

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
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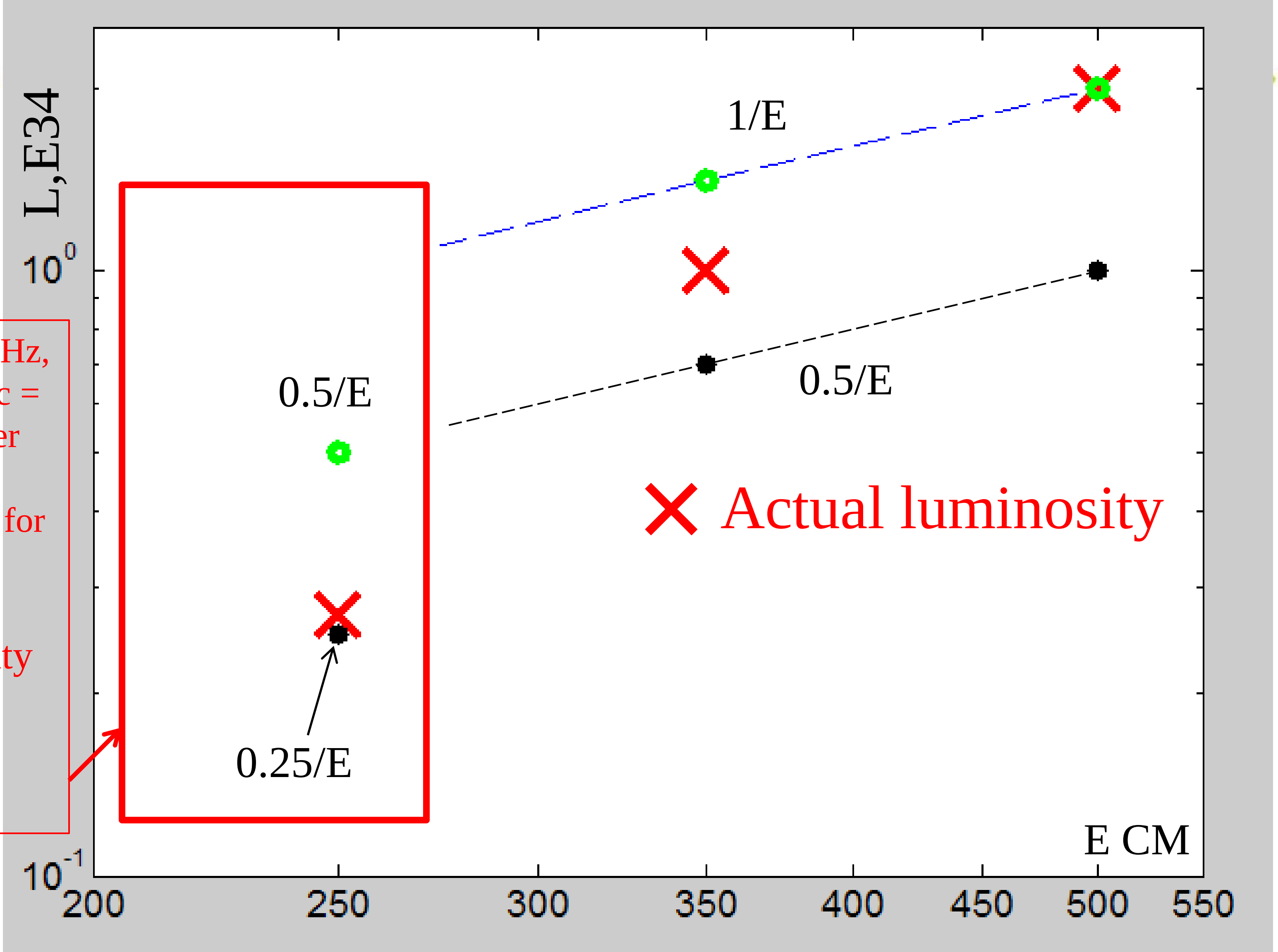
Rate at IP = 2.5Hz,
Rate in the linac = 5Hz (every other pulse is at 150GeV/beam, for e+ production)

Low luminosity at this energy reduces the physics reach

SB2009 Lumi



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Low luminosity at this energy reduces the physics reach

Lumi(E) dependence in SB2009

- Factor determine shape of L(E) in SB2009
  - Lower rep (/2) rate below ~125GeV/beam
  - Collimation effects: increased beam degradation at lower E due to collimation wakes and due to limit (in X) on collimation depth

- Understanding the above limitations, one can suggest mitigation solutions:
  - 1) Consider doubling the rep rate at lower energy
  - 2) Consider Final Doublet optimized for 250GeV CM

Work on mitigations of L(E) with SB2009 during ILC2010

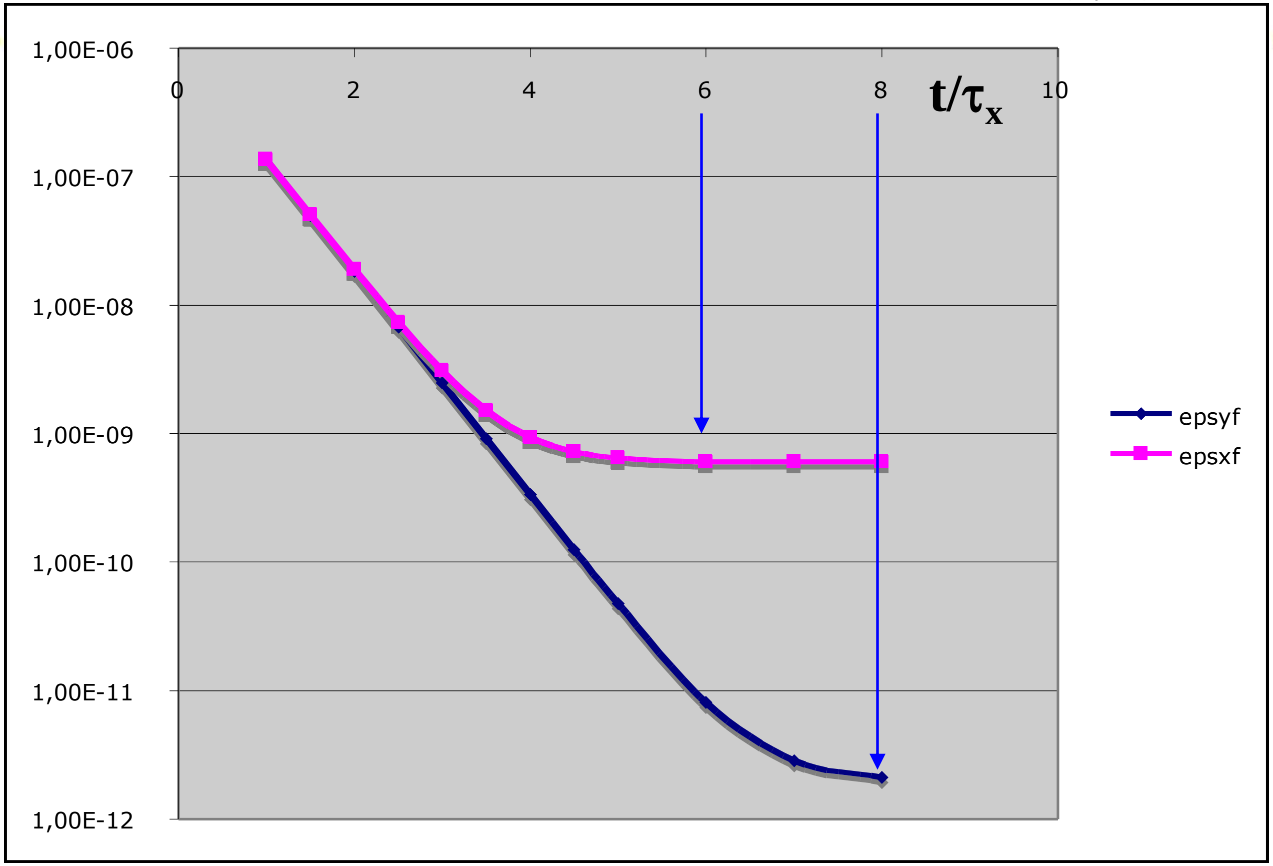
- Have initiated discussion of double rep rate ~month before the ILC2010
- Doubling the rep rate (below ~125GeV/beam)
  - BDS WG discussed implications with other Working Groups:
    - DR => OK! (new conceptual DR design was presented!)
    - Sources => OK!
    - Linac, HLRF, Cryogenics => OK!
- FD optimized for ~250GeV CM
  - Shorter FD reduce beam size in FD and increase collimation depth, reducing collimation related beam degradation
  - Will consider exchanging FD for low E operation or a more universal FD that can be retuned

SLIDES FROM LCWS2010

Emittance damping

SLIDES FROM LCWS2010

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) et al

	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

DR (3.2km) at 10Hz is feasible

Double rep rate: Sources

- Electron Source:
  - doubling rep rate is not critical
    [Axel Brachmann, Tsunehiko Omori et al]
- Positron Source:
  - For SB2009 250b case there should be no issues
    - For 250a, which is not a preferred solution, the most important consequence of the increased rep rate will be the increased average power on the positron target
    - Even for this case there is a hope that it can be managed, but need more detailed studies [Jim Clarke, Wei Gai, et al]

Linac and double rep rate

- At lower gradient, considering the cryo load (which should not be exceeded) and the efficiency of rf power sources (their efficiency decreases with power) concluded, that at 125 GeV/beam one can work at 10Hz rep rate in the linac
- At 150GeV/beam one can work at 8Hz in the linac
  - And this is possible only because the e+ source is at the end of the linac!

Chris Adolphsen, et al

=> SB2009 OK for linac rep rate 10 Hz for 125 GeV/beam & 8 Hz for 150 GeV/beam

Linac OK for double rep rate

Chris Adolphsen:

- At lower gradient, it would be easy to increase the rep rate of the cavities to maintain a constant cryo load (the rep rate scales roughly as 1/gradient^2). However, one cannot readily increase the rep rate of the rf power sources as their efficiency decreases with power. In particular the klystron output power scales as V^3.5 where V = the modulator voltage while the power flow in the modulators and klystrons scales as V^2.5, and their rep rate scales as 1/(flow*pulse width) (limited mainly by the site power capacity and the modulator charging supply ratings). For example, at half the gradient, the klystron voltage could be lowered to .5^3.5 = .82 of its nominal value and rep rate could then be increased by a factor of 1/.82^2.5 = 1.64 times the pulse width factor of ~ 1.6/1.3 (due to the shorter filling time) **for a net factor of 2.0 (up to 10 Hz).**
- There would be some additional costs associated with designing the modulators to run at a variable rep rate. However, I believe the main problem would be in the damping rings as the beams need 200 ms to be fully damped (one would need to increase the damping rate with more undulators). And of course, at low beam energy, half the pulses have to run at 150 GeV or above to generate photons to produce positrons (although such pulses probably do not have to be fully damped, the modulators would probably need to run at a constant pulse spacing). Thus with damping times of 5/8 nominal, one could perhaps run 4 Hz at 150 GeV (for e+ production) interleaved with 4 Hz of luminosity production (vs 2.5 Hz in the report) at < 150 GeV per beam. Also, for beam energies of 250 GeV down to **150 GeV,** all pulses would be for luminosity and the rep rate would increase from 5 Hz to **8 Hz** (which is an advantage of putting the undulators at the end of the linacs)

=> SB2009 OK for linac rep rate of 10 Hz for 125 GeV/beam & 8 Hz for 150 GeV/beam

Cryo load is OK

	#1	#2
	G=31.5 MV/m	G=15.75 MV/m
	Nb=2625	Nb=1312
	Ne+=2E10	Ne+=2E10
2K	8.6 W	5.5 W
4K	8.2 W	7.7 W
40K	131 W	106.8 W
Total per cryomodule	9.8 kW	8.2 kW

Notes:
Qext(#1)=Qext(#2)
Conversion:
2K=> 703 W/W
4K=> 197 W/W
40K=> 16.45 W/W

Ratio:
Total (#2)/ (#1) = 0.73

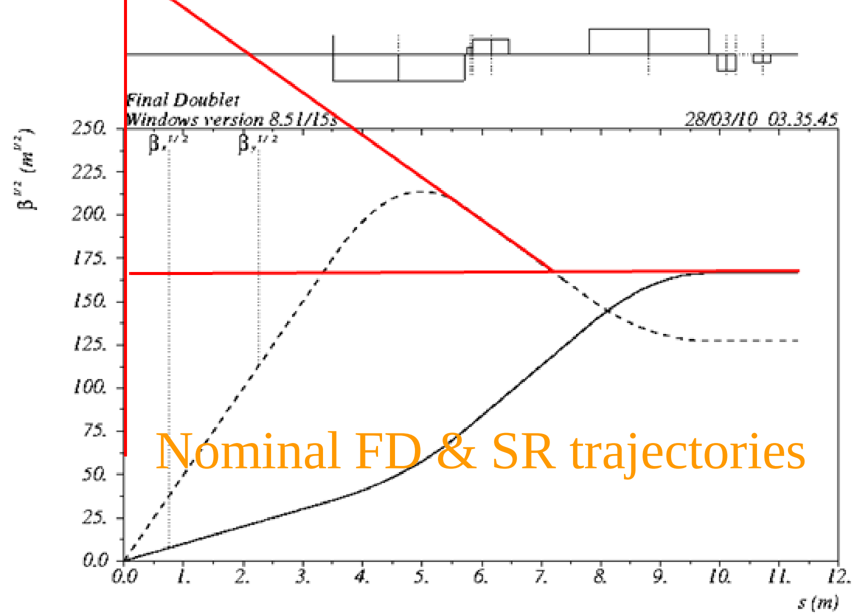
8 Cavity losses:
#1: 5.98 W (out of 8.6)
#2: 2.99 W (out of 5.5)

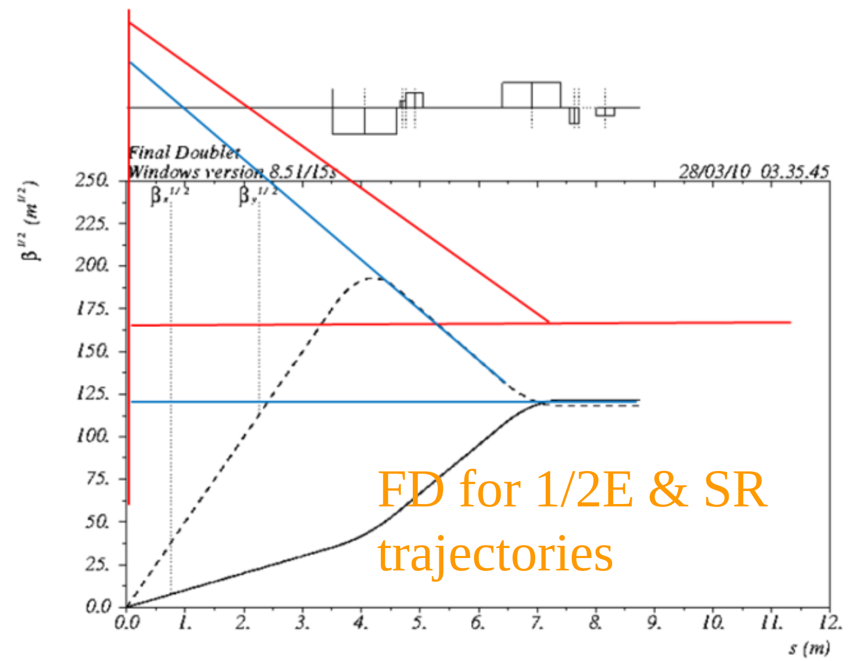
Nikolay Solyak:

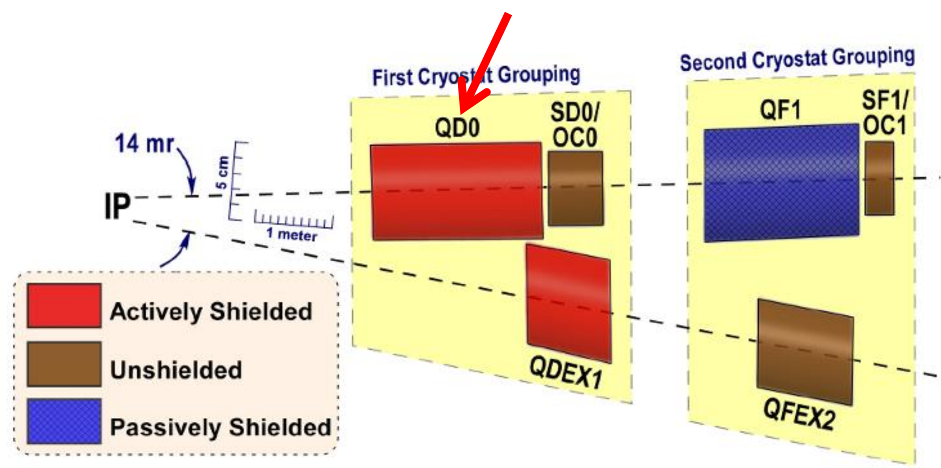
FD for low E

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)







Beam Parameters & mitigation

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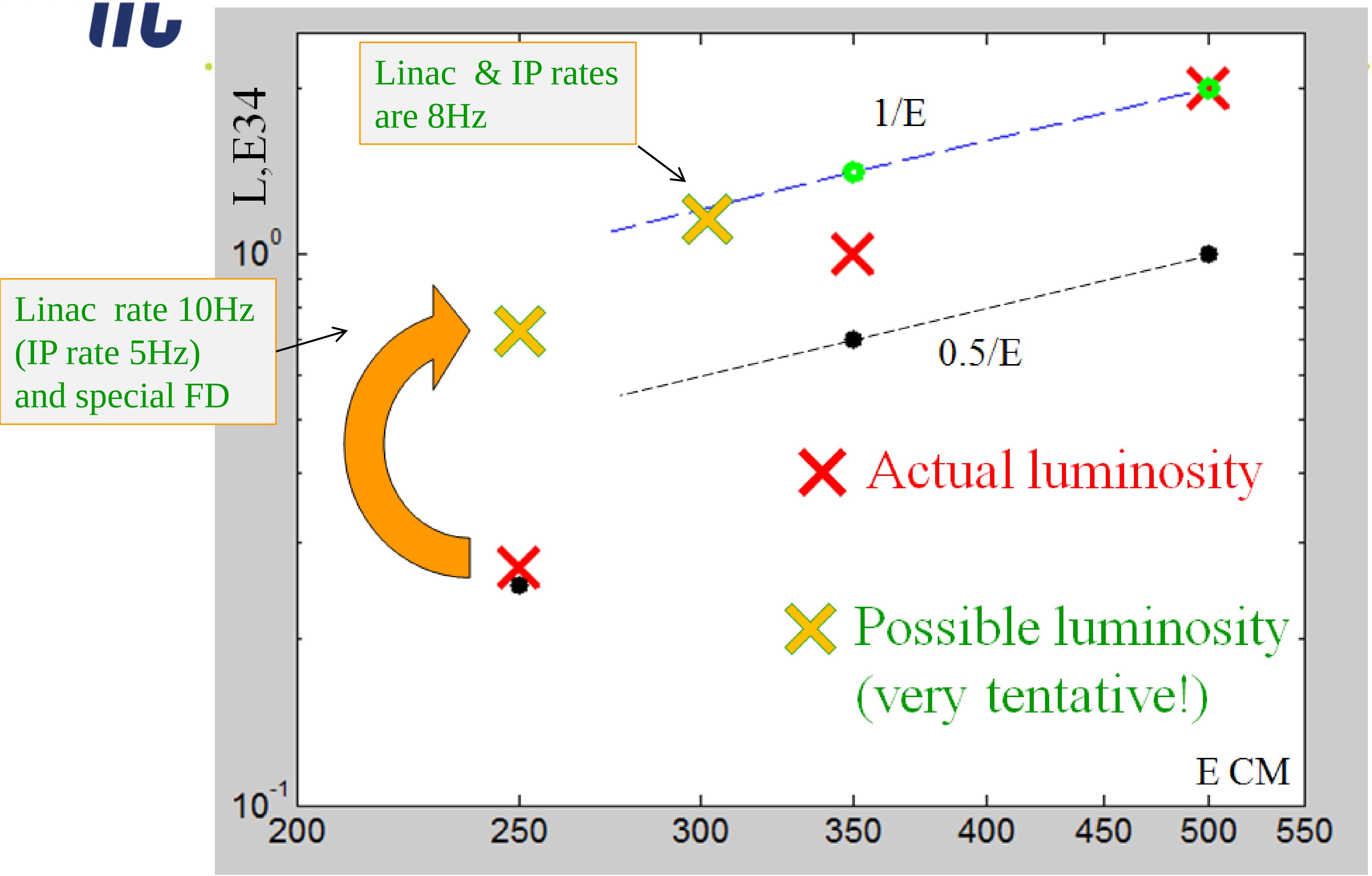
- Tentative! At 250 GeV CM the mitigations may give
  - * 2 L due to double rep rate
  - * about 1.4 L due to FD optimized for low E

SB2009 Lumi


Linac & IP rates
are 8Hz
1/E
0.5/E
L, E34
10^0
10^{-1}
Linac rate 10Hz
(IP rate 5Hz)
and special FD
Actual luminosity
Possible luminosity
(very tentative!)
E CM
200
250
300
350
400
450
500
550