Discussion of ILC high luminosity parameters

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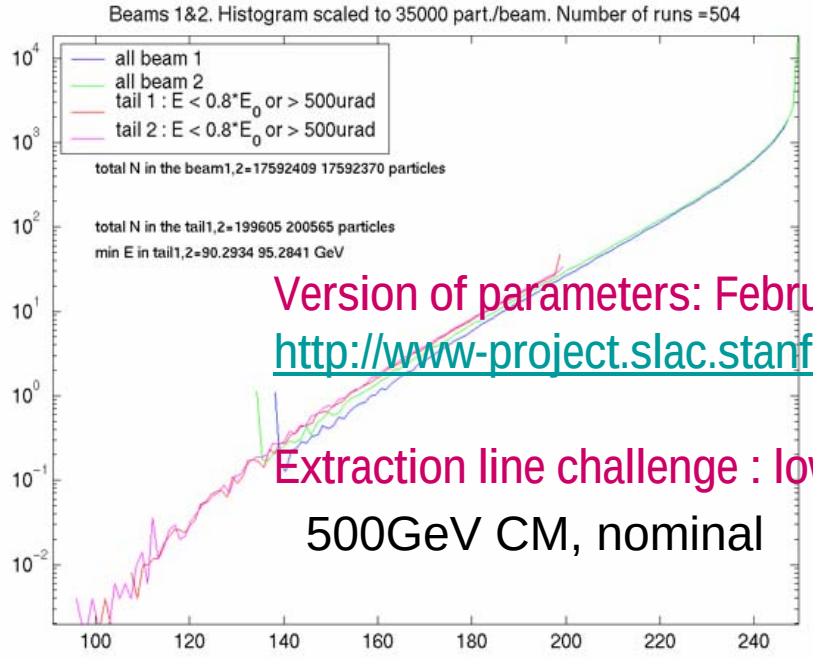
with suggestions from Tor Raubenheimer
and critical comments by Peter Tenenbaum and Andy Wolski

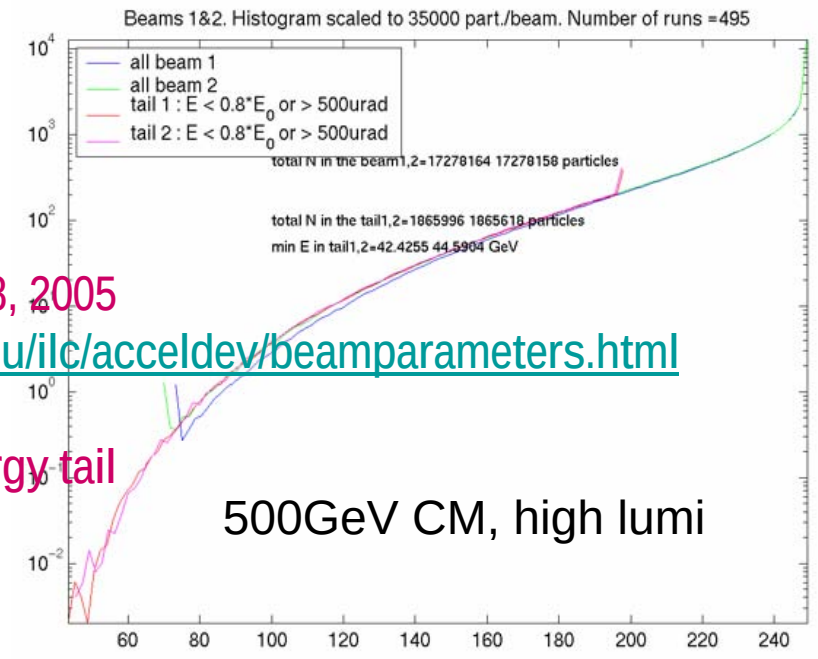
First discussed on July 25, 2005
http://www-project.slac.stanford.edu/lc/bdir/Meetings/beamdelivery/2005-04-12/index.htm
Since then discussed by detector groups and used to evaluate BDS performance

Design challenges and 1 TeV high lumi case

- Extraction of the disrupted beam is one of ILC challenges
- Energy acceptance of extraction beamline is not unlimited
  - so far achieved acceptance of approximately 35% to 100%
- Need to treat E acceptance in a similar way as other limits
  - like emittance growth in the linac, or
  - DR emittance due to coupling or collective effects
  - ...

- Below, a very tentative set of parameters is suggested for discussion for 1 TeV high lumi case
  - It is designed to relax extraction line problems, but it certainly push other parts of the design





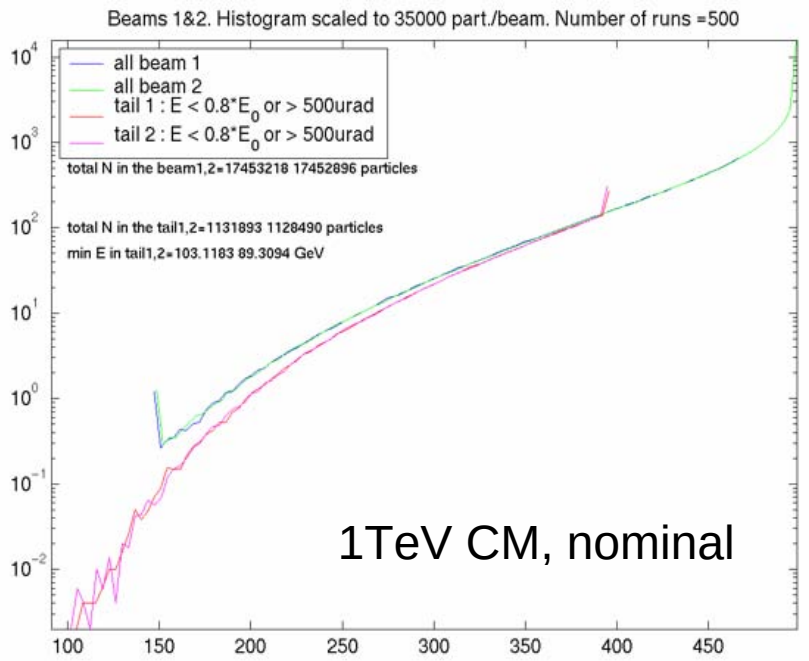
Version of parameters: February 28, 2005

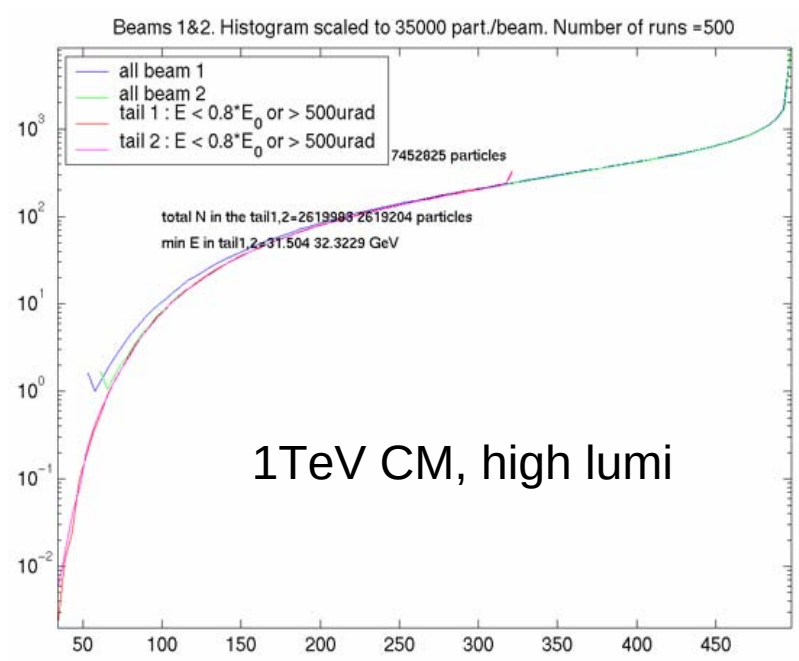
http://www-project.slac.stanford.edu/ilc/acceldev/beamparameters.html

Extraction line challenge : low energy tail

500GeV CM, nominal

500GeV CM, high lumi

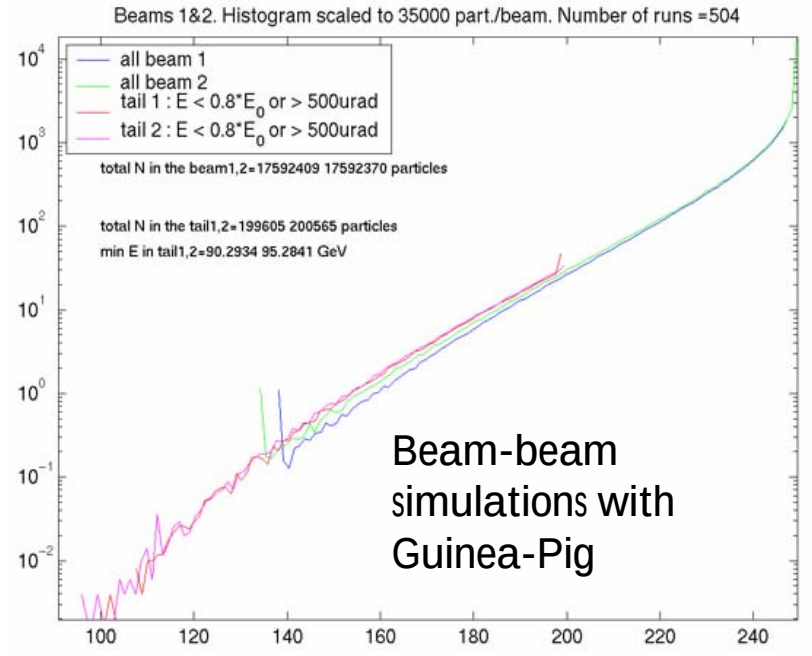




1TeV CM, nominal

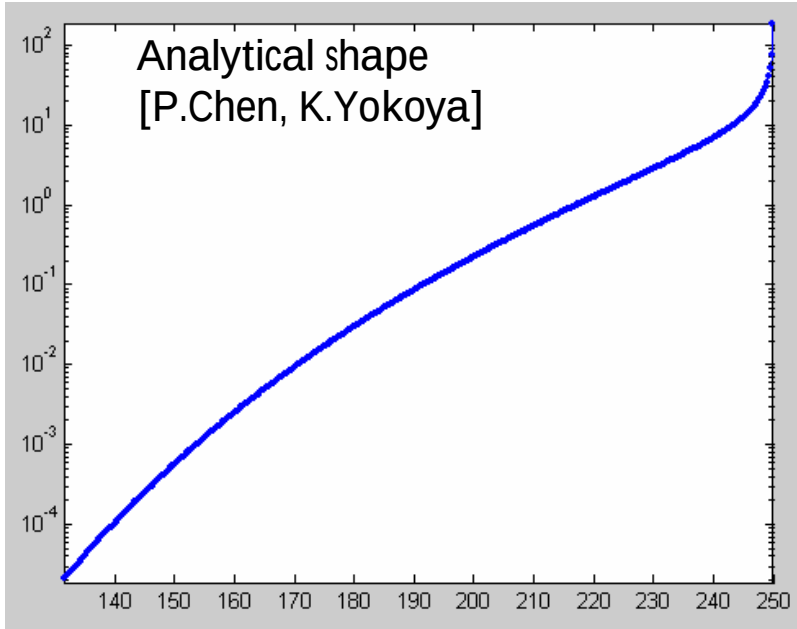
1TeV CM, high lumi

- For quick optimization used analytical expression for spectrum after collision
- Shape reproduced nicely, but the relative energy is somewhat lower in GP simulations
- Used as a criteria the energy, below which there is less than 10W of tail

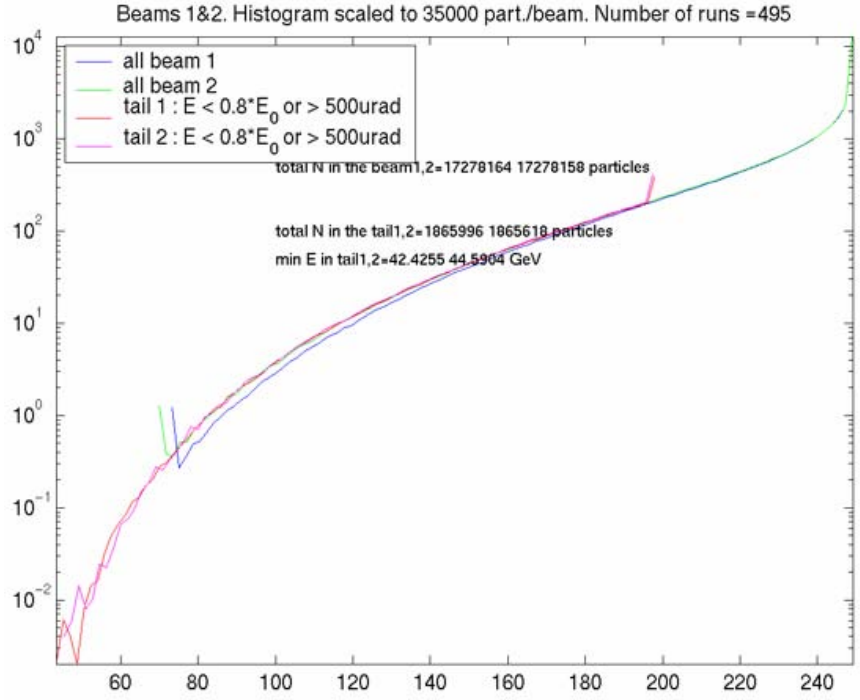


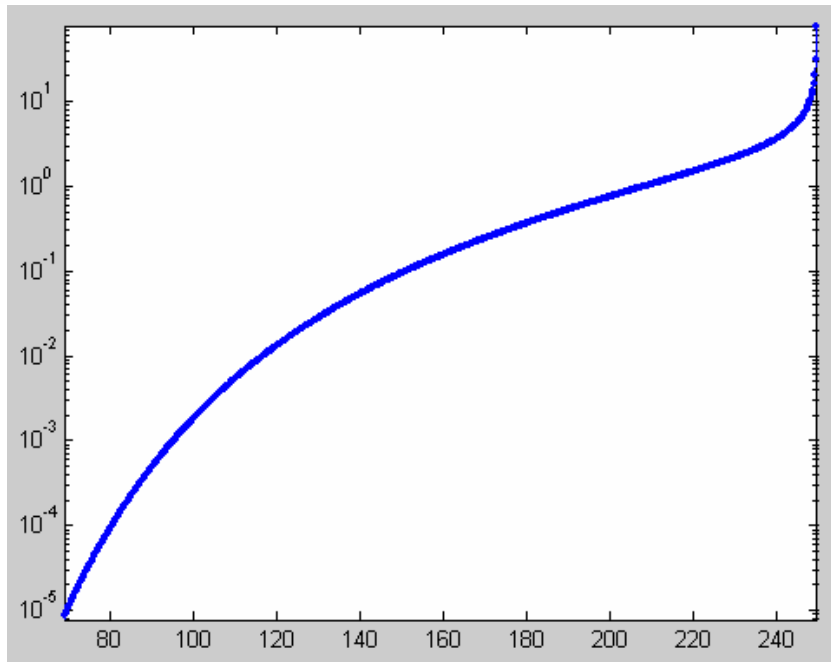
500GeV CM nominal

---Input :	----Output (analytical numbers):
energy=250	P_b=11280000
particles=2	Dx=0.16
sigma_x=655	Dy=18.4
sigma_y=5.7	Hd=1.69
sigma_z=300	LumG=1.20e+038
emitt_x=10	Lum=2.03e+038
emitt_y=0.04	P_beamstrh=243670
beta_x=0.021	Upsilon=0.045
beta_y=0.0004	nG=1.26
frep*nb=14100	delB=0.0216
	inc. pairs/bc total=206900
	Elower10W=136 GeV (54.5%)



- For High Lumi 500 GeV CM, the 10W limit occur at 30% of the nominal energy (analytical number)
- This case is barely works (or not) with 20mrad extraction
- Let's consider this 30% as the limit

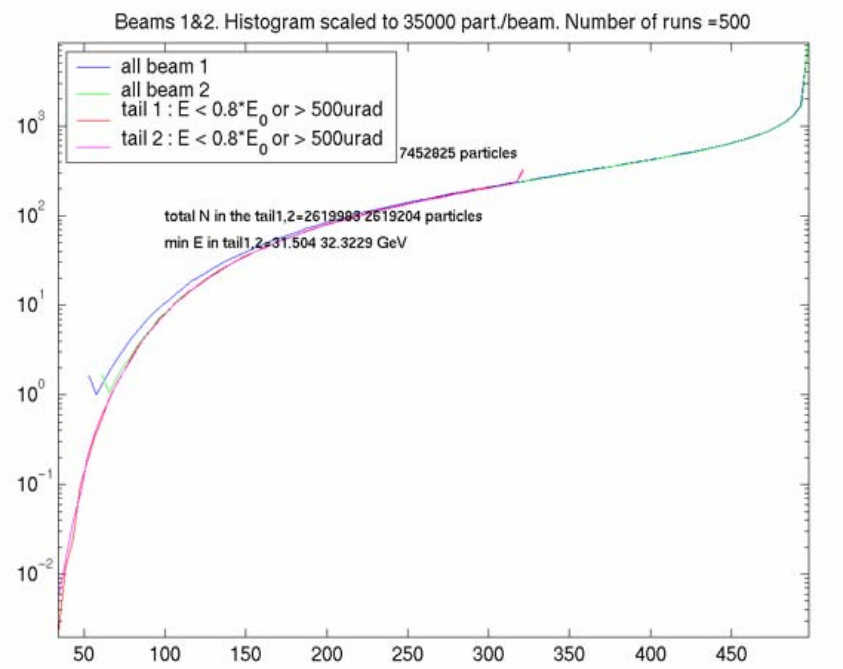




---Input :
energy=250
particles=2
sigma_x=452
sigma_y=3.5
sigma_z=150
emitt_x=10
emitt_y=0.03
beta_x=0.01
beta_y=0.0002
frep*nb=14100

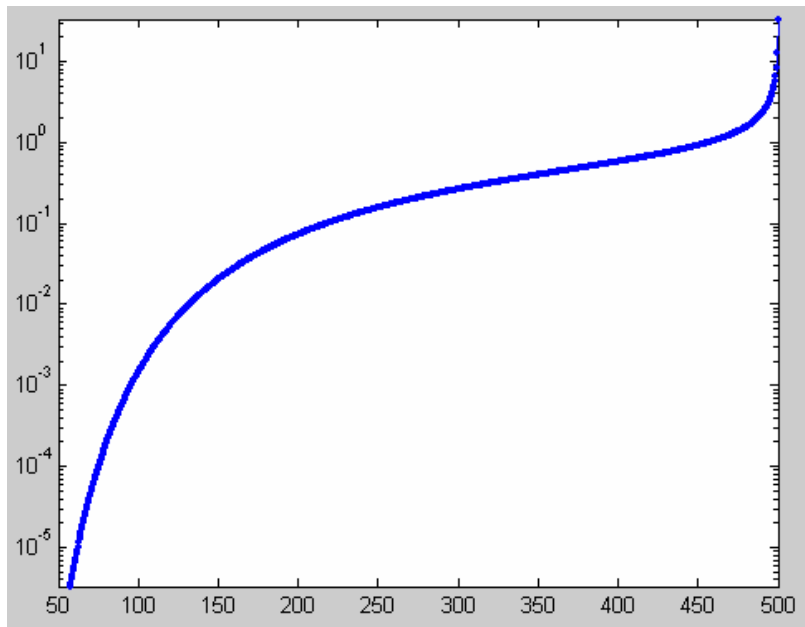
----Output :
P_b=11280000
Dx=0.168
Dy=21.71
Hd=1.733
LumG=2.837e+038
Lum=4.916e+038
P_beamstrh=780104
Upsilon=0.13
nG=1.73
delB=0.069
inc. pairs/bc total=507646
Elower10W=75 (30%)

- For High Lumi 1 TeV CM, the 10W limit presently occur at 13.3% of E0
- With present extraction design, with downstream diagnostics, this set does not appear to work
- Let's modify parameters so that 10W limit increase at least to 30% of E0



---Input :
energy=500
particles=2
sigma_x=320
sigma_y=2.5
sigma_z=150
emitt_x=10
emitt_y=0.03
beta_x=0.01
beta_y=0.0002
frep*nb=11280

----Output :
P_b=18048000
Dx=0.167
Dy=21.46
Hd=1.74
LumG=4.488e+038
Lum=7.812e+038
P_beamstrh=3176989
Upsilon=0.369
nG=2.22
delB=0.176
inc. pairs/bc total=1084825
Elower10W=66.5 (13.3%)



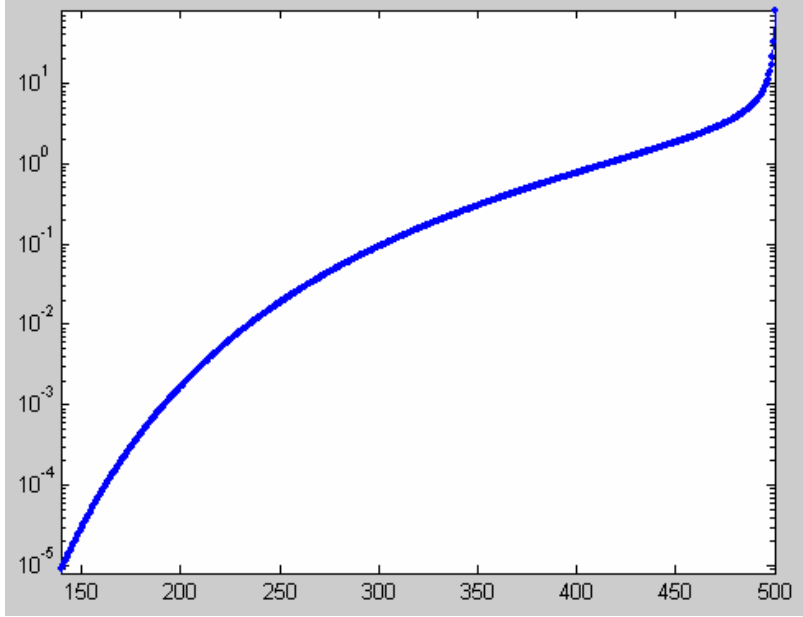
- For new 1TeV high lumi case, basically need to decrease Υ more than twice, while keeping L almost same and keeping D_y below ~28
  - aim for "high L" = 2*nominal, not higher (presently high/nom=2.8)
  - aim that disrupted beam tail has < 10W below 30% of E0
- Remind scaling

$$\text{Lumi} \sim \frac{N^2}{\sigma_x \sigma_y} \qquad D_y \sim \frac{N\,\sigma_z}{\sigma_x \sigma_y} \qquad \Upsilon \sim \frac{N}{\sigma_x \sigma_z} \qquad \delta_E \sim \frac{N^2}{\sigma_x^2\,\sigma_z}$$

- Reduction of Υ twice seem to possible only with twice longer bunch
- Further reduce Υ by increasing σ_x faster then N (also helps to keep D_y < 28)
- Same σ_y with 2*long bunch (twice β_y^*) require smaller ε_y ,
  => slight increase of σ_y , so that required ε_y is more feasible

- In summary, the suggested 1TeV high L parameter set has:
  - twice longer bunch (300um, not 150um as in present 1TeV high L set)
  - somewhat lower y emittance (0.023 , not 0.030)
  - somewhat higher charge (2.4 , not 2.0)
  - larger beam at IP (550*2.7 , not 320*2.5)
  - higher y disruption (~ 27 , not 21)

- Suggested new 1 TeV High Lumi case



Suggested 1TeV high L

----Input :
energy=500
particles=2.4
sigma_x=550
sigma_y=2.7
sigma_z=300
emitt_x=10
emitt_y=0.023
beta_x=0.0296
beta_y=0.00031
frep*nb=11280

----Output :
P_b=21657600
Dx=0.136
Dy=27.75
Hd=1.64
LumG=3.48e+038
Lum=5.718e+038
P_beamstrh=1450127
Upsilon=0.128
nG=1.697
delB=0.0669
inc. pairs/bc total=786246
Elower10W=146.5 (29.3%)

- If the higher charge is not possible, one can reoptimize with somewhat lower luminosity

February 28, 2005

Suggested for discussion

Case	1TeV nominal	1TeV high L	new high L	new' high L
energy/beam , GeV	500	500	500	500
particles , 1E10	2	2	2.4	2
sigma_x , nm	554	320	550	470
sigma_y , nm	3.5	2.5	2.7	2.7
sigma_z , um	300	150	300	300
emitt_x , E-6 m	10	10	10	10
emitt_y , E-6 m	0.04	0.03	0.023	0.023
beta_x , mm	30	10	30	21.6
beta_y , mm	0.3	0.2	0.31	0.31
frep*nb , 1/s	11280	11280	11280	11280
P_beam, MW	18.05	18.05	21.66	18.05
Dx	0.11188	0.16767	0.13622	0.15545
Dy	17.71	21.46	27.75	27.06
Hd	1.52	1.74	1.64	1.64
LumGeom, m-2 s-1	1.85E+38	4.49E+38	3.48E+38	2.83E+38
Lum , m-2 s-1	2.81E+38	7.81E+38	5.72E+38	4.64E+38
Lum / Lum Nominal	1	2.78	2.03	1.65
P_beamstrh , MW	0.874	3.177	1.45	1.164
Upsilon	0.106	0.37	0.128	0.125
nG	1.42	2.22	1.7	1.66
delB	0.0484	0.176	0.0669	0.0645
inc. pairs/bc (LL)	64487	179110	131135	106509
inc. pairs/bc (BW)	1273	4684	3347	2639
inc. pairs/bc (BH)	281851	901029	651763	521591
inc. pairs/bc total	347612	1084825	786246	630741
Elower10W , GeV	168.5	66.5	146.5	150.5
Elower10W , %	33.7	13.3	29.3	30.1

Discussion

- The new 1TeV high L set need to be further discussed

- The biggest push is of course for DR performance and LET performance
  - E.g. DR extracted emittance = 18nm
  - LET emittance dilution budget = 5nm

- Other sets, e.g. high Lumi 500 GeV CM, need to be considered from the same assumptions

From: Minutes of the fifth meeting for the IR task force 3rd August, 14:00-15:00

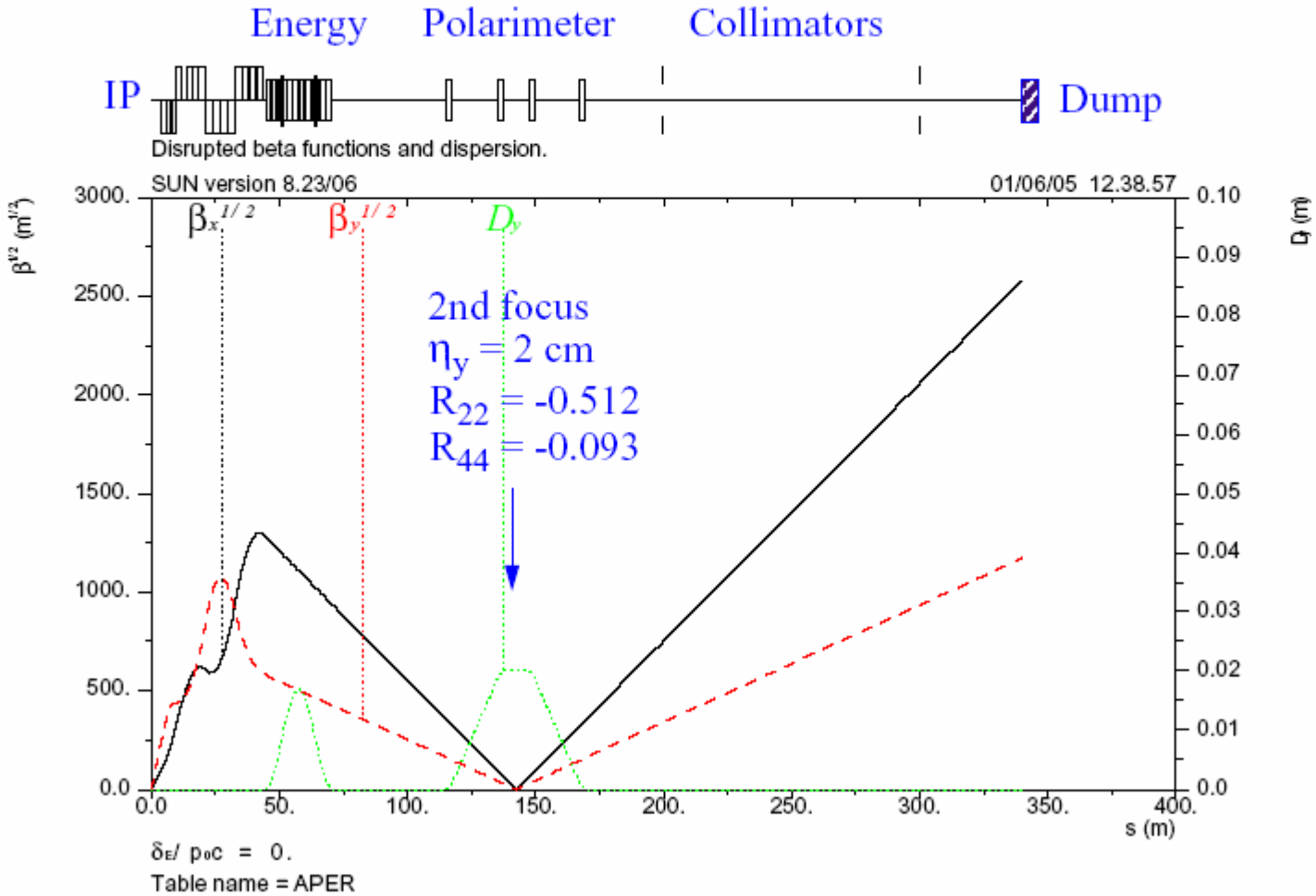
- "1. B and Machine-option dependence of RVTX, by Y.Sugimoto

- The B-dependence was shown with the 500GeV nominal parameter sets. The 500GeV high luminosity parameter set was compared with the nominal one. Also, the new high luminosity parameter sets were compared with the 1TeV high luminosity one. The radii of Be beam pipe (VTX innermost layer) vary from 12.5 (16.6) to 9.5 (13.2) mm in B=3 to 5T, respectively, with the nominal set. This radius vary from 18.5 (24.1) to 14 (18.4) mm in B=3 to 5 T, respectively, with the 500GeV high luminosity set. In the cases of 1TeV high luminosity sets, the new set of High L" can significantly reduce these radii from 20.5 (25.8) to 13.5 (17.8) mm .

- Finally, he concluded ; (1) Minimum radius of the vertex detector has been calculated based on a consideration of direct pair background hits on beam pipe (Other factors such as backscattering from BCAL should also be taken into account for the actual design); (2) RVTX has a weak B dependence of B-1/2; RVTX has a strong dependence on machine parameter set ; (3) Andrei's new parameters for High Luminosity option are very preferable from the viewpoint of background. His approach should also be applied to 500 GeV case if possible."

20mrad extraction

Beam optics



Disrupted electron and beamstrahlung loss

E_{CM}	y-offset at IP (nm)	Max. e-loss density in magnets (W/m)			Total e-loss (kW)			γ-loss in collimators (kW) (L. Keller)	
		SC quads	Warm quads	Bends	Excluding Coll. 1,2	Coll. 1	Coll. 2	Coll. 1	Coll. 2
0.5 TeV nominal	0	0	0	0	0	0	0	0	0
	200	0	0	0.13	0.003	0	0	0.15	0.05
0.5 TeV high-L	0	15 (2.1*)	60	37	1.9	47	74	2.8	0.7
	120	3.8 (0*)	95	372	11	47	95	151	10
1 TeV nominal	0	0	1.8	4.8	0.19	0.85	0	0	0
	100	0	7.1	77	2.4	4.8	0.11	0	0
1 TeV high-L (c25)	0	1106	4379	2032	98	64	44	1.5	0.2
	80	1071	5391	7362	280	129	15	69	9.5
1 TeV high-L (c26)	0	0	16	25	1.6	3.6	0.50		
	100	0	49	352	11	17	1.3		
1 TeV high-L (c27)	0	0	14	22	1.1	2.7	0.21		
	100	0	27	213	7.2	12	1.2		

* After increasing aperture in QDEX1C and QFEX2A to r = 25 and 36 mm, respectively.