A preliminary look at a Low P Parameter set for consideration in a Minimum Machine Study

Presenter

Ewan at TAGL meeting Aug 22

The RDR Parameter Plane

TABLE 2.1-2
Beam and IP Parameters for 500 GeV cms.

Parameter	Symbol/Units	Nominal	Low N	Large Y	Low P
Repetition rate	f_{rep} (Hz)	5	5	5	5
Number of particles per bunch	N (10^{10})	2	1	2	2
Number of bunches per pulse	n_b	2625	5120	2625	1320
Bunch interval in the Main Linac	t_b (ns)	369.2	189.2	369.2	480.0
in units of RF buckets		480	246	480	624
Average beam current in pulse	I_{ave} (mA)	9.0	9.0	9.0	6.8
Normalized emittance at IP	$\gamma\epsilon_x^*$ (mm·mrad)	10	10	10	10
Normalized emittance at IP	$\gamma\epsilon_y^*$ (mm·mrad)	0.04	0.03	0.08	0.036
Beta function at IP	β_x^* (mm)	20	11	11	11
Beta function at IP	β_y^* (mm)	0.4	0.2	0.6	0.2
R.m.s. beam size at IP	σ_x^* (nm)	639	474	474	474
R.m.s. beam size at IP	σ_y^* (nm)	5.7	3.5	9.9	3.8
R.m.s. bunch length	σ_z (μm)	300	200	500	200
Disruption parameter	D_x	0.17	0.11	0.52	0.21
Disruption parameter	D_y	19.4	14.6	24.9	26.1
Beamstrahlung parameter	Υ_{ave}	0.048	0.050	0.038	0.097
Energy loss by beamstrahlung	δ_{BS}	0.024	0.017	0.027	0.055
Number of beamstrahlung photons	n_γ	1.32	0.91	1.77	1.72
Luminosity enhancement factor	H_D	1.71	1.48	2.18	1.64
Geometric luminosity	$\mathcal{L}_{geo}$ $10^{34}/\mathrm{cm}^2/\mathrm{s}$	1.20	1.35	0.94	1.21
Luminosity	$\mathcal{L}$ $10^{34}/\mathrm{cm}^2/\mathrm{s}$	2	2	2	2

Revisit with Emphasis on Cost

- Low P looks interesting if one makes maximum use of lower power in beam in all systems from beginning to end.
  - **This includes installed electrical distributions, cryo-systems, RF power, Beam dumps etc etc**
    - Consider 3km DR ***or*** 6km rings with less RF & SR power?
    - Full luminosity with half the number of bunches but it stresses parameters like bunch length, beamstrahlung etc
    - Asked Andrei to revisit old ideas like “travelling focus” and to dust off old computer codes to study parameter sensitivities around this part of the parameter plane.
    - I wanted to get some confidence before proposing this as Min Machine study which would be independent, i.e. additive, to others.

Why not Low Power via Lower Bunch Current

- My assumption is that bunch trains **5120** long are probably off the real axis for any reasonable injector/damping ring complex.
- Therefore with **N=1**you start with half the geometric luminosity even using the lowest emittances and beta's used elsewhere on the plane.
- Could my assumption be wrong?

Study of Parameter Sets which are Variations on Low P Set

Q1 What are the resulting Parameter Sets with standard assumptions when each of the noted parameters listed is varied independently around the RDR low power set?

		Low P	Other possible values
Energy cms	GeV	500	500
Repetition rate		5 Hz	Fixed
Number of Particles per bunch		2x10*10	2 +/- ?
Number of bunches per pulse		1320	Fixed
Bunch interval in main linac		480 ns	?
In units of RF buckets		624	?
Average beam current in pulse		6.8 mA	Calc from above
Normalized emittance at IP	x (mm-mrad)	10	constant 10
Normalized emittance at IP	y (mm-mrad)	0.036	0.04 or 0.03
Beta function at IP	ßx (mm)	11	11 or 20?
Beta function at IP	ßy (mm)	0.2	0.2 or 0.6
R.m.s beam size at IP	σ_x (nm)	474	Calc from above
R.m.s beam size at IP	σ_y (nm)	3.8	Calc from above
R.m.s bunch length	σ_z (µm)	200	300 or 500
Disruption Parameter	D_x	0.21	Derived
Disruption Parameter	D_y	26.1	Derived
Beamstrahlung Parameter		0.097	Derived
Energy loss by beamstrahlung	δ_{BS}	0.055	Derived
Number of beamstrahlung photons	n_γ	1.72	Derived
Luminosity enhancement factor	H_D	1.64	Derived
Geometric luminosity	L_{geo} 10*34/cm²/s	1.21	Derived
Luminoity	**L** 10*34/cm²/s	2.0	Derived

Q2 What is the affect of applying "Travelling Focus" techniques in some of the parameter sets. Even if the affects are small they might be useful in decreasing the sensitivity to beam parameters.

Q3 What is the optimum bunch spacing in the linac for a fixed number of 1320 bunches with different charge perbunch

TENTATIVE

For discussion of low power ILC

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SLAC

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Cases considered

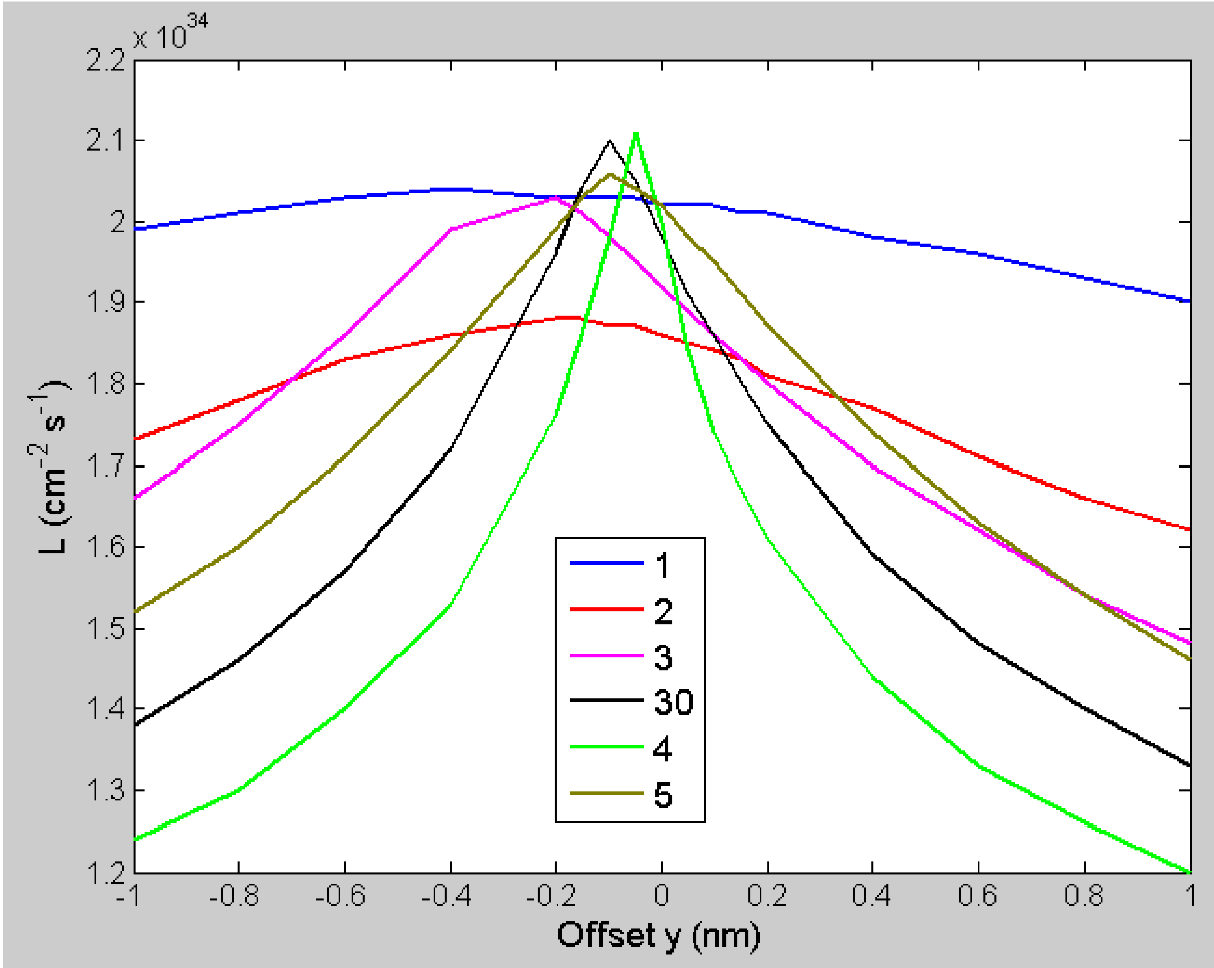
- RDR cases
  - **1: Nominal RDR**
  - **2: Low Power RDR**
- *JMP Note Consider only cases 1,2,3 for now*
- Traveling focus cases:
  - **3: similar as "2", but longer σ_z**
  - **30: similar as "3", FLAT Z distribution, lower β_y**
  - **4: even Lower P, FLAT Z, long σ_z**
  - **5: FLAT Z, not so long σ_z**
- Analytical predictions not valid – use Guinea-Pig code

Comparison of parameter sets

	Nom. RDR	Low P RDR	new Low P	new Low P	new Low P	new Low P
Case ID	**1**	**2**	**3**	**30**	**4**	**5**
E CM (GeV)	500	500	500	500	500	500
N	2.0E+10	2.0E+10	2.0E+10	2.0E+10	2.0E+10	2.0E+10
n_b	2625	1320	1320	1320	**1105**	1320
F (Hz)	5	5	5	5	5	5
P_b (MW)	**10.5**	**5.3**	**5.3**	**5.3**	**4.4**	**5.3**
$\gamma\varepsilon_X$ (m)	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05
$\gamma\varepsilon_Y$ (m)	4.0E-08	3.6E-08	3.6E-08	3.6E-08	**3.0E-08**	**3.0E-08**
βx (m)	2.0E-02	1.1E-02	1.1E-02	1.1E-02	**7.0E-03**	**1.5E-02**
βy (m)	4.0E-04	2.0E-04	2.0E-04	**1.0E-04**	**1.0E-04**	**1.0E-04**
Traveling focus	No	No	**Yes**	**Yes**	**Yes**	**Yes**
Z-distribution *	Gauss	Gauss	Gauss	**Flat**	**Flat**	**Flat**
σ_x (m)	6.39E-07	4.74E-07	4.74E-07	4.74E-07	3.78E-07	5.54E-07
σ_y (m)	5.7E-09	3.8E-09	3.8E-09	2.7E-09	2.5E-09	2.5E-09
σ_z (m)	3.0E-04	2.0E-04	**3.0E-04**	3.0E-04	**5.0E-04**	**2.0E-04**
Guinea-Pig $\delta E/E$	0.023	0.045	0.036	0.036	0.039	0.038
Guinea-Pig Lumi ($cm^{-2}s^{-1}$)	**2.02E+34**	**1.86E+34**	**1.92E+34**	**1.98E+34**	**2.00E+34**	**2.02E+34**
Guinea-Pig Lumi in 1%	1.50E+34	1.09E+34	1.18E+34	1.17E+34	1.06E+34	1.24E+34

Higher sensitivity to offset

- In traveling focus case, higher disruption is needed for the bunches to keep focusing each other
- It then produces higher sensitivity to offset of the beams
- Operation of intratrain luminosity optimization is more challenging



First look and IMHO

- Need to review assumptions and codes used in RDR tables and use same for Low P studies.

  Lumi definition, within 1%, 2% etc
- “Mild” application of ‘Traveling Focus’ optics in the BDS (Case 3) helps with bunch length and beamstrahlung. Looks encouraging!
- Should this Low P parameter region become an area for study in MM design?
- The cost reductions are not easy to estimate and involve many policy decisions on upgrade paths or staging scenarios but here is a scenario where we can have a major impact on machine design and at least on paper, start with full luminosity at full energy!