Update on Parameters

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The $p_\perp$ of an individual track cannot be determined to better than the beam divergence times $p_\parallel$

At 275 GeV

	x' μrad	$dp_\perp$ MeV/c	$dp\perp/p_\perp$ $p_\perp$=200 MeV/c %	$dp\perp/p_\perp$ $p_\perp$=1.3 GeV/c %
HL in x	131	39	20	3.0
in y	381	104	52	8.1
HA in x	51	14	7	1.1
in y	381	104	52	8.1
VHL in x	219	60	30	4.6
in y	381	104	52	8.1

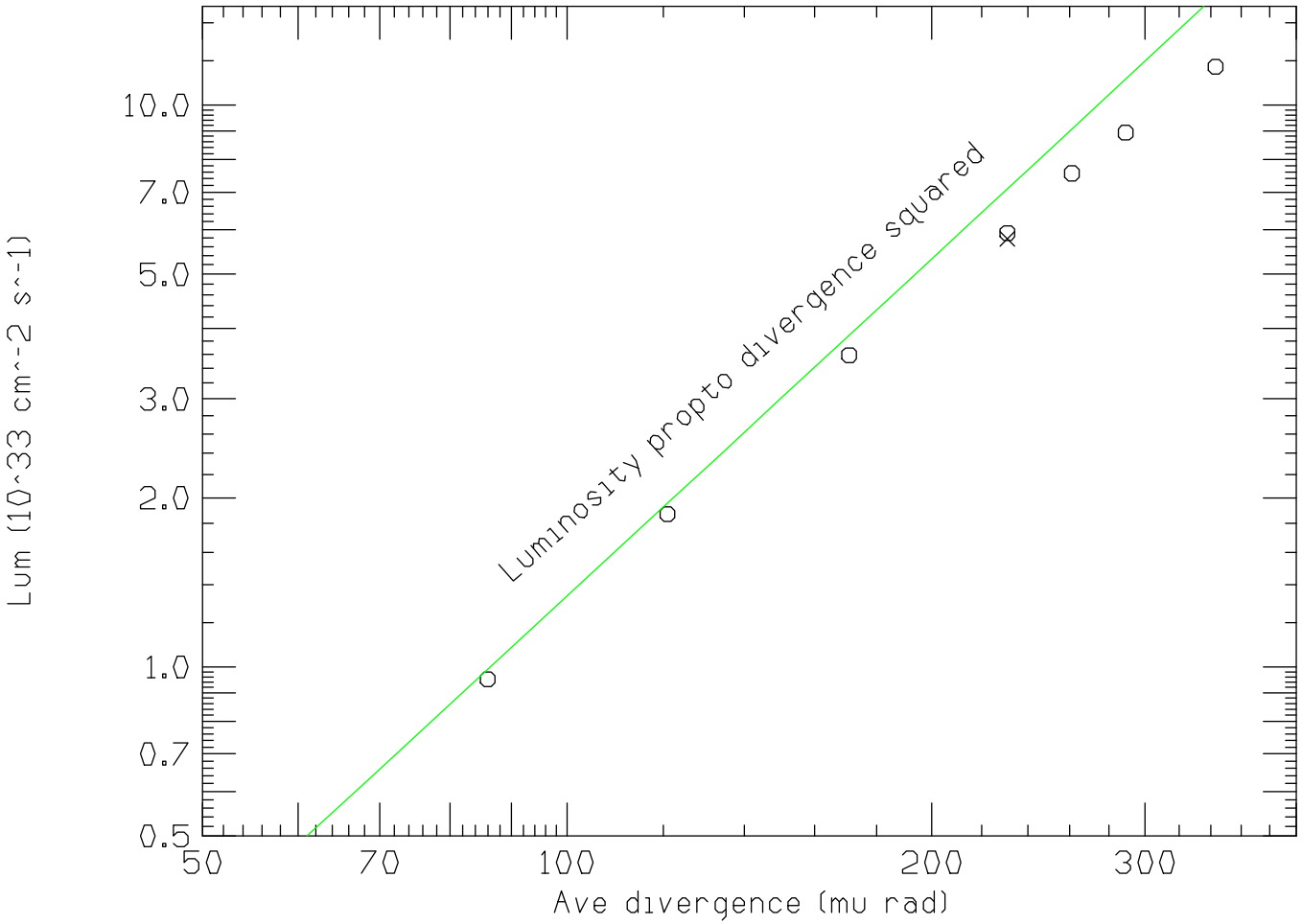
High Acceptance is no better than High Lum. Problem is in y

Even Very High Luminosity is no worse Problem still in y

Discussion

1. Without Roman pots at high dispersion, divergences in x were constrained to be less than 0.2 GeV/c over $p_{\|}$. Other divergences could be larger, leading to the "High Acceptance" parameters with $x'_p \approx 56$ μm, but $y'_p \approx 400$ μm.
2. With high dispersion Roman pots, this x divergence constraint is removed.
3. When Kinematic fitting constrains the initial proton transverse momenta from measurements of all outgoing particles, as appears the case in our diffractive e p scattering, it removes the restriction on divergences, leading to the "Very High Luminosity" (or "High Divergence") parameters.
4. For other physics, this may not be possible, yet the need to know the initial p direction may still be required. For such cases, all divergences should be minimized leading to "Low Divergence", or "Medium Divergence" parameters, such as those obtained by scaling (multiplying all β^*s by the same factor) from the "High Divergence" solution, accepting that the resulting luminosities will be less.

Luminosities vs. divergence



Lum vs. average divergences plotted for 660 bunches

Lum $\propto$ Divergence^2, but rolls off at smaller βs from hourglass

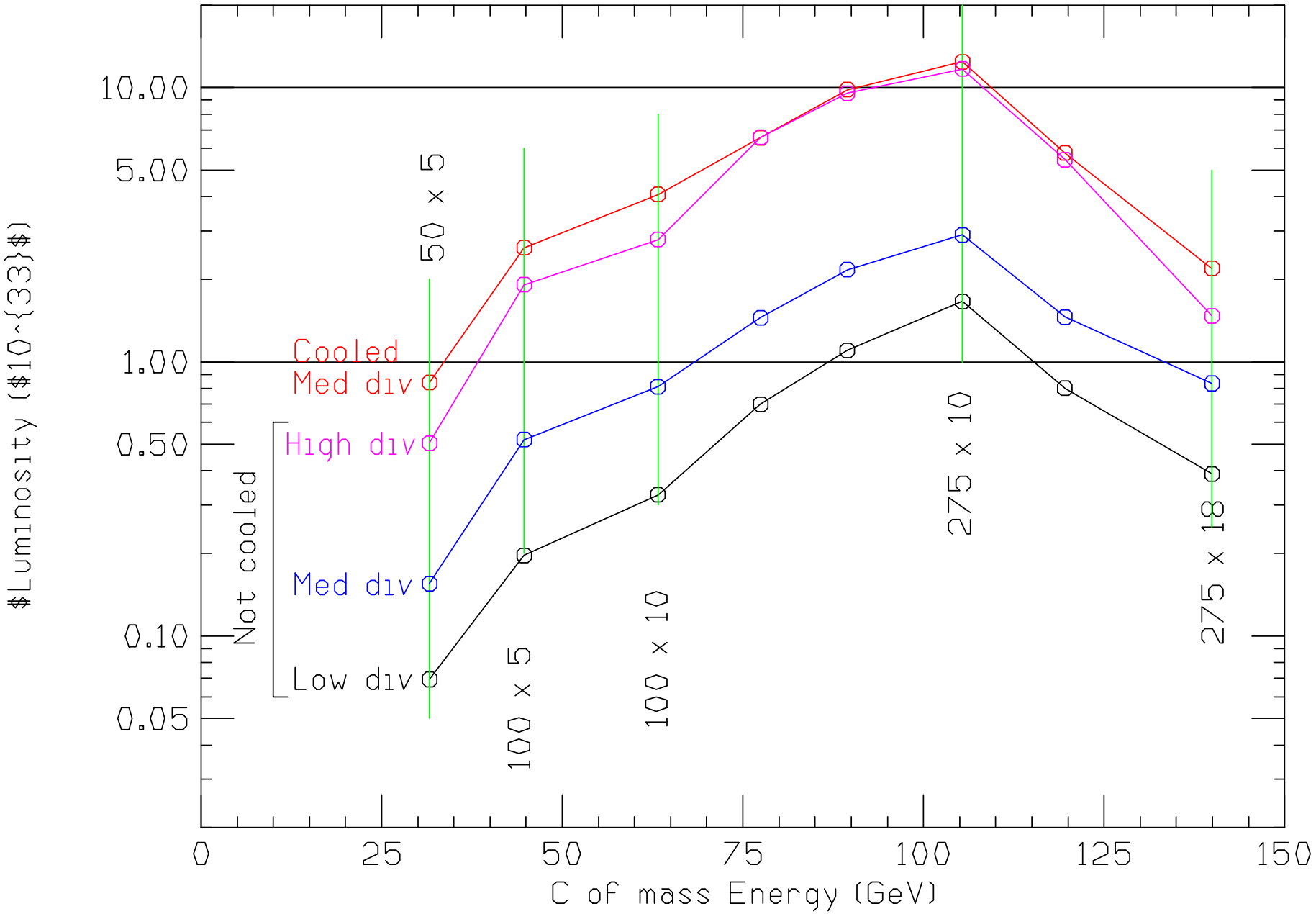
Low divergences available but at steep price in Luminosity

Lower Divergence Cases

	Ave μrad	x'_p μrad	y'_p μrad	x'_e μrad	y'_e μrad	Lum$_{330}$ 10^{33}	Lum$_{660}$ 10^{33}
Old HL	231	131	381	197	217	2.89	5.78
1 High Divergence(VHL)	344	219	381	393	382	5.8	11.7
2 Med Divergence	231	147	257	265	258	3.08	6.16
3 Low Divergence	130	83	144	148	144	1.08	2.17
4 Very Low Divergence	91	58	102	105	102	.53	1.07

- The old High Luminosity parameters had a moderate x divergence (131 μrad), but large (381 μrad) y divergence
- Scaling all βs from the Very High Luminosity case we get:
  1. With the same average divergence as HL, the "Med." case has a similar luminosity and maximum divergence of 265 μrad
  2. The Low divergence case has maximum divergence of 148
  3. And the Very Low divergence has a maximum of 105

Luminosities vs. Energy



Some Other Parameters

	Lum 10^{33}	min ϵ_N μm	n_{bunch}	crab V MV	rf f MHz	max rf V MV	min τ_{IBS} hr.	max $Q_{100\ m}$ nC	min $\epsilon_{\|}$ evsec
Very Low	0.54	1.8	330	6	394	20	7		0.8
Low Div.	1.06	1.8	330	9	394	20	7		0.8
Med Div.	3.08	1.8	330	12.5	394	20	7.6		0.8
High Div.	11.7	1.8	660	23	394	20	7.6		0.8
Med+Cooling	12.4	0.5	1320	15	788	20	0.9	60	0.22

Appendix

Initial (HL)

(par14g)

		E GeV	N 10^{10}	Nb	$\epsilon_x(\epsilon_{Nx})$ nm(μm)	$\epsilon_y(\epsilon_{Ny})$ nm(μm)	β_x cm	β_y cm	σ_x μm	σ_y μm	σ'_x μrad	σ'_y μrad	ξ_x	ξ_y	ΔQ	σ_s cm	I A	SR MW	HG %	lum 10^{33}
1	com	31.6																		
	p	50	9.7	330	86.8(4.6)	33.8(1.8)	130.0	22.0	336	86.2	258	392	.013	.009	.020	17.8	0.40		73	0.16
	e	5.0	31.1	330	37.5(367)	9.20(90)	301.0	80.9	336	86.3	112	107	.094	.099	.000	1.0	1.28	0.3		
2	com	44.7																		
	p	100	9.7	330	43.4(4.6)	16.9(1.8)	101.1	10.6	209	42.3	207	399	.014	.007	.007	13.2	0.40		74	0.52
	e	5.0	31.1	330	37.5(367)	7.58(74)	117.5	23.9	210	42.6	179	178	.099	.099	.000	1.0	1.28	0.3		
3	com	63.2																		
	p	100	15.0	330	43.4(4.6)	16.9(1.8)	100.0	10.6	208	42.3	208	399	.014	.007	.010	13.2	0.62		74	0.81
	e	10.0	31.1	330	37.5(734)	5.97(117)	115.0	30.0	208	42.3	181	141	.076	.097	.000	1.0	1.28	4.9		
6	com	105.4																		
	p	275	11.1	330	16.1(4.7)	6.1(1.8)	94.4	4.2	123	16.1	131	382	.014	.005	.002	7.0	0.46		82	2.89
	e	10.1	30.5	330	24.2(478)	3.47(69)	62.5	7.4	123	16.0	197	217	.092	.084	.000	1.0	1.26	5.0		
8	com	139.9																		
	p	275	15.0	330	17.4(5.1)	6.1(1.8)	83.0	4.2	120	16.1	145	382	.003	.001	.003	7.0	0.62		83	0.83
	e	17.8	6.3	330	23.7(826)	3.33(116)	61.0	7.7	120	16.0	197	208	.072	.068	.000	1.0	0.26	10.0		

	γ	N_b	freq MHz	Volts MV	ϵ_{xN} μm	ϵ_{yN} μm	σ_z cm	dp/p 10^{-4}	evsec eV sec	N_p 10^{11}	$\tau_\parallel$ hr.	$\tau_\perp$ hr.	Q_{100m} nC	β^4_{crab} m	f_{crab} MHz	V^5_{crab} MV	HG %	Lum 10^{33}	eff %	lum*eff 10^{33}
1	53	330	394	2.11	4.63	1.80	17.8	14.00	0.80	1.0	15.7	20.4	3.6[1]	288	336	4.04	73	0.16	68[4]	0.11
2	107	330	394	4.18	4.63	1.80	13.2	9.50	0.80	1.0	12.2	17.0	20[2]	576	336	6.48	74	0.52	65[4]	0.34
3	107	330	394	4.18	4.63	1.80	13.2	9.50	0.80	1.5	7.9	11.0	30[2]	576	336	6.51	74	0.81	59[4]	0.48
6	293	330	394	19.86	4.72	1.80	7.0	6.50	0.80	1.1	9.9	10.5	166[3]	1553	336	11.23	82	2.89	60	1.73
8	293	330	394	19.86	5.10	1.80	7.0	6.50	0.80	1.5	7.6	8.5	237[3]	1437	336	12.45	83	0.83	56	0.47

New Med Divergence

Replacing HL

(par14h2)

		E	N	Nb	$\epsilon_x(\epsilon_{Nx})$	$\epsilon_y(\epsilon_{Ny})$	β_x	β_y	σ_x	σ_y	σ'_x	σ'_y	ξ_x	ξ_y	ΔQ	σ_s	I	SR	HG	lum
		GeV	10^{10}		nm(μm)	nm(μm)	cm	cm	μm	μm	μrad	μrad				cm	A	MW	%	10^{33}
1	com	31.6																		
	p	50	15.0	330	86.8(4.6)	33.8(1.8)	228.8	48.4	446	127.9	195	264	.013	.009	.031	18.0	0.62		75	0.13
	e	5.0	31.1	330	56.2(550)	17.83(174)	353.2	91.9	446	128.0	126	139	.095	.086	.000	1.0	1.28	0.3		
2	com	44.7																		
	p	100	15.0	330	43.4(4.6)	16.9(1.8)	129.7	23.3	237	62.8	183	269	.013	.009	.011	13.0	0.62		76	0.49
	e	5.0	31.1	330	60.0(587)	14.69(144)	94.2	27.1	238	63.1	252	233	.091	.098	.000	1.0	1.28	0.3		
3	com	63.2																		
	p	100	15.0	330	36.2(3.9)	16.9(1.8)	65.2	23.3	154	62.8	236	269	.014	.012	.011	13.0	0.62		72	0.71
	e	10.0	31.1	330	27.8(544)	11.57(226)	84.3	34.1	153	62.8	181	184	.088	.086	.000	1.0	1.28	4.9		
6	com	105.4																		
	p	275	15.0	330	15.9(4.7)	6.1(1.8)	73.3	9.2	108	23.7	147	257	.013	.007	.003	7.0	0.62		86	3.08
	e	10.1	29.9	330	28.6(565)	6.13(121)	40.8	9.2	108	23.8	265	258	.098	.100	.000	1.0	1.23	4.9		
8	com	139.9																		
	p	275	15.0	330	17.4(5.1)	6.1(1.8)	45.6	9.2	89	23.7	195	257	.001	.001	.003	7.0	0.62		84	0.39
	e	17.8	3.2	330	23.7(826)	6.18(215)	33.5	9.1	89	23.8	266	260	.064	.066	.000	1.0	0.13	5.0		

	γ	N_b	freq	Volts	ϵ_{xN}	ϵ_{yN}	σ_z	dp/p	evsec	N_p	$\tau_\parallel$	$\tau_\perp$	Q_{100m}	β^4_{crab}	f_{crab}	V^5_{crab}	HG	Lum	eff	lum*eff
			MHz	MV	μm	μm	cm	10^{-4}	eV sec	10^{11}	hr.	hr.	nC	m	MHz	MV	%	10^{33}	%	10^{33}
1	53	330	394	2.05	4.63	1.80	18.0	14.00	0.81	1.5	10.3	13.4	5.6[1]	288	336	3.04	75	0.13	62[4]	0.08
2	107	330	394	4.28	4.63	1.80	13.0	9.50	0.79	1.5	7.8	10.9	30[2]	576	336	5.72	76	0.49	59[4]	0.29
3	107	330	394	4.28	3.85	1.80	13.0	9.50	0.79	1.5	7.0	8.9	27[2]	691	336	7.36	72	0.71	56[4]	0.40
6	293	330	394	19.86	4.67	1.79	7.0	6.50	0.80	1.5	7.2	7.7	222[3]	1568	336	12.67	86	3.08	55	1.69
8	293	330	394	19.86	5.10	1.79	7.0	6.50	0.80	1.5	7.6	8.4	236[3]	1437	336	16.78	84	0.39	56	0.22

New Low Divergence

par14h3)

		E GeV	N 10^{10}	Nb	$\epsilon_x(\epsilon_{Nx})$ nm(μm)	$\epsilon_y(\epsilon_{Ny})$ nm(μm)	β_x cm	β_y cm	σ_x μm	σ_y μm	σ'_x μrad	σ'_y μrad	ξ_x	ξ_y	ΔQ	σ_s cm	I A	SR MW	HG %	lum 10^{33}
1	com	31.6																		
	p	50	15.0	330	86.8(4.6)	33.8(1.8)	728.0	154.0	795	228.1	109	148	.013	.009	.031	18.0	0.62		84	0.04
	e	5.0	31.1	330	56.2(550)	17.83(174)	1123.7	292.3	795	228.3	71	78	.095	.086	.000	1.0	1.28	0.3		
2	com	44.7																		
	p	100	15.0	330	43.4(4.6)	16.9(1.8)	412.8	74.2	423	112.0	103	151	.013	.009	.011	13.0	0.62		85	0.17
	e	5.0	31.1	330	60.0(587)	14.69(144)	299.9	86.3	424	112.6	141	130	.091	.098	.000	1.0	1.28	0.3		
3	com	63.2																		
	p	100	15.0	330	36.2(3.9)	16.9(1.8)	207.4	74.2	274	112.0	132	151	.014	.012	.011	13.0	0.62		81	0.25
	e	10.0	31.1	330	27.8(544)	11.57(226)	268.3	108.4	273	112.0	102	103	.088	.086	.000	1.0	1.28	4.9		
6	com	105.4																		
	p	275	15.0	330	15.9(4.7)	6.1(1.8)	233.4	29.4	193	42.3	83	144	.013	.007	.003	7.0	0.62		94	1.06
	e	10.1	29.9	330	28.6(565)	6.13(121)	129.7	29.4	193	42.4	148	144	.098	.100	.000	1.0	1.23	4.9		
8	com	139.9																		
	p	275	15.0	330	17.4(5.1)	6.1(1.8)	145.3	29.4	159	42.3	109	144	.001	.001	.003	7.0	0.62		93	0.13
	e	17.8	3.2	330	23.7(826)	6.18(215)	106.8	29.1	159	42.4	149	146	.064	.066	.000	1.0	0.13	5.0		

	γ	N_b	freq MHz	Volts MV	ϵ_{xN} μm	ϵ_{yN} μm	σ_z cm	dp/p 10^{-4}	evsec eV sec	N_p 10^{11}	$\tau_\parallel$ hr.	$\tau_\perp$ hr.	Q_{100m} nC	β^4_{crab} m	f_{crab} MHz	V^5_{crab} MV	HG %	Lum 10^{33}	eff %	lum*eff 10^{33}
1	53	330	394	2.05	4.63	1.80	18.0	14.00	0.81	1.5	10.3	13.4	5.6^1	288	336	1.71	84	0.04	62^4	0.03
2	107	330	394	4.28	4.63	1.80	13.0	9.50	0.79	1.5	7.8	10.9	30^2	576	336	3.21	85	0.17	59^4	0.10
3	107	330	394	4.28	3.85	1.80	13.0	9.50	0.79	1.5	7.0	8.9	27^2	691	336	4.13	81	0.25	56^4	0.14
6	293	330	394	19.86	4.67	1.79	7.0	6.50	0.80	1.5	7.2	7.7	222^3	1568	336	7.11	94	1.06	55	0.58
8	293	330	394	19.86	5.10	1.79	7.0	6.50	0.80	1.5	7.6	8.4	236^3	1437	336	9.41	93	0.13	56	0.08

New Very Low Divergence

par14h4)

		E GeV	N 10^{10}	Nb	$\epsilon_x(\epsilon_{Nx})$ nm(μm)	$\epsilon_y(\epsilon_{Ny})$ nm(μm)	β_x cm	β_y cm	σ_x μm	σ_y μm	σ'_x μrad	σ'_y μrad	ξ_x	ξ_y	ΔQ	σ_s cm	I A	SR MW	HG %	lum 10^{33}
1	com	31.6																		
	p	50	15.0	330	86.8(4.6)	33.8(1.8)	1456	308.0	1124	322.7	77	105	.013	.009	.031	18.0	0.62		89	0.02
	e	5.0	31.1	330	56.2(550)	17.83(174)	2247	584.5	1124	322.8	50	55	.095	.086	.000	1.0	1.28	0.3		
2	com	44.7																		
	p	100	15.0	330	43.4(4.6)	16.9(1.8)	825.7	148.4	599	158.4	73	107	.013	.009	.011	13.0	0.62		89	0.09
	e	5.0	31.1	330	60.0(587)	14.69(144)	599.7	172.6	600	159.3	100	92	.091	.098	.000	1.0	1.28	0.3		
3	com	63.2																		
	p	100	15.0	330	36.2(3.9)	16.9(1.8)	414.8	148.4	387	158.4	93	107	.014	.012	.011	13.0	0.62		86	0.13
	e	10.0	31.1	330	27.8(544)	11.57(226)	536.7	216.7	386	158.3	72	73	.088	.086	.000	1.0	1.28	4.9		
6	com	105.4																		
	p	275	15.0	330	15.9(4.7)	6.1(1.8)	466.8	58.8	273	59.9	58	102	.013	.007	.003	7.0	0.62		96	0.54
	e	10.1	29.9	330	28.6(565)	6.13(121)	259.4	58.8	272	60.0	105	102	.098	.100	.000	1.0	1.23	4.9		
8	com	139.9																		
	p	275	15.0	330	17.4(5.1)	6.1(1.8)	290.5	58.8	225	59.9	77	102	.001	.001	.003	7.0	0.62		96	0.07
	e	17.8	3.2	330	23.7(826)	6.18(215)	213.5	58.1	225	59.9	105	103	.064	.066	.000	1.0	0.13	5.0		

	γ	N_b	freq MHz	Volts MV	ϵ_{xN} μm	ϵ_{yN} μm	σ_z cm	dp/p 10^{-4}	evsec eV sec	N_p 10^{11}	$\tau_\parallel$ hr.	$\tau_\perp$ hr.	Q_{100m} nC	β^4_{crab} m	f_{crab} MHz	V^5_{crab} MV	HG %	Lum 10^{33}	eff %	lum*eff 10^{33}
1	53	330	394	2.05	4.63	1.80	18.0	14.00	0.81	1.5	10.3	13.4	5.6^1	288	336	1.21	89	0.02	62^4	0.01
2	107	330	394	4.28	4.63	1.80	13.0	9.50	0.79	1.5	7.8	10.9	30^2	576	336	2.27	89	0.09	59^4	0.05
3	107	330	394	4.28	3.85	1.80	13.0	9.50	0.79	1.5	7.0	8.9	27^2	691	336	2.92	86	0.13	56^4	0.08
6	293	330	394	19.86	4.67	1.79	7.0	6.50	0.80	1.5	7.2	7.7	222^3	1568	336	5.02	96	0.54	55	0.30
8	293	330	394	19.86	5.10	1.79	7.0	6.50	0.80	1.5	7.6	8.4	236^3	1437	336	6.65	96	0.07	56	0.04

High Divergence (VHL)

Upgrade without cooling

(par14h1)

		E	N	Nb	$\epsilon_x(\epsilon_{Nx})$	$\epsilon_y(\epsilon_{Ny})$	β_x	β_y	σ_x	σ_y	σ'_x	σ'_y	ξ_x	ξ_y	ΔQ	σ_s	I	SR	HG	lum
		GeV	10^{10}		nm(μm)	nm(μm)	cm	cm	μm	μm	μrad	μrad				cm	A	MW	%	10^{33}
1	com	31.6																		
	p	50	15.0	660	86.8(4.6)	33.8(1.8)	104.0	22.0	300	86.2	289	392	.013	.009	.031	18.0	1.24		68	0.51
	e	5.0	31.1	660	56.2(550)	17.83(174)	160.5	41.8	300	86.3	187	207	.095	.086	.000	1.0	2.57	0.6		
2	com	44.7																		
	p	100	15.0	660	43.4(4.6)	16.9(1.8)	59.0	10.6	160	42.3	271	399	.013	.009	.011	13.0	1.24		67	1.91
	e	5.0	31.1	660	60.0(587)	14.69(144)	42.8	12.3	160	42.6	374	345	.091	.098	.000	1.0	2.57	0.6		
3	com	63.2																		
	p	100	15.0	660	36.2(3.9)	16.9(1.8)	29.6	10.6	104	42.3	349	399	.014	.012	.011	13.0	1.24		64	2.79
	e	10.0	31.1	660	27.8(544)	11.57(226)	38.3	15.5	103	42.3	269	273	.088	.086	.000	1.0	2.57	9.8		
6	com	105.4																		
	p	275	15.0	660	15.9(4.7)	6.1(1.8)	33.3	4.2	73	16.0	219	381	.013	.007	.003	7.0	1.24		74	11.70
	e	10.1	29.9	660	28.6(565)	6.13(121)	18.5	4.2	73	16.0	393	382	.098	.100	.000	1.0	2.47	9.8		
8	com	139.9																		
	p	275	15.0	660	17.4(5.1)	6.1(1.8)	20.8	4.2	60	16.0	290	381	.001	.001	.003	7.0	1.24		73	1.47
	e	17.8	3.2	660	23.7(826)	6.18(215)	15.3	4.2	60	16.0	394	386	.064	.066	.000	1.0	0.26	10.0		

	γ	N_b	freq	Volts	ϵ_{xN}	ϵ_{yN}	σ_z	dp/p	evsec	N_p	$\tau_\parallel$	$\tau_\perp$	Q_{100m}	β^4_{crab}	f_{crab}	V^5_{crab}	HG	Lum	eff	lum*eff
			MHz	MV	μm	μm	cm	10^{-4}	eV sec	10^{11}	hr.	hr.	nC	m	MHz	MV	%	10^{33}	%	10^{33}
1	53	660	394	2.05	4.63	1.80	18.0	14.00	0.81	1.5	10.3	13.4	5.6[1]	288	336	4.52	68	0.51	62[4]	0.31
2	107	660	394	4.28	4.63	1.80	13.0	9.50	0.79	1.5	7.8	10.9	30[2]	576	336	8.48	67	1.91	59[4]	1.12
3	107	660	394	4.28	3.85	1.80	13.0	9.50	0.79	1.5	7.0	8.9	27[2]	691	336	10.92	64	2.79	56[4]	1.57
6	293	660	394	19.86	4.67	1.79	7.0	6.50	0.80	1.5	7.2	7.7	222[3]	1568	336	18.80	74	11.70	55	6.43
8	293	660	394	19.86	5.10	1.79	7.0	6.50	0.80	1.5	7.6	8.4	236[3]	1437	336	24.90	73	1.47	56	0.83

Upgrade with Cooling

(par14gd)

		E	N	Nb	$\epsilon_x(\epsilon_{Nx})$	$\epsilon_y(\epsilon_{Ny})$	β_x	β_y	σ_x	σ_y	σ'_x	σ'_y	ξ_x	ξ_y	ΔQ	σ_s	I	SR	HG	lum
		GeV	10^{10}		nm(μm)	nm(μm)	cm	cm	μm	μm	μrad	μrad				cm	A	MW	%	10^{33}
1	com	31.6																		
	p	50	4.8	1320	43.4(2.3)	16.9(0.9)	65.0	11.0	168	43.1	258	392	.013	.009	.071	5.0	0.80		98	0.84
	e	5.0	15.6	1320	37.5(367)	4.60(45)	75.3	40.5	168	43.1	223	107	.047	.099	.000	1.0	2.57	0.6		
2	com	44.7																		
	p	100	4.8	1320	21.7(2.3)	8.4(0.9)	50.6	5.3	105	21.2	207	399	.014	.007	.018	5.0	0.80		93	2.60
	e	5.0	15.6	1320	37.5(367)	3.79(37)	29.4	11.9	105	21.3	357	178	.049	.099	.000	1.0	2.57	0.6		
3	com	63.2																		
	p	100	7.5	1320	21.7(2.3)	8.4(0.9)	50.0	5.3	104	21.2	208	399	.014	.007	.027	5.0	1.24		94	4.08
	e	10.0	15.6	1320	37.5(734)	2.98(58)	28.8	15.0	104	21.2	361	141	.038	.097	.000	1.0	2.57	9.8		
6	com	105.4																		
	p	275	5.6	1320	7.6(2.2)	2.4(0.7)	47.2	2.1	60	7.2	127	341	.015	.005	.003	5.0	0.92		78	12.42
	e	10.1	15.1	1320	23.0(454)	1.39(27)	15.6	3.7	60	7.2	384	194	.049	.097	.000	1.0	2.49	9.9		
8	com	139.9																		
	p	275	6.2	1320	5.0(1.5)	1.7(0.5)	41.5	2.1	46	6.0	110	285	.002	.001	.005	5.0	1.02		76	2.24
	e	17.8	1.6	1320	16.0(558)	0.93(32)	13.0	3.8	46	6.0	352	156	.044	.099	.000	1.0	0.26	10.0		

	γ	N_b	freq	Volts	ϵ_{xN}	ϵ_{yN}	σ_z	dp/p	evsec	N_p	$\tau_\parallel$	$\tau_\perp$	Q_{100m}	β^4_{crab}	f_{crab}	V^5_{crab}	HG	Lum	eff	lum*eff
			MHz	MV	μm	μm	cm	10^{-4}	eV sec	10^{11}	hr.	hr.	nC	m	MHz	MV	%	10^{33}	%	10^{33}
1	53	1320	788	13.31	2.31	0.90	5.0	14.00	0.22	0.5	4.0	2.5	1.1[1]	576	336	4.04	98	0.84	38	0.32
2	107	1320	788	14.47	2.31	0.90	5.0	9.50	0.30	0.5	4.2	2.8	5.7[1]	1152	336	6.48	93	2.60	40	1.04
3	107	1320	788	14.47	2.31	0.90	5.0	9.50	0.30	0.8	2.7	1.8	8.9[1]	1152	336	6.51	94	4.08	32	1.31
6	293	1320	788	19.46	2.24	0.72	5.0	6.50	0.57	0.6	5.4	2.4	61[2]	2000	336	13.99	78	12.42	39	4.85
8	293	1320	788	19.46	1.47	0.50	5.0	6.50	0.57	0.6	3.1	0.9	60[2]	2000	336	14.92	76	2.24	22	0.50

Note 1: Non magnetic cooling possible with ≈1/3 charge

Note 2: Magnetic cooling possible

Note 3: Only Coherent Electron Cooling possible

Note 4: β_{crab} is maximum value for 10 σ_{crab}= 5 cm

Note 5: V_{crab} is minimum for maximum β_{crab}