CESR Charm

CESR will be modified to provide high luminosity colliding beams over the (beam) energy range from 1.5 to 5.6 GeV/c in order to maximize the contribution of CLEO-III and CESR to HEP.

Foundations of the project:

- ***April, 2000*** *Assessment of energy dependence of critical parameters*
- ***Oct., 2000*** *Formation of CESR Charm working group*
- ***Jan., 2001*** *Formation of wiggler prototype task force*

Energies (E_{beam}) of interest :

J/ψ :	***1.55 GeV***
Charm threshold (ψ'') :	***1.885 GeV***
Above D_S-D_s threshold:	***2.1-2.5 GeV***
Υ states:	***4.7-5.6 GeV***

CESR-C Accelerator Physics Issues

Performance Factors:

- *Radiation damping time*
- *Beam emittance*
- *Beam-beam space charge limits (ξ)*
- *Parasitic crossings*
- *Solenoid compensation*
- *Experiment background*
- *Magnet non-linearities*
- *Wiggler non-linearities*
- *Touschek scattering*
- *Elastic scattering – residual gas*
- *Vacuum pumping (DIP's)*
- *Coupled bunch instabilities*
- *Bunch lengthening*
- *Injection*
- *Injector*

Restoration of damping (0.5 sec $\rightarrow$ 0.05 sec) and emittance are primary accelerator physics issues with low energy.

Wiggler radiation dominated storage ring scaling

1. Scaling with wiggler field and length

Damping time: $t \propto \dfrac{1}{L_W B_W^2}$

Horizontal Emittance: $e_X \propto B_W \, \mathrm{H}_W$

Energy spread: $\dfrac{s_E}{E_0} \propto B_W$

2. Scaling with energy

Damping time: $t \propto g^{-1}$

Synchrotron radiation power: $P_R \propto g^2$

Horizontal Emittance: $e_X \propto g \, \mathrm{H}_W$

Horizontal B-B parameter: $x_X \propto \dfrac{n_b}{g e_X} \propto \dfrac{n_b}{g^2}$

Energy spread: $\dfrac{s_E}{E_0} \propto \sqrt{g}$

Beam-beam limits: $x \propto g^{??}$

Comparison of beam parameters at 5.3 and 1.5<Eo<2.5 GeV

	HEP 12/93	HEP 11/00	Charm 1	Psi	Charm Ds
Lattice	I9818A800 .GE7_4S	L9A18A000.SH ORTER_SOL	BMAD_TILT_P M_NOSYM.	BMAD_TILT_P M_NOSYM.	BMAD_TILT_P M_NOSYM.
E[GeV]	**5.30**	**5.30**	1.89	1.55	2.50
Luminosity [10^33/cm^2/sec]	**0.25**	**1.10**	**0.30**	**0.15**	**0.50**
Xi/beta* (1+r) [/m]	2.25	3.08	4.04	3.53	4.04
nb (number of bunches)	**7**	**36**	**45**	**45**	**45**
r (aspect ratio)	0.014	0.009	0.010	0.009	0.010
N[x10^11] (e/bunch)	2.21	1.38	0.65	0.45	0.81
I (mA/bunch)	13.86	8.66	4.06	2.82	5.10
Itot [Amps] (current in one beam)	0.10	0.31	0.18	0.13	0.23
Xiv (vert. tune shift parameter)	**0.04**	**0.055**	**0.040**	**0.035**	**0.040**
Xih (horiz. tune shift parameter)	0.0304	0.0281	0.0355	0.0284	0.0337
2*pi*R [m](circumference)	**768.43**	**768.43**	**768.43**	**768.43**	**768.43**
rho(arc)[m]	**87.89**	**87.89**	**87.89**	**87.89**	**87.89**
rho(hb)[m]	**31.65**	**31.65**	**31.65**	**31.65**	**31.65**
I2 (sum l/rho^2) (w/ wigglers)	**0.1078**	**0.1072**	0.9841	1.4095	0.4309
I3 (sum l/rho^3)	**0.0027**	**0.0025**	0.2476	0.4439	0.0550
sigma*h[mm]	0.56	0.46	0.44	0.45	0.44
sigma*v[µm]	7.61	4.22	4.45	4.19	4.22
beta*h[m]	**1.00**	**1.00**	**0.87**	**0.87**	**0.87**
beta*v[cm]	**1.80**	**1.80**	**1.00**	**1.00**	**1.00**
theta(c) [mr] (crossing half-angle)	**0.00**	**2.30**	**3.50**	**3.50**	**3.50**
sig(l)[cm](bunch length)	**2.20**	**1.80**	1.00	0.97	1.00
e(h)[x10^-7m](emittance)	**3.10**	**2.10**	2.19	2.31	2.19
emittance coupling (?)	0.0104	0.0047	0.0091	0.0076	0.0081
alpha(p)[10^-2] (mom. comp.)	**1.54**	**1.15**	1.11	1.11	1.11
D*h[m] (dispersion at ip)	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Qs (synchrotron tune)	0.061	0.054	0.110	0.105	0.104
Qh (betatron tune)	**8.57**	**10.53**	**10.52**	**10.52**	**10.52**
sigE/E[10^-4] (energy spread)	7.13	6.96	8.11	7.46	7.66
tau e [ms](energy damping time)	11.35	11.41	27.63	34.69	27.04
tau x,y[ms] (betatron damping time)	22.69	22.82	55.25	69.38	54.09
Uo[MeV] (s.r. loss/turn)	1.20	1.19	0.18	0.11	0.24
Psr [MW] (per beam)	0.12	0.37	0.03	0.01	0.05
Vc[MV](accel cavity voltage)	6.28	6.68	10.00	7.50	12.01
k[V/pc] (loss parameter)	**9.03**	**8.00**	**8.00**	**8.00**	**8.00**
Phom[kW](per beam)	30.86	54.92	15.04	7.28	23.78
Pbeam [MW] (both beams)	0.29	0.85	0.09	0.04	0.16
Pfield [kW] (per 5 cell n.c. structure)	68.40	0.03	0.07	0.04	0.05
Ptot [MW] (both beams + n.c. struct.)	0.57	0.85	0.09	0.04	0.16
nc(number of cells/ring)	**20.00**	**4.00**	**4.00**	**4.00**	**6.00**
Nk(number of 0.6 MW klystrons)	1.00	2.00	1.00	1.00	1.00
Prf[MW] (available rf power)	0.60	1.20	0.60	0.60	0.60
lambda rf[cm](rf wavelength)	**60.00**	**60.00**	**60.00**	**60.00**	**60.00**
Wiggler peak field [T]			2.10	2.10	1.60
Wiggler length total [m]			18.20	18.20	20.80

Wiggler Design

We have examined available magnet technologies –

- **Normal conducting copper/iron**

  Similar sized magnets require ~ 300 kW/wiggler

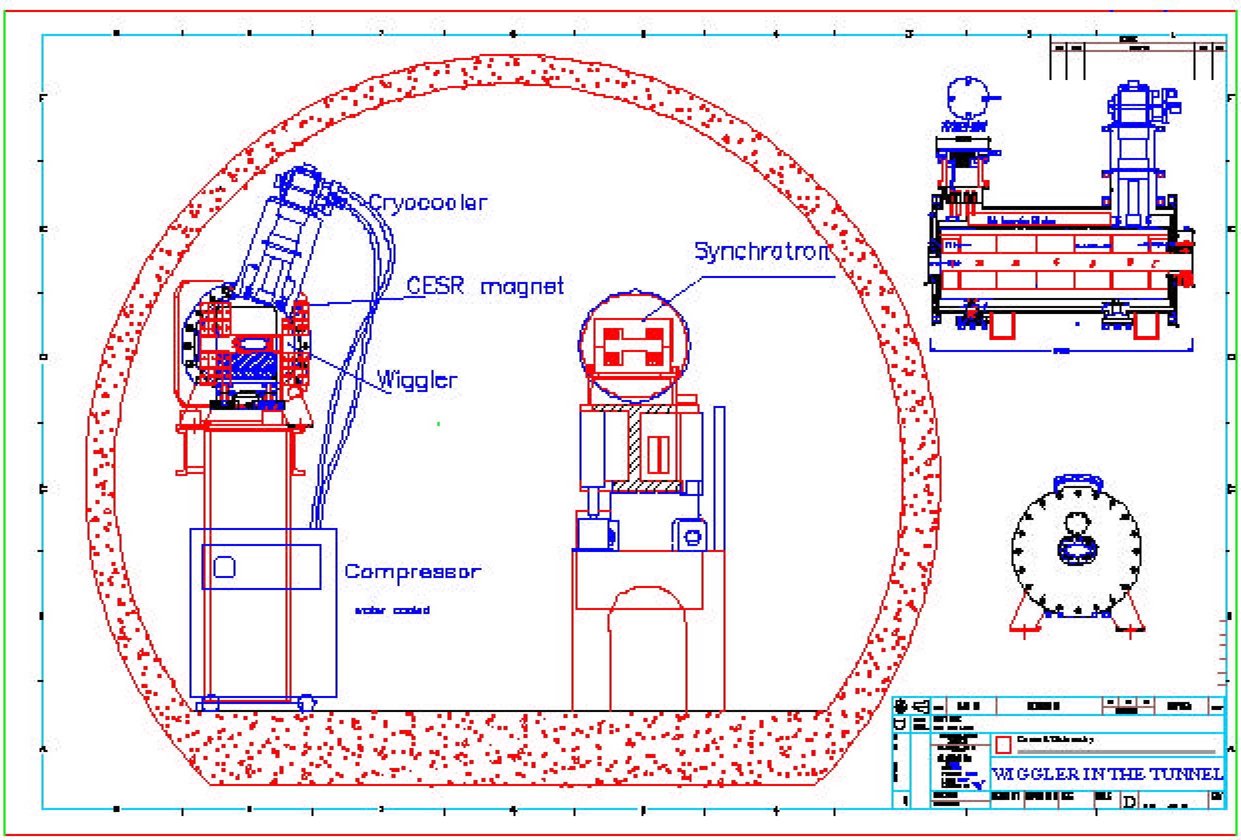
- **Permanent magnet (NdFeB)**

  Fields limited to 1.2-1.3 T in 5 cm gap

- **Superconducting technology only option for high (2T) fields over 5 cm beam aperture.**

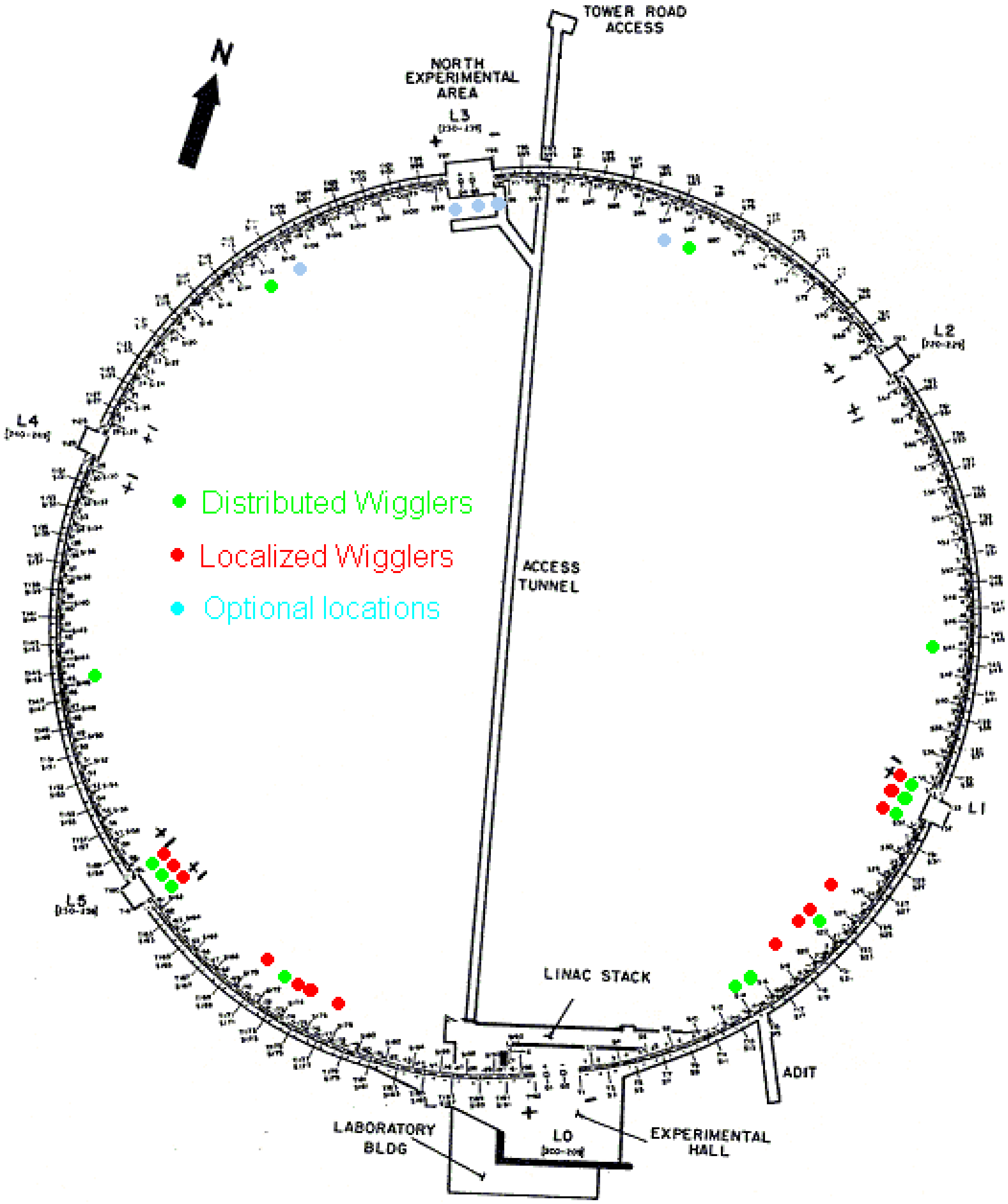
Many short "available" spaces have been identified around tunnel.

Decision made to build small, "modular" wiggler units, all identical



Location of wigglers:

1. ***Distribute around tunnel in available short spaces***
2. ***Make more space in South 1/3 of tunnel and cluster wigglers between L1 and L5.***



Optics issues

Wiggler effects

90% of radiation is in wigglers ® emittance depends only on H_W

Wigglers exhibit strong vertical focusing – even in perfect wiggler

- **Each wiggler shifts** Q_V **by about 0.1 integer !** $\Delta Q_Y \approx \frac{L_W < b_Y > B_W^2}{7.3x10^{-5} g^2}$

  Linear optics design is intimately coupled to wigglers !

- **Strong vertical octupole will require consideration in design**
- **Wiggling beam trajectory lengthens orbit slightly.**

Transverse field fall off, combined with wiggling trajectory, introduces additional quadrupole and non linear terms in both planes.

A detailed wiggler model which includes systematic non-linearities has been incorporated in BMAD optics analysis/design software and a design integrating all wiggler properties into the optics is in progress.

Magnet field quality

CESR arc magnets

- **fields have been measured at 2 GeV excitation**
  ® all CESR magnet fields satisfactory for low energy operation.

IR Quads

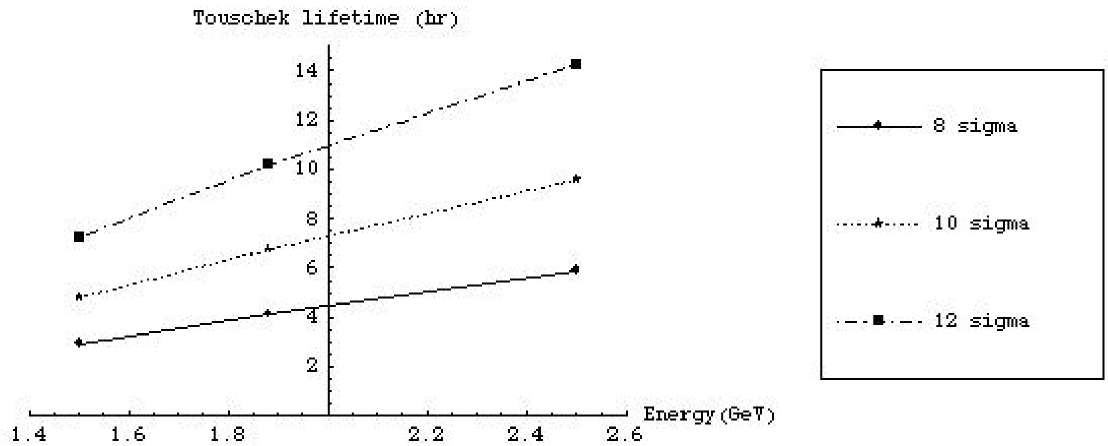
- **Measured multipoles modeled in 2 GeV optics and found OK**

Solenoid compensation

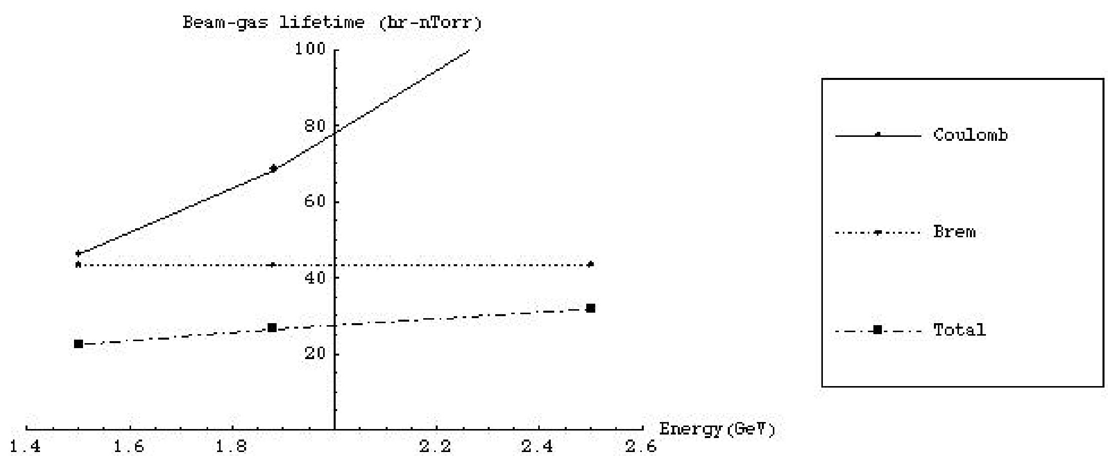
CLEO has agreed to lower solenoid field to 1.0 Tesla,

- **Coupling is still stronger by factor 5.3/1.9 *1.0/1.5 = 1.86**
- **IR beam diagnostics are being upgraded to provide effective measurements and adjustment during operation.**

Beam lifetime from Touschek and Beam Gas scattering



Touschek lifetime vs. energy; curves labeled by momentum aperture



Beam-gas lifetime (hour-ntorr at room temperature) vs. energy;
curves labeled by scattering process

Beam-beam effects

Main beam-beam effects

What determines limits to beam-beam parameter ??

If damping, beam-beam tune shift scales slowly with damping time –

- **If x scales as E in a normal machine, then x µ t$^{-1/3}$**
- **2x damping time Þ x is reduced by about 25%**

Parasitic crossing beam-beam effects

Most effects scale as $n^{0.5®1}$ i_b x g^{--1} x b^{-2}

Bunch current roughly ½ so pc effects about 40% stronger at 1.9 GeV with nominal currents.

Continuing study in progress.

Operating point

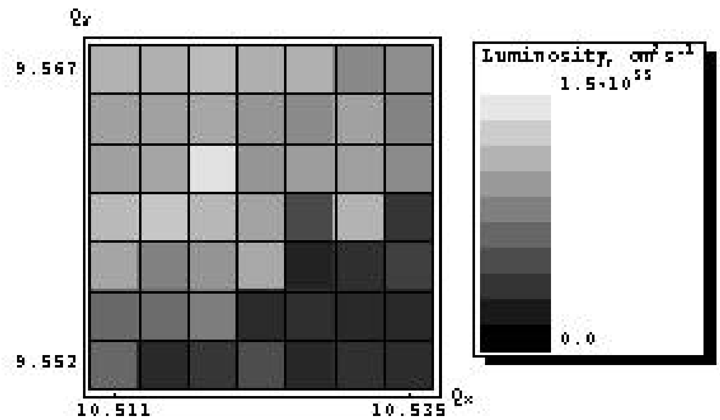
Q_S = 0.11 (43 kHz) will require reassessment of Q_X, Q_Y tune plane.

Results from strong-strong b-b simulation (no adjustable param!)

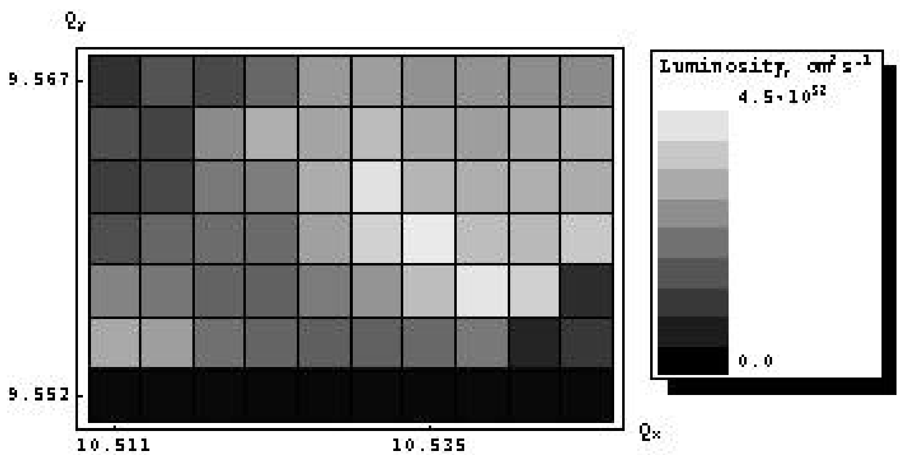
Table: Luminosity predicted by beam-beam simulation.

E (GeV)	Q_s	I_b (mA)	Calc. L (cm^{-2} s^{-1})	Calculated x_v
5.30	0.056	7.68	1.33×10^{33}	0.060
2.50	0.104	5.10	4.45×10^{32}	0.036
1.89	0.110	4.06	4.13×10^{32}	0.055
1.55	0.105	2.82	1.46×10^{32}	0.034

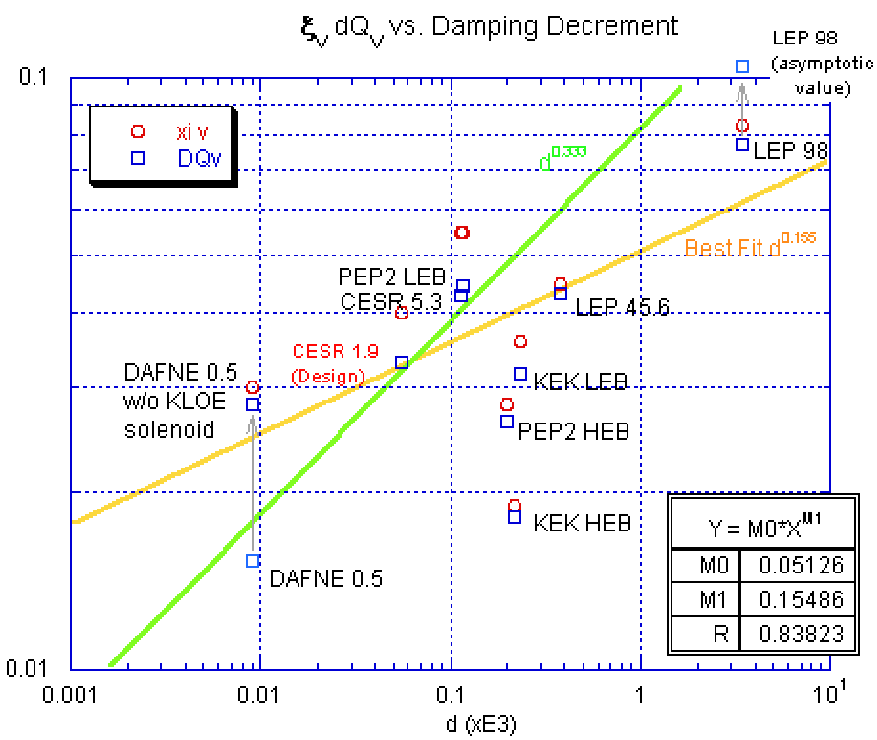
Beam-beam effects (cont.)



Calculated luminosity at **5.3 GeV** from the beam-beam simulation.
Full scale 1.5E33



Calculated luminosity at **1.89 GeV** from the beam-beam simulation.
Full scale 4.5E32



CESRc Summary

We have not found any compelling reason why CESR cannot operate effectively over the 1.5-5.6 GeV energy range.

Wiggler non-linearities, IR optics and pc b-b interactions are primary accelerator physics concerns.

Wiggler production schedule will be challenging.

Our target is HEP operation at 1.9 GeV by the end of 2002.