CESR-c

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1.55GeV - 5.6GeV Operation of CESR

- Energy Scaling
- Machine Layout
- Lattice
- Machine parameters
- Lifetime
- Single beam stability
- Background
- Luminosity at 1.88 GeV

ENERGY SCALING

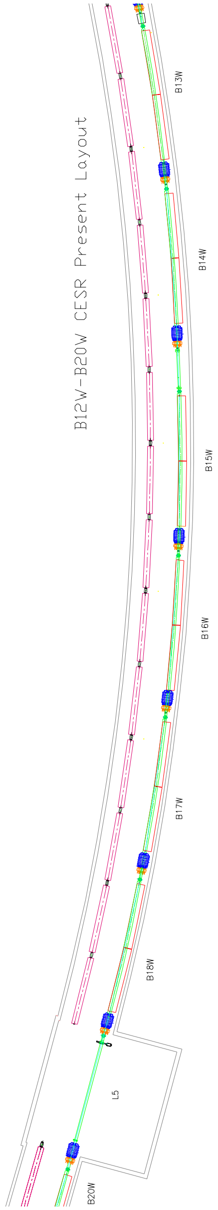
- For fixed bend radius
    - Emittance - $\epsilon_x \propto E^2$
    - Radiation damping rate - $\alpha \propto E^3$
- And in general
    - Beam-beam interaction (parasitic and principle) $\Delta Q \propto \frac{I_{bunch}}{E_0}$
    - Touschek lifetime $\frac{1}{\tau} \sim \frac{I_{bunch}}{E^3}$
    - Solenoid coupling $\theta \propto \frac{Bsol}{E}$

ENERGY SCALING

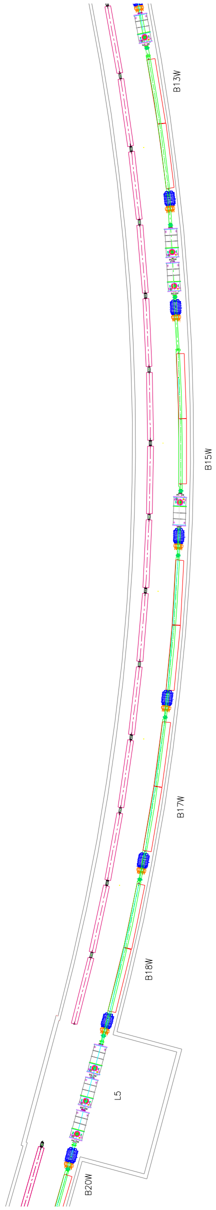
- Damping and emittance wigglers
  - At low energy, radiation damping, emittance, energy spread, dominated by wigglers
    - ◇ $\frac{1}{\tau} \propto EB_w^2$
    - ◇ $\frac{\sigma E}{E} \propto \sqrt{EB_w}$
    - ◇ $\epsilon_x \propto EB_w$
  - With 18m of 2.1T wigglers in CESR arcs, then at 1.88GeV:
    - ◇ $\tau \sim 50ms$

      $\tau = 23$ms in CESR at 5.3GeV
    - ◇ $0.1\text{mm} - \text{mrad} < \epsilon_x < 0.4$mm-mrad
    - ◇ $\sigma_E/E = 0.08\%$

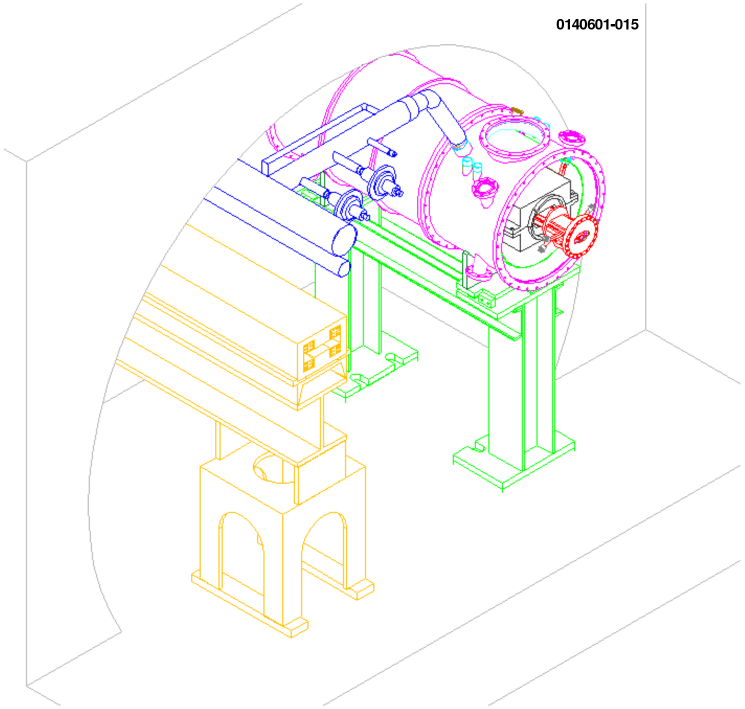
B12W–B20W CESR Present Layout

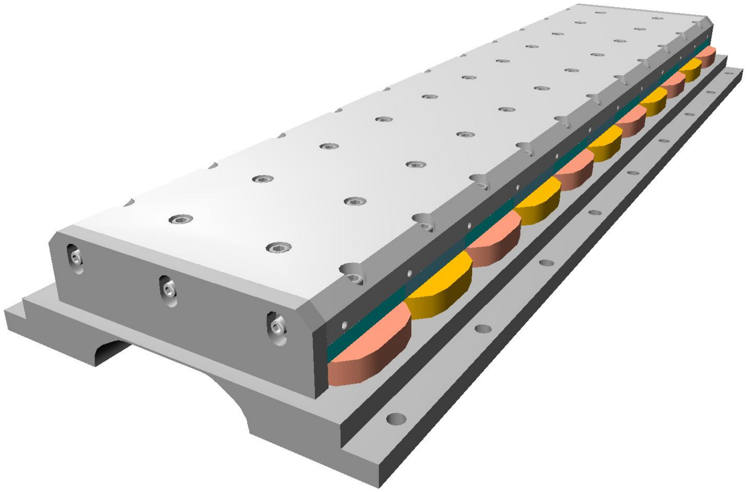


B12W–B20W CESR_Charm Layout
(With 7 Wigglers)



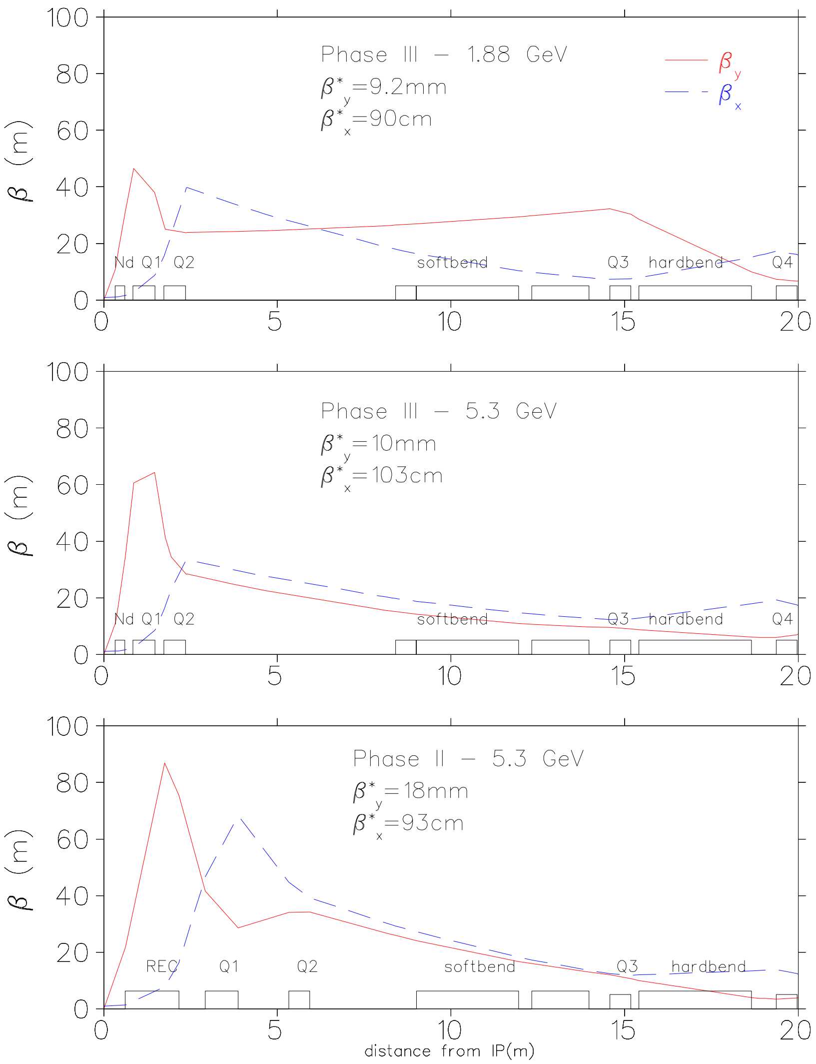
WIGGLERS





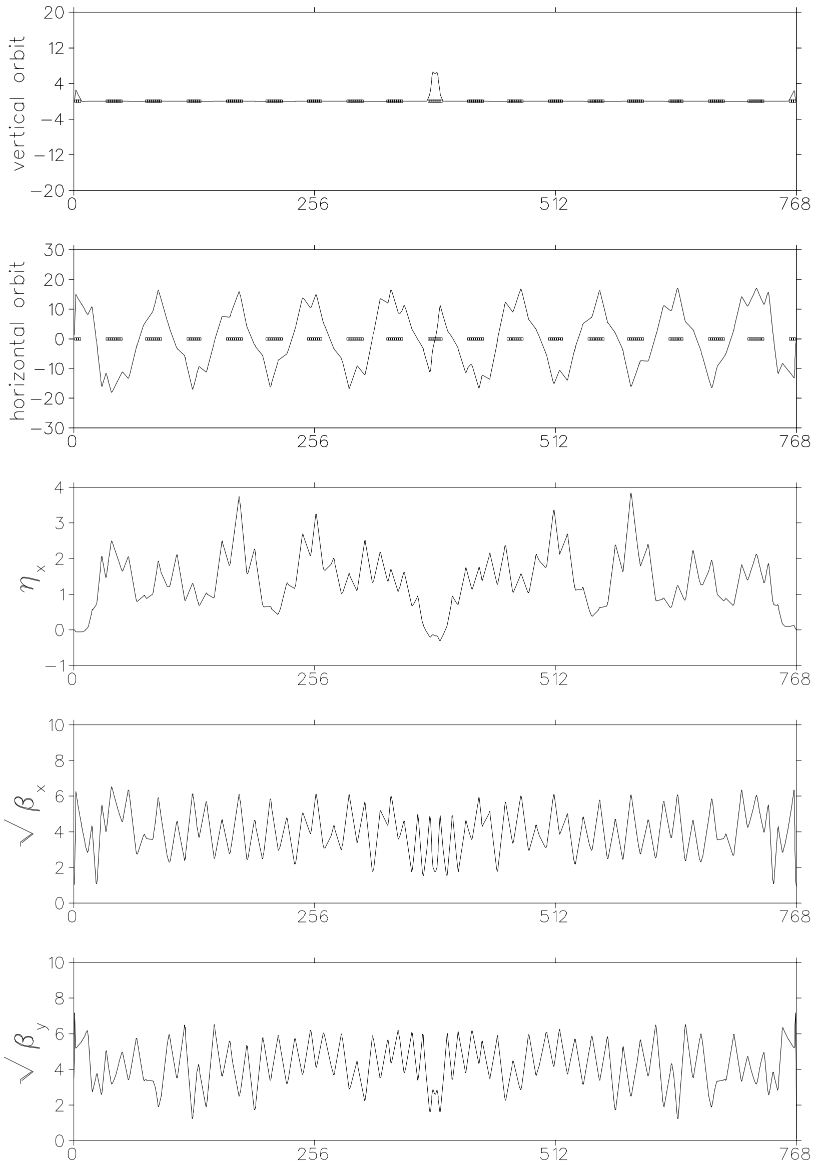
LINEAR OPTICS - IR

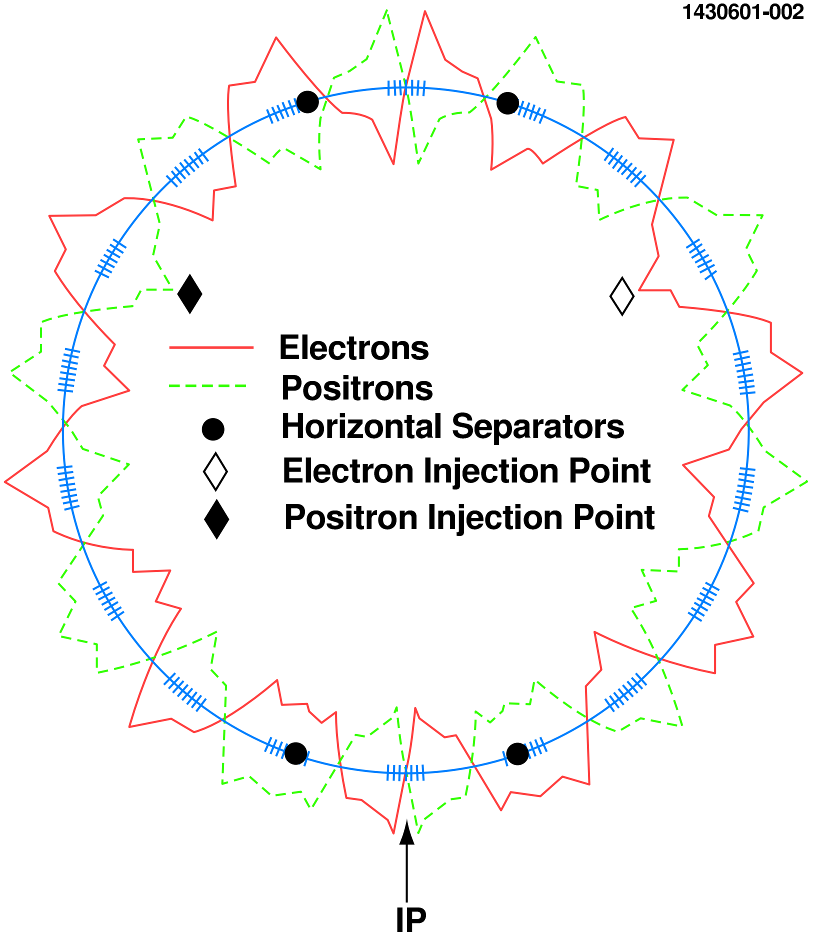
- Replace 1.5m REC pm final focus quad with superconducting-pm hybrid
  - 1.88GeV
    - 20cm permanent magnet quad $k = -5.09m^{-2}$
    - Q1 - 65cm vertically focusing sc quad $k = -1.92m^{-2}$
    - Q2 - 65cm horizontally focusing sc quad $k = 1.32m^{-2}$
    - CLEO solenoid @ 1.0T
    - All IR quads rotated 4.5° about axis
    - skew quad coils superimposed on Q1 and Q2 permit compensation of coupling over wide range
  - 5.3GeV
    - CLEO solenoid @ 1.5T



Linear Optics - global

parameter	value
Beam energy	1.88GeV
β_v^*	9.2mm
β_h^*	90cm
crossing angle	3.1mrad
Q_v	9.59
Q_h	10.53
Number of trains	9
Bunches/train	5
Bunch spacing	14ns
Accelerating voltage	10MV
Bunch length	10mm
Wiggler peak field	2.1T
Wiggler length	18.2m
ϵ_x (incl. wigglers)	0.14mm-mrad
σ_E/E (incl. wigglers)	0.81×10^{-3}
Energy loss/turn (incl. wigglers)	0.21MeV

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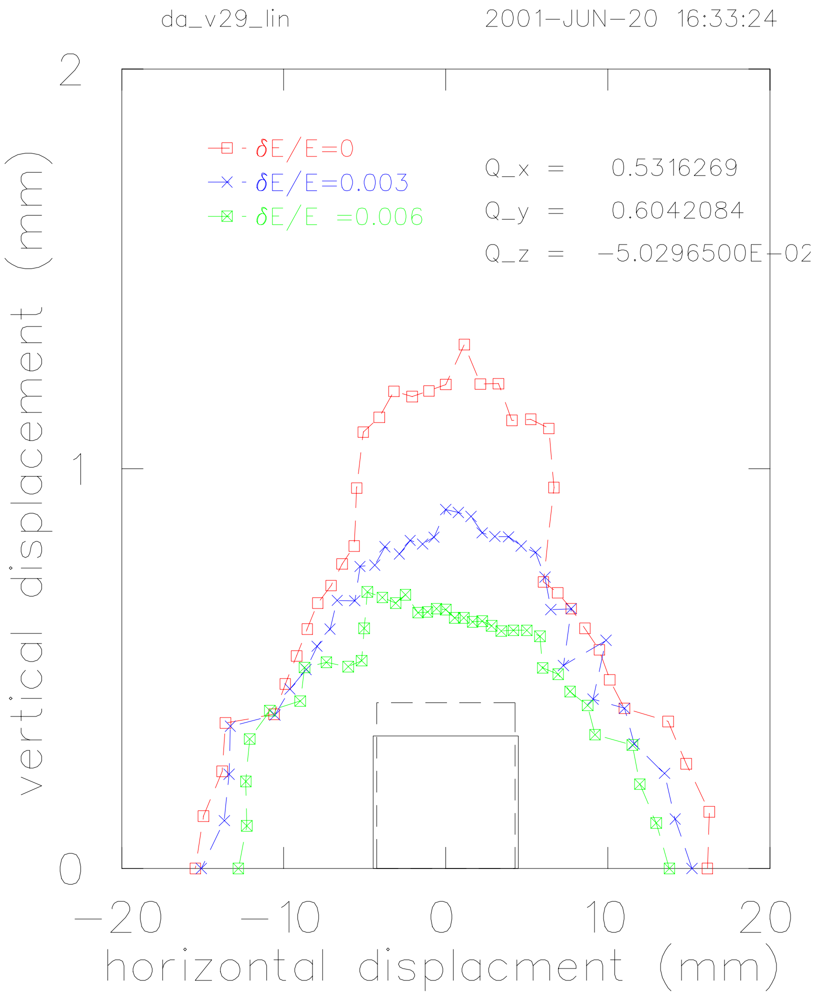
Electrons
Positrons
Horizontal Separators
Electron Injection Point
Positron Injection Point
IP

Dynamic Aperture

- Nonlinearities
  - Sextupoles chosen to
    - Correct chromaticity
    - Minimize energy and amplitude dependence of β and coupling
    - Minimize *pretzel* dependence of β
- Not included
  - Wiggler nonlinearities
  - field and alignment errors

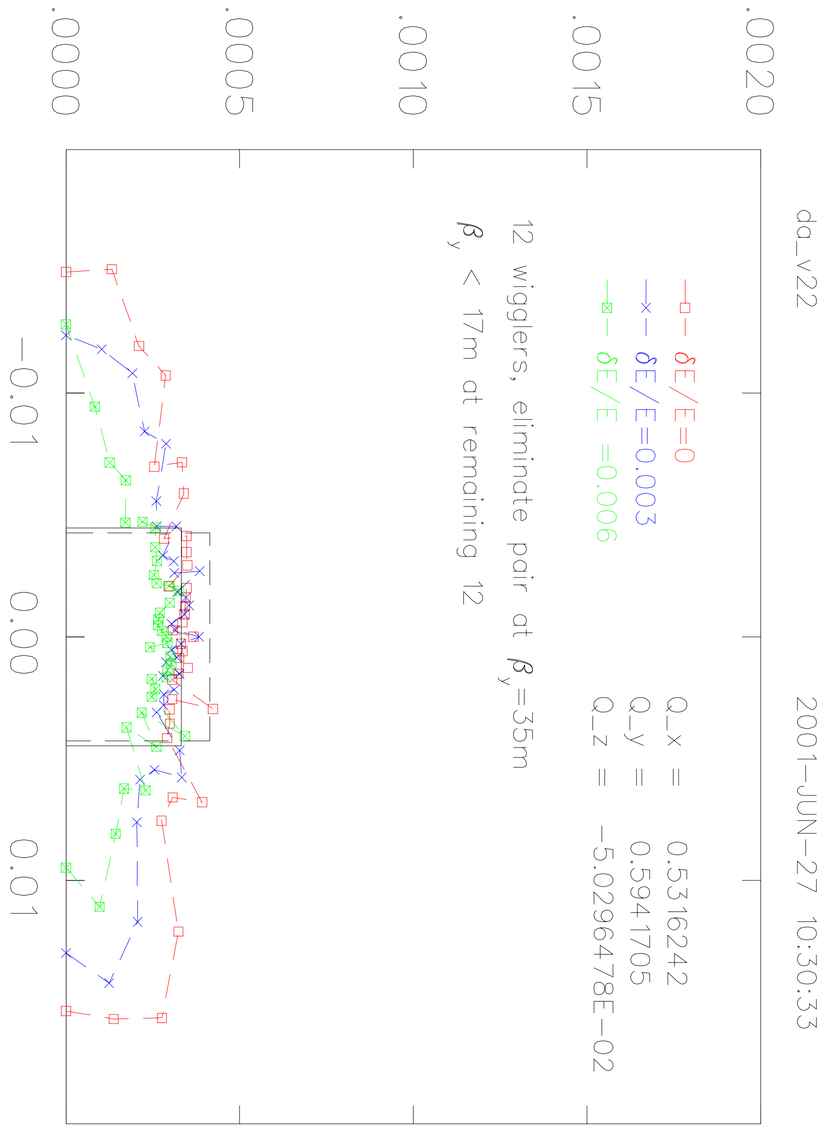


Wiggler nonlinearity

- Nonlinearity of *perfect* wiggler
  - Effective integrated B_x is

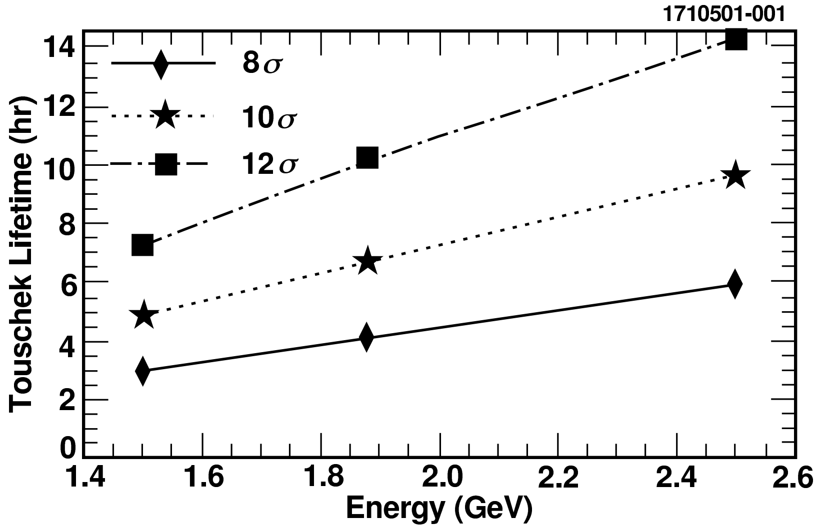
$$\int_0^N B_x ds = -\frac{N_w B_0^2}{2B\rho}\left(y + \frac{2}{3}k_s^2 y^3 + \ldots\right)$$

    - ◇ Octupole term $\propto k_s^2 = \frac{2\pi}{\lambda^2}$
    - ◇ Long period ⇒ greater horizontal displacement and increased sensitivity to horizontal roll off
  - Dynamic aperture tracking with →
    - ◇ $\lambda = 37$cm
    - ◇ No horizontal rolloff
    - ◇ $\beta_y < 15$m in all 12 wigglers
      - - - physical aperture
      - —— 10σ fully coupled
  - Exploring use of octupole correctors to compensate amplitude dependent tune shift



TOUSCHEK SCATTERING

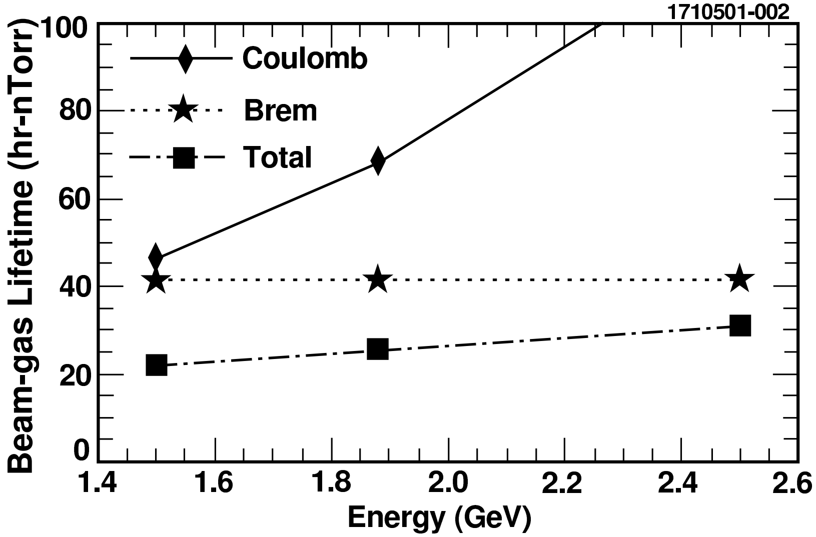
Parameter	E=1.55 GeV	E=1.88 GeV	E=2.5 GeV
Particles per bunch	4.5×10^{10}	6.5×10^{10}	8.2×10^{10}
Bunch length (rms)	9.9 mm	10.2 mm	10.2 mm
Relative momentum spread	0.075%	0.081%	0.077%
Horizontal emittance(rms)	214 nm	214 nm	214 nm
Vertical emittance (rms)	0.92nm	0.83nm	0.83 nm



For typical optics, energy aperture $> 10\frac{\sigma_E}{E}$

VACUUM PUMPING AND BACKGROUND

- TiSP IR pumping performance independent of energy
- DIP performance depends on dipole field
  - ○ Hardbend field >1500G at 1.5GeV, sufficent for full pumping speed
  - ○ Arc bend field $\sim$ 700G, inadequate
    - ◇ Measurements and modeling indicate $< P > \sim 0.9$nT with only lumped pumps and wall pumping
    - ◇ No degradation in wall pumping for $\int I dt >> 500$A-hr
    - ◇ $\sim$50A-hr at 5 GeV sufficient to recondition



BEAM STABILITY

- Single bunch stability
  - Head-tail growth rate $\frac{1}{\tau} \propto \frac{N_b}{E}$
  - Measured threshold at 5.3GeV and $dQ_y/d\delta = 1, > 50\text{mA}$
  - $\Rightarrow$ Head-tail $I_{thresh} >>$ design current at 1.88GeV
  - $\Rightarrow$ Transverse mode coupling instability estimated $\sim$ 92mA at 1.88GeV.
  - Bunch lengthening - $(\sigma - \sigma_0) \propto \frac{I_b}{E}$
  - Measurements at 5.3GeV with 10.5mm bunch length $\rightarrow$

    $$\sigma = 10.46\text{mm} + (0.193\text{mm/mA})I_b$$
  - $\Rightarrow$ Bunch lengthening at 1.88GeV $\sim$ 0.125mm/mA (5% at design current)
- Multi-bunch stability
  - At 5.3 GeV multi-bunch longitudindal and transverse instabilities are damped with bunch-by-bunch feedback
  - And with feedback $I_{thres} > 750\text{mA}$
  - Multi bunch growth rates and feedback damping rate $\propto E^{-1}$
  - $\Rightarrow$ no multi-bunch instability limit at 1.88GeV design current

Detector Background

- Coulomb scattering $\frac{d\sigma}{d\Omega} \propto \frac{1}{E^2}$
- Bresstrahlung $\sim$ independent of energy
- Touschek $\sim \frac{1}{E^3}$
  - ◦ Residual gas pressure $\sim I^2 E$
    - ⋄ → Coulomb strike rate $\sim \frac{I^2}{E}$
    - ⋄ → Bremsstrahlung strike rate $\sim I^2 E$

DETECTOR BACKGROUND

IR mask strike rates and energy deposition from beam-gas interactions for three CESR configurations.

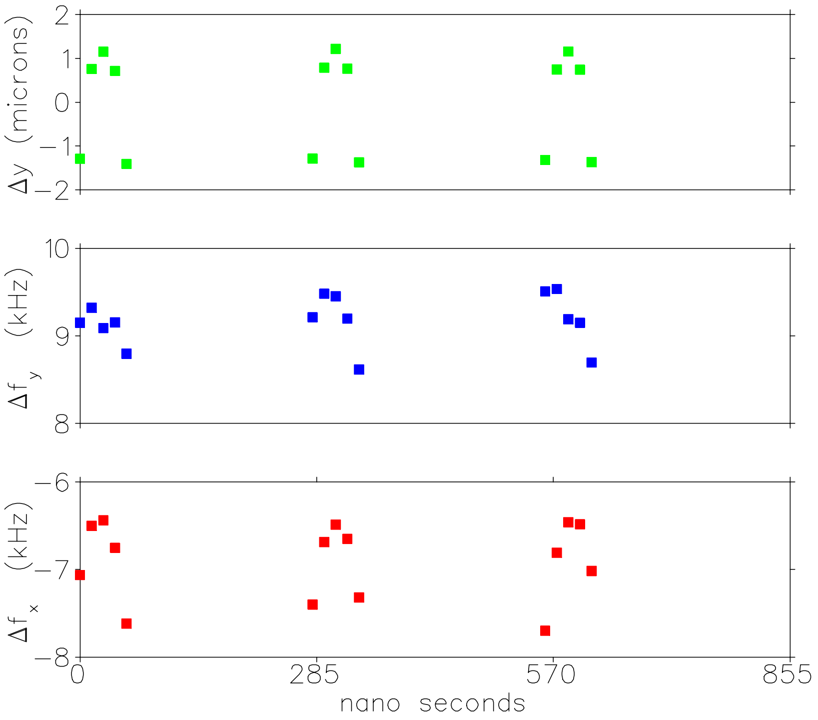
	Present	Phase III	CESR-c
Energy [GeV]	5.3	5.3	1.88
Total Current [A]	0.70	1.0	0.36
Coulomb Strike Rate [kHz]	9.0	3.4	0.8
Bremsstrahlung Strike Rate [kHz]	101	41.7	2.3
Total Strike Rate [kHz]	110	45.1	3.1
Coulomb Energy Deposition [MeV/μs]	49	18	1.5
Bremsstrahlung Energy Deposition [MeV/μs]	330	77	1.5
Total Energy Deposition [MeV/μs]	379	94	3.0

LUMINOSITY AT 5.3GEV

- Nine trains with 5 bunches/train
- Bunch current $I_b \sim 8.5\mathrm{mA}$
- I_b limited by parasitic interactions
  - Uneven spacing ⇒ bunch dependent tune and closed orbit
  - Particles in the horizontal tails of one bunch interact with core of opposing bunch and are lost
  - Parasitic effects scale as I_{bunch}/E

Bunch dependent electron positron orbit difference at IP for first 3 trains with 7.5mA/bunch. $\sigma_y \sim 4\mu$. →

Bunch dependent tune shift for first 3 trains with 7.5mA/bunch. →



LUMINOSITY SCALING

- Simulation indicates that limiting beam-beam tune shift scales as $\delta^{\frac{1}{3}}$
- If we suppose that limiting bunch current $I_b \propto E$

○ E=5.3GeV	○ E=1.88GeV
○ $\beta_v^* = 21\text{mm}$	○ $\beta_v^* = 10\text{mm}$
○ $I_b \sim 8.5\text{mA}$	○ $I_b \sim 3\text{mA}$
○ $\delta = 2.2 \times 10^{-4}$	○ $\delta = 1.1 \times 10^{-4}$
○ $\xi_v = 0.07$	○ $\Rightarrow \xi_v = 0.056$
○ Nine trains of five bunches	○ Nine trains of five bunches
○ $L = 1.3 \times 10^{33} cm^{-2} s^{-1}$	○ $\Rightarrow L = 2.7 \times 10^{32} cm^{-2} s^{-1}$

- Bunch current limit may be increased with
  - RFQ to eliminate tune spread
  - Bunch by bunch orbit correction