Some Alignment and Instrumentation Issues for CESR as a Damping Ring Test Facility

M. Tigner, R. Helms, M. Palmer, D. Rubin, D. Sagan

Cornell University

Laboratory for Elementary-Particle Physics

CesrTF Goals

- Primary Goals
  - Electron cloud measurements
    - e^- cloud buildup in wigglers
    - e^- cloud amelioration in wigglers
    - Instability thresholds
  - Ultra-low emittance
    - Study emittance diluting effect of the e^- cloud on the e^+ beam
    - Detailed comparisons between electrons and positrons
    - Also look at fast-ion instability issues for electrons
    - Alignment issues and emittance tuning algorithms
    - Beam dynamics issues (including energy dependence 1.5 to 5.5 GeV operation)
- Secondary Goals
  - ILC DR hardware testing

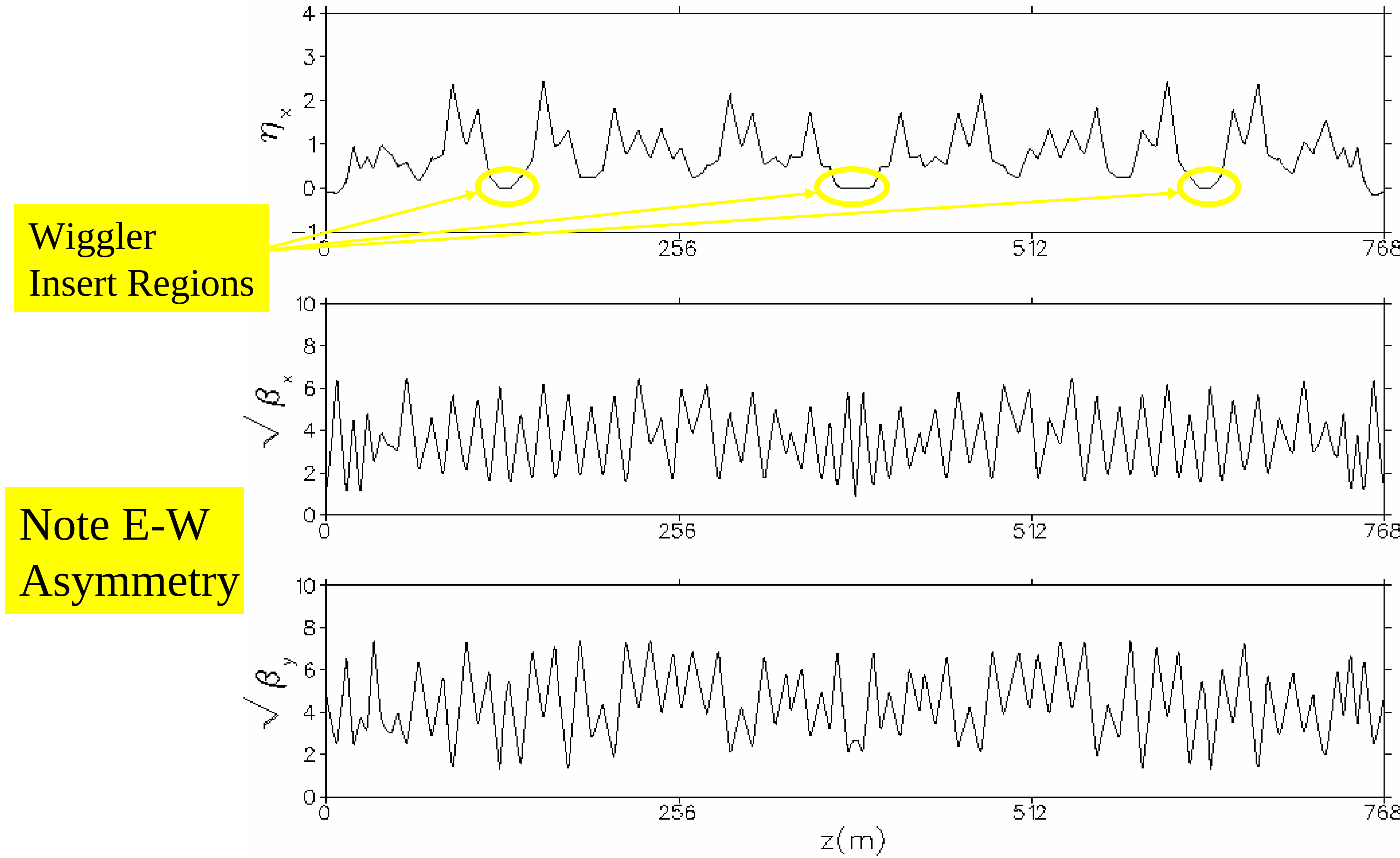
Low Emittance Lattice Parameters

Parameter	Value	Comments
Wigglers	12 @ 2.1T	
Beam Energy	2.0 GeV	Will explore low ε designs in the 1.5-2.5 GeV range
σ_E/E	8.6×10^{-4}	
ε_x	3.0 nm	Wiggler-dominated value. Further reduction possible with β function (in wigglers) and wiggler field tuning and/or fewer active wigglers
$\tau_{x,y}$	47 ms	
Q_x	14.53	
Q_y	9.59	
Q_z	0.1	Requires higher RF voltage than we typically use
σ_z	6.9 mm	
α_c	7.1×10^{-3}	

Further Parameter Information

- Energy: 1.5 to 5.5 GeV
- Bunch Spacing:
  - Presently use 14 ns
  - Can use alternating 6ns, 8ns scheme with activation of existing parallel feedback systems
  - Intend to explore 2ns and/or 4ns option if needed for ILC DR studies
- Touschek Lifetime
  - In ultra-low emittance operation expect lifetimes of a few to several minutes

Low Emittance Lattice Functions



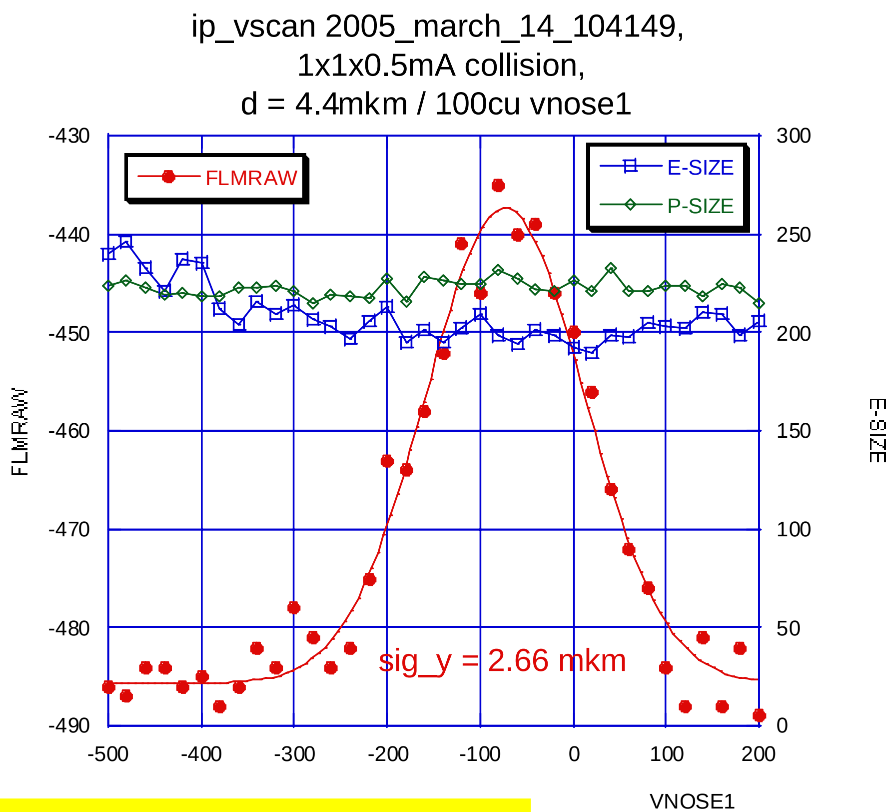
Vertical Emittance Estimates

- Beam-Beam Scan with low current 1-on-1 Collisions in 1.88 GeV HEP Conditions (with pretzel)
  - Differential vertical displacement controlled by phase advance between vertical separators in North
  - Fast Luminosity Monitor provides measurement of overlap

    Peak ⇨ 8.4×10^{28} cm^{-2} s^{-1}
- Measure σ_y = 2.66 μm (with β_y^*=11.2 mm and ε_h=136 nm)

  ⇨ ε_y = 0.63 nm

  ⇨ $\varepsilon_y / \varepsilon_x \sim 0.005$



Vertical Emittance Estimates from Coupling Contribution:

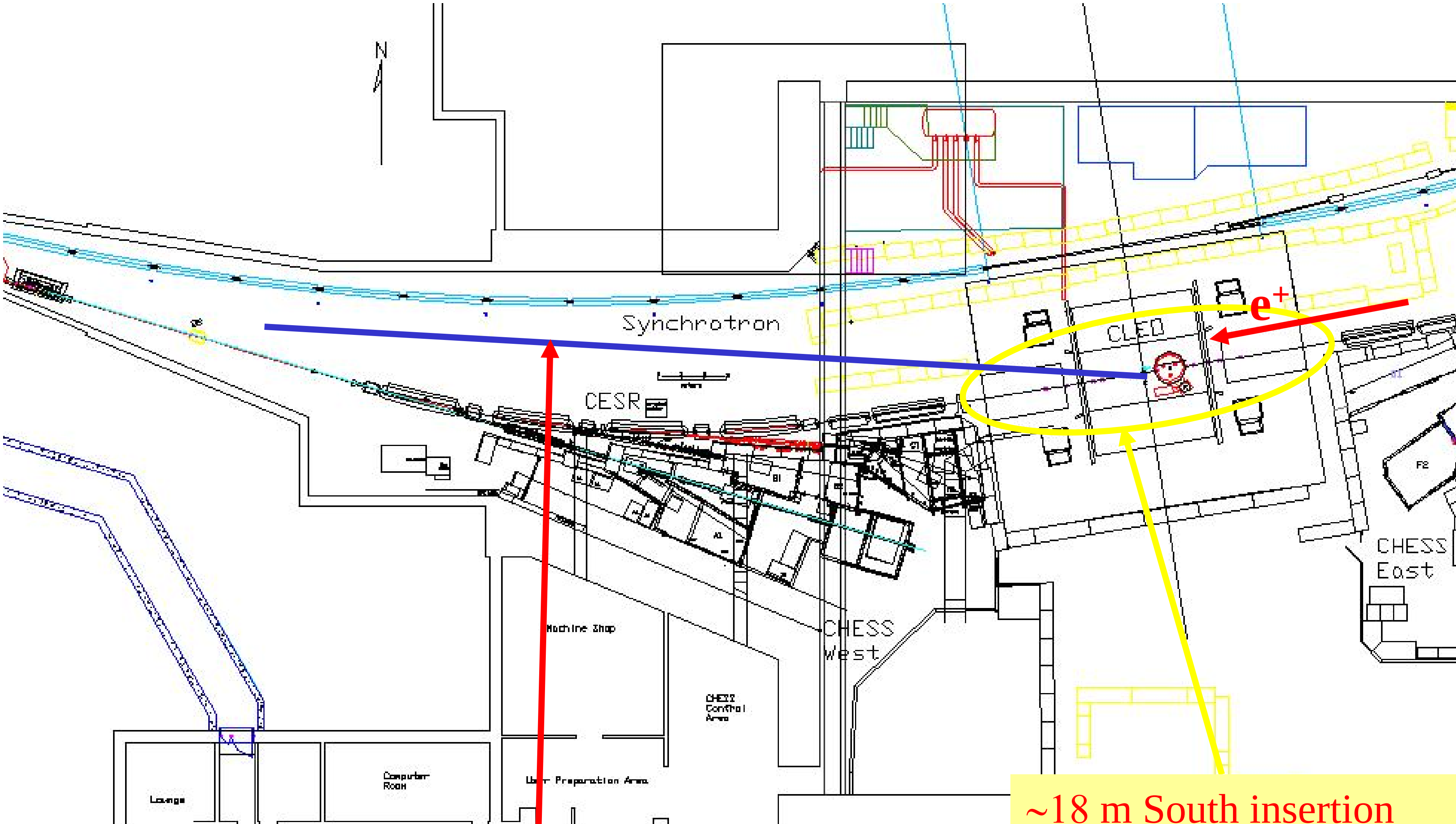
With ε_x=3.0 nm ⇨ $\varepsilon_y \sim$ 15 pm

With ε_x=2.0 nm and $\varepsilon_y/\varepsilon_x \sim 0.0025$ ⇨ $\varepsilon_y \sim$ 5 pm

Likely improvement without CLEO solenoid and pretzel!

A. Temnykh
M. Forster

South IR Extraction Line Option



~40 m available for possible extraction line and diagnostics

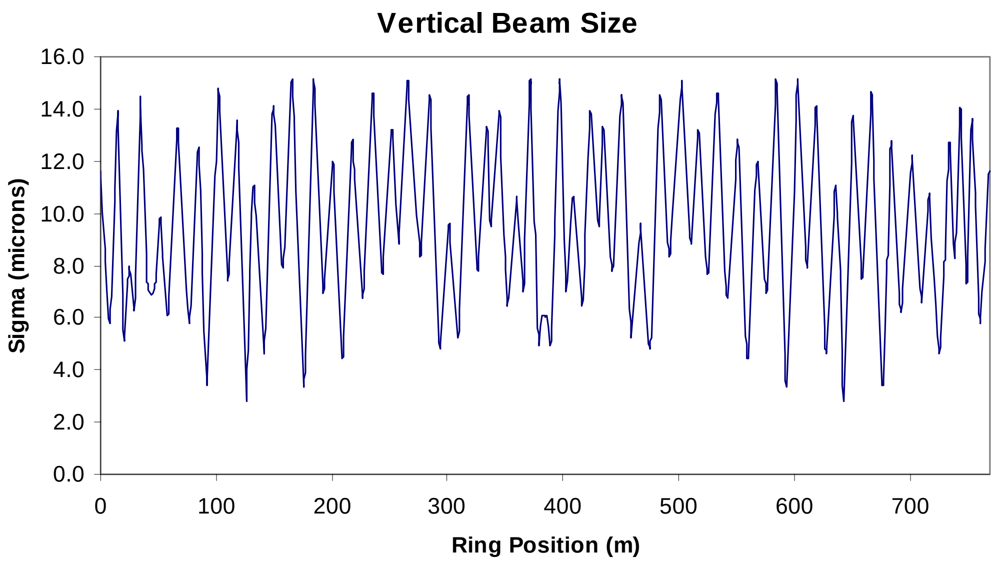
~18 m South insertion region for diagnostics and test devices

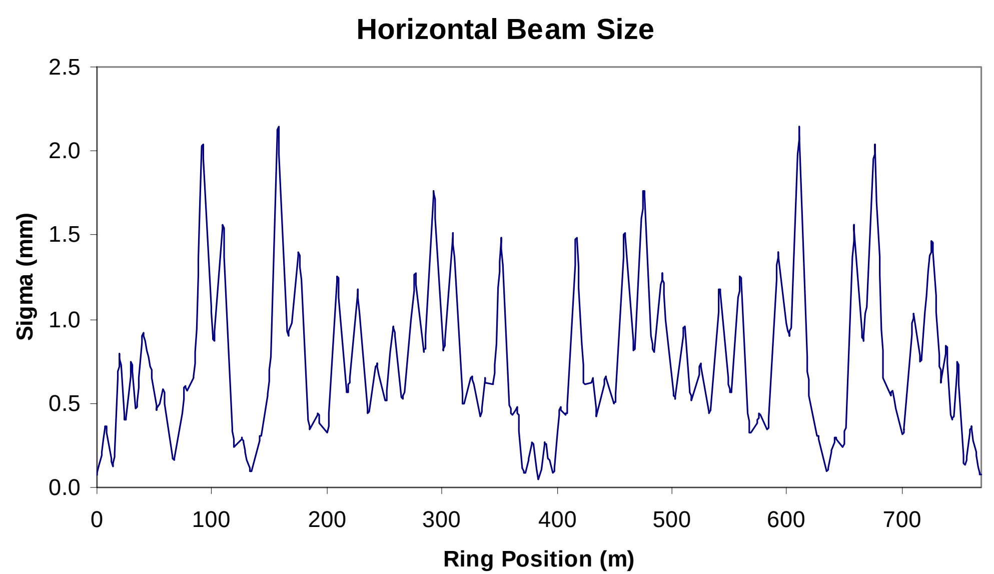
Emittance Measurement

- High resolution transverse size measurements
  - Laserwire
  - Also working on x-ray beam profile monitor
- Desired laserwire capabilities
  - Bunch-by-bunch capability
    - Possibly 2 ns to 14 ns bunch spacing
  - Fast measurement
    - Touschek lifetimes are short (minutes)
  - Resolution suitable for $\sigma_y \sim 10\ \mu m$

Beam Sizes

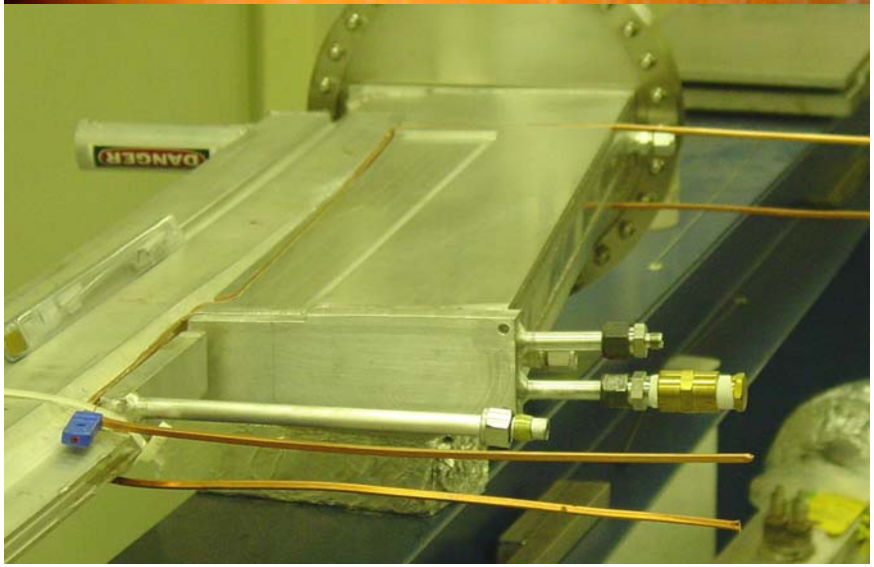
- Expected beam sizes
  - Vertical assumes perfect dispersion correction
  - Values at center of South IR:
    - $\sigma_y \sim 11.6\ \mu m$
    - $\sigma_x \sim 79\ \mu m$
    - Compton scattering from the positron beam can be viewed through the present CESR-c luminosity monitor window





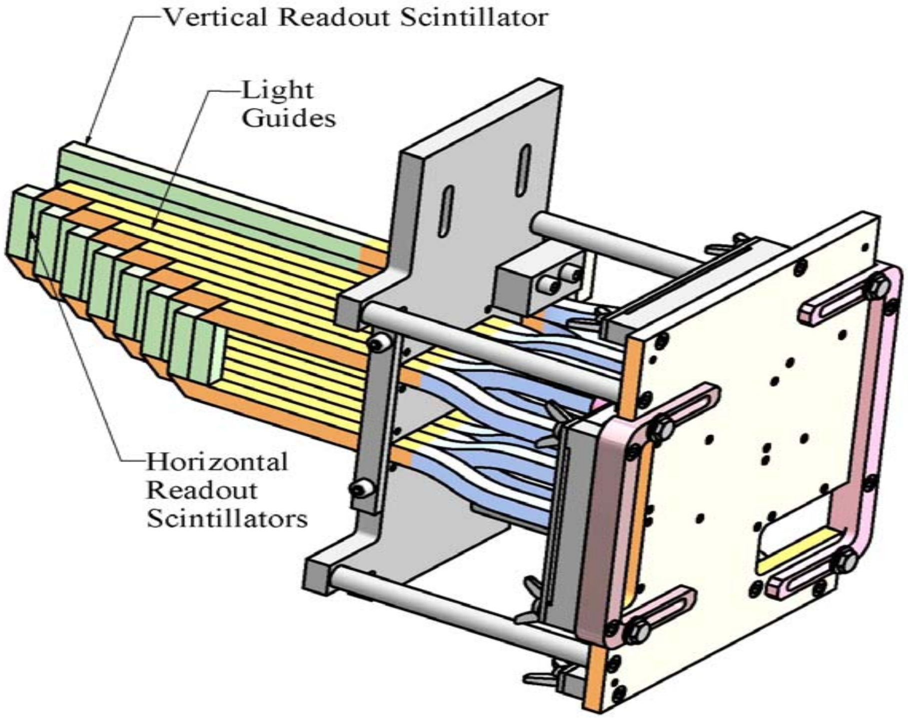
Luminosity Monitor Window

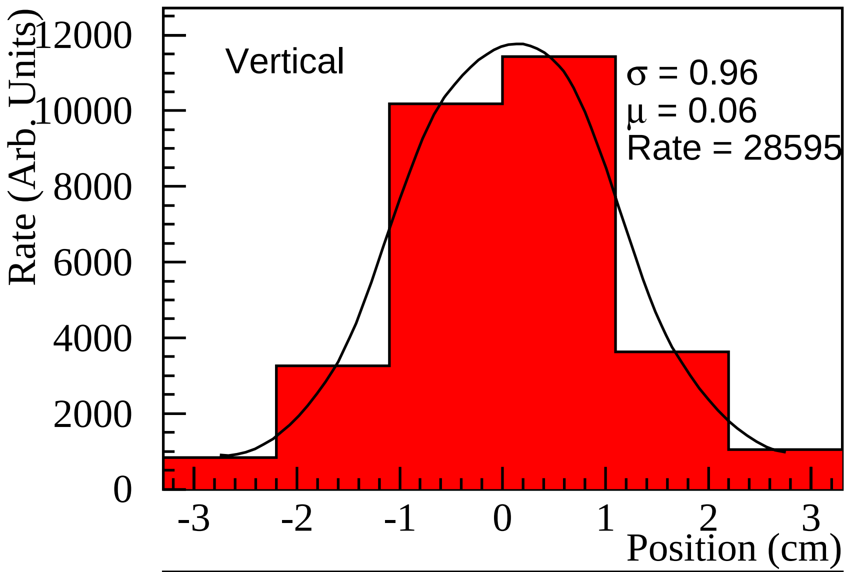
- Aluminum γ Window
  - Faces into South IR
  - 1 in thick (0.26 X_0)
  - 16.1 m from center of CesrTF insertion region
  - Looks at e^+ beam
  - Aperture (for 16.1 m):
    - +/- 1.5 mrad vertical
    - -5 to +2 mrad horizontal (negative is to inside of ring)

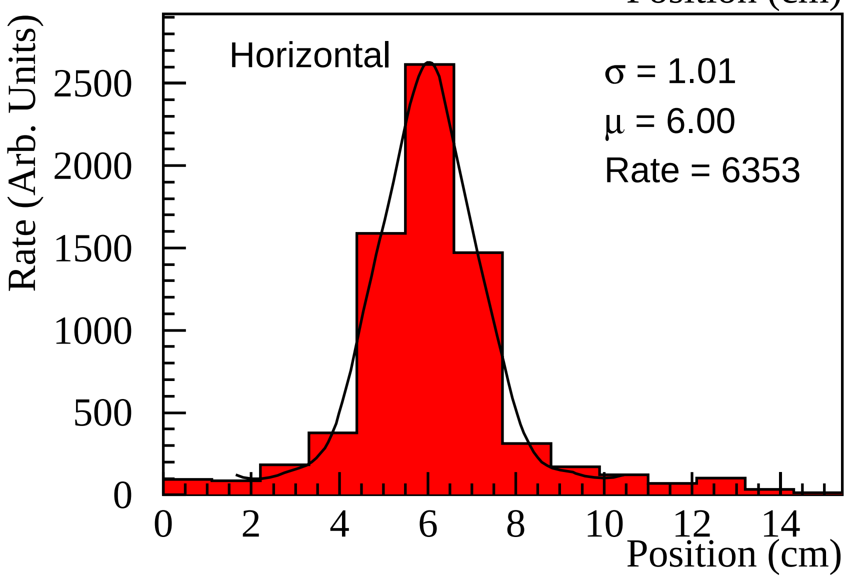


Radiative Bhabha γ Detector ⇨ Compton γ Detector ?

- Segmented Scintillator Detector
  - Offers possibility of measuring the Compton photon angular distribution
  - Fast R7400 PMTs offer bunch-by-bunch response
  - Well-understood operation







Some Laserwire Discussion Points

- Beam sizes are comparable to ATF
- ATF scanning times seem somewhat long given the short beam lifetime and questions of stability
  - 6 minutes for y scan
  - 15 minutes for x scan
  - Can we consider a system with sufficient power on the beam to complete a scan with $\Delta t < \tau_{Touschek}$?
- CW laser system with fast detector versus pulsed laser system
  - What are pros and cons?
  - What are the costs?

CesrTF Alignment Sensitivity Estimates

- Analytical estimates using CesrTF parameters
- Utilize A. Wolski's procedures in his DR evaluation note
  http://www.desy.de/~awolski/ILCDR/Documentation_files/ILCDRAlignment.pdf
- Make rough sensitivity estimates for comparison purposes
- Some sources of vertical emittance
  - Vertical steering ⇨ vertical dispersion
  - Betatron coupling from horizontal to vertical
  - Horizontal dispersion coupled into vertical
- Closed orbit errors from quadrupole misalignments
  - Sensitivity: RMS quad misalignment to give a vertical orbit distortion equal to the beamsize for the target emittance (5 pm in our case)

$$\frac{\langle y^2 \rangle}{\langle \sigma_y^2 \rangle} \approx \frac{\langle \Delta Y_q^2 \rangle}{8\varepsilon_y \sin^2 \pi\nu_y} \Sigma_{1O}$$

$$\Sigma_{1O} = \sum_{quads} \beta_y (k_1 L)^2$$

Alignment Sensitivity Estimates (cont'd)

- Coupling and dispersion from quadrupole rotations
  - Sensitivity: RMS quadrupole rotation to generate the target vertical emittance

$$\frac{\varepsilon_y}{\left\langle \Delta\Theta_q^2 \right\rangle} \approx \frac{J_x}{J_y} \frac{1-\cos 2\pi\nu_x \cos 2\pi\nu_y}{\left(\cos 2\pi\nu_x - \cos 2\pi\nu_y\right)^2} \varepsilon_x \Sigma_{1C} + J_\varepsilon \frac{\sigma_\delta^2}{\sin^2 \pi\nu_y} \Sigma_{1D}$$

$$\Sigma_{1C} = \sum_{quads} \beta_x \beta_y \left(k_1 L\right)^2 \qquad \Sigma_{1D} = \sum_{quads} \beta_y \eta_x^2 \left(k_1 L\right)^2$$

- Coupling and dispersion from sextupole misalignments
  - Sensitivity: RMS sextupole misalignment to generate the target vertical emittance

$$\frac{\varepsilon_y}{\left\langle \Delta Y_s^2 \right\rangle} \approx \frac{J_x}{J_y} \frac{1-\cos 2\pi\nu_x \cos 2\pi\nu_y}{4\left(\cos 2\pi\nu_x - \cos 2\pi\nu_y\right)^2} \varepsilon_x \Sigma_{2C} + J_\varepsilon \frac{\sigma_\delta^2}{4\sin^2 \pi\nu_y} \Sigma_{2D}$$

$$\Sigma_{2C} = \sum_{sexts} \beta_y \beta_x \left(k_2 L\right)^2 \qquad \Sigma_{2D} = \sum_{sexts} \beta_y \eta_x^2 \left(k_2 L\right)^2$$

Lattice Comparisons

	CesrTF	ATF	TESLA	ILC 6 km
Cicumference (m)	768	139	17000	6114
Energy (GeV)	2.0	1.28	5.0	5.066
Horizontal Emittance (nm)	2.5	1.0	5.1	5.5
Vertical Emittance (pm)	5.0 (target)	5.0	1.4	1.4
Energy Spread (x10^{-3})	0.86	0.55	1.3	1.5
J_x	1.0	1.6	1.0	1.0
J_y	1.0	1.0	1.0	1.0
Q_x	14.53	15.141	76.310	56.584
Q_y	9.59	8.759	41.180	41.618

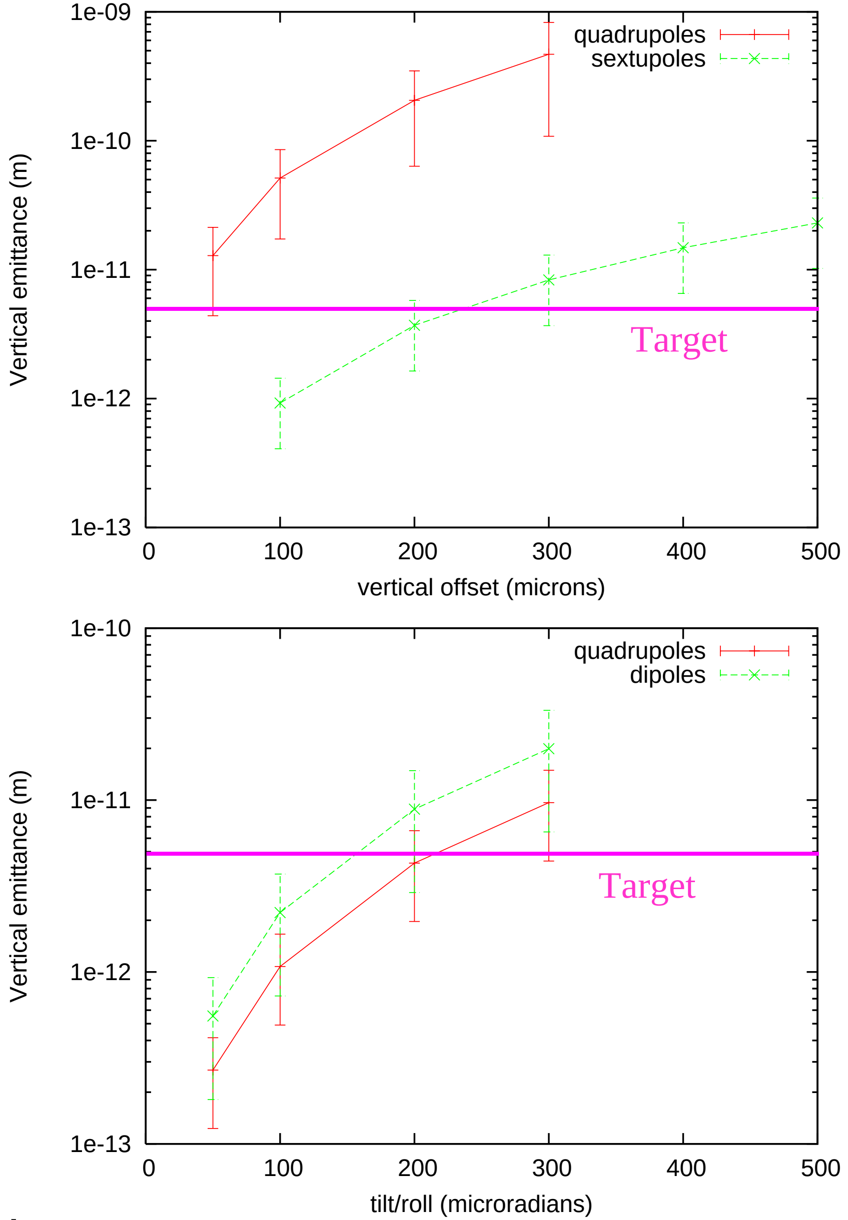
Lattice Sensitivities

	CesrTF	ATF	TESLA	ILC 6km
Quadrupole Alignment (nm)	756	241	80.7	198
Quadrupole Rotation (μrad)	245	825	40.5	58.3
Sextupole Alignment (μm)	227	45.6	11.3	40.4

- ATF / TESLA / ILC from A. Wolski
- Note: these are sensitivity estimates and *not* actual tolerances
- Alignment sensitivities tend to be significantly less for CesrTF!
- Nominal CESR alignment *resolutions* and *tolerances*
  - Quad Position: ~100 μm ~100-200 μm
  - Quad Rotation: ~100 μrad ~100 μrad
  - Sextupole Position: ~100 μm ~200-400 μm
- Local errors may be (are in a number of cases) larger

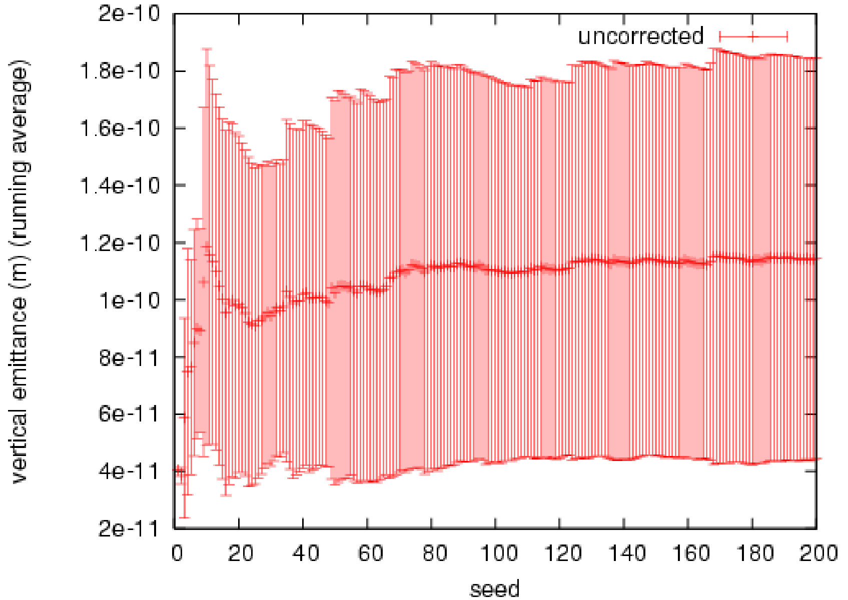
Vertical Emittance Simulation

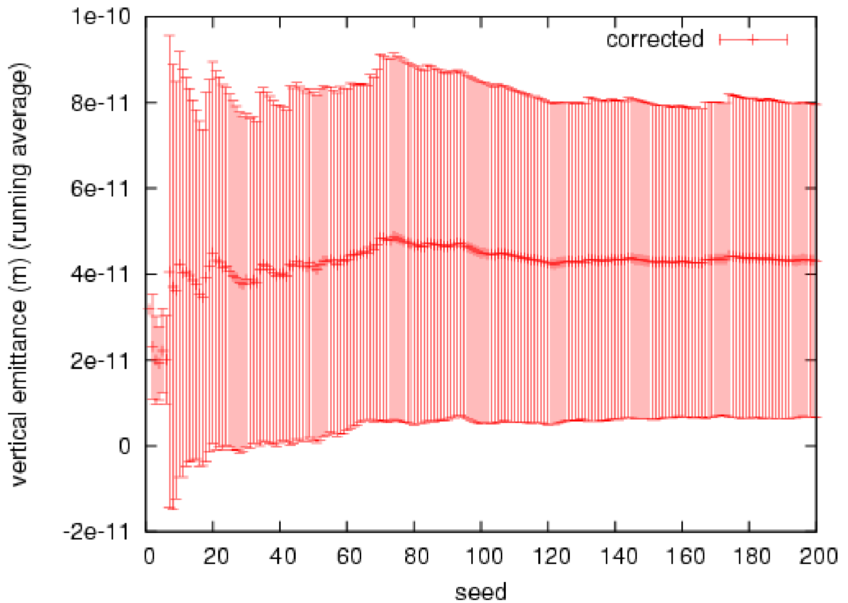
- Presently at an early stage of evaluation
  - As expected from sensitivity estimates, most critical item is quadrupole alignment errors
  - Need to pursue improvements in both the starting point alignment and in correction methods



Machine Corrections

- Starting the study of machine corrections
- Plots at right show impact of closed orbit correction
  - Running average and standard deviation are plotted for a series of 200 seeds
  - Thus right edge gives expected value
- Still testing/evaluating the full suite of corrections
- Then will explore emittance tuning schemes





Alignment and Survey Issues

- Quadrupole alignment is a critical issue
  - Need a ring-wide improvement
    - Has major implications for the scope of the alignment upgrade
  - In order to have a starting point consistent with 5-10 pm vertical emittance goal, should aim for better than 100 μm initial alignment capability
  - We still need to review the impact of vibration/ground motion issues and magnet support stability (also magnet stability)
- Question: How much will upgrading the CesrTF alignment and survey capabilities benefit the alignment and survey R&D needed for the ILC damping rings?