ILC Damping Ring R&D Using CESR

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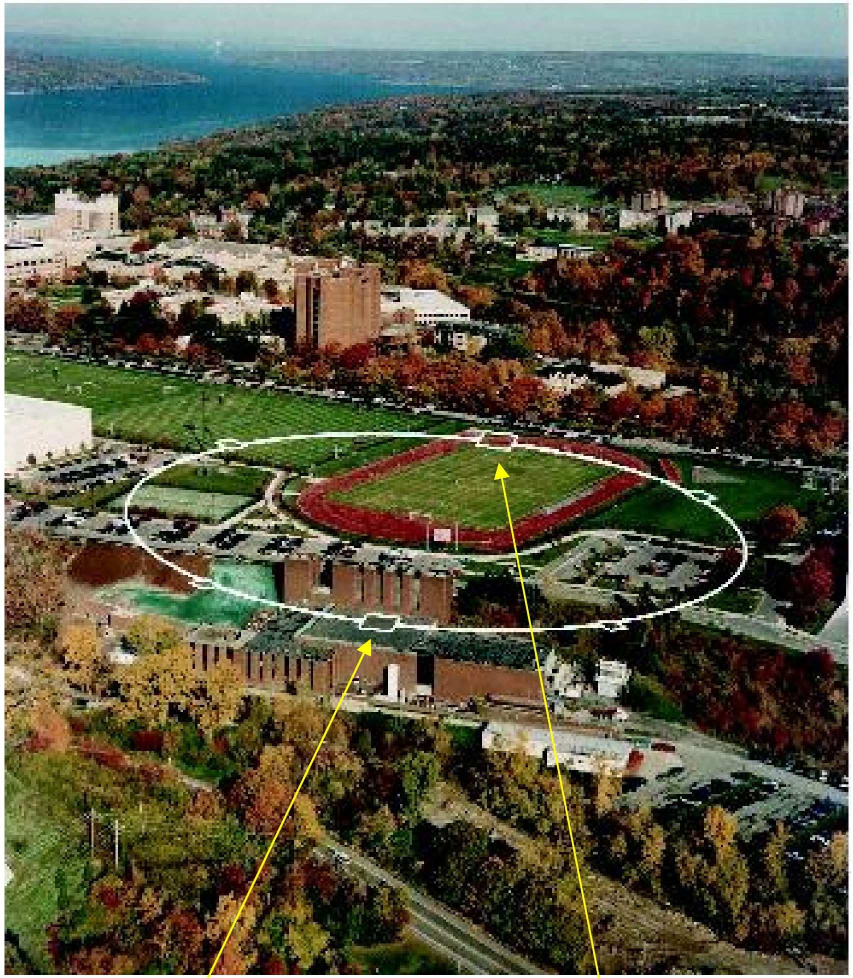
Accelerator-Based Science and Education

Outline

- Possibilities for CESR as an ILC Damping Ring Test Facility (CesrTF)
  - CesrTF Overview
  - What Can CesrTF Offer?
  - CESR-c ⇨ CesrTF Conversion
    - CESR Modifications
    - CesrTF Low Emittance Optics
  - Proposed CesrTF Schedule
- CesrTF R&D Program
- Conclusion

CesrTF Overview

- CESR-c HEP operations scheduled to conclude on March 31, 2008
- Design studies are presently underway to modify CESR for ILC Damping Ring R&D ⇨ CesrTF
- 4 Key Questions:
  1. What can CESR offer as a damping ring test facility?
  2. How extensive are the required modifications?
  3. What is the resulting experimental reach?
  4. Can important R&D results be provided in a timely fashion for the ILC TDR and (*hoped for*) start of construction?



South (CLEO) and North Interaction Regions

CesrTF Concept

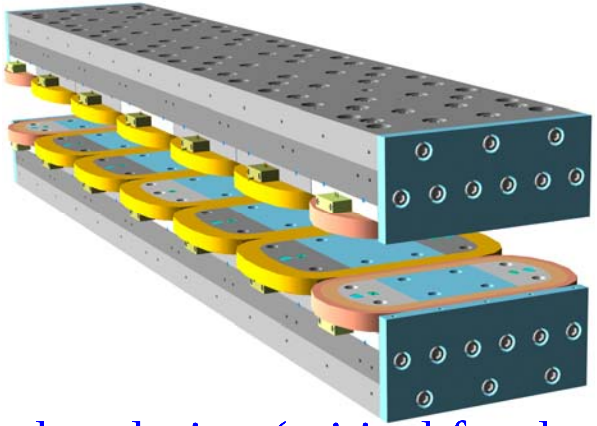
- Reconfigure CESR as a damping ring test facility
  - Move wigglers to zero dispersion regions for low emittance operation
  - Open up space for insertion devices and instrumentation
- Explore issues critical to the design and operation of the ILC damping rings
- Provide an R&D program that is complementary to work going on elsewhere (eg, KEK-ATF)
- Provide a vehicle for
  - R&D needed for the TDR
  - Operating and tuning experience with ultra-low emittance beams
  - DR technical systems development
- Provide significant amounts of dedicated running time for damping ring experiments

1) What Can CESR Offer?

CESR offers:

- The only operating wiggler-dominated storage ring in the world
- The CESR-c damping wigglers
  - Technology choice for the ILC DR baseline design
- Flexible operation with positrons *and* electrons
- Flexible bunch spacings suitable for damping ring tests
  - Presently operate with 14 ns spacing
  - Can operate down to 2 ns spacings with suitable feedback system upgrades
- Flexible energy range from 1.5 to 5.5 GeV
  - CESR-c wigglers and vacuum chamber specified for 1.5-2.5 GeV operation
  - An ILC DR prototype wiggler and vacuum chamber could be run at 5 GeV
- Dedicated focus on damping ring R&D for significant running periods after the end of CLEO-c data-taking
- A useful set of damping ring research opportunities…
  - The ability to operate with positrons and with the CESR-c damping wigglers offers a unique experimental reach

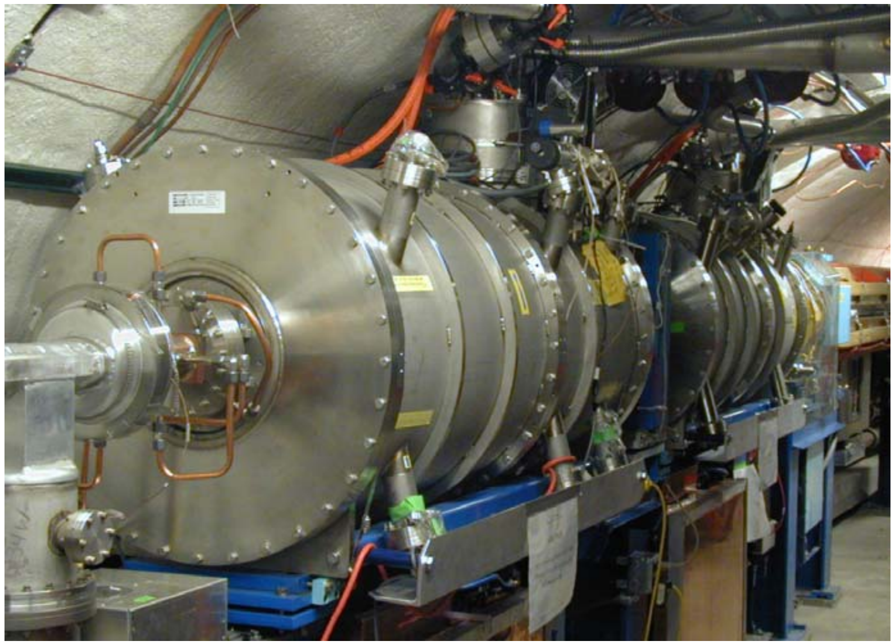
CesrTF Goals

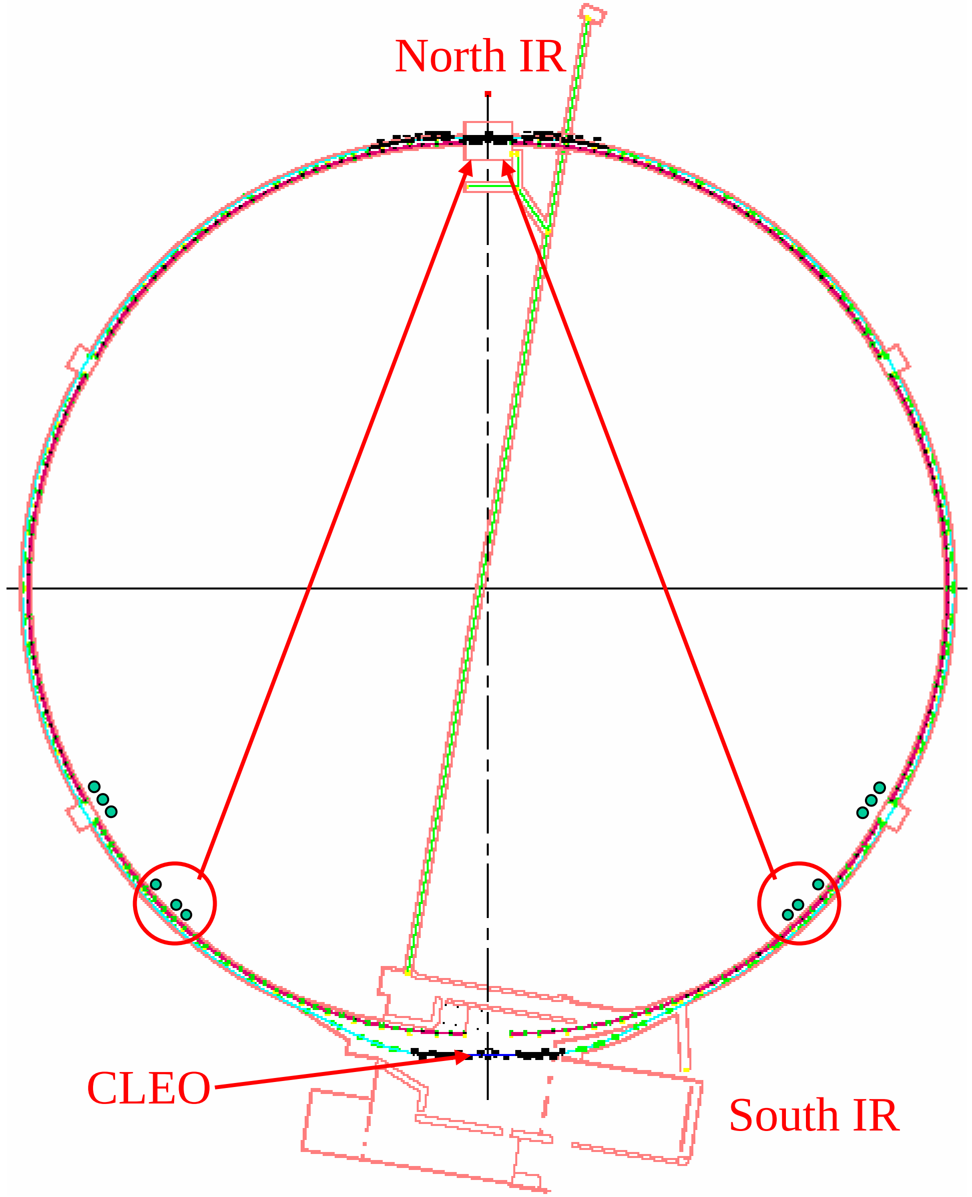


- Primary Goals
  - Electron cloud measurements
    - e^- cloud buildup in wigglers
    - e^- cloud amelioration in wigglers
    - Instability thresholds
    - Validate the ILC DR wiggler and vacuum chamber design (critical for the single 6 km positron ring option)
  - Ultra-low emittance operations and beam dynamics
    - 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
    - Study alignment issues and emittance tuning methods
    - Emittance measurement techniques
  - ILC DR hardware testing
    - Wigglers, wiggler vacuum chamber, SRF, kickers, alignment & survey techniques, instrumentation, *etc*.

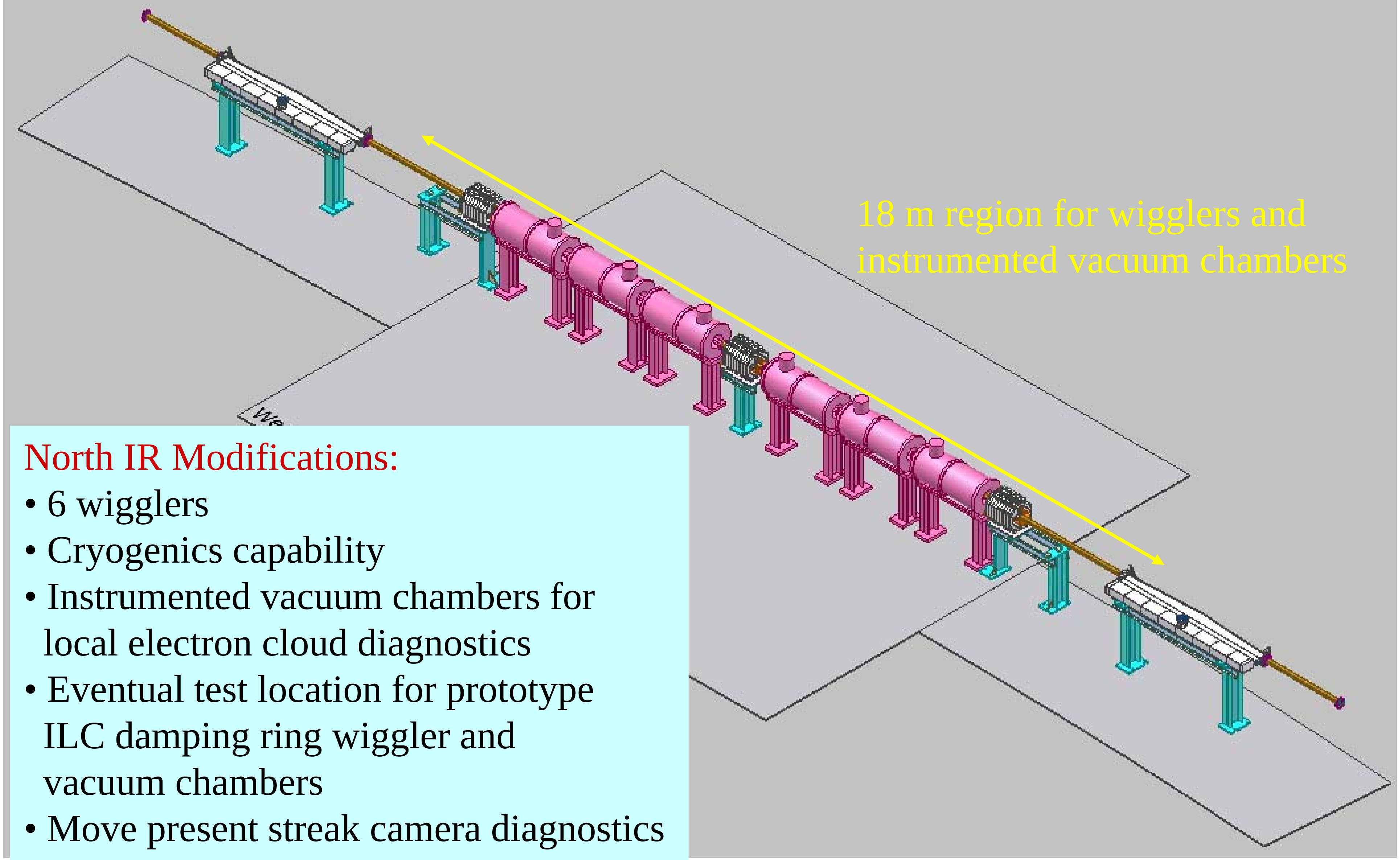
2) CESR Modifications

- Move 6 wigglers from the CESR arcs to the North IR (zero dispersion region)
  - New cryogenic transfer line required
  - Zero dispersion regions can be created locally around the wigglers left in the arcs
- Make South IR available for insertion devices and instrumentation
- Instrumentation and feedback upgrades





The North IR



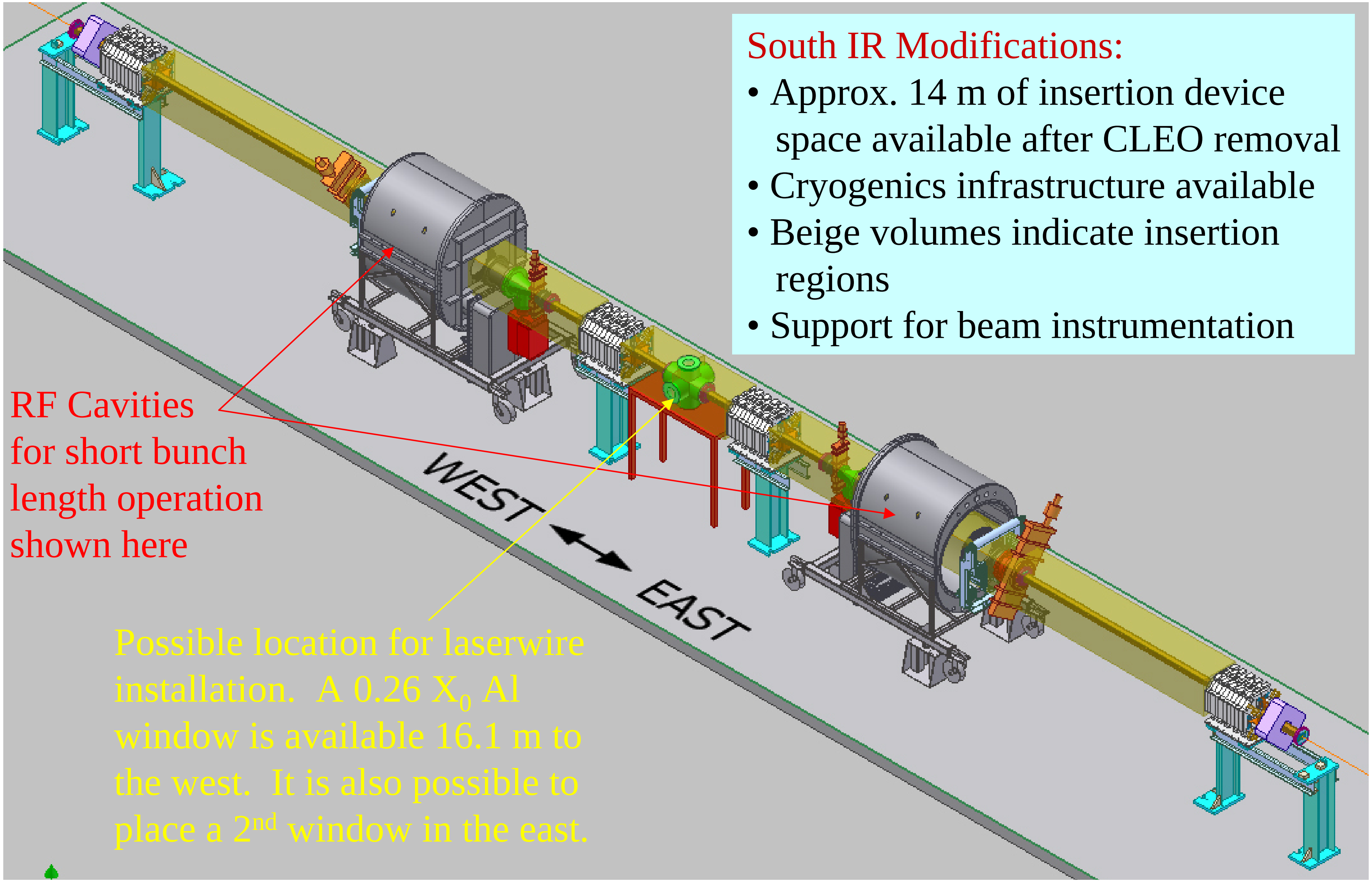
North IR Modifications:

- 6 wigglers
- Cryogenics capability
- Instrumented vacuum chambers for local electron cloud diagnostics
- Eventual test location for prototype ILC damping ring wiggler and vacuum chambers
- Move present streak camera diagnostics area to South IR

The South IR

South IR Modifications:

- Approx. 14 m of insertion device space available after CLEO removal
- Cryogenics infrastructure available
- Beige volumes indicate insertion regions
- Support for beam instrumentation



Instrumentation for Ultra-Low Emittance Measurement

- Typical Beam Sizes
  - Vertical: σ_y~10-12 μm
  - Horizontal: σ_x ~ 80 μm (at a zero dispersion point)
- Have considered laserwire and X-ray profile monitors
  - Fast X-ray imaging system (Alexander)
    - Core diagnostic for CesrTF
    - Plan for integrating systems into CHESS lines
  - Laserwire
    - CESR-c fast luminosity monitor offers window suitable for laserwire use
    - Detector potentially could be used for fast segmented readout of Compton photon distribution

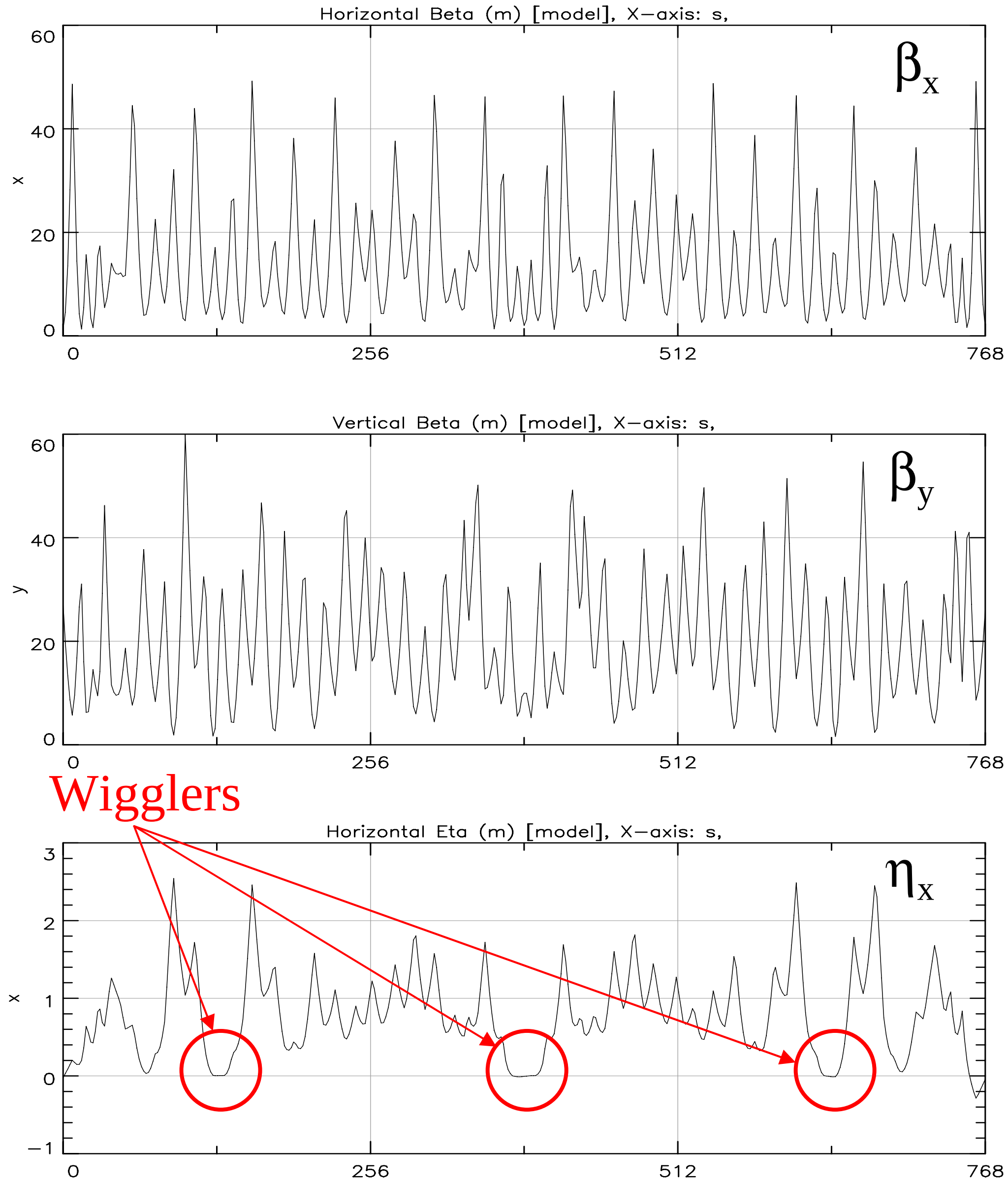
CESR Modifications Summary

- Answer to question #2:
  - Significant changes to the two IRs (however, certainly no more difficult than a detector and IR magnet upgrade)
  - Cryogenics transfer line must be run to the North IR
  - 6 wigglers must be moved to the North IR
  - Feedback amplifiers and electronics will be upgraded to allow operation with 4 ns bunch spacing
    - Could go to 2 ns with a more substantial upgrade – is this desirable?
  - Instrumentation must be upgraded
    - Extend multi-bunch turn-by-turn BPM system to entire ring (presently single sector)
    - High resolution emittance measurement techniques
- Conversion is relatively modest
  - Approximately 7 months of down time required (with existing laboratory resources) to remove CLEO and carry out the conversion
  - Key preparation work carried out between now and April 2008

3) Experimental Reach

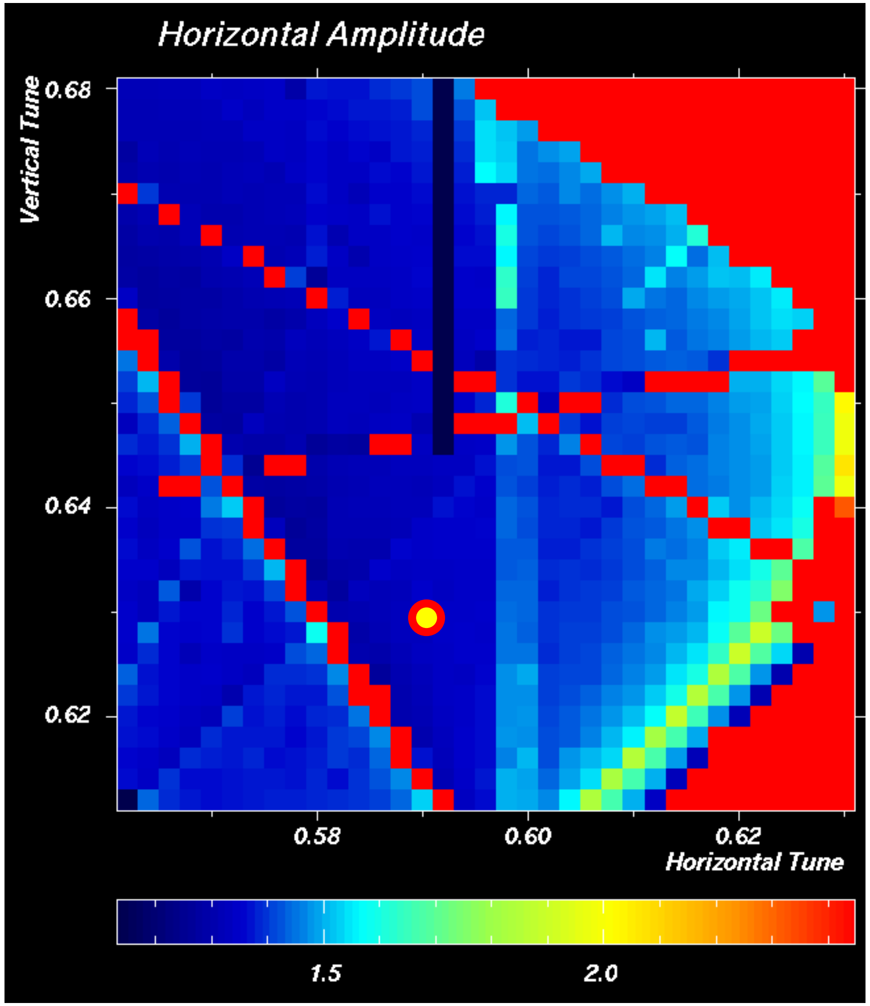
Baseline Lattice

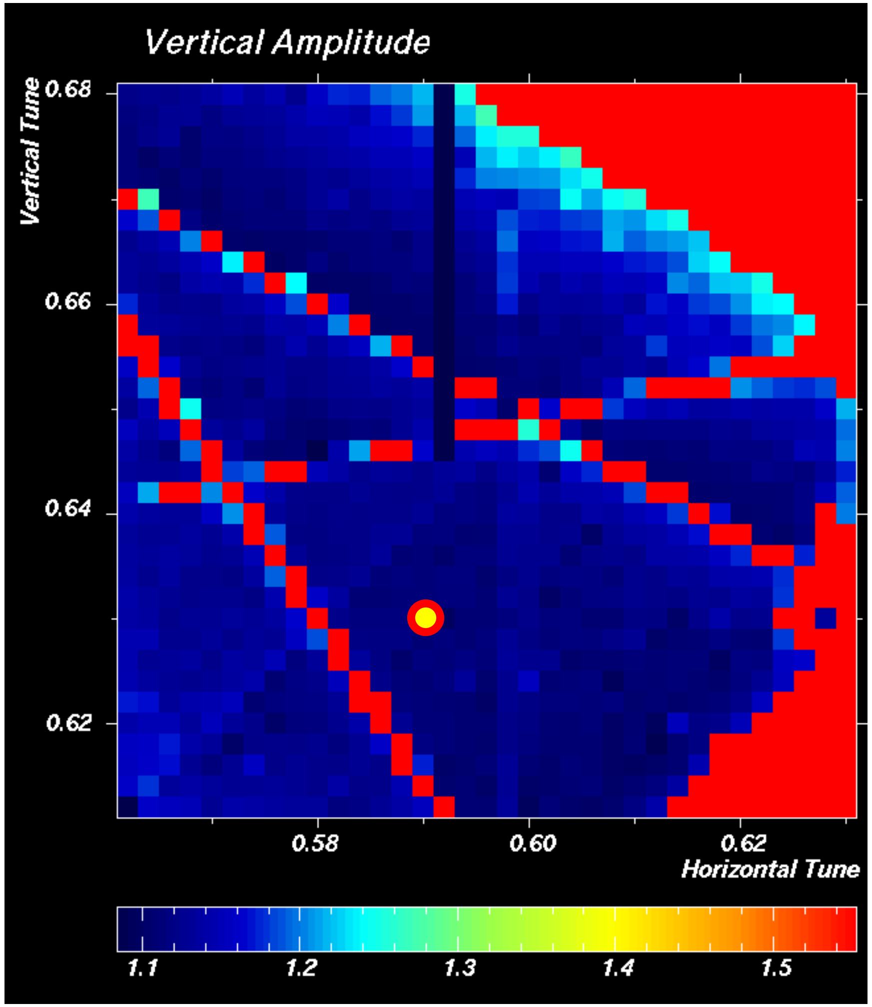
Parameter	Value
E	2.0 GeV
$N_{wiggler}$	12
B_{max}	2.1 T
ε_x	2.25 nm
Q_x	14.59
Q_y	9.63
Q_z	0.098
σ_E/E	8.6×10^{-4}
$\tau_{x,y}$	47 ms
σ_z (with V_{RF}=15MV)	6.8 mm
α_p	6.4×10^{-3}
$\tau_{Touschek}$(N_b=2×10^{10} & ε_y=5pm)	7 minutes



Tune scans

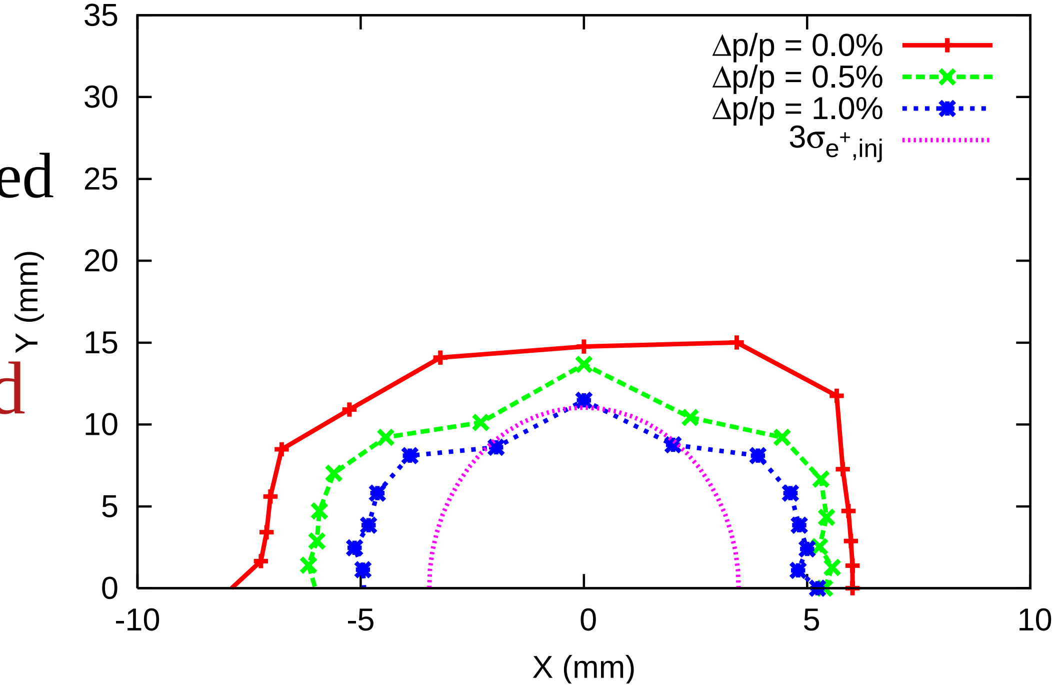
- Tune scans used to identify suitable working points





Lattice Evaluation

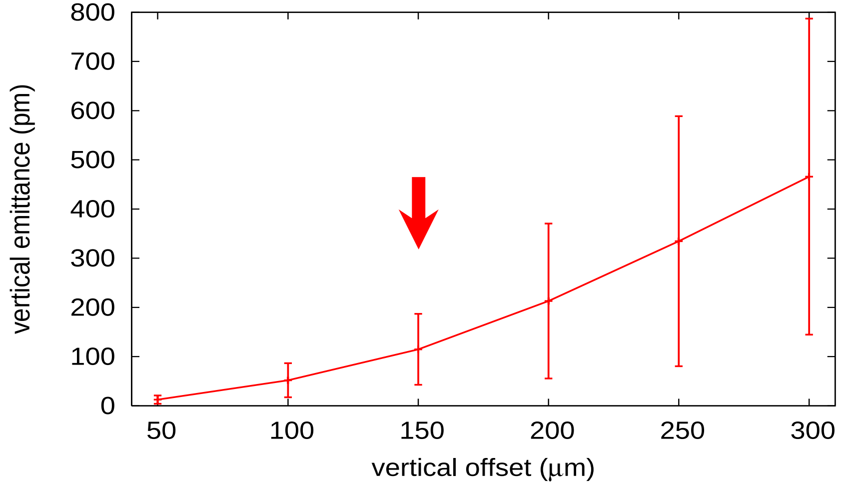
- Dynamic aperture
  - 1 damping time
  - Injected beam fully coupled
    - ex = 1 mm
    - ex = 500 nm
- Alignment sensitivity and low emittance correction algorithms
  - Simulations based on nominal CESR alignment
  - capabilities



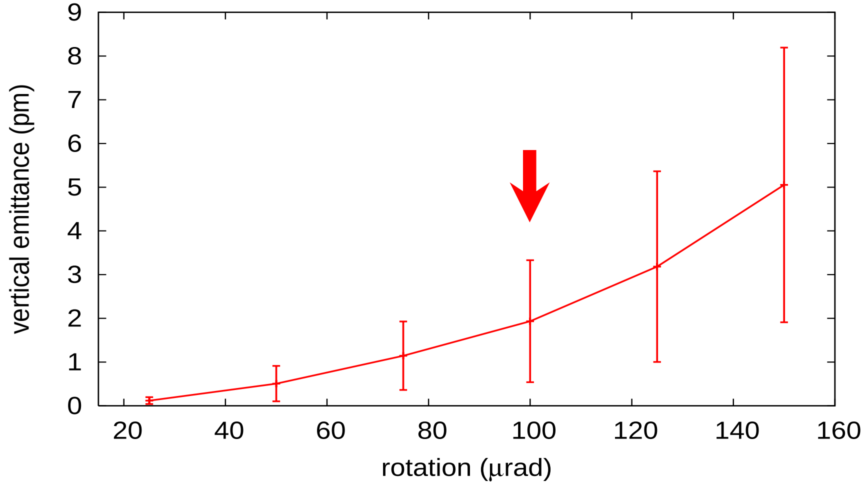
Misalignment	Nominal Value
Quadrupole, Bend and Wiggler Offsets	150 μm
Sextupole Offsets	300 μm
Quadrupole, Bend, Wiggler and Sextupole Rotations	100 μrad

Vertical Emittance Sensitivities (Selected Examples)

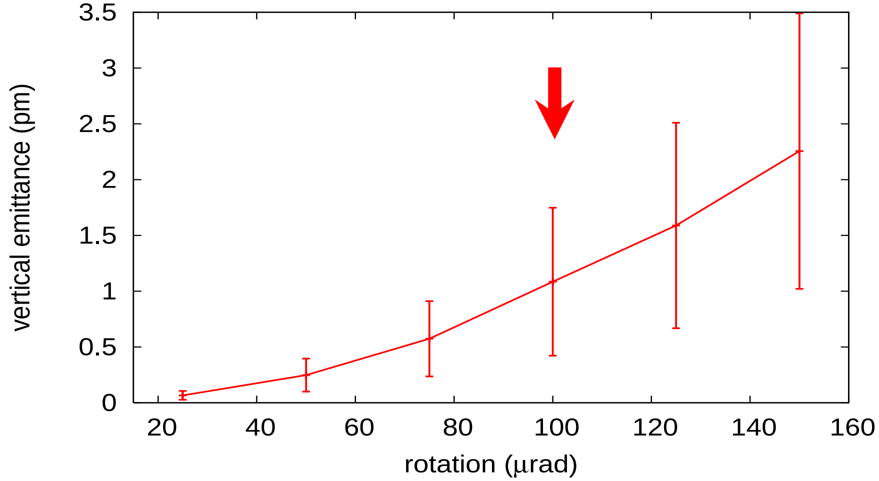
Emittance contribution from vertical quadrupole misalignment
(nominal = 150µm)



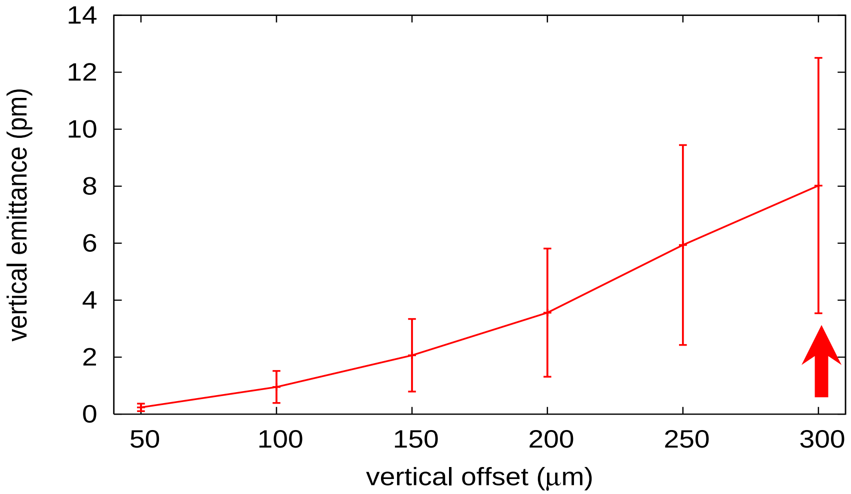
Emittance contribution from bend rotation
(nominal = 100µrad)



Emittance contribution from quad rotation
(nominal = 100µrad)

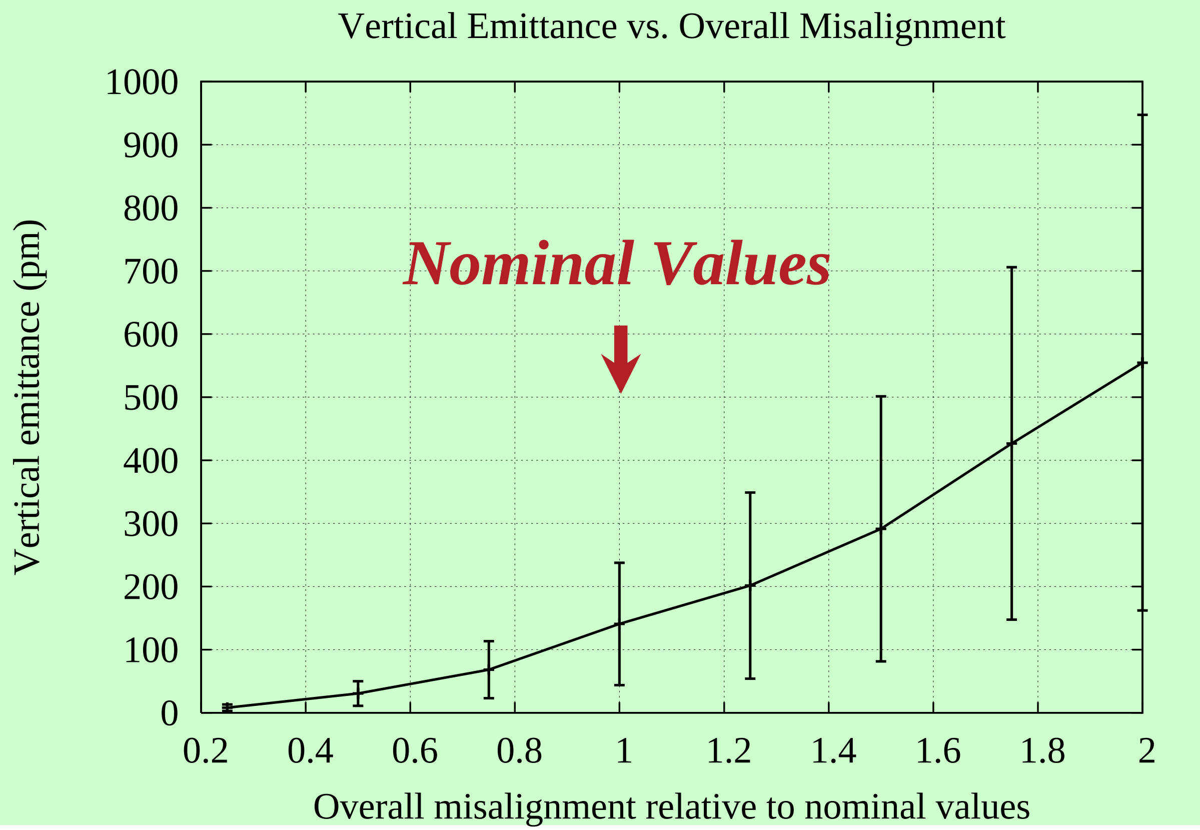


Emittance contribution from vertical sextupole misalignment
(nominal = 300µm)



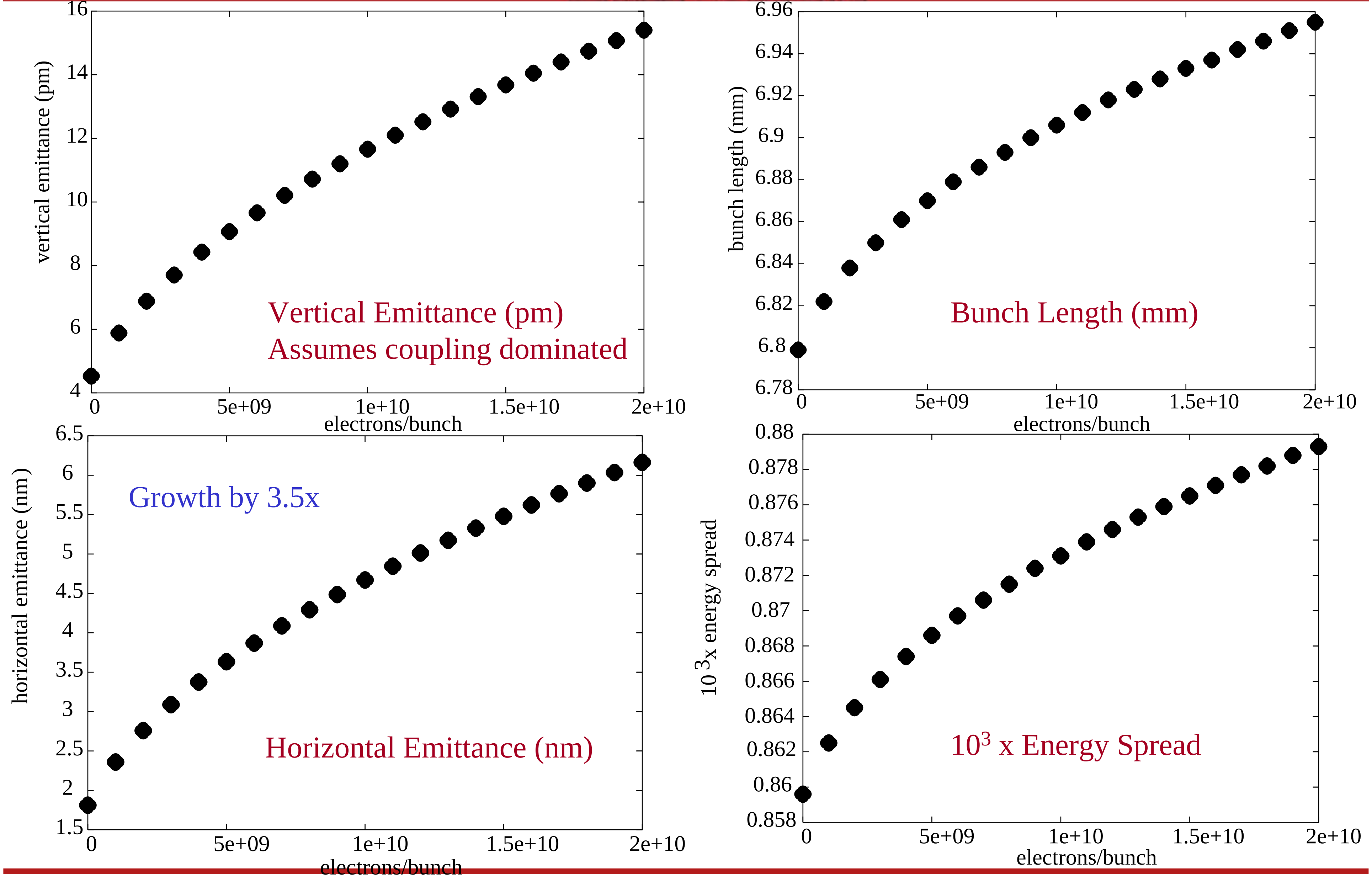
Low Emittance Operations

- Have evaluated our ability to correct for ring errors with the above lattice
  - Goal: ε_y~5-10 pm at zero current
  - Simulation results indicate that we can reasonably expect to meet our targets



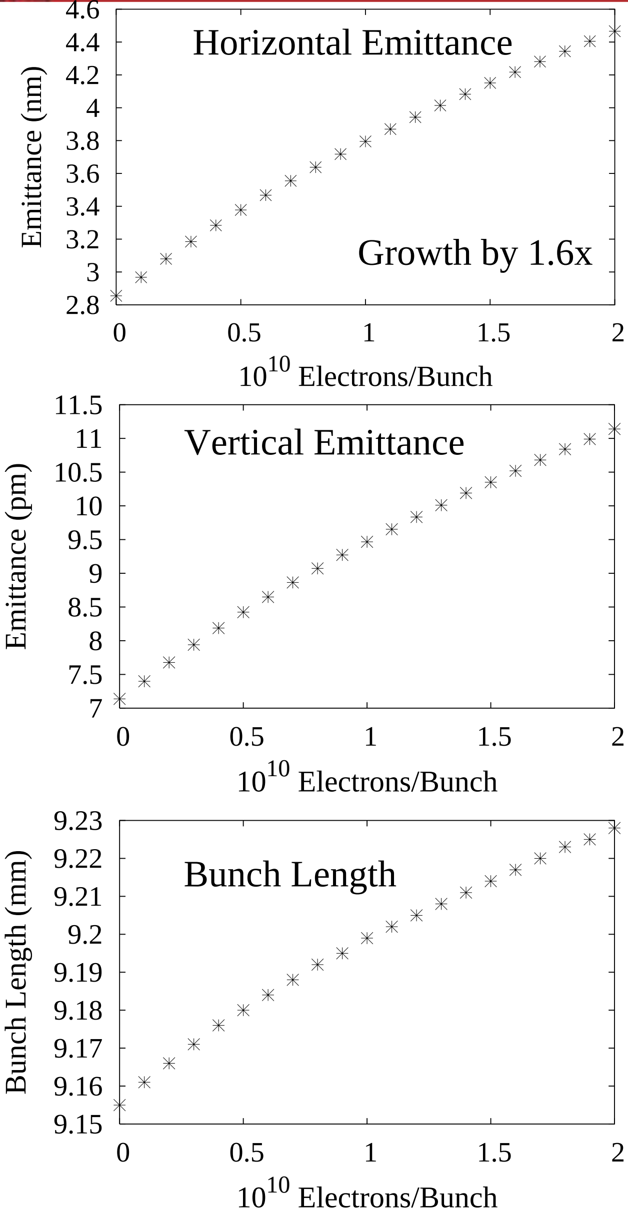
Correction Type	Average Value	95% Limit
Orbit Only	10.2 pm	21.4 pm
Orbit+Dispersion	3.9 pm	8.2 pm

IBS Evaluation (Baseline Lattice)



Alternate Operating Point

- Want to study ECE impact at ILC DR bunch currents
  - 2.5 GeV lattice with $\sigma_z \sim$ 9mm
  - Zero current vertical emittance chosen to be consistent with above alignment simulations
  - This emittance regime appears consistent with studying the impact of the ECE (and other effects) on emittance dilution
- Presently working towards more complete beam dynamics simulations



4) When Will R&D Results Become Available?

- Immediate Plans
  - Conceptual design work and validation complete by Fall
  - Proposal submission before end of year
- FY07
  - Engineering design work
  - Begin fabrication of items critical for 2008 down
- End of scheduled CESR-c/CLEO-c physics: Mar 31, 2008
- First dedicated CesrTF run in June 2008!
  - Alternating operation with CHESS
  - Estimate ~4 months/year of operations as a DR test facility
- This schedule is consistent with:
  - Early results before TDR completion
  - Significant program contributions before start of ILC construction

The Next 1.5 Years

FY07						FY08					
Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Ongoing Development Work for CesrTF											
Retrofit 2 spare CESR-c 8-pole wigglers with new vacuum chambers											
Preparatory Machine Studies: Electron Cloud, Ions, Low Emittance CESR-c Optics											
General Preparation: Cryogenic Transfer Lines to North IR, Instrumentation,…											

- Continue to develop the CesrTF Conversion Plan
- Prepare for wiggler vacuum chamber studies
  - Collaboration: SLAC, LBNL
- Machine Studies
  - See presentations by D. Rice and L. Schachter about electron cloud and ion studies
  - Plan to continue such work through the end of CESR-c
  - Low emittance CESR-c (existing machine layout) optics have been designed: $\varepsilon_x \sim 6.5$ nm
- General infrastructure preparation as can be supported by manpower and funding resources

Proposed Transition Plan

<table>
<tr><th colspan="12">FY08</th><th colspan="12">FY09</th></tr>
<tr><th colspan="2">Apr</th><th colspan="2">May</th><th colspan="2">Jun</th><th colspan="2">Jul</th><th colspan="2">Aug</th><th colspan="2">Sept</th><th colspan="2">Oct</th><th colspan="2">Nov</th><th colspan="2">Dec</th><th colspan="2">Jan</th><th colspan="2">Feb</th><th colspan="2">Mar</th></tr>
<tr><td>Down</td><td colspan="3">CHESS</td><td colspan="2">Cesr TF</td><td colspan="6">Down for North IR Conversion</td><td colspan="3">CHESS</td><td colspan="3">CesrTF</td><td colspan="6">Down for South IR Conversion (4 months)</td></tr>
<tr><td colspan="6">Install/Test 2 wigglers w/modified Vacuum Chambers</td><td colspan="12">Install/Test full wiggler complement (including cryo support) and vacuum diagnostics in North IR.</td><td colspan="6"></td></tr>
<tr><td colspan="24">Instrumentation and Vacuum Diagnostics Upgrades</td></tr>
<tr><td colspan="24">LiCAS Alignment/Survey Upgrades</td></tr>
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- Initial focus on local ECE measurements
  - Provides key TDR information
  - Provides guidance for subsequent CesrTF investigations
- Start exploring low emittance operations

Prototype Operations Schedule

FY09						FY10					
May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr

CHESS	CesrTF	Down	CHESS	CesrTF	CHESS	CesrTF	Down
Supporting work can occur here (eg, instrument-ation)	Flexible Operations and Machine Access		Supporting work can occur here (eg, instrument-ation)	Flexible Operations and Machine Access	Supporting work can occur here (eg, instrument-ation)	Flexible Operations and Machine Access	Install ILC Proto-type Wig-gler?
Running periods approximately 50% CHESS/50% CesrTF			Running periods approximately 50% CHESS/50% CesrTF		Running periods approximately 50% CHESS/50% CesrTF		

- Schedule along these lines presently under consideration
  - Other variations clearly possible
  - Need input from ILC DR community as to machine time and operating schedule during CesrTF "runs"
  - Provides 4 dedicated running periods prior to TDR completion
- Envision a 5-year NSF operations proposal: April 1, 2008 – March 31, 2013
  - Last 3 years would have a similar operating schedule to the FY09-FY10 version

Organization

- CesrTF will be a collaborative endeavor
  - LEPP will operate the machine
  - LEPP will also contribute to the experimental program
  - We expect to provide a significant fraction of the machine time to collaborator experiments
  - LEPP will provide accelerator physics and machine support for collaborator experiments
- Expressions of Interest from members of the damping ring community are most welcome!

CesrTF R&D Program

- Cornell Interests
  - Electron cloud studies (with particular focus on its growth and amelioration in the wigglers)
  - Low emittance operation over full range of ILC bunch currents
    - Tuning (WBS 2.1.3)
    - Study impact of beam dynamics effects (WBS 2.2.3 – electron cloud, WBS 2.2.4 – ions, WBS 2.2.5 – IBS/Touschek lifetime , …)
  - System prototype tests
    - ILC wiggler prototype along with vacuum chamber (WBS 3.4.6, WBS 3.1.1)
    - Instrumentation and methods (WBS 3.7.3 – fast X-ray beam profile monitor, WBS 3.7.5 – fast dispersion measurements, …)
    - Other (WBS 3.5.1 – kicker, WBS 3.6.1 – SRF)
- Collaboration/Coordination
  - Electron Cloud Simulation/Measurement/Suppression (M. Pivi, L. Wang – SLAC; L. Schachter – Technion; K. Harkay – ANL)
  - Wiggler vacuum chamber (S. Marks, *etal*. – LBNL; M. Pivi, L. Wang – SLAC)
  - Alignment and Survey (A. Reichold, D. Urner – LiCAS, Oxford)
  - Requirements and experimental plan (J. Urakawa – KEK; A. Wolski – Cockroft Inst.)
  - Low emittance instrumentation (G. Blair – Adams Inst.)
  - Simulation (A. Wolski – Cockroft Inst., M. Pivi – SLAC; P. Spetznouris – FNAL)

Conclusion

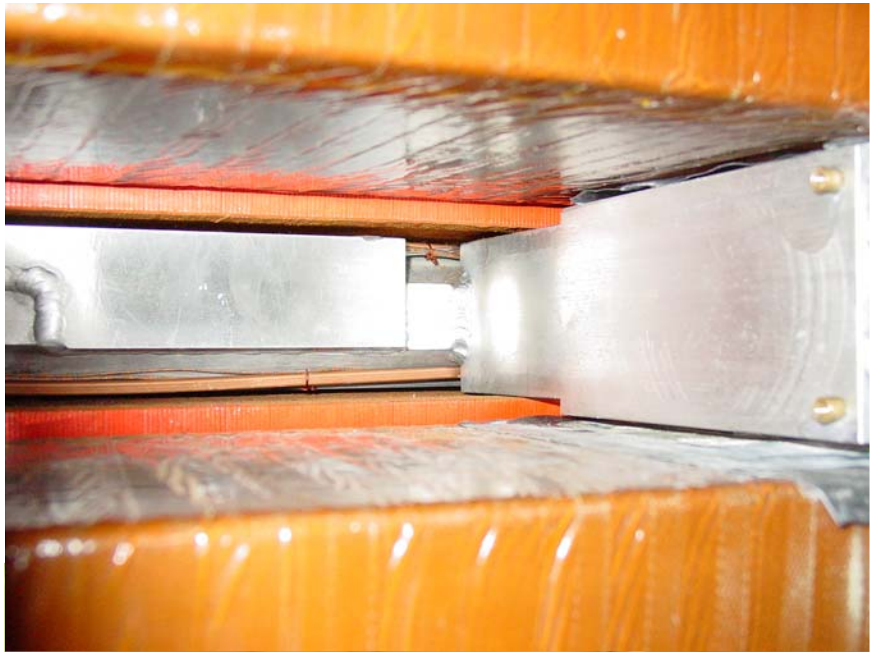
- CesrTF conceptual design work is ongoing
  - The machine offers unique features for critical ILC damping ring R&D
    - CESR-c wigglers
    - Operation with positrons and electrons
    - Flexible bunch configuration
    - Wide range in operating energy
  - Simulations indicate that the emittance reach is suitable for a range of damping ring beam dynamics studies
  - The experimental schedule will allow timely results for ILC damping ring R&D
- We would like to extend an open invitation to anyone interested in collaborating on this project

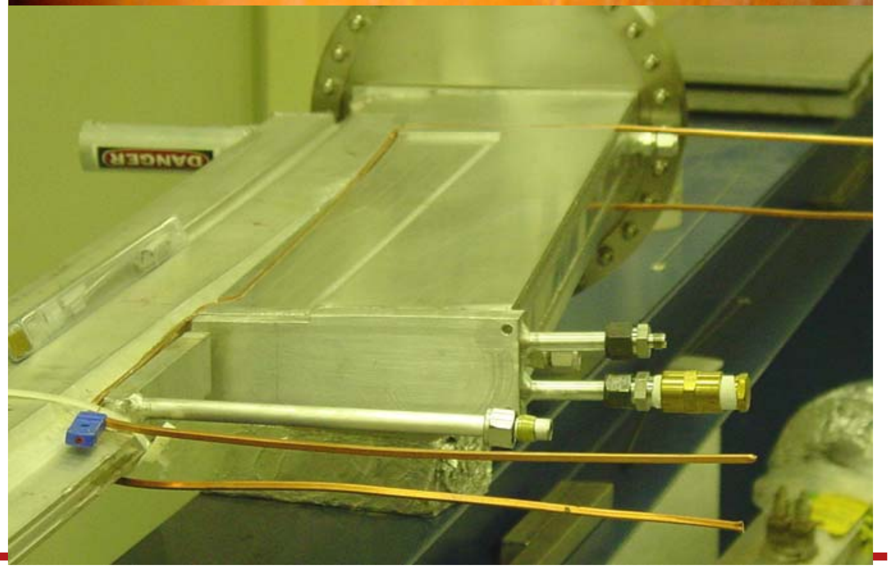
Done

- Extra Slides Follow

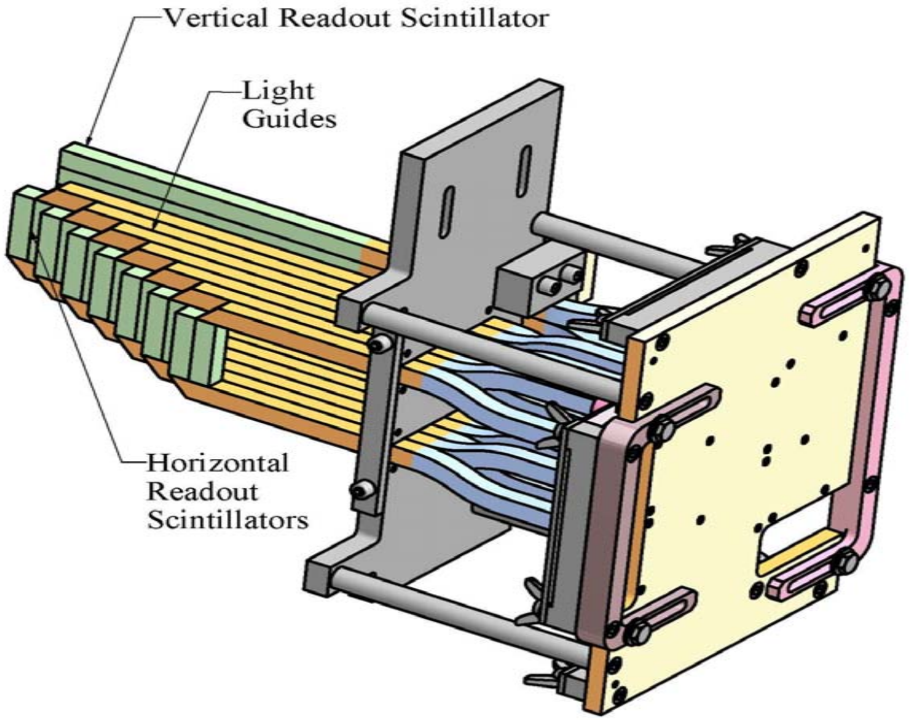
Luminosity Monitor Window

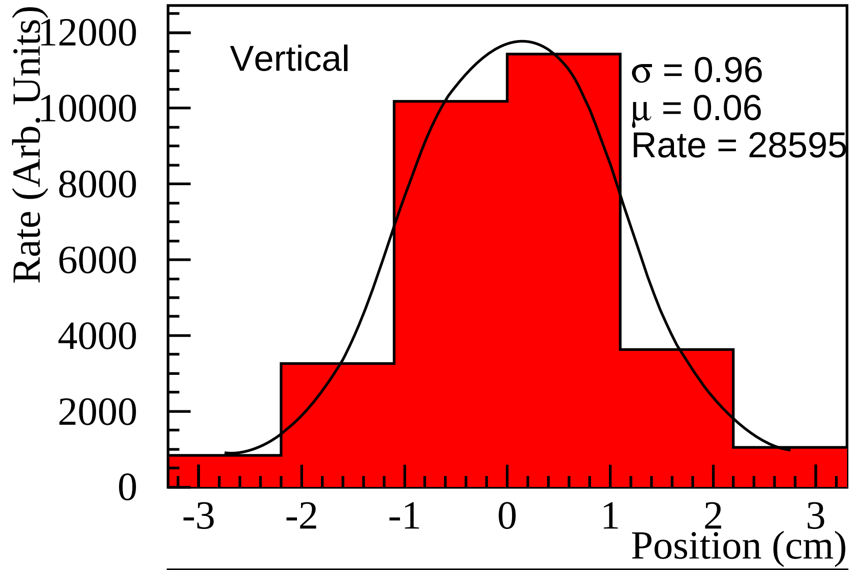
- Available for laserwire use
- Aluminum γ Window
  - Faces into South IR
  - ~1 in thick (0.26 X_0)
  - 16.1 m from center of CesrTF insertion region
  - Looks at e^+ beam
  - Aperture (for 16.1 m):
    - +/- 1.7 mrad vertical
    - -7 to +2 mrad horizontal (negative is to inside of ring)
- A similar window, but with smaller horizontal aperture, could potentially be added for monitoring the electron beam

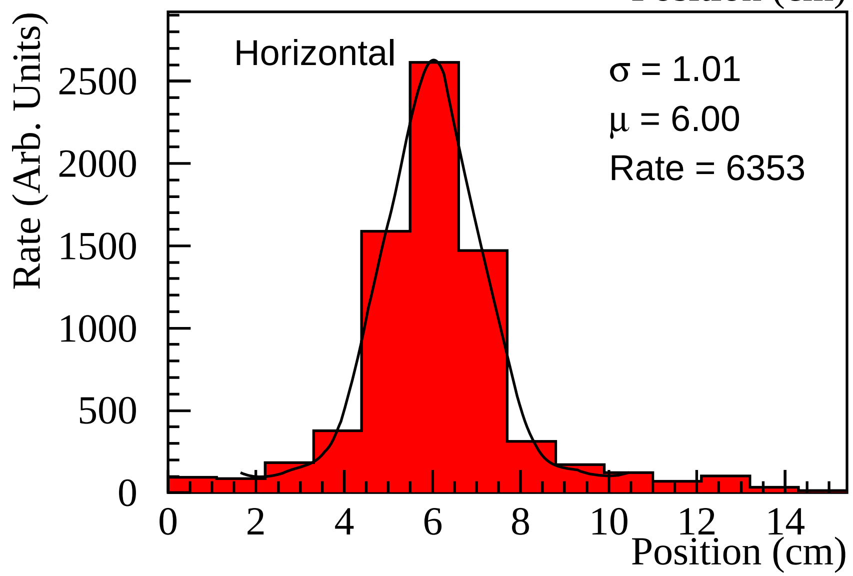




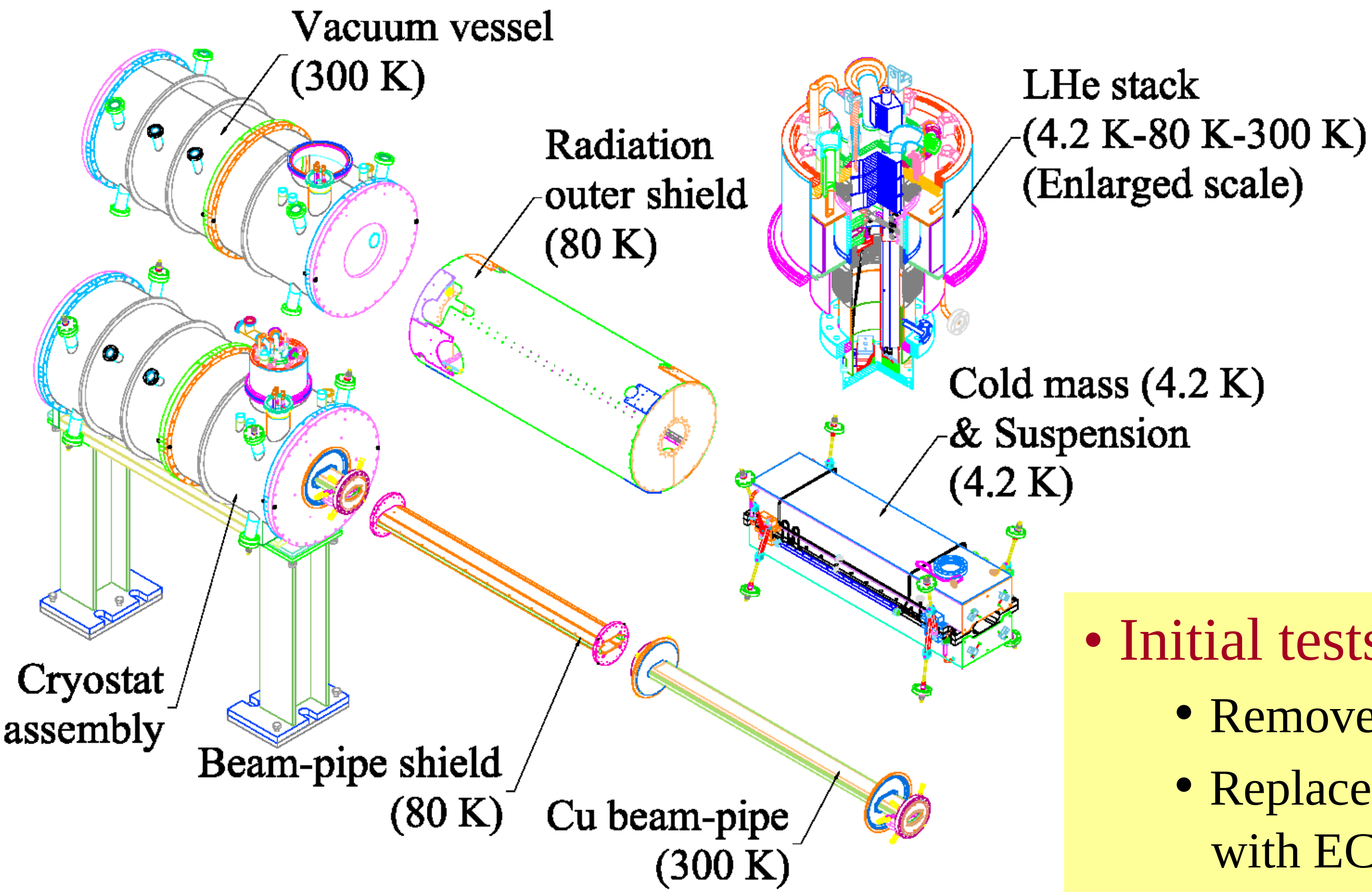
- Segmented Scintillator Detector
  - Offers possibility of more detailed signal analysis with background suppression
  - Fast R7400 PMTs offer bunch-by-bunch response
  - Well-understood operation





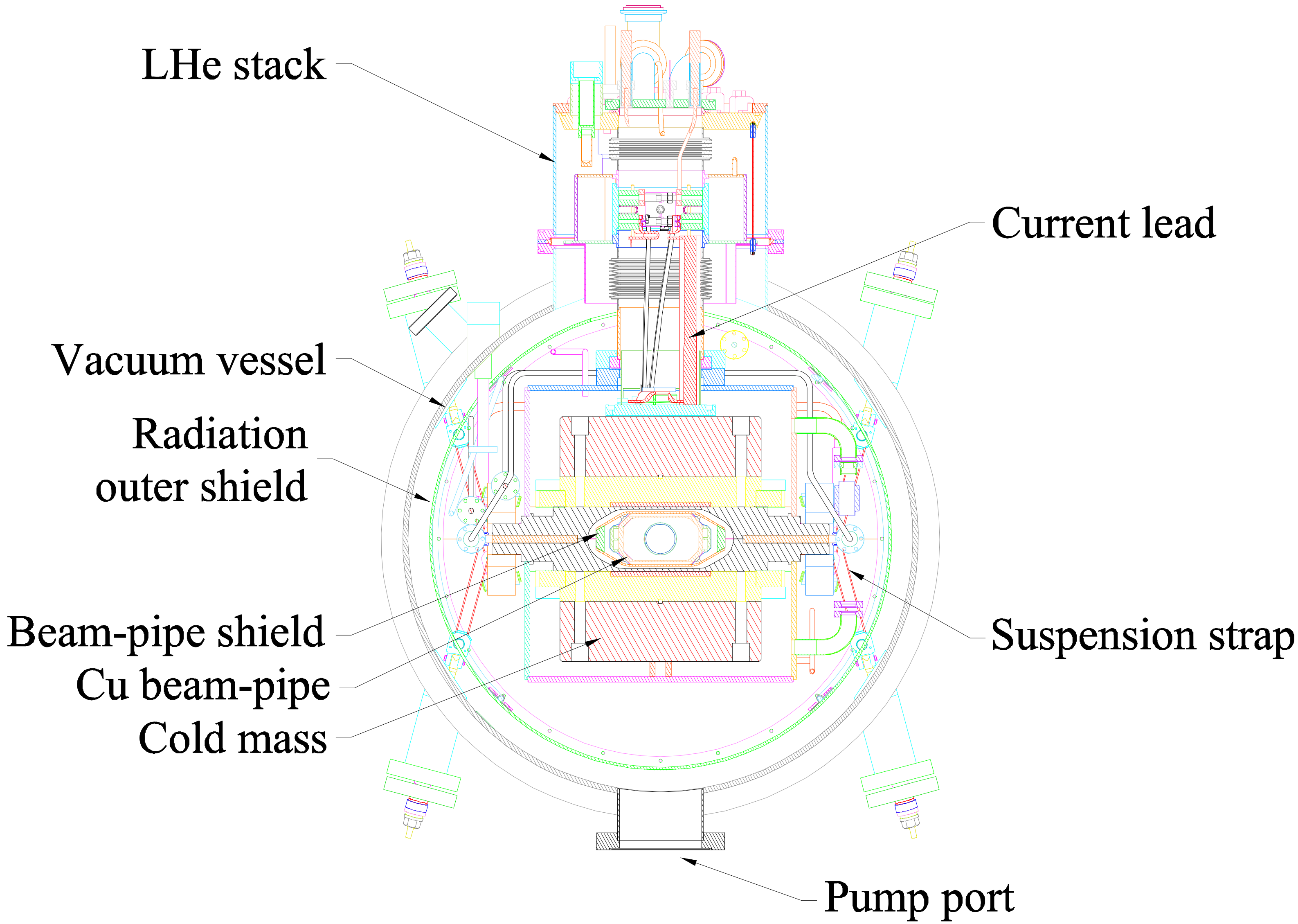


CESR-c Wiggler

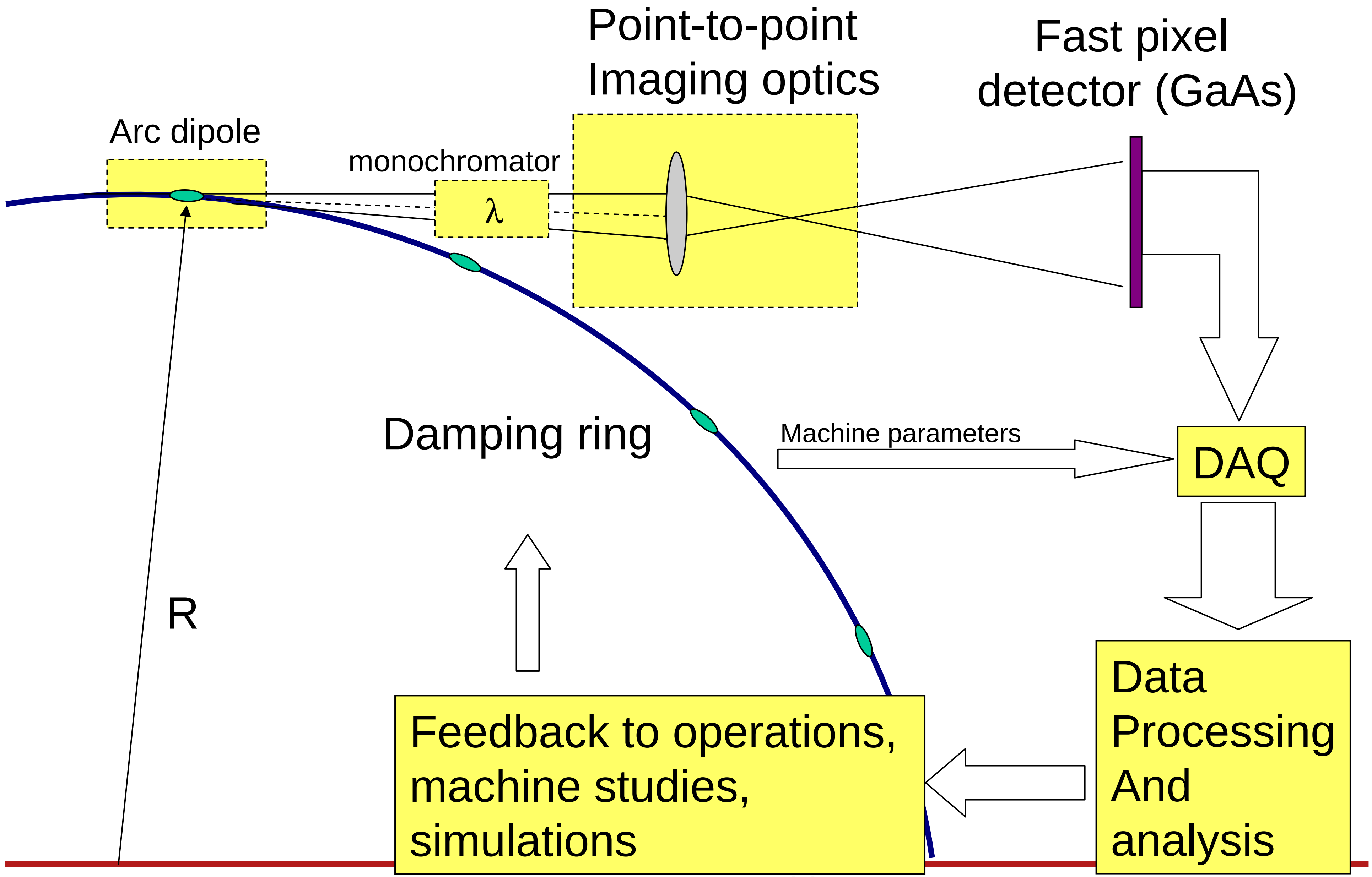


- Initial tests in CesrTF
  - Remove Cu beam-pipe
  - Replace with beam-pipe with ECE suppression and diagnostics hardware

CESR-c Wiggler End View



X-ray Beamsize Concept



GaAs Detector

First bunch-by-bunch beam size data in CHESS conditions ⇨
Significant CHESS support

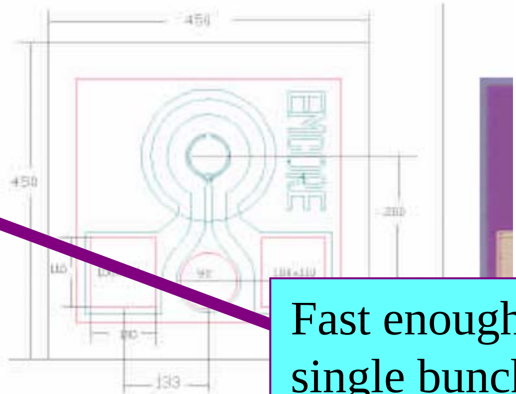
10 Gbps GaAs PIN Photodiode*

Product Description

EMCORE's 10 Gbps Gallium Arsenide (GaAs) PIN photodiode is designed for multimode fiber
EMCORE's own state-of-the-art MOCVD wafer foundry and device fabrication facility guarantees
fabrication source of package ready die to meet the growing needs of fiber optic component ma
device performance and robust operation makes this the superior device for high speed multimode
applications.

Features

- Data rates of 10 Gb/s
- Excellent responsivity
- Large aperture size
- Low capacitance
- Low dark current

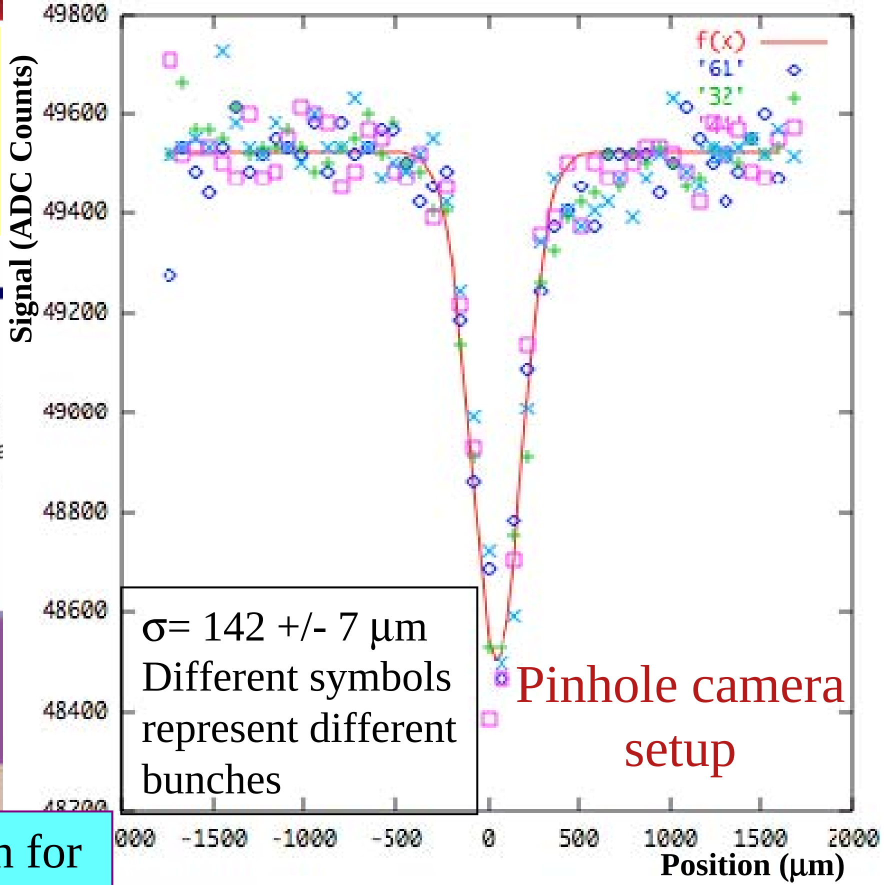


Fast enough for single bunch resolution

Product Specifications

Electro-Optical Characteristics (T = 30°C)

	Conditions	Min.	Typical	Max.	Unit
Speed	-1.6 V		8.5		GHz
Responsivity	3 to -26 dBm, 850 nm Epoxy coated, n=1.6		.5		A/W
Active Area (aperture)	-		60		µm
Rise/Fall Time	20% / 80%, -1.6 V bias		30/35		ps
Dark Current	-1.6 V, -70 dBm		<.2	1	nA
Capacitance	-1.6 V, 1 MHz		.28		pF
Reverse Breakdown	1 µA	20	50		V
Reflectivity	Epoxy coated, n=1.6			1	%



σ= 142 +/- 7 µm
Different symbols represent different bunches

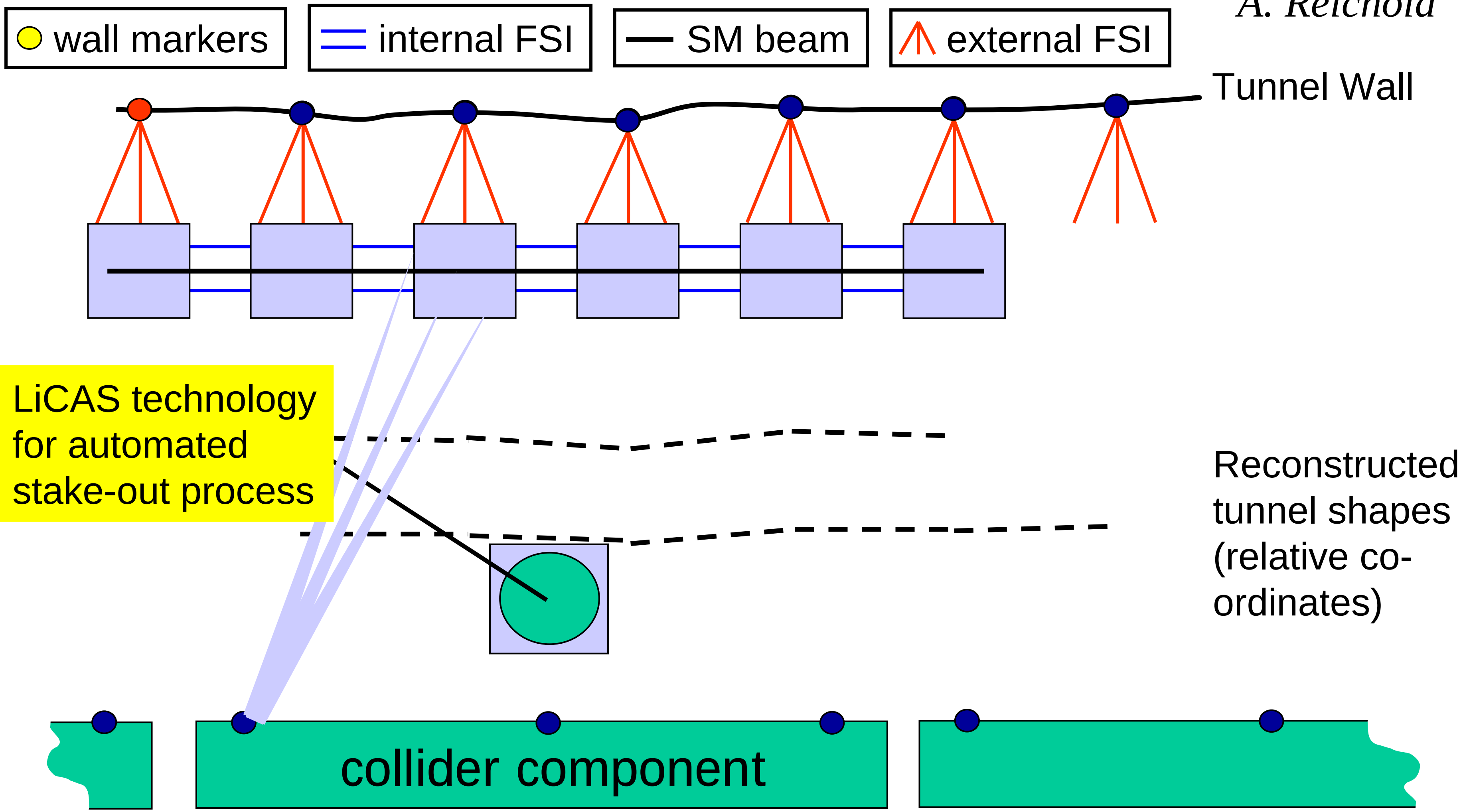
Pinhole camera setup

NEW: GaAs arrays from Hamamatsu
- 1x512 linear array
- 25 µm pitch
- 1st sample should arrive soon

Rapid Tunnel Reference Surveyor (RTRS) Concept

Proposal submitted for ILC DR alignment and survey studies using CesrTF

A. Reichold



Lattice Comparisons

	CesrTF	ATF	TESLA	ILC 6.7 km
Cicumference (m)	768	139	17000	6695
Energy (GeV)	2.0	1.28	5.0	5.0
Horizontal Emittance (nm)	2.25	1.0	5.1	0.515
Vertical Emittance (pm)	5.0 (target)	4.5	1.4	1.4
Energy Spread ($x10^{-3}$)	8.6 $x10^{-4}$	5.5 $x10^{-4}$	1.3 $x10^{-3}$	1.3 $x10^{-3}$
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	52.397
Q_y	9.59	8.759	41.180	49.305