III. CesrTA Configuration and Optics for Ultra-Low Emittance

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Introduction

- Outline
  - **CESR Overview**
    - CESR Layout
    - Injector
    - Wigglers
  - Modifications for CesrTA
  - Optics for low-emittance operation

CESR Layout / Injector

e+/e- colliding beams 1.5-5.5 GeV

Circumference 768 m

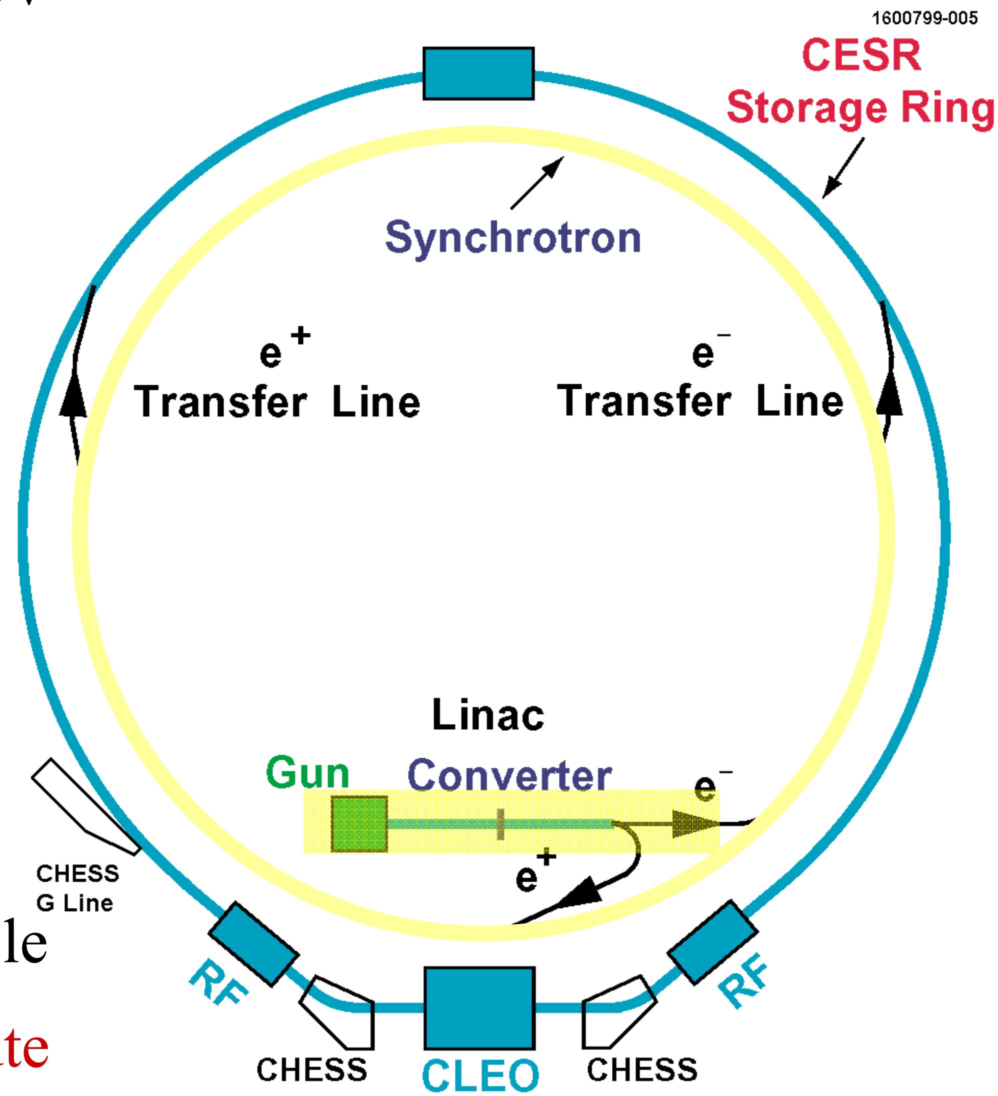
45 bunches/beam in trains, electrostatic separation

Currents in CESR to
2x350 mA @ 5.3 GeV
>1x150 mA @1.9 GeV

120 keV gridded gun
150/300 MeV linac
Full energy synchrotron (60 Hz)

Flexible timing, ~20 bunches/cycle

Filling rates to 100/300 mA/minute



RF Numerology

- RF frequencies critical to CesrTA bunch patterns
  - CESR / Synchrotron / Linac / Gun prebuncher
  - All RF systems phase locked from common source
  - Highest common frequency 71.4 MHz (T=14 ns)

System	Frequency	Mult x h.c.f.	Bucket Spacing	Harmonic # in CESR
Highest common freq.	71.4 MHz	1	14 ns	183
Injector Prebuncher	214 MHz	3		
Linac	2856 MHz	40		
Synchrotron	714 MHz	10		
CESR	499.8 MHz	7	2 ns	1281

Multiple CESR buckets on 14 ns pattern can be filled on a single injection cycle. Injector RF chain can be phase shifted between injection cycles to fill any CESR buckets.

Wiggler Magnets

- The OCS6 ILC Damping Ring lattice employs 80 wiggler magnets to achieve its radiation-determined parameters to meet ILC requirements.
    - Effective length: 2.5 m
    - Peak operating field: 1.67 T (max 2.1 T)
    - Magnetic period: 40 cm
- The 12 wiggler magnets in CESR were designed for CESR-c conditions – e+/e- colliding beams 1.5-2.5 GeV beam energy.
- The basic magnetic properties of the CESR-c wigglers closely match the ILC DR design.

Wiggler Magnets

- Several considerations for CESR-c operation determined the principal wiggler properties:
  - Large vertical aperture – 5 cm in warm bore
    - w/ 2.1 T field → super-ferric technology
  - ± 2 cm horizontal "pretzel" orbits
    - wide good-field region – ΔB_Y = +0.0, -0.3% over aperture
  - Flexibility in operating field
    - Even # poles to reduce center-end pole difference effects
  - Ring layout constraints
    - ~1.7 m flange-flange

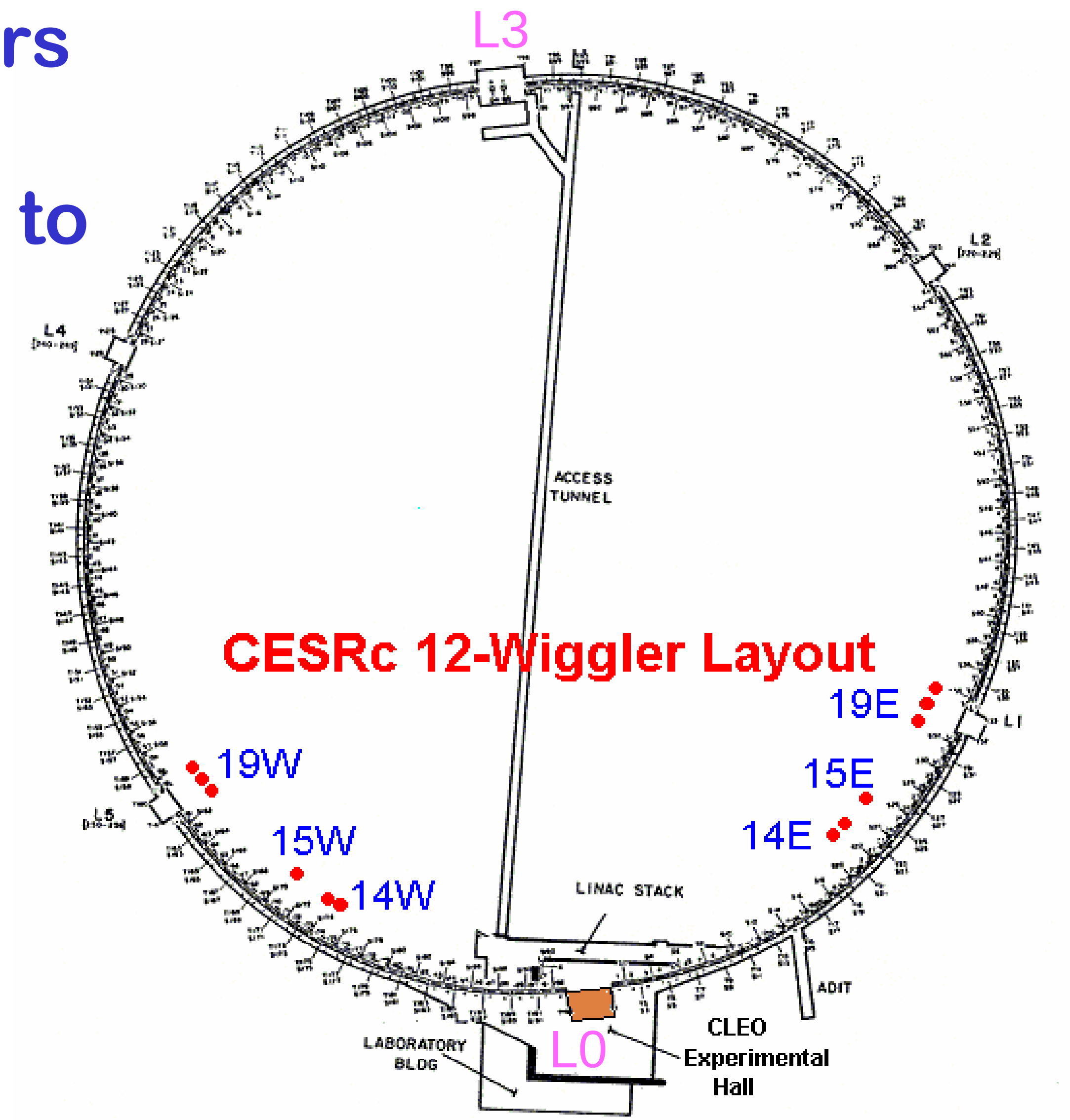
Wiggler Parameters

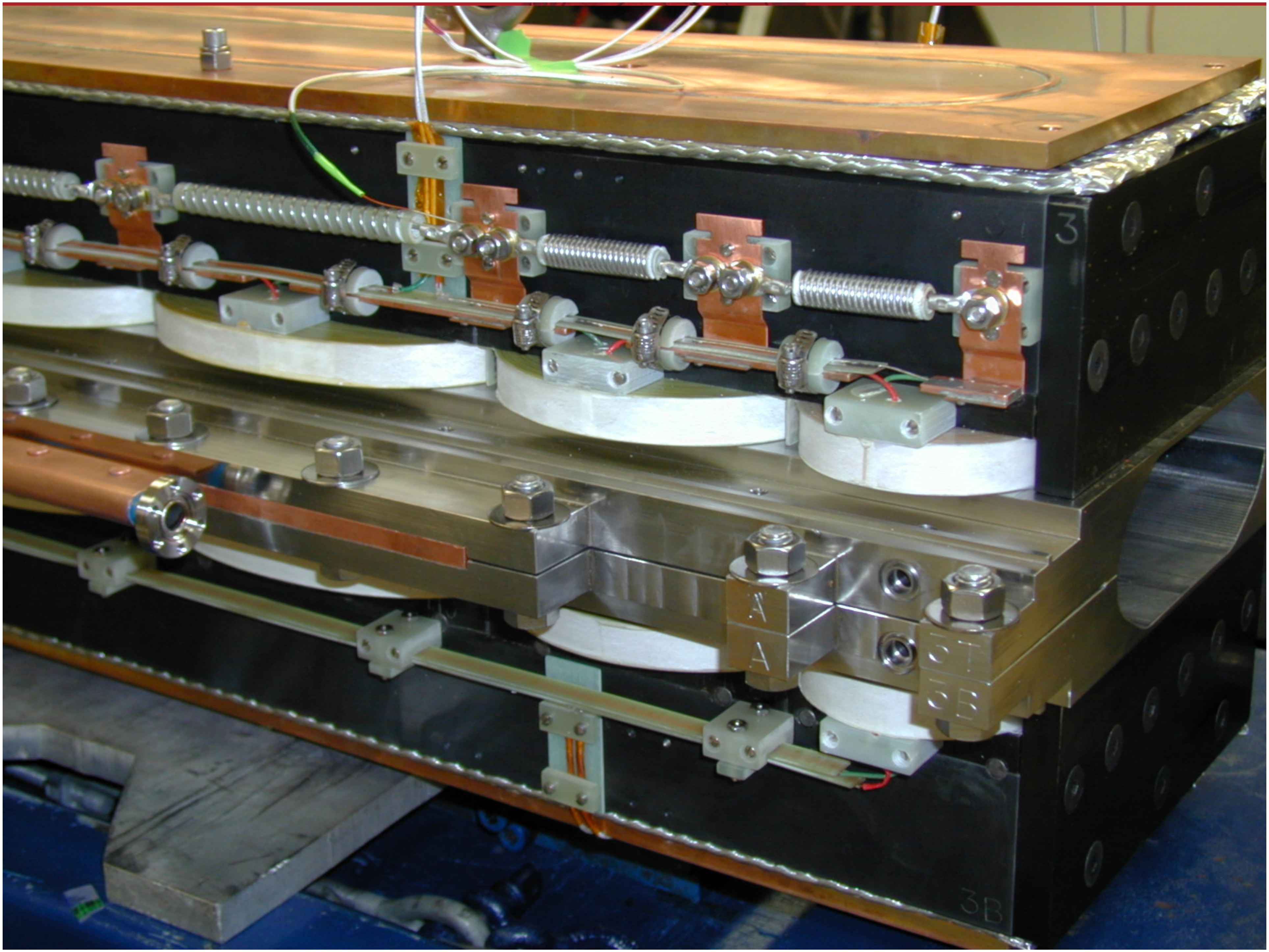
Parameter	Value
Technology	Super-ferric
Peak Field	1.5-2.1 T
Wiggler Length	1.3 m
Number of wigglers	12
Field period	40 cm
Transv. width of poles	23 cm
Number of poles	6-20 cm, 2-10 cm, 2-5 cm
Pole gap	7.6 cm
Operating Current (2.1 T)	185 A
Wire operating margin	50%

CESR-c Wiggler Layout

12 damping wigglers are placed in 6 clusters according to available space in CESR.

- Cryogen distribution
- Optics manipulation

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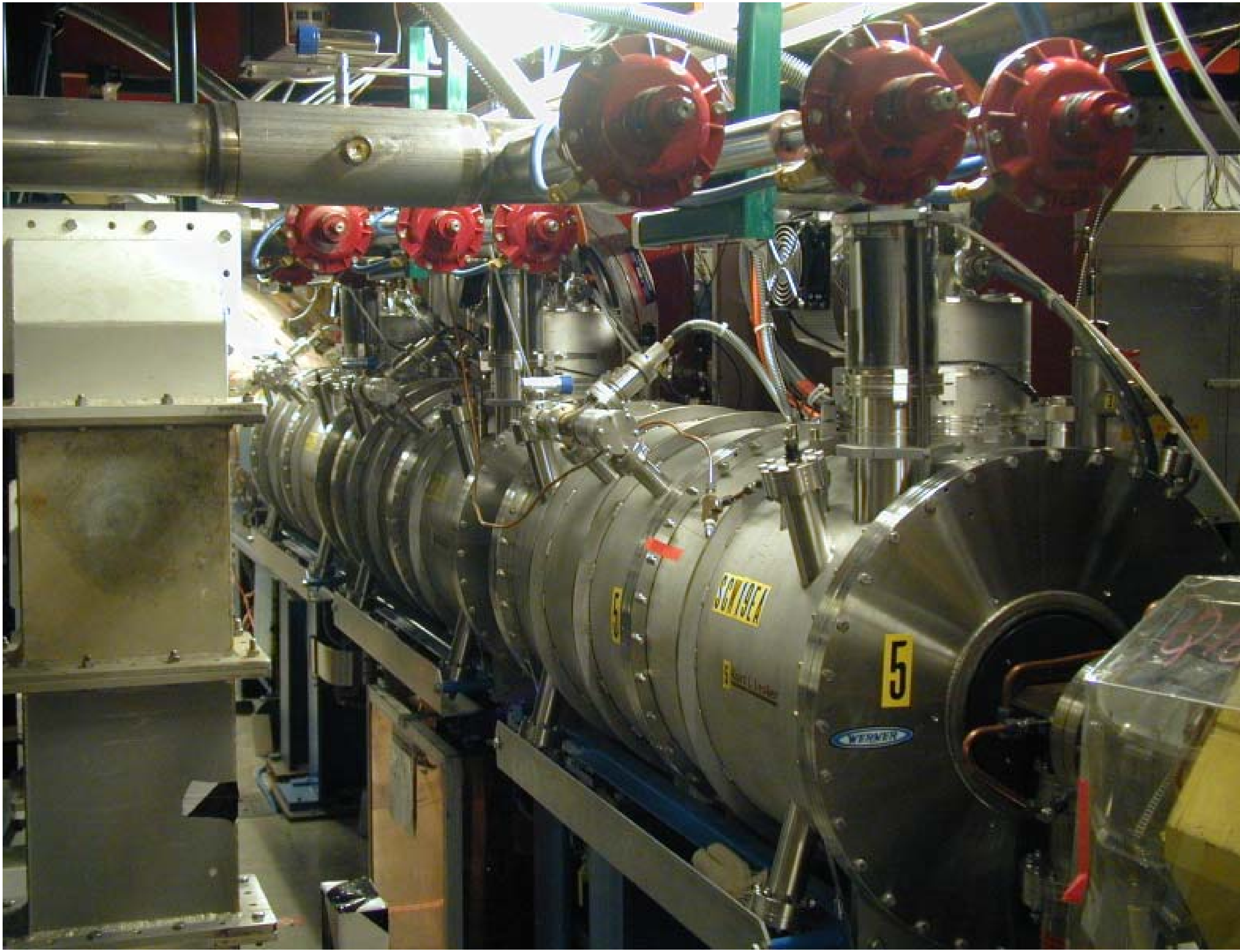
A
A
3B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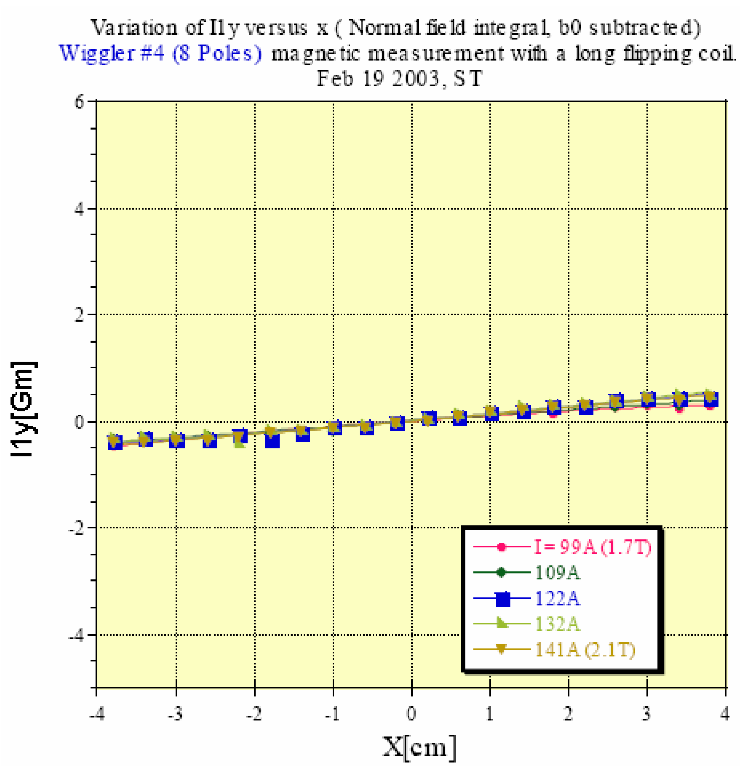
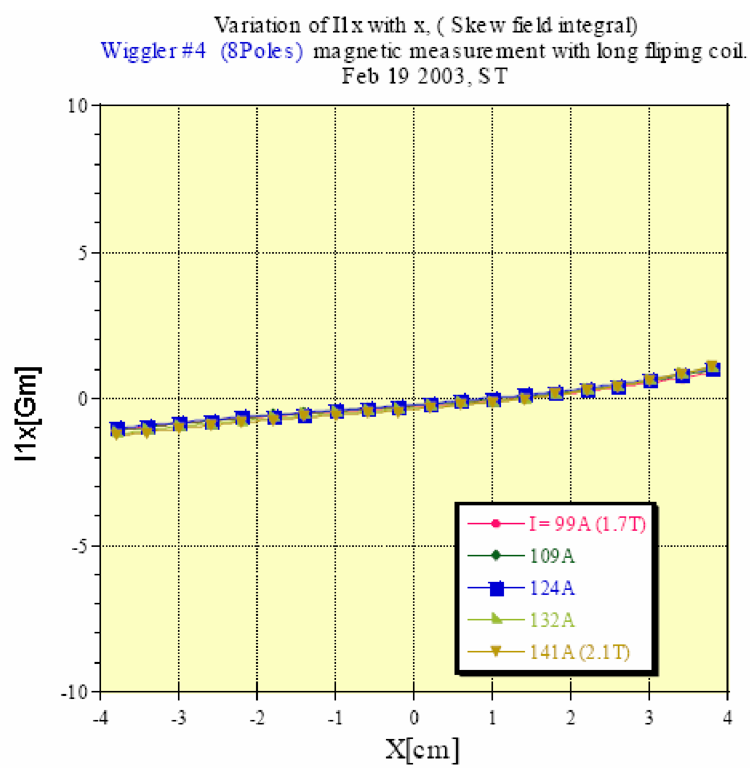
Wiggler Field Quality Validation

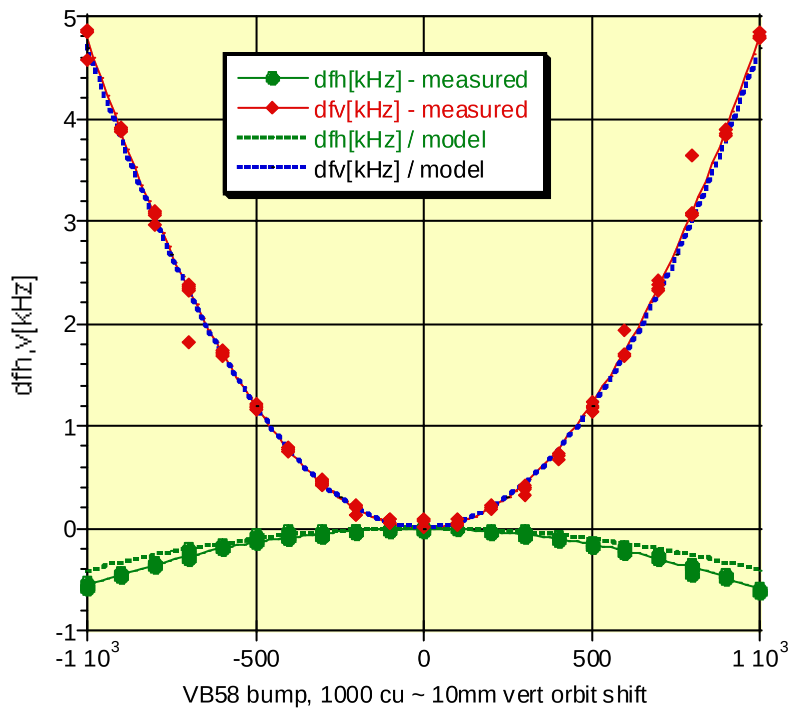
- Rigorous training and measurement program
  - Most trained with 2-3 quenches to 2.3 T – no operational problems with magnets.
  - Hall probe and long flip coil, folded flip coil measurements

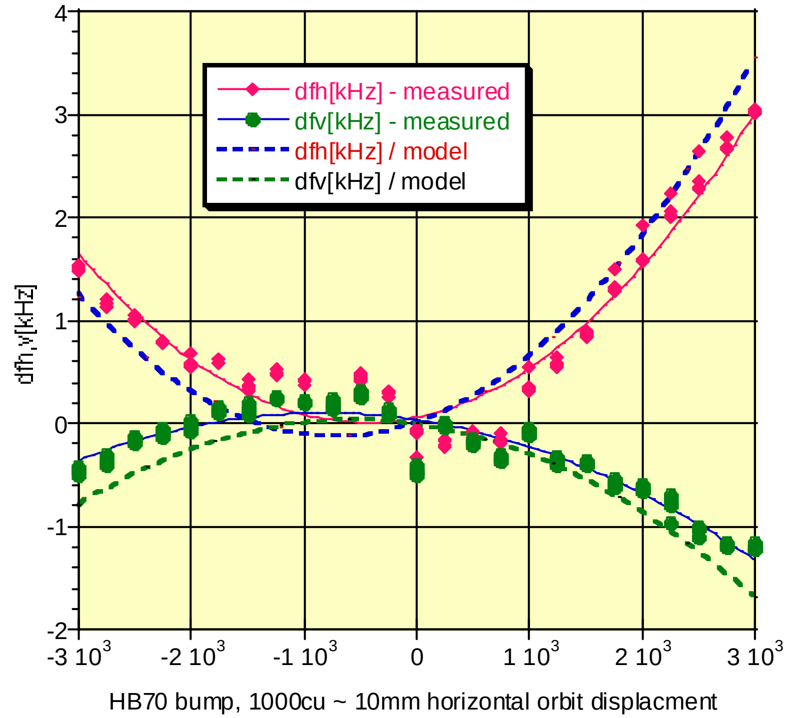




Wiggler Field Validation w/Beam

- Beam based measurements confirmed field quality:
  - Bunch length ($\rightarrow \sigma_E/E_0$ = 8.62 vs. 8.47x10^{-4})
  - Betatron tunes vs beam position, wiggler field

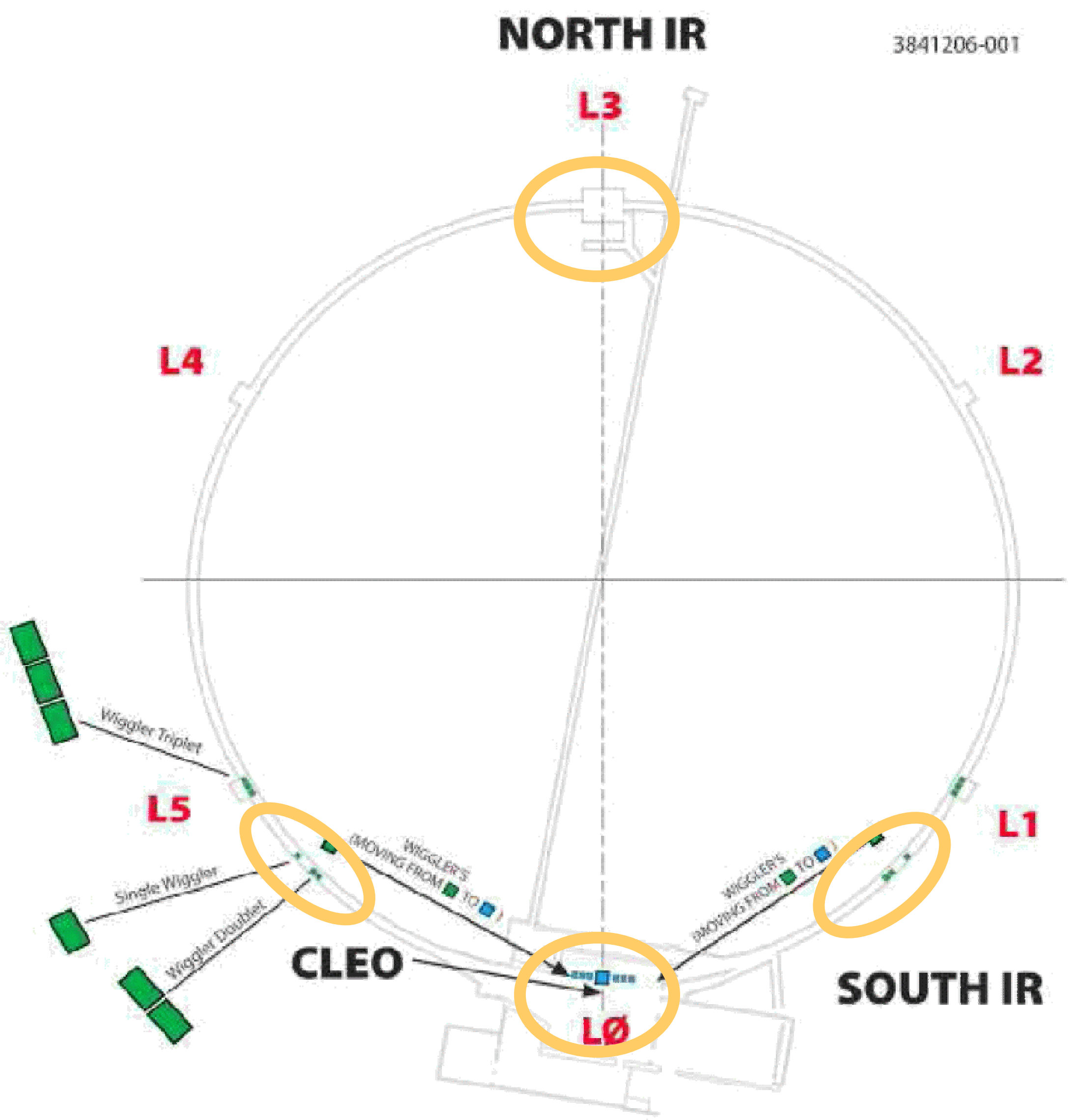




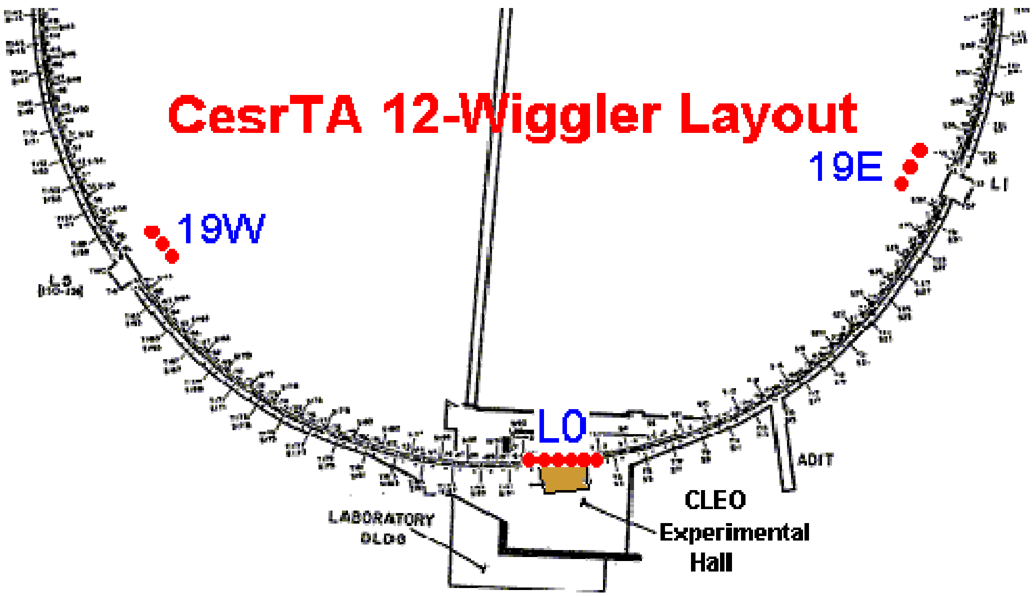
Modifications

- Outline
  - CESR Overview
  - **Modifications for CesrTA**
    - L0 (CLEO detector)
    - L3 (180° from CLEO)
    - Arc magnets
    - Feedback, diagnostics, survey & alignment
  - Optics for low-emittance operation

Modification Regions

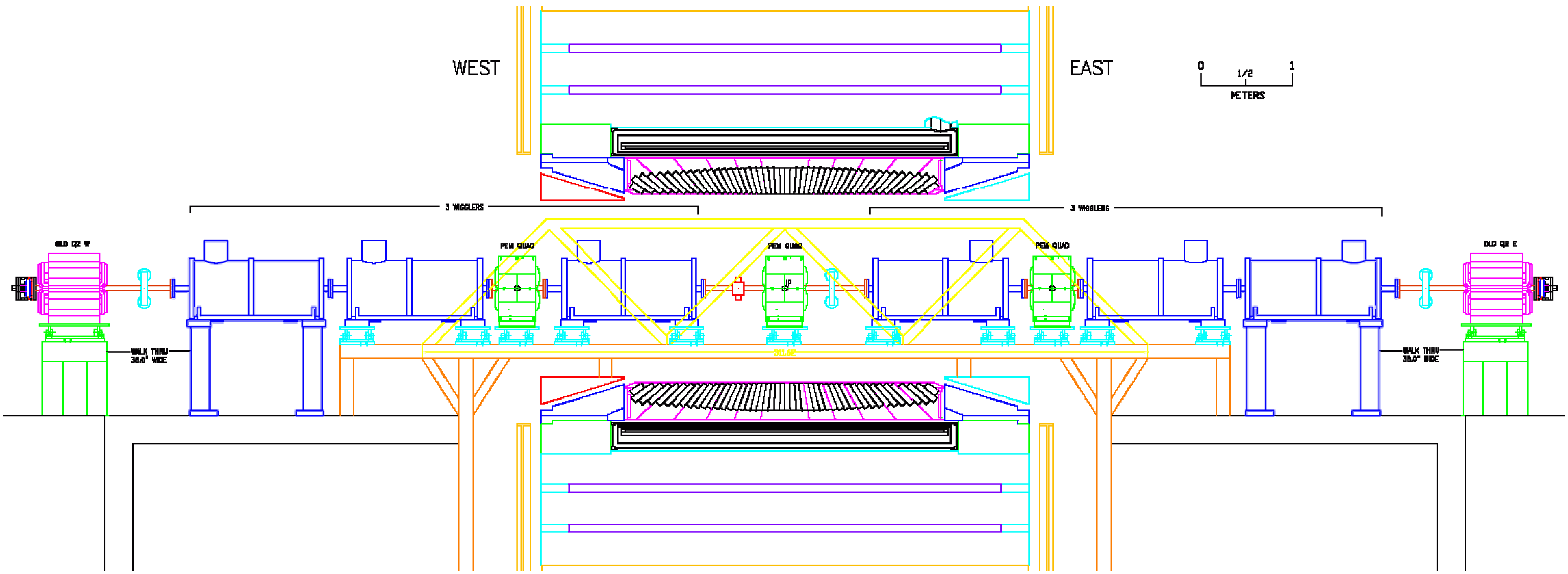


- Conversion for low-emittance operation:
  - Minimize number of wiggler regions to facilitate dispersion control



L0 Modifications

- L0 Layout w/ wigglers, quads, steering (FY08)
  - Remove CLEO VD, DR, RICH, ENDCAP
  - Install elements on rails
  - Cryogenics services from existing SC quad facilities

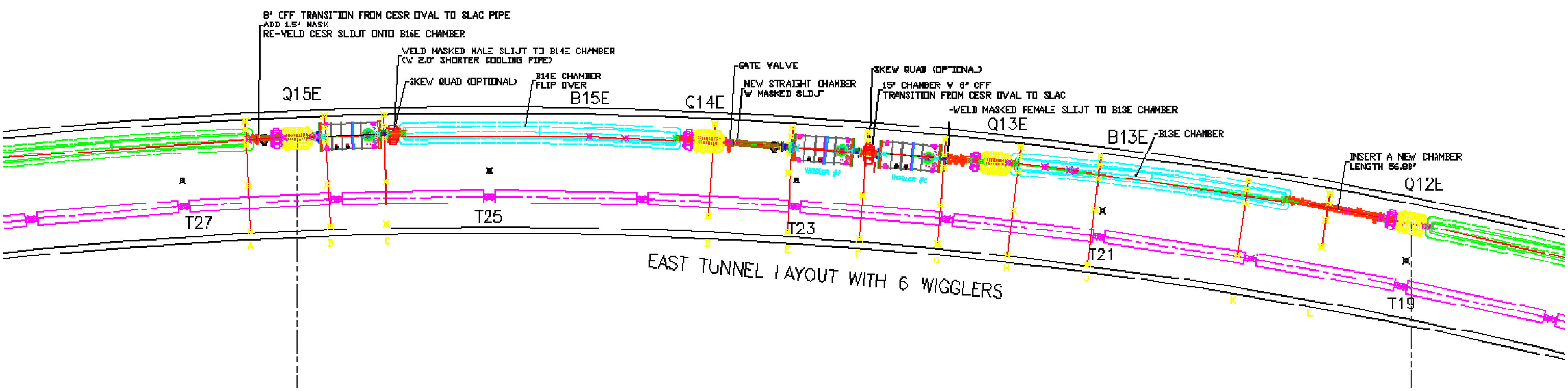


L3 Modifications

- L3 changes
  - Remove 2 vertical separators, replace with instrumented beam pipes (FY08)
  - Install upgraded s.r. optics (streak camera) (FY08)
  - Install EC instrumentation in quads and drifts (FY09-10)

Arc Modifications

- 6 wigglers to be removed from arcs – instrument replacement chambers
  - RFA's in drifts, bends (FY08, 09)



Survey and Alignment

- Quad, sextupole alignment system upgrade
  - LiCAS-II system not funded by STFC
  - Modify alignment fixtures for better resolution (FY08)
  - Install new target system (FY08,09)
  - Purchase and implement laser tracker system (FY09)
    - → x2-3 speedup in survey & alignment process
    - → improved survey accuracy

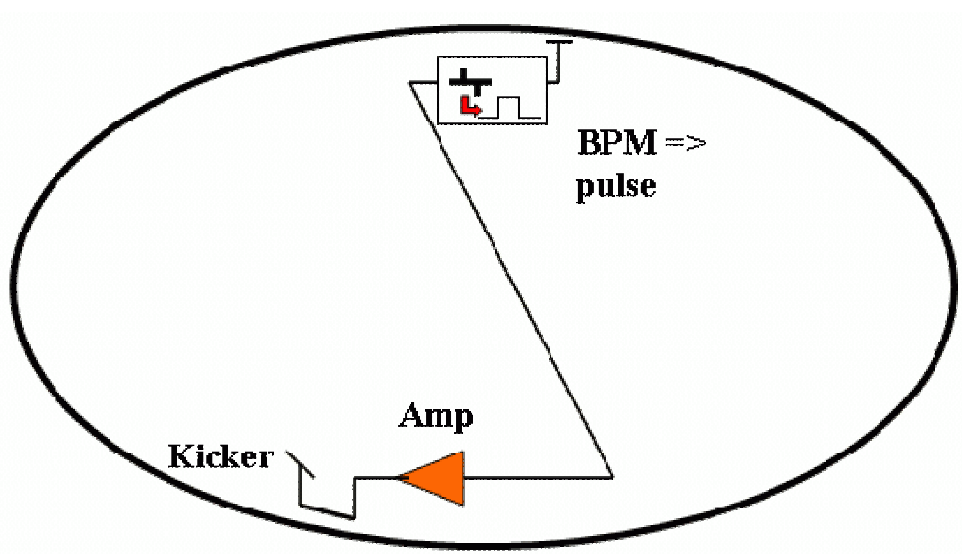
Instrumentation Modifications

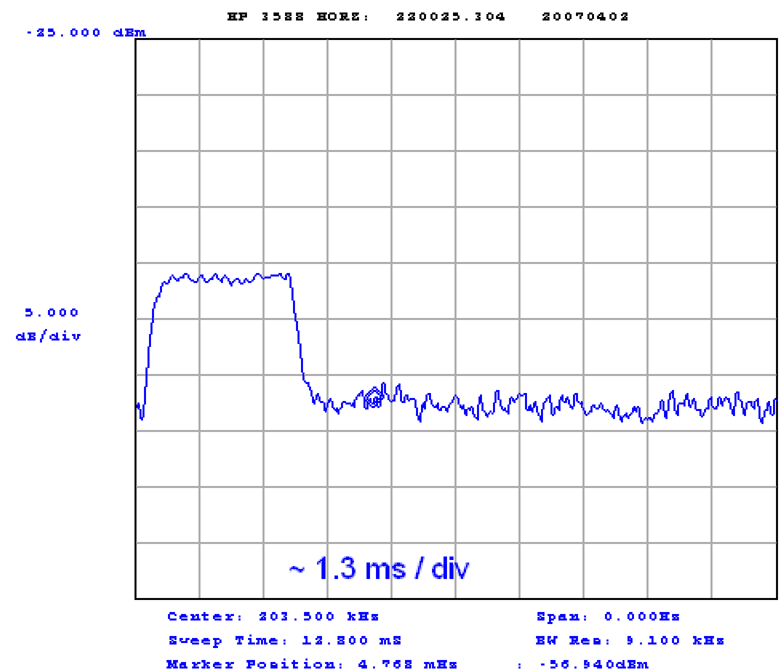
– Electron Cloud diagnostics
  - Retarding Field Analyszers in drift and quad chambers
  - Low profile RFA’s in wigglers and bend chambers
– Low emittance diagnostics
  - Upgrade BPM processing electronics – higher resolution, speed
  - High resolution X-ray beam profile monitor – single pass bunch-by-bunch, extendable to 2-D
– Other
  - Upgrade Synchroscan streak camera unit for 4 ns spacing, optics for 2-D recording
  - Extend vacuum instrumentation
    – Partial pressure analyzers, controlled leaks for selected gases, temperature monitoring, gate valves for quick changes, etc.

Feedback Systems

- Present CESR bunch-by-bunch feedback systems in place for bunches in 14 ns buckets.
  - Transverse systems:
    - Standard bpm position pickup
    - Digital processing bunch-by-bunch, variable turns delay
    - Strip line kickers
    - Damping rates ~ 2000 /s
  - Longitudinal system:
    - Standard bpm pickup
    - Digital processing bunch-by-bunch
    - Low Q DAFNE style cavity to drive beam
    - Damping rates ~ 50 /s

- CesrTA Feedback (4 ns bunch spacing)
  - Transverse:
    - Wideband system with direct path across tunnel diameter





CesrTA Longitudinal Feedback

– CesrTA Longitudinal Feedback

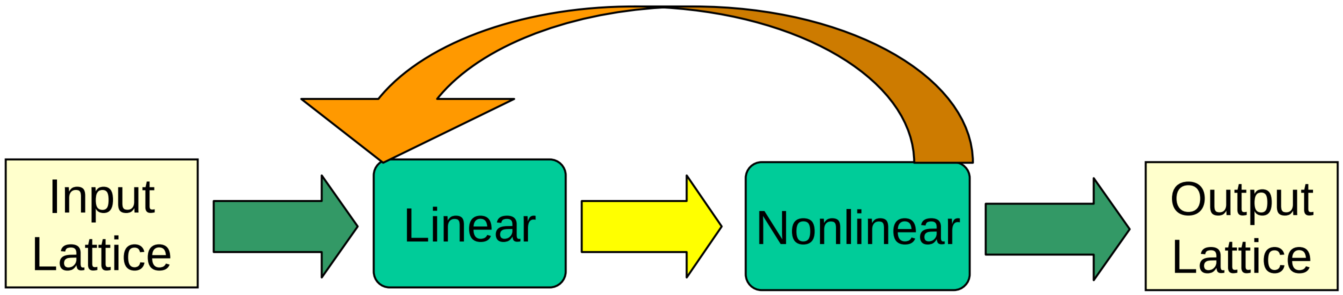
- Upgrade of processing electronics and a slightly modified cavity design and amplifier will permit feedback near present damping rates.
- Removal of vertical electrostatic separators in L3 is predicted to raise longitudinal instability threshold x4-5

Optics

- Outline
  - CESR Overview
  - Modifications for CesrTA
  - **Optics for low-emittance operation**
    - CESR Optics process
    - CesrTA in-progress optics

Optics Design Process

- Every quadrupole & sextupole is independently controllable
- No "standard cell"
- Optics realization:
  - Several optimizer engines available
  - Tracking with non-linearities to find partial derivatives
  - 27 years experience using technique with CESR optics

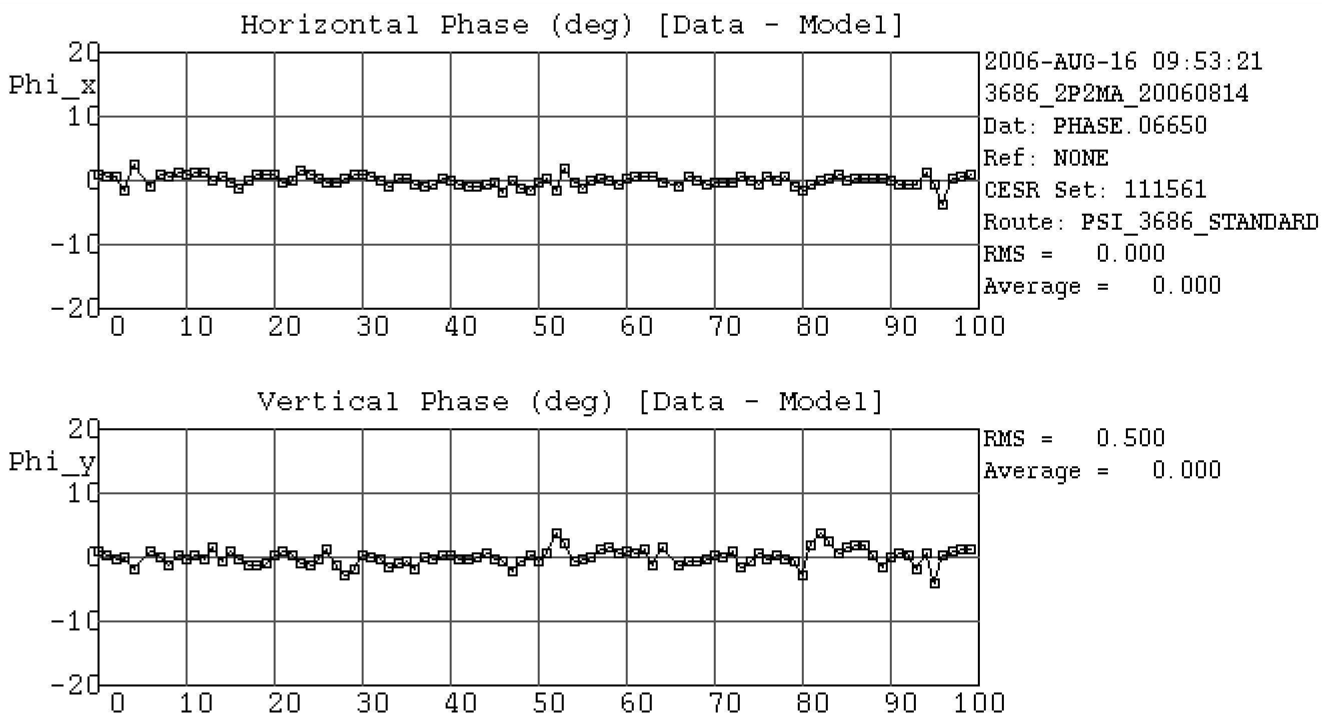


Wiggler modeling

- Wigglers are modeled using OPERA-3D, producing a 3-D field map.
- The field map is fit to satisfy Maxwell's equations
- The fit is then integrated symplectically using the Hamiltonian to a user defined order – usually third order
- The wiggler is not varied in the optimization process, however optimizations have been done at discrete wiggler fields - 2.1T, 1.9T, 1.7T

Optics Correction

- Fast phase measurements system permits full (including coupled) optics correction in a few minutes.



- Dispersion, chromatic corrections also possible.

2 GeV Optics

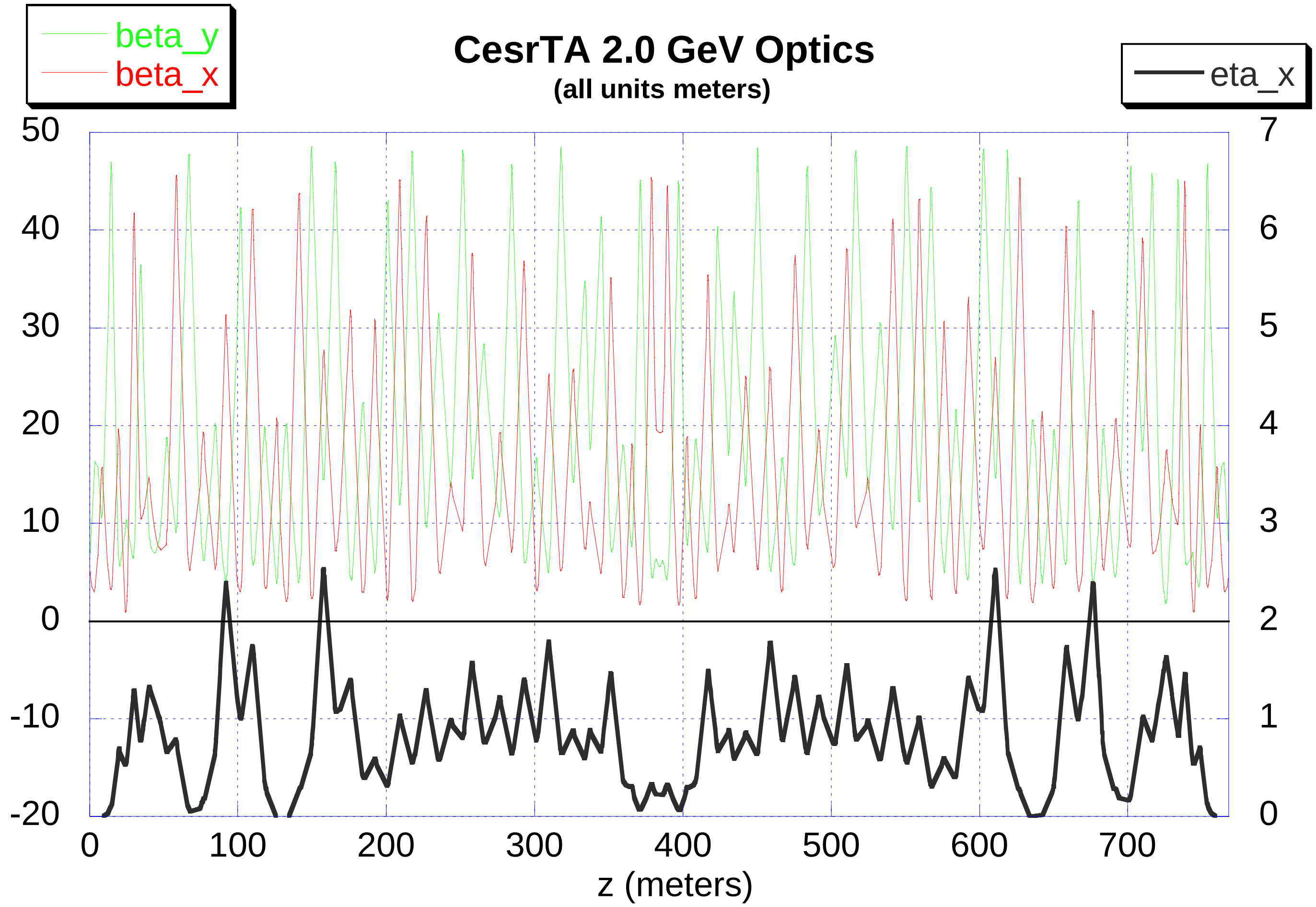
- Preliminary optics results

ε_x = 2.3 nm

$Q_{x,y}$= 14.57,9.62

$\tau_{damp\ x,y}$= 56.4 ms

$\tau_{Touschek} \approx$ 12 m



2 GeV Dynamic Aperture

Dynamic aperture calculations use ACTUAL physical apertures to identify lost particles.

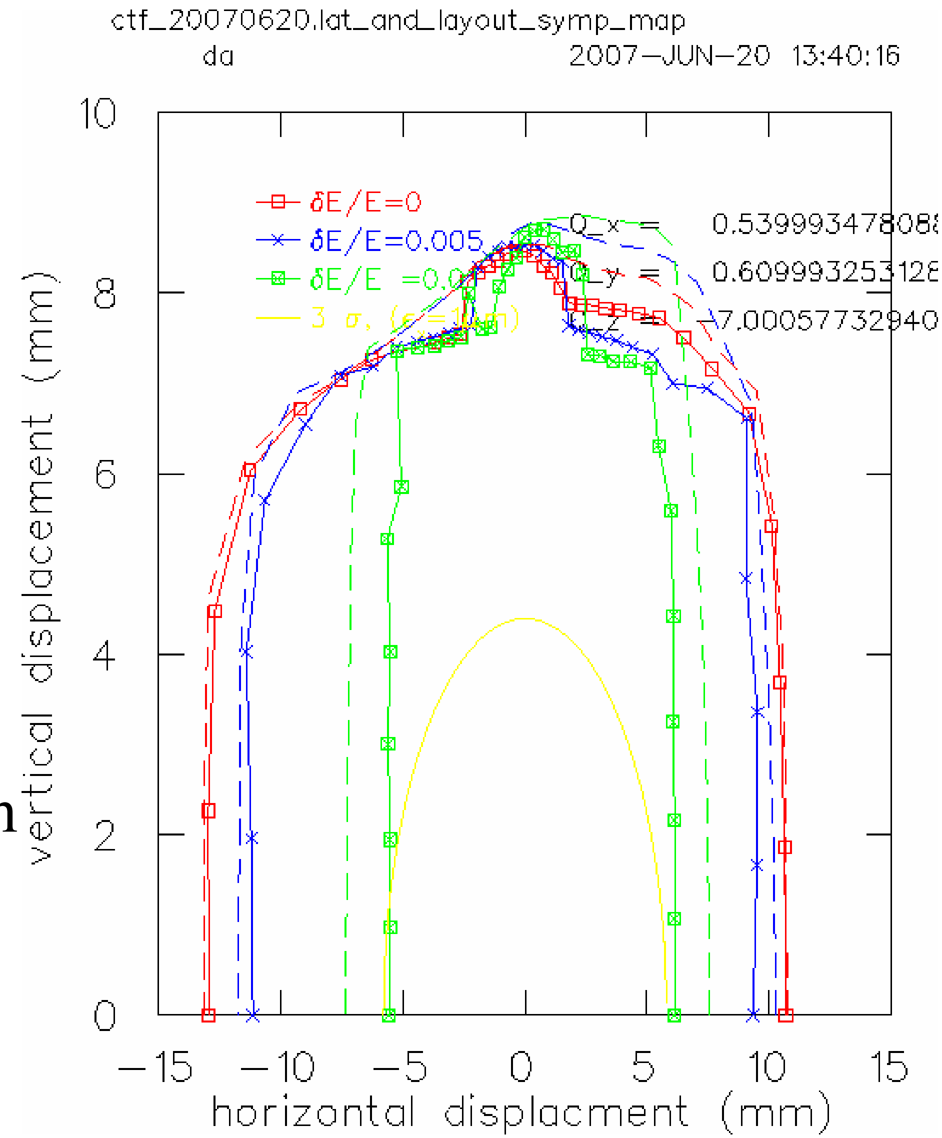
Dashed lines show losses in 20 turns (~physical aperture).

Solid lines show losses in 1000 turns ("dynamic aperture")

0, 0.5%, 1% dp/p_0

Yellow curve = 3 σ injected beam (ϵ_x=1000 nm, ϵ_y= ½ ϵ_x)

Sextupole, wiggler nonlinearities included



Optics Summary

- Development of optics at 2, 2.5, 5 GeV **<u>in progress</u>**

Parameter	**2.0 GeV**	**2.5 GeV**	**5.0 GeV**
B_{Wig}	1.9 T	2.1 T	1.9 T
ε_x	2.3 nm	3.4 nm	30.7 nm
$Q_{x,y}$	14.57, 9.62	14.57, 9.62	14.57, 9.62
$\tau_{damp(x,y)}$	56.4 ms	35.7 ms	19.1 ms
$\tau_{i.b.s.}$	~12 m	~22 m	—
Q_z @ MV_{RF}	0.054@4.6	0.081@12.5	0.05@9
σ_z	9 mm	9 mm	9 mm

Summary

- Most topics discussed will be described in more detail in subsequent talks.
- The LEPP staff have extensive experience making effective use of the optics flexibility of the CESR facility.
- This flexibility and the experienced LEPP staff provide an effective and economical conversion path to CesrTA.