CORNELL UNIVERSITY LEPP

LABORATORY FOR ELEMENTARY-PARTICLE PHYSICS

Linear Collider Accelerator Research

D.Rubin, Cornell University

- Damping rings - measurement and simulation
- Fast kicker - design study and protytpe
- Polarized positron source - design study and model wiggler
- Main linac - simulation

Damping Rings

Wigglers

- In linear collider damping rings, energy loss and radiation damping time are dominated by wigglers

  NLC - $E_w/E_T \sim 66\%$, $L \sim 46m$, $B_P \sim 2.15T$
  TESLA - $E_w/E_T \sim 95\%$, $L \sim 300m$, $B_P \sim 1.8T$

- As it is in CESR-c

  $E_w/E_T \sim 90\%$, $L \sim 18m$, $B_P \sim 2.1T$

-> With low emittance optics, CESR-c is a damping ring

Damping Rings

Wigglers

Nonlinearities with high field wigglers and low energy beam

- Cubic nonlinearity (vertical) resulting from wiggling beam interacting with longitudinal field at edges
- Horizontal and vertical nonlinearity due to
  - Finite width of pole
  - Nonuniformity in iron
  - Manufacturing misalignments

  etc.

We have developed techniques to

- Model and measure wiggler fields
- Incorporate detailed field in simulation
- Included nonlinearities in optimization of lattice for dynamic aperture

Damping Rings

Wigglers

We will begin to test our understanding of the effect of damping wiggler with the installation of the first next week.

LC damping ring studies will require a low emittance lattice
(*All quadrupoles and sextupoles are independently powered and optics are very flexible*)

- Beam based measurements =>
  - Effect on dynamic aperture
    - Tune / coupling vs displacement
    - Lifetime vs pulsed bump amplitude
  - Linear and nonlinear coupling that would degrade emittance
  - Effect of the increased damping on collective instability thresholds

Damping Rings

Collective Effects

In low emittance mode

- We can study the intra beam scattering that threatens to degrade emittance by measuring beam size vs bunch current and as a function of
  - Transverse coupling
  - RF voltage

With a complementary effort to model IBS, we will try to resolve exisitng descrepancies between theory and measurement

Damping Rings

Collective Effects - space charge

-Space charge in low emittance beams will induce a tune shift that is greatest near the core of the bunch and falls to zero for particles in the tail

-With the resulting tune spread it becomes increasingly difficult to find an operating point about which all particles will have good lifetime

- In the low emittance lattice we will measure the dependence of this tune shift on beam size, bunch current, radiation damping time
  and
  scan lifetime vs tune and determine how working depends on space charge

And again coupled with a program of theory and simulation we hope to identify difficulties or establish the credibility of exisiting damping ring designs

Damping Rings

Collective Effects

In low emittance mode we can measure thresholds for

- Electron cloud effect
- Fast ion instability
- Impedance driven instabilities associated with short bunches

Damping Rings

Coupling/dispersion/emittance correction

Operation of CESR in low emittance mode will require that we develop

- Techniques for precise measurement of coupling and vertical dispersion
- Algorithms for correcting guide field errors to minimize vertical emittance
- Detectors for measuring size of stored beams and in a singe pass

Collaboration with SLAC, DESY, LBNL

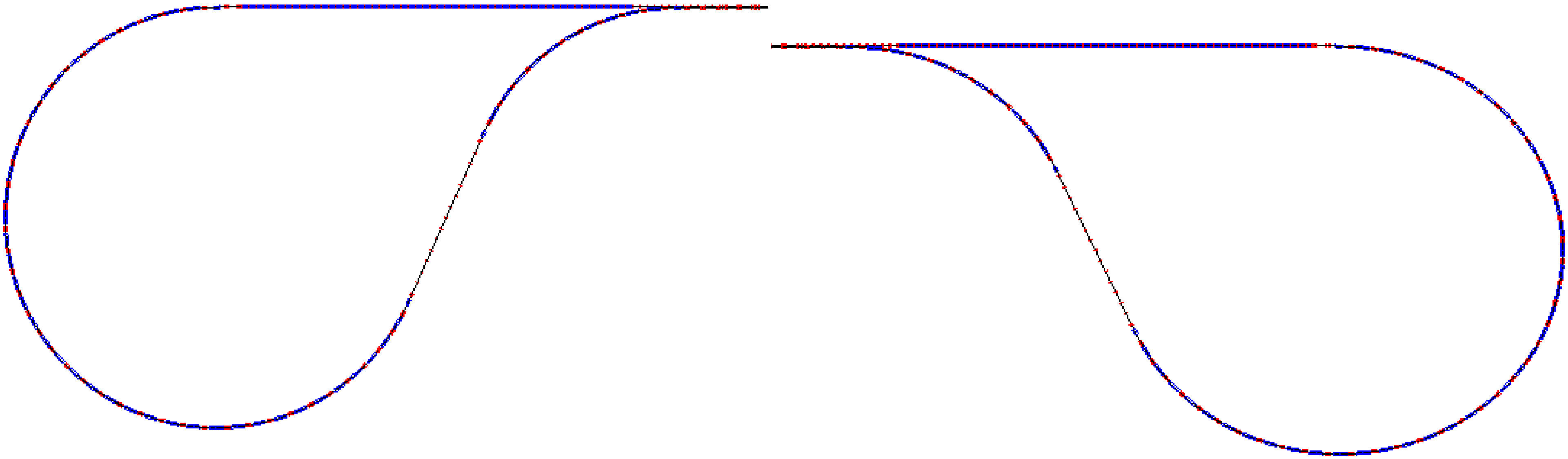
Damping Rings

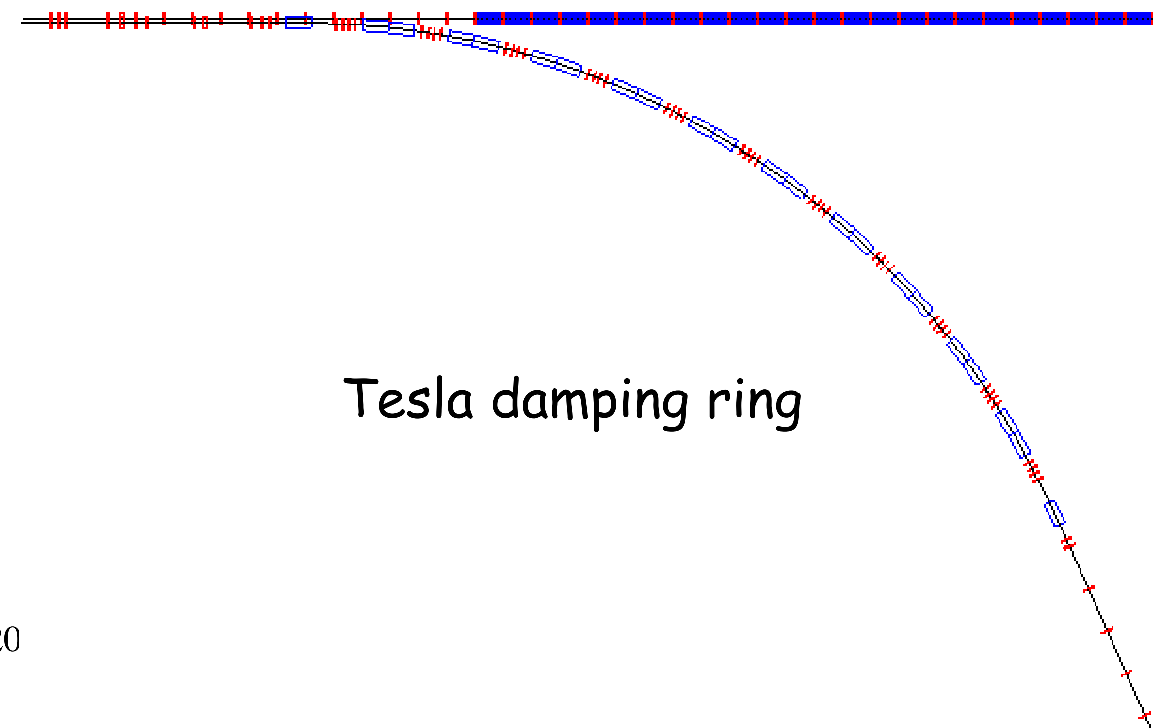
Simulation

Develop modeling tools to support the measurements

- Based on code extensively tested against measurements in CESR and used to diagnose and correct CESR optics/orbits/coupling/dispersion
- Flexibility for integration or mapping through nonlinear wiggler fields
- Extended to include intra-beam scattering and space charge

Just getting started with (REU) summer students

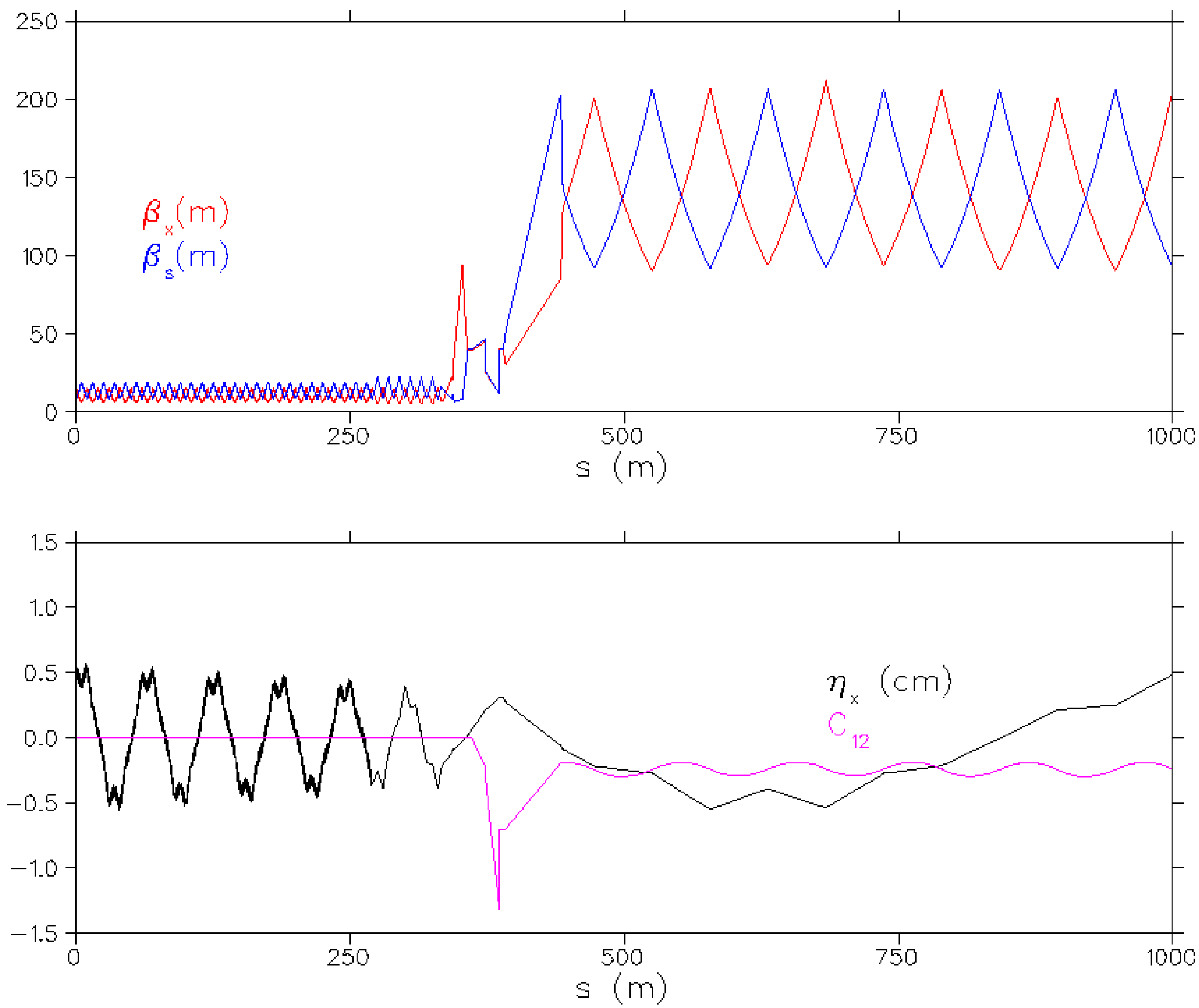




Tesla damping ring

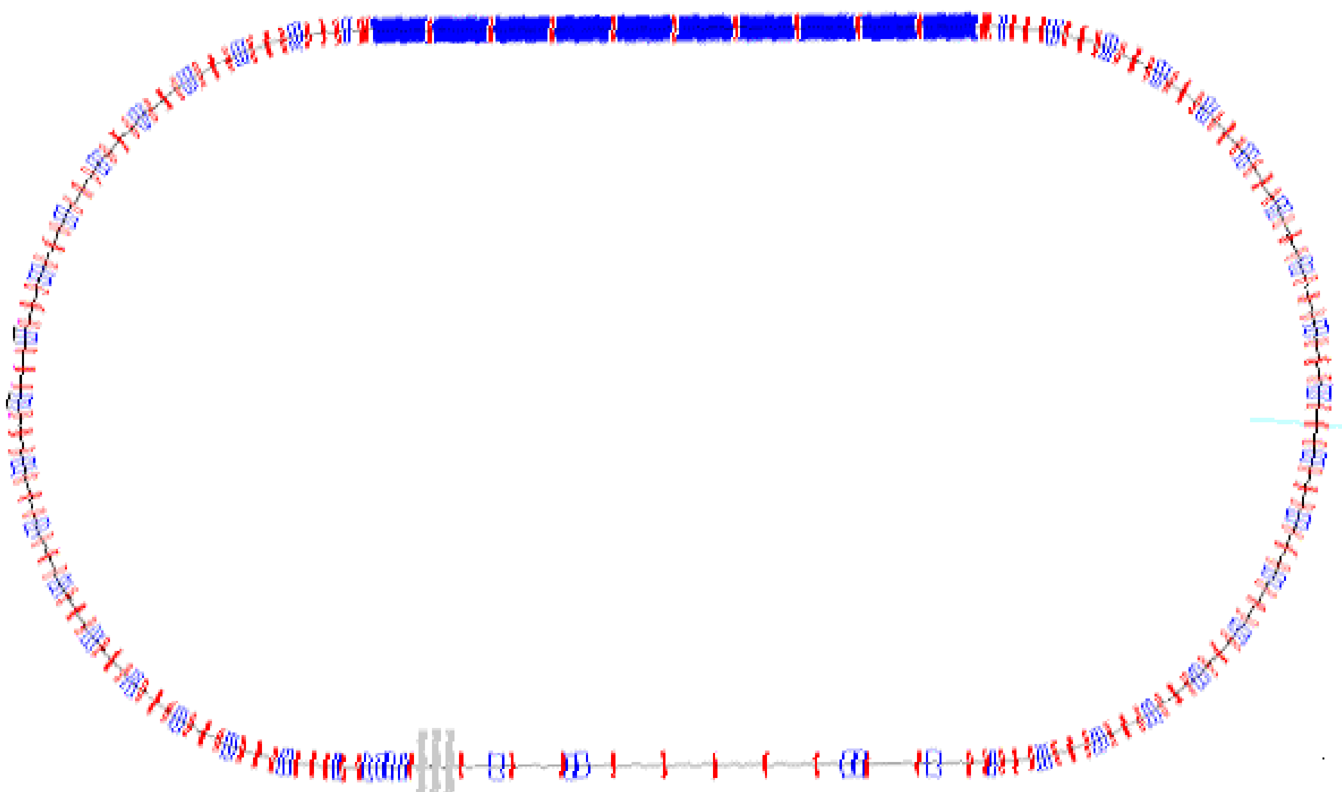
Tesla Damping Ring

Optical functions at transition to long straight

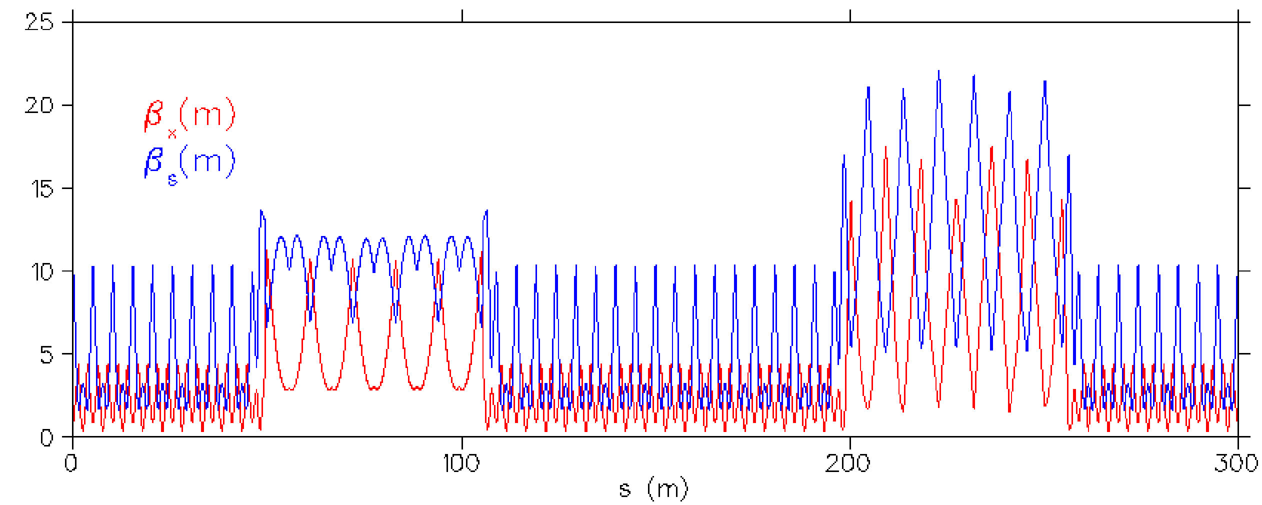


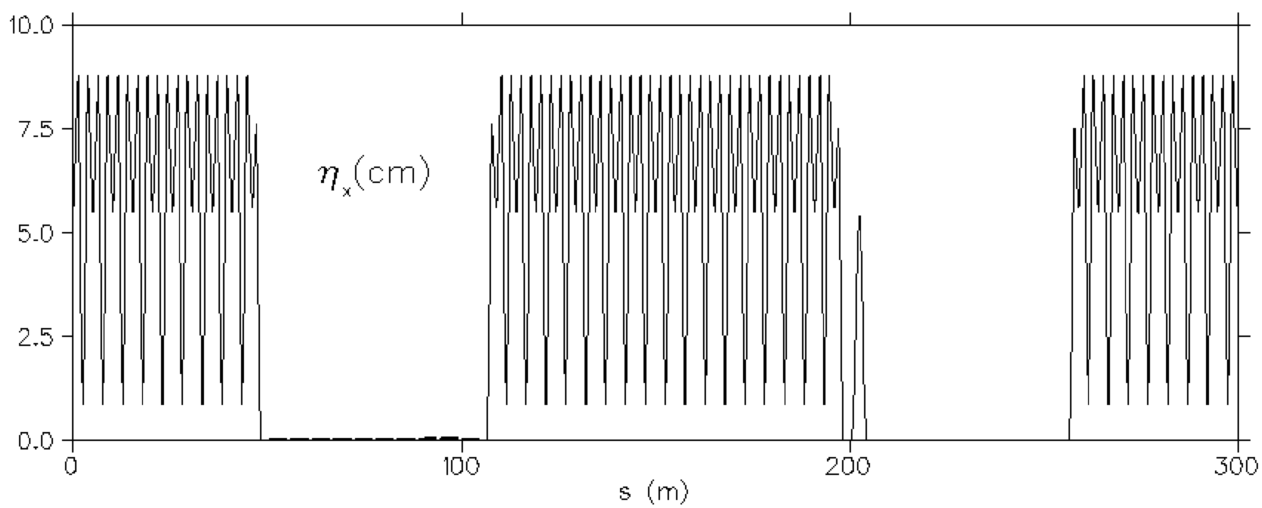
Lattice file courtesy W.Decking and plots - A.Amsel

NLC Damping Ring



NLC Damping Ring Optical functions





Lattice file courtesy A.Wolski And plots - V.Borum

Damping Ring

We have
- Confirmed docmented tolerances to misalignments that generate vertical dispersion and transverse coupling
- Recovered dependence of vertical emittance on vertical dispersion
- And BPM resolution required to adequately measure and correct vertical dispersion

We will
- Recompute and then explore optimization of dynamic aperture by experimenting with alternative optics and sextupole distributions

Fast Kicker

- The size of the TESLA damping ring is determined by the large number of bunches in the train and the bunch spacing.
- The minimum spacing depends on the width of the pulsed injection and extraction kicker
- The baseline TESLA designs calls for a 20ns pulse.
- With bunches spaced 20ns apart, the 2820 bunch train requires a 17kM damping ring
- A reduction in the pulse width translates to a smaller ring

Fast Kicker

We plan to investigate designs

- For conventional kickers with narrower pulses
- Schemes using electron beams to provide very fast kicks

including evaluation of jitter

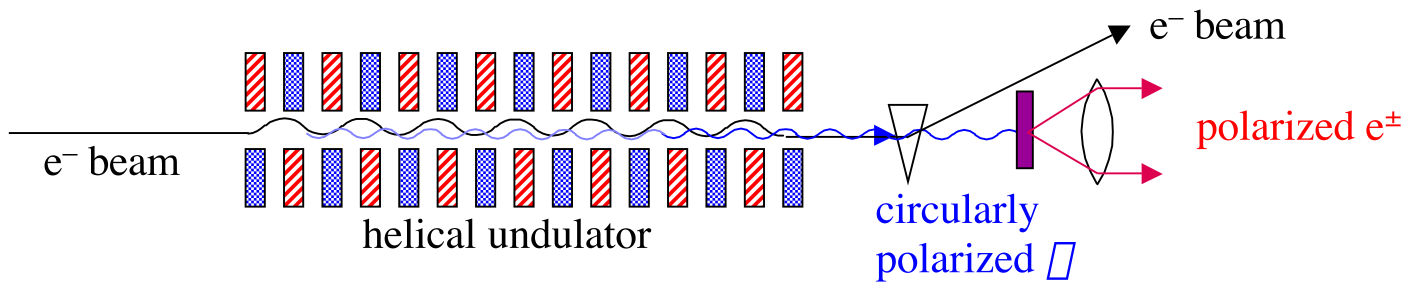
- And to build a prototype of a promising design

Collaboration with FNAL, DESY, Illinois

Polarized Positron Source

High energy electron beam in a helical undulator produces circularly polarized photons, which are then converted to e^+e^- pairs in a thin target.

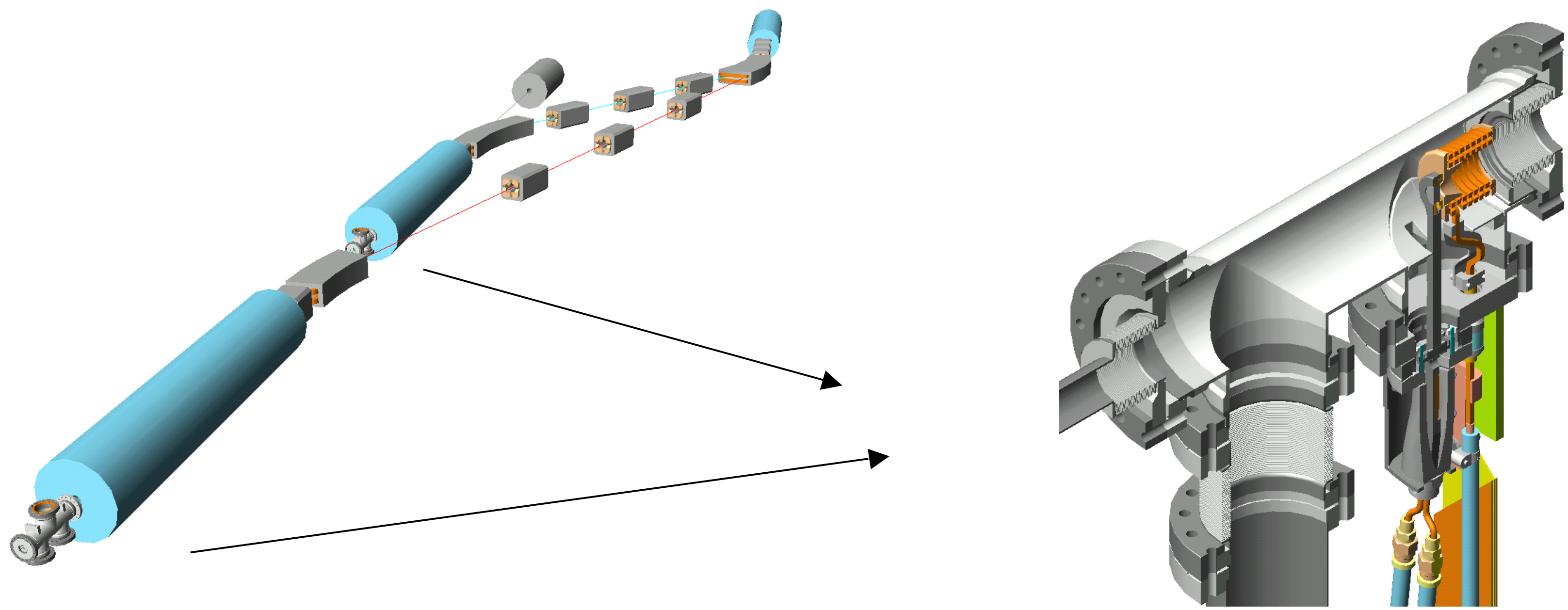
Proposed by TESLA and now being considered for both superconducting and warm linear collider designs.
Positron polarization ~ 45 - 60%.



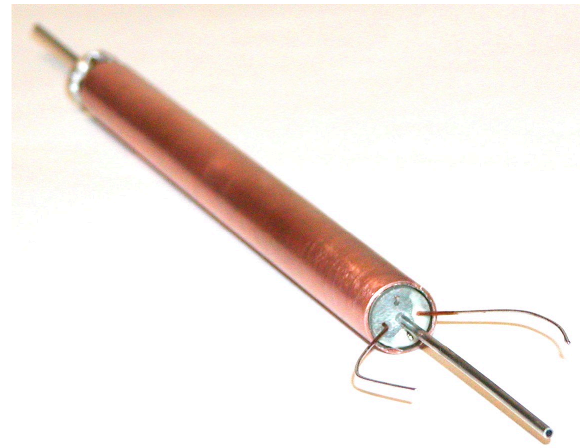
Planned Cornell R&D:

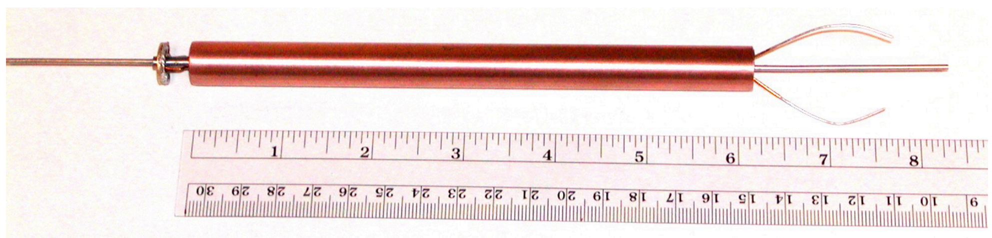
- Design study for target and transport.
- Short undulator model achieving magnetic field specifications.
- ~ 1cm at 250GeV, 2.4mm at 50GeV

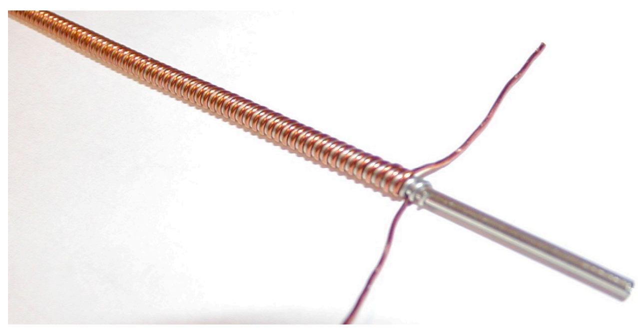
Polarized Positron Source



Polarized Positron Source







A.Mikhailichenko

Main Linac - Simulation

- Preservation of small vertical emittance during acceleration through linac
- Effective beam-based techniques for correcting guide field errors that degrade emittance

Are both critical to collider performance
And both depend on modeling of beam transport

- Elaborate simulations have been developed at SLAC, DESY and CERN which can incorporate
  - Static and dynamic alignment errors
  - Permit tests of correction algorithms and feedback mechanisms
  - Including BPM resolution etc.

Main Linac - Simulation

- Assemble existing simulation tools at Cornell
  (Merlin - *Walker*, LIAR - *Tennenbaum et. al.*)
- Exercise with already solved problems
  - See for ourselves how emittance depends on guide field errors, RF phase errors, misalignments…
- In collaboration with experts, identify inadequacies of existing tools and help to address them

- Investigate
  Beam halo transport
  Spin transport
  and other issues that are likely to emerge

Main Linac - Simulation

Flexible modeling tools will be critical to the timely commissioning of the new machine

Simulations are a powerful tool for educating ourselves and our students with respect to design choices

-> Develop the expertise that will be so important to the commissioning and operation of the collider

Summary

Damping ring study

Measurement and supporting simulation for nearly all aspects of wiggler dominated low emittance, short damping time ring

Investigation of fast kicker designs

Polarized positron production

Simulation of main linac

Collaboration