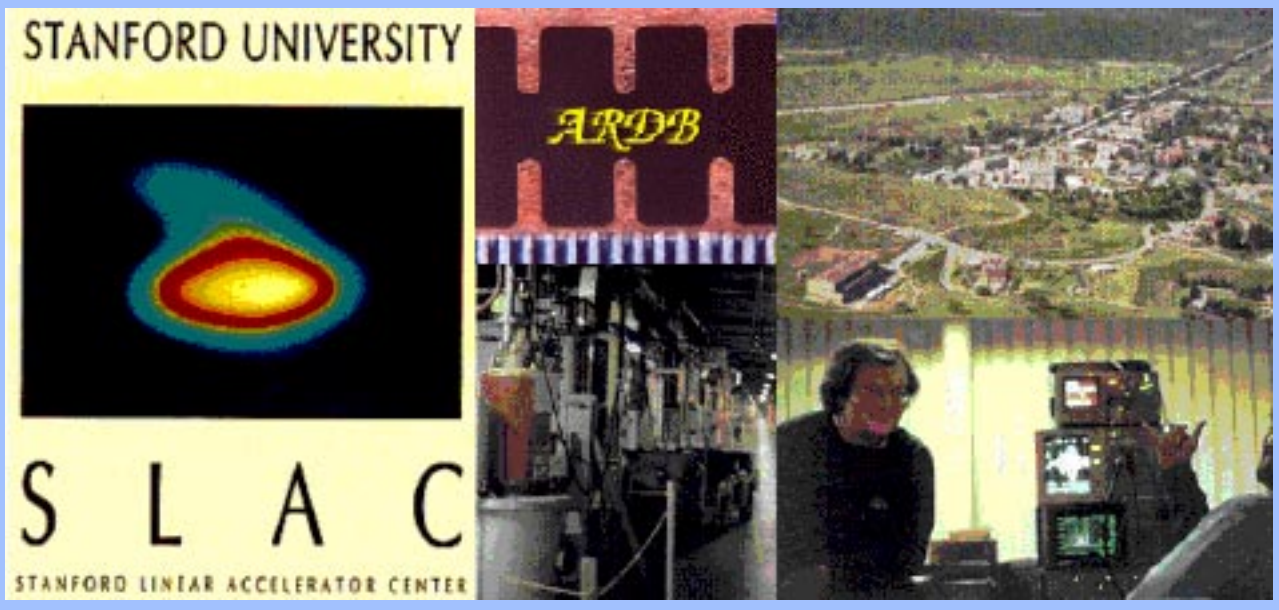
Toward a 5 TeV e^+e^- Collider

Accelerator Research Department B,
SLAC, Stanford University
http://beam.slac.stanford.edu



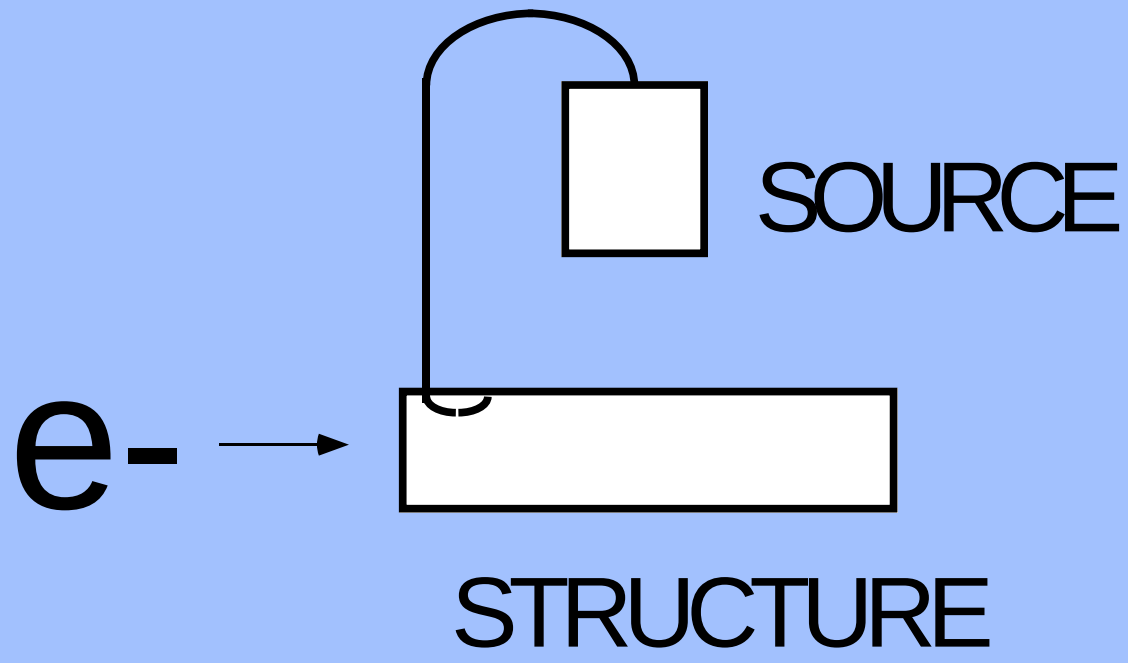
Our Charge

Invent, Design,
Build & Commission

a 1 GeV/m x 1m linac,

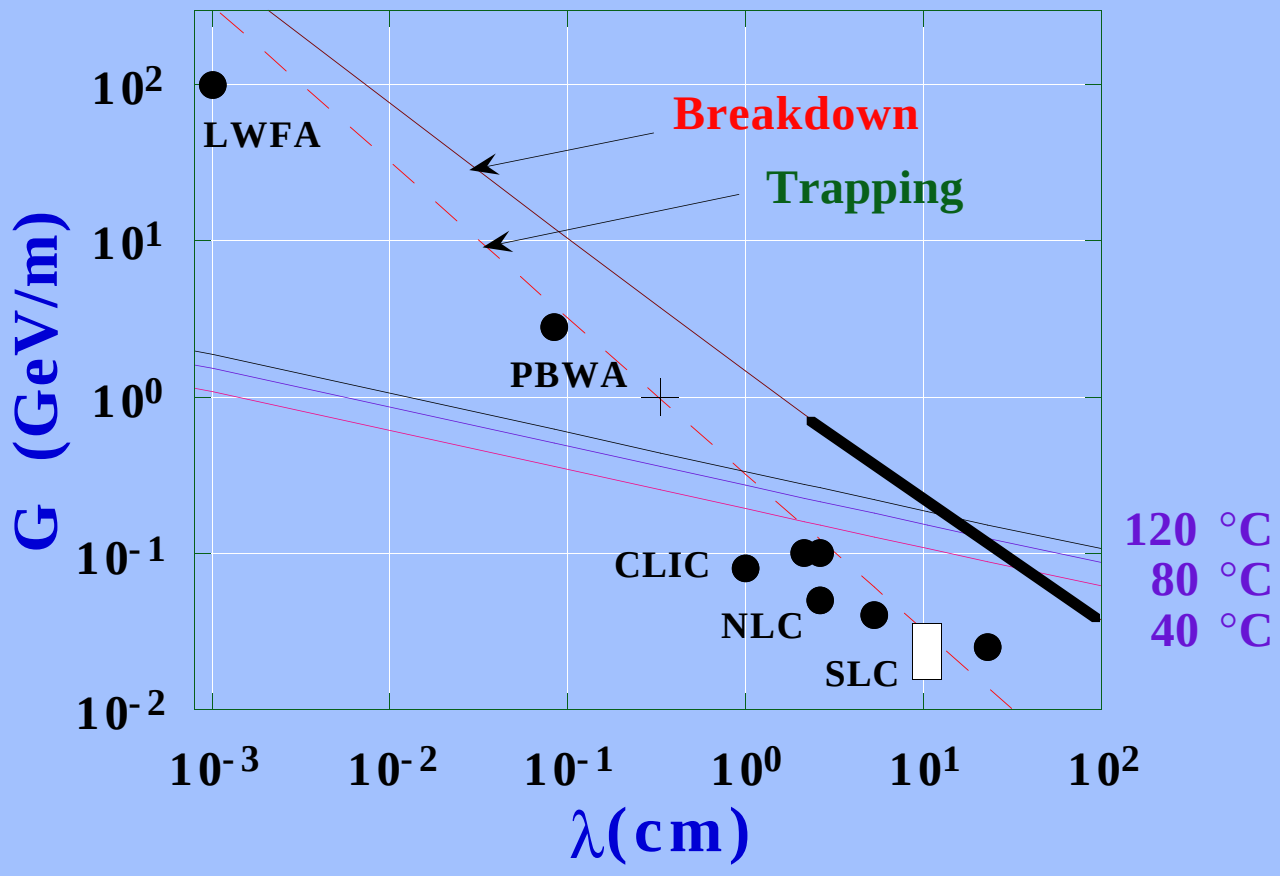
with a technology
scalable to a 5TeV e+e-
collider.

How to Invent an Accelerator?



Problem:
1 GeV/m =>
structure damage?

Gradients Today



5 TeV Discussions at Snowmass

Themes

lasers & beams
laser wakefield acceleration
$\gamma\gamma$ collider
klystrons & gyrotrons
short-bunch wakefields
superconducting linacs & technology
THz radiation
dielectric accelerators
mm-wave accelerators & microfabrication, LIGA

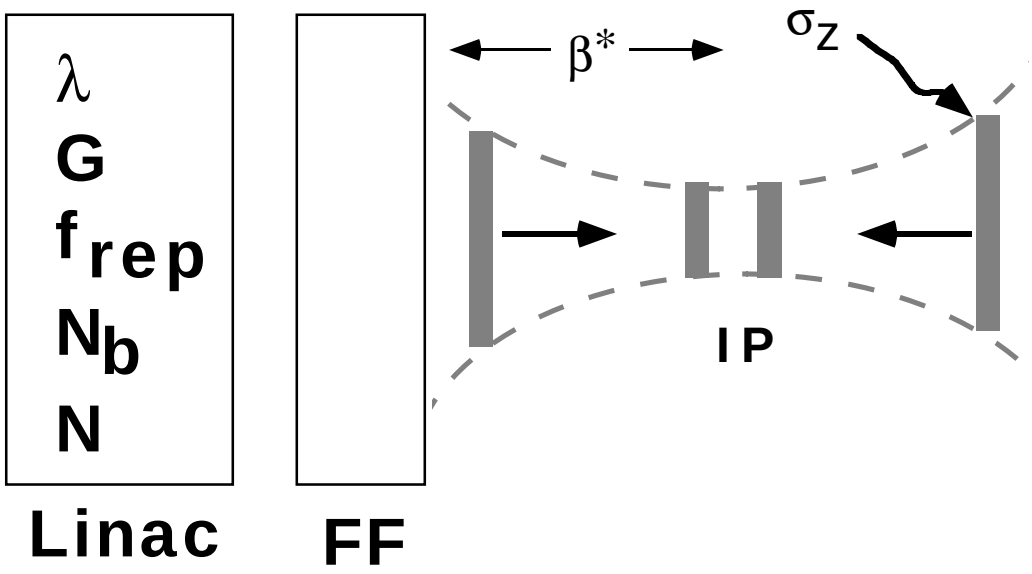
Directions

SCRF	Padamsee, Cornell
30GHz	**Two-Beam** - Westenskow, LBNL
	Tube Driven - Wilson & Irwin, SLAC
90GHz	**Dielectric** - Gai, ANL
	Conducting - Song, ANL, Whittum & Siemann, SLAC
1THz	Chattopadhyay, Zolotorev - LBNL
Laser	**Structure-Based**, Huang, Stanford
	Plasma-Based, [Esarey & Multitudes]
Beam	**Structure-Based**, Gai, ANL
	Plasma-Based, UCLA
$\gamma\gamma$	Kim, Xie, LBNL

Status of 5 TeV Concepts

SCRF	100MV/m	60km	SC materials research, site
	200MV/m	30km	
30GHz TBA	power source prototype, drive beam dynamics, site		
30GHz Tube Driven	sheet beam klystron research, site		
	1GV/m	<10km	
90GHz Dielectric	power source **invention**		
90GHz Conducting	power source **invention**, structure **invention**		
1THz	power source **invention**, structure **invention**		
	10GV/m	~km	
Laser Structure-Based	module prototype, rep rating, staging		
Laser Plasma-Based	module prototype, rep rating, staging		
Beam Structure-Based	module prototype, staging		
Beam Plasma Based	module prototype, staging		
$\gamma\gamma$	[this or neutral beams a required adjunct to other concepts]		

Scalings



high Y

γγ

neutral beams

Vocabulary

Luminosity

$$L = \frac{f_{rep} N_b N^2}{4\pi\sigma_y^2 R} \approx 10^{35} cm^{-2}\,\mathrm{sec}^{-1}$$

Upsilon

avg γ energy/beam e- energy

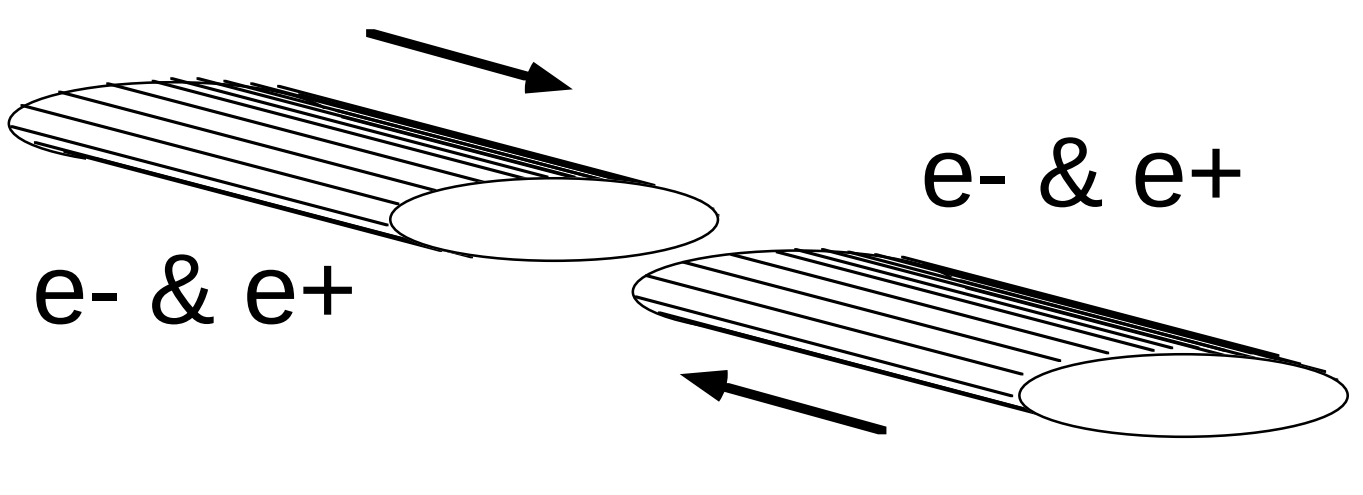
$$\Upsilon = 0.833 \frac{N\, r_e^2 \gamma}{\alpha\sigma_z\sigma_y(1+R)} = 0.3 - 1000$$

Beamstrahlung

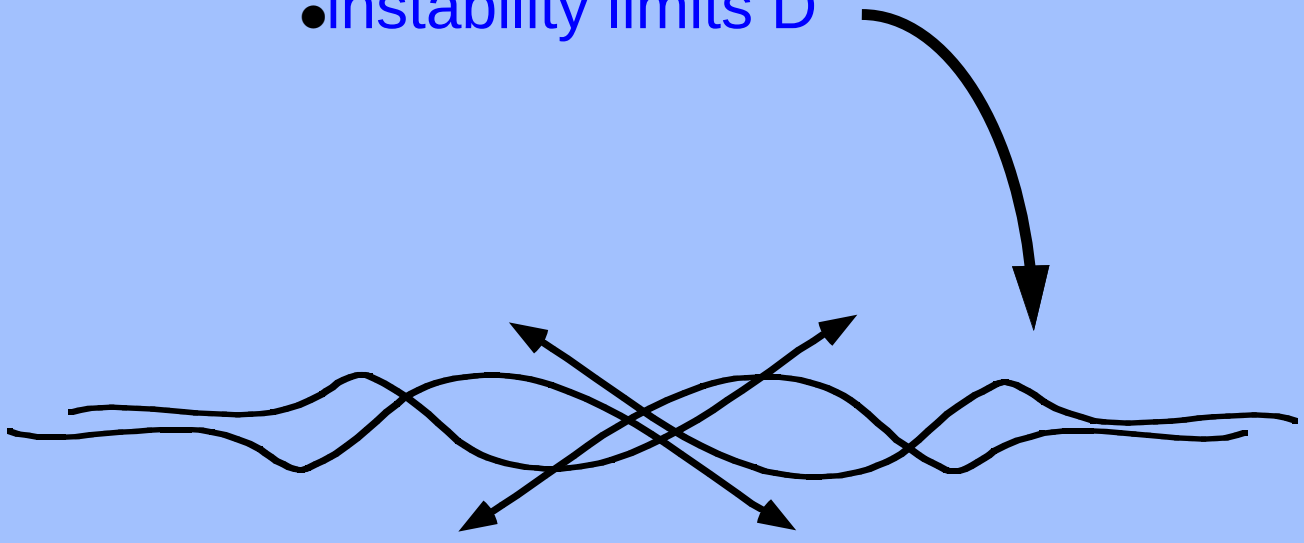
avg e- energyloss /beam e- energy

$$\delta_B \approx 1.24 \left(\frac{\alpha^2\sigma_z}{\gamma r_e}\right) \frac{\Upsilon^2}{\left(1+(1.5\Upsilon)^{2/3}\right)^2} = 0.01 - 1$$

Neutral Beams

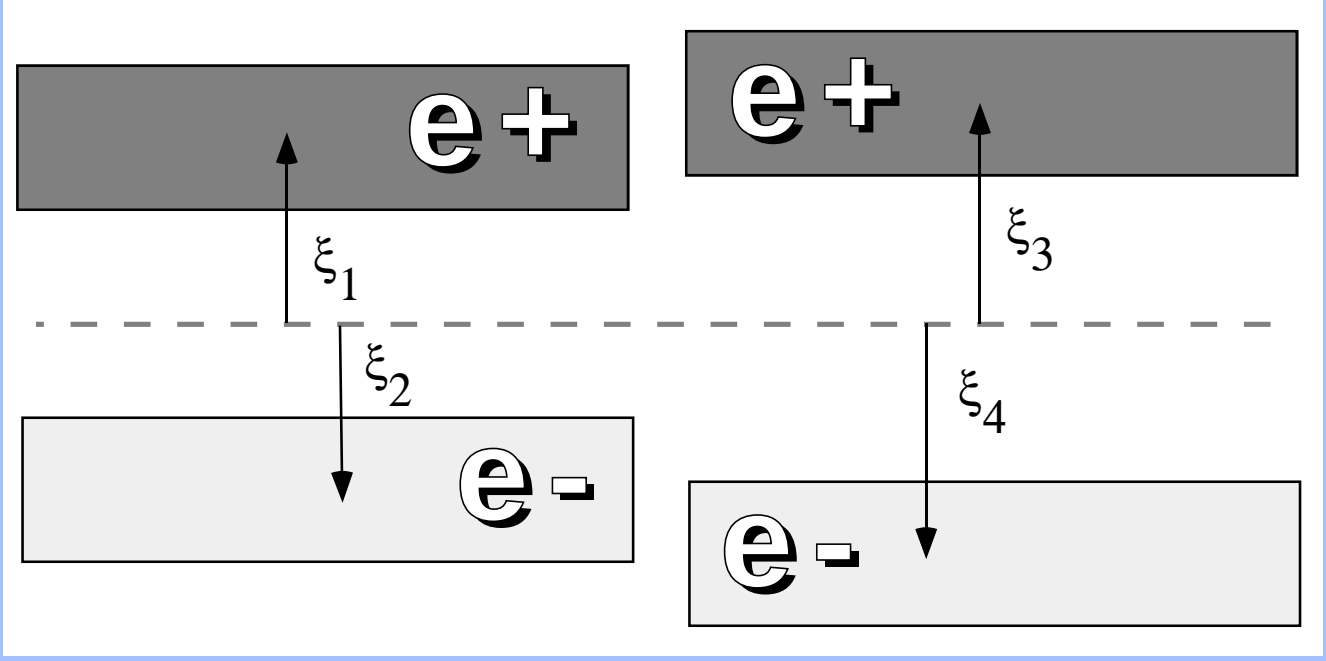


- multiple bunch linac
- beam combining
- uncertain initial state
- alignment, optics, N
- instability limits D

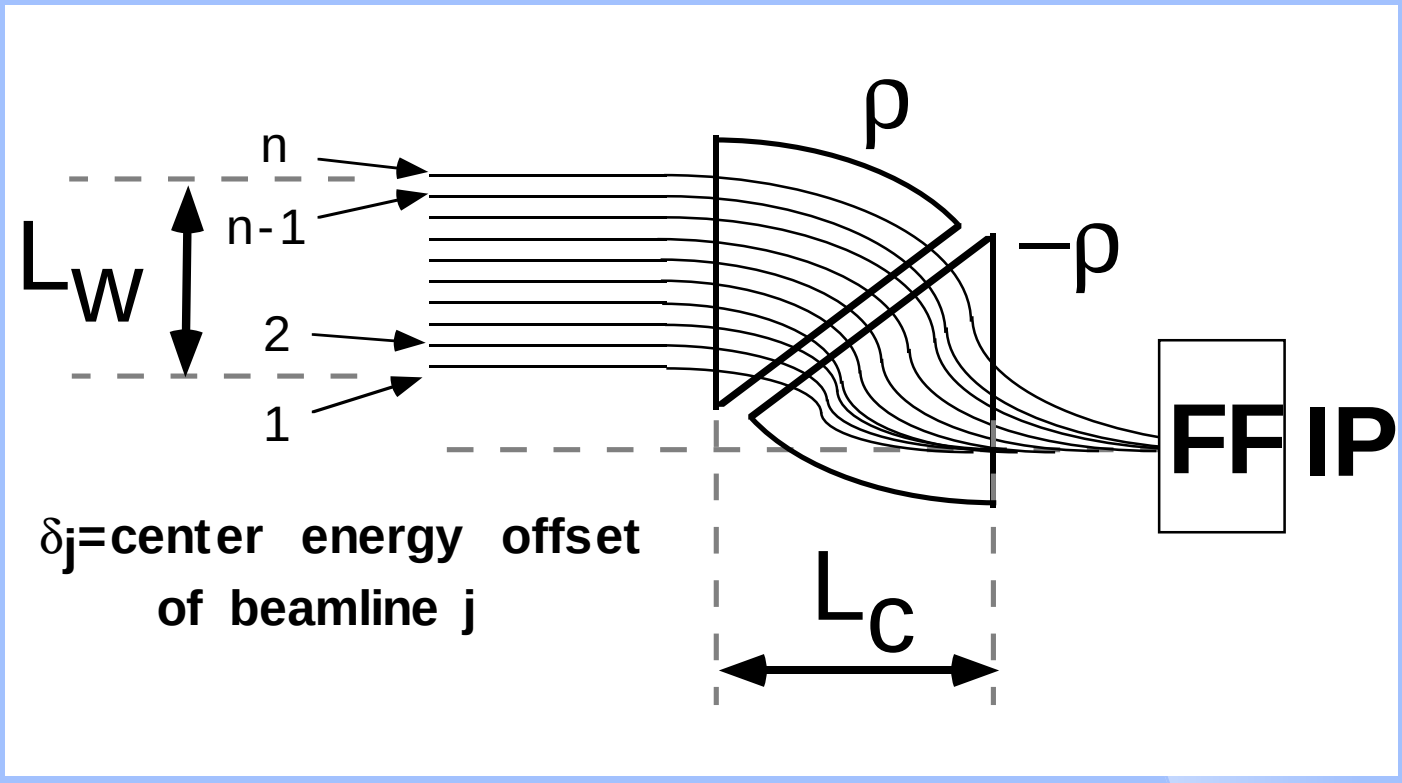


Hose Instability

(Rosenzweig, et al.)



Beam Combining



- L_c is bounded below due to emittance growth from synchrotron radiation
- neutral beams are required

Structure Research
(at different λ)

- Channel Guiding for LWFA
  (Multitudes)
- DDS Structure
  (Kroll, *et al*., NLC)
- Laser Linac
  (Huang & Byer, Stanford)
- mm-wave fabrication
  (Song, ANL)

Power Sources

- sheet beam klystron
- two-beam accelerator
- gyroklsytrons
- lasers

Wakefield Research

- planar structure wakefields
- short-bunch wakefields
- SLC collimator wakefield
- wakefield instrumentation

5 TeV Problems

Small Spot?
➜IP Limitations

New Structure?
➜Wakefields , Beam Dynamics

2cm>λ>10μm?
➜Power Source, Efficiency

G>100MeV/m?
➜Efficiency

Ultra-Low Emittance?
➜Source, Beam Dynamics

Parameters
for λ=1cm 3mm 1mm LWFA, LS, PWFA...

ARDB People

Grad Students
Boris Podobedov
David Pritzkau

Visitors
Dr. Xiaoxi Xu
Prof. Heino Henke

Post-Docs
Ralph Aβmann
Mike Seidel
Ping Chou

Staff
Angie Seymour
Al Menegat

Prof's
Bob Siemann
David Whittum

Accelerator Physics

Alex Chao - wakefields, spin-transport, beam instabilities, nonlinear dynamics, SLC, NLC, LHC

Tom Himel - accelerator controls, accelerator physics for colliders, SLC, PEPII

Roger Miller - microwave linear accelerators,rf structures, guns, SLC, NLCTA, NLC

Ron Ruth - nonlinear beam dynamics, linear colliders, NLCTA, NLC

Bob Siemann - beam measurements, diagnostics & instrumentation, high gradient accelerators, mm-waves, SLC

David Whittum - collective effects, beam interactions with microwaves, plasma, free-electron lasers, mm-waves, SLC

Perry Wilson - microwave linear accelerators, structures, pulse compression, mm-waves SLC, NLCTA, NLC

Courses in Beam Physics

This year...

Electromagnetic Radiation from Relativistic Electrons
Helmut Wiedemann
AP 453A - 3 units - Fall
Collective Effects in Accelerators
Alex Chao
AP 453B - 3 units - Winter
Microwave Linear Accelerators
Roger Miller, Perry Wilson, David Whittum
AP 453C - 3 units -Spring

Previous courses...

Introduction to Accelerator Physics
Bob Siemann
Laboratory Electronics
John Fox

Nonlinear Dynamics in Accelerators
Alex Chao & David Whittum
Beam Dynamics in Storage Rings
Alex Chao
Physics of Free Electron Lasers
David Whittum

In addition, US & CERN Particle Accelerator Schools - see http://beam.slac.stanford.edu/

Courses This Year

AP 453A: **Electromagnetic Radiation from Relativistic Electrons**
Helmut Wiedemann (Fall, 3 units)

The emission of electromagnetic radiation from relativistic electron beams is derived from first principles with special attention to coherent and incoherent synchrotron radiation, transition radiation, free electron lasers. This includes discussions of undulator and wiggler radiation with linear and elliptical polarization. The course is intended primarily for graduate students using such radiation for basic and applied research and students in accelerator physics concentrating on source developments and the study of particle beam characteristics and stability. Prerequisite: EM, Optics and special relativity is desirable.

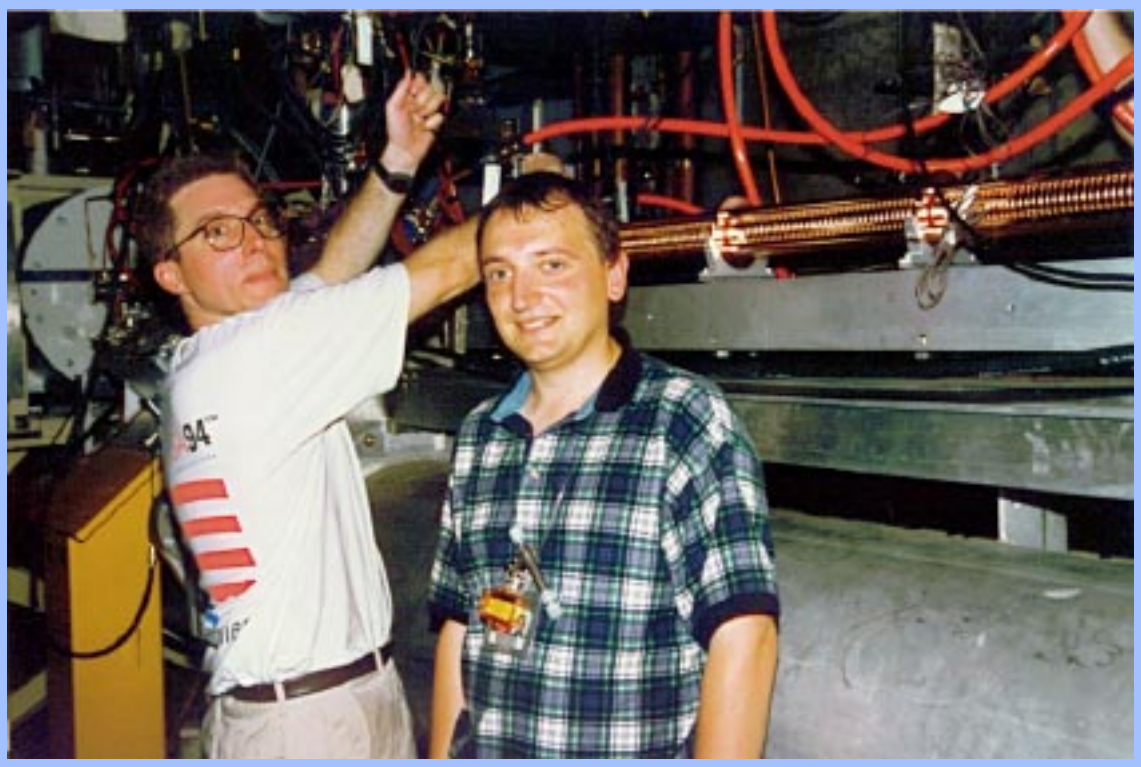
AP 453B: **Collective Effects in Accelerators**
Alex Chao, (Winter, 3 units)

An intense beam in an accelerator is subject to a variety of instability mechanisms. This course is a systematic introduction of these mechanisms, starting with Maxwell's equations. Topics of interest include wake fields, impedances, Landau damping, intra beam scattering, and the Vlasov equation. The instabilities studied include those for storage rings as well as linacs.

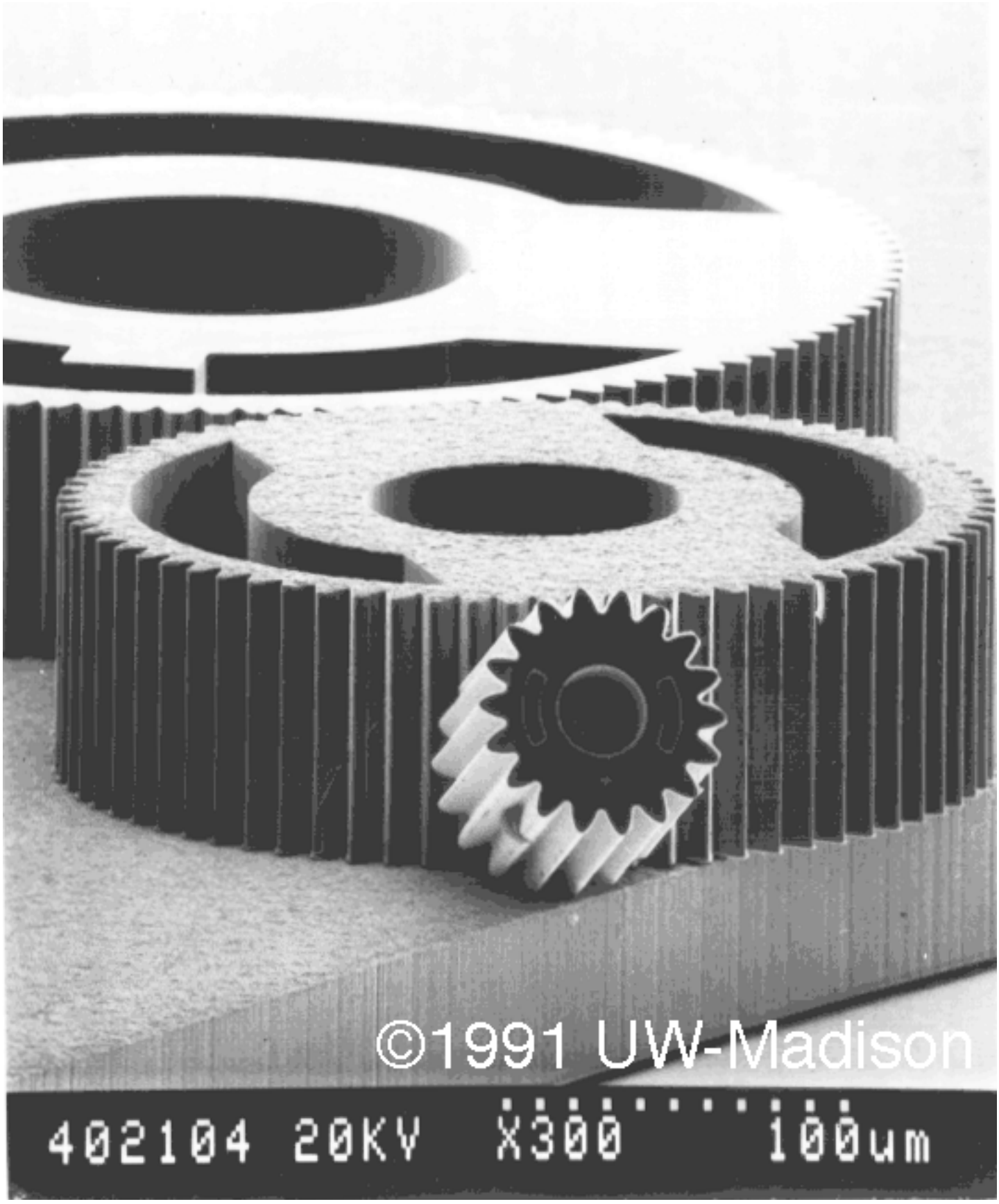
AP 453C: **Microwave Linear Accelerators**
Roger Miller, David Whittum and Perry Wilson, (Spring, 3 units)

For students with a general interest in electron linear accelerators, in electron linacs for free electron lasers or in future linear colliders. Review of beam transport and emittance concepts; electron injection (guns, bunching and capture); accelerating structures; klystron theory and rf pulse compression; concepts of beam loading and wake potential; introduction to advanced particle acceleration, such as wake field and plasma accelerators.

Wakefield Instrumentation



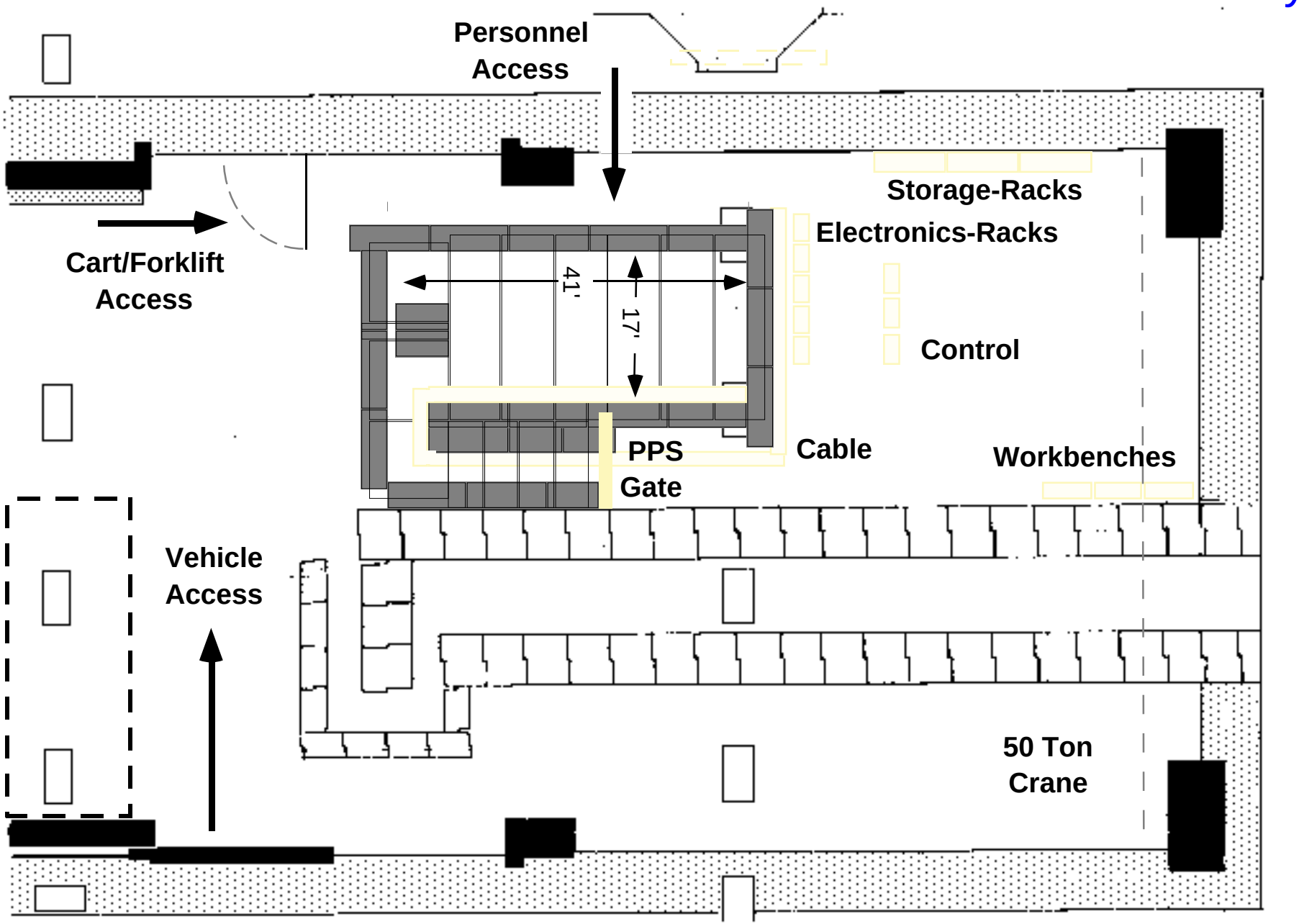
LIGA



LIGA

(in perspective)

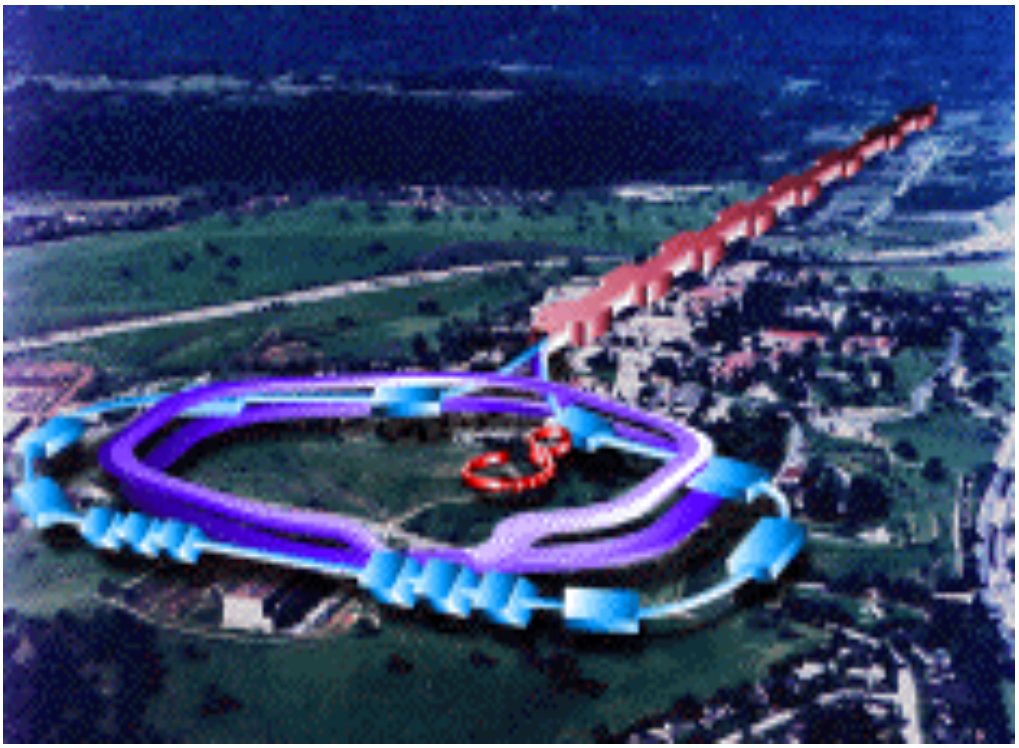
ESB Facility



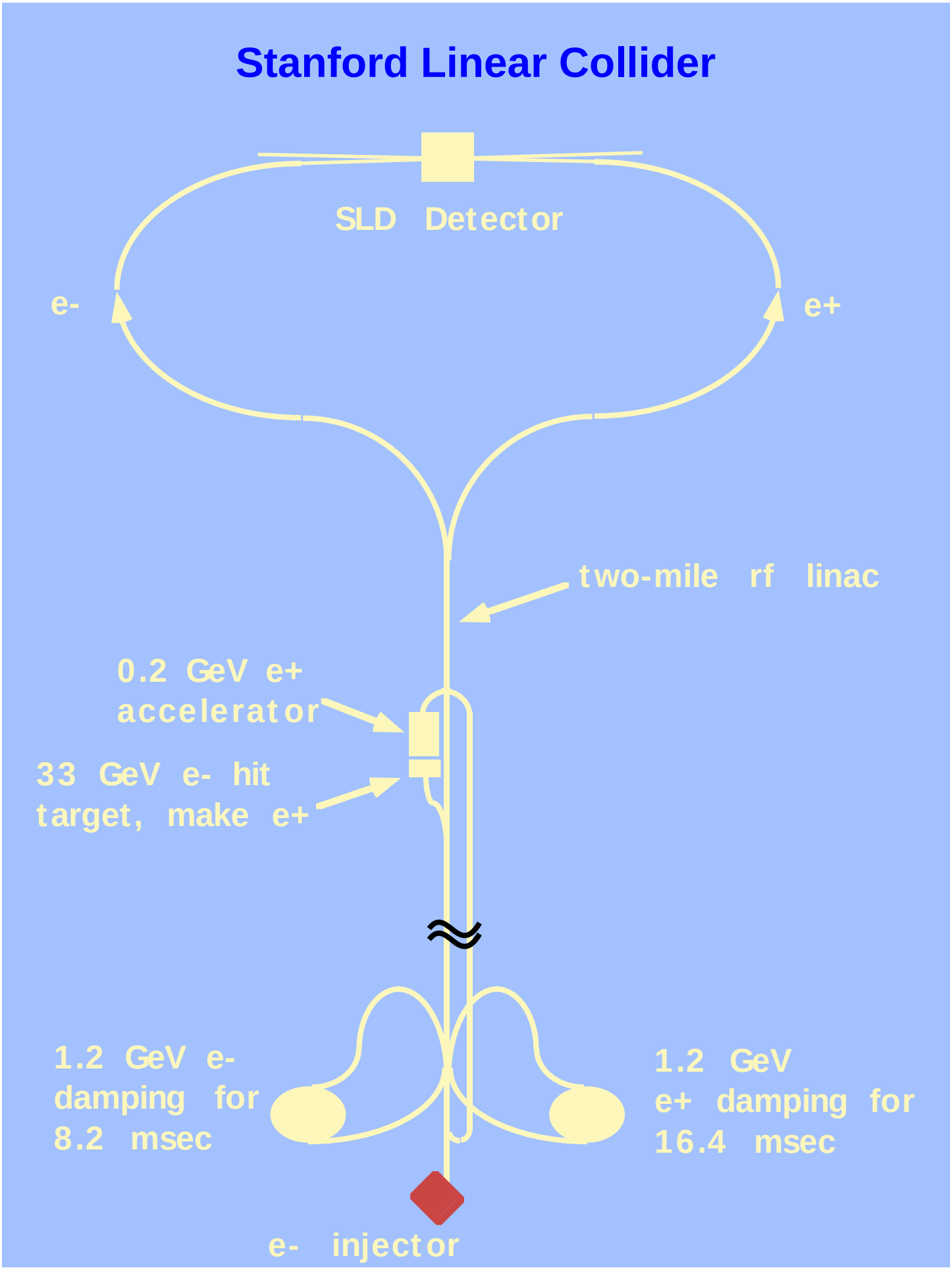
Accelerator Research at the SLC

Linear Collider Beam Dynamics
Ralph Aβmann & Accelerator Dept.

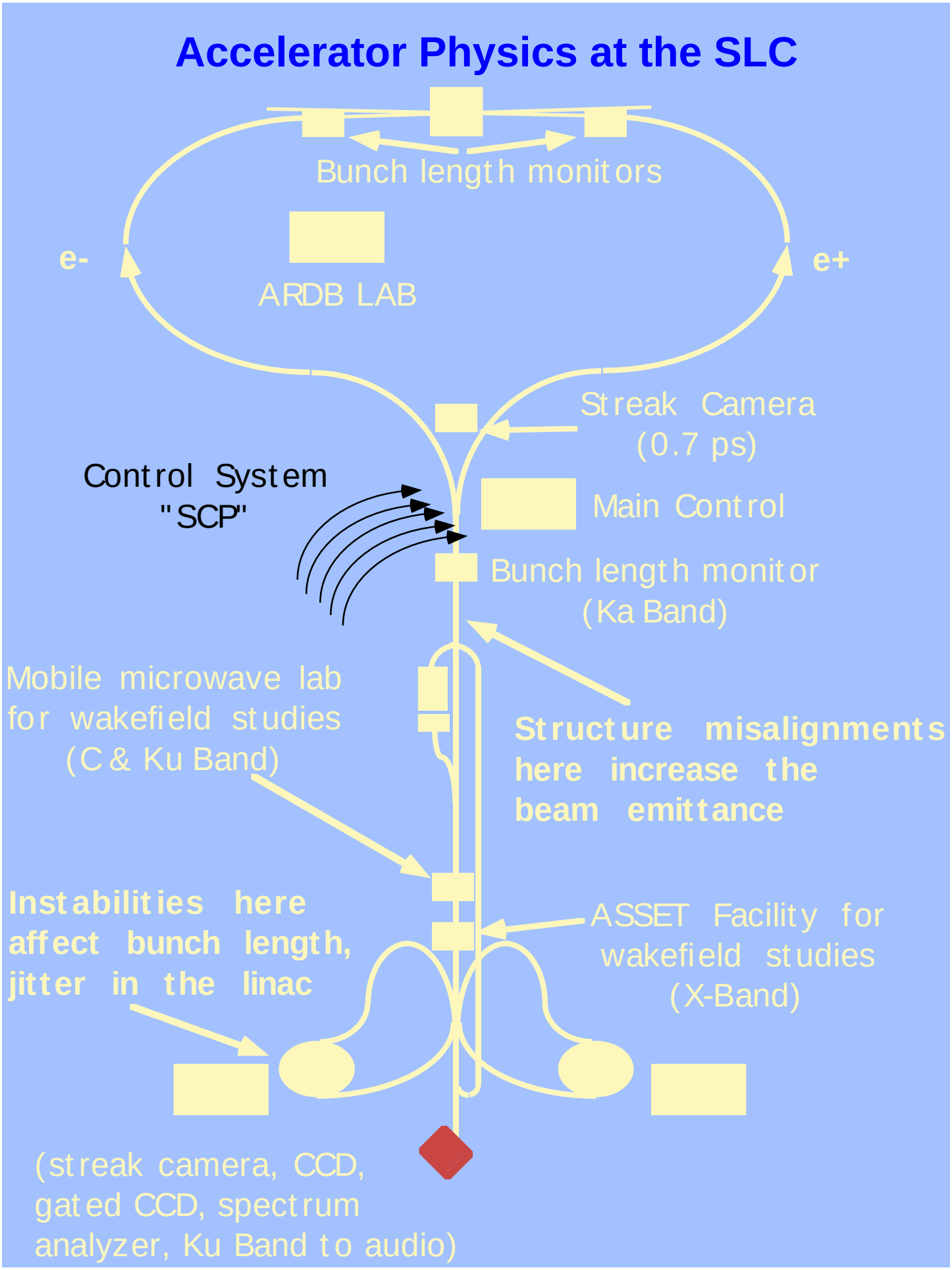
Beam Dynamics of Damping Rings
Boris Podobedov & Accelerator Dept.



Stanford Linear Collider



Accelerator Physics at the SLC



Other Projects

Beam Dynamics in a mm-Wave Linac
Laser-Wakefield 5 TeV Collider "Design"
S-Band Structure Wakefield Studies at LI02
[Mike Seidel]
a)modelling b)bench measurements on a 10' section
c)hardware implementation d)commissioning
Sub-Micron Resolution Cavity BPM for Moller Scattering Experiment
[Nicolo deGroot]
a)modelling b)prototype cavity fabrication
c)cold-testing d)commissioning
Sub-Micron Resolution mm-Wave BPM for X-Ray Light Source
[Bob Hettel, Fritz Caspers]
a)modelling b)prototype cavity fabrication & cold-testing
c)commissioning
mm Bunch Length Monitor for Precision Z0 Studies
[Jerry Yocky, Frank Zimmermann]
a)modelling b)hardware implementation
b)commissioning
S-band Structure Dimpling for Precision Z0 Studies
[Franz-Josef Decker, Pantaleo Raimondi]
a)theory of long range wakefields, effect of dimpling
b)implementation on test stacks
c)implementation on five sectors of the SLC d)commission on SLC
Studies of Field Emission on a Resonant Ring
[Xiaoxi Xu]
a)modelling of a resonant ring b)implementation of ring diagnostics
mm-Wave Tube ("ubitron") [Klystron Dept.]
a)modelling b)engineering design
c)fabrication d)commissioning
mm-wave Structure Design [Heino Henke, Norman Kroll]
a)circuit analysis b)field calculations
c)wakefield analysis

What Has Changed?

New Results

- high-power, short-pulse,efficient lasers
- phase,amplitude, jitter control of T^3 lasers
- channel guiding
- microfabrication
- wakefield instrumentation

New Directions (or Slightly-Used)

- PWFA Test at SLAC
- beam-combining
- neutral beam collisions
- matrixed linacs

Predictions

in the next year...

Can Do

- CLIC will machine a DDS structure
- PWFA at SLAC standying by for e-time
- channel-guided LWFA results are in
- NLC in engineering phase

Maybe Can Do

- ultimate G in Cu known to 10%
- field emission β understood, held to 20
- 30 MW W-Band tube being engineered
- LWFA systems study in progress
- beam combining, neutralization proposal
- wakefields for 0.5mm bunch agree w/theory
- AA Community particpates in SLC's Last Run

For More Information on ARDB, Contact...

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