

Report on the Sub-Group for
Advanced Accelerator Technologies

Snowmass, Colorado
June 27 - July 10, 1996

Convenor: Jonathan Wurtele, UC Berkeley/LBNL
Sub-Group Leaders: Swapan Chattopadhyay, LBNL
David Whittum, Stanford/SLAC

bit of history on Snowmass

Outline

① Charge & Results

② Talks

③ What Next?

① Charge

- ☞ Discuss and evaluate concepts for achieving 5 TeV center-of-mass $e^+e^- \gamma$ collisions with luminosity $10^{35} \text{ cm}^{-2} \text{ sec}^{-1}$.
- ☞ Attention should be given to **gradient, emittance, efficiency & collective effects**.
- ☞ Promising R&D directions should be identified, particularly for power-sources, structures & instrumentation.

Results

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, Zolotarev - LBNL
Laser	Structure-Based , Huang, Stanford Plasma-Based , [Esarey & Multitudes]
Beam	Structure-Based , Gai, ANL Plasma-Based , UCLA
$\gamma\gamma$	Kim, Xie, LBNL

g vs I plot

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

γ

[this or neutral beams a required adjunct to other concepts]

What Has Changed?

New Results

- high-power, short-pulse, efficient lasers
- phase, amplitude, jitter control of T³ lasers
- channel guiding
- microfabrication
- wakefield instrumentation

New Directions (or Slightly-Used)

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

② Talks

37 Speakers

June 27 Thursday

June 28 Friday

July 1 Monday

July 2 Tuesday

July 5 Friday

July 8 Monday

July 9 Tuesday

A Menu of 5 TeV Colliders

Structures

Low-Emittance Beams

Wakefields

Power Sources

$\gamma\gamma$ at 5 TeV

Laser Acceleration

Directions for Research

Ad Hoc

26 Other Participants

LBNL - Wen-Hao Cheng, Andy Sessler,
Bradley Shadwick

FNAL - Pat Colestock, David Finley, Fred Mills,
Robert Noble

LLNL - Dan Klem

ANL - Jim Norem

UCLA - David Cline, Claudio Pellegrini

U. Michigan, Ann Arbor - Lawrence Jones

BNL - Harold Kirk, Q.S. Shu

US DOE - David Sutter

Cornell U. - James Welch

UC San Diego - Norman Kroll

SLAC - Chris Adolphsen, Ralph Aßmann,

Keith Jobe, Tor Raubenheimer, Bob Siemann, Kathy Thompson,

Juwen Wang, Dian Yeremian, Michiko Minty

June 27 Thursday

A Menu of 5 TeV Colliders

Prof. Jonathan Wurtele, UC Berkeley,
**"Constraints on Laser-Driven Accelerators
for a High-Energy Linear Collider"**

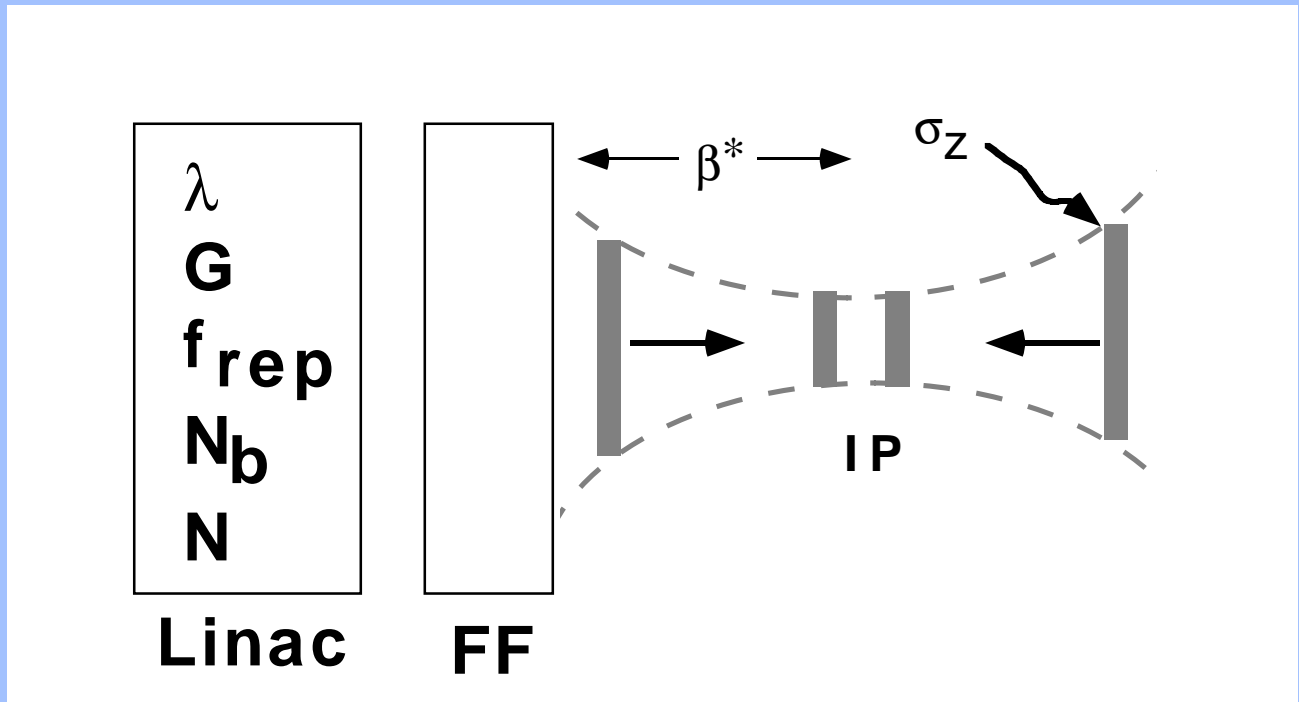
Prof. Hasan Padamsee, Cornell University
**"A scheme for a 5 TeV cm at 10^{35} luminosity linear
collider (with a parameter set) for a linear collider based
on SC cavities"**

Dr. Glen Westenskow, LLNL,
**"5TeV Linear Collider Based on a Two-Beam
Accelerator at <30GHz"**

Prof. David Whittum, SLAC
"5TeV Linear Collider at 91GHz"

Prof. Tom Katsouleas, USC
"Plasma and Laser 5 TeV Colliders"

Scalings



high γ

$\gamma\gamma$

neutral beams

Vocabulary

Luminosity

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

Upsilon

avg γ energy/beam e- energy

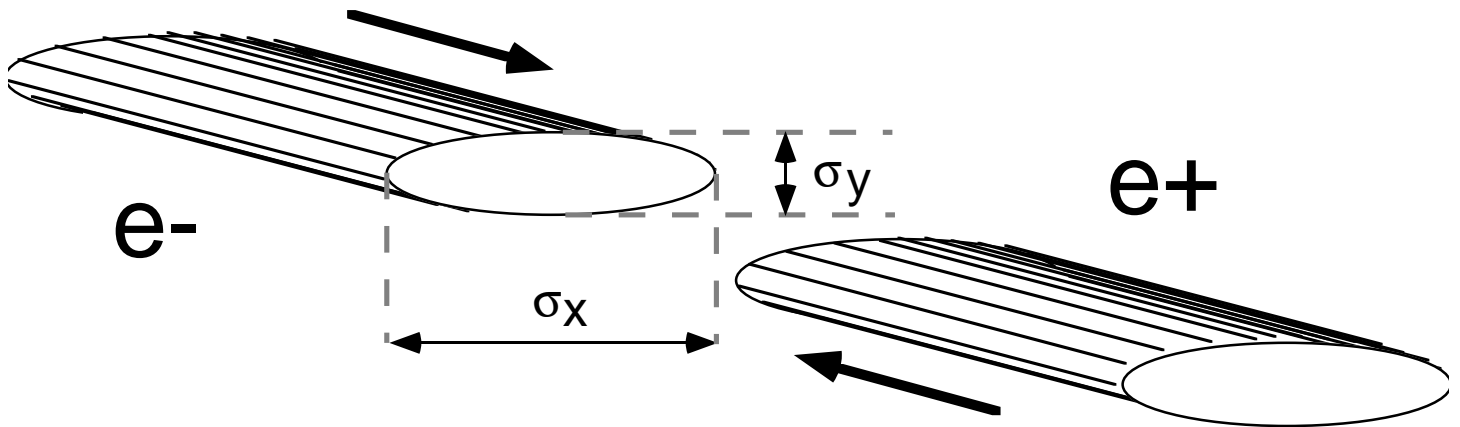
$$Y = 0.833 \frac{N r_e^2 \gamma}{\alpha \sigma_z \sigma_y (1+R)} = 0.3 - 1000$$

Beamstrahlung

avg e- energyloss /beam e- energy

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

IP Notation



$$R = \frac{\sigma_x}{\sigma_y}$$

$$\beta_{x,y}^* = \sigma_z \hat{\beta}_{x,y}$$

$$\sigma_z = \frac{\lambda}{100} \hat{\sigma}_z$$

$$\gamma = 5 \times 10^6 \hat{\gamma}$$

$$L = 10^{35} \text{ cm}^{-2} \text{ sec}^{-1} \hat{L}$$

$$\varepsilon_{nx,y} = 10^{-6} \text{ m-rad} \hat{\varepsilon}_{x,y}$$

$$\hat{\lambda} = \frac{\hat{\sigma}_z}{\hat{\gamma}} \lambda(\text{cm})$$

$$R = 1-10$$

$$\hat{\beta}_{x,y} = 0.5-1$$

$$\hat{\sigma}_z = 1-2$$

$$\hat{\gamma} = 1$$

$$\hat{L} = 1$$

$$\hat{\varepsilon}_{x,y} = 10^{-3} - 1$$

$$\lambda(\text{cm}) = 1-10^{-4}$$

IP Scalings

$$\delta_B \approx 0.506 \frac{\hat{\lambda} Y^2}{\left(1 + (1.5Y)^{2/3}\right)^2}$$

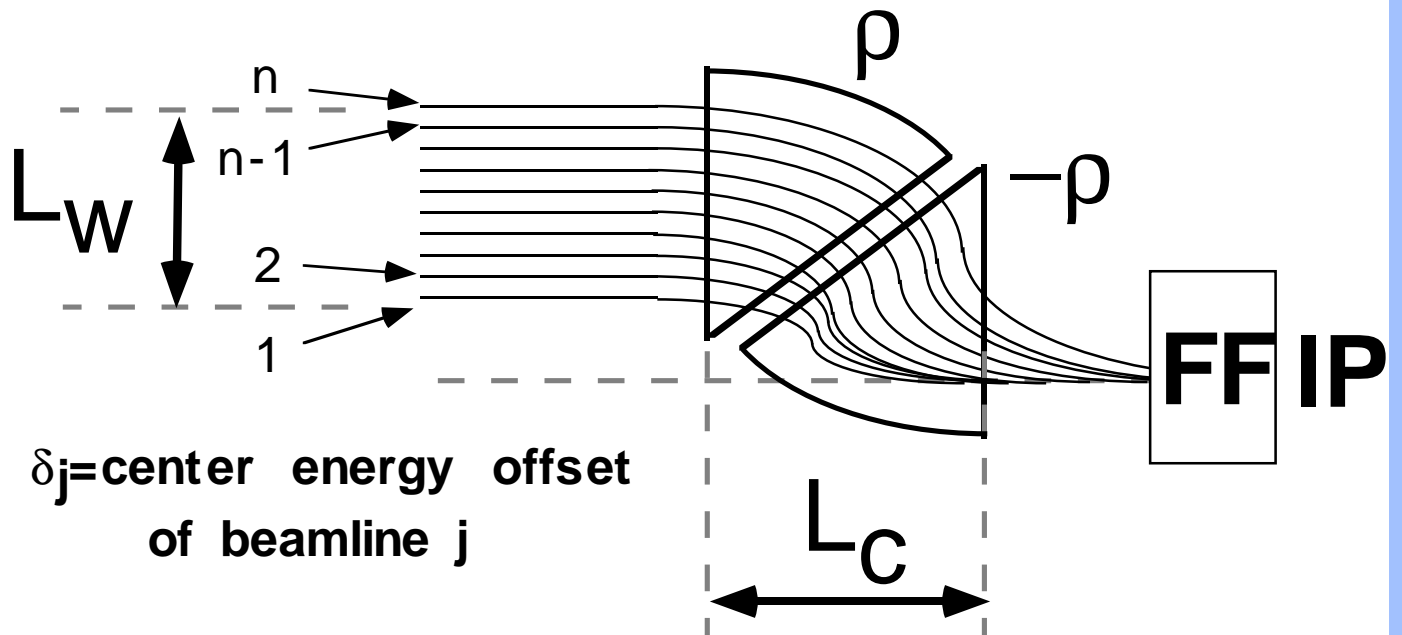
$$N = 9.86 \times 10^7 (\hat{\epsilon}_x \hat{\beta}_x)^{1/2} \left(\frac{1+R}{R}\right) \hat{\lambda}^{3/2} Y$$

$$N_b f_{rep} = 2.58 \times 10^7 \text{ Hz} \frac{R}{(1+R)^2} \frac{\hat{L}}{\hat{\lambda}^2 Y^2}$$

$$P_b = 2.08 \times 10^9 \text{ W} \frac{\hat{\gamma} \hat{L}}{1+R} \frac{(\hat{\epsilon}_x \hat{\beta}_x)^{1/2}}{\hat{\lambda}^{1/2} Y}$$

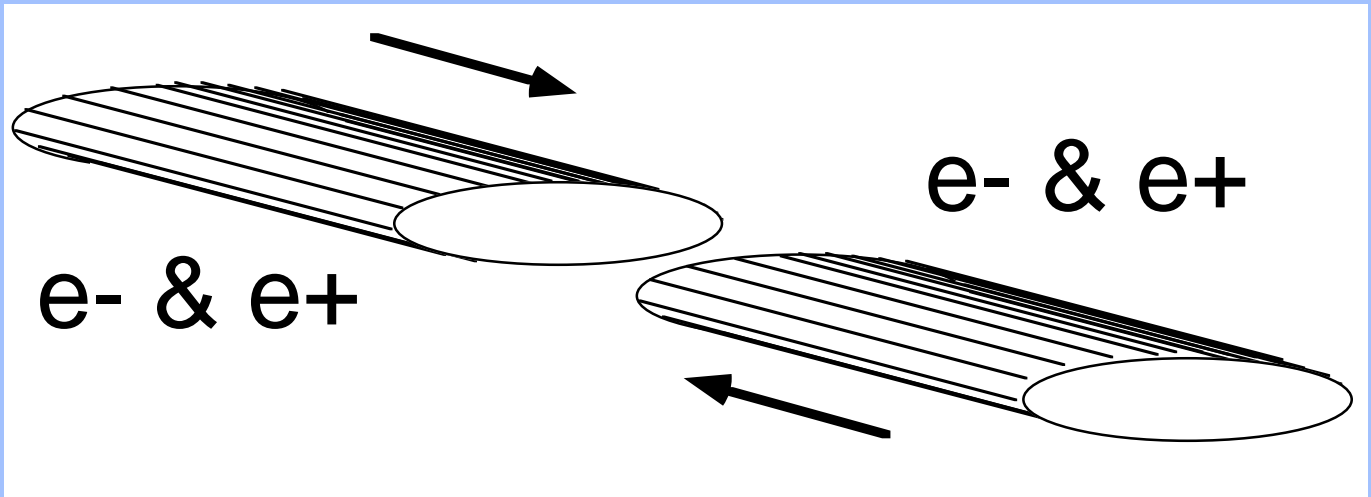
$$D_y = 0.55 \frac{\hat{\lambda}^{3/2} R Y}{(\hat{\epsilon}_x \hat{\beta}_x)^{1/2}}$$

Beam Combining

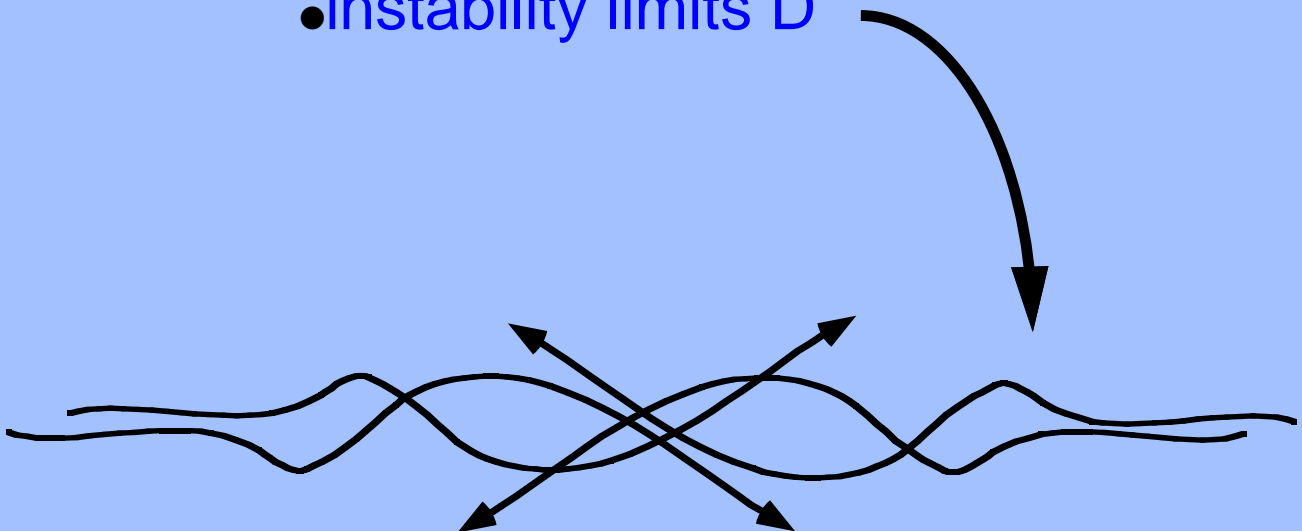


- L_C is bounded below due to emittance growth from synchrotron radiation
- neutral beams are required

Neutral Beams

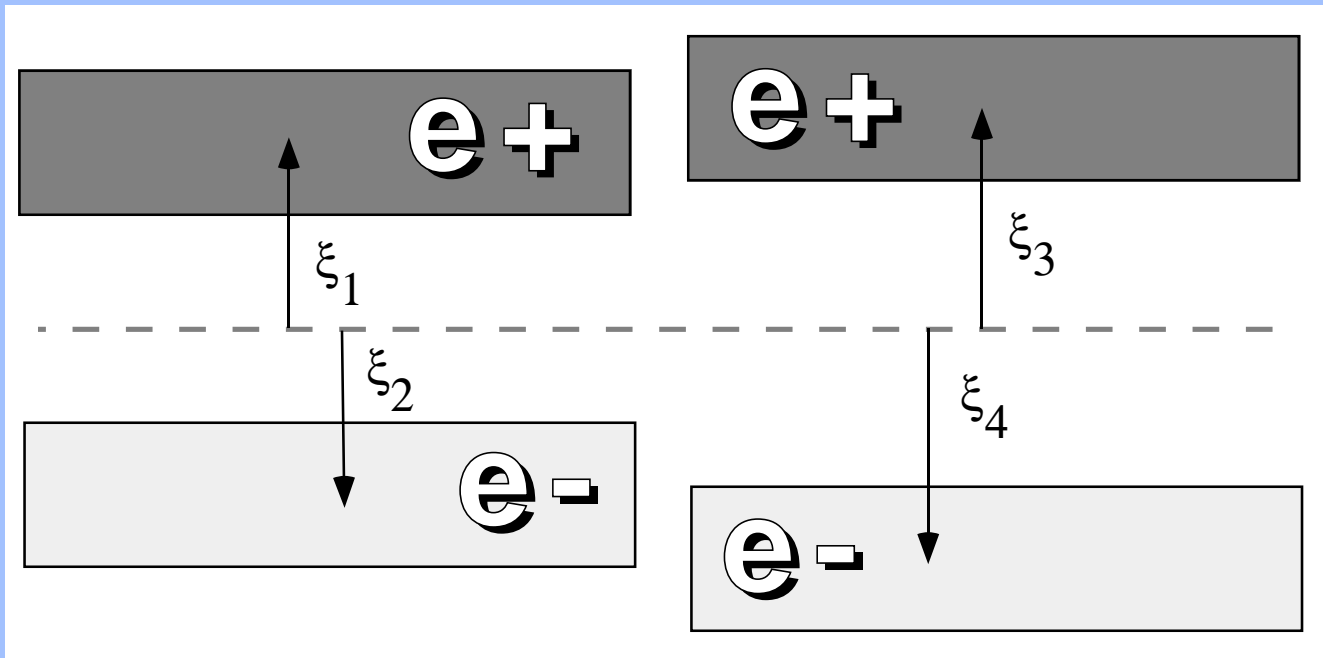


- multiple bunch linac
- beam combining
- uncertain initial state
- alignment, optics, N
- instability limits D



Hose Instability

(Rosenzweig, et al.)



June 28 Friday

Structures

Prof. Hasan Padamsee, Cornell University

"Promise of and R&D directions for Nb₃Sn and high T_c SC cavities"

Dr. David Yu, DULY Research Inc.

"mm-Wave Structures"

Dr. Yoon Wan Kang, ANL

"RF, Thermal & Dynamics Considerations for mm-Wave Structures"

Dr. Wei Gai, ANL

"100 GHz Travelling Wave Dielectric Acceleration Structures"

Dr. Yen-Chieh Huang, Stanford University

"Dielectric-Based Structures for Laser-Driven Accelerators"

Dr. Gennady Shvets, Princeton University

**"Creating Guiding Structures in Plasmas:
Beam-Channeled Laser-Wakefield Accelerators"**

Structure Research

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

July 1 Monday
Part I

New Approaches to Low-Emittance Beams

Dr. Max Zolotarev, LBNL

"Laser-Based High-Brightness Sources & Optical Manipulation of Beams"

Dr. Pisin Chen, SLAC -

"Considerations for Channeling & Damping"

Dr. Alex Bogacz, UCLA

"Development of Crystal-Based Components for Future Accelerators: Experience from the Bent Crystal Extraction Experiment at Fermilab (E853)"

Dr. Jie Wei, BNL

"Cooling & Crystalline Beams"

July 1 Monday
Part II

Wakefields

Dr. John Irwin, SLAC

"NLC Collimator Wakefields"

Dr. Karl Bane, SLAC

"The Bane-Morton Model"

Mr. Peter Stoltz, University of Colorado

**"Nonlinear Theory of Beam Bunching and
Deceleration Due to Cavity Damping"**

Prof. Alex Chao, SLAC

"General Planar Wake Conditions"

Dr. Frank Zimmermann, SLAC

"Diffraction Model With Image Currents"

Dr. Franz-Josef Decker, SLAC

"SLC Collimator Experience"

Wakefields

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

July 2 Tuesday
Part I

Power Sources

Prof. Perry Wilson, SLAC,
**"A 5 TeV Linear Collider Based on 34 GHz
Technology"**

Dr. Simon Yu, LBNL,
"Two Beam Accelerator for a 5 TeV Collider"

Prof. Victor Granatstein, University of Maryland
**"Gyrotron Amplifiers for Driving Multi-TeV
Colliders in the Frequency Range 20GHz to 100GHz"**

Prof. Martin A. Gundersen, USC
"Research Issues in Power Conditioning"

Prof. Toshi Tajima, UT Austin
"T³ Laser Initiatives in the US & Japan"

Power Sources

- sheet beam klystron
- two-beam accelerator
- gyrotrons
- lasers

July 2 Tuesday
Part II

$\gamma\gamma$ at 5 TeV

Dr. Ming Xie, LBNL

**"Parameter Optimization and IP Simulation
of Electron and Photon Colliders at 5 TeV"**

μ -TESLA

Dr. David Neuffer, FNAL

**"Upgrade from 500 GeV TESLA to a
10+ TeV $\mu^+ \mu^-$ Collider"**

γγ

July 5 Friday

Laser Acceleration

Dr. Eric Esarey, NRL

"Laser Acceleration of Electrons in Vacuum, Gases and Plasmas"

Prof. Toshi Tajima, UT Austin

"5 TeV Laser-Based Collider"

Prof. Donald Umstadter, Center for Ultrafast Optical Science,
University of Michigan, Ann Arbor

"Laser Acceleration"

Dr. Chris Clayton, UCLA

"Plasma Beat-Wave Accelerator"

Prof. Martin A. Gundersen, USC

**"Development of Practical Devices
for Implementation of Plasma-Based Concepts"**

Laser

Directions for Research

July 8 Monday

Dr. Joshua Song, ANL

"Fabrication of mm-Wave Structures via Deep X-Ray Lithography"

Dr. Wei Gai, ANL

"Inverse Cherenkov Acceleration using a Dielectric Channeled Waveguide"

July 9 Tuesday

Dr. John Irwin, SLAC

"5 TeV Linear Collider on the NLC Site"

Dr. Kwang-Je Kim, LBNL

"5 TeV $e+e-\gamma$ Collider Parameters"

Directions

- ANL is making mm-wave structures
- $\gamma\gamma$ IP work is well-in-hand
- NLC Group interested in 30GHz

③ What Next?

Small Spot?

→ IP Limitations

New Structure?

→ Wakefields , Beam Dynamics

$2\text{cm} > \lambda > 10\mu\text{m}$?

→ Power Source, Efficiency

$G > 100\text{MeV/m}$?

→ Efficiency

Ultra-Low Emittance?

→ Source, Beam Dynamics



Parameters

for $\lambda = 1\text{cm}$ 3mm 1mm LWFA, LS, PWFA...

Example of One Person's "To-Do" List for this Workshop

Channeled **LWFA** Parameter Set
& Beam Dynamics, $P_{\text{site}}=?$ Min $\varepsilon=?$

PWFA Collider Parameter Set
& Beam Dynamics, $P_{\text{site}}=?$ Min $\varepsilon=?$

W-Band Power Tube Parameters
Including Wiggler Design, Max $P=?$

Beam Combiner Design with
10% ε growth, Minimum Length=?

Neutral Beam Forming, FF,
Instability, Maximum $D=?$

W-Band Structure Design for
Minimum Pulsed Heating
(Ultimate Gradient in Copper)
and Sensible Power Feed Scheme

Predictions

in the next year...

Can Do

- CLIC will machine a DDS structure
- PWFA at SLAC standing 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 participates in SLC's Last Run