Higgs Factory R&D and Facilities

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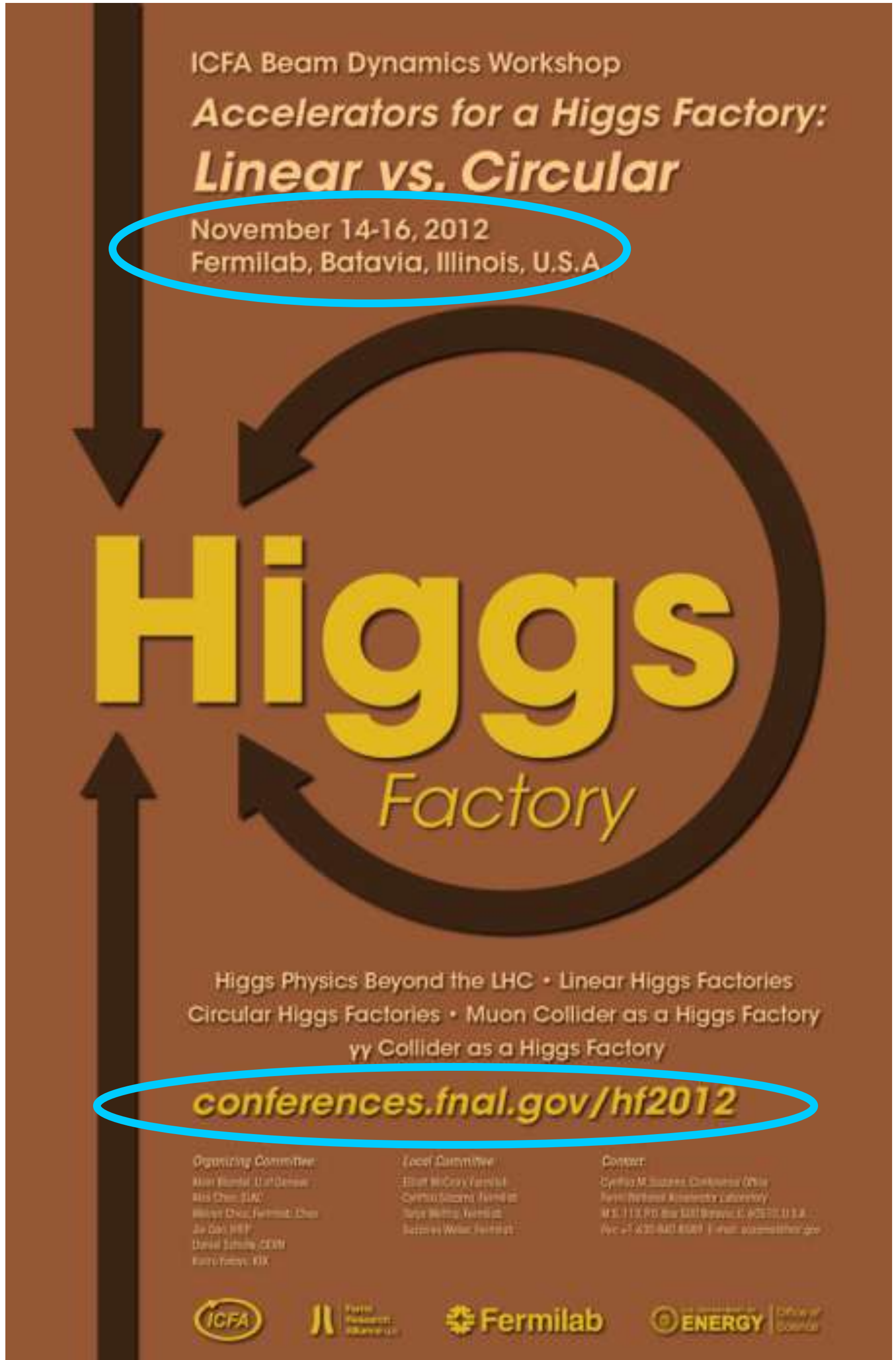
Wei Gai (ANL)
Yuri Bylinski (TRIUMF)

Presentation at the Snowmass Preparation Mini-Workshop
25-26 February 2013, U. of Chicago


ICFA Beam Dynamics Workshop
Accelerators for a Higgs Factory:
Linear vs. Circular
November 14-16, 2012
Fermilab, Batavia, Illinois, U.S.A
Higgs
Factory
Higgs Physics Beyond the LHC • Linear Higgs Factories
Circular Higgs Factories • Muon Collider as a Higgs Factory
γγ Collider as a Higgs Factory
conferences.fnal.gov/hf2012
Organizing Committee
Local Committee
Contact
ICFA
Fermilab
ENERGY

The World HEP Landscape Planning – a Circle?

2001 Snowmass → **2004** → **After 4th of July 2012**

2001 Snowmass

- Linear e+e-
  - Cold (TESLA)
  - Warm (NLC/JLC)
- Circular e+e-
- VLHC
- Muon collider

2004

- **Cold Linear e+e- (ILC)**

After 4th of July 2012

- Linear e+e-
  - ILC
  - CLIC
  - X-band klystron based
- Circular e+e-
  - Fermilab site filler
  - LEP3 and TLEP
  - SuperTRISTAN
  - China Higgs Factory (CHF)
  - VLLC
- Muon collider
- Photon cillider
  - ILC-based
  - CLIC-based
  - SAPPHiRE
  - SLC-type
  - ERL-based

	Wednesday, November 14	Thursday, November 15	Friday, November 16
08:00 – 09:00	Registration		
09:00 – 12:30 (30' coffee)	***Introduction and physics*** (Chair: *Alain Blondel*) 1. Strategy for Higgs study (*Young-Kee Kim*) 2. Higgs at the LHC (*Fabio Cerutti*) 3. Higgs beyond the LHC – theories (*Chris Quigg*) 4. Higgs beyond the LHC – experiments (*Patrick Janot*) 5. Accelerators for a Higgs factory (*Stuart Henderson*)	***Circular e+e- Higgs factories*** (Chair: *Daniel Schulte*) 1. LEP3 and TLEP (*Frank Zimmermann*) 2. SuperTristan (*Katsunobu Oide*) 3. Fermilab site-filler (*Tanaji Sen*) 4. IHEP Higgs factory (*Qing Qin*) 5. LBNL/SLAC ring and lattice issues (*Yunhai Cai*) 6. Topping up injection (*John Seeman*)	***Low emittance rings*** (Chair: *Weiren Chou*) 1. Light sources (*Riccardo Bartolini*) 2. Colliders (*Yoshihiro Funzkoshi*) ***Muon collider as a Higgs factory*** (Chair: *Weiren Chou*) 1. Physics of $\mu\mu \rightarrow$ Higgs (*Tao Han*) 2. Muon collider (*Dave Neuffer*) 3. Background and MDI (*Ron Lipton*)
12:30 – 14:00	*Lunch*	*Lunch*	*Lunch*
14:00 – 17:30 (30' coffee)	***Linear e+e- Higgs factories*** (Chair: *Jie Gao*) 1. ILC as a Higgs factory (*Nick Walker*) 2. CLIC as a Higgs factory (*Daniel Schulte*) 3. SLC- & NLC-type Higgs factory (*Tor Raubenheimer*) 4. Machine-detector interface for the ILC and CLIC (*Marco Oriunno*)	***Limits for circular e+e- colliders*** (Chair: *Alex Chao*) 1. Beamstrahlung – calculations and cure (*Valery Telnov*) 2. Beamstrahlung – simulations (*Marco Zanetti*) 3. Scaling law (*Kaoru Yokoya*) 4. Beam-beam tune shift (*Jie Gao*) 5. Synchrotron radiation – RF (*Andy Butterworth*) 6. Synchrotron radiation – vacuum (*Nadine Kurita*)	***$\gamma\gamma$ collider as a Higgs factory*** (Chair: *Kaoru Yokoya*) 1. Physics of $\gamma\gamma \rightarrow$ Higgs (*Mayda Velasco)* 2. $\gamma\gamma$ collider (*Tohru Takahashi*) 3. Laser for CLIC-based $\gamma\gamma$ collider (*Andy Bayramian*) 4. SAPPHiRE (*Frank Zimmermann*) ***Summary Talks (Joint with the Wine-and-Cheese Seminar)*** (16:00 – 17:00) (Chair: *John Campbell*) 1. Higgs factory – physics (*Alain Blondel*) 2. Higgs factory – accelerators (*Weiren Chou*)
17:30 – 19:30	*Reception (Wilson Hall, 2nd floor)*	*Dinner (18:30 – 20:30, Chez Leon)*	*Adjourn (17:00)*

Purpose and Report

- The purpose of the workshop was not to recommend any specific machine.
- The purpose was to make technical comparison between these candidates:
  - Physics reach
  - Performance (energy, luminosity)
  - Upgrade potential
  - Technology maturity and readiness
  - Technical challenges requiring further R&D
- A parameter comparison table was compiled during the workshop.

- A draft report was sent to all participants on January 18.
- More than 100 e-mails were received with comments on the draft.
- A revised final report was published on February 15.

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SLAC-PUB-15370
CERN-ATS-2013-032
arXiv: 1302.3318 [physics.acc-ph]

Report of the ICFA Beam Dynamics Workshop

"Accelerators for a Higgs Factory: Linear vs. Circular"

(HF2012)

Alain Blondel[1], Alex Chao[2], Weiren Chou[3], Jie Gao[4], Daniel Schulte[5] and Kaoru Yokoya[6]

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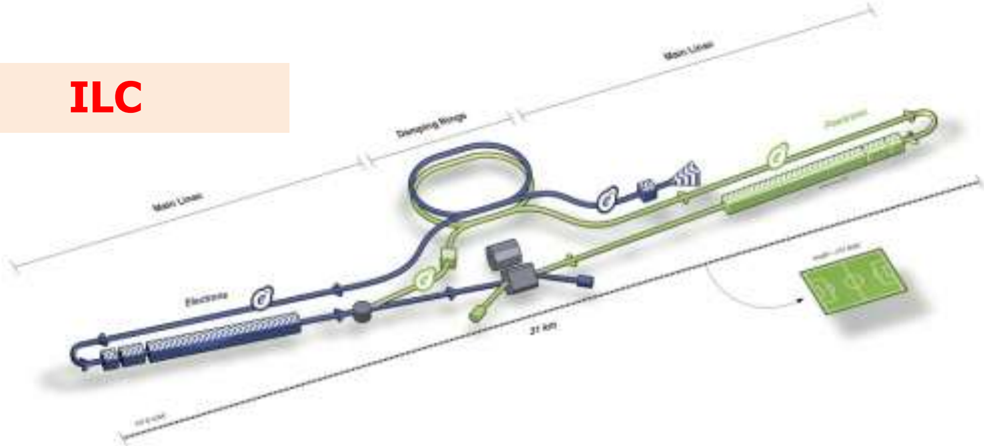
[6] KEK, Tsukuba, Japan

February 15, 2013

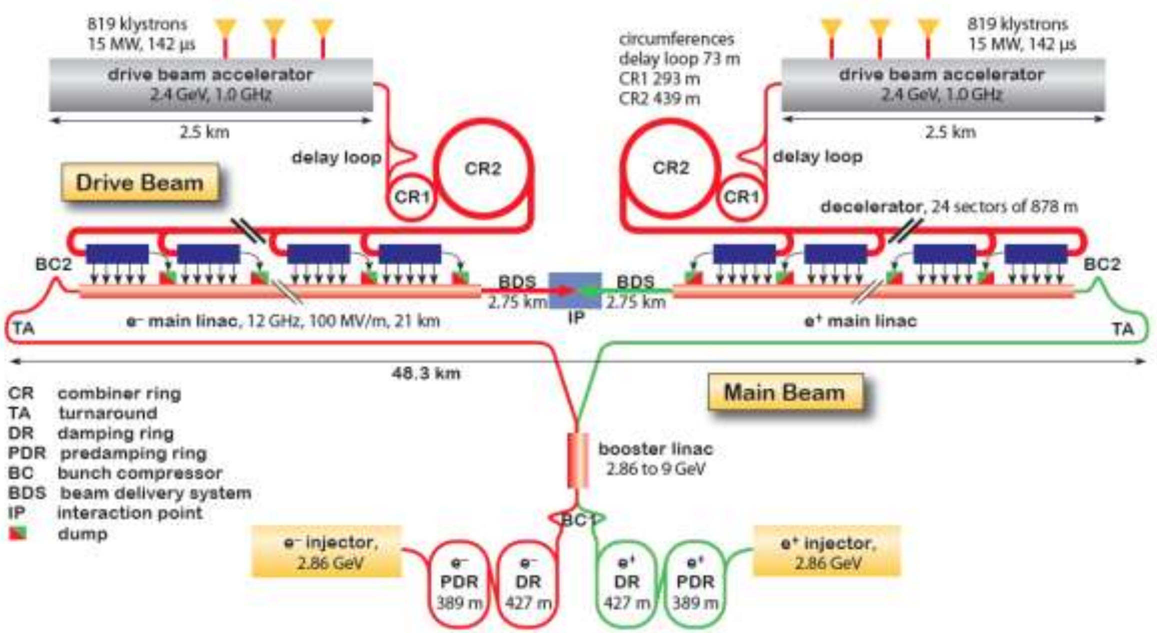
Contents

(1) Linear e^+e^- Collider as a Higgs Factory

ILC



CLIC (also has a klystron version for low energy)



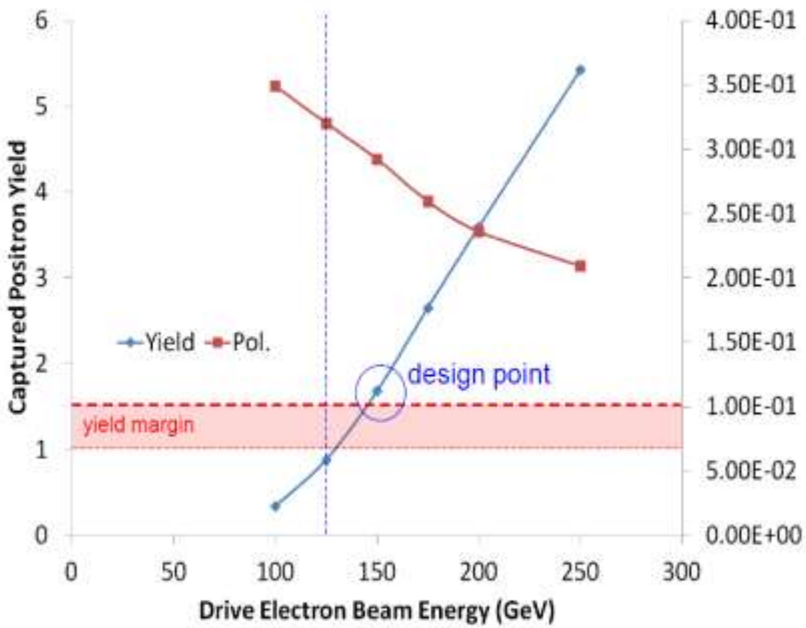
(1) Linear e^+e^- Collider as a Higgs Factory (cont.)

- Advantages:
  - Extensive design and prototyping work have been done
  - Key technologies are in hand after large investment for R&D.
  - There exist well-organized international collaborations led respectively by the ILC GDE and CLIC Collaboration (now combined in the Linear Collider Collaboration)
  - Important step towards high energy e+e- collisions
  - Polarized beams (e- 80%, e+ 30%)
  - A front runner (in terms of readiness)
- Challenges:
  - High cost
- Specific issues:
  - ILC
    - FFS
    - Positron source for a Higgs factory needs 10 Hz operation of the e- linac for e+ production, or the use of an unpolarized e+ beam as a backup scheme
  - CLIC
    - Accelerating structure
    - Industrialization of major components
    - From CDR to TDR

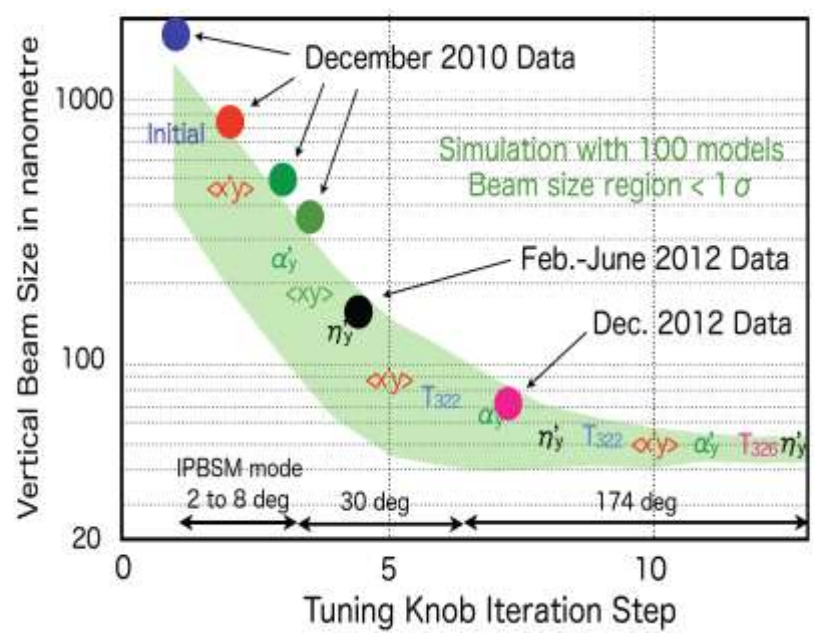
(1) Linear e^+e^- Collider as a Higgs Factory (cont.)

In terms of readiness, the ILC is clearly a front runner. But even this candidate has its technical challenges for a Higgs factory. For example:

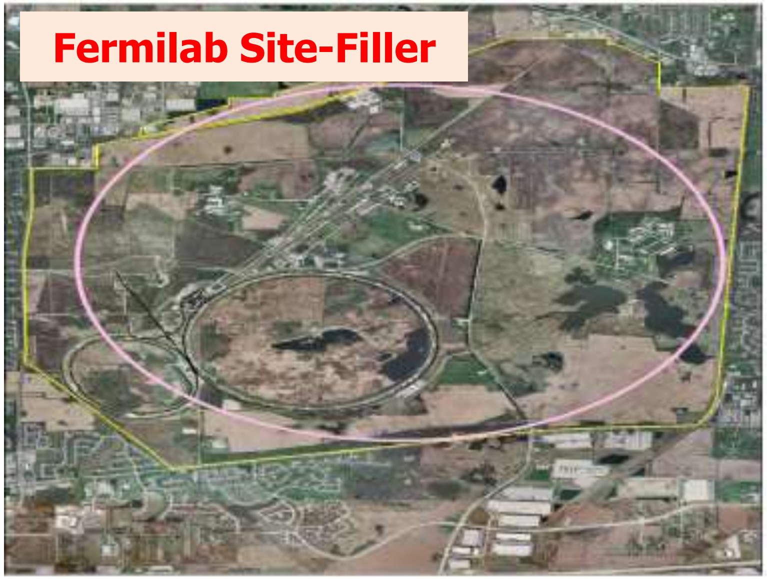
e+ production

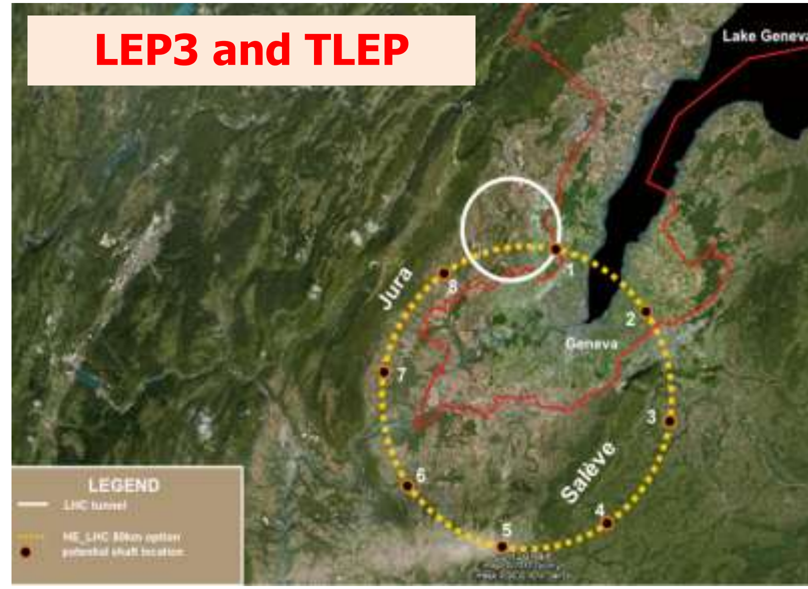


Vertical beam size at IP

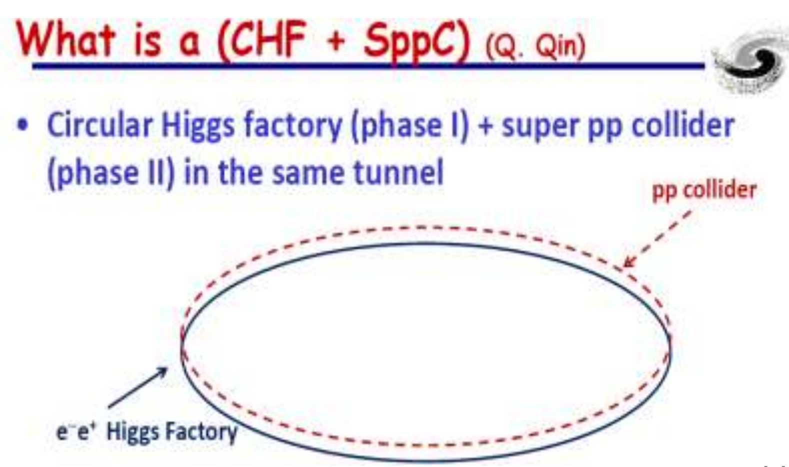


(2) Circular e^+e^- Collider as a Higgs Factory





China Higgs Factory

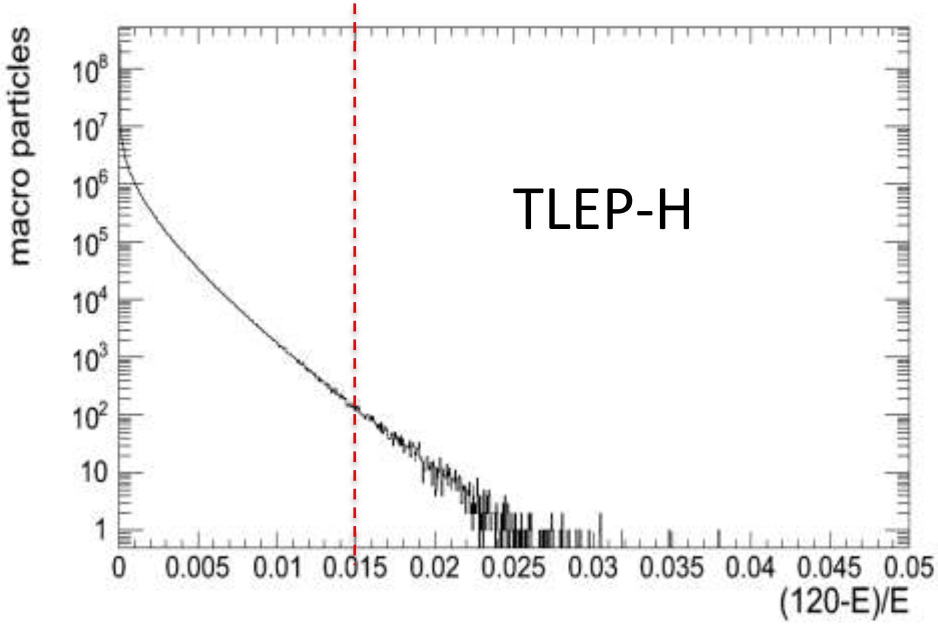


(2) Circular e^+e^- Collider as a Higgs Factory (cont.)

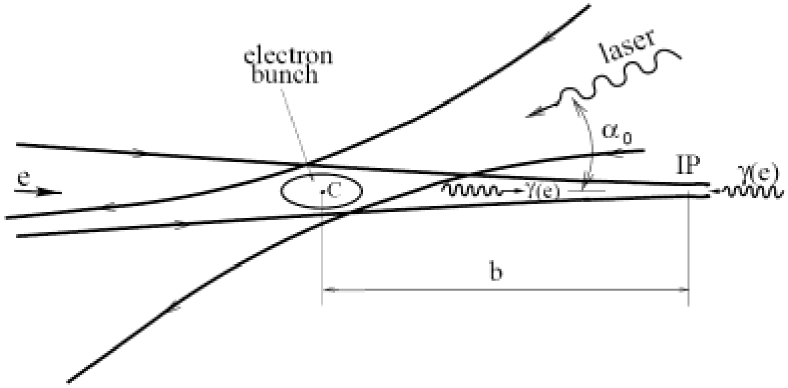
- Advantages:
  - At 240 GeV and below, a higher luminosity than a linear collider when the ring size is sufficiently large
  - Based on mature technology and rich experience
  - Some designs can use existing tunnel and site
  - More than one IP
  - Tunnel of a large ring can be reused as a pp collider in the future
- Challenges:
  - Beamstrahlung limiting beam life time requires lattice with large momentum acceptance
  - RF and vacuum problem from synchrotron radiation
  - A lattice with low emittance
  - Efficiency of converting wall power to synchrotron radiation power
  - Limited energy reach
  - No comprehensive study; design study report needed.

BS lifetime (M. Zanetti)

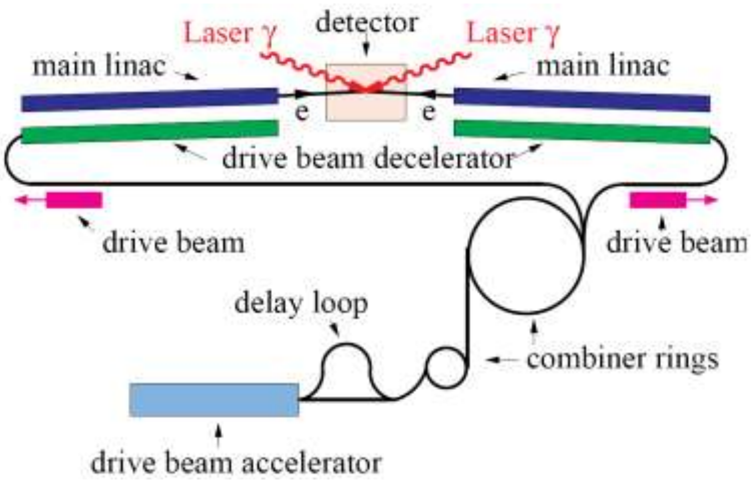
- Simulate and track O(10^8) macroparticles and check the energy spread spectrum
- Lifetime computed from the fraction of particles beyond a given momentum acceptance (η)
- Exponential dependence on η



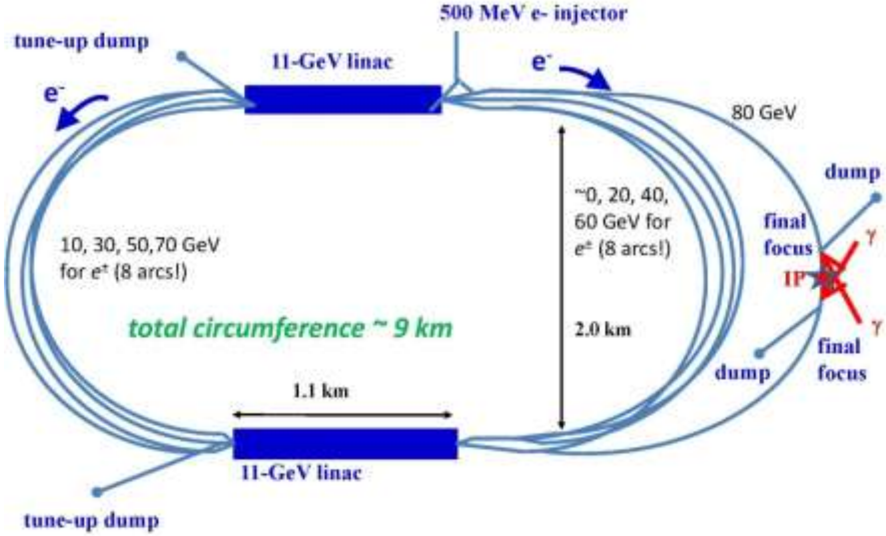
(3) Photon Collider as a Higgs Factory



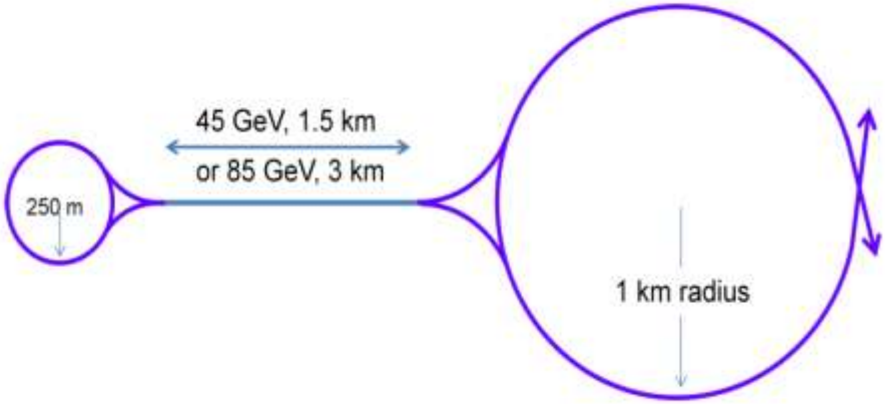
CLIC-based



SAPPHiRE



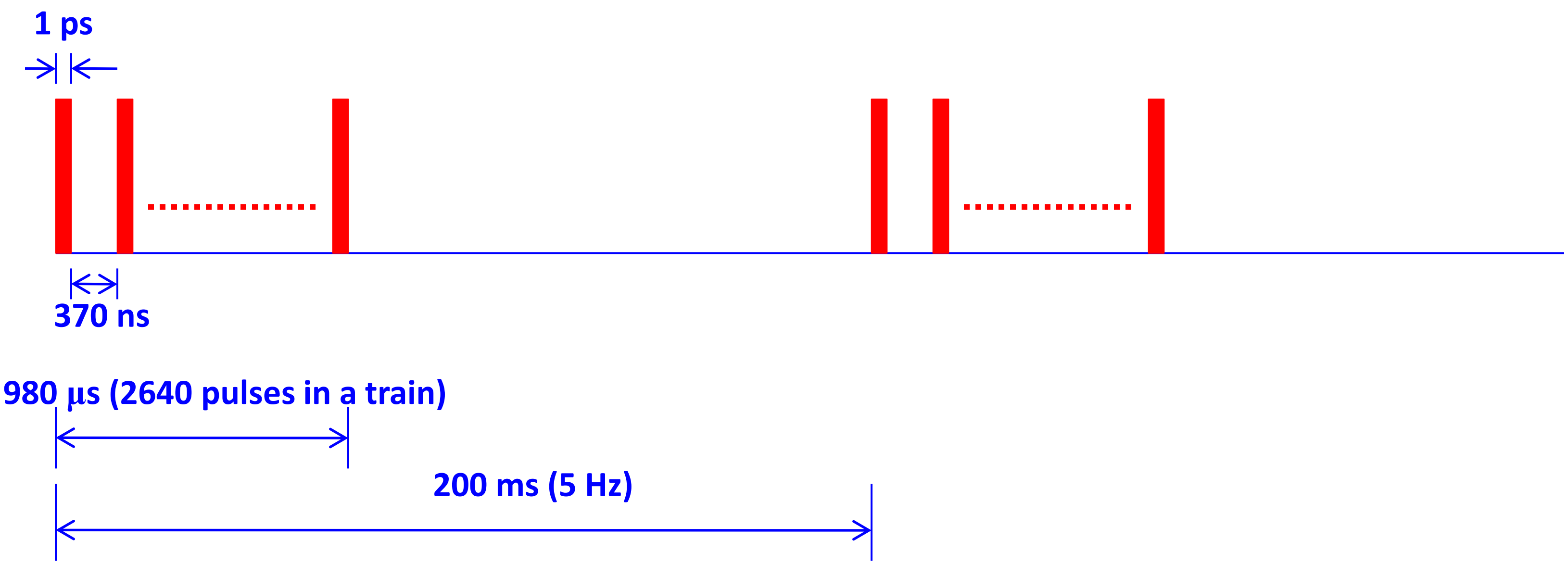
SLC-type



(3) Photon Collider as a Higgs Factory (cont.)

- Advantages:
  - Allow access to CP property of the Higgs
  - Lower beam energy (80 GeV per e- beam to generate 63 GeV γ beam)
  - High polarization in the colliding γ beams
  - No need for e+ beam
  - 160 GeV e- linac has a lower cost w.r.t. a 240 GeV linear e+e- collider
  - Can be added on a linear e+e- collider
- Challenges:
  - Physics not as comprehensive as a 240 GeV e+e- collider would be.
  - Background problem
  - Complex IR design
  - No comprehensive study.; design study report needed.
- Specific issues:
  - ILC-based
    - Optical cavity
  - CLIC-based
    - Laser can piggy-back on the Livermore LIFE fusion project. (But the project schedule is unknown.)
  - Recirculating linac-based:
    - Polarized low emittance e- gun

ILC-based $\gamma\gamma$ Collider

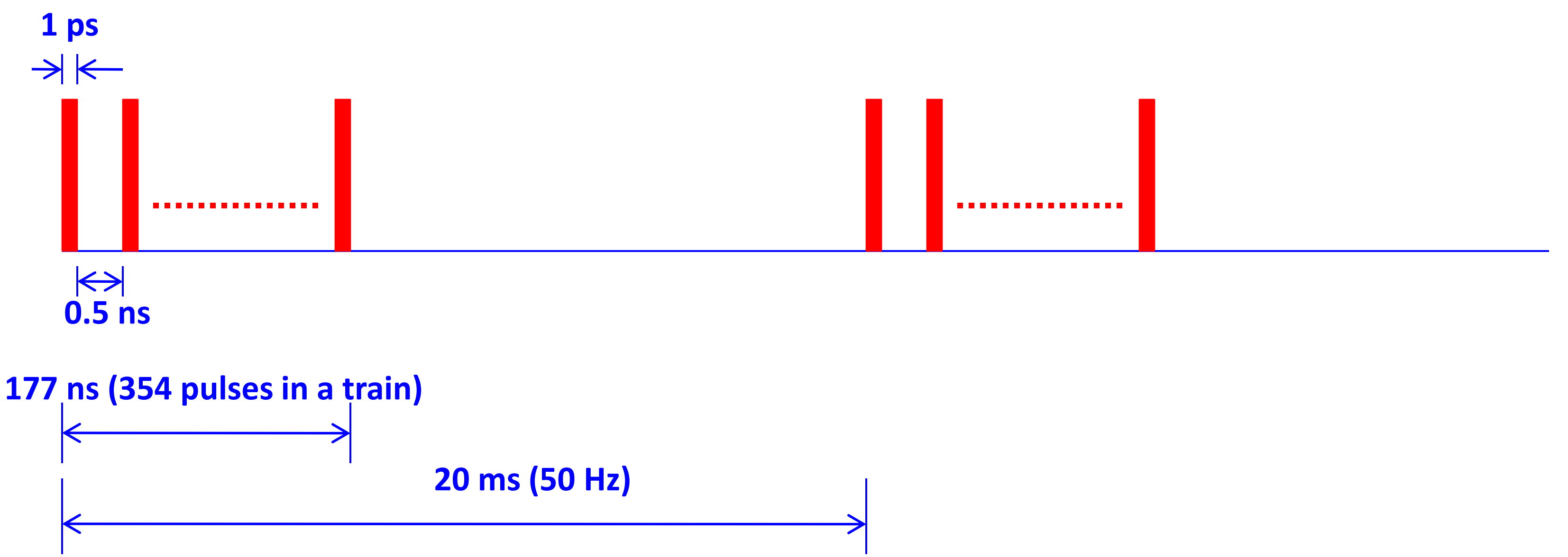


Laser Requirements

Pulse width	Pulse energy	Pulse spacing	No. pulses in a train	Laser power in a train	Laser average power	Rep rate	Wavelength	Spot size	Crossing angle
1 ps	10 J /Q	370 ns	2640	25 MW /Q	150 kW /Q	5 Hz	1 μm	120 nm x 2.3 nm	25 mrad

Need an optical cavity with Q ~ 300

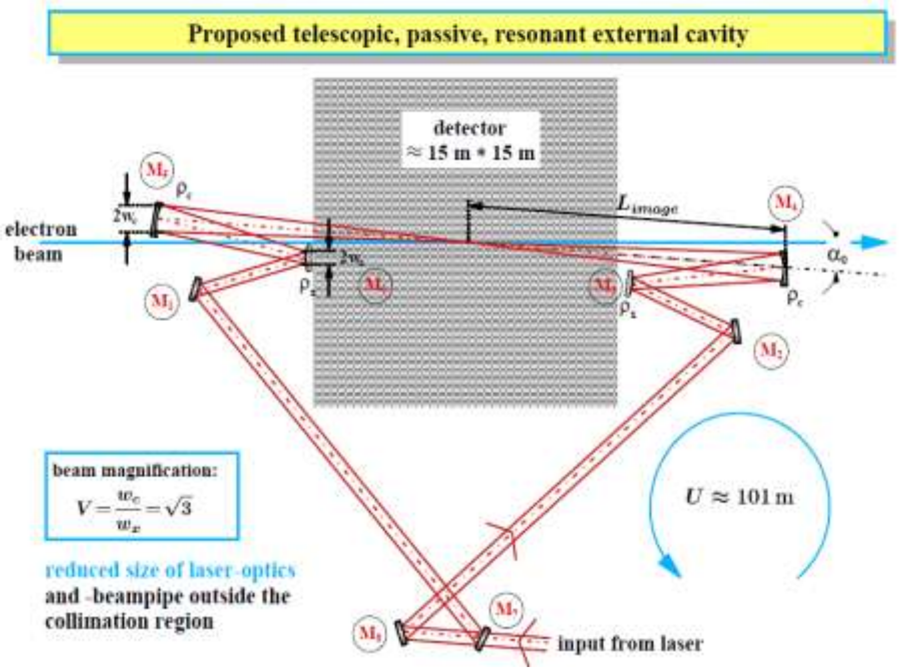
CLIC-based $\gamma\gamma$ Collider



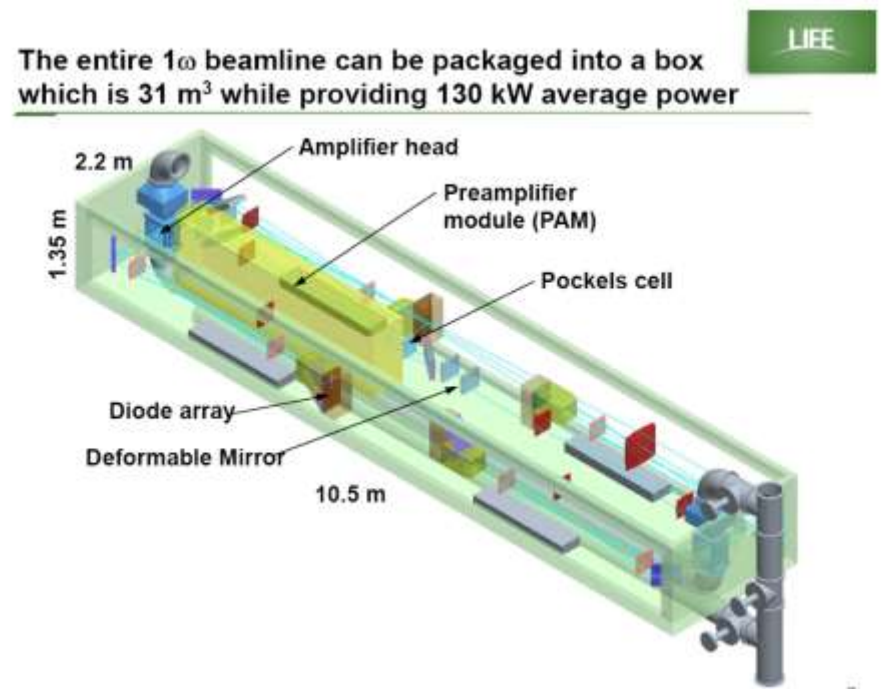
Laser Requirements

Pulse width	Pulse energy	Pulse spacing	No. pulses in a train	Laser power in a train	Laser average power	Rep rate	Wavelength	Spot size	Crossing angle
1 ps	5 J	0.5 ns	354 (5 x 354 = 1770 J per train)	10 GW	88.5 kW	50 Hz	1 µm	120 nm x 2.3 nm	25 mrad

Laser for cold RF-based γγ collider – KEK optical cavity



Laser for warm RF-based γγ collider – Livermore fusion project LIFE laser box



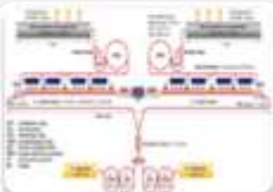
(1) Linear e+e- Higgs Factory R&D and Facilities

Type	R&D	Goal	Facility
ILC	Optimization for 250 GeV E_{CM}	Cost effectiveness	LLC, XFEL
	Final Focusing System	37 nm vertical size	ATF2
		Collision point stability	ATF2
	High gradient 1.3 GHz 9-cell cavity	Eacc > 35 MV/m	DESY, IHEP, Jlab, KEK
	Beamloading effect	31.5 GeV/m with ILC beam	LLC, XFEL, ASTA
	e+ production with 125 GeV e- beam • Longer undulator (from 150 m to 230 m) • 10 Hz e- linac • New undulator with shorter period (from 11.5 mm to 8-9 mm)	Yield rate > 1	ANL, LLNL, KEK
CLIC	Power efficiency		CTF3
	Optimization for 250 GeV E_{CM}	Cost effectiveness	CTF3
	Accelerating structure	100 MeV/m in a complete unit	CFT3
NLC-type X-band	New RF sources, better cavity design, new energy-efficient modulators	Cost effectiveness, energy efficiency	CTF3, SLAC, KEK

Project Implementation Plan 2012-16

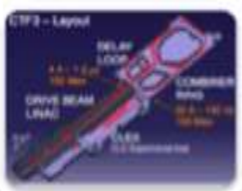
Define the scope, strategy and cost of the project implementation

LHC data crucial – also at nominal energy
Costs, power, scheduling, site, etc



Define and keep an up-to-date optimized overall baseline design that can achieve the scope within a reasonable schedule, budget and risk.

Overall design and system optimisation, activities across all parts of the machine from sources to beam-dump, links to technical developments and system verification activities



Identify and carry out system tests and programs to address the key performance and operation goals and mitigate risks associated to the project implementation.

Priorities are the measurements in: CTF3+, ATF, FACET and related to the CLIC Drive Beam Injector studies, addressing the issues of drive-beam stability, RF power generation and two beam acceleration, as well as beam delivery system studies.

Develop the technical design basis. i.e. move toward a technical design for crucial items of the machine – X-band as well as all other parts.

Priorities are the modulators/klystrons, module/structure development including significantly more testing facilities and alignment/stability







(2) Circular e+e- Higgs Factory R&D and Facilities

Type	R&D	Goal	Facility
All	Forming a study group	To produce a design report	Fermilab, SLAC, CERN, SLS, ESRF, DAFNE, Diamond, SuperKEK-B, IHEP
	Lattice design in the arc and IR	Large η (2-6%), small ε	Fermilab, SLAC, , CERN, IHEP, IOTA(?)
	RF coupler, 1.3 GHz	50 kW CW	ARIEL, IHEP
	650 MHz (700 MHz)	200 kW CW	ASTA, SLAC, IHEP (CERN)
	HOM damper		ASTA, SLAC, IHEP
	Vacuum	Cooling	Fermilab, SLAC
		Radio activation with MeV γ	?
	Wall plug efficiency	50%	ILC, CLIC, Proj X, CERN
	Radiation shielding		KEK-B
	Beam-beam	Limit for multiple IPs	CERN
	Top-up injector	Ramp speed	CESR (5 GeV/0.1 s) SRF?
	Collective effects	Stabilities	Fermilab, SLAC, IHEP

(3) Photon Collider Higgs Factory R&D and Facilities

Type	R&D	Goal	Facility
All type	Forming a study group	To produce a design report	Fermilab, SLAC, CERN, KEK, Jlab
	IR optics	A feasible design	Fermilab, SLAC, CERN, KEK, Jlab
	Removal of spent electrons		ASTA
	Inverse Compton Scattering		ASTA, SLAC, KEK
	High average power laser		LLNL, LBNL, LANL, ELI, SPARC-X, FERMI, IRIDE
ILC-based	Optical cavity		SLAC, KEK
CLIC-based and SLC-type	50 Hz high power laser		LLNL (LIFE), ELI
SAPPHiRE	FEL design		SLAC

Questions?