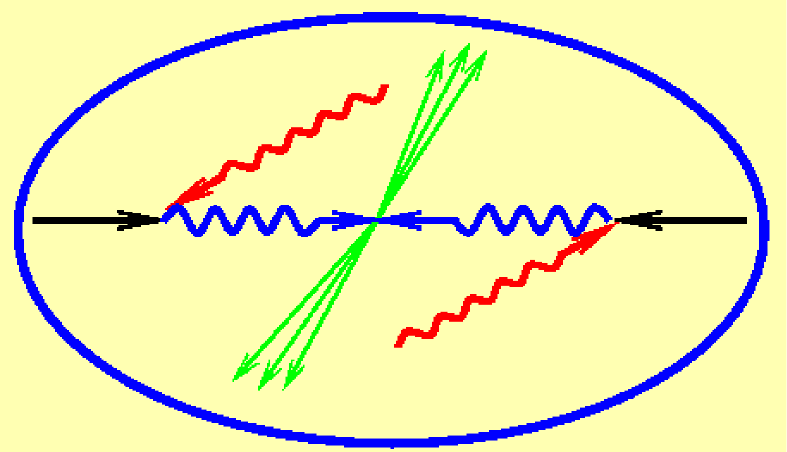

Photon colliders: summary

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LCWS 2012, Arlington, US, October 24, 2012

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Introduction

Some people distribute rumors that a few years ago there had been a study on the physics case for a gamma-gamma collider, initiated by former KEK director Sugawara san, and the result of this study was that there is no physics case, and that even I have agreed.

Indeed, in 2008 H. Sugawara suggested to build γγ collider for the Higgs study on the energy 2E=160-180 GeV, as a precursor to the e+e- ILC.

My opinion was: such PLC will be not much cheaper, because needs DR and laser system. The Higgs decay modes, even invisible, can be studied much better in e+e→ZH at 2E~230 GeV due to lower physics backgrounds.

This opinion was confirmed by physics and accelerator groups and followed by corresponding ILCSC statement. The ILCSC has not supported PLC as precursor to the ILC, but not PLC in general. PLC is very natural and cheap addition to any LC, has very rich physics program complementary to e+e- collider.

Physics motivation for PLC

(shortly)

In $\gamma\gamma$, γe collisions compared to e^+e^-

1. the energy is smaller only by 10-20%
2. the number of events is similar or even higher
3. access to higher particle masses (H,A in γγ, charged and light neutral SUSY in γe)
4. higher precision for some phenomena
5. different type of reactions (different dependence on theoretical parameters)

(unfortunately, LHC does not see new physics, only h-boson)

It is the unique case when the same collider allows to study new physics in several types of collisions at the cost of rather small additional investments

List of talks and discussions on γγ colliders at LCWS12

- V.I. Telnov, View on photon colliders at ILC, CLIC, Higgs factory SAPPHIRE and super γγ factory
- Tim Barklow, Compton Collision Parameter Optimization for a Gamma Gamma Higgs Factory
- Tohru Takahashi, Status of the optical cavity R&D at KEK-ATF
- Tohru Takahashi, Simulation of Higgs boson pair creation in a photon collider
- Maria Krawczyk (presented by F.Cornet), Testing 125 GeV Higgs's from 2HDM at PLC
- Discussion of the laser for CLICHÉ and SAPPHiRE photon colliders
- Discussion of γγ-summary for ILC TDR

Photon collider at ILC

The photon collider at ILC (TESLA) has been developed in detail at conceptual level, all understood, simulated, reported and published (TESLA TDR, etc).

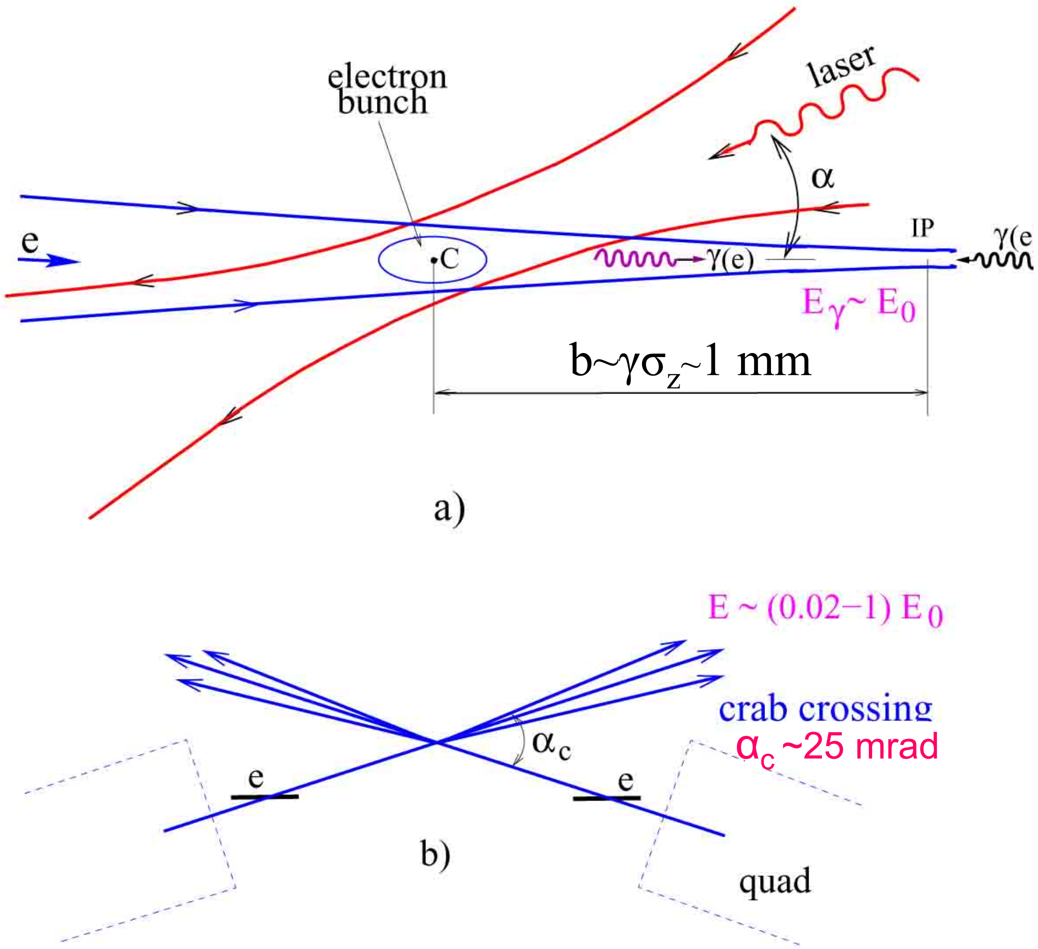
The conversion region: optimization of conversion, laser scheme. The interaction region: luminosity spectra and their measurement, optimization of luminosity, stabilization of collisions, removal of disrupted beams, crossing angle, beam dump, backgrounds.

The laser scheme (optical cavity) was considered by experts, there is no stoppers, LLNL has all technologies to build the required laser system. Similar laser technique are developed for many other applications based on Compton scattering.

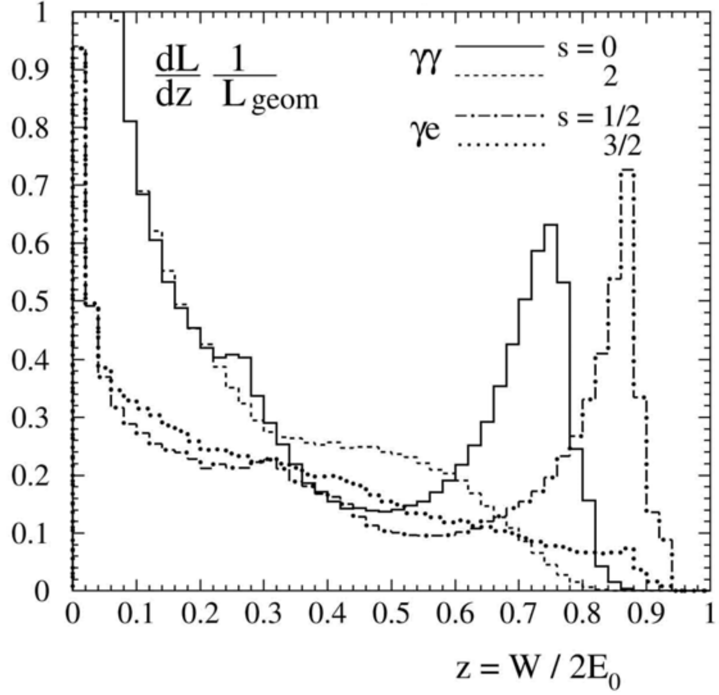
All special requirements to the ILC design have been formulated and reported to the GDE.

Further developments need political decisions and finances.

Scheme of $\gamma\gamma$, γe collider



ILC(500)

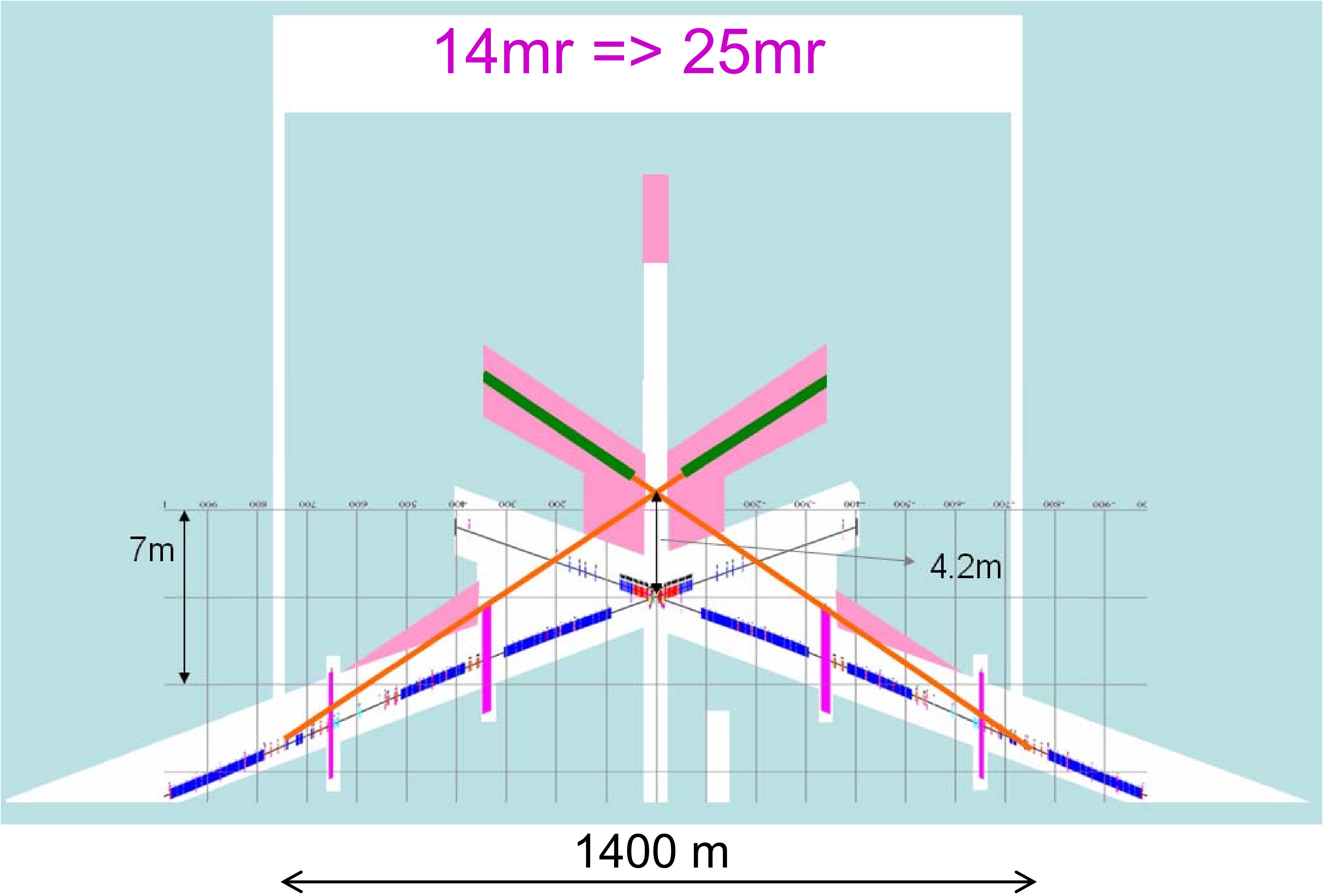


$L_{\gamma\gamma}(z>0.8z_m) \sim (0.15\text{-}0.3)\, L_{e+e-}$

(determined by beam emittances)

$$\omega_{max} \sim 0.8\, E_0$$
$$W_{\gamma\gamma,\, max} \sim 0.8 \cdot 2E_0$$
$$W_{\gamma e,\, max} \sim 0.9 \cdot 2E_0$$

14mr => 25mr

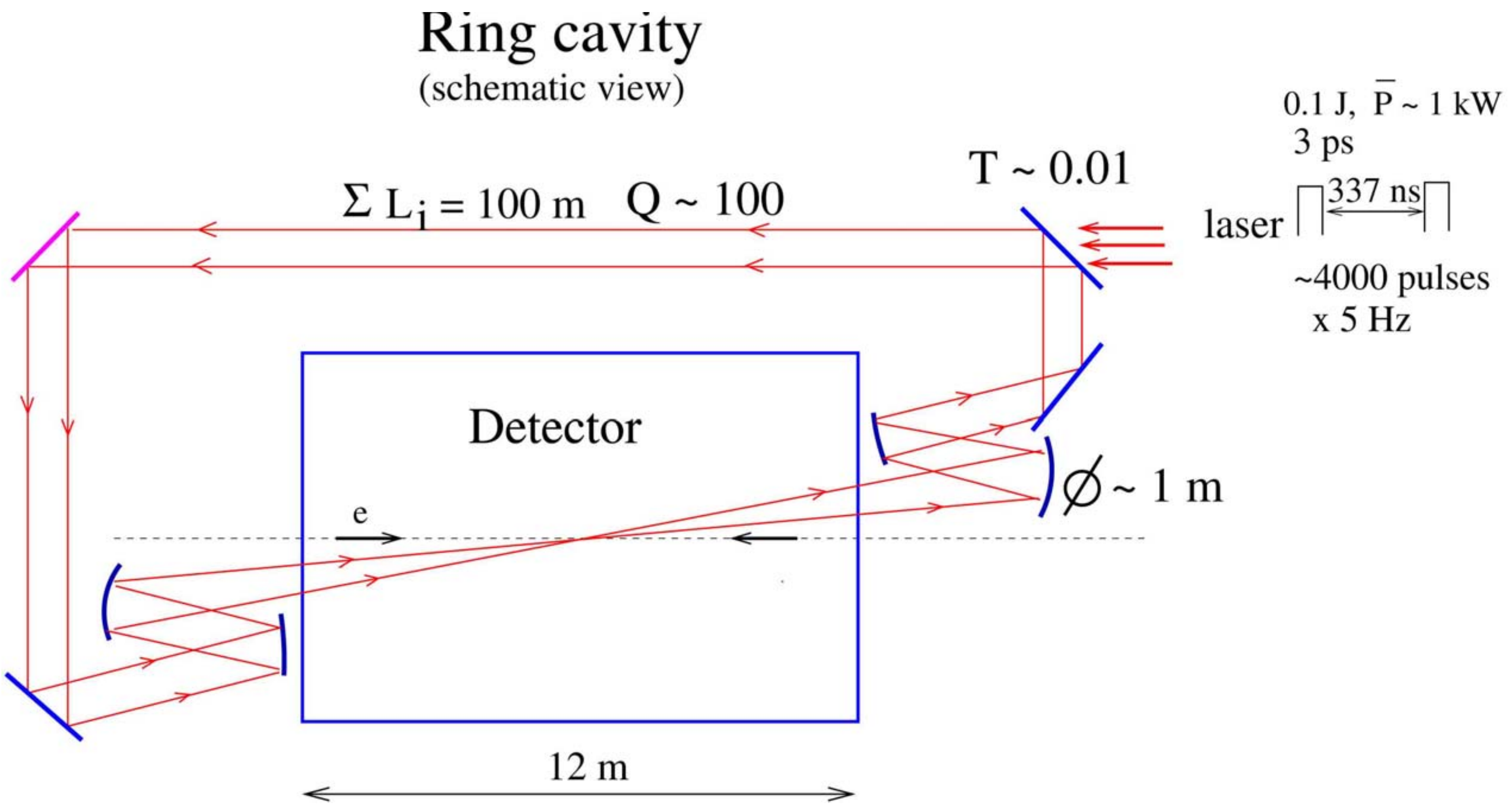


- add. angle is 5.5mrad and detector need to move by about 3-4m

Special requirements to the ILC design:

1. For removal of the disrupted beams the crossing angle at one of the interaction regions should be about 25 mrad.;
2. the $\gamma\gamma$ luminosity is almost proportional to the geometric e^-e^- luminosity, therefore the product of horizontal and vertical emittances should be as small as possible;
3. the final focus system should provide a spot size at the interaction point as small as possible the horizontal beta-functions can be smaller by one order of magnitude than that in the e^+e^- case;
4. the beam dump should withstand absorption of narrow photon beams and follow a straight line from the interaction point (deflectors are not possible);
5. the detector design should allow replacement of elements in the forward region (<100 mrad);
6. a space is needed for laser beam lines and housing.

Laser system



The cavity includes adaptive mirrors and diagnostics. Optimum angular divergence of the laser beam is ±30 mrad, A≈9 J (k=1), $\sigma_t \approx 1.3$ ps, $\sigma_{x,L} \sim 7$ μm

Rough estimate of the cost by LLNL experts: 20 M$

Photon collider at CLIC

Comparison of ILC and CLIC parameters

Laser wave length $\lambda \propto E$

for ILC(250-500) λ~1μm, for CLIC(250-3000) λ~ 1 - 4.5 μm

Laser flash energy A~10 J for ILC, A~5J for CLIC

Duration of laser pulse τ~1.5 ps for ILC, τ~1.5 ps for CLIC

Pulse structure

ILC Δct~100 m, 3000 bunch/train, 5 Hz (f_{col}~15 kH)

CLIC Δct~0.15 m, ~350 bunch/train, 50 Hz (f_{col}~15 kH)

Laser system ILC – a ring optical cavity with Q>100

CLIC –one pass system

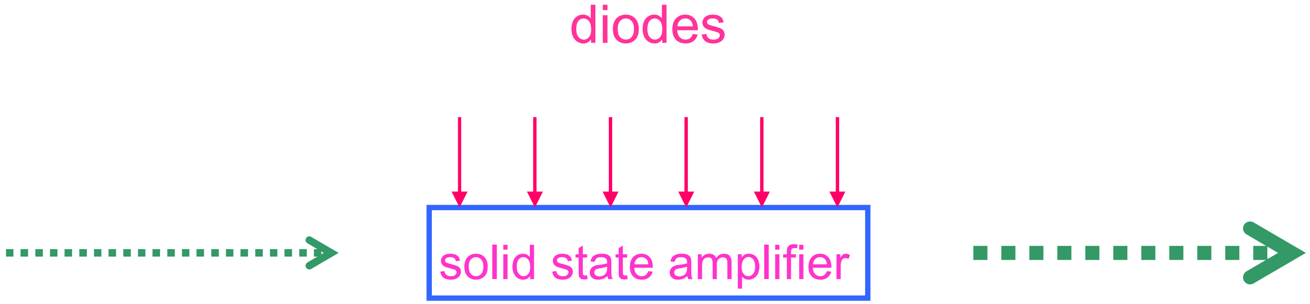
(or short linear cavity?)

The average power of one laser is ~100 kW (two lasers 200 kW).

Possible approaches to CLIC laser system

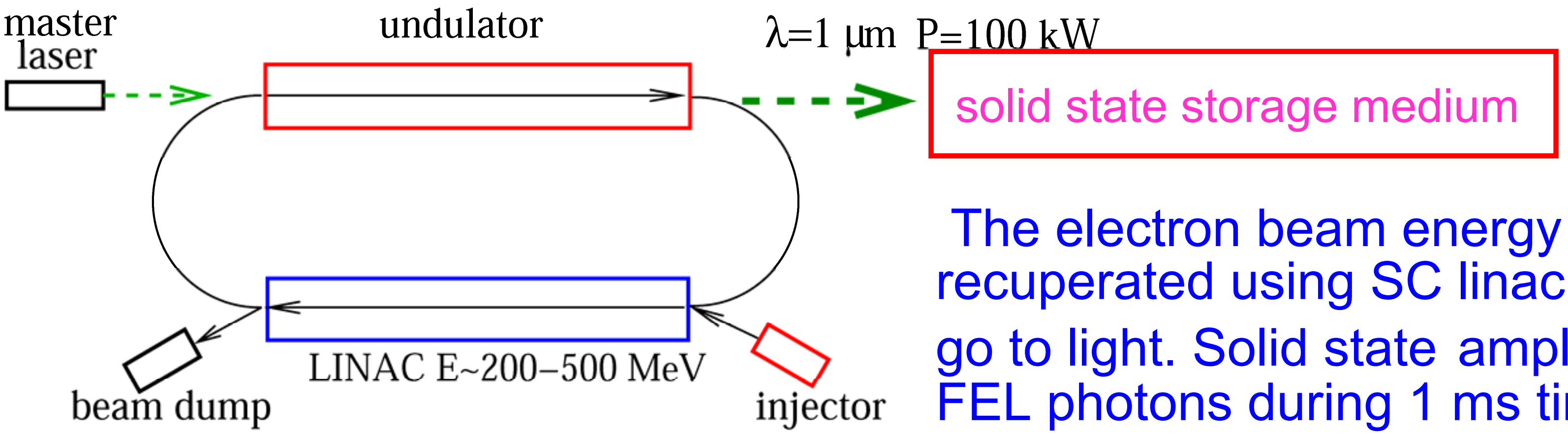
1. Solid state lasers pumped by diodes.

One can use solid state lasers pumped by diodes. There are laser media with a storage time of about 1 ms. One laser train contains the energy about 5x350~2000 J. The total power of diodes (in 1 ms storage time) should be P~20 MW. At present, the cost of only diodes for the laser system will be ~O(50-100) M$.



Second approach to CLIC laser system

2. FELs with the energy recuperation instead of diodes for pumping the solid state laser medium.

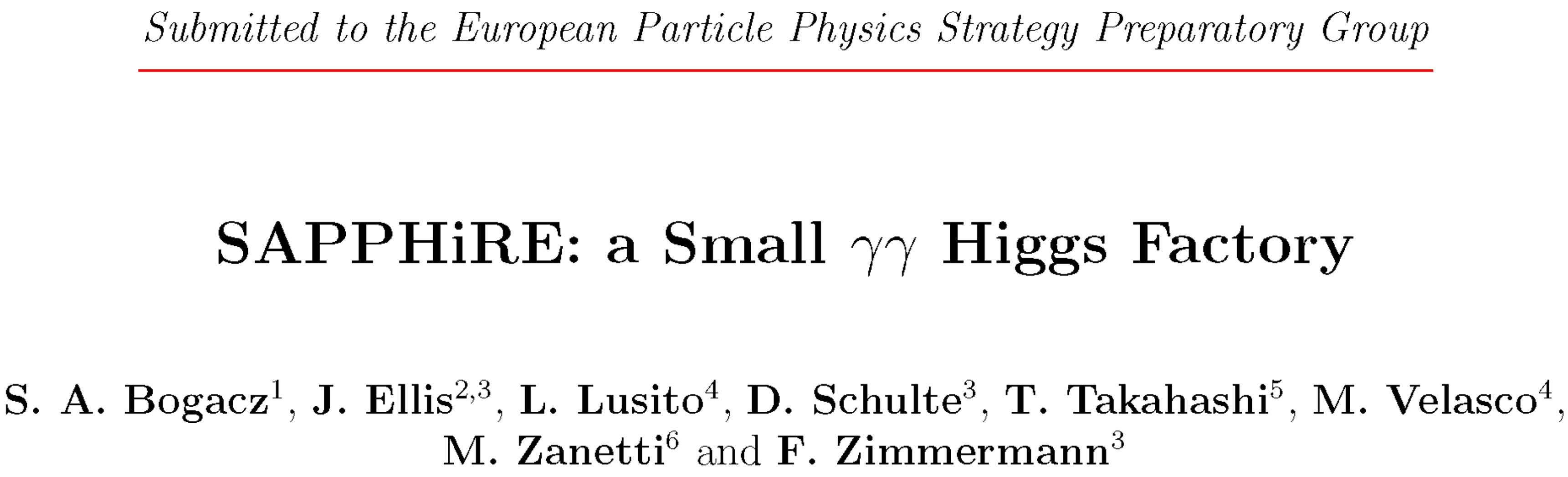


The electron beam energy can be recuperated using SC linac. About 3% go to light. Solid state amplifiers collects FEL photons during 1 ms time and than generate 350 pulse train.

With recuperation and 20% wall plug RF efficiency the total power consumption of the electron accelerator from the plug will be about 200 kW/ 0.2 ~ 1-2 MW.

Storage of the pumping energy inside solid-state laser materials reduces the required peak FEL power by a factor of 1 ms/177ns=5600! Such a laser can be build now.

Photon collider Higgs factory SAPPHiRE



Submitted to the European Particle Physics Strategy Preparatory Group

SAPPHiRE: a Small $\gamma\gamma$ Higgs Factory

S. A. Bogacz[1], **J. Ellis**[2,3], **L. Lusito**[4], **D. Schulte**[3], **T. Takahashi**[5], **M. Velasco**[4],
M. Zanetti[6] and **F. Zimmermann**[3]

Aug. 2012

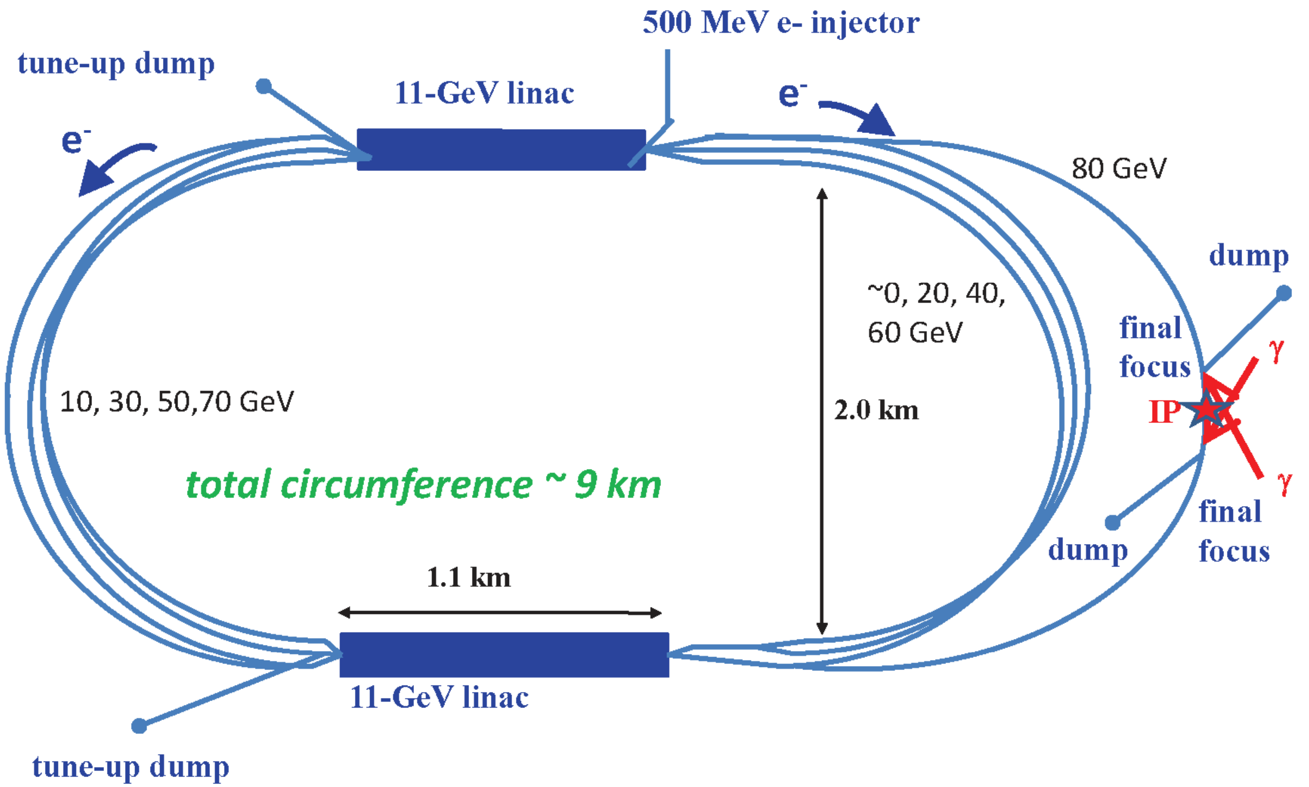


Figure 3: *Sketch of a layout for a $\gamma\gamma$ collider based on recirculating superconducting linacs – the SAPPHiRE concept.*

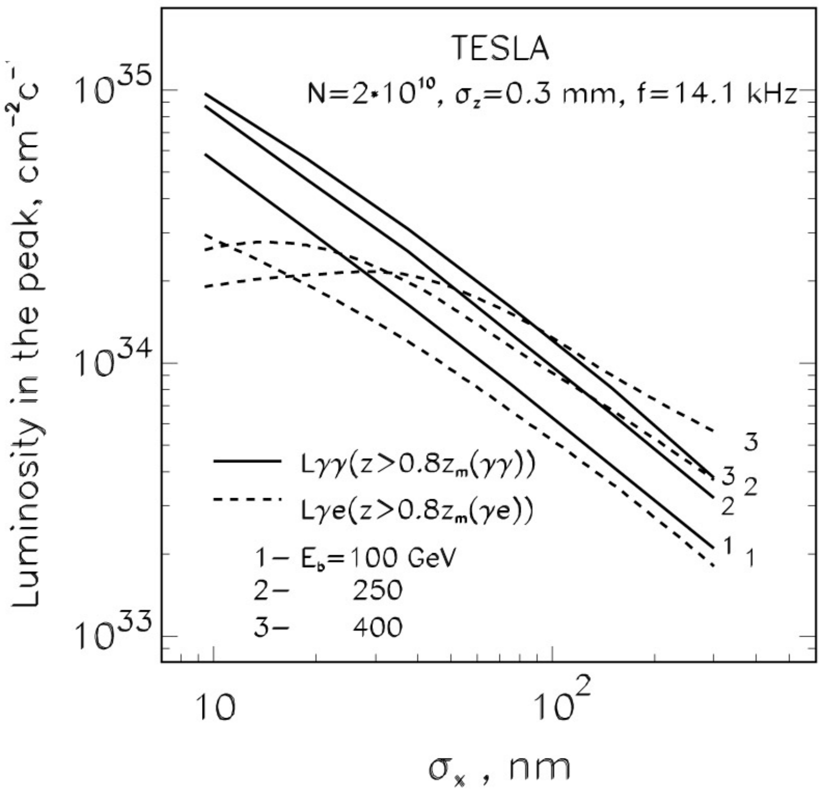
Main critical remarks on SAPPHIRE

1. The emittance dilution in arcs is too optimistic (while shortening bending magnet period quadrupole gradients were not scaled).
2. The initial beam normalized emittances, 5 and 0.5 mm mrad in X and Y directions corresponds to best emittances of unpolarized RF guns, while the PLC needs polarized electrons. Present polarized DC guns (polarized RF guns do not exist yet) have emittances > 20 times larger! It means that the luminosity will be 20 times smaller. That is why at present the PLC at ILC assumes DR.
3. The length of the ring 9 km (2.2 km linac, 30 km arcs). The LC with G=30 MeV/m would have L=6 km total length (with the final focus), can work with smaller emittances and thus can have a higher luminosity. Where is profit?
4. It is obvious that e+e- is better for the Higgs study, there is no chance to get support of physics community, as soon as this collider is instead of e+e- (worse that precursor).

Dreams of γγ factories

Telnov,1998

For 2E<1 TeV the ILC γγ luminosity is not restricted by collsions effects, it is just proportional to e-e- geometric luminosity. At the ILC nominal parameters of electron beams σ_x ~ 300 nm is available at $2E_0$=500 GeV. Having beams with smaller emittances one could obtain much higher γγ luminosity. Physics does not forbid an increase of the γγ luminosity by a factor of 30-50.



So, one needs: ε_{nx}, ε_{ny} as small as possible

There are at least two method to make emittances smaller than in damping rings.

1. Laser cooling of electron beams for linear colliders, allows to reach much lower emittances desired small transverse emittances and preserves the longitudinal polarization (V.Telnov, 1987).
2. Merging low charge bunches from RF guns in longitudinal phase space (V. Telnov, IWLC 2010). Problem: absence of low emittance polarized RF guns.

Both methods need detail considerations.

Conclusion

- Photon colliders have sense as a very cost effective addition for e+e- colliders: as the LC second stage or as the second IP (preferable).
- PLC at ILC is conceptually clear, needs technical study and prototyping of the laser system (optical cavity).
- PLC at CLIC is more difficult due to much shorter trains. The solution for laser system is visible, needs a detailed study.
- PLC SAPPHIRE proposal is inconsistent, one problem can be corrected by increasing PLC radius, the second one can be corrected only by addition of damping rings. In any case, the PLC for Higgs without e+e- has not sufficient physics case.
- PLC without damping rings are possible, in principle, needs careful study.
- It is very important to include PLC requirements to basic LC designs.