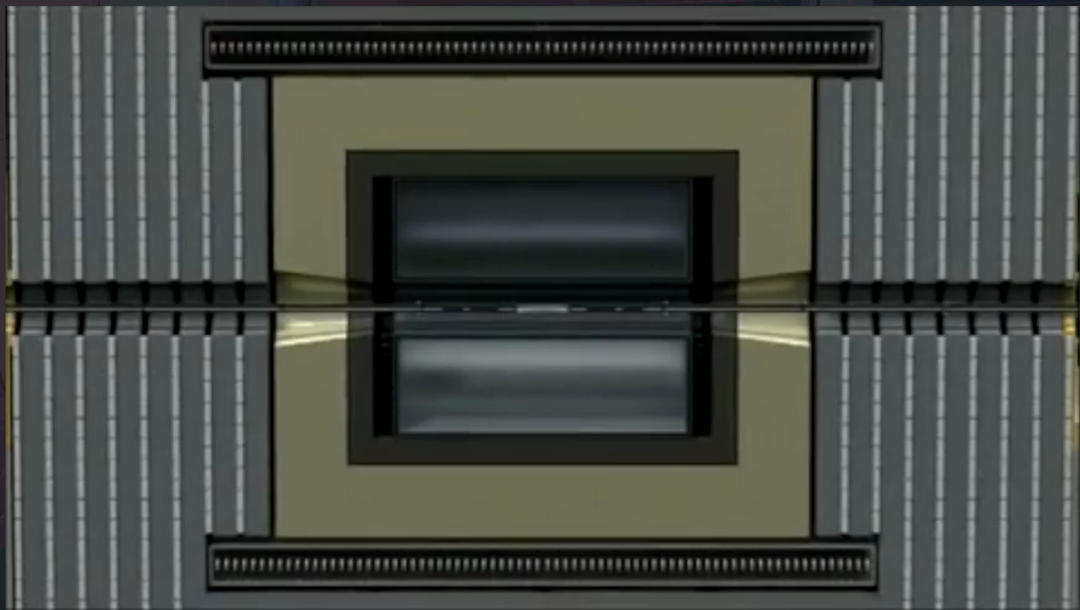
LINEAR COLLIDER COLLABORATION

JSPS specially-promoted research

A Global R&D Program of a State-of-the-art Detector System for ILC

5th Annual Meeting 2015



Hitoshi Yamamoto

Rey Hori

December 8, 2015, KEK

Standard ILC Running Scenario

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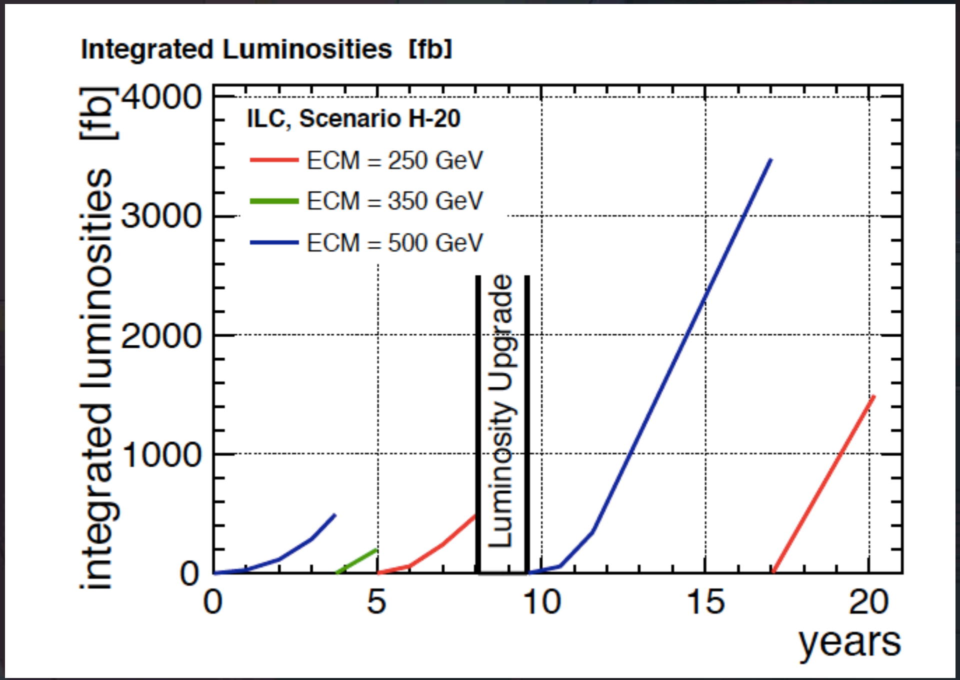
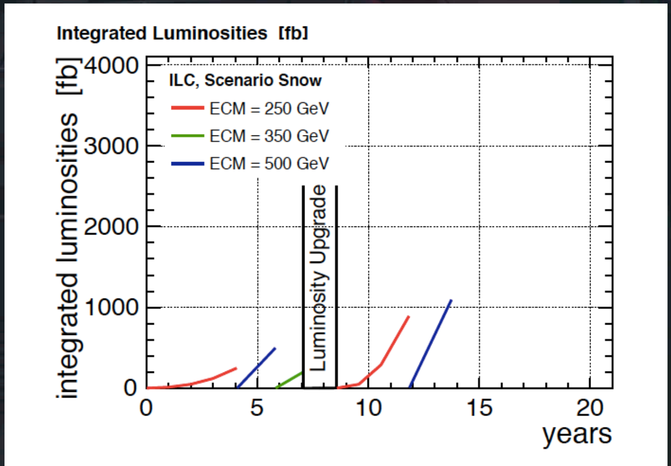
LCC Parameter Joint WG

With realistic ramp up and shutdown for upgrade

'H20': Standard Running Scenario



Reference: Snowmass study scenario
Fits within 15 years



Measurement precisions are somewhat improved wrt the Snowmass numbers

Higgs Couplings : compare with LHC
model-dependent

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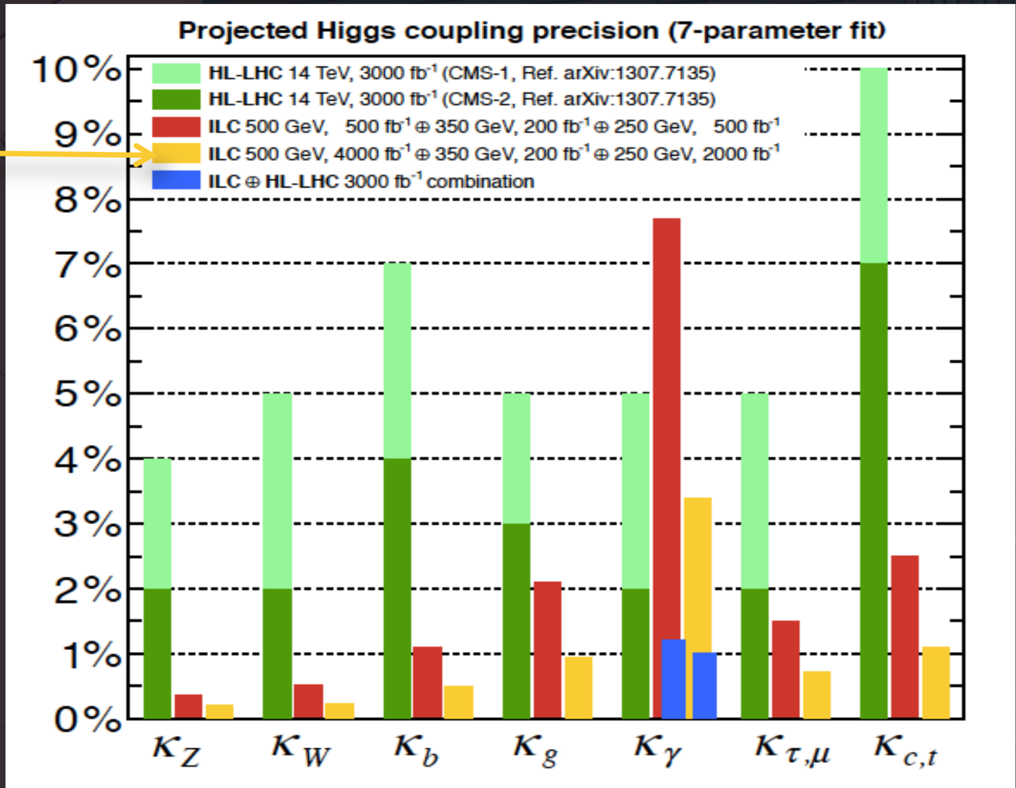
H20



- All assume generation universality, no BSM → Fit : model-dependent
  - CMS-1: HL-LHC pessimistic (sys err : no change)
  - CMS-2: HL-LHC optimistic (sys.err : theory = 1/2, exp. $N^{-1/2}$),
  - ILC is for 1IP, HL-LHC is for CMS only
    - If CMS and ATLAS are combined, error would decrease (1/sqrt2 if stat dominated, ~1 if sys dominated)
- Apart from γ, ILC (H20) is 1/5 ~ 1/15 of HL-LHC
  - Statistical power of ILC: ~100 HL-LHC running simultaneously

Notes on Higgs Couplings

- For κ_Z and κ_W , production rates give high precision
  - e+e- $\rightarrow$ ZH for κ_Z and e+e- $\rightarrow$ $\nu\nu$H for κ_W [with Br(H$\rightarrow$bb)]
- In general for κ_X , Γ_{tot} is necessary in addition to Br(H$\rightarrow$x)
  - Γ_{tot} = Γ(H$\rightarrow$ZZ)/Br(H$\rightarrow$ZZ) with Γ(H$\rightarrow$ZZ) from κ_Z
  - Γ_{tot} = Γ(H$\rightarrow$WW)/Br(H$\rightarrow$WW) with Γ(H$\rightarrow$WW) from κ_W
  - W mode is far more powerful: 350 GeV or higher running is needed
- For κ_γ , LHC and ILC are combined
  - Br(H$\rightarrow\gamma\gamma$)/Br(H$\rightarrow$ZZ) by LHC and κ_Z by ILC
- For κ_t (ttH final state)
  - Error 6% $\rightarrow$ 3% by going from 500 GeV to 550 GeV
- Physics: Higgs self coupling
  - 1TeV: 16% with 2000 fb-1, 10% with 5000 fb-1
  - 500 GeV: 27 % with 4000 fb-1 (H20)

Top Mass @ Threshold

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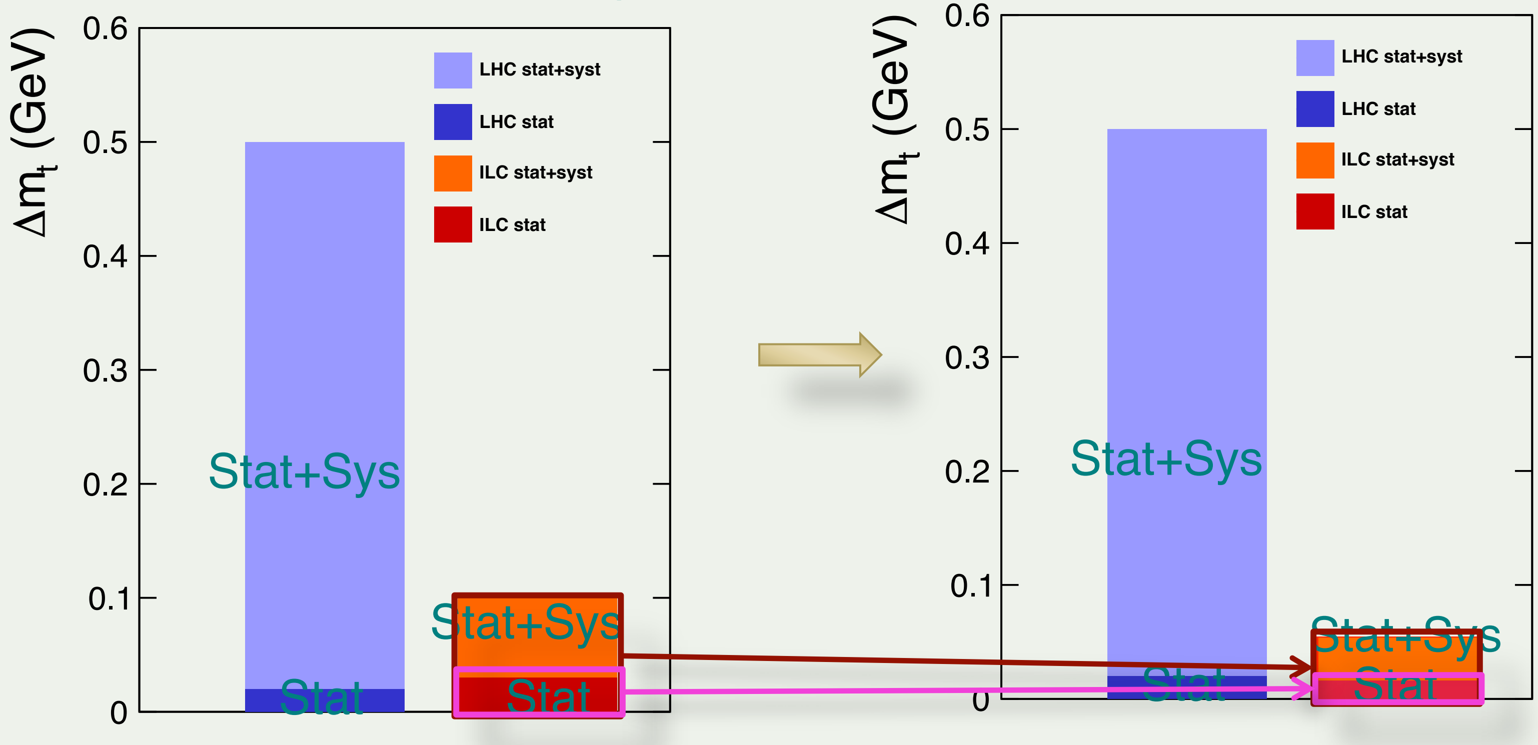
Top quark mass (msbar)
(@350 GeV: CLIC+ILC study)

Theoretical systematic error is to go down significantly for ILC, but not so for LHC

Snowmass ILC500-up

‘H20’(standard running scenario)



HL-LHC
3000 fb^{-1}
$\sqrt{s}$=14 TeV

ILC
100 fb^{-1}
$\sqrt{s}$=350 GeV

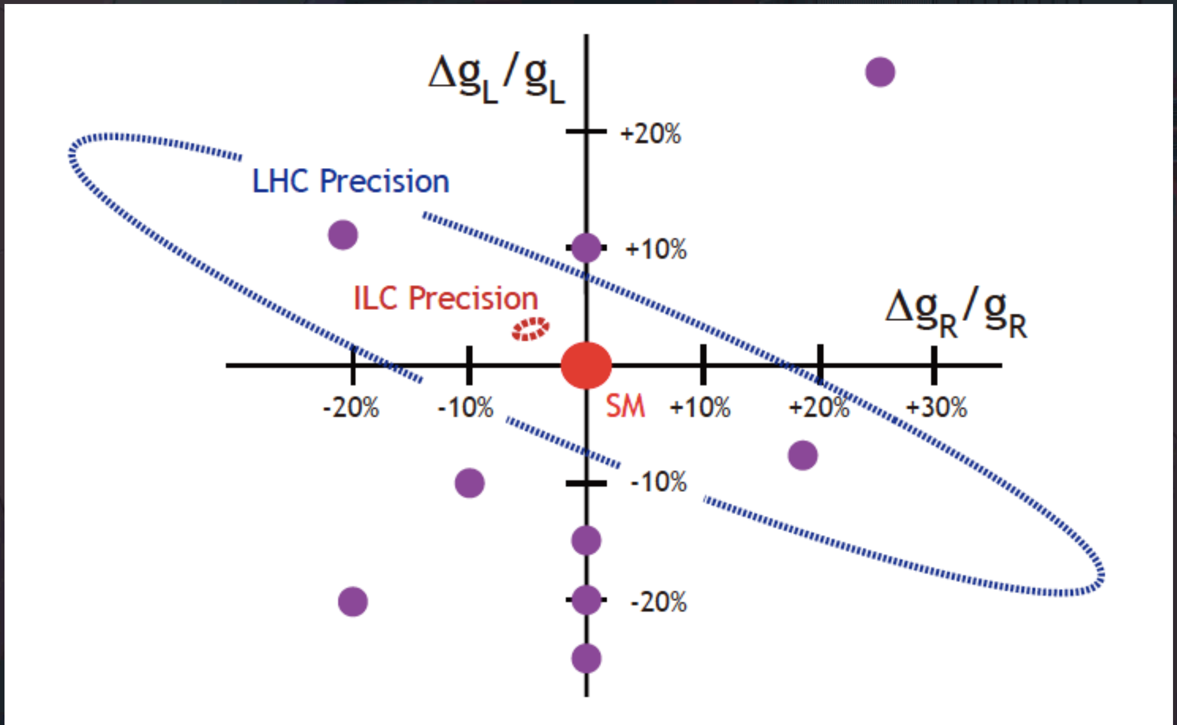
HL-LHC
3000 fb^{-1}
$\sqrt{s}$=14 TeV

ILC
200 fb^{-1}
$\sqrt{s}$=350 GeV

Top Pair Production at 500 GeV

Anomalous top-Z couplings

Use beam polarization
(separates γ and Z, R and L)



Distinguish variety of BSM models

New Particle Search

FNAL Tevatron

Tevatron has a long list of glorious physics achievements (top discovery etc.)

For Higgs, however, it did not see clear signal even though ~20000 Higgs Were produced. Needed to wait for LHC (~1M Higgs produced in Run 1)

At ILC, only a handful of Higgs (a few tens) will do. It is possible that a new particle is already produced at LHC but should wait for ILC for discovery. CLIC will have a larger energy range to cover.

ILC vs CEPC

- Ecm
  - CEPC: 250 GeV and below
  - ILC: 250 and above

- Luminosity
  - CEPC: 2×10^{34} /cm^{2}s /IP (x 2 IPs ?)
  - ILC: 3×10^{34} /cm^{2}s /IP (upgrade)
    - (Baseline 0.75×10^{34} /cm^{2}s)

- Wall plug power
  - CEPC: '500MW'
  - ILC: 200 MW @250 GeV (upgrade)
    - (Baseline : 129 M W)

Goal of This Program

Goal

Develop the state-of-the-art components and systems, and complete the detector design based on the concept of PFA that realizes the physics of ILC within a framework of international collaboration.

→ lead the formation of a detector collaboration

PFA

Key components : Vertex detector, TPC, Calorimeters

9

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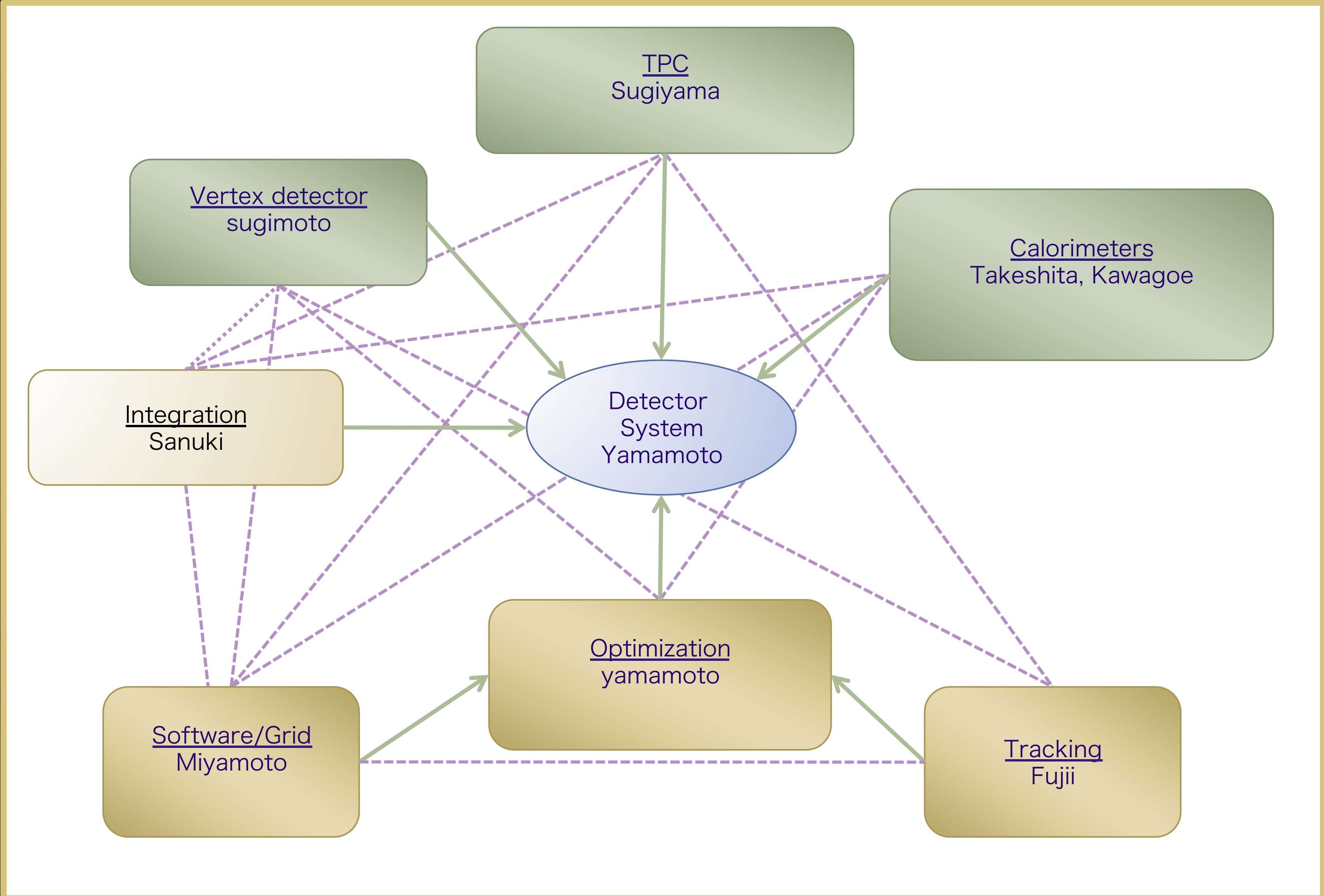
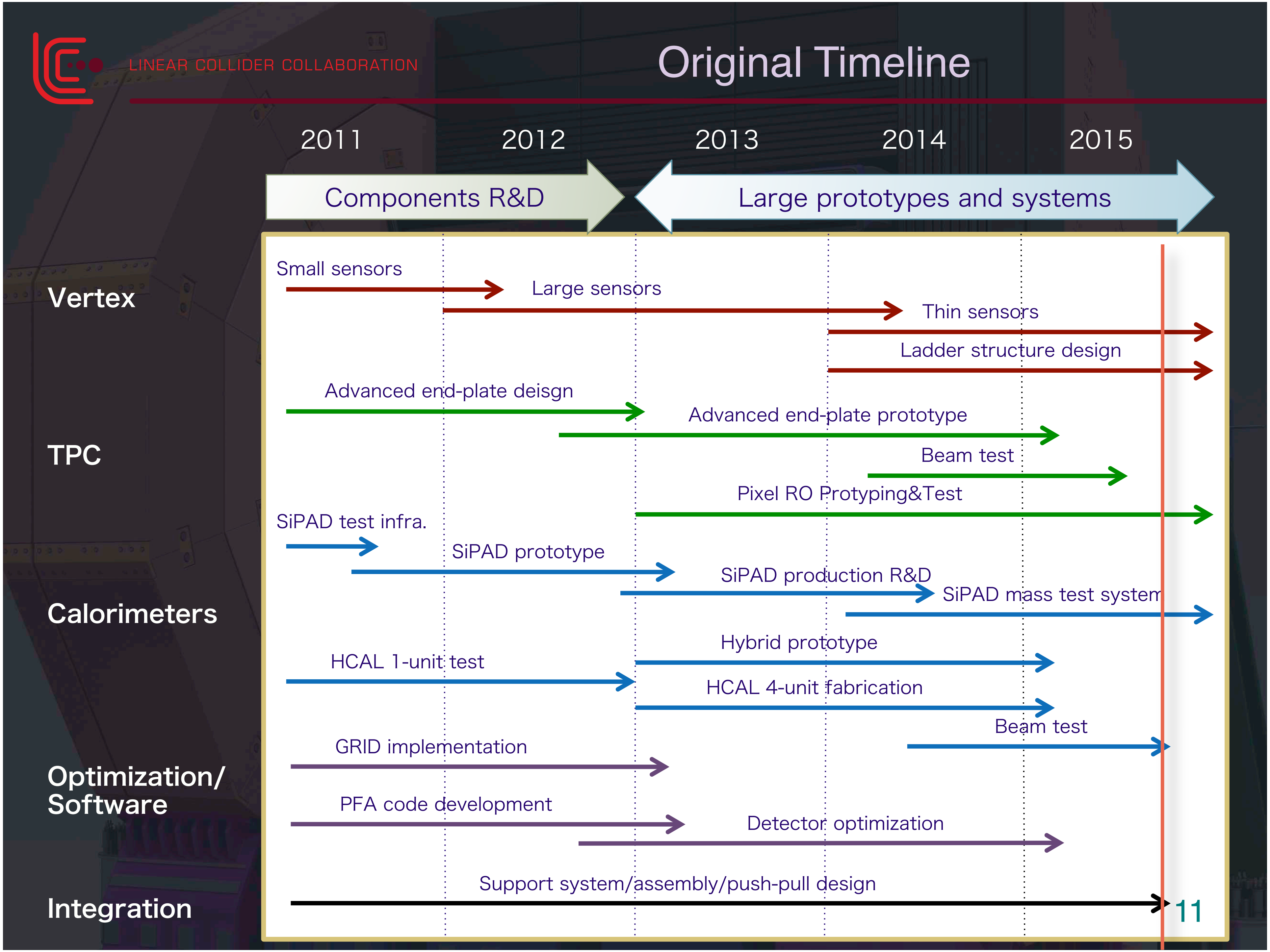
Organization




LINEAR COLLIDER COLLABORATION
Original Timeline
2011
2012
2013
2014
2015
Components R&D
Large prototypes and systems
Vertex
Small sensors
Large sensors
Thin sensors
Ladder structure design
TPC
Advanced end-plate deisgn
Advanced end-plate prototype
Beam test
Pixel RO Protyping&Test
Calorimeters
SiPAD test infra.
SiPAD prototype
SiPAD production R&D
SiPAD mass test system
Hybrid prototype
HCAL 1-unit test
HCAL 4-unit fabrication
Beam test
Optimization/
Software
GRID implementation
PFA code development
Detector optimization
Integration
Support system/assembly/push-pull design
11

Progress Review

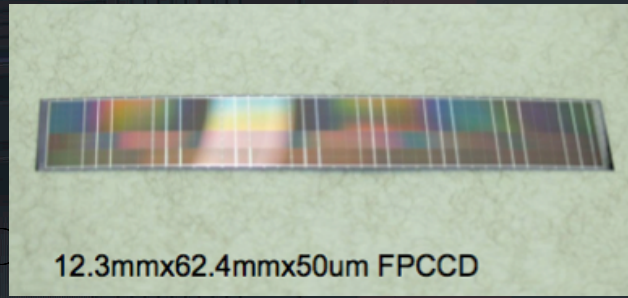
- Aug 5, 2014

- Graded A: The project is progressing well toward the original goals, and results as planned are likely to be achieved. (out of A+, A, A-, B, and C)

- Evaluation: Based on the discovery of Higgs particle by the LHC at CERN, the ILC is attracting attention as a next-generation accelerator that can usher in a new development in the field of particle physics. This research project aims at building an international collaborative structure and developing state-of-the-art detector technologies toward the ILC. Even though there are some uncertainties about the construction of the ILC itself, this research group is leading the international detector group ILD, and steadily developing detector elements such as fine-pixel CCD and GEM in order to establish necessary experimental basic technologies. In addition, it is expected that there will be ripple effects to the other fields and surrounding technologies.

At the time of the Progress Review I

- Detector Optimization
  - Constructed PFA software
    - Applied to strip scintillator
  - Appled to physics analyses
  - Future: Detector re-optimization, ILC physics analyses



Thin large CCD sensor

- Vertex Detector
  - Developed thin and large prototype
  - Verifed functions down to $(6\mu m)^2$ pixel
  - Verified functions of RO electronics
  - Future: $(5\mu m)^2$, radiation tolerance、support structure

TPC test system at DESY

- TPC
  - Built electron detection system based on GEM
  - Performed beam tests by international collaboration
    - Achieved goal position resolution
    - Understood the resolution theoretically
  - GEM ion gate: 80% electron transparency achieved
  - Future: Improvement of ion gate, 2-phase CO_2 cooling
    Develop modules with RO built in

GEM ion gate

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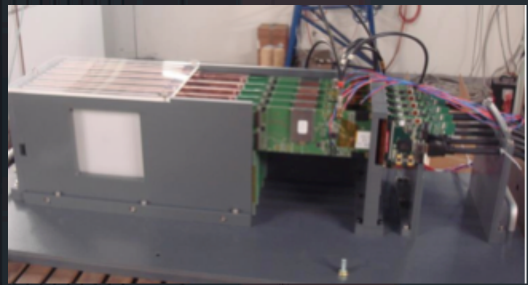
At the time of the Progress Review II

Calorimeter

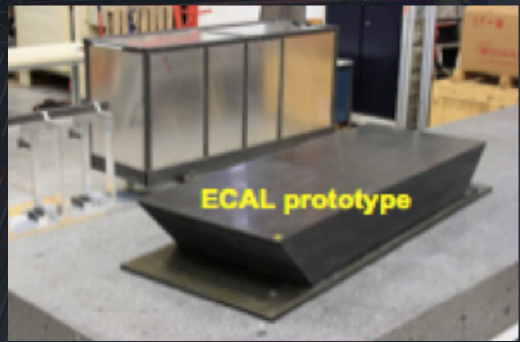
- EM cal beam test w/ same structure as real detector
- Power pulsing succeeded
- Optimization of silicon-scintillator hybrid started
- Future: Optimization of overall structure
  Establish mass production/test of Si



Beam test at DESY

Software

- Established international data exhange & resoruce sharing
- General tracking algorithm realized
- Flavor id software written, internationally used
- Future: Monte Carlo production



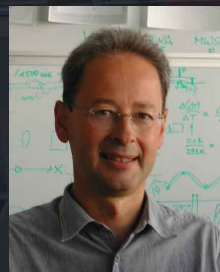
Calorimeter structure

Integration

- Assembly method specific to the site conceived
- Access to detector hall figured out
- Future: Continue the above

Physics and Detector Advisory Panel (PDAP)

- LCCPD Executive Board agreed that we will have a light weight panel
  - A few members
  - To conduct informal reviews
  - Could be expanded to a full-scale review panel when the time is right
- PDAP Members
  - Paul Grannis (chair)   Junji Haba   Sandro Palestini



- First meeting at the LCWS2015 (Whistler)
  - Wednesday afternoon (closed)
    - ILD 30 min
    - SiD 30 min
    - CLICdp 15 min
    - Detector R&Ds 45 min

PDAP Report (Excerpts)

On ILD

The committee applauds the recent focus on optimization of costs and complexity based on the simulated physics performance.

Traditionally ILD has carried several optional subdetector technology choices, feeling that until a decision to proceed with the project is made, decisions are premature. They do have a defined set of performance benchmarks and an agreed list of options and open issues. The committee suggests however that analyses of the timetables required for making such decisions should be undertaken now, within the global context of ILD. Different subdetector choices will require system tests of different complexity and duration, and the construction schedule implied by the assembly sequence will dictate different schedules for decisions. These evaluations should also include studies of the time required for system integration and detailed engineering.

PDAP Report (Excerpts)

On detector R&Ds

The final item discussed was whether the R&D groups are serving the needs of the detector consortia well. There was general consensus in the affirmative. There were comments that the R&D groups need to seek new innovations, as was done at the outset of the linear collider program (e.g. particle flow calorimetry and minimally thin vertexing and tracking detectors with full timing and analog capabilities). The flexibility to upgrade detector performance with state-of-the-art capabilities should be retained up to the time of freezing for construction. It was also noted that the R&D groups need to not only to do frontier R&D, but also to work on translation of results into real projects.

Goals

- Physics Case for ILC
  - Sharpen the physics motivations on Higgs, top, newparticles/newphysics (incl. systematics)
  - Prepare&respond to results from LHC
  - Actively pursue outreach
- Detector Optimization
  - Prepare for downselection of options
  - Evaluate time/effort rquired for detailed engineering and system integration
- Detector R&Ds
  - Pursue state-of-the-art technologies while reinforcing connection with real detector