Measuring the branching ratio of $h \to \mu^+\mu^-$ at the International Linear Collider

Shin-ichi Kawada, Jenny List, Mikael Berggren (DESY)

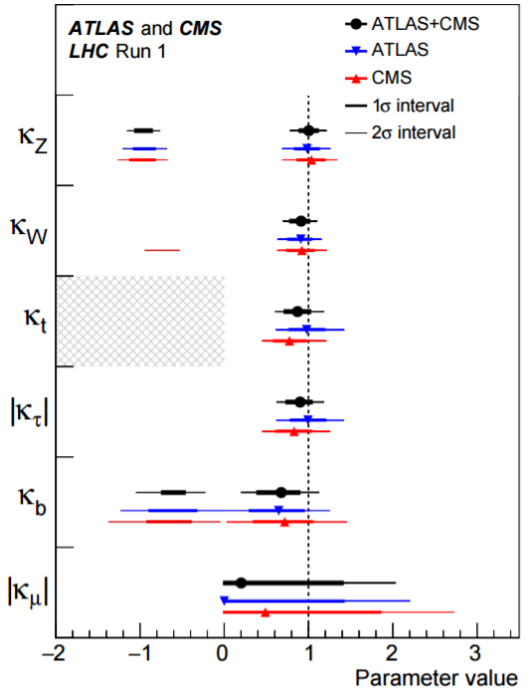
2017/March/27

DPG Münster17

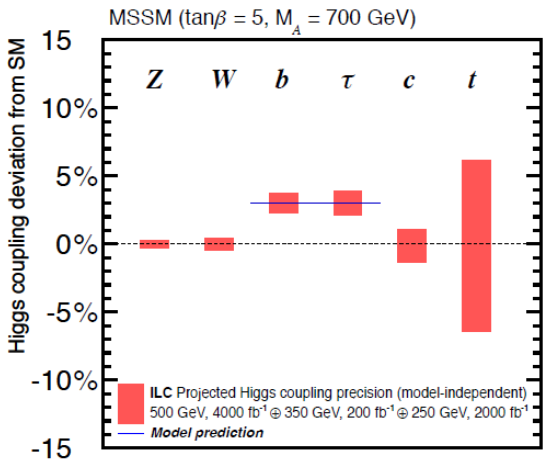
Introduction

Discovery of Higgs-like boson at the LHC
--> Last particle of SM? Or beyond SM?

Goal: model-independent determination of
EWSB sector with precise measurements
- mass-coupling relation
- any deviation shows the existence of BSM



JHEP **08** (2016) 045

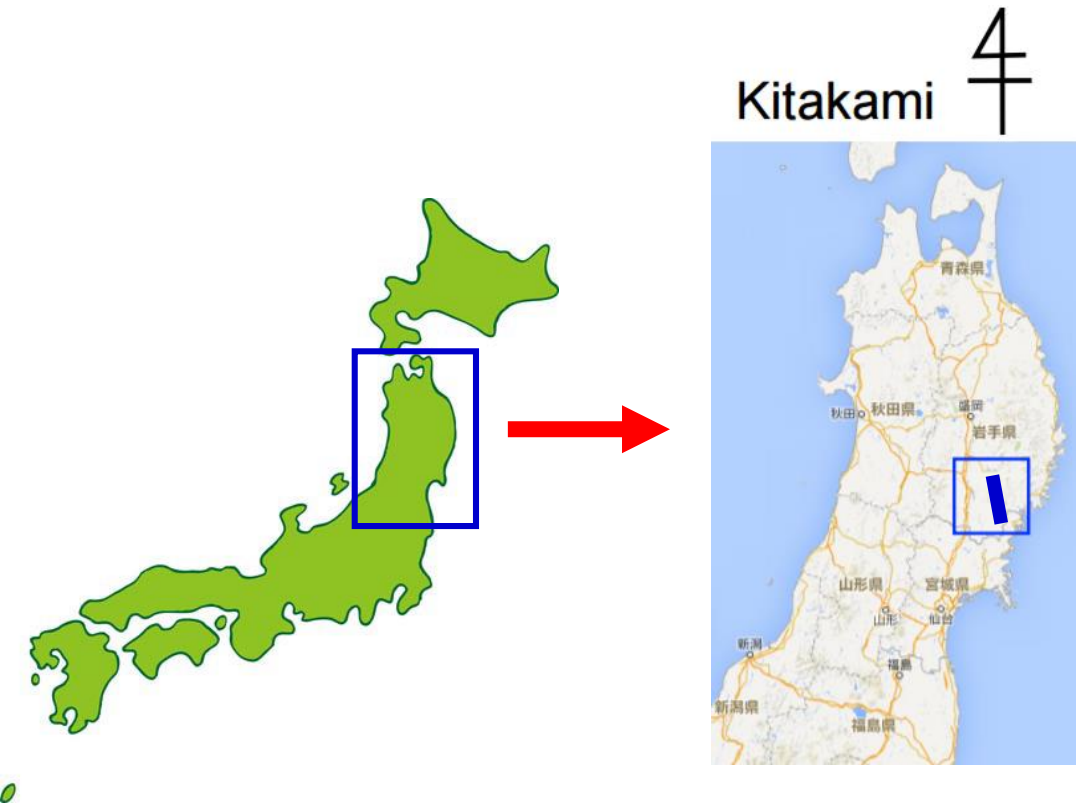


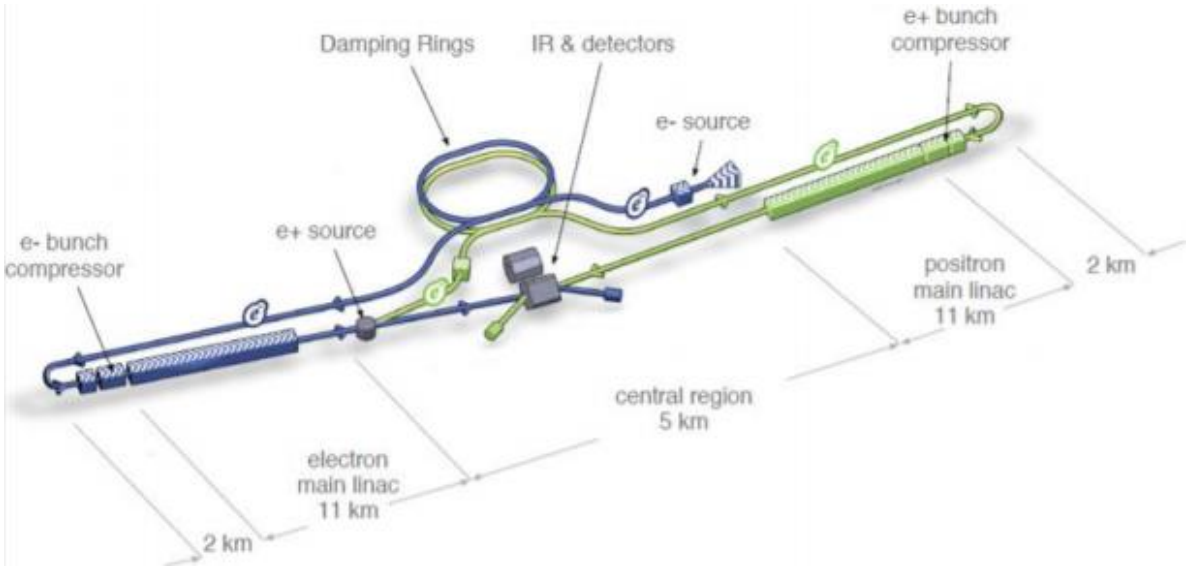
arXiv: 1506.05992 [hep-ex]

ILC

The International Linear Collider

- e^+e^- collider, E_{CM} = 250 - 500 GeV (upgradable to 1 TeV)
- polarized beam (e^-: 0.8, e^+: ≥ 0.3(0.6))
- clean environment, known initial state



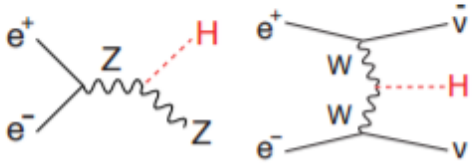


Japan shows great interest to host ILC.

Key Point

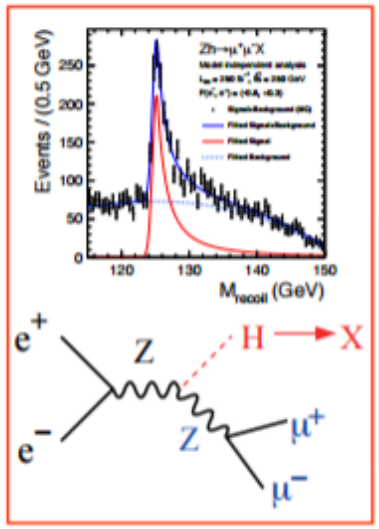
At LHC all the measurements are σ×BR measurements.

At ILC all but the σ measurement using recoil mass technique is σ×BR measurements.



$$g^2_{HAA} \propto \Gamma(H \to AA) = \Gamma_H \cdot BR(H \to AA)$$

σ×BR → BR → g coupling



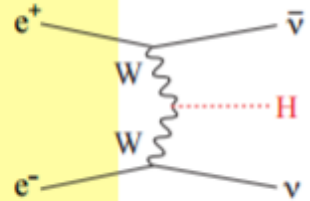
The Key

σ from recoil mass

Γ_H total width

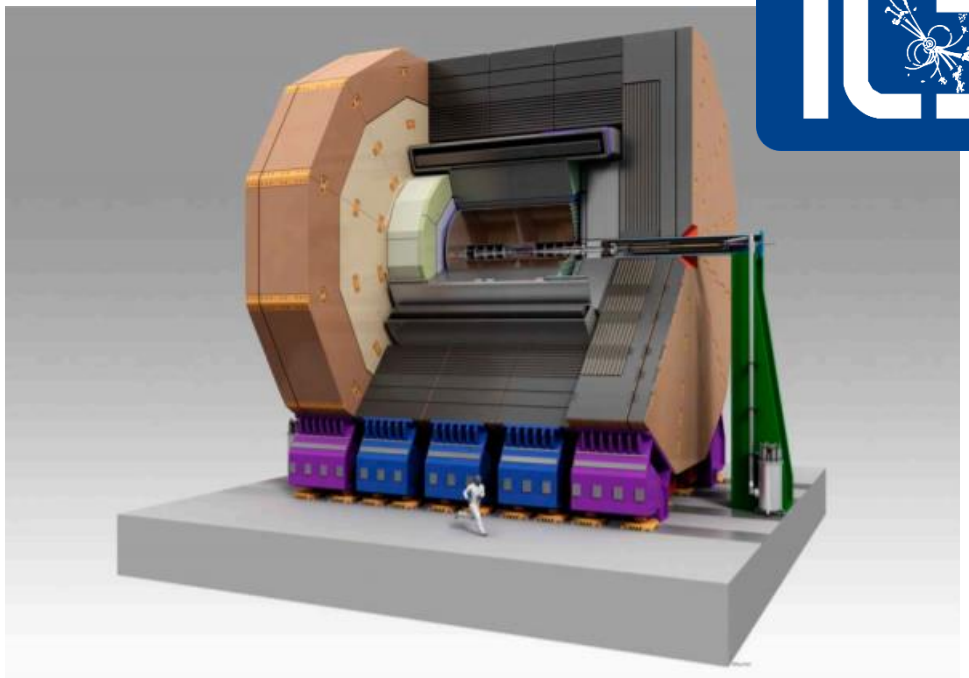
Z→qq is also usable.

WW-fusion is crucial for precision total width measurement → Ecm > 350GeV

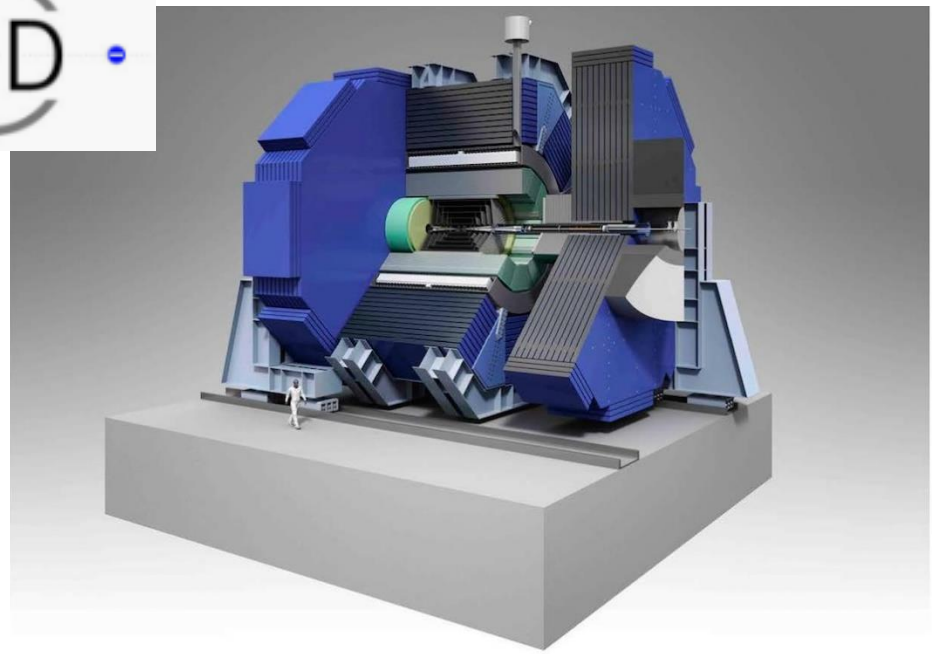


Detector Concepts at the ILC

- optimized for particle flow analysis
- trackers, calorimeters, solenoid coil, muon detector, and forward systems

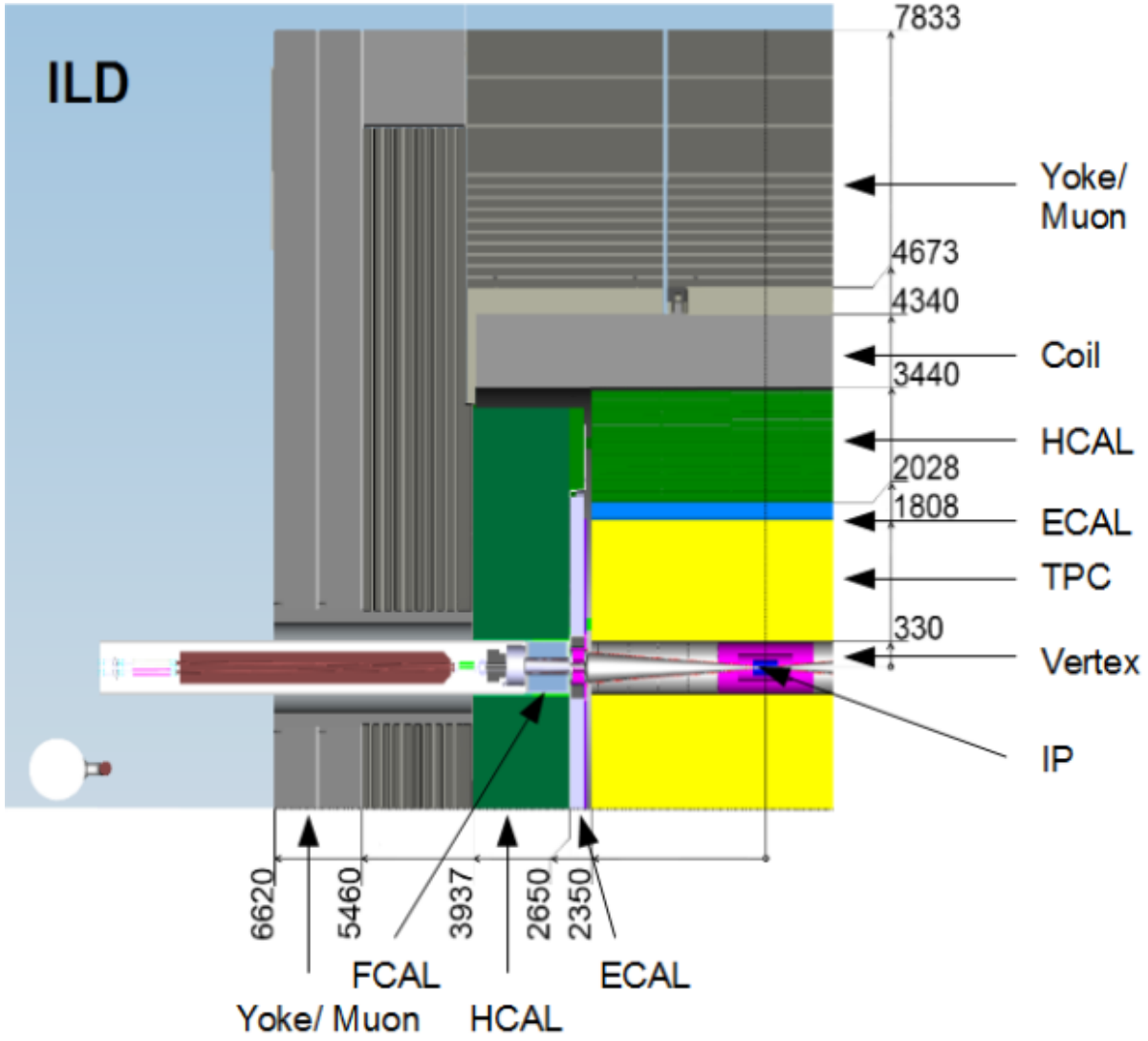


ILD (International Large Detector)



SiD (Silicon Detector)

ILD System



Tracker: Vertex, TPC
Calorimeter: ECAL, HCAL
3.5T magnetic field
Yoke for muon, Forward system

Requirements:
- Impact parameter resolution

$$\sigma_{r\phi} < 5 \oplus \frac{10}{p\sin^{3/2}\theta}\ (\mu\mathrm{m})$$

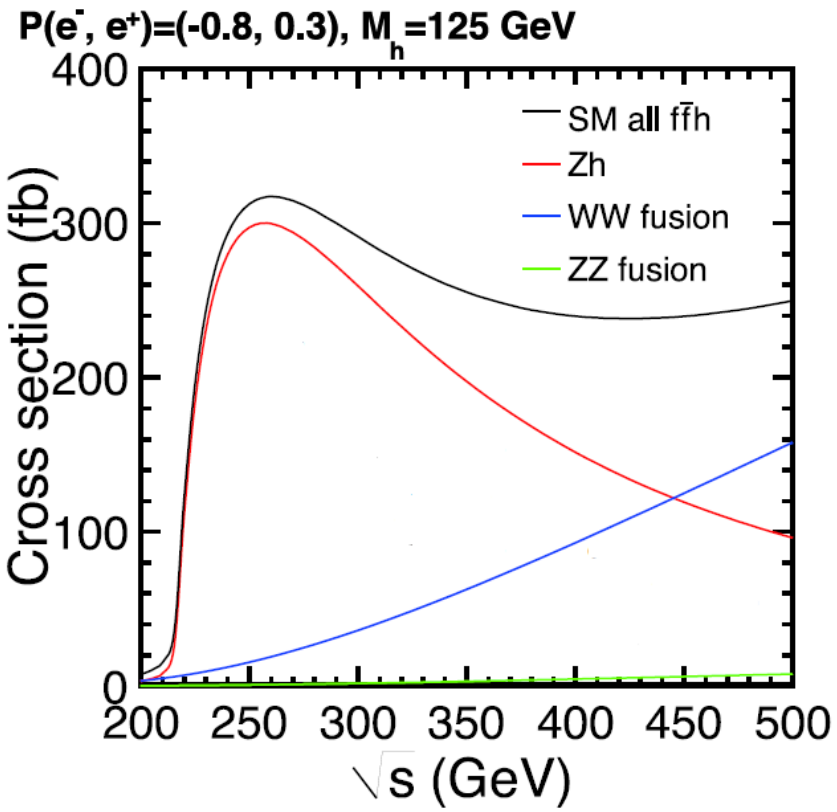
- Momentum resolution

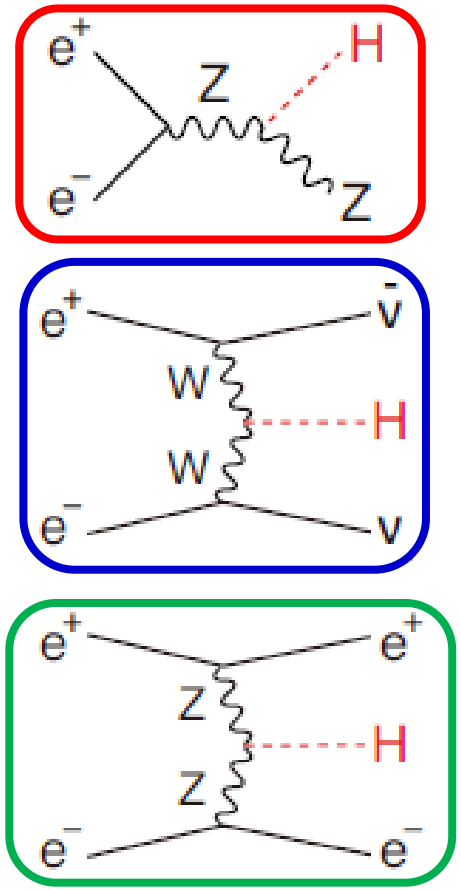
$\sigma_{1/p_T} < 2*10^{-5}$ (GeV^{-1})

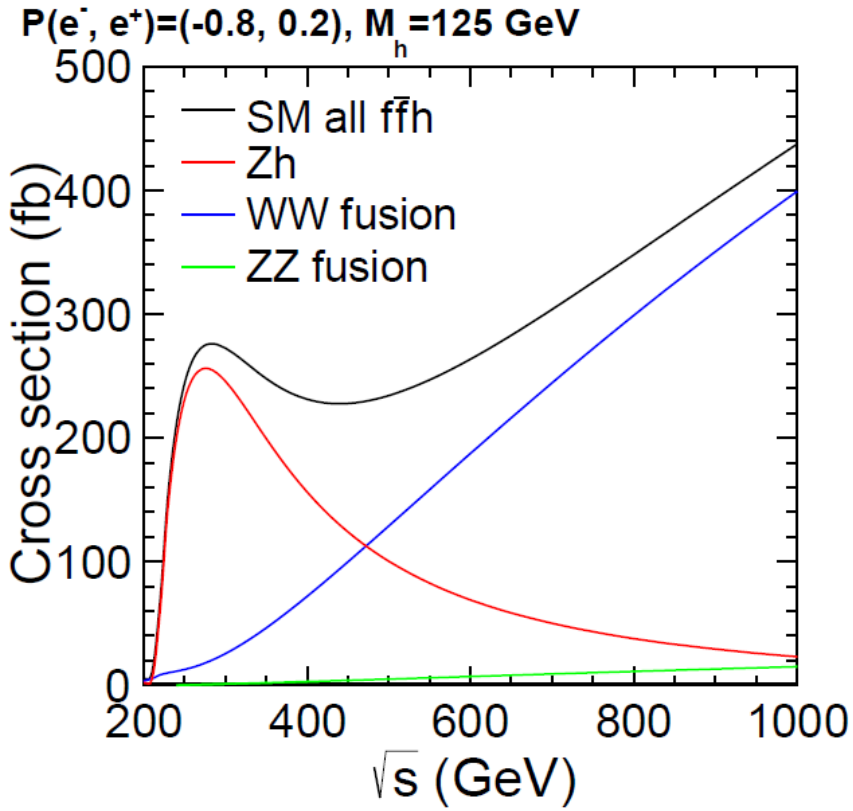
- Energy resolution

σ_E/E = 3 - 4%

Higgs Production at the ILC

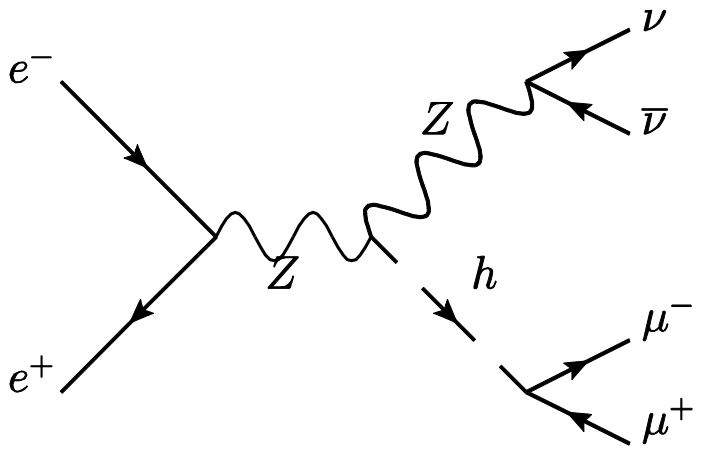


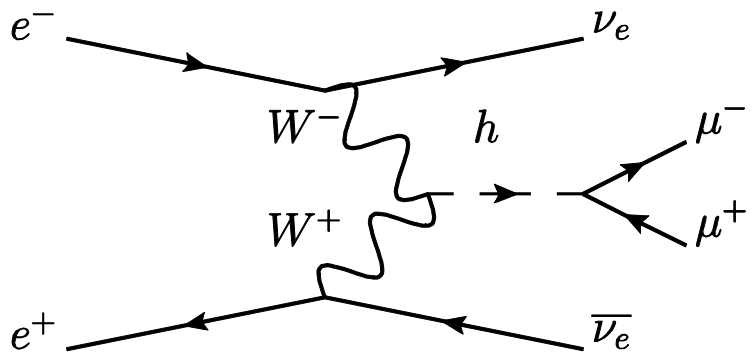




1 TeV: WW-fusion (WWF) dominant
500 GeV: WWF + Zh contribution

Higgs Decaying into Muons at the ILC





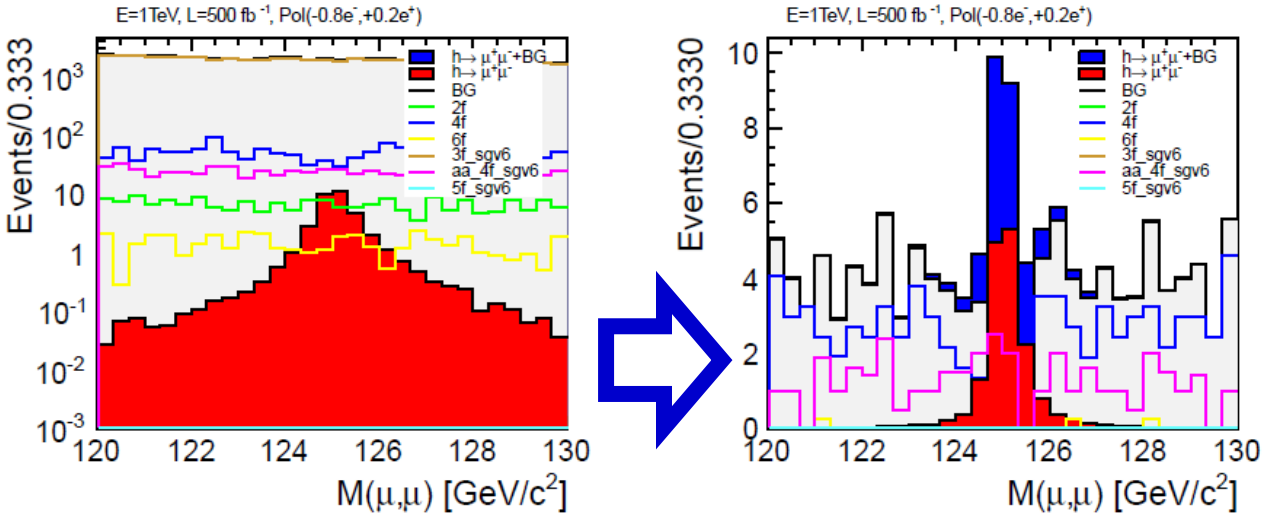
Left: Zh
Right: WWF

Due to tiny branching ratio ($\mathrm{BR}(h \to \mu^+\mu^-)$ = **2.2*10^{-4}**), we have very limited number of signals.

E_{CM}	$P(e^-, e^+)$	$\int Ldt$	$\nu\nu h$ events
1 TeV	(-0.8, +0.2)	3200 fb^{-1}	~290
500 GeV	(-0.8, +0.3)	1600 fb^{-1}	~60

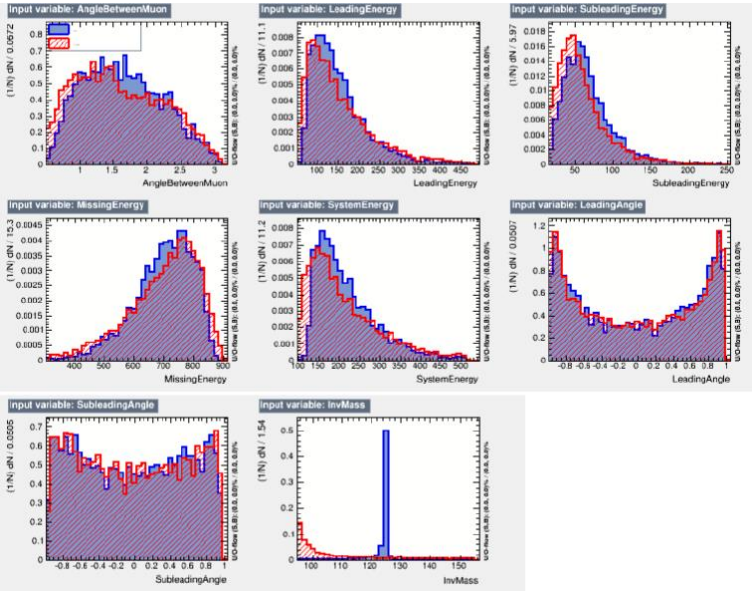
C. Calancha, LC-REP-2013-006
M. F. Giannelli, S. Celani, arXiv:1603.04718 [hep-ex]

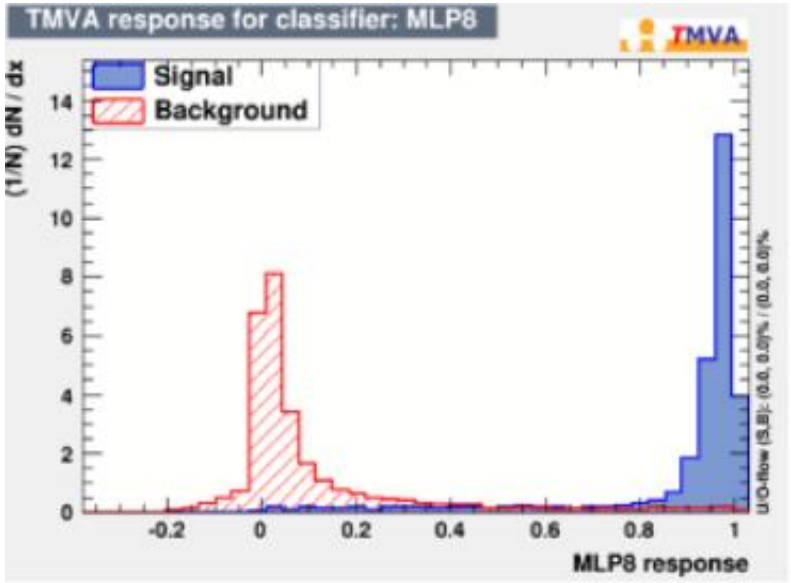
Measuring $h \to \mu^+\mu^-$ at 1 TeV



- Geant4-based full simulation
- Cut-based analysis
  + toy-MC evaluation
- $\frac{\Delta(\sigma\times BR)}{(\sigma\times BR)}$ = 44%(500 fb^{-1})

---> 17%(3200 fb^{-1})





- TMVA (ANN) analysis
- $\frac{\Delta(\sigma\times BR)}{(\sigma\times BR)}$ ~ 36%(500 fb^{-1})

---> 14%(3200 fb^{-1})

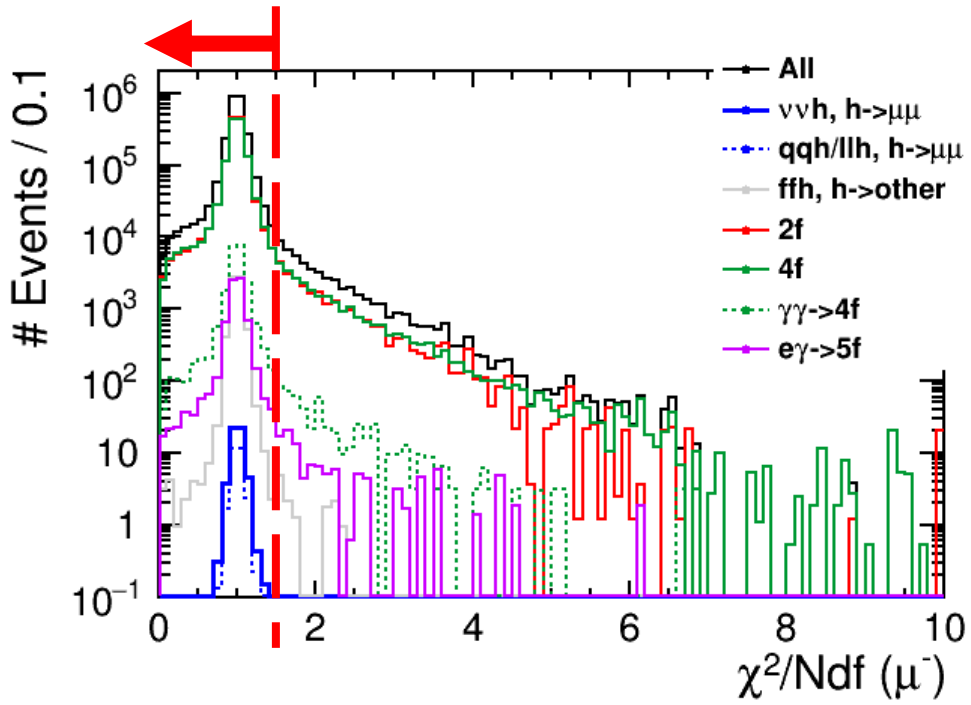
- improvement by ~20%

Study of Measuring $h \to \mu^+\mu^-$ at 500 GeV

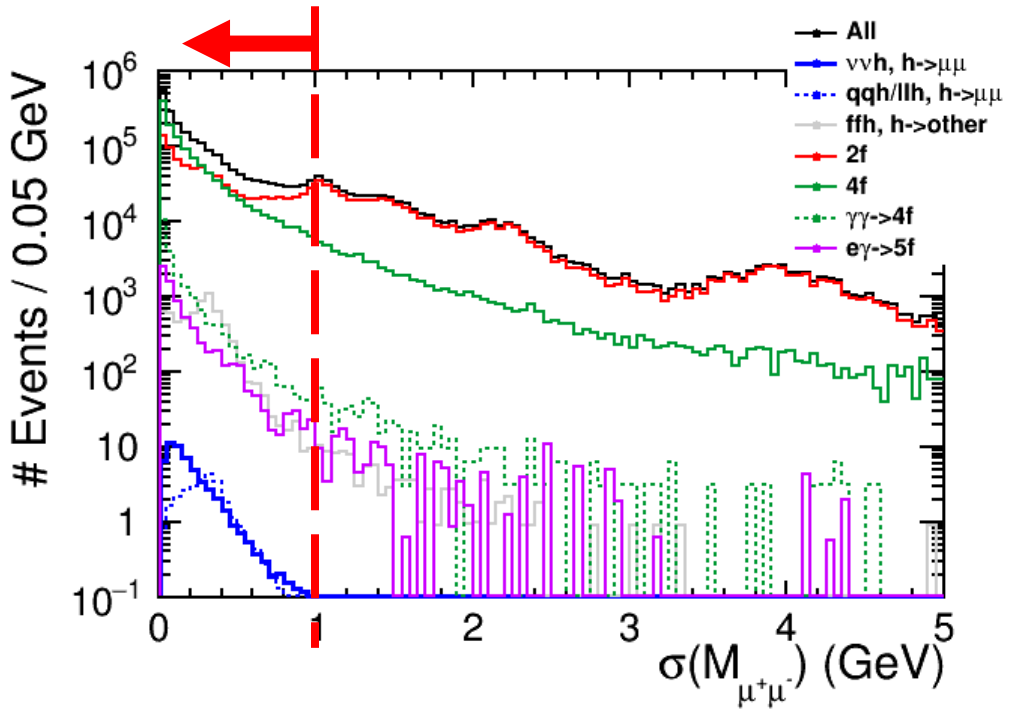
- Cross section is smaller than 1 TeV, but we are planning to take data of 4000 fb^{-1} at E_{CM} = 500 GeV.
  - Currently working on 1600 fb^{-1} with $P(e^-, e^+)$ = (-0.8, +0.3)
- Good benchmark process for detector optimization (high P_t tracking)

- Geant4-based fully-simulated MC samples
- Used track parameter and $\sigma\left(M_{\mu^+\mu^-}\right)$ (mass error) for selecting only well-measured muons

Select well-measured Muons

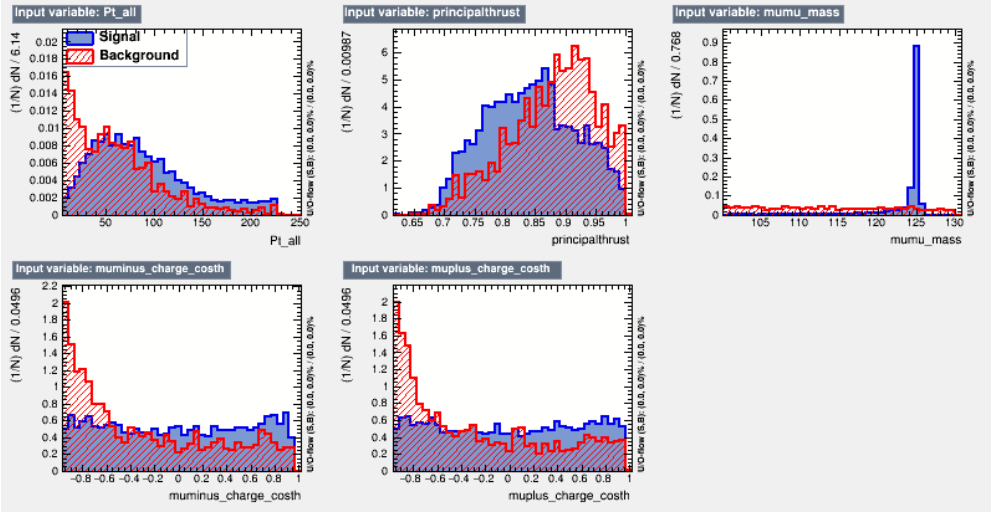


χ^2/Ndf (track fitting parameter)

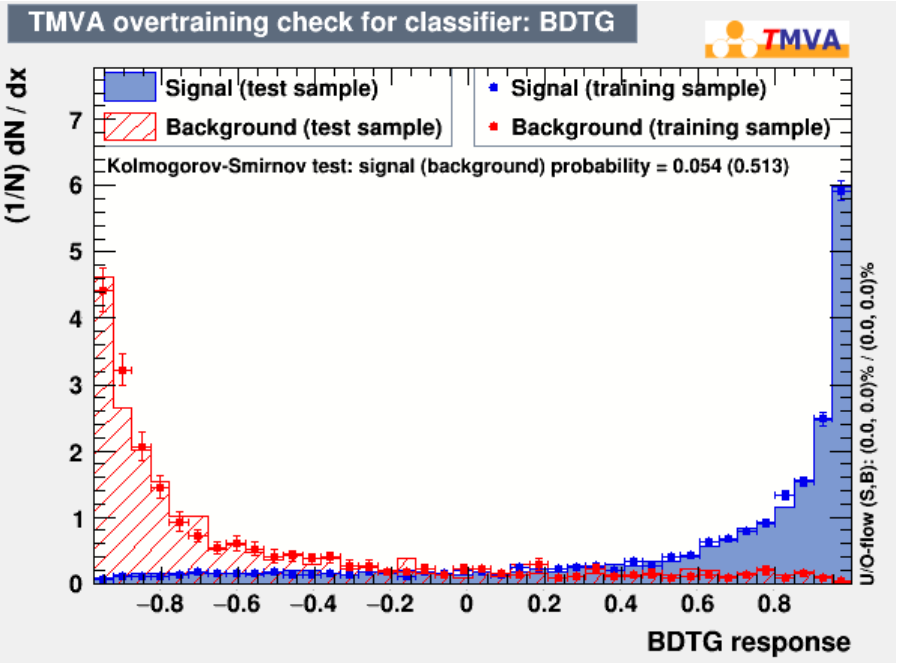


$\sigma(M_{\mu^+\mu^-})$ (mass error of muon pair) typically large value when going to forward region

Results (Preliminary)



TMVA (BDTG) analysis
5 variables:
P_t, thrust, $M_{\mu^+\mu^-}$,
charge*$\cos\theta_{\mu^\pm}$



After optimization

N_{sig} = 13.04, N_{bkg} = 0.30

$\frac{S}{\sqrt{S+B}}$: 3.6

$\frac{\Delta(\sigma\times BR)}{(\sigma\times BR)}$: 28%

Factor 2 from ideal case!
(13% in ideal limit)

Summary

- Model-independent and precise determination of mass-coupling relation of EWSB sector is possible at the ILC.
- Reported very challenging $h \to \mu^+\mu^-$ analysis
  - Good benchmark for detector optimization
  - Select well-measured muons, use TMVA
  - Can reach 28%(14%) precision at E_{CM} = 500 GeV(1 TeV)
- Plans
  - increase MC statistics
  - FSR correction study
  - other channels (qqh, e^+e^-h), other E_{CM} cases

BACKUP

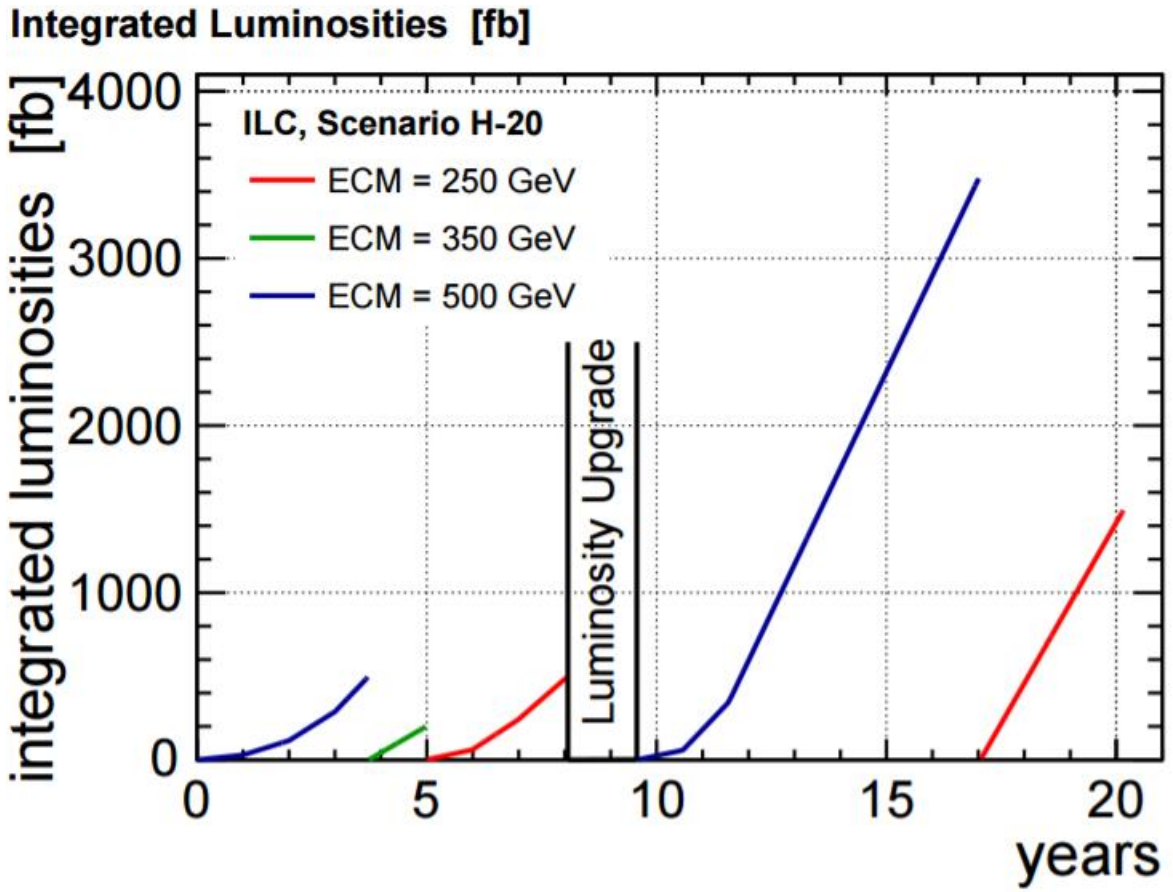
arXiv:1506.07830 [hep-ex],
J. Brau's talk @ ICHEP2016

ILC Running Scenario

optimized scenario with considering
- Higgs precise measurements
- Top physics
- New physics search

20 years running with
E_{CM} = 250 - 500 GeV
---> then possible 1 TeV upgrade

preferred scenario:
2000 fb^{-1} @ 250 GeV
200 fb^{-1} @ 350 GeV
4000 fb^{-1} @ 500 GeV



※will depend on physics results
from LHC and early ILC