Study of
Higgs couplings to leptons
and
Higgs CP properties
at the ILC

Daniel Jeans, KEK
for the
International Large Detector
concept group

ICHEP 2018, Seoul

International Linear Collider

electron – positron collisions

beam polarisation:

e^- 80%, e^+ 30%

luminosity ~10^{34} cm^{-2} s^{-1}

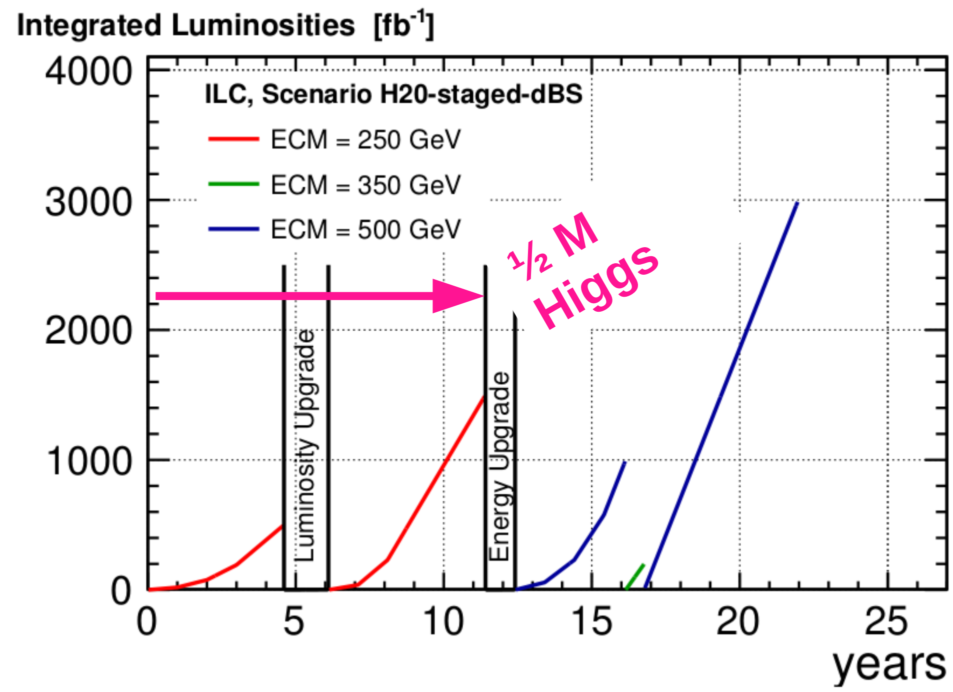
0.5 M Higgs in ~11 years

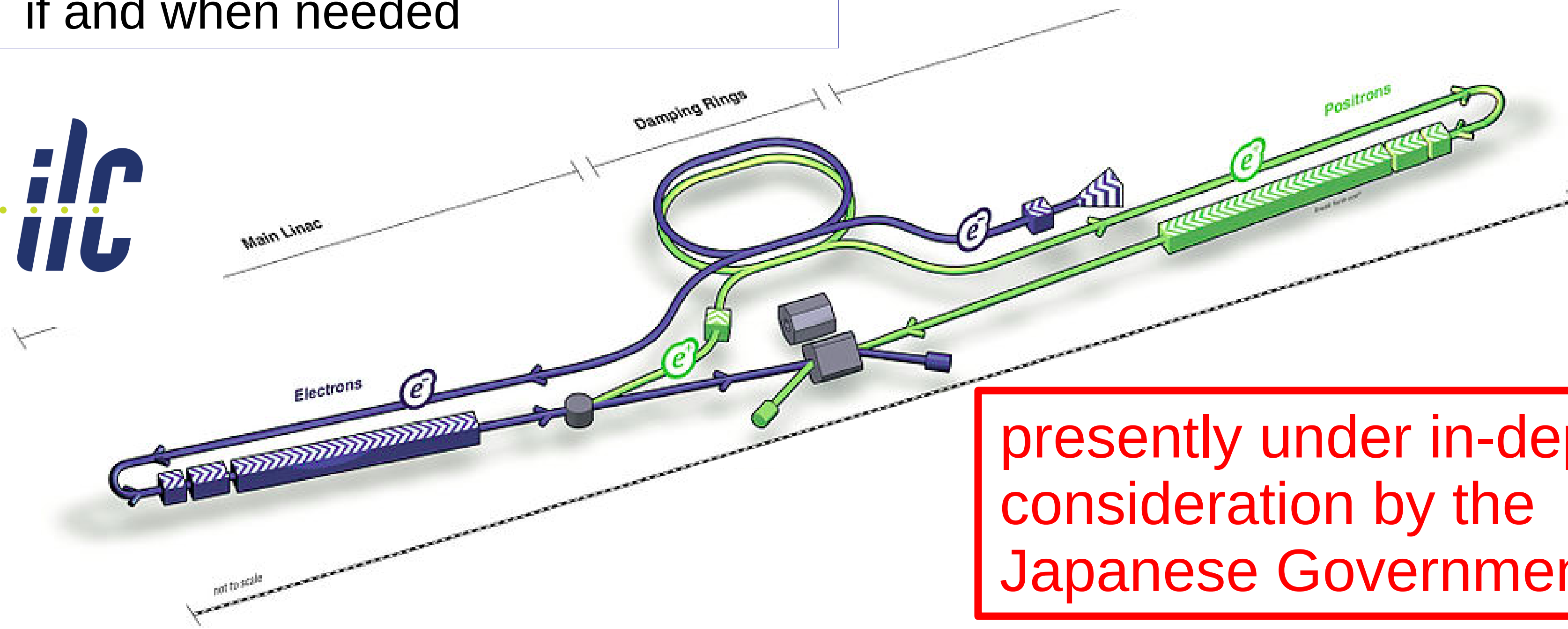
start with collisions at 250 GeV

linear accelerator

→ future energy upgrades possible, if and when needed

see talk by J. Reuter





presently under in-depth consideration by the Japanese Government

ILC 250 physics program

2 ab^{-1} over ~11 years

electro-weak symmetry breaking

comprehensive and precise study of Higgs sector

see talk by T. Ogawa

electro-weak processes
LEP2 + beam polarisation
+ better detectors
+ 1000 times more data

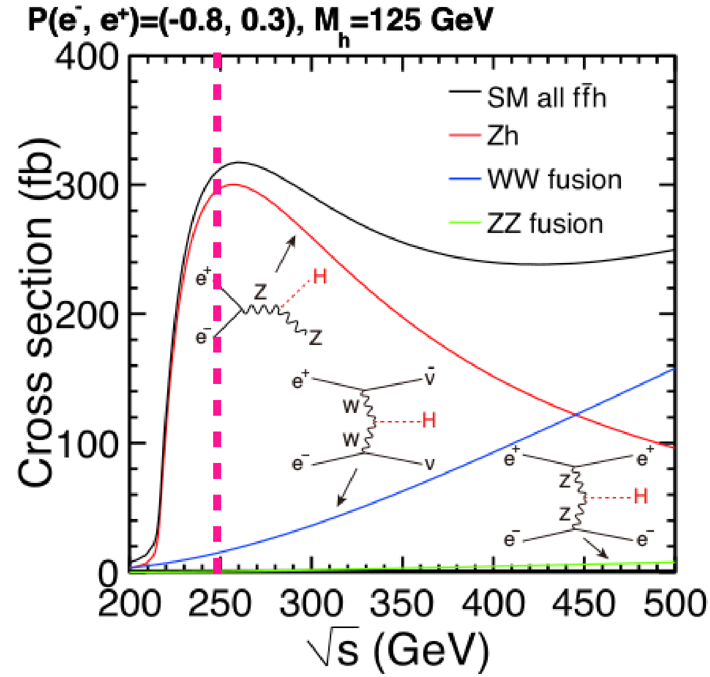
see talk by S. Bilokin

→ indirect probe of BSM physics

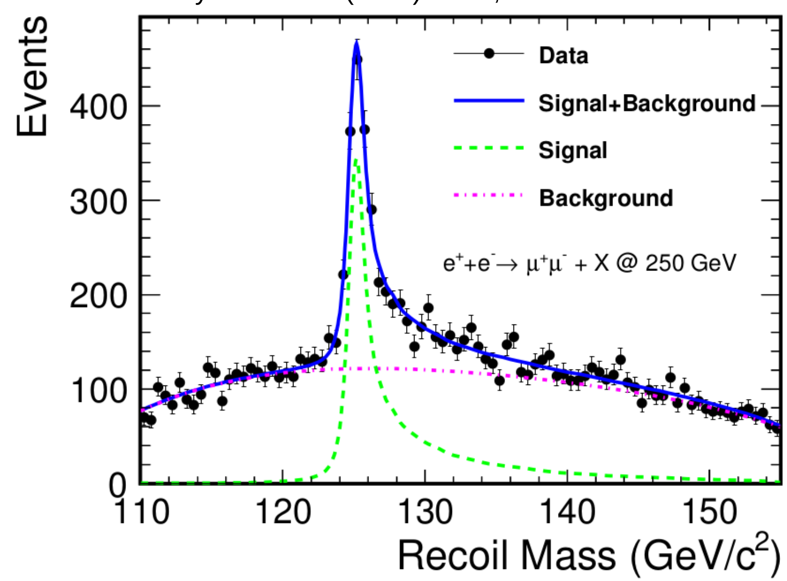
direct searches for BSM particles

profit from trigger-less readout, efficiency for lower energy signatures

see talks by M. Berggren, Y. Wang



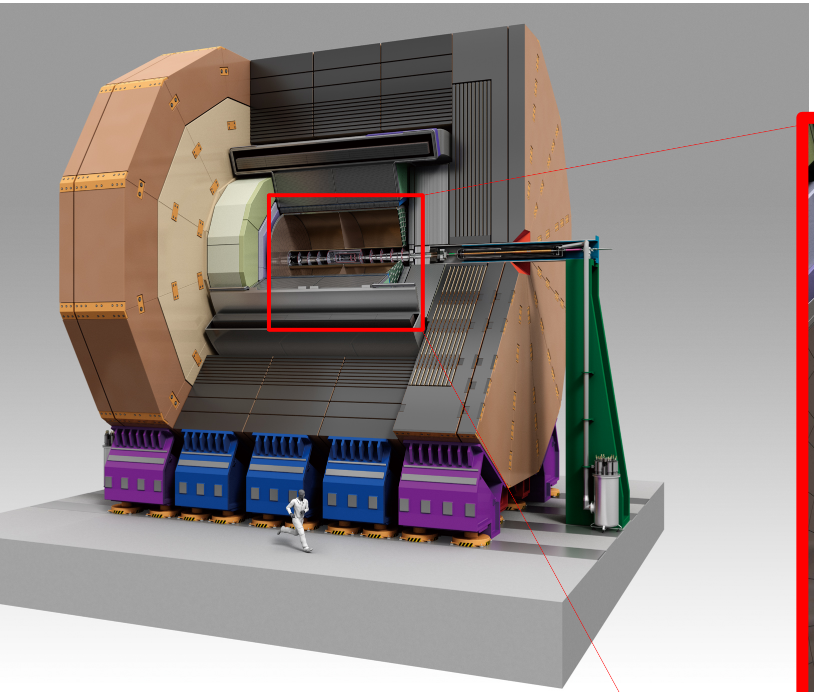
Phys.Rev. D94 (2016) no.11, 113002

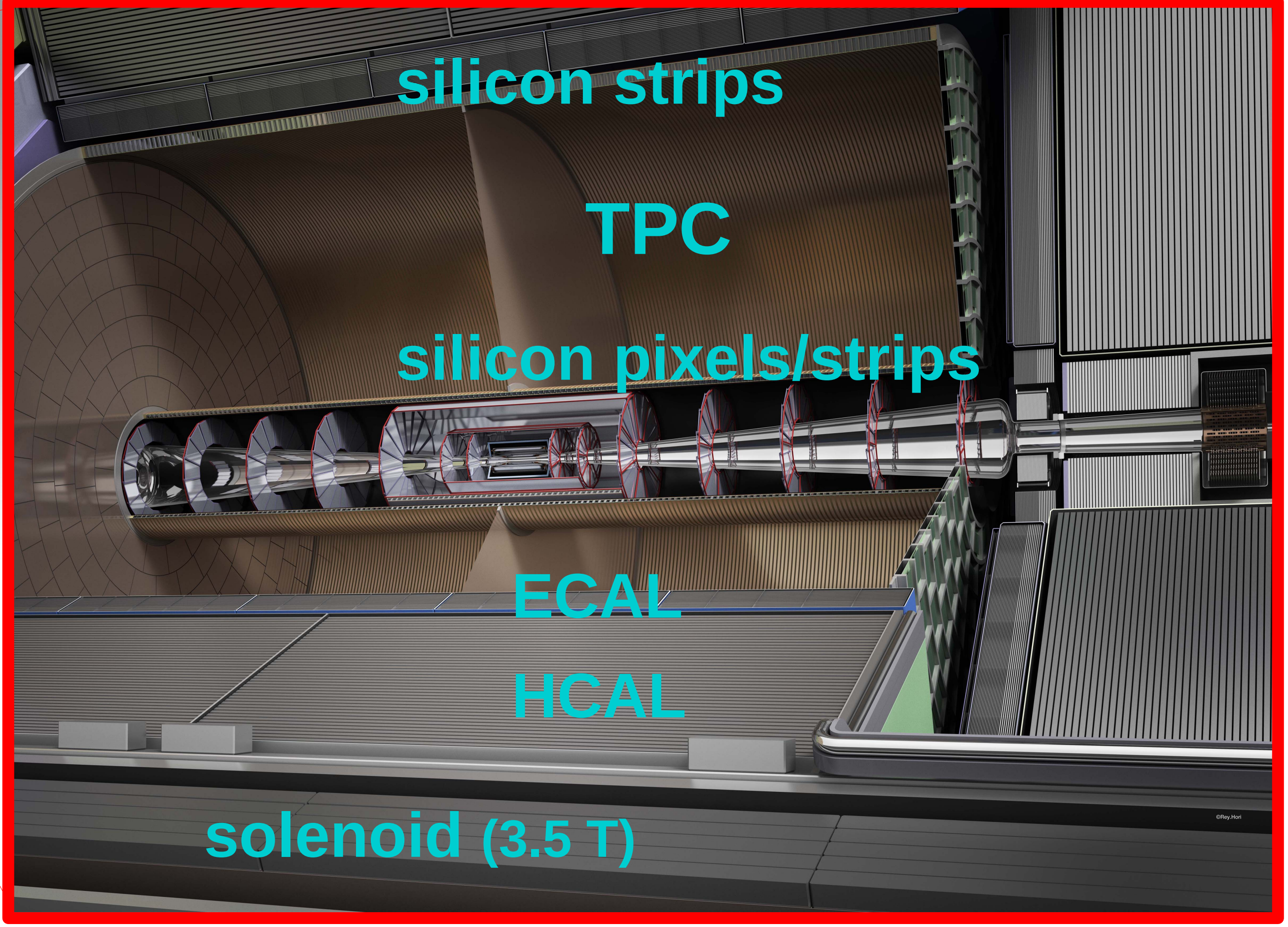


International Large Detector

one of two detector concepts being developed for ILC

high precision detector optimised for
particle flow reconstruction





silicon, gaseous
tracking systems

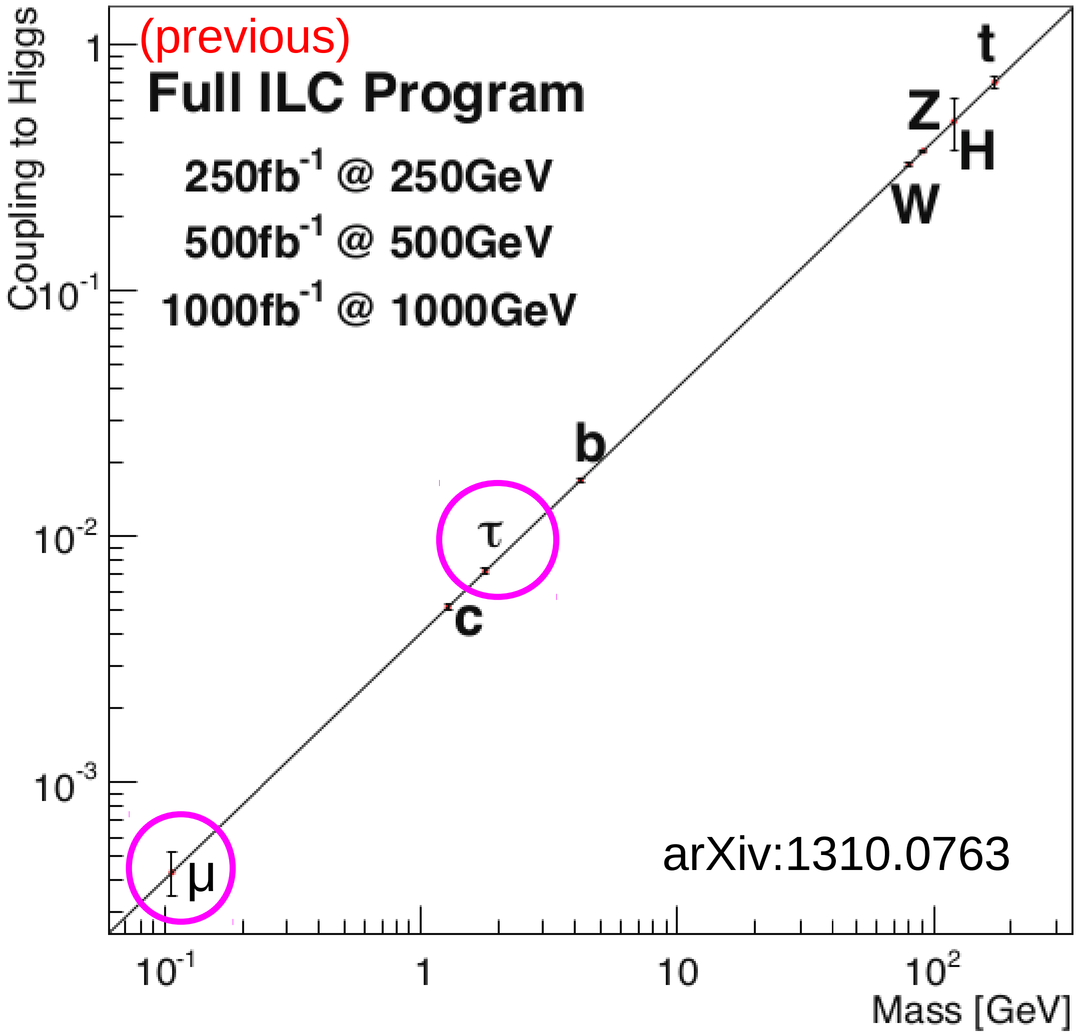
σ_{d0} → 5 μm

σ_{pT}/p_T → $2 \times 10^{-5}\, p_T$

high granularity calorimetry

jet energy resolution 3-4%

test the lepton Yukawa – mass relation



Higgs boson coupling to τ τ

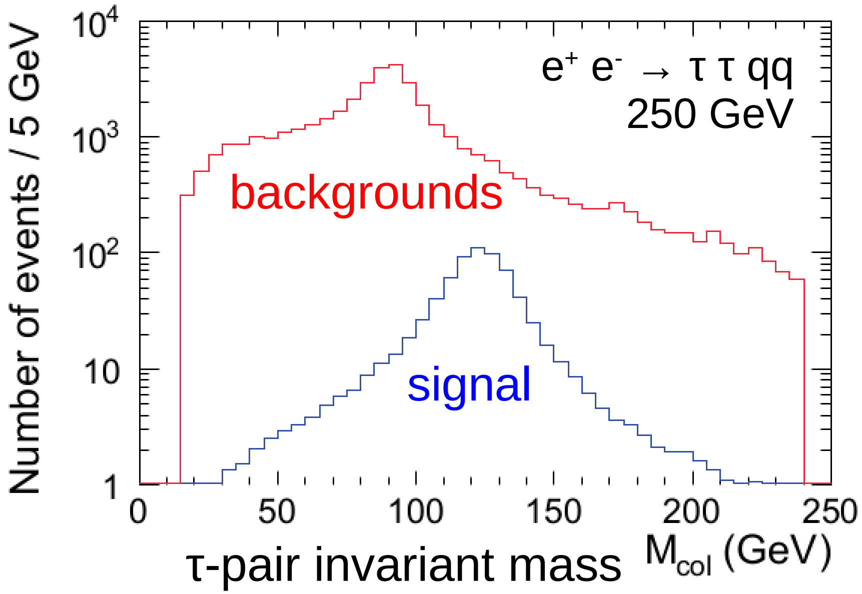
Eur. Phys. J. C75 (2015) no.12, 617

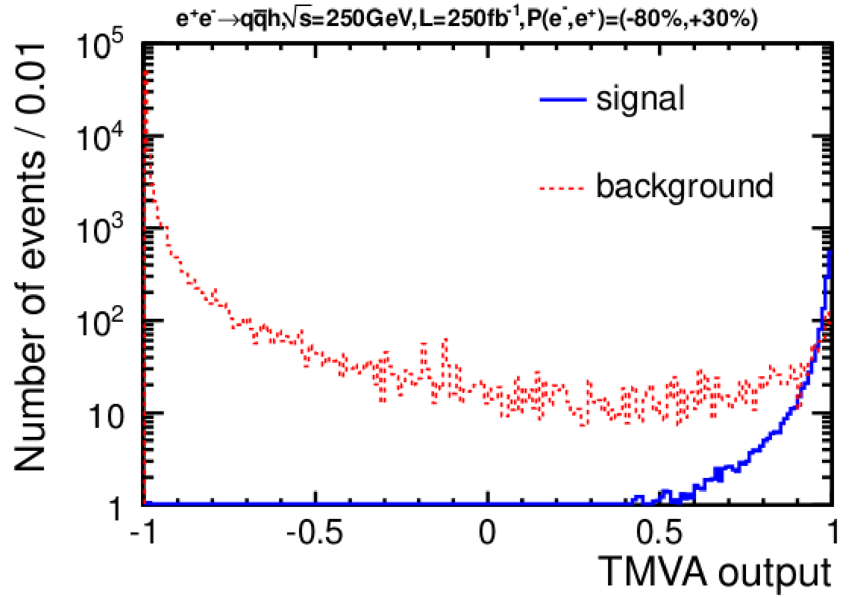
$e^+ e^- \rightarrow H Z \rightarrow \tau \tau + (ee, \mu \mu, q q)$

isolated narrow jets,
- 1 or 3 charged particles
- total jet charge ±1
- invariant mass < 2 GeV/c^2

estimate ν_τ momenta
→ colinear approximation

various cuts to reduce backgrounds
final multivariate analysis [BDT]





expected precision at ILC on
$\sigma (h + X) \cdot BR (h \rightarrow \tau \tau)$:
1.2 % [ILC250 / 2 ab^{-1}]
1.0 % [+ ILC500 / 4 ab^{-1}]

Higgs boson coupling to μ μ

arXiv:1801.07966

challenge: small sample due to tiny BR (h → μ μ) ~ 2×10^{-4} [in SM]

Full detector simulation, realistic reconstruction algorithms

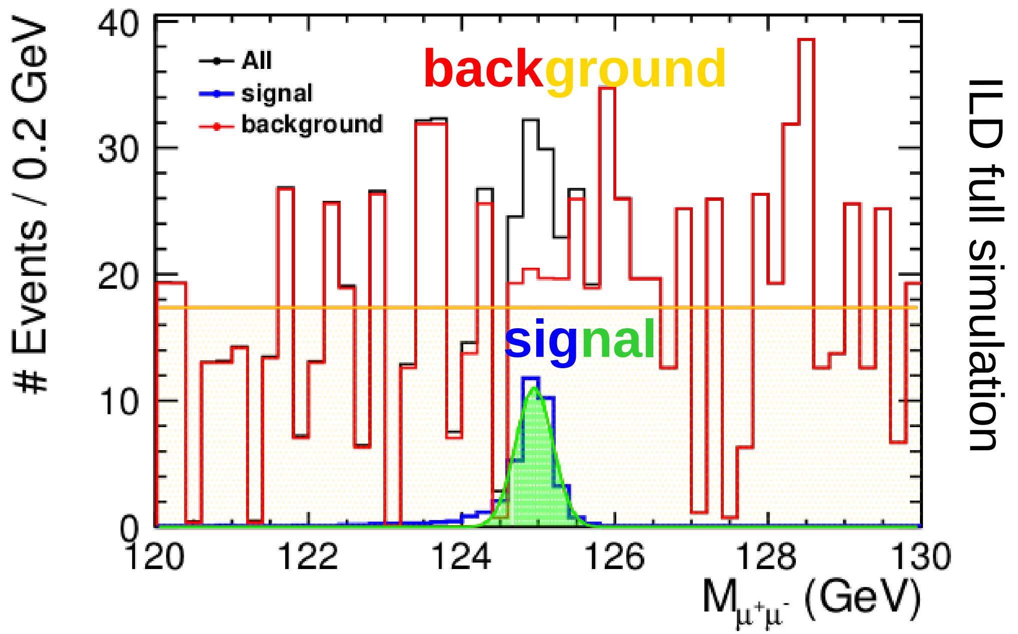
$e^+ e^- \rightarrow H Z$
→ μ μ q q
→ μ μ ν ν

pair of
prompt, isolated,
oppositely charged,
well-measured,
μ candidates

cuts on "Z", μ angles

Multivariate analysis to suppress backgrounds

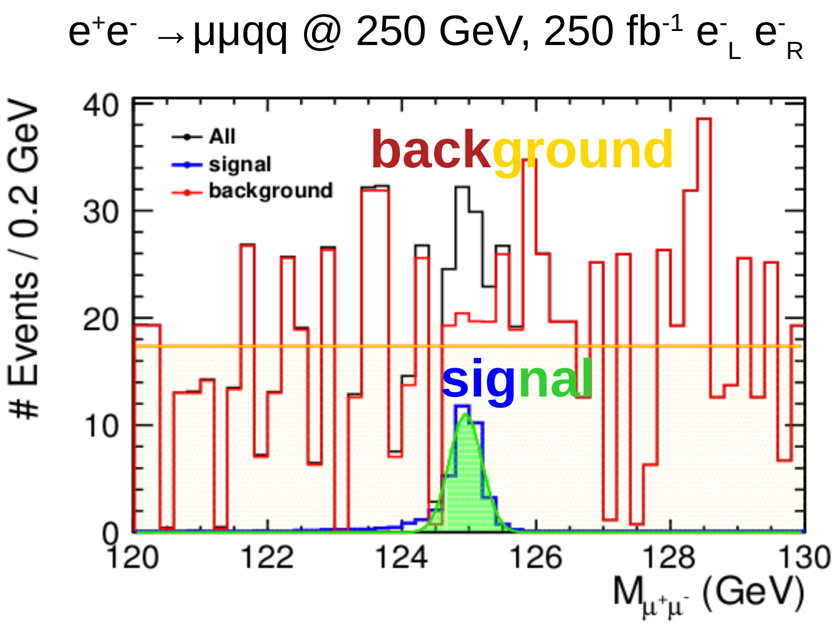
$e^+e^- \rightarrow \mu\mu qq$ @ 250 GeV

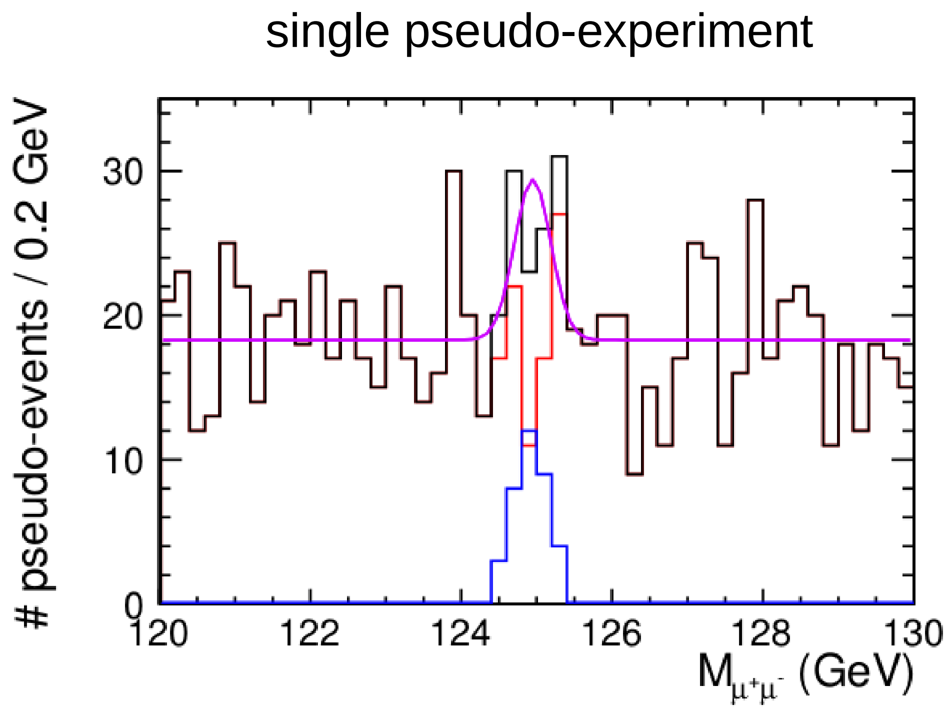


key: excellent momentum resolution
→ narrow signal distribution
$dp_T/p_T \rightarrow 2 \times 10^{-5} p_T$

h → μ μ : estimating sensitivity

arXiv:1801.07966





fit full simulation results to
gaussian (signal) +
constant (background)

fit results
→ large ensemble of pseudo–experiments
→ estimate measurement precision

expected relative precision on
σ (h + X) · BR (h → μ μ) at ILC :

20 % [ILC250 / 2 ab^{-1}]
15 % [+ ILC500 / 4 ab^{-1}]

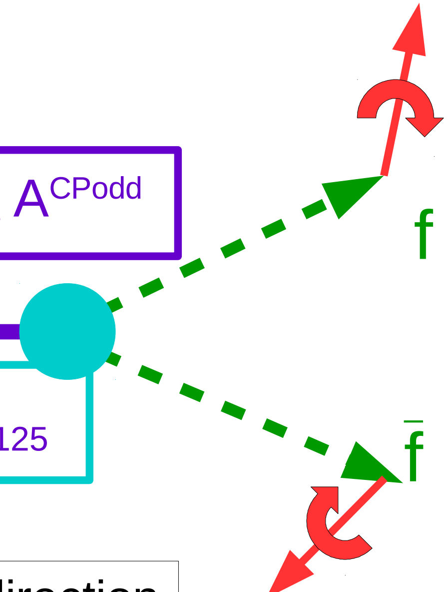
preliminary

does Higgs → τ τ conserve CP ?

arXiv:1804.01241
to appear in PRD

$h_{125} = \cos\psi_{CP}\, h^{CPeven} + \sin\psi_{CP}\, A^{CPodd}$

$g\,\bar{f}\,(\cos\psi_{CP} + i\,\gamma^5 \sin\psi_{CP})\, f\, h_{125}$

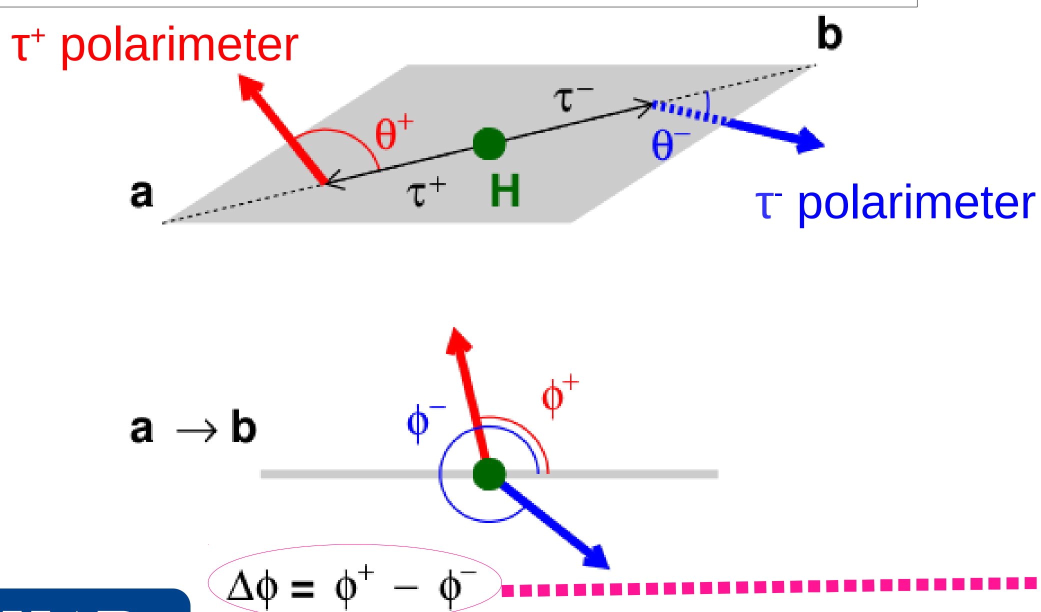


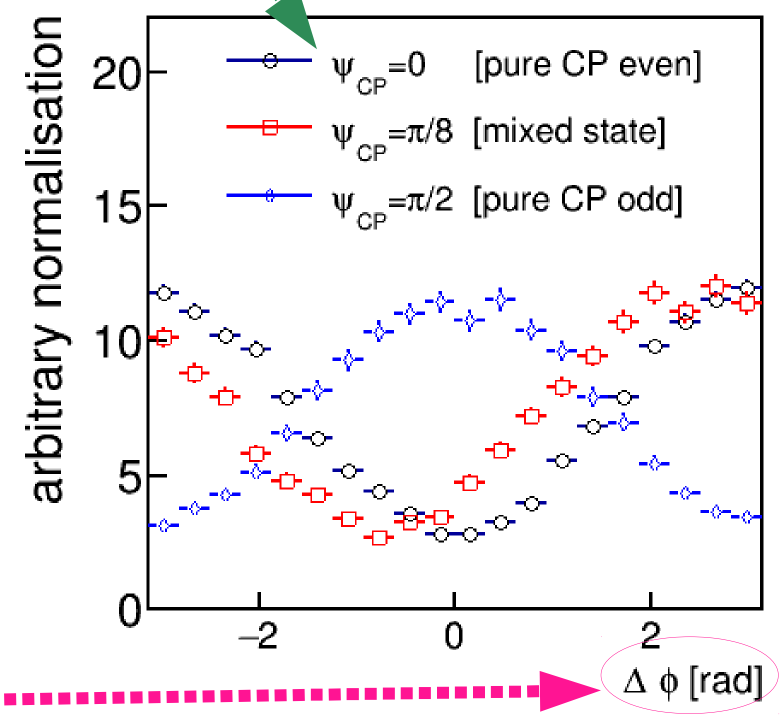
h is a spin 0 state:

$|f\ \bar{f}> = |\uparrow\downarrow> + e^{2i\,\psi CP}\, |\downarrow\uparrow>$

[ψ_{CP} = 0 CP even,
π/2 CP odd]

"**polarimeter**" - estimator of spin direction from τ decay products





full τ reconstruction

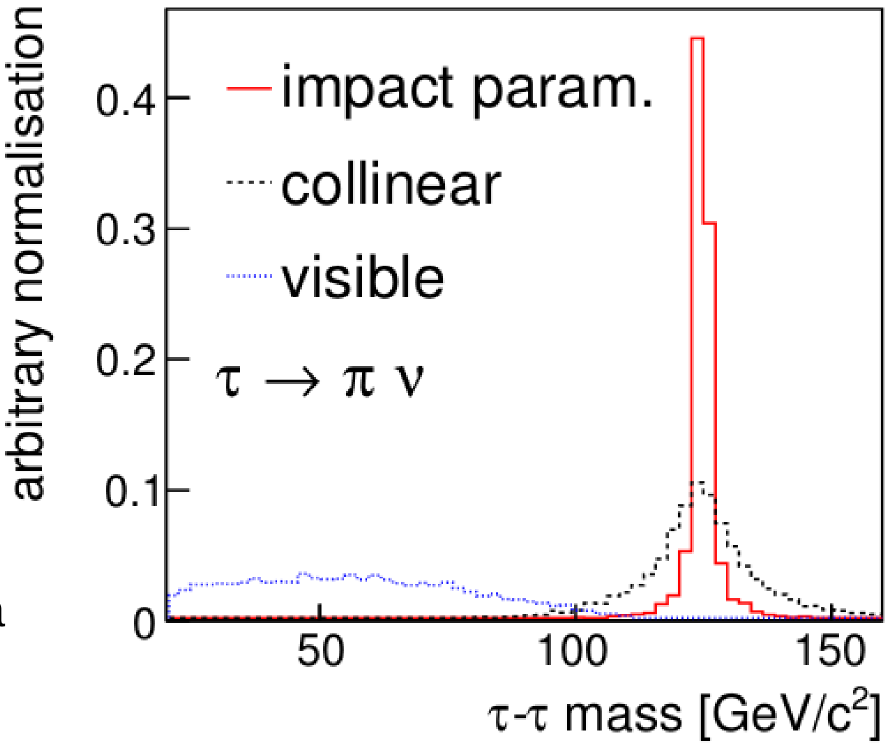
NIM A810 (2016) 51
arXiv:1507.01700

in Higgs-strahlung $e^+ e^- \rightarrow ZH$, $H \rightarrow \tau\,\tau$

visible Z decay:
- → τ production vertex
- → p_T of di-τ system

excellent vertex detector:
- → trajectory of τ decay products
  - → plane of τ momentum

ILD full simulation



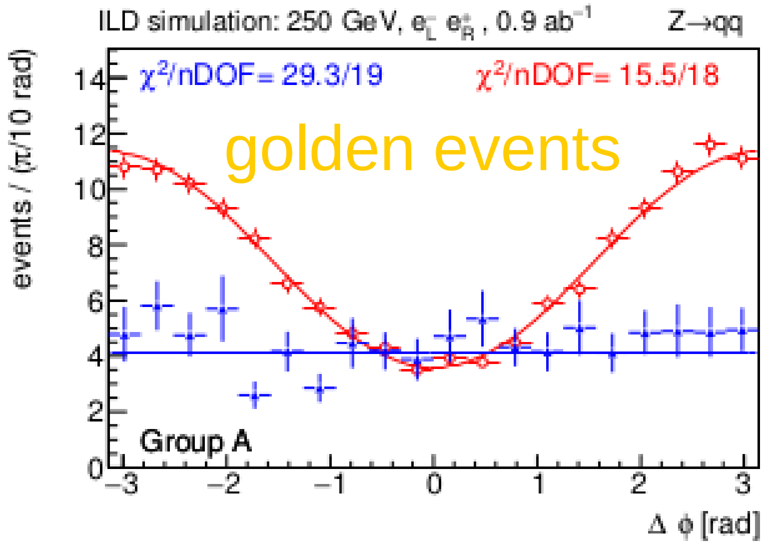
6 constraints to solve for
6 unknowns / event with hadronic τ decays
2 × neutrino 3-momenta

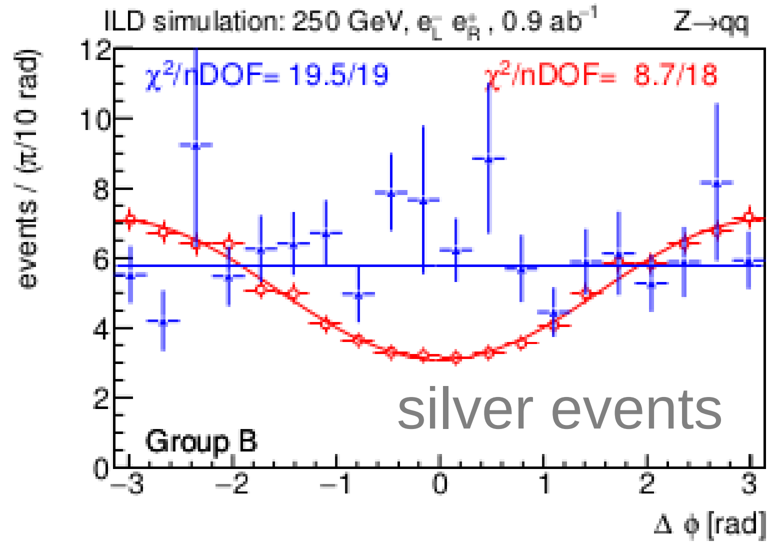
optimal information on τ momentum and spin
relies on excellent detector performance:
impact parameter, tracking, photon and jet measurement

CP in h → τ τ : sensitivity

arXiv:1804.01241
to appear in PRD

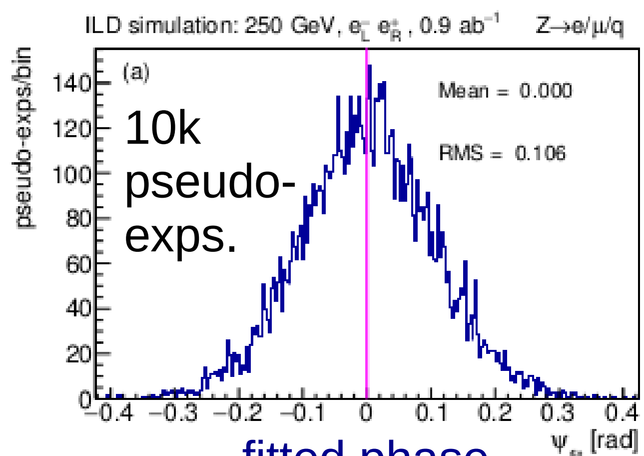
signal background





signal distribution: **phase** of Δφ distribution sensitive to CP
backgrounds: consistent with flat distribution

pseudo-experiments:
simultaneous
likelihood fit to
Δφ distributions
in all channels



fitted phase

with 2 ab^{-1} @ ILC250,
measure ψ_{CP} to
75 mrad (4.3 deg)

Summary

International Linear Collider will enable comprehensive set of Higgs measurements, shining light on BSM physics

In this talk:

$\sigma(h) \cdot BR(h \rightarrow \tau\tau)$ with a precision of 1.2 %

→ several times more precise than HL-LHC projections

$\sigma(h) \cdot BR(h \rightarrow \mu\mu)$ with a precision of 20 %

→ statistically limited

→ similar to HL-LHC projections

CP mixing in $h \rightarrow \tau\tau$ with a precision of 75 mrad

→ baryogenesis at electro-weak scale ?