AWLC14

ILC Parameter WG Report

from "ILC Parameters" Session

May 14, 2014

ILC Parameters

Conveners: Jim Brau (U. Oregon), Nicholas Walker (DESY)

Location: One West WH1W

16:00 **Introduction** *15'*

Speaker: Jim Brau (U. Oregon)

Material: Slides

16:15 **Recent physics studies** *30'*

Speaker: Keisuke Fujii (IPNS, KEK)

Material: Slides

16:45 **Machine staging issues** *25'*

Speaker: Nicholas Walker (DESY)

Material: Paper Slides

17:10 **Discussion** *40'*

2014/06/13

Keisuke Fujii

ILC Parameter Joint Working Group

- Membership appointed by Hitoshi Yamamoto and Mike Harrison
  - PHYSICS AND DETECTORS:
    T. Barklow, J. Brau (co-convener), K. Fujii, J. List
  - ACCELERATOR:
    Jie Gao, N. Walker (co-convener), K. Yokoya
- Charge (next slide)

ILC Parameter Joint Working Group – Charge

March 19, 2014

- The ILC parameter working group reports to the LCC Directorate. It consists of members from both the ILC accelerator and the physics & detector groups where each team selects a co-convener for this working group.

- This working group prepares information on ILC machine parameters and staging scenarios as well as potential upgrade paths in a form readily usable by the LCC. In doing so, the WG will take into account technical machine constraints and physics and detector needs regarding the fundamental ILC machine parameters such as energy, luminosity, crossing angles, etc.

- The first task for the working group is to prepare multiple scenarios for staging up to about 500 GeV. The report should contain the pros and cons of each scenario as well as luminosities needed at each energy to produce corresponding physics results.

Physics Considerations

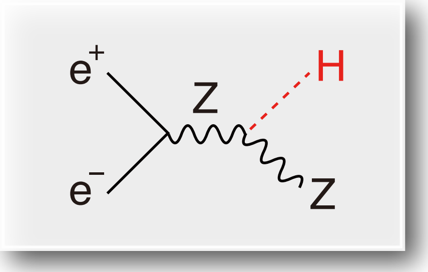
- Phases of energy operation from 250 GeV to maximum baseline energy (eg. 350 GeV, etc.)
  - including required and available int. lumi.
- Maximum reach baseline energy (we note physics motivation for 550 GeV based on tth)
- Operation at energies below 250 GeV
- Safety margin in energy reach and luminosity
- Polarization

Higgs-related Physics at Ecm ≲ 500 GeV

Three well know thresholds

ZH @ 250 GeV (~M_Z+M_H+20GeV) :

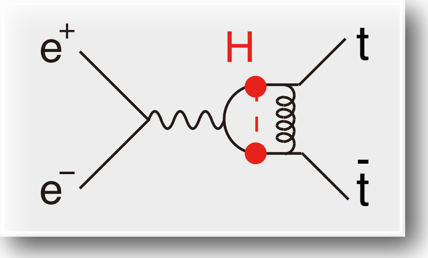
- Higgs mass, width, J^{PC}
- Gauge quantum numbers
- Absolute measurement of HZZ coupling (recoil mass) →***Higgs couplings (other than top)***
- BR(h->VV,qq,ll,invisible) : V=W/Z(direct), g, γ (loop)

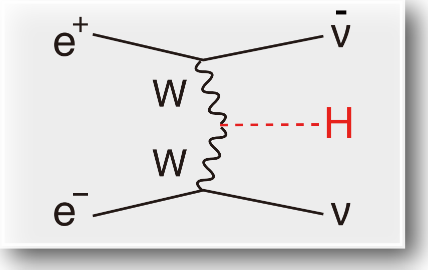


ttbar @ 340-350GeV (~2mt) : ZH meas. Is also possible

- Threshold scan --> theoretically clean ***mt*** measurement: $\Delta m_t(\overline{MS}) \simeq 100\,\mathrm{MeV}$
  --> test stability of the SM vacuum
  --> indirect meas. of ***top Yukawa*** coupling
- A_{FB}, Top momentum measurements
- Form factor measurements

γ γ → HH @ 350GeV possibility



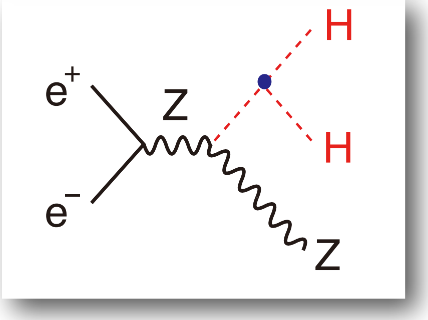


vvH @ 350 - 500GeV :

- ***HWW coupling*** -> ***total width*** --> absolute normalization of Higgs couplings

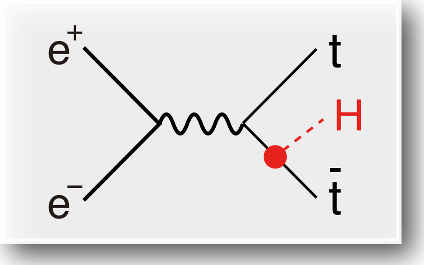
ZHH @ 500GeV (~M_Z+2M_H+170GeV) :

- Prod. cross section attains its maximum at around 500GeV -> ***Higgs self-coupling***



ttbarH @ 500GeV (~2mt+M_H+30GeV) :

- Prod. cross section becomes maximum at around 800GeV.
- QCD threshold correction enhances the cross section -> ***top Yukawa*** measurable at 500GeV concurrently with the self-coupling



We can access all the relevant Higgs couplings at ~500GeV for the mass-coupling plot!

How do Higgs coupling precisions depend on staging scenario?

Starting Point

= Input Observables

Summary table of Higgs measurements @ ILC

Baseline

w/ new extrapolated results @ 350 GeV

ECM	@ 250 GeV		@ 350 GeV		@ 500 GeV		@ 1 TeV
luminosity · fb	250		330		500		1000
polarization (e-,e+)	(-0.8, +0.3)		(-0.8, +0.3)		(-0.8, +0.3)		(-0.8, +0.2)
process	ZH	ννH	ZH	ννH	ZH	ννH	ννH
cross section	2.6%	-	***X%***		-	-	-
	σ·Br	σ·Br	σ·Br	σ·Br	σ·Br	σ·Br	σ·Br
H-->bb	1.2%	10.5%	1.3%	1.3%	1.8%	0.66%	0.32%
H-->cc	8.3%		9.9%	13%	13%	6.2%	3.1%
H-->gg	7%		7.3%	8.6%	11%	4.1%	2.3%
H-->WW*	6.4%		6.8%	5.0%	9.2%	2.4%	1.6%
H-->ττ	4.2%		4.6%	19%	5.4%	9%	3.1%
H-->ZZ*	19%		22%	17%	25%	8.2%	4.1%
H-->γγ	29-38%		29-38%	39%	29-38%	19%	7.4%
H-->μμ	-						31%
H-->Inv. (95% C.L.)	< 0.95%		< 1.5%		< 3.2%		
ttH, H-->bb	-				28%		6%

mostly from White Paper; being updated by new studies with mH = 125 GeV (see backup)

From the Observables to Couplings

From observables to couplings

- σ_{ZH} (from recoil mass)
- $\sigma_{ZH}\times Br(H \rightarrow XX)$
- $\sigma_{\nu\nu H}\times Br(H \rightarrow XX)$
- $\sigma_{ttH}\times Br(H \rightarrow XX)$

X=b,c,g,W,Z,τ,μ,γ

$$Y_i' = F_i \cdot \frac{g^2_{HZZ} g^2_{HXX}}{\Gamma_0}$$

$$Y_i' = F_i \cdot \frac{g^2_{HWW} g^2_{HXX}}{\Gamma_0}$$

$$Y_i' = F_i \cdot \frac{g^2_{Htt} g^2_{HXX}}{\Gamma_0}$$

global fit (model independent)

$$\chi^2 = \sum_{i=1}^{i=34} \left(\frac{Y_i - Y_i'}{\Delta Y_i}\right)^2$$

ΔY_i is the measurement error

minimization (10 free parameters)

$$g_{HZZ},\ g_{HWW},\ g_{Hbb},\ g_{Hcc},\ g_{Hgg},\ g_{H\tau\tau},\ g_{H\gamma\gamma},\ g_{H\mu\mu},\ g_{Htt},\ \Gamma_0$$

What observables limit the coupling precisions?

The 4 most important ones

- *Y_1: recoil mass*
- *Y_2: WW-fusion h→bb*
- *Y_3: higgsstrahlung h→bb*
- *Y_4: WW-fusion h→WW**

$$Y_1 = \sigma_{ZH} \propto g^2_{HZZ}$$

$$Y_2 = \sigma_{\nu\bar{\nu}H} \cdot \mathrm{Br}(H \to b\bar{b}) \propto \frac{g^2_{HWW} g^2_{Hbb}}{\Gamma_H}$$

$$Y_3 = \sigma_{ZH} \cdot \mathrm{Br}(H \to b\bar{b}) \propto \frac{g^2_{HZZ} g^2_{Hbb}}{\Gamma_H}$$

$$Y_4 = \sigma_{\nu\bar{\nu}H} \cdot \mathrm{Br}(H \to WW^*) \propto \frac{g^4_{HWW}}{\Gamma_H}$$

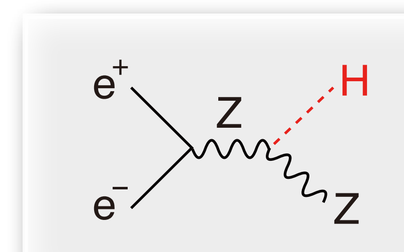
$$\Delta g_{HZZ} \sim \frac{1}{2}\Delta Y_1$$

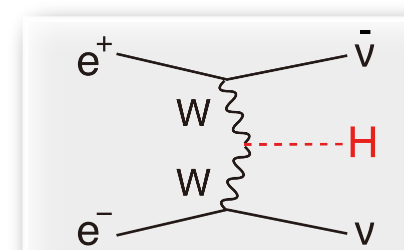
$$\Delta g_{HWW} \sim \frac{1}{2}\Delta Y_1 \oplus \frac{1}{2}\Delta Y_2 \oplus \frac{1}{2}\Delta Y_3$$

$$\Delta g_{Hbb} \sim \frac{1}{2}\Delta Y_1 \oplus \Delta Y_2 \oplus \frac{1}{2}\Delta Y_3 \oplus \frac{1}{2}\Delta Y_4$$

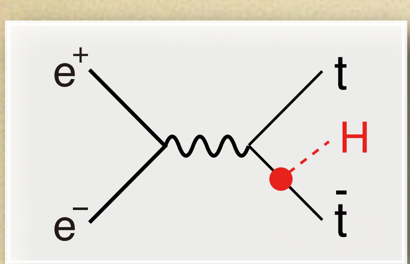
$$\Delta \Gamma_H \sim 2\Delta Y_1 \oplus 2\Delta Y_2 \oplus 2\Delta Y_3 \oplus \Delta Y_4$$

Both ZH and vvH productions matter!

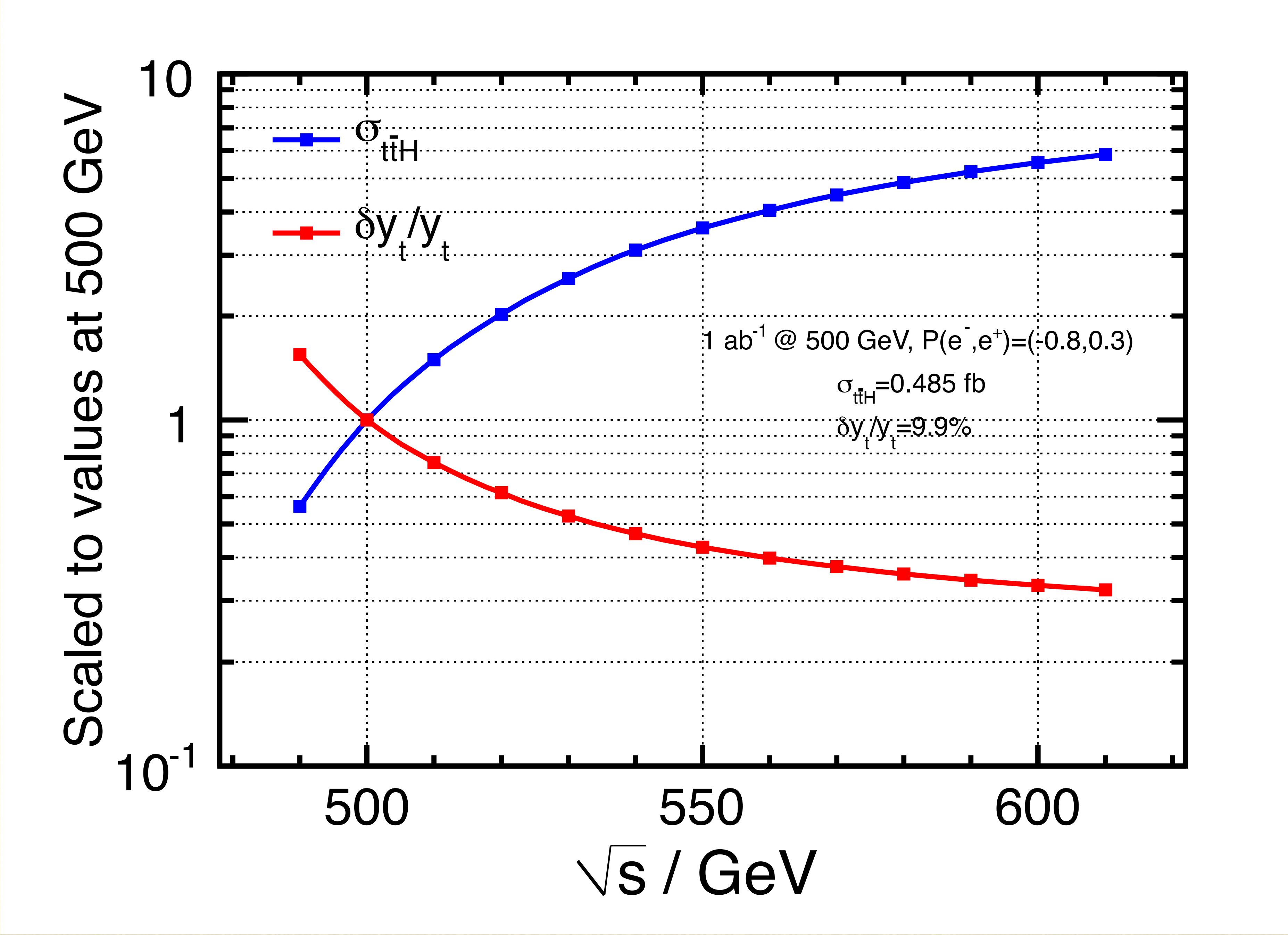




For more details, see J.Tian @ Tokusui Workshop 2013



Top Yukawa coupling



Y. Sudo

Slight increase of E_{max} is very beneficial!

Sample Results

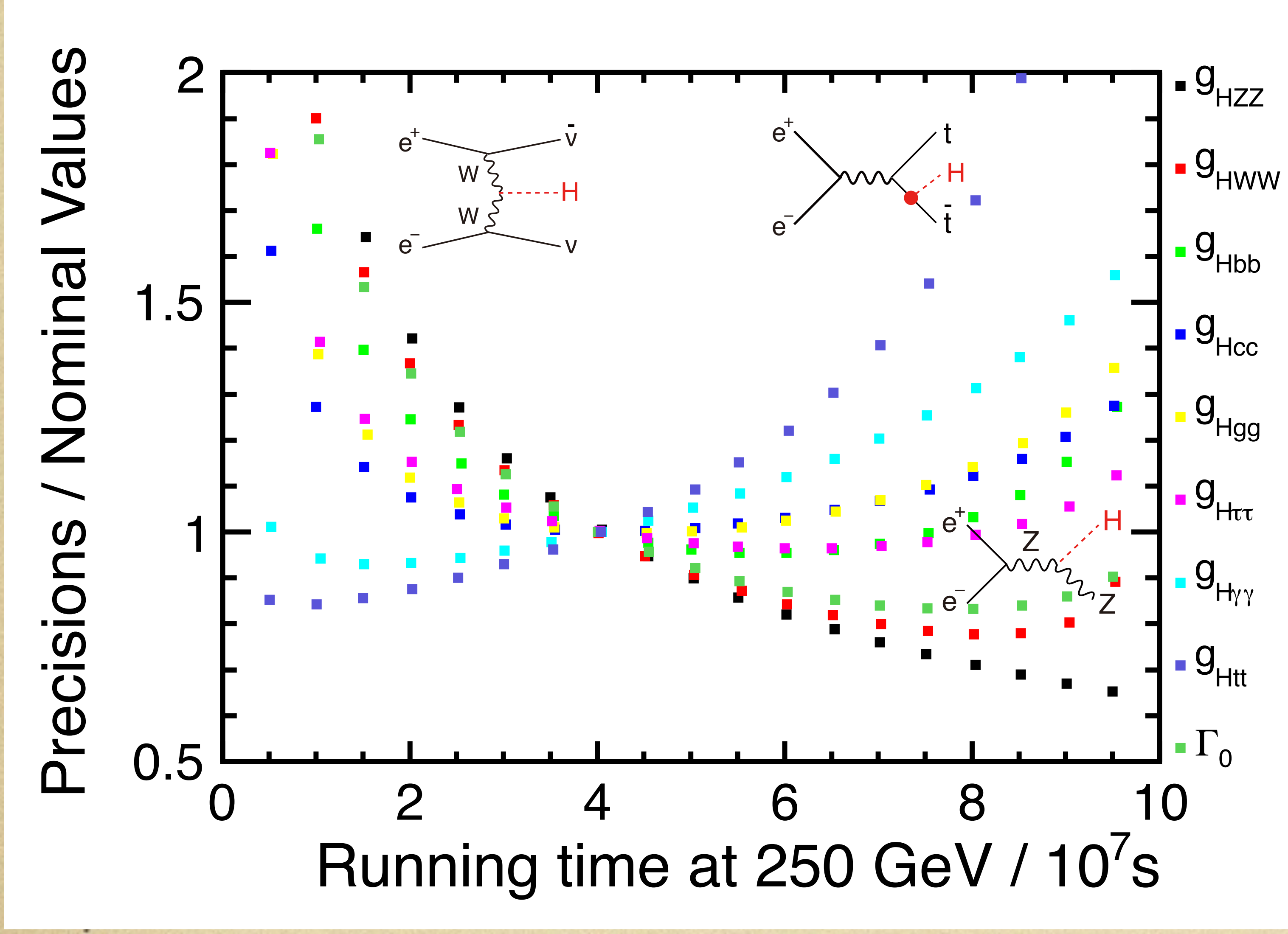
to show what kind of results we expect
from the on-going analysis

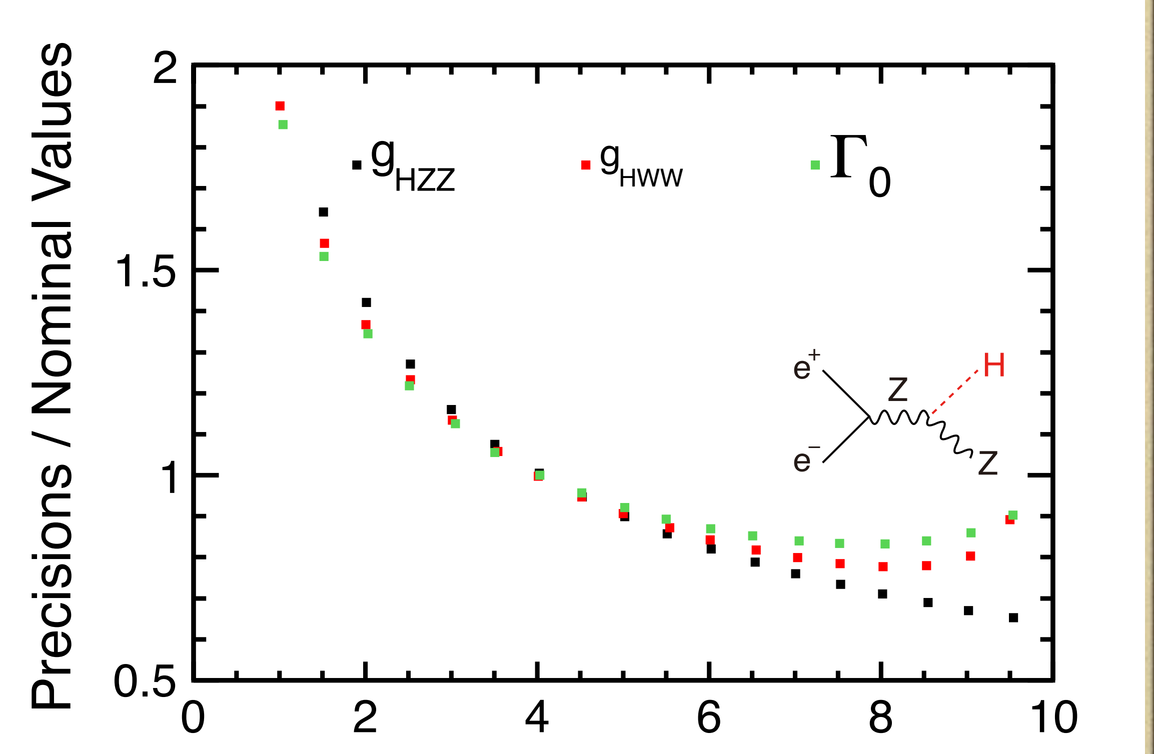
Very preliminary, depending on extrapolations
(the most crucial is the σ_{ZH} at 350 GeV)

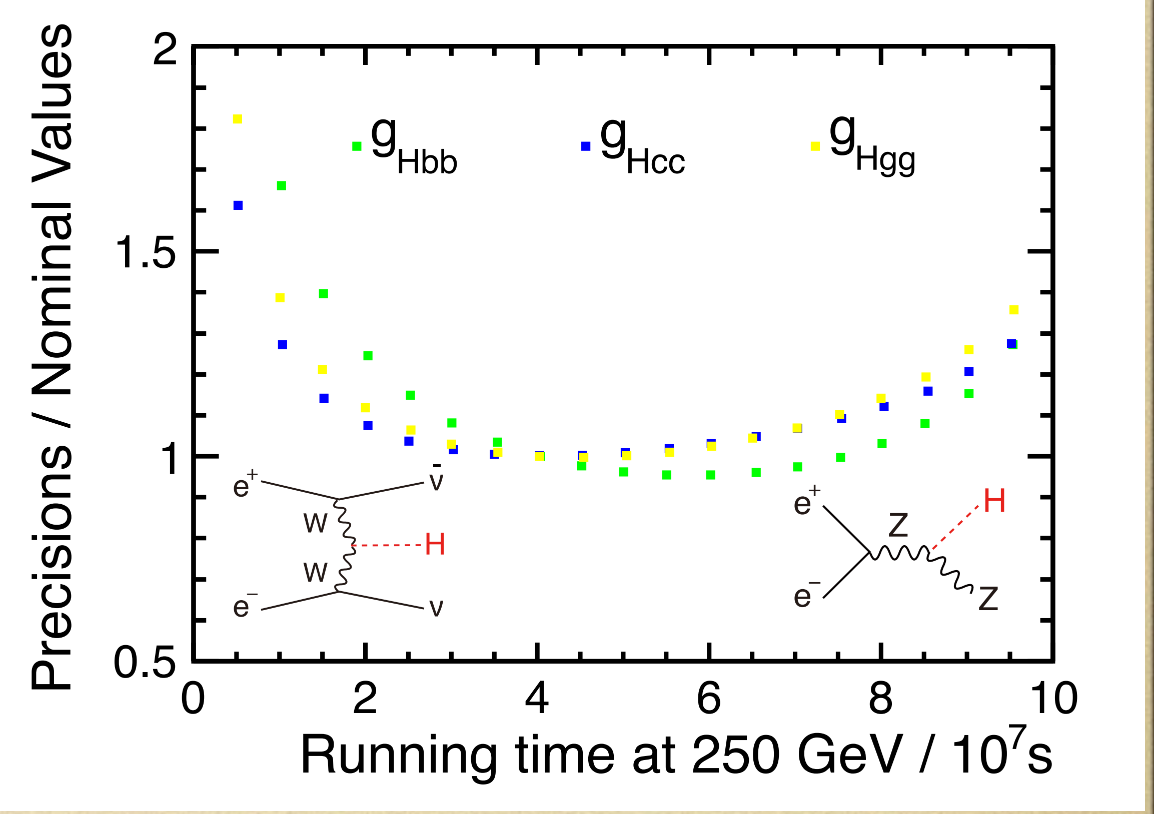
Staging: 250 + 500 GeV

fraction dependence

- for comparison, first consider nominal running: 4y @ 250 GeV + 6y @ 500 GeV (1y ~ 10^7s)
- then vary running time @ 250 GeV (in total 10y) to see how precisions depend on run time @ 250 GeV



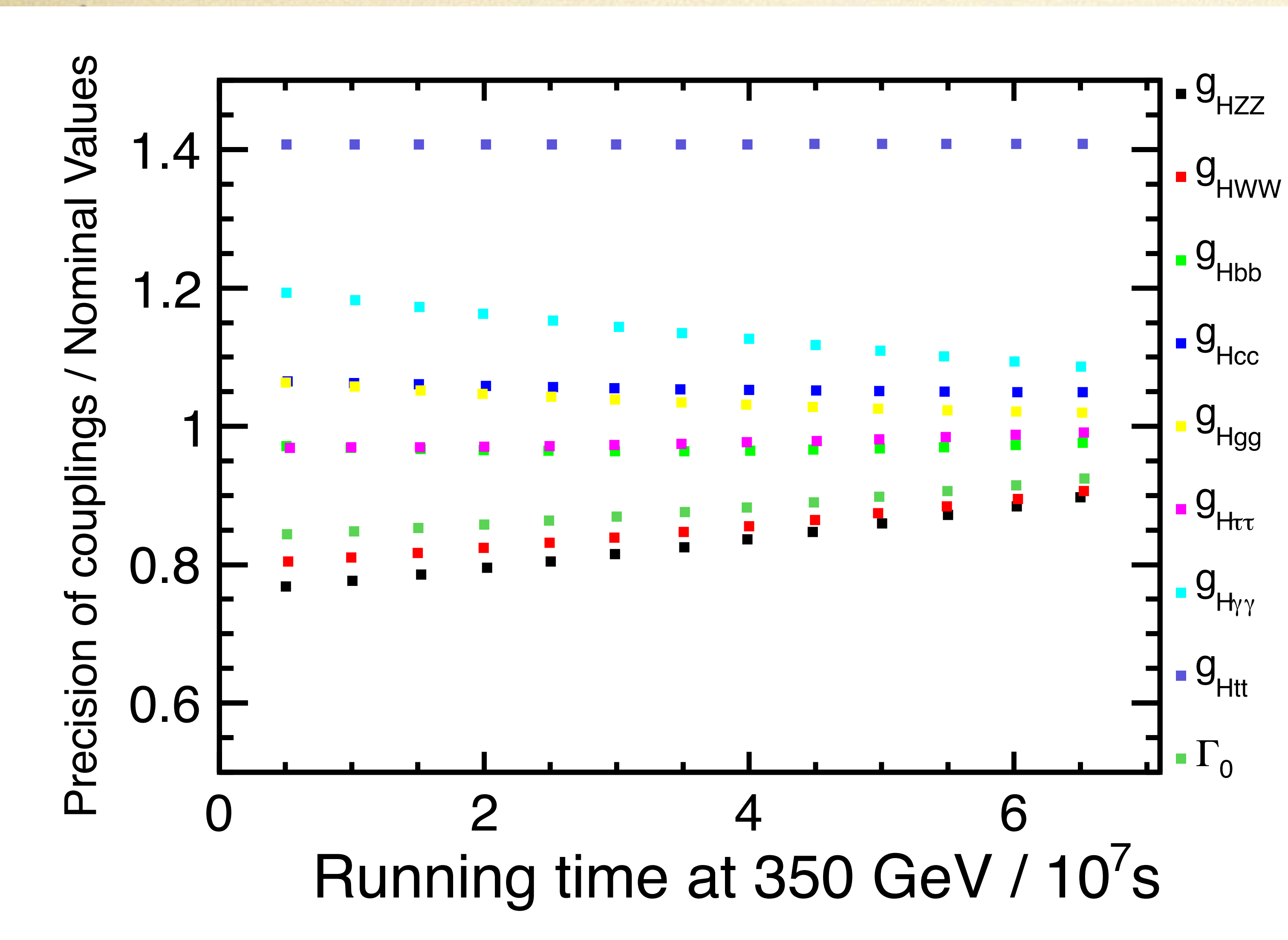


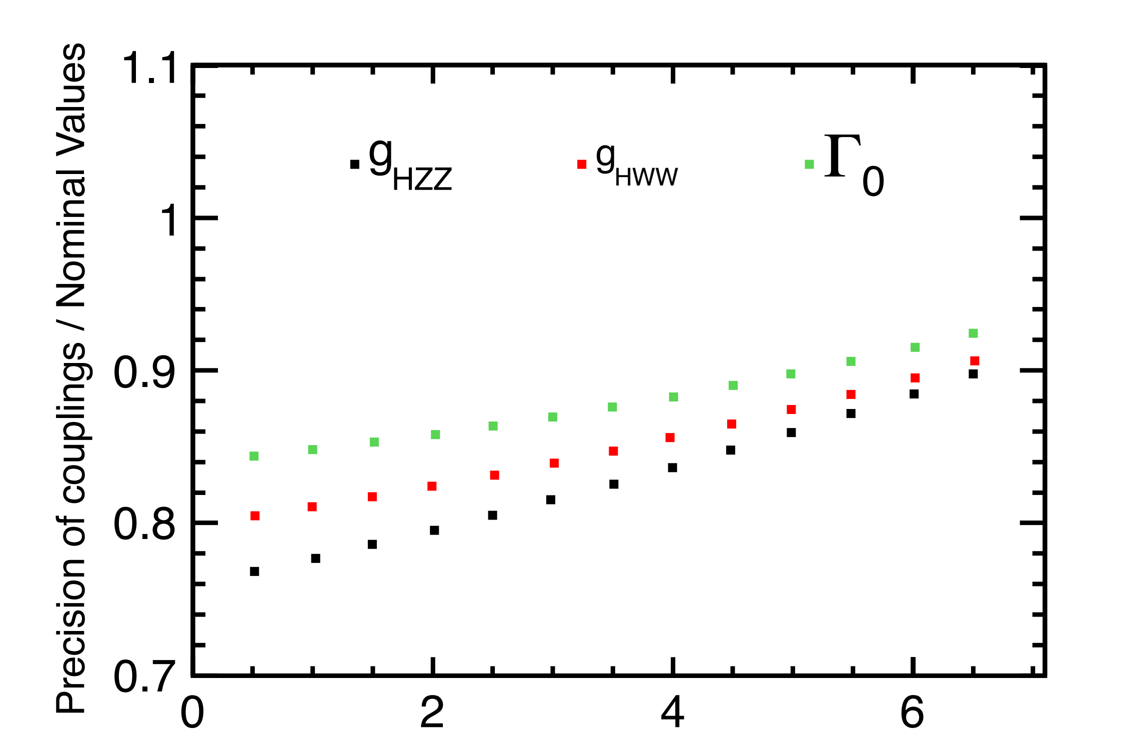


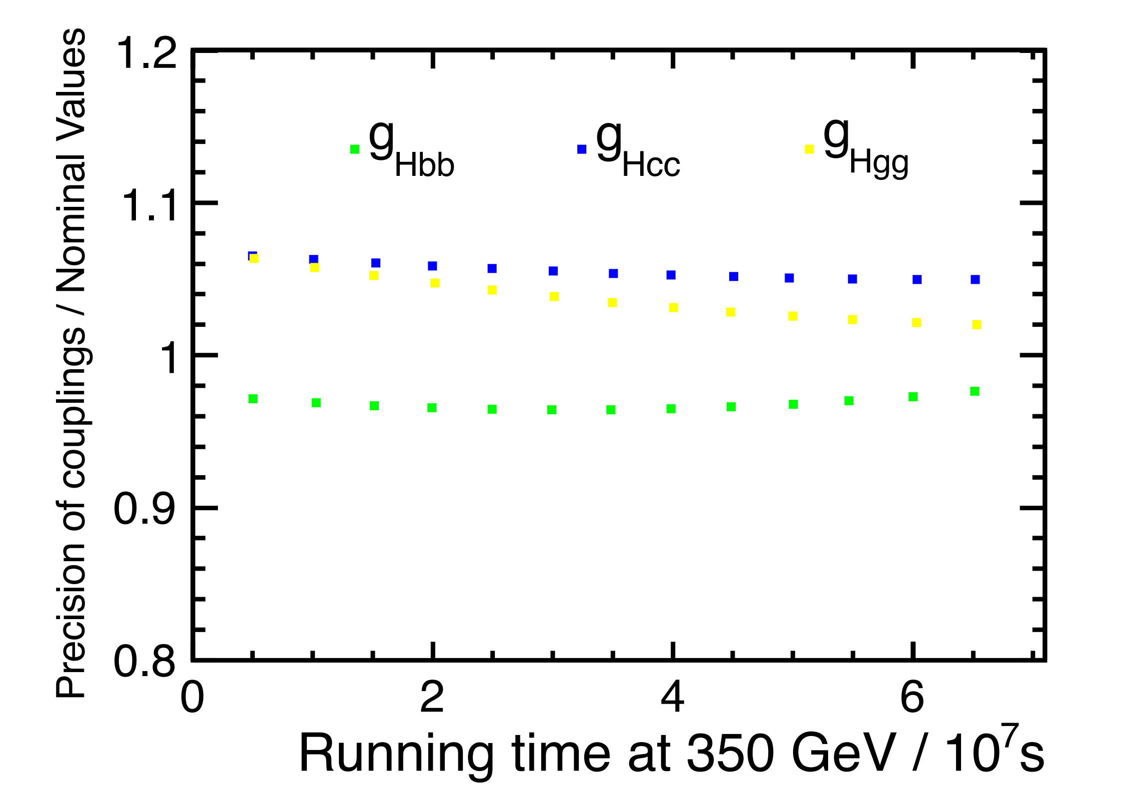
Assuming full luminosity from t=0

Staging: 250 + 350 + 500 GeV

- assume 10y in total, of which 3y @ 500 GeV.
- then vary running time @ 350 GeV.







Once 500 GeV data become available,
the role of 350 GeV data diminish.

Assuming full luminosity from t=0

Sample Staging Scenarios

Sample Staging Scenarios

a. 250 inv.fb @ 250, 500 inv.fb @ 500 **baseline**

b. 250 inv.fb @ 250, 500 inv.fb @ 550 550GeV

c. 250 inv.fb @ 250, 1000 inv.fb @ 500 (for comparison with scenario b) ***more @ 500GeV***

d. 100 inv.fb @ 250, 200 inv.fb @ 350, 500 inv.fb @ 500 a+350GeV

e. 100 inv.fb @ 250, 200 inv.fb @ 350, 500 inv.fb @ 550 b+350GeV

f. 25 inv.fb @ 250, 350 inv.fb @ 350, 500 inv.fb @ 500 short run @250GeV

g. 500 inv.fb @ 250, 500 inv.fb @ 500 **more @ 250GeV**

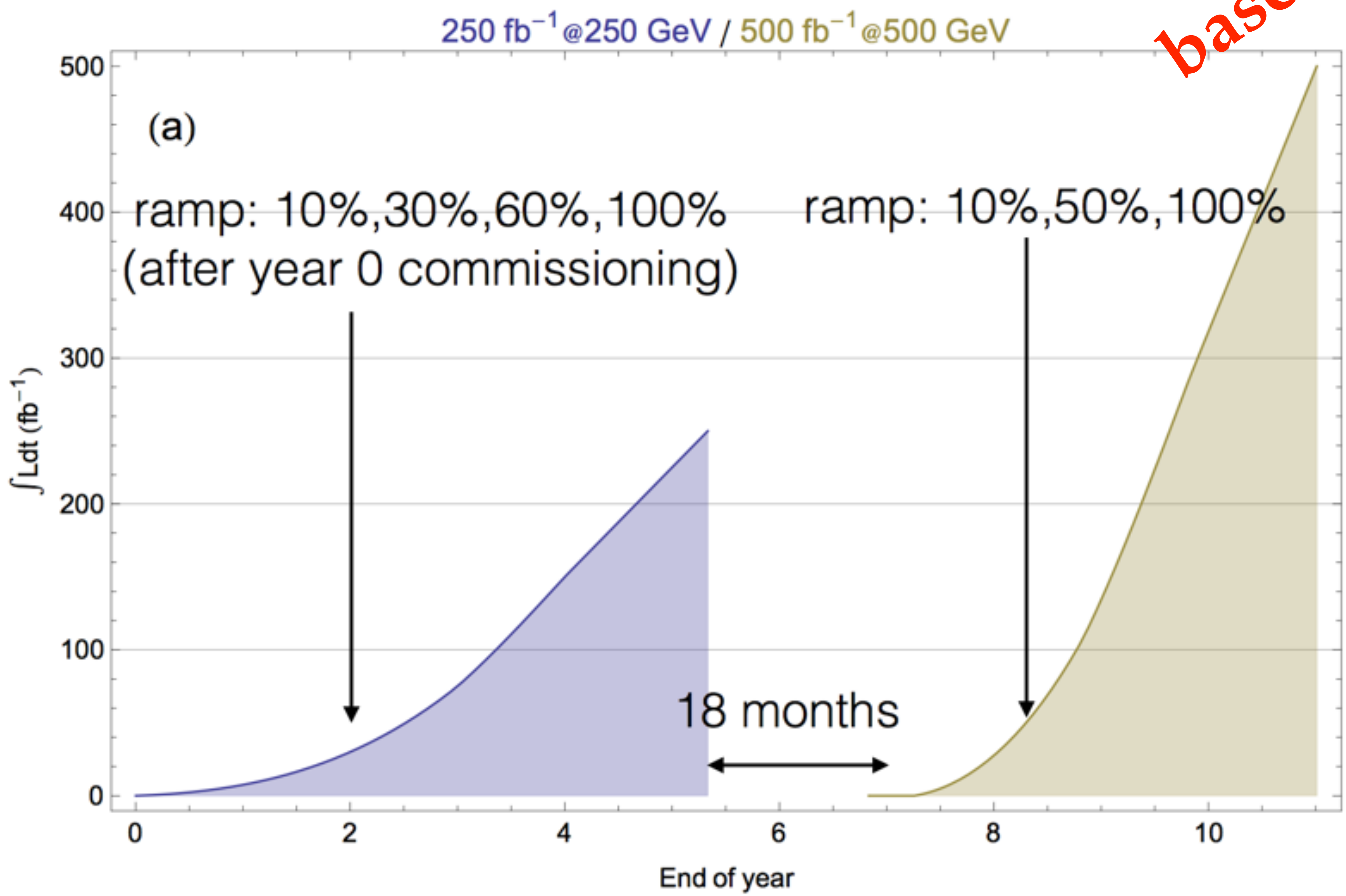
a*. 350 inv.fb @ 350, 500 inv.fb @ 500 350 instead of 250

h. 50 inv.fb @ 250, 200 inv.fb @ 350, 500 inv.fb @ 500, 1 inv.ab @ 250 **250GeV again**

i. 50 inv.fb @ 250, 200 inv.fb @ 350, 500 inv.fb @ 550, 1 inv.ab @ 250 550GeV and 250GeV again

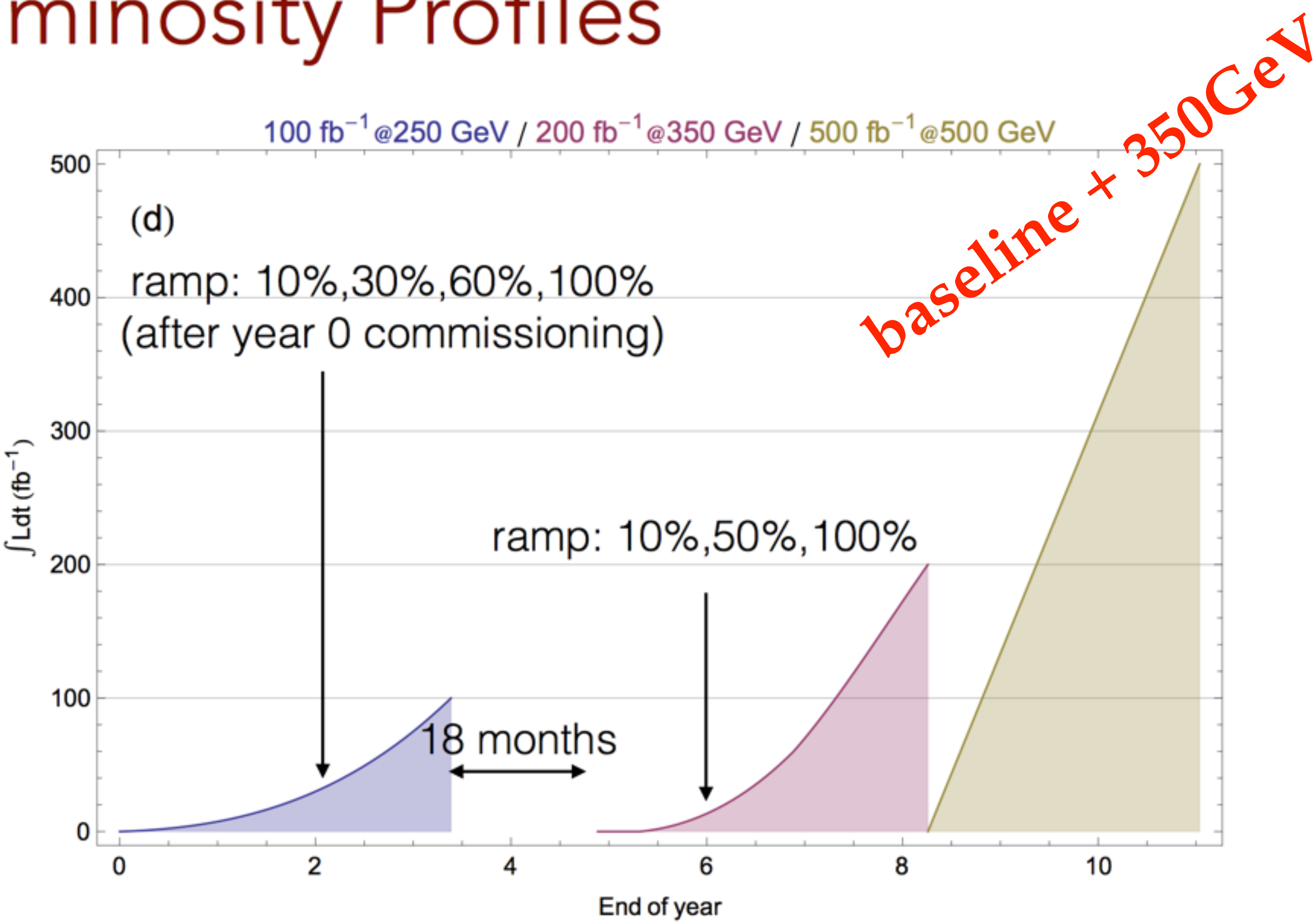
Luminosity Profiles

baseline



250 GeV and then 500 GeV

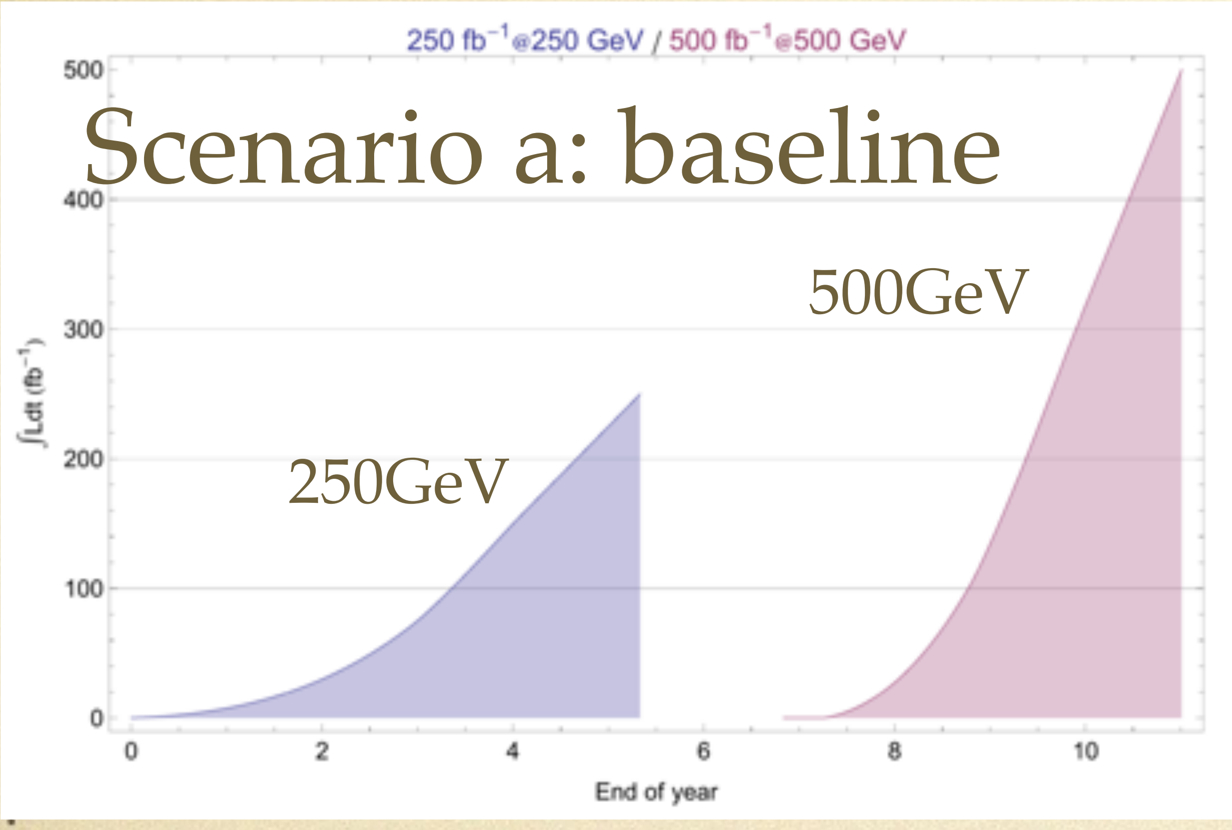
Luminosity Profiles

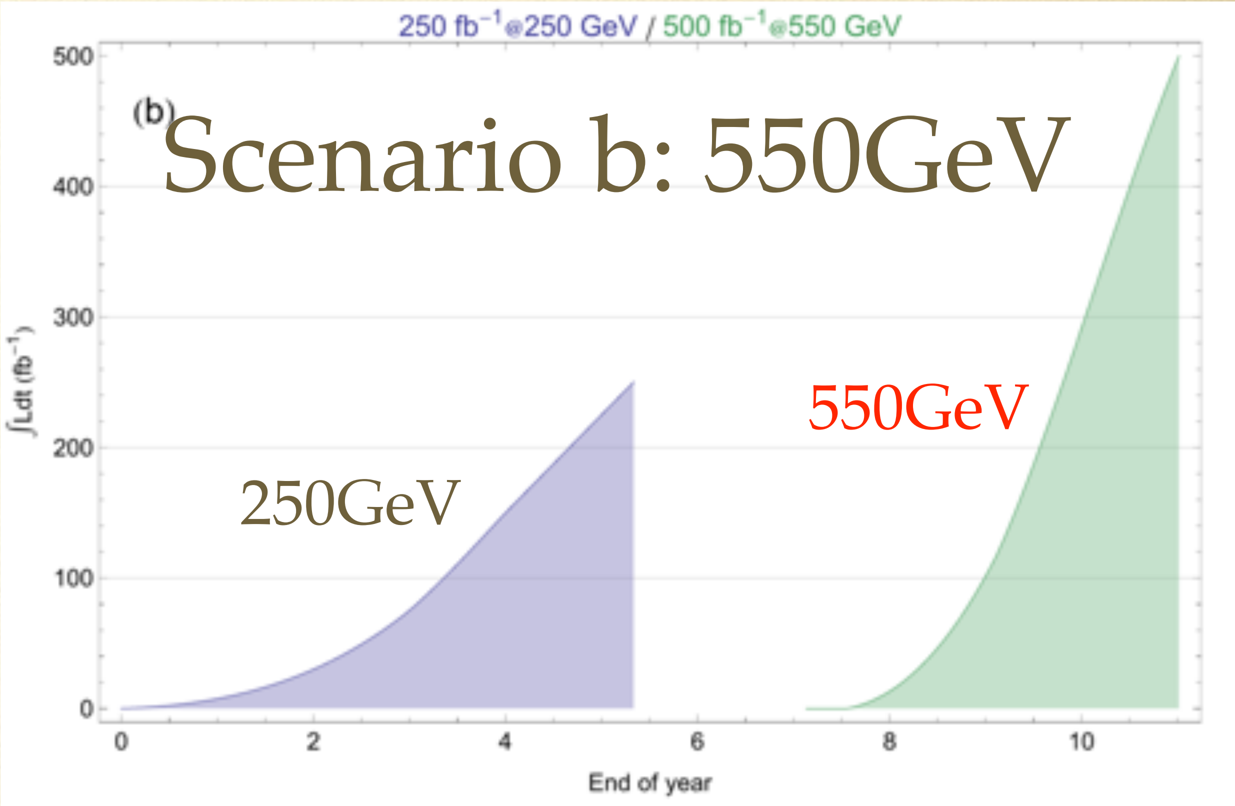


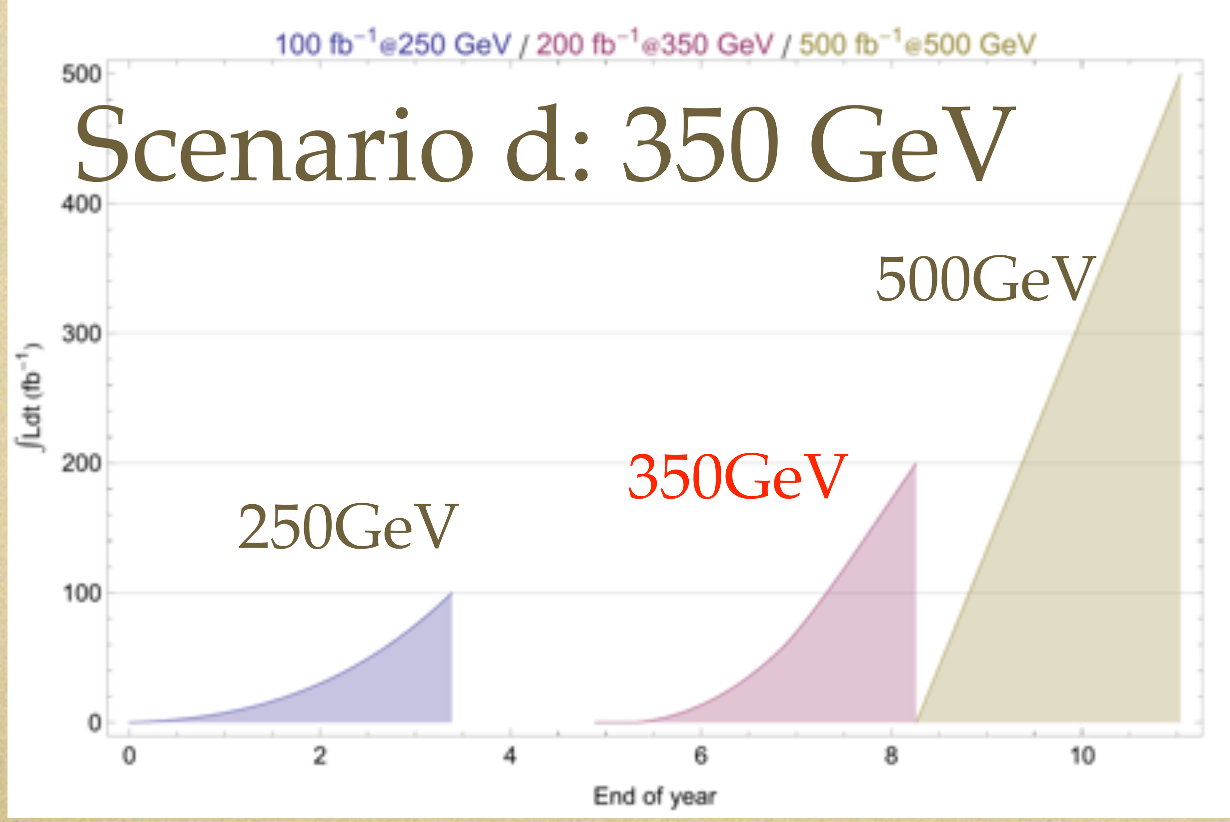
Insertion of 350GeV run

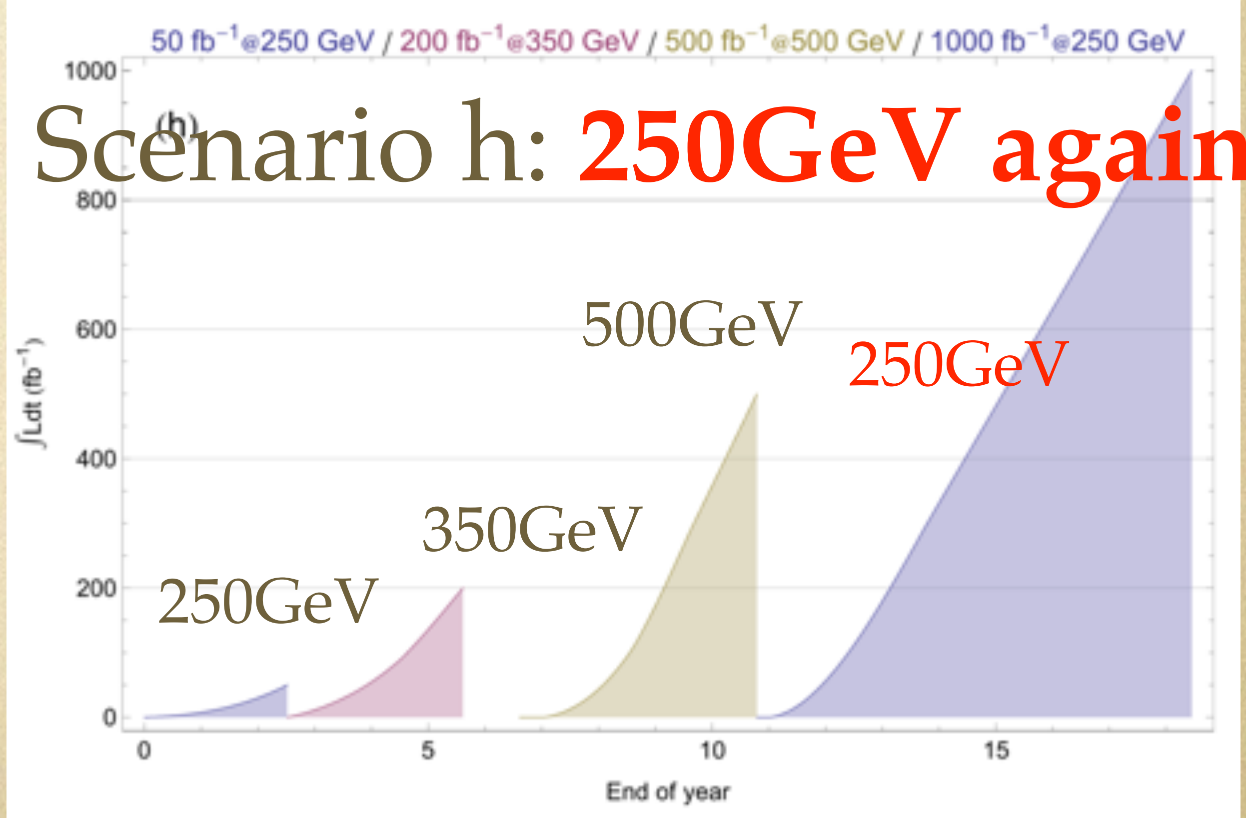
Sample Running Scenarios

from Nick Walker









Implications for Physics

Precisions for Benchmark Scenarios

coupling Δg/g	a (baseline)	b (550GeV)	c (more @ 500GeV)	d (+350GeV)	e (+350GeV +550GeV)	f (short run @250GeV)	g (more @250GeV)	h (250GeV again)	i (550GeV and 250GeV again)	a* (350 GeV +500GeV)
HZZ	1.3%	1.3%	1.3%	1.5%	1.5%	1.6%	0.92%	0.61%	0.61%	1.7%
HWW	1.4%	1.4%	1.4%	1.6%	1.6%	1.7%	1%	0.72%	0.71%	1.8%
Hbb	1.8%	1.7%	1.6%	1.9%	1.9%	1.9%	1.5%	1.1%	1.1%	2.1%
Hcc	2.9%	2.8%	2.4%	3%	2.9%	3%	2.5%	1.9%	1.9%	3.1%
Hgg	2.4%	2.3%	2%	2.5%	2.4%	2.5%	2.1%	1.6%	1.6%	2.6%
Hττ	2.5%	2.4%	2.1%	2.6%	2.6%	2.6%	2%	1.5%	1.4%	2.7%
Hγγ	7.6%	7.2%	5.7%	7.3%	7%	7.1%	6.9%	5.6%	5.4%	7.2%
Htt	14%	6.2%	10%	14%	6.2%	14%	14%	14%	6.1%	14%
Γ	5.9%	5.9%	5.7%	6.7%	6.7%	6.9%	4.5%	3.2%	3.1%	7.4%
inv. (95% up limit)	0.91%	0.91%	0.88%	1.1%	1.1%	1.2%	0.6%	0.45%	0.45%	1.33%
Ny1	6.1	5.8	8.9	6.1	5.8	6.6	9.4	12	12	6.3
Ny2	12	12	14	12	12	13	14	18	18	11

i) X=36% worse for σ(ZH) at 350 GeV (from Jacqueline's analysis)
ii) extrapolation for 350 GeV shown in backup slides
iii) much simpler extrapolation for 550 GeV (just scale σ(ZH) and σ(ννH))
iv) Ny1: total running time assuming peak luminosity (snowmass year)
v) Ny2: based on Nick's ramp up assumption

Precisions for Benchmark Scenarios

coupling Δg/g	a (baseline)	b (550GeV)	c (more @ 500GeV)	d (+350GeV)	e (+350GeV +550GeV)	f (short run @250GeV)	g (more @250GeV)	h (250GeV again)	i (550GeV and 250GeV again)	a* (350 GeV +500GeV)
HZZ	1.3%	1.3%	1.3%	1.5%	1.5%	1.6%	0.92%	0.61%	0.61%	1.7%
HWW	1.4%	1.4%	1.4%	1.6%	1.6%	1.7%	1%	0.72%	0.71%	1.8%
Hbb	1.8%	1.7%	1.6%	1.9%	1.9%	1.9%	1.5%	1.1%	1.1%	2.1%
Hcc	2.9%	2.8%	2.4%	3%	2.9%	3%	2.5%	1.9%	1.9%	3.1%
Hgg	2.4%	2.3%	2%	2.5%	2.4%	2.5%	2.1%	1.6%	1.6%	2.6%
Hττ	2.5%	2.4%	2.1%	2.6%	2.6%	2.6%	2%	1.5%	1.4%	2.7%
Hγγ	7.6%	7.2%	5.7%	7.3%	7%	7.1%	6.9%	5.6%	5.4%	7.2%
Htt	14%	6.2%	10%	14%	6.2%	14%	14%	14%	6.1%	14%
Γ	5.9%	5.9%	5.7%	6.7%	6.7%	6.9%	4.5%	3.2%	3.1%	7.4%
inv. (95% up limit)	0.91%	0.91%	0.88%	1.1%	1.1%	1.2%	0.6%	0.45%	0.45%	1.33%
Ny1	6.1	5.8	8.9	6.1	5.8	6.6	9.4	12	12	6.3
Ny2	12	12	14	12	12	13	14	18	18	11

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iv) Ny1: total running time assuming peak luminosity (snowmass year)
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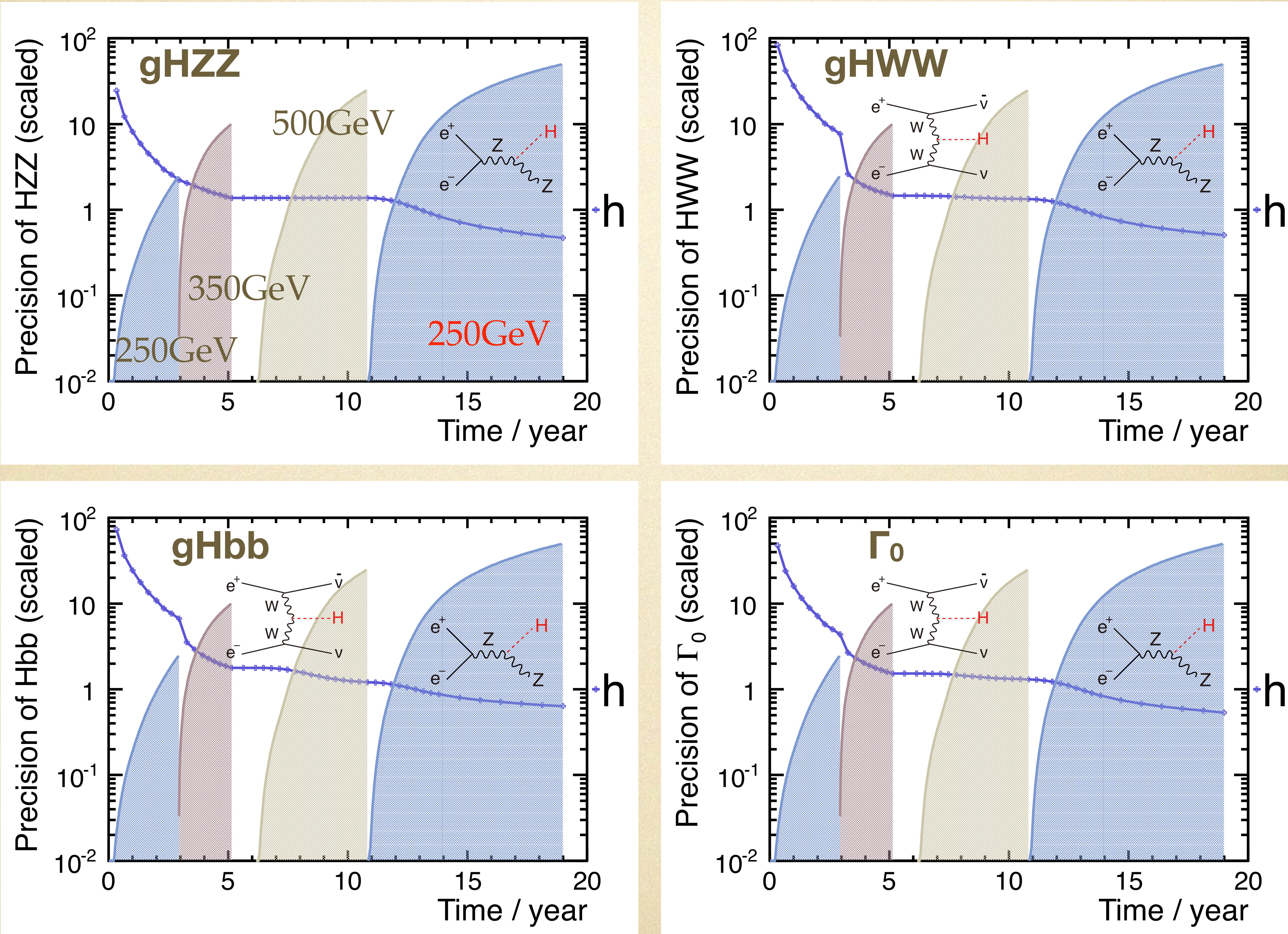
Evolution of Precisions over Time

Caution

All results are very preliminary!

(all precisions are scaled to their values at the end of scenarios "a", which are shown in table)

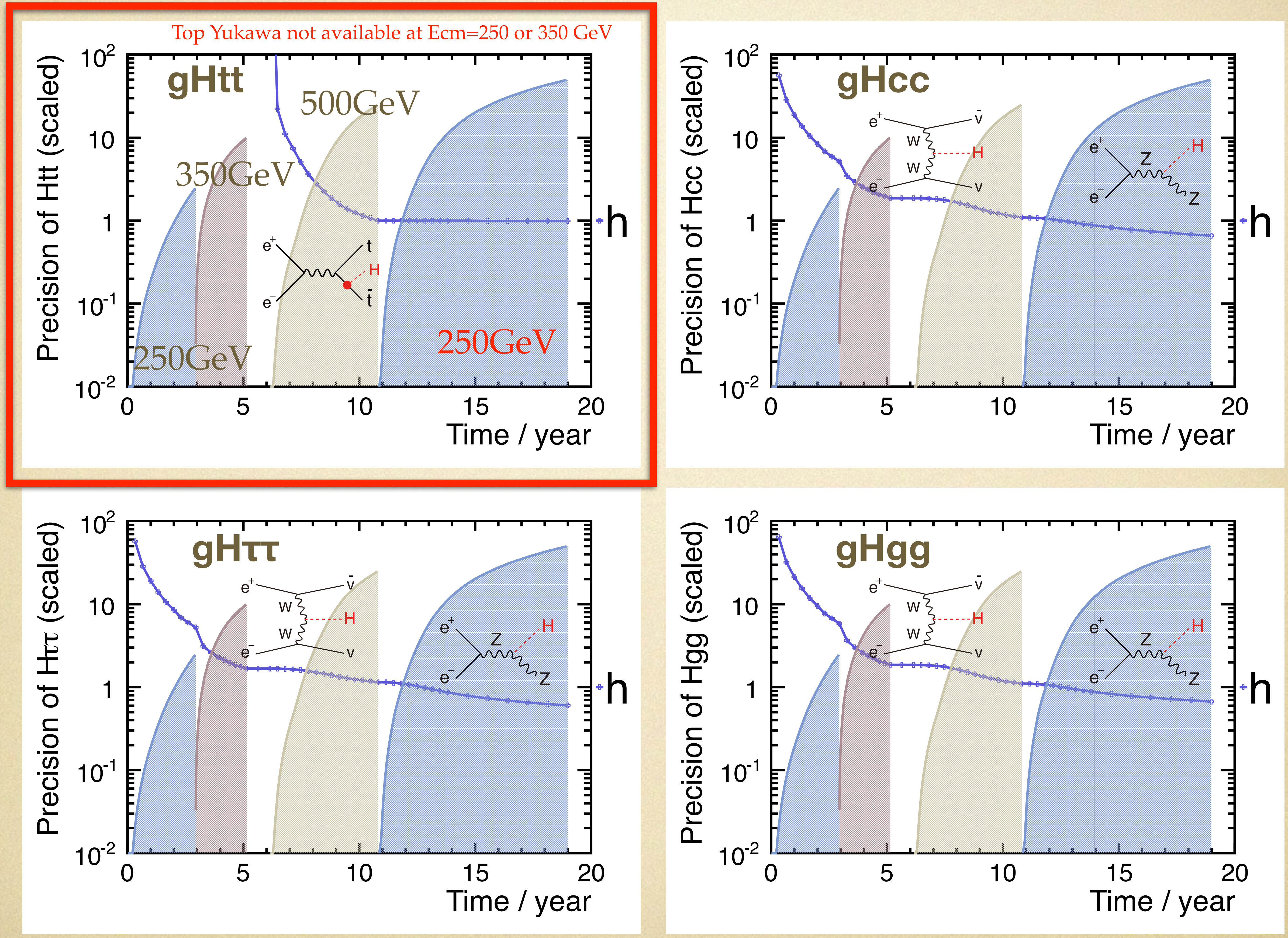
Evolution



50 inv.fb @ 250, 200 inv.fb @ 350, 500 inv.fb @ 500, 1 inv.ab @ 250

Top Yukawa

Evolution



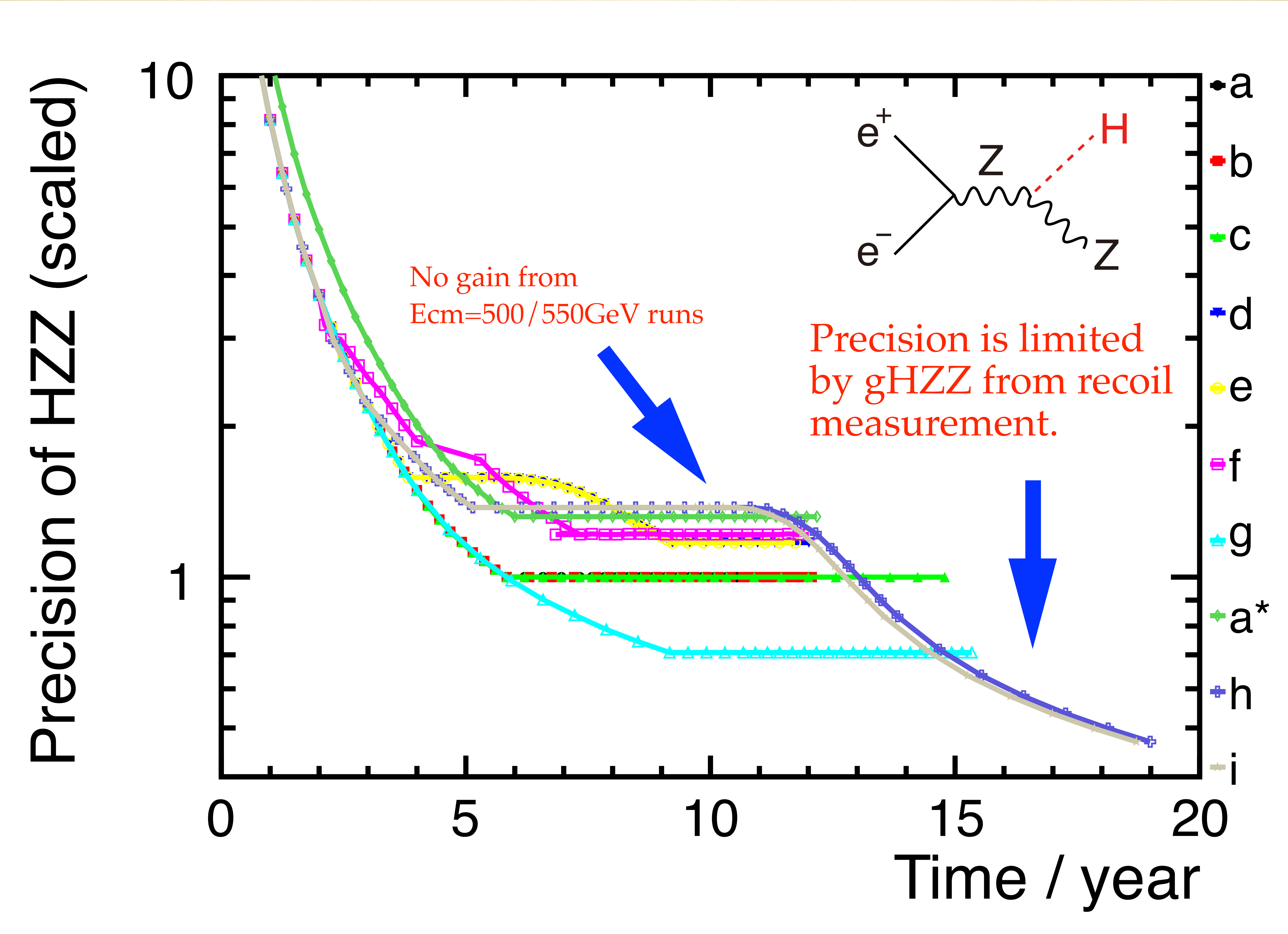
50 inv.fb @ 250, 200 inv.fb @ 350, 500 inv.fb @ 500, 1 inv.ab @ 250

General Observations (no conclusions yet)

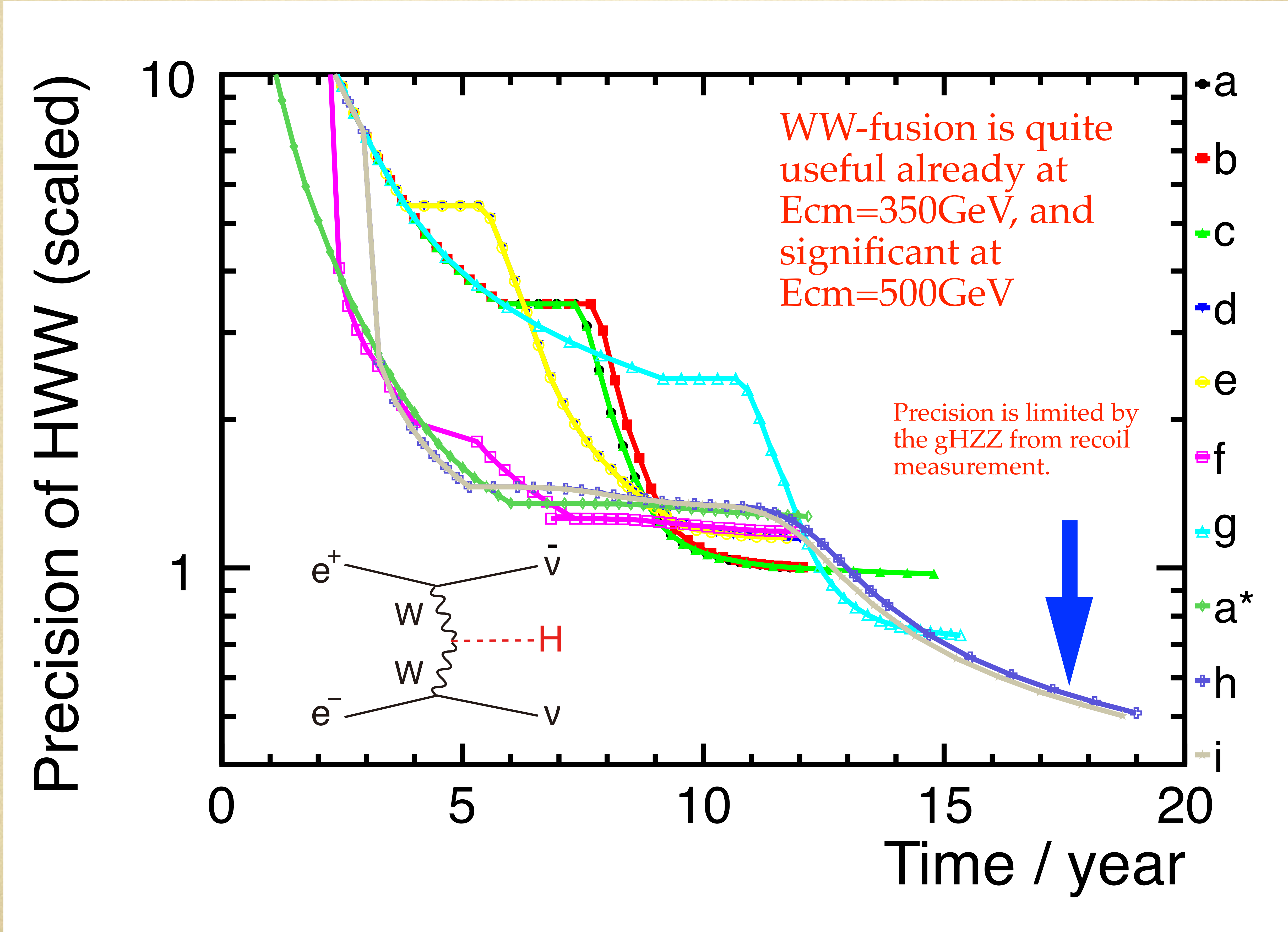
- Staged running of ILC is a choice to optimize coupling measurements through the processes: ZH, ννH, ttH, ZHH, and ννHH.
- Earlier running at 350 GeV can provide nicer measurements at earlier lifetime of ILC. Overall importance of 350 GeV running highly depends on results of recoil mass analysis @ 350 GeV (analysis on-going). The benefit from the WW-fusion process at 350 GeV will quickly diminish when data at 500 GeV become available.
- Increasing energy a little bit from 500 GeV makes a big difference for top-Yukawa coupling measurement.
- Different couplings have different dependence on running scenarios. Usually HVV and Γ_H are mainly limited by recoil mass channel, while others are limited by just statistics.
- Hence, adding more data at 250GeV with full luminosity after accumulating enough data at the highest energy will benefit us significantly in general.

Backup

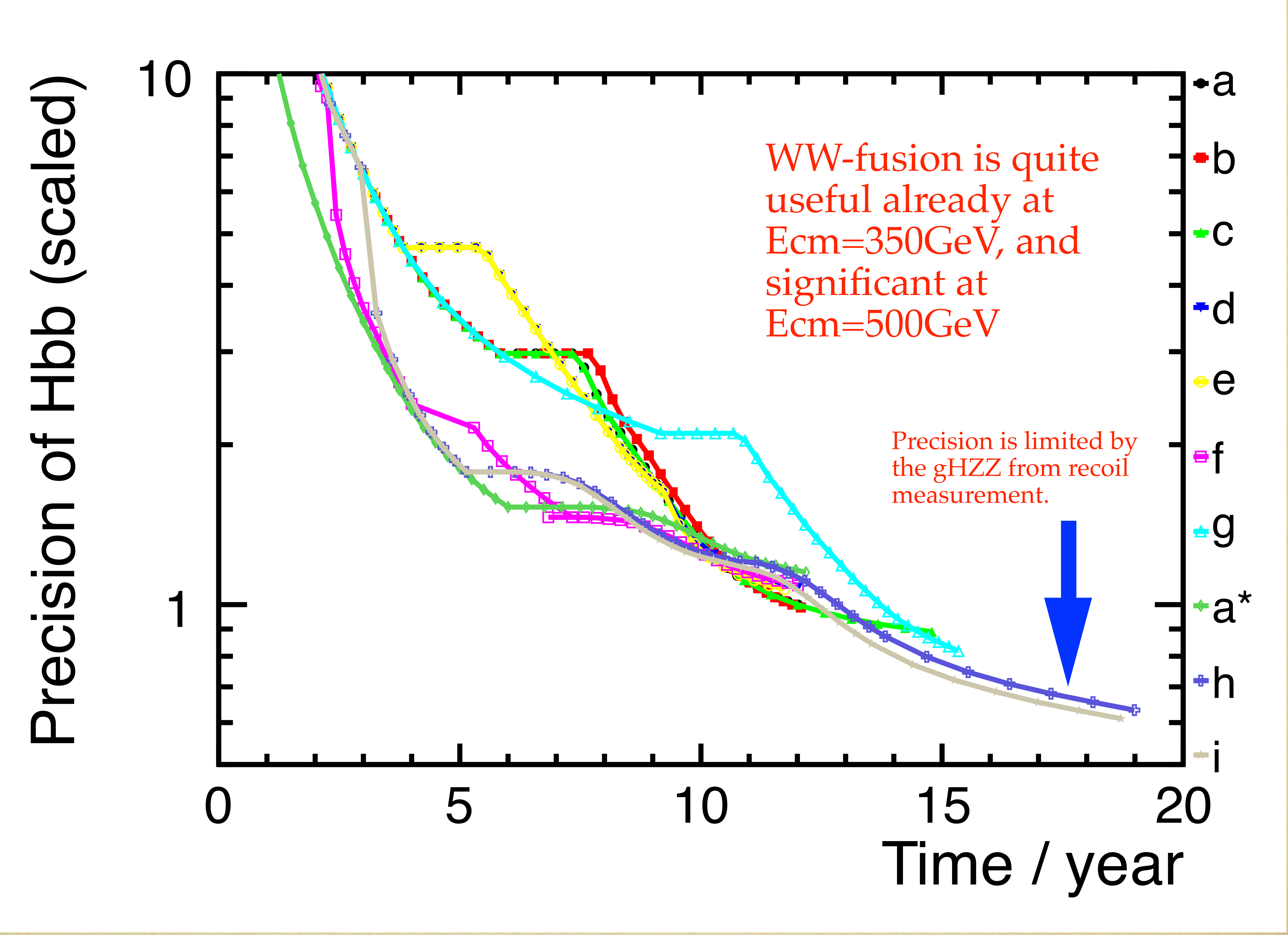
Evolution: g_{HZZ}



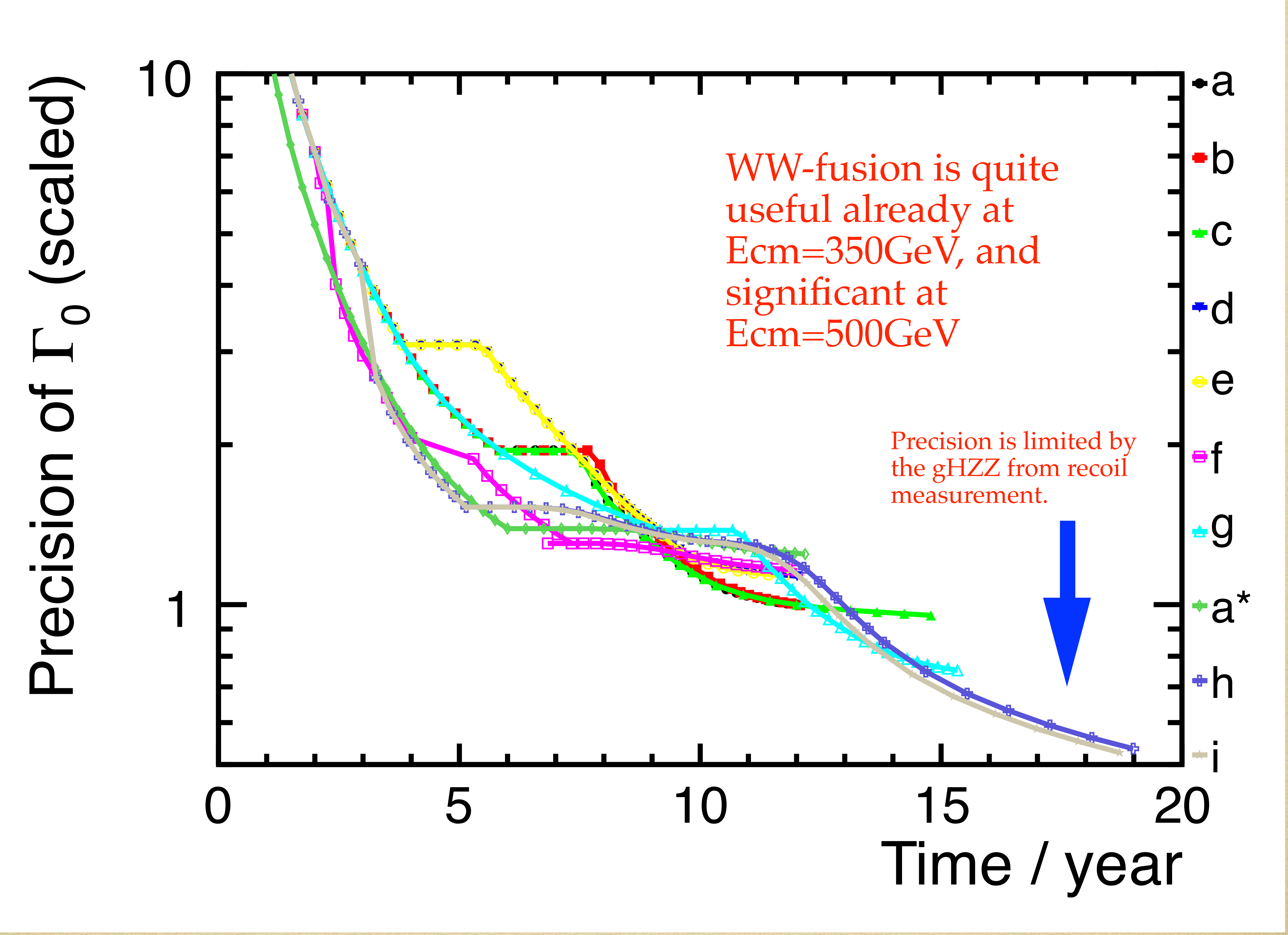
Evolution: g_{HWW}



Evolution: g_{Hbb}



Evolution: Γ_H



analysis status

ECM	@ 250 GeV		@ 350 GeV		@ 500 GeV		@ 1 TeV
luminosity · fb	250		330		500		1000
polarization (e-,e+)	(-0.8, +0.3)		(-0.8, +0.3)		(-0.8, +0.3)		(-0.8, +0.2)
process	ZH	ννH	ZH	ννH	ZH	ννH	ννH
cross section	EH	-	G		-	-	-
	σ·Br	σ·Br	σ·Br	σ·Br	σ·Br	σ·Br	σ·Br
H-->bb	EH	F	EH	EEF	EEH	F	F
H-->cc	EH		EH	EEH	EEH	EH	F
H-->gg	EH		EH	EEH	EEH	EH	F
H-->WW*	EH		EEH	EEF	EEH	F	F
H-->ττ	EH		EEH	EEH	EH	EH	EEH
H-->ZZ*	F		EEG	EEG	G	G	G
H-->γγ	G		G	EEF	G	F	F
H-->μμ	-						F
H-->Inv. (95% C.L.)	F		EEF		EEF		-
ttH, H-->bb	-				EH/EF		F

F: done by full simulation w/ mH=125GeV
EH: extrapolated from full simulation w/ mH=120GeV
EEH: extrapolated from full simulation at other ecm w/ mH = 120 GeV
EEF: extrapolated from full simulation at other ecm w/ mH = 125 GeV
G: guesstimate from old fast simulation
black: ongoing or completed
red: still missing