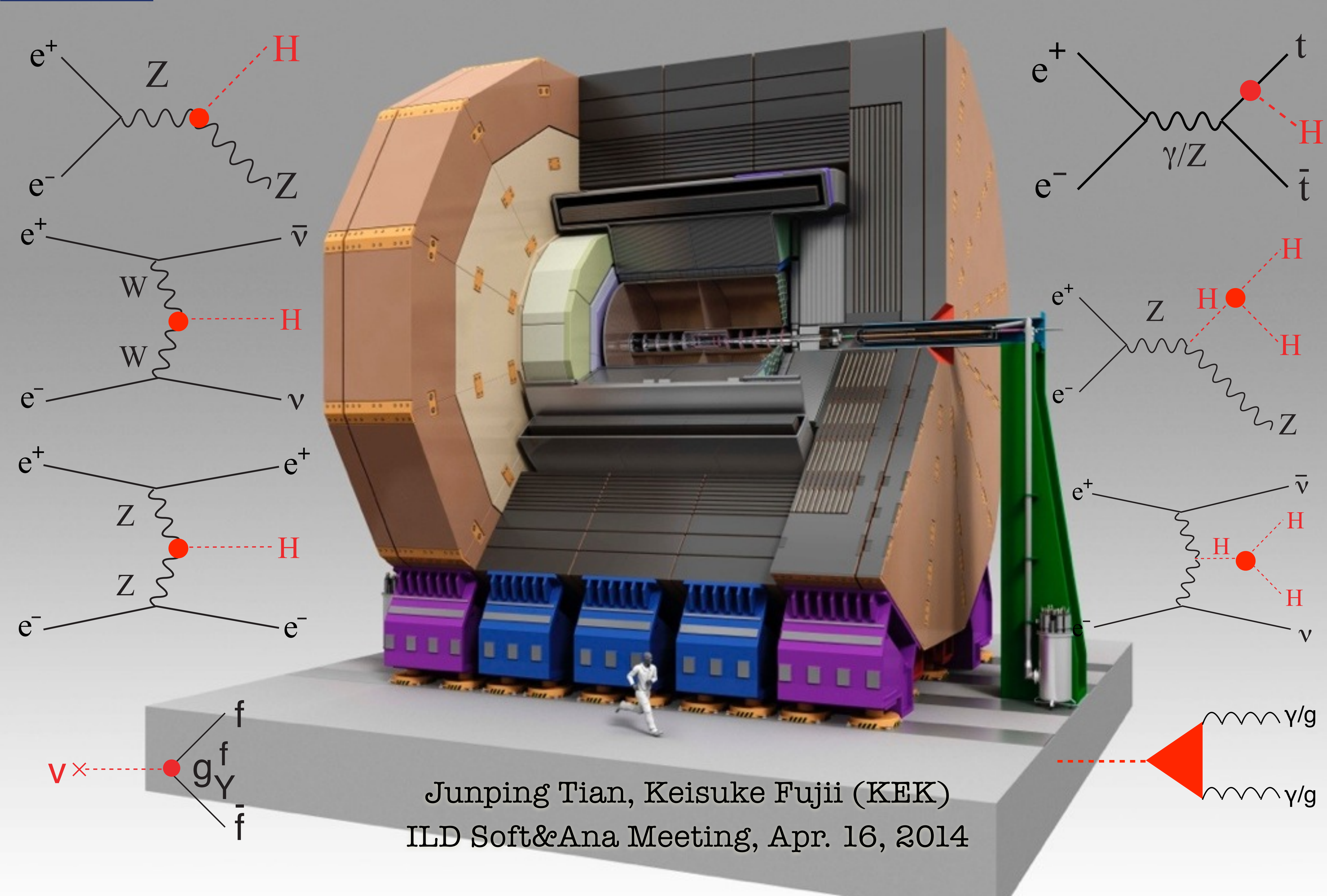
Study of ILC Staging Scenarios



Junping Tian, Keisuke Fujii (KEK)

ILD Soft&Ana Meeting, Apr. 16, 2014

outline

- limiting factors of coupling precisions
- fractions of running time at each stages
- precisions for benchmark scenarios
- evolution of couplings precisions

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%				-		
ttH, H-->bb	-				28%		6%

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

from observables to couplings

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

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)

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

limiting factors of coupling precisions

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

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

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

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

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

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

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

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

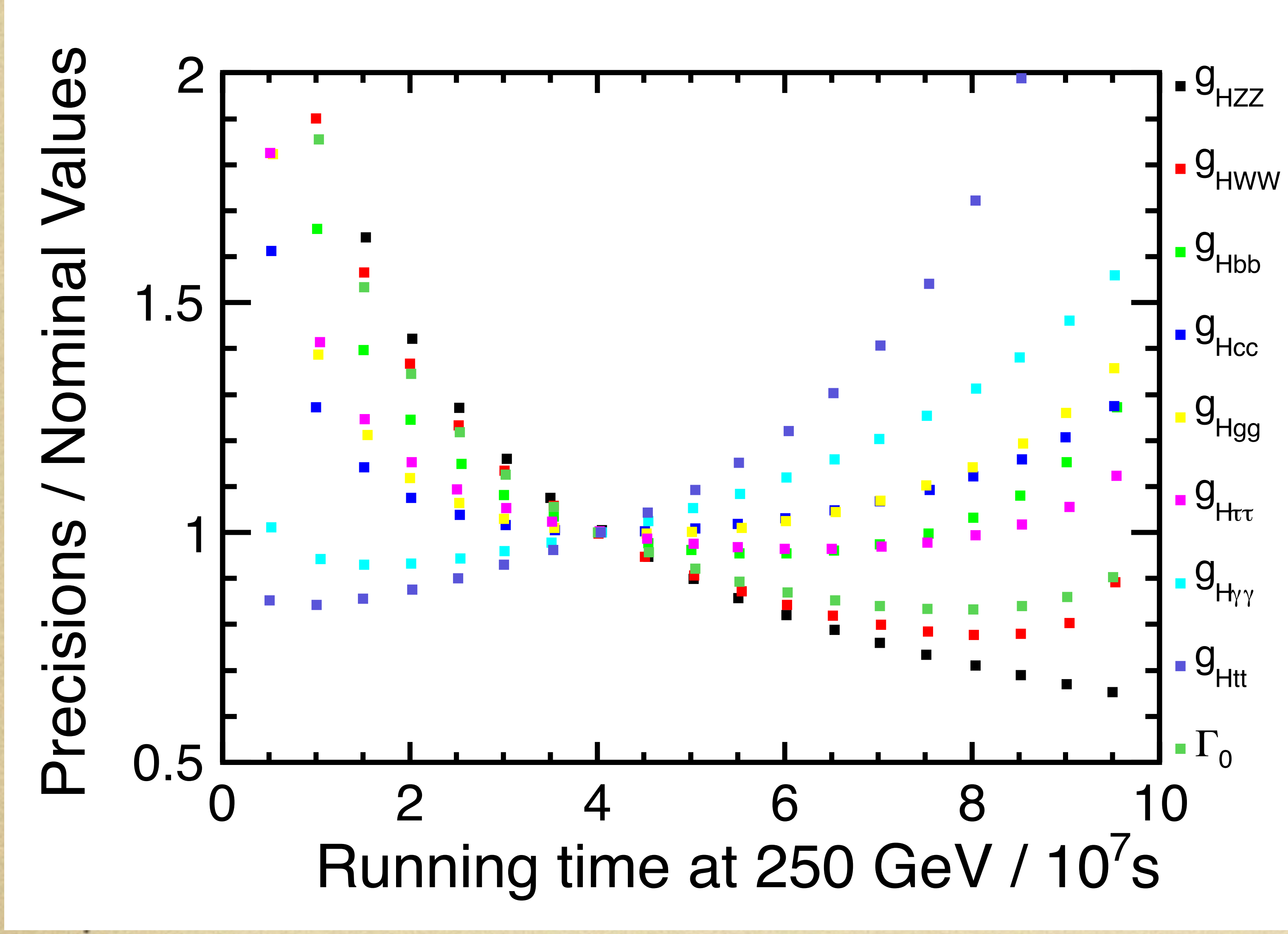
both ZH and ννH productions matter!

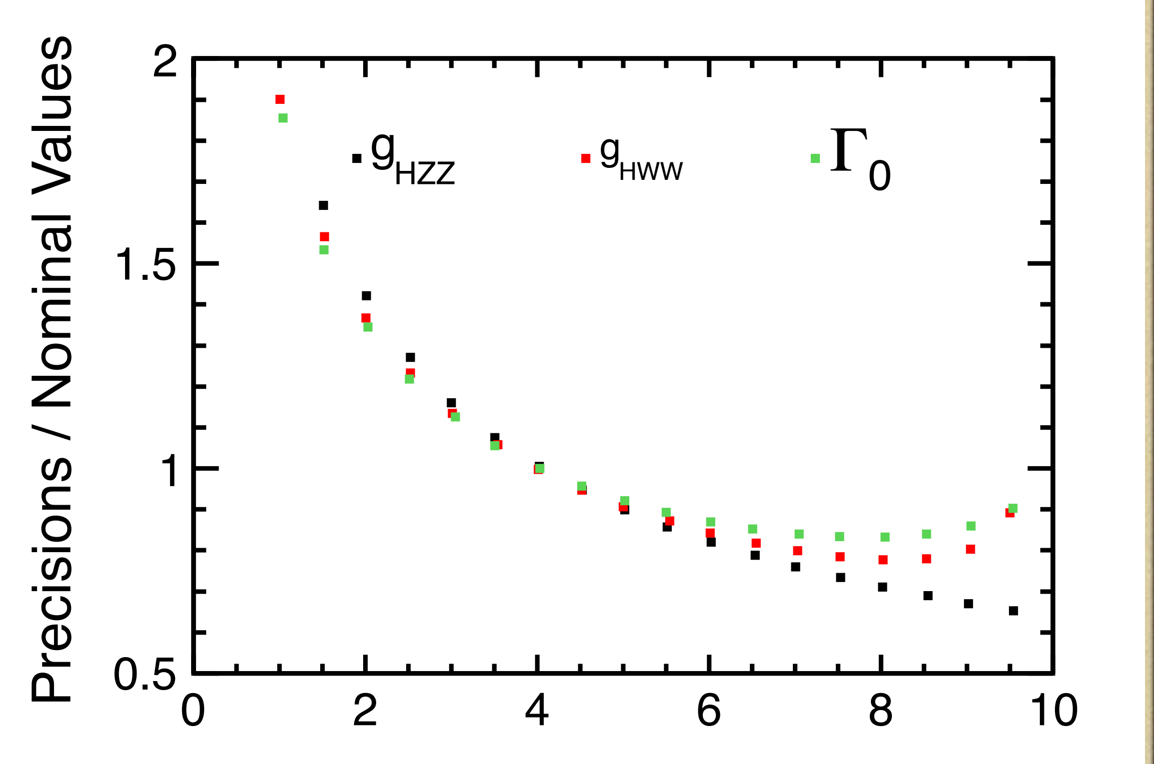
see more details: JT @ Tokusui Workshop 2013

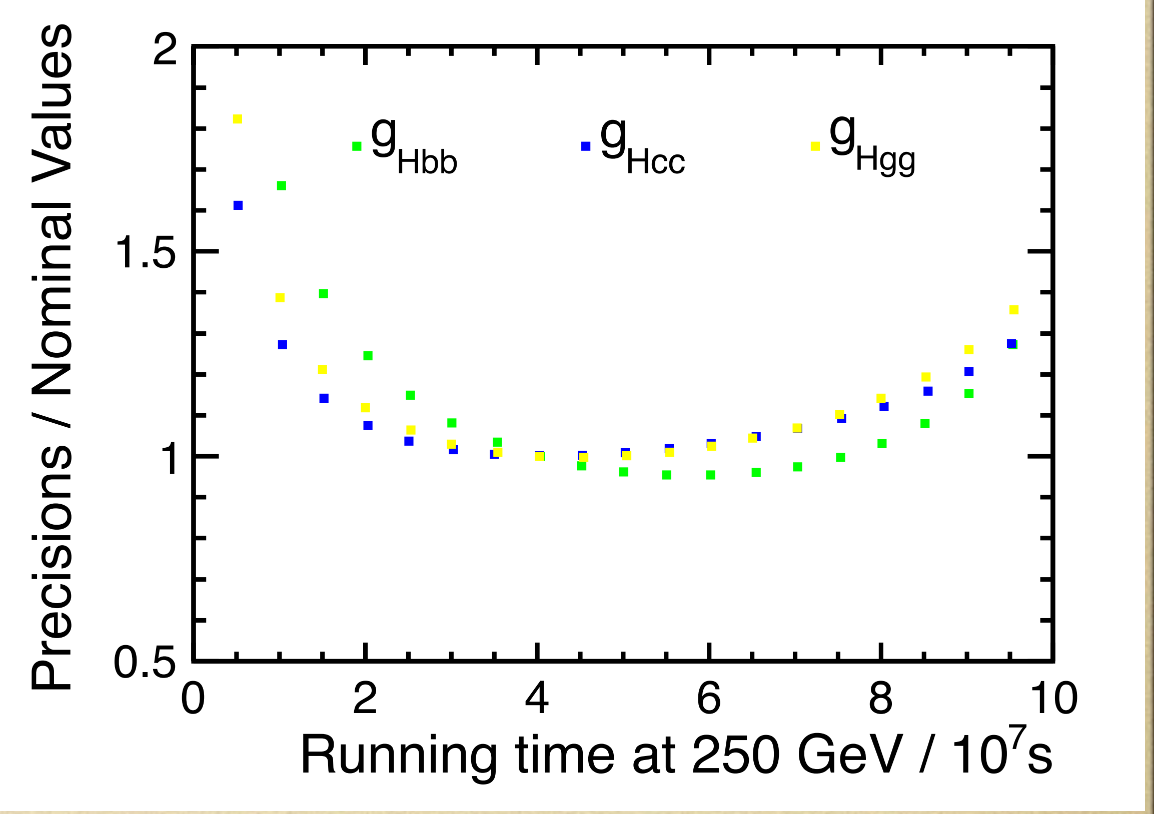
staging: 250 + 500 GeV

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



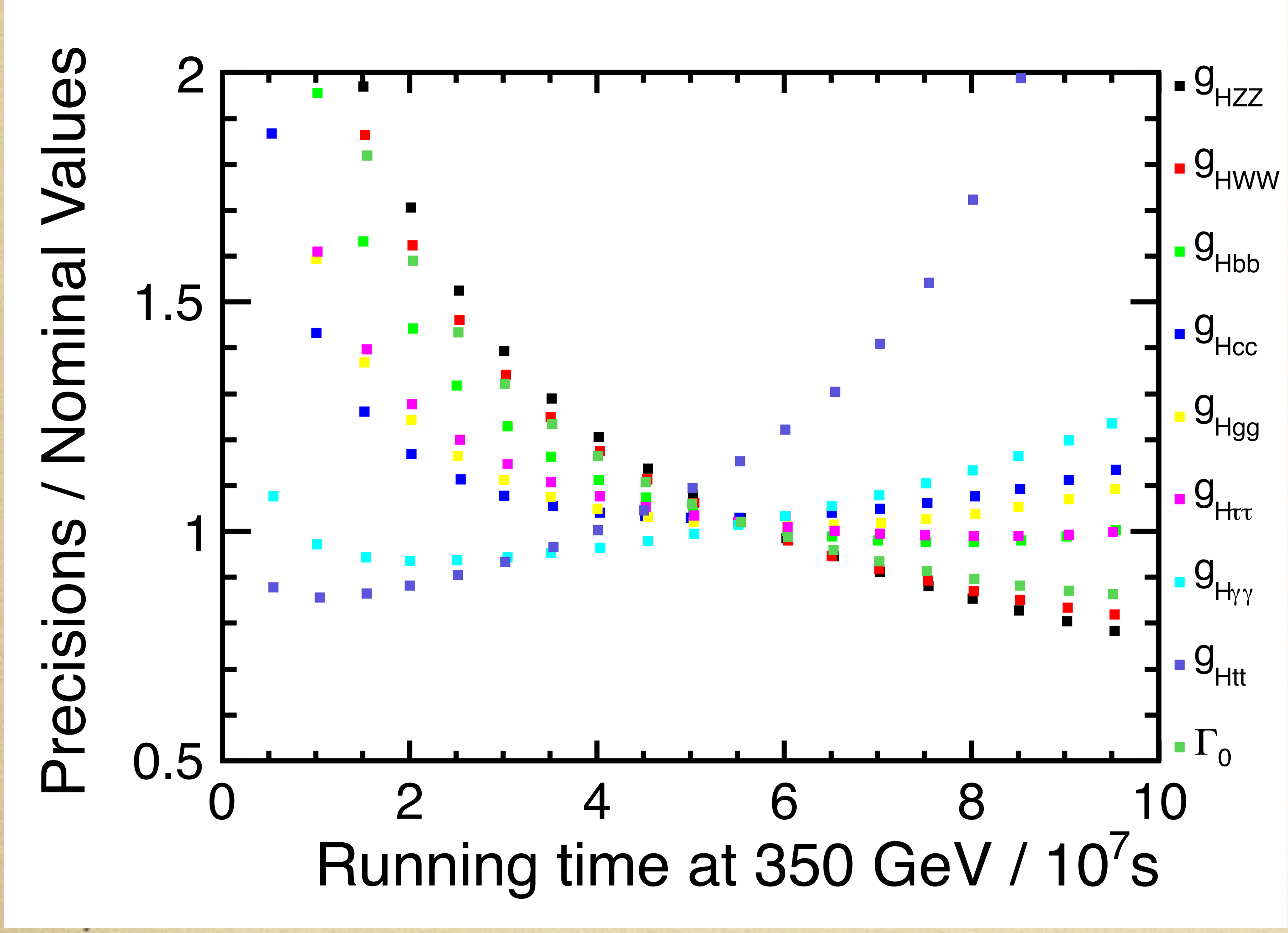


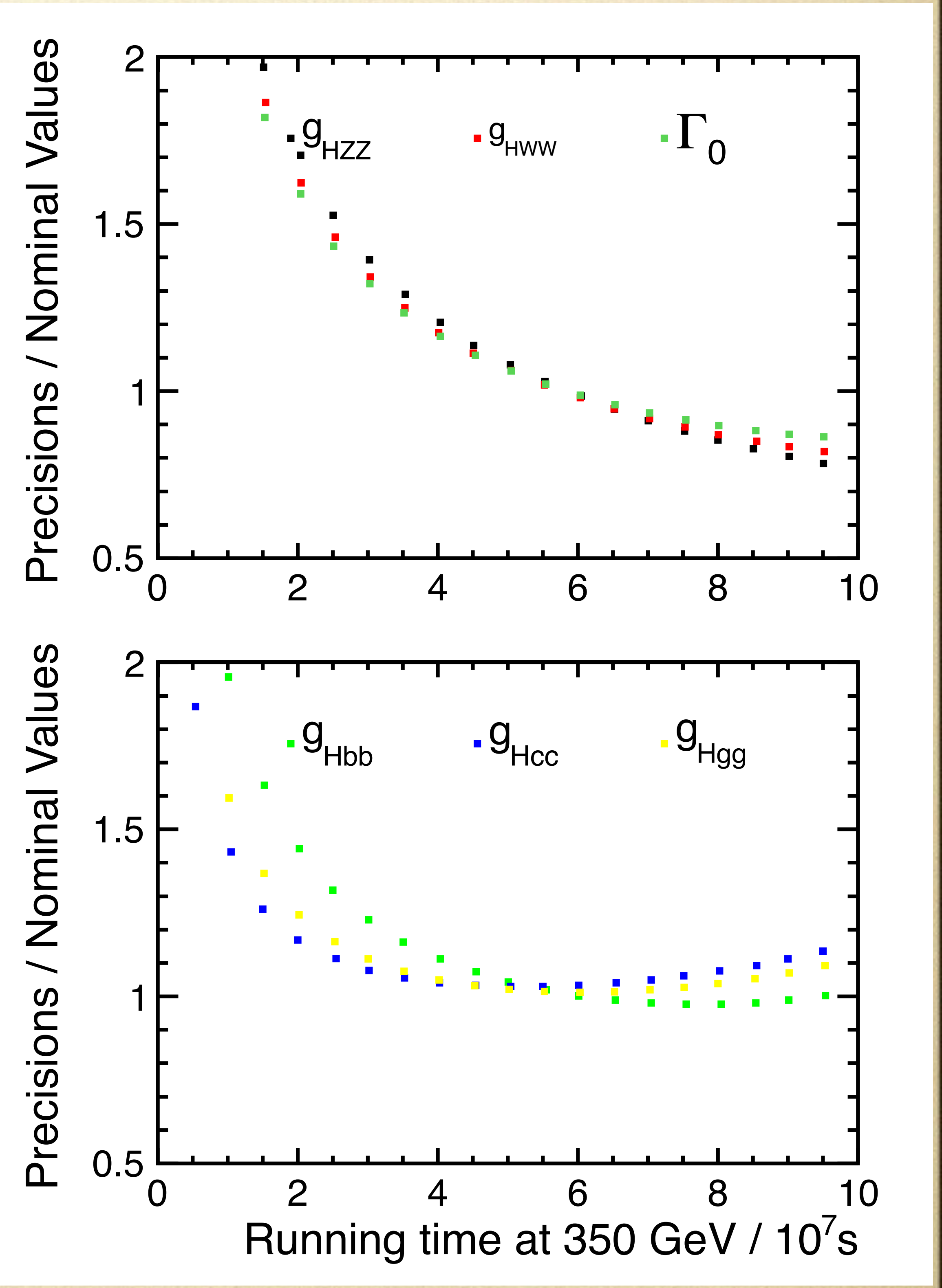


staging: 350 + 500 GeV

fraction dependence

- vary running time @ 350 GeV (in total 10y) to see how precisions depend on run time @ 350 GeV

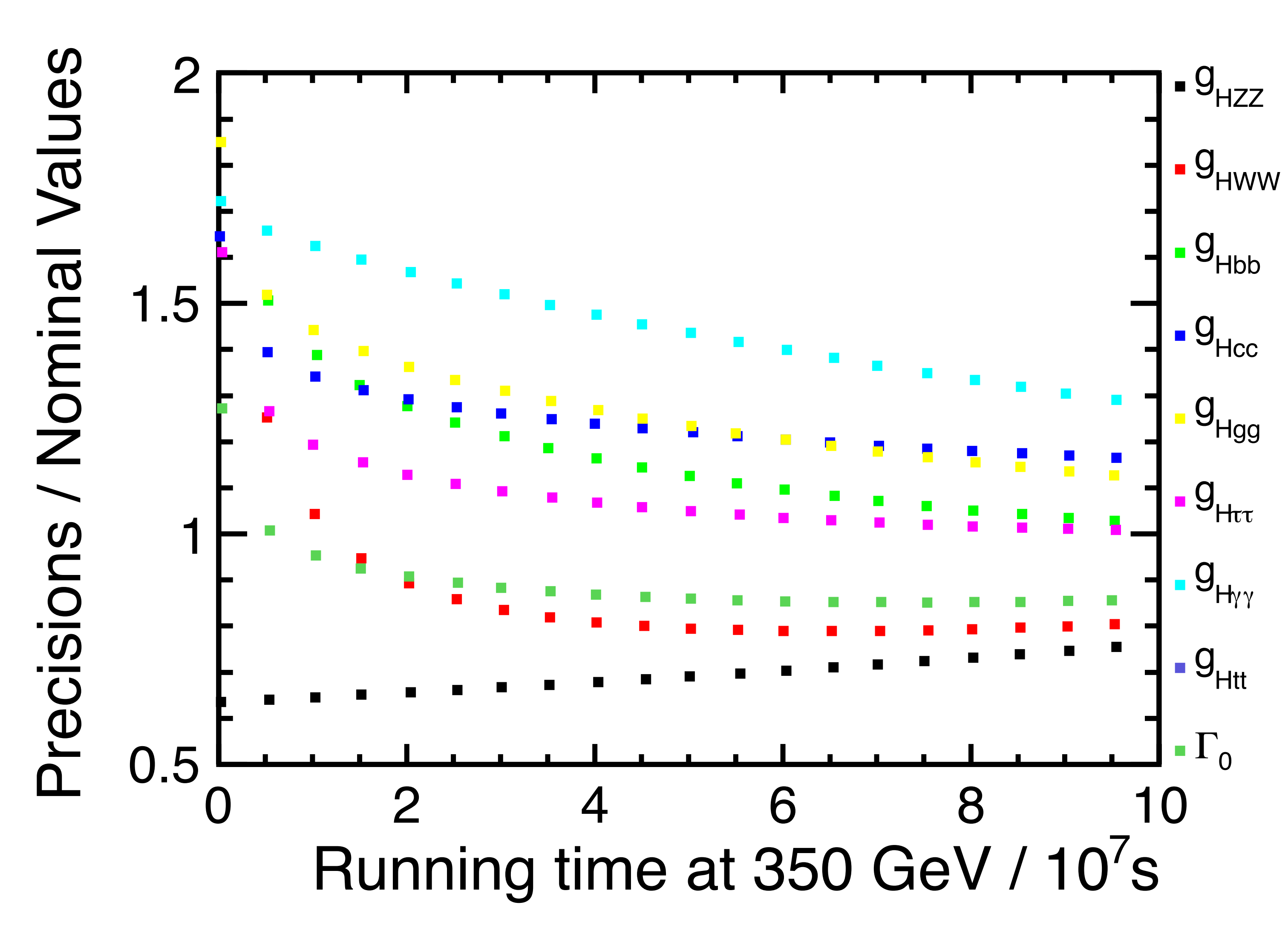


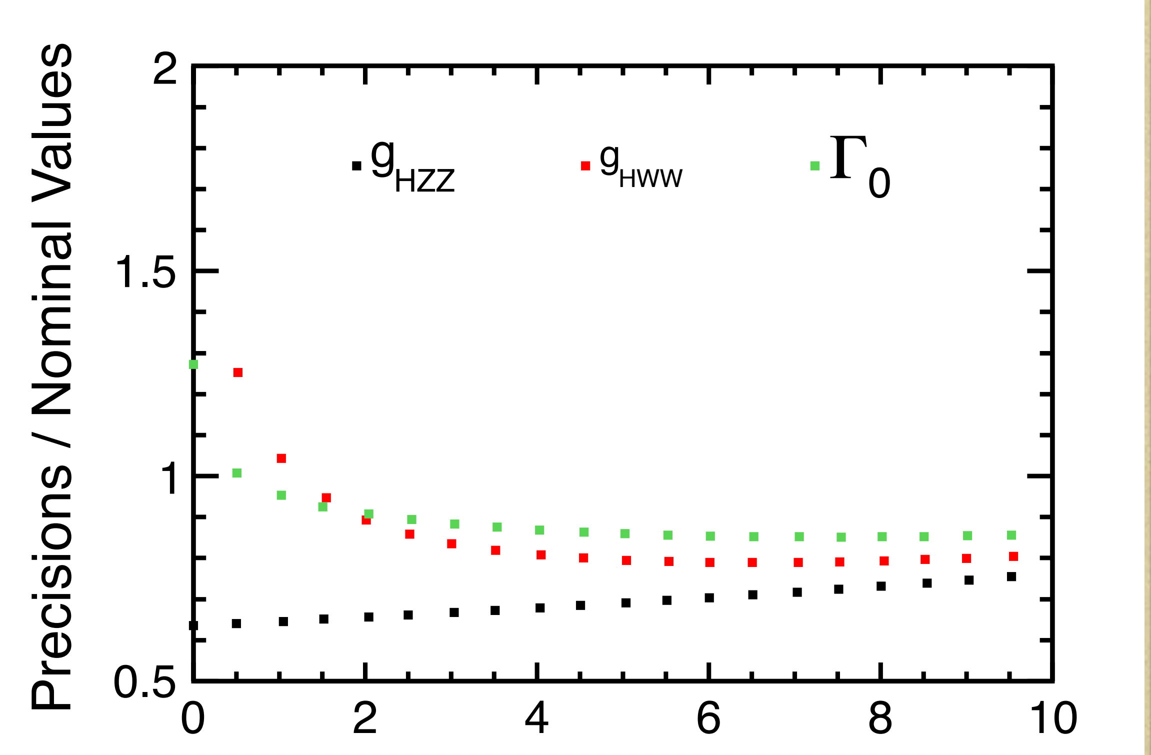


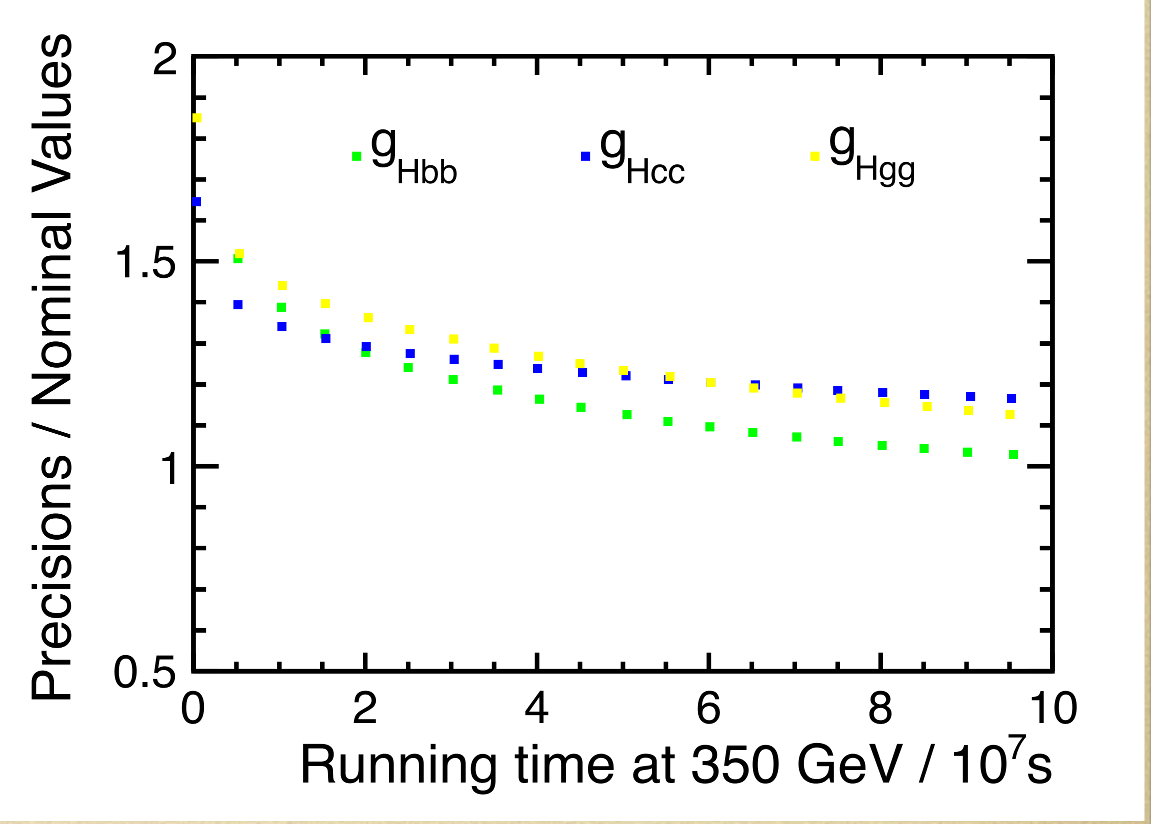
staging: 250 + 350 GeV

fraction dependence

- w/o 500 GeV data: vary running time @ 350 GeV (in total 10y) to see how precisions depend on run time @ 350 GeV

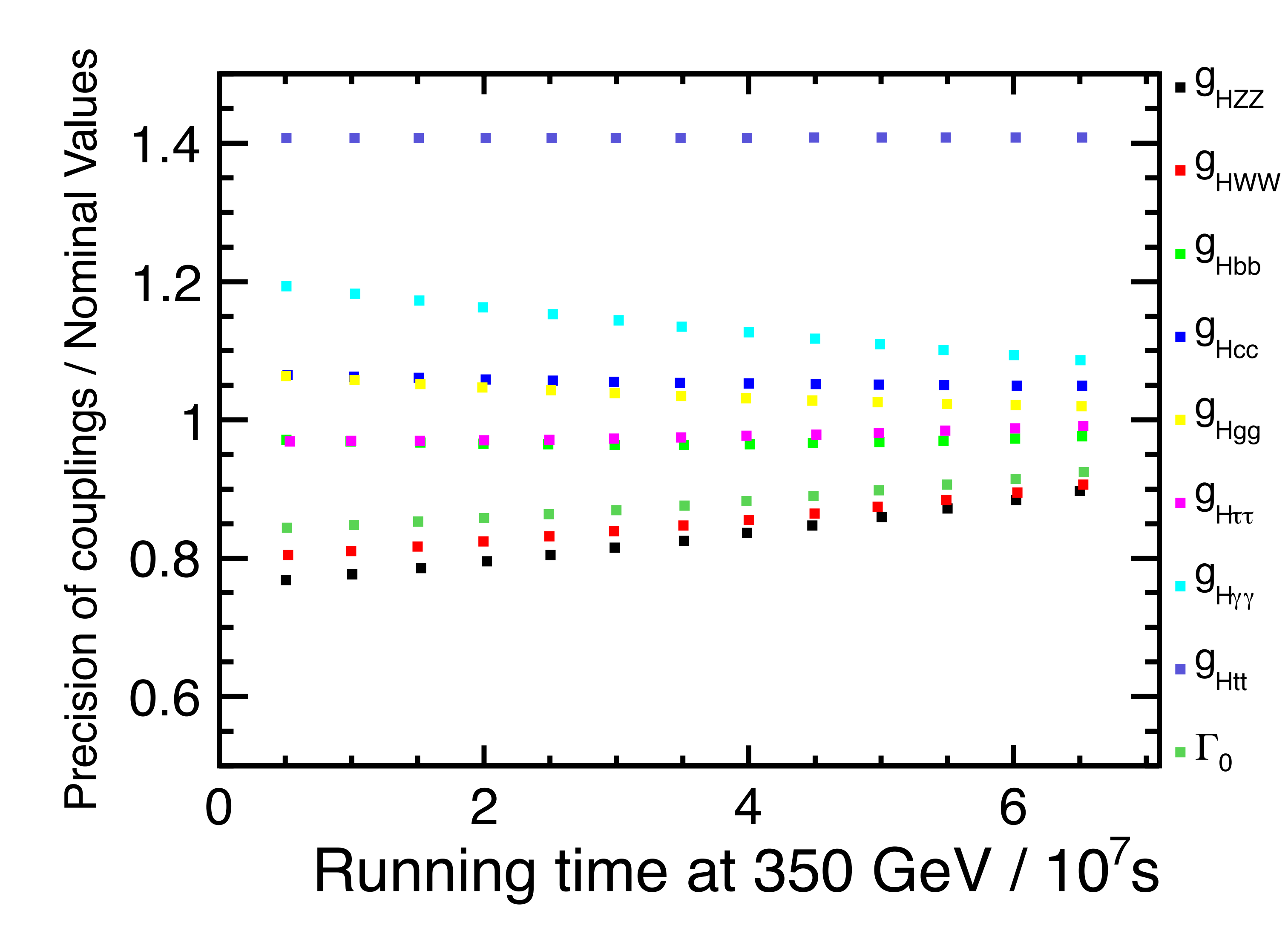


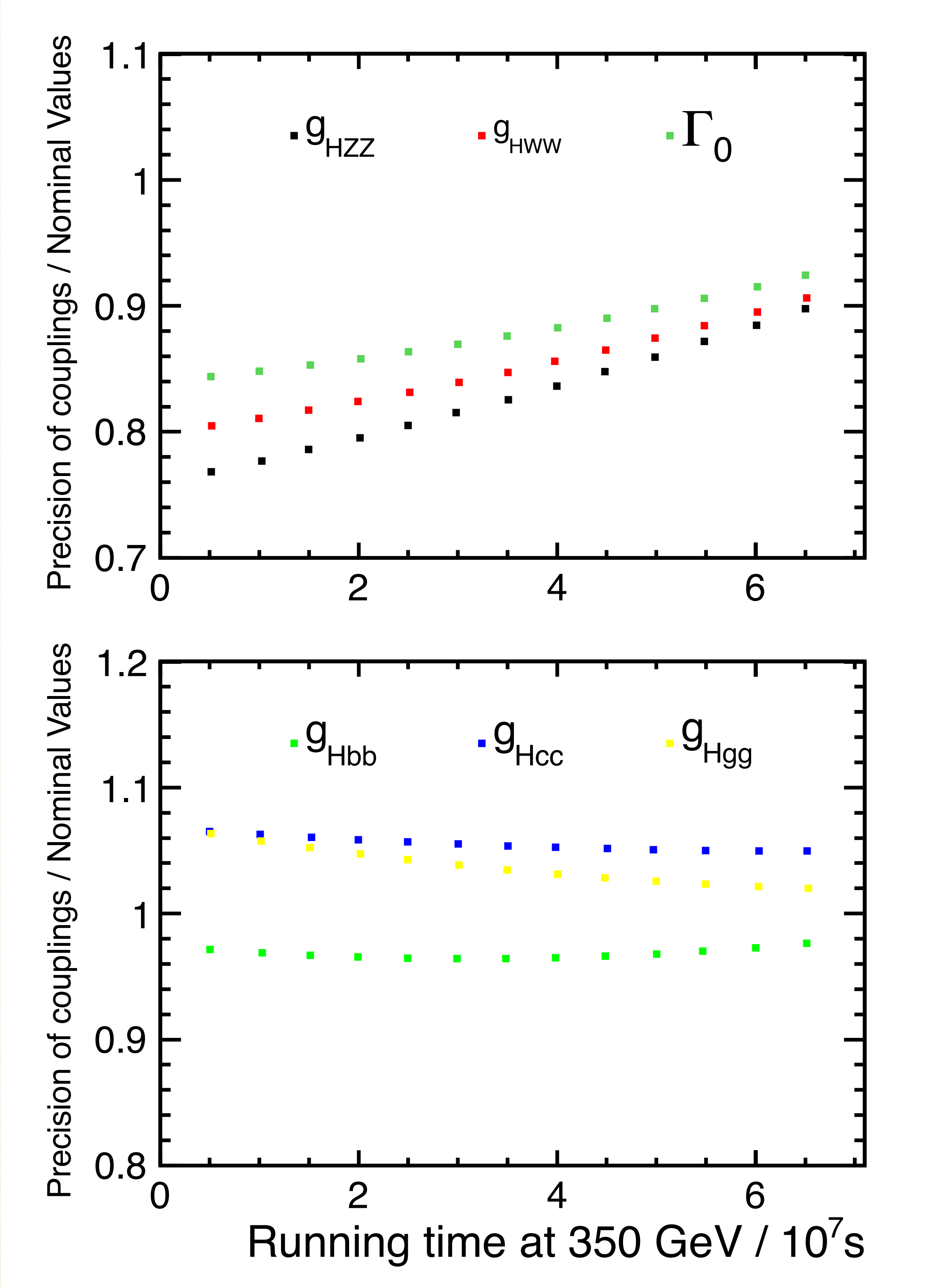




staging: 250 + 350 + 500 GeV

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





some benchmark scenarios

(defined by ILC Parameter group)

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

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

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

d. 100 inv.fb @ 250, 200 inv.fb @ 350, 500 inv.fb @ 500

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

f. 25 inv.fb @ 250, 350 inv.fb @ 350, 500 inv.fb @ 500

g. 500 inv.fb @ 250, 500 inv.fb @ 500

a*. 350 inv.fb @ 350, 500 inv.fb @ 500

precisions for benchmark scenarios

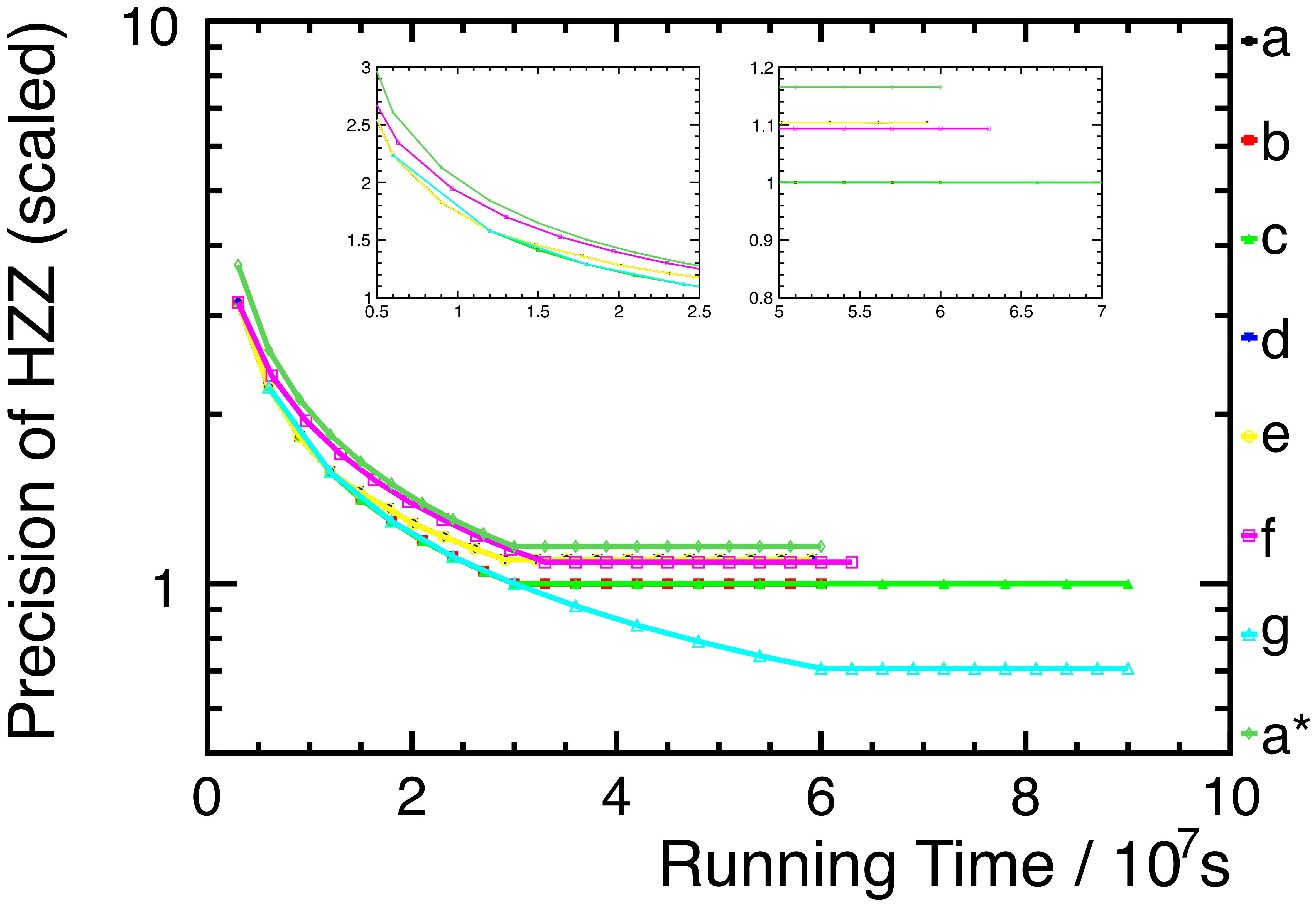
couplin g $\Delta g/g$	a	b	c	d	e	f	g	a*
HZZ	1.3%	1.3%	1.3%	1.43%	1.43%	1.42%	0.919%	1.51%
HWW	1.42%	1.41%	1.38%	1.54%	1.54%	1.52%	1.03%	1.61%
Hbb	1.79%	1.73%	1.59%	1.86%	1.81%	1.82%	1.46%	1.9%
Hcc	2.93%	2.8%	2.39%	2.95%	2.83%	2.87%	2.5%	2.95%
Hgg	2.44%	2.33%	2.02%	2.45%	2.36%	2.38%	2.1%	2.45%
$H\tau\tau$	2.45%	2.43%	2.12%	2.53%	2.51%	2.46%	1.99%	2.56%
$H\gamma\gamma$	7.6%	7.22%	5.72%	7.33%	6.99%	7.04%	6.91%	7.11%
Htt	14.1%	6.18%	9.99%	14.1%	6.21%	14.1%	14%	14.1%
Γ	5.93%	5.88%	5.67%	6.39%	6.35%	6.29%	4.46%	6.65%

assumptions
- i) X=20% worse for $\sigma(ZH)$ at 350 GeV
- ii) extrapolation for 350 GeV shown in backup slides
- iii) much simpler extrapolation for 550 GeV (just scale $\sigma(ZH)$ and $\sigma(\nu\nu H)$)

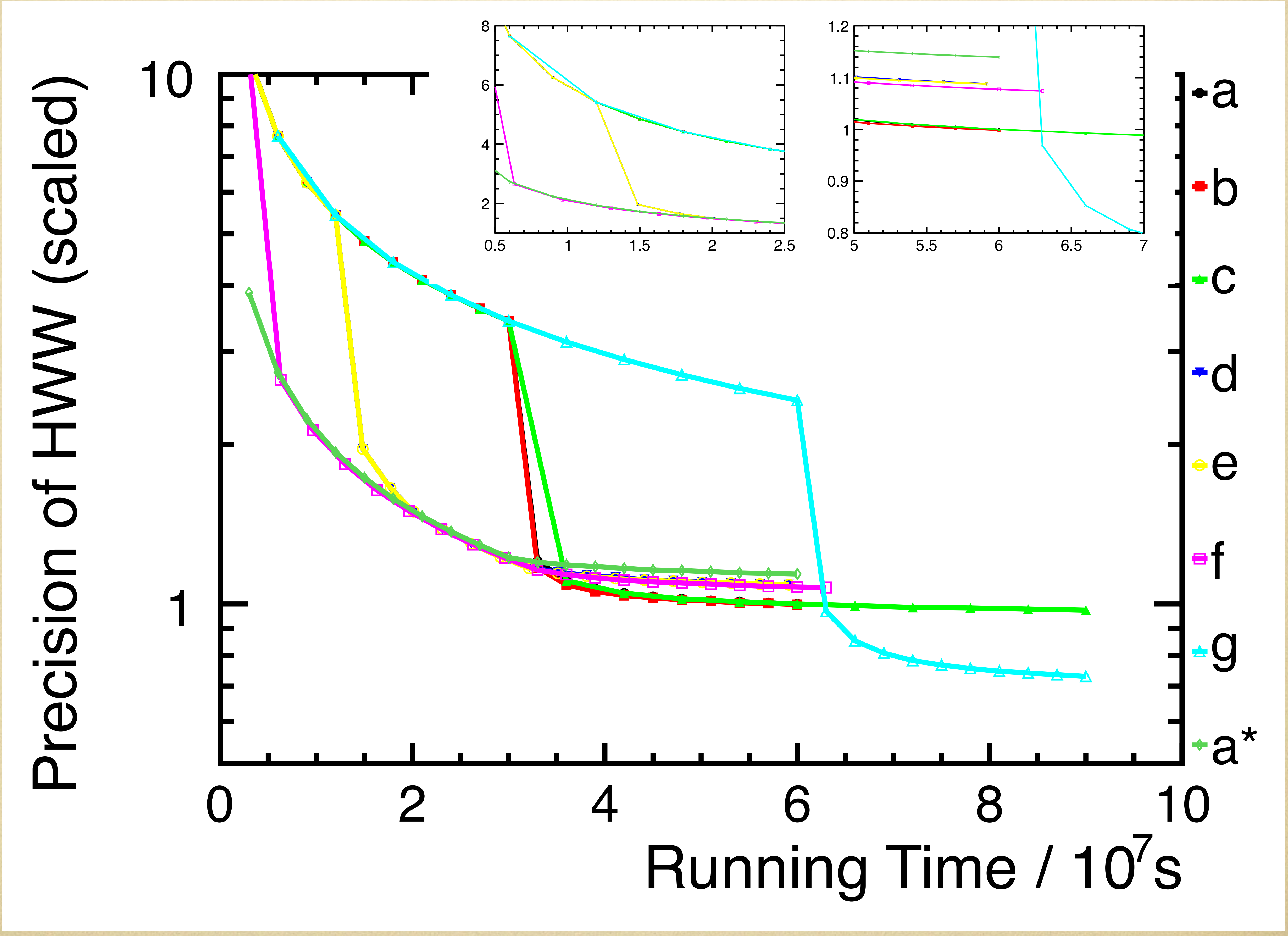
evolution of precisions over time

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

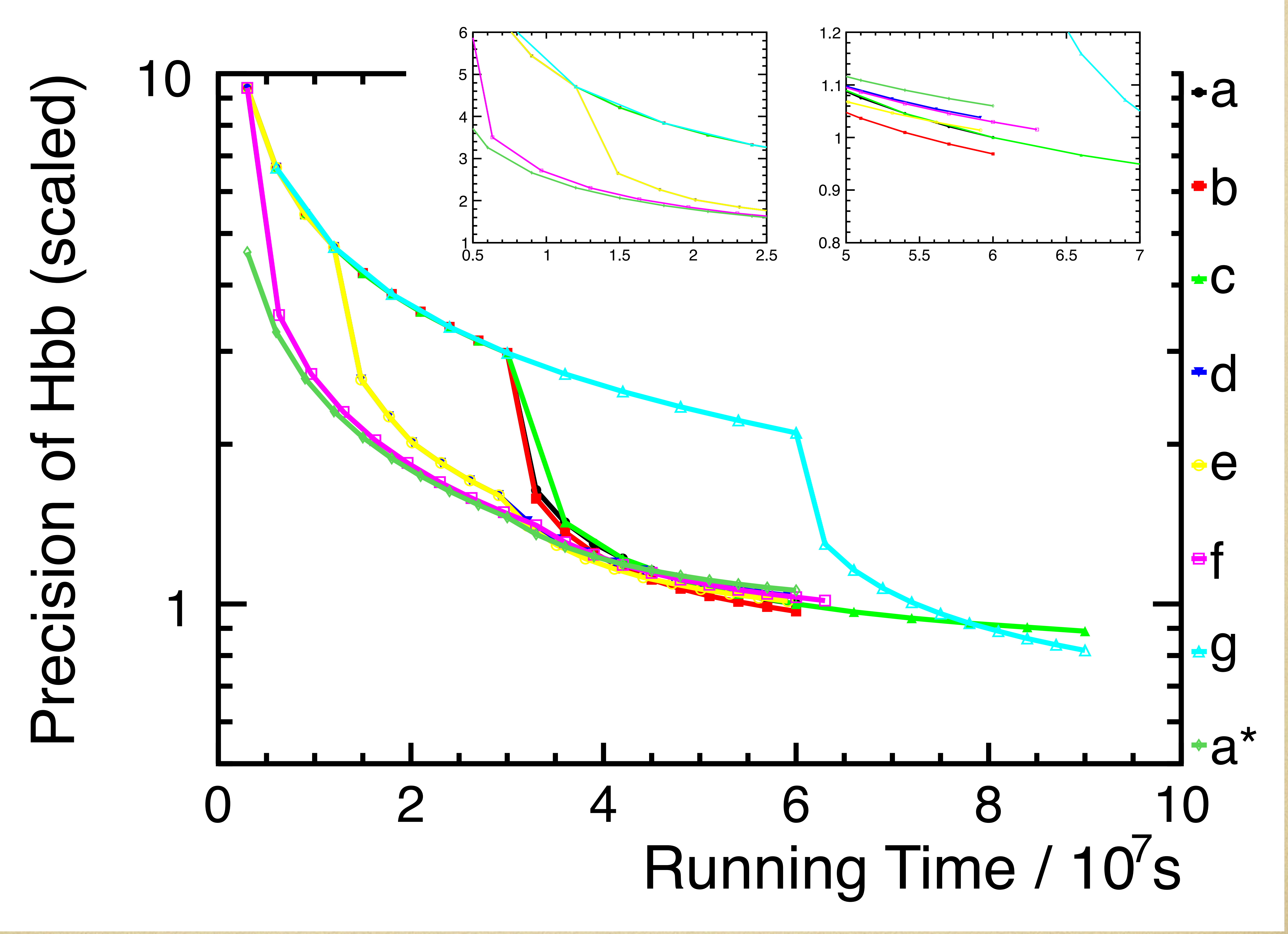
evolution: g_{HZZ}



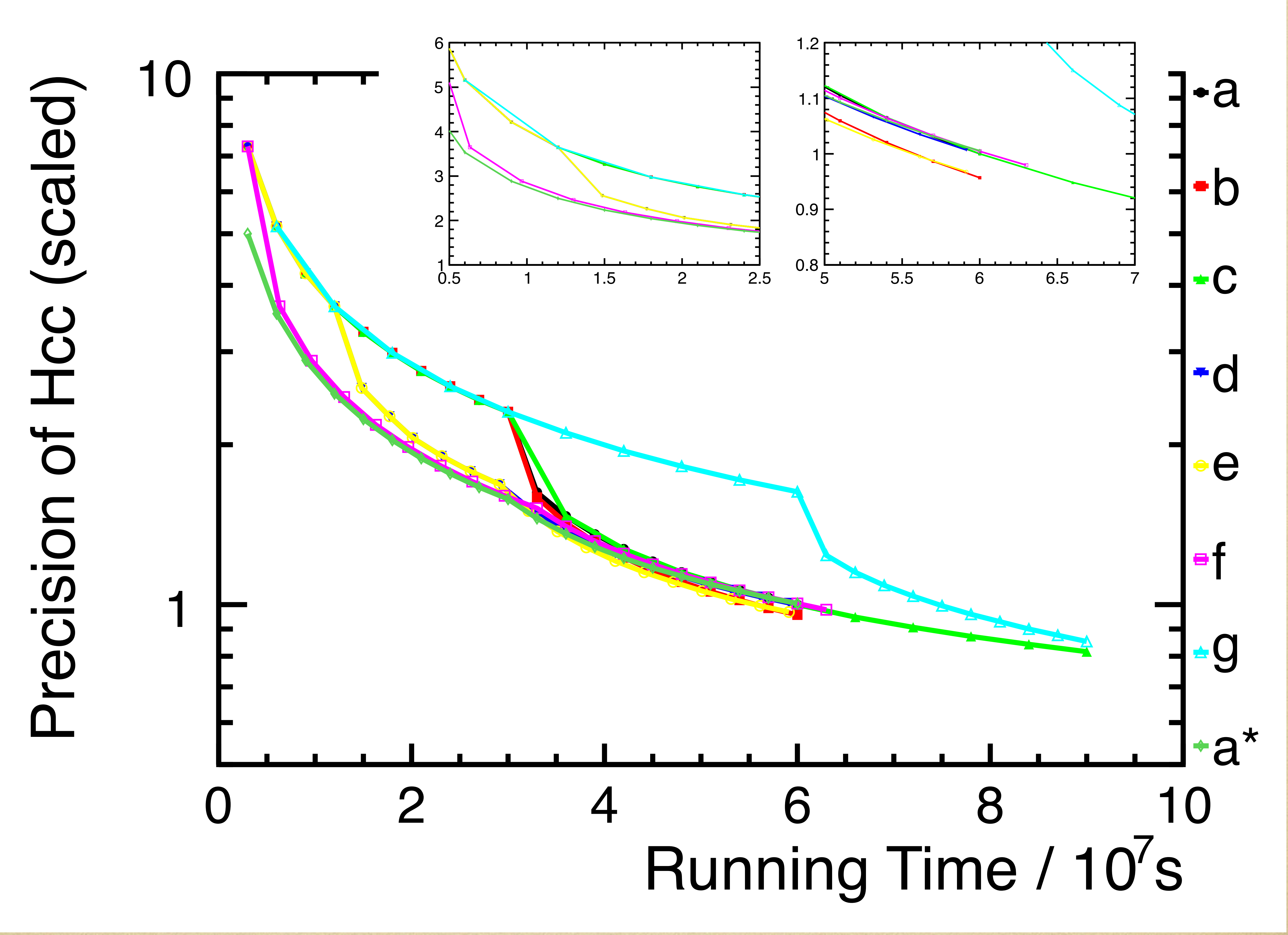
evolution: g_{HWW}



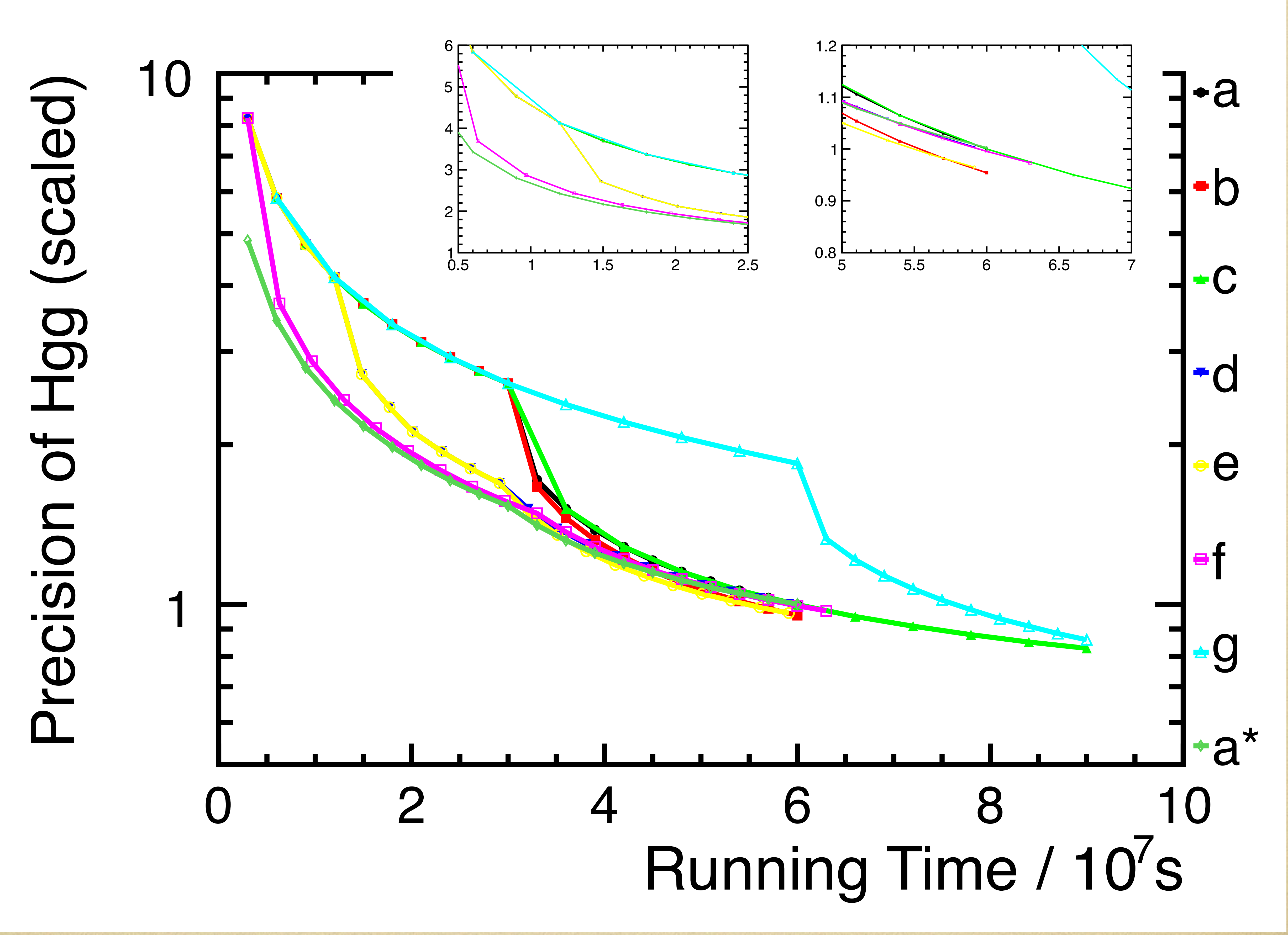
evolution: g_{Hbb}



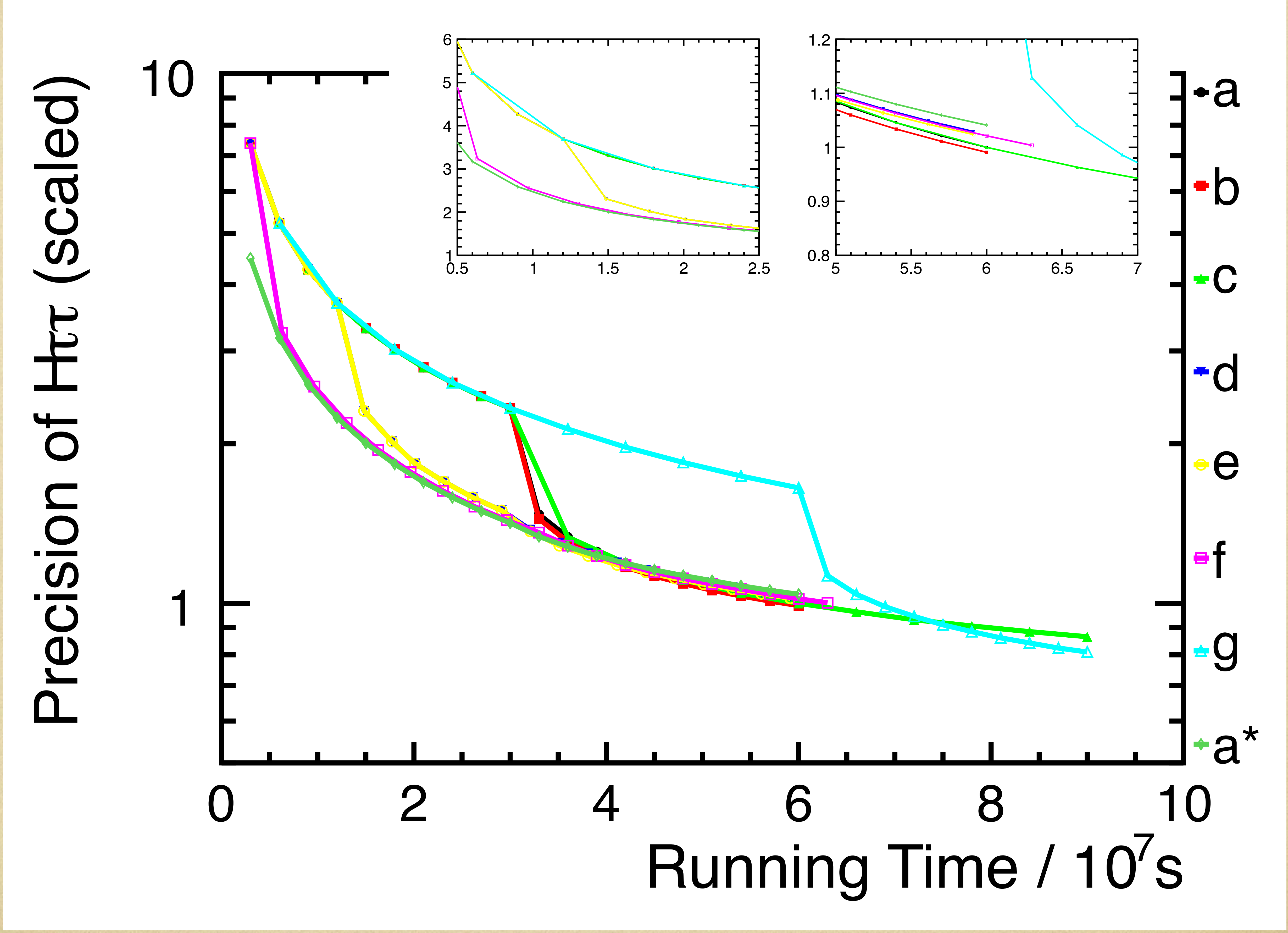
evolution: g_{Hcc}



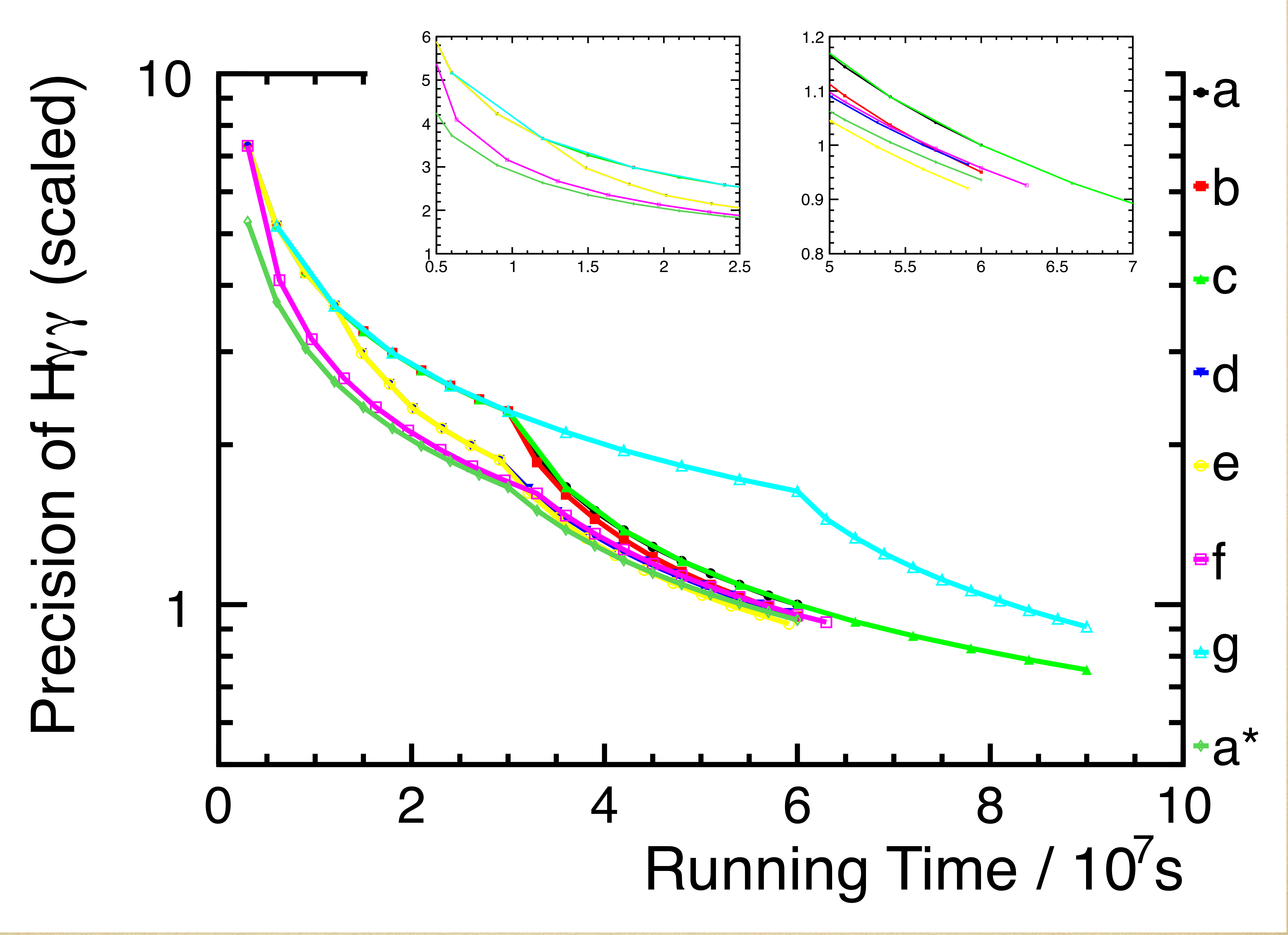
evolution: g_{Hgg}



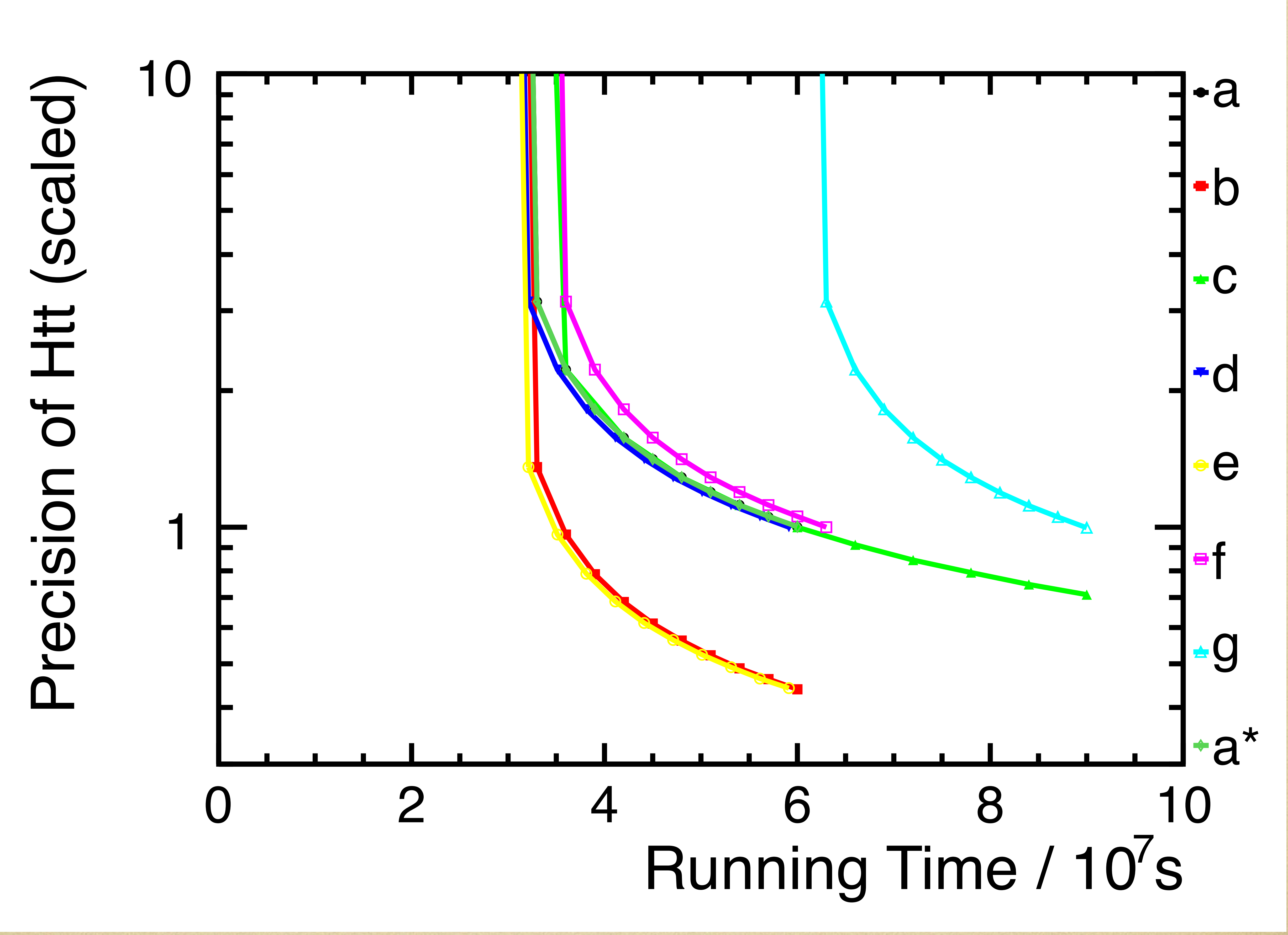
evolution: $g_{H\tau\tau}$



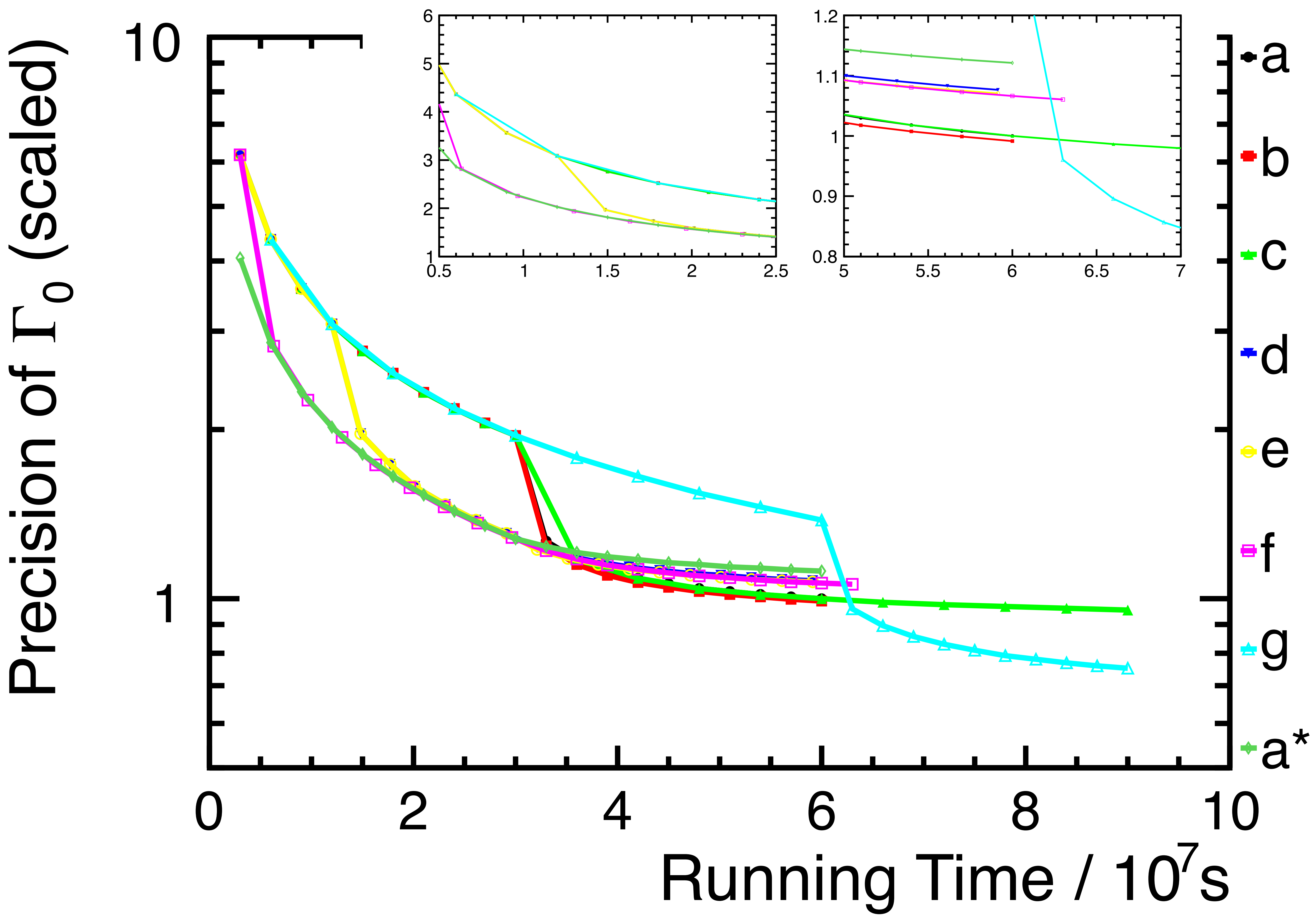
evolution: $g_{H\gamma\gamma}$



evolution: g_{Htt}



evolution: Γ_H

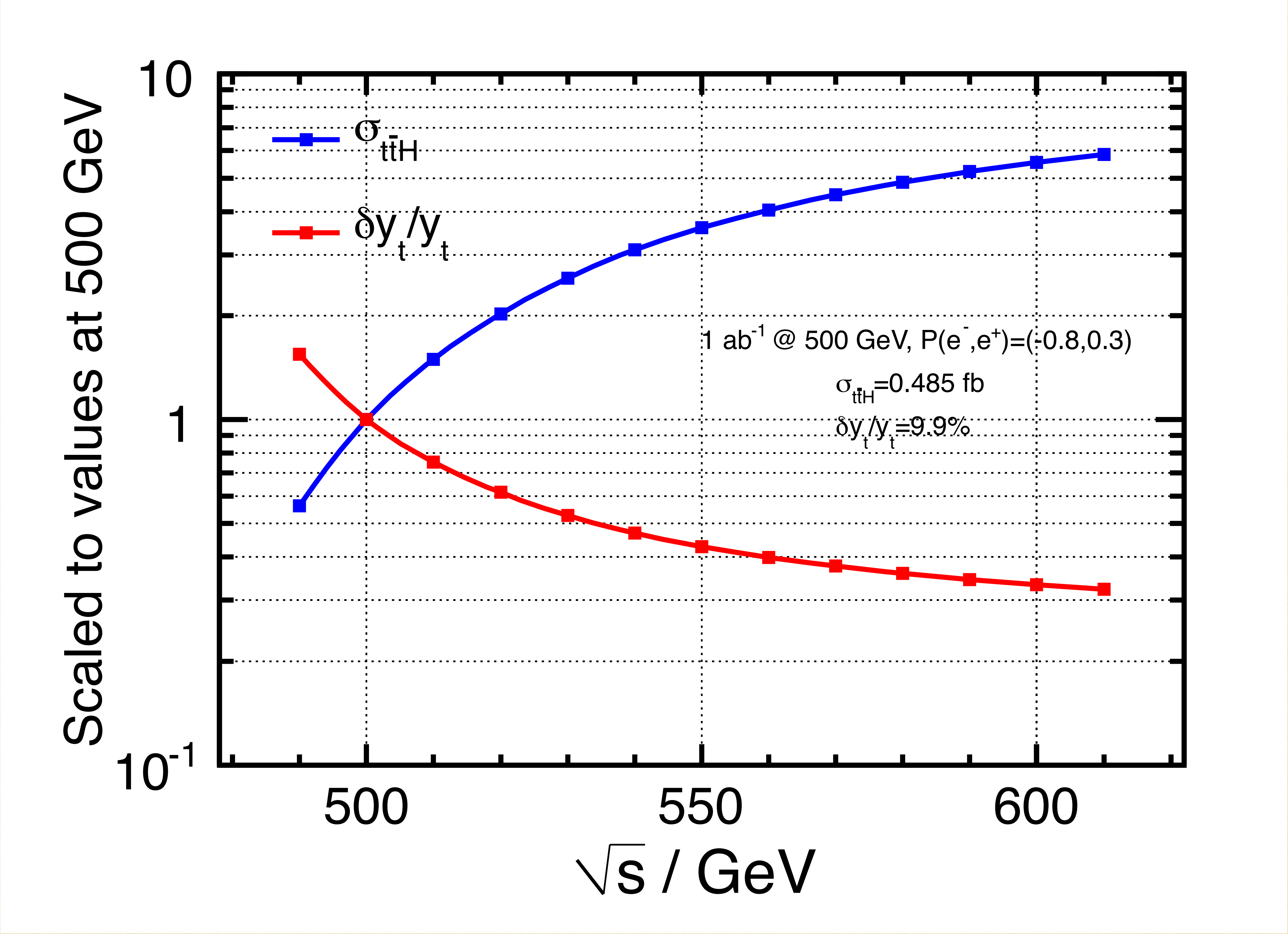


no conclusion yet

- staged running of ILC is a choice to optimize measurements through physics processes ZH, ννH, ttH, ZHH and ννHH.
- starting 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 (waiting for Jacqueline's results); the benefit from the WW-fusion process at 350 GeV will quickly diminish when data at 500 GeV become available.
- increasing a bit at 500 GeV makes 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, others are limited by just statistics.
- more conclusions by YOU (check with Jenny's slides).

back up

top-Yukawa coupling



many thanks to Y. Sudo!

analysis status

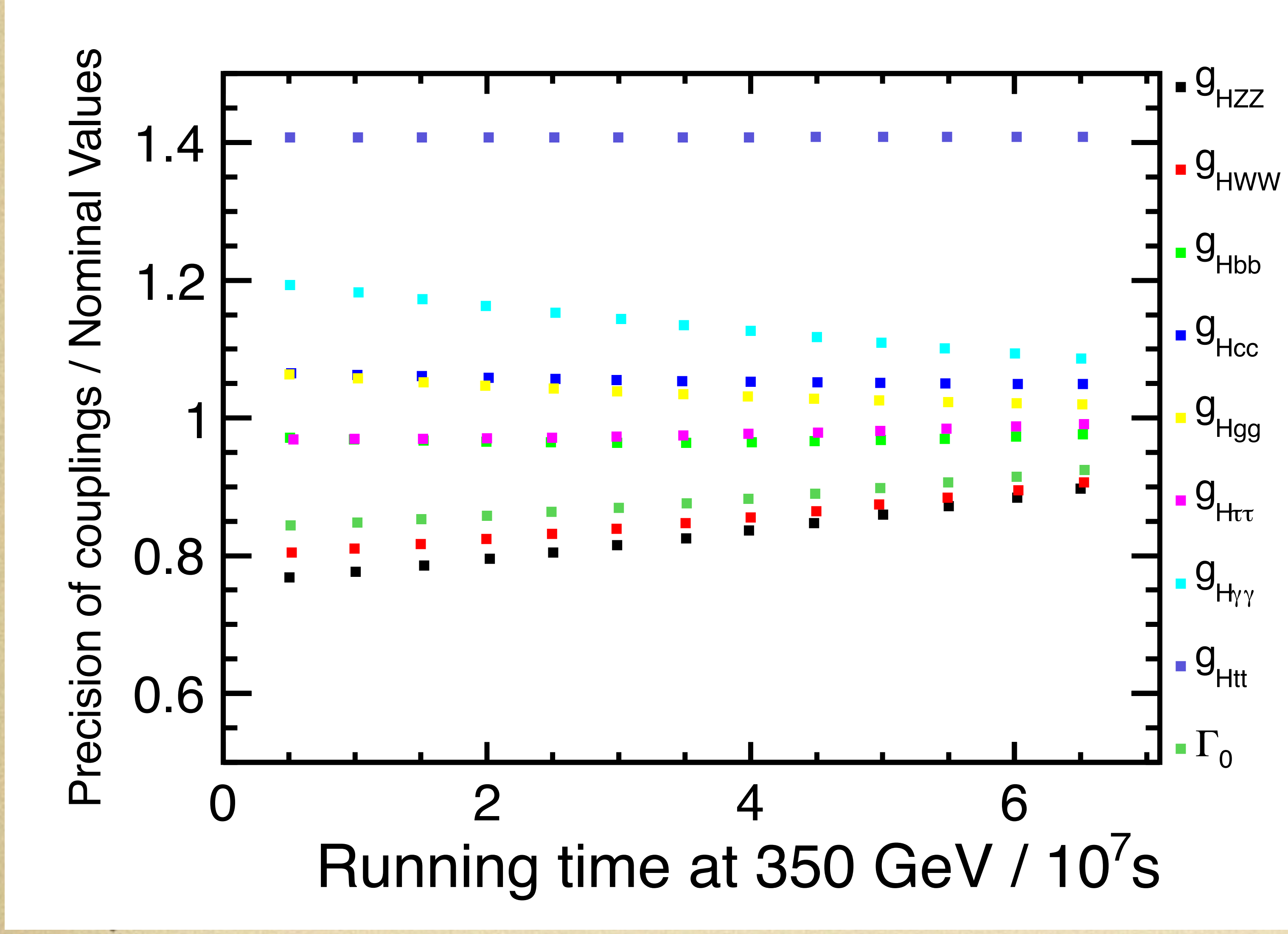
ECM	@ 250 GeV		@ 350 GeV		@ 500 GeV		@ 1 TeV
luminosity · fb	250		330		500		1000
polarization (e-,e+)	(-0.8, +0.3)		(-0.8, +0.3)		(-0.8, +0.3)		(-0.8, +0.2)
process	ZH	ννH	ZH	ννH	ZH	ννH	ννH
cross section	EH	-	G		-	-	-
	σ·Br	σ·Br	σ·Br	σ·Br	σ·Br	σ·Br	σ·Br
H-->bb	EH	F	EH	EEF	EEH	F	F
H-->cc	EH		EH	EEH	EEH	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				-		
ttH, H-->bb	-				EH/EF		F

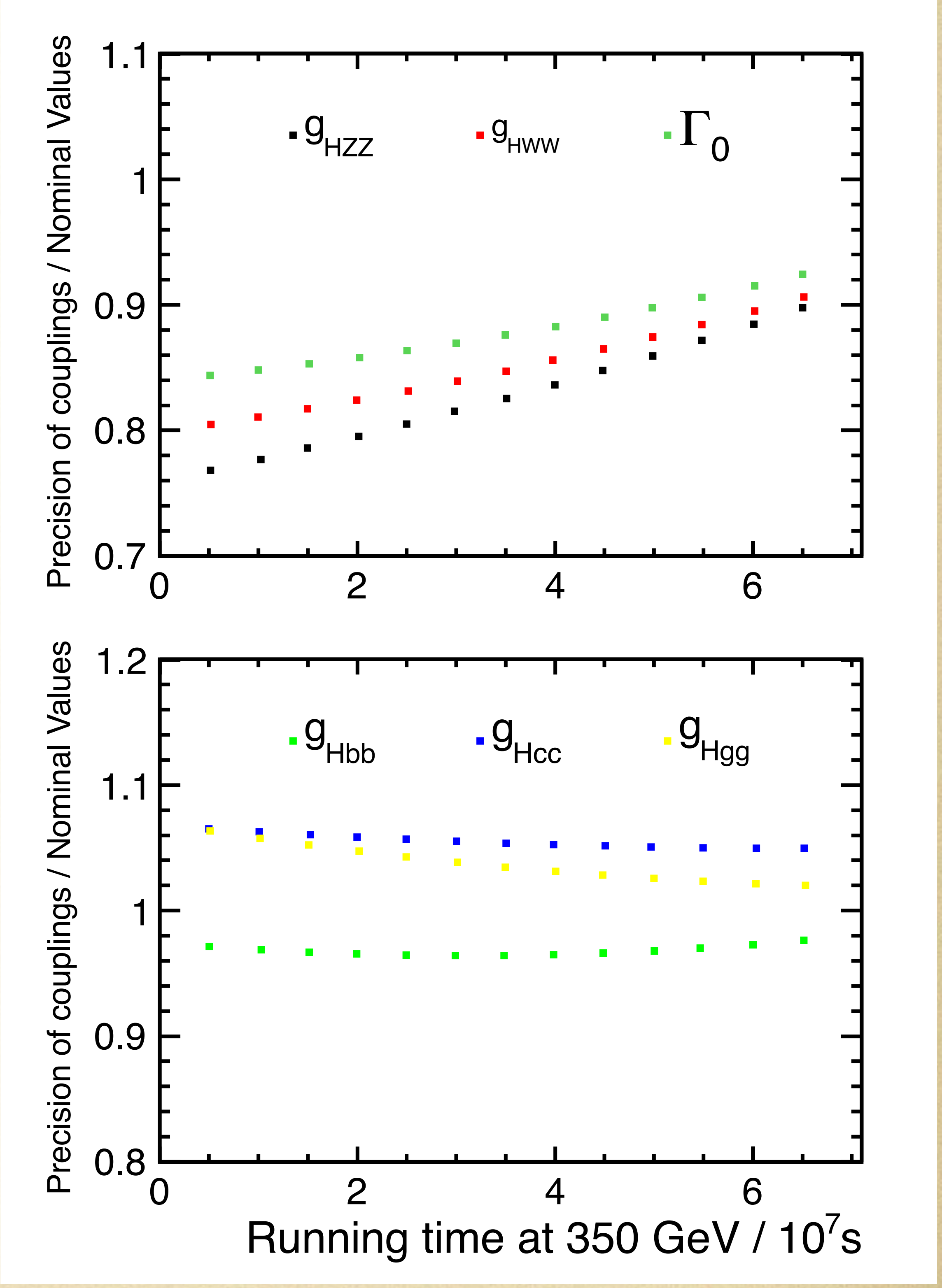
F: done by full simulation w/ mH=125GeV
EH: extrapolated from full simulation w/ mH=120GeV
EEH: extrapolated from full simulation at other ecm w/ mH = 120 GeV
EEF: extrapolated from full simulation at other ecm w/ mH = 125 GeV
G: guesstimate from old fast simulation
black: ongoing or completed
red: still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

250 + 500 + 350 GeV running

X=20% worse

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

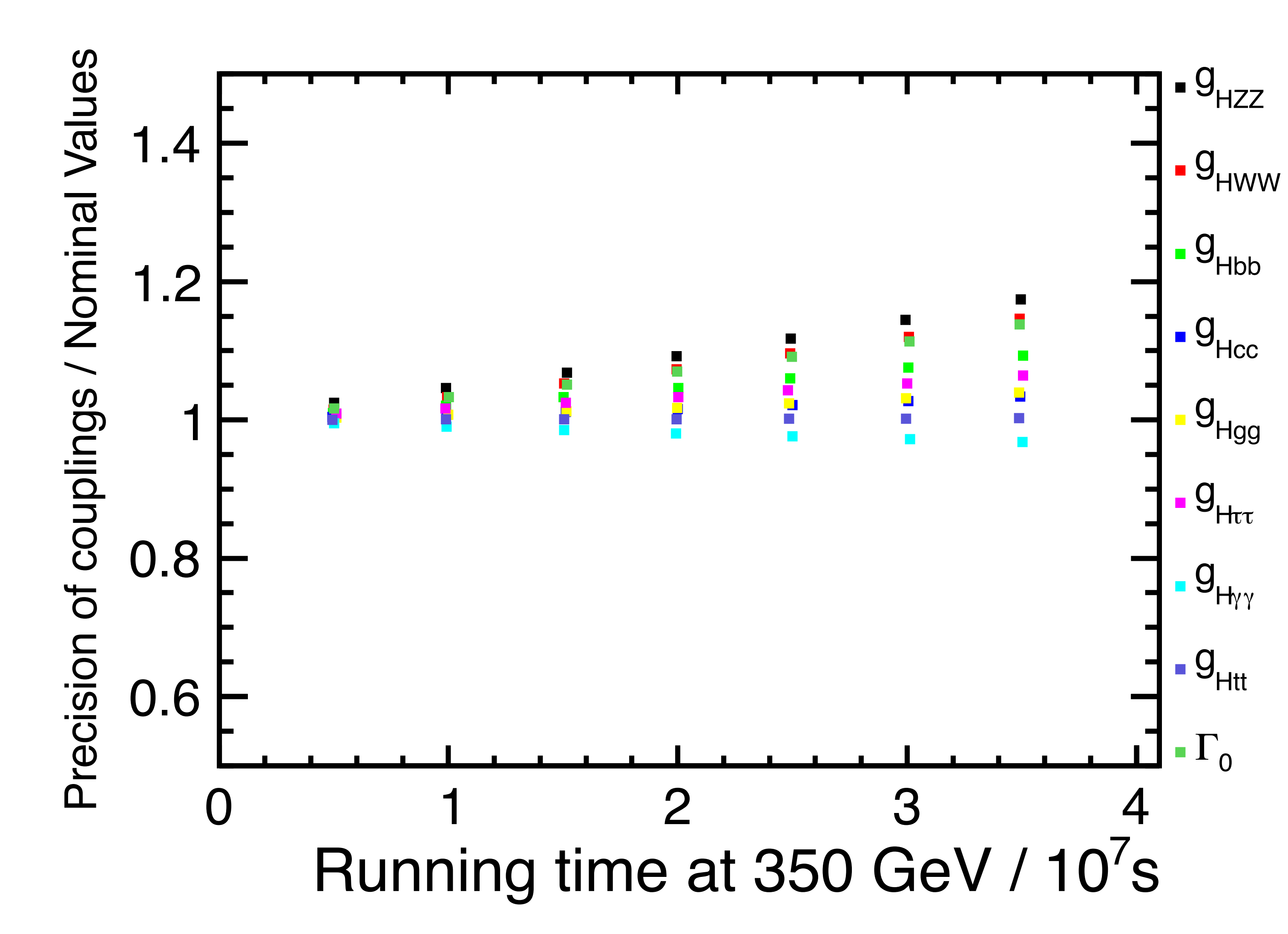


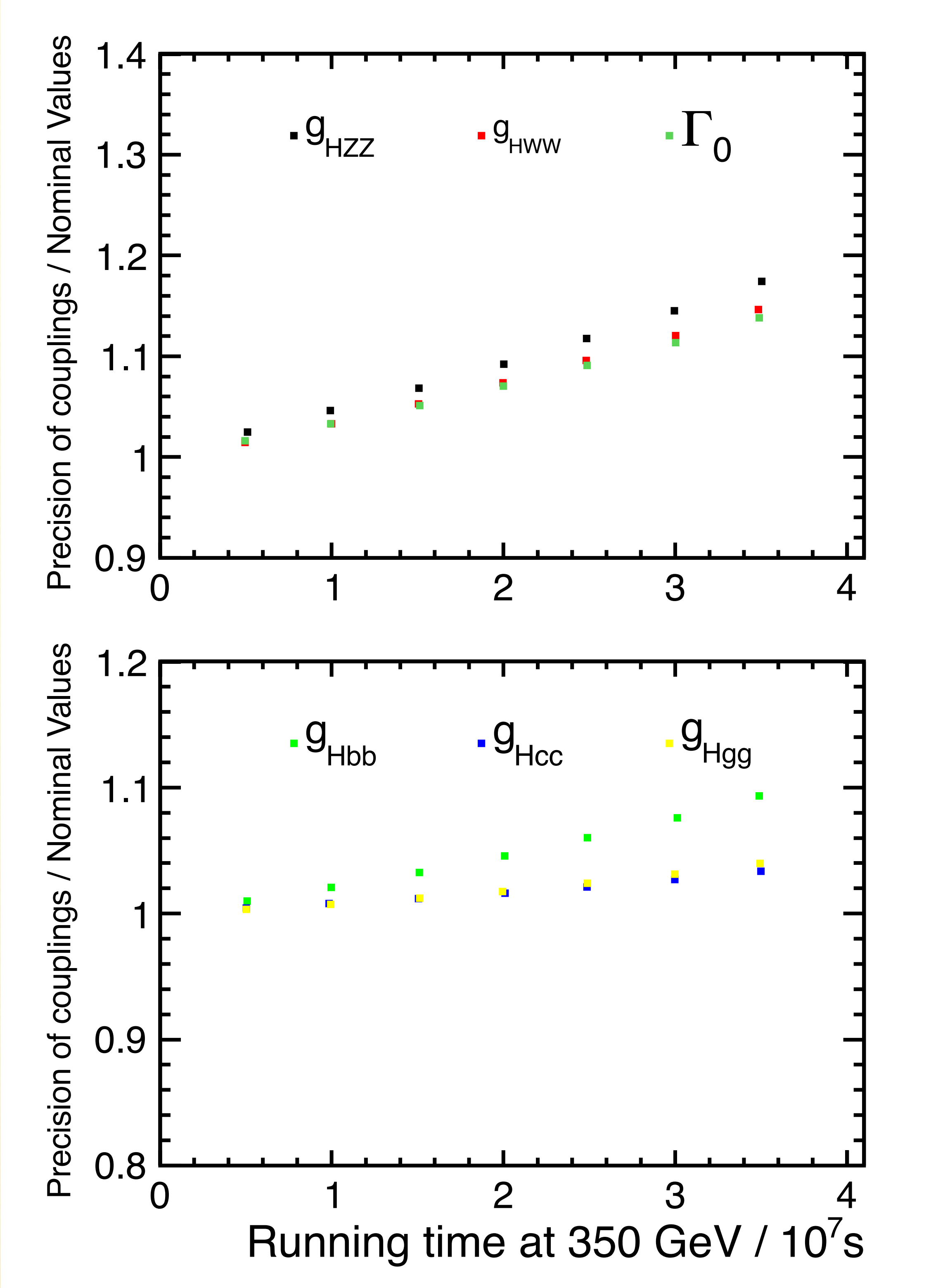


250 + 500 + 350 GeV running

X=20% worse

- assume 10y in total, and 6y @ 500 GeV.
- then vary running time @ 350 GeV.



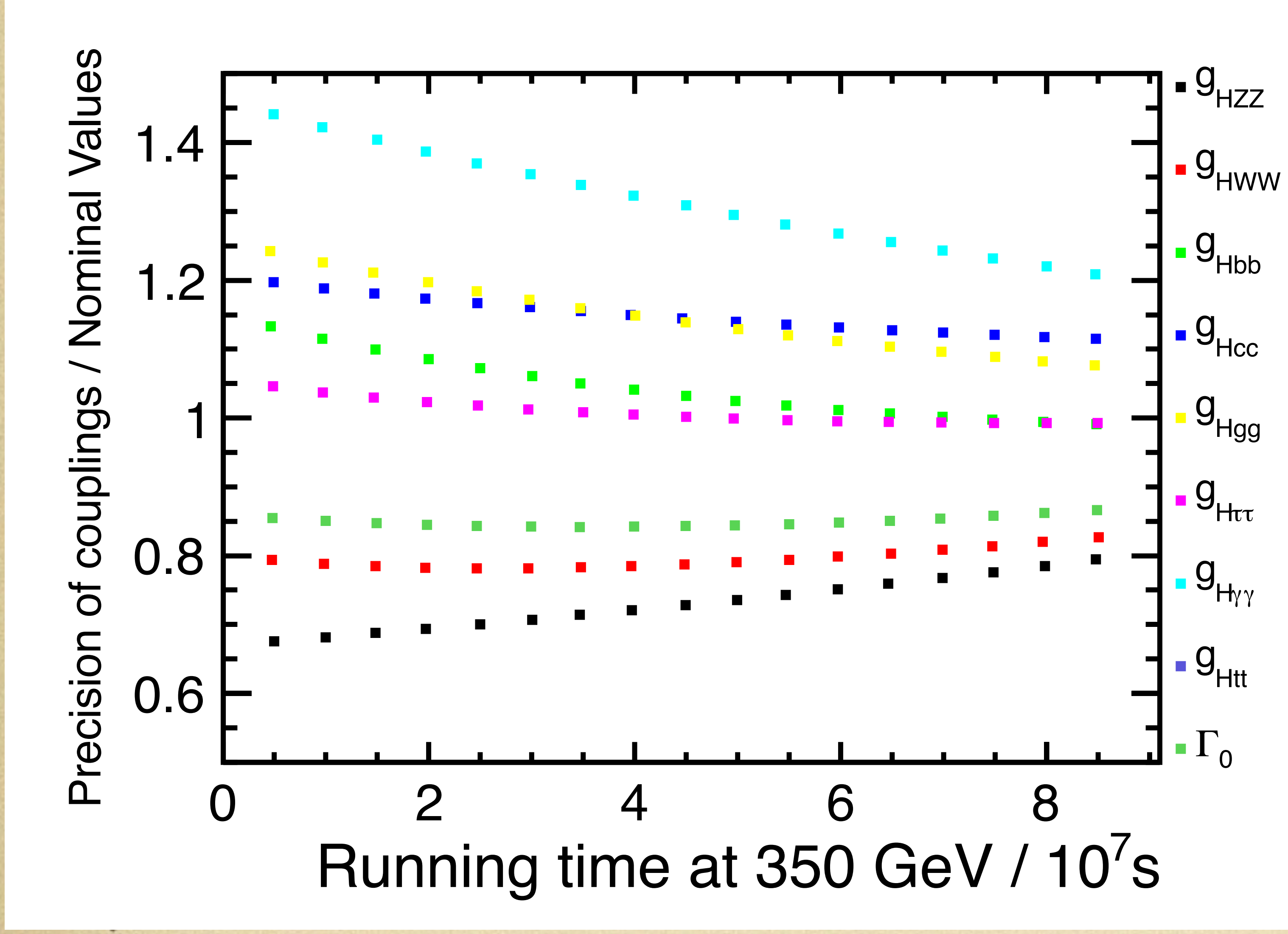


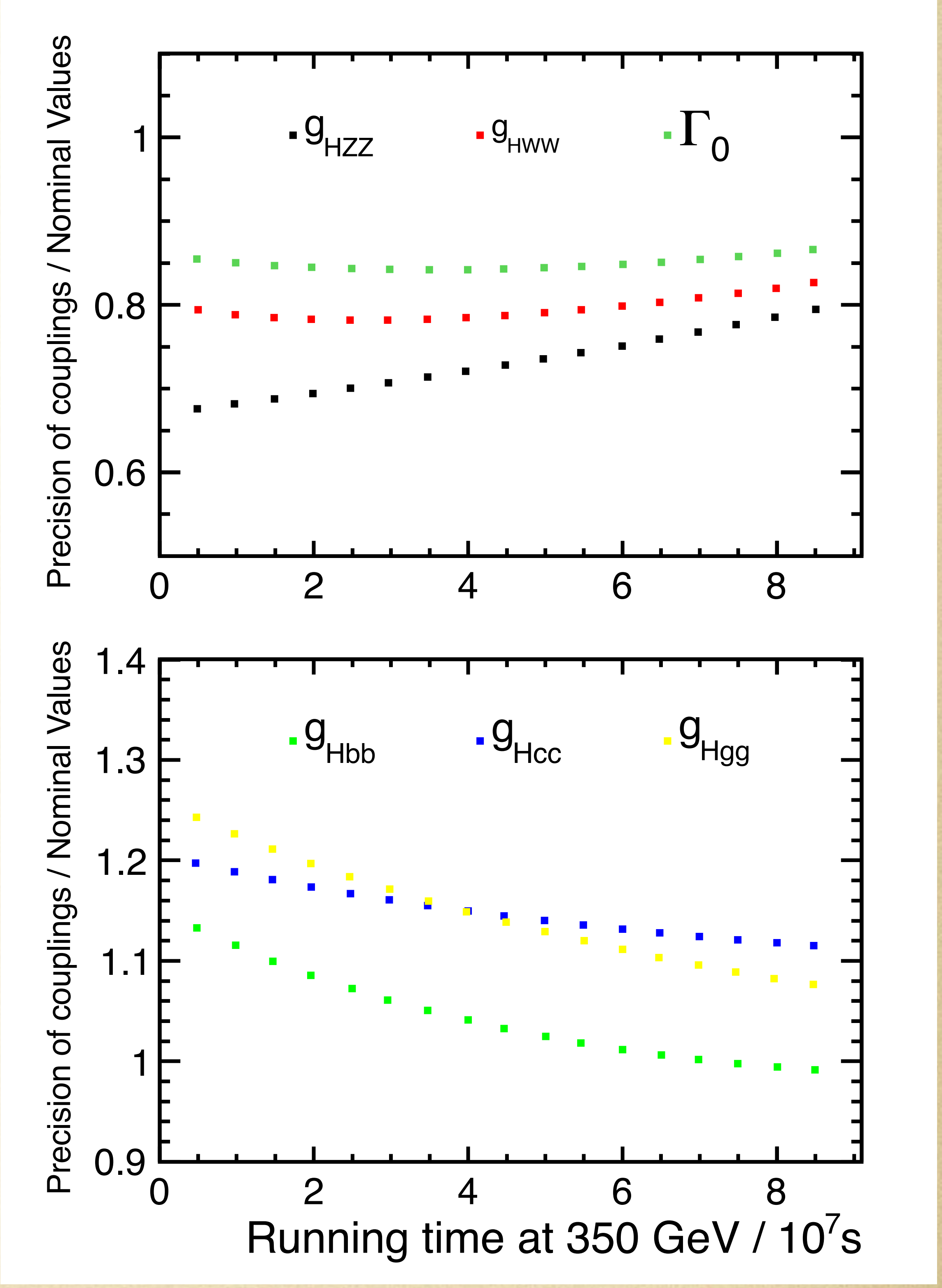
If we run long enough at 500 GeV, the role of 350 GeV will be very small

250 + 500 + 350 GeV running

X=20% worse

- assume 10y in total, and 1y @ 500 GeV.
- then vary running time @ 350 GeV.





Significant fraction of measurements become worse than the baseline

Extrapolation to 350 GeV and some update

- No full simulation results with TDR machine parameters and detector configurations available for 350 GeV and mH=125GeV
- according to TDR luminosities, nominal 330 fb^{-1} data assumed at 350 GeV corresponding to 250 fb^{-1} at 250 GeV. (luminosity: 1.0 versus 0.75 x 10^{34})
- results for both production channels, ZH and $\nu_e\nu_e H$, are extrapolated to 350 GeV; ZH part from 250 GeV results, $\nu_e\nu_e H$ part from 500 GeV results.
- For ZH @ 350 GeV, nominal N_S = 0.87 x N_S @ 250 GeV, dominant background is WW/ZZ, N_B = 0.96 x N_B @ 250 GeV.
- For $\nu_e\nu_e H$ @ 350 GeV, nominal N_S = 0.26 x N_S @ 500 GeV, dominant background is $\nu_e\nu_e Z$, N_B = 0.30 x N_B @ 500 GeV.
- update: H—>γγ @ 500 GeV and 1 TeV new results by C.Calancha, better than previous estimates.

recoil mass analysis at 350 GeV

- most critical measurement is σ(ZH) @ 350 GeV, however not available now; analysis based on DBD full simulation is ongoing (by Jacqueline from Tokyo U'), preliminary results show much wider Higgs peak; results might be ~10-20% worse than 250 GeV (wait for completion of the analysis).

- comments on previous study by H.Li: RDR luminosities assumed, 188 fb^{-1} @ 250 GeV and 300 fb^{-1} @ 350 GeV; fast simulation; only WW and ZZ backgrounds considered.

- just as an example, let us assume two cases, precision would be 20% or 10% worse on σ(ZH) @ 350 GeV, and consider optimization of running plan in next slides.

global fit --model independent

X=10%

couplin g Δg/g	a	b	c	d	e	f	g	a*
HZZ	1.3%	1.3%	1.3%	1.37%	1.37%	1.32%	0.919%	1.39%
HWW	1.42%	1.41%	1.38%	1.48%	1.48%	1.42%	1.03%	1.5%
Hbb	1.79%	1.73%	1.59%	1.81%	1.76%	1.73%	1.46%	1.8%
Hcc	2.93%	2.8%	2.39%	2.92%	2.8%	2.82%	2.5%	2.88%
Hgg	2.44%	2.33%	2.02%	2.41%	2.32%	2.32%	2.1%	2.37%
Hττ	2.45%	2.43%	2.12%	2.49%	2.48%	2.4%	1.99%	2.48%
Hγγ	7.6%	7.22%	5.72%	7.31%	6.98%	7.02%	6.91%	7.09%
Htt	14.1%	6.18%	9.99%	14.1%	6.19%	14.1%	14%	14.1%
Γ	5.93%	5.88%	5.67%	6.15%	6.12%	5.91%	4.46%	6.2%

global fit --model independent

X=0%

couplin g Δg/g	a	b	c	d	e	f	g	a*
HZZ	1.3%	1.3%	1.3%	1.3%	1.3%	1.21%	0.919%	1.26%
HWW	1.42%	1.41%	1.38%	1.41%	1.41%	1.32%	1.03%	1.38%
Hbb	1.79%	1.73%	1.59%	1.75%	1.71%	1.65%	1.46%	1.7%
Hcc	2.93%	2.8%	2.39%	2.88%	2.77%	2.77%	2.5%	2.82%
Hgg	2.44%	2.33%	2.02%	2.37%	2.27%	2.26%	2.1%	2.3%
Hττ	2.45%	2.43%	2.12%	2.45%	2.44%	2.35%	1.99%	2.41%
Hγγ	7.6%	7.22%	5.72%	7.3%	6.97%	7%	6.91%	7.06%
Htt	14.1%	6.18%	9.99%	14.1%	6.18%	14.1%	14%	14.1%
Γ	5.93%	5.88%	5.67%	5.89%	5.86%	5.53%	4.46%	5.75%