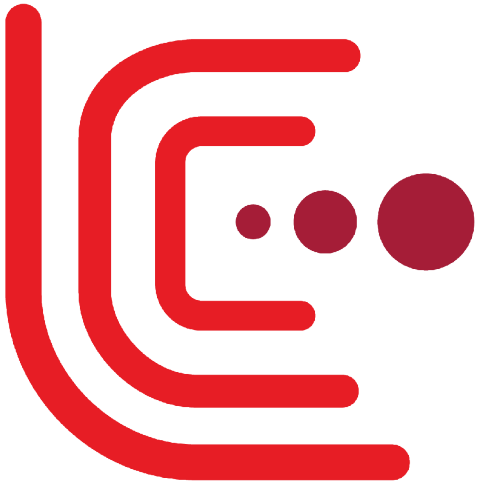
Update from the LCC Parameter Group



ILC @ DESY

General Project Meeting

April 10, 2015

J.List (DESY)

On behalf of the LCC Parameter Group

History...

- Jan / Feb 2014: Parameter group established
  (N. Walker, J. Gao, K. Yokoya, J.Brau, T.Barklow, K.Fujii, JL)

  = > Original charge: develop running scenarios
  for a *staged* ILC starting operation at 250 GeV

- May 2014: First public presentation of intermediate status and community feed-back at AWLC14

- October 2014: presentation at LCWS14,
  report submitted to the LCB / LCC

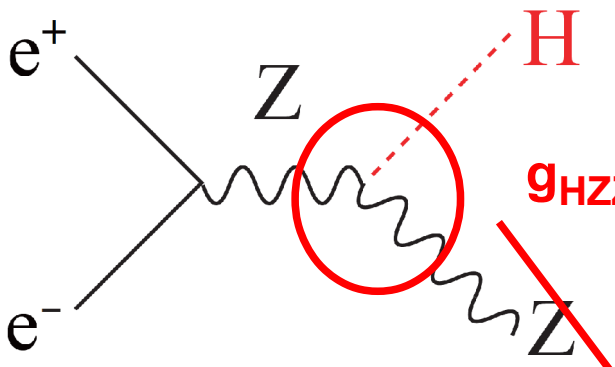
  => "the contruction of the full 500 GeV ILC from the start
  remains the preferred plan of the LCC"

  => since then: new running scenarios, new version of report...

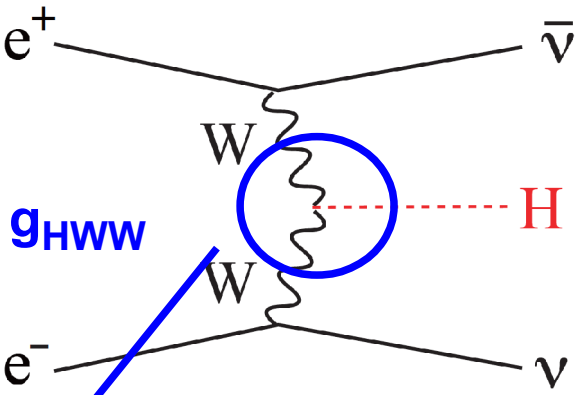
Overview

- Higgs coupings: some basic mechanisms
- A side remark about CEPC
- Running scenarios for ILC500
  - The scenarios
  - Physics

Higgs Physics

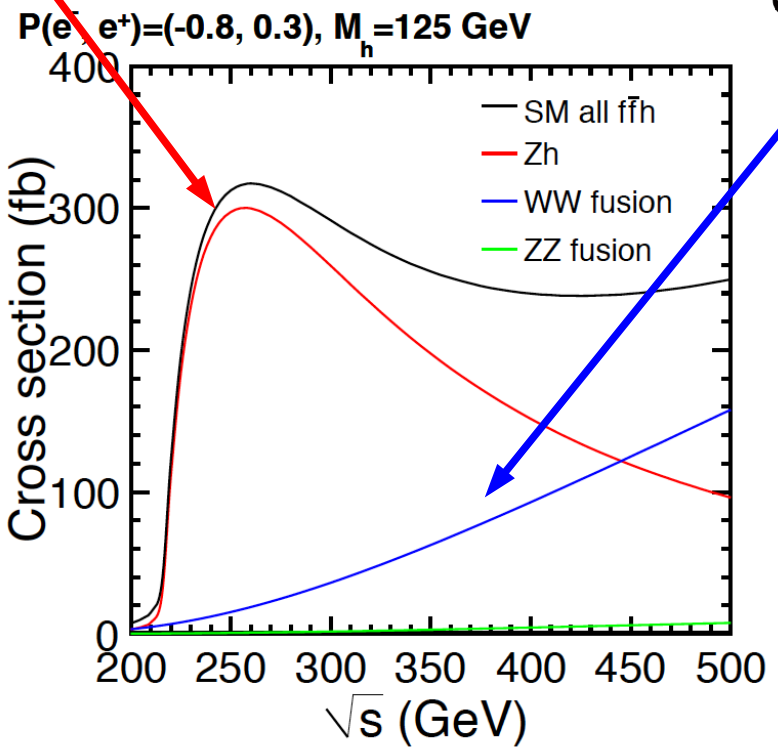


g_{HZZ}



g_{HWW}

- Recoil method:
  - g_{HZZ}
  - M_H



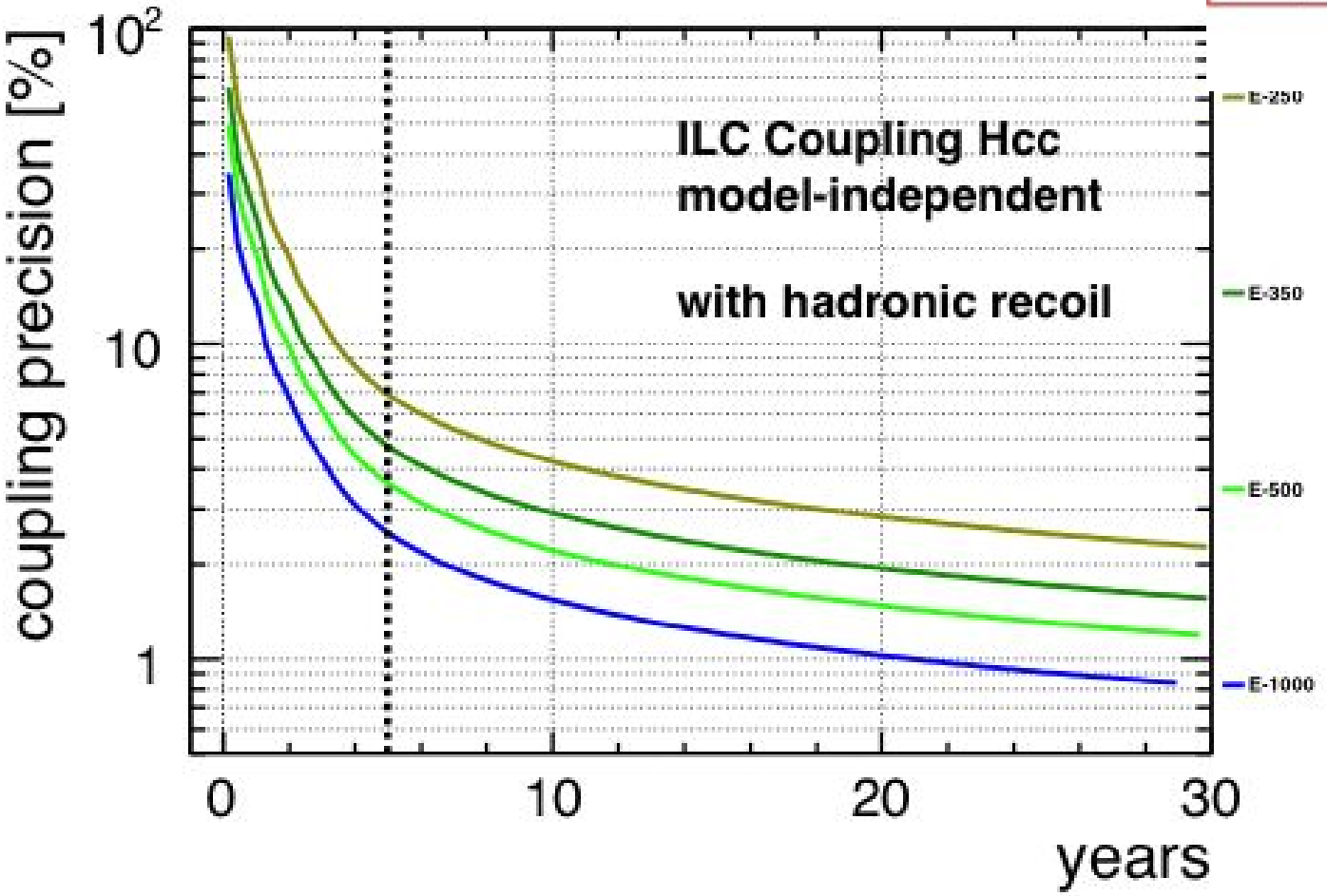
- WW-Fusion:
  - g_{HWW}
  - High rates, precision $\sigma \times BR$

Coupling precisions for single ECM

The higher E_{CM} the better for:

- H->bb, H->cc, H->gg, H- μμ, H->γγ
- ttH, ZHH

Run **only** at **this** E_{CM} (with baseline lumi after inital ramp-up)

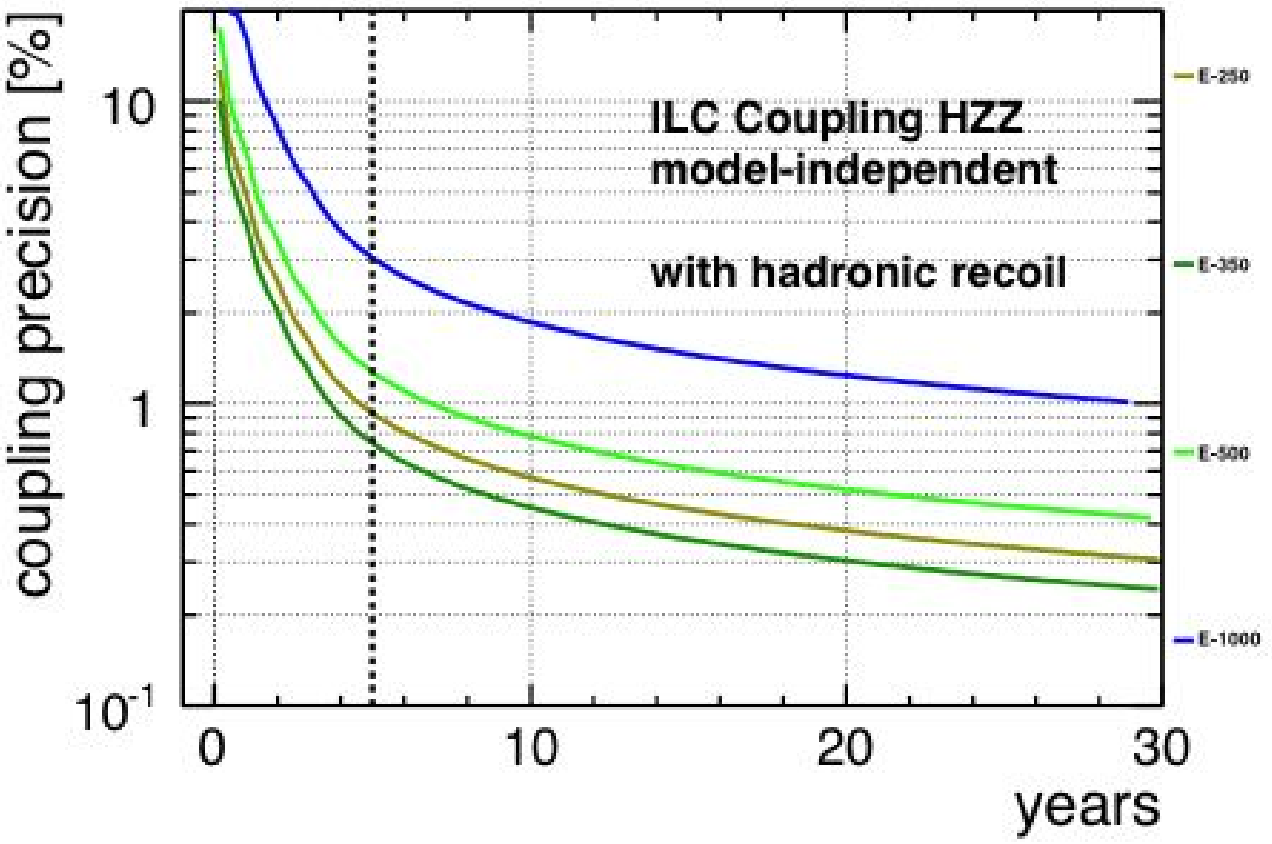


Higgs coupling: special case ZHH

HZZ coupling:

- naively expect best performance at 250 GeV
- but 350 GeV wins in fit since HWW also contributes via global fit

similar:
H->ττ
(absolute value of coupling, CP properties not yet studied!)

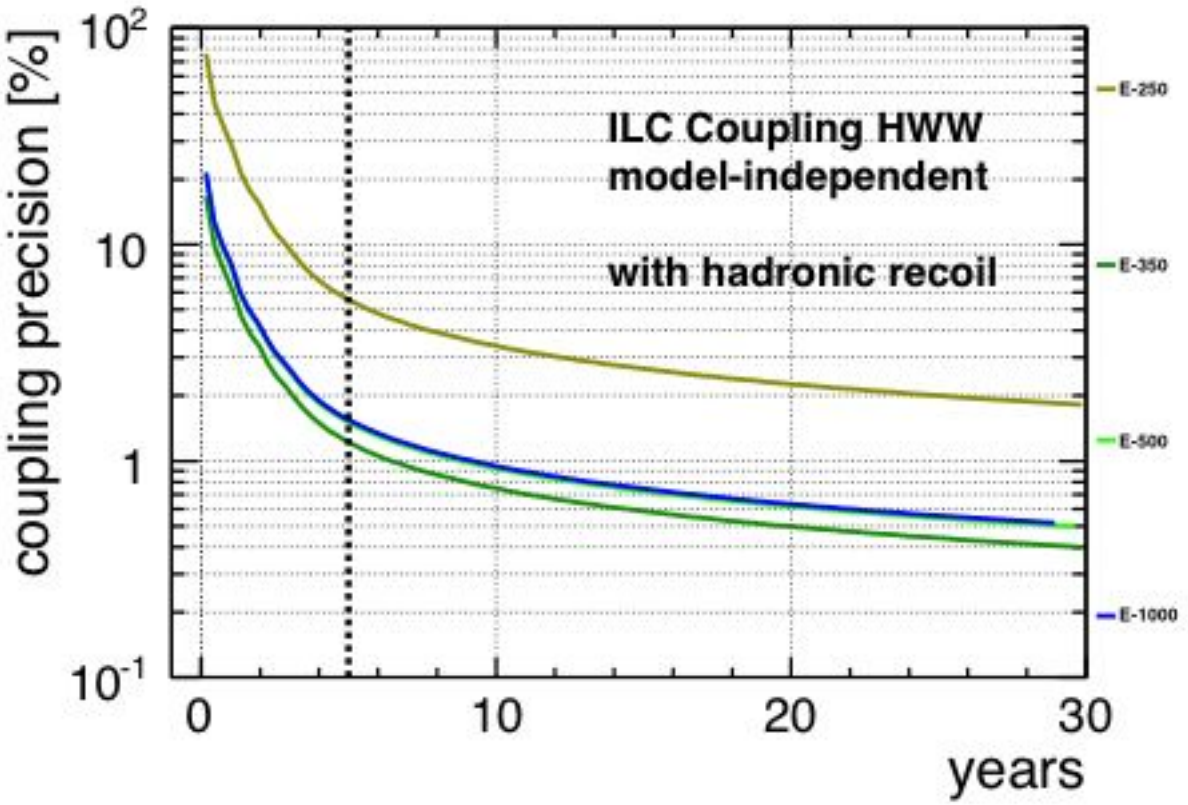


Higgs couplings: special case HWW

HWW coupling:

- naively expect best performance at highest energy
- but **again** 350 GeV wins in fit since HZZ also contributes via fit

Conclusion:
extended 350 GeV run?
... it depends!



Candidate Reasons to prefer 250 over 350 GeV

- Higgs mass from leptonic recoil
  - need δm_H < 20-30 MeV
  - doable at high E_{CM} from H->bb & Co?
  - probably, but currently not yet proven
  - only proven alternative:
    leptonic recoil => ~3ab^{-1} @ 250 GeV ☹

- Higgs -> invisible (95%CL limit)
  - new full sim studies coming in, but still work in progress
  - best sensitivity at 250 GeV with P=(+80%,-30%) (!)
  - impact from global fit?

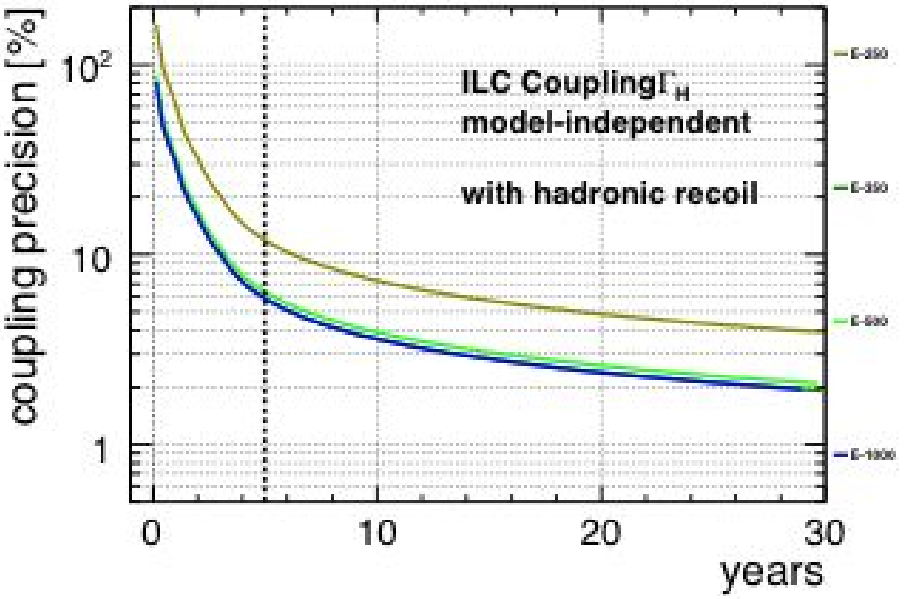
- Higgs -> ττ: CP properties of H-fermion coupling
  - existing studies rely on Z to reconstruct angles in Higgs restframe
    => 250 GeV
  - but: in principle Higgs restframe not needed => could also use
    WW-fusion => higher E_{CM} ???

Higgs->invisible (95% CL)

	previous P=(-80%,+30%)	Mark Thomson	Akimasa Ishikawa	A.I. P=(+80%,-30%)
250 fb-1 @ 250 GeV	0.95%		0.95%	0.69%
350 fb-1 @ 350 GeV	1.5% (Extrap)	1.2%	1.5%	1.4%
500 fb-1 @ 500 GeV	3.2% (Extrap)		3.2%	2.3%

However, from global fit:

- Γ_H better at higher energies
- so BR(H->inv) should behave the same in fit?
- however: remember there is a tiny, tiny model-dependence!



What about CEPC?

- Chinese Electron Positron Collider assumes:
  - instantaneous lumi: 1.8 – 2.0 x 10^{34} /cm^2 /s x 2 IPs
  - integrated luminosity at 250 GeV
    from ICFA-Seminar presentation: 5 ab^{-1}
- no official power estimate yet, but priv. comm:
  - total power consumption (prel.): **several 100 MW**

How does this compare to ILC at 250 GeV?

	CEPC	5 Hz, 1315 bunches	10 Hz, 1315 bunches	10 Hz, 2625 bunches
inst. lumi [10^{34} / cm^2 / s]	**3.6 - 4**	0.75	1.5	**3**
total power [MW]	**498**	100	160 ?	**190**

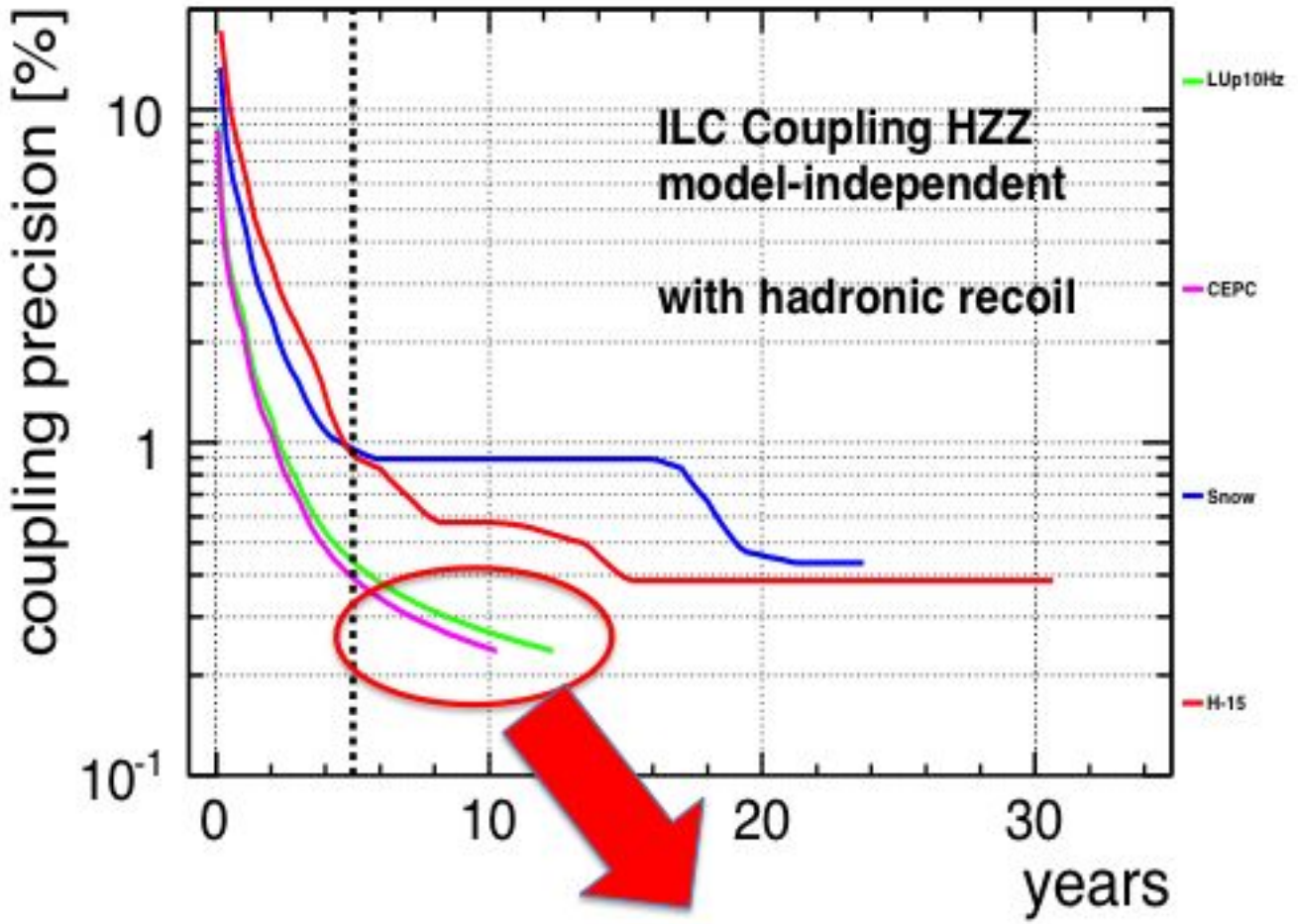
⇒ ILC: 75% of CEPC lumi for ~40% of CEPC power

- not a bad deal !!!

[also interesting: how do CEPC and FCC-ee numbers compare? Are their assumptions consistent?]

=> we don't have a scientific problem
– but a communication / presentation problem!

But for the fun of it...



Build 500 GeV full power (~RDR) right away and run it at 250 GeV in 10 Hz mode

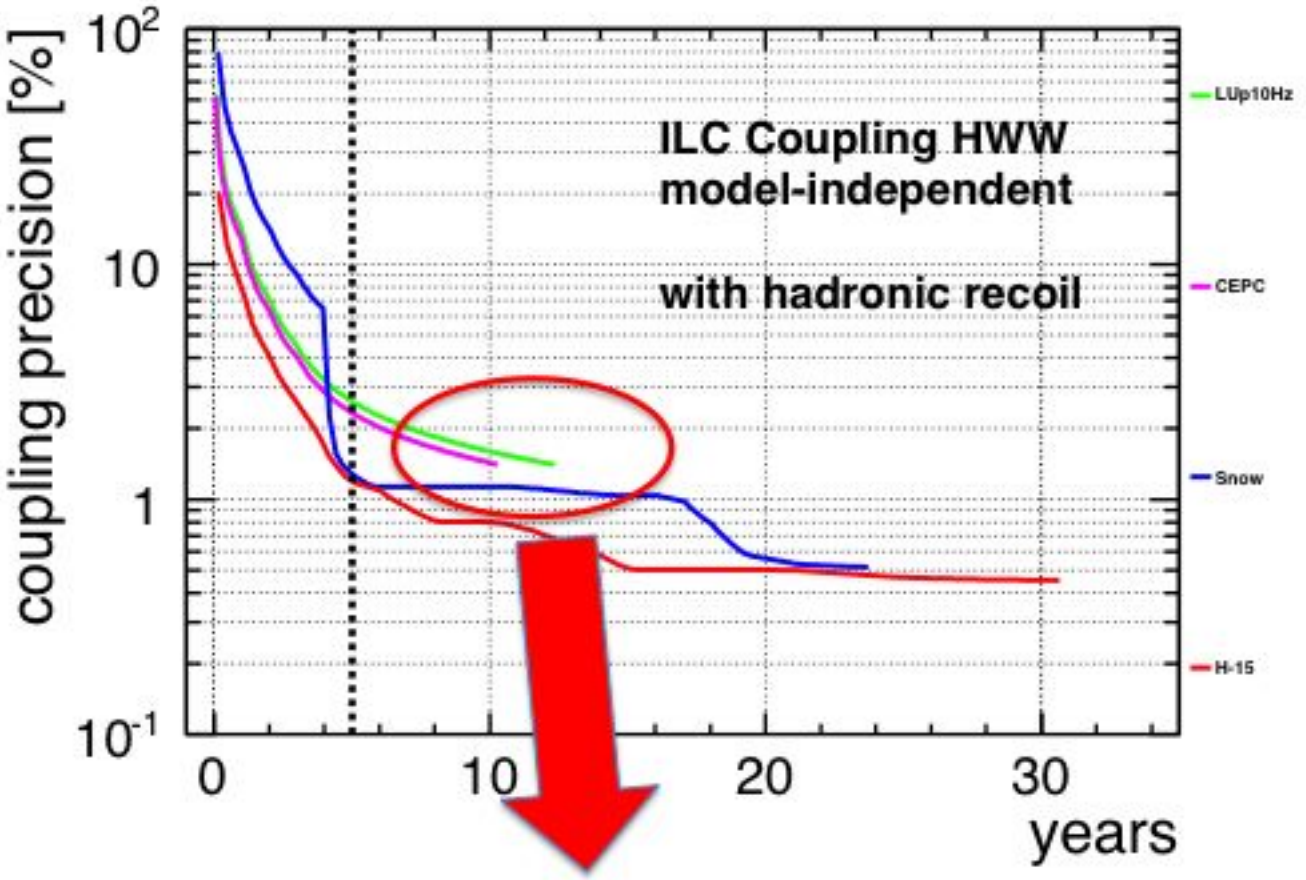
CPEC

Snowmass

our new 15 year scenario

nearly the same for less than half the power!

But fot the fun of it ....



Build 500 GeV full power (~RDR) right away and run it at 250 GeV in 10 Hz mode

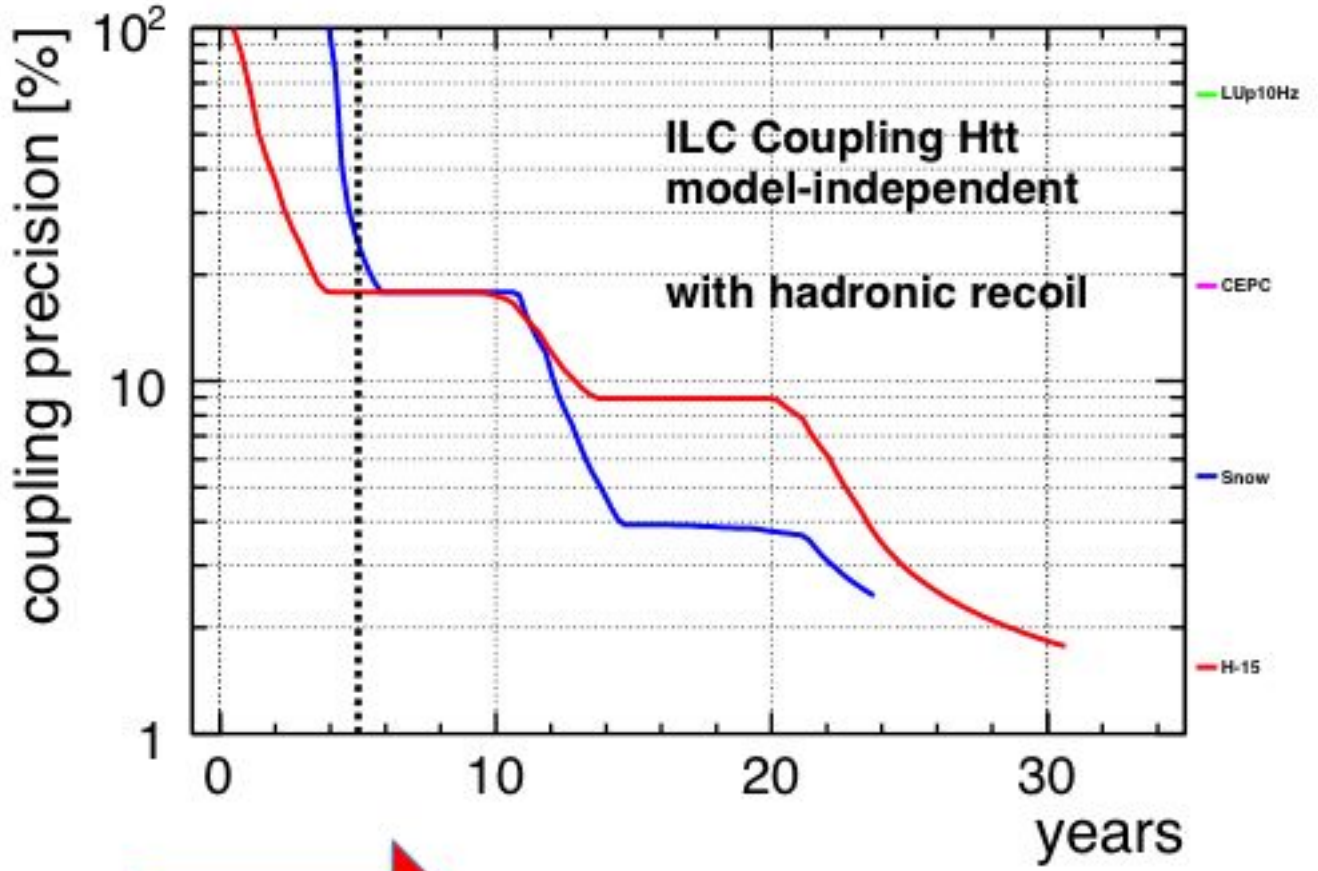
CPEC

Snowmass

our new 15 year scenario

HWW difficult with 250 GeV only

... and no direct ttH, ZHH, ... at all



Build 500 GeV full power (~RDR) right away and run it at 250 GeV in 10 Hz mode

CPEC

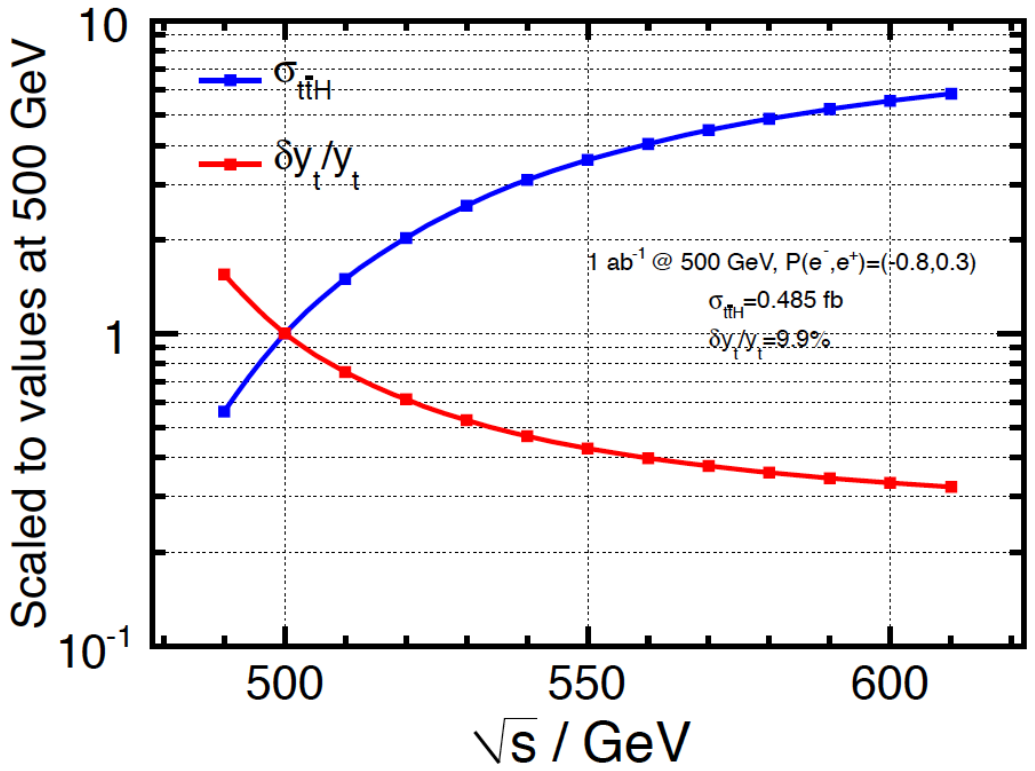
Snowmass

our new 15 year scenario

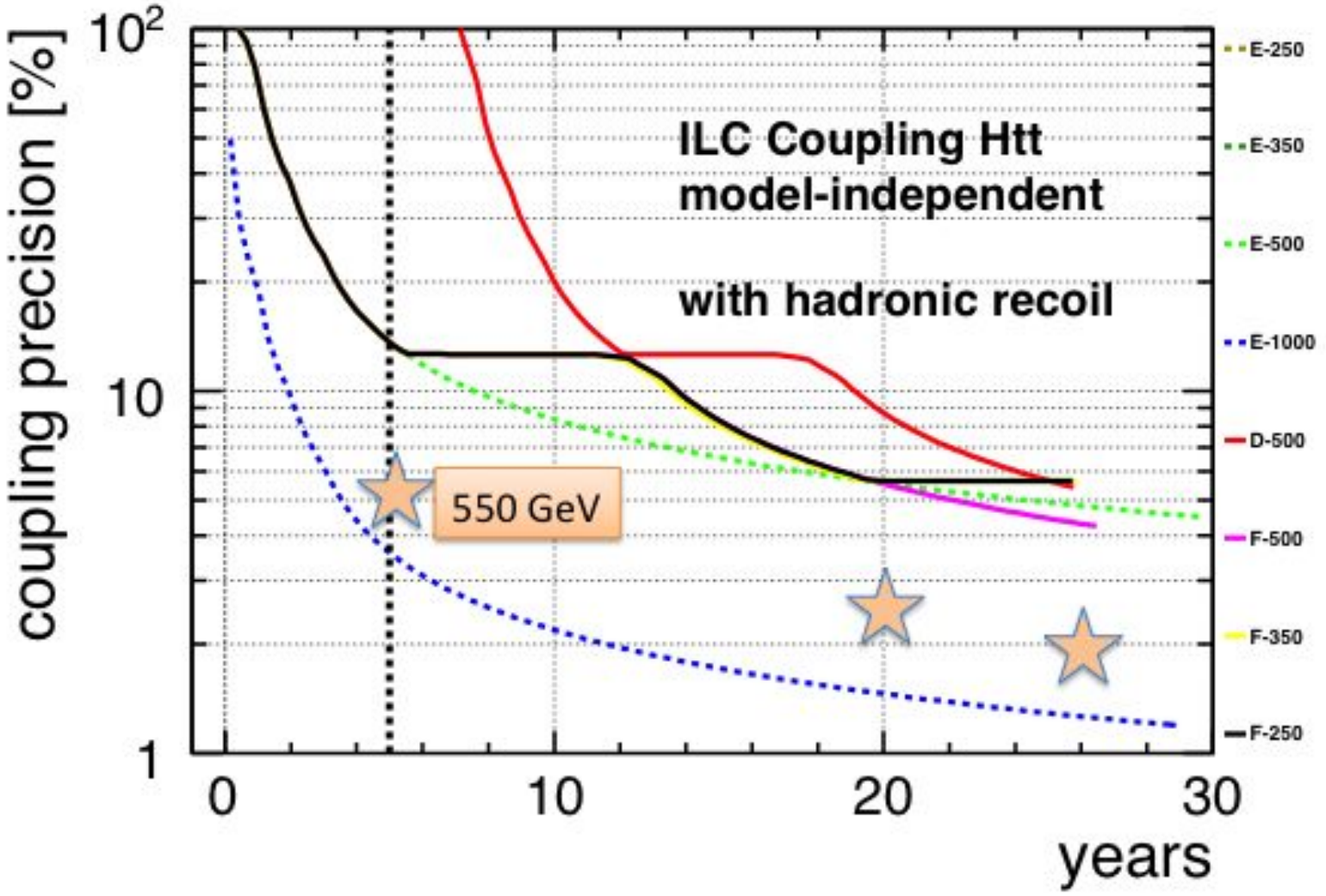
no ttH at all with 250 GeV only

ttH: 500 GeV vs 550 GeV

- 550 GeV gives a factor 2.4 improvement over 500 GeV (for same integrated luminosity)
- below 500 GeV: sensitivity **vanishes** quickly!



ttH: 550 GeV nearly as good as 1 TeV



500 GeV

1 TeV

Running scenarios for ILC500

- Consider 3 scenarios of ~20 years *realtime*
  - ramp-up of luminosity at beginning and after changes to the machine
  - Shutdown for **luminosity upgrade**
  - Stick with “baseline” energies (500,350,250 GeV)
  - Start at 500 GeV:
    1. How much luminosity at 250/350 GeV?
    2. When to do luminosity upgrade?
  - **Use spare RF&Cryo power to run at higher rep rate:**
    500 GeV: 5 Hz , 250 GeV: 10 Hz, 350 GeV: 7 Hz
- Compare to the scenario assumed in the ILC Higgs Whitepaper for Snowmass

The scenarios

- G-20: focus on 500 GeV data taking, lumiUP @ 10y
- H-20/I-20: include extended run at 250/350 GeV
  (nearly) without reduction of 500 GeV data
  due to earlier luminosity upgrade

	$\int \mathcal{L} dt$ [fb^{-1}]			
$\sqrt{s}$	G-20	H-20	I-20	Snow
250 GeV	500	2000	500	1150
350 GeV	200	200	1700	200
500 GeV	5000	4000	4000	1600

- Polarisation splittings (for all scenarios)

	fraction with sgn($P(e^-), P(e^+)$) =			
	(-,+)	(+,-)	(-,-)	(+,+)
$\sqrt{s}$	[%]	[%]	[%]	[%]
250 GeV	67.5	22.5	5	5
350 GeV	67.5	22.5	5	5
500 GeV	40	40	10	10

G-20 & H(I)-20

- G-20:

	$\sqrt{s}$	$\int \mathscr{L} dt$	L_{peak}	Ramp				T	T_{tot}	Comment
	[GeV]	[fb^{-1}]	[fb^{-1}/a]	1	2	3	4	[a]	[a]	
Physics run	500	1000	288	0.1	0.3	0.6	1.0	5.5	5.5	TDR nominal at 5 Hz
Physics run	350	200	160	1.0	1.0	1.0	1.0	1.2	6.7	TDR nominal at 5 Hz
Physics run	250	500	240	0.25	0.75	1.0	1.0	3.1	9.8	operation at 10 Hz
Shutdown								1.5	11.3	Luminosity upgrade
Physics run	500	4000	576	0.1	0.5	1.0	1.0	8.4	19.7	TDR lumi-up at 5 Hz

- H-20 (I-20 the same but last run at 350 GeV with 7Hz)

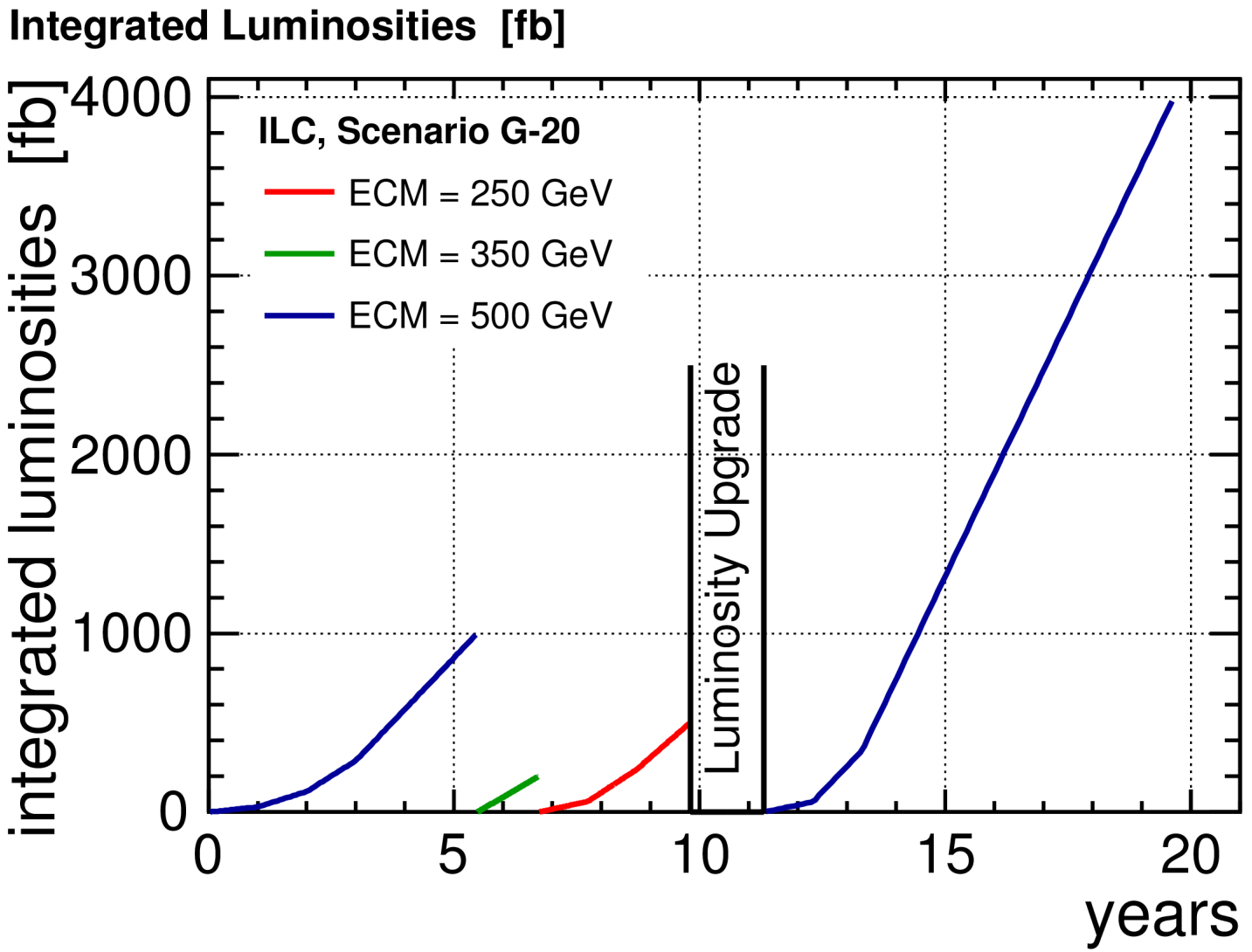
	$\sqrt{s}$	$\int \mathscr{L} dt$	L_{peak}	Ramp				T	T_{tot}	Comment
	[GeV]	[fb^{-1}]	[fb^{-1}/a]	1	2	3	4	[a]	[a]	
Physics run	500	500	288	0.1	0.3	0.6	1.0	3.7	3.7	TDR nominal at 5 Hz
Physics run	350	200	160	1.0	1.0	1.0	1.0	1.3	5.0	TDR nominal at 5 Hz
Physics run	250	500	240	0.25	0.75	1.0	1.0	3.1	8.1	operation at 10 Hz
Shutdown								1.5	9.6	Luminosity upgrade
Physics run	500	3500	576	0.1	0.5	1.0	1.0	7.4	17.0	TDR lumi-up at 5 Hz
Physics run	250	1500	480	1.0	1.0	1.0	1.0	3.2	20.2	lumi-up operation at 10 Hz

Scenario “Snow”

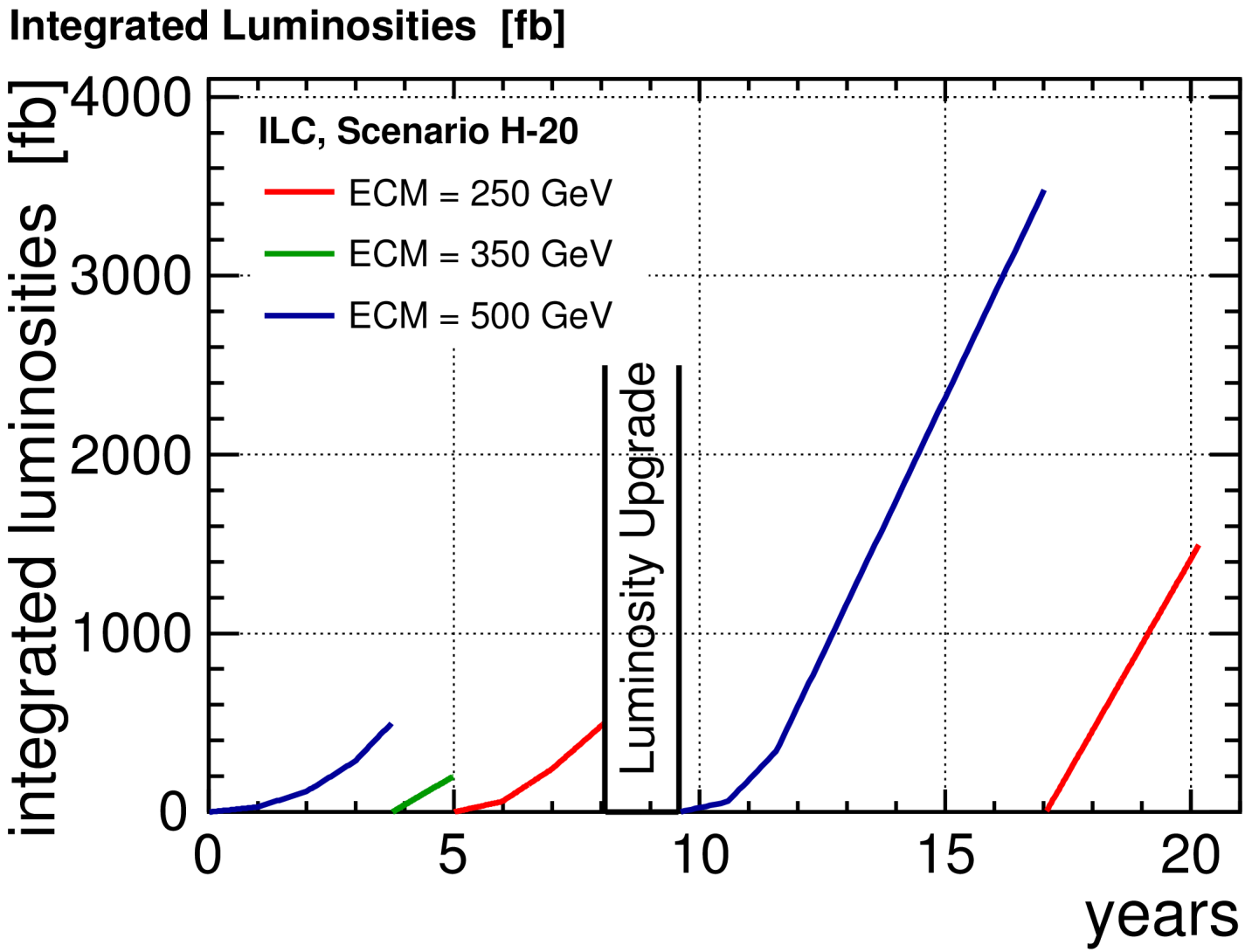
- Inspired by Snowmass, but
  - Added top threshold scan
  - No 1 TeV
  - Same polarisation mix as for the other scenarios (orig. Snowmass was *only* LR)

	$\sqrt{s}$	$\int \mathcal{L} dt$	L_{peak}	Ramp				T	T_{tot}	Comment
	[GeV]	[fb^{-1}]	[fb^{-1}/a]	1	2	3	4	[a]	[a]	
Physics run	250	250	120	0.1	0.3	0.6	1.0	4.1	4.1	TDR nominal at 5 Hz
Physics run	500	500	288	1.0	1.0	1.0	1.0	1.7	5.8	TDR nominal at 5 Hz
Physics run	350	200	160	1.0	1.0	1.0	1.0	1.3	7.1	TDR nominal at 5 Hz
Shutdown								1.5	8.6	Luminosity upgrade
Physics run	250	900	480	0.1	0.5	1.0	1.0	3.0	11.8	lumi-up operation at 10 Hz
Physics run	500	1100	576	1.0	1.0	1.0	1.0	2.0	13.8	TDR lumi-up at 5 Hz

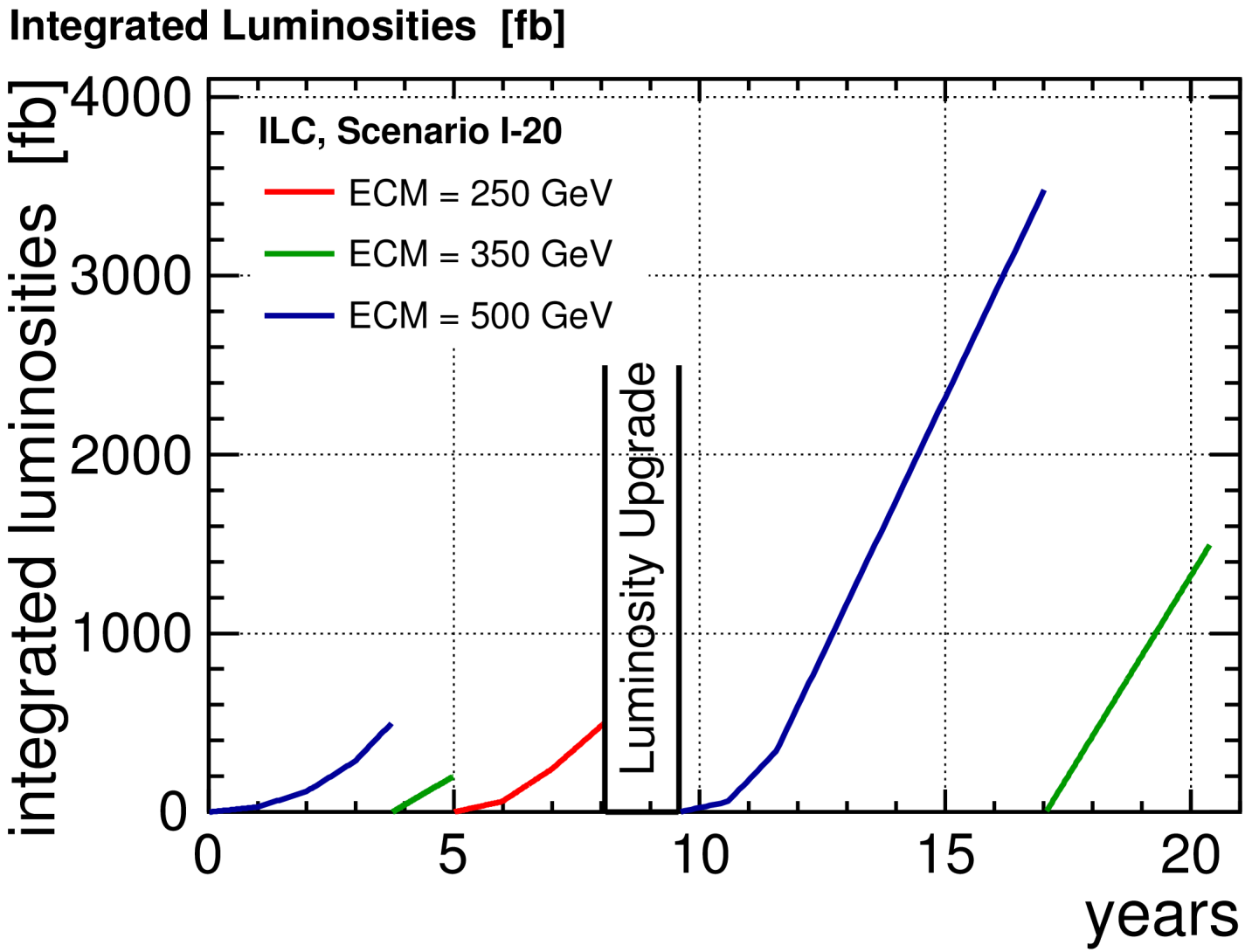
G-20


Integrated Luminosities [fb]
ILC, Scenario G-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
Luminosity Upgrade
integrated luminosities [fb]
4000
3000
2000
1000
0
0
5
10
15
20
years

H-20


Integrated Luminosities [fb]
ILC, Scenario H-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
Luminosity Upgrade
integrated luminosities [fb]
4000
3000
2000
1000
0
0
5
10
15
20
years

I-20


Integrated Luminosities [fb]
ILC, Scenario I-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
Luminosity Upgrade
integrated luminosities [fb]
4000
3000
2000
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0
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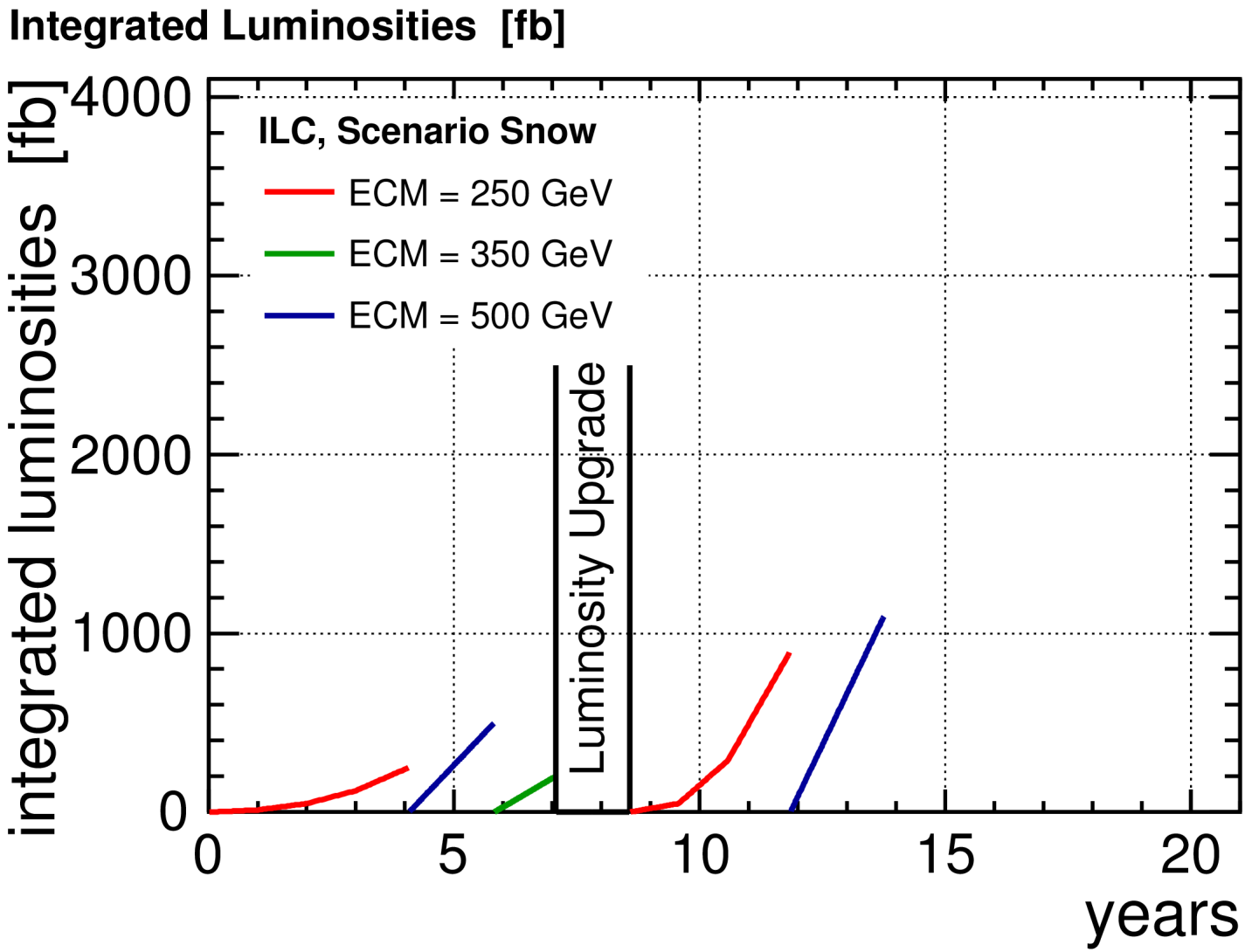
15
20
years

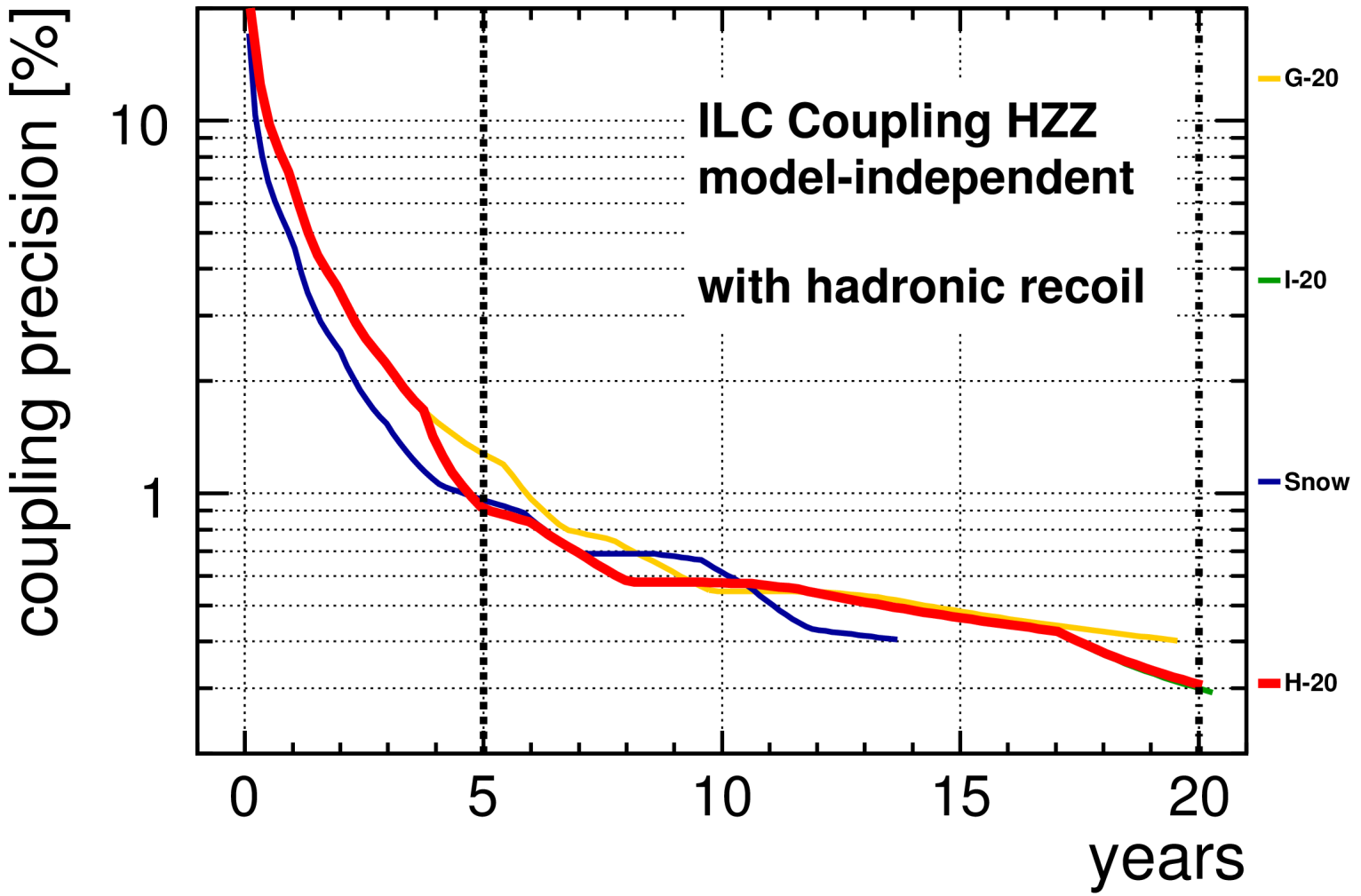
Snow


Integrated Luminosities [fb]
ILC, Scenario Snow
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
Luminosity Upgrade
integrated luminosities [fb]
4000
3000
2000
1000
0
0
5
10
15
20
years

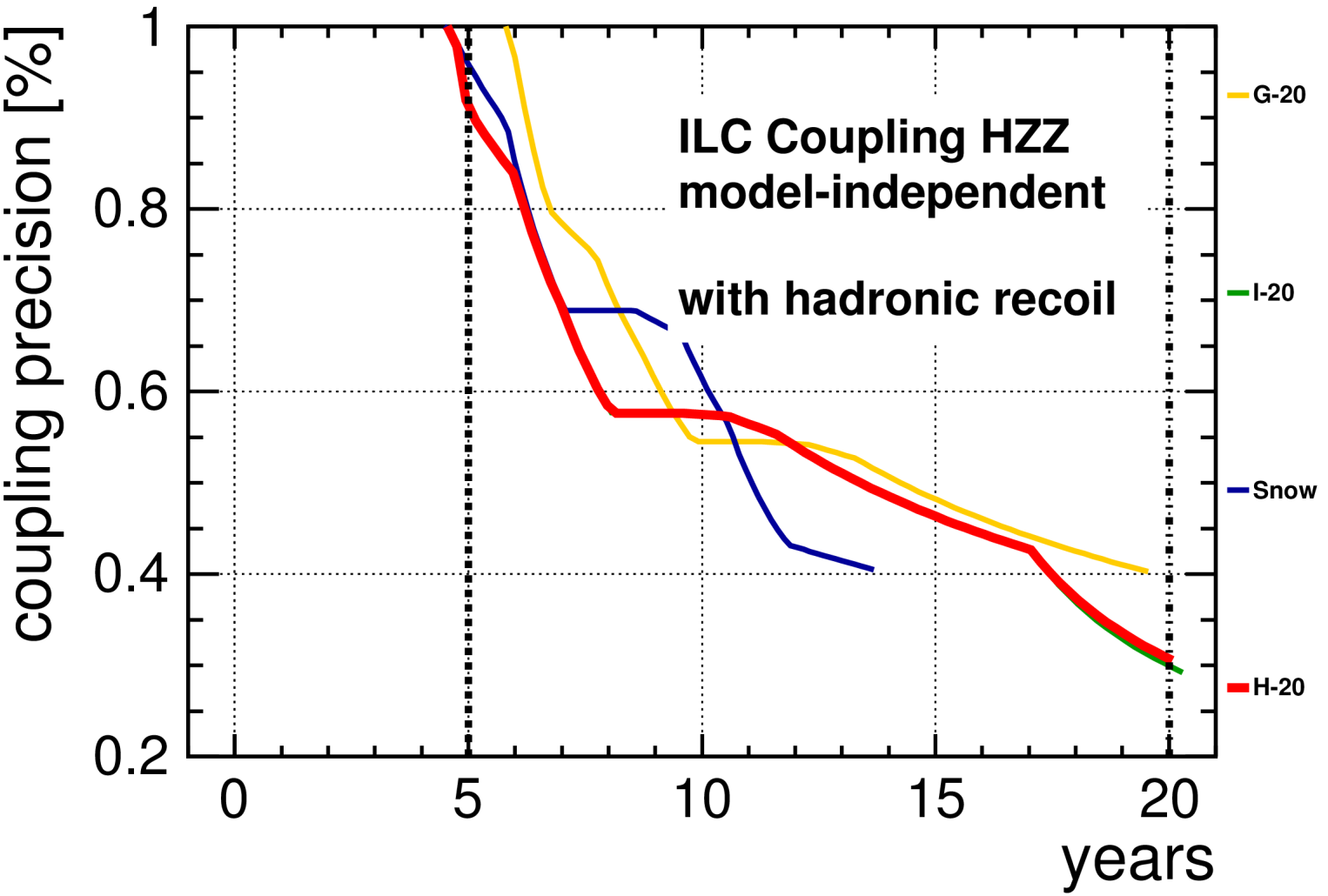
Big questions for running scenarios

- Is it possible to measure the total ZH cross-section in a sufficiently model-indepent way at ECM > 250 GeV from hadronic recoil?
  - residual decay-mode dependency of selection?
  - migration from off-shell region (M > 150 GeV) into signal region?
- Do we have alternatives to the leptonic recoil at 250 GeV for measuring M_H at the 20 MeV level?
  - Kinematic reconstruction of H->bb ?
  - Kinematic reconstruction of H->WW* ?

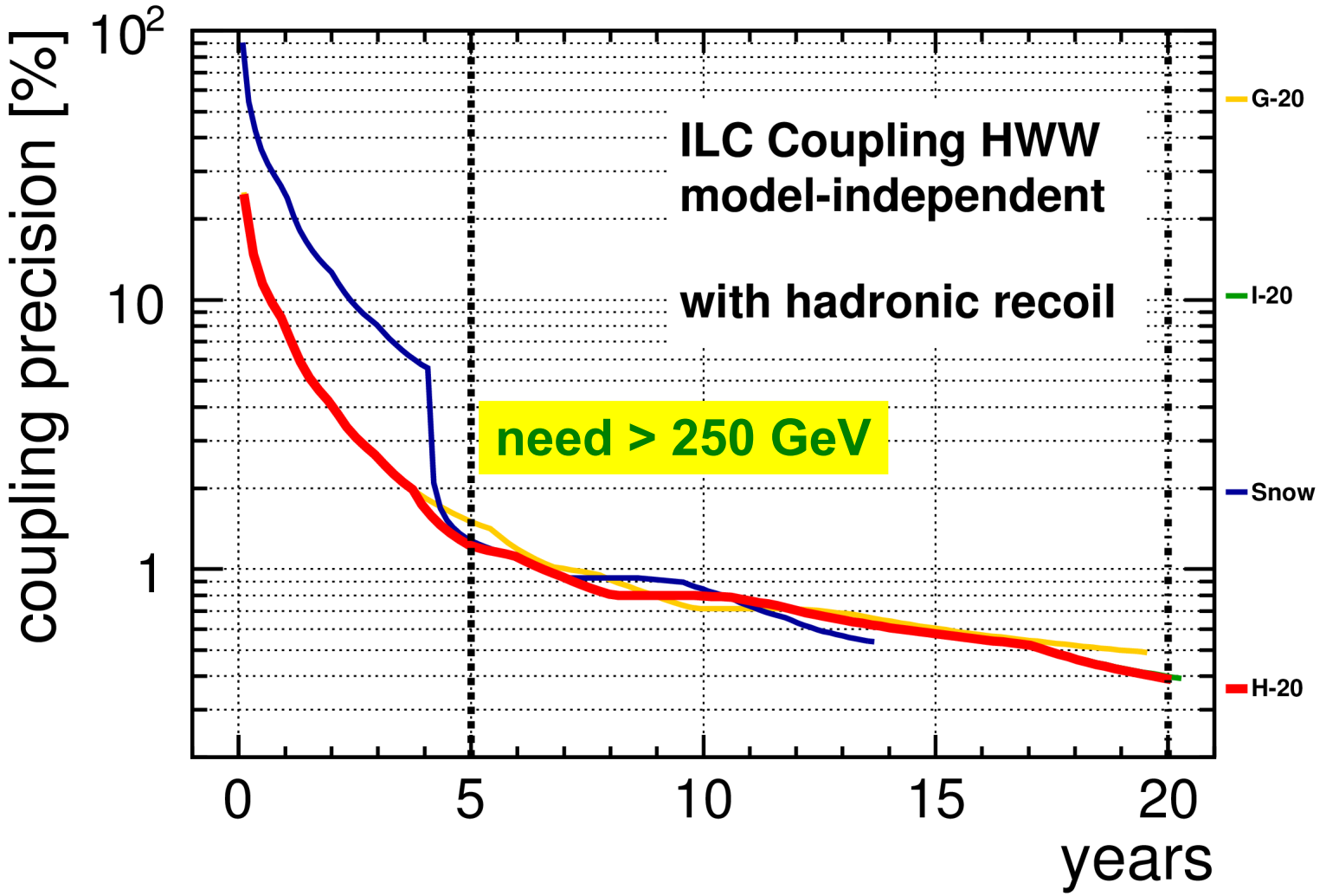
HZZ coupling – log scale



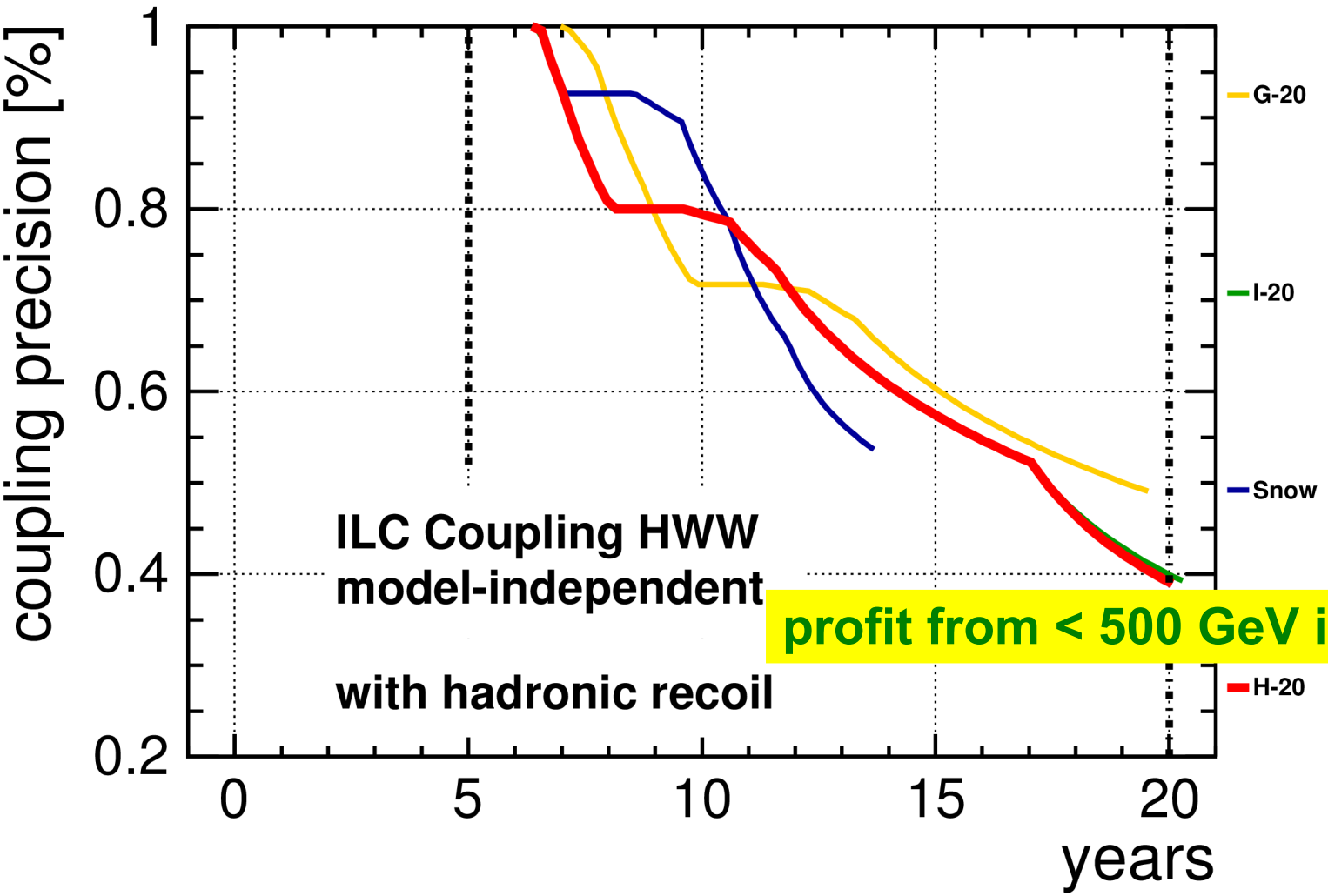
HZZ coupling – lin scale



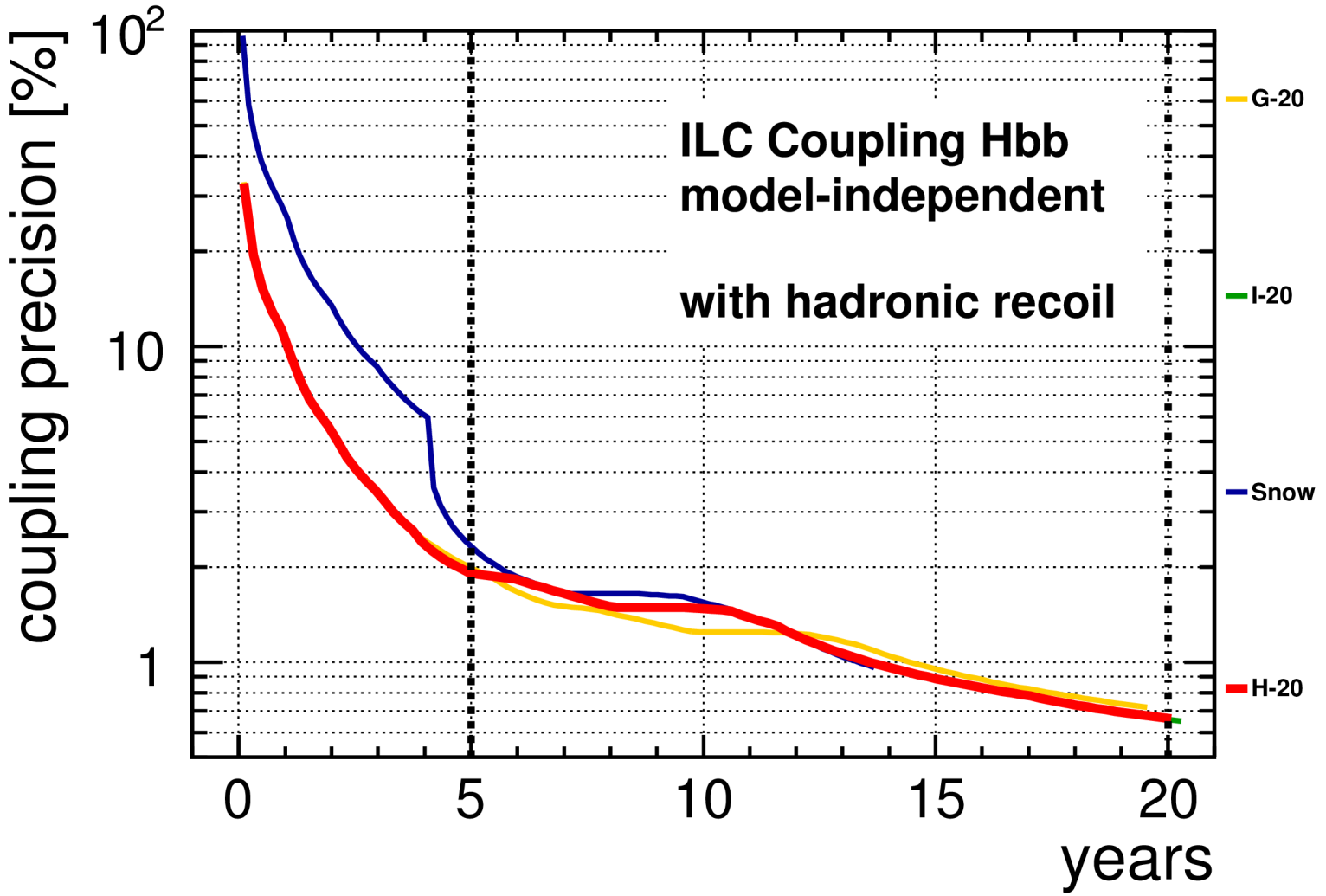
HWW coupling – log scale



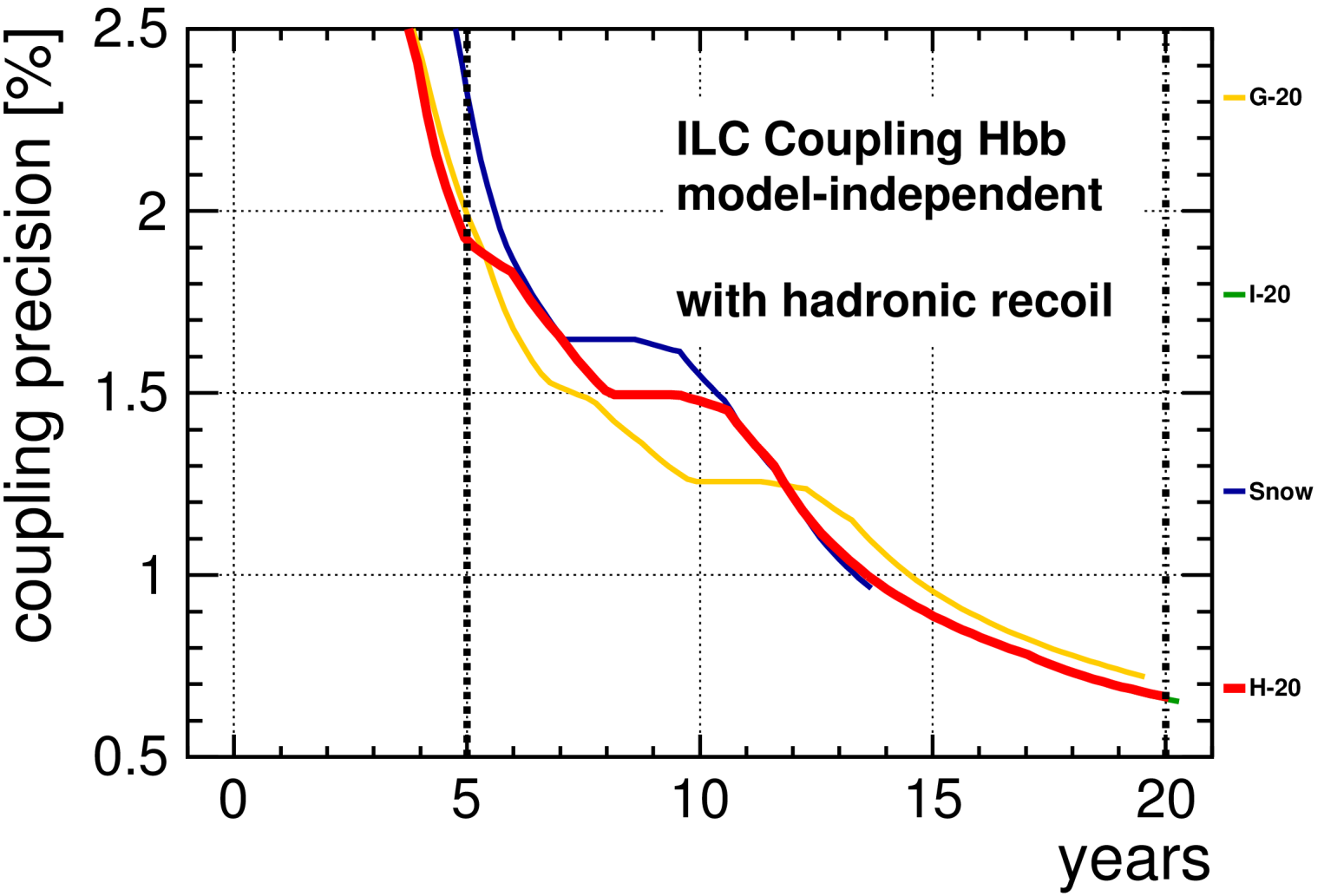
HWW coupling – lin scale



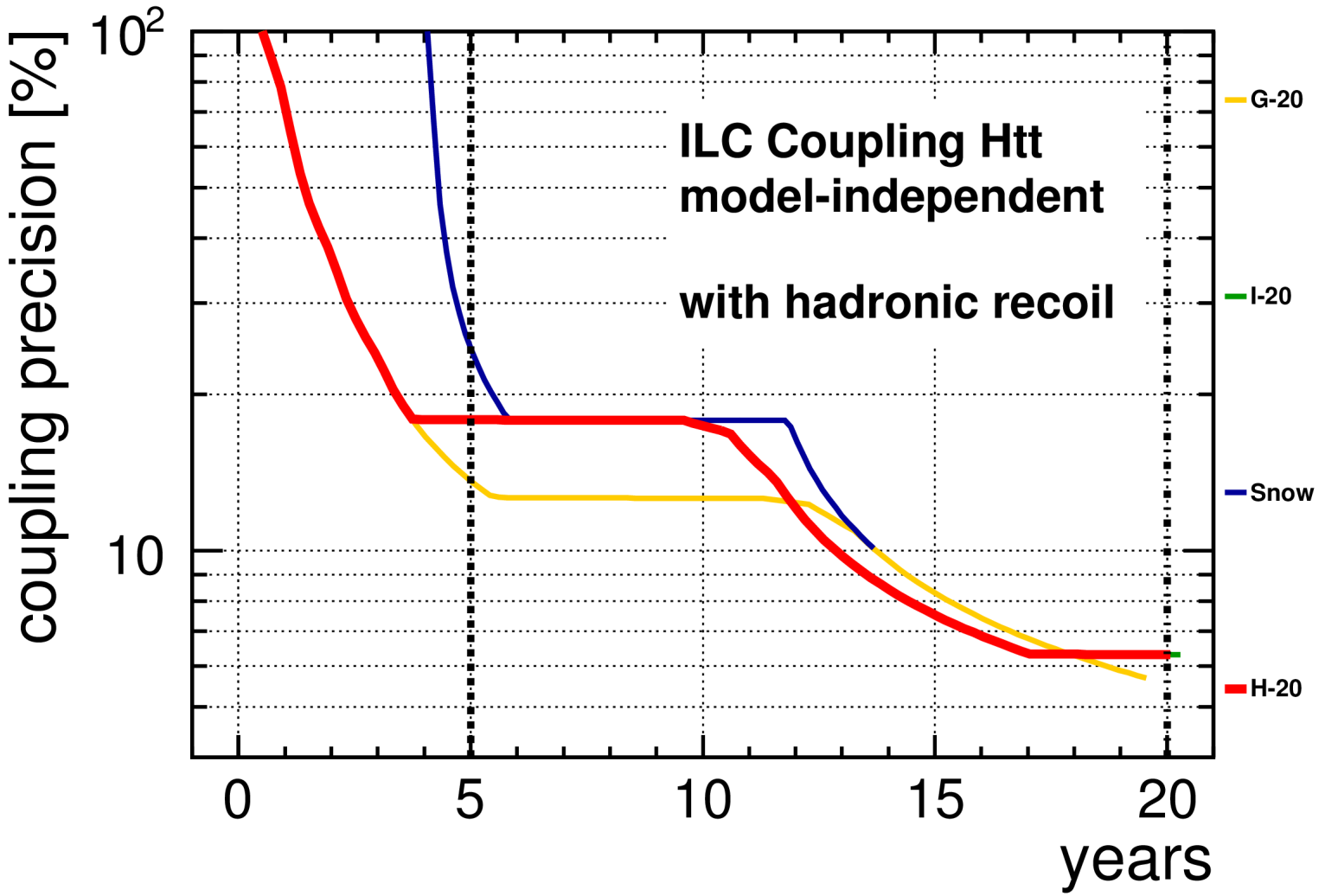
Hbb coupling – log scale



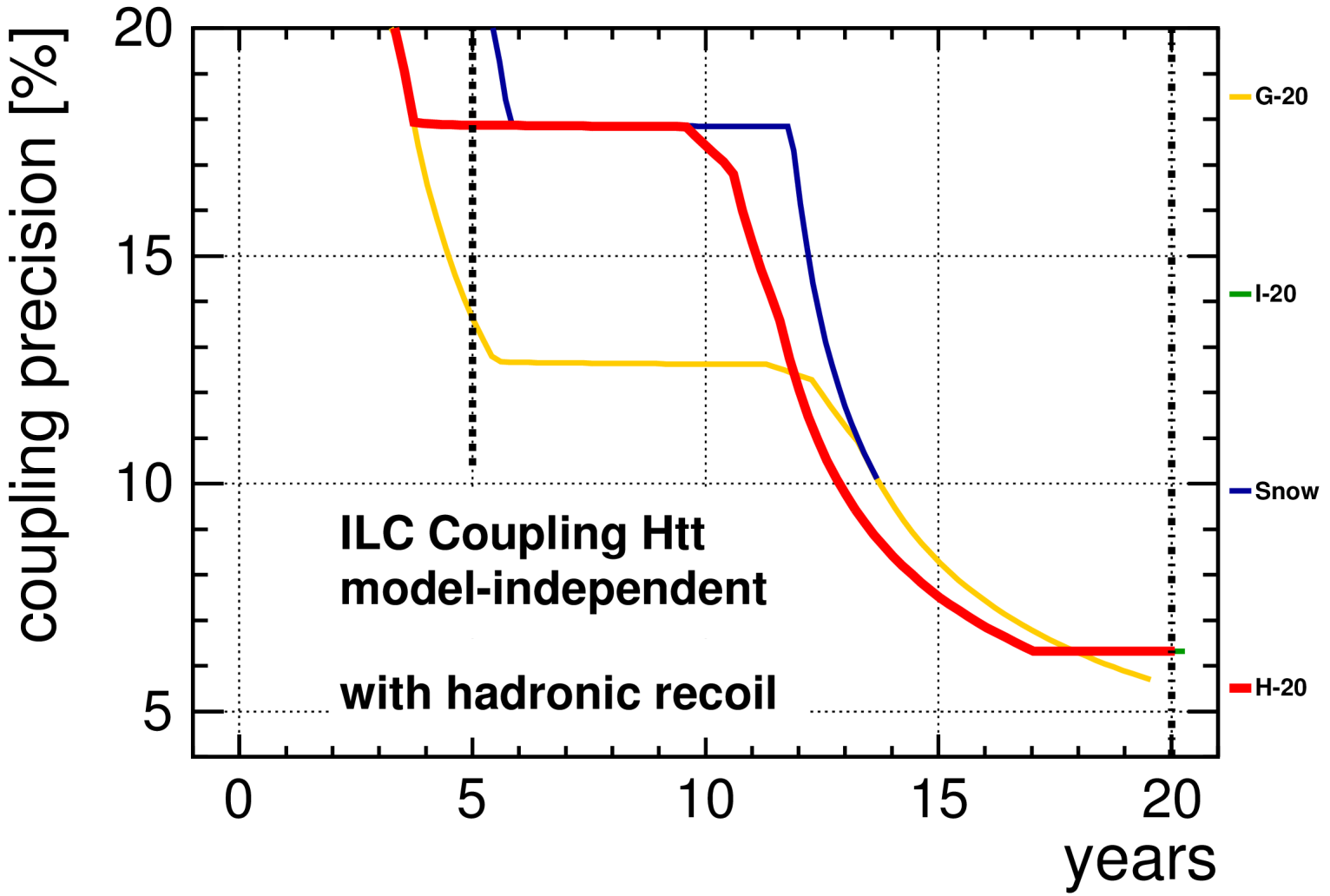
Hbb coupling – lin scale



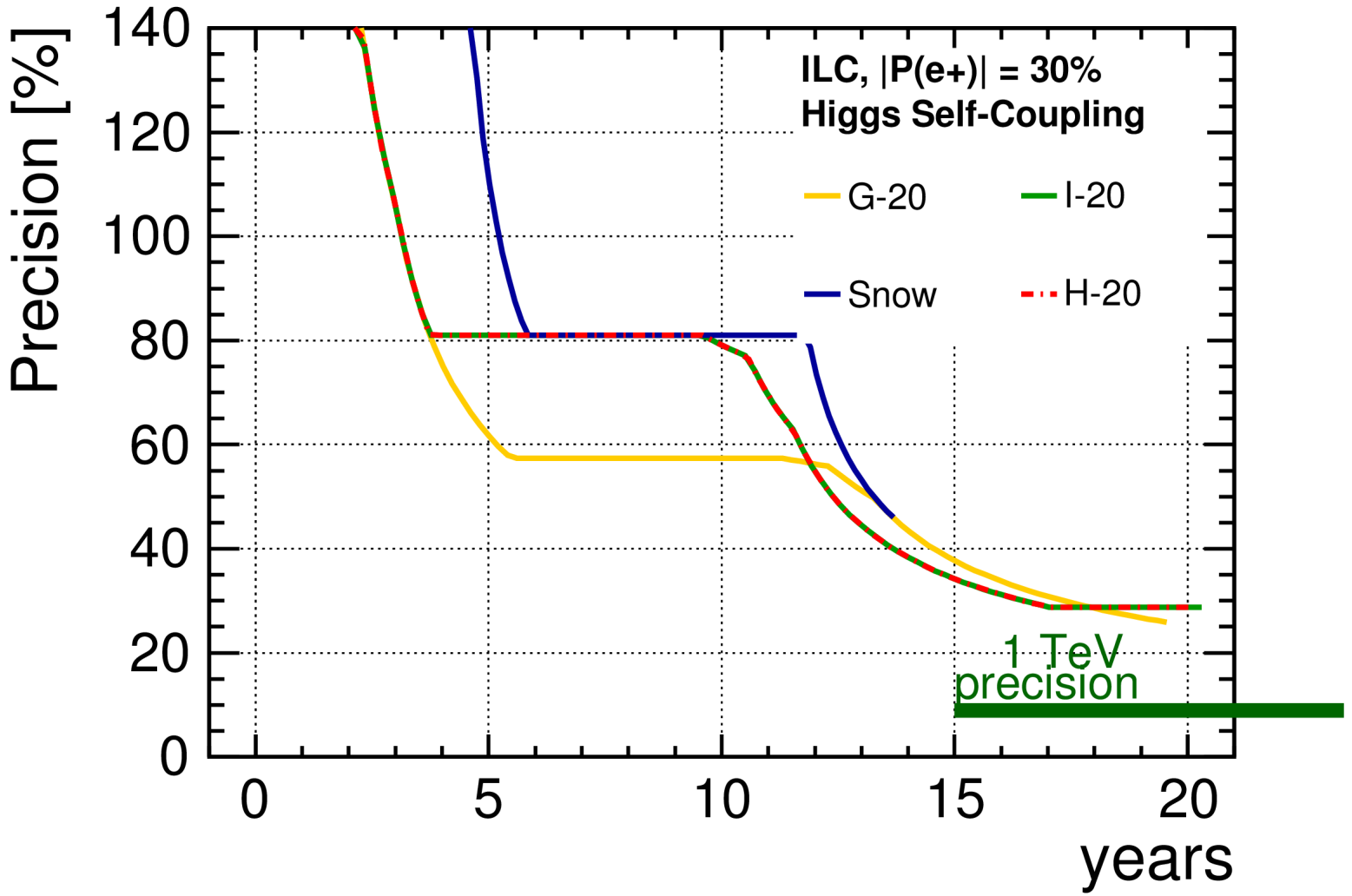
Htt coupling – log scale



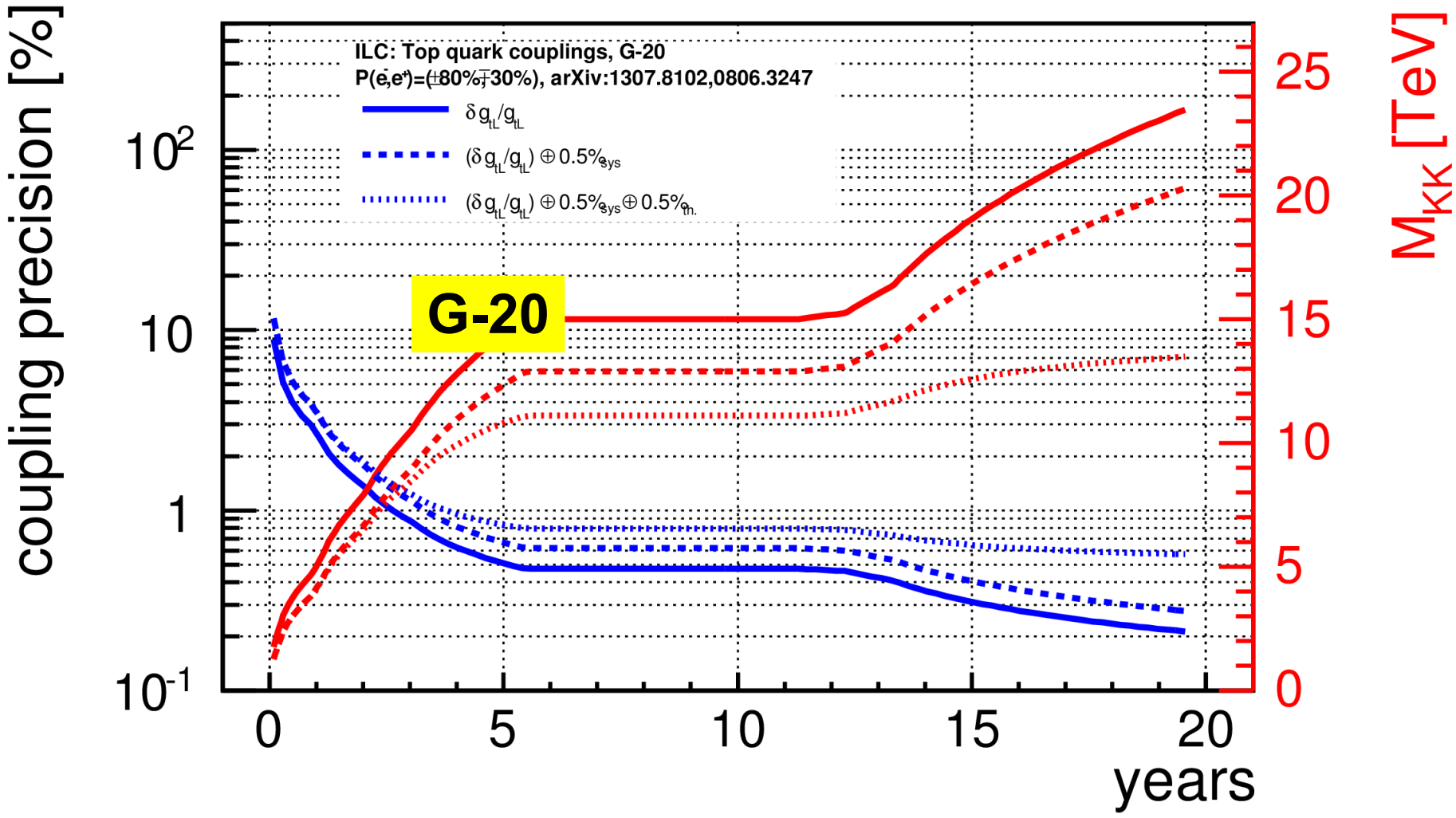
Htt coupling – lin scale



Higgs Self-coupling



Top EW Couplings & Sensitivity to KK Scale



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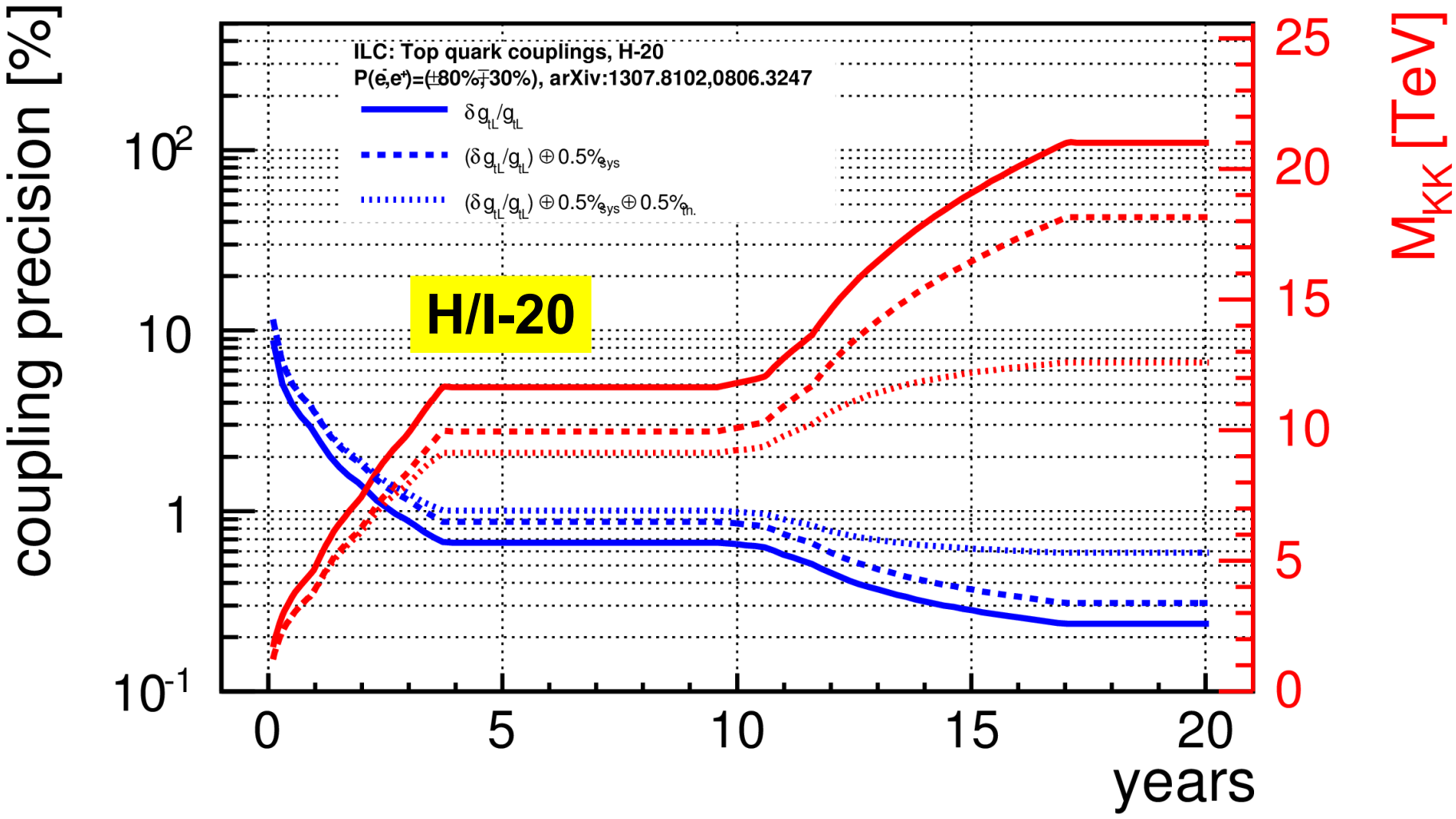
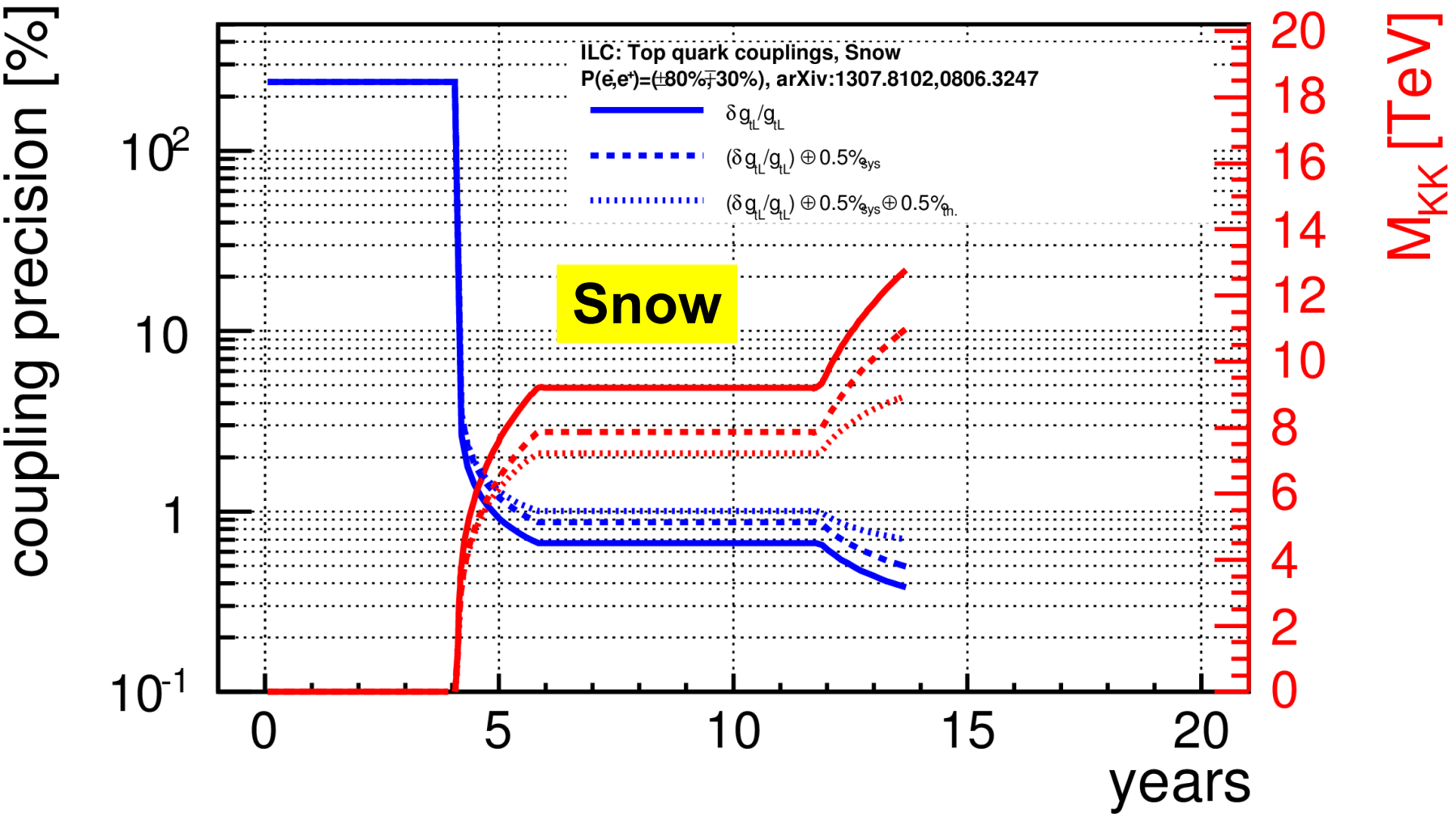
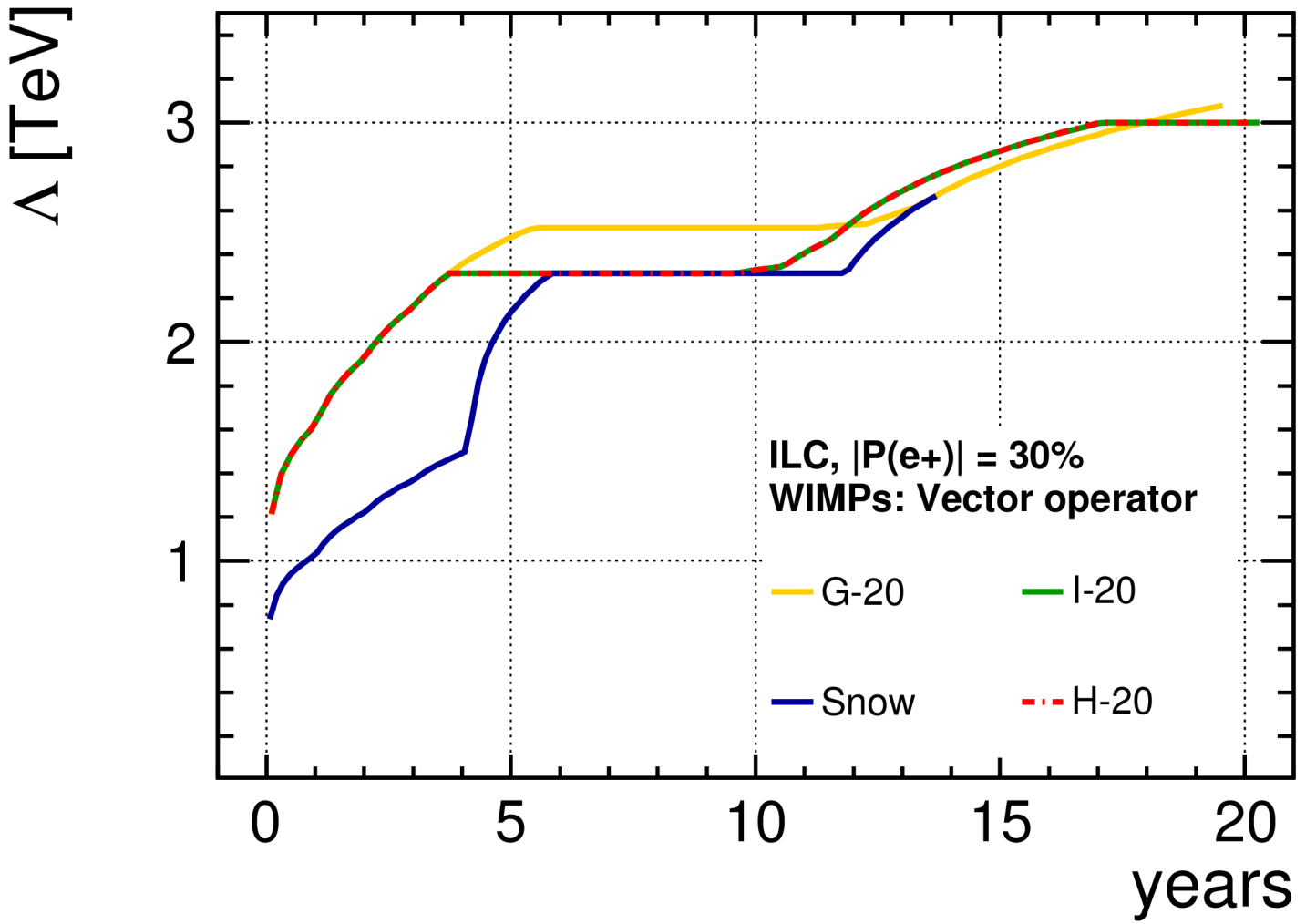


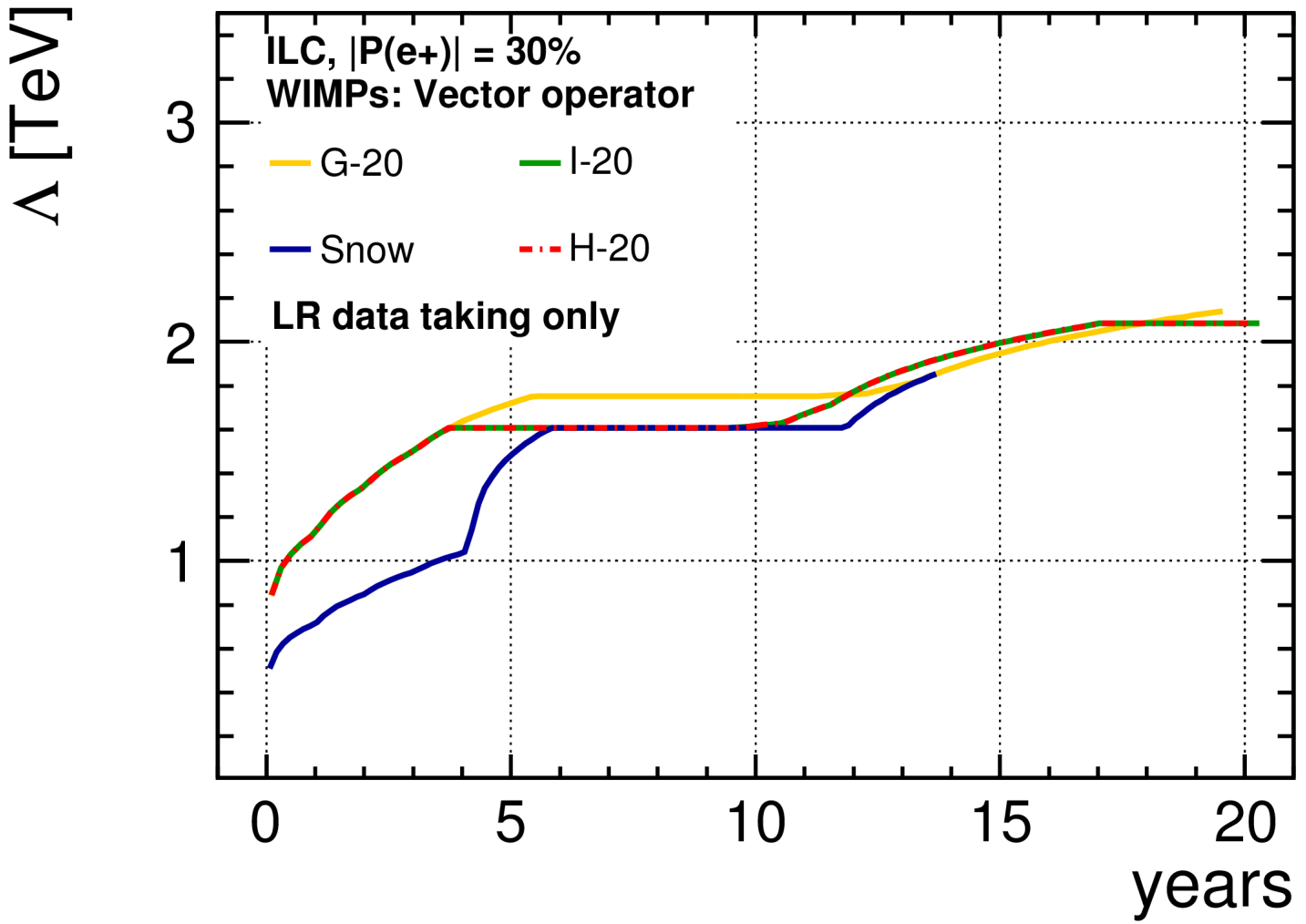
Top EW Couplings & Sensitivity to KK Scale



Dark Matter Sensitivity (M=10 GeV, Vector)



Dark Matter Sensitivity – only LR data



Conclusions I – Early Performance

***Early* Physics performance** significantly improves when starting at 500 GeV (wrt start at 250/350 GeV):

- ttH, triple-Higgs-coupling: **unreachable at < 500 GeV**
- H -> μμ, γγ, gg, cc, bb: substantially better
- ΓH, H -> ττ, HWW: about equal
- HZZ: worse, ultimately needs some 250/350 GeV data
- mH: probably fine with 500 GeV as well. If not: needs *lots* of 250 GeV data

Plus: Searches, Triple & Quartic Gauge couplings, top couplings ....

Starting operation at 350 GeV might be a fall-back, but *not* the "publicity scenario"!

Conclusions II – Final Performance

No striking differences in *final* Higgs physics performance, except:

- ttH & Triple-Higgs-coupling:
  prefer maximum lumi at 500GeV,
  will be superseeded by few years at 1 TeV!
  (but note: ttH @ 550 GeV nearly as good as at 1 TeV...)
- HZZ: ultimately profits from lots of 250 or 350 GeV data
- mH: probably fine with 500 GeV as well.
  If not: needs *lots* of 250 GeV data

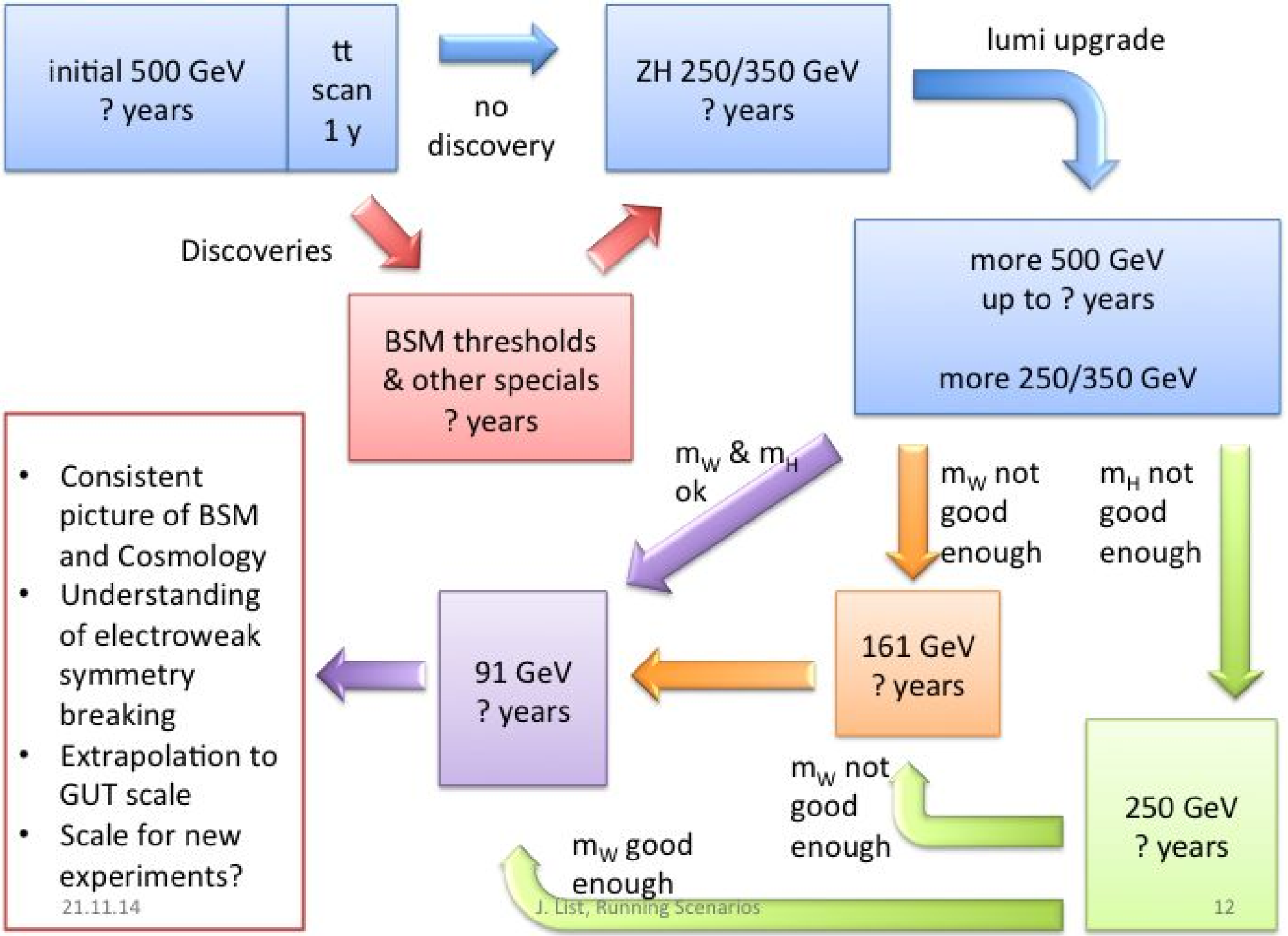
Balance a long run at 500 GeV vs 1 TeV upgrade ?!

What's next?

- For now:
  - suggest H-20 as baseline to PAC/LCC/LCB
  - ask for official support for the “beyond TDR” features:
    - luminosity upgrade
    - > 5 Hz running for physics
      (entails longer undulator instead of 10 Hz for e+ production!)
- If successful, this will be a significant improvement of the physics potential of the machine
- in parallel we should
  - understand better amount of data required at 250 / 350 GeV
  - be prepared to scale results to higher luminosities!
  - take care about systematic uncertainties, exp & theo!

The wider perspective

.... my private view...


initial 500 GeV
? years
tt
scan
1 y
no
discovery
ZH 250/350 GeV
? years
lumi upgrade
Discoveries
BSM thresholds
& other specials
? years
more 500 GeV
up to ? years
more 250/350 GeV
m_W & m_H
ok
m_W not
good
enough
m_H not
good
enough
91 GeV
? years
161 GeV
? years
m_W not
good
enough
250 GeV
? years
m_W good
enough
• Consistent picture of BSM and Cosmology
• Understanding of electroweak symmetry breaking
• Extrapolation to GUT scale
• Scale for new experiments?
21.11.14
J. List, Running Scenarios
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