ILC Running Scenarios

ILC Parameters Joint Working Group

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Background

- Construction of the full 500 GeV ILC from the start remains the preferred plan of the LCC
  - In response to 2013 suggestion (JAHEP) that a staged approach might be necessary the WG was charged to prepare a discussion on staging should it be necessary
  - Working group presented staging report to LCWS14 in Belgrade (ILC-NOTE-2015-066)
- Second recent study has been prepared
  1. to compare various running scenarios for a 500 GeV machine
  2. to recommend a standard set of total integrated luminosities for use in physics studies

Construct 500 GeV from start

- 500 GeV scenarios study
  - TDR Baseline
  - Emphasizes higher energy - strength of ILC
- Study parameters
  - assume 20 years of operation
  - compare 3 scenarios (studied more)
    - G20, H20, I20
  - Snowmass white paper studied also for comparison
    - arXiv:1310.0763 [hep-ph]
- Draft report: http://pages.uoregon.edu/jimbrau/temp/parameters-draft-150419.pdf - comments welcome!

Assumptions

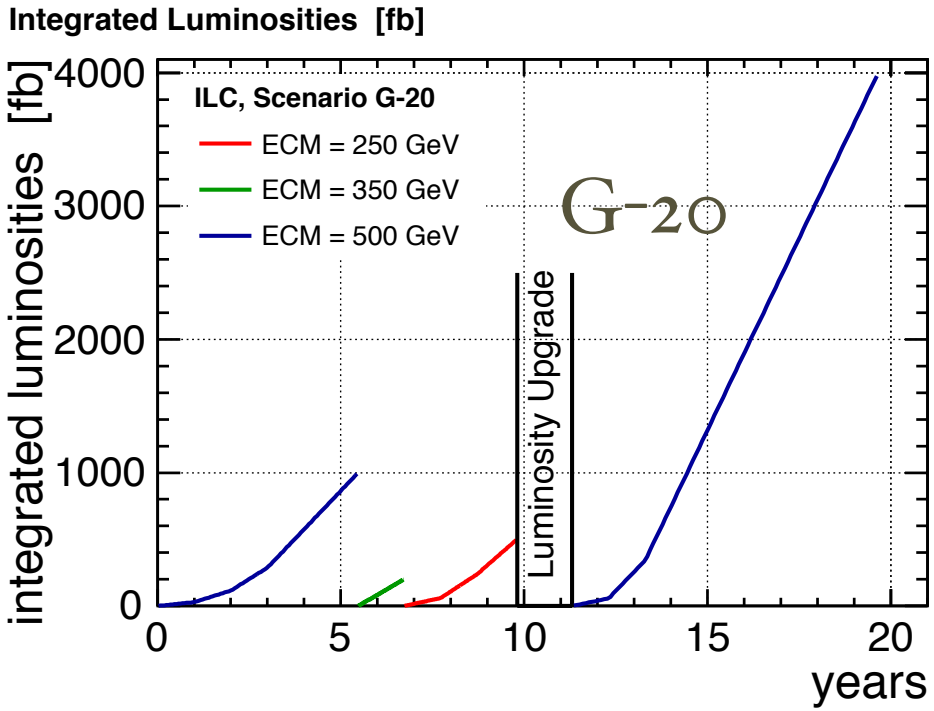
- Full calendar year is assumed to be 8 months at a *75%* efficiency (the RDR assumption). This corresponds to Y = 1.6 x 10^7 seconds of integrated running. (significantly higher than a Snowmass year of 10^7 seconds.)
- A **ramp-up** of luminosity performance is in general assumed after:
  - (a) initial construction and after 'year 0' commissioning;
  - (b) after a downtime for a luminosity upgrade;
  - (c) a change in operational mode which may require some learning curve (e.g. going to 10-Hz collisions).
- For initial physics run *after construction and year 0 commissioning*, the RDR ramp of *10%*, *30%*, *60%* and *100%* is assumed over the first four years.
- The ramp *after the shutdowns for installation of the luminosity upgrade* is assumed slightly shorter (*10%*, *50%*, *100%*) with no year 0.
- *Going down in centre of mass energy* from 500 GeV to 350 GeV or 250 GeV is assumed to have no ramp, since there is no machine modification.
- *Going to 10-Hz operation at 50% gradient* does assume a ramp (*25%*, *75%*, *100%*), since 10-Hz affects the entire machine.
- A major 18 month shutdown is assumed for the luminosity upgrade.
- Unlike TDR: 10-Hz and 7-Hz operation assumed at 250 GeV and 350 GeV

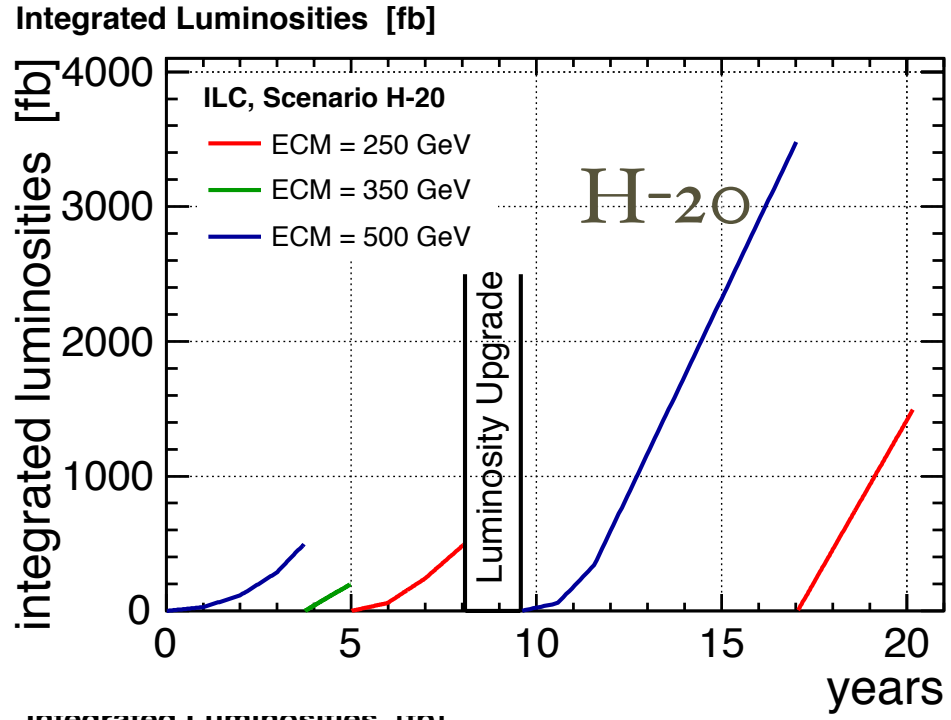
Polarization

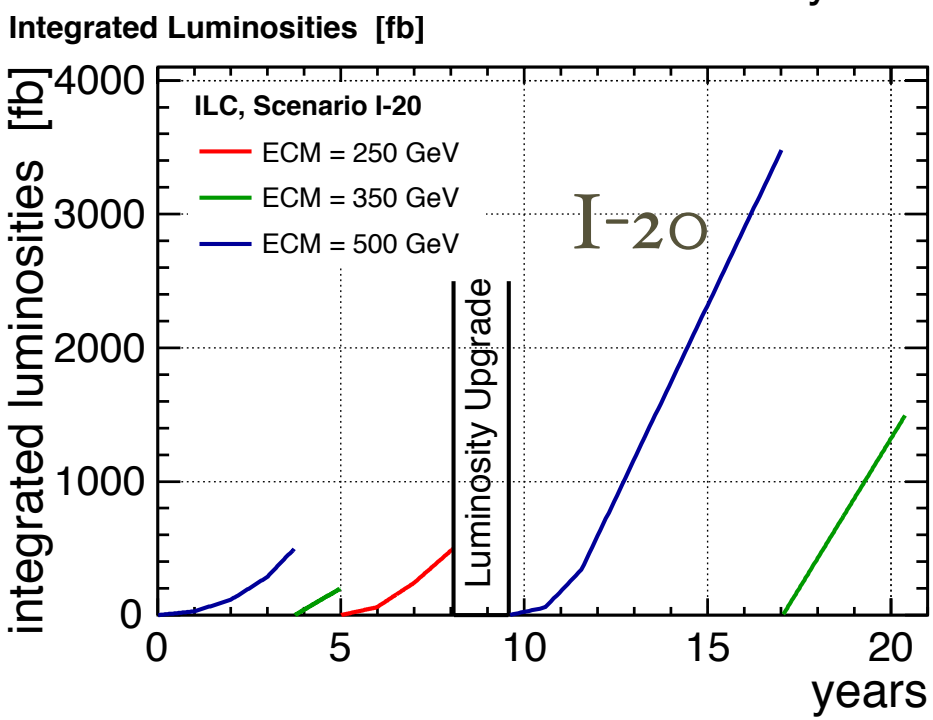
	fraction with $\mathrm{sgn}(P(e^-), P(e^+)) =$			
	(-,+)	(+,-)	(-,-)	(+,+)
$\sqrt{s}$	[%]	[%]	[%]	[%]
250 GeV	67.5	22.5	5	5
350 GeV	67.5	22.5	5	5
500 GeV	40	40	10	10

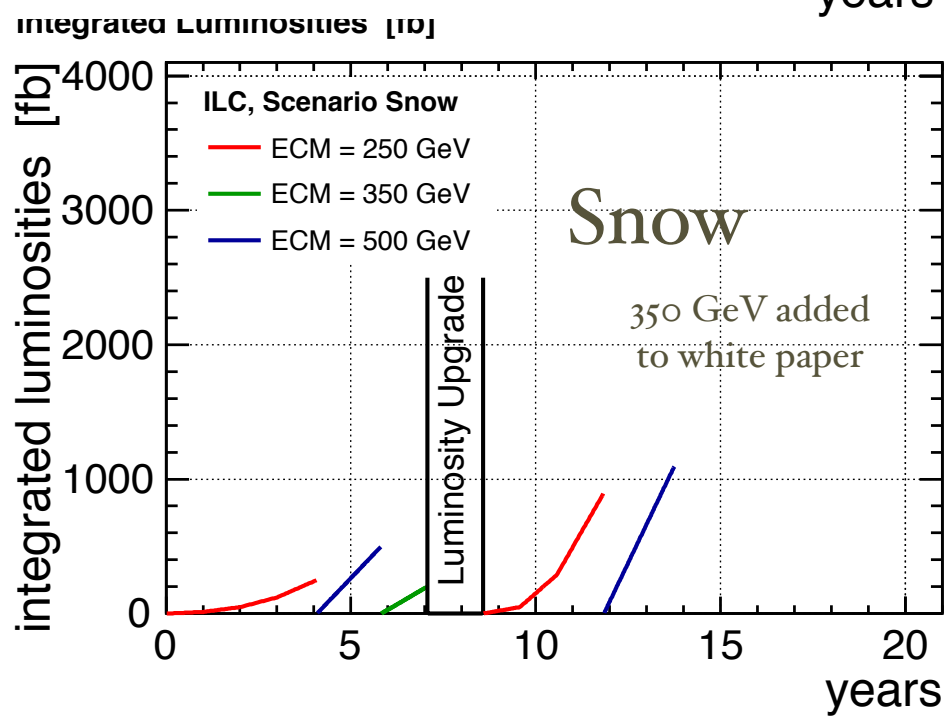
Table 2: Relative sharing between beam helicity configurations proposed for the various center-of-mass energies.

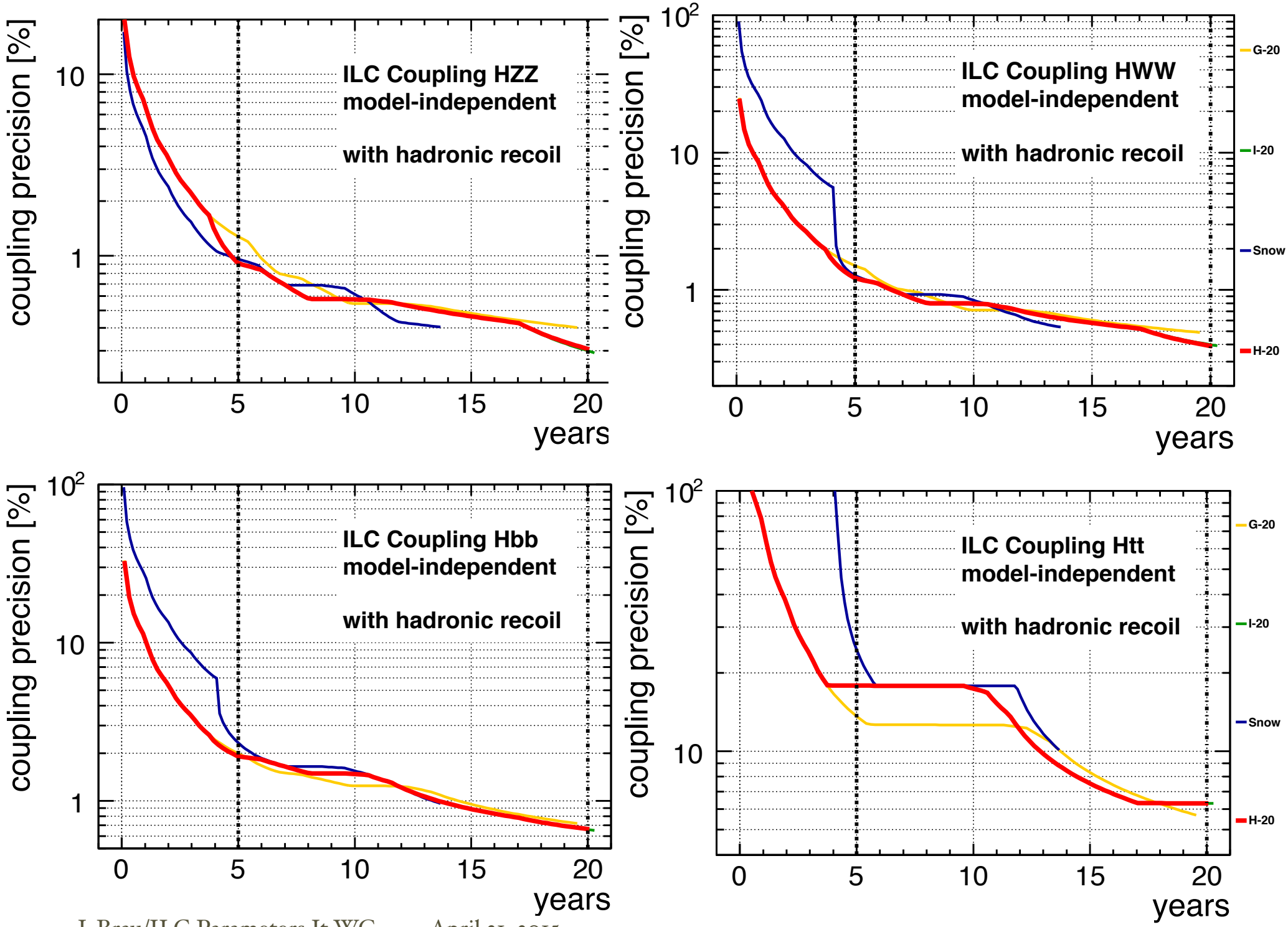
- TDR: $|P(e^-)| = 80\%$, $|P(e^+)| = 30\%$
- Cross sections depend on polarizations
  - s-channel Z/γ allowed for $e_L^- e_R^+$ & $e_R^- e_L^+$, where Z favors $e_L^- e_R^+$
  - t-channel Z/γ allowed for $e_L^- e_L^+$ and $e_R^- e_R^+$
  - BSM t-channel allows like sign helicities, but W or ν_e t-channel exchange only for unlike sign helicities


Integrated Luminosities [fb]
ILC, Scenario G-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
G-20
Luminosity Upgrade
integrated luminosities [fb]
years


Integrated Luminosities [fb]
ILC, Scenario H-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
H-20
Luminosity Upgrade
integrated luminosities [fb]
years

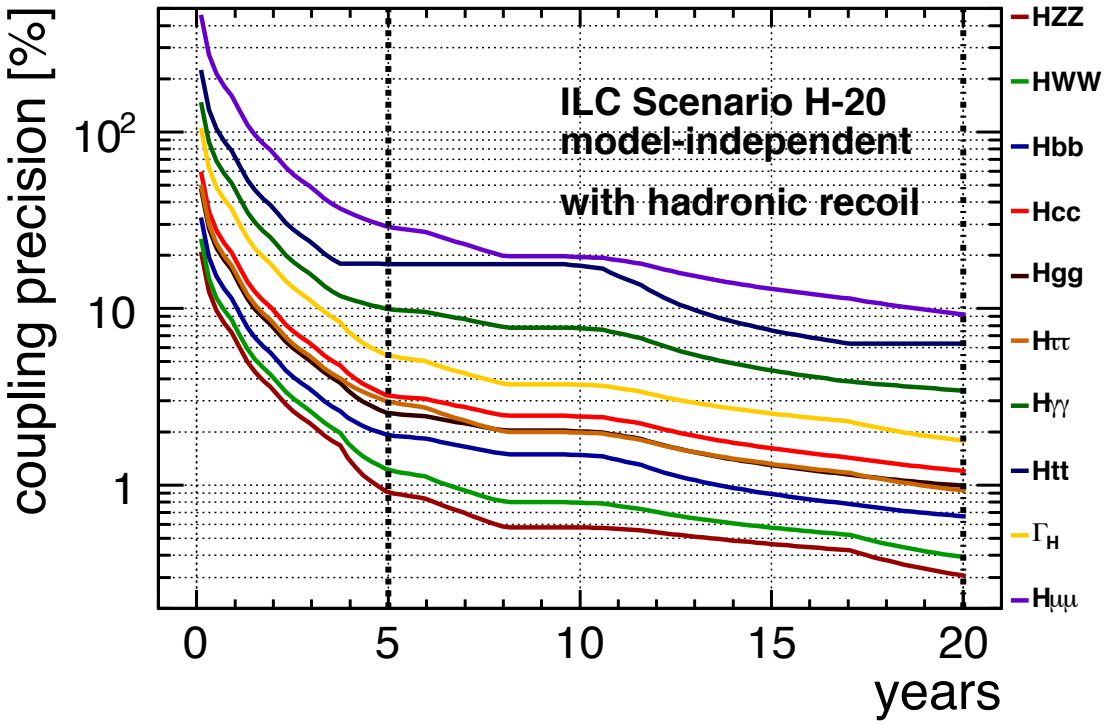

Integrated Luminosities [fb]
ILC, Scenario I-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
I-20
Luminosity Upgrade
integrated luminosities [fb]
years


ILC, Scenario Snow
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
Snow
350 GeV added
to white paper
Luminosity Upgrade
integrated luminosities [fb]
years


ILC Coupling HZZ
model-independent
with hadronic recoil
ILC Coupling HWW
model-independent
with hadronic recoil
ILC Coupling Hbb
model-independent
with hadronic recoil
ILC Coupling Htt
model-independent
with hadronic recoil
coupling precision [%]
years
G-20
I-20
Snow
H-20

Higgs couplings (H-20)

- H-20 preferred for
  - slightly better early precision (compared to G-20)
  - current best reliability of m_h and $\sigma(e^+e^- \rightarrow Zh)$ measurements when done at 250 GeV
- Model independent
  - Higgs recoil from hadronic decaying Z is nearly model independent
- Recommended H-20 to ILC PAC last week



Recommended for ILC studies

H-20

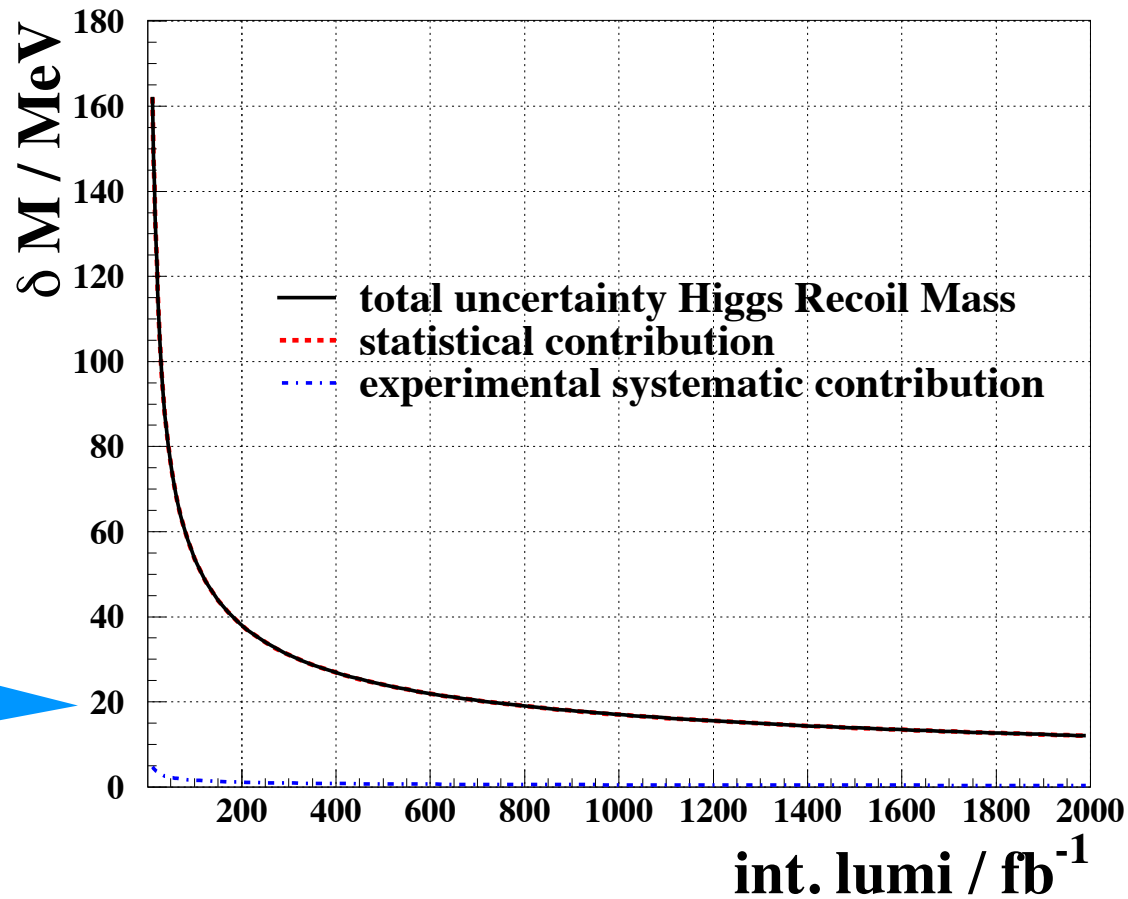
	first phase	lumi upgrade	total	Snowmass Lum-up†
250 GeV	500 fb^{-1}	1500 fb^{-1}	2 ab^{-1}	1.15 ab^{-1}
350 GeV	200 fb^{-1}		0.2 ab^{-1}	
500 GeV	500 fb^{-1}	3500 fb^{-1}	4 ab^{-1}	1.6 ab^{-1}
time	8.1 yrs	10.6 yrs	20.2 yrs*	

✳ includes 1.5 years for luminosity upgrade

† ILC Higgs whitepaper: arXiv:1310.0763

Higgs mass

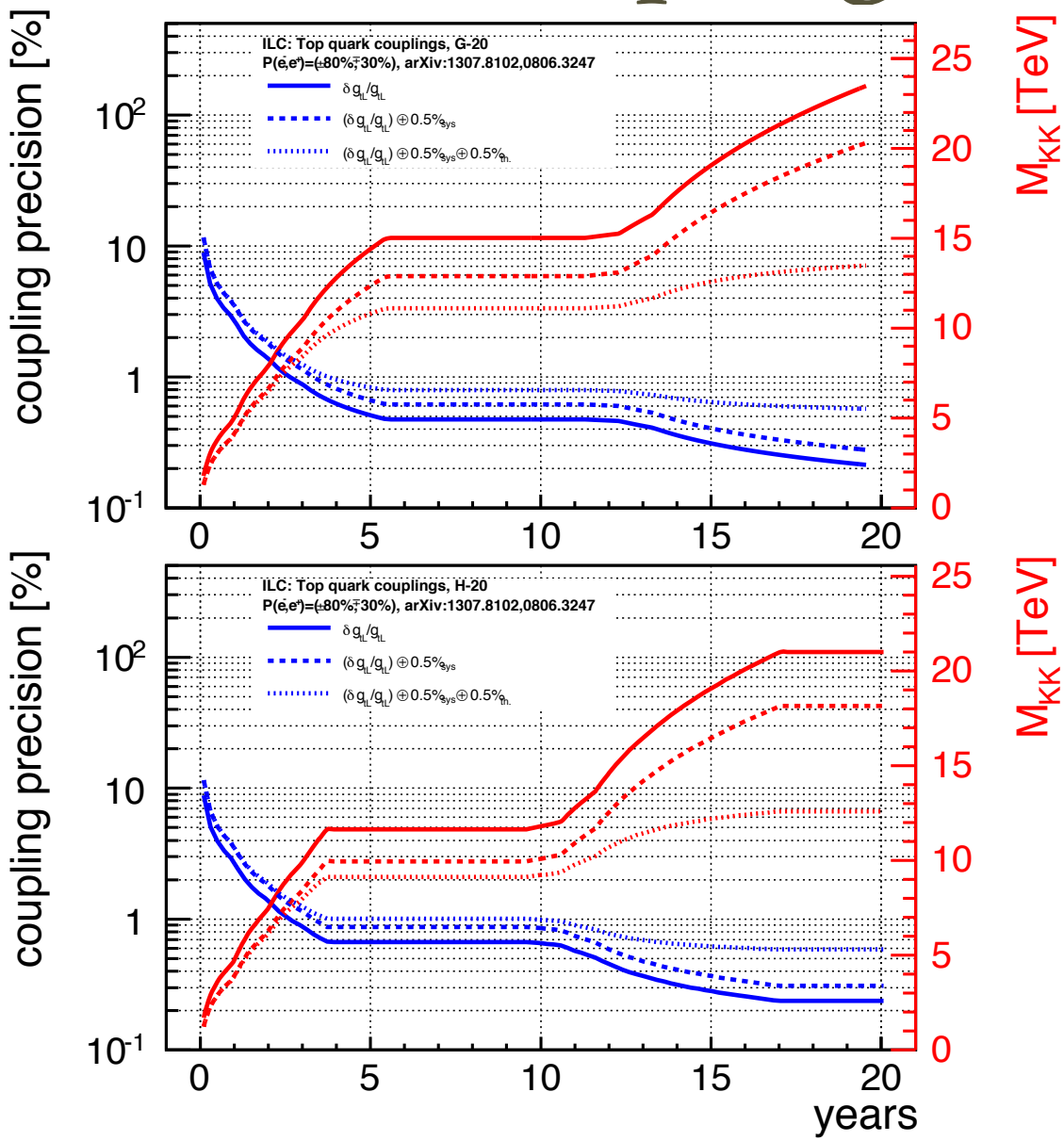
- Fundamental parameter of SM, important to know in own right
- Higgs decay partial width dependence on m_h requires 20 MeV m_h precision to achieve desired 0.2% on partial widths



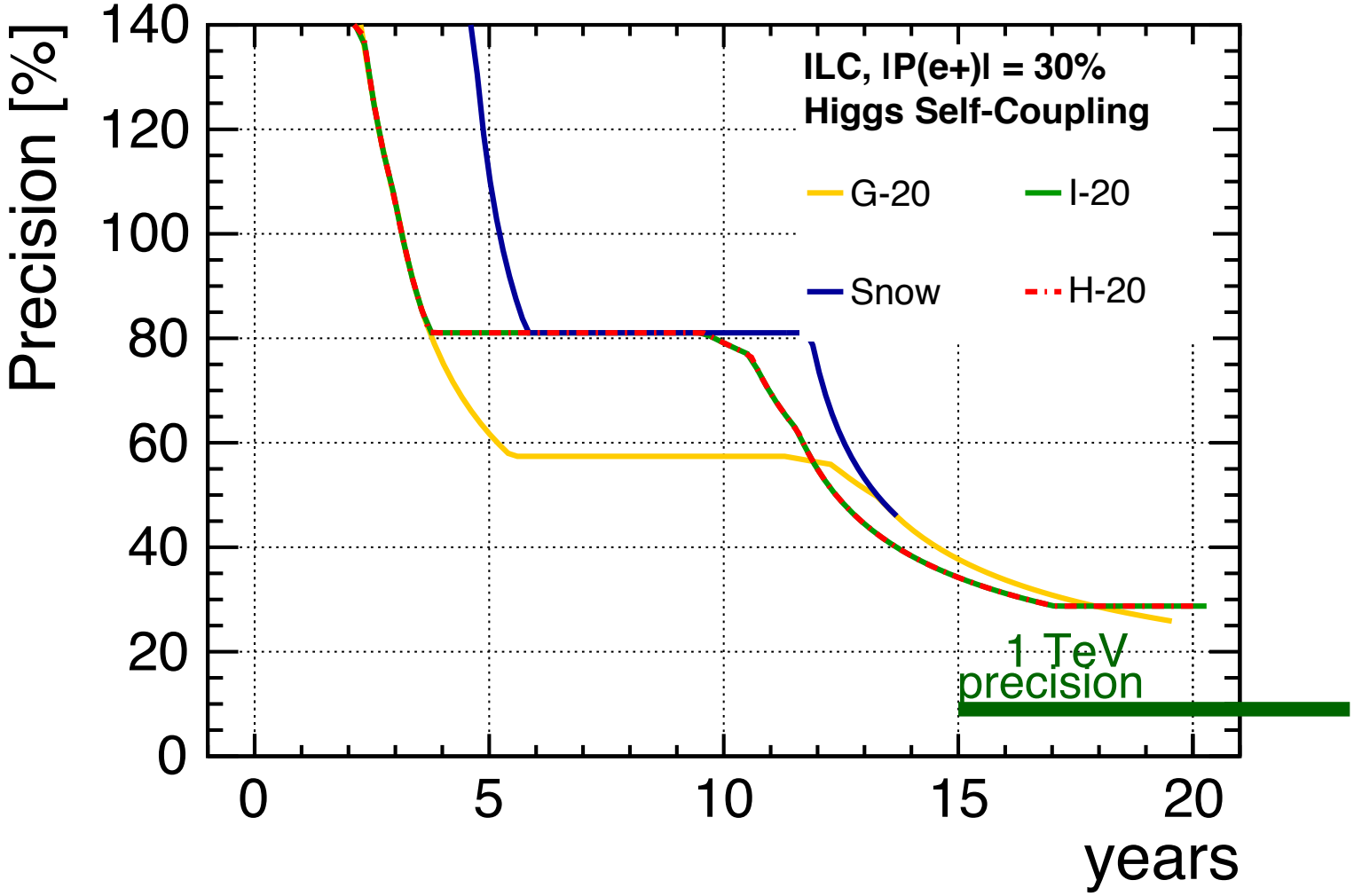
- Higgs recoil from $Z \rightarrow \mu\mu$ (expect 1 MeV systematic uncertainty)
- Note - direct reconstruction at 500 GeV in $h \rightarrow bb$ and $\rightarrow WW$ shows similar level of promise

Top electroweak couplings

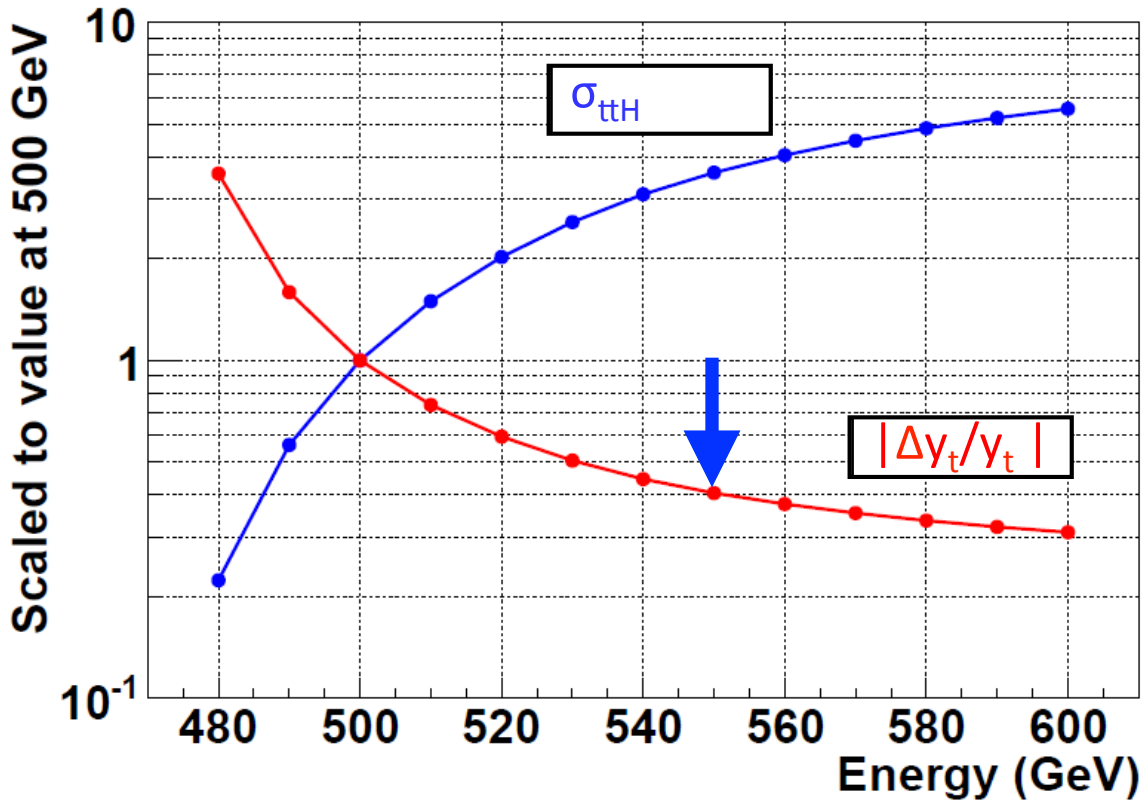
- Left-handed top coupling, and the derived mass scale sensitivity for Kaluza-Klein excitations in and extra-dimensions model



Higgs self-coupling

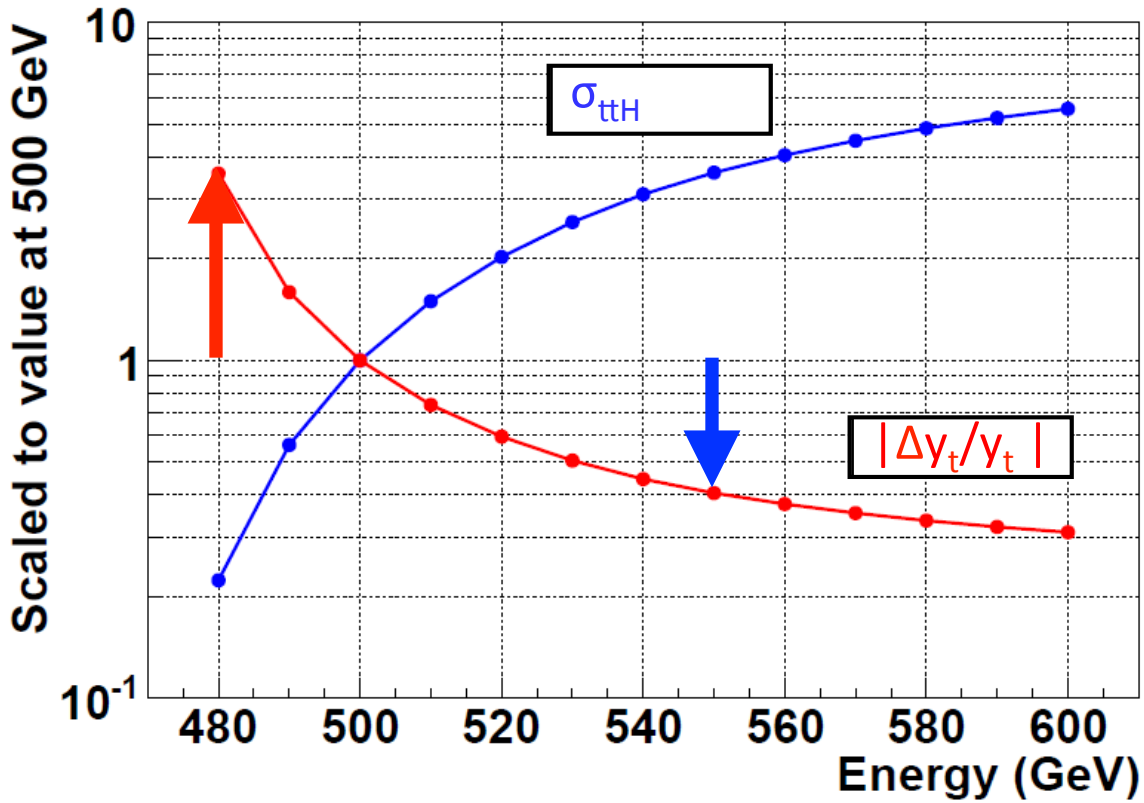


500 GeV vs. 550 GeV & ttH



550 GeV is 2.4 precision improvement over 500 GeV

500 GeV vs. 550 GeV & ttH



550 GeV is 2.4 precision improvement over 500 GeV
- Failing to achieve 500 GeV loses reach quickly

Other issues considered

- BSM physics
  - Draft report discusses Light Higgsinos & WIMP dark matter & follow up energy scans for new particle discoveries
  - Examples of adjustments for BSM scenarios being prepared
- Model independency of $ZH \rightarrow qqH$
- WW threshold
- Z-pole for physics
- Z-pole for calibration
- Also, working on white paper regarding complementarity of ILC with circular collider

Issues for experiments

- Detectors
  - data taking at various repetition rates
    - 5, 7, 10 Hz
  - Z pole calibration requirement
- Physics
  - prospects for m_h measurement from kinematic reconstruction
  - model-independency of hadronic recoil

Recommendations to the PAC on TDR running scenario

- After considering various running scenarios for a 500 GeV machine, we put forward a preferred scenario based on current knowledge: H-20
    - 500 GeV startup, 20 yr duration
    - luminosity upgrade after 8 years
    - after several years of 500 GeV operation with upgraded luminosity, return to 250 GeV
- tth benefits from stretching to 550 GeV capability
- Actual running scenario will depend on physics results of LHC and early ILC
- Draft report: http://pages.uoregon.edu/jimbrau/temp/parameters-draft-150419.pdf - comments welcome!

Recommended for ILC studies

H-20

	first phase	lumi upgrade	total	Snowmass Lum-up†
250 GeV	500 fb^{-1}	1500 fb^{-1}	2 ab^{-1}	1.15 ab^{-1}
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time	8.1 yrs	10.6 yrs	20.2 yrs*	

✳ includes 1.5 years for luminosity upgrade

† ILC Higgs whitepaper: arXiv:1310.0763

- Acknowlegements

contributions to study from
Mikael Berggren, Roberto Contino, Christophe Grojean, Benno List, Maxim Perelstein, Michael Peskin, Roman PÖschl, Juergen Reuter, Tomohiko Tanabe, Mark Thomson, Junping Tian, Graham Wilson and all members of the ILC Physics Working Group.

please refer to the draft report for specific references (not listed in this talk)

EXTRAS

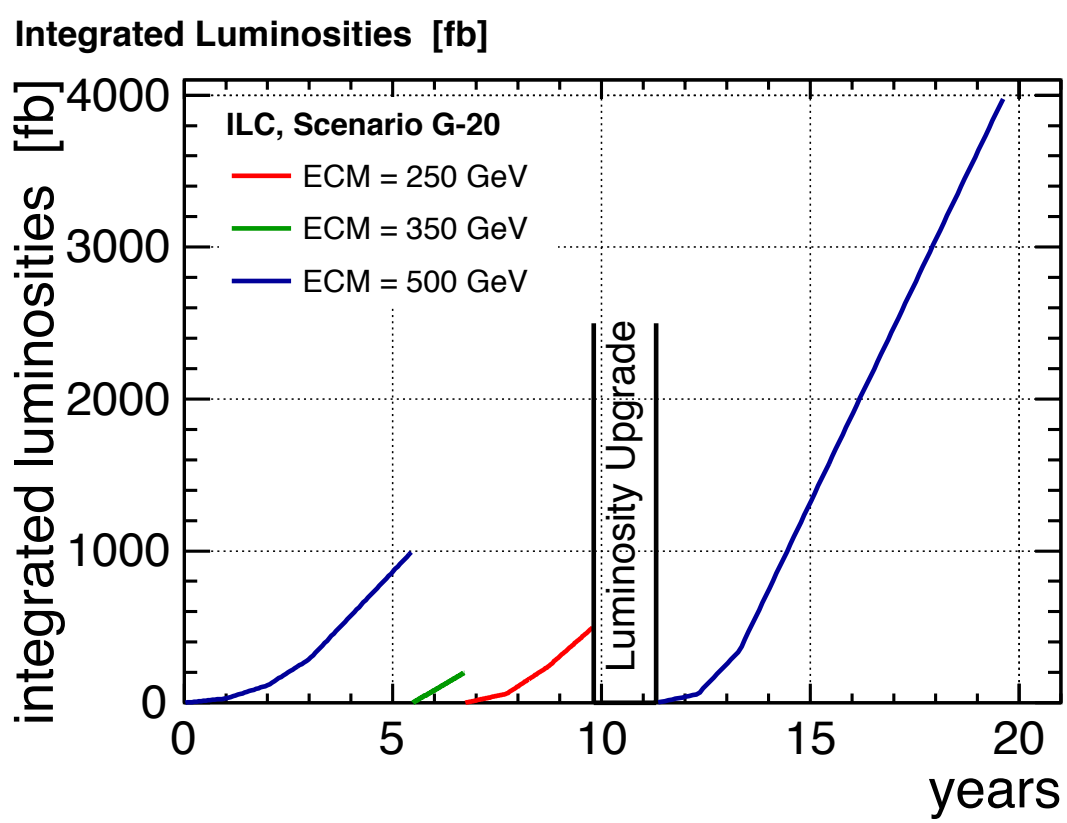
Original Charge - early 2014

- Charge:
  - 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.

G-20 Luminosity profile

	$\sqrt{s}$	$\int \mathscr{L} dt$	L_{peak}	Ramp				T	T_{tot}	Comment	inst. $\mathscr{L}$
	[GeV]	[fb^{-1}]	[fb^{-1}/a]	1	2	3	4	[a]	[a]		[10^{34} cm^{-2}s^{-1}]
Physics run	500	1000	288	0.1	0.3	0.6	1.0	5.5	5.5	TDR nominal at 5 Hz	1.8
Physics run	350	200	160	1.0	1.0	1.0	1.0	1.2	6.7	TDR nominal at 5 Hz	1.0
Physics run	250	500	240	0.25	0.75	1.0	1.0	3.1	9.8	operation at 10 Hz	1.5
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	3.6

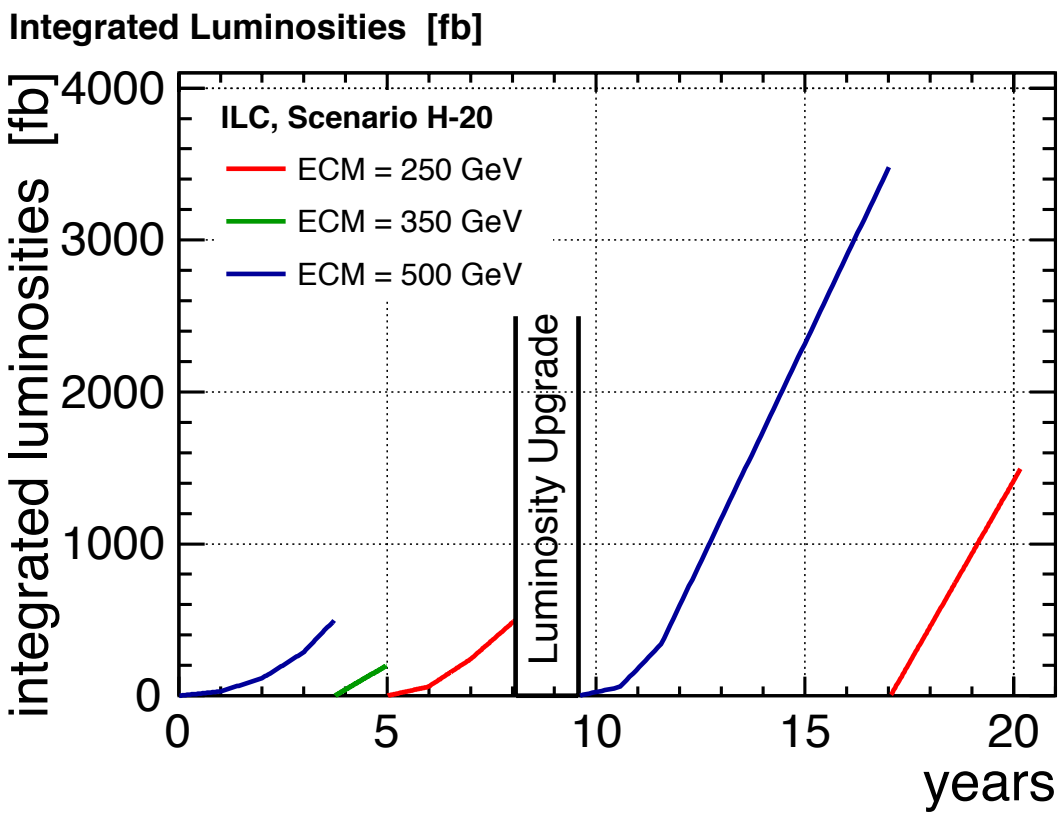
Table 6: Scenario G-20: Sequence of energy stages and their real-time conditions.



H-20 Luminosity profile

	$\sqrt{s}$	$\int \mathscr{L} dt$	L_{peak}	Ramp				T	T_{tot}	Comment	inst. $\mathscr{L}$
	[GeV]	[fb^{-1}]	[fb^{-1}/a]	1	2	3	4	[a]	[a]		[10^{34} cm^{-2}s^{-1}]
Physics run	500	500	288	0.1	0.3	0.6	1.0	3.7	3.7	TDR nominal at 5 Hz	1.8
Physics run	350	200	160	1.0	1.0	1.0	1.0	1.3	5.0	TDR nominal at 5 Hz	1.0
Physics run	250	500	240	0.25	0.75	1.0	1.0	3.1	8.1	operation at 10 Hz	1.5
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	3.6
Physics run	250	1500	480	1.0	1.0	1.0	1.0	3.2	20.2	lumi-up operation at 10 Hz	3.0

Table 7: Scenario H-20: Sequence of energy stages and their real-time conditions.

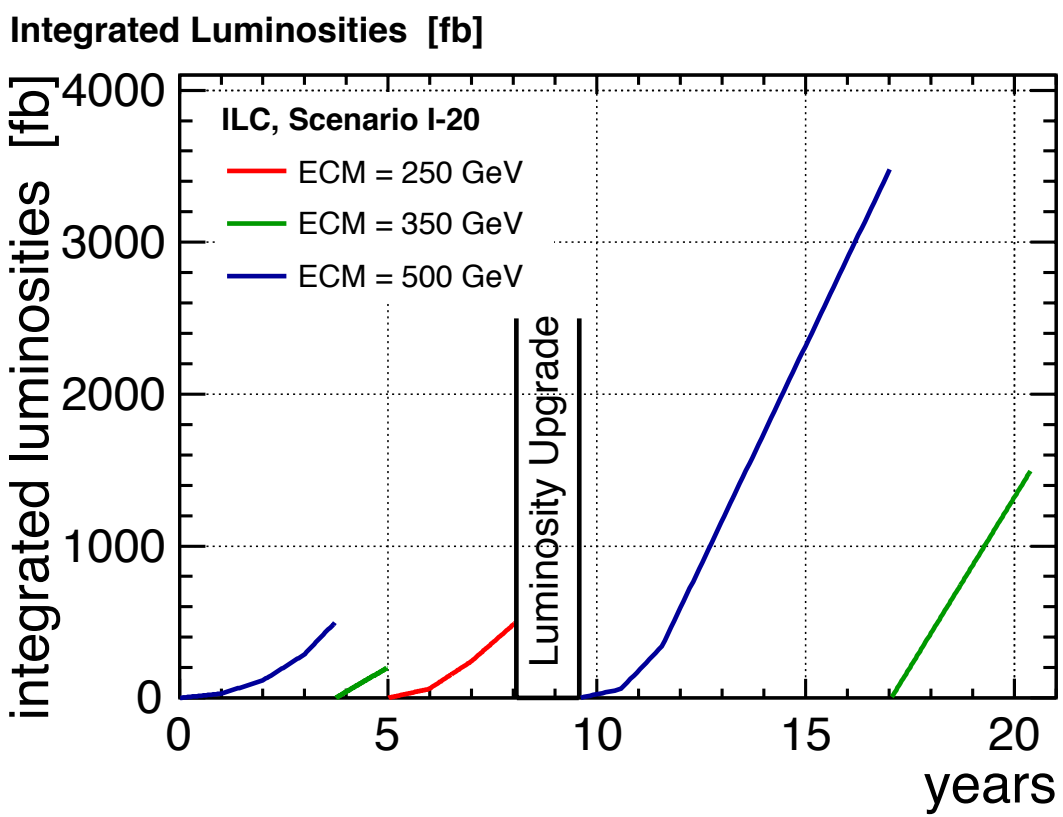


- Briefer initial 500 GeV operation than G-20
- Return to 250 GeV operation after lumi upgrade

I-20 Luminosity profile

	$\sqrt{s}$	$\int \mathscr{L} dt$	L_{peak}	Ramp				T	T_{tot}	Comment	inst. $\mathscr{L}$
	[GeV]	[fb^{-1}]	[fb^{-1}/a]	1	2	3	4	[a]	[a]		[10^{34} cm^{-2}s^{-1}]
Physics run	500	500	288	0.1	0.3	0.6	1.0	3.7	3.7	TDR nominal at 5 Hz	1.8
Physics run	350	200	160	1.0	1.0	1.0	1.0	1.3	5.0	TDR nominal at 5 Hz	1.0
Physics run	250	500	240	0.25	0.75	1.0	1.0	3.1	8.1	operation at 10 Hz	1.5
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	3.6
Physics run	350	1500	448	1.0	1.0	1.0	1.0	3.4	20.4	lumi-up operation at 7 Hz	2.8

Table 8: Scenario I-20: Sequence of energy stages and their real-time conditions.

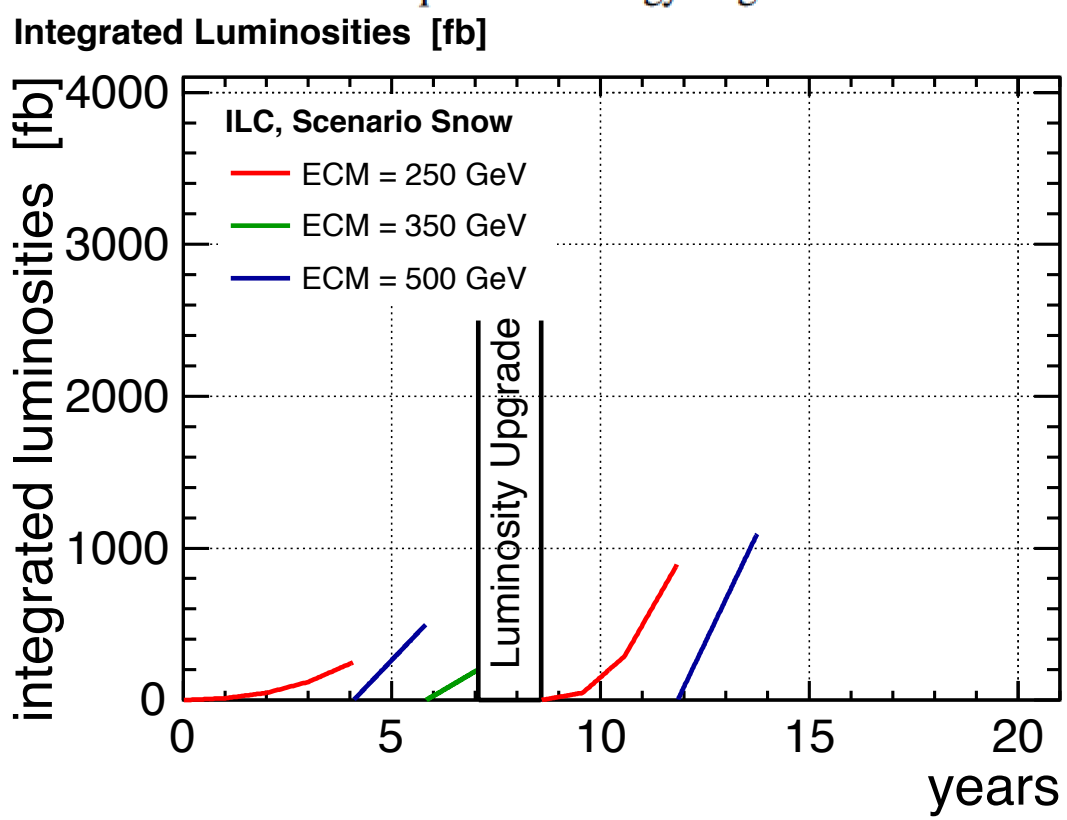


- Briefer initial 500 GeV operation than G-20 (like H-20)
- Return to <u>350 GeV</u> operation after lumi upgrade

Snow Luminosity profile

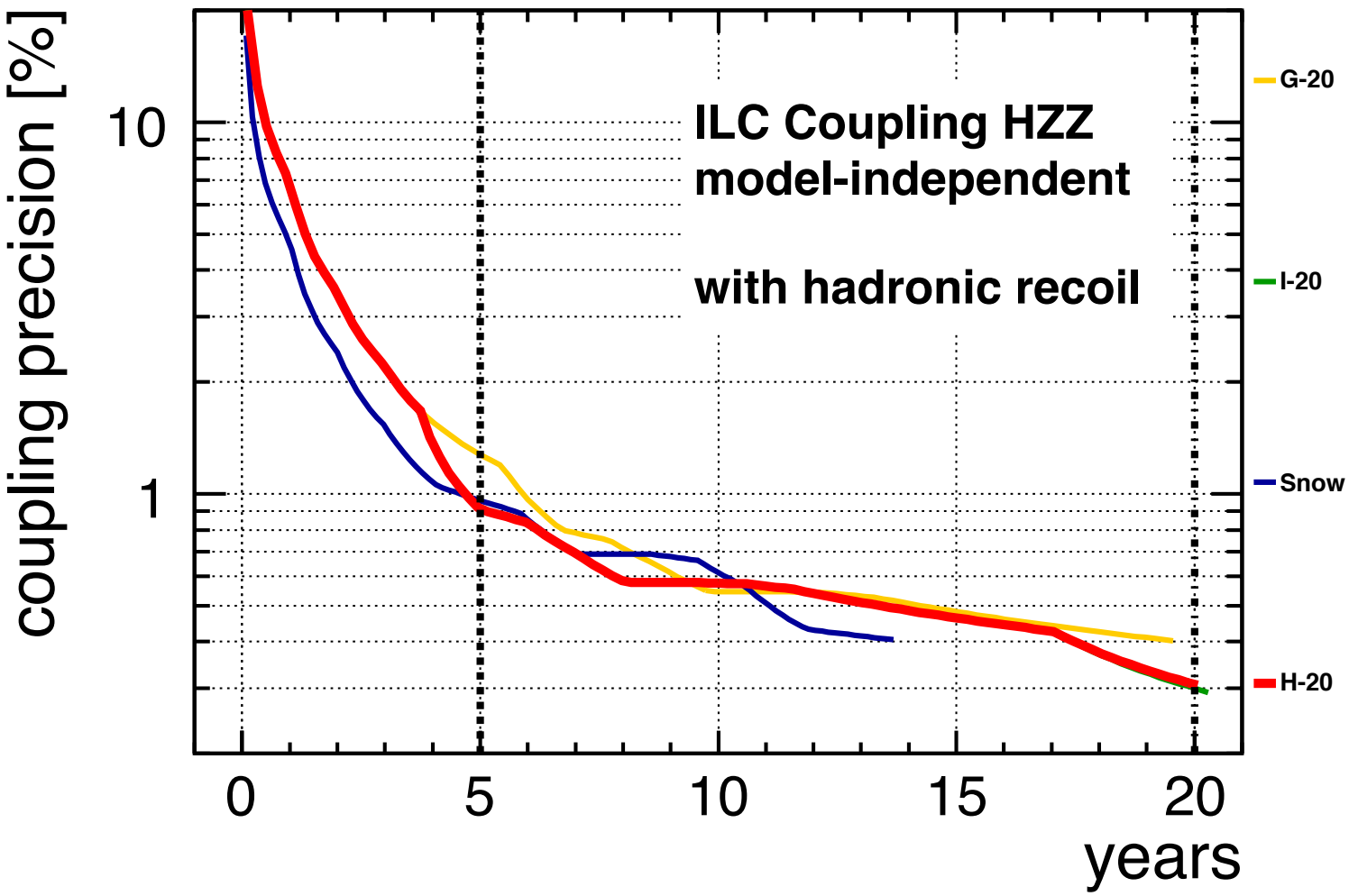
	$\sqrt{s}$	$\int \mathscr{L} dt$	L_{peak}	Ramp				T	T_{tot}	Comment
	[GeV]	[fb^{-1}]	[fb^{-1}/a]	1	2	3	4	[a]	[a]	
Physics run	250	500	120	0.1	0.3	0.6	1.0	4.1	4.1	TDR nominal at 5 Hz
Physics run	500	500	288	1.0	1.0	1.0	1.0	1.7	5.8	TDR nominal at 5 Hz
Physics run	350	200	160	1.0	1.0	1.0	1.0	1.3	7.1	TDR 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

Table 9: Scenario Snow: Sequence of energy stages and their real-time conditions.

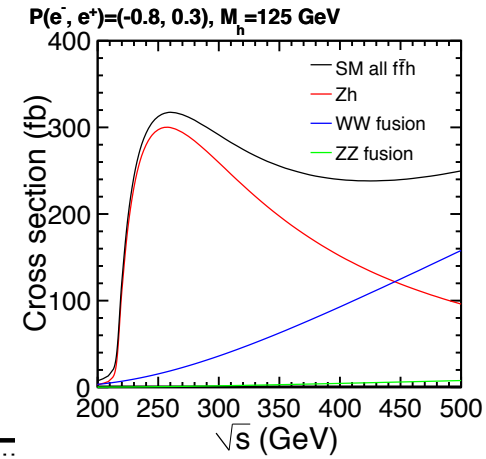


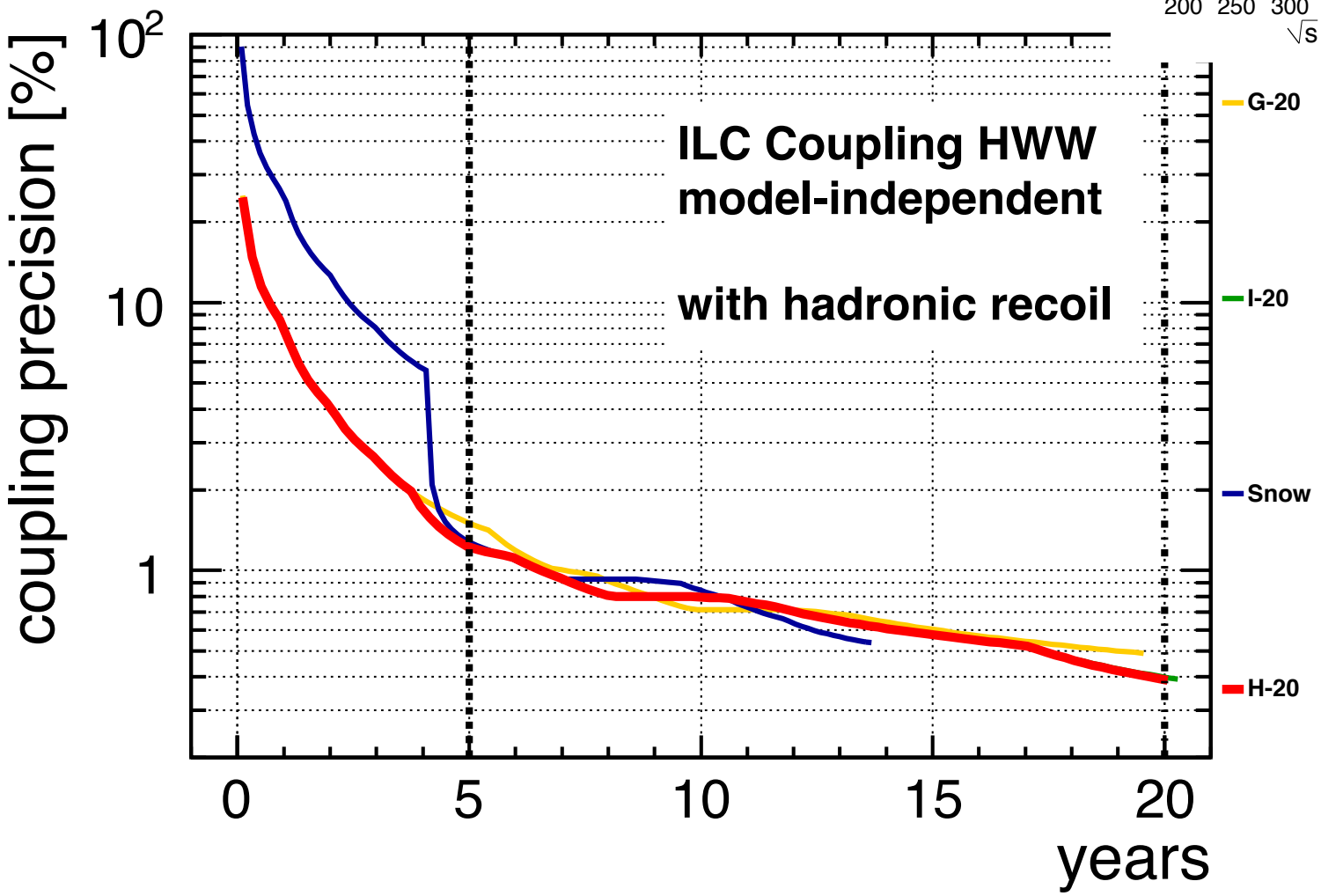
- Start at 250 GeV
- Stop 500 GeV operations after 13.8 years

HZZ evolution

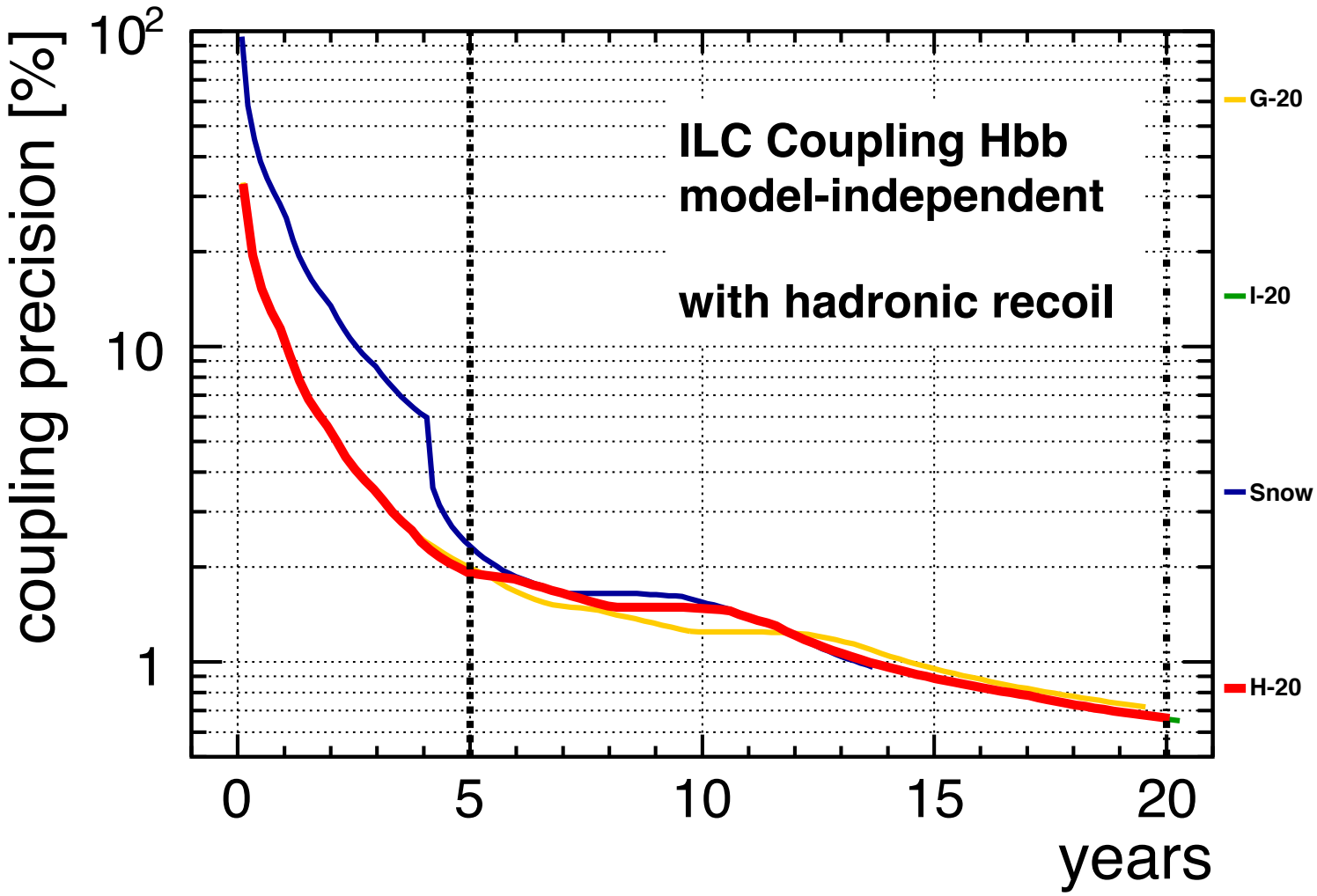


HWW evolution





Hbb evolution



Htt evolution