500 GeV ILC Operating Scenarios

ILC Parameters Joint Working Group

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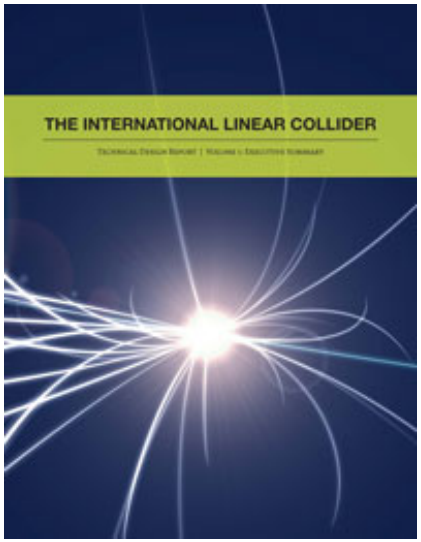
ILC Technical Design Report



- Five-volumes published 12 June 2013
- Blueprint for ILC based on many years of globally coordinated R&D
- Realistic technical design and implementation plan, optimized for performance, cost and risk
- TDR based on successful R&D program:
  - construction and commissioning of superconducting RF test facilities for accelerators all over the world,
  - improvement in accelerating cavities production processes,
  - and plans for mass production of 16,000 superconducting cavities needed to drive the ILC's particle beams.
- Details of the two state-of-the-art detectors included
- Extensive outline of the geological and civil engineering studies conducted for siting the ILC

ILC Physics Goals	***500 GeV***
• precision Higgs couplings	✔
• **g**HWW and overall normalization of Higgs couplings	✔
• search for invisible and exotic Higgs decay modes	✔
• Higgs couplings to top	✔
• Higgs self-coupling	✔
• search for extended Higgs states	✔
• precision electroweak couplings of the top quark	✔
• precision **W** couplings	✔
• precision search for **Z′**	✔
• search for supersymmetry	✔
• search for Dark Matter	✔

ILC Physics Goals	*500 GeV*	*350 GeV*
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• search for supersymmetry	✔	
• search for Dark Matter	✔	
• top quark mass from threshold scan		✔

ILC Physics Goals	*500 GeV*	*350 GeV*	*250 GeV*
• precision Higgs couplings	✔	✔	✔
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• search for supersymmetry	✔		
• search for Dark Matter	✔		
• top quark mass from threshold scan		✔	
• precision Higgs mass			✔

Operating scenarios

- While the TDR specifies the upper energy (500 GeV) of the ILC, there is flexibility in operating energy
  - this is one strength of the ILC
- To plan for optimized operations, considering machine and physics issues, a Working Group was charged by the Linear Collider Collaboration to
  1. compare various running scenarios for a 500 GeV machine
  2. recommend a standard set of total integrated luminosities for use in physics studies

NOTE - actual running scenario will depend on many future factors, including physics results of the LHC and ILC

ILC scenarios study

- 500 GeV scenarios study
  - TDR Baseline
  - Emphasizes higher energy - one strength of ILC
- Study parameters
  - assume 20 years of operation
  - report compares 3 scenarios (studied many more)
    - G20, H20, I20
  - Snowmass white paper compared (snow study < 15 years)
    - arXiv:1310.0763 [hep-ph]

- Report: http://arxiv.org/abs/1506.07830

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

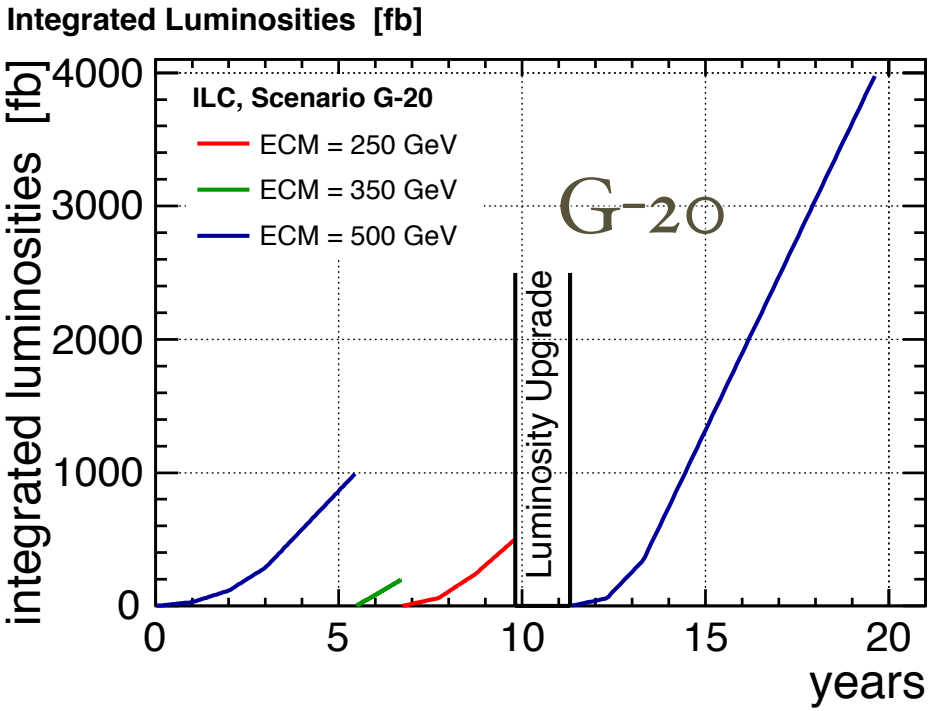
Polarization

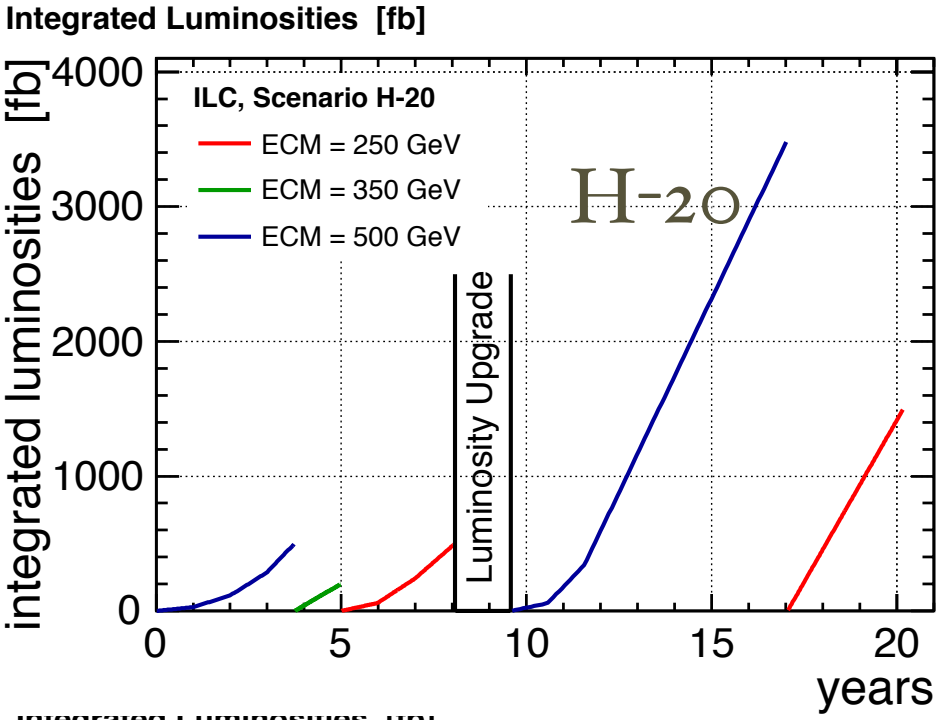
- TDR: $|P(e^-)| = 80\%$, $|P(e^+)| = 30\%$

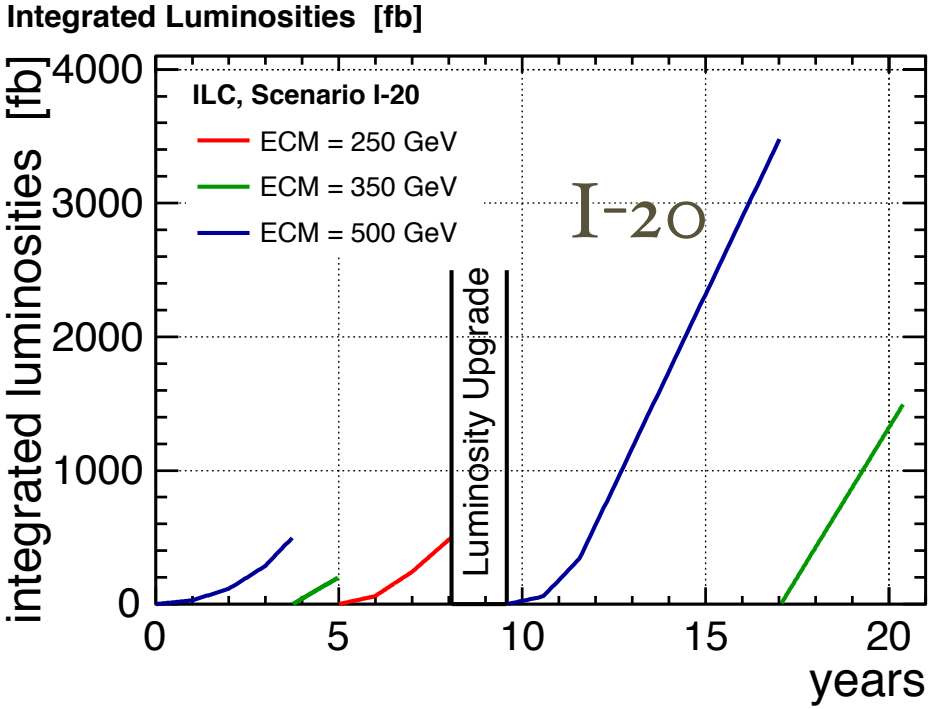
	fraction with $\mathrm{sgn}(P(e^-), P(e^+)) =$			
	(-,+)	(+,-)	(-,-)	(+,+)
$\sqrt{s}$	[%]	[%]	[%]	[%]
250 GeV	67.5	22.5	5	5
350 GeV	67.5	22.5	5	5
500 GeV	40	40	10	10

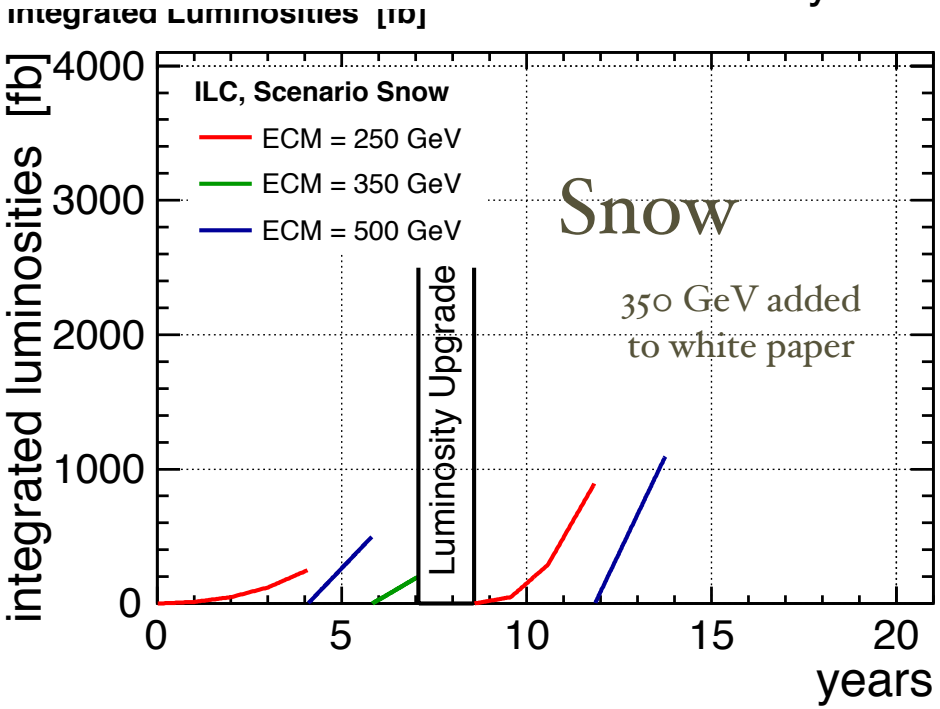
Table 2: Relative sharing between beam helicity configurations proposed for the various center-of-mass energies.

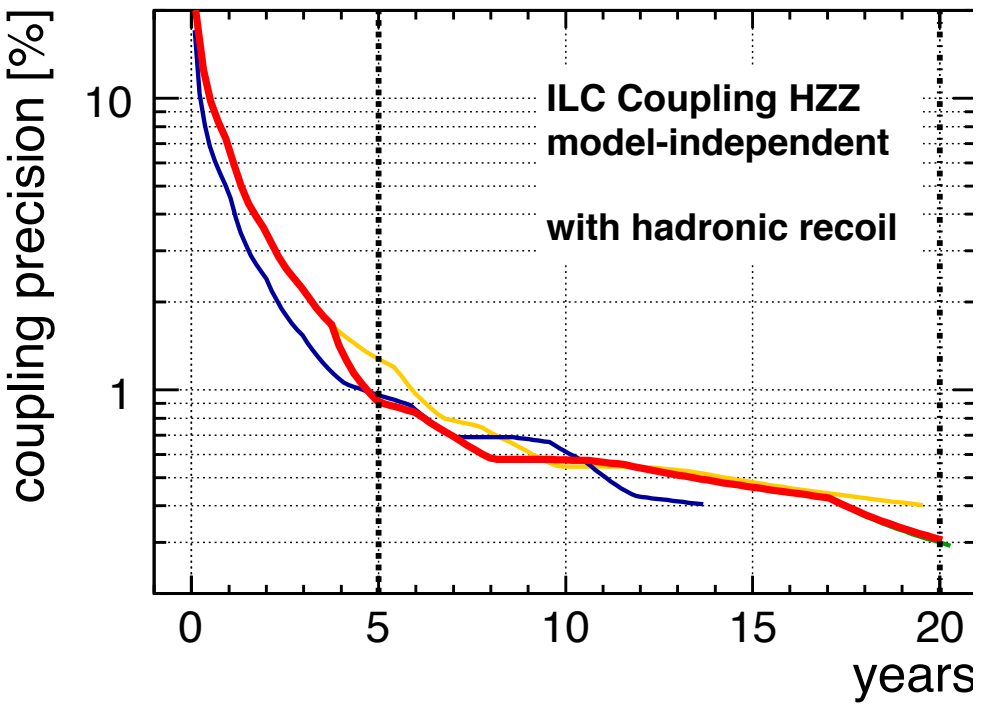
- Cross sections depend on polarizations
  - s-channel Z/γ allowed for $e_L^- e_R^+$ & $e_R^- e_L^+$, where Z favors $e_L^- e_R^+$
  - t-channel Z/γ allowed for $e_L^- e_L^+$ and $e_R^- e_R^+$
  - BSM t-channel allows like sign helicities, but W or ν_e t-channel exchange only for unlike sign helicities

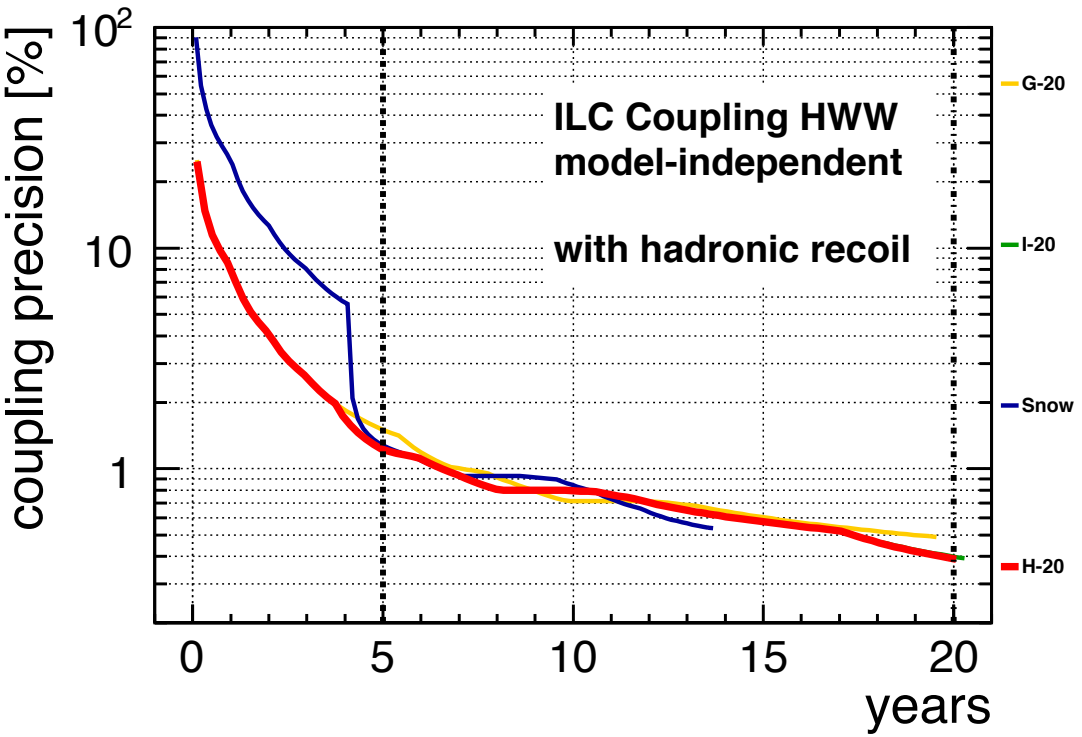

Integrated Luminosities [fb]
ILC, Scenario G-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
G-20
Luminosity Upgrade
integrated luminosities [fb]
years
0
1000
2000
3000
4000
0
5
10
15
20

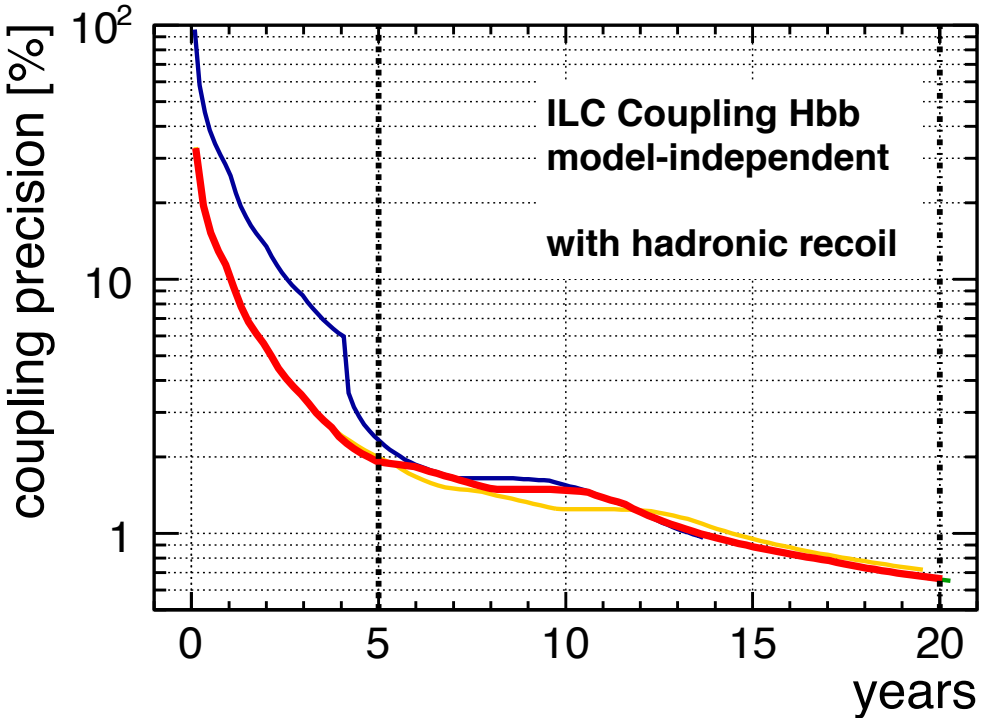

Integrated Luminosities [fb]
ILC, Scenario H-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
H-20
Luminosity Upgrade
integrated luminosities [fb]
years
0
1000
2000
3000
4000
0
5
10
15
20

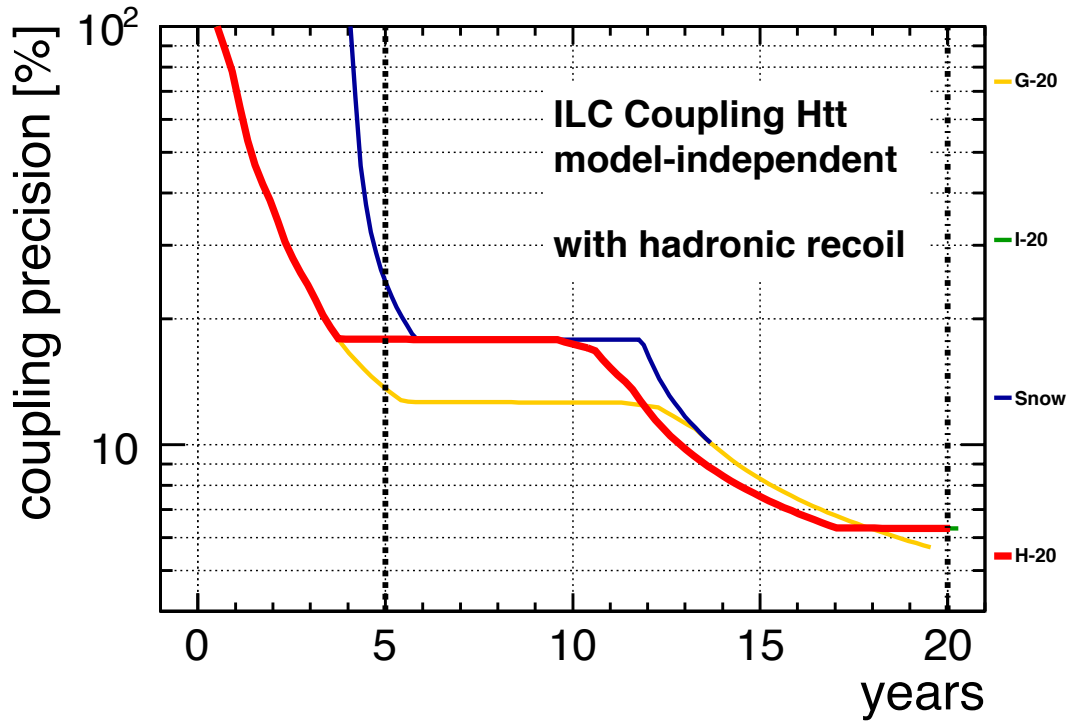

Integrated Luminosities [fb]
ILC, Scenario I-20
ECM = 250 GeV
ECM = 350 GeV
ECM = 500 GeV
I-20
Luminosity Upgrade
integrated luminosities [fb]
years
0
1000
2000
3000
4000
0
5
10
15
20


Integrated Luminosities [fb]
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
0
1000
2000
3000
4000
0
5
10
15
20


ILC Coupling HZZ
model-independent
with hadronic recoil
coupling precision [%]
10
1
0
5
10
15
20
years

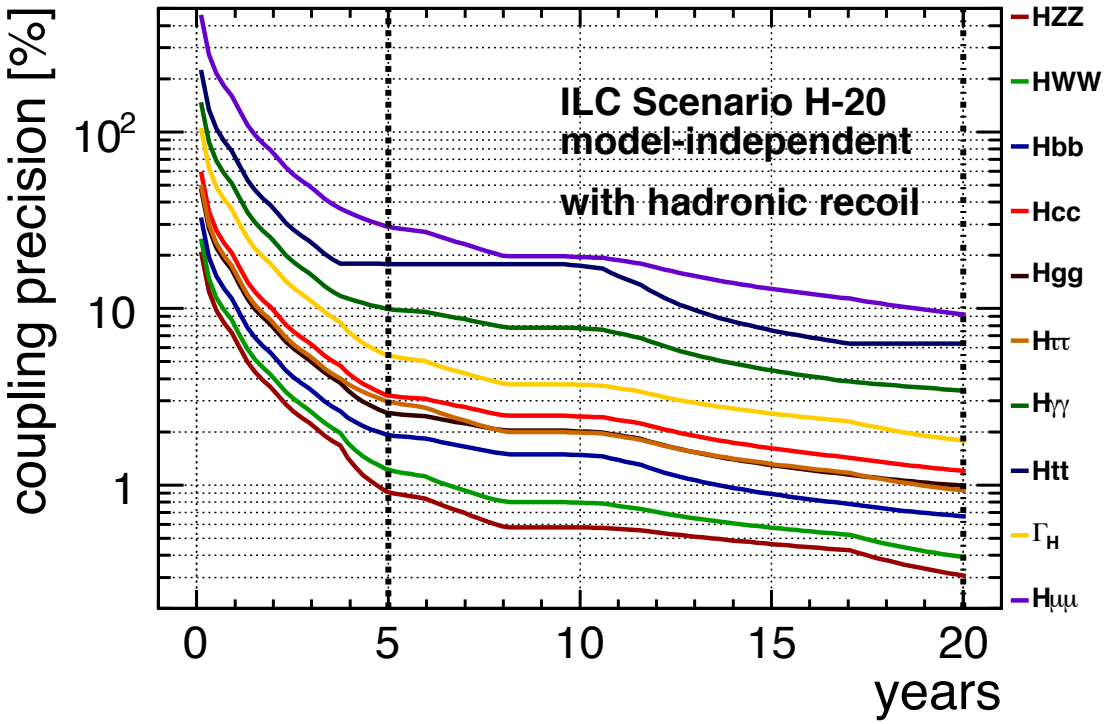

ILC Coupling HWW
model-independent
with hadronic recoil
coupling precision [%]
10^2
10
1
0
5
10
15
20
years
G-20
I-20
Snow
H-20


ILC Coupling Hbb
model-independent
with hadronic recoil
coupling precision [%]
10^2
10
1
0
5
10
15
20
years


ILC Coupling Htt
model-independent
with hadronic recoil
coupling precision [%]
10^2
10
0
5
10
15
20
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
- H-20 approved (June 2015) by Linear Collider Board



Recommended for ILC studies

H-20 - approved by LCB

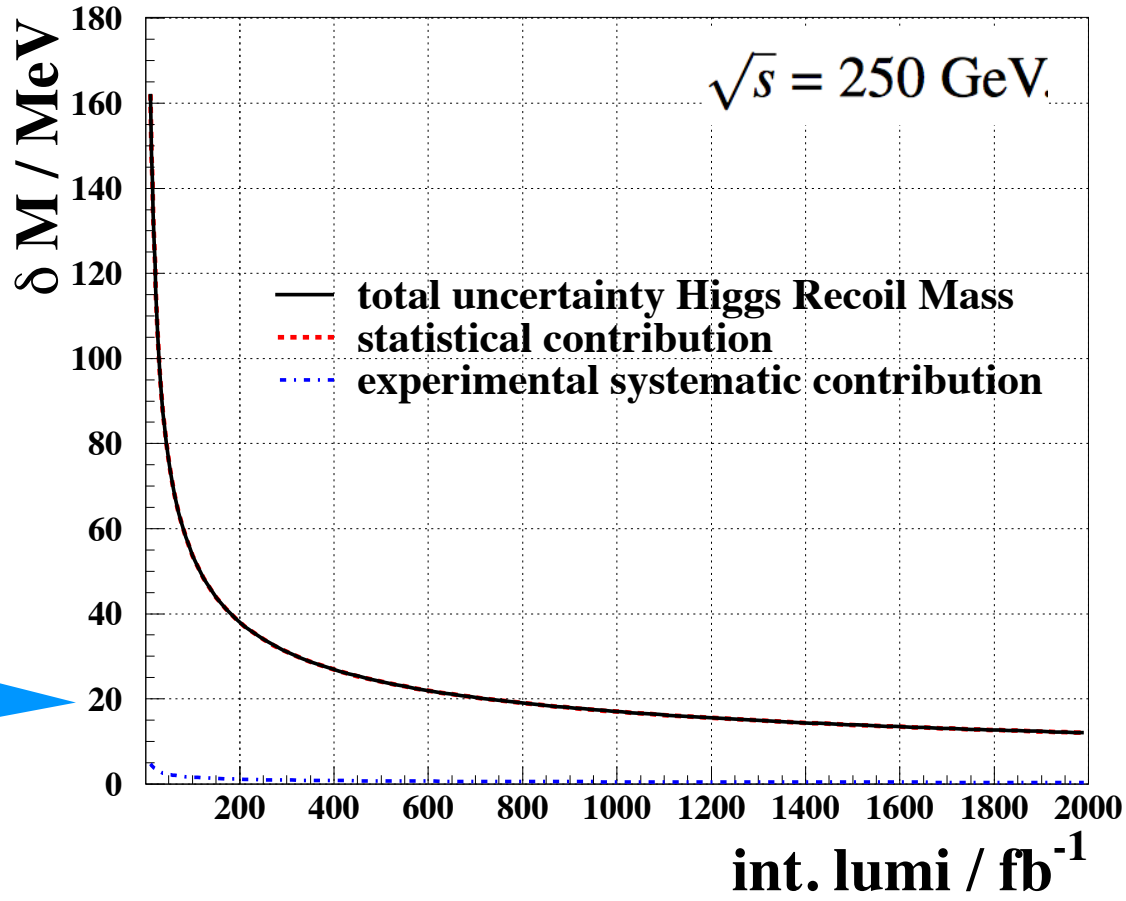
	first phase	lumi upgrade	total	Snowmass Lum-up†
250 GeV	500 fb^{-1}	1500 fb^{-1}	2 ab^{-1}	1.15 ab^{-1}
350 GeV	200 fb^{-1}		0.2 ab^{-1}	
500 GeV	500 fb^{-1}	3500 fb^{-1}	4 ab^{-1}	1.6 ab^{-1}
time	8.1 yrs	10.6 yrs	20.2 yrs*	

✳ includes 1.5 years for luminosity upgrade

† ILC Higgs whitepaper: arXiv:1310.0763

Higgs mass

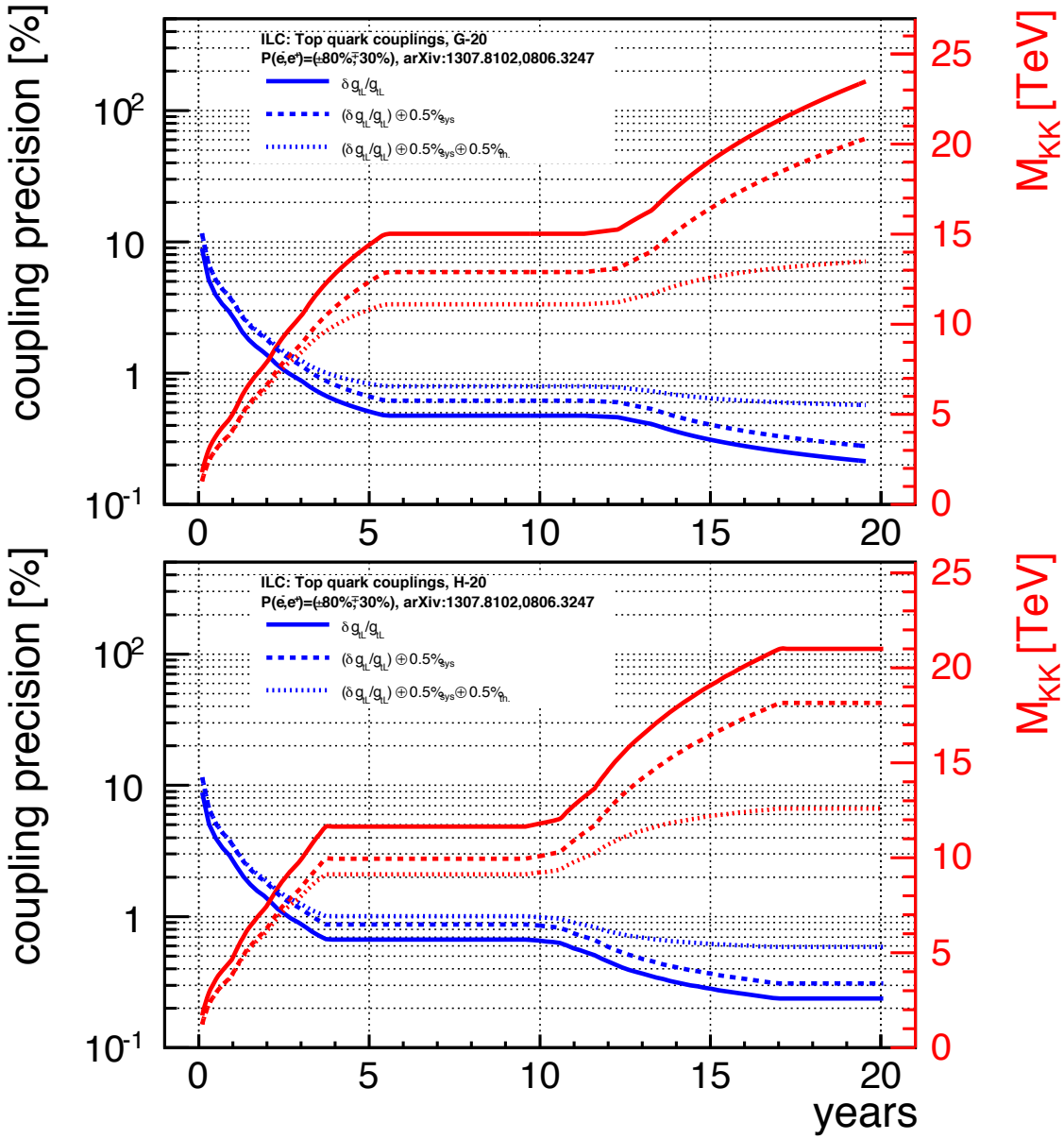
- Fundamental parameter of SM, important to know in own right
- Higgs decay partial width dependence on m_h requires 20 MeV m_h precision to achieve desired 0.2% on partial widths



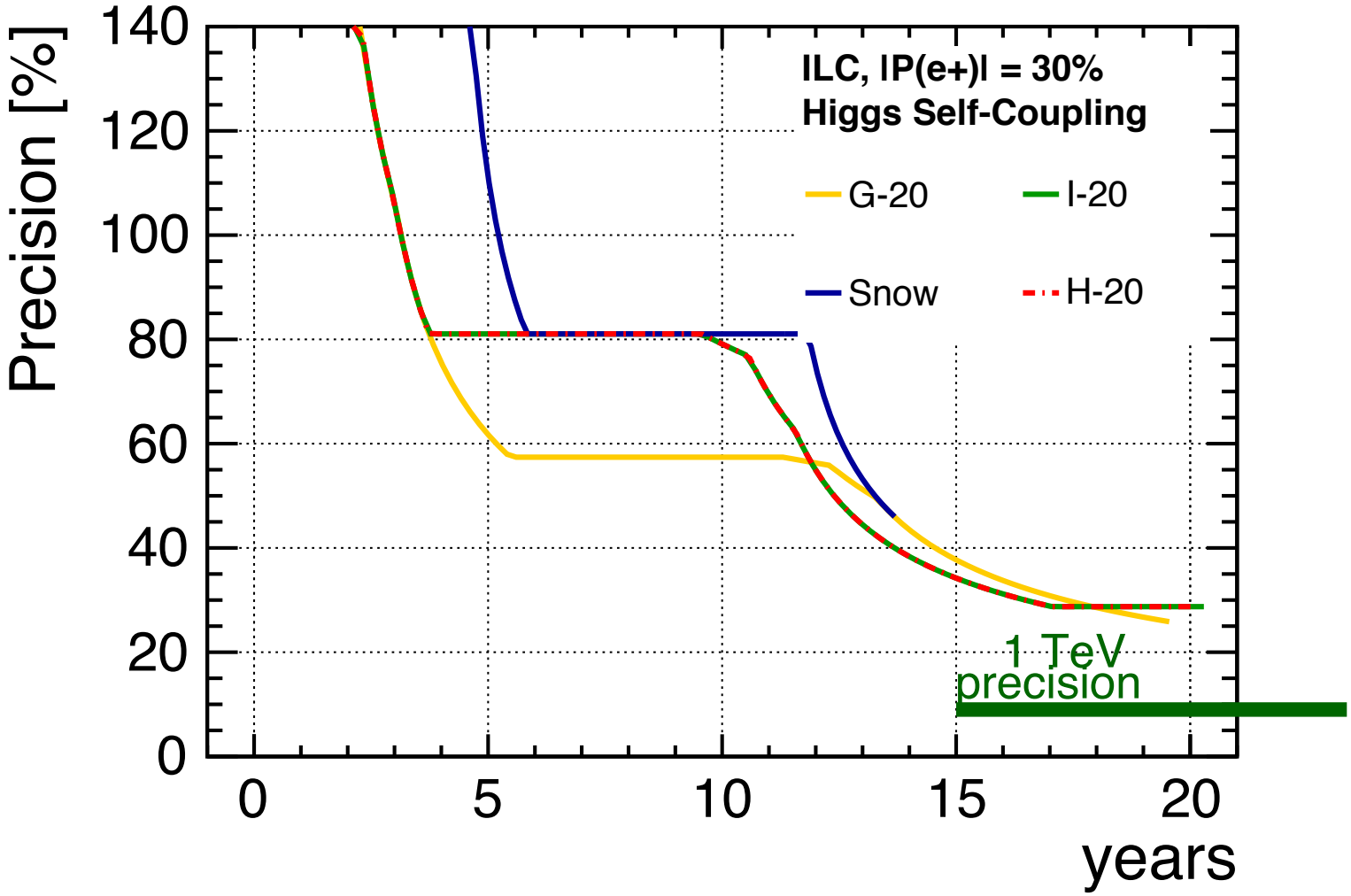
- Higgs recoil from Z → μμ (expect 1 MeV systematic uncertainty)
- Note - direct reconstruction at 500 GeV in h → bb and → WW shows similar level of promise

Top electroweak couplings

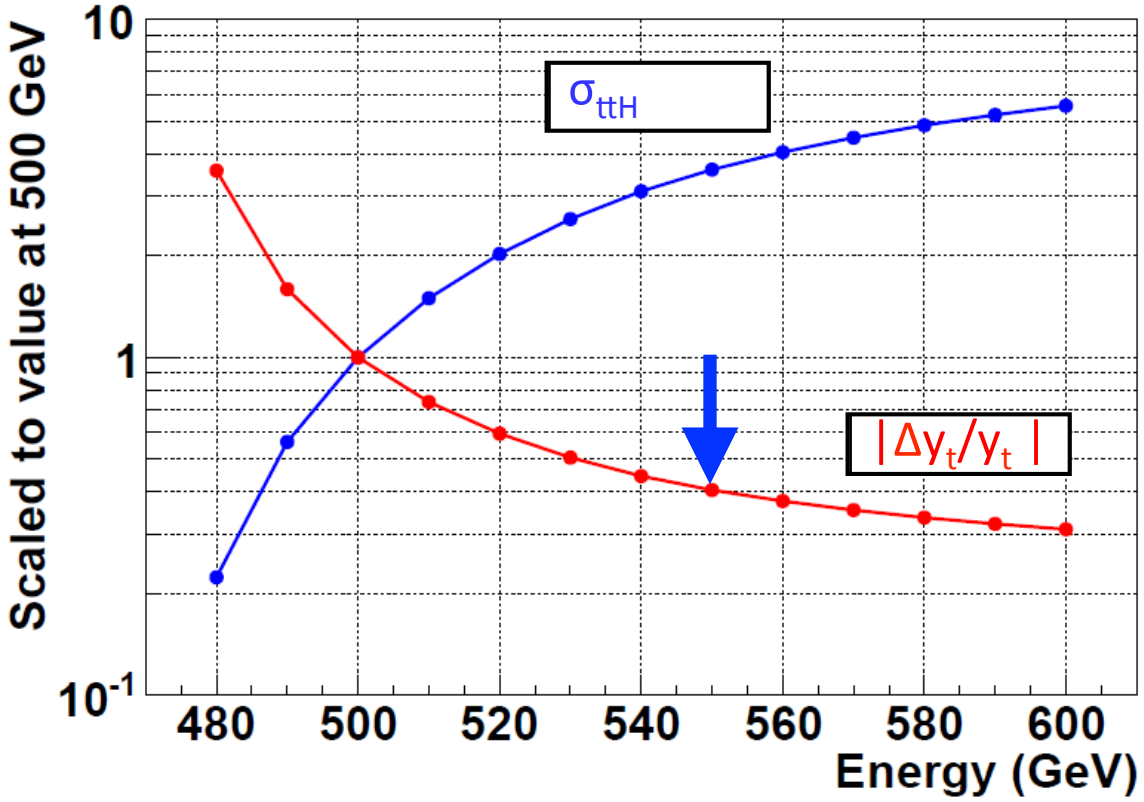
- Left-handed top coupling, and the derived mass scale sensitivity for Kaluza-Klein excitations in and extra-dimensions model



Higgs self-coupling

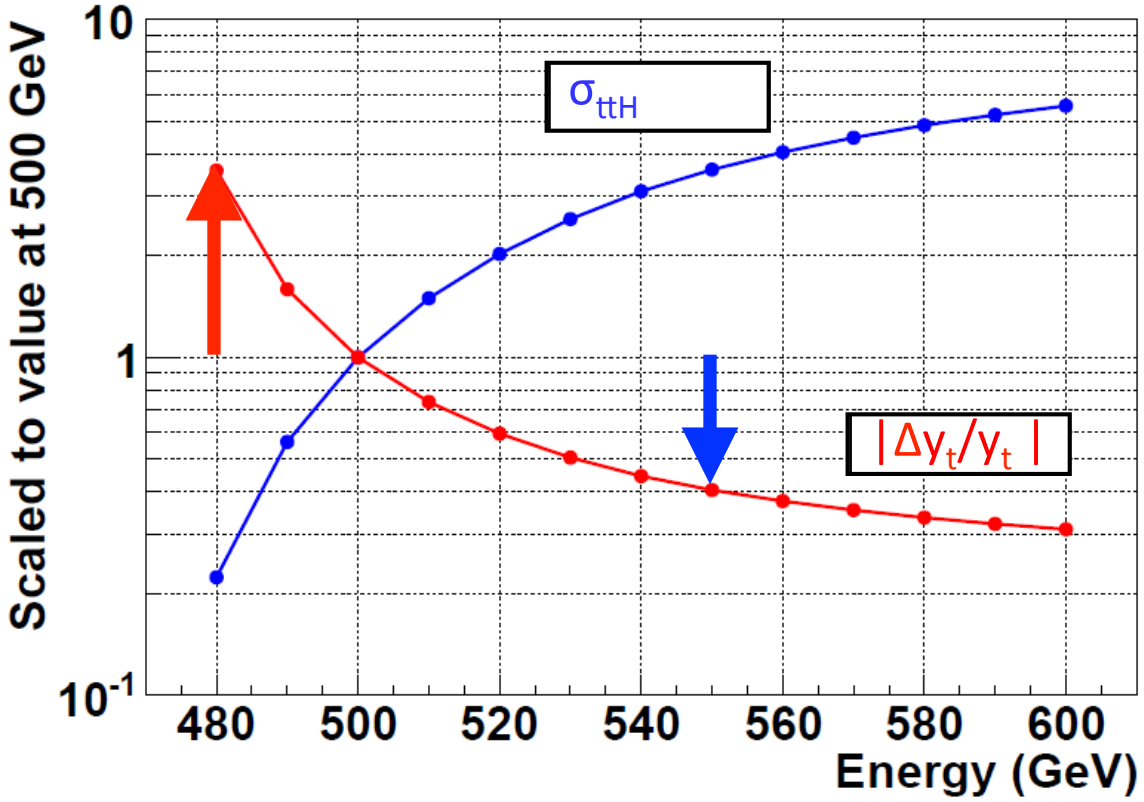


500 GeV vs. 550 GeV & ttH



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

Conclusions on TDR running scenario

- After considering various running scenarios for 500 GeV ILC, we find preferred scenario based on current knowledge: H-20 (approved by Linear Collider Board - June 2015)
    - 500 GeV startup, 20 yr duration (run at 500, 350 & 250 GeV)
    - 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 (eg. other energy in 250-500 GeV range)
- http://arxiv.org/abs/1506.07830

Recommended for ILC studies

H-20

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✳ includes 1.5 years for luminosity upgrade

† ILC Higgs whitepaper: arXiv:1310.0763

- Acknowlegements

contributions to study from
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please refer to the report for specific references (not listed in this talk)