Running Scenarios for ILC500 – First Considerations

Jenny List, Jan 21 2015

Introduction

- We have a nice document for staged scenarios
  - Still waiting for detailed response from LCB?
- Since Belgrade: operate under assumption that
  - scenarios for a staged machine are more or less accepted
  - **but we need also scenarios for building directly the full ILC500**
    - separate document?
    - or include into existing one?
- Open point from before Belgrade:
  - compare Higgs results for our scenarios with Snowmass, make sure we're not doing worse....
  - **basis for agreeing on a set of canonical integrated luminosities and polarisations with Physics Group**

Basic Considerations for ILC500

- 550 GeV is still better than 500 GeV,
  so 500 GeV always means 500 or higher...
- If we *have* a 500 GeV machine, we want to see what's out there -> initial run ~5 (?) years at 500 GeV

  -> e+e- at 500 GeV was never done before
  -> *Discovery Potential !*
- We'll need a top threshold scan
  -> 100-200 fb-1 @ 350 GeV
- We still want a luminosity upgrade
- Future discoveries will change the picture

BUT:
Are there measurements which require
lower centre-of-mass energies?

Candidate Reasons for E_{CM}<500 GeV

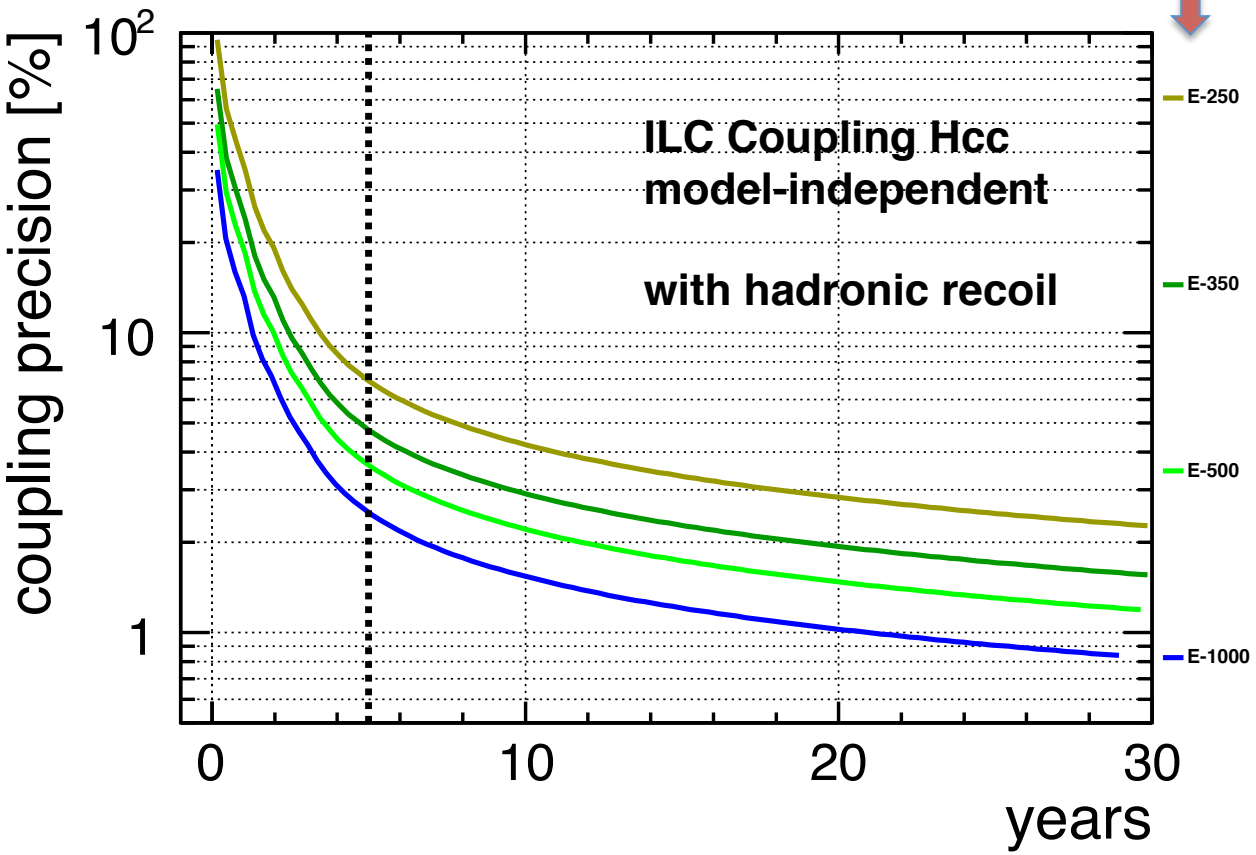
- Top threshold scan -> 200fb^{-1} @ 350 GeV ✔
- Higgs: ZH dies out at higher E_{CM}
  - ZH coupling
  - BR measurements in "difficult" modes which profit a lot from reconstruction of Z ?
    - H->ττ ? incl. CP properties of H-fermion coupling?
    - H-> invisible ?
  - Higgs mass ?
- W mass ?
- New Physics: threshold scans, sub-threshold running
- GigaZ

Higgs Couplings

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

The higher E_{CM} the better for:

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

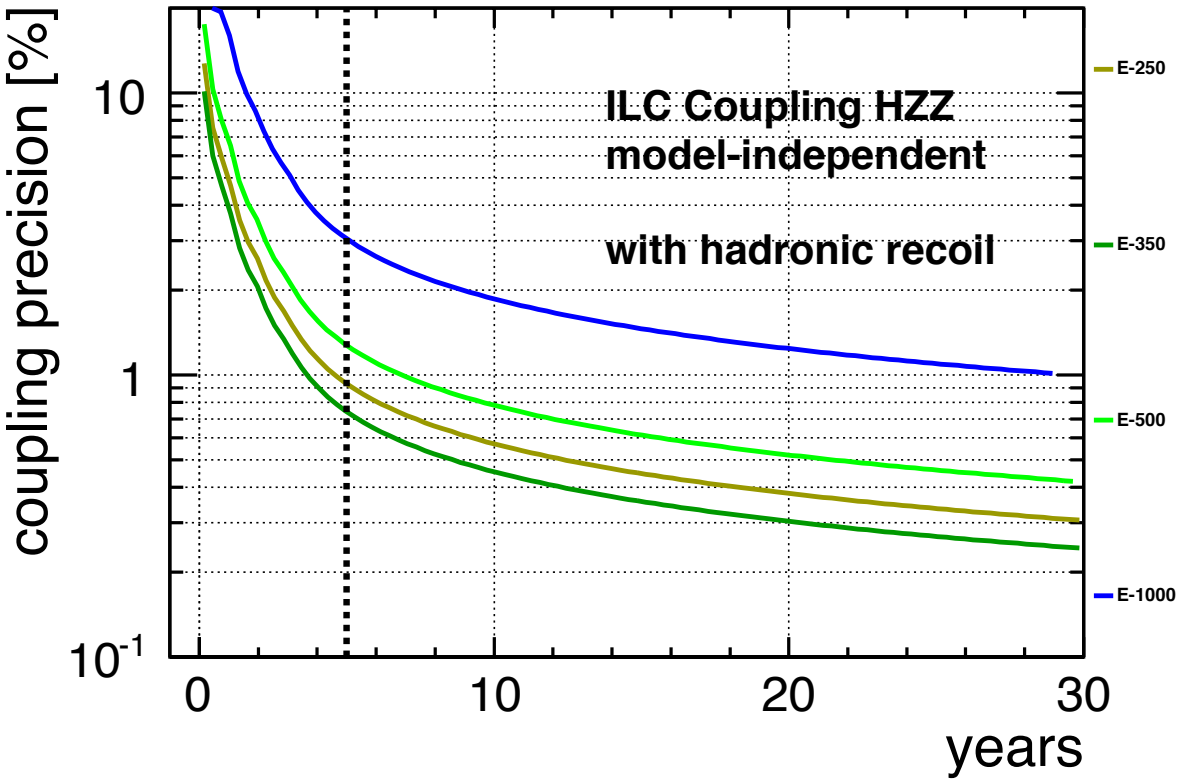


Higgs Couplings: Special Cases

HZZ coupling:

- naively expect best performance at 250 GeV
- but 350 GeV wins in fit since HWW also contributes via Σ(BR)=1

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



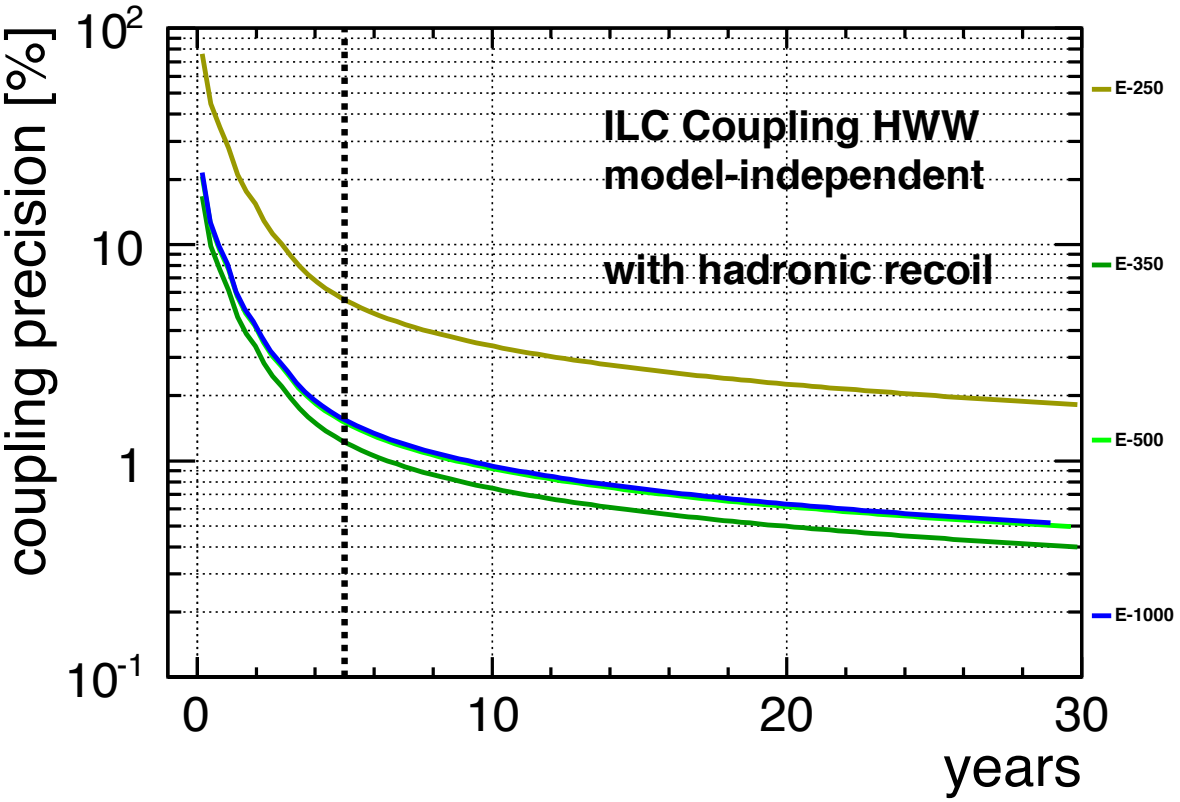
Higgs Couplings: Special Cases

HWW coupling:

- naively expect best performance at highest energy
- but **again** 350 GeV wins in fit since HZZ also contributes via Σ(BR)=1

Conclusion: extended 350 GeV run?

... it depends!



Candidate Reasons to prefer 250 GeV over 350 GeV

- Higgs mass from leptonic recoil
  - need $\delta m_H < 20\text{-}30$ 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?

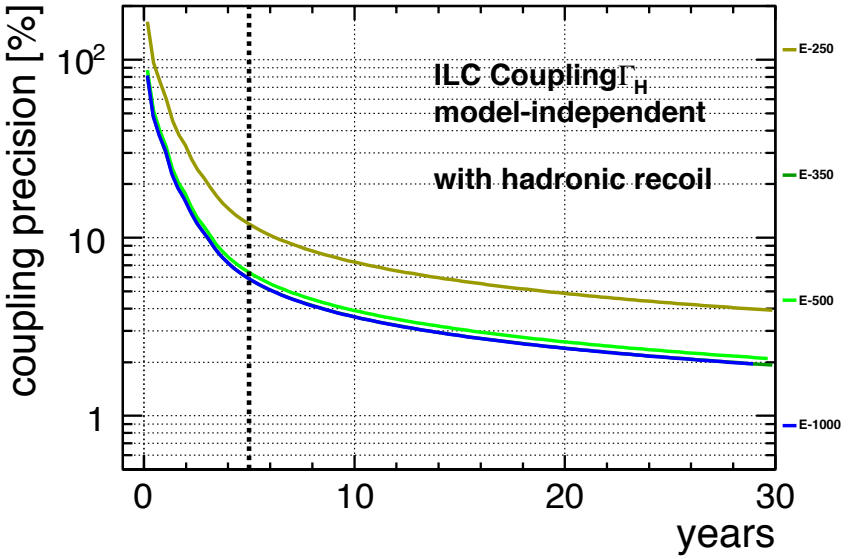
- Higgs -> ττ: CP properties of H-fermion coupling
  - existing studies rely on Z to reconstruct angles in Higgs restframe => 250 GeV
  - but: in principle Higgs restframe not needed => could also use WW-fusion => higher E_{CM} ???

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!



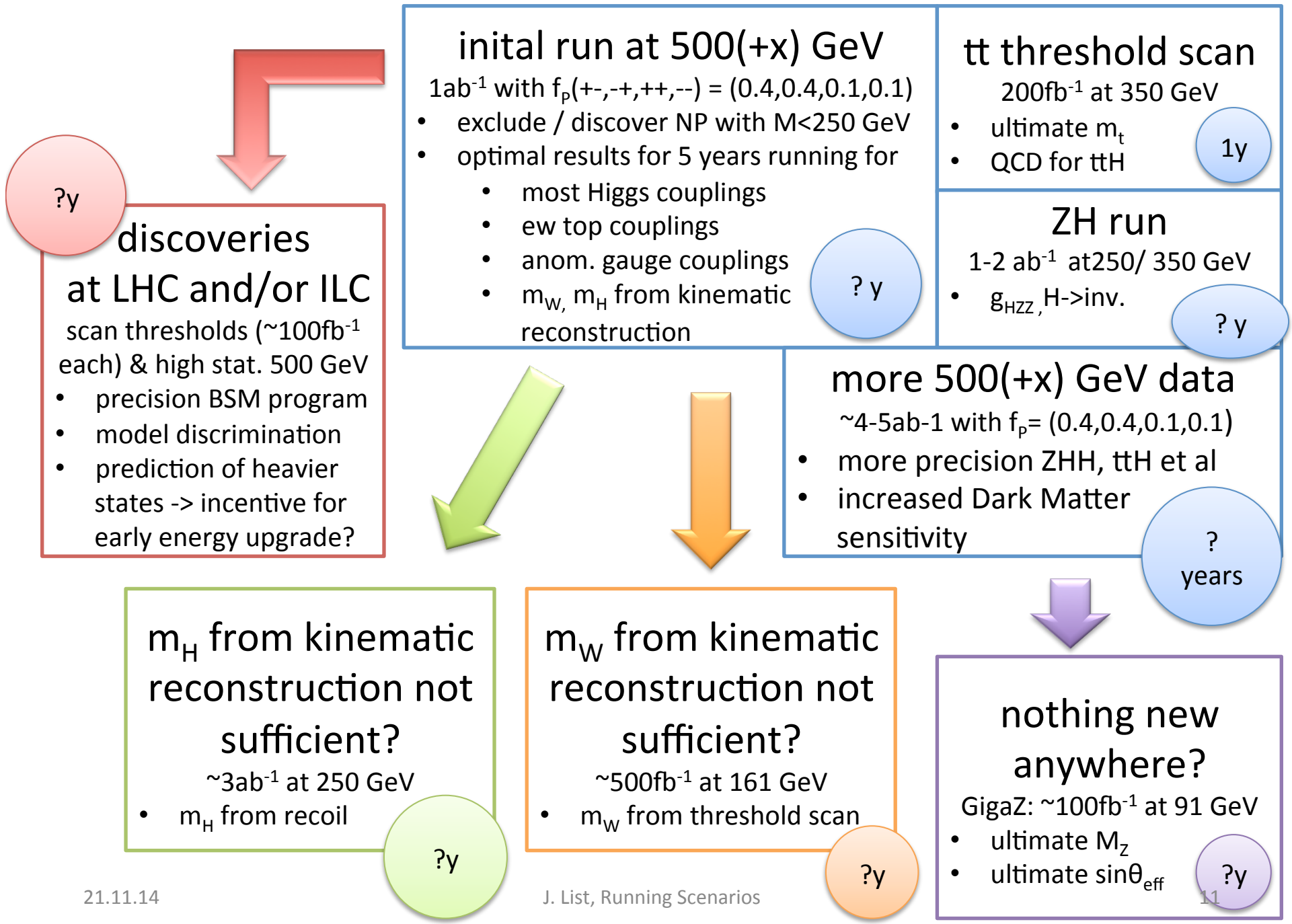
Polarisation Sharing

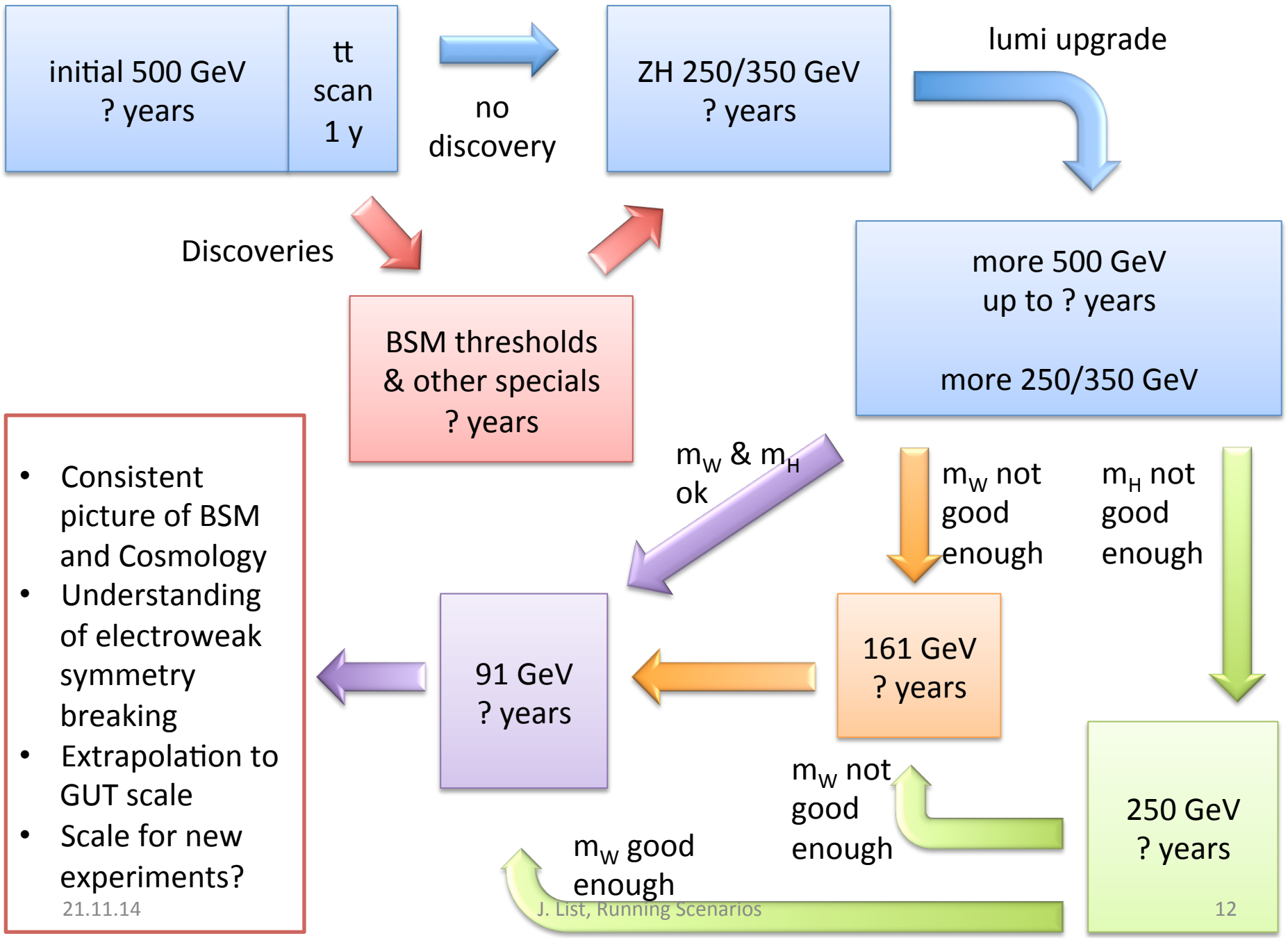
- sofar, many Higgs studies considered only left-handed electron case P=(-80%,+30%)
- since summer, studies for P=(+80%,-30%) are coming in => often better due to suppressed WW background!

$\Rightarrow$ should revisit suggested sharing at lower E_{CM}:

250 GeV / 350 GeV:

67%, 22.5%, 5%, 5% => 45%, 45%, 5%, 5% ?

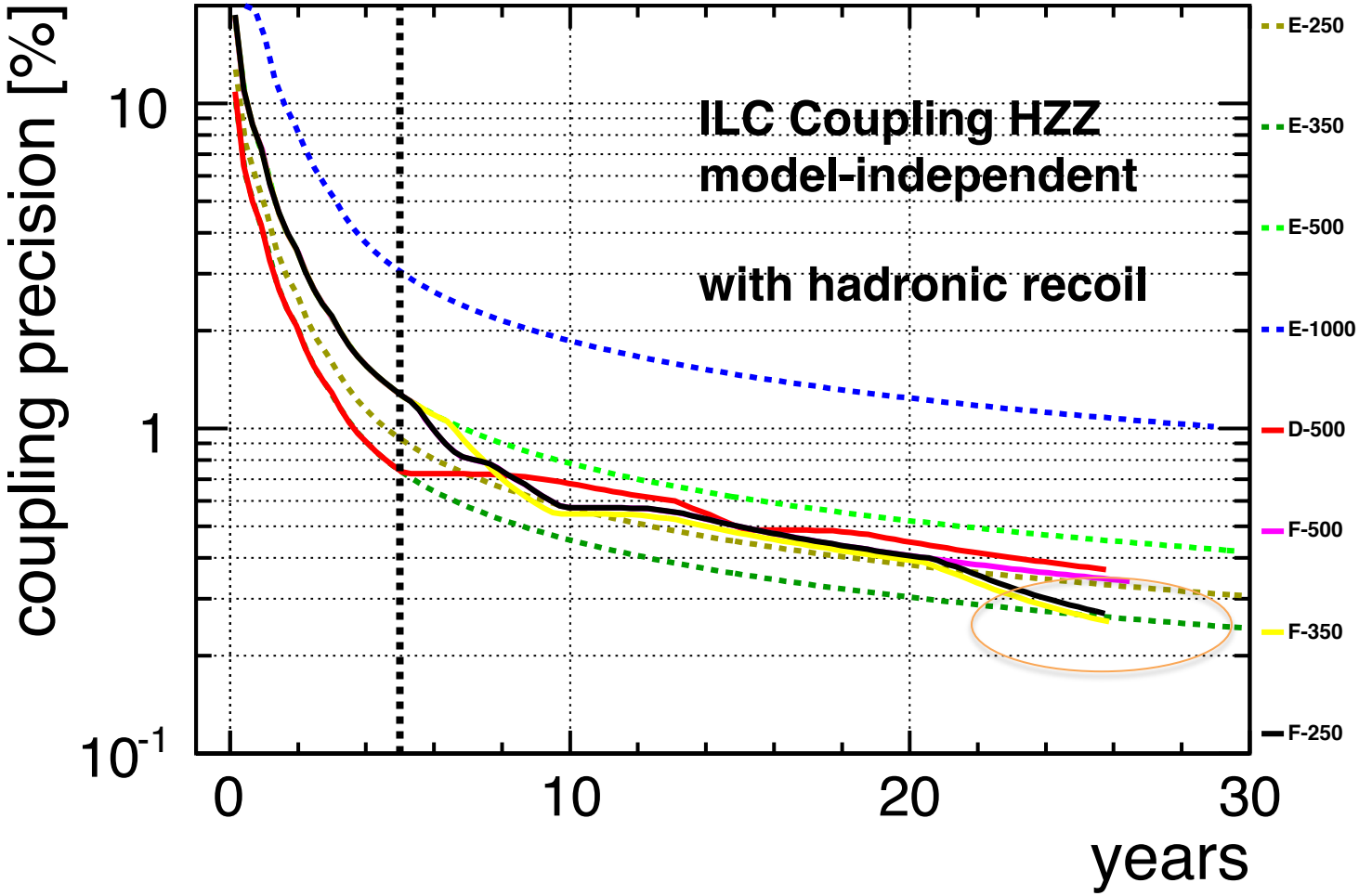

inital run at 500(+x) GeV
1ab-1 with fP(+-,-+,++,--) = (0.4,0.4,0.1,0.1)
• exclude / discover NP with M<250 GeV
• optimal results for 5 years running for
• most Higgs couplings
• ew top couplings
• anom. gauge couplings
• mW, mH from kinematic reconstruction
? y
tt threshold scan
200fb-1 at 350 GeV
• ultimate mt
• QCD for ttH
1y
ZH run
1-2 ab-1 at250/ 350 GeV
• gHZZ, H->inv.
? y
?y
discoveries
at LHC and/or ILC
scan thresholds (~100fb-1 each) & high stat. 500 GeV
• precision BSM program
• model discrimination
• prediction of heavier states -> incentive for early energy upgrade?
more 500(+x) GeV data
~4-5ab-1 with fP= (0.4,0.4,0.1,0.1)
• more precision ZHH, ttH et al
• increased Dark Matter sensitivity
? years
mH from kinematic reconstruction not sufficient?
~3ab-1 at 250 GeV
• mH from recoil
?y
mW from kinematic reconstruction not sufficient?
~500fb-1 at 161 GeV
• mW from threshold scan
?y
nothing new anywhere?
GigaZ: ~100fb-1 at 91 GeV
• ultimate MZ
• ultimate sinθeff
?y


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?

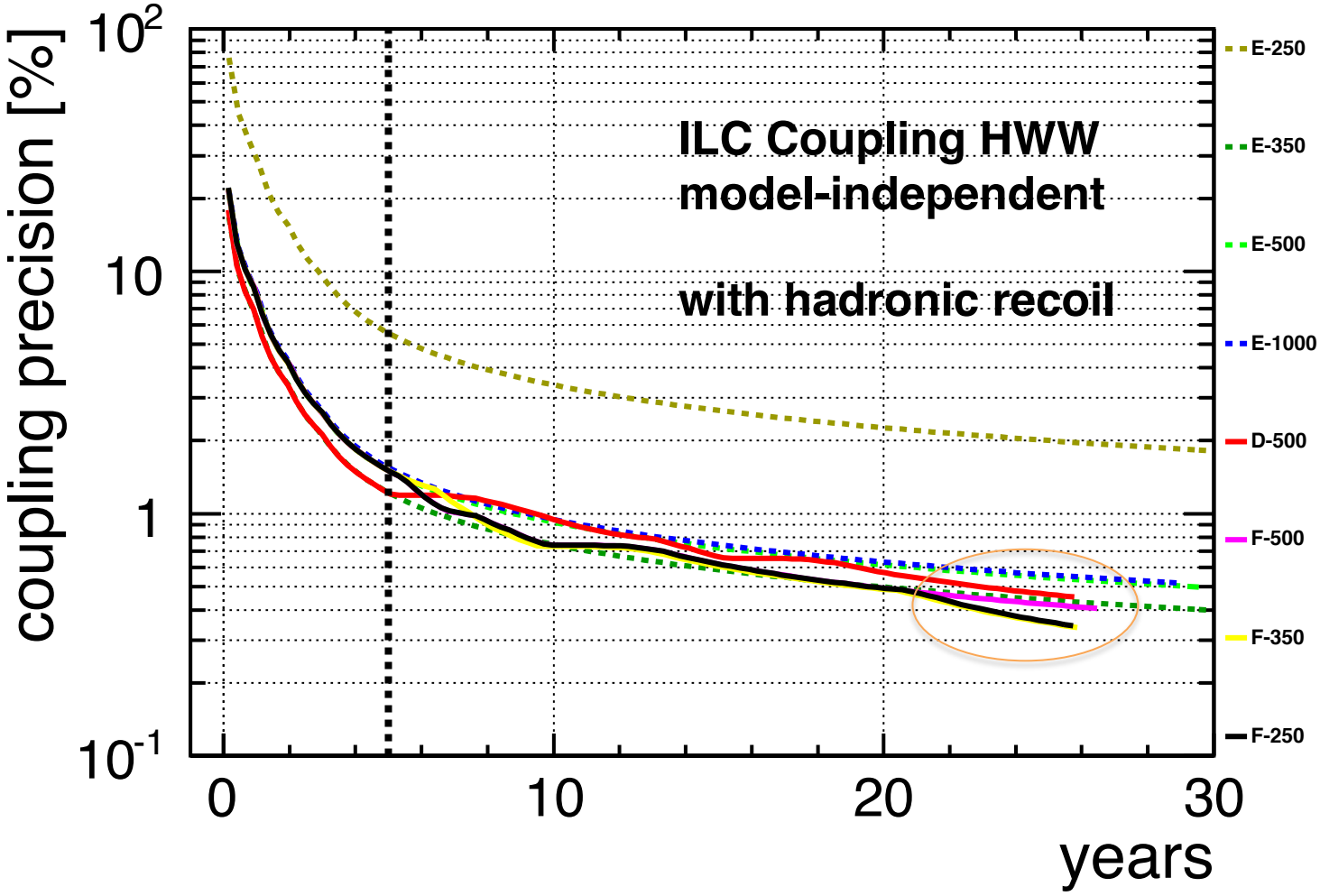
Some Running Scenarios

(Not considering: Zpole, WW, New Physics, 1 TeV)

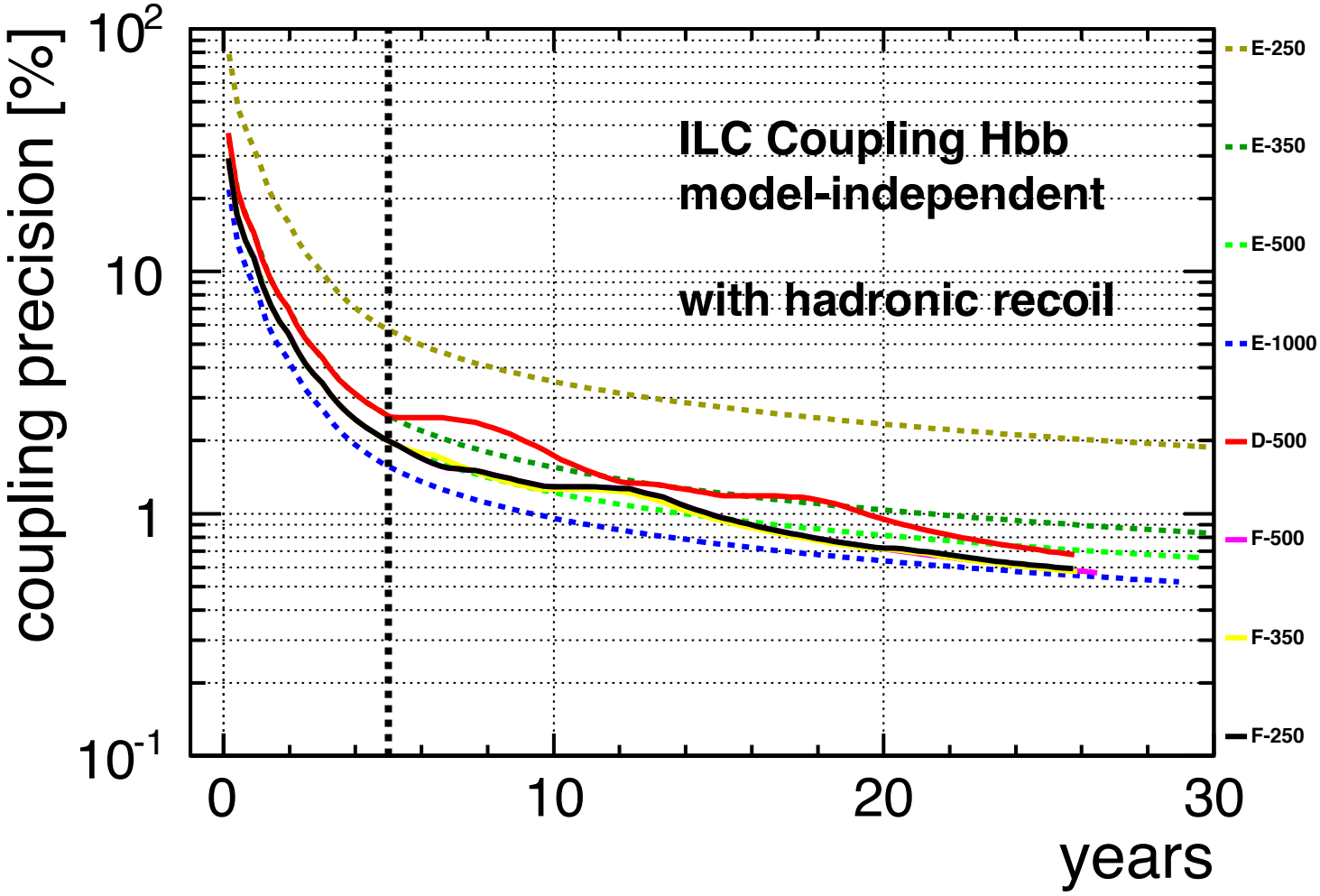
- F-250
  - baseline: 1ab^{-1}@ 500 GeV, 200fb^{-1} @ 350 GeV, 500fb^{-1} @250 GeV (10Hz)
  - **lumi-up: 4ab^{-1} @ 500 GeV, 2.5 ab^{-1} @ 250 GeV (10 Hz)**
- F-350
  - baseline: 1ab^{-1}@ 500 GeV, 700fb^{-1} @ 350 GeV (7Hz)
  - **lumi-up: 4ab^{-1} @ 500 GeV, 2.5 ab^{-1} @ 350 GeV (7Hz)**
- F-500
  - baseline: 1ab^{-1}@ 500 GeV, 200fb^{-1} @ 350 GeV, 500fb^{-1} @250 GeV (10Hz)
  - **lumi-up: 8ab^{-1} @ 500 GeV**



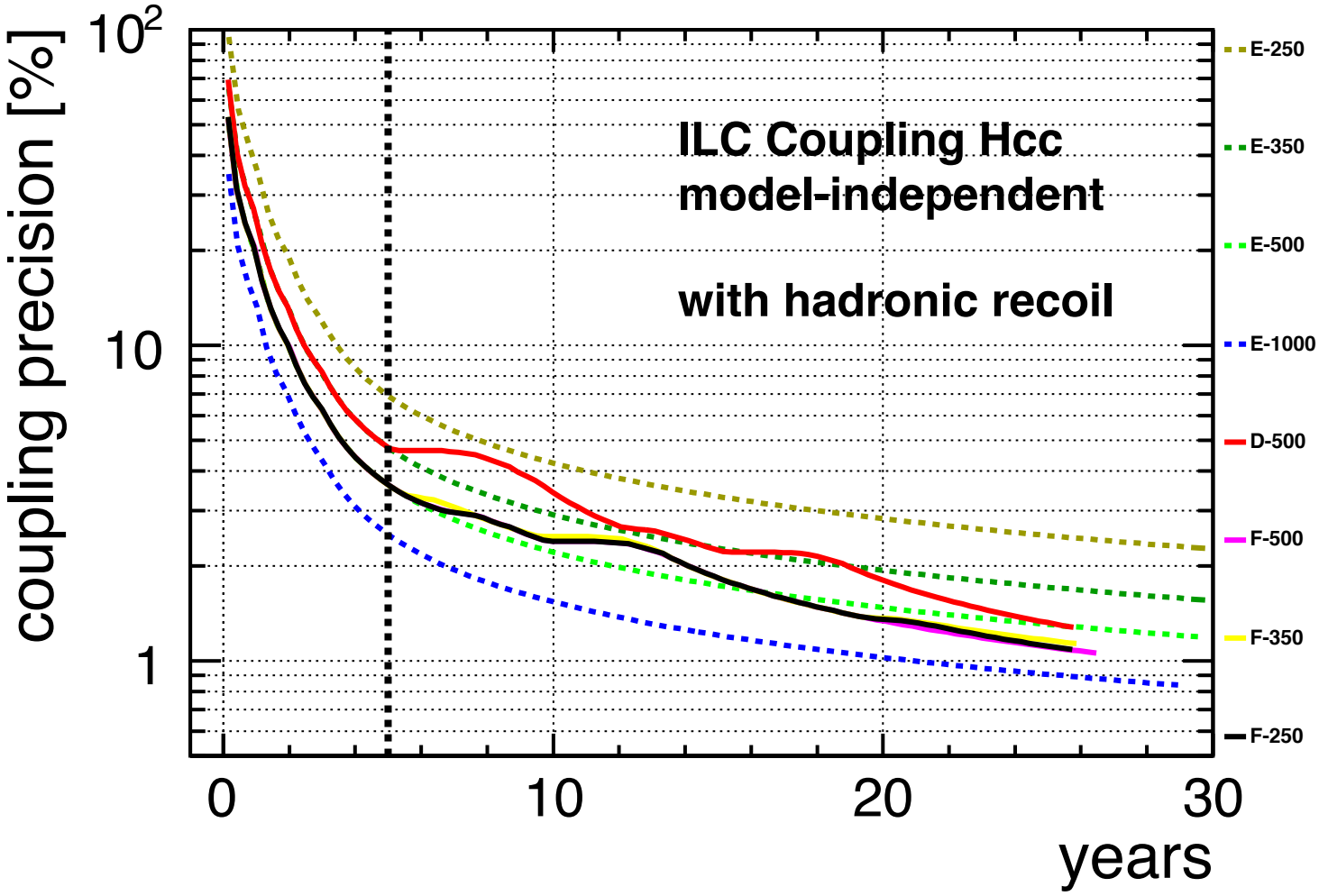
HZZ:
250 GeV
or
350 GeV



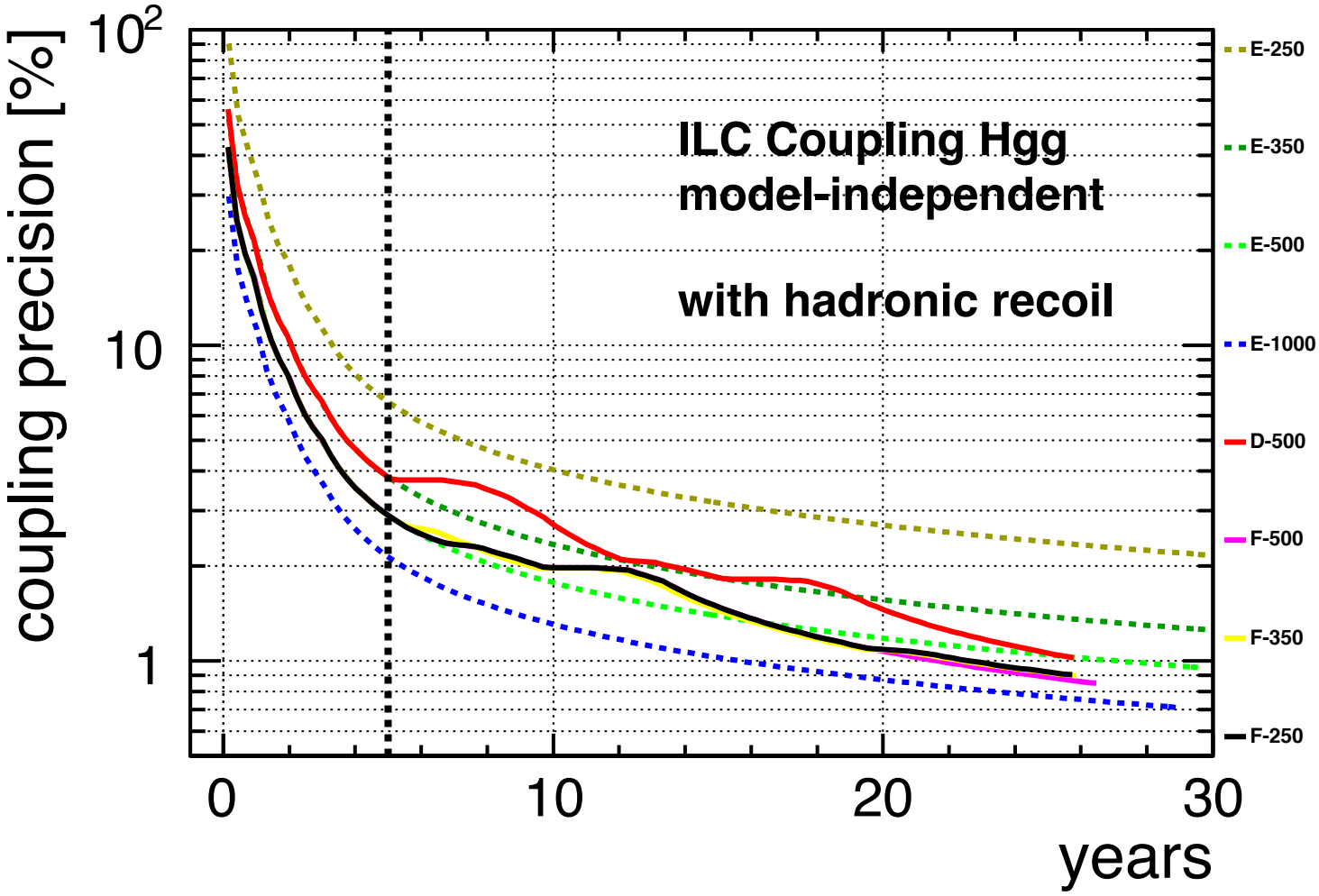
even HWW does not prefer 500 GeV!


coupling precision [%]
10^2
10
1
10^{-1}
0
10
20
30
years
ILC Coupling Hbb
model-independent
with hadronic recoil
E-250
E-350
E-500
E-1000
D-500
F-500
F-350
F-250

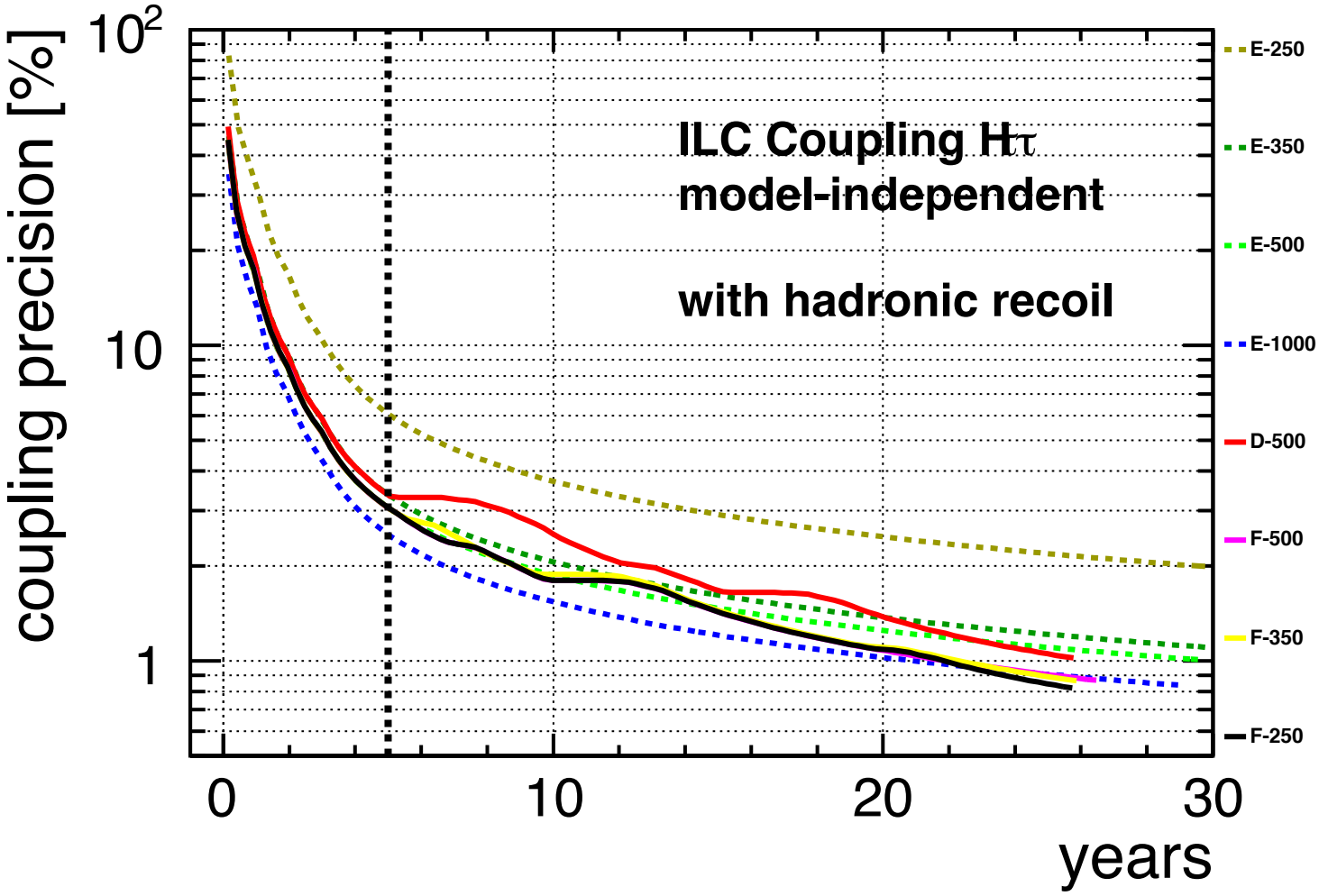
doesn't care


coupling precision [%]
10^2
10
1
0
10
20
30
years
ILC Coupling Hcc
model-independent
with hadronic recoil
E-250
E-350
E-500
E-1000
D-500
F-500
F-350
F-250

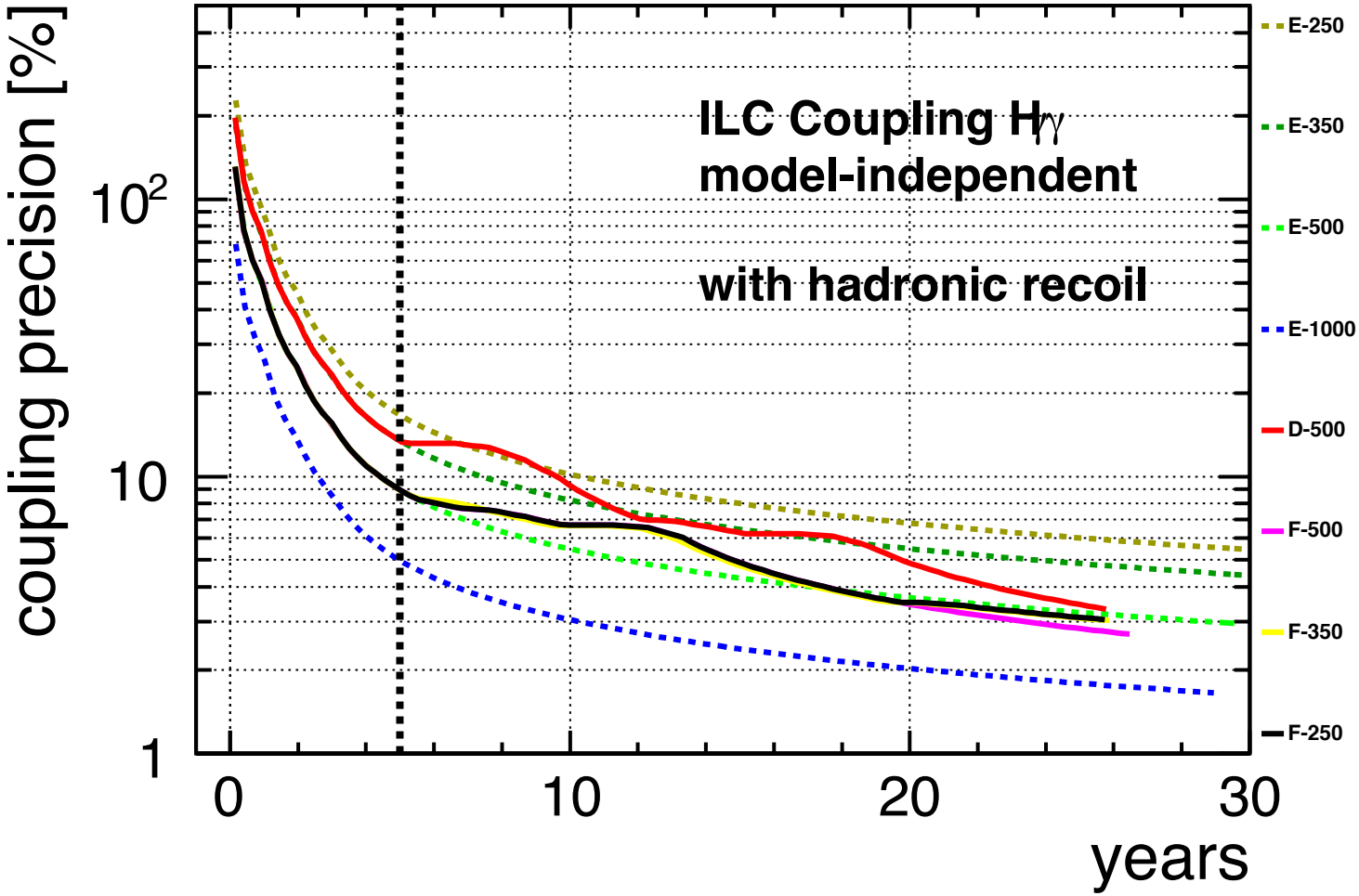
doesn't care


coupling precision [%]
10^2
10
1
0
10
20
30
years
ILC Coupling Hgg
model-independent
with hadronic recoil
E-250
E-350
E-500
E-1000
D-500
F-500
F-350
F-250

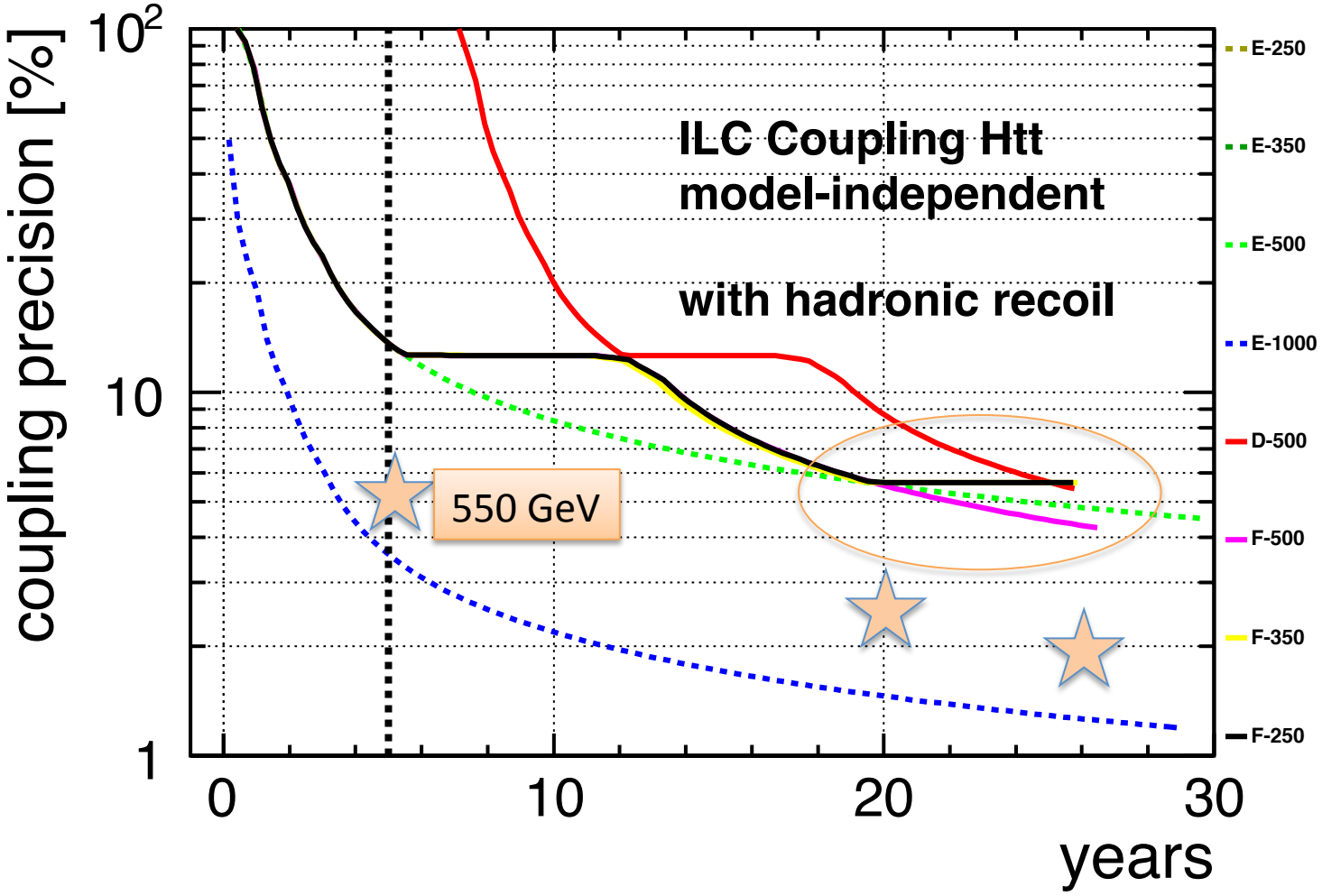
doesn't care


coupling precision [%]
10^2
10
1
0
10
20
30
years
ILC Coupling Hττ
model-independent
with hadronic recoil
E-250
E-350
E-500
E-1000
D-500
F-500
F-350
F-250

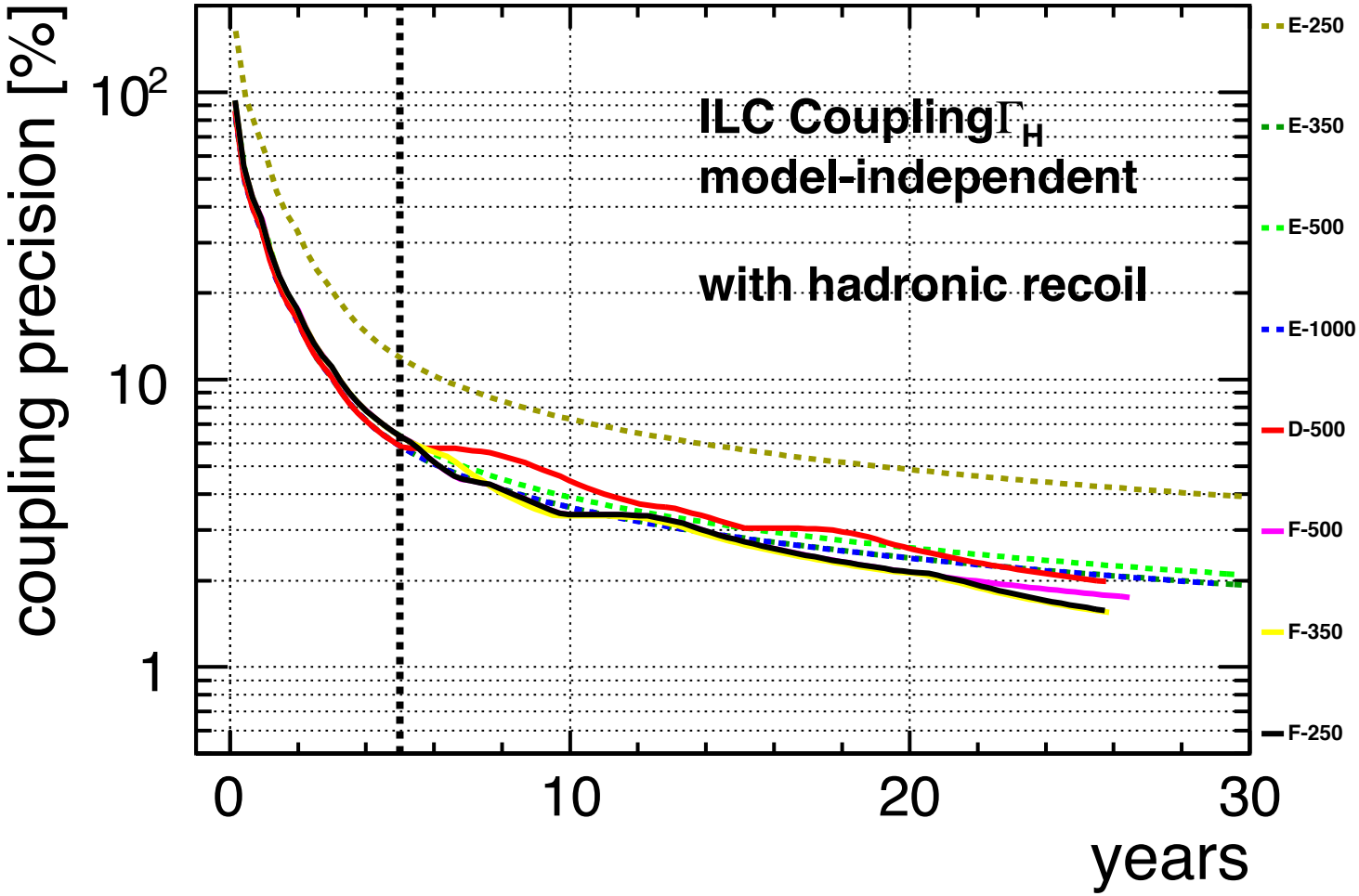
doesn't care


ILC Coupling Hγγ
model-independent
with hadronic recoil
coupling precision [%]
10²
10
1
0
10
20
30
years
E-250
E-350
E-500
E-1000
D-500
F-500
F-350
F-250

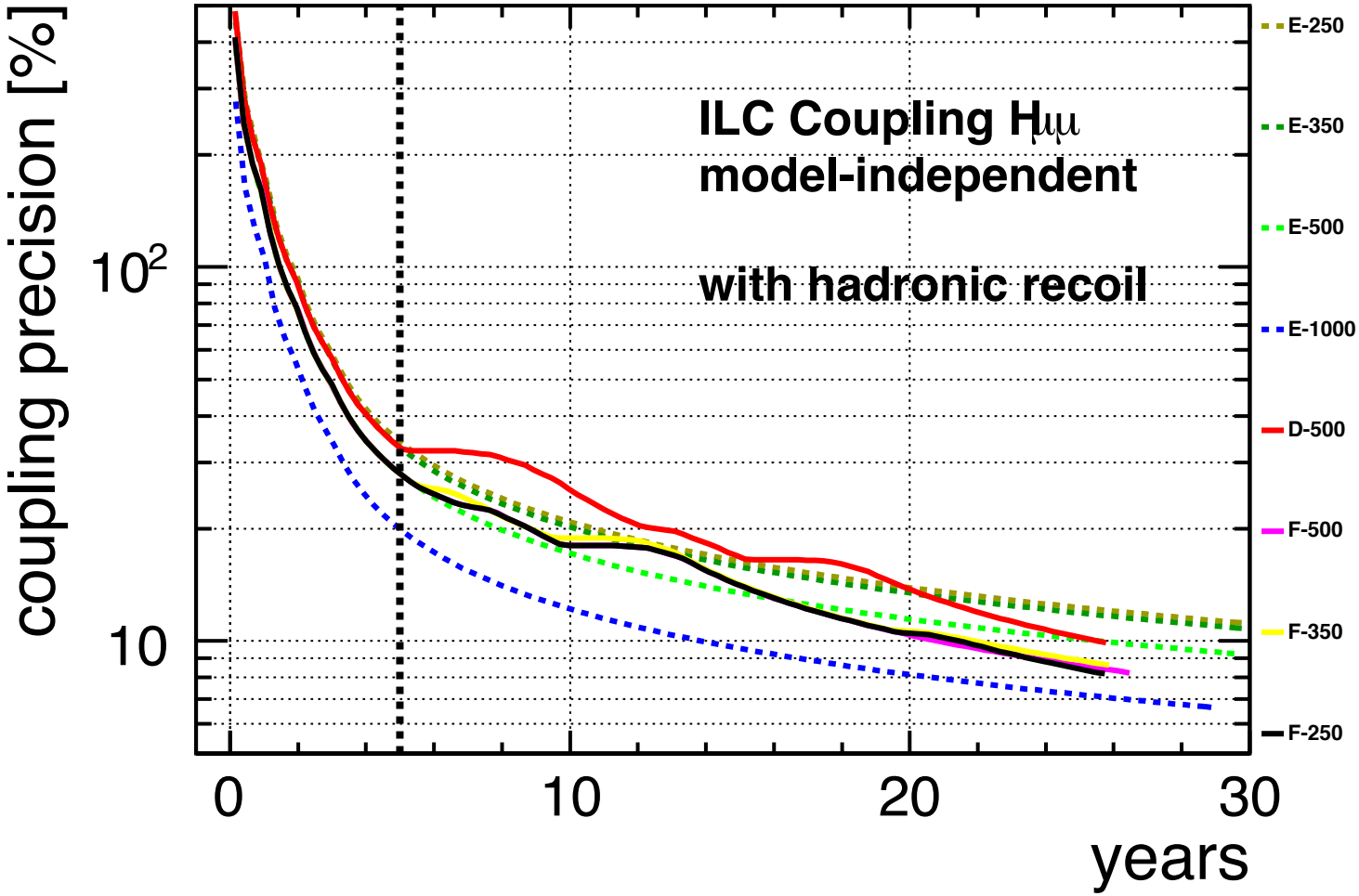
doesn't care



F500 slightly prefered, but small effect compared to increase in ECM!


coupling precision [%]
10^2
10
1
0
10
20
30
years
ILC Coupling Γ_H
model-independent
with hadronic recoil
E-250
E-350
E-500
E-1000
D-500
F-500
F-350
F-250

doesn't care


coupling precision [%]
10^2
10
0
10
20
30
years
ILC Coupling Hμμ
model-independent
with hadronic recoil
E-250
E-350
E-500
E-1000
D-500
F-500
F-350
F-250

doesn't care

Comparison with Snowmass

- Table 1-16 from arxiv:1310.8361
- incl 0.5% theory uncertainy!!!!
- for our scenarios: for today just added in quadrature to fit result (should be included in fit)
- for full details, see .ods attached to agenda page

Snowmass Comparison

Parameter	Accuracy ΔX/X, total width constrained (case 8)					Snowmass
	Scen. A	Scen B	Scen D-500	D-500 + 1TeV	D-500 + 1TeV	LumiUp
m_h	can put here recoil numbers from 250 GeV alone. Contributions				Incl 0.5% theory uncertainty!	
g_hZZ	0.21%	0.21%	0.22%	0.21%	0.54%	0.50%
g_hWW	0.26%	0.26%	0.22%	0.18%	0.53%	0.60%
g_hbb	0.53%	0.53%	0.45%	0.31%	0.59%	0.80%
g_hcc	1.20%	1.20%	1.20%	0.73%	0.88%	1.10%
g_hgg	1.00%	1.00%	0.92%	0.59%	0.77%	0.90%
g_hττ	0.86%	0.86%	0.87%	0.64%	0.81%	1.00%
g_hγγ	3.70%	3.70%	3.20%	1.70%	1.77%	2.40%
g_htt	7.30%	7.30%	5.40%	1.30%	1.39%	2.00%
g_hμμ	9.80%	9.80%	9.70%	6.40%	6.42%	10.00%
Γ_h	1.00%	1.00%	0.92%	0.73%	0.88%	1.90%
BR(h-> inv), 95%CL	0.83%	0.83%	0.55%	0.55%	0.74%	0.40%

Note: limit on Br (H->inv) for our scenarios from direct search for H->invis.
for Snowmass probably from global fit?

Conclusions I – Early Performance

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

- ttH, triple-Higgs-coupling: **unreachable at < 500 GeV**
- H -> μμ, γγ, gg, cc, bb: substantially better
- Γ_H, H -> ττ, HWW: about equal
- HZZ: worse, ultimately needs some 250/350 GeV data
- m_H: 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 F500, 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
- m_H: 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 !

Conclusions III – Other considerations

- Snowmass comparison: looks ok to me – how do we want to present this?
- Beam polarisations: *reconsider polarisation splitting* in view of newest Higgs results preferring e^-_R e^+_L due to lower backgrounds ?
- top couplings: use less extreme New Physics model -> got information from Roman in December, *need to redo plots*
- Stress again importance of the flexibility of the ILC – some choices concerning the operation will only be made while the ILC physics program proceeds!