Status of ILC
+
Physics of Linear e+e- Colliders

thanks to my ILC IDT and ALCC colleagues!

M. E. Peskin
Energy Frontier meeting
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In this talk, I am asked to address two questions:

What is the current status of the International Linear Collider ?

How is physics at linear e+e- collider different from physics at a circular e+e- collider ?

Everything that you would like to know about the ILC — and more — is reviewed in the ILC Snowmass white paper

arXiv:2203.07622

This report covers the physics case for the ILC, the current political situation, the machine design, detectors and experimentation, projected precision of measurements, theoretical interpretation of ILC results, and the future of the ILC Lab after ILC.

I encourage you to endorse this report. Please visit

https://agenda.linearcollider.org/event/9135/

Part 1:

Status and Prospects for ILC

The ILC issued its Technical Design Report in 2013. This is a fully engineered by not yet site-specific design.

A technically limited schedule for ILC construction is:

begin tunnelling in 2023
contract for SRF cavity manufacture in 2023
first data in 2033

Of course, this does not address some real-world issues.

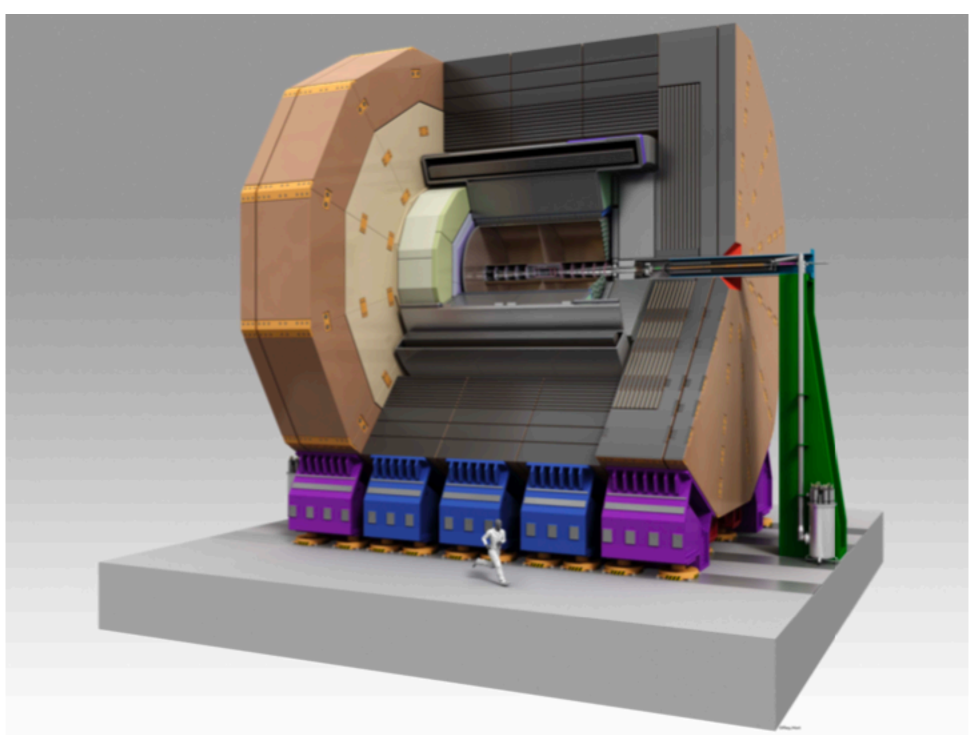
a more realistic, but still optimistic, schedule is:

2023 - increased funding from Japan for final R&D issues
2024 - begin discussions on international cost sharing
2028 - begin tunnel construction, SRF cavity procurement
2039 - commissioning and first data

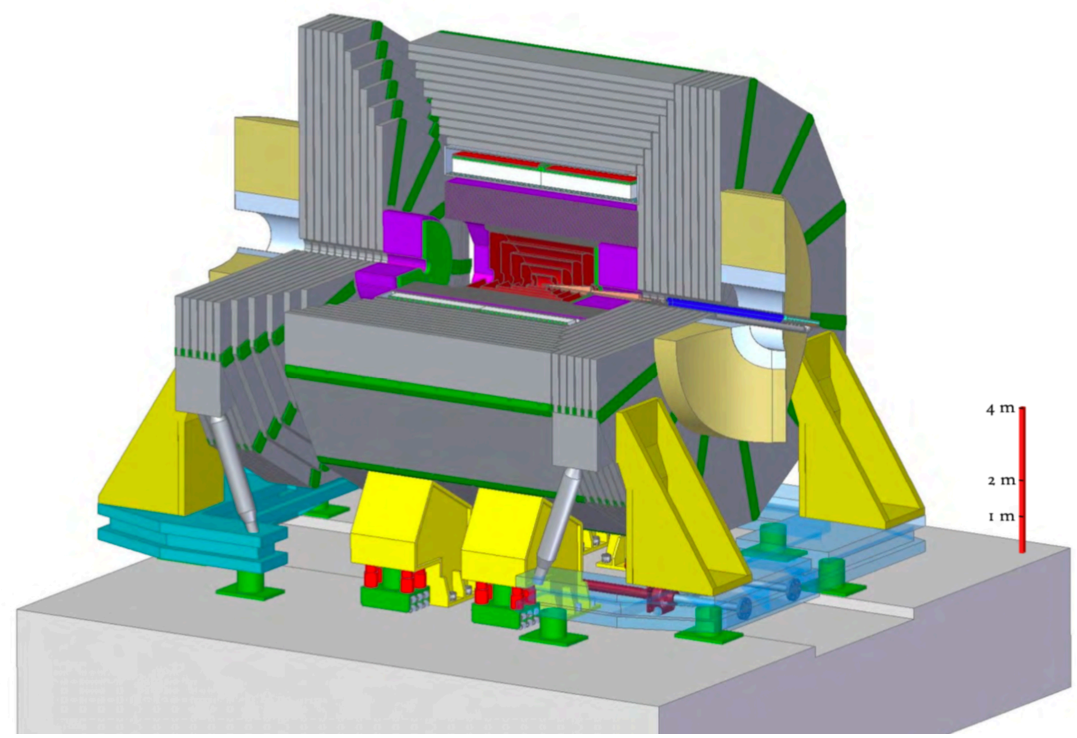
At this time, we are requesting funding only for the 250 GeV stage of the ILC.

ILC is the only Higgs factory proposal fully engaged with governments and negotiating funding. As of now, it is the only proposal with a path to first data before 2040.

Two ILC detector designs have been carried out at the CDR level and have been used for full-simulation studies of the ILC capabilities. These include all known beam-related backgrounds. They also estimate systematic uncertainties of event reconstruction and luminosity and polarization measurement.



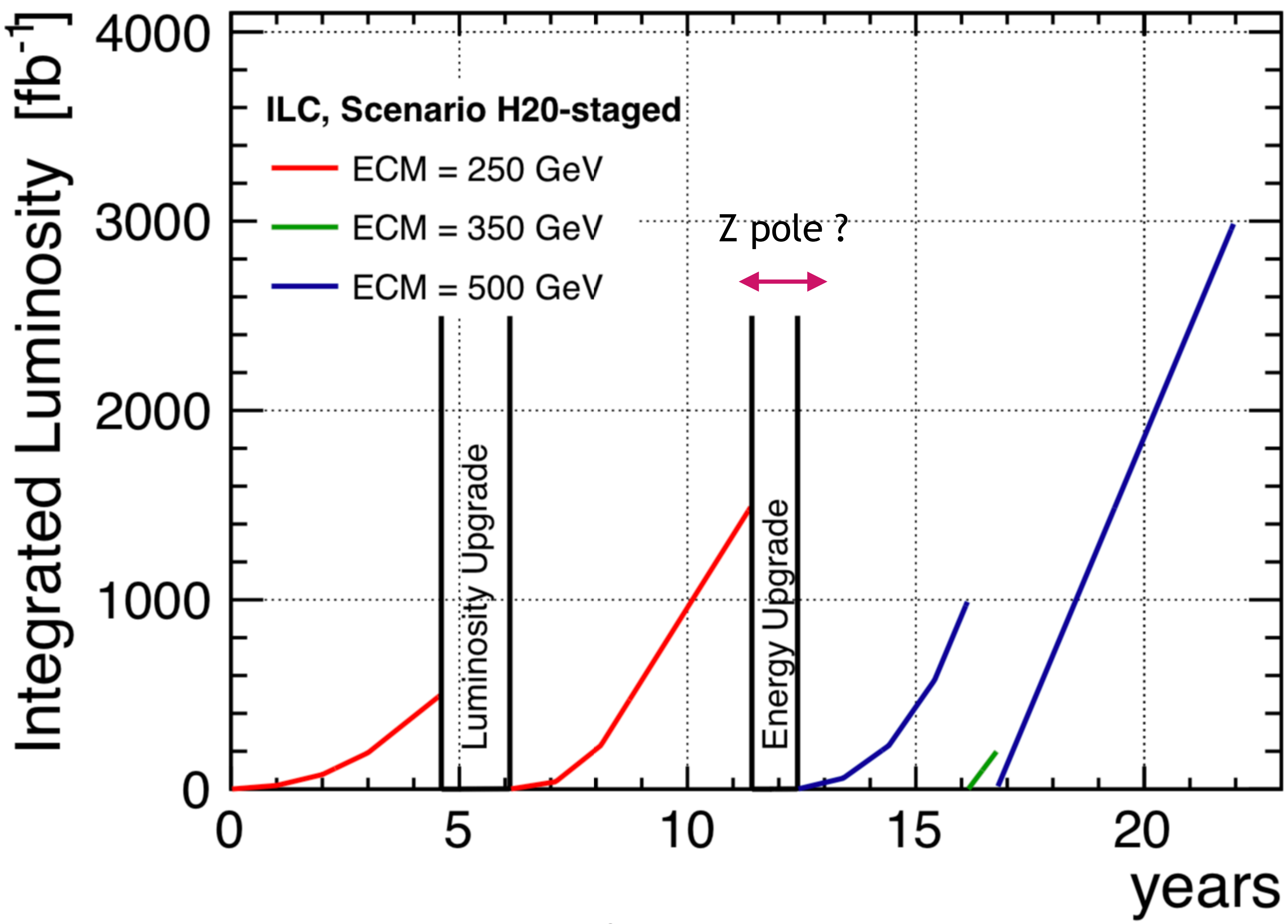
ILD



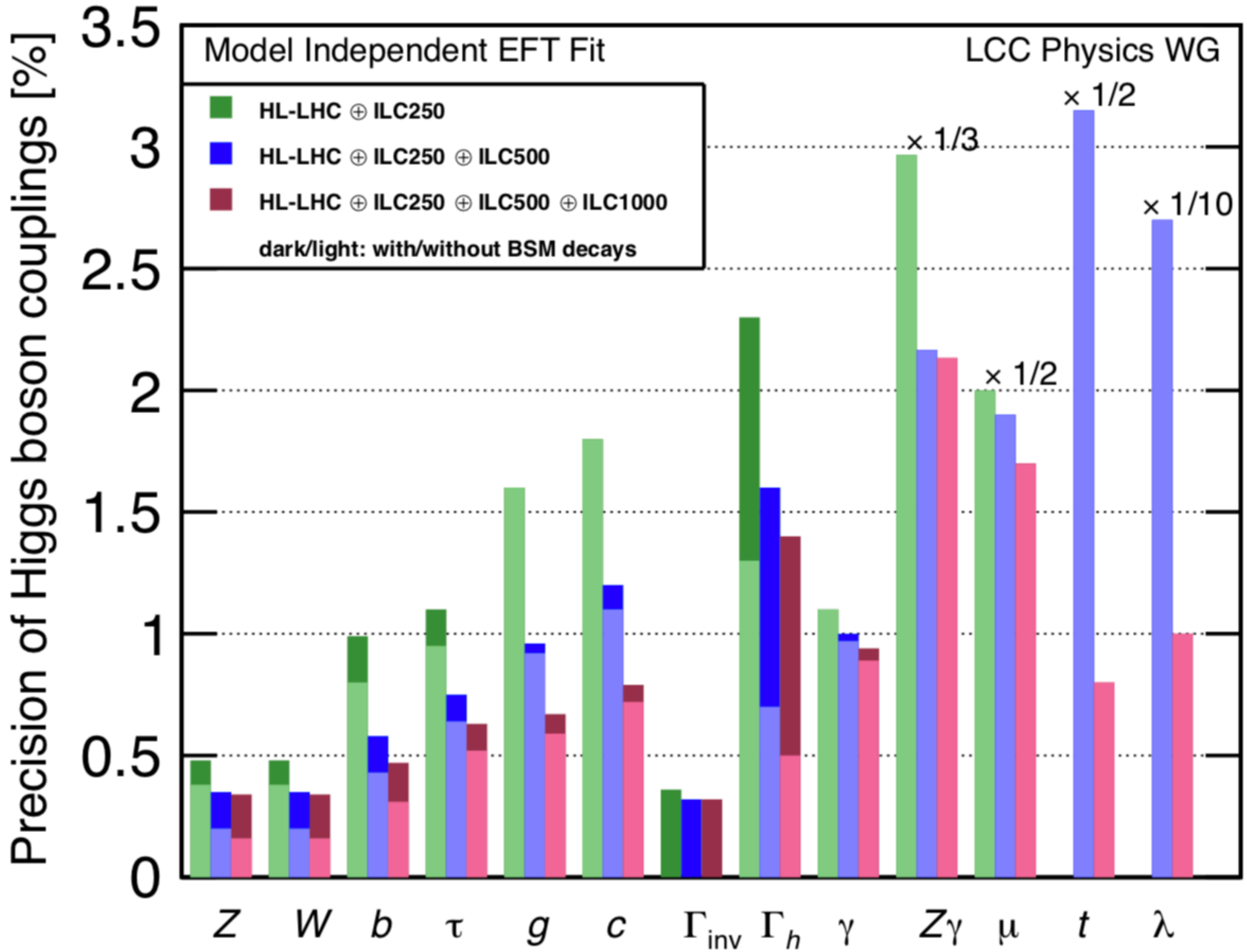
SiD

	91 GeV	250 GeV	350 GeV	500 GeV
$\int \mathcal{L}$ (ab^{-1})	0.1	2	0.2	4
duration (yr)	1.5	11	0.75	9
beam polarization (e^-/e^+; %)	80/30	80/30	80/30	80/30
(LL, LR, RL, RR) (%)	(10,40,40,10)	(5,45,45,5)	(5,68,22,5)	(10,40,40,10)
δ_{ISR} (%)	10.8	11.7	12.0	12.4
δ_{BS} (%)	0.16	2.6	1.9	4.5

ILC
run plan:



Projected uncertainties on Higgs boson couplings:



(projections from FCC-ee and CEPC are very similar)

The ILC program is primarily aimed at the Higgs boson and, in its higher energy stages, at the top quark and the Higgs self-coupling.

However, the ILC will improve on the current precision electroweak measurements. Beam polarization is an important asset here.

uncertainty on $\sin^2\theta_{w,eff}$ in Z decays:

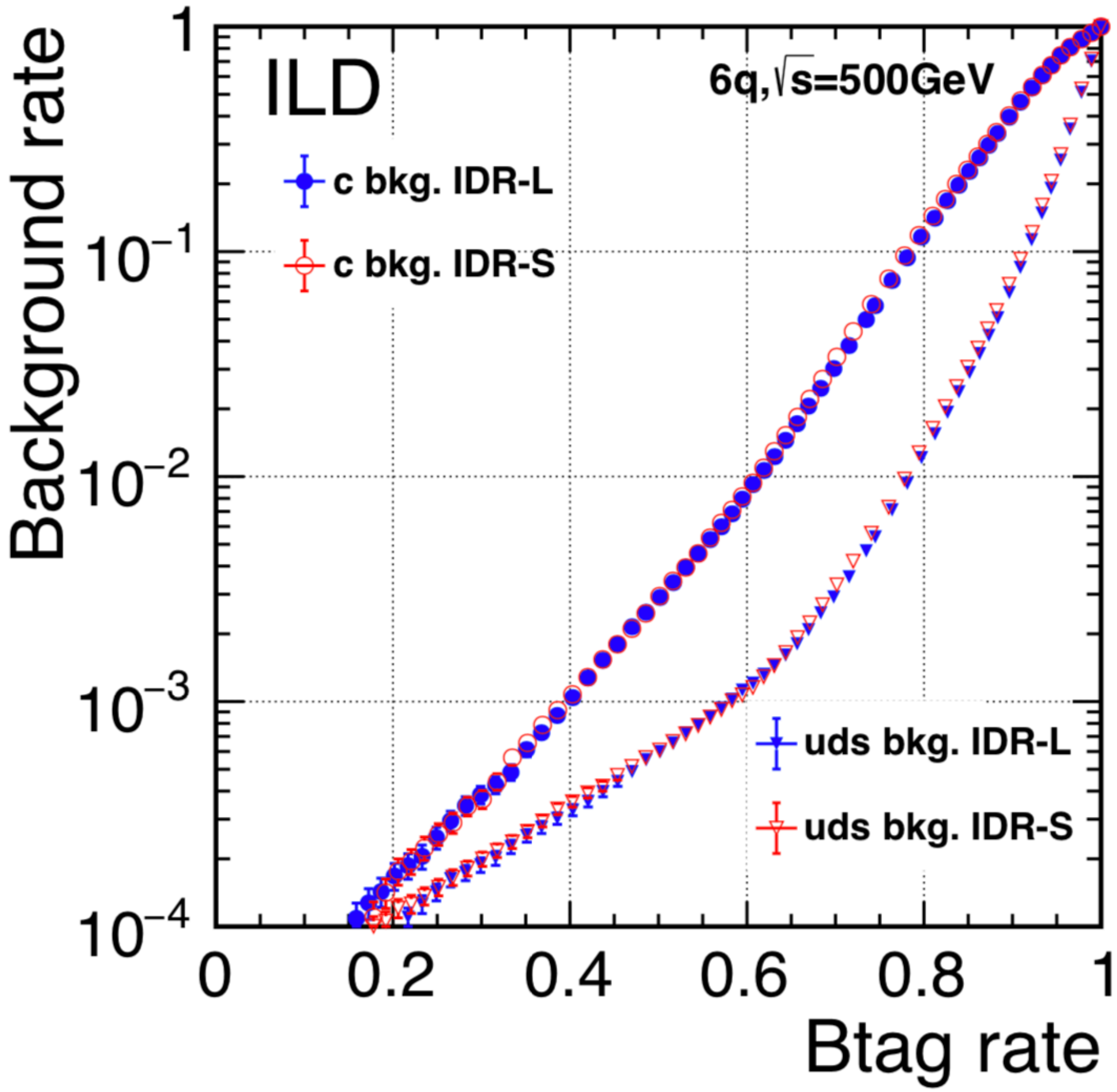
SLD only:	0.00026
LEP + SLD:	0.00016
250 GeV radiative return:	0.000018
ILC Z pole program:	0.0000095
FCC-ee Tera-Z:	0.000005

Part 2:

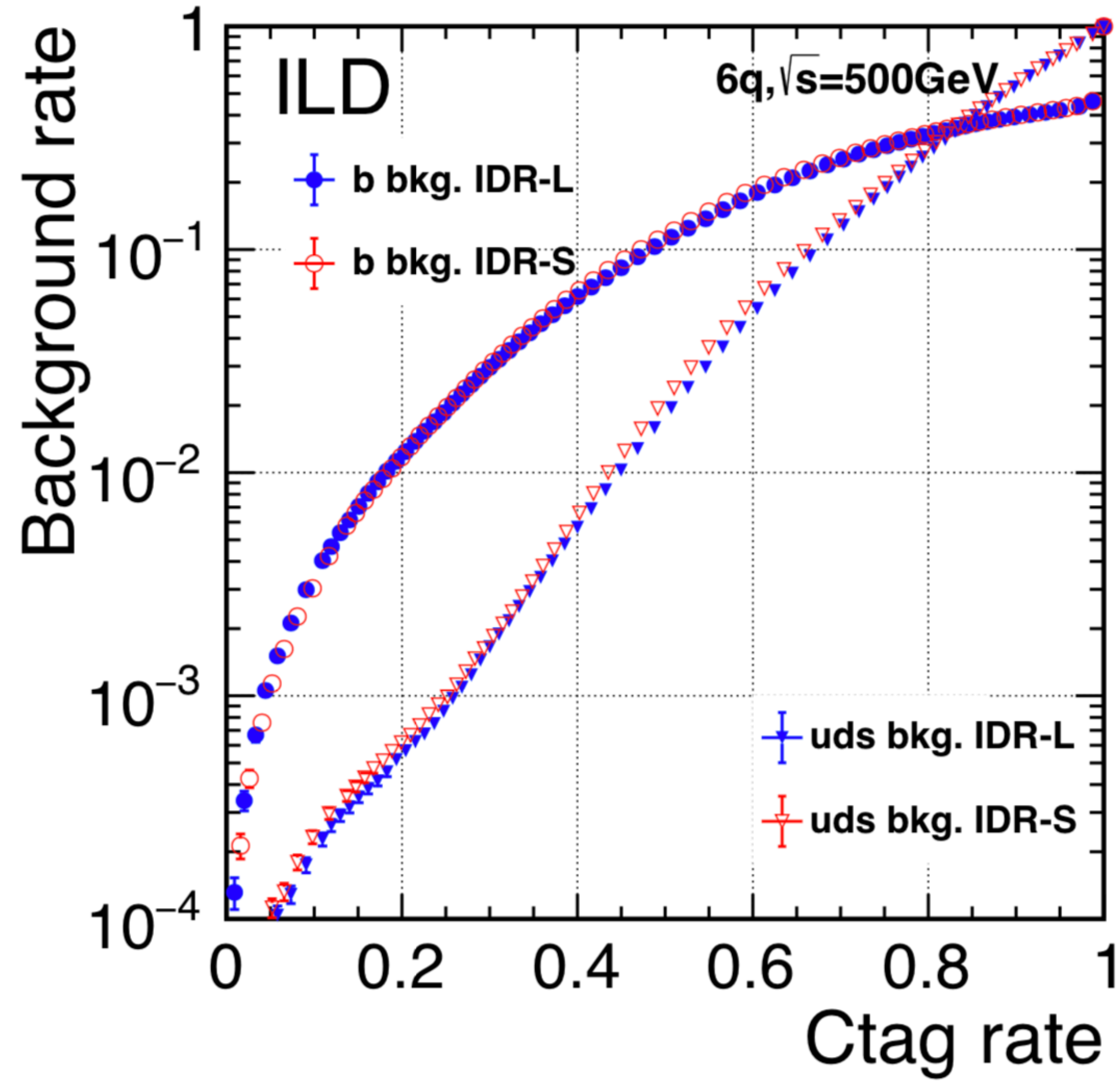
Physics at Linear e+e- Colliders

Experimentation at all e+e- colliders benefits from general features of this method:

minimal soft hadronic background
democratic production of light and heavy particles
full event reconstruction in 3-d
excellent hadron calorimetry using particle flow
    (3% jet energy measurement at 100 GeV)
high b and c vertex tagging efficiency



ILD
6q,√s=500GeV
c bkg. IDR-L
c bkg. IDR-S
uds bkg. IDR-L
uds bkg. IDR-S
Background rate
Btag rate

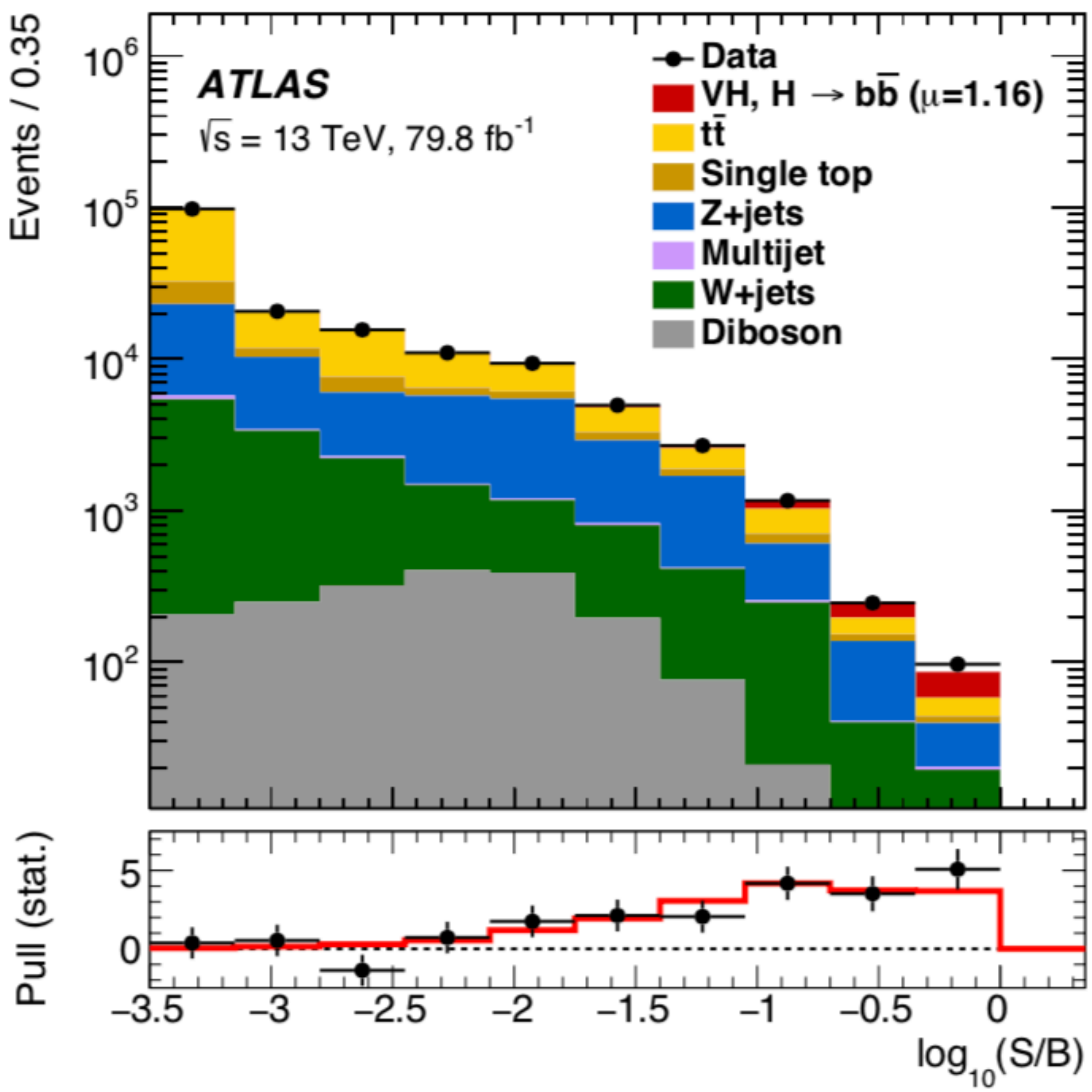


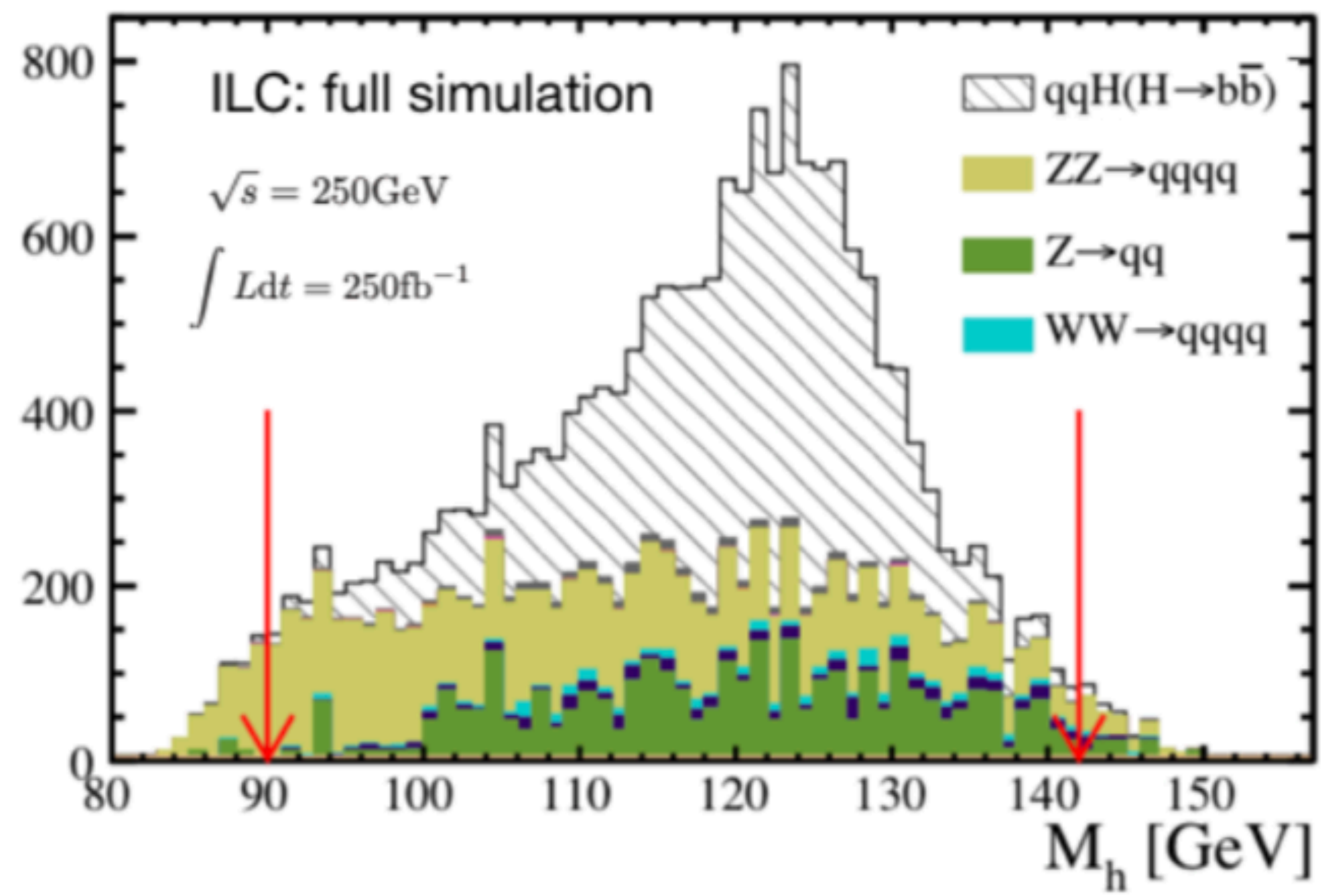
ILD
6q,√s=500GeV
b bkg. IDR-L
b bkg. IDR-S
uds bkg. IDR-L
uds bkg. IDR-S
Background rate
Ctag rate

This is especially important because the goal of Higgs factory experiments is not to improve the error bars.
It is to demonstrate that the Standard Model is violated.

For this, we need measurements with controlled and well-understood systematic uncertainties. It is also advantageous to be able to continuously improve the measurements, bringing in new and complementary data sets.

e+e- measurements of the Higgs boson at 250 and 500 GeV provide this.





(1/8 of the ILC data set at 250 GeV)

Specific advantage of Linear colliders:

Beam polarization:

e^-_L and e^-_R have different electroweak quantum numbers. They are different species at energies above 100 GeV. Measuring these with separate beams has many advantages:

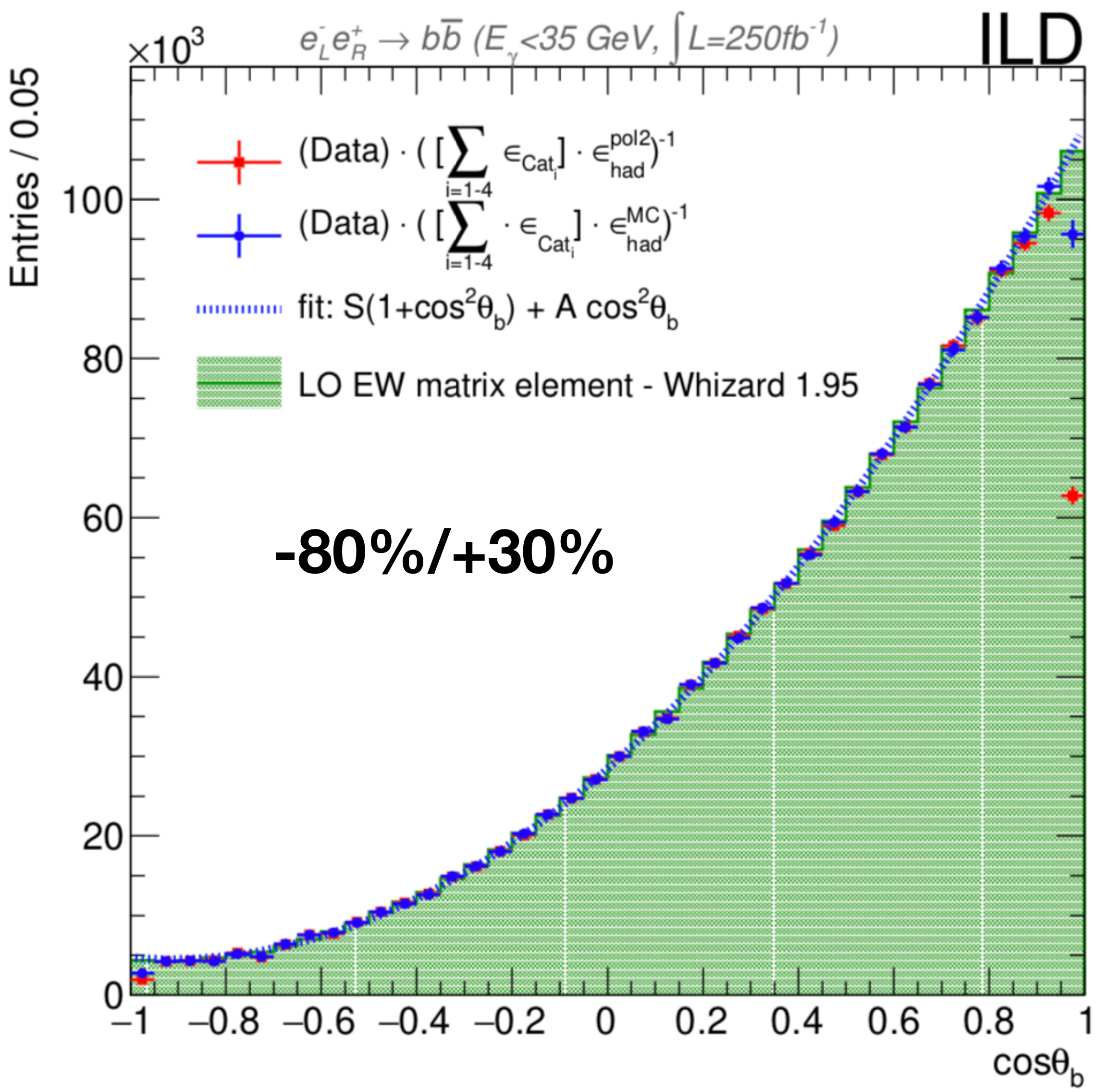
1. measurement of chirality-specific cross sections

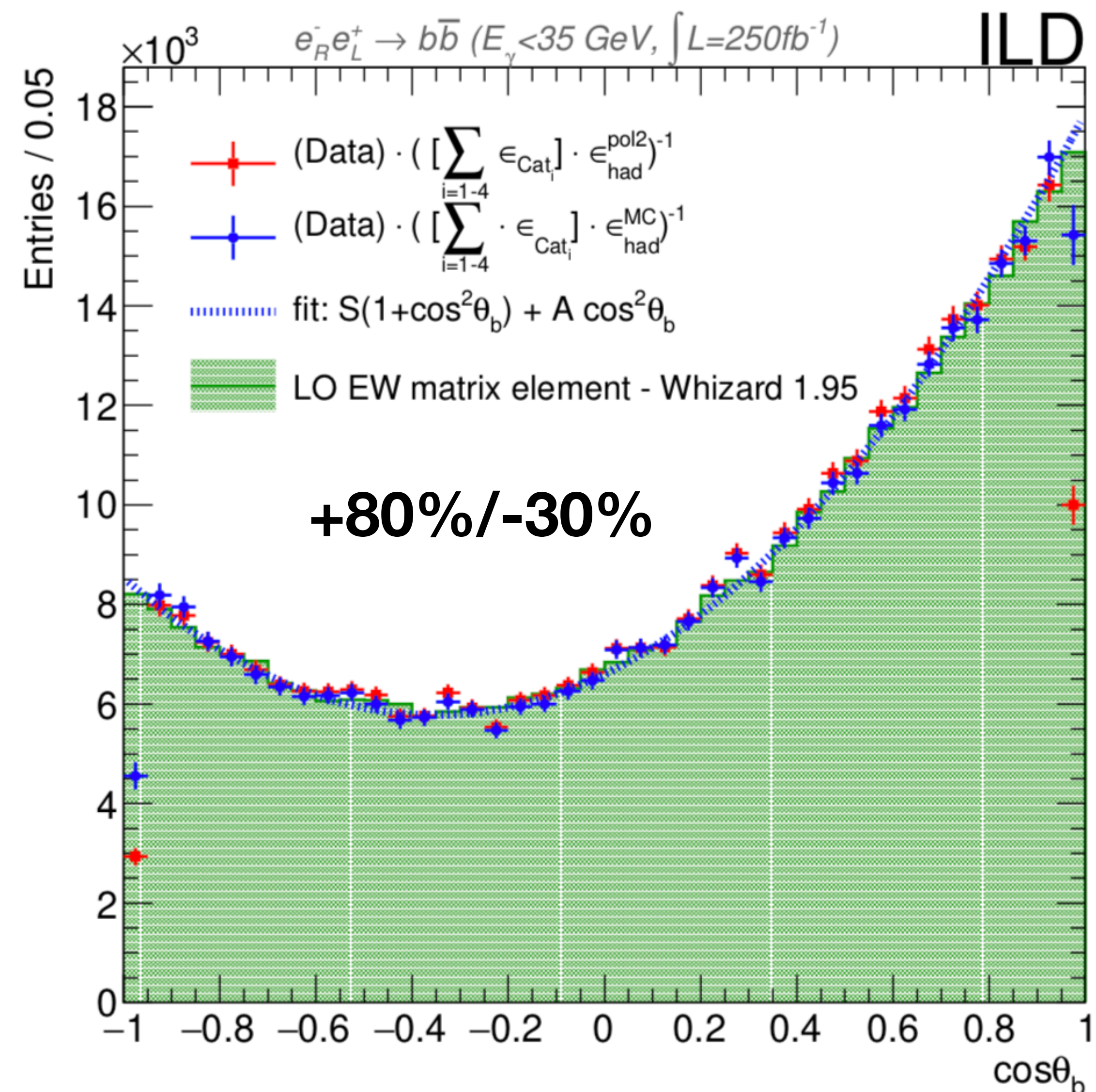
$$P_{eff} = \frac{P_{e-} - P_{e+}}{1 - P_{e-}P_{e+}} = \mp 89\% \qquad \text{at ILC}$$

2. luminosity enhancement (processes from $e^-_L e^+_R$ only)

$$\mathcal{L}_{eff}/\mathcal{L} = (1 + P_e)(1 - P_p) = 2.3 \quad \text{at ILC}$$

$e^+e^- \to b\bar{b}$ at 250 GeV





(note factor 6 changes in scale between the plots)

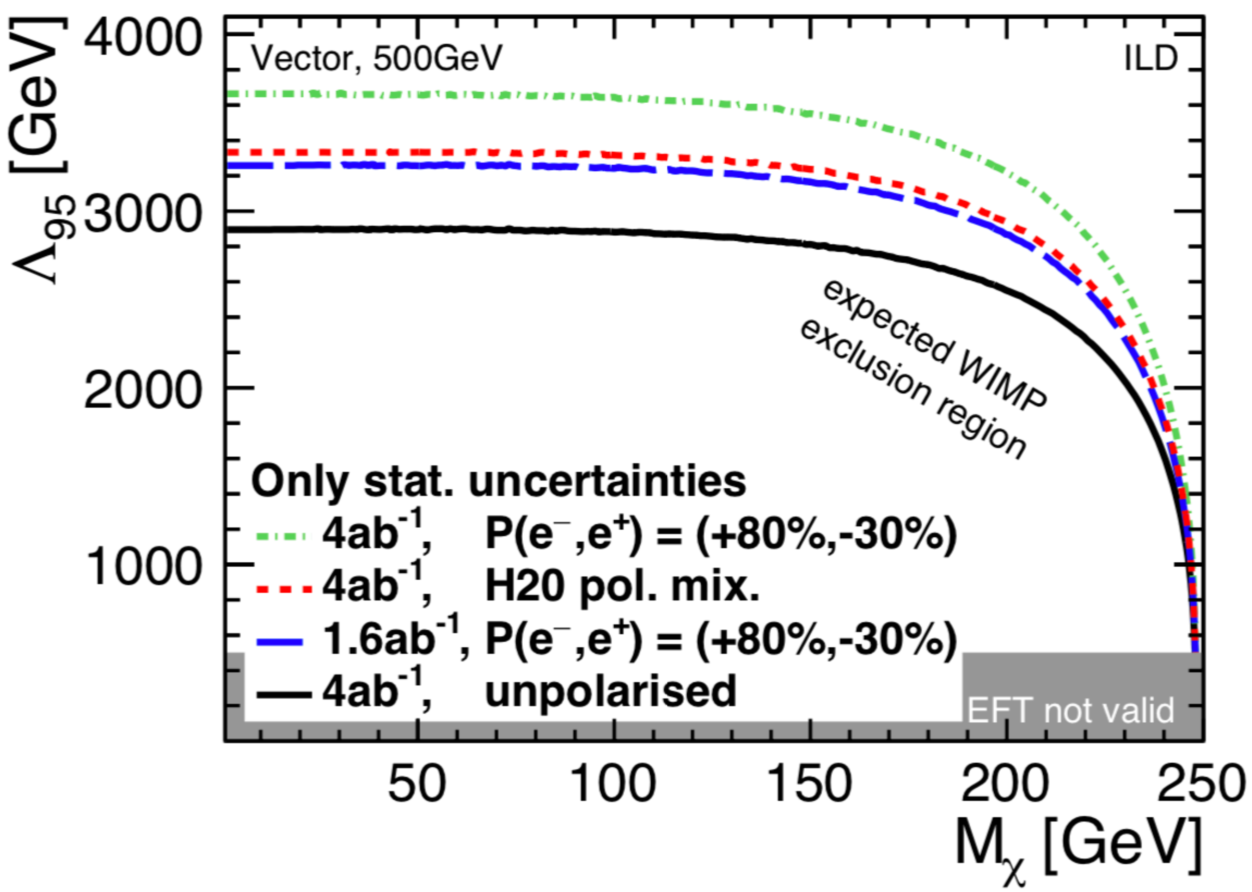
3. control of backgrounds

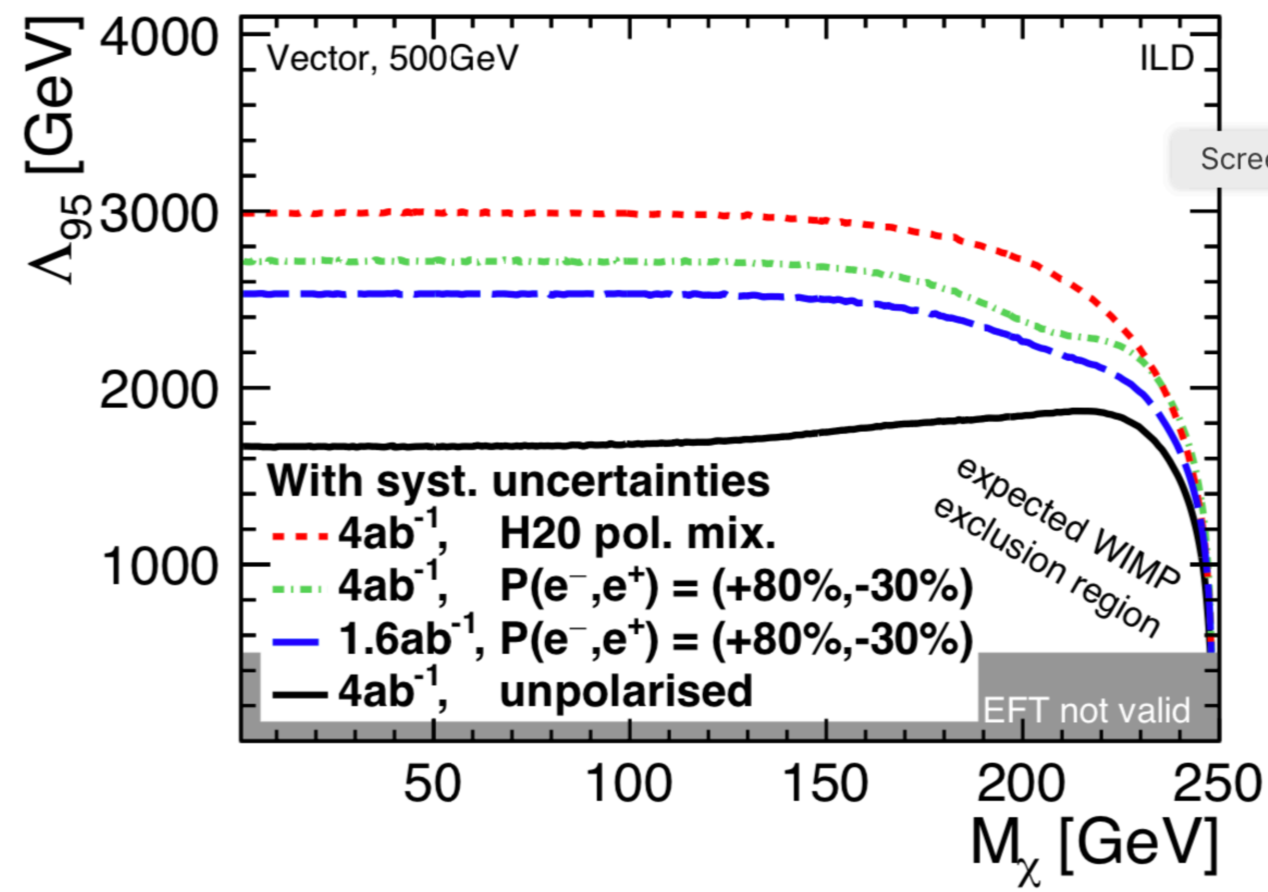
$e^+e^- \to W^+W^-$ is a major background to new particle searches. The cross section for this reaction is a factor 30 lower using e^-_R beams.

4. control of detector systematics

with e- and e+ polarization, it is possible to run in modes (e.g. $e^-_L e^+_L$) highly depleted in e+e- annihilation events.

dark matter search at 500 GeV using monophoton events
(higher is better)





M. Habermehl Ph.D thesis

Power pulsing:

the length of an ILC bunch train is 1 msec, repeated at 5 Hz. So, the detector can be powered off 99% of the time. This makes cooling simpler and allows a very small material budget in the tracker.

High energy:

To operate a linear collider at higher energy, just make it longer. The luminosity scales as

$$\mathcal{L} \sim E^1$$

The ILC site in Kitakami can accommodate colliders of up to 50 km in length. With GeV/m accelerating fields promised by plasma wakefield and other technologies, this site can compete for the true energy frontier.

But, first things first.

There is an excellent physics case for an e+e- in the 240-600 GeV energy range, to carry out precision studies of the Higgs boson and the top quark.

This machine is the future for the next generation of particle physicists. Let’s concentrate our energies to make it happen.