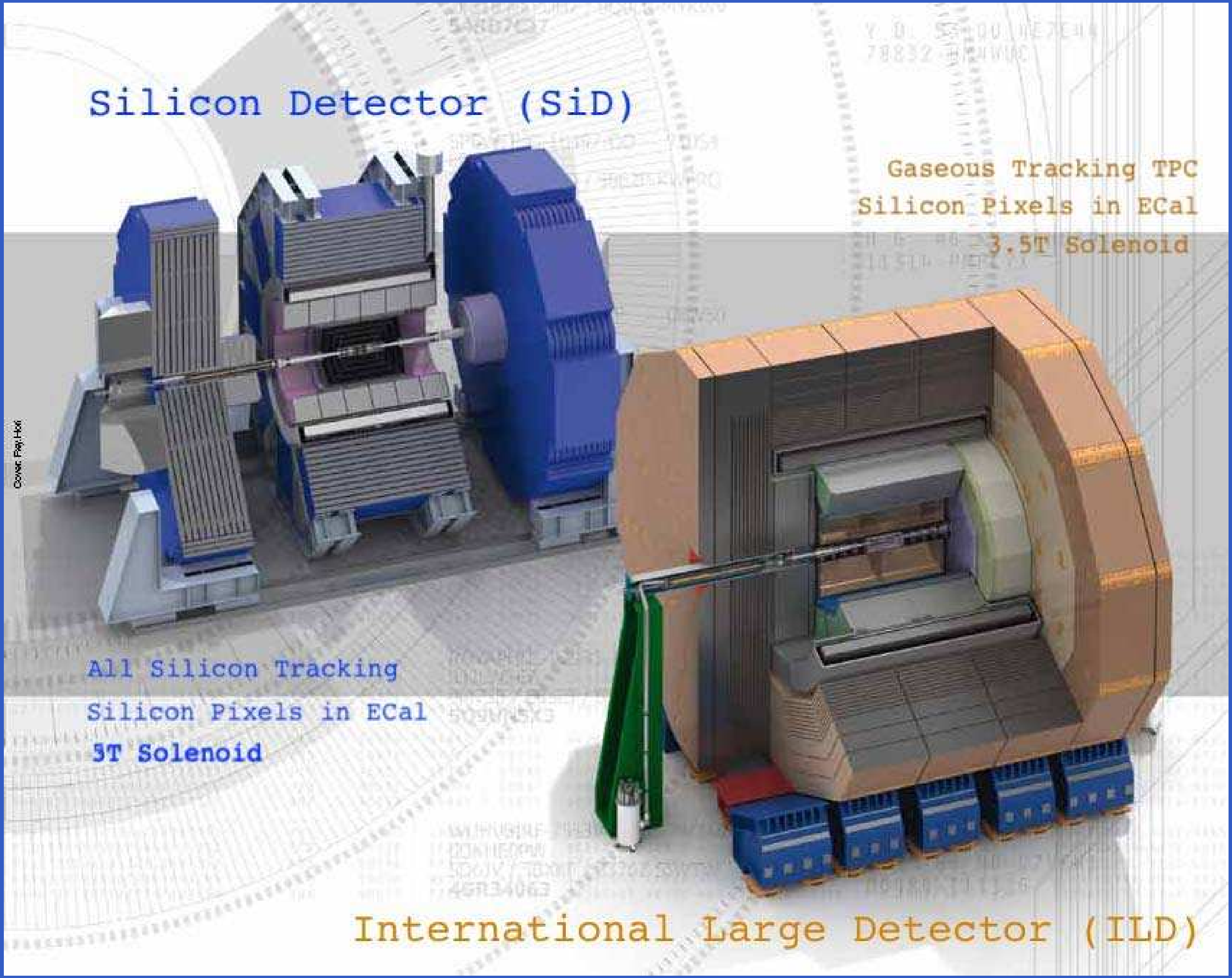
ILC/SiD Higgs to Invisible

Chris Potter [a]

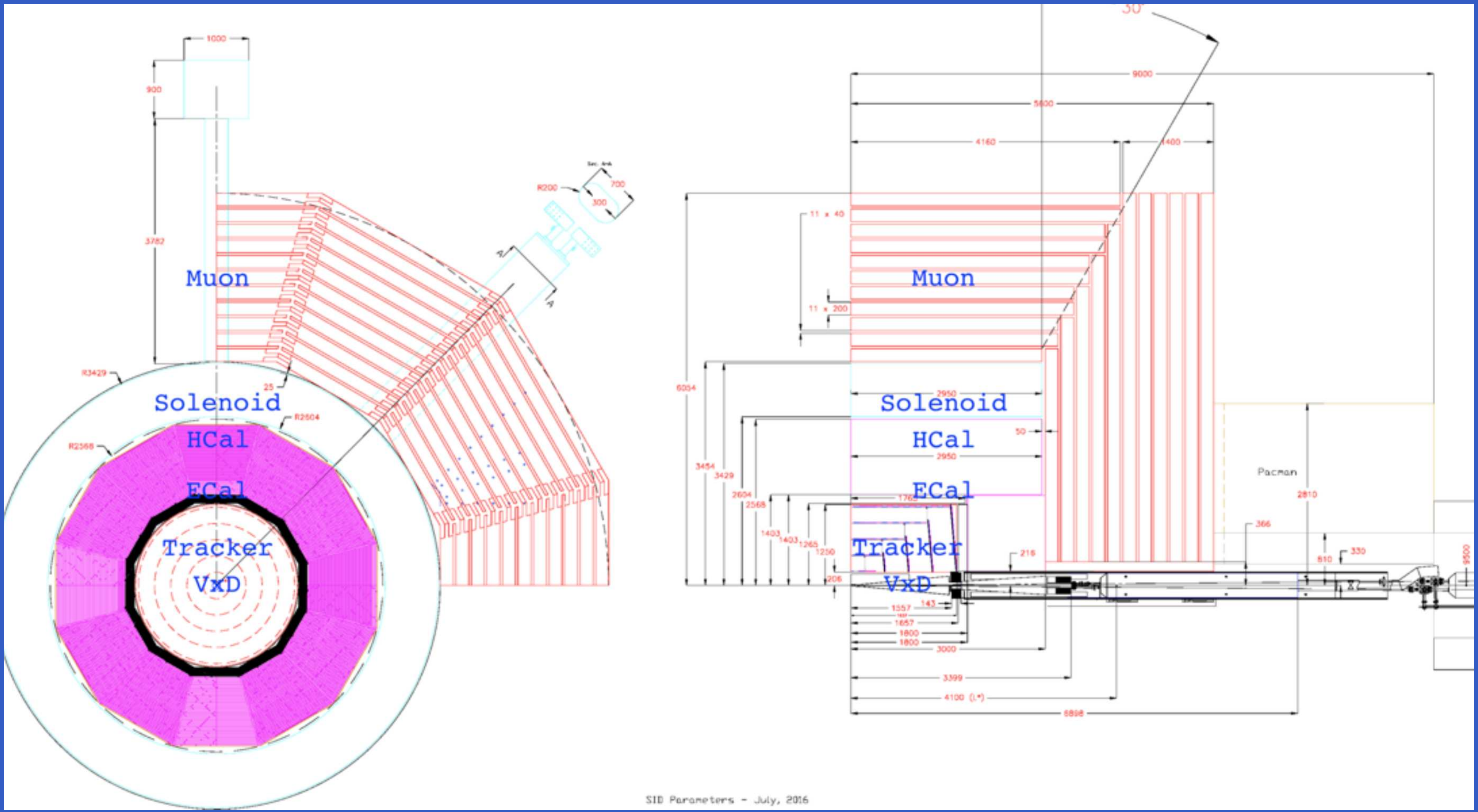
University of Oregon / SiD

[a] On behalf of Jim Brau, Makayla Massar, CP, Austin Prior, Amanda Steinhebel and Andy White

SiD and ILD: ILC TDR Volume 4 (arXiv:1306.6329)



Silicon Detector: ILC TDR Volume 4 (arXiv:1306.6329)



- The vertex detector (blue) has five layers instrumented with Silicon pixels while the tracker has five layers (orange dashed) instrumented with Silicon strips.
- The ECal (black) alternates Tungsten absorbing layers with Silicon pixels, the HCal (magenta) alternates Steel with Resistive Plate Chamber sensitive layers.

LOI - ILC/SiD Higgs to Invisible

Andrew White, Austin Prior, University of Texas at Arlington,
James Brau, Christopher Potter, Amanda Steinhebel, Makayla Massar, University of Oregon

August 2020

1 Introduction

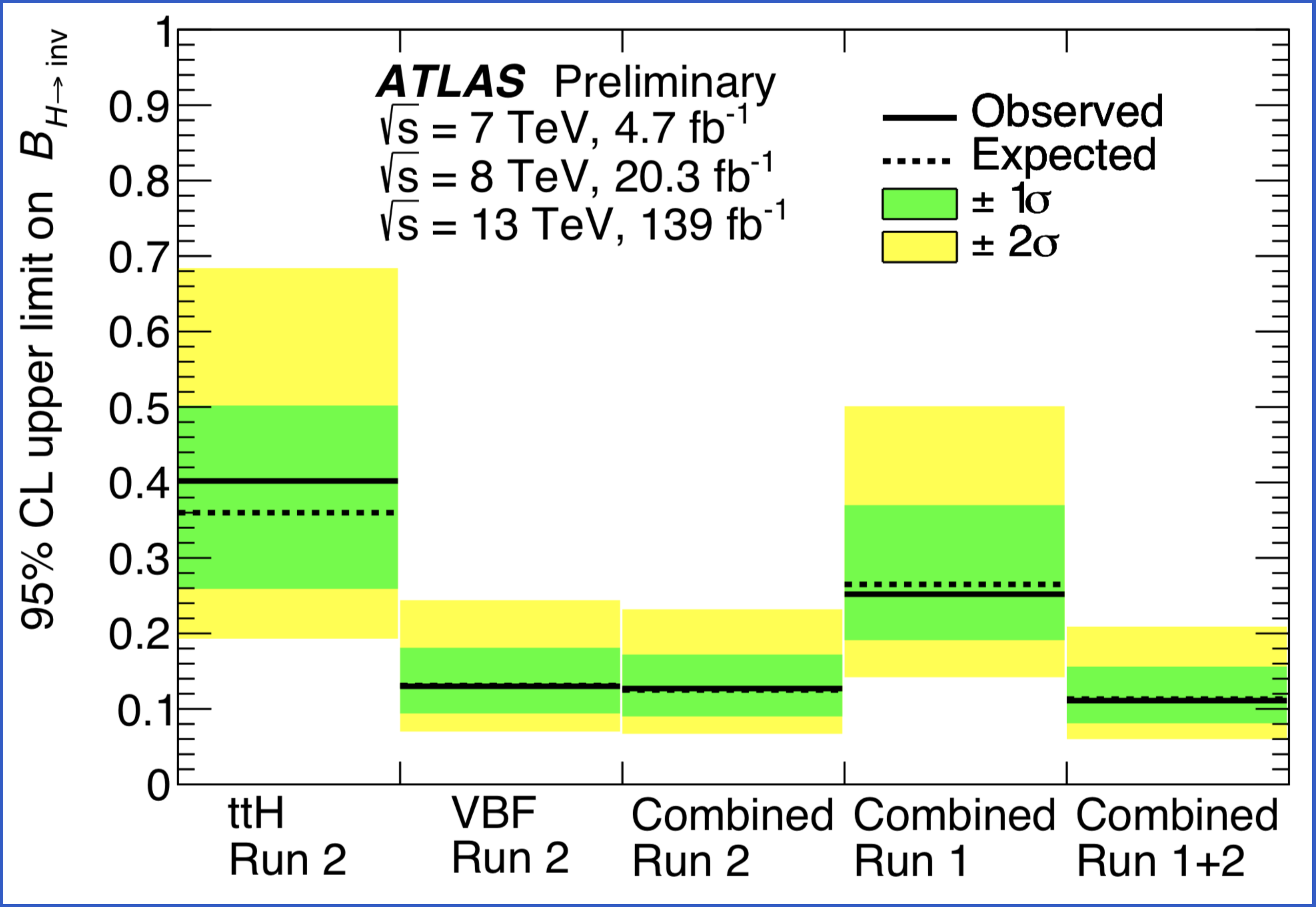
The Higgs Boson, being the only true scalar particle yet discovered, is a fundamentally new entity in the world of high energy physics. As such, it imperative to explore every aspect of the Higgs properties. While, so far, experimental results are in line with the Higgs having the properties expected in the Standard Model, there is significant room for connections to new physics beyond the Standard Model. This LOI describes a study of possible decays of the Higgs into invisible particles, such as might comprise the Dark Matter.

2 The search for invisible decays of the Higgs

The ATLAS and CMS experiments at the LHC have searched for invisible decays of the Higgs in a variety of channels. The current best limit, from a single search, is from ATLAS in the vector boson fusion process [2]. The limit set is 13% at 95% c.l. This limit has, in turn, been used to set a limit as a function of mass on the dark matter-nucleon scattering cross-section, as seen in Figure 1.

ATLAS-CONF-2020-052 released last week, updating to a combined Run 1+2 result (next slide).

New ATLAS Combination



ATLAS-CONF-2020-052, “0.11 (0.11+0.04) at 95% confidence level is observed (expected)”.

Tokyo/ILD Analysis: arXiv:2002.12048

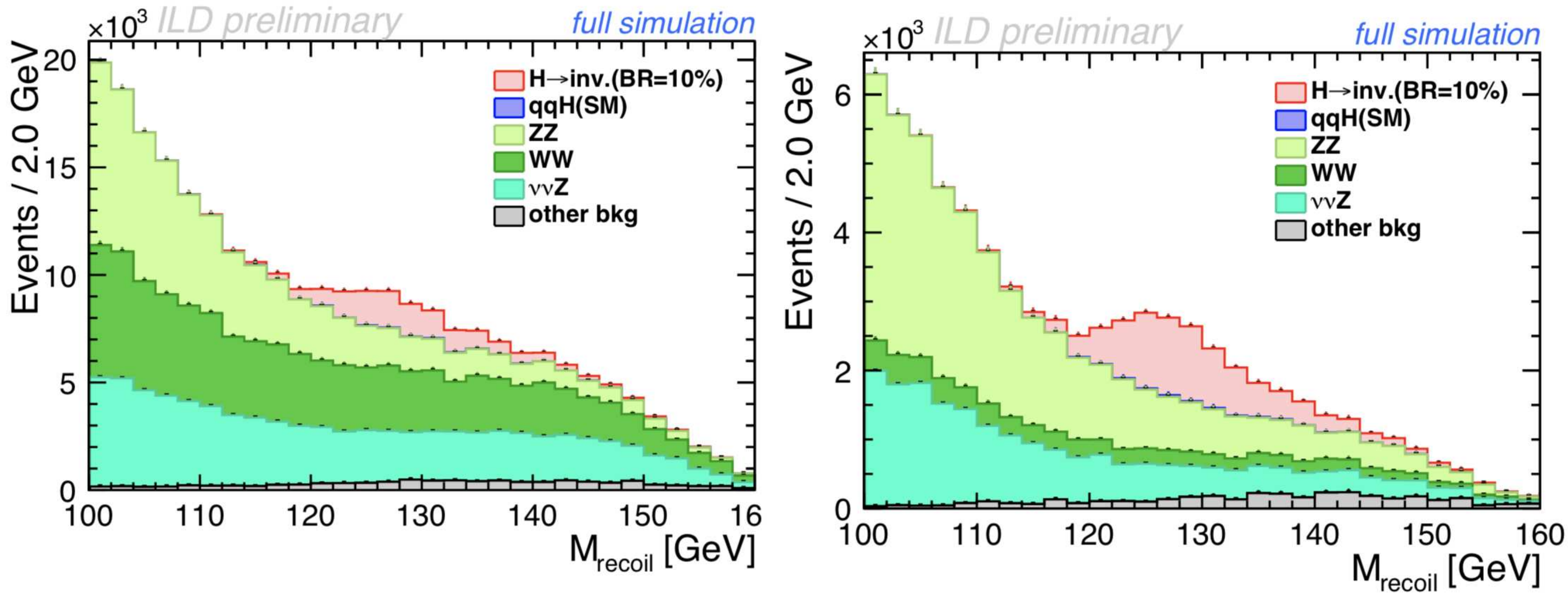


Figure 2: Recoil mass distribution after event selection at $\sqrt{s} = 250$ GeV. (left): $(P_{e^-}, P_{e^+}) = (-0.8, +0.3)$, (right): $(P_{e^-}, P_{e^+}) = (+0.8, -0.3)$.

Table 2: Selection table for $\sqrt{s} = 250$ GeV, $(P_{e^-}, P_{e^+}) = (-0.8, +0.3)$.

cut condition	signal (efficiency)	all bkg (efficiency)	significance
No Cut	18917 (1.000)	1.417×10^8 (1.000)	1.59
$N_{lep} = 0$	18880 (0.998)	9.732×10^7 (0.687)	1.91
Pre-Cut	18202 (0.962)	3.358×10^6 (0.024)	9.91
$N_{pfo} > 15 \& N_{charged} > 6$	17918 (0.947)	2.539×10^6 (0.018)	11.2
$p_{T jj} \in (20, 80)$GeV	16983 (0.898)	1.368×10^6 (0.010)	14.4
$M_{jj} \in (80, 100)$GeV	14158 (0.748)	713194 (0.005)	16.6
$\lvert\cos\theta_{jj}\rvert < 0.9$	13601 (0.719)	539921 (0.004)	18.3
$M_{recoil} \in (100, 160)$GeV	13585 (0.718)	244051 (0.002)	26.8

Table 3: Selection table for $\sqrt{s} = 250$ GeV, $(P_{e^-}, P_{e^+}) = (+0.8, -0.3)$.

cut condition	signal (efficiency)	all bkg (efficiency)	significance
No Cut	12776 (1.000)	7.785×10^7 (1.000)	1.45
$N_{lep} = 0$	12752 (0.998)	4.893×10^7 (0.628)	1.82
Pre-Cut	12270 (0.960)	1.329×10^6 (0.017)	10.6
$N_{pfo} > 15 \& N_{charged} > 6$	12067 (0.945)	852285 (0.011)	13.0
$p_{T jj} \in (20, 80)$GeV	11394 (0.892)	285847 (0.004)	20.9
$M_{jj} \in (80, 100)$GeV	9481 (0.742)	165798 (0.002)	22.6
$\lvert\cos\theta_{jj}\rvert < 0.9$	9126 (0.714)	130070 (0.002)	24.5
$M_{recoil} \in (100, 160)$GeV	9115 (0.713)	62979 (0.001)	33.9

Luminosity is 900 fb^{-1} (left), 900 fb^{-1} (right). "...95% C.L. UL on BR(H →invisible) of 0.23%"

ILC Studies from ILD and SiD

- Assuming ILC $\sqrt{s} = 250$ GeV, $e^+e^- \rightarrow ZH$ with hadronic Z decay and invisible H decay.
- Tokyo/ILD study: documented in arXiv:2002.12048
  - Samples are full ILD simulation, signal exclusive for $Z \rightarrow q\bar{q}$.
  - Polarization scheme is 80% e^-, 30% e^+ polarized beams.
  - Luminosity sharing is 900/900 fb^{-1} (LR/RL).

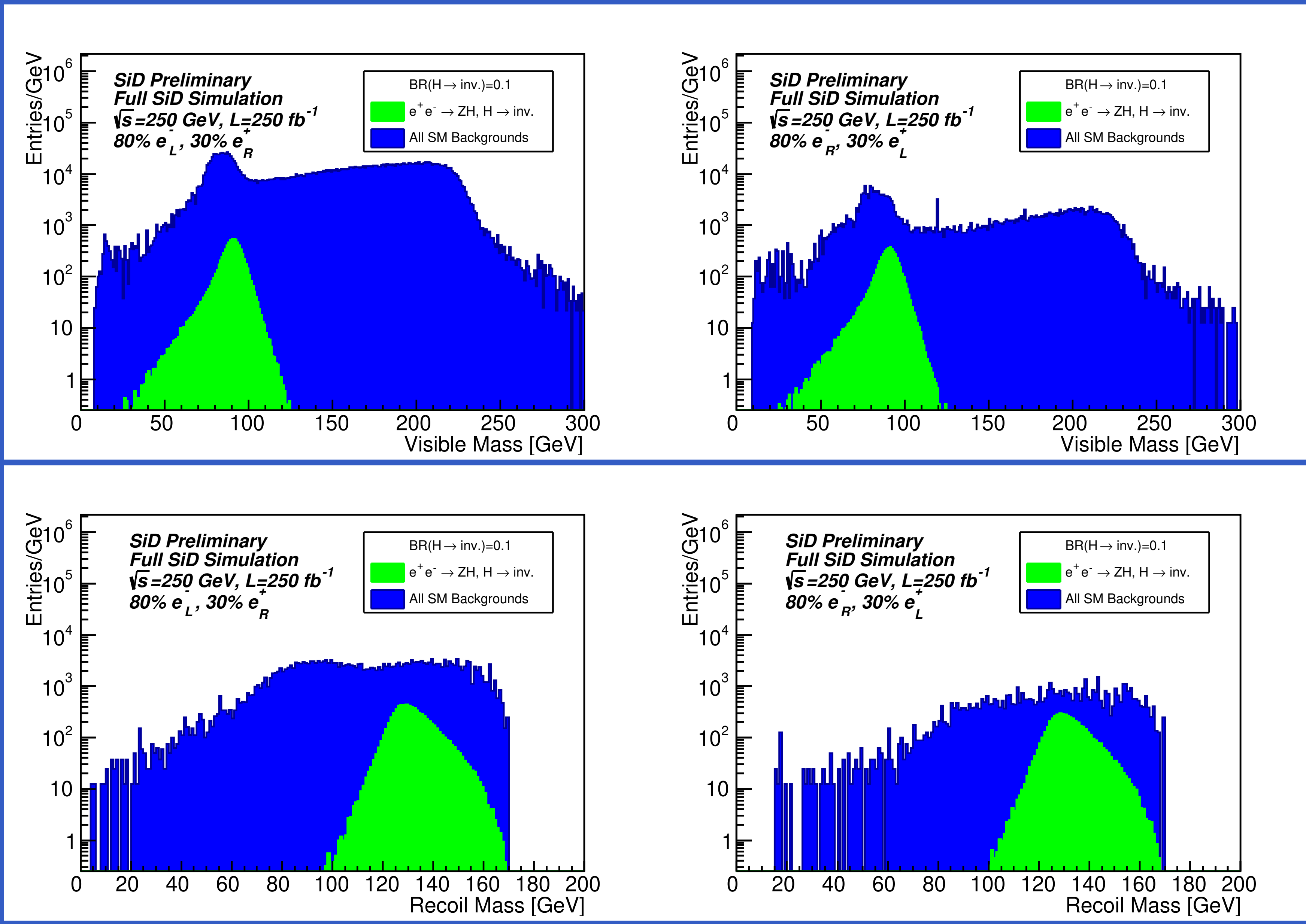
ILC Studies from ILD and SiD

- Assuming ILC $\sqrt{s} = 250$ GeV, $e^+e^- \to ZH$ with hadronic Z decay and invisible H decay.
- Tokyo/ILD study: documented in arXiv:2002.12048
  - Samples are full ILD simulation, signal exclusive for $Z \to q\bar{q}$.
  - Polarization scheme is 80% e^-, 30% e^+ polarized beams.
  - Luminosity sharing is 900/900 fb^{-1} (LR/RL).
- This study: preliminary analysis based on ILD signal selection
  - Samples are full SiD simulation in ILCSoft v02-00-02 with SiD option 2 version 3.
    - 10ab^{-1} signal generated with Whizard 2.6.4, inclusive Z decays
    - 250fb^{-1} backgrounds Whizard 1.95 generated for Detailed Baseline Design study.
    - Background events are weighted with weights larger than 1.
  - Polarization scheme is 80% e^-, 30% e^+ polarized beams.
  - Luminosity sharing is 250/250 fb^{-1} (LR/RL).

ILC Studies from ILD and SiD

- Assuming ILC $\sqrt{s} = 250$ GeV, $e^+e^- \rightarrow ZH$ with hadronic Z decay and invisible H decay.
- Tokyo/ILD study: documented in arXiv:2002.12048
  - Samples are full ILD simulation, signal exclusive for $Z \rightarrow q\bar{q}$.
  - Polarization scheme is 80% e^-, 30% e^+ polarized beams.
  - Luminosity sharing is 900/900 fb^{-1} (LR/RL).
- This study: preliminary analysis based on ILD signal selection
  - Samples are full SiD simulation in ILCSoft v02-00-02 with SiD option 2 version 3.
    - 10ab^{-1} signal generated with Whizard 2.6.4, inclusive Z decays
    - 250fb^{-1} backgrounds Whizard 1.95 generated for Detailed Baseline Design study.
    - Background events are weighted with weights larger than 1.
  - Polarization scheme is 80% e^-, 30% e^+ polarized beams.
  - Luminosity sharing is 250/250 fb^{-1} (LR/RL).
- We intend to do the following for this Snowmass study:
  - Establish if our results are broadly consistent using the Tokyo/ILD selection
  - Investigate if signal sensitivity can be improved with a new signal selection
  - Investigate the impact of subdetector design variations on signal sensitivity

SiD Preliminary: Visible and Recoil Masses



Previous requirements from Tokyo/ILD analysis are imposed (see slide 5).

The Path Forward

- Preliminary signal sensitivity results with SiD full simulation are broadly consistent with Tokyo/ILD results when the Tokyo/ILD selection is used.
- Preliminary investigation indicate that signal sensitivity can be improved over the Tokyo/ILD results by boosting to the Z candidate frame and exploiting event shape variables.
- Investigation of the impact of varying the SiD calorimetry design on signal sensitivity has begun. Results will be included in our final writeup.
- The results here focus on the hadronic Z channel. A parallel study on the leptonic Z channel is also underway.
- A careful consideration of systematic uncertainties will also be included in our expected limit calculation.