

Studies of
the SB2009 Impact
on ILC Physics

Jim Brau
representing
the SB2009 Physics and Detectors
Working Group

SB2009 Working Group

- working group established to study SB2009 physics and detector performance issues, and to communicate with the GDE in a systematic way:

Tim Barklow(SiD) , Mikael Berggren(ILD), Jim Brau (convener),
Karsten Buesser(MDI), Keisuke Fujii (Physics), Norman Graf(SiD),
JoAnne Hewett(theory), Tom Markiewicz(SiD), Takashi Maruyama(SiD),
David Miller(ILD), Akiya Miyamoto (Software), Yasuhiro Okada(theory),
Mark Thomson(ILD), Georg Weiglein(theory)

Understanding Matter, Energy, Space and Time: the Case for the Linear Collider

More than 2700 scientists signed 2003 statement, expressing the world-wide consensus for the linear collider:

- Understanding the Higgs boson
 - accurate, model independent measurements
 - essential if EWSB broken in subtle, complicated way
- New discoveries beyond the standard model expected
 - disparate energy scales suggest TeV-scale new physics
- Benefit of precision measurements and LHC/LC interplay
 - historical success from direct discovery and inference based on precision measurement working together
- Cross connections
 - LC exp's, ν & quark, cosmo/astro, HE nuclear

An example of precision measurement: Higgs threshold spin analysis

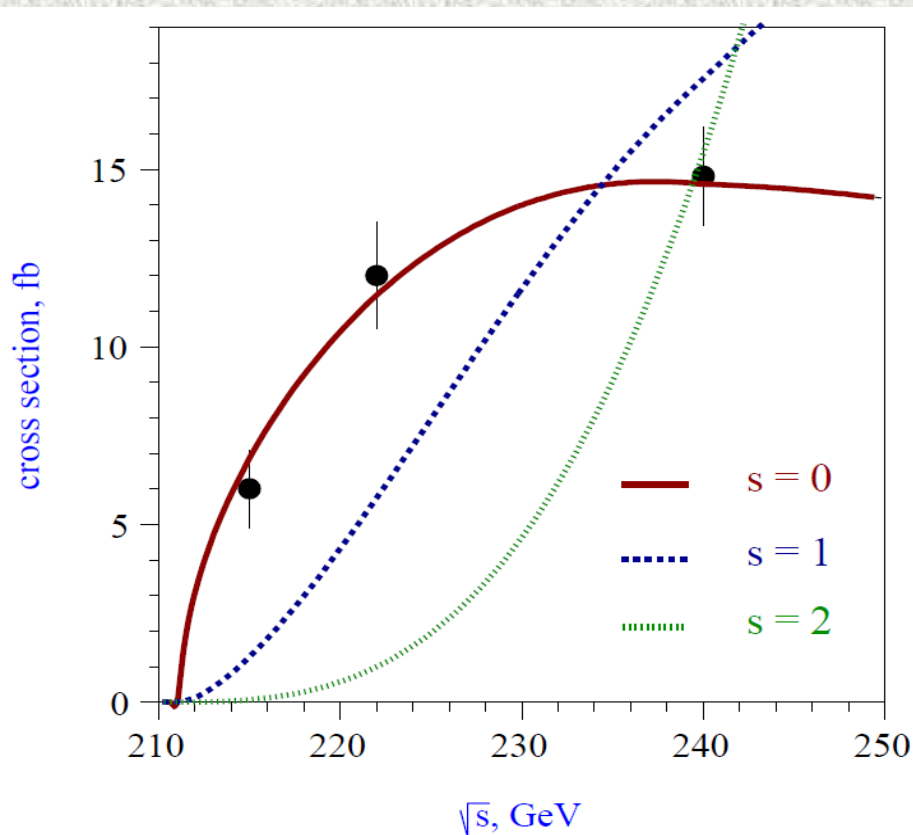


FIGURE 2. The cross sections determined at $\sqrt{s} = 215, 222$ and 240 GeV (dots) and the predictions for $s=0$ (full line), $s=1$ (dashed line) and $s=2$ (dotted line).

- In this study, 20 fb^{-1} at each energy point
- Limited duration of running depends on good low energy luminosity



RDR vs ILC Physics Goals

- E_{cm} adjustable from 200 – 500 GeV
- Luminosity $\rightarrow \int L dt = 500 \text{ fb}^{-1}$ in 4 years
- Ability to scan between 200 and 500 GeV
- Energy stability and precision below 0.1%
- Electron polarization of at least 80%

- The machine must be upgradeable to 1 TeV

The RDR Design meets these “requirements,” including the recent update and clarifications of the reconvened ILCSC Parameters group!

SB2009 Parameters

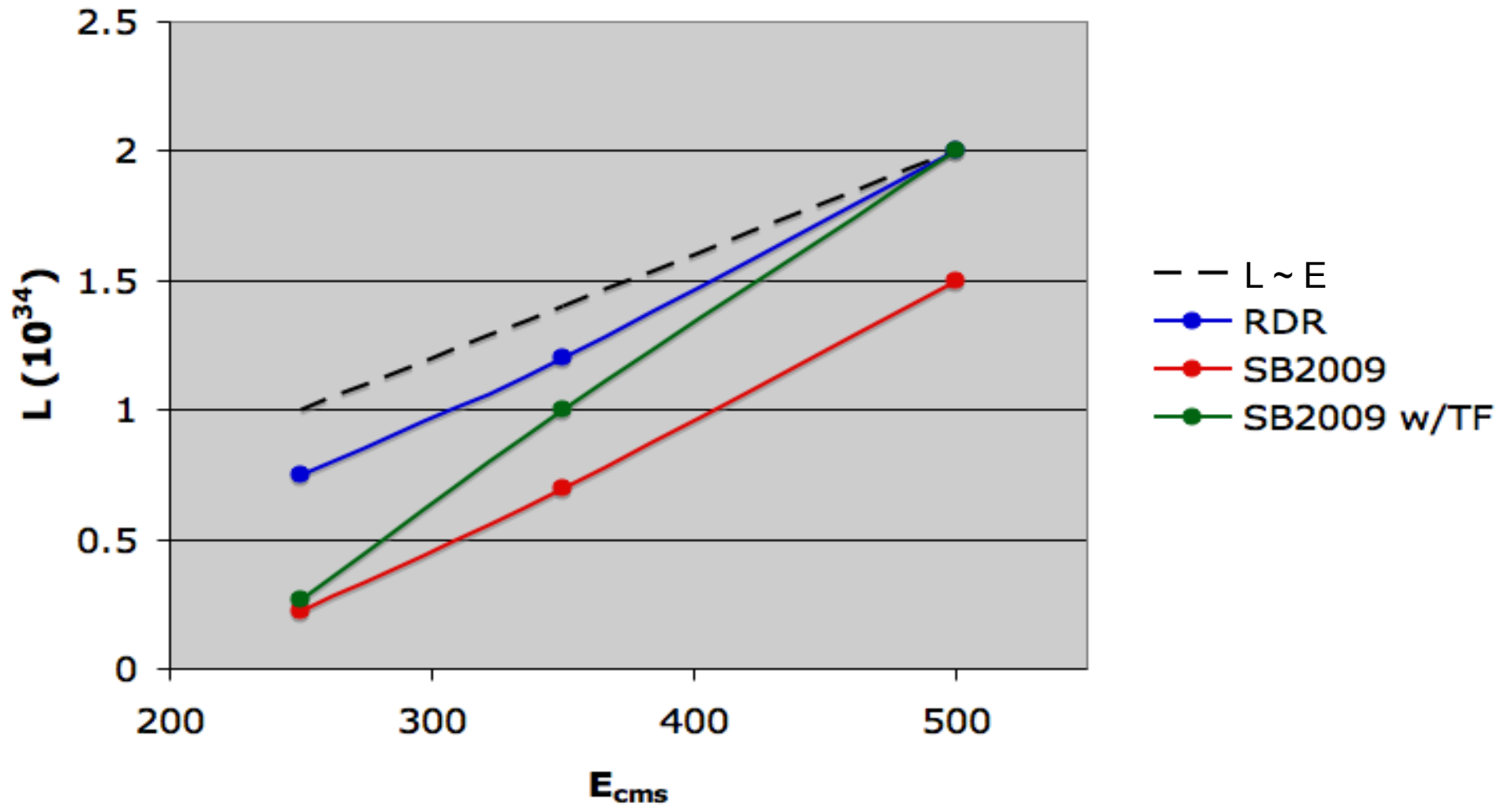
- GDE Physics Questions Committee

	RDR			SB2009 w/o TF				SB2009 w TF			
CM Energy (GeV)	250	350	500	250.a	250.b	350	500	250.a	250.b	350	500
Ne- (*10¹⁰)	2.05	2.05	2.05	2	2	2	2.05	2	2	2	2.05
Ne+ (*10¹⁰)	2.05	2.05	2.05	1	2	2	2.05	1	2	2	2.05
nb	2625	2625	2625	1312	1312	1312	1312	1312	1312	1312	1312
Tsep (nsecs)	370	370	370	740	740	740	740	740	740	740	740
F (Hz)	5	5	5	5	2.5	5	5	5	2.5	5	5
γ_{ex} (*10⁻⁶)	10	10	10	10	10	10	10	10	10	10	10
γ_{ey} (*10⁻⁶)	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
β_x	22	22	20	21	21	15	11	21	21	15	11
β_y	0.5	0.5	0.4	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
σ_z (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
σ_x eff (*10⁻⁹ m)	948	802	639	927	927	662	474	927	927	662	474
σ_y eff (*10⁻⁹ m)	10	8.1	5.7	9.5	9.5	7.4	5.8	6.4	6.4	5.0	3.8
L (10³⁴ cm⁻²s⁻¹)	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.25	0.27	1.0	2.0
δE %	0.6	1.2	2.4	0.3	0.6	1.6	4.1	0.3	0.6	1.6	3.6
Npairs* 10³	97	156	288	48.7	97.4	214	494	57.4	115	255	596
\mathcal{L}	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.24	0.27	1.0	2.0
\mathcal{L} (1%)/ \mathcal{L}	0.97	0.92	0.83	0.98	0.96	0.88	0.73	0.94	0.89	0.77	0.72

SB2009

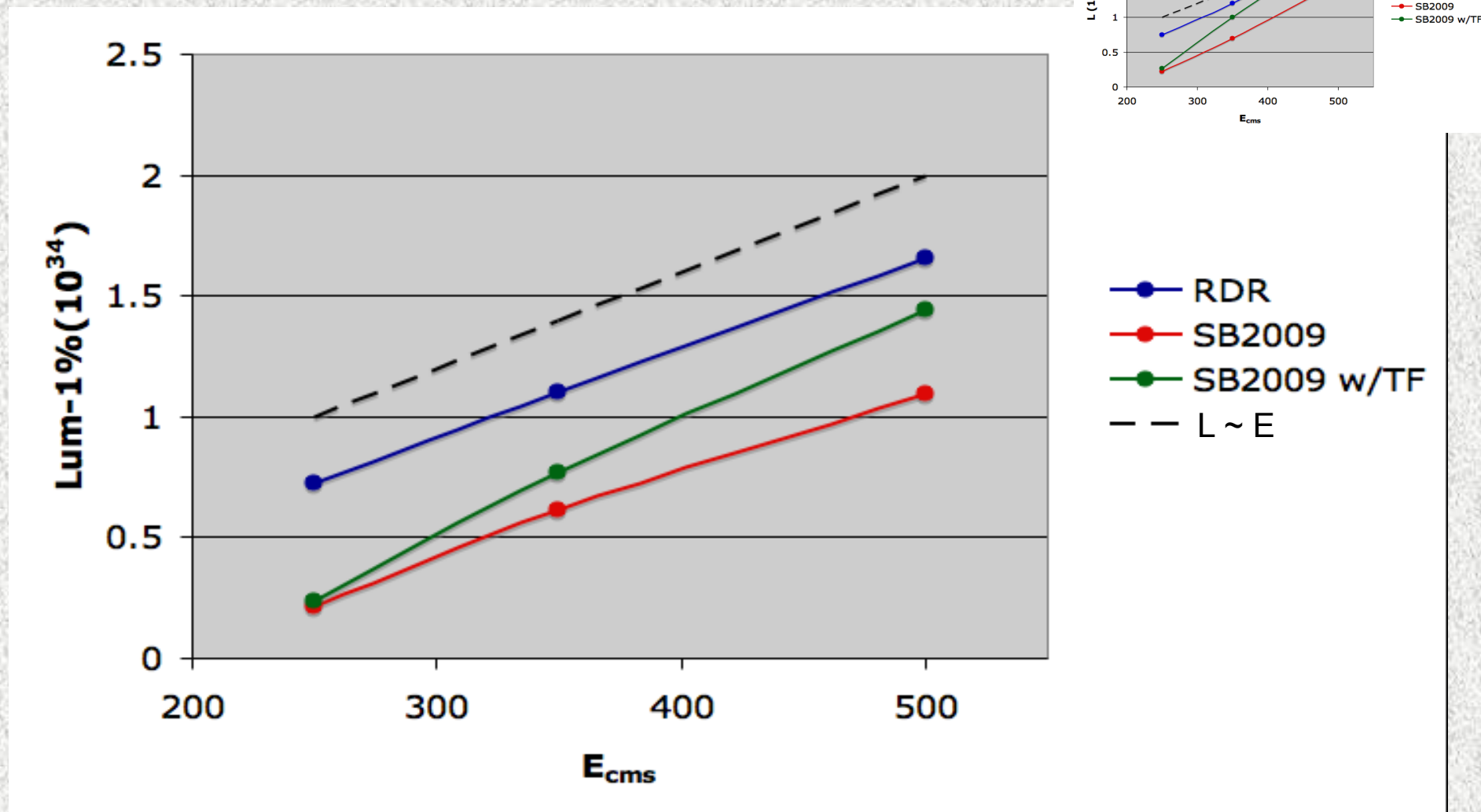
- Particular concern for good Higgs threshold luminosity and for energy scans at the threshold for light new states
- Increased beamstrahlung reduces useful luminosity
- Beam energy spread
 - limiting factor for the Lol studies of Higgs recoil mass analysis (RDR parameters) – need to assess SB2009
- Increased backgrounds impact detector performance
 - may reduce marginal space between the beamstrahlung pairs and the beam pipe
 - may damage inner acceptance of the forward calorimeters (LumiCAL/BCAL) reducing the hermeticity of the detector

Luminosity vs. E_{cms}



Luminosity and Beamstrahlung

- Luminosity in the 1% energy peak

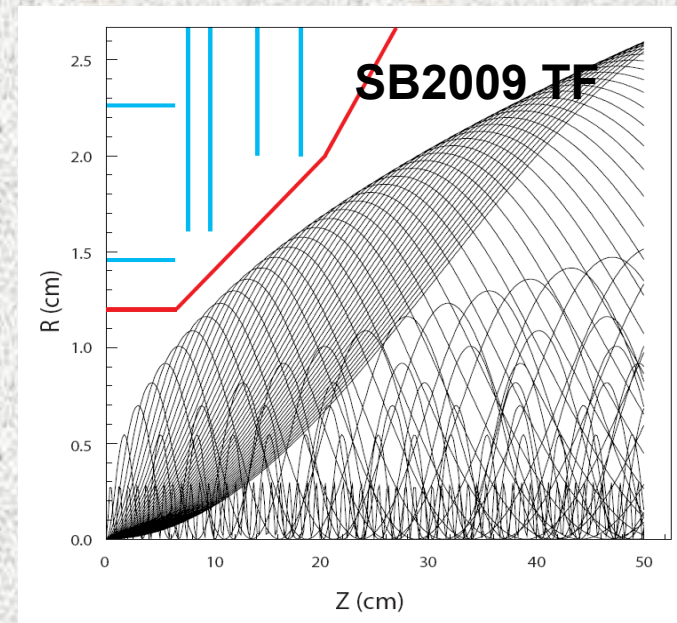
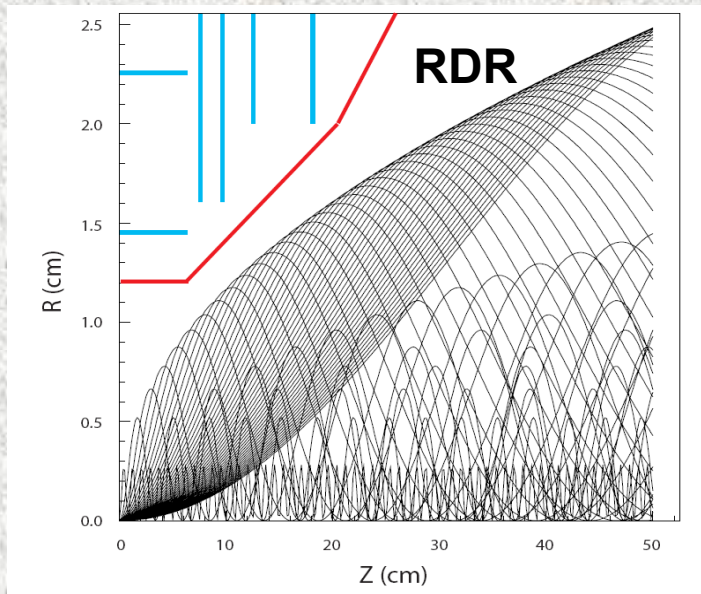


Beamstrahlung background

- The number of beamstrahlung pairs increases for SB2009, with or without traveling focus turned on
 - (T. Maruyama Guinea Pig study)

	E_{tot} (TeV)	No.(e^\pm)	$\langle E \rangle$ (e^\pm)
RDR	215	85.5k	2.5 GeV
SBTF	635	203k	3.1 GeV

- SiD beam pipe and the vertex detector are compatible with the SB2009 beam parameters



SB2009 w/o TF
nearly identical to
SB2009 TF

- Pairs will impact forward detection of electrons for two-gamma veto - needs to be assessed

SB2009 Physics Studies

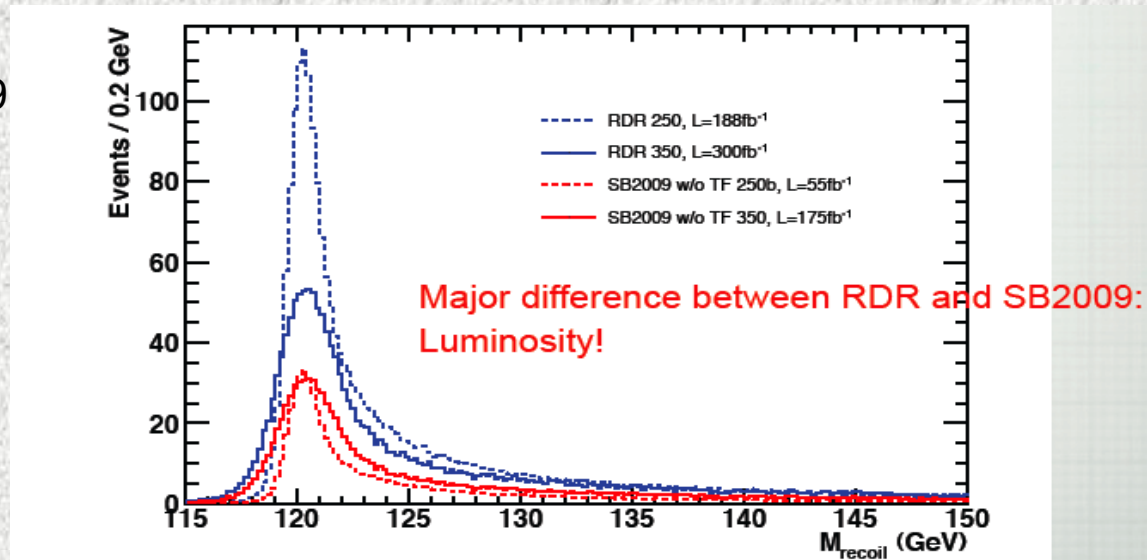
- **Three effects have been studied**
 - Reduced luminosity at low E_{cms}
 - Reduced effective luminosity due to Beamstrahlung
 - Increased backgrounds
- **Processes used to assess impact (so far)**
 1. $e^+e^- \rightarrow \mu^+ \mu^-$ Higgs
 - Higgs mass
 - Higgs cross section
 - (important future study – Higgs branching ratios)
 2. Stau detection (forward electron vetoes)
 3. Low mass SUSY scenarios study
 - Snowmass SM2 benchmark
 - ($m_0 = 100$ GeV, $m_{1/2} = 250$ GeV, $\tan \beta = 10$, $A_0 = 0$, and $\text{sign } \mu = +$)
 - similar to SPS1a point

1. Higgs Mass and Cross Section

Constant run time – 500 fb⁻¹ effective for RDR 500 GeV

Beam Par	\mathcal{L}_{int} (fb ⁻¹)	ϵ	S/B	M_H (GeV)	σ (fb) ($\delta\sigma/\sigma$)
RDR 250	188	55%	62%	120.001 ± 0.043	11.63 ± 0.46 (3.9%)
RDR 350	300	51%	92%	120.010 ± 0.084	7.13 ± 0.28 (4.0%)
SB2009 w/o TF 250b	55	55%	62%	120.001 ± 0.079	11.63 ± 0.83 (7.2%)
SB2009 w/o TF 350	175	51%	92%	120.010 ± 0.110	7.13 ± 0.37 (5.2%)
SB2009 w/ TF 250b	68	55%	62%	120.001 ± 0.071	11.63 ± 0.75 (6.4%)
SB2009 w/ TF 350	250	51%	92%	120.010 ± 0.092	7.13 ± 0.31 (4.3%)

Coupling precision (cross section) better at 350 GeV than 250 GeV for SB2009
 Higgs mass precision degrades by more than factor of 2 from RDR
 δM : 43 MeV → 92 MeV (wTF)
 $\delta\sigma$: 3.9% → 4.3% (wTF)
 (Do theoretical considerations motivate sub-100 MeV Higgs mass precision?)



2. stau's at the SPS1a' point

Mikael Berggren
LOI ref- arXiv:0908.0876

- Benchmark point

$$e^+e^- \rightarrow \tilde{\tau}_1^+ \tilde{\tau}_1^- \rightarrow \tau^+ \tilde{\chi}_1^0 \tau^- \tilde{\chi}_1^0$$

- Sensitive to beam backgrounds and detector hermiticity
- Underlines advantage of a collider that is tunable in energy and polarization
- For SPS1a' ($M_{\tilde{\tau}_1} = 107.9 \text{ GeV}$ $M_{\tilde{\chi}_1^0} = 97.7 \text{ GeV}$)
 - rather low mass-difference between the lightest stau and the LSP, giving a soft spectrum
 - rather low signal cross-section
 - mass of $\tilde{\tau}_2$ is 194.9 GeV

2. stau's at the SPS1a' point

- Three issues
 - Increased background pairs in the BeamCal might increase gamma-gamma background in the selected sample
 - Increased beam-background will reduce signal efficiency
 - Fewer events and a broadened peak, might reduce the precision of the end-point measurement, and hence the mass determination
- Assumption - running time $E_{cm} = 500 \text{ GeV}$, 500 fb^{-1}

Mikael Berggren

	Endpoint errors:		Cross-section errors:	
	stau_1	stau_2	stau_1	stau_2
	(107.9 GeV)	(194.9 GeV)	(158 fb)	(17.7 fb)
RDR	0.129 GeV	1.83 GeV	2.90%	4.24%
SB2009 wTF	0.152 GeV	2.10 GeV	3.52%	5.09%
SB2009 noTF	0.179 GeV	2.42 GeV	3.79%	5.71%

- 15-20% degradation w/ TF
 - Primarily due to loss of signal

3. Low mass SUSY scenarios study

- Study of Snowmass SM2 point (~ SPS1a point)

- hep-ex/0211002v1, P. Grannis

($m_0 = 100$ GeV, $m_{1/2} = 250$ GeV, $\tan \beta = 10$, $A_0 = 0$, and $\text{sign}\mu = +$).

	M	Final state	(BR(%))			
\tilde{e}_R	143	$\tilde{\chi}_1^0 e$ (100)				
\tilde{e}_L	202	$\tilde{\chi}_1^0 e$ (45)	$\tilde{\chi}_1^\pm \nu_e$ (34)	$\tilde{\chi}_2^0 e$ (20)		
$\tilde{\mu}_R$	143	$\tilde{\chi}_1^0 \mu$ (100)				
$\tilde{\mu}_L$	202	$\tilde{\chi}_1^0 \mu$ (45)	$\tilde{\chi}_1^\pm \nu_\mu$ (34)	$\tilde{\chi}_2^0 \mu$ (20)		
$\tilde{\tau}_1$	135	$\tilde{\chi}_1^0 \tau$ (100)				
$\tilde{\tau}_2$	206	$\tilde{\chi}_1^0 \tau$ (49)	$\tilde{\chi}_1^- \nu_\tau$ (32)	$\tilde{\chi}_2^0 \tau$ (19)		
$\tilde{\nu}_e$	186	$\tilde{\chi}_1^0 \nu_e$ (85)	$\tilde{\chi}_1^\pm e^\mp$ (11)	$\tilde{\chi}_2^0 \nu_e$ (4)		
$\tilde{\nu}_\mu$	186	$\tilde{\chi}_1^0 \nu_\mu$ (85)	$\tilde{\chi}_1^\pm \mu^\mp$ (11)	$\tilde{\chi}_2^0 \nu_\mu$ (4)		
$\tilde{\nu}_\tau$	185	$\tilde{\chi}_1^0 \nu_\tau$ (86)	$\tilde{\chi}_1^\pm \tau^\mp$ (10)	$\tilde{\chi}_2^0 \nu_\tau$ (4)		
$\tilde{\chi}_1^0$	96	stable				
$\tilde{\chi}_2^0$	175	$\tilde{\tau}_1 \tau$ (83)	$\tilde{e}_R e$ (8)	$\tilde{\mu}_R \mu$ (8)		
$\tilde{\chi}_3^0$	343	$\tilde{\chi}_1^\pm W^\mp$ (59)	$\tilde{\chi}_2^0 Z$ (21)	$\tilde{\chi}_1^0 Z$ (12)	$\tilde{\chi}_1^0 h$ (2)	
$\tilde{\chi}_4^0$	364	$\tilde{\chi}_1^\pm W^\mp$ (52)	$\tilde{\nu} \nu$ (17)	$\tilde{\tau}_2 \tau$ (3)	$\tilde{\chi}_{1,2} Z$ (4)	$\tilde{\ell}_R \ell$ (6)
$\tilde{\chi}_1^\pm$	175	$\tilde{\tau}_1 \tau$ (97)	$\tilde{\chi}_1^0 q \bar{q}$ (2)	$\tilde{\chi}_1^0 \ell \nu$ (1.2)		
$\tilde{\chi}_2^\pm$	364	$\tilde{\chi}_2^0 W$ (29)	$\tilde{\chi}_1^\pm Z$ (24)	$\tilde{\ell} \nu_\ell$ (18)	$\tilde{\chi}_1^\pm h$ (15)	$\tilde{\nu}_\ell \ell$ (8)

3. Low mass SUSY scenarios study

Table 1: Run allocations for the SPS1 Minimal SUGRA parameters.

Beams	Energy	Pol.	$\int \mathcal{L} dt$	$[\int \mathcal{L} dt]_{\text{equiv}}$	Comments
e^+e^-	500	L/R	335	335	Sit at top energy for sparticle masses
e^+e^-	M_Z	L/R	10	45	Calibrate with Z 's
e^+e^-	270	L/R	100	185	Scan $\tilde{\chi}_1^0 \tilde{\chi}_2^0$ threshold (L pol.) Scan $\tilde{\tau}_1 \tilde{\tau}_1$ threshold (R pol.)
e^+e^-	285	R	50	85	Scan $\tilde{\mu}_R^+ \tilde{\mu}_R^-$ threshold
e^+e^-	350	L/R	40	60	Scan $t\bar{t}$ threshold Scan $\tilde{e}_R \tilde{e}_L$ threshold (L & R pol.) Scan $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ threshold (L pol.)
e^+e^-	410	L	60	75	Scan $\tilde{\tau}_2 \tilde{\tau}_2$ threshold Scan $\tilde{\mu}_L^+ \tilde{\mu}_L^-$ threshold
e^+e^-	580	L/R	90	120	Sit above $\tilde{\chi}_1^\pm \tilde{\chi}_2^\mp$ threshold for $\tilde{\chi}_2^\pm$ mass
e^-e^-	285	RR	10	95	Scan with e^-e^- collisions for \tilde{e}_R mass

hep-ex/0211002v1, P. Grannis

$\sim 1000 \text{ fb}^{-1}$ equivalent luminosity
(scaled by $L \sim E$)

3. Low mass SUSY scenarios study

- Two possible strategies to adjust to lower luminosity capability of SB2009
 - Run longer at each point
 - Dividing running differently to reduce overall run time
- We have looked at the impact of ILC parameters on the physics program, assuming the same division of luminosity at selected E_{cm}

3. Low mass SUSY scenarios study

(a la Grannis)

Year	1	2	3	4	5	6	7
$\int \mathcal{L} dt$	10	40	100	150	200	250	250

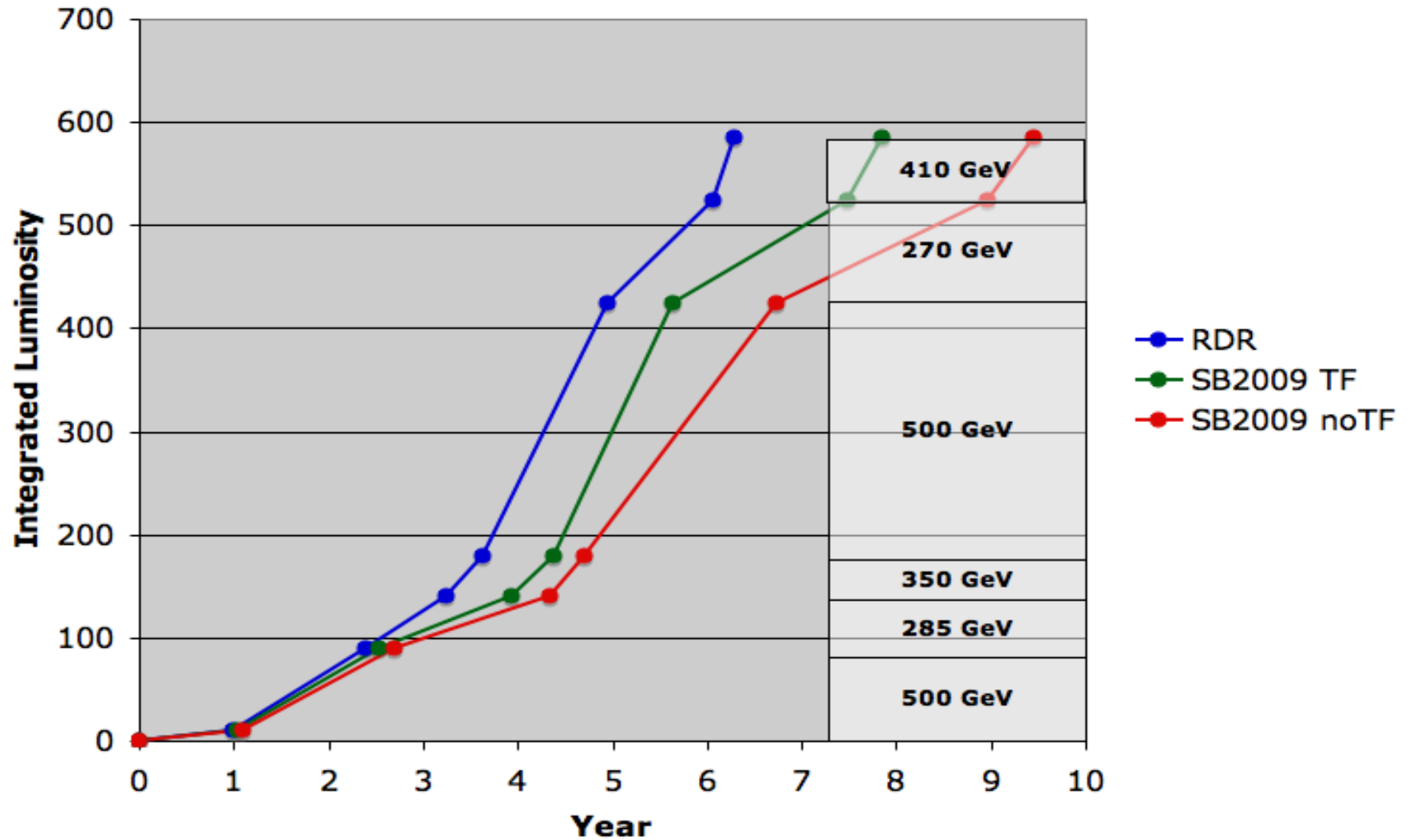
hep-ex/0211002v1,
P. Grannis

- **Year 1** 500 GeV - if possible (10 fb⁻¹)
- **Year 2-3** 500 GeV ~ 80 fb⁻¹
 - Achieve twice the ultimate errors on sparticle masses
- **Year 3** scan at 285 GeV 50 fb⁻¹ (85 fb⁻¹ equiv.)
 - Smuon threshold
- **Year 4** scan at 350 GeV 40 fb⁻¹ (60 fb⁻¹ equiv.)
 - Top, selectron, chargino thresholds
- **Year 4-5** complete 500 GeV run (total 335 fb⁻¹)
 - Ultimate precisions
- **Year 6** scan at 270 GeV 100 fb⁻¹ (185 fb⁻¹ equiv.)
 - Neutralino and stau thresholds
- **Year 7** scan at 410 GeV 60 fb⁻¹ (73 fb⁻¹ equiv.)
 - Stau and smuon thresholds

Note -
Assume L ~ E
Not quite RDR

Also -
10 fb⁻¹ Mz cal,
10 fb⁻¹ e-e- (285),
90 fb⁻¹ 580 GeV

3. Comparion of RDR w/SB2009 (Low Mass SUSY Scenario)



Summary

- Several physics impacts of SB2009 have been investigated
 - Higgs mass and cross section
 - δM : 43 MeV \rightarrow 93 MeV
 - $\delta\sigma$: 3.9% \rightarrow 4.3%
 - Stau detection
 - 15-20% degradation w/TF
 - Low mass SUSY scenario (an example)
 - Stretched out run plan (~ 6 years \rightarrow +1.5 years wTF, +3 years w/o)
 - Can run strategy be streamlined? - scenario dependent
- Plan to re-assess Higgs branching ratio (250 vs. 350 GeV), and investigate 350 GeV spin-parity analysis (as alternative to threshold cross section measurement)
- A significant lower-energy luminosity reduction may have very negative impact on the ILC program

Minimize negative impact by running at 350 GeV (rather than 250 GeV) w/ traveling focus Worse without TF

Future Steps

- GDE is studying new machine designs with improved low energy luminosity (double rep rate at low E, and opt. Final Focus)
- When new parameter is available we are set to repeat and extend studies
- Working Group
 - Expanded membership by adding three phenomenologists
 - Will broaden physics studies
 - Higgs branching ratios
 - Higgs angular spin-parity analysis
 - Stau parameter space
 - Will reassess physics impacts with new machine parameters