Higgs Factory Fever
or
Thoughts on How to Get Ready for Snowmass in Minnesota

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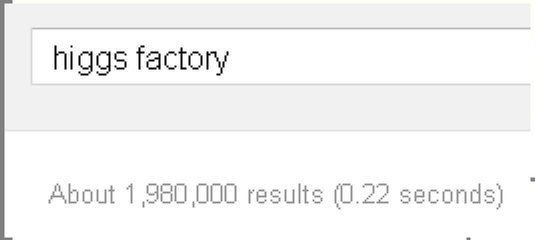

higgs factory

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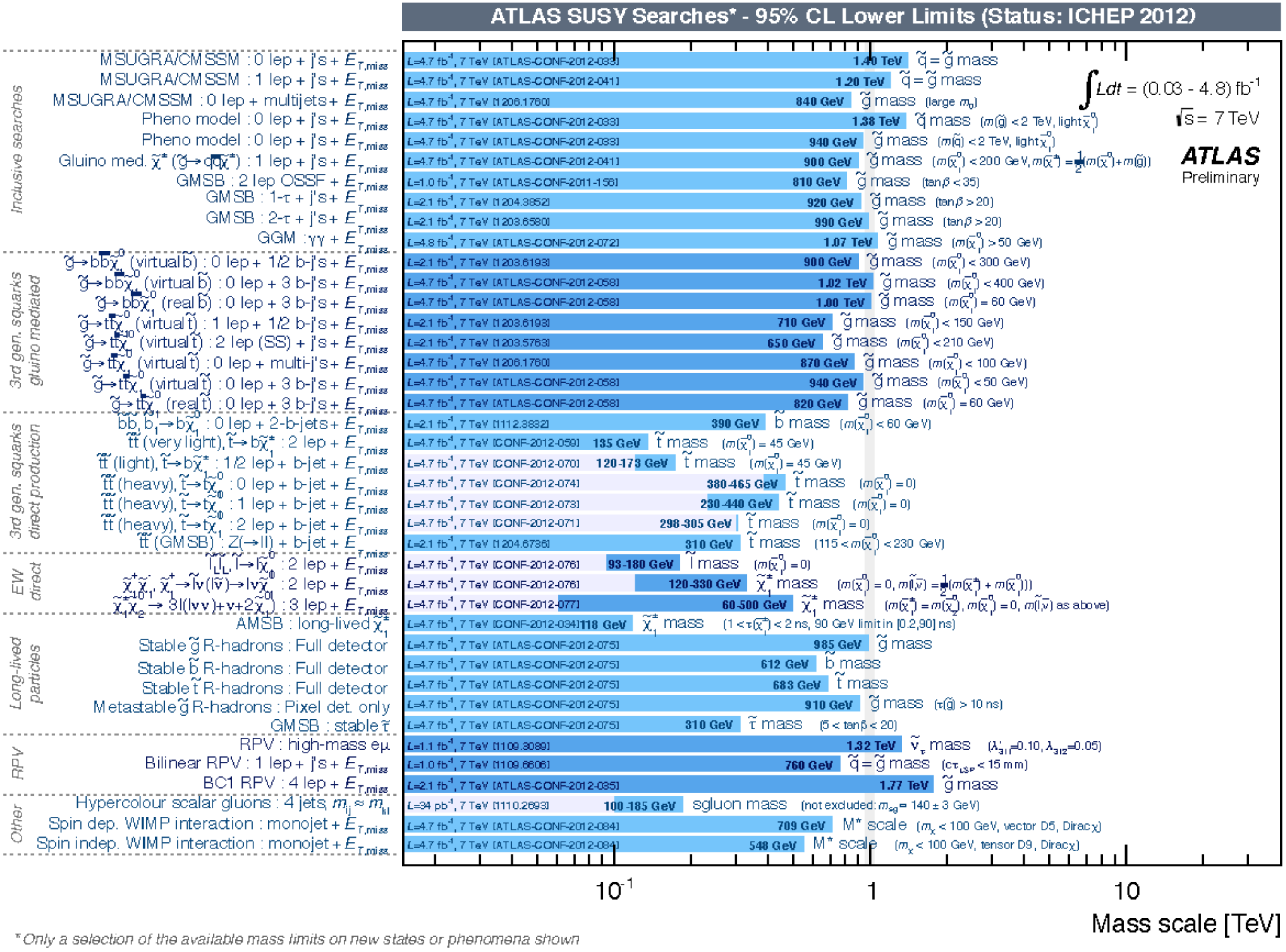
Lessons from the LHC, 10 fb^{-1}

- A new boson with exists with m_X~125 GeV, decaying into $\gamma\gamma$ and 4 leptons.
- It is consistent with the expected Higgs boson. 3 month extension of the current LHC run at 7 TeV should provide convincing evidence for/against the Higgs interpretation by the Spring of 2013.
- There is no evidence for any other new physics.

- Question: Given these findings, what the strategy of the HEP/US HEP/Fermilab should be. 'Snowmass 2013' is supposed to address these question. We should prepare as much of the scientific and technical input as possible to make the discussions better informed and more productive.


ATLAS SUSY Searches* - 95% CL Lower Limits (Status: ICHEP 2012)

*Only a selection of the available mass limits on new states or phenomena shown

Primary Objective for the 'Next Step'

- Determine the nature of the newly discovered boson: production mechanism and cross section. decay modes, branching fractions, quantum numbers
- Is it a source the electroweak symmetry breaking?
- Is it the only source of the EWSB?
- Are there any indications for any deviation from the SM predictions?

Whereas many people may agree with the objective, it is likely that opinions on the best strategy to accomplish are likely to be quite different. This strategy (a.k.a. Higgs Factory) is likely to be the central focus of the Snowmass meeting.

Solving the Higgs puzzle at the LHC

- The LHC machine works remarkably well.
- The experiments are hugely successful. They have demonstrated their capabilities to detect and analyze Higgs-like objects already so early in the game.
- Further improvements of the machine: 13 TeV, higher luminosity, 25 ns bunch spacing are expected.
- Experiments will be upgraded to cope with the improved machine performance.
- Question:
  - How well the LHC experiments can establish the nature and measure the properties of the Higgs-like object?
  - Is there any need/room for a new machine to study the 125 GeV bump?
- One should expect a thorough analysis of the potential of the LHC experiments to be prepared/presented by the CMS and ATLAS collaborations.

The Case for the ILC

- The physics potential of the ILC as a Higgs laboratory through ZH production is very well established, including very detailed detector simulation.
- Technical design of the machine and the experiments are very mature..
- Given the current lack of evidence for any new physics below 1 TeV what is the best staging/phasing strategy:
  - Low energy 250 GeV machine to study ZH
  - 350-400 GeV machine to study Higgs and ttbar threshold?
  - Higher energy machine to establish/measure Higgs self-coupling?
- Technical/cost optimization of the staging scenario
- Fast track project organization/approval/funding scenario.
- One should expect a detailed analysis and evaluation of this scenario from the ‘ILC Community’.

Muon Collider Higgs Factory

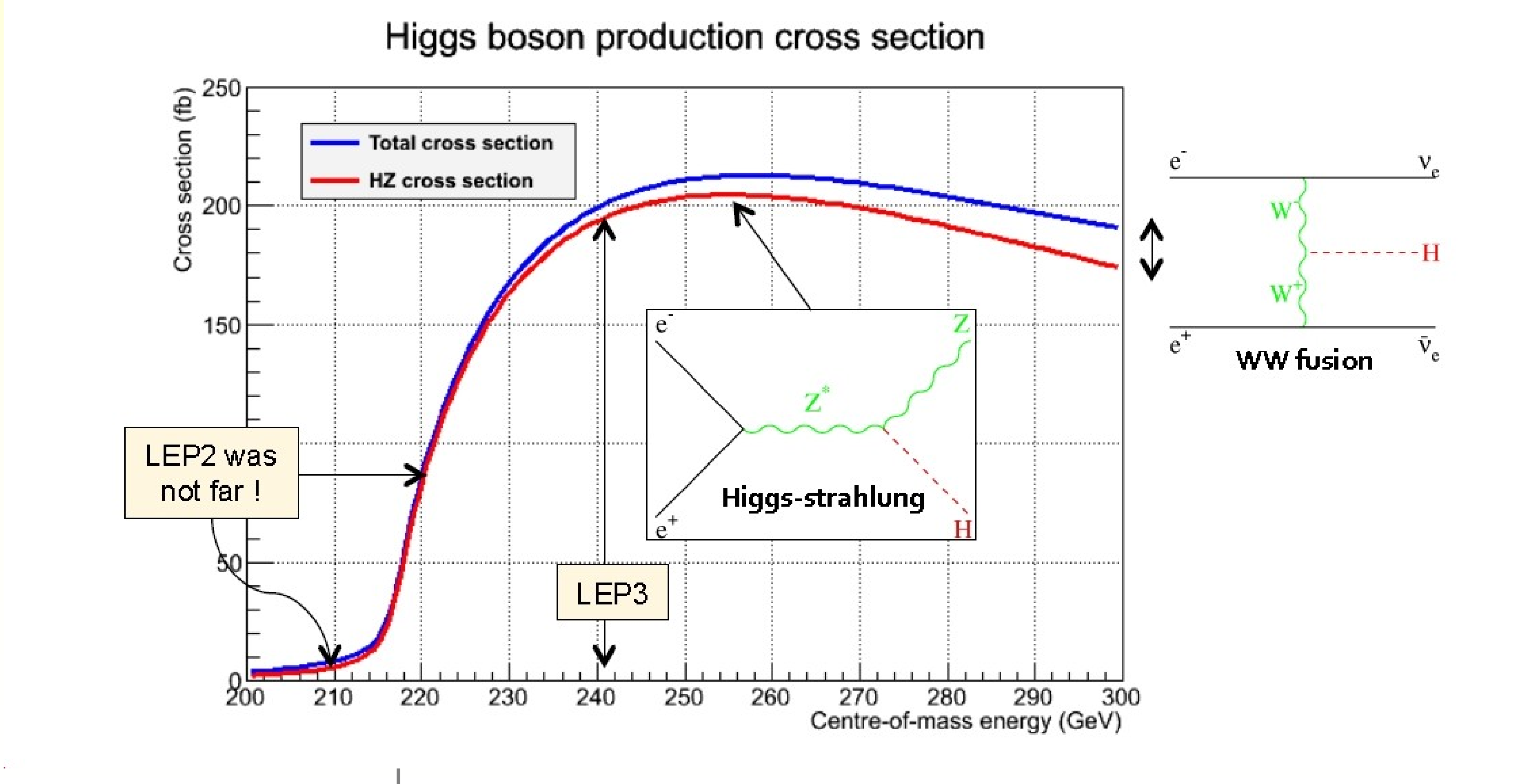
- Physics case for the s-channel muon has been studied in great details ~10-15 years ago. Most of he attention was directed lately to the ‘very high energy’ case.
- 125 GeV bump has re-ignited the interest (UCLA workshop in December)
- Machine issues: need to establish a list of the most critical issues and collect known information or stimulate the new analysis focused on known (finally) target beam energy.
  - Energy spread/Higgs width
  - Absolute energy scale in a rapid cycled synchrotron
  - Luminosity, cooling requirements
  - R&D strategy: the critical path
  - Possible time scales and cost estimated
- One should expect the MAP people to prepare the ‘machine’ case.

Detector for the Muon Collider Higgs Factory

- Several ‘experimental’ studies carried out ~ 10-15 years ago. Need to review these studies and update where necessary.
- Generic, ILC-like detectors are likely to be quite sufficient for the studies.
- Detector simulation tools, Icism, optimized for the muon collider case developed and available for use on DETSIM cluster (Hans Wenzel). Need an organized and coherent effort.
- Major issue: beam induced backgrounds and their implication for the detector/physics capabilities.

ZH Higgs Factory: Linear vs Circular

- 125 GeV Higgs case is very interesting, especially if it can be asserted that there is no need/interest EVER to go to higher energies.



LEP3/DLEP parameters in comparison -1

	LEP2	LHeC	LEP3	DLEP
beam energy E_b [GeV]	104.5	60	120	120
circumference [km]	26.7	26.7	26.7	53.4
beam current [mA]	4	100	7.2	14.4
#bunches/beam	4	2808	4	60
#e-/beam [10^{12}]	2.3	56	4.0	16.0
horizontal emittance [nm]	48	5	25	10
vertical emittance [nm]	0.25	2.5	0.10	0.05
bending radius [km]	3.1	2.6	2.6	5.2
partition number J_ε	1.1	1.5	1.5	1.5
momentum compaction α_c [10^{-5}]	18.5	8.1	8.1	2.0
SR power/beam [MW]	11	44	50	50
β^*_x [m]	1.5	0.18	0.2	0.2
β^*_y [cm]	5	10	0.1	0.1
σ^*_x [µm]	270	30	71	45
σ^*_y [µm]	3.5	16	0.32	0.22
hourglass F_{hg}	0.98	0.99	0.67	0.75
ΔE^{SR}_{loss}/turn [GeV]	3.41	0.44	6.99	3.5

LEP3/DLEP parameters in comparison -2

	LEP2	LHeC	LEP3	DLEP
E^{SR}_{loss}/turn [GeV]	3.41	0.44	6.99	3.5
$V_{RF,tot}$ [GV]	3.64	0.5	12.0	4.6
$d_{max,RF}$ [%]	0.77	0.66	4.2	5.0
ξ_x/IP	0.025	N/A	0.09	0.05
ξ_y/IP	0.065	N/A	0.08	0.05
f_s [kHz]	1.6	0.65	3.91	0.91
E_{acc} [MV/m]	7.5	11.9	20	418
eff. RF length [m]	485	42	606	376
f_{RF} [MHz]	352	721	1300	1300
δ^{SR}_{rms} [%]	0.22	0.12	0.23	0.16
$\sigma^{SR}_{z,rms}$ [cm]	1.61	0.69	0.23	0.17
L/IP[$10^{32}cm^{-2}s^{-1}$]	1.25	N/A	107	142
number of IPs	4	1	2	2
beam lifetime [min]	360	N/A	16	22
Υ_{BS} [10^{-4}]	0.2	0.05	10	8
n_γ/collision	0.08	0.16	0.60	0.25
[illegible]S/collision [MeV]	0.1	0.02	33	12
[illegible]S$_{rms}$/collision [MeV]	0.3	0.07	48	26

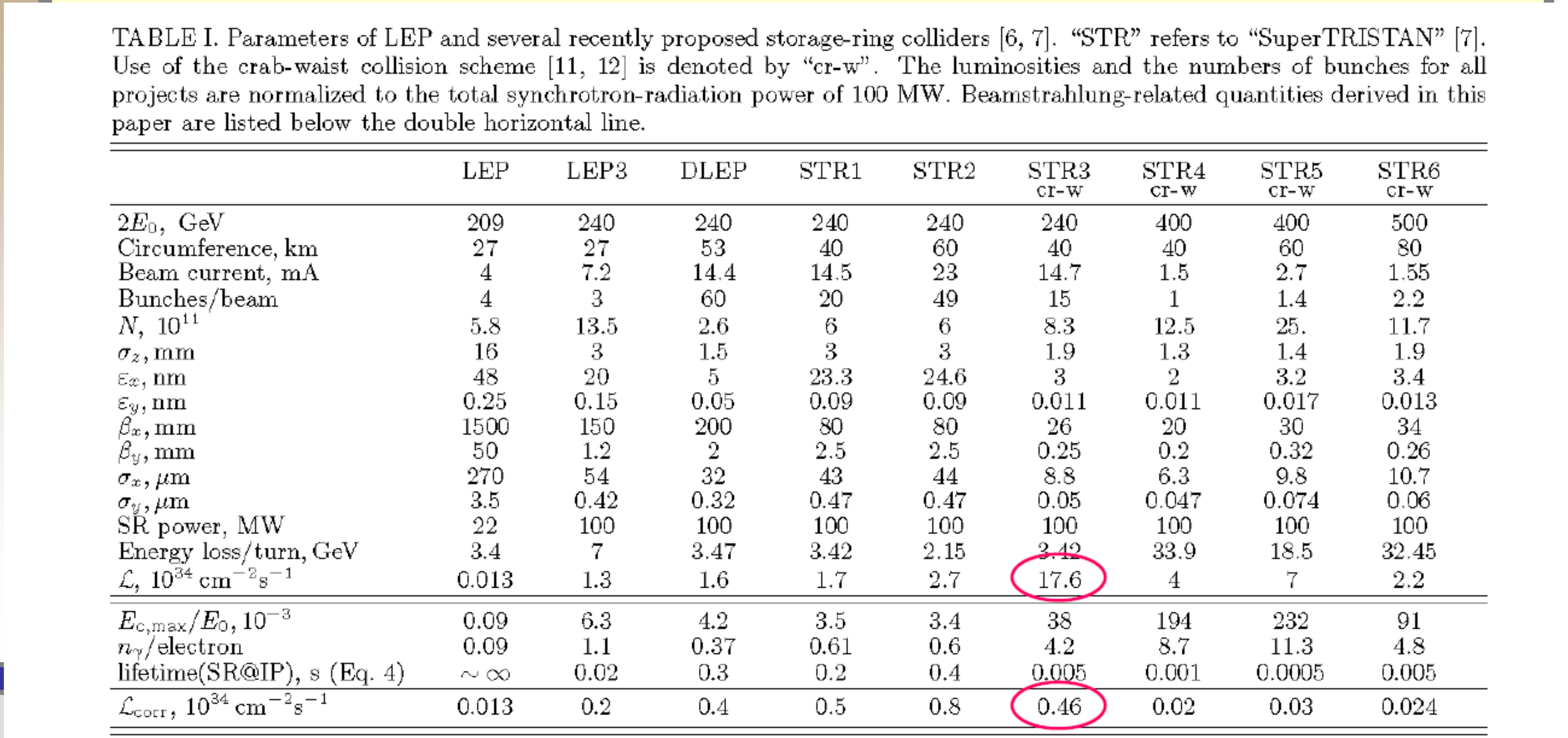


TABLE I. Parameters of LEP and several recently proposed storage-ring colliders [6, 7]. "STR" refers to "SuperTRISTAN" [7]. Use of the crab-waist collision scheme [11, 12] is denoted by "cr-w". The luminosities and the numbers of bunches for all projects are normalized to the total synchrotron-radiation power of 100 MW. Beamstrahlung-related quantities derived in this paper are listed below the double horizontal line.

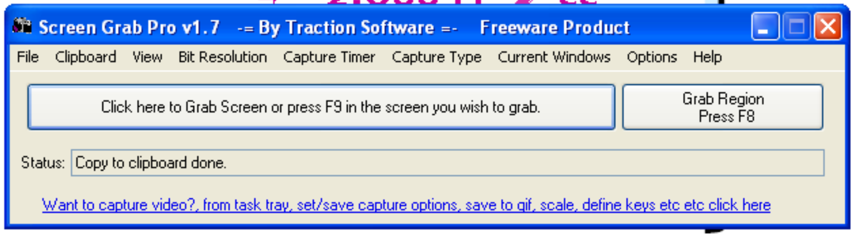
	LEP	LEP3	DLEP	STR1	STR2	STR3 cr-w	STR4 cr-w	STR5 cr-w	STR6 cr-w
$2E_0$, GeV	209	240	240	240	240	240	400	400	500
Circumference, km	27	27	53	40	60	40	40	60	80
Beam current, mA	4	7.2	14.4	14.5	23	14.7	1.5	2.7	1.55
Bunches/beam	4	3	60	20	49	15	1	1.4	2.2
N, 10^{11}	5.8	13.5	2.6	6	6	8.3	12.5	25.	11.7
σ_z, mm	16	3	1.5	3	3	1.9	1.3	1.4	1.9
ε_x, nm	48	20	5	23.3	24.6	3	2	3.2	3.4
ε_y, nm	0.25	0.15	0.05	0.09	0.09	0.011	0.011	0.017	0.013
β_x, mm	1500	150	200	80	80	26	20	30	34
β_y, mm	50	1.2	2	2.5	2.5	0.25	0.2	0.32	0.26
σ_x, μm	270	54	32	43	44	8.8	6.3	9.8	10.7
σ_y, μm	3.5	0.42	0.32	0.47	0.47	0.05	0.047	0.074	0.06
SR power, MW	22	100	100	100	100	100	100	100	100
Energy loss/turn, GeV	3.4	7	3.47	3.42	2.15	3.42	33.9	18.5	32.45
$\mathcal{L}$, 10^{34} cm^{-2}s^{-1}	0.013	1.3	1.6	1.7	2.7	17.6	4	7	2.2
$E_{c,\max}/E_0$, 10^{-3}	0.09	6.3	4.2	3.5	3.4	38	194	232	91
n_γ/electron	0.09	1.1	0.37	0.61	0.6	4.2	8.7	11.3	4.8
lifetime(SR@IP), s (Eq. 4)	$\sim\infty$	0.02	0.3	0.2	0.4	0.005	0.001	0.0005	0.005
$\mathcal{L}_{\rm corr}$, 10^{34} cm^{-2}s^{-1}	0.013	0.2	0.4	0.5	0.8	0.46	0.02	0.03	0.024

LEP3 Motivation (11)

- LEP3 as a Higgs factory, √s = 240 GeV
  - With 1.5 10^{34} cm^{-2} s^{-1}, deliver 500 fb^{-1} in ~3 years, with little beamstrahlung
    - 100,000 HZ events / experiment, of which
      - 58,000 $H \rightarrow bb$
      - 22,000 $H \rightarrow WW$

        σ_{HZ} x BR measurable to ~ 2-3% / expt
      - 8,200 $H \rightarrow gg$
      - 6,400 $H \rightarrow \tau\tau$
      - 2,800 $H \rightarrow cc$

        σ_{HZ} x BR measurable to ~ 5-10% / expt



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x BR measurable to ~ 20% / expt

      - ? $H \rightarrow \chi^0\chi^0$ Invisible decay to dark matter, along with a visible Z
    - σ_{HZ} measurable to 2-3%
      - With the 6,600 HZ events in which $Z \rightarrow e^+e^-, \mu^+\mu^-$

        Independently of the Higgs decay channel

        (also invisible and other non-standard decays are caught there)

History at KEK (LEP3Day Yokoya)

- Stimulated by the LEP3, Katsunobu Oide proposed possible ring collider at Ecm=240GeV in Tsukuba region in an LC meeting in January.
- Higher energy colliders Ecm=400-500GeV were also proposed in a meeting on future of KEK in February.
- I raised the issue of beamstrahlung and concluded
  - Beam energy spread induced by beamstrahlung demands large momentum aperture.
  - Ring colliders with Ecm=400-500GeV with luminosity and power consumption similar to those of ILC/CLIC are impossible
  - A collider with Ecm=240GeV is at the border of feasibility. A large momentum acceptance (several percent) would be required
- Later Valery pointed out importance of the critical energy of beamstrahlung

Circular Higgs Factory in Illinois ?

- Physics/detector case pretty much identical to the ILC case.
- A lot of machine design aspects studied at considerable depth at CERN and KEK. They may need to be reviewed/updated for the specific Fermilab-centric case.
- Site/tunelling/etc – a lot of ILC-oriented work can be re-used or adopted for the circular machine.
- Synergy with the Superconducting RF work..
- Synergy wit Fast Ramping Dipole Design work (H. Piekarz)
- It is very likely that the machine performance (luminosity!) would be limited in practice by beamstrahlung. Need very careful optimization.
- May be an initial stage for the future proton machine.
- Way to go? Invite CERN/KEK people to present the work done so far, do not reinvent the wheels but address the fine print isues?