ECFA/DESY AMSTERDAM

e^-e^- parallel session:

THE NEED FOR COMPLEMENTARITY OF e^+e^- AND e^-e^- COLLISIONS:

Recall that the $|in\rangle$ states of best definition are

$$|e_L e_L\rangle, \quad |e_L e_R\rangle, \quad |e_R e_R\rangle.$$

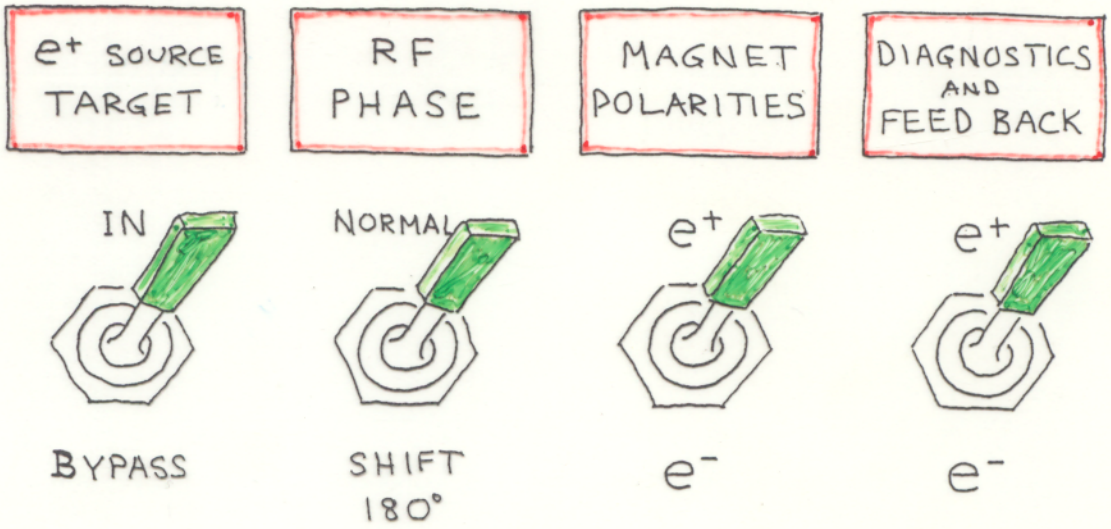
There is no other state so fully parameterized.

GIVEN THAT THE $|e^+e^-\rangle$ COLLIDER IS MOSTLY VAUNTED FOR ITS "VACUUM" QUANTUM NUMBERS, THERE IS A STRONG CASE TO BE MADE FOR PROVIDING BOTH AT THE FIRST STAGE OF LINEAR COLLIDER OPERATION.

RECALL THAT THE 1995 INTERNATIONAL LINEAR COLLIDER TECHNICAL REVIEW COMMITTEE REPORT STATED:

"Since the e^-e^- collider requires only minor changes to the hardware of the e^+e^- machine and detector, its programme could be pursued during the first phase of the facility...."

- International Linear Collider Technical Review Committee Report - 1995



THE ONLY REALLY PURE FIELD AT OUR DISPOSAL IS

$$\boxed{\ell_L, \quad \ell_R}$$

NOT AVAILABLE IN e^+
γ
hadron beams

(also, to a certain extent, $\boxed{\mu}$'s; but we cannot switch their polarization).

$|\vec{P}_{e^-}| = 80\%$ is routinely reached in SLD running at SLAC

- There is no known cath' limit'n
- Theoretical estimates put attainable $|\vec{P}|_{e^-}$ values at $< 95\%$

$|\vec{P}|_{e^+}$ is a much harder task

NO PROJECT BEYOND 65% IS BEING ENVISIONED

UNIQUE QUANTUM NUMBERS FOR e^-e^- INITIAL STATE.

A POTENT TOOL FOR

CONSERVATION STUDIES IN

SEARCH OF

⇒ FUNDAMENTAL SYMMETRIES

⇒ EXTENDED GROUP STRUCTURES BEYOND THE STANDARD MODEL

TO WIT: e^-e^- INITIAL STATE HAS

$Q_e = -2$	
$L = +2$	$L_e = +2$
$I_W = -1$	
$Y_W = -2$	
$S_z = 1, 0, -1$ (easily tunable)	

THESE PROPERTIES PERMIT STUDIES OF

- THE MEANING OF LEPTON #
  ($\sum (B-L) = \text{const}$?)
- m_{DIRAC} vs. $m_{MAJORANA}$ FOR ν_e

A CLOSER LOOK AT THE DESIGN FEATURES SHOWS THAT

THE JLC, TESLA, NLC, CLIC ARE ALL NATURAL e^-e^- COLLIDERS

IF

WE PROVIDE THE NEEDED COMPLEMENTARY FEATURES FROM THE START!

THE SAME HOLDS FOR I.R., DETECTOR.

THE ACCESSIBILITY OF

I

- HIGH DEGREES OF POLARIZATION
- EASY HELICITY REVERSAL

FOR <u>BOTH</u> INCOMING BEAMS

IS ESSENTIAL FOR ENHANCEMENT OF SIGNA

AND SUPPRESSION OF BACKGROUND

→ <u>EASY</u> CHOICE OF CHIRAL COUPLINGS

II

- DISTINCTIVE CHOICE OF INCOMING QUANTUM #'S FOR INITIAL STATE:

	Q_{ee}	S_z	L	L_e	I_3^W	Y^W
$e_L^- e_L^-$	-2	$+1$	2	2	-1	-2
$e_L^- e_R^-$	-2	0	2	2	$-1/2$	-3
$e_R^- e_R$	-2	-1	2	2	0	-4

PERMITS PROBING BEYOND THE CAPABILITIES

OF LHC AND e^+e^- COLLIDERS

PHYSICS PROMISE

Same-sign colliders are
COMPLEMENTARY
to opposite-sign colliders.

→ MØLLER SCATTERING — MARCIAN
& ANOMALIES
(→ Z', $\sin^2\theta_W$)

HIGGS (minimal, MSSM)

EXTENDED HIGGS SECTOR — J. Gunion

→ SUSY — J. Feng, M. Peskin

STRONG EWSB — T. Han

→ COMPOSITENESS — T. Barklow

HEAVY MAJORANA NEUTRINOS — H-Min

DILEPTON GAUGE BOSONS — FRAMPTON

LEPTOQUARKS — T. Rizzo

ANOMALOUS GAUGE COUPLINGS — CUYPERS

e^-e^- PROVIDES A LABORATORY FOR PROBING

→ THE S.M. TO ITS LIMITS

→ HIGHER SYMMETRIES BEYOND THE REACH OF e^+e^-, pp

THE ACCESSIBILITY OF SUCH CLEAN,

- "EXOTIC" QUANTUM NUMBERS
- A CLEAR CHOICE OF CHIRAL COUPLINGS THROUGH INSTANTLY SWITCHABLE $e_L e_L$, $e_L e_R$, $e_R e_R$ COMPOSITIONS

MAKES e^-e^- A UNIQUE TOOL FOR PROBING DETAILED FEATURES THAT ARE

HARDER TO DETECT IN e^+e^-, $p\bar{p}$
COMPLEMENTARY TO WHAT CAN BE DISCOVERED OR EXPLORED IN OTHER CHANNELS

EXAMPLES: ANOMALOUS GAUGE COUPLINGS
STRONG WW SECTOR
EXTENDED HIGGS MODELS

WHAT'S SPECIAL ABOUT e^-e^- VS. e^+e^-?

- BEAM CURRENT MAY BE HIGHER
- "ANTI-PINCH" - BEAM-BEAM DISRUPTION

→ MAY LEAD TO CONSIDERATION OF INSERTION OF A PLASMA LENSE

(BEAM-GAS BACKGROUNDS?)

- e^-e^- IS THE NECESSARY STARTING POINT FOR $e^-\gamma$, $\gamma\gamma$ PROGRAM

→ THIS UNDERLINES THE NEED TO ESTABLISH e^-e^- FROM THE START,

BUT, DETECTOR ISSUES HAVE MOREIN COMMON WITH e^+e^- THAN WITH $e^-\gamma$, $\gamma\gamma$

- CROSSING ANGLE?

e^- WILL NOT BE GUIDED INTO e^- BEAM OPTICS ON OTHER SIDE OF I.R. (LIKE e^+e^-!)

- BEAM DISPOSITION, BEAM DUMPS ARE TO BE CONFIGURED SPECIALLY!
- PERMANENT-MAGNET SCENARIO: ROTATION

e^- POLARIZATION

A VITAL INGREDIENT IN ESSENTIALLY ALL THE MAIN PHYSICS MOTIVATIONS WE DISCUSSED

MAJOR RECENT DEVELOPMENTS
(HAVE PUT S.L.C. BACK INTO THE DRIVER'S SEAT...)

WE EXPECT TO POLARIZE BOTH INCOMING e^- BEAMS "AT WILL" WITH $|\vec{P}| \gtrsim 80\%$ prob'ly 90%
(superior to μ beams that hail from π, K decays!)

<u>QUESTION</u>: CAN THIS POLARIZATION BE MAINTAINED FOR BOTH BEAMS IN $10^{19}\, e^- \, cm^{-3}$ BUNCH-BUNCH INTERACTIONS?

DEPOLARIZATION SIMULATIONS INDICATE ONLY SMALL EFFECTS
→ MORE WORK NEEDED.

"EXOTIC" QUANTUM #'s

easy high polarizability and helicity reversal permit definition of

	Q_e	S_z	L	L_e	I_3^W	Y^W
$e_L^- e_L^-$	-2	1	2	2	-1	-2
$e_L^- e_R^-$	-2	0	2	2	$-1/2$	-3
$e_R^- e_R^-$	-2	-1	2	2	0	-4

→ signal identification, enhancement

→ background reduction

→ signal interpretation

for compositeness scales well into the 100 TeV range with
TeV e^-e^- colliders.

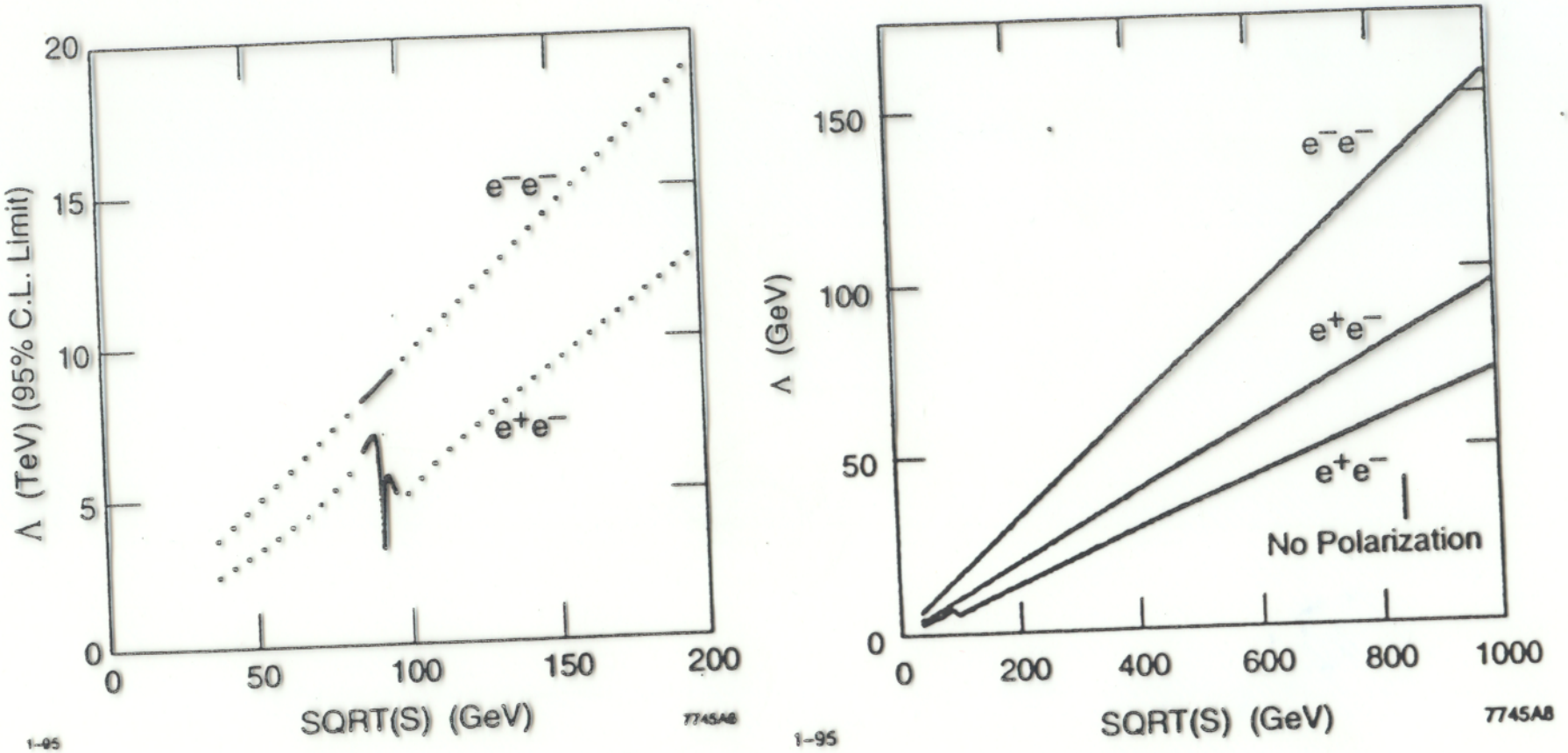


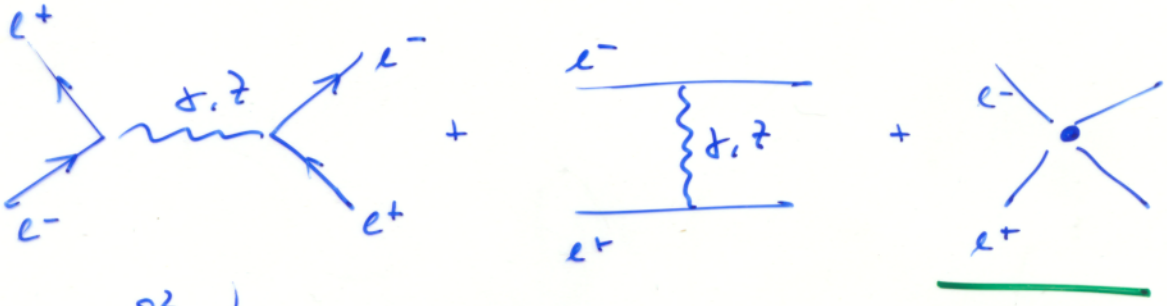
Figure 8: a) The sensitivity of Møller vs. Bhabha scattering below and above the Z resonance, in the absence of polarization of the incoming beams, to a compositeness scale Λ [TeV]. b) The corresponding sensitivity comparison in the case where the incoming electron (but not positron) beams are 90% polarized. The luminosity is chosen such that the statistics at each energy corresponds to the integrated values reached at PETRA for the compositeness limits set there.

• COMPOSITENESS OF ELECTRONS

TIM BARKLOW

AT SOME NEW-INTERACTION ENERGY SCALE Λ, ELECTRON COMPOSITENESS MAY MANIFEST ITSELF.

STANDARD LAGRANGIAN WITH THIS NEW FIELD:



$$\mathcal{L}_{\psi\psi} = \frac{g^2}{2\Lambda^2}\Big\{\eta_{LL}\,\bar{\psi}_L\gamma_\mu\psi_L\bar{\psi}_L\gamma^\mu\psi_L + \eta_{RR}\cdots + \eta_{RL}\,\bar{\psi}_R\gamma_\mu\psi_R\bar{\psi}_L\gamma^\mu\psi_L\Big\}$$

THE EXPLICIT TREATMENT SHOWS THAT THE NEW CONTACT INTERACTION IS CONSIDERABLY MORE EFFECTIVE FOR e^-e^- THAN FOR e^+e^-

PARTICULARLY WHEN THE e^- ARE STRONGLY POLARIZED

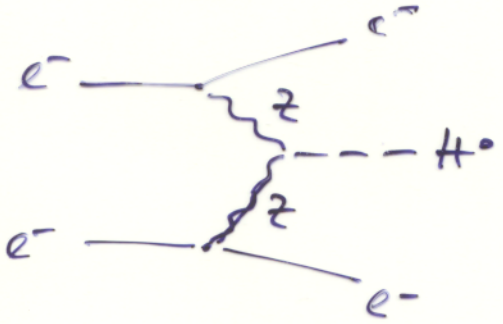
Λ – NEW-INTERACTION SCALES ACCESSIBLE ARE MUCH HIGHER

→

HIGGS BOSON PRODUCTION:

STANDARD HIGGS SCALAR

FROM ZZ FUSION



$(\sim 110 < m_{H^0} < 188 \text{ GeV})$

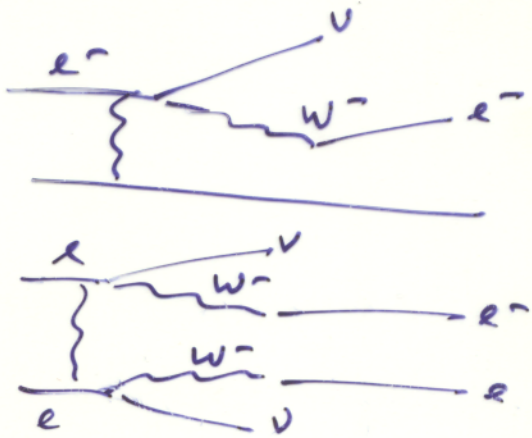
EXCELLENT CHANNEL FOR DISCOVERY, DETAILED STUDY FOR $\sqrt{s} \gtrsim 2.5\, m_H$

$\Rightarrow$ σ_{tot} SATURATES FOR ENERGIES BEYOND THRESHOLD

$\Rightarrow$ e^-e^- FINAL STATE CAN OFTEN BE DETECTED (UNLIKE $e^+e^- \to \nu\bar{\nu}H$)

$\rightsquigarrow$ INVISIBLE HIGGS DECAYS FROM "MISSING CENTRAL MASS"

$\Rightarrow$ PRODUCTION CROSS-SECTION HAS LITTLE DEPENDENCE ON e^- POLARIZATION, BUT



DECOUPLE FOR e_R !

REFERENCES:

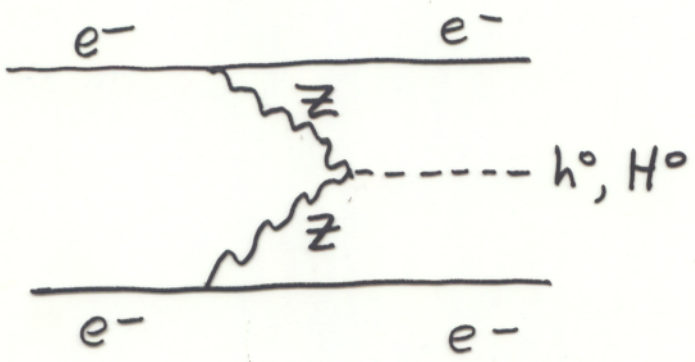
K. HIKASA (1988)
T. HAN (1996)
P. MINKOWSKI (1996)

Higgs boson production at e^-e^- $\{\gamma\gamma\}$ colliders:

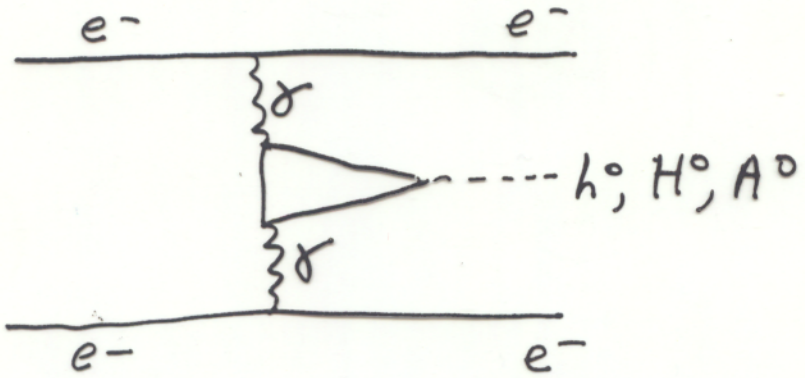
{ minimal H^0
MSSM h^0 }

1. Single Higgs production:

via $\gamma\gamma$ and ZZ fusion

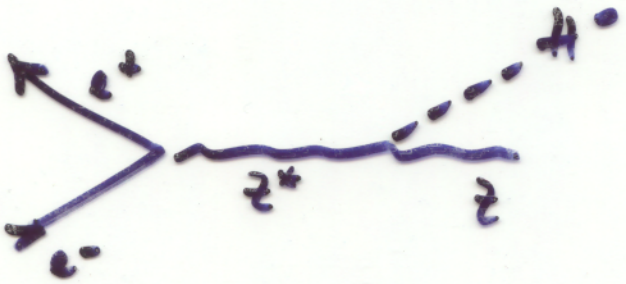


basically a "missing central mass" measurement



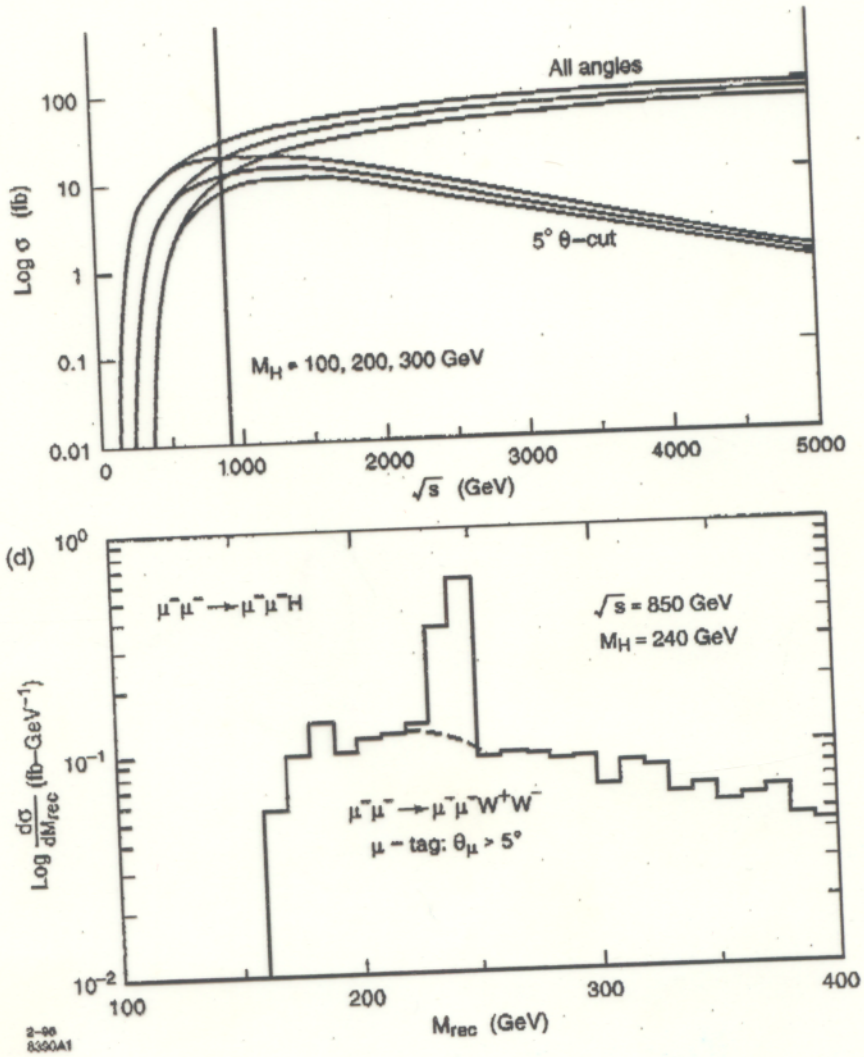
{ add CP-odd A^0 }

vs. e^+e^- collider standard prop.



$\sigma \sim \frac{1}{s}$

H. Haber (EE97)

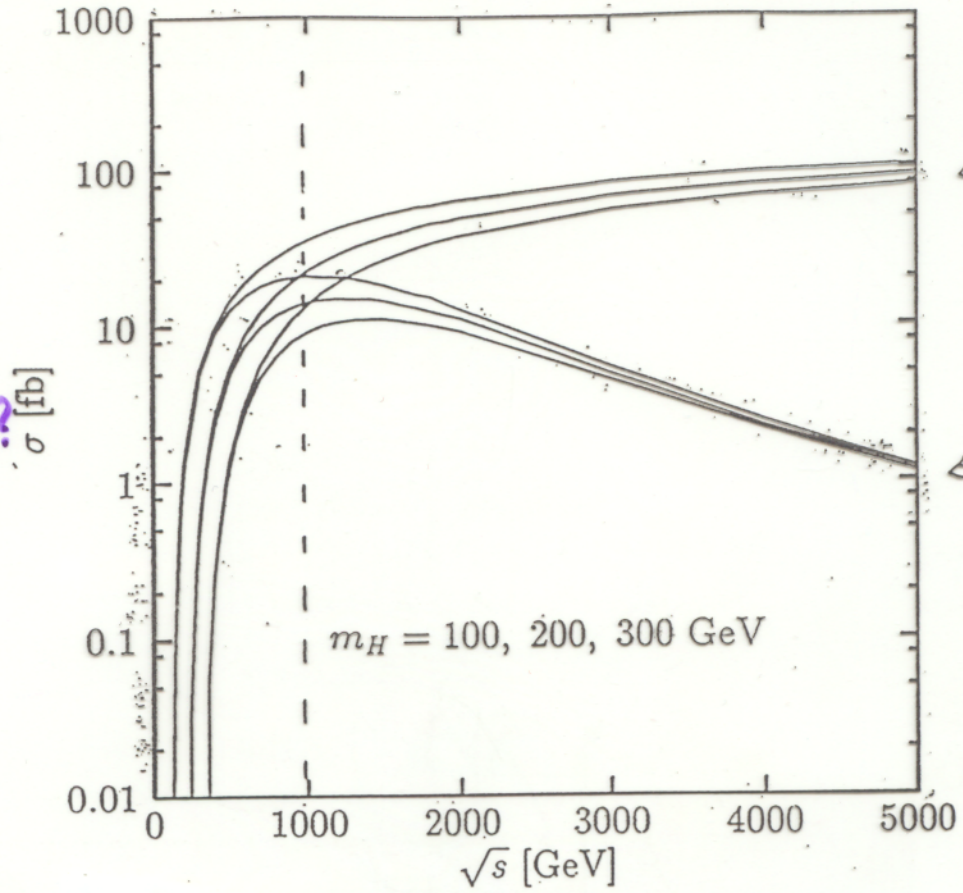


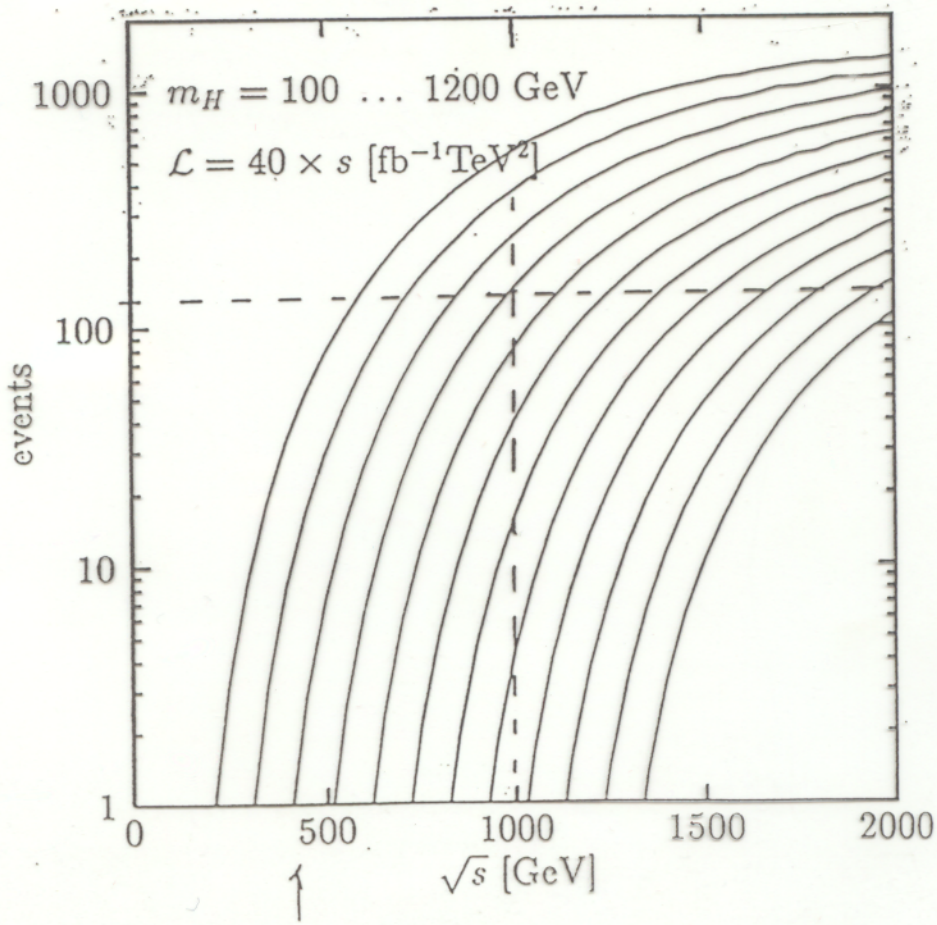
a) Central production of neutral bosons by gamma-gamma or ZZ fusion. b) same as a), but the lepton loop also permits the production of CP-odd bosons. c) Production cross section for the kinematical parameters given: the saturation at higher energies is obvious; a reasonable detector-originated cut of 5 degrees is entirely acceptable. d) Simulated signal (on a log scale). for the parameters given, irrespective of the boson decay modes. It can almost act as a "Higgs trigger".

P. Minkowski, 5-6-97

$e^-_L e^-_L \to (e^- e^-)\, H$

DETECTOR CUT AT $\Theta = \left\{ \begin{matrix} 5^\circ \\ 10^\circ \end{matrix} \right\}$?





SPECTACULAR ADVANTAGES OF

e^-e^- COLLISIONS FOR <u>SUSY</u> STUDIES:

→ $\tilde{e}$ ARE <u>SCALARS</u>!

→ $m(\tilde{e}_R) \neq m(\tilde{e}_L)$!

SEE SUSY PARALLEL SESSION

TOMORROW!