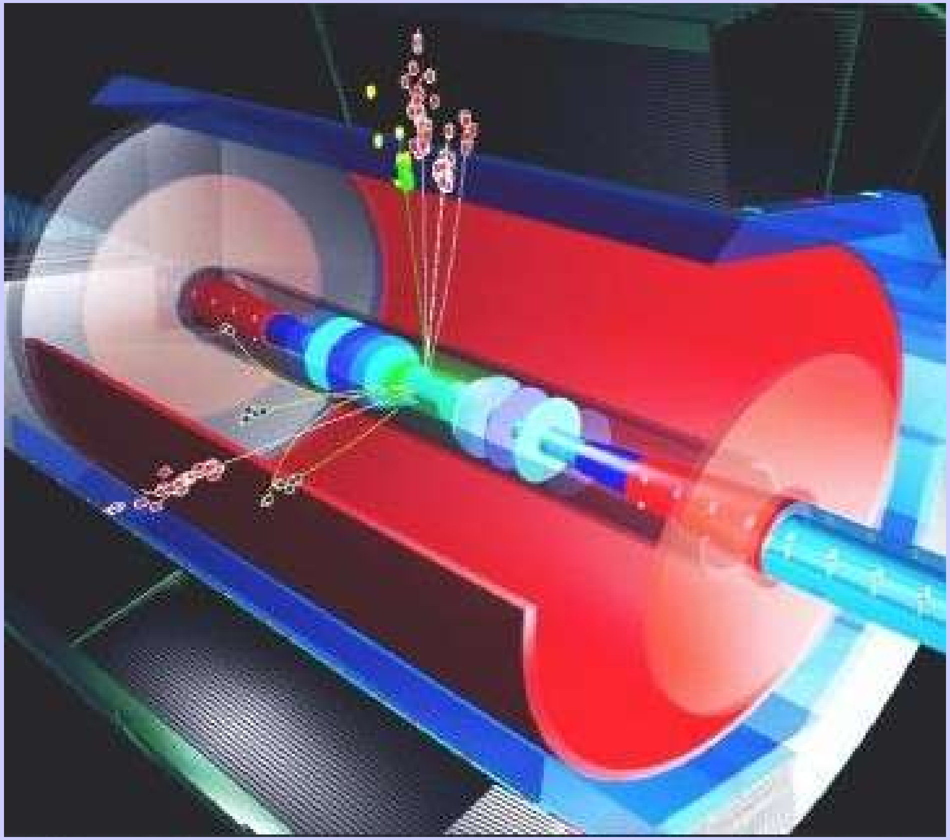
Physics @ Future Linear e^+e^- Collider



A. Raspereza, DESY

QFTHEP 2004 Conference, 18/06/2004

Synergy Between Hadron & Lepton Machines

- Hadron colliders : higher energy reach – higher discovery potential, high backgrounds - moderate precision measurements → machines of “scientific breakthrough” (SPS, Tevatron)
- Lepton colliders : lower energy reach – lower discovery potential, clean experimental environment - high precision measurements → machines of “model validation and indirect prediction” (LEP, SLAC)

Historical retrospective : establishment of SM

- *CERN SPS : discovery of weak bosons Z and W (early 80s)*
- *LEP experiments, SLD : validation of the SM through high precision measurements, indirect prediction of top mass*
- *Tevatron : discovery of top quark*
- *LEP, SLD, Tevatron : indirect constraints on Higgs mass and new physics through precise measurements in EW sector and direct measurements*

Anticipated Nearest Future of HEP

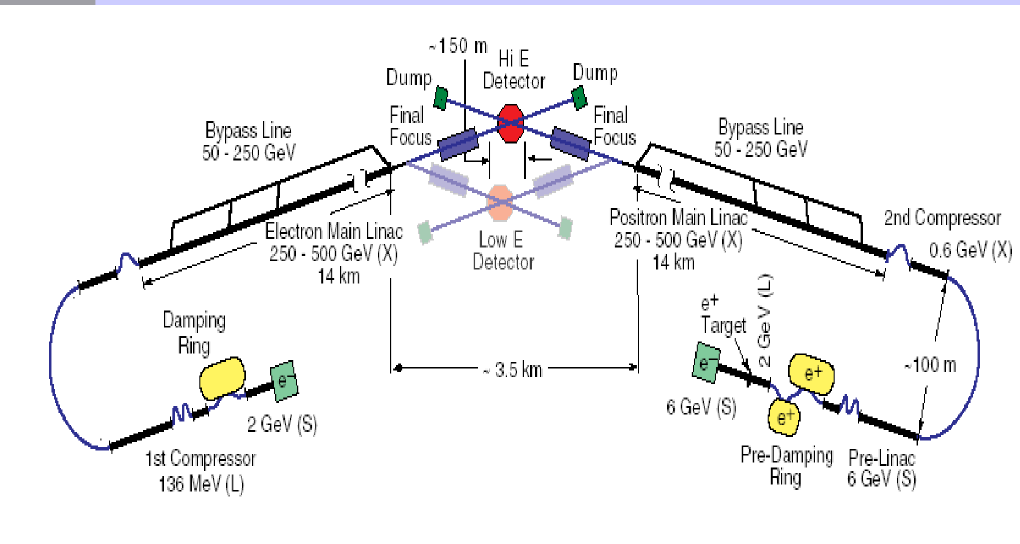
- One of the possible scenarios :
  - EWSB is realized in nature through Higgs mechanism
  - Low-energy supersymmetry is “true model”
- LHC :
  - discovers Higgs and supersymmetric particles
  - performs moderate precision measurements of Higgs boson(s) properties and properties of SUSY particles
- Linear collider :
  - performs high precision measurements in the Higgs sector – complete establishment of EWSB mechanism
  - performs precise measurements in SUSY sector
  - possible discoveries in those regions of model parameters space where LHC is “blind”
- LHC + Linear collider :
  - Joint reconstruction of SUSY Lagrangian
  - Indirect constraints through the precise measurements in the EW, Higgs and SUSY sectors on new physics at GUT and Planck scales

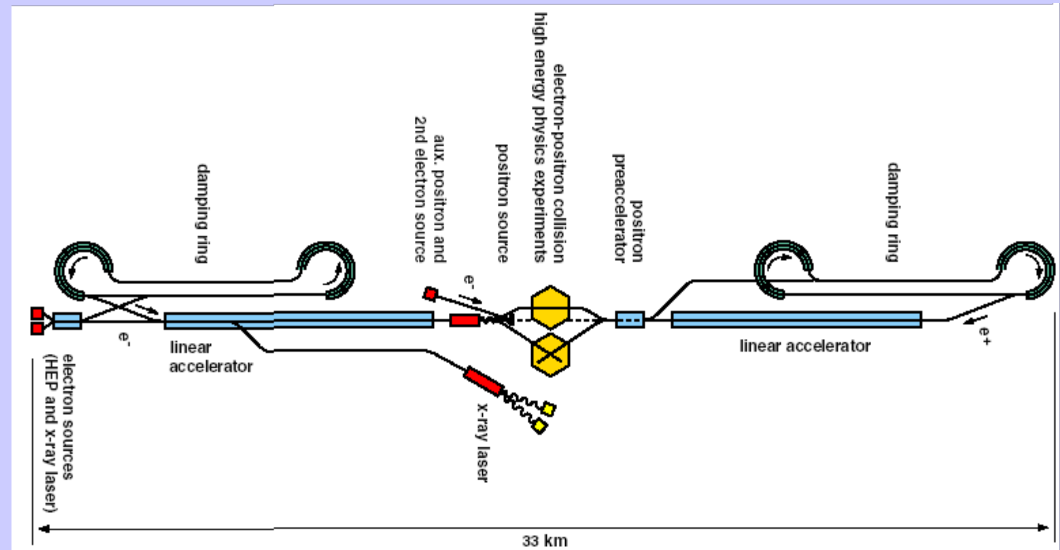
But... Nature may be much reacher than our imagination!

Features of Linear e^+e^- Collider

- Linear Collider = precision tool
  - CMS energy 500..1000 GeV = scale of EWSB
  - High luminosity (~3–5 $\times 10^{34}$ $cm^{-2}s^{-1}$)
  - Clear path to “phase 2” (multi-TeV) exists (CLIC)
- Well defined initial state
  - Complete kinematic reconstruction
  - Threshold scans (disentangle complicated new physics)
- Clean environment
  - Experimental systematics small
  - O(%) level measurements possible (= challenge for theory!)
- Running options ($\gamma\gamma$, γe, e-e-, GigaZ)
  - Redundancy of measurements = cross – checks
  - Complementarity of measurements
  - Specific physics for specific option
- Beam polarization (crucial for studying SUSY processes)
  - Important to pin down model parameters
  - Disentangle various states, suppress some of backgrounds

Machine Technology Options





Conventional warm technology (NLC)

- ➔ 500 – 1000 GeV CMS energy
- ➔ 1.4 ns (40 cm !) bunch separation
- ➔ 11.4 GHz RF frequency
- ➔ 192 bunches in train
- ➔ 200 – 300 MW AC power
- ➔ σ_x / σ_y = 220-250/2-3 nm
- ➔ σ_z = 110 µm
- ➔ N_e / bunch at IP = 0.8×10^{10}
- ➔ Lumi : $2–3 \times 10^{34}$ $cm^{-2}s^{-1}$

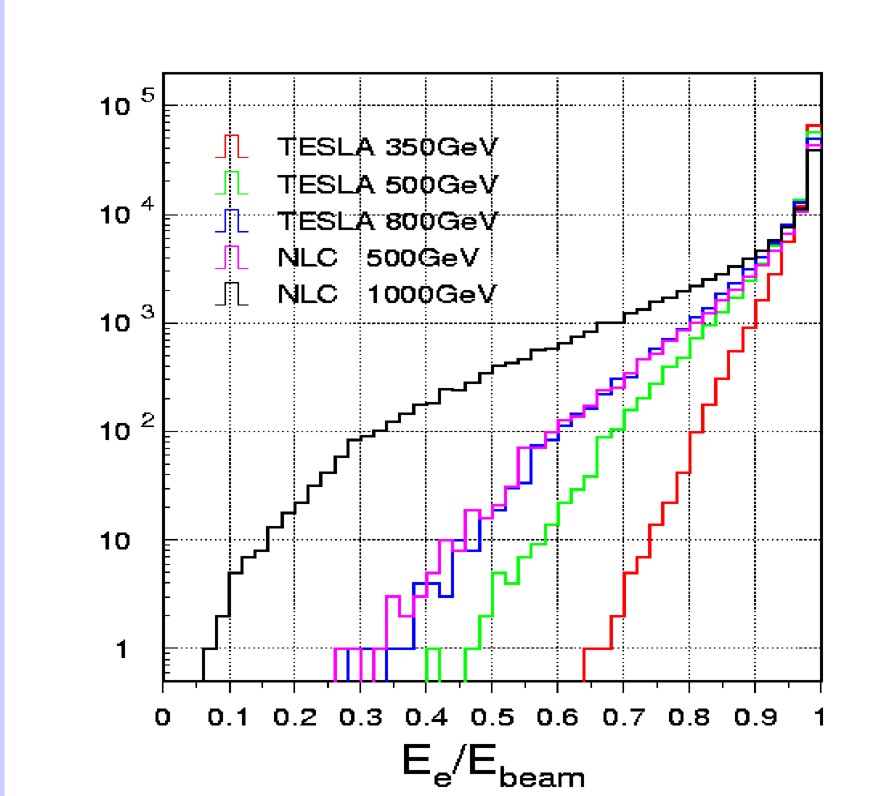
Superconducting Cols Technology (TESLA)

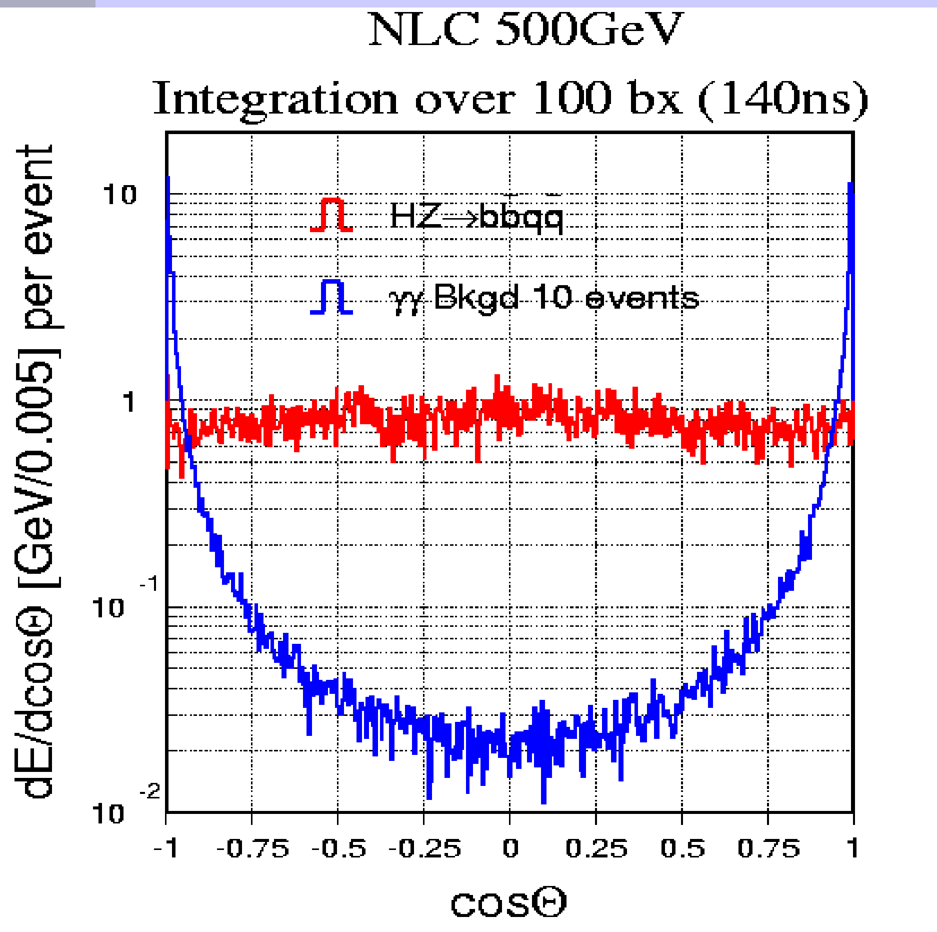
- ➔ 500 – 800 GeV CMS energy
- ➔ 180–340 ns bunch separation
- ➔ 1.3 GHz RF frequency
- ➔ 2820–4886 bunches in train
- ➔ 100–160 MW AC power
- ➔ σ_x / σ_y = 400-550/3-5 nm
- ➔ σ_z = 300 µm
- ➔ N_e / bunch at IP = $1.4 - 2 \times 10^{10}$
- ➔ Lumi : $3.4–5.8 \times 10^{34}$ $cm^{-2}s^{-1}$

Unpleasant Features of LC

✔ "well define" initial state?

- Beams are extremely collimated with large bunch charge → electrons of one bunch radiate against coherent field of other bunch
- Average energy loss 1.5% for e^-/e^+ @ 500GeV



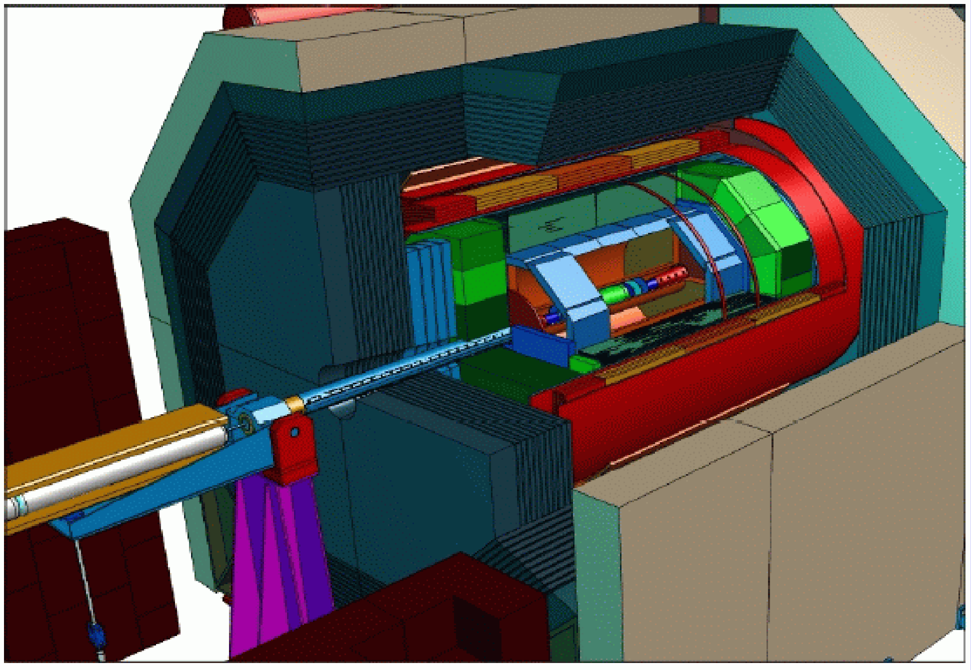


✔ "clean environment"?

- N_γ / bunch ~ N_e / bunch ~ 10^{10}
- Beam-beam interactions (e.g. ~10^5 $\gamma\gamma \rightarrow e^+e^-$ / bx, few $\gamma\gamma \rightarrow$ hadrons / 10 bx)
- Pile-up : excessive energy @ low cosΘ
- High time-stamp capability for NLC detector (1.4 ns bunch separation) is needed to reduce hadronic $\gamma\gamma$ background

Detector Concept

EXAMPLE : **TESLA Detector**



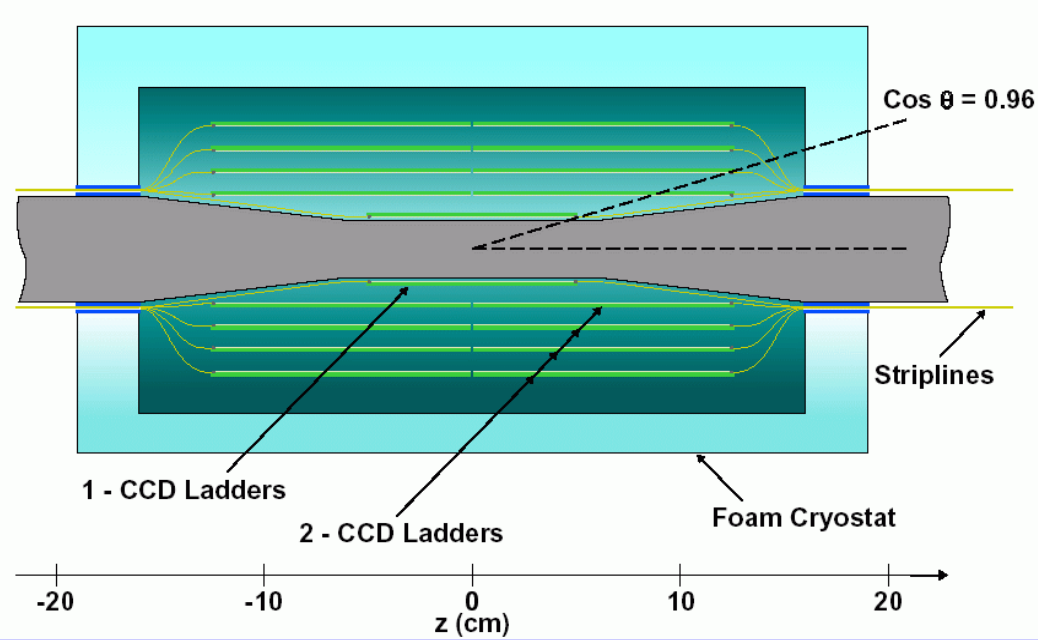
- $\delta p/p = 10^{-4} \cdot p$
- $\delta IP = 5\mu m \oplus 10\mu m/\sin^{3/2}\Theta$
- $\delta E_{em}/E_{em} = 11\%/\sqrt{E}$
- $\delta E_{jet}/E_{jet} = 30\%/\sqrt{E}$

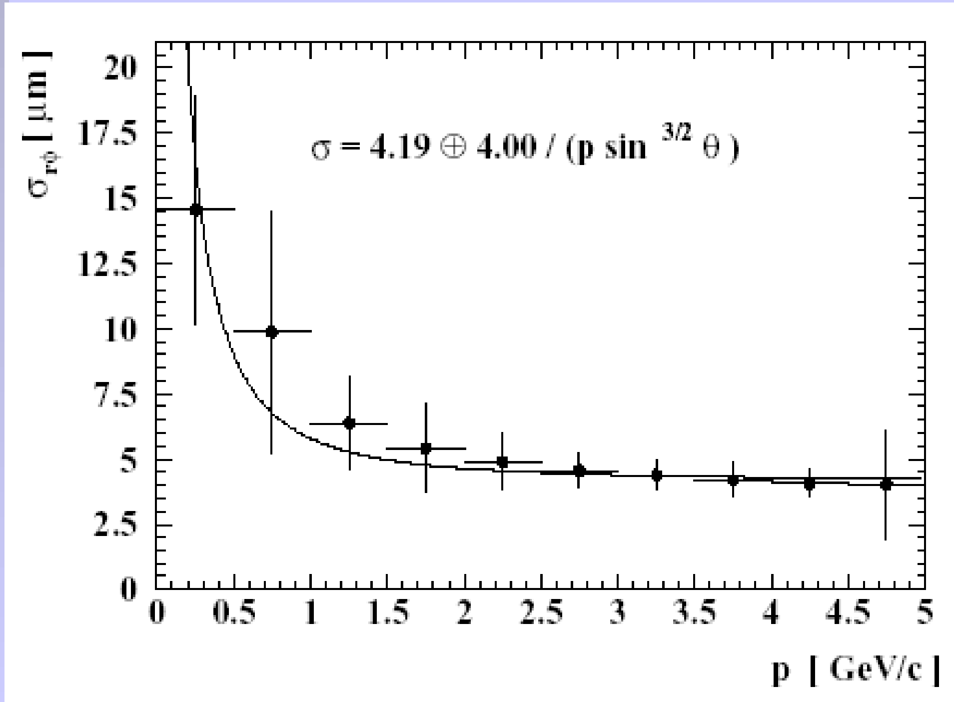
- Silicon VTX → heavy flavour tagging
- Large volume tracker (TPC + SIT) → precise reconstruction of charged particle momenta
- Finely segmented ECAL and HCAL → efficient separation of showers within jet
- Tracking + calorimeter inside magnet coil (4T)
- Forward calorimetry (LCAL+LAT) → hermeticity down to very small angles, luminosity measurements with bhabha

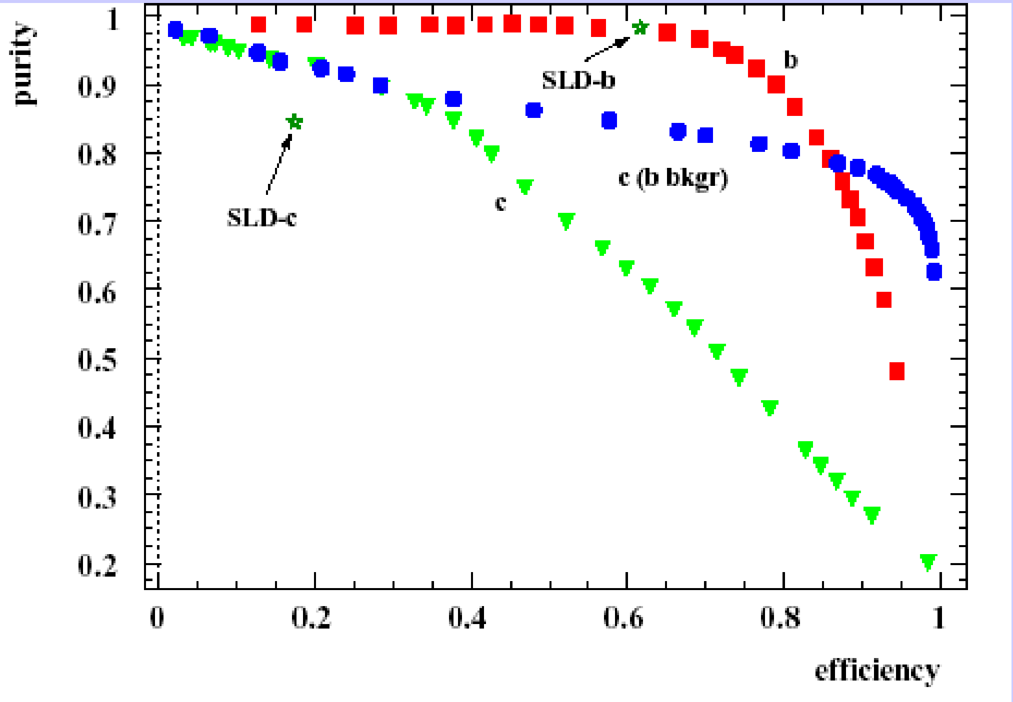
Vertexing

Pixel-based vertex detector

- Options: CCD, APS, CMOS
- 3 – 5 layers
- Inner layer @ R ~ 10mm
- Flavour tag - b/c separation →
- Measurements of hadronic branching fractions of Higgs

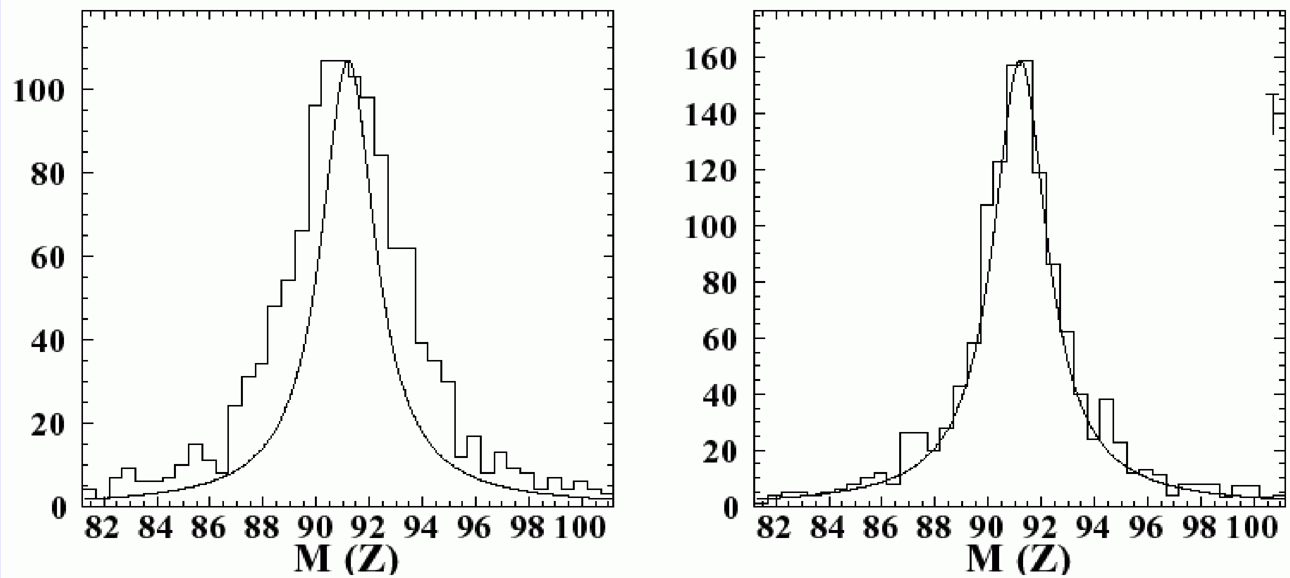




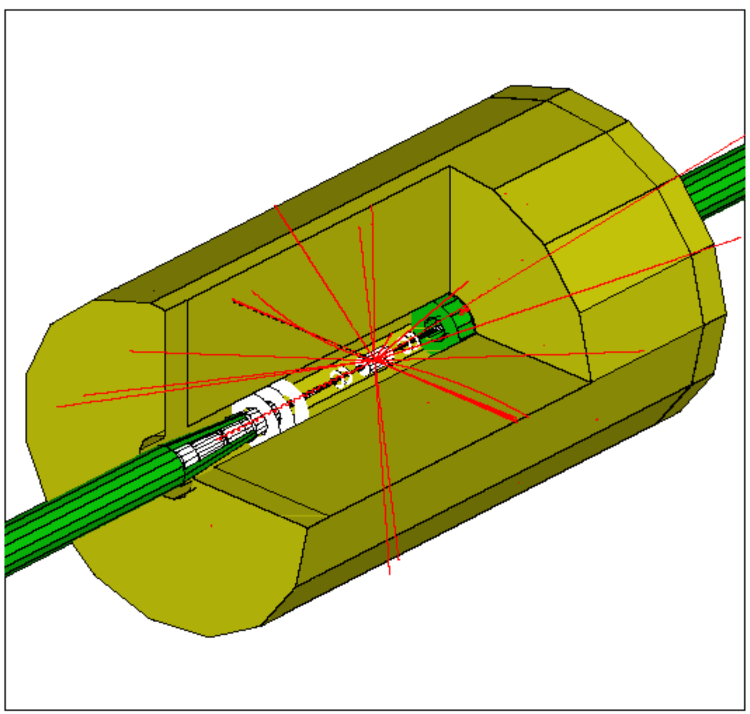


Tracking

- Benchmark for momentum resolution : $e^+e^- \rightarrow HZ \rightarrow X(e^+e^-,\mu^+\mu^-)$
- try to reconstruct m_z better than Γ_z



$\sigma(p_t)/p_t^2 = 2.8 \times 10^{-4}$GeV $\sigma(p_t)/p_t^2 = 0.7 \times 10^{-4}$GeV



Advantages of a TPC:

- tracking to large radius $\longrightarrow$ sensitivity to long lifetimes
- many space-points $\longrightarrow$ large redundancy
- true 3D reconstruction (1 time, 2 space coordinates)
- gaseous detector, no wires $\longrightarrow$ not much material
- particle ID through dE/dx

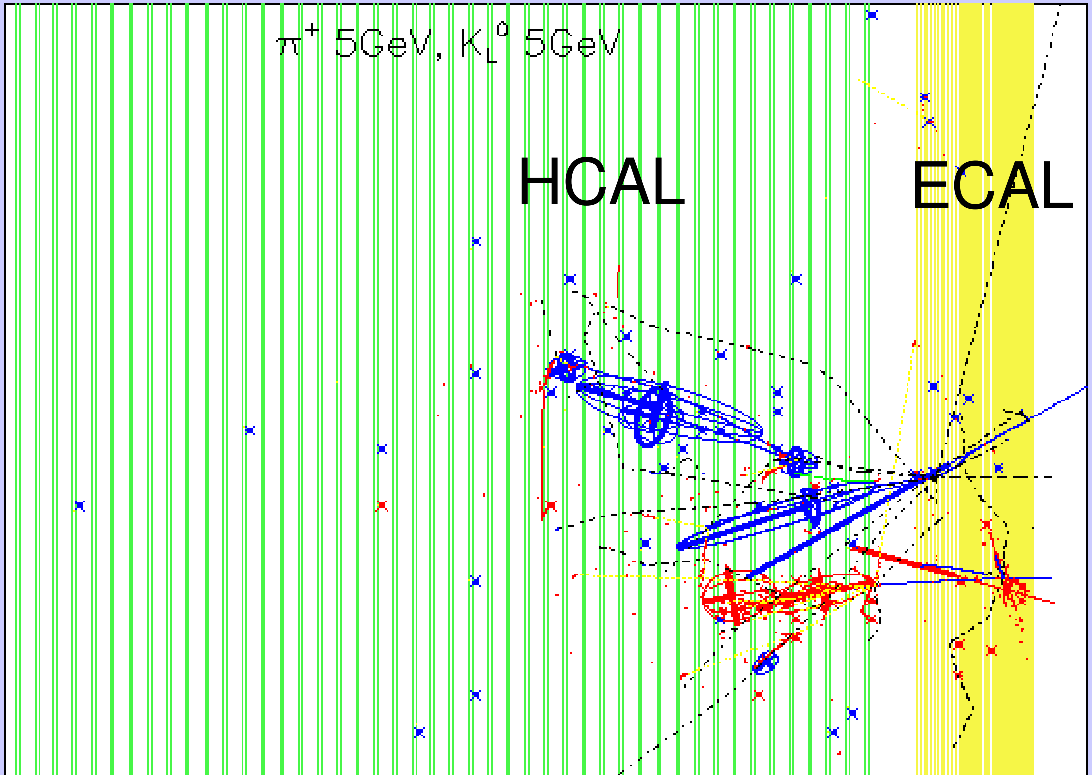
Imaging Calorimetry @ LC

Requirements

- Ability to separate close-by showers to improve jet energy resolution and enable realization of Particle-flow (P-flow) concept
- Good containment of shower
- Ability to reconstruct objects non-pointing to IP (crucial for some SUSY signatures)
- ID of low momentum μ, not reaching muon system
- High ECAL resolution → measurements of photons
- Moderate HCAL resolution measurements of neutral hadrons
- Good time resolution for both calorimeters to avoid pil-up

Solution : highly granulated calorimeters

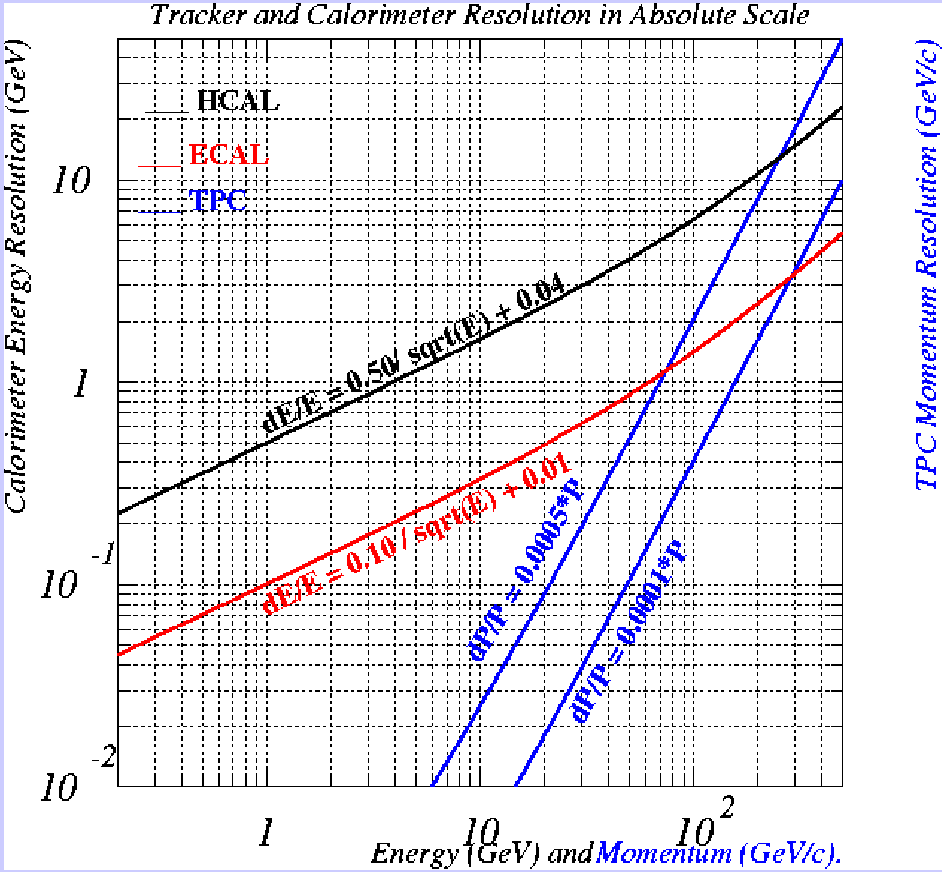
- W-Si ECAL (1x1 cm^2 cells, $24X_0$ depth)
- Analog Tile HCAL (5x5 cm^2 cells, 4-6λ depth)
- Digital (RPC, Tile or GEM-based) HCAL (1x1 cm^2 cells, 4-6λ depth)
- Fine segmentation = ability to see intrinsic structure of the shower : imaging device

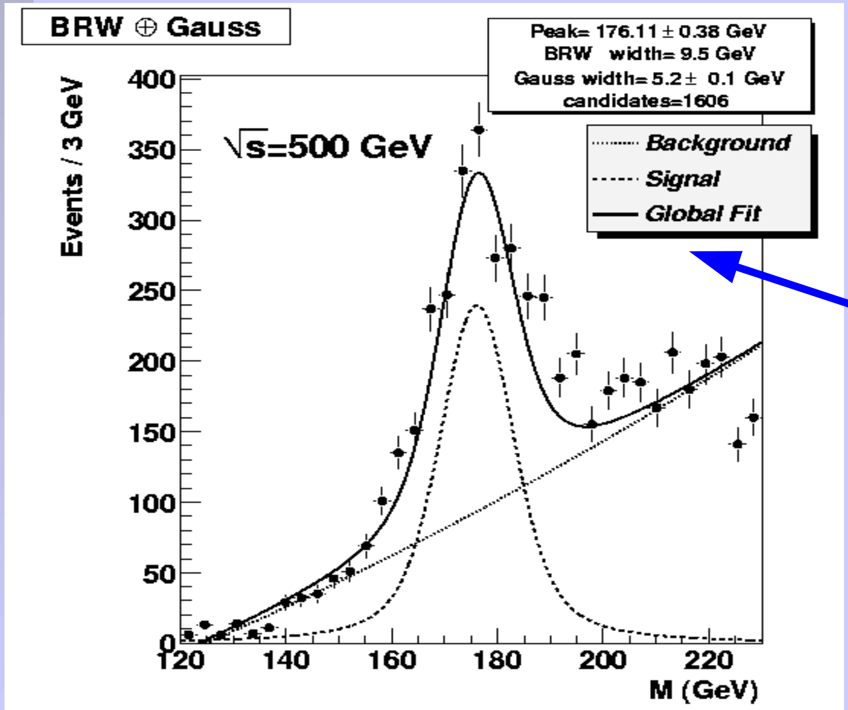


Particle-Flow Concept
Ideology of event reconstruction @ LC

Reconstruction of every particle

- Superiority of tracker w.r.t. calorimeters → use tracker to measure charged objects
- Assign calo hits to tracks, perform clustering on remaining hits → neutral objects
- Use ECAL to measure photons
- Use ECAL+HCAL to measure neutral hadrons





P-Flow @ work

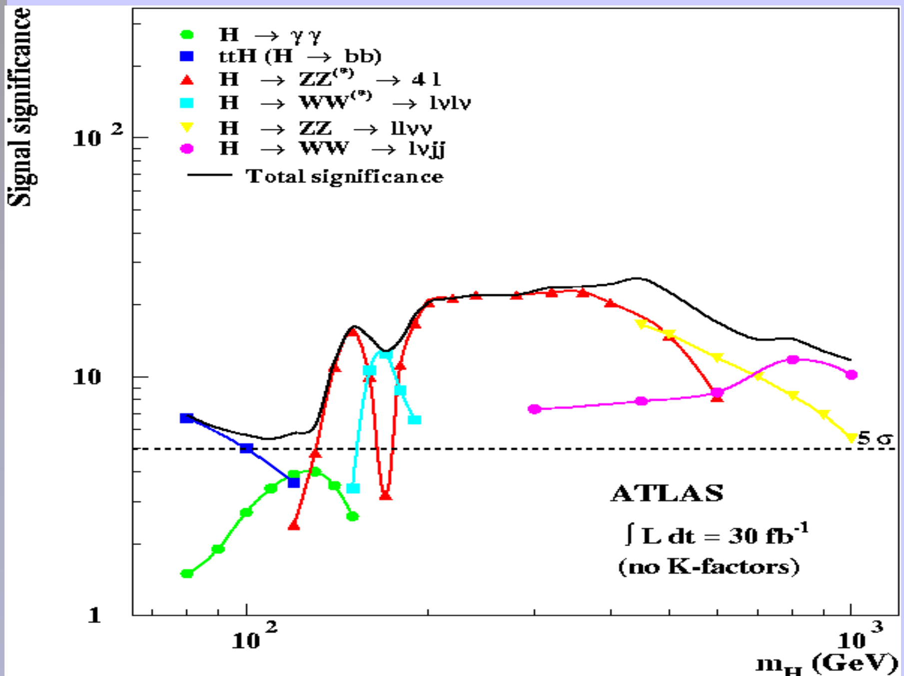
- Reconstruction of complex topology tt → 6jets
- Full Geant3 simulation of TESLA detector
- Full reconstruction based on P-flow concept
- No kinematic fits

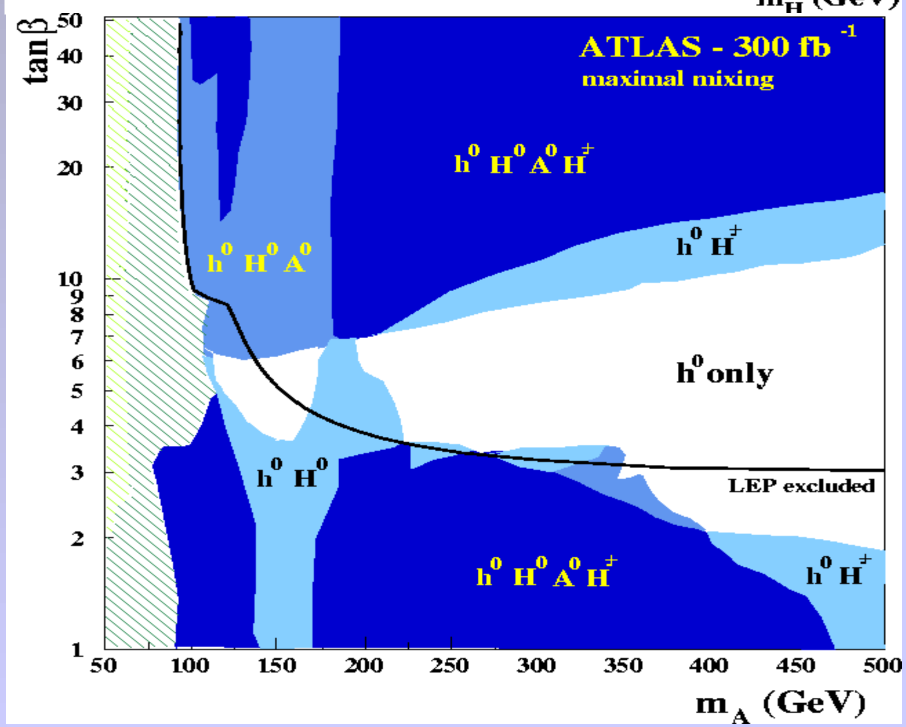
Long awaited by you
Physics Topics

Picture of Modern HEP

- Key question : mechanism of EWSB
  - Conventional Higgs mechanism?
  - Structure of the Higgs sector (single doublet, 2HDM, CP-violation in the Higgs sector)?
  - Alternatives (dynamical EWSB, composite models, strong EWSB)
- Hierarchy problem, unification of forces, gravity as QFT $\rightarrow$ new physics
- Castle of New Physics
  - The two towers : Supersymmetry and Extra Dimensions
  - The ancient (renewed?) tower : new strong interactions
  - Extended Gauge Theories $\rightarrow$ GUT's

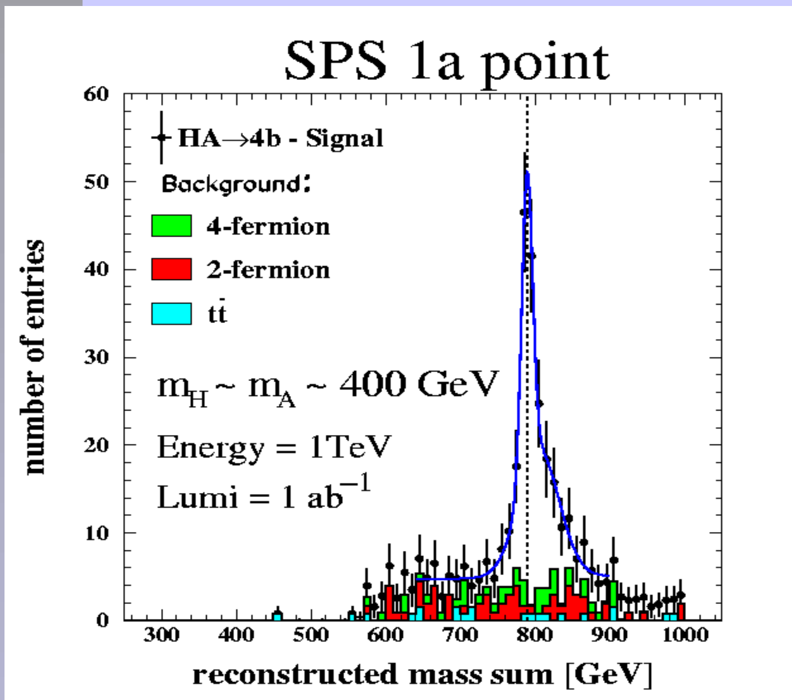
Higgs Mechanism of EWSB (LHC corner)



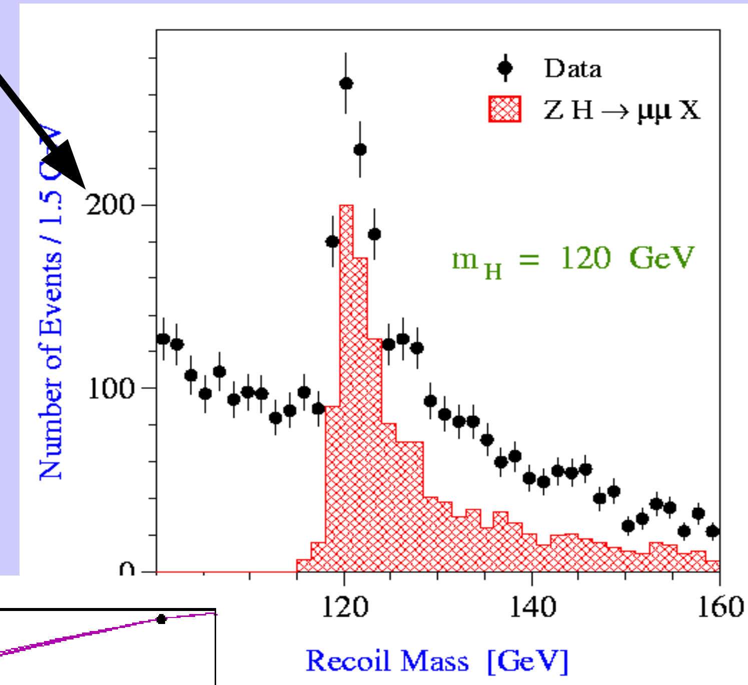


- LHC : detection of Higgs via vari- ous production mechanisms and decay channels, discovery poten tial over the whole mass range
- At least one Higgs (light SM-like) will be detected
- First measurements of Higgs boson properties (mass, couplings)
- Extended Higgs sector (MSSM) – more than one Higgs particle
- Regions in parameter space where additional Higgs particles may es cape detection

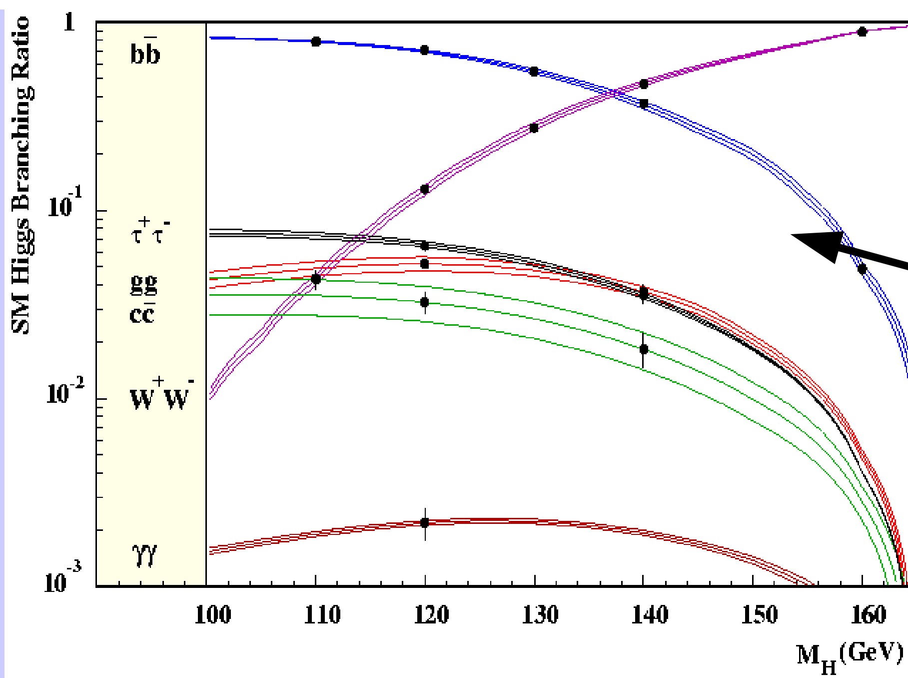
Higgs at LC



Detection of Higgs independent of its decay mode in HZ→ X(ee+μμ) : model independent extraction of HZZ coupling



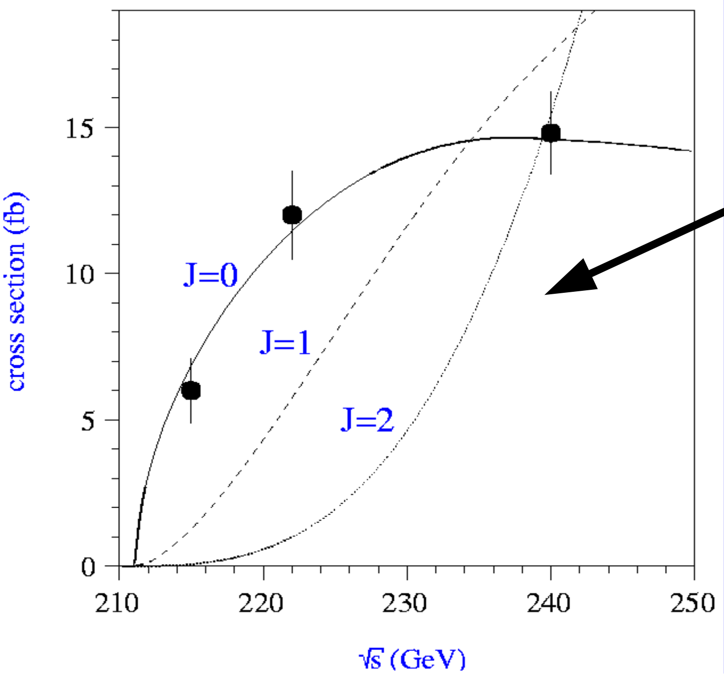
Exploration of extended Higgs sectors, detection of heavy Higgs bosons in a wedge region of LHC



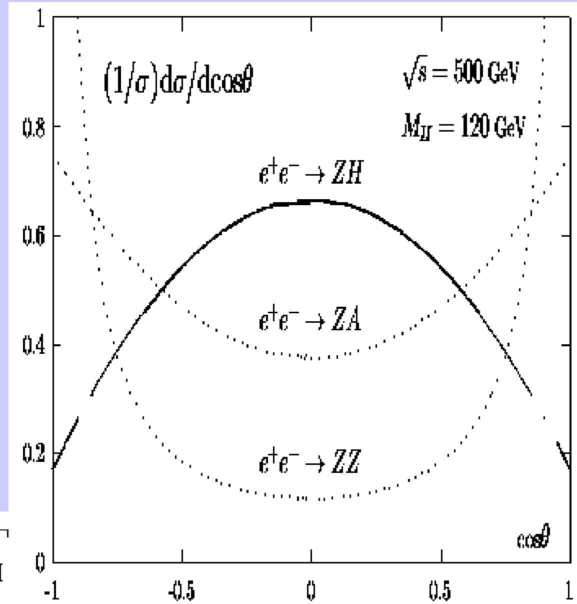
Mass, width, branching measurements in variety of channels with high precision

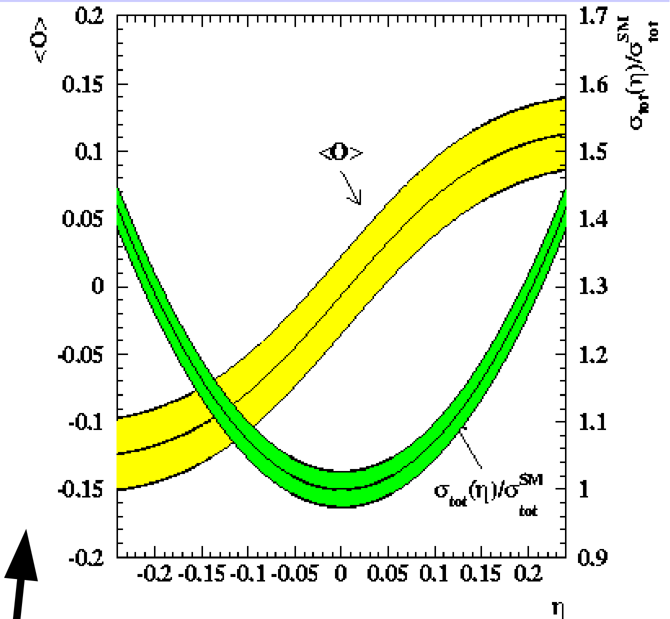
Higgs at LC (Continued)

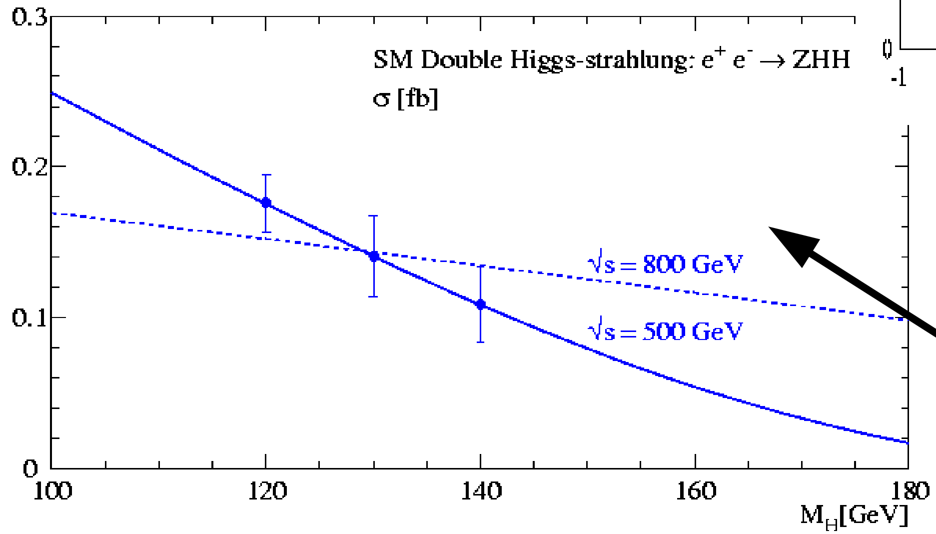
Higgs quantum numbers & reconstructed Higgs potential → complete establishment EWSB mechanism



Higgs spin through threshold scan



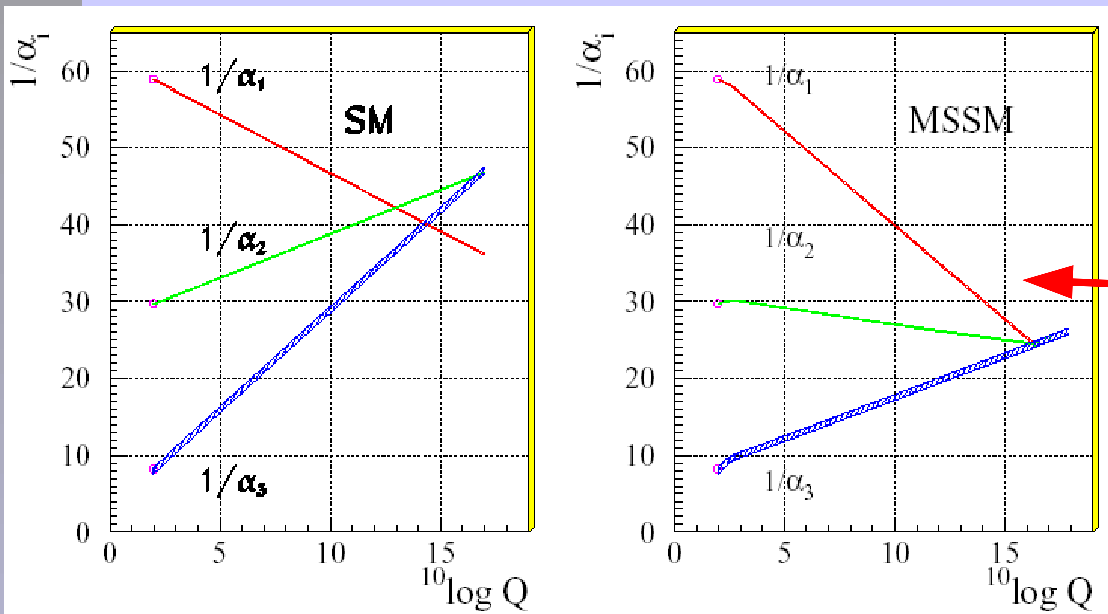


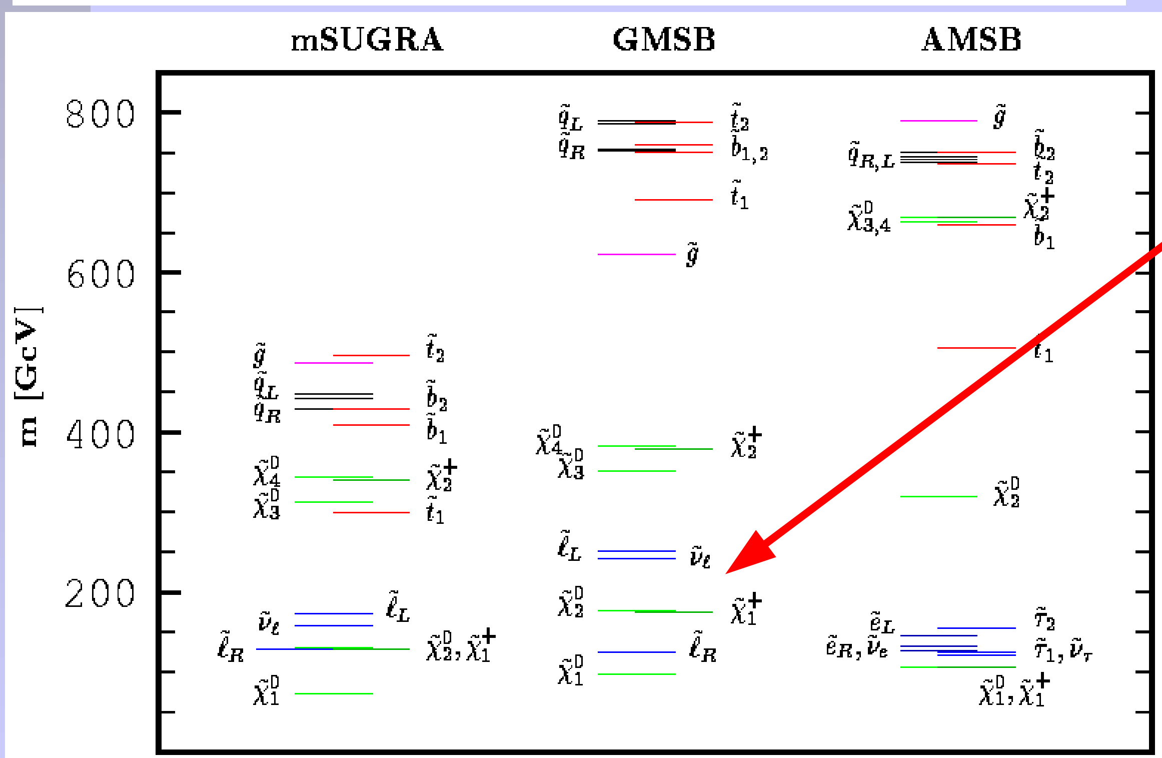


Higgs parity from HZ xsec and angular spectrum

Higgs self-coupling from $e^+e^- \rightarrow HHZ$

Supersymmetry

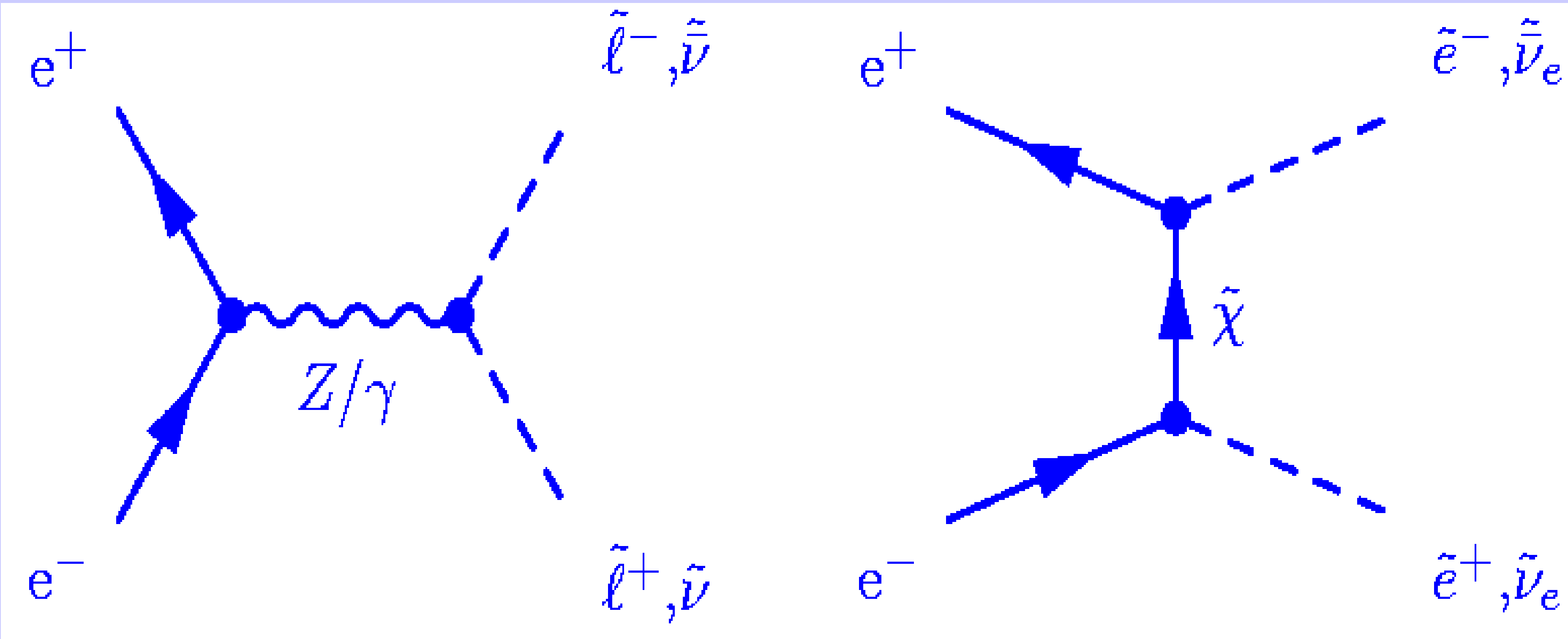




- ➔ Low energy SUSY gold plated candidate for new physics
  - Hierarchy problem solved
  - Clear path to grand unification
  - Planck scale models naturally supersymmetric
- ➔ Most of the spectrum of SUSY particles is within reach of sub-TeV LC
  - Excellent chance to observe SUSY particles at early stage of LC operation (500GeV)
  - Clean signatures, low back-grounds precision measure ments of physics observables in SUSY sector
  - From observables to SUSY La-grangian (joint LHC LC effort)

Sleptons

(Production in @ LC and Decays)



$$\tilde{\ell}^- \to \tilde{\chi}^0 \ell^- \qquad m_{\tilde{\ell}} > m_{\tilde{\chi}^0}$$

$$\tilde{\ell}^- \to \tilde{\chi}^- \nu \qquad m_{\tilde{\ell}} > m_{\tilde{\chi}^-}$$

$$\tilde{\nu} \to \tilde{\chi}^0 \nu \qquad m_{\tilde{\nu}} > m_{\tilde{\chi}^0}$$

$$\tilde{\nu} \to \tilde{\chi}^- \ell^+ \qquad m_{\tilde{\nu}} > m_{\tilde{\chi}^-}$$

Main signatures :

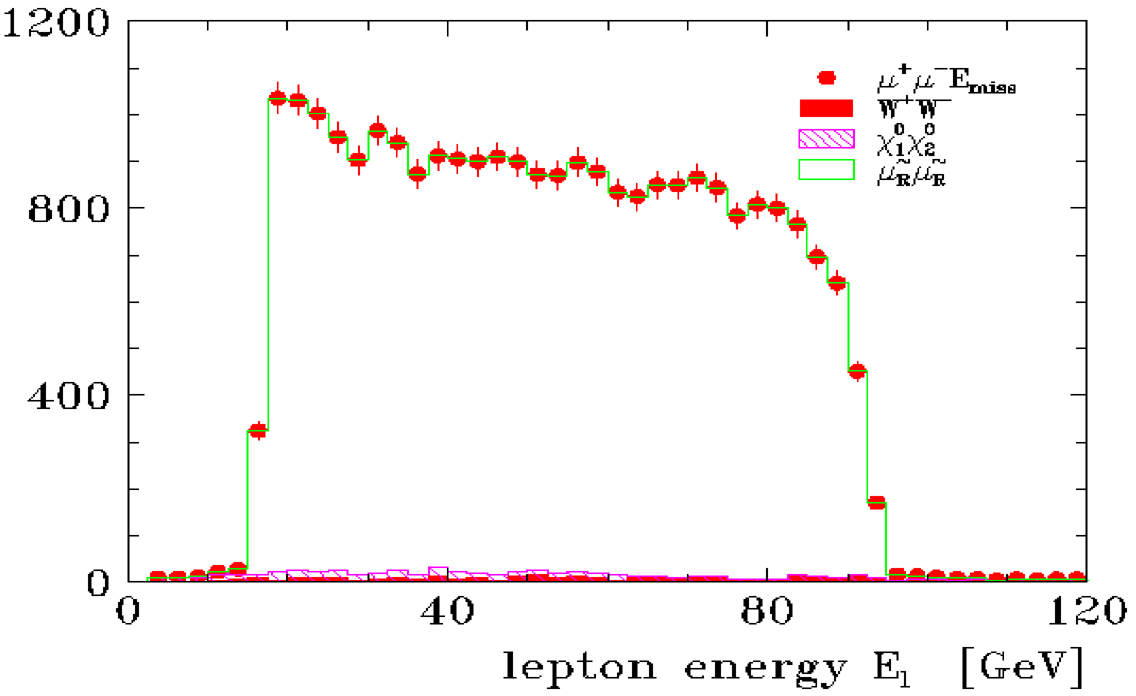
1) two leptons + missing E

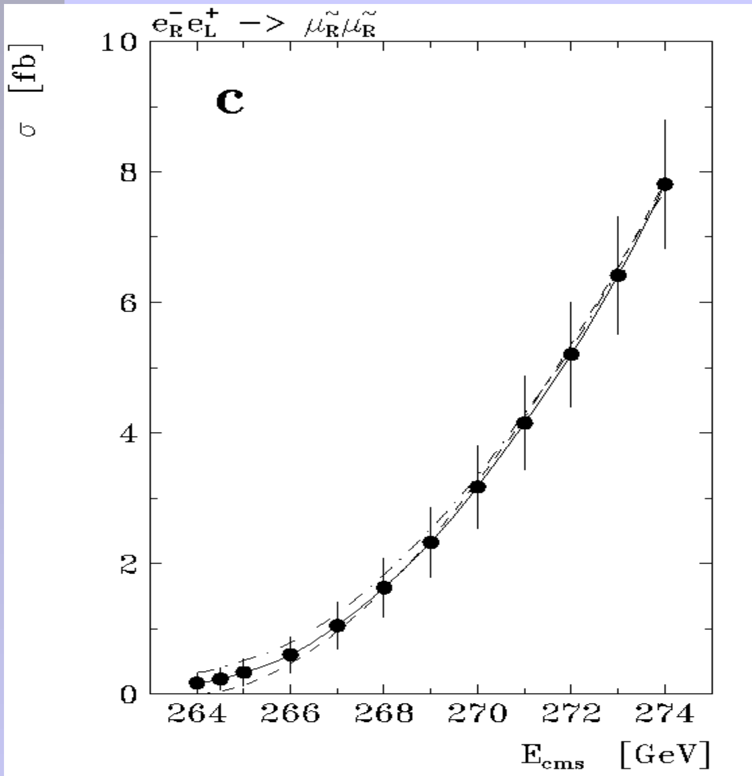
2) two narrow jets (τ 's) + missing E

Sleptons at Linear Collider

e.g. $e^+e^- \to \tilde{\mu}_R^+\tilde{\mu}_R^-$
$\to \mu^+\mu^-\tilde{\chi}_1^0\tilde{\chi}_1^0$
large rates
small background
(mainly SUSY)

Masses of $\tilde{\chi}_1^0$ and $\tilde{\mu}$ from kinematic edges





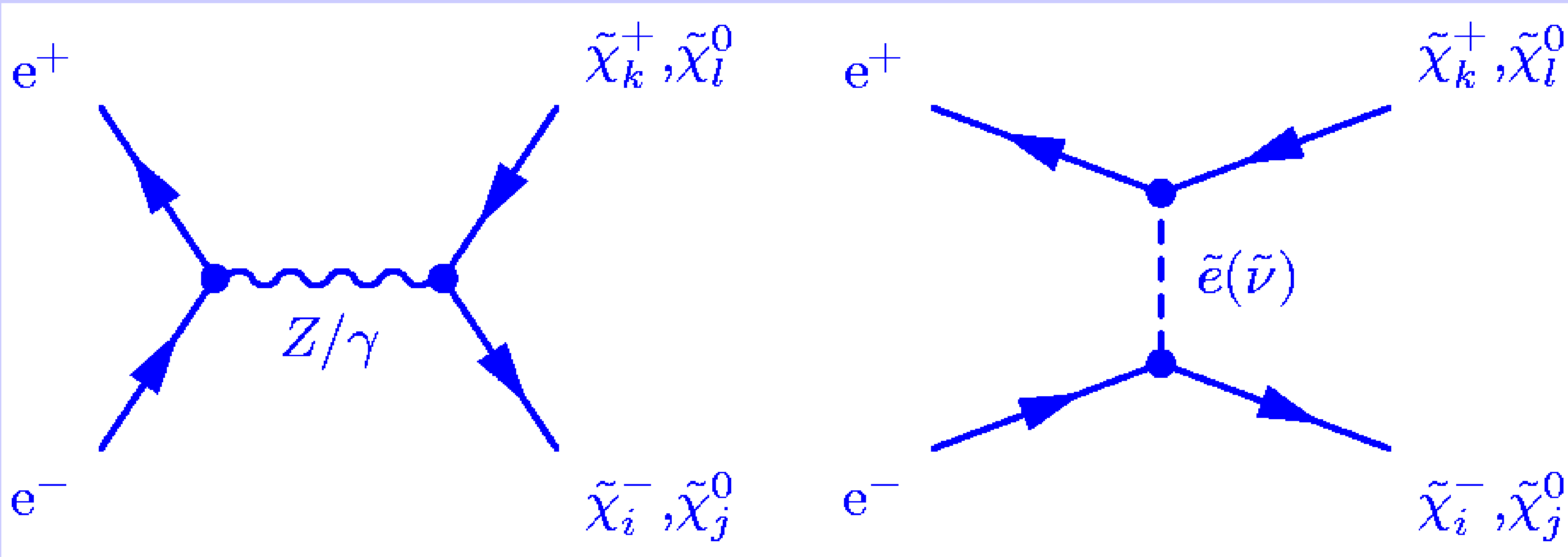
Masses from threshold scans (10 fb^{-1} / point)

Slepton masses in mSUGRA SPS 1A

	m, GeV	δ_m, GeV		m, GeV	δ_m, GeV
$\tilde{e}_R$	143.0	0.05	$\tilde{\mu}_R$	143.0	0.2
$\tilde{e}_L$	202.1	0.2	$\tilde{\mu}_L$	202.1	0.5
$\tilde{\nu}_e$	186.0	1.2	$\tilde{\tau}_1$	133.2	0.3
$\tilde{\nu}_{\mu,\tau}$	inaccessibe		$\tilde{\tau}_2$	133.2	1.1

Gaugino Production and Decays

Gaugino's = mixture of wino's, zino, photino and higgsino's
$\rightarrow$ in total 6 physical states : 2 charginos, 4 neutralinos



$$\begin{array}{lll} \tilde{\chi}_i & \rightarrow Z/W\tilde{\chi}_j & \rightarrow f\bar{f}\tilde{\chi}_j \\ \tilde{\chi}_1^+ & \rightarrow \tilde{\tau}_1^+\tilde{\chi}_1^0 & \rightarrow \tau^+\nu_\tau\tilde{\chi}_1^0 \\ \tilde{\chi}_2^0 & \rightarrow \tilde{\ell}\ell & \rightarrow \ell\ell\tilde{\chi}_1^0 \end{array}$$

Variety of signatures:

1) 4 observable fermions + missing E
2) 3 observable fermions + missing E
3) 2 observable fermions + missing E
4) 1 lepton + missing E

Gaugino Mass Determination

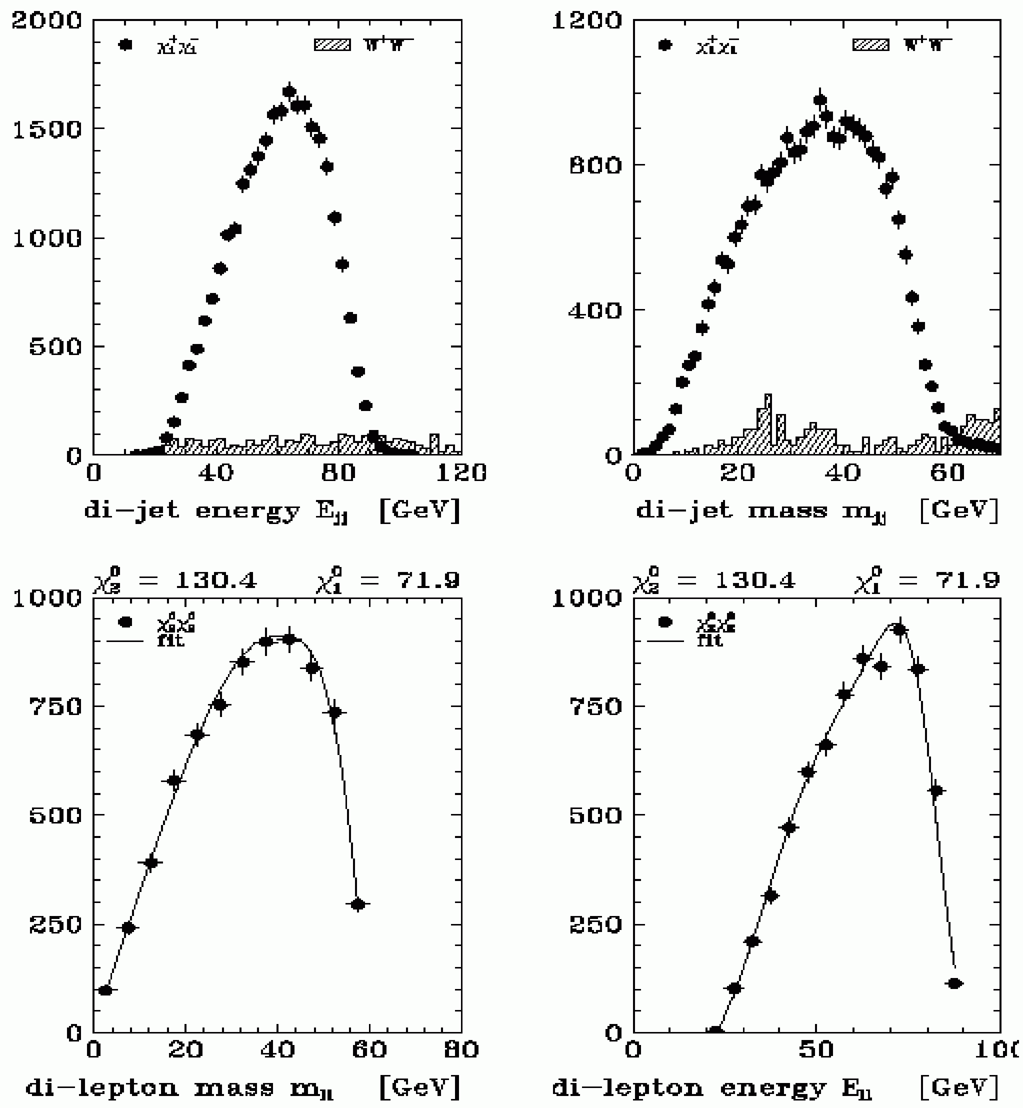
Exploit sensitivity of dijet and dilepton energy & mass spectra to gaugino masses

Charginos:

e.g. $e^+e^- \rightarrow \tilde{\chi}_1^+\tilde{\chi}_1^-$
$\rightarrow 4jets + \tilde{\chi}_1^0\tilde{\chi}_1^0$

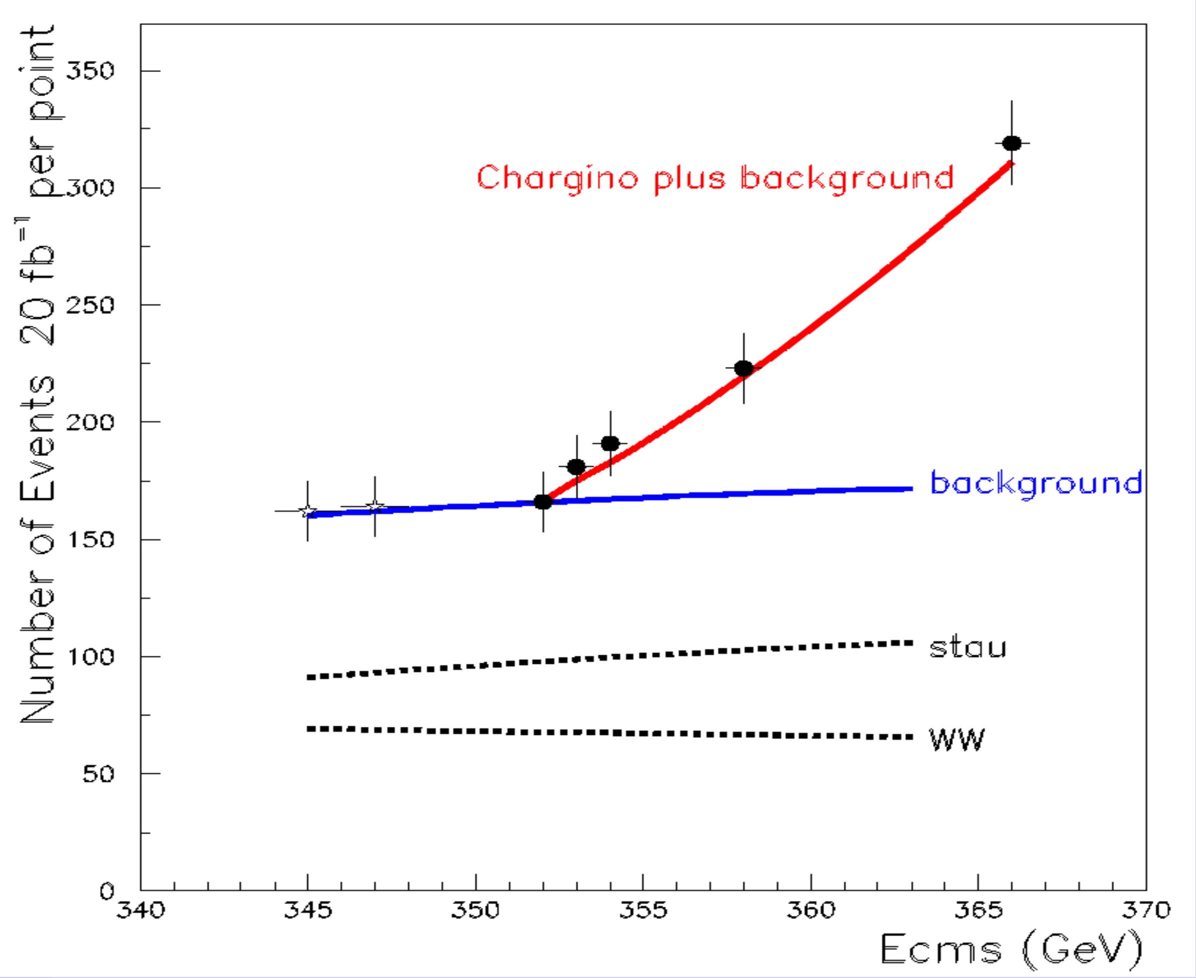
Neutralinos:

e.g. $e^+e^- \rightarrow \tilde{\chi}_2^0\tilde{\chi}_2^0$
$\rightarrow 4\ell + \tilde{\chi}_1^0\tilde{\chi}_1^0$



Gaugino Masses

Or use traditional threshold scan technique



Threshold scan of $\tilde{\chi}_1^+\tilde{\chi}_1^- \to \tau^+\nu_\tau\tilde{\chi}_1^0\tau^-\bar{\nu}_\tau\tilde{\chi}_1^0$

Gaugino masses (mSUGRA SPS 1A point)

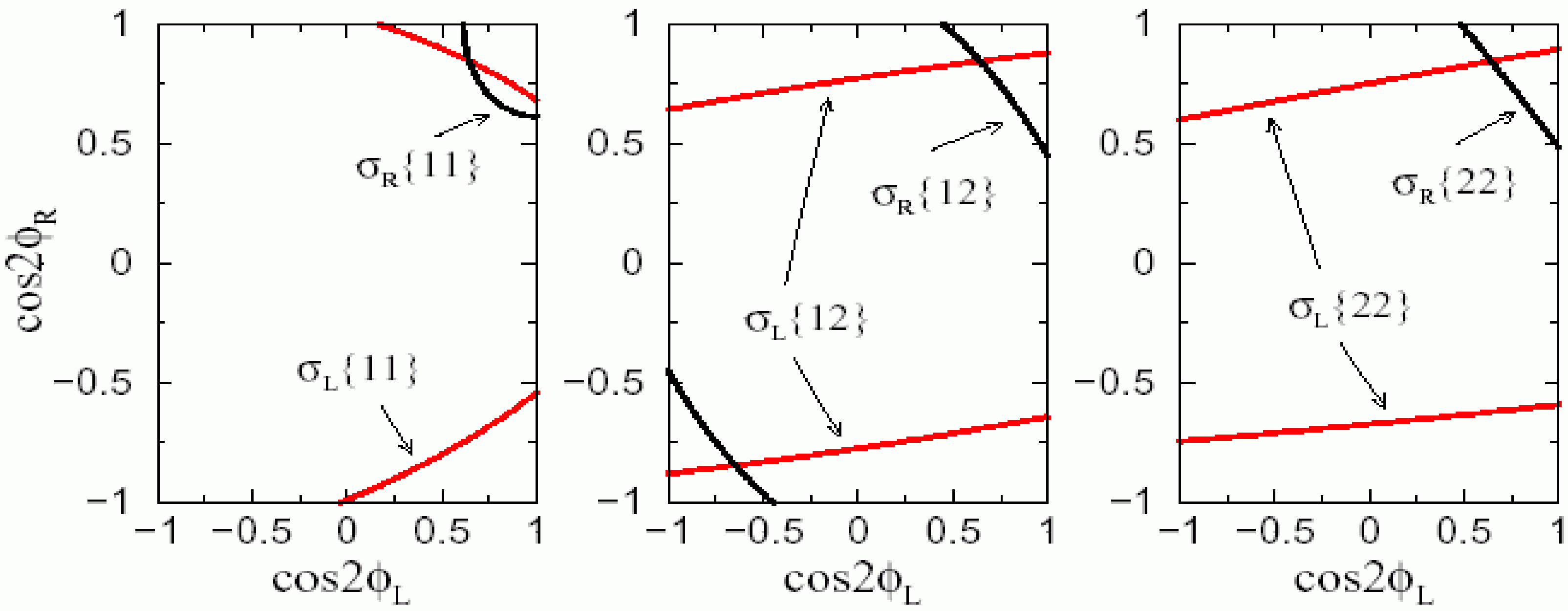
	m, GeV	δ_m, GeV
$\tilde{\chi}_1^\pm$	176.4	0.55
$\tilde{\chi}_2^\pm$	378.2	3
$\tilde{\chi}_1^0$	96.1	0.05
$\tilde{\chi}_2^0$	176.8	1.2
$\tilde{\chi}_3^0$	358.8	3–5
$\tilde{\chi}_4^0$	377.8	3–5

Chargino Properties

Disentangle Wino/Higgsino admixture of Charginos:

$$\mathcal{M}_C = \begin{pmatrix} M_2 & \sqrt{2}\, m_W \cos\beta \\ \sqrt{2}\, m_W \sin\beta & \mu \end{pmatrix} \Rightarrow \text{2 mixing angles } \Phi_R, \Phi_L$$

μ, M_2 and (moderate) $\tan\beta$ can be uniquely determined with polarisation:



P{-}=80%

P{+}=60%

	input 1	fit	input 2	fit
M_2	152 GeV	152 ± 1.8 GeV	150 GeV	150 ± 1.2 GeV
μ	316 GeV	316 ± 0.9 GeV	263 GeV	263 ± 0.7 GeV
$\tan\beta$	3	3 ± 0.7	30	> 20

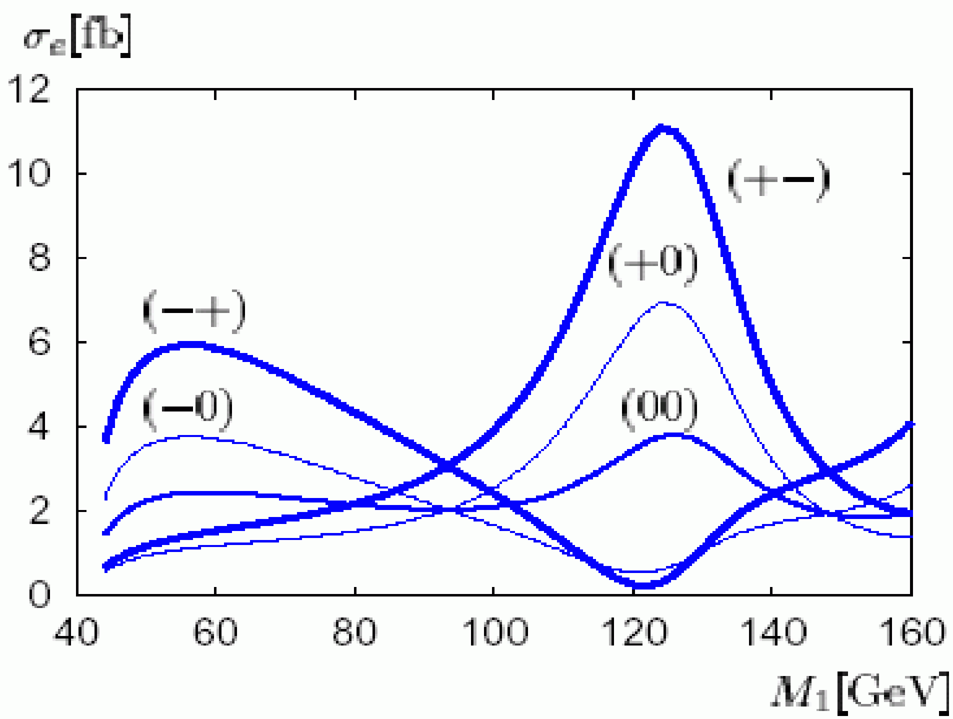
Neutralino Properties

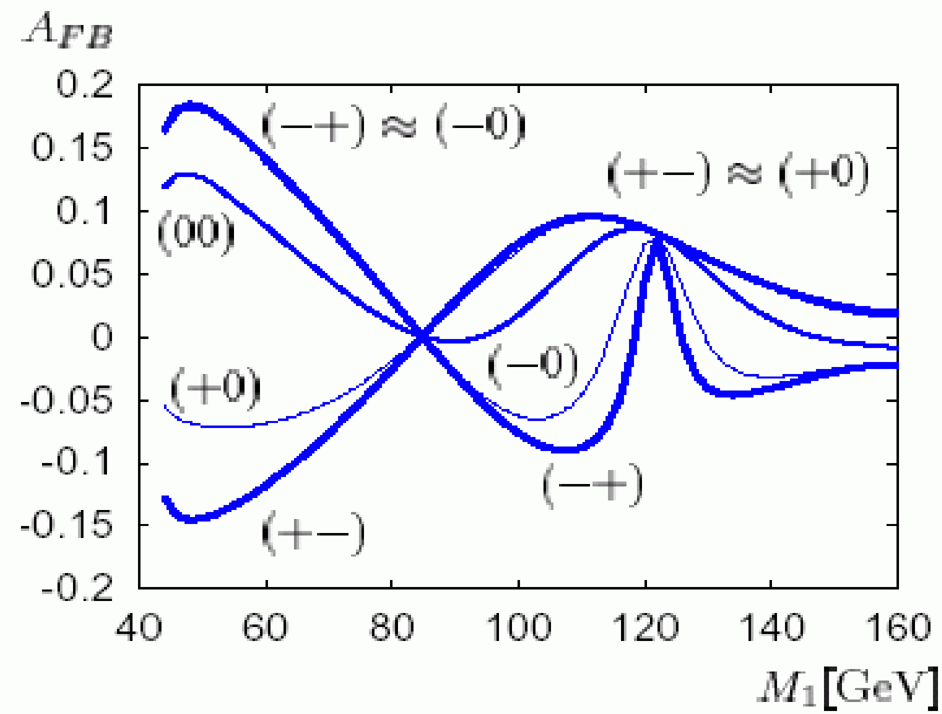
Neutralino system depends also on M_1 (in addition to M_2, μ, $\tan\beta$)

Exploit spin correlation in two lepton final state from

$$e^+e^- \to \tilde{\chi}^0_2\tilde{\chi}^0_1 \to \ell^+\ell^-\tilde{\chi}^0_1\tilde{\chi}^0_1$$

beam polarisation essential!

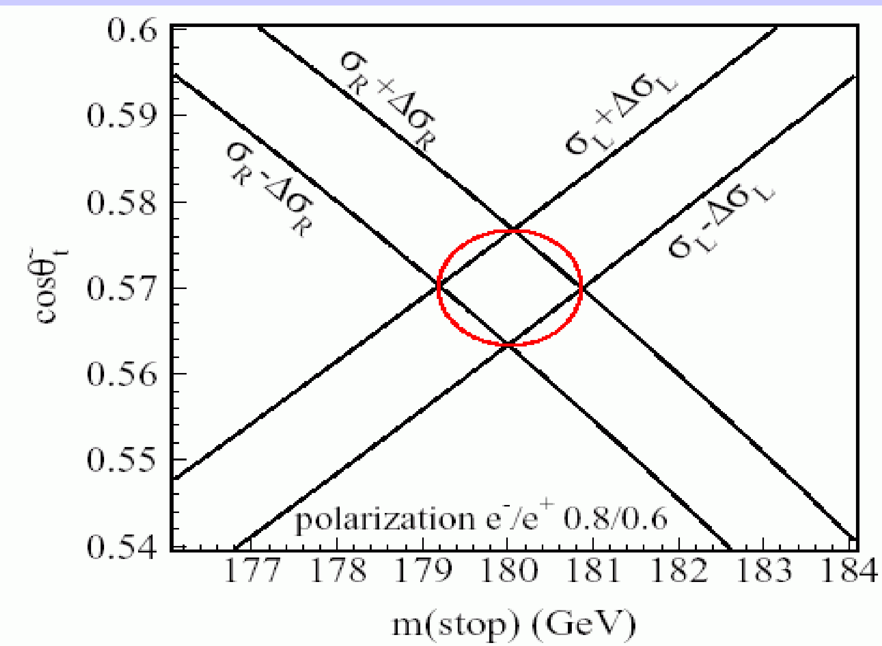


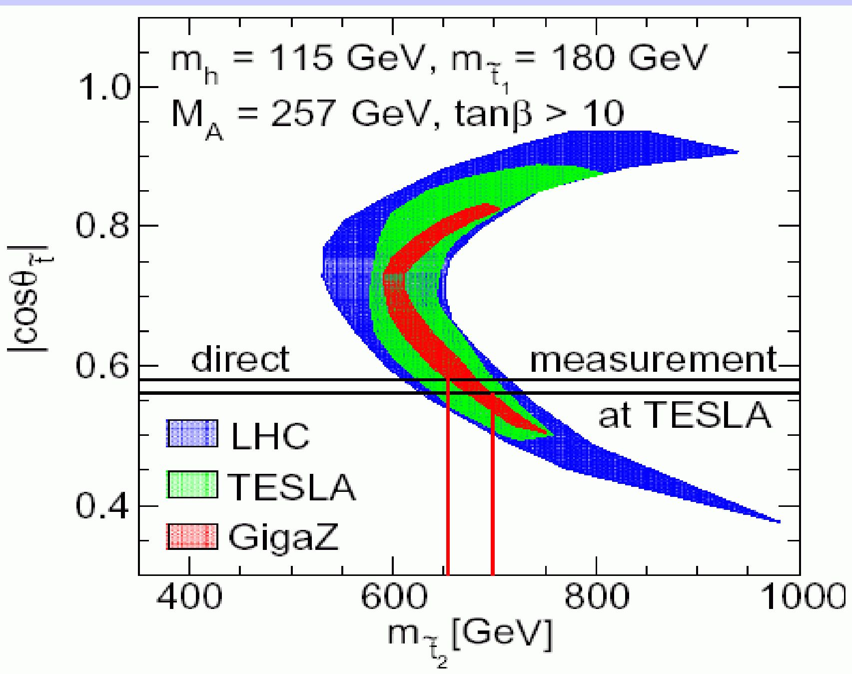


	input 1	fit	input 2	fit
M_1	78.7 GeV	78.7 ± 0.7 GeV	78.0 GeV	78.0 ± 0.4 GeV

Stop Particles

- Large mixing in $\tilde{s}\tilde{t}op$ sector → large mass splitting is possible
- Process $e^+e^- \rightarrow \tilde{t}_1\bar{\tilde{t}}_1$ most likely within reach of sub-TeV LC
- Decays : $\tilde{t}_1 \rightarrow \tilde{\chi}^0_1 c, \tilde{\chi}^+_1 b$
- Exploited topologies : 2 c-jets + E_{mis} ; b-jet + c-jet + τ-jet + E_{mis} ; 2 b-jets + 2 τ-jets + E_{mis}
- Extraction of mass and mixing angle through simultaneous measurements of $\sigma_R \equiv \sigma(-P\{-\},P\{+\})$ & $\sigma_L \equiv \sigma(P\{-\},-P\{+\})$, P{-}=80%, P{+}=60%





R-parity violating SUSY @ LC

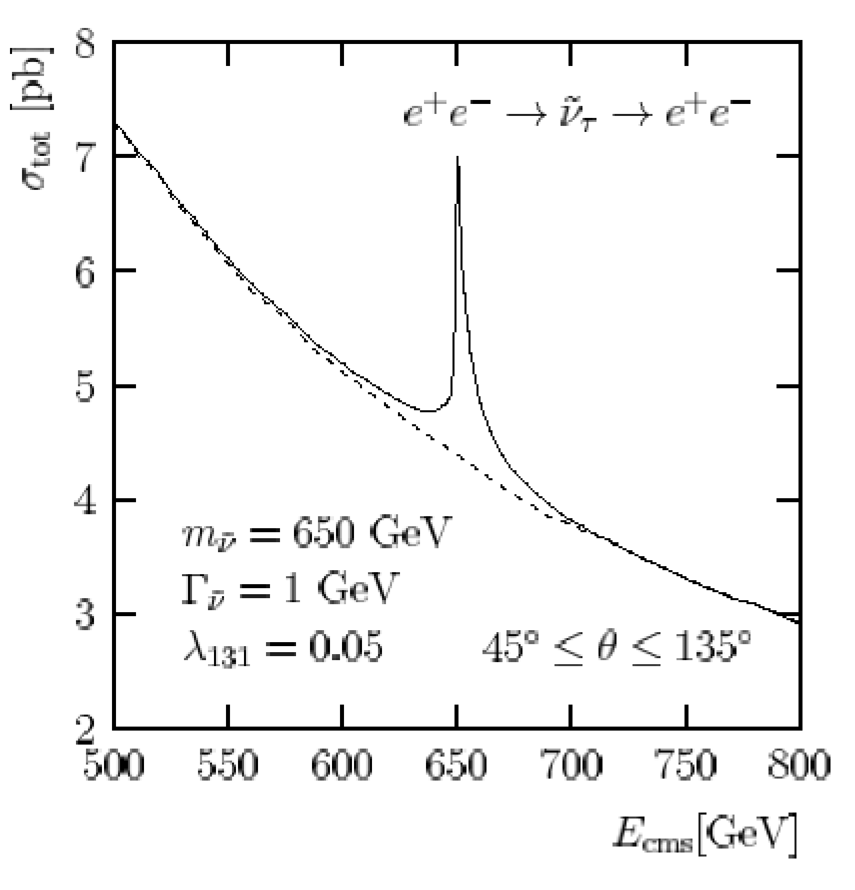
- $R=(-1)^{L+3B+2S}$, 1 for SM particles, -1 for sparticles
- R conservation prevents proton from fast decay
- Consequences
  - Sparticles produced in pairs
  - LSP (presumably $\tilde{\chi}^0_1$) is stable

R-parity violation $\Longrightarrow$

$e^+e^- \to \tilde{\nu} \to \ell\ell, \nu\tilde{\chi}^0, \ell^\pm\tilde{\chi}^\mp$

$\Longrightarrow$ extension of mass reach

may provide spectacular signatures!



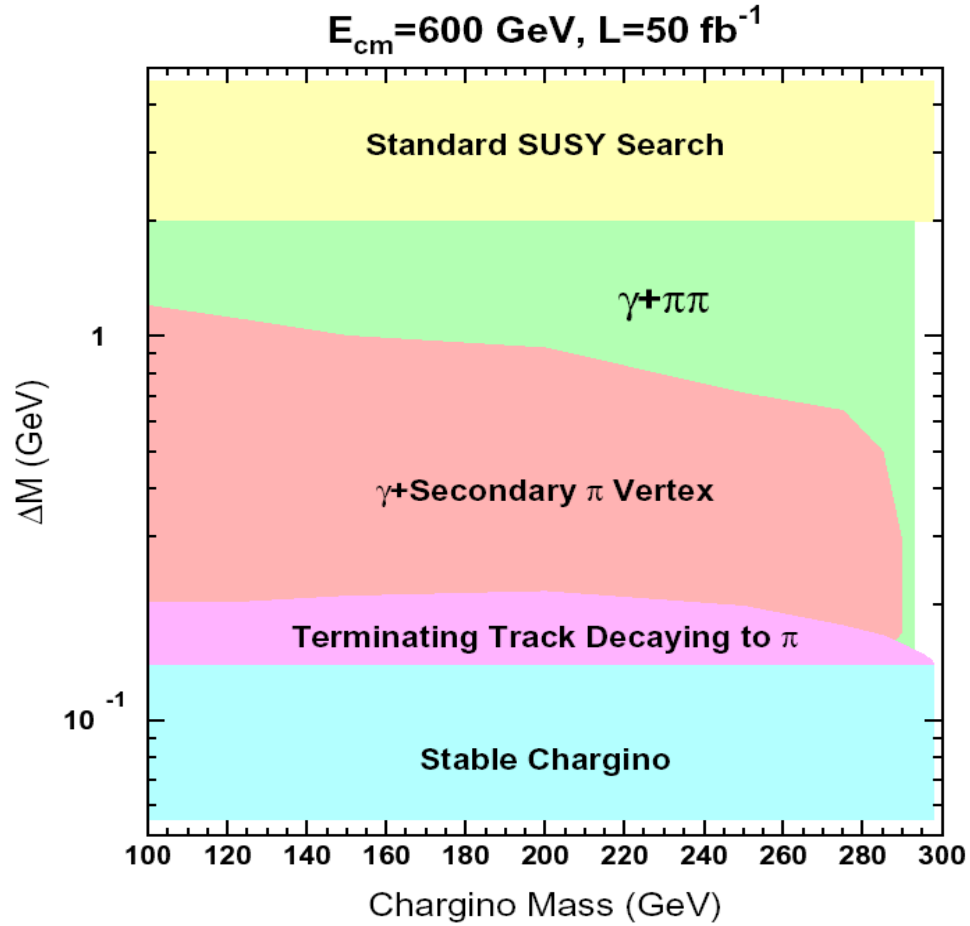
Specific SUSY Signatures & Detector Universality Issues

Anomaly Mediated SUSY Breaking:

typically $\Delta M = m_{\tilde{\chi}_1^{\pm}} - m_{\tilde{\chi}_1^0}$ very small

$\Longrightarrow$ variuos signatures and methods

$\Longrightarrow$ universality of the detector

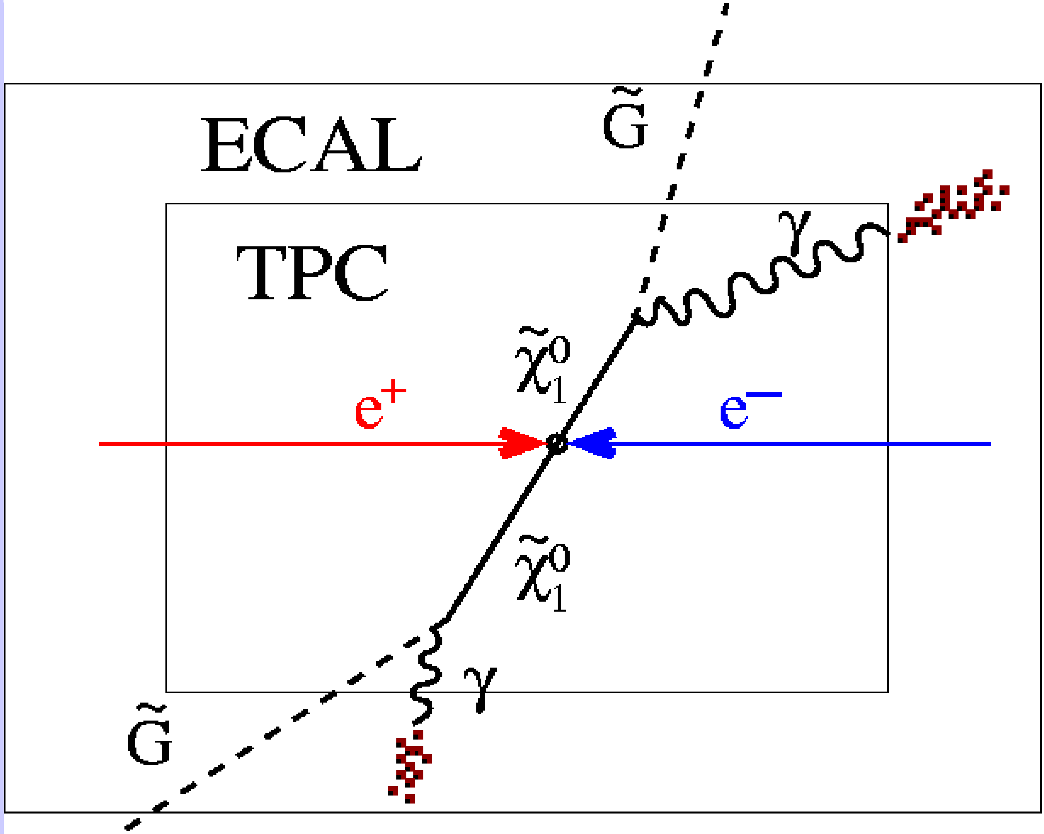


Gauge Mediated SUSY Breaking

with $\tilde{\chi}_1^0$ NLSP : delayed $\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma$

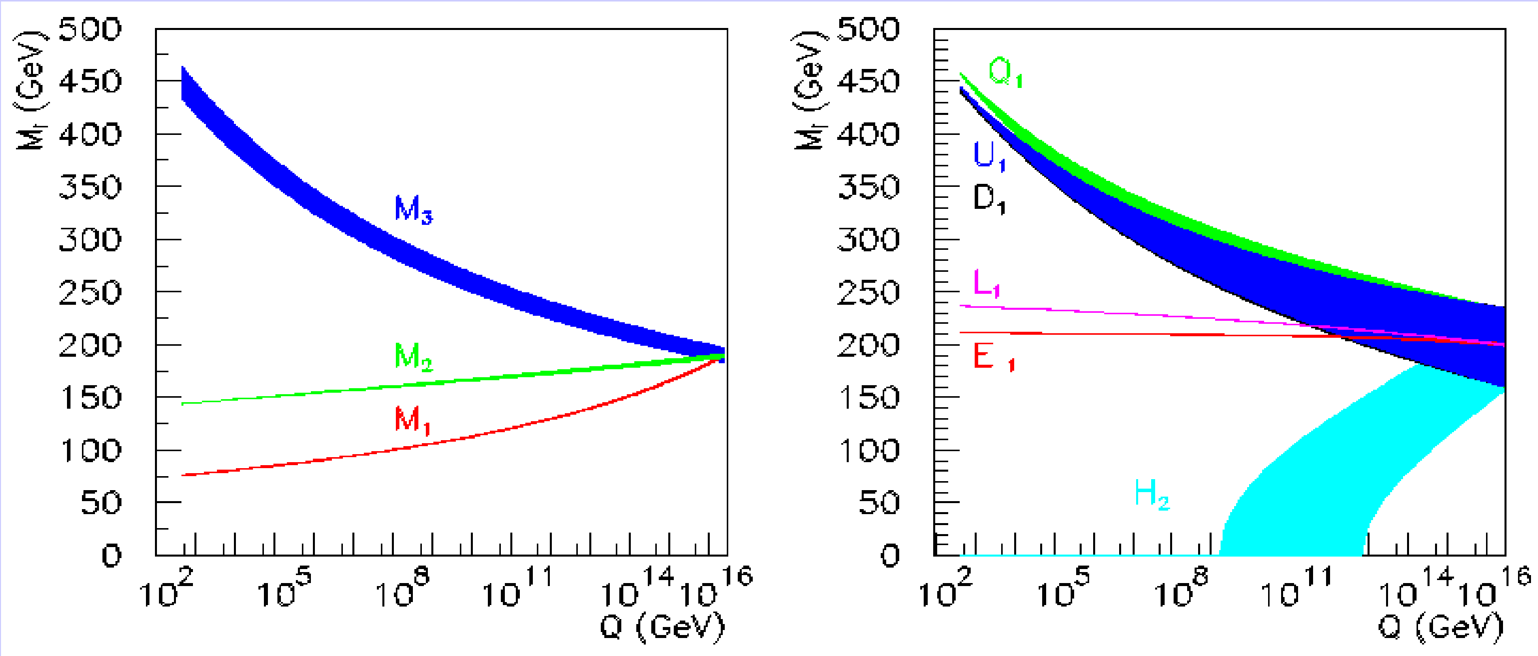
with photons non-pointing to IP

$\Longrightarrow$ challenging signature for calorimetry



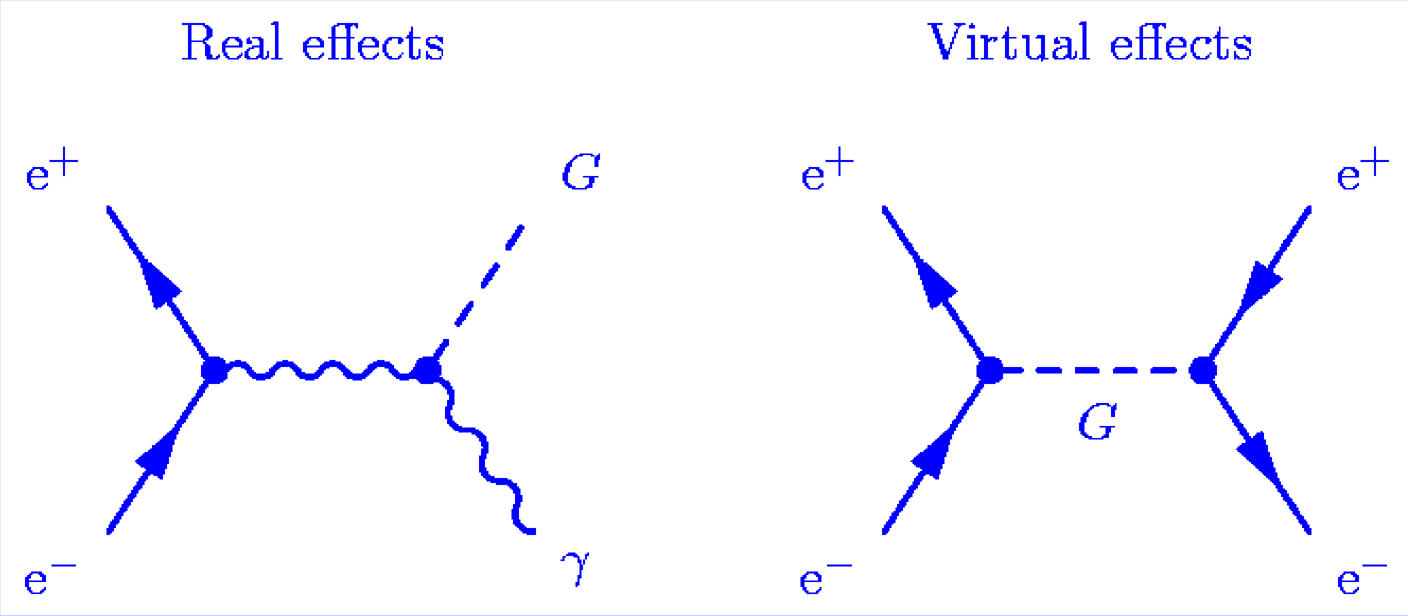
Extrapolating SUSY Parameters to Higher Scales

- Key steps towards revealing SUSY breaking mechanism and understanding more fundamental theories
  - ➔ Reconstruction of SUSY Lagrangian from physics observables
  - ➔ Extrapolating SUSY parameters to higher (GUT) scales
- Joint effort of LHC and LC : combination of higher mass reach and high production rates of strongly interacting sparticles ($\tilde{g}$, $\tilde{q}$) @ LHC with high precision measurements in slepton and gaugino sectors @ LC



Extra Dimensions

- Alternative solution of hierarchy problem
  - SM fields live in "*3+1*" space, but gravity feels *4+n* dimensions
  - Additional compactified dimensions of size *R*
  - Large M_{Pl} is artifact : $M_{Pl}^2 = M_D^{2+n} R^n$
  - $M^D \sim$ O(TeV) for particular choice of *R* and *n*
- Two scenarios
  - ➔ Many (n ≥ 2) XD's
  - ➔ One XD with specific properties (Randall-Sundrum model)
- Signals at LC :



Production of KK Graviton

Real graviton emission:

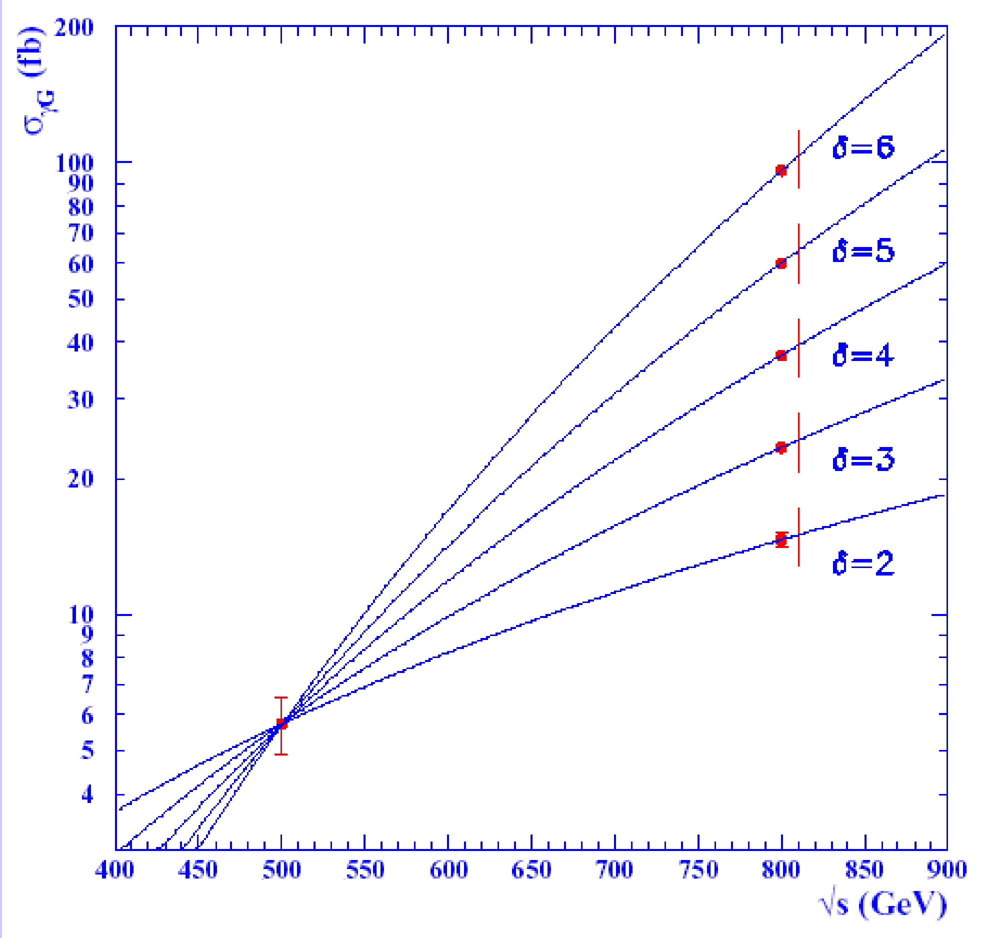
$e^+e^- \to \gamma G_n$

G_n - KK tower of states with

tiny mass splitting :

~ $10^{-3}...10^{7}$ keV ($2 \le n \le 6$)

Determine number of XD's with running at two different energies

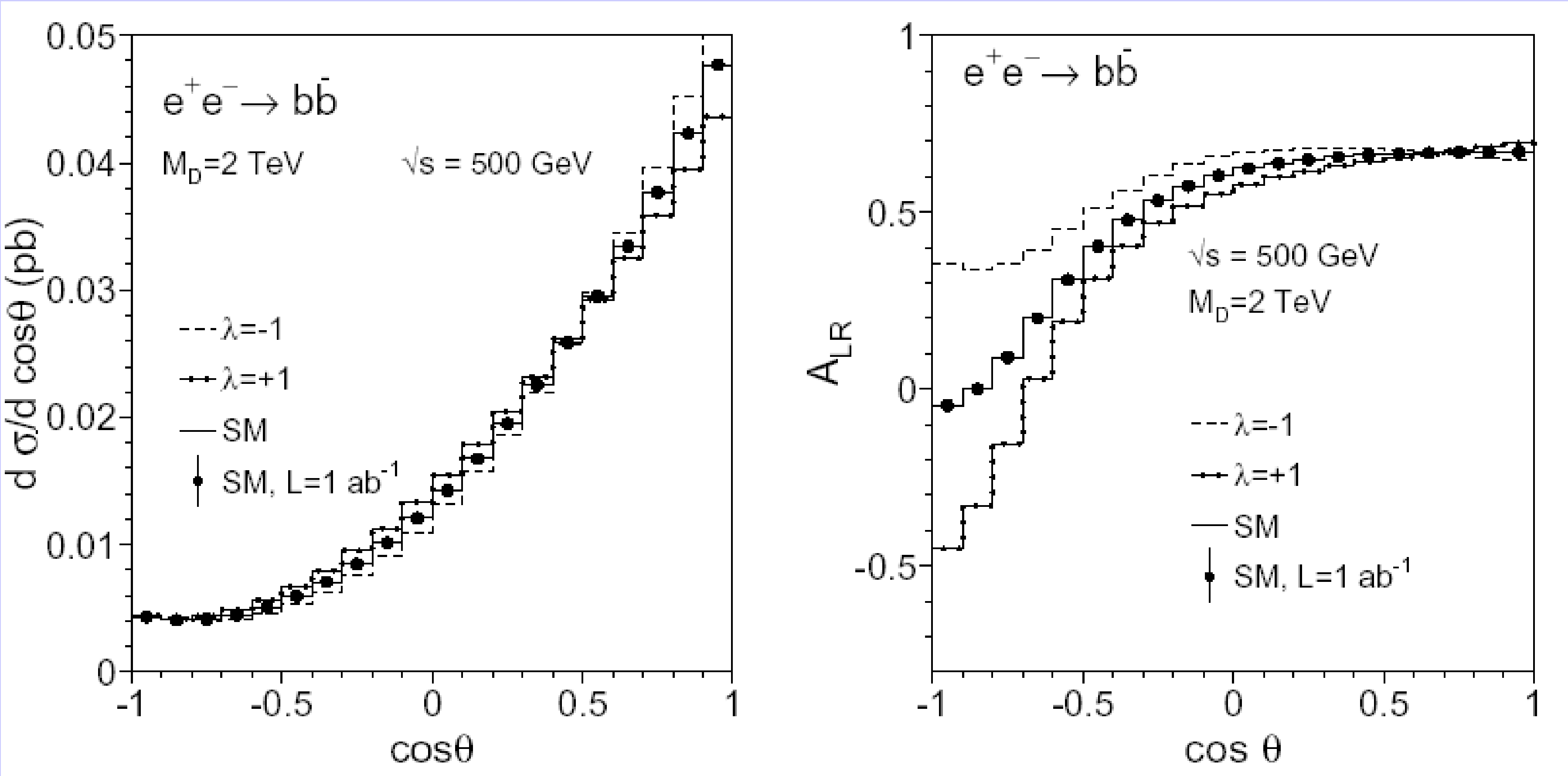


Pol.	$\delta = 2$	$\delta = 4$	$\delta = 6$
0	5.9	3.5	2.5
0.8(e^-)	8.3	4.4	2.9
0.8(e^-) 0.6(e^+)	10.4	5.1	3.3

Sensitivity to M_D (in TeV) @ 800GeV with 1 ab^{-1}

XD's via Virtual Effects

- *Virtual graviton exchange in 2 → 2 scattering e.g. $e^+e^- \to b\bar{b}$*
  - modified angular distribution
  - modified left-right asymmetry : beam polarization!



Randall-Sundrum Model

➔5-dimensional space

➔hierarchy via exponential function of compactification radius R_c

$$ds^2 = e^{-2kR_c|\phi|}\eta_{\mu\nu}dx^\mu dx^\nu - R_c^2 d\phi^2$$

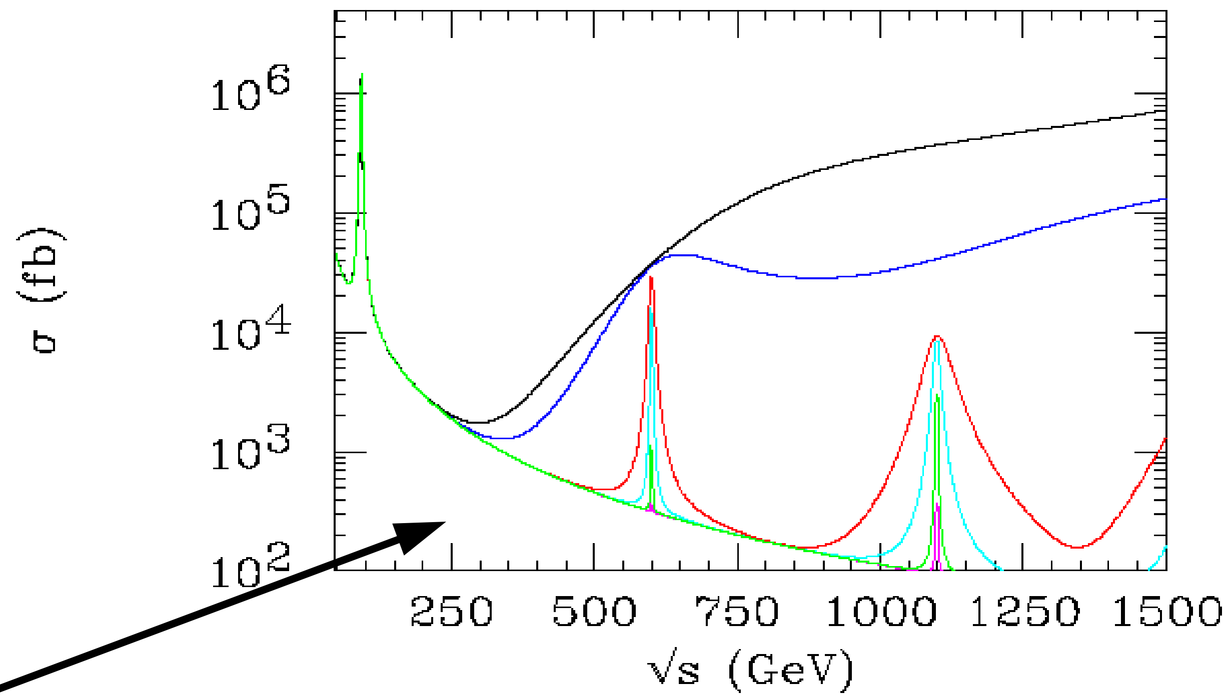
- KK states may have largely splitted masses:

$$m_n = x_n k e^{-kR_c\pi}$$

x_n - root of Bessel function

$$J_1(x_n) = 0$$

- Non-zero states (n > 0) couple to SM fields (e.g. fermions)



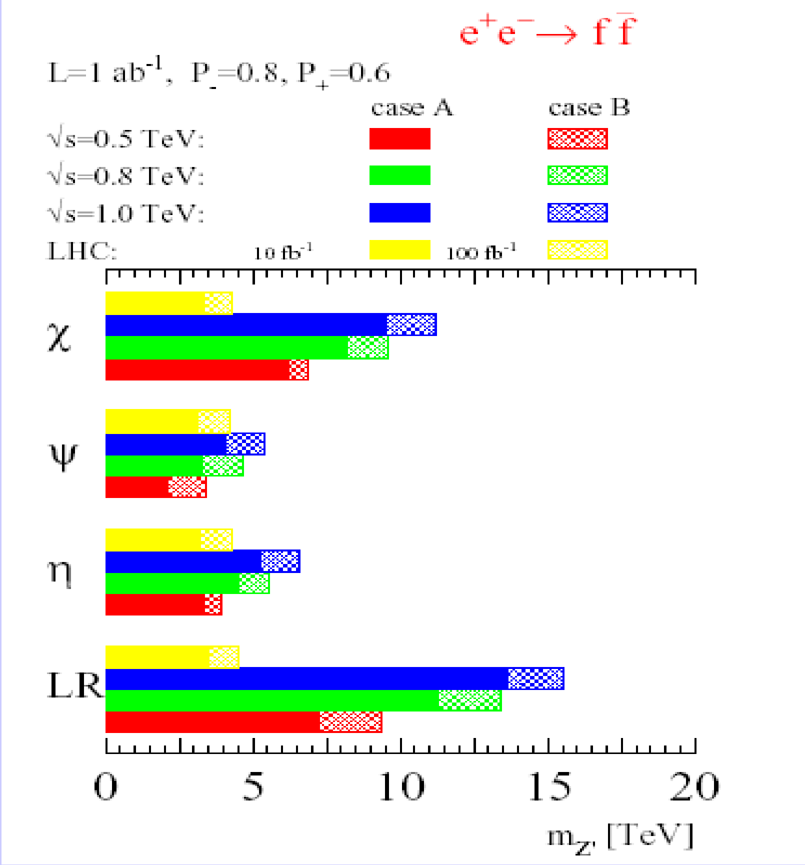
- KK states become visible as single resonances in $2 \to 2$ scattering, e.g. $e^+e^- \to \mu^+\mu^-$

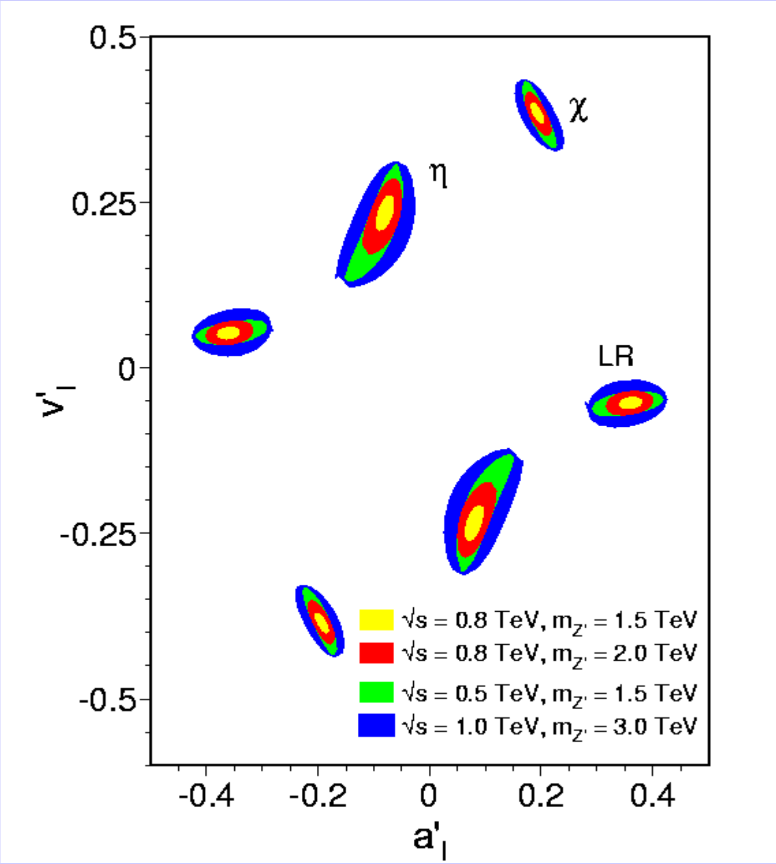
Extended Gauge Theories

- GUT : all forces are described by single group G_{GUT} at high scales
- G_{GUT} contains SU(3)×SU(2)×U(1) as subgroup
- But GUT gauge group may be broken in steps
  - $E_6 \to SU(3)\times SU(2)\times U(1)\times U(1)_{Y'}$
    - ➔ new light gauge boson Z' @ TeV scale
  - $SO(10) \to SU(3)\times SU(2)_R\times SU(2)_L\times U(1)$
    - ➔ Three additional gauge bosons $(W^+,W^-)_R$, Z_R
- Extended fermion representations : new fermion states
- These scenarios can be verified both at LHC (direct observation) and LC (virtual effects)

Probing Extended Gauge Theories
Example : Accessing Z' properties

- Assume new state is outside experimental reach
- From the analysis of propagator effects on various observables in the process $e^+e^- \to Z, Z', \gamma \to f\bar{f}$ Z' mass and couplings to fermions can be constrained





Renewed Old-Fashioned EW Physics

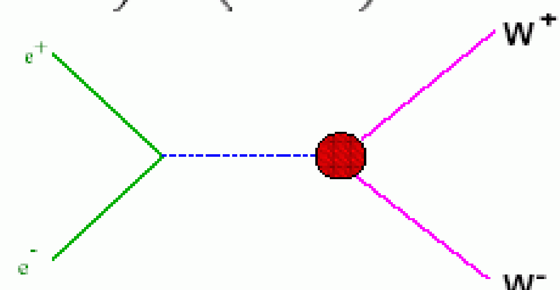
- Measurements in EW sector as they are done @ LEP but with higher statistics (higher precision), higher energy reach (extended kinematic domain) $\rightarrow$ access to new physics
- Novel measurements which were not done @ LEP
- Example : measuring anomalous TGC's and QGC's & probing Strong EWSB

Anomalous Gauge Couplings & Strong EWSB

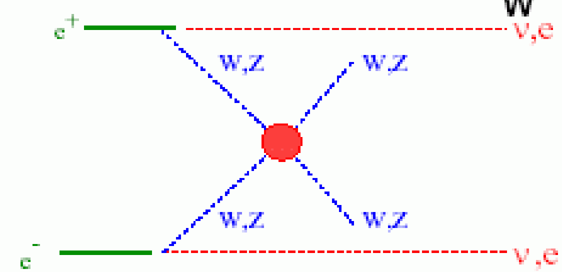
Generalized SU(2)$_c$ conserving effective Lagrangian for TGC's and QGC's:

$$
\begin{aligned}
L_1 &= \frac{\alpha_1}{16\pi^2}\frac{gg'}{2}B_{\mu\nu}\,\mathrm{tr}\Big(\sigma_3 W^{\mu\nu}\Big)\\
L_2 &= \frac{\alpha_2}{16\pi^2}\mathrm{i}g' B_{\mu\nu}\,\mathrm{tr}\Big(\sigma_3 V^{\mu}V^{\nu}\Big)\\
L_3 &= \frac{\alpha_3}{16\pi^2}2\mathrm{i}g\,\mathrm{tr}\Big(W_{\mu\nu}V^{\mu}V^{\nu}\Big)\\
L_4 &= \frac{\alpha_4}{16\pi^2}\,\mathrm{tr}\Big(V_{\mu}V_{\nu}\Big)\,\mathrm{tr}\Big(V^{\mu}V^{\nu}\Big)\\
L_5 &= \frac{\alpha_5}{16\pi^2}\,\mathrm{tr}\Big(V_{\mu}V^{\mu}\Big)\,\mathrm{tr}\Big(V_{\nu}V^{\nu}\Big)\,,
\end{aligned}
$$

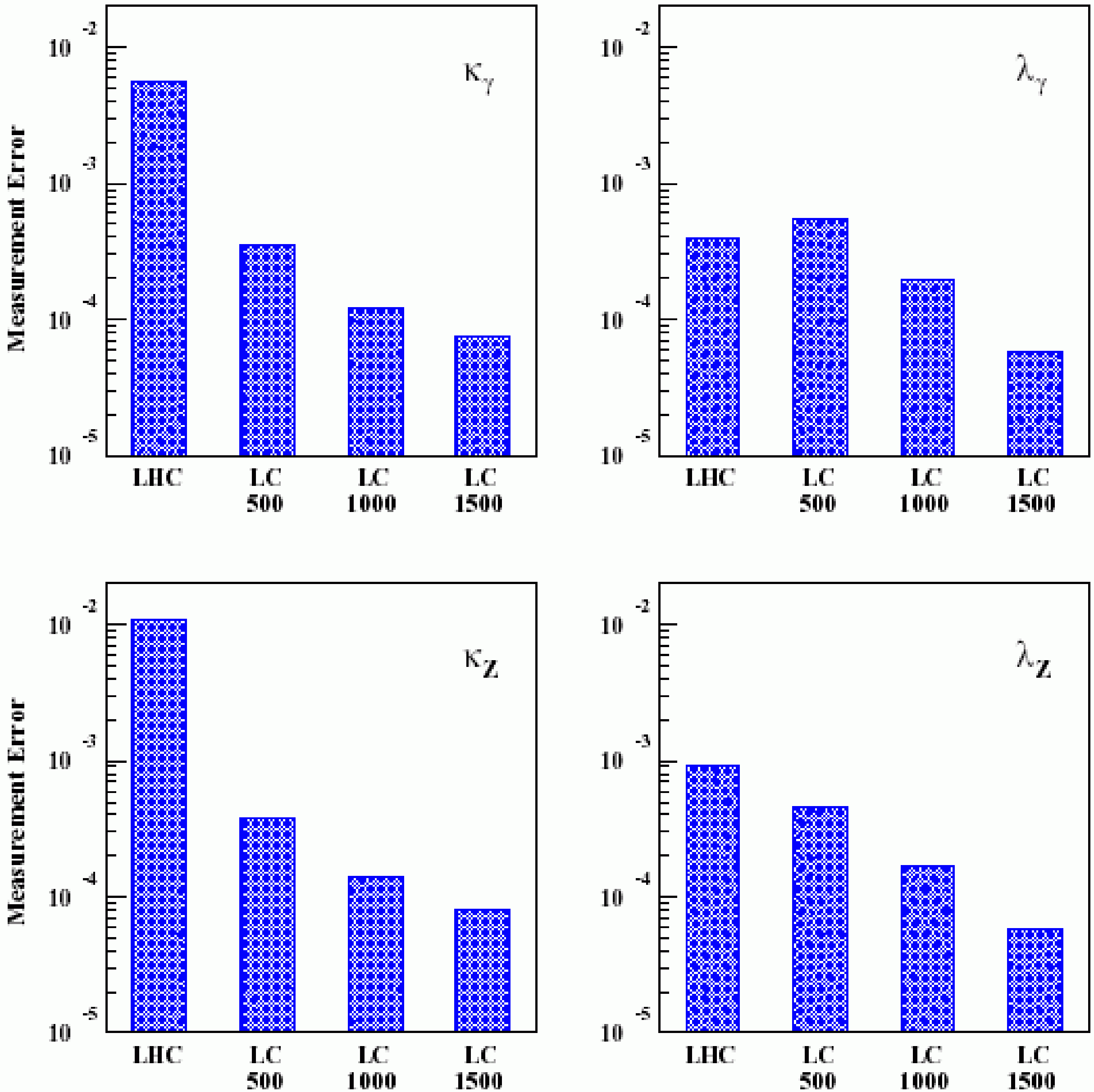
$\alpha_1, \alpha_2, \alpha_3 \Rightarrow$ Triple Gauge Couplings:

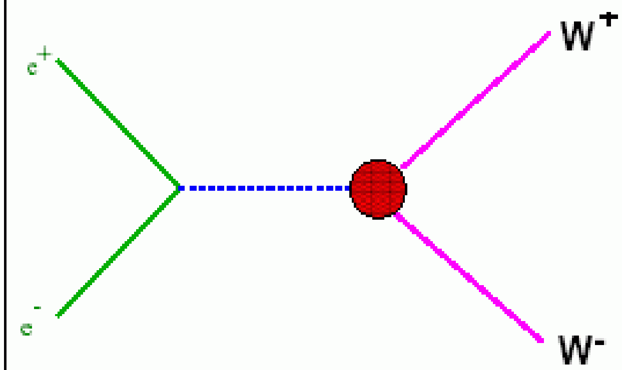


$\alpha_4, \alpha_5 \Rightarrow$ Quartic Gauge Couplings:



Triple Gauge Couplings





TGC's are a universal precision probe for new physics

Strong EWSB Scale Sensitivity:

$\alpha_1 = 0$	80%+0%	80%+60%
Λ_2^*	5.4 TeV	8.8 TeV
Λ_3^*	8.2 TeV	10.7 TeV

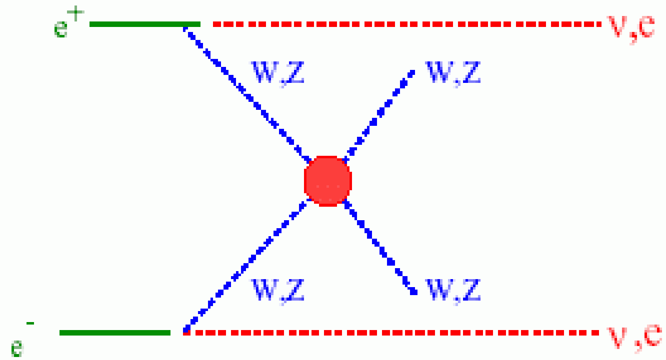
$\sqrt{s} = 500$ GeV, 500 fb^{-1}

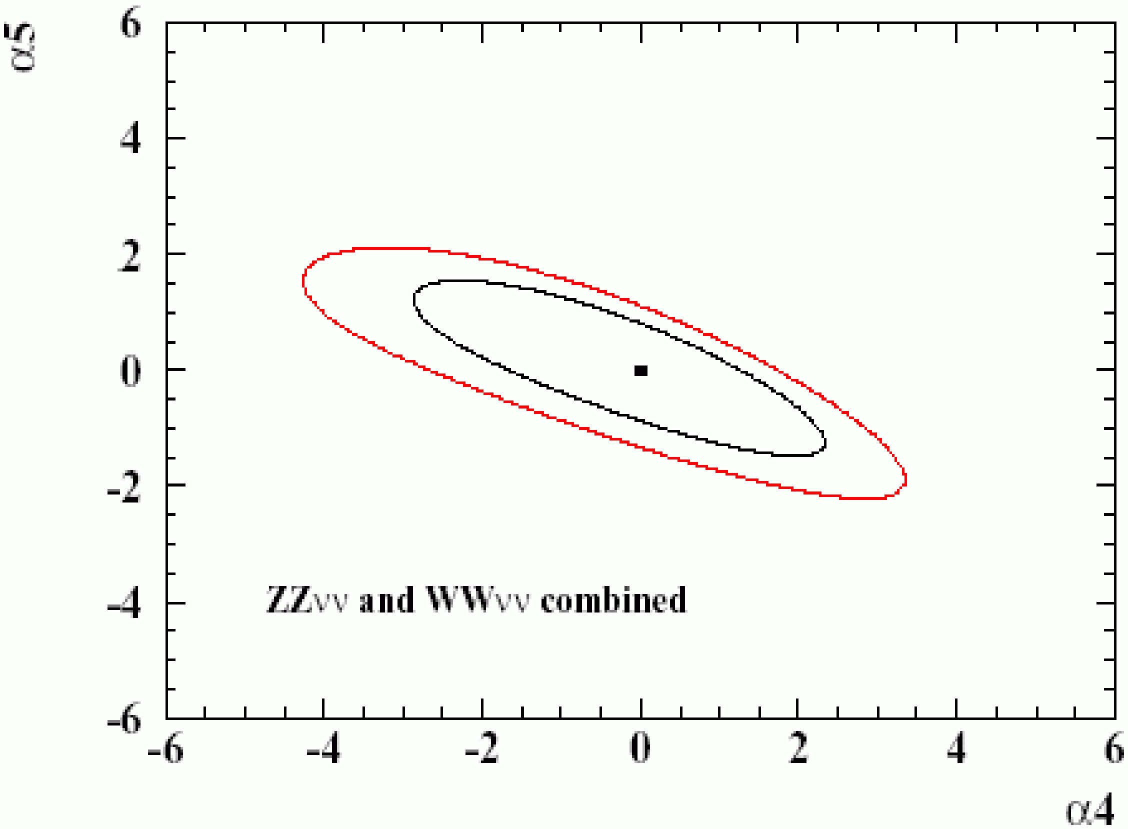
Quartic Gauge Couplings

look at $e^+e^- \to \nu\bar{\nu}q\bar{q}q\bar{q}$

include full 6-fermion backgrounds ($\longrightarrow$ MC generators!)

disentangle WW from ZZ !





Strong EWSB Scale Sensitivity:

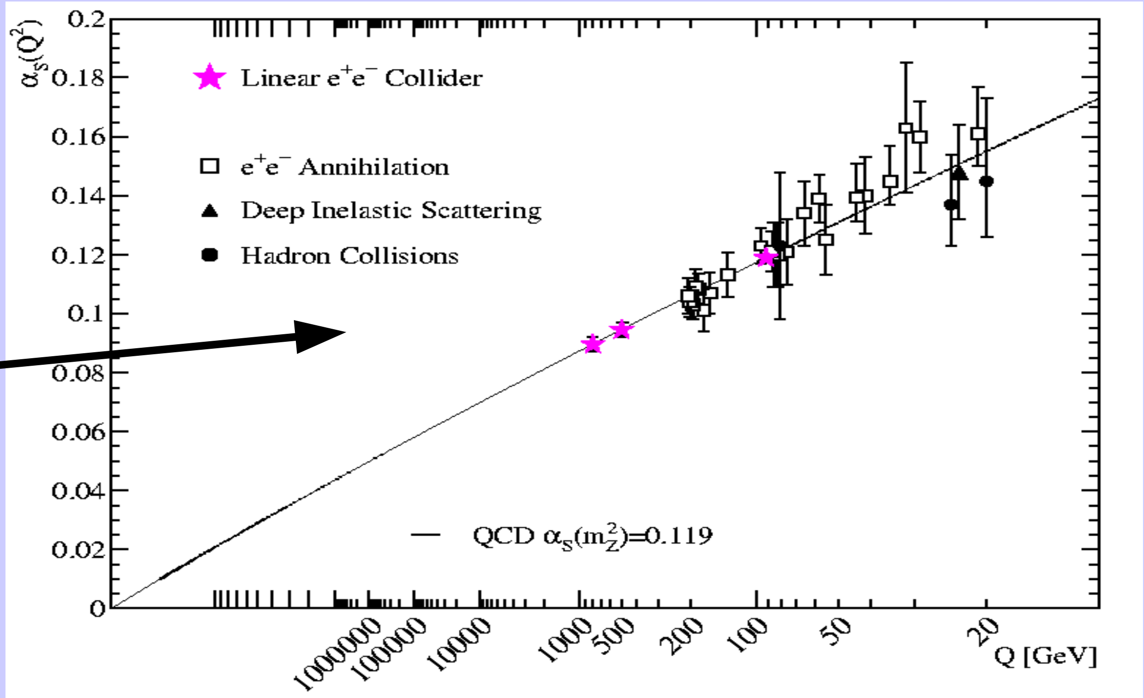
$\alpha_1 = 0$	80%+40%
Λ_4^*	2.9 TeV
Λ_5^*	4.9 TeV

$\sqrt{s} = 800$ GeV, 1000 fb^{-1}

single parameter fits

Quantum Chromodynamics

- High precision measurement of α_s @ Z pole (GigaZ) and higher energies → "chasing" running strong coupling



✔ analysis of event shape variables

➔ constraints on the GUT scale

➔ improving prediction power of perturbative QCD

Uncovered (partially covered) Topics

- Little Higgs models
- Composite models
- Strong EW Symmetry Breaking
- QCD & top quark physics
- CKM matrix & CP-violation in all sectors (EW, SUSY, Higgs)
- Lepton flavour violation
- ....

✔ Many topics still need to be scrutinized

✔ Any interesting topic for you?

✔ Expertise is needed, volunteers are searched

Summary

- Linear e^+e^- collider – next large experimental facility after LHC (possible concurrent running)
- Fascinating physics anticipated
  - ✔ Elucidating mechanism of EWSB
  - ✔ Exploration of SUSY models
  - ✔ Access to higher scales via RGE and high precision studies of virtual effects @ sub-TeV and TeV scales
  - ✔ Probing alternative models, new physics & “physics beyond new physics”
- Will complement knowledge we'll obtain with LHC
- Yet not just “complementary” machine but has value on its own

Summary (Continued)

- Universality of detector (from hardware side) and universality of thinking (from human side) is mandatory to grasp all expected and even unexpected and surprising physics signatures
- Should be **global** (not national or regional) project : enhanced chances of success
- Current LC detector R&D and LHC project are nice examples of global efforts in HEP – Encouraging sign!
- Interested, intrigued? Join us!