If no new physics appears at the LHC in 2011, is there a case for the ILC ?

M. E. Peskin
for the PEB Physics Panel
CERN LC Workshop
October 2010

It is our expectation that the LHC will discover new particles and forces that explain electroweak symmetry breaking and cosmic dark matter.

The scientific case for the ILC based on precision measurements of the Higgs boson is very strong,

but for presidents and legislators, more might be needed.

I will assume here that a LC project as expensive as the LHC needs the following justification:

The LHC has discovered new particles that cannot be a part of the Standard Model of particle physics. These particles indicate new laws of physics which we must know to understand the form and structure of the universe. We need a tool to advance our knowledge of these new particles beyond what can be learned at the LHC.

The appearance of new particles at the LHC will provide a magical moment of discovery when we will have the world's attention, from ministers to the man and lady on the street.

In conventional wisdom, what follows from this is the following:

1.) If new particles are found at 7 TeV and 1 fb-1, their energy scale is likely to be about 500 GeV. Then the ILC is the tool that we need.

2.) If the new particles are not found at 7 TeV, their energy scale is higher, and ILC is not the right machine.

If we are lucky, new particles will be found in 2011,

but the real expectation is simply that these particle have masses at the TeV energy scale and will be found in the longer LHC program.

There are two important caveats, recognized by everyone:

A light Higgs boson -- of the type found in the Standard Model and most viable BSM models -- will not be found in the 2011 LHC run.

"Hadron colliders are powerful for discovery, but they have great difficulty making exclusions." -- Gordy Kane

But, there is a deeper problem with point 2. The statment is completely wrong !

It asks the wrong question. The right question is:

When we discover new particles at LHC and are mystified by their properties, when energy must we have in e+e- to obtain information that will solve the mystery ?

Particle physicists will always ask for higher energies. But, what we really want is better knowledge.

Example of supersymmetry:

Eventually, the LHC will probe for SUSY over essentially all of the interesting parameter region. Most of the SUSY masses will be measured in SUSY cascade decays.

A role of the ILC will be to supply precision studies of the chargino, neutralino, and Higgs sectors. This information is needed for many issues, including, Is it really SUSY ?

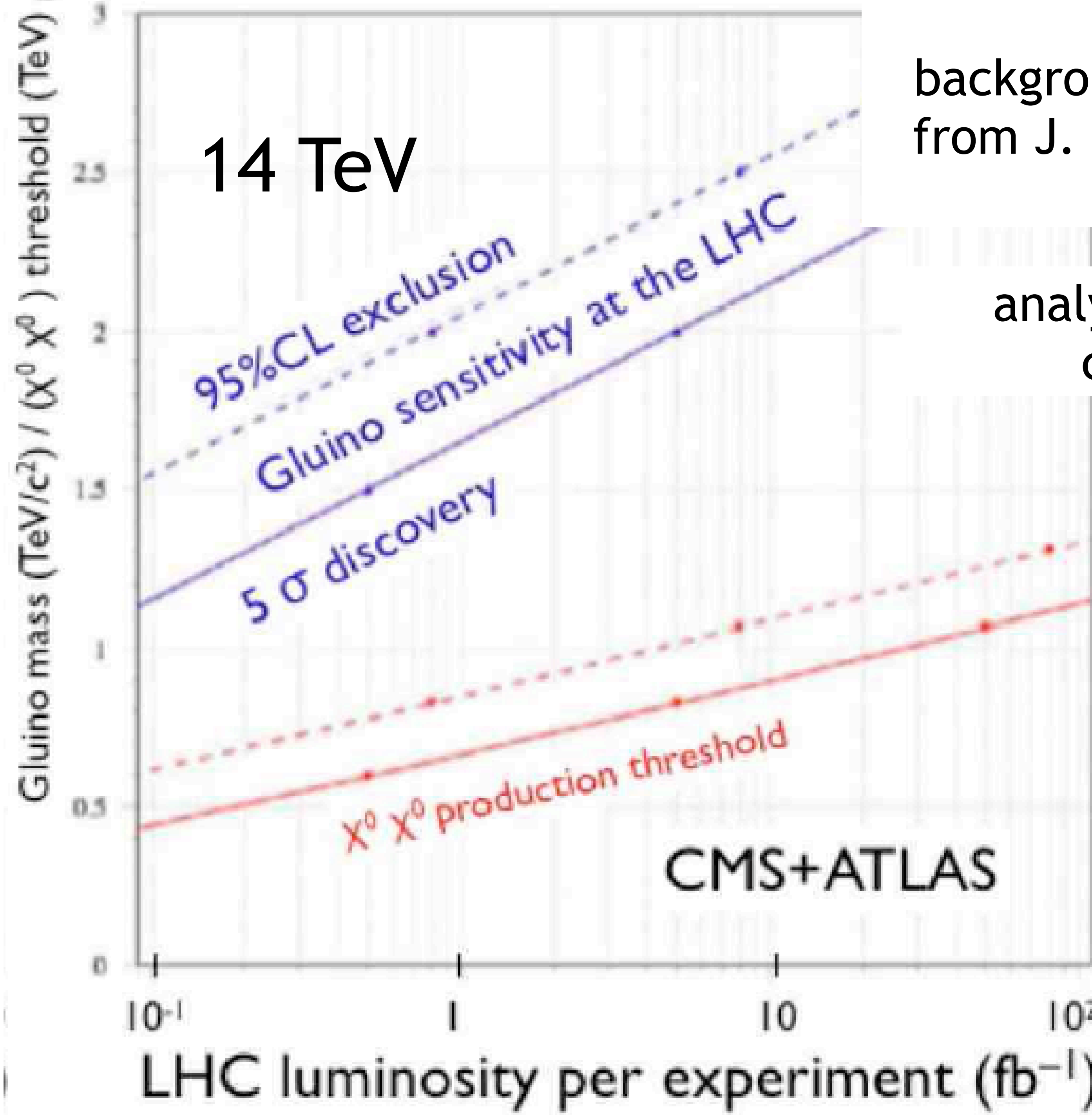
What will we know about these after the 2011 run of the LHC ?

Only QCD pair prodution reactions will be strongly constrained. Inferences about the color singlet superparticles will come from "gaugino universality":

$$m(\widetilde{g}) \approx 3.5\, m(\widetilde{w}) \approx 7\, m(\widetilde{b})$$

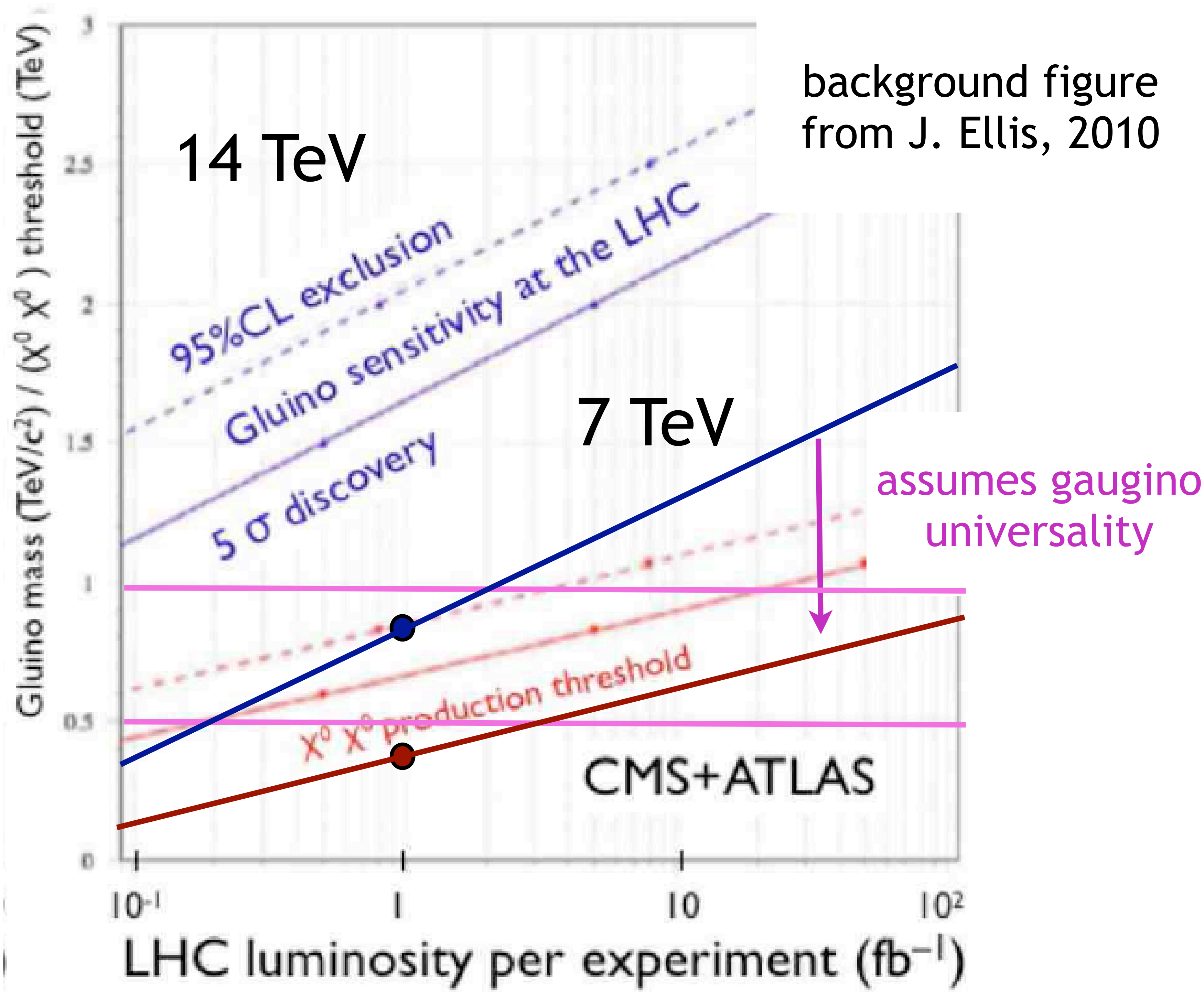
This relation is true in many benchmark models, but it is an assumption that is not well motivated theoretically. It is introduced as a simplification of the large SUSY parameter space.

14 TeV



background figure from J. Ellis, 2010

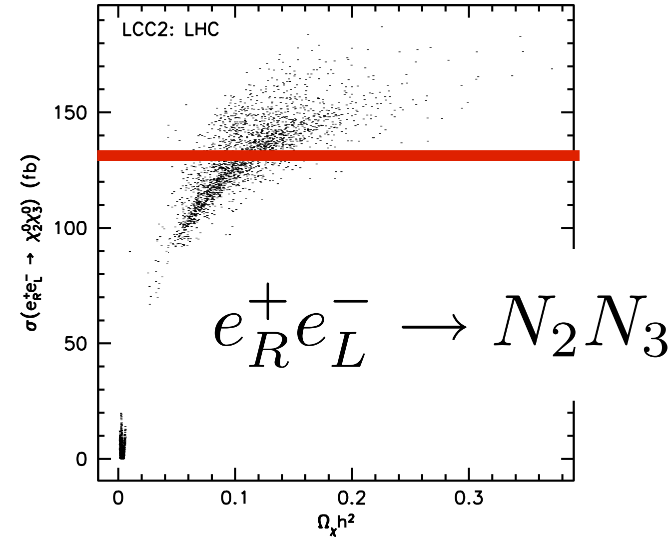
analysis in the cMSSM



background figure
from J. Ellis, 2010
14 TeV
7 TeV
95%CL exclusion
Gluino sensitivity at the LHC
5 σ discovery
assumes gaugino universality
X⁰ X⁰ production threshold
CMS+ATLAS
Gluino mass (TeV/c²) / (X⁰ X⁰) threshold (TeV)
LHC luminosity per experiment (fb⁻¹)

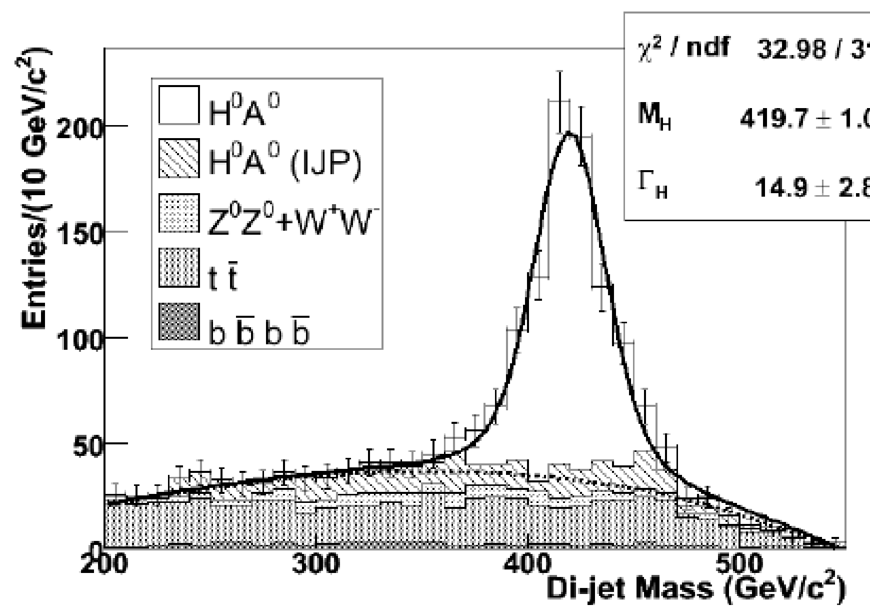
Why do we need to study neutralinos and Higgs bosons ? Here are two questions about supersymmetry that cannot be answered at the LHC:

Does the lightest neutralino really have the correct cross sections to be the dark matter particle?



requires knowledge of the chargino/neutralino mixing angles and Higgs couplings

Does the stop/Higgs sector generate the potential that explains Higgs boson spontaneous symmetry breaking ?

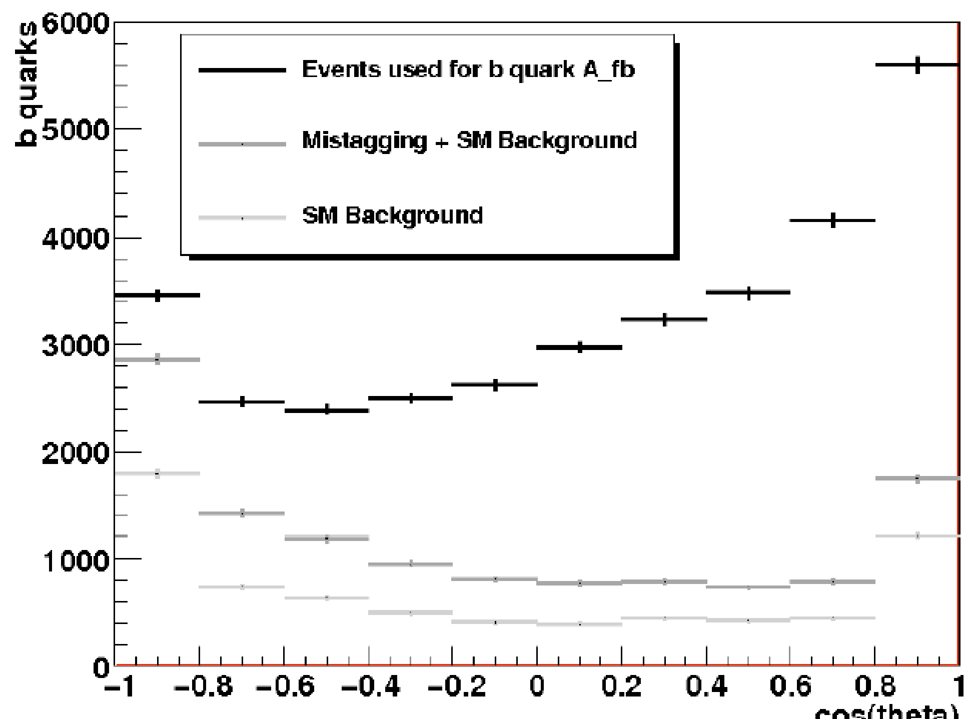


requires knowledge of $\mu, \tan\beta$, and the stop mass matrix

Example of top quark dynamics:

The top quark may be heavy because it has new strong $t\bar{t}$ interactions, or because it couples to a new strong interaction sector. Such models can produce resonances that decay to .
These resonances could appear already above 1 TeV, although flavor constraints suggest masses of ~3 TeV.

If the top quark has new interactions, we will want to measure the pointlike current form factors of the top quark. These can be measured through FB and polarization asymmetries in $e^+e^- \rightarrow t\bar{t}$.



Example of a Z′:

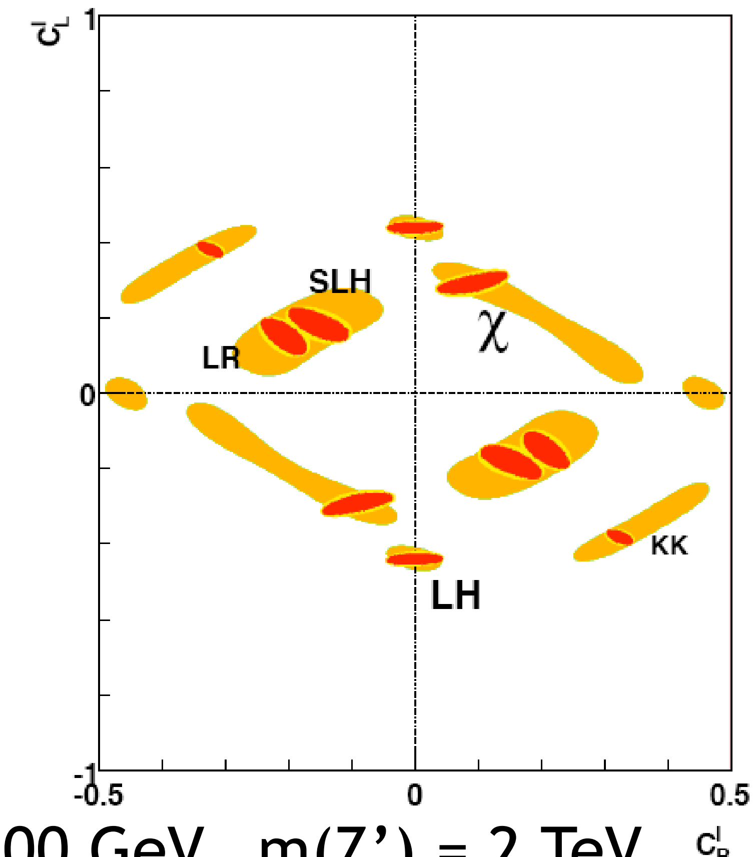
LHC can find Z′ boson up to about 5 TeV. The reach in 2011 is about 1.5 TeV.

If a resonance is discovered, don't we want to go there ?

The immediate question will be to learn the full set of helicity-dependent couplings of the Z′ to fermions. These can be measured by observing the interference with γ, Z in polarized

$$e^+e^- \rightarrow e^+e^-, \mu^+\mu^-, \tau^+\tau^-$$
$$e^+e^- \rightarrow q\bar{q}, c\bar{c}, b\bar{b}$$

500 GeV and high luminosity is already sufficient.



500 GeV, m(Z') = 2 TeV
1 ab-1, $e^+e^- \rightarrow \mu^+\mu^-$

summary:

A discovery profound enough to motivate the next collider will open a new and unexplored realm of physics.

This discovery will raise questions that we will want to answer urgently.

We will not want an ultimate-energy machine. We will want the machine that gives the answers to these urgent questions.

In this talk, I have given several examples in which the LHC discovery involves particles of high mass, but new information from a Linear Collider requires only 500 GeV.

This is the logic that motivated the ILC proposal in the first place. That logic is still correct.

one final point:

There is a significant opportunity for the discovery of new particles in the 2011 LHC run at 7 TeV. In this case, the magic moment of discovery will come in 2011 or 2012.

Presidents, legislators, and journalists have an attention span of years, not decades. We should be ready with a case for a new collider that addresses the physics questions raised by this discovery and can be implemented immediately.

In 2012, the only LC technology on the table will be ILC. To take advantage of the opportunity, we have be ready, as a community, to go forward with the ILC.