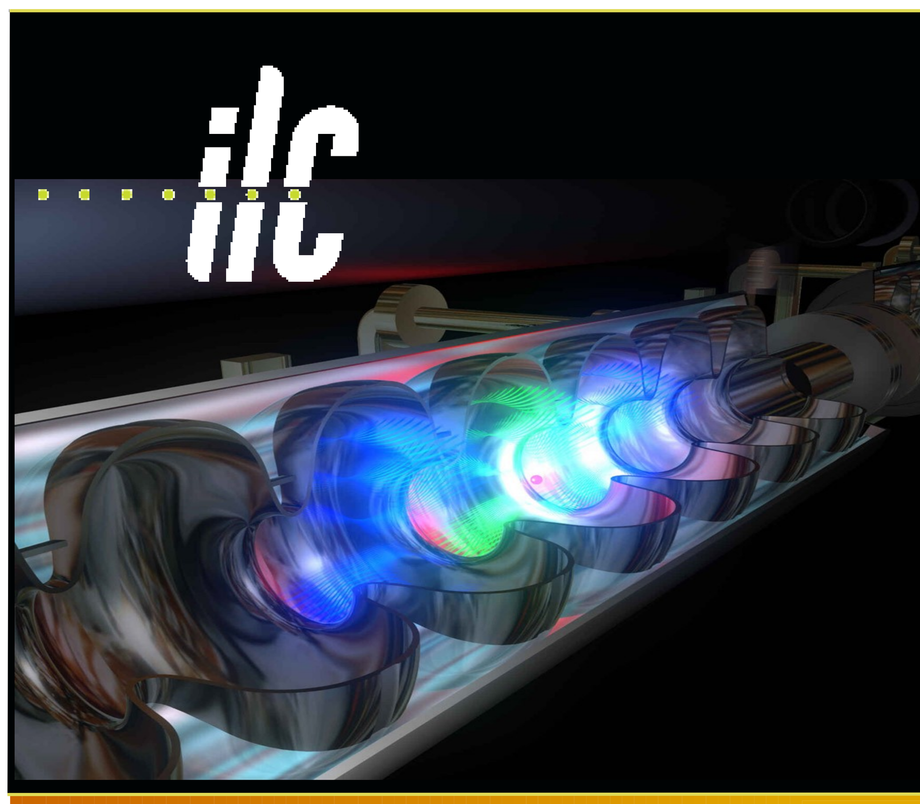
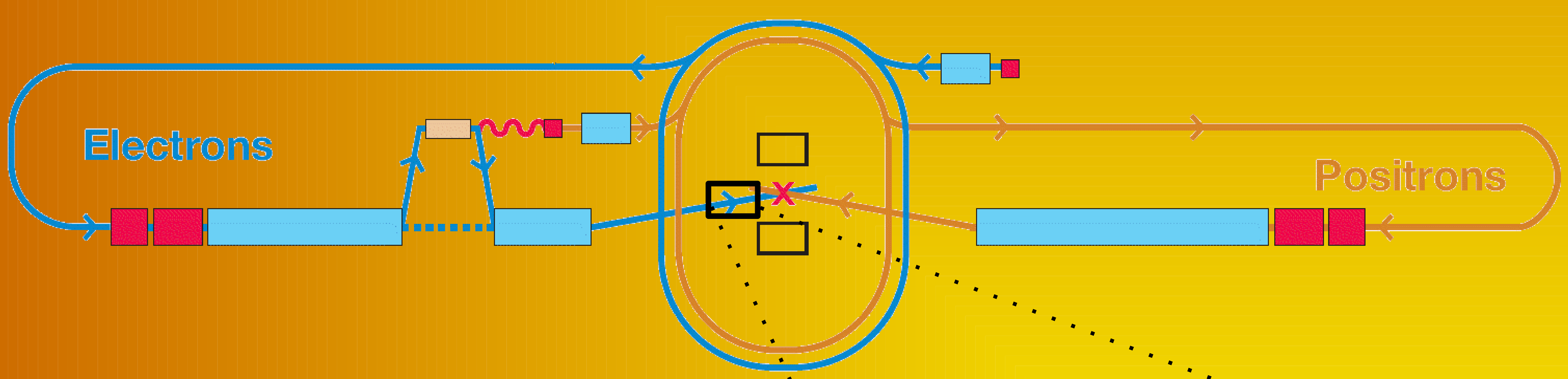
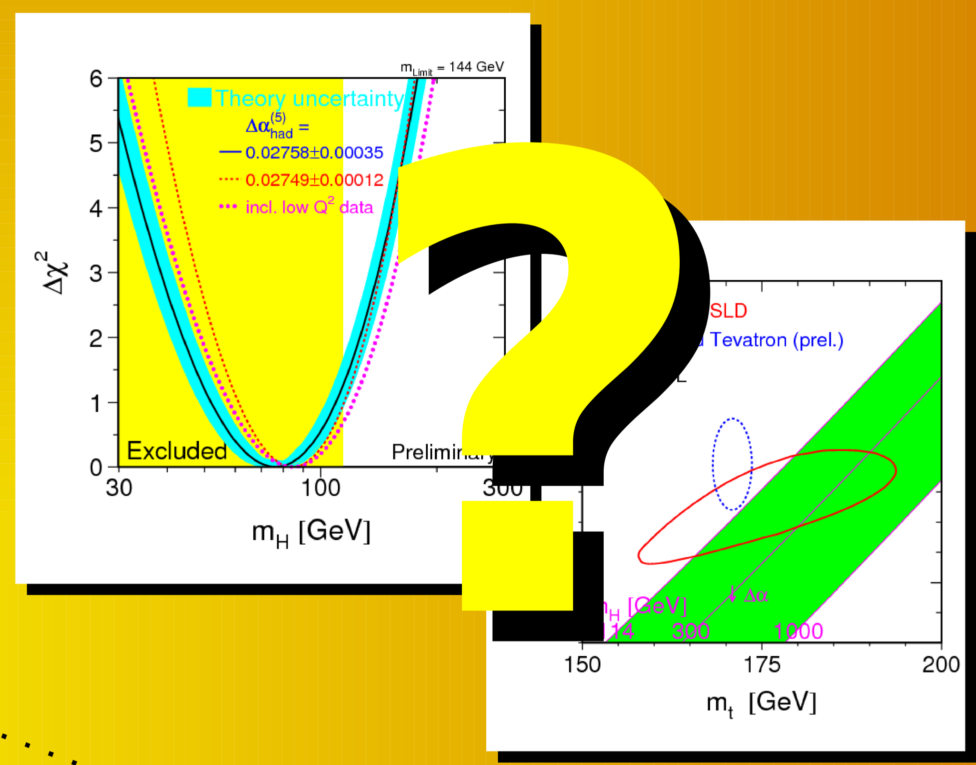


The International Linear Collider
Measuring the Beam Energy

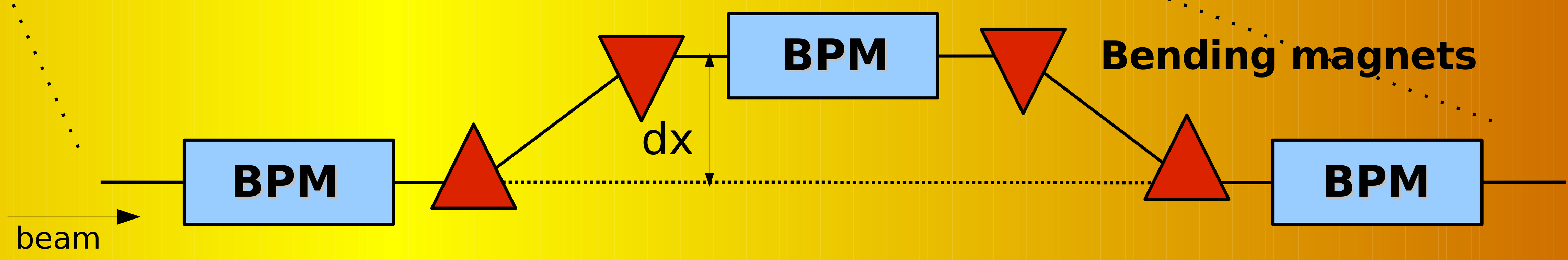
UCL



At the International **Linear Collider**, or ILC, electrons and positrons collide head-on with an **energy roughly that of a flying mosquito.** We however need to know this energy **better than 1 part in 10000** if we are to make good physics measurements of e.g. the Higgs boson mass or top quark mass. Since it is a **linear machine**, we only get **one shot** to measure this energy as precisely as possible. Here's how we intend to do it :



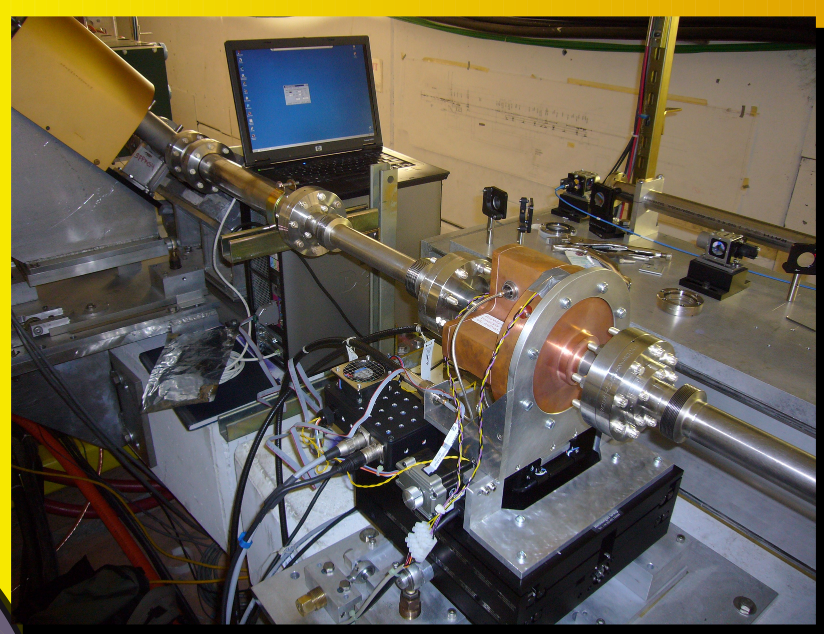
The **energy spectrometer** will be part of the **beam delivery system**, which transports the high energy beam from the accelerator to the interaction region.



$$dx \propto \frac{q}{E} \int B.dl$$

By sending the electron and positron beams through a magnetic chicane, we offset their trajectory by about 5 mm. The measured **beam deflection dx is inversely proportional to the beam energy E** (Lorenz Force) ! Various techniques allow us to measure the magnetic field of the bending magnets to a very high accuracy, so if we can **measure the beam offset precise enough**, we can determine the energy of the beam to the level which is required by the physics goals of the machine.

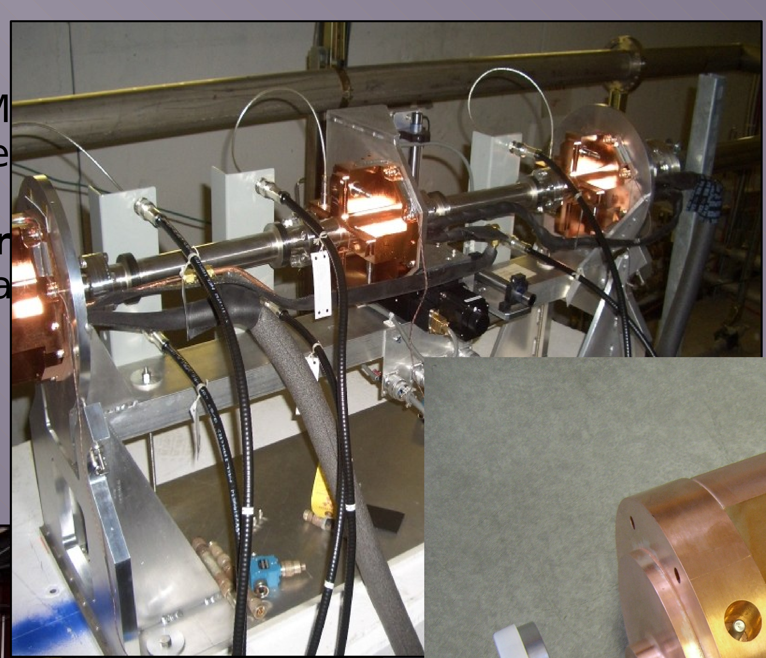
We here in the UK are heavily involved into the development and commissioning of these cavity BPMs :

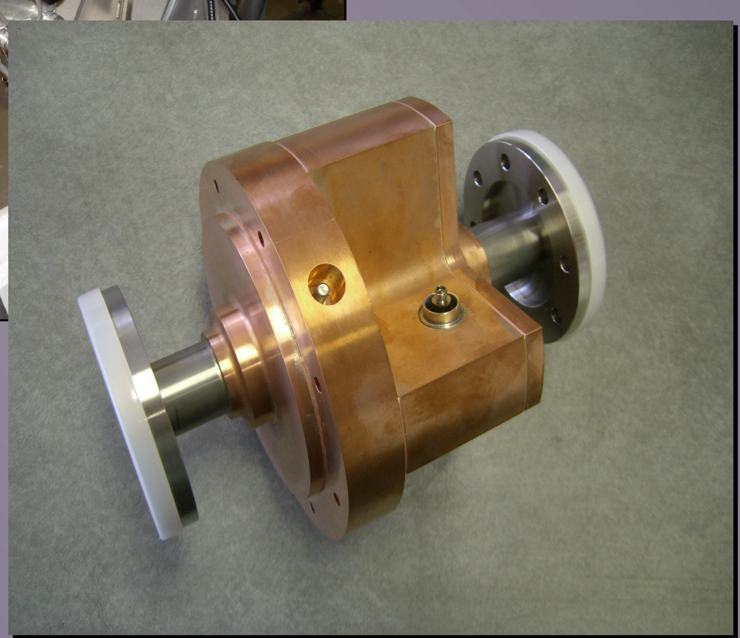


Our BPM prototype installed in the beam line on a 2D mover system.

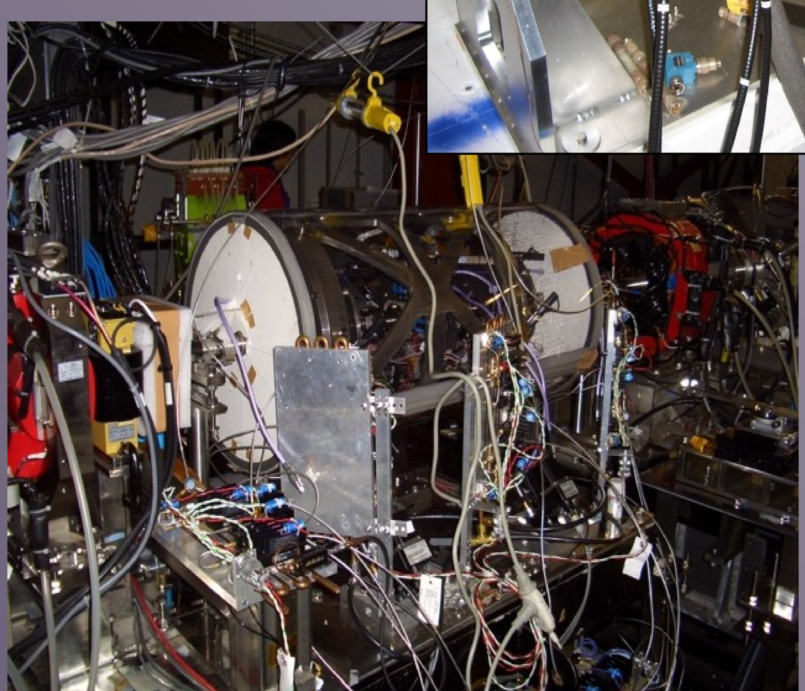
Cavity BPMs are able to measure the electron beam position to **better than 100 nm** (that's 1000 times less than the thickness of a piece of paper !!!)

ILC accelerator BPM prototypes at the **Stanford Linear Accelerator Center** in California





Energy spectrometer BPM prototype, developed at **University College London** and **Royal Holloway University of London**



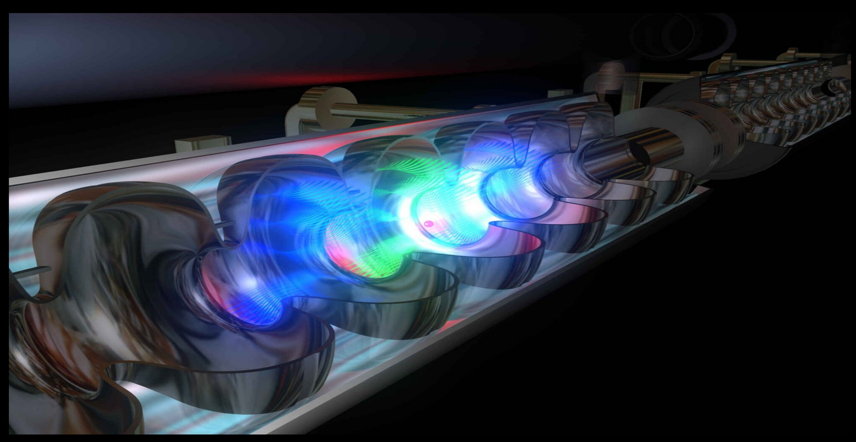
This system at **ATF in Japan** even measures down to **10 nm** !!!

Our BPM prototype read-out electronics

The UK is a key player in the **T474 test experiment at SLAC** which developed a prototype energy measurement chicane that serves as a miniature test bench of the future ILC energy spectrometer...

The International Linear Collider at UCL :

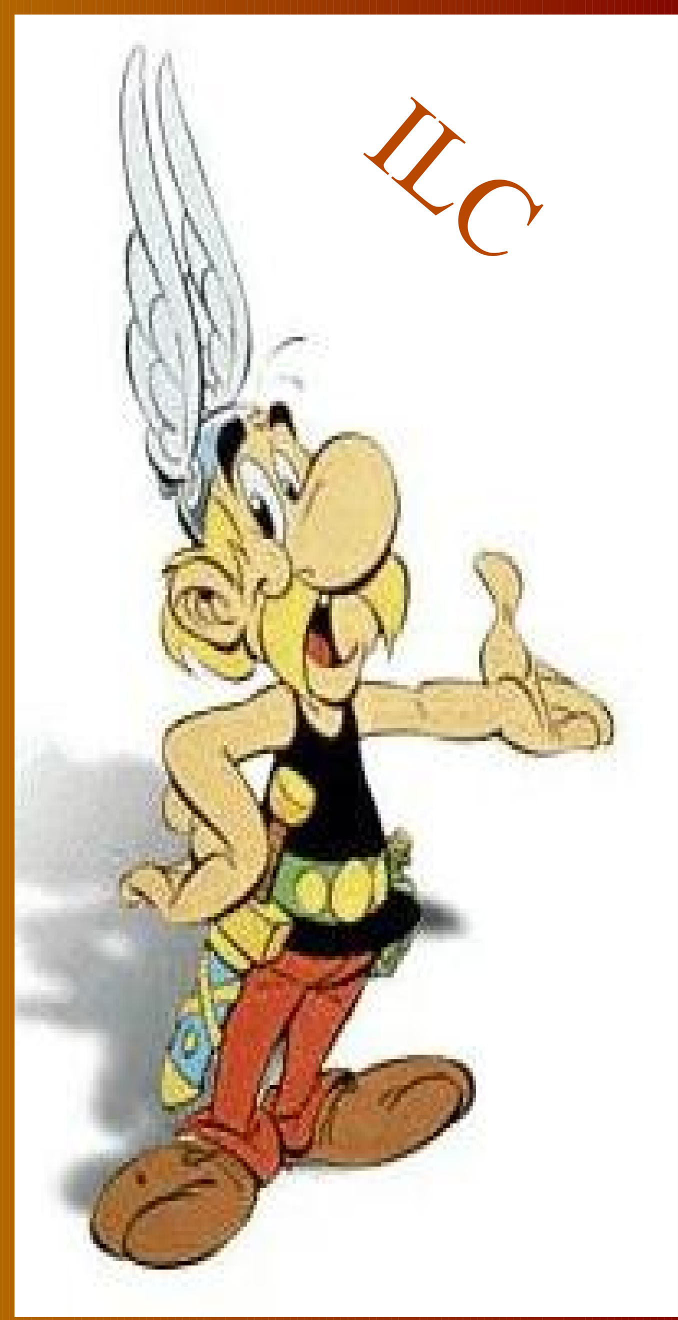
`http://www.hep.ucl.ac.uk/lc`

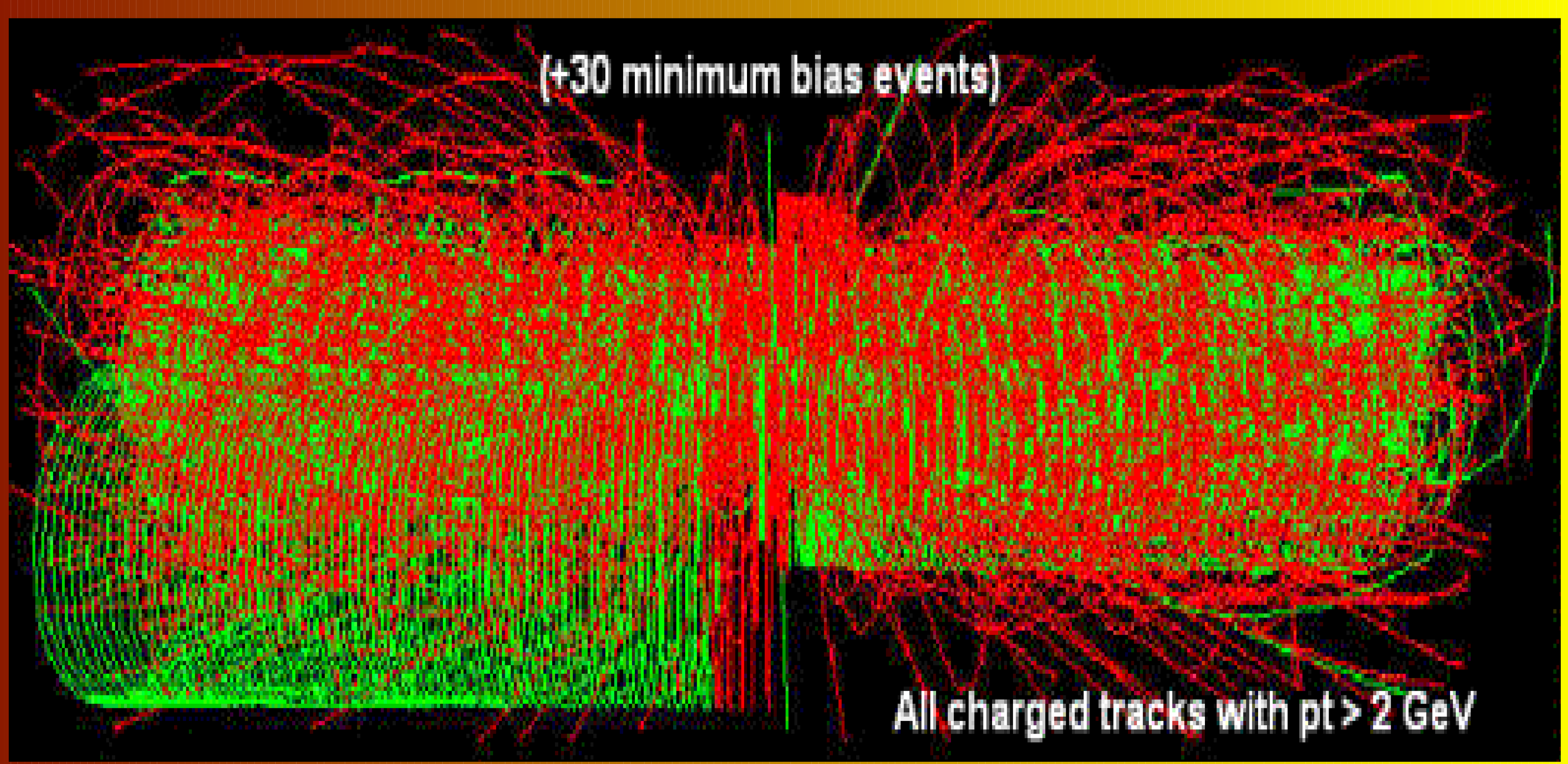


SYNERGY OF LHC AND ILC

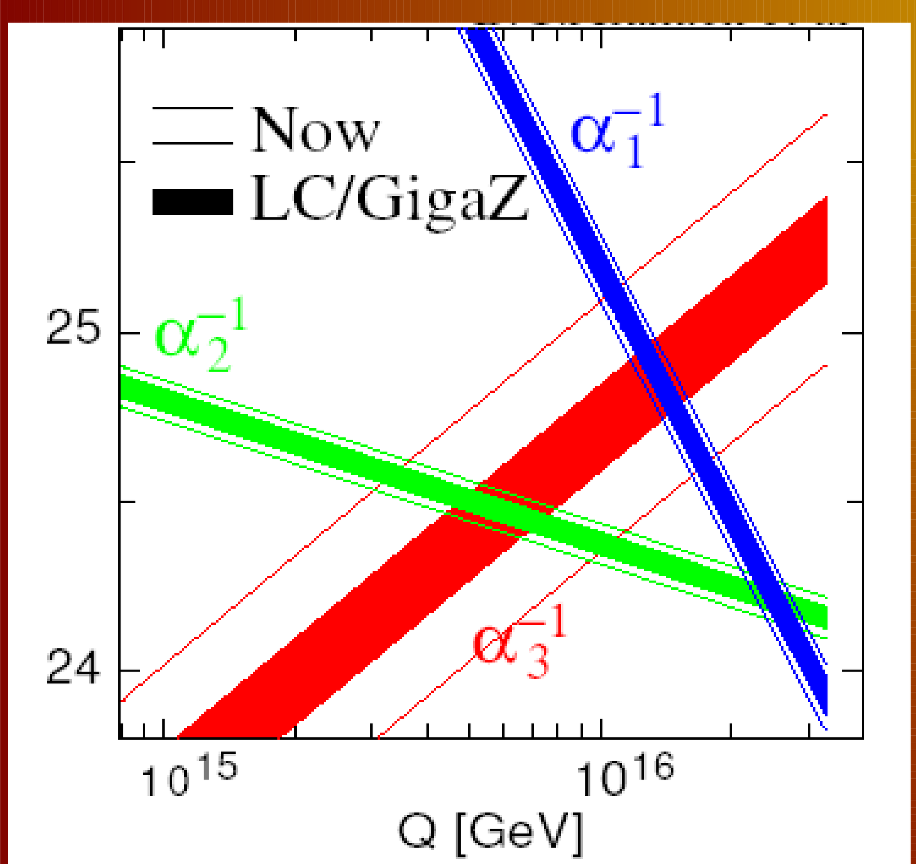
At the Large Hadron Collider (LHC), protons will be fired around the CERN ring. Protons are composite particles – each proton is composed of three quarks. The LHC is a discovery machine, and will shed light on high energy physics.

At the International Linear Collider (ILC), electrons and their anti-particles, positrons, will be fired towards each other and annihilate into pure energy. Since electrons are fundamental particles, these collisions will produce clean, clear signals.



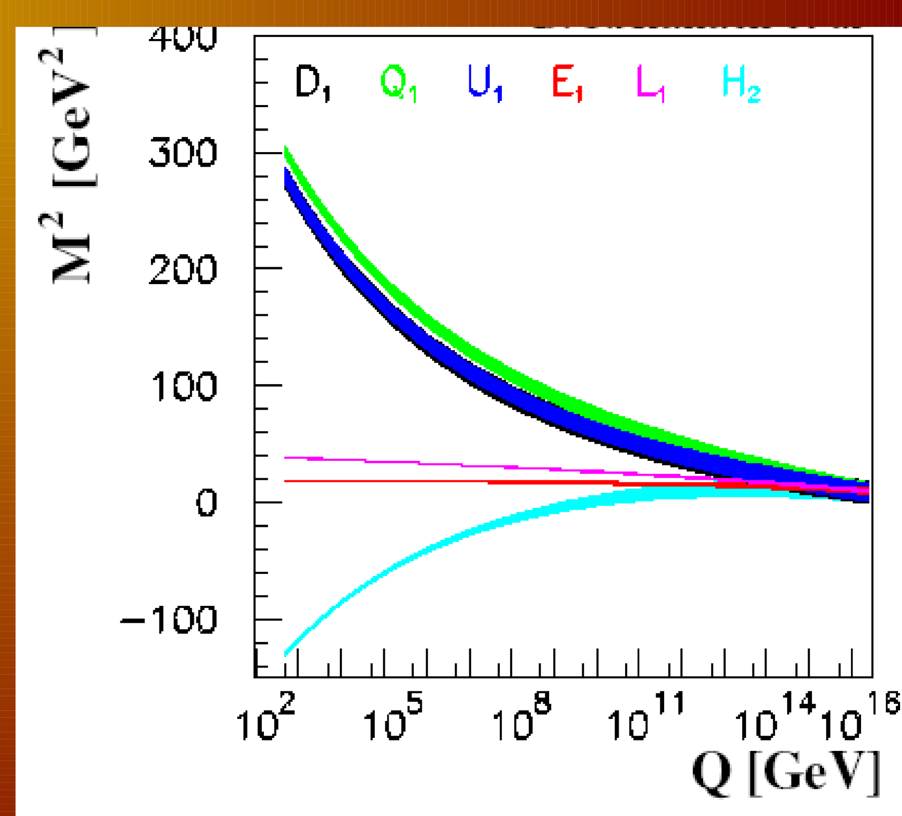


The synergy between the LHC and the ILC during simultaneous running of the two machines has the potential to maximise the physics gain from both facilities. Due to its high collision energy and luminosity, the LHC has a large mass range for the discovery of new heavy particles, and the ILC's clean experimental environment and tunable collision energy allows it to perform detailed studies of directly accessible new particles. The ILC also has exquisite sensitivity to quantum effects of unknown physics - indeed, the fingerprints of very high scale new physics will often only show up in small effects whose measurement requires the greatest possible precision.



The International Linear Collider together with the Large Hadron Collider: Fundamental research towards the Theory of Everything

LHC / LC Study Group World-wide working group:
www.ippp.dur.ac.uk/~georg/lhclc



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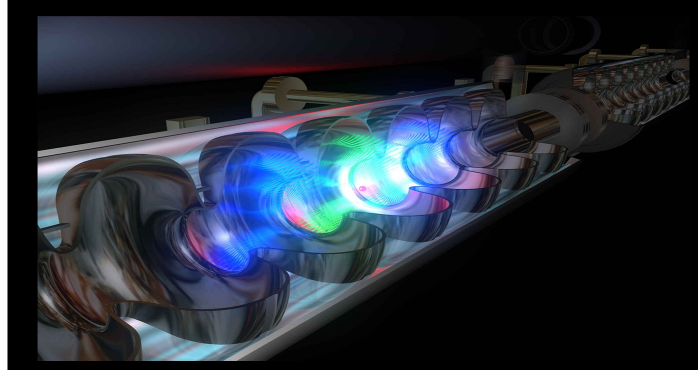
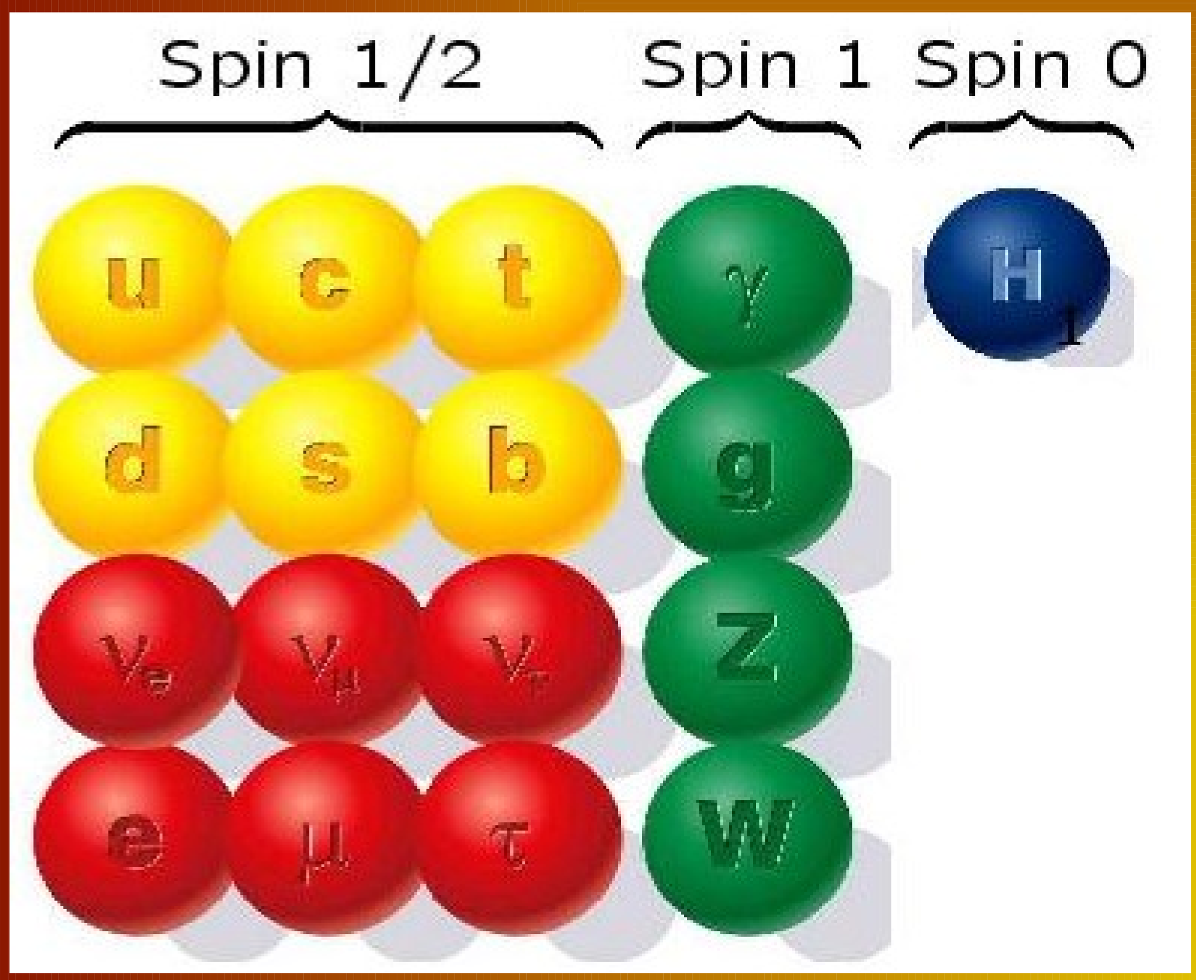
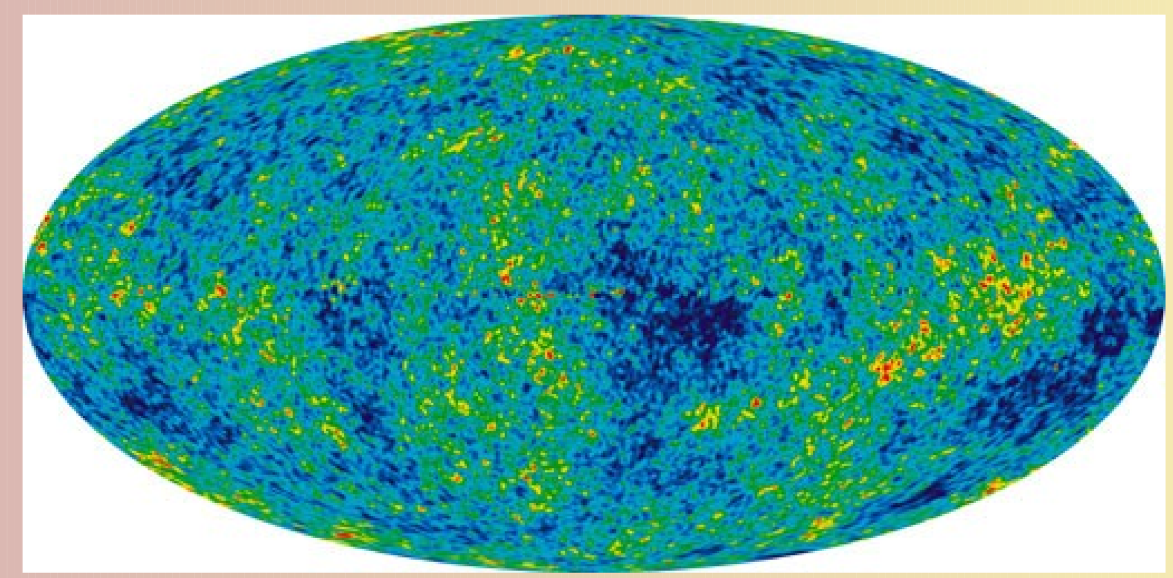


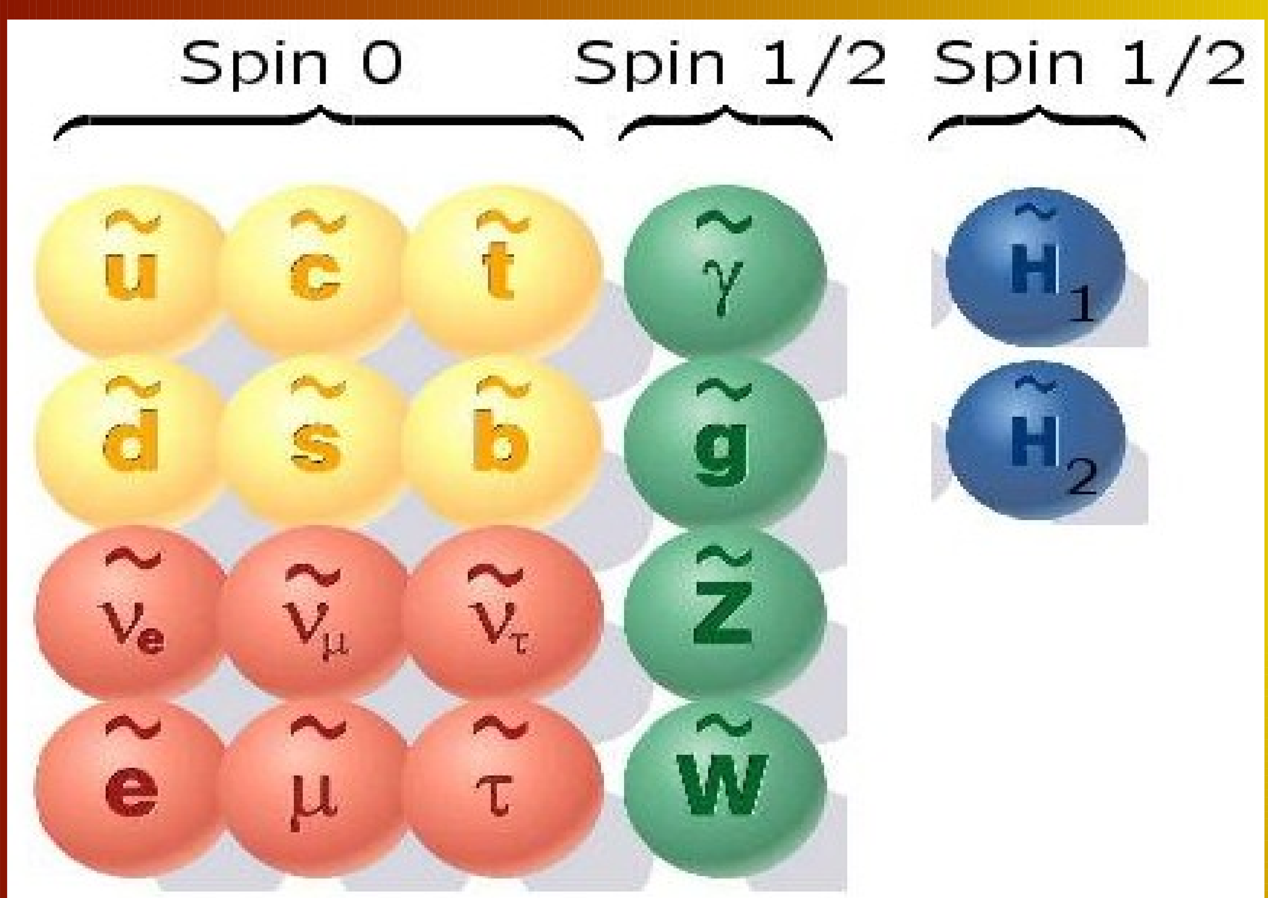
SUPERSYMMETRY AT THE ILC



The Standard Model is an extremely precise model of the particles in our Universe and their interactions. There are two types of particle – fermions and bosons. All of the matter around us is made up of fermions, like electrons and quarks. The bosons are responsible for carrying the three forces of the Standard Model: electromagnetism, the strong force and the weak force.

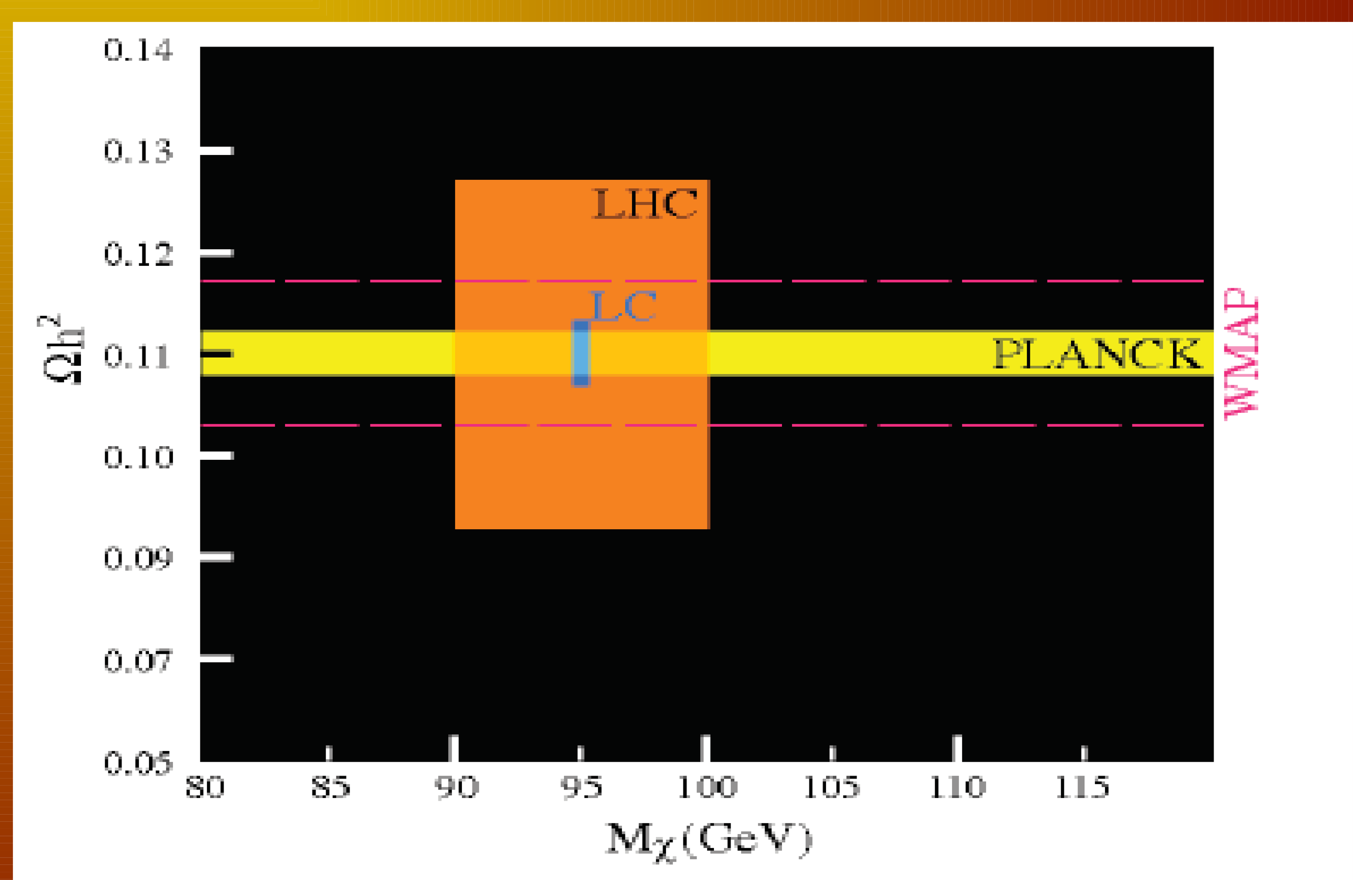


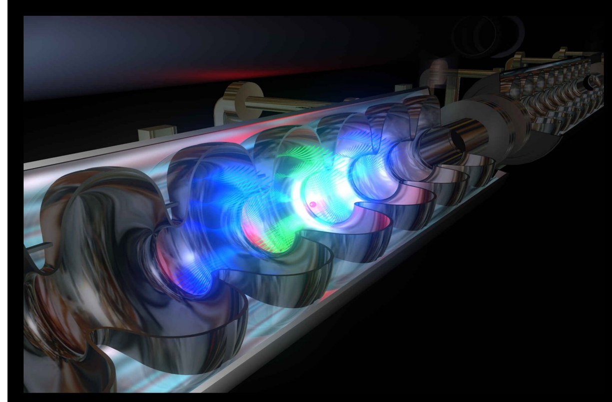
Despite its many triumphs, there are some problems with the Standard Model. For example, by studying the cosmic microwave background, and the rotation curves of galaxies, astronomers have determined that there is far more mass in the Universe than can be accounted for by the normal 'shiny' matter that makes up stars and gas. Approximately a quarter of the Universe consists of dark matter, which isn't made up of any of the particles that are included in the Standard Model.



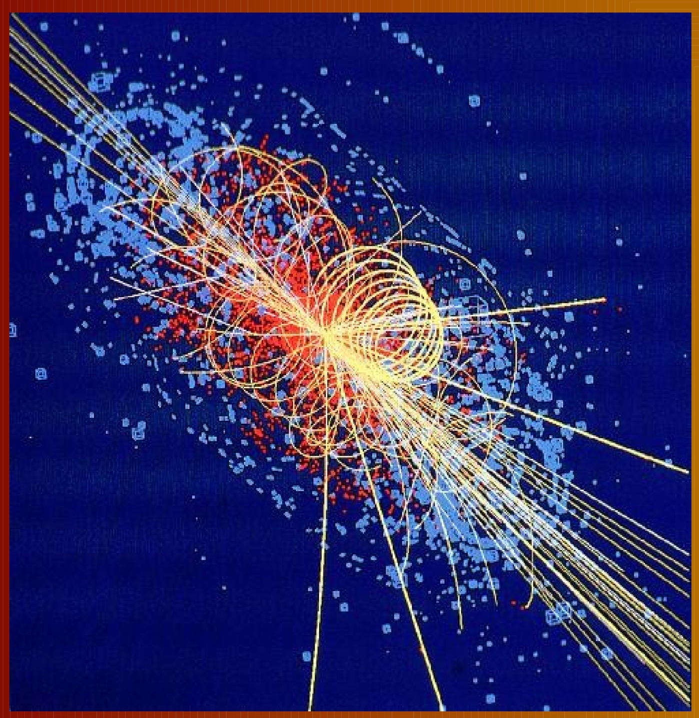
Supersymmetry is a way of directly relating fermions and bosons. The theory postulates that every particle in the standard model has a supersymmetric partner of the opposite type: for every Standard Model fermion, there is a corresponding supersymmetric boson, and for every boson there is a corresponding fermion.

The lightest supersymmetric particle provides an ideal candidate for dark matter. Precise measurements are needed to verify whether the properties of the lightest particle are consistent with cosmological data. The ILC will give us the chance to discover and study supersymmetry in depth, allowing the most precise measurements of supersymmetric particles.



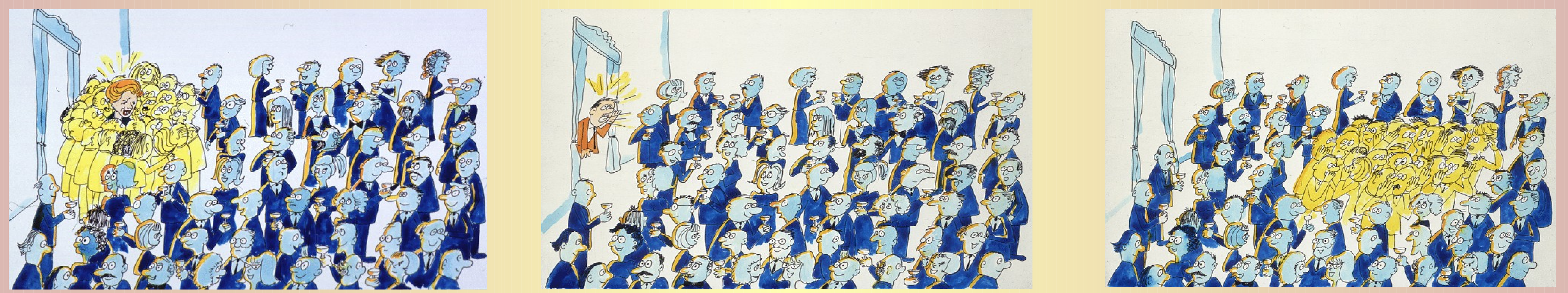


THE HIGGS BOSON AT THE ILC

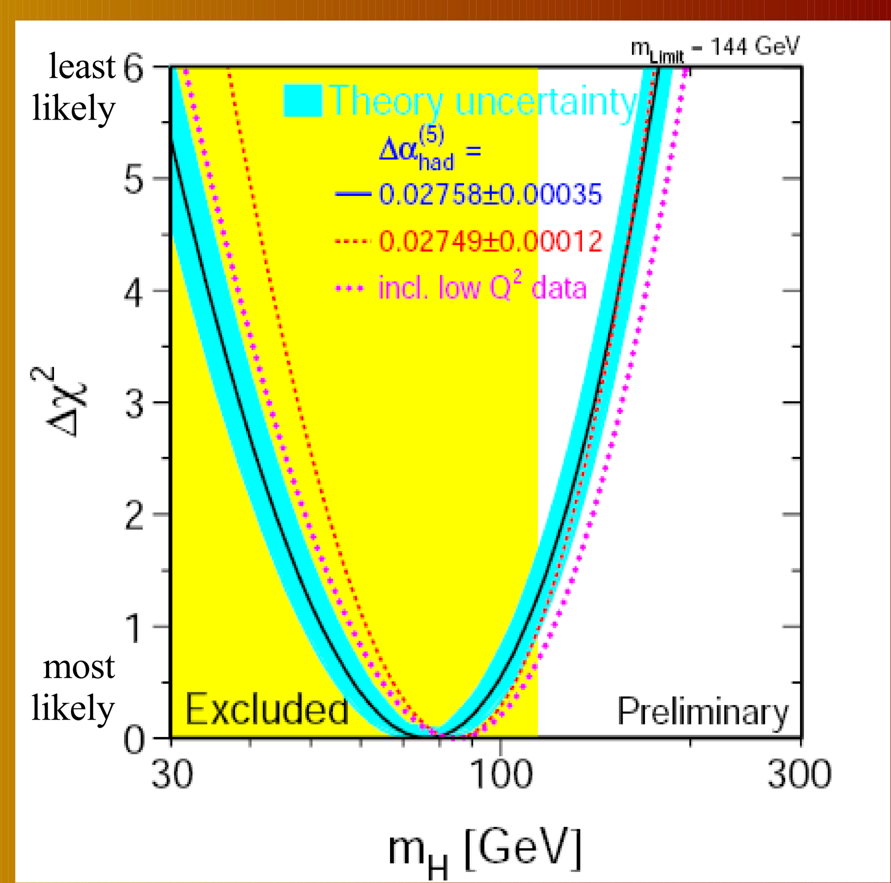


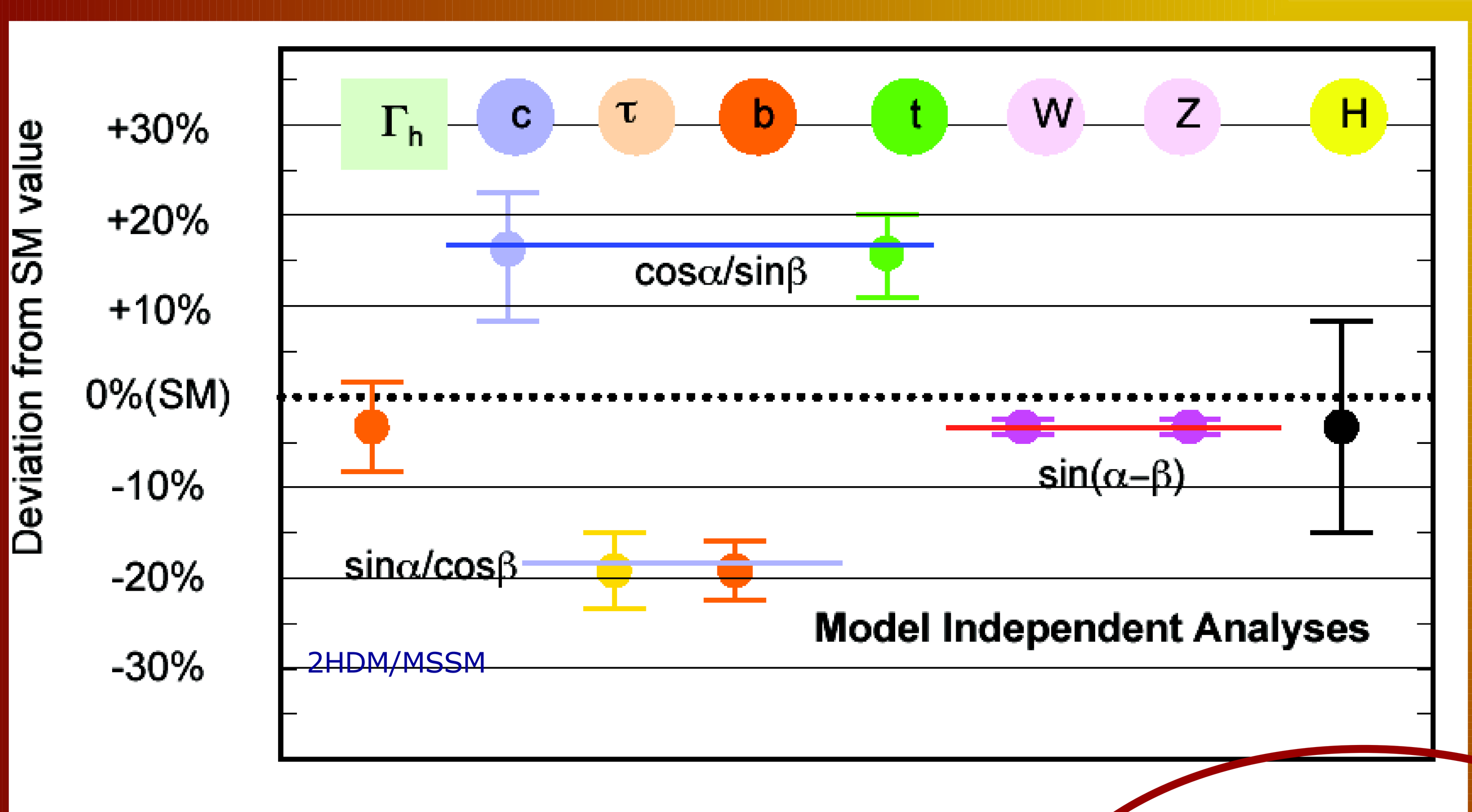
In 1964, Peter Higgs suggested the existence of a new field (now called the Higgs field) to explain why particles have mass. The Higgs mechanism explains mass by saying that the Universe is filled with the Higgs field. Interacting with the Higgs field gives the particles mass.

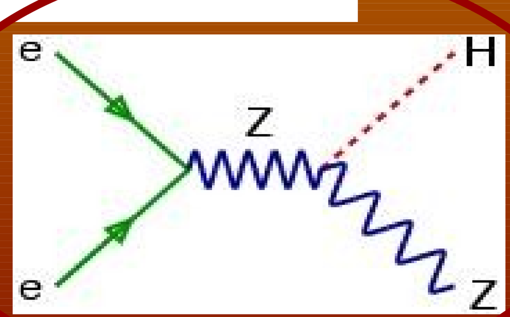
The Higgs boson would be experimental evidence of the Higgs mechanism. The Higgs field doesn't just interact with particles – it also interacts with itself. This self-interaction is the Higgs boson, see following story (by David J. Miller):
1. The Higgs mechanism: imagine the vacuum as a form of a cocktail party of political workers, uniformly spread across the room. A beloved ex prime-minister enters and is immediately surrounded by well-wishers. The cluster of admirers gives her extra mass, i.e. more inertia; just as an electron acquires extra mass from the lattice in a semiconductor; or the W and Z from the Higgs field in vacuum. **2. The Higgs Boson:** Now a scandalous rumour is launched into the party. The partygoers clump to transmit the rumour, just as they clumped around the ex-leaderine. Similar "dilaton" effects occur in solids. The clump can travel like a particle. In the vacuum such a clump in the Higgs field is a Higgs boson. It has spin=0.



Although we haven't yet directly detected a Higgs boson, there is a vast amount of indirect evidence that its mass is within the kinematic range to be seen at the LHC and ILC. In order to understand the origin of mass we need to measure its mass and couplings with high precision. The ILC will be able to make these precision measurements and to establish uniquely the Higgs mechanism. It will even be possible to verify whether it behaves like a Standard Model Higgs boson or whether it points to new physics beyond the Standard Model, such as Supersymmetry.



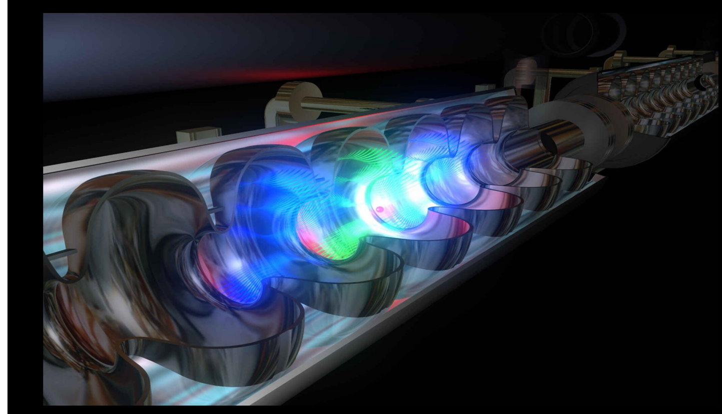




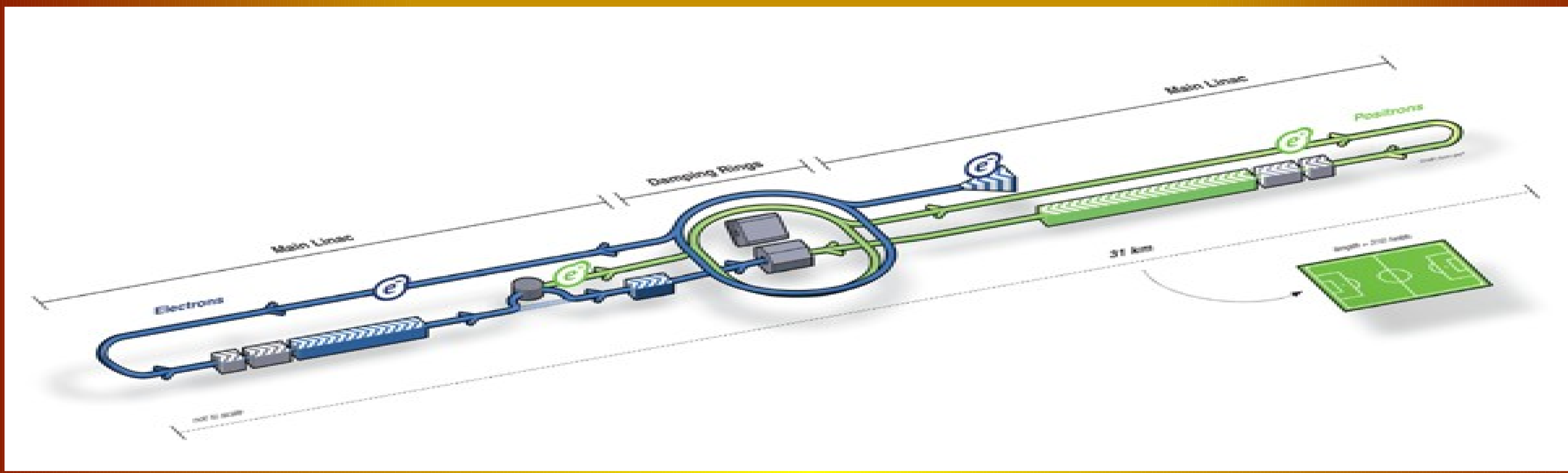
At the ILC, we will be able to make a decay-mode-independent observation of the properties of the Higgs boson to incredible precision. For instance,

* Mass (to within 50MeV)
* Absolute couplings (to within 1-5 %)
* Total width
* Self coupling (to within ~20%)

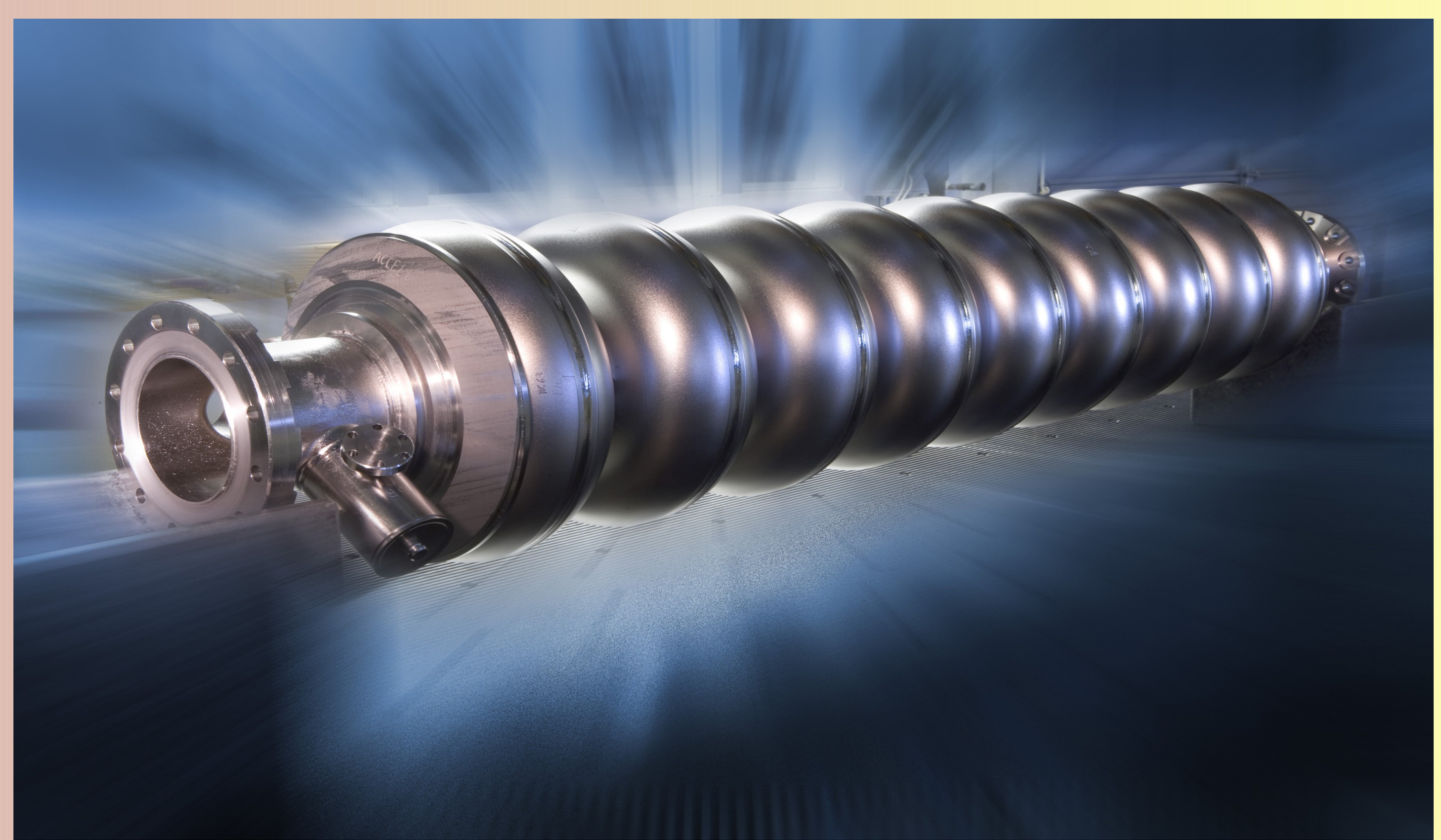
The International Linear Collider at UCL : http://www.hep.ucl.ac.uk/lc



THE INTERNATIONAL LINEAR COLLIDER

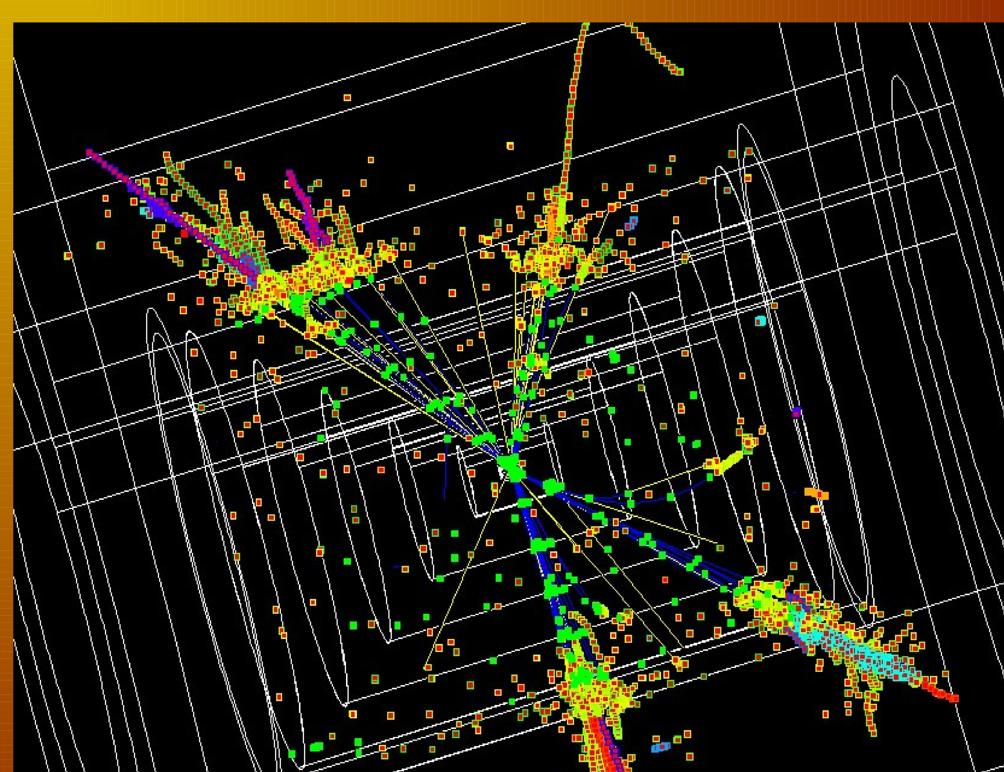


At 31km in length, the **ILC** will be the largest and also the most complex accelerator ever built. Besides the main linacs, damping rings with a circumference of 6 km for electrons and positrons are needed to produce the high quality beam required at interaction point. Physicists from all over the world participate in its design, but it is not yet known where the machine will be built.



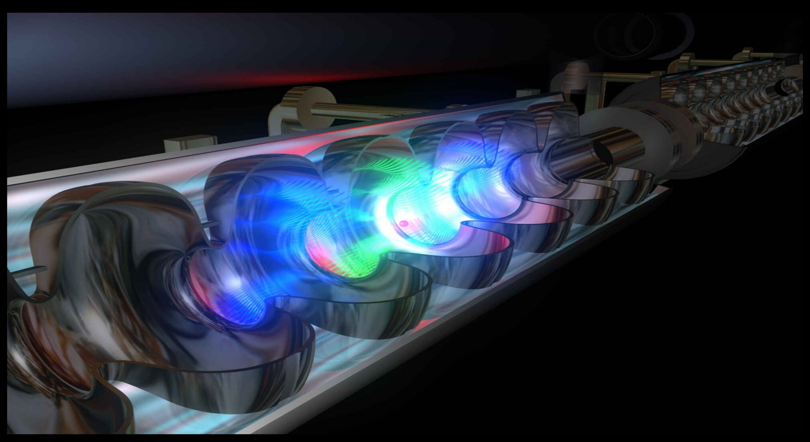
The ILC proposes 250 GeV (ugrade: 500 GeV) beams at a luminosity of over 10^{34}. That is ten times more energetic and corresponds to a hundred times more interactions per second than the SLC at SLAC. The main linac consists chiefly of superconducting acceleration structures with an acceleration gradient of 31MeV per metre. The beam delivery system prepares the beam to be focused by a final quadrupole magnet to a vertical beam size of 5 nm. This ensures a high e^+e^- interaction rate since unlike circular colliders non-interacting electrons are lost. Every second 5 trains of 3000 bunches of electrons and positrons will be sent to interact in the middle of the detector.

The ILC includes study of Higgs, SUSY or any other new phenomena. Precision achieved at ILC will allow for model independent observation of Higgs and will study in detail the mass generation mechanism of the Standard Model. If SUSY exists in Nature, ILC can determine its symmetry breaking mechanism and precisely measure properties of accessible supersymmetrical particles



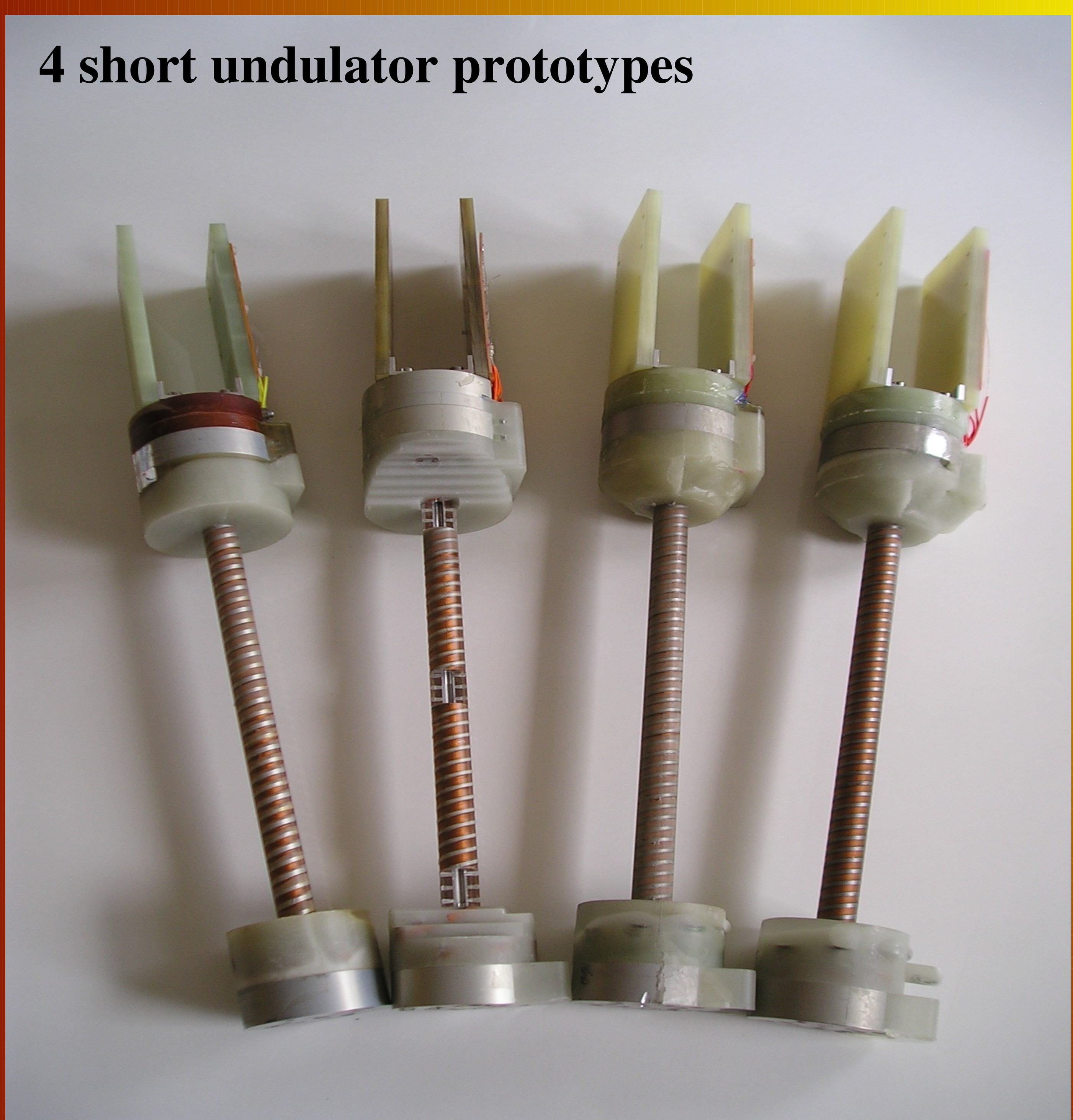
The International Linear Collider at UCL : `http://www.hep.ucl.ac.uk/lc`

POLARISED POSITRONS AT THE ILC



The International Linear Collider will collide electrons and positrons at high energy. One of the major technological challenges will be to produce positrons at the required rate of 100,000,000,000,000 per second.

A number of solutions were proposed, including a European suggestion to use an undulator-based design for the positron source. This design also has the extra characteristic of being able to produce polarised positrons. A UK-led collaboration showed that using a polarised beam would significantly increase the scientific reach of the ILC, which led to the undulator-based design becoming the international favourite.



4 short undulator prototypes

Working with the polarised beam requires many additional theoretical and technical advances, and the UK is currently world-leading in this field. Now that the UK is no longer in the collaboration, there is a danger that the idea of using polarised beams will be dropped, which would reduce the amount of science the ILC is able to do.

More physics information:

http://www.ippp.dur.ac.uk/~gudrid/source/

The International Linear Collider at UCL : `http://www.hep.ucl.ac.uk/lc`