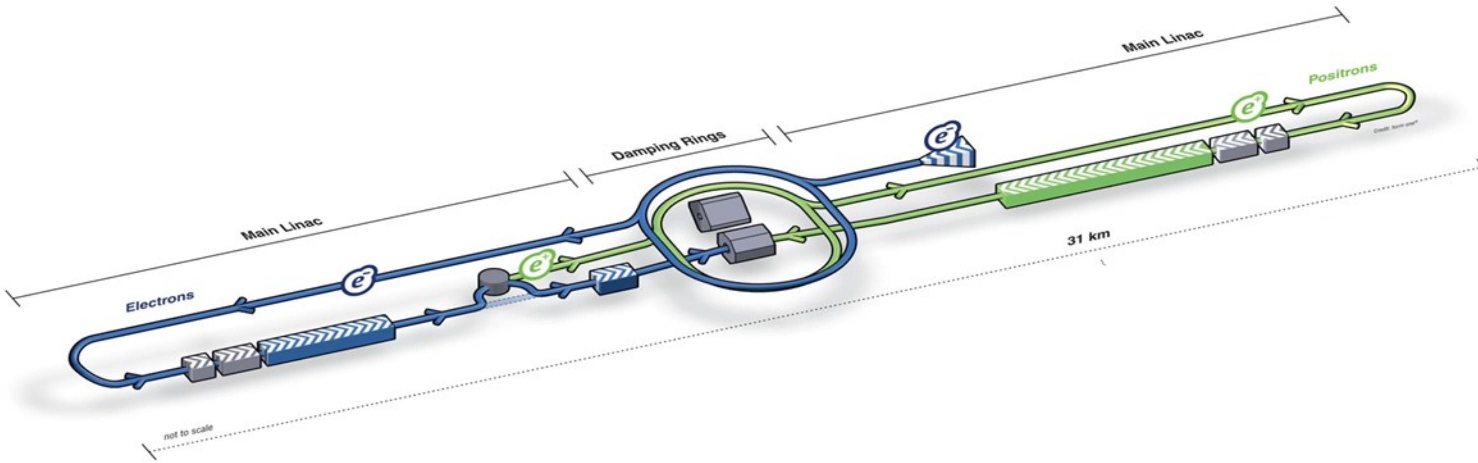
ILC: Physics and Detectors
Electron positron collisions

Ties Behnke, DESY

ILC: The Collider



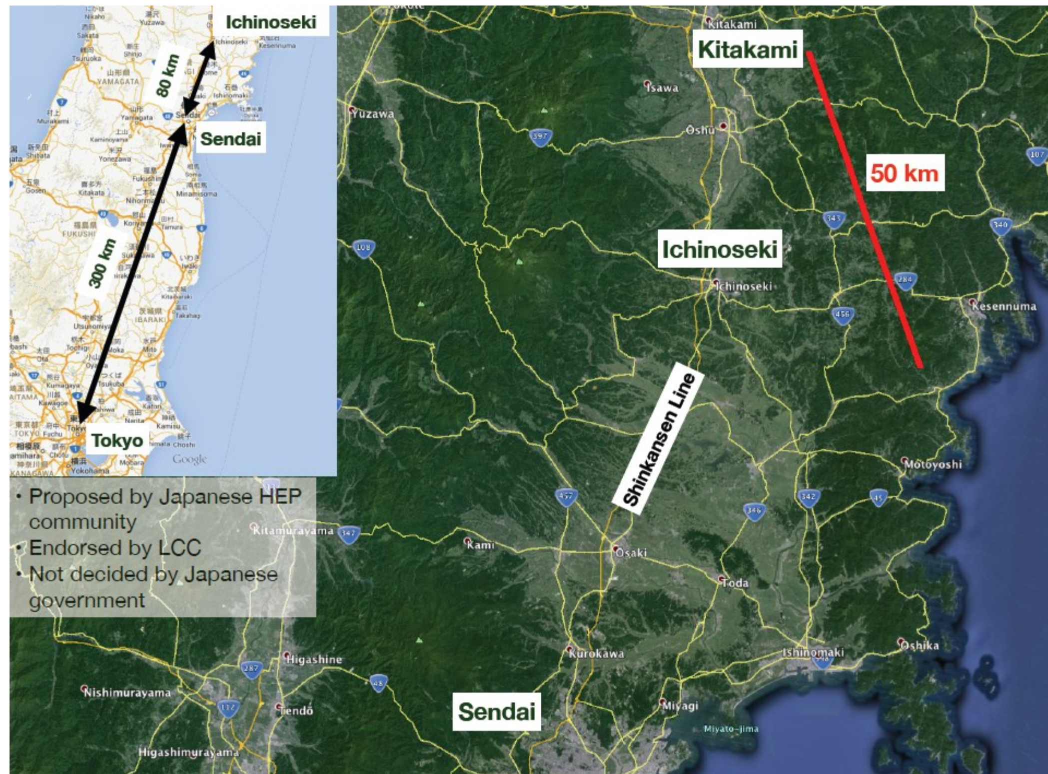
- 500 GeV collider, electrons positrons, upgradable to 1 TeV
- High luminosity
- Proven technology (XFEL is build using the same technology)

The ILC and Japan

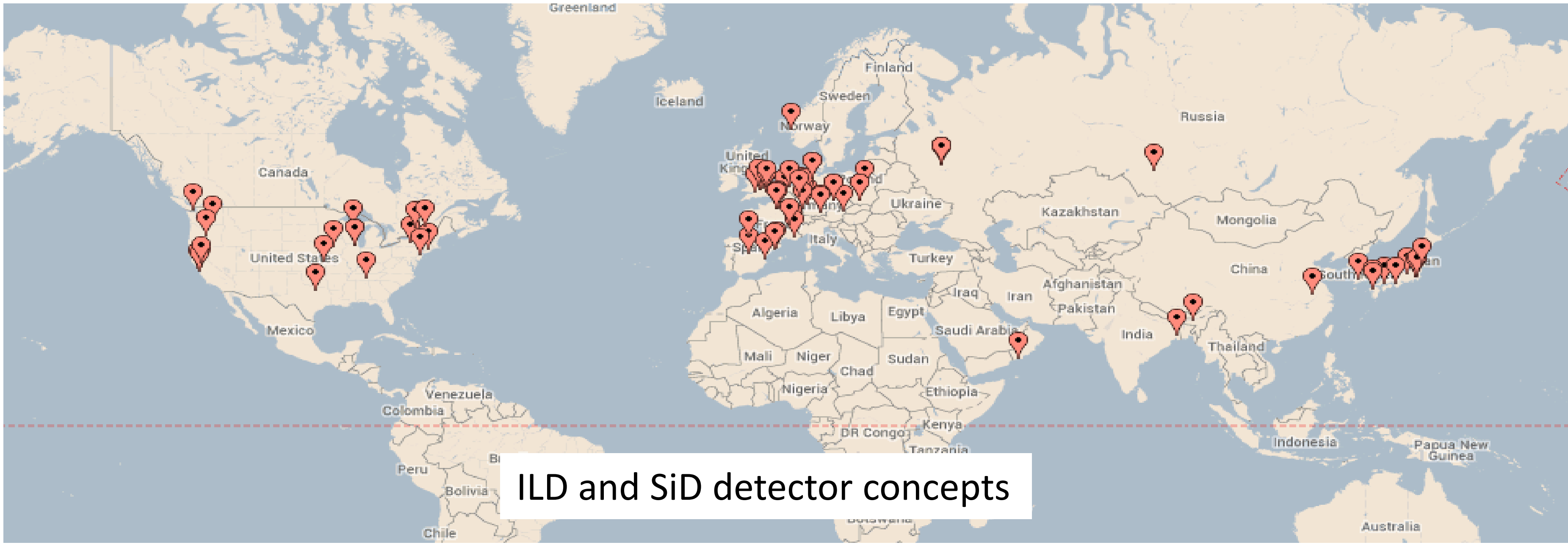
Japanese community has expressed a strong desire to host the ILC in Japan.

Evaluation by MEXT ongoing.

Site in the north of Japan
proposed by community
no official decision



The Physics and Detector Community

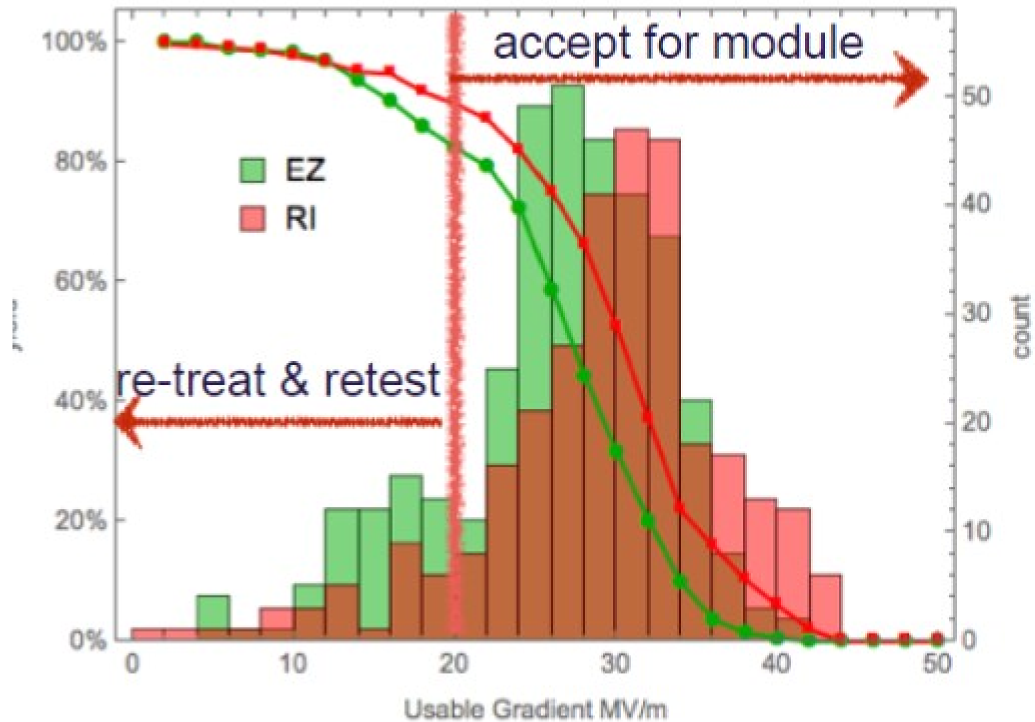


ILD and SiD detector concepts

ILC Technology

Superconducting RF:

Technology well proven,
Used by E-XFEL very
sucessfully



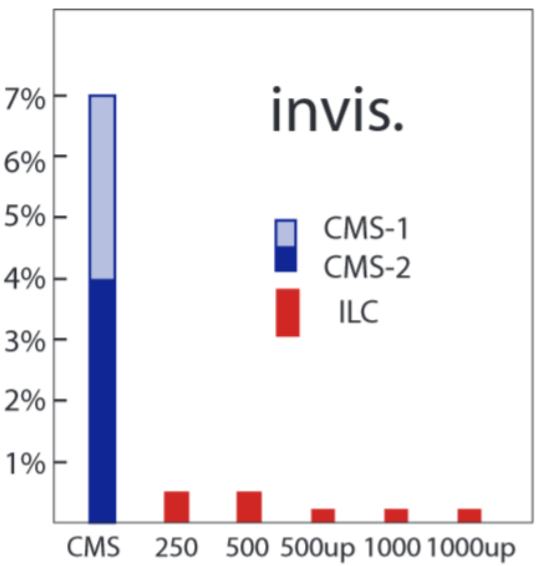
Yield (gradient) of cavities
produced for the XFEL

ILC goal: 35MV/ m

After the Higgs Discovery

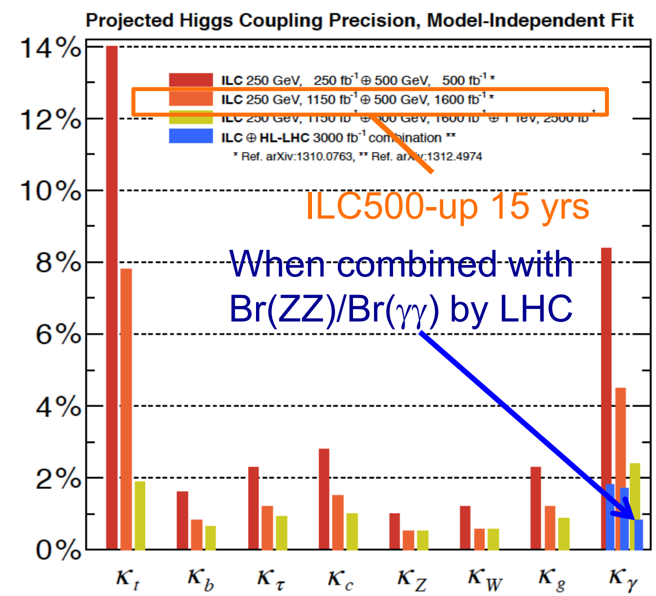
The discovery of the Higgs changes our view of the microscopic world.

The Higgs becomes a tool for the exploration of the microcosm.



%-level precision:

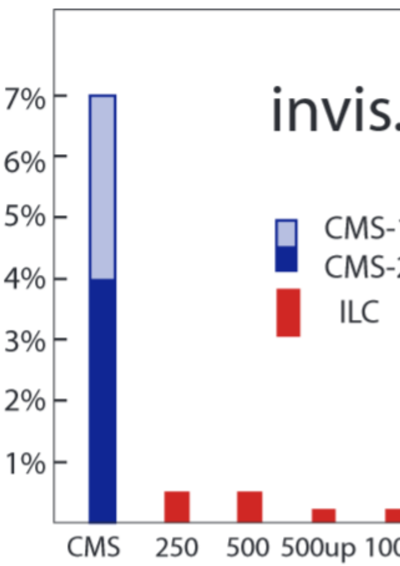
Sensitivity to
non – Standard Model
physics and effects.

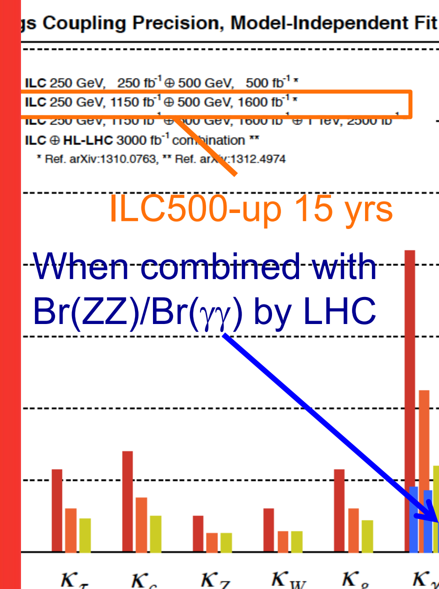


Aft ery

The discovery of t world.

The Higgs becom





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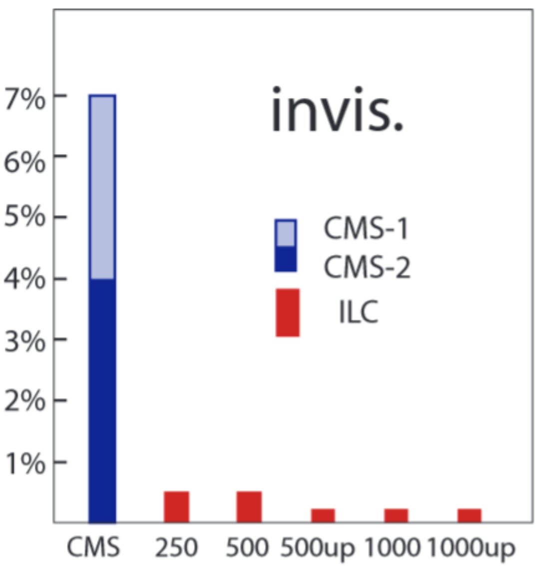

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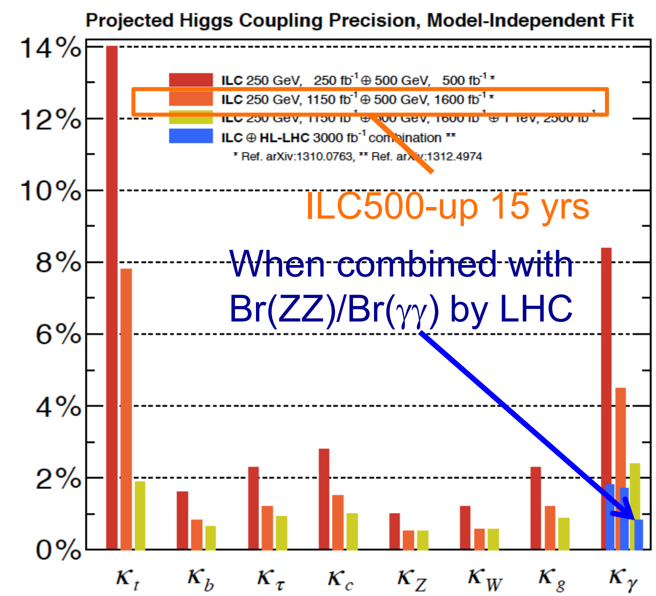
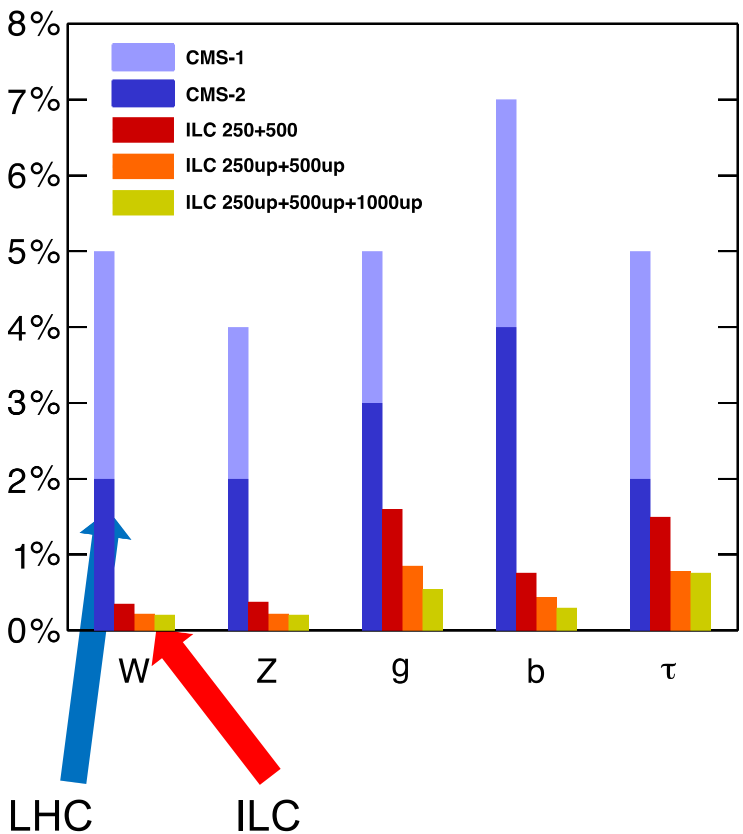
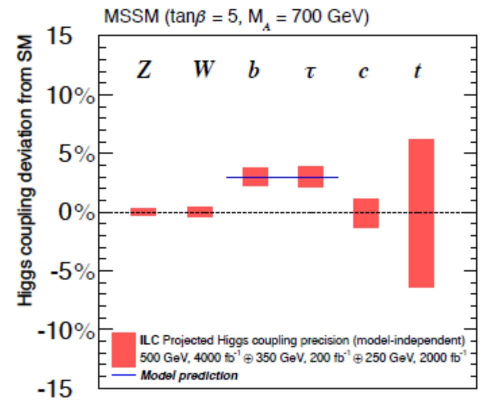
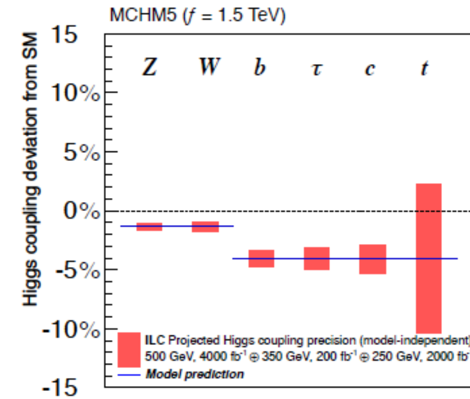


Comparison to the LHC





MSSM



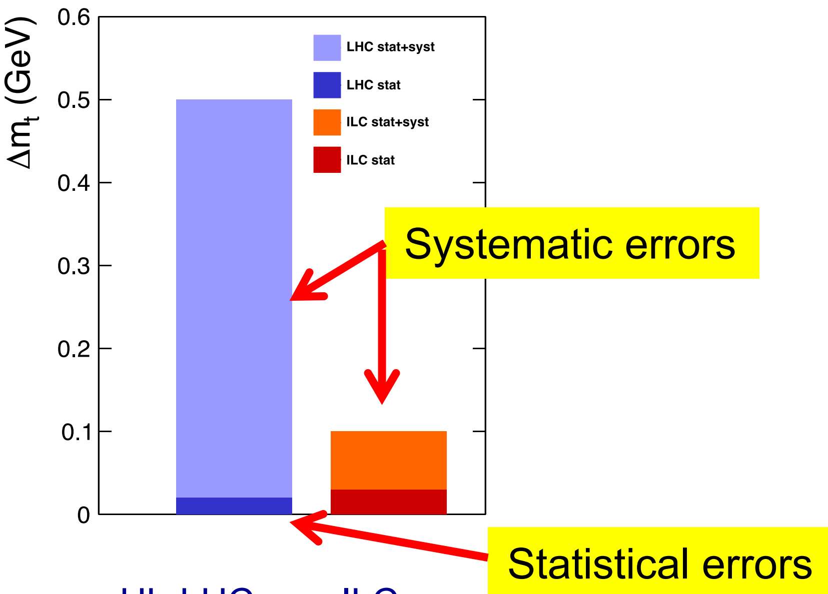
Composite Higgs

Precision enables us to use the Higgs as a tool for the search for new phenomena

The top

Utilize precision to explore unknown territories

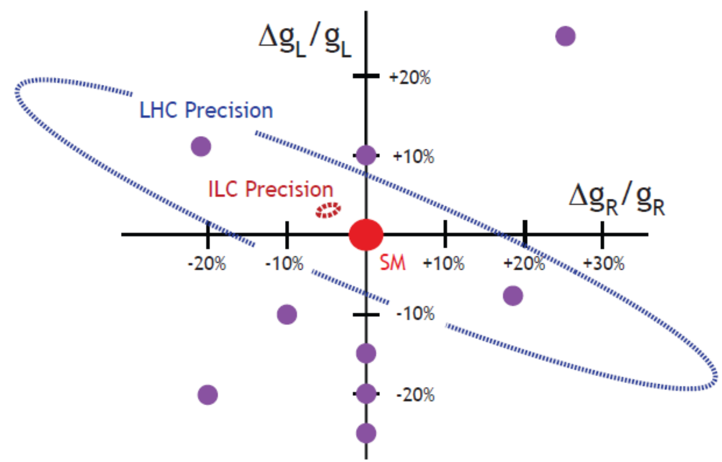
Top quark mass (MSbar)
(@350 GeV)



HL-LHC	ILC
3000 fb-1	100 fb-1
$\sqrt{s}$=14 TeV	$\sqrt{s}$=350 GeV

e+e- → t tbar (@500 GeV)

Right-handed e- does not couple to W^0
Use polarization to separate Z and γ
in S-channel



top-Z coupling

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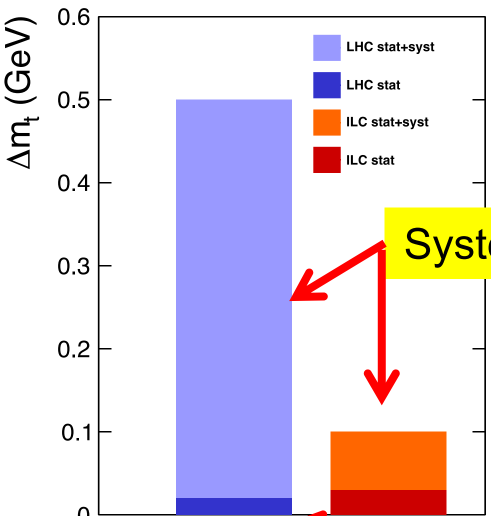

Systematic errors

Statistical errors

HL-LHC	ILC
3000 fb-1	100 fb-1
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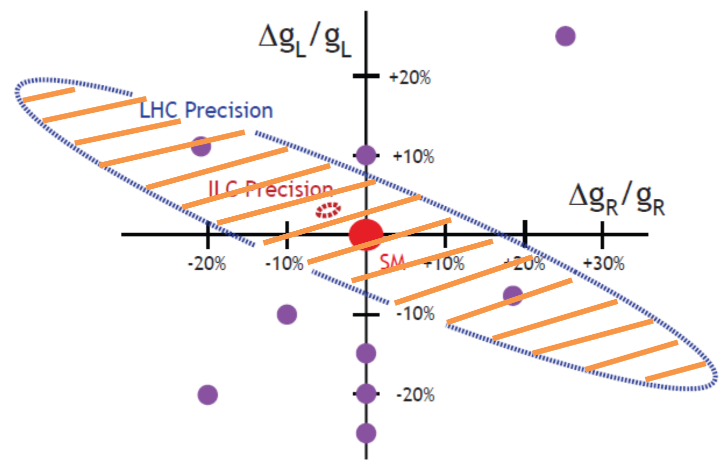

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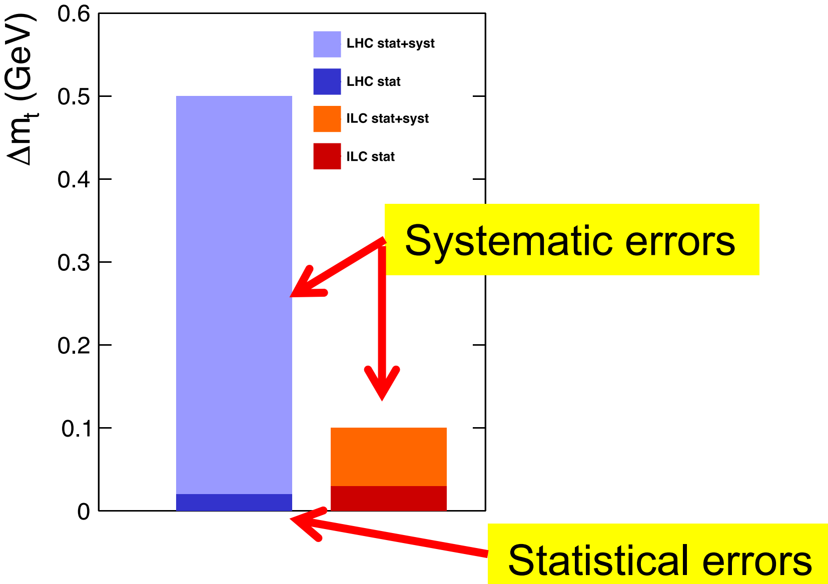

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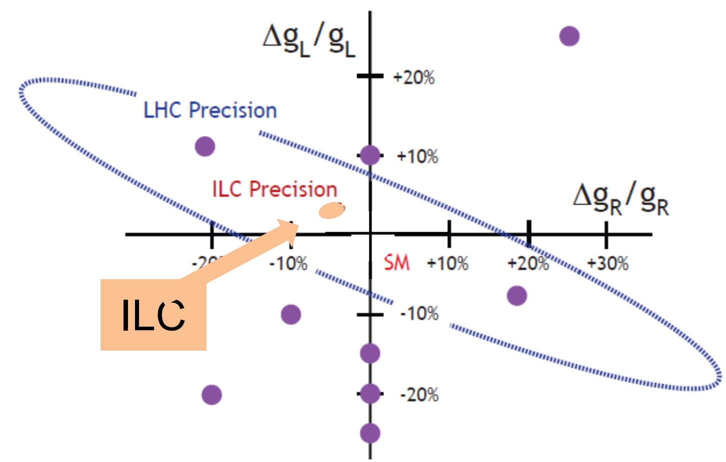


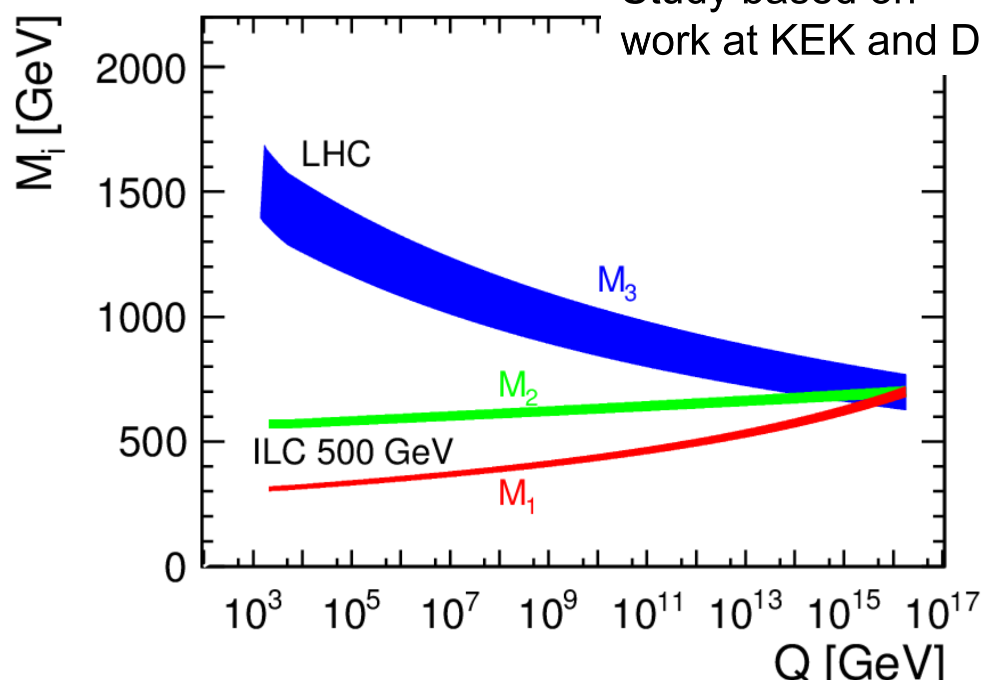
top-Z coupling

The ILC as a Telescope

- The Higgs has defined the electroweak breaking scale and model

- The Higgs tells us that
  this is not the end of the story

Study based on
work at KEK and DESY



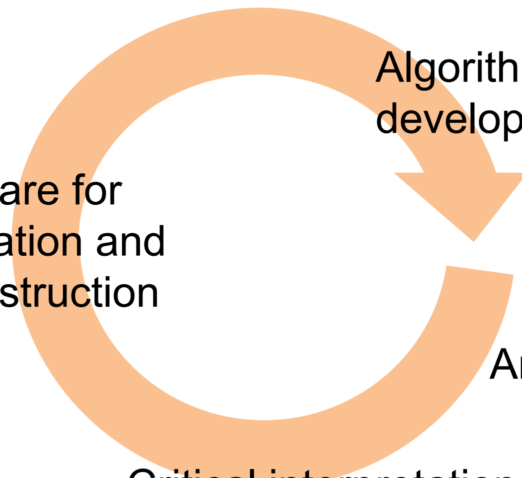
Ultimate Goal:
Unification of all forces.

Requires:
- New physics phenomena
- Excellent precision
- Long–range extrapolation

Making the Science Case for the ILC

International working group led by Michael Peskin from SLAC

Strong participation from people from KEK and DESY in all steps of the process



About
10 PhD theses
over the last 3 years

European Strategy

Update of the European strategy, decision by CERN council May 30, 2013

There is a strong scientific case for an electron-positron collider, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded. The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation. The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate. Europe looks forward to a proposal from Japan to discuss a possible participation.

US strategy makes very similar choices.
Asian strategy has identical direction.

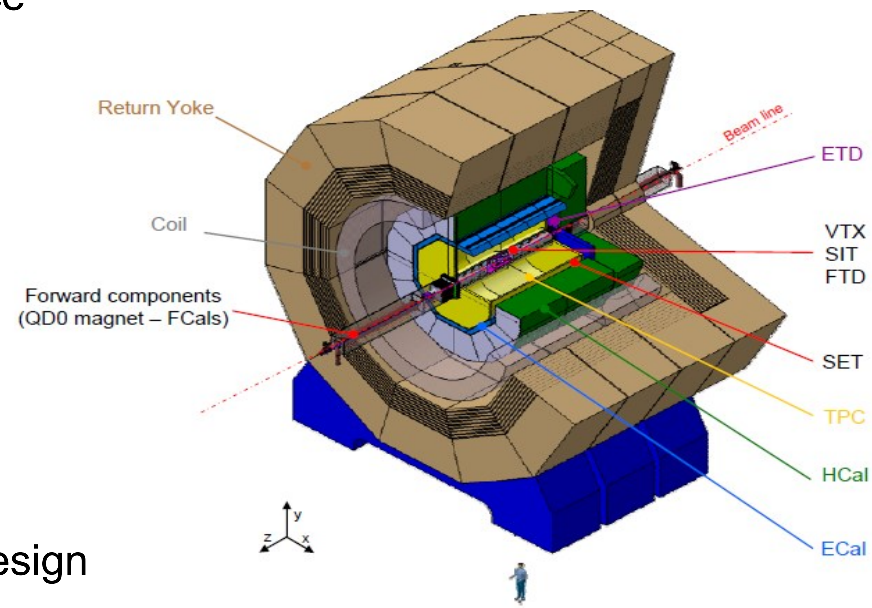
A Detector for the ILC

Requirement from Science

Find / develop technologies
to meet the requirements

Validate the technologies

Integrate technologies
into a coherent detector design



The Concept

Precision measurements
of decays and particle properties

Precision measurement of
event properties

Vertexing, tracking, particle ID

Energies, jets, charged particles

Extreme precision
Vertex (pixel) detectors

Imaging calorimeters

Particle flow combined
excellent tracker/ Vertex

Vertex Detector Technologies

Fine pixel CCD detectors:

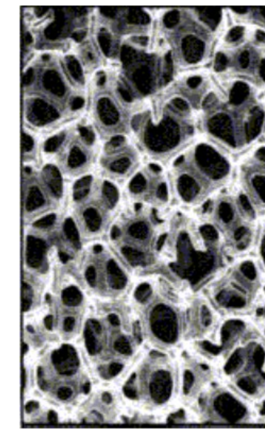
- Go to very small pixels (O(5 um)^2)
- Very large number of cells
- Excellent spatial resolution
- Very robust against background

First real size ladder, thinned to 50um
KEK group (Y. Sugimoto)

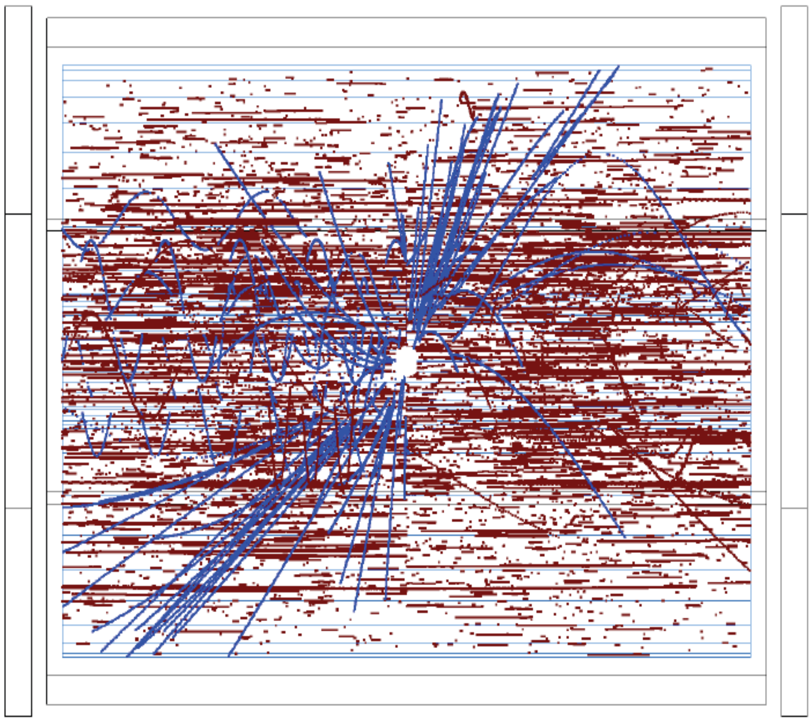
PLUME

Collaboration to develop thin CMOS based VTX detectors

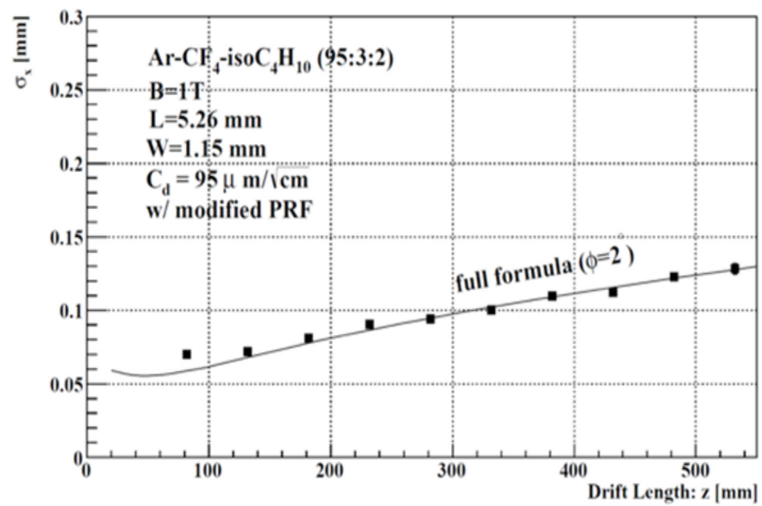
Cooperation DESY/ Strassbourg/ Bristol



Time Projection Chamber

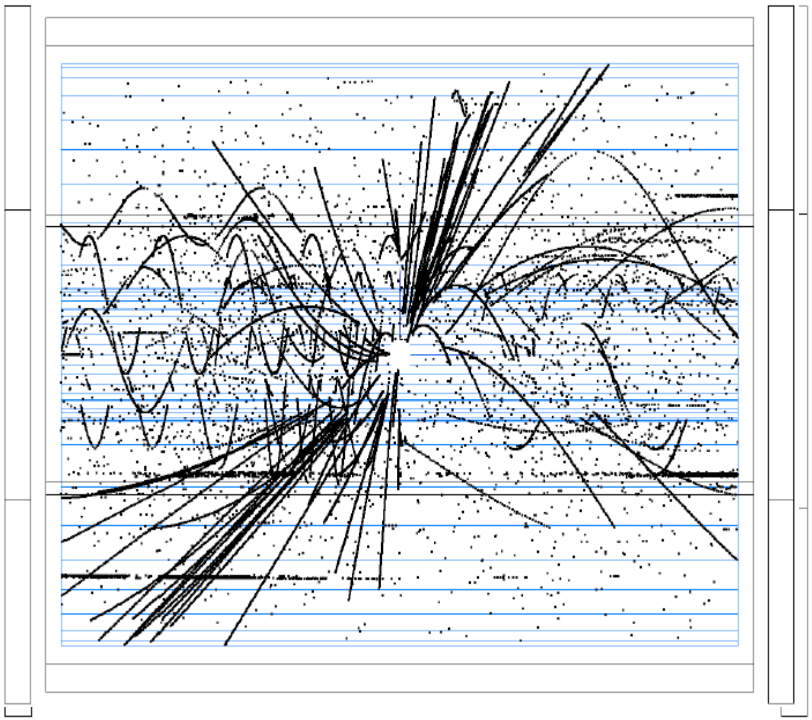


- 220 space points
- Resolution <100um (60 um asymptotic) in r-Φ
- Resolution ~1mm in z



Powerful, stable basis for pattern recognition and track reconstruction.

Time Projection Chamber



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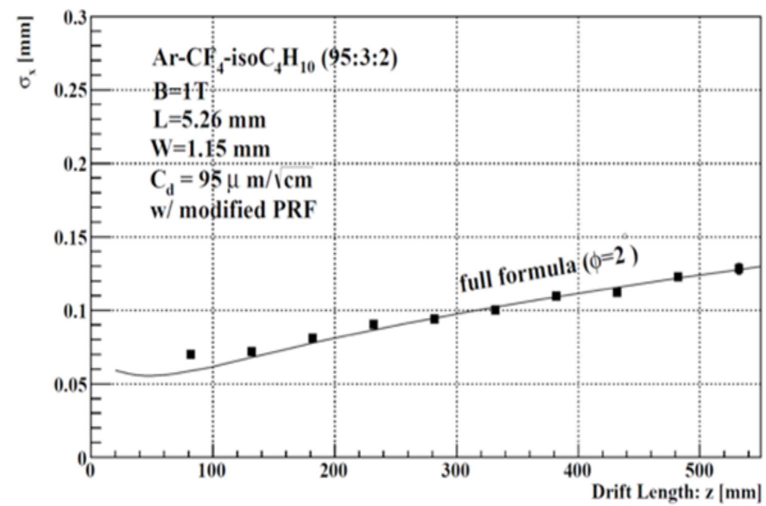

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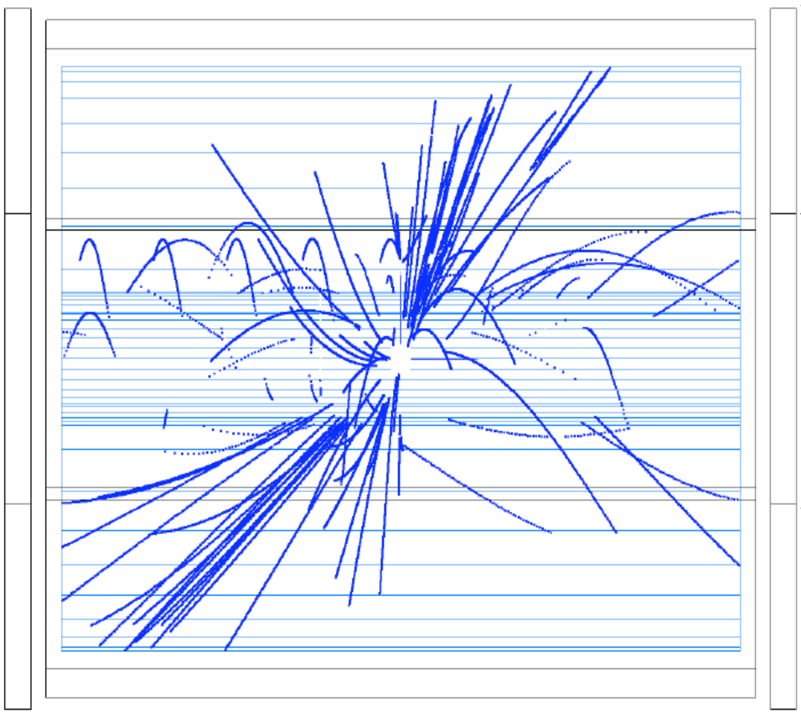

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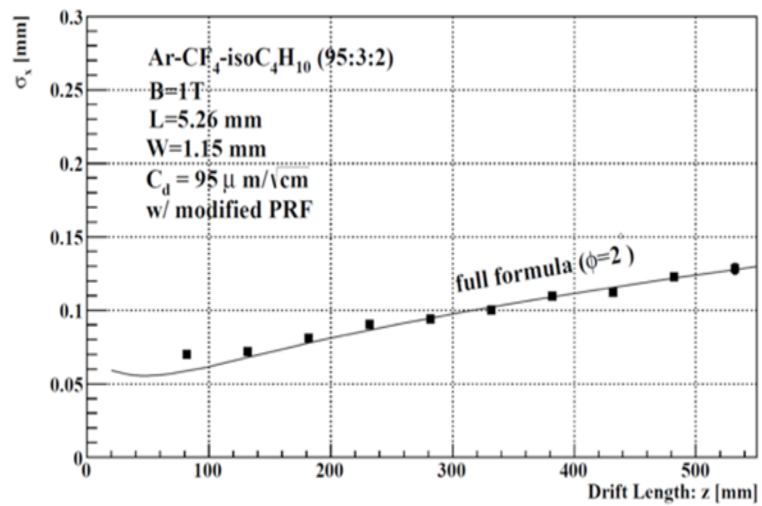


Powerful, stable basis for pattern recognition and track reconstruction.

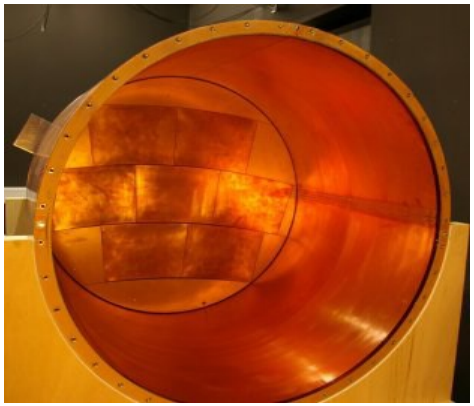
The Prototype TPC

Goal: develop a TPC with excellent spatial resolution and good particle ID capability: Factor 10 better than current systems

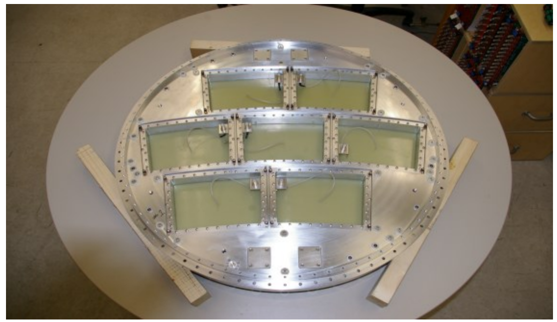
- Driven by requirements from the ILC physics program
- Interesting for other applications

Bonn, CEA, Carlton, Cornell, DESY, KEK, NIKHEF, others

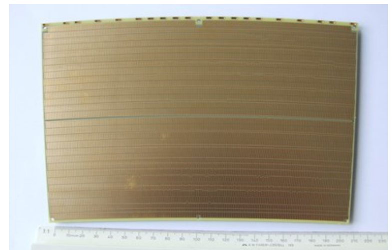
Components of a TPC



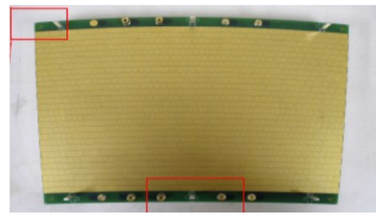
Field cage



Endplate



DESY



KEK

Readout Module

See talk by H. Graafsma parallel session

Shared Infrastructure between DESY and KEK

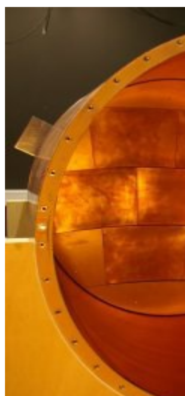
LCTPC

The Prototype TPC

Goal: develop a TPC
particle ID capabilit

- Driven by requir
- Interesting for o

Components of a TPC

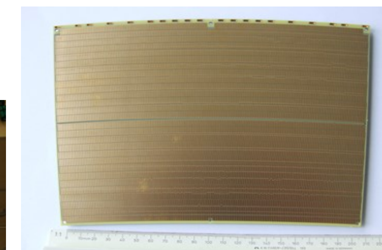


Fie

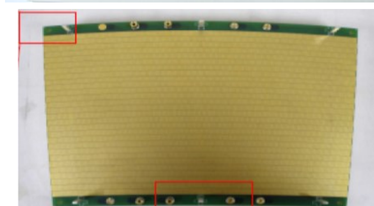
Share

See talk by H. Graafsma parallel session

Bonn, CEA, Carlton, Cornell, DESY, KEK, NIKHEF, others



DESY

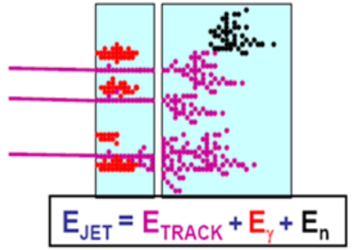


KEK

Readout Module

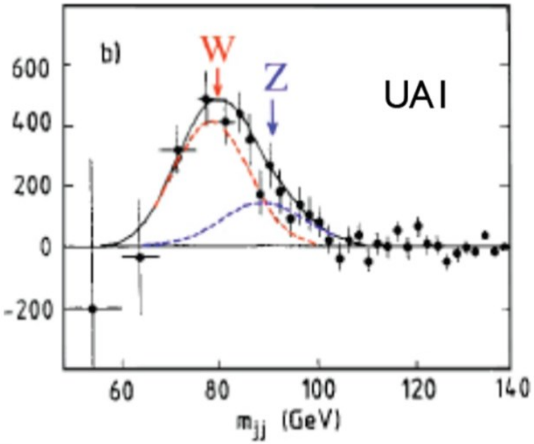
Particle Flow

Particle flow is the method of choice for high precision experiments at the ILC.
Requires significantly different calorimeters than previous experiments.

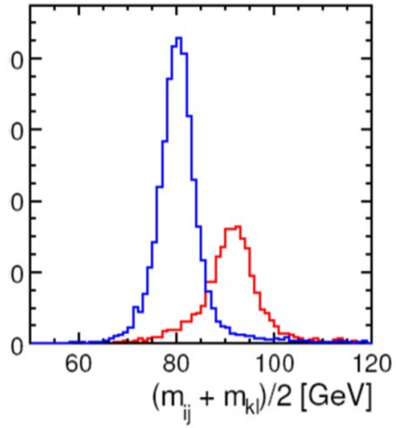


Complex final states (e.g. W/ Z)

Traditional approach



Particle Flow approach



Jet-jet mass resolution

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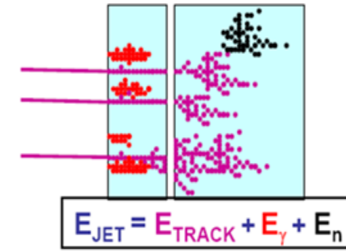

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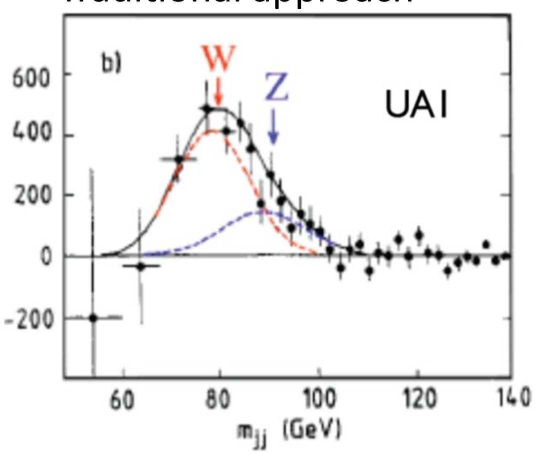

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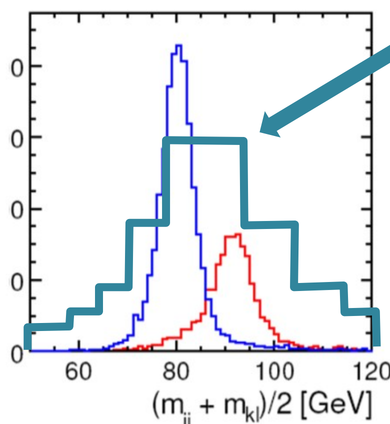
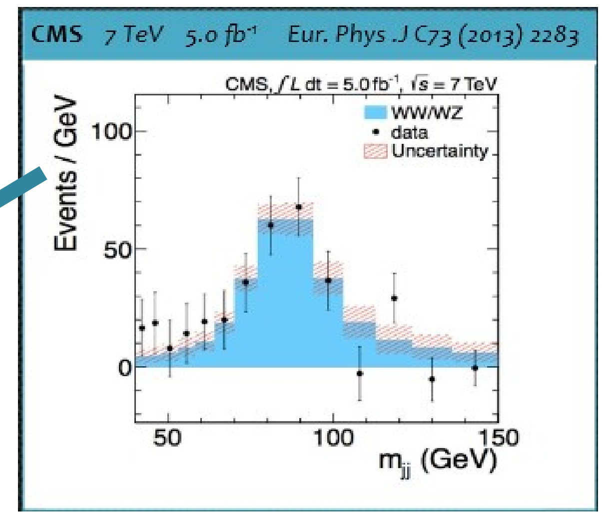


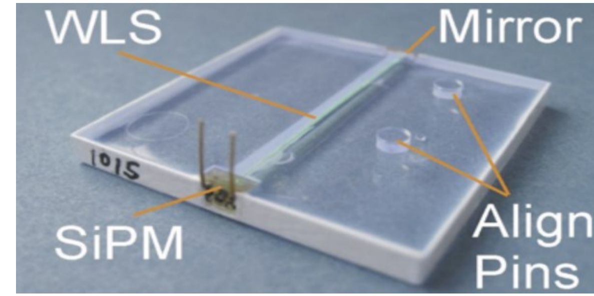


Jet-jet mass resolution

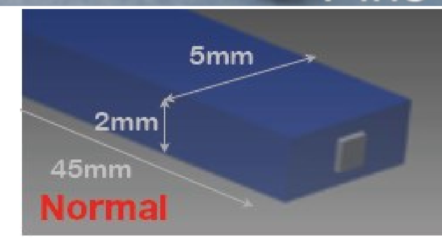
Particle-Flow Based Calorimetry

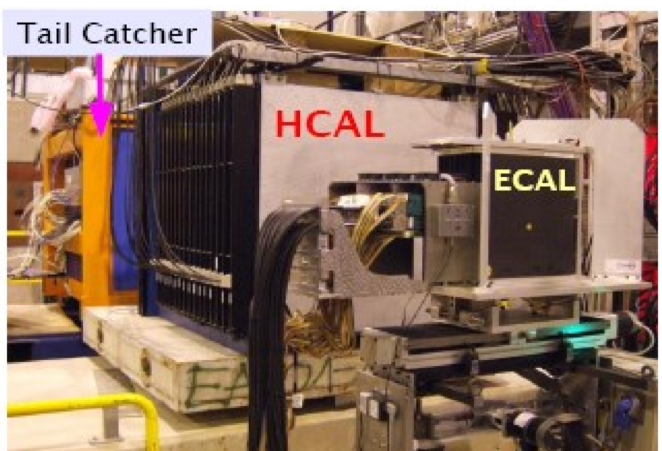
- Availablity of SiPM allows highly granular scintillator based designs
- HCAL: 3x3cm^2 segmentation of 3mm thick scintillator read out by SiPM through wavelength shifting fiber (Elimination of WLS under study)
- Software compensation (e/p ~1.2) technique was show to work well through beam tests: 58%/E$^{1/2}$ → 45%/E$^{1/2}$

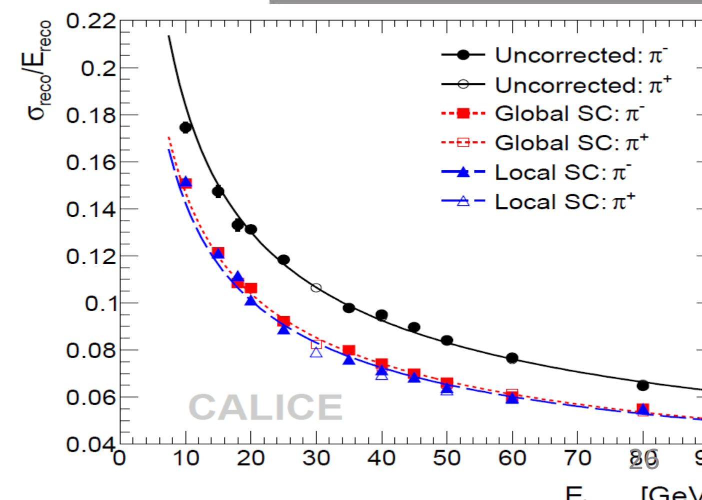
DESY HCAL



Japan ECAL







Particle Flow

Generic PFLOW algorithm developed within ILC

Has evolved into a general purpose software used by many experiments and groups

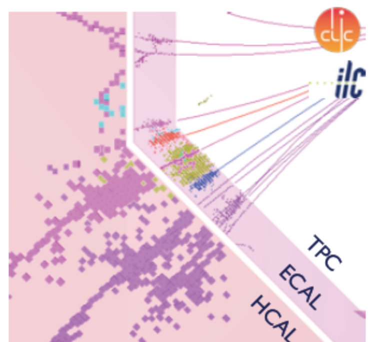
UNIVERSITY OF CAMBRIDGE

Pandora Particle Flow

iLCSoft

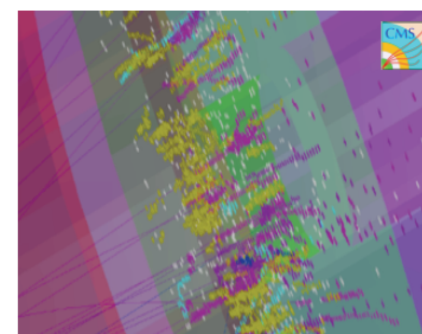
- **Pandora Software Development Kit:** aids multi-algorithm approach to pattern recognition, with advanced reclustering and recursion abilities and visualisation.
- Development of new client applications, enabling use of algorithms for different detector concepts and in different software frameworks.
- Development of pattern recognition for both LC (inc. LHC upgrade) and LAr TPC. Continued validation and exploitation of existing algorithms e.g. via detector optimisation studies.
- A lot of work ongoing!

ILC/CLIC event topology



Example LAr TPC event topology

Showers in CMS HGCAL



Current Pandora use-cases: ILC (NIMA.2009.09.009), CLIC (NIMA.2012.10.038), LAr TPC reco at DUNE/MicroBooNE (arXiv:1307.7335, 1506.05348) and CMS HGCAL upgrade (LHCC-P-008).

Particle Flow

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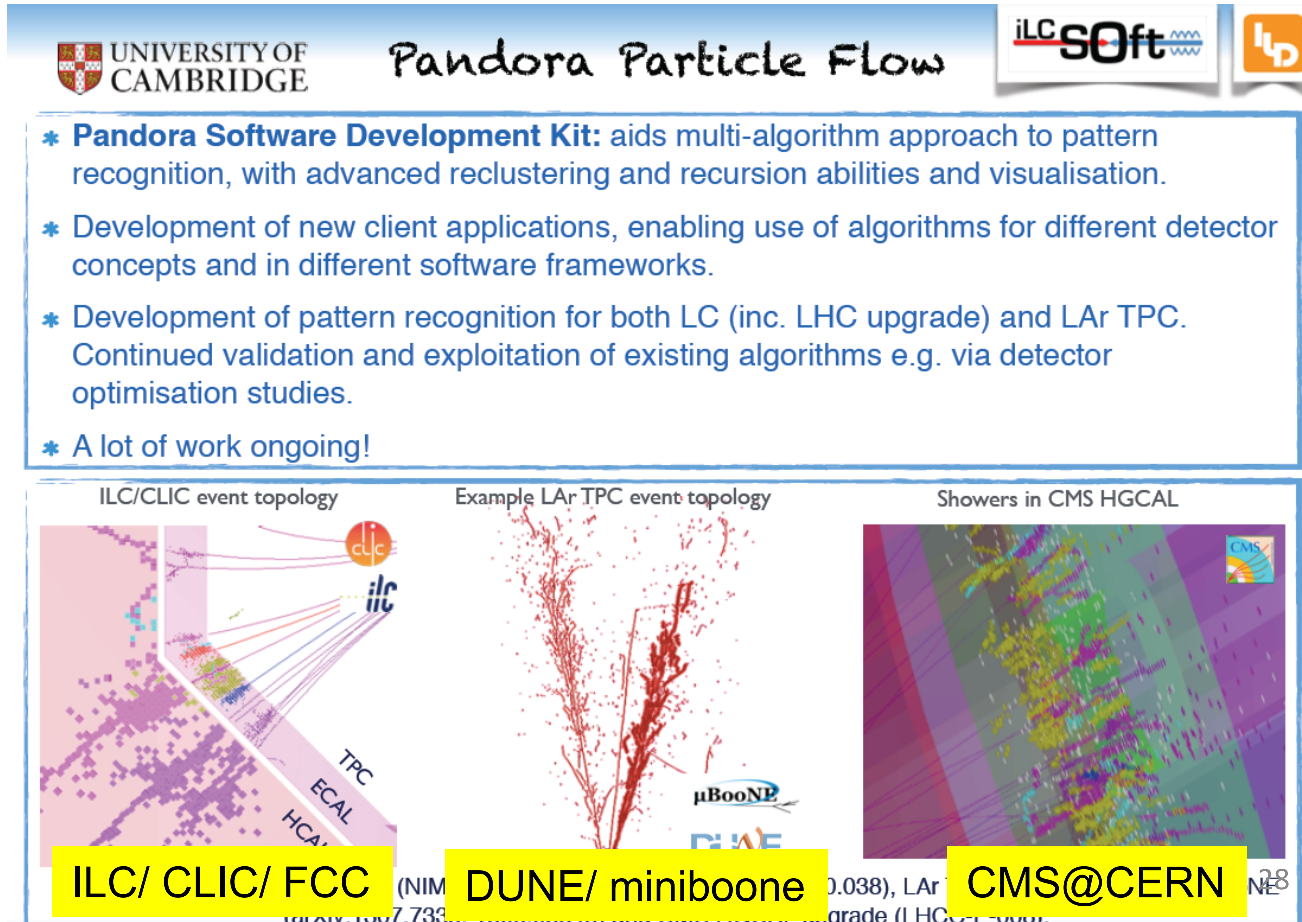
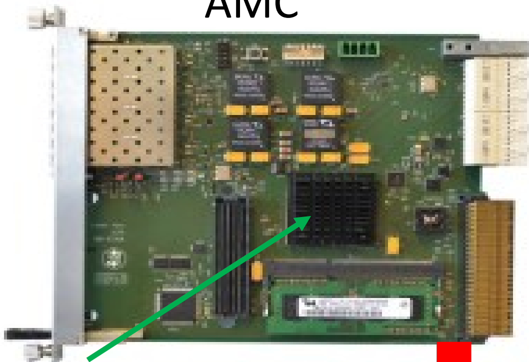
Has evolved into a general purpose software used by many experiments and groups



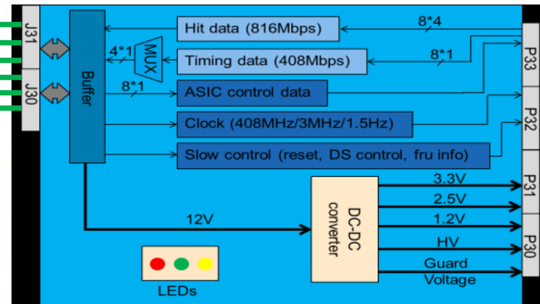
Fast Imager based on DSiPM

AMC

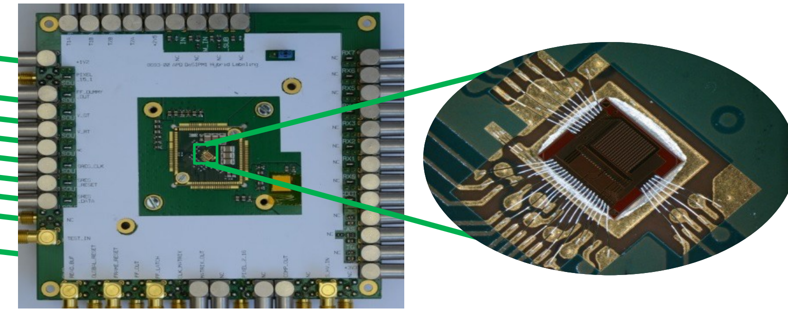


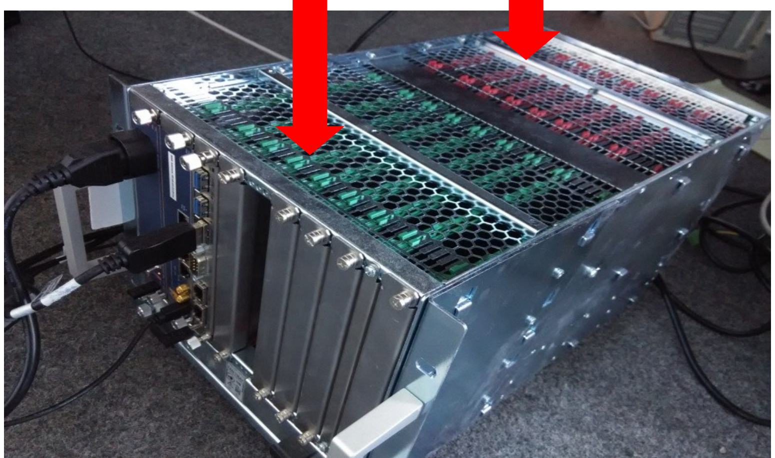
FPGA

RTM



ASIC





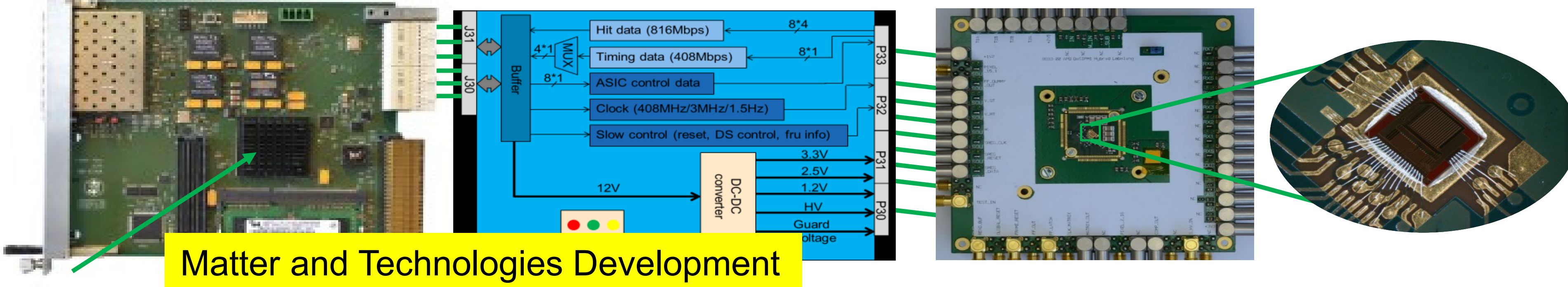
mTCA (power, cooling, …)

- 3MHz frame rate
- 50µm spatial resolution
- 100ps time resolution
- Compact and flexible
- Ultrafast particle tracking and Ultrafast single photon imaging

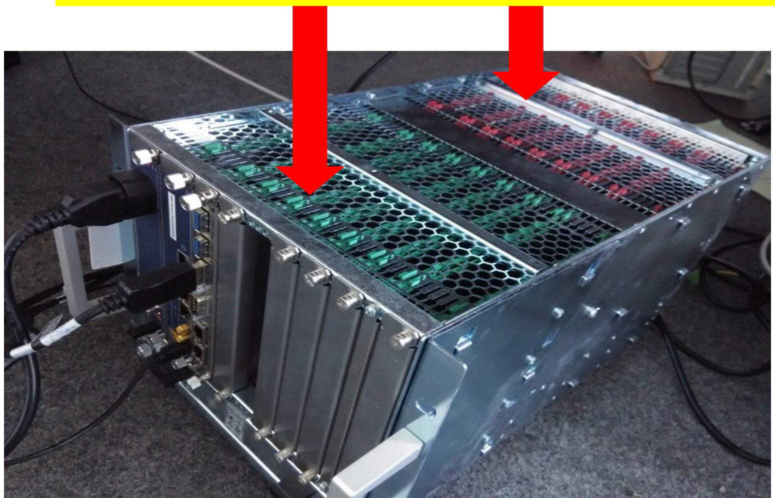
I.Diehl, K.Hansen, K.Krüger, F.Sefkow, X.Wang

Fast Imager based on DSiPM

AMC RTM ASIC



FPGA



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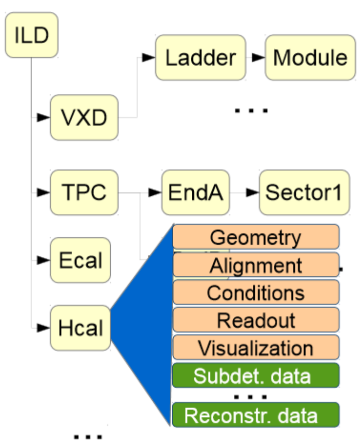
- Compact and flexible
- Ultrafast particle tracking and Ultrafast single photon imaging

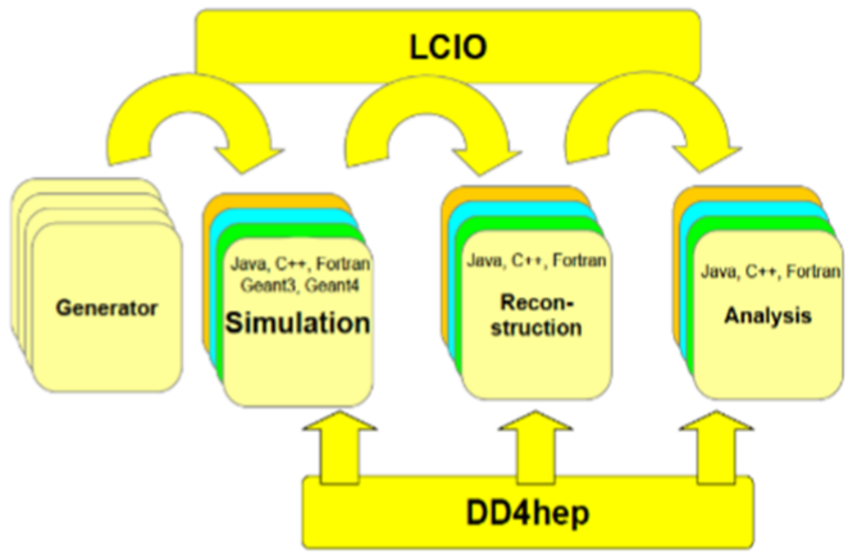
I.Diehl, K.Hansen, K.Krüger, F.Sefkow, X.Wang

Software

Powerful software is needed to study physics and experiments

DESY and KEK have joined forces in developing and maintaing this system.





Core Software framework:

DESY and KEK

Production software jobcontrol:

KEK and DESY

Work supported by the European Commission

Summary

A Electron Positron Collider is central to our field

ILC is the most mature option to realize this

Japan is considering hosting the ILC

KEK and DESY have been at the core of R&D towards ILC

KEK and DESY cooperate closely on physics and detector studies towards the ILC

We enjoy an excellent and close cooperation with our KEK (and other Japanese) colleagues.