Forschung mit Lepton-Collidern
Research with Lepton Colliders

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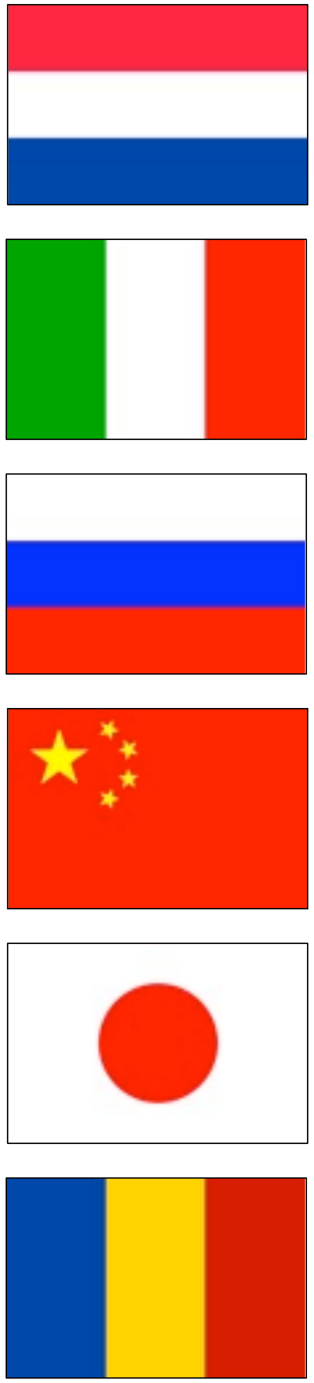
DESY, 24.08.2011

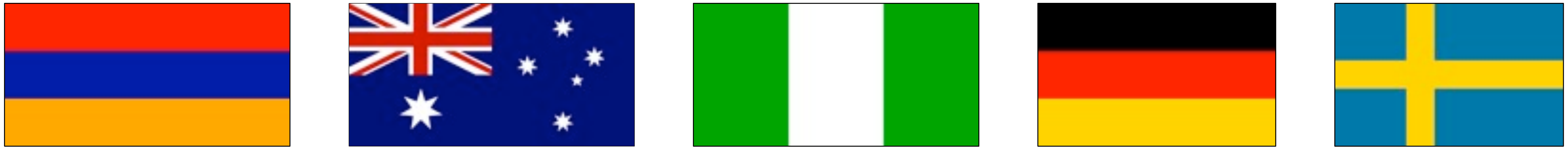
HELMHOLTZ GEMEINSCHAFT

DESY

The FLC Group



- Management:
  - Ties Behnke (group leader)
  - Felix Sefkow (deputy)
  - Andrea Schrader (administration)
- 4 Staff scientists
- ~5 Guest scientists
- 13 Postdocs and non-permanent scientific staff
- ~18 Students (PhD and diploma)
- 9 Technical staff (engineers, technicians, administrative)
- Strong links to University of Hamburg
  - Prof. Gudrid Moortgat-Pick and group
  - AvH Prof. Brian Foster and group



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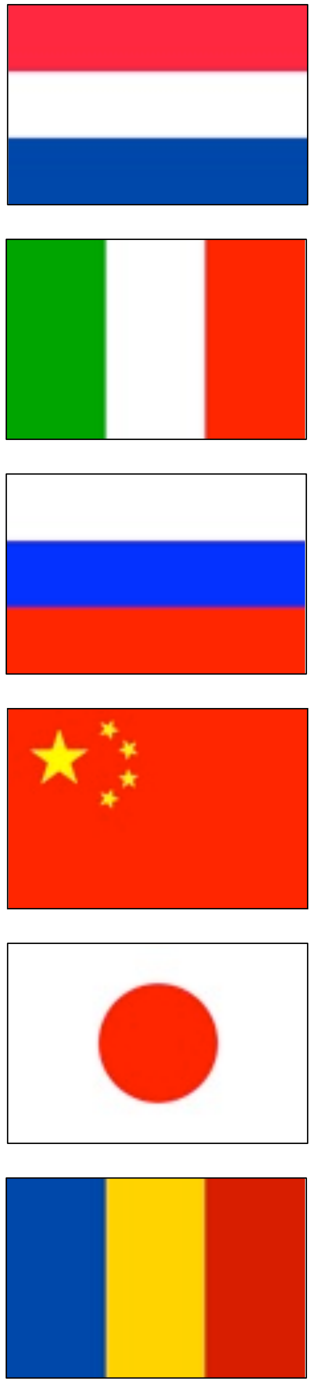
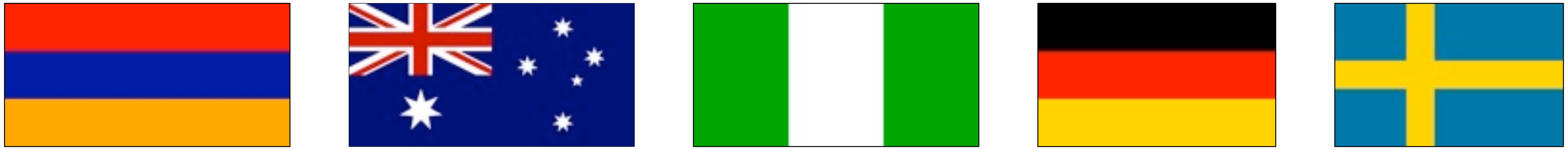
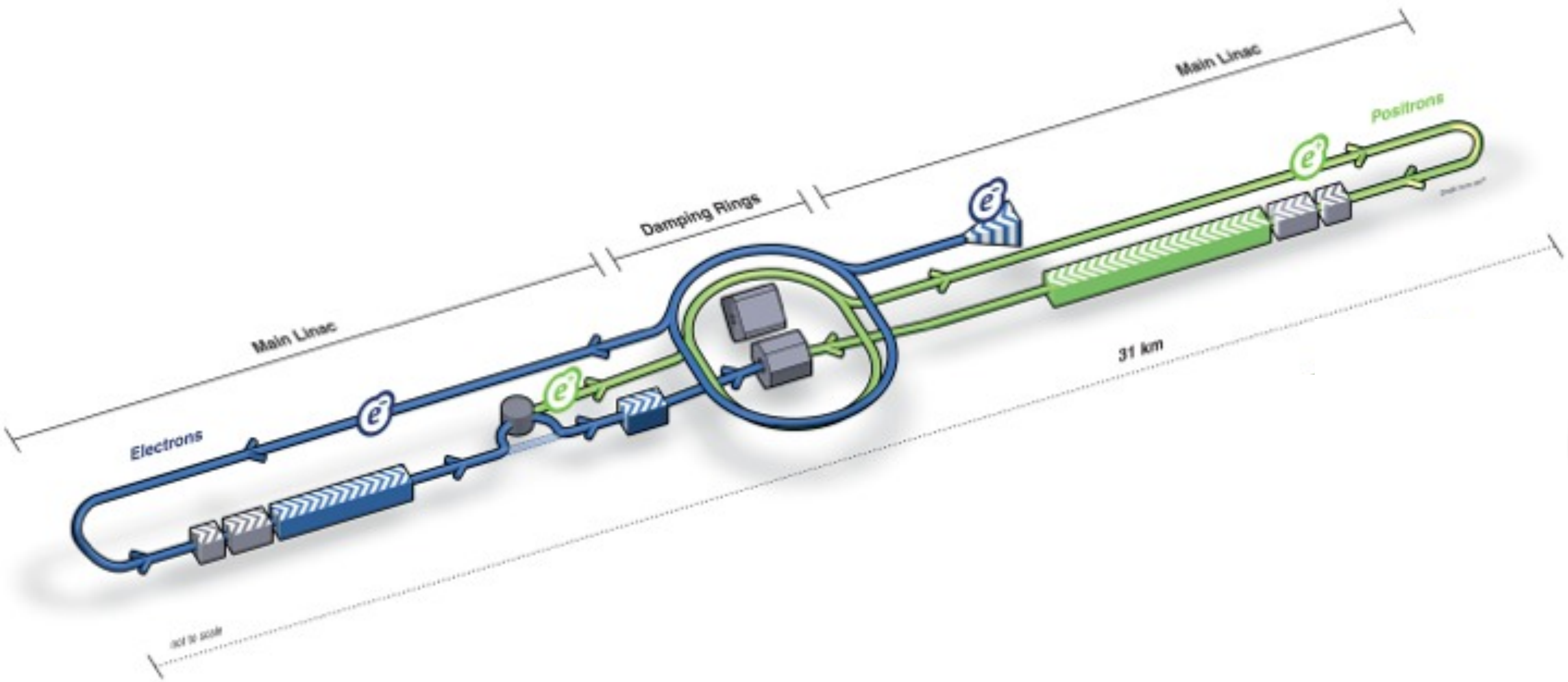
plus 7 summer students!





The FLC Group Objectives

- Physics studies and detector developments for a future linear electron-positron collider:
  - International Linear Collider
  - CLIC
- Group has its roots also in analysis of data from (formerly) existing lepton collider experiments (OPAL@LEP, H1@HERA)



Studies for a Future Linear Collider

> Detector developments:

- Design and optimisation of a detector concept for the ILC:
  the International Large Detector ILD

> Hardware developments for sub-detector components:

- Calorimetry: hadronic calorimeter for ILD
- Tracking: Time Projection Chamber for ILD
- Polarimetry: beam diagnostics and impact on physics
- Generic studies: tests and applications of novel photodetector for HEP experiments and medical applications

> Analysis activities:

- Optimisation of the ILD detector concept
- Physics studies of the ILC physics menu

> Engineering activities:

- Integration studies of the ILD detector
- Machine-Detector Interface for ILC

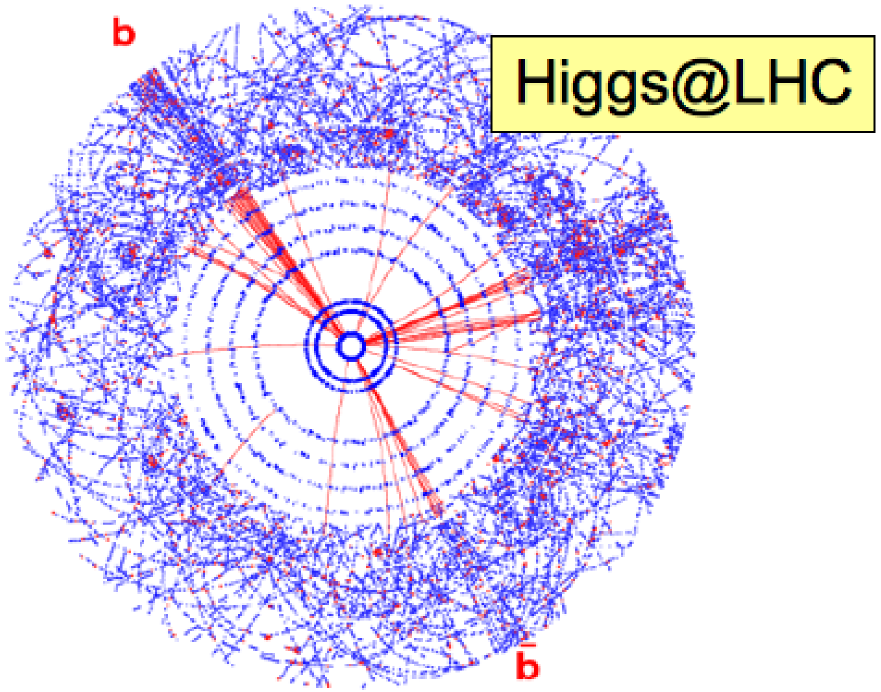
The ILC Detector Challenge

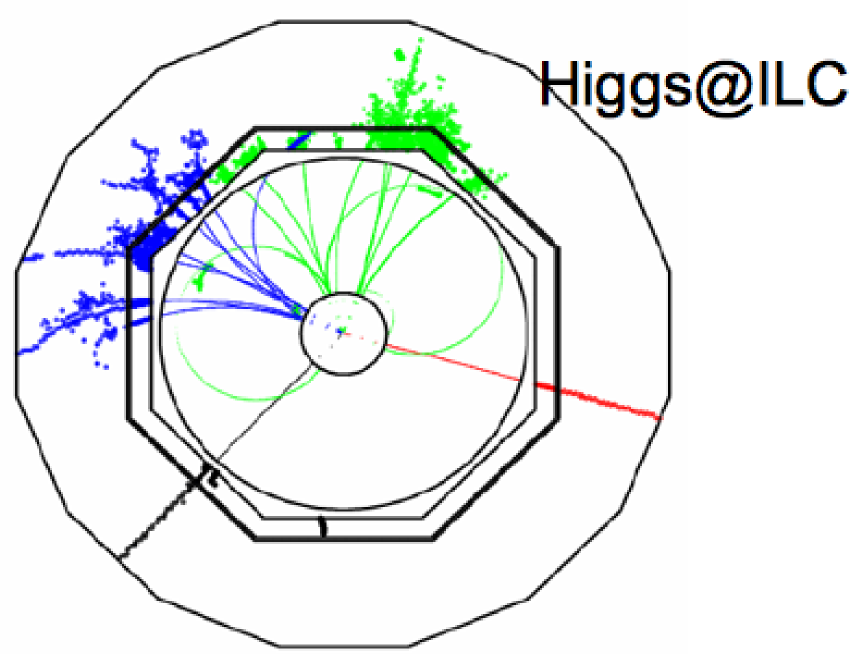
> Why not copy LHC detectors?

LHC detectors were primarily designed to survive the harsh LHC environment (radiation hardness) and to cope with the short bunch spacing (25 ns).

ILC detector design is driven by precision:

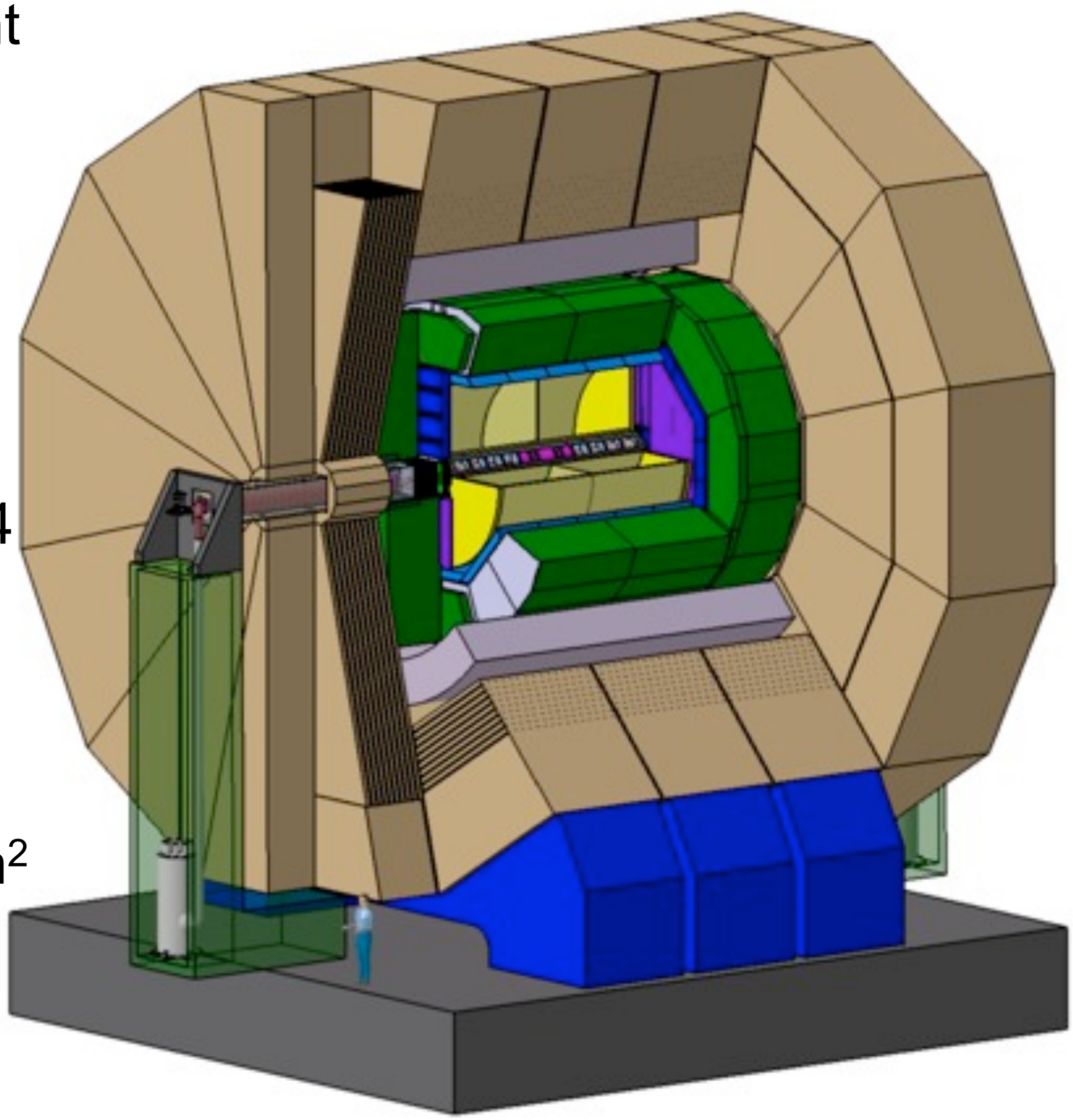
- Inner vertex layer ~3-6 times closer to IP
- Vertex pixel size ~30 times smaller
- Vertex detector layer ~30 times thinner
- Material in tracker ~30 times less
- Track momentum resolution ~10 better
- Granularity in electromagnetic calorimeter ~200 times better





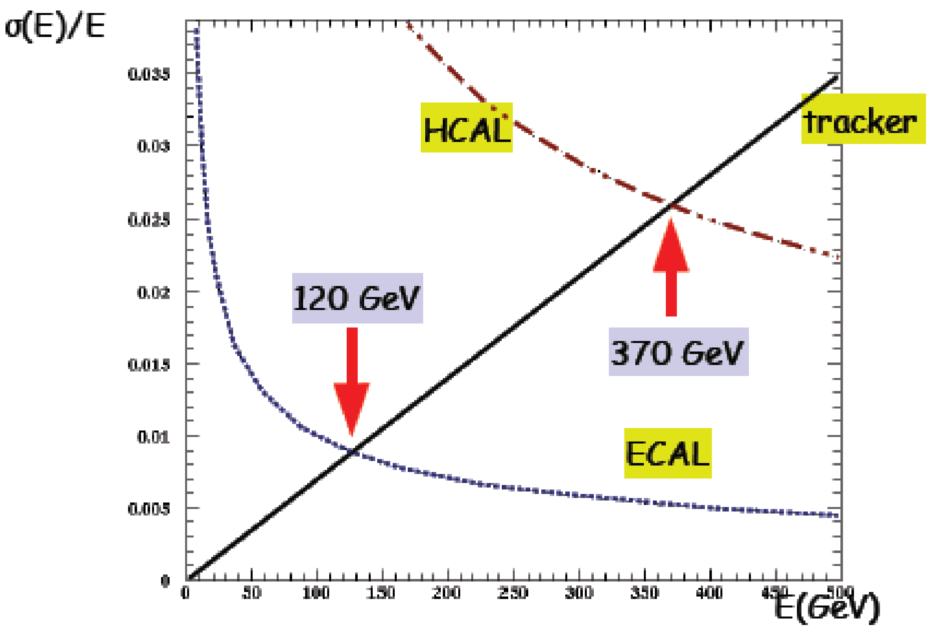
The ILD Detector Concept

- ILD: International Large Detector
- Designed following the particle flow paradigm
  - Excellent precision in spatial and energy measurement
- Subcomponents:
  - Mult-layer pixel vertex detector with excellent point resolution and minimum material budget
  - SI based intermediate tracking system
  - Large volume Time Projection Chamber with up to 224 3d points per track, dE/dx measurement, low material budget
  - Highly segmented ECAL, cell size 5x5 mm^2
  - Highly granular HCAL (3 x 3 cm^2 analogue or 1 x 1 cm^2 digital)
  - Forward instrumentation below 5 mrad
  - Large superconducting coil (3.5 T)
  - Instrumented iron yoke

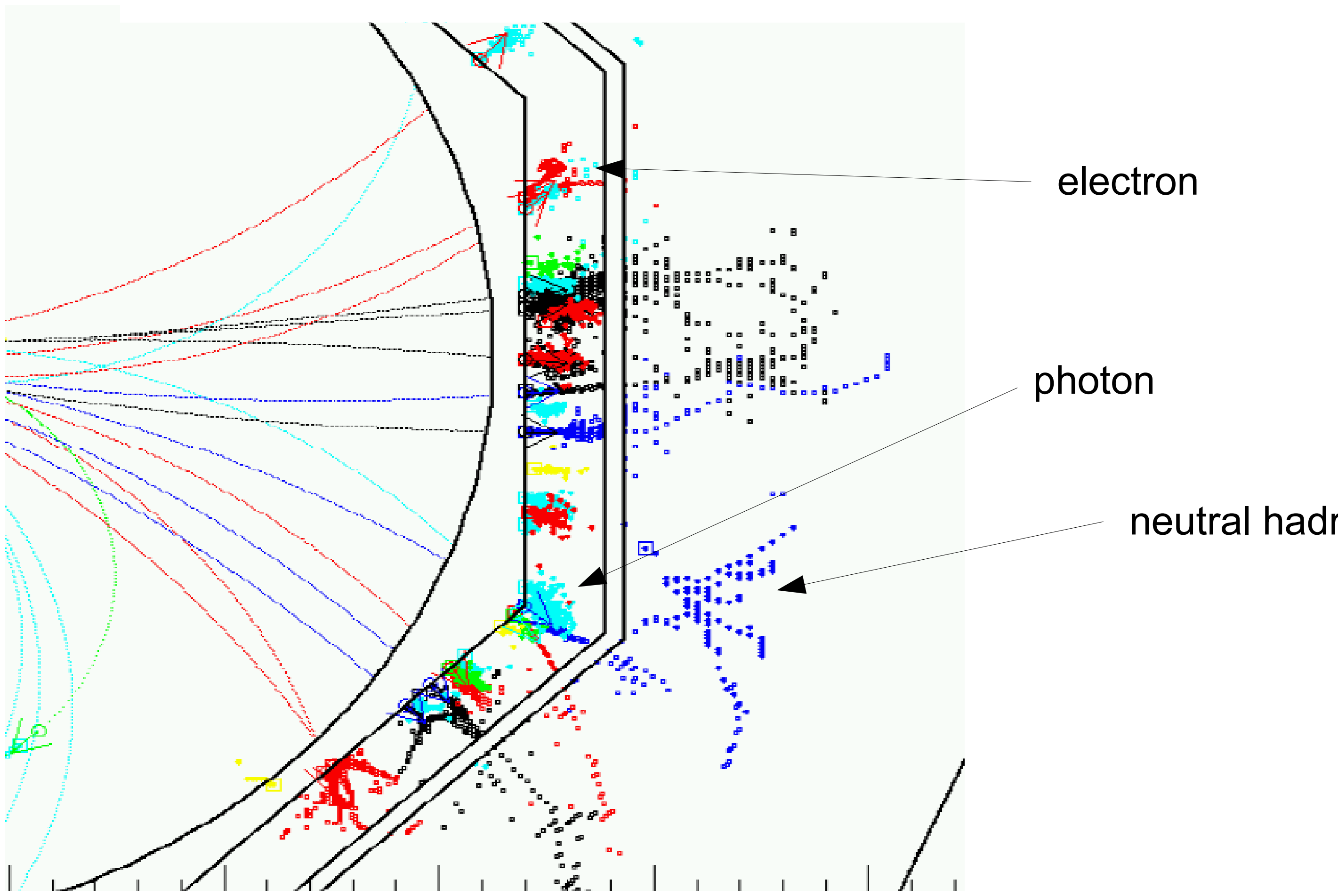


Particle Flow

- Idea: use sub-detector with the best resolution for the energy measurement:
  - Charged particles: tracking sstem
  - Photons: electromagnetic calorimeter
  - Neutral hadrons: hadronic calorimeter



- Main problem: double counting:
  - Trace every single particle through the detector

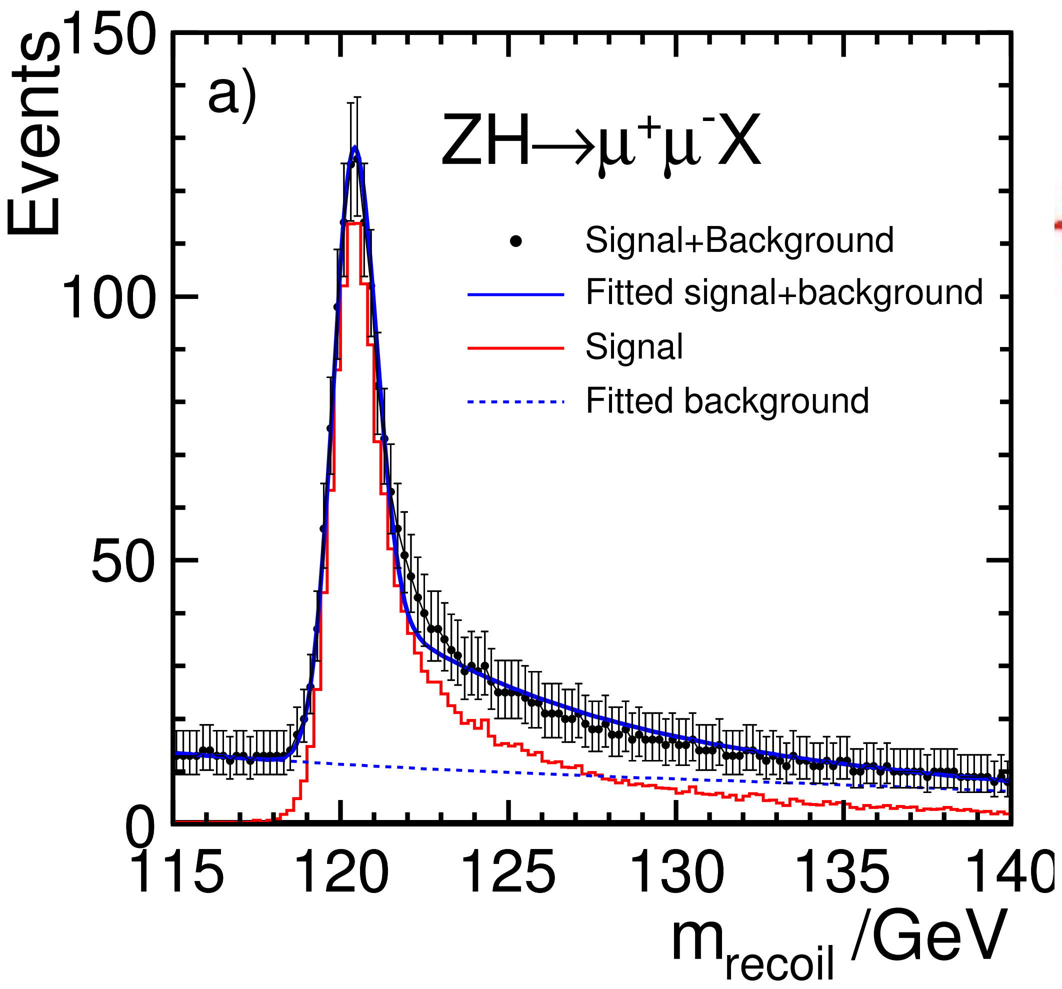


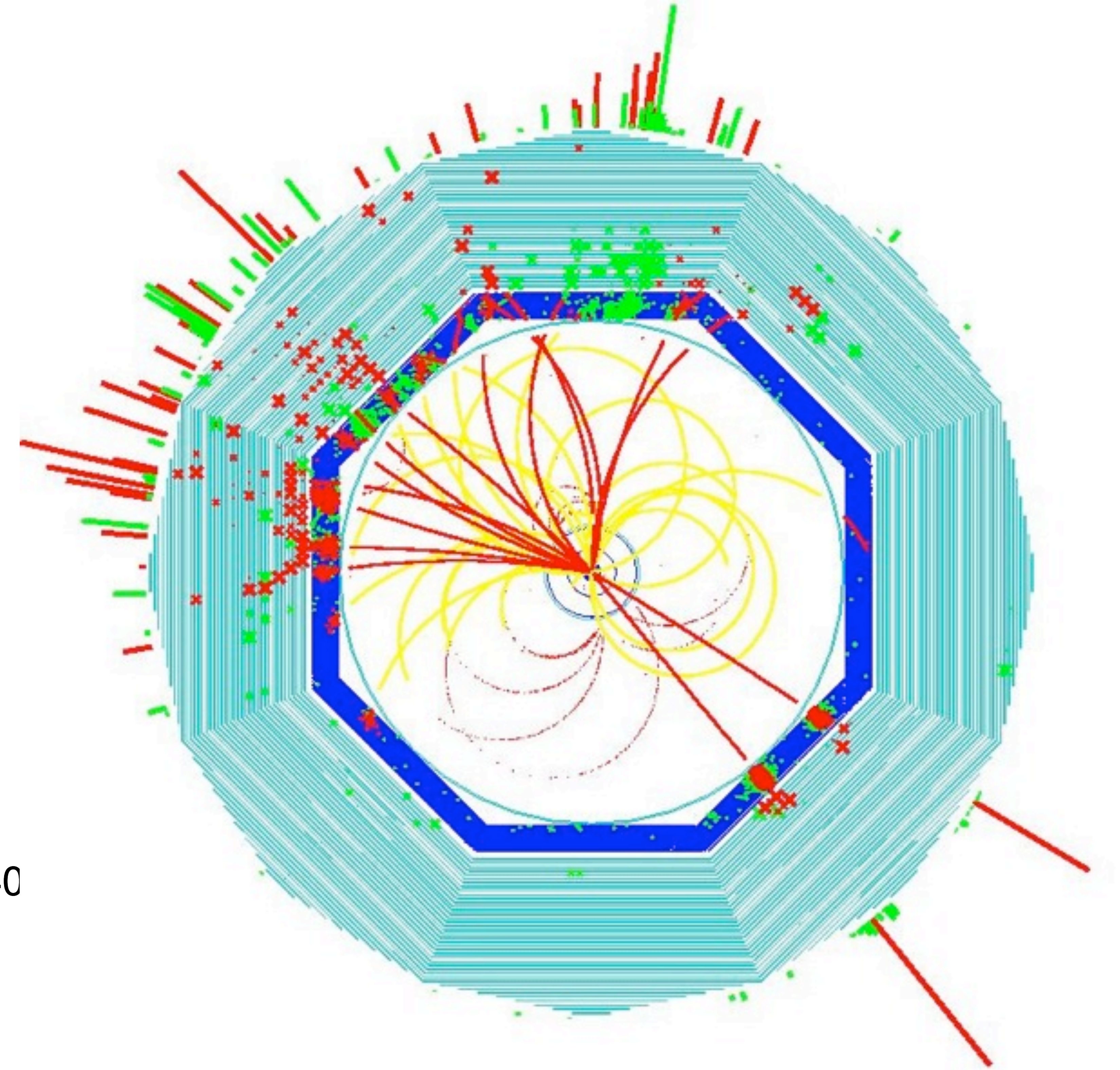
- $E_{jet} = E_{charged} + E_{photons} + E_{neutral\ hadr.}$

- $\sigma^2(E_{jet}) = \sigma^2(E_{charged}) + \sigma^2(E_{photons}) + \sigma^2(E_{neutral\ hadr.}) + \sigma^2_{confusion}$

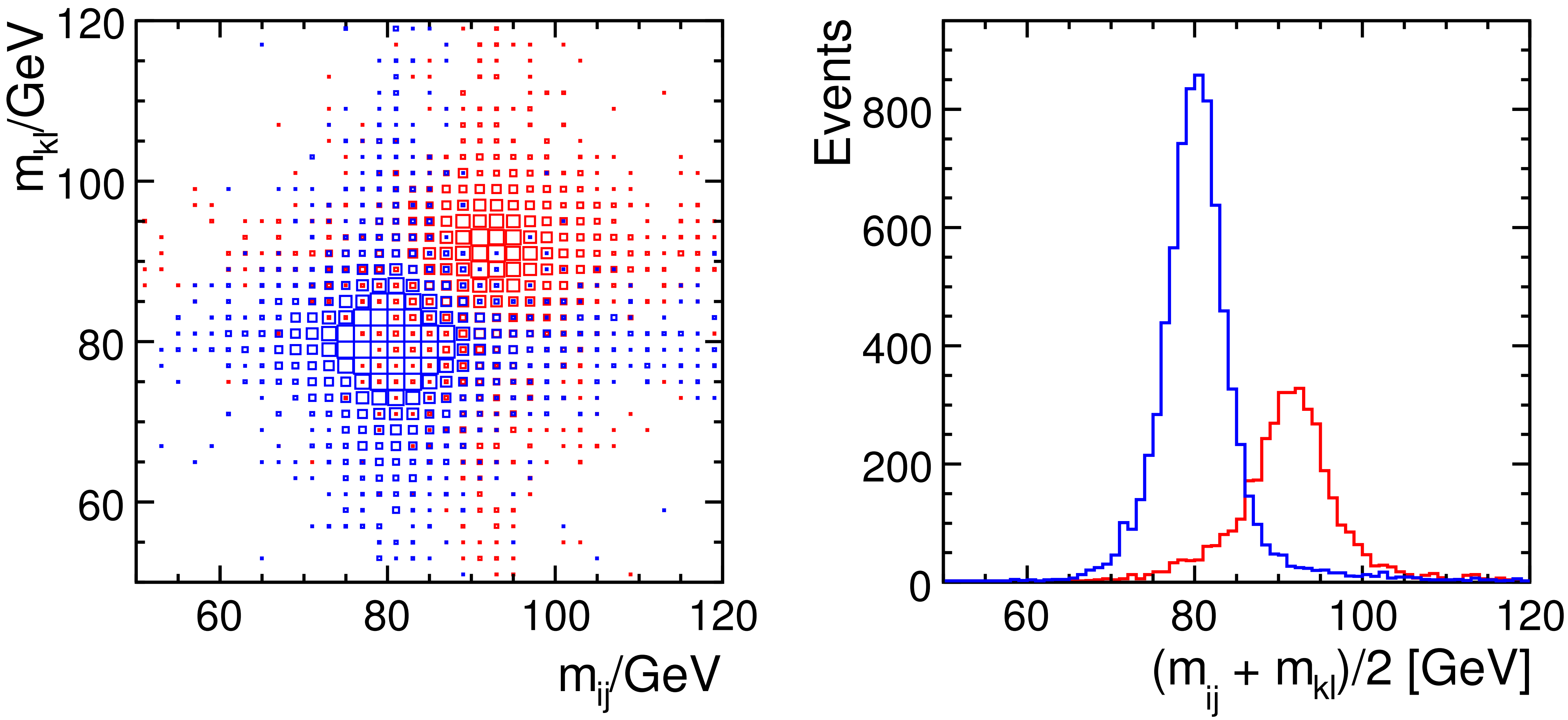
Imaging Detector

- $e^+e^- \rightarrow ZH$





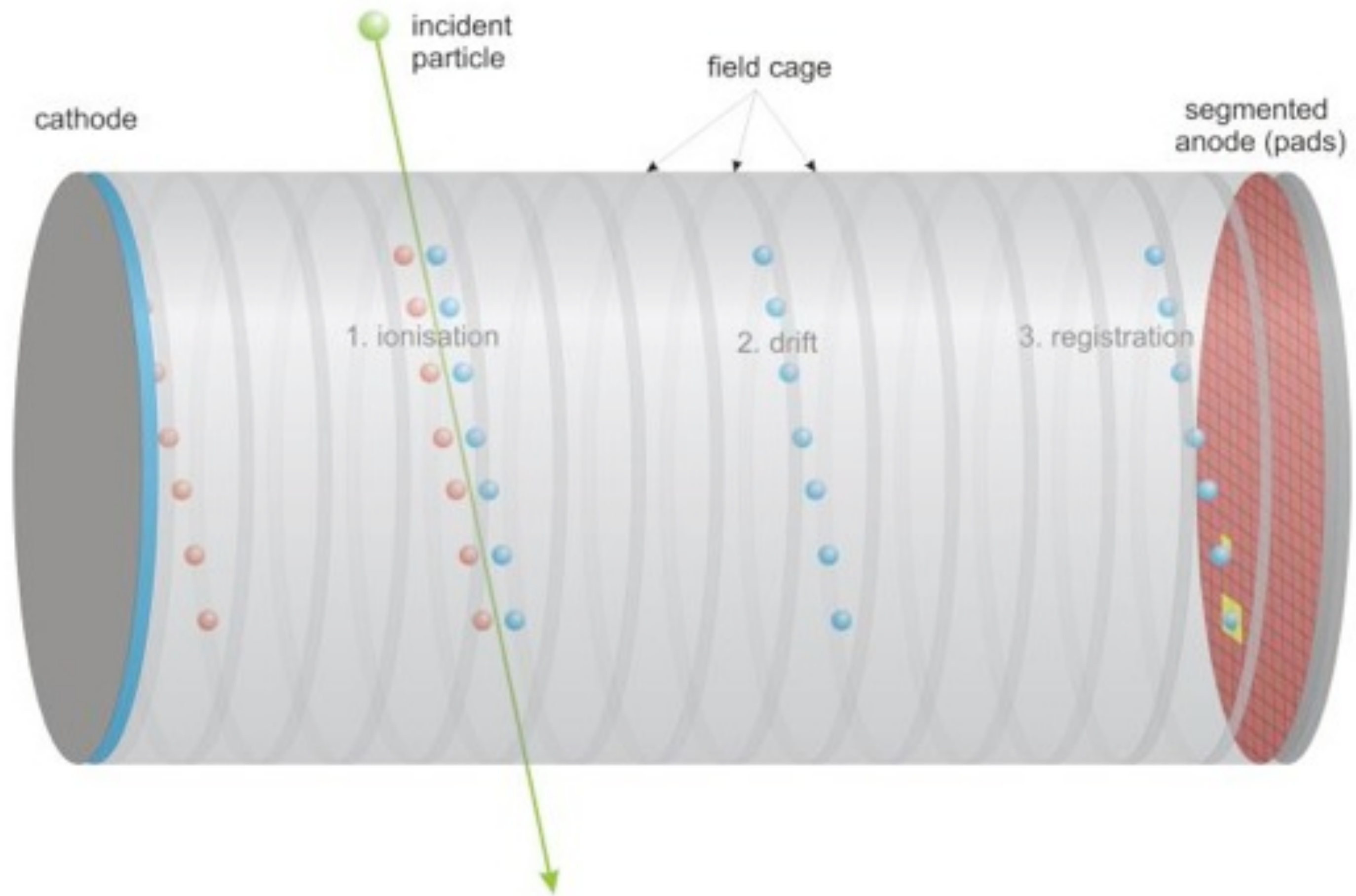
- If electroweak symmetry breaking is strong: WW-scattering process is important!
- Need to distinguish WW from ZZ

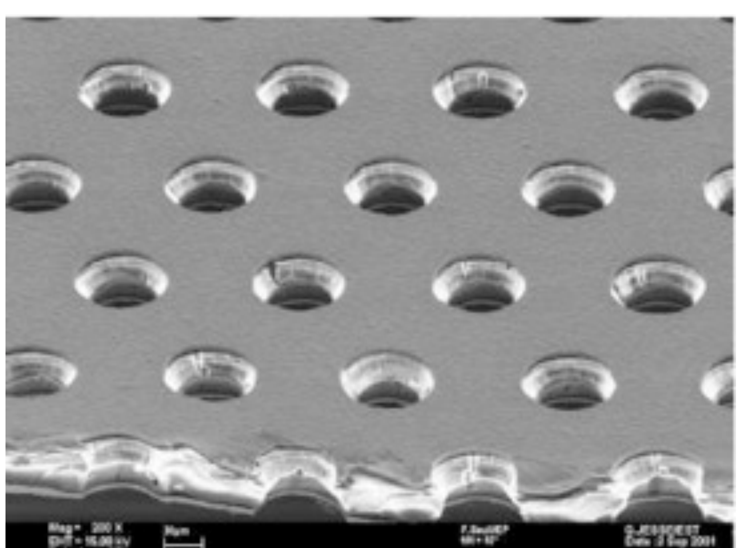


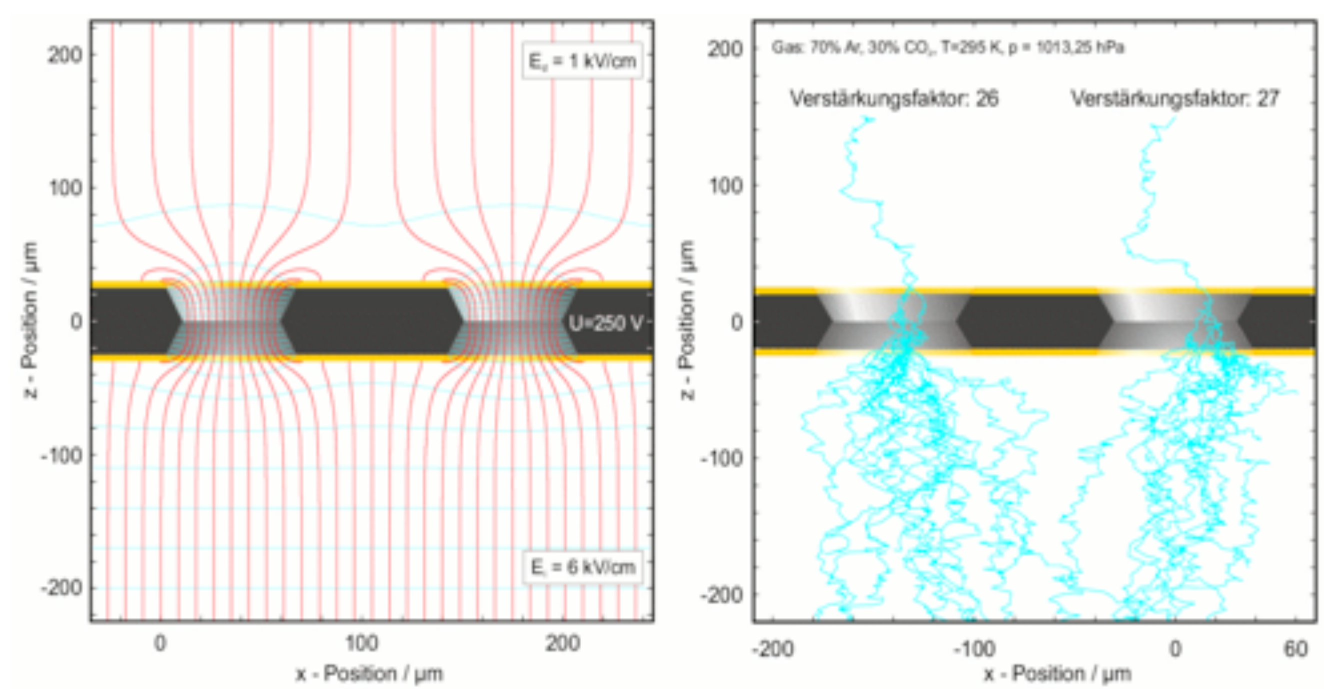
- $e^+e^- \rightarrow \nu\nu ZZ$ (red) $e^+e^- \rightarrow \nu\nu WW$ (blue)
- Excellent jet energy resolution needed: $\Delta E/E \leq 30\%/\sqrt{E}$

Time Projection Chamber

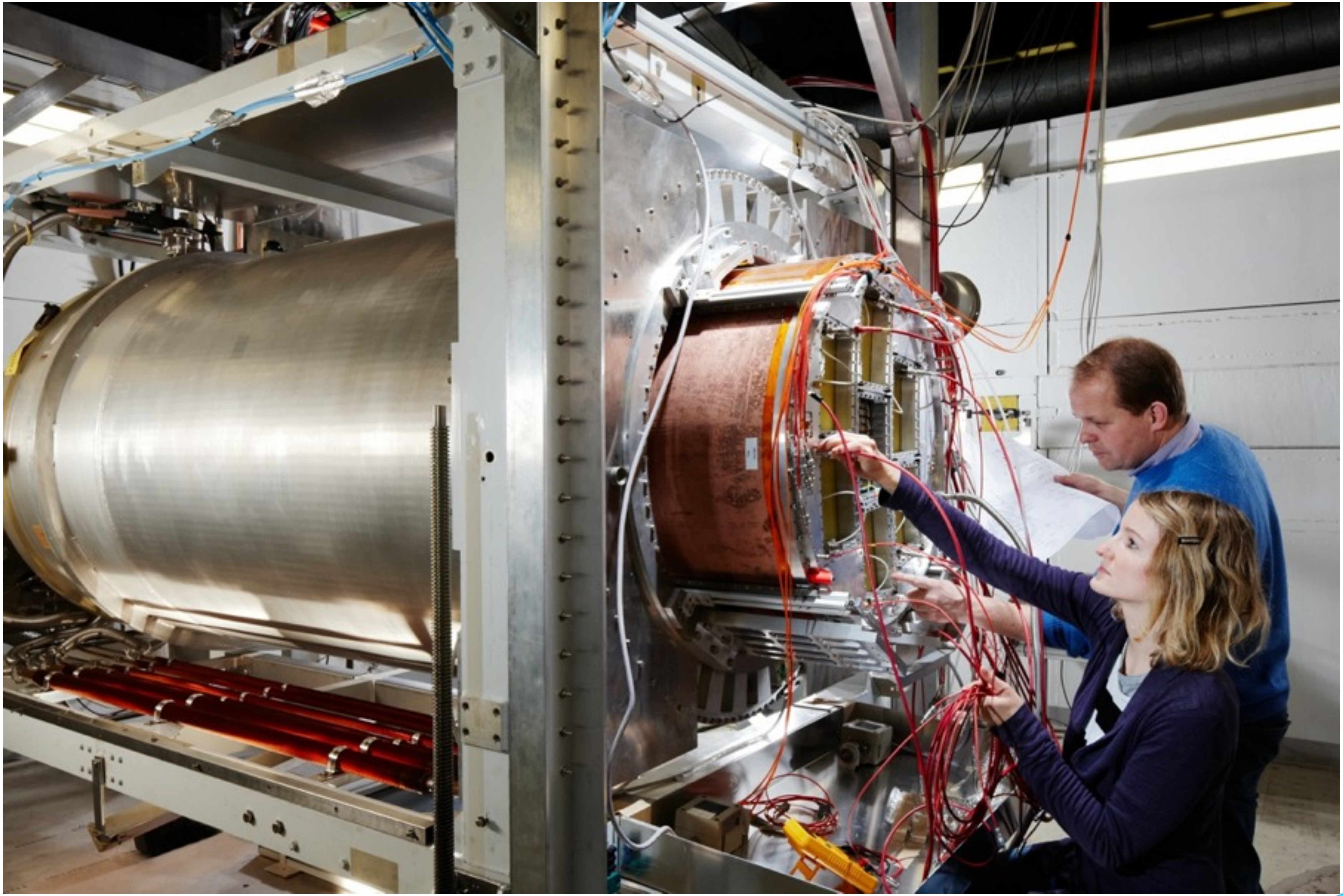
- A Time Projection Chamber is the central tracking device at ILD:
  - genuine 3d trajectory measurement
  - spacepoint resolution: ~100 µm
  - minimise material budget
- Novel gas amplification schemes:
  - e.g. Gas Electron Multipliers (GEMs)
  - less material
  - reduced ExB effects
  - intrinsic ion backdrift suppression





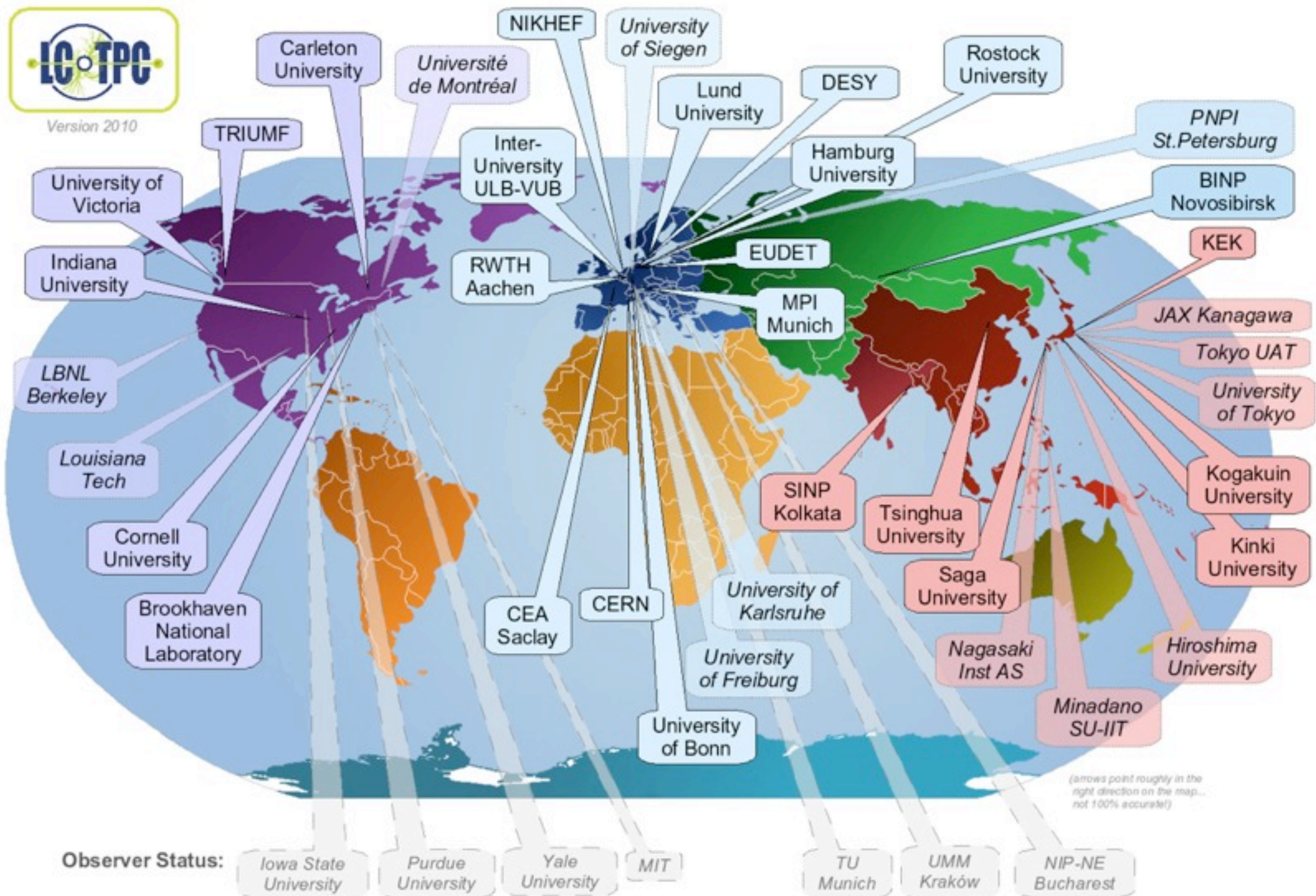


TPC Protoype at the DESY Testbeam



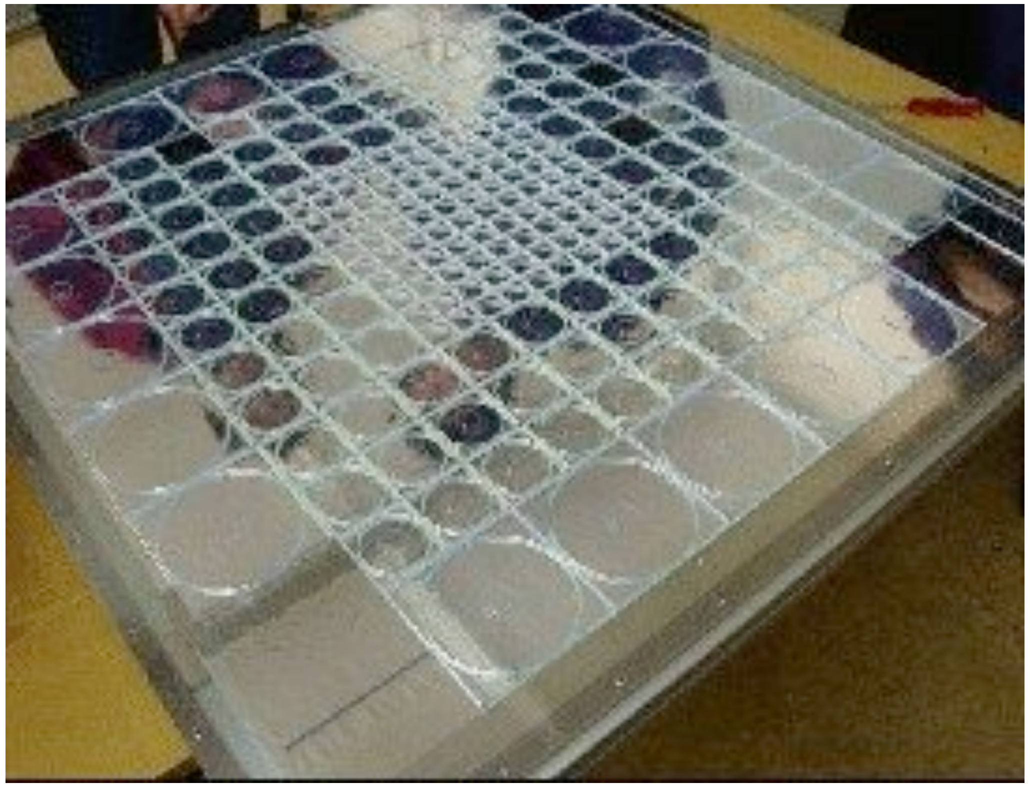
LC-TPC Collaboration

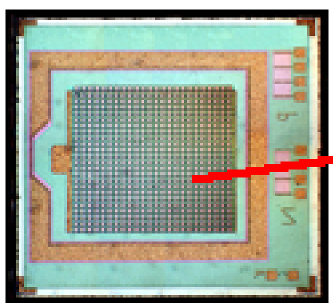
> R&D collaborations are already significant international endeavours



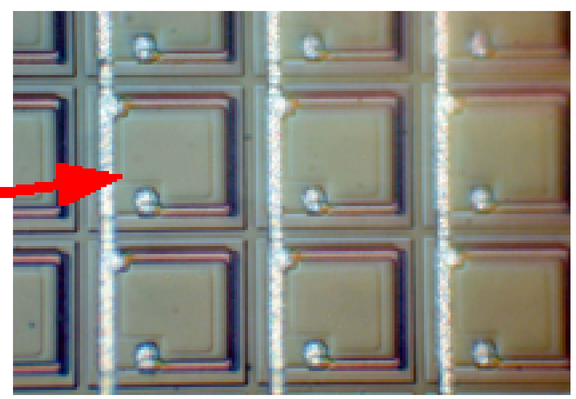
Analogue Hadronic Calorimeter for ILD

- Steel-scintillator sampling calorimeter
- High granularity 3 x 3 cm^2
- Scintillator tiles read out by pixel photo detectors: SiPMs

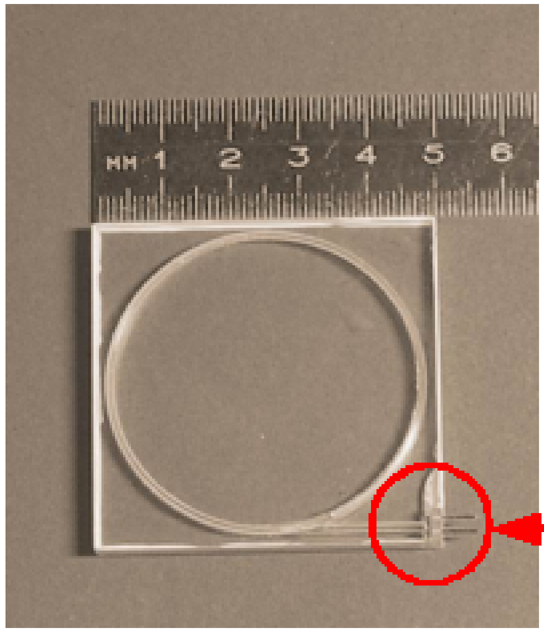




SiPM



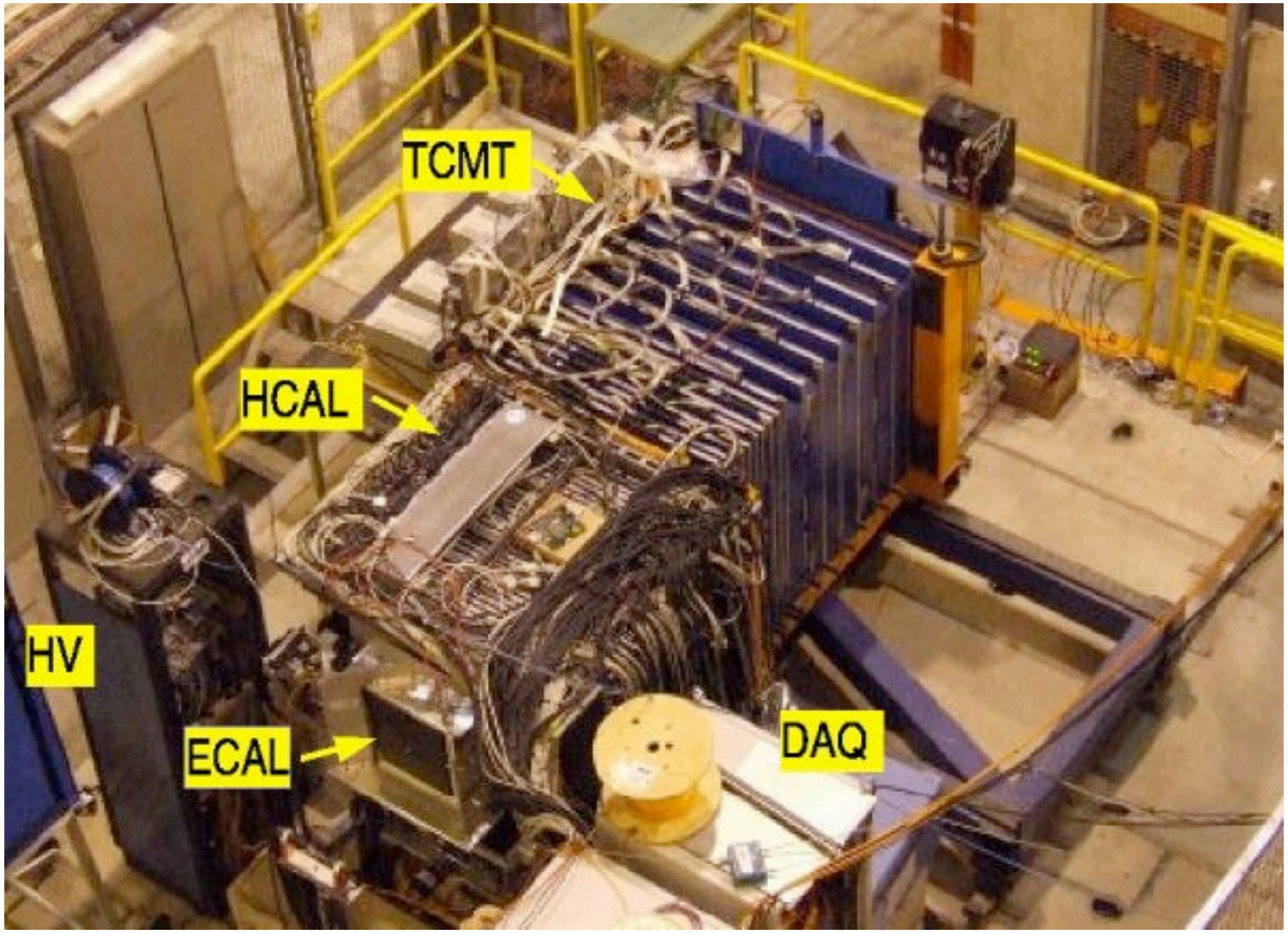
Pixels of the SiPM



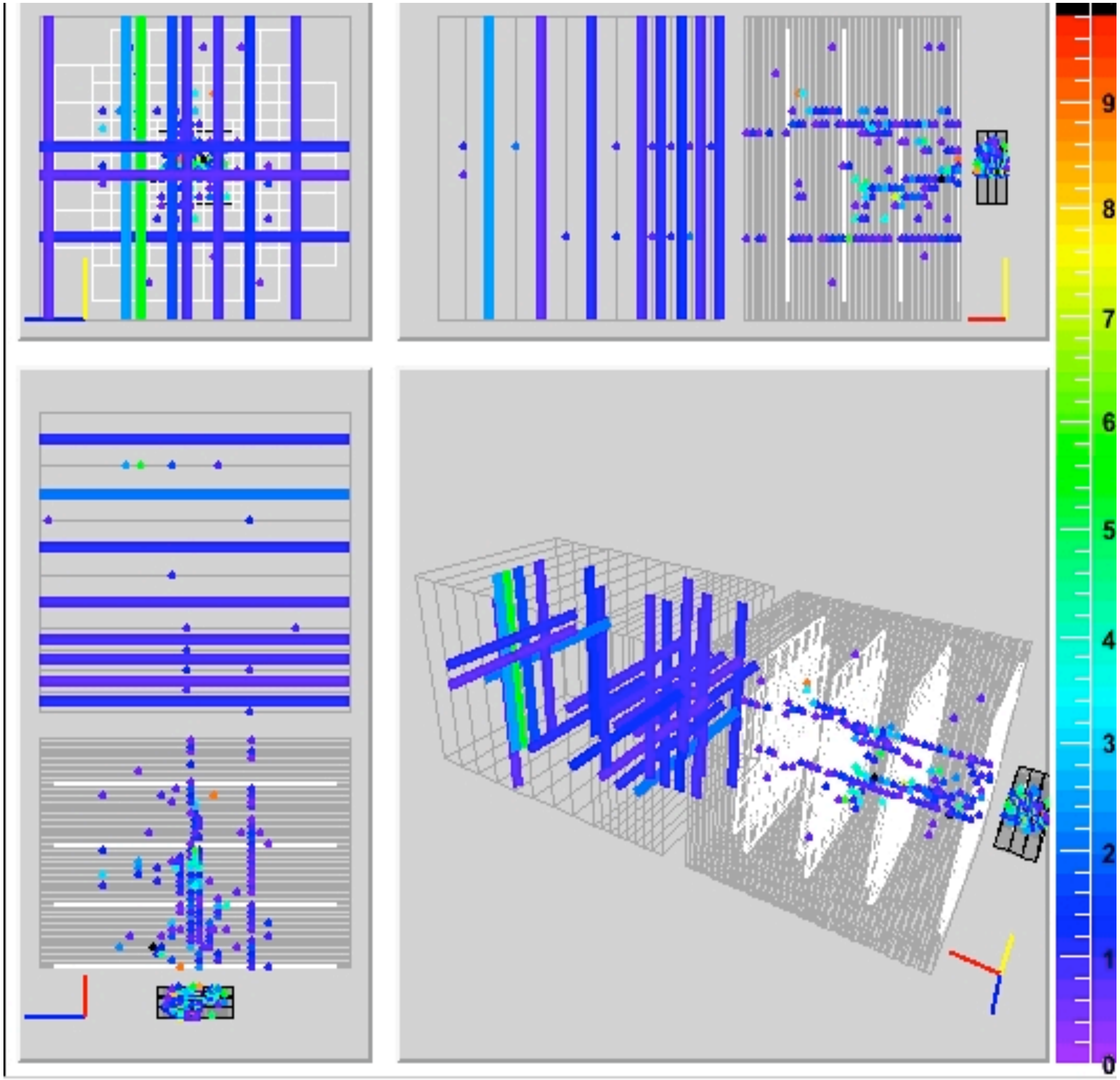
A scintillator tile with a SiPM

CALICE Collaboration

- R&D Collaboration for the development of high granularity calorimeter systems for a linear collider
- Integrated testbeam experiments of full calo systems: ECAL, HCAL, Tail Catcher/Muon System:

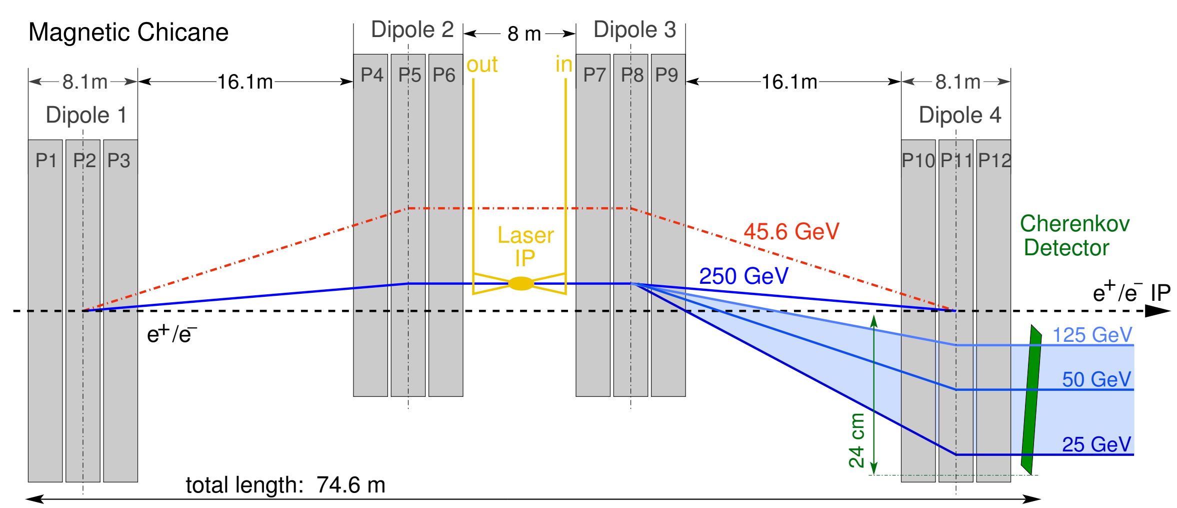


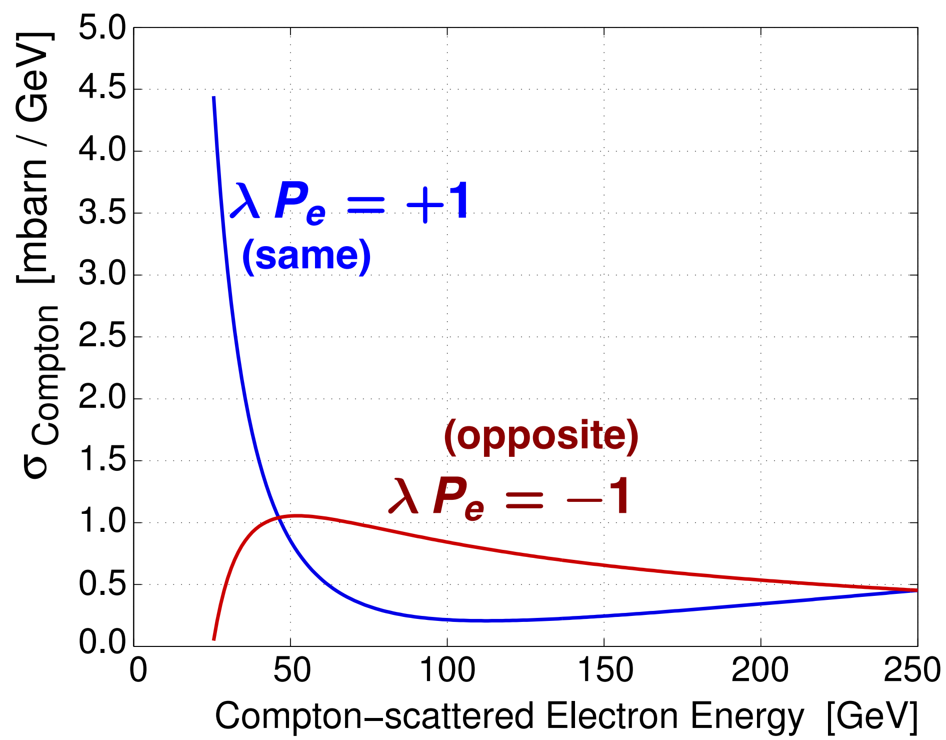
Imaging Calorimetry

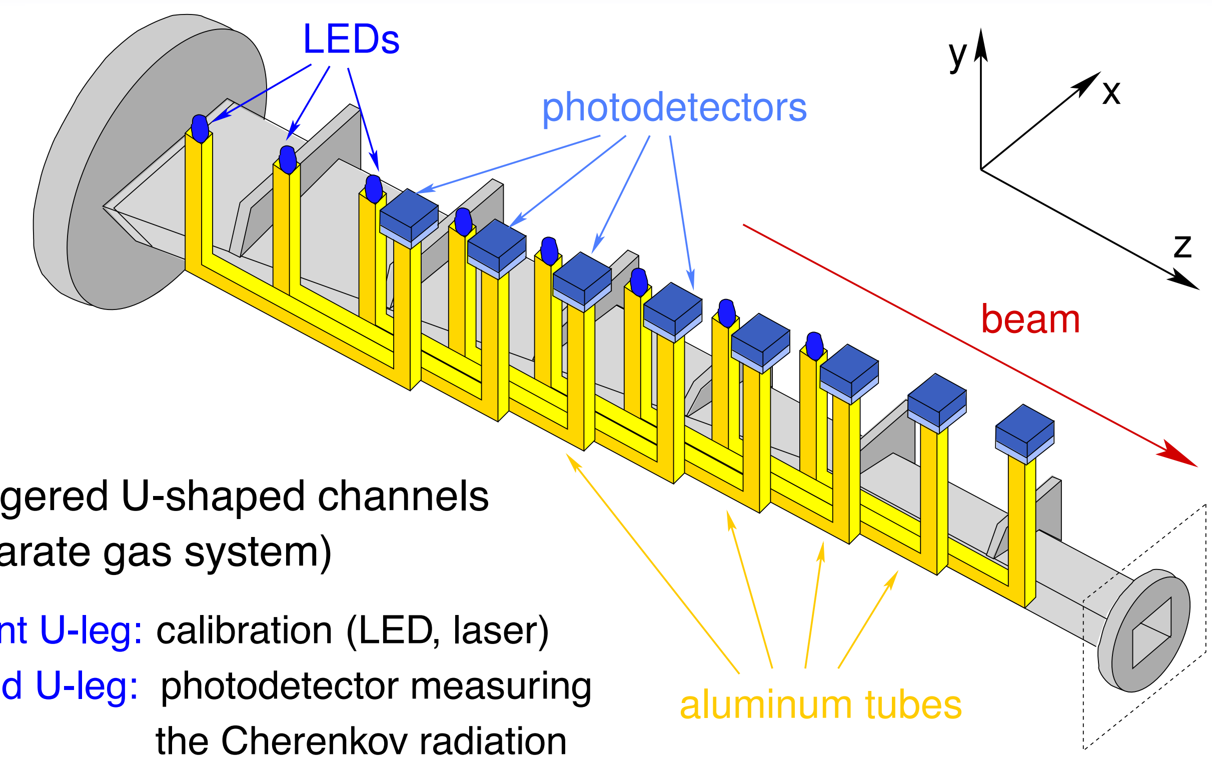


Polarimetry at the ILC

- **>** ILC will have polarised beams
  - Physics needs precise knowledge of polarisation: ΔP/P ≤ 0.25%
- **>** Compton Polarimeter:
  - scatter circular polarised laser off the electron beam
  - cross section is dependent on laser helicity times beam polarisation
  - asymmetry in Compton event rate w.r.t. known laser helicity gives polarisation





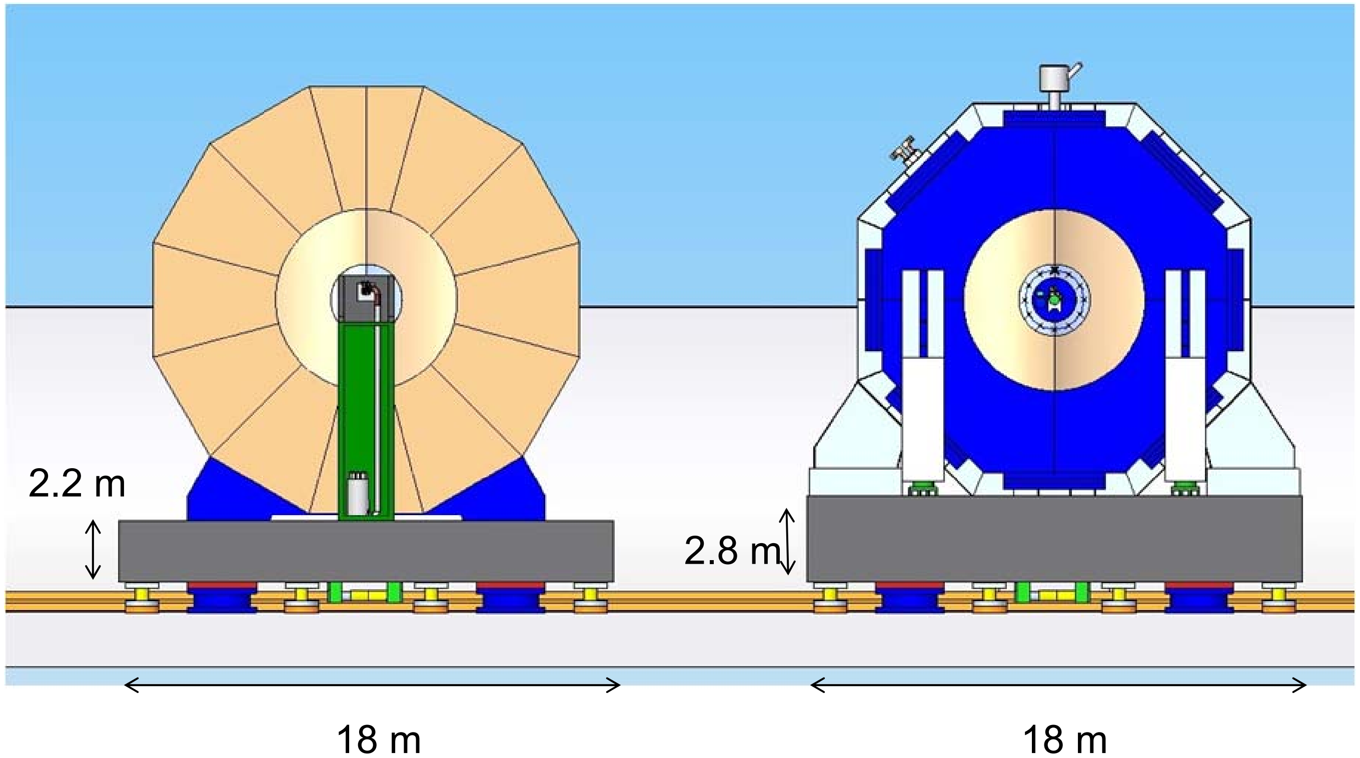


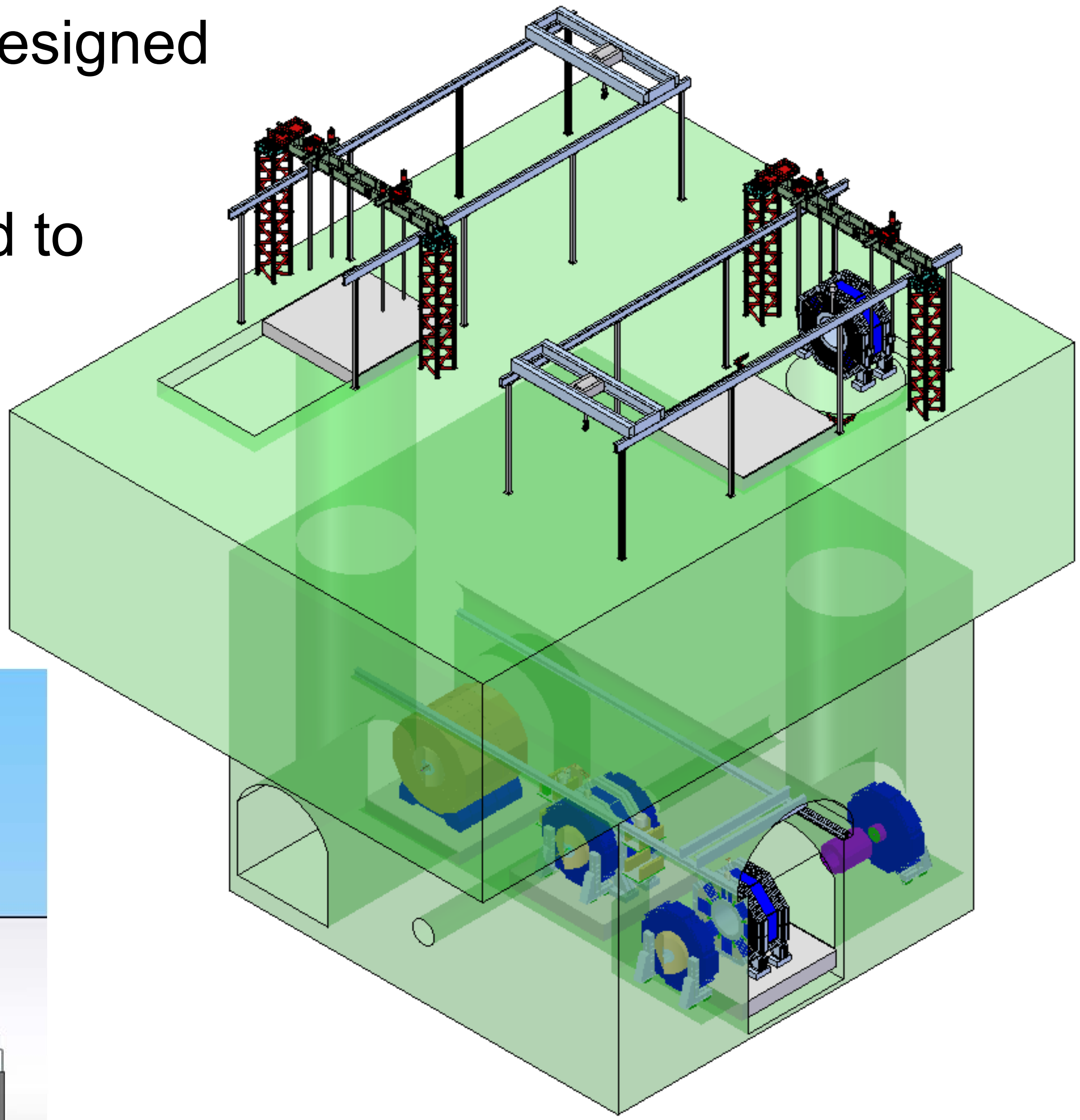
Staggered U-shaped channels
(separate gas system)

▷ front U-leg: calibration (LED, laser)
▷ hind U-leg: photodetector measuring the Cherenkov radiation

Engineering Challenges: e.g. the Push-pull System

- ILC: two detectors share one interaction region
- Fast push-pull system needs to be designed
  - Change-over time: ~1 day
- 15 kt detectors need to be positioned to sub-mm precision
- Final focus quadrupoles are carried by the detectors
  - much higher alignment precision needed





Summary

- FLC is one of the driving forces in the world for the development of future detectors at lepton colliders
- Prominent hardware activities are embedded in international R&D collaborations
- The physics challenge of the TeV scale at lepton colliders is being evolved following the results from LHC
- A unique group where hardware, software and analysis topics are being studied in close cooperation with our international partners

- Students and postdocs are always welcome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