International Linear Collider at DESY

Machine, Detector, Project

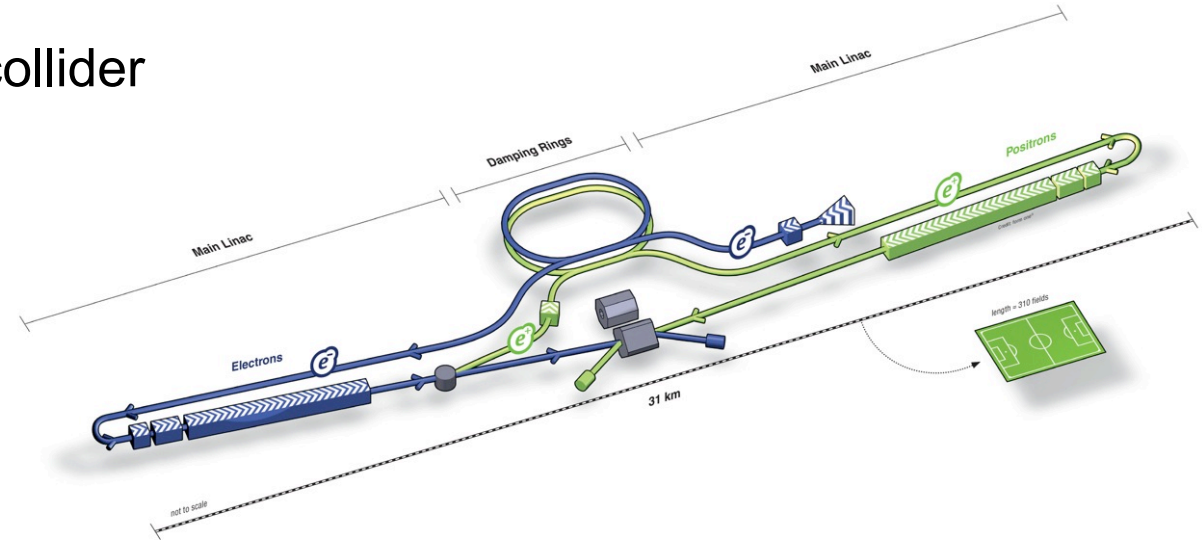
Karsten Buesser
75. Physics Research Committee
DESY, 11.04.2013

HELMHOLTZ ASSOCIATION

DESY

The International Linear Collider

- 200-500 GeV E_{cm} e^+e^- collider
  - Upgrade: ~1 TeV
- L ~$2x10^{34}$ cm^{-2} s^{-1}
- SCRF Technology
  - 1.3 GHz, 31.5 MV/m
  - 17000 cavities
  - 1700 cryomodules
  - 2x11 km linacs
- Global Collaboration
  - ~130 Institutes
  - no central host lab
  - www.linearcollider.org



DESY and the ILC

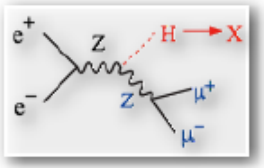
- DESY is in an exceptional position to support the ILC developments
  - XFEL experience in pushing the superconducting RF technology to industrial production readiness is unique in the world
  - FLASH is the only operating ILC-like linac worldwide
  - Advanced detector infrastructure enables DESY to play a role as a European focus for advanced detector technology R&D
  - Strong physics studies groups (theory and experiment)
- Main objectives:
  - Accelerator:
    - SCRF high gradient developments using XFEL recipes
    - FLASH beam tests with ILC-like high current beams
    - Source developments
  - Physics/Detector
    - Physics studies
    - Detector concept design
    - R&D on advanced detector technologies (HCAL, TPC, FCAL, Vertex)
  - Integration
    - Project office for machine and detector integration

ILC Physics Studies - Exploring the Higgs Sector

> After the CERN discovery: understand how well a LC can do in detail:

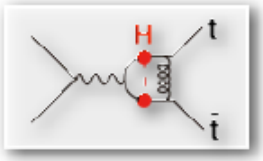
ZH @ 250 GeV (~mZ+mH+20GeV) :

- Higgs mass, width, J^{PC}
- Gauge quantum numbers
- Absolute measrement of HZZ coupling (recoil mass) -> couplings to H (other than top)
- BR(h->VV,qq,ll,invisible) : V=W/Z(direct), g, γ (loop)



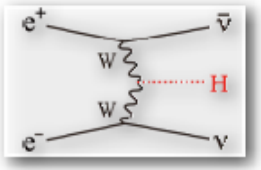
ttbar @ 340-350GeV (~2mt) : ZH meas. Is also possible

- Threshold scan --> indirect meas. of top Yukawa coupling
- A_{FB}, Top momentum measurements
- Form factor measurements γ γ → HH @ 350GeV possibility



vvH @ 350 - 500GeV :

- HWW coupling -> total width --> absolute normalization of couplings

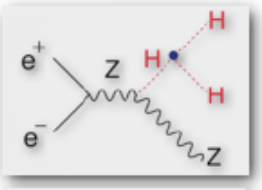


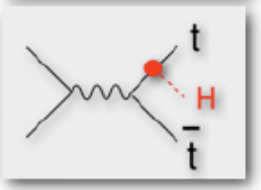
ZHH @ 500GeV (~mZ+2mH+170GeV) :

- Prod. cross section attains its maximum at around 500GeV -> Higgs self-coupling

ttbarH @ 500GeV (~2mt+mH+30GeV) :

- Prod. cross section becomes maximum at around 700GeV.
- QCD threshold correction enhances the cross section -> top Yukawa measurable at 500GeV concurrently with the self-coupling

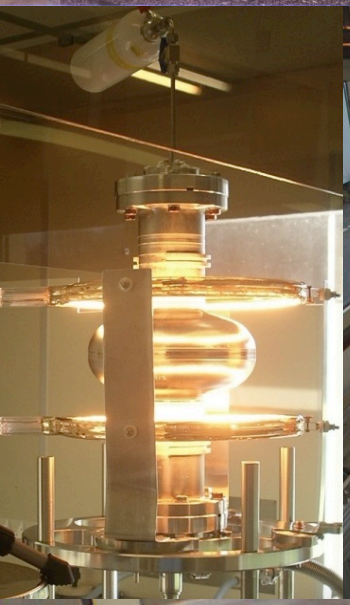


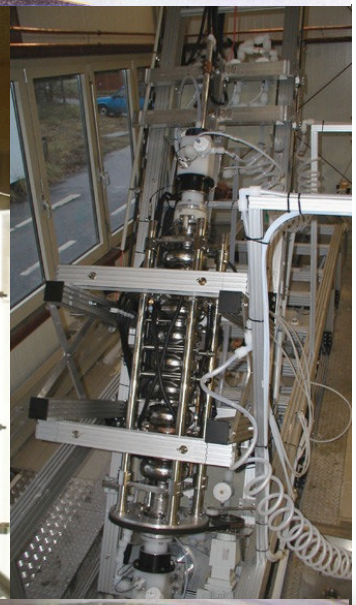


We can complete the mass-coupling plot at ~500GeV!

K.Fujii @ LCWS12, Oct.24, 2012

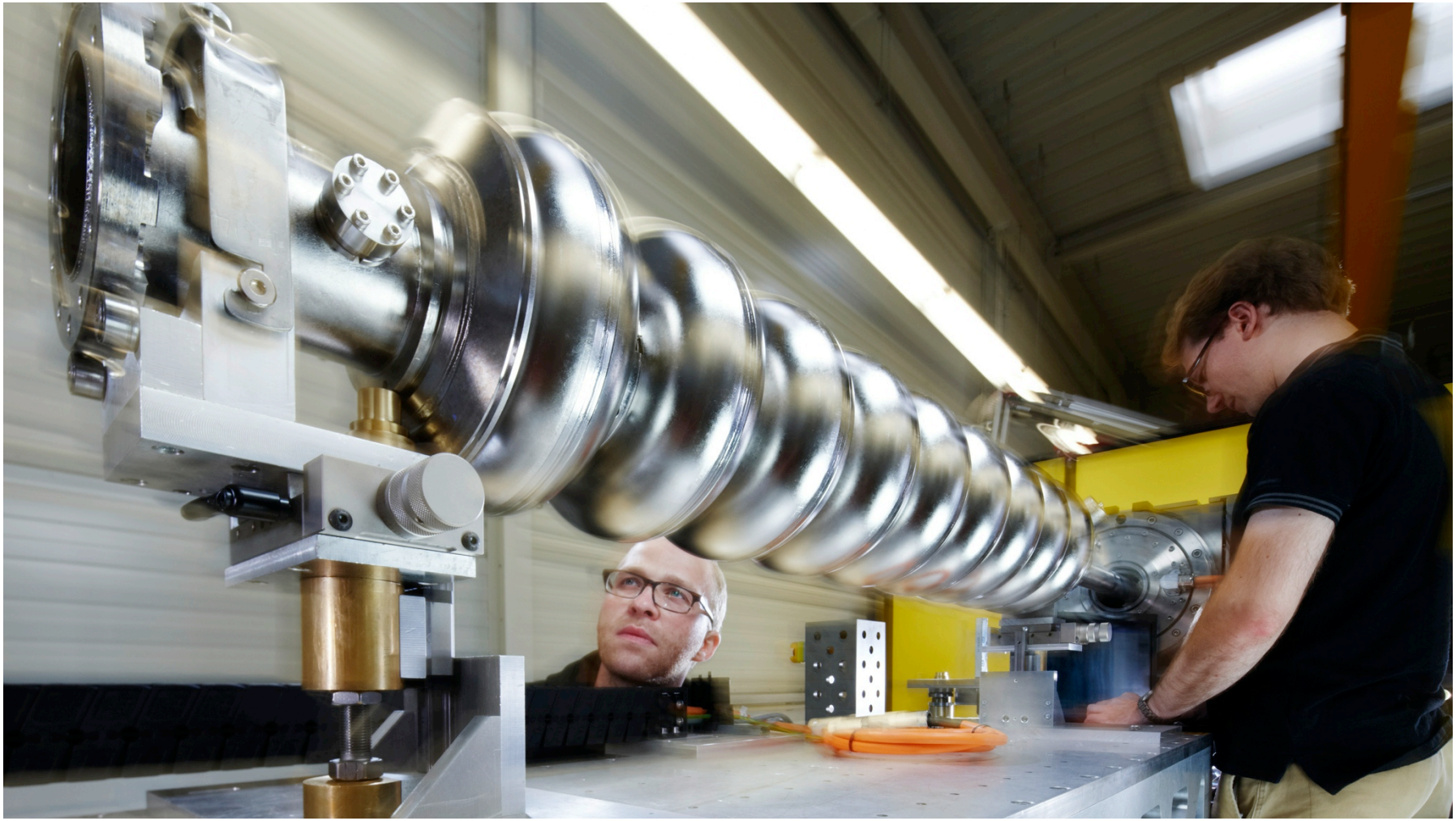
SCRF: The Path to High Performance



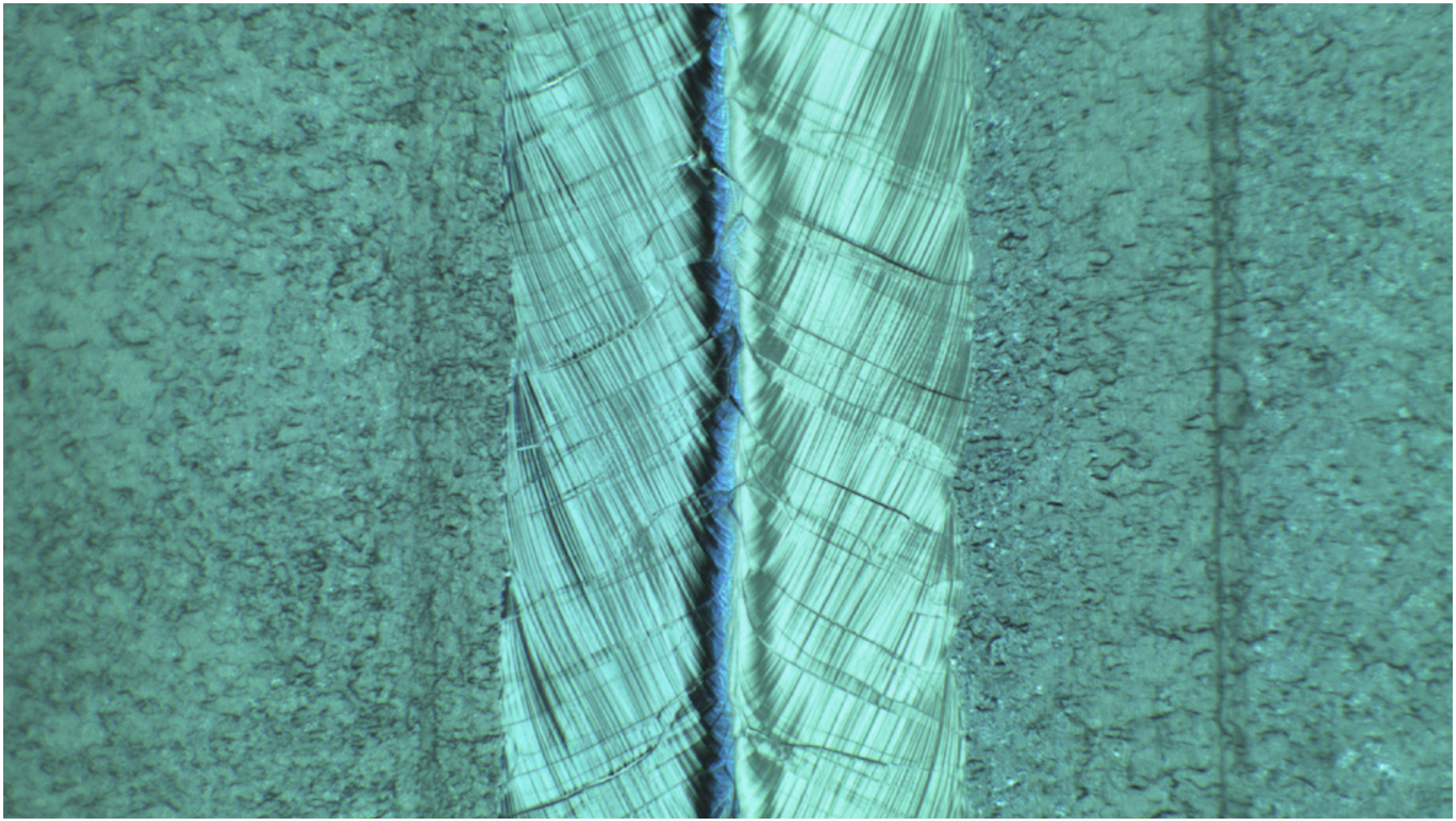


- Control of niobium material
- Mechanical construction
  - electron-beam welding (EBW)
- Preparing RF (inner) surface ultra-clean mirror surface
  - electro-polishing (EP)
- Removing hydrogen from the surface layer
  - 800 deg C bake
- Removing surface contamination
  - alcohol and/or detergent rinsing
  - 2-4 bar high-pressure rinsing (HPR)

Automatic Optical Cavity Inspection

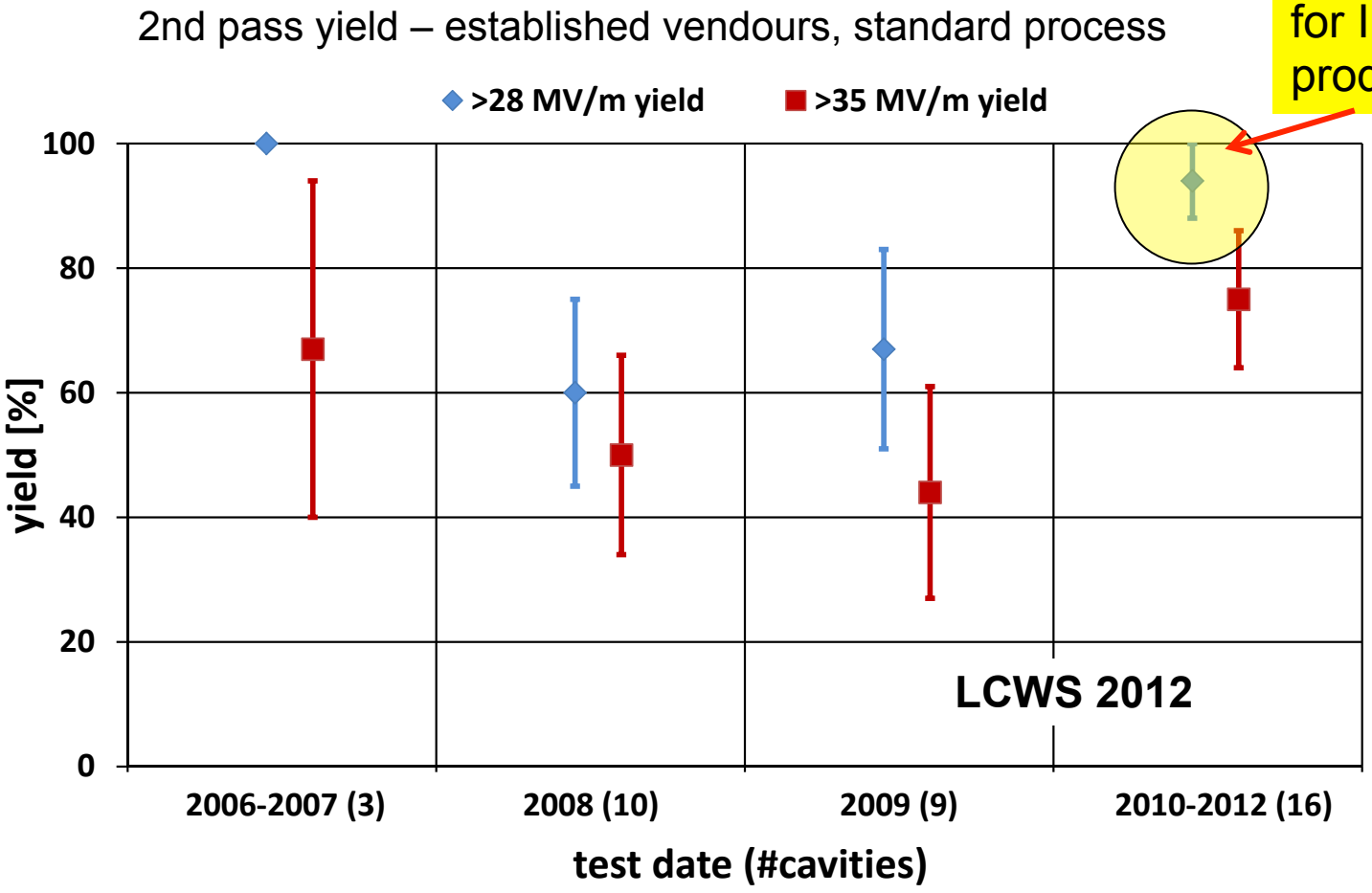


Optical Inspection: Cavity Weld

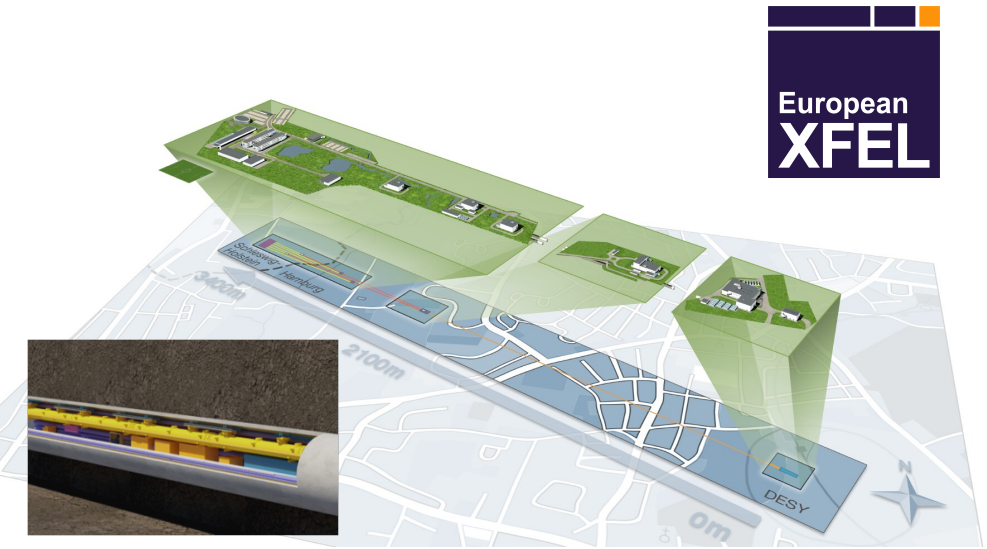


Cavity Gradient Yield

94% (±6%) acceptable for ILC mass production



XFEL Mass Production and the ILC



- 17.5 GeV
- 100 cryomodules
- 800 cavities
  - 23.6 MV/m
- Industrialisation and mass production
  - 1 CM/week

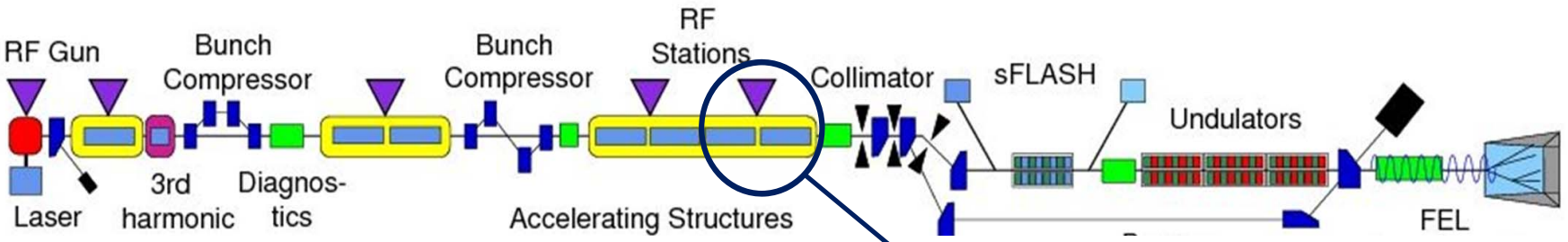
- 800 tested cavities increase worldwide statistics by orders of magnitude

ilc higrade

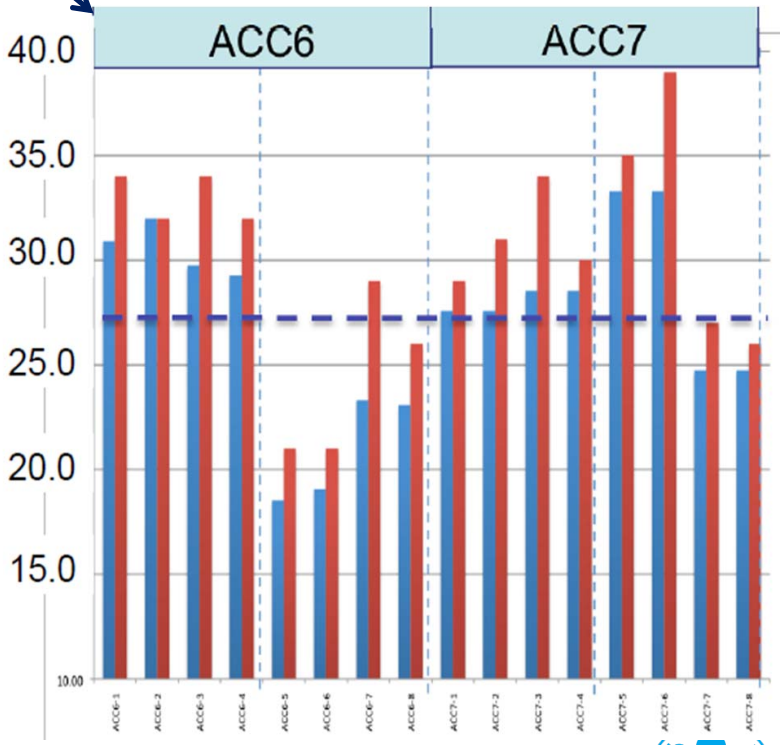
- 24 cavities from ILC-HiGrade project foreseen for ILC high-gradient programme
- Expect very reliable yield numbers for 1st pass treatment
  - good impression of 2nd pass...
- Centrifugal barrel polishing machine for surface preparations coming soon

DESY

9mA Beam Studies at FLASH



		XFEL	ILC	FLASH design	9mA studies
Bunch charge	nC	1	3.2	1	3
# bunches		3250	2625	7200*	2400
Pulse length	μs	650	970	800	800
Current	mA	5	9	9	9



Unique ILC type beam facility

9mA Beam Tests at FLASH

High beam power and long bunch-trains *(Sept 2009)*

Metric	ILC Goal	Achieved
Macro-pulse current	9mA	9mA
Bunches per pulse	2400 x 3nC (3MHz)	1800 x 3nC 2400 x 2nC
Cavities operating at high gradients, close to quench	31.5MV/m +/-20%	4 cavities > 30MV/m

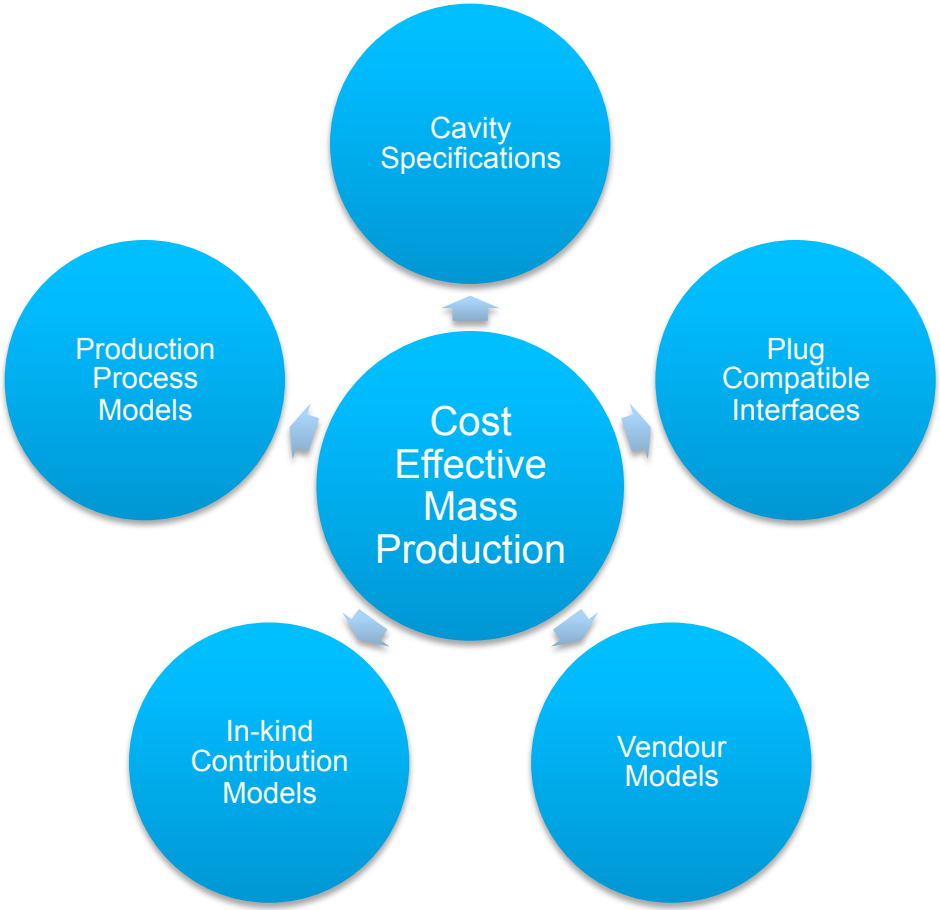
Gradient operating margins *(Feb 2012)*

Metric	ILC Goal	Achieved
Cavity gradient flatness (all cavities in vector sum)	2% ΔV/V (800μs, 5.8mA) (800μs, 9mA)	<0.3% ΔV/V (800μs, 4.5mA) *First tests of automation for Pk/QI control*
Gradient operating margin	All cavities operating within 3% of quench limits	Some cavities within ~5% of quench (800us, 4.5mA) *First tests of operations strategies for gradients close to quench*
Energy Stability	0.1% rms at 250GeV	<0.15% p-p (0.4ms) <0.02% rms (5Hz)

DESY

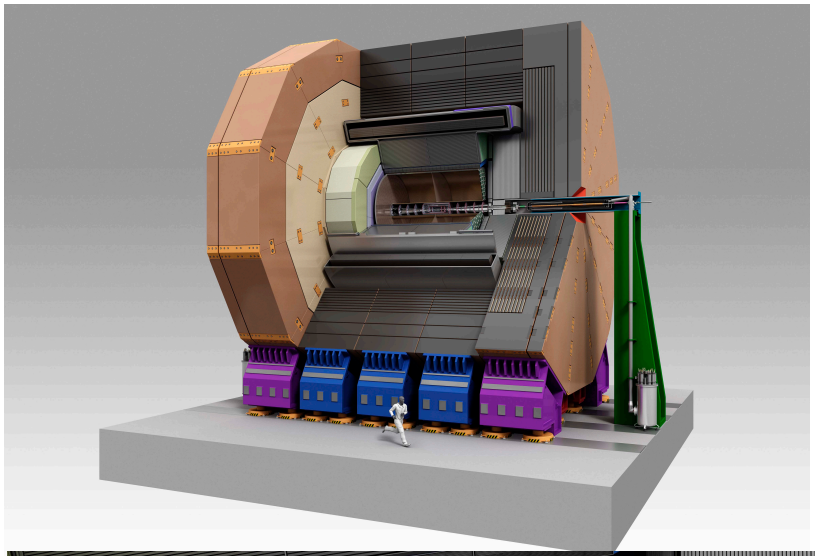
Global Mass Production Scenarios

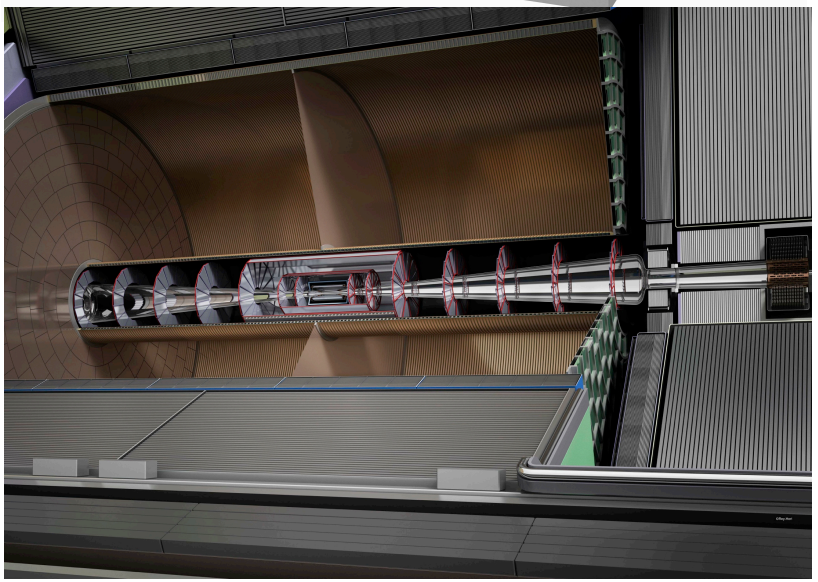
- Industrialisation studies are the key to realistic cost estimates
- Major DESY contributions:
  - XFEL experience
  - ILC-HiGrade
  - Industrial studies
    - Cavity construction and surface preparation (Research Instruments)
    - Cryomodule assembly (Babcock-Noell, CERN)
- Impact on TDR cost update



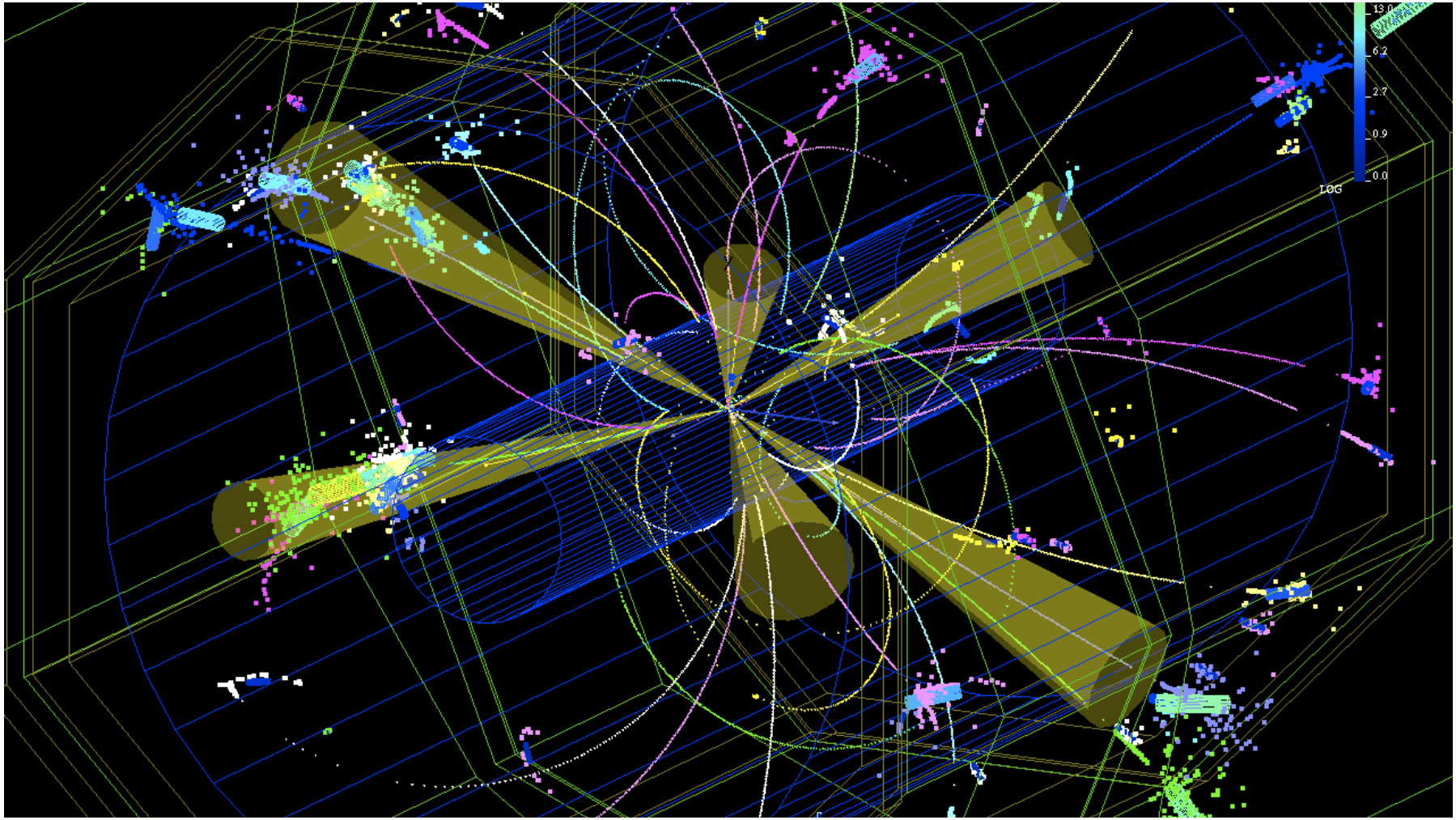
DESY Detector Strategy

- Strategy:
  - Define a detector concept for the Linear Collider that is optimised for particle flow and maximises the physics performance
- Physics studies:
  - Understand and optimise the analysis strategies
  - Optimise detector requirements
- Detector System R&D:
  - Tracking system with high efficiency:
    - Time Projection Chamber
  - Calorimetry for particle flow:
    - HCAL with high granularity
  - Vertexing, Very Forward Calorimetry (hermeticity), Polarimetry
- Concept definition:
  - Simulation and reconstruction software for particle flow
  - Detector engineering and integration
- New detector technologies:
  - Sensor studies: pixel and pad sensors, SiPM
  - Electronic studies: integrated readout systems

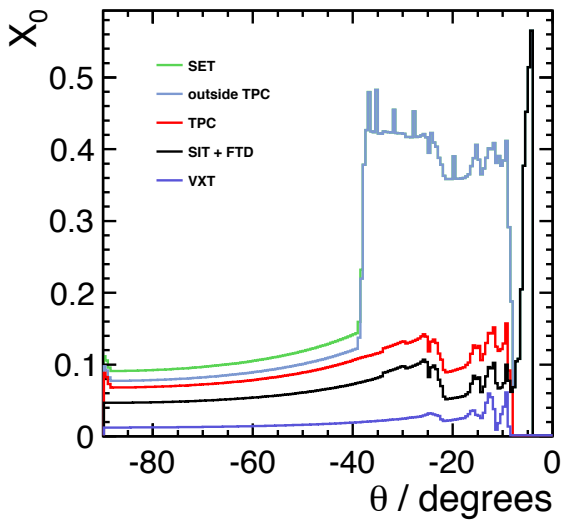




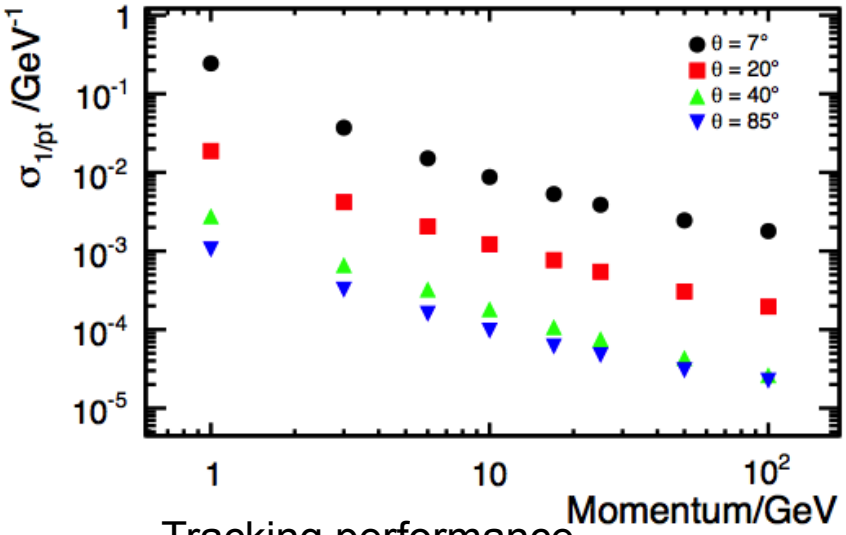
Particle Flow Reconstruction



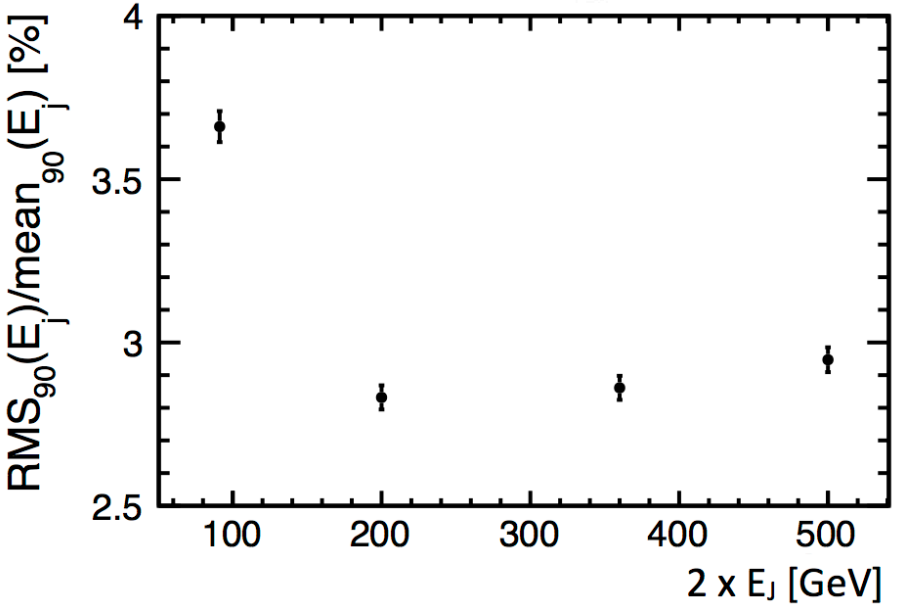
ILD Performance



Realistic description of material budget



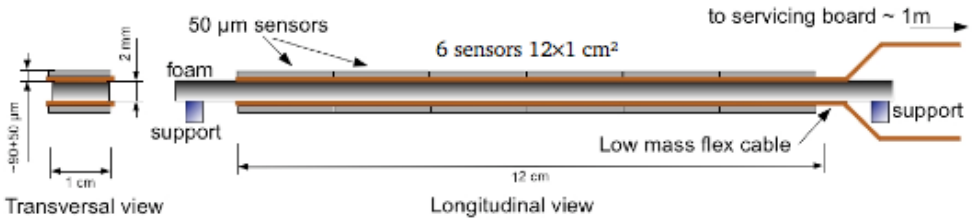
Tracking performance for single muons reaches 2 x 10^{-5} /GeV



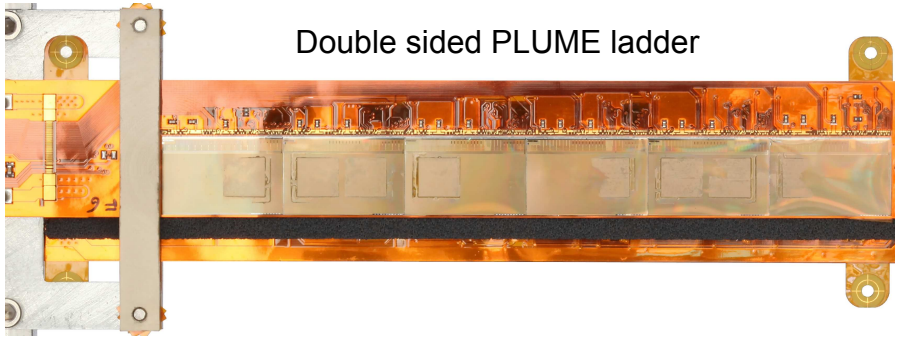
Pandora PFA performance exceeds requirement (Goal: 3% - 4%)

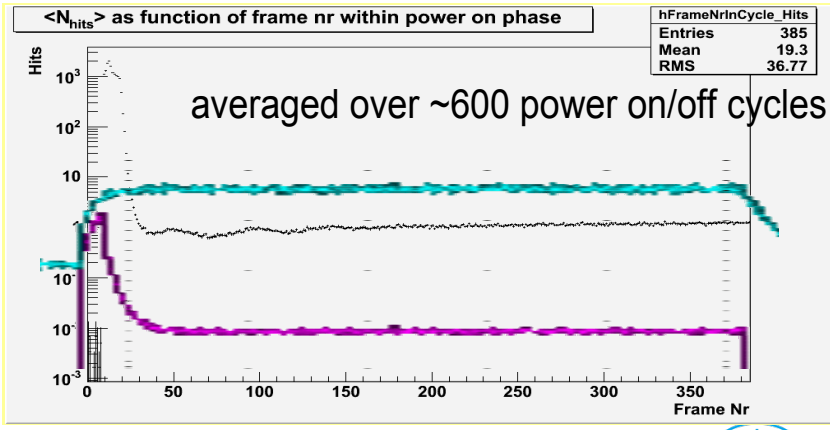
Vertex Detector R&D: PLUME

- Pixelated Ladder with Ultra-low Material Embedding PLUME
- Goal: double-sided ladder prototype for ILD vertex detector with material budget < 0.3% X_0
- First full-scale ladders fabricated in 2011(0.6% X_0)
  - 12 MIMOSA26 thinned to 50µm
  - One ladder at DESY for power pulsing studies
  - Silicon carbide foam stiffener
- Beam tests at CERN proved good electrical performance
- Beam tests at DESY planned for this summer
- Power pulsing study at DESY ongoing:
  - MIMOSA26 full operational 4-5ms after full turn on

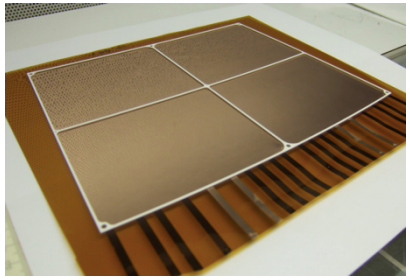


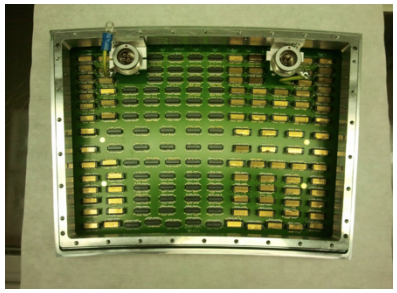
Double sided PLUME ladder



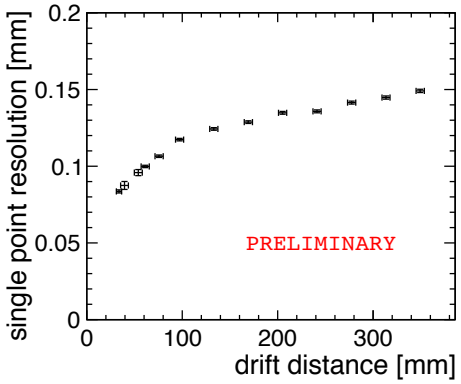


TPC Large Prototype: DESY GridGEM Module

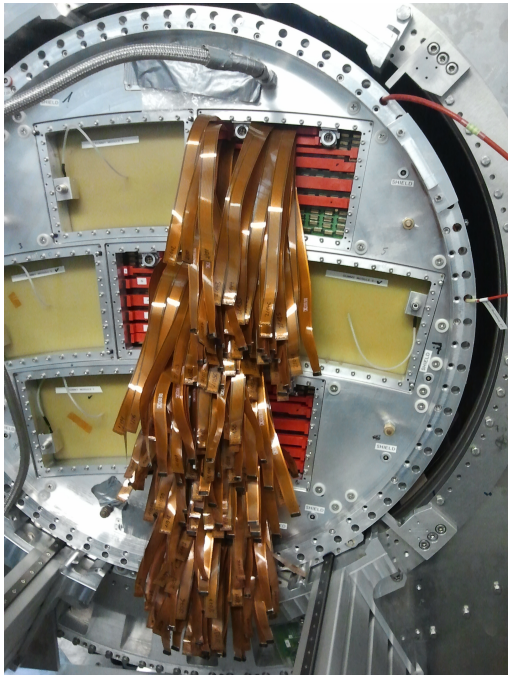




Light weight, self-supporting GEM structure with minimal dead zones

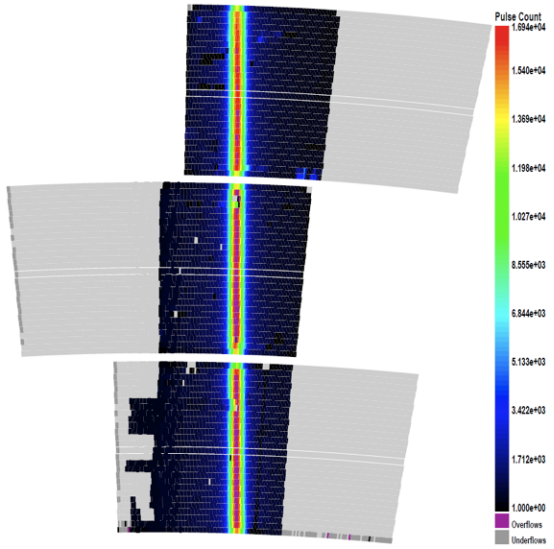


Measured single point resolution



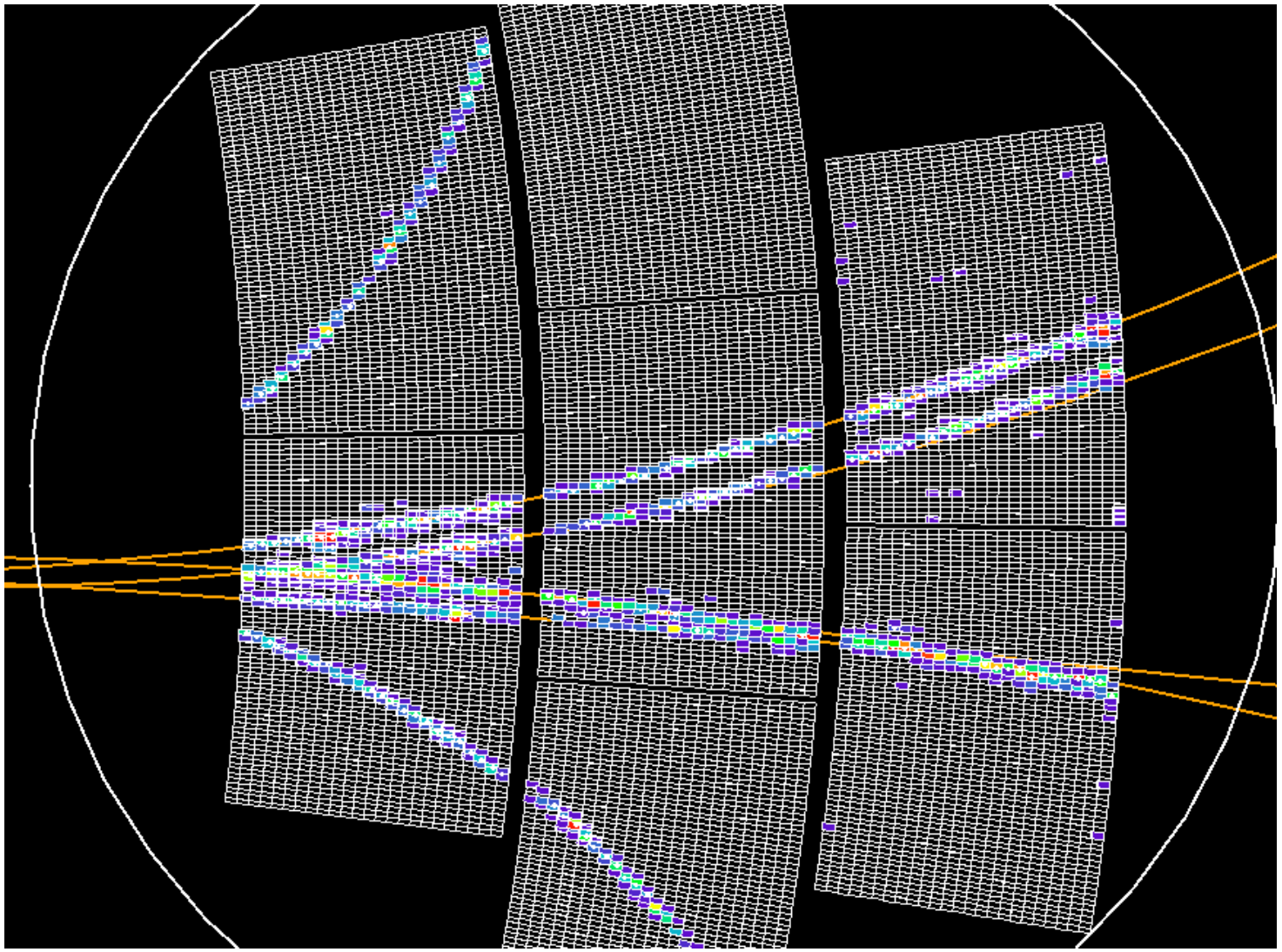
LC TPC

Test beam 2012/13:
Operated successfully three modules in large prototype with 1T B-field



DESY

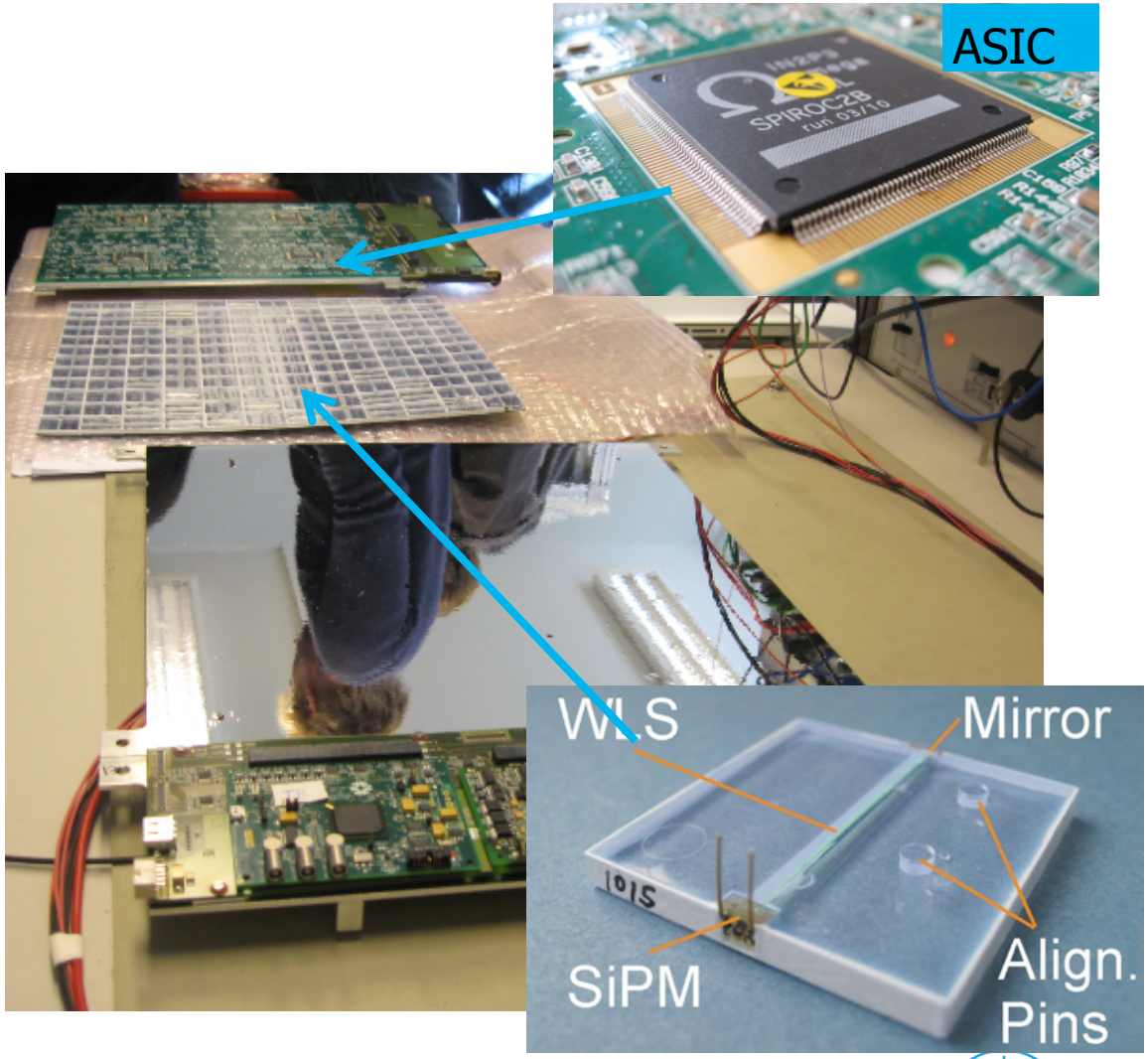
TPC Large Prototype: 7 MICROMEGAS Modules



Carleton, NIKHEF, UL Brussels, CEA

Scintillator Hadronic Calorimeter

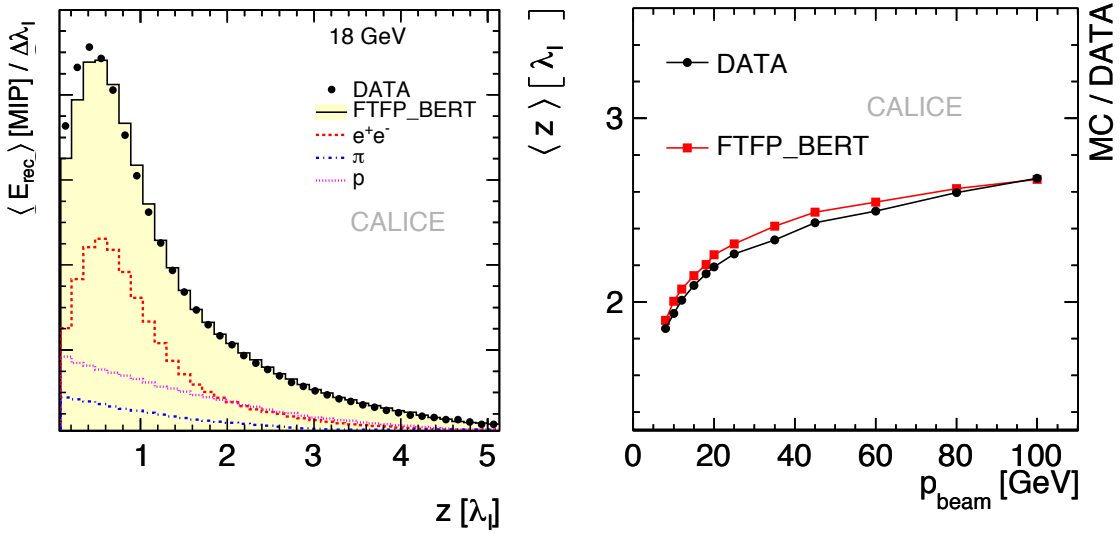
- Addressing the high granularity challenge for particle flow algorithms
- Integrated readout, trigger, digitisation, LED calibration
- DESY-led international effort within CALICE:
  - Hamburg, Heidelberg, Mainz, Wuppertal, MPI, CERN, ITEP, Dubna, LAL, Prague, Bergen, NIU, Matsumoto
  - Cooperation with Japanese groups: same design used in scintillator ECAL
- DESY active in mechanics, electronics, system integration, test beam support, software, analysis



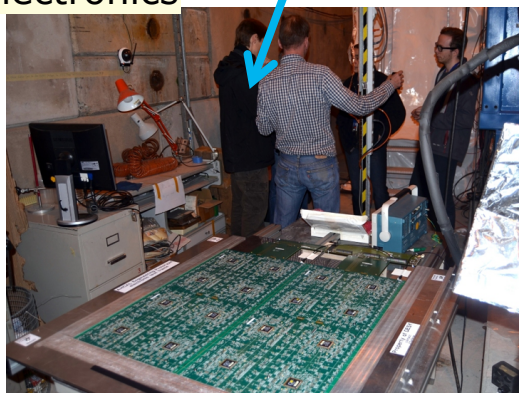
HCAL Analysis Highlights

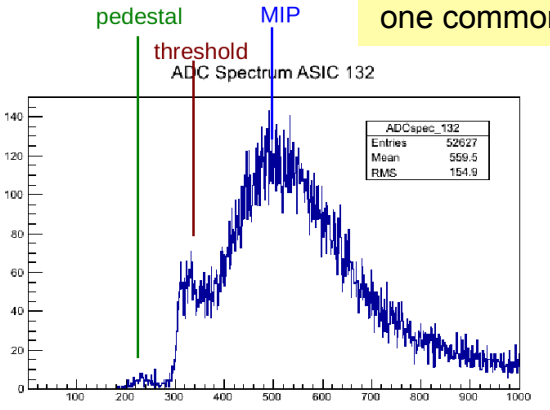
- Analysis of 1st generation scintillator HCAL data nearly complete
- Precise validation of Geant 4 models
- First data from SPS test beam (11/2012) with 2nd generation layer available

CALICE internal paper draft

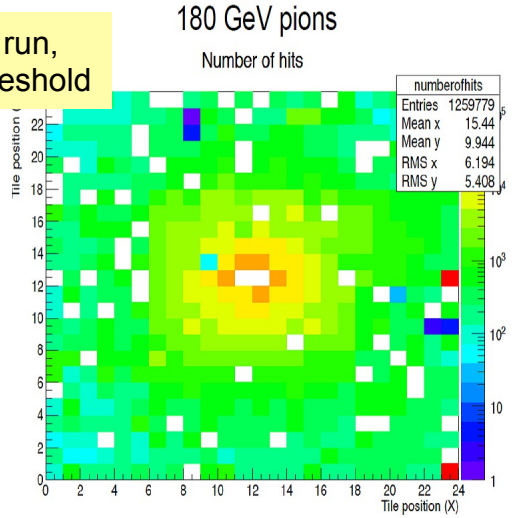


integrated electronics





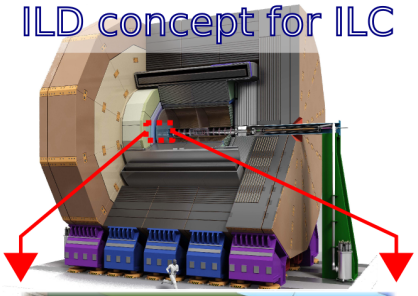
auto-triggered run, one common threshold

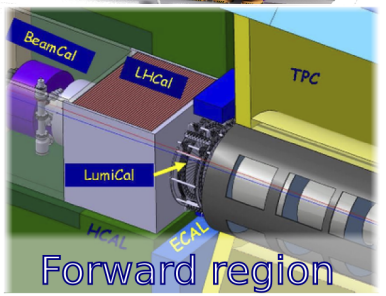


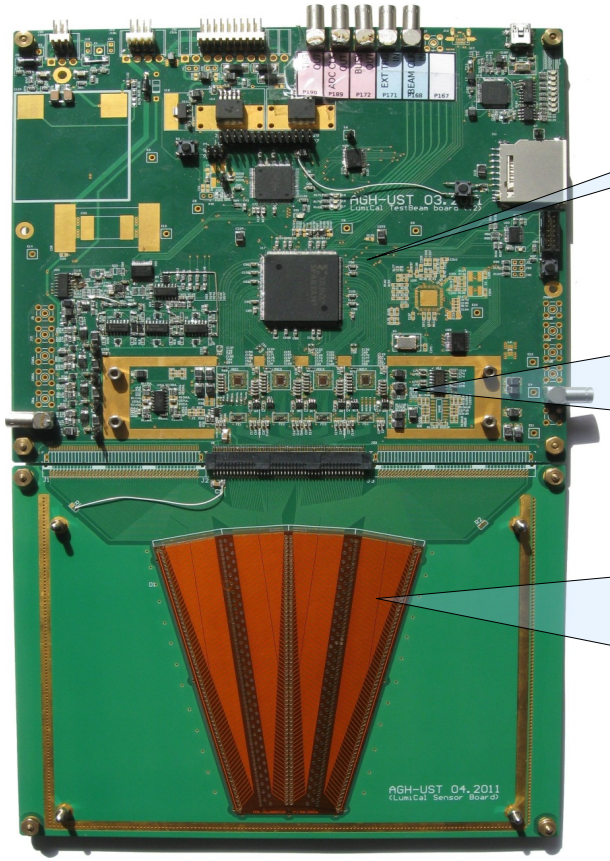
Plots: Katja Krüger

Forward Calorimeters

- LumiCal: precise luminosity measurement (Bhabha scattering)
  - fast, high precision
- BeamCal: luminosity optimisation and hermeticity (θ > 5.8 mrad)
  - fast, radiation hardness

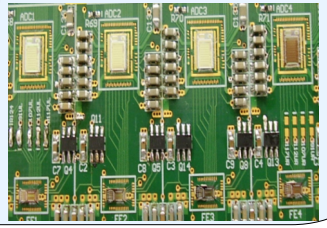




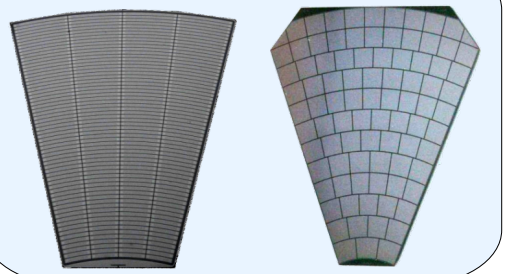


Data concentrator
Xilinx Spartan 3E

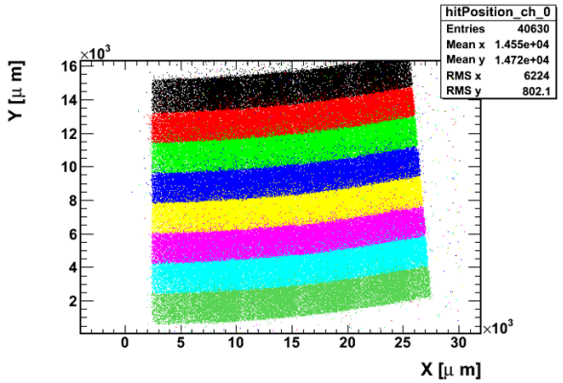
4 pairs of Front-end + ADC



LumiCal / BeamCal sensors



Fully assembled plane in DESY test beam



AGH-UST, DESY, Tel Aviv

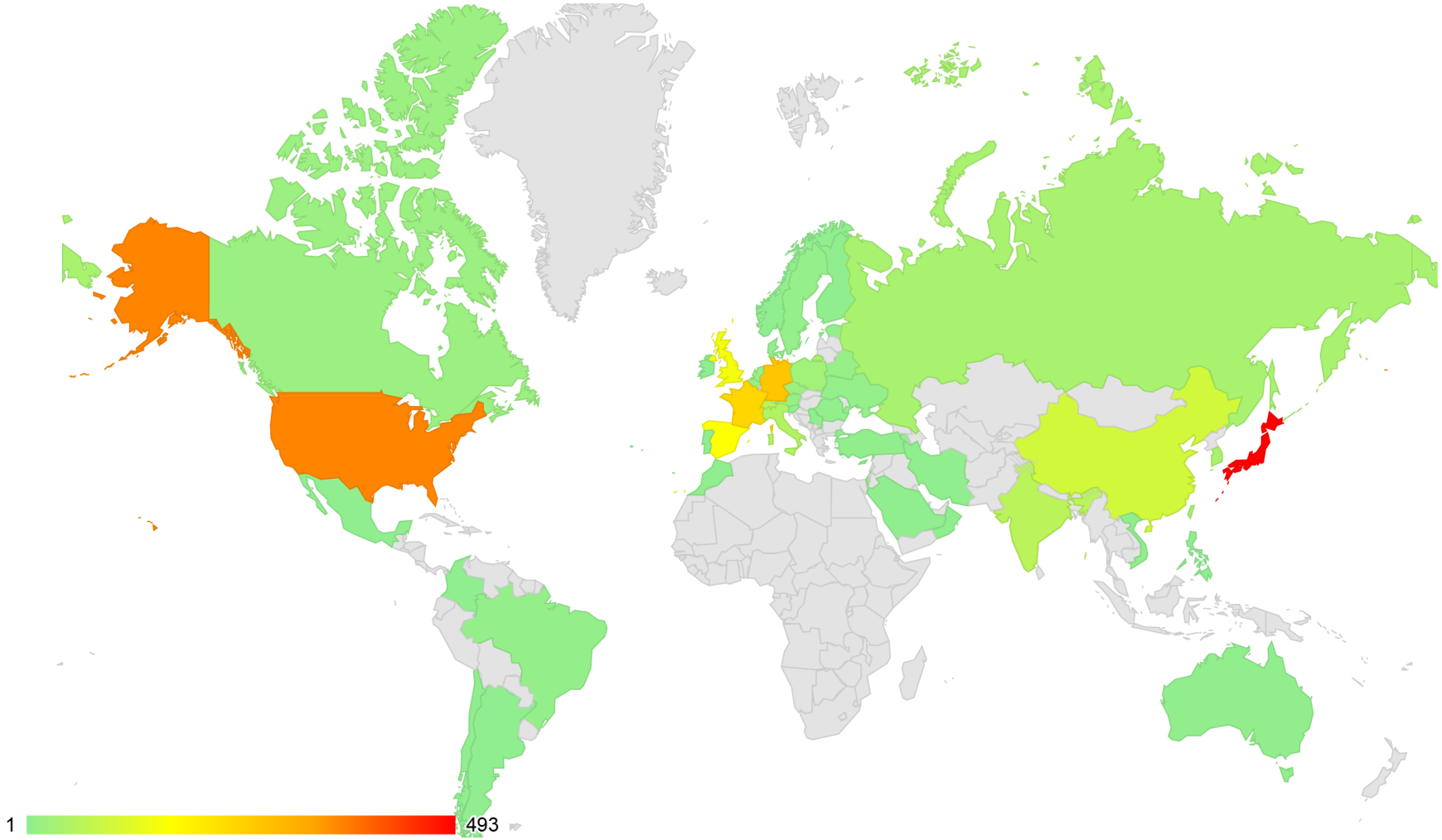
ILC Global Integration

- Central integration facility at DESY
  - ILC EDMS System
- Incorporating 3D models from worldwide collaborating institutes
- Integration of sub-systems for accelerator and detectors
- Exploit XFEL mass production and construction experience
- „ILC Project Office“

ILC Status

- Technical Design Report is being published now
  - Worldwide Linear Collider Event: June 12th 2013
  - Putting the TDR/DBD together was a major effort at DESY....
- Worldwide HEP strategies are under review
  - ILC top priority for Japanese community after discovery of „a Higgs“ at LHC
  - ILC in Japan on the priority list of CERN Council strategy update 2013
    - „(...) 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 is just being updated („Snowmass process“)
- Japanese government expressed interest to start discussions about hosting the ILC as a global project in Japan

Technical Design Report Signatories (Supporters)



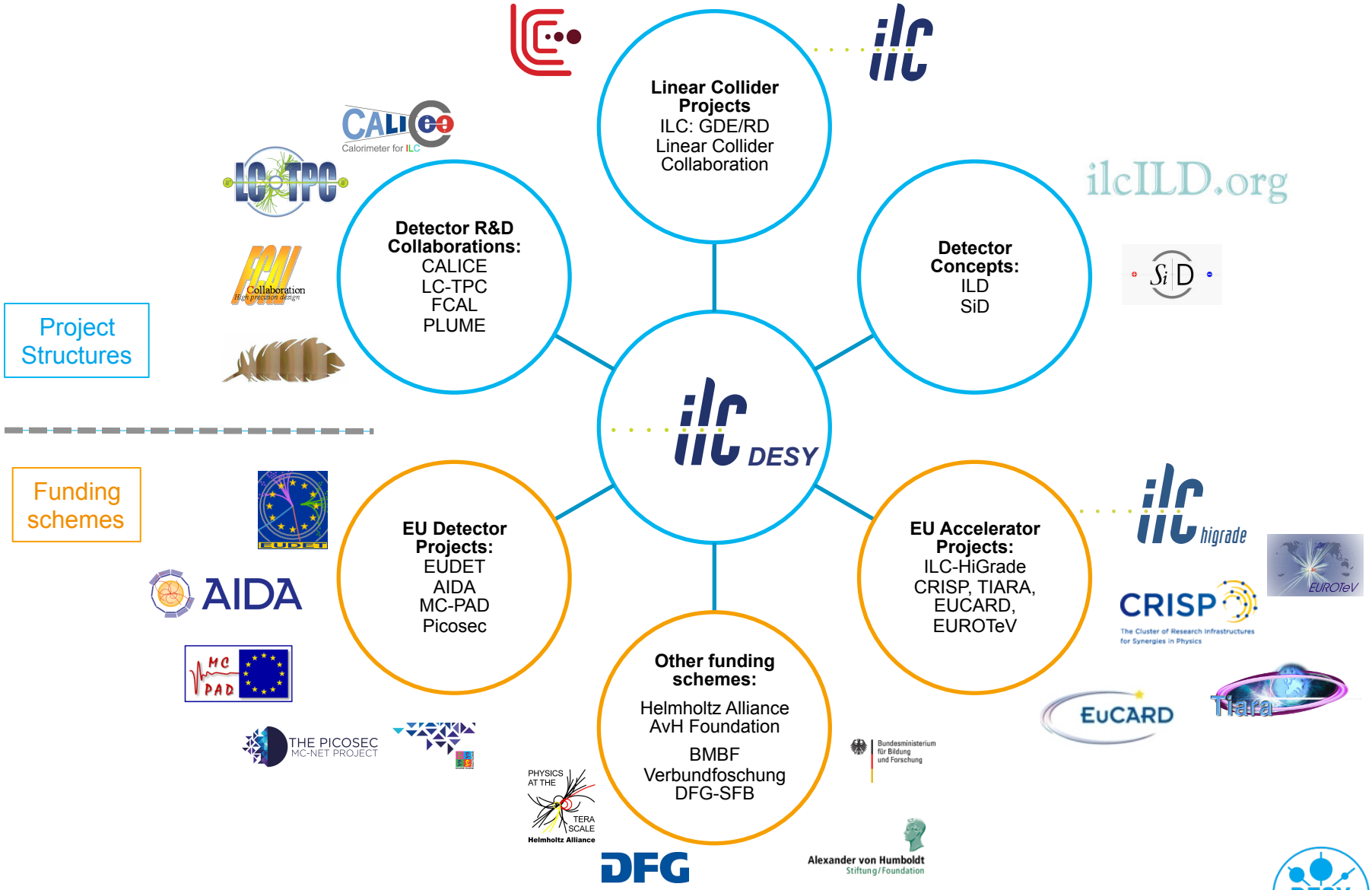
10.04.2013: 2285 Signatories

www-flc.desy.de/dbd

Linear Collider Collaboration

Linear Collider Collaboration

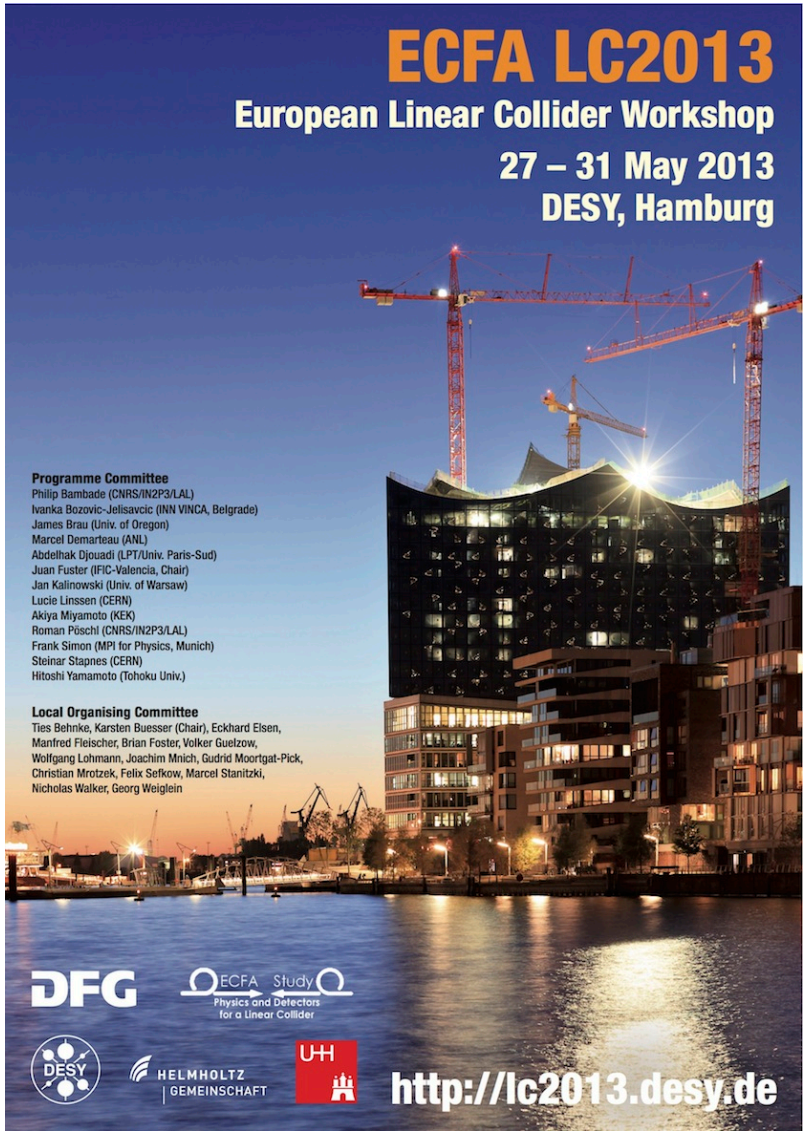
ILC@DESY Towards an International LC



ECFA LC2013

- European Linear Collider Workshop
- May 27-31 2013, DESY, Hamburg

- lc2013.desy.de



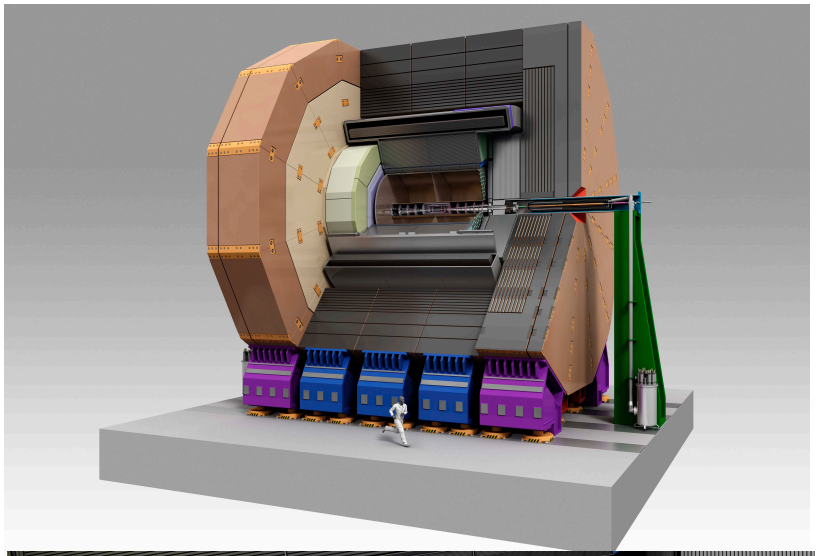
ILC Outlook

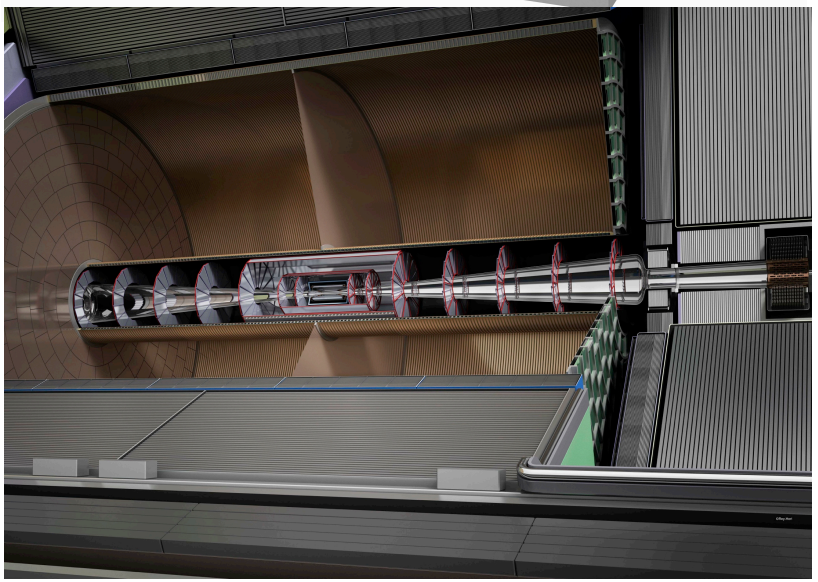
- The discovery of the new Higgs-like boson sets the first definitive energy scale for new physics, in time with major developments:
  - HEP strategy updates in Europe, Japan, USA
  - ILC Technical Design Report to be published now
- Japan shows a strong interest to host a staged Linear Collider
  - Start with a E_{cm}~250 GeV Higgs Factory
  - Evolve in energy over time
- DESY has a strong in-house ILC programme and is in a excellent position to support such a project as a joint European effort
  - XFEL experience
  - Test facilities
  - Detector R&D excellence centre

Backup

Detector Concept

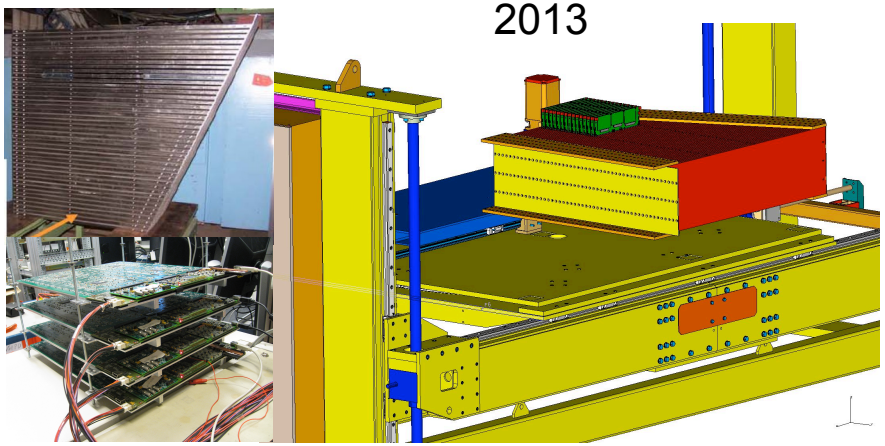
- ILD: International Large Detector
- Optimised for Particle Flow Reconstruction
- Performance goals:
  - Jet energy resolution < 3-4% over relevant energy range
  - Track momentum resolution
    $\delta(1/p_T) \approx 2 \times 10^{-5}$ /GeV /c
  - Excellent vertexing for b & c identification
  - Hermeticity
- Main requirements and challenges:
  - High granular calorimeters
  - Low material budget before calorimeters
  - Efficient tracking
  - Highly integrated electronics
  - Low power consumption
  - Triggerless readout

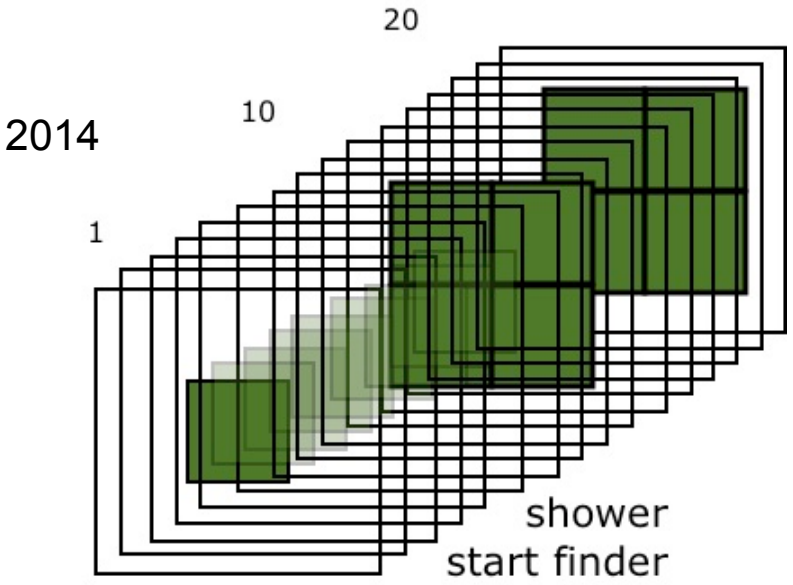




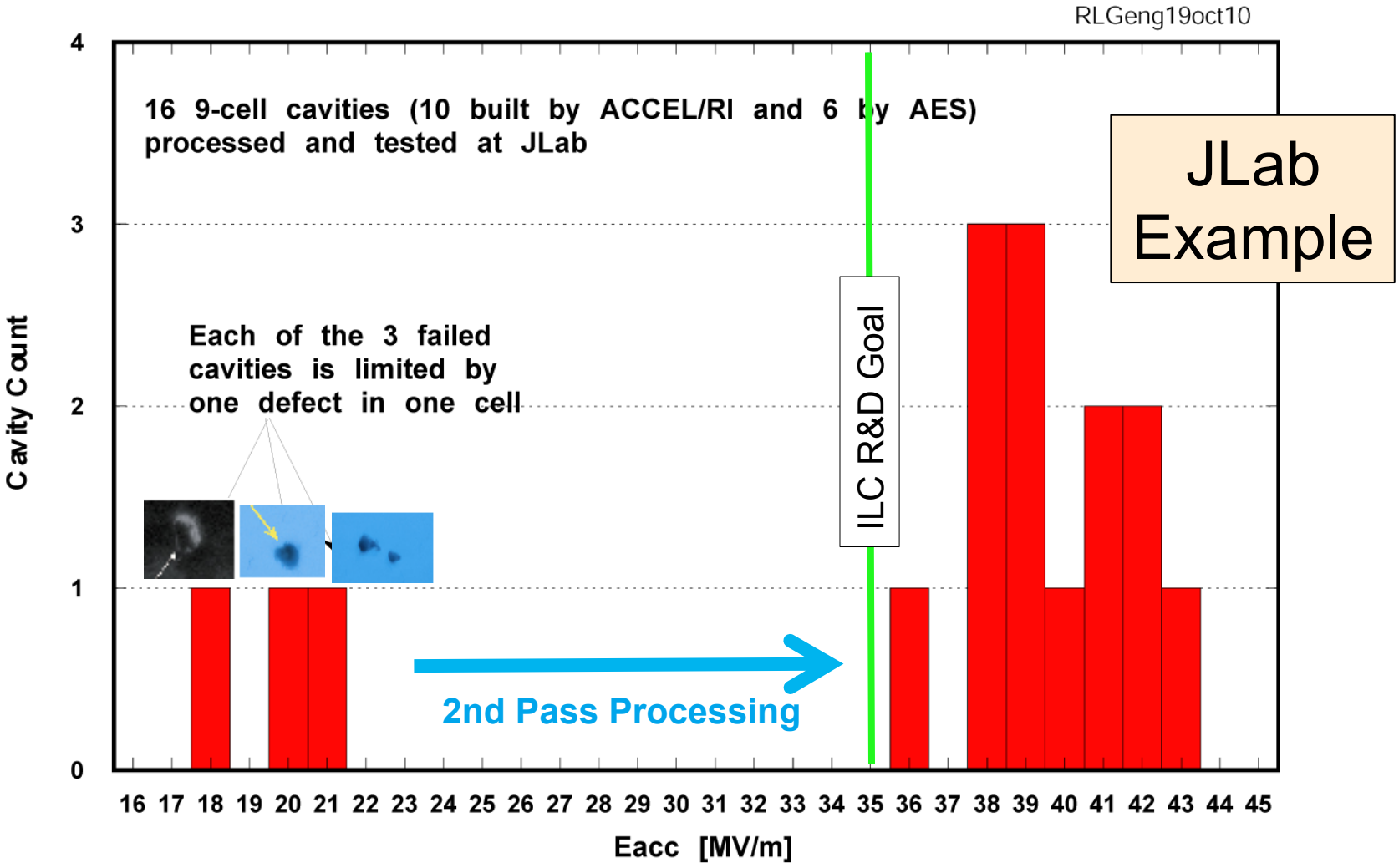
HCAL Future Plans

- Proceed in parallel on
  - Sensor technology frontier
  - Integration and industrialisation frontier
  - Possible thanks to versatile electronics
- Goals for 2nd generation prototype
  - Re-establish performance
  - Demonstrate scalability in al steps
    - Production, QC, calibration
  - Remaining integration tasks
    - Data concentrator, power, cooling
- Next test beam campaigns:
  - 2013: e.m. stack at DESY, 1k chn.
  - 2014: hadron beam tests, 3k chn.
  - 2016: full hadron stack, 20k chn.





Gradient Limit Understanding and Control



2nd pass processing: 100% yield at 39 MV/m average gradient

Coherent Integration Effort