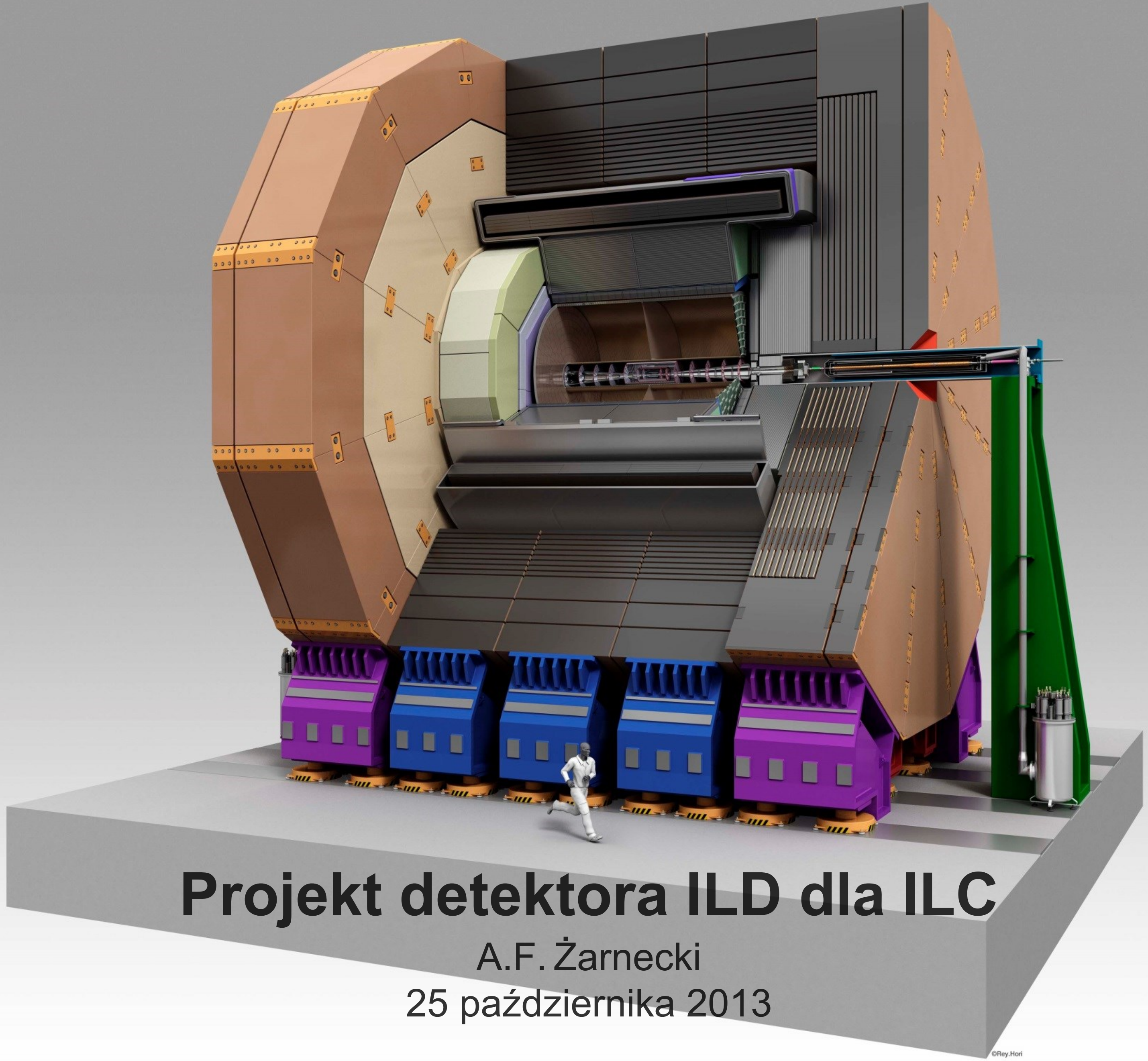


Projekt detektora ILD dla ILC

A.F. Żarnecki

25 października 2013

Plan seminarium:

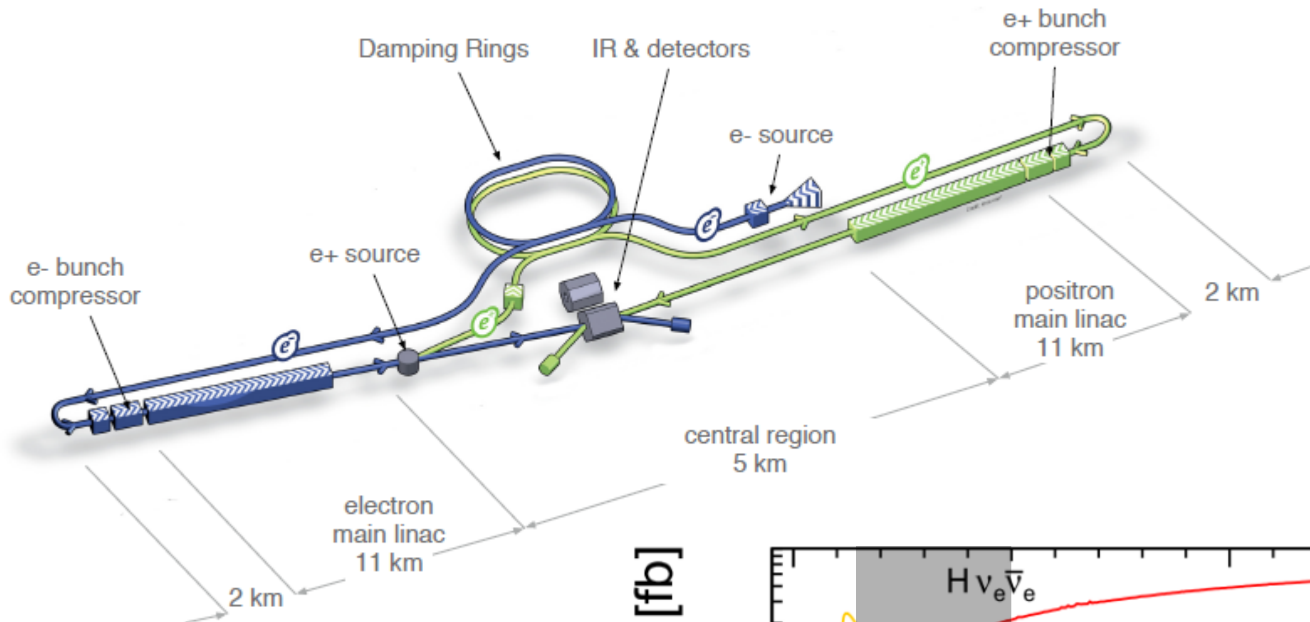
- Wprowadzenie: status projektu ILC
- Lokalizacja ILC w Japonii
- Koncepcja ILD
- Projekty poddetektorów
- Optymalizacja
- Plany

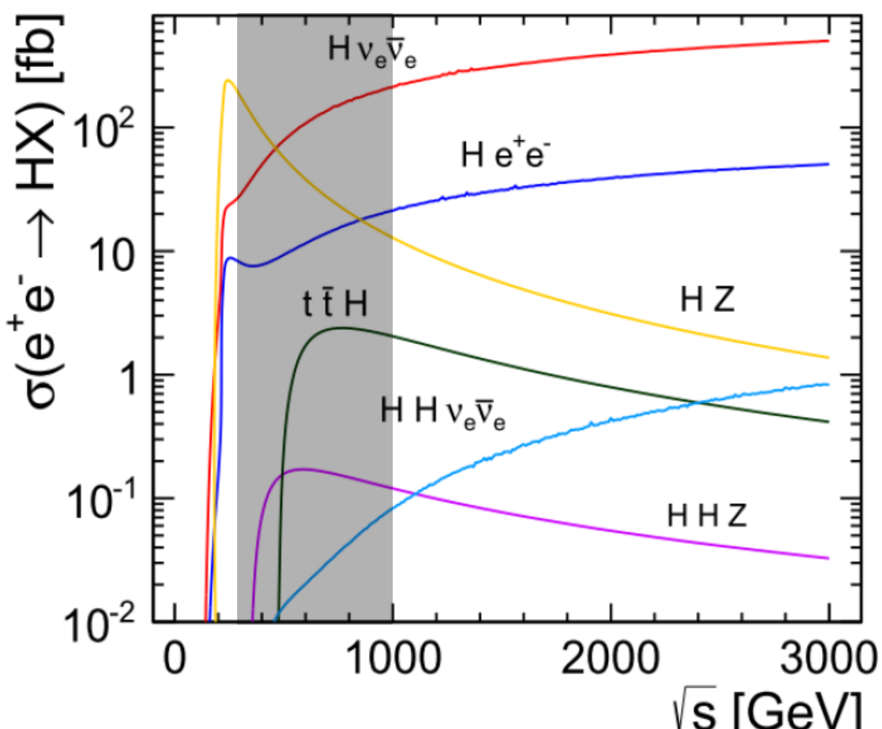
Prezentacja oparta na materiałach z:

- ILD meeting, Kraków, wrzesień 2013
- ECFA LC Workshop, Hamburg, maj 2013

oraz innych spotkań i konferencji.

ILC : e^+e^- Linear Collider at 250 GeV < $\sqrt{s}$ < 1000 GeV





Very Brief History of the Linear Collider Project

1980s LC Accel. R&D was started at DESY, KEK, SLAC

1991 **First Linear Collider Workshop (Finland)**

1990s Five major accelerator technologies were under hard competition :
TESLA , S-band, C-band, X-band, CLIC

1998 Physics and detector issues are rather accelerator independent
World-wide-studies of physics and detector for LCs was formed (grass-roots-organization)

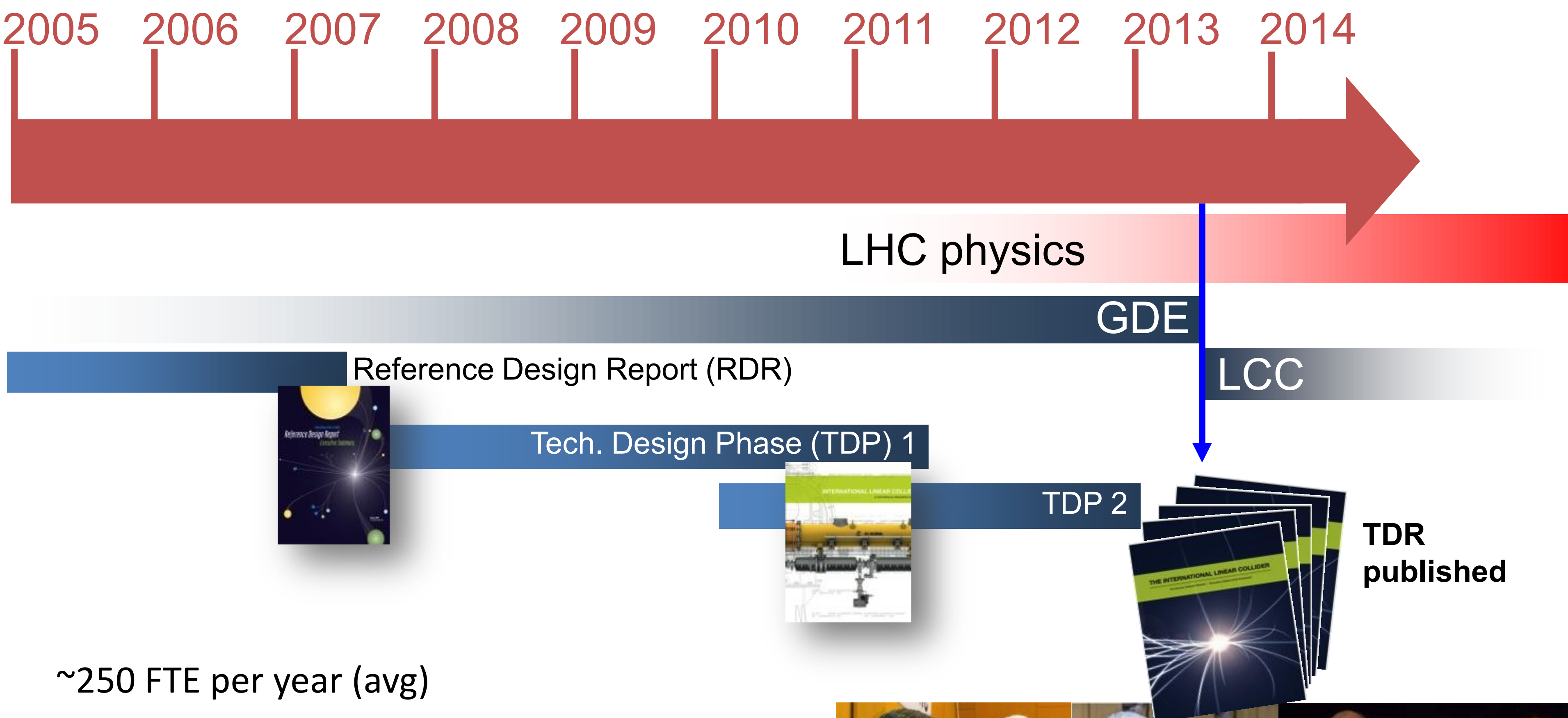
2000 Under OECD Global Science Forum, Consultative Group of High Energy Physics started (2000-2002)

2002 ICFA created **ILC Steering Committee (ILCSC)**

2004 International Technology Recommendation Panel **(ITRP) chose super-conducting RF for the main linac technology**

LINEAR COLLIDER COLLABORATION

GDE Timeline



~250 FTE per year (avg)

~2,000 MY (→ ~5,000 if pre-GDE included)

~300 M$ globally

Global Event
June 12

Recommendations in the subcommittee report

February 11, 2012

The committee makes the following recommendations concerning large-scale projects, which comprise the core of future high energy physics research in Japan.

- **Should a new particle such as a Higgs boson with a mass below approximately 1 TeV be confirmed at LHC, Japan should take the leadership role in an early realization of an e^+e^- linear collider.** In particular, if the particle is light, experiments at low collision energy should be started at the earliest possible time. In parallel, continuous studies on new physics should be pursued for both LHC and the upgraded LHC version. Should the energy scale of new particles/physics be higher, accelerator R&D should be strengthened in order to realize the necessary collision energy.
- **Should the neutrino mixing angle θ_{13} be confirmed as large, Japan should aim to realize a large-scale neutrino detector through international cooperation, accompanied by the necessary reinforcement of accelerator intensity, so allowing studies on CP symmetry through neutrino oscillations.** This new large-scale neutrino detector should have sufficient sensitivity to allow the search for proton decays, which would be direct evidence of Grand Unified Theories.

It is expected that the Committee on Future Projects, which includes the High Energy Physics Committee members as its core, should be able to swiftly and flexibly update the strategies for these key, large-scale projects according to newly obtained knowledge from LHC and other sources.

It is important to complete and start the SuperKEKB including the detector, as scheduled. Some of the medium/small scale projects currently under consideration have the implicit potential to develop into important research fields in the future, such as neutrino physics and as such, should be promoted in parallel to pursue new physics in various directions. Flavour physics experiments such as muon experiments at J-PARC, searches for dark matter and neutrinoless double beta decays or observations of CMB B-mode polarization and dark energy are considered as projects that have such potential.

A Proposal for a Phased Execution of the International Linear Collider Project

In March 2012, the Japan Association of High Energy Physicists (JAHEP) accepted the recommendations of the Subcommittee on Future Projects of High Energy Physics[1] and adopted them as JAHEP's basic strategy for future projects. In July 2012, a new particle consistent with a Higgs Boson was discovered at LHC, while in December 2012 the Technical Design Report of the International Linear Collider (ILC) will be completed by a worldwide collaboration.

On the basis of these developments and following the subcommittee's recommendation on ILC, JAHEP proposes that ILC be constructed in Japan as a global project with the agreement of and participation by the international community in the following scenario:

(1) Physics studies shall start with a precision study of the "Higgs Boson", and then evolve into studies of the top quark, "dark matter" particles, and Higgs self-couplings, by upgrading the accelerator. A more specific scenario is as follows:

(A) A Higgs factory with a center-of-mass energy of approximately 250 GeV shall be constructed as a first phase.

(B) The machine shall be upgraded in stages up to a center-of-mass energy of ~500 GeV, which is the baseline energy of the overall project.

(C) Technical extendability to a 1 TeV region shall be secured.

(2) A guideline for contributions to the construction costs is that Japan covers 50% of the expenses (construction) of the overall project of a 500 GeV machine. The actual contributions, however, should be left to negotiations among the governments.

October, 2012 The Japan Association of High Energy Physicists

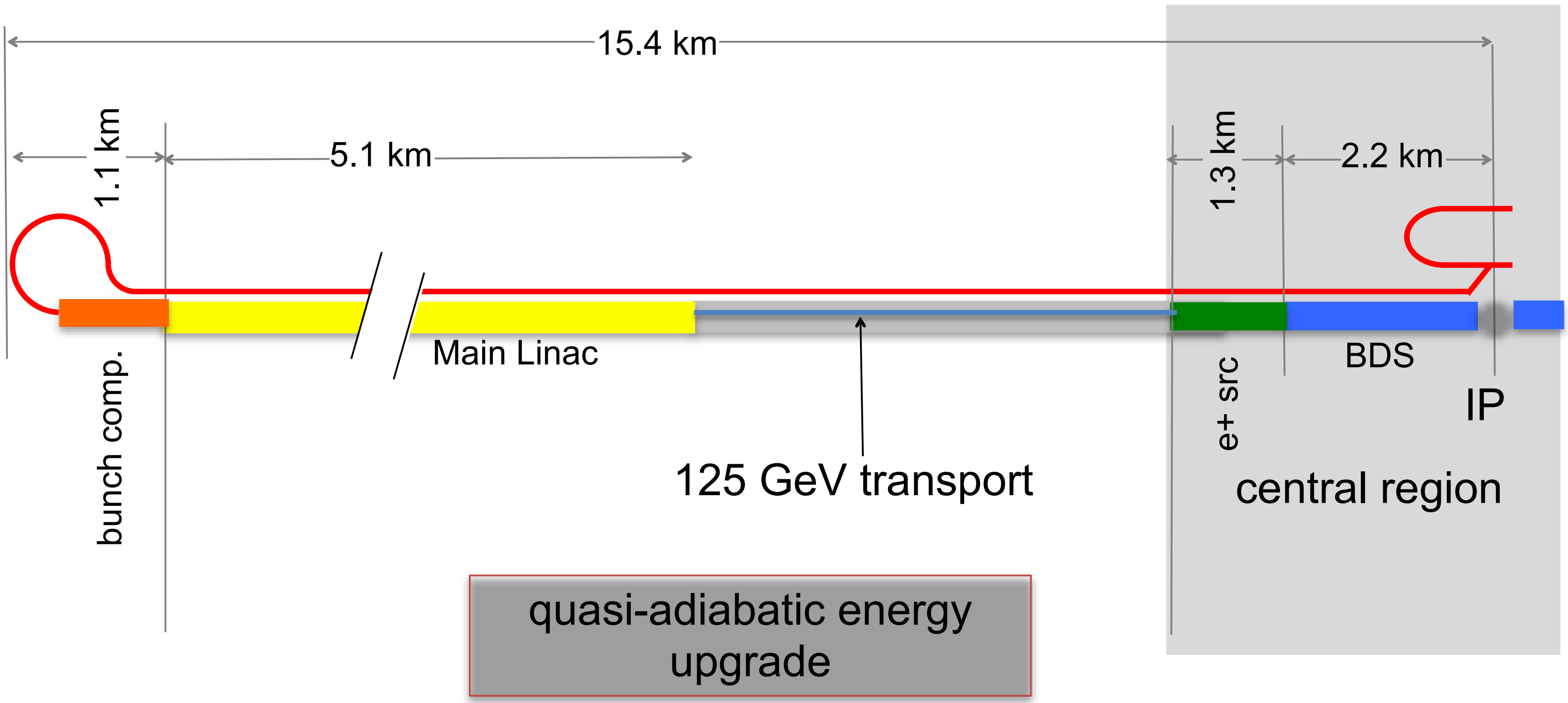
3 important points

TDR is ready now.
Technically Ready

ILC is a global Project.
Japan wish to play a important role as a Host.

ILC is not only Higgs Factory
Target is ～ 500GeV
and 1TeV extendability

Staged construction: 250 GeV



- Complete civil construction for 500 GeV machine
- Install ~1/2 linacs for fist stage operation (and long transport line)
- Capital savings ~25%
- Adiabatic energy upgrade (lower rate cryomodule production)

Favoured by Japan

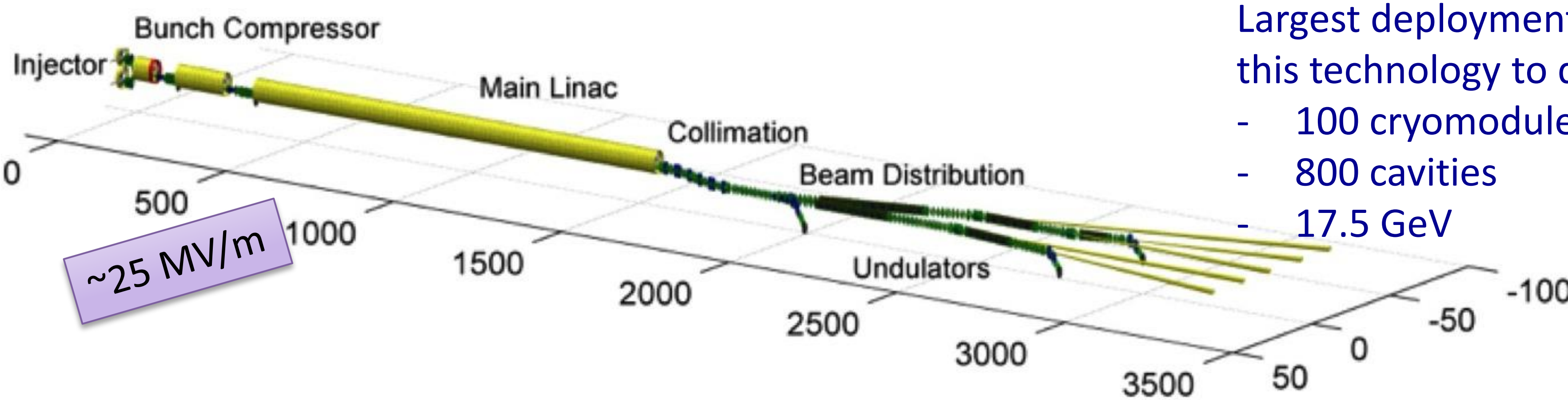
Four large scale projects with high priority

e) 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*.

- Complementarity between e^+e^- machines and the LHC for Higgs studies and search for new particles.
- Europe is not in the position to construct another large accelerator right now.
- If the ILC were realised within the LHC lifetime outside of Europe, a logical conclusion is to contribute, i.e. optimisation of the global resources.

LINEAR COLLIDER COLLABORATION

European XFEL @ DESY



Largest deployment of this technology to date

- 100 cryomodules
- 800 cavities
- 17.5 GeV



Institute	Component Task
CEA Saclay / IRFU, France	Cavity string and module assembly; cold beam position monitors
CNRS / LAL Orsay, France	RF main input coupler incl. RF conditioning
DESY, Germany	Cavities & cryostats; contributions to string & module assembly; coupler interlock; frequency tuner; cold-vacuum system; integration of superconducting magnets; cold beam-position monitors
INFN Milano, Italy	Cavities & cryostats
Soltan Inst., Poland	Higher-order-mode coupler & absorber
CIEMAT, Spain	Superconducting magnets
IFJ PAN Cracow, Poland	RF cavity and cryomodule testing
BINP, Russia	Cold vacuum components

The ultimate ‘**integrated systems test**’ for ILC.

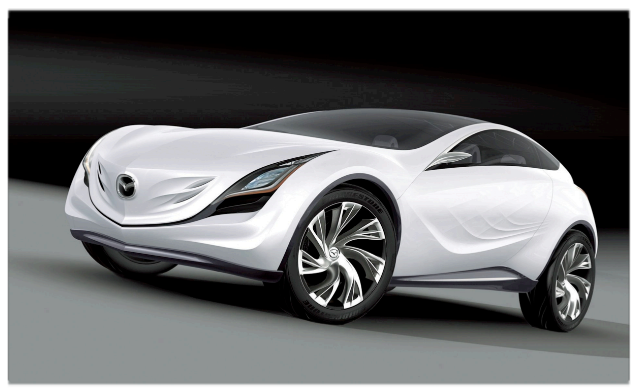
ILC, up to 500 GeV

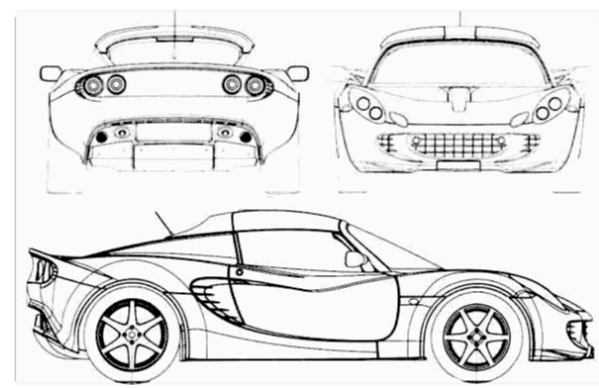
1. **Tagged Higgs study in e+e–> Zh: model-independent BR and Higgs Γ, direct study of invisible & exotic Higgs decays**
2. **Model-independent Higgs couplings with % accuracy, great statistical & systematic sensitivity to theories.**
3. Higgs CP studies in fermionic channels (e.g., tau tau)
4. **Giga-Z program for EW precision, W mass to 4 MeV and beyond.**
5. Improvement of triple VB couplings by a factor 10, to accuracy below expectations for Higgs sector resonances.
6. Theoretically and experimentally precise top quark mass to 100 MeV.
7. **Sub-% measurement of top couplings to gamma & Z, accuracy well below expectations in models of composite top and Higgs**
8. Search for rare top couplings in e+e- -> t cbar, t ubar.
9. Improvement of α_S from Giga-Z
10. No-footnotes search capability for new particles in LHC blind spots -- Higgsino, stealth stop, compressed spectra, WIMP dark matter

Higgs EW Top QCD NP/flavor

the Proposal Frontier

LHC 100/fb	LHC 300/fb	LHC 3/ab	ILC 250-500GeV	ILC 1TeV	CLIC >1TeV	MC	TLEP	VLHC
years beyond TDR	TDR	LOI	TDR	TDR	CDR			





Science Council of Japan

Remarks on the ILC, September 30, 2013

(translated by Hitoshi Yamamoto)

The Science Council of Japan organized the issues in examining the value of the ILC project and that of siting it in Japan in two steps. Namely, (1) the necessity and case for electron positron colliders and the position of the ILC as the next generation project thereof, and, (2) examination of various issues toward judging the advisability of siting the ILC project in Japan.

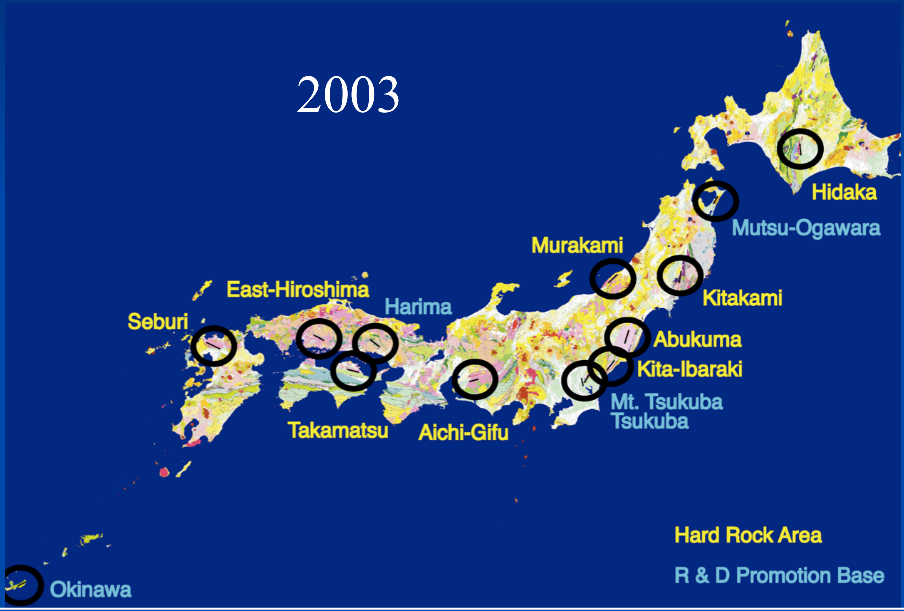
environmental problems. In order to execute the ILC project in Japan, the political, bureaucratic, and academic branches need to gather ideas and present a sustainable framework that can be supported by the Japanese public for how to solve the problem of the long-term and large financial burden under the condition of tight national budget. We should avoid situations where efforts to solve various national problems are affected by the allocation of resources to the ILC, or other academic fields are stagnated that are to support the nation building based on science and technology. Considering these issues, we have to say that it is too early at present to endorse a full-scale implementation of the ILC project in Japan.

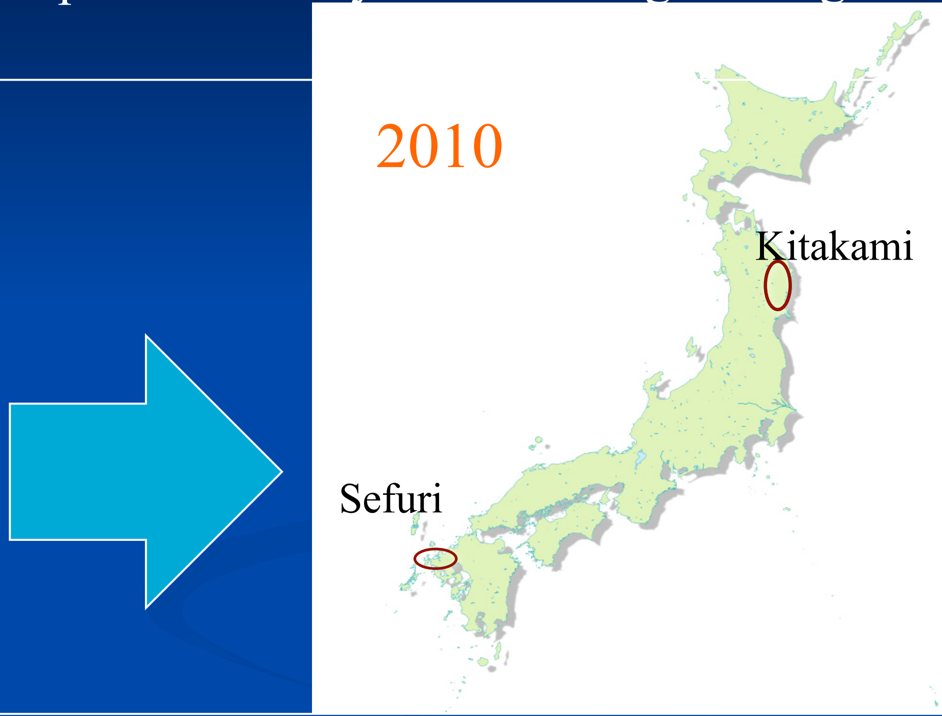
Based on the viewpoints above, the Science Council of Japan proposes that the Japanese government appropriate necessary fund to study various issues toward judging the advisability of implementing the ILC project, and intensively conduct examinations and studies for 2 to 3 years by a group consisting of experts outside of the relevant field and related government offices.

Site investigation, civil engineering

1990s - 2011

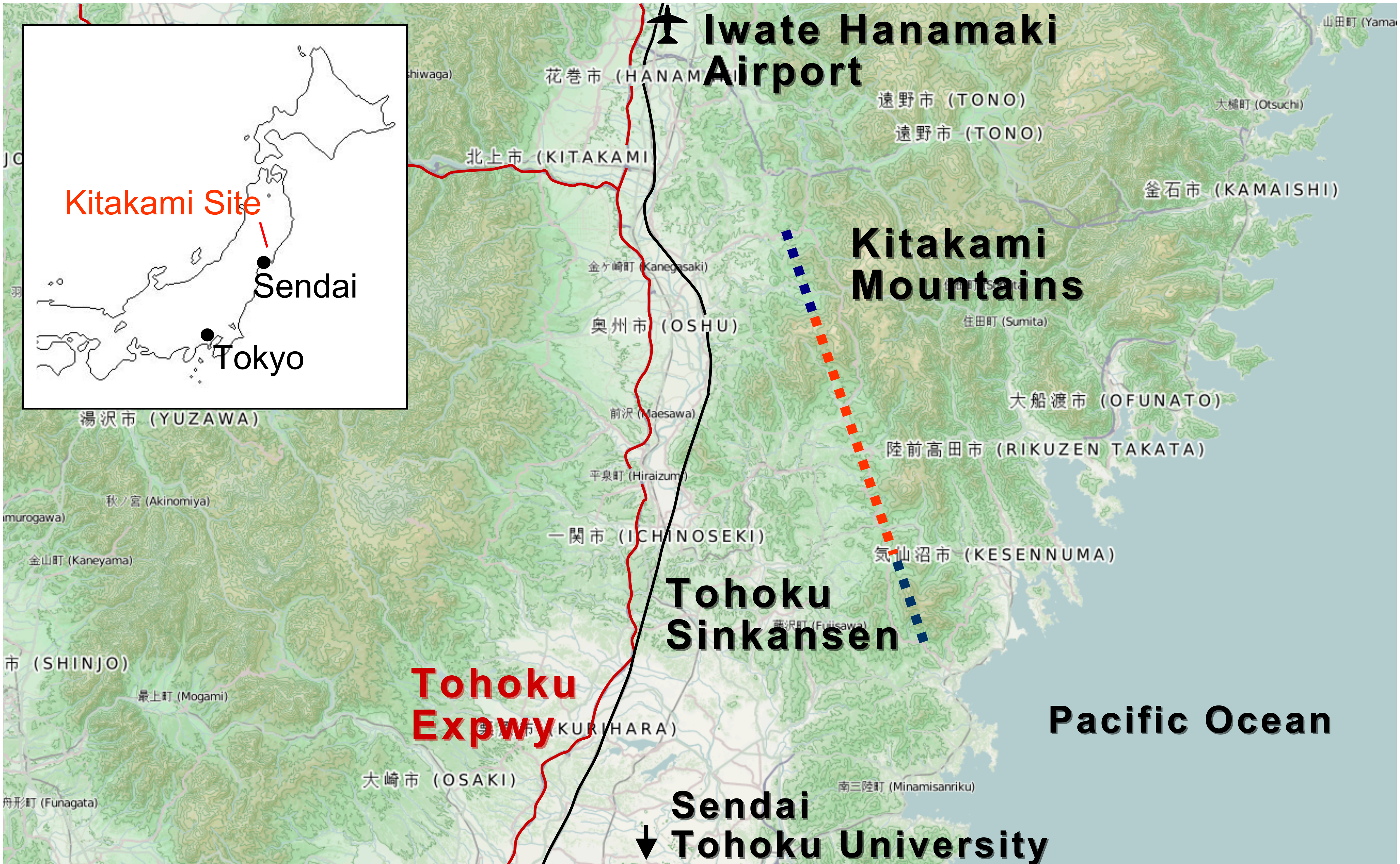
1. Survey of domestic candidate sites (1990s, 2000-2009)
2. Cooperation with experts of geology, Japanese Society for Civil Engineering (2006-)





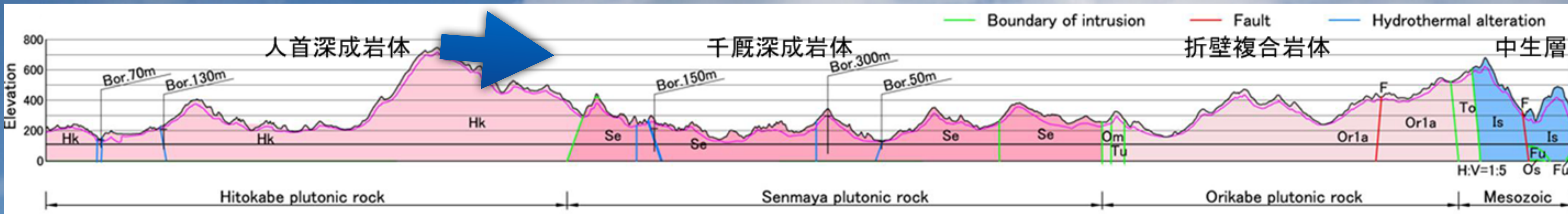
3. Establishment of local core-groups in two candidate areas (2007-2009)
4. Start of the dedicated investigation of geology by joint efforts by local governments and universities in the area. (2010-)
5. New activity for ILC (standard guidance for civil engineering) by **Japanese Society for Civil Engineering (JSCE)** (2010-)
6. Detailed study in the various construction process by KEK with AAA (2010-2011).

Site A : Kitakami in Japan



0 10 20 30km

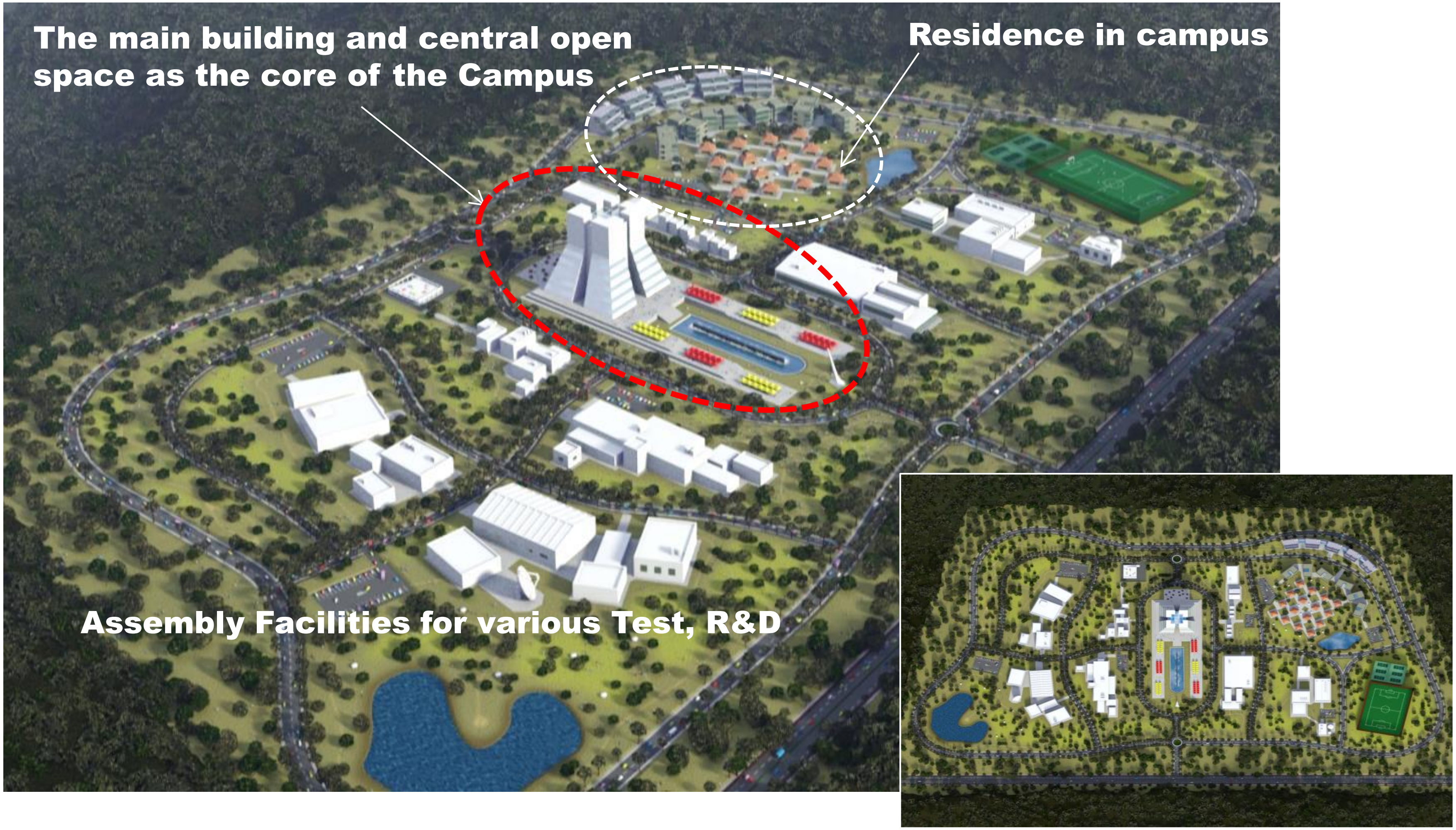
LEGEND :
ILC 500GeV
ILC 1TeV


Boundary of intrusion
Fault
Hydrothermal alteration
Elevation
800
600
400
200
0
人首深成岩体
千厩深成岩体
折壁複合岩体
中生層
Bor.70m
Bor.130m
Bor.150m
Bor.300m
Bor.50m
Hk
Se
Om
Tu
Or1a
To
Is
F
Fu
Os
H:V=1:5
Hitokabe plutonic rock
Senmaya plutonic rock
Orikabe plutonic rock
Mesozoic

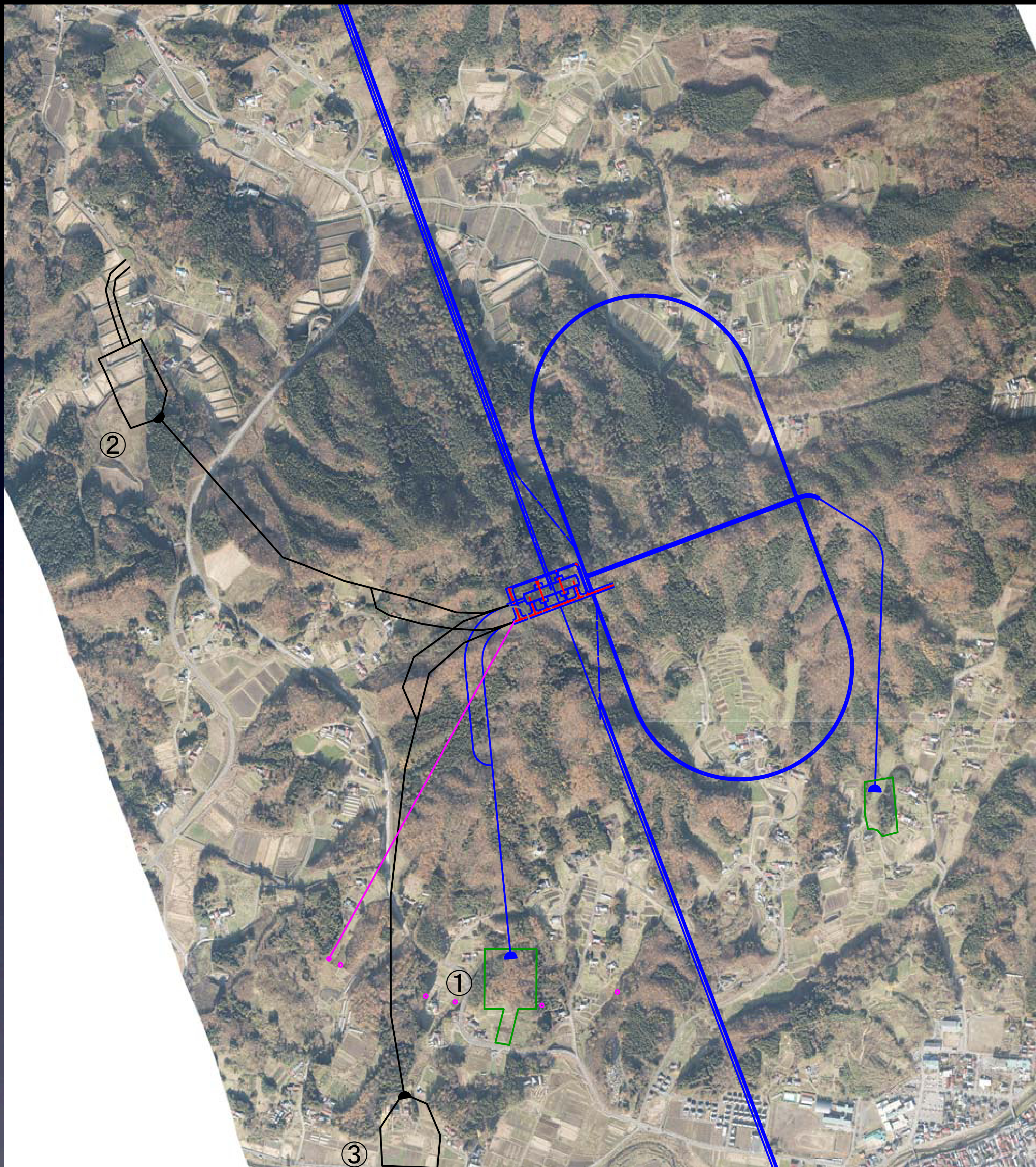

IP (~12km away)

Image of ILC Central Campus, suggested

Model plan of assuming the site area 80ha



More detail will be discussed during this workshop



500m

can find some candidate sites for assembly yard

Access tunnel:
The shorter, the better

Seismic Conditions

- Talk by Tauchi-san on Thursday
- Need to follow ISO3010:

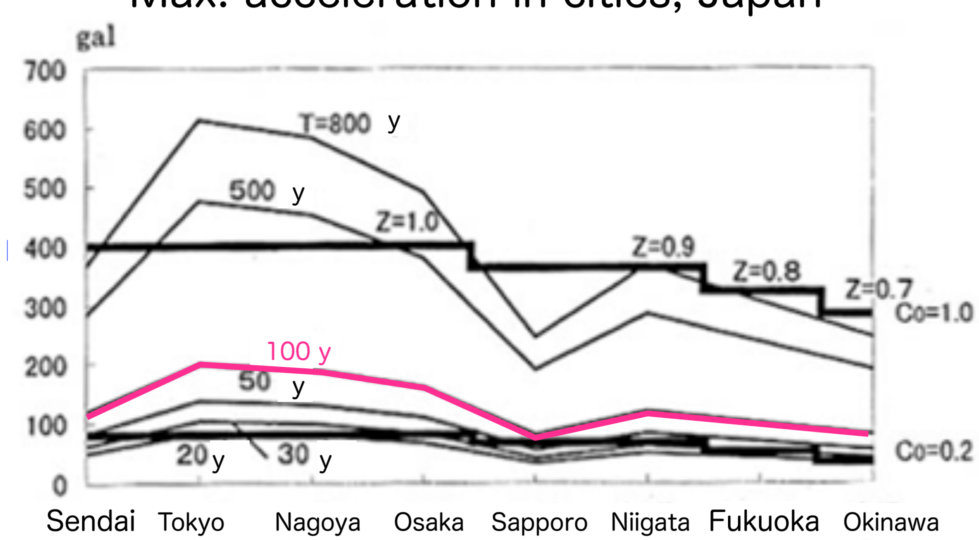
a) (ultimate limit state: ULS) The structure should not collapse nor experience other similar forms of structural failure due to severe earthquake ground motions that could occur at the site .

b) (serviceability limit state: SLS) The structure should withstand moderate earthquake ground motions which may be expected to occur at the site during the service life of the structure with damage within accepted limits.

In both cases, the seismic force can be the maximum acceleration of earthquakes in the recurrence intervals of 100 years.

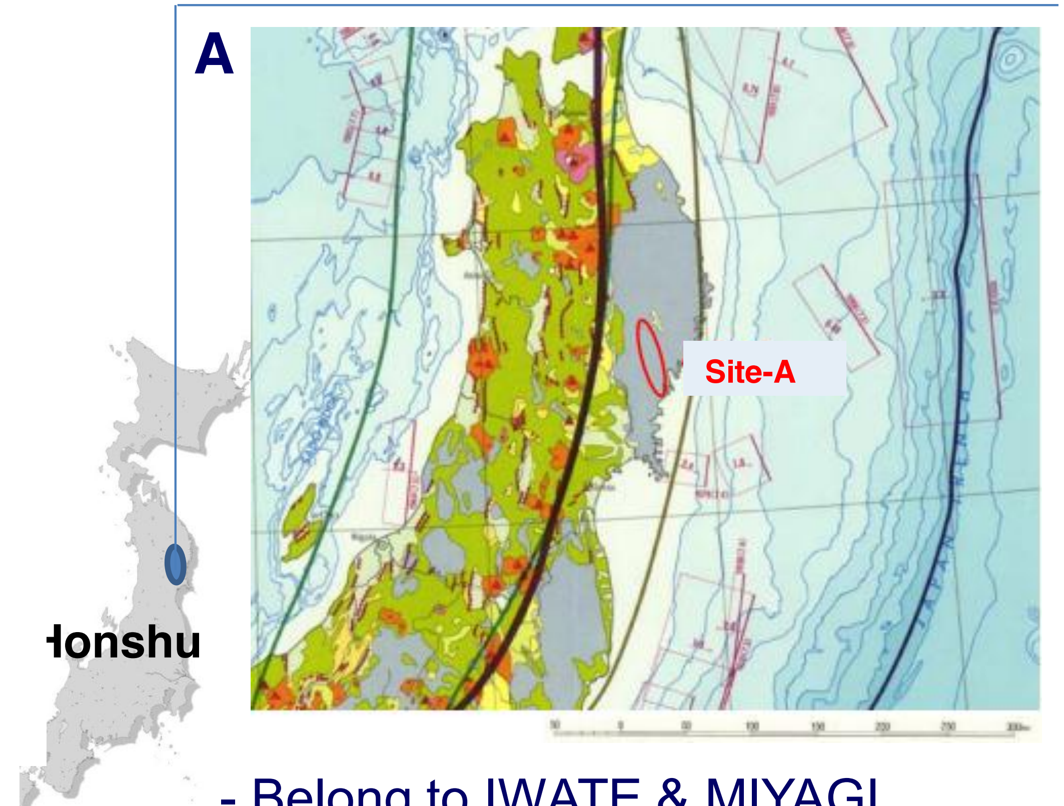
- 1 gal ~ 0.001g

Max. acceleration in cities, Japan



Site-A Site-B

KITAKAMI-Site



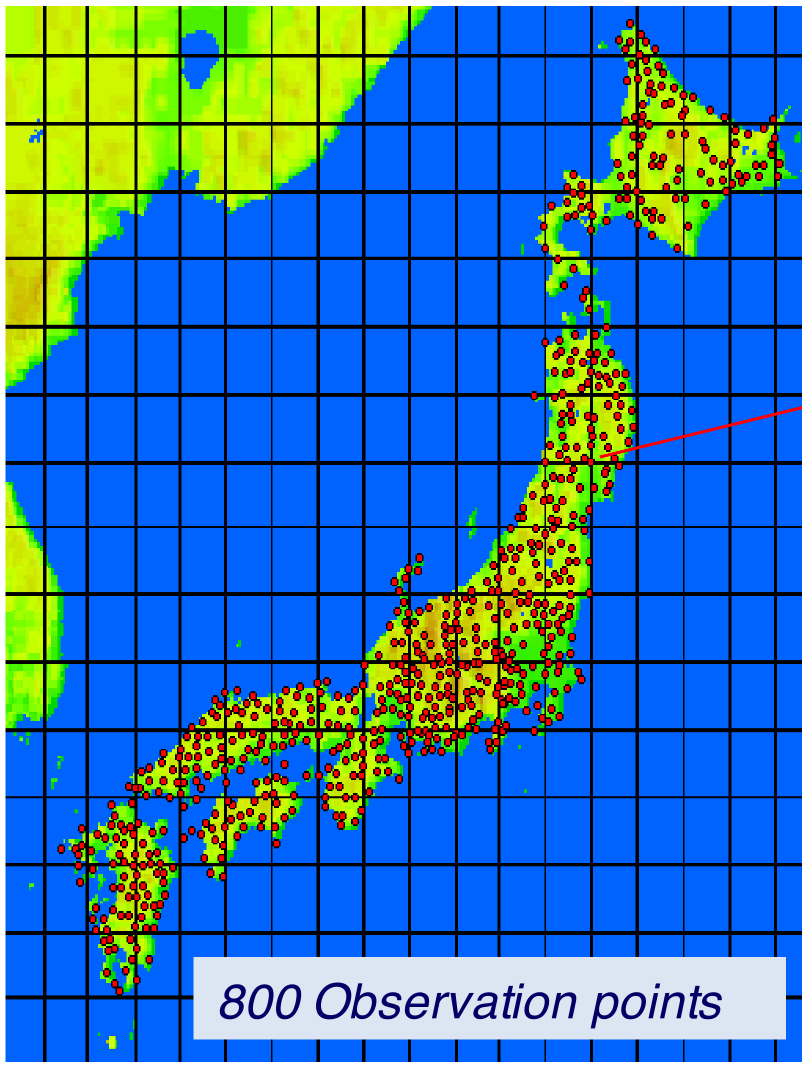
- Belong to IWATE & MIYAGI Prefecture in TOHOKU District
- Located in stable Granite zone
- Have not Active Fault zone
- Separate from Volcano Front line
- Annual average Temperature:10℃
- Annual total Precipitation : 1,300mm

T. Tauchi

Seismic Conditions

Global Design Effort - CFS

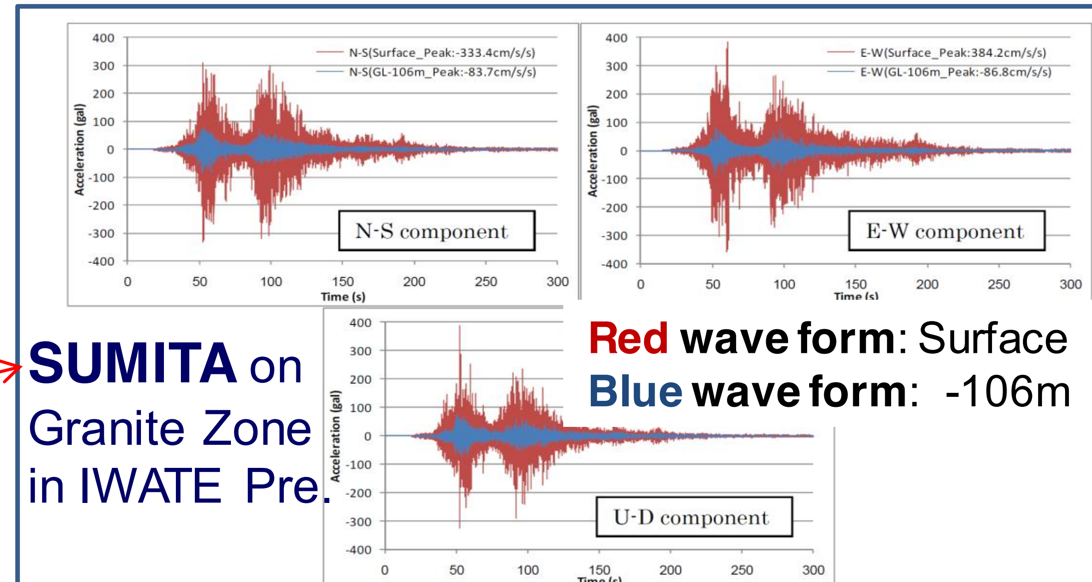
3.11 Seismic Observation



***KiK-net* Observation Network**

(Kiban:Bedrock, Kyoshin:Strong-Motion)

Data by "National Research Institute for Earth Science and Disaster Prevention"



Acceleration comparison of the Surface & underground at SUMITA in IWATE

Observation Data

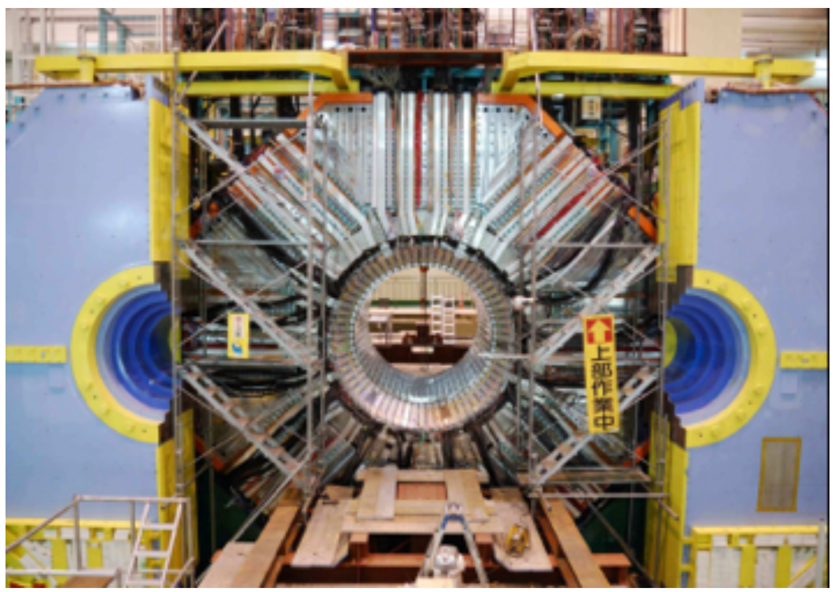
Direction	Acceleration (gal)		Rate Undergrund /Surface
	Surface	Underground	
N-S	333.4	83.7	0.25
E-W	384.2	86.8	0.23
U-D	388.9	73.5	0.19

M. Miyahara

When an Earthquake Hits...

- From KEK 03/11 earthquake damage report

Belle detector



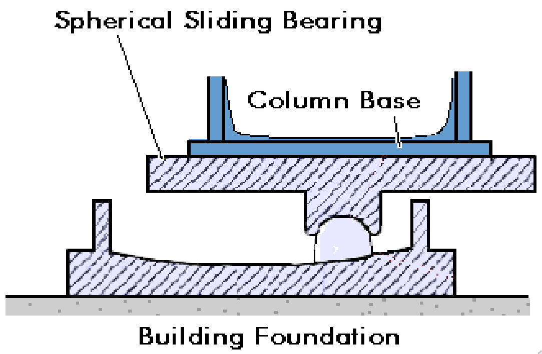
Belle detector was positioned in the assembly hall next to the collision hall, for the major upgrade (8 meters each, weight: 1400 ton)

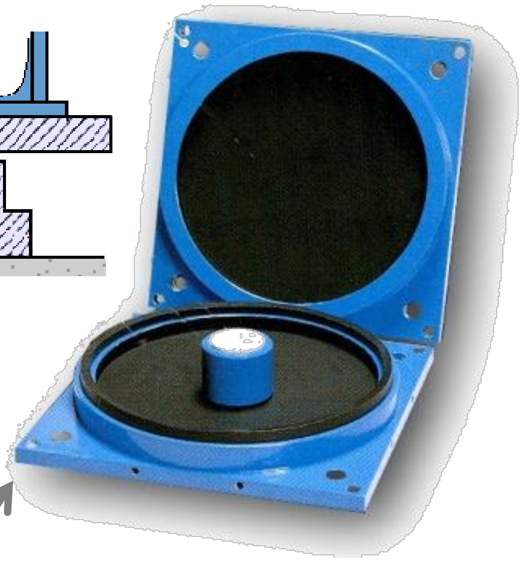
The detector was fixed with 32 anchor bolts thru brackets. All anchor bolts were broken by the earthquake and the entire detector slid by about 6 cm.

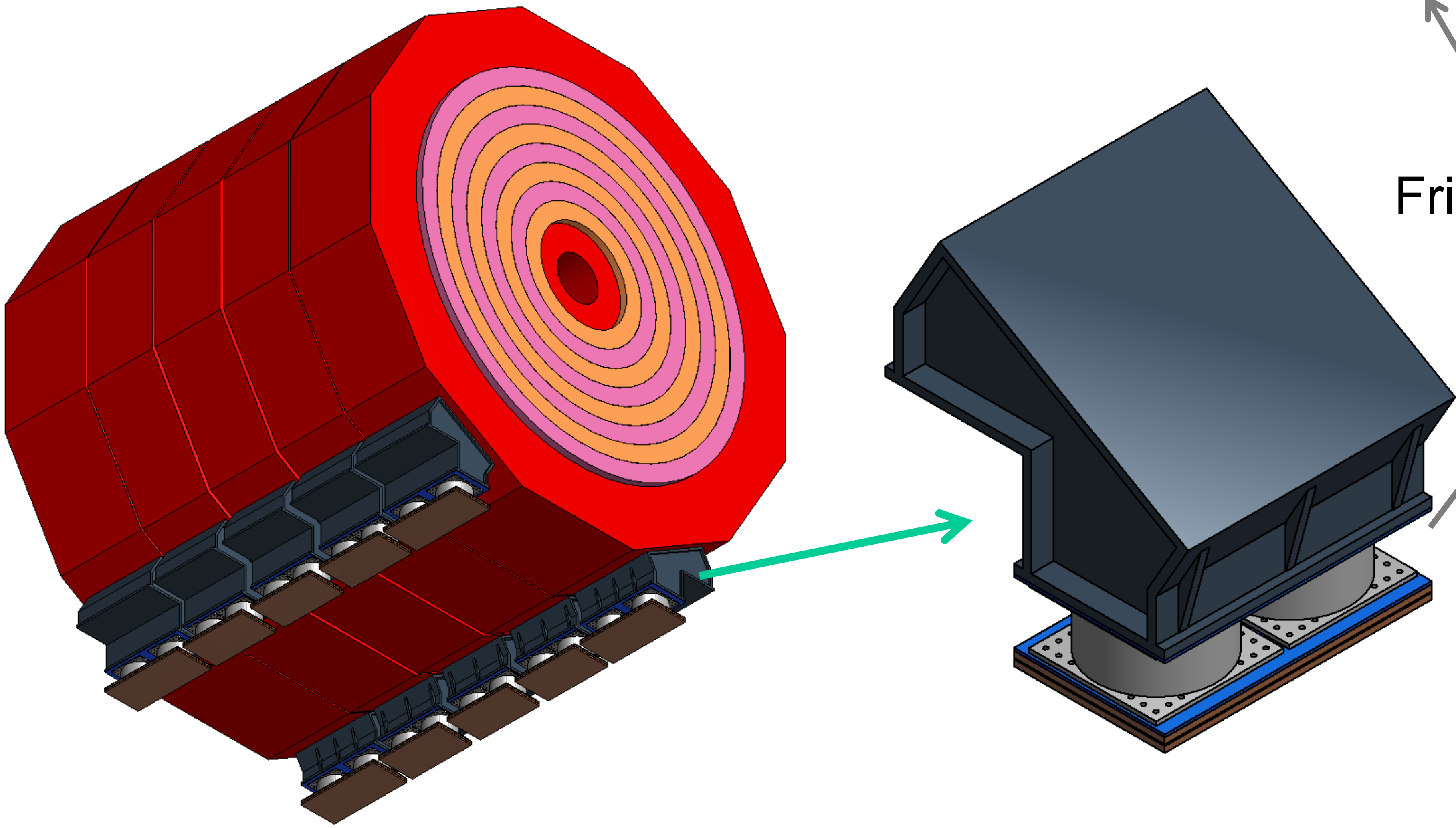
No serious damages were observed by visual inspections. Further inspections are necessary, especially for inner part such as CsI crystals and glass plate detectors.

Detector with seismic isolated feet

Each barrel stands on feet that are isolated
In this solution separated parts are still protected during maintenance when detector is opened



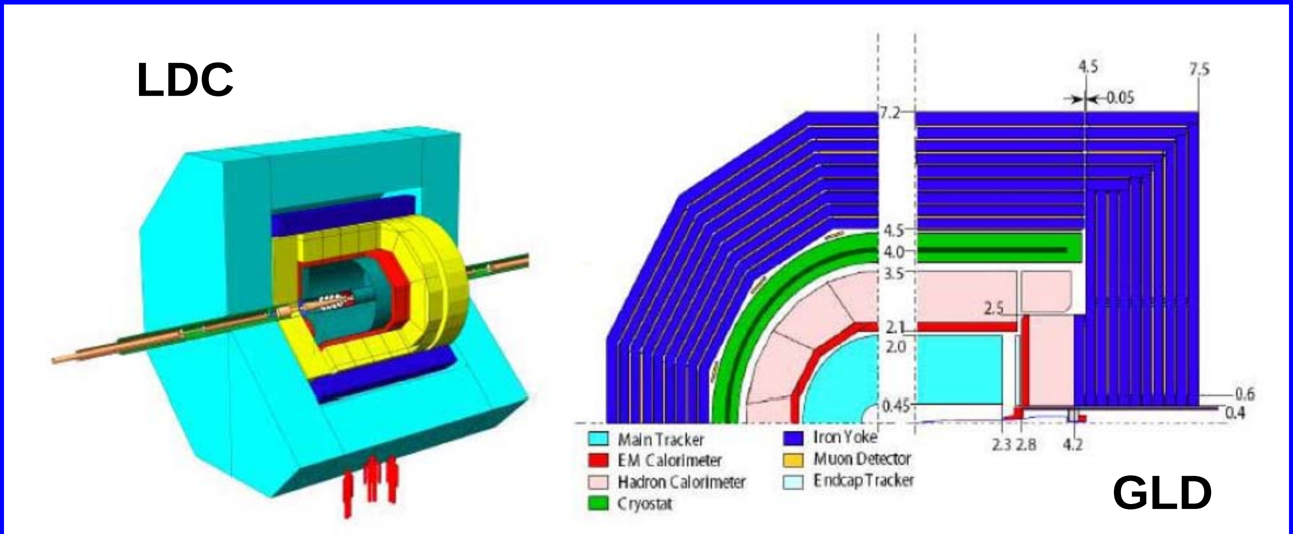




Friction pendulum bearings

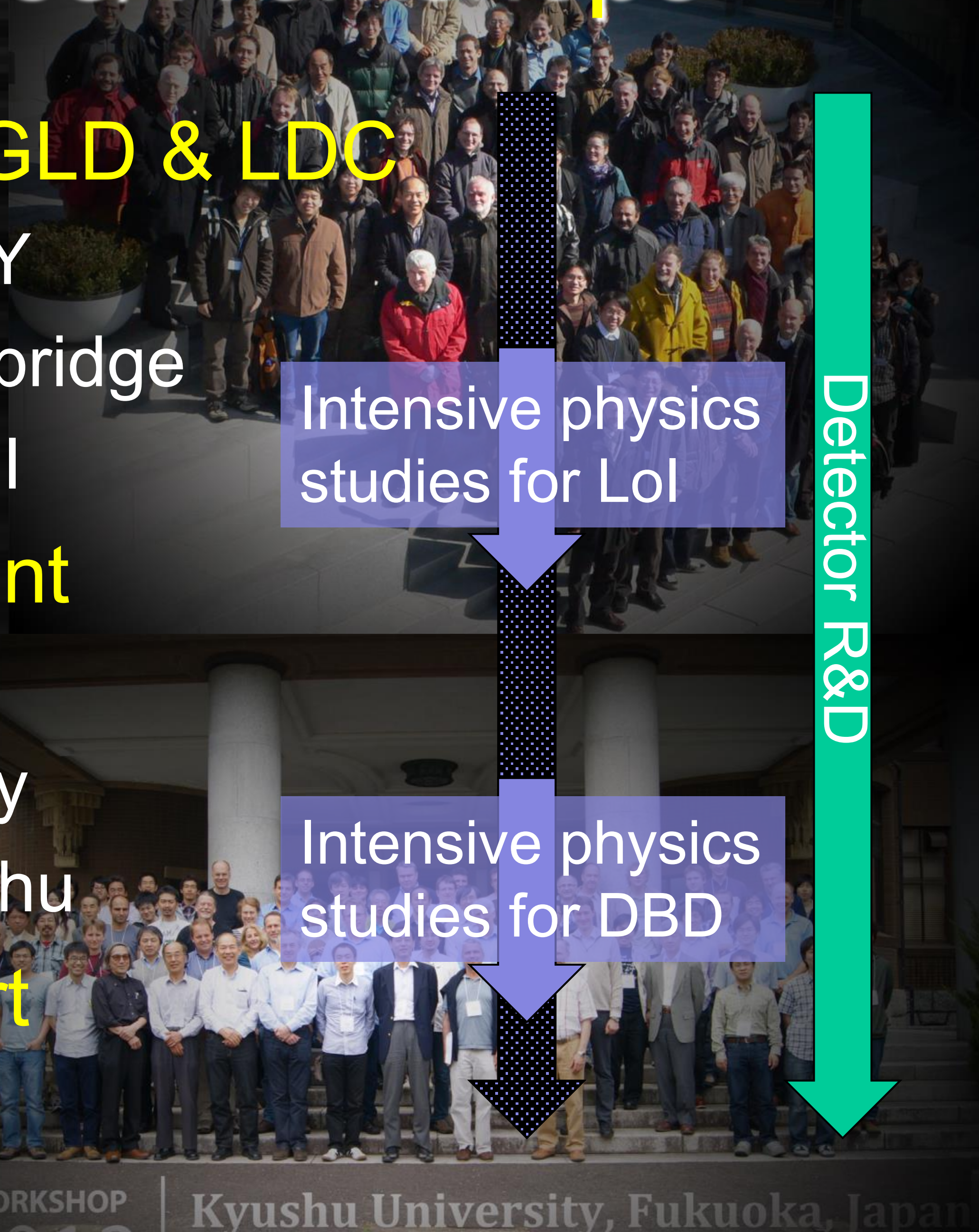
ILD

- Origins in the TESLA, JLC and LD detector concepts.
- First conceptual reports in the mid 90s.
- ILC Reference Design Report (RDR) 2007
  - GLD Detector Outline Document (DOD) arXiv:physics/0607154
  - LDC DOD http://www.ilcldc.org



ILD Timelines/Workshops

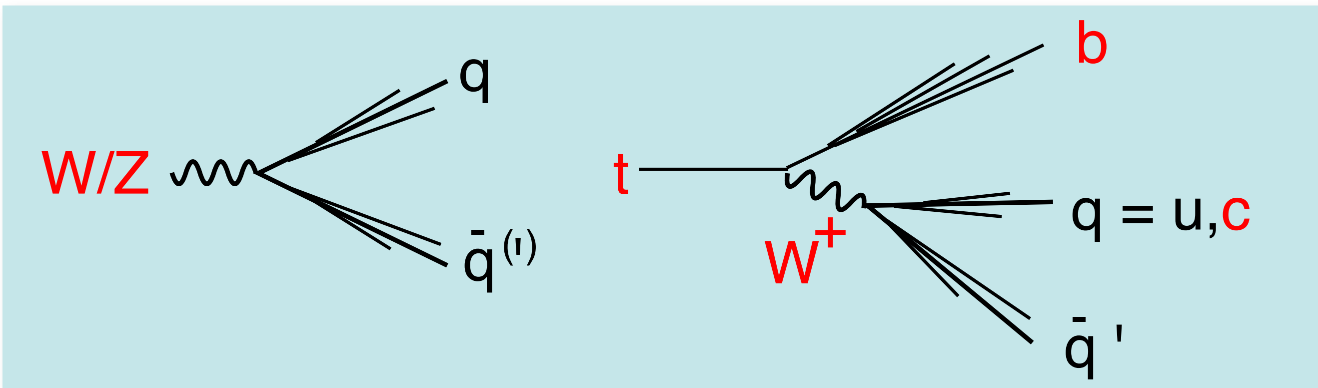
- 2007 Unification of GLD & LDC
  - 2008.1 ILDWS DESY
  - 2008.9 ILDWS Cambridge
  - 2009.2 ILDWS Seoul
- 2009.3 Letter of Intent
  - 2010.1 ILDWS Paris
  - 2011.5 ILDWS Orsay
  - 2012.4 ILDWS Kyushu
- 2012.12 DBD Report



Design Principle: Intact!

Goal

- Reconstruct events in terms of fundamental particles such as quarks, leptons, gauge/higgs bosons
  --> View events as viewing Feynman diagrams



Jet invariant mass → W/Z/t/h ID → p^μ
→ angular analysis → s^μ

Missing momentum → neutrinos

b/c ID with 2ndary/3tiary vertices

Thin and high resolution vertexing

Particle Flow Analysis

High resolution tracking

high granularity calorimetry

Hermeticity

down to O(10mrad) or better

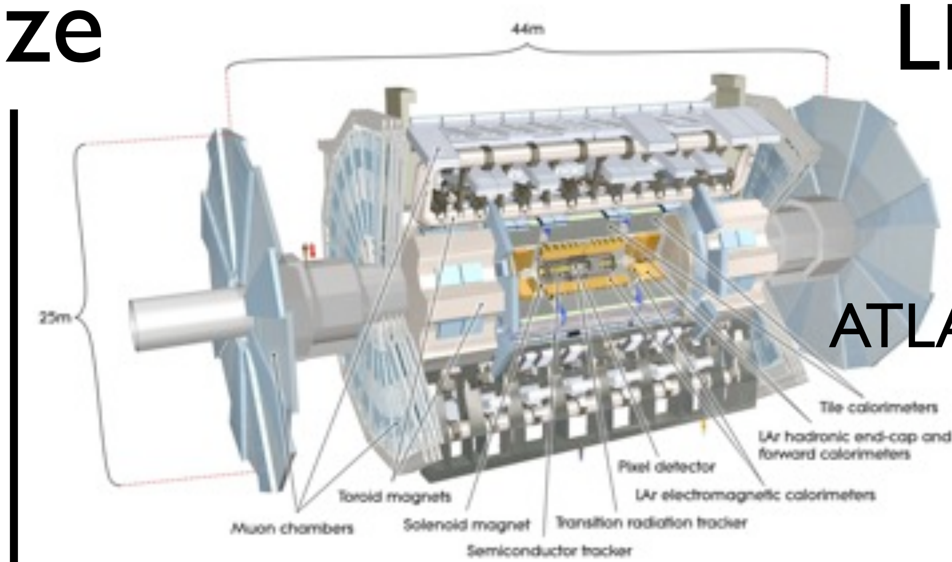
Particle Flow Analysis

- Is this really limiting physics performances?
  - Yes, unless limited by jet-clustering
    - enW, nnZ, nnh, ..
  - Need to improve analysis methods: color-singlet clustering, flavor tagging, jet charge ID, etc. to fully take advantage of the potential of ILD

Detector Evolution

From LHC to ILC

Size



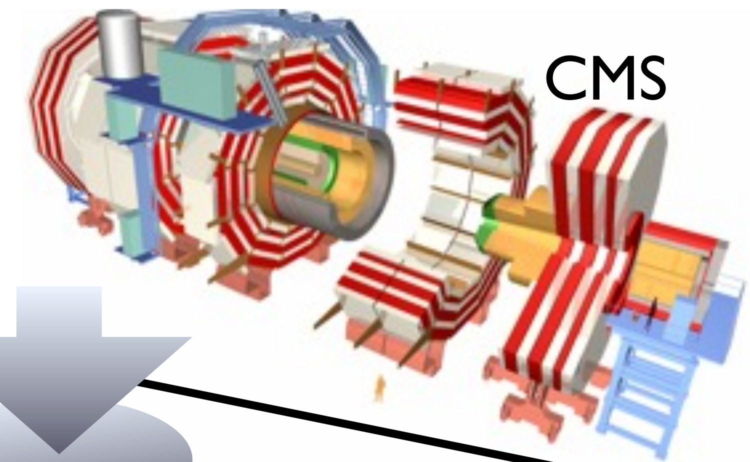
ATLAS

LHC : current state of the art

Use the cleanest modes to beat the huge QCD BG.

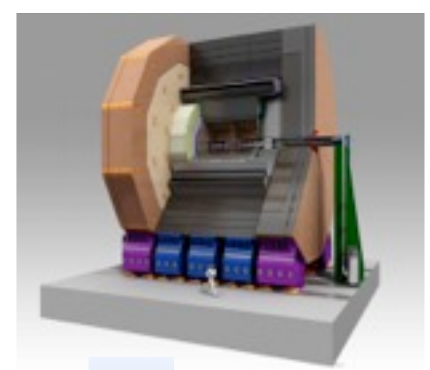
Moral

Energy Frontier Collider Detectors spearhead state-of-the-art detector technologies



CMS

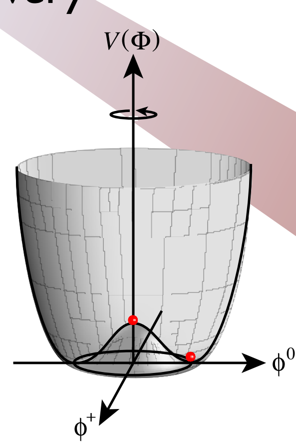
ILD



ILC : next generation

Use the dominant (jet) modes to take advantage of clean environment

LHC : Higgs Discovery



ILC : Full understanding of Higgs sector

Resolution

As compared to ATLAS

Vertex resolution	2-7 times better
Momentum resolution	10 times better
Jet energy resolution	2 times better

Granularity

As compared to ATLAS

Vertex	x800
Tracker	x2
EM Cal	x61 (Si)
	x7 (Sci)

Detector design requirements

- Detector design should be able to do excellent physics in a cost effective way.
  - both the physics we expect, and the new unexpected world that awaits
- Very good **vertexing** and **momentum** measurements

$$\sigma_b = 5 \oplus 10/(\, p\, \beta\, \sin^{3/2}\theta)\ \mu m \qquad \sigma(1/p_T) \leq 5 \times 10^{-5}\ GeV^{-1}$$

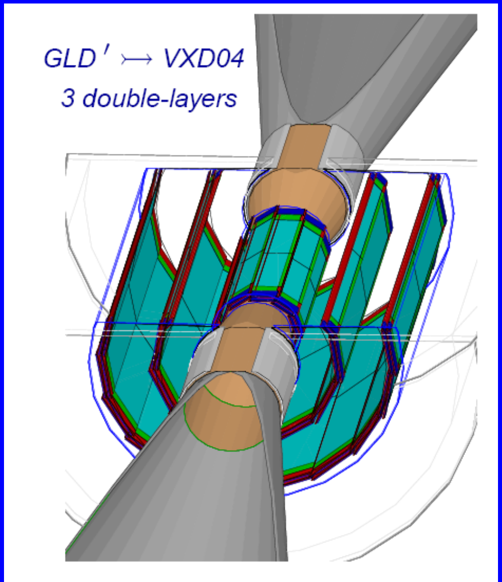
- Good **electromagnetic energy** measurement.

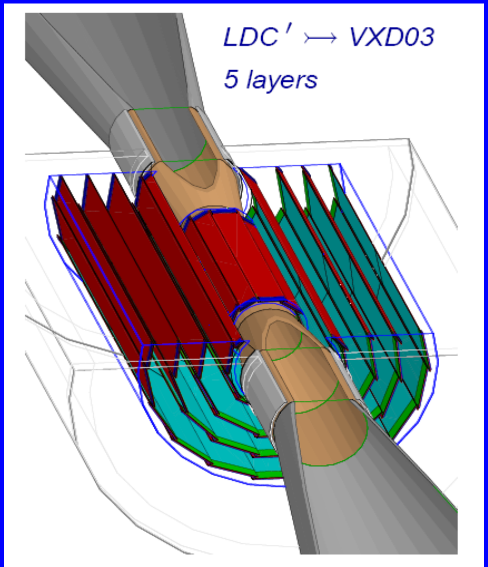
$$\sigma_E/E \approx 15\%/\sqrt{E\ (GeV)} \oplus 1\%$$

- The physics demands hermeticity and the physics reach will be significantly greater with state-of-the art **particle flow**
  - Close to 4π steradians.
  - Bubble chamber like track reconstruction.
  - An integrated detector design.
  - Calorimetry designed for resolving individual particles.

$$\sigma_{E_{jet}}/E_{jet} \approx 30\%/\sqrt{E_{jet}\ (GeV)}$$

Vertex Detector



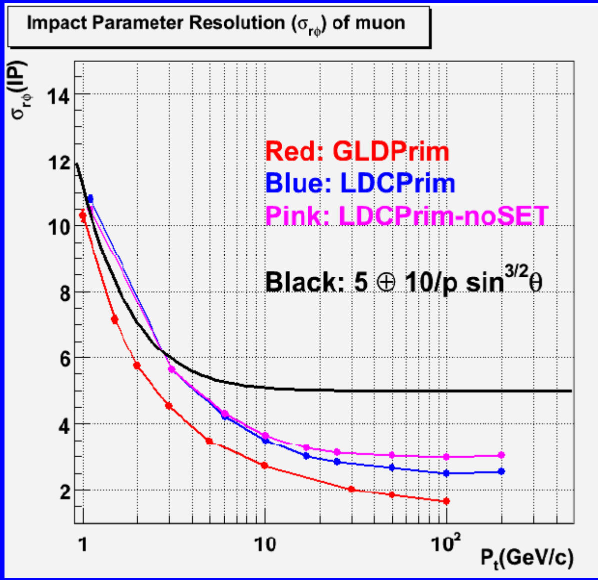


Several different technologies:

pixel sensors, readout scheme, material budget

Pairs background => Inner radius ~ √B

Studying two "technology-neutral" geometries :
3 double-layers, 5 layers

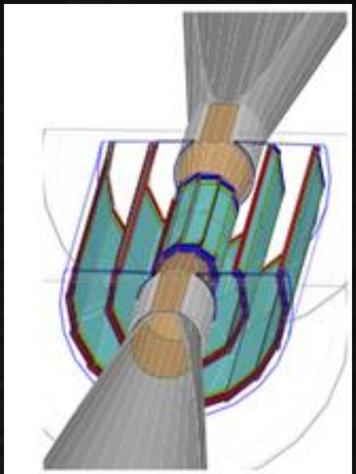


Performance studies indicate better resolution particularly at high p_T for 3 double-layers (GLD' model)

Studies ongoing and plan to include backgrounds

Inner layer at r=1.6 cm for B=3.5 T

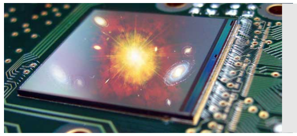
1. Vertex Detector



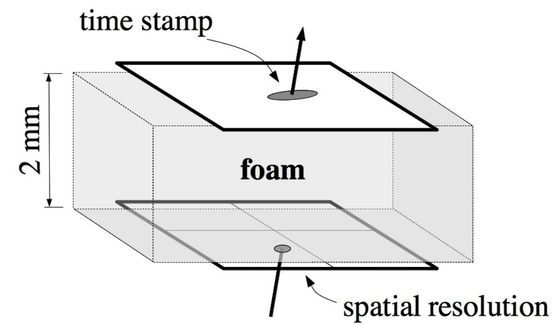
Target: 5 μm IP resolution for high-p tracks within high background environment

3 x 2 layers: r = 16 & 18, 35 & 37, 58 & 60 mm
(option: equally spaced 5 layers at 15-60 mm)
Length: 125 mm (first 2 layers) & 250 mm (others)
cosθ up to 0.9-0.97 is covered

Technology	CMOS	FPCCD	DEPFET
Pixel size	17 / 34 μm	5 / 10 μm	20 μm
Readout time	50 / 100 μs	Slow (intra-train)	50 / 100 μs
Resolution	2.8 / 4 μm	1.4 / 2.9 μm	Similar to CMOS
Occupancy	OK	OK	OK
Temperature, heat	30 C, 10 W	-40 C, 35 W	30 C, 10 W
Cooling	Air or N_2	CO_2 (two phase)	Air or N_2
Radiation	Tested	Will be checked	Tested
Technology	Matured	Developing	Used in Belle2



Vertex detector based on CPS



Concept of vertex detector

- ✗ Doube-sided layer → 2 different optimizations inner/outer side

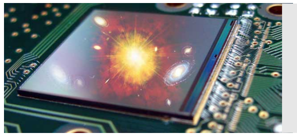
	Radius (mm)		√s = 500 GeV		√s = 1 TeV	
Side	**inner**	**outer**	**Inner**	**outer**	**inner**	**outer**
Layer 1	16	18	3 µm / 50 µs	6 µm / 10 µs	3 µm / 50 µs	6 µm / 2µs
Layer 2	37	39	4 µm / 100 µs		4 µm / 100 µs	10 µm / 7 µs
Layer 3	58	60				

State-of-the-art with process 0.35 µm

- ✗ sensitive volume :
  - ↪ ~14 µm thick
  - ↪ Resistivity > 0.4 kΩ.cm
- ✗ MIMOSA 26 sensor → Eu-EUDET
- ✗ MIMOSA 28 sensor → STAR-PXL

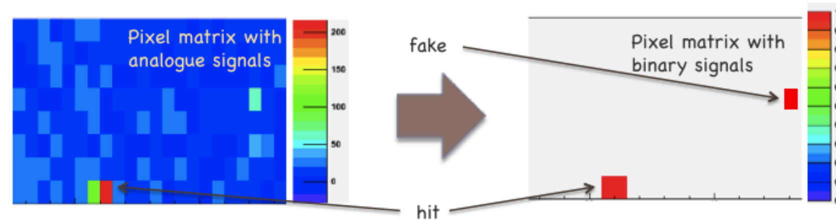
New process 0.18 µm

- ✗ Higher µ-circuits integration & 6 metal layers
  - ➡ faster & smarter pixel
- ✗ Sensitive volume:
  - ↪ 18 to 40 µm thick
  - ↪ resistivity > 1-2 kΩ.cm
  - ➡ allow larger pixel size / aspect ratio



Spatial resolution

- **Emulation of Binary output**
  - ✗ Same threshold applied off-line to all pixel signals
    - ↪ pixel outputs converted to 0 or 1

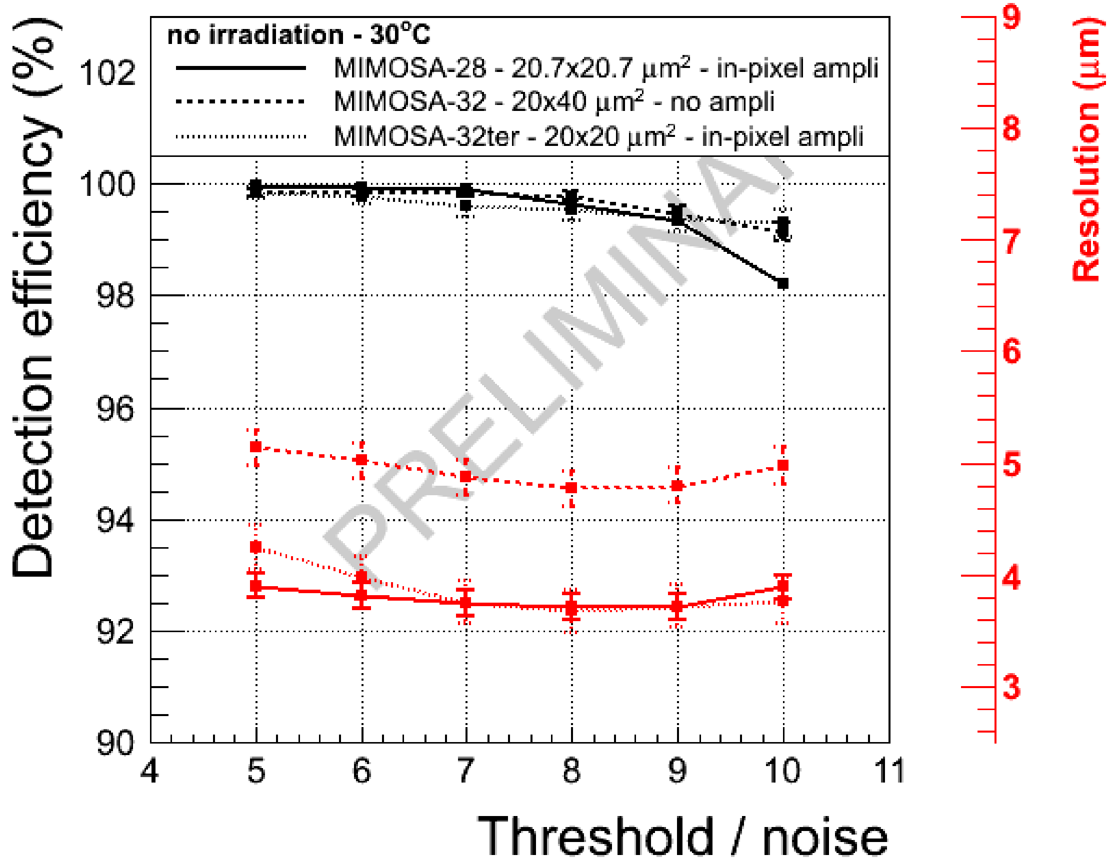


- **Comparison of**
  - ✗ **MIMOSA-28** (true binary output)

    0.35 µm technology (< 1 kΩ.cm)
    20.7x20.7 µm² pixel
    in-pixel ampli+CDS
  - ✗ **MIMOSA-32**

    0.18 µm technology (> 1 kΩ.cm)
    20x40 µm² pixel
    no ampli in-pixel
  - ✗ **MIMOSA-32ter**

    0.18 µm technology (> 1 kΩ.cm)
    20x20 µm² pixel
    in-pixel ampli+CDS

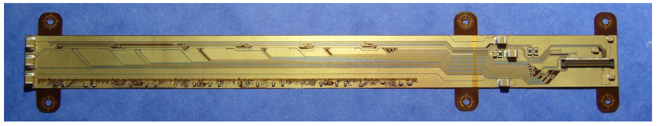


First CPS-based vertex detector operating in STAR since this month

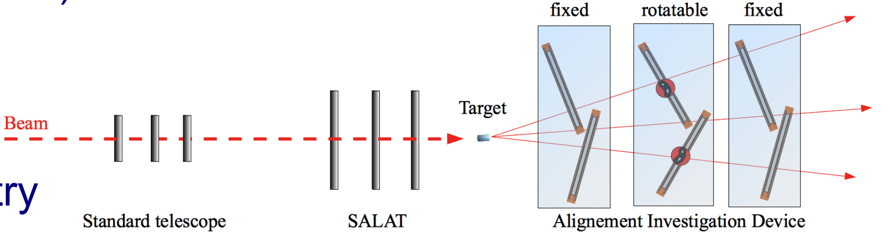
(May 2013)

System roadmap

- **PLUME**
  - ✗ Double-sided ladders with ILD geometry and material budget 0.6 % X_0
    - ↪ produced, tested in beam, power-pulsing in progress
  - ✗ New double-sided ladders with material budget 0.35 % X_0
    - ↪ Production in progress (aluminum cable fab. slow)



- **Alignment Investigation Device**
  - ✗ 3 stations with 2 ladders each in sector-like geometry
    - ↪ delayed due to collaboration recomposition



- **Integration studies performed by ALICE collaboration**
  - ✗ Internal Tracker System upgrade → 9 m^2 equipped with CPS
    - ↪ 7 single-sided layers from r = 2.2 cm to r = 43 cm
    - ↪ material budget goal = 0.3 to 0.5 % X_0 (depends on radius)
  - ✗ Mechanical support
    - ↪ light carbon-fiber trussed structures
  - ✗ Cooling
    - ↪ micro-channel manufactured in polyimide cable
  - ✗ Bonding
    - ↪ “cold” ball-grid array type interconnection

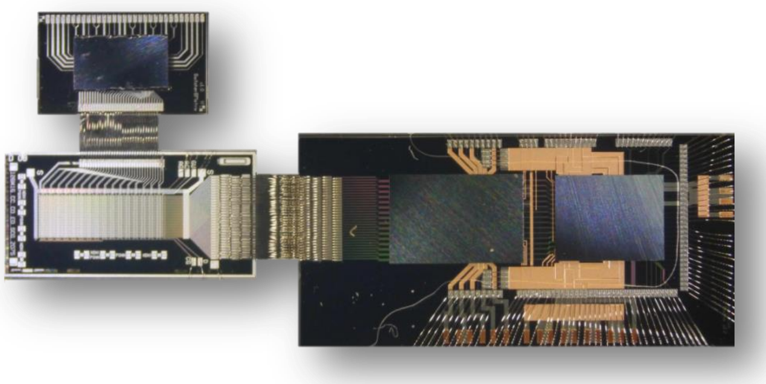
Final sensors for ALICE-ITS: 2015

Adaptation to ILC-VTX: 2017-19

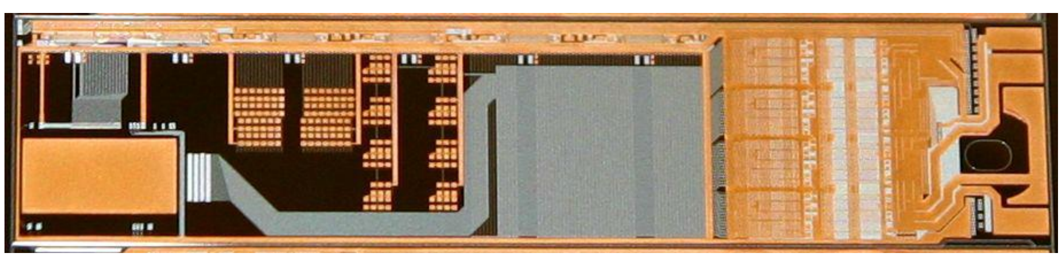
Pixel technologies

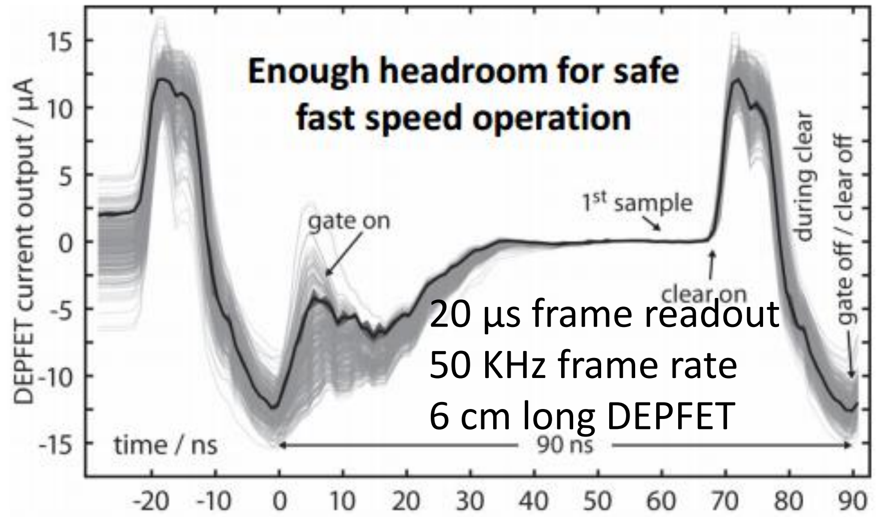
DEPFET Carlos Marinas (Bonn)
Benjamin Schwenker (Goettingen)

- Belle II PXD almost prototype of L1, L2 ILD-VXD
- System demonstrator:
  Small thin (50 µm) DEPFET+ final ASICS + DAQ
- TB 2013: Efficiency> 99.5 %, g_q~500 pA/e^-

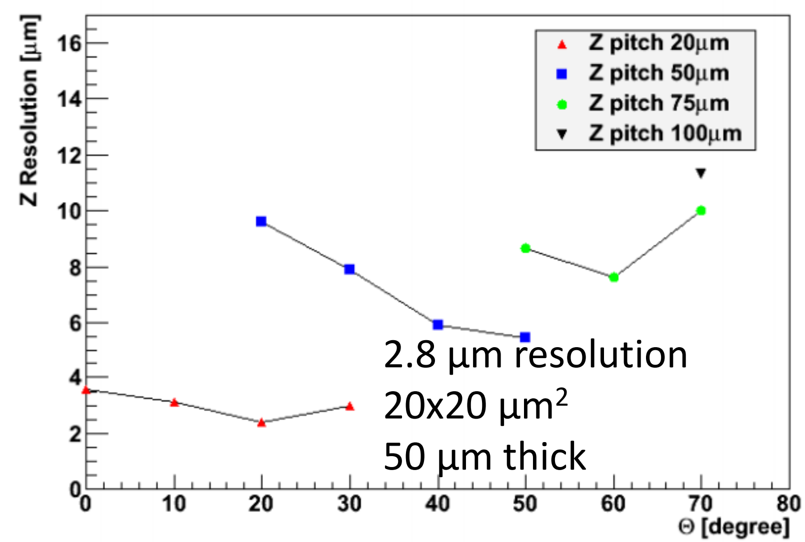


- Electrically active prototype of a half ladder + flipchip





20 µs frame readout
50 KHz frame rate
6 cm long DEPFET



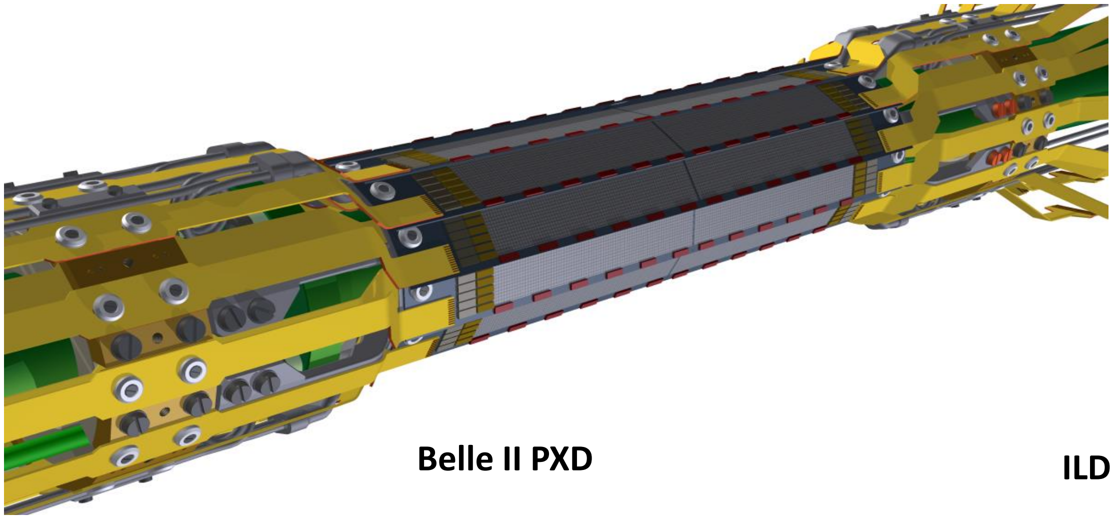
2.8 µm resolution
20x20 µm^2
50 µm thick

Simulation tuned with TB data

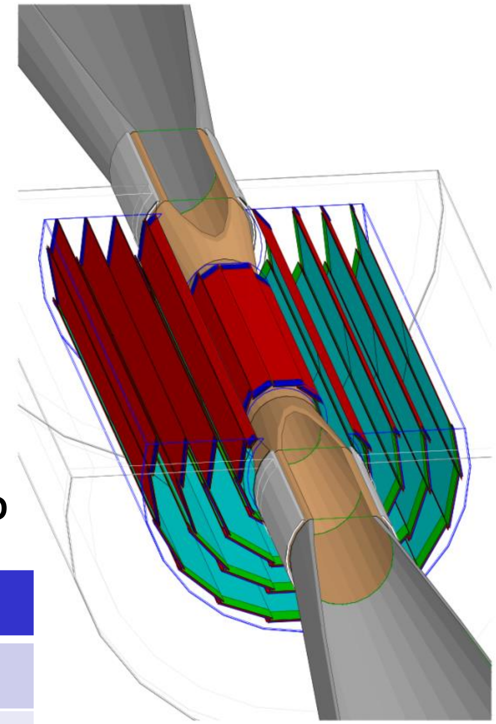
cmarinas@uni-bonn.de

The ILD vertex detector

The Belle II Collaboration decided on DEPFET as baseline for the pixel detector



Belle II PXD



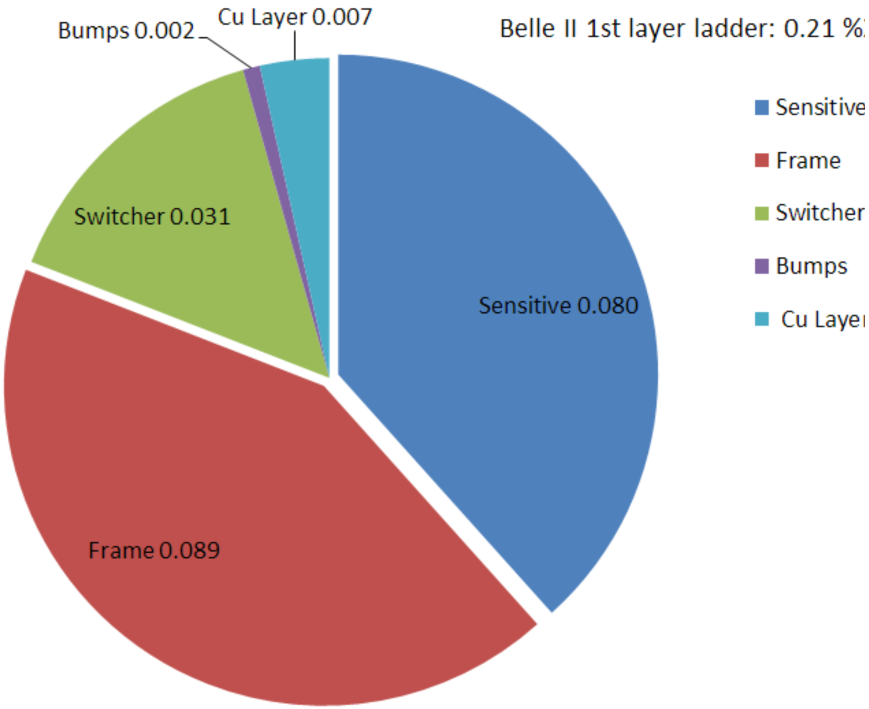
ILD 5-layer VXD

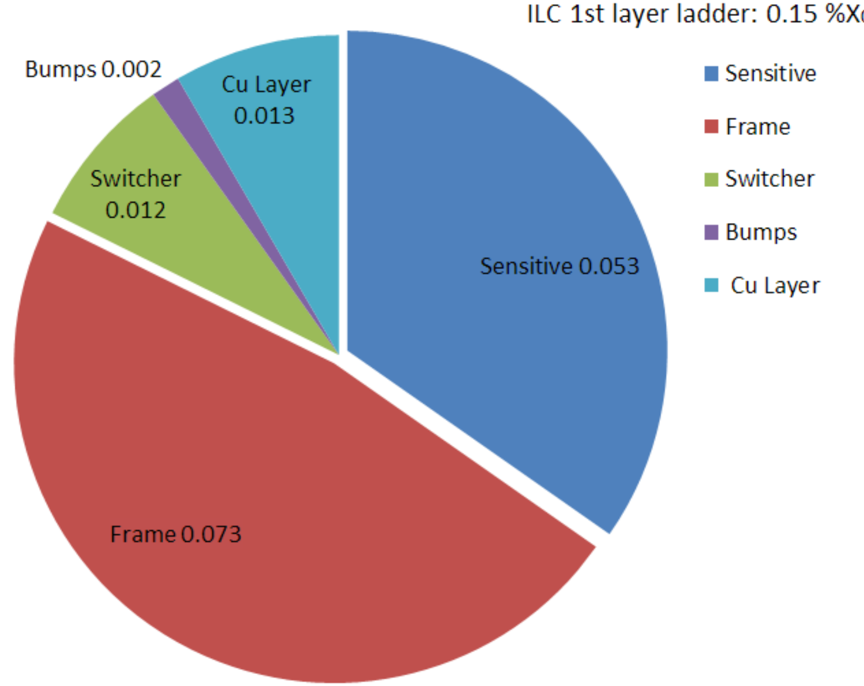
	ILD LOI 5-layer layout	Belle II	
Radii	15, 26, 38, 49, 60	14, 22	mm
Ladder length	123 (L1), 250 (L2-L5)	90 (L1), 122 (L2)	mm
Sensitive width	13 (L1), 22 (L2-L5)	12.5 (L1-L2)	mm
Number of ladders	8, 8, 12, 16, 20	8, 12	
Pixel size	25x25 (L1-L5)	50x50 (L1), 50x75 (L2)	μm^2
Frame rate	20 (L1), 4 (L2-L5)	50	kHz

The Belle II PXD DEPFET ladders: *almost* prototypes for L1 and L2 of ILD

cmarinas@uni-bonn.de

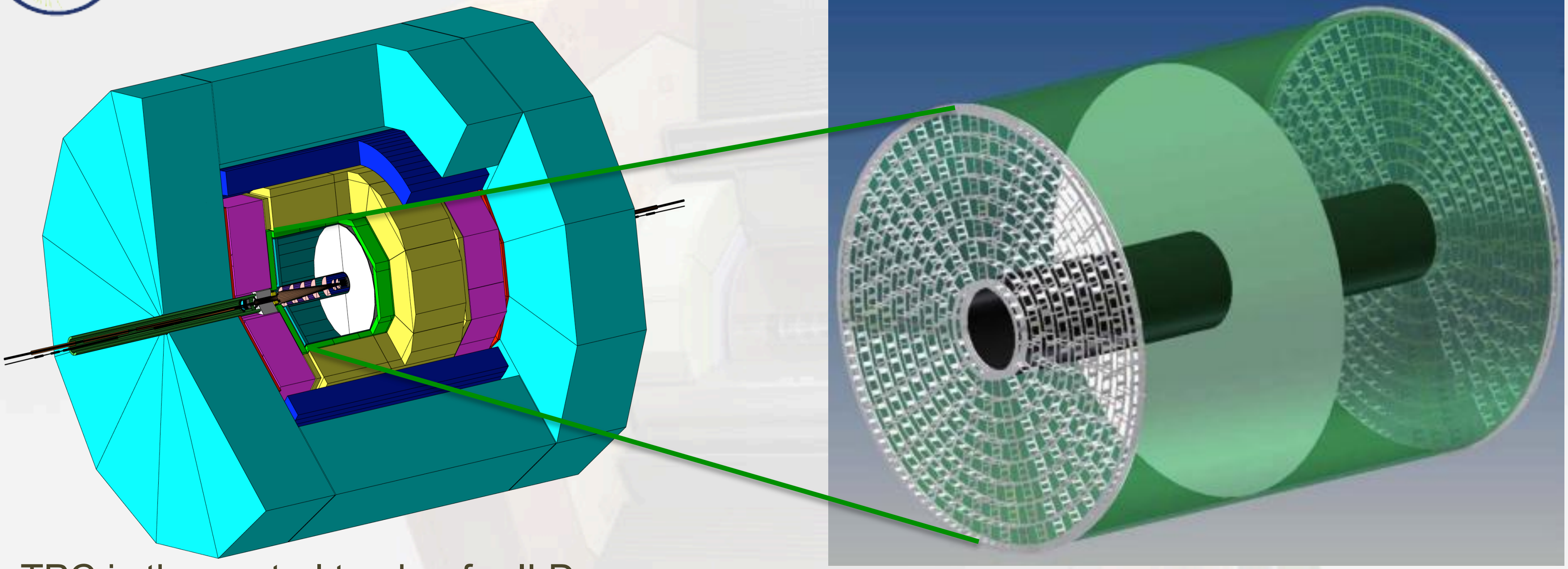
Material budget





	Belle II	ILC
Frame thickness	525 µm	450µm
Sensitive layer	75 µm	50µm
Switcher thickness	500µm	100µm
Cu layer	only on periphery	50% cover over all
Total	0.21 %X0	0.15 %X0

Time Projection Chamber (1)

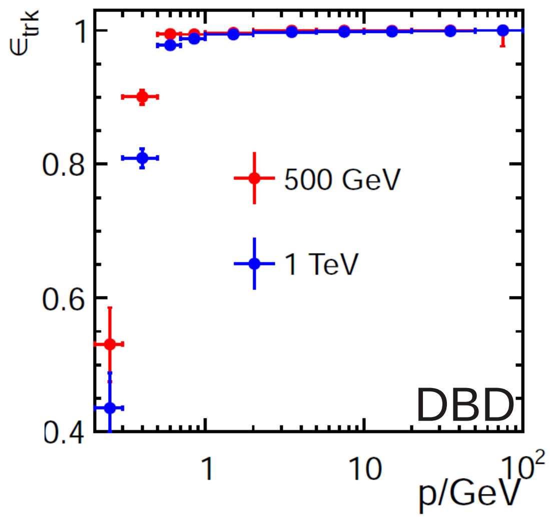


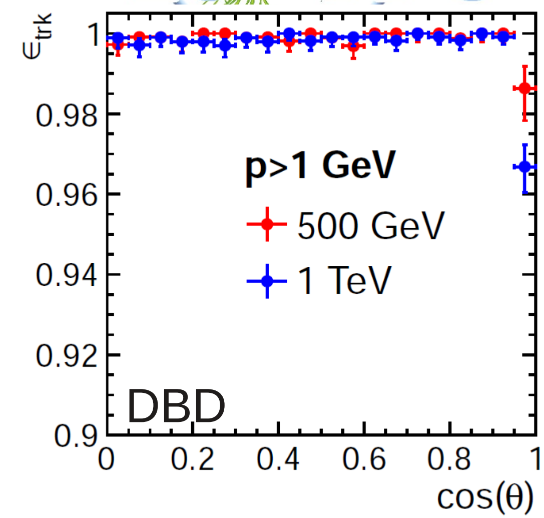
- TPC is the central tracker for ILD
  - Large number of 3D points → continuous tracking
- Low material budget inside the calorimeters important for PFA
  - Barrel: ~5% X_0
  - Endplates: ~25% X_0
- Two options:
  - **GEM:** 1.2x5.4 mm^2 pads, 28 pad rows x 176-192 pads/row
  - **Micromegas:** 3x7 mm^2 pads, 24 pad rows x 72 pads/row
- Alternative: **pixel** read out with pixel size ~55x55 μm^2

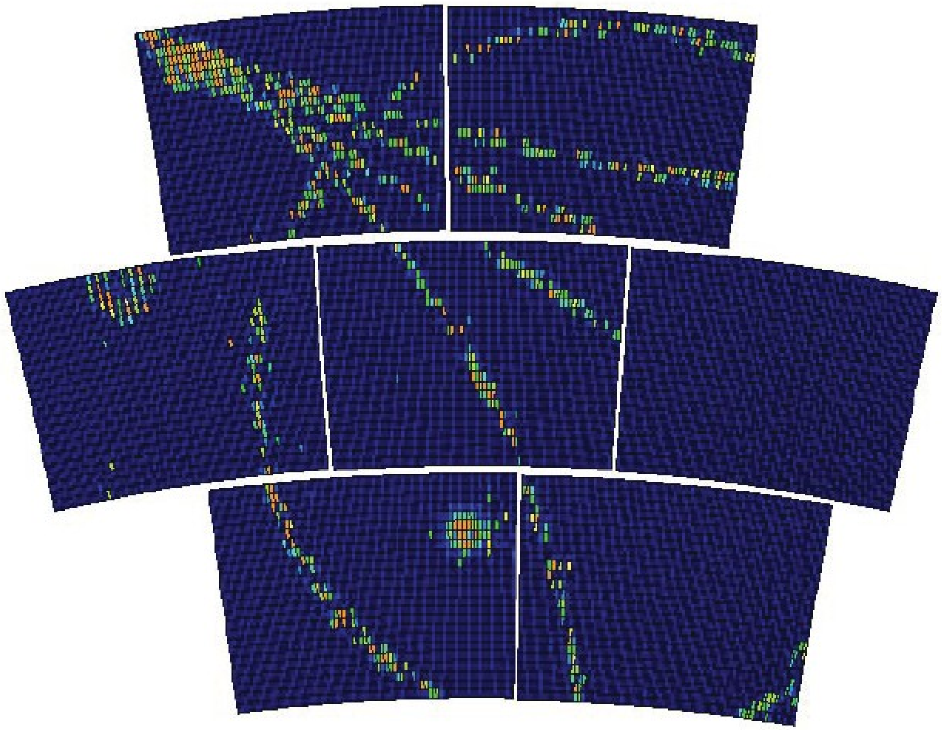
Requirements
Momentum resolution:
$\delta(1/p_T) < 9\times10^{-5}$ GeV
Spatial resolution:
$\sigma(r\phi) < 100\ \mu m$
$\sigma(z) < 500\ \mu m$
97% tracking eff. for p_T>1 GeV
dE/dx resolution ~5%

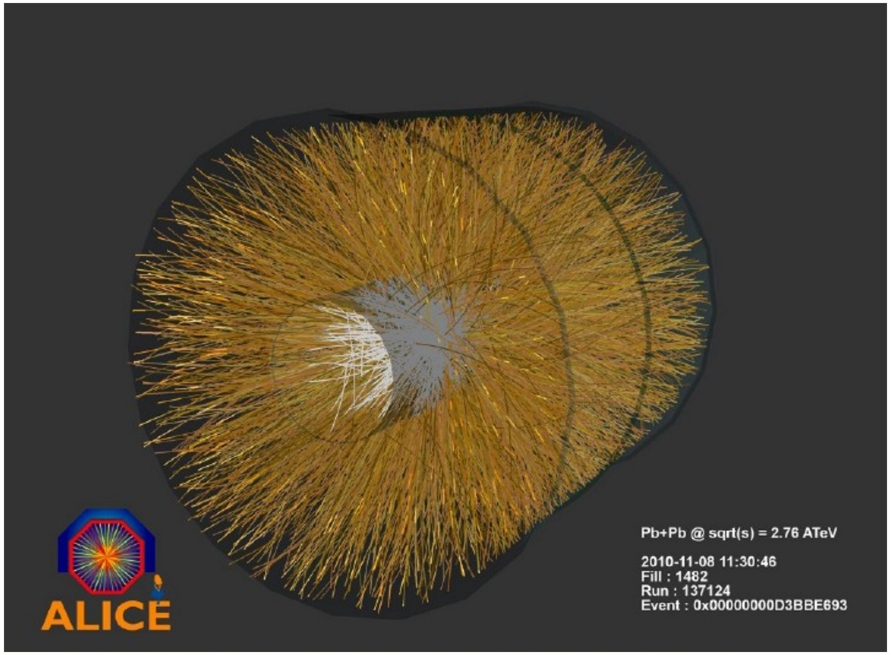
1. Continuous Tracking

- Large number of track points
- High granularity (~10^9 voxels)
- Truly 3D points
  facilitates track finding
  and background rejection
  (s. next transparency)







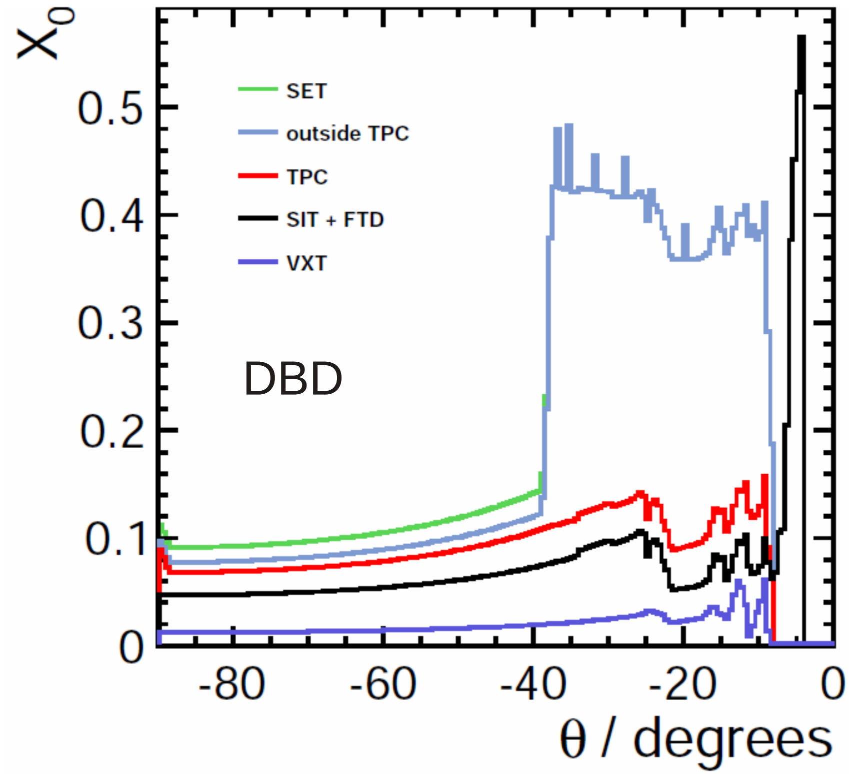


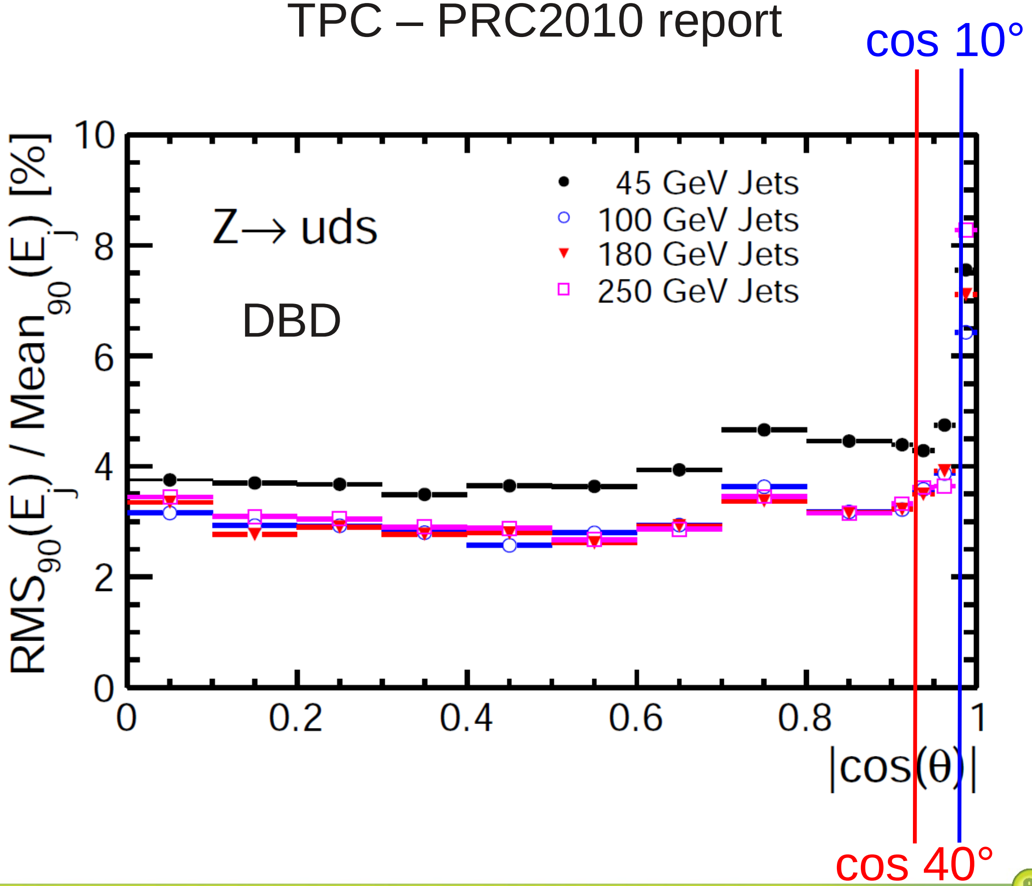
2. Minimum Amount of Material

Low material budget
Homogeneously distributed
Also the end plate with 0.25 X_0
has no significant impact.

	45 GeV	100 GeV	250 GeV
15% X_0	0.28±0.01	0.32±0.01	0.47±0.02
30% X_0	0.30±0.01	0.31±0.01	0.47±0.02
45% X_0	0.30±0.01	0.32±0.01	0.52±0.02
60% X_0	0.32±0.01	0.33±0.01	

TPC – PRC2010 report

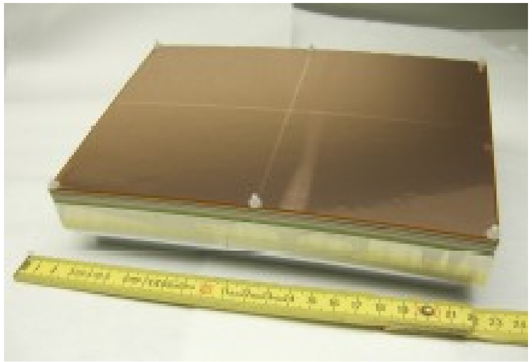


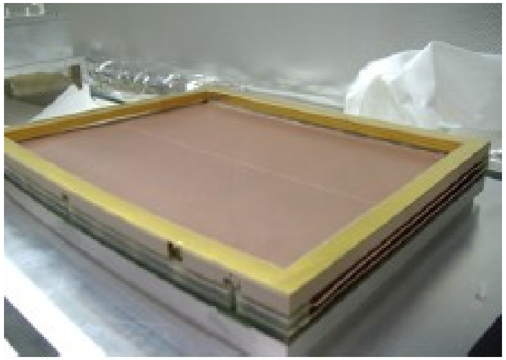


Gas amplification stage

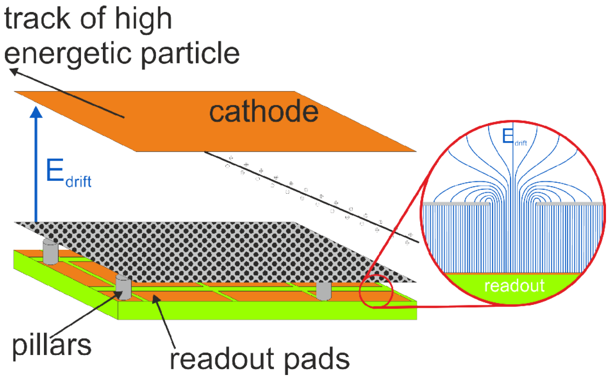
Three different approaches are under study

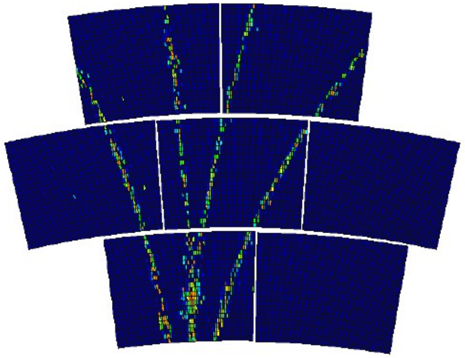
GEMs

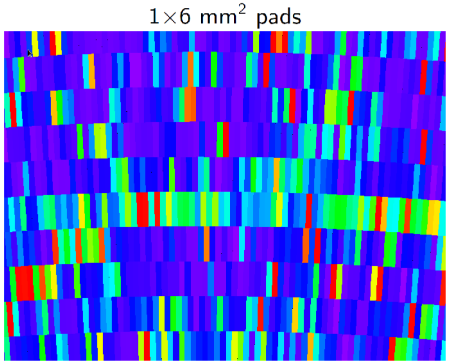




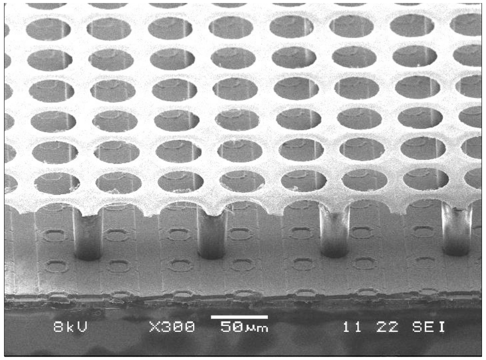
Micromegas

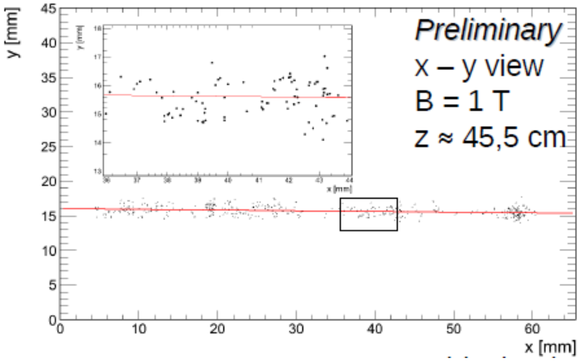


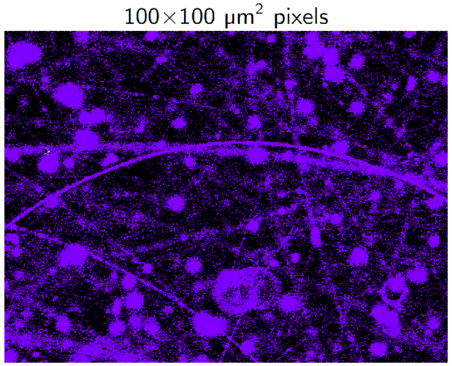




InGrids



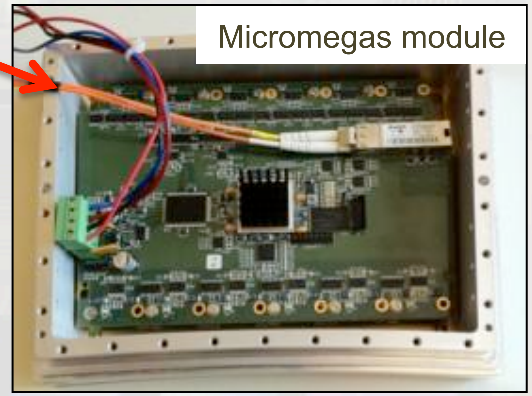




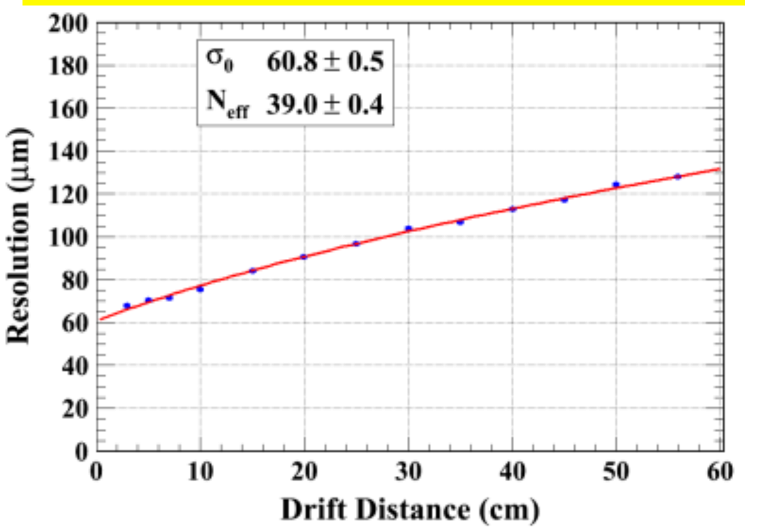
Time Projection Chamber (2)

R&D with TPC Large Prototype (LP)

- Second endplate for LP built & tested, realistic structure, good rigidity, agrees with simulation.
- Magnet module (PCMAG) & test facility upgraded (EUDET @ DESY)
- Test beams this summer for 7 new Micromegas & GEM readout modules

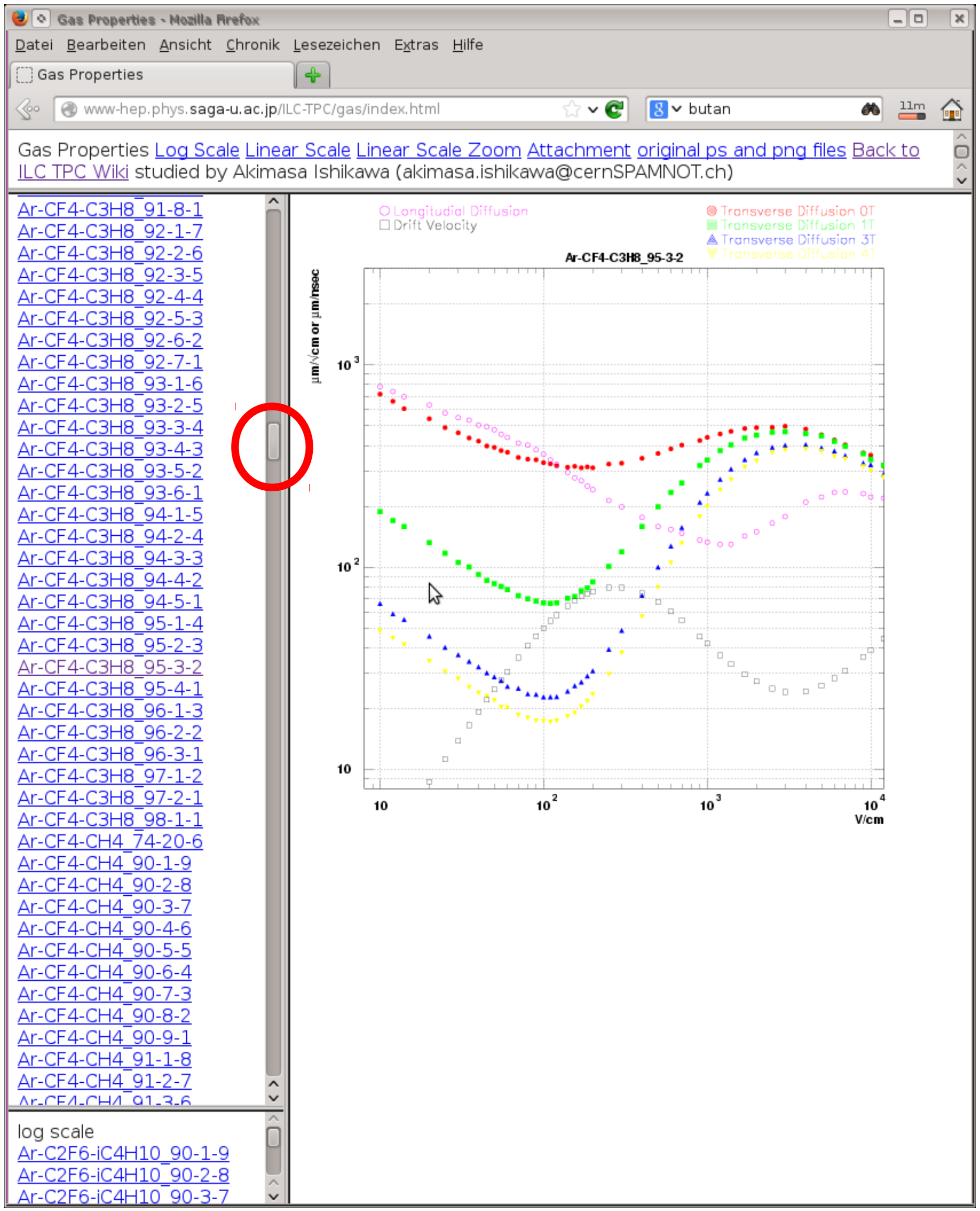


Micromegas: transverse position resolution vs. drift distance (B=1T)

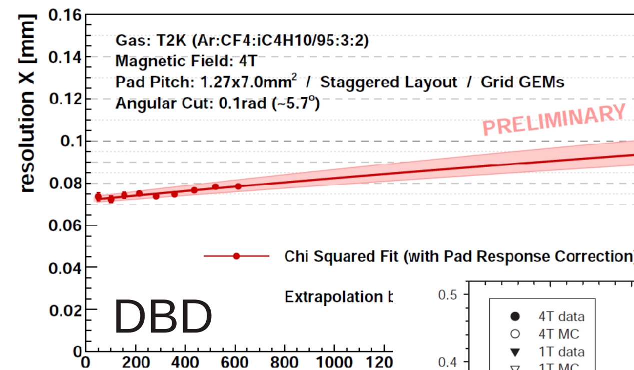


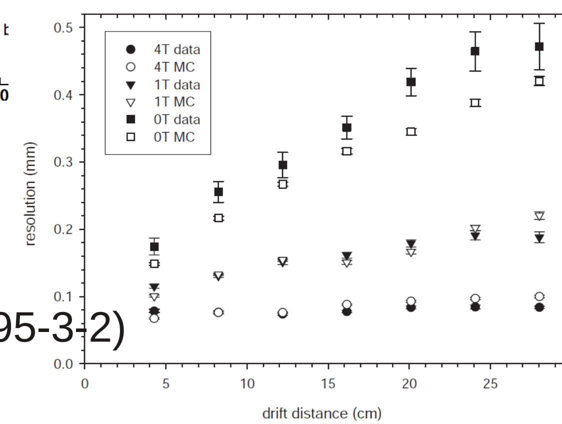
- Readout chip (S-ALTRO16) fully tested, available; implements power-pulsing at chip-level
- New readout chip (GdSP, 128 channel) being developed: 130nm tech, low power (<1mW/ch)
- Effect of migration of ions in gating devices understood better

Gas Choice



A lot of gas mixtures have been looked at with MC. A few promising ones have been tested.



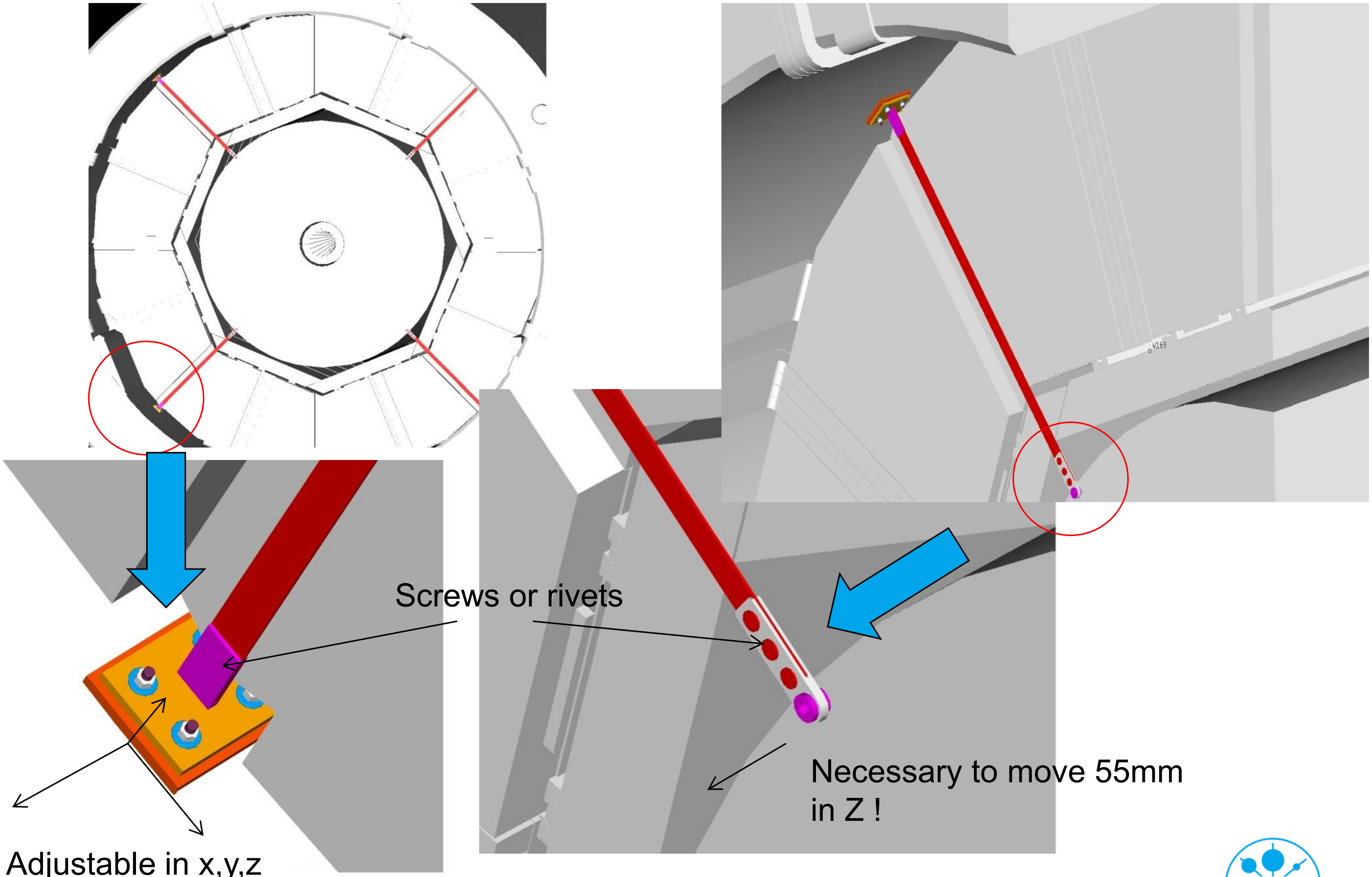


LOI
$ArCH_4CO_2$ (95-3-2)

It's magic!

We have found a mixture which can fulfill the requirements, but needs to be tested for aging, etc.

Flat ribbon support



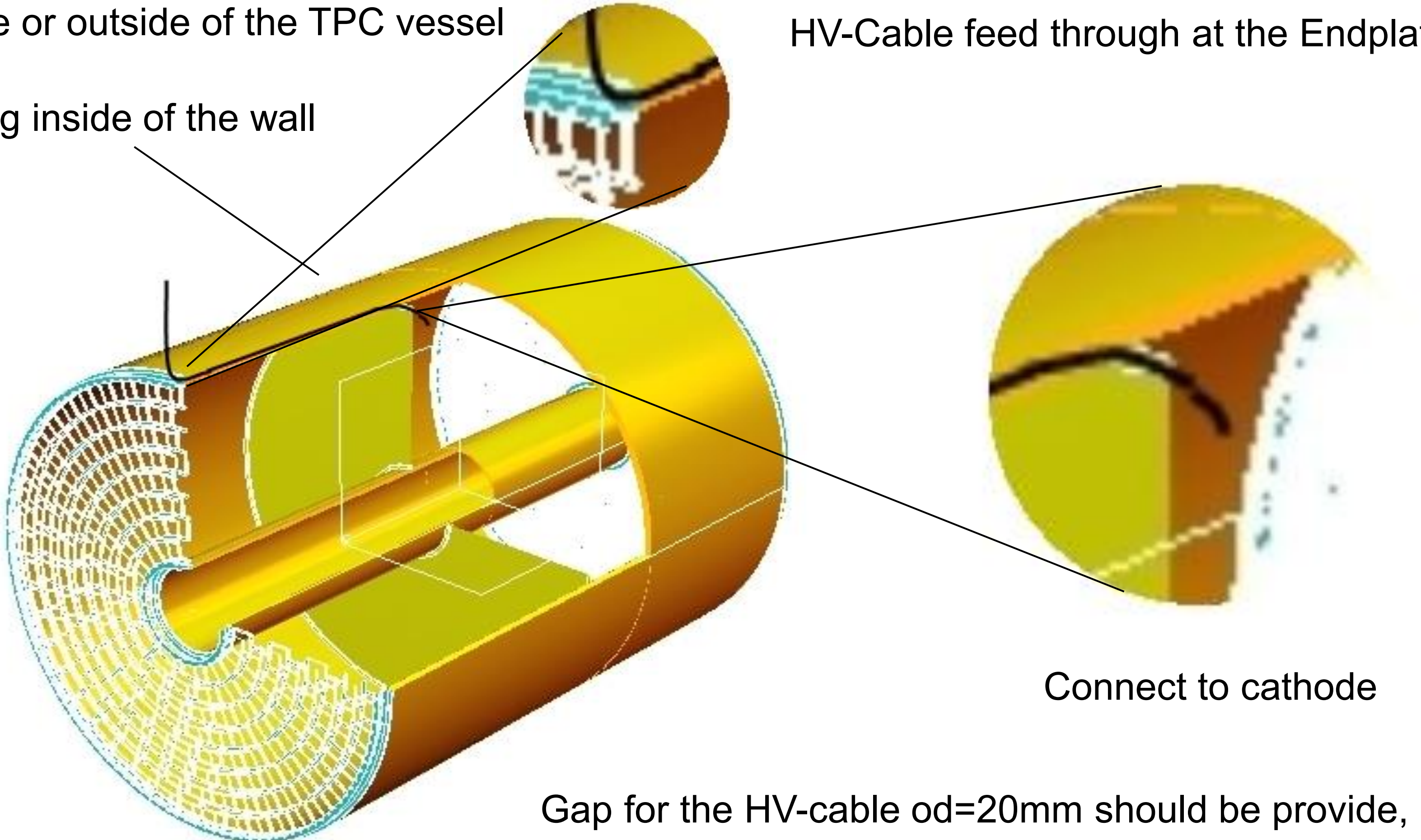
HV Cable and routing

Overview of an first idea of the HV-cable routing

Inside or outside of the TPC vessel

Laying inside of the wall

HV-Cable feed through at the Endplate



Connect to cathode

Gap for the HV-cable od=20mm should be provide, the bending radius maybe an issue

HV Cable and routing

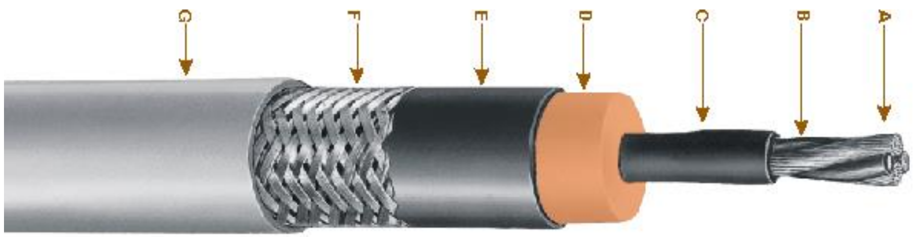
Samples of HV-cables

Okonite Hi-Voltage Cable: www.okonite.com

100kV, od= 16,76mm,

bending radius = 4*od > 70mm

A Coated Stranded Copper Conductors
B Polyester Insulation
C Extruded Semiconducting Layer
D Primary Insulation – Okoguard
E Extruded Insulation Shield
F Coated Copper Braid
G Jacket – Okoseal



Heinzinger HVC100 Best. No.:00.220.853.9 www.heinzinger.com

100kV, od= 14mm, bending radius min. 280mm!

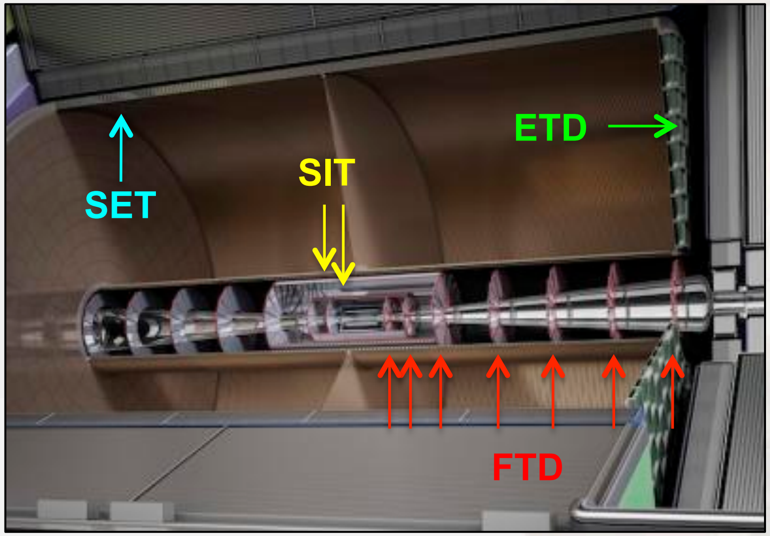
FUG C 2124, Mat.- No.: 0502032124

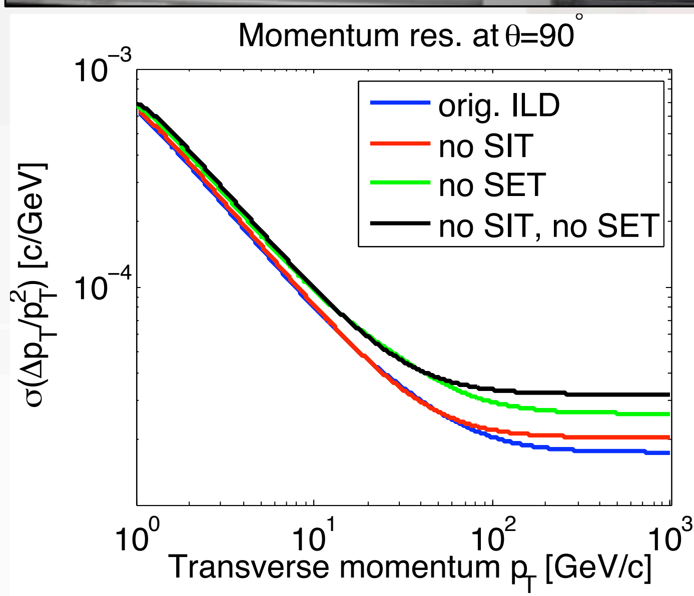
Cross section of the HV-cable: 255-300mm^2 necessary

http://www.fug-elektronik.de/webdir/PDF/e/Access_data_sheet.pdf

100kV, od= 11,2mm, bending radius min. 152mm

Silicon Tracking





Extra silicon trackers provide:

- Better angular coverage (FTD: ~0.15 rad)
- Improve momentum/position resolution
- Time stamping (20-40 ns for beam bunch)
- Calibration & alignment

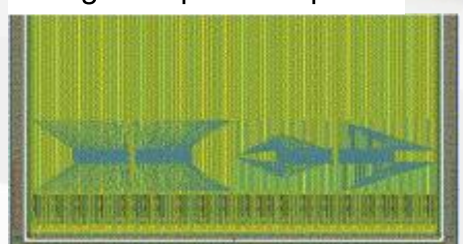
LHC-LC synergy in R&D:

- $10\times10cm^2$ strip sensor for SIT, SET, ETD
- Edgeless sensors, integrated pitch adapters
- New on-detector electronics, support architecture
- Embedded sensors

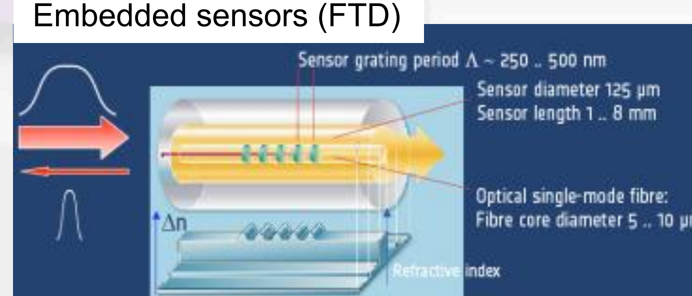
Challenges:

- **Material budget**, low power consumption, high spatial resolution

Integrated pitch adapters



Embedded sensors (FTD)

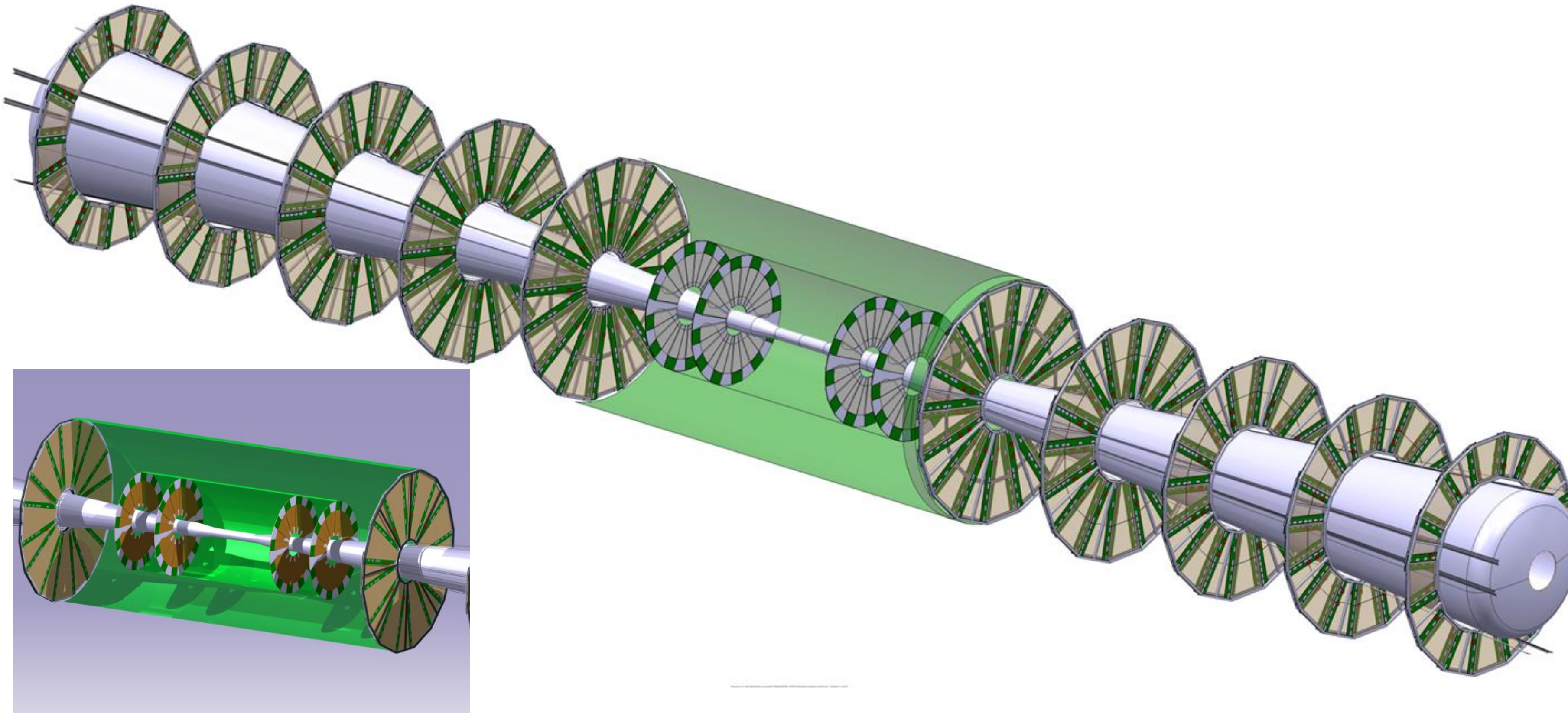


T. Tanabe (tomohiko@icepp.s.u-tokyo.ac.jp)

FORWARD TRACKER STATUS

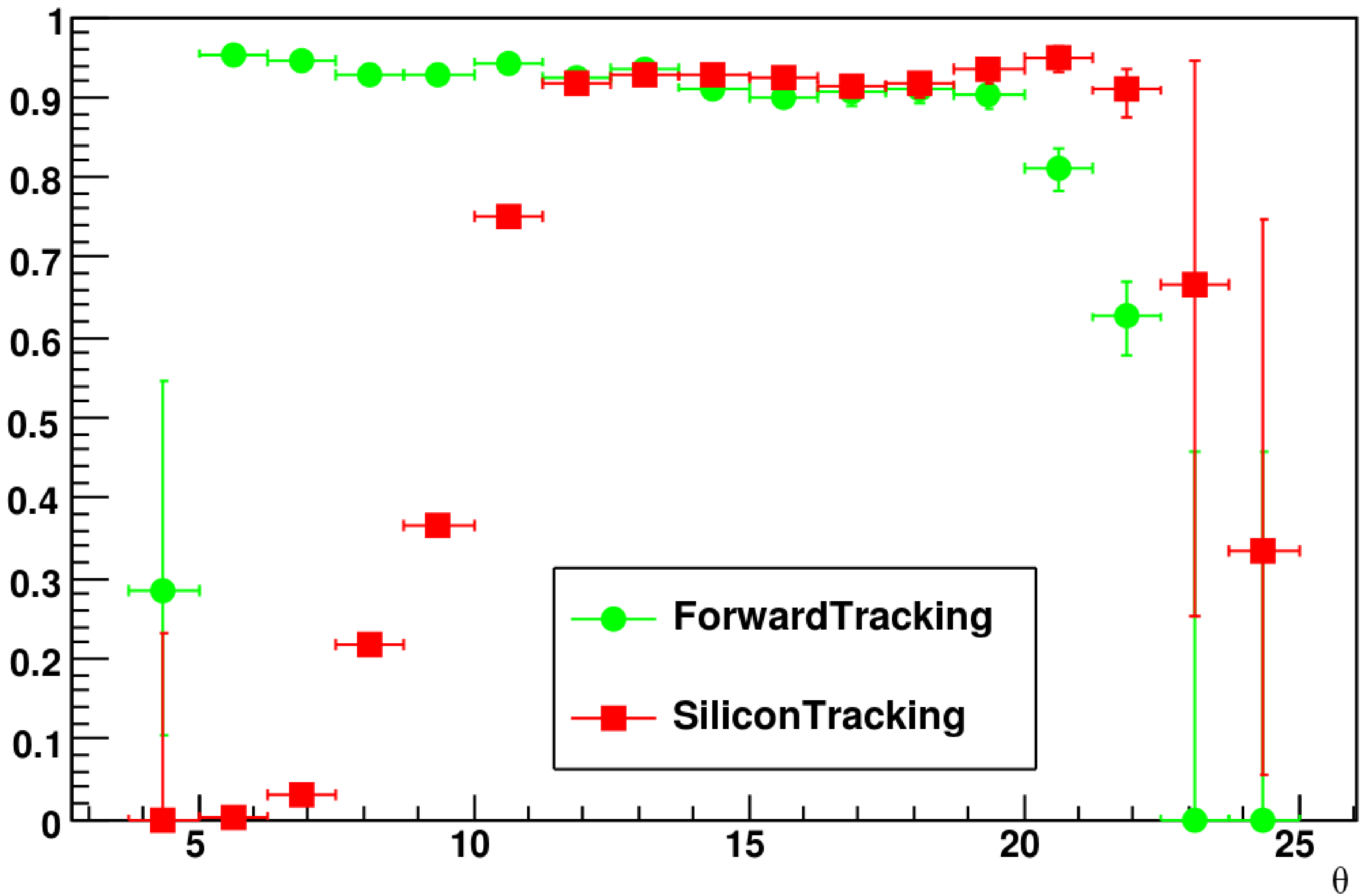
Baseline sensor: *conventional microstrip sensor with integrated signal routing in a second metal layer.*

Baseline operational unit: *petal (sensor+standard hybrid board(s) with readout, powering and data link circuitry.*



R&D on future technologies (see I. Vila talk)

Efficiency



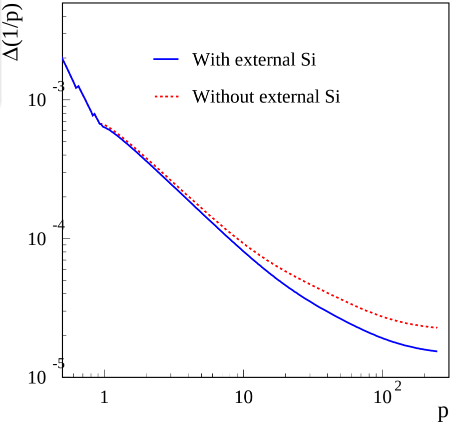
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
10
15
20
25
θ
ForwardTracking
SiliconTracking

Effects on tracking performance

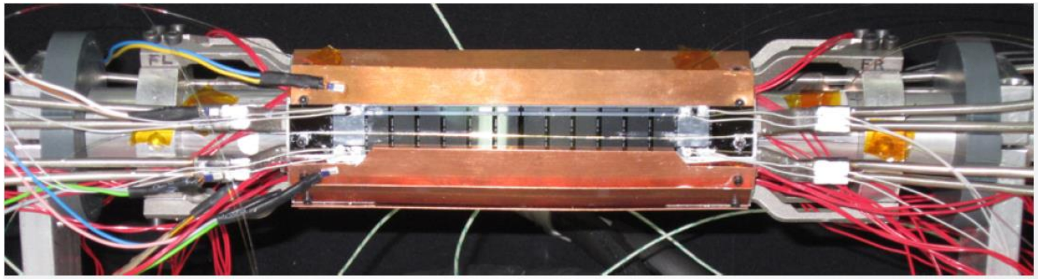
Master formula:

$$\Delta(1/p) = \frac{8 \times 330 \sin\theta \sigma_{sagita}}{BL_{coda}^2}$$

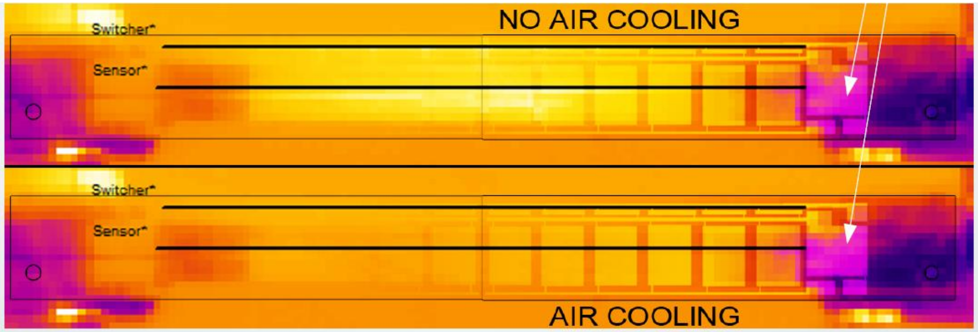
- SET:
  - up to 30% better $\Delta(1/p)$.
  - Amelioration still sizeable down to $\sim$ 10 GeV.
  - Amelioration at all angles for p=250 GeV.
  - Almost no effect on $\Delta(D_0)$
- ETD:
  - Very modest amelioration for p > 25 GeV.



COOLING



Valencia PXD Mockup



Sensor T	Ambient T = 25ºC	
Without convective cooling	T_{MAX}=~40ºC	ΔT=~15ºC
With convective cooling	T_{MAX}=~25ºC	ΔT=~5ºC

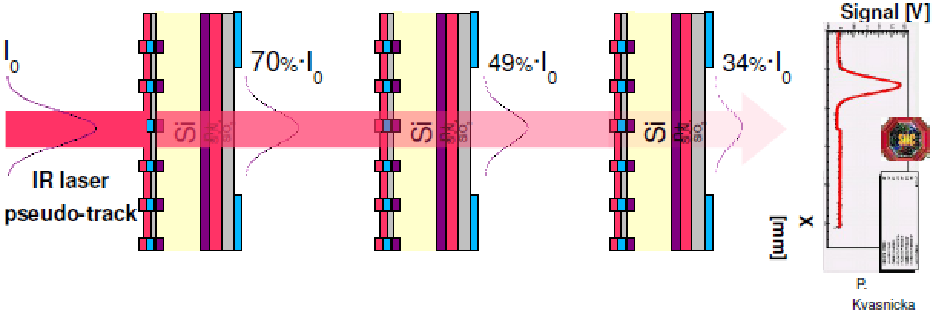
BELLE II (IFIC-IFCA DESY May 2013)

- Cooling of a working fine pixel sensor works properly
  - Combining contact and convective cooling
- No vibrations observed at the pressures studied for cooling

- <u>ILD</u>
  - Naively ~900 to ~1080 W total
  - ~4 to 5 W with power pulsing (ideal 1:200 duty cycle)
  - No active cooling due to angular acceptance requirements
    - Convective cooling (performance demonstrated in Belle II)

ALIGNMENT

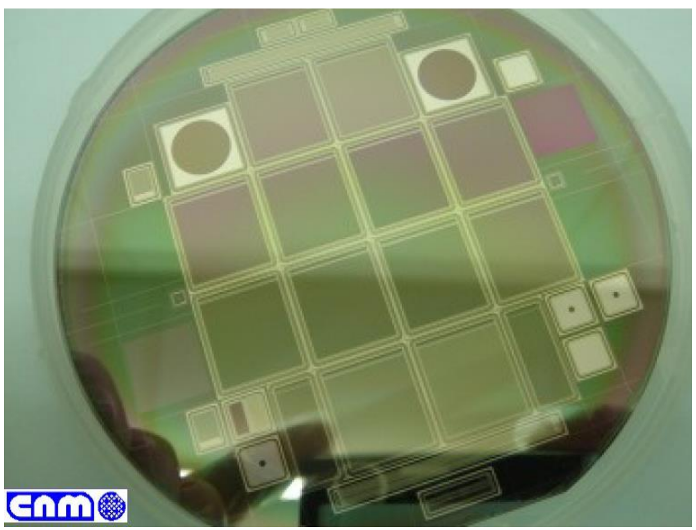
• Laser tracks can be used by a hardware system to align the tracker

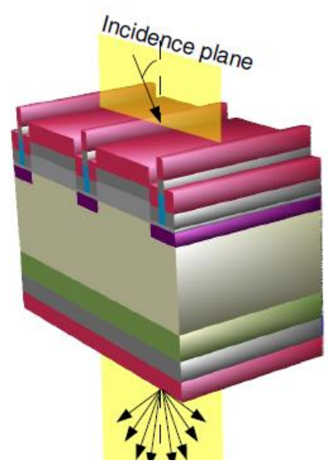


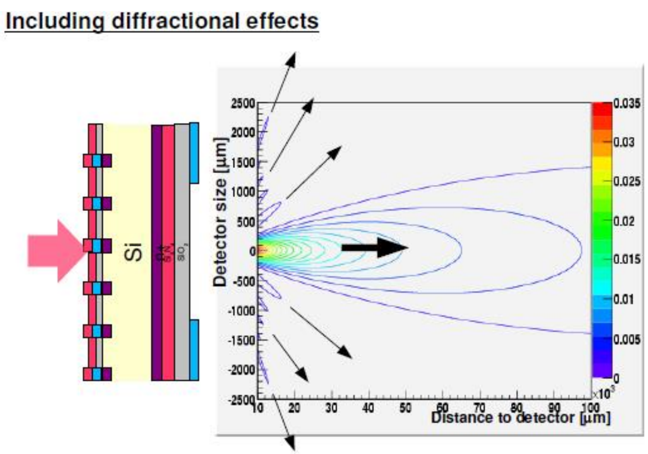
Improved InfraRed transparent microstrips detectors for tracker alignment

• First implemented by AMS I, then AMS II and CMS

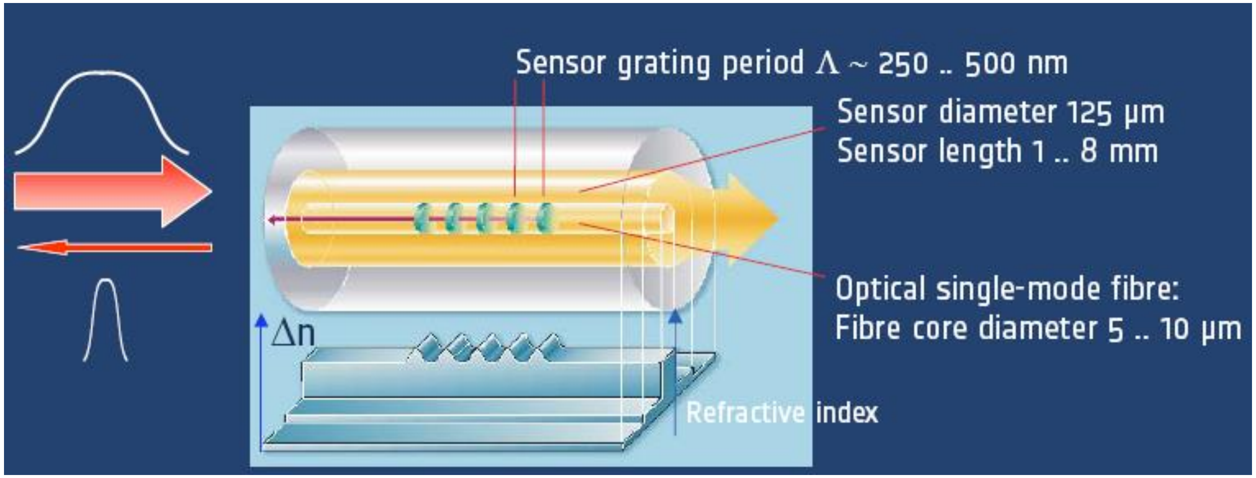
WELL ADVANCED

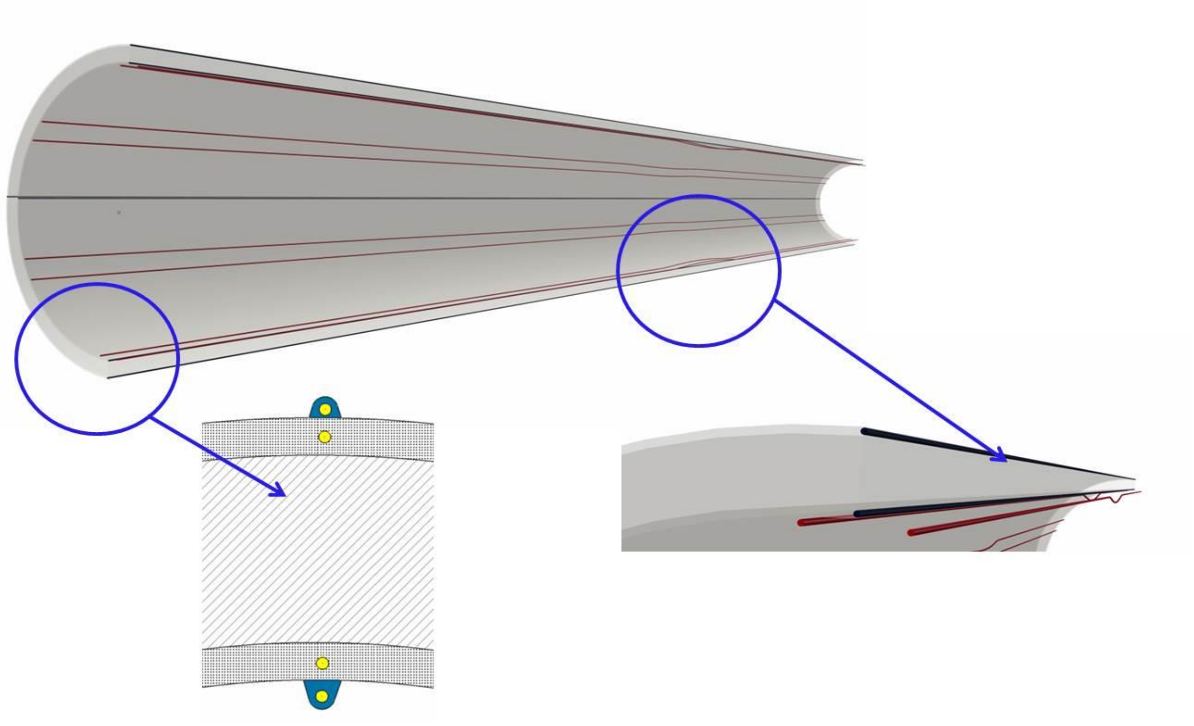






Real Time Structural and Environmental Monitoring

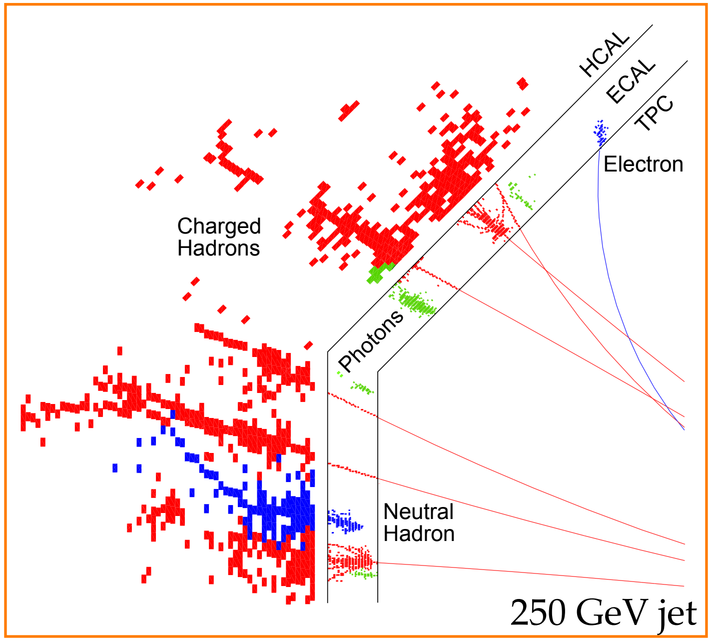




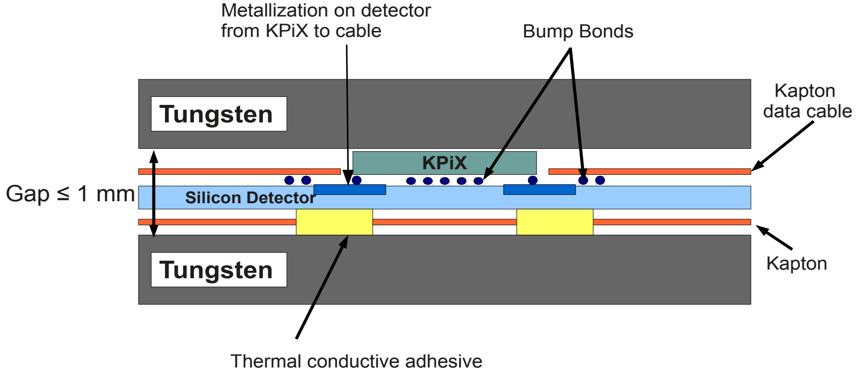
PROGRESSING

ECAL & HCAL → designed with PFA in mind

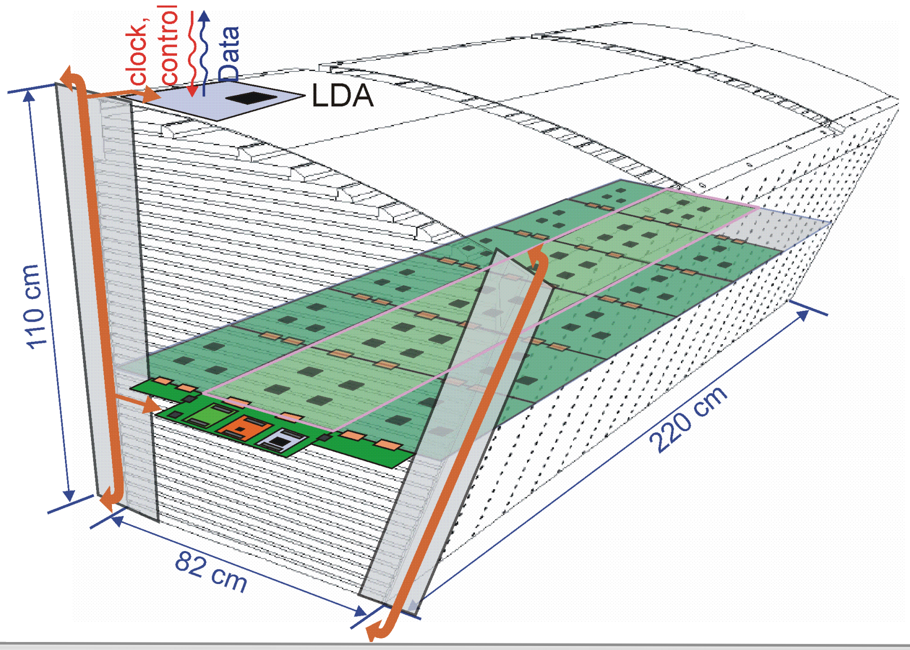
- Need calorimeters with very high granularity



Example – SiD SiECAL approach:



Example of HCAL module:



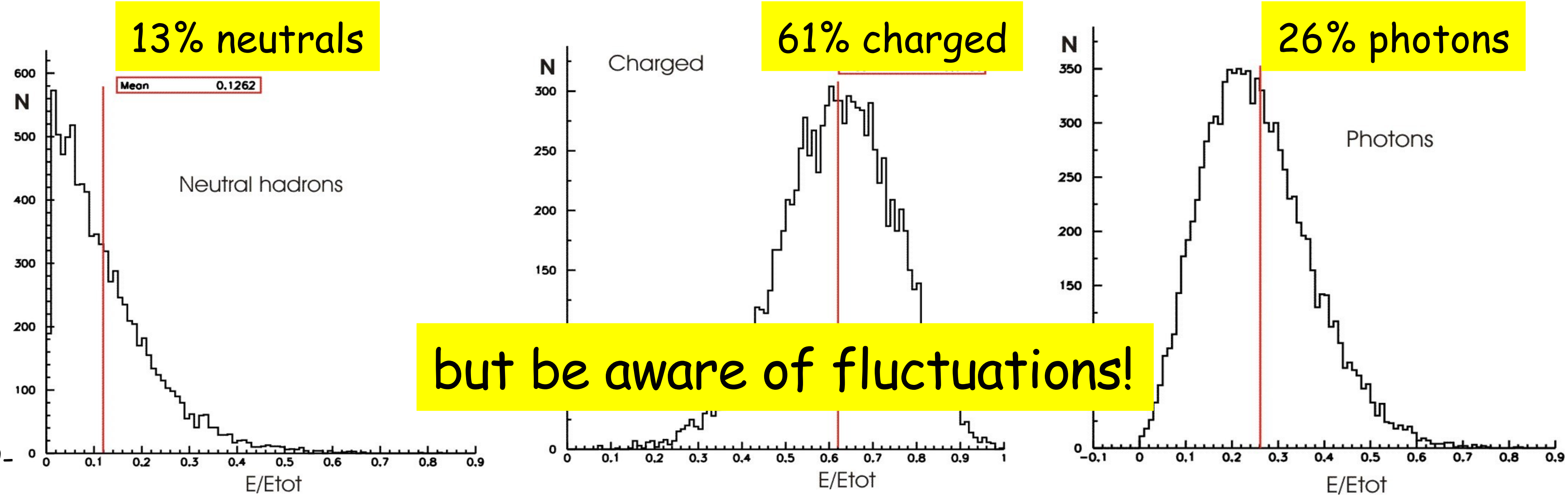
Perfect PFA : What theory predicts

- Jet energy resolution
  $\sigma^2(E_{jet}) = \sigma^2(ch.) + \sigma^2(\gamma) + \sigma^2(h^0) + \sigma^2(conf.)$
- Excellent tracker :
  $\sigma^2(ch.) \ll \sigma^2(\gamma) + \sigma^2(h^0) + \sigma^2(conf.)$
- Perfect PFA : $\sigma^2(conf.) = 0$
  $\sigma^2(E_{jet}) = A_\gamma E_\gamma + A_h E_{h0} = w_\gamma A_\gamma E_{jet} + w_{h0} A_h E_{jet}$
  $\sigma(E_{\gamma,h})/E_{\gamma,h} = A_{\gamma,h}/\sqrt{E_{\gamma,h}}$

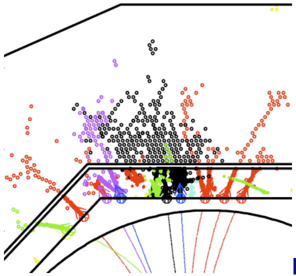
Typically $w_g = 25\%$; $w_{h0} = 13\%$

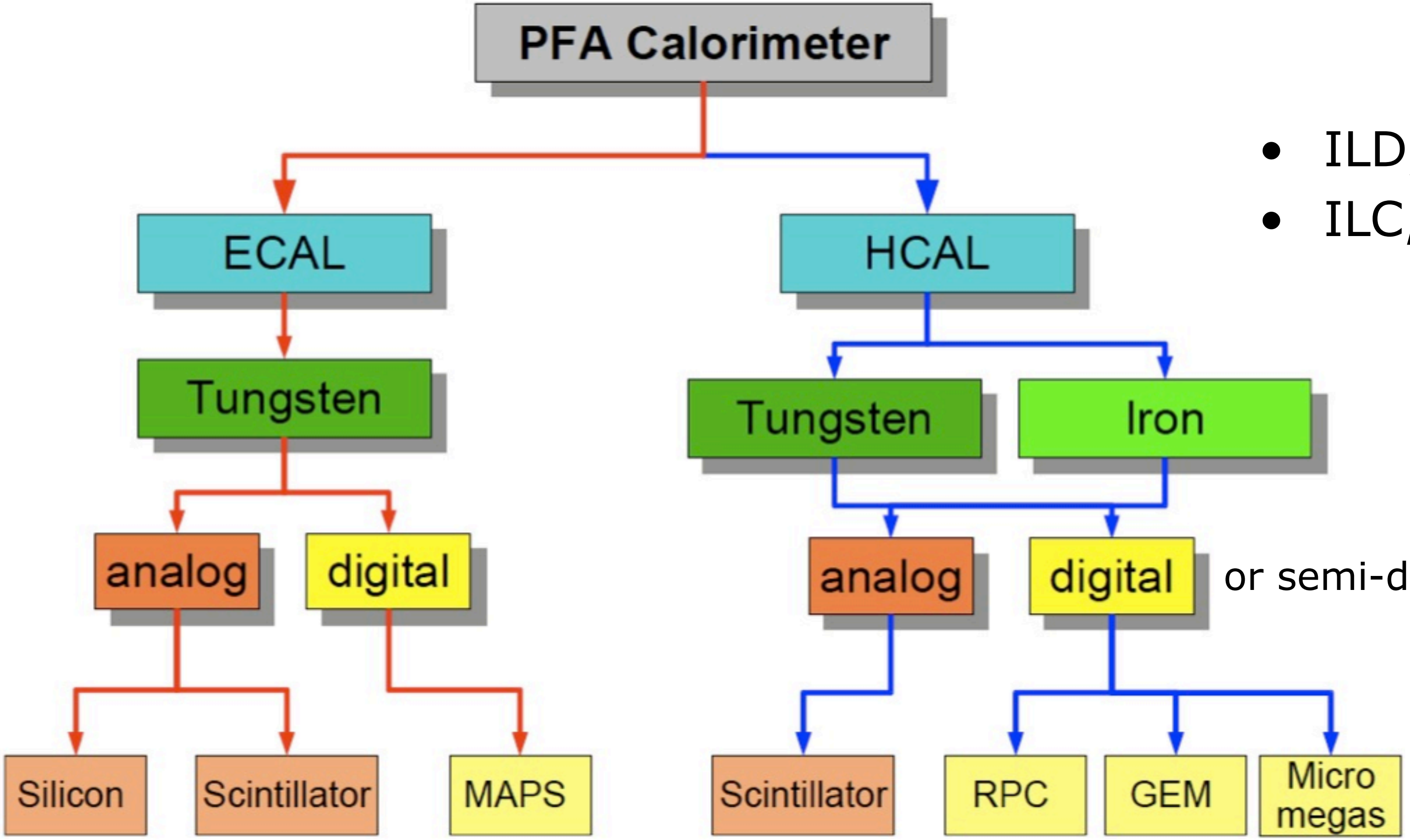
$A_g = 11\%$; $A_{h0} = 34\%$
$\Rightarrow s(E_{jet})/E_{jet} = 14\%/\sqrt{E_{jet}}$

$A_g = 11\%$; $A_{h0} = 50\%$
$\Rightarrow s(E_{jet})/E_{jet} = 17\%/\sqrt{E_{jet}}$



Calorimeter technology tree





or semi-digital

- ILD, SiD
- ILC, CLIC

ECAL

Sampling calorimeter with tungsten as absorber.

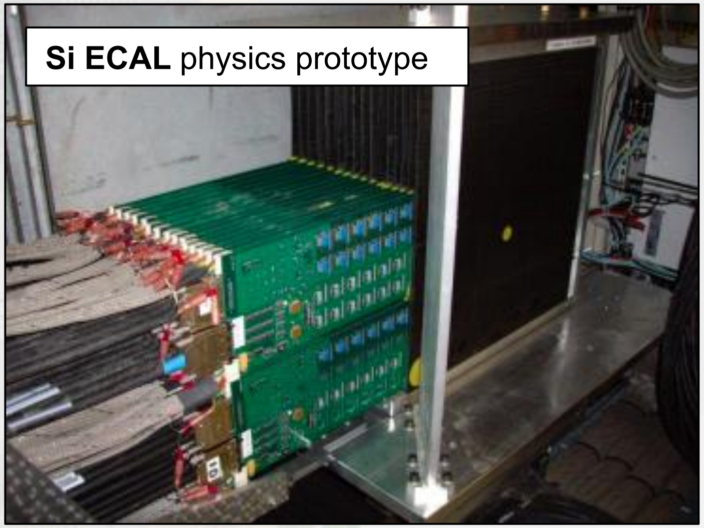
→ Compact design, 24 X_0 within 20 cm

→ Longitudinal segmentation: ~30 layers

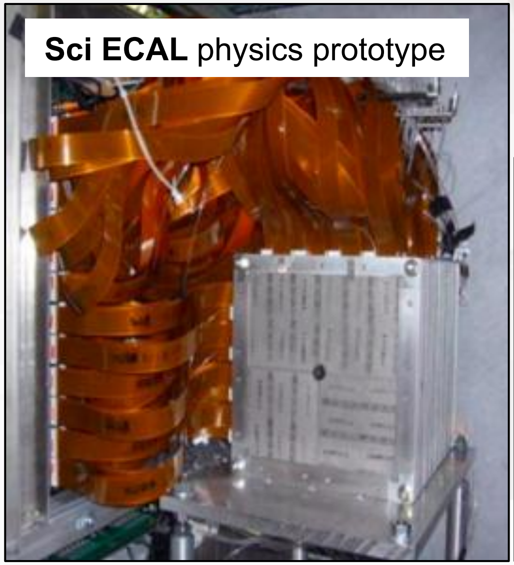
Options for active layers:

- **Silicon PIN diodes** (0.5 x 0.5 cm^2)
- **Scintillator strips** (0.5 x 4.5 cm^2), MPPC readout
- Silicon/scintillator **hybrid**

Basic performance established; transition from physics prototype to technological prototype ongoing

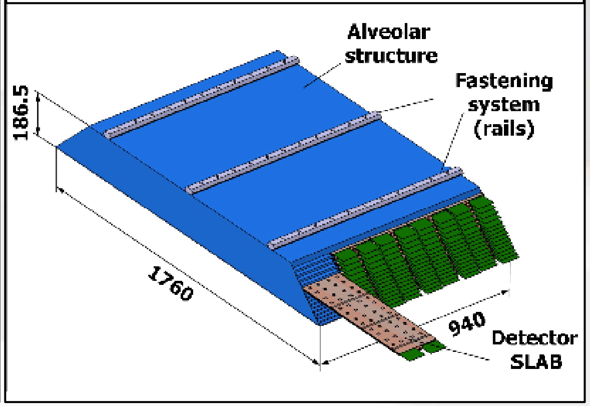


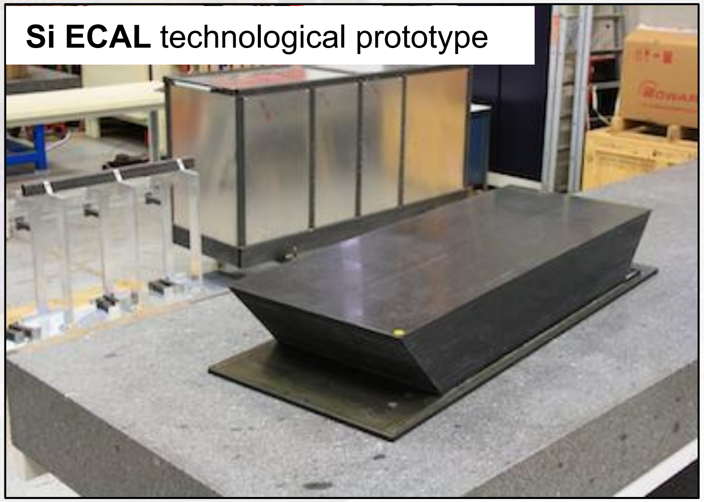
Si ECAL physics prototype



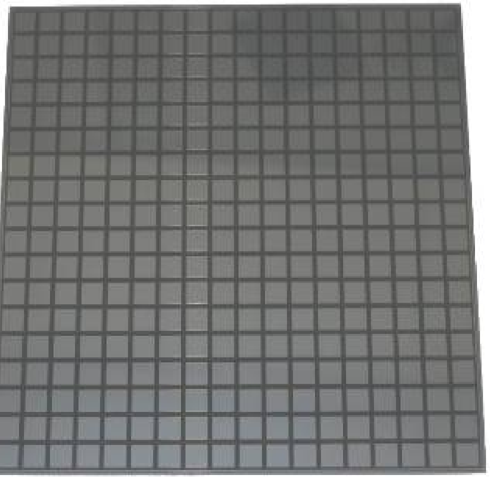
Sci ECAL physics prototype

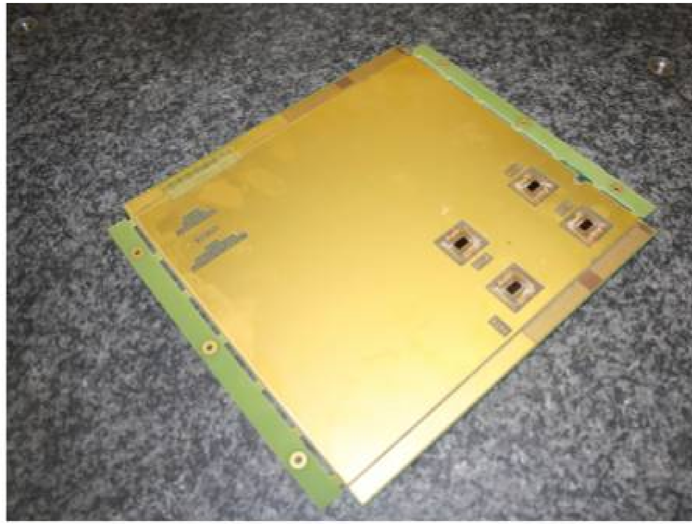
Sci ECAL technological prototype under development

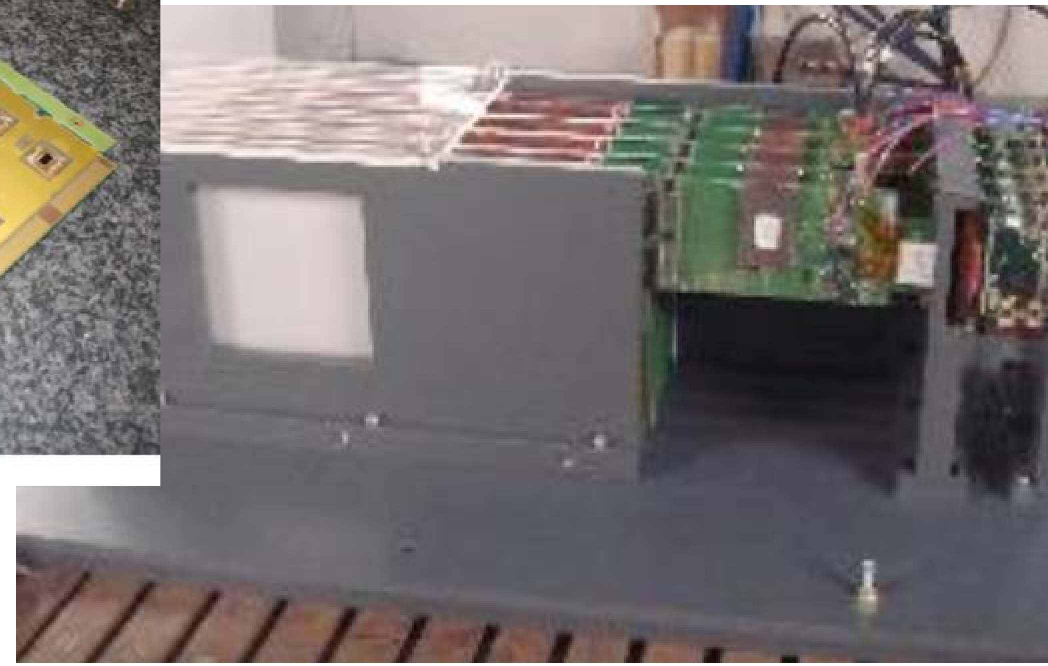




Si ECAL technological prototype



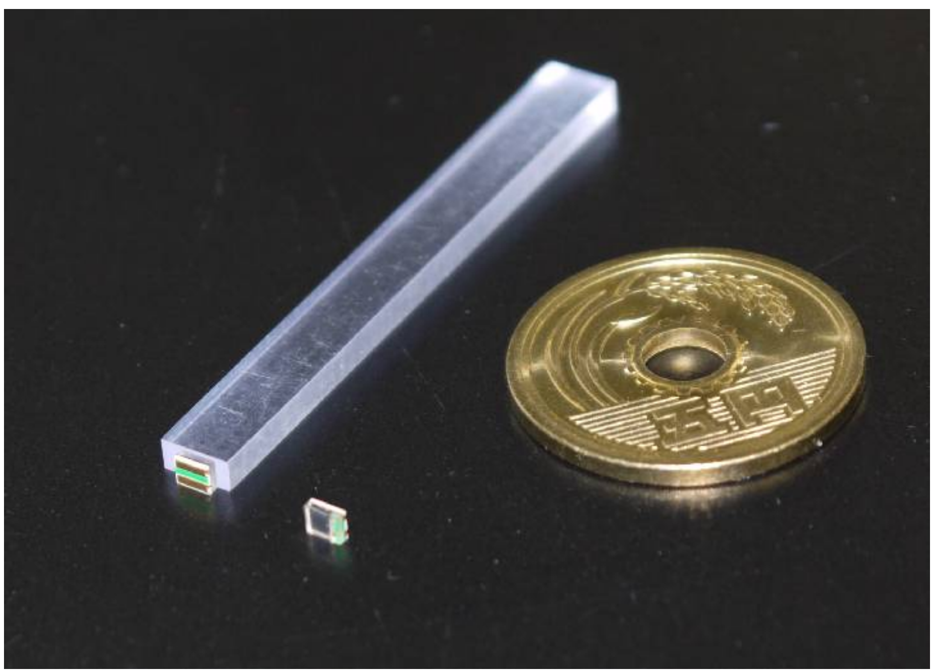


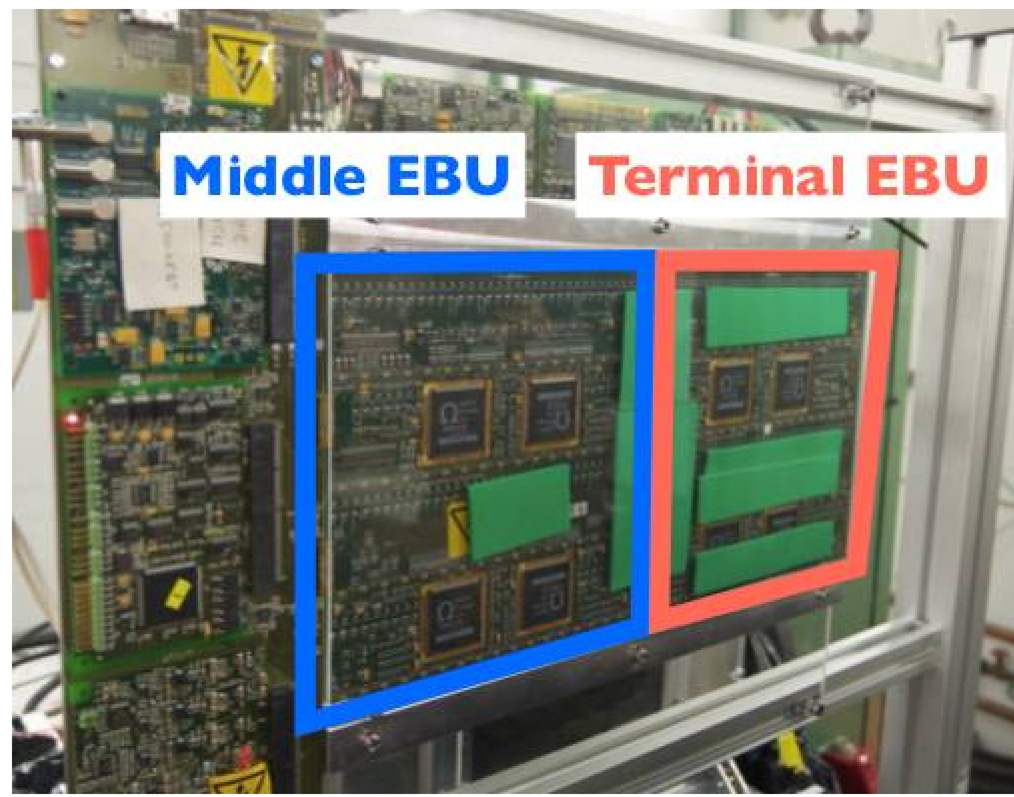


Si ECAL

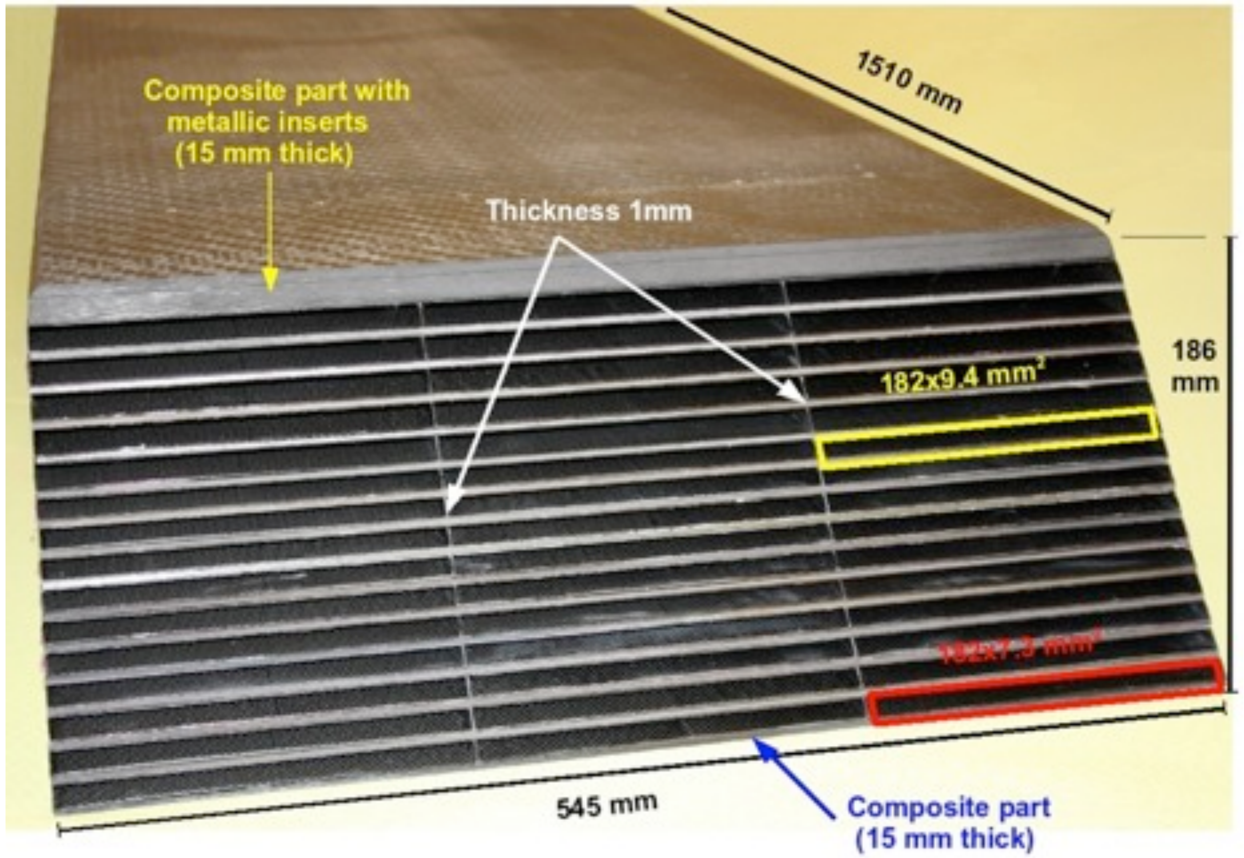
technological prototypes

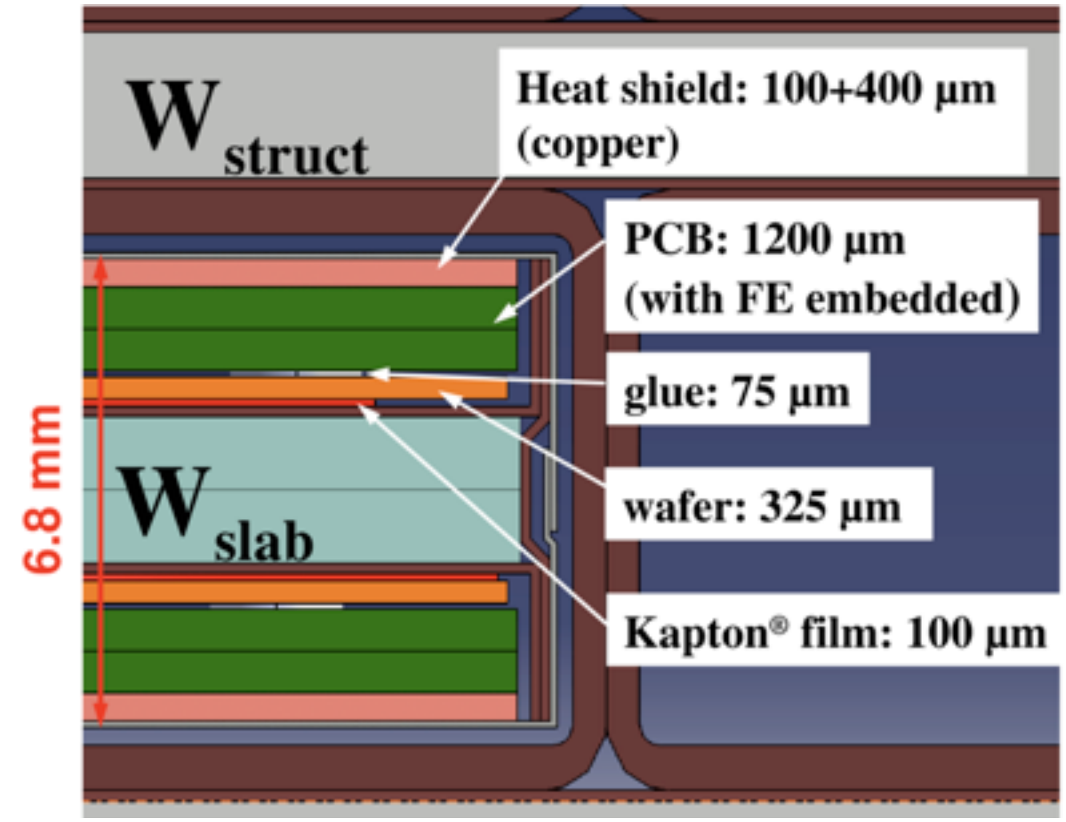
Sc ECAL

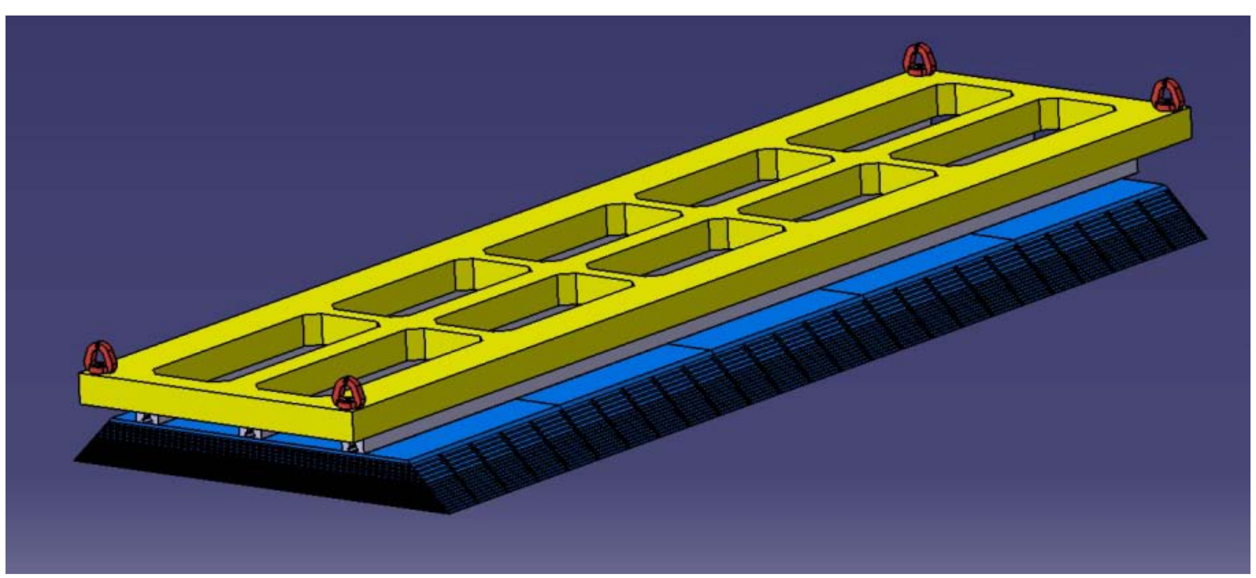




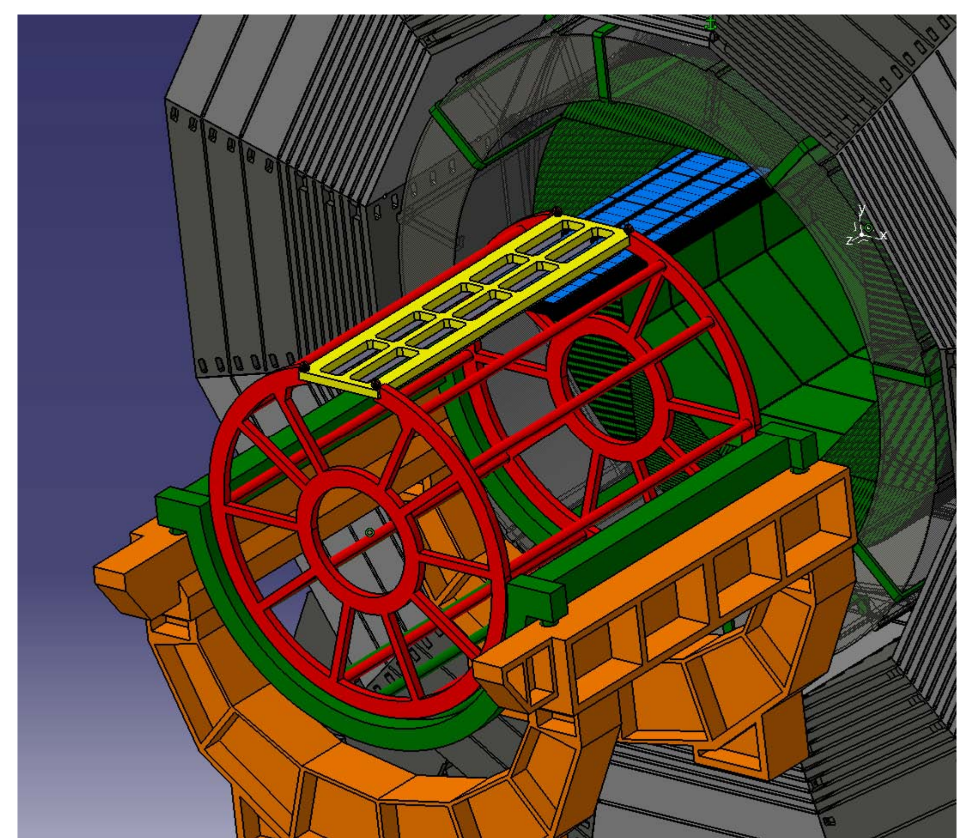
Si/W ECAL







C. Clerc



HCAL

Absorber material: **steel**. Active material options:

- **Analog HCAL:** 3x3 cm^2 scintillator with SiPM
- **Semi-Digital/(Digital) HCAL:** 1x1 cm^2 glass RPC

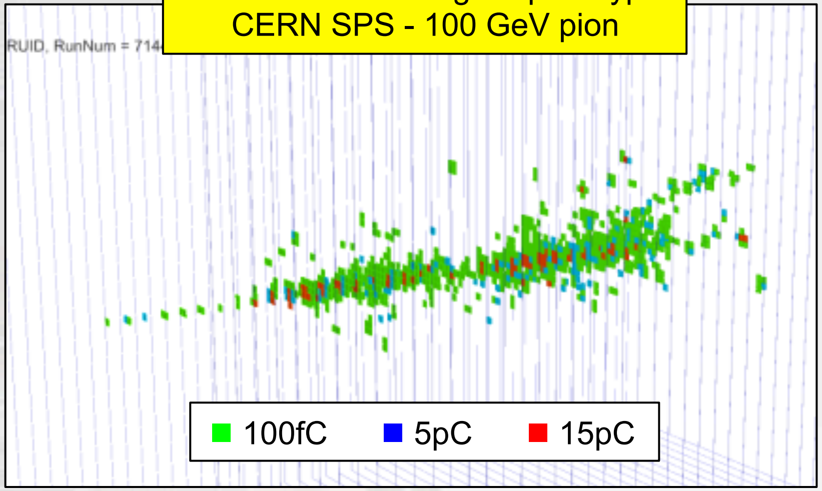
Both have constructed 1 m^3 sized prototypes and exposed them to test beams.

AHCAL: physics prototype with external electronics built. Completed data taking and analysis, validated the simulation and tested first technological demonstrator units.

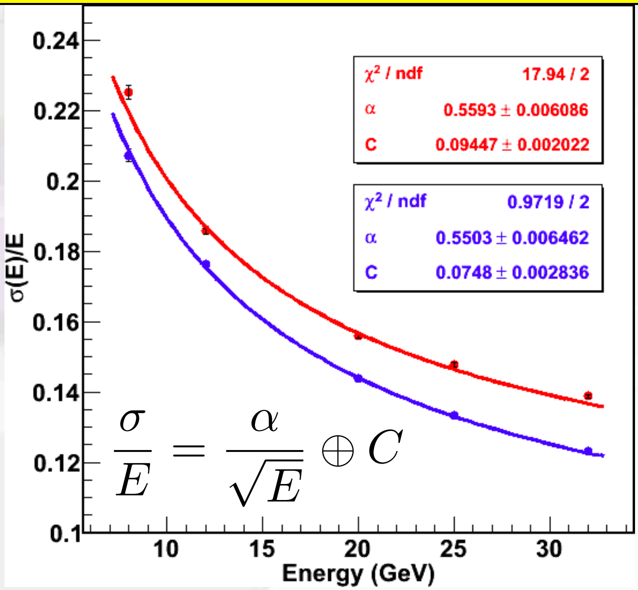
SDHCAL: technological prototype with embedded electronics and power-pulsing built. Data taking is ongoing, first look into data is encouraging.

DHCAL: test beams with physics prototype → proof of principle demonstrated.

SDHCAL technological prototype
CERN SPS - 100 GeV pion

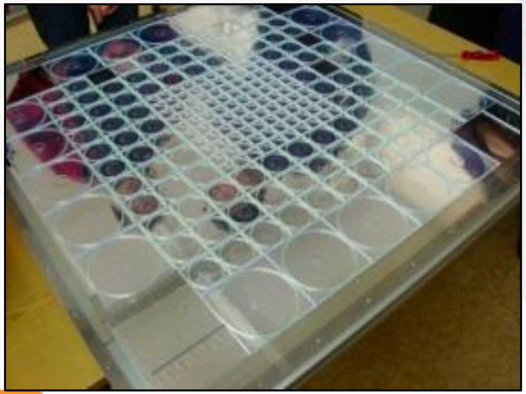


DHCAL test beam: pion energy resolution

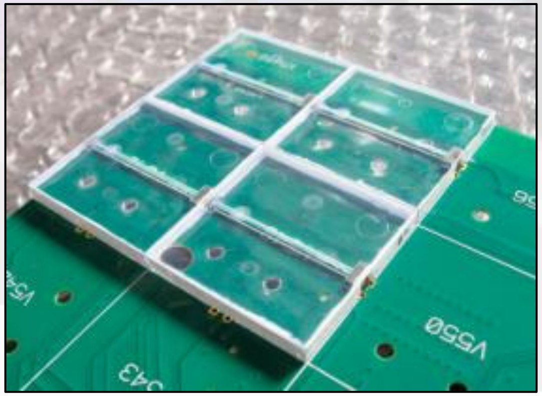


$$\frac{\sigma}{E} = \frac{\alpha}{\sqrt{E}} \oplus C$$

AHCAL physics prototype

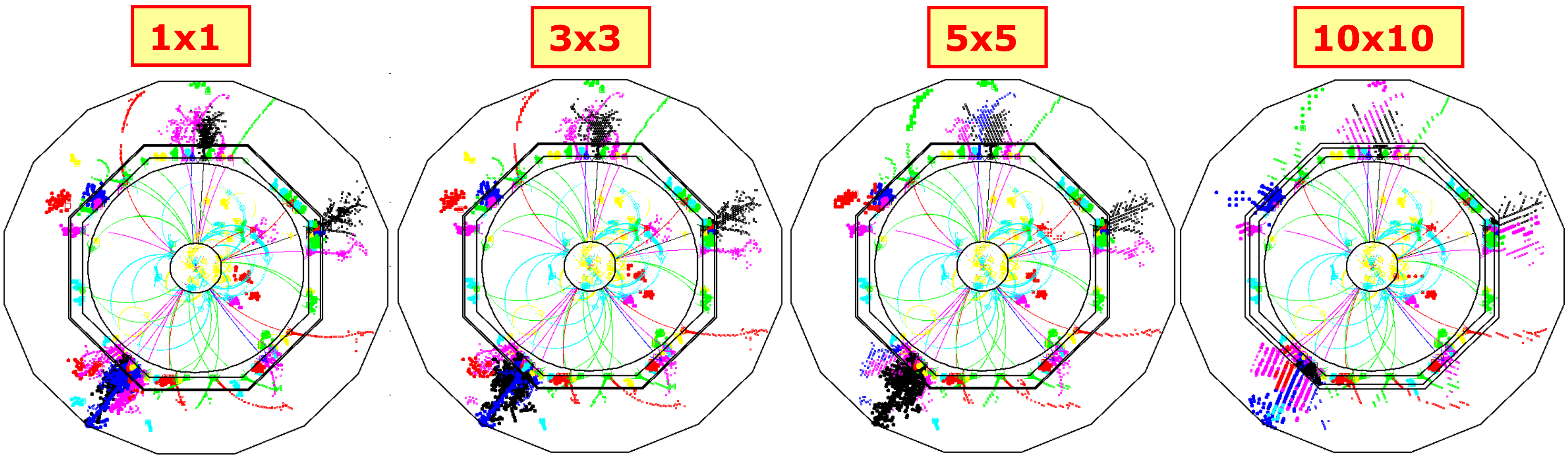


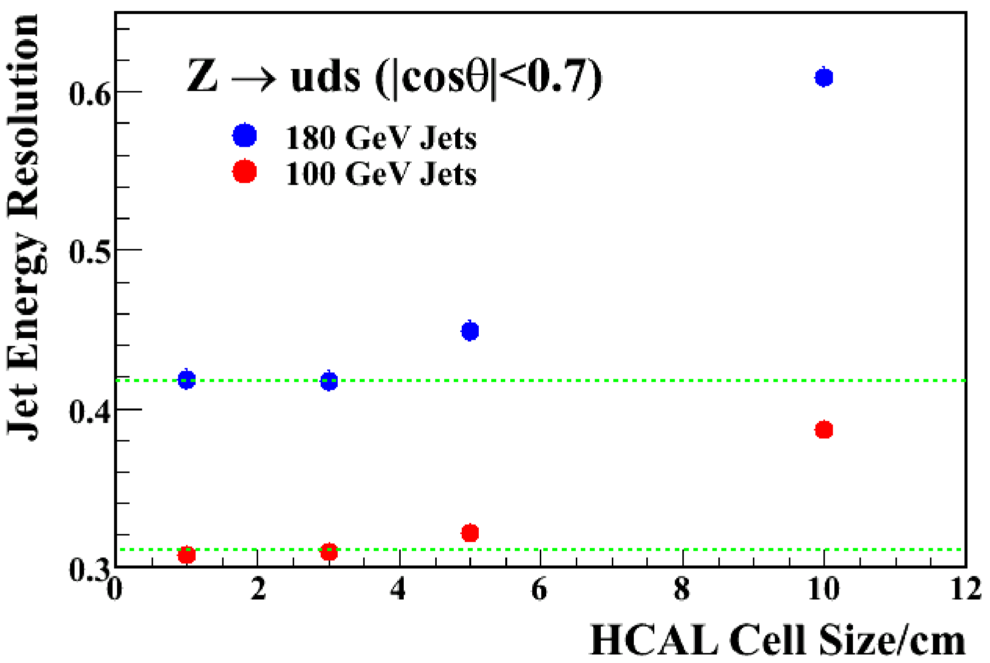
AHCAL tiles and SiPMs for technological prototype



Detector Optimization: HCAL

M. Thomson, Paris 2007





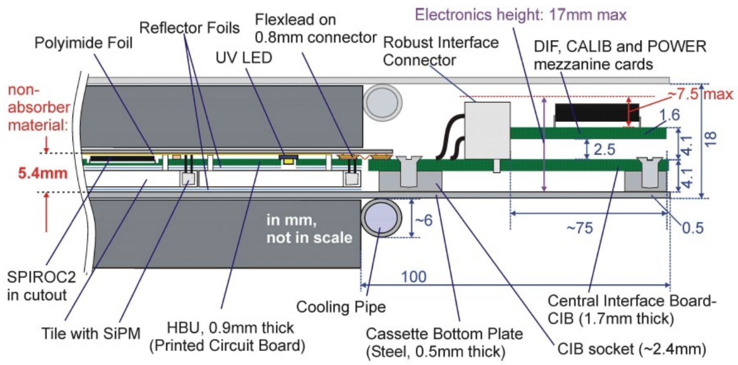
<u>"Preliminary Conclusions"</u>

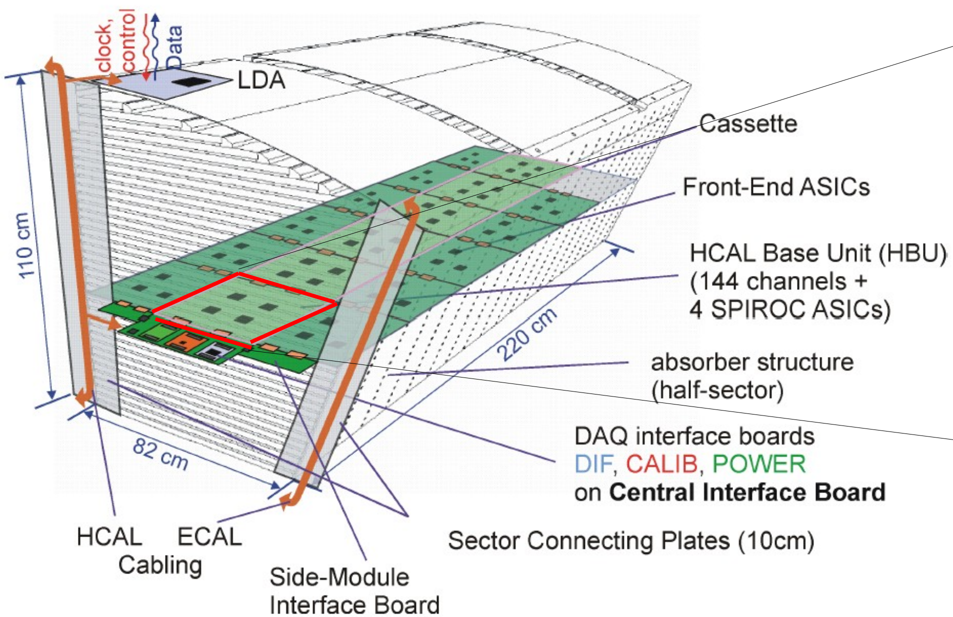
- 3x3 cm² cell size ok
- No advantage → 1x1 cm²
  - physics ?
  - algorithm artefact ?
- 5x5 cm² degrades PFA

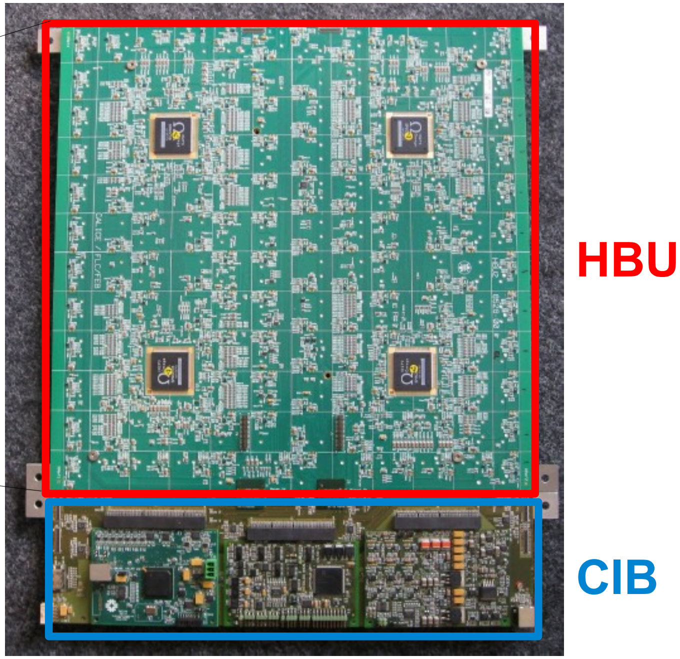
Update today

AHCAL engineering prototype: Integrated Electronics

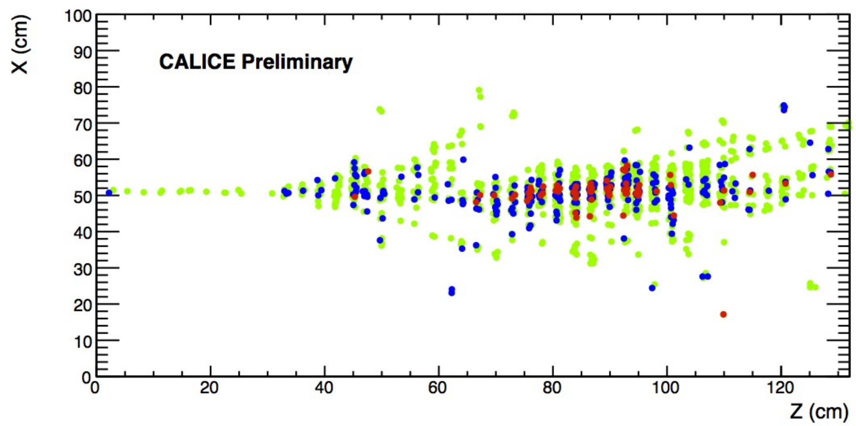
- **H**CAL **B**ase **U**nit: 36*36 cm^2, 144 tiles, 4 SPIROC2 readout ASICs
- **C**entral **I**nterface **B**oard: DIF, Calibration, Power for 1 layer
- 5.4 mm active layer thickness
- 1 layer has up to 3*6 HBUs

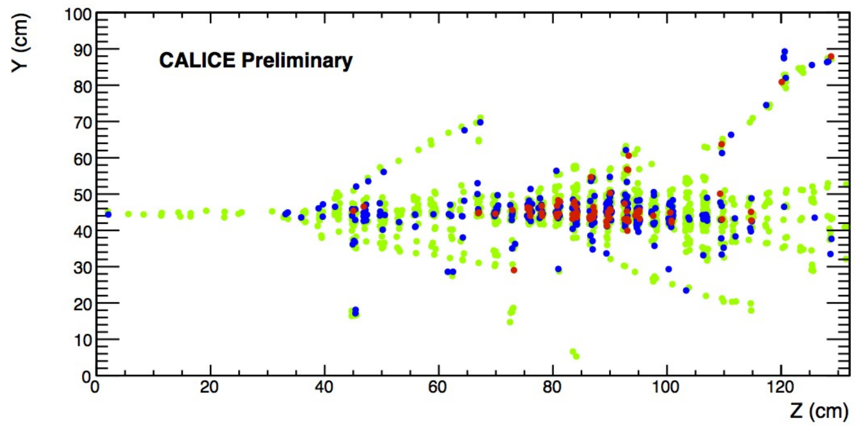




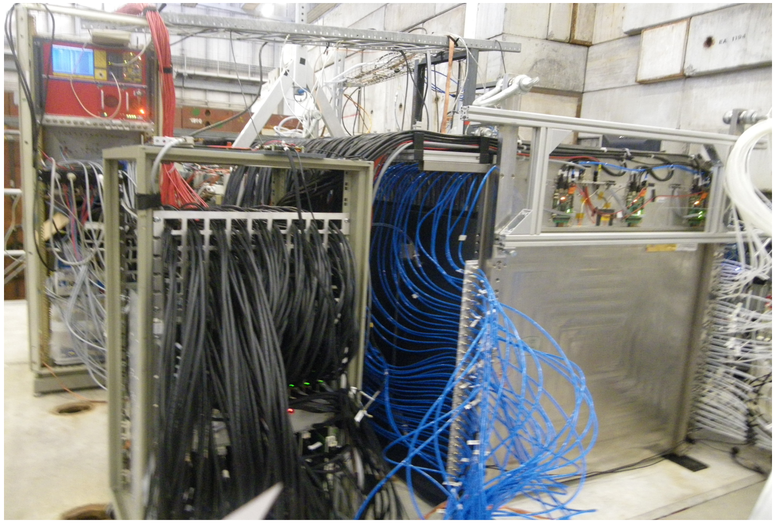


Semi-Digital HCAL



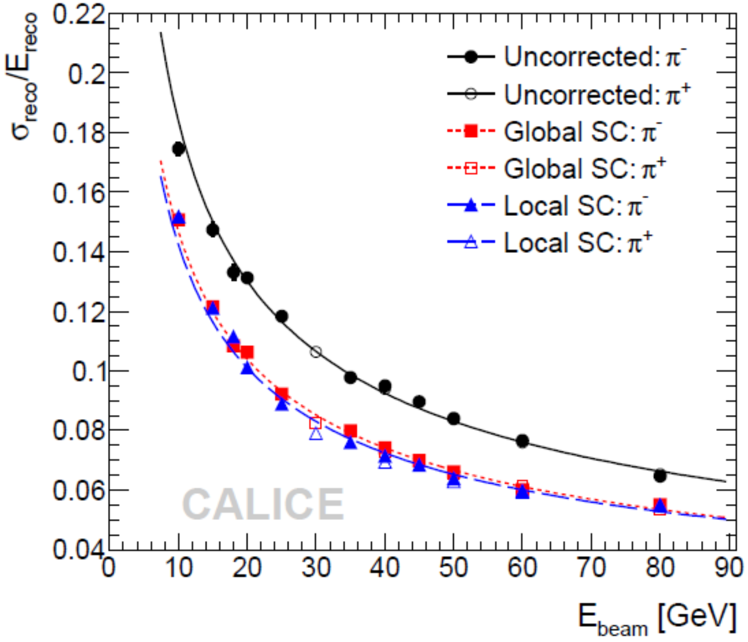


- Glass Resistive Plate Chambers
- 1*1 cm^2 pads
- read-out: 2 bit (semi-digital)



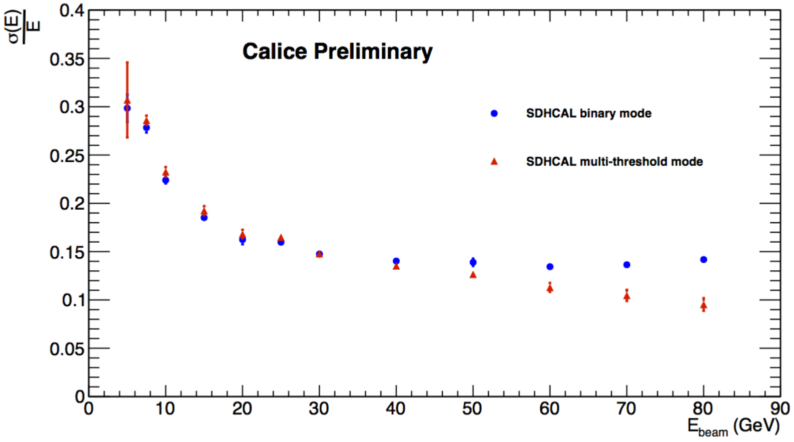
Energy Resolution for Hadrons

AHCAL



Software Compensation improves stochastic term:
58%/√E → 45%/√E

SDHCAL

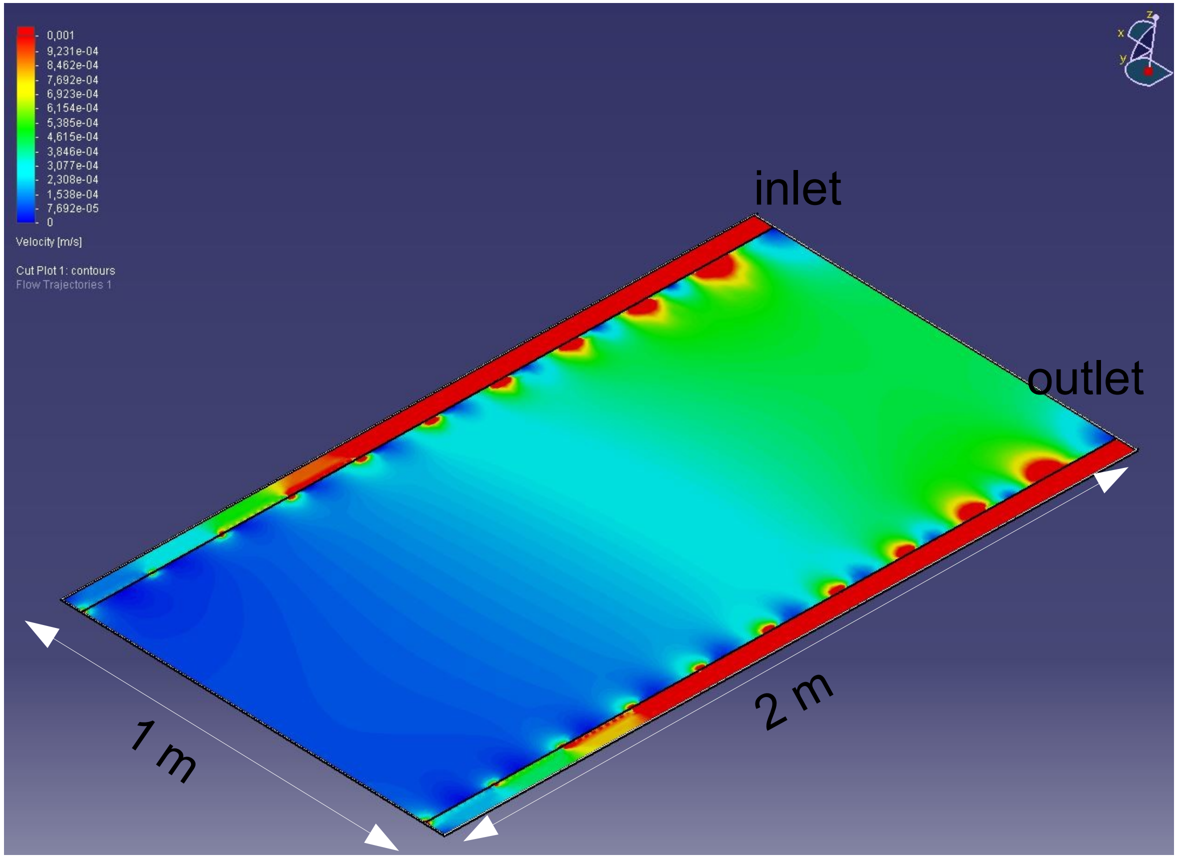


Resolution with 1 or 3 thresholds

3 thresholds improve resolution at large energies

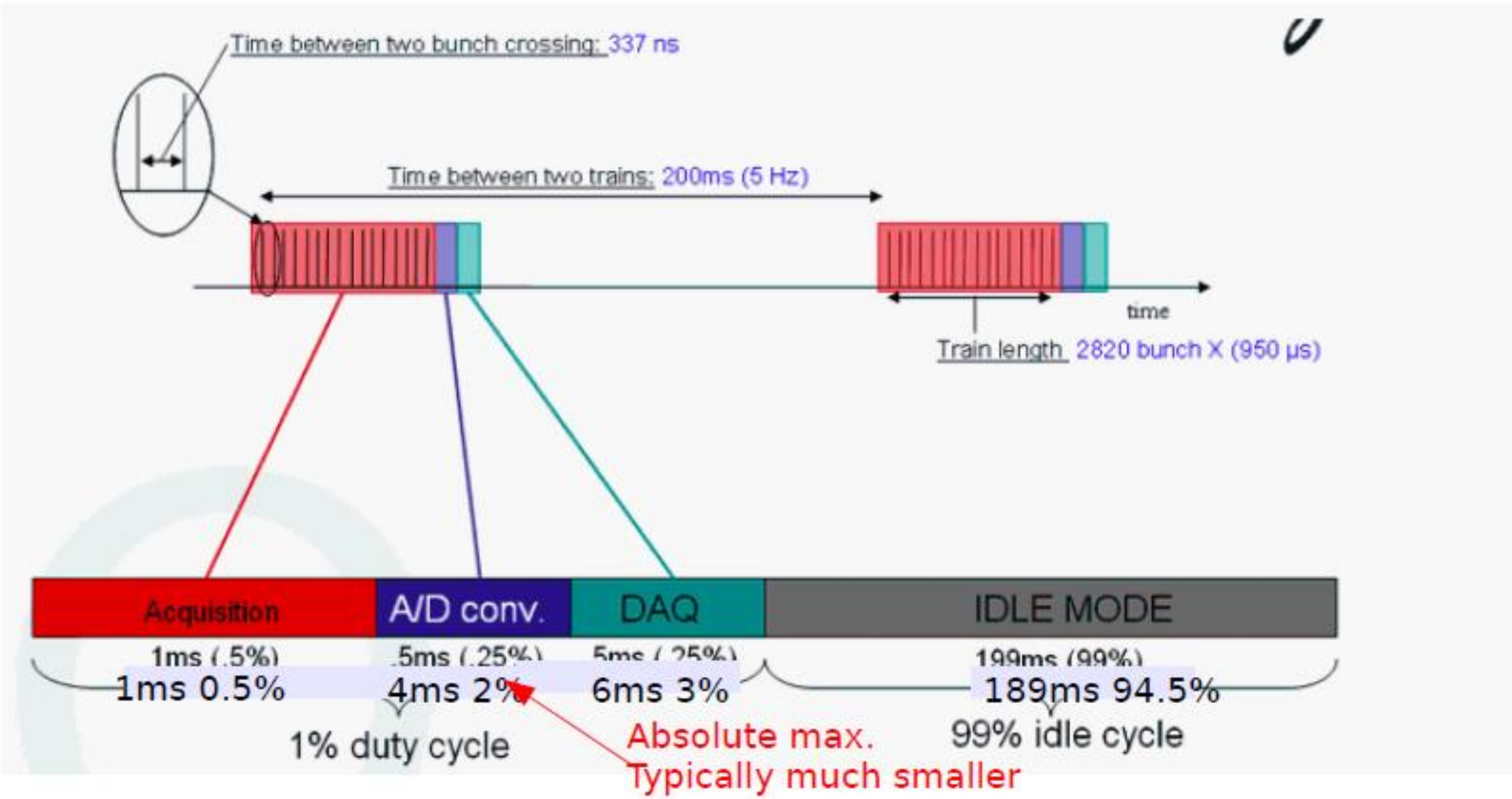
SDHCAL: Large GRPC for ILD

- for ILD, GRPC with a surface of up to 3 m^2 are needed
- intend to build a 2 m^2 GRPC (glass are already there)
- currently studying the gas distribution system to ensure a good gas renewal
  - scaling from 1 m^2 to larger surface needs more study to ensure fast gas renewal



DESY

Power Pulsing

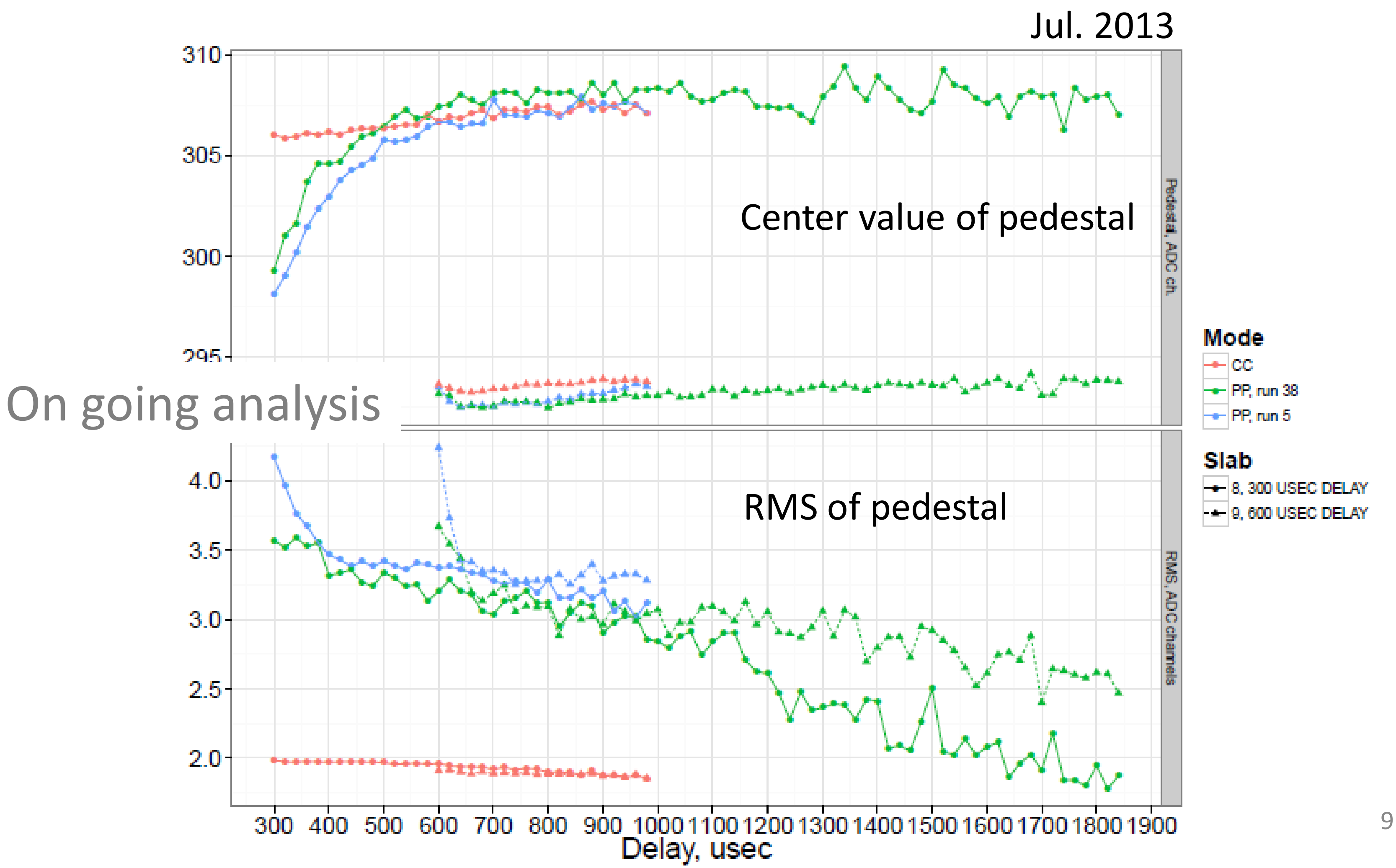


- Electronics switched on during > 1ms of ILC bunch train and immediate data acquisition
- **Bias currents** shut down between bunch trains
- Mastering of technology is essential for operation of ILC detectors

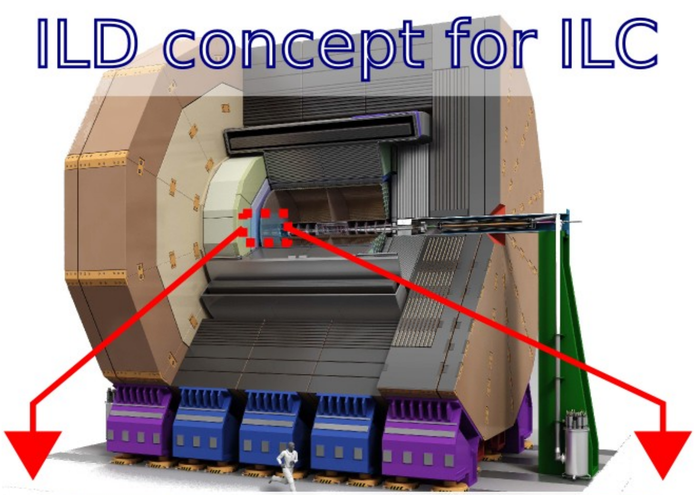
Measurements for SKIROC ship 1.7 mW ⇔ 27 µW/ch

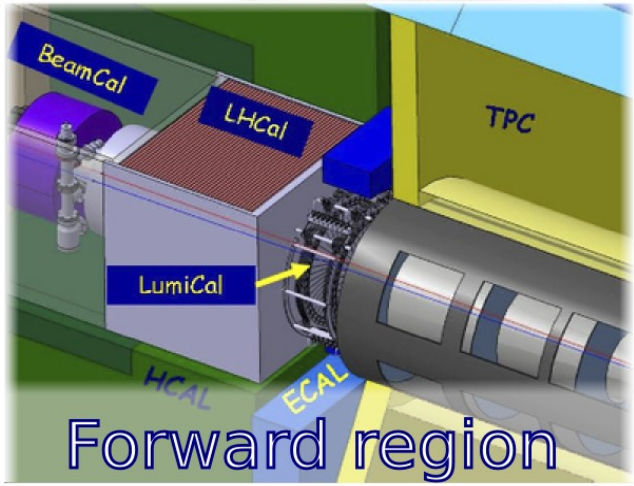
Stability of SKIROC in PP Operation

- After spill start, center value of pedestal drifts during ~500 μs
- RMS approaches CC value in > 2 ms.



Introduction
Subdetectors





BeamCal (+Pair Monitor)

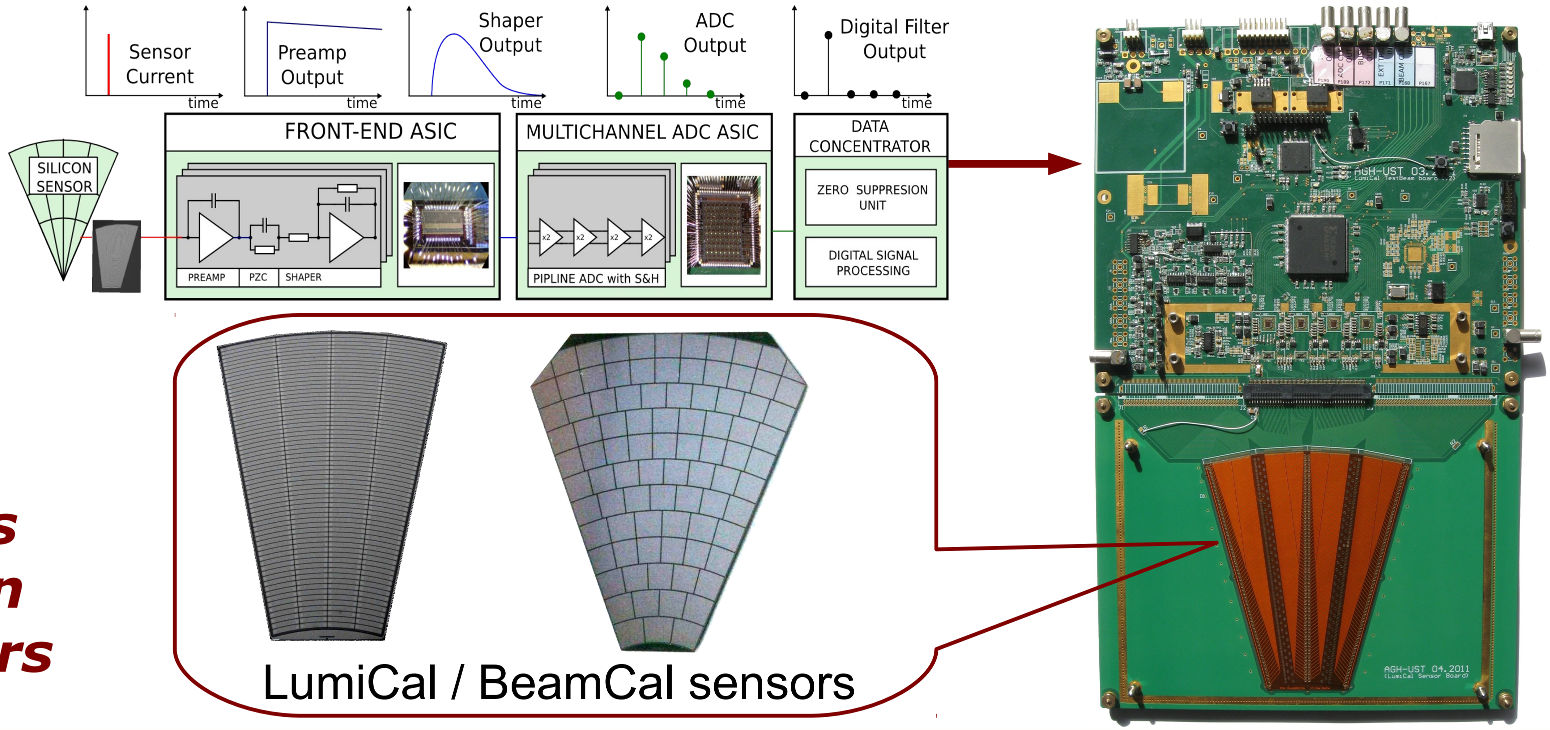
- Fast luminosity estimate (bunch-by-bunch at ILC)
- Beam parameter estimation
- Fast feedback to the machine
- Hermeticity & Low angle electron tagging

LumiCal

- Precise measurement of luminosity
- 10^{-3} at ILC
- Hermeticity
- Low angle physics

FCAL Detector R&D Status
Prototype subdetectors

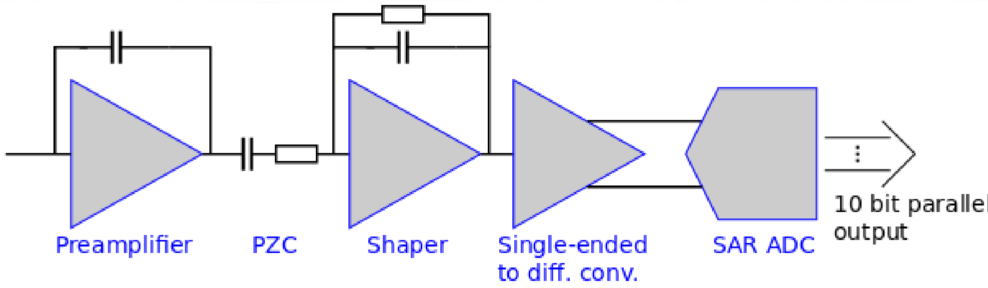
- Readout module (LumiCal) for 32 channels
- LumiCal sensors
- BeamCal sensors

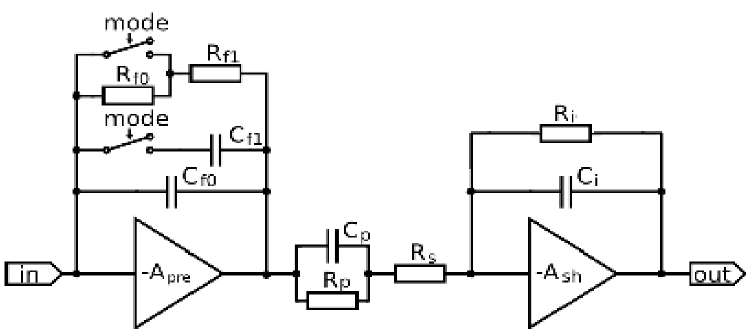


Few succesful test-beams were run in recent years

Readout R&D in IBM CMOS 130 nm
Development of LumiCal readout at AGH-UST
AIDA milestone

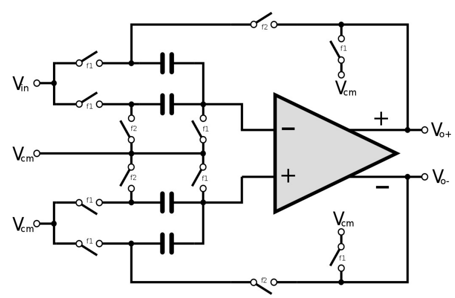
New readout in 130 nm has very similar architecture to existing one in 0.35um but should consume much less power and be radiation resistant





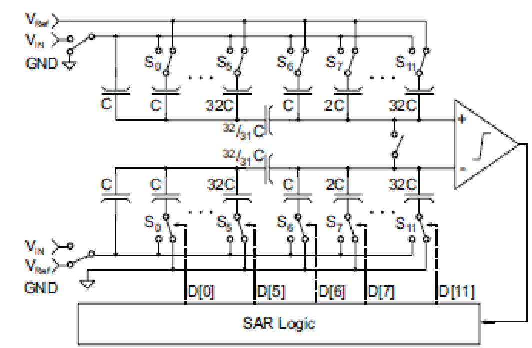
Front-end specs:

- Cdet ≈ 5 ÷ 50pF
- 1st order shaper (Tpeak ≈ 50 ns)
- Variable gain, two modes:
  - calibration: MIP sensitivity
  - physics: Q_{in} up to ~6 pC
- Power pulsing implemented
- Peak power cons. ~1.5 mW/channel



Single-to-Diff specs:

- Max freq. > 40MHz
- Power pulsing
- Peak power ~ 0.5mW

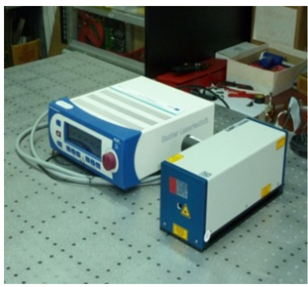


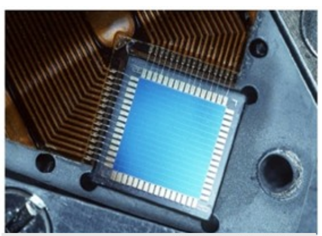
ADC specs:

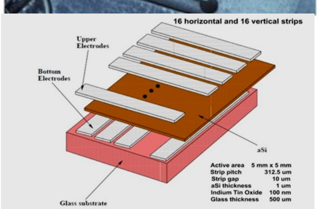
- 10-bit resolution
- Architecture: SAR ADC with segmented/split DAC
- Max frequency > 40 MHz
- Power pulsing
- Peak power 1-2 mW @40MHz

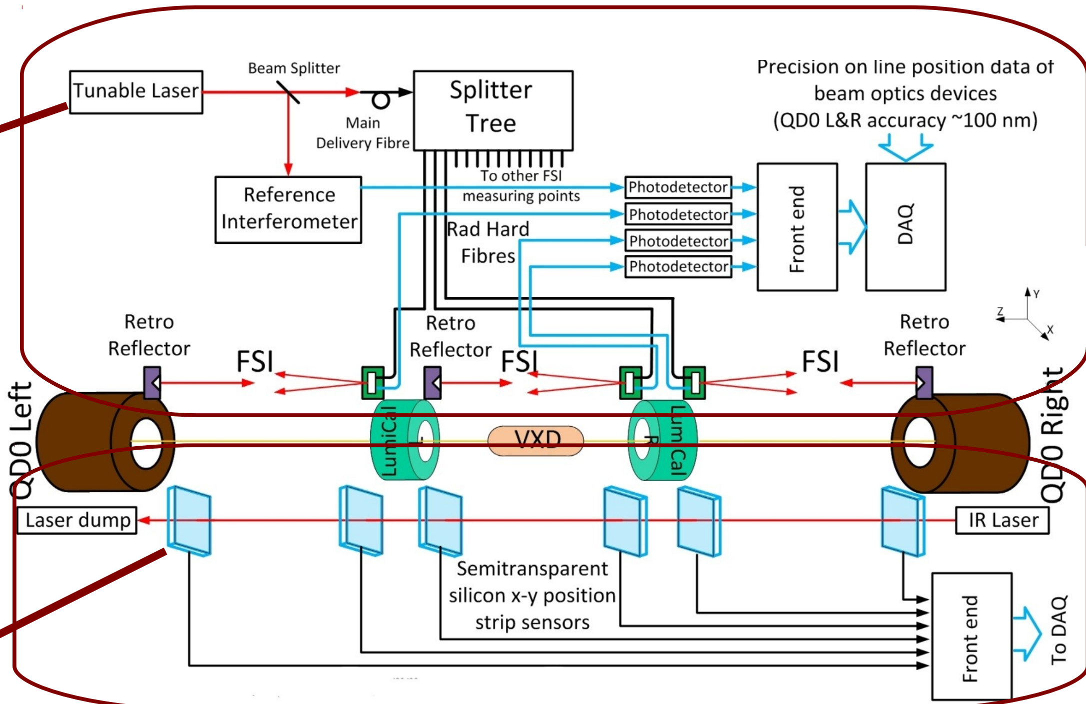
Laser alignment R&D at INP PAN
LumiCal Laser Alignement System (LAS)

The proposed laser alignmet system for LumiCal combines two components:
- infra-red laser beam and semi-transparent position sensitive detectors (PSDs) - already available
- tunable laser(s) working within Frequency Scanning Interferometry (FSI) system - in preparation





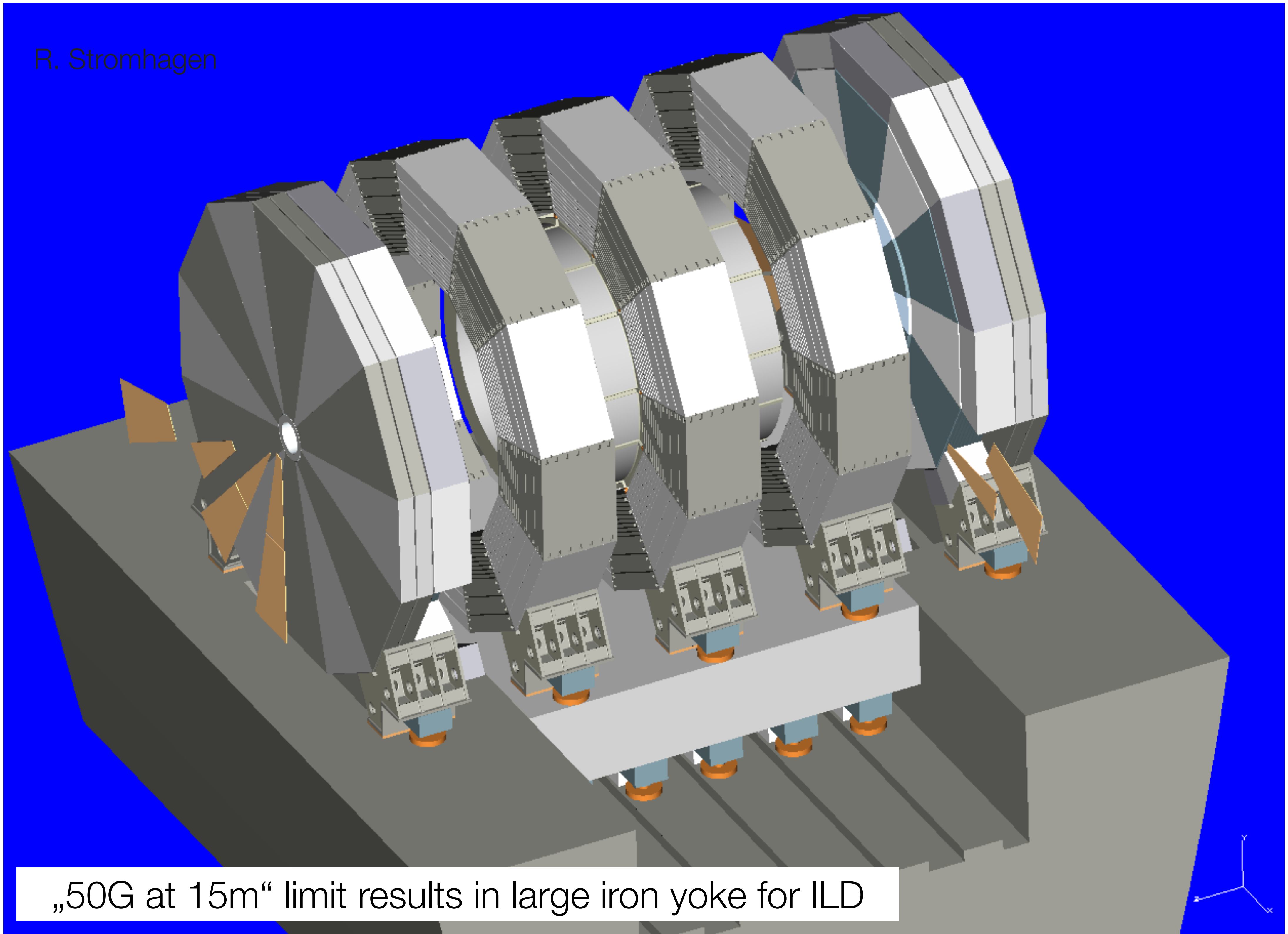




FSI – using tunable lasers will measure the absolute distance between LumiCal calorimeters by measurement of interferometer optical path differences (counting the fringes)

Semi-transparent sensors : LumiCal displacements of the internal Si layers and detectors relative positions

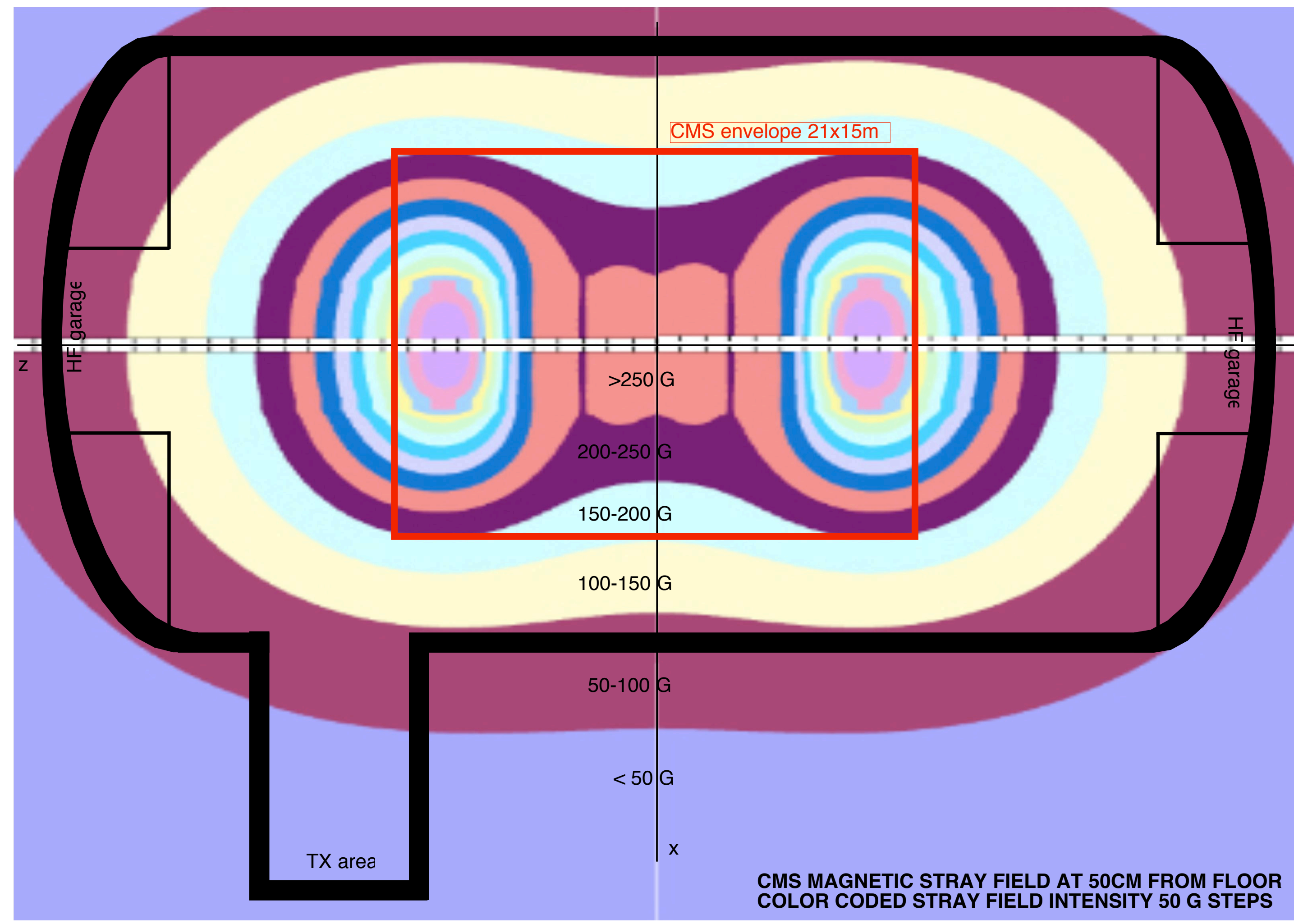
ILD Mechanical Design



„50G at 15m“ limit results in large iron yoke for ILD

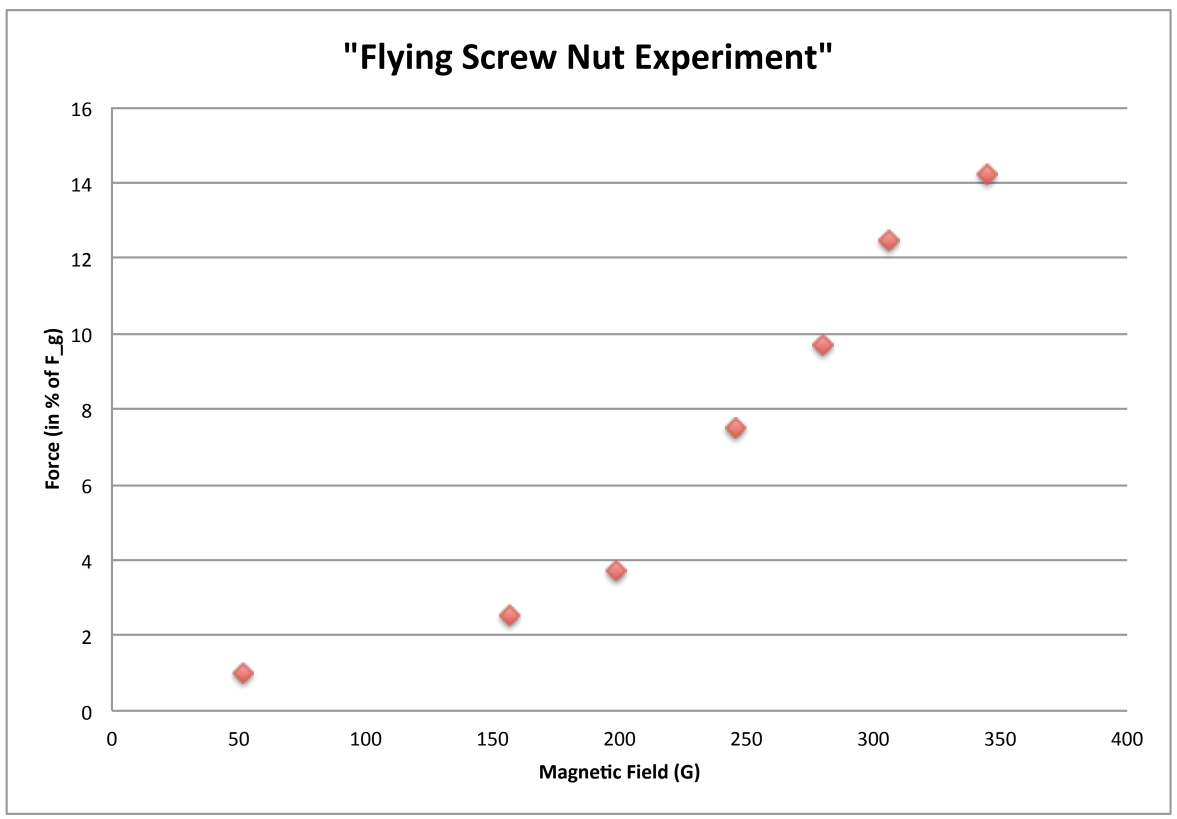
CMS Experience

- From „Mechanical Works in Magnetic Stray Fields“ (A. Gaddi, CERN EDMS No 973739)
- Tests performed in CMS hall while magnet (4T) was on
- Below 50G:
    - no special precaution, standard workshop tools and procedures
- 50 to 150G:
    - more and more difficult, use of non-magnetic tools mandatory
- Over 150G:
    - real difficult work, dangerous above 200G, even difficult to handle non-magnetic tools



The „Flying Screw Nut Experiment“

- Screw Nut: 108g
- PCMAG Solenoid: 1T central field
- Measured fringe fields in 50-300G range
- Determined magnetic fore on nut

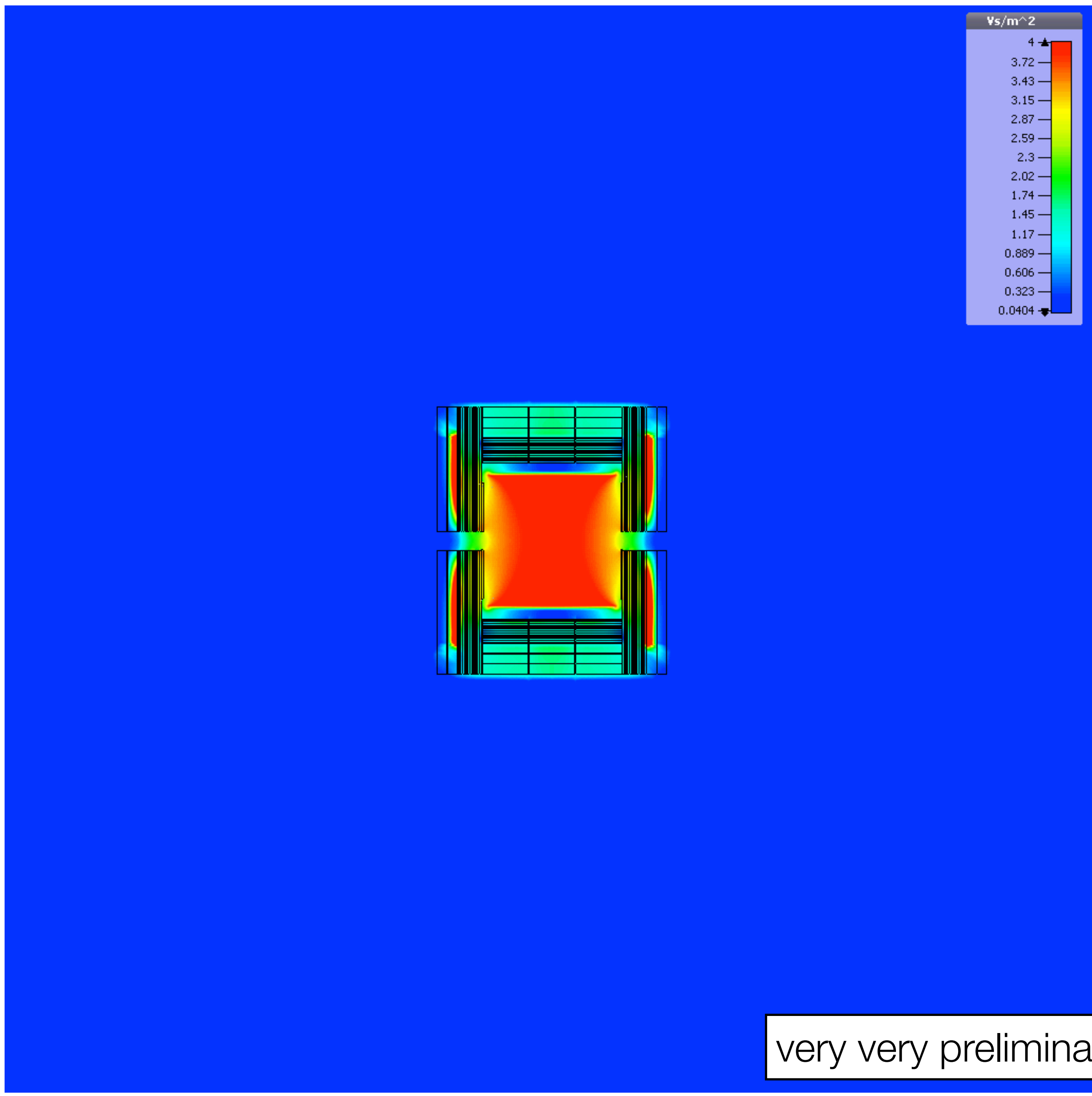


- Below 200G: magnetic force a few % of gravitational force
- Confirmation of CMS results: things get dangerous above 300G....

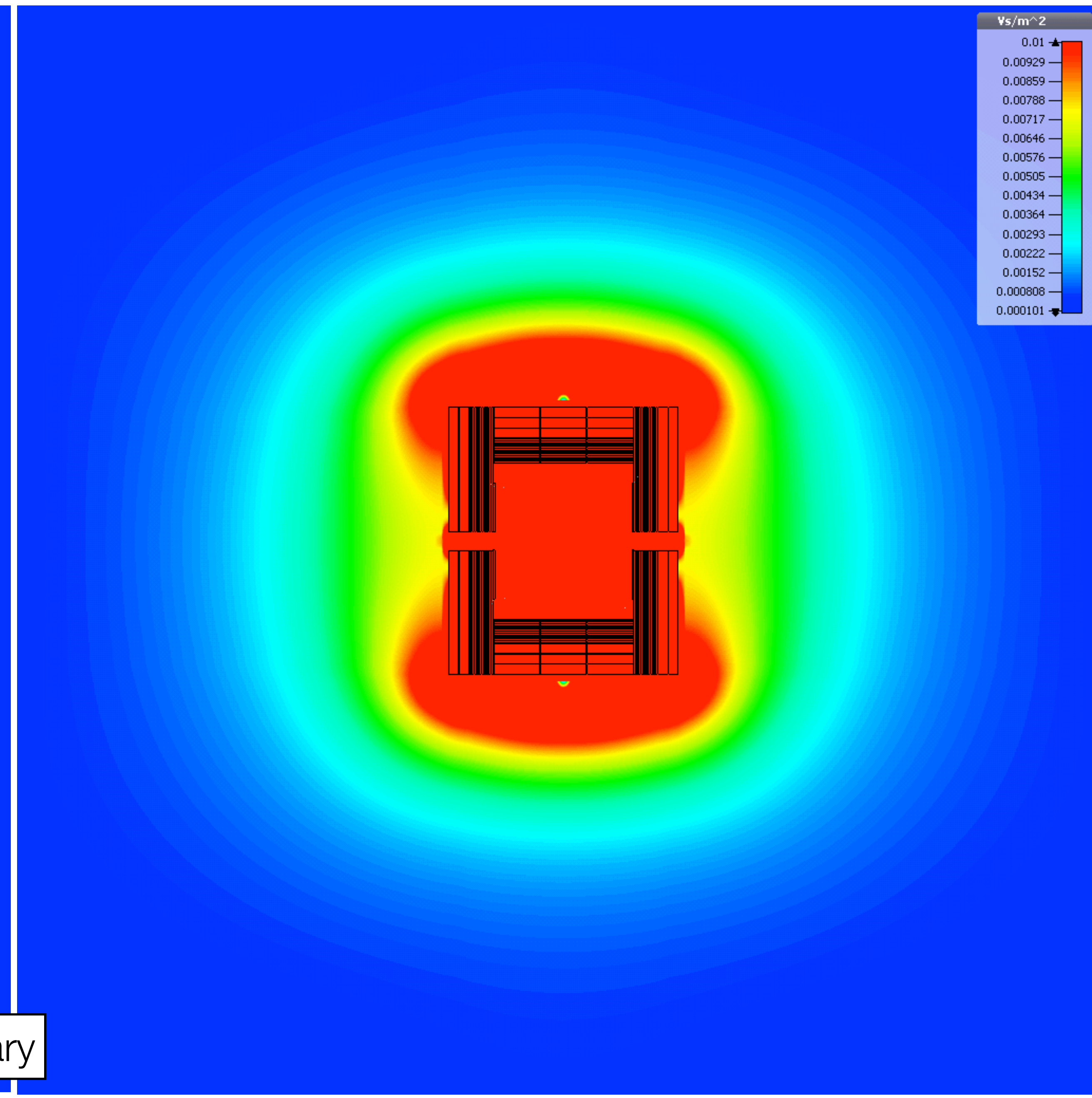
ILD Magnetic Field Simulations

- CST EM Studio

0 - 4 T

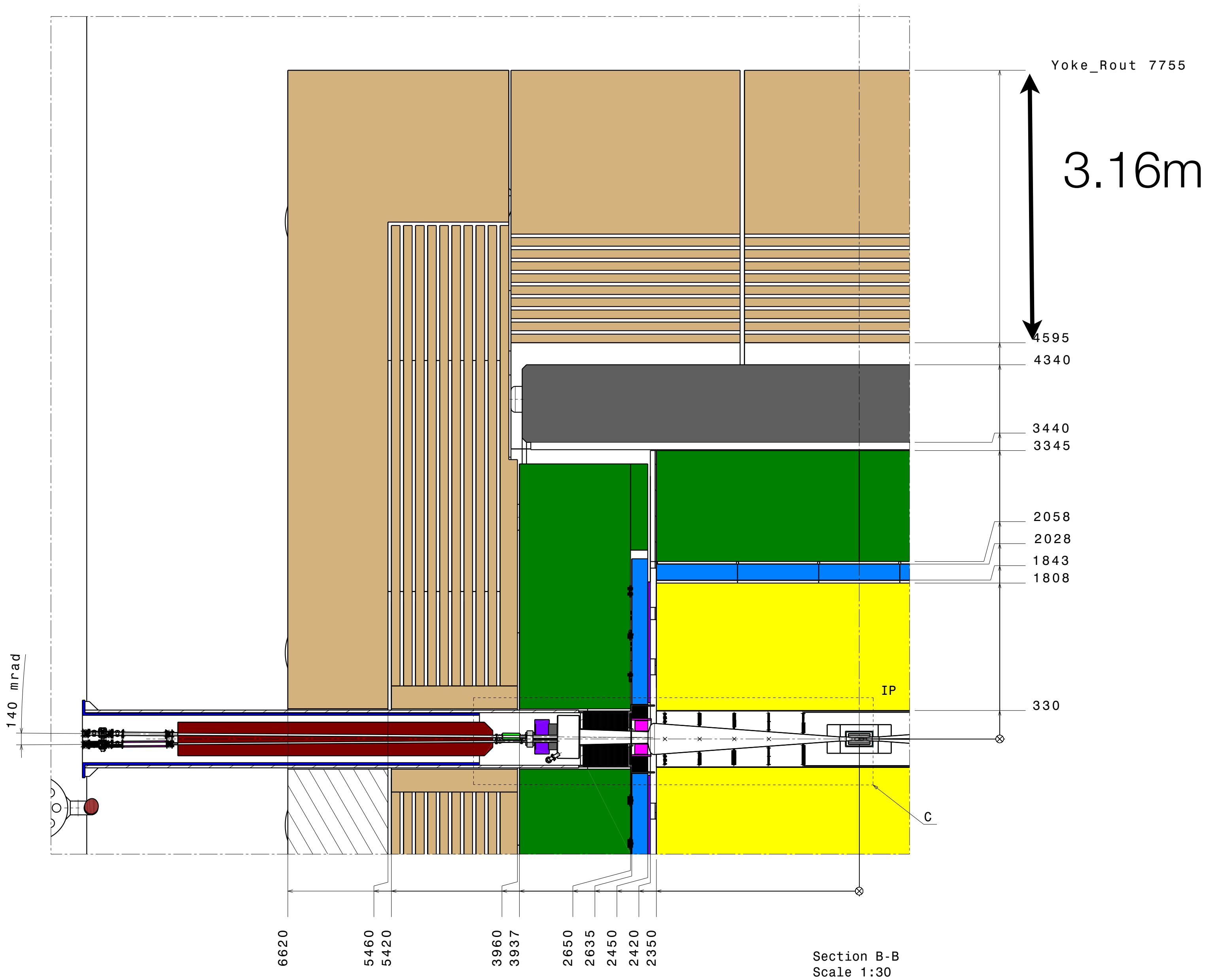


0 - 0.01 T

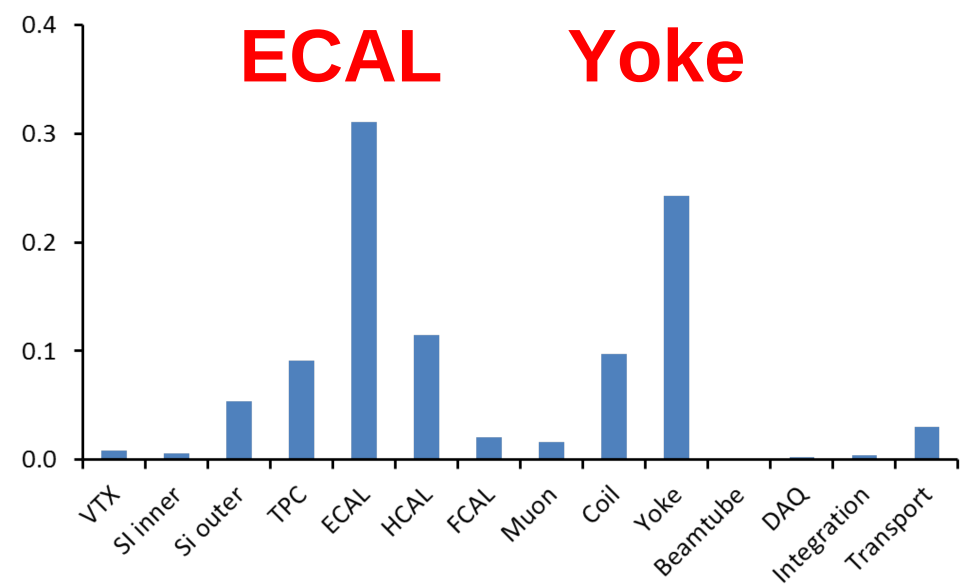


very very preliminary

ILD Iron Yoke

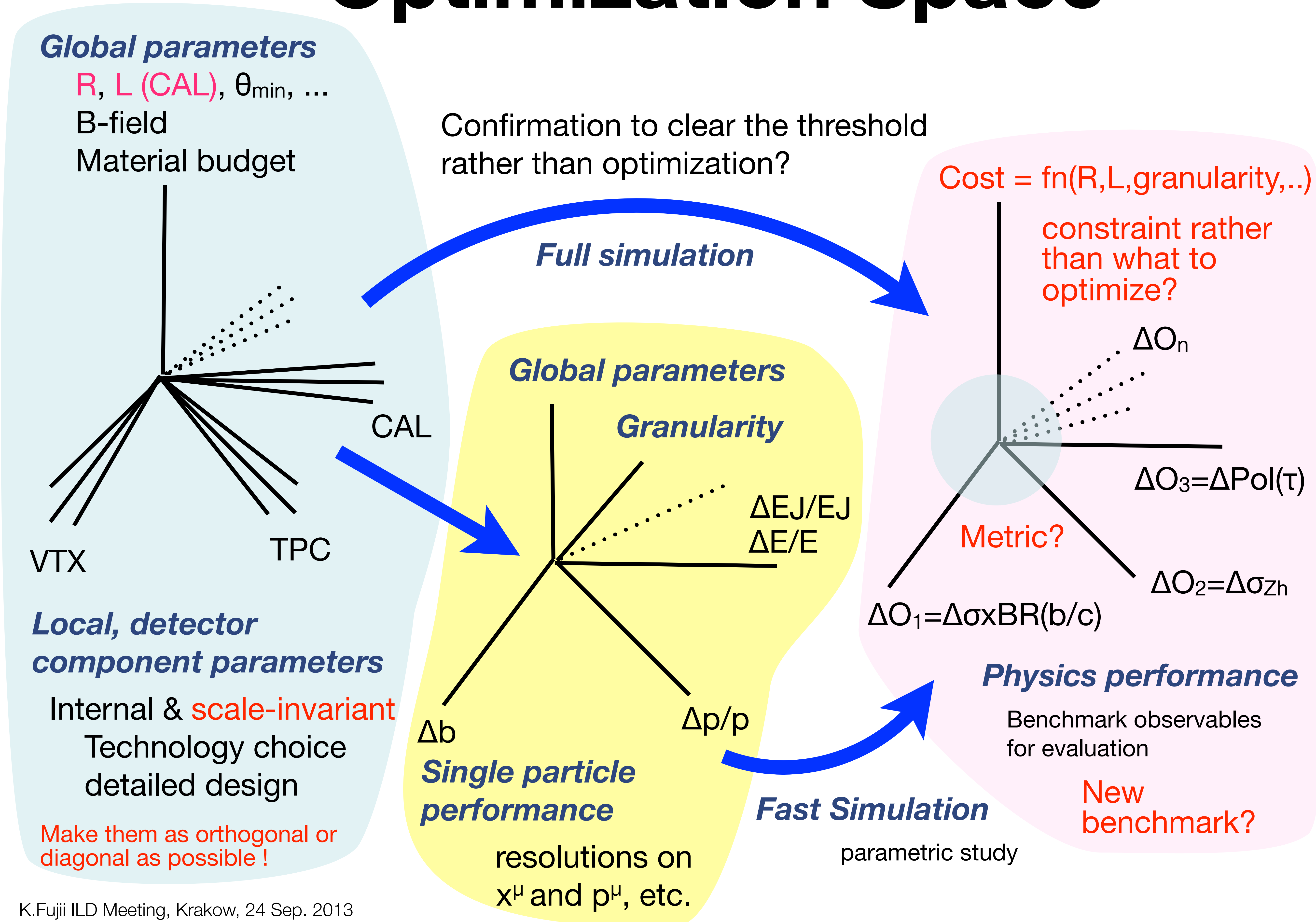


- Total cost of yoke:
  - 95 MILCU
  - 80 MILCU for steel and machining



- A reduction of the iron could save a lot

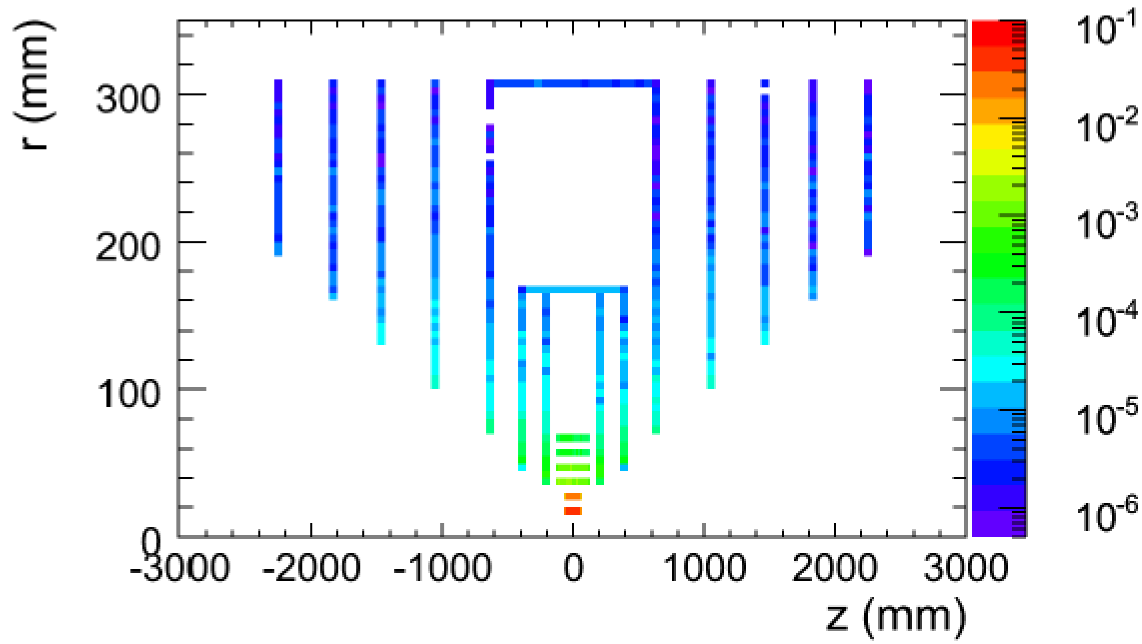
Optimization Space



Good pattern recognition

OCCUPANCY

Detector element	Hit density (hits/mm^2/BX)
VXD1	3.2×10^{-2}
VXD6	2.4×10^{-4}
SIT2	4.0×10^{-5}
FTD1	10^{-3} - 10^{-5}
FTD7	1.0×10^{-5}



FTD1 (ee→tt) average

$$1 \times 10^{-4}\frac{\text{hits}}{\text{mm}^2} + 1.6 \times 10^{-4}\frac{\text{hits}}{\text{mm}^2\text{BX}}.$$

FTD1 (ee→tt) peak

$$1 \times 10^{-2}\frac{\text{hits}}{\text{mm}^2} + 1.6 \times 10^{-3}\frac{\text{hits}}{\text{mm}^2\text{BX}}.$$

Pixels of 25*25 μm^2 in the most inner region allows robust pattern recognition for a readout time of 50 μsec (about 100 BX)

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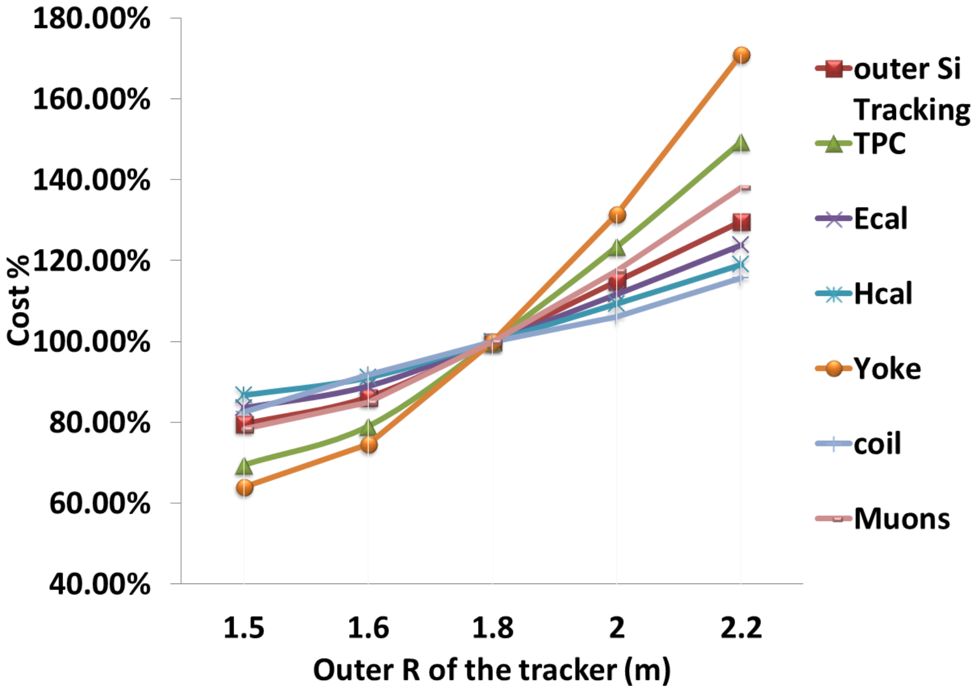
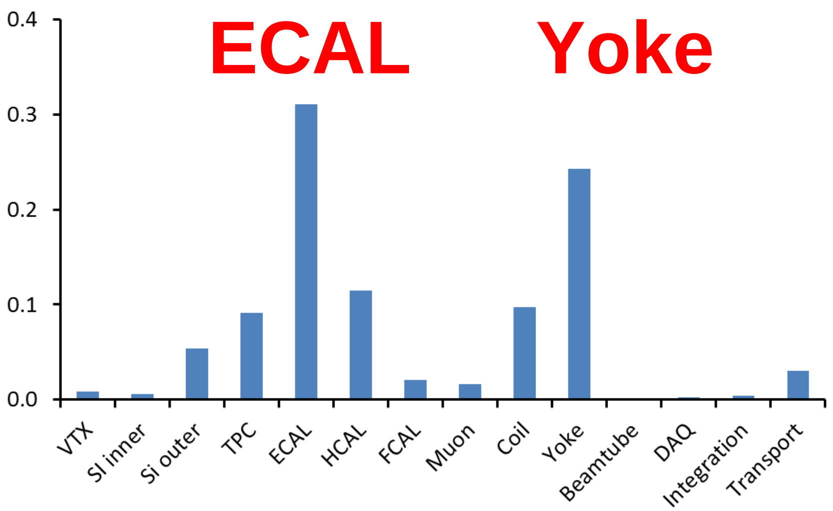
Costs

– One way to reduce overall costs is to reduce the size
– Reducing the size of ILD by 10% (to 1.6 m for the tracker) saves about 20% for the tracking, 15% for Ecal, 15% for Hcal, 15% for the coil, and 30% for the yoke.

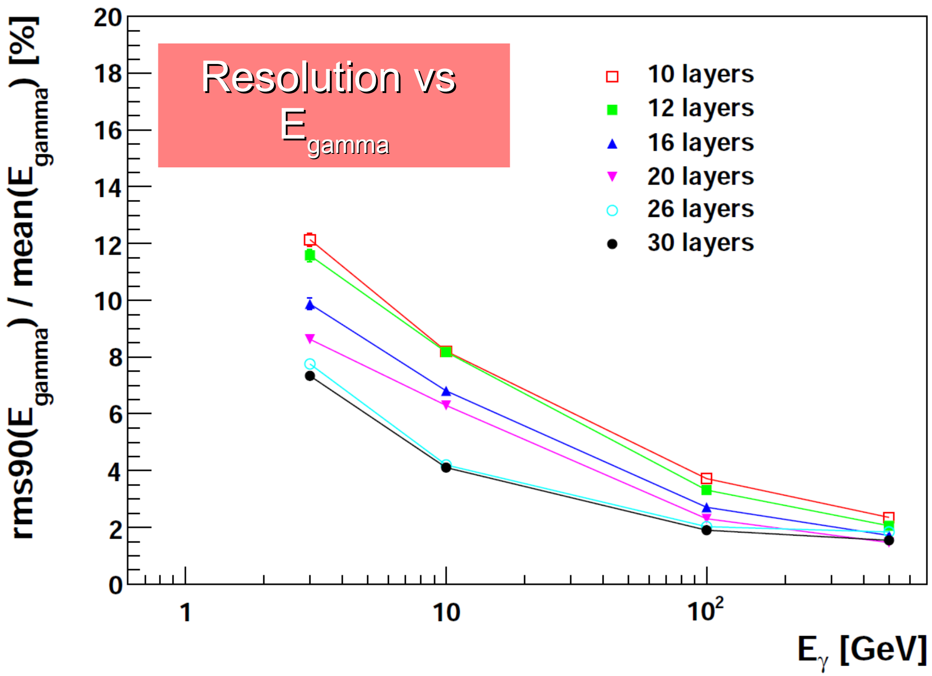
20% x 15% ≈ 3% for the tracking,
15% x 30% ≈ 4.5% for the Ecal,
15% x 10% ≈ 1.5% for the Hcal,
15% x 10% ≈ 1.5% for the coil, and
30% x 25% ≈ 7.5 % for the yoke.

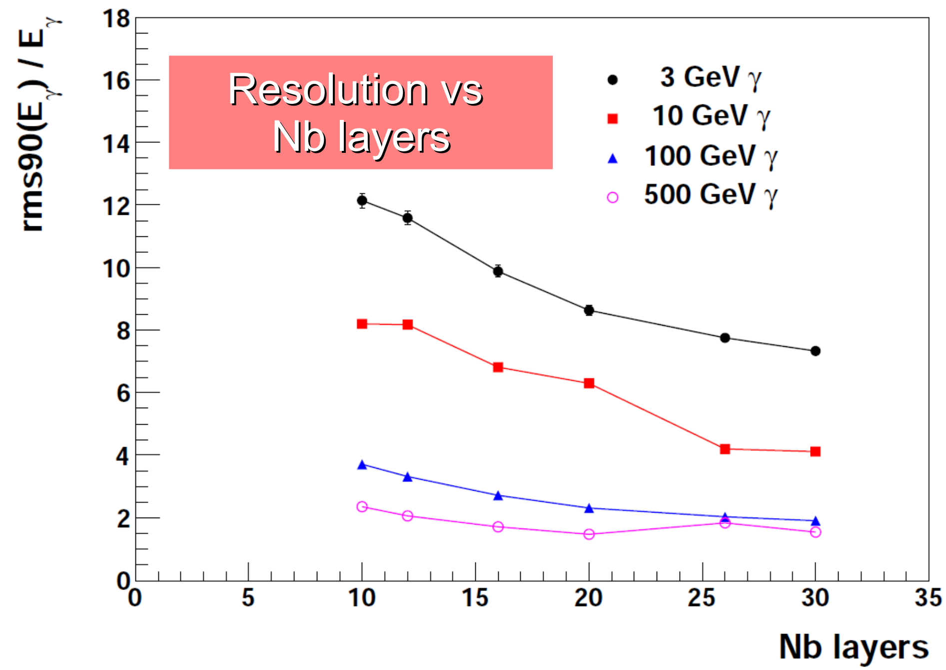
about 100M€ altogether





Photon energy resolution



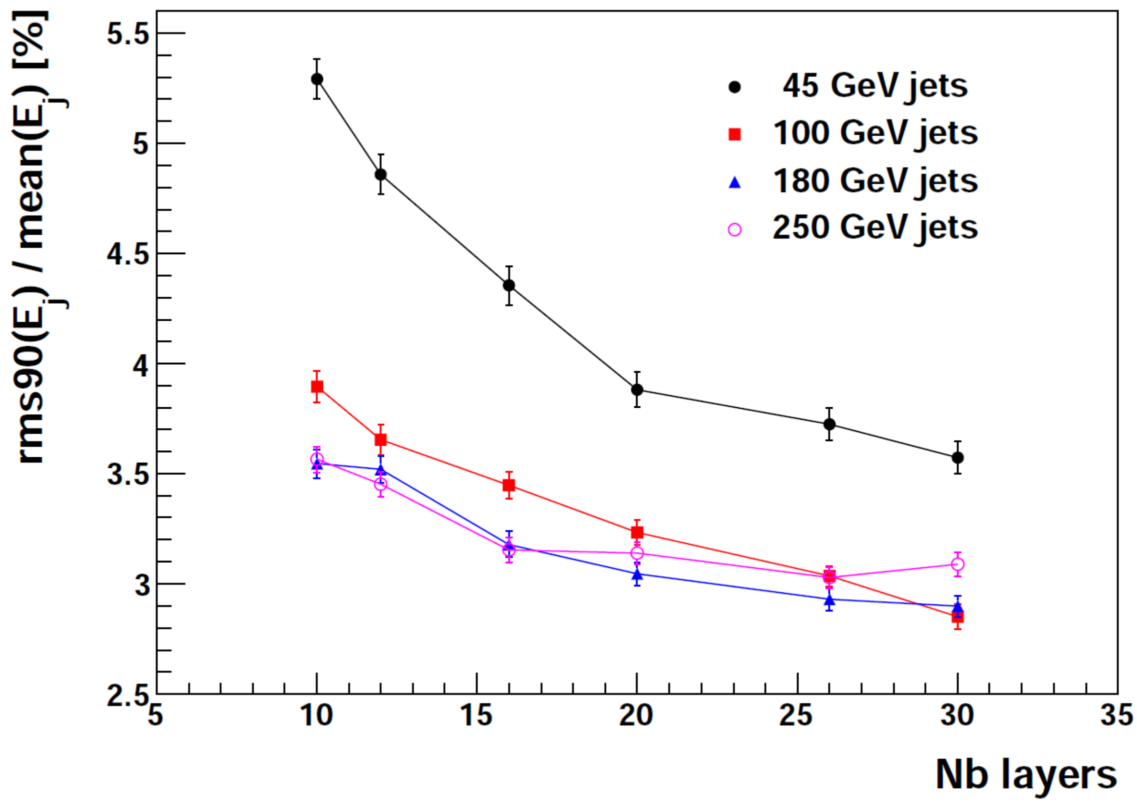


- Photon energy resolution as a function of E_{photon} (left) and N-layers (right)
- Slight degradation observed going from 30 to 20 layers (≤ 9%)
  and quite significant with smaller number of layers (16 downto 10)

Jet energy resolution

- Single JER as a function of number of layers for 91, 200, 360, 500 GeV Z → u/d/s.

A cut |cos(theta_jet)| < 0.7 is applied to avoid the Barrel/Endcap overlap area

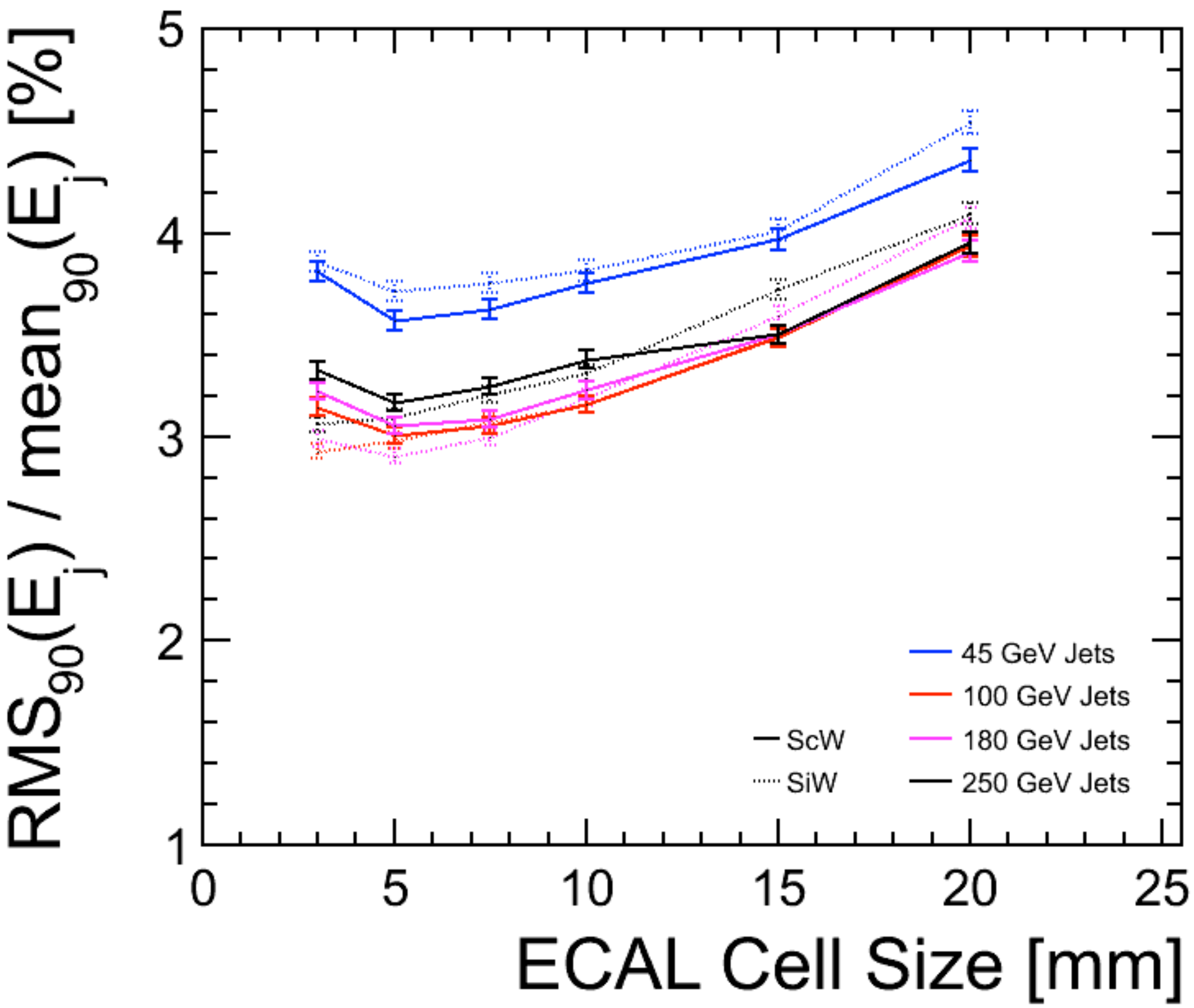


The error bars are taken from a fit.

- 9% of degradation when going from 30 to 20 layers for the worse case, 45 GeV
- effect is less important for higher energies

$$\frac{\mathrm{rms}_{90}(E_j)}{E_j} = \frac{\mathrm{rms}_{90}(E_{jj})}{E_{jj}}\sqrt{2}$$

Standard Pandora PFA

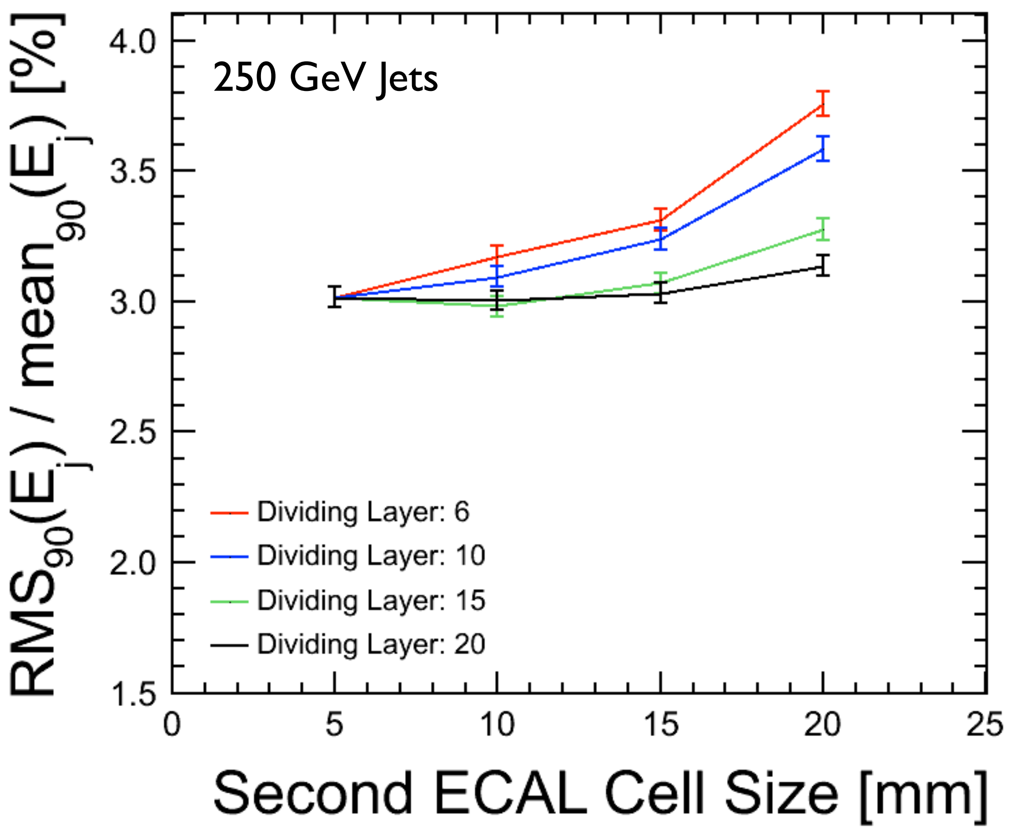


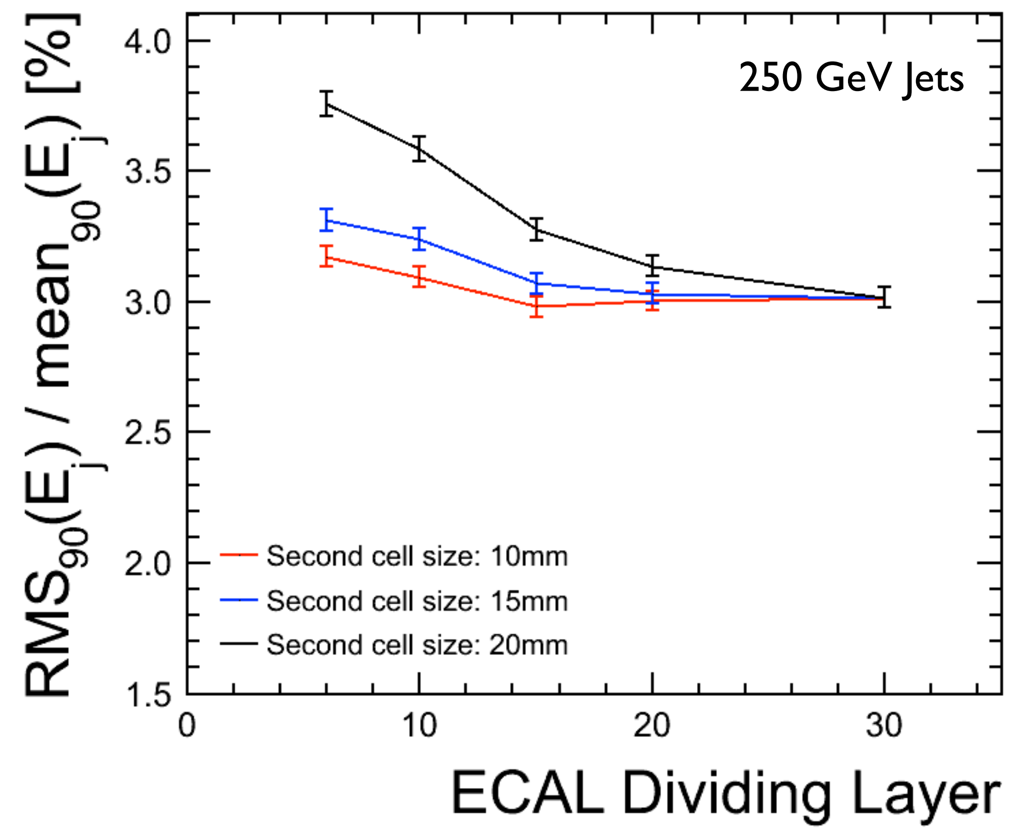
Resolutions for 250 GeV jets:

	3 mm	5 mm	7.5 mm	10 mm	15 mm	20 mm
SiW	3.06%	3.10%	3.21%	3.31%	3.72%	4.09%
ScW	3.33%	3.17%	3.25%	3.38%	3.51%	3.95%

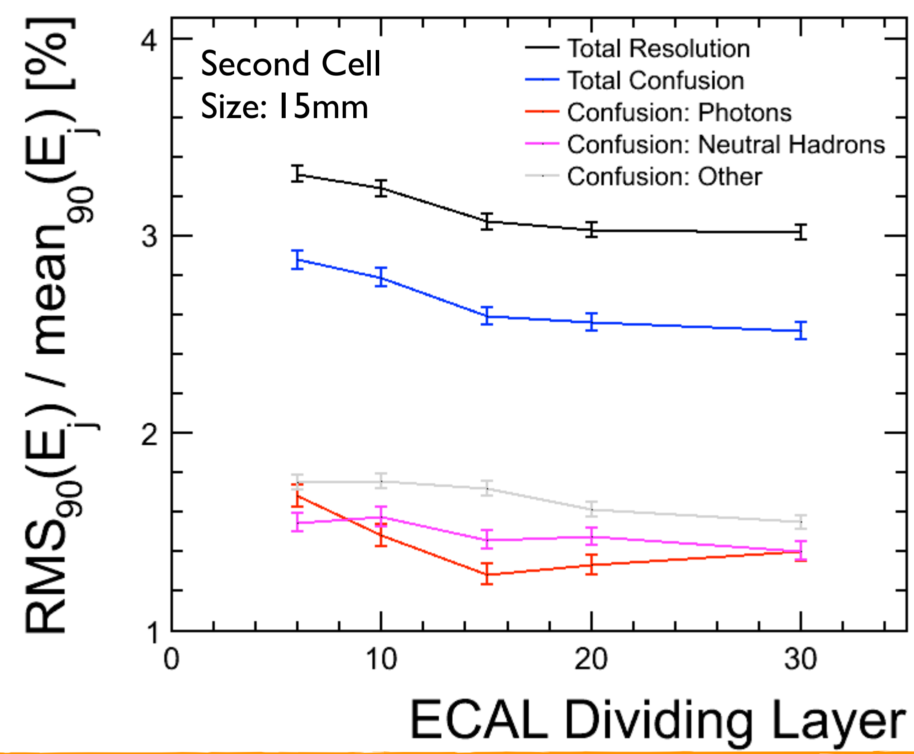
- Begin by examining jet energy resolutions achieved using standard Pandora algs.
- Recall that these algs only optimised for 5x5mm^2 cells; improvements possible.
- However, achieve 3.5% resolution goal, for 100-250GeV jets, up to ~15x15mm^2.
- SiW/ScW performance similar, except at high jet energies with 3x3mm^2 cells.
- Now vary choice of Pandora algs...

Two Granularity Regions





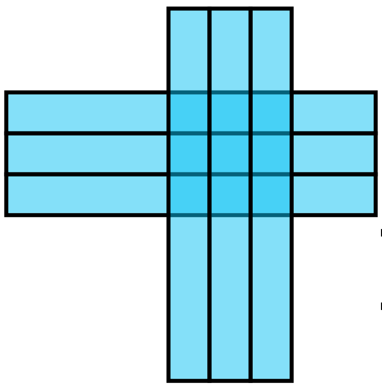
- Fix jet energy at 250 GeV and examine resolutions obtained with newly-trained standalone photon alg.
- Plot resolution vs. second cell size and vs. dividing layer. Note: second cell size of 5mm and dividing layer of 30 both correspond to a uniform 5x5mm^2 ECAL.
- Second cell size of 15mm and dividing layer of 10 is most aggressive configuration for which photon confusion remains less than neutral hadron confusion.



Hybrid ECAL Configuration

Sc layer

45mmx5mm strips

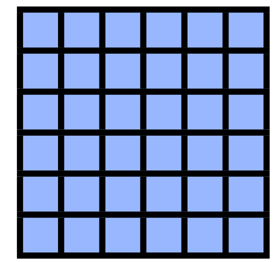


orthogonal

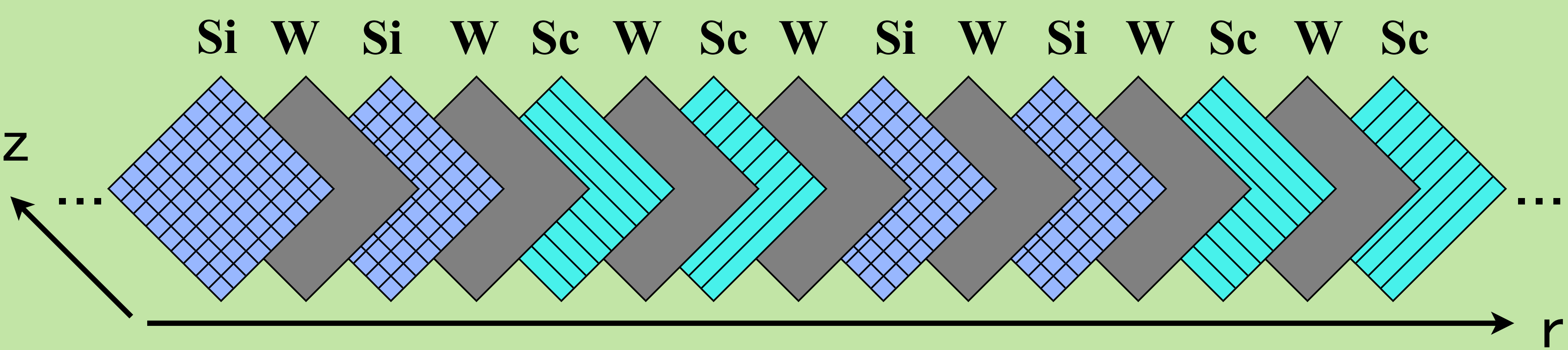
- 5mmx5mm spacial resolution
- possibility of ghost

Si layer

5mmx5mm cells



The configration of Hybrid ECAL

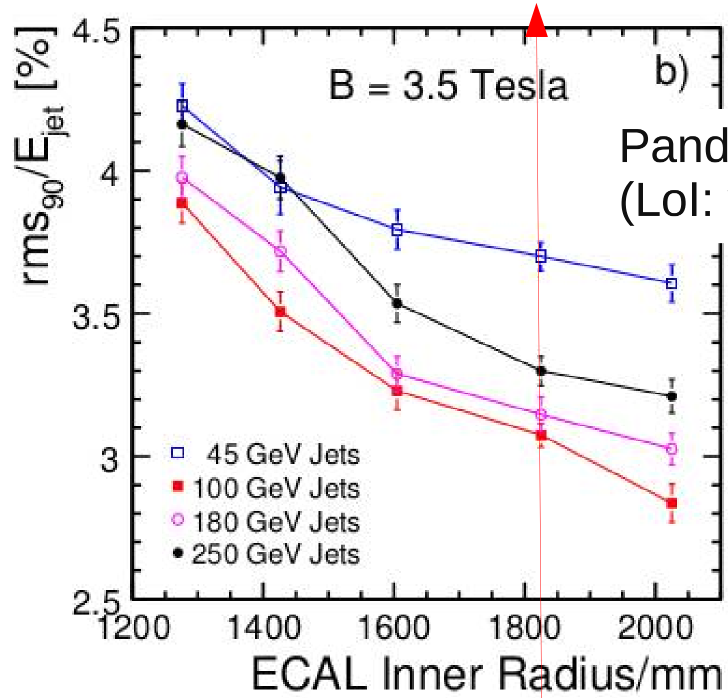


detector optimisation

clear that

“bigger is better”

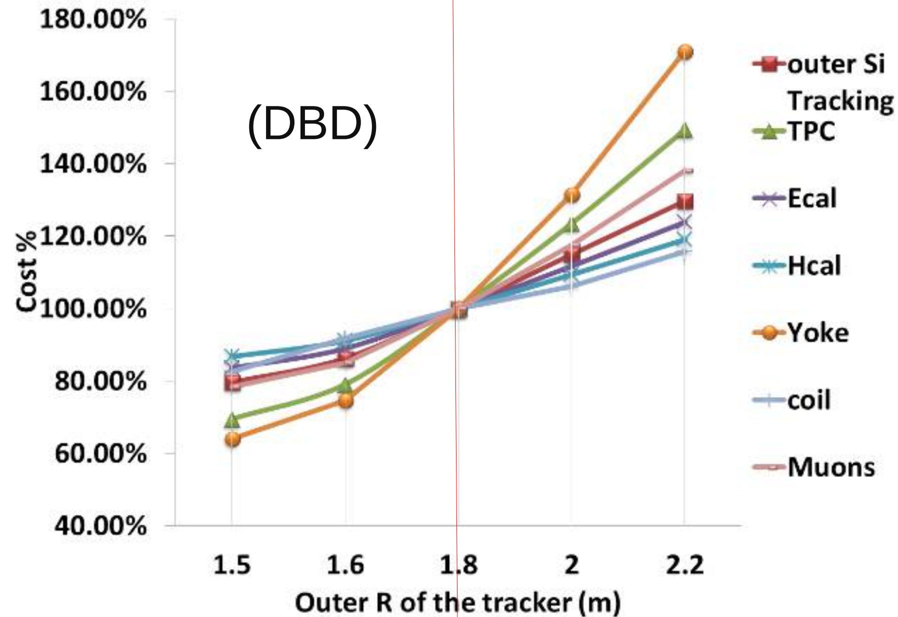
ILD is now here



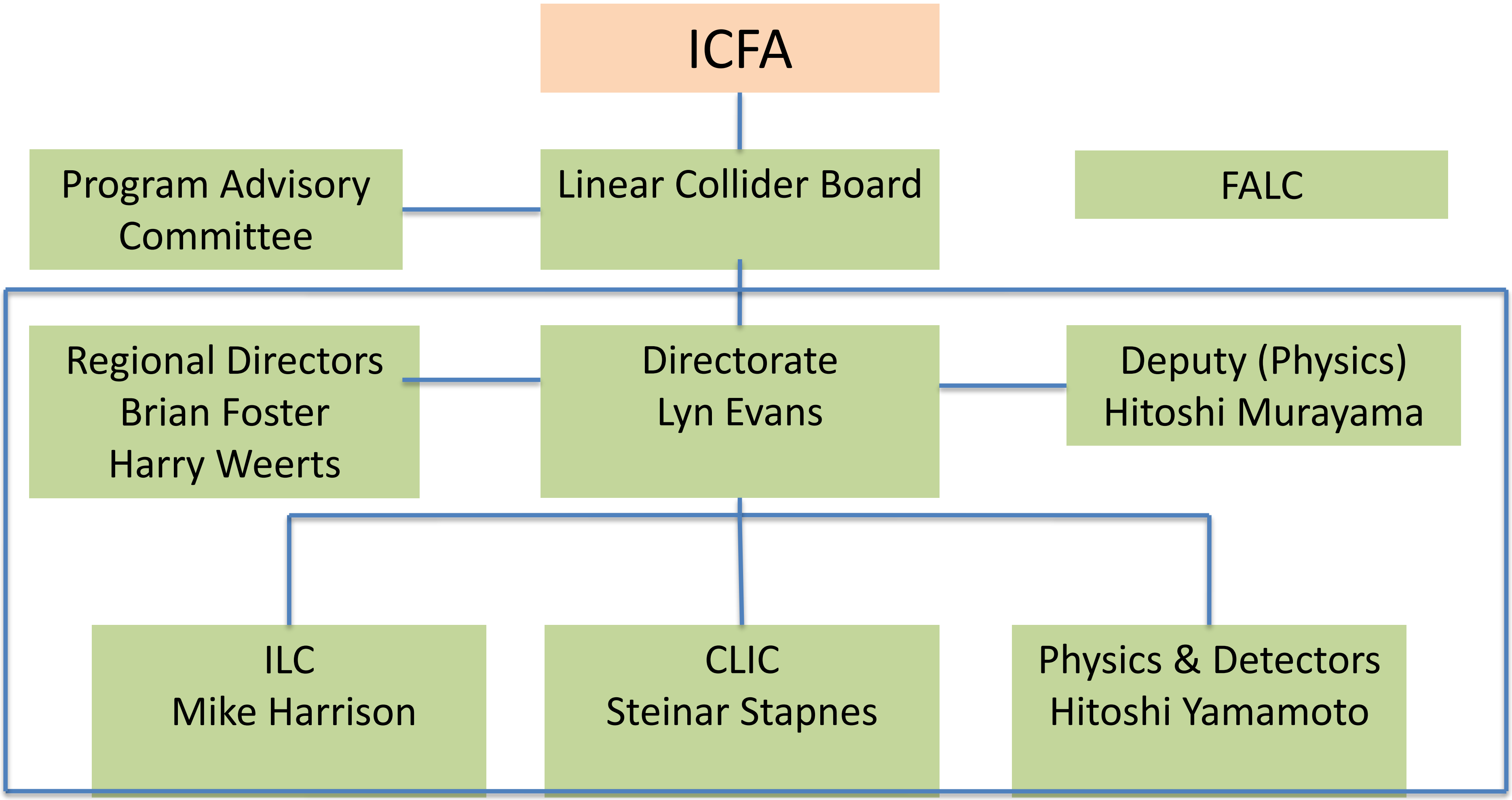
PandoraPFA
(LoI: worth repeating study)

“smaller is cheaper”

(DBD)



Organization



ILD post DBD

What are the next steps:

- We move towards a linear collider project (Japan)
- We need to be prepared so that ILD can come forward ones this is required
- We need to continuously improve and keep out design up-to-date
- Short term: make sure ILD participates properly in ongoing strategy discussions around the world (Snowmass, other countries and regions)

- Results from the DBD

  - Re-optimization in performance / cost space
  - Adapt to the physics landscape post Higgs-discovery
  - Understand hardware / technologies better

ILD structure

From concept towards collaboration

2013 → 20XX?

Goals of the transition phase organization:

- Develop enough structure to push ILD forward
- Make ILD attractive enough that it will be one of the two experiments at the ILC
- Make ILD attractive enough that new groups will want to join as the ILC moves towards reality

We need

- transparent, simple structures
- Adequate representation so that we can function as a community
- Enough support to maintain stably the central tasks

ILD members

ILD membership is on an institutional basis.

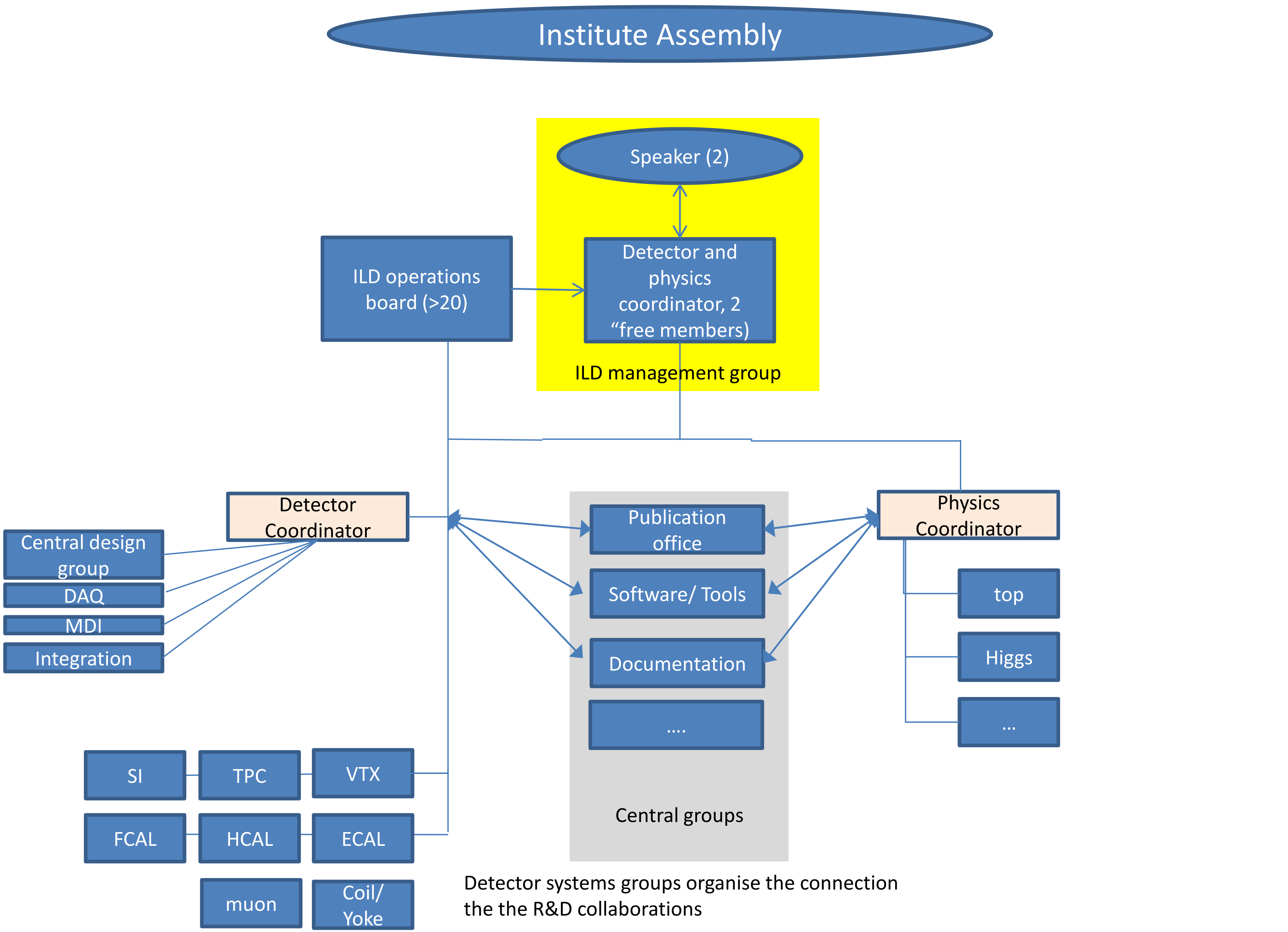
There is no private ILD membership

Each ILD member institute has a seat and one vote in the institute assembly

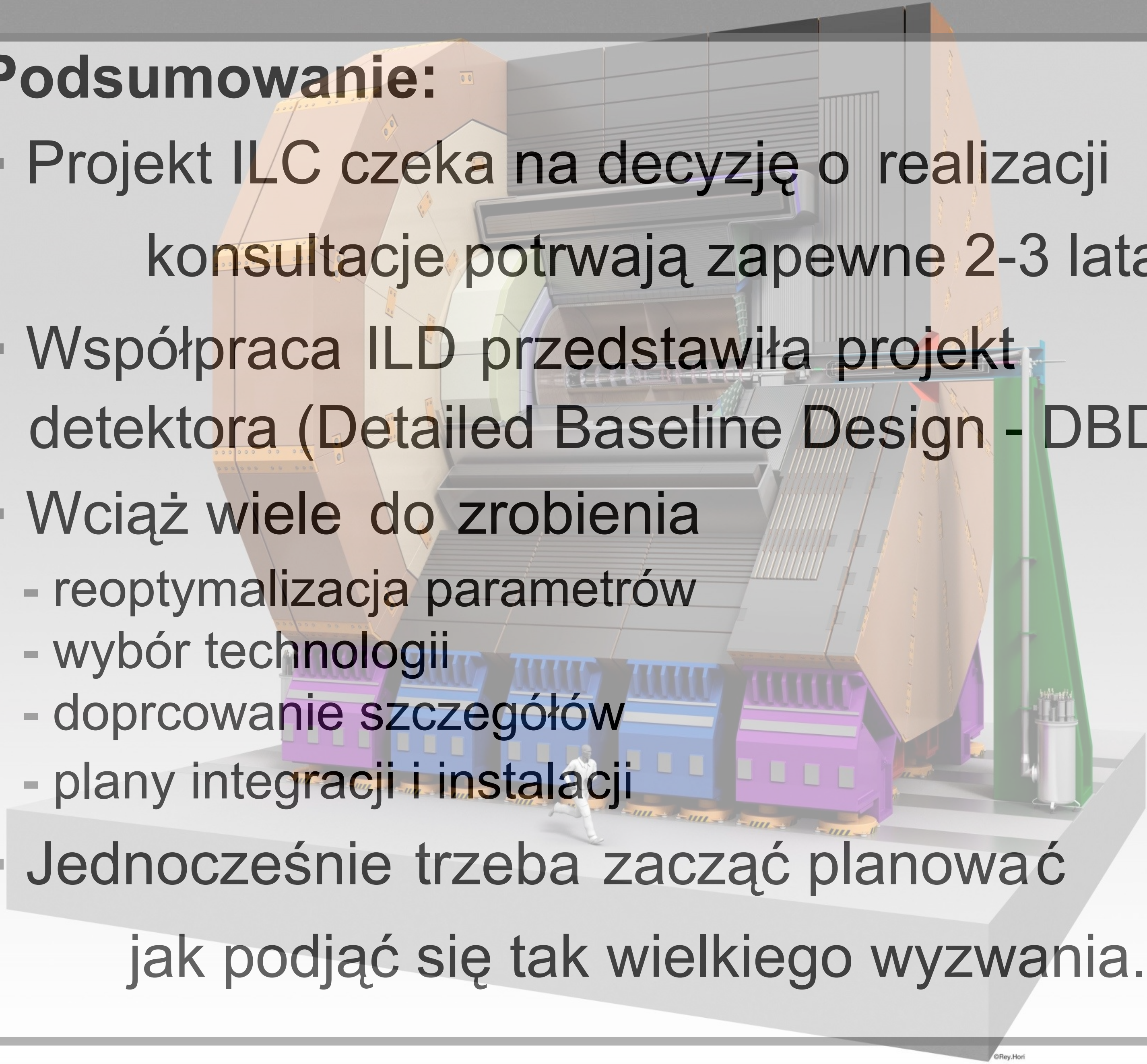
Joining or leaving ILD is possible at any time

The management of ILD will maintain

- a list of ILD member institutes
- a list of ILD members at the institutes as far as they have been designated such by the institute contact
- A list of commitments / central services agreed to by member institutes



Institute Assembly
Speaker (2)
Detector and physics coordinator, 2 "free members)
ILD operations board (>20)
ILD management group
Detector Coordinator
Central design group
DAQ
MDI
Integration
Publication office
Software/ Tools
Documentation
....
Central groups
Physics Coordinator
top
Higgs
...
SI
TPC
VTX
FCAL
HCAL
ECAL
muon
Coil/ Yoke
Detector systems groups organise the connection the the R&D collaborations



Podsumowanie:

- Projekt ILC czeka na decyzję o realizacji

  konsultacje potrwają zapewne 2-3 lata

- Współpraca ILD przedstawiła projekt detektora (Detailed Baseline Design - DBD)

- Wciąż wiele do zrobienia
  - reoptymalizacja parametrów
  - wybór technologii
  - doprcowanie szczegółów
  - plany integracji i instalacji

- Jednocześnie trzeba zacząć planować

  jak podjąć się tak wielkiego wyzwania...