Refondation des Labos
CSNSM - IMNC - IPNO - LAL - LPT

Instrumentation ILC

Roman Pöschl

Refondation labos de la vallée
Journée Thématique Grands Accélérateurs
Mars 2018

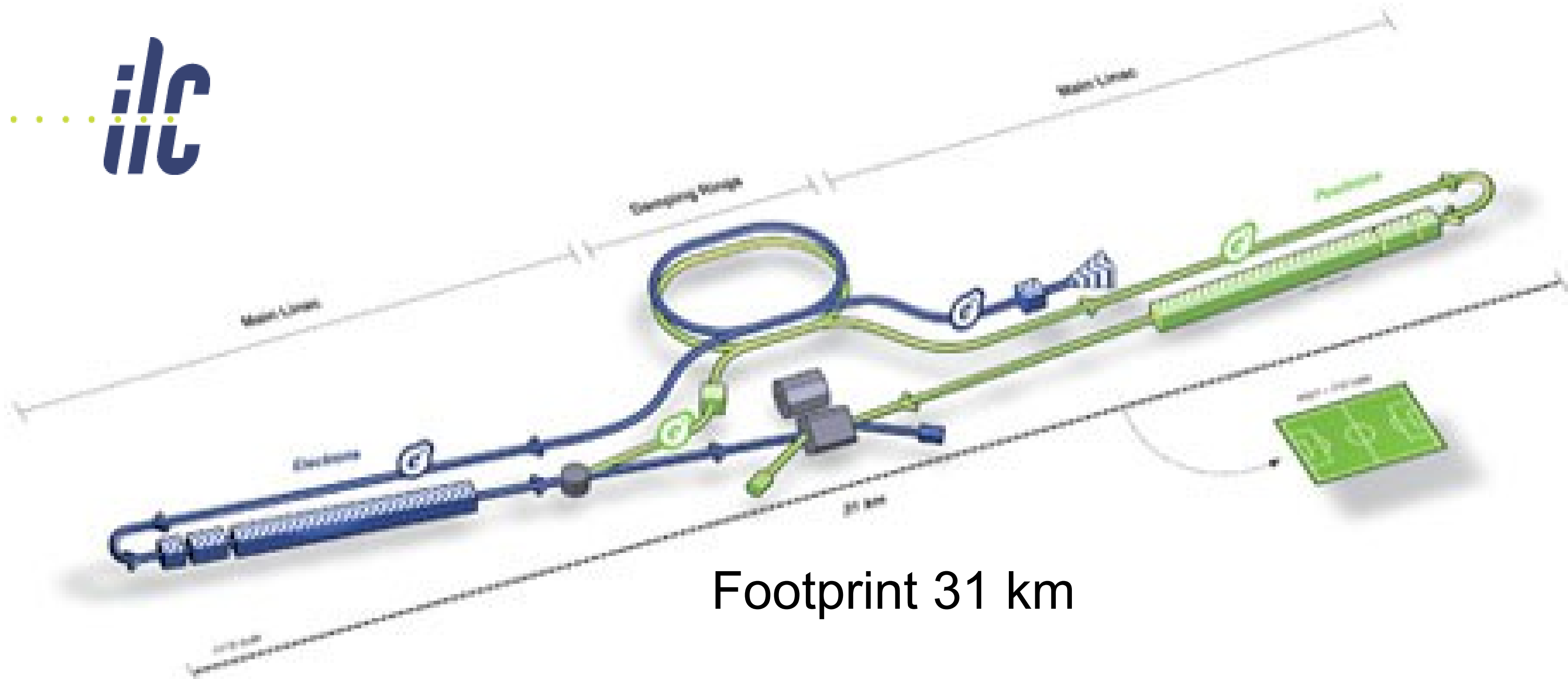
Outline of talk

- Chapter 1: Introduction

- Chapter 2: R&D for SiW electromagnetic
  Calorimeter and ILD Integration

- Chapter 3: Outlook

Linear Electron-Positron Colliders Projects - ILC



Footprint 31 km

- CM-Energy: 100 - 1000 GeV, 500 GeV baseline in TDR
  Superconducting cavities
- Electron (and positron) polarisation
- TDR in 2013 + DBD for detectors
- **ILC would be staged and start at 250 GeV with smaller footprint**
- ILC benefits from construction of European XFEL
  - first light on May 3rd 2017)

Projets CLIC, CEPC, FCC-ee -> voir annexe

ILC Group at LAL

Refondation des Labos
CSNSM - IMNC - IPNO - LAL - LPT

Responsible
Roman Pöschl

Physics studies

D. Zerwas, F. Richard
E. Kou, F. LeDiberder,
S. Bilokin, R.P., A. Irles

Detector R&D

- Tests Ecal : R.P., D. Zerwas, Adrian Irles

  Digital Electronics Ecal (since 2017):
  Dominique Breton (SERDI)
  Jihane Maalmi (SERDI)
  Jimmy Jeglot (SERDI)

  Integration Ecal:
  J. Bonis (SDTM),
  A. Thiebault (SDTM)
  A. Gallas

  Integration ILD:
  C. Bourgeois (SDTM),
  A. Gonnin (SDTM)
  B. Mercier (SDTM)
  C. Prevost (SDTM)

- **Algorithms and beam Test analysis**
- S. Bilokin, R.P., A Irles
- B Kegl

Formation:
5 thesis since 2006
4 young postdocs
~15 internships since 2006

Collaborations and funding

ILC group of LAL is member of:

CALICE ILD

Funding:

Base Level

CNRS IN2P3 Les deux infinis

3rd party funding

HIGHTEC P2IO Physique des 2 Infinis et des Origines CAMPUS FRANCE campusfrance.org PRESTIGE POSTDOCTORAL RESEARCH FELLOWSHIPS IN FRANCE A MARIE CURIE FELLOWSHIP PROGRAMME

AIDA 2020 E-JADE FRANCE-JAPAN PARTICLE PHYSICS TOSHIKO YUASA LAB. FKPPL

3. R&D for SiW electromagnetic Calorimeter and ILD Integration

Detector requirements

Track momentum: $\sigma_{1/p} < 5 \times 10^{-5}$/GeV (1/10 x LEP)

(e.g. Measurement of Z boson mass in Higgs Recoil)

Impact parameter: $\sigma_{d0} < [5 \oplus 10/(p[GeV]\sin^{3/2}\theta)]$ μm(1/3 x SLD)

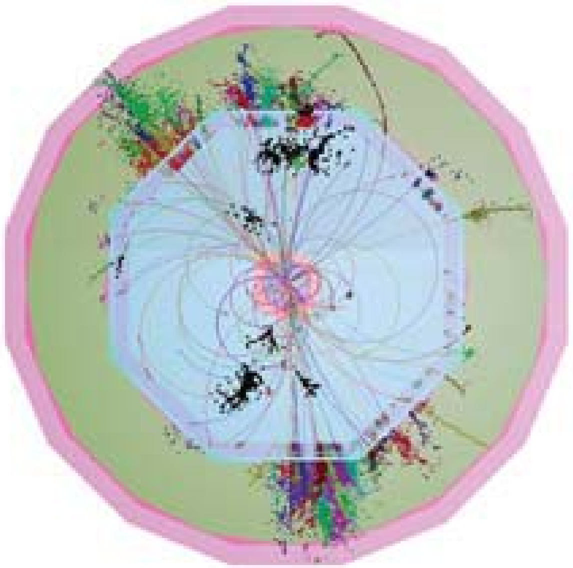
(Quark tagging c/b)

Jet energy resolution : $dE/E = 0.3/(E(GeV))^{1/2}$ (1/2 x LEP)

(W/Z masses with jets)

Hermeticity : θ_{min} = 5 mrad

(for events with missing energy e.g. SUSY)



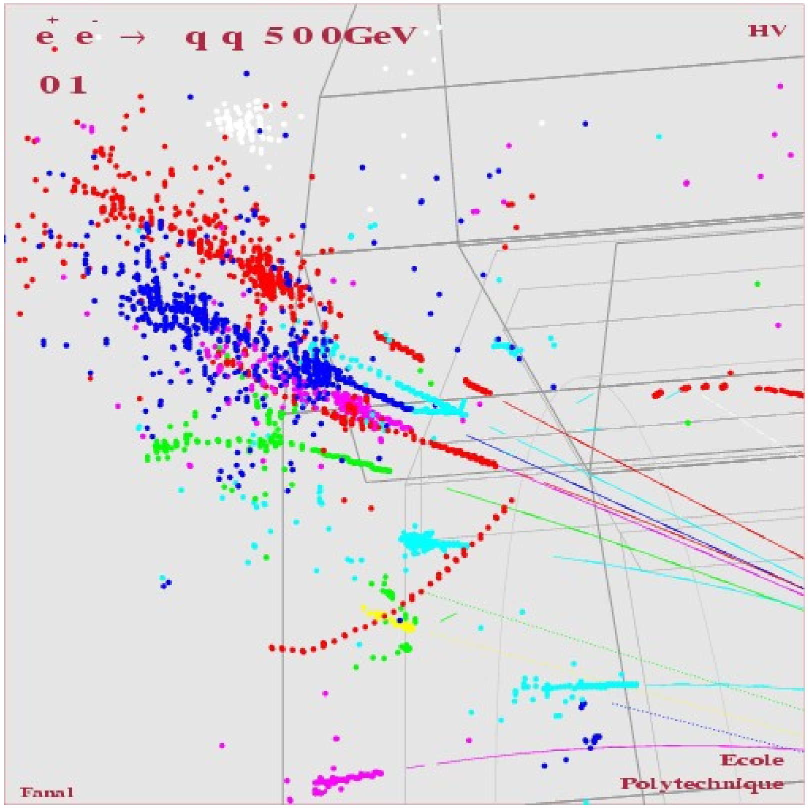
Final state will comprise events with a large number of charged tracks and jets(6+)

- High granularity
- Excellent momentum measurement
- High separation power for particles

- Particle Flow Detectors

Confusion term

- Base measurement as much as possible on measurement of charged particles in tracking devices
- Separate of signals by charged and neutral particles in calorimeter



- Complicated topology by (hadronic) showers
- Overlap between showers compromises correct assignment of calo hits

 Confusion Term

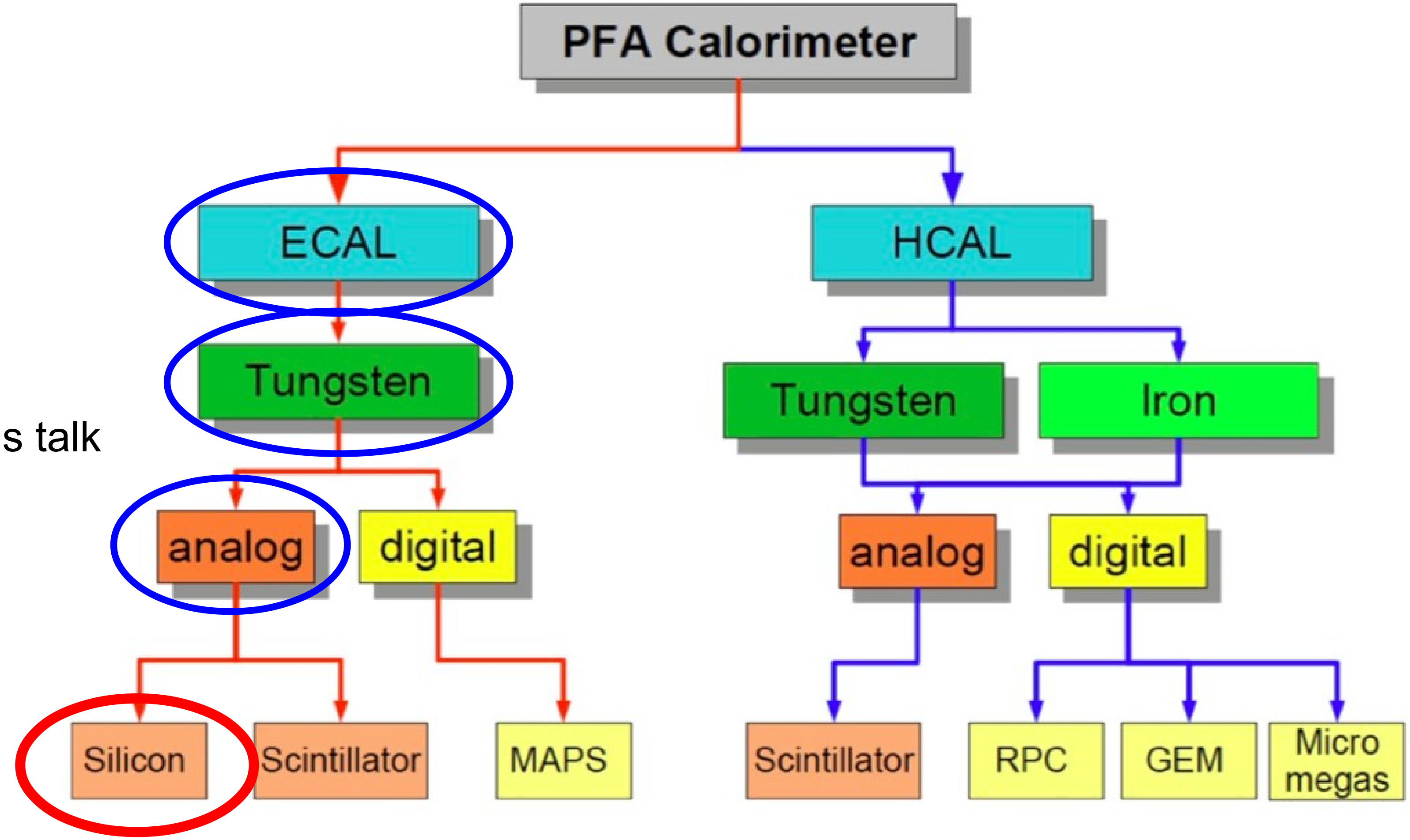
Need to minimize the confusion term as much as possible !!!

Particle separation needs highly granular calorimeters

Technologies for Particle Flow Calos

Collaboration since 2003 – World leading R&D collaboration

This talk



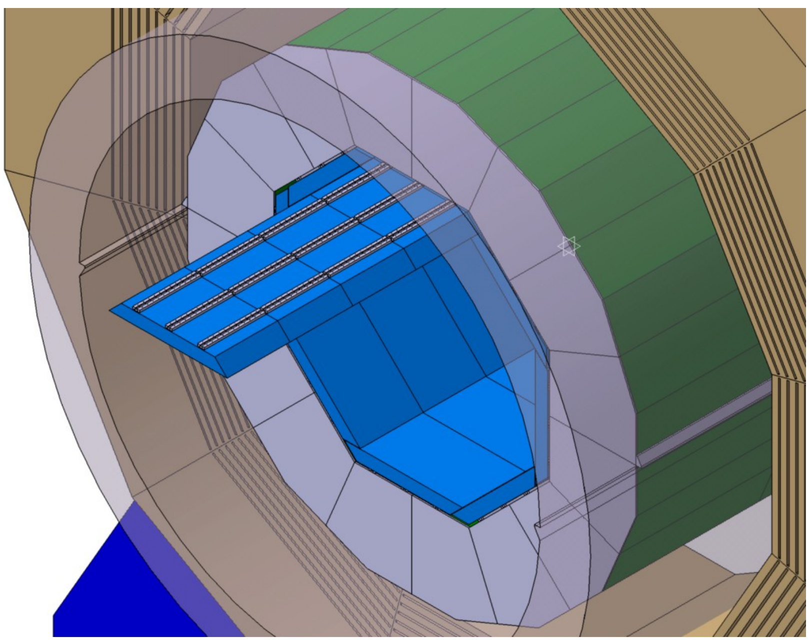
French institutes among founding members
R.P.: Technical Coordinator 2009 - 2015

SiW Ecal for a future LC

- SiW ECAL is baseline for future LC detectors

→ Optimized for Particle Flow Algorithm

Jet energy resolution 3-4%, Excellent photon-hadron separation
Remark: New kid on the block – Timing



The SiW ECAL in the ILD Detector

Basic Requirements:

- Extreme high granularity
- Compact and hermetic (inside magnetic coil)

Basic Choices:

- Tungsten as absorber material
  X_0=3.5mm, R_M=9mm, λ_I=96mm
  Narrow showers
  Assures compact design

- Silicon as active material
  Support compact design
  Allows for pixelisation
  Robust technology
  Excellent signal/noise ratio: ~10

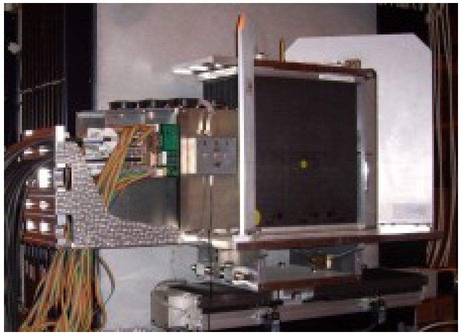
Partners:

SiW ECAL for a future LC

Physics Prototype

Proof of principle

2003 - 2011



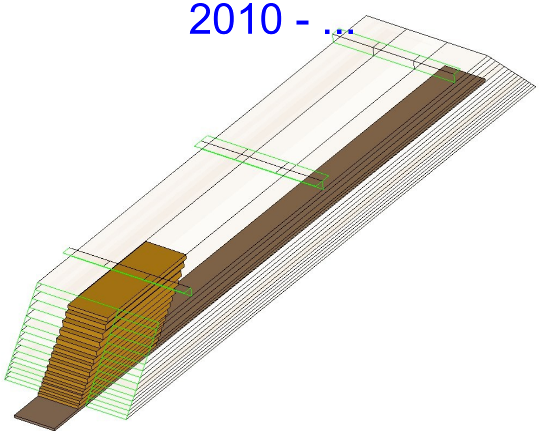
Number of channels : 9720

Weight : ~ 200 Kg

Technological Prototype

Engineering challenges

2010 - ...

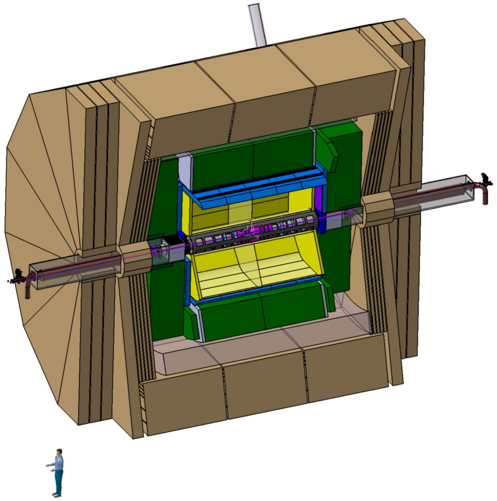


Number of channels :

up to 45360

Weight : ~ 700 Kg

LC detector



ECAL :

Channels : ~100 10^6

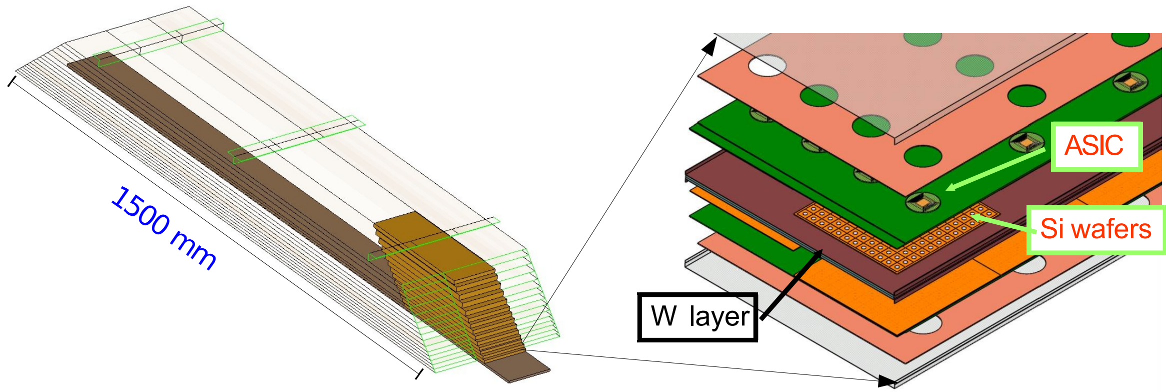
Total Weight : ~130 t

CALICE/LC R&D inspired upgrades LHC detectors (CMS, ATLAS and since recently also LHCb)

SiW ECAL – Technological Prototype

- **Technological and industrial solutions for the final detector**
- R&D start start: 2010

  First beam tests : 2012 - 2013



Total height few mm

- Realistic dimensions
- Integrated front end electronic

  No drawback for precision measurements (NIM A (2011) 97)
- Small power consumption (Power pulsed electronics)

  NIM A 778 (2015) 78 and PhD thesis Jérémy Rouëné

PCB R&D

Two options:

BGA packaged chips

BGA version is conservative approach:

test of chips before soldering ;

Space for external decoupling capacitors

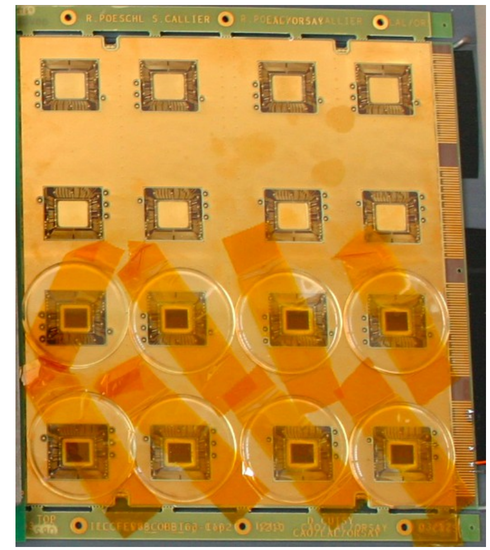
Symmetric stacking will improve flatness,

good for wafer gluing

Optimal shielding of signal traces

Solution for technological prototype

PCB with naked die (Chip-On-Board)



- Thin board (~1.2mm)
  => maximal channel density
  Collaboration LAL, OMEGA, SKKU (Korea)

- Tests since 2015
  => Intensive test programme
  e.g. Noise and cross talk

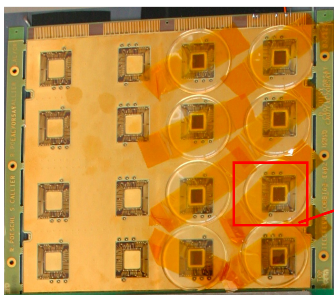
- New production expected Nov. 2017
  Validation during 2018

SiW ECAL – Long layer

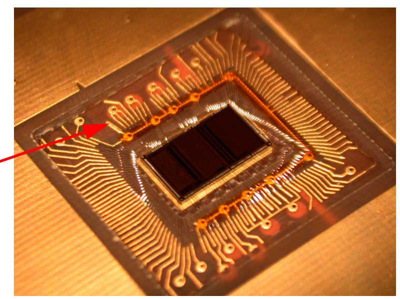
A layer is composed of several short ASUs:

- A.S.U. : Active Sensors Units

ASIC+PCB+SiWafer
=ASU, 18x18cm²



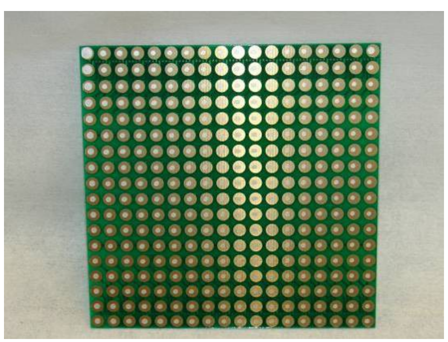
Wire Bonding or BGA

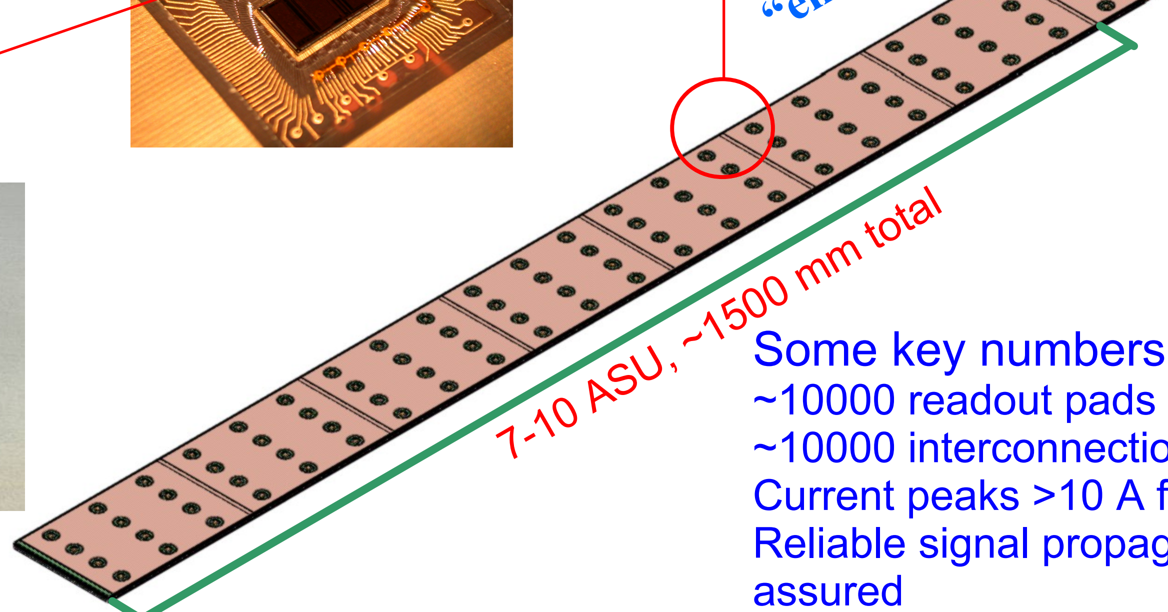


Interconnection
with
Flat flexible cable

PCB
is glued
onto
SiWafers

using a gluing
robot





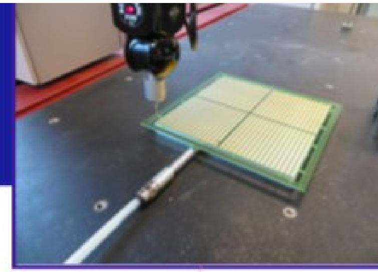
Some key numbers:
~10000 readout pads
~10000 interconnections
Current peaks >10 A for 2ms
Reliable signal propagation to be assured
Further details in backup

Successful realisation of a long layer is maybe one of the most challenging R&D projects in worldwide detector R&D

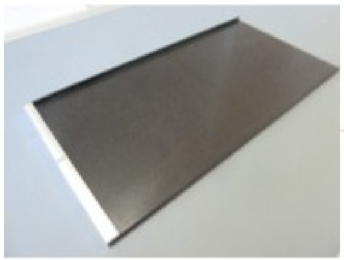
Assembly chain - Overview

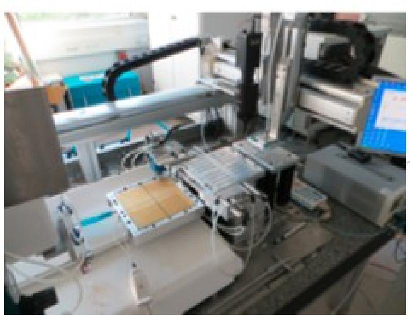
Full assembly chain

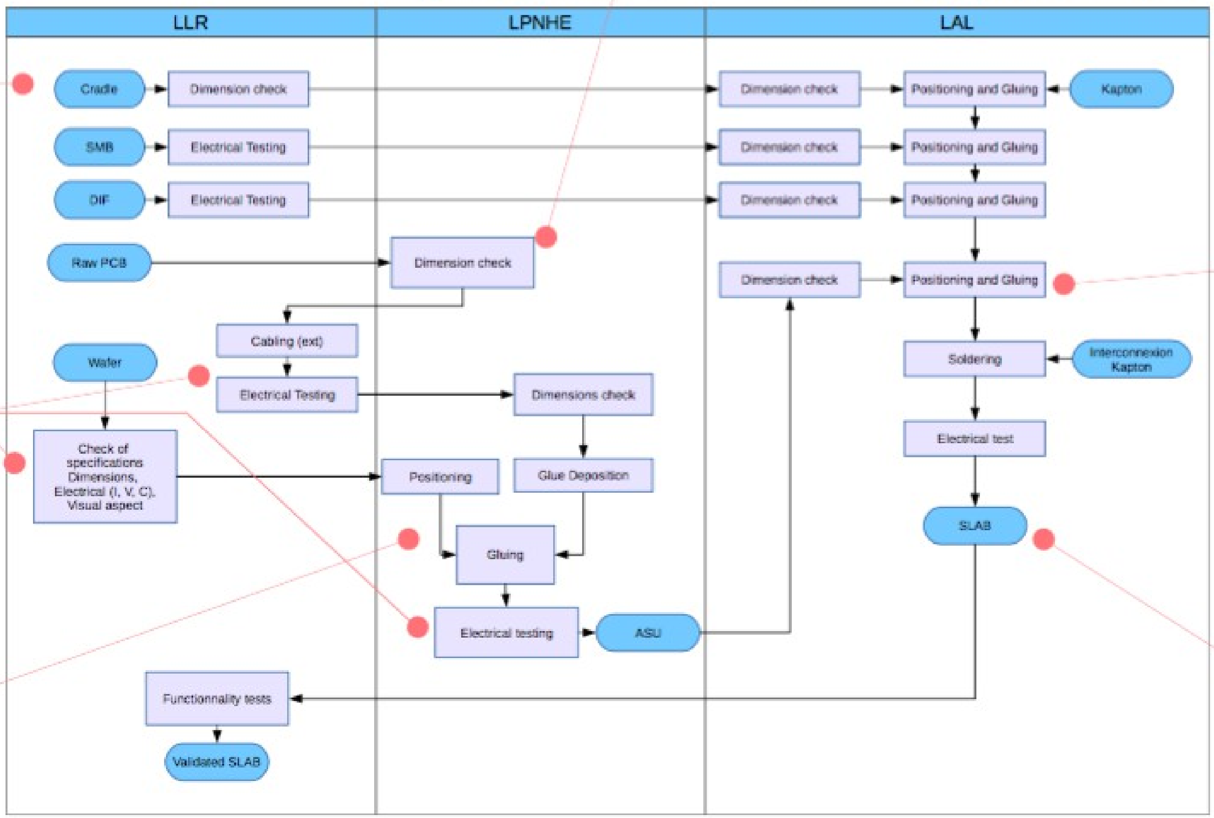
resp: R. Cornat

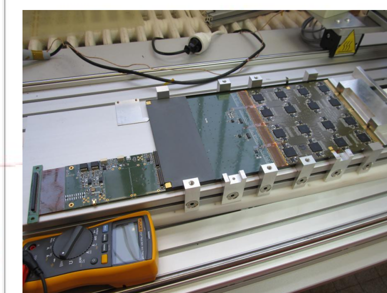


'Simplified view'







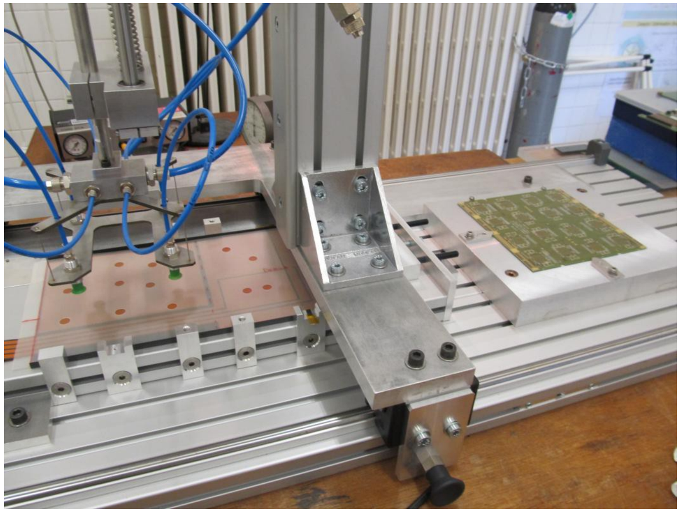


V. Boudry, ECFA Workshop 2016

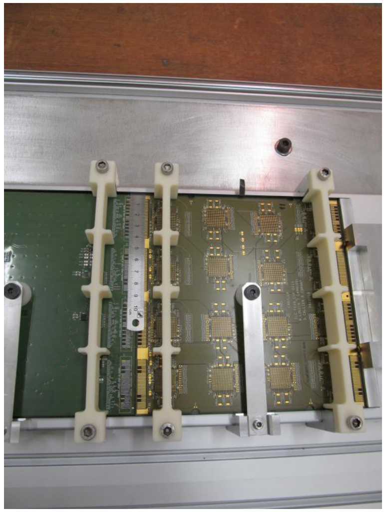
LAL in charge of final detector assembly

SiW ECAL Assembly

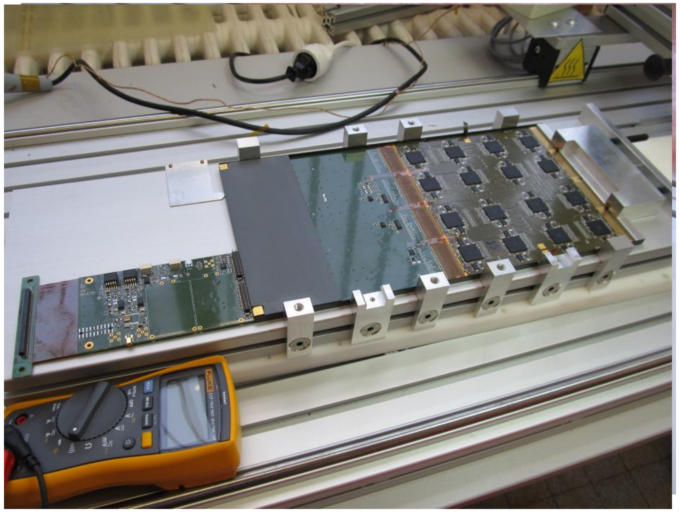
Pick and place



Precise alignment



Ready for test



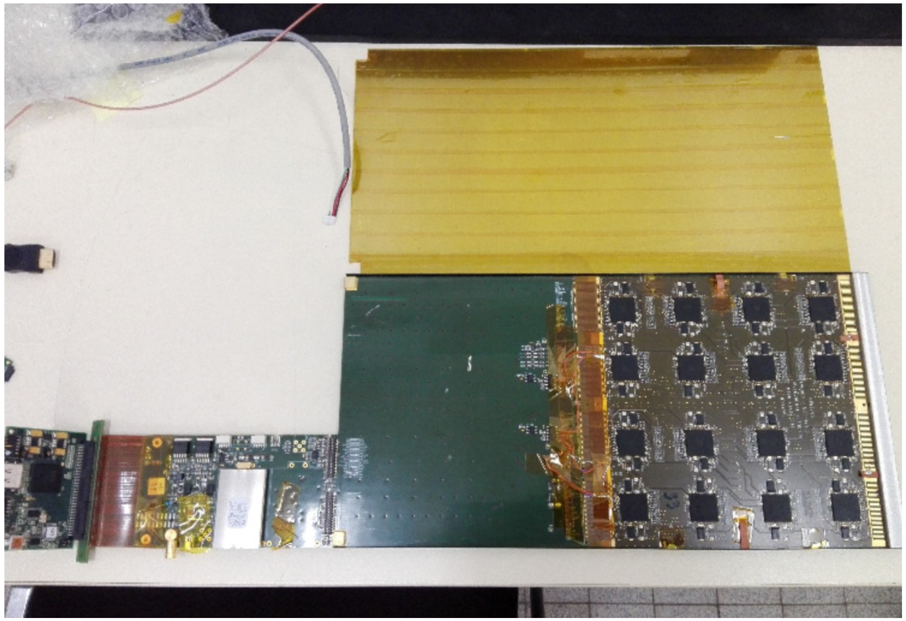
- Assembly steps are validated with **short layers** (13 assembly steps)

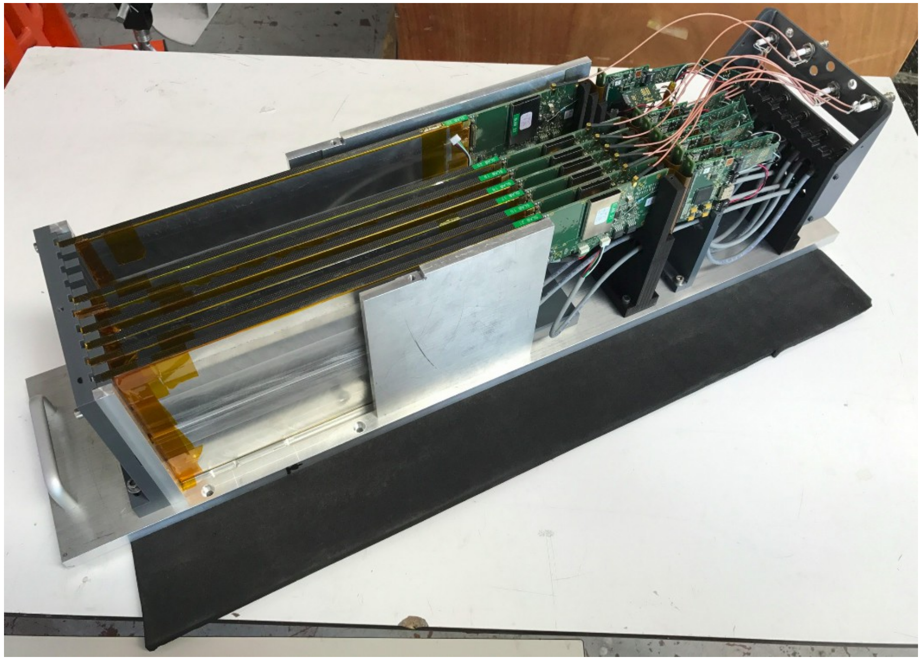
- Need big step towards **long layer** to assure high quality product
  - Automated pick-and-place and alignment
  - Interplay of many different working steps
    a) Assembly proper
    b) Continuous control of up to 8 (14) ASUs during assembly

- Successful product requires a lot of testing and exercising of well trained technical staff!!!

Thiebault/Bonis/Gallas

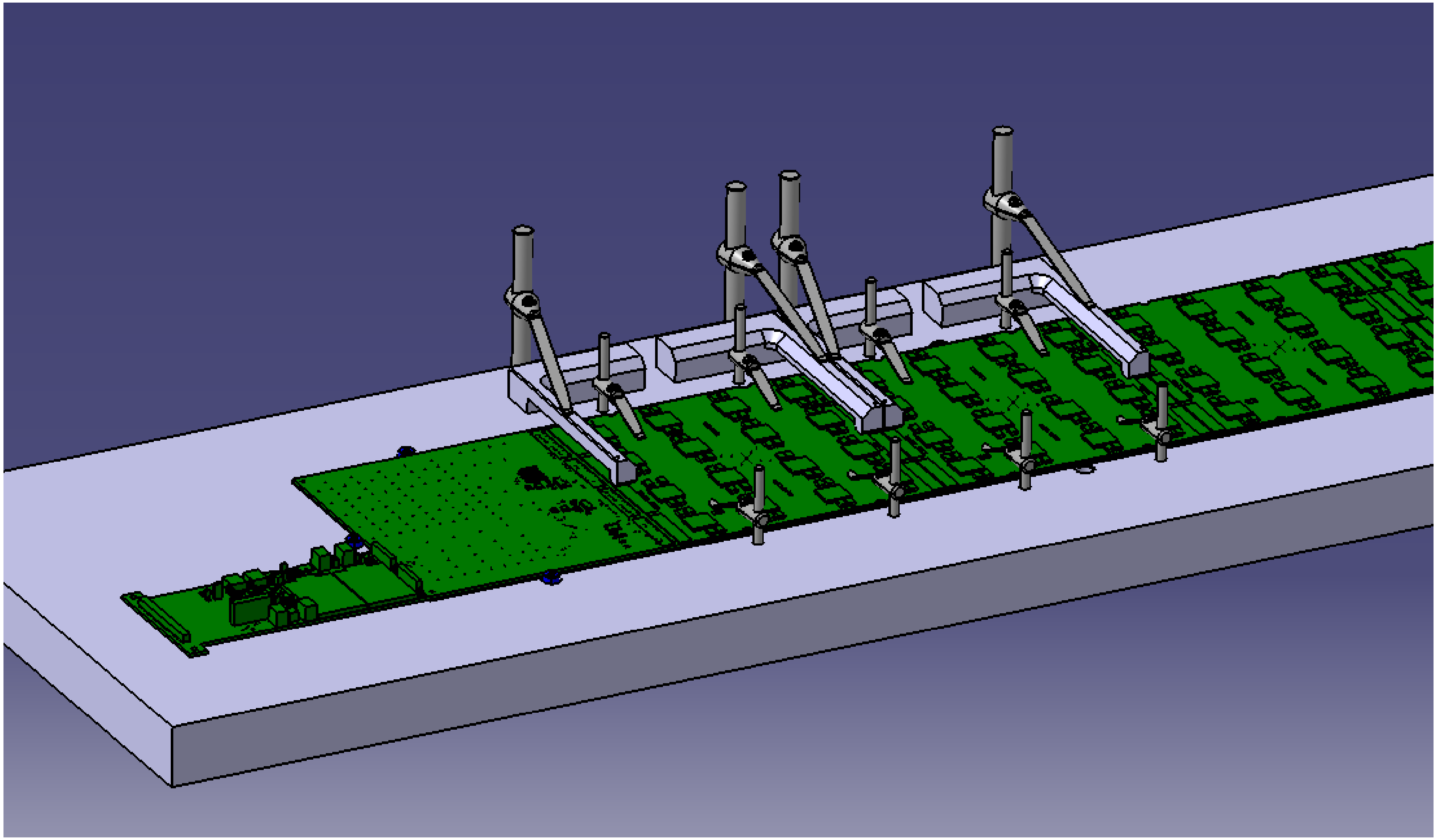
Test beam prototype – Short layers





- Stack with short layers debugged at LAL in 2017
  With support by LLR and LPNHE engineers
- Debugging piloted by Adrian Irles
- June 2017 Beam test at DESY

SiW ECAL – Assembly bench drawing

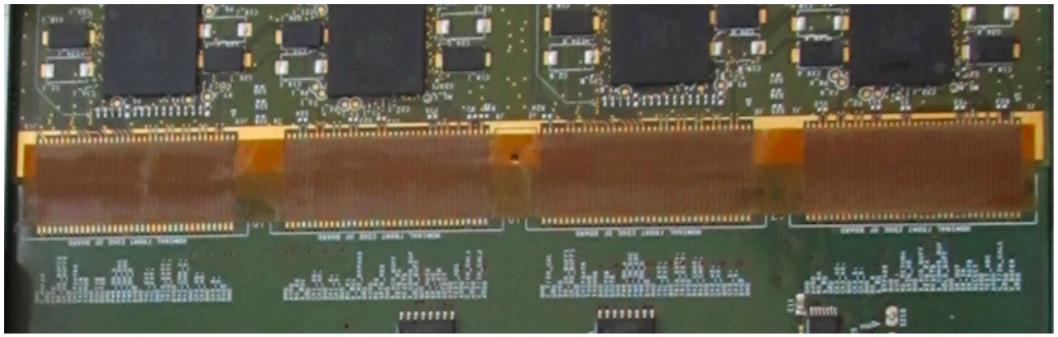


- Preparation of upgraded testbench
- Pieces are ordered expect first tests during March 2018
- Updated assembly bench is AIDA-2020 deliverable due in April 2018

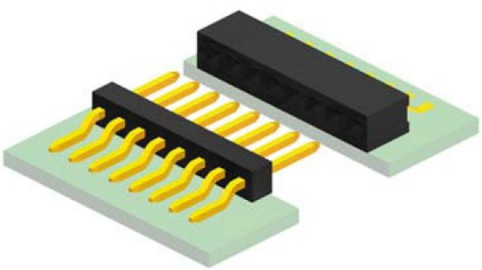
Thiebault/Bonis/Gallas

On interconnection

- Interconnection is maybe the most involved piece of the assembly



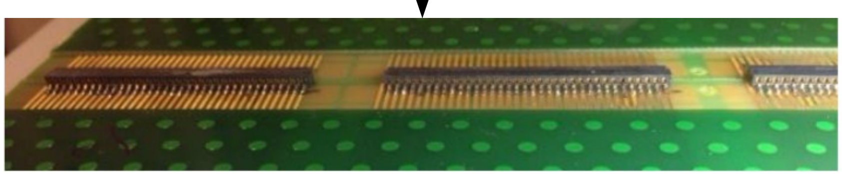
- Current solution with Flat Kapton **works**
  - Proven for short slabs
  - Interconnection so far made by hand
  - Delicate work
- Had difficulties to find supplier for (semi) industrial procedure



- Alternative with 'real' connector identifies
  - Take advantage of mobile phone technology
  - 1.27 – 1.5 mm height
  - Delicate work

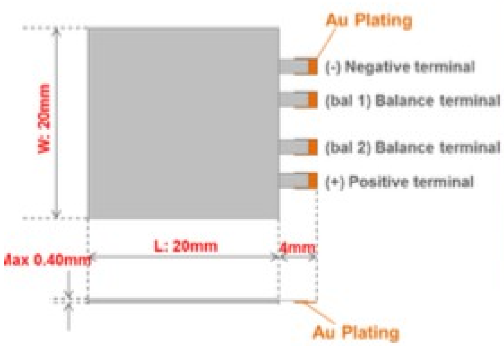
- May enable to realise individual ASUs

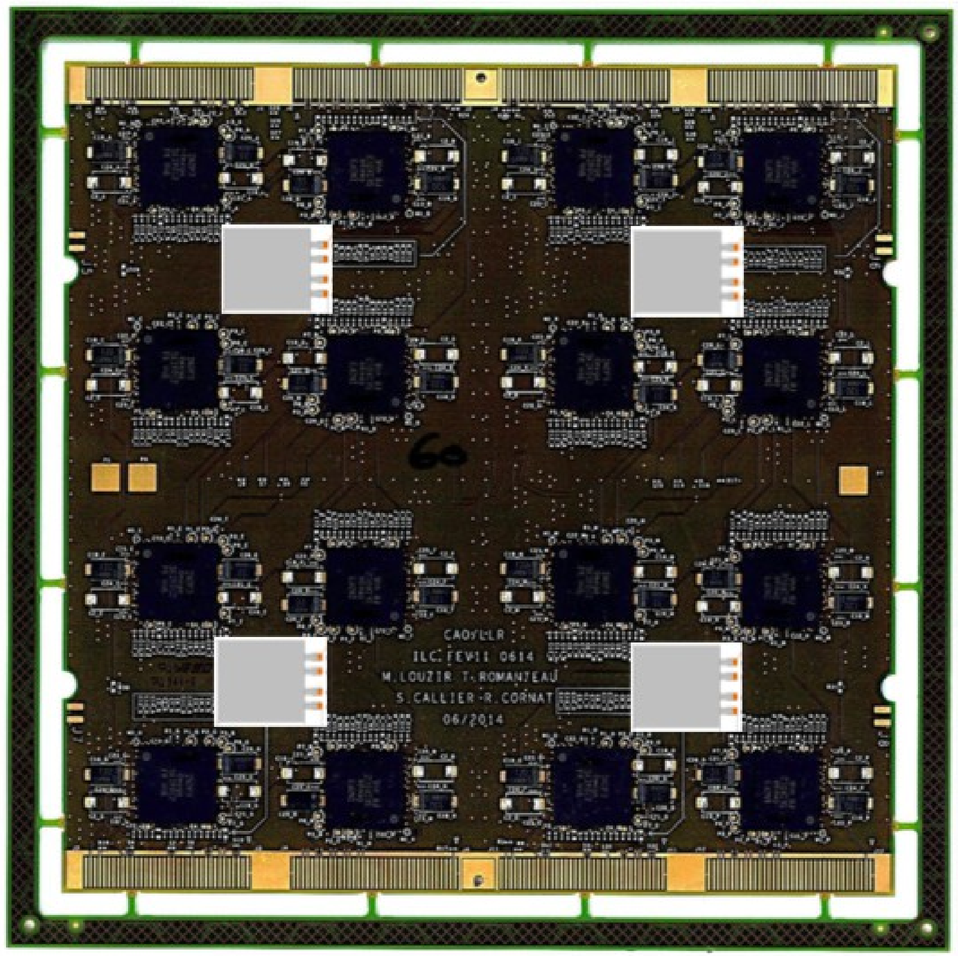
- Compatible with BGA type PCBs
- Not a penalty for COB type PCBs

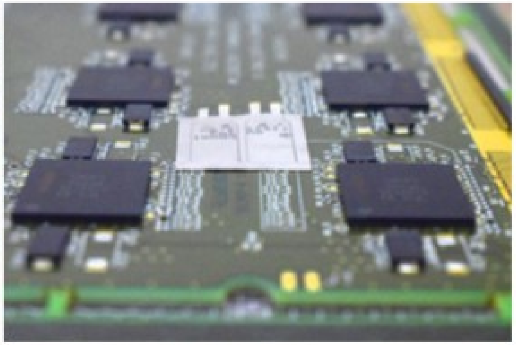


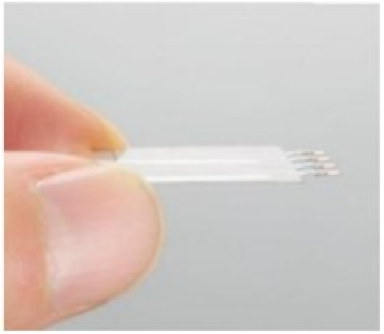
Avoiding huge peak currents

Ultra-Thin Supercapacitor
DMH series
DMHA14R5V353M4ATA0
35 mF / 4.5 V









Raised Question! Life time has to be checked, depends on voltage and temperature…

Maalmi/Jeglot/Breton

Towards compact r/o system I

Space constraints for the Active Sensor Units (ASUs):

- Maximum Height for Electronics (including PCB): depends on number of layers (20-30?)
  - For final design: x.x mm ?
  - For prototype: (PCB + components for the **SKIROC-2 BGA option**) : **~ 3mm**

Current ASU Electronic board design:

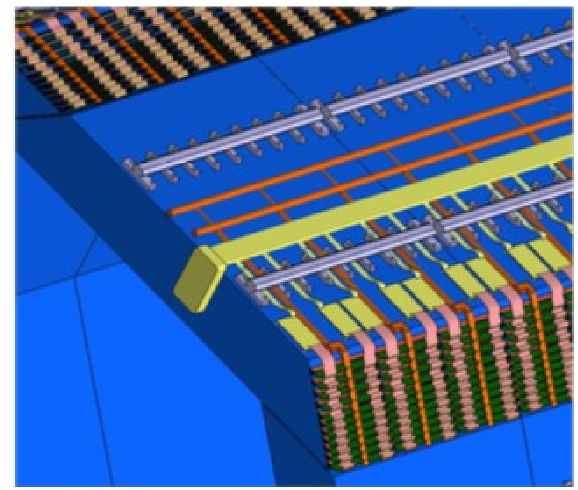
- Last PCB Height (FEV 11): **1.6 mm** , FEV12 : xx mm??
- SKIROC BGA height: **1.4 mm**

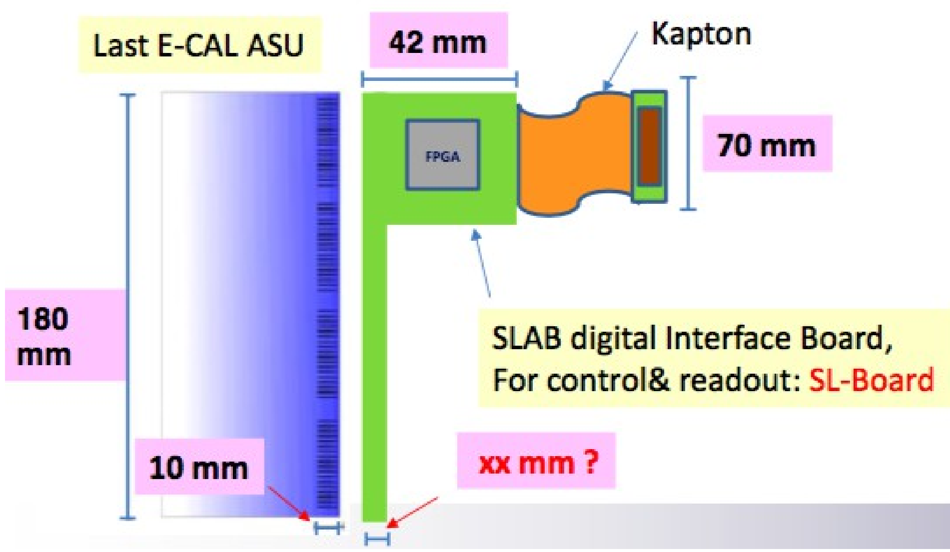
Total : 3 mm

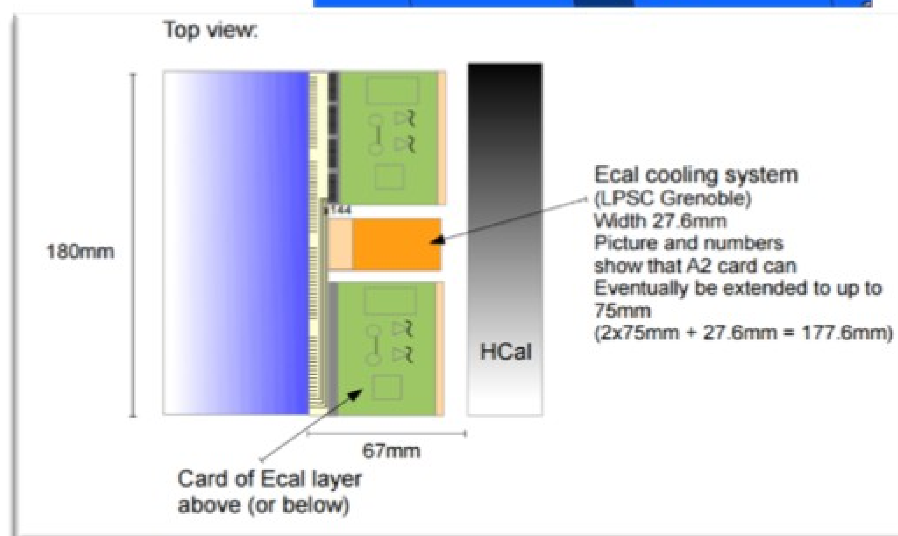
Space constraints for the Slab Interface Board (SL-Board):

- L-shape (even and odd ASUs) Dimensions: see below.
- Maximum Height: **~ 12 mm**

E-CAL Services







New activity that recently started with technical support by SERDI of LAL

Compact readout system is deliverable in AIDA-2020 and HIGHTEC at beginning of 2019

Towards compact r/o system II

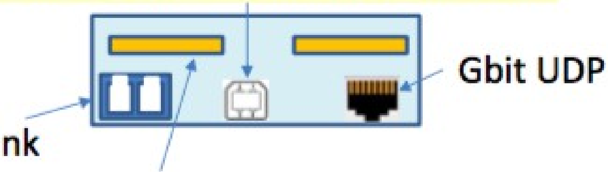
The new developments for the control and readout electronics are based on :

- **SL-Board :**
  It's the digital interface board situated at the extremity of the Slab, based on a MAX10 FPGA, which handles:
  - Control & readout of the chained ASUs (SKIROC interface)
  - Interface to the CORE acquisition module through a kapton cable in order to have flexibility for the connection inside the detector (45° angle constraint)

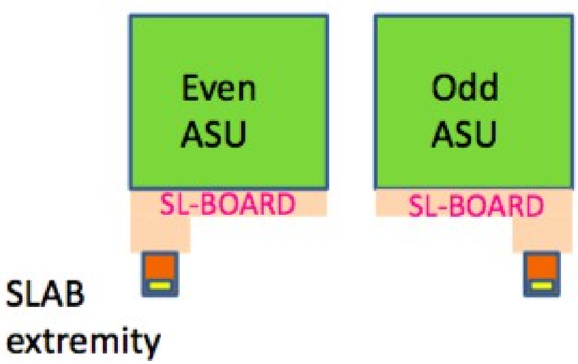
- **CORE-Module** : Control & Readout module that handles a column of Slabs, for the prototype phase.

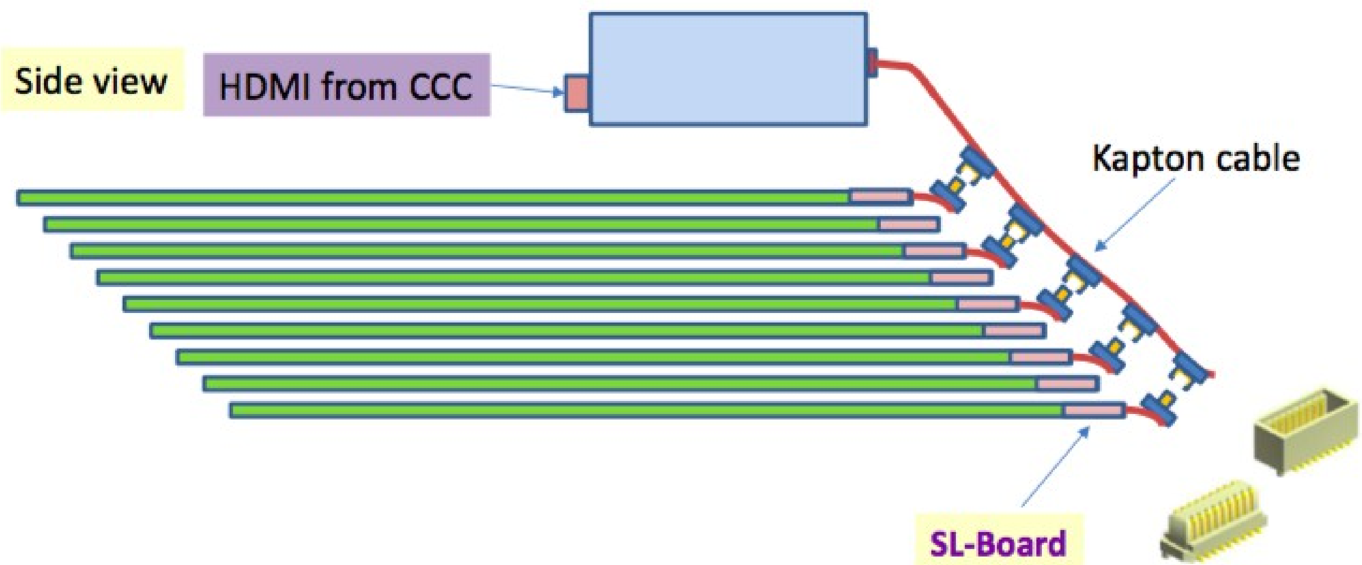
USB

CORE Module : Control & Readout Module



Hirose FX18- 100 pin, 0.8 pitch

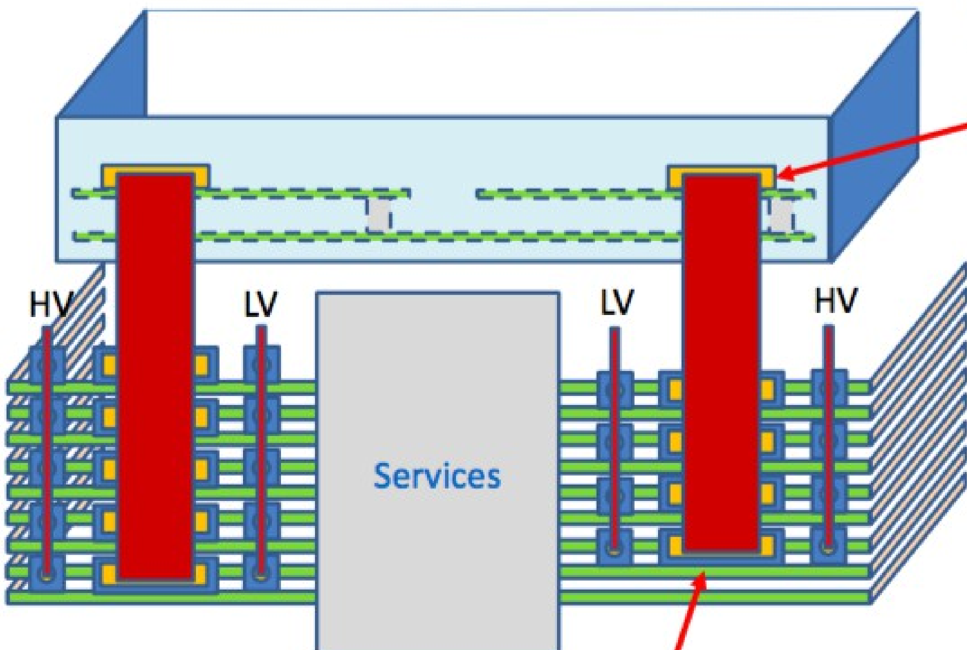




Breton/Maalmi/Jeglot

Towards compact r/o system II

Core Module connector:
9 common differential pairs for CCC and JTAG, *30 individual pairs* for control and readout, spare, Address, GND



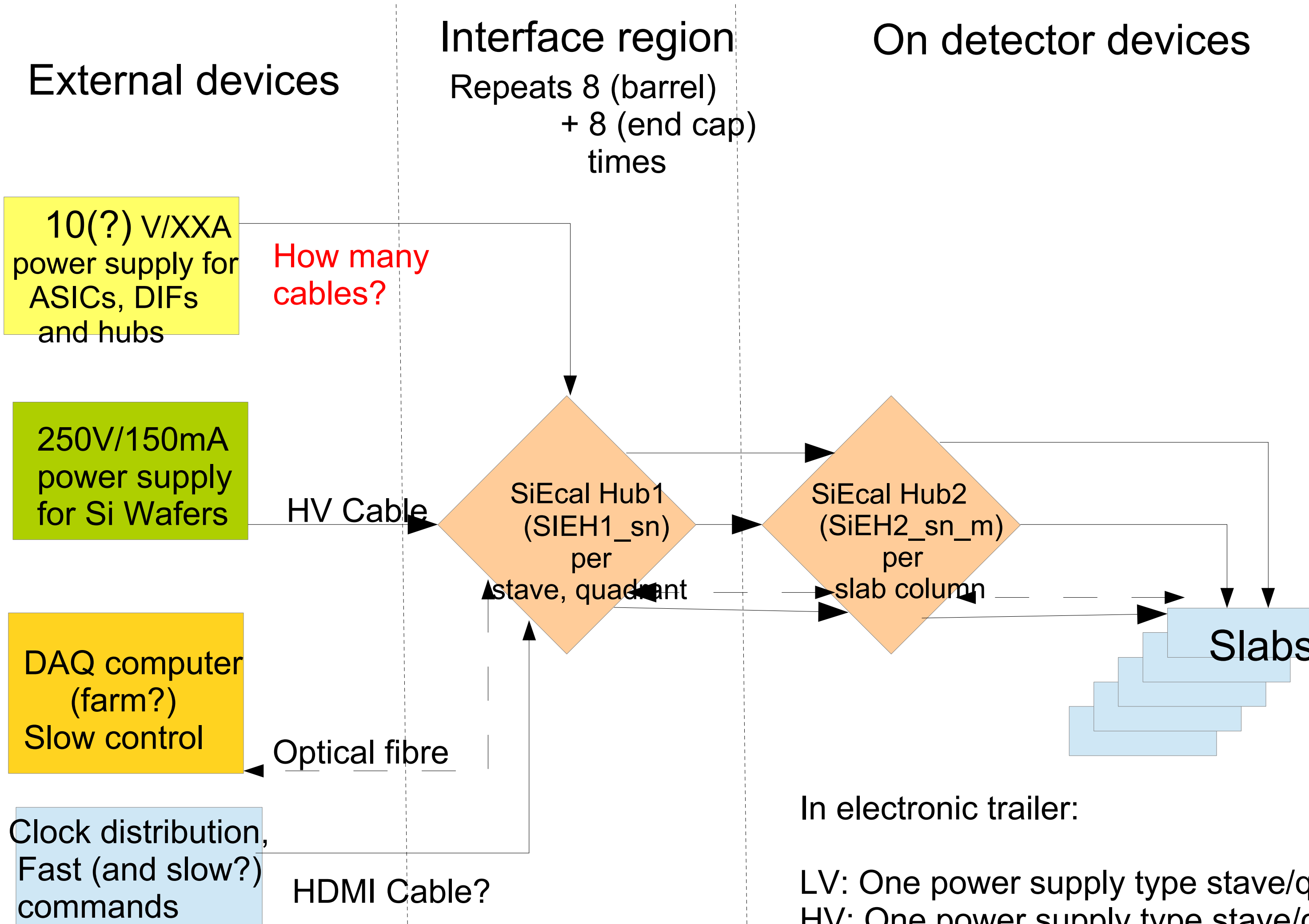
SL-Board Connector
9 differential pairs for CCC and JTAG, 2 individual pairs for control and readout, spare, GND

	Signals
	Clk
	Trigger
	Start/Stop
	Busy
	Control
JTAG	TCK
JTAG	TMS
JTAG	TDI
JTAG	TDO
SPI	SCK
SPI	SDI
SPI	SDO

Signals
Rx_i
Tx_i
Spare …
GND …
ADD[0]
ADD[1]
ADD[2]
ADD[3]

Breton/Maalmi/Jeglot

Supplies – Naive block scheme



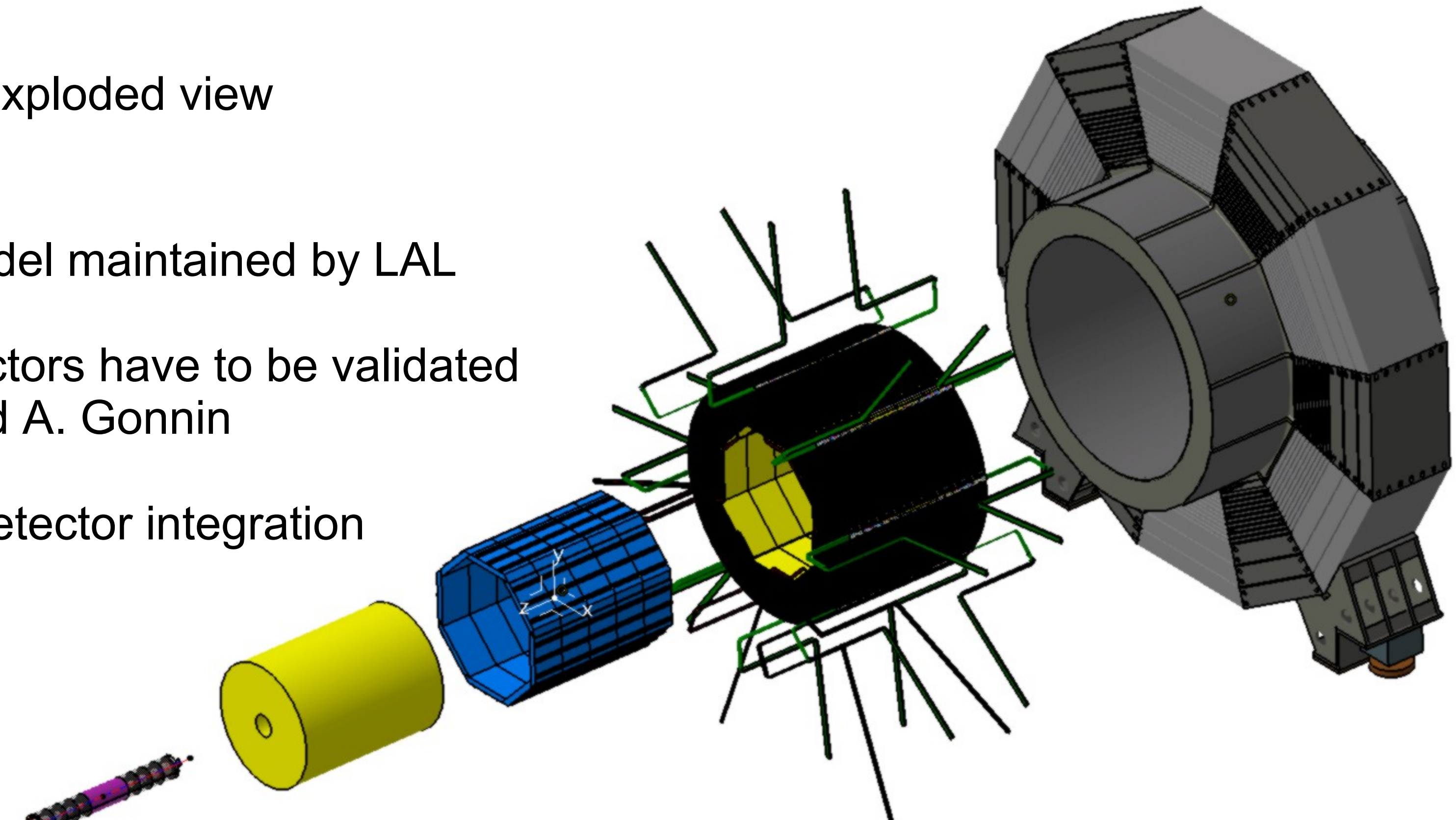
In electronic trailer:

LV: One power supply type stave/quadrant
HV: One power supply type stave/quadrant
DAQ farm: 1 computer stave/quadrant for acquisition
Slow control: One slow control computer
One clock source

At the very beginning of integration work

Putting it all together – ILD Integration

Exploded view

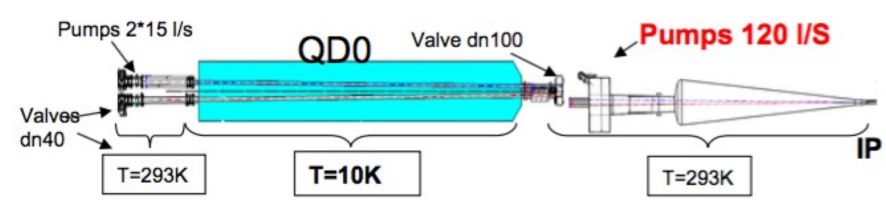


- ILD Engineering model maintained by LAL
- Updates of subdetectors have to be validated by C. Bourgeois and A. Gonnin
- R.P. Co-convenor detector integration

- Coherence between ILD subdetectors assured by Interface Control Document
  Intensive communication with Videau for Ecal
- Effort will grow in importance in coming years

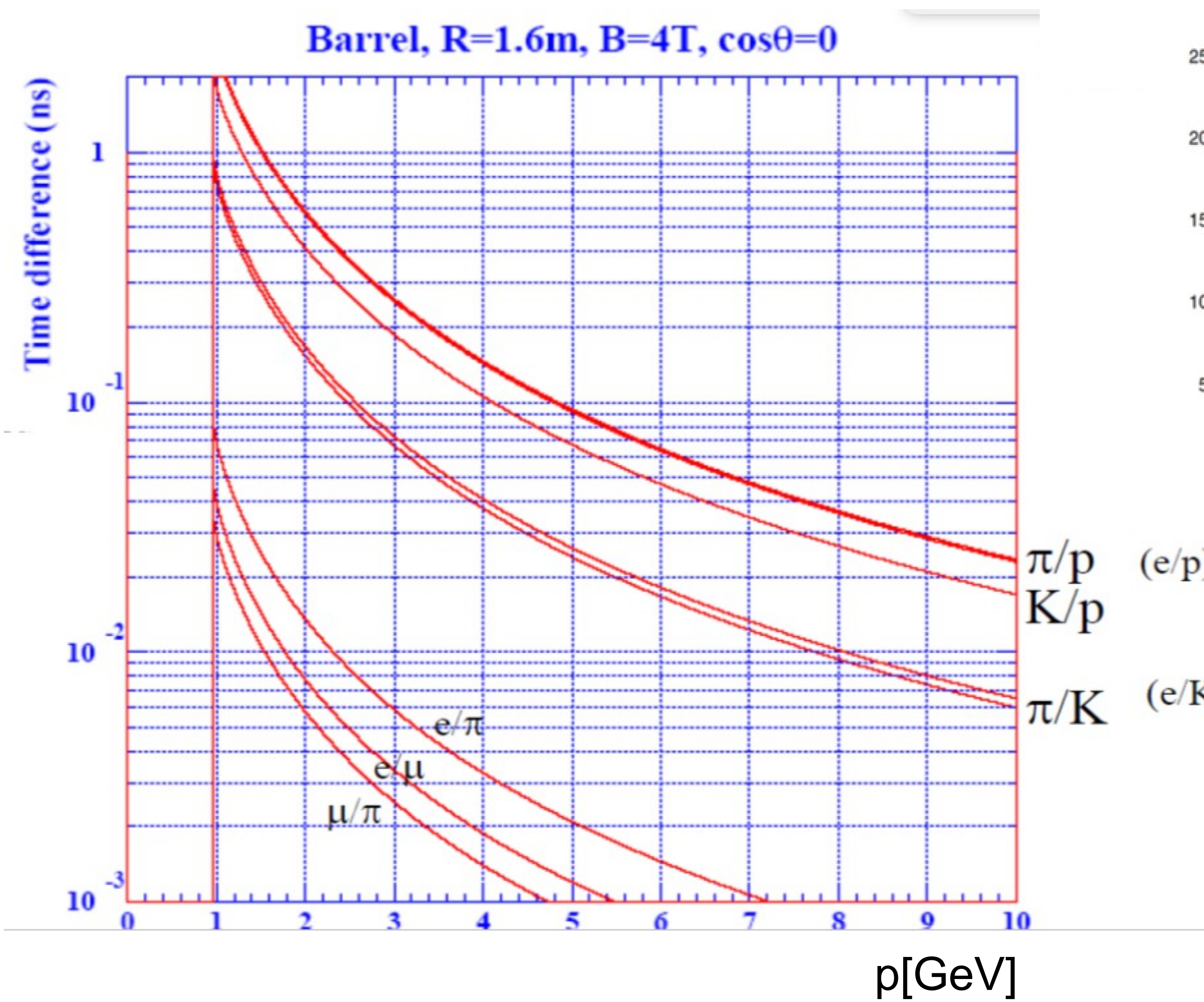
Gonnin/Bourgeois

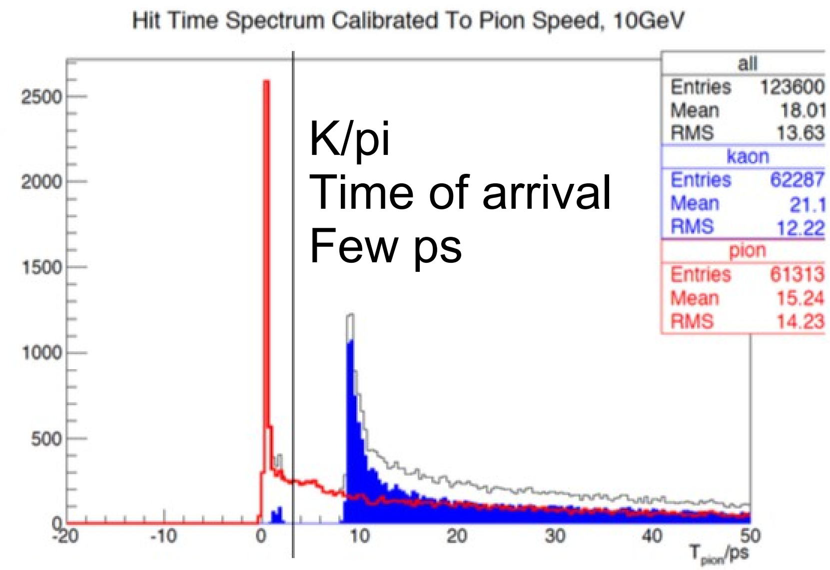
- Vacuum studies for ILD
  - => Acceptation of new L* of ILC

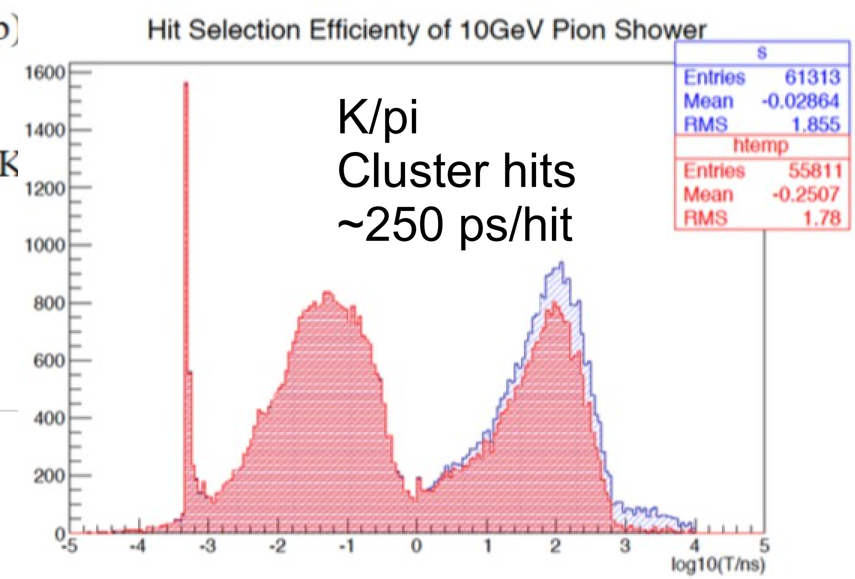


Mercier/Prevost

New R&D Trens - Timing

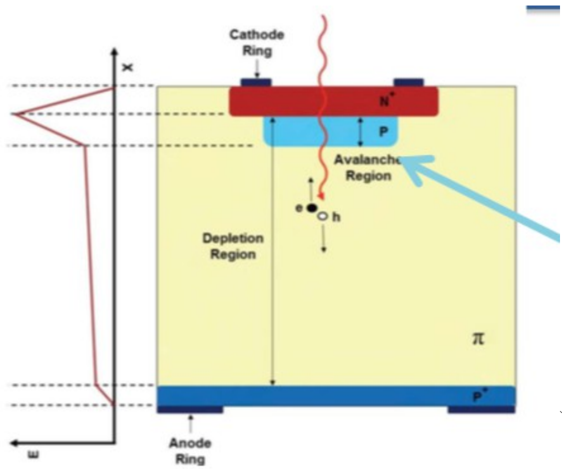




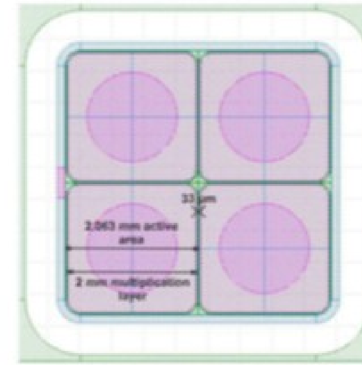


Timing resolution needs to be well below 1ns level, rather ps!

New R&D Trends - Timing



Add to n-on-p sensor an extra thin p-layer
=> gain of 50 w/o breakdown



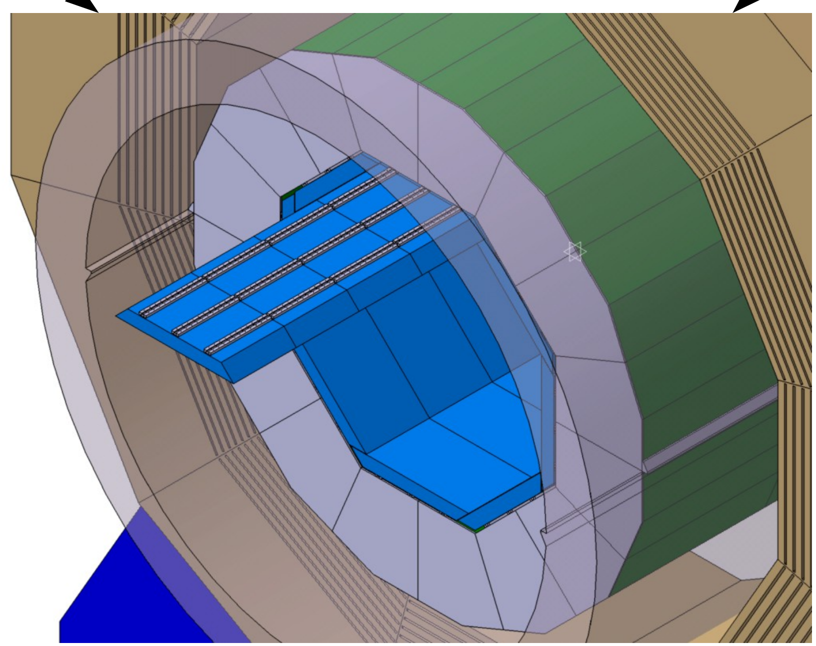
- LGAD for e+e- Detector?
  or CMS Solution?

- Current resolution ~30ps

- Would need 10ps or better

- Interesting but big R&D program that could build up on LHC experience

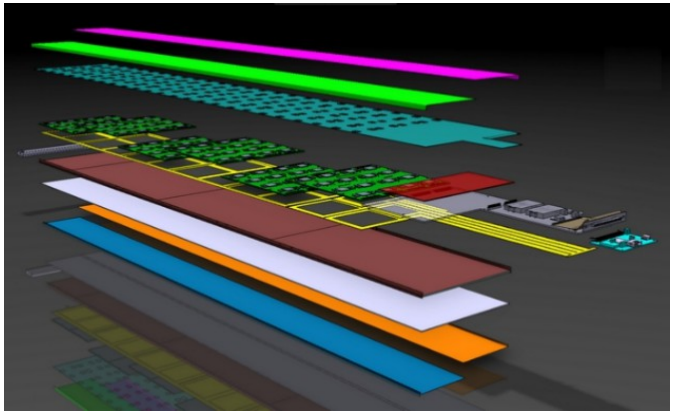
- e+e- detector concepts about to make up their mind now



Anticipated evolution ~3 years

- **Staff**
  - New PhD student
  - Getting joined by researchers of other projects

- **Activities**
  - Preliminary conclusions on physics potential of heavy quark physics at LC
  - New studies according to « needs »
  - Production of a long slab of Ecal and revision of digital readout



  - Contribution to proposal of SiW Ecal for a LC detector
  - Extension of ILD integration activities

Thanks to all of the LAL staff, tachnicians, missions, achats, logistics secretaries (in part. Sylvie of 208) for support of our work

ILC Group at LAL

Refondation des Labos
CSNSM - IMNC - IPNO - LAL - LPT

Responsible
Roman Pöschl

Physics studies

D. Zerwas, F. Richard
E. Kou, F. LeDiberder,
S. Bilokin, R.P., A. Irles

Detector R&D

Tests Ecal : R.P., D. Zerwas, Adrian Irles

Digital Electronics Ecal (since 2017):
Dominique Breton (SERDI)
Jihane Maalmi (SERDI)
Jimmy Jeglot (SERDI)

Integration Ecal:
J. Bonis (SDTM),
A. Thiebault (SDTM)
A. Gallas

Integration ILD:
C. Bourgeois (SDTM),
A. Gonnin (SDTM)
B. Mercier (SDTM)
C. Prevost (SDTM)

- **Algorithms and beam Test analysis**
- S. Bilokin, R.P., A Irles
- B Kegl

Core team for detector construction

Anticipated evolution ~10-12 years

- Assumption positive evaluation of Japanese Government during 2018
=> Preparation phase will start

- Assembly of Ecal (includes r/o electronics and assembly proper)

0) Definition of concepts and procedures
~ Until end of 2019

0.5) 2020 Sharing of work with (inter)national partners

1) Construction of Module 0 (150 layers or 75 slabs)
~2020 – 2023
This is already a big beast!!!
Preparation for mass production ([local] infrastructure, contracts with industrial partners)

2) Ecal construction (~8000 layers or 4000 slabs)
~2024 – 2028 (for start of data taking in 2030)

3) Detector commissioning
~2024 [2025] – 2030
This includes reception of material at experimental site, check-out and Installation

Will discuss in the following the needs in terms of RH (ITA) and infrastructure

Scenario 1: Ecal assembly on site

- Refurbishment of infrastructure
  - Infrastructure services at our labs (2 FTE four 3-4 years starting from ~2019)

- Investment in corresponding assembly and quality control chains
  - Planning through mechanical and electronics department
    - All members of current core team with large fraction of their time (8 FTE)
  - N.B.: The current core team may help establishing other assembly sites
    Unrealistic that all 8000 layers would be assembled at LAL

- Operators of assembly chains that are trained and supervised by current core team
  => At least four operators nearly full time over ~6 years

- Development of computing control software
  - IT Experts may need to integrate quickly current core team 2 FTE?
  - May need to evaluate further contributions by IT Services

- Material reception and shipment
  - Logistics, storage

- Reception, validation and commissioning of material on-site
  - May be reasonable to plan with some technical staff on-site

- Some of the material may be exposed to beams e.g. at CERN
  - Particular during Module 0 phase

For this scenario we may have altogether to account for a need of **~15+x** ITA until 2030 with a peak need between 2022 and 2028

Scenario 2: External Ecal assembly

- Refurbishment of infrastructure
  - Less infrastructure than for "in house" construction
- Set up of a industrial production of layers
  - Planning through mechanical and electronics department
    - All members of current core team with large fraction of their time (8 FTE)
  - Definition of specification and tight communication with industrial partners
  - Quality assurance of production
  - Need to acquire new competences?
  - Take into account that production can/should be at several sites (even if one company)
- Operators for quality control station(s)
  - Clearly less work intensive than full assembly (Total 2 FTE)
  - ... but requires to give well defined feedback to industrial partners
- Development of computing control software
  - IT Experts may need to integrate quickly current core team 1 FTE?
  - May need to evaluate further contributions by IT Services
- Material reception and shipment
  - Logistics, storage
- Reception, validation and commissioning of material at ILC site
  - May be reasonable to plan with some technical staff on ILC site
- Some of the material may be exposed to beams e.g. at CERN
  - Particular during Module 0 phase

For this scenario we may have altogether to account for need of **15-x ITA** until 2030 with a peak need between 2022 and 2028

ILD Integration

- Central task for assuring coherence of ILD Engineering Model
  - Extremely important during design phase until ~2021
  - Will determine specifications of ILD sub components
  - So far mainly mechanics, electronics integration (including power supply) becomes increasingly important
  - LAL members (2 ITA) occupy currently key positions within ILD

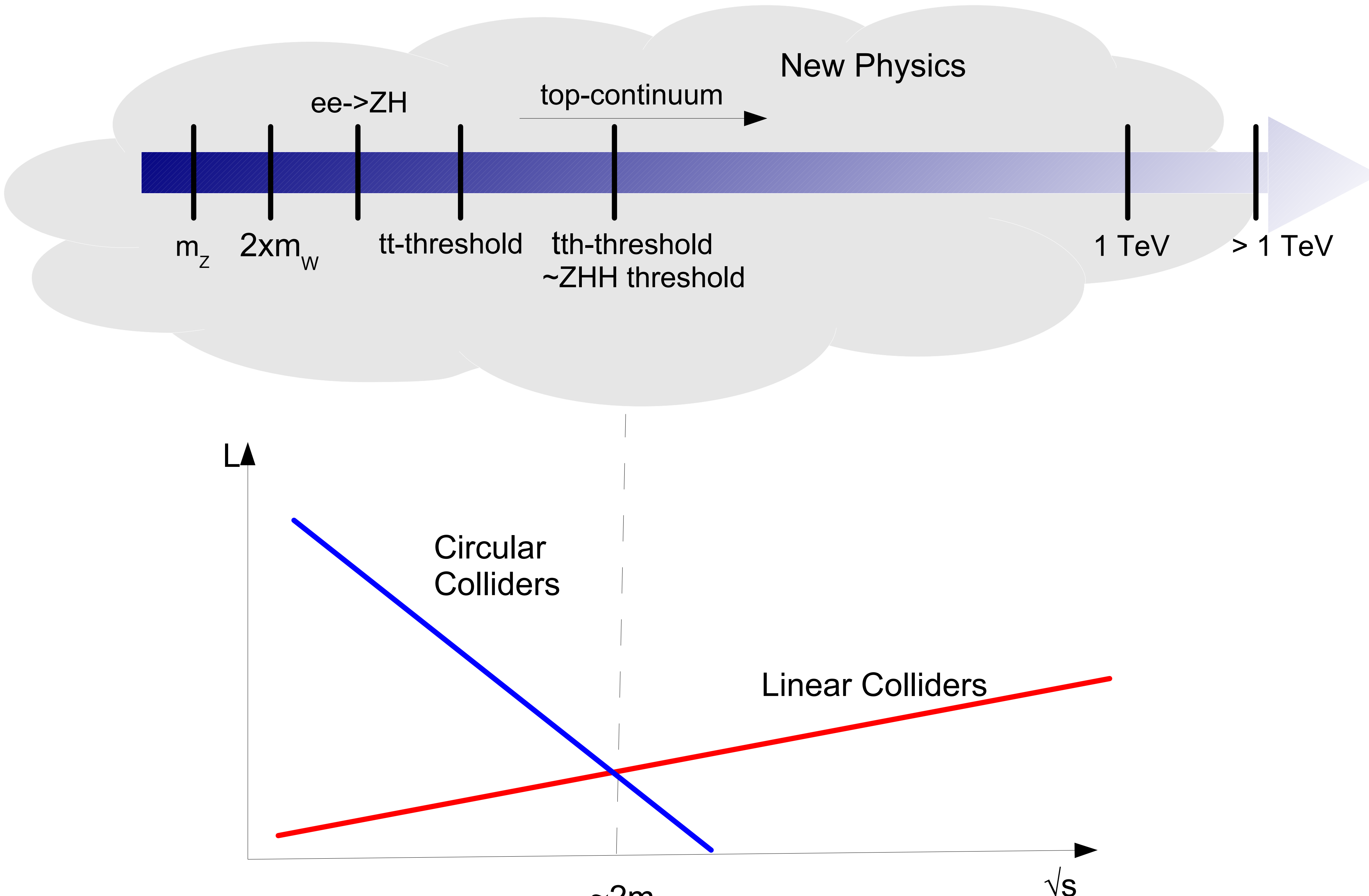
- Will smoothly transit into concrete planning phase
  - Collaborative effort but we would like to sit on the table

- Operators for quality control station(s)
  - Clearly less work intensive than full assembly (Total 2 FTE)
  - ... but require to give well defined feedback to industrial partners

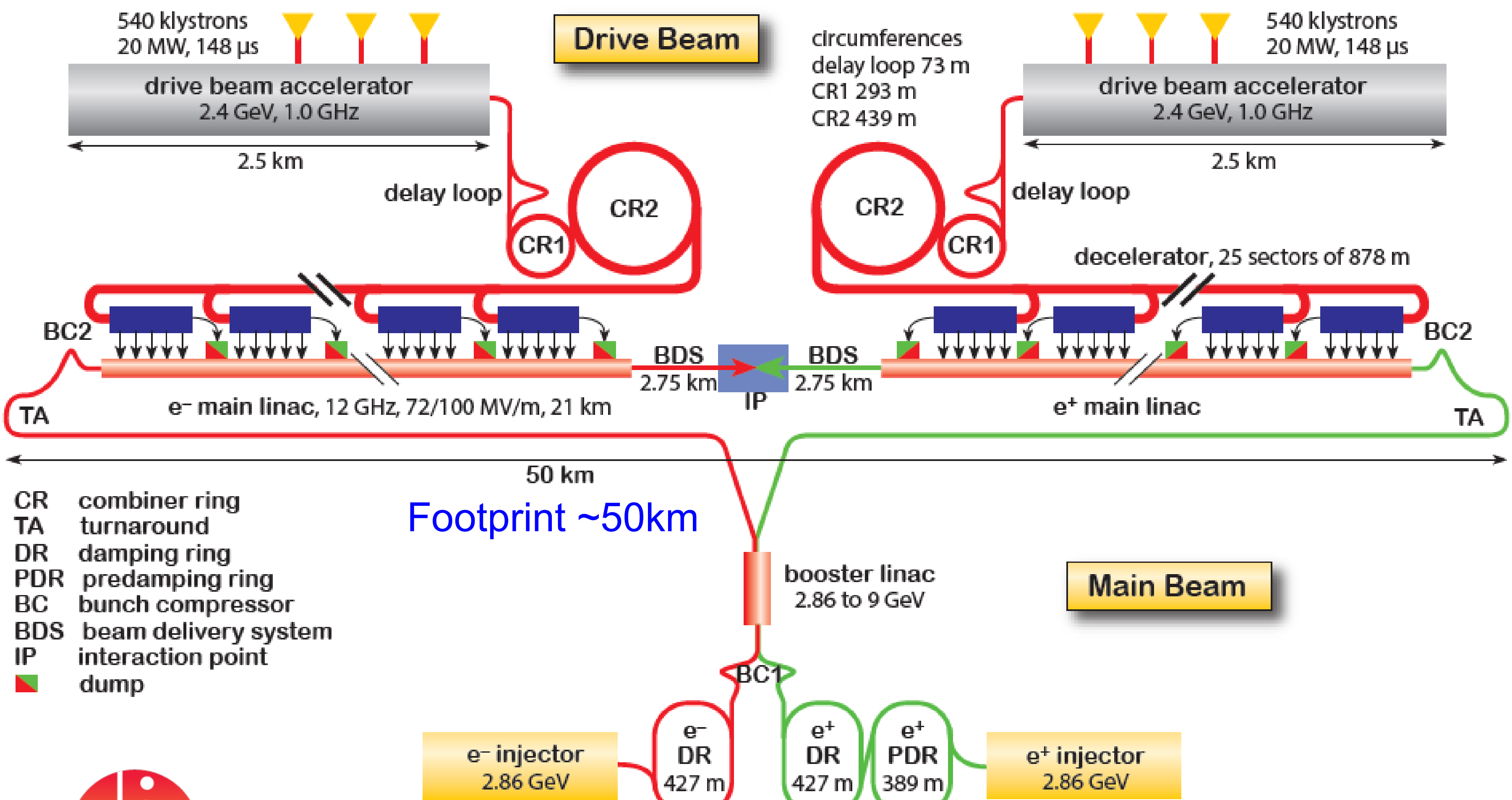
ILD Integration but of course also Ecal assembly require technical and mangement skills

e+e- Physics program

Refondation des Labos
CSNSM - IMNC - IPNO - LAL - LPT



3 TeV Layout



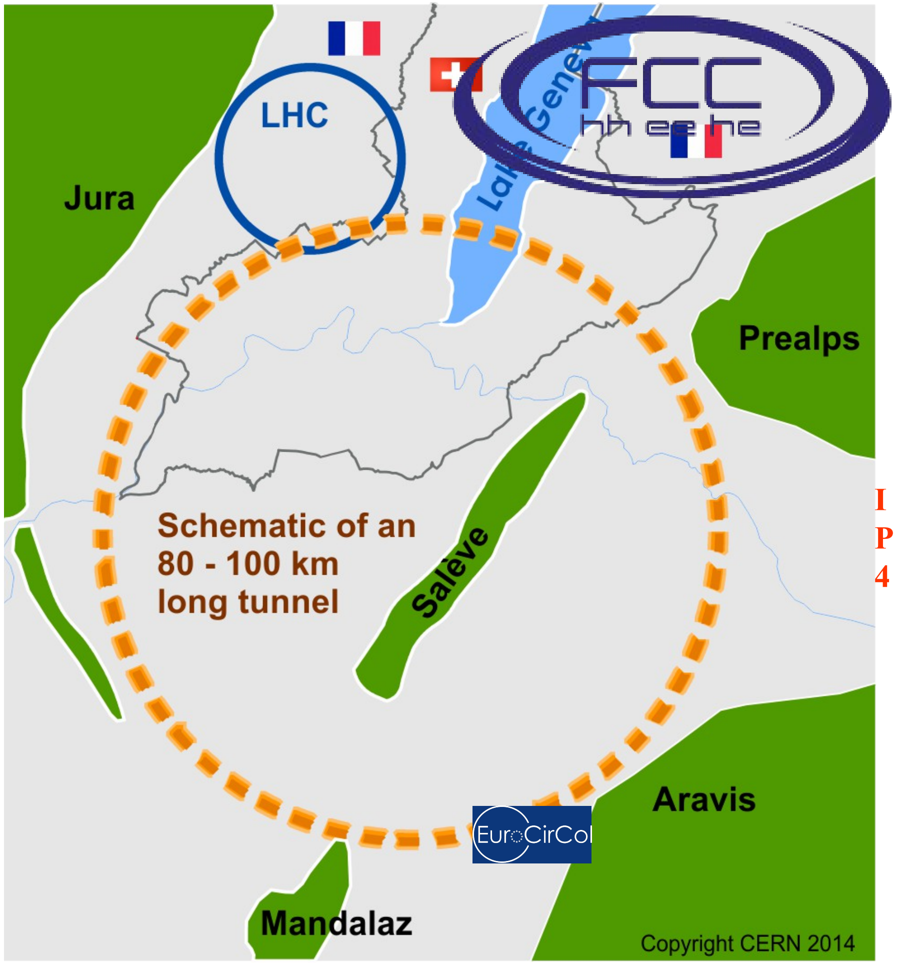
Energy: 0.5 - 3 TeV

Electron polarisation

Drive beam to reach high gradients

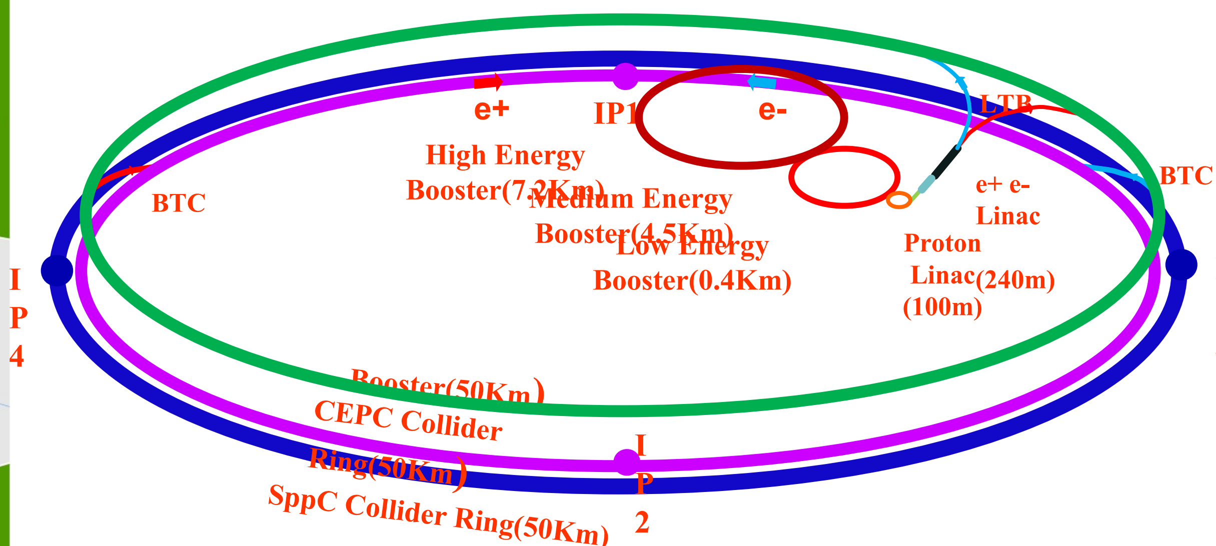
CDR in 2012 – Rebaselining 2016

Circular Electron-Positron Colliders Proposals



- ~100 km storage rings
- Coupled to hadron collider proposal
- 90 – 350 GeV cms energy
- No long. beam polarisation
- CDR Phase

CEPC



- ~50 km storage rings
- Coupled to hadron collider proposal
- 90 – 240 GeV cms energy
- No long. beam polarisation
- (Pre-)CDR Phase

Important news: CEPC/SppC related

习近平主持召开中央全面深化改革领导小组

第二次会议（2018年1月23日）

会议审议通过了...《积极牵头组织国际大科学计划和大科学工程方案》...

会议强调，牵头组织国际大科学计划和大科学工程，要按照国家创新驱动发展战略要求，以全球视野谋划科技开放合作，聚焦国际科技界普遍关注、对人类社会发展和科技进步影响深远的研究领域，集聚国内外优秀科技力量，量力而行、分步推进，形成一批具有国际影响力的标志性科研成果，提升我国战略前沿领域创新能力和国际影响力。

The China Reform and Development Committeee (led by President J.P. Xi) had the meeting on Jan 23, 2018, and passed the plan of "Chinese Initiated International Large Scientific Plan and Large Sicentific Project"

Jan 23, 2018, is a historical time node for CEPC/SppC: facing to Chinese government, CEPC/SppC has a dedicated passage for project proposal, evaluation, R&D, project aproval, and construction...