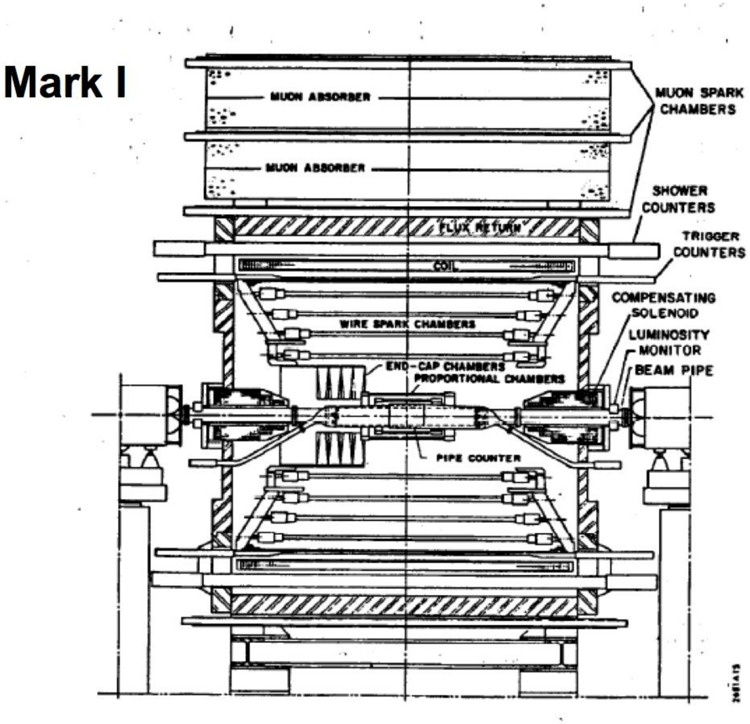
THE DEVELOPMENT OF COMMON THERMO-MECHANICAL FACILITIES

Evolution of Particle Detectors

Mark I @ SPEAR (SLAC), 1973

Mark I or the SLAC-LBL Magnetic Detector was the first 4π detector built with different detector types arranged in layers around the interaction point.



Evolution of Particle Detectors

SPEAR, SLAC:
MARK I, First 4π detector,
1973

DORIS, DESY
PLUTO, 1973:
First detector with super conducting solenoid

PETRA, DESY
JADE, 1978
Mark-J
CELLO
PLUTO
TASSO

SPS, CERN
UA1, 1981

LEP
DELPHI, 1989
ALEPH,
OPAL
L3

Tevatron, Fermilab
CDF, 1989
D0

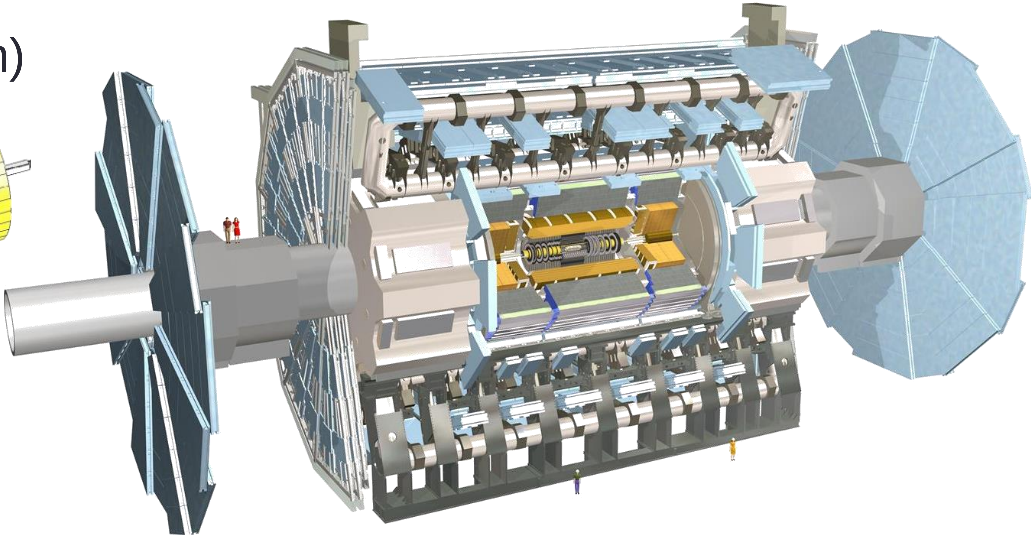
LHC,
ATLAS, 2008
CMS

FLC
ILD, SiD

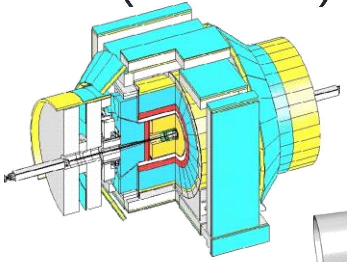
Since the Mark I times at 1970's quite some detectors have been built with increasing complexity

Evolution of Particle Detectors

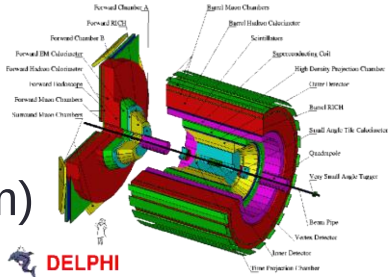
ATLAS (25x40 m)



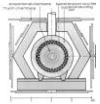
CDF (12x12 m)

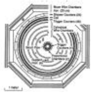


DELPHI (10x10)m



PLUTO (4x4 m)



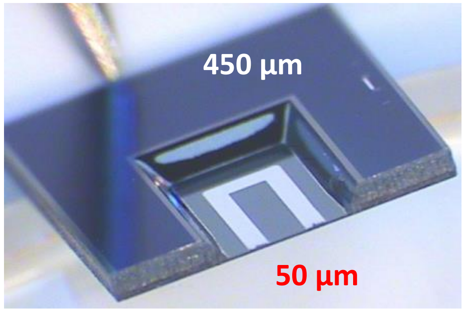


Mark I (4x4 m)

Volume of both detectors and collaborations have grown considerably.

The working model has also changed dramatically

The Challenges of the Future



- ✓ Minimize mass.
  - Structure/service mass has to be seen in context of sensor mass
  - …and this is going down significantly (75µm thick DEPFETs @ Belle II, thinned down MAPS,…)
- ✓ Stability (required for offline alignment) under various loads
  - Vibrations
  - Thermal loads
    - Change in front-end power or cooling parameters
  - Moisture variations (for composite structures)
  - External loads from magnet ramps, etc.
- ✓ Cooling
  - Power/channel figures goes down, but increase granularity and trigger rates will always require significant power
  - In high radiation environments, control leakage currents
  - Liquid (evaporative) cooling gives good control locally but “ruins” your material budget
  - Gas (convective) cooling very difficult to demonstrate: requires a full system mock-up.

The challenges of the future

- Cost and integration (in particular for large systems)
  - Provide a design which can reliably and quickly be put together
    - …and eventually be taken apart
  - Hierarchical and modular design:
    - Simple interfaces, pre-tested, where possible identical in large numbers
      - Not only at detector module, but throughout the system (services, cooling plant, …)

There is a need (and possibilities) for much more aggressive designs than we see today.

These need to be verified – that's where discussion on test facilities comes in

The new paradigm

- ✓ No lone discoverers making experiments in the basement of their house anymore.
  - ❑ We have to work in increasingly large collaborations.
- ✓ We do not drive the technology any more
  - ❑ Need to follow what industry does and adapt it to our needs
- ✓ The contribution of a single institution both in terms of personnel and equipment is limited
  - ❑ Work model has changed and it is also very distributed
  - ❑ Likewise, knowledge –which exists-- is also spread

The new paradigm

- ✓We may profit a lot from a new model that integrates existing and foreseen installations and infrastructures into a distributed facility
- ✓This facility could serve as incubator for
  - ❑ Higher performance testing procedures
  - ❑ A sort of standardization of procedures and
  - ❑ Dissemination of best practices in the community.
  - ❑ … a pool of knowledge.

We need a new paradigm that is able to manage the equipment and knowledge which is spread all over the world.
…the equivalent of the “grid” in computing

The AIDA-2020 proposal

- AIDA (Advanced European Infrastructures for Detectors and Accelerators)
  - addresses infrastructures required for detector development for future particle physics experiments.
- It is coming to an end and will apply to H2020 with AIDA-2020
- One of the work packages is a Joint Research Activity that tries explore this new paradigm. The EU defines the JRA's as

> (iii) **Joint Research activities**. These activities should be innovative and explore new fundamental technologies or techniques underpinning the efficient and joint use of the participating research infrastructures. They should involve, whenever appropriate, industries and SMEs to promote innovation. In order to improve, in quality and/or quantity, the services provided by the infrastructures, the joint research activities could address (non-exhaustive list):
>
> - higher performance methodologies and protocols, higher performance instrumentation, including the testing of components, subsystems, materials, techniques and dedicated software;
> - integration of installations and infrastructures into virtual facilities;
> - innovative solutions for data or sample collection, management, curation annotation, and deposition;
> - innovative software solutions for making new user communities benefit from computing services.

This is exactly what we want to do..

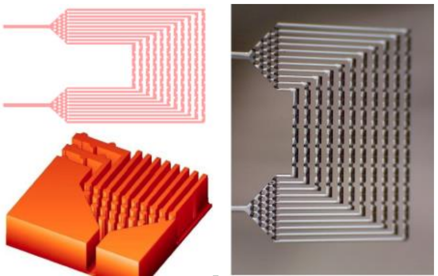
AIDA-2020 JRA on common facilities

- ✓ AIDA-2020 has WP13: *μ-channel cooling and support structures*
  - ❑ special emphasis in creating common, specialized infrastructures to help developing and characterizing
    - Integrated μ-channel cooling
    - Mechanical support structures
- ✓ When speaking of common infrastructures we also include
  - ❑ Standardization of production techniques
  - ❑ Development of common building blocks
  - ❑ Dissemination of best practices

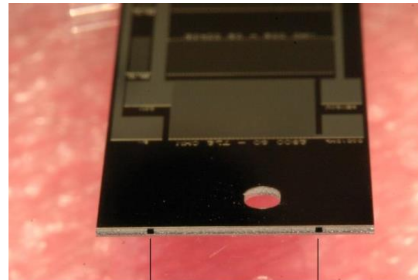
μ-channel cooling

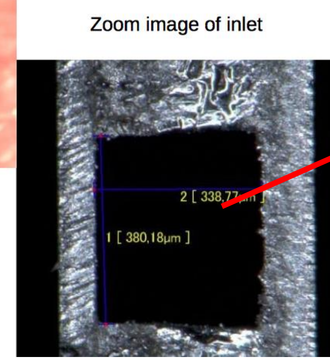
- ✓ Develop the building blocks that will lead to the "production standards" and best practice
- ✓ This will be achieved by
  1. access to the fabrication technologies at HLL and FBK
  2. development of a simulation library for micro-fluidics and bi-phase flows in distributed μ-channels
  3. development of a "standard" for the connection of the devices
  4. fabrication of prototypes to validate the models and characterize the different fabrication technologies

What such a facility should provide



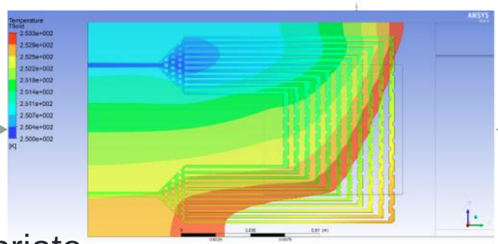
Access to fabrication technologies





Develop connectors for devices

In & outlet



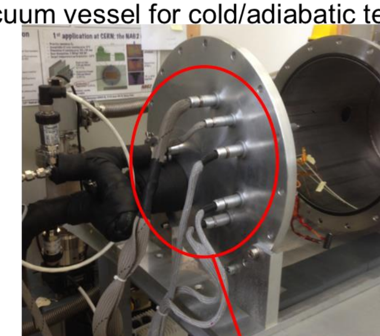
Model with appropriate FEA libraries and feedback to technology for optimal design

DAQ modules

Coriolis massflow meter

Flow/pressure regulation

Vacuum vessel for cold/adiabatic testing



A specialized facility to characterize devices and validate models

Feed-through lid(s)

Ports for IR/optical imaging

Low mass mechanical structures

- ✓Study of system issues of integrating detector modules and services into low mass support structures
- ✓The name of the game: stiffness under changing mechanical and thermal loads
- ✓Build up a “cloud” of specialized facilities that provide
  - ❑ Controlled loads to the tested devices (vibrations, thermal/humidity loads, etc.)
  - ❑ Systems to measure the mechanical and thermal characteristics nad performance of the test structures
  - ❑ A repository of validated FEA models
- ✓This should also provide
  - ❑ Standards for characterization and
  - ❑ Procedures for measurements

What do we need for such a facility?

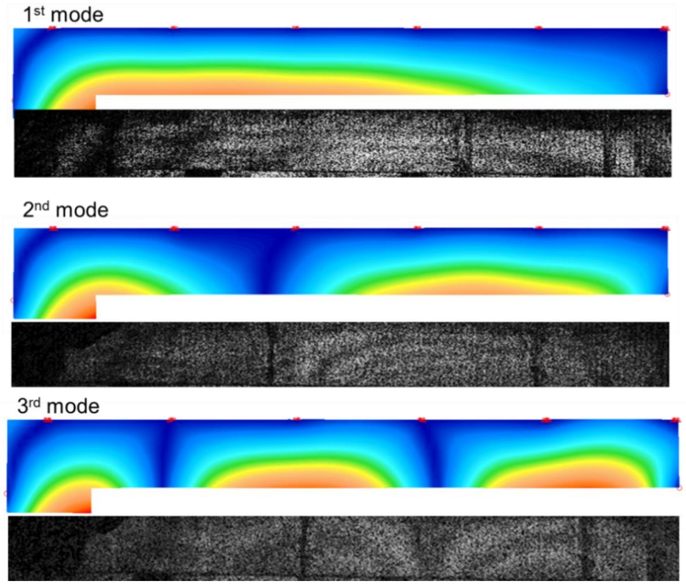
- Systems providing a load
  - Vibrations:
    - Acoustic, electro-magnetic, piezo, etc. excitations: good to study resonance frequencies/mode shapes, but difficult to assess amplitudes quantitatively (for a defined base ASD)
    - Shaker tables: not readily available (in particular for the low ASDs we need)
  - Thermal/humidity loads
    - Environmental chambers: quite common in small size, but not for objects of real tracker size
    - Heaters and cooling systems (on-detector cooling and environment)
  - Other (external) loads
- Systems to measure deformations
  - Deformations are typically small (few μm)
  - Resonance frequency and mode shape measurements for cross-checking and feeding FEA
  - For both these measurements we need to track deformation information over large surfaces
  - Preferably non-contact
  - Ideal are optical systems (ESPI, video survey systems, etc.), but they have sometimes constraints (some techniques need optically dispersive surfaces, targets, etc.)
  - Discrete systems (Electro-magnetic (capacitive, magnetic pick-ups), optical (laser reflection, FSI), etc….)

What do we need for such a facility?

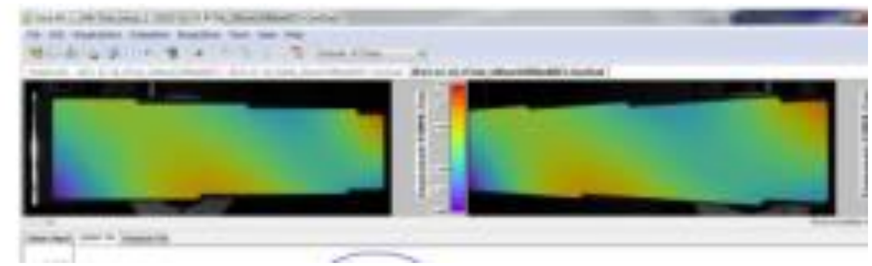
- ✓Other measurement and test systems
  - ❑Thermal imaging
  - ❑Material studies and composites QA (DSC, DMA, FTIR, …)
  - ❑Cooling pipes (pressure and leak testing, thermal shock tests,…)
- ✓Equipment like this does exist within the community at a few locations. The idea is to make it more widely available for the community
- ✓To make it useful we need input from you on what capabilities we actually should include into such a facility

Some examples of this equipment

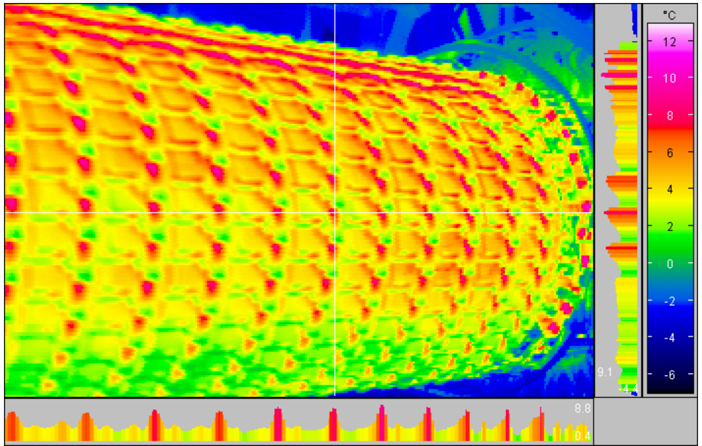
Comparison FEA – ESPI of ATLAS strip staves



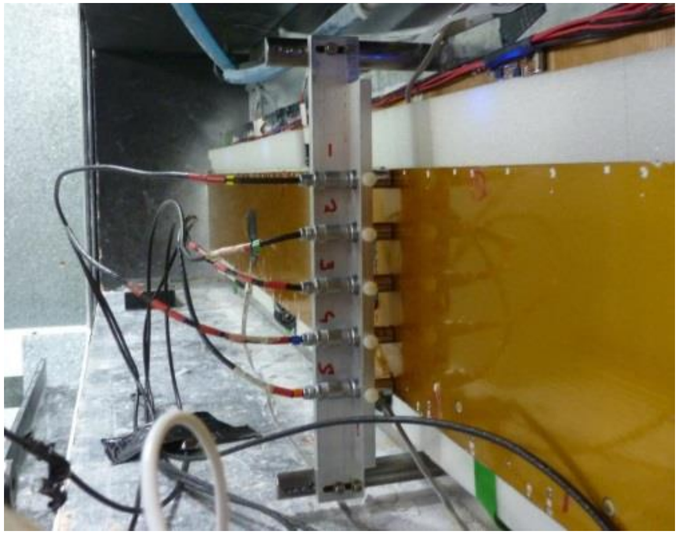
Mode shape studies using DIC



TI of ATLAS SCT barrel 5 (Ø80cm) in Oxford cold room



Capacitive displacement sensors



Beyond AIDA-2020

- ✓ We do not know yet if AIDA-2020 will fly
- ✓ However, it is clear that for the future detectors, with the challenging requirements that the physics goals impose in their performance, the integration of sensors, services and their mechanical support has a relevance that was not that obvious in the past.
- ✓ A new kind of “specialization” is needed that can only be provided by distributed knowledge and therefore even if AIDA-2020 does not fly this new paradigm is a route that we should explore.
- ✓ One aspect of the AIDA-2020 proposal will be facilities for characterizing micro-channel cooling and thermo-mechanical characterization of structures
    - ❑ Your input is needed on what capabilities will be useful for these facilities.