ATLAS Pixel Upgrade for HL-LHC

Elisabeth Petit
on behalf of the LPSC and LAPP teams

Enigmass general meeting
9th of December 2016

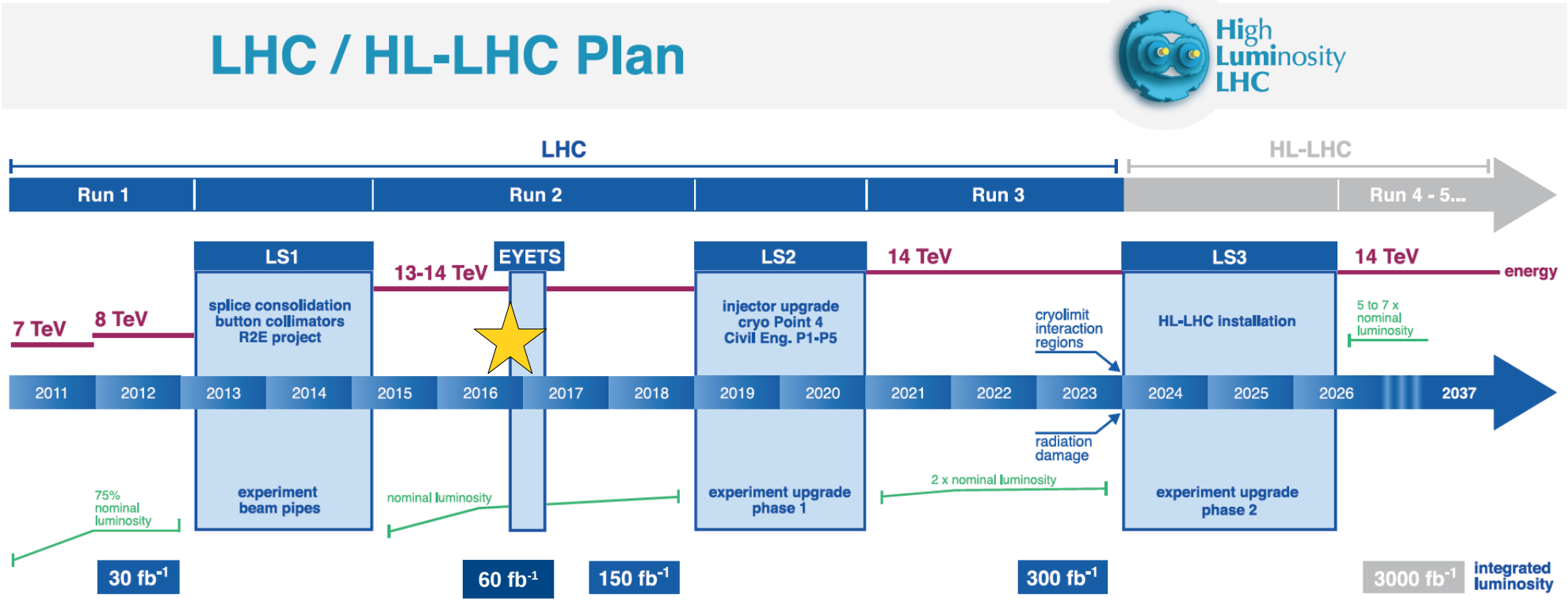
The teams

- Physicists:
  - P. Barroca, S. Jézéquel, R. Lafaye, J. Levêque, B. Smart (Enigmass Postdoc – 11/2018), A. Rummler (Enigmass Postdoc – 07/2017), S. Todorova
- Mechanics:
  - P. Delebecque, N. Geffroy, D. Kiteze (Enigmass CDD – xx/2016), T. Rambure
- Electronics:
  - N. Massol, P.Y. David, J. M. Nappa, S. Vilalte

- Physicists:
  - A. Bethani (Enigmass post-doc – 08-16), J. Collot, F. Ledroit, E. Petit, N. Readioff (Enigmass post-doc 01/16 –), J. Stark
- Mechanics:
  - D. Bondoux, D. Grondin, C. Le Tulle, J.F. Muraz, L. Vivargent
- Electronics:
  - L. Eraud, J.P. Scordilis

The ITk projet

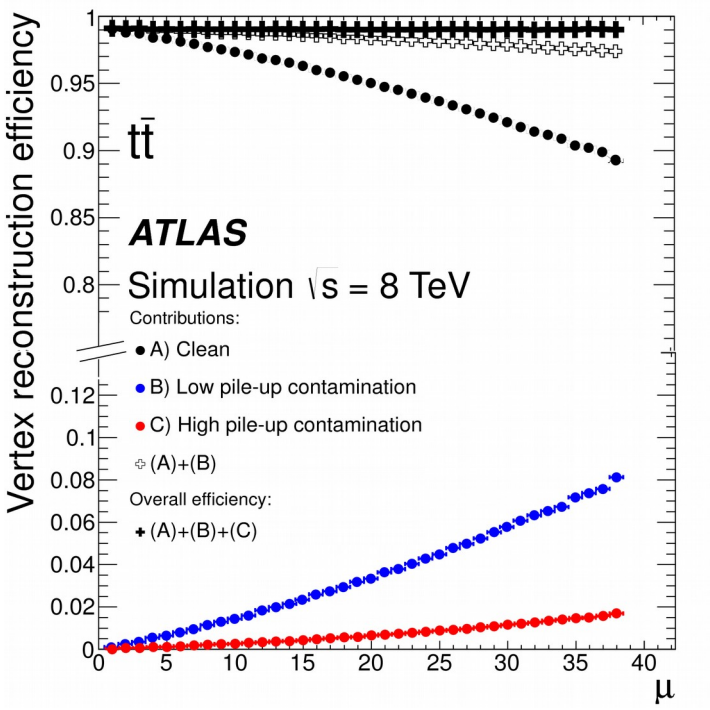
- HL-LHC officially approved by CERN council last June

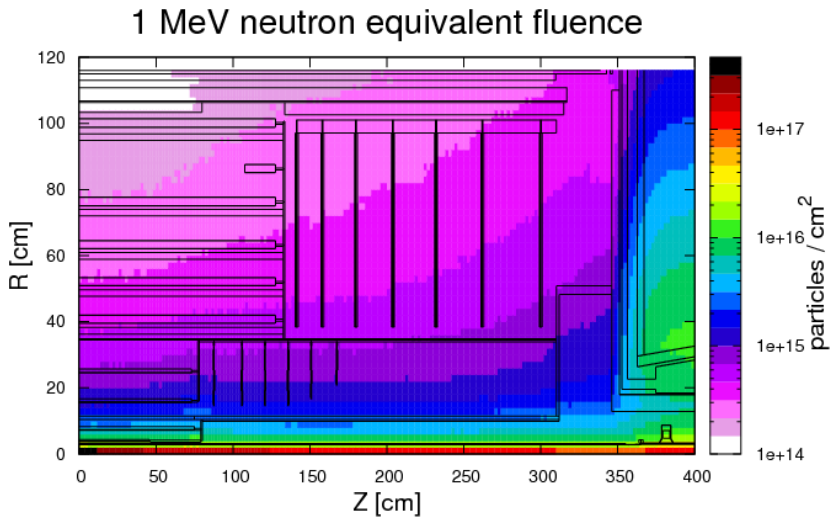


- Biggest upgrade of the ATLAS experiment: replace the inner detector
  - entirely made of silicon
  - pixel and strip technology
  - 100/138 ATLAS institutes involved (5/6 IN2P3 institutes)

Why a new inner detector

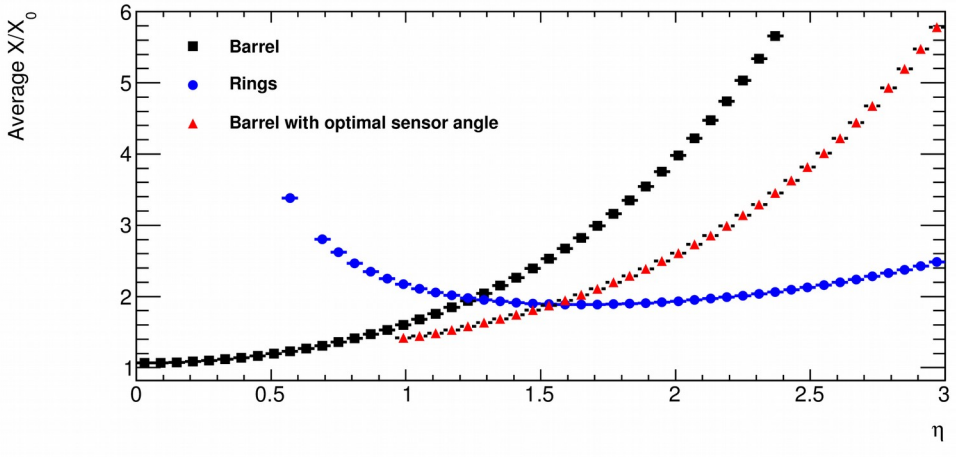
- Expected number of interactions /bunch crossing (pile-up): 200
  - ATLAS design value: 25
  - better detector needed to maintain tracking, vertexing, b-tagging performance
- Much higher radiation environment
  - total ionisation dose: 7.7 MGy
  - end of Run 3: 1.5 MGy → ATLAS design
- Extension of the tracker acceptance
  - η = 2.5 → 3.2 or 4.0
  - increase of lepton acceptance
  - pile-up rejection

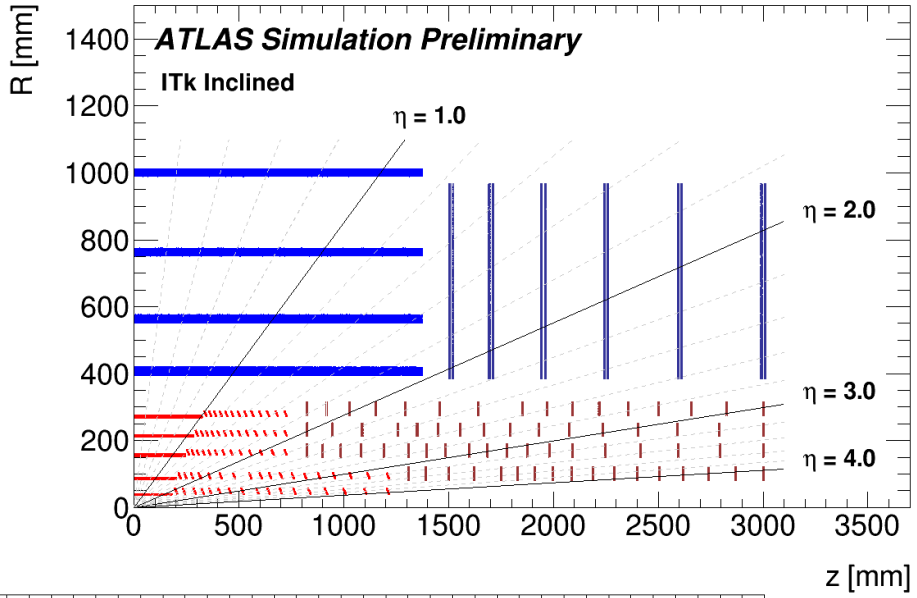


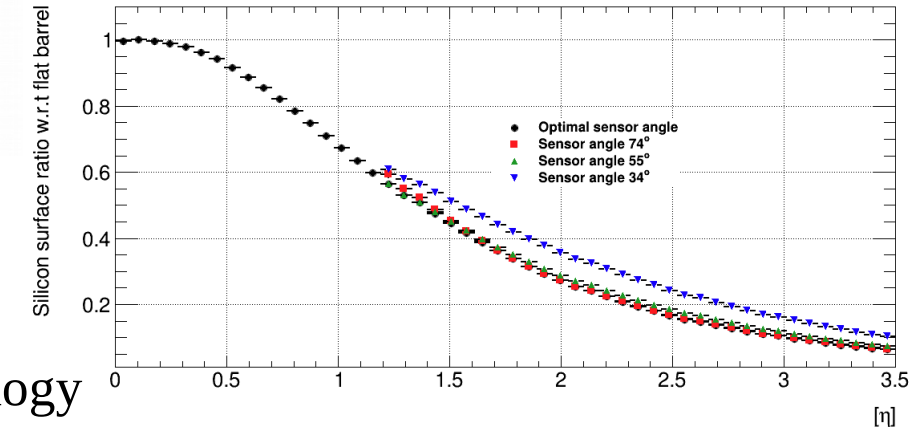


Inclined layouts

- Main idea: sensors perpendicular to track
  - less material
  - less silicon needed



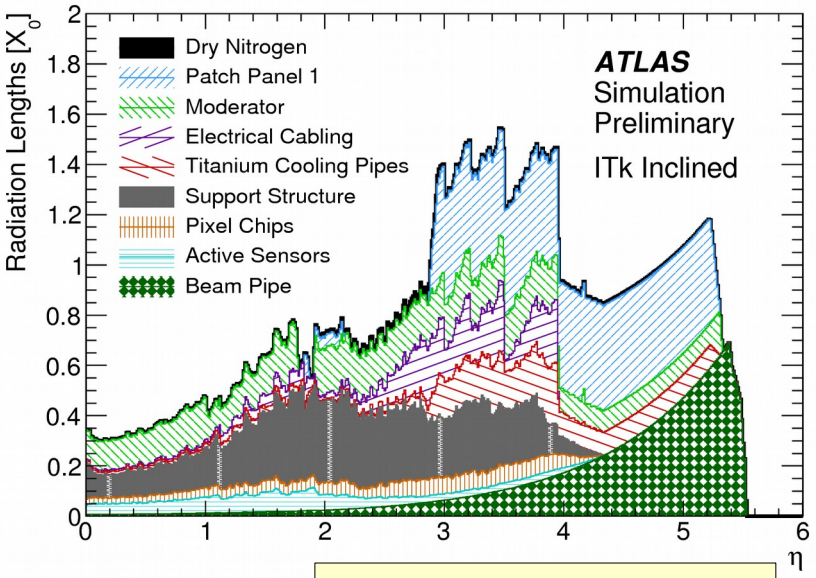




- Proposed by LAPP in 2011
  - LPSC joined the effort in 2014
  - *Alpine* layout based on IBL technology
    - additional pixel layer for Run 2, LAPP and LPSC involved
- Growing collaboration between all teams working on an inclined layout
  - CERN, Uni Genève, LAPP, LPSC, ...
  - working now on a common design

Simulation

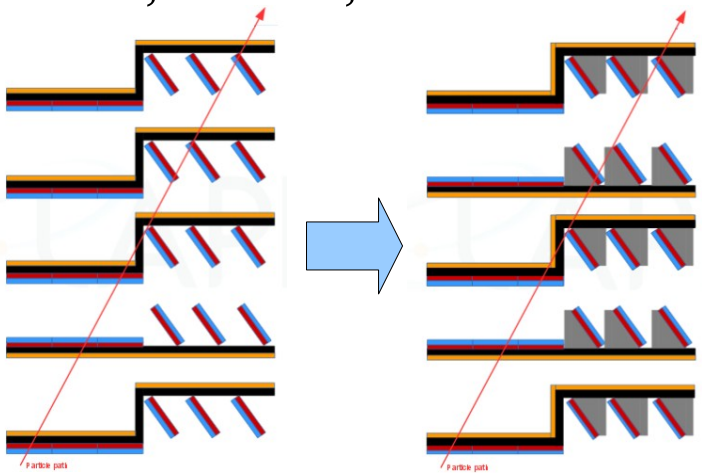
- Detector geometry description developed with LAPP now widely used in ATLAS
  - used for results in ECFA, will be used for the choice of layout and the Strip TDR
  - includes tool to compute radiation length



Ben Smart, Enigmass post-doc

- More and more precise description of layouts
  - support structures, services, ...

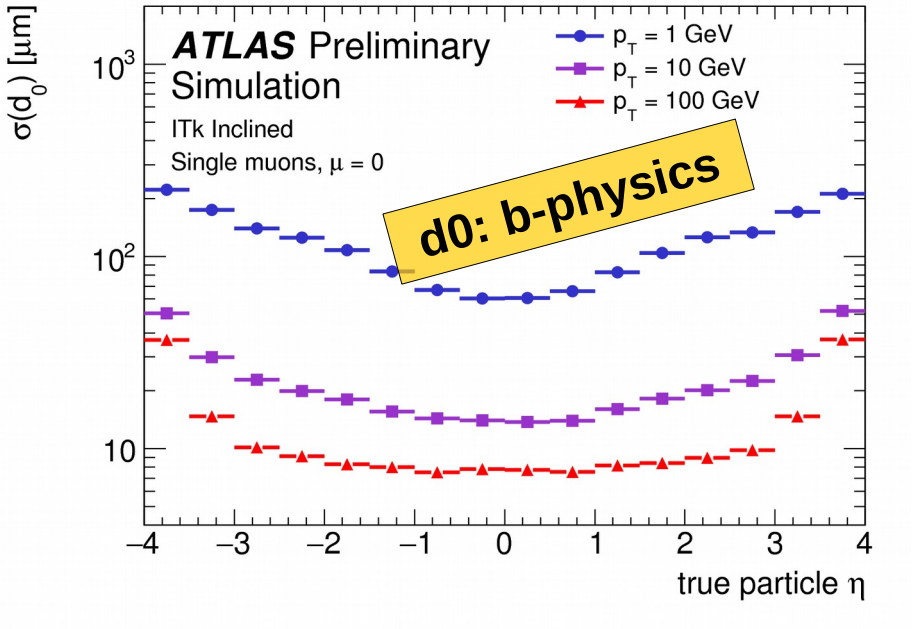
pixel sensors
pixel chips
support structure
services

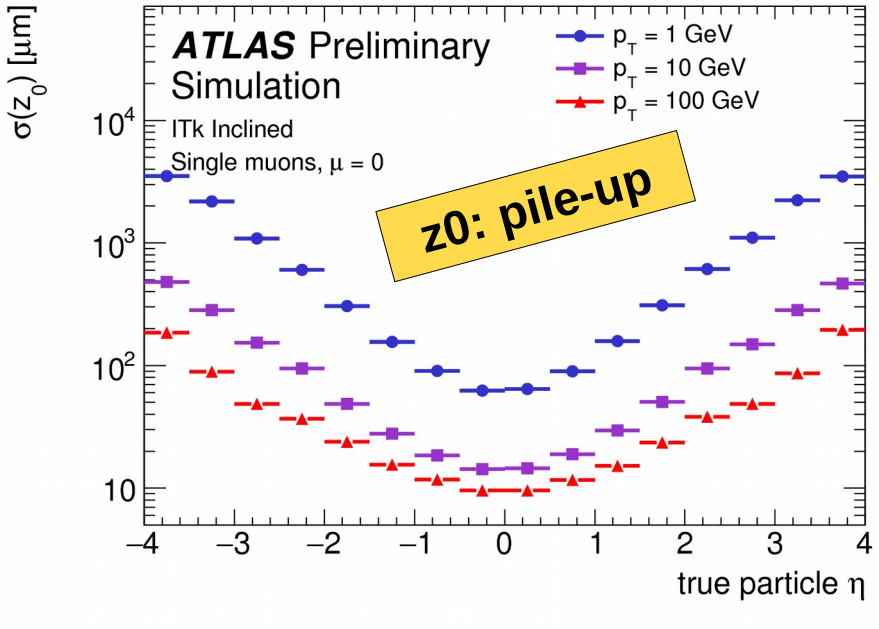


- Public code for optimisation of layout
  - transition between flat, inclined, ring
  - position of sensors
  - ...

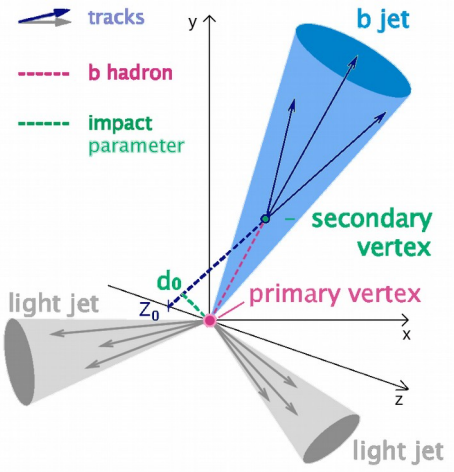
Performance

- Tracking performance for inclined layout shown in the last ECFA meeting
  - similar to ATLAS Run-2, with 10 times more pile-up



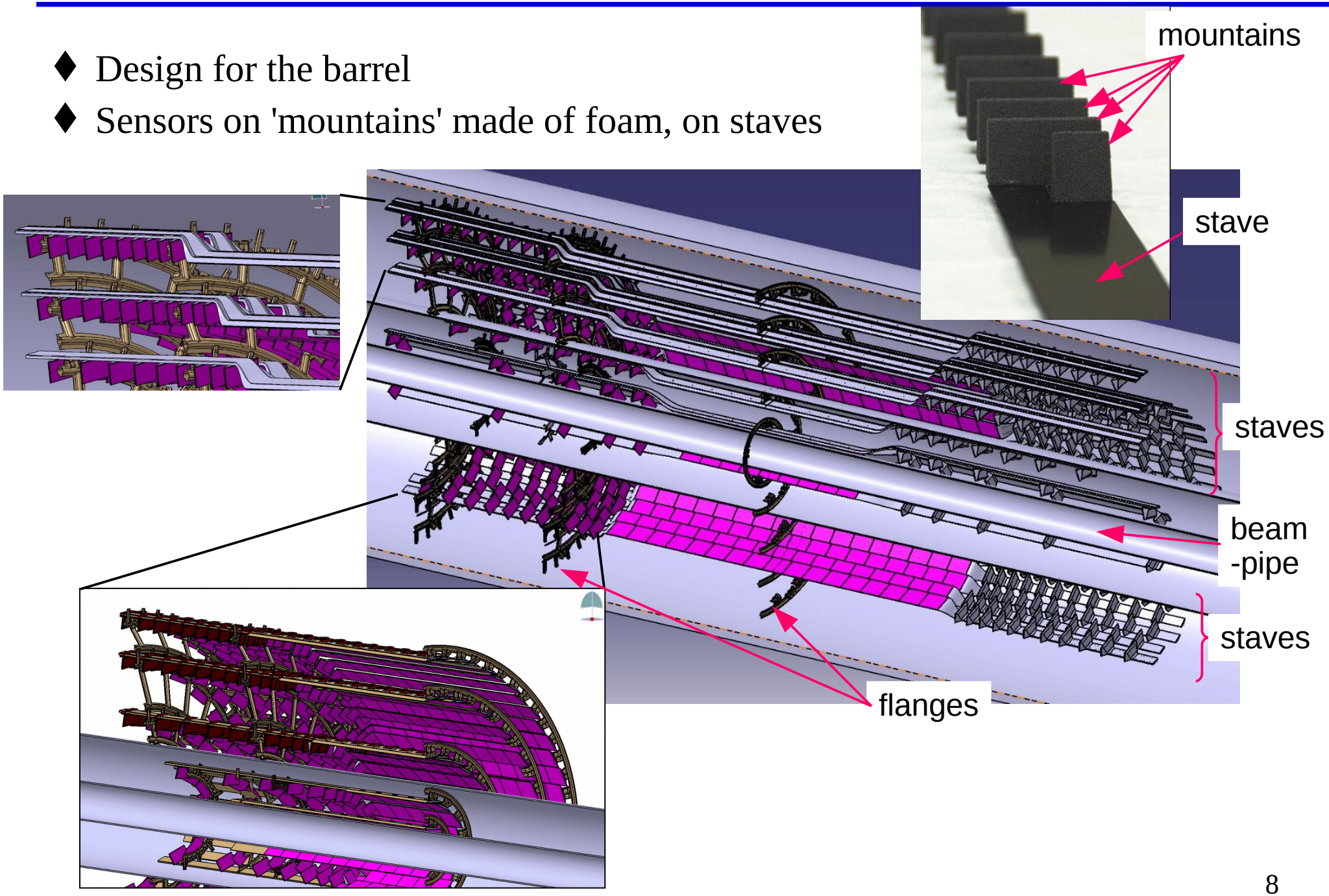


- Work ongoing to check effect on performance
  - of material in general
  - of services (description, position)
  - of pixel pinch and chip orientation
  - ...



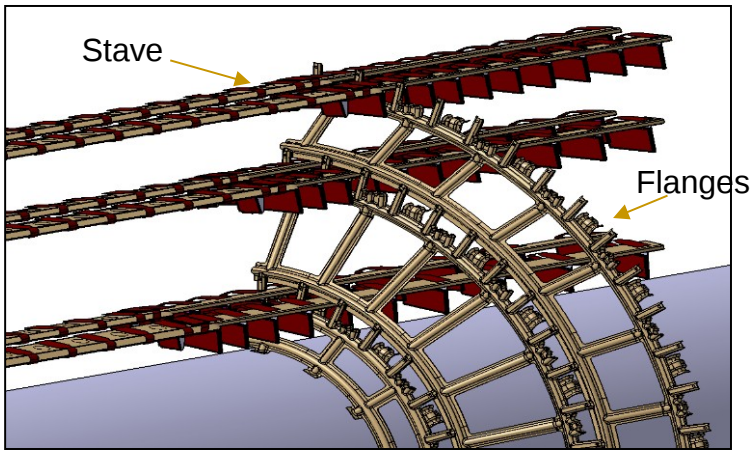
Mechanics: Alpine layout 2.0 (1)

- Design for the barrel
- Sensors on 'mountains' made of foam, on staves

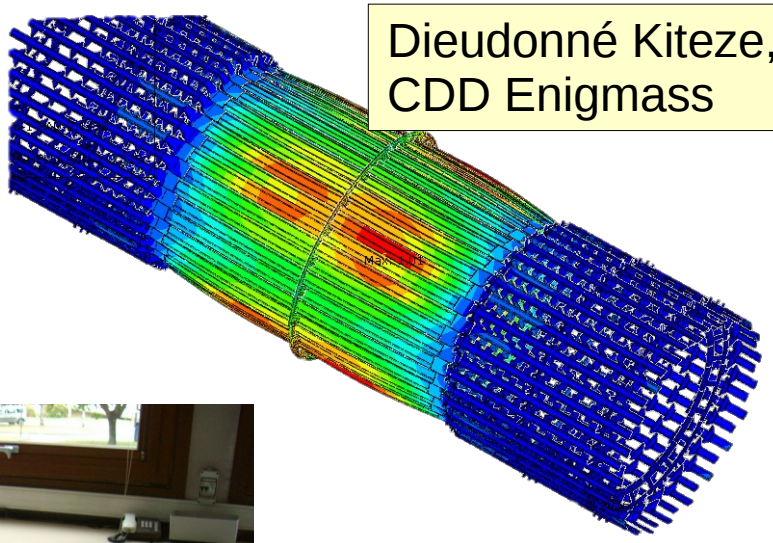


Mechanics: Alpine layout 2.0 (2)

- Mechanical performance tested on simulation
  - optimisation of the number and positions of the flanges which support the structure

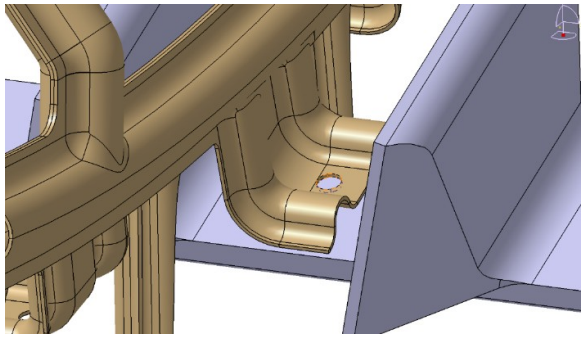


- Sagging and natural frequency fulfilling ATLAS specifications



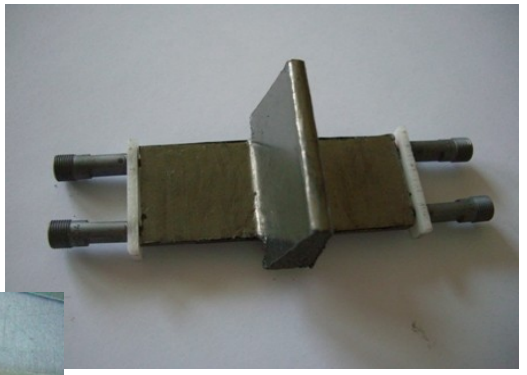
Dieudonné Kiteze, CDD Enigmass

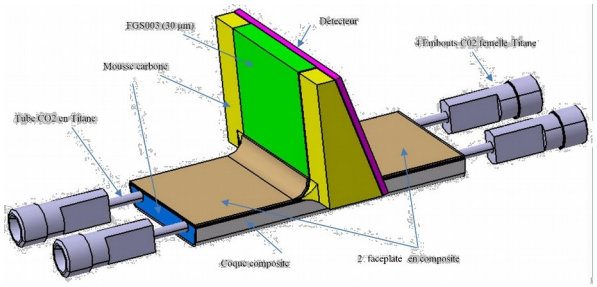
- Tests of stave/flanges link assumptions
  - with FEA simulation
  - laser test bench being developed at LPSC

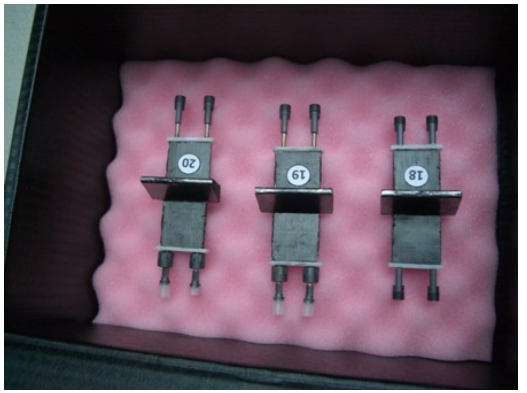


Mechanics: prototypes

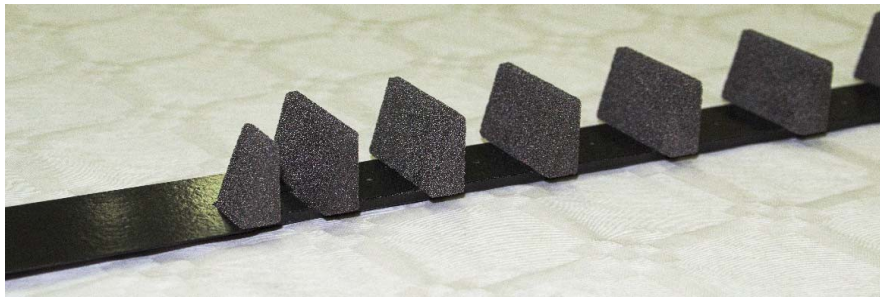
- 12 prototypes of *Alpine* mountains made at LPSC
  - for thermal measurements at LAPP
  - different materials, geometries, pipes, etc





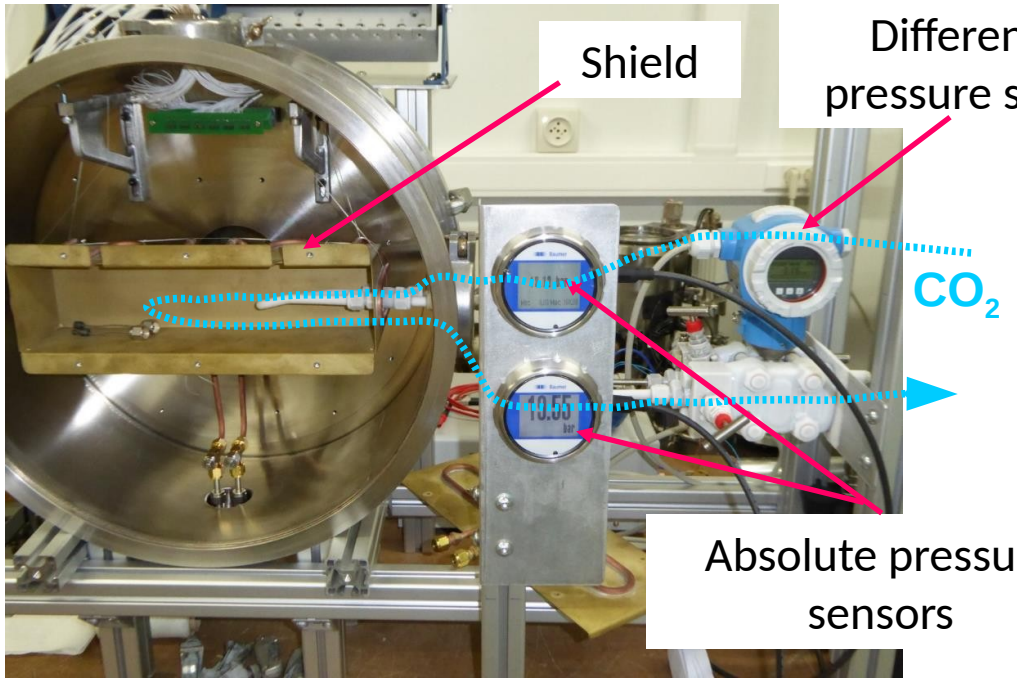


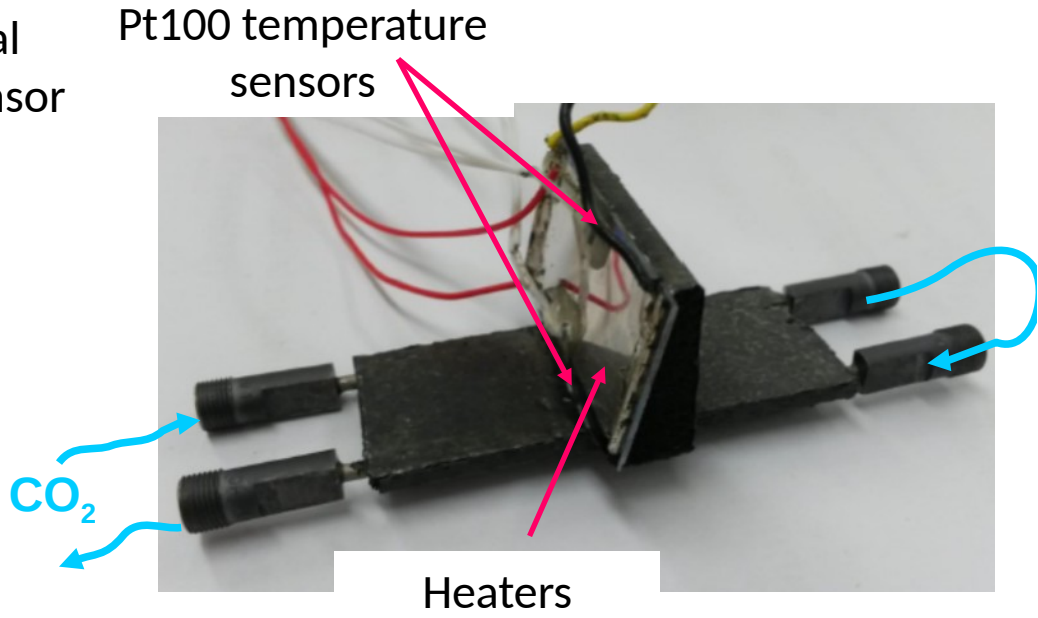
- Also long size prototypes made for mechanical validations



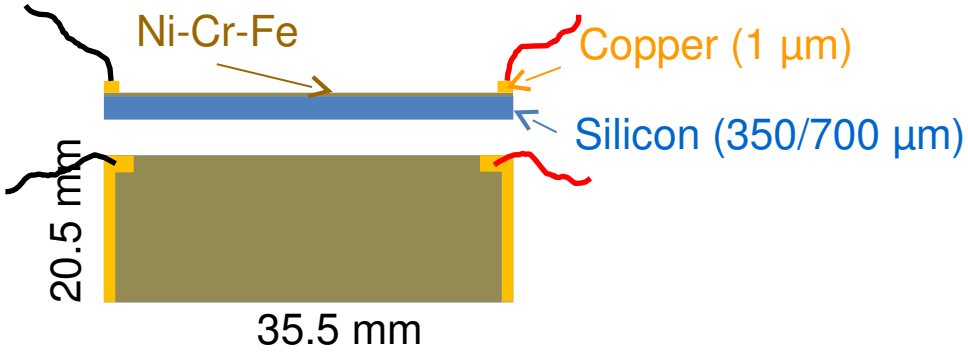
Mechanics: thermal measurements (1)

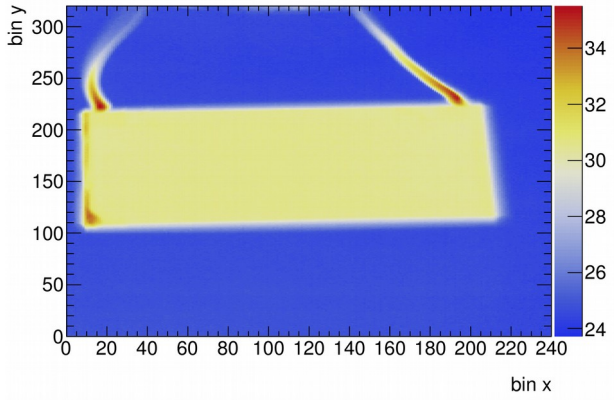
- New setup developed at LAPP:





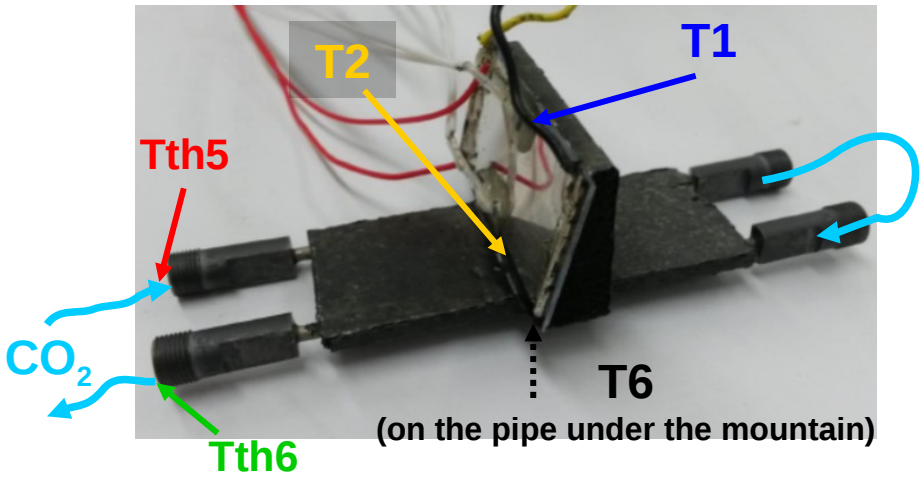
- Heaters to mimic the sensors made at LPSC:
  - homogeneity controlled with IR camera: < 0.7°C

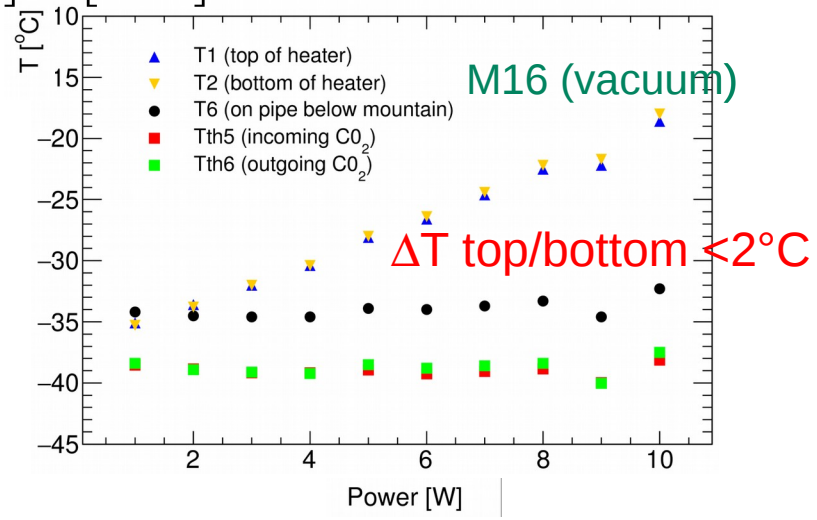




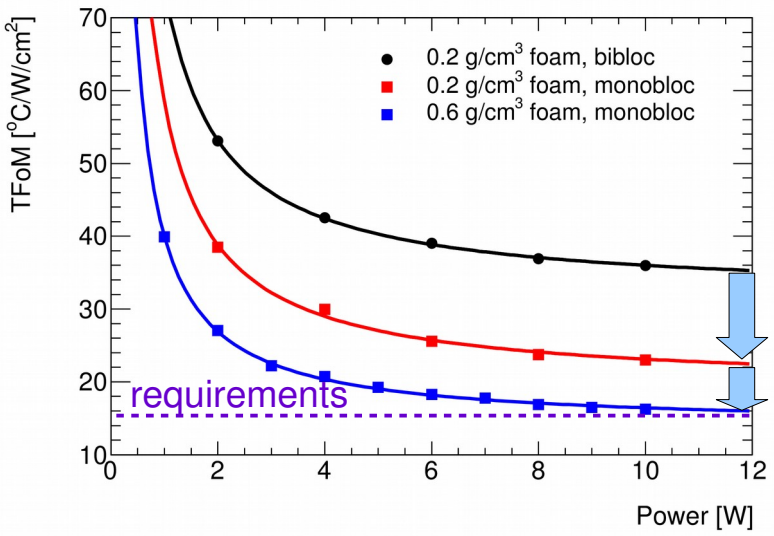
Mechanics: thermal results (2)

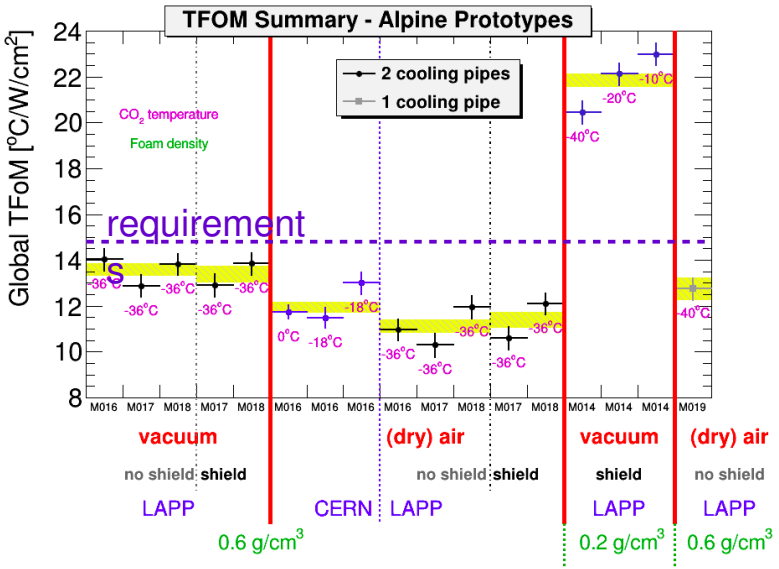
- Thermal figure of merit: $TFoM = \frac{T_1 - T_{th6}[^\circ C]}{P[W]/S[cm^2]}$





- Improvement of prototypes:



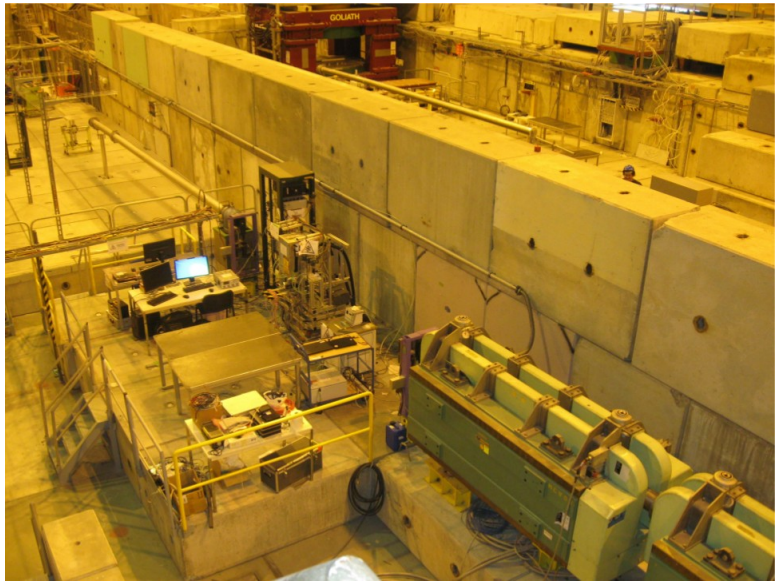


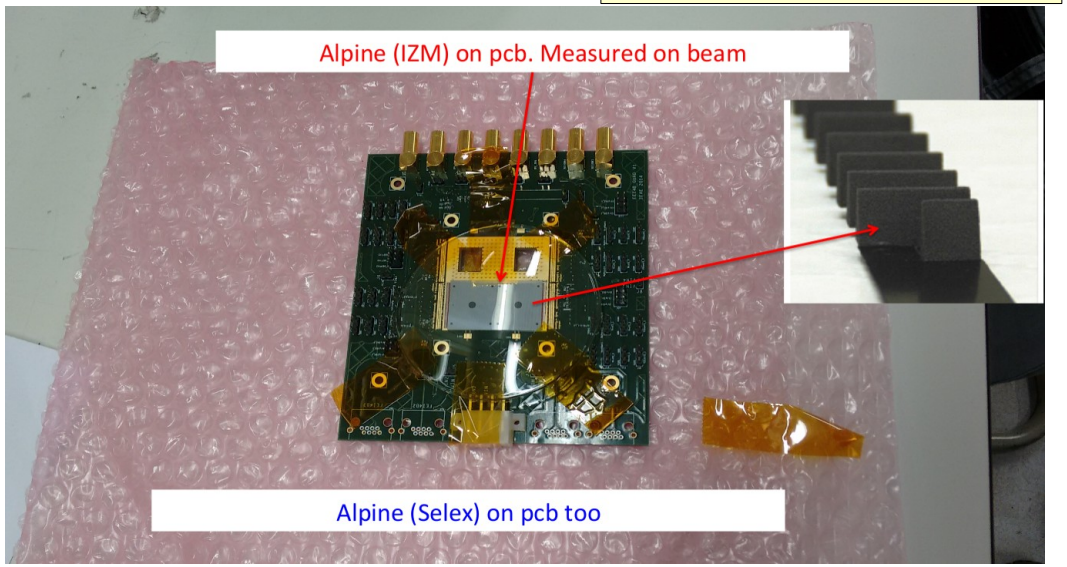
- Best thermal results in ATLAS so far

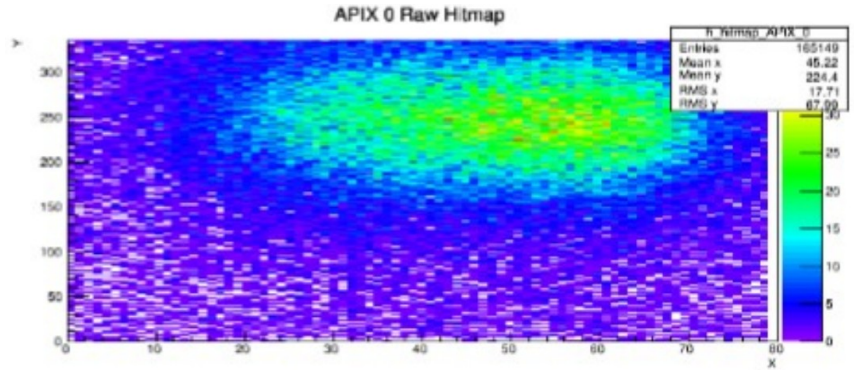
Electronics: module tests

- First pixel sensors adapted to inclined layout
  - dedicated chip orientation
  - collaboration with Barcelona, LPNHE, CERN
- Tested in the lab at LAPP
- Tested in test beams at CERN last summer

André Rummler,
Enigmass post-doc



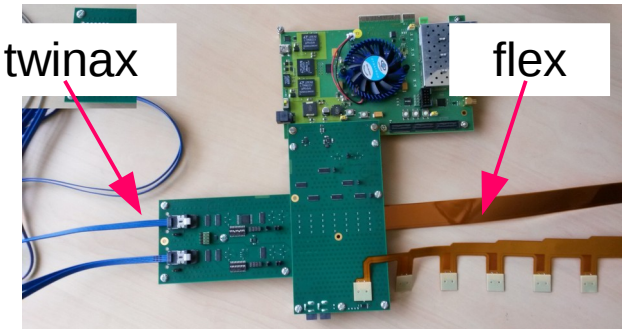




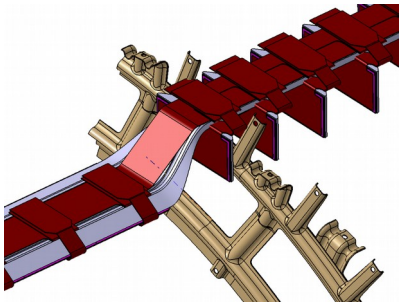
- Analysis of results ongoing

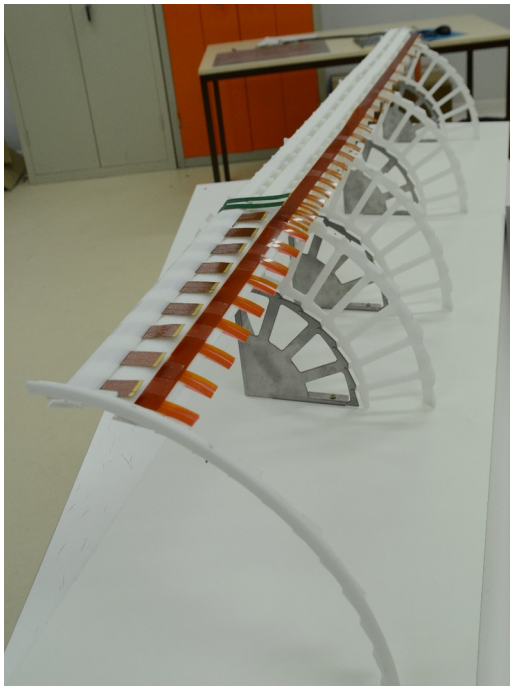
Electronics: services (1)

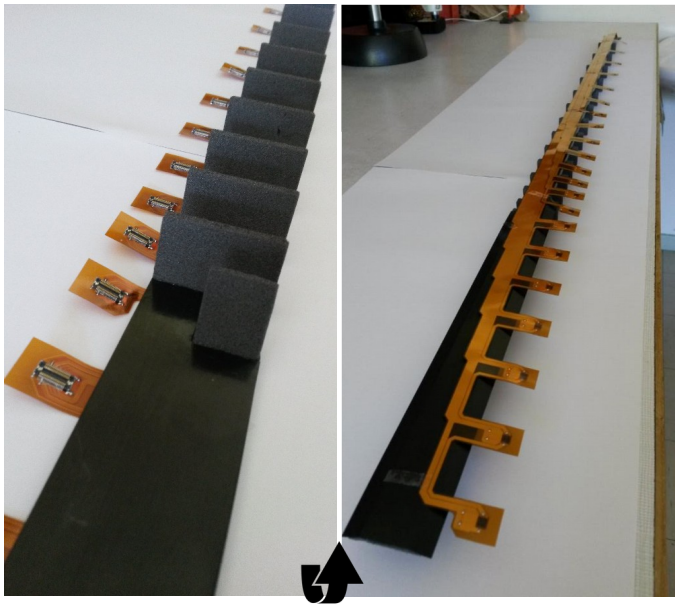
- Flex cables proposed by LAPP
  - 10 times less X_0 than other solution (twinax cables)



- Interplay with mechanics: routing of services
  - also for common design with CERN/Geneva

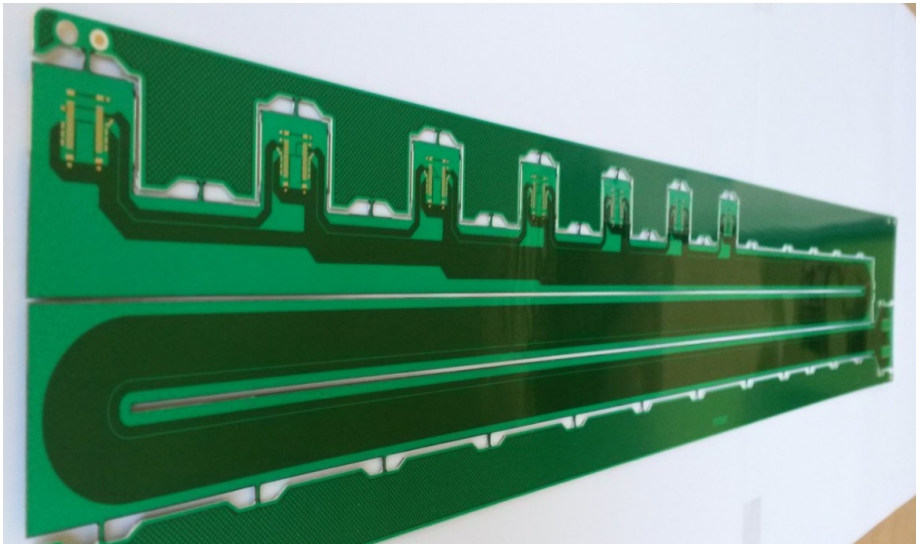




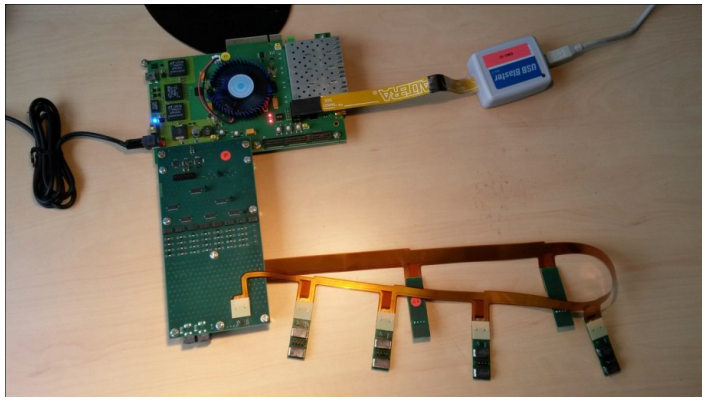


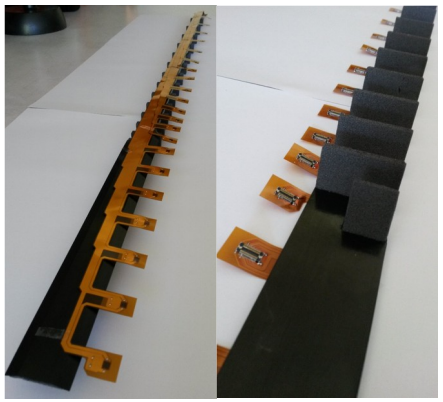
Electronics: services (2)

- Now industrial version produced
  - long flexes



- Test of rates
  - ATLAS requirements met! (5 Gb/s)





- Irradiation tests started

Next steps

- ATLAS wide:
  - Feb 2017: choice between 'inclined' and 'extended barrel' concepts
    - main criteria: physics performance, thermal performance, material/weight, total cost
  - Q3 2017: final choice of layout
  - End of 2017: pixel Technical Design Report (TDR)

- For us: huge implication in TDR preparation
  - simulation, tracking, performance
  - common layout design with CERN and Geneva
  - size 1 prototypes (including flexes, improved heaters)
  - new sensors for tests of module flex

- Preparation for ITK construction
  - thermo-mechanical bench with ^{90}Sr source at LAPP
  - glue lab for module loading at LPSC
  - CO_2 cooling system

Conclusion

- Inclined layout now serious option for the ITk project
  - decision next February
- Performance of Alpine layout assessed, meeting requirements
  - best thermal performance among all proposals
  - possible to cool an inclined layout!
- Recognised expertise in detector geometry and simulation
- Next year fully busy in the preparation of the TDR
- Also start of work towards the construction of Itk

Back-up

Next steps: longer term