# ATLAS Upgrade
# Detector and Physics

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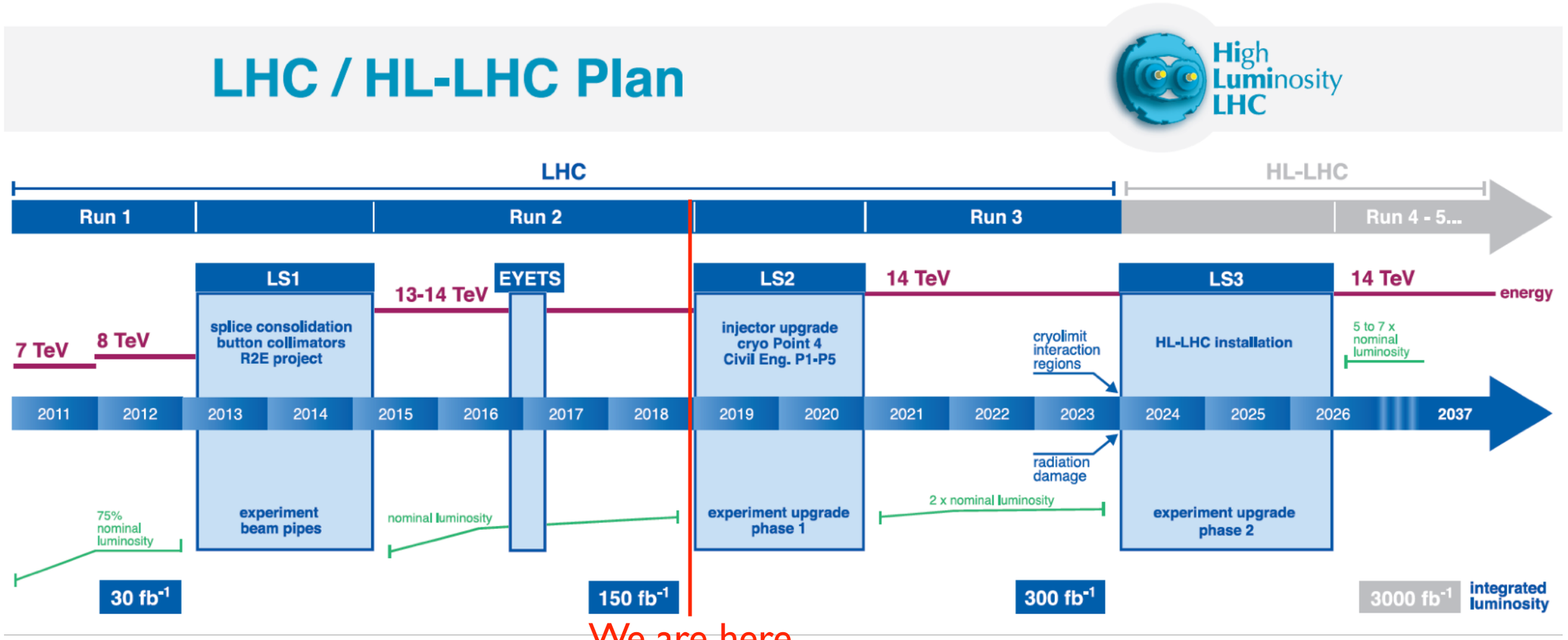
on behalf of ATLAS LPSC & LAPP Groups
28/11/18



# Introduction

- Extensive work ongoing to prepare for various future upgrades to LHC and ATLAS
- Phase 1 to be implemented in next long shutdown
  - Maintenance and upgrades of collider and detectors
- Phase 2 to begin after Run 3 completed
  - Transition from LHC to High-Luminosity LHC (HL-LHC)
- HL-LHC will be first Higgs factory
  - Will allow precision measurements of Higgs couplings and differential cross-sections
  - Will provide access to rare decays
  - Will provide probes for New Physics
  - ATLAS detector will receive significant improvements and upgrades



# Laboratory Activities

- LAPP and LPSC have complete set of activities covering ATLAS hardware, software, and physics studies
- Phase 1:
  - LAr Calorimeter upgrades
- Phase 2:
  - Further LAr Calorimeter upgrades
  - New ATLAS Inner Tracker R&D
    - Pixel Detector stave design, prototype construction and testing
    - $CO_2$ cooling studies
    - Detector modelling and simulation
  - Preparation for ATLAS inner tracker construction
  - Documentation of ATLAS inner tracker (Pixel TDR…)

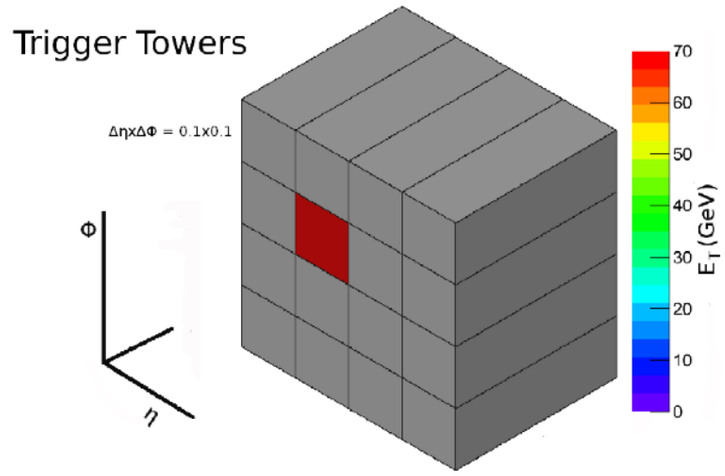
- Efforts ongoing to provide complete picture of Higgs physics at HL-LHC, with 3000 $fb^{-1}$ at 14 TeV
  - Preparation of upcoming CERN Yellow Report (input to the European strategy forum)
- Prospects studies being refined to take into account:
  - Effects of latest ATLAS detector upgrade geometries
  - Improved understanding of particle/object reconstruction performances
  - Improved analysis techniques developed for Run 2 (36 $fb^{-1}$ at 13 TeV)
  - Improved theoretical calculations
- LAPP and LPSC studying:
  - Higgs couplings
  - Vector boson scattering
  - diHiggs production (measurements of Higgs self-coupling constant)
- Also evaluating physics potential of HE-LHC, with 15 $ab^{-1}$ at 27 TeV

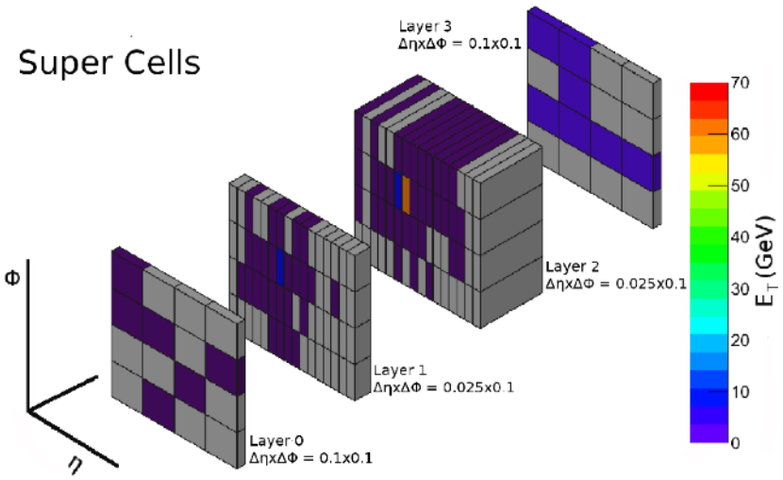
- Presentation will focus on ENIGMASS funded activities

# LAr Calorimeter Upgrades: Phase 1

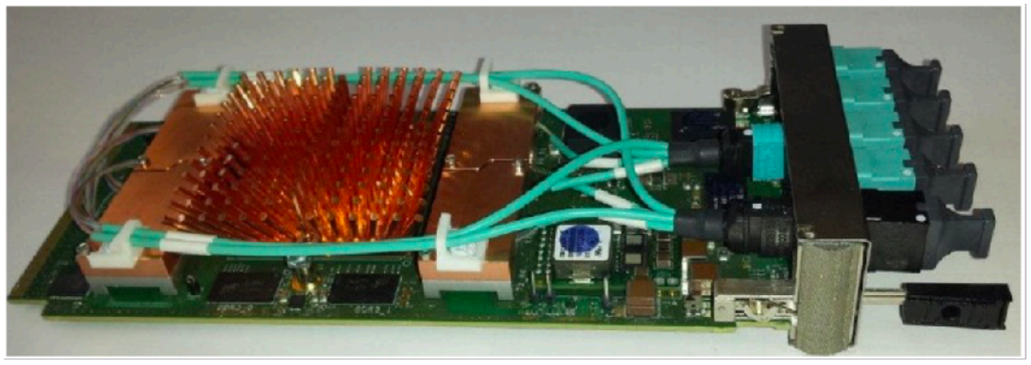
- ATLAS currently groups LAr cells into 5.4k towers for trigger readout
- Phase 1 upgrade to change grouping into 34k supercells

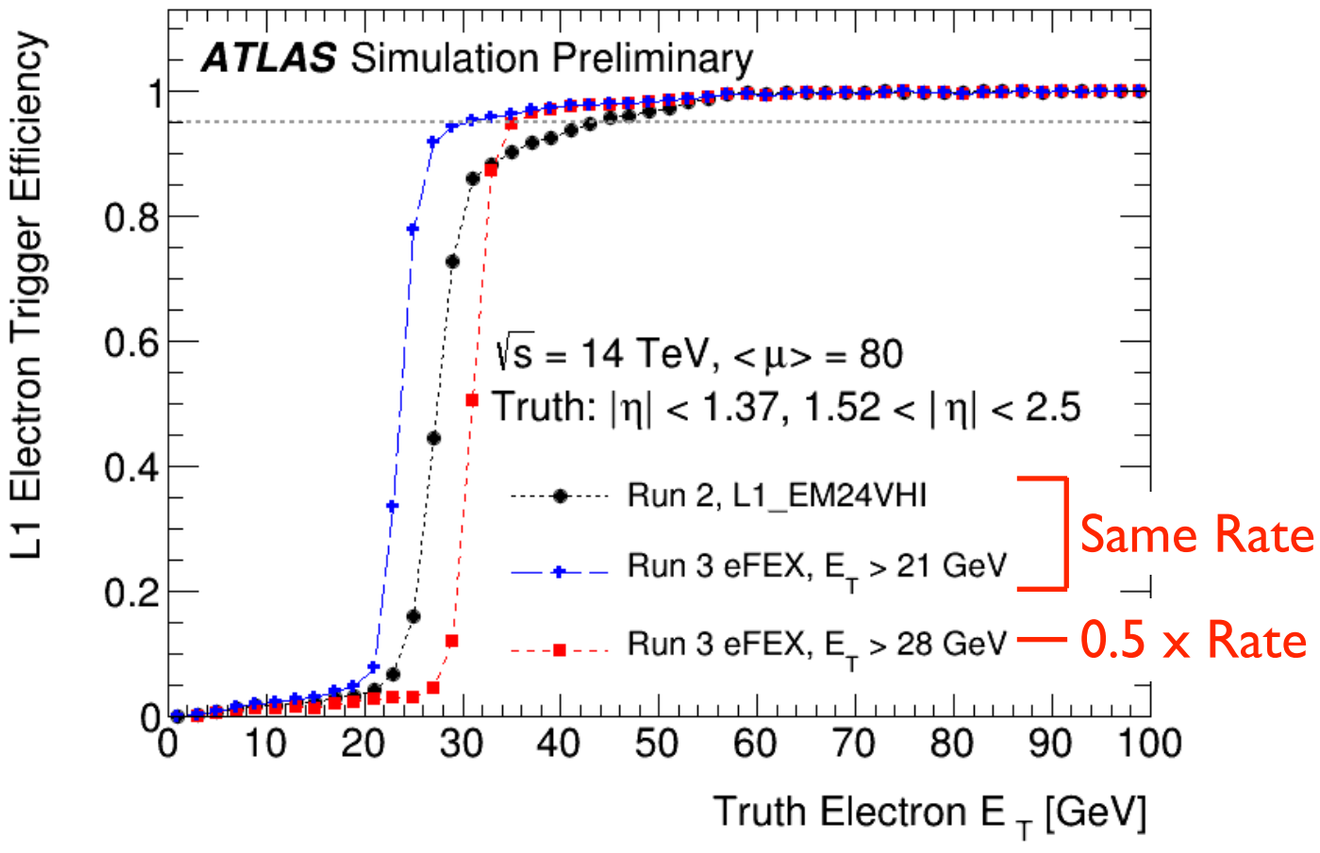
- Use of the supercells provides:
  - Longitudinal layer information
  - Higher granularity in η (front and middle layers)
  - Shower shape information to the L1 trigger
    - Better rejection of jet background with electron triggers
  - Significant improvement in energy resolution
  - e/γ trigger performance improvements (+ jets, $E_T^{miss}$ and τ)




LAPP responsible for developing back-end mezzanine cards, 150 cards in progress

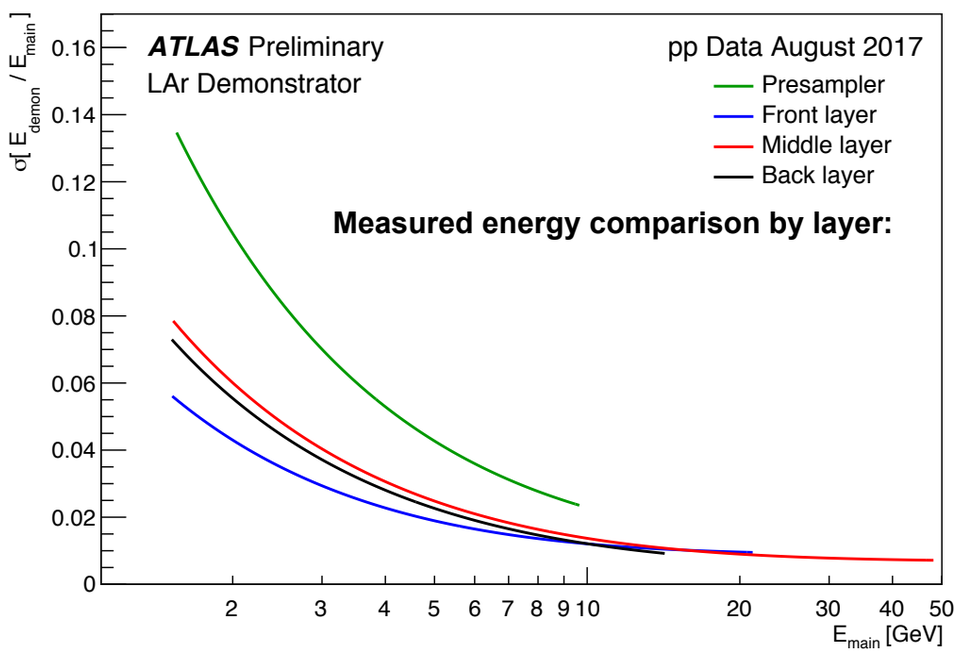


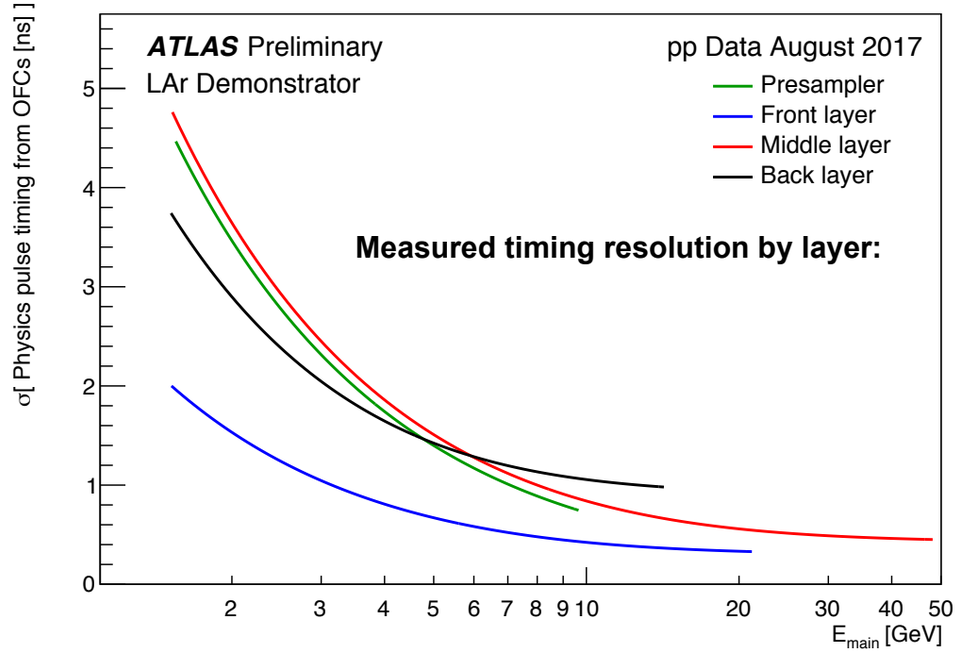


# LAr Calorimeter Upgrades: First supercell results (1)

- Demonstrator installed and taking data since 2015 (upgraded in 2018 to the latest readout version)
- Two different prototypes of LAr Trigger Digitizer boards (LTDBs):
  - One for region φ = 1.81 and φ = 1.91
  - One for region φ = 2.01 and φ = 2.11
  - Results in different calibration, slightly different results for those regions

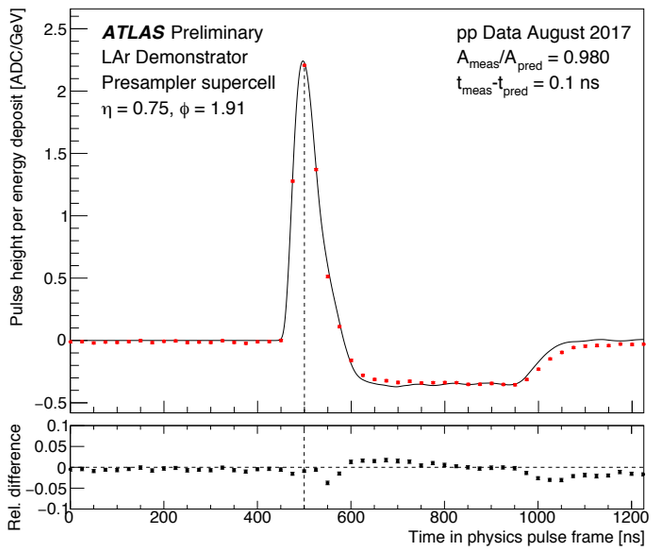
- Data obtained from pp collisions, physics run 334487, recorded on August 30, 2017
- Events from LAr demonstrator matched to events collected in main read-out
  - Using bunch-crossing ID and bunch-crossing time (alternative method matches L1 ID of events)
- Dedicated calibration coefficients obtained for supercells
  - Based on calibration scheme for LAr cells, using adapted code framework
- First supercell results:
  - Energy-dependence of energy comparison and timing resolution:
  - Width of energy ratio approaches 1-2%
  - Timing resolution approaches 0.5-1.0 ns, possible to identify bunch crossing

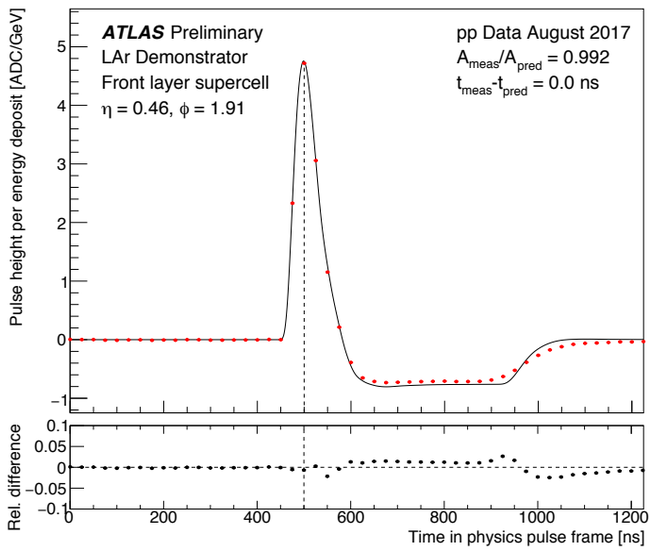


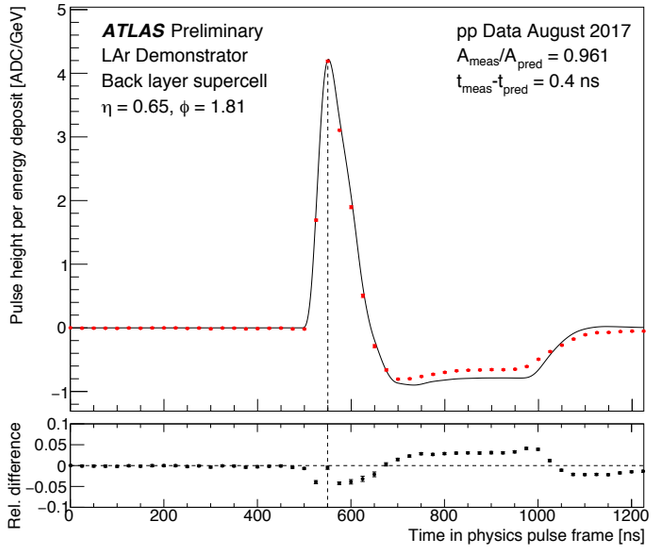



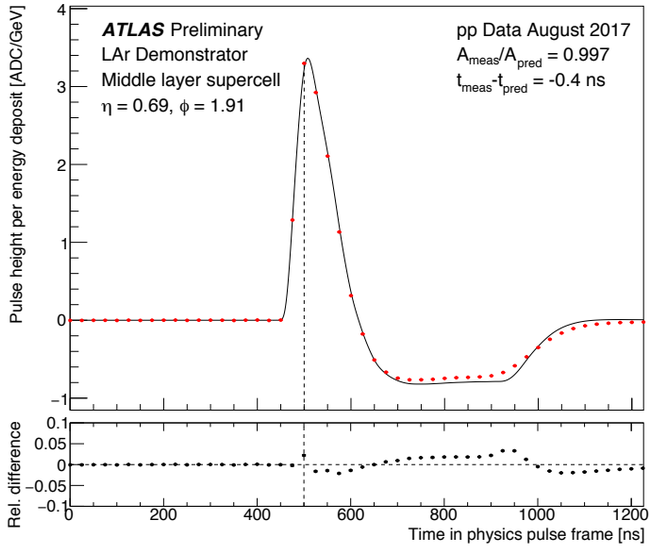
# LAr Calorimeter Upgrades: First supercell results (2)

- Measured pulse shapes for each layer:
  - Measured pulse shapes (red) of supercells in the LAr Phase I demonstrator
  - Independently obtained, predicted pulse shapes (black)
- Good agreement is observed between measurement and prediction
  - Remaining small normalisation offsets are due to the preliminary calibration of the supercells.



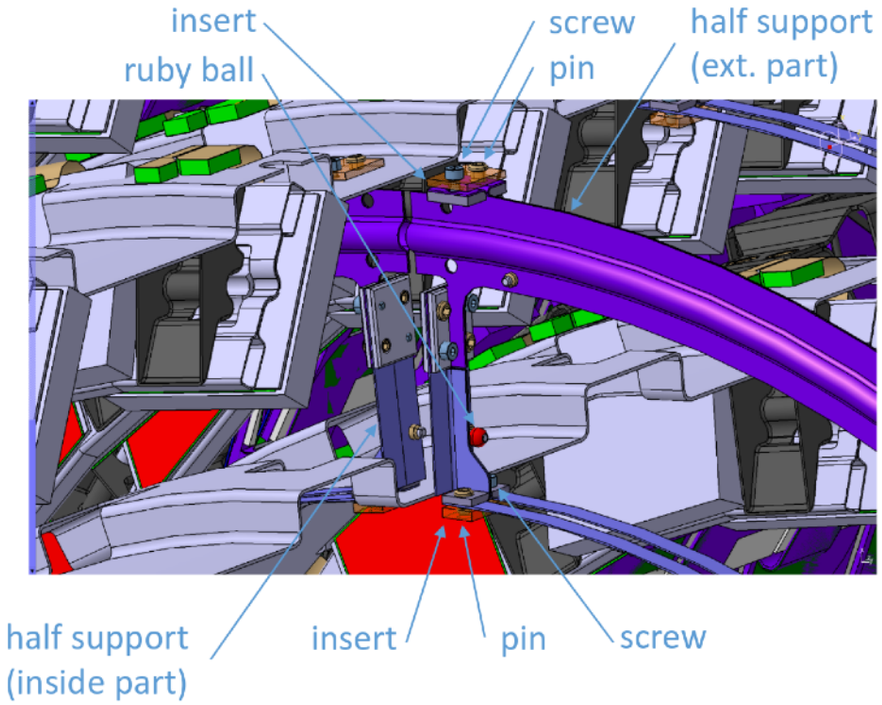



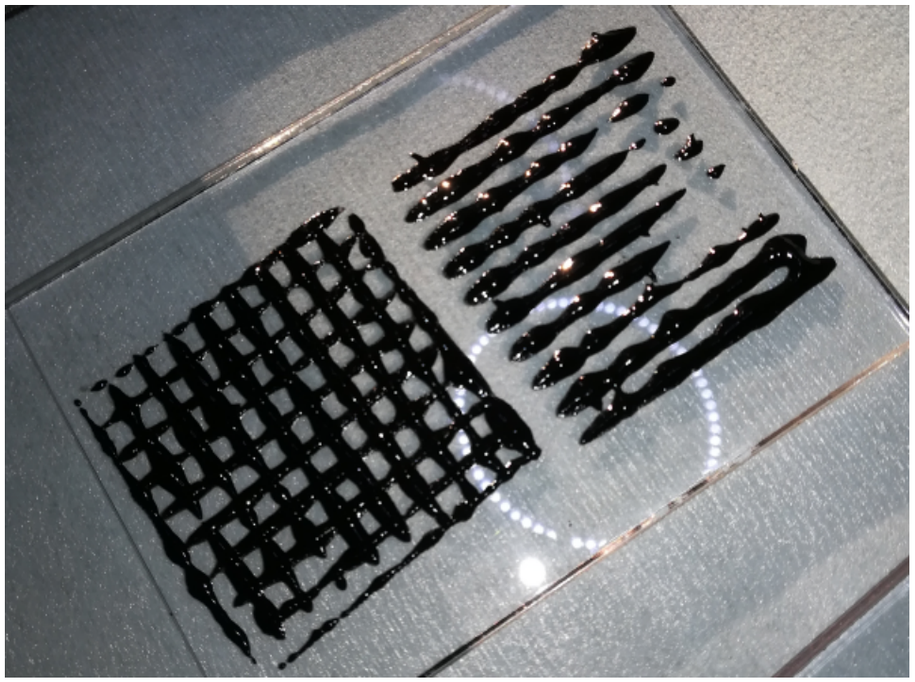



# Detector Upgrade: Mechanical Activities

- LPSC responsible for design and production of intermediate flanges
- LAPP performing extensive work on simulation models



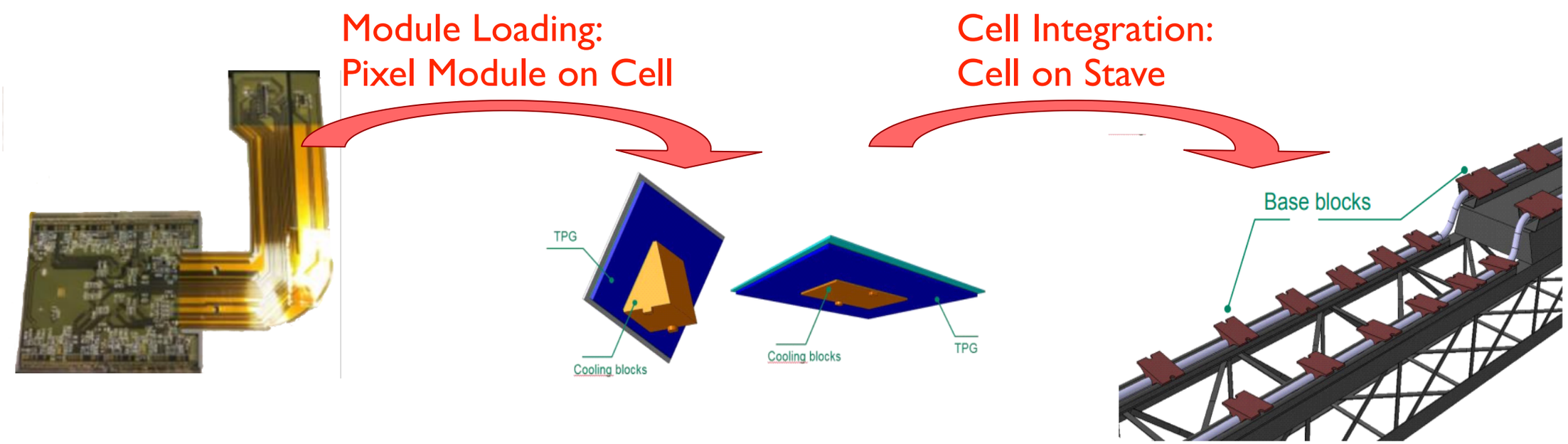

- Studies on glue deposit for module-on-mechanical structures loading
  - Choice of glue (radiation hardness, viscosity, etc)
  - Test of deposits with stamps



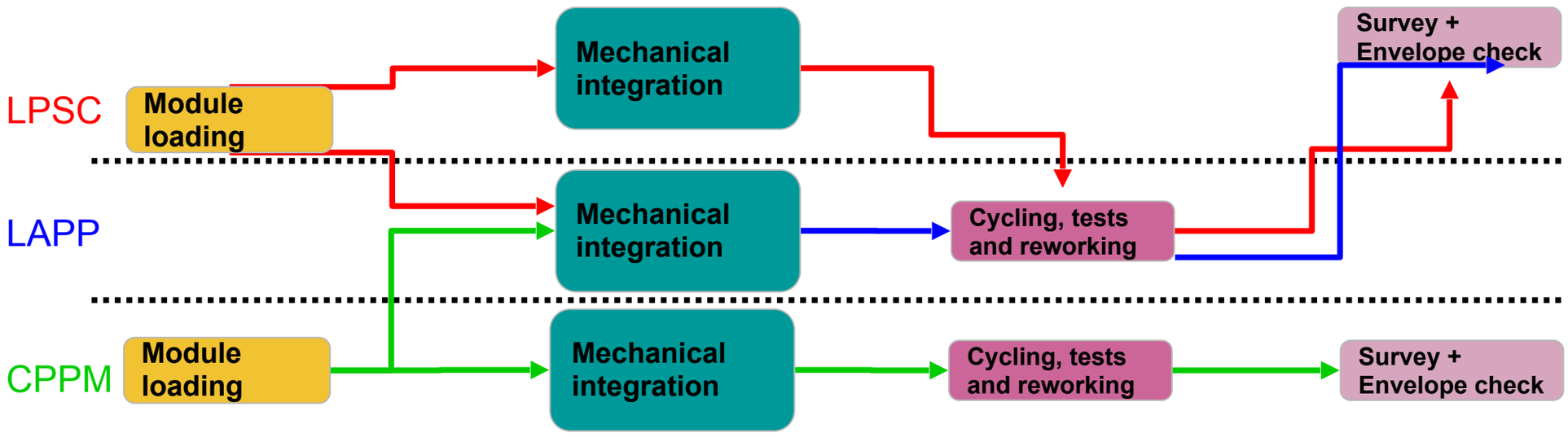
- Clean room at LPSC ready last spring
- MMT (metrology machine for loading) installed last week!

# Construction: Alpaca Cluster (CPPM-LAPP-LPSC)

- Simplified sketch of module loading/integration in two steps:

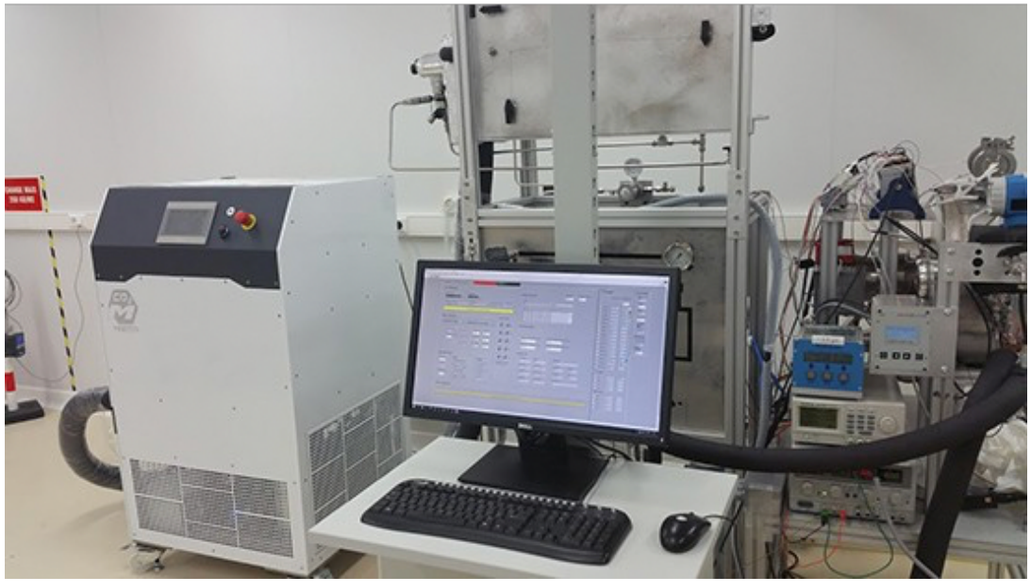



- New organisation for production:
- Module loading: task sharing between LPSC and CPPM
- Cell integration: task sharing between LAPP, LPSC and CPPM



# Detector Upgrade: $CO_2$ Cooling

- MARTA is first portable $CO_2$ cooling plant in France
  - Installed at LAPP
  - Funded by ENIGMASS
  - System performance being evaluated
  - Will be used for assembly and testing of staves at LAPP

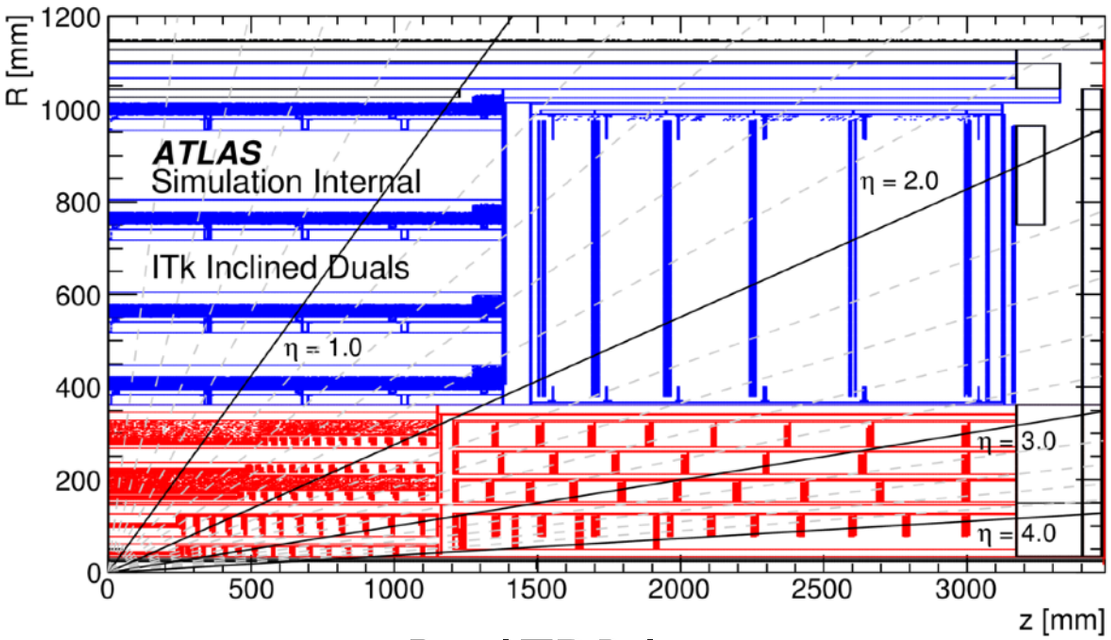


- Test bench installed at LAPP
  - Used to test prototypes in collaboration with:
  - LPSC, Geneva, CERN
- LAPP has recognised expertise with $CO_2$ cooling simulations
  - Testing $CO_2$ diphasic model of new, unexplored condition regions
  - Publication in progress

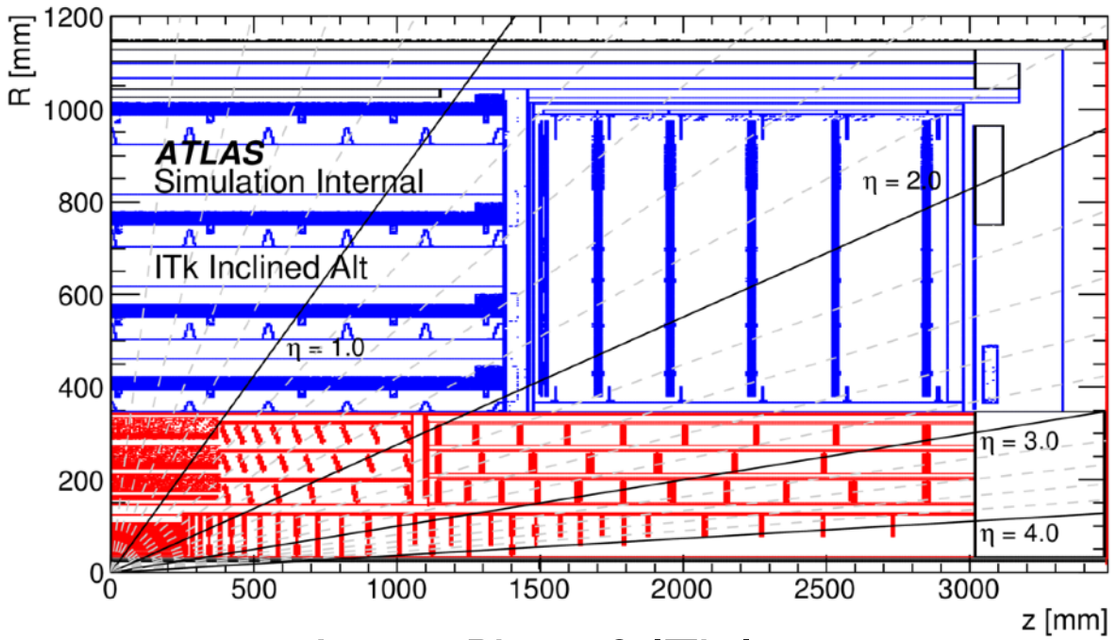
- Surface storage necessary for $CO_2$ cooling
- LPSC committed to design and production of accumulators
  - Regulate pressure of return line, hence detector temperature
  - Surface storage vessel used to limit accumulator volume
- Plans for 2019:
  - Design full-scale accumulator for DEMO
  - Design surface storage vessel
  - Test interplay between local accumulator and surface vessel
    - Use Baby-demonstrator installed at CERN
    - Tests funded by ENIGMASS

# Detector Upgrade: Pixel Simulation (1)

- Extensive work to create accurate computer simulations of new detector
- LAPP and LPSC focus on ITk pixel detector
- Pixel TDR published earlier this year
  - Some changes needed to be made to the design:
    - High-Granularity Timing Detector (HGTD) requires more space along ATLAS z-axis
    - Services at each end of ATLAS ITk required additional space
- ITk design modified to reduce impact of services material
  - Design changes to be published in upcoming Layout Task Force Report



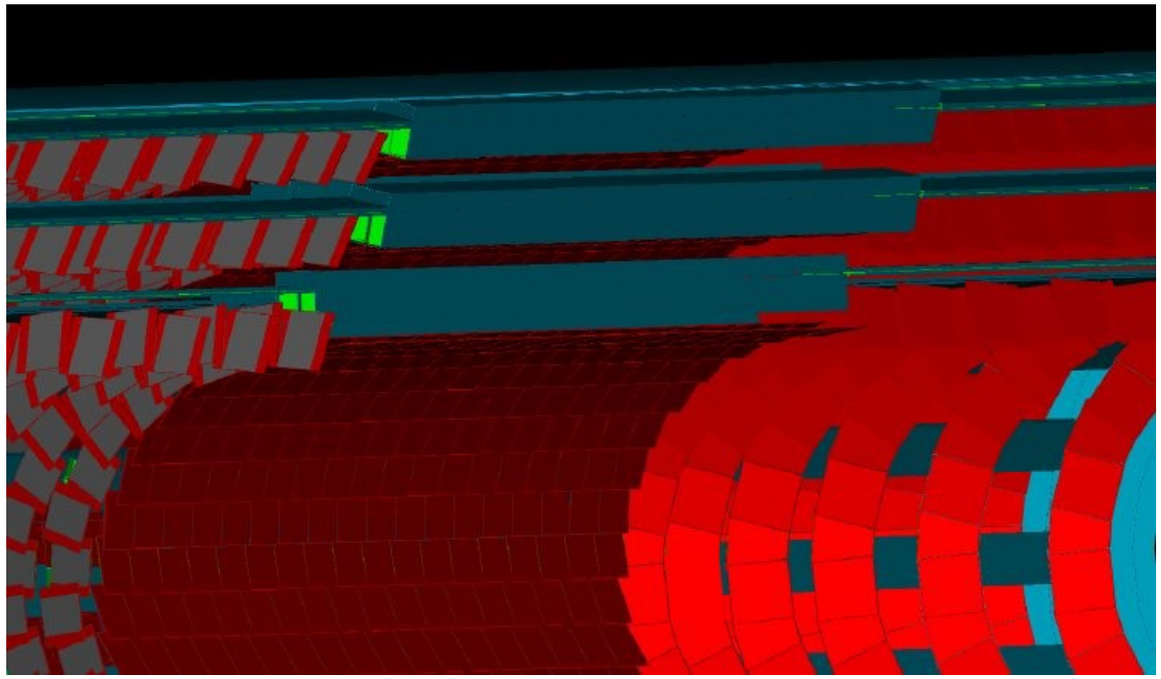

Pixel TDR layout



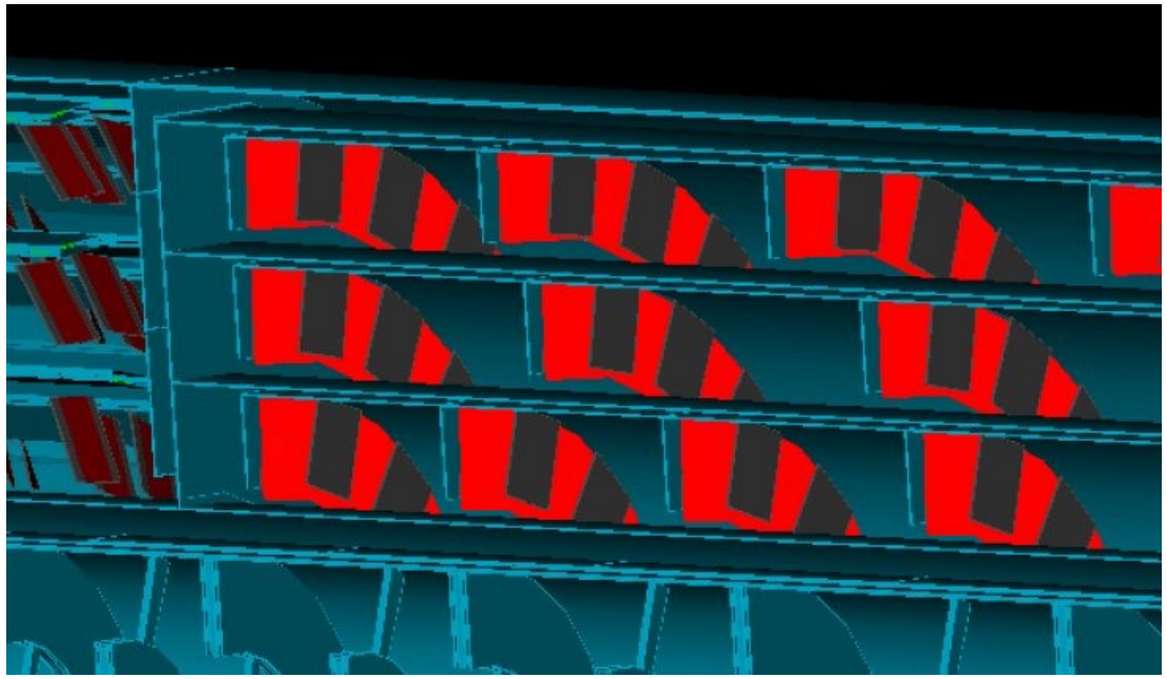

Latest Phase 2 ITk layout

# Detector Upgrade: Pixel Simulation (2)

- Simulation constantly refined with latest engineering inputs
- Material is evolving and has strong impact on the design
- Tremendous effort by LPSC and LAPP to ensure accurate description of materials in simulation



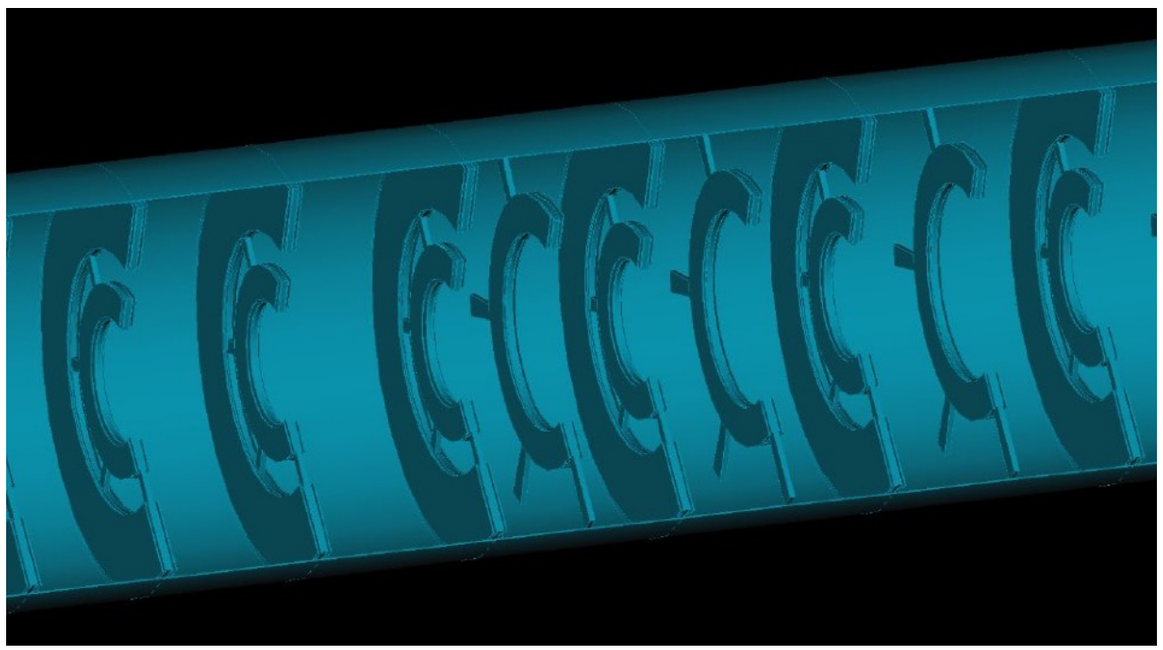
Outer barrel longerons accurately modelled



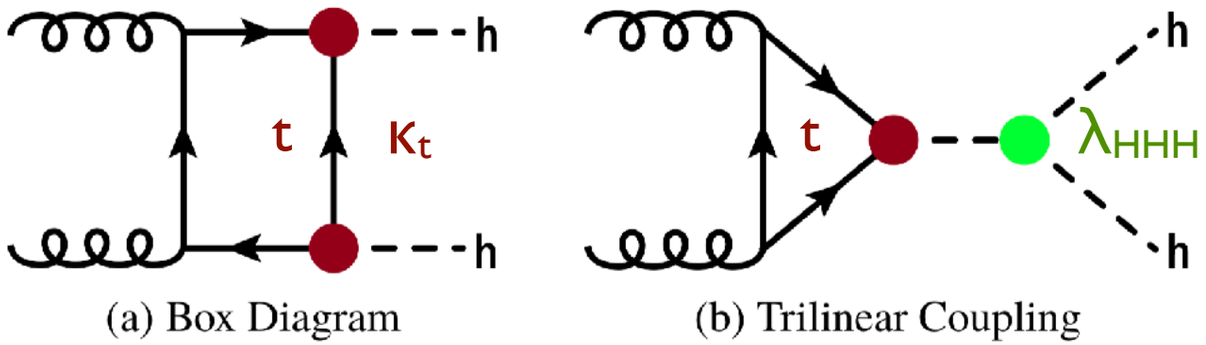
Endcaps follow pixel-ring half-shell design

Plans to migrate conical rings to corrugated shell:

Detailed models of inner barrel support structures



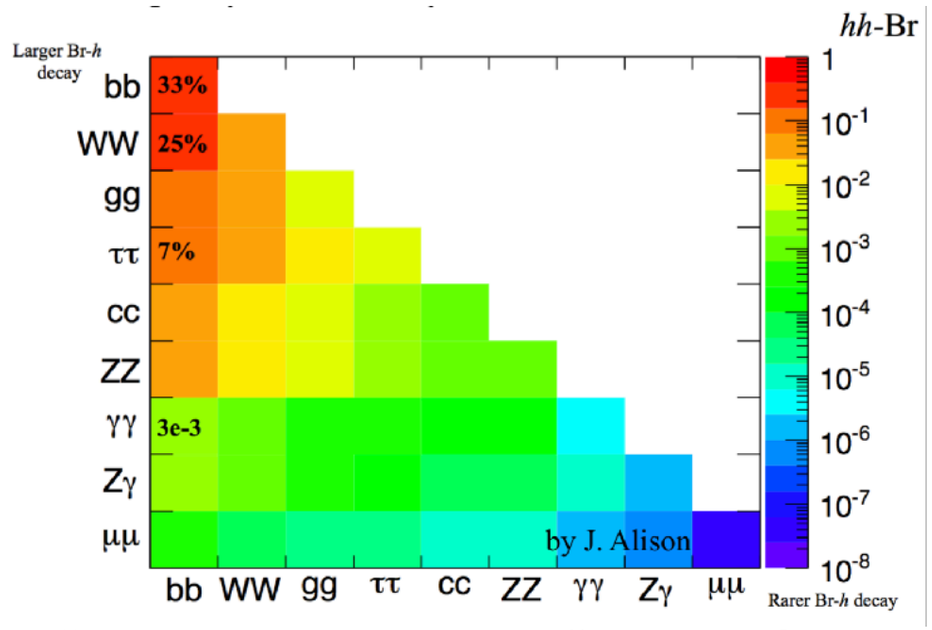
# HL-LHC: DiHiggs




(a) Box Diagram (b) Trilinear Coupling

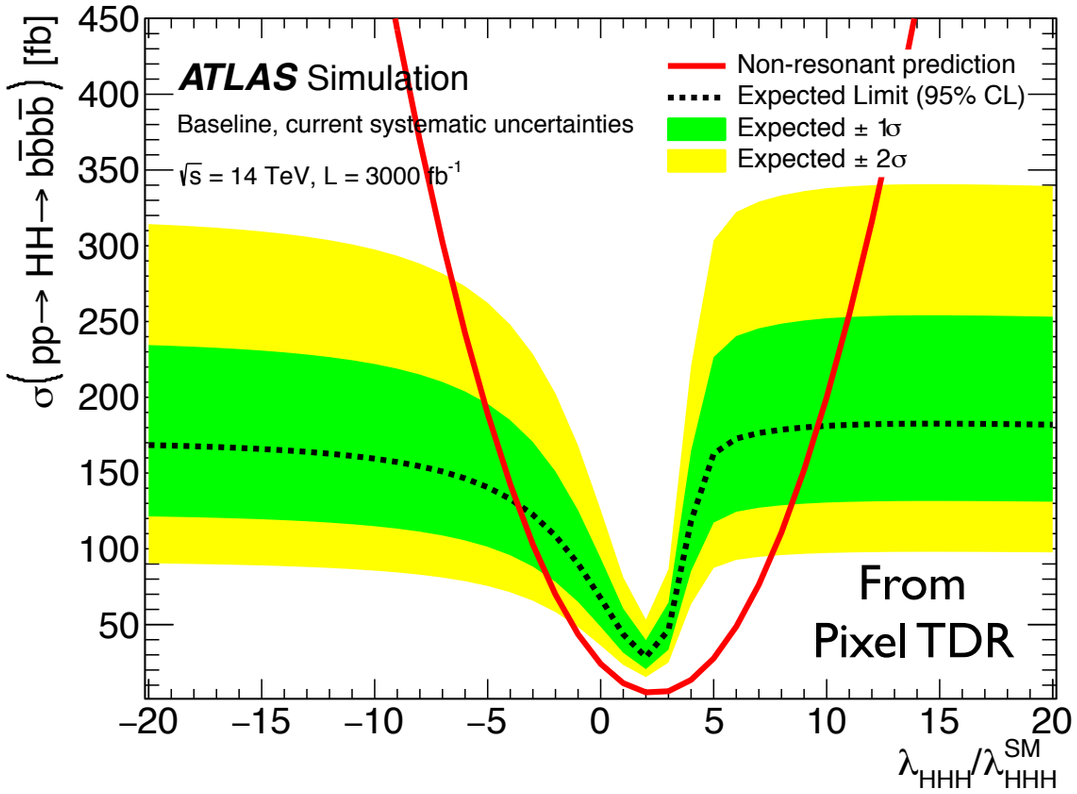
- Aim to make first observation of HH production
- Measure $\lambda_{HHH}$ and $\kappa t$ (top-Yukawa coupling)

- HH Production has rich variety of final states
  - $bb\gamma\gamma$ has low branching ratio
  - $bb\tau\tau$, bbbb have high background




From "Double Higgs Production", Dorival Gonçalves, HL/HE-LHC Workshop, Cern, 18/06/18

- Various institutes working on $bb\tau\tau$, bbbb
- Analyses performed as extrapolations of Run 2 data
- For bbbb:
  - 95 % C.L. (stat only): $4.1<\lambda_{HHH}/\lambda_{HHH}^{SM}<8.7$
  - $0.6\sigma$ significance
- For $bb\tau\tau$:
  - 95 % C.L. (stat only): $-4.0<\lambda_{HHH}/\lambda_{HHH}^{SM}<12.0$
  - $0.6\sigma$ significance



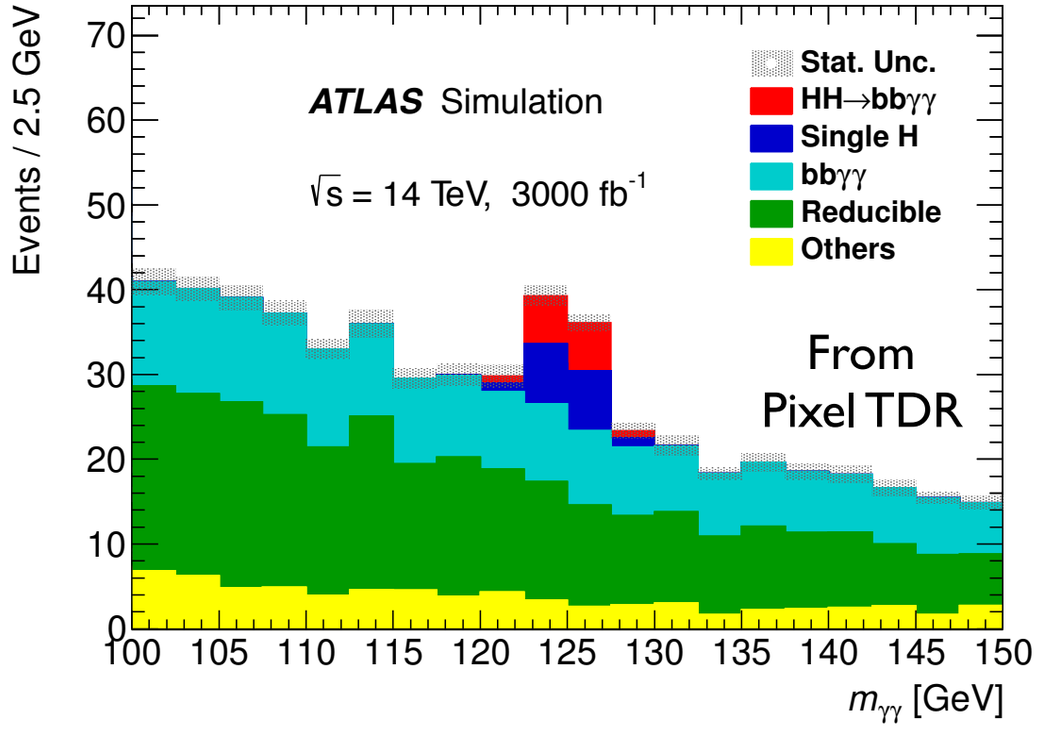
# HL-LHC: HH→bbγγ

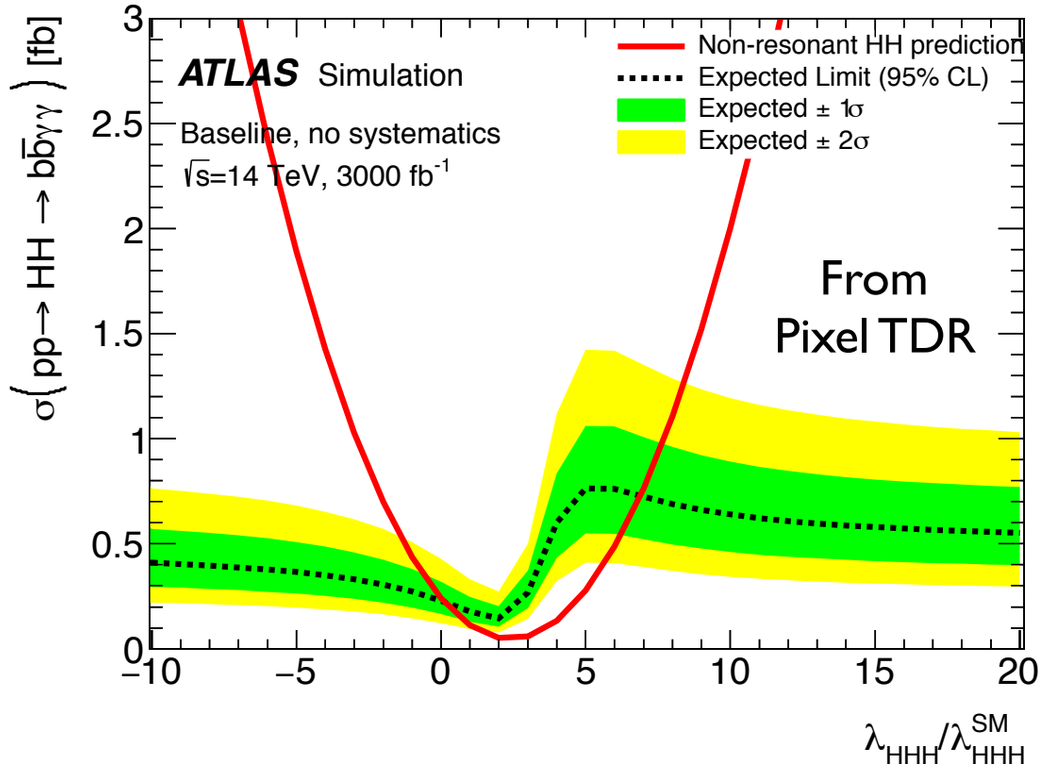
- LAPP+LPSC focus on bbγγ channel
- Latest public HL-LHC projections in Pixel TDR

- Analysis uses truth level MC samples
- Smearing functions approximate detector response
- Cut-based analysis
- Without systematic uncertainties:
  - 95 % C.L. (stat only): $0.2<\lambda_{HHH}/\lambda_{HHH}^{SM}<6.9$
  - 1.5σ significance

- 2018 has seen exciting developments in bbγγ analysis
- Analysis method refinements:
  - Improved b-tagging algorithm (better c-jet rejection)
  - Improved photon energy resolution
  - Boosted Decision Tree for event selection
  - Results not public yet :(

- Note summarising new results in preparation for YR
  - Currently being circulated round ATLAS
  - ATL-COM-PHYS-2018-1364
  - Presents updated bbττ results
  - Presents combination of bbbb, bbττ, bbγγ
  - Presents first extrapolations of bbττ, bbγγ to HE-LHC



# Summary

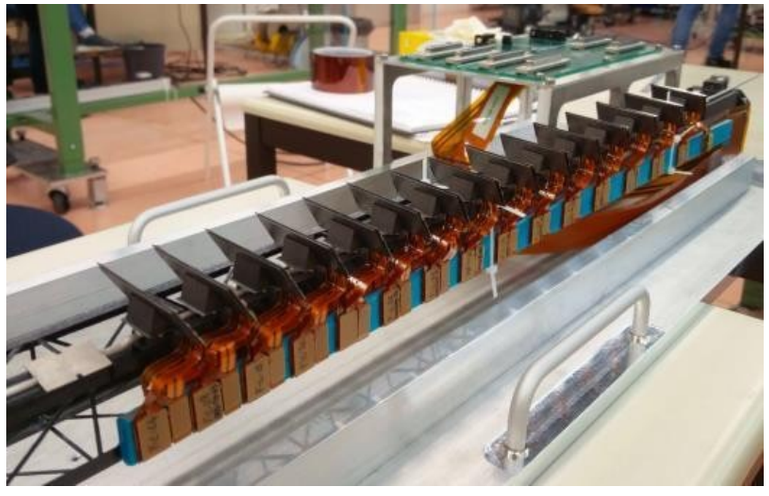
- LAPP and LPSC are engaged in a complete set of activities
  - ATLAS hardware,
  - ATLAS software and simulation
  - Physics prospects studies
- Tremendous progress on all fronts!

Thank you for your attention!

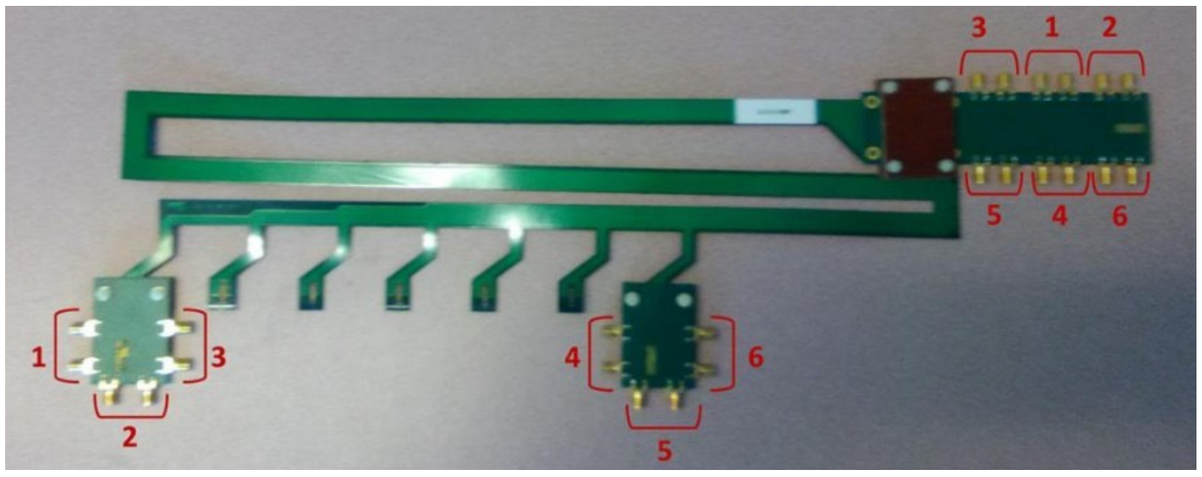
# Backup

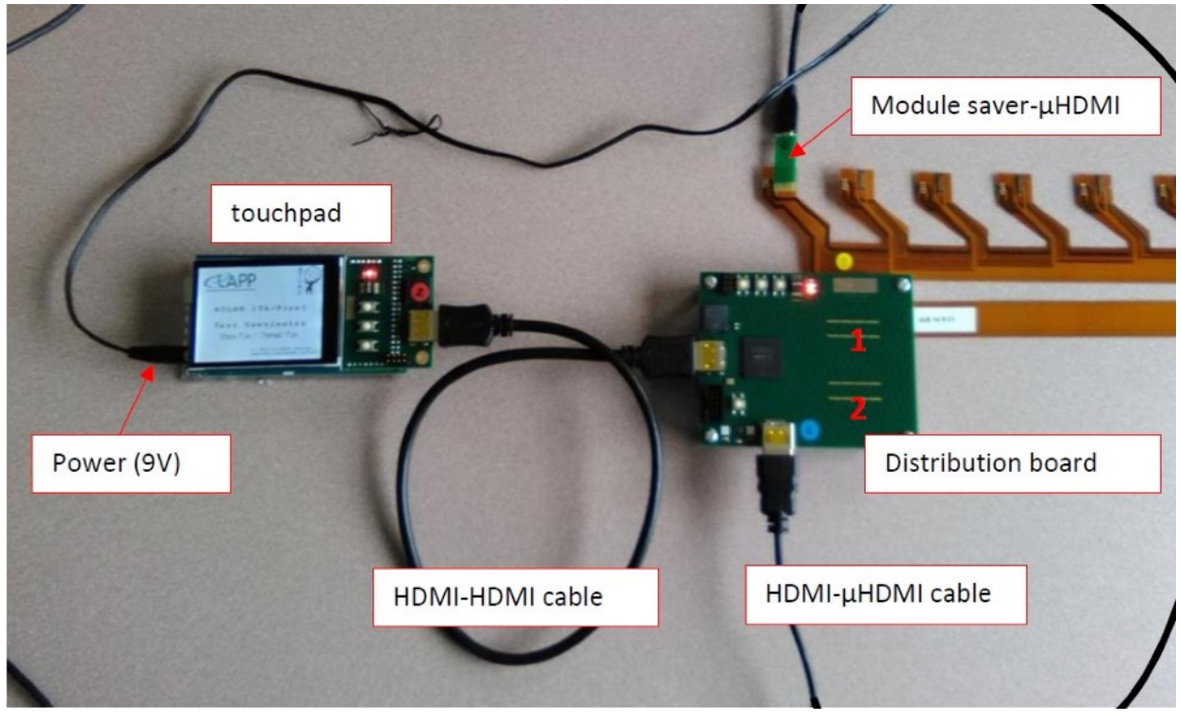
# Detector Upgrade: Demonstrator Stave

- Upgraded outer pixel barrel will have sensors and services mounted on longerons
- Construction of a full scale prototype launched beginning of 2017
  - IN2P3, CERN, Geneva, Germany, Japan collaboration



- Data and power routed via stave flexes
  - Design and production by LAPP
  - Design to be finalised in 2019



# Detector Upgrade: Mechanical Activities

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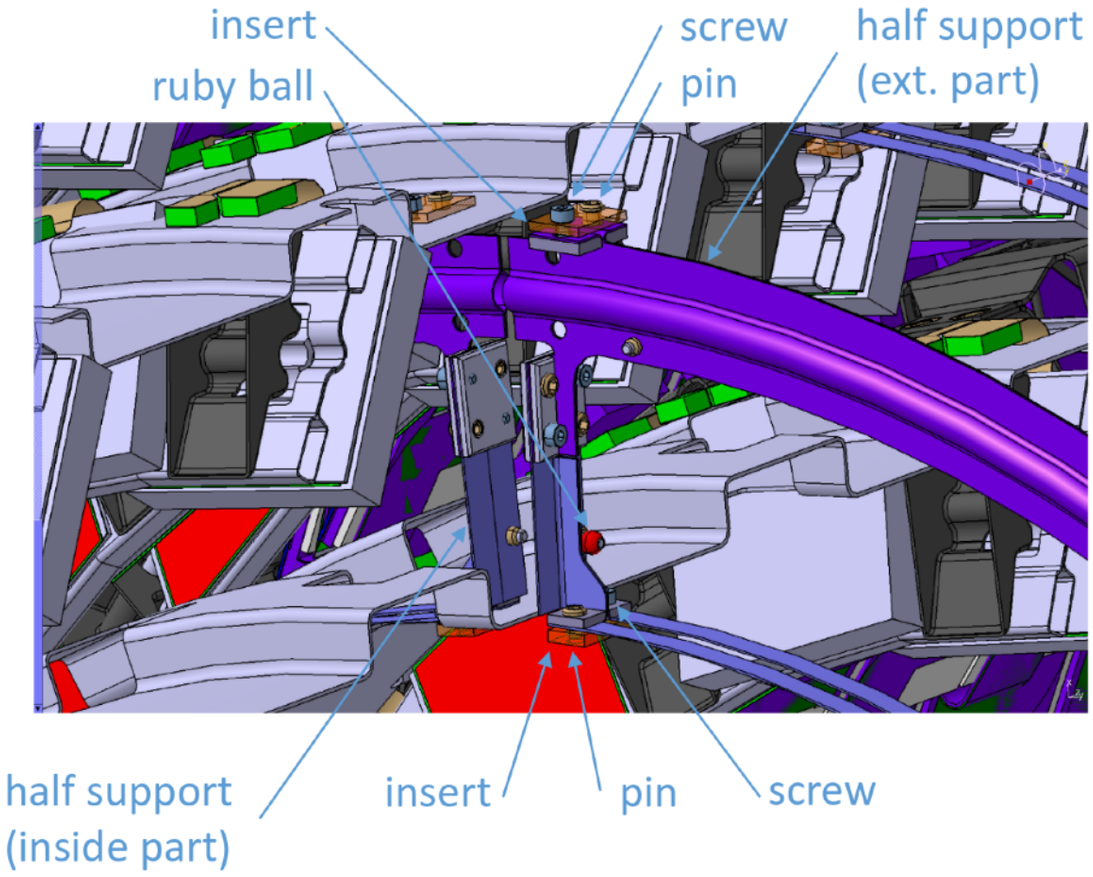
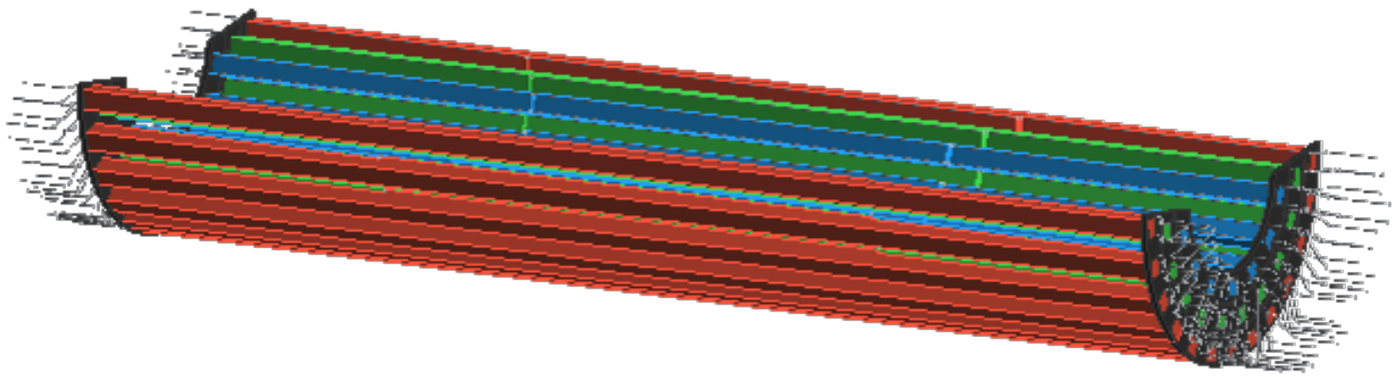
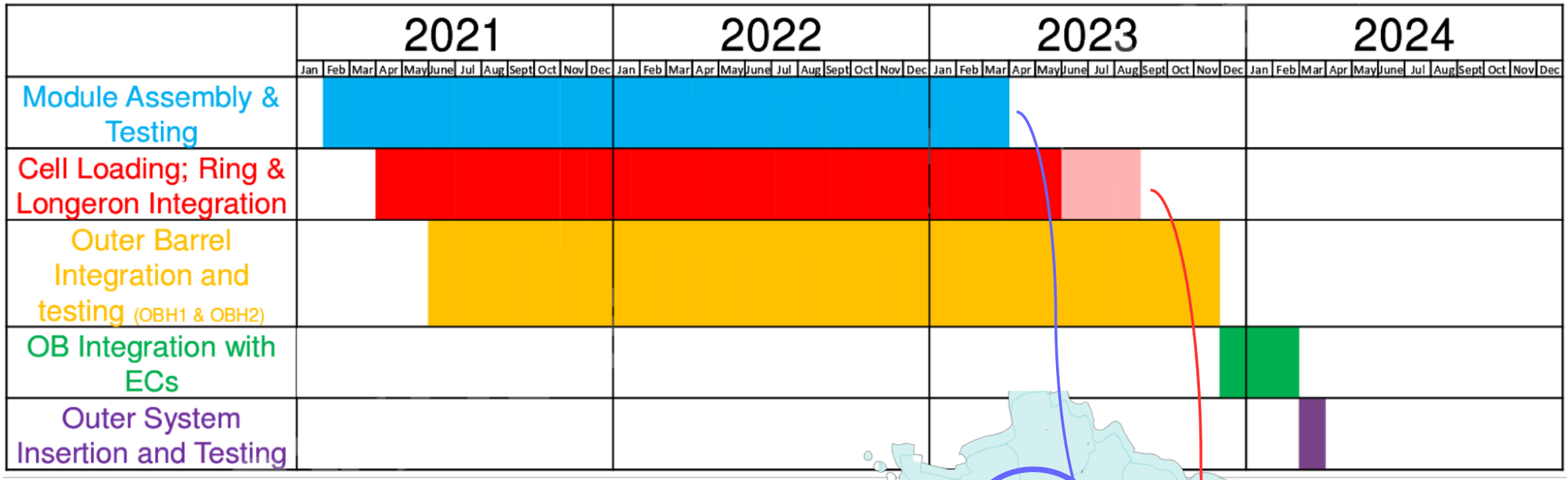


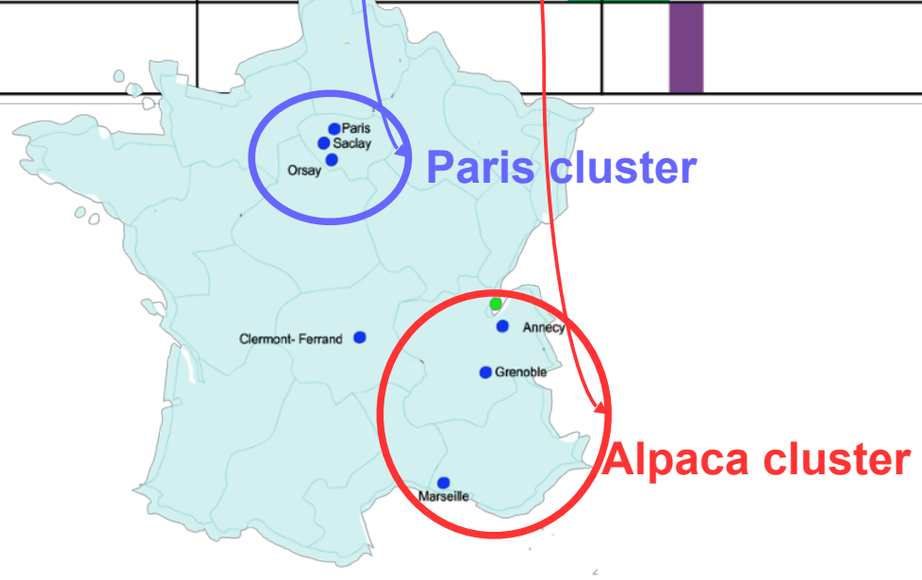



- LPSC involved in several activities
- Calibration of heaters for OuterBarrel Pixel Layers

# Construction of the Pixel Outer Barrel

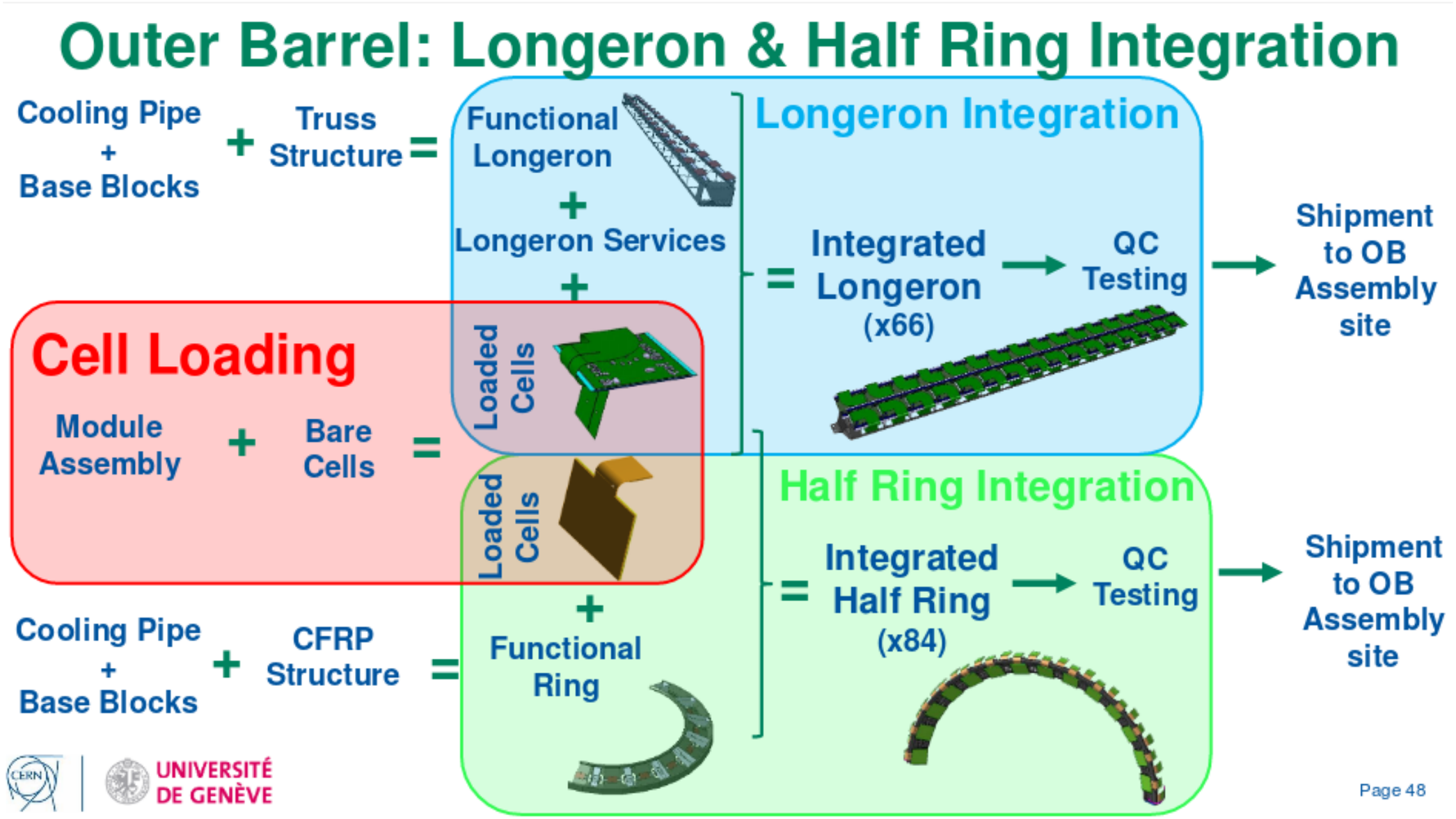
- R&D : 2014-2018
- Preparation of production : 2019-2020
- Production : 2021-2024




- Other labs :
  - Suisse : CERN, Genève, Bern
  - Allemagne : Bonn, Wuppertal,
  - Gottingen, Siegen, MPI Munich,
  - Dortmund
  - Japon : KEK
  - Norvège : Oslo

# Cell loading/integration (1)



# Cell loading/integration (2)

- Number of modules and mechanical supports

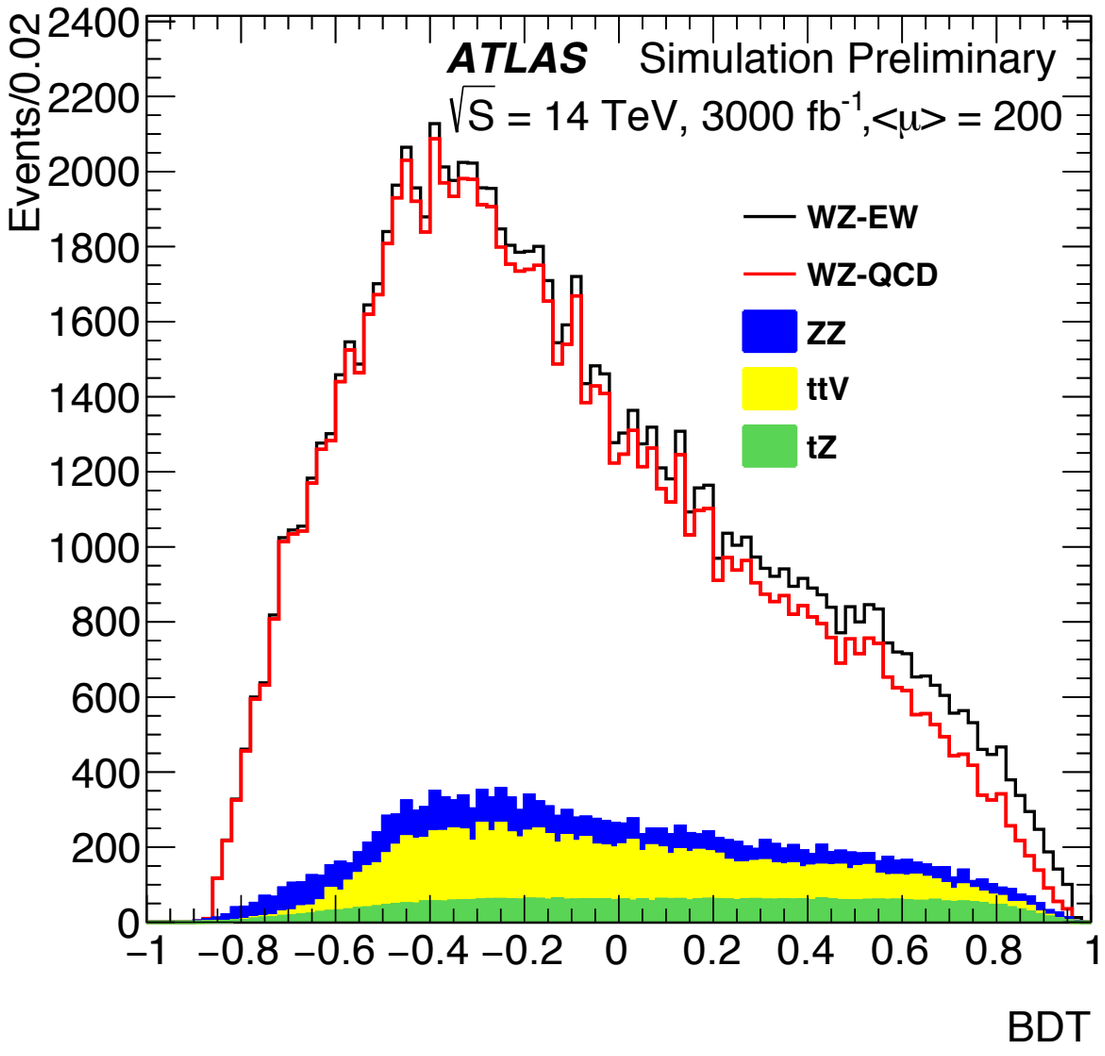
| Layer | # Module rows in Φ | #Longerons | #Modules per Longeron | #Half Rings | #Modules per Half Ring | # Spare Longerons | # Spare Half Rings | # Modules including spare CLs | # Modules including spares and loading & integration yield |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 32 | 16 | 40 | 24 | 16 | 1 | 1 | 1080 | 1200 |
| 3 | 44 | 22 | 40 | 28 | 22 | 1 | 1 | 1558 | 1732 |
| 4 | 56 | 28 | 40 | 32 | 28 | 1 | 1 | 2084 | 2316 |
| **Total** | | **66** | | **84** | | **3** | **3** | **4722** | **5249** |

- Scheduled sites:
  - 4 sites for cell loading
  - 4 sites for integration of longerons
  - 3 sites for integration of half-rings

- Total time to integrate a longeron: 5 weeks
- Total time to integrate a half-ring: 4 weeks

# HL-LHC: Vector boson scattering with WZ

- Vector boson scattering provides probe for electroweak symmetry breaking
- Provides Benchmark for forward detector optimisation
- New note presents prospects for measuring VBS with WZ in fully leptonic final state




- Improvements with extended tracker, timing detector (HGTD)
- Using multivariate techniques
- Polarisation studies

# Higgs couplings

- ATL-PHYS-PUB-2018-010
- HL-LHC aims allow precision measurements of Higgs boson properties
- Investigations performed on most critical theory uncertainties on Higgs production mechanism
- Presented in June HL/HE-LHC workshop
- Based on extrapolations from Run 2 analysis