ATLAS LNF activity Status Report

Giada Mancini
on behalf of the ATLAS LNF group

The ATLAS LNF Group

The Group:

P.Albicocco, M. Antonelli, C. Arcangeletti, M. Beretta, H. Bilokon, S. Cerioni, V. Chiarella, M. Curatolo, M. Dreucci, B. Esposito, M. Gatta, C. Gatti, S. Lauciani, P. Laurelli , G. Maccarrone, G. Mancini, A. Martini, G. Pileggi, B.Ponzio, A. Sansoni, M. Testa, T. Vassilieva, E. Vilucchi

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- **H->ZZ*->4l** analysis
- **Particle Flow** and Missing Transverse Energy reconstruction
- **ATLAS upgrade**
  - **FTK:** Trigger upgrade with fast tracks reconstructions (Phase 1)
  - **NSW:** Muon spectrometer upgrade with the construction of the New Small Wheels (Phase 1)
  - **ITk:** Inner Tracker upgrade for HL-LHC (Phase 2)
- **Computing Activities**

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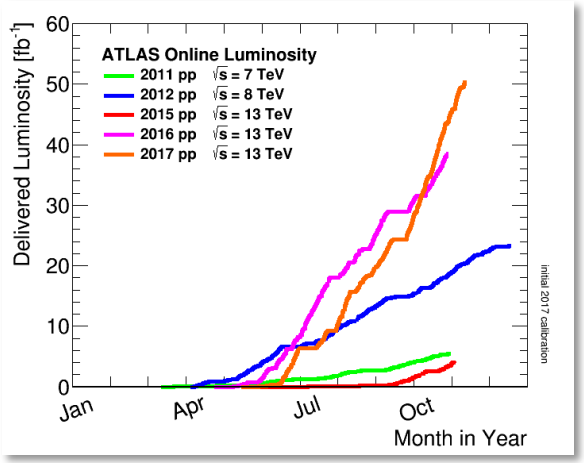
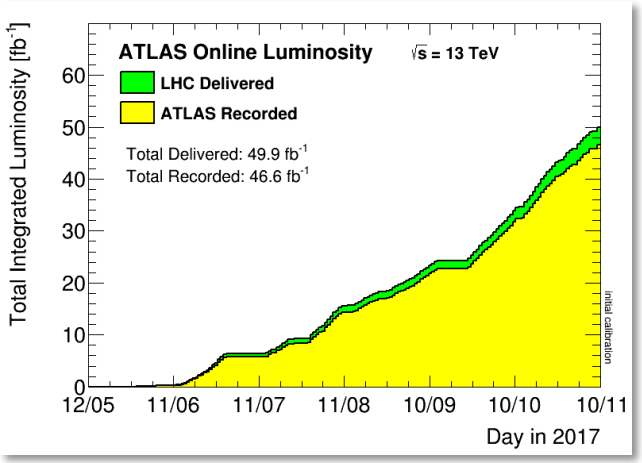
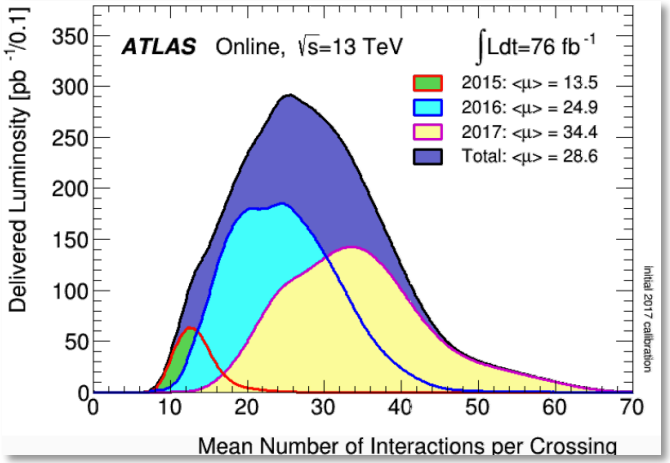
LHC and ATLAS at √s = 13 TeV

2017 has been a very successful year of data- taking.

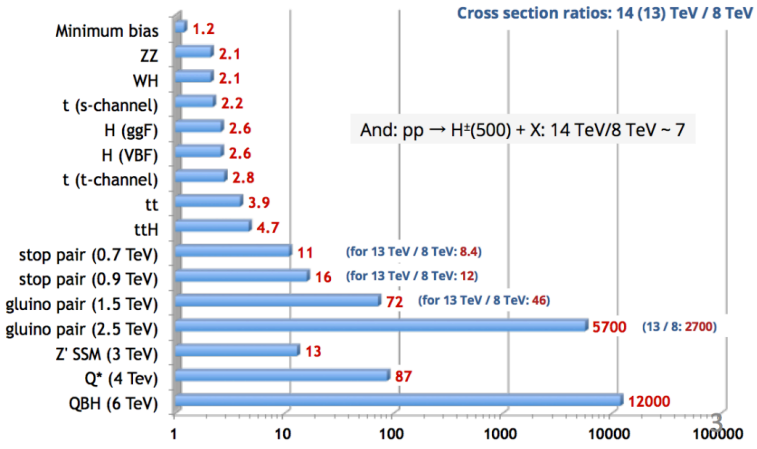
Initial goal of 45 fb-1 well within reach!





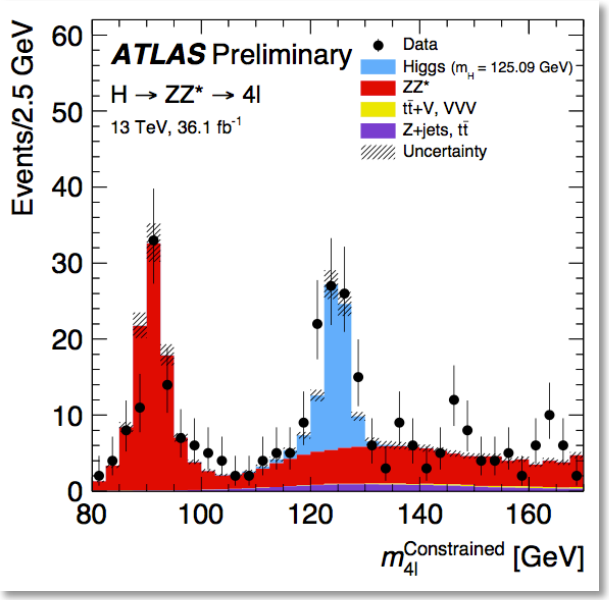


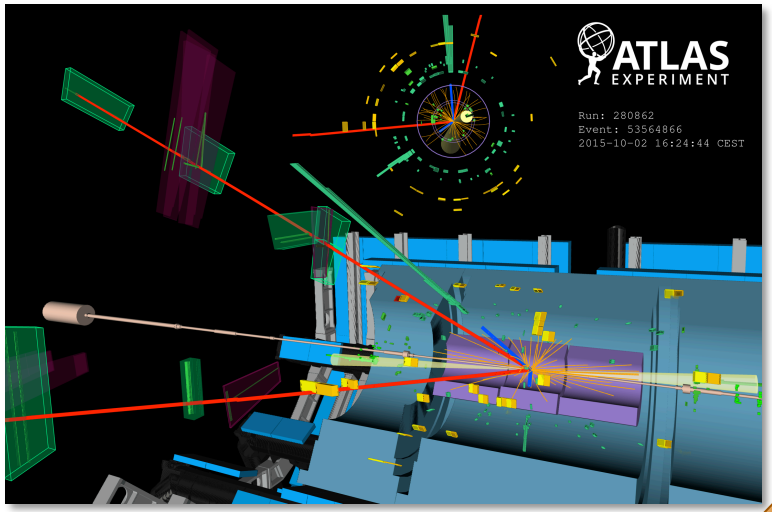
- steeper slope above earlier predictions
- often 3-4 fb^{-1} in a week
- ATLAS data taking efficiency >~94%
- hugely increased potential for discovery of heavy BSM particles thanks to the higher √s



H->ZZ*->4l decay channel

- Run1 -> Run2 : clear transition from the "discovery mode" to "precision" measurements
- Great potential of the H->ZZ*->4l to study the properties of the Higgs boson thanks to the fully reconstructed final state
  - despite the low BR, very clean signature
  - two same flavour opposite sign lepton pairs
  - S/B~2
- Fundamental contribution of the LNF ATLAS group to the studies of the Higgs boson properties in the H->ZZ*->4l decay channel (editor of the supporting note ATLAS-CONF-2017-046)

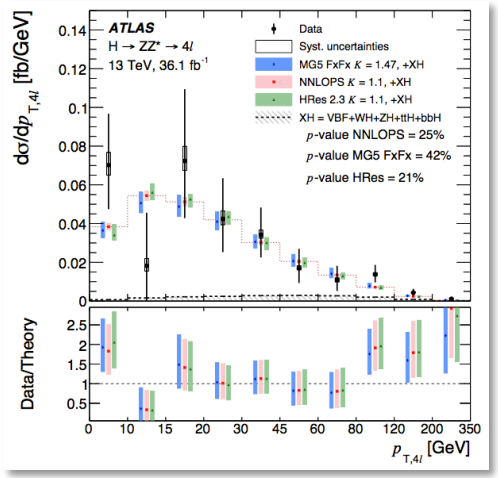


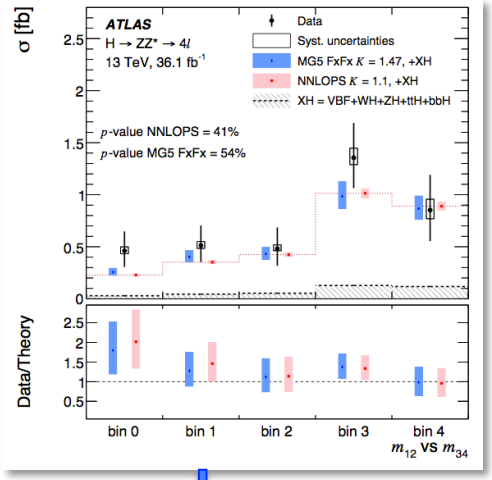


Fiducial and Differential XS

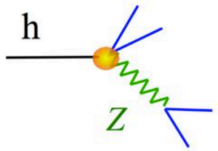
Differential distributions in variables chosen to be sensitive to:

- Higgs boson kinematics: p_T, $|y|$, $|\cos\theta^*|$
- Jet activity: N_{jet}, $p_{Tlead.jet}$, m_{jj}, $\Delta\phi_{jj}$
- Double differential: p_{TH} vs N_{jet}
- Decay related: m_{12} vs m_{34}



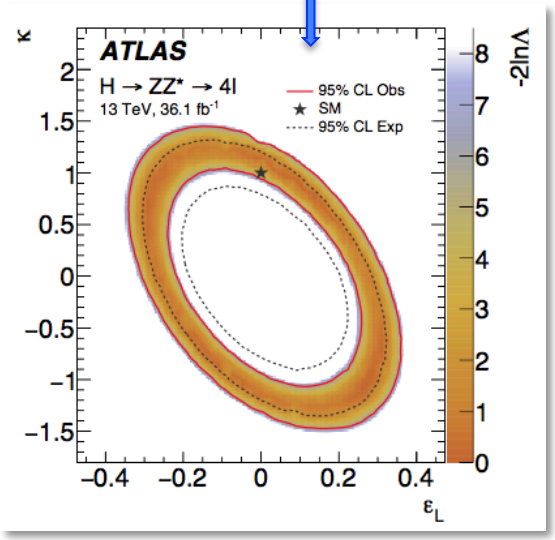


EFT Interpretation using Pseudo Observables (POs):



- ε_L, ε_R are couplings related to contact interactions of the Higgs boson and left- and right-handed leptons
- k modifies the H to Z boson coupling

Sensitivity on the contact terms related to exclusion of BMS theories.

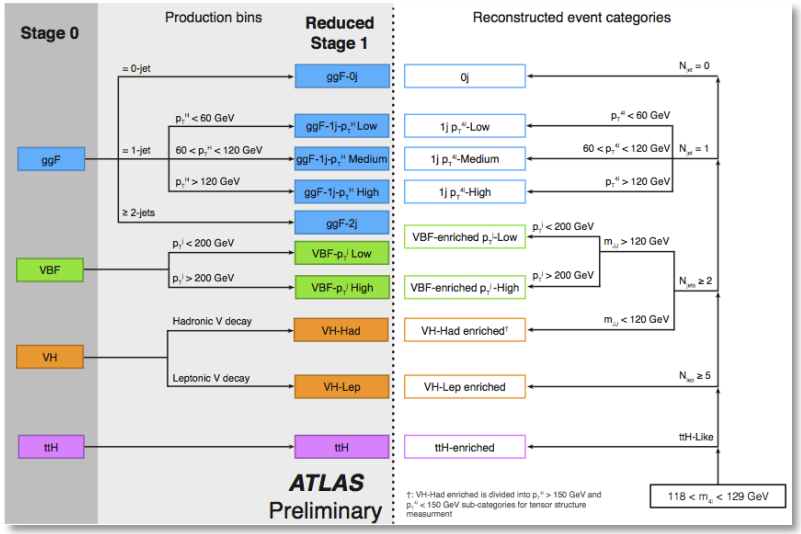


Results show no deviations within the unc. with respect to the SM expectations.

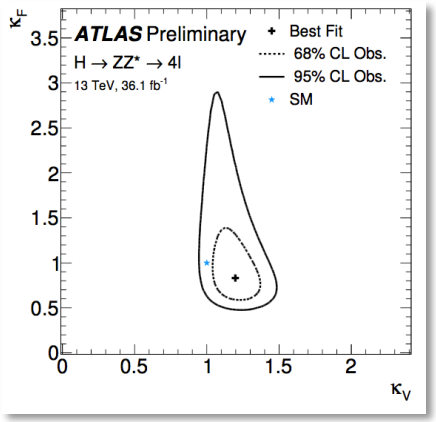
XS per production mode measurements

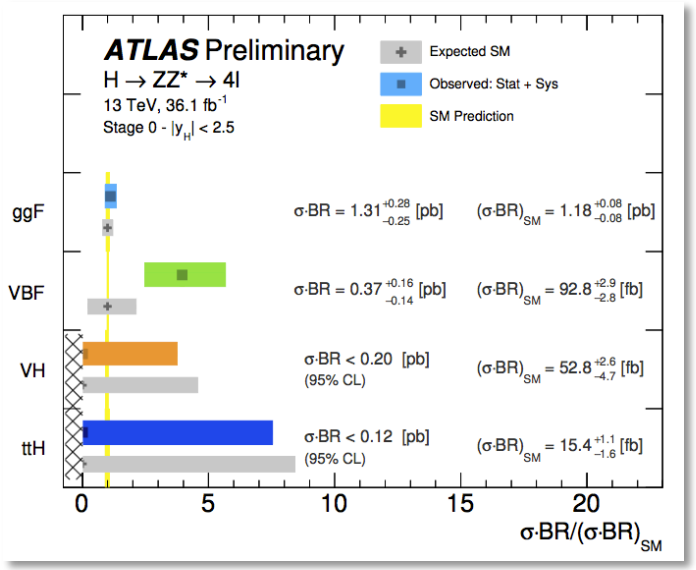
Event categorization aiming for production mode separation:

- depending on event characteristics based on Njets, b-tag jets, extra leptons
- also sensitive to BSM effects parametrized by EFT terms in the Lagrangian (non SM couplings to the Higgs boson)



Couplings to fermions k_F (*ggF, bbH, ttH*) or vector bosons k_V (*VBF, WH, ZH*)





- VBF excess
- results on SM XS per production mode and BSM couplings consistent within the unc. with the SM predictions

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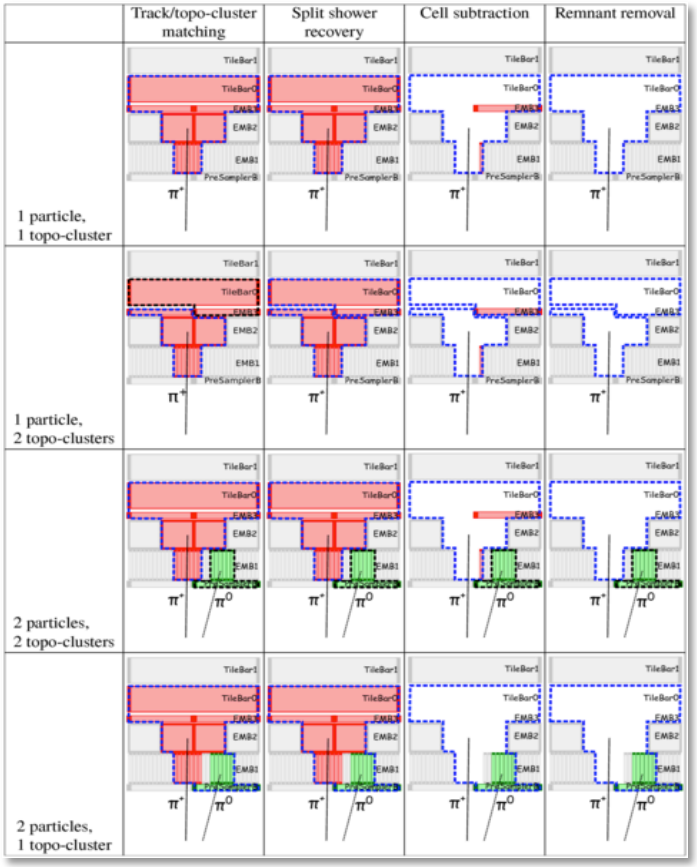
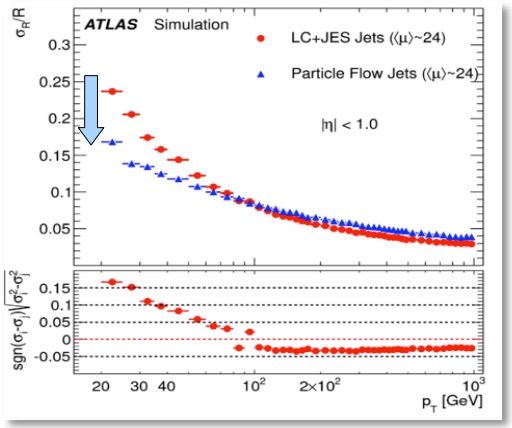
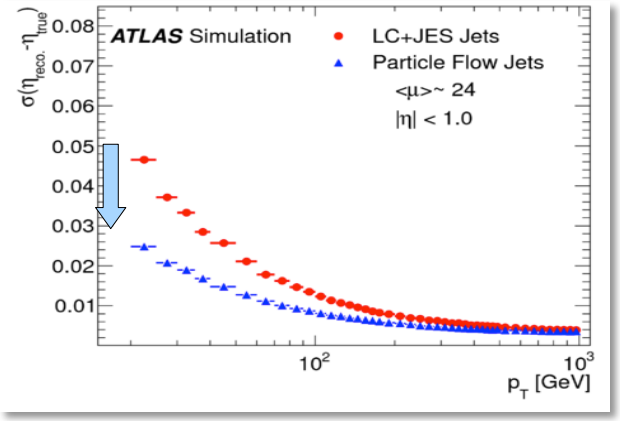
Jet reconstruction and performance using Particle Flow with the ATLAS Detector

Removes calorimeter energy deposits from charged hadrons using p_T measurements from tracker

- **better jet p_T resolution at low p_T:**
  - removal of charged pile-up contributions
  - better track momentum resolution
- **better angular resolution from tracker meas.**
- more important at increasing pile-up condition at Run 2 (already reached $<\mu> = 80$)







- Contact editor of [Eur. Phys. J. C 77 (2017) 466]

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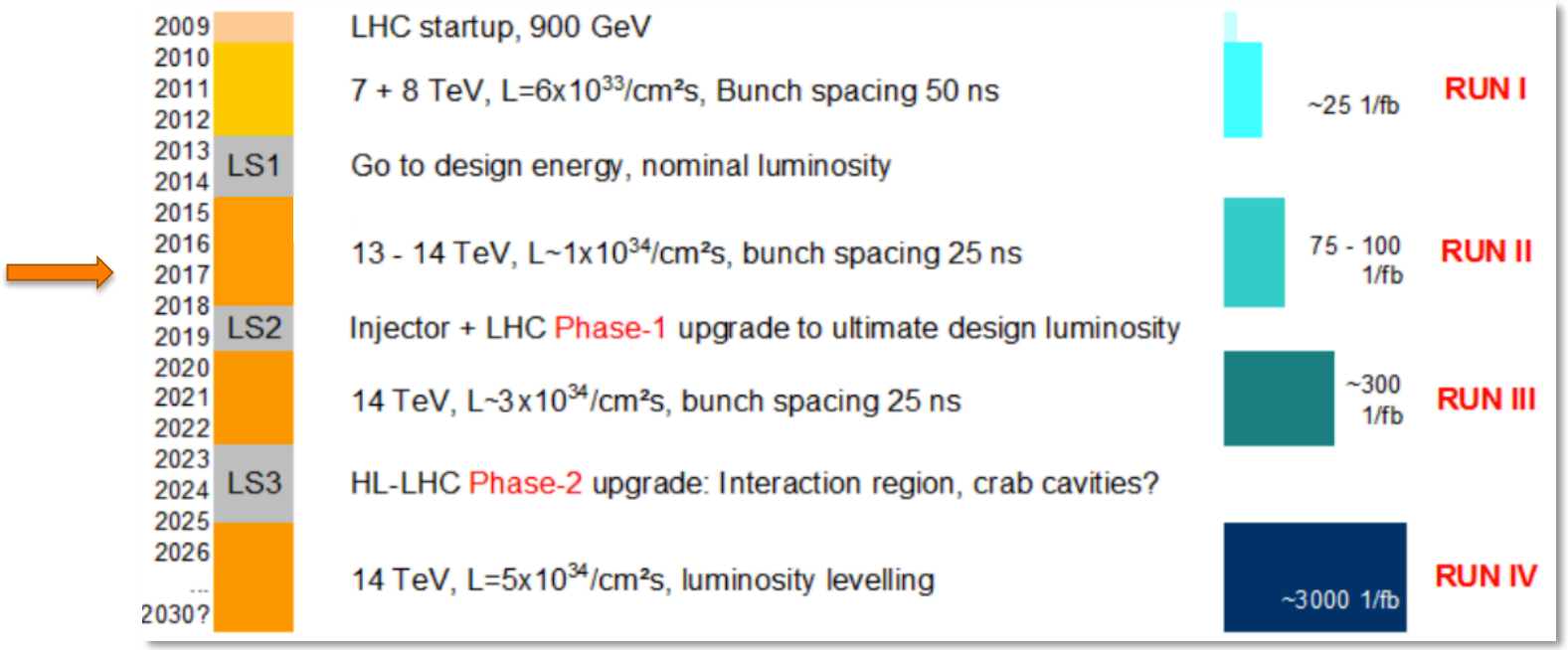
The ATLAS Upgrade Program



Phase 0 Upgrade:

– Consolidation + Insertable B-Layer (IBL) in LS1 already in for Run 2 -> DONE!

- **Phase 1 Upgrade**

– New Small Wheel, Calorimeter trigger upgrade, FTK

- **Phase 2 Upgrade**

– Inner Tracker

-> LNF group already fully involved in Phase 1 and Phase 2 upgrades!

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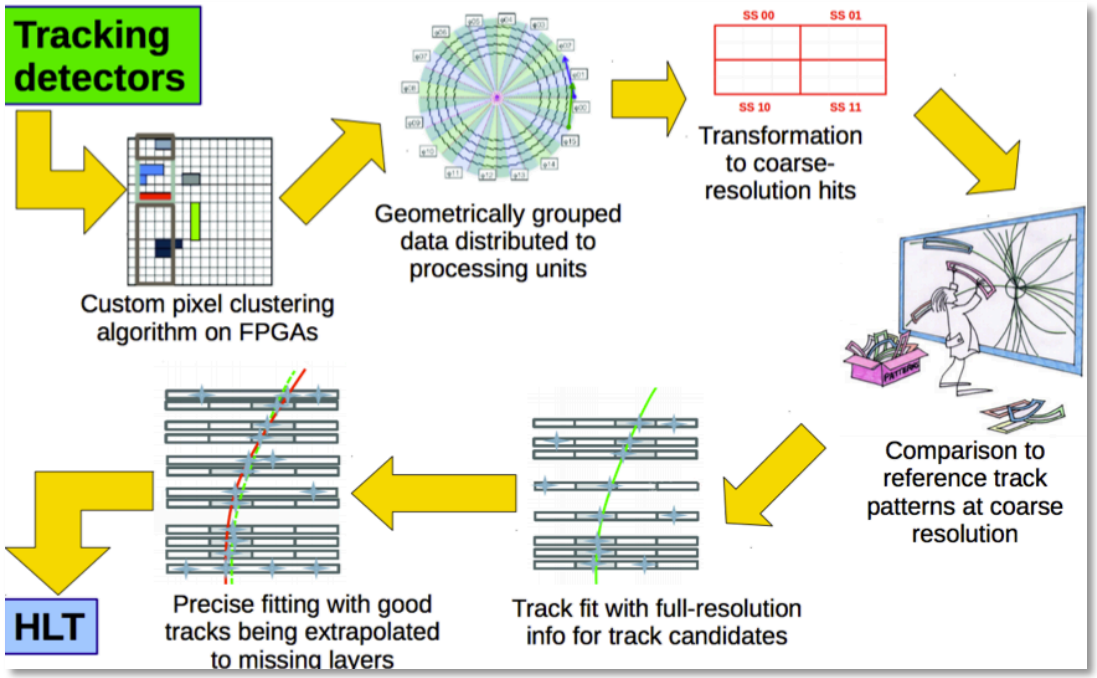
Fast TracKer system

FTK is a track trigger defined to cope with the higher luminosity foreseen in Run 2 (<μ>~40-50):

- **tracking** at **trigger level** can keep **under control rates** and **keep good efficiency** for relevant physics processes
- helps to **resolve complex topologies** with b- and τ-jets -> Higgs and BSM physics
- determine Nvertex and improves the **robustness** in jet and MET selections in events with **pileup**



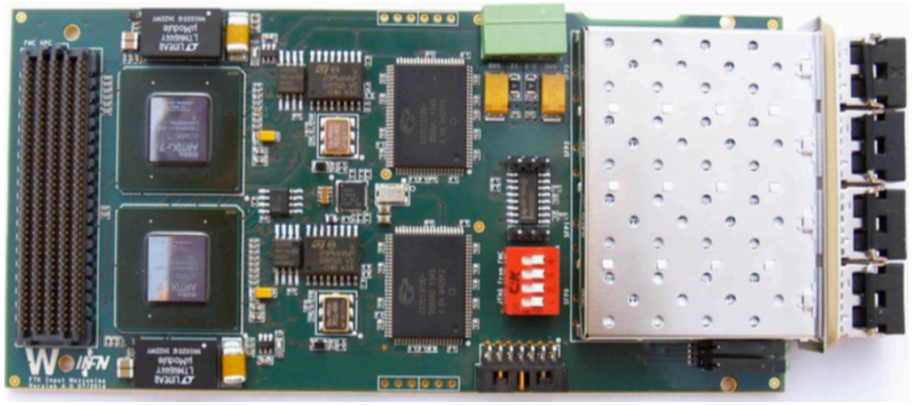
- custom electronics (made of ~8000 ASICs and 2000 FPGAs) for global track reconstruction in the pixel and silicon strip detectors after every level-1 trigger (100 kHz)
- rapid pattern recognition and track fitting for global track reconstruction of all tracks with p_T > 1 GeV (~100 μs)
- provide the tracks at the beginning of High Level trigger (HLT) event processing

LNF: leading activity in the Associative Memory chip and Input Mezzanine production and tests

Input Mezzanine:

- IM Artix7 (LNF): IBL compatible FTK Input Mezzanine
- receives 4 inputs links from 2 SCT and 2 Pixel or 2 IBL
- perform the hit clustering by FPGA
- send the clustered hit data to Data Formatter board (DF) that sort the hits in their FTK η/ϕ towers and delivers them to processing units (PU)

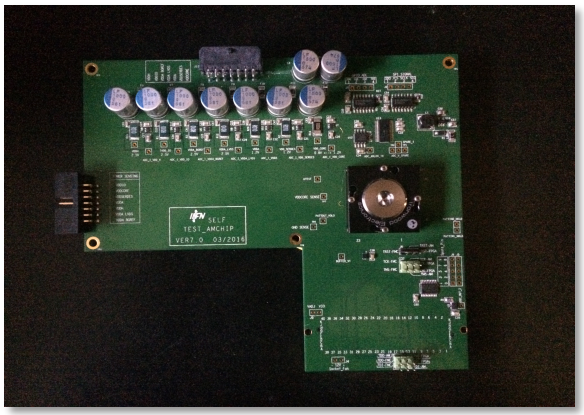
- ✓ all IM boards have been produced and tested and installed in ATLAS
- ✓ the firmware works fine -> optimization in progress
- ✓ maintenance of the IM boards under our resposibility
- ✓ up to now only one board has been sent back for repair



FTK status: Associative Memory chip

Associative Memory chip:

- AM06 Chip (LNF - INFN Milano - LPNHE Paris) 160mm2 65nm ASIC (400M transistors)
- track detection:
  - compare detectors data with patterns stored in memory (*roads*)
  - the AM identifies the presence of stored patterns in the incoming data
  - consumption: 2.5 W for 128 k patterns
  - performing 10^{14} parallel comparisons at 16 bits per sec



8000 chip under production

Delivery

Ready for january 2018

Test

Ready for mounting summer 2018

Test is LNF Resposibility:

- ✓ up to now we have tested about 10000 Amchip06
- ✓ during these tests some problems of reliability of the test system have been solved
  - improved reliability of contacts changing the socket with one having metallic spring contacts (guaranteed for massive production tests)
  - new test board under production (ready by 11/17)

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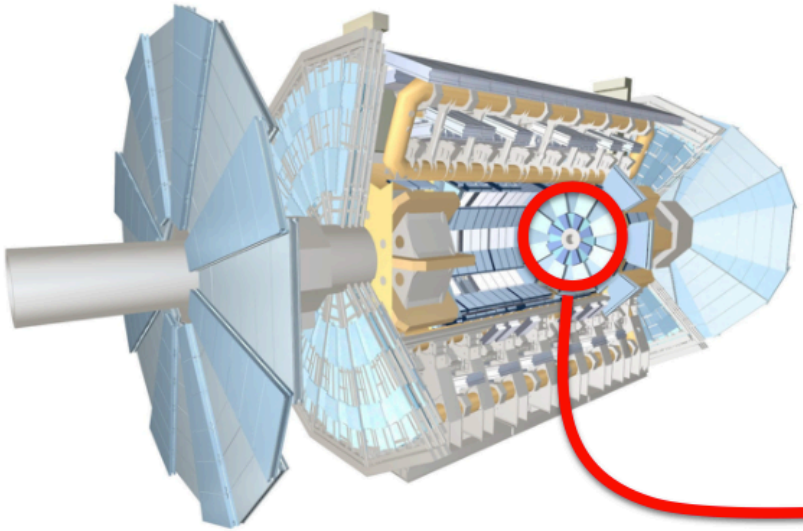
ATLAS muon spectrometer is realized by:

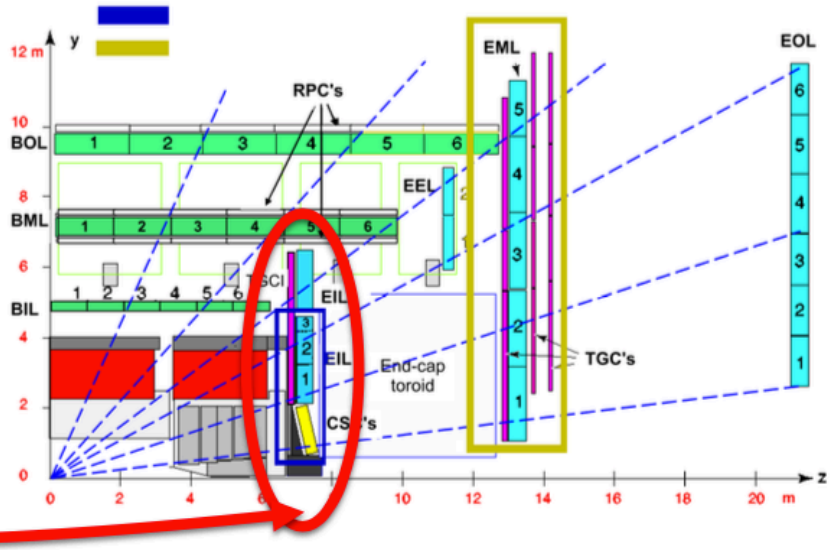
- RPC(trigger) and MDT (tracking) in the barrel region (|eta| <1)
- CSC, MDT (tracking) and TGC (trigger) in the endcap

-> Trigger & Tracking strongly affected when LHC lumi will be above the design values

Full new muon detector (including electronics & services): New Small Wheels to be placed in the ATLAS cavern during LS2 (2019-2020)

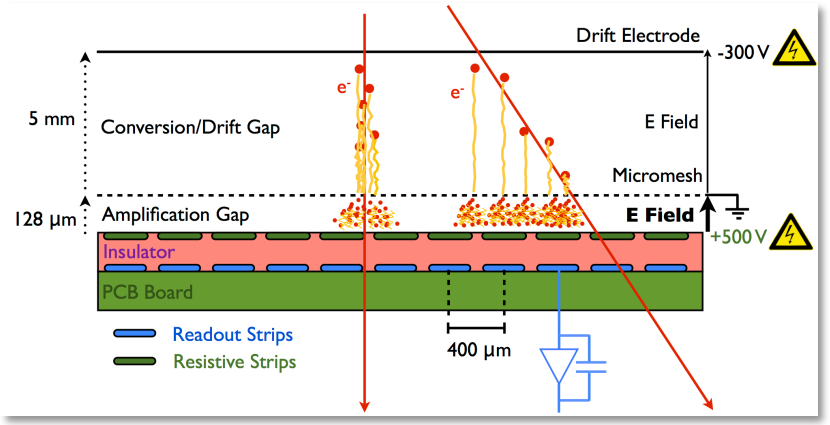
- will replace the innermost end-cap stations of the Muon Spectrometer
- good tracking capability (p_T resolution ~15% for 1TeV)
- high rate capability (15 kHz/cm^2)

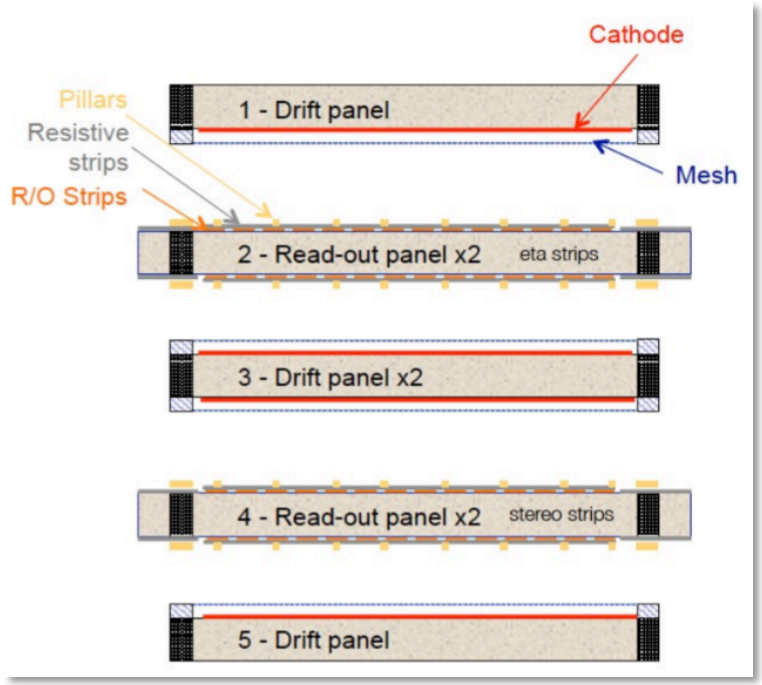




Micromegas (Micro Mesh Gas Detectors) are micro pattern gaseous detectors

- Charged particles ionize the detector gas (100 e/cm in Ar:CO 93:7 by muons)
- Electrons from the ionization are amplified in avalanche between a fine micro mesh and the readout strips (resistive strips, anode)
- High resolution: strip width 300 μm, strip pitch 425 to 450 μm
- fast evacuation of positive ions: 100 ns, high-rate capability (tested with flux densities of 7MHz/cm^2 and above)
- In two out of the four layers the strips are inclined by ±1.5° to allow for the measurement of a second coordinate (track, goal 100 μm resolution)





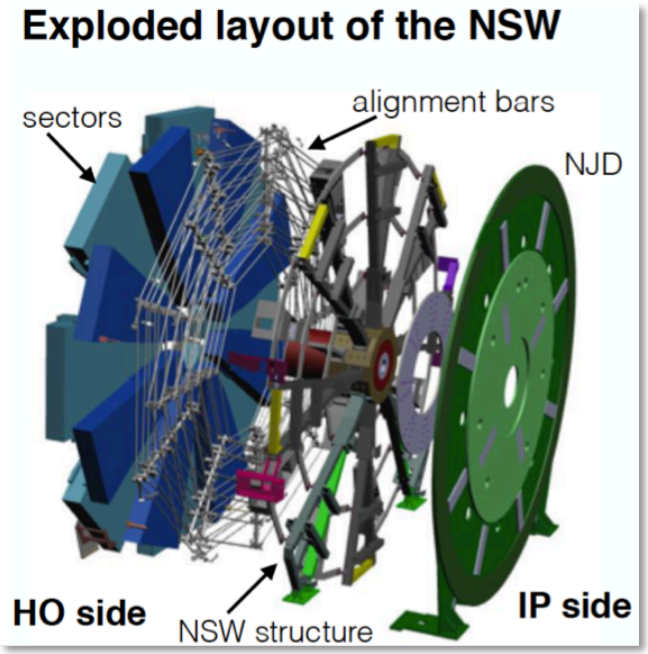
NSW Layout

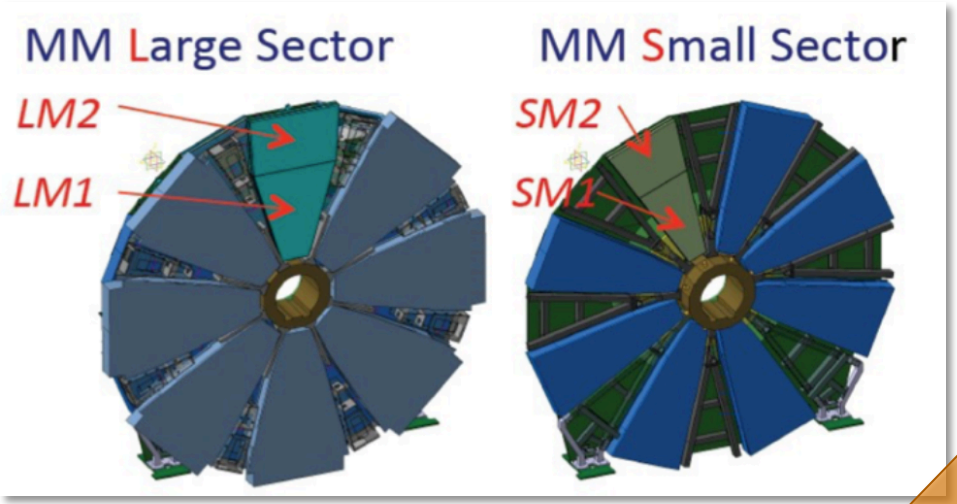
Wheel-like design:

- 8 large and 8 small sectors (2 modules per sector, 4 MM quadruplets)
- main focus: precision tracking (sandwiched by sTGC quadruplets for trigger)
- 4 different chamber types: LM 1-2, SM 1-2
- Production distributed over several institutes and some components from industry
  - Italy(SM1), Germany(SM2), France(LM1), Russia/Greece/CERN (LM2)

2 Module0 constructed and tested!

1st done among all the collaboration!

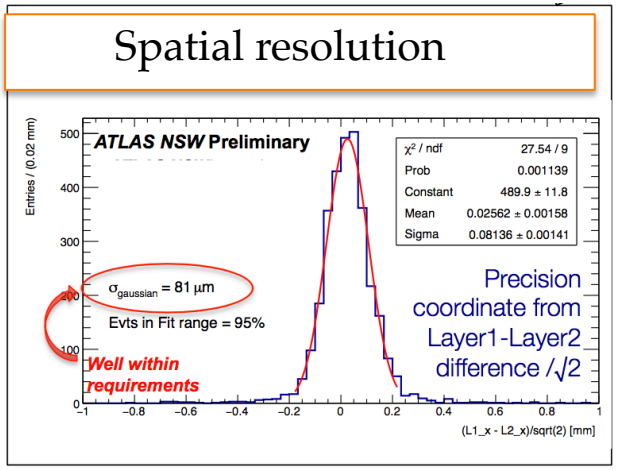


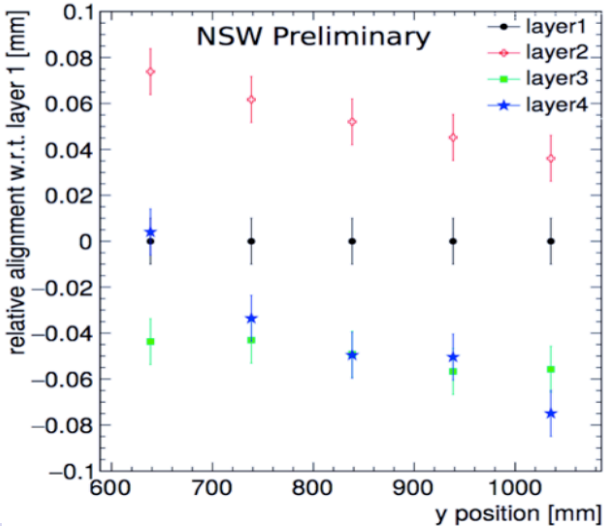


Module 0 and 0.5 tests

Mod 0 tested at CERN North Area:

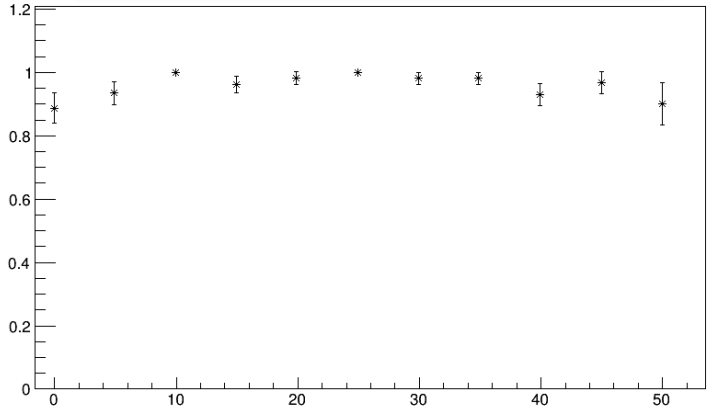
Spatial resolution





Mod 0.5 tested with cosmics at LNF CRS:

Efficiency

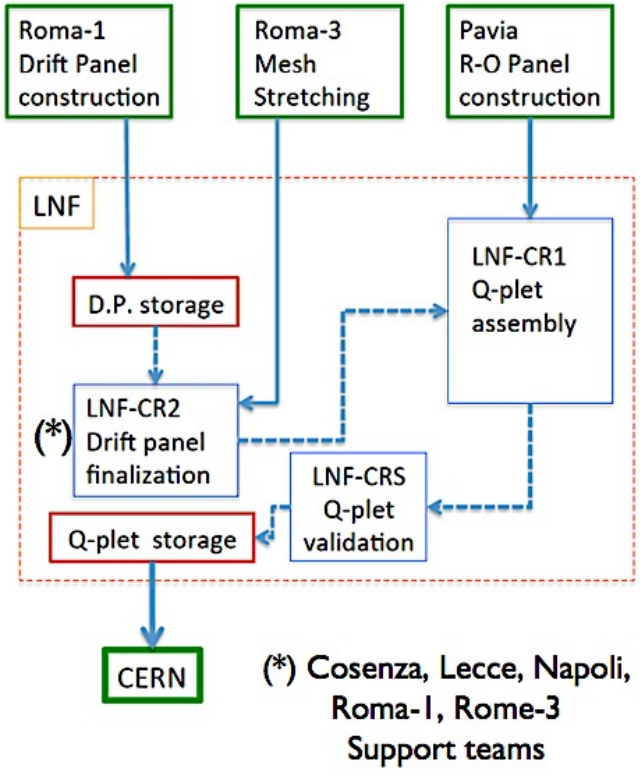


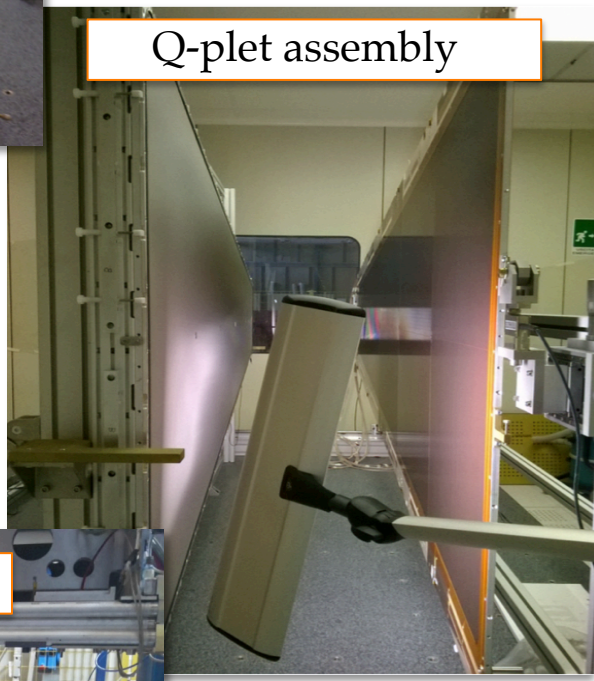
- in operation over several months
- DAQ and read-out configuration under final optimization
- ready to test production modules

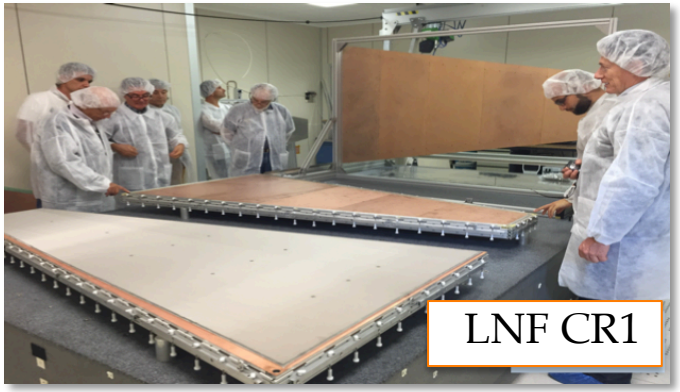
Relative alignment with respect to layer_1 :

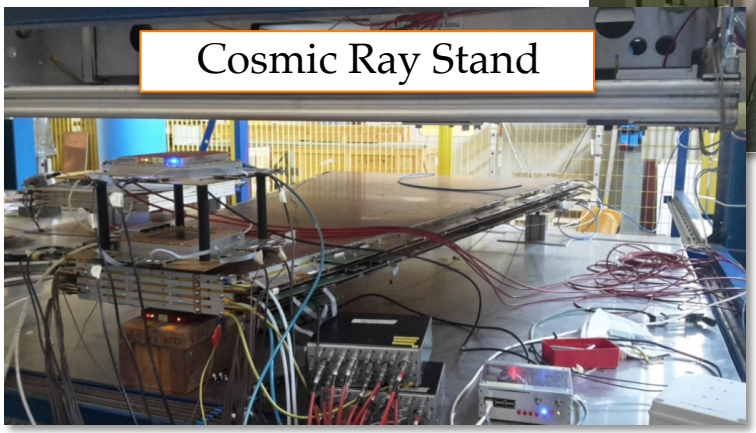
- all layers aligned within a maximum deviation of ±80 μm
- indication of layer-to-layer rotation or strip pattern global d

NSW production scheme

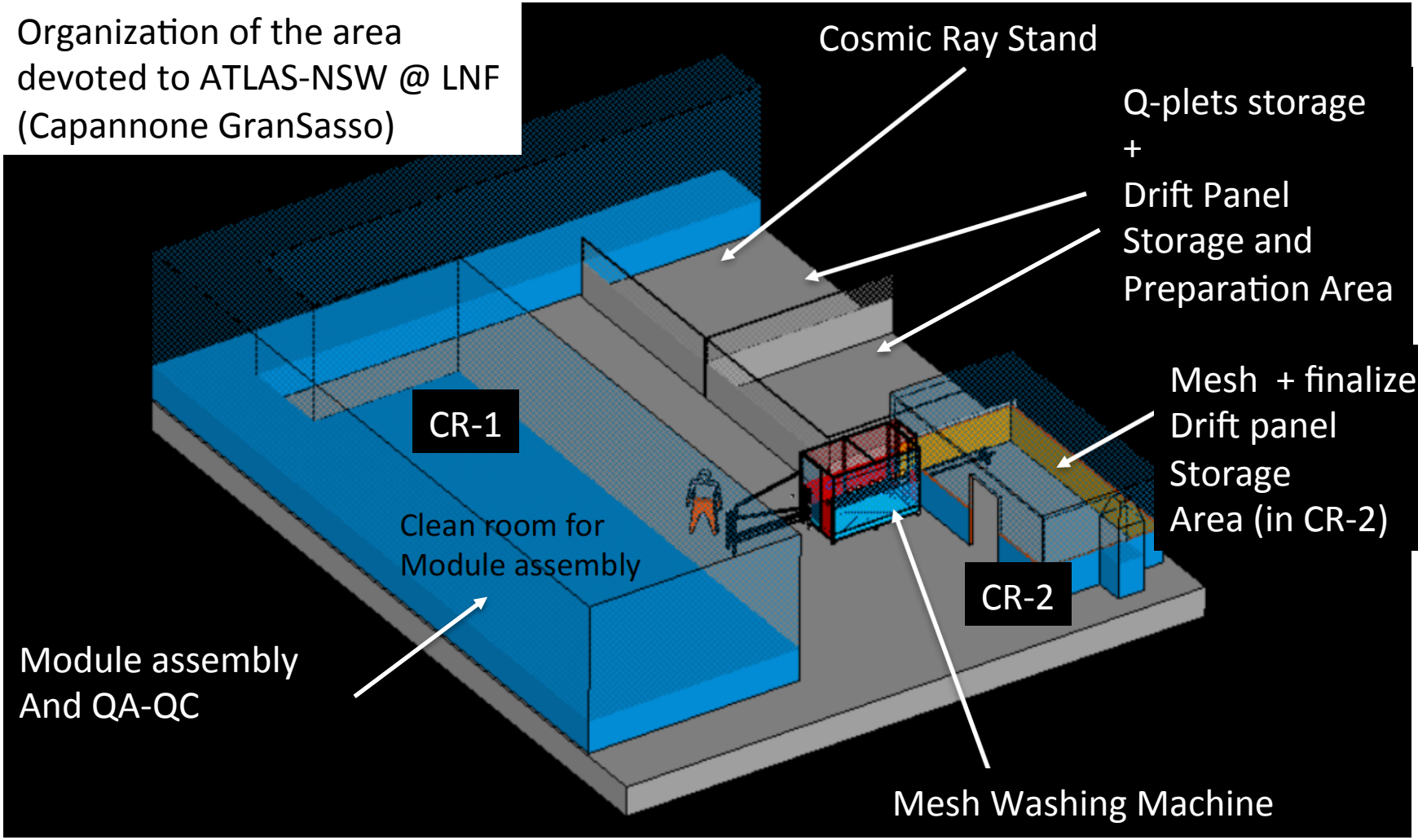








Organization of the area devoted to ATLAS-NSW @ LNF (Capannone GranSasso)



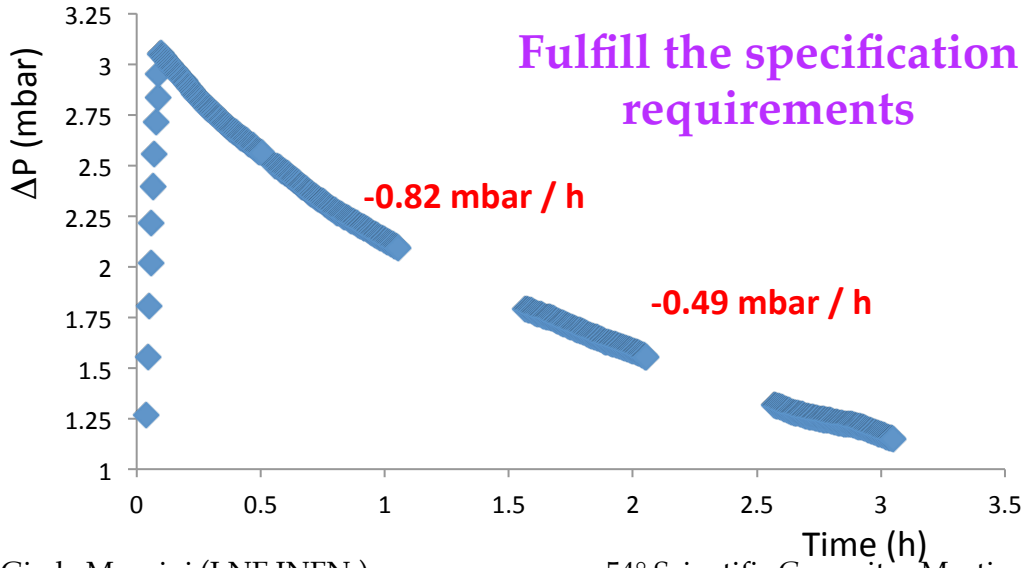
Status of production

- drift panels ready for 5 modules
- 1 read-out panel ready (eta-type)
- waiting for stereo-type panels (PCBs just delivered from QAQC)

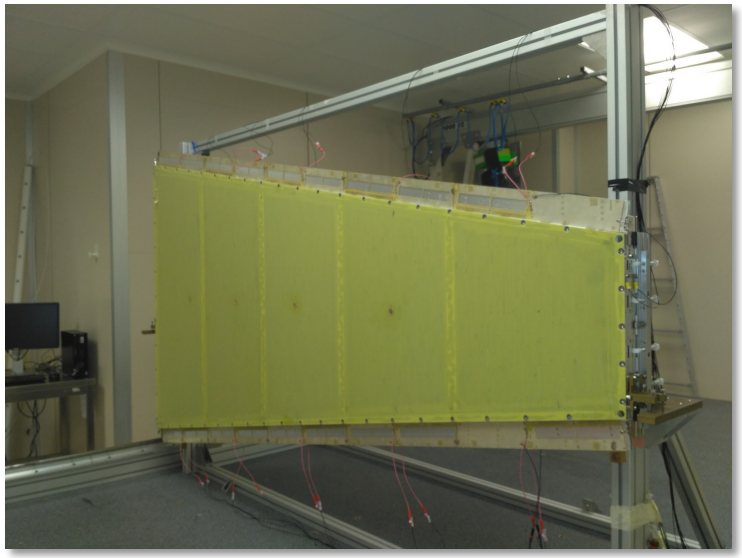
-> Production will start in ~2 weeks

Doublet has been assembled to:

1) test the assembly procedure with final design configuration
2) check the expected improvement in gas tightness
3) verify PCB quality



Fulfill the specification requirements



The ATLAS LNF Group

The Group:

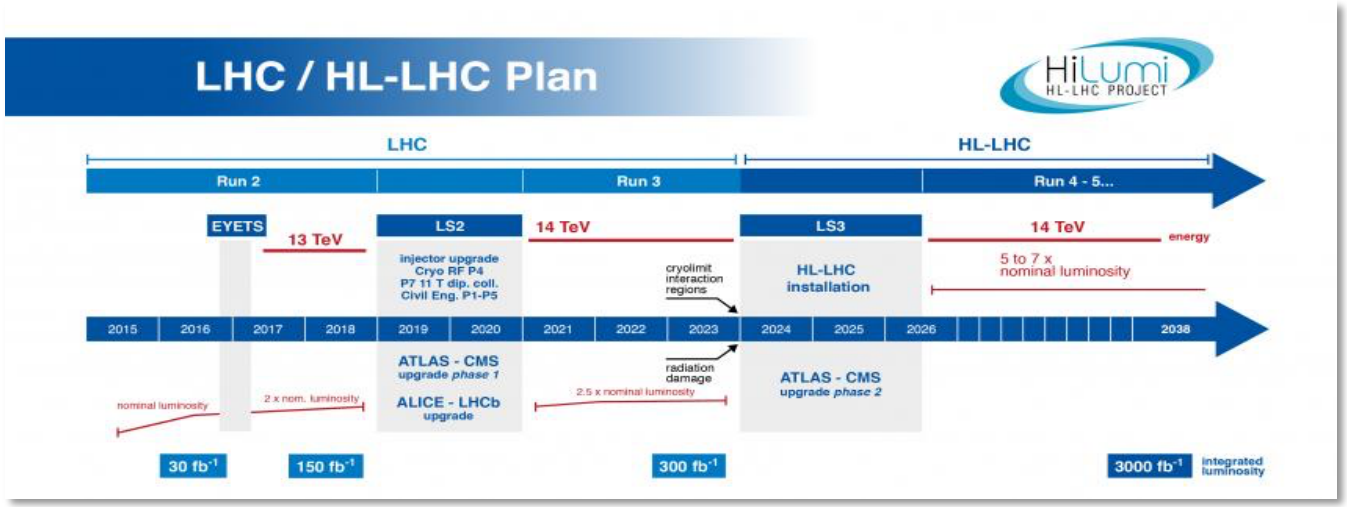
P.Albicocco, M. Antonelli, C. Arcangeletti, M. Beretta, H. Bilokon, S. Cerioni, V. Chiarella, M. Curatolo, M. Dreucci, B. Esposito, M. Gatta, C. Gatti, S. Lauciani, P. Laurelli , G. Maccarrone, G. Mancini, A. Martini, G. Pileggi, B.Ponzio, A. Sansoni, M. Testa, T. Vassilieva, E. Vilucchi

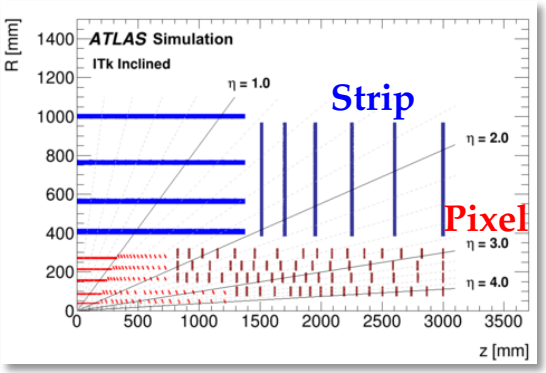
Presently, the LNF group is deeply involved in six activities :

- **H->ZZ*->4l** analysis
- **Particle Flow** and Missing Transverse Energy reconstruction
- **ATLAS upgrade**
  - **FTK:** Trigger upgrade with fast tracks reconstructions (Phase 1)
  - **NSW:** Muon spectrometer upgrade with the construction of the New Small Wheels (Phase 1)
  - **ITk:** Inner Tracker upgrade for HL-LHC (Phase 2)
- **Computing Activities**

Phase 2: HL-LHC

The current Inner Detector (ID) will need to be replaced to keep the excellent tracking performance at HL-LHC environment (inner most layers approaching end of life during Run 3 due to radiation damage)



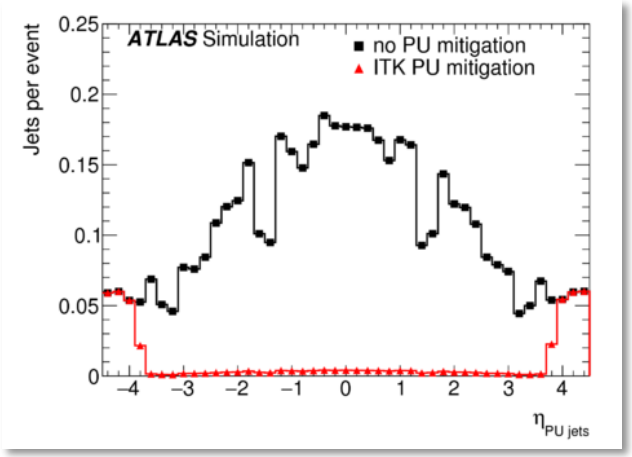


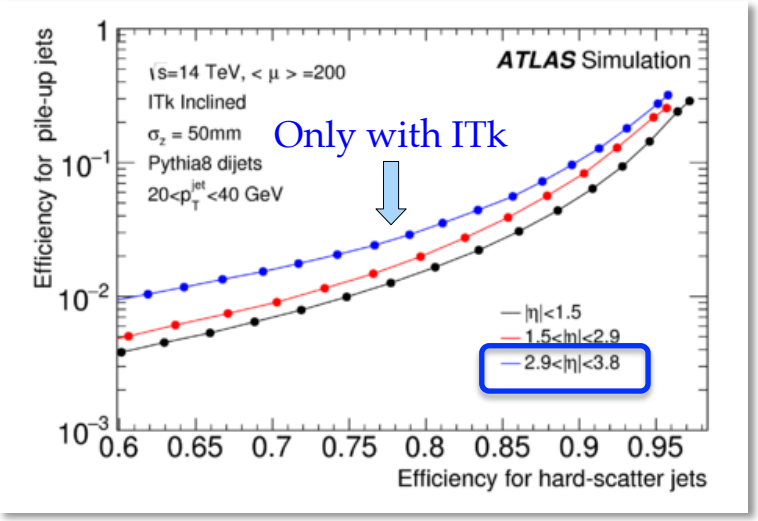
HL-LHC environment demands:

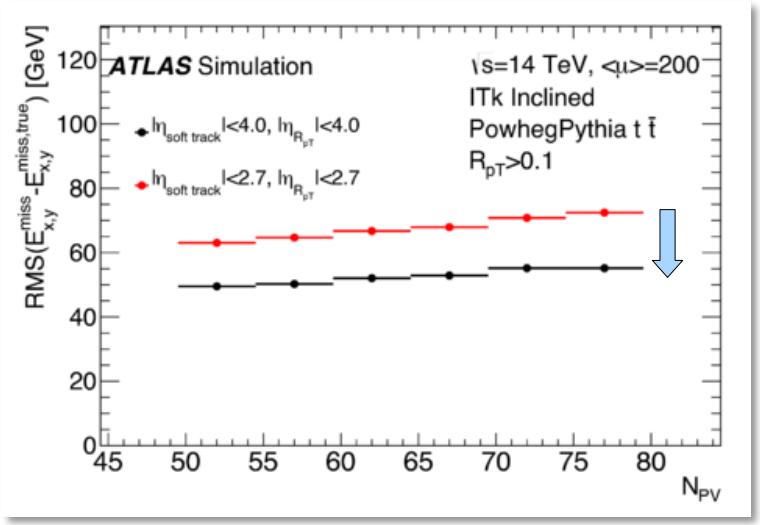
- increased radiation hardness
- higher granularity of pixel detector to reduce the occupancy and to handle the high pile-up environment (μ=200 increasing the peak luminosity by ~4)
- reduction of material to benefit tracking and calorimeter performance
- extended coverage of the tracking volume up to $|\eta| < 4.0$ mainly to identify pile-up jets and mitigate their effect

Design of ITk for jet and E_t^{miss} reconstruction

- **Pile-up suppression in jet and E_T^{miss} reconstruction main motivation for increased acceptance up to $|\eta| < 4.0$** (currently $|\eta| < 2.5$)
  - could suppress pile-up jets in the forward region using tracking information
  - improve E_T^{miss} resolution
- critical for layout decision
- main contribution from LNF



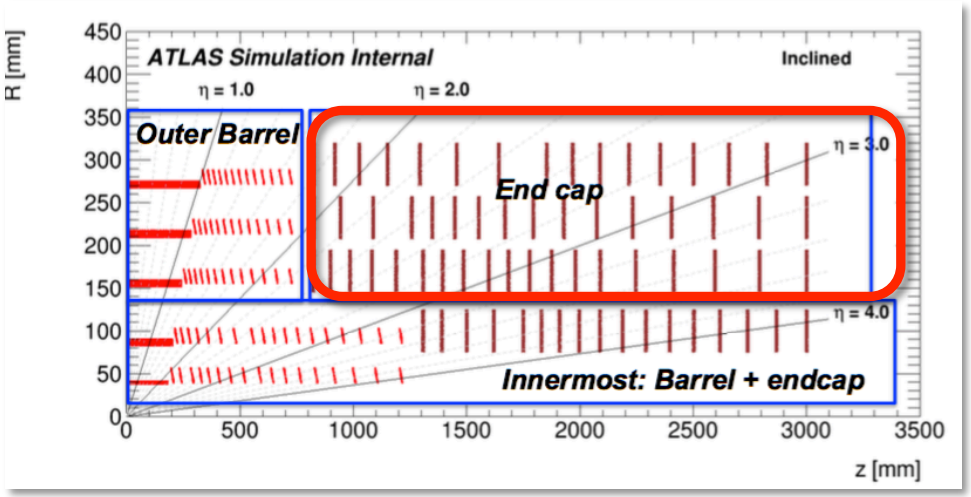


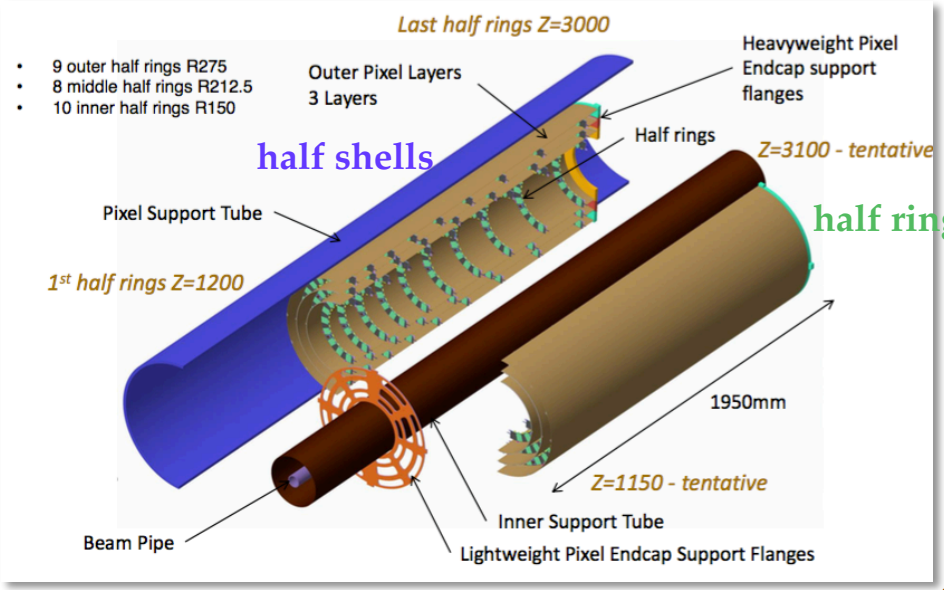


- Strip TDR
- Pixel TDR in preparation

Italy will build one endcap of the pixel ITk detector

- each Outer Endcap is an assembly of three coaxial cylinders each supporting a number of arc-shaped structures on which the modules are glued
- this design allows more flexibility in layout
- all mechanical supports are made of carbon composite material
- half shells to be built by UK partner, shared production for half rings
- short term plan is to produce first half ring prototypes and start their qualification

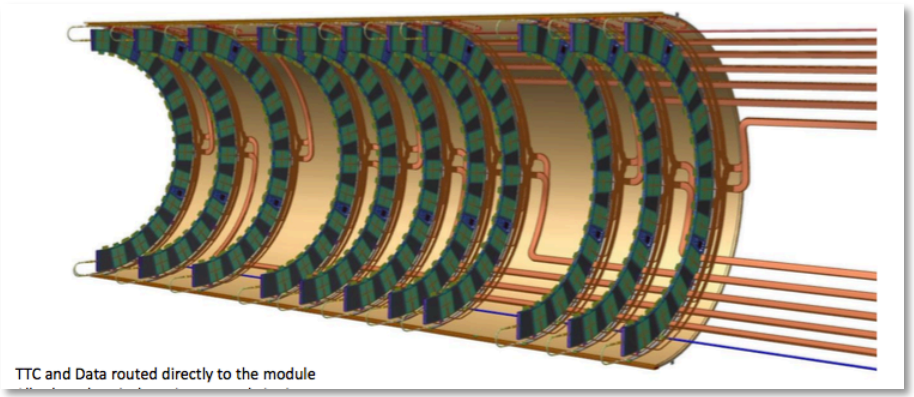


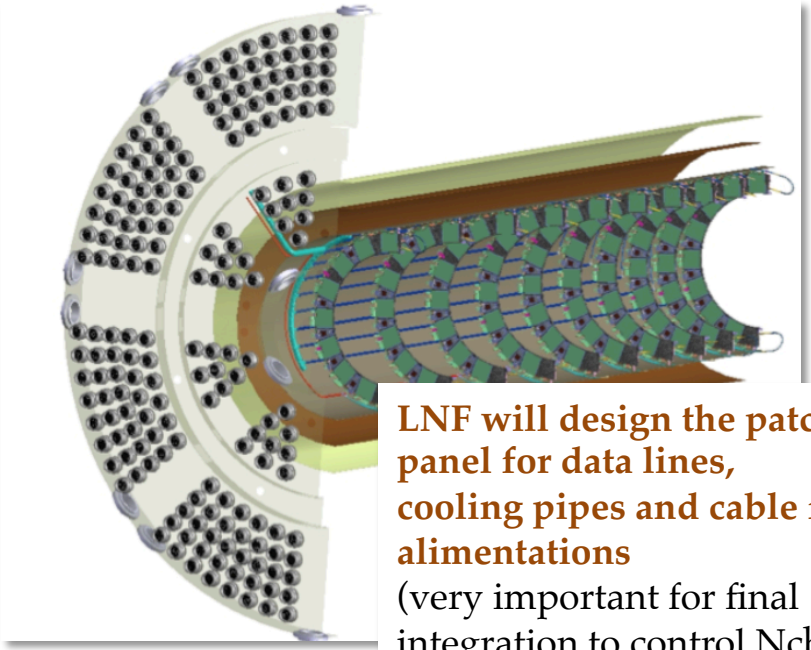


LNF activities include:

- reception tests of half-rings
- integration of half-rings in half-shell
- qualification of half-shell (*)
- assembly of a full shell (for all 3 layers)
- qualification of a full shell (*)
- assembly of the 3 full shells to the endcap
- qualification for the endcap (*)

(*) test of cooling system, thermal cycles, pressure cycles for cooling pipes, test of a module fraction per time





Multiple LNF divisions involved

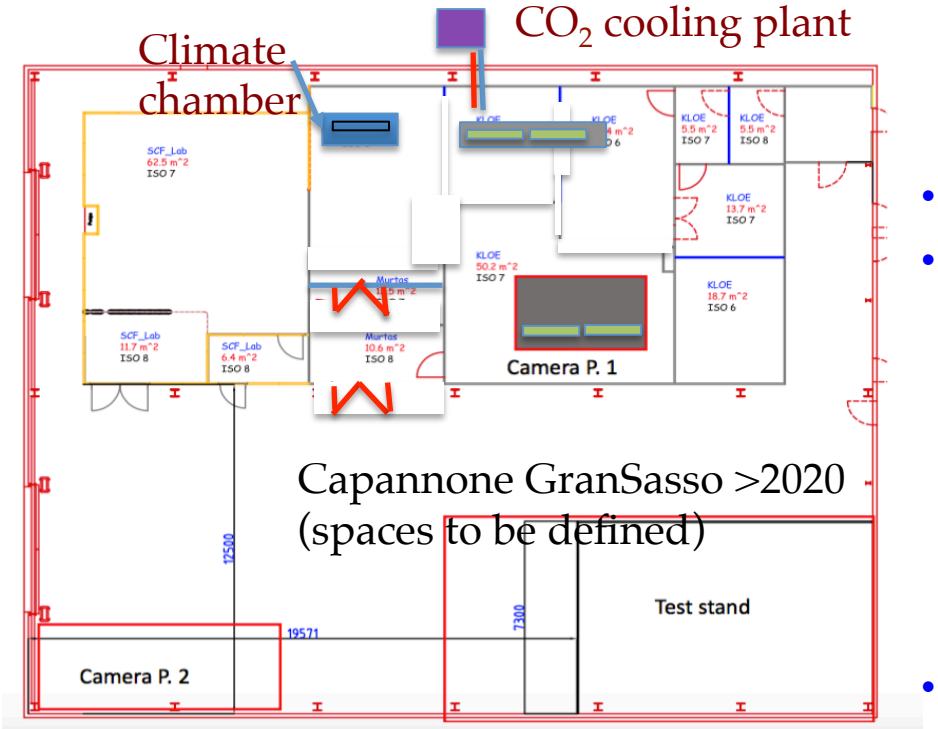
- Research and Technical Division Mechanical Services
- Research Division Electronic Service
- Accelerators Division Cryogenic Group

LNF will design the patch panel for data lines, cooling pipes and cable for alimentations
(very important for final integration to control Nch and spaces)

Plan toward integration of Pixel Endcap at LNF

Need new infrastructures

- CO_2 cooling system large at 2kW
- large climate chamber
- refurbishment of cleaning rooms



Plan toward integration at LNF:

- **Detector design with all services:**
  - cooling pipes, electrical services, data lines
- **Tools design:**
  - supports for half cilinders
  - rails for coaxial insertion of one cylinder into the other
  - measurement systems
- **Define system tests**
- **Strategy for transfer lines of the CO_2 cooling system**
  - define splitting box to send cooling lines to different working spaces

  → decision on how to organize the spaces of the cleaning rooms

  → preliminary tools and strategies during 2018
- **Design and mockup of patch panel in 2018**

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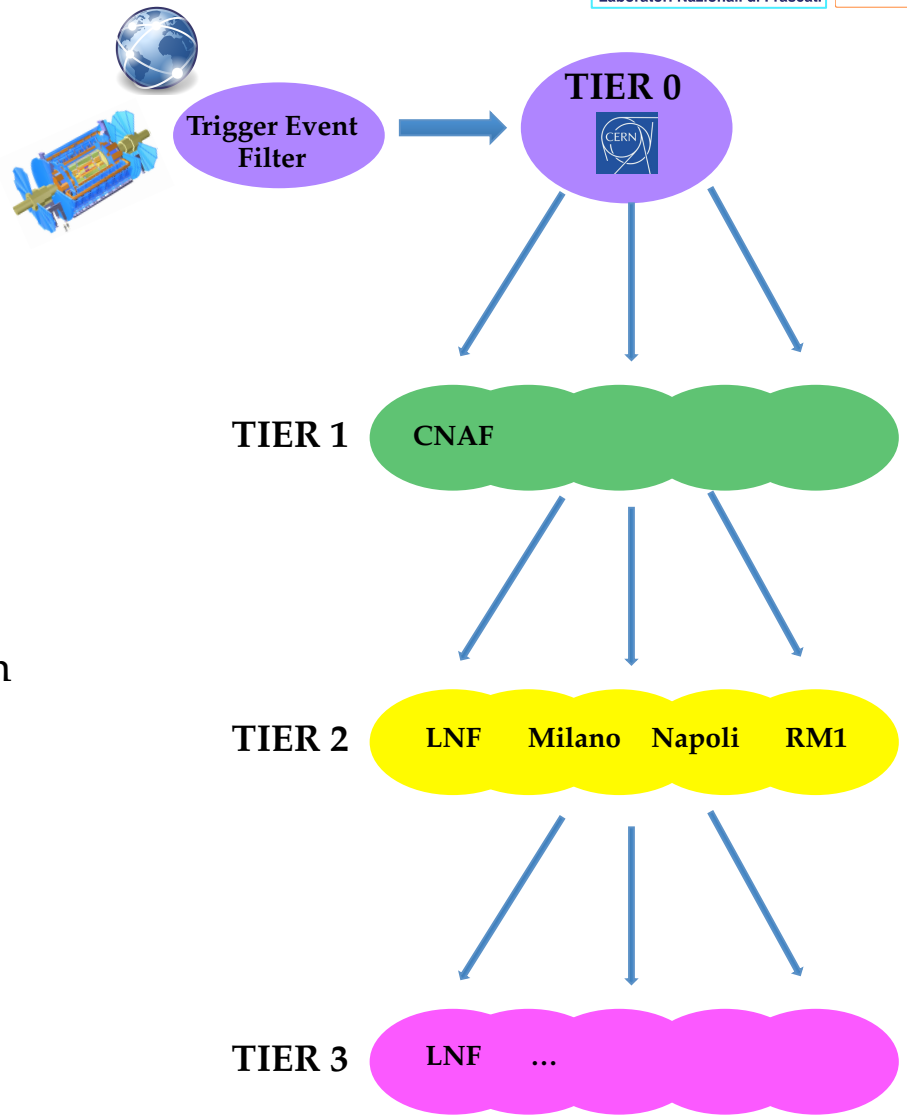
ATLAS computing model

Hierarchical structure based on multi-tier distributed architecture

- **Tier0** -> online data storage and first reconstruction RAW->RECO (ESD)
- **Tier1** -> data storage and services: simulation, reconstruction, calibration, skimming (AOD)
- **Tier2** -> simulation for computing system commissioning, AOD used for analysis
- **Tier3** -> user's analysis



The ATLAS Italian cloud

- 1 Tier1 at CNAF
- 4 ATLAS Tier-2s
  - **Frascati**, Milano, Napoli ,Roma1

ATLAS LNF Tier2:

Storage system and computing farm in Grid, for productions and analysis jobs :

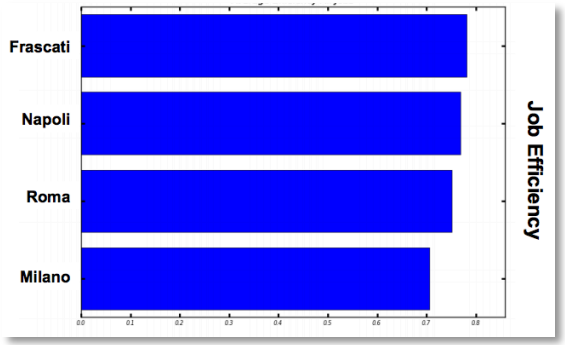
CPU: ~26kHS06 (~ 2500 virtual cores)
Storage: 1.5PB n (1.8 PB raw)
Services: ~50 servers (both bare metal and virtual machines)

High availability and reliability in the last years (data for 2015-2017):
Availability = ~ 97% Reliability = ~97%
Efficiency > 80 %

Other supported VOs:

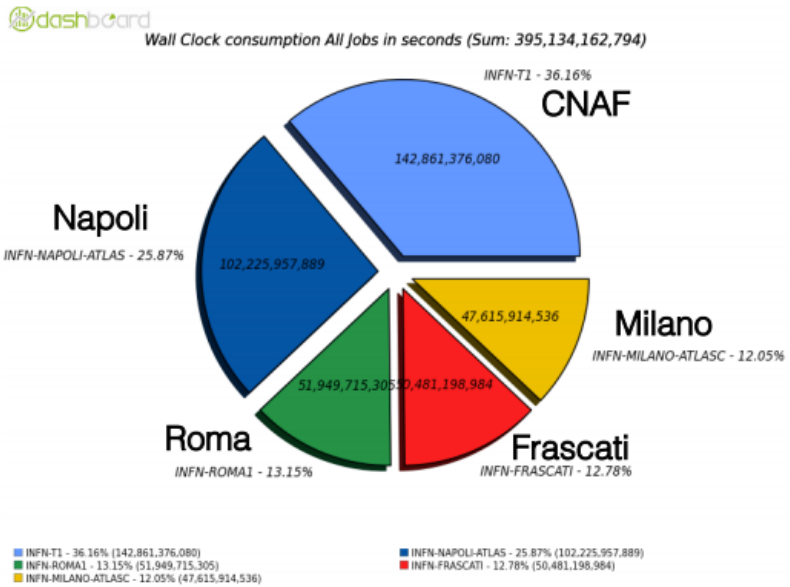
- Atlas Tier 3 (within Tier2)
  PADME (financed resources) , LHC VOs, Belle II and KM3Net (opportunistic resources)

Since 2014: New computing Room



Other Tier2 activities:

- **ATLAS VO (Virtual Organization) management** (inkind activity)
- **Test and development of DPM software** for storage management in Grid inside DPM collaboration
  - host of DPM test-bed for testing
- **Test and development of more performant storage systems**:
  - **Dynafed**: HTTP Dynamic Federation of Grid storage elements (SEs)
  - **Storage Federations**: an example is the XROOD federation of SEs
  - **Caching systems**: cache of popular datasets for diskless Tier3 and more efficient Tier2 SEs
  - **Remote pooling**: remote DPM disk pools to reduce SE endpoints in order to simplify ATLAS central operations



Conclusion

ATLAS detector worked extremely well:

- huge amount of measurement and papers, exploiting the potential of data
- increasing cross section and statistics allow to investigate more restricted phase spaces

LNF group heavily involved in the ATLAS activities:

- strong contribution in Higgs analysis and performance studies
- fully committed to the two major Phase 1 upgrade of the ATLAS detector + ITK for Phase 2 upgrade
  - central role in the construction of the NSW with micromegas detector
  - committed in the finalization and testing of the FTK components (AM and IM) developed in the past years @ LNF
  - involved in the commissioning for the construction of the ITK pixel detector (end-cap)

Thanks for your attention

Backup

HV Status for SM1 Mod 0.5

L4	HV (V)	I (nA)	L3	HV (V)	I (nA)	L2	HV (V)	I (nA)	L1	HV (V)	I (nA)
1 UP	580	116	1 UP	590	0	1 UP	590	2	1 UP	590	1
1 DW	580	117	1 DW	590	1	1 DW	590	2	1 DW	590	15
2 UP	590	6	2 UP	590	13	2 UP	590	1	2 UP	590	2
2 DW	590	4	2 DW	590	18	2 DW	590	0	2 DW	590	1
3 UP	590	79	3 UP	590	3	3 UP	590	3	3 UP	590	408
3 DW	590	1	3 DW	590	5	3 DW	590	30	3 DW	590	253
4 UP	590	337	4 UP	590	1	4 UP	590	4	4 UP	590	1
4 DW	590	62	4 DW	590	2	4 DW	590	0	4 DW	590	4
5 UP	590	211	5 UP	590	0	5 UP	590	3	5 UP	590	1108
5 DW	590	7	5 DW	590	2	5 DW	590	1	5 DW	590	761

	I < 100 nA		100 nA < I < 500 nA		I > 500 nA

This is a results of many weeks of conditioning working in gas

For the moment Cosmic data taking is concentrate on PCB 5 (last two rows)

Introduction

H->ZZ*->4l event selection:

- 2 pair of SFOS leptons with p_T >20, 15, 10, 5(7) GeV and $|\eta| < 2.7(2.47)$ for μ (e)
- $50 < m_{12} < 106$ GeV , $12 < m_{34} < 115$ GeV
- J/Psi veto: $m_{ll} > 5$ GeV
- $\Delta R(l,l') > 0.10$ (0.20) for same (different) flavour leptons in the quadruplet

Background ZZ* + ttV + VVV:

- ZZ* (major) -> estimated from MC
- ttV + VVV: smaller bkg from MC
- Validated in control region: (m4l < 115 || m4l ∈ [130, 170] GeV)

Reducible bkg estimates:

- Z+μμ: extrapolation from inv.d0, inv.iso, eμ+μμ CRs (Z+jets, tt)
- Z+ee: extrapolation from 3l+X CR (e from fakes), MC (e from heavy flavour)

Introduction

- **NSW requests:**

– 3 FTE technicians for 2 years starting from march 2016

– Infrastructures:

- 1 clean room for assembly (available)
- 1 clean room for panels refinement (soon available)
- Cosmic Ray stand for Chamber commissioning

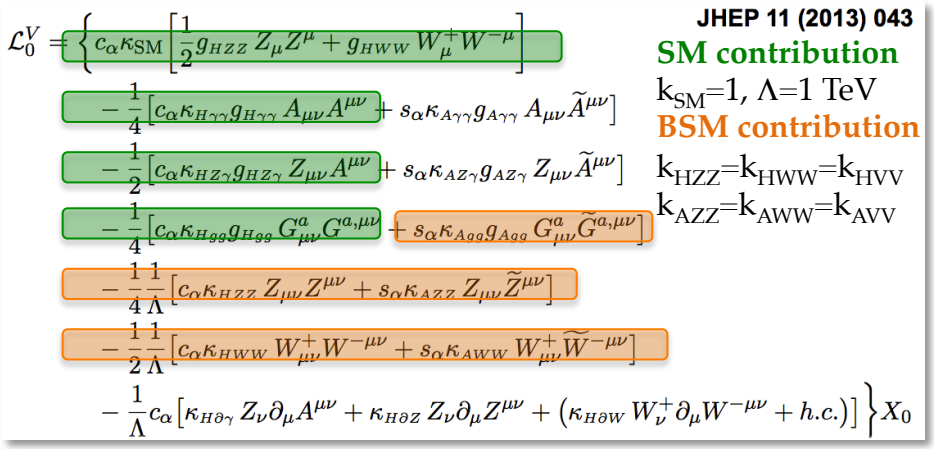
– **some FTE(~1.5) after construction for installation**

- **FTK**

– Final production of the input Mezzanine, tests of IM and AM06 chip to be done by July 2016

– Need at least 1 FTE to complete mezzanine production and for test of amchip06

Introduction



- studies on k_{Agg} and k_{HVV} , k_{AVV} coupling constants, which represent respectively the *CP*-odd coupling to gluons (*CP*-even is SM) and the coupling to scalar pseudoscalar particles with the W and Z SM bosons have been performed

NSW Motivation

Trigger and Tracking strongly affected when LHC luminosity will be above the design values

- **Trigger**:

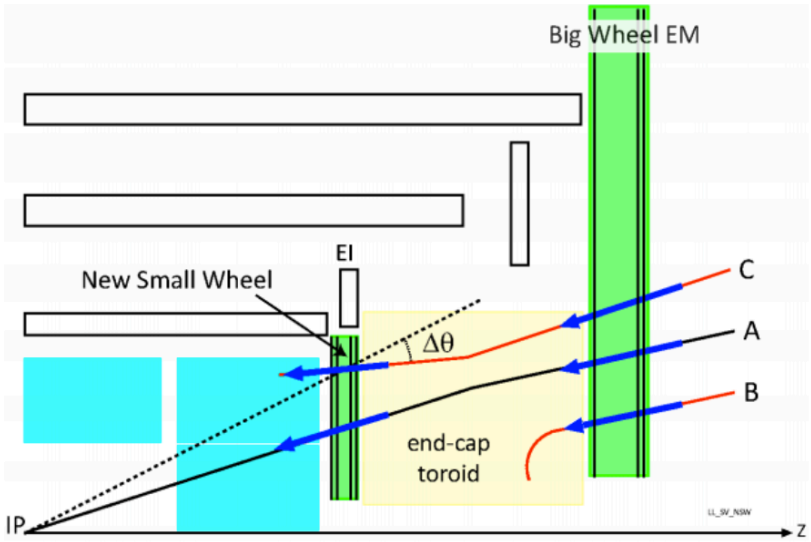
– Current μ-trigger in the EndCap rely only on the Large Wheel information

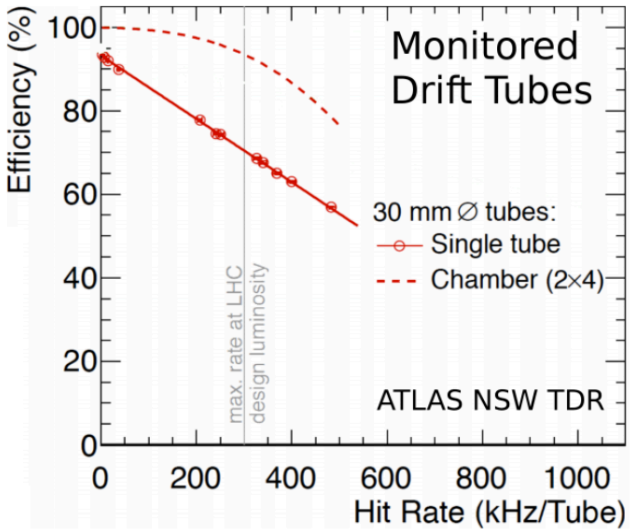
- In this region L1 trigger is dominated by fake triggers
- @ 3x1034 pT>20 GeV estimated trigger rate ~60kHz (available bandwidth ~20kHz)
- **Tracking**

– At HL-LHC luminosity, the hit rate in the fwd region ~15kHz/cm2

- expected ~5MHz /MDT/tube for the current MDT
- >300kHz/tube MDT efficiency drop due to deadtime from bkg hits + resolution decrease due to space charge

⇒ New Small Wheel needs trigger and high rate capable new technology





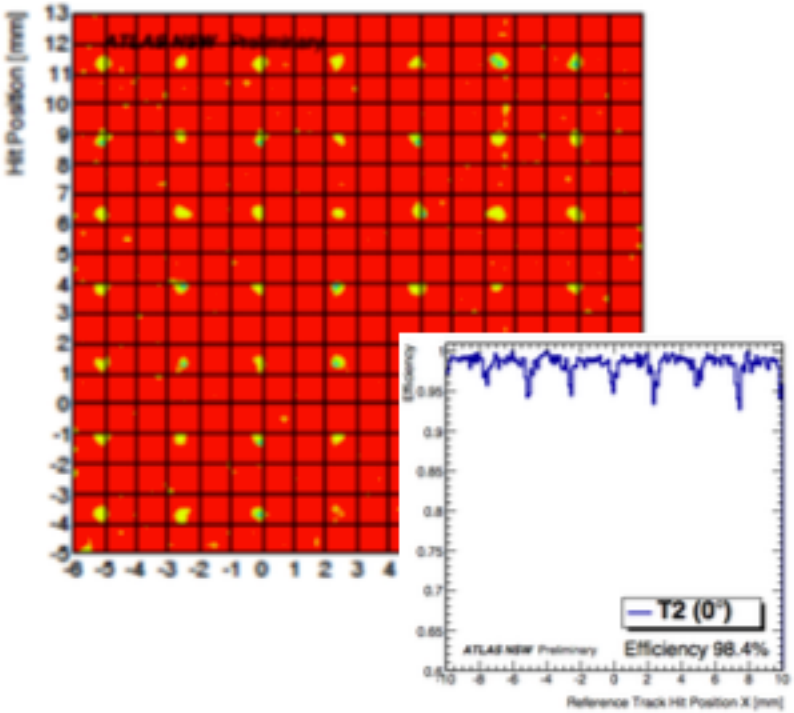
Micromegas Performances

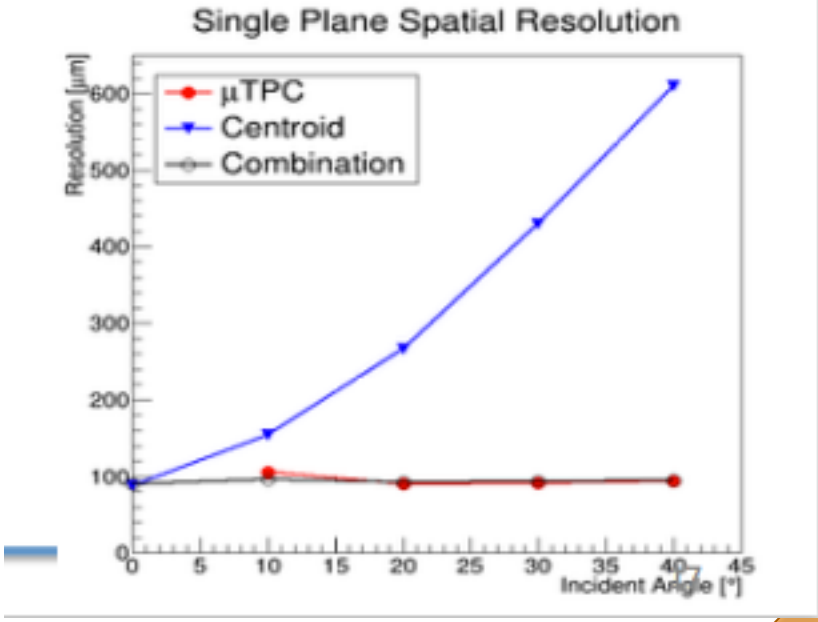
Performances studied with small prototypes
with several Test beam campaigns (also @ LNF)

– **Efficiency 98-99%**, consistent with the dead area from pillars supporting the mesh
– **<100μm** resolution for perpendicular tracks from charge centroid
– μTPC mode exploited for incident angle >10o , **~100μm** resolution

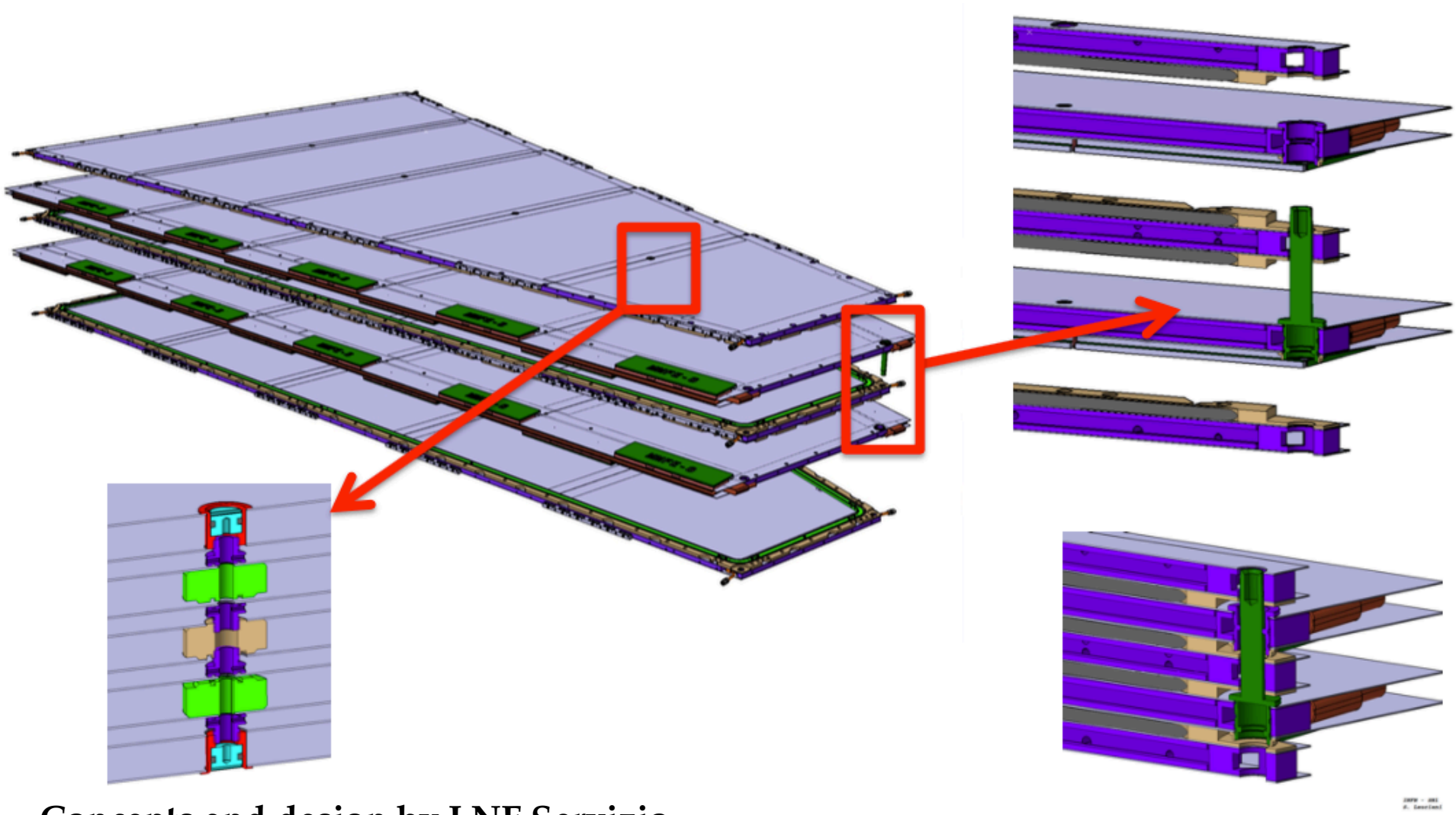
- Use time information from hit arrival

– Impact of copper-resistive strip misalignment
– Different gas – mixture composition
– Magnetic field effect
– Performances of the RO electronic



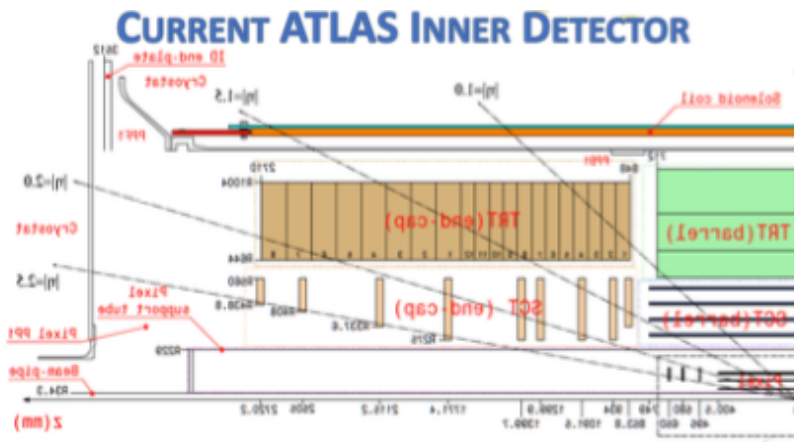


SM1 design

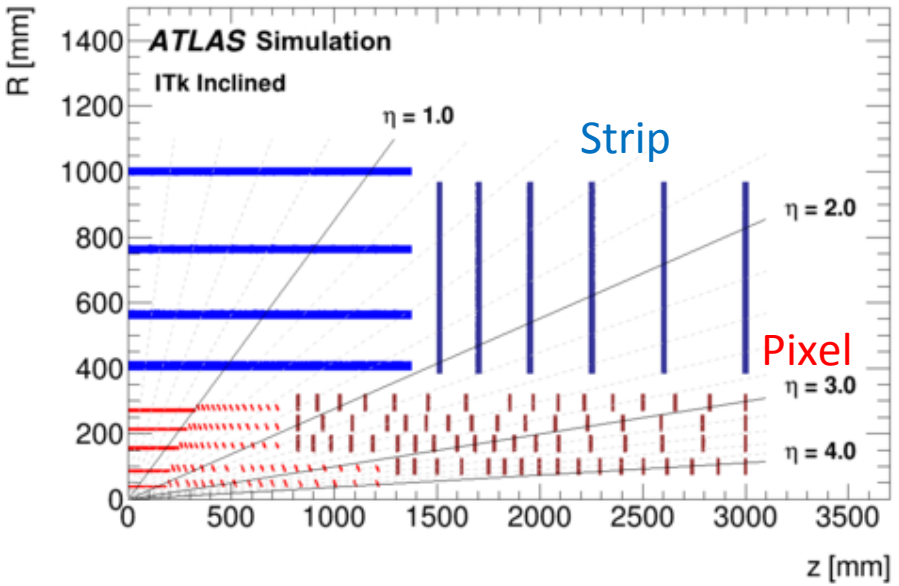


Concepts and design by LNF Servizio Progettazione Apparati Sperimentali

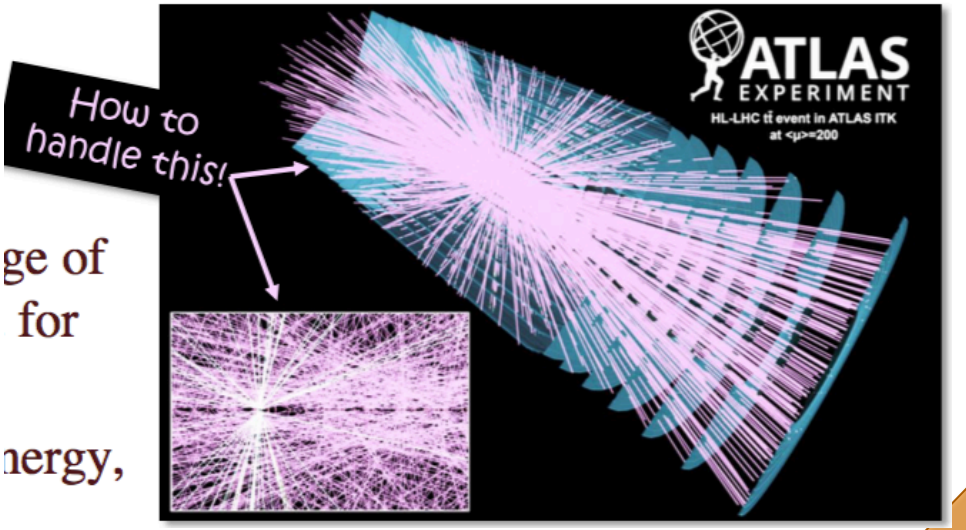
Overview of ITk (Inner Tracker)



ATLAS ITk



- All silicon design,
- Eta coverage increased from 2.5 to 4.0
- Need same performance as the current detector, but in the harsher environment of the HL-LHC



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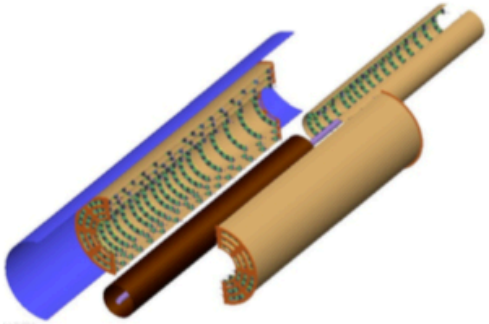
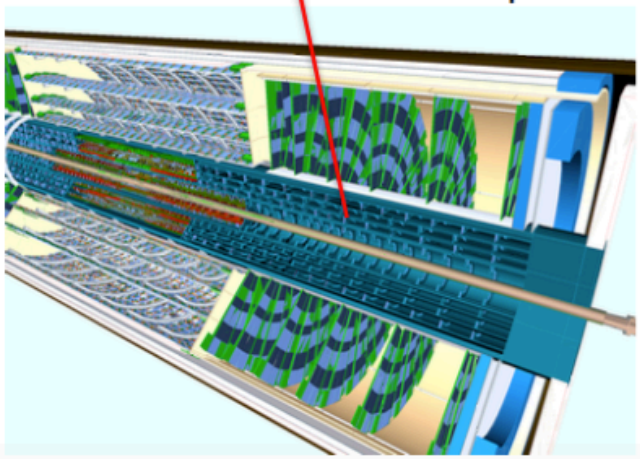
Pixel Endcap: some details

Half-rings on half-shell

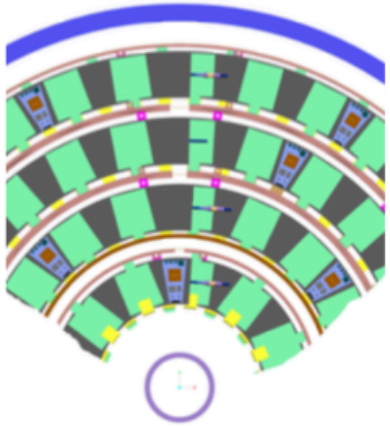


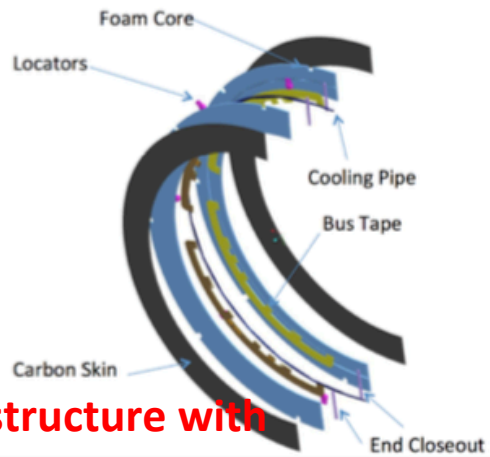
Pixel Endcap: half cylindrical shells supporting quad modules

Designed to minimise mass of ring system in order to reduce the particle background reaching forward calorimeter and to improve tracking performance at high-eta



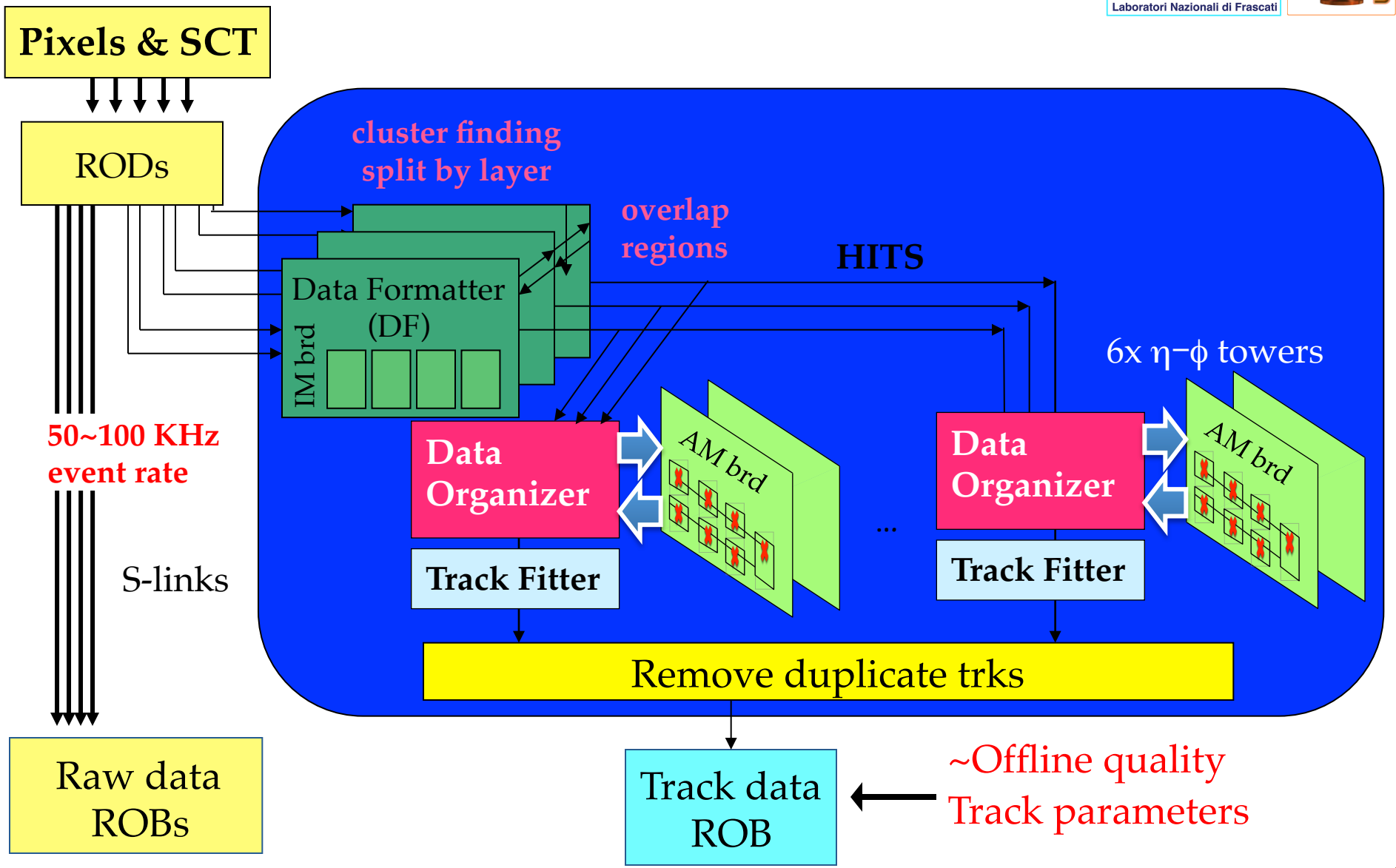
Modules on half rings





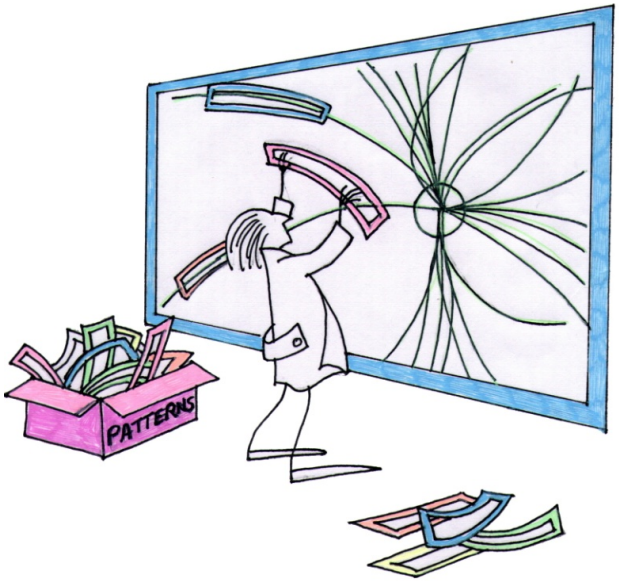
Half-ring structure with cooling pipe

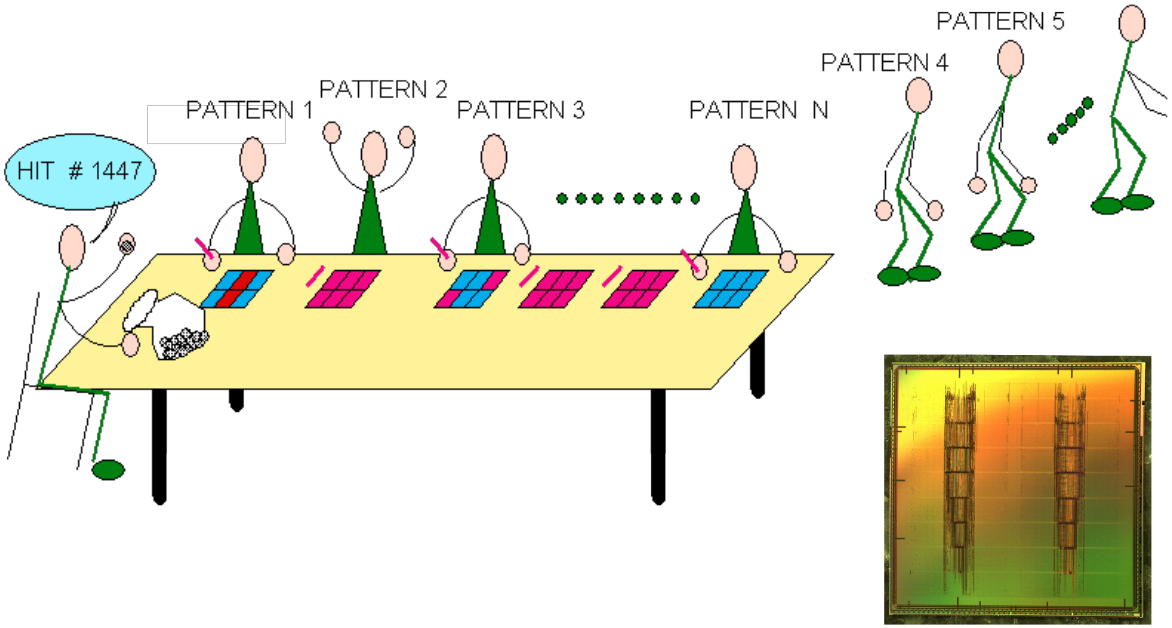
Introduction



Two time-consuming jobs in tracking: Pattern recognition & Track fitting

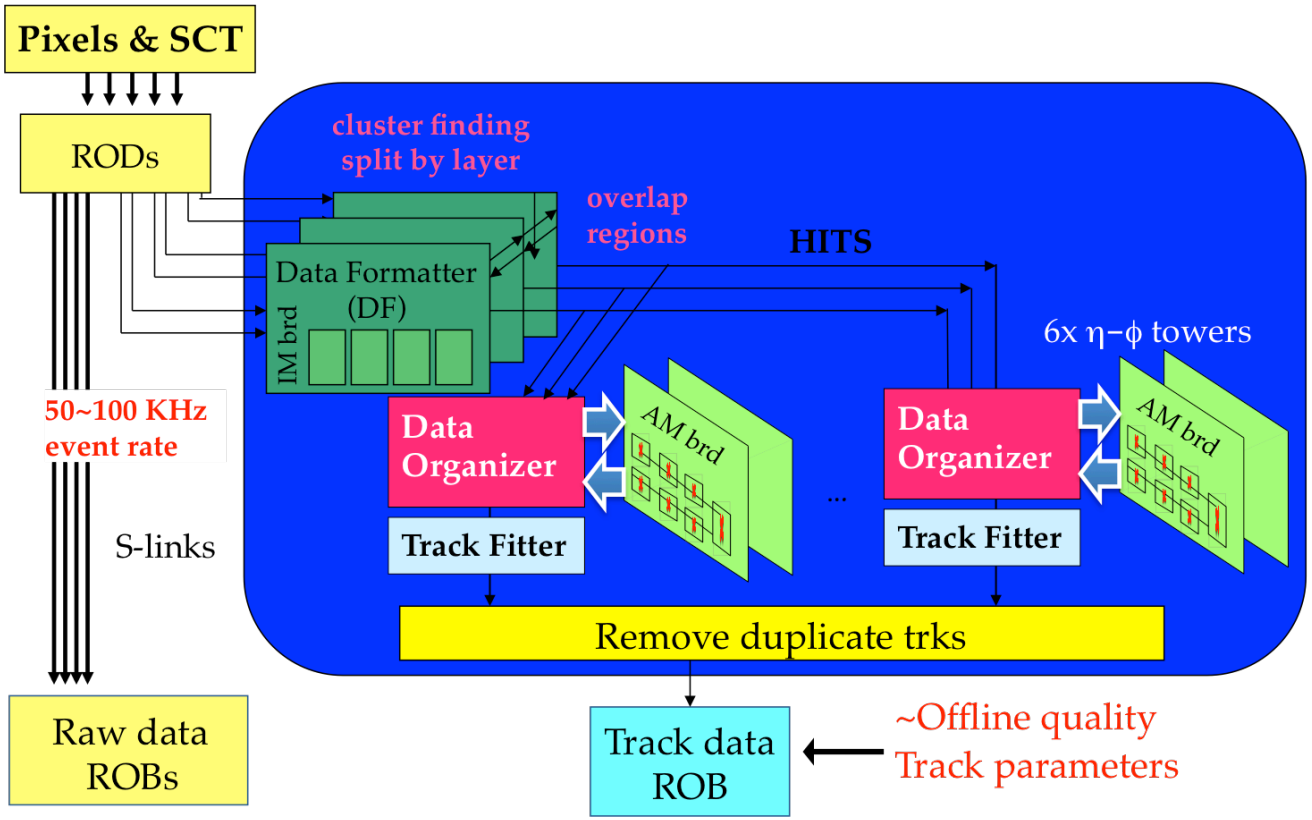
- Pattern recognition – find track candidates with enough Si hits





  - 10^9 prestored patterns (roads) simultaneously see the silicon hits leaving the detector at full speed.
  - Based on the Associative Memory chip (content-addressable memory) initially developed for the CDF Silicon Vertex Trigger (SVT).

Introduction



Trigger studies using FTK

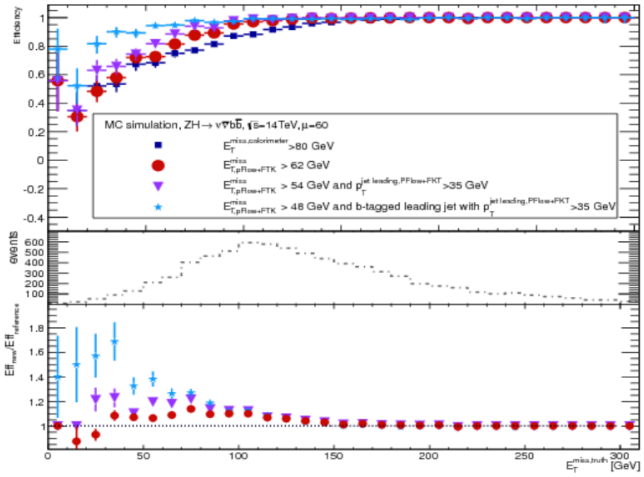
High Level Trigger with FTK for the search of the Higgs Boson in the ZH→vvbb channel

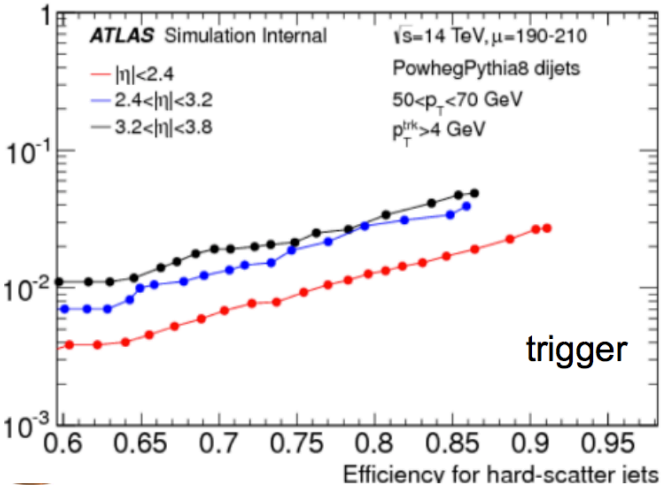
– (LNF master thesis)

- High Potential of FTK tracks in combination

with Particle-Flow MissingET trigger

- Increase of signal efficiency ~8%, up to 20% at low MET
  - keeping HLT rate constant





Trigger upgrade studies with L1 Track and FTK++ in the context of phase 2 upgrade

- High potential to suppress online pile- up using forward tracking + FTK