ATLAS LNF activity Status Report

Roberto Di Nardo

on behalf of the ATLAS LNF group

50° LNF Scientific Committee

November 23rd 2015, Frascati

The ATLAS LNF group

- **The Group:**
  - M. Antonelli, H. Bilokon, S. Cerioni, V. Chiarella, M. Curatolo, B. Esposito, P. Laurelli , G. Maccarrone, A. Martini, A. Sansoni, M. Gatta, C. Gatti, M. Testa, R. Di Nardo, G. Mancini, E. Vilucchi, M. Beretta, P.Albicocco, S. Lauciani, B.Ponzio, G. Pileggi, M. Dreucci

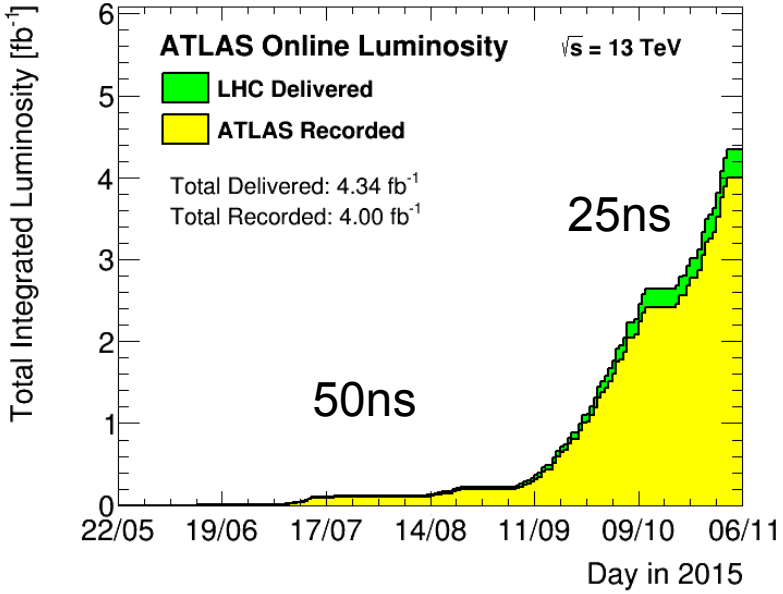
- Presently, the LNF group is deeply involved in five activities :
  - **H->ZZ->4l** analysis
  - **Particle Flow** and Missing transverse energy reconstruction
  - **ATLAS upgrade**
    - Trigger upgrade with fast tracks reconstructions (**FTK**)
    - Muon spectrometer upgrade with the construction of the New Small Wheels (**NSW**)
  - **Computing Activities**

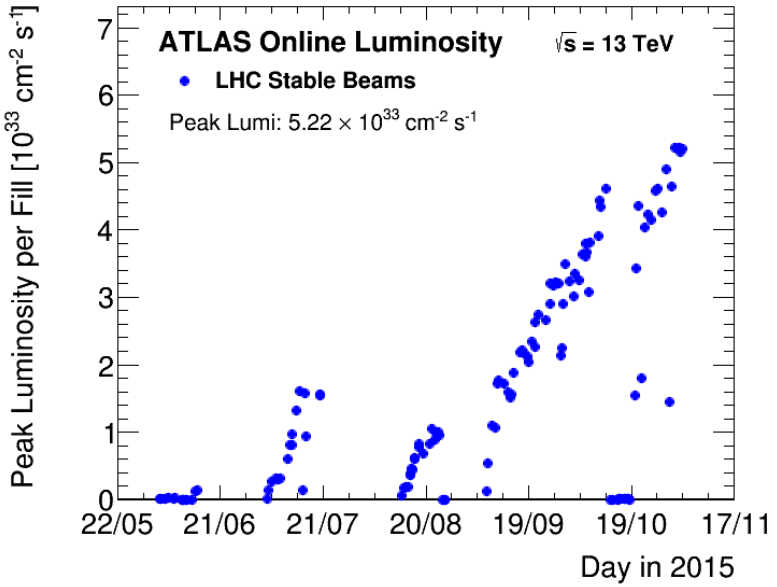
- Several member of the group have responsibility role within ATLAS
  - INFN coordinator for the NSW upgrade project
  - JET/MET Data Quality coordinator
  - HZZ convener

Roberto Di Nardo – INFN Laboratori nazionali di Frascati

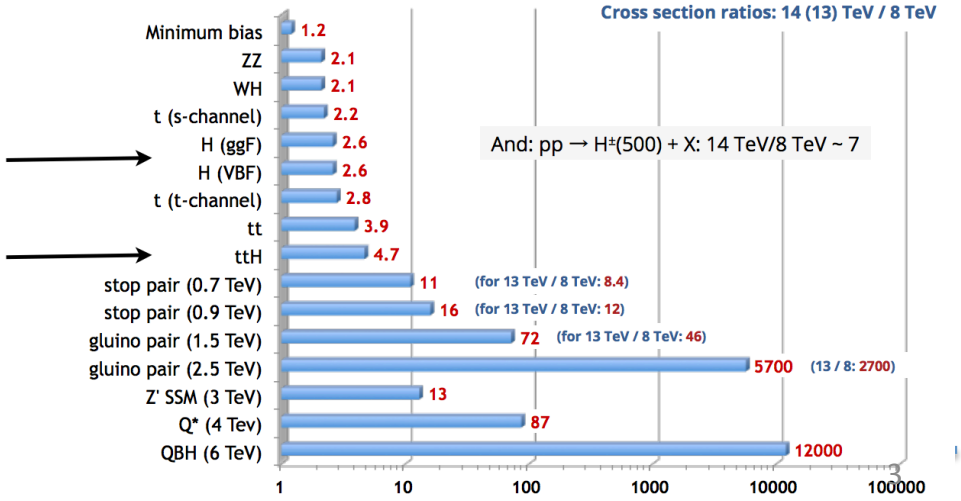
LHC and ATLAS at √s=13 TeV

- LHC started the √s =13 TeV operation at the beginning of this year
  - 4 fb^{-1} collected in 2015 that can be used already for the analyses !
  - ATLAS data taking efficiency >~90%





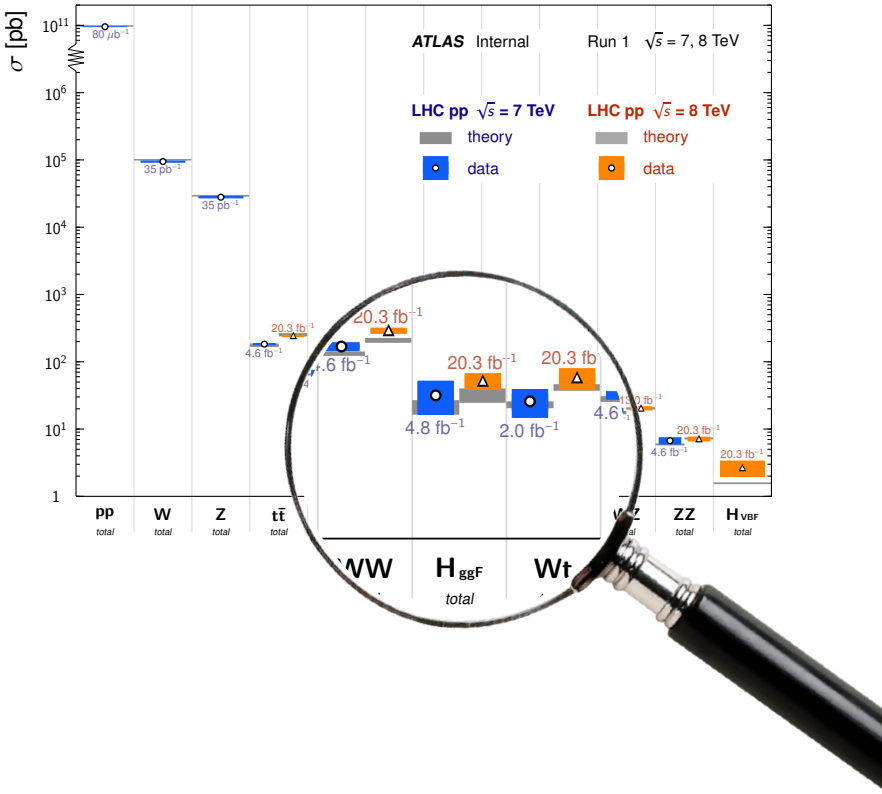
- Hugely increased potential for discovery of heavy BSM particles thanks to the higher √s



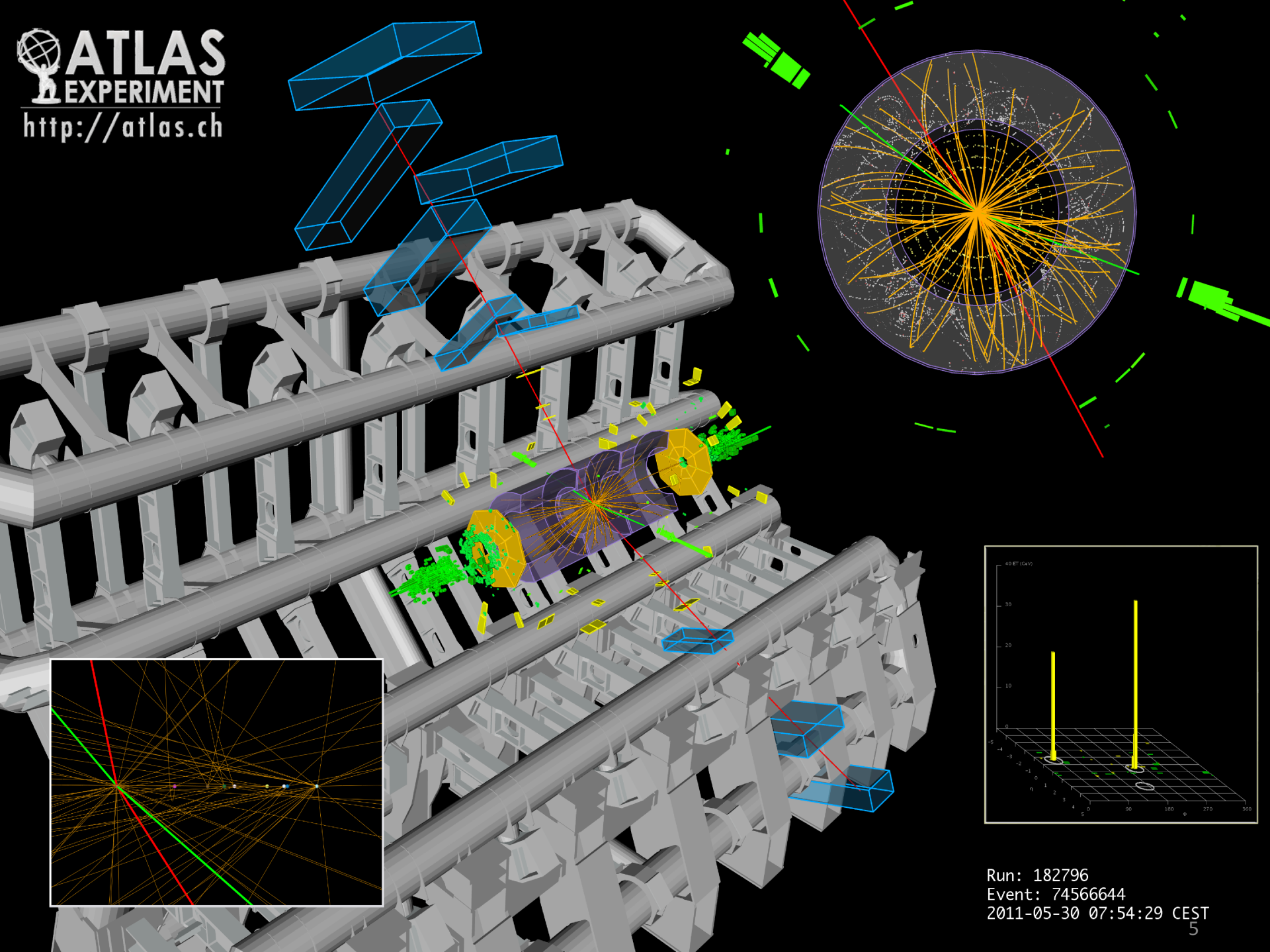
Roberto Di Nardo – INFN Laboratori nazionali di Frascati

Physics Analysis in Run1: H->ZZ->4l

- Very successful RUN1 Higgs Program
- After discovery, a 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
  - Mass, couplings, spin and parity, differential cross section, off-shell production

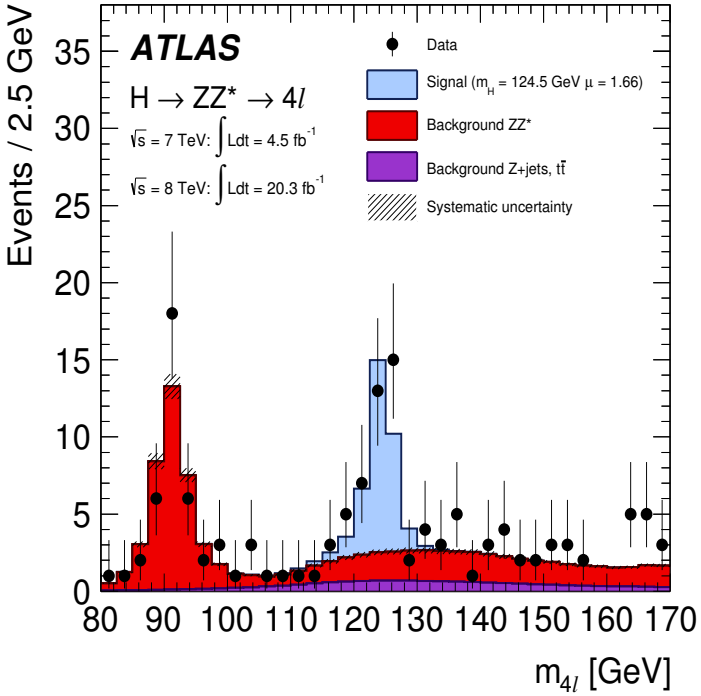


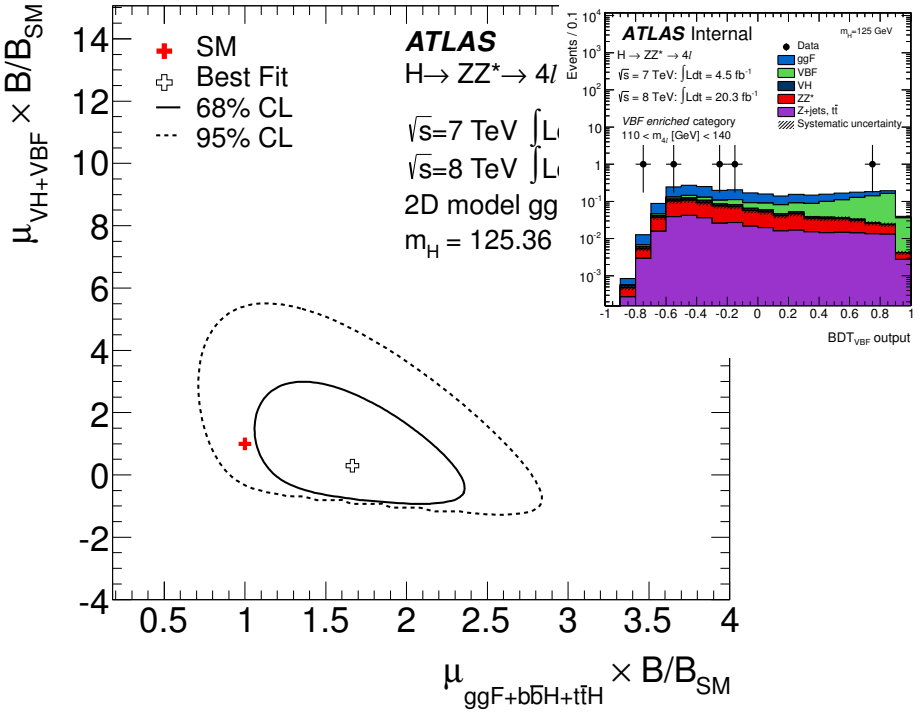
- Despite the low BR, signature very clean
  - Two same flavour opposite sign lepton pairs
  - S/B~2
- Fundamental contribution of the LNF ATLAS group to the Higgs boson discovery and to the study of its properties with the H->ZZ->4l


ATLAS
EXPERIMENT
http://atlas.ch
Run: 182796
Event: 74566644
2011-05-30 07:54:29 CEST

Mass and couplings

- RUN 1 Results:
  - Higgs boson mass measurement: $m_H = 124.51 \pm 0.52(stat) \pm 0.06(sys)$ GeV
    - Input for the ATLAS-CMS combination -> **m_H=125.09±0.21(stat)±0.11(syst) GeV**
  - Event categorized as ggF-VBF-VH-like
    - 1 VBF-like event observed

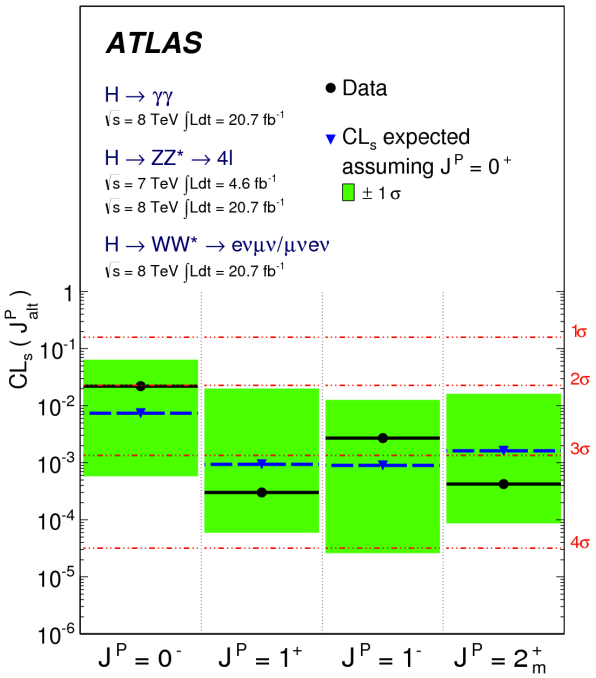


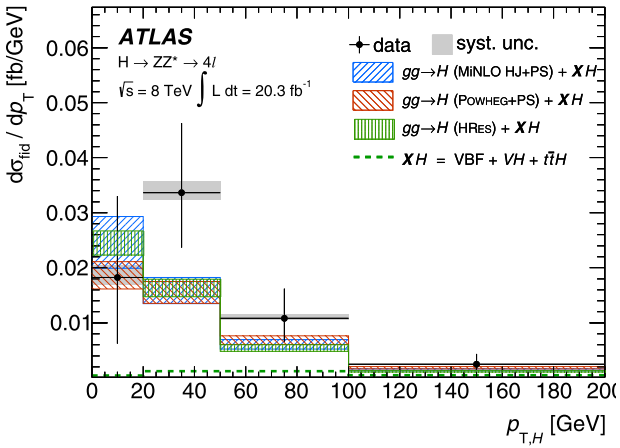


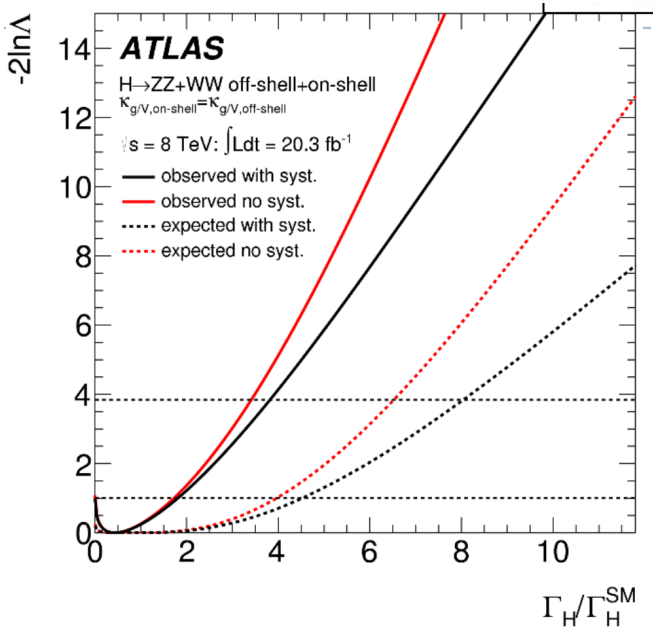
- Huge LNF involvement:
  - contact editor for: Phys. Lett. B 726 (2013)120, Phys. Rev. D 90 (2014) 052004, PhysRevD.91.012006

Properties measurement

- CP analysis to probe the coupling structure of the HZZ interaction
  - Evidence for the spin-0 nature of the Higgs boson







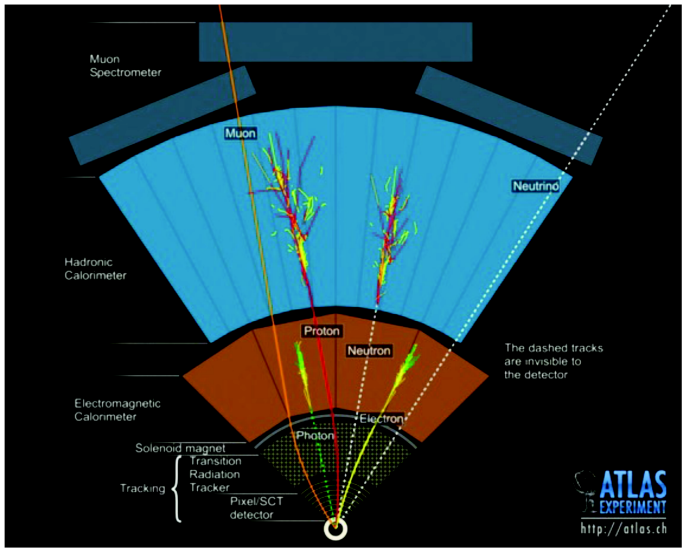
- Fiducial and differential cross section to probe several properties of the Higgs boson
  - Kinematics, spin and parity, jet activity , production modes
  - Compatible with SM, very powerful measurements for RUN2 and beyond
- Limits on Off-shell Higgs production set as well with RUN1 data
  - Assuming same on-shell and off-shell couplings: $\Gamma_H < 23$ MeV

Roberto Di Nardo

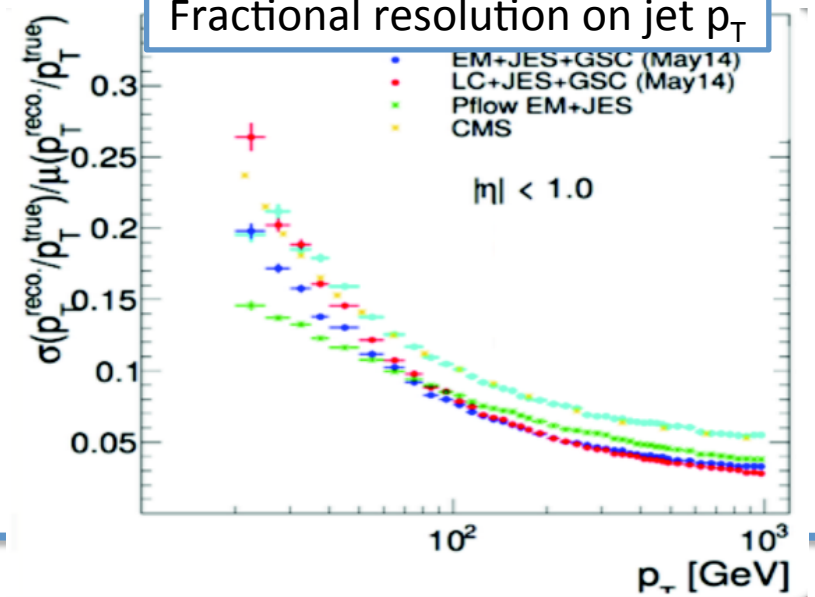
- Active contribution of the Frascati group also in the performance studies, both for near future and for the ATLAS upgrades

Particle flow

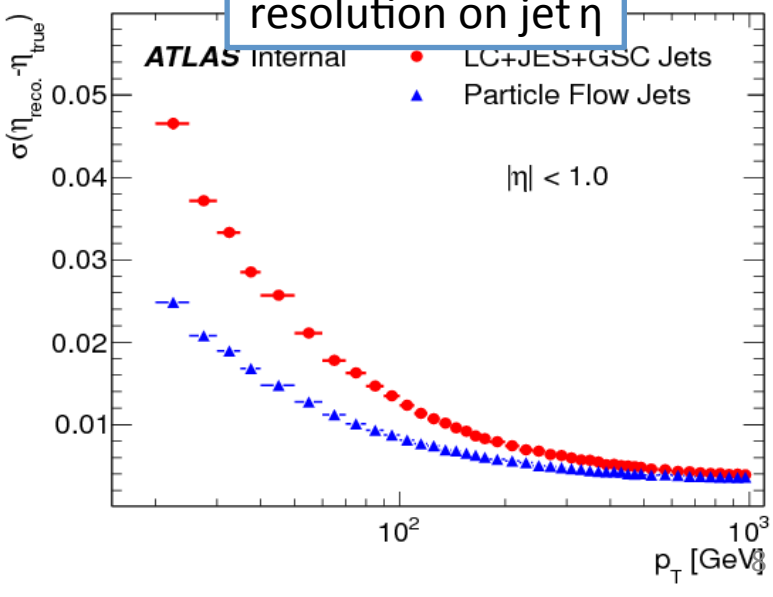
- PF algorithms try to follow the path of individual particles trough the detector
- Combined information of the sub-detectors
- Removal of charged pile-up
- Improved p_T and angular resolution of jets
  - Contact editor for foreseen publication



Fractional resolution on jet p_T



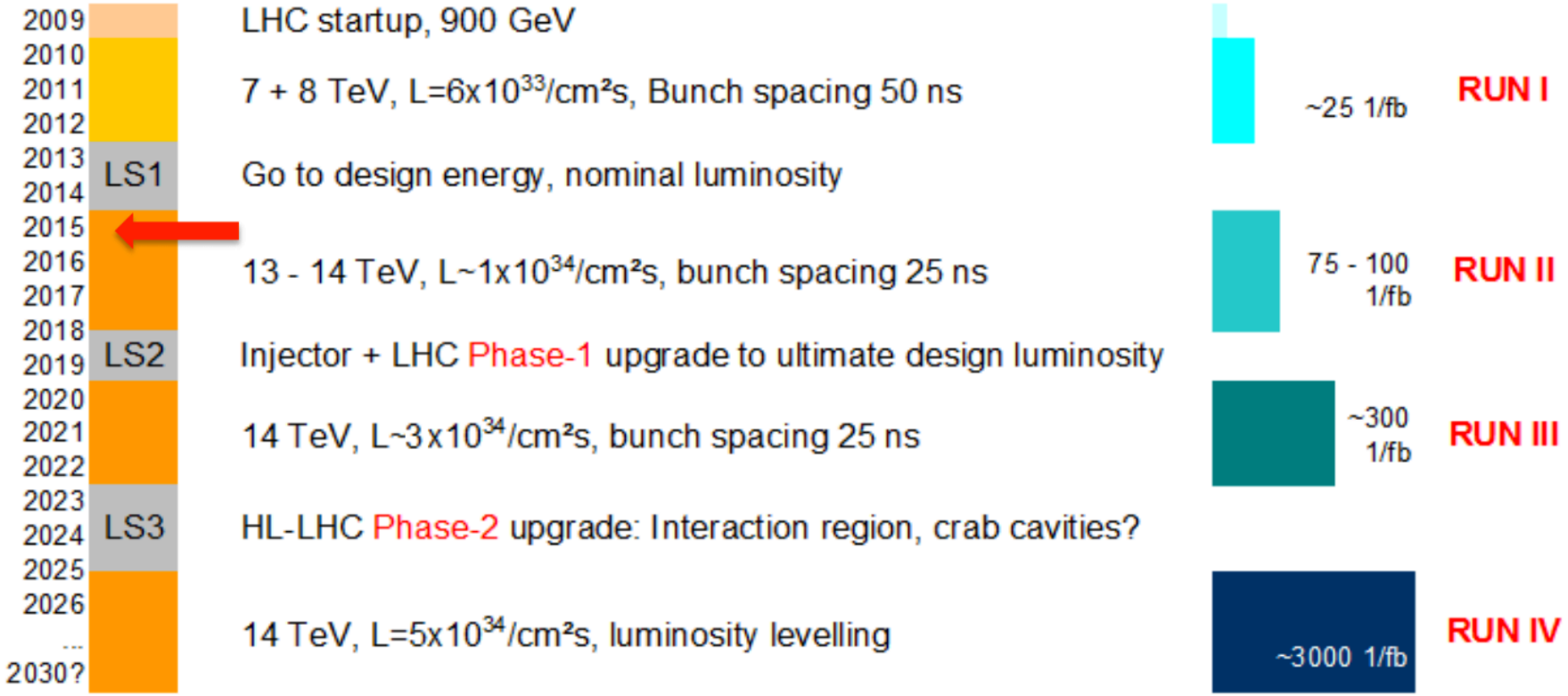
resolution on jet η



ATLAS Upgrade: the New Small Wheel and the Fast TracKer

Roberto Di Nardo – INFN Laboratori nazionali di Frascati

The ATLAS upgrade program



- **Phase-0 Upgrade:**
  - Consolidation + Insertable B-Layer (IBL) in LS1 already in for Run2
- **Phase-1 Upgrade**
  - New Small Wheel, Calorimeter trigger upgrade, FTK
- **Phase-2 Upgrade**
  - Inner Tracker, Muon spectrometer (?)
- **LNF group already fully involved in two major Phase1 upgrade (NSW and FTK)**

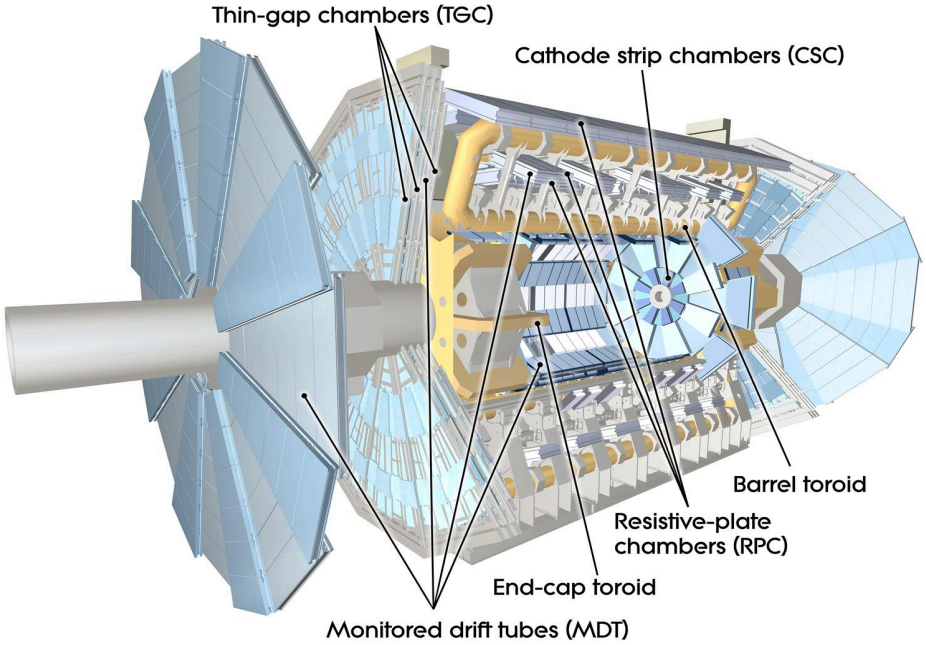
FTK and NSW timeline and LNF requests

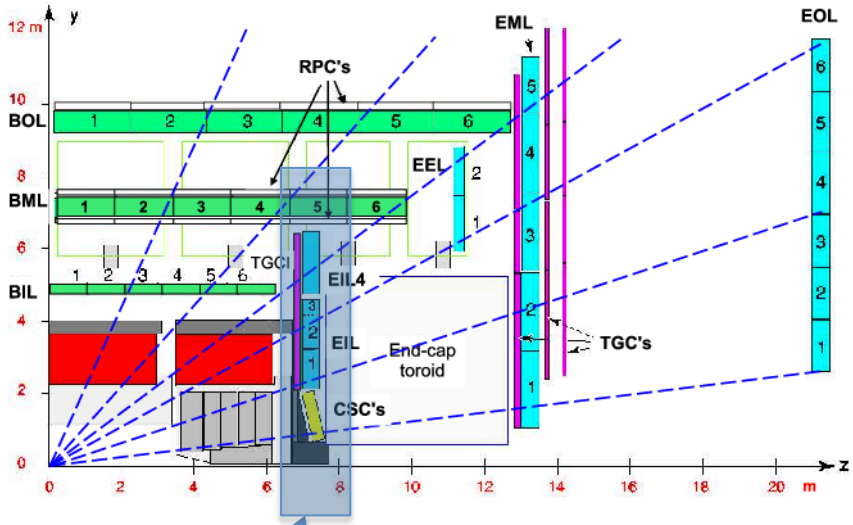
- **NSW requests:**
  - 3 FTE technicians for 2 years starting from march 2016
  - Infrastructures:
    - 1 clean room for assembly (available)
    - 1 clean room for panels refinement (soon available)
    - Cosmic Ray stand for Chamber commissioning
  - **some FTE(~1.5) after construction for installation**

- **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

Roberto Di Nardo – INFN Laboratori nazionali di Frascati

NSW and the ATLAS muon spectrometer



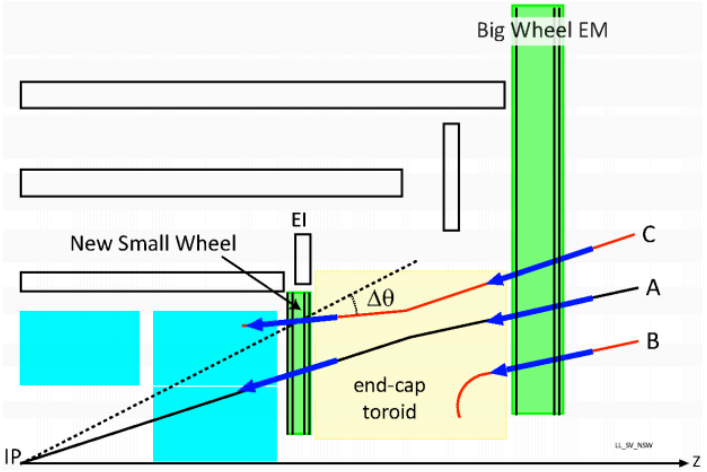


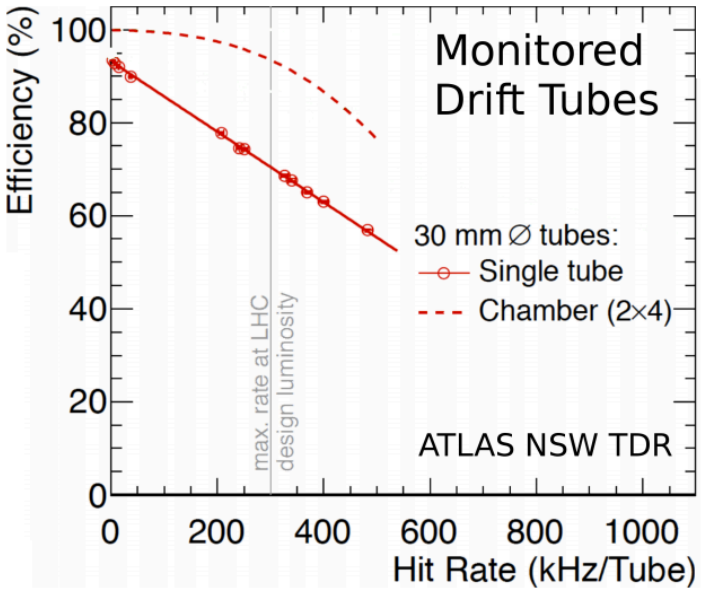
- ATLAS muon spectrometer is realized by:
  - RPC(trigger) and MDT (tracking) In the barrel region (|eta|<1)
  - CSC, MDT (tracking) and TGC (trigger) in the endcap
- The innermost endcap muon station (Small wheel) has the highest background rates in the Muon Spectrometer
  - Located actually between endcap calorimeter and endcap toroid
- Challenging region for LHC **RunIII** (2 x L_{design}) and **RunIV** (5-7 x L_{design})

Roberto Di Nardo – INFN Lat

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
    - @ $3x10^{34}$ 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



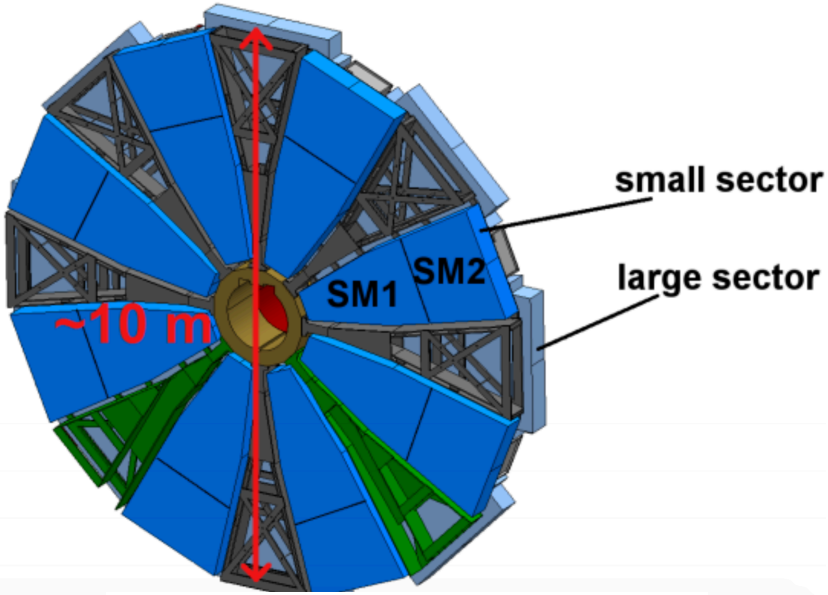


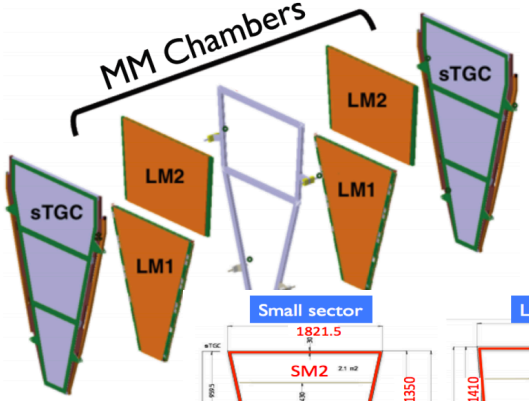
⇒ New Small Wheel needs trigger and high rate capable new technology

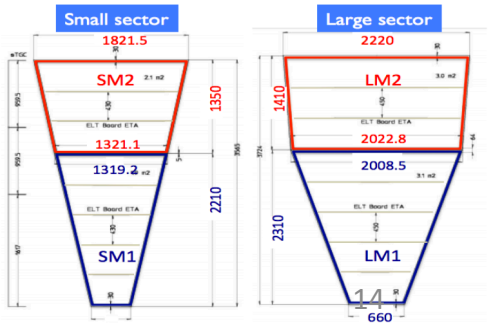
Roberto Di Nardo – INFN Laboratori nazionali di Frascati

NSW layout

- ⇒ Small-Strip Thin Gap Chambers (**sTGC**) and MICROMEsh GAseous Structures (**Micromegas**)
- Wheel like design
  - 8 large and 8 small sectors
  - Each sector divided in two modules
  - 1 module-> 2 micromegas quadruplets (main focus: precision tracking) sandwiched by 2 sTGC quadruplets (main focus: trigger)
- NSW and MM Layout finalized
  - 4 different chamber types
  - Production distributed over several institutes and some components from industry
    - Italy(SM1), Germany(SM2), France(LM1), Russia/ Greece/CERN (LM2)
  - Module0 construction started to fully certify production sites

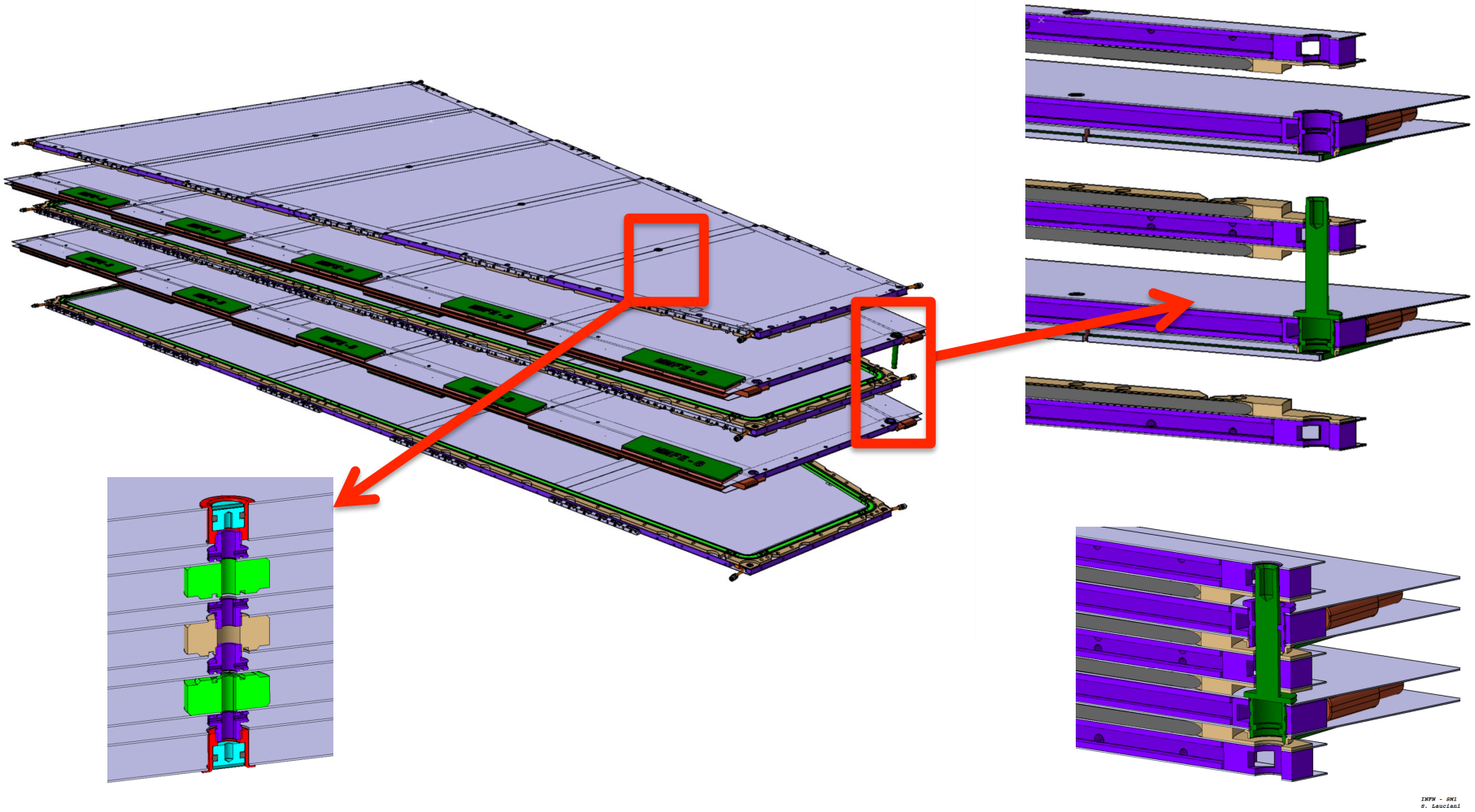






Roberto Di Nardo – INFN Laboratori nazionali di Frascati

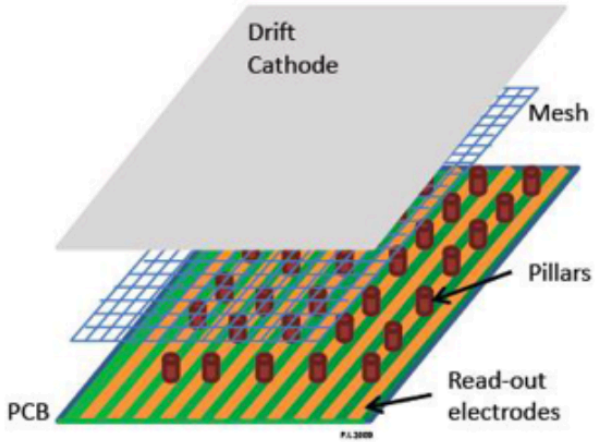
SM1 design



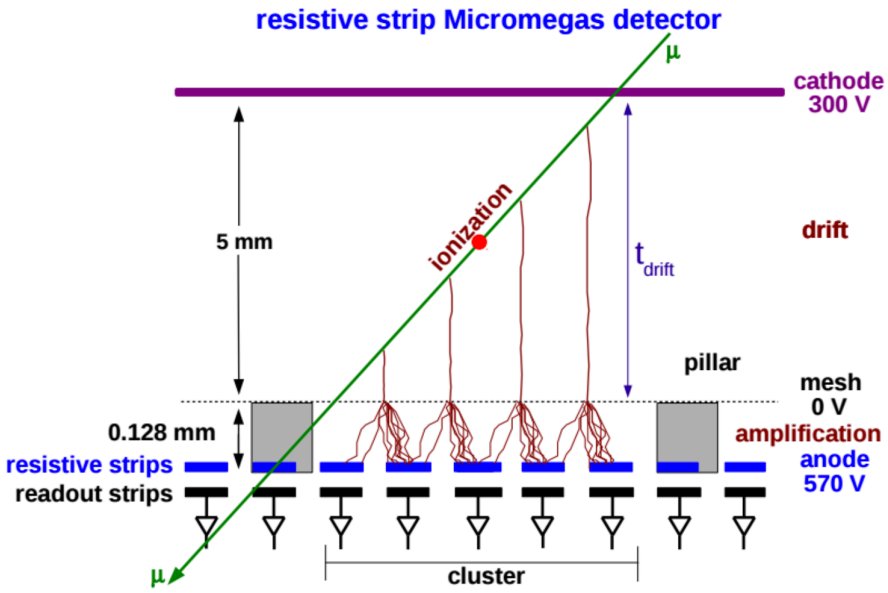
- Concepts and design by LNF Servizio Progettazione Apparati Sperimentali

Micromegas technology

- Ionization of about 100 e /cm in Ar:CO 93:7 by muons
- Electron drift velocity 47 μm/ns
- Collection of the avalanche charges on the resistive strips (anode)
- Capacitive coupling between resistive and copper readout strips
- Pulseheight and timing information from signal shape
- Strip width: 300 μm, Strip pitch: 425 to 450 μm
- Resistivity of strips: ~10 MΩ/cm

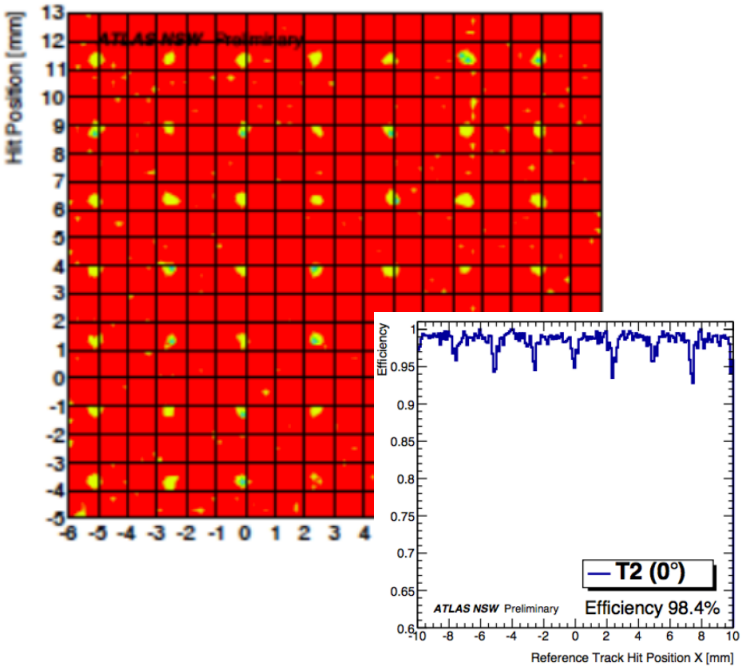


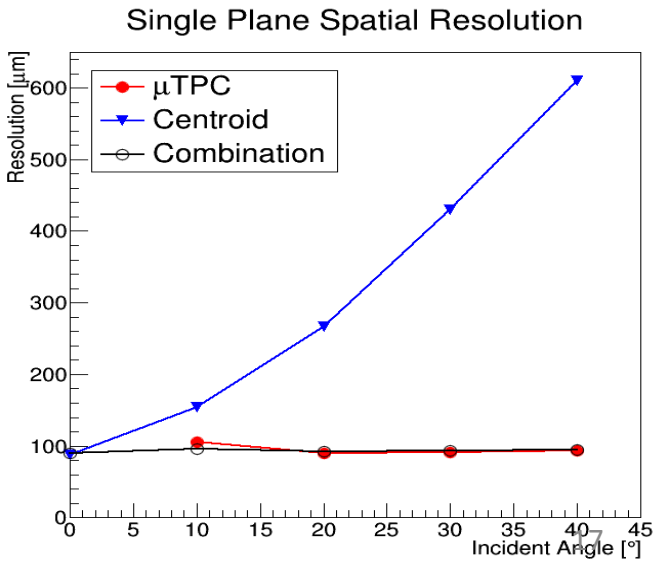
- **Performances requirements** to reach **15%** μ momentum resolution **@1TeV**
  - strip position along eta **~30μm rms**
  - Position of strip position along z (orthogonal to the detector plane) **~80μm rms**



Micromegas performances

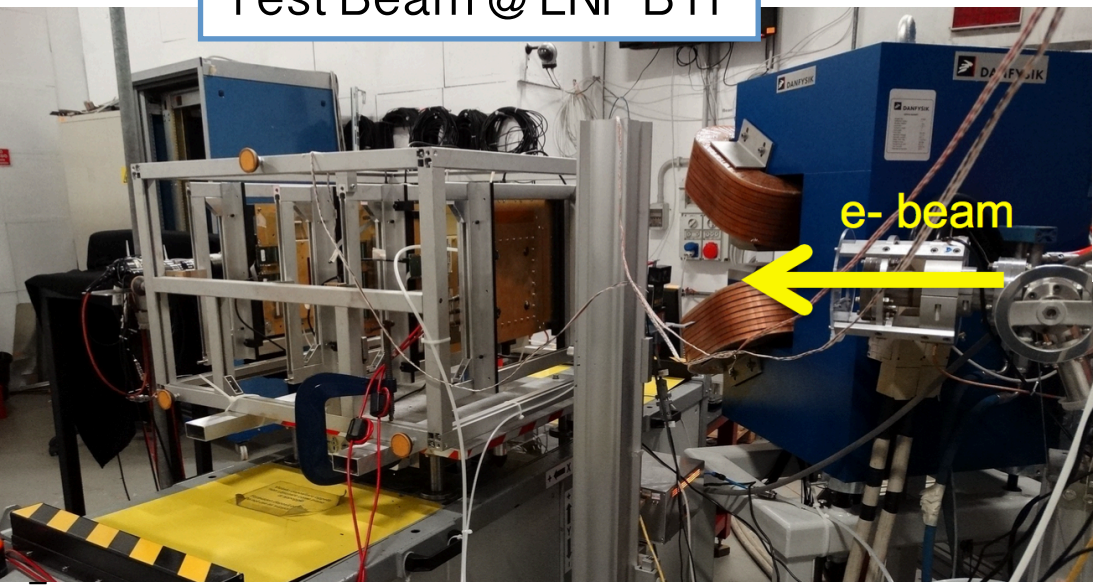
- Performances studied with small prototypes with several Test beam campaigns (also @ LNF)
  - **Efficiency 98-99%**, consistent with the dead area from pillars supporting the mesh
  - **<100µm** resolution for perpendicular tracks from charge centroid
  - µTPC mode exploited for incident angle >10° , **~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

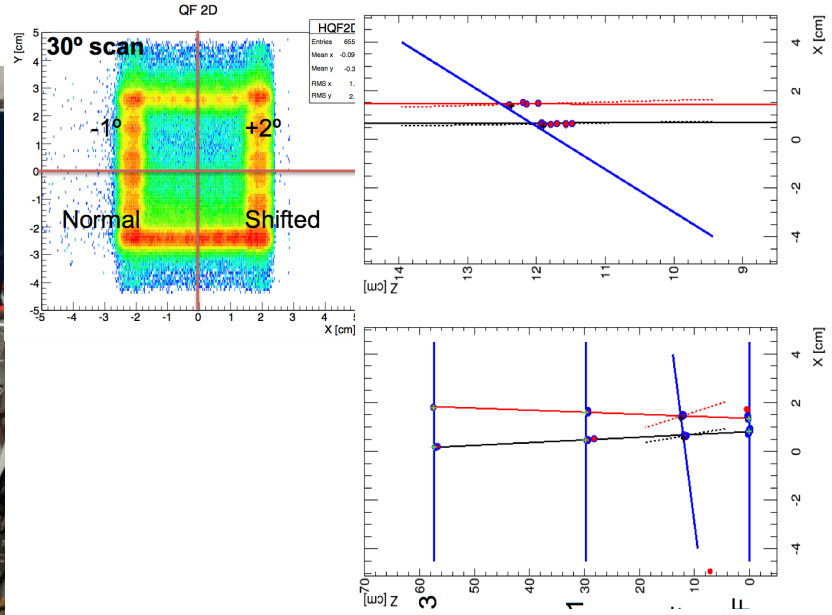




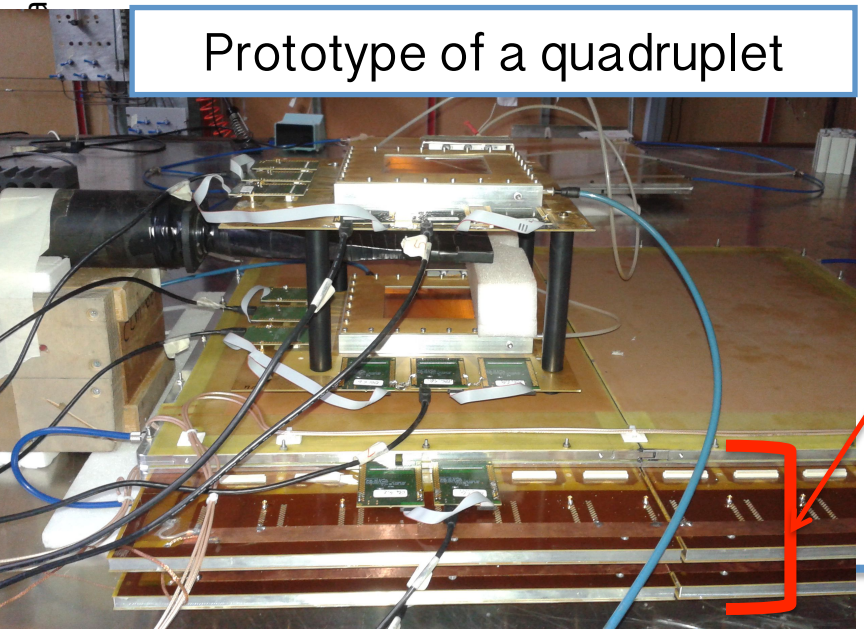
NSW activities @ LNF: from the first prototypes…

Test Beam @ LNF BTF

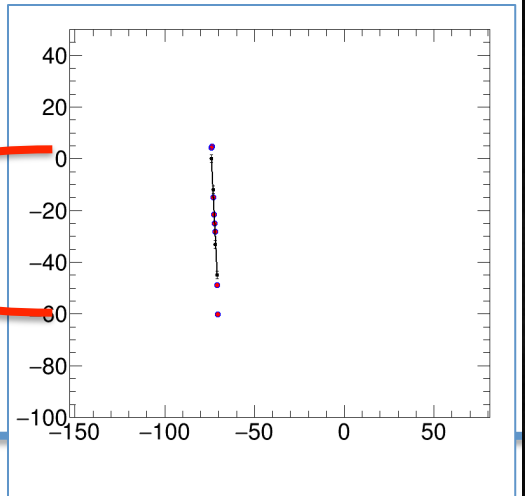


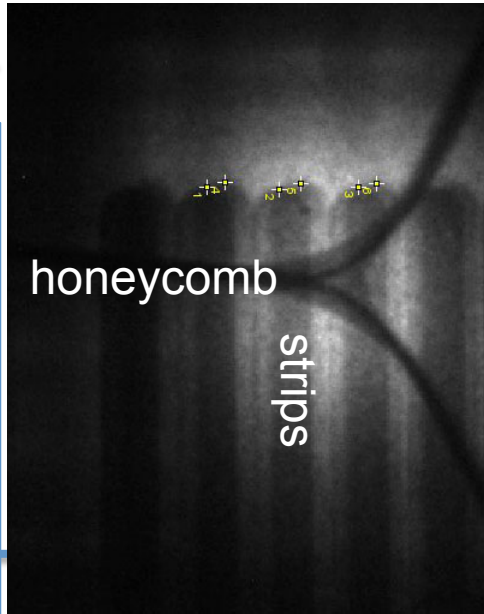


Prototype of a quadruplet



Top-bottom strip alignment verified @50μm with Xray

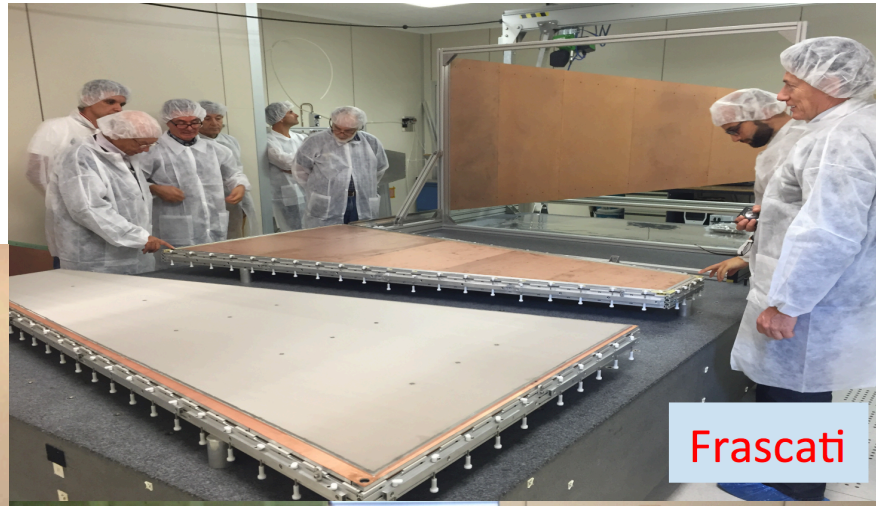




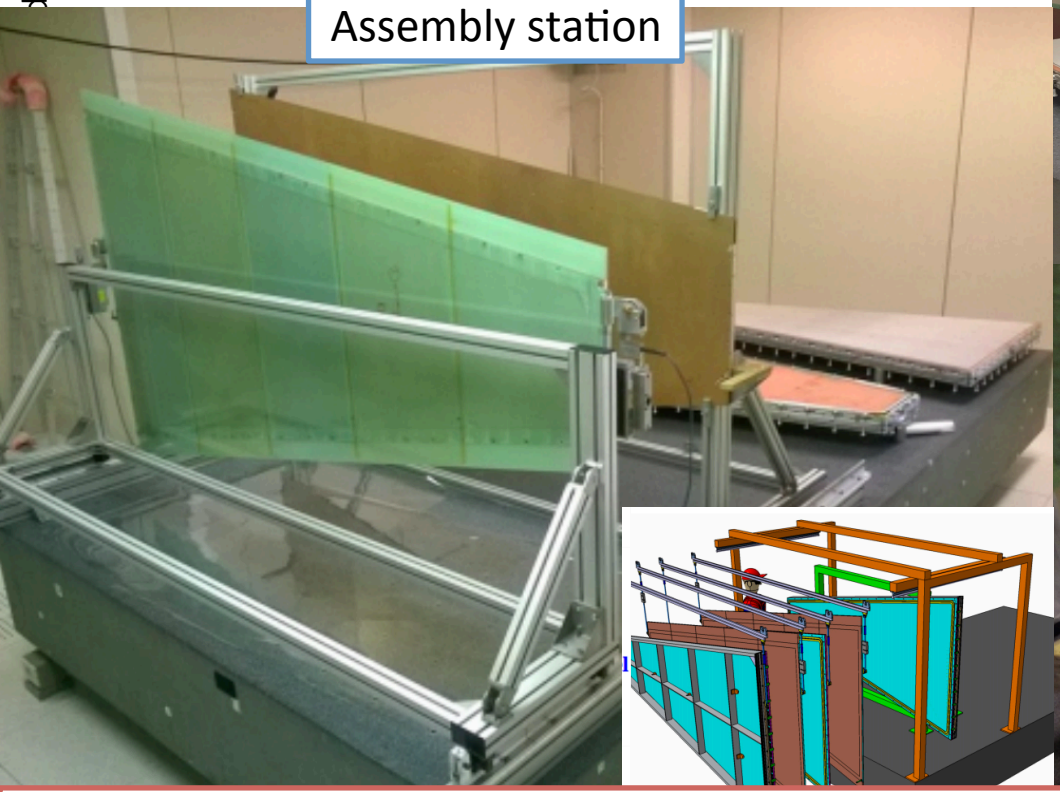
…to the M0 construction

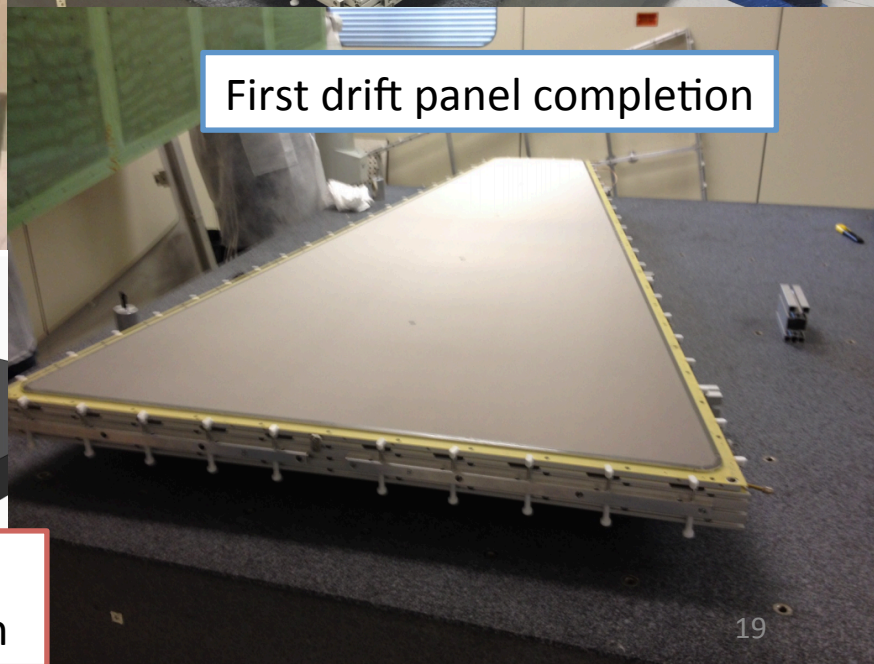
- Planned activities in Frascati within the SM1 production:
  - Drift panels preparation: gas sealing and test, mesh frame and mesh gluing
  - Panels assembly
    - Two panels ready
  - Tests with cosmic rays

di Frascati



Assembly station



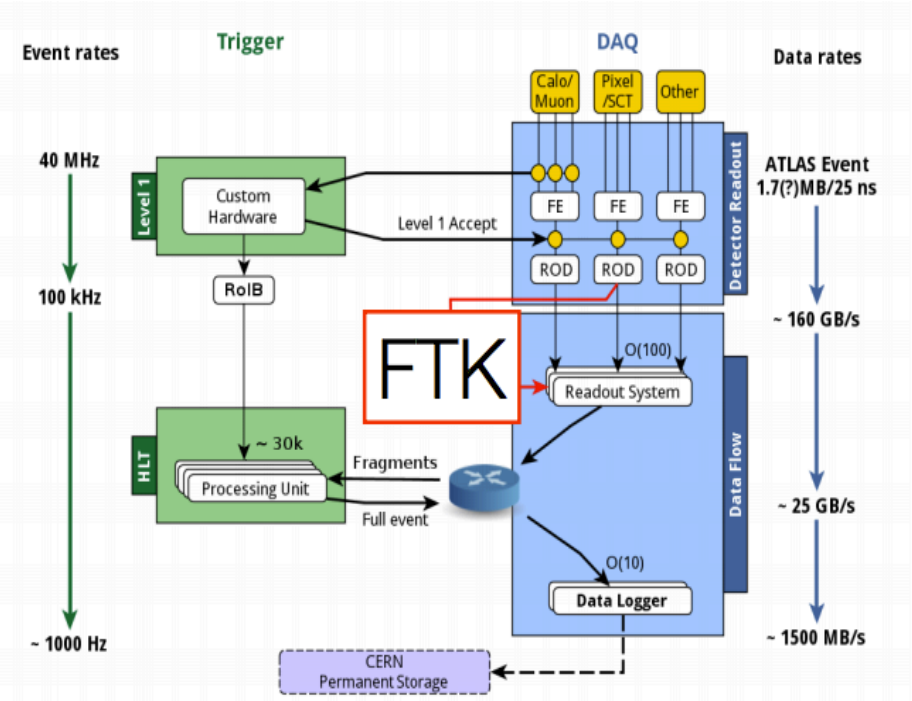


Precise dimension measurements of panels and components from Metrology of Accelerator Division

Fast TracKer system

- higher luminosity foreseen in RUN2, expected <μ>~40-50 ->Triggering will be more difficult
  - **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 tau-jets -> important for Higgs and BSM physics
  - Determine the number of vertex and improves the **robustness** in jet and MET selections in events with **pileup**

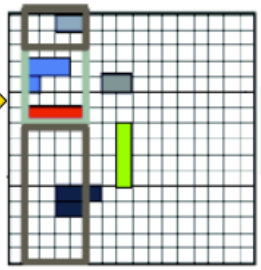
nazionali di Frascati



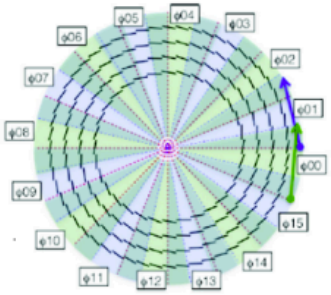
- **FTK is a track trigger**
  - system of custom electronics (made of ~8000 ASICs and 2000 FPGAs) for global track reconstruction in the pixel and silicon strip detectors after every level-1 trigger (100 kHz).
  - Rapid pattern recognition and track fitting for global track reconstruction of all tracks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

The FTK data flow

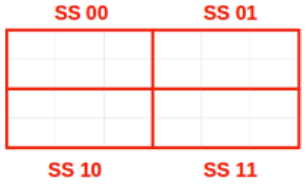
Tracking detectors



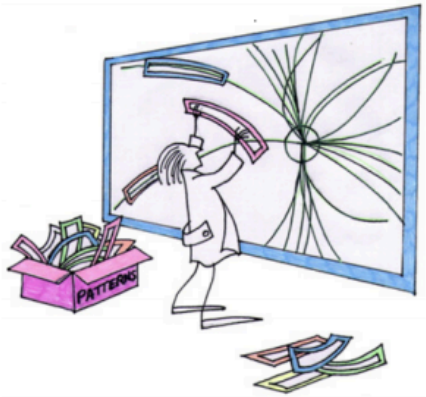
Custom pixel clustering algorithm on FPGAs



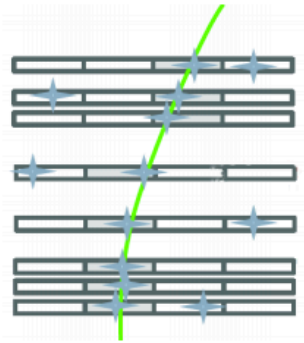
Geometrically grouped data distributed to processing units



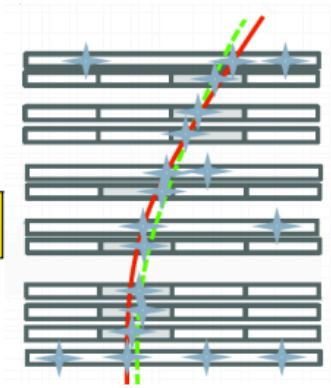
Transformation to coarse-resolution hits



Comparison to reference track patterns at coarse resolution



Track fit with full-resolution info for track candidates



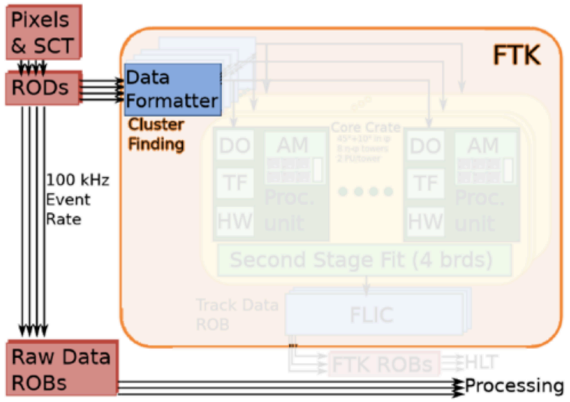
Precise fitting with good tracks being extrapolated to missing layers

HLT

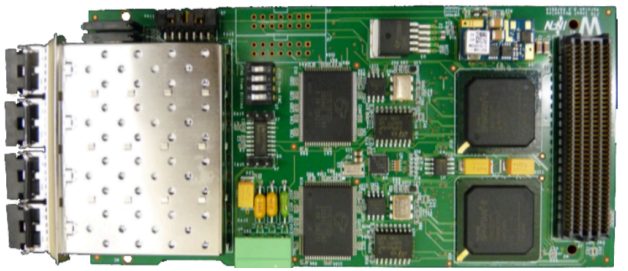
Roberto Di Nardo – INFN Laboratori nazionali di Frascati

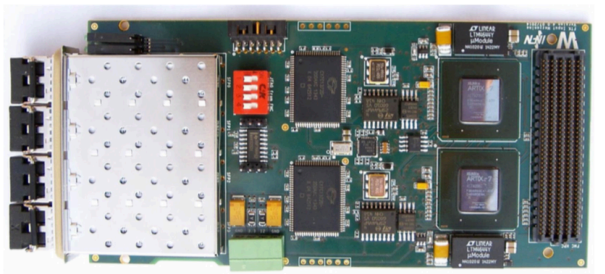
LNF FTK activities: Input Mezzanine

- Leading activity in the Associative Memories and Input Mezzanine production and tests



- **Input Mezzanine:**
  - IM Spartan6 (LNF – WASEDA) :FTK Input-Mezzanine based on Xilinx Spartan6 FPGA
  - IM Artix7 (LNF):IBL compatible FTK Input Mezzanine (upgrade to Xilinx Artix7 FPGA)
  - 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)



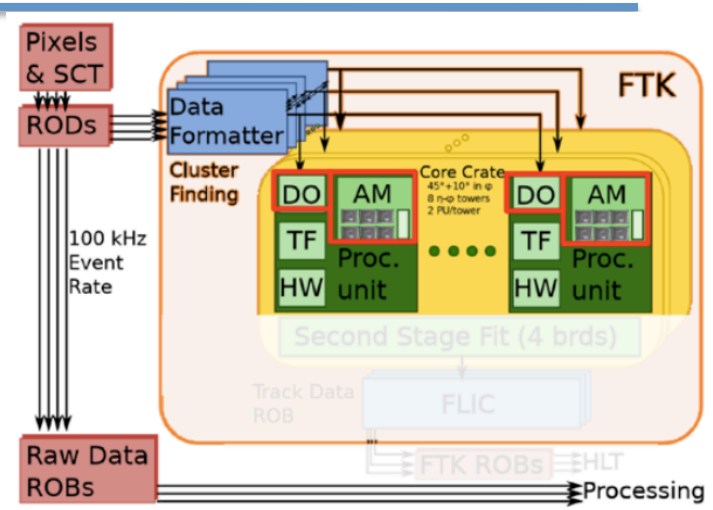


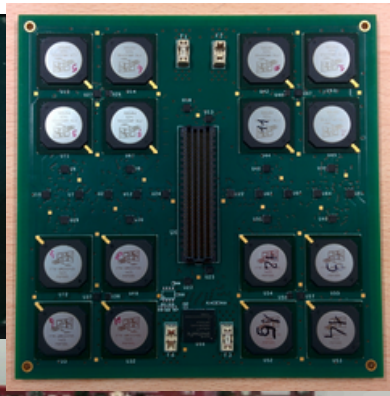
- Spartan6-IM Production
  - 80 board produced and successfully tested, firmware fully developed and tested
- Artix7-IM Production
  - Preproduction completed and tested, bulk production done and tests ongoing

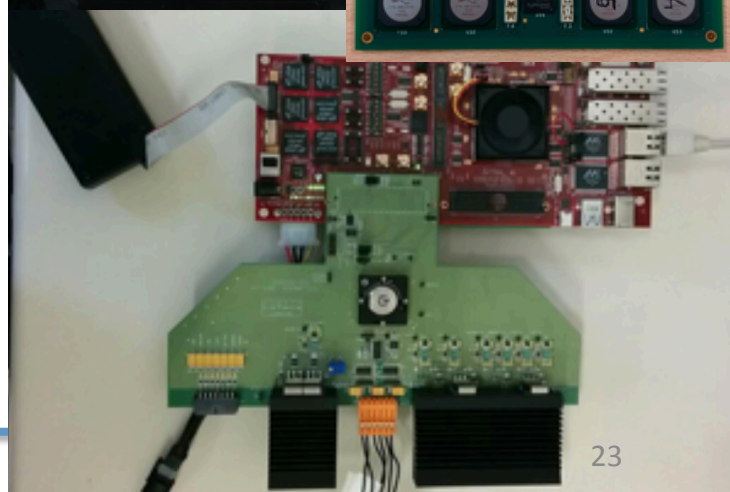
Roberto Di Nardo – INFN Laboratori nazionali di Frascati

LNF FTK activities: Associative Memories

- AM06 Chip (LNF - INFN Milano - LPNHE Paris) 160mm^2 65nm ASIC (400M transistors)
  - Track detection:
    - Compare detectors data with patterns stored in memory.
  - 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 second
  - Pre production: 3K chip done and in test
    - Bulk 11Kchip tested by July 2016
- AM06 Test Board (LNF) Test Board for AM06 Chip
  - 6 boards produced, fully tested and working

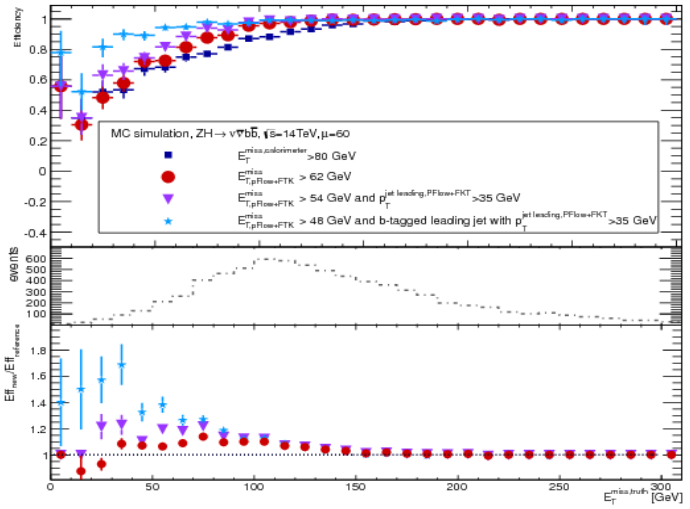


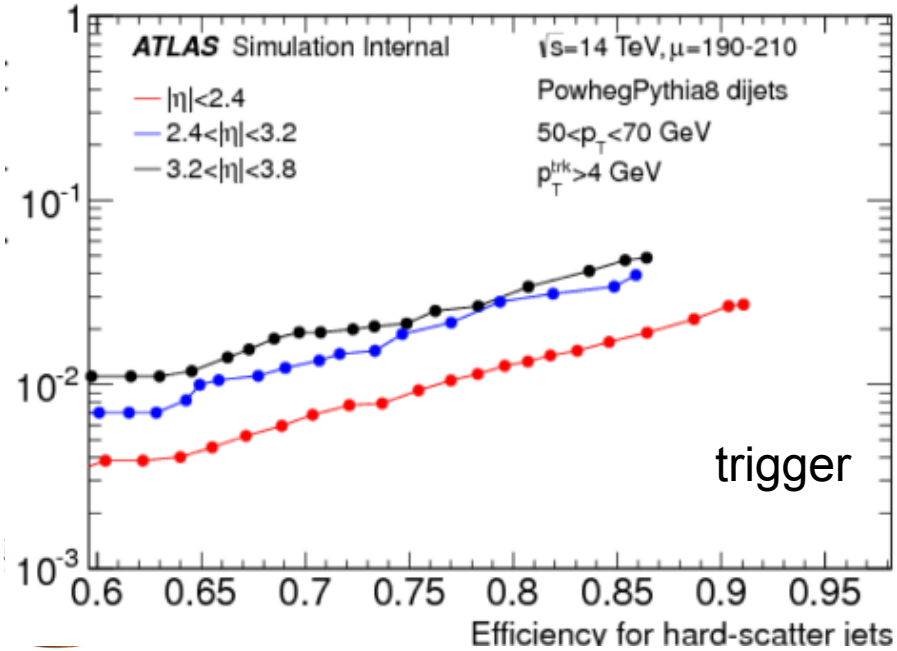




Trigger studies using FTK

- 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



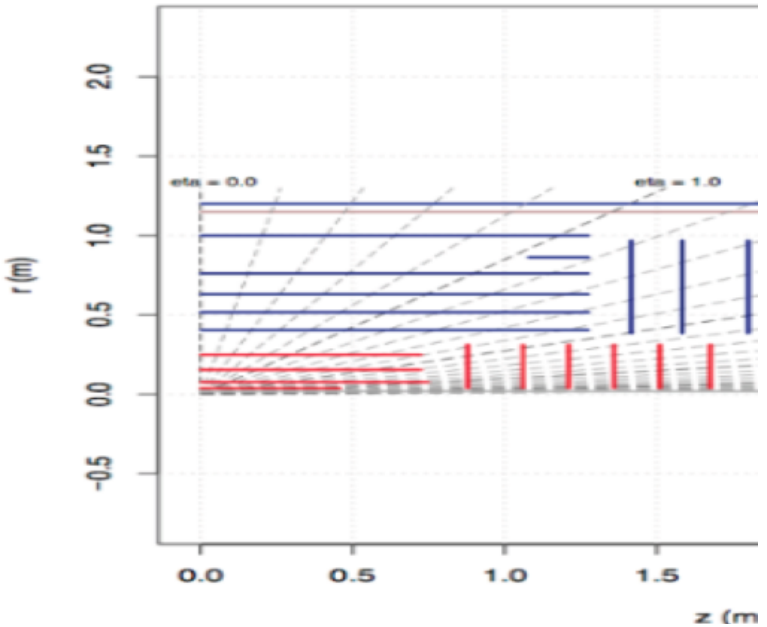


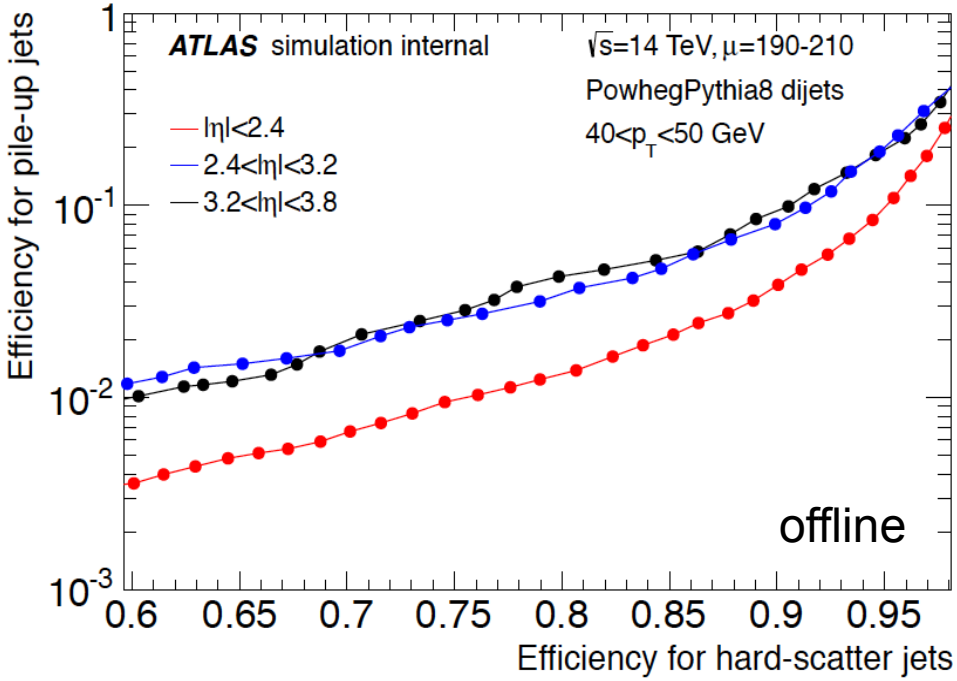
- Trigger upgrade studies with L1 Track and FTK++ in the context of phase 2 upgrade
- High potential to suppress online pile-up using forward tracking + FTK

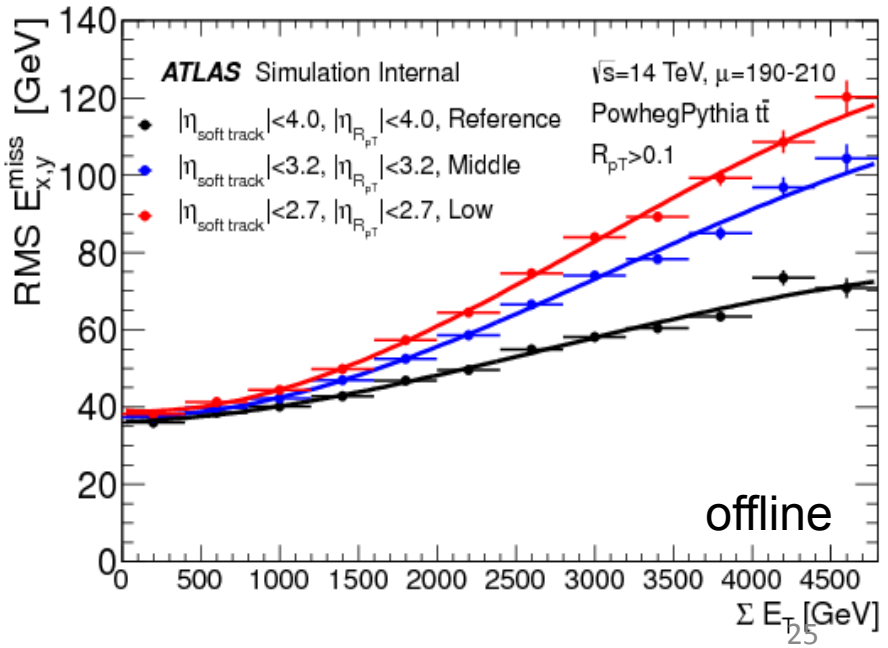
ori nazionali di Frascati

Studies for Phase II upgrade

- One of the main phase 2 upgrade is the ID angular extension
  - 3 scenarios explored: $|\eta|<2.7$, $|\eta|<3.2$, $|\eta|<4.0$
  - High potential for
    - Suppress pile-up forward jets
    - Improve MET resolution
  - Contact editor for the "Large Eta Task Force report)



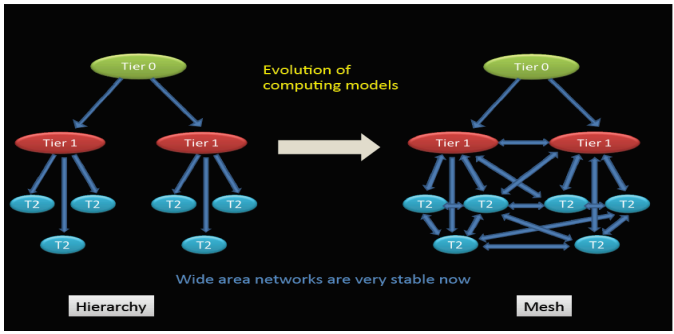




Computing activities

LNF ATLAS computing

- Original ATLAS computing model
  - Hierarchical structure based on multi-tier distributed architecture
- Model changed thanks to the improved network (WAN) performances
  - Migration to a mesh model , with interconnection between sites
- Data management also improved
  - Popularity concept introduced
- The ATLAS Italian cloud
  - 1 Tier 1 at CNAF
  - 4 ATLAS Tier-2s
    - **Frascati**, Milano, Napoli ,Roma1



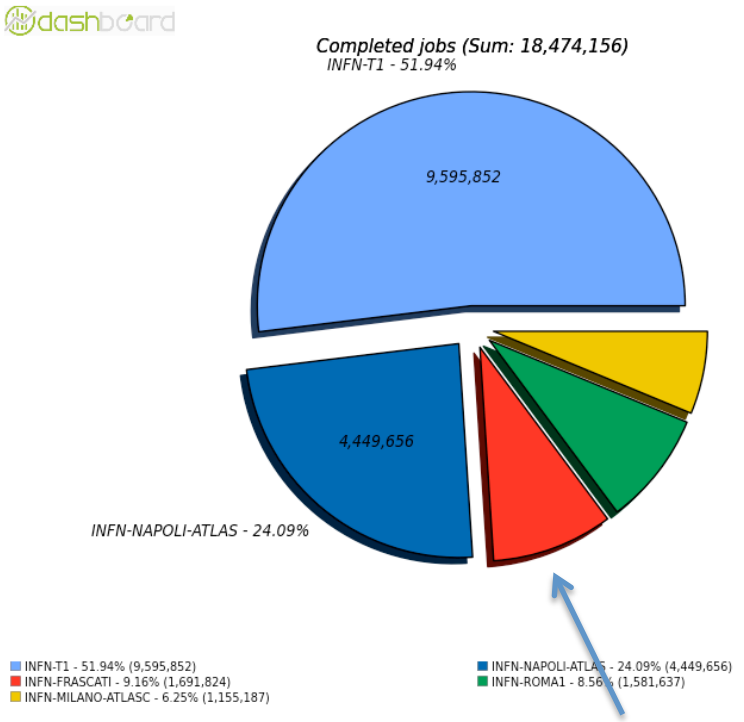
The ATLAS LNF Tier-2

- ATLAS Tier-2 and other collaborations
- CPU: 17 kHEPSPEC
  - 84 computing nodes, 168b CPU, 1596 cores, **2056** job slots (x4 in 3yr)
- Storage: **~1.38 PBr**, ~1 PBn (x4 in 3yr)
  - The head node and 11 disk servers
- Network: 10Gbps WAN connection, 10Gbps LAN (disk servers and rack switches)
- Around 30 servers for various services:
  - Production systems: EMI-3 midlleware, Disk Pool Manager (DPM) as SRM, Torque/Maui batch system, Argus /GLExec Auth/Authz, cvmfs for experiments software
  - Testing activities

Since 2014: New computing Room

Computing activities

- ATLAS Tier-2: simulation, analysis (end-user, physics groups)
  - High availability and reliability in the last years:
    - **Availability = ~ 95% Reliability = ~97% Efficiency > 90 %**
- ATLAS VO management
  - Supported also other LHC VOs, Belle2 VO, Km3net and (in the future) CTO
- PRIN_STOA
  - PROOF-based user analysis with PROOF on Demand (PoD) on Grid computing nodes.
  - User analysis transparently accessing distributed input data through FAX and HTTP federations
- Host of DPM test-bed for testing activity inside DPM collaboration
- Recent collaboration with RM2 and RM3 to setup a regional cloud system



Conclusions

- ATLAS detector worked extremely well during RUN1
  - Huge amount of measurement and papers, espoliting the full potential of data collected up to the end of 2012
  - Fully operational and ready for the $\sqrt{s}$=13TeV challenge
  - Activities already ongoing for future (planned and proposed upgrades upgrades

LNF group heavily involved in the ATLAS activities

- Leading role in Higgs analysis and performance studies
- Fully committed to the two major Phase 1 upgrade of the ATLAS detector
  - 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

Roberto Di Nardo – INFN Laboratori nazionali di Frascati