Clouds for High Energy Physics

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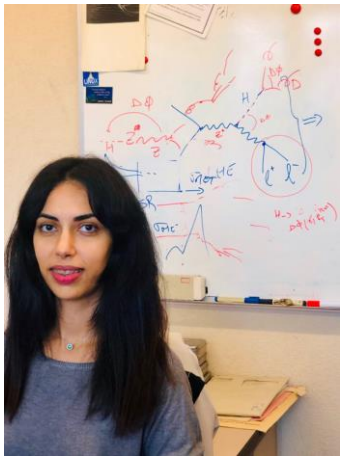
Regional Conference on "MARWAN: an innovation enabler through advanced e-Infrastructures"

13 October 2022

Outline

- HEP activities with : ATLAS, ANTARES and KM3NeT
- WLCG : ATLAS cloud model
- ASCC: African SuperComputer Center

Group



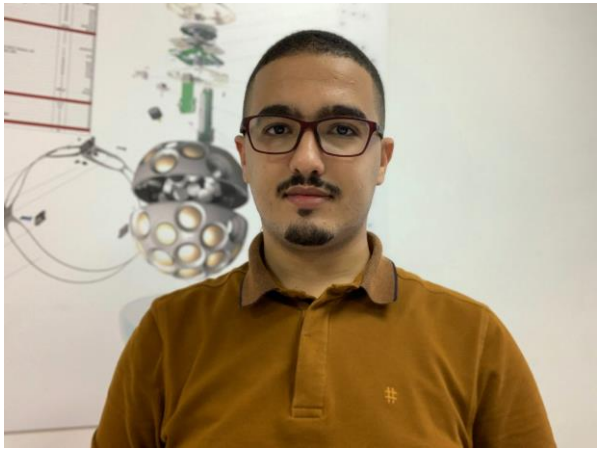
Hassnae EL Jarrari

Hassane Hamdaoui

Malak Tamlihat

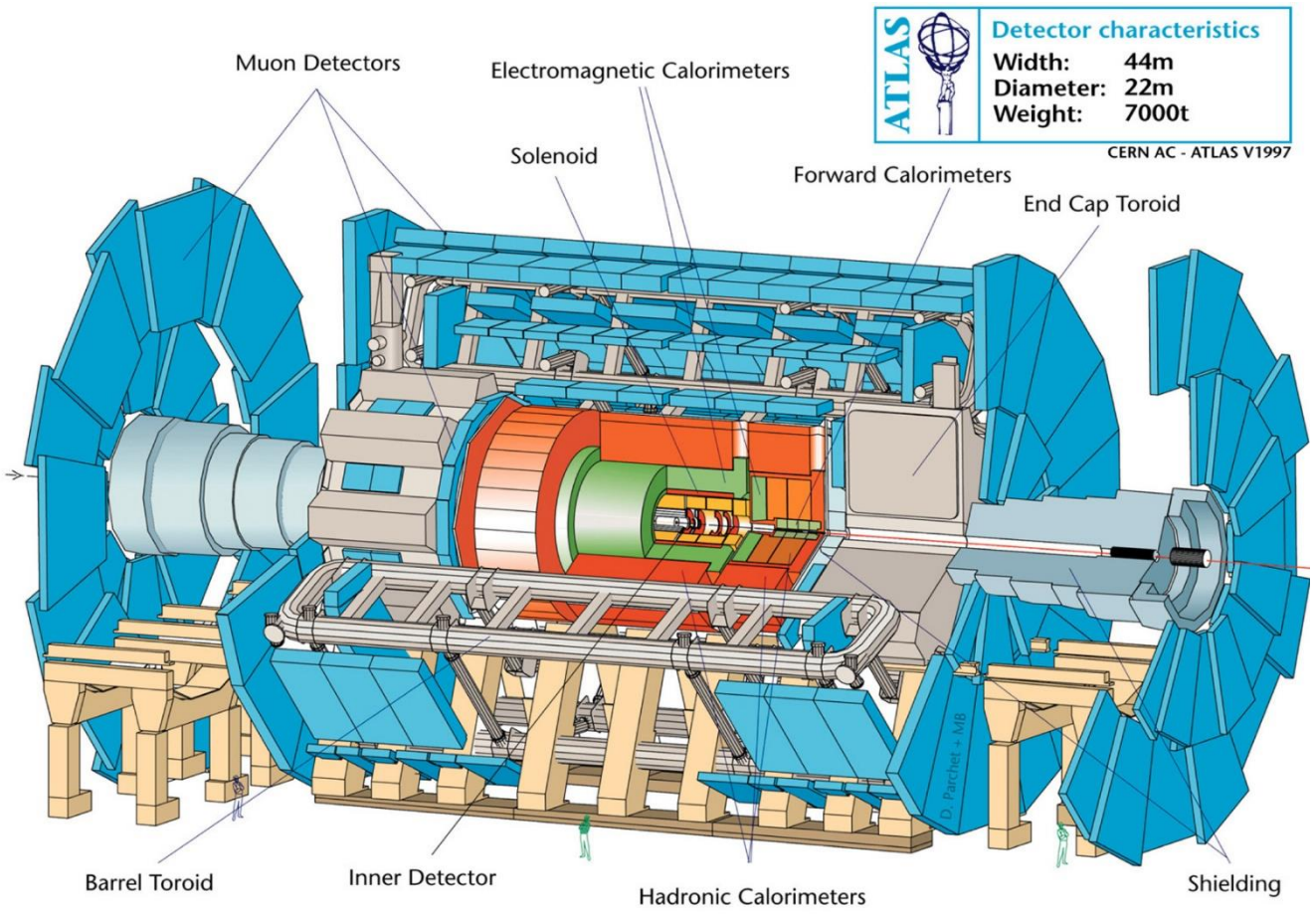
Jihad Boumaaza

Meriem Bendahman



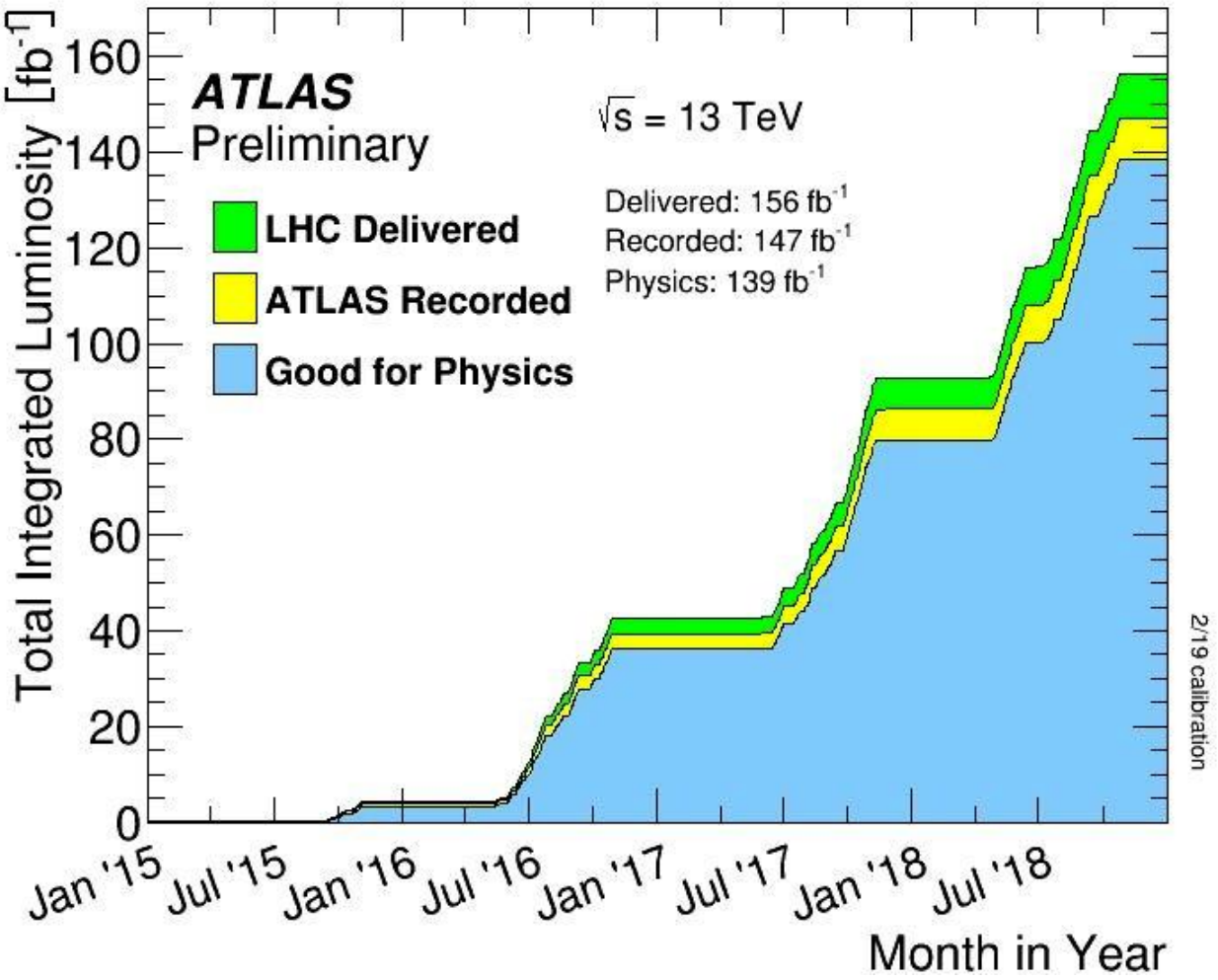
Ahmed Eddymaoui

ATLAS



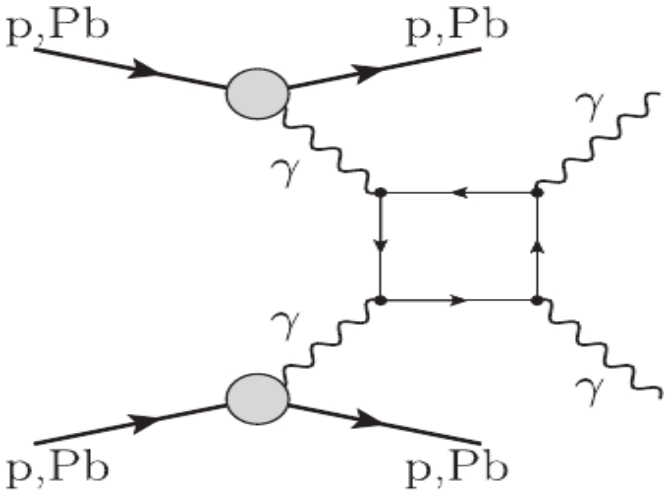
181 Institutions
3000 Scintific authors, 1200 PhD students
41 Countries

ATLAS (LHC luminosity)

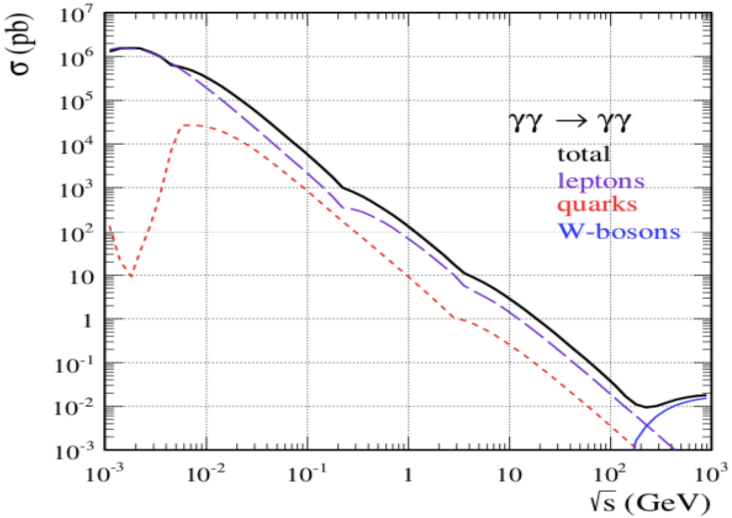


One-loop process

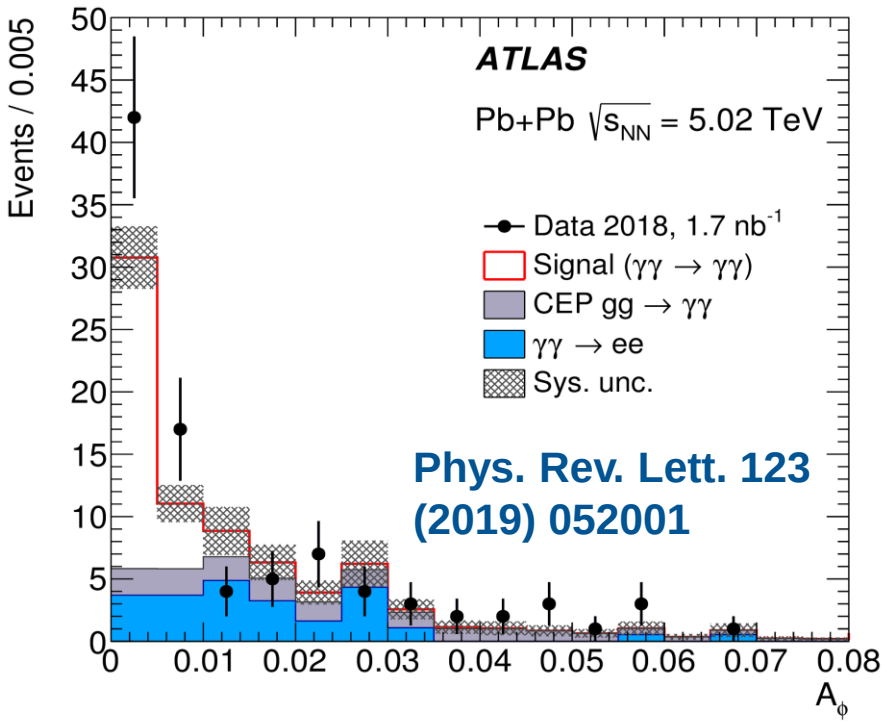
- The standard Model predicts the possibility of light by light scattering via 1-loop diagrams
- Loops contains virtual charged particles ($q, l, W^{\pm}$) from SM
- Heavy ions create huge EM fields (10^{14}T) from coherent action of Z protons: cross section Z^4
- UPC provide a flux of quasi-real photons probing the nuclear structure
- The process sensitive to BSM physics

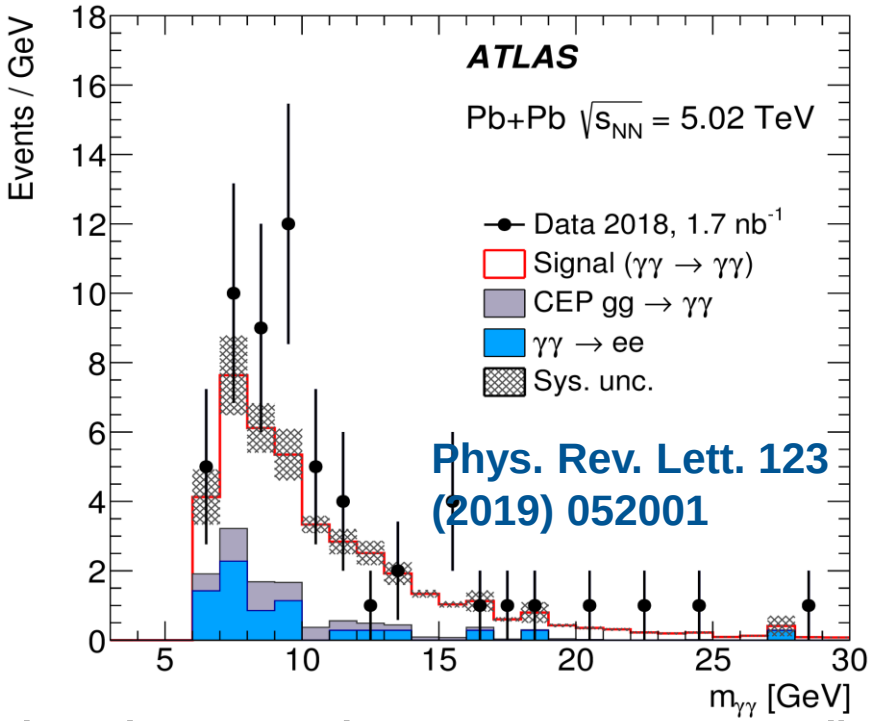


$\sigma(\gamma\gamma \to \gamma\gamma \propto \alpha^4)$



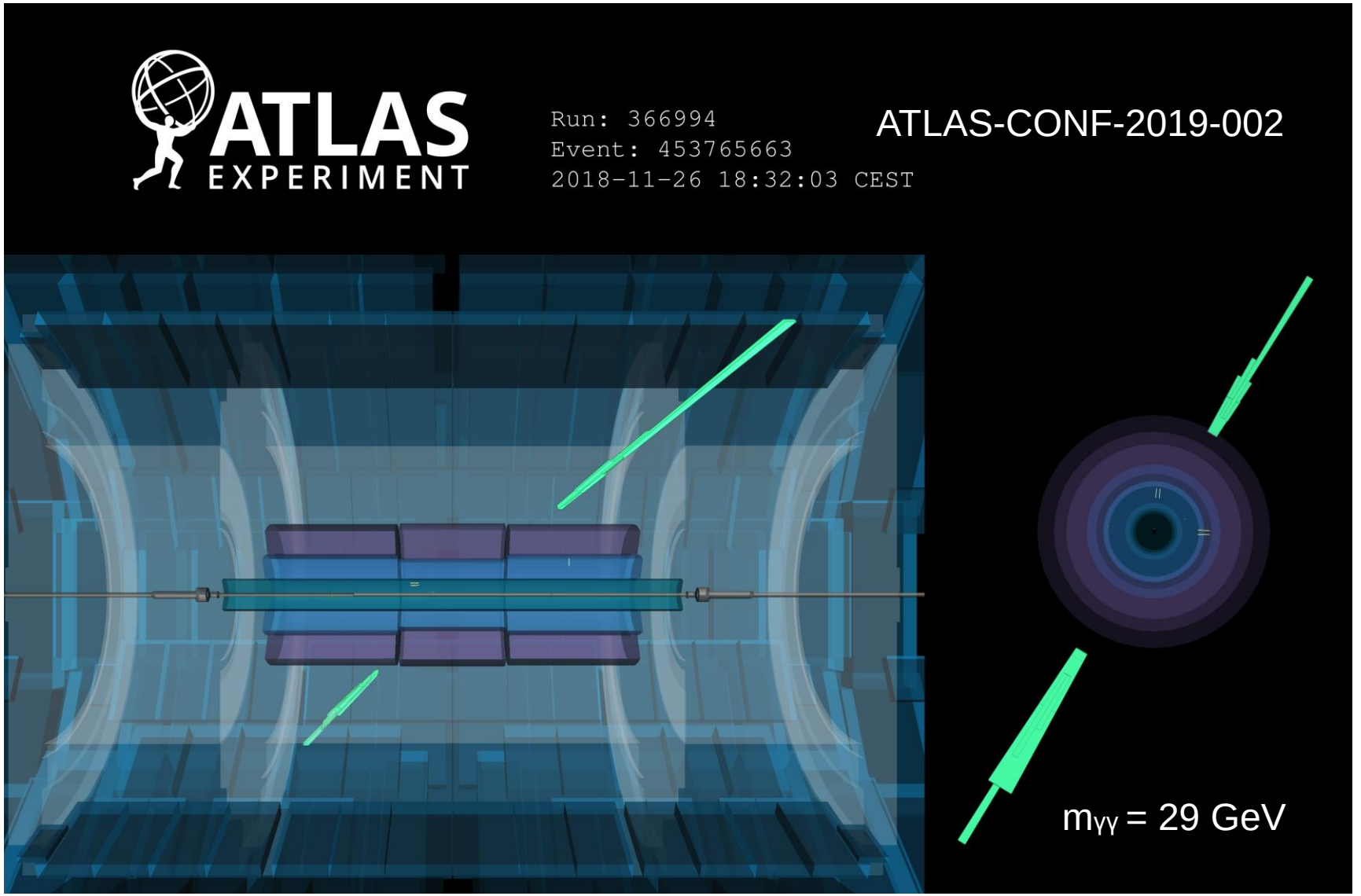
Results





- **59** events observed (where **12 ± 3** background events expected)
- Observed signal significance over the background only hypothesis is of **8.2σ**
- Updated cross-section: **σ = 78 ±13 (stat) ±8 (sys) nb**
- SM predictions: **51 ±5 nb** Phys. Rev. C 93 (2016) 044907
  50 ±5 nb Eur. Phys. J. C 79 (2019) 39

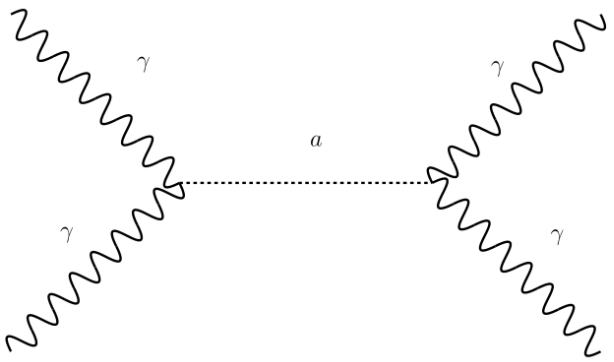
Results


ATLAS
EXPERIMENT
Run: 366994
Event: 453765663
2018-11-26 18:32:03 CEST
ATLAS-CONF-2019-002
$m_{\gamma\gamma}$ = 29 GeV

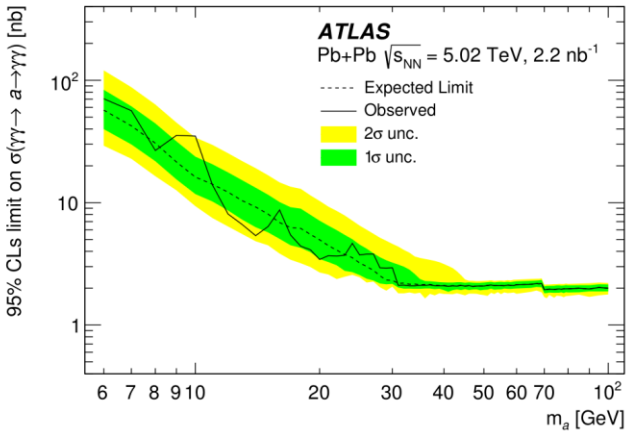
Results

Search for ALPs in UPC Pb+Pb collisions

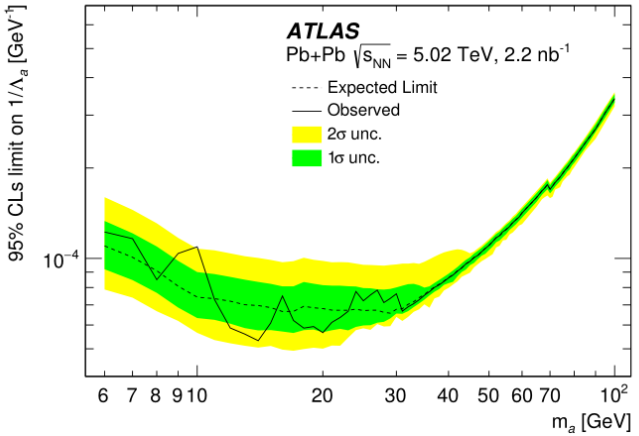
Same event topolgy as light-by-light
Data : 2015+2018 heavy ions (UPC)
MC Signal : Starlight generator
Backgrounds : same as light-by-ight + light-by-light



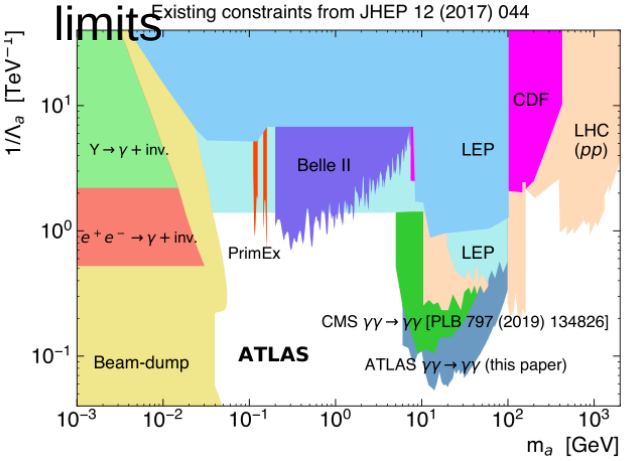
Limit on cross section



Limit on coupling



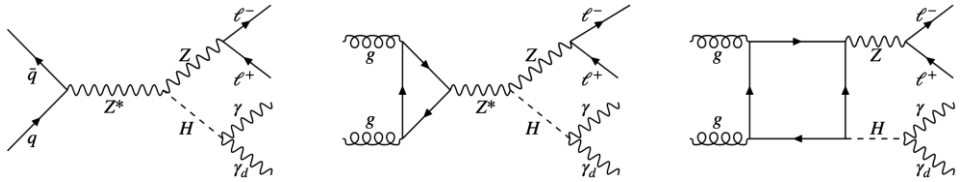
Compilation of exculsion limits



arXiv:2008.05355

Search for dark photons in ZH mode

- This is a search for a Higgs boson decaying into a photon and a dark photon (missing transverse momentum).
- Considering the (qq, gg) ZH production mode, benefitting from a clean final state ($Z \rightarrow l^+l^-$) to search for $H \rightarrow \gamma\gamma_d$ within a dark photon mass range of $0 \rightarrow 40$ GeV



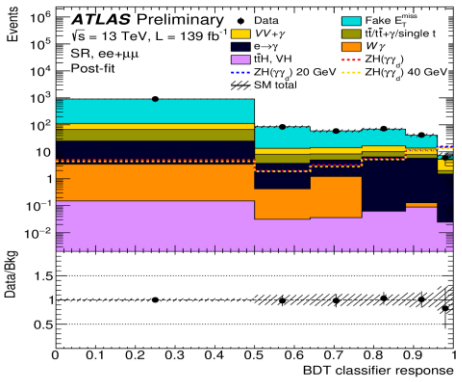
SIGNAL REGION OPTIMISATION

Two same flavour, opposite sign, medium ID and loose isolated leptons, with leading $p_T > 27$ GeV, sub-leading $p_T > 20$ GeV
Veto events with additional lepton(s) with loose ID and $p_T > 10$ GeV
76 GeV $< m_{\ell\ell} <$ 116 GeV
Only one tight ID, tight isolated photon with $E_T^{\gamma} > 25$ GeV
$E_T^{miss} > 60$ GeV with $\Delta\phi(\vec{E}_T^{miss}, \vec{p}_T^{\ell\ell\gamma}) > 2.4$ rad
$m_{\ell\ell\gamma} > 100$ GeV
$N_{jet} \leq 2$, with $p_T^{jet} > 30$ GeV, $\lvert\eta\rvert < 4.5$
Veto events with b-jet(s)

BACKGROUND ESTIMATION

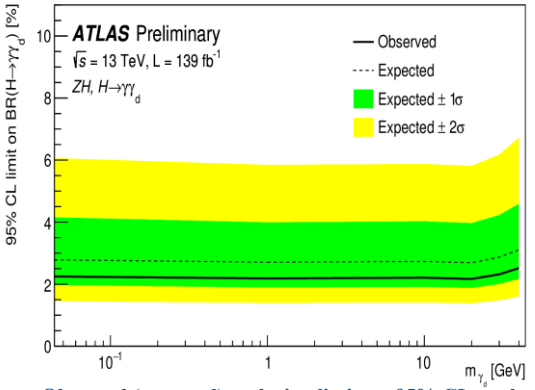
- **Fake E_T^{miss}:** $Z\gamma$ + jets, Z + jets ⇒ **Data-driven ABCD**
- **$e \rightarrow \gamma$ fake:** VV, VVV ⇒ **Data-driven fake rate and probe-electron CR**
- ***top*:** MC, with 20% systematic uncertainty from the ***top* VR** (>=1 b-tag).
- $VV\gamma$: MC normalised to data in the $VV\gamma$ **CR** (enhanced in $WZ\gamma$ ($3\,\mu + 1\gamma$)).
- $W\gamma$, ***Higgs*:** pure MC.

RESULTS AND INTERPRETATION



Post fit distribution of the BDT classifier response

No excess is observed with respect to the Standard Model predictions



Observed (expected) exclusion limits at 95% CL on the ($\rightarrow \gamma\gamma$) as a function of the dark photon mass: [2.19-2.52]% ([2.71-3.11]%).

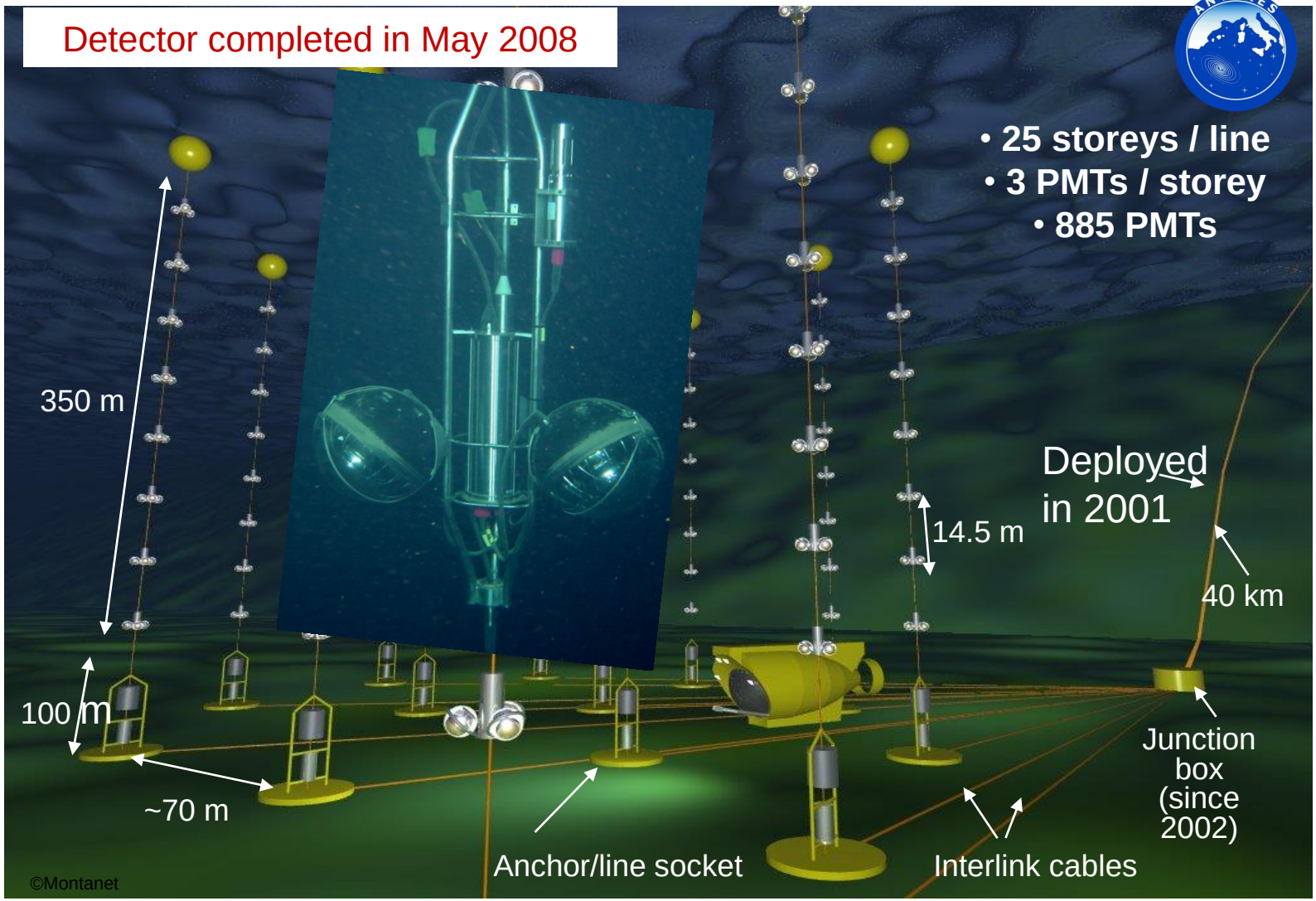
Observed (expected) LHC Limits on ($\rightarrow \gamma\gamma$) for massless dark photons :

Production	ZH	VBF
ATLAS	**2.3 (2.8)%**	1.8 (1.7)%
CMS	4.6 (3.6)%	3.5 (2.8)%

Exotic Physics with ANTARES

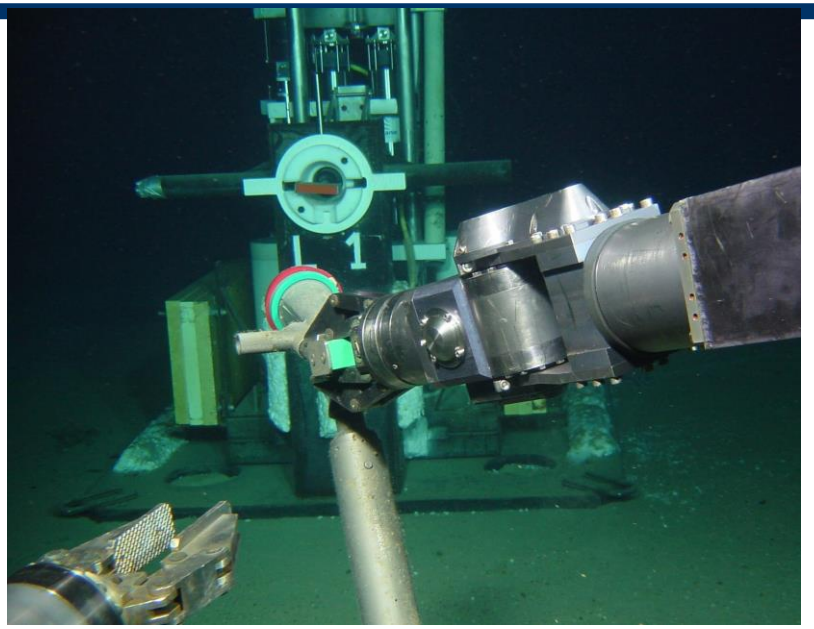
Morocco joined the collaboration in 2011, represented by Mohammed I University in Oujda. Mohammed V University in Rabat, Cadi Ayyad University of Marrakesh and the National Center of Energy, Sciences and Nuclear Techniques CNESTEN.

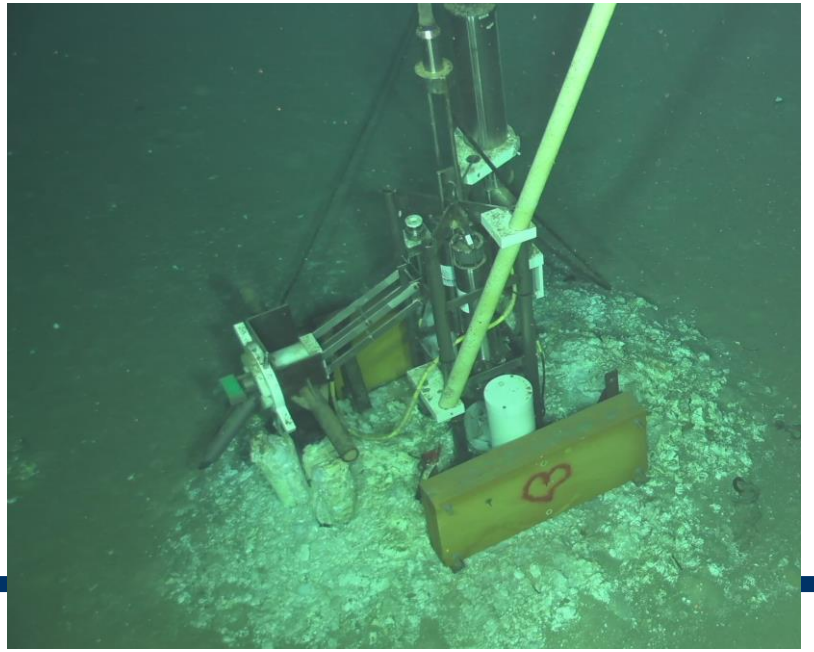
ANTARES Telescope



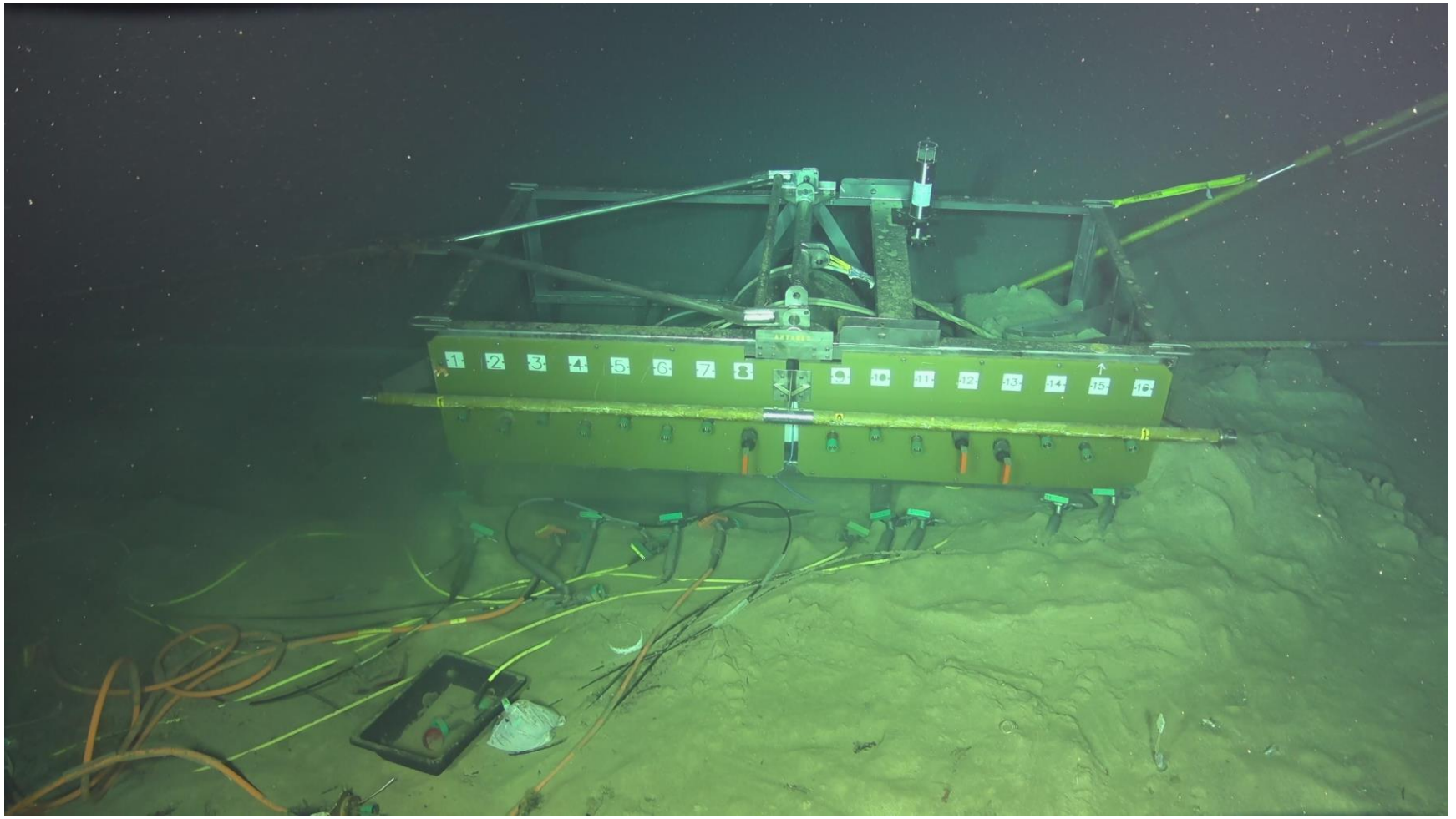
ANTARES First detector line (2006-2022)

Deployment 14/02/2006
Connection March 2006
Disconnection February 2022



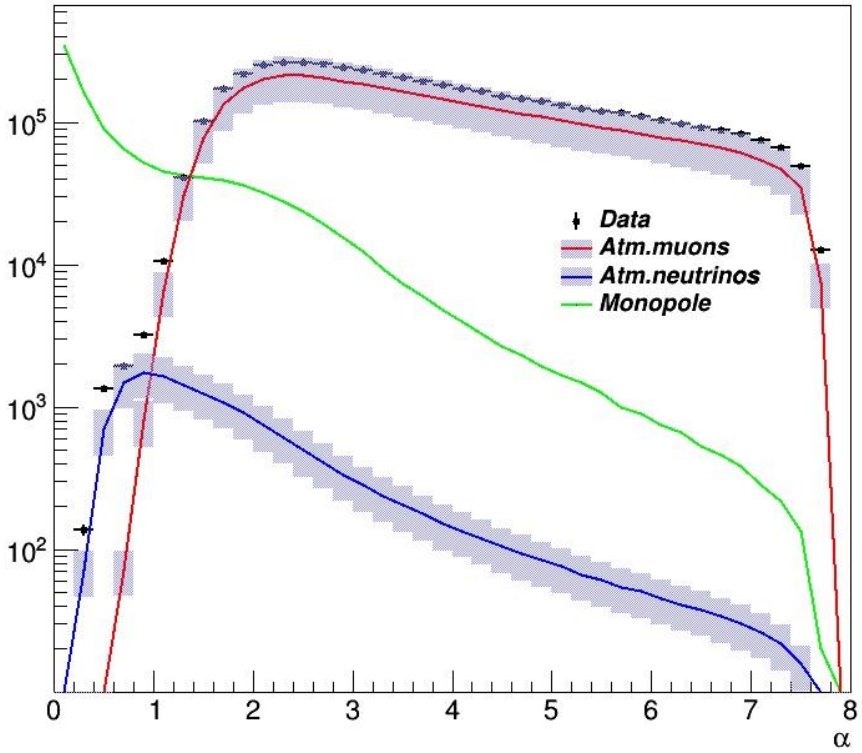


ANTARES. (Junction Box)



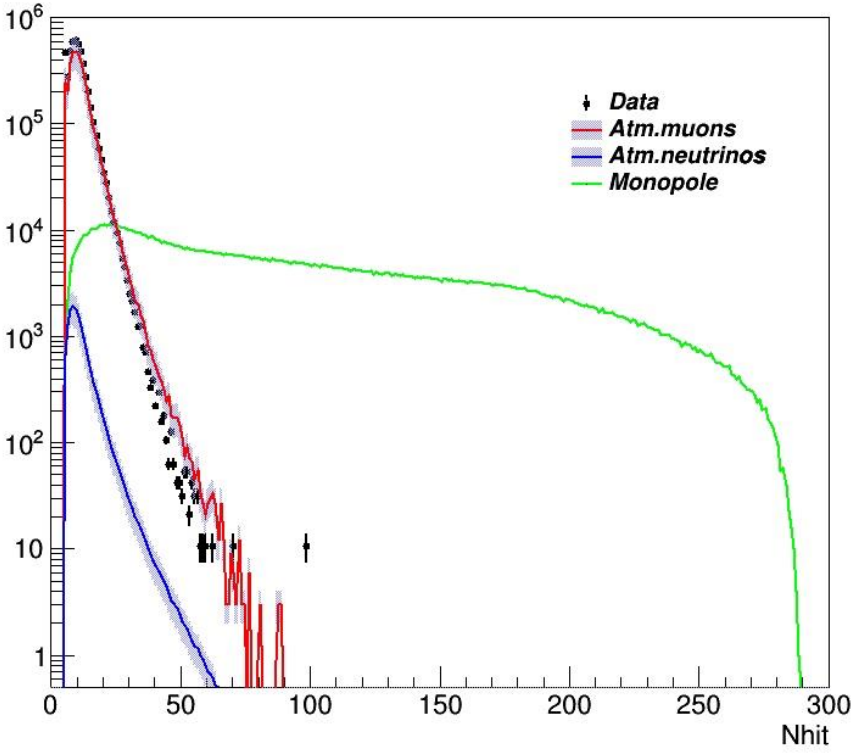
Search for Magnetic Monopoles

β in [0.906 , 0.9505]



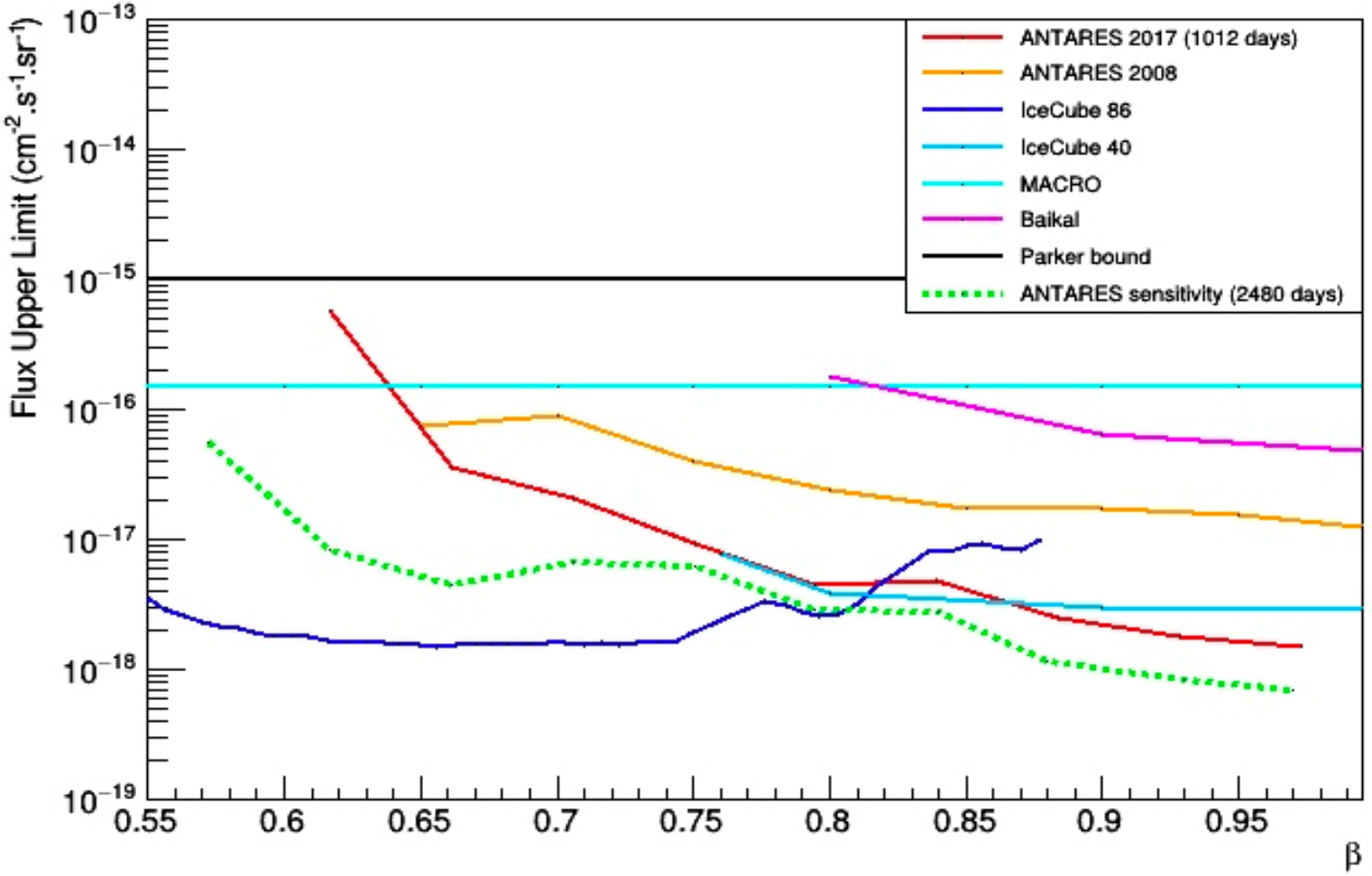
$\alpha = t\chi 2 / (1.3+(0.04\times(Nhit-5))^2)$

β in [0.906 , 0.9505]



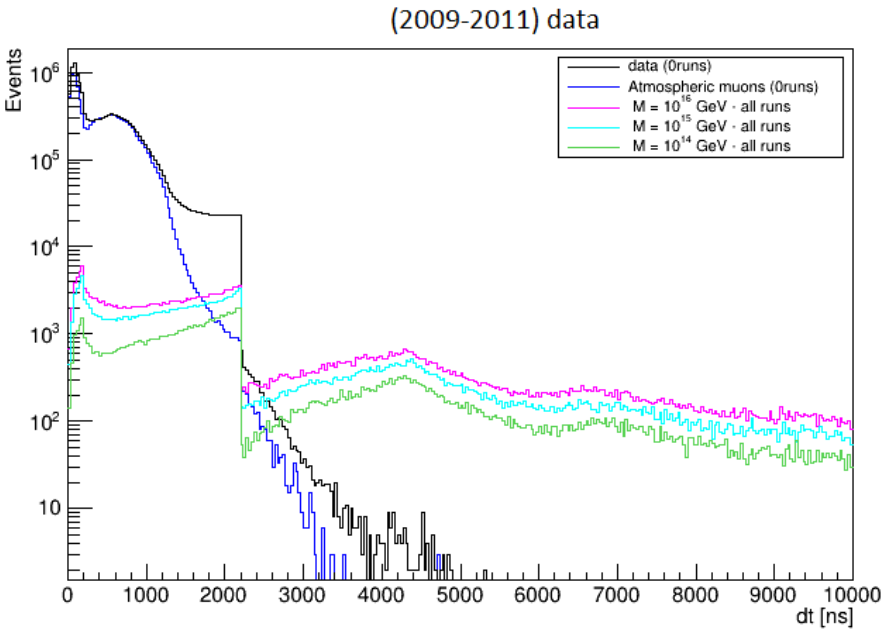
number of fired PMTs in the track

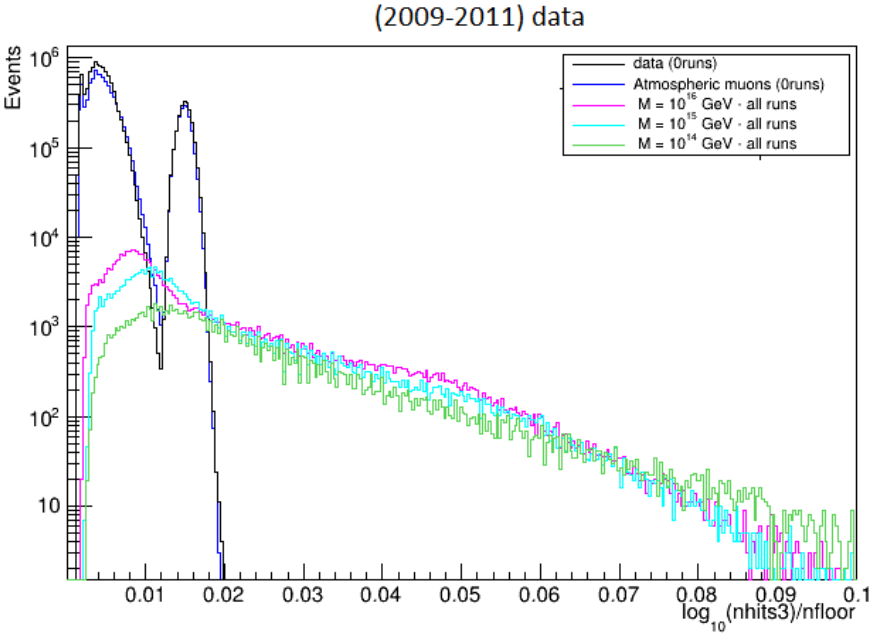
Search for Magnetic Monopoles



JHEP 07 (2017) 54
JHEA 34 (2022) 1-8

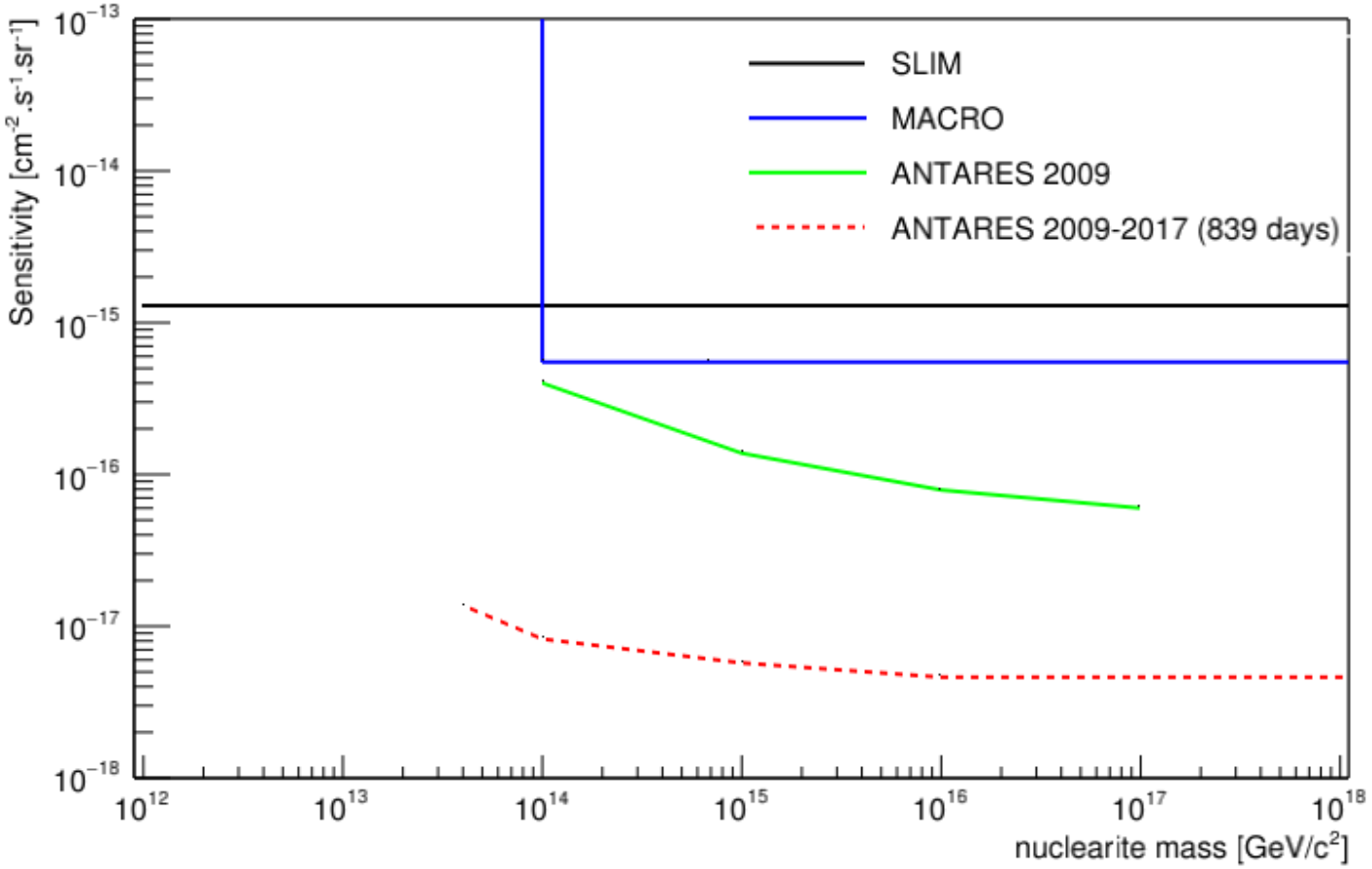
Search for Nuclearites





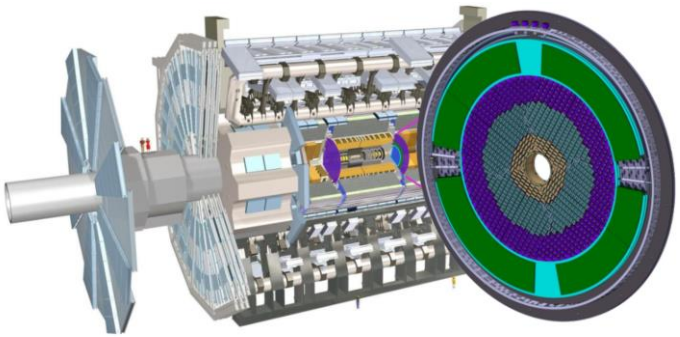
Snapshot duration (dt) left, and log10(nhits3)/nfloor distributions; these two variables are the best discrimination variables for nuclearites

Search for Nuclearites



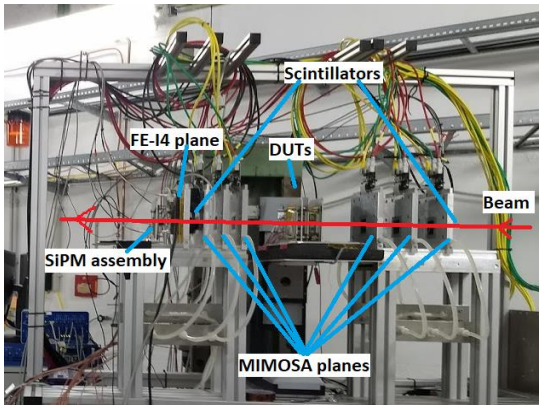
Sensitivity obtained for nuclearites in ANTARES

High Granularity Timing Detector

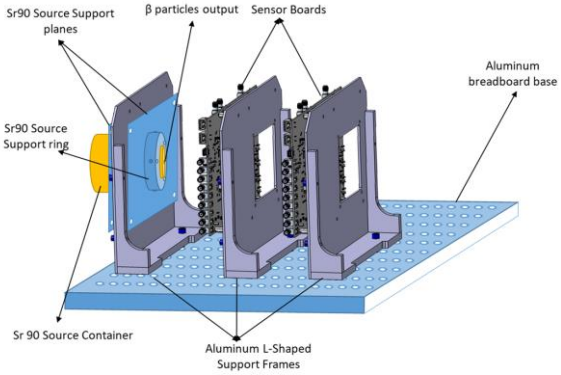


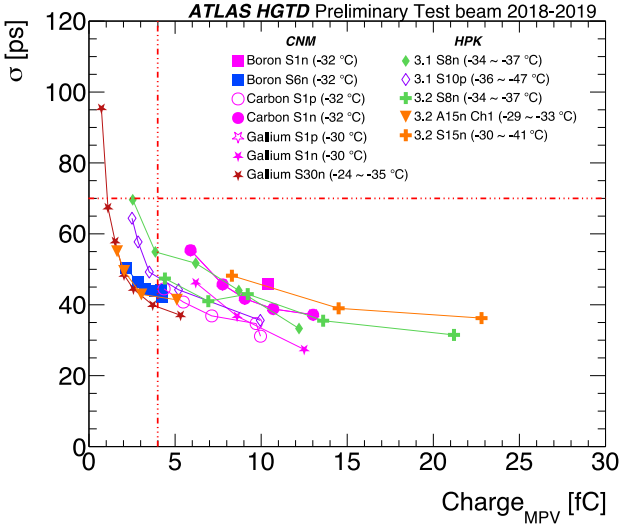
- HGTD is expected to start data taking in 2028 and will be the first large-scale application of LGAD technology to highly reduce pileup in the forward region of the ATLAS detector during the HL-LHC physics program.
- LGADs and their readout ALTIROCs are optimised to reach a $\sigma_t < 50$ ps per track up to the end of the lifetime.
- Measurements of LGAD sensors from laboratory and test beams have shown promising results.

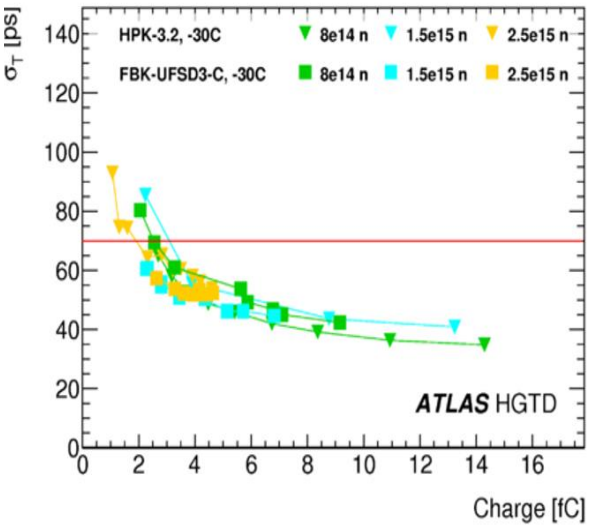
TestBeam



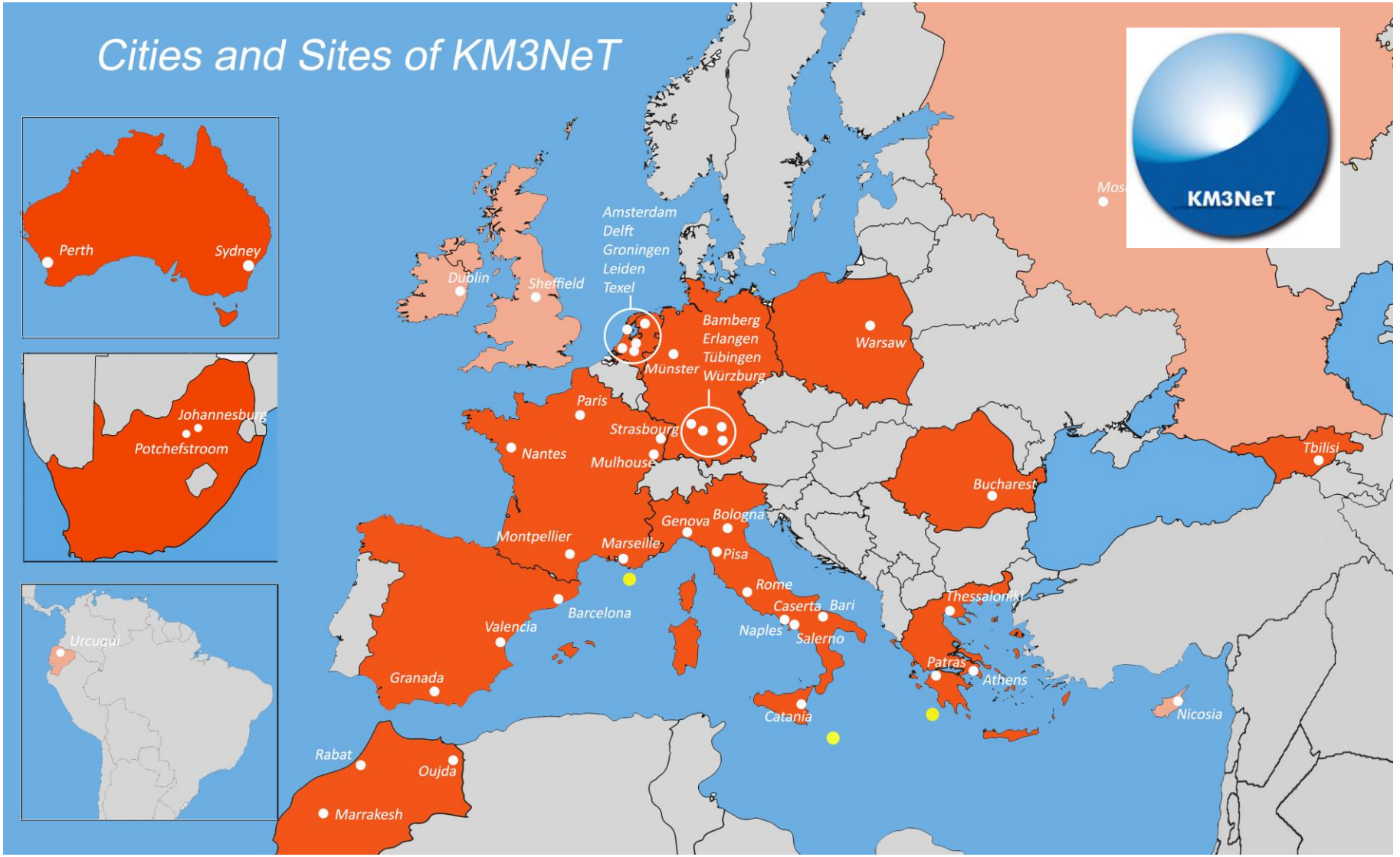
Laboratory



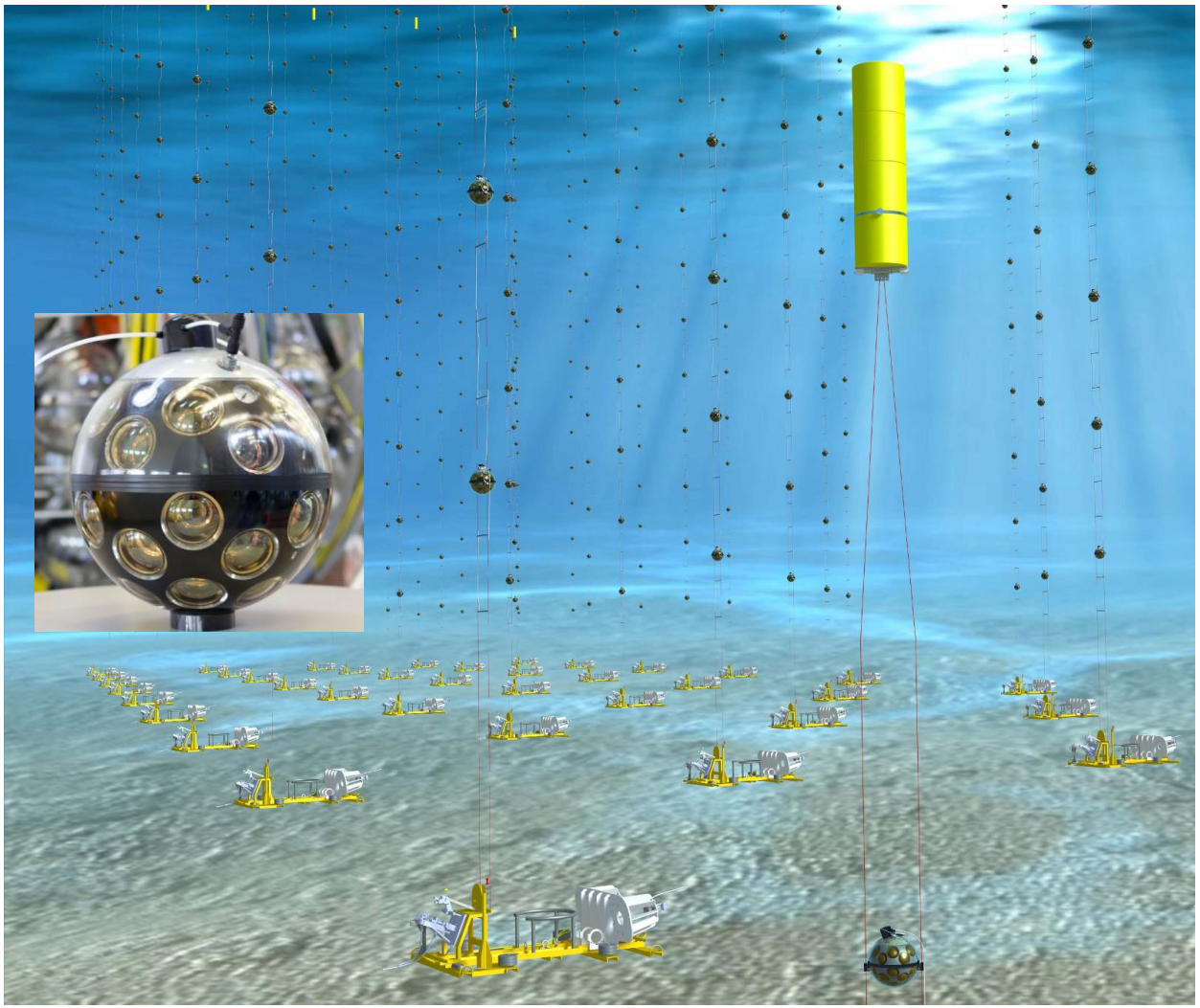


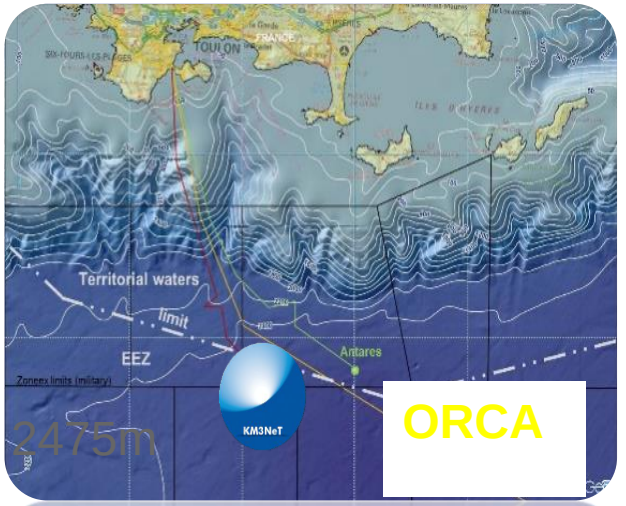


KM3NeT


Cities and Sites of KM3NeT
KM3NeT
Perth
Sydney
Johannesburg
Potchefstroom
Urcuqui
Dublin
Sheffield
Amsterdam
Delft
Groningen
Leiden
Texel
Münster
Bamberg
Erlangen
Tübingen
Würzburg
Warsaw
Paris
Strasbourg
Nantes
Mulhouse
Montpellier
Marseille
Genova
Bologna
Pisa
Rome
Caserta
Bari
Naples
Salerno
Barcelona
Valencia
Granada
Catania
Rabat
Oujda
Marrakesh
Bucharest
Tbilisi
Thessaloniki
Patras
Athens
Nicosia

KM3NeT




Territorial waters
limit
EEZ
Antares
KM3NeT
2475m
ORCA


KM3NeT
3400m
ARCA

KM3NeT

- 31 PMTs in one sphere
- 3 x cathode area wrt ANTARES OM
- Single photon counting
- Directional information
- Inspiring design for IceCube-Gen 2

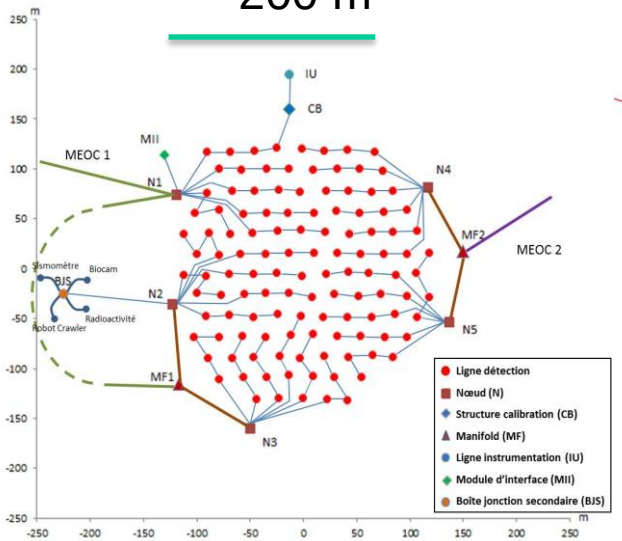
KM3NeT ARCA/ORCA

Astrophysics/**O**scillation **R**esearch
with **C**osmics in the **A**byss

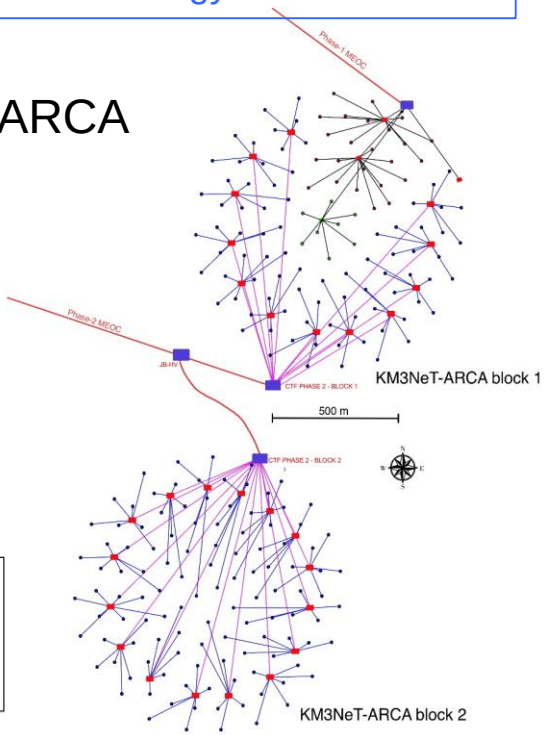
ARCA: 3.5km depth, 100km from Capo Passero (Sicily)
Focus: Cosmic Neutrino Sources
large, sparse grid -> high energy
ORCA: 2.5 km depth, 40km from Toulon (France)
Focus: Atmospheric neutrino oscillations
small, dense grid -> low energy

ORCA

200 m



ARCA

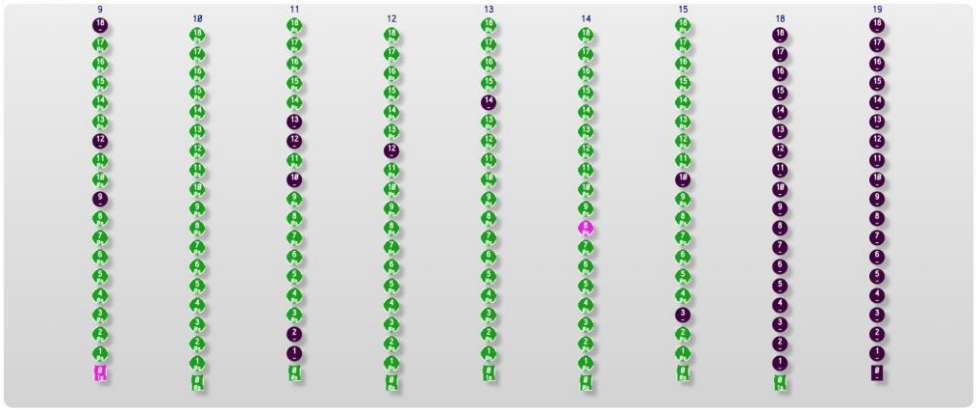


KM3NeT : Current status

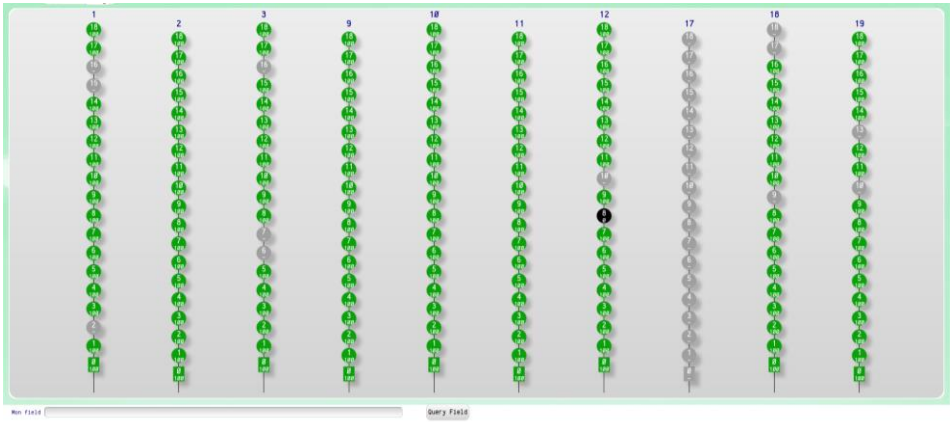
- 8 functional lines in ARCA (Italie)
- 10 functional lines in ORCA (France)

PS: 11 new lines added to ARCA very recently (June 2022)

ARCA8



ORCA10



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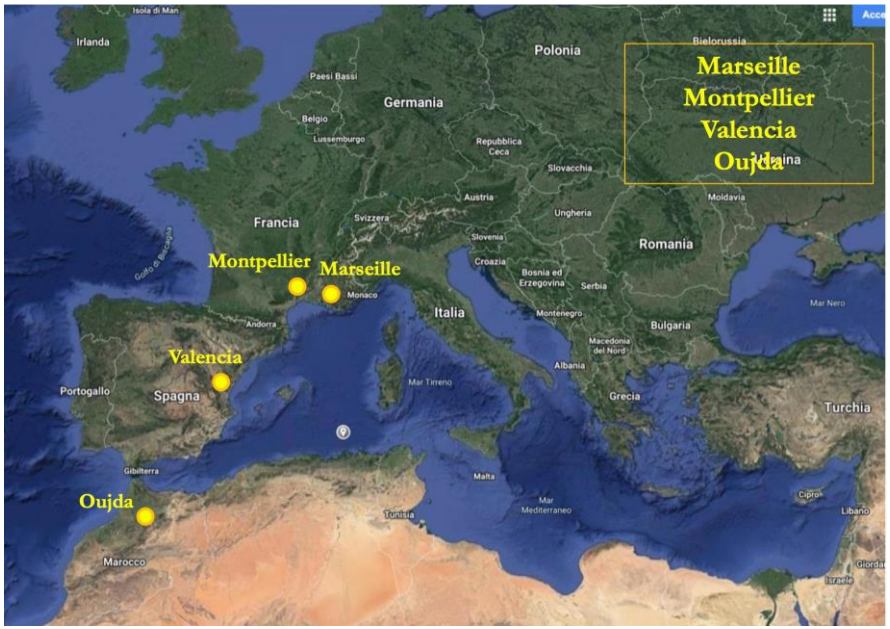
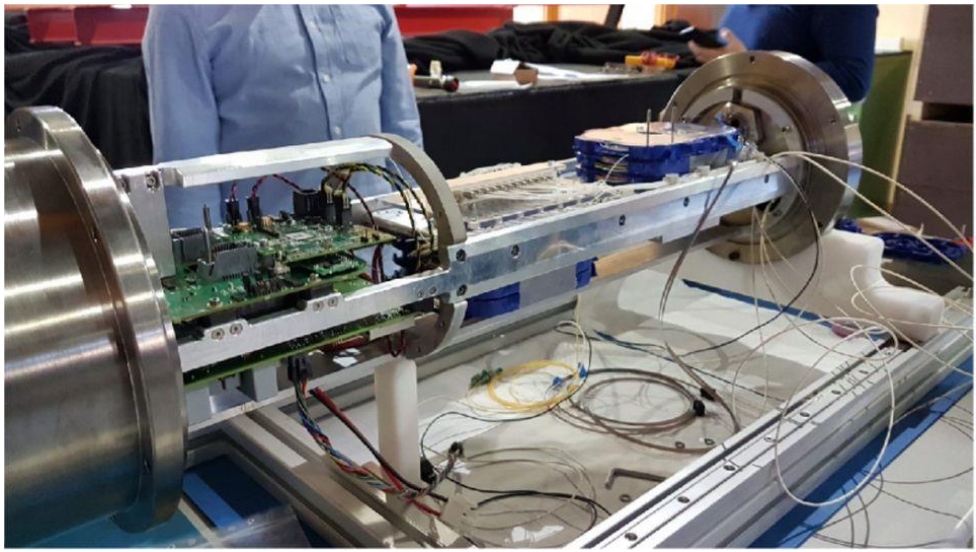
National DOM integration site in Rabat

National BM integration site in Oujda

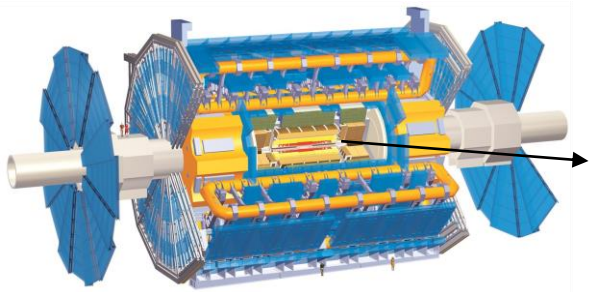


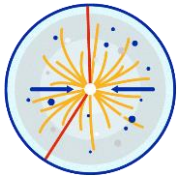
Agreement for the establishment of a second national site which will be installed at the Mohammed Premier University of Oujda.

This large-scale project will be dedicated to the integration of "Base Modules" for the KM3NeT-ORCA Telescope.



ATLAS data processing chain





Trigger

Reconstruction

Derivation

Generation

Simulation

Digitization+Trigger

Reconstruction

Derivation

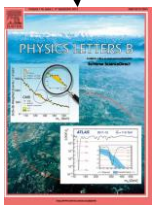
Organized production

Heterogeneous analysis

Detector data

Analysis

Simulated data



Online

Tier-0

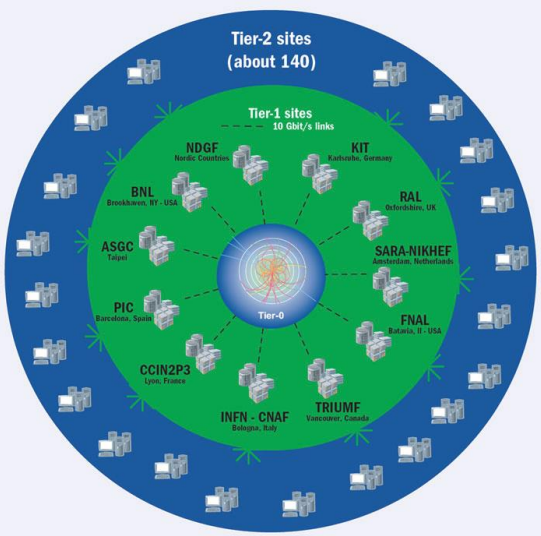
Grid

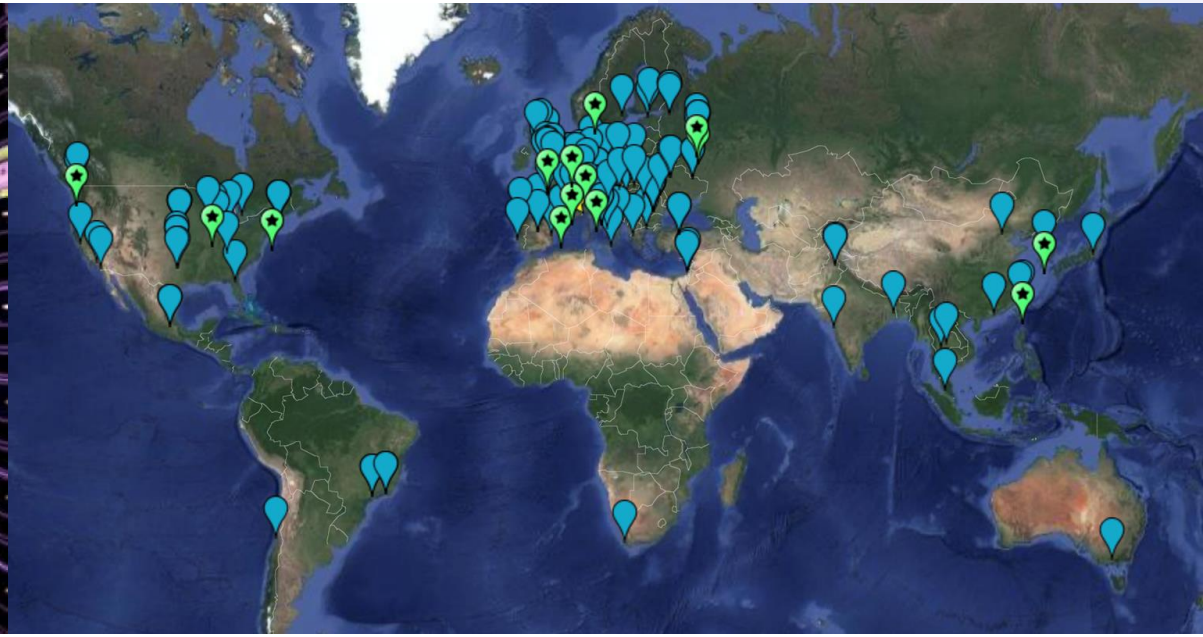
Grid & Analysis Facilities

40M of photos / sec
Only 1k are saved

Our Computing Centers (WLCG)

- We have a pretty traditional, though evolving, computing infrastructure
- Racks of linux boxes distributed around the world in “sites”
- Sites classified in “tiers” and organized into “clouds”
- Integrating High-Performance Computing systems and Cloud resources





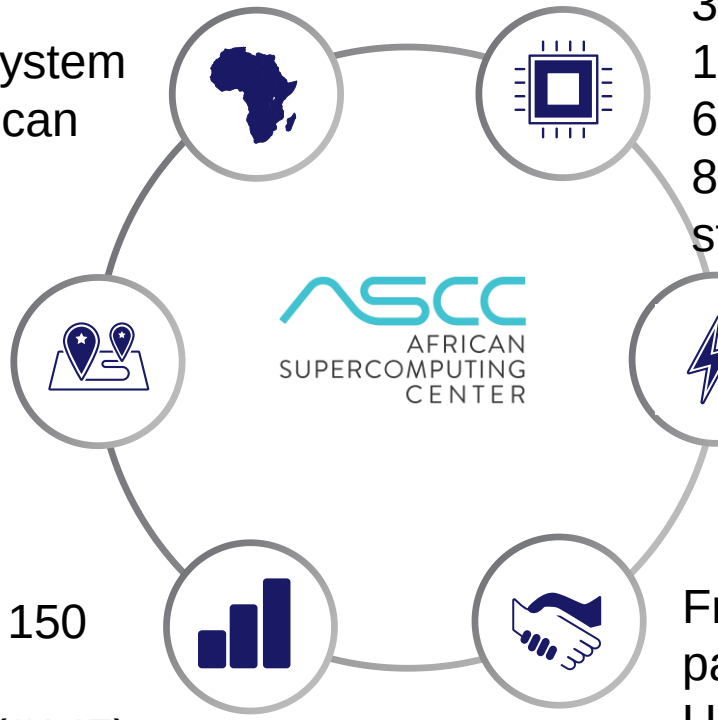
How Much, How Big?

Worldwide, LHC-wide:

- **1.5M CPU cores**
- **1.4 EB of disk+tape**
- **200 PB/month of data transfers** (between computing centers)

African SuperComputing Center

ASCC



Largest system in the African continent

3.15 PF of performance
1300+ servers
67000+ CPU cores
8000 TB of combined storage

Regional Academic Research Hub

About 650KW of electrical power at full capacity

In the TOP 150 systems worldwide (#147)

Fruit of a partenership with the University of Cambridge

ASCC: What is the vision?

Provide a world-class capability in advanced computing

- Support Data-Driven initiatives and research projects
- Attract talent and researchers to universities in the region
- Increase the competitiveness of research and innovation in the region

Set the pace for Innovation using Data Analytics

- Create a Data Analytics community (National and Regional levels)
- Accelerate AI/ML initiatives

Regional Academic Research Hub

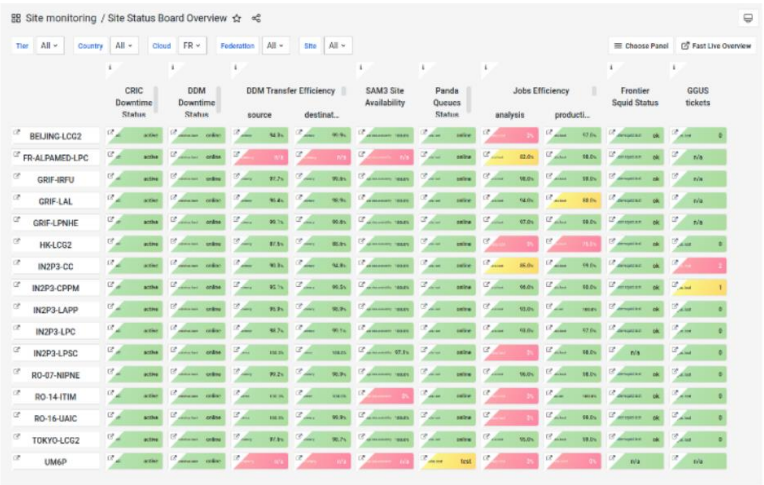
- Create a hub between the industrial and academic worlds
- Exchange ideas, create synergies and collaboration opportunities

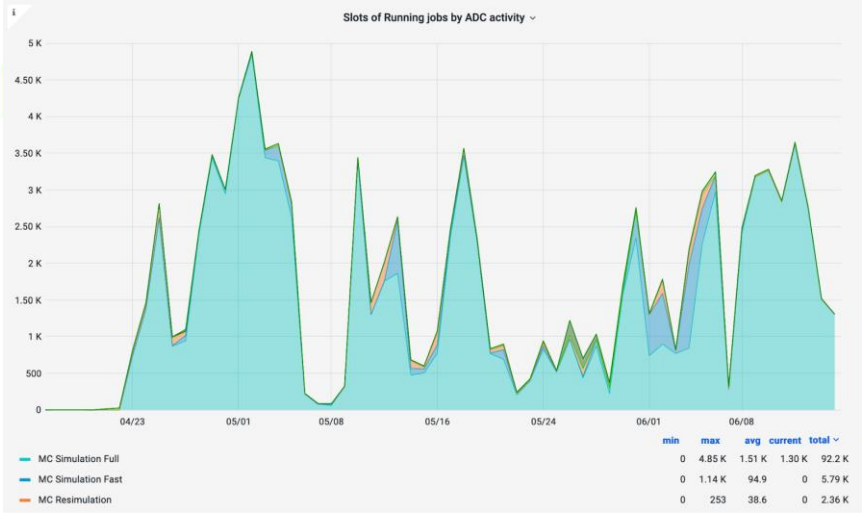
National ATLAS Tier2

FR-cloud

FR-cloud groups Tier 1 and several Tier 2 and Tier 3 sites for operational issues

- countries : China, France, Japan, Morocco, Romania
- Tier 1 site : IN2P3-CC
- Tier 2 sites : BEIJING-LCG2, GRIF-IRFU, GRIF-LAL, GRIF-LPNHE, HK-LCG2, IN2P3-CPPM, IN2P3-LAPP, IN2P3-LPC, IN2P3-LPSC, RO-07-NIPNE, RO-14-ITIM, RO-16-UAIC, TOKYO-LCG2, UM6P



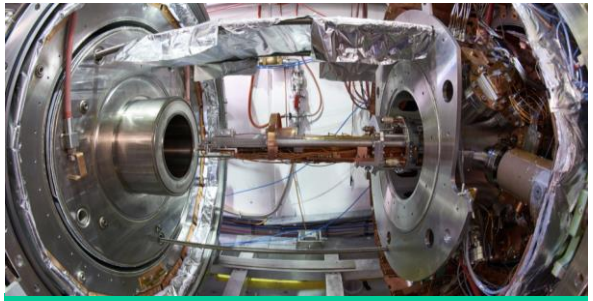


Welcome to the T2 site of University Mohammed VI Polytechnique (UM6P),
Ben Guerir, Morocco
https://ascc.um6p.ma/
https://atlas-cric.cern.ch/core/experimentsite/detail/UM6P/

Quantum R&D Areas

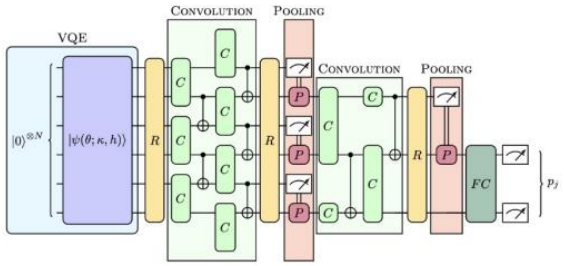
QUANTUM TECHNOLOGY INITIATIVE

https://quantum.cern



CERN has years of experience in designing technology with direct applications to QUANTUM COMPUTING, COMMUNICATIONS, AND SENSING and complex COMPUTATIONAL NEEDS

The CERN QTI was designed to EXPLORE the applications of quantum technologies and CONTRIBUTE to the advancement of the state-of-the-art bridging fundamental research, quantum information science, and engineering

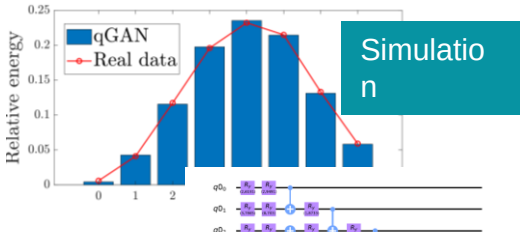


Quantum Phase Detection Circuit

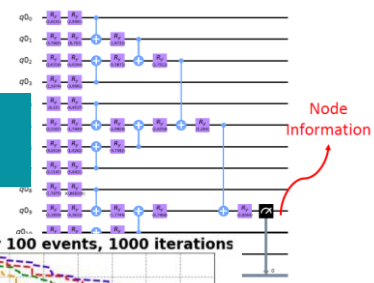
Technologies to directly CAPTURE, STORE AND PROCESS QUANTUM STATES from future detectors would allow to accelerate new physics discoveries and enable revolutionary new applications in many fields

Quantum R&D Areas

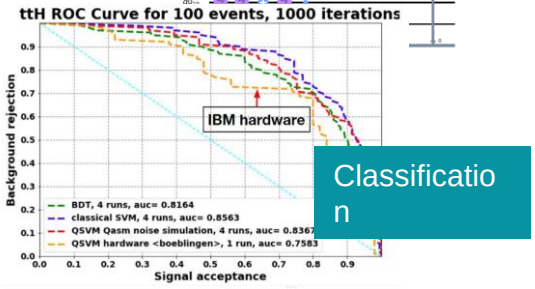
Computing



Simulation

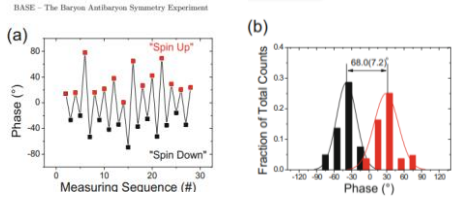


Reconstruction



Classification

Sensing

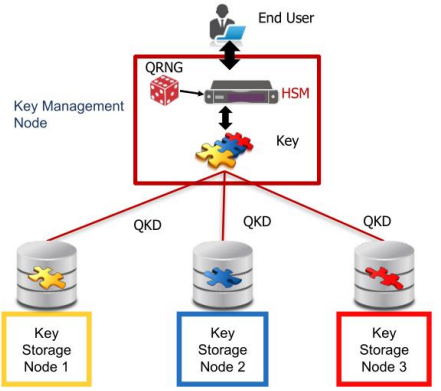


https://doi.org/10.1140/epjst/e2015-02607-4

Low-energy experiments, quantum states measurements, nano-technologies

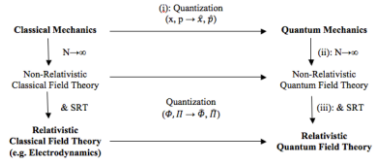
Future HEP Detectors

Communications

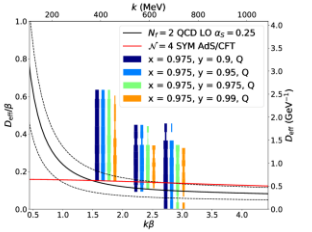


QKD infrastructures Quantum Internet

Theory



Quantum Field Theory



https://cds.cern.ch/record/2703396

Lattice QCD

Quantum Technology Collaborations

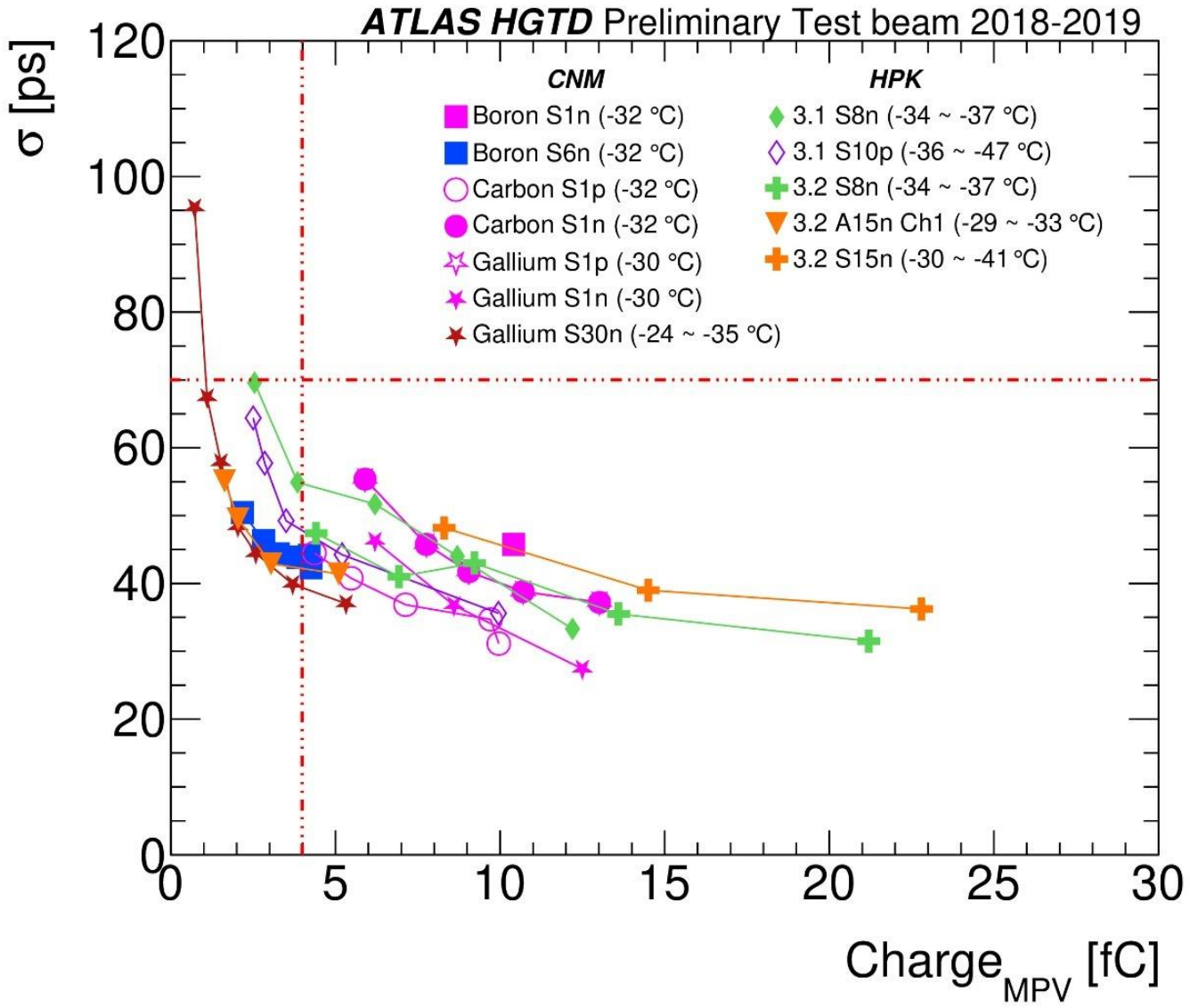
Conclusions

- Technology Transfer through HEP and Astroparticles

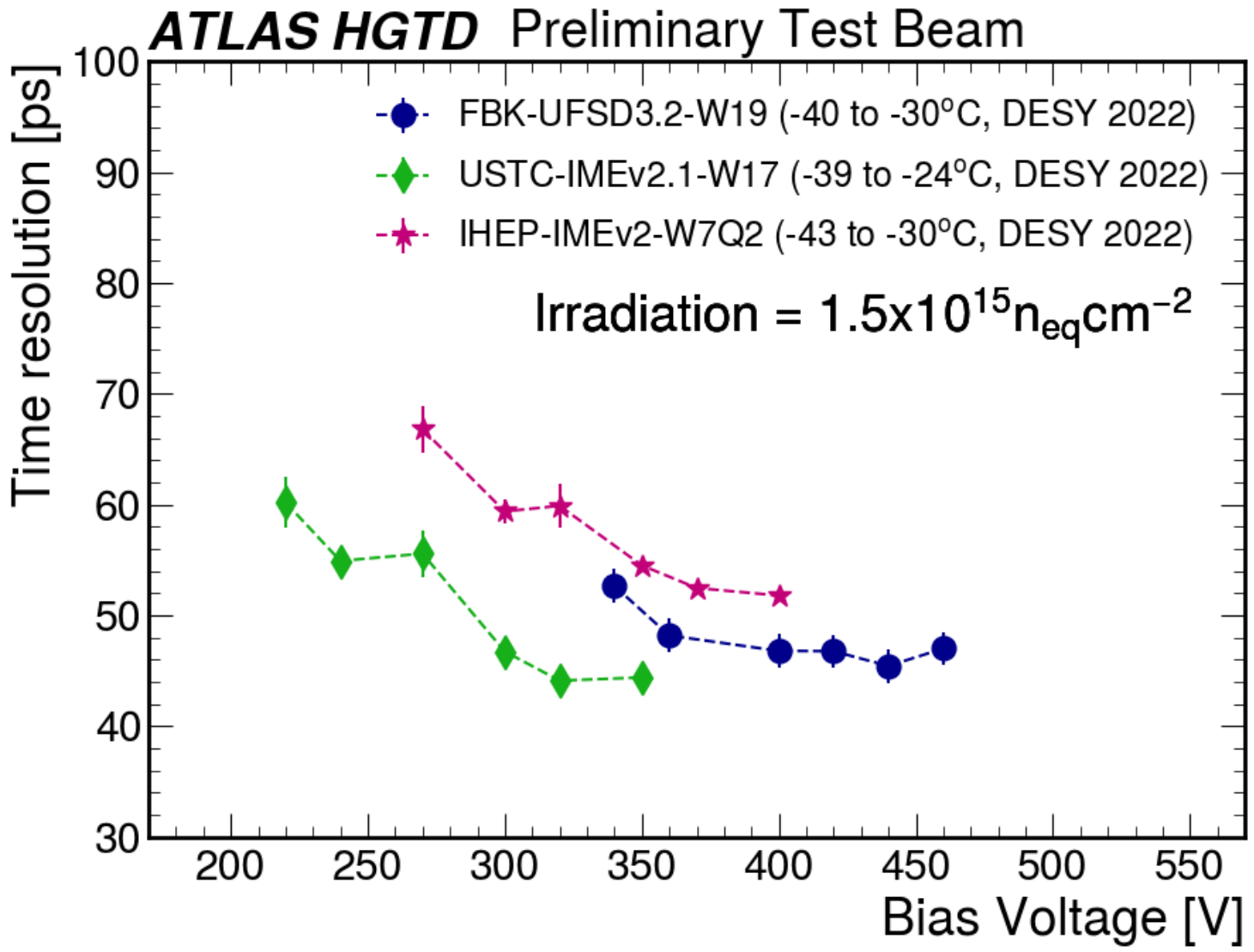
- To become a Tier2 it would be important to be able to run all the ATLAS workflows, including the I/O intensive ones like derivations and analysis.

We need an upgrade at least at the 10Gbps level, and on storage, which ideally should be above 0.75 PB

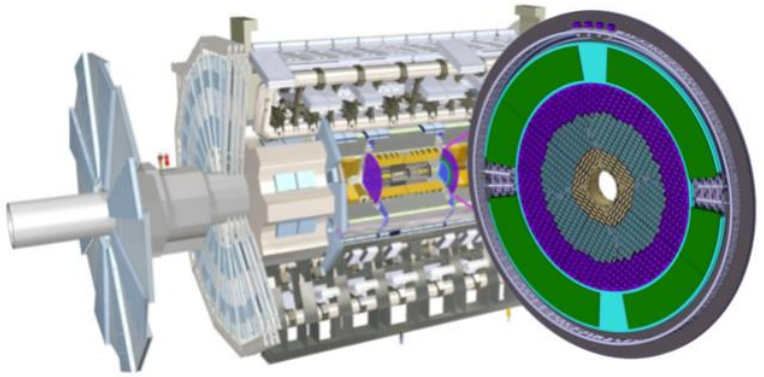
ATLAS upgrade (HGTD)



ATLAS upgrade (HGTD)



ATLAS upgrade (HGTD)



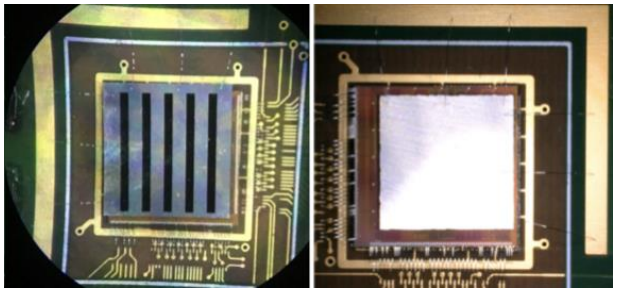
ATLAS Technical Associate

optimization and design of a prototype of the HGTD in order to participate in the assembly of part of this detector.

Benefit from the expertise of the MAScIR Foundation in terms of applied research, in particular as regards the methods of validation and verification of electronic systems intended to ensure the smooth running of experiments during the operation of the LHC collider.

MAScIR one of the six sites chosen for the production and quality control of 16% of the overall volume of the HGTD project, in its final phase.

LGAD : 30ps



MAScIR
Moroccan Foundation for Advanced Science, Innovation and Research

Preparing the future — the grand plan