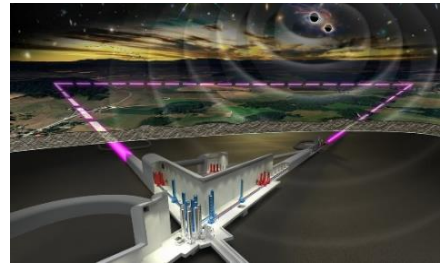
M2Tech 2024 project

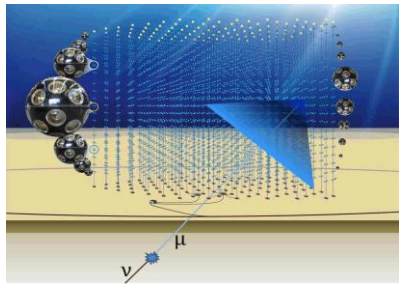
Edwige Tournefier

March 6th, 2024

M2Tech : Technologies for Multi-Messenger Astrophysics

Aim: **develop innovative technologies for the current and the next generation of detectors operating for multi-messenger astrophysics** with the generic aims to improve the **sensitivity, efficiency, duty cycle, and sustainability** of those detectors



- Answer the EU INFRATECH call (see next slide)
- Involved research infrastructures:
  - **CTAO and MAGIC** for gamma-ray astronomy,
  - **ET** and **Virgo** for gravitational wave interferometry
  - **KM3NeT** for neutrino astronomy
- Diversity of the *messengers* $\Rightarrow$ heterogeneity of the technologies used in the observatories
- **M2Tech's specific aims**:
  - develop prototypes of detectors, software tools and methods and test them for validation,
  - directly engage with the industry to co-develop those technologies,
  - build upon existing knowledge of current infrastructures to expand the potential of future infrastructures,
  - create connections between multi-messenger research infrastructures (common software platforms, scientific exchange).

"R&D for the next generation of scientific instrumentation, tools, methods, solutions for RI upgrade"

- Aspects to be addressed by the proposals :

  1. R&D of new scientific instrumentation, tools and methods for RIs

  - Taking into due account **resource efficiency** (e.g. energy consumption) and **environmental (including climate-related) impacts**.
  - This could also include the **development of new, more sustainable and efficient methods of collecting data and/or of providing access**, including remote and digital, as well as **digitization of instrumentation, services and results**.

  2. Their **technology validation and prototyping**;

  3. Training of RI staff for the operation and use of these new solutions. When relevant, developing skills on technical validation to industrial standards;

  4. The **innovative potential for industrial exploitation of the solutions and/or for the benefit of society**, including facilitating proof of concept for use by SMEs.

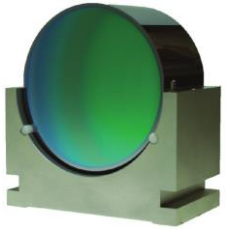
  5. Consortia should be built around a leading core of **at least 3 world-class RIs being ESFRI infrastructures**,...

- The total budget for the call is 62 million euros and the expected total budget per project is **5 to 10 million euros** (indicative number of grants: 7).

From the astrophysical signal collection to multi-messenger alerts

Astrophysical signal

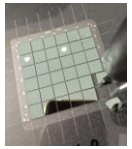
High quality mirrors optical windows



WP2

Sensitivity
Sustainability

Advanced photosensors analog electronics



WP3

Sensitivity
Sustainability

Precise synchronisation and timing distribution WP5

Sensitivity

Efficient digitisation, High rate data processing and transfer

WP4

Efficiency
Sustainability

Efficient detector monitoring WP5

Efficiency
Duty cycle

Efficient and sustainable data processing

MM Alert system

WP6

Efficiency
Sustainability

MM detector network

- M2Tech 2022 project submitted to the EU INFRATECH call "R&D for the next generation of scientific instrumentation, tools and methods"
  - 39 partners, duration 4 years, total budget: 12 Meuros (10 EU + 2 Swiss)
  - Built in ~3 months
  - Evaluation: 11.5/15 – positive review but weaknesses identified
    - Some parts insufficiently described/justified: how the goals will be achieved, precise aims, open science practices, risk mitigation strategies, portability of technologies
    - WP6 dominates the effort
    - Unclear what "Digital Twins" will provide that is new and upgraded, Machine Learning approach (supervised/unsupervised),..
    - Consortium very large: not convincing case that all partners are needed and what they bring to the project
    - ...

- Revised project to be submitted to 2024 EU call "R&D for the next generation of scientific instrumentation, tools, methods, solutions for RI upgrade" (HORIZON-INFRA-2024-TECH-01-01)
  - ⇒ Revised the project's objectives and work plan – better focus the WPs contents – reduce number of partners
  - ⇒ WPs detailed contents and build consortium: summer 2023 + consortium meeting with all partners in October at LAPP
  - ⇒ Write the proposal and define budget (Jan/Feb 2024) - WPs leaders meeting in February at UNIGE

Duration: 4 years (start 2025)

Technological areas:

WP 2- Optical coatings and surface treatments:

WP 3- Advanced and adaptable photosensors:

WP 4- Advanced electronics:

WP 5- synchronisation, monitoring and control

WP6- Efficient and sustainable computing:

WP7 – Technology transfer

co-developments between academia and industry

Management and communication:

WP1 - Project management, coordination and communication activities

WP2: optical coatings and surface treatments

WP leader: Stuart Reid (ET)

- Objectives: improve optical performances and durability
  - Gamma-ray telescopes: increase the UV-B reflectivity, IR suppression, and robustness/durability to environmental conditions
  - GW detectors: lower the optical absorption, scattering, and thermal noise of coatings
  - Neutrino detectors : increase the robustness to abrasion and minimize biofouling of the optical coatings/surfaces

- How:
  - Investigate combination of key manufacturing techniques with post-manufacturing treatments
  - Push further the existing synergies between these different goals to produce new optical samples
  - Extensive characterisation + test in facilities which are present in the consortium
  - Make use of modelling/simulation

- Partners: Strathclyde, Glasgow, Maastricht, CNRS, INFN, INAF, UPOL, DESY, IJF PAN, ELI, HELIA Photonics

WP3: Advanced and adaptable photosensors

WP leader: Teresa Montaruli (CTA)

- Objectives:
  - a new high-quantum efficiency silicon sensor suitable for covering large photosensing areas of more than a few m^2 with maximum photodetection efficiency (PDE) between 350-550 nm
  - coatings for the sensors in collaboration with WP2
  - Development of high-quantum efficiency and low reflectivity photodiodes for ET_LF in the 1500-2000 nm range to be used for under vacuum

- How/contents:
  - Develop in partnership with FBK large area SiPM based on new technology
  - Develop algorithms for high level trigger (analog)
  - Develop coatings to be deposited on SiPMs with WP2 to filter unwanted wavelengths

  - Develop high-quantum efficiency photodiodes for ET_LF + low AR coating
  - Produce mirror baffle prototype to be tested at ET_Pathfinder and/or Cern

- Partners: UNIGE, IFAE, FBK, STRATH, CAMK PAS, CIEMAT, CSEM

WP4: Advanced electronics

WP leader: Sergio Gomez (CTAO)

- Objectives:
  - Develop low noise and low power electronics and more efficient/cleaner signal extraction
  - Develop a modular detection unit (FlexiTile) including photo-sensors (from WP3), and optical links to equip a wide-range of instruments requiring sensitive cameras (CTAO, KM3NeT,...)

- How/contents:
  - Development of Front end board (signal amplification and shaping), including ADC
  - Synchronisation: accurate low noise clock based on White Rabbit (linked to WP5)
  - Optical links and transceivers for data transmission away from detectors
  - Development of readout boards for data processing (photon counting, demodulation+filtering,...)
  - Development of ML based trigger

- Partners: UPC, UCM, UB, UV, IFAE, CNRS, INFN, UNIGE, EPFL, CIEMAT

WP5: Synchronisation, monitoring and control

WP leader: Tommaso Chiarusi (KM3NeT)

- Objectives:
  - Significantly enhance the White Rabbit technology: to support high data throughput (up to 10GbE), low phase-noise clock reconstruction and distribution for large scale infrastructures
  - Enhance the control and monitoring of large scale instruments: predictive maintenance and fault-tolerance technology

- How/contents:
  - Develop prototypes of WR components: WR switch, network interface card evolving the technology from 1 to 10 GbE and mezzanine board to link WR slave nodes – expertise from White Rabbit Collaboration based at Cern
  - Develop a generic framework for monitoring and control based on Digital Twins based on building blocks from the interTwin EU project

- Partners: INFN, CERN, COSYLAB, UV, INAF

WP6: Efficient and sustainable computing

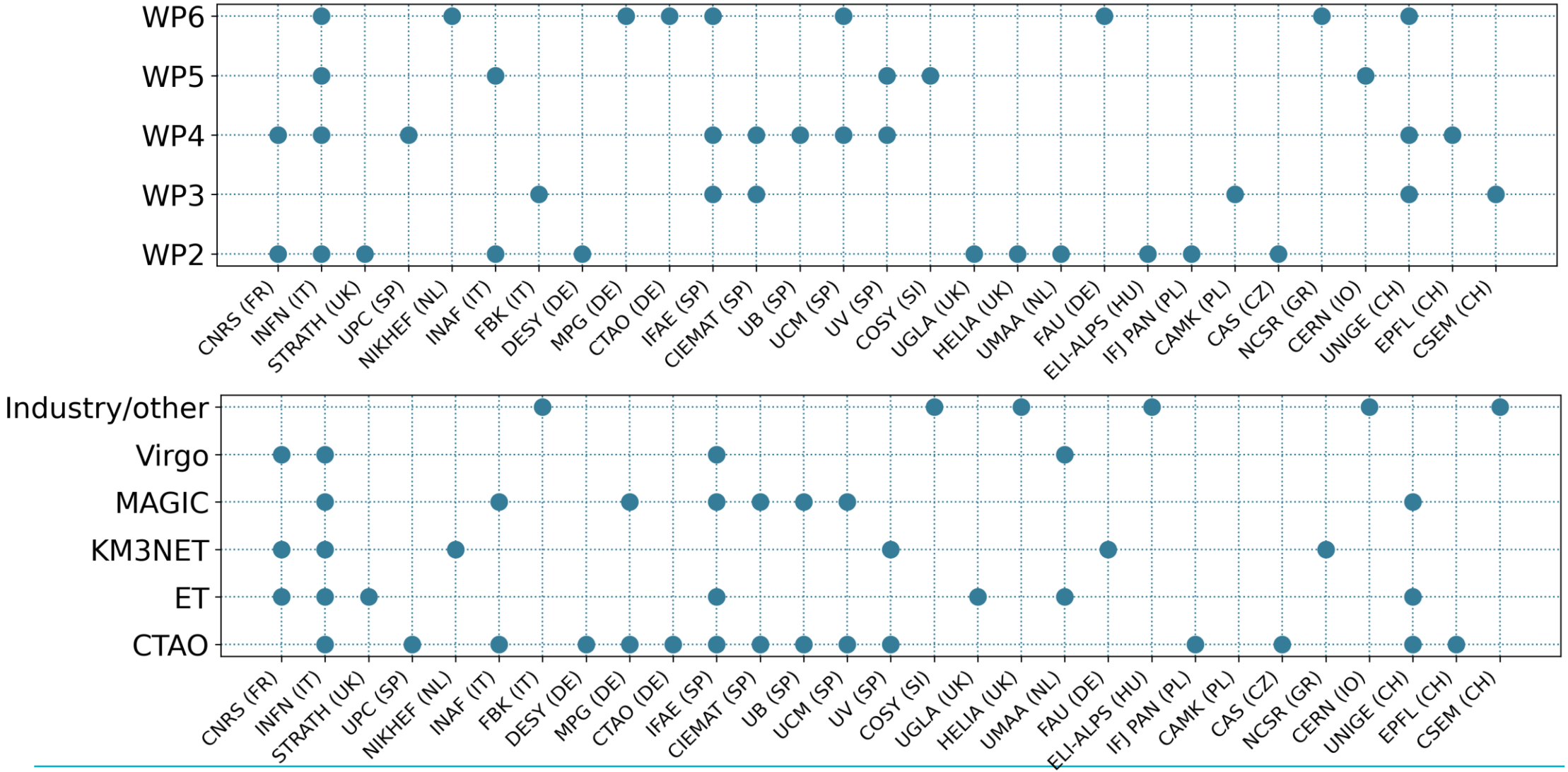
WP leader: Steve Schramm (ET)

- Objectives:
  - Establish efficient data processing strategies to reduce the overall energy footprint
  - Evaluate sustainable large-scale computing strategies to reduce energy requirements and carbon foot print
  - Ensure that Ris can communicate effectively

- How/contents:
  - Develop ML techniques within a common framework for faster date processing and data volume reduction
  - Understand the carbon cost involved in multi-messenger workflow (related to increased rate of events) and identify strategies for reduction – in partnership with computing centers (PIC, CNAF)
  - Define and implement new interoperability standards and database for multi-messenger alerts - in agreement with Virtual Observatories (IVOA, CEVO)

- Partners: UNIGE, MPG, INFN, FAU, CTAO, UCM, IFAE, NIKHEF, NCSR

All RIs involved in all WPs => sharing of knowledge and knowhow



- Revised M2Tech project to be submitted to 2024 call (March 2024)
  - same technological areas: from the astrophysical signal collection to the MM alerts
  - more focussed content
  - opportunity to create connections between multi-messenger research infrastructures
  - start 2025 – 4 years

- Many technologies to be developed and of interest for Virgo_nEXT and ET:
  - Improved coatings
  - Photodiodes for instrumented baffles
  - Electronics for photodiodes signal processing
  - Enhanced White Rabbit technology
  - Framework for monitoring and control
  - Efficient and sustainable computing for signal detection
  - Implementation of new standards for multi-messenger alert management

- INFN labs:
  - 1) Sezione di Bologna
  - 2) Sezione di Torino
  - 3) Sezione di Perugia
  - 4) Sezione di Padova
  - 5) Sezione di Genova
  - 6) Sezione Roma Tor Vergata
  - 7) Sezione di Napoli - Gruppo Collegato di Salerno
  - 8) Sezione di Roma
  - 9)Laboratori Nazionali del Sud
  - 10) CNAF

- CNRS labs:
  - IP2I (LMA)
  - LAPP
  - CPPM