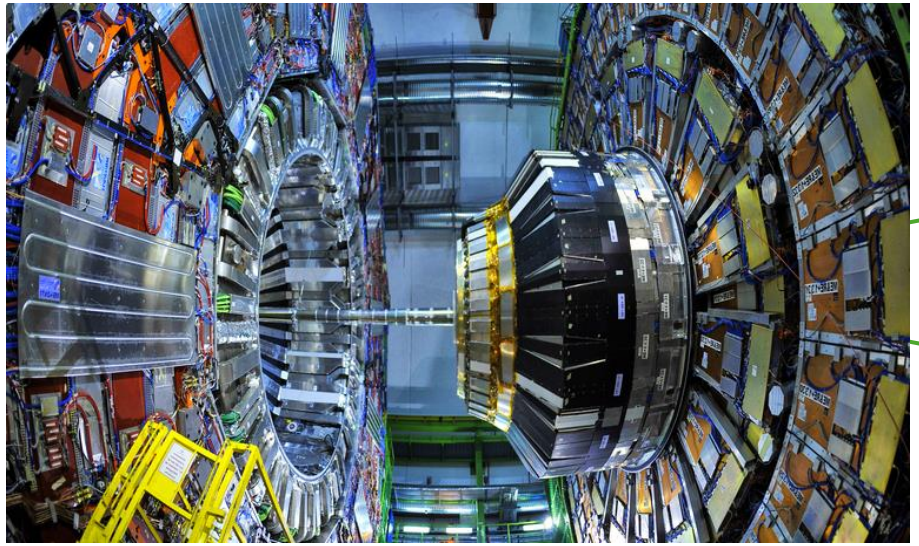
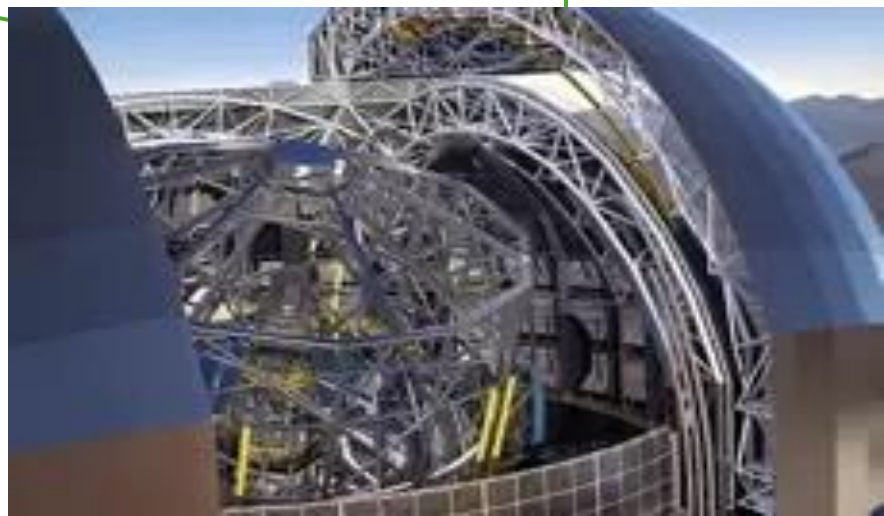
PhD Program of National Interest in Technologies for Fundamental Research in Physics and Astrophysics

Retreat 2025 - LNGS



CURRICULUM

DETECTORS, LASERS and OPTICS



Università degli Studi di Padova, INFN, INAF, Gran Sasso Science Institute,
Università degli Studi di Cagliari, Politecnico di Torino,
Università degli Studi di Napoli Federico II, Università degli Studi di Bari Aldo Moro

INFN Istituto Nazionale di Fisica Nucleare

INAF Istituto Nazionale di Astrofisica

CURRICULUM BOARD MEMBERS

1	Felicia Carla Tiziana Barbato	Gran Sasso Science Institute
2	Andrea Bianco	INAF, Arcetri
3	Francesco Bertazzi	Politecnico di Torino
4	Elisabetta Bissaldi	Politecnico di Bari
5	Lorenzo Busoni	INAF, Arcetri
6	Alessandro Cardini	INFN, Cagliari
7	Nicola Giglietto	Politecnico di Bari
8	Mosè Mariotti	Università degli Studi di Padova
9	Mauro Morandin	INFN, Padova
10	Arianna Morozzi	INFN, Perugia
11	Matteo Munari (co-coordinator)	INAF, Catania
12	Salvatore My (co-coordinator)	Università degli Studi di Bari
13	Lorenzo Pagnanini	Gran Sasso Science Institute
14	Francesco Quochi	Università degli Studi di Cagliari
15	Paolo Soffitta	INAF, Roma
16	Giacomo Volpe	Università degli Studi di Bari

CURRICULUM MAIN TOPICS

Tecnlogical Developments for

- **detectors**
  - charged and neutral particles, em radiation
  - performances (sensitivity, spatial resolution, timing resolution, acquisition rate, ...)
  - improve materials
  - improve detection techniques
  - superconducting and quantum technologies
- **laser systems**
  - power, stability
- **optics and complex opto-mechanical systems**
  - adaptive optics
  - lightweight mirrors
  - coatings to increase sensitivity and to minimize noise
  - techniques to improve design and simulation

DETECTOR DEVELOPMENTS ROADMAPS

The 2021 ECFA Detector Research and Development Roadmap

The NuPECC Long Range Plan 2024 for European Nuclear Physics

European Astroparticle Physics Strategy 2017-2026

R&D for the Next Generation of Ground-Based Gravitational-Wave Detectors

INAF Piano Triennale 2023-2025

Future Facilities I

Future Facilities II

The CERN Experimental Programme

Update of the European Strategy for Particle Physics is ongoing

https://europeanstrategy.cern

Open Symposium, Venice Lido, 23-27 June 2025

https://agenda.infn.it/event/44943/overview

Fee reduction for undergraduate, master and PhD students

CURRICULUM 39th Cycle PhD STUDENTS

	PhD Name	Project Title	Supervisor(s)
1	Muhammad Ali	Hadron Calorimeter MPGD-baed development for future Muon Collider Experiment	Rosamaria Venditti (Uniba), Salvatore My (Uniba)
2	Maria Bazzicalupo	Sensing phase discontinuities on ELT segmented pupil with a rotational shearing interferometer	Lorenzo Busoni (INAF, Arcetri)
3	Gabriel Botogoske	Study of the light detection properties of PoWER: A proposed Far Detector for DUNE	Francesco di Capua (Unina)
4	Salvatore Camposeo	High energy photon emissions from Solar System objects	Elisabetta Bissaldi (Poliba), Leonardo Di Venere (INFN, Bari)
5	Tommaso Croci	Development of innovative radiation-hard silicon particle detectors for 4D tracking in future high-energy physics experiments	Daniele Passeri (Unipg), Arianna Morozzi (INFN, Perugia), Pisana Placidi (Unipg)
6	Gupta Dhiraj Hiralal	Innovative holographic optical elements for modern optical instrumentation	Andrea Bianco (INAF, Arcetri)
7	Michele Verdoglia	High spatial and temporal resolution pixelated radiation sensors characterization for next generation experiments in fundamental physics	Alessandro Cardini (INFN, Cagliari), Adriano Lai (INFN, Cagliari)

CURRICULUM 40th Cycle PhD STUDENTS

	PhD Name	Project Title	Supervisor(s)
1	Mohamed Yahia Bournane	Optical Design of MezzoCielo	Demetrio Magrin (INAF, Padova)
2	Federico Cittadini	Development of solid-state detectors for clinical beam dosimetry, both conventional and FLASH modality	Leonello Servoli (INFN, Perugia)
3	Camilla Forza	Study and Characterization of Silicon Photomultipliers with Applications to Large Area Radiation Detectors	Gian Maria Collazuol (Unipd), Alberto Gola (FBK, Trento)
4	Arbab Imtiaz	Characterization of sensors with impedence spectroscopy techniques and noise analysis	Alberto Aloisio (Unina), Pierluigi Casolaro (Unina)
5	Samiullah Khan	Development and characterisation of CMOS sensors for X-ray imaging in space, medical and industrial applications	Manuel Rolo (Polito), Alberto Tibaldi (Polito)
6	Raja Yasir Mehmood Khan	Reducing the impacts of natural radioactivity on superconducting qubits with phonon traps	Lorenzo Pagnanini (GSSI)
7	Prajkta Nehete	Optics and Thermo-optics of dielectric coatings for Gravitational-wave Interferometer	Francesco Quochi (Unica)
8	Felice Nenna	Development and exploitation of MPGD detectors for the upgrade of the CMS experiment	Federica Simone (Poliba), Piet Verwilligen (INFN, Bari)
9	Riccardo Pavarani	Background mitigation techniques and sensitivity studies for cryogenic noble-liquid detectors	Matteo Cadeddu (INFN, Cagliari), Francesca Dordei (Unica)
10	Isabella Sofia	Development and characterization of the Small-Sized Telescope camera for the Cherenkov Telescope Array	Andrea Chiavassa (Unito), Richard White (MPI), Federico Di Pierro (INFN, Torino)
11	Remon van Gaalen	Simulations, analysis and procedures definition for alignment, test and calibration of complex Adaptive Optics systems in the framework of the new generation of telescopes	Maria Bergomi (INAF, Padova)
12	Alessandra Zingaretti	Development of CMOS pixel detectors for applications at future colliders	Serena Mattiazzo (Unipd)

EDUCATIONAL OFFER

IN PRESENCE REMOTE BLENDED

- 2 INTRODUCTORY COURSES
  - **Radiation Matter Interaction,** Raffaella Radogna (Uniba), 16h, 2 CFU
  - **Physics with High Energy Particle Detectors from Photographic Plates to the LHC Experiments,** Simone Paoletti (INFN), Antonio Cassese (INFN), Rudy Ceccarelli (INFN), 18h, 2 CFU

- 15 LECTURE COURSES
  - **Gaseous Detectors for Experimental Particle Physics,** Rosamaria Venditti (Uniba), Federica Maria Simone (Poliba), 16h, 2 CFU
  - **Solid State Detectors,** Donato Creanza (Poliba), Ilirjan Margjeka (INFN), 16h, 2 CFU
  - **High-energy particle physics detectors in space,** Serena Loporchio (Poliba), 16h, 2 CFU
  - **New technologies for Cherenkov telescopes,** Serena Loporchio (Poliba), 16h, 2 CFU
  - **Cryogenic sensors for astroparticle physics,** Andrei Puiu (GSSI), 12h, 2 CFU
  - **Novel detectors for future experiments at collider,** Domenico Colella (Uniba), 16h, 2 CFU
  - **Astronomical Observations with Adaptive Optics,** Carmelo Arcidiacono (INAF), 12h, 2 CFU
  - **Radio and Optical Interferometry,** Fabrizio Massi (INAF), 12h, 2 CFU
  - **Adaptive Optics for Astronomy**, Kalyan Kumar Radhakrishnan Santhakumari (INAF), 16h, 2 CFU
  - **Electronic systems in high energy physics,** Adriano Lai (INFN), 36h, 4 CFU
  - **Metodologies and techniques for experimental data analysis,** Alexis Pompili (Uniba), 16h, 2 CFU
  - **Advanced scientific programming in Matlab,** Paolo Bardella (Polito), Stefano Scialò (Polito), 30h, 6 CFU
  - **Cabling and shielding for low noise applications,** Alberto Aloisio (Unina), 10h, 1,2 CFU
  - **Semiconductor light sources for engineers,** Mariangela Gioannini (Polito), Lorenzo Columbo (Polito), 20h, 2,5 CFU
  - **Scientific Project management**, Maria Bergomi (INAF), 16h, 2 CFU

EDUCATIONAL OFFER

IN PRESENCE REMOTE BLENDED

- 8 LECTURE COURSE + HAND-ON SESSION
  - **Rare Event Search with Noble Liquids,** Paolo Agnes (GSSI), 12h, 2 CFU
  - **Numerical Simulation of Electronic Devices with TCAD for High Energy Applications,** Daniele Passeri (Unipg), Arianna Morozzi (INFN), 20h, 2,5 CFU
  - **Simulation of Optical Photon Propagation for Generic Scintillator-Based Detectors,** Davide Serini (INFN), 16h, 2 CFU
  - **Front-end and readout electronic systems for High Energy Astroparticle Physics,** Felicia Barbato (GSSI), Adriano Di Giovanni (GSSI), 15h, 2 CFU
  - **Advanced Electronic Sensing Devices,** Andrea De Iacovo (Uniroma3), 15h, 2 CFU
  - **Cosmic radiation and radiation hardness assurance,** Pierluigi Casolaro (Unina), 15h, 2 CFU
  - **Programmable System on Chip (SoC) for data acquisition and processing,** Andrea Fabbri (Uniroma3), 20h, 4 CFU
  - **Fundamentals of system engineering and project management for large scientific projects,** Marco Xompero (INAF), Runa Briguglio (INAF), **12h, 1,5 CFU**
- 2 LECTURE COURSE + LABORATORY SESSION
  - **Scintillators and Silicon Photomultipliers,** Elisabetta Bissaldi (Poliba), 16h, 2 CFU
  - **Vacuum Technologies,** Oscar Azzolini (INFN), 8h+8h, 2 CFU
- 2 LABORATORY COURSES
  - **Laboratory of low-energy radiation measurement,** Andrei Puiu (GSSI), Lorenzo Pagnanini (GSSI), 20h, 5 CFU
  - **Laboratory of high-energy radiation measurement,** Felicia Barbato (GSSI), Adriano Di Giovanni (GSSI), 20h, 5 CFU

https://www.dfa.unipd.it/fileadmin/DottNazionale/Educational_offer_24-25_DETECTORS.pdf

DETECTORS, LASERS and OPTICS SESSION Schedule

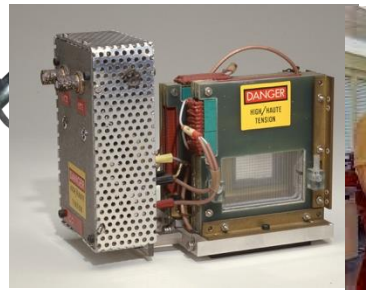
Room «E. Majorana»

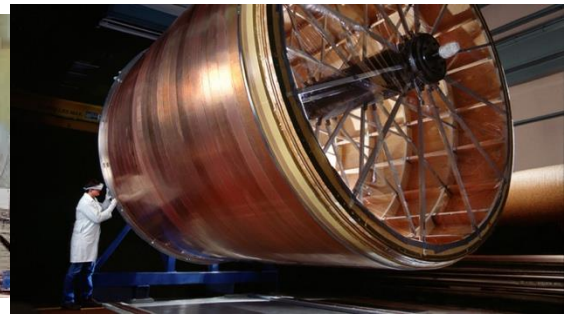
15:00	Introduction (M. Munari, S. My)
15:10	Perspectives on Gaseous Detectors (Piet Verwilligen, INFN-Bari)
16:00	Perspectives on Solid State Detectors (Gregor Kramberger, Jozef Stefan Institut, Ljubljana – CERN)
16:50	Coffee Break
17:30	Radiation Detectors in Medical Application (Raffaella Radogna, UNIBA)
18:15	First Year Students Introduce Themselves
19:00	Poster Session

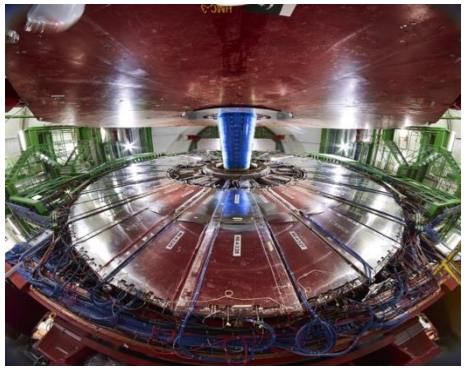
SUPPLEMENTARY SLIDES

GASEOUS DETECTORS

- Rutherford, Geiger (1908) Geiger, Muller (1928)
  - PPC → RPC, 1981
  - PC → MWPC (Charpak-1968, Nobel 1992), Drift Chamber
    - TPC, 1974
    - CSC, 1979
    - MSGC, 1988 (MPGD Technology)
      - μMEGAS, 1996
      - GEM, 1997
      - μRWELL, 2015







Applications on Nuclear, Particle, Astroparticle Physics Experiments, X-ray and Neutron Imaging:

charged particles tracking, triggering, muon detectors, photon detectors, calorimeters

Technological Challenges:

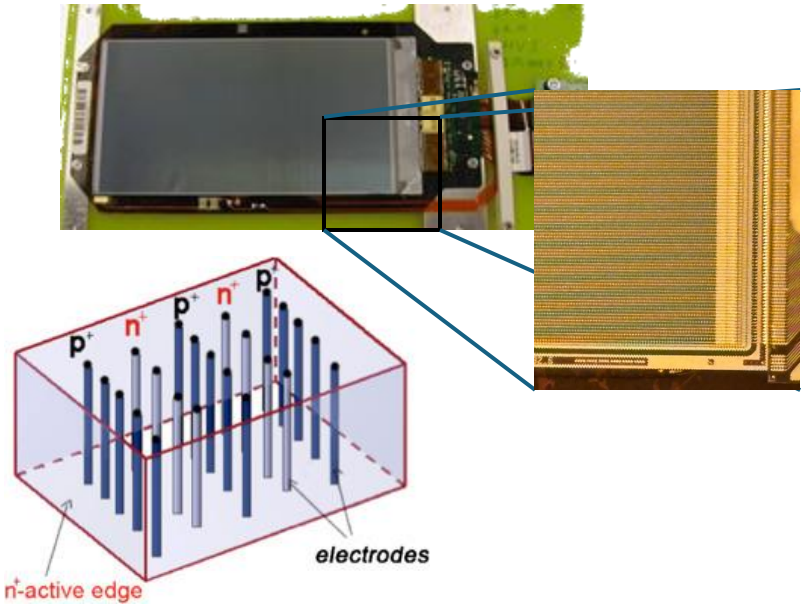
- Improve time and spatial resolution and long-term stability
- Find the best environment friendly gas mixture mantaining high-rate capability
- Achieve particle identification in large volume with low material budget
- Achieve high sensitivity in TPC

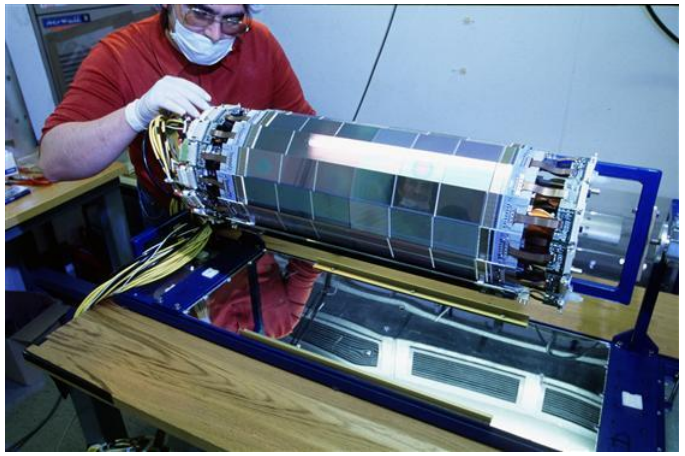
SOLID STATE DETECTORS

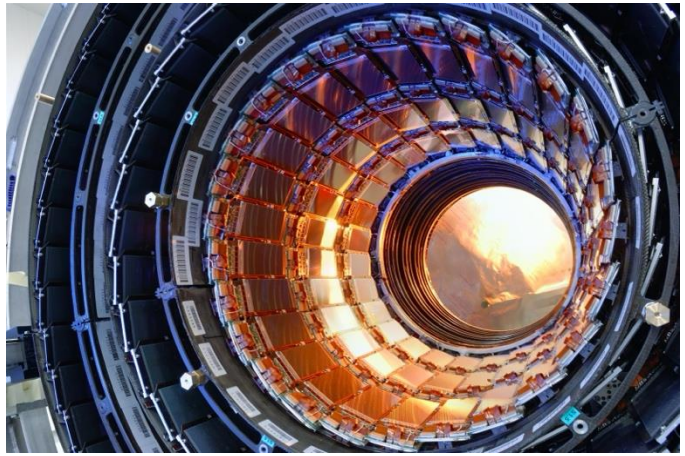
Can achieve excellent spatial resolution thanks to techniques allowing a high electrodes segmentation

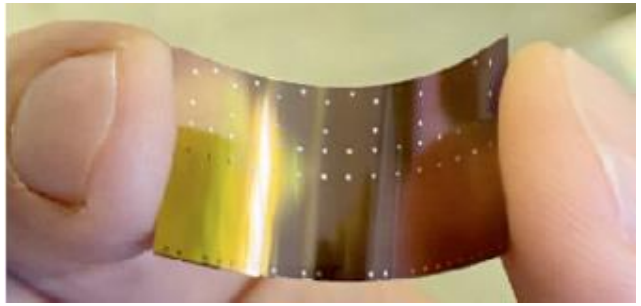
Used in almost all particle physics experiments, since the beginning of 1980s, in primary and secondary vertex detectors and in charged particles tracking as silicon planar strips, planar pixels and more recently as 3D pixels

Play an important role in photon detectors (SiPM)









CMOS Monolithic Active Pixels Sensors bent cylindrically, ultra-thin

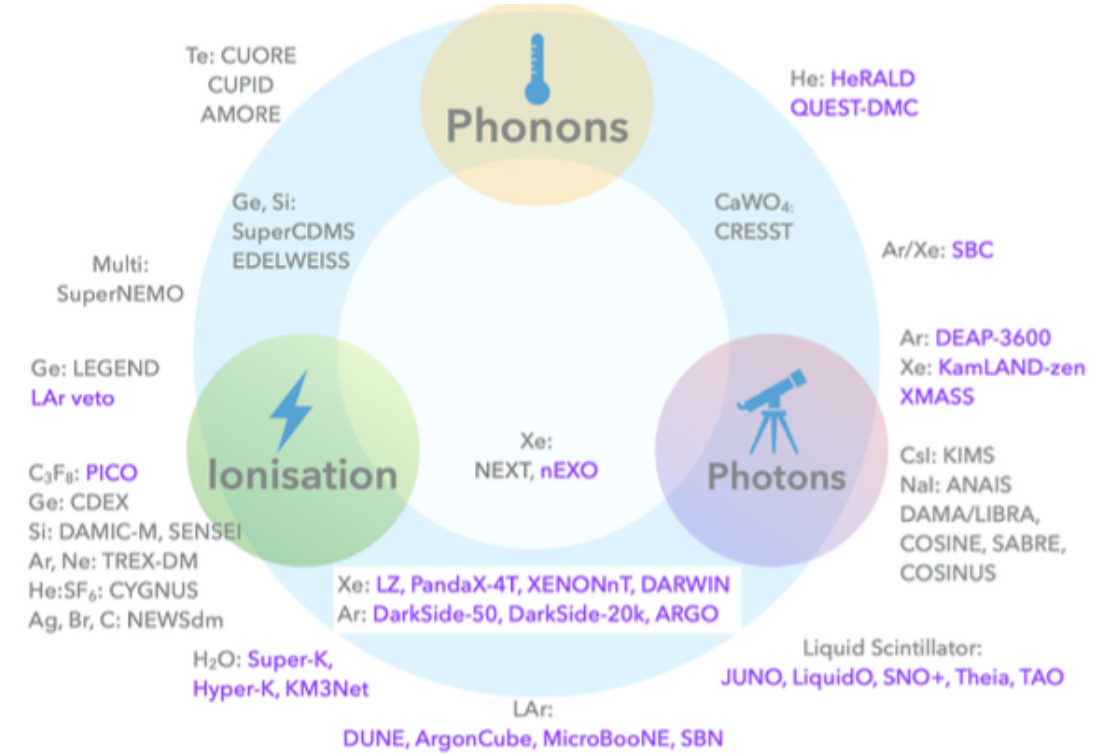
Technological Challenges:

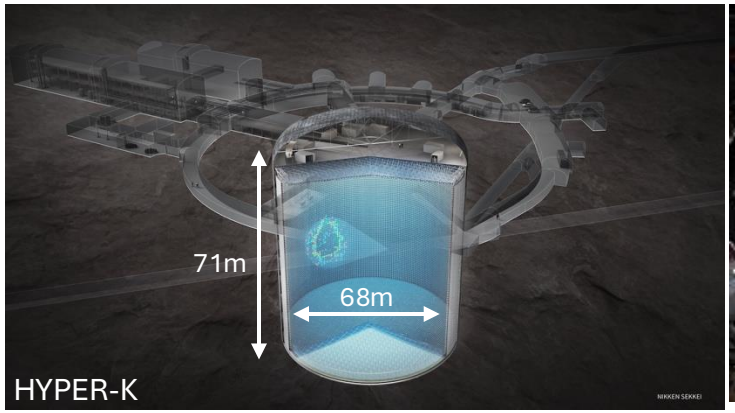
- Extend capabilities of solid-state sensors (silicon and diamond) to operate at extreme fluence
- Develop solid state sensors with 4D-capabilities for tracking and calorimetry
- Achieve full integration of sensing and microelectronics in monolithic CMOS pixel sensors
- Develop full 3D-interconnection technologies for solid state devices
- Develop new High Purity Ge (HPGe) detectors for γ spectroscopy

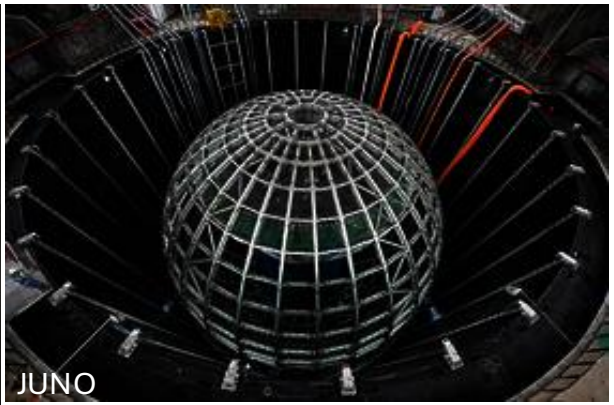
LIQUID DETECTORS

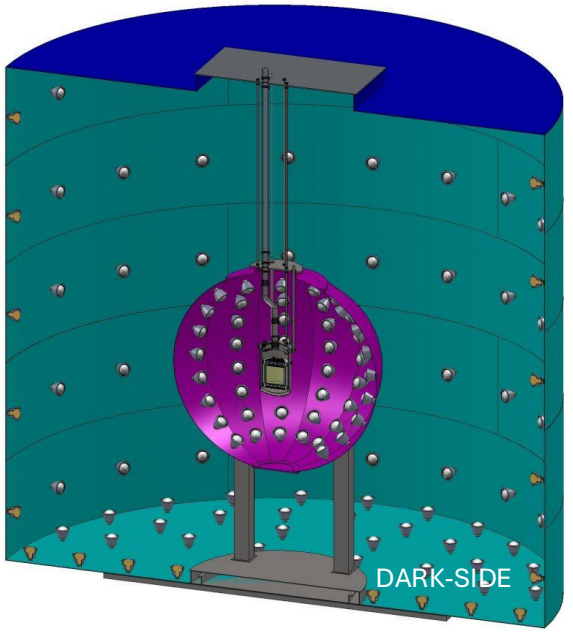
Based on target media of water, liquid scintillator, cryogenic nobles (as liquid argon, xenon, helium)

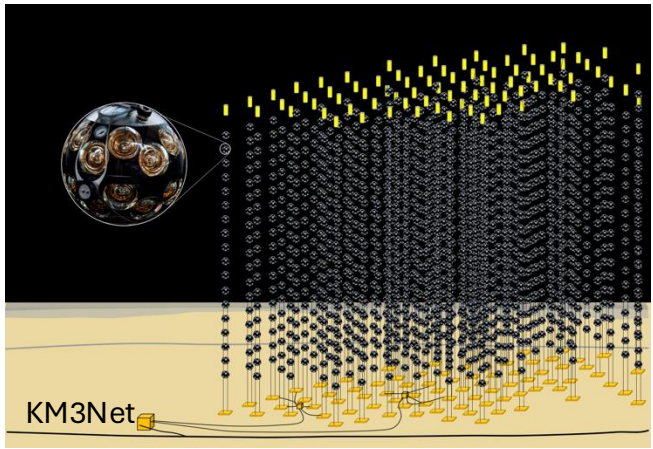
Used in rare event searches and in neutrino physics, both in accelerator and non-accelerator experiments since the 50s











Technological Challenges:

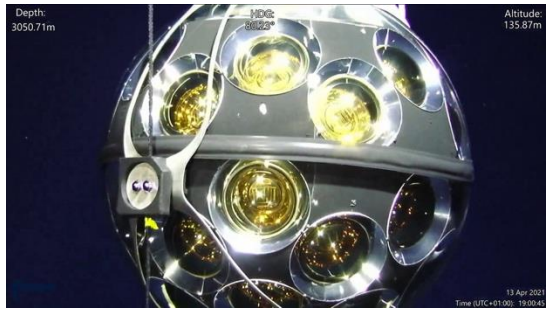
- Develop readout technology to increase spatial and energy resolution
- Noise reduction to lower signal threshold
- Improve target material properties
- Integration of large systems

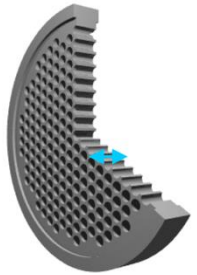
PHOTON DETECTORS

Ubiquitous in physics, astronomy and society (optical communication, medical imaging, environmental monitoring, solar cell)

Photon detectors instruments PID, calorimeters, tracking, neutrino, dark matter and all astroparticles experiments

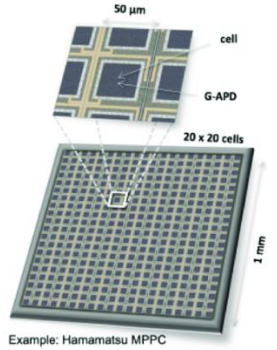
For many years the most important sensor has been the PMT
evolved into MCP-PMT, MaPMT, HPD, HAPD, …

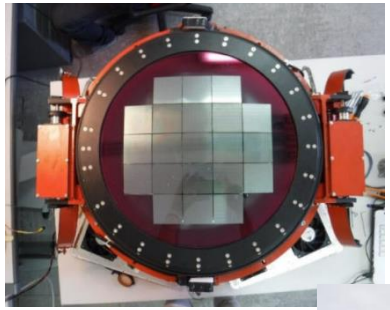




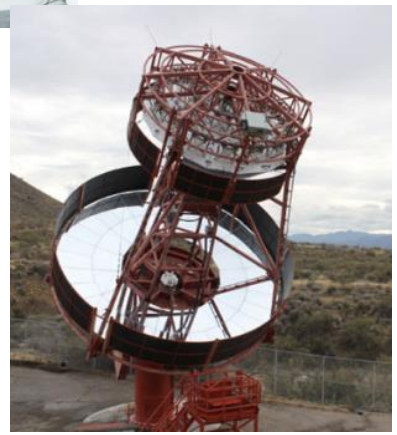
Gaseous Photo-Detectors (GPD) represent the most effective
solution to instrument large surfaces

SiPM are modern photodetectors with a large number of applications





Superconducting photodetectors:
superconducting nano-wire single photon (SNSPD), transition edge (TES),
microwave kinetic inductance detector (MKID)



Technological Challenges:

- **Develop novel photodetectors, including SiPM, vacuum-based**
- **Enhance timing resolution and spectral range**
- **Develop phosensors for extreme environments**
- **Develop low mass imaging detectors**
- **Study innovative scintillation materials and light collection methods**

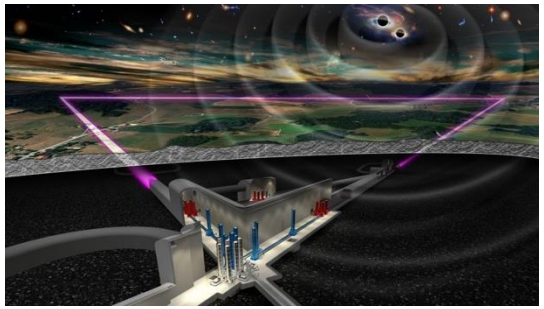
GRAVITATIONAL WAVES INTERFEROMETERS

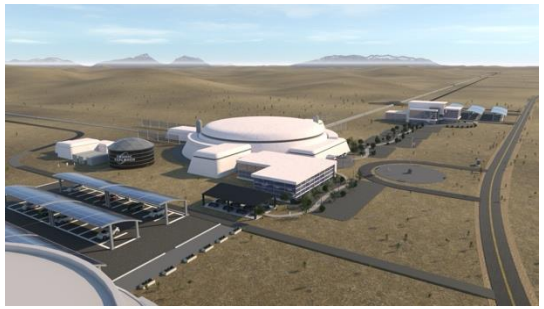
GW detectors rely on the measurement of the variations in the light travel time between separated reference points (‘test masses’)

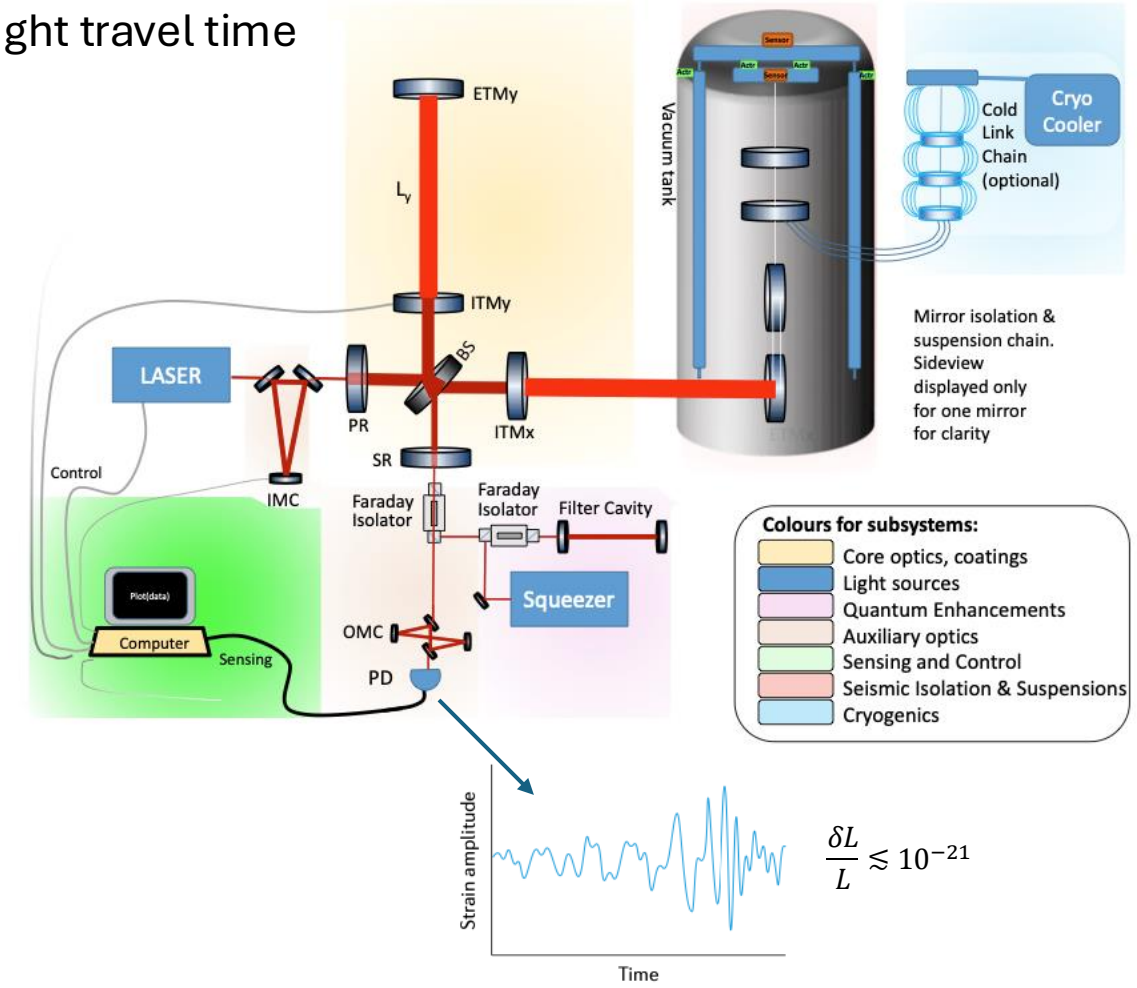
Next Generation ground-based GW Observatories (2030s)

- Einstein gravitational-wave Telescope (ET) – Europe (🤞)
- Cosmic Explorer (CE) – USA

target sensitivity 10 times larger than those of aLIGO, aVIRGO, KAGRA







Technological Challenges:

- Attenuating the vibrations to extremely low levels
- Cryogenic technology to suppress thermal noise
- Optics, coating, special materials, laser technology
- Vacuum technology

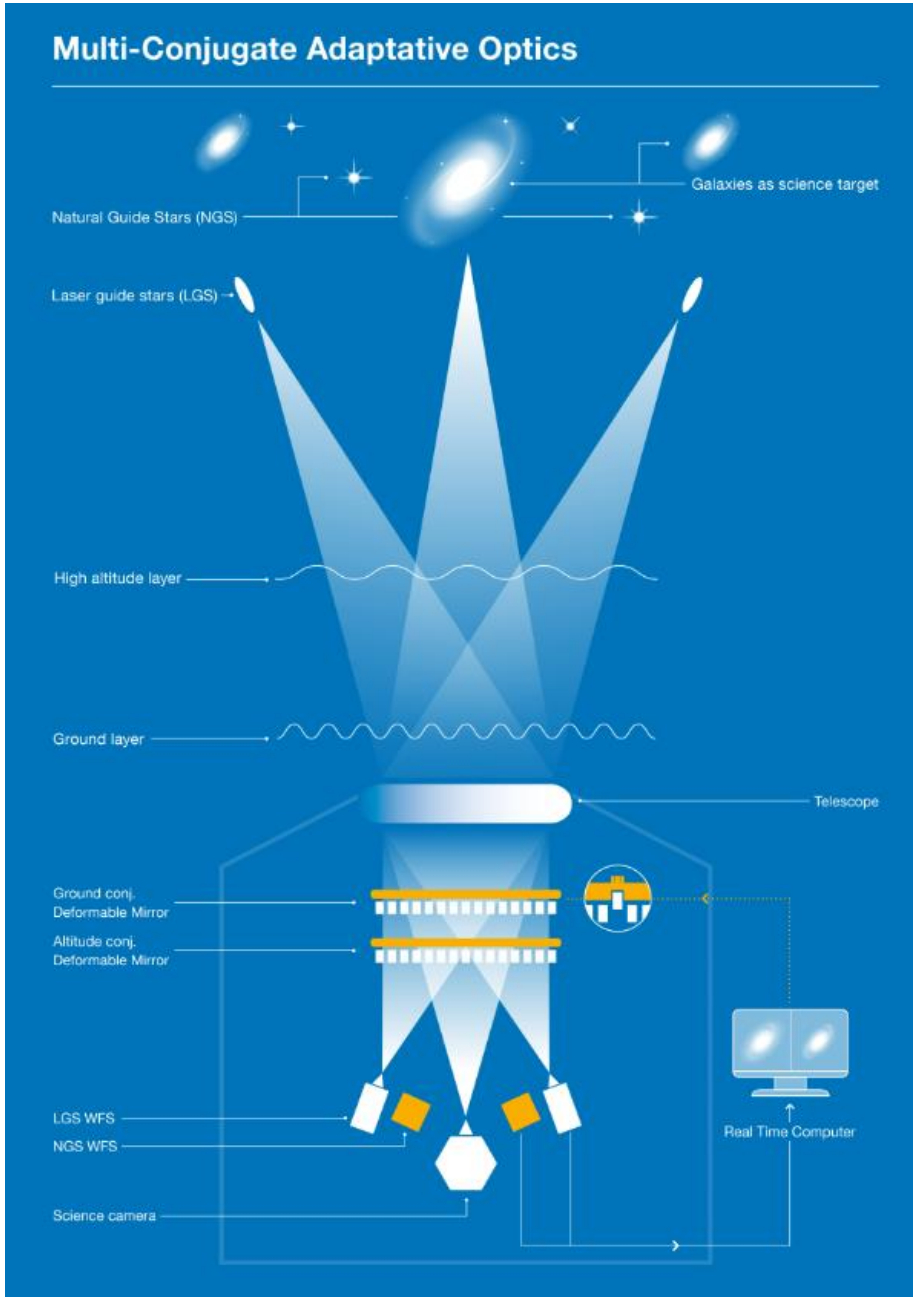
ADAPTIVE OPTICS

Adaptive Optics aims to reduce image degradation in optical systems caused by turbolence of atmosphere, using wavefront sensors and deformable mirrors.
Teorized in 50s-60s, applied in telescopes starting from the 90s , AO is a key part of all new generation (giant) telescopes, both stellar and solar

- ELT (Extremly Large Telescope)
- TMT (Thirty Meter Telescope)
- GMT (Giant Magellan Telescope)

Technological Challenges:

- **Optic and optomechanical design of systems and elements**
- **Reliable Prefomances simulations**
- **Develop of coatings, materials and manufacturing techniques**



Credits: ESO

INNOVATIVE OPTICAL SYSTEMS DESIGNS

Devising new designs for future systems is of paramount importance, given the always growing complexity of new instruments , and the need to push them to the limit in terms of
Field size
Resolution
Throughput
Space and weight optimization
…

Possible answers to these problems may be
‘Smart’ opto-mech designs
Develop and Use of novel materials / methodologies
Use of integrated systems
Use of new algorithms
…

Technological Challenges:

- Simulations methods
- Use of AI
- New materials
- …