HORIZON 2020

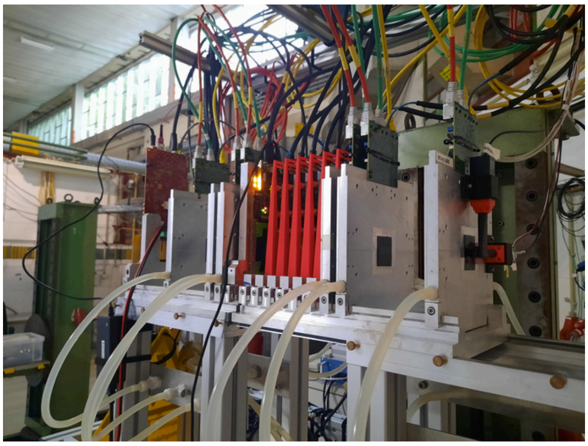
Advancement and Innovation for Detectors at Accelerators

Results in Brief

Shaping detector technologies for tomorrow's experiments

Future high-energy physics experiments at particle colliders demand cutting-edge detectors and supporting systems to meet their ambitious goals. AIDAinnova developed new and upgraded detectors along with the necessary infrastructure – electronics, software, mechanics and test beams – to enable groundbreaking experiments.

FUNDAMENTAL RESEARCH



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The EU-funded AIDAinnova project is a collaborative effort involving Europe's leading research facilities and academic institutions, working together to push the boundaries of particle detector technology. With participation from 15 countries and CERN, the project built on the achievements of a former initiative, AIDA-2020.

While continuing to refine detectors for the Large Hadron Collider and other colliders, AIDAinnova addressed future challenges, such as developing advanced instrumentation for a potential Higgs factory as the recently recommended FCC-ee, contributing to neutrino research and strengthening engagement with industry. "We innovated in detector technologies, including monolithic and hybrid pixel, calorimetric, gaseous and cryogenic detectors, as well as the electronics, mechanics and software needed for next-generation particle physics experiments," notes project coordinator Paolo Giacomelli.

Advanced sensors breaking radiation tolerance limits

A research activity involved determining whether a new type of sensor – depleted monolithic active-pixel sensors (DMAPSs) – which track particle paths created during high-energy collisions could meet the stringent performance requirements of future collider tracking detectors. The focus was on their ability to handle intense radiation and deliver high spatial resolution.

Using advanced CMOS technology, the team built and improved small-pitch DMAPS prototypes. Tests showed excellent detection efficiency, precise spatial resolution and stable performance under extreme radiation levels (exceeding 10^15 neq/cm2). This breakthrough overcomes past radiation tolerance limits, making DMAPS a strong candidate for future tracking systems. Work continues on scaling up, optimising and integrating these sensors into larger systems.

High-precision tracking sensors both in space and time

Another project activity was the development of active-pixel sensors that combine extremely precise spatial resolution (few micrometres) with ultra-fast time resolution (tens of picoseconds) – precision levels essential for accurately reconstructing particle trajectories. These sensors are combined with the read-out electronics in hybrid detectors, which handle signals from the high-resistivity sensor that detects particles.

Researchers worked on hybrid detectors as these detectors are currently the only technology that can deliver these precision levels. The team advanced low-gain avalanche diodes (LGADs) (found in high-resistivity sensors) for amplifying particle signals, and enhanced 3D pixel structures to boost timing accuracy. Furthermore, new interconnection methods between LGADs and active-pixel sensors, such as anisotropic conductive films, pastes and wafer-to-wafer bonding, were developed.

Sustainable gas detector technology

Another major focus was on developing eco-friendly gas mixtures for future gas detectors to replace current ones that harm the environment, owing to their high warming potential or fluorinated components.

The team also collaborated with industry to develop a new type of micro-pattern gas detector (MPGD). “This marks a significant milestone in transferring technology from academia to industry and has far-reaching implications: future large-scale gas detectors, composed of mosaics of similar MPGDs, could be directly manufactured by industry. The technology could also be adapted for use in other fields – homeland security and healthcare,” remarks Giacomelli.

Expanding the limits of detector performance

AIDAInnova also focused on high-risk ideas to reshape detector technology, emphasising early experimental validation over incremental improvements. A success was the development of advanced LGAD sensors that maintained stable performance under extreme radiation levels (up to 5×10^15 neq/cm2), extending precision timing capabilities into radiation levels previously deemed inaccessible for gain-based silicon sensors.

“Another achievement was the creation of a high-speed wireless read-out system using 60-GHz links, enabling multi-gigabit data transmission with low latency and stable performance. These advancements surpass current technology and are now being further developed for future detector systems,” concludes Giacomelli.

Keywords

AIDAinnova
gas detector
active-pixel sensors
radiation tolerance
Higgs factory
Large Hadron Collider

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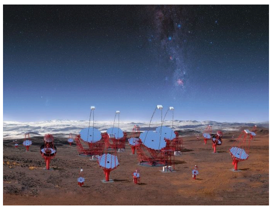

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AIDAinnova

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