2. DPG-Herbsttagung: 100 Years of Quantum Physics (Göttingen)

Report of Contributions

https://indico.desy.de/e/50539

Contribution ID: **1** Type: **not specified**

Symposium introduction: semiconductor quantum sensors/detectors in particle physics - a success story

Thursday 11 September 2025 10:45 (15 minutes)

Introduction to the symposium

Presenter: WERMES, Norbert (Univ. Bonn)

Session Classification: Symposium: Precise Quantum Detectors in Space, Time and Energy –Semi- and Superconductors in Particle and Condensed Matter Physics

Contribution ID: **2** Type: **not specified**

Precision Timing with Silicon Detectors

Thursday 11 September 2025 11:00 (25 minutes)

At the core of nearly every current or planned particle detector lies a silicon-based tracking system capable of reconstructing the momenta of particles produced in high-energy collisions.

The continuous advancement of tracking systems, from a few electronic channels three decades ago to the many millions in today's detectors, has been a key enabler of our current understanding of nature. This evolution now faces its greatest challenge, as future high-energy physics experiments impose stringent requirements on spatial and temporal resolution, detector dimensions, and power consumption.

Over the past 15 years, silicon detectors have undergone rapid development, establishing themselves as the technology of choice not only for precision tracking but also for accurate timing measurements. This transformation has been driven by several design innovations, such as Low-Gain Avalanche Diodes (LGADs) and Resistive Silicon Detectors (RSDs), as well as improvements in techniques like Monolithic Active Pixel Sensors (MAPS) and Silicon-Germanium-based readout electronics.

In this contribution, I will review the recent evolution of silicon detector technologies and discuss how the integration of precise timing capabilities is redefining the way experiments are designed.

Presenter: CARTIGLIA, Nicolo (University of Turin and INFN)

Session Classification: Symposium: Precise Quantum Detectors in Space, Time and Energy –Semi- and Superconductors in Particle and Condensed Matter Physics

Contribution ID: **3** Type: **not specified**

Quantum sensor systems for enhanced precision particle detection

Thursday 11 September 2025 11:25 (25 minutes)

In the context of the requirements of future particle physics experiments, quantum sensors look likely to play a central role. Among the wide range of possible quantum sensors, five technological axes (Quantum systems in traps and beams; Low-dimensional quantum materials; Superconducting quantum devices; Macroscopic scaled-up quantum systems; Quantum techniques for sensing) look particularly well suited to particle physics. This presentation will give an overview with examples of the range of applications and will highlight their relevance to, and potential impact on, both low and high energy particle physics.

Presenter: DOSER, Michael (CERN / MIT / Oxford University)

Session Classification: Symposium: Precise Quantum Detectors in Space, Time and Energy –Semi- and Superconductors in Particle and Condensed Matter Physics

Contribution ID: **4** Type: **not specified**

High-performance superconducting nanowire single photon detectors

Thursday 11 September 2025 11:50 (25 minutes)

The ability to detect single photons is crucial for quantum optics as well as for a wide number of applications. Several technologies have been developed for efficient single photon detection in the visible and near infrared. The invention of the superconducting nanowire single photon detector in 2001 enabled the development of a new class of detectors that can operate close to physical limits. Different aspects will be discussed including wavelength detection range, time resolution, dark counts, saturation rates and photon number resolution along with various applications such as Lidar, quantum communication, deep space communication, microscopy and bio-medical measurements.

Multipixel single photon detectors based on superconducting nanowires will also be discussed, including a quantum spectrometer that is based on an array of high-performance single photon By time stamping single photon detection events at the output of a spectrometer we generate data that can yield spectra as well as photon correlations such as g(2), g(3) to g (n) as well as cross correlations among different spectral lines, under pulsed excitation, transition lifetimes can also be extracted. This instrument therefore replaces a spectrometer, a streak camera, a Hanbury-Brown Twiss interferometer and operates with far higher signal to noise ratio than is possible with existing detectors that are commonly used in the infrared.

Presenter: ZWILLER, Val (Royal Institute of Technology, Stockholm)

Session Classification: Symposium: Precise Quantum Detectors in Space, Time and Energy –Semi- and Superconductors in Particle and Condensed Matter Physics

Contribution ID: **5** Type: **not specified**

ALICE ITS3 –the ultimate paper wrap pixel detector

Thursday 11 September 2025 12:15 (25 minutes)

Over the last decade, Monolithic Active Pixel Sensors (MAPS), fabricated in commercial CMOS Imaging technologies, have made their way into several high-energy physics applications, where low material budgets and high resolution are crucial. With its current, record-holding 10 m2, 12.5 GPixel Inner Tracking System, ITS2, ALICE currently showcases this technology and harvests physics data of unprecedented resolution.

To further improve the experiment, ALICE is upgrading the innermost three tracking layers in the next Long Shutdown of LHC (LS3, 2026–2030) with a novel detector, the ITS3. This detector will be based on truly cylindrical, bent (down to radii of 19 mm), wafer-scale (up to 10×27 cm) MAPS. The sensors are thinned down to 50 μm, and are wrapped around the beam pipe, held in place by carbon foam spacers.

During the R&D phase (2019–2024), a number of novel developments have been demonstrated, notably including the qualification of 65nm MAPS, the demonstration of wafer-scale stitched MAPS, and the demonstration of bent MAPS.

In this talk, the detector concept will be introduced, key R&D results presented, and the path towards detector installation in 2028 given.

Presenter: MAGER, Magnus (CERN)

Session Classification: Symposium: Precise Quantum Detectors in Space, Time and Energy –Semi- and Superconductors in Particle and Condensed Matter Physics

Contribution ID: **6** Type: **not specified**

The Higgs Boson –Key to our Understanding of the Universe

Wednesday 10 September 2025 10:45 (30 minutes)

The Higgs boson was discovered 48 years after its postulation based on symmetry principles that are required to hold at the quantum level. It plays a central role in our understanding of the Universe: Through its couplings to all massive particles and as a door opener to dark sectors, it is able to give us answers to our most pressing open questions. These include the nature of Dark Matter and why there is more matter than antimatter in the Universe. Tested to highest precision at the quantum level, it builds a bridge between elementary particle physics, astroparticle physics, and cosmology. In this context, gravitational waves provide us with an exciting tool to investigate its role in the evolution of the Universe by connecting the quantum world with classical physics. The talk will shed light on the central role of the Higgs boson not only for the Standard Model of particle physics but also for our understanding of the Universe as a whole.

Presenter: Prof. MÜHLLEITNER, Milada Margarete (Karlsruhe Institute of Technology (KIT))

Session Classification: Symposium: Quantum Physics at the High-Energy Frontier –The Higgs Boson in the Standard Model and Beyond

Contribution ID: **7** Type: **not specified**

The path to the discovery of the Higgs boson

Wednesday 10 September 2025 11:15 (30 minutes)

The announcement of the discovery of the Higgs boson on July 4, 2012 by the ATLAS and CMS experiments at the European Research Centre for particle physics, CERN in Geneva, marked an important milestone in the research on the fundamental building blocks of matter and the forces acting between them, and on the verification of quantum field theory-based predictions of the Standard Model of particle physics.

The Large Hadron Collider (LHC) was designed back in the 1990s to clarify the question of the existence of the Higgs boson, the last missing building block in the Standard Model. In this talk, the path from the establishment of the Standard Model and its quantum structure to the discovery of the Higgs boson and the first measurement of its properties will be described. In addition, insights into the realisation of the LHC and the associated experiments will be given.

Presenter: JAKOBS, Karl (University of Freiburg)

Session Classification: Symposium: Quantum Physics at the High-Energy Frontier –The Higgs Boson in the Standard Model and Beyond

Contribution ID: **8** Type: **not specified**

The Higgs boson revealed: What current experiments teach us about this unique quantum state

Wednesday 10 September 2025 11:45 (30 minutes)

At the heart of the Standard Model of particle physics lies the Higgs boson –an exceptional elementary particle distinguished not only by its spin-0 nature. It plays a crucial role within the quantum realm of particle physics in generating the masses of gauge bosons, fermions, and even itself. The Higgs boson is deeply connected to fundamental questions in quantum physics, the early stages of the Universe, and even the underpinnings of everyday chemistry. In this talk, I will present the latest Higgs boson measurement results from the ATLAS and CMS collaborations. I will also discuss ongoing efforts to observe the rare production of Higgs boson pairs –an essential step toward probing the structure of the Higgs potential.

Presenter: KOENEKE, Karsten (Uni Göttingen)

Session Classification: Symposium: Quantum Physics at the High-Energy Frontier –The Higgs Boson in the Standard Model and Beyond

Contribution ID: **9** Type: **not specified**

A Quantum Leap Forward: Unlocking the Higgs Boson at Future Colliders

Wednesday 10 September 2025 12:15 (30 minutes)

The Higgs boson stands out as the most intriguing and unique particle in the Standard Model – both a manifestation of the Higgs field and a potential key to new physics. While the Large Hadron Collider has opened the door, the precision frontier –where subtle deviations from the Standard Model may reveal themselves –lies ahead. In this talk, we explore how future experiments, from the High-Luminosity LHC to proposed next-generation colliders like the FCC, aim to transform the Higgs boson from a known particle into a precision tool. By measuring its self-interaction, rare decays, and couplings with unprecedented accuracy, we may uncover clues about the nature of electroweak symmetry breaking, the hierarchy problem, and possible connections to dark matter and the early universe. These future measurements are not just incremental steps –they are a quantum leap forward in our understanding of nature.

Presenter: KLUTE, Markus (KIT)

Session Classification: Symposium: Quantum Physics at the High-Energy Frontier –The Higgs Boson in the Standard Model and Beyond

Contribution ID: **10** Type: **not specified**

Plenary Talk: The Higgs Boson and the Quantum Vacuum: Understanding Mass and Symmetry Breaking

Wednesday 10 September 2025 08:30 (1 hour)

In 2012, the ATLAS and CMS collaborations at CERN announced the discovery of the Higgs boson * the quantum excitation of the scalar field responsible for electroweak symmetry breaking within the Standard Model of particle physics. This long-sought particle provides direct evidence for the Higgs mechanism, which explains how elementary particles acquire mass through their interaction with the Higgs field. The Higgs field constitutes an essential component of the quantum vacuum: its nonzero vacuum expectation value spontaneously breaks the electroweak symmetry, thereby endowing gauge bosons and fermions with mass.

In this talk, we will examine the theoretical framework of the Higgs mechanism and the role of the Higgs field in quantum field theory. We will discuss how spontaneous symmetry breaking shapes the structure of the Standard Model and consider the broader implications for our understanding of fundamental interactions and the vacuum structure of the universe. The presentation will also highlight the experimental challenges and milestones in the search for the Higgs boson, culminating in its discovery at the Large Hadron Collider. Particular emphasis will be placed on the key measurements, detector technologies, and the collaborative global effort that led to one of the most significant achievements in contemporary physics.

Presenter: HEINEMANN, Beate (DESY and University of Hamburg (Germany))