WP3 - Advanced Software

Scientific Coordination
Witold Pokrski (CERN)
Frank Gaede (DESY)

Objectives
- Vectorisation and multithreading support for detector geometry packages
- Implementation of modular simulation toolkit with alignement procedures
- Design and implementation of event data model with high performance I/O
- Development of advanced parallelisation strategies for event processing frameworks
- Development of advanced particle flow and track reconstruction algorithms

WP3 – Advanced Software

Main Results of the WP:

AIDA-2020 Advance Software WP3 addresses core, simulation and reconstruction software for HEP.

- The new release of the VecGeom library contains almost the full set of solids used by the setups at the LHC. VecGeom can be used directly with Geant4, ROOT and GeantV as a Unified Solids package.
- Implementation of the additional packages DDCond and DDAlign, supporting detector conditions and alignment constants in the framework of DD4hep toolkit.
- The BACH alignment package has been extended to use geometries and conditions data from DD4hep.
- Additionally, DD4hep is being considered for use with the LHCb experiment and work is ongoing to modify the LHCb alignment software to use it.
- Development of PODIO - an event data model toolkit for the efficient creation of Event Data Models in C++ with high performance I/O.
- Development of DDG4 gateway to Geant4 based on the DD4hep geometry framework and the Geant4 simulation tool-kit (DDG4 allows users of DD4hep to simulate the physics response of their detector with minimal effort).
- Developments on sophisticated pattern recognition software: development of pattern recognition algorithms in Pandora. Successfully used in the reconstruction of neutrino interactions and cosmic-ray muons in many different physics analyses.

Reviewed

WP3 – Advanced Software

No connections with industry found.

Mail to the WP leader sent 10/02/2020. – (Witold)

WP4 – Micro-electronics and interconnections

Scientific Coordination
Christophe de La Taille (CNRS)
Valerio Re (INFN)

Objectives
- Deliver CLICPIX and ATLAS/CMS 65 nm CMOS readout chips for planar, 3D and HV-CMOS pixel sensors
- Share expertise on TSMC 65 nm CMOS and coordinate developments with CERN RD53 R&D program on microelectronics for pixels
- Select best SiGe 130/180 nm process for high speed/high dynamic range ASIC design to upgrade current SiGe 350 nm AMS process
- Deliver SPIROC3 SiPM readout chip for calorimeter readout and RPC high timing readout chip
- Produce through-silicon vias (TSV) on 65 nm CMOS wafers and connect 65 nm chips with and without TSVs to pixel sensors

WP4 – Micro-electronics and interconnections

Main Results of the WP:

- Achievement of the deliverables and milestones for chips in 130 nm and 65 nm CMOS; these chips were made available to AIDA2020 sensor work packages and are intensively used for sensor R&D and qualification.
- A large scale 65 nm CMOS chip called RD53A was designed for the readout of silicon pixel sensors developed in WP6 and WP7. The chip was fabricated in an engineering run and successfully tested. Availability of the run with the "ATLAS/CMS" and CLICPIX pixel chips.
    - *Current work is focused on the design of the next 65 nm CMOS chip generation RD53B, which will provide full-scale prototypes to the ATLAS and CMS experiment.*
- Selection of TSV process.
- Through Silicon Vias production (fabrication of TSV in wafers of RD53A engineering run).
- Proven feasibility of TSV in 100 nm-scale CMOS integrated circuits, and provides confidence that this technology can be applied to the next generation of pixel readout circuits in 65 nm CMOS.
- BICMOS SiGe engineering run (availability of run with SiPM calorimeter-WP14 and gas detectors-WP13 chips). The community has selected the TSMC 130 nm CMOS process to realize the design of ASICs that will be used to readout the detectors of WP13 and WP14.

Reviewed

WP4 – Micro-electronics and interconnections

Connections with industry

ZMI - German Company - *https://zmi.de/unternehmen/*

What have been done at ZMI?

Worked on trough silicon vias process (mostly manufacturing work).

Outcome

Sharing of expertise with the professionals involved in the project.

French Start-up WEEROC - *https://www.weeroc.com/*

What have been done at WEEROC?

Outcome

Expertise gained that helped their R&D department.

This new expertise led to a proposal successfully approved for an ATTRACT project.

WP4 – Micro-electronics and interconnections

Connections with industry?

Waiting for validation by WP leader Christophe de La Taille – meeting at CERN on 29 January

WP5 – Data acquisition system for beam test

Scientific Coordination
David Cussans (UNIBRIS)
Matthew Wing (UCL)

Objectives

- Specification of interfaces and provision of a control and timing system to allow multiple detectors to be linked together.
- Develop a central data acquisition software and run control to enable multiple detectors to be combined in one experiment.
- Develop monitoring systems to automatically check the data quality.
- Develop a system to monitor the environmental conditions, such as temperature, of several detectors.
- Define an event for online data where data is combined from detectors with very different signals and properties.

WP5 – Data acquisition system for beam test

Main Results of the WP:

1. Common DAQ (WP5) helped tied together the work of different teams working on detector development.
2. Hardware and software tools developed
    - The AIDA-2020 TLU has been designed and prototyped.
    - EUDAQ2 software has been shown to work in a beam test involving the CALICE analogue hadronic calorimeter and the EUDET beam telescope along with other devices and detectors. The software has also been used in ATLAS pixel detector upgrade beam tests.

3. TLU hardware designed during AIDA2020 to replace TLU designed during EUDET (19 units produced in total)
    - Units successfully deployed at CERN and DESY beam-lines as well as several laboratories. (Slowly replacing old EUDET TLUs).
    - TLUs have been used by several users/experiments.

4. Software EUDAQ2 released.
    - EUDAQ2 used as a way of providing some integration for combined beam tests within Calice.
    - Provided valuable way of finding some beam-telescope specific assumptions that had been missed in move from EUDAQ1 ->EUDAQ2.
    - Different levels of integration possible: Run control, Timing / synchronization hardware, Data collection.

WP5 – Data acquisition system for beam test

Connections with industry?

Nothing found in the documents – Email sent the WP Leader David Cussans – waiting for reply

WP6 – Novel High Voltage and Resistive CMOS Sensors

Scientific Coordination
Sebastian Grinstein

Objectives
- Perform TCAD process simulations and Geant4 simulations for test structures and sensor prototypes for different CMOS processes to optimise sensor design
- Prepare designs for MPWR submissions exploring different foundries
- Characterise test-structures and sensors using electrical measurements, lasers, sources and test beams
- Perform basic R&D on capacitive interconnection
- Deliver full assemblies to all participating projects

WP6 – Novel High Voltage and Resistive CMOS Sensors

Main Results of the WP:

- The activities of the AIDA 2020 WP6 have generated significant advances in the understanding of the HV/HR-CMOS devices.
- The developments with AC and DC coupled devices have made the process more robust and have improved the reliability of the process.
- HV/HR CMOS structures developed within the AIDA-2020 project were used as active sensors (H35demo and LFCPIX) and interconnected to the FE-I4 readout chip.
- Test structures were used to fine tune the AC coupling process. AC coupled devices based on the H35Demo and the FE-I4 ASIC were successfully produced and tested.
- H35Demo devices that combine AC and DC coupled pixels to the FE-I4 chip were also fabricated.
- LFCPIX DC coupled devices were produced.
- The process to obtain DC bump-bonded devices with SnAg bumps was developed on precise alignment machinery in serval AIDA institutes (IFAE, UNILIV and Geneva).
- The Wafer Level Packaging process has been developed in a strict collaboration between AIDA2020 and MicroFab Solutions.

Reviewed

WP6 – Novel High Voltage and Resistive CMOS Sensors

Companies where were fabricated CMOS devices for WP6:

- LFoundry http://www.lfoundry.com/

  (Maybe future partnership in AIDA++)
- AMS https://ams.com/
- TowerJazz https://towerjazz.com/
- XFab https://www.xfab.com/home/

Software Company: Users of their services:

- Synopsys - https://www.synopsys.com/

Collaboration with the Company MicroFab Solutions

(*Spin-off company from FBK - Fondazione Bruno Kessler. Specialized in the realization of micro-devices and thin film technologies.)*

Goal: investigating existent technologies and testing innovative procedures.

What have been done at MicroFab Solutions?

- Production of dummy wafers for capacitive coupling test.
- Production of pillars to improve the planarity of AC devices.
- Costume implementation of WLP (Wafer Level Packaging) - optimizing the process parameters to make it compatible with industrial production.

The project was abandoned - New approach in WP6 with focus on monolithic devices.

Good outcome for the company:

- Worked in new solutions for challenging problems
- Improvement of their R&D in wafer level Packaging area.

Reviewed

WP7 – Advanced hybrid pixel detectors

Scientific Coordination
Anna Macchiolo (MPG-MPP)
Ivan Vila (CSIC)

Objectives
- Define technological guidelines for the production of advanced silicon pixel sensors for HEP tracking and timing applicatio
- Improve access to a pool of specialised foundries for the production of planar and 3D sensors
- Optimize the technology of Low Gain Avalanche Detectors (LGAD), for tracking and timing applications
- Validation of the produced sensors

WP7 – Advanced hybrid pixel detectors

Main Results of the WP:

- Fine-pitch 3D sensors have been investigated using two-dimensional and three-dimensional finite-element TCAD simulations with reference to both FBK and CSIC-CNM fabrication technologies.

- Simulation tools have demonstrated to be an excellent starting point in the LGAD design, and they are now being refined by incorporating the inputs of the experimental measurements.

- Layouts of the photolithographic mask designed for the LGAD, planar and 3D sensors AIDA-2020 manufacturing runs.

- Characterization of hybrid pixel modules composed of 3D and planar sensors with active edges for applications at HL-LHC and CLIC.

WP7 – Advanced hybrid pixel detectors

Connections with industry?

ADVACAM
1. Work that was done in collaboration with AIDA2020.
Production of planar sensor. Employment of Silicon on Insulator wafers (SOI) to produce
50, 100 and 150 microm thick sensors.

2. Outcome

D7.6

Active edge sensors are one of the possible options to realize sensors with a very reduced insensitive area. obtained with this technology in different productions at FBK [FBK] and
ADVACAM [ADVACAM] were tested with radioactive sources and beams. The sensors were interconnected via solder bump bonding to ATLAS FE-I4, Timepix and CLICpix read-out chips.

- Mail sent to Anna – waiting for reply

WP8 – Large scale cryogenic liquid detectors

Scientific Coordination
D. Autiero (IPNL)
S. Murphy (ETHZ)

Objectives
- Purification and monitoring
- Charge readout and double phase
- Light readout
- Very high voltage (VHV)
- Magnetisation

WP8 – Large scale cryogenic liquid detectors

Main Results

- Purification and monitoring developments in the Large Cryogenic Detectors community

  Contributed to the construction of different monitoring devices for temperatures, level controls, cameras and to the investigation of purification and cryogenics in a first prototype of cryostat for LAr Time Projection Chamber built with the LNG vessel construction technique.

- Charge Readout developments in the Large Cryogenic Detectors community.

  Contributed to the design and construction of the charge readout systems (including the dual-phase detectors and the associated electronics) implemented at progressively larger scale on two prototypes of LAr Time Projection Chambers at the CERN Neutrino Platform.

- Light readout developments in the Large Cryogenic Detectors community

  Contributed to the development of testing, coating and deployment techniques for photo-detection systems based on cryogenic photomultipliers. All these developments were performed in view of scaling over very large sensitive volumes LAr Time Projection Chambers.

- Very High Voltage developments in the Large Cryogenic Detectors community

  Contributed to the construction of a new VHV feedthrough capable of reaching 300 kV and to the innovative design of field cages to be built in order to define uniform drift field over very large sensitive volumes.

- Missing last deliverable

WP8 – Large scale cryogenic liquid detectors

Collaboration with the company CINEL Strumenti Scientifici – (D8.4)

What have been done at CINEL

- Manufacture of the first feedthrough (?)

Email sent to the WP Leader and the author of D8.4 – No response so far

WP9 – New support structures and micro-channel cooling

Scientific Coordination
Paolo Petagna (CERN)
Georg Viehhauser (UOXF)

Objectives
- Improve the integration of ultra-light support structures and cooling devices in the design of future detectors
- Develop the missing building blocks for a generalized implementation of micro-channel cooling devices
- Provide common standards for the fabrication and testing of micro-channel cooling devices
- Develop a facility for low-mass support structure testing, with adequate standards for characterization and validation
- Provide and validate test structures and libraries for FEA simulations

WP9 – New support structures and micro-channel cooling

Main Results

- Production of prototype cooling structures of several designs and development of several solutions for the connectivity of micro-channel cooling circuits.
- Production of silicon samples with integrated micro-channel cooling circuits: validation of the production process and test the performance in a range of experimental situations.
- The structures produced with AIDA-2020 funding have been extensively tested.
- The production and characterization of small-scale structures has provided a strong impulse to the deployment of novel micro-channel cooling techniques in high-energy physics experiments. Understanding and characterization of the mechanical properties of carbon fibre and silicon structures.
- R&D activity on connectors. Study of three standardized techniques to connect microchannels to laboratory test setups and to primary cooling circuits in experiments. Interesting microfluidic connection and interconnection techniques have been reviewed.
- Development of a new methodology for the validation of the best-suited semi-empirical correlation for the determination of the heat transfer coefficient of a CO2 evaporator with defined parameters.
- Creation of a mechanical characterization facility to characterize low-mass structures for particle physics experiments: this facility is now ready at the University of Oxford.

WP13 - Innovative gas detectors

Scientific Coordination
Paolo Petagna (CERN)
Georg Viehhauser (UOXF)

Objectives
- Improve the integration of ultra-light support structures and cooling devices in the design of future detectors
- Develop the missing building blocks for a generalized implementation of micro-channel cooling devices
- Provide common standards for the fabrication and testing of micro-channel cooling devices
- Develop a facility for low-mass support structure testing, with adequate standards for characterization and validation
- Provide and validate test structures and libraries for FEA simulations

WP13 - Innovative gas detectors

Main Results of the WP:

- Upgrade of the RPCs - Improvement of the performance.
- Large 2-gap RPC detectors made with two different materials (low resistivity glass and HPL- High Pressure Laminate) were built and successfully tested. A new readout electronics system using excellent timing electronics was conceived and used to study these detectors.
- Construction of large μ-RWELL prototypes. Breakthrough technology suitable for large area tracking devices.
- Characterization of novel MPGD-based photon Detectors.
- Advance in the interface of the RD51 Scalable Readout System with new front-end ASICs (BNL VMM, CERN TimePix3 and AGH GEMROC). SRS/VMM prototype systems have been produced and commissioned. License agreement between CERN KT and SRS Technology start-up has been established.
- Development of laboratory instrumentation for MPGD: HV power supply (starting collaboration with XPOWER Germany), signal processing (APIC), femto-ammeter and data logger. APIC – the most advanced in term of concept and imminent industrialization – has been covered by license agreement between CERN KT and SRS Technology start-up.
- The “Leopard” system, capable of a hole-by-hole gain mapping of standard and thick GEMs, has been constructed capable to cover large size layers, with a measurement procedure compatible with series production quality control.
- The engineering design and production protocols of gaseous detector based on Resistive Plate Chamber (RPC) technology have been optimized.
- New tooling for small production.
- Progress in MPGD fabrication by industry.

Reviewed

WP13 - Innovative gas detectors

Collaboration with Industry

- A parallel activity of Technology Transfer of the manufacturing process of the single-resistive layer layout has been carried both for ELTOS SpA (Italy) and ELVIA (France)
- Working with CERN has helped them in the R&D of the company and increase of know-how in the field of large size PCB's;
- Standard PCB manufacturing procedures open the way towards a unique example of mass production of MPGDs;
- All manufacturing steps of the detector are performed at the companies, except for the etching of the amplification stage realized on the Kapton foil, that is carried out at CERN;
- Etching test of the amplification stage at TECHTRA, a Polish company, is planned in the near future.

From ELTOS SpA: what have been done

- Small prototypes (10x10 cm2 active area) with pad and strip readout;
- Two large area single-resistive layer detectors (1.2x0.5 m2 and 1.9x1.2 m2 trapezoidal sized) developed in the framework of the R&D for the phase-2 upgrade of the CMS muon apparatus;
- The large area detectors manufactured by ELTOS have been finalized at CERN where as usual the etching of the amplification stage has been performed.

Reviewed

WP14 - Infrastructure for advanced calorimeters

Scientific Coordination
Roman Pöschl (CNRS-LAL)
Frank Simon (MPG-MPP)

Objectives

- Extend the infrastructure in Europe for the development of calorimeter systems for the HL-LHC and for future colliders, capitalising on investments made in the EUDET and AIDA projects:
- Develop facilities for the systematic examination of novel optical materials and for the large scale investigation of silicon photomultipliers coupled to plastic scintillators for highly granular calorimeters
- Preparation of the construction of large scale calorimeters with silicon readout and validation of sensors in the context of LHC temperature and radiation hardness requirements
- Implementation of standards to enable the common running of prototypes of highly granular calorimeters with other detector systems and development of highly compact data acquisition systems for full sized detectors
- Enabling the study of the thermal behaviour of large scale calorimeter systems and validation of production techniques for massive absorber structures

WP14 - Infrastructure for advanced calorimeters

More compact designs and strongly segmented → Possible by the development of microelectronics embedded in the detector volume. → Faces numerous technical challenges:

- Low-power (eventually pulsed) read-out electronics very close to the sensors in a confined environment.
- Design of maximum compactness to avoid dead spaces and to permit the best possible particle separation.

↓ Will allow

- More precise energy measurements of single particle and jets
- Three-dimensional reconstruction of the hadronic shower
- Identification of individual particle tracks

Collaboration

1. Collaboration between CALICE and other calorimeter collaborations (ATLAS HGTD, CMS HGCAL).
2. In the future beam tests and combined beam tests with these system can be performed using the developments of AIDA2020 - WP5 (Data acquisition system for beam tests) and WP3 (software tools)
3. The work developed will be useful for supporting WP13.
4. Partnership between CIEMAT and a German Company - ARKU Maschinenbau GmbH - world experts in roller levelling.
5. Further partners KETEK (Germany) on SiPMs and Würth (Germany) on PCBs [List to be completed]
6. Calorimeter prototype with 39 layers (~1m^3) based on scintillators and SiPM using test infrastructure put in place by DESY, Uni Mainz, MPI Munich, Uni Heidelberg
7. A set of ten short layers (18×50 cm2) has been produced using a first version of an assembly and quality assurance chain set up by CNRS-LLR, CNRS-LPNHE and CNRS-LAL for highly granular Si-W ECAL for future lepton colliders.

The developed tools and techniques are also partially applicable for corresponding upgrade projects at the High-Luminosity LHC, especially in term of ASIC testing and wafer gluing.

The AIDA-2020 benches will serve as models for the production chain to be built for an e+e– collider.

Reviewed

WP14 - Infrastructure for advanced calorimeters

Collaboration

1. In the future beam tests and combined beam tests with these system can be performed using the developments of **AIDA2020 - WP5** (Data acquisition system for beam tests) and **WP3** (software tools)
2. The work developed will be useful for supporting **WP13**.
3. Partnership between CIEMAT and a German Company - **ARKU Maschinenbau GmbH -** world experts in roller levelling.
    - Allowed them to reach further in problem's solutions and increase the nivel of expertise

4. Further partners KETEK (Germany) on SiPMs and Würth (Germany) on PCBs [List to be completed]

WP15 – Upgrade of beam and irradiation test infrastructure

Scientific Coordination
Marcel Stanitzki (DESY)
Federico Ravotti (CERN)

Objectives
- Improve the test beam and irradiation facilities infrastructures at various European sites
- Upgrade the facilities design towards qualitative and quantitative enhancements
- Enhance the services offered to users
- Ensure the follow up of the tasks and monitor the use of the resources
- Prepare of the periodic and final project reports

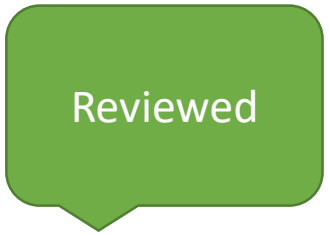
WP15 – Upgrade of beam and irradiation test infrastructure

Main Results: Upgrade of Test-beam Infrastructure

- The AZALEA beam telescope was successfully delivered to CERN PS beam line T10. A new DAQ system has been also delivered with AIDA-2020 TLU fully integrated.
- A slow control system unit has been successfully built for the DESY test-beam areas, integrated into the common EUDAQ framework within the AIDA2020 project, and commissioned at DESY.
- The two new beam-lines of the Frascati beam-test facility, BTF-1 and BTF-2, have been successfully developed and will be soon starting the full operation.

Main Results: Irradiation Test Infrastructure

- The design and construction of the irradiation device / transport system for large object irradiations at the JSI TRIGA reactor (Deliverable 15.9) has been successfully achieved.
- Improvement of the instrumentation of some of the equipment used and operated at the CERN Proton Irradiation Facility (IRRAD).
- The user and sample management system was successfully developed and is now being used by the IRRAD team.
- The irradiation facilities database has been completed (the webpage has been online since February 2017) and a new one about test beam facilities will be also soon released
- Over the duration of 2017-18, the design of the cold box for the Cyclotron Irradiation facility at the University of Birmingham has been fully evaluated and proven to work reliably with better cooling to prevent silicon sensor annealing. An improved servo motor powered robotic system has been also constructed by, and the full system is now used at the Birmingham facility.
- New mixing units are operational and additional gas distribution panels have been included at the supply and in the gas systems.
- New gas recirculation modules have been developed and built for GIF++. This developments also allowed to design gas recirculation systems for detectors requiring high gas filtering capacity.
- Gas analysis and gas chromatography are now available to all GIF++ users: two infrared analysers have been installed for detectors using flammable gas components. An automated O2/H2O analysis module has been built.



Collaboration with a Italian Company – ORMET s.r.l. (D15.4)

Ormet is a medium sized company, specialized in the manufacturing of coil winding, repairing of big size electrical machines, with a good mechanical workshop, but also cooperating with other specialized companies for precision mechanical components and mechanical measurements in the Genova hinterland.

Contact Person: Mr. Barreca (barreca@ormetsrl.it)

What have been done at ORMET s.r.l.

- The company was required to manufacture the magnet and to suggest some construction details.
- Ormet was appointed to produce DP01, a single C-shaped normal conducting dipole, with laminated iron core.
- Built the two branches of the new beam-line. In particular, the main magnet (15° pulsed dipole DHPTB102).

Outcome

- A Good outcome for the company was the acquirement of knowledge.
- Working with INFN within AIDA2020 allowed ORMET to apply what has been learned mostly to give greater continuity to the electromechanical department.
- The acquired knowledge is applicable in ORMET in the field of study and particles research.
- The created partnership is used by ORMET on advertising the company and/or it's projects.
- INFN fruitfully cooperated during the contract in the choice of several solutions and taking advantage of their skill and know-how.

Reviewed