SIAP Report

AIDAinnova 2nd Annual meeting

Valencia, Spain, 27 April 2023

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Scientific and Industrial Advisory Panel

What are we?

The **Scientific and Industrial Advisory Panel** is an external advisory body, whose members are proposed by the Management Team and nominated by the Governing Board, based on their expertise in the activity areas of AIDAinnova. It will include at least one industrial representative. The SIAP has the mandate **to advise the GB on technical and strategic matters related to the scientific programme of the project and the relations with European industry**. The SIAP will provide an internal assessment to the Project Management as regards the status of the project and industrial collaborations on occasion of the Annual meetings.

Scientific and Industrial Advisory Panel

Who are we?

Daniel Fournier, IJCLab

Ingrid Jonak-Auer, ams OSRAM

Matthias Kasemann, DESY

Pier Simone Marrocchesi, Univ. Siena

Petra Merkel, FNAL

Jim Strait, LBNL, Chair

Intro

AIDAinnova has two complementary goals.
From the Abstract of the proposal:

> AIDAinnova **provides state-of-the-art upgrades of research infrastructure** such as test beam and irradiation facilities, and it **covers all key technologies for future detectors**.
>
> AIDAinnova advances the **European detector development infrastructures** through fostering an **intensified co-innovation with industry**. … **Knowledge transfer** will be catalysed through co-innovative work in common detector projects, and it will **strengthen the competence and competitiveness of the industrial partners in other markets.**

Much of emphasis in this meeting has (correctly) been on the first goal of advancing detector technologies in support of science, especially particle physics.

Attention to the second goal of knowledge transfer and strengthening industrial partners has also appeared in many places.

WP1: PROJECT MANAGEMENT AND COORDINATION

The job of the Project Management Team per the proposal:

> The overall scientific and administrative management and steering of the project will be implemented in this WP by the Project Management Team and the Steering Committee. It includes the preparation of technical and financial reports and the communication with the EC.

Among the most important jobs of the Management Team is to ensure that the (contractually required) Deliverables are successfully delivered by the end of the AIDAinnova Project.

Milestones track the progress toward the deliverables.

WP1: PROJECT MANAGEMENT AND COORDINATION

49 Deliverables

- 4 of 7 planned deliverables achieved (57%), on average 91 days late
- 1 Achieved on-time
- 3 of 7 are past due, average delay >75 days
- 7 are planned for year 3
- 35 are planned for year 4 of which 29 are in the last 6 months

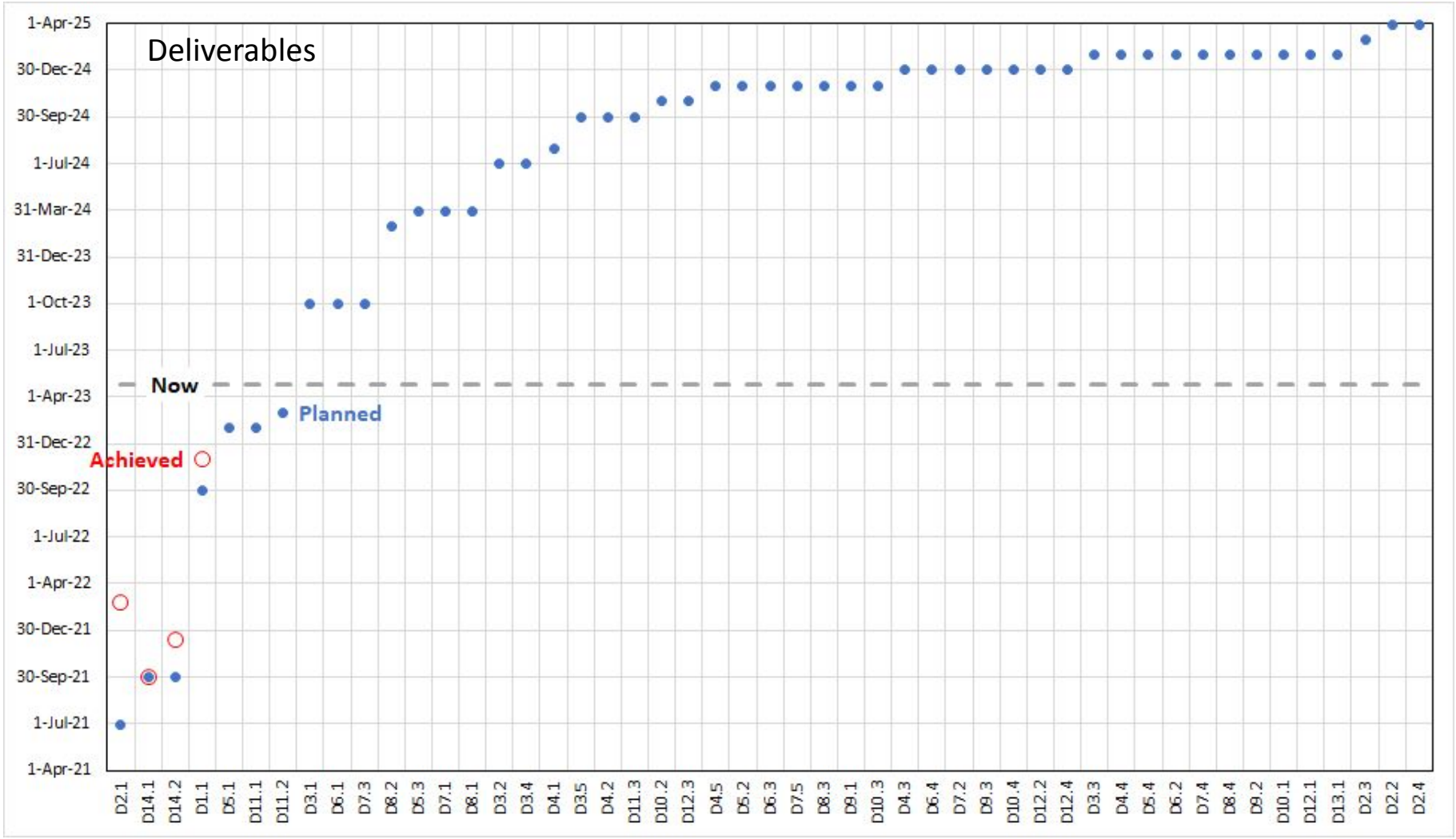
51 Milestones, of which

- 27 of 40 planned milestones (68%), on average 41 days late
- 12 Achieved on-time (30%)
- 13 Past due, average delay >70 days
- 8 planned for year 3 and 3 planned for year 4

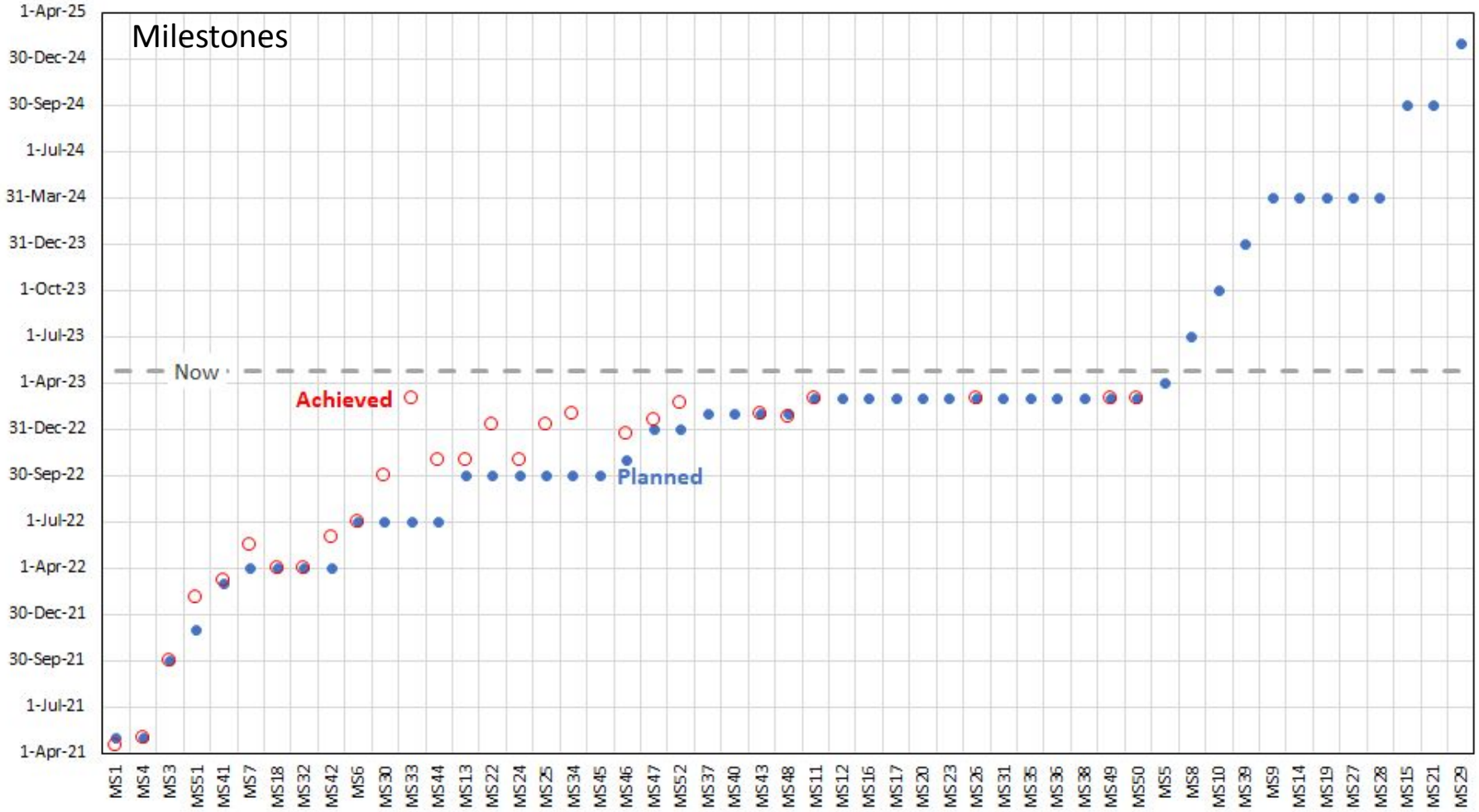
Delays in achieving milestones could be a concern for the ability to achieve the deliverables on-time.

Focus will be required to ensure that all deliverables, which are contractually required, are achieved within the next 2 years.

WP1: PROJECT MANAGEMENT AND COORDINATION



WP1: PROJECT MANAGEMENT AND COORDINATION



WP2: COMMUNICATION, OUTREACH AND KNOWLEDGE TRANSFER

WP2: Communication, Outreach and Knowledge Transfer

This WP will implement and coordinate the **communication, dissemination and outreach**, and **support the relations with industry and the knowledge transfer activities** of the project. It will provide website, newsletter and communication support as well as organise “Academia meets Industry events” and special measures to support young researchers. A KT network between participants and the connection with the KT activities of the other innovation pilots will be established, and support in management of intellectual property be provided.

WP2: COMMUNICATION, OUTREACH AND KNOWLEDGE TRANSFER

Milestones:

- MS4 Launching of project website. Due M1, achieved 30-Apr-21
- MS7 Analysis of innovations needed in markets and technologies. Due M12, achieved 17-May-22
- MS6 Young Scientist Publication Committee established. Due M15, achieved 30-Jun-22
- MS5 Academia Meets Industry Symposium. Due M24, achieved 27-Apr-23

4 of 4 achieved with minor delays

Deliverables:

- D2.1 Presentation video. Due M3, achieved 25-Feb-22 (8 months late)

This WP is successfully performing the normal communications and outreach activities and has organized today's "Academia Meets Industry" event.

So far 23 out of a goal os 60 journal publications => OK for the first half of the program

So far 3 out of a goal of 50 conference contributions => Why so few? Could WP2 help increase this number?

Greater interaction between WP2 and the other WPs would substantially strengthen the work of WP2, especially regarding interactions with industry and knowledge transfer and regarding dissemination of scientific and technical results through journal articles as well as less formal means.

WP3: TEST BEAM AND DAQ INFRASTRUCTURE

Goals: State of the art, high resolution and sub-ns test beam infrastructure.

3.1 Coordination and Communication

- Very active (not very large) group, directly involved in the development and, to some extent, operation of test beams

3.2 Upgrading the EUDET-style beam telescope infrastructure

- On track for MS8(M27): Telescopes upgraded with ALPIDE sensor

3.4 Development of DAQ software for next generation beam tests

- New monitoring/online reconstruction software on track

3.3 Sub-ns timing capabilities for EUDET-style telescopes

- Successfully reconstructed tracks with Timepix4 telescope and SPIDR4 readout
  - Achieved sub-ns time resolution
- Progress towards 100-ps Trigger-Logic-Unit

3.5 Development of common DAQ hardware

- MS11(M23 achieved): Common readout boards designed

WP3: TEST BEAM AND DAQ INFRASTRUCTURE

Risks identified:

R4: generic hardware or software too late:

Observation: overall situation is difficult and schedules shift, both for developers and users

R5: Generic hardware or software tools not ready on time

Again: schedules shift for both sides: developers and users

Additional Risk:

at smaller institutes - finding person power, filling positions -> delays

Try hard, try to leverage with existing effort

State of the art, high resolution and sub-ns test beam infrastructure is key for next generation detector development.
AIDA innova WP3 is addressing this.

WP4: UPGRADE OF IRRADIATION AND CHARACTERISATION FACILITIES

WP4 has five deliverables, all planned for the last year of AIDAinnova:

D4.1	Integrate the data acquisition and control system at RBI-AF	31-Jul-24
D4.2	Evaluate Non-Ionizing Energy Loss (NIEL) of irradiation facilities with dedicated dosimeter structures	30-Sep-24
D4.3	Deploy full prototype for irradiation facilities data management including sample tagging and spectrometry features	31-Dec-24
D4.4	Offer support towards the implementation of TPA-TCT systems and contribute to the evaluation of newly developed sensors technologies	31-Jan-25
D4.5	Develop a conductive noise test bench for irradiation facilities	30-Nov-24

Since these provide capabilities to the broader detector development community, it is important that they be achieved as planned.

The teams developing these tools have all the expertise needed for these tasks.

Four milestones achieved so far, on-time or with modest delays.

=> currently on track.

WP5: DEPLETED MONOLITHIC ACTIVE PIXEL SENSORS

Milestones and Deliverables:

- MS18: High granularity prototype fabrication, due Month 12: achieved and reported on 31st March 2022.
- D5.1: Report on performance of high granularity DMAPS Version1, due Month 22: achieved

Comments:

- All participating teams are working successfully on their respective devices regarding development of high granularity DMAPS as well as development of radiation hard DMAPS. Foundry submissions were done at 2 different Foundries (TowerJazz/TPSCo and LFoundry) on 4 different Process Nodes TJ180nm, TJ110nm, TJ65nm and LF150nm employing a variety of different Si starting materials (n-type, p-type, epi, bulk-CZ, different doping concentrations etc.). Very promising characterization results have been achieved for high granularity, radiation hardness and timing.
- AIDAinnova offers a platform for participating project teams to share information on various process options' pros and cons. It would be desirable to compare different process nodes (e.g. 180nm, 150nm, 110nm) and make a common effort towards reducing the number of process/material options for future use. This would ultimately lead to more cost efficiency and will enable easier access CMOS foundries.
- As the DMAPs roadmap is heading towards smaller process nodes (65nm and below) this exercise is of special importance for future developments. Putting together an overview of available Foundries and Process Nodes and matching them with the DMAPs requirements of various WP5 project teams would be an important step towards next generation DMAPs development.

WP6: HYBRID PIXEL SENSORS FOR 4D TRACKING & INTERCONNECTION TECHNOLOGIES

Milestones and Deliverables:

- MS22, MS24 and MS25: achieved
- MS23: Draft of MS23-report is available and will be submitted to management by end April.

Comments:

- Sensor development and processing @ FBK (small pitch Trench-isolated LGAD and 3D) is progressing well; layout is competed, processing is ongoing, wafers are expected by Sep/23; ok for Deliverable D6.1.
- Sensor development and processing of production lots @ CNM (iLGAD and 3D) is delayed due to clean room issues; CNM AIDAinnova production lot will most likely not meet D6.1 deadline.
- Dedicated Process Development for LGADs and 3D sensors at FBK and CNM is highly desirable, as these institutions are flexible to adapt processes for best sensor performance. It must be kept in mind though, that for large volume production a process transfer to an industrial partner would presumably be necessary.
- TCAD Simulations of LGAD and 3D sensors are progressing well, especially for LGADs. For 3D sensor simulations model improvements are needed to better match leakage current simulations to measurement results. System simulations were not presented at the 2nd Annual meeting, but during a previous WP6 meeting. Aim here would be a further development of timing simulations in framework of ALLPIX2.
- Development of interconnection technologies employing Die-to-Die attachment by Anisotropic Conductive Films as well as Wafer-to-Wafer bonding is running according plan. Also for the interconnection technologies high volume processing would presumably need access to industrial partners.

WP7: GASEOUS DETECTORS

Deliverables: two are planned within the next 12 months

D7.1	Characterisation of small size MRPC prototypes for fast timing and high rates	31-Mar-24
D7.2	Validation of the eco-friendly gas mixtures for RPCs at GIF++	31-Dec-24
D7.3	Production with industry of small-size of μ-RWELLs	30-Sep-23
D7.4	A small-scale TPC prototype (#10 1) with hybrid charge/optical read-out and a hydrogen rich gas mixture with high scintillation yield	31-Jan-25
D7.5	Small-size prototype of a MPGD single photon detector for compact RICHs	30-Nov-24

Milestones:

- MS26 Production of DLC with ion beam deposition and pulsed laser deposition. Due M23, achieved 28-Feb-23.

Deliverable 7.3 is forecast to be up to 6 months late. Otherwise good progress.

Good example of co-innovation with industry and knowledge transfer. All four subtasks involve industrial beneficiaries or partners who are working closely with the research community.

WP8: CALORIMETERS AND PARTICLE IDENTIFICATION DETECTORS

Until the DRD put forward by CERN is in place, the Calorimeter community is lacking resources.

Still, some progress observed within AIDAinnova.

- In view of a future e^+e^- Collider, a large dual readout (Cerenkov and Scintillation) prototype (EM and hadron) is being built, with a strong contribution from INFN. Associated developments on SiPMs.
- The feasibility of high-granularity noble liquid (10x Atlas) calorimetry was tested with a first set of (small) electrodes. Need to be pursued/enlarged.
- The high granularity Si-W EM calorimeter is finding applications in ongoing experiments (LUXE)

Concerning particle ID, the main developments are on SiPM:

- Improved radiation résistance for a future LHCb upgrade.
- Specific developments for a Belle-II upgrade (Time Of Propagation detector).

WP9: CRYOGENIC NEUTRINO DETECTORS

Excellent progress on cold liquid neutrino detectors thanks to the backing of the strong Europeen DUNE community.

- Charge readout with vertical drift validated by a cold test in NP02 cryostat
- Forward steps made for the light readout using WLS in already sizeable dimensions
- Ambitious R&D started on combined pixels and SiPM (VUV sensitive) readout planes. Long term aim is to make future DUNE detectors able to study supernova burst neutrinos, solar neutrinos, and even the diffuse supernova background!

WP10: ADVANCED MECHANICS FOR TRACKING AND VERTEX DETECTORS

The WP10 activities on Advanced mechanics for tracking and vertex detectors can approximately be grouped into 3 broad R&D lines.

3D-printing technologies including developments on:

- ceramics at LITHOZ;
- metal alloys and diamond composites at CSEM;
- integrated cooling and ultra-light mechanical structures at CERN.

Cooling technologies including developments on:

- Single-Phase SOI-Based Microchannel Coolers at Max-Planck Semiconductor Lab;
- Cooling microchannels on the surface of the die (FPGA cooling) at INFN;
- Micro-Channel Cooling at IMB-CNM;
- Supercritical refrigerants at CERN and NTNU.

Advanced bonding and Precision mechanics including:

- Low-temperature bonding compatible with post-processing at CNM and HLL;
- Advances in Frequency Scanning Interferometry (FSI) at UNIOXF.

Observations: Very impressive advances in 3-D printing both in industry and in research labs. Intense activity on cooling techniques and related test articles. Interesting developments in wafer bonding and precision mechanics. Mostly long term efforts with deliverables (CSIC, CNRS, NTNU, UOXF) foreseen at > 42 months. Milestones MS41-MS44 are on target.

WP11: MICROELECTRONICS

Most participating groups have reported on their activities and achievements, except University of Bonn, DESY, INFN/BA/PV and INFN/BO/LNF.

Microelectronics is a key technology enabler for novel detectors. WP 11 has two main pillars:

1) Explore 28 nm technology performance for HEP
2) Provide readout ASICs in 130 nm for other WPs

The milestones and deliverables for WP11 each concern Multi-Project Wafer (MPW) production:

1) MS11.1: Design review of 28 nm MPW
2) MS11.2: Design review of 65/130 nm run
3) D11.1: MPW 28 nm: The deliverable is a multi-project wafer fabrication with the different test ASICs in CMOS 28 nm
4) D11.2: MPW 65/130 nm: The deliverable is a multi-project wafer fabrication with ASICs in CMOS 65 and/or 130 nm that can be used to readout detectors from the other WPs and in particular WP8
5) D11.3: Measurement reports: Each of the ASIC fabricated in the two previous deliverables will have its design and performance documented in a report

MS11.1 and MS11.2 have been achieved in November 2022.
Fabrication deliverables (D11.1 and D11.2) planned for Jan-Feb 2023 but not yet achieved.

WP11: MICROELECTRONICS

In addition, the following have been achieved:

1) Networking activity and sharing of expertise among participants. Several ASICs have been developed in co-design.
2) Working with one industrial partner for technology transfer and spinoff.

Some delays have been experienced due to the setting up and signing process of the NDA.

Once the chips will have been received back, they need to be tested thoroughly. Test set-ups are under preparation. The plans include functional tests on the bench and irradiation tests (TID and SEE).

The group should make sure that the different efforts and ASICs result in a coherent set of results and outputs.

The innovative aspects of the newly designed chips should be communicated effectively to the community with the help of WP2.

Observations

- AIDA Innova effort is well embedded into existing R&D communities
- 4 milestones delivered on time (MS47-MS50)
  - one in each of WP 12.2,12.3,12.4,12.5

12.1 Coordination and Communication

- very active group that is aware of the big picture and state of the art R&D

12.2 Turnkey Software

- Key4hep used exclusively for FCC, big overlap with CLIC,
- Total effort 15-20 people, much leveraged

12.4 Track Reconstruction

- Developing ML techniques on GPUs

12.3 Simulation

- Fast simulation with ML techniques
- Implementation into Geant 4,
- Integration into LHC experiments

12.5 Particle Flow Reconstruction

- Used for dual readout calorimeters
- Experiments: SDHCAL, DUNE ND

Risks Identified

R20: ML methods are not as performant as expected

Observation: progress is impressive and promising

R21: Community abandons generic toolkit approaches

Observation:

- Embedding in communities/R&D is key, it is widely established
- When a tool comes too late for projects:

  - the exchange of experience in both directions is well established

Additional Risk: finding person power, filling positions -> delays

- Try hard, try to leverage with existing effort

General Observation: Research and development of software for HEP needs support from projects such as AIDA innova.

We should find ways to continue this kind of support.
HEP is based on both: state-of-the-art detectors AND software.

WP13: PROSPECTIVE AND TECHNOLOGY-DRIVEN DETECTOR R&D

- The **eXFlu-innova** activities are focused on the development of LGADs with a compensated gain layer.
  - Deliverable 1 ($p^+ – n^+$ design) has been completed. Production of p–n compensated sensors (M12) has been carried out (part of D2).
  - Testing campaigns with different ratios of p^+, n^+ doses were carried out. However an optimal tuning is under study as some difficulties emerged with the tested configurations (e.g., either too low gain w.r.t. standard LGADs, or too high gain, etc).
  - The design of p-in-n is ongoing for an LGAD production to study the donor removal coefficient. Different designs of the n^+ gain layer are being investigated.

Observations: the development of compensated LGADs for extreme fluences is strongly innovative and challenging. The WG is actively pursuing several alternatives to improve their present results. The expertise of the WG members and their effort are well adequate to address the still open challenges of the project.

WP13: PROSPECTIVE AND TECHNOLOGY-DRIVEN DETECTOR R&D

- The **NanoCal** project pursues the development of Nanomaterial Composite (NC) scintillators for fine-sampling calorimetry.
  - Two prototypes in shashlyk configuration were beam-tested at CERN. However the scintillator has ~4 times less light-yield than conventional scintillators. Therefore improvement is needed. Efforts are focused along two directions: (i) increase of CsPbBr3 concentration; (ii) reduction of self-absorption via internal WLS.
  - The time resolution has been found approximately the same as for conventional scintillators (taking into account the inferior light-yield).
  - Additional tests with small modules are planned and New NanoCal prototypes are under construction. A beam test is scheduled in June 2023.

Observations: the development of innovative NC scintillators is valuable but challenging. The WG expertise and the work plan of the project seem adequate to improve the present achievements.

WP13: PROSPECTIVE AND TECHNOLOGY-DRIVEN DETECTOR R&D

- **The Wireless Data Transfer** for HEP applications is a technological project aiming at enabling the access to this technology for new user communities. Intermediate steps foresee the delivery of a first 1 Gbps demonstrator for D1 and a 2-3 Gbps for D2.
  - The first mockup demo for 1 Gbps 1 is being put together (uses commercially available components).
  - A new PCB is under development at UU for the second demo.

Observations: the timeline of the project should be monitored. So far no tests were carried out to assess the e.m. compatibility of the system in a harsh electromagnetic background. Such tests are highly recommended.

WP13: PROSPECTIVE AND TECHNOLOGY-DRIVEN DETECTOR R&D

- **SiEM (Silicon Electron Multiplier)** goal: achieve charge multiplication via high fields while not relying on high doping implantation (insensitive to acceptor removal).
  - first deliverable (test structure) by mid 2023;
  - efforts to to overcome the limitations on charge multiplications due to pillar width;
  - first demonstrator by mid 2024.

Observations: the development is innovative and challenging. The project time profile should be monitored. There are concerns related to an ongoing parallel CERN-PSI development (with metal-assisted etching) that might impact on the schedule.

Summary / Conclusions

AIDAinnova is an important program that appears to be proceeding well, with only a few glitches.

There are indications that some tasks are behind schedule. **At this halfway point** through the project, this is the right time to **assess progress and make course corrections** where necessary to ensure that the deliverables are delivered on time and that AIDAinnova can have the greatest impact.

AIDAinnova is well on track to achieve the goal to **provide state-of-the-art upgrades of research infrastructure** and **cover all key technologies for future detectors**.

AIDAinnova includes examples of **intensified co-innovation with industry** that can foster **Knowledge transfer.**

It is less clear the extent to which AIDAinova is **strengthening the competence and competitiveness of the industrial partners in other markets.**

Keep up the good work!

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 101004761.

Thank You

This has been a productive, interesting and enjoyable workshop.

We appreciate the high quality of the presentations and the openness of the discussion … and the kind hospitality of our local hosts!

We hope that the SIAP has been helpful, both through these comments and the discussions during this week.

We look forward to seeing the progress by the time of next year's annual meeting.