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AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Horizon 2020 Research Infrastructures project AIDA-2020

DELIVERABLE REPORT

Y1 AIDA-2020 REPORT

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Abstract:

A report of the work performed during year 1 of the AIDA-2020 project (from 1 May 2015 until 30 April 2016) including the work progress and the use of the resources.

For more information on AIDA-2020, its partners and contributors please see www.cern.ch/AIDA2020

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Delivery Slip

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1. EXPLANATION OF THE WORK CARRIED OUT BY THE BENEFICIARIES AND OVERVIEW OF THE PROGRESS

1.1. OBJECTIVES

List the specific objectives for the WP as described in section 1.1 of the DoA and described the work carried out during the reporting period towards the achievement of each listed objective. Provide clear and measurable details. (maximum ½ page)

1.2. EXPLANATION OF THE WORK CARRIED DURING THE PERIOD

Explain the work carried out in WP3 during the reporting period giving details of the work carried out by each beneficiary involved.

1.2.1. WP3: Advanced software (NA2)

The WP addresses the three main fields of software for HEP, namely Core Software, Simulation and Reconstruction. The first three tasks aim at providing basic tools like geometry description packages or Event Data Models (EDM) that are needed for the simulation and reconstruction. The fourth task will be directly focussed on the simulation and will provide a flexible framework that can be used for the implementation of specific detector simulation applications. Finally, the last two tasks will deal with advanced tracking tools and reconstruction algorithms (PFA). The WP includes 7 tasks:

- Task 3.1 Scientific coordination
- Task 3.2 Detector Description for HEP (DD4hep) and Unified Solids (USolids) extensions
- Task 3.3 Alignment and conditions data (test beam)
- Task 3.4 Event Data Model (EDM) toolkit and framework extensions
- Task 3.5 DDG4 (Detector Description Geant 4): Geant4 based simulation toolkit Work package meetings
- Task 3.6 Advanced Tracking Tools
- Task 3.7 Advanced particle flow algorithms

The following sub-sections describe the details of the work done by the beneficiaries within each of the Task of the WP3.

1.2.1.1. Task 3.1: Scientific coordination

Progress towards objectives and significant results

The main focus in this first reporting period for the scientific coordination of the work package has been on ensuring good communication and exchange of information between the participating working groups. To this end monthly phone meetings with short status reports from all partners involved where organized. Additionally the work package coordinators have joined meetings from WP5 and WP14 in order to discuss possible synergies and common activities.

Dates	*Type of meeting*	*Venue*	*Attendance*	*Indico link*
30.09.2015	**Monthly phone meeting**	**CERN**	**all WP3**	https://indico.cern.ch/event/447462/
12.11.2015	**Monthly phone meeting**	**CERN**	**all WP3**	https://indico.cern.ch/event/456921/
17.12.2015	**Monthly phone meeting**	**CERN**	**all WP3**	https://indico.cern.ch/event/464536/
03.02.2016	**Monthly phone meeting**	**CERN**	**all WP3**	https://indico.cern.ch/event/484297/
11.03.2016	**Monthly phone meeting**	**CERN**	**all WP3**	https://indico.cern.ch/event/504409/

Contractual milestones and deliverables

In the Y1 reporting period, task 3.1 had no milestones and no deliverables to submit.

1.2.1.2. Task 3.2: DD4hep and USolids extensions

Progress towards objectives and significant results

A new component DDAlign has been added to DD4hep. It enables users to describe the misalignment of individual detector elements with respect to the idealized perfect layout at all levels of the geometry hierarchy. This is schematically illustrated in Figure 1 (left) for a hypothetical time projection chamber (TPC) that can either be misplaced as a whole with respect to the surrounding experiment (a), each of the endcaps could be tilted or moved with respect to the TPC coordinate system (b) or individual endcap sectors could be misplaced with respect to their mother volume (c). The existing prototype implementation has served for testing design and implementation choices.

The USolids package developed in AIDA has now been integrated into the VecGeom project with the aim to evolve its interfaces and algorithms to support multi-particle transport and SIMD vectorisation. A first version of VecGeom has been released with Geant4 10.2. The testing suite has been extended for comparing scalar and vectorised algorithms and is used for a systematic review of the existing implementations. New shapes like generic/simple trapezoids and a parallelepiped have been added, as well as the functionality to scale shapes along the Cartesian axes (see Figure 1). An interface to ROOT has now been developed that allows replacing the native shapes for navigation and visualization.

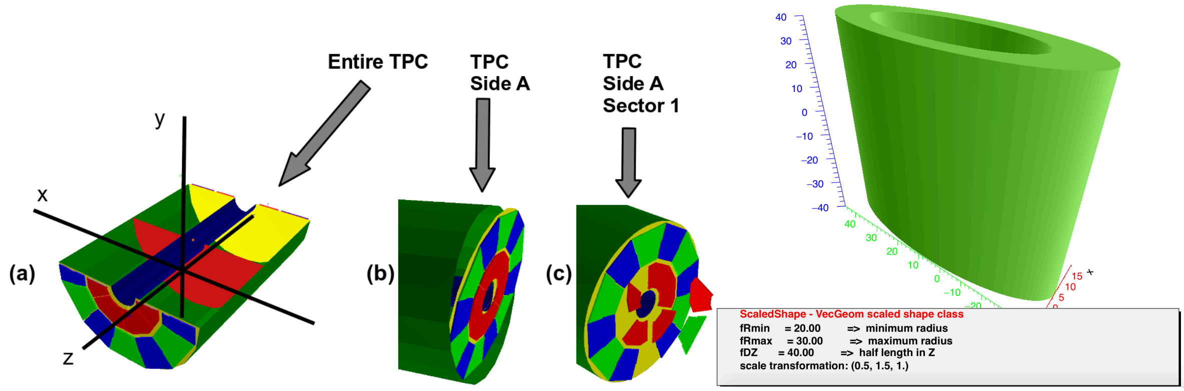

Figure 1: Left: Different misalignment modes for a TPC in DDAlign: a) global b) endcap c) module. Right: A shape (tube) scaled along X and Y Cartesian axes in VecGeom.

Contractual milestones and deliverables

In the Y1 reporting period, task 3.2 had no milestones and no deliverables to submit.

1.2.1.3. Task 3.3: Alignment and conditions data (test beam)

Progress towards objectives and significant results

LHCb has introduced a novel alignment and calibration strategy in 2015 where the constants are computed within a few minutes at the beginning of each fill. Identical constants are then utilized both by the trigger and the offline processing which allows the optimal performance to be obtained already at the trigger level. Consequently, analysis is then possible using the output of the trigger directly. The first two LHCb papers of LHC Run II have both been published using this new functionality. The new strategy was tested in 2015 where both the raw data and the trigger reconstruction output were kept. In 2016, for selected high bandwidth channels, the reconstructed information on the signal candidate tracks only will be retained allowing for an order of magnitude reduction in the data size for these events. The procedure has been discussed at a number of major international conferences and other LHC collaborations are showing interest in applying it as well. Figure 1 shows the stability of the alignment of the halves of the vertex detector (LHCb) in 2015.

A prototype of the LHCb VELO upgrade alignment procedure has been successfully implemented in the reconstruction software package of the experiment, providing good performance for the primary degrees of freedom (x,y translations and rotations around the z-axis) as shown by simulation studies.

The alignment software BACH developed in AIDA has continued to be applied to the AIDA/LHCb TimePix telescope and has also started to attract external users. It has been used to perform the alignment of the upstream and downstream trackers in MICE (International Muon Ionization Cooling Experiment), and considered for LHC beam monitors.

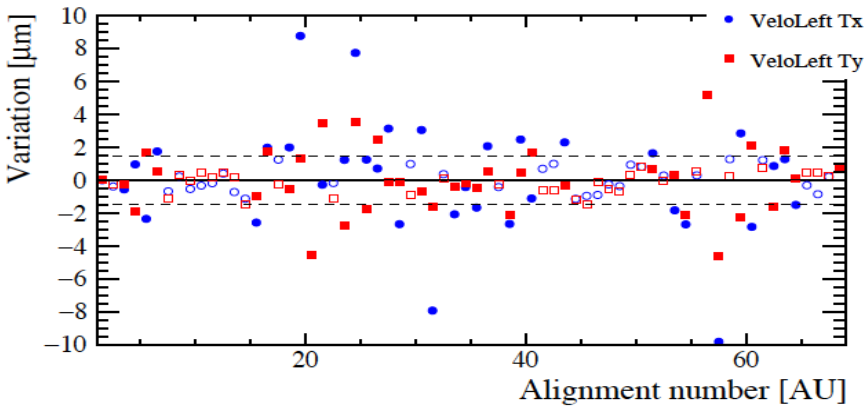

Figure 2 Alignment of the halves in x (blue) and y (red) of the LHCb vertex detector VELO during 2015. The dashed lines show the limits proposed for 2016, alignment constants outside these limits will trigger the use of updated alignment constants in the trigger.

Contractual milestones and deliverables

In the Y1 reporting period, task 3.3 had no milestones and no deliverables to submit.

1.2.1.4. Task 3.4: EDM toolkit and framework extensions

Progress towards objectives and significant results

A first version of the EDM toolkit PODIO has been created in this reporting period.
PODIO is based on the idea of employing plain-old-data (POD) structures wherever possible, while avoiding deep-object hierarchies and virtual inheritance in order to improve runtime and I/O performance. At the same time it provides the necessary high-level functionality to the physicist, such as support for inter-object relations, and automatic memory-management.
First prototype implementations of PODIO are under investigation by LHCb, FCC and the LC community in order to optimize the design and functionality of the toolkit. The code is available at https://github.com/hegner/podio.

For the framework extensions the condition handling in multithreaded experiment frameworks has been identified as a first work item. Specifically the following issues were identified:

1. The multithreaded Gaudi framework is currently unable to safely process multiple events that correspond to different distinct detector states.

2. The condition database software that is used by the ATLAS and LHCb experiments is largely unmaintained and possesses major conceptual flaws. Its replacement, which is currently being implemented, will need to be integrated into Gaudi.

After iterating with experiment and framework stakeholders, several implementation alternatives were proposed and are currently under evaluation, aiming at a condition handling solution that is suitable for all Gaudi-based experiments thereby reducing the need for experiment-specific code. Although the focus has been on Gaudi-based experiments so far, it is planned to explore the possibility of integrating this infrastructure into other HEP frameworks in the longer term.

Contractual milestones and deliverables

In the Y1 reporting period, task 3.4 had no milestones and no deliverables to submit.

1.2.1.5. Task 3.5: DDG4: Geant4 based simulation toolkit

Progress towards objectives and significant results

DDG4 is a sub-component of DD4hep developed in AIDA and provides an easy-to-use pathway to full simulation toolkit Geant4 that is commonly used in HEP. In the reporting period DDG4 has been extended and finalized to provide the necessary core functionality. It has been integrated into the software framework used by all linear collider experiment study groups: CLICdp, ILC and SiD as well as the calorimeter collaboration CALICE. Figure 3 shows the CLICdp new simulation model used with DDG4. A fully configurable python program ddsim, serves as application framework to run simulations of all detector-design models that are under consideration in the process of overall detector optimization. Input and output modules for LCIO, the EDM and persistency used in the Lc community, have been implemented. DDG4 is in addition used by the FCC study groups to investigate the physics potential of a future circular collider project at CERN.

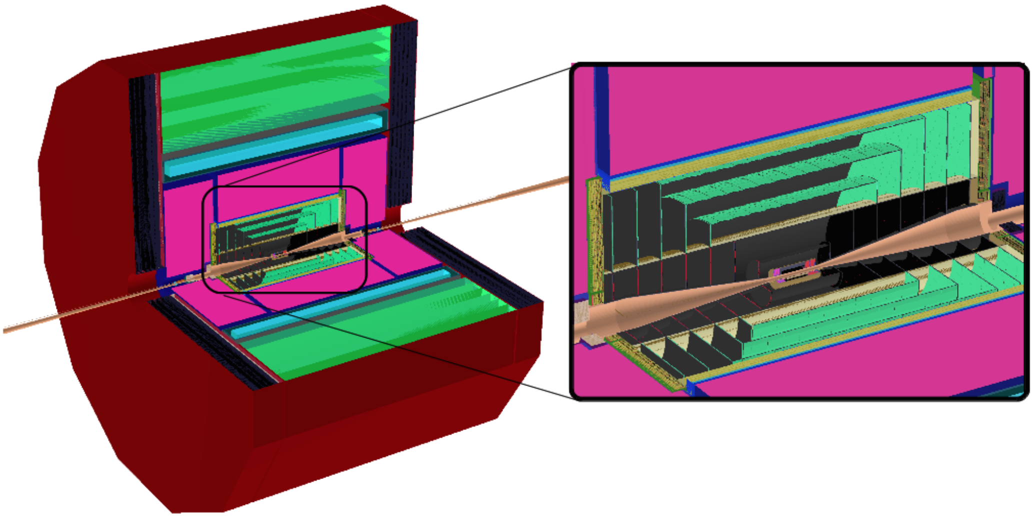

Figure 3: Detailed new simulation model for CLICdp used with DDG4 for full simulations with Geant4.

Contractual milestones and deliverables

In the Y1 reporting period, task 3.5 had no milestones and no deliverables to submit.

1.2.1.6. Task 3.6: Advanced tracking tools

Progress towards objectives and significant results

The tracking toolkit aidaTT that has been developed in AIDA has been extended and restructured in this reporting period. The calculation of all surface intersections for a given track hypothesis has been made more efficient and the calculation of intersections with conical surfaces have been added. The MarlinTrk interface used in the LC software framework has been now been fully implemented thereby allowing to transparently switch between Kalman filters and General Broken Lines (GBL) for fitting of track parameters. The detailed evaluation of the tracking algorithms is currently ongoing in the context of the CLICdp and ILD detector concept groups.

Contractual milestones and deliverables

In the Y1 reporting period, task 3.6 had no milestones and no deliverables to submit.

1.2.1.7. Task 3.7: Advanced particle flow algorithms

Progress towards objectives and significant results

Significant progress has been made in the development of Pandora algorithms for reconstruction of cosmic ray and neutrino interactions in LAr TPCs. The TPC readout provides three 2D images of events and the algorithms perform a separate 2D reconstruction for each image and make iterative adjustments until the features are consistent in all three images and 3D particles can be identified without ambiguity. Recent developments have focused on addressing issues with noise and gaps in the detector instrumentation, in preparation for processing data taken by the MicroBooNE experiment. Support for 1D detector 'LineGaps' has been added to the Pandora SDK and algorithms can then access LineGap information to merge 2D clusters across gap regions, leading to significant pattern recognition improvements (see Figure 4). For the LC reconstruction, new Pandora algorithms have been added to carefully separate nearby photons and to remove fragments of photon clusters, merging the fragments to improve reconstructed photon completeness. Calibration tools have also been provided to optimise the energy estimators used for electromagnetic and hadronic showers. Major progress has been made in the implementation of the DDMarlinPandora application, which provides the link between the DD4hep detector geometry description and the Pandora algorithms. The Pandora SDK has now been formally documented [1] and the Pandora codebase is now hosted at https://github.com/PandoraPFA.

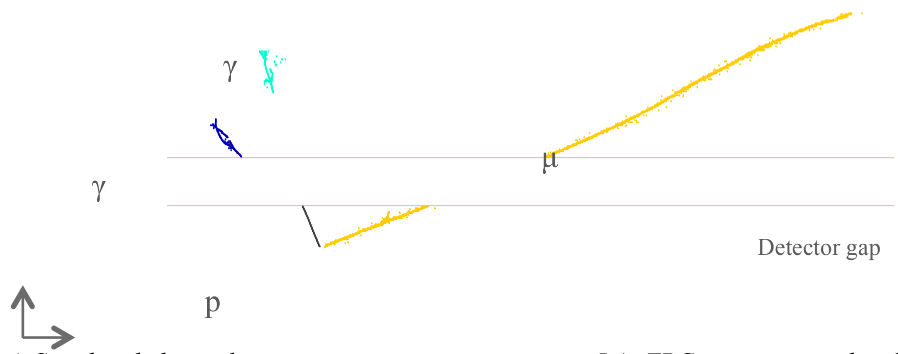

Figure 4. Simulated charged-current neutrino interaction in a LAr TPC, reconstructed with Pandora. Final state particles here consist of a muon, proton and two photons, from π^0 decay. A gap in the detector readout is shown.

Contractual milestones and deliverables

In the Y1 reporting period, task 3.7 had no milestones and no deliverables to submit.