Advanced European Infrastructures for Detectors at Accelerators

Advanced Software (WP3) summary

Frank Gaede, DESY

Witek Pokorski, CERN

AIDA-2020 Second Annual Meeting

07.04.2017

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Content

- Overview of WP3
  - Deliverables and milestones
- Status of the tasks
- Conclusion

WP3 Overview

- Advanced simulation and reconstruction for HEP
- Core software
  - DD4hep and USolids extensions
  - alignment and conditions data
  - EDM toolkit and framework extensions
- Simulation
  - DDG4: Geant4 based simulation toolkit
- Reconstruction
  - advanced tracking tools
  - advanced particle flow algorithms

- address high performance computing in all tasks: parallelization, vectorization → added value
- Partners:
  - CERN, DESY, LAL, LLR, U-Manchester, U-Cambridge

WP3 Overview

Objectives

Task 3.1 Scientific coordination

- Coordinate and schedule the execution of the WP tasks
- Monitor the work progress (milestone and deliverable reports), follow-up on the WP budget and the use of resources
- Organise WP meetings

Task 3.2 Detector Description for HEP (DD4hep) and Unified Solids (USolids) extensions

- Extend USolids for vectorisation using Single Instruction, Multiple Data (SIMD) instructions and reviewed algorithms
- Define proper interfaces for use of USolids in Geant4, Root and Vector prototype
- Implement thread safety and alignment procedures in DD4hep

Task 3.3 Alignment and conditions data (test beam)

- Complete alignment toolkit with tight coupling to DD4hep for simulating the misalignment
- Provide alignment and conditions data for DD4hep

Task 3.4 Event Data Model (EDM) toolkit and framework extensions

- EDM toolkit for efficient creation of Event Data Models in C++ with high performance I/O
- Implementation of parallel algorithm scheduling mechanisms in HEP frameworks

Task 3.5 DDG4 (Detector Description Geant 4): Geant4 based simulation toolkit

- Modular and flexible simulation toolkit based on DD4hep and Geant4
- Application to LC and FCC

Task 3.6 Advanced Tracking Tools

- Development of advanced parallel algorithms for track finding and fitting in AIDA Tracking Tool toolkit (aidaTT)
- Application to LHC and LC

Task 3.7 Advanced particle flow algorithms

- Development of advanced particle flow and pattern recognition algorithms in PandoraPFA (particle flow algorithms toolkit)
- Application to LHC, LC and neutrino experiments

WP3 Milestones and deliverables

4 milestones for M21 achieved

achieved

MS3.1	Design document for alignment Toolkit with tight coupling to DD4hep	3, 15	M14	Reviewed by StCom
MS3.2	Design document for Event Data Model toolkit	3, 5	M14	Reviewed by StCom
MS3.3	Design document for parallel algorithm scheduling mechanism	3	M14	Reviewed by StCom
MS3.4	Running prototype of USolids using SIMD instructions	3	M21	Released, documented and running prototype
MS3.5	Running prototype for alignment Toolkit	3, 15	M21	Released, documented and running prototype
MS3.6	Running prototype for parallel algorithm scheduling mechanism	3	M21	Released, documented and running prototype
MS3.7	Running prototype for Geant4 based simulation toolkit	3	M21	Released, documented and running prototype
MS3.8	Integration of USolids extensions for vectorisation in Geant4, ROOT and Geant Vector Prototype	3	M44	Documented software release
MS3.9	Application of alignment toolkit to external tracker for PCMAG	3, 15	M44	Document describing alignment procedure and results
MS3.10	Application of Event Data Model toolkit with high performance I/O to Linear Collider	3, 5	M44	Documented software release
MS3.11	Integration of parallel algorithm scheduling mechanism in Gaudi, Marlin and PandoraPFA frameworks	3	M44	Documented software release

achieved

D3.1	Implementation of extensions in USolids *(extended signature of classes, reviewed algorithms, well defined interfaces for Geant4, Root and Vector prototype)*	3	CERN	other	PU	M32
D3.2	Implementation of DD4hep extensions *(added alignment functionality and thread safety)*	3	CERN	other	PU	M34
D3.3	Alignment Toolkit *(generic toolkit with tight coupling to DD4hep)*	3	UNIMAN	other	PU	M36
D3.4	Event Data Model toolkit *(creation of EDM model in C++ with high performance I/O)*	3	DESY	other	PU	M40
D3.5	Parallel versions of event processing frameworks *(validation of parallelisation of algorithms and event processing)*	3	CNRS	other	PU	M42
D3.6	Geant4 based simulation toolkit DDG4 *(modular and flexible toolkit based on DD4hep and Geant4)*	3	CERN	other	PU	M35
D3.7	Advanced Tracking tools*(implementation of advance parallel track finding and fitting algorithms)*	3	DESY	other	PU	M39
D3.8	Advanced Particle Flow algorithms *(implemented within the PandoraPFA framework)*	3	UCAM	other	PU	M38

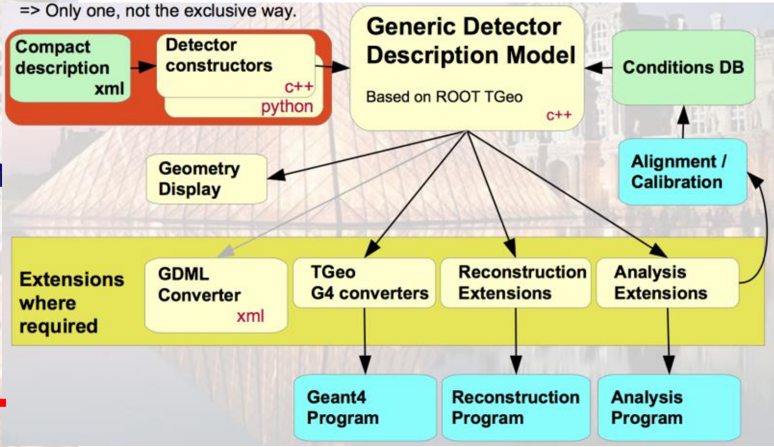
2nd Annual Meeting WP3 session

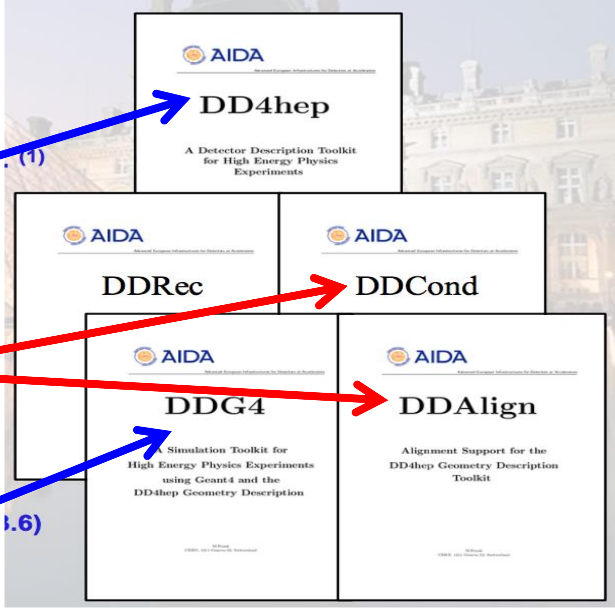
Introduction	*Witold Pokorski et al.*	
Salle des séminaires- 1222-RC-08, LPNHE		09:00 - 09:10
DD4Hep	*Markus Frank*	
Salle des séminaires- 1222-RC-08, LPNHE		09:10 - 09:30
DDG4	*Markus Frank*	
Salle des séminaires- 1222-RC-08, LPNHE		09:30 - 09:50
USolids	*Gabriele Cosmo et al.*	
Salle des séminaires- 1222-RC-08, LPNHE		09:50 - 10:10
Alignment and conditions data	*Christopher Mark Burr*	
Salle des séminaires- 1222-RC-08, LPNHE		10:10 - 10:30
Event Data Model	*Benedikt Hegner et al.*	
Salle des séminaires- 1222-RC-08, LPNHE		11:00 - 11:20
Framework extensions	*Hadrien Benjamin Grasland*	
Salle des séminaires- 1222-RC-08, LPNHE		11:20 - 11:40
Advanced tracking tools	*Frank-Dieter Gaede*	
Salle des séminaires- 1222-RC-08, LPNHE		11:40 - 12:00
Advanced particle flow algorithms	*John Marshall et al.*	
Salle des séminaires- 1222-RC-08, LPNHE		12:00 - 12:20
Session wrap-up	*Frank-Dieter Gaede et al.*	
Salle des séminaires- 1222-RC-08, LPNHE		12:20 - 12:30

DD4hep - goals

M.Frank

- **Develop a detector description**
  - **For the full experiment life cycle**
    - **detector concept development, optimization**
    - **detector construction and operation**
    - **"Anticipate the unforeseen"**
  - **Consistent description, with single source, which supports**
    - **simulation, reconstruction, analysis**
  - **Full description, including**
    - **Geometry, readout, alignment, calibration etc.**





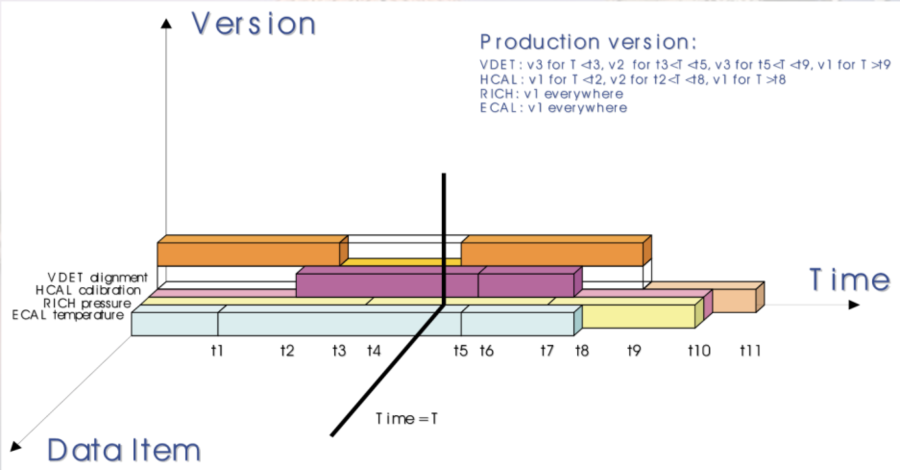
core modules

current main development

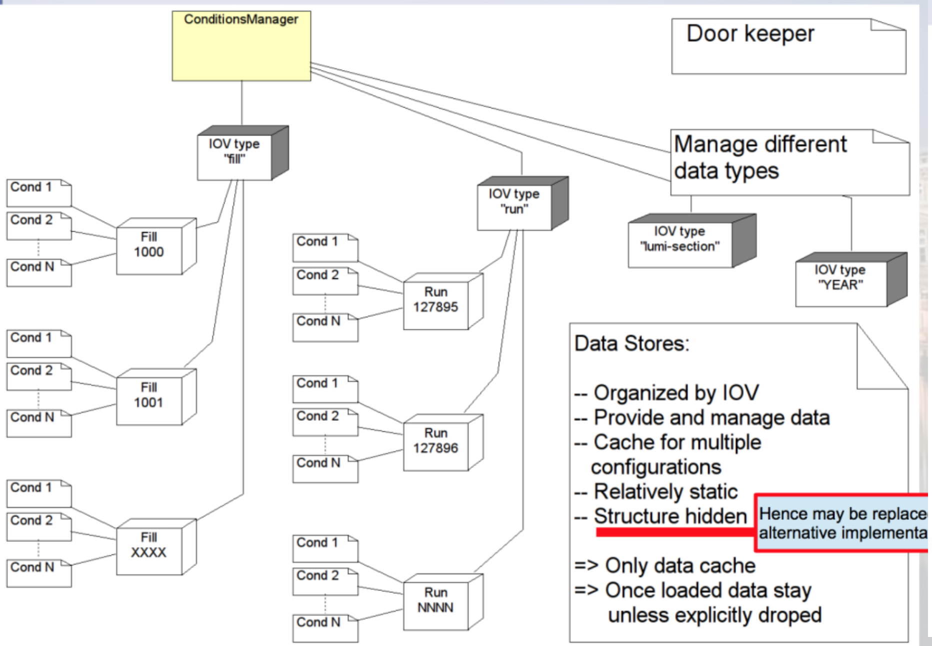
simulation using Geant4

DDCond: Conditions Data

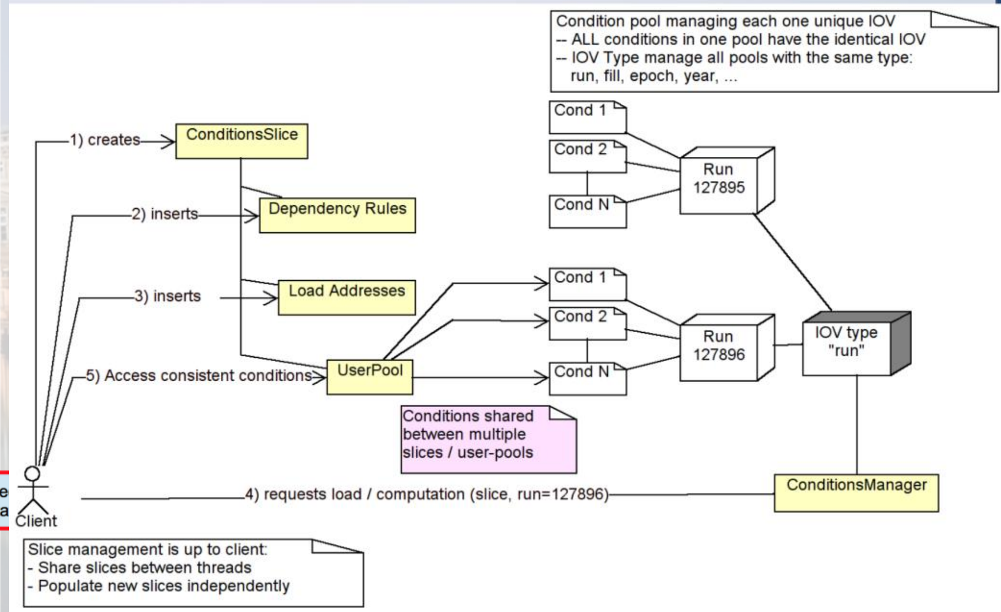
- Time dependent data necessary to process the detector response [of particle collisions]
- Conditions data support means to Provide access to a consistent set of values according to a given time
  - Fuzzy definition of a “consistent set” typically referred to as “interval of validity”: time interval, run number, named period, ...
  - Configurable and extensible
- Data typically stored in a database



DDCond: The Data Cache



DDCond: User Data Access

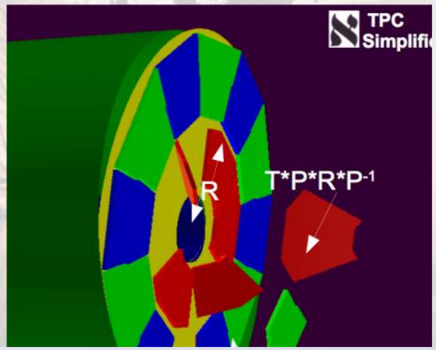


DDCond: Status

- **Described functionality is implemented**
  - **Tested with xml-input**
  - **Interfaced to LHCb conditions database for performance tests**

DDAlign: Detector Alignment

- Fundamental functionality to interpret event data
  - Model mis-placement by construction
    - Non-ideal mounts of detector components
  - Must handle imperfections
    - Geometry => (Mis)Alignment
  - Anomalous conditions
    - Pressures, temperatures
    - Contractions, expansions



DDAlign: Global and Local Alignment

- Global alignment corrections
  - Physically alters geometry
  - Intrinsic support by ROOT
  - By construction not multi-threaded
  - Possibility to simulate misaligned geometries
- Local alignment corrections
  - Geometry stays intact (either ideal or globally alig
  - Multi-threading supported, multiple versions
  - Local alignment corrections are conditions
  - Provide matrices from ideal geometry to world e.g. to adjust hit positions

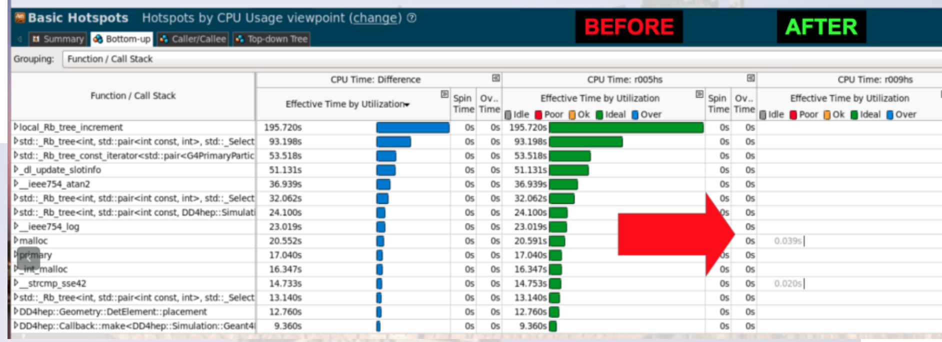
Support both, emphasis on local alignment

DDAlign: Status

- Implemented Global and Local (mis-)alignment
  - xml parser for Global (mis-)alignment constants needs re-visiting
- Started to integrate Local misalignments with the alignment procedures developed within WP3, Task 3.3
  - MS40: Running prototype for alignment Tooll
  - To be tested in "real world" during test-beam at Desy (S. Borghi, C. Burr, C. Parkrski

DDG4: Optimization

vtunes output from 20 events $e^+e^- \rightarrow t\bar{t}$



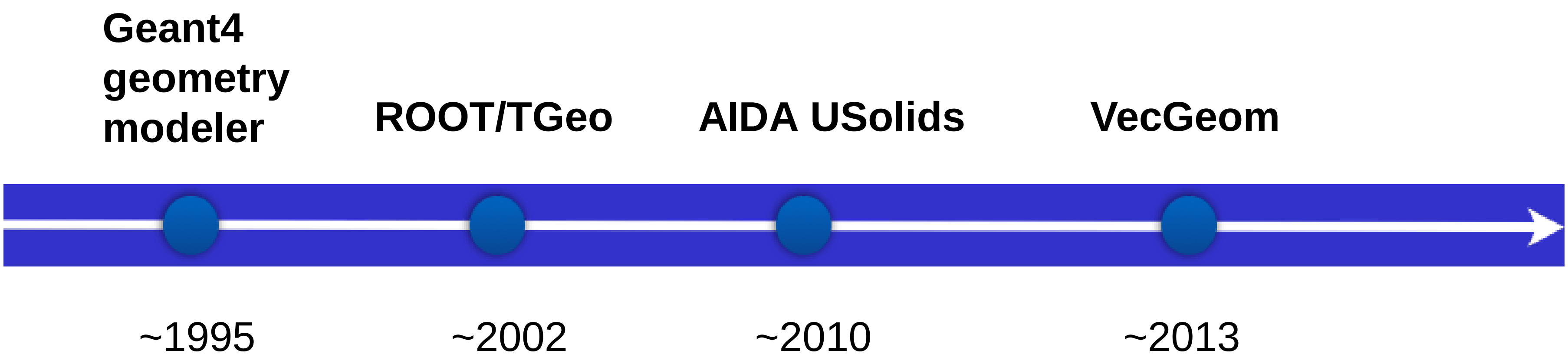
Simulation: DDG4

- Simulation = Geometry + Detector response + Physics
- Mature status
  - Eventual bug fixes, smaller improvements
- Improvements
  - Support for multiple primary vertices from a single input source
  - Multiple input sources were already supported
- Full framework used by the Linear Collider community
- Individual components used by the FCC community

Usolids/VecGeom

G.Cosmo, M. Gheata

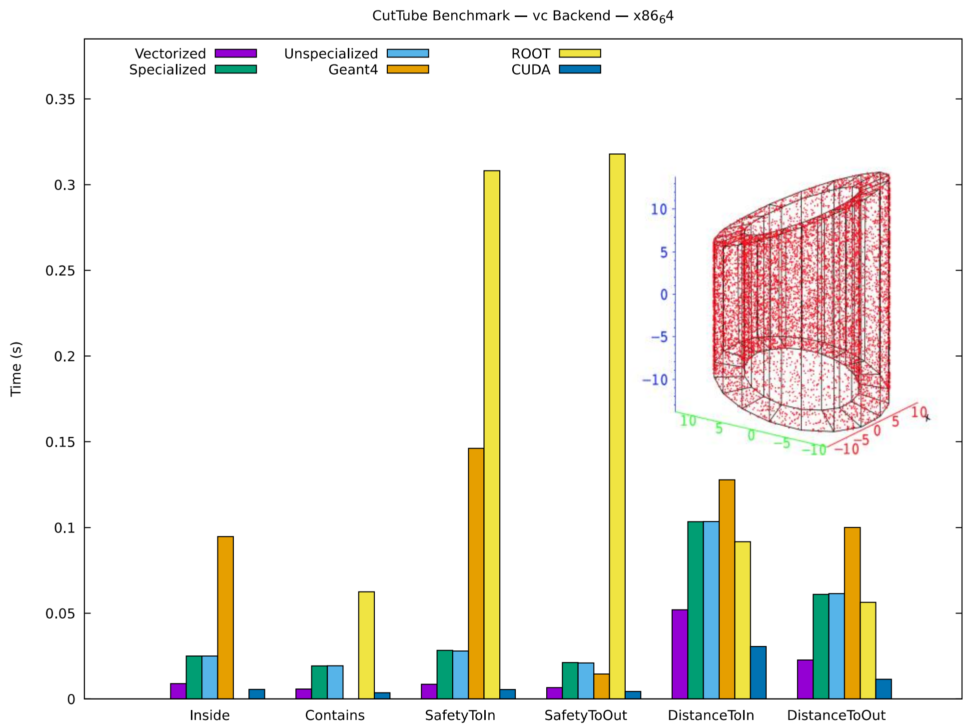
- USolids (Unified Solids) library: started as AIDA project
  - Aiming to develop a new library of geometrical primitives to unify and improve algorithms existing in Geant4 and ROOT
- VecGeom: started as a project for developing a vectorised geometry modeler (as main requirement of GeantV)
  - Vectorization of algorithms, boost further performance and port to parallel architectures



USolids/VecGeom MS 39 achieved

G.Cosmo, M. Gheata

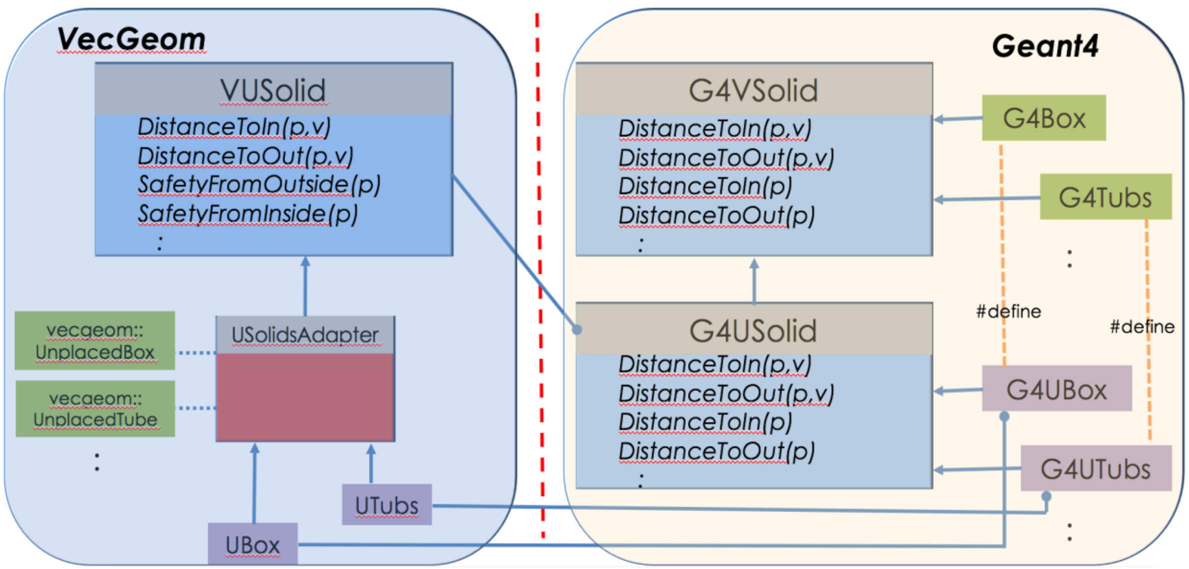
- Running prototype of USolids using SIMD instructions
- USolids package revised and extended to support vector signatures
  - usage of SIMD (Single Instruction, Multiple Data)
  - extension of API to provide vector signatures
- prototype is now available with VecGeom v00.03.00 and can be used for detector simulation in Geant4 and from ROOT
  - required for MS42



USolids/VecGeom MS 42 achieved

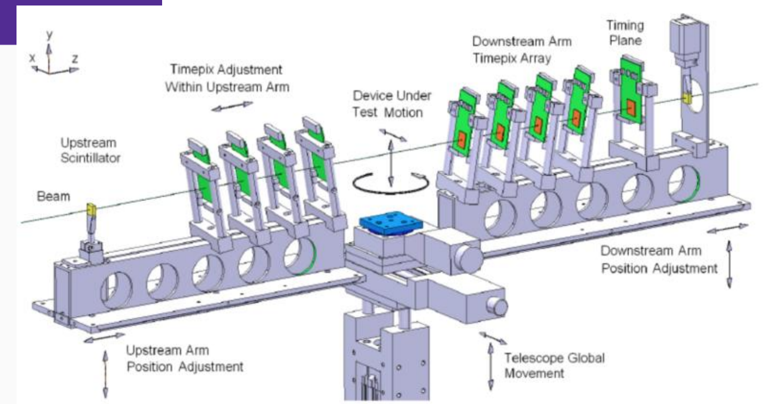
G.Cosmo, M. Gheata

- Running prototype for Geant4 based simulation toolkit
- Geant4 simulation toolkit can now make use of VecGeom primitives replacing the original Geant4 shapes
- latest Geant4 release 10.3 tested against VecGeom v00.03.00
- Validation performed on realistic detector setups like the CMS or the LHCb full geometries

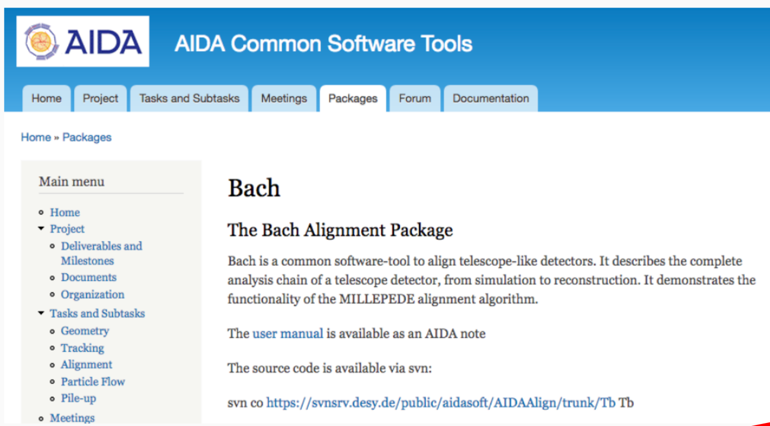


S.Borghi, C.Burr, C.Parks

The Bach alignment toolkit



- An package for the alignment of telescope like detectors
- Minimal external dependencies (ROOT+boost)
- Developed as part of the previous AIDA project


AIDA Common Software Tools

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Home » Packages

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  - Pile-up
- Meetings

Bach

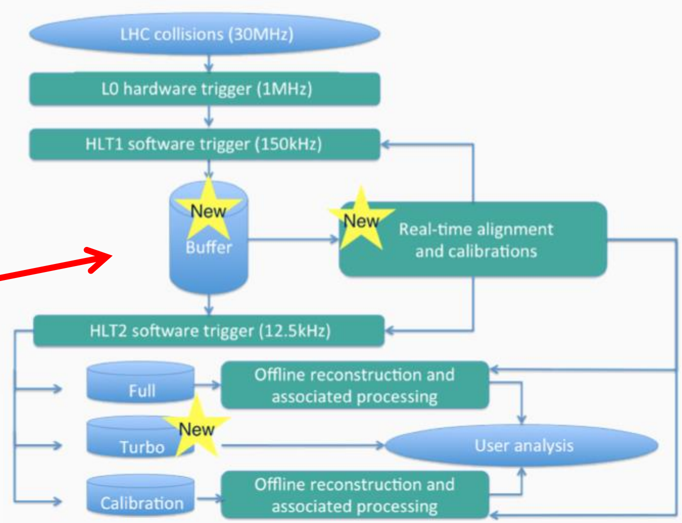
The Bach Alignment Package

Bach is a common software-tool to align telescope-like detectors. It describes the complete analysis chain of a telescope detector, from simulation to reconstruction. It demonstrates the functionality of the MILLEPEDE alignment algorithm.

The user manual is available as an AIDA note

The source code is available via svn:

svn co https://svnsrv.desy.de/public/aidasoft/AIDAAlign/trunk/Tb Tb

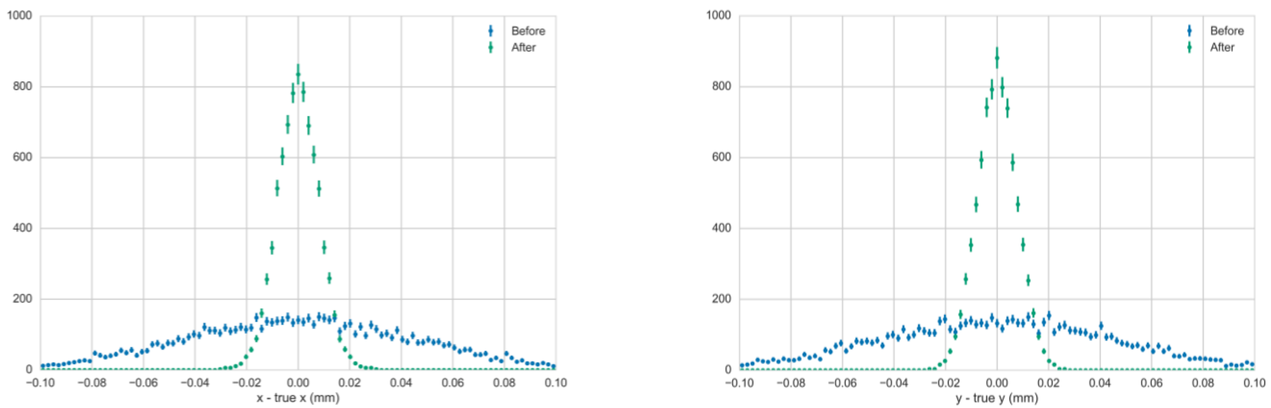


- In Run2, a novel real-time alignment procedure was developed at LHCb
- Alignment is evaluated within a few minutes for each fill and updated if needed
- Parallelised across ~ 1700 nodes of the online farm

Alignment MS40 achieved

S.Borghi, C.Burr, C.Parks

- Milestone: MS40 Running prototype for alignment toolkit
- prototype alignment package capable of correcting misalignments in DD4hep geometries
  - can be read back with DDAlign
- preliminary validation performed to show the true alignment can successfully recovered; future work further improve the integration with DD4hep.



Difference between the position of a detector element and the true position in x (left) and y (right). The blue points show the positions simulated with random misalignments. The green points show the position after running the alignment package.

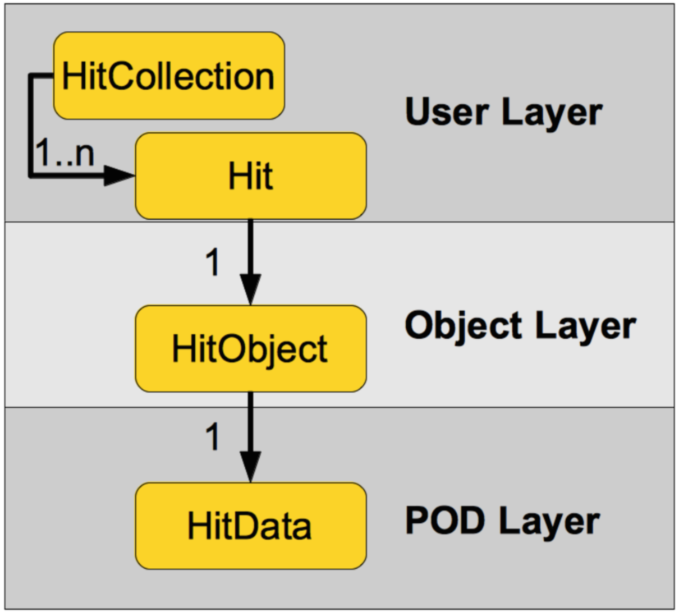
EDM Toolkit

B. Hegner, F. Gaede

- solving the problems of overly complex, deep object hierachies with many virtual function calls and non-optimal I/O performance
- exploiting C++ objects <-> Plain Old Data structures duality

Implementation: the three PODIO layers

- user layer (API):
  - handles to EDM objects (e.g. **Hit**)
  - collection of EDM object handles (e.g. **HitCollection**).
- object layer
  - transient objects (e.g. **HitObject**) handling vector members and *references* to other objects
- POD layer
  - the actual POD data structures holding the persistent information (e.g. **HitData**)



AIDA[2020] EDM Toolkit status

B. Hegner, F. Gaede

- EDM toolkit PODIO developed in context of FCC/LC
  - with general HEP in mind
  - storing EDM objects in arrays of PODs
  - currently using ROOT I/O
  - code automatically generated for C++ and Python
  - first implementation in full use by FCC

AIDA-2020-NOTE-2016-004

AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Scientific/Technical Note

PODIO: Design Document for the PODIO Event Data Model Toolkit

B. Hegner (CERN) *et al*

30 June 2016

AIDA[2020]

The AIDA-2020 Advanced European Infrastructures for Detectors at Accelerators project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

This work is part of AIDA-2020 Work Package 3: **Advanced software.**

The electronic version of this AIDA-2020 Publication is available via the AIDA-2020 web site <http://aida2020.web.cern.ch> or on the CERN Document Server at the following URL: <http://cds.cern.ch/search?p=AIDA-2020-NOTE-2016-004>

Recent Developments (since last annual meeting)

- moved to use C++14
- implemented support for I/O of *std::array*
  - needed iteration with ROOT developers
  - requires recent ROOT version
- simplified the example event store
- fixed a number of bugs and issues
- iterated on definition of FCC EDM
  - making use of new std::array features
- implemented streamer methods for EDM classes
- implemented prototype for usage with LCIO

Standardizing Gaudi condition handling

- Multi-processing is becoming too memory-intensive:
  - CPU core counts are exploding, but RAM prices vary slowly
  - Main memory bandwidth is becoming a major bottleneck
  - Importance of caches & scratchpads is increasing
- Result: many experiments must move to multi-threading
- Frameworks need to adapt to concurrent event processing
- One issue: time-dependent detector state, aka conditions
  - Detector state was historically modeled as a singleton...

Milestone MS41 achieved

RUNNING PROTOTYPE FOR PARALLEL ALGORITHM SCHEDULING MECHANISM

- main focus on the concurrent detector condition handling
- common condition handling interface for the Gaudi framework implemented allowing in particular to
  - Register condition inputs and outputs
  - Allocate and access condition storage through a backend-agnostic interface
  - Tune balance between event processing efficiency and condition memory usage.
  - Delegate the processing of the “raw” conditions to Gaudi algorithms
- https://gitlab.cern.ch/hgraslan/conditions-prototype

Advanced tracking tools

F.Gaede, H. Grasland

- Task objectives
  - Development of advanced parallel algorithms for track finding and fitting in AIDA Tracking Tool toolkit (aidaTT) Application to LHC and LC

- ACTS (A Common Tracking Software) was released as open source software
  - Based on ATLAS Run2 tracking software
  - Used for FCC, use planned for ATLAS Run3, interest from LC

- Decided to invest large fraction of the work in ACTS
  - Parallelization of track finding and fitting tools
  - Integration of generic pattern recognition tools from aidaTT Investigate application of ACTS to LC software

Discussion on Common Tracking Forum

by Frank Gaede, Markus Elsing

- idea was ground up initiative to develop tracking tools
- first ACTS releases exit, with repository + build system
  - ➡ see talk by Andi, some talks mentioned they develop against it already
- what are the next steps to make more codes available ?
  - ➡ detector independent ...
  - ➡ building/integration, against ACTS and/or standalone ?
  - ➡ who is interested ? how shall we go about it ?

Advanced tracking tools

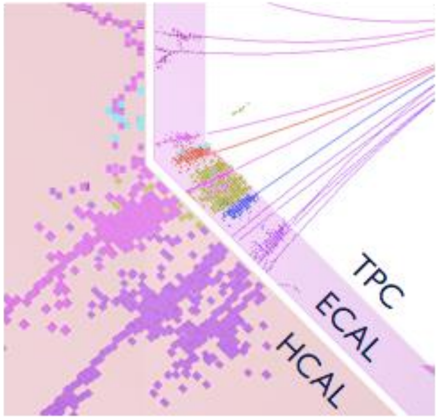
F.Gaede, H. Grasland

- recent LAL work on ACTS (A Common Tracking System)
  - made the ACTS test framework multithreaded, allowing to process multiple events in parallel
  - Recent activity: working on consistent implemention of *const correctness* in ACTS (remove *mutable* in code)

- DESY
  - Current focus on validation of tracking tools for two new ILD simulation models for large MC production
  - Started to evaluate use of ACTS for iLCSoft
  - Plan to contribute generic pattern recognition algorithms from iLCSoft (developed in AIDA) to the ACTS ecosystem
    - Activity planned for second half of the year

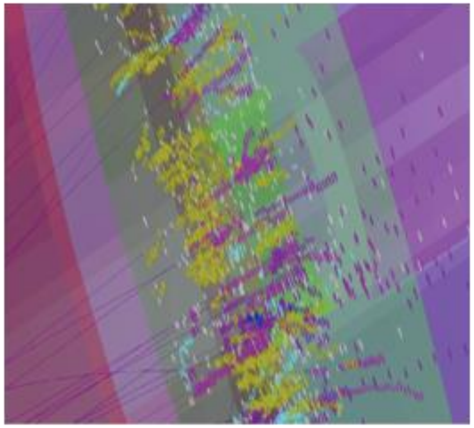
- **Continued support of Pandora Software Development Kit:** aids multi-algorithm approach to pattern recognition, with advanced reclustering and recursion abilities and visualisation.
- Development of new client applications, enabling use of algorithms for different detector concepts and in different software frameworks.
- Development of pattern recognition for both LC (inc. LHC upgrade) and LAr TPC. Continued validation and exploitation of existing algorithms e.g. via detector optimisation studies.

NIMA.2009.09.009, NIMA.2012.10.038



arXiv:1307.7335, 1506.05348

LHCC-P-008



AIDA2020 Advanced PFA

Pandora has been used for the official MicroBooNE summer analyses presented at Neutrino 2016

Public note available here

MicroBooNE Public Notes Page

Back to the Publications Page

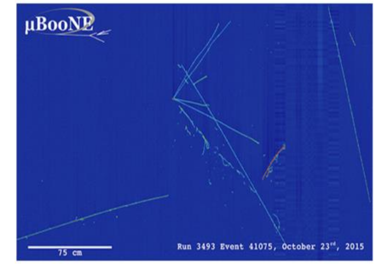
- 7/4/16 MICROBOONE-NOTE-1019-PUB
  Convolutional Neural Networks Applied to Neutrino Events in a Liquid Argon Time Projection Chamber
- 7/4/16 MICROBOONE-NOTE-1017-PUB
  A Method to Extract the Charge Distribution Arriving at the TPC Wire Planes in MicroBooNE
- 7/4/16 MICROBOONE-NOTE-1016-PUB
  Noise Characterization and Filtering in the MicroBooNE TPC
- 7/4/16 MICROBOONE-NOTE-1015-PUB
  The Pandora multi-algorithm approach to automated pattern recognition in LAr TPC detectors

MicroBooNE paper in preparation!(with the Editorial Board now)

n track
News for the Detector Community

Pandora: opening the box for neutrinos

Barbara Warmbein (DESY), 13/02/2017



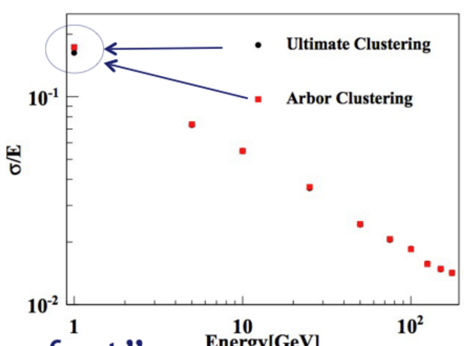
Pattern recognition rules in particle physics. When particles collide, many things happen at the

CERN: DDMarlinPandora

In the last year, the CERN group continued development of DDMarlinPandora interfacing DD4hep geometry and PandoraPFA reconstruction for high granularity calorimeters:

- More use of DD4hep Geometry information
- Replacing previous assumptions about the order of polygons
- updating track selection criteria for pure silicon tracking
- bug fixes

- Continuous cooperation between LLR (V. Boudry H. Videau, J.C. Brient), IHEP (M. Ruan, D. Yu, L. Liao) and IPNL (B. Li, R. Été) on ARBOR integration
  - Rémi Été's PhD defended March 2017.
    - Includes description of ArborPFA and integration in PandoraPFA on ILD cases



"perfect"

Cambridge: Pandora LC

- Final results for study optimising the calorimeters for future linear collider completed
- Full calibration procedure was applied to each detector model to ensure optimal performance was achieved

Summary

- AIDA-2020 Advance Software WP3 addresses core, simulation and reconstruction software for HEP
- all the WP3 tasks going according to the plan
  - good progress in the software development
  - good communication
    - running regular phone meetings (every ~6 weeks) with all the WP3 task coordinators invited
- all milestones until now achieved on time
- next deliverables for M32+ all well within the reach