AIDA 2020 3rd annual meeting Advanced Software (WP3) summary

Witek Pokorski

14.05.2018

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654168.

Content

- Overview of AIDA2020 annual meeting
- Overview of WP3
  - Deliverables and milestones
- Status of the tasks
- Conclusion

History

- FP6: EUDET: 2006-2010
  - Detector development for linear collider
- FP7: AIDA: 2011-2014
  - Detector development for LHC upgrades and linear colliders
  - Project-specific work packages
- FP8: AIDA-2020 started in May 2015
  - Common LC and LHC work packages
  - New communities: large cryogenic neutrino experiments, new topics
  - New innovation measures, with industry

Increasing level of integration

- **All projects have a strong leverage on matching funds**
- **Next call: closing in 2020**

Fact sheet

- Integrated infrastructure initiative in EU FP8 “Horizon 2020”

- “infrastructure”
  - Facilities
  - Common interest
  - Shared developments

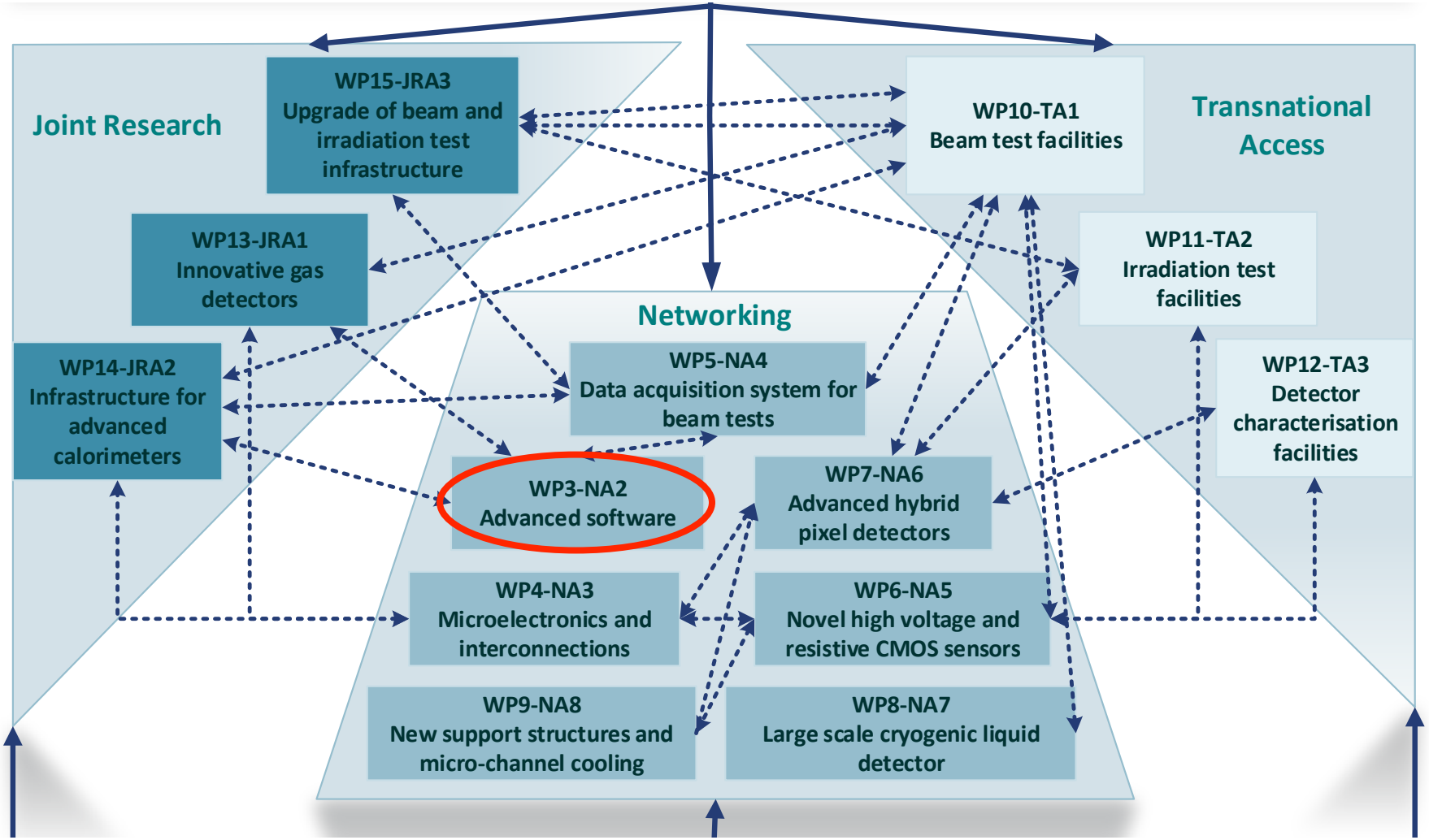
- Original duration: 1.5.2015 – 30.4.2019
  - extension under discussion

- EU contribution 10 M€
- Total budget 29.7 M€

https://aida2020.web.cern.ch

- Coordinating institute: CERN
- Scientific coordinator L.Serin (LAL) (-30.4.2016), F.Sefkow (DESY)

Work packages



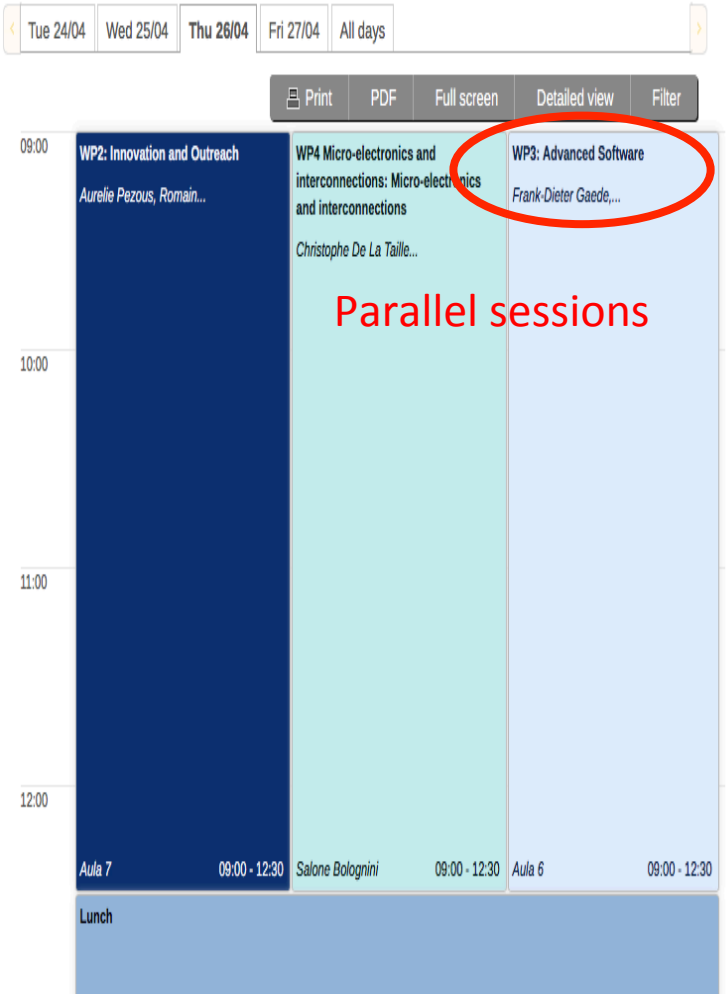
Project extension

- AIDA-2020 originally scheduled to finish May 2019
- next call (for 'FP9') closing in Spring 2020
  - gap of 1.5-2 years between end of AIDA-2020 and possible start of the follow-up
- AIDA-2020 management proposing to EC extension of the project
  - request made immediately after Annual meeting
    - **Benefits: Keeping the community together**
      - Bridging the gap w.r.t. to a follow-up project under a Call closing in March 2020.
      - Flexibility to some of the Deliverables
    - **Justifications:**
      - Increased impact (extended usage or scope of some Deliverables),
      - Need of extension due to external and unforeseen events
      - Committed TA units cannot be provided within the original project duration
    - **No additional reporting**
      - Period 3 will be extended by 12 months
      - The Final report will also be submitted after Month 60
    - **No additional EC funding**
      - Final payments (15% of the EC contribution) will be delayed by one year
    - **Eligibility of costs**
      - Costs claimed for year 5 should be related to activities in that year
      - But do not require a Deliverable to be postponed

AIDA-2020 Third Annual Meeting

24-27 April 2018
Centro San Domenico
Europe/Paris timezone

Agenda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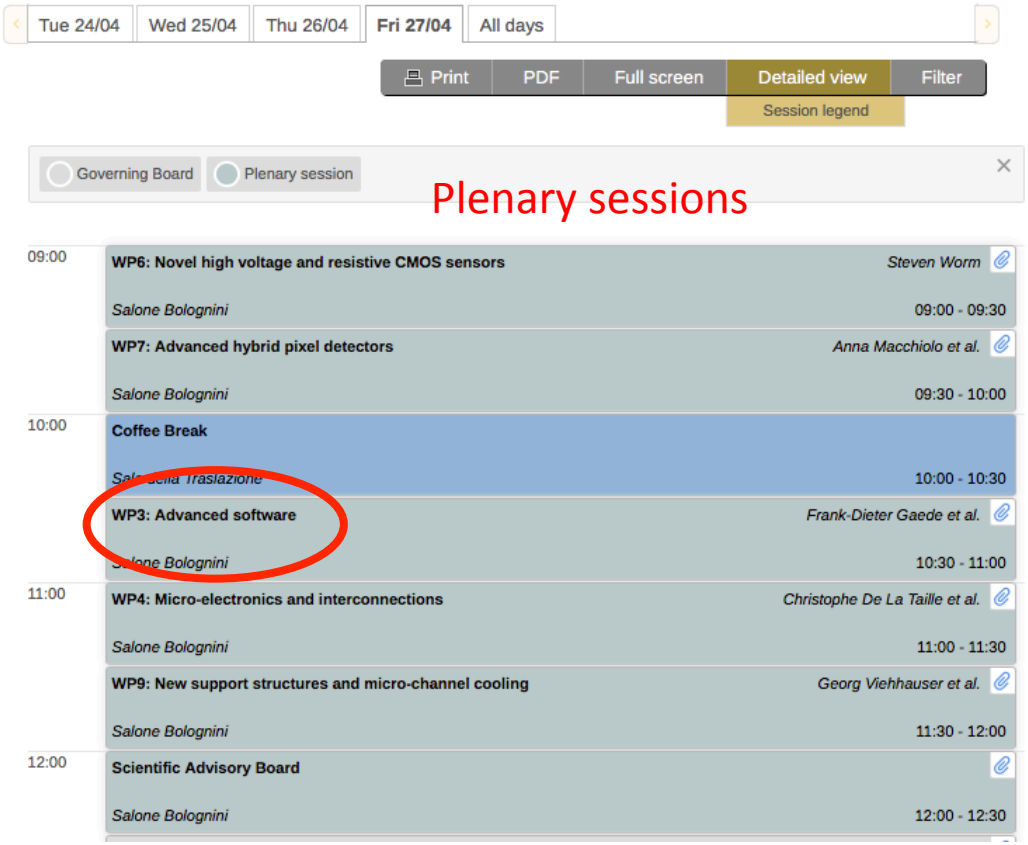
WP2: Innovation and Outreach
Aurelie Pezous, Romain...
Aula 7
09:00 - 12:30
WP4 Micro-electronics and interconnections: Micro-electronics and interconnections
Christophe De La Taille...
Salone Bolognini
09:00 - 12:30
WP3: Advanced Software
Frank-Dieter Gaede,...
Aula 6
09:00 - 12:30
Lunch
Parallel sessions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Governing Board
Plenary session
Plenary sessions
09:00
WP6: Novel high voltage and resistive CMOS sensors
Steven Worm
Salone Bolognini
09:00 - 09:30
WP7: Advanced hybrid pixel detectors
Anna Macchiolo et al.
Salone Bolognini
09:30 - 10:00
10:00
Coffee Break
10:00 - 10:30
WP3: Advanced software
Frank-Dieter Gaede et al.
10:30 - 11:00
11:00
WP4: Micro-electronics and interconnections
Christophe De La Taille et al.
Salone Bolognini
11:00 - 11:30
WP9: New support structures and micro-channel cooling
Georg Viehhauser et al.
Salone Bolognini
11:30 - 12:00
12:00
Scientific Advisory Board
Salone Bolognini
12:00 - 12:30

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

AIDA2020 WP3 Milestones and Deliverables

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

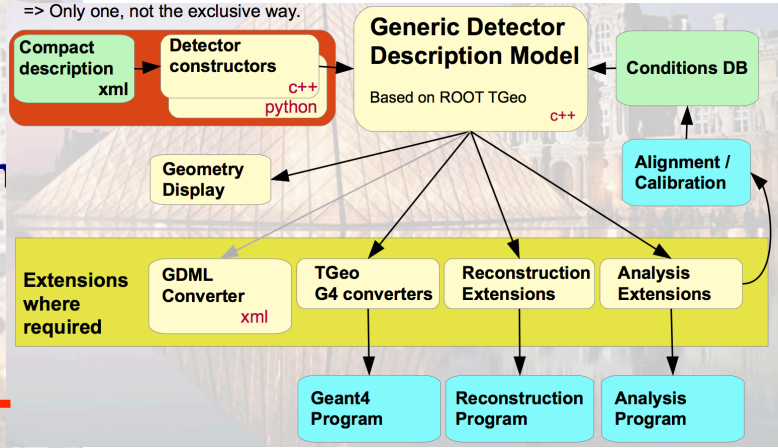
Introduction	*Witold Pokorski et al.*
Aula 6	09:00 - 09:05
DD4Hep	*Markus Frank*
Aula 6	09:05 - 09:25
DDG4	*Markus Frank*
Aula 6	09:25 - 09:45
VecGeom	*Mihaela Gheata*
Aula 6	09:45 - 10:05

Alignment and conditions data	*Christopher Mark Burr*
Aula 6	10:35 - 10:55
Event Data Model	*Frank-Dieter Gaede et al.*
Aula 6	10:55 - 11:15
Framework extensions	*Hadrien Benjamin Grasland*
Aula 6	11:15 - 11:35
Advanced tracking tools	*Hadrien Benjamin Grasland*
Aula 6	11:35 - 11:55
Advanced particle flow algorithms	*Vincent Boudry*
Aula 6	11:55 - 12:15
Session wrap-up	*Frank-Dieter Gaede et al.*
Aula 6	12:15 - 12:30

Task 3.2: DD4hep - goals

M.Frank

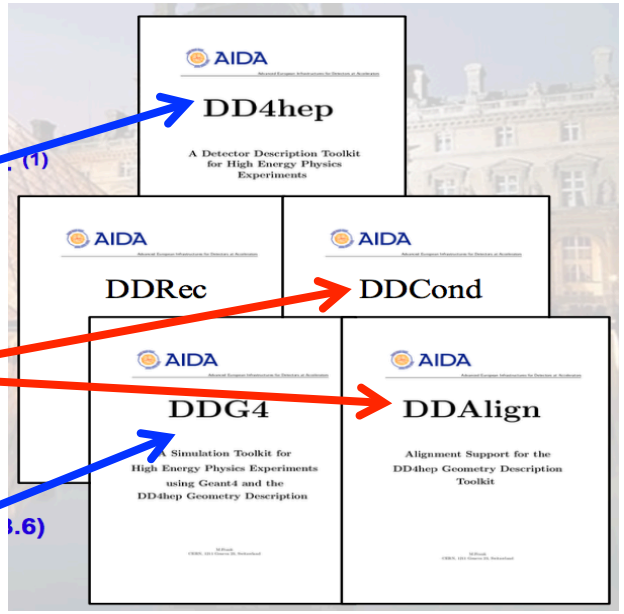
- **Develop a detector description**
  - **For the full experiment life cycle**
    - **detector concept development, optimization**
    - **detector construction and operation**
    - **“Anticipate the unforeseen”**
  - **Consistent description, with single source, which supports**
    - **simulation,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



core modules

current main development

simulation using Geant4



DD4hep/DDG4

M.Frank

Simulation: DDG4

- Simulation = Geometry + Detector response + Physics
- Mature status
  - Eventual bug fixes, smaller improvements
  - Phase of constant re-validation
- CLICdp implementation was presented at CHEP 2017 (M. Petric)
- Deliverable 3.6 Submitted in time March 2018


AIDA

Grant Agreement No: 654168

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GEANT4 BASED SIMULATION TOOLKIT DDG4

DELIVERABLE: D 3.6

currently used for large scale Monte Carlo productions by ILD O(10e8) evts

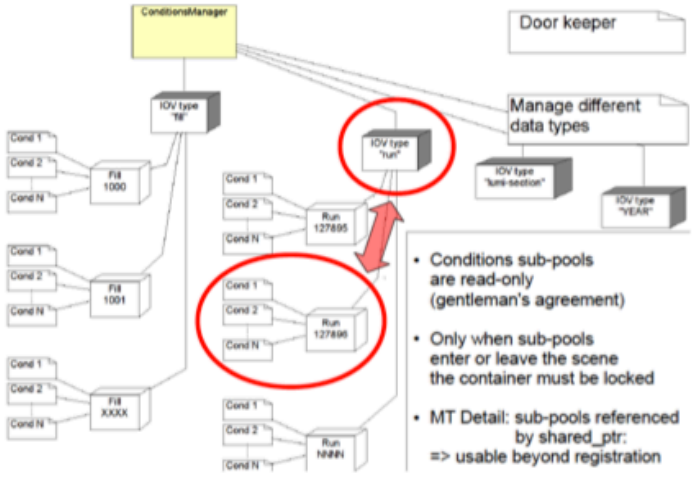
DD4hep/DDCond

M.Frank

DDCond: Conditions Data

- Time dependent data necessary to process the detector response [of particle collisions]
  - slowly changing: every run O(1h), lumi section O(10min) ...
  - multiple conditions change in batches: require discipline
  - conditions may be the result of computation(s)
- DDCond deals with the management of these da
  - Efficient and fast, if used according to design ideas
  - Manage resources
  - Supports multi threading by design
    Well define locking points
  - Cache where necessary but no more

- DDCond now finalized
- and used !



DDCond: Status

- Described functionality is implemented
  - Tested with LHCb conditions data
- Accomplished implementation deliverable D3.2, Submitted February 2018
  - Includes alignment support to handle geometry imperferctions
- Local Alignments are derived conditions
  - Convert Δ parameters (translation, rotation, pivot-point) to transformations to world or reference point


AIDA-2020

Implementation of DD4hep Extensions

Deliverable: D 3.2

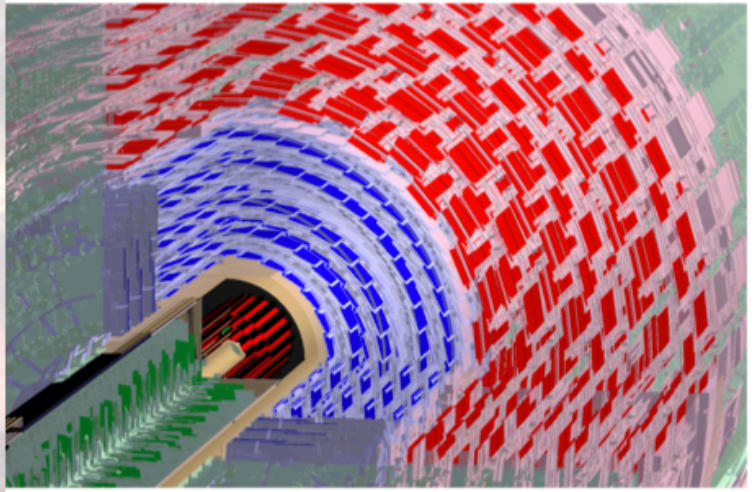
AIDA2020 April 26th, 2018 AIDA2020 Annual Meeting 2018, Bologna Markus Frank / CERN 15

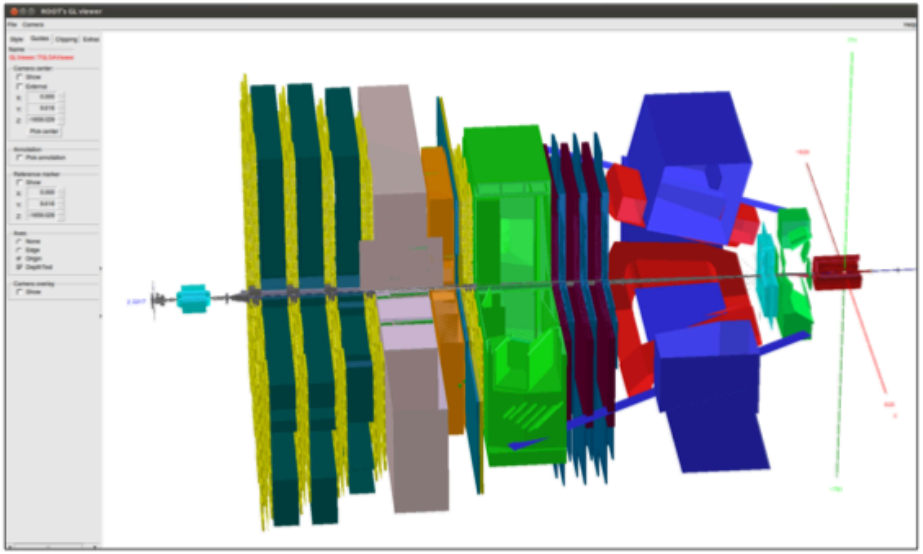
DD4hep Users

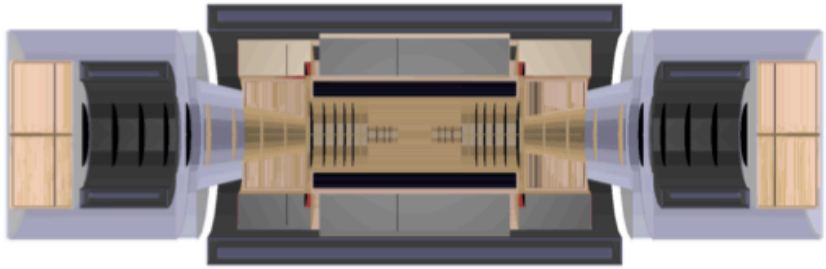
M.Frank

Increasing interest in the HEP community

ILC	F. Gaede et al.
CLICdp	A. Sailer et al.
SiD	W. Armstrong
FCC-eh	P. Kostka et al.
FCC-hh	A. Salzburger et al.
FCC-ee	O. Viazlo (CLD design), N. Alipour, G. Voutsinas
CMS	Evaluation for upgrade started (202x) (I.Osborne et al.)
LHCb	Evaluation for upgrade started (2019) (B.Couturier et al.)
CALICE	Calorimeter R&D, started
EIC	Evaluation considered/started





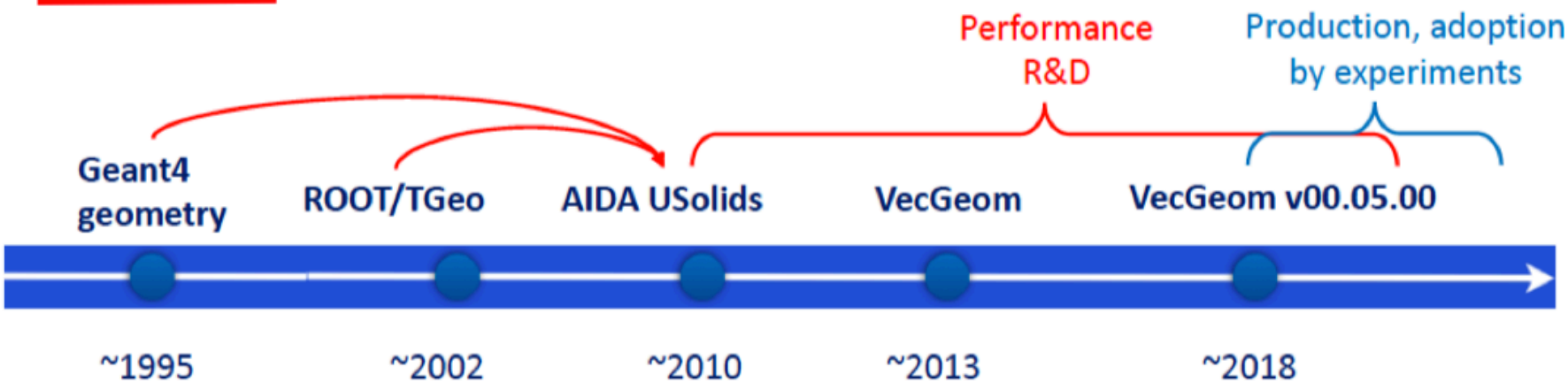


DD4hep about to become a real HEP community tool

USolids -> VecGeom

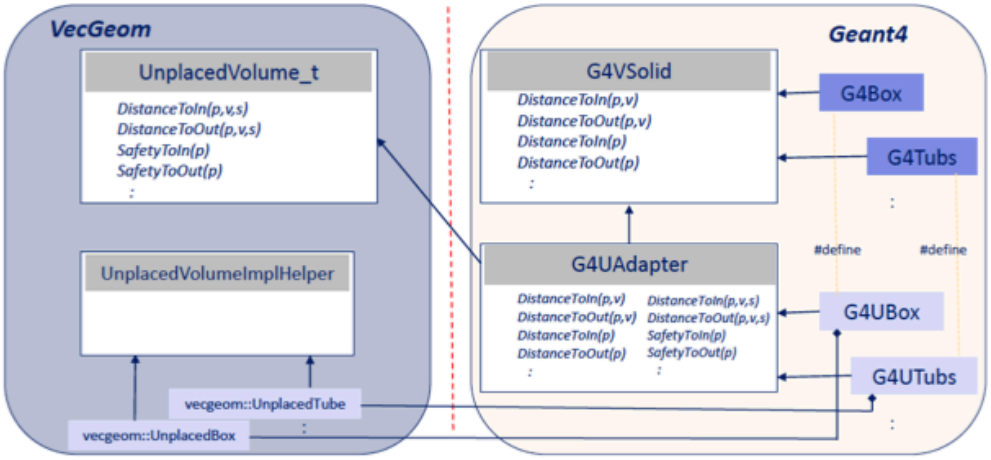
M. Gheata

- AIDA project aiming initially to unify and modernize geometry algorithms
- Scope extended to encompass parallelism/vectorization and multi-architecture/multi-platform support -> **VecGeom**
- 2018 marks phasing out the initial USolids implementation while entering the production phase for VecGeom
  - Adopted Apache 2.0 license
- Next: integration in ROOT & Geant4 as complete alternative to native navigation



VecGeom and Geant4

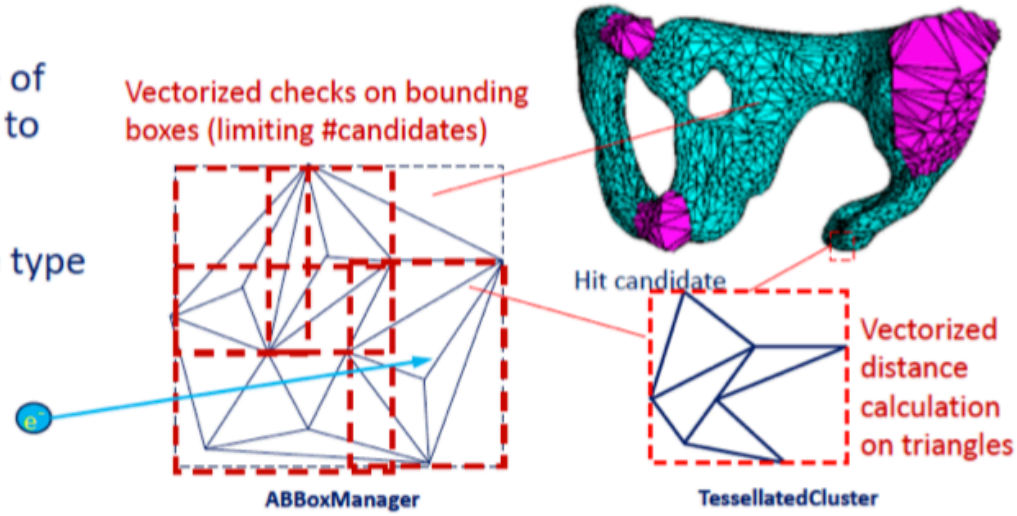
M. Gheata



- redesigned the interface between Geant4 and VecGeom shape classes
- VecGeom tested and validated to be used in Geant4 (since 10.3)

- In CMS, tests of Geant4 10.4 with VecGeom started early in 2017, during the development process
  - Coordinated work between the VecGeom, Geant4 and CMS teams
  - Observed 7-13% improvement in CPU performance with similar memory usage when using Geant4 10.4 + VecGeom
  - Decided to use VecGeom for 2018 productions

- Complete re-write of algorithms aiming to vectorize in single particle mode on facets of the same type (triangles)



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Advanced European Infrastructures for Detectors at Accelerators

Horizon 2020 Research Infrastructures project AIDA-2020

DELIVERABLE REPORT

IMPLEMENTATION OF EXTENSIONS IN USOLIDS

DELIVERABLE: D3.1

Document identifier:	AIDA-2020-D3.1
Due date of deliverable:	End of Month 32 (December 2017)
Report release date:	20/12/2017
Work package:	WP3: Advanced Software
Lead beneficiary:	CERN
Document status:	Final

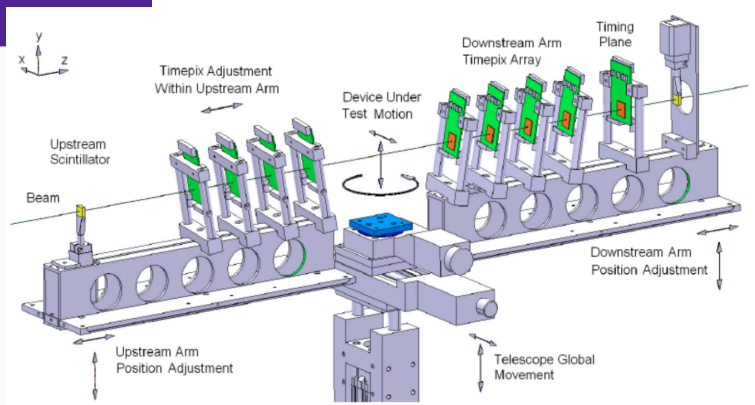
Abstract:

The Unified Solids (USolids) [1] interfaces have now been fully integrated within the VecGeom [2] library with extended vector signatures and implementing most of the shapes defining the standard set in the GDML schema [3]. This makes it possible in Geant4 [4, 5] version 10.4 to wrap calls to VecGeom directly and in a transparent manner, with minimal performance penalty. Preliminary tests done with both CMS and LHCb simulation applications using the new approach show overall performance gains of 5-8% compared to the native Geant4 primitives. Developments for new shapes such as the tessellated and extruded solids were focused on providing internal vectorization of the algorithm for the fast detection of facets intersections, with considerable performance gains compared to previous implementations. The global vectorised navigation interfaces of VecGeom are now completed and are used by the GeantV [6] prototype.

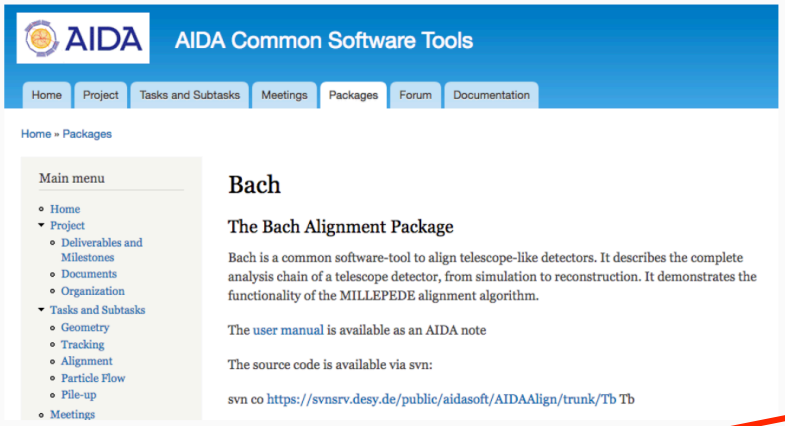
- improved vectorized treatment of many-faceted volumes (tesselated)
- restructured code
- created general purpose library: **VecCore**
  - used in ROOT, GeantV, experiments ...
- achieved Deliverable D3.2

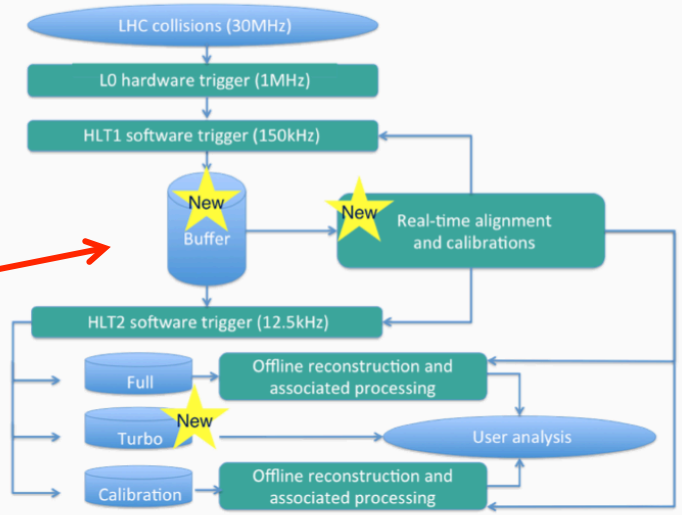
S.Borghi, C.Burr, C.Parks

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

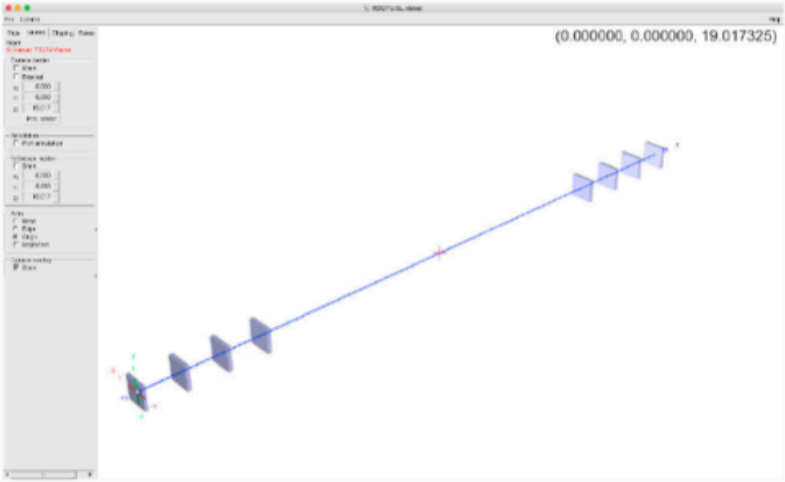




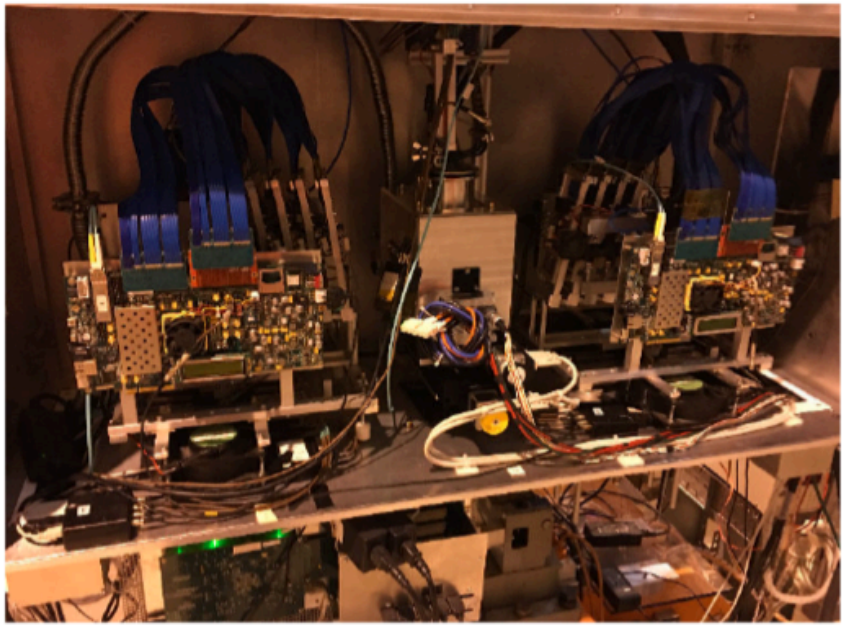
- In Run2, a novel real-time alignment procedure was developed at LHCb
- Alignment is evaluated within a few minutes for each fill and updated if needed
- Parallelised across ~ 1700 nodes of the online farm

AIDA2020 Bach recent developments

S.Borghi, C.Burr, C.Parks



- Test geometry needed to perform validation studies
- Developed a DD4hep driver for a "LHCb timpix3 telescope" like geometry



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DELIVERABLE REPORT

ALIGNMENT TOOLKIT

DELIVERABLE: D3.3

2. THE BACH ALIGNMENT PACKAGE

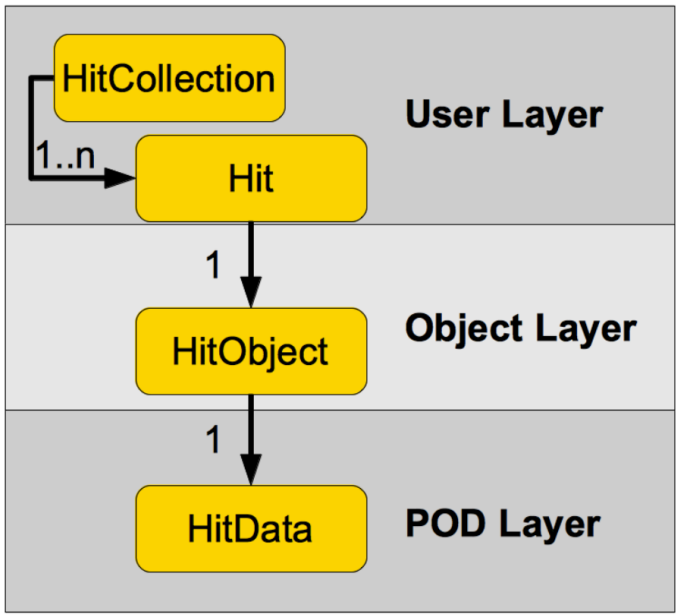
3. APPLICATION OF DD4HEP AND DDALIGN IN LHCB

- improved BACH alignment toolkit for telescopes
- implemented in **DD4hep** – using
  - **DDCond**
  - **DDAlign**
- applied to real Timepix3 telescope
- achieved Deliverable D3.3

- 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

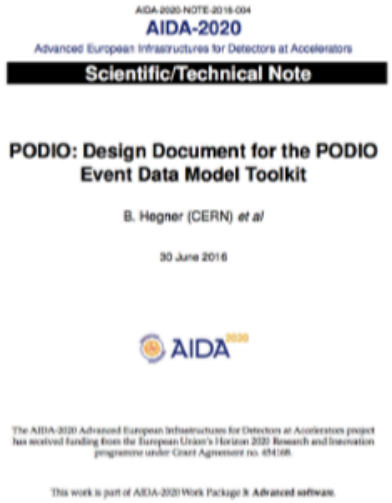
- user layer (API):
  - handles to EDM objects (e.g. **Hit**)
  - collection of EDM object handles (e.g. **HitCollection**).
- object layer
  - transient objects (e.g. **HitObject**) handling vector members and *references* to other objects
- POD layer
  - the actual POD data structures holding the persistent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



Milestones and Deliverables

Name	What	When
MS19	Design document for EDM Toolkit	M14
MS90	Application of EDM Toolkit to LC	M44
D3.4	Event Data Model Toolkit	M40

- reached MS19 on time
- some time to go for MS90 and D3.4
- **still on track to reach both in time**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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

AIDA2020

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 8: **Advanced software**.

- 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
  - under evaluation for LC

Framework Extensions

H.Grasland et al

- Original task objectives (from AIDA2020 proposal):
  - Parallel algorithm scheduling for HEP frameworks
  - To be developed in a framework-independent way
  - Then integrated in Gaudi, Marlin, PandoraPFA
- However, parallel Gaudi algorithm scheduling work was completed before AIDA-2020 started
- Decided to refocus on another obstacle to Gaudi parallelization, namely detector condition handling

Project status

- Done:
  - Devise a design which can work for any Gaudi user
  - Demonstrate and validate it through prototyping
- In progress:
  - Add some missing Gaudi infrastructure
- Pending:
  - Integrate condition handling prototype in Gaudi

Framework Extensions

H.Grasland et al

Running prototype

- All these concepts have passed the implementation test: https://gitlab.cern.ch/hgraslan/conditions-prototype
- Early performance numbers* are satisfactory:
  - Scheduling an event with "hot" conditions takes **~5.4 µs**
  - Reading a condition from an Alg takes **~10 ns**
  - Writing a condition takes ~0.3 µs
  - Scheduling condition IO takes ~$(12.3 + 0.3 \times N_{cond})$ µs
  - Deriving conditions takes ~$(1.0 + 0.1 \times N_{alg} + 0.3 \times N_{cond,out})$ µs
  - **No synchronization** on reads, fine-grained locks elsewhere

- suggested to postpone the deliverable to the extension period of AIDA2020
- started discussion on how this can be integrated with DDCond
- would like to also work on **Marlin parallelisation**

Summary

- Multi-threaded Gaudi needs better condition support…
  - …which, in turn, require reentrant data handles…
    - …which, in turn, require other framework clean up and rework
- All of this is being worked on
  - From the depths of the framework, going upwards

Advanced tracking tools

H. Grasland,F.Gaede

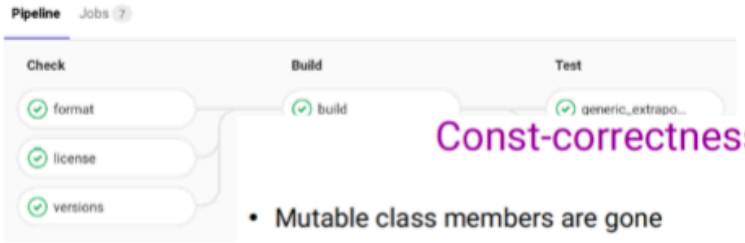
Task 3.6 – Advanced Tracking Tools

- Original task objectives (from AIDA2020 proposal):
  - Development of advanced parallel algorithms for track finding and fitting in AIDA Tracking Tool toolkit (**aidaTT**)
  - Application to LHC and LC
- Since then, ACTS 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 a large fraction of the work in ACTS:
  - Parallelization and optimization of ACTS tools
  - Integration of generic pattern recognition tools from aidaTT
  - Investigate application of ACTS to LC software

- LAL is already very actively contributing to ACTS
- investigating the use of ACTS for Belle II
  - time critical
  - effort needed ?

Parallel ACTS validation

- ACTS' test framework now runs in parallel **by default**
- Parallel run results are **bitwise identical** to sequential case
- This is validated by the test framework's CI…

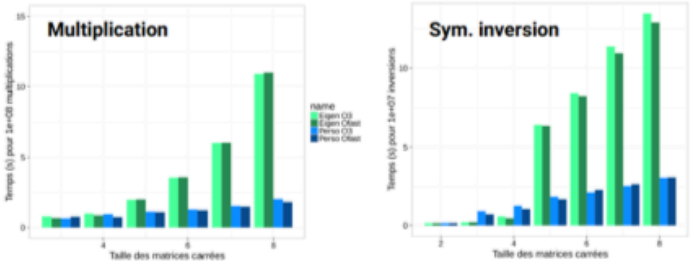


Const-correctness

- Mutable class members are gone
- Static variables are gone
- Fixed a couple const-incorrect interfaces along the way

Kalman Filter investigation

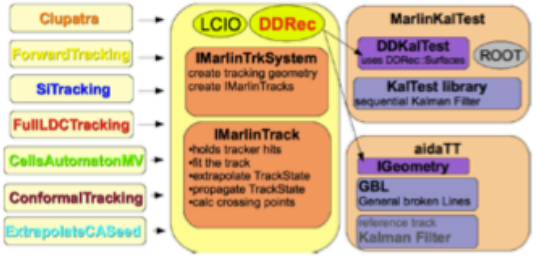
- Lucas Serrano investigated Kalman Filter vectorization
  - We previously knew that hand-written SIMD can outperform Eigen by factors of ~2x on 5x5 matrix algebra
  - Lucas proved that this can be done without sacrificing portability or a high-level code interface

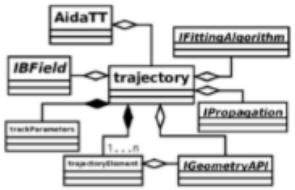


Advanced tracking tools

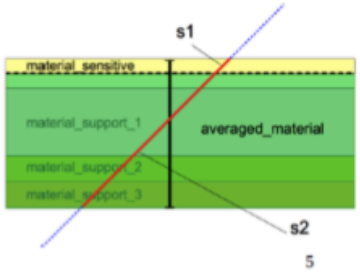
H. Grasland,F.Gaede

Tracking tools for Linear Colliders





- Developed in AIDA/AIDA2020:
  - MarlinTrk: abstract interface to track fitting for ILCSoft framework (Marlin, LCIO, ...)
  - aidaTT: interface for arbitrary track fitting tool
  - DDRec: geometry view for tracking in DD4hep-based detector models
    - uses *Surfaces* with material properties
  - Developed various – partly detector independent – pattern recognition algorithms
- Used by ILD, SiD, CLICdp (and FCC-ee)



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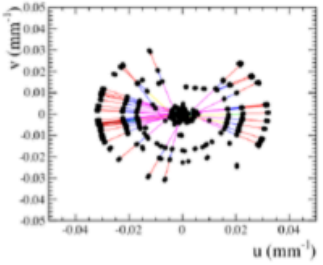
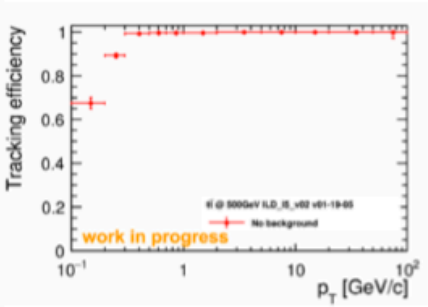
ConformalTracking for ILD

- pattern recognition developed for CLICdp
  - $u=x*r^{-2}$, $v=y^{-2}$, $r^2=x^2+y^2$
  - straight line search with *Cellular Automaton*
- code is rather detector independent



ConformalTracking



- Applied ConformalTracking to ILD
  - Si-trackers only (no TPC)
- Worked (almost) out-of-the-box
- Much improved efficiency at low p
- Could build a truly detector- (and framework-) independent version

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Plans for remainder of project

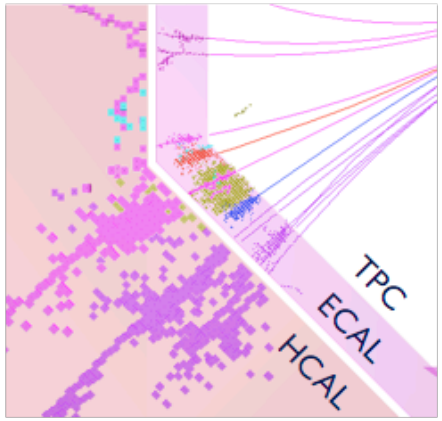
- at DESY strong focus on preparing large scale MC production – **done !**
- start to actively address tracking task
- will have to **delay D3.9 Advanced Tracking Tools (M39)** towards end of project

- Move focus to improving the tracking tools
- Plan to investigate the possibility of using ACTS in the aidaTT/ MarlinTrk tracking interface and application to LC
  - Need to understand the best way to interface to ILCSoft
  - First prototype of tracking in CLICdp-like tracking detector with ACTS exists (CLICdp group)
- Plan to contribute some of the detector independent pattern recognition to ACTS examples

Task 3.7: Advanced Particle Flow Algorithms

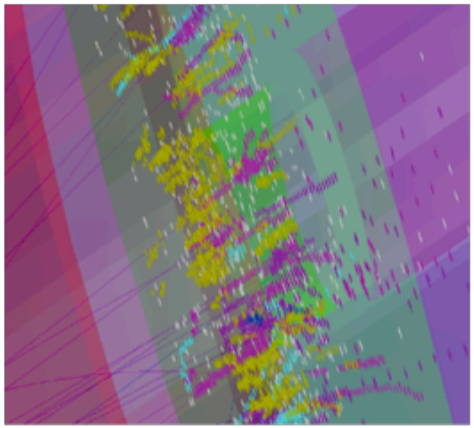
- Pandora - generic pattern recognition toolkit
  - originally implementing the Particle Flow Algorithms
  - now, large numbers (100+) of algorithms to address specific event topologies
  - widely used: ILC (ILD & SiD), CLIC, MicroBooNE, DUNE, CMS HGCAL upgrade studies

NIMA.2009.09.009, NIMA.2012.10.038



arXiv:1307.7335, 1506.05348

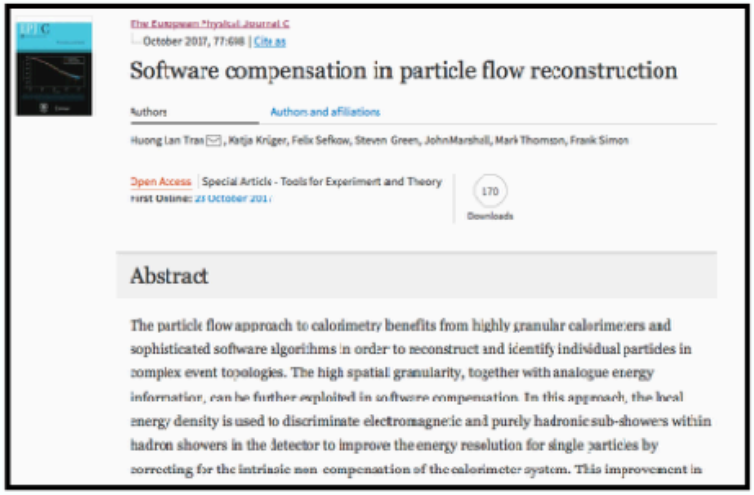
LHCC-P-008

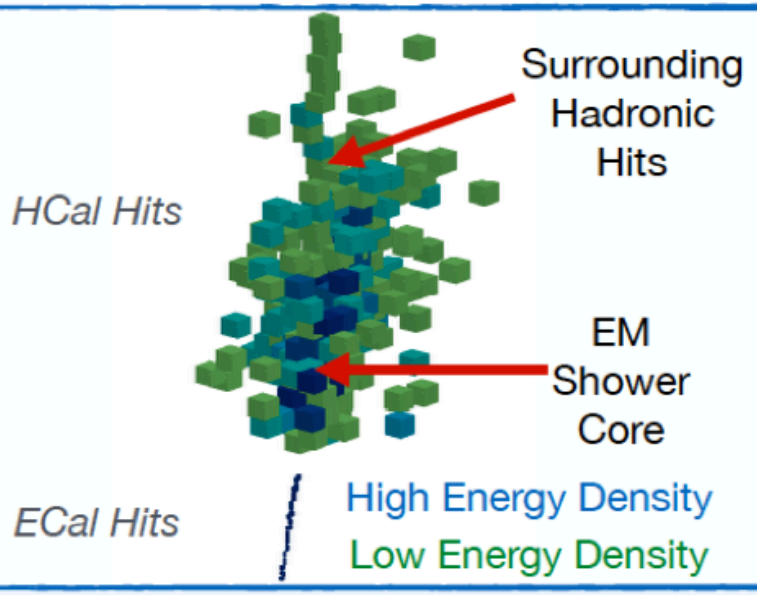


AIDA2020 Advanced PFA: Pandora

V.Boudry

- There is continued exploitation of the Pandora pattern recognition at the linear collider.
- A paper describing a novel software compensation technique applied inside Pandora was published in October 2017.
- This technique compensates for the invisible energy component found in hadronic showers by reweighing the energy of calorimeter hits based on their energy density.
- Many thanks to F. Simon and H.L.Tran for their efforts getting this to publication!





Software Licenses

- recommendation from SAP at last annual meeting:
  - all AIDA2020 software tools should have a proper **license**
  - this is essentially the case now
- however:
  - most tools are released under **GPLv3**
    - strong copy-left license (used to be standard CERN recommendation for HEP)
  - recent discussions in context of HSF and LHC experiments discourage the us of **GPL** and would prefer **LGPL**
    - weak copy-left license, more compatible w/ most other open source licenses
  - started discussion among software developers in WP3
  - in principle should be able to re-license relevant packages
    - need agreement of all copyright holders ...

Summary

- AIDA-2020 is starting it's 4th year
  - very likely to be extended by 1 year until May 2020
  - next annual meeting in Oxford (spring 2019)
- 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 M38 all well within the reach

- due to the extension, suggested to delay 3.5 (Framework Extensions) to AIDA2020 extension
  - will probably also have to delay D 3.7 (Advanced Tracking Tools)