Alignment in the ATLAS computing model

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on behalf of the ATLAS alignment community

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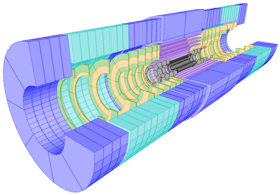
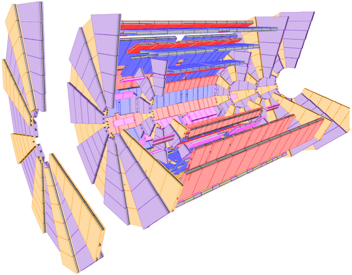
Overview of ATLAS alignment tasks

1 Internal alignment of the Inner Detector

- mostly track based, plus FSI in SCT
- 7 mechanically independent subdetectors
- $\sim$ 6000 modules $\times$ 6 DoF $\Rightarrow$ in overall about 36000 DoFs
- Alignment tolerances, μm:

	Azimuthal	Radial (Brl/EC)	Axial (Brl/EC)
Pixel	7	10/20	20/100
SCT	12	100/50	50/200
TRT	30	–	–





2 Internal alignment of the Muon Spectrometer

- based mostly on optical sensors, plus muon tracks in overlap regions
- 3 large subsystems
- 1252 MDT precision chambers each with 6 positional DoF and 8 deformation parameters $\Rightarrow$ about 17500 DoFs in total
- alignment tolerance is 30 μm in R-z plane

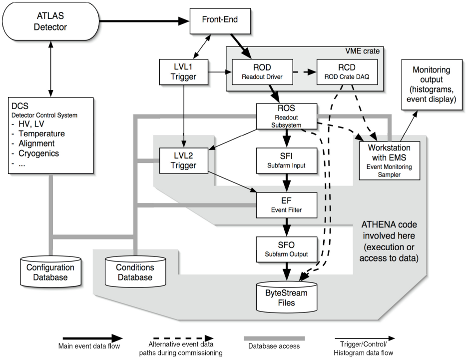
3 Global alignment of the Muon Spectrometer and Calorimeter with respect to the Inner Detector

- alignment tolerance is on the level of few hundred microns

Alignment constants in data processing

Goal of the alignment tasks: generate alignment constants which are needed for the proper reconstruction of ATLAS event data

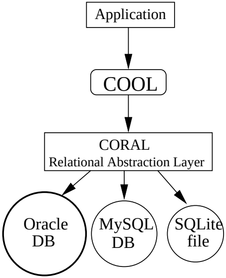
- processing in HLT system (online)
  - the ID alignment constants from previous fill/day are used
  - the MS optical alignment system works as part of DCS and can update alignment constants (not all of them) once per hour
- first-pass, or prompt, reconstruction
  - alignment constants must be computed within 24 hours after the end of the fill before the start of first-pass reconstruction of the physics stream from this fill at Tier-0
  - the ID alignment algorithms are run on a special alignment stream from the EF
  - the global fit of the MS optical sensors and muon tracks data from a special muon alignment stream from LVL2 trigger is performed
- reprocessing of event data 2-3 months after acquisition
  - aiming at the ultimate detector performance, improved alignment constants will be produced from the full reconstructed physics data sample for the reprocessing



Storage of alignment constants in ATLAS conditions database

Alignment constants are stored in the COOL conditions database which associates stored data with some *interval of validity (IOV)*

IOV_{start}	IOV_{end}	$(ChannelID_1)$	(Tag_1)	$Payload_1$
IOV_{start}	IOV_{end}	$(ChannelID_2)$	(Tag_2)	$Payload_2$



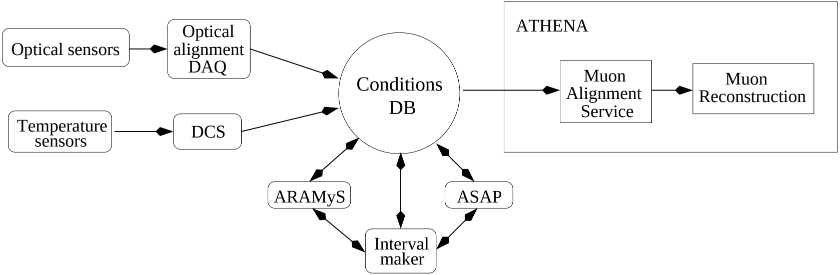
- IOV is 63-bit integer which can be interpreted as absolute timestamp or Run/Luminosity Block number for which a particular set of constants is valid
- multiple tags can be used to distinguish between sets of constants valid for the same interval but produced by different algorithms or corresponding to different processing passes
- payloads with alignment constants
  - for the ID – referenced POOL ROOT files which contain actual data objects with alignment δ-transforms (CLHEP HepTransform3D objects)
  - for the MS – Oracle tables with alignment A-lines and B-lines (stored as $CLOB$s within the CondDB itself)
- size of alignment constants payloads (uncompressed): ~70 kB for the MS and ~150 kB for the ID

Production of alignment constants: general remarks

What is needed for production of alignment constants:

- Input data
  - for the ID – bytestream files from the Event Filter containing tracks with associated ID hits
  - for the MS – analyzed images from the optical alignment DAQ plus bytestream files from the Level2 Trigger containing muon tracks with associated MS hits
- Alignment algorithms
  - for the ID – three alignment algorithms are used within ATHENA framework (which one will be used during real data taking is not decided yet)
  - for the MS – two optical alignment programs (ASAP and ARAMyS) plus an ATHENA algorithm for track based alignment
- Computing resources (CPUs, disk space, network bandwidth)
  - rather moderate requirements, exact numbers are still under evaluation
  - alignment of the MS is a more involved procedure in terms of required infrastructure: number of data file transfers, number of Conditions database connections and updates, synchronization issues

Production of alignment constants in MS: optical alignment

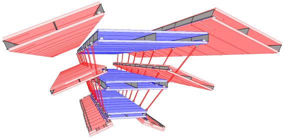


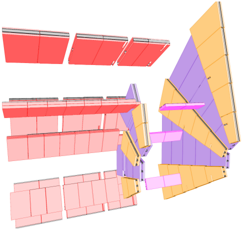
- a separate cluster of $\sim$15 CPUs, located in the ATLAS pit, is used to run optical alignment DAQ and reconstruction programs
- ASAP and ARAMyS run χ^2 minimization on optical sensors data online $\Rightarrow$ new sets of alignment constants can be computed once per hour
- a special sequence of images is saved to disk once per day ($\sim$600 MB)
- ARAMyS can produce 100% of the alignment constants for the muon system endcaps, ASAP can output $\sim$80% of the alignment constants for the barrel part
- the remaining 20% of the barrel alignment constants must be obtained from reconstruction of muon tracks in overlap regions between the optically aligned chambers and chambers without projective optical alignment

Production of alignment constants in MS: muon alignment data stream

- The special muon alignment data stream from the Level2 Trigger contains MS hits within a predefined road around muon tracks found by μFast algorithm (part of TDAQ system)
- To be included in the stream, the muon tracks must pass through one of the overlap regions between:
  - small and large barrel chambers
  - BEE chambers and endcap EMS/EIS chambers
  - $BIS8$ and $BIS7/EMS$ chambers
  - $BOL/BML/BIL$ and EML chambers (barrel-to-endcaps alignment)

- Estimated stream parameters: muons with $p_T > 6$ GeV, rate ∼100 Hz, events size ∼2 kB, ∼15 GB of data per day
- The stream data files are copied to Munich MDT calibration center (part of Munich Tier-2) where a track based alignment algorithm is run (∼30 CPUs are allocated for this task)
- Output of the track based alignment (track pseudo-sensor data) is stored in the Conditions database from which ASAP/ARAMyS program can extract it for the second, combined, fit of the optical and tracking data to produce all of the alignment constants
- An additional data stream from the Event Filter containing high p_T muons which pass through several overlap regions might be set up

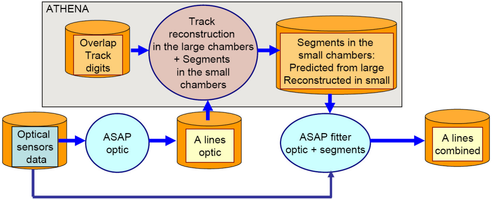




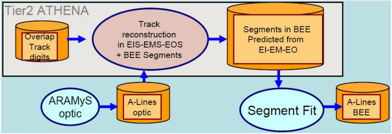
Production of alignment constants in MS: combined optical and tracking data fit

- A combined fit of the muon optical and tracking data can be done by ASAP/ARAMyS using a few CPUs (in principle, just one is enough) $\Rightarrow$ the final location is not yet decided (most likely CERN Tier-0)

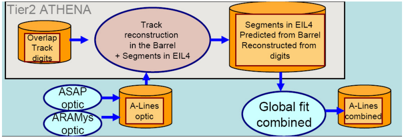
Small-to-large barrel chambers alignment



BEE chambers alignment



Barrel-to-endcap alignment

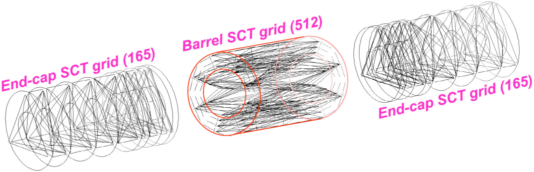


Production of alignment constants in ID: alignment data stream

- The special ID alignment data stream from the Event Filter contains ID tracks with associated hits selected by a special algorithm
- Track selection requirements:
  - track $p_T > 2$ GeV
  - well separated (no ambiguities) and well reconstructed (enough hits) tracks
  - a correct mixture of track topologies is crucial
    - prescaling of redundant tracks
    - bookkeeping of different track topologies
- Estimated stream parameters: rate $\sim$100 Hz, events size $\sim$10 kB, $\sim$30 GB of data per fill
- The stream data files are stored at Tier-0 where the alignment algorithm is run
- CPU requirements: $\sim$40 for Pixel$+$SCT alignment, $\sim$20 for TRT alignment and calibration

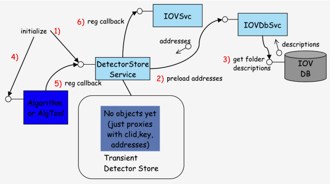
Production of alignment constants in ID: FSI system in SCT

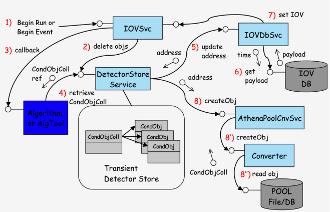
- Frequency Scanning Interferometry is an online alignment system which monitors SCT shape stability over short (mins) and long (months) periods of time with expected precision of $\sim$1 μm
- FSI system has been just recently deployed $\Rightarrow$ many open issues, the code is still under development
- Computing model aspects of the FSI operation:
  - the program which calculates SCT distortions from grid measurements can be run on a single CPU
  - $\sim$400 MB of raw data per grid measurement
  - readout frequency varying from every 10 min to every hour $\Rightarrow$ at least 12 GB of raw data per day
  - load on the Conditions database: $\sim$300 kB of grid data plus $\sim$100 kB of updated alignment constants for SCT modules per measurement



Dataflow of alignment constants in offline reconstruction and simulation

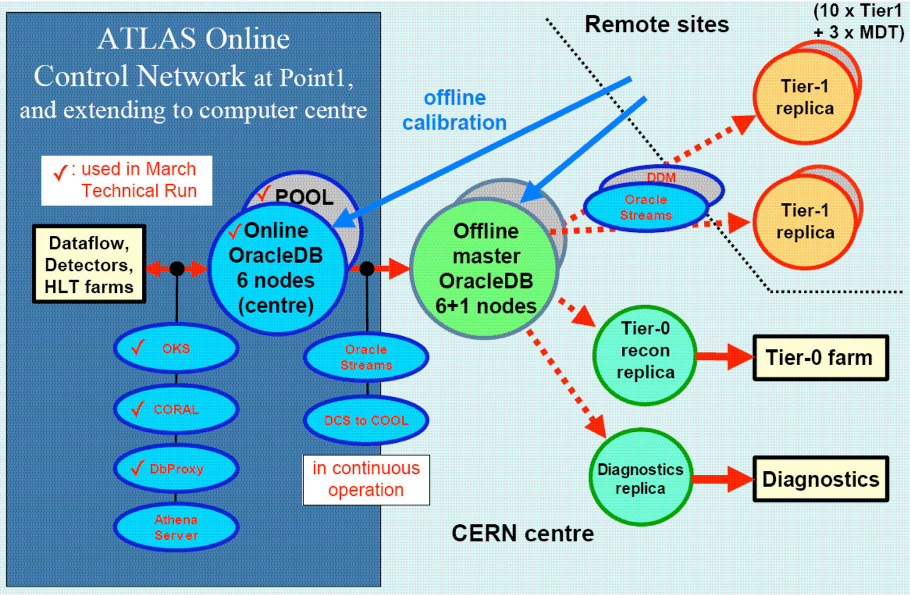
- Client algorithms in reconstruction and simulation packages can retrieve alignment constants via interfaces provided by *DetectorStoreSvc*
- *IOVSvc* keeps track of the validity of alignment constants at BeginRun/BeginLuminosityBlock incidents and triggers a retrieve of a new set of constants
- *IOVDBSvc* provides interfaces to the COOL database: manages DB connections, fetches intervals and data payloads from COOL database
  - registers interval of validity with *IOVSvc*
  - returns payload as a reference ($IOpaqueAddress$) for ATHENA conversion service to "read in"
- *AthenaPoolCnvSvc* provide interfaces for converting of objects stored in persistent format (POOL ROOT files and Object Relational DBs) to DetectorStore transient format





- MDT deformations can be properly treated in reconstruction but are not simulated in GEANT4 ⇒ deformations must be applied at digitization level

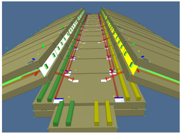
ATLAS conditions database operations

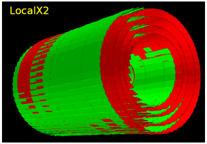


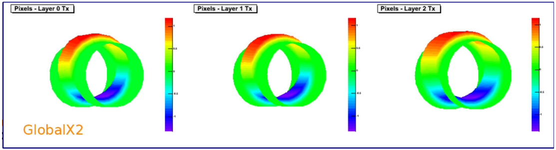
slide from Hans von der Schmitt

Additional tools for alignment

- ATLAS is establishing a Data Quality Monitoring Framework
  - the same software is run on different data samples
  - comparison to reference histograms and quality criteria is done automatically (plus manual look-throughs by shifters)
  - web pages with DQMF histograms and comparison results are automatically generated
- ID alignment is following this suit, while MS optical alignment has its own monitoring tools (JdbPlot: Java based database browser)
- several visualization tools are used by the ATLAS alignment community: HEPvis, ATOS, ROOT OpenGL viewer







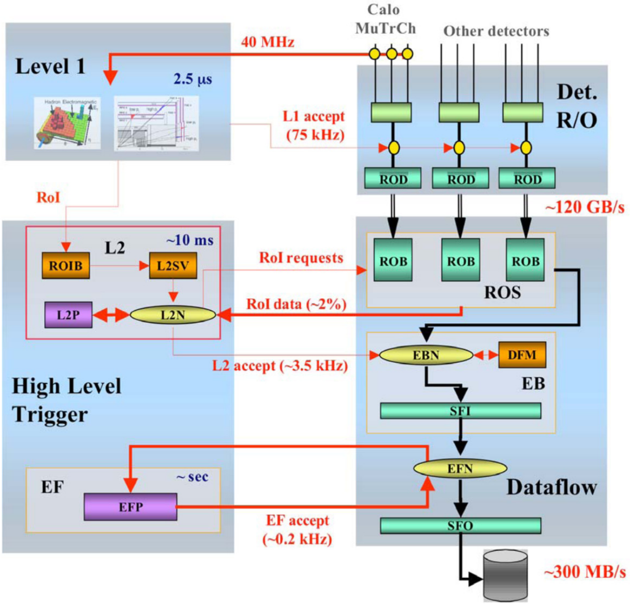
Summary

- Requirements on the computing resources posed by the ATLAS alignment tasks are quite moderate:
  - $\sim$45 CPUs for the Muon Spectrometer (15 online, 30 offline) and $\sim$60 CPUs for the Inner Detector
  - $\sim$15 GB for the MS and $\sim$80 GB for the ID of data output per day
  - alignment constants payloads for the Conditions database are $<$1 MB per day, optical sensors data amounts to $\sim$10 MB per day
- Core software to output alignment data streams from the ATLAS TDAQ/HLT system is written and being tested
- Conditions database infrastructure for storing and retrieving of alignment constants is in place
- MS optical alignment system (almost) fully operational
- Track based algorithms for computing alignment constants are well advanced

Still a lot of testing and validation work needs to be done

Backup slides

ATLAS TDAQ/HLT architecture



ATLAS Data Quality Assessment