Upgrade of ATLAS data quality monitoring for multithreaded reconstruction

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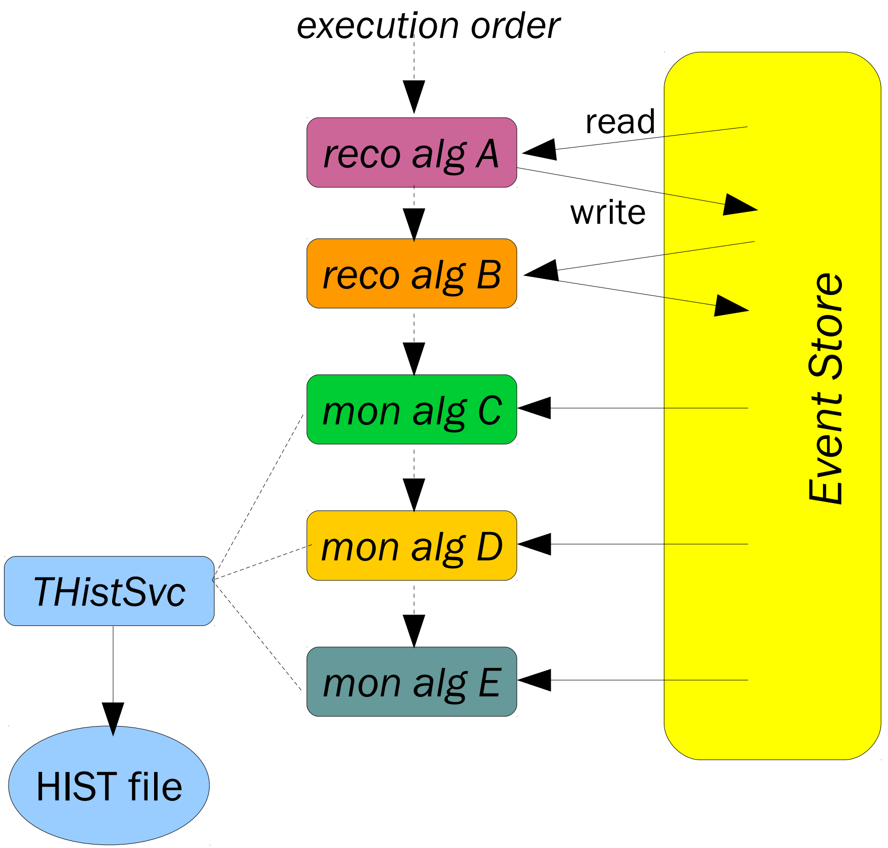
Scope

- "Monitoring" here = "making histograms" (& other ROOT objects)
  - Online (control room) → status of detectors
  - Offline (post-reconstruction) → status of detectors, calibrations, reco software
- Specifically covering changes in "AthenaMonitoring"
  - i.e., monitoring that uses the Athena framework to make histograms and runs as part of the reconstruction workflow
- Not covering visualization, automated extraction of DQM decisions, persistency …

online apps: see talk by Serguei Kolos

Athena Execution

- A sequence of *algorithms* is run in an order determined by Python configuration
- Algorithms can execute *tools* and interact with *services*
  - e.g., THistSvc service to persist TH1, etc. into ROOT files
- Event data read from/written to whiteboard



Current Implementation

- AthenaMonitoring is part of the standard Athena codebase
  - provides base classes for Athena *tools* that generate histograms
  - generic Athena *algorithms* manage monitoring tools
  - provides top-level configuration of monitoring depending on reconstruction settings
- Runs in several modes
  - *offline*: either directly in reconstruction or as an afterburner
  - *online*: specialized Athena jobs that sample & reconstruct raw events as they are being recorded
- DQM is memory-intensive
  - a typical single-core offline reconstruction job: ~ 80k histograms, ~ 1 GB in memory

DQ Code Anatomy

- User code subclasses a parent monitoring tool class
- User code is responsible for:
  - initial memory allocation of histogram
  - histogram binning & properties (declared in C++)
  - holding raw pointers to histograms & filling them
- Common code is responsible for:
  - applying event filters (trigger, standard cleaning, …)
  - storing the histograms in appropriate locations in output ROOT files
  - rebooking histograms when necessary (e.g. for time-dependence)

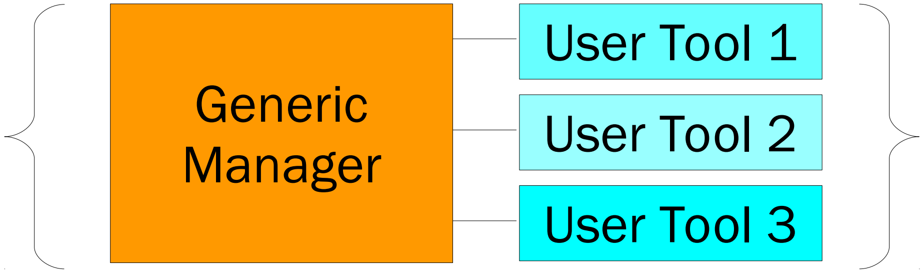
```
InDetPixelMonManager          tauMonManager
InDetSCTMonManager            JetTagMonManager
TRTMonManager                 RpcLv1RawMonManager
InDetAlignMonManager          RpcLv1SLRawMonManager
GlobalMonManager              CscRdoBsRawMonManager
GlobalMonPhysicsManager       MdtRawMonManager
L1CaloMonManager              RpcRawMonManager
L1MonManager                  RpcTrackMonManager
CTMonManager                  rpcLv1RawEfficiencyMonManager
HLTMonManager                 TgcRawMonManager
IDPerfMonManager              TgcLv1RawMonManager
InDetDiMuMonManager           CscPrdRawMonManager
ManagedAthenaTileMon          CscClusterEsdRawMonManager
LArMonManager                 CscSegmEsdMonManager
CaloMonManager                MdtVsRpcRawMonManager
EgammaMonManager              MdtVsTgcRawMonManager
ETmissMonManager              MuonTrackMonManager
JetMonManager                 LucidMonManager
```

Monitoring algs in a typical Athena reco job

Athena "Algorithm"

instance of standard AthenaMonManager class

directly scheduled in reconstruction



Athena "Tools"

instances of user subclasses of ManagedMonitorToolBase

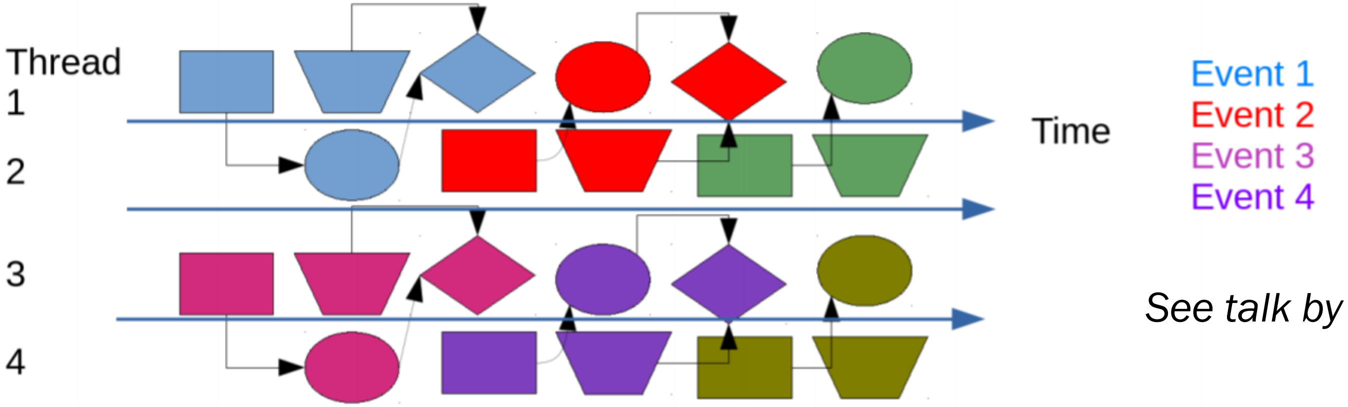
executed by parent algorithm

Challenges in Existing Framework

- User code declares histograms & other objects
  - C++ declaration → changing histogram binning often requires new Athena releases!
  - user code needs to know underlying technology, e.g. TH1F vs TH1D vs TProfile vs non-ROOT
  - Adding new types of objects to the framework that aren't subclasses of TH1 / TGraph / TTree (e.g. TEfficiency) is *hard*: ROOT object memory, I/O semantics are wildly variable
- User code has raw pointers to histograms, controls memory by default
  - strongly limits what central management code can do, e.g. implementation of rebooking of time-dependent histograms is very fragile
  - transitions to new technologies have uneven adoption

The Multithreaded Future

- LHC Run 3: Athena → AthenaMT
  - multiple threads, multiple events in flight
  - reduce memory/core by reducing # of needed algorithm instances in a job
- Algorithms need not be scheduled by user
  - algorithms & tools declare dependencies via the data they consume/produce
  - scheduler builds dependency graph, determines order of execution
- For thread-safety, algorithms can be
  - *legacy* – only one instance, use serialized;
  - *cloneable* – multiple instances, with separate memory;
  - *re-entrant* – single instance, simultaneous use by multiple threads

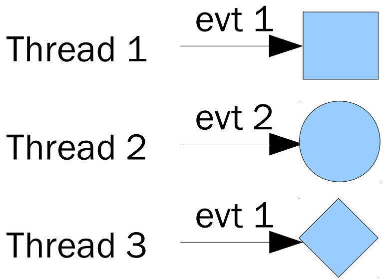


Different shapes: different algorithms; different colors: different events.

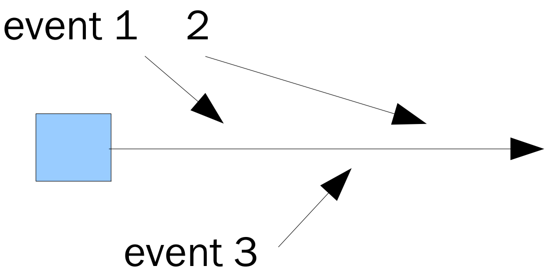
See talk by Scott Snyder

Concurrency & Multithreading

- Strictly speaking, algorithm concurrency is not really needed for monitoring code in AthenaMT
  - many relatively small pieces of code, produce no event data so no interdependencies ⟶ can execute multiple monitoring algorithms in parallel
  - do *not* want to clone monitoring algorithms – this clones their histograms, with huge memory cost!
  - re-entrancy is necessary only for massive parallelism, requires thread-safe histograms

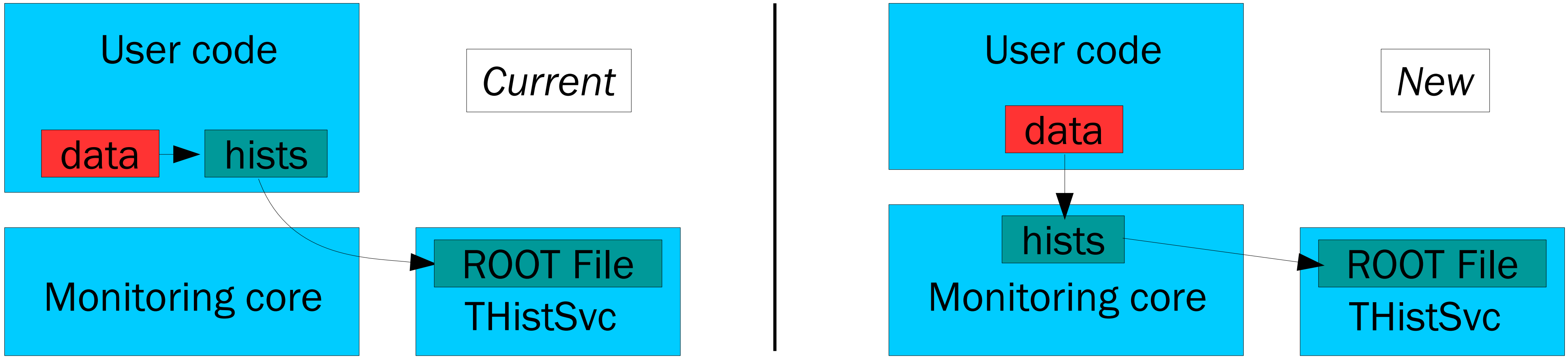


- Monitoring algorithms could see events out of order
  - upsets assumptions of strict time-ordering



Conceptual Design

- Move management, filling of histograms to centralized code
  - user code declares variables to be monitored
  - central code fills and manages histograms
  - central code configured to fill histograms with Python scripts
  - underlying technologies can be changed, adapted without changing user code
- Adopts a solution proposed for monitoring in the High Level Trigger upgrade



Practical Example

C++: definition of monitored variables

```
using namespace Monitored;
auto et     = MonitoredScalar::declare<float>( "Et", 0 );
auto ex     = MonitoredScalar::declare<float>( "Ex", 0 );
auto ey     = MonitoredScalar::declare<float>( "Ey", 0 );
auto phi    = MonitoredScalar::declare<float>( "Phi", 0 );
auto sumet  = MonitoredScalar::declare<float>( "SumEt", 0 );
auto sourceIndex = MonitoredScalar::declare<int>( "SourceIndex", 0 );
```

C++: retrieval of monitored information into variables

```
auto &monTool = m_sourcesMonTools[ m_sourcesToolMap[xaod_key] ];
ex = (*xMissEt)[xaod_subkey]->mpx() / CLHEP::GeV;
ey = (*xMissEt)[xaod_subkey]->mpy() / CLHEP::GeV;
et = (*xMissEt)[xaod_subkey]->met() / CLHEP::GeV;

if (et > 0.) {

    phi = (*xMissEt)[xaod_subkey]->phi();
    sumet = (*xMissEt)[xaod_subkey]->sumet() / CLHEP::GeV;
    Monitored::save( monTool, et, ex, ey, phi, sumet );
```

retrieve data

take snapshot

Python: definition of histograms to book

```
from AthenaMonitoring.GenericMonitoringTool import GenericMonitoringTool, defineHistogram

def srcMonTool( src, etRange, nEtBins=800, nPhiBins=100, doProfiles=False ):
    mon = GenericMonitoringTool(src)
    mon.HistPath = "Srcs"
    mon.ExplicitBooking = True

    mon.Histograms = [ defineHistogram( "Et;Et_" + src, title="Et Distribution (%s);MET Et (GeV);Events"  % src,
                                        xbins = nEtBins, xmin = 0.0, xmax = etRange ),
                       defineHistogram( "Ex;Ex_" + src, title="Ex Distribution (%s);MET Etx (GeV);Events" % src,
                                        xbins = nEtBins, xmin = -etRange, xmax = etRange ),
                       defineHistogram( "Ey;Ey_" + src, title="Ey Distribution (%s);MET Ety (GeV);Events" % src,
                                        xbins = nEtBins, xmin = -etRange, xmax = etRange ),
                       defineHistogram( "Phi;Phi_" + src, title="Phi Distribution (%s);MET Phi (radian);Events" % src,
                                        xbins = 100, xmin = -math.pi, xmax = math.pi ),
                       defineHistogram( "SumEt;SumEt_"+ src, title="SumEt Distribution (%s);SumEt (GeV);Events"  % src,
                                        xbins = nEtBins, xmin = 0.0, xmax = etRange*10 ),
                       defineHistogram( "SumEt,Et;metVsSumEt_"+src, "MET Vs SumEt Distribution (%s);SumEt (GeV);MET Et (GeV)" % src,
                                        xbins = nEtBins, xmin = -etRange*10, xmax = etRange*10 ),
                       defineHistogram( "Phi,Et;metVsSumEt_"+src, "MET Vs MetPhi Distribution (%s);MET Phi (radian);MET Et (GeV)" % src,
                                  xbins = nEtBins, xmin = -etRange*10, xmax = etRange*10 ),
    ]
    return mon
```

configure one histogram filling tool per MET source

1D histogram

2D histogram

Lessons Learned

Discoveries about a 10+ year old codebase…

- Many features of the current system are unused
  - will remove and simplify

e.g. "fill"-length histograms, annotations for parent trigger chain

- Users use many ROOT features
  - things like alphanumeric bin labels, varying bin widths, etc. are easy enough to implement
  - need to be able to make all standard ROOT object types (TH*, TProfile, TGraph, TTree …)
- Logic for quantities of interest can be complex
  - example: "distribution of mean per-event occupancy over the many modules of this subdetector"
  - not possible to express as a purely per-event fill operation; requires a postprocessing step after accumulation – map/reduce

“No-build alternative”

- “No-build”: what if we tried to change as little as possible? Development work is costly…
- Make existing monitoring algorithms “legacy” - only one instance of each in an AthenaMT job, access serialized
  - fine in principle as long as access to ROOT files is thread-safe
- Not truly “no-build”:
  - all AthenaMonitoring code needs some modification to enable the AthenaMT scheduler to work,
  - the ATLAS-developed sparse histogram solution is not thread-safe and not planned to be modified
- Strongest motivation to change: allow us to replace backends without user intervention
  - e.g. migration to ROOT 7 histograms can be handled centrally
- “No-build” and “build” are not exclusive

Summary

- ATLAS framework for data quality monitoring in Run 1 and 2 has worked well, but is inflexible, fragile, and requires a lot of users
- Transition to multithreaded AthenaMT framework in Run 3 → good opportunity to move to a more flexible system
  - separate extraction of data features from histogramming code
  - ease introduction of new features by centralizing implementation
  - prototype code in place
  - Fallback to “Run 2-style” monitoring is possible but user code needs to adapt to AthenaMT regardless
- Requires an audit of how people currently use the monitoring
  - attempt to address all practical use cases

Monitoring birds-of-a-feather session: 1 pm in Room 7.2