DAQExpert

An expert system to increase CMS data-taking efficiency

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ON BEHALF OF THE CMS DAQ GROUP

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Track: 1. Computing Technology for Physics Research

Topic: Online computing

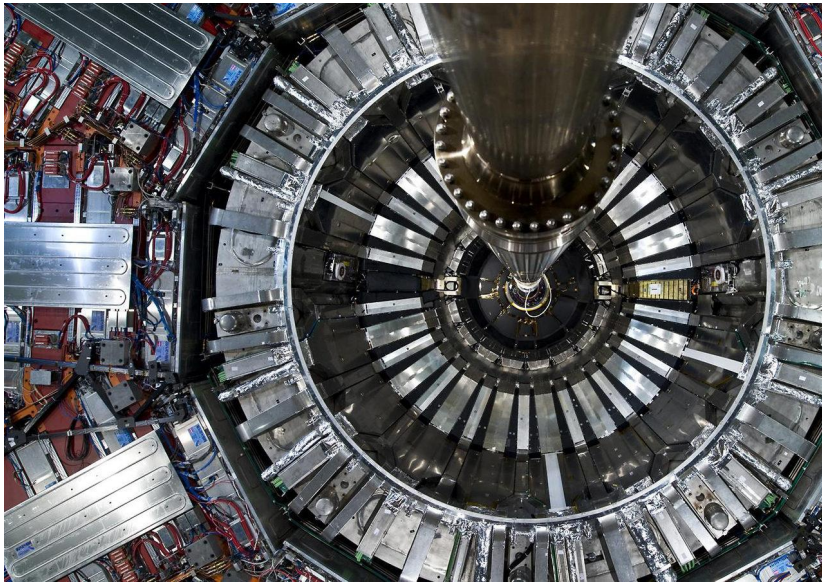
Subtopic: Advanced Monitoring, Diagnostics and Control

CMS - Compact Muon Solenoid

1. data-taking efficiency
2. operator crew challenges
3. automation in operations

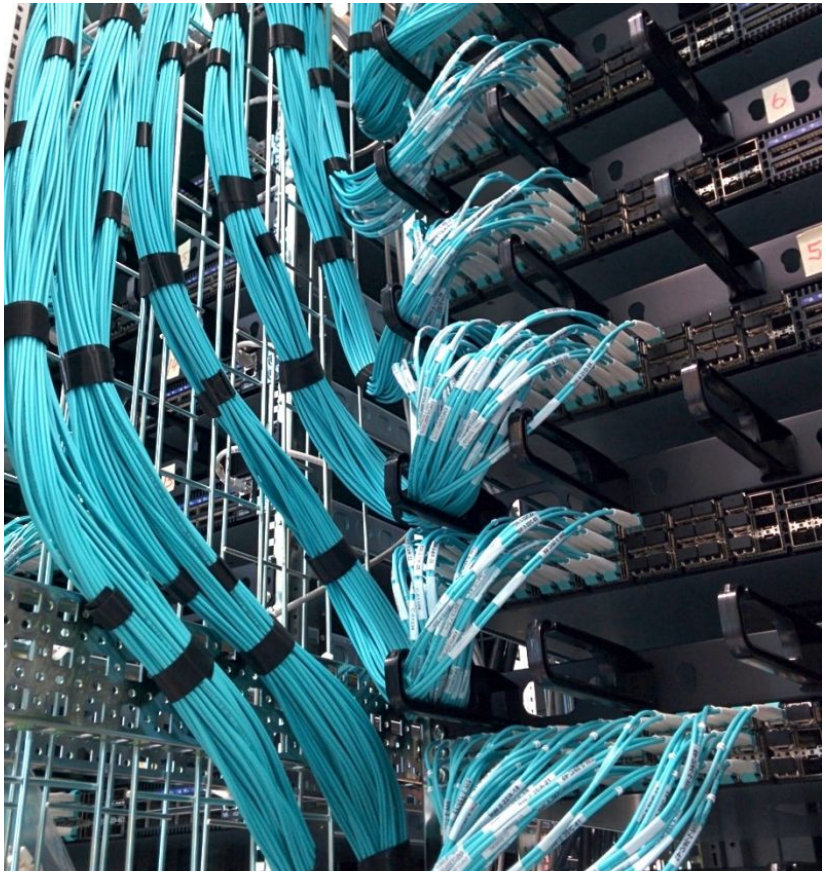
Basic information

- general -purpose detector @ LHC, CERN
- Higgs Boson discovery (as 1 of the 2 experiments)
- 21x15x15 m, 12 500 tonnes



DAQ -
Data Acquisition 1

- read out the data
- banch crossing 40 MHz rate
- event size 1-2MB
- 2-level triggering
- hardware trigger selects 100 kHz
- full events built at 200GB/s
- 26 000 cores in HLT farm select O(1 kHz)



DAQ - Data Acquisition 2

- human operators 24/7
- sometimes dataflow is stuck
  - recovery procedures
  - challenging during time-critical operations
- human on-call experts 24/7
- 5% downtime
- optimize this part of the operations

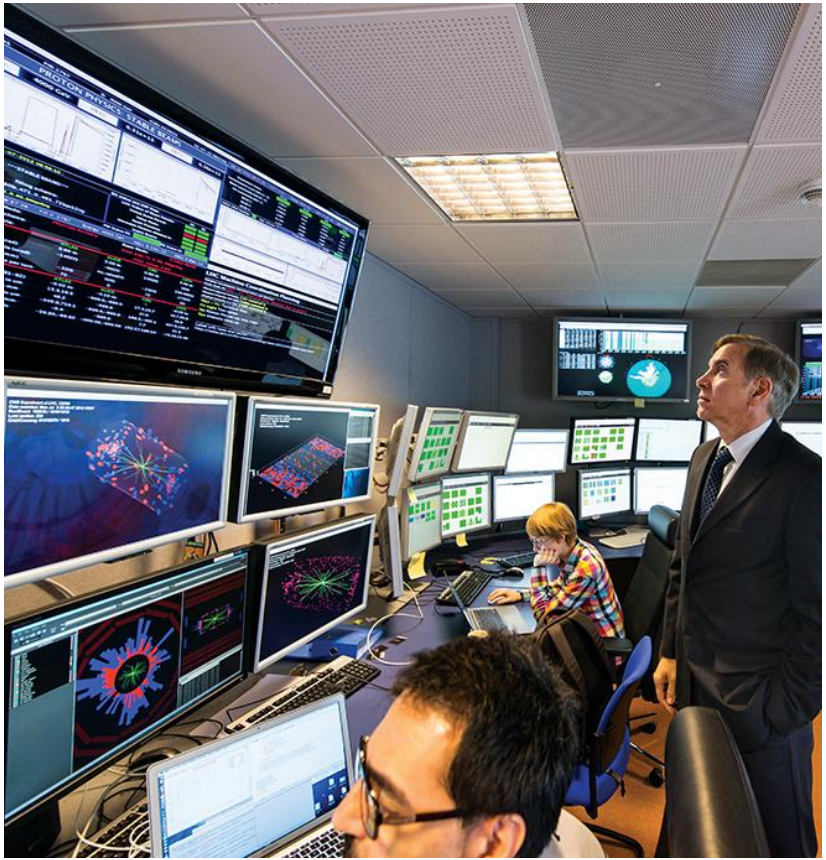
Motivation for new tool

objectives

- reactive recovery from data-taking upsets
- monitoring data-taking health

areas to improve

- reaction time
- suboptimal recovery actions
- external help demand



Evolution of expert tools in DAQ

DAQDoctor

- DAQ- 1
- Run 1
- Perl
- Single person

2009

Esper research project

- Long Shutdown 1
- Declarative approach
  - Group not used to this paradigm

2013

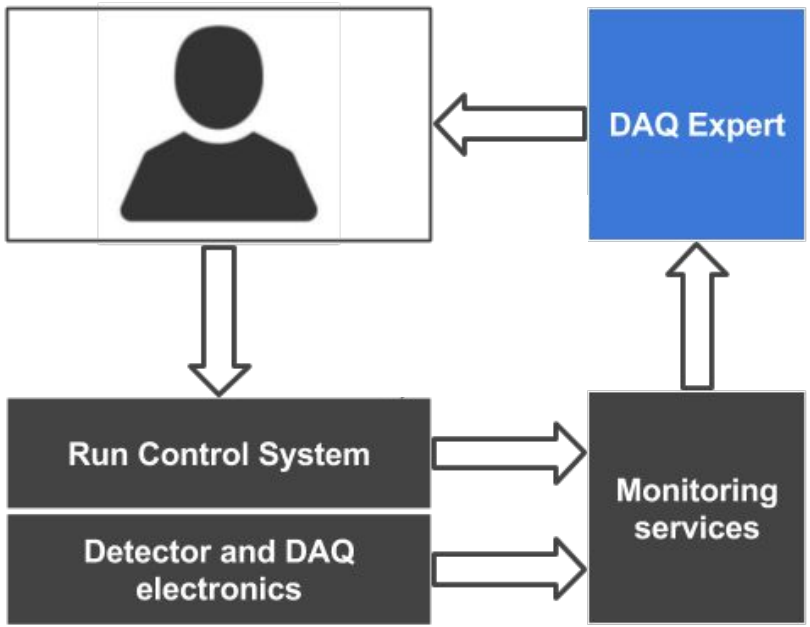
DAQExpert

- DAQ-2
- Based purely on Java
  - Language widely known in the group
- modular

2016

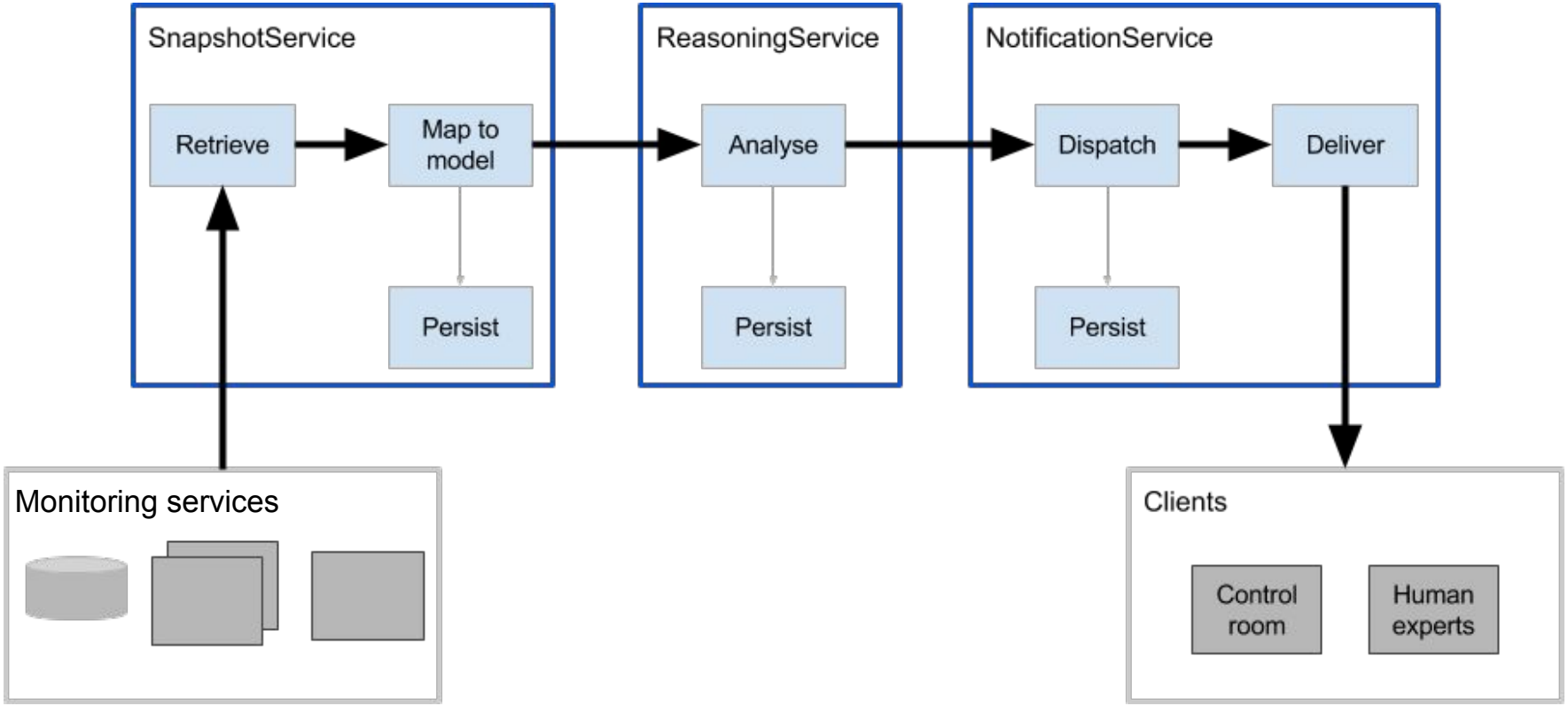
Environment

- operator has final decision
- advise the operator
- human factor



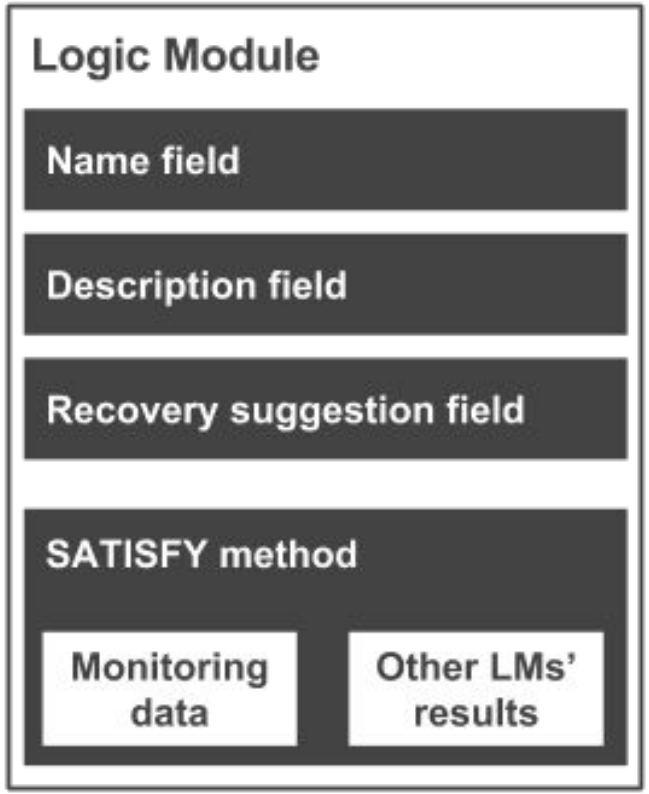
And online software

Solution Identify the problem → Find optimal recovery → Advise operators

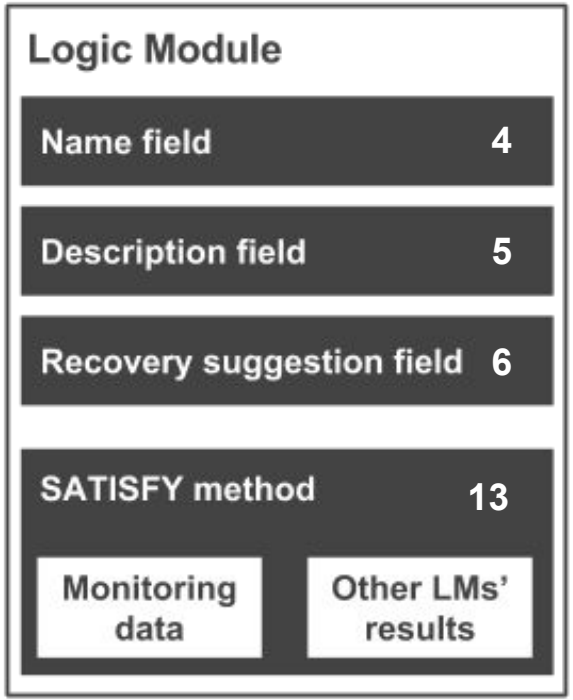


Reasoning

- Expert-knowledge representation
- Logic Module as building block
- Each LM defines some condition
- Condition in *satisfy* method, returns true if satisfied, false otherwise
- Reusing the results



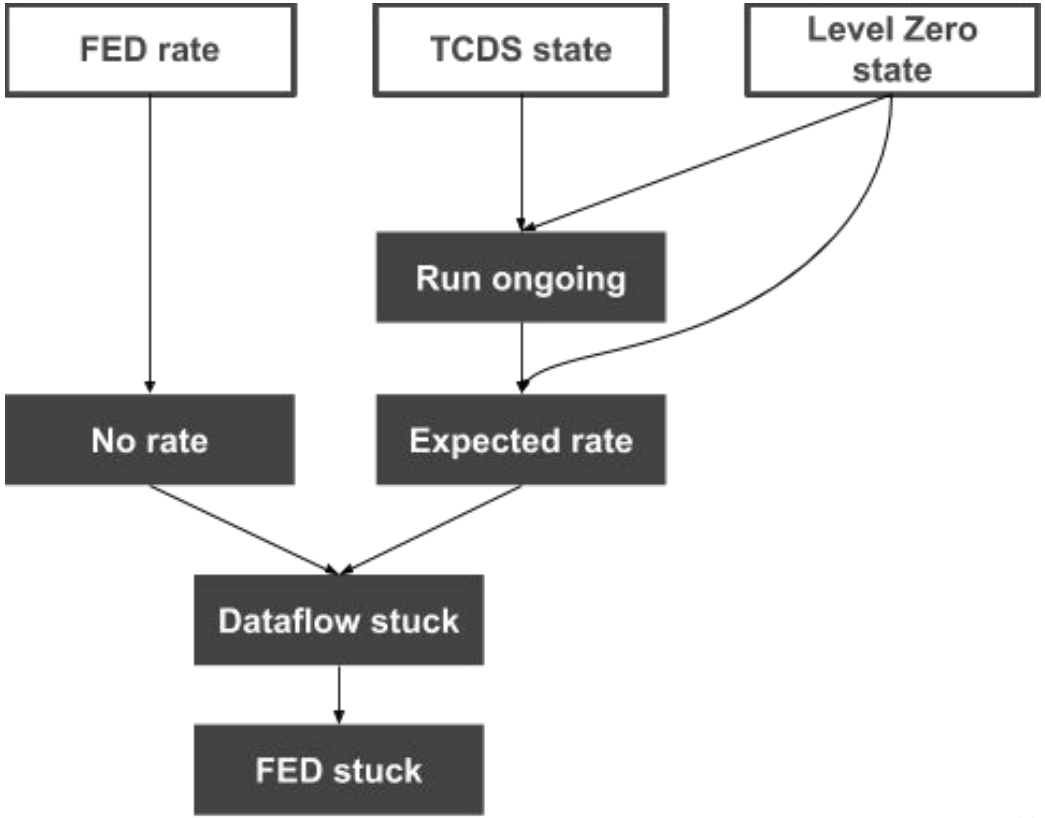
Reasoning II




```java
1 public class PartitionProblem extends KnownFailure {
2
3   public PartitionProblem() {
4     this.name = "Partition problem";
5     this.description = "Partition {{P}} in subsystem {{S}} is blocking triggers";
6     this.action = new SimpleAction("Issue a TTCHardReset",
7         "Problem not fixed: Stop current run & start a new run.",
8         "Problem still not fixed: Call the DOC of {{S}}",
9         "Problem fixed: Make an e-log entry.");
10  }
11
12  @Override
13  public boolean satisfied(DAQ daq, Map<String, Boolean> results) {
14    boolean result = false;
15    if (!results.get(DataFlowStuck.class.getSimpleName()))
16      return false;
17
18    for (SubSystem subSystem : daq.getSubSystems()) {
19      for (TTCPartition ttcp : subSystem.getTtcPartitions()) {
20        TTSState currentState = getParitionState(ttcp);
21        if (currentState == TTSState.OUT_OF_SYNC) {
22          context.register("S", subSystem.getName());
23          context.register("P", ttcp.getName());
24          context.register("C", currentState.name());
25          result = true;
26        }
27      }
28    }
29    return result;
30  }
31 }
```

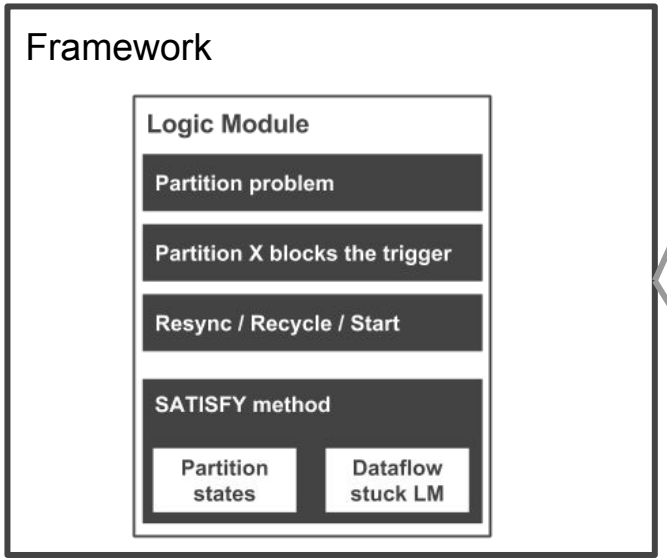
Reasoning III

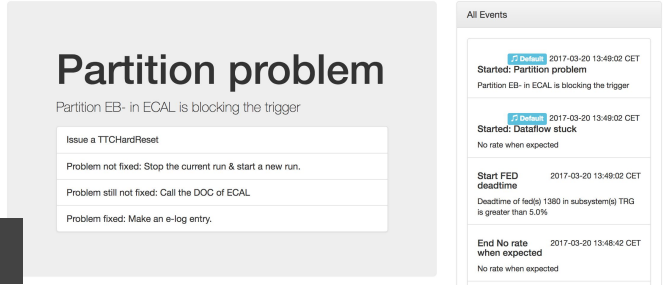
- Hierarchy of LM represents the knowledge
- Key parameters are monitored
- LMs cooperate
- Chain of LMs is activated to reach final conclusion
- Currently
  - 20+ LMs in the system
  - 78% coverage
- LMs ran every iteration of analysis



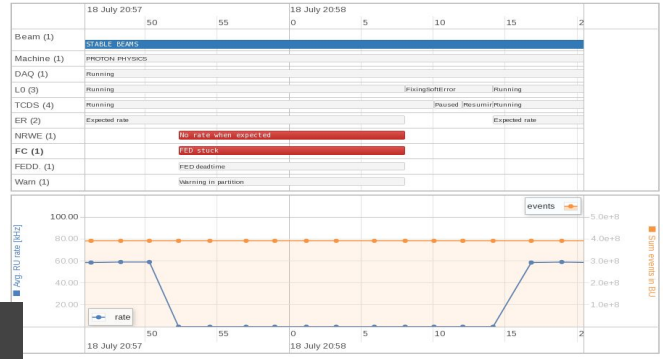
Framework

- Framework delivers LM results
- Real time notifications (1)
- Entries on the timeline (2)





1



2

DAQ Expert Dashboard Browser Archive

Out of sequence data received

Run blocked by out-of-sync data from FED 1386 received by RU ru-c2e12-40-01.cms - now in syncloss state. Problem FED belongs to partition MUTFUP in TRG subsystem. This causes backpressure at FED 1380 in partition MUTFUP of TRG

- Try to recover (try up to 2 times)
- Stop the run. Red & green recycle the subsystem. Start a new Run
- Problem not fixed: Call the DOC of TRG (subsystem that caused the SyncLoss)
- Problem fixed: Make an e-log entry.Call the DOC TRG (subsystem that caused the SyncLoss) to inform about the problem

Recent Suggestions

FED deadtime 2017-03-20 13:49:02 CET Ongoing

Deadtime of fed(s) 1380 in subsystem(s) TRG is greater than 5.0%

All Events

Start Out of sequence data received 2017-03-20 13:49:02 CET
Run blocked by out-of-sync data from FED 1386

Start FED deadtime 2017-03-20 13:49:02 CET
Deadtime of fed(s) 1380 in subsystem(s) TRG is greater than 5.0%

End No rate when expected 2017-03-20 13:48:42 CET
No rate when expected

WBM alarm WBM sound 2017-03-20 13:48:40 CET
text to talk
additional detailed message

DAQ state RunBlocked 2017-03-20 13:48:39 CET
New DAQ state identified

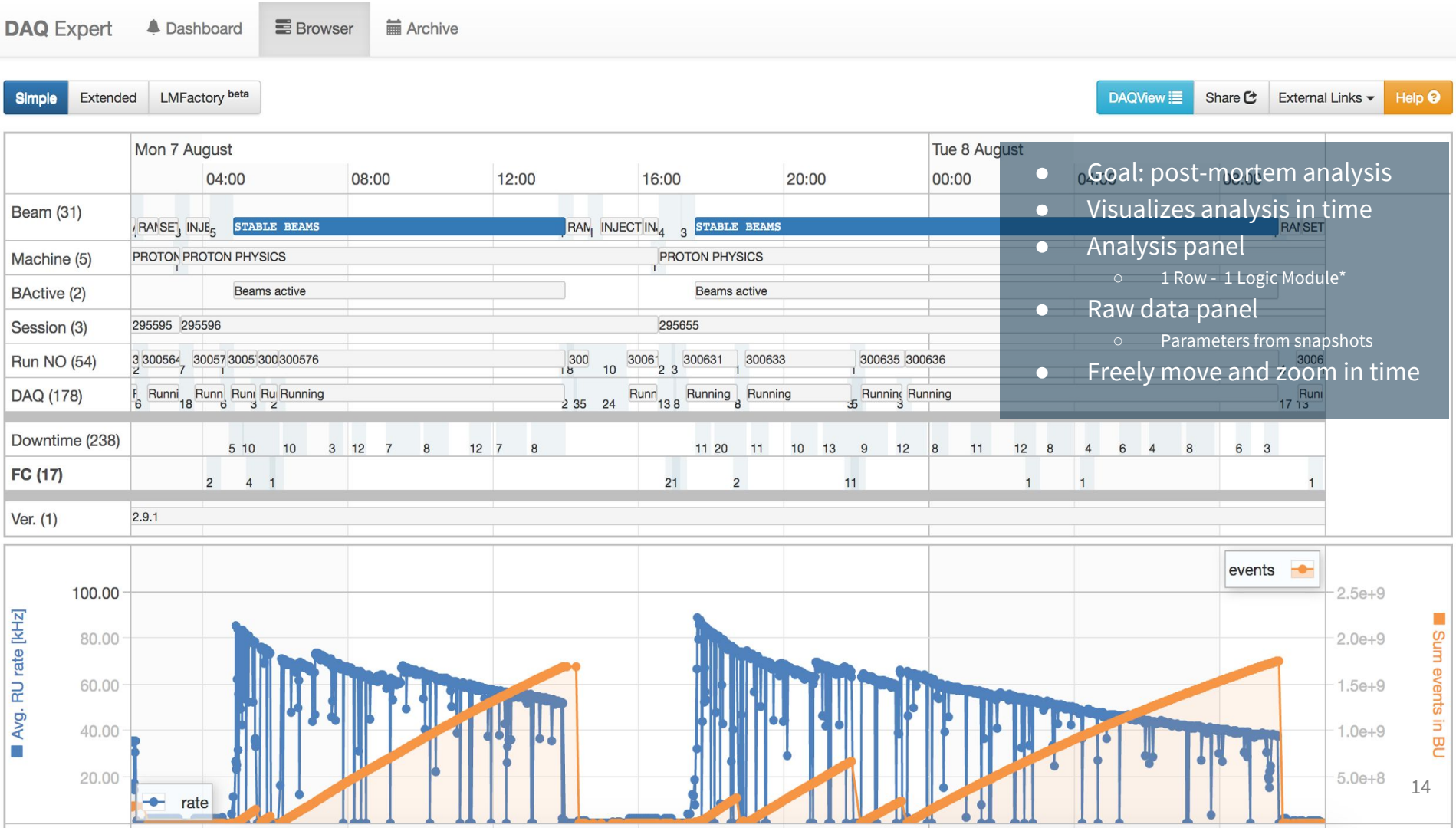
Start Run ongoing New run 2017-03-20 13:00:01 CET
Run is ongoing [illegible] DAQ state

LHC Machine Mode: SHUTDOWN 2017-03-20 13:00:01 CET
New LHC Machine mode identified

Session: [illegible] 2017-03-20 13:00:01 CET
DAQ session [illegible]

LHC Beam [illegible] CET
New LHC beam mode identified

- Main view for CR
- RT suggestions to shifters:
  - Reduce reaction time
  - Avoid wrong decisions
- Suggestion format:
  what's the problem +
  what's the best action to take



- Goal: post-mortem analysis
- Visualizes analysis in time
- Analysis panel
  - 1 Row - 1 Logic Module*
- Raw data panel
  - Parameters from snapshots
- Freely move and zoom in time

DAQ Expert | Dashboard | Browser | Archive

source | 19 selected | event type | Start | date range | showing all | Help

	Date	Event Type	Sender	Title	Displayed message	Source LM	Audible
	2017-08-16 08:06:34	Start	Expert *2.9.1*	Started: FED stuck	TTCP TOB of TRACKER subsystem is blocking trigger, it's in WARNING TTS state, The problem is caused by FED 434 in WARNING	Fed stuck	Default
	2017-08-16 00:30:01	Start	Expert *2.9.1*	Started: Partition problem	Partition EB- in ECAL subsystem is in ERROR TTS state. It's blocking trigger.	Partition problem	Default
	2017-08-15 17:30:35	Start	Expert *2.9.1*	Started: FED stuck	TTCP TIBTID of TRACKER subsystem is blocking trigger, it's in WARNING TTS state, The problem is caused by FED [163,143] in WARNING	Fed stuck	Default
	2017-08-15 17:29:14	Start	Expert *2.9.1*	Started: Partition problem	Partition EB- in ECAL subsystem is in ERROR TTS state. It's blocking trigger.	Partition problem	Default
	2017-08-15 16:29:53	Start	Expert *2.9.1*	Started: FED stuck	TTCP TOB of TRACKER subsystem is blocking trigger, it's in WARNING TTS state, The problem is caused by FED 434 in WARNING	Fed stuck	Default
	2017-08-15 09:19:35	Start	Expert *2.9.1*	Started: Partition problem	Partition EB- in ECAL subsystem is in ERROR TTS state. It's blocking trigger.	Partition problem	Default
	2017-08-14 22:59:49	Start	Expert *2.9.1*	Started: FED stuck	TTCP TIBTID of TRACKER subsystem is blocking trigger, it's in WARNING TTS state, The problem is caused by FED 79 in WARNING	Fed stuck	Default

first « 1 2 3 4 5 » last

1398 entries (140 pages)

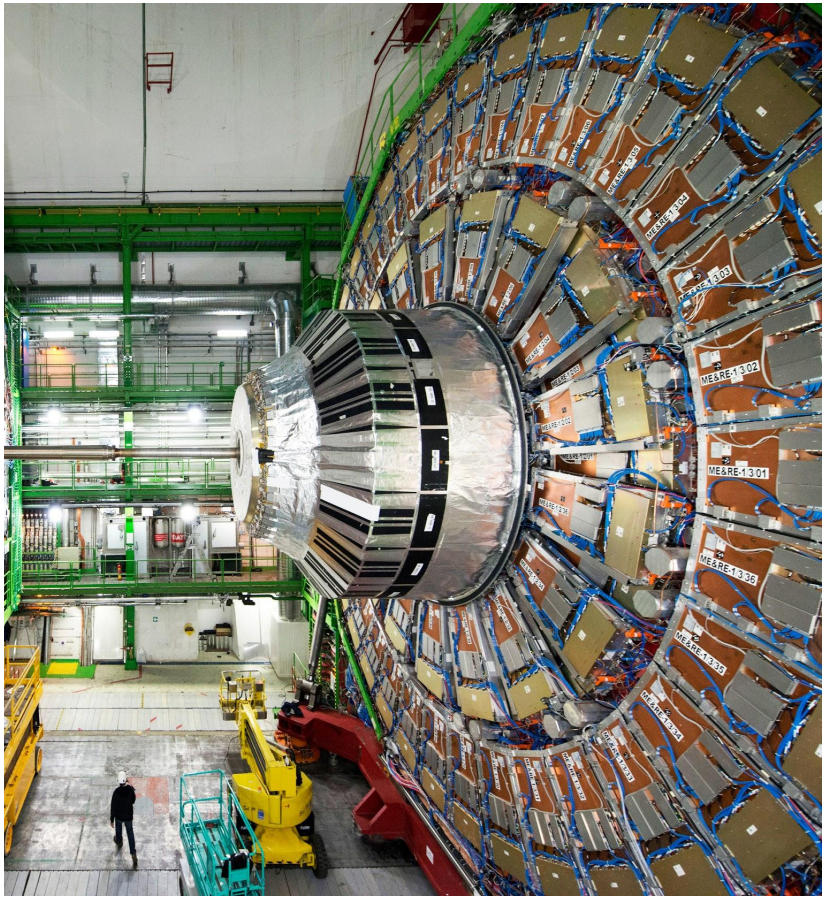
- Goal: browse all generated notifications
- Filter by key fields
- Inspect link

Technologies used

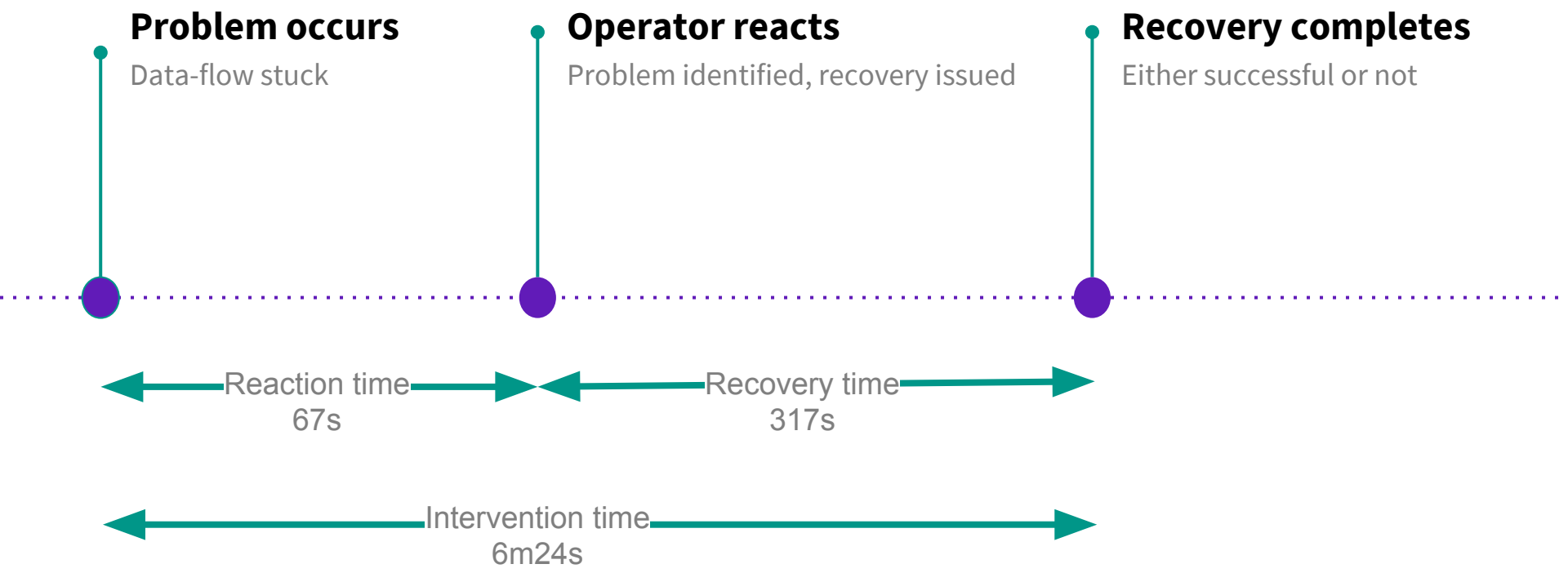
- Presentation layer
  - Web application
  - Javascript, VisJS
  - Bootstrap
- Backend
  - Micro service architecture
  - RESTFul services
  - Hibernate
  - Oracle

Results

- Efficiency of CMS
  - Many other factors interfering
- User feedback
  - Positive but not quantitative
- Recovery selection correctness



Key parameters



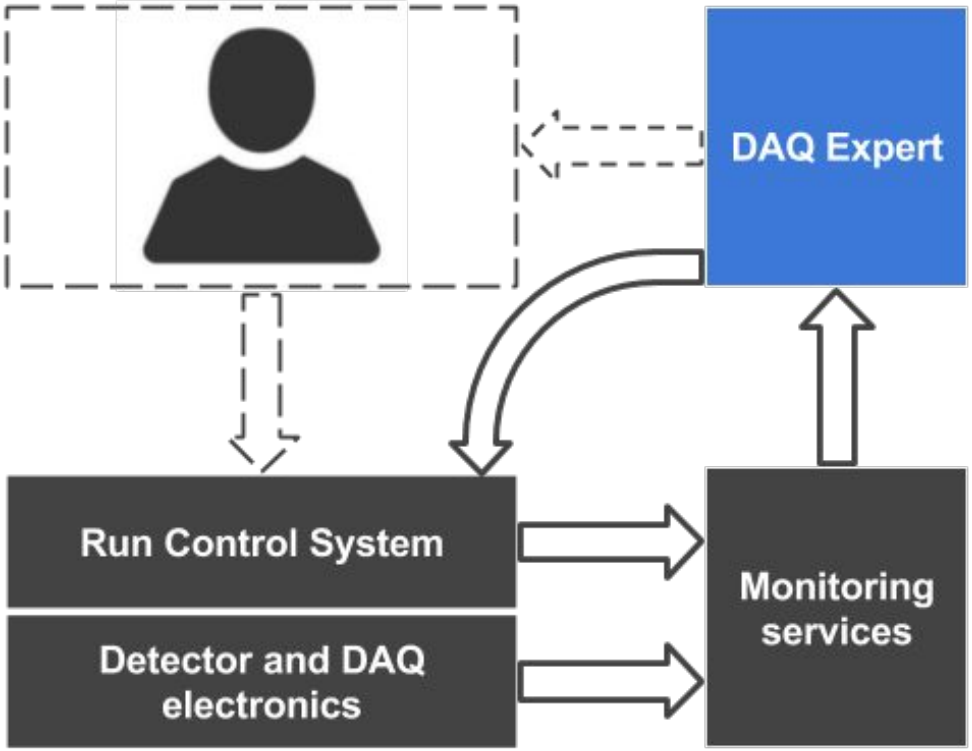
Avg on 2016

Recovery selection correctness

- Comparison based on
  - 3 months from 2016 and 2 months from 2017
  - During stable beams only
- In 2016 operators had no guidance
  - 36 data-taking failures
  - 32 optimal decisions
- In 2017 there was guidance
  - 29 data-taking failures
  - 29 optimal decisions
- Clear increase of fraction of optimal recovery 88% → 100%

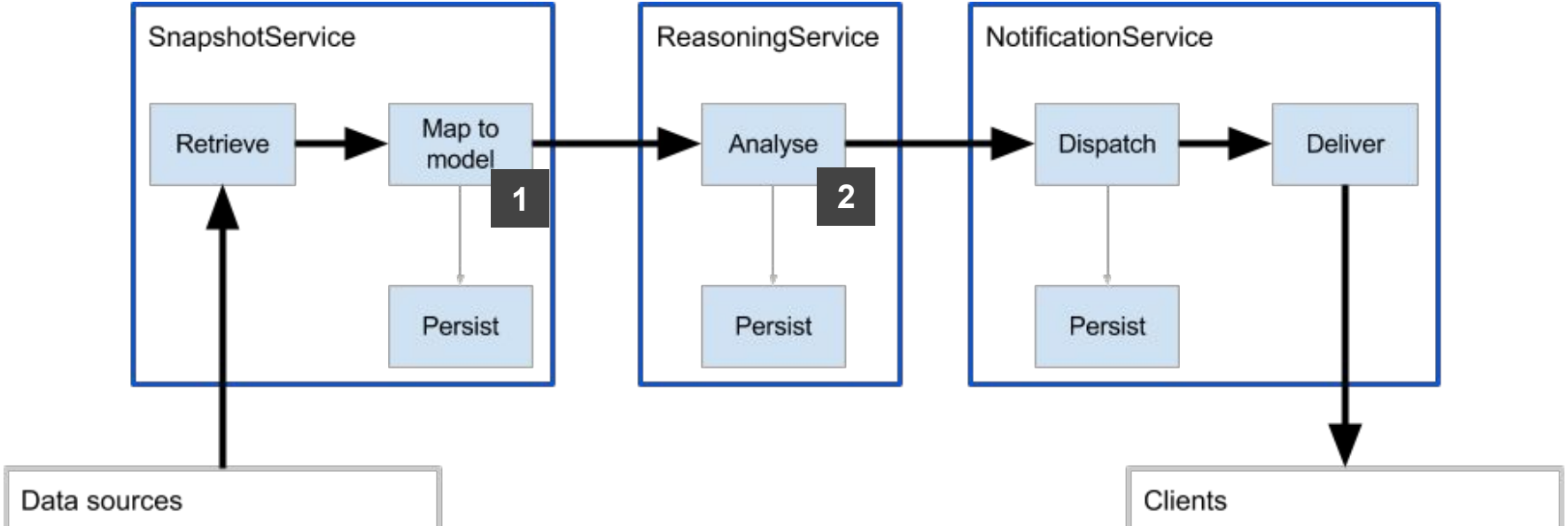
Future

- Bypass the operator - automatic recovery wherever possible
- Extend coverage
- Predicting failures



Using framework elsewhere

- Define your monitoring model (1)
- Define your knowledge as LMs (2)



Summary

1. **New expert tool**
   Pure imperative language (java) to implement reasoning
2. **Successful at CMS DAQ**
   Recovery selection correctness: 88% → 100%
3. **Generic solution**
   Can be used elsewhere

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