A scalable monitoring for the CMS Filter Farm based on elasticsearch

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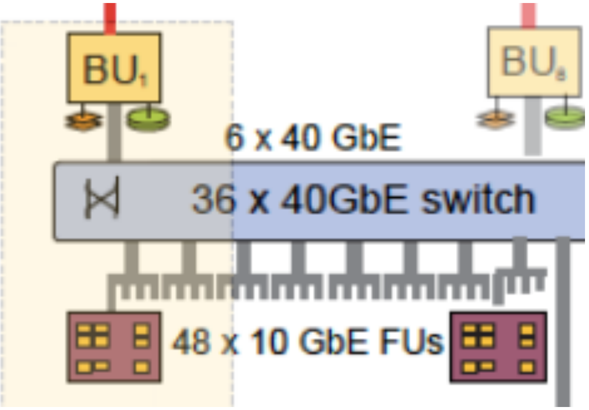
Introduction

* DAQ2 Event Builder, Filter Farm and Storage System described in talks:
E. Meschi : File-based data flow in the CMS Filter Farm
R. Mommsen: A new Event Builder for CMS Run II
L. Darlea: Online data handling and storage at the CMS experiment

CMS DAQ2 Filter Farm

- Divided into 62 sub-farms (“appliances”)
- Fully built events copied to Filter Units (FUs), up to 20 FUs / appliance
- 40-Gbit network (BU) to 10 Gbit (FU) per appliance



File-based Filter Farm (FFF) monitoring

- JSON metadata produced at each FFF data handling stage, accompanying and describing:
  - RAW data in ramdisk
  - FU HLT (accepted) output per stream
  - Three stages of output file merging (micro, mini, macro merging)
- Of interest for monitoring: event rate, completeness of processing/merging per lumisection (LS), CPU usage statistics, disk occupancy, logs

Requirements on the monitoring system:

- Scalability – scaling to large number of HLT nodes
- Low latency – fast feedback for the Online shift crew/experts
- Ability to directly insert JSON documents

Elasticsearch

- NoSQL DB and search server based on Apache Lucene library
  - Open source, large user base and community, used commercially
- Quasi-realtime
    - Low latency document insertion and searching
- Indexed JSON document storage using lightweight schema
- RESTful JSON-based HTTP interface
    - Multitenant (serving multiple clients)
    - Several client libraries available
- Clustered architecture
  - Data distributed over *indices* which can be split over many data nodes in the cluster
- Documents searched across cluster with a single query
  - Initiated from any node in the ES cluster
  - Possible aggregation according to algorithms
    - e.g. histogram documents with per-stream bins, or time interval bins

FFF elastisearch cluster

- Dedicated cluster of ~ 20 machines running elasticsearch instances (**Central ES**)
- Permanently storing low-volume information aggregated from the Filter Farm appliances:
  - Run information
  - Filter Farm cluster status
  - Logs
- Separate set of indices used for Central DAQ, and for other dedicated DAQ clusters (miniDAQ, DAQVal …)
- Example: “end of luminosity” document injected by one of the BUs:

```
{
  “fm_date": "2015-01-09T03:34:17.839651”,
  "TotalEvents": 233528,
  "NEvents": 10368,
  "ls": 1,
  "NFiles": 30,
  "id": "run231913_ls0001_EoLS_bu-c2f16-19-01”
}
```

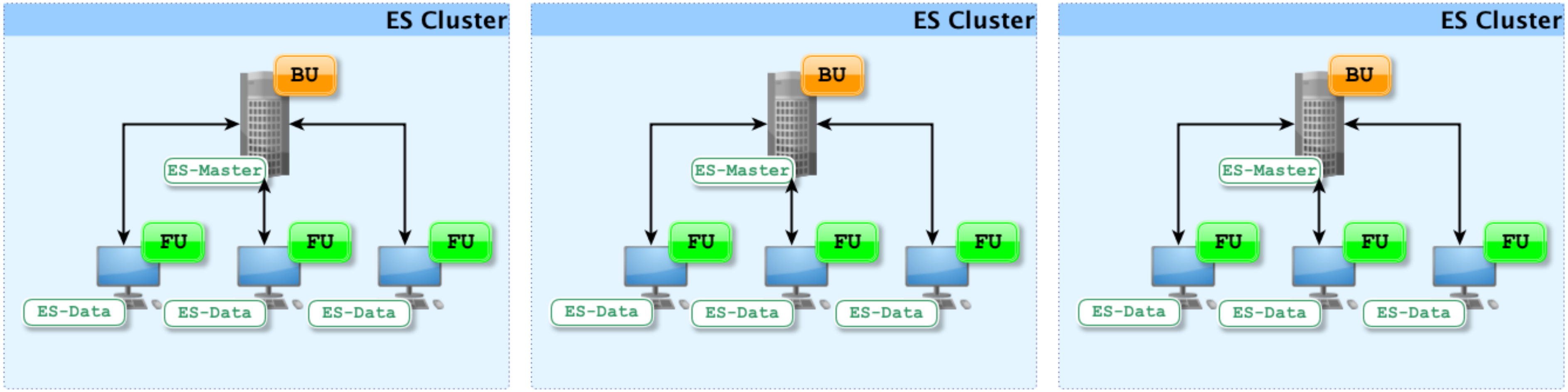
Contains number of events and files in LS 1 in one appliance

Retrieved by query:

```
curl –XGET http://es-srv:9200/run_index/eols/_search –d’{
"query":
          {"prefix”: { "id":"run231913"} },
"query":
          {"term": {"ls":1702} }
}’
```

FFF appliance ES clusters

Appliance 1 Appliance 2 .... Appliance N

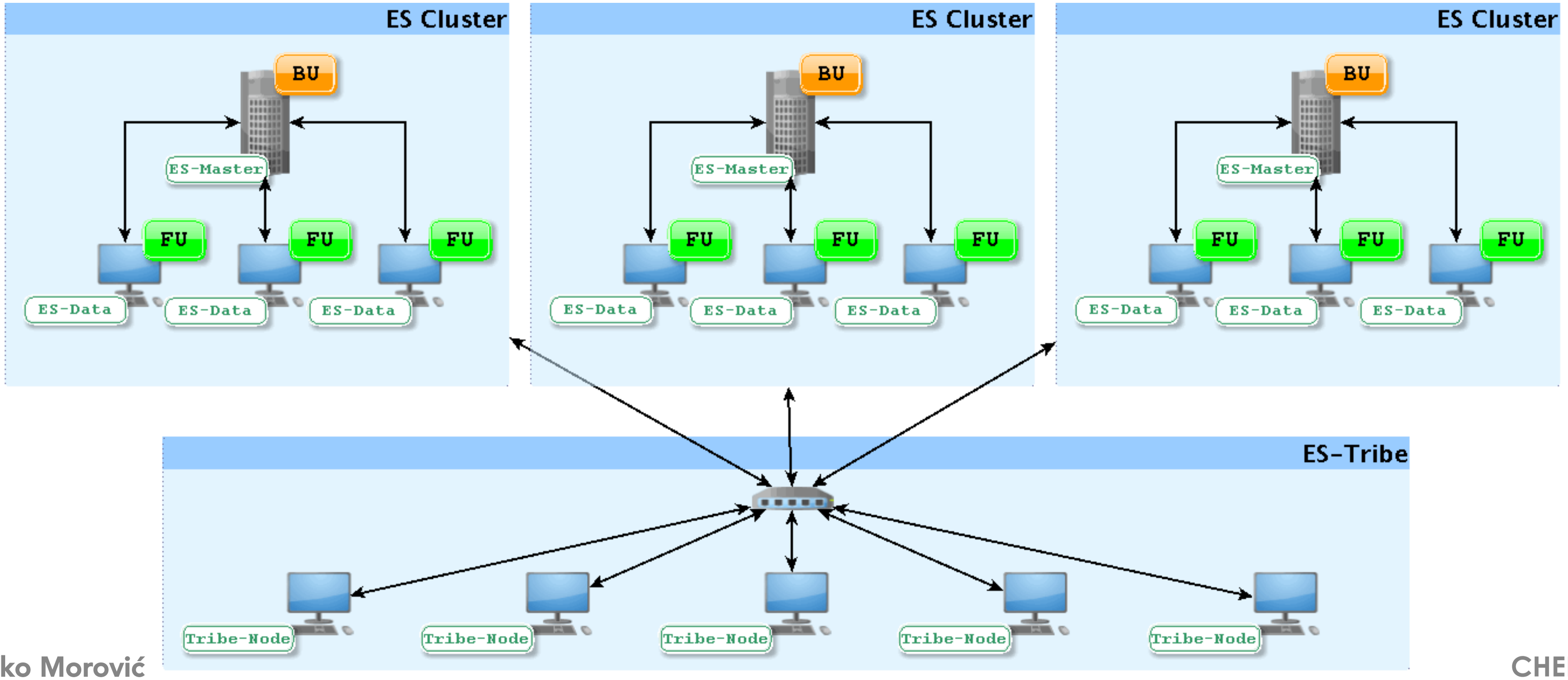


- Elasticsearch service running on each FFF BU and FU node
  - Profit from FFF architecture: ES clusters match appliance (unit of processing) structure
  - lightweight: low CPU (~ 10% single-CPU) and moderate memory usage (≤1 GB JVM heap)
- Natural horizontal scaling in FFF
  - processing nodes are elasticserch data nodes
  - Appliances clusters are independent of each other
- FFF services on FUs inject JSON files into local ES instance as they appear
  - Storing "full-detail" run information (down to process-level granularity)

Connecting clusters

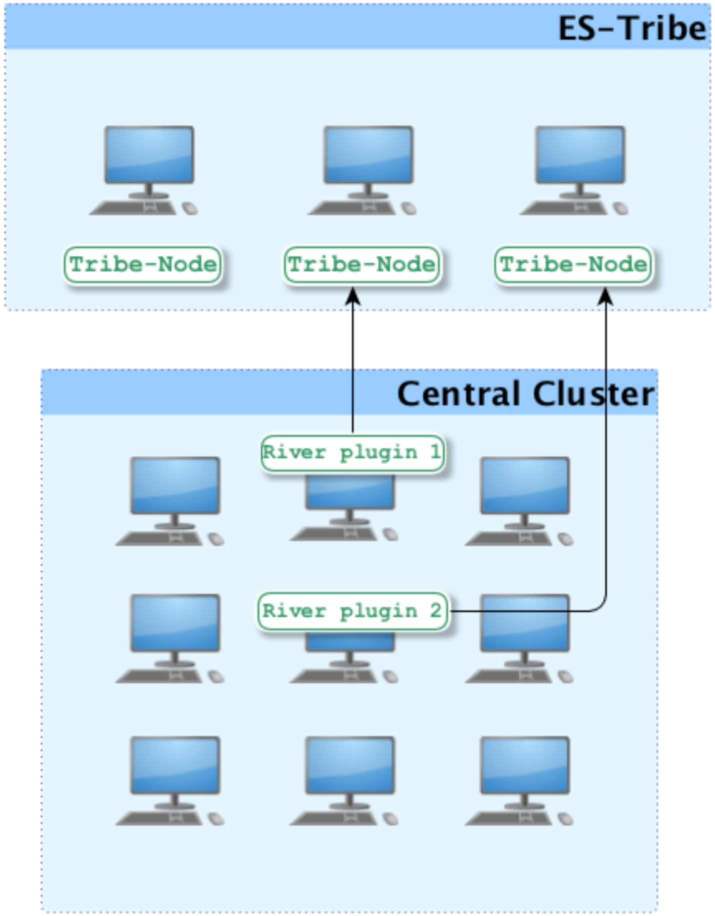
- Need to collect monitoring data from appliances
  - Running queries on each cluster individually is cumbersome
  - Requires sending query to each cluster and client-side merging JSON results

- Using ES **Tribe** feature – allows to form cluster of clusters
  - Tribe nodes join each cluster as non-data members
  - Queries to tribe nodes run on all connected appliance ES clusters
  - ~ 10 (independent) tribe nodes for redundancy and load balancing



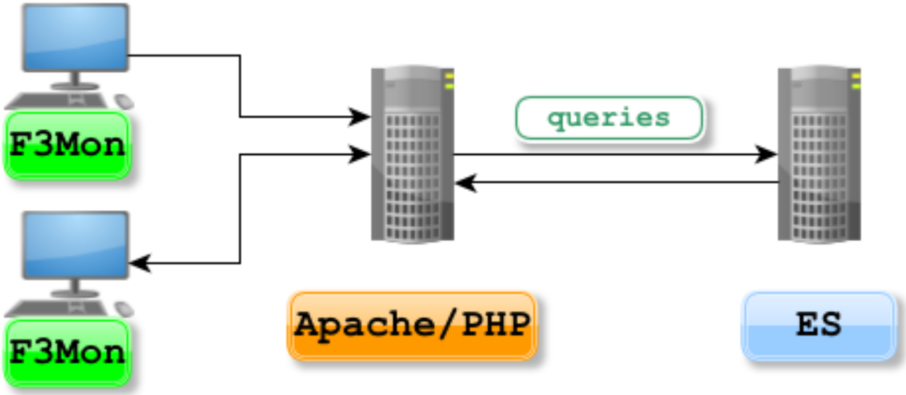
Data collection from appliances

- Some information written to central ES directly (e.g. logs, ramdisk JSONs)
- FU-level run data aggregated into central ES by querying appliances
- RunRiver data collector plugin
  - built using ES plugin API
  - Plugin automatically started and managed in one of cluster nodes
  - Independent instance per run
- Execute queries in Tribe and store aggregated results in central ES cluster
  - Special aggregation queries result in compact histogram-like documents, small enough for handling by the monitoring web UI



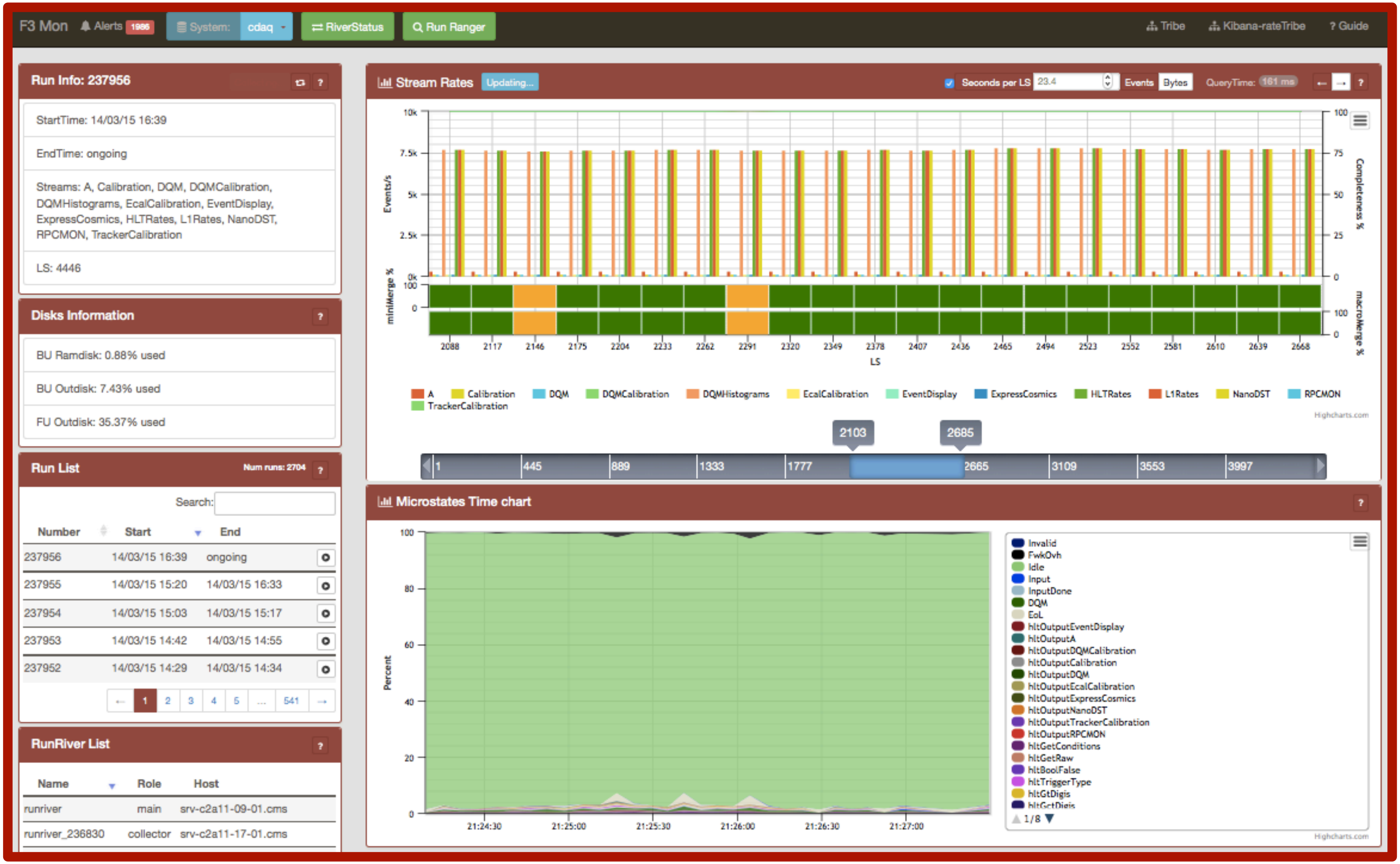
F^{3}Mon GUI

- FFF web-based monitoring built on top of elasticsearch infrastructure
- One of general DAQ monitoring pages used by everyone
- Interface based on modern JS libraries
  - Bootstrap, jQuery, HighCharts
- Server-side PHP fetches data from central ES



  - Multiple server instances, one running on each central ES host
  - Central ES is isolated by direct access by clients (better data security)
  - Possible to use server-side caching for expensive queries
- PHP runs queries on request from F3Mon, which is polling for new data
  - Parameters Determined by what the user has requested (e.g. run number)

F^{3}Mon GUI



Run Info: 237956

StartTime: 14/03/15 16:39

EndTime: ongoing

Streams: A, Calibration, DQM, DQMCalibration, DQMHistograms, EcalCalibration, EventDisplay, ExpressCosmics, HLTRates, L1Rates, NanoDST, RPCMON, TrackerCalibration

LS: 4446

Disks Information

BU Ramdisk: 0.88% used

BU Outdisk: 7.43% used

FU Outdisk: 35.37% used

Run List Num runs: 2704

Search:

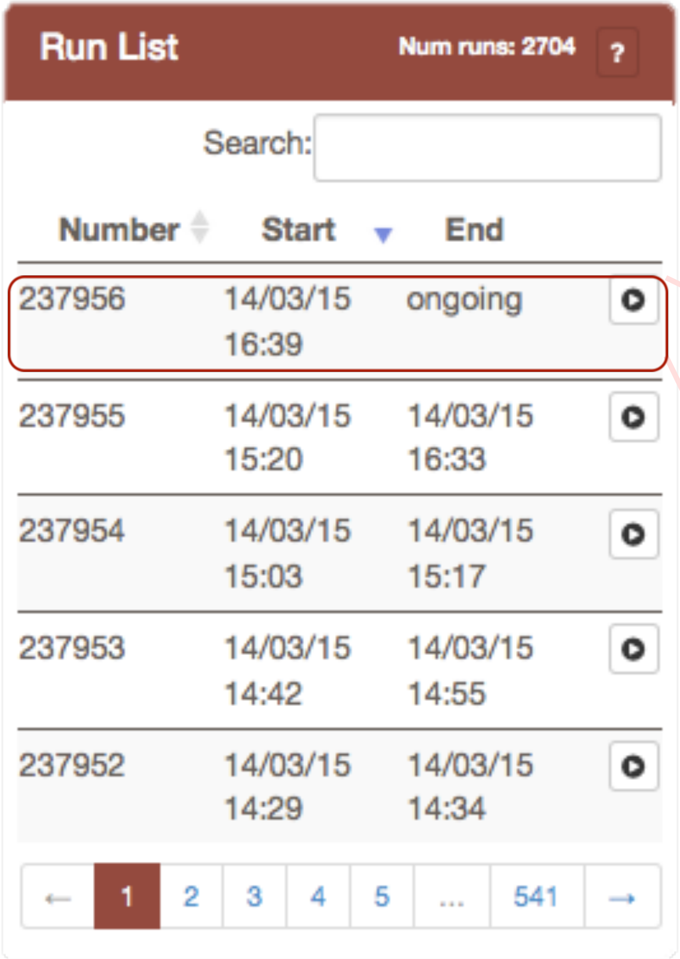
Number	Start	End
237956	14/03/15 16:39	ongoing
237955	14/03/15 15:20	14/03/15 16:33
237954	14/03/15 15:03	14/03/15 15:17
237953	14/03/15 14:42	14/03/15 14:55
237952	14/03/15 14:29	14/03/15 14:34

← 1 2 3 4 5 ... 541 →

RunRiver List

Name	Role	Host
runriver	main	srv-c2a11-09-01.cms
runriver_236830	collector	srv-c2a11-17-01.cms

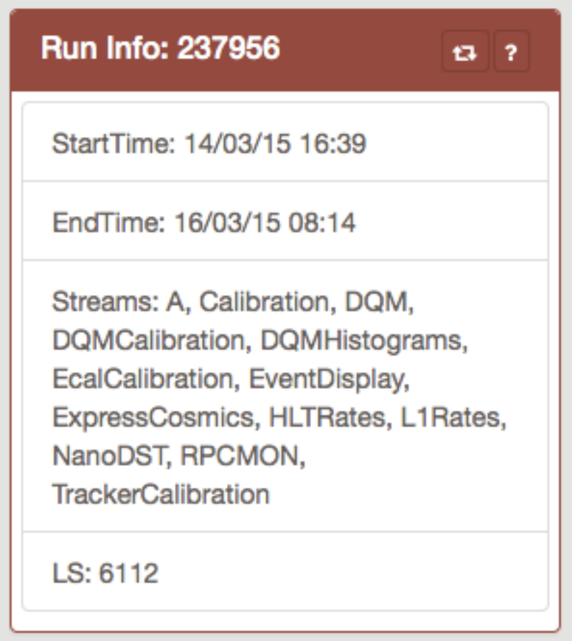
Run information



Run List Num runs: 2704

Number	Start	End
237956	14/03/15 16:39	ongoing
237955	14/03/15 15:20	14/03/15 16:33
237954	14/03/15 15:03	14/03/15 15:17
237953	14/03/15 14:42	14/03/15 14:55
237952	14/03/15 14:29	14/03/15 14:34

- By default, UI shows status of the live run
- Full history of runs with all information available for selection within the UI



Run Info: 237956

StartTime: 14/03/15 16:39

EndTime: 16/03/15 08:14

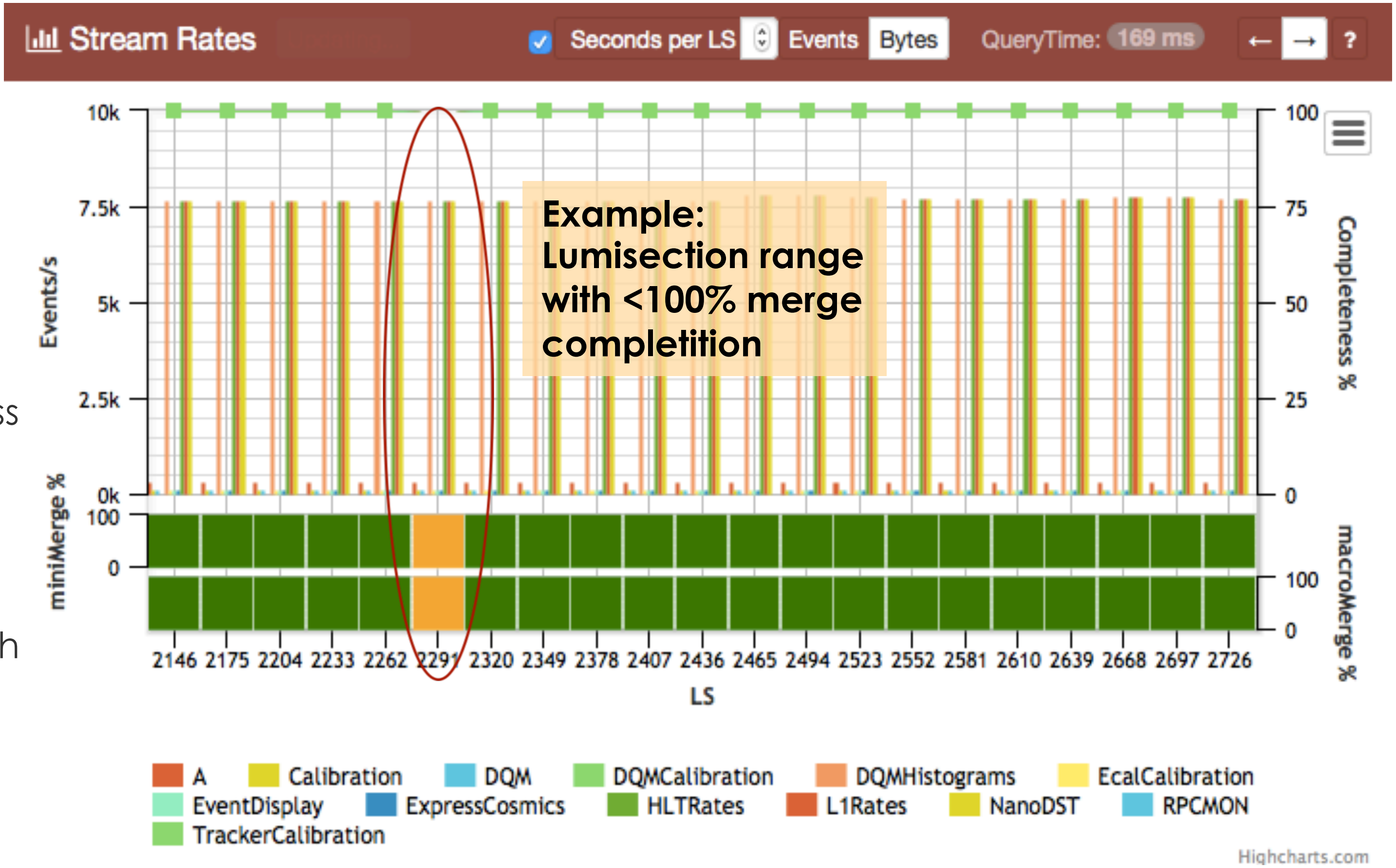
Streams: A, Calibration, DQM, DQMCalibration, DQMHistograms, EcalCalibration, EventDisplay, ExpressCosmics, HLTRates, L1Rates, NanoDST, RPCMON, TrackerCalibration

LS: 6112

HLT output/merger monitoring

- Display of aggregated per-LS HLT-output rates and merging completion for each merging stage

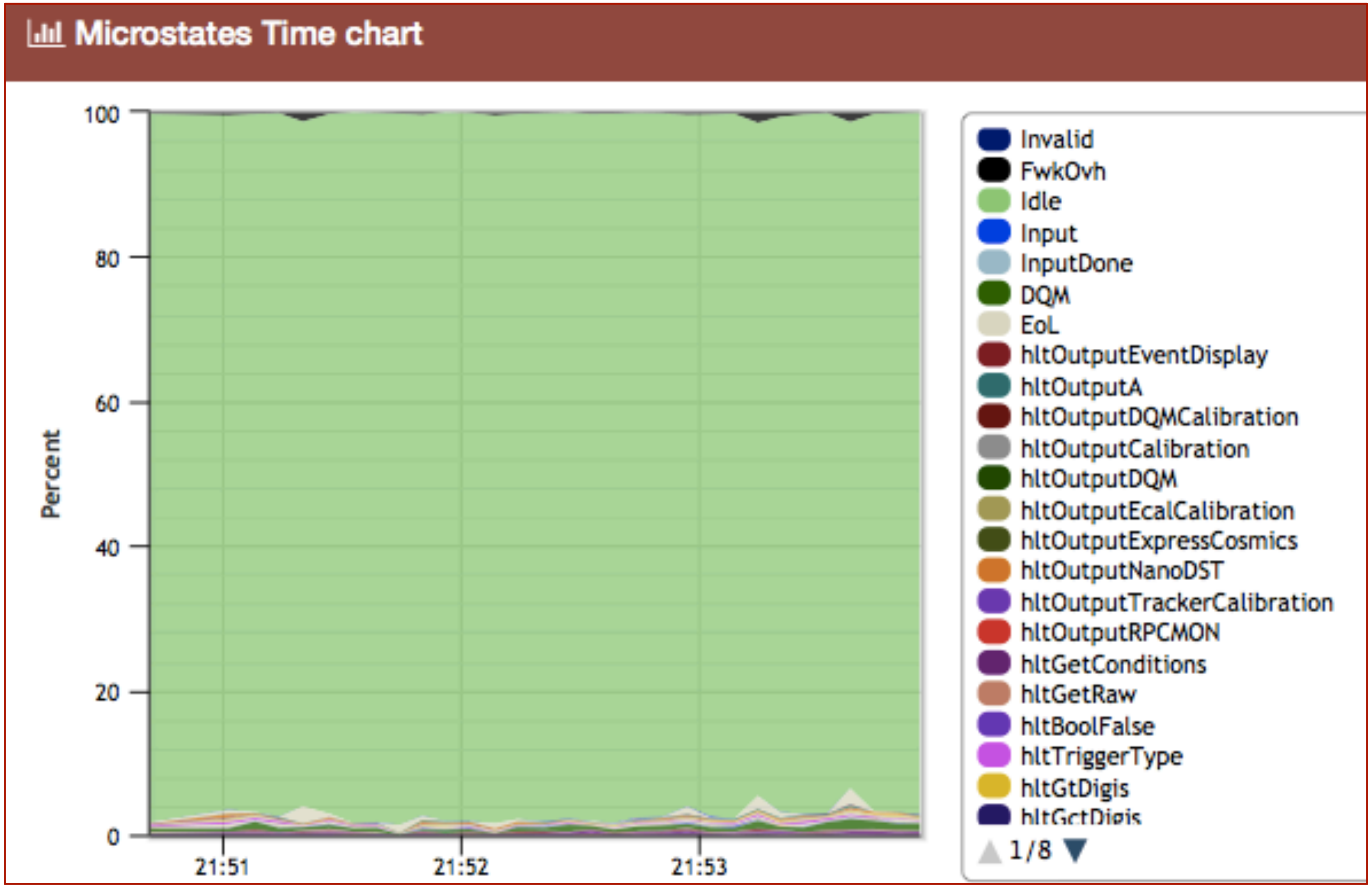
- By default: displays status of current (recent) lumisections
  - Ability to display any lumisection range in the run
- "drill-down" (on-click) available to display merging completeness per stream and appliance level
- Example: LS range with incomplete merging problem



Example: Lumisection range with <100% merge completition

HLT CPU usage monitoring

- Aggregated process-level CPU usage
- Breakdown per HLT module (important to identify inefficiencies in HLT)



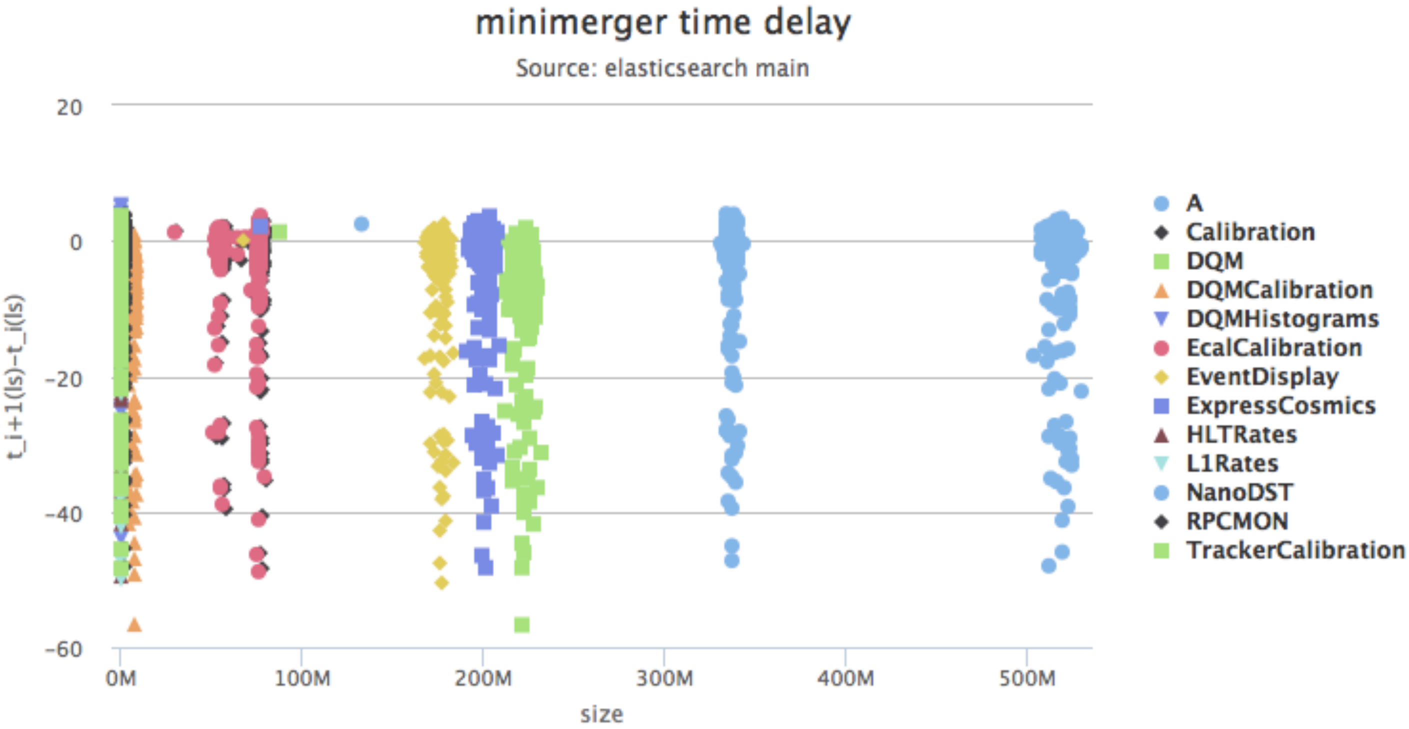
Example: period with the Filter Farm >95% ide

Expert tools

- es allows cross-correlation of monitored variables without a need for a-priori adjustment on how data is stored/indexed

  (possible to analyze data in a way that was not originally intended)

Example: a tool showing correlation of merging latency vs. file size per stream



minimerger time delay

Source: elasticsearch main

Aggregation query:

```
{
  "query": {"term":
    {"_parent":237955} },
  "sort":{"ls":"asc"},
  "aggs":
    {"streams":
      {"terms":
        {"field":"stream","size":100,
         "order":{"_term":"asc"}},
         "aggs":{
           "lss":{
             "terms":{
               "field":"ls","size":100000,
               "order" :
                 { "_term" : "asc" }
             },
             "aggs":{"sizes":
               {"avg":{"field":"filesize"}
}}}}}}}
```

Summary

CMS Filter Farm monitoring has been implemented using elasticsearch

- Dedicated ES cluster for permanently storaging monitoring data
- Appliance clusters: ES running all BU and FU nodes,
  in the background of event processing

  →Horizontal scalability with Filter Farm expansion

- No big problems
  - Stable, used in production Central DAQ
  - Scales well, after solving several limitation issues (e.g. – had to increased threads limit in Tribe hosts)
- F^{3}Mon UI
  - Monitoring runs in Filter Farm (HLT processing, merging) with low latency
- Several expert tools built on top of the ES infrastructure
- Serving also non-web based clients (LabView)

Outlook

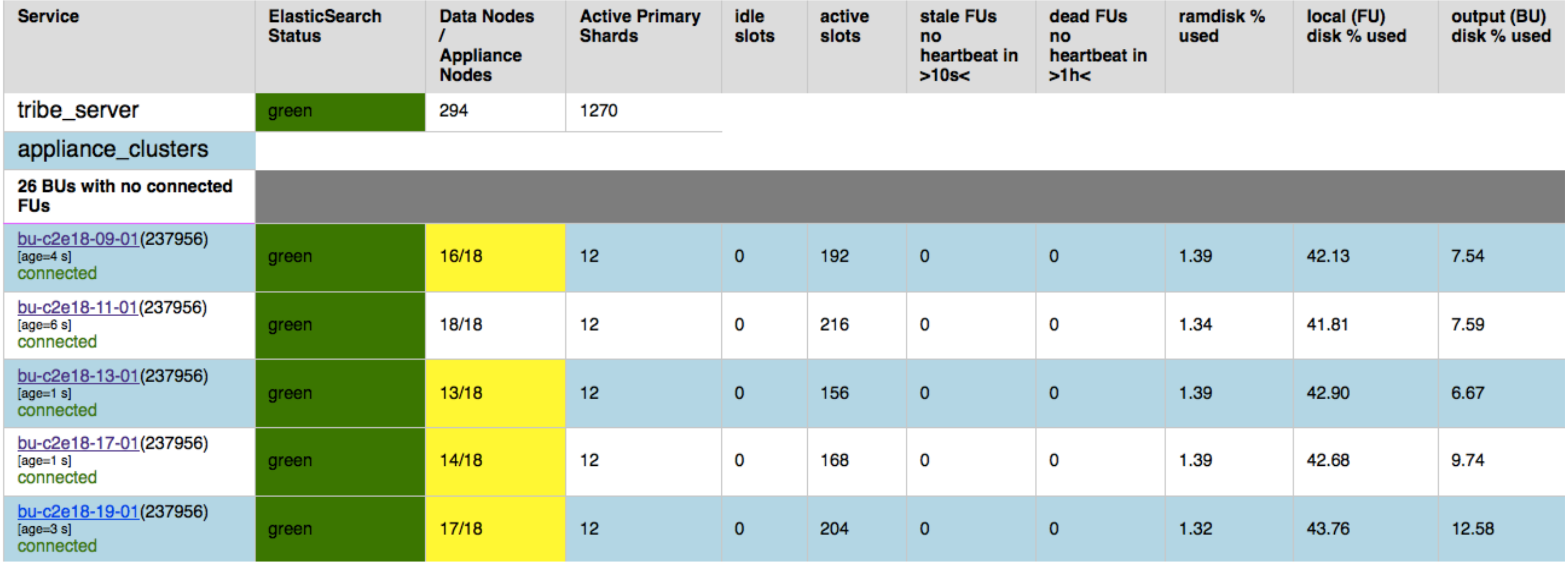
- Looking forward to integrate the full Filter Farm (nearly 50% complete)
- Experimenting with elasticsearch in other parts of DAQ

BACKUP

Filter Farm status page

Status of various parameters of the farm

- Used/Available CPU resources, ramdisk and disk usage, ongoing runs in HLT/ FFF, detection of problems (network problems, crashes) …



Service	ElasticSearch Status	Data Nodes / Appliance Nodes	Active Primary Shards	idle slots	active slots	stale FUs no heartbeat in >10s<	dead FUs no heartbeat in >1h<	ramdisk % used	local (FU) disk % used	output (BU) disk % used
tribe_server	green	294	1270							
appliance_clusters										
26 BUs with no connected FUs										
bu-c2e18-09-01(237956) [age=4 s] connected	green	16/18	12	0	192	0	0	1.39	42.13	7.54
bu-c2e18-11-01(237956) [age=6 s] connected	green	18/18	12	0	216	0	0	1.34	41.81	7.59
bu-c2e18-13-01(237956) [age=1 s] connected	green	13/18	12	0	156	0	0	1.39	42.90	6.67
bu-c2e18-17-01(237956) [age=1 s] connected	green	14/18	12	0	168	0	0	1.39	42.68	9.74
bu-c2e18-19-01(237956) [age=3 s] connected	green	17/18	12	0	204	0	0	1.32	43.76	12.58

Example: data injection

- End of LS document insertion:

```
curl –XPUT es-srv:9200/run_index –d'{
  "fm_date": "2015-01-09T03:34:17.839651",
   "TotalEvents": 233528,
   "NEvents": 10368,
   "ls": 1,
   "NFiles": 30,
   "id": "run231913_ls0001_EoLS_bu-c2f16-19-01"
}'
```

```
curl –XPUT es-srv:9200/run_index –d'{
  "fm_date": "2015-01-09T03:34:17.839651",
   "TotalEvents": 233528,
   "NEvents": 10368,
   "ls": 2,
   "NFiles": 30,
   "id": "run231913_ls0002_EoLS_bu-c2f16-19-01"
}'
```

mapping(document description):

```
"runindex_index" : {
    "mappings" : {
      "eols" : {
        "_id" : { "path" : "id" },
        "_parent" : { "type" : "run"},
        "_timestamp" : {"path" : "fm_date"}.
        "properties" : {
          "NEvents" : {"type" : "integer"},
          "NFiles" : {"type" : "integer"},
          "NLostEvents" : {"type" : "integer"},
          "TotalEvents" : {"type" : "integer"},
          "fm_date" : {"type" : "date",
            "format" : "dateOptionalTime"}},
          "id" : {"ype" : "string","index":"not_analyzed"},
          "ls" : {"type" : "integer"}
        },…
```

query:

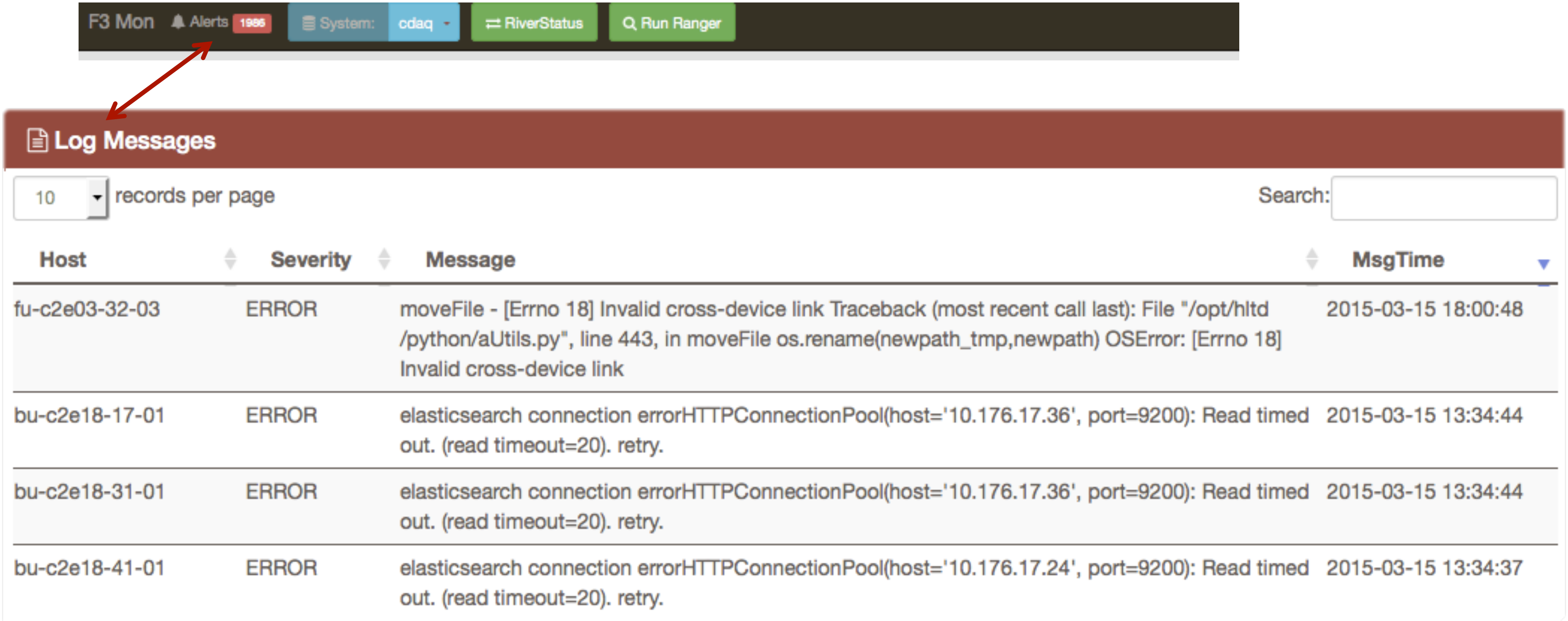
```
curl –XGET http://es-srv:9200/run_index/eols/_search
–d'{
  "query":{
    "term":{"ls":2}
  }
}'
```

result:

```
{    "_index" : "run_index",
     "_type" : "eols",
     "_id" : "run231913_ls0002_EoLS_bu-c2f16-19-01",
     "_score" : 1.0,
     "_source":{
       "fm_date": "2015-01-09T03:34:17.839651",
       "TotalEvents": 233528,
       "NEvents": 10368,
       "ls": 2,
       "NFiles": 30,
       "id": "run231913_ls0002_EoLS_bu-c2f16-19-01"
     }
}
```

Logging

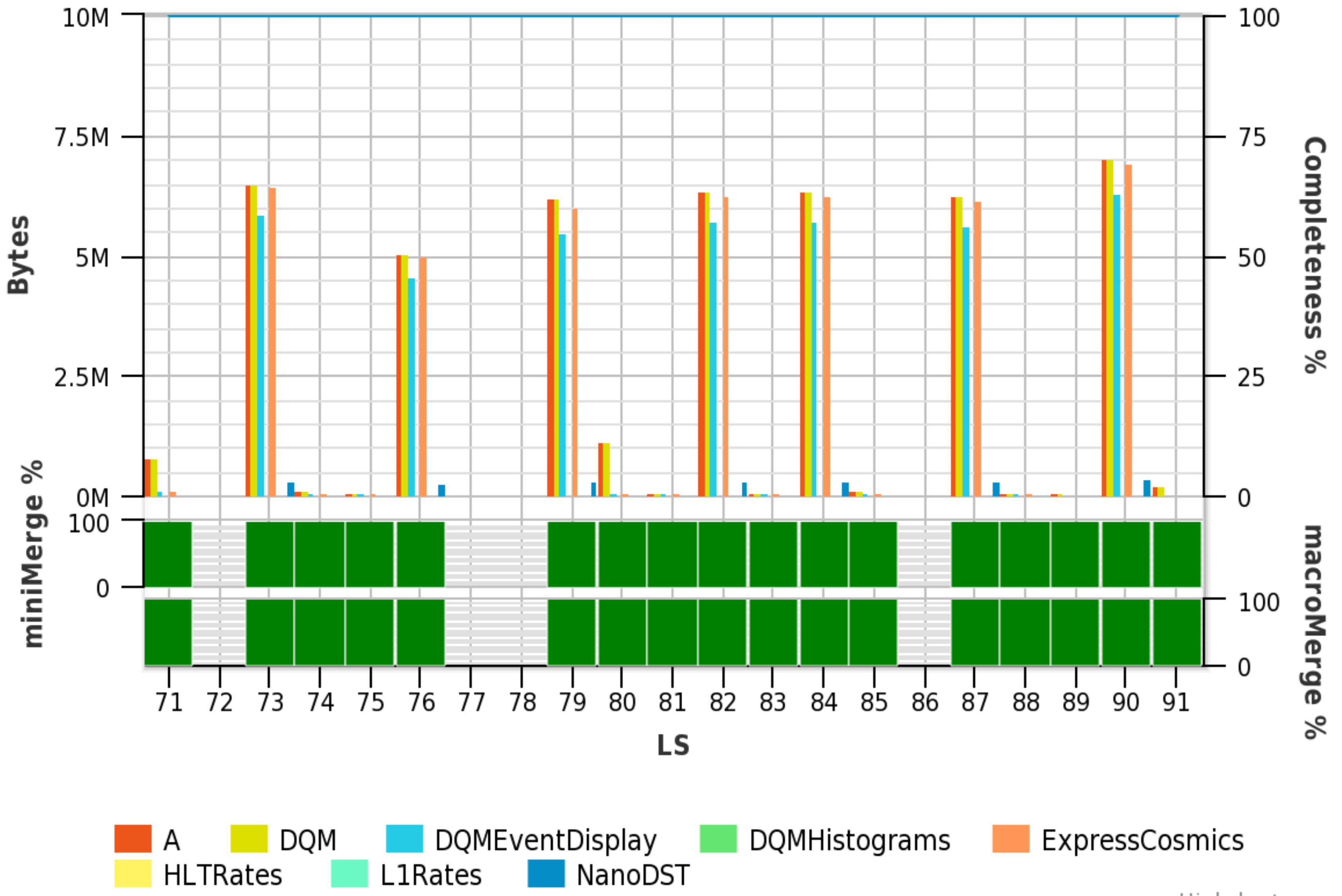
- Logs of FU services (excluding HLT jobs) stored in central-ES cluster
- Documents built by locally running script parsing log files and injected directly into central ES
- UI: logs fetched using a query selecting timestamps within run window



Host	Severity	Message	MsgTime
fu-c2e03-32-03	ERROR	moveFile - [Errno 18] Invalid cross-device link Traceback (most recent call last): File "/opt/hltd /python/aUtils.py", line 443, in moveFile os.rename(newpath_tmp,newpath) OSError: [Errno 18] Invalid cross-device link	2015-03-15 18:00:48
bu-c2e18-17-01	ERROR	elasticsearch connection errorHTTPConnectionPool(host='10.176.17.36', port=9200): Read timed out. (read timeout=20). retry.	2015-03-15 13:34:44
bu-c2e18-31-01	ERROR	elasticsearch connection errorHTTPConnectionPool(host='10.176.17.36', port=9200): Read timed out. (read timeout=20). retry.	2015-03-15 13:34:44
bu-c2e18-41-01	ERROR	elasticsearch connection errorHTTPConnectionPool(host='10.176.17.24', port=9200): Read timed out. (read timeout=20). retry.	2015-03-15 13:34:37

- HLT (CMSSW) logs saved in appliance ES indices

Easter beam splashes in F^{3}Mon


10M
7.5M
5M
2.5M
0M
Bytes
Completeness %
miniMerge %
macroMerge %
LS
A
DQM
DQMEventDisplay
DQMHistograms
ExpressCosmics
HLTRates
L1Rates
NanoDST
Highcharts.com