A generic ROOT monitoring tool for EUDAQ2

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General motivation

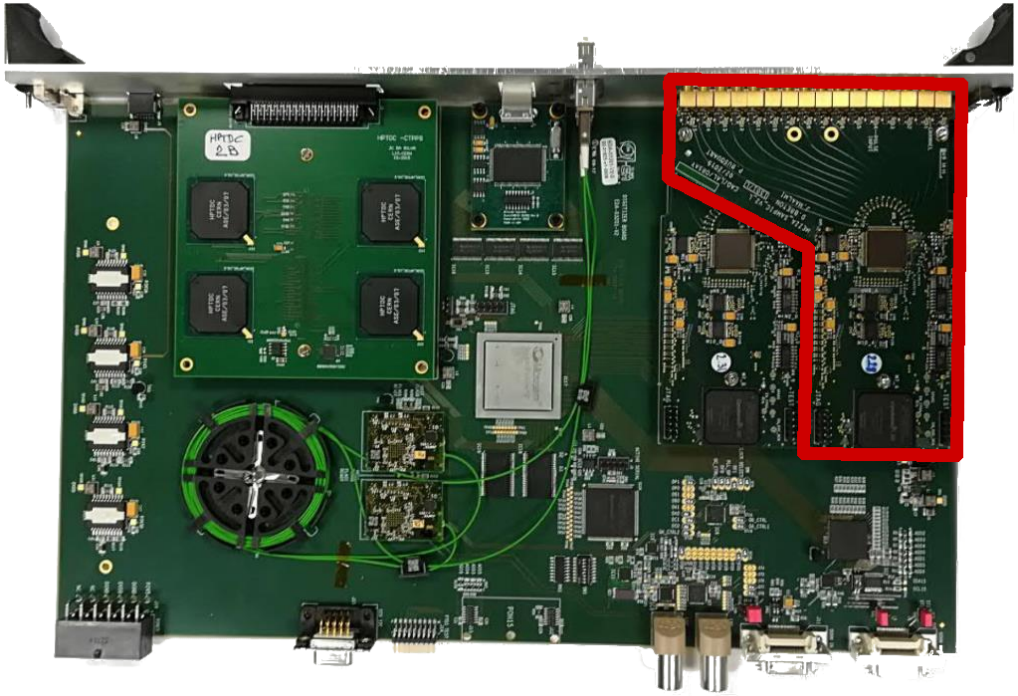
- **Scope**: CMS-TOTEM campaign for the testing of CMS Precision Proton Spectrometer (PPS) timing sensors at DESY-II test beam facilities
  - see E. Bossini's talk on Thursday for a general introduction to PPS, an in-depth description of DUTs and setup, and test beam results

- In need for a (fast...) and **scalable online monitoring tool** for:
  - spatial alignment of the DUT: "tomography" using EUTelescope's MIMOSAs, ... (feasible with EUDAQ1&2's `StdEventMonitor`)
  - characterisation of sensor performance (timing, signal shape and amplitude, ...)

- Two possible strategies considered:
  - large extension of `StdEventMonitor` to account for hardware- and user-specific variables monitoring (and subsequent extension to derivatives of the `eudaq::StandardEvent` object)
  - introduction of a **new monitoring tool** into the EUDAQ2 environment (**this presentation**)

- Developed, commissioned, and **integrated in EUDAQ since** `v2.4.2`

General motivation - PPS DUT readout & CMS-TOTEM motherboard



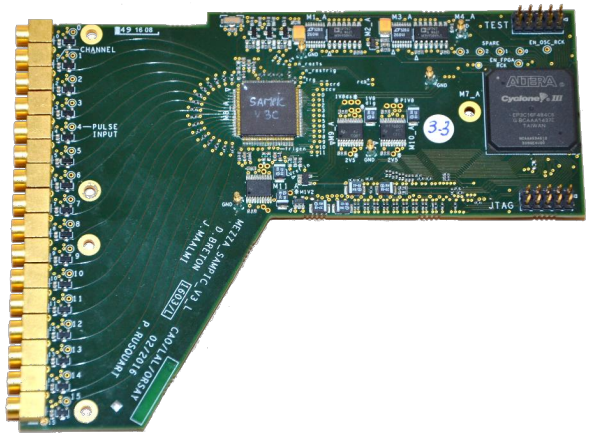
CMS-TOTEM digitiser board used intensively along LHC's run 2 operations

- readout: OptoRx optical link and/or USB 2.0 (Quick USB)
- designed to host up to two **16-channels Sampic mezzanines** (1 module highlighted in red)
- firmware (E. Bossini) handling digitiser sanity checks, frame building, and communication/data transfer

General motivation - Sampic ASIC (Nucl.Instrum.Meth. A787 (2015) 245)

Time- and waveform-to-digital (fast sampling) converter

- 16 channels/chip, up to 64 samples/hit at 10 GSa/s
- 1V ADCs dynamic range, full signal shaping allowing for extraction of advanced features (charge, amplitude, ...)
- 1.5 GHz bandwidth with 8 − 11 bits resolution (0.25 − 1.6 μs dead time/channel for full conversion)
- self-triggering, event building performed at the digitiser level
- 3.5 ps RMS time difference resolution after calibration



Integration of **slow control and readout software** into the EUDAQ2 environment (Aug-Sep 2019)

- DUT/MIMOSAs synchronisation handled through (FPGA) interfacing board propagating EUDET Trigger Logic Unit (AIDA-2020) to CMS-TOTEM digitiser board (→ Sampic event counter)
- basic `eudaq::Producer` handling slow control (steering through sequential ASCII configuration definition) and frames unpacking and recasting into EUDAQ's `StandardEvent` derivative
  - dynamic data format ($1 < n_{ch} < 32$/"event" frame)

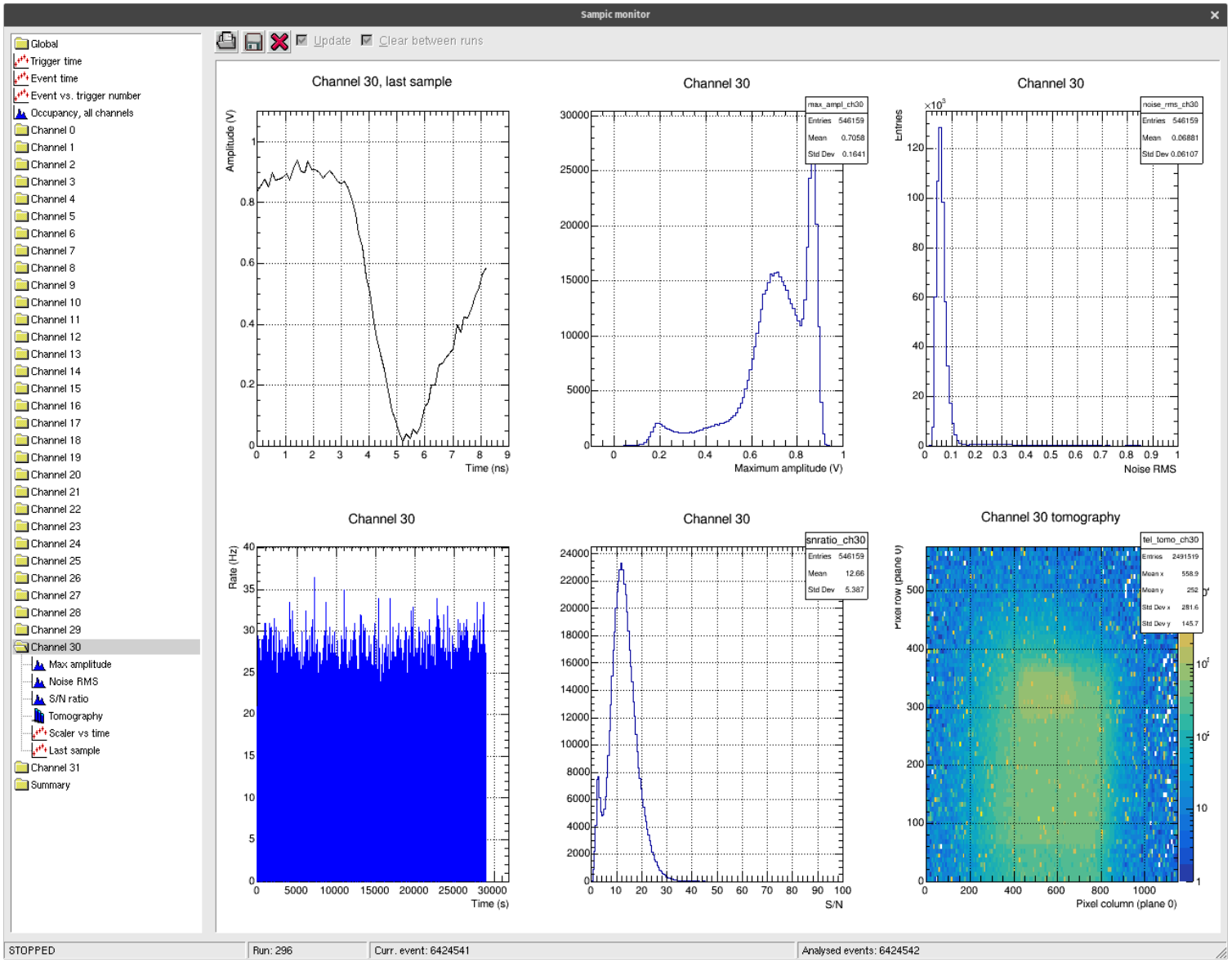
ROOT monitor for EUDAQ2

ROOT monitor

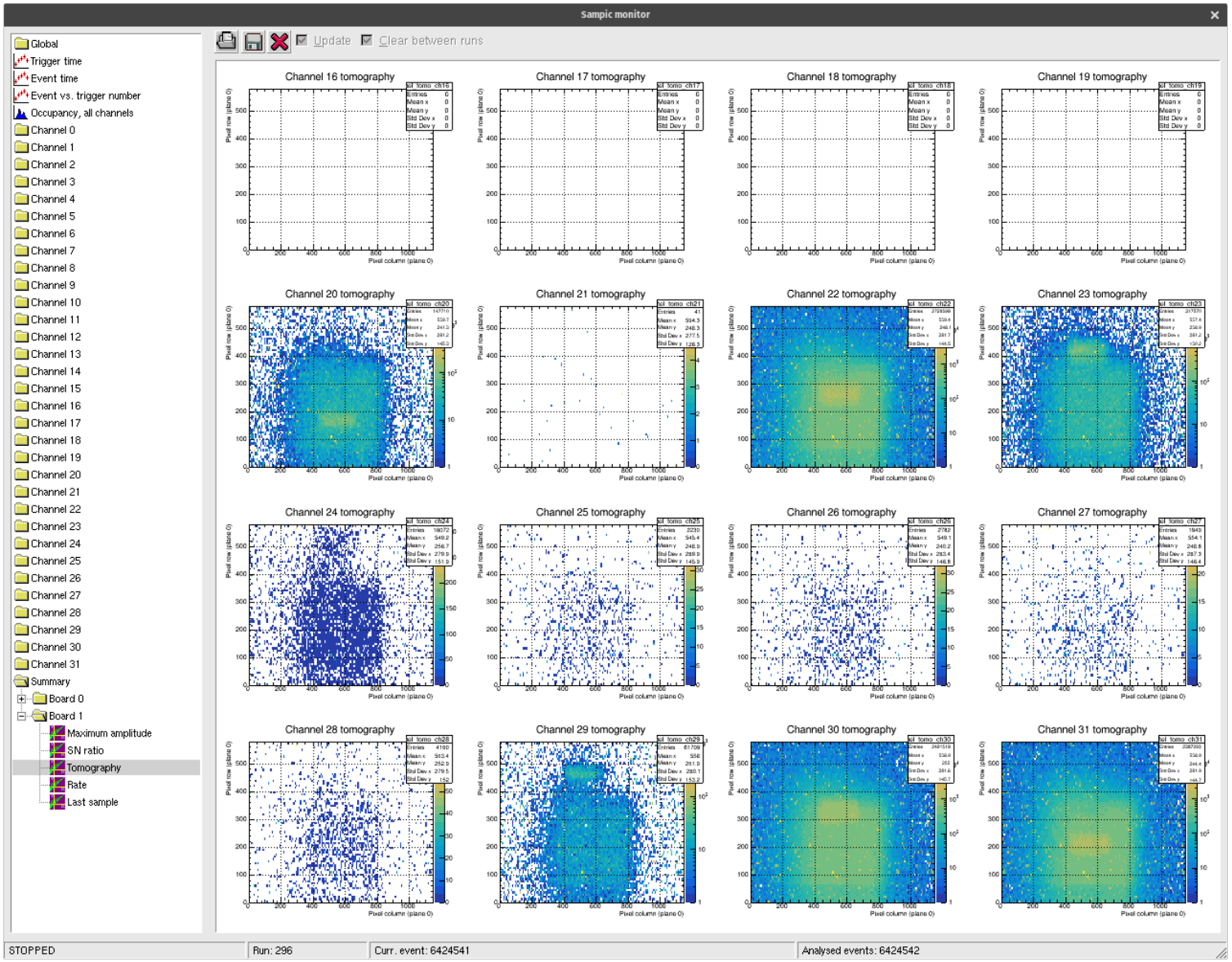
New **base class** for the definition of a GUI monitor

- standard ROOT `TApplication`, embedding EUDAQ2 TCP socket communication capability (commands/data stream/...)
- user configurable **"folder hierarchy"** for all monitored variables
  - each **single monitor**, or **summaries of multiple vistars** (directory view) can be displayed
  - allows combination of monitors from different folder into global summaries (e.g. single monitor for all channels)
- allows to output a hierarchised ROOT file containing all monitors after integration over full run
- **"playback mode"**: asynchronous loading of RAW EUDAQ files, or monitor output ROOT files
  - allows emulating the data collection stage in offline mode, and **reproducing the monitoring** under different conditions (binning, ranges, ...)
  - designed as a tool for **follow-up developments** between two test beams campaigns
- not meant as a replacement for EUDAQ1&2's `StdEventMonitor`, and may be run in parallel
  - possible re-implementation into this new scheme, though...

A live example: Sampic event monitor (single-channel summary)



A live example: Sampic event monitor (global per-monitor summary)



“Hands-on”

Monitor declaration

A minimal working example: declare a monitor with a few generic ROOT objects as monitored collections

- e.g. a 1-dimensional histogram, a 2-dimensional graph, and a profile histogram

```
#include "eudaq/ROOTMonitor.hh" // base dependency
// all required ROOT dependencies
#include "TH1.h"
#include "TH2.h"
#include "TGraph2D.h"
#include "TProfile.h"

class MyROOTMonitor : public eudaq::ROOTMonitor {
public:
  MyROOTMonitor(const std::string& name, const std::string& runcontrol):
    eudaq::ROOTMonitor(name, "Ex0 ROOT monitor", runcontrol){}
  void AtConfiguration() override;
  void AtEventReception(eudaq::EventSP ev) override;

  static const uint32_t m_id_factory = eudaq::cstr2hash("MyROOTMonitor");
private:
  TH1D* m_my_hist;
  TGraph2D* m_my_graph;
  TProfile* m_my_prof;
};
```

Monitor implementation

Register the new monitor into the runtime database:

```
namespace{
  auto my_mon = eudaq::Factory<eudaq::Monitor>::Register<MyROOTMonitor, const std::string&,
        const std::string&>(MyROOTMonitor::m_id_factory);
}
```

Build any ROOT's `TObject`-derivative for monitoring, using the templated booking method from the `m_monitor` protected member inherited from `eudaq::ROOTMonitor` base class:

```
template<typename T, typename... Args> T* Book(const std::string& path, const std::string&
      name, Args&&... args);
```

Build all monitored objects at e.g. the `eudaq::ROOTMonitor::AtConfiguration` declaration:

```
void MyROOTMonitor::AtConfiguration(){
  m_my_hist = m_monitor->Book<TH1D>("Channel 0/my_hist", "Example 1D histogram",
    "h_example", "A histogram;x-axis title;y-axis title", 100, 0., 1.);
  m_monitor->SetDrawOptions(m_my_hist_2d, "lego");
  m_my_graph = m_monitor->Book<TGraph2D>("Channel 0/my_graph", "Example graph");
  m_my_graph->SetTitle("A graph;x-axis title;y-axis title;z-axis title");
  m_monitor->SetDrawOptions(m_my_graph, "colz");
  m_my_prof = m_monitor->Book<TProfile>("Channel 0/my_profile", "Example profile",
    "p_example", "A profile histogram;x-axis title;y-axis title", 100, 0., 1.);
}
```

Monitor implementation

Monitors populated through a callback at each standard event reception

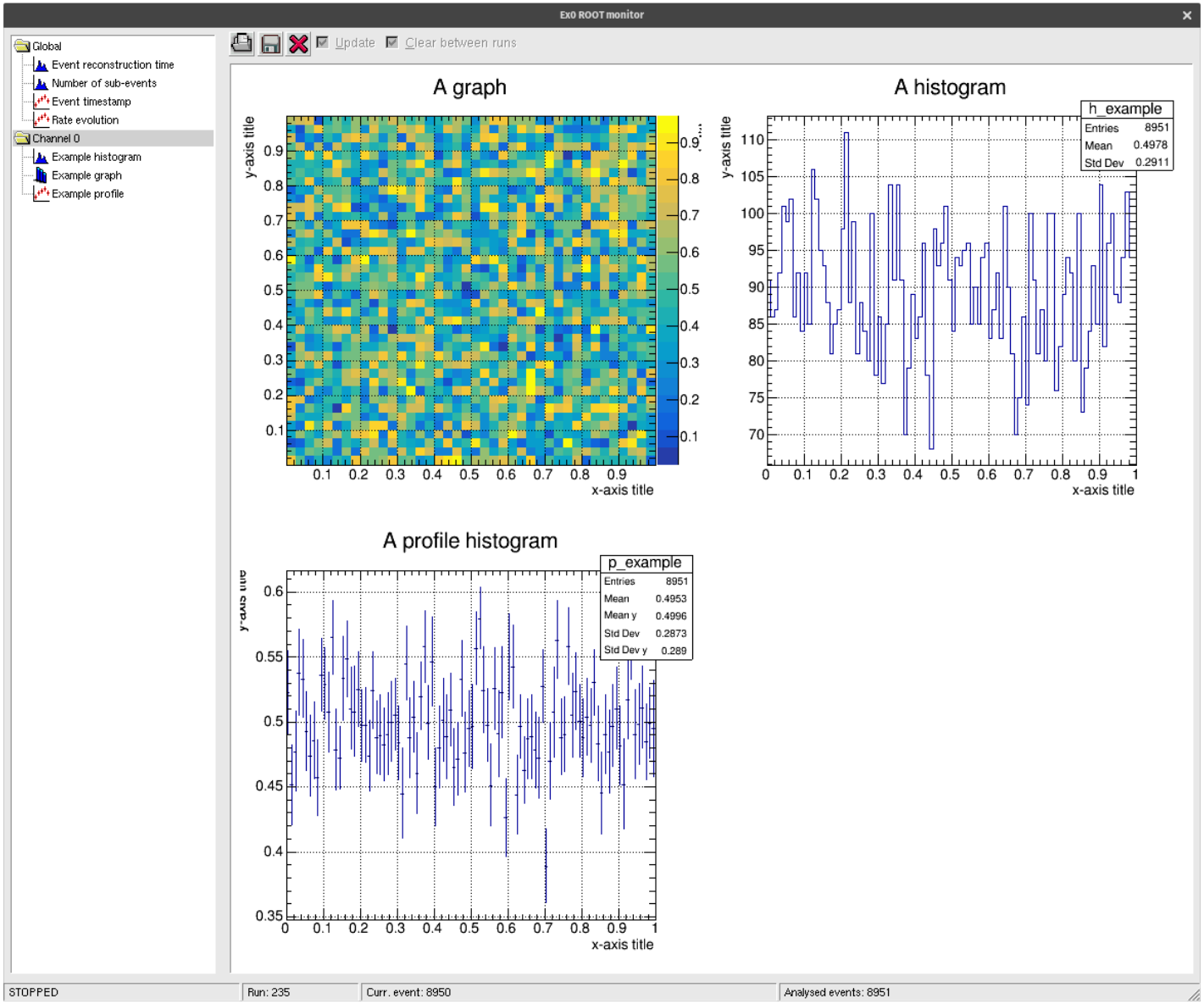
- if needed with proper casting to user-defined data format

```
void MyROOTMonitor::AtEventReception(eudaq::EventSP ev){
  auto event = std::make_shared<MyEventDataFormat>(*ev);
  // let there be a user-defined MyEventDataFormat, containing e.g. three
  // double-precision attributes get'ters:
  //   double GetQuantityX(), double GetQuantityY(), and double GetQuantityZ()
  m_my_hist->Fill(event->GetQuantityX());
  m_my_graph->SetPoint(m_my_graph->GetN(),
    event->GetQuantityX(), event->GetQuantityY(), event->GetQuantityZ());
  m_my_prof->Fill(event->GetQuantityX(), event->GetQuantityY());
}
```

Other overridable members:

- two global `void AtInitialisation()`/`void AtReset()` methods,
  - e.g. resetting accumulative variables, re-booking histograms, ...
- two "run-local" `void AtRunStart()`/`void AtRunStop()` methods
  - e.g. prepare and write to a per-run external dump file, R/W access to conditions database, ...

A sample monitor - output



Summary and next steps

- Integration of the CMS-TOTEM motherboard into the EUDAQ2 environment
  - Successfully tested last September at DESY-II test beam facilities, no synchronisation loss observed
- New tool developed for the fast monitoring of basic, and complex observables at test beams
  - Designed to fit EUDAQ users' needs, can be tailored for all data formats
  - GUI building as overhead, allows to concentrate on the monitors...

Work ongoing

- Integration of the DUT reconstruction in the EUTelescope data analysis framework for the synchronised MIMOSAs+DUT event content
- Helper for the definition of variables correlation monitoring (DUT $\leftrightarrow$ EUTelescope, DUT1 $\leftrightarrow$ DUT2, ...)
- "Trivial" monitors for EUDAQ's `StandardEvent` and `TTreeEvent`-compatible data formats
  - further motivation for users to develop converters in their workflow

The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF)