H4DAQ

A modern and versatile data-acquisition package for calorimeter prototypes test-beams

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on behalf of the CMS Collaboration

CHEF 2017

Introduction & Motivations

a DAQ for CMS-ECAL test beams:

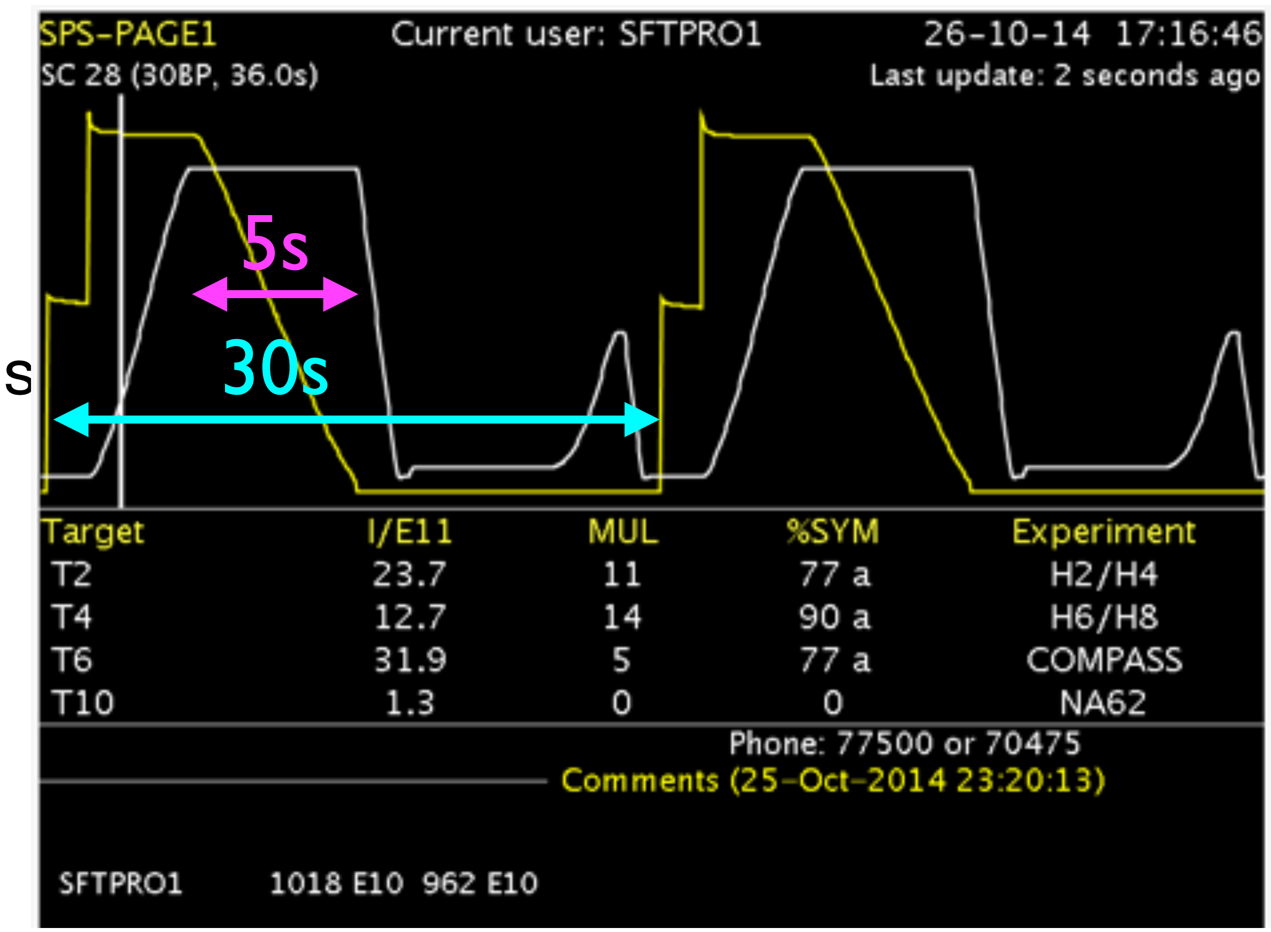
- fast & stable
- versatile
- configurable
- handling read-outs located in different places
- running on conventional desktop PCs

Used in CERN-North Area H6 / H4 / H2 beams line, in CERN T9, and in Frascati BTF

Concept & Design

- Using commercial PCs and commercial ethernet communications

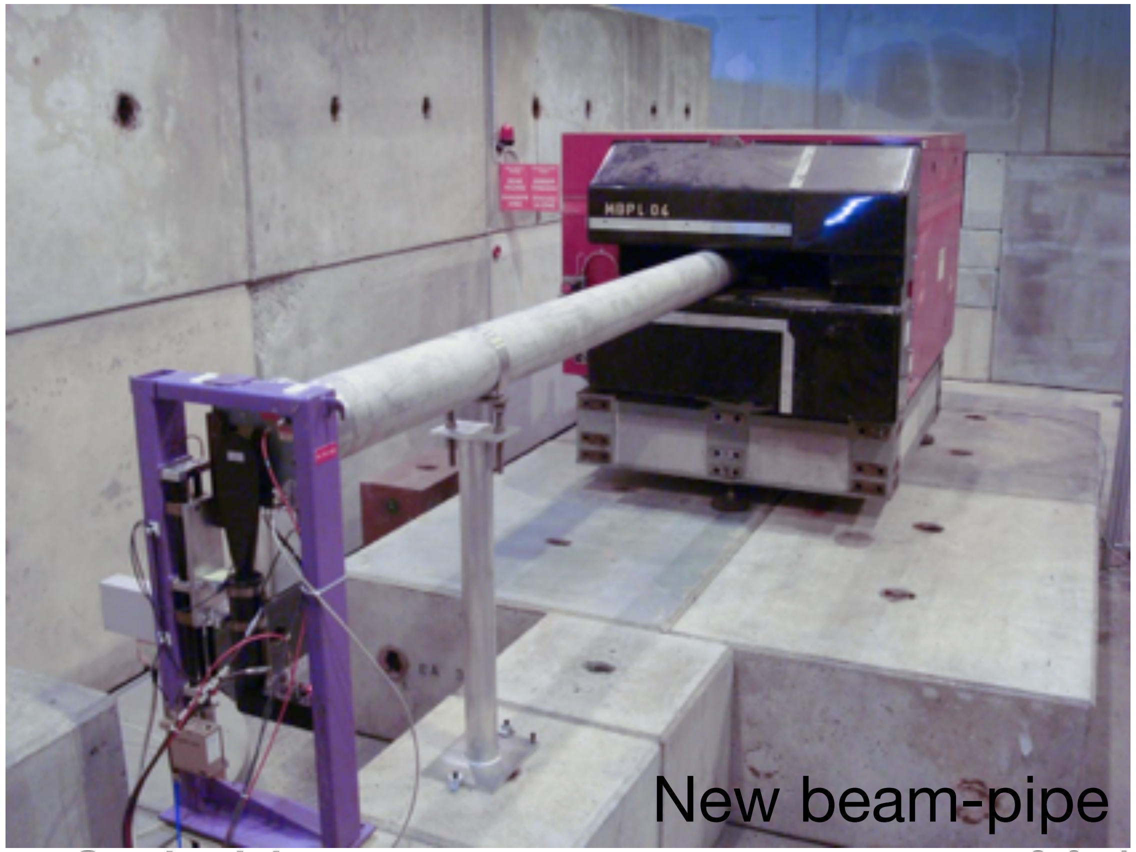
- Optimized for CERN-North Area delivery: ~5s spill every ~30s
  - using time w/o event to complete slow operations (event building, network communications, …)
  - Fast software without latency
  - Operating with CERN-SPS status informations



- Successfully used in other beam areas:
  - Frascati BTF
  - Cosmic muon table-top laboratory setup

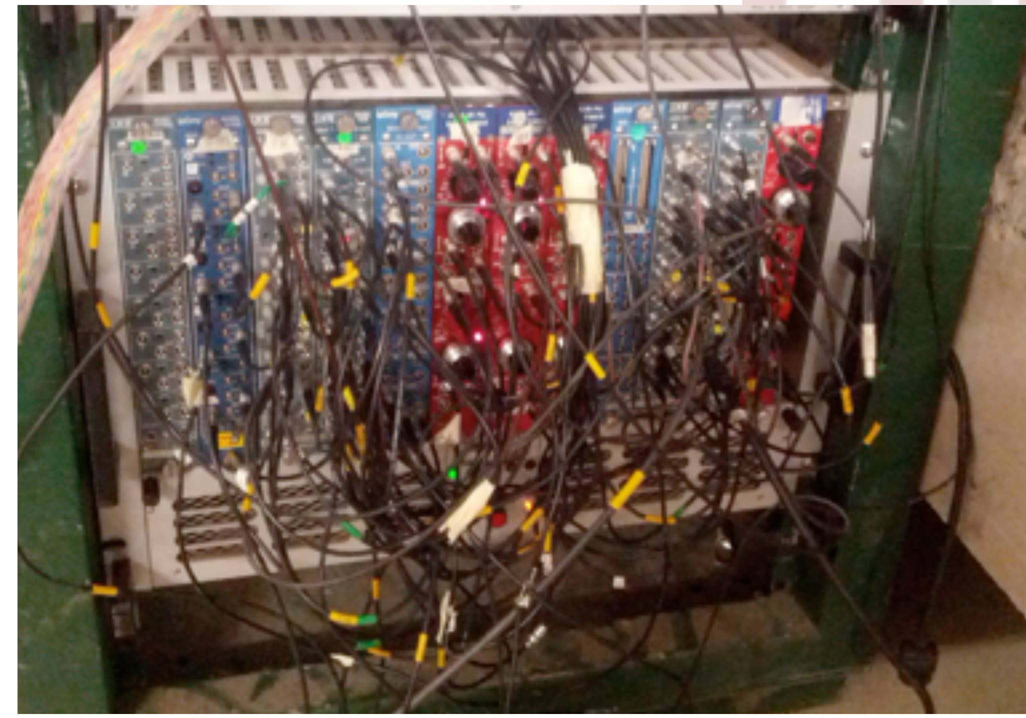
Concept & Design

- Different hardware / software parts with specific tasks
  - Each software component organized as a finite state machine (FSM)
- Hardware boards for analog to digital conversion
- Hardware triggers (from beam telescopes)
- Global interlock to triggers if read-out machines (hardware or software) are “busy”



Read-outs

- VME Acquisition:
  - CAEN ®
  - LeCroy
  - …
- NIM
- Ipbus doi: 10.1088/1748-0221/10/02/C02019
- TOFPET doi: 10.1088/1748-0221/11/03/C03042
- Connection with the software
  - DAQ is interfaced with Boards with proprietary libraries



LECROY_1182.hpp
MAROC_ROC.hpp
VFE_adapter.hpp

CAEN_V1290.hpp
CAEN_V1495PU.hpp
CAEN_V1742.hpp
CAEN_V265.hpp
CAEN_V513.hpp
CAEN_V560.hpp
CAEN_V785.hpp
CAEN_V792.hpp
CAEN_V814.hpp
CAEN_VX718.hpp

Network

- Communication among PC over ethernet networks
  - Synchronous communications for acknowledging machine status (DAQ internal commands)
  - Asynchronous communications for data stream
  - Multicast (one-to-many)

- Using ØMQ messaging library [zeromq.org]
  - open source

Finite State Machines (FSM)

- Software unit have been divide in FSM
- Each state represent precise status of the DAQ
- Changing of states are induced by SPS commands, triggers, network communication, …
- Mainly 3 FSM:
  - Run Controller
  - Data Readout
  - Event Builder (in multi DR mode) [more on next slide]
  - Data Receiver (Optional)

Run Controller:

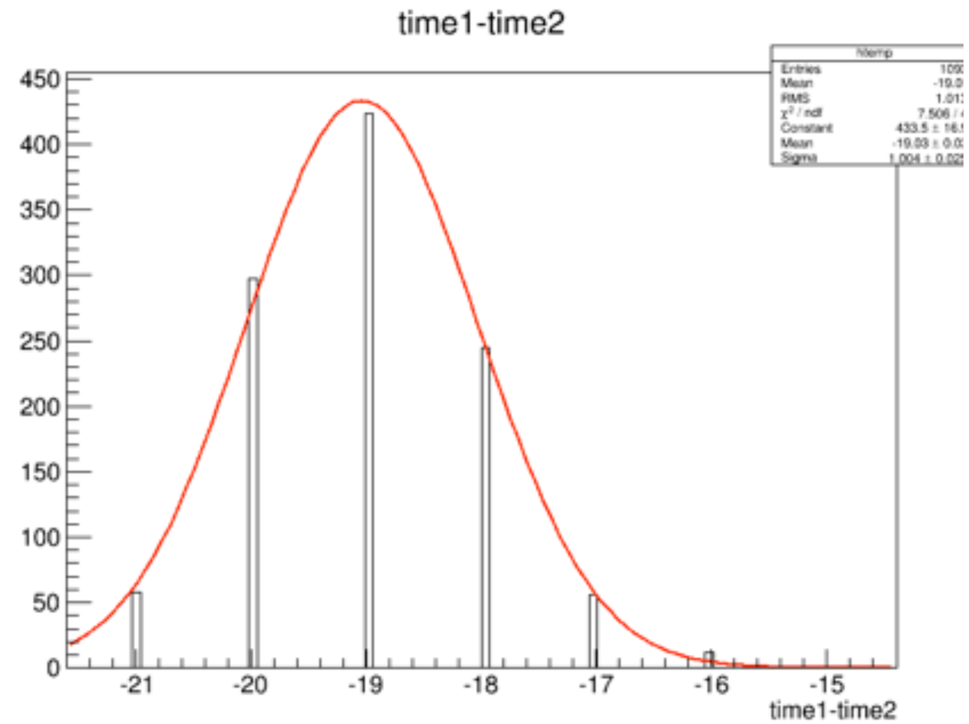
- Control and synchronize operations from the different units
- Receive user input (from GUI or debug tools)
- Receive machine (SPS) inputs
- Report back problems

Data Readout:

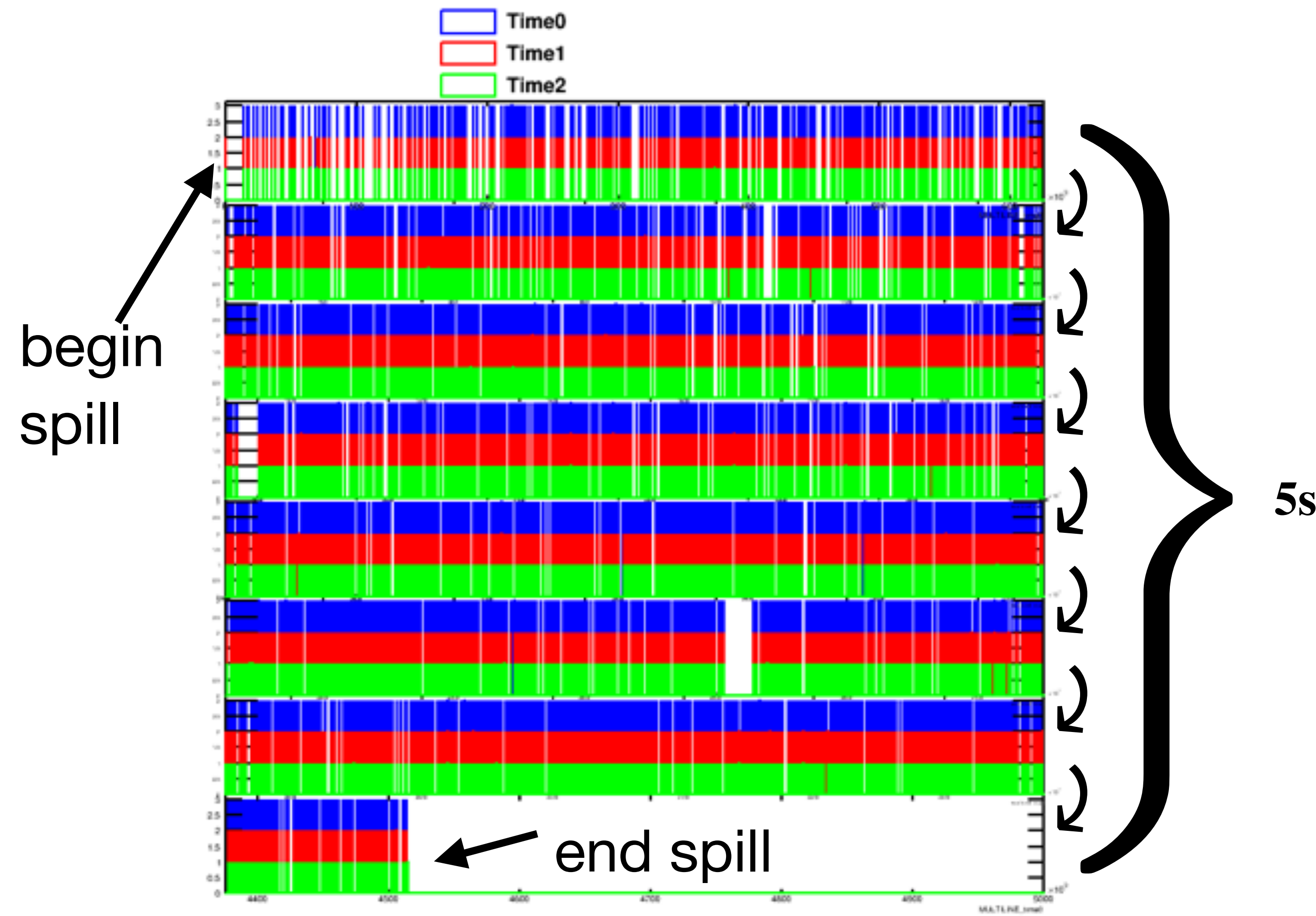
- Handles hardware boards
- Communicates and update its status to the run controller
- Reads data and send them to the event builder

Event Building

- Event in each read out is built separately and sent to the Event Builder machine
- events are efficiently matched in time
  - commercial laptops have sufficient precision on time differences (~10μs)
- Building starts online after “spill” ends
- Raw events are saved on disk.



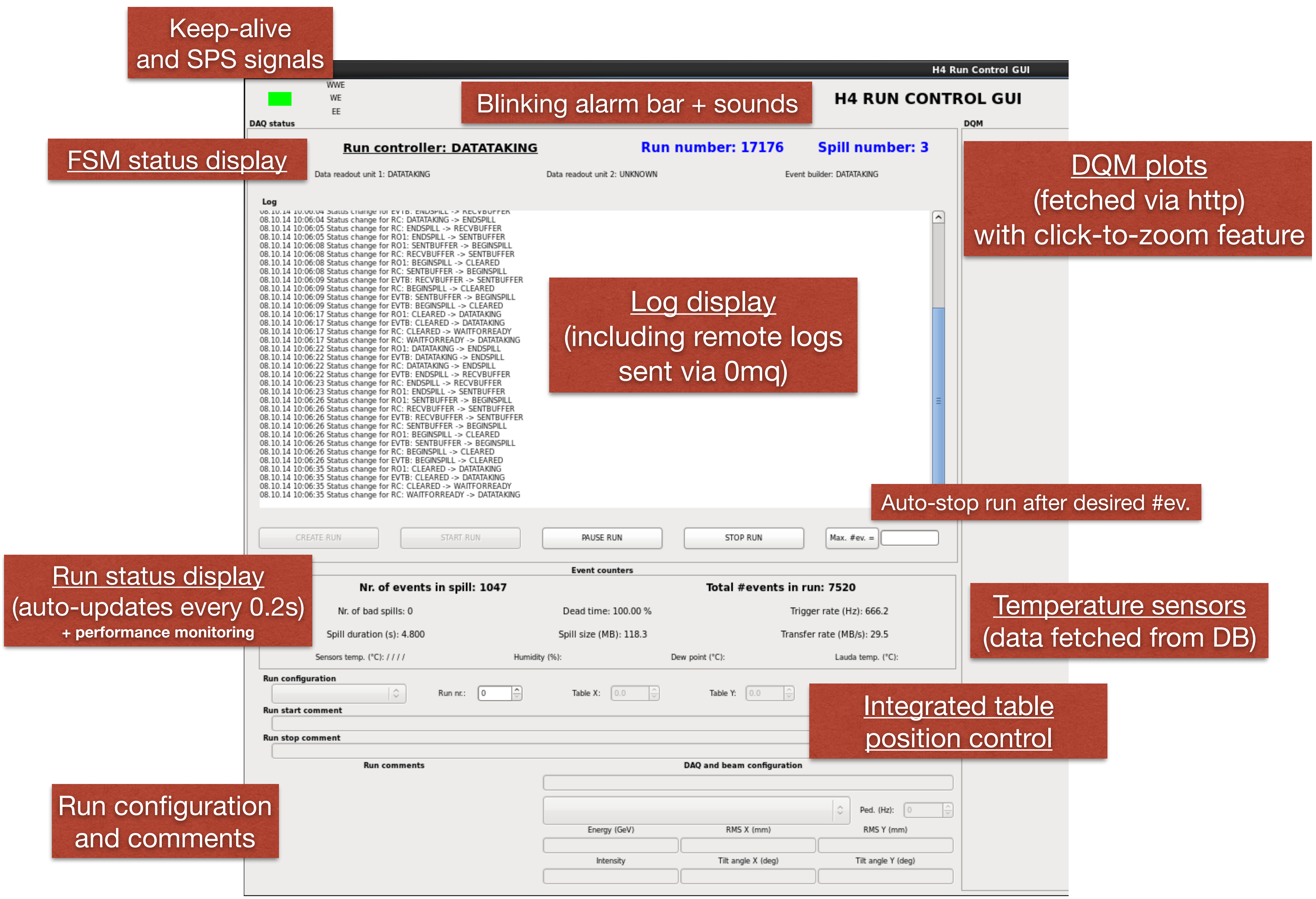
Time difference in the event of one spill (timestamp) in 10 μs



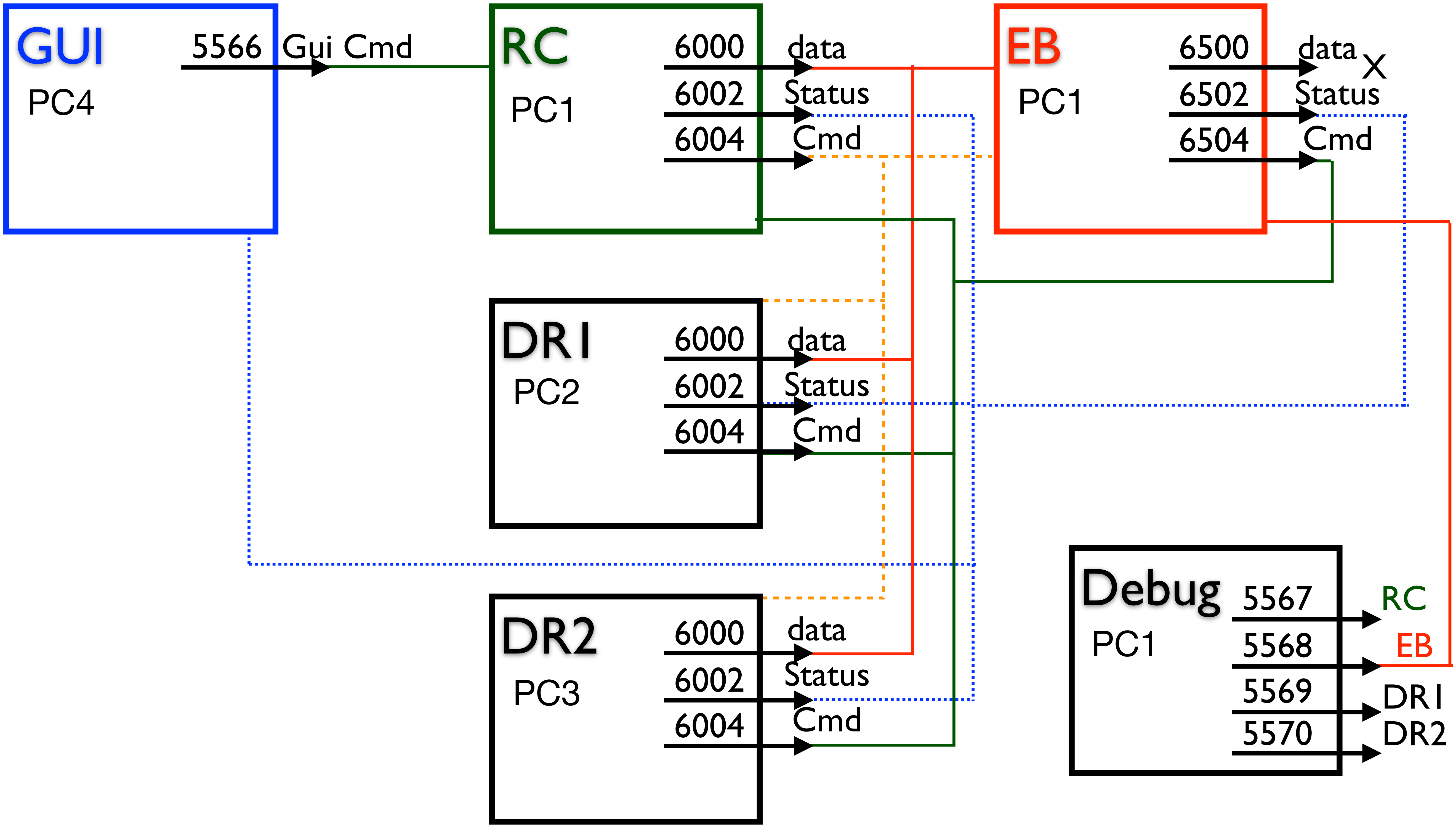
One of the first tests, showing the possibilities of aligning read outs and building the event with conventional desktops

Graphical User Interface

- Simple User Interface
- Interfaced to LabView and web-browser:
  - control position of the test-channel from control room
  - automize operation on the DAQ system
  - monitor with IP webcam different read-outs

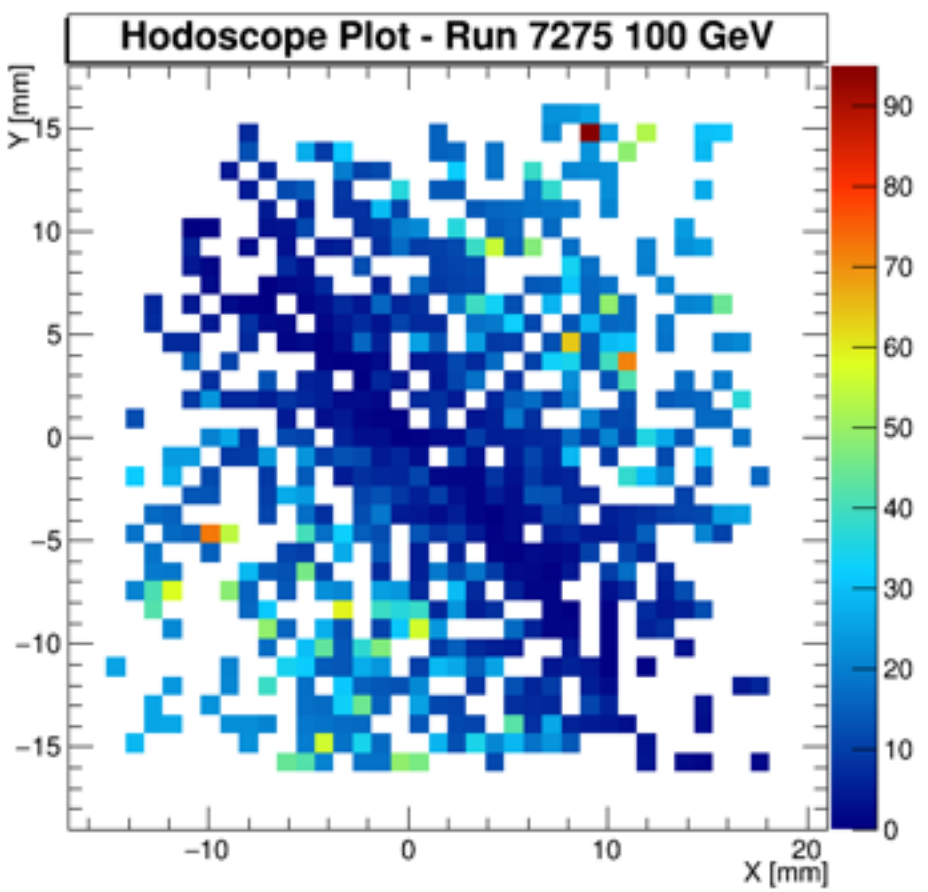


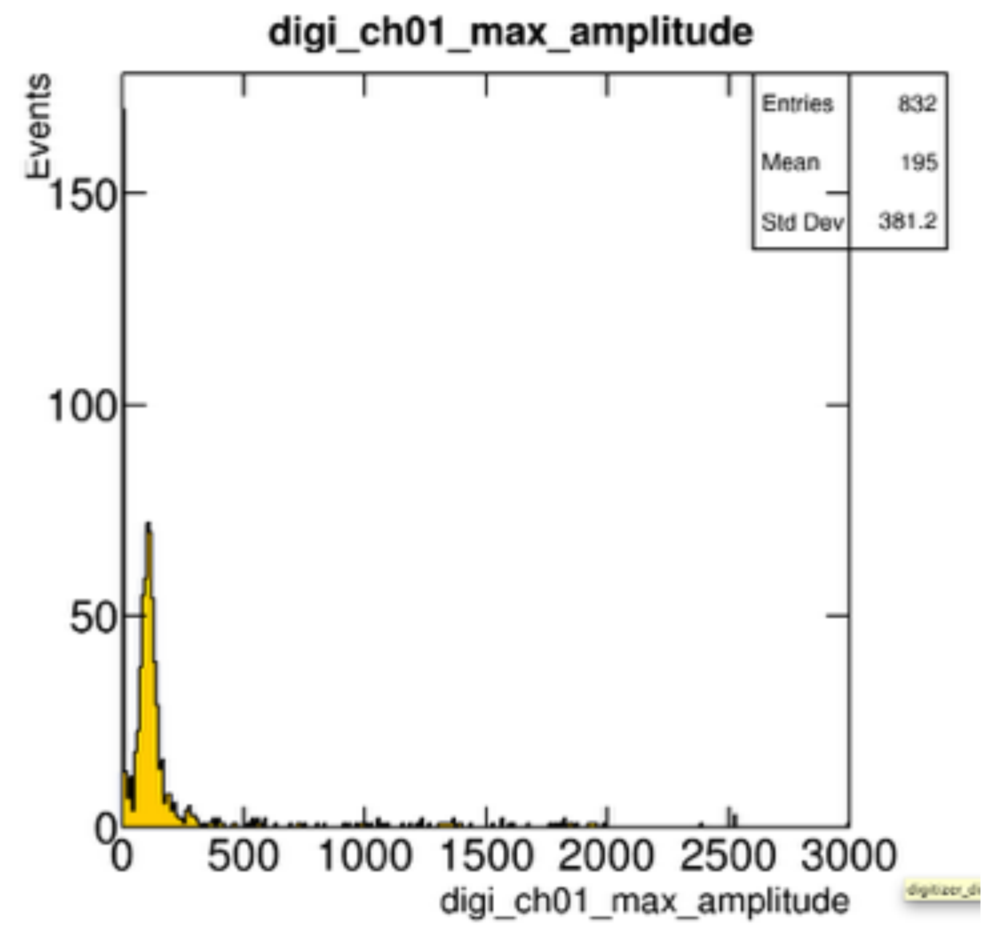
Setup example



Data Quality Monitor (DQM)

- Online data quality monitor can be run
  - with an optional pre-scale on the acquired events per spill
  - allow for fast response to problems from shifter





- Analysis packages:
  - modular
  - can be integrated to deal with different detectors/electronics

H4DAQ: a very successful data-taking!

W/CeF_3 test beam results R&D:

- doi:10.1109/NSSMIC.2015.7581770 "*High-energy electron test results of a calorimeter prototype based on CeF3 for HL-LHC applications*"
- doi:10.1016/j.nima.2015.09.052 "*Test beam results with a sampling calorimeter of cerium fluoride scintillating crystals and tungsten absorber plates for calorimetry at the HL-LHC*"
- doi:10.1088/1748-0221/10/07/P07002 "*Beam test results for a tungsten-cerium fluoride sampling calorimeter with wavelength-shifting fiber readout*"
- doi:10.1016/j.nima.2015.09.055 "*Performance of a Tungsten-Cerium Fluoride Sampling Calorimeter in High-Energy Electron Beam Tests*"

LYSO+SiPM:

- doi:10.1016/j.nima.2016.05.030 "*Detection of high energy muons with sub-20 ps timing resolution using L(Y)SO crystals and SiPM readout*"
- doi:10.1016/j.nima.2017.02.008 "*Timing capabilities of garnet crystals for detection of high energy charged particles*"

H4DAQ: a very successful data-taking!

iMCP test beam results:

- doi:10.1088/1748-0221/12/08/C08014 "*Micro-channel plates in ionization mode as a fast timing device for future hadron colliders*"
- arXiv:1707.08503 "*Response of microchannel plates in ionization mode to single particles and electromagnetic showers*"
- doi:10.1088/1748-0221/12/03/C03019 "*A fast timing calorimetric layer using micro-channel plates in ionisation mode*"
- doi:10.1016/j.nima.2016.05.101 "*Micro-channel plates in ionization mode as a fast timing device for future hadron colliders*"
- doi:10.1016/j.nima.2015.06.057 "*Response of microchannel plates to single particles and to electromagnetic showers*"

Si timing:

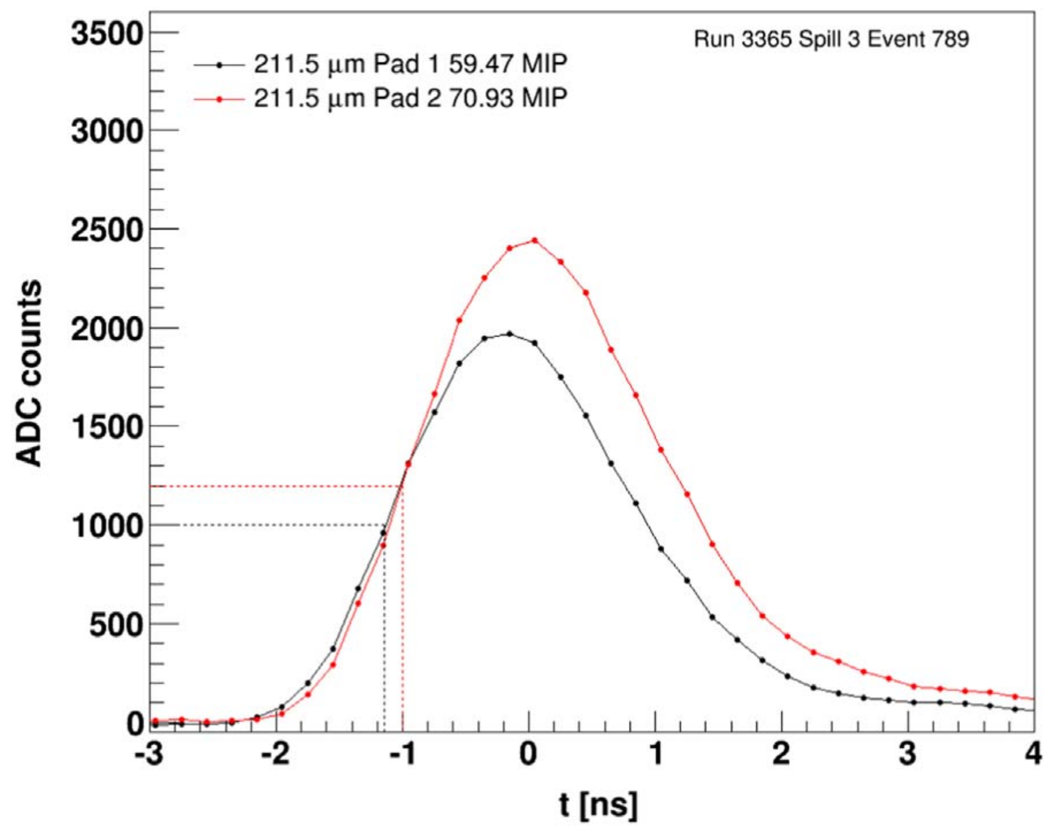
- doi:10.1016/j.nima.2017.03.065 "*On the timing performance of thin planar silicon sensors*"

Talk & poster at CHEF using H4DAQ:

- A. Massironi: "*Prospects for a precision timing upgrade of the CMS PbWO crystal electromagnetic calorimeter for the HL-LHC*"

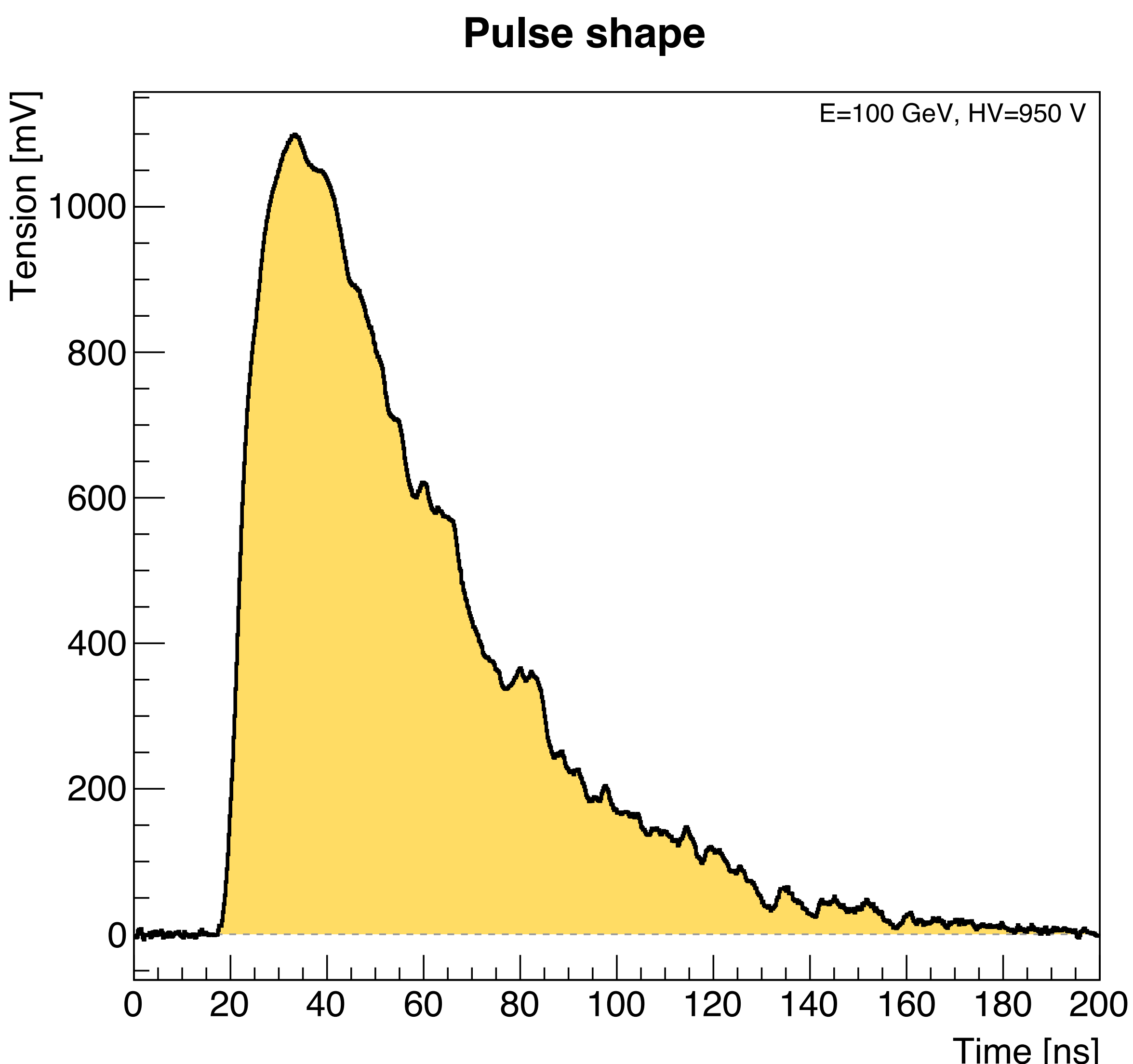
at CHEF

Examples of data acquired



Example of pulse-shape taken with Si precision timing detector

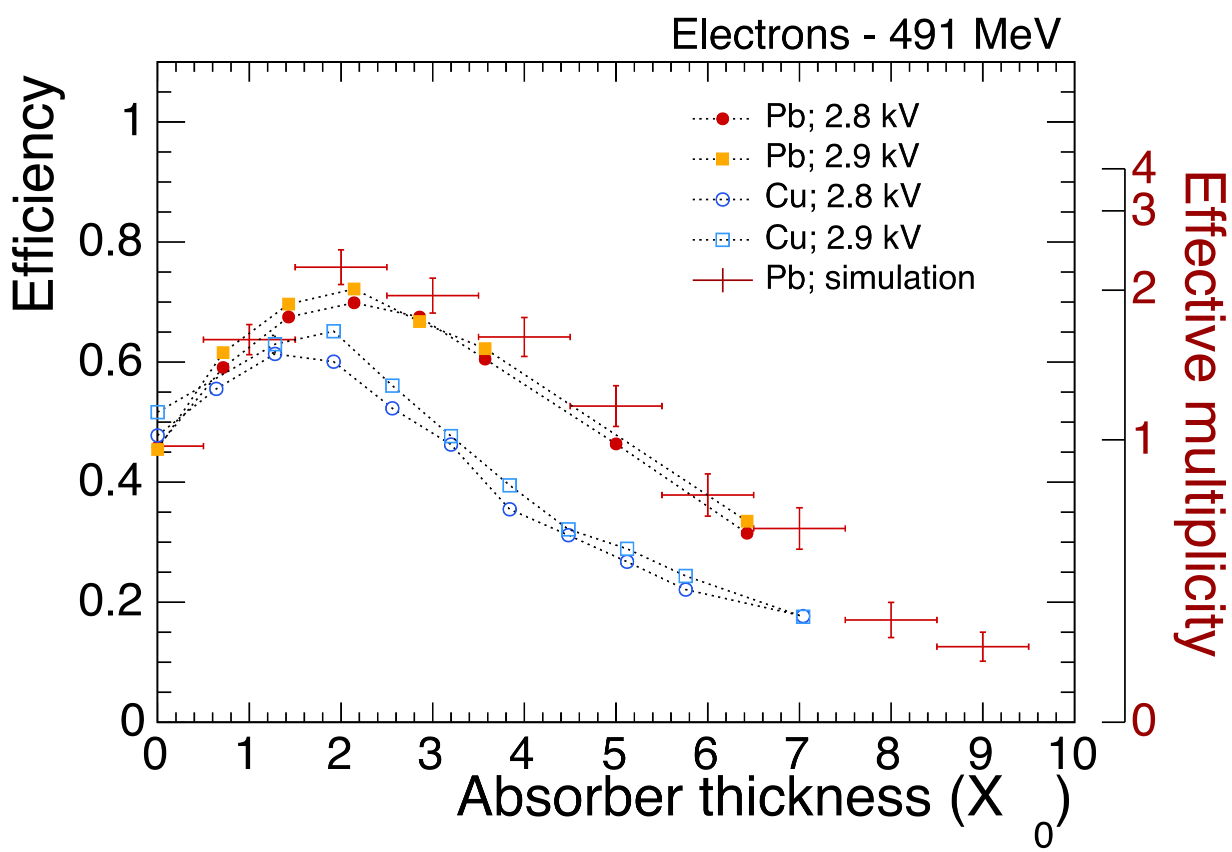
doi:10.1016/j.nima.2017.03.065



Example of single pulse-shape taken with W-CeF3 tests

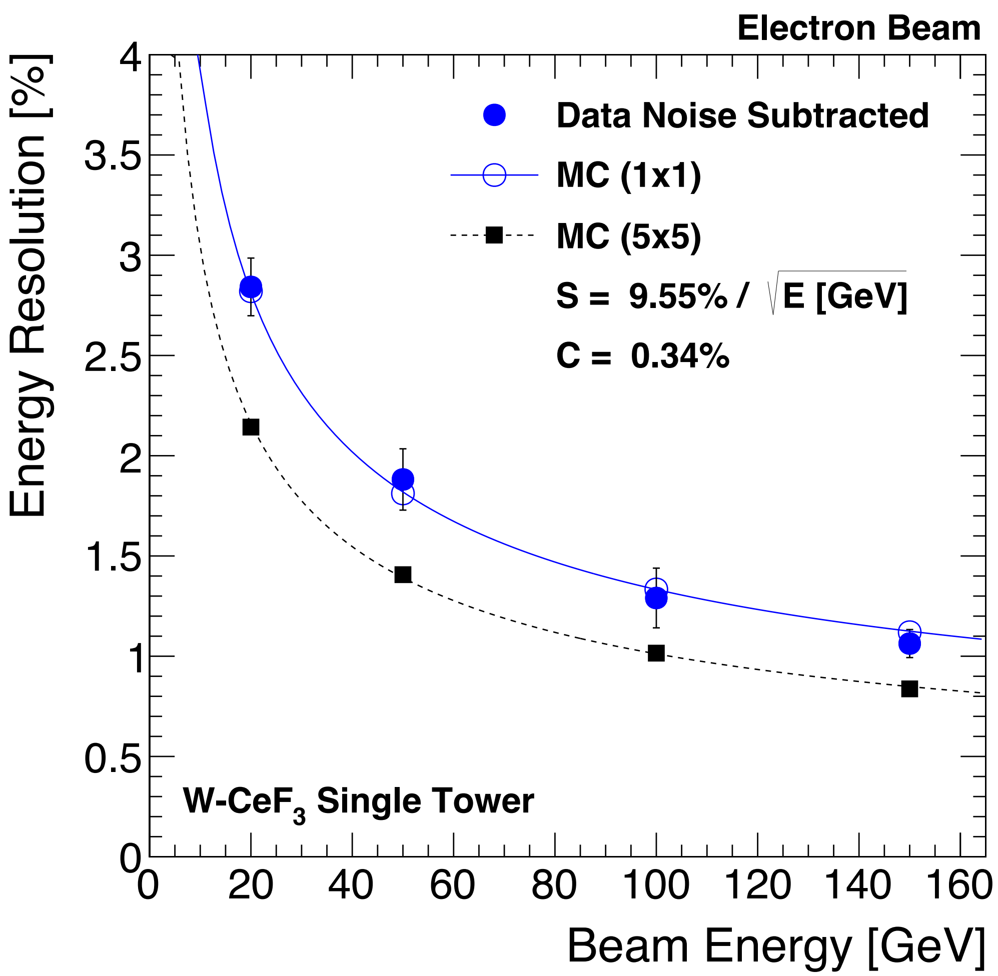
doi:10.1016/j.nima.2015.09.055

Example of analysis



Efficiency of a 491 MeV electron in a i-MCP detector

doi:10.1016/j.nima.2015.06.057



Energy resolution of a W-CeF3 single tower sampling calorimeter

doi:10.1016/j.nima.2015.09.055

Summary & Conclusions

- A Data acquisition system deployed for CMS-ECAL related beam tests
  - mainly developed having in mind CERN beam lines
  - easily adaptable to other situations:
    - Frascati BTF
    - Cosmic muon table-top laboratory setup

- Fast, very reliable, and robust

- Currently used and being used in several configurations:
  - limitations are mainly due to data-transfer from board to PC
  - read with many digitizer channels

- Open source code:
  - github.com:cmsromadaq/H4DAQ
  - github.com:cmsromadaq/H4GUI
  - github.com:cmsromadaq/H4DQM