WP9.3 AIDA Testbeam Telescope Offline Software

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for the developers team
AIDA Final Meeting
CERN, 9-11 December 2014

Core developers

DESY :	Denys Lontkovsky (ZEUS), Alex Morton (ATLAS), Hanno Perrey (CMS), Igor Rubinskiy (ATLAS) Many thanks to Claus Kleinwort
Uni Goettingen:	Tobias Bisanz (ATLAS)

Many contributors from the R&D community

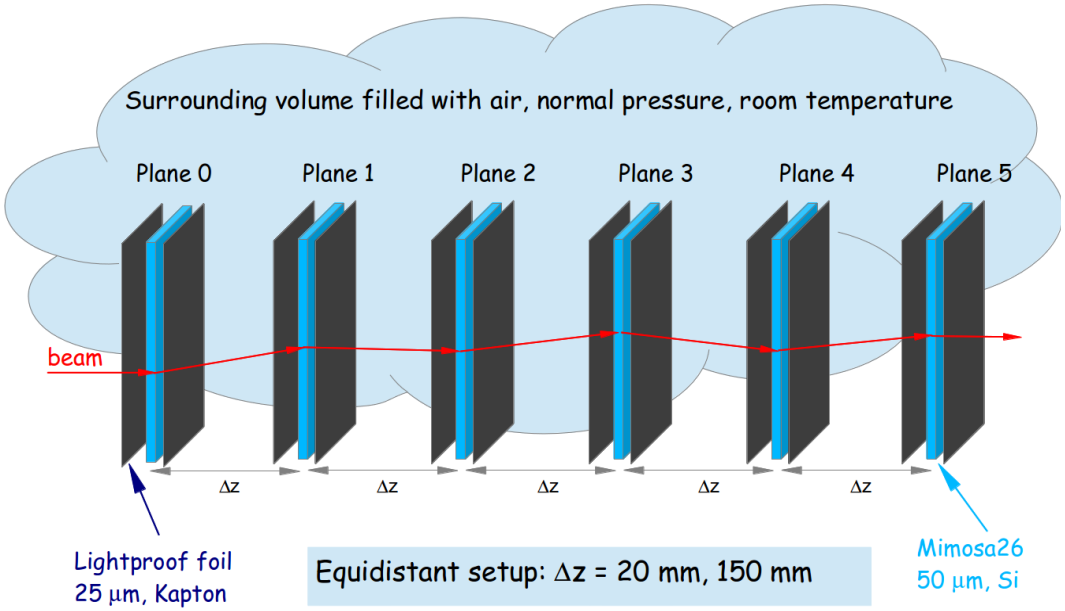
Code refactoring:	DESY -	Philipp Hamnet (ATLAS), Thomas Eichorn(CMS), Simon Spannagel (CMS)
Nightly builds monitoring:	DESY -	Yuri Soloviev (Belle II)
Strip detectors integration:	DESY -	Eda Yildirim (ATLAS)
Geant4 simulations:	CERN -	John Idarraga (NASA), Mathieu Benoit (CLICpix)
Various topics:	many users from BelleII, ATLAS, CMS, CLICpix, and R&D projects	

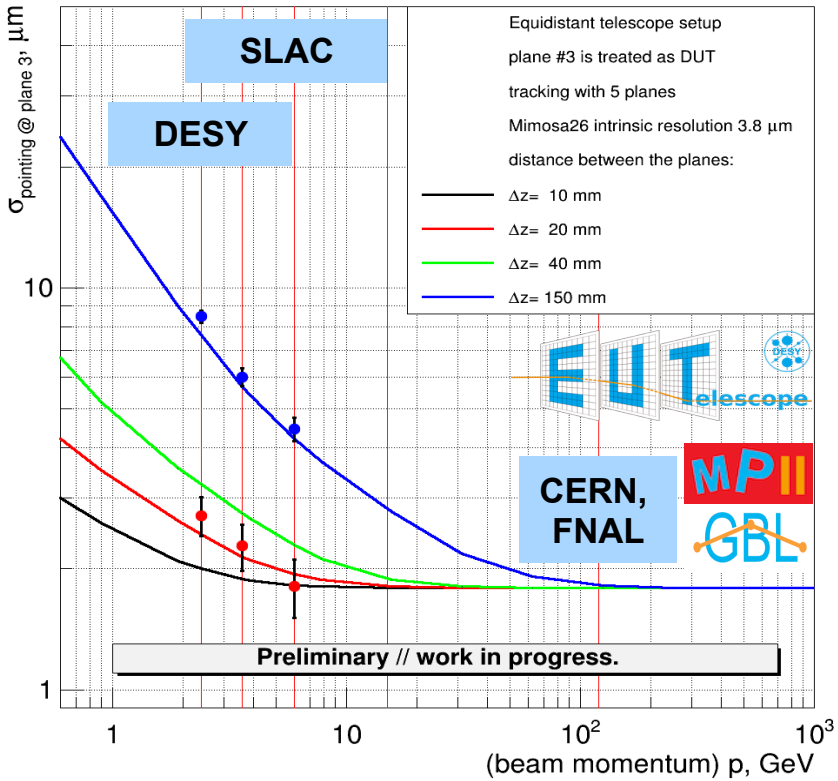
HELMHOLTZ ASSOCIATION

AIDA

DESY

EUDET/AIDA pixel beam telescope, tracking precision





The interplay between
- the telescope detector resolution,
- multiple scattering,
- distance between telescope planes
- distance to the DUT (track fit “passive” plane)

and their impact on alignment and tracking are well understood.

There are more low energy beam facilities not mentioned on this plot

In many cases the R&D groups revise their DUT mechanics to get optimal track pointing precision on the DUT

Software: Offline reconstruction

Over the four years of the AIDA project the EUTelescope library (part of the ILCSoft package for testbeam tracking) has undergone a major revision:

Code refactoring:

- Removed obsolete code (out of 150 k lines of code!)
- compile time warnings strongly reduced
- consistent approach to the messages (errors, warnings, info levels)
- code comments

Redesign:

- New geometry layout of the telescope setup (still with ILCSoft Gear)
- Navigation between sensitive and non sensitive layers with new class EUTelGeometry based on ROOT::TGeo
- Revised basic element class EUTelGenericPixel (fits also strips)
- Clustering in non-standard pixel detectors with EUTelGeo (for L-type pixels, honeycomb, etc.)
- Pattern Recognition, Alignment, Tracking – with GBL+Millepede II libraries
- allows dead material layers and B-field presence
- Added one more package: Allpix for pixel/strip detectors digitisation models validation

Well defined Examples

- Introduced examples with reference data: Telescope only data, and with DUTs. Shows how the data processing flow should take place.

Nightly builds

- For all examples nightly build tests are running and displayed with Aidasoft/Cdash, we get emails every morning about (un)successful changes to the repository

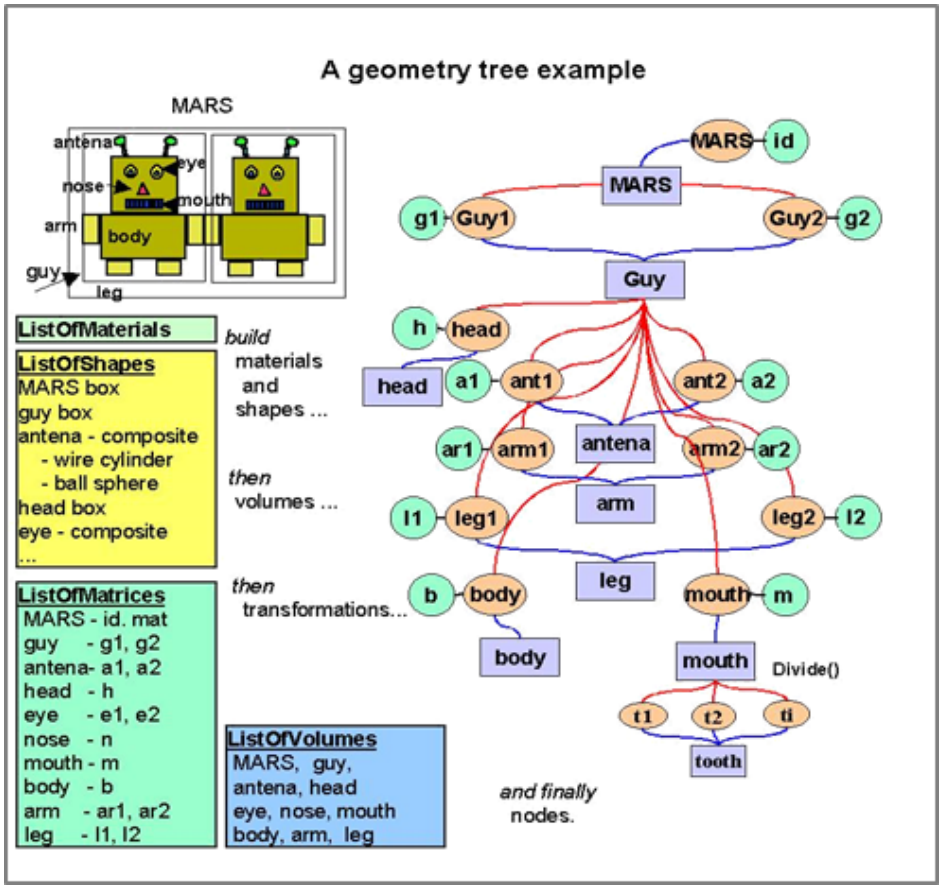
GitHub: Decentralized repository and version control

- Improves branching, tagging, interaction between developers by really a lot (same for EUDAQ)

… pixel beam telescope º R&D Tracker, Offline Software 1/2

Reconstruction Software EUTelescope highlights

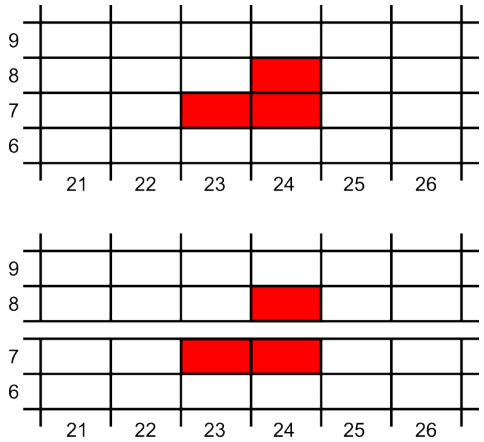
- based on ILCSoft/Marlin framework and LCIO data format
- generic implementation of data processing: clustering, alignment, tracking
- new implementation of the telescope geometry
  - relies on ROOT::TGeo as major construction block and benefits from built-in methods:

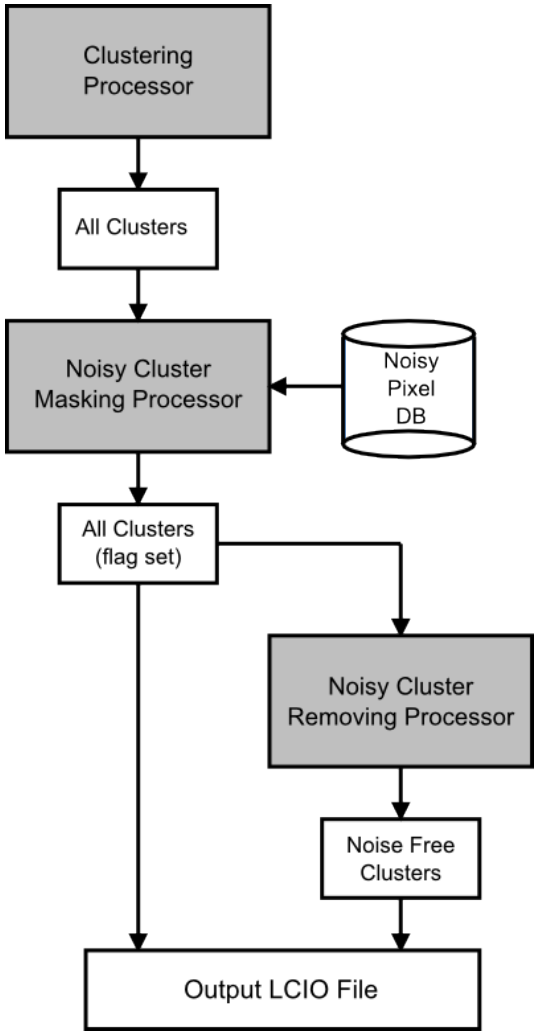


- new generic clustering algorithm
  - (TGeo neighbor search)
  - allowing generic pixel shapes
- navigation from one volume to next one:
  - fetch next volume ID
  - by global 3D point coordinate
  - Track incidence with next volume surface,
  - Track direction tilt to the volume surface
- coordinate system transformation
  - Global frame ↔ Local Measurement

Updated Geometry Framework and New Noise Treatment

- Updated geometry framework
  - extends/replaces GEAR
  - based on ROOT's Tgeo
- Allows for more sophisticated pixel layouts
  - prolonged pixels (e.g. ATLAS pixel 4-chip modules)
  - staggered pixels
- New noise treatment scheme
  - more LCIO like
  - new processors for finding noisy pixels
  - and masking/removing them
- New processor for geomtry based clustering:





… pixel beam telescope º R&D Tracker, Offline Software 2/2

Reconstruction Software highlights (continues)

- General Broken Lines (GBL) for tracking and alignment via Millepede-II
  - implementation benefits a lot from new Geometry model
  - with new Geometry accurate description of all inactive material
    - more realistic Chi2 of the tracks for low energy beam
    - X0 map of the DUT

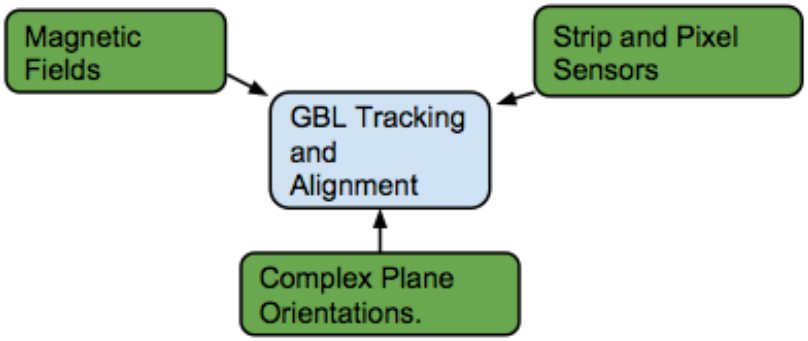
The result of the track fit now is a collection of track points (hits) on every scattering plane. Every track point contains X,Y (local, module frame) and incidence angle to the volume surface normal

➔ basically this is all we want to know about a track at DUT surface to match Cluster info.

Free way towards grazing angle test beams
(high interest from RD50, ATLAS)
And Lorentz Angle measurements for highly irradiated detectors
(ATLAS, CMS)

Requirements from Tracking and Alignment

- Many interesting studies require a versatile track fitter and alignment procedure.

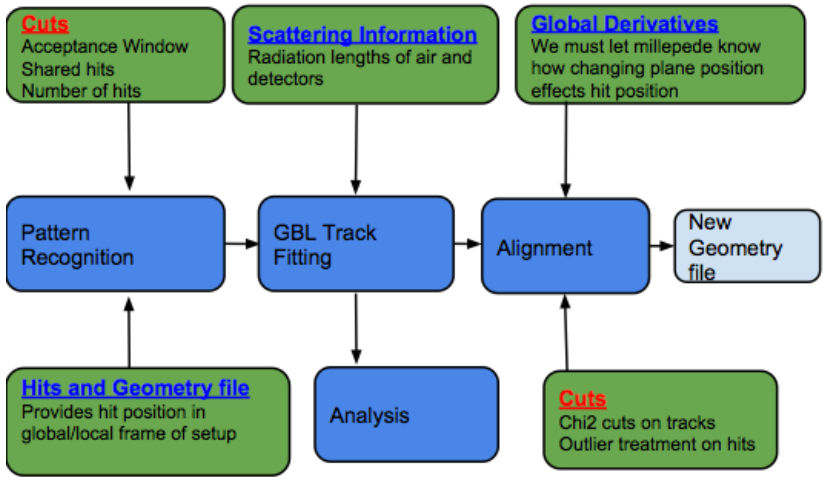


You want a single track fitter and alignment procedure to allow easy analysis of any test beam data.

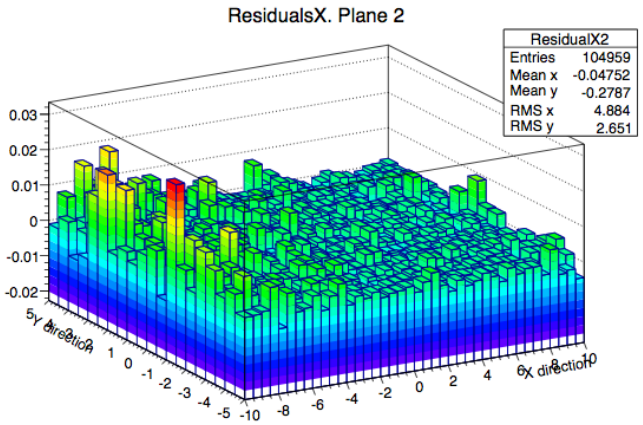
- We want to design software which is as plug and play as possible.
- Allows a single analysis code to be written once for a multiple setups and DUTs.
- Use past analyses as an example for future work.
- To achieve all these goals we use a combination of the General Broken Lines (GBL) for track fitting and millepede 2 to align the mimosa and DUT planes.
  - You can run a simple example after installing the EUTelescope software within jobsub/examples/GBL and following the README file.

Tracking and Alignment

- The GBL algorithm needs many input parameters to have the optimum track fit.
- Pattern recognition based on predicted kinematics of beam particles provide hits to fit track



How the pattern recognition, GBL and alignment processors function together.
Certain input parameters are needed to find the correct tracks from a collection of hits on a series of planes. We must align before we do this. We use GBL tracks to align in steps. Each step producing a new geometry file and repeating process until we have aligned the planes. The final tracks can easily be used in some final analysis.

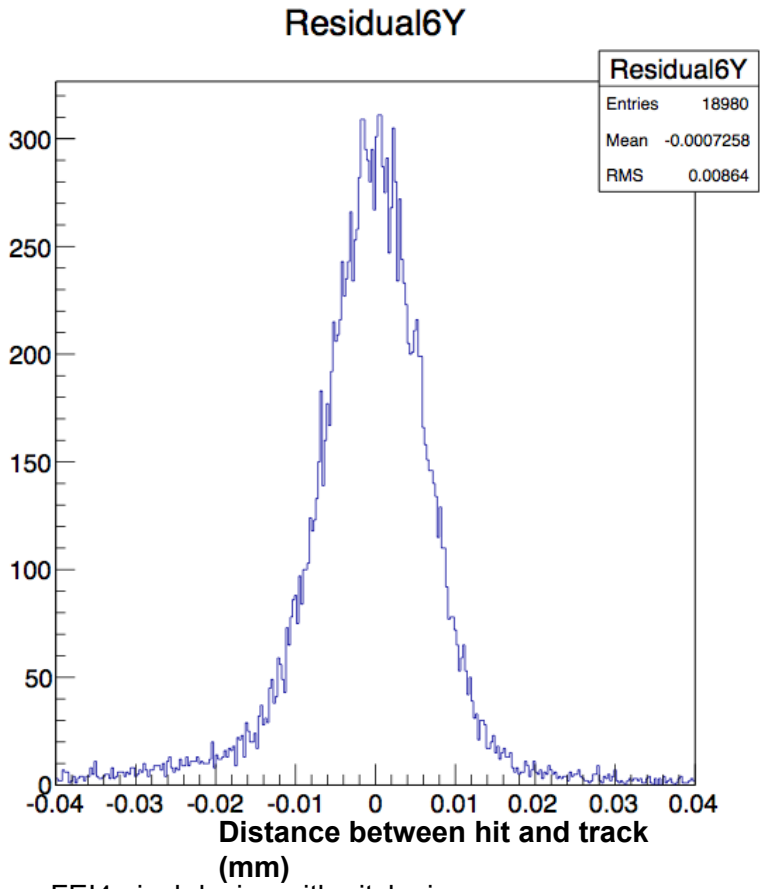


- Analysis code will work for any DUT using tracks produced by GBL processors.

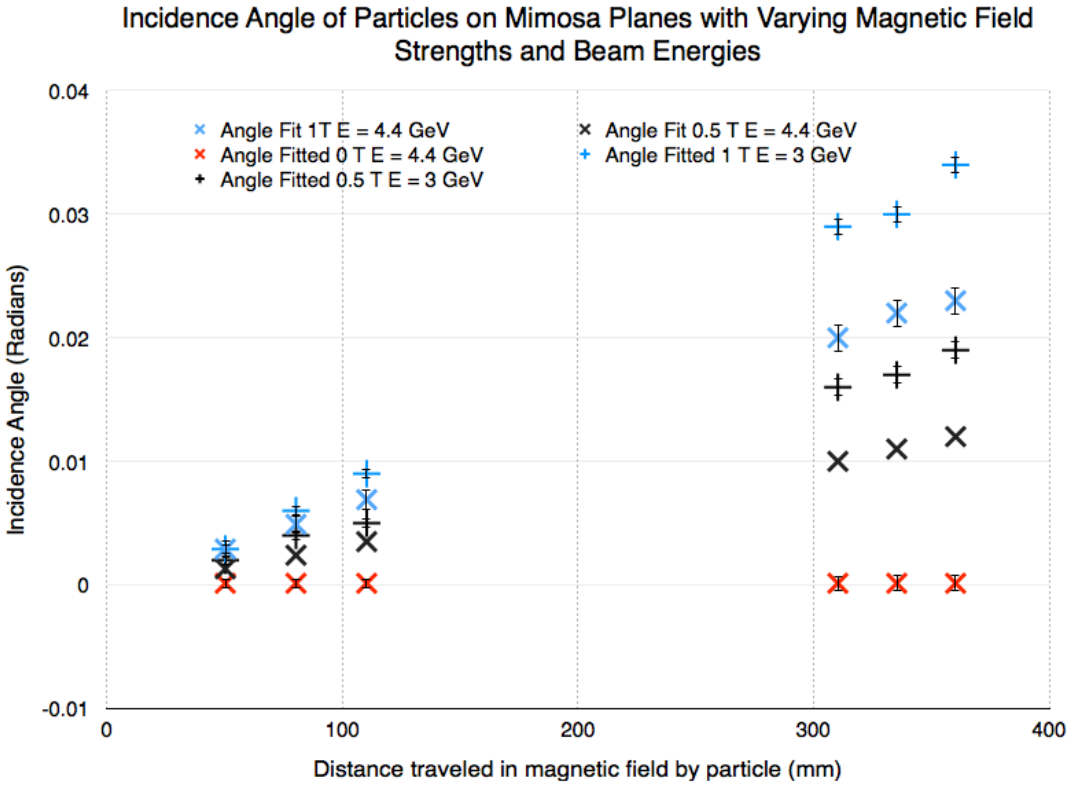
We can look at how residual of tracks varies with position on sensor. This example is one of the mimosa sensors with residual in X direction.

The GBL Track Fitting and Alignment in Action

- The fitting and alignment procedure has been used with DUTs and magnetic fields.



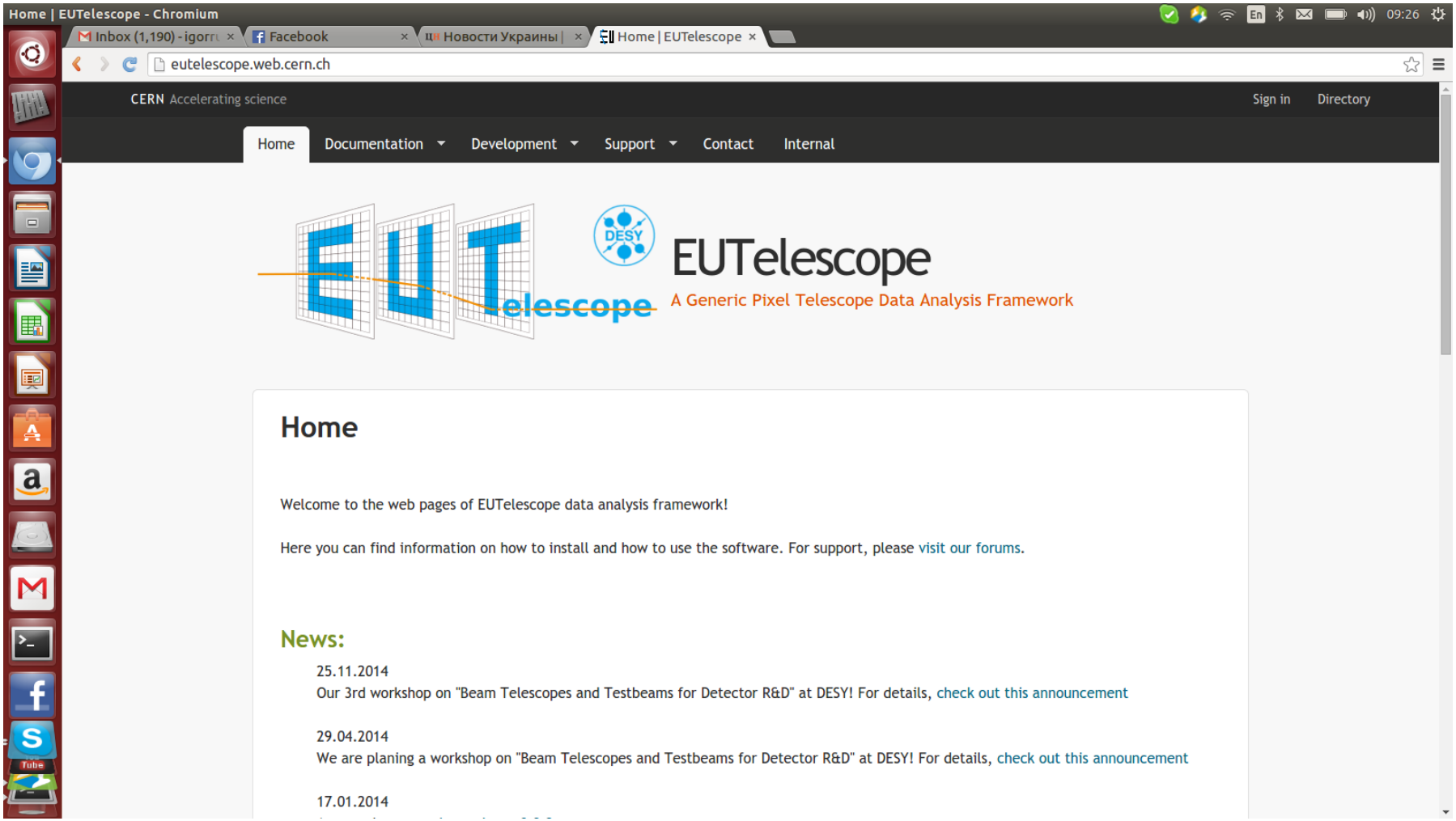
FEI4 pixel device with pitch size 250x50 micron.



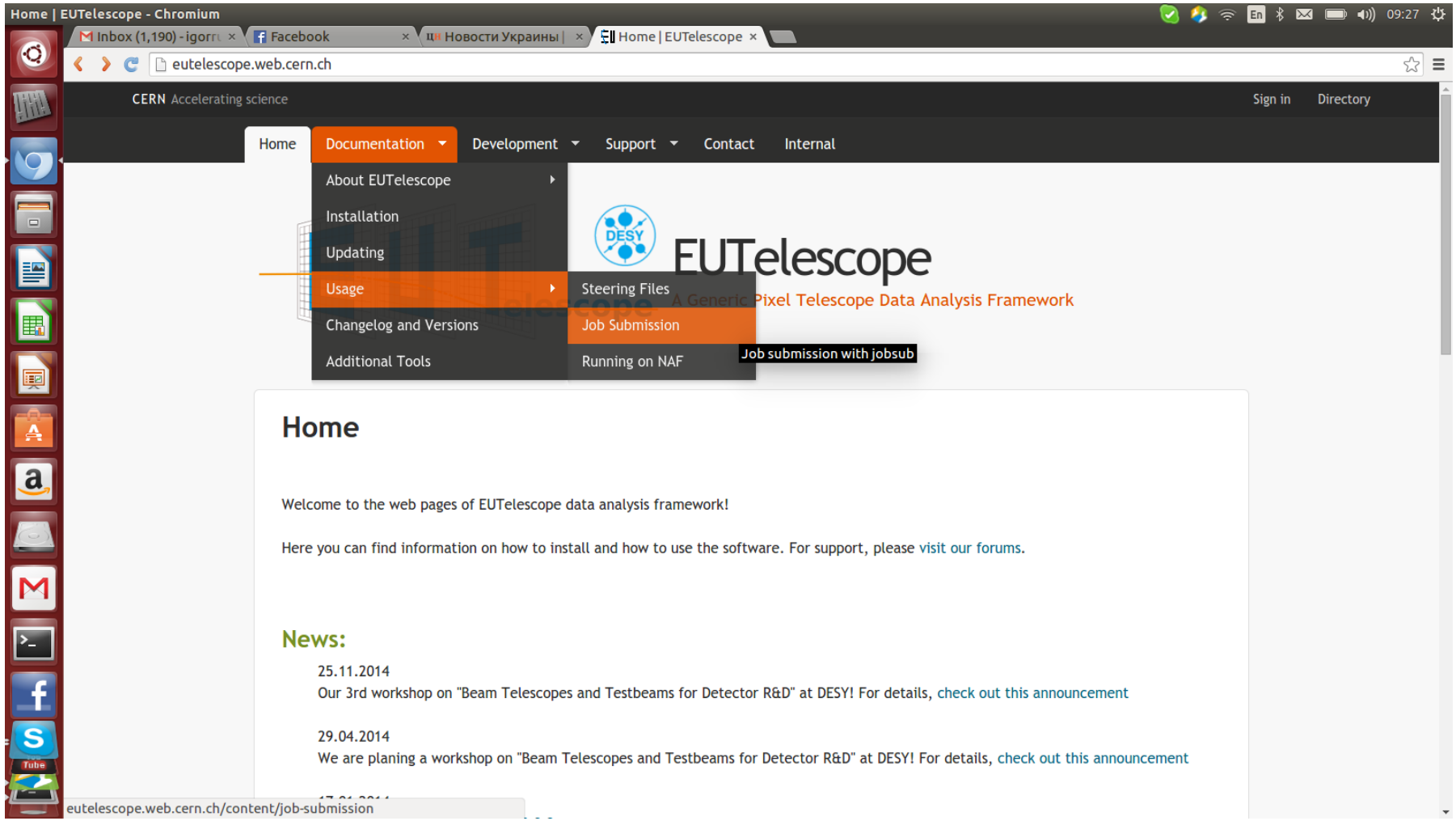
Incidence angle on 6 mimosa planes. Observe how the incidence angle is effected by varying magnetic field and beam energy for the same geometric setup.

- Software completed to work with strip sensors and tilted sensors
  - Testing still ongoing.

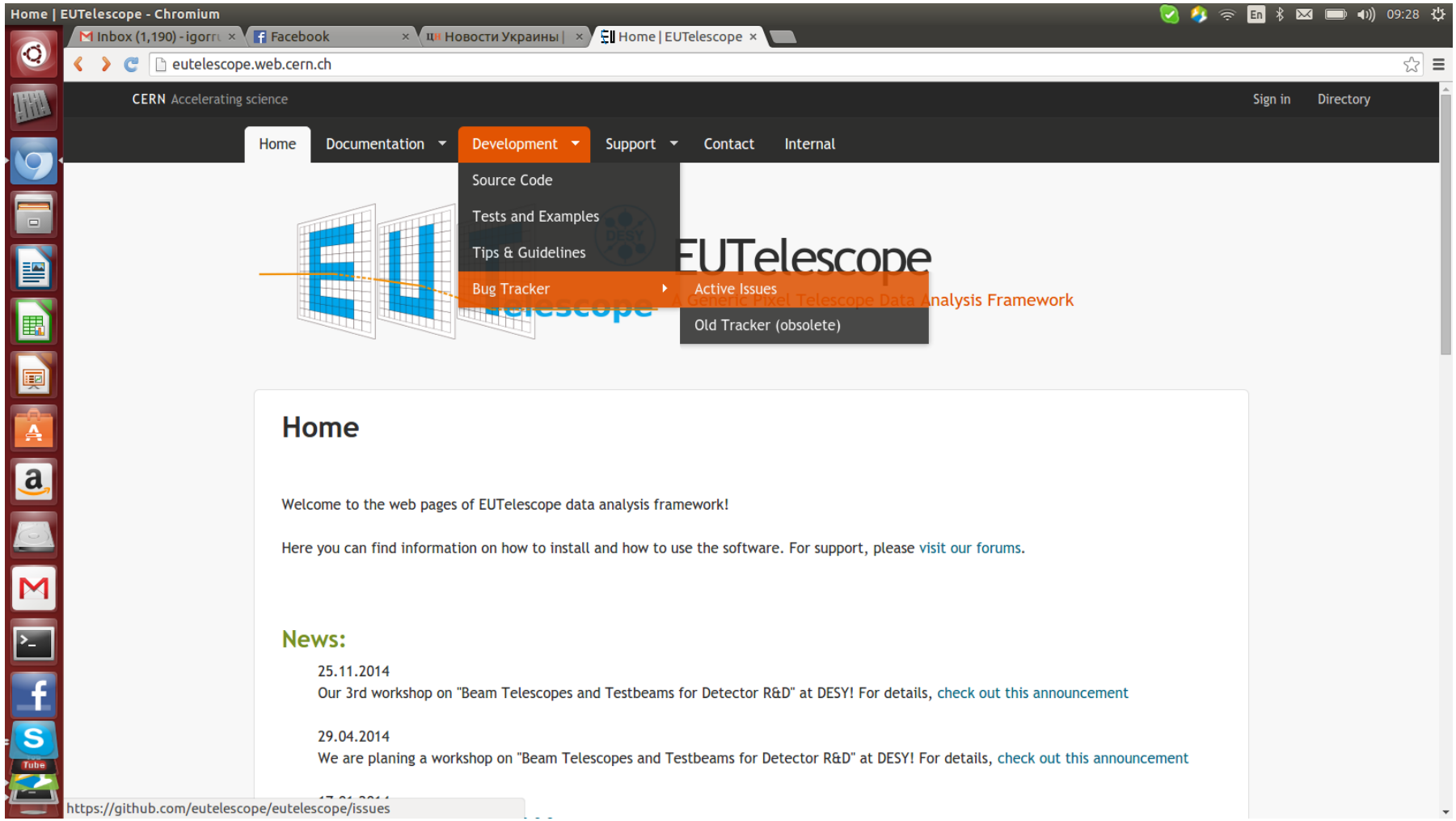
Webportal – announcements, user forum



Webportal – announcements, user forum



Webportal – announcements, user forum



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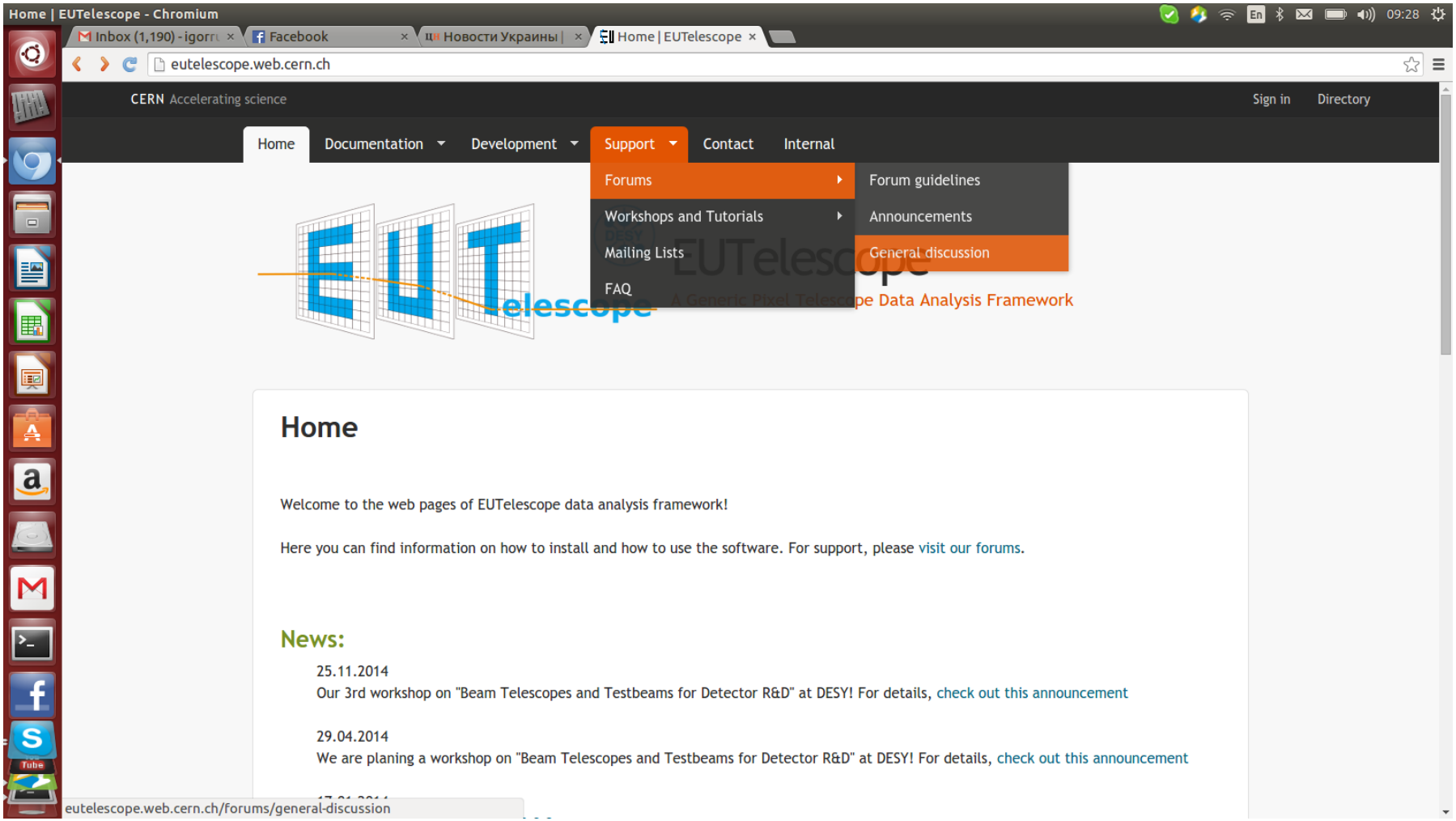
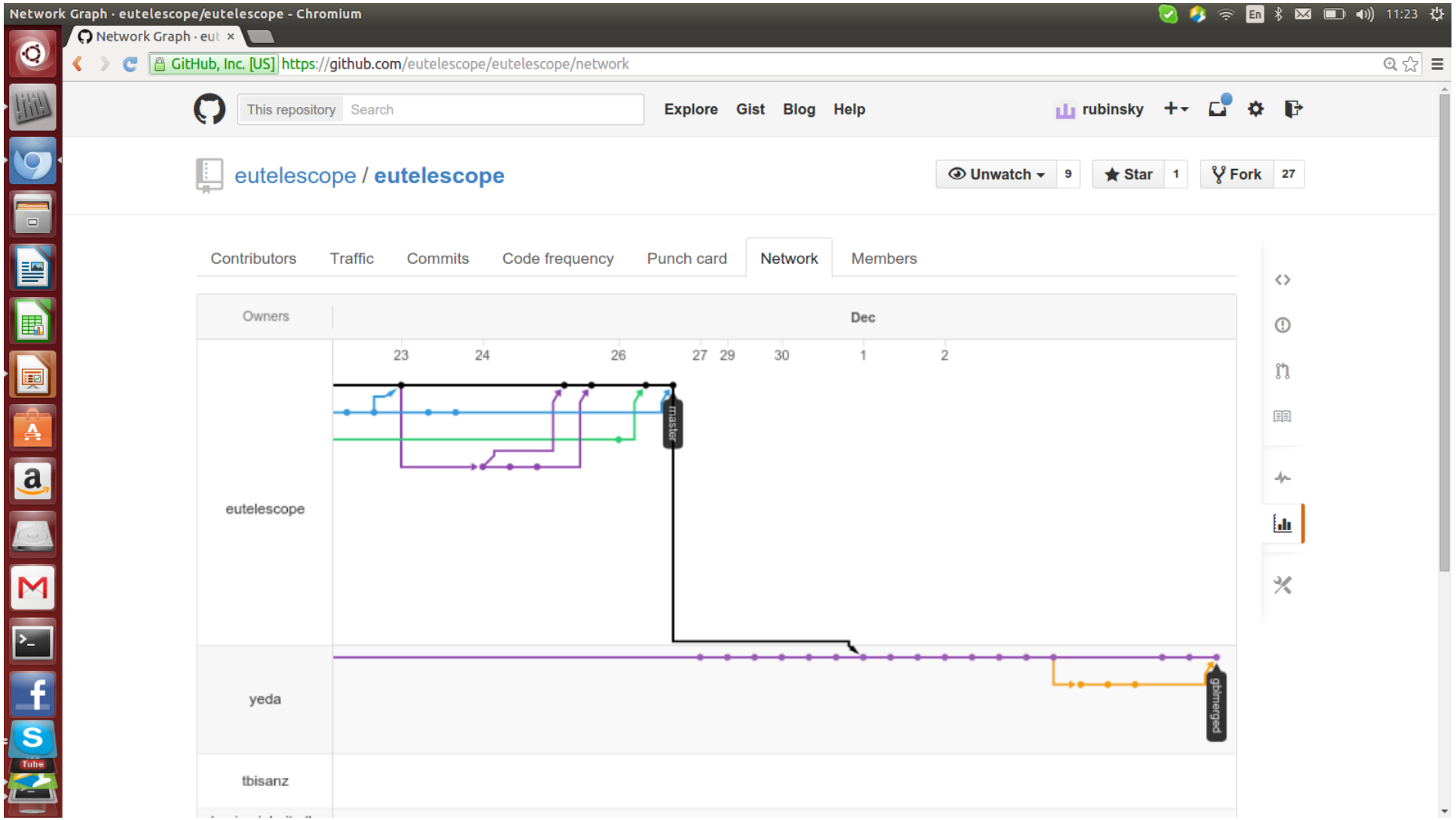


Github – decentralized code development, and version control



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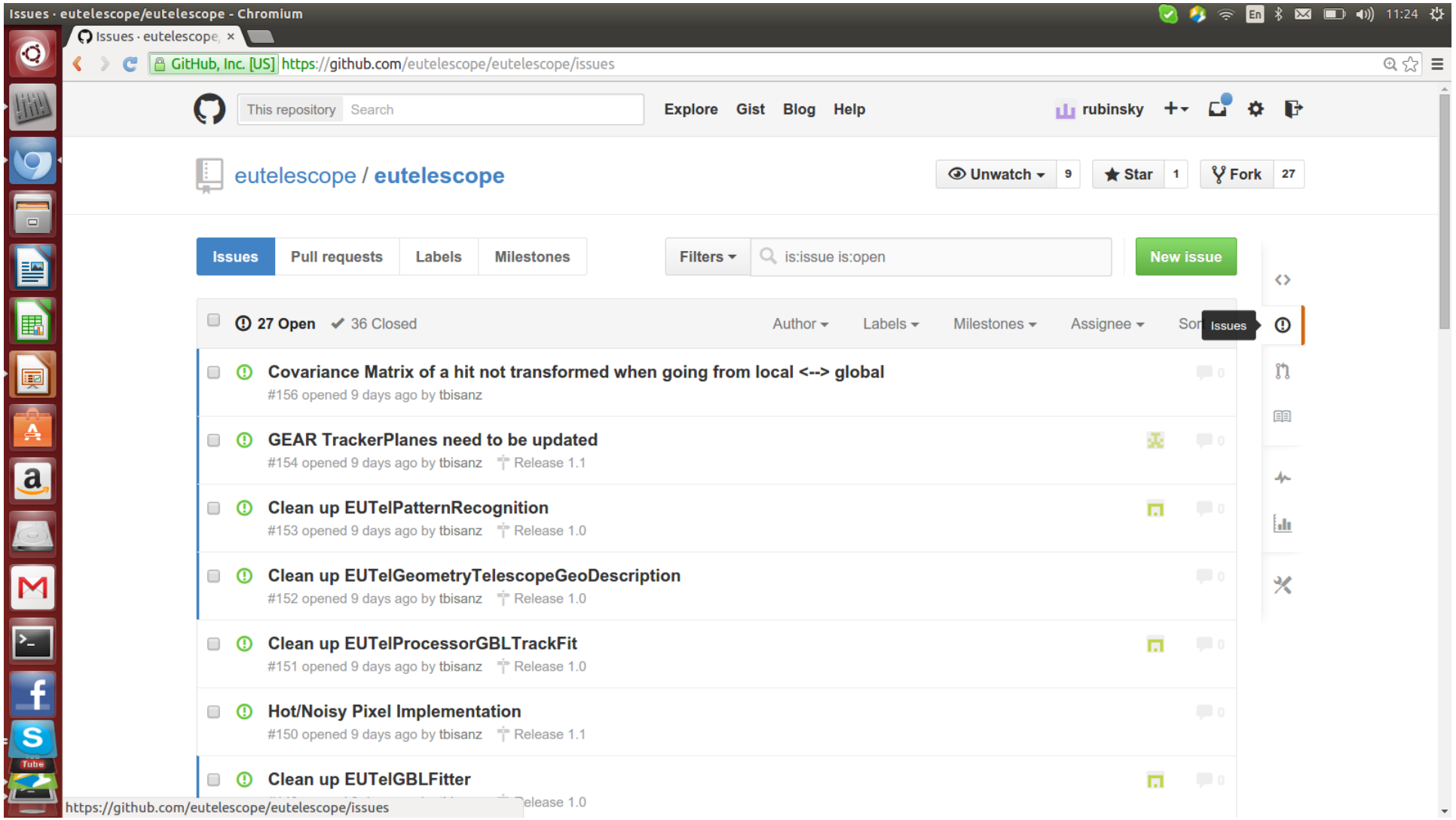
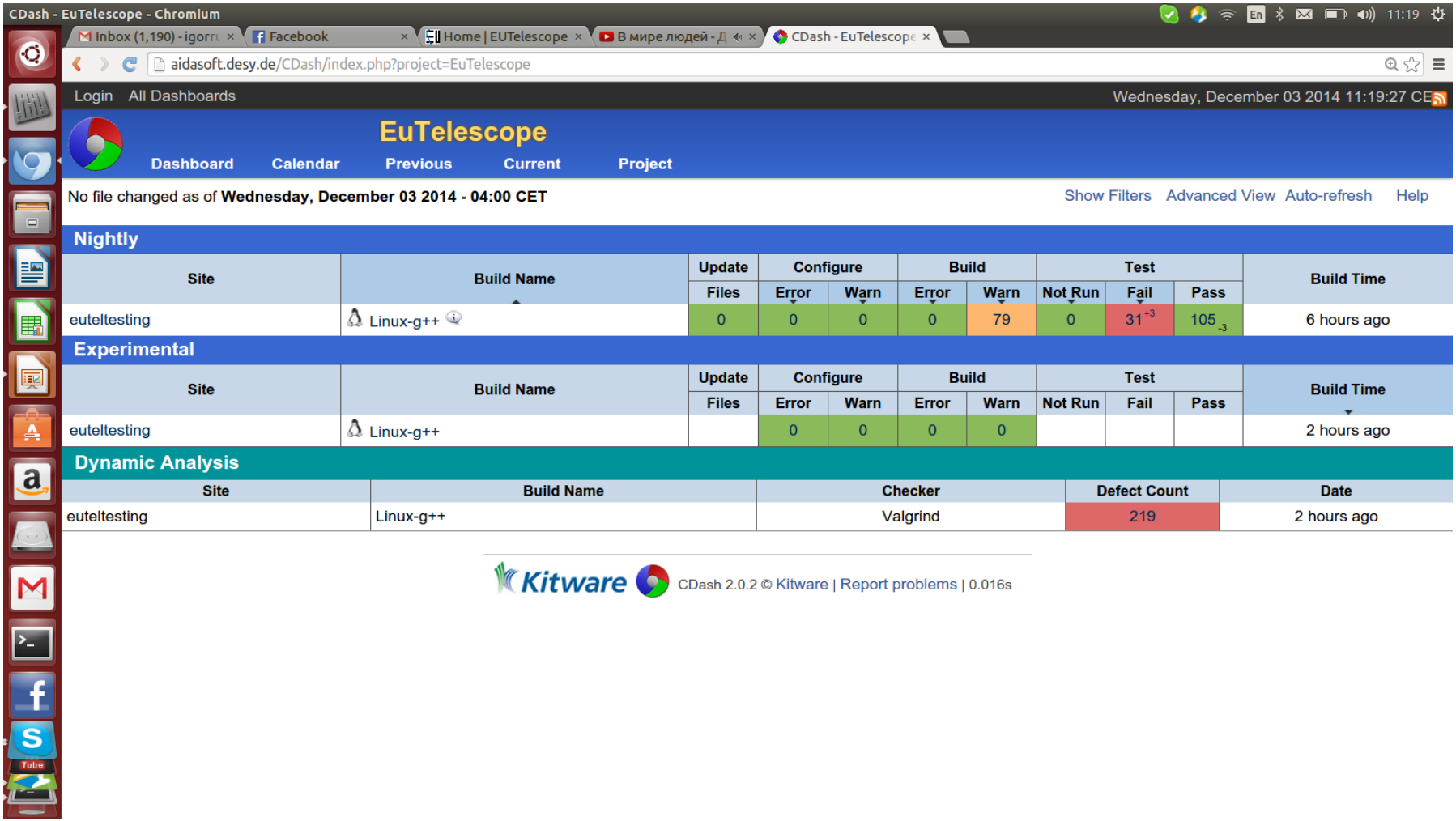


Aidasoft / Cdash – nightly builds monitoring



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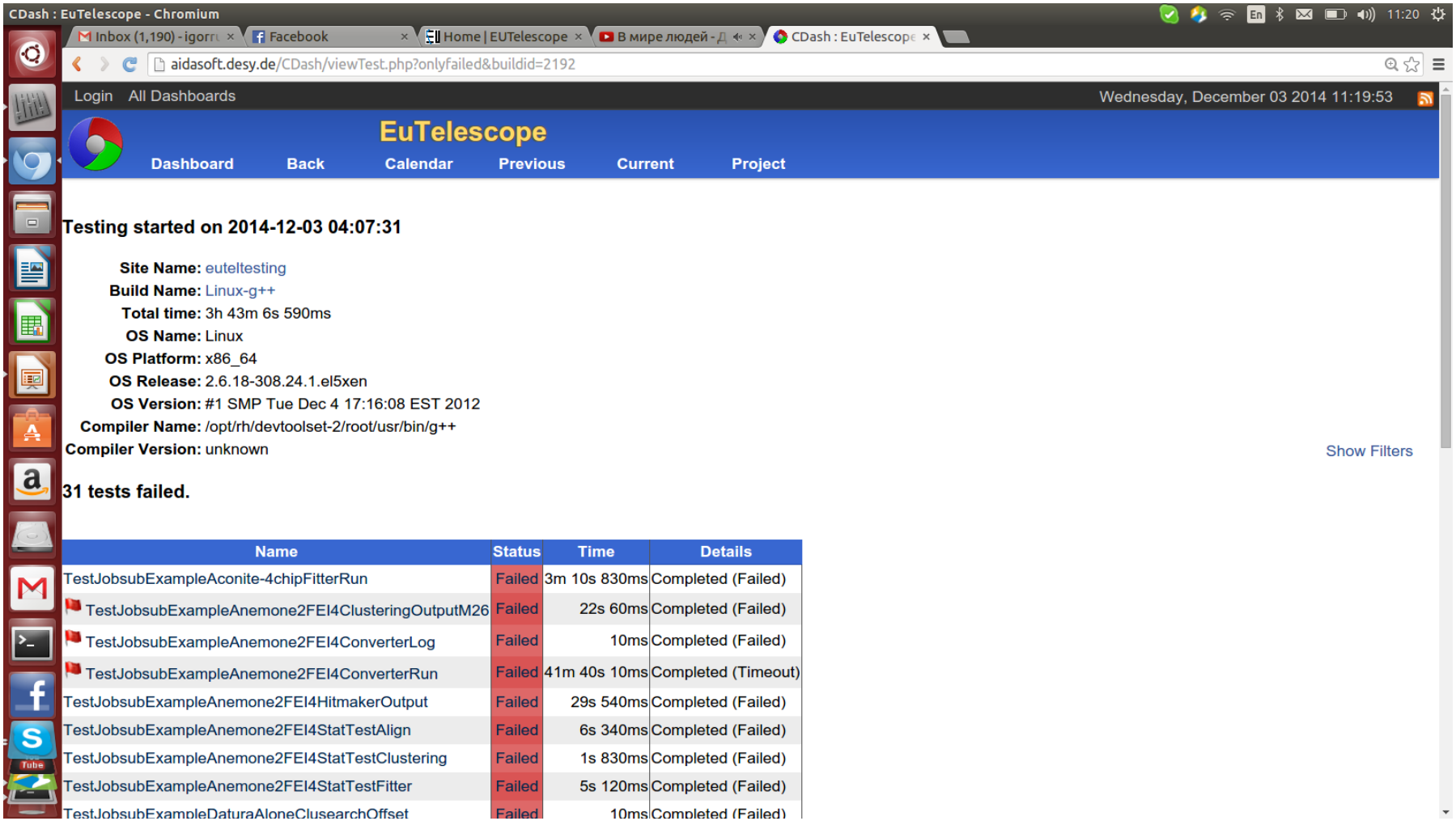
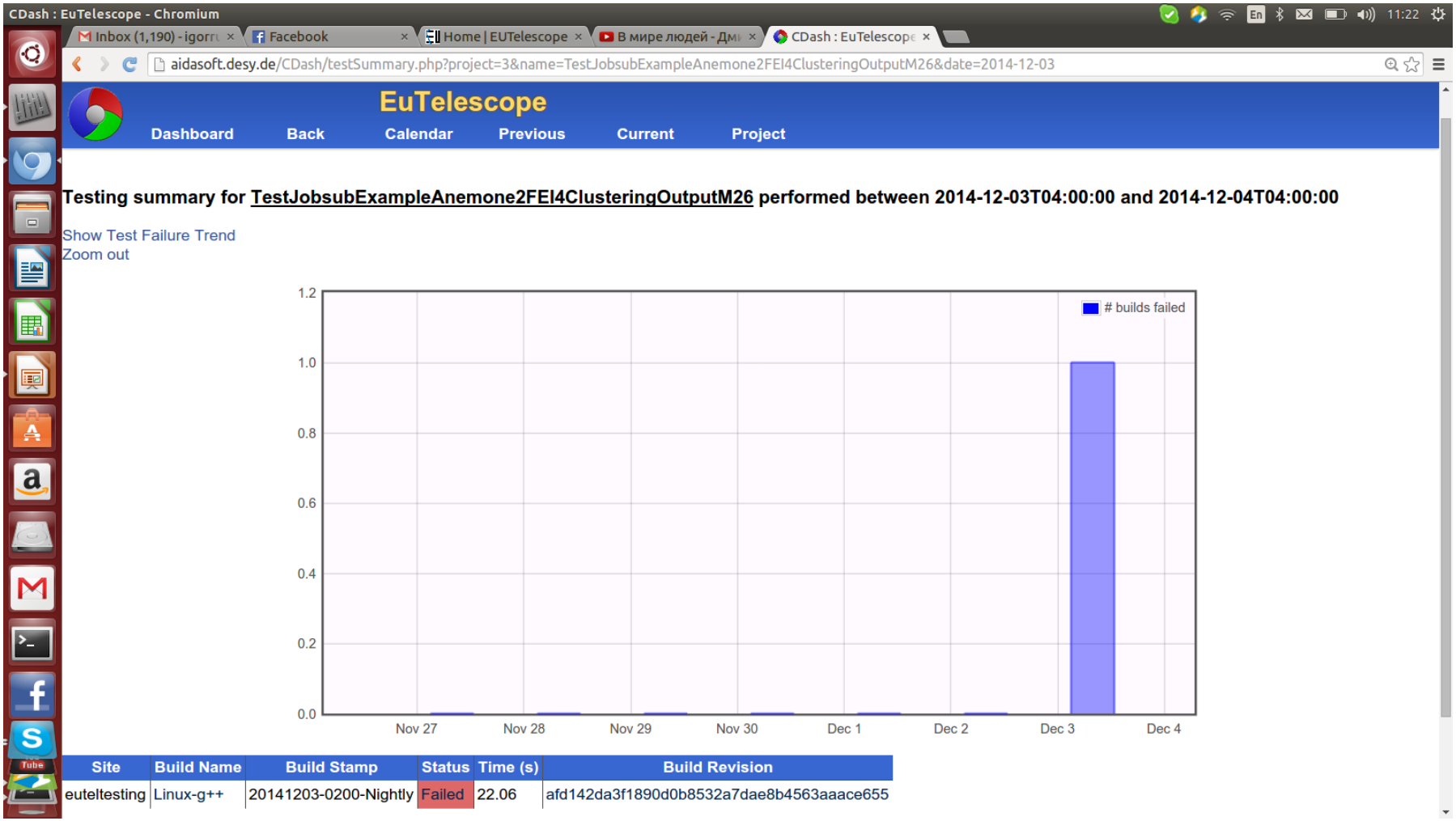
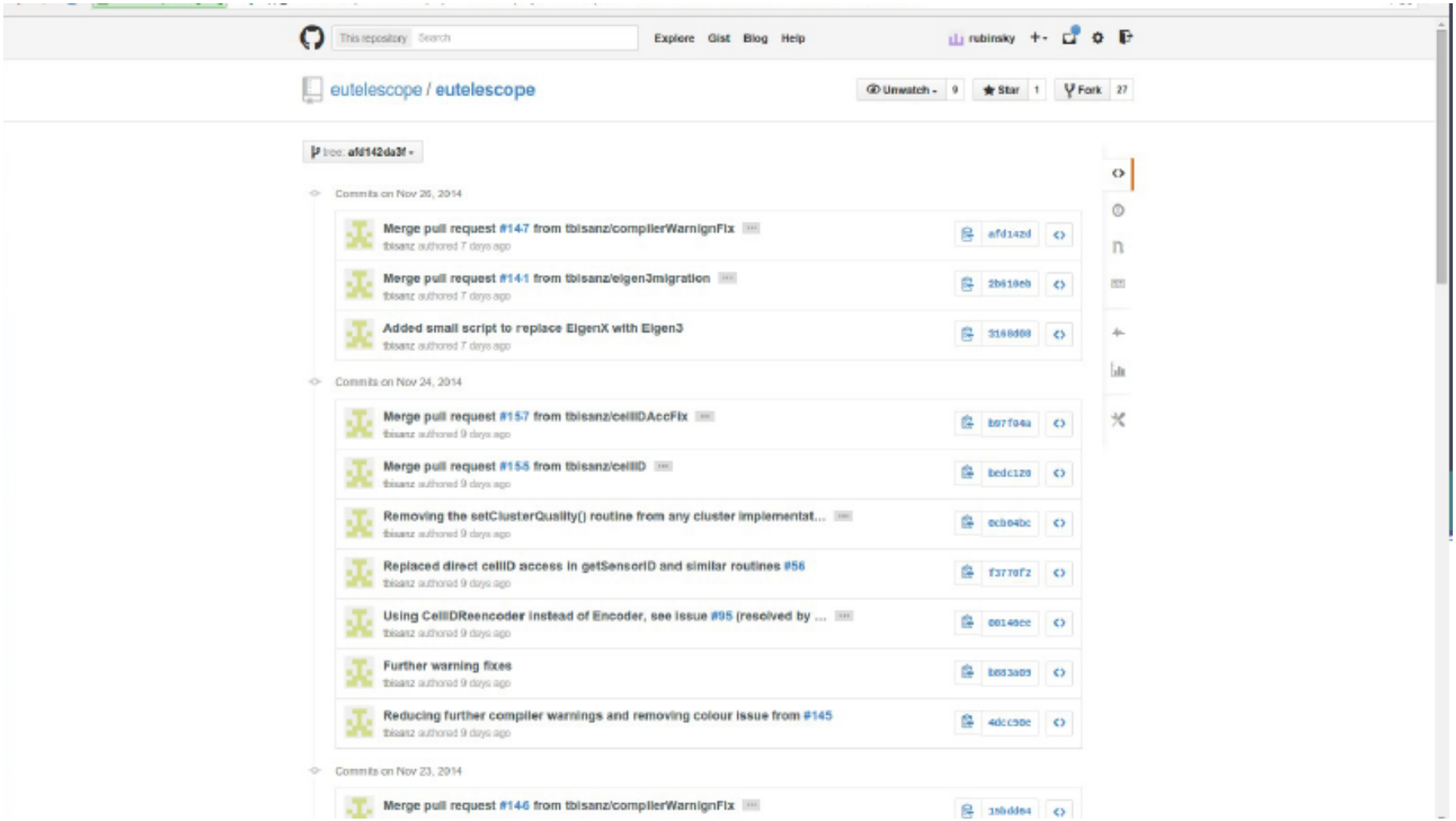


Name	Status	Time	Details
TestJobsubExampleAconite-4chipFitterRun	Failed	3m 10s 830ms	Completed (Failed)
TestJobsubExampleAnemone2FEI4ClusteringOutputM26	Failed	22s 60ms	Completed (Failed)
TestJobsubExampleAnemone2FEI4ConverterLog	Failed	10ms	Completed (Failed)
TestJobsubExampleAnemone2FEI4ConverterRun	Failed	41m 40s 10ms	Completed (Timeout)
TestJobsubExampleAnemone2FEI4HitmakerOutput	Failed	29s 540ms	Completed (Failed)
TestJobsubExampleAnemone2FEI4StatTestAlign	Failed	6s 340ms	Completed (Failed)
TestJobsubExampleAnemone2FEI4StatTestClustering	Failed	1s 830ms	Completed (Failed)
TestJobsubExampleAnemone2FEI4StatTestFitter	Failed	5s 120ms	Completed (Failed)
TestJobsubExampleDaturaAloneClusearchOffset	Failed	10ms	Completed (Failed)

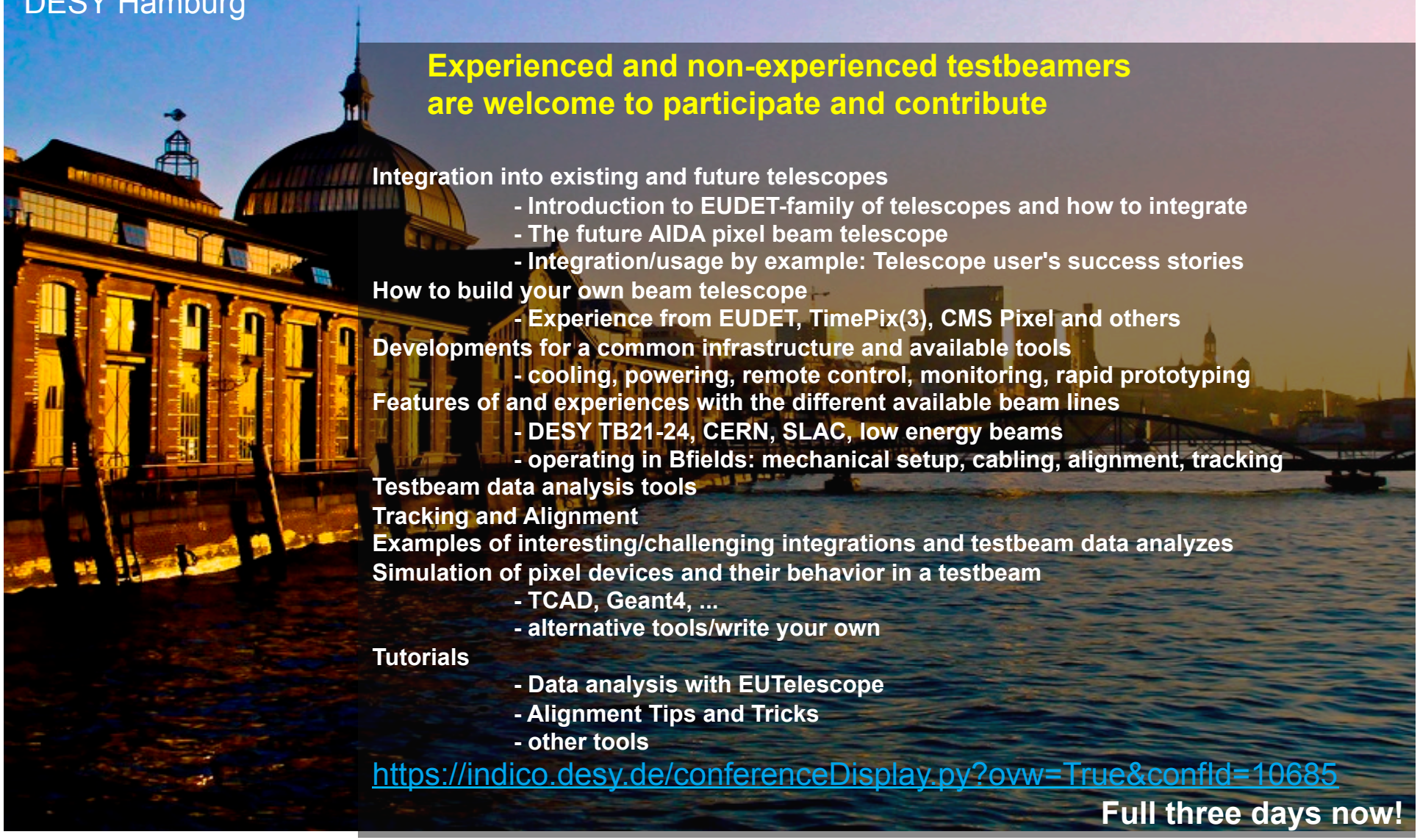
Aidasoft / Cdash – nightly builds monitoring



Aidasoft / Cdash – nightly builds monitoring → link to the latest build



Workshop on “Beam Telescopes and Test beams for Detector R&D”
From: 19 January 2015
To: 21 January 2015
DESY Hamburg



Experienced and non-experienced testbeamers are welcome to participate and contribute

Integration into existing and future telescopes
- **Introduction to EUDET-family of telescopes and how to integrate**
- **The future AIDA pixel beam telescope**
- **Integration/usage by example: Telescope user's success stories**

How to build your own beam telescope
- **Experience from EUDET, TimePix(3), CMS Pixel and others**

Developments for a common infrastructure and available tools
- **cooling, powering, remote control, monitoring, rapid prototyping**

Features of and experiences with the different available beam lines
- **DESY TB21-24, CERN, SLAC, low energy beams**
- **operating in Bfields: mechanical setup, cabling, alignment, tracking**

Testbeam data analysis tools

Tracking and Alignment

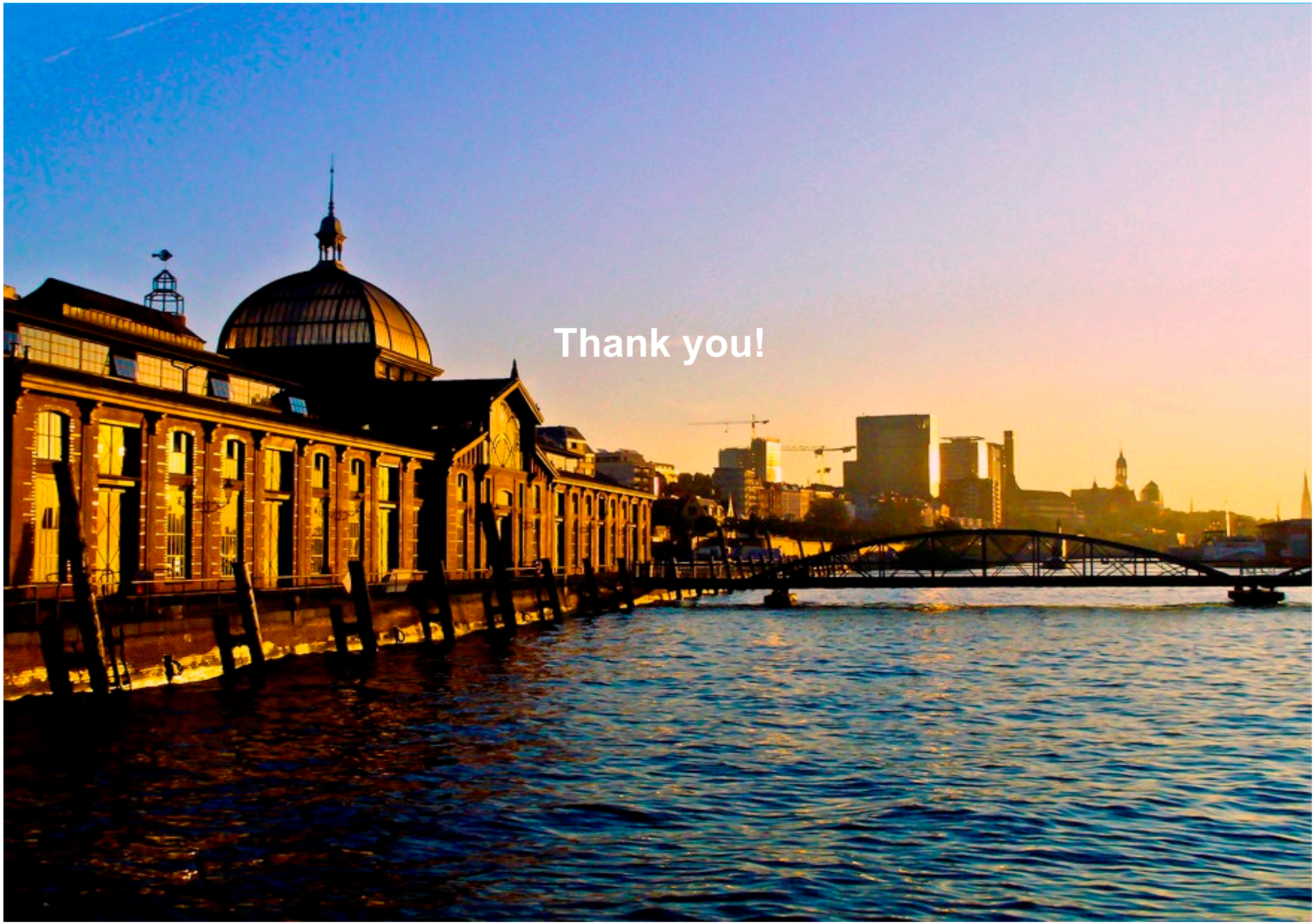
Examples of interesting/challenging integrations and testbeam data analyzes

Simulation of pixel devices and their behavior in a testbeam
- **TCAD, Geant4, ...**
- **alternative tools/write your own**

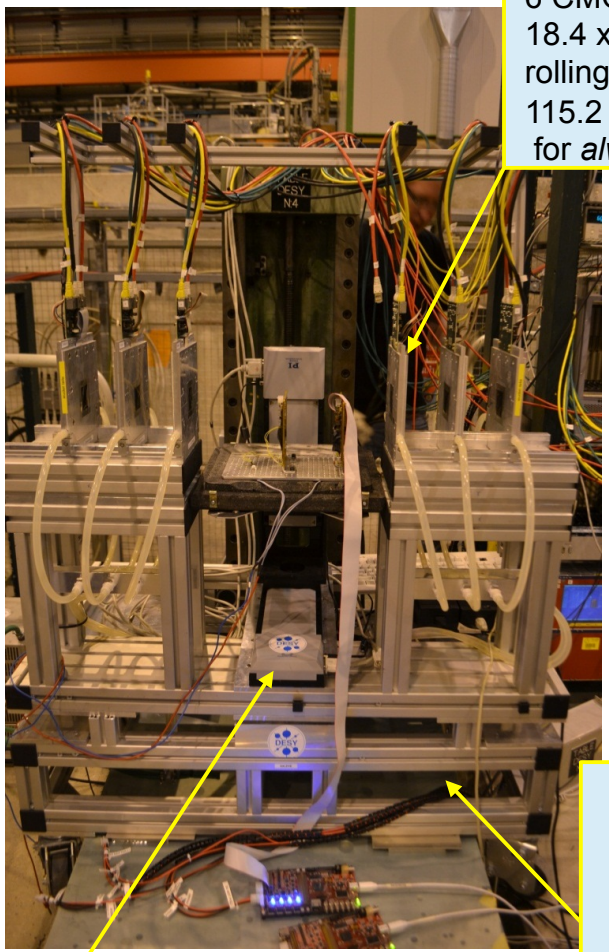
Tutorials
- **Data analysis with EUTelescope**
- **Alignment Tips and Tricks**
- **other tools**

https://indico.desy.de/conferenceDisplay.py?ovw=True&confId=10685

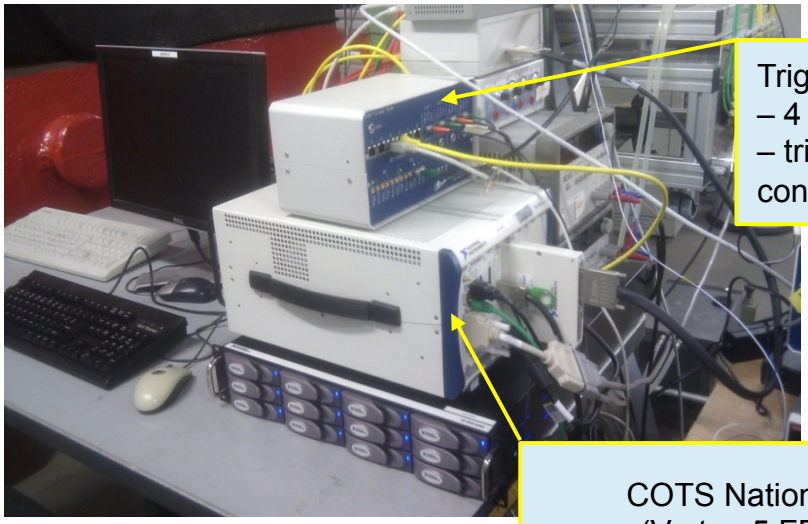
Full three days now!


Thank you!

EUDET pixel beam telescope ≡ high resolution R&D Tracker



6 CMOS pixel detectors (IPHC Strasbourg): Mimosa26 thinned to **50 µm thickness**
18.4 x 18.4 µm → 1152 columns x 576 rows (2x1 cm)
rolling shutter = continuous readout = deadtime free
115.2 µs integration time/frame → 8.68 kFrames in 1 second
for *always* sensitive telescope planes



Trigger Logic Unit (TLU):
– 4 inputs from PMTs
– trigger/busy handshake to connect up to 6 DAQ systems

COTS National Instruments Flex RIO (Vertex-5 FPGA) based solution for
Mimosa26=1x2 cm2 (<20 MB/s)

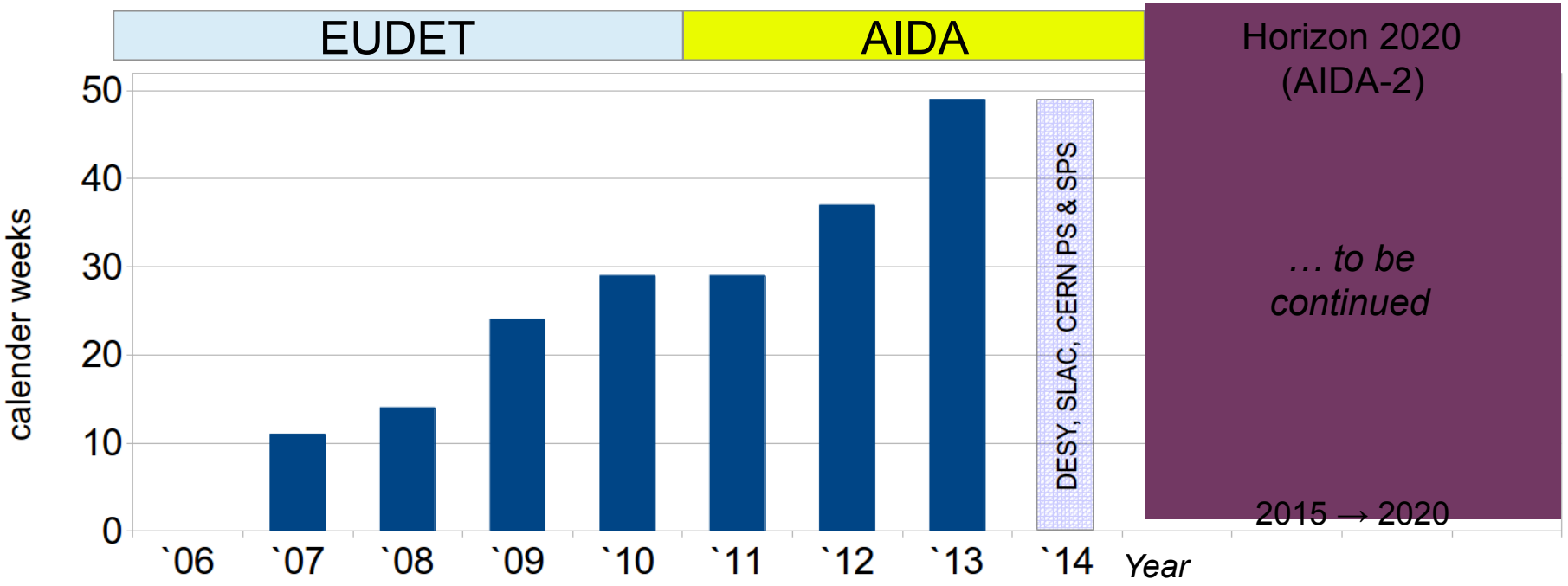
Immediate writing on RAID

Mechanical support
based on rigid Al profiles
~1 µm precision rotation
in horizontal plane (µ- screw)

Device Under Test (DUT)
with precise XY/rotation stage

The DAQ components interact via Hard & Soft layers → miniTLU and **EUDAQ2**
Data reconstruction within ILCSoft/Marlin/ **EUTelescope**

EUDET/AIDA telescope demand over the years



The EUDET telescope
– Mimosa26 sensors
CDS, ZS, binary, 18.4 μm square pitch

- the NI COTS readout system
introduced to replace VMEx64
and custom made electronics
to solve scalability issues

AIDA Single Arm Large Area Telescope

AIDA upgrades to EUDET telescopes
Trigger, DAQ integration, offline reco
→ *TLU, EUDAQ, EUTelescope*

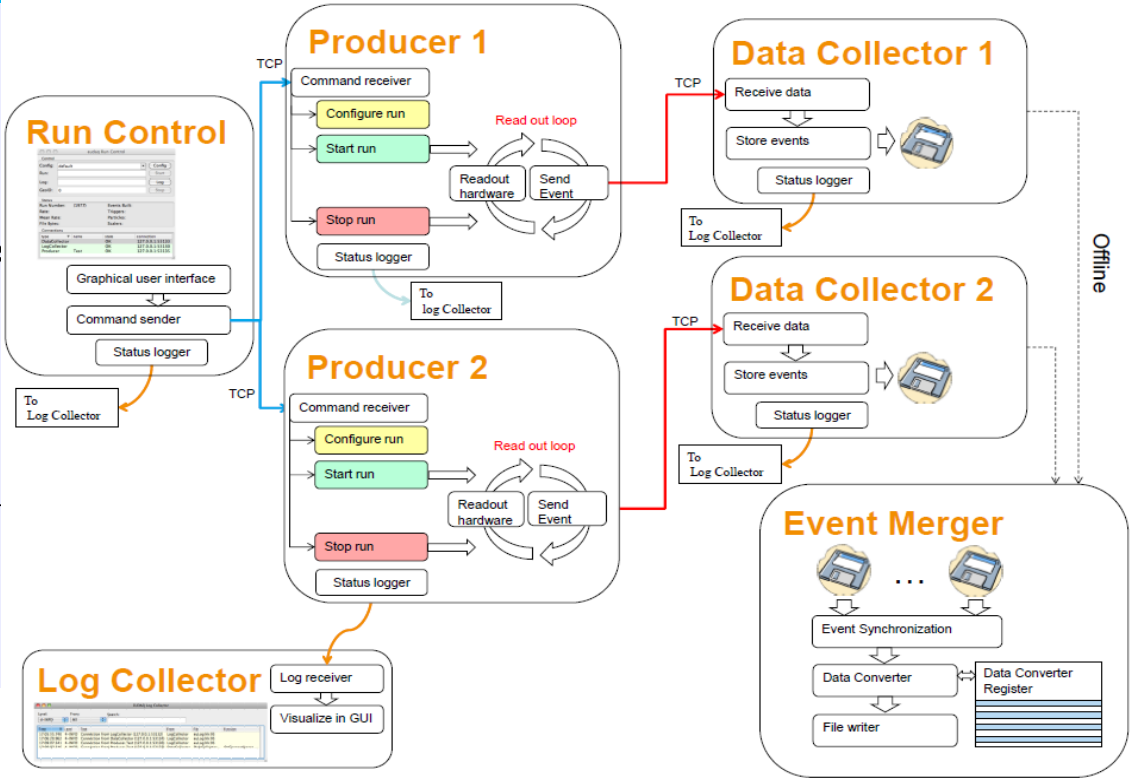
CALADIUM (for Carlton, Canada) (at FNAL)
ACONITE (for ATLAS)
DATURA (for DESY)
ANEMONE (for Bonn) (at ELSA)

… pixel beam telescope ≡ R&D Tracker, DAQ

https://twiki.cern.ch/twiki/pub/MimosaTelescope/EUDAQ/EUDET-Memo-2010-01.pdf

EUDET 1.0 DAQ shared library and binaries
– Windows 7 (MSVS, default), Linux, MacOS
– an integration layer for other DAQ systems
– Modular design, communication over TCP/IP
RunControl: central authority, provides
DataCollector: stores data to disk
Producers engage DUT DAQ
– bottlenecks:
– single central data collector (DC)
– One Trigger by definition is
→ one Producer Event –
– Online Monitoring for every event

EUDAQ 1.0



EUDAQ 2.0

DAQ for the high-rate AIDA telescope:
bottlenecks being sorted out:
– optionality → local and/or central data storage
– extended data format storing time stamps [DUT DAQ]
– backward-compatible to EUDAQ 1.0
– multiple triggers per device readout [AIDA TLU]
– more flexible online verification and monitoring
New Producer Interface (scriptable, Python)