CMS Running Experience

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Kick-off Workshop of the Project
"Enabling Technologies for Silicon Microstrip Tracking Detectors at the HLLHC"

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The CMS Silicon Strip Tracker

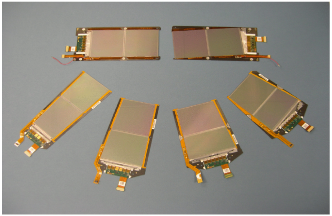
- Largest silicon tracker ever built (active area $\sim$200 m^2)
- 5 m long, 2.5 m diameter
- First "all-silicon" central tracker
- Approx. 9.6 million electronic channels

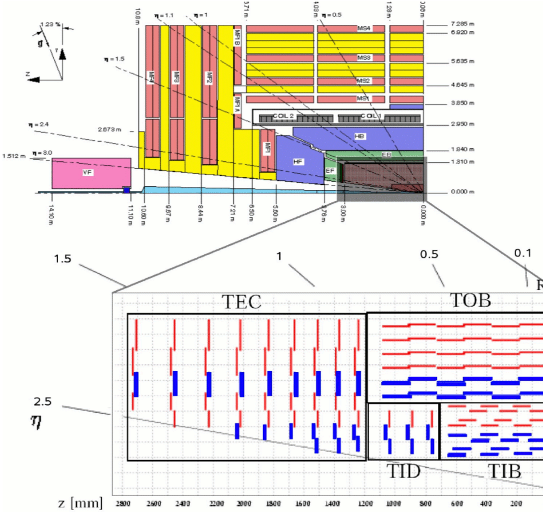
  10 layers in barrel region

  4 Inner Barrel (TIB),

  6 Outer Barrel (TOB)

  and 9 discs in the endcaps
- Analog readout

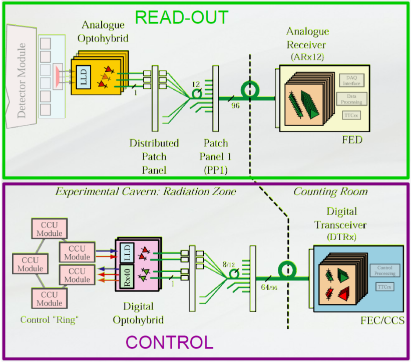




- Angular coverage down to 9° to the beam-pipe ($|\eta| < 2.5$)
- 4 layers (3 rings) contain stereo modules for 2-D hit reconstruction

Readout and Services

- tracker has 440 Front End Drivers (FEDs) to read out detector modules
- 356 control (token) rings to program the detector electronics

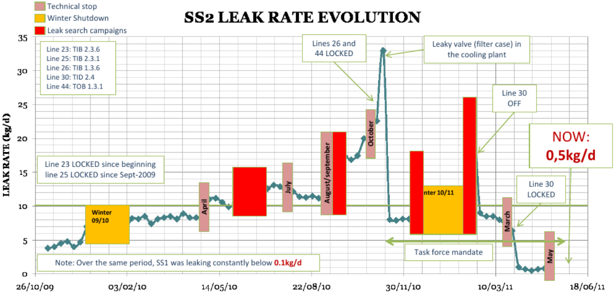


- 1944 power groups, 3888 HV channels
- two cooling plants to remove dissipated heat
  - 1st plant with leak rate close to zero
  - 2nd plant with low leak but with 5 closed lines

Cooling

SS2 cooling plant leak rate

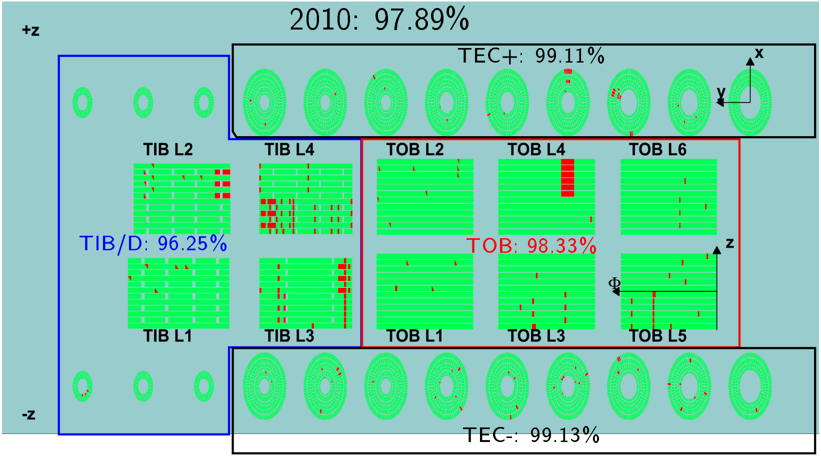
- in 2009 introduced overpressure on SS2 cooling in an accident
- caused an increase in leak rate in some cooling lines



2011

- pressure to the detector reduced (0.6-0.8 Bar reduction) → no change in module T
- CP pressure reduced from 9 to 7 bar and safety pressure switches were installed
- Pump running with Variable Frequency Driver: longer lifetime, smoother operation, no pressure glitches, vibrations (pump were replaced due to overheat)
- Bigger bypass valve installation to allow a smoother operation

Detector Status 2010 - 2013



- Major failures during operation
  - control ring in TIB (1 FED, 0.8 % of inner barrel) started showing non-standard behavior
  - few CCUs and power groups developed problems (groups of 6-12 modules)
  - some modules masked in loops with passive cooling to reduce heat load

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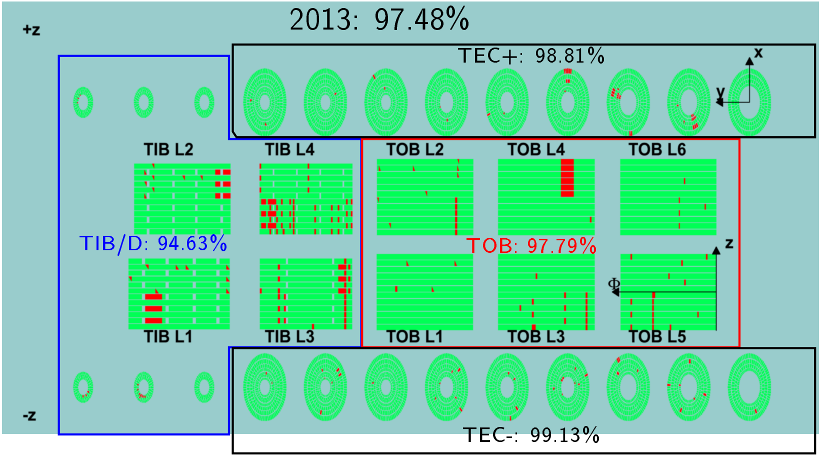

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Detector Control and Safety System

- TCS and TSS working reliably with close to zero downtime caused over three years of running
- Alarms with SMS to experts and Tracker DOC[1] for e.g. problems with cooling, dry gas, power supply trips,. . .

- In addition: SMS from DAQ, DQM in case of critical problems for data taking (but not detector safety)

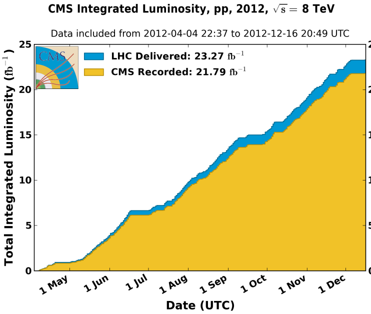
[1]DOC = detector on-call

Experience with shifts (short timeline)

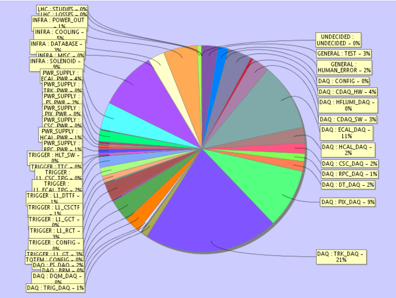
- 2009: Tracker DOC + Tracker shifter at P5, responsible for monitoring and switching on HV
- mid-2010: no more shifters at P5, centrally attended operation BUT
  - 2 DOCs:
    - one daily monitoring (environment,. . .)
    - one coming to P5 at start of every physics fill to give green light for HV raising and check of DQM
- mid-2011: HV switch-on handed to central crew, DOC performing checks remotely (only one DOC)
- mid-2012: HV raising automated using semaphore, DOC performs daily monitoring

CMS Operational Efficiency

2012

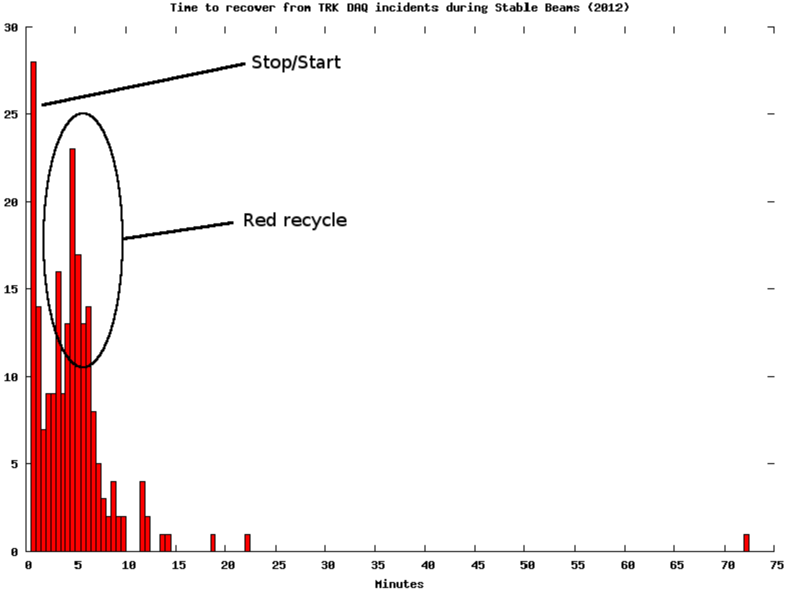


Luminosity lost by CMS subsystem

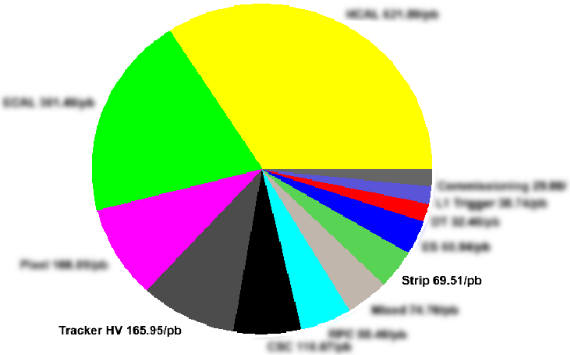


- CMS with 93.6 % data taking efficiency (4.7% downtime, 1.7% deadtime)
- strip tracker caused 0.98% of downtime (21% of 4.7%)
  $\rightarrow$ $\sim$ 230 pb^{-1} pb

Downtime length



Data losses from certification



- data loss from HV raising unavoidable due to safety considerations
  - $\longrightarrow$ high voltages are only raised when LHC declares beams to be *stable*
- very little data certified as bad (70.0 of 21790 pb^{-1} = 3.2 ‰)

Data losses

Infrastructure failures

- over the three years of running had very few failures of infrastructure
- O(10) failures of VME crate items (PS, Fans)
  - some times lucky to have them happen outside stable beams
  - time to fix can be 1/2 – 3 hours depending on circumstances
- few bigger problems with CAEN power supplies
  - exchange rate of PSUs below 1% per year, exchange done opportunistically
  - recently one CAEN mainframe had to be exchanged

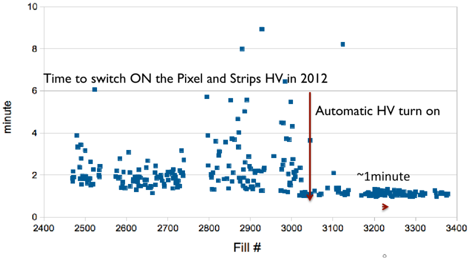
  $\rightarrow$ done in < 2h

Improvements to operational procedures

- Several approaches to reduce data losses caused by the strip tracker
- reduce time needed to raise high voltage after the declaration of stable beams (next slides)
- make use of *soft error recovery* mechanism
- improvements in FED firmware
- speeding up of state transitions (hardware configuration, run starting/stopping, etc. . .)
- power supply recovery policy
  - during 2010-11 whenever a power supply went spontaneously off
  - at next run stop power supply switched back on and tracker reconfigured
  - → 5 minutes (minus time needed for initial reason for stopping)
  - end of 2011: for single power supplies, no run stop, only recover after end of fill
  - → trading redundancy in layout for data taking efficiency

HV raising

- high voltages are only raised when LHC beams are declared *stable*
- several steps to shorten time delay till HV is up
  - increased number of CAEN Mainframes: 4 $\longrightarrow$ 8 in early 2011
  - reduced time needed to raise HV from 5 to 1.5 minutes
- since 2012 the high voltages of the strip (and pixel) tracker are raised automatically at *stable beams*



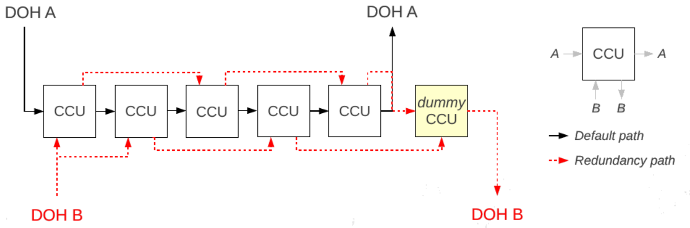
- semaphore checks beam conditions 30 s before *stable beams* are declared
  - now takes $\sim$1 minutes from declaration of stable beams to HV up
  - before $\sim$1.5-2 minutes with large outliers

$\longrightarrow$ further possible improvements:

- ways to allow raising before stable beams are declared
- shorten HV raising time

Soft Error Recovery

- The 'soft error recovery' is the standard way for the CMS DAQ to recover from SEU-like events.
  - subdetector detects 'soft error' and goes to *RunningSoftErrorDetected* state
  - cDAQ pauses the trigger and sends 'fix soft error' command to subdetector
  - subdetector 'fixes' problem and goes back to 'running' state
  - cDAQ sends *resync* and resumes triggers
- The strip tracker is using this mechanism to recover a control ring in the TIB layer 2
  - uses the redundant path (entering the control ring through channel B) which gets spontaneously reset during running.



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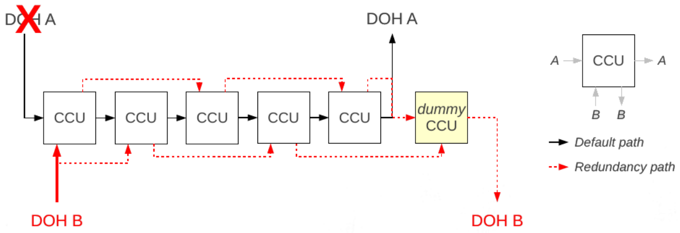
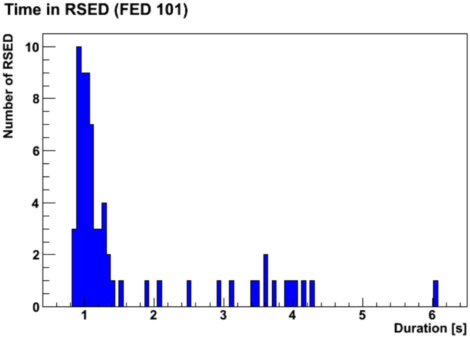


Soft Error Recovery

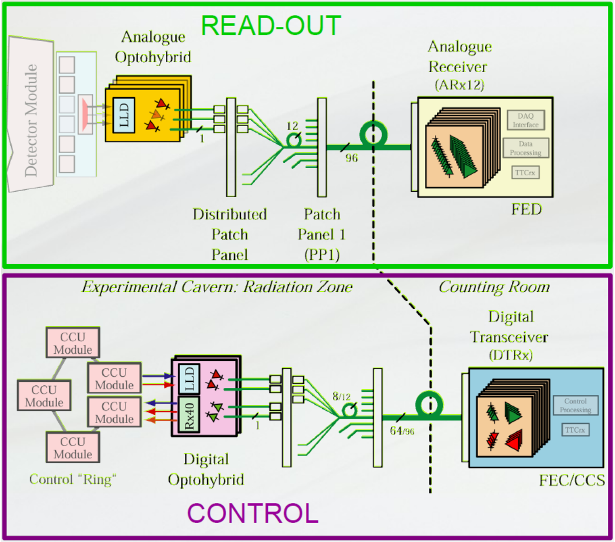
Time spent for Soft Error Recovery (only strip tracker part)



- re-application of redundancy performed in 1-2 seconds

→ CMS back to running state in $\ll 30 seconds$

Complications for Recovery



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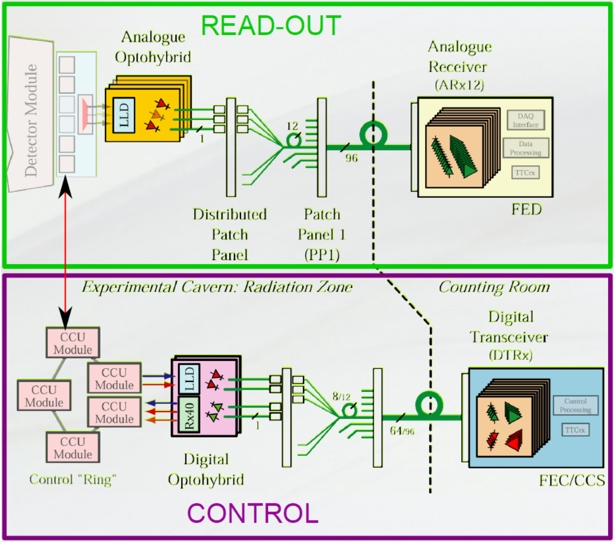

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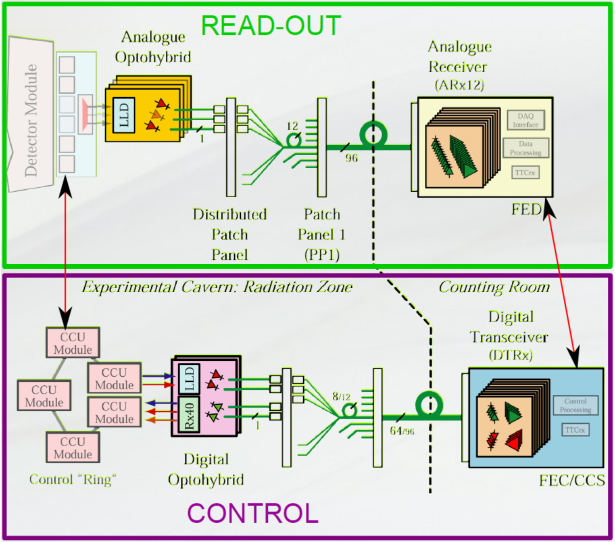

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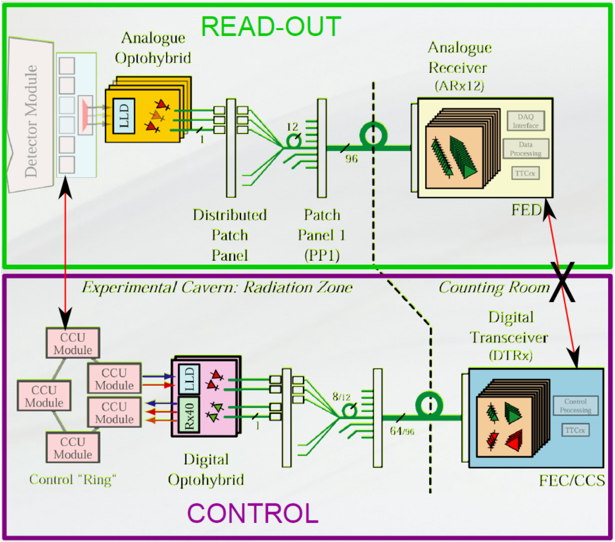

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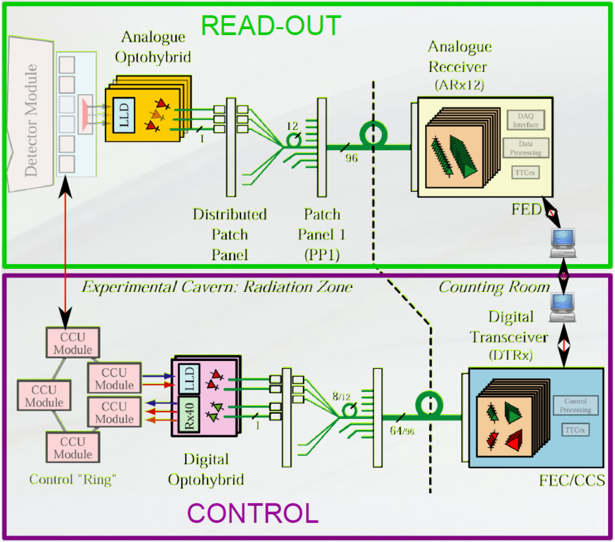

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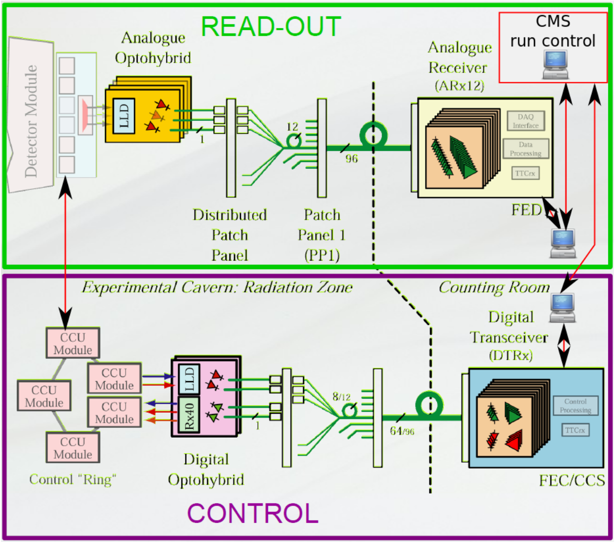
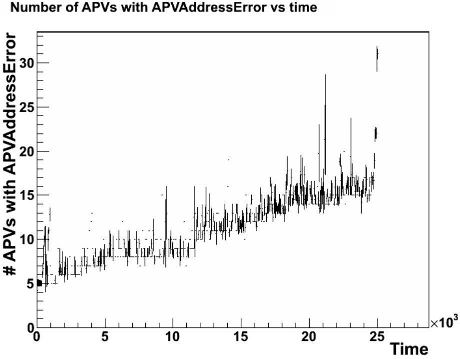


SEUs in general

- most features seen in the strip tracker to this date are **not** classic SEUs, i.e.
    - no clear radial dependence
    - no clear dependence on instantaneous luminosity
- There are some effects that occur predominately during collision runs
    - these manifest mostly on single APV readout chips
    - there is a pedestal of APVs with problems for many runs and
    - there is a slight increase of the number of affected APVs over the course of a run



Extra Events

- Problem of extra events is caused by one or more modules starting to output data w/o a trigger associated with it
- Strip Tracker FED is a *capturing* device, i.e. if things looking like data are detected on a sufficient number of inputs, this is captured as an *event*
- will associate this to a trigger and ship it to CMS DAQ

  $\longrightarrow$ one trigger too little available if real data comes
  $\rightarrow$ FED is stuck since it has data that it cannot ship out

- solved by sending FED to *out-of-sync* when this situation is detected

  $\longrightarrow$ results in *resync* signal issued by CMS DAQ

- extra data is discarded and run can continue

FED Firmware

- FED firmware underwent several iterations during 2012
- some bugs were found and fixed,
- more importantly: iterative process to properly address various situations FEDs are exposed to **not** foreseen in original design
  - extra events (single or continuous)
  - missing events
  - resyncs under backpressure (i.e. CMS DAQ not accepting events)

Summary and Outlook

- CMS Strip Tracker running well also in its third year of more or less continuous operation
- operational procedures continuously improved over the last three years
- no big surprises *so far*
- several smaller and bigger problems have plagued us and caused our share of data-loss
- infrastructure failures easily contribute non-negligible amounts of lost data