



O² Project Status Report

LHCC Review 11-Sep-2017

Pierre Vande Vyvre for the O² Project



Author List

Thanks to:

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P. Buncic, G. Eulisse, C. Grigoras, U. Fuchs, P. Hristov,
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V. Lindenstruth, G. Neskovic, R. Shahoyan, B. von Haller, S. Wenzel,
For the slides and feedback.

Outline

- O² project – Work Packages
- System architecture
 - Hardware facility
 - Software architecture
 - Software process
- Software foundations: ALFA, Data model, Data distribution
- Software applications:
 - Detector read-out
 - Control Configuration and Monitoring
 - Physics simulation
 - Reconstruction
- Software integration: Test timeframe, FLP Prototype
- Hardware : CR0 procurement
- Milestones and schedule

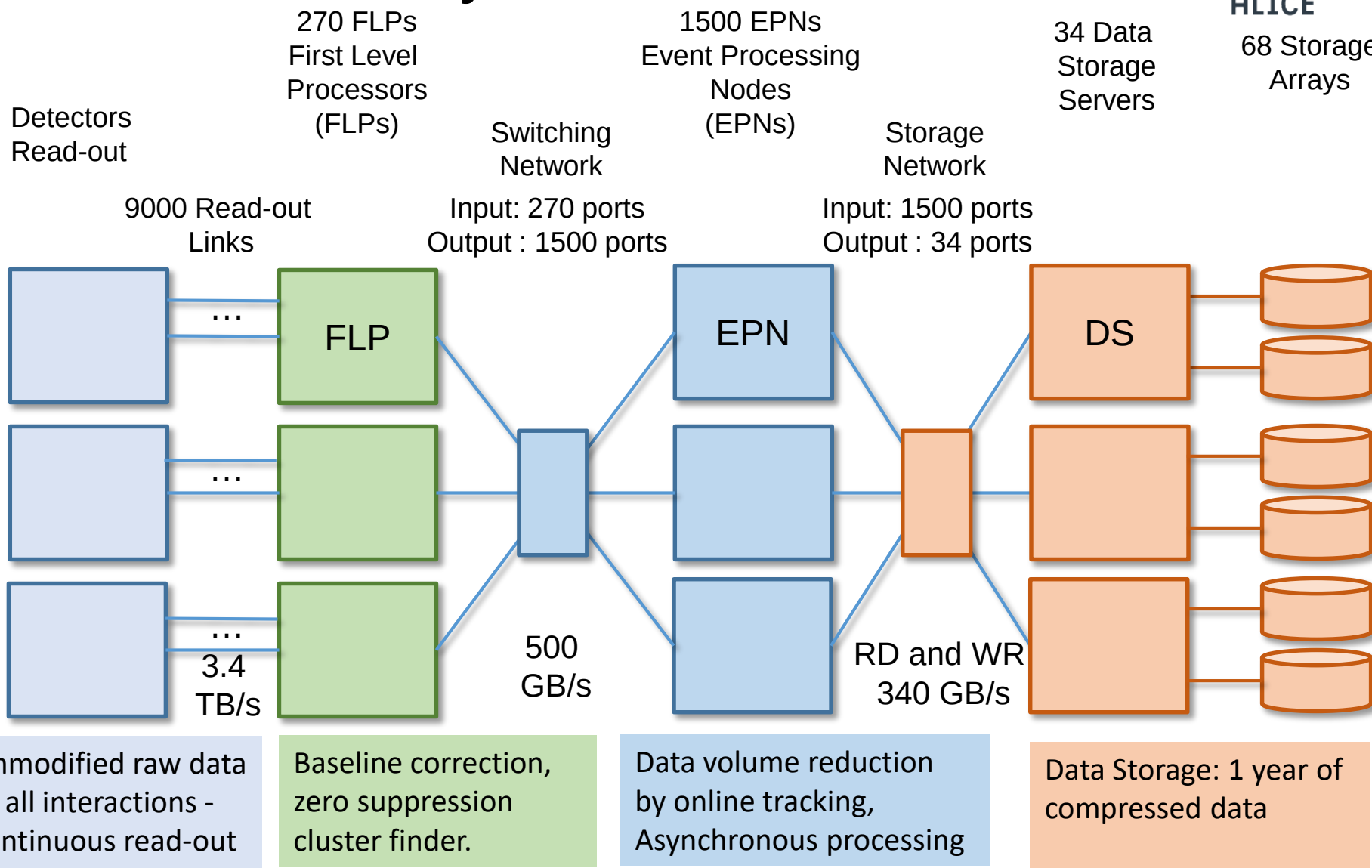
WP	Topic	WP leader	WP Institutes
WP 1	Data Model	Mikolaj Krzewicki	FIAS Frankfurt , CERN
WP 2	Data Flow and System Simulation	Iosif-Charles Legrand	CERN , LIPI Jakarta, FESB Sp RIKEN Wako, KMUTT Bangko COMSATS Islamabad
WP 3	Common Tools and Software infrastructure	Dario Berzano	CERN
WP 4	O ² Software Framework	Giulio Eulisse	CERN , GSI
WP 5	Data distribution and load balancing	Gvozden Neskovic	FIAS , CERN
WP 6	Detector read-out	Filippo Costa	CERN , Wigner Budapest
WP 7	Quality Control	Barthelemy Von Haller	CERN , WUT Warsaw, AGH Krakow, Jammu, INFN, COMS
WP 8	Control, Configuration and Monitoring	Vasco Chibante Barroso	CERN , INFN Bari, IFI Frankfur KMUTT Bangkok, NPI Prague
WP 9	Event Display	Julian Wojciech Myrcha	WUT Warswa
WP 10	CCDB	Costin Grigoras	CERN , GSI
WP 11	ALFA	Mohammad Al-Turany	GSI Darmstadt , CERN
WP 12	Physics Simulation	Sandro Christian Wenzel	CERN (+detector projects)
WP 13	Reconstruction and Calibration	Ruben Shahoyan	CERN (+detector projects)
WP 14	Analysis framework and facilities	Peter Hristov	CERN , GSI
WP 15	Data Management	Latchezar Betev	CERN
WP 16	Computing Room CR1 (FLP)	Ulrich Fuchs	CERN , FIAS
WP 17	Computing Room CR0 (EPN)	Johannes Lehrbach	FIAS , CERN



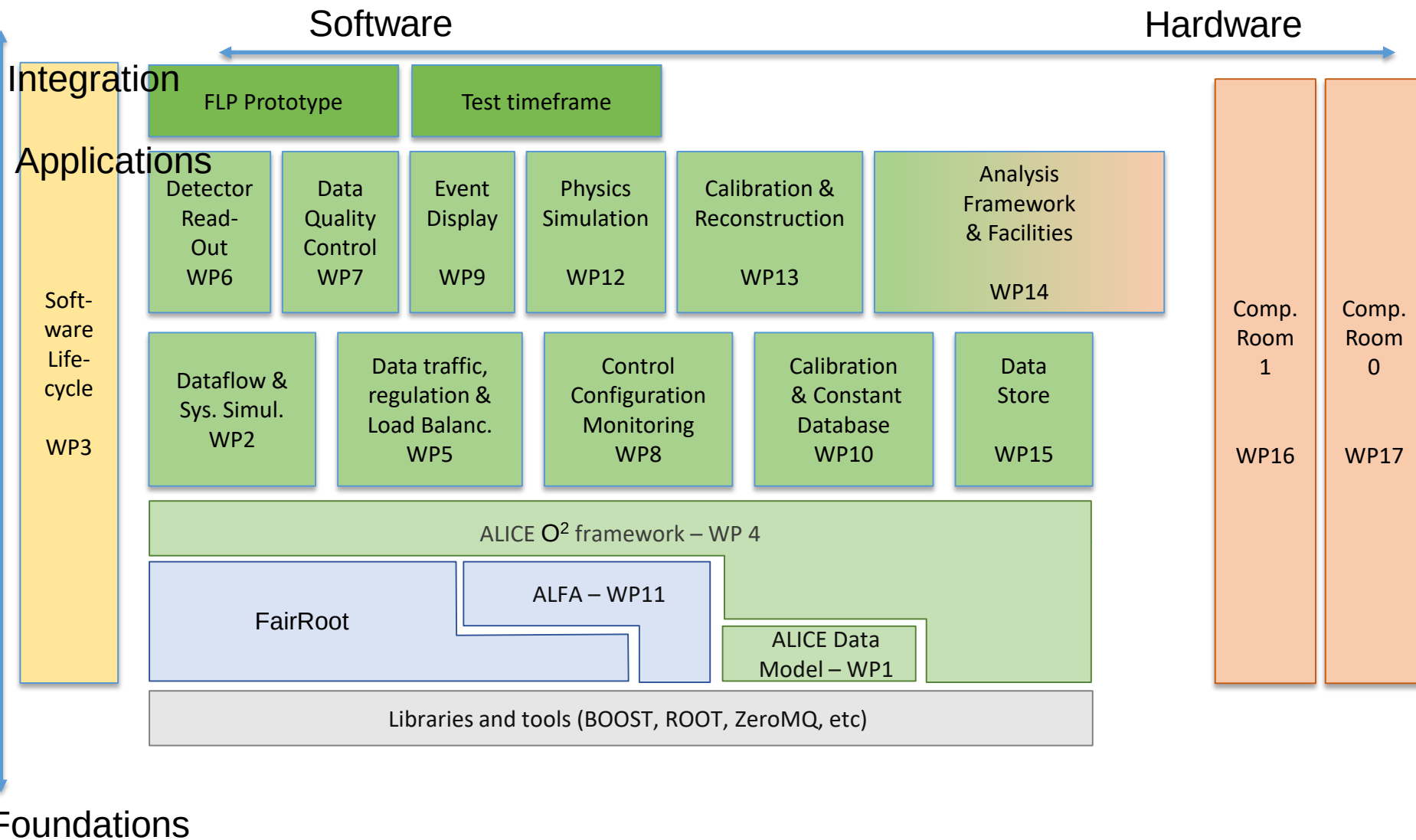
ALICE

68 Storage
Arrays

Hardware Facility



O² Software Architecture

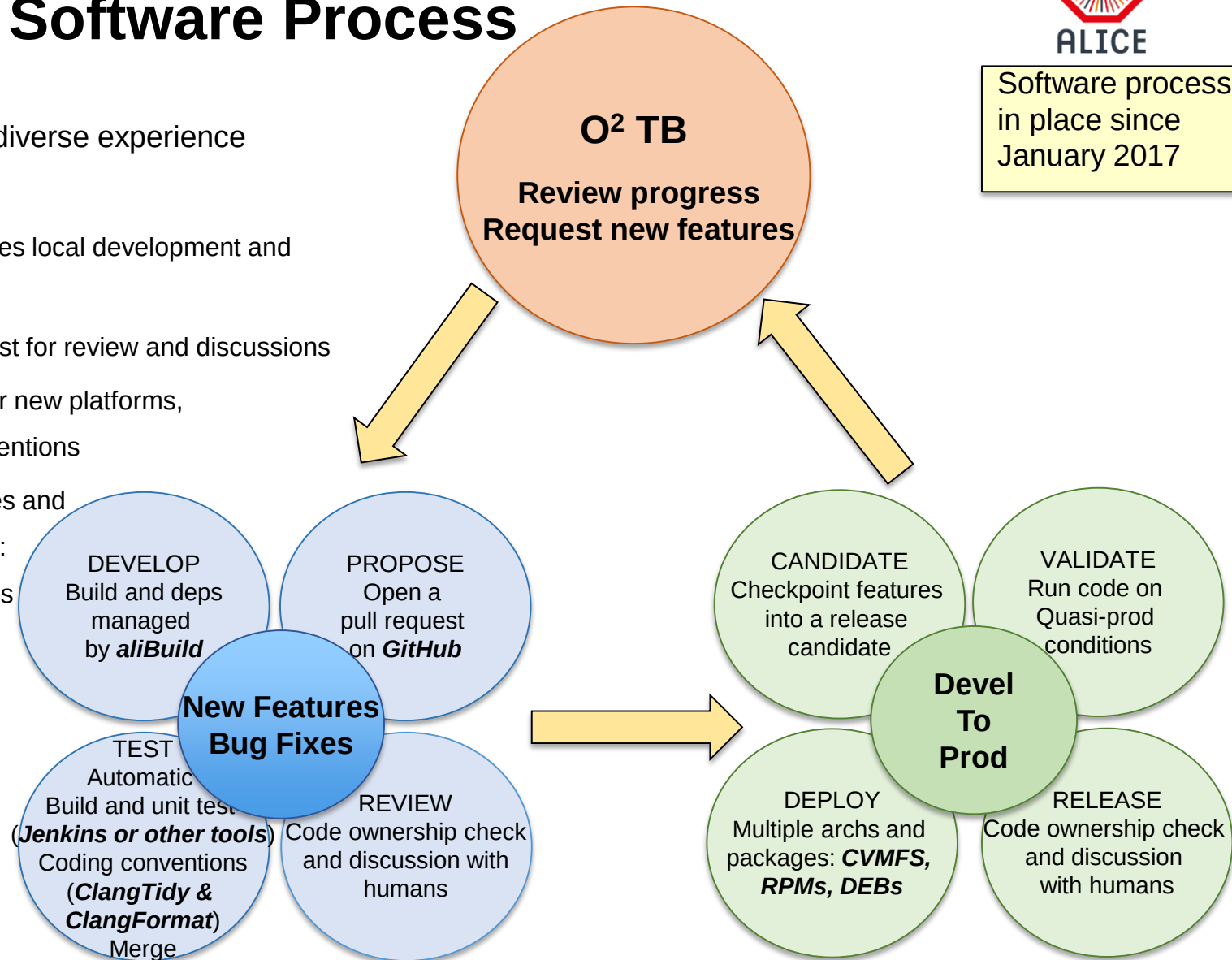


WP3 - Software Process

Software process
in place since
January 2017

Enabling users with diverse experience
to contribute to O²

- Same build tool eases local development and centralized builds
- Leverage pull request for review and discussions
- Easy to add tests for new platforms, pitfalls, coding conventions
- Multiple architectures and installation methods: support all use cases



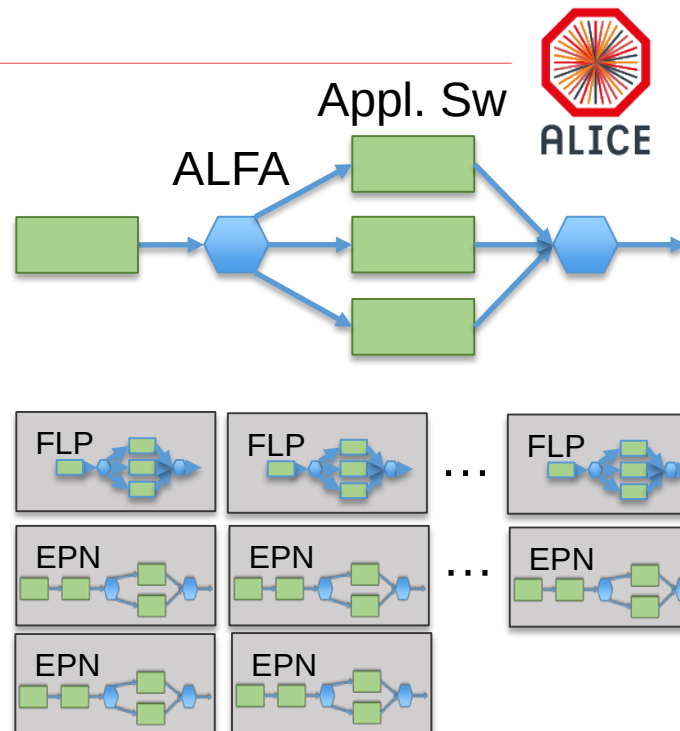
WP11 - ALFA

All features of the production release are available

- Application Programming Interface stable and used by the integrations developments (Test timeframe, FLP prototype)
- Message Queues based parameter and conditions abstraction layer available for reconstruction software (CCDB abstract interface)
- Stable Dynamic Deployment System (DDS) release available for large scale tests
- The transport layer supporting multiple transports within one device (network, shared memory)
- Plugin-infrastructure available for integration with external configuration, command & control, telemetry or logging services
- Generic devices identified and implemented: Merger, Splitter, Sampler, Sink, Proxy, Multiplier

Work has started on the next release

- Support of RDMA for the data transport



Milestone: ALFA release June 2017

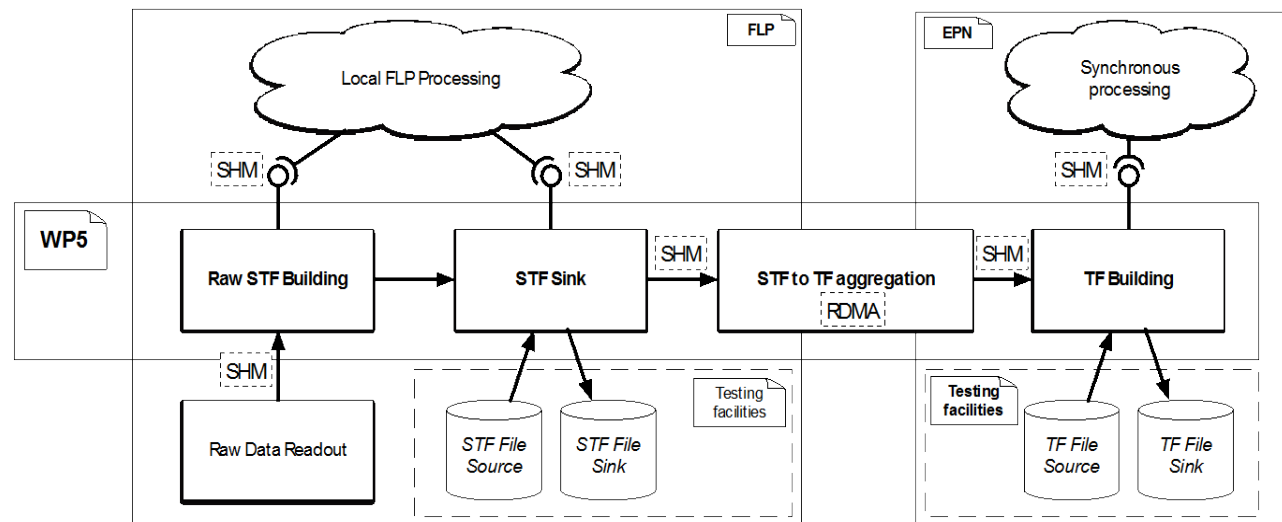
Production release done and used in the integration activities

WP1 – Data Model

- Goal: develop a data model suitable for the high throughput, multi process online data processing in O².
- Delivered: generic in-memory data layout suitable for interprocess data exchange, maximizing the potential of zero-copy data transports (e.g. shared memory, RDMA).
 - In use by framework demonstrator/test timeframe.
 - Data exchanged in fully self described contiguous buffers, annotation handled by the metadata model.
 - For performance critical data paths (e.g. reconstruction) data representation is flat (POD, no pointers) to avoid serialization/deserialization and copy overhead.
 - Support efficient data pruning/joining.
 - Preference for columnar data representations (i.e. structs-of-arrays).
- Serialized ROOT objects allowed and supported where performance considerations allow for it (e.g. quality monitoring data).
- In memory RAW data layout first version available.
- Persistent data storage format (CTF,ESD/AOD) in development (Q3 2017/Q1 2018).

WP5: Data distribution and load balancing

- Developed a concept for efficient data handling during readout, network distribution, and processing
 - Zero-copy transports from CRU (FLP) to EPNs
 - Built upon Shared Memory (SHM) and Remote Direct Memory Access (RDMA) capable interconnects

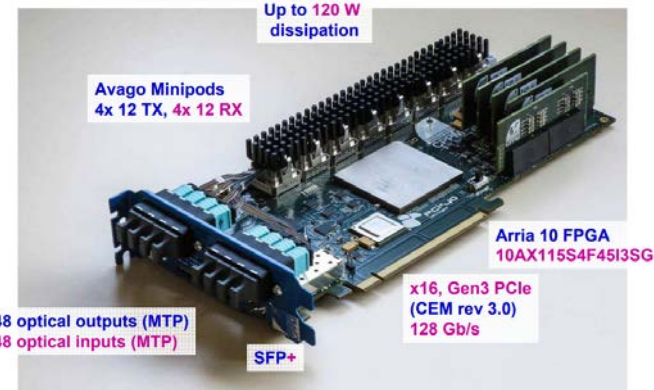


- Ongoing efforts:
 - Investigating zero-copy primitives
 - Finalizing Readout Data and HBMap formats
 - Defining suitable and cost-effective FLP-EPN interconnect topology

WP6 – Transition to Run 3 detector read-out

2016

2017



C-RORC (RUN2 ALICE readout CARD) + GBT link = G-RORC

Firmware adapted to readout and configure detector electronics using GBT links.

Support of detector readout card test (lab and test beam).

TOF, TPC, MID, MCH, MFT, FIT

DAQ software based on RUN2 DATE and RORC driver

ARRIA X development kit to develop and test the CRU firmware and the O² software. Used by a few detector teams (ITS and MCH).

Not all the hardware features of the CRU, but very useful to test the readout of detectors using GBT readout system and the O² software

CRU, the new readout card for RUN3.

Currently 4 cards at CERN.
3 firmware releases have been released to the user.

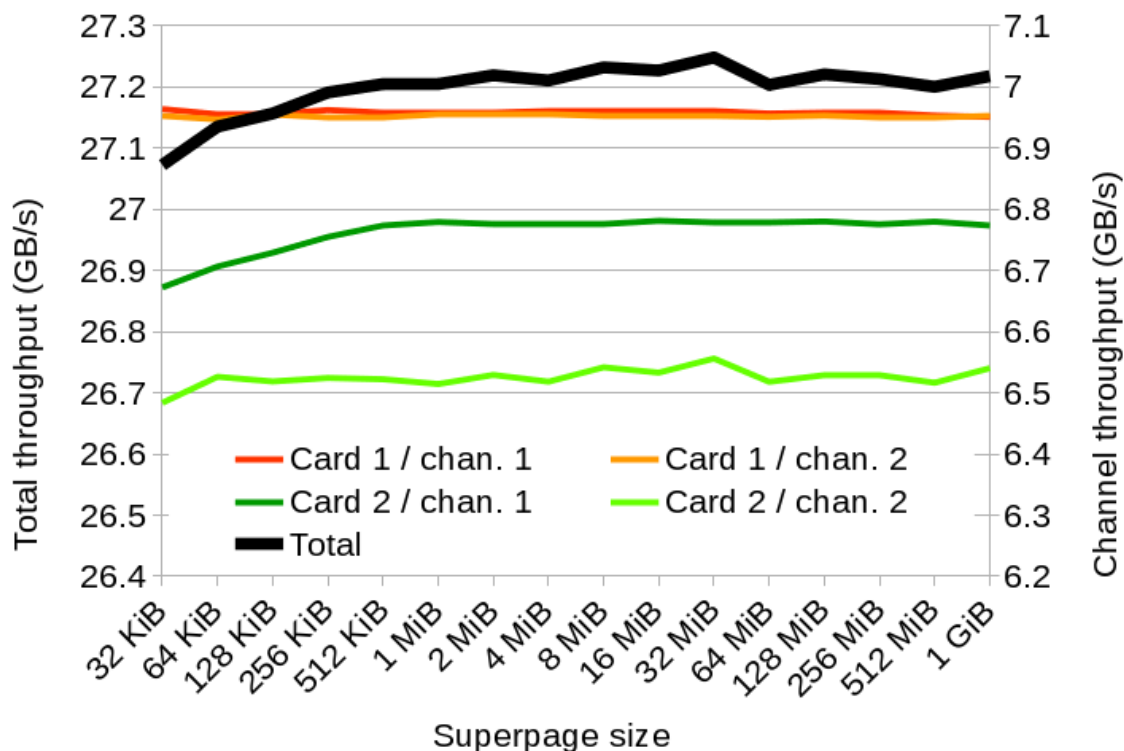
Support for GBT readout (continuous and packet), interface with the TRIGGER and DCS system.

Several tests are progressing in parallel between the central systems (O², CRU, DCS and TRIGGER) and the detectors (mainly ITS and TPC)

WP 6 – Run 3 Detector Read-Out

- Performance test with 1 FLP (Dell PowerEdge R730) and 2 CRUs each with two channels PCIe Gen3 x 8
- Measured channel throughput 6.50 - 6.95 GB/s out of a maximum of 7.8 GB/s
- First detector readout test with GBT and CRU performed with the ITS Read-out Unit
- Test in progress with the TPC FEC

Throughput as function of superpage size



Milestone: detector read-out GBT/CRU June 2017

- Complete solution (hw, fw, sw) available for the detector read-out at the performance needed for Run 3
- First integration test performed with ITS RU

WP8 - Control

- Control prototype
 - Framework to deploy and start/stop the various components of the FLP prototype
 - Based on Ansible and systemd units
 - Command-line interface for detector tests allows easy rollout of multi-node setups
- Design refinement and tools evaluation in progress
 - Several tools/technologies under consideration
 - Final decision by Q2 2018
- Web-based Control GUI in progress
 - Development environment defined
 - Base widgets available
 - C++ library for bidirectional (websockets) communication between GUI and Control system
 - Will be reused by other O² web-based GUIs

```
[tmrnjava@teo-fpctl81 ~]$ fpctl -h
usage: fpctl [-h]
           {deploy,de,configure,co,run,start,status,stop,update,up,setup}
           ...

==> FLP prototype control utility

positional arguments:
  {deploy,de,configure,co,run,start,status,stop,update,up,setup}
  deploy (de)          deploy FLP prototype software and configuration
  configure (co)       deploy FLP prototype configuration
  run                  run a custom command on one or all nodes
  start                start some or all FLP prototype processes
  status               view status of some or all FLP prototype processes
  stop                 stop some or all FLP prototype processes
  update (up)         update fpctl deployment information
  setup               install and configure fpctl
[tmrnjava@teo-fpctl81 ~]$ fpctl status
==> Hosts in inventory:
-> teo-fpctl85.cern.ch [authentication: GSSAPI/Kerberos]
-> teo-fpctl86.cern.ch [authentication: GSSAPI/Kerberos]
==> Checking status...
```

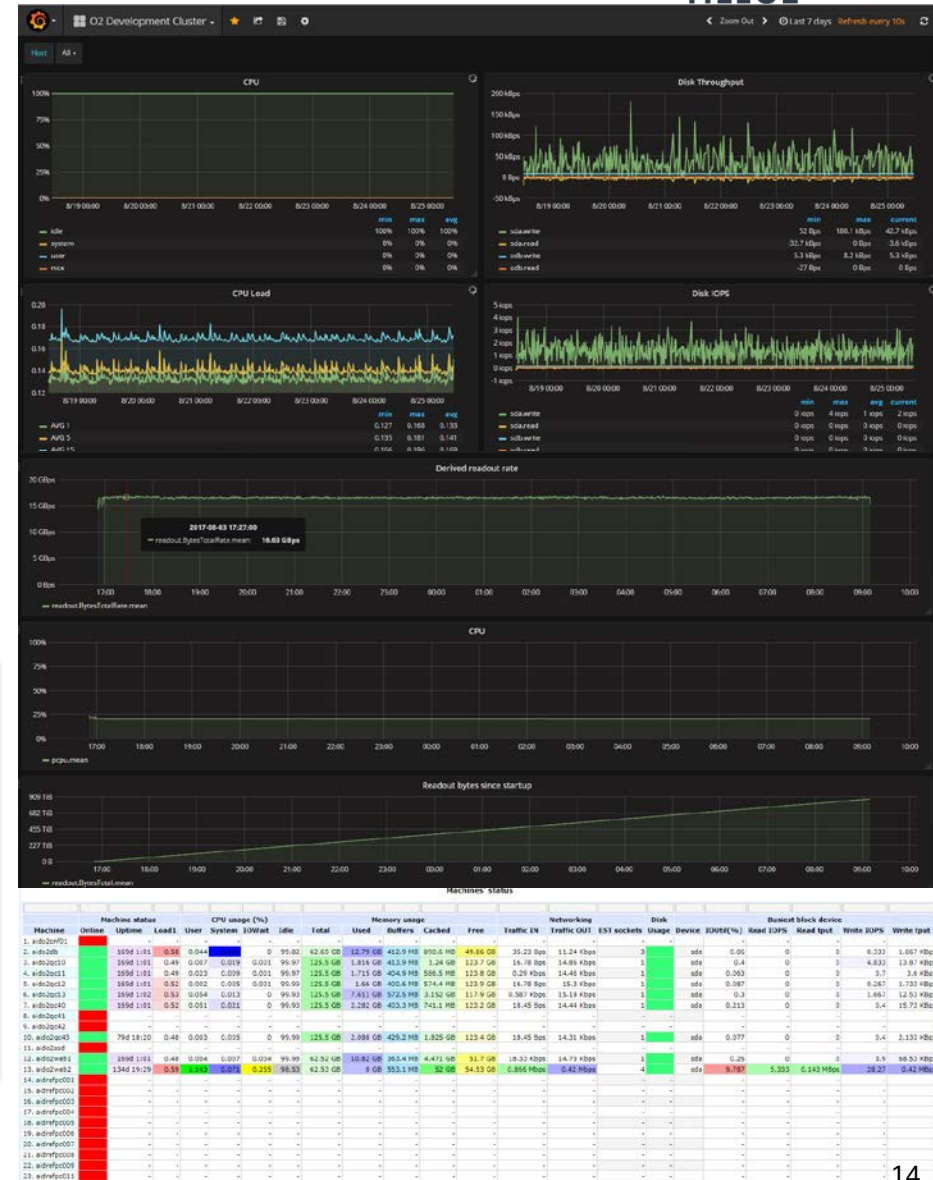
Inventory group	Task	Status
Target hosts	Systemd units	
[flp-readout]		readout
teo-fpctl85.cern.ch	flpprototype-readout	● active
teo-fpctl86.cern.ch	flpprototype-readout	● active
[qc-task]		qctask
teo-fpctl85.cern.ch	flpprototype-qctask	● active
[qc-checker]		qcchecker
teo-fpctl85.cern.ch	flpprototype-qcchecker	● active

WP8 - Monitoring

- Prototype ready
 - C++ library for application and process metric injection, 5 backends supported for max flexibility
 - InfoLogger, influxdb, Apache Flume, MonALISA, Zabbix
 - Community service available for detector tests
 - Installation recipes available for private setups
- Tool evaluation for backend selection in progress
 - 3 candidates: MonALISA, Zabbix, Modular stack
 - Functional and performance comparison criteria defined and approved
 - Final decision by Q4 2017
- Configuration and Logging: see spare slides

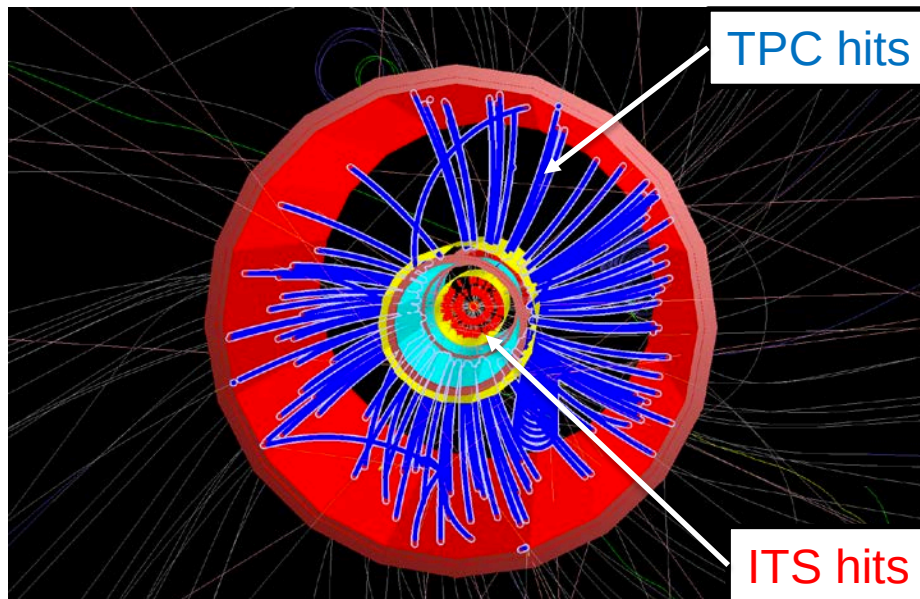
Milestone CCM June 2017

- Prototypes of all functions (Control, Configuration, Logging and Monitoring) have been developed and used in integration activities
- Use to test, evaluate and benchmark
- Final technology choice
 - Monitoring Q4 '17
 - Configuration Q1 '18
 - Control Q2 '18



WP 12 – Physics Simulation: ITS and TPC

- O² major milestone: “ITS and TPC in simulation framework (6/17)”
 - Produce hits and simulation digits for TPC + ITS using the new O² simulation framework based on FairRoot taking into account Run 3 event pile-up and continuous detector readout of
 - Both ITS, TPC provided upgraded geometry and all functional blocks for detector response (hits + digits) within the new framework
 - Demonstrated working setup tested with large events (central Pb-Pb collisions with up to 100000 primaries)
 - Several improvements (CPU performance) over Run 2 software could be achieved at the same time (TPC digitization)
 - Demonstration of integration: hits produced in new framework (box generator)



WP 12 – Physics Simulation

Major deliverables	TPC	ITS
Upgraded geometry implemented in O ²	Completed (06/16)	Completed (07/17)
Geant stepping + hits (energy deposit) simulation	Completed (03/17)	Completed (04/17)
Implementation of digitization procedure for Run3 setup (including pile-up and continuous readout effects)	Functional version available (05/17)	Functional version available, under review (08/17)
	Integration into O ² device-processing workflow in progress	
Stress test with realistic event size	Completed (06/17) Lead to identification of a few issues (ROOT, FairRoot) which were fixed	

WP 12 – Physics Simulation: other detectors

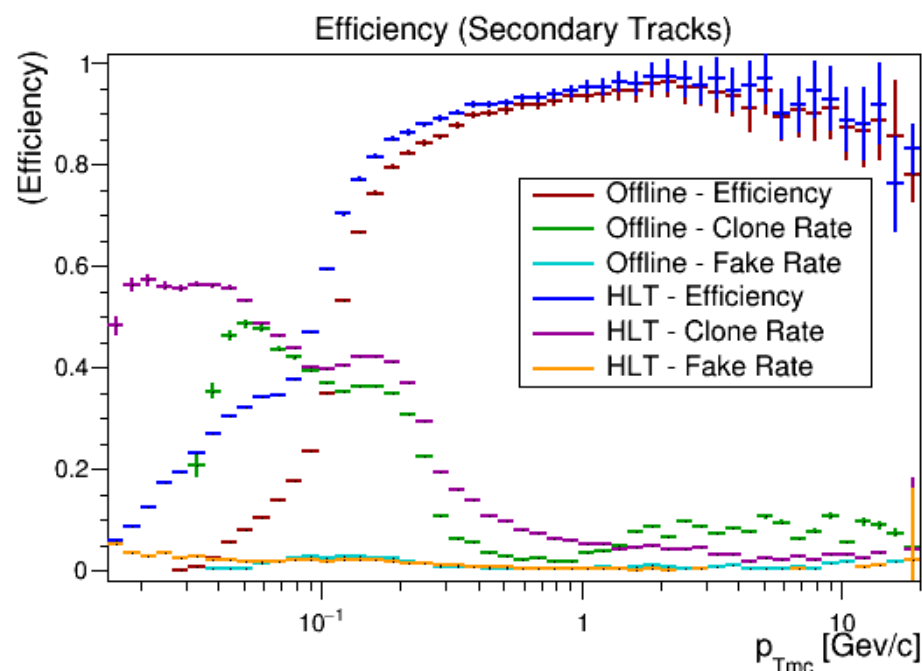
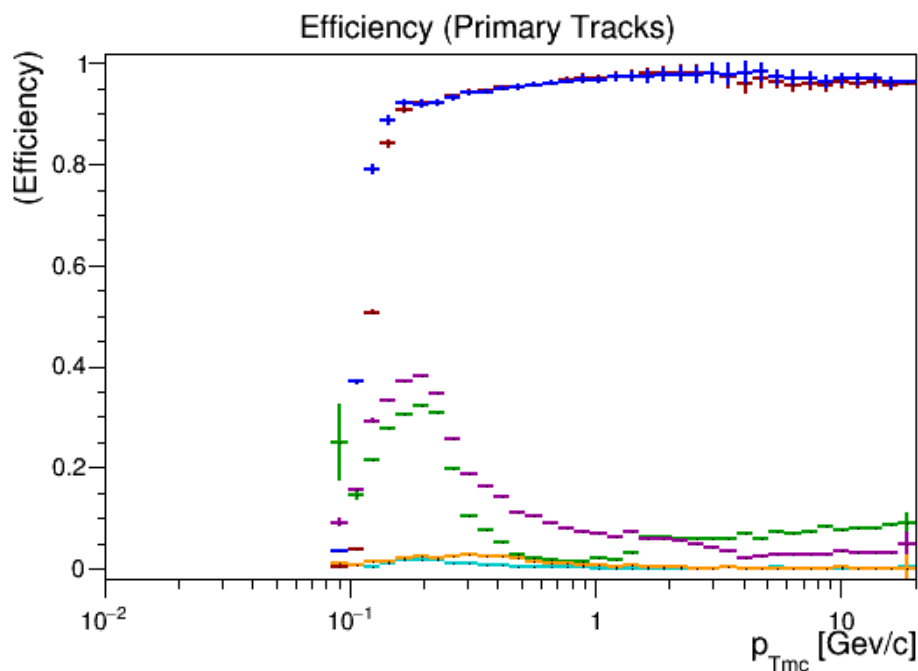
- Good progress with EMCAL, MFT, TOF, TRD
 - Ported geometry description in O²
 - Geant stepping and hit production
 - Digitization currently being addressed for these detectors
- Other passive support structures have been ported almost completely and work correctly in the new simulation framework
 - Frame, Magnet, Absorber, Dipole, BeamPipe
- A few detectors have not yet started the Run3 activity
 - Some are missing manpower or their planning foresee completion mid 2018
 - These detectors will benefit from the experienced gained so far
- Overall:
 - Good progress for this milestone
 - However, complete achievement with original target 12/2017 unlikely
 - A shift of due date to Q3 2018 seems reasonable and necessary

Milestone: ITS and TPC detectors simulation in the O² framework – June 2017

- Milestone reached
- Good progress for the other detectors
- Complete achievement delayed by 3 months

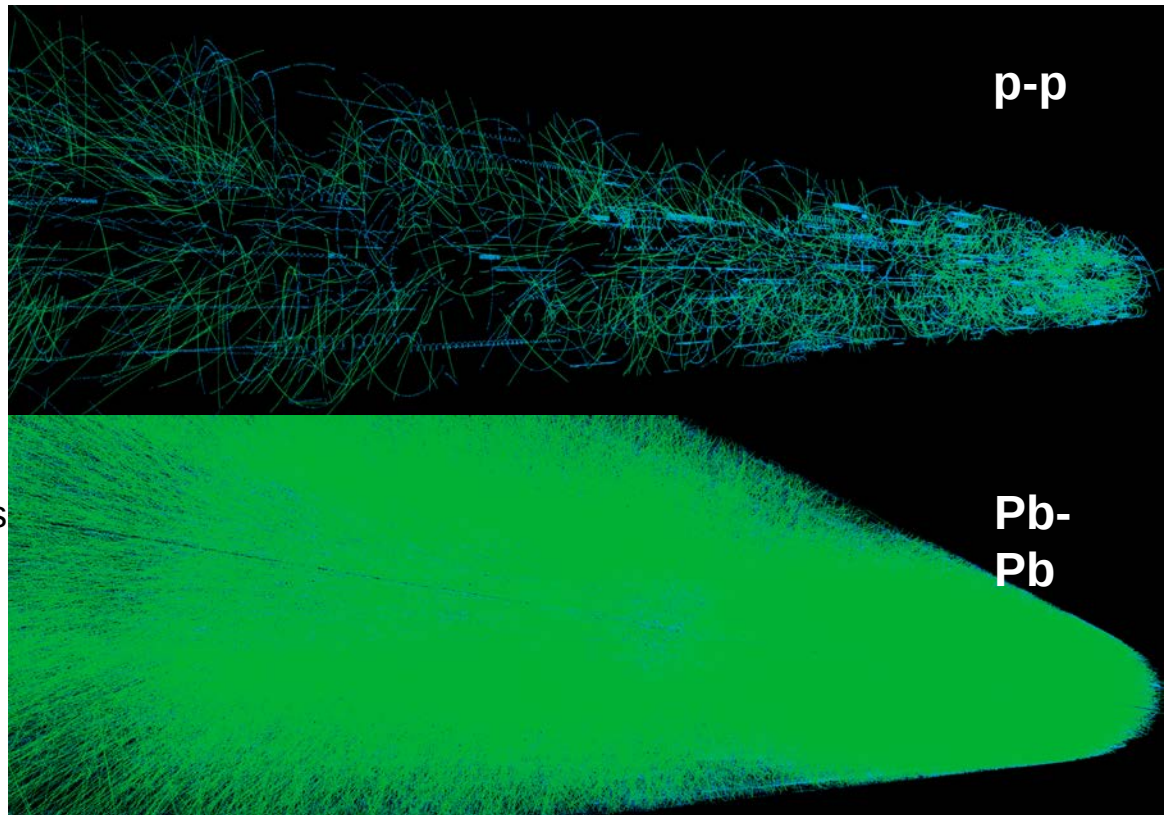
WP13 - TPC tracking

- HLT tracking code adapted for O² including many improvements:
 - More robust treatment of outlying clusters
 - Improvements low p_T tracking (needed for data compression, see later)
- HLT reconstruction efficiency already equivalent (or better at low p_T) than in the Offline
- More development is needed to improve resolutions, particularly in Pb-Pb



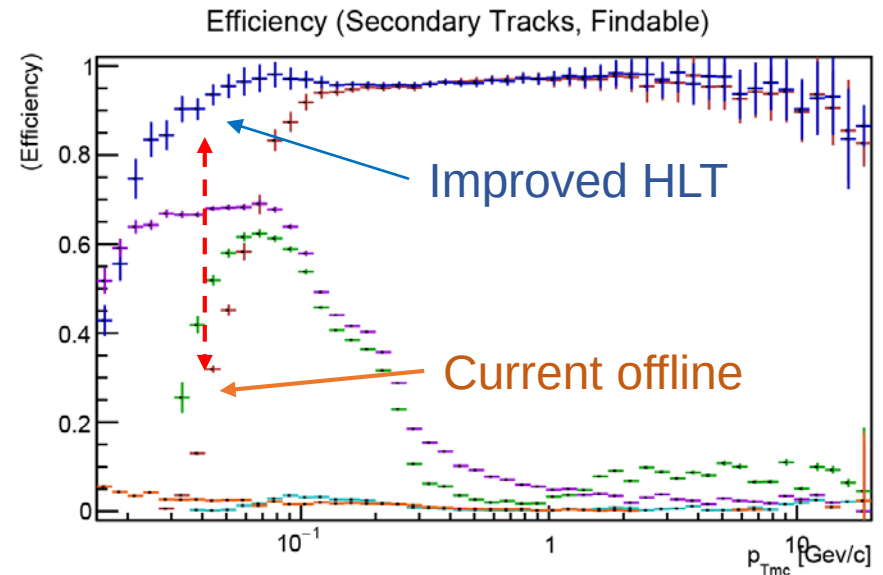
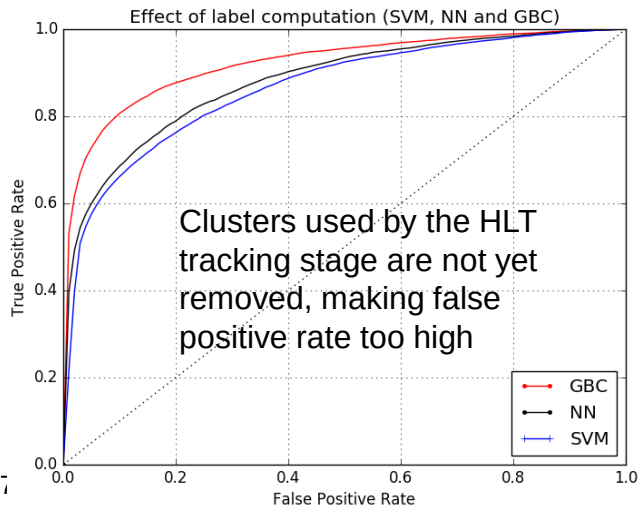
WP13 - TPC tracking of continuous data

- Screenshot of reconstructed tracks for overlapped collisions (50 kHz interaction rate equivalent)
- Reconstruction of continuously read-out data:
 - Absence of t_0 used to convert the cluster drift time to drift length (e.g. Z coordinate)
- HLT code is modified to find tracks with arbitrary Z coordinates
 - Real Z position will be needed for calibration purposes only
- The merging of segments for track crossing TPC CE still to be implemented
- 25 min.bias overlapping events:
 - 2.5 s: 8 threads on i7-6700K CPU
 - 273 ms: GTX1080 GPU + 4 CPU cores
 - Benchmark for Track Finding/Fitting, some non-dominant contributions are not accounted yet)



WP13 - TPC data compression

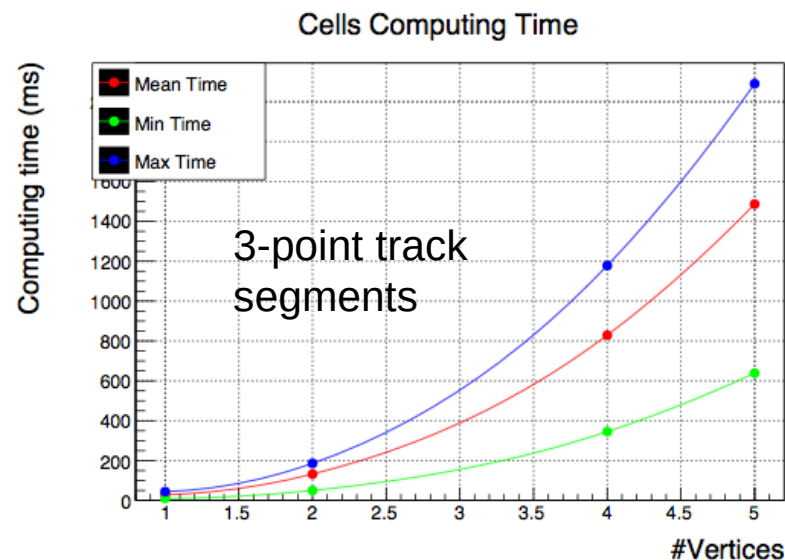
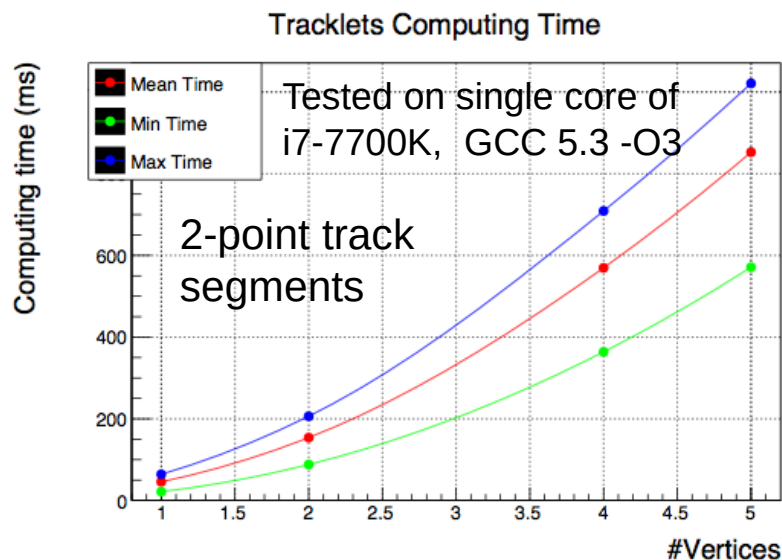
- Target factor ~ 20 wrt TPC zero-suppressed data
- Thanks to a better noise suppression and some format optimization the current compression was improved by 40% ($5.18 \rightarrow 7.28$). Already deployed in Run2 data taking.
- With track-based cluster data representation, arithmetic (instead of Huffman) compression and a few minor improvements, the reduction factor is now at 9.1
- The remaining factor ~ 2 should be obtained by discarding clusters which do not contribute to physics: secondaries at $p_T < 50$ MeV, excess legs of looping tracks.
- Complementary approaches:
 - HLT tracking during the synchronous phase:
 - Extend p_T reach as low as possible (in progress, ~ 15 MeV is realistic)
 - Merge multiply reconstructed legs of the same tracks, extra/interpolate helix to find non-attached clusters
 - Discard clusters attached to unusable tracks



- Run afterburner on clusters not used by previous step to tag remaining very-low p_T loopers using Hough transform and ML techniques, eliminate their clusters

WP13 – ITS Tracking

- No differences between “continuous” vs “triggered” readout in ITS: hits from any given collision are in the same RO frame for all chips, therefore frames are processed independently from each other.
- Improved tracking with CPU
 - Pre-allocation of vectors and few trivial changes
⇒ factor ~ 2 speedup in pattern recognition wrt old (alroot) version
 - Pile-up event reconstruction enabled
 - No efficiency degradation with 5 central (0-5%) Pb-Pb piled up
 - Track finding efficiency still to be improved at low p_T



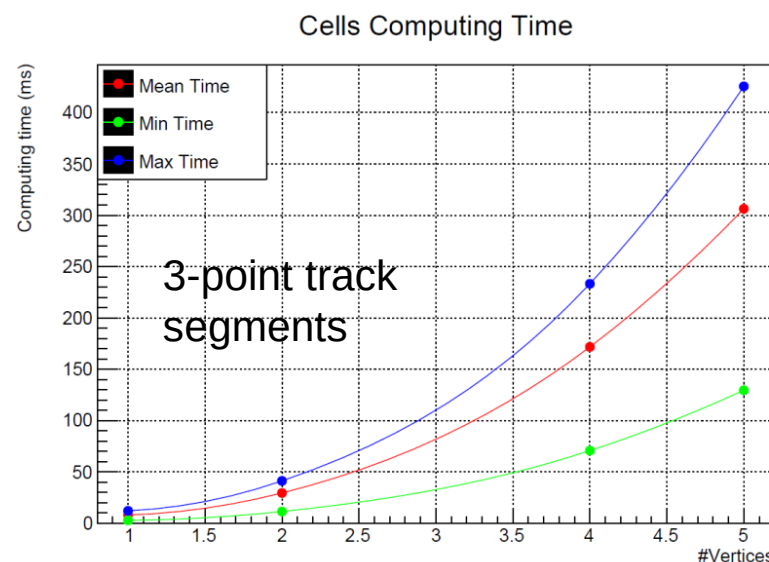
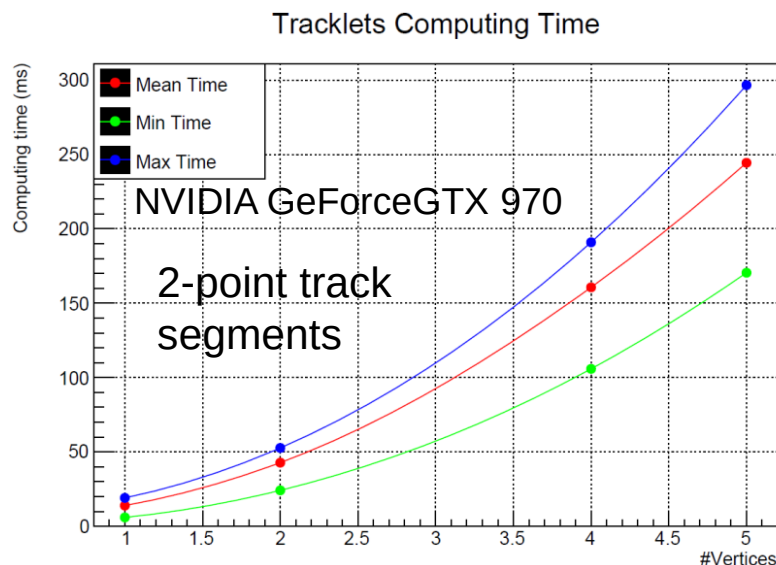


WP13 - ITS tracking using GPUs

- First implementation on GPU using CUDA
 - Choice of technology driven by the available hardware
 - Usage of CUDA intrinsics limited / avoided as much as possible to ease the porting to OpenCL
- Only tracklet and cell finding (90% of computing time) ported on GPU
- Overall speedup of a factor 2.5 for single event, increasing up to ~5 with pileup
- No tracking efficiency differences wrt CPU version

- Substantial progress with the reconstruction since the beginning of '17

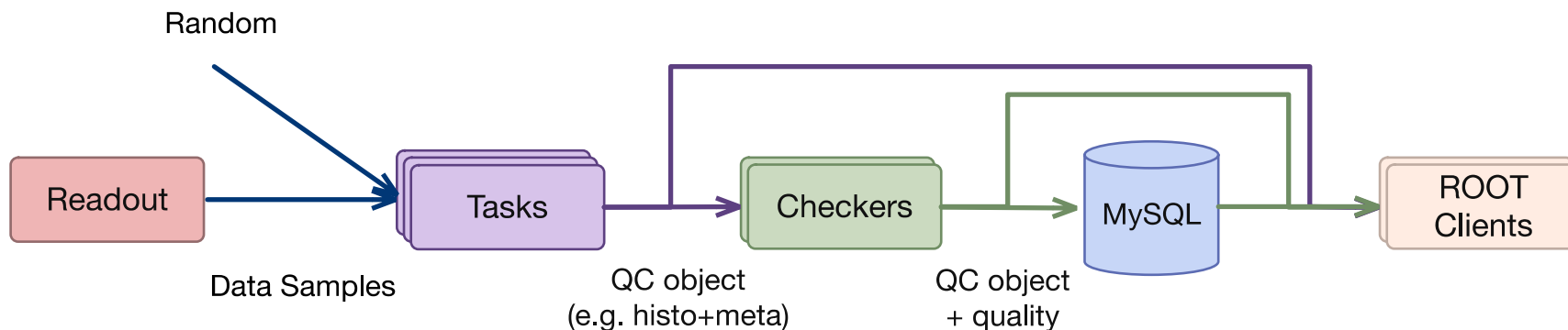
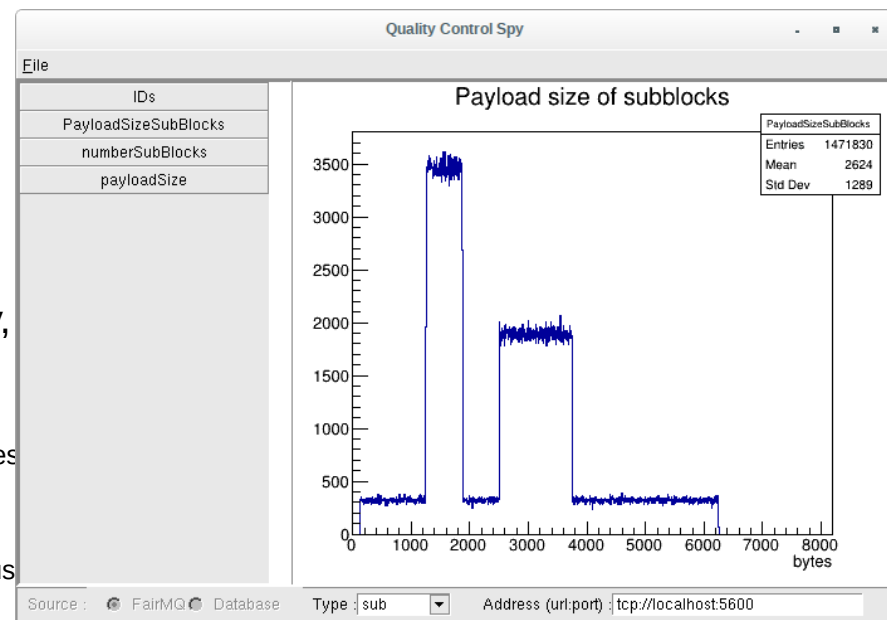
- Well on its way to reach the milestone of ITS-TPC reconstruction by the end of the year



[Details in I.Colonnelli slides at ITS WP1&2](#)

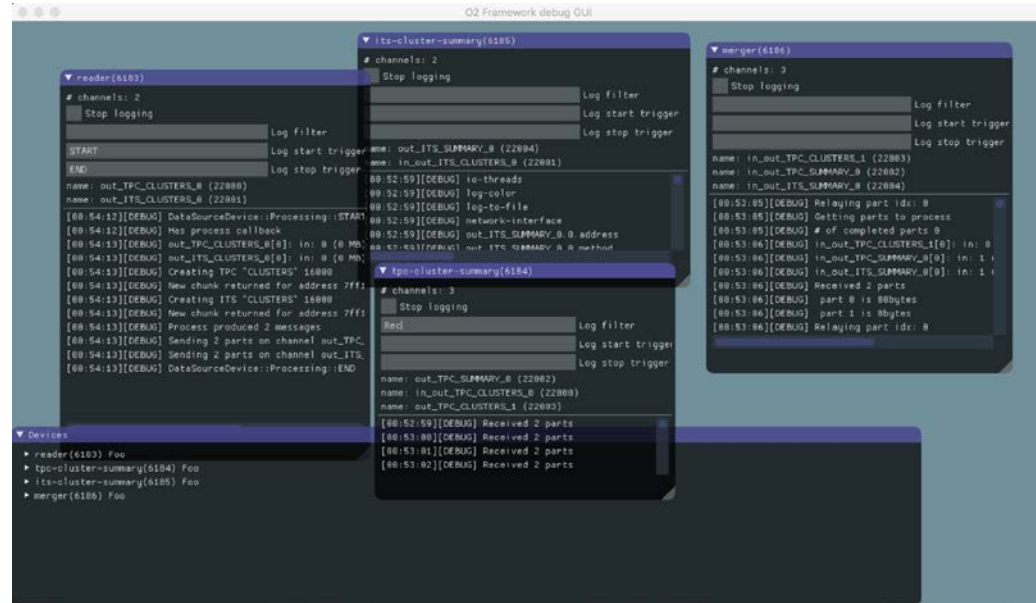
Integration: FLP Prototype

- Integration and documentation of the existing software of WPs 6, 7 and 8 into a release for the FLP software:
 - The main readout components for the end-user:
 - ROC**: Drivers, library, and command line utilities to access readout cards (CRU, CRORC)
 - Readout**: a process able to readout and record data from multiple devices, with connections to monitoring and data sampling
 - Services (usually consisting of an API, library, central services and display):
 - InfoLogger**: a logging system, to collect, store and browse log messages
 - Configuration**: configuration system for distributed processes (runtime parameters, ...)
 - Monitoring**: monitoring system for distributed processes (performance, status, ...)
 - Control**: framework to start/stop (and even install) the various components
 - QC**: framework to control quality of data



Integration: Test timeframe

- Integration milestone
 - Data distribution prototype using the existing O² Data Model
 - RUN 1 HLT data injector to use the O² Data Model and based on preliminary data specifications for raw data format.
 - Create utilities to simplify managing shuffling, stripping and merging of raw data streams.
 - Stream and read-back the test timeframe to disk, in some prototype format.
 - On the fly index creation for Test Timeframe contents.
- Will now be used as a reference for further tests:
 - Integrate final components of DAQ and Data Distribution
 - Reassess performance and scaling test

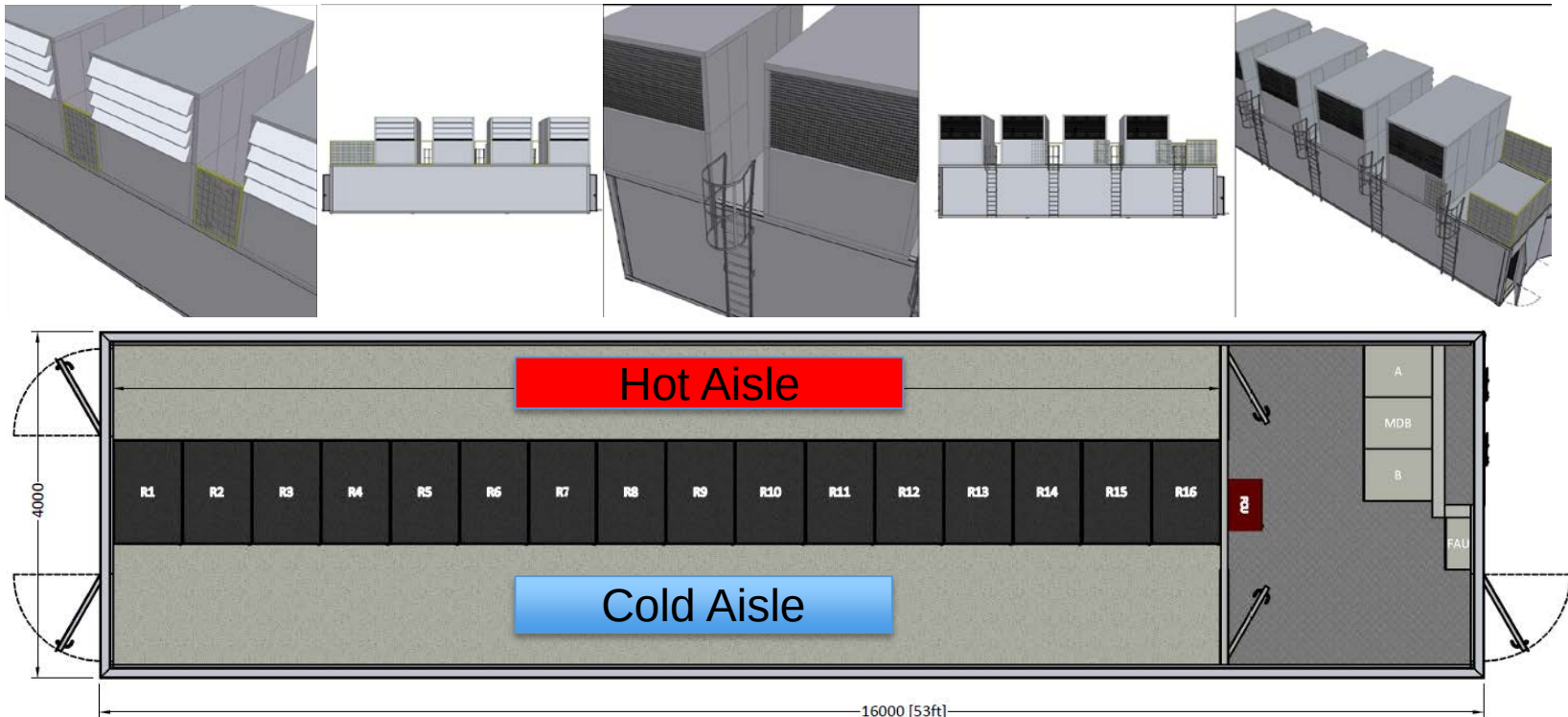


Milestone test timeframe met.
By-product: O² framework debug tool



WP17 - CR0 procurement

- In May decision by the CERN:
 - A plan will be elaborated for the construction of a computing center in 2020-2021
 - ALICE & LHCb should now work on the “container” solution.
- The result of the container tender for a capacity of 2300 U and 2 MW cooling
 - 4 containers with a cooling capacity of up to 564 kW
 - Each container includes 4 air handling units of up to 141 kW each with indirect air with adiabatic



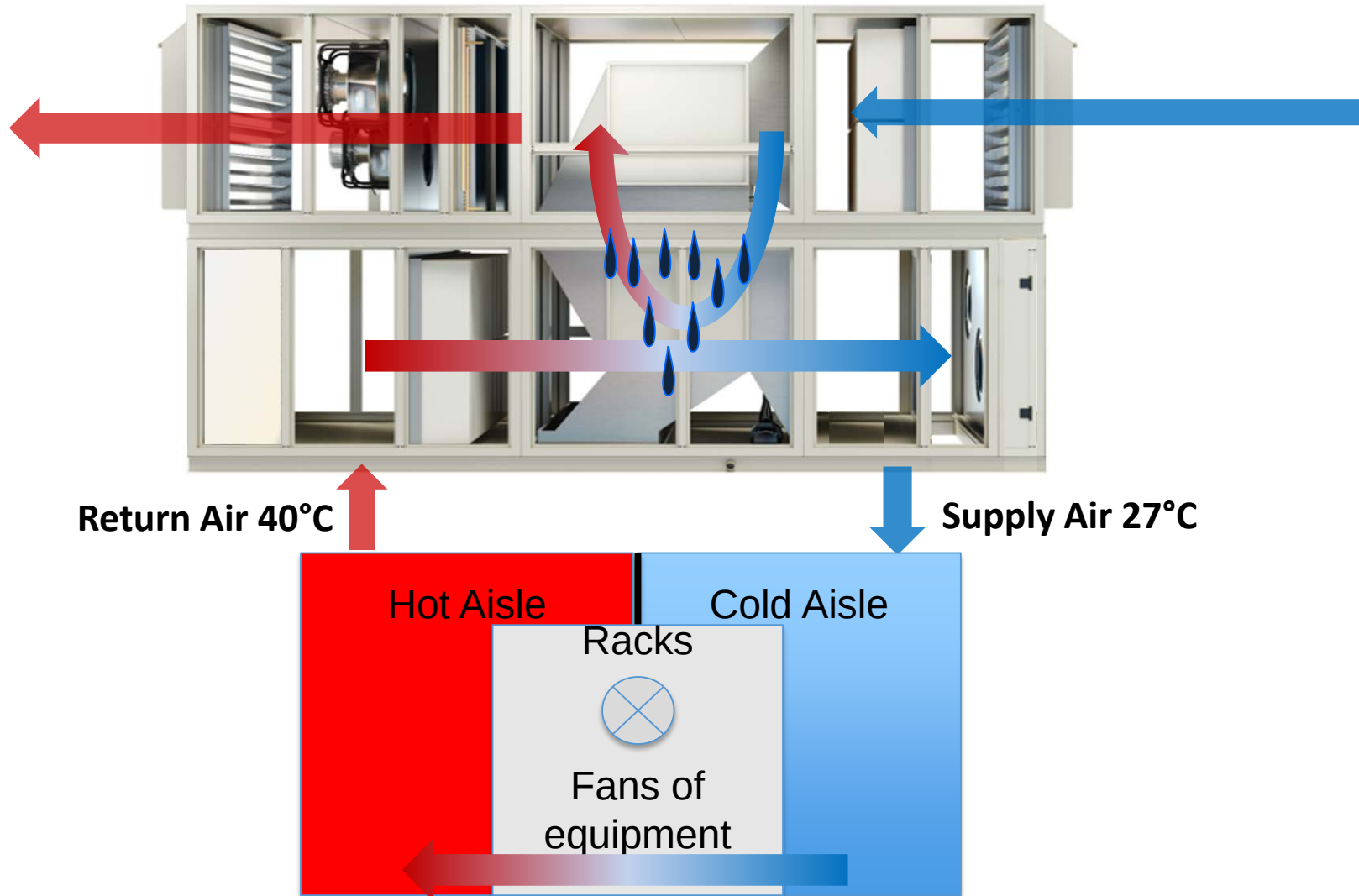
WP17 – Containers at P2



Indirect free air with adiabatic cooling

Fans running 10 - 100%

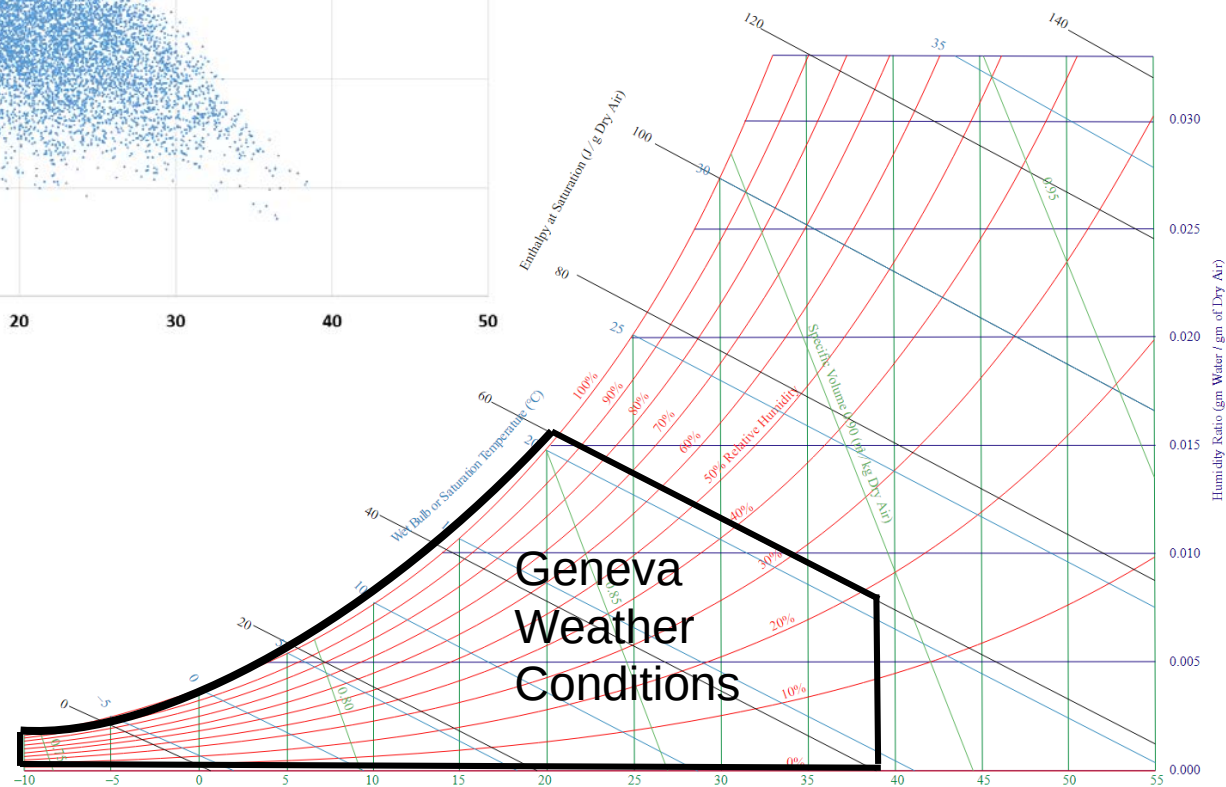
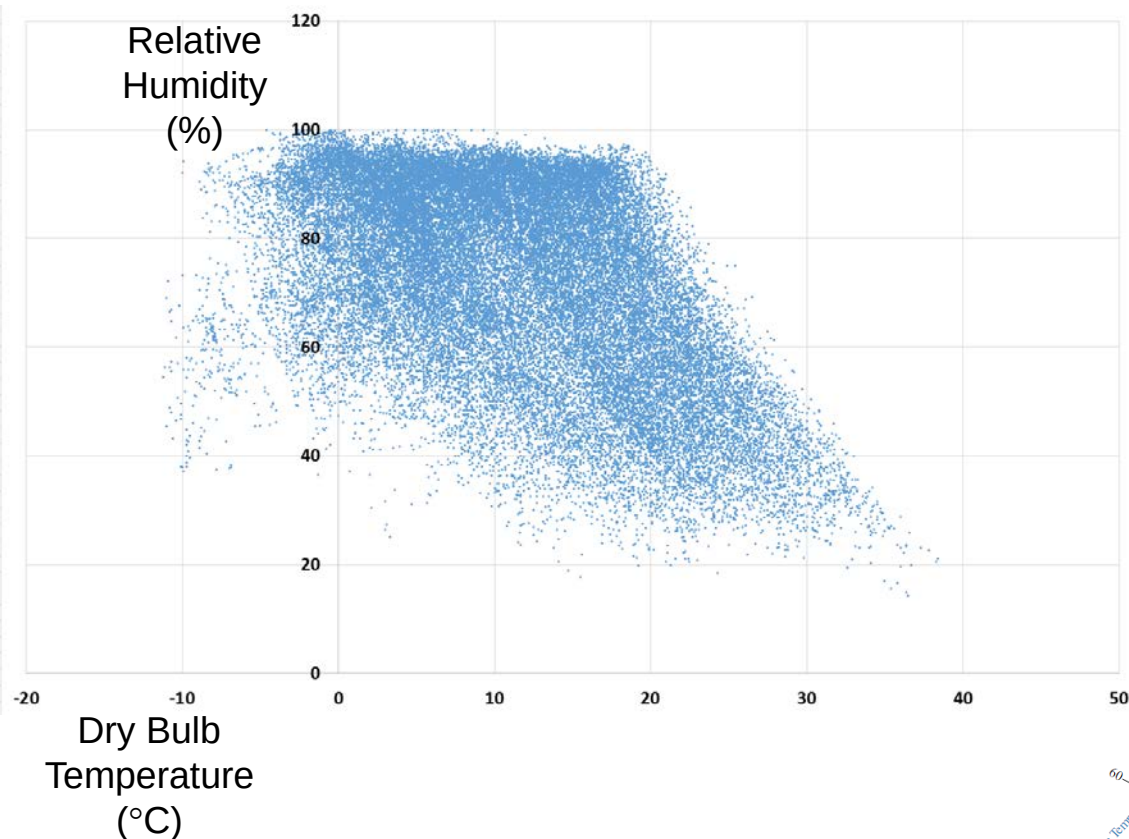
Outdoor Temp. -10°C / 38°C



Weather conditions in Geneva

Complete collection of temperature and humidity in hourly average from the Swiss Weather forecast

From January 1st 1981 till September 2015

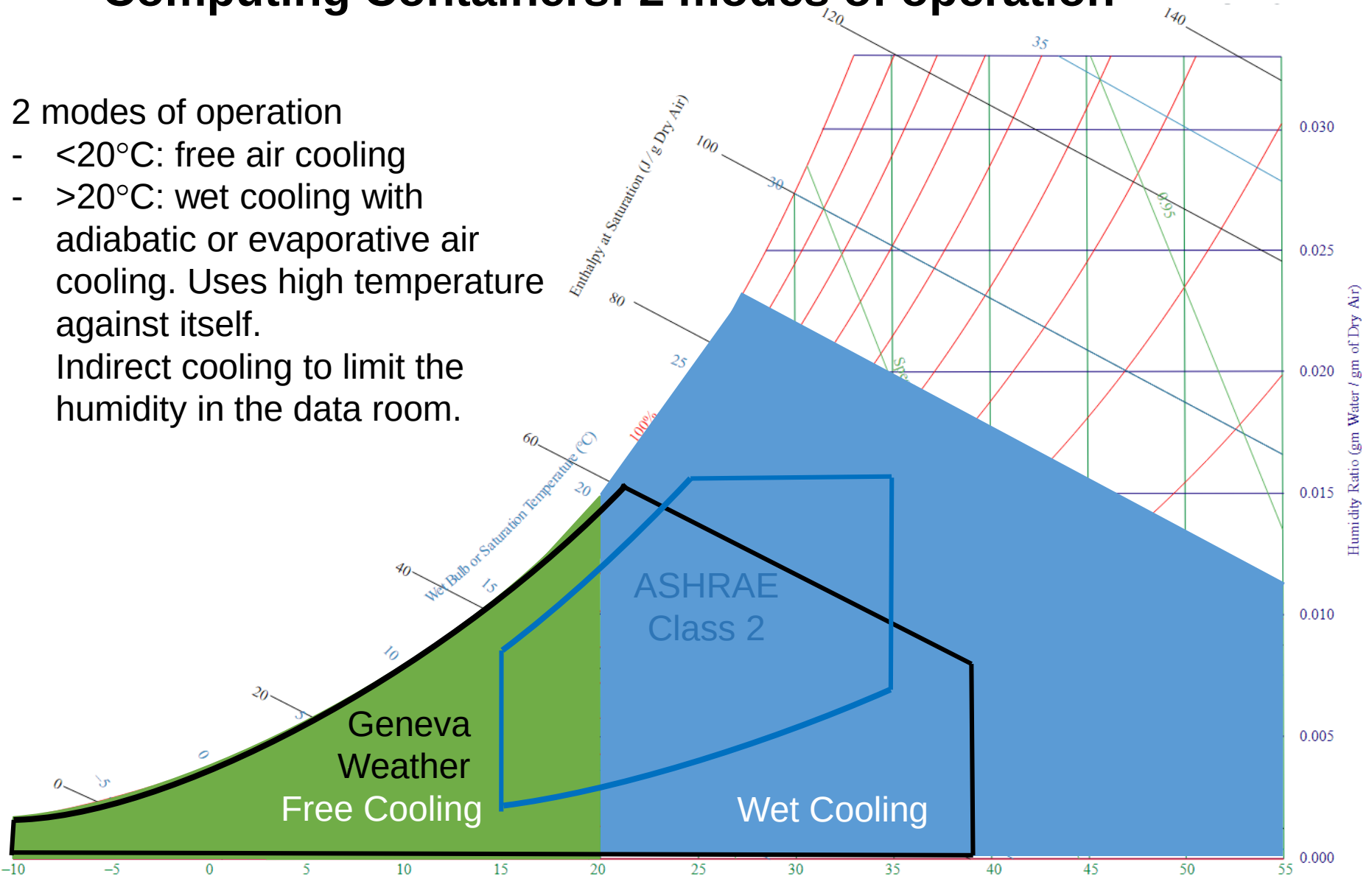




Computing Containers: 2 modes of operation

2 modes of operation

- $< 20^{\circ}\text{C}$: free air cooling
 - $> 20^{\circ}\text{C}$: wet cooling with adiabatic or evaporative air cooling. Uses high temperature against itself.
- Indirect cooling to limit the humidity in the data room.

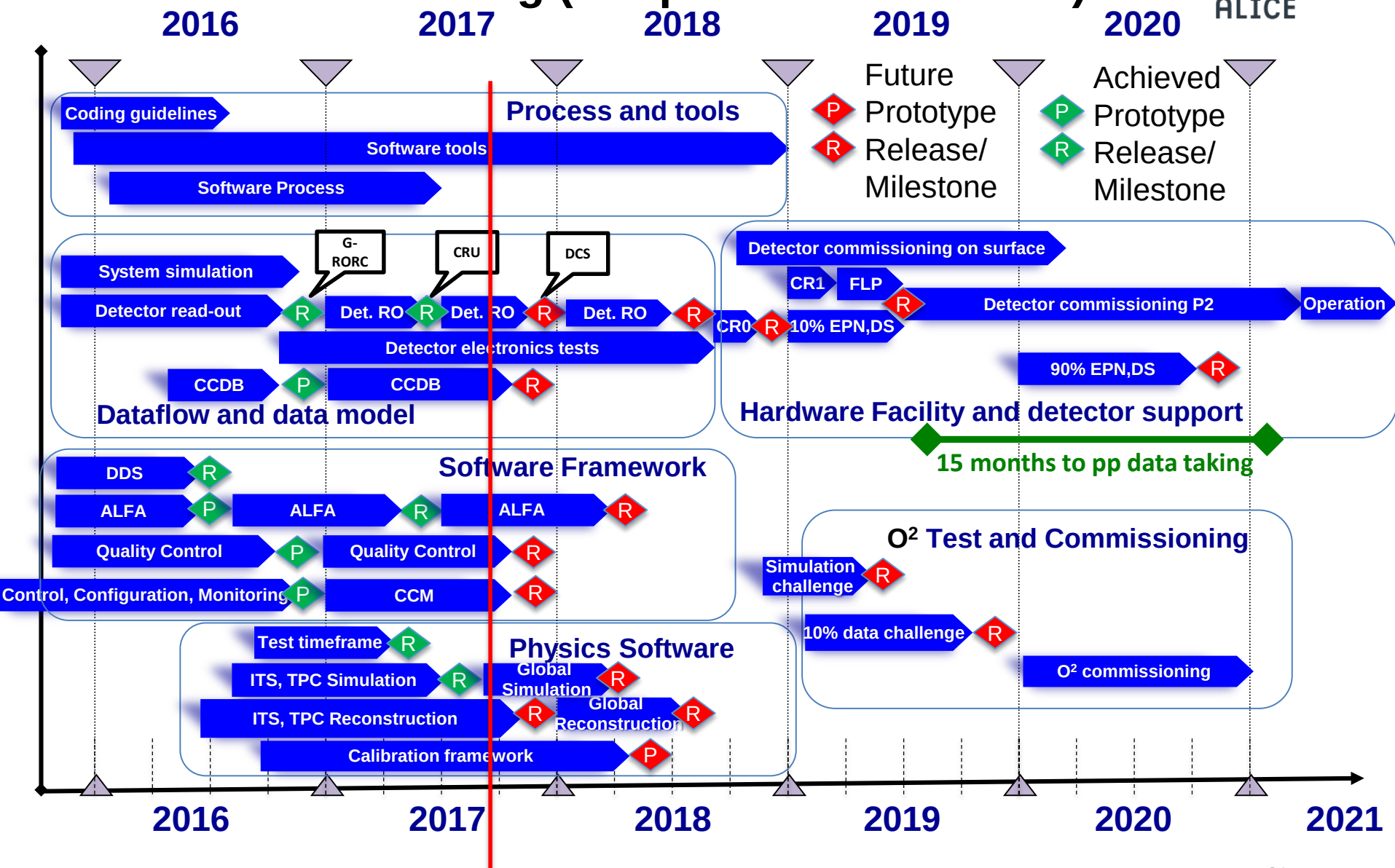


Computing containers procurement

- Meeting with Automation, Stulz, Lubron, Panduit on 10.08.2017
Resolved the open questions
- Computing containers with similar cooling density have not been produced yet by the contractor: two check points are part of the procurement schedule.
- Tentative delivery schedule
 - Sep '17: Results of the tender presented to the September Finance Committee
 - Oct '17: Final selection of the options
 - Nov '17: Purchase request by CERN
 - Feb '18: Factory acceptance test of the first air handling unit in Stulz (Madrid)
 - May '18: Factory acceptance test of the first computing container in Automation (Brussels)
 - Sep '18: Installation of the first container at the LHC P2

- Technology choice done
- Same containers size as LHCb with higher density
- Clear plan for an installation at P2 by Sept. 2018

Overall O² Planning (Simplified Global View)





Spare Slides





ALICE O² in a nutshell

Requirements

1. LHC min bias Pb-Pb at 50 kHz
~100 x more data than during Run 1
2. Physics topics addressed by ALICE upgrade
 - Rare processes
 - Very small signal over background ratio
 - Needs large statistics of reconstructed events
 - Triggering techniques very inefficient if not impossible
3. 50 kHz > TPC inherent rate (drift time ~100 μs)
Support for continuous read-out (TPC)
 - Detector read-out triggered or continuous

New computing system

- Read-out the data of all interactions
- ➔ Compress these data intelligently by online reconstruction
- ➔ One common online-offline computing system: O²
- Paradigm shift compared to approach for Run 1 and 2

Unmodified raw data of all interactions shipped from detector to online farm in triggerless continuous mode

HI run 3.4 TByte/s ↓

Baseline correction and zero suppression
Data volume reduction by zero cluster finder.
No event discarded.
Average compression factor 6.6

500 GByte/s ↓

Data volume reduction by online tracking.
Only reconstructed data to data storage.
Average compression factor 5.5

90 GByte/s ↓

Data Storage: 1 year of compressed data

- Bandwidth: Write 170 GB/s Read 270 GB/s
- Capacity: 60 PB

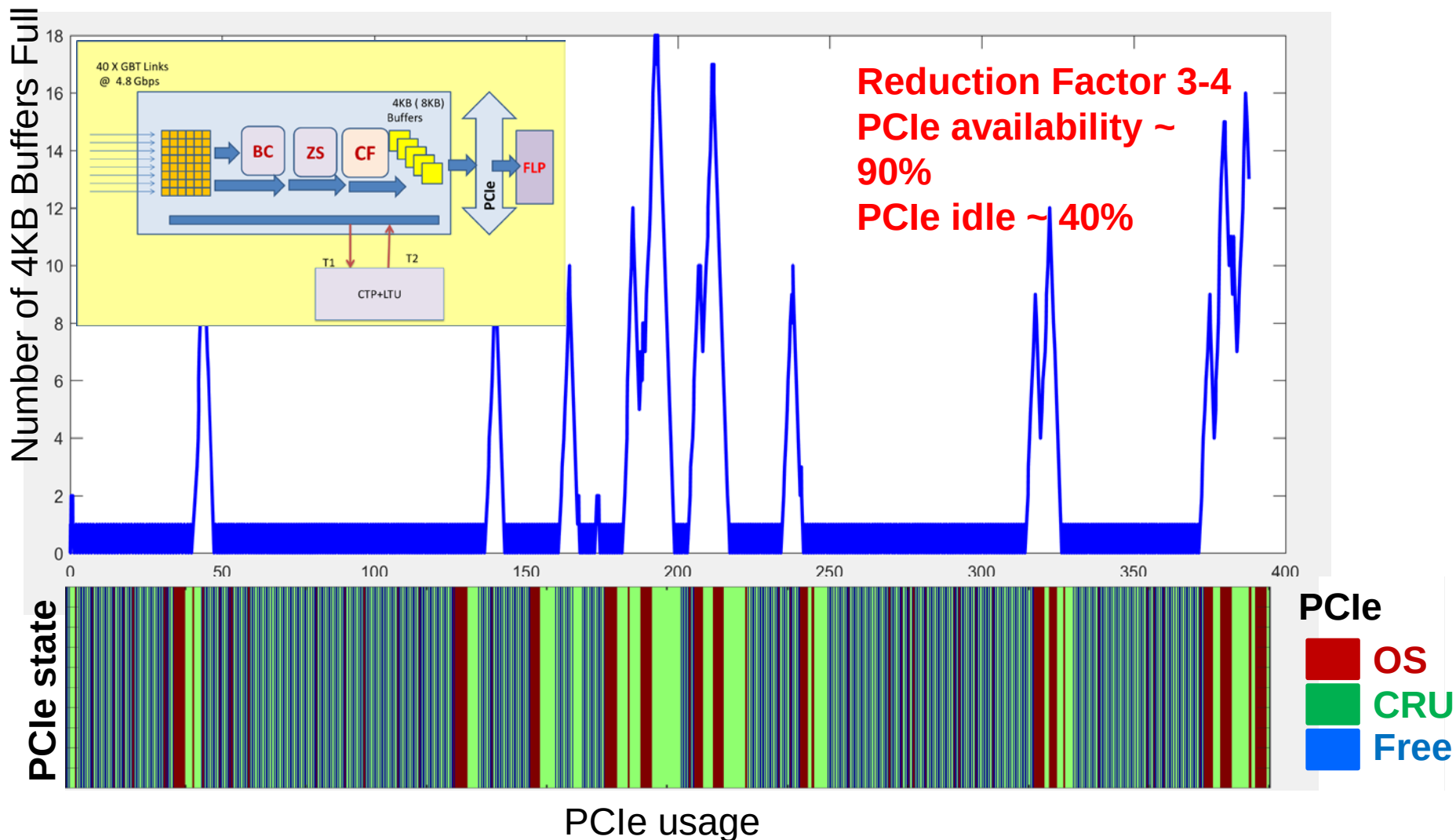
20 GByte/s ↔

Tier 0, Tiers 1
and
Analysis Facilities

↕

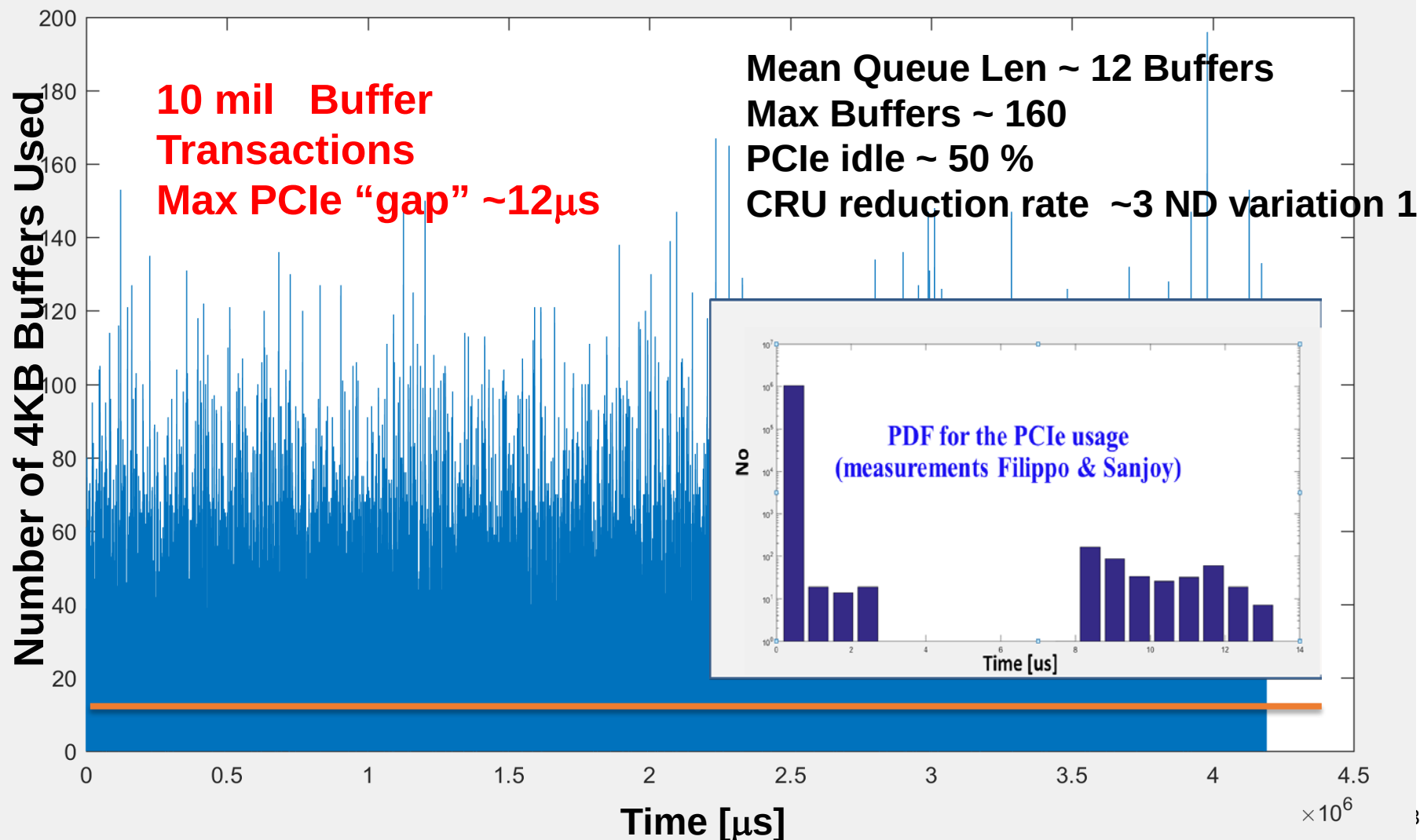
Asynchronous (few hours)
event reconstruction with
final calibration

WP2 - Simulation CRU-FLP



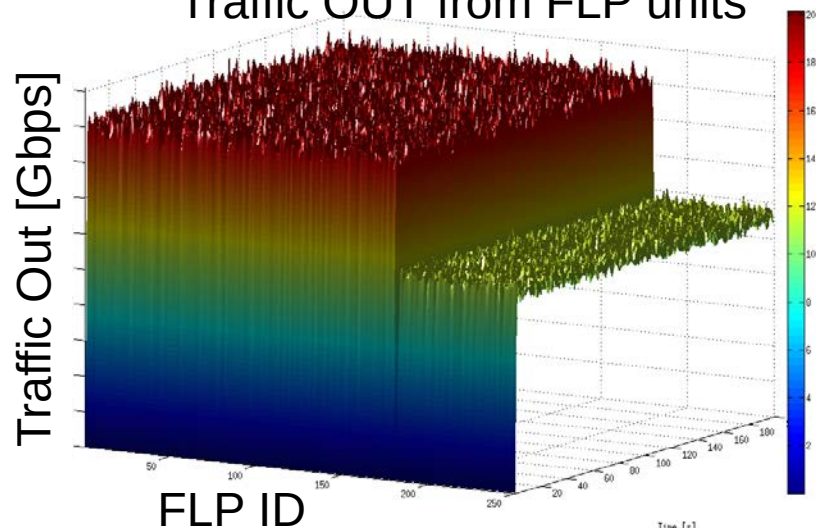
WP2 - Large Scale Simulation

Continuous Mode –realistic PCIe - PDF

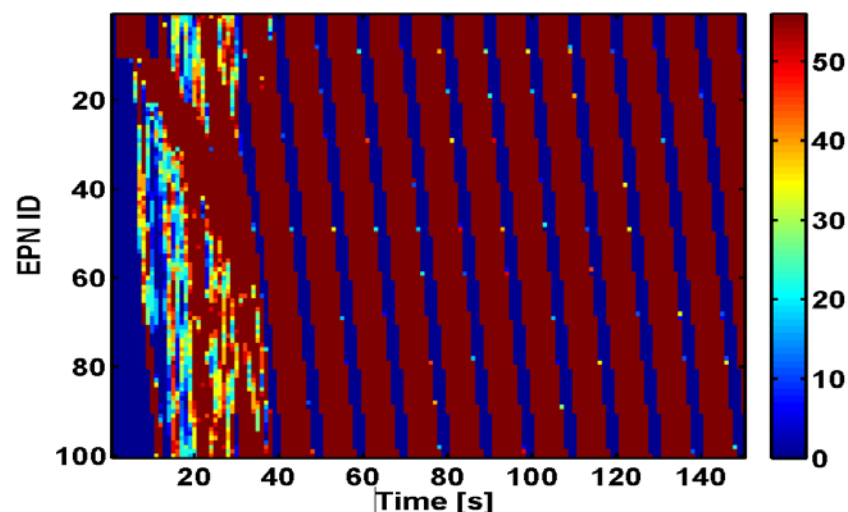


WP2 – FLP-EPN Network Simulation Studies for the Time Frame Building

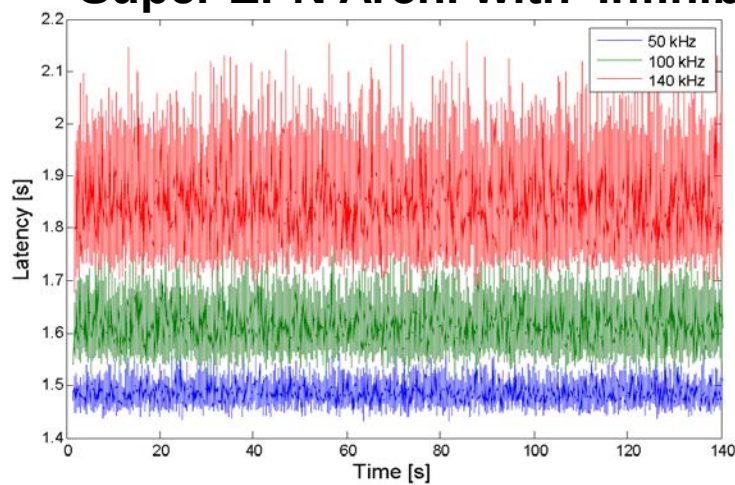
Traffic OUT from FLP units



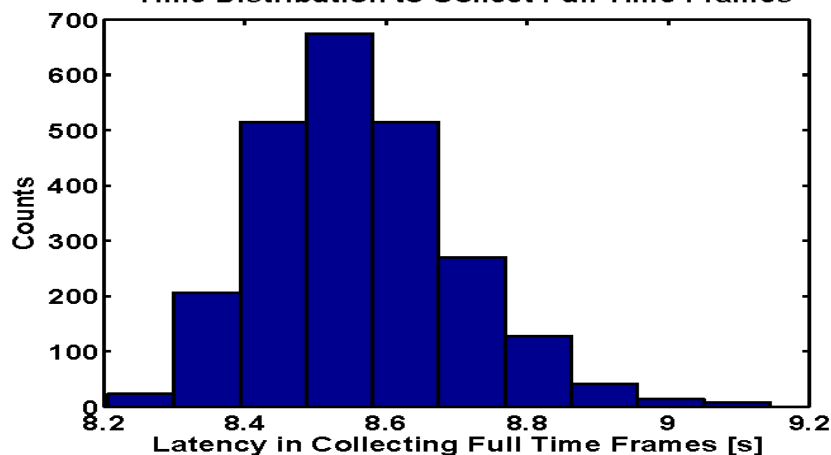
Traffic on EPNs [Gb/s]



Time Frame transport Latency
Super EPN Arch. with Infiniband

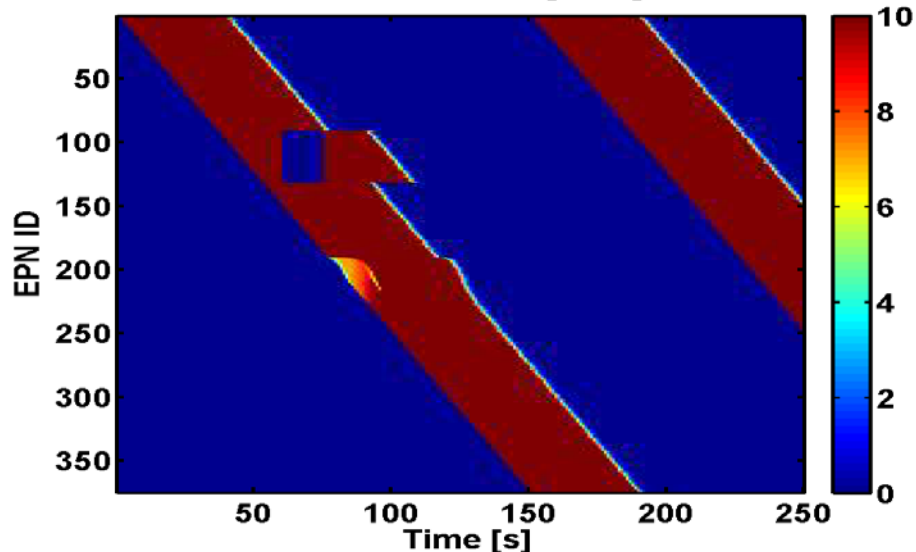


Time Distribution to Collect Full Time Frames

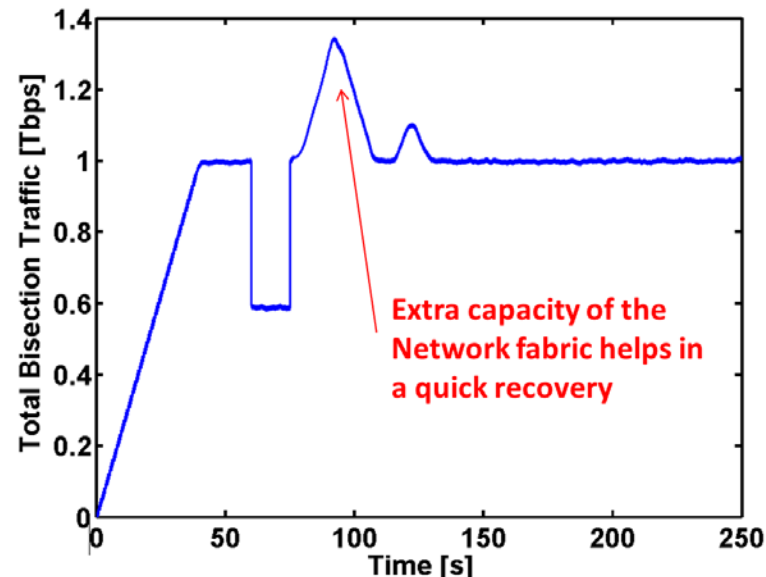


WP2 - Simulation of an Error on EPNs connection

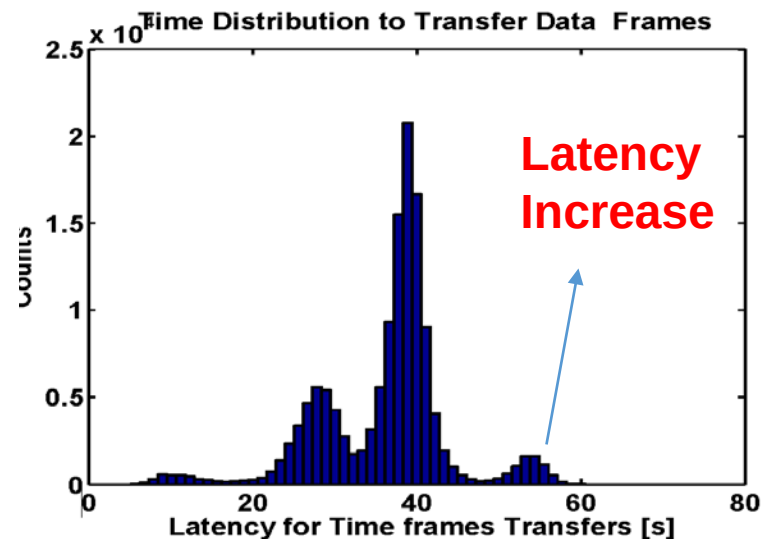
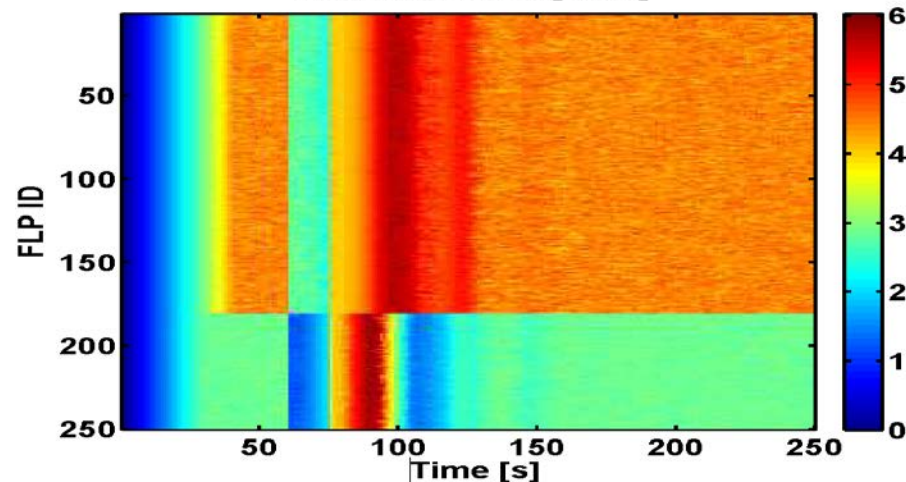
Traffic on EPNs [Gb/s]



Total Bisection Traffic



Traffic on FLPs [Gb/s]



WP 6 – Detector Read-Out Tests

DET	# GBT	# FEE	GBT readout	GBT SCA	Location	SW	READOUT CARD
FIT	1	1	Packet	Y	Lab	DATE	G-RORC
MCH	1	1	Continuous	Y	Lab & Test beam	DATE	G-RORC
MID	1	1	Continuous	Y	Lab	DATE	G-RORC
ITS	1	1	Packet	N	Lab	DATE	G-RORC
	1	1	Packet	N	Lab	O ²	CRU/ Dev Kit
TOF	2	2	Packet	N	Lab	DATE	G-RORC
	1	1	Clock test	N	Lab	O ²	CRU
TPC	2	1	Continuous	Y	Lab	DATE	G-RORC
	2	1	Continuous	Y	Lab	O ²	CRU (Sep '17)



WP8 - Configuration

- Prototype ready
 - C++ library for get/set values, 4 backends supported for max flexibility
 - INI files, JSON files, etcd and Consul
 - MySQL backend will be added soon
 - Command-line tools for easy access
 - Community service available for detector tests
 - Installation recipes available for private setups
- Tool evaluation for backend selection in progress
 - 3 candidates: etcd, Consul, MariaDB
 - Functional and performance comparison criteria defined (to be approved)
 - Final decision by Q1 2018

• JSON

```
{
  "equipment_1":
  {
    "enabled": true,
    "type" : "rorc",
    "serial": 33333,
    "channel": 0
    "other_stuff":
    {
      abc:123
      xyz:456
    }
  },
  "equipment_2":
  {
    "enabled": true,
    "type" : "dummy",
    "serial": -1,
    "channel": 0
  }
}
```

• C++ Tree data structure

```
Node tree = Branch
{
  {"equipment_1", Branch
  {
    {"enabled", true},
    {"type", "rorc's"},
    {"serial", 33333},
    {"channel", 0},
    {"stuff", Branch
    {
      {"abc", 123},
      {"xyz", 456}
    }
  }
  },
  {"equipment_2", Branch
  {
    {"enabled", true},
    {"type", "dummy's"},
    {"serial", -1},
    {"channel", 0}
  }
  }
};
```

• Key-value pairs

```
/equipment_1/enabled = true
/equipment_1/type = rorc
/equipment_1/serial = 33333
/equipment_1/channel = 0
/equipment_1/other_stuff/abc = 123
/equipment_1/other_stuff/xyz = 456
/equipment_2/enabled = true
/equipment_2/type = dummy
/equipment_2/serial = -1
/equipment_2/channel = 0
```

• INI

```
[equipment_1]
enabled=true
type=rorc
serial=33333
channel=0

[equipment_2]
enabled=true
type=dummy
serial=-1
channel=0
```

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Put some values

```
$ configuration-put --uri=etcd-v3://localhost:2379 \
--key=/foo/bar --value=abc123
```

Get them back

```
$ configuration-get --uri=etcd-v3://localhost:2379 \
--key=/foo/bar
abc123
```

Copy values (does a recursive copy)

```
$ configuration-copy --source=etcd-v3://localhost:2379/foo/ \
--dest=consul://aido2cnf01:8500/test/foo/
```

Get copied values

```
$ configuration-get --uri=etcd-v3://localhost:2379 \
--key=/test/foo/bar
```



SERVICES

NODES

KEY/VALUE

ACL

DC1



PBOESCHO/CONF-BENCH/BENCH_0
/MONITORING/INFLUXDB/ +

db

enableHTTP

enableUDP

hostname

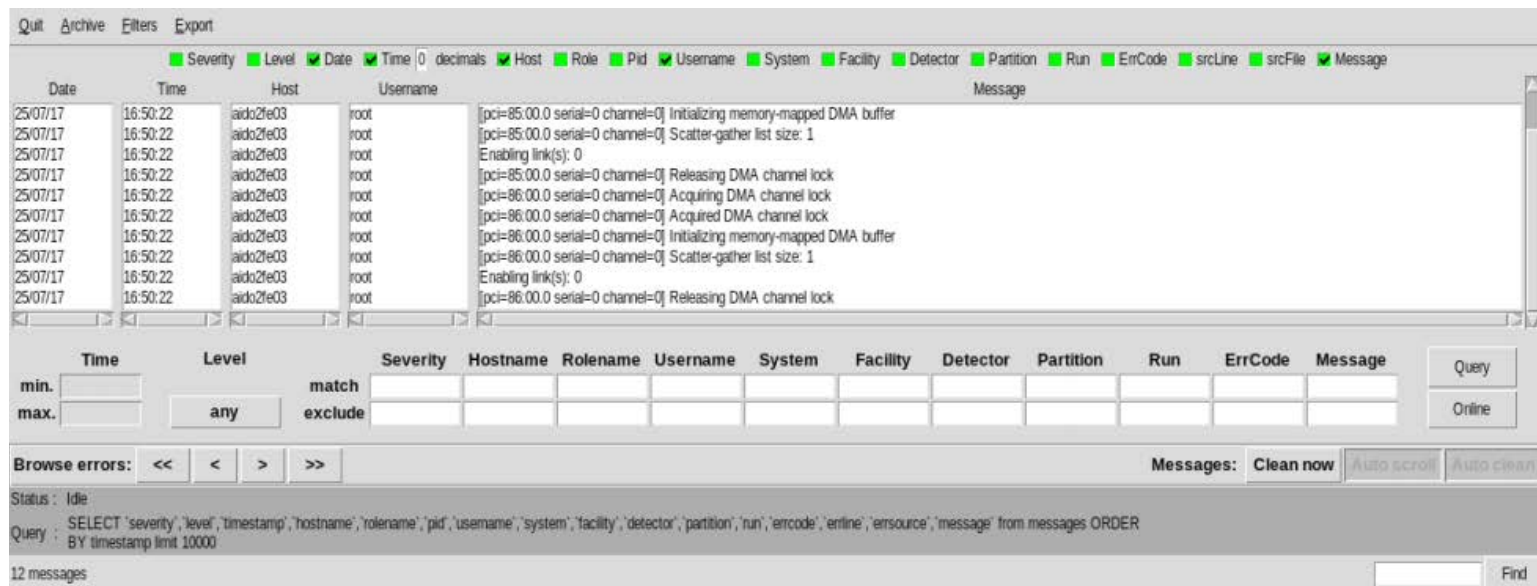
port

pboescho/conf-bench/bench_0/monitoring
/InfluxDB/db

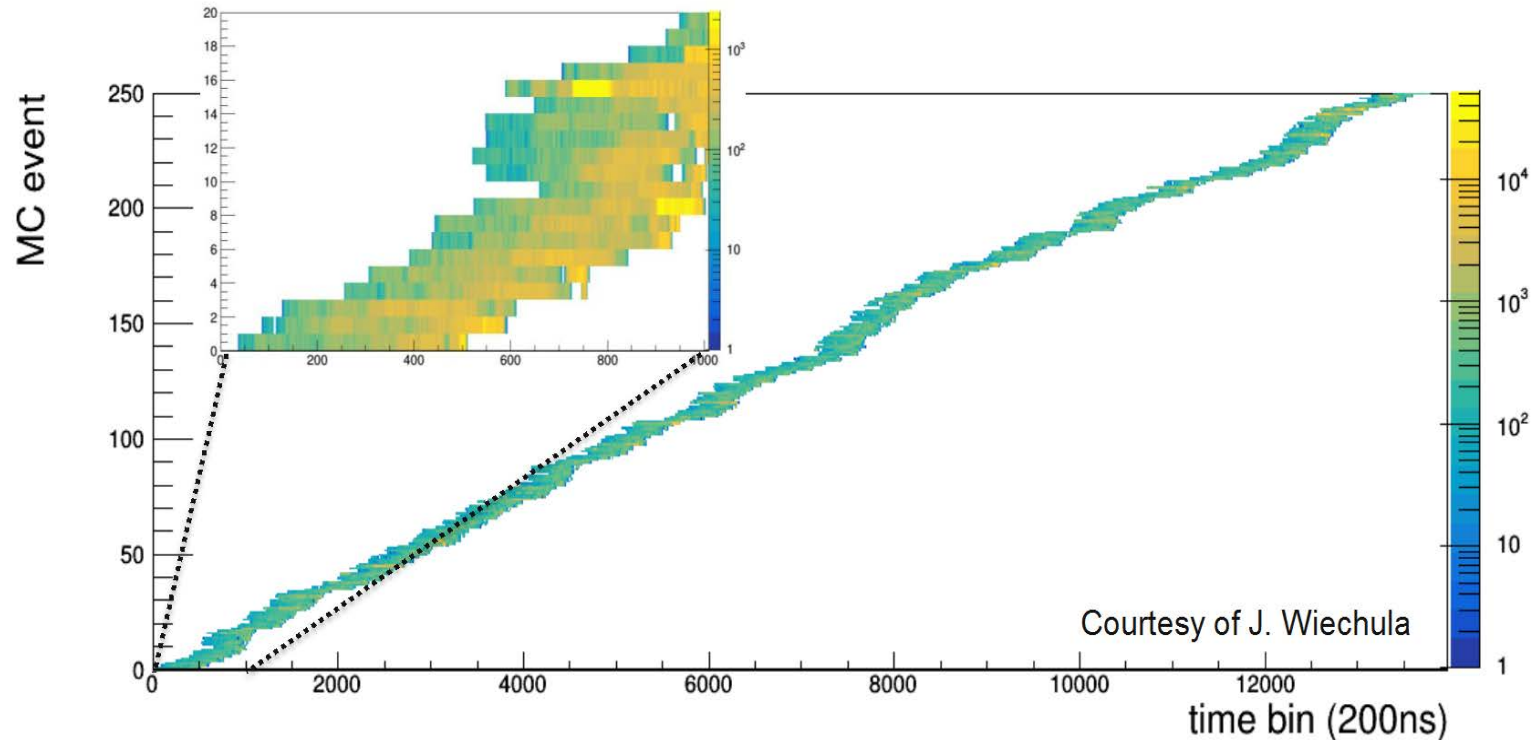
o2_config_bench

WP8 - Logging

- Prototype ready
 - Based on existing InfoLogger product from ALICE DAQ
 - C++ library for message injection
 - Local collecting daemon + central server daemon + MySQL backend
 - Desktop-based GUI: Web-based GUI will be developed



TPC simulation: continuous time digitization



- Demonstration of pile-up in readout electronics “time bins” from multiple events
- For details, see reports at the recent TPC upgrade meeting



Psychrometric Chart

Psychrometric Chart

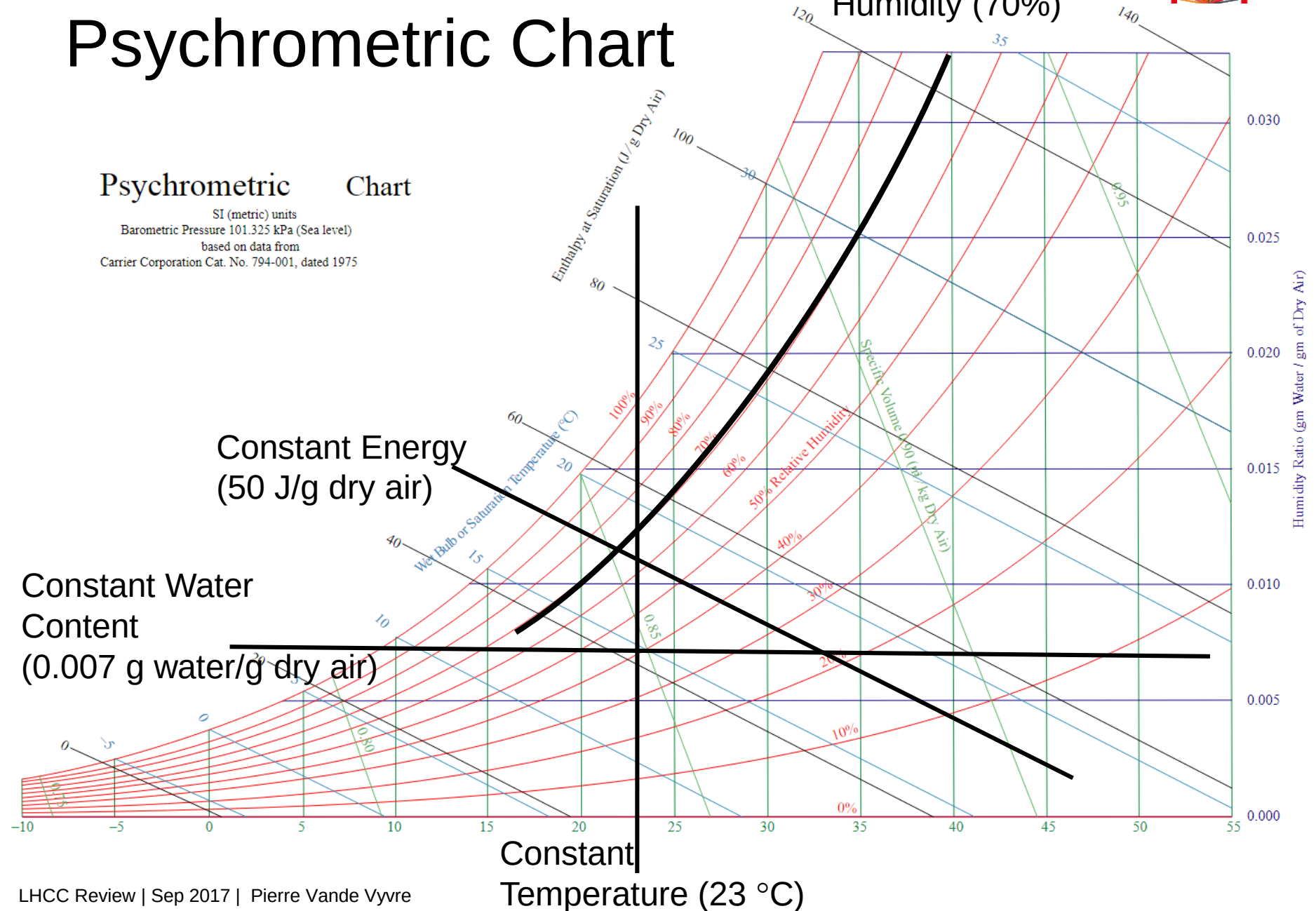
SI (metric) units
Barometric Pressure 101.325 kPa (Sea level)
based on data from
Carrier Corporation Cat. No. 794-001, dated 1975

Constant Energy
(50 J/g dry air)

Constant Water
Content
(0.007 g water/g dry air)

Constant
Temperature (23 °C)

Constant Relative
Humidity (70%)



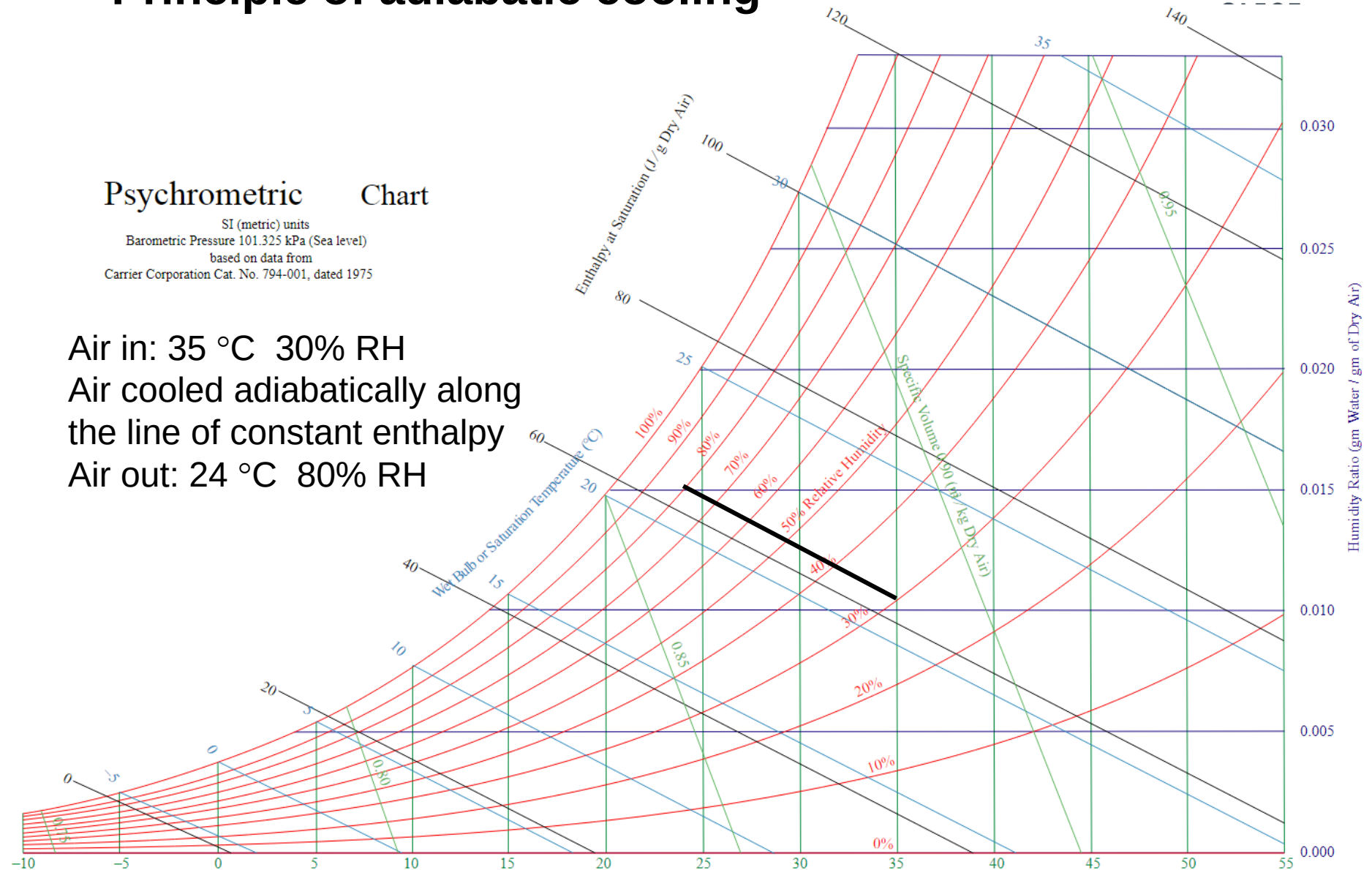


Principle of adiabatic cooling

Psychrometric Chart

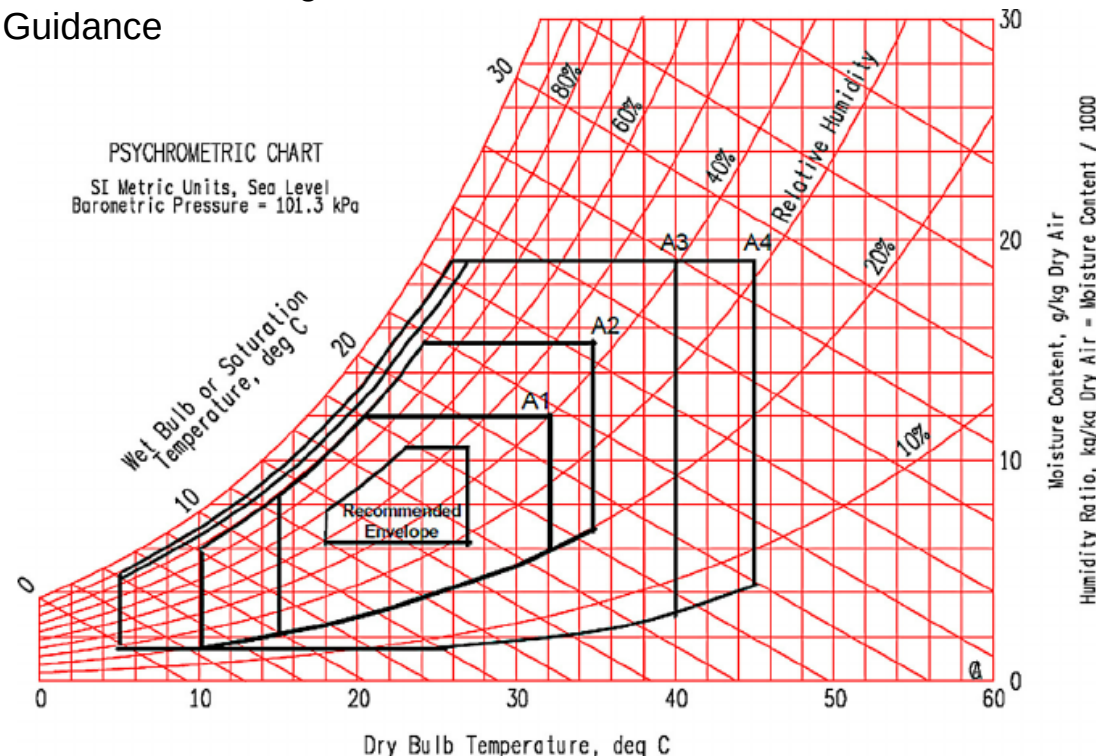
SI (metric) units
Barometric Pressure 101.325 kPa (Sea level)
based on data from
Carrier Corporation Cat. No. 794-001, dated 1975

Air in: 35 °C 30% RH
Air cooled adiabatically along
the line of constant enthalpy
Air out: 24 °C 80% RH



Thermal Guidelines for Data Processing Environments

- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published standards which are used as reference for data processing environments
- First published about higher-temperature data centers in 2008
- Emphasis was put on the Power Usage Effectiveness (PUE) (data center efficiency)
- ASHRAE TC 9.9 2016 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance
 - Requirement: Class A2
(Information technology space with control of environmental parameters)
 - Computing equipment run very well with inlet air temperatures in the 25°C to 27°C range
 - Allowed: 10 to 35°C and RH 20-80 %
 - Recommended: 18 to 27°C





Cooling of the ALICE Data Room above specs

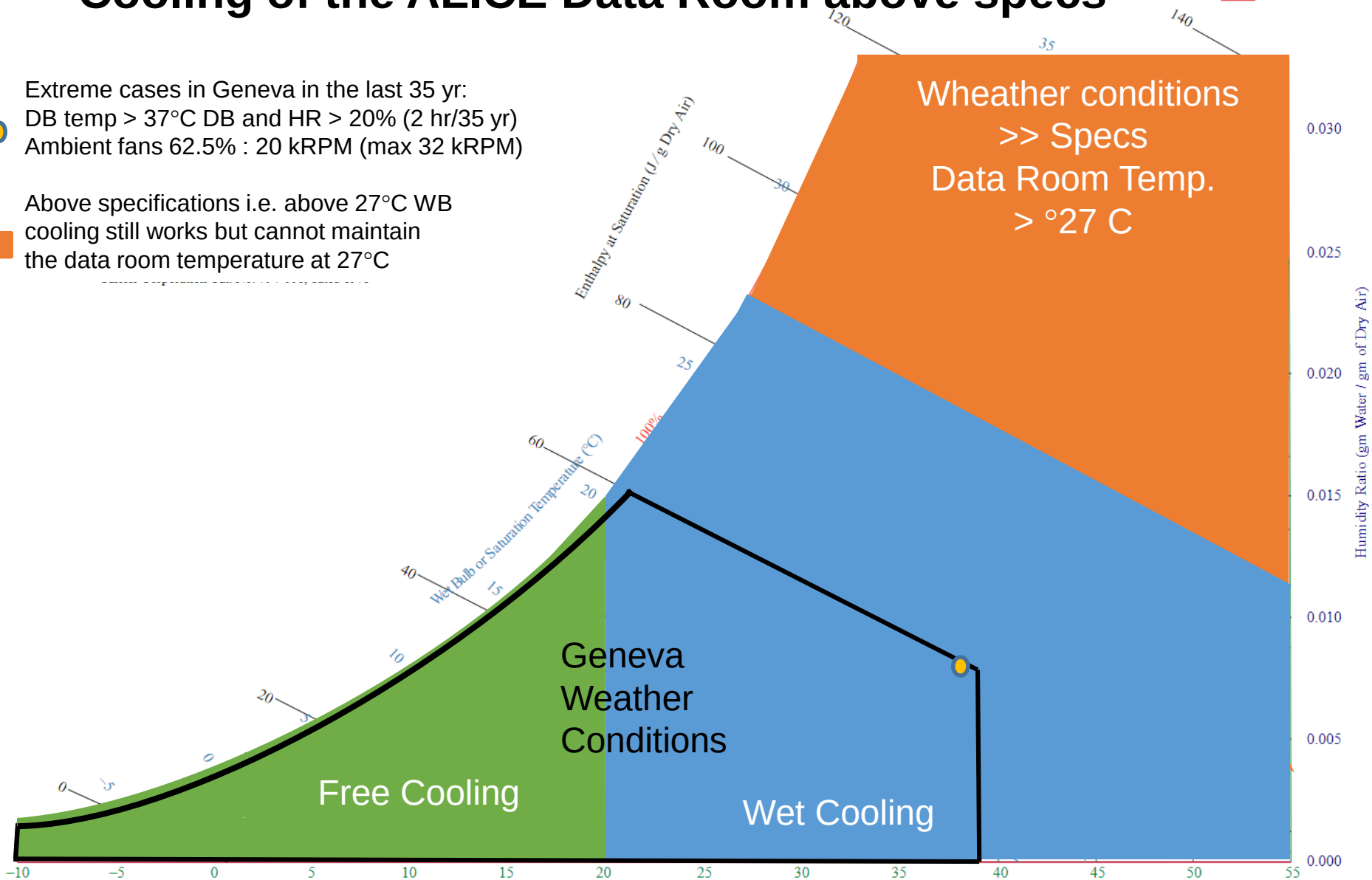
Extreme cases in Geneva in the last 35 yr:

DB temp > 37°C DB and HR > 20% (2 hr/35 yr)

Ambient fans 62.5% : 20 kRPM (max 32 kRPM)

Above specifications i.e. above 27°C WB

cooling still works but cannot maintain the data room temperature at 27°C



Noise simulation

- Noise at P2 is very close to the legal limit
- The simulated noise of the containers must be 10 dB below the limit so that the addition can be considered as negligible
- Several configurations have been simulated
 1. 3 containers parallel and 1 orthogonal: not within the CERN limits
 2. 4 containers parallel: a bit better but still not within the CERN limits
 3. 4 containers parallel 60cm noise dampers in front of the exhaust are inside the CERN limits
 4. 4 containers parallel with additional 90cm noise dampers in front of the exhaust and 60cm noise dampers in front of the suction are well below the limits

Noise simulation results

Simulated noise at 6 different locations for 4 different configurations

Point de calcul	ZER 1	ZER 2	ZER 3	LdP 2	LdP 4'	LdP 5
Data center : 4 Modules configuration 1	20.4	30.0	34.3	24.7	33.7	37.9
Data center : 4 Modules configuration 2	20	27.5	32	22.6	33.6	37.0
Data center : 4 Modules configuration 3	13.1	19.8	26.2	15.5	30.1	32.4
Data center : 4 Modules configuration 4	6.2	14.7	17.9	8.5	23.7	23.9
Objectif (sources CERN futures)	37.8	35.8	37.8	60.0	57.8	59.9