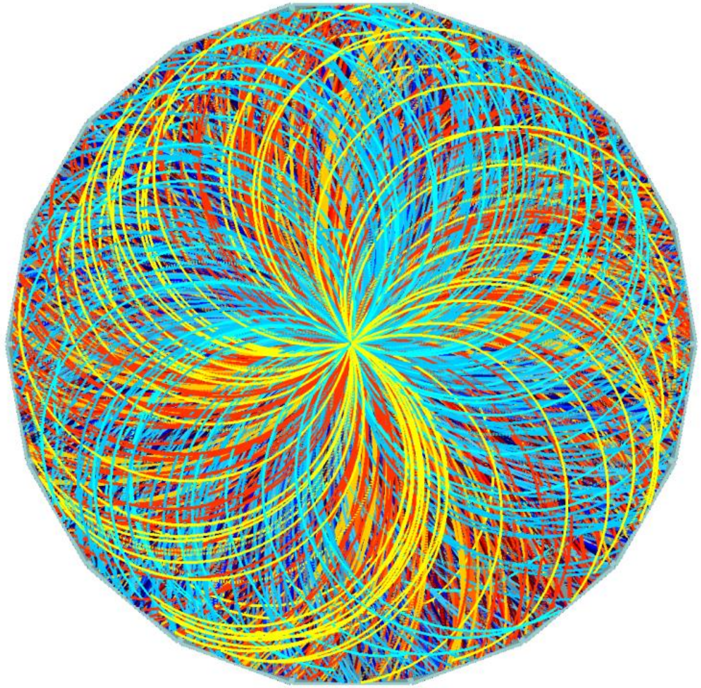


ALICE Trigger Overview

R. Lietava on behalf of the ALICE collaboration

The University of Birmingham

Triggering Discoveries in High Energy Physics

9-14 September 2013 , Jammu, India

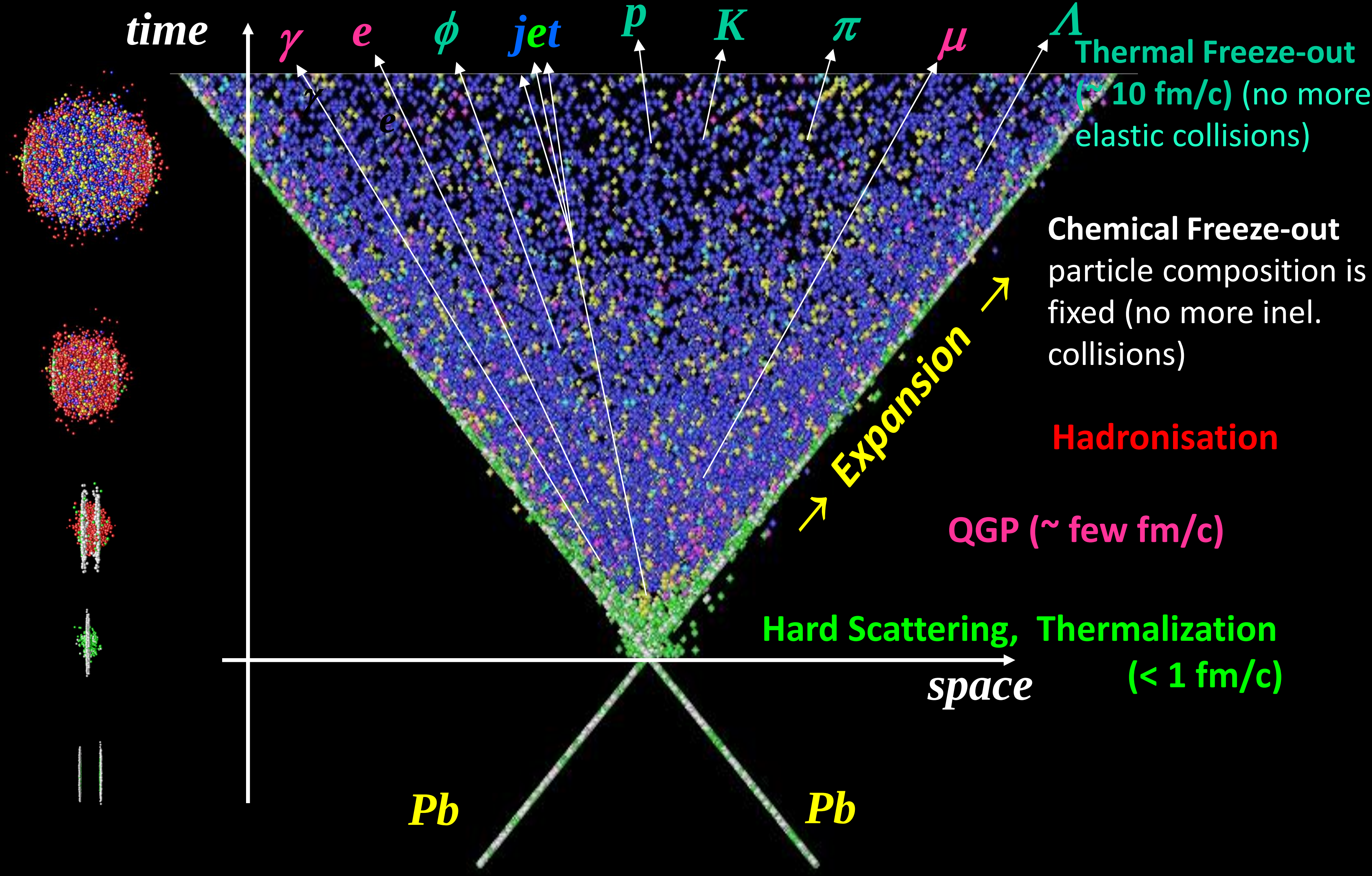
Content

- ALICE physics
- Trigger requirements
- Central Trigger Processor (CTP)
- Trigger Distribution
- Local Trigger Unit (LTU)
- Control and Monitoring
- Upgrades

ALICE physics

- **A-A**
  - properties of the **Quark Gluon Plasma** and the **QCD Phase Transition**
- **p-A**
  - initial state effects
- **p-p**
  - reference to AA
  - minimum bias physics => soft QCD (underlying event)
  - unique pp physics with Alice (baryon transport, charm cross section)

Space-time evolution of the Collision

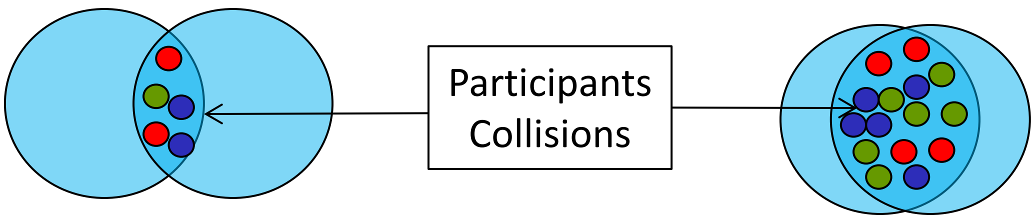


Observables

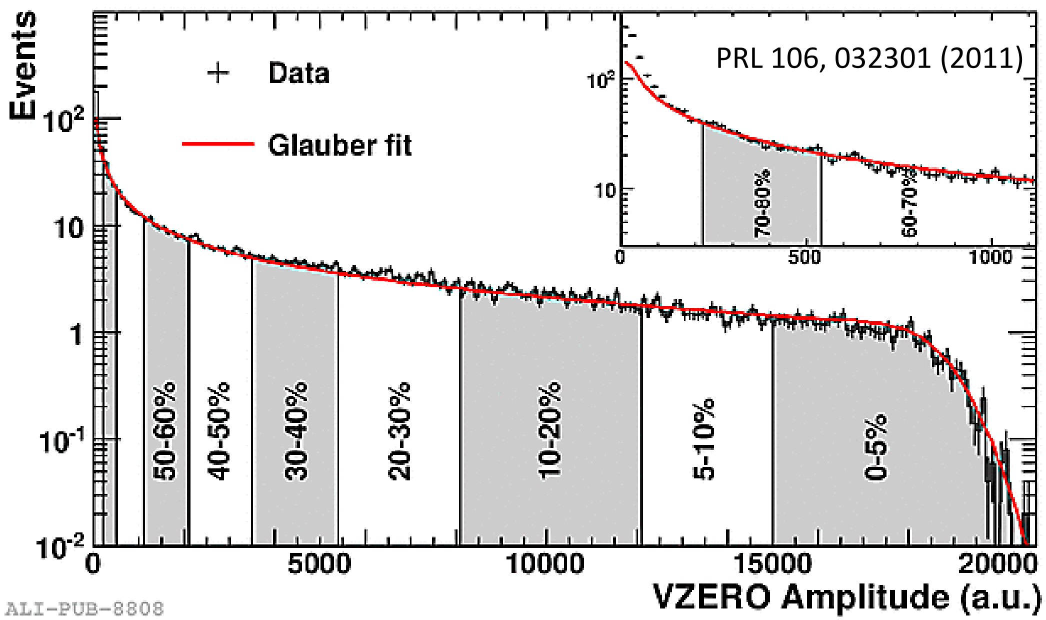
- Soft observables
  - Particle yields and spectra
  - HBT correlations
  - Flow and fluctuations
- Hard probes
  - Jets
  - Heavy flavour
  - Quarkonia
  - Photons
  - Electroweak bosons

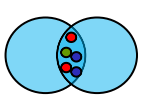
Geometry of Heavy Ion Collisions

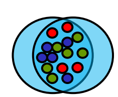
We can control (a posteriori) the geometry of heavy ion collisions



Peripheral **Central**







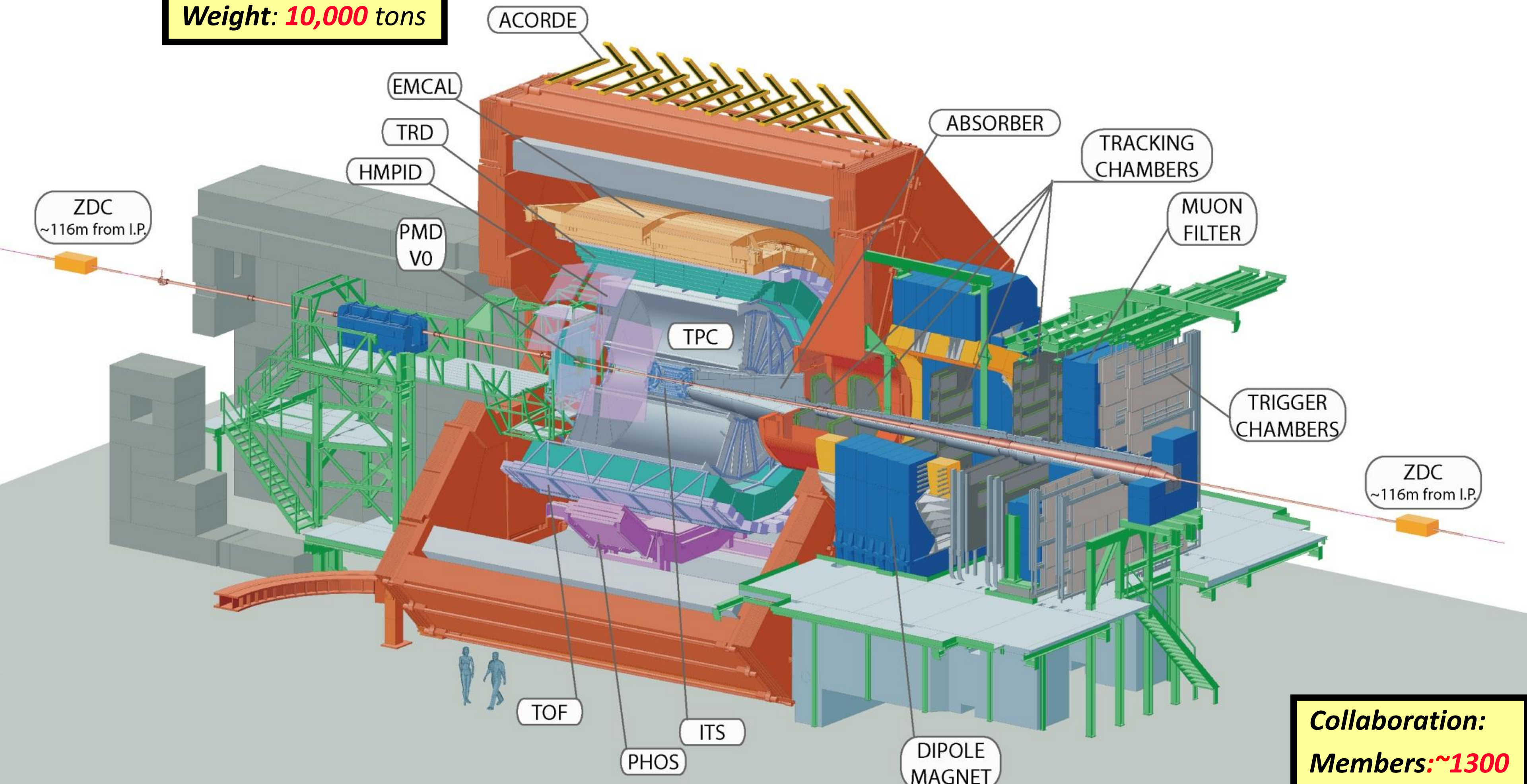
Centrality Variables:

- **percentile of hadronic cross section**
- N_{col}, N_{part}

ALICE

Technologies:18
Tracking: 7
PID: 6
Calo. : 5

Detector:
***Size**: 16 x 26 metres*
***Weight**: 10,000 tons*



Collaboration:
Members:~1300
***Countries**: 37*
***Institutes**: 132*

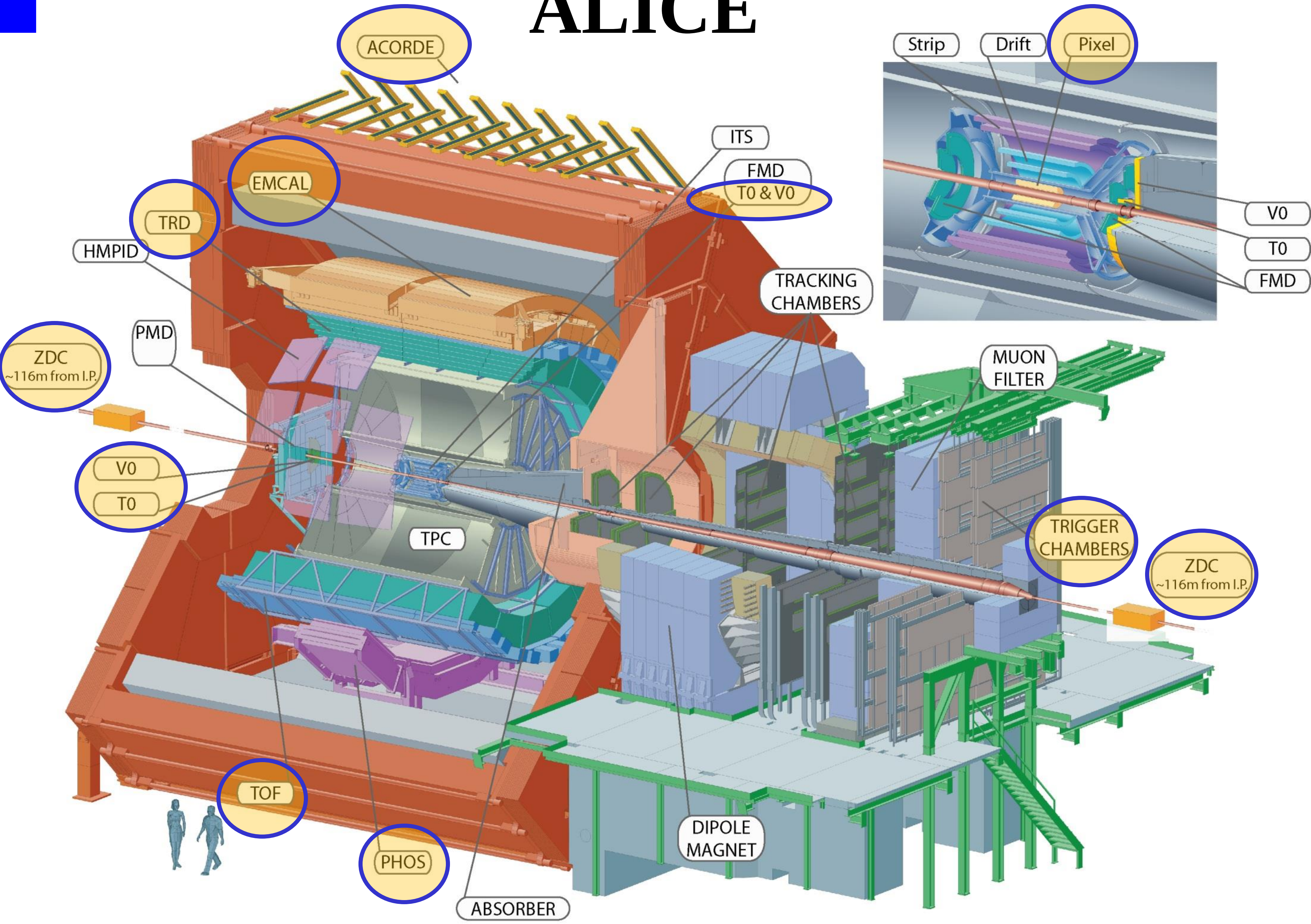
ALICE trigger challenges

- Select different physics
  - Different triggering detectors
- Optimise for different running scenarios – pp, pA, AA – with different interaction rates
- Optimise rates according to physics requirements
  - downscaling
- Optimise use of detectors with widely different busy times (generally no pipelining)
  - Detector grouping – trigger clusters
- Different latency requirements
  - 3 trigger levels

Selecting different physics

- Minimum bias and Centrality: **V0,T0,SPD,TOF**
  - Global variables (identified particle spectra , HBT, flow, nuclear modification factors)
- Jets: **EMCAL,PHOS**
  - Jets in medium (quenching, fragmentation)
- Photons/electrons: **EMCAL,PHOS,TRD**
  - π^0, η, charm, beauty, quarkonia
- Muons: **Muon Arm**
  - Charm, beauty, quarkonia
  - Weakly interacting probes (W,Z)
- Ultra peripheral: **V0,ZDC,SPD**
  - QED lepton pair production, elmag dissociation, photonuclear reactions

ALICE



ACORDE
EMCAL
TRD
HMPID
PMD
ZDC
~116m from I.P.
V0
T0
ITS
FMD
T0 & V0
TRACKING
CHAMBERS
Strip
Drift
Pixel
V0
T0
FMD
MUON
FILTER
TPC
TRIGGER
CHAMBERS
ZDC
~116m from I.P.
TOF
PHOS
ABSORBER
DIPOLE
MAGNET

Alice Running Conditions

	pp	Pb-Pb 2010	Pb-Pb 2011	p-Pb 2013
$<\mathcal{L}>$ $cm^{-2}s^{-1}$	1×10^{31}	2×10^{25}	3×10^{26}	1×10^{29}
σ_{inel} (mb)	70	8000	8000	2500
rate (Hz)	1×10^{6}	1.6×10^{2}	$2.5\ 10^{3}$	2×10^{5}
Multiplicity Density	3.6	1600	1600	17

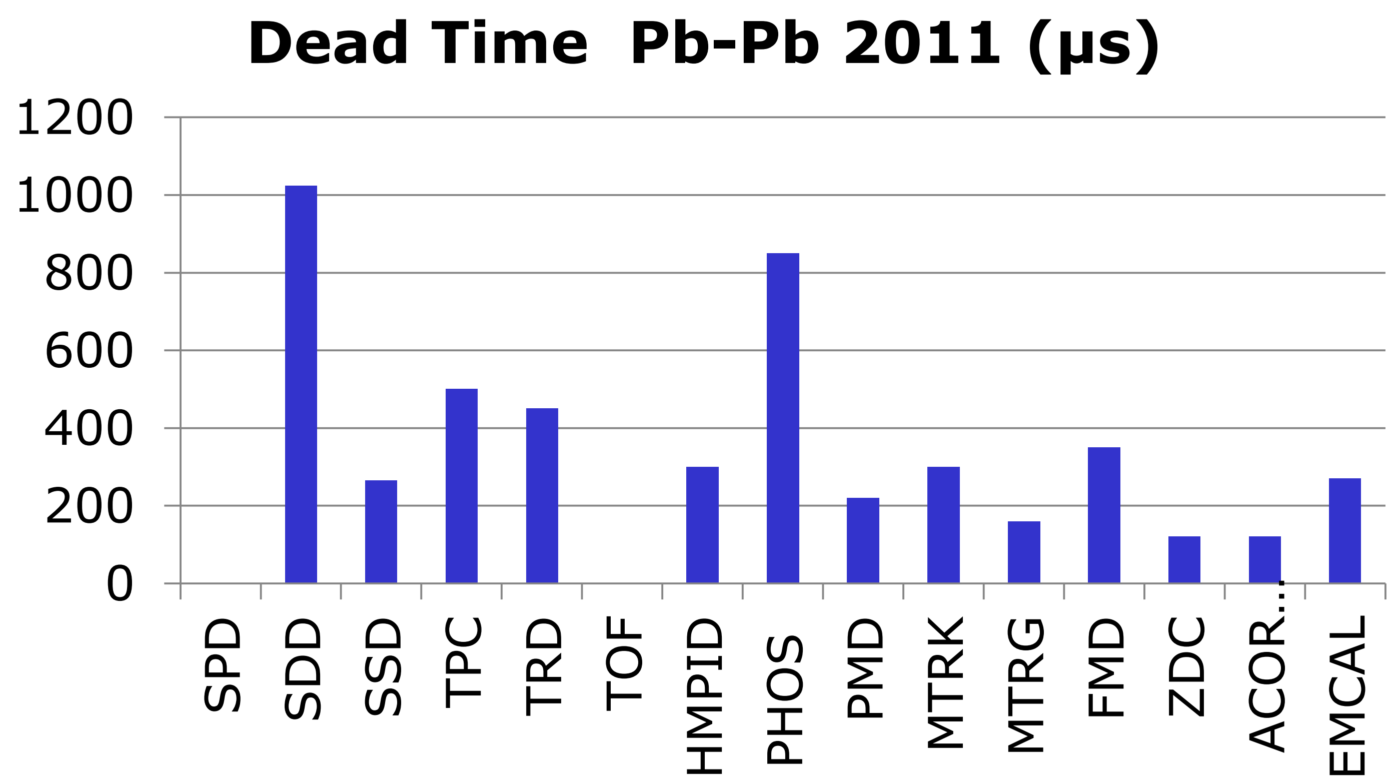
- Pb-Pb:
  - modest luminosity rates
  - large event size (~100MB)
  - Rate of recorded events several hundred per second
- pp:
  - ALICE Luminosity limited < 10^{31} cm^{-2} s^{-1} due to 100 μs TPC drift time

Optimise Rates

Trigger menu: pA_rare.v33

Class prefix	Clusters (* no ACE)	Description	classes	Downscaling	L2a rate @ 180kHz
CTRUE-[B,ACE]	ALLNOTRD	No bias	2	rnd = 50 Hz	3
CINT7-[B,ACE]	ALL, ALLNOTRD	Min. bias V0AND	4	fixlum = 30 Hz/b	35
CSHM7-[B,ACE]	ALL, ALLNOTRD*	Centrality	3	fixpower4 = 40 Hz/mb	5
CPHI7-[B,ACE]	ALL, ALLNOTRD	PHOS L0	4	fixloss = 39 Hz/mb	7
CEMC7-[B,ACE]	CENT, CENTNOTRD	EMCAL L0 (thr. 3 GeV, rejection 100)	4	fixloss = 5.1 Hz/mb	3.5
CEMC7EG1-B	CENT, CENTNOTRD	EMCAL L1 gamma high, ~2kHz L0 inspection	2		16
CEMC7EG2-B	CENT, CENTNOTRD	EMCAL L1 gamma low, ~2kHz L0 inspection	2	fixloss = 23 Hz/mb	3.5
CEMC7EJ1-B	CENT, CENTNOTRD	EMCAL L1 jet high, ~2kHz L0 inspection	2		18
CEMC7EJ2-B	CENT, CENTNOTRD	EMCAL L1 jet low, ~2kHz L0 inspection	2	fixloss = 9.2 Hz/mb	4
CEMC7WUHEE-B	CENT	EMCAL-TRD L1, ~ 2kHz L0 inspection	1		0
CINT7WUHJT-[B,ACE]	CENT,FAST*	TRD L1 jet, ~10kHz L0 inspection	3	fixloss = 28 Hz/mb	L0a: CENT ~ 6.5k FAST ~ 7.3k
CINT7WUHSE-[B,ACE]	CENT,FAST*	TRD L1 electron, ~10kHz L0 inspection	3	fixloss = 28 Hz/mb	
CINT7WUHQU-[B,ACE]	CENT,FAST*	TRD L1 quarkonium, ~10kHz L0 inspection	3	fixloss = 28 Hz/mb	
CMSL7-B	ALLNOTRD	Single muon low-pt for mu-hadron cor.	1	fixloss = 4 Hz/mb	9
CMSL7-[B,ACE]	MUON	Single muon low-pt	2	fixlum = 3 Hz/mb	180
CMSH7-B	MUON	Single muon high-pt	1		150
CMLL7-B	MUON	Dimuon like-sign low-pt	1	fixlum = 10 Hz/mb	50
CMUL7-B	MUON	Dimuon unlike-sign low-pt	1		200
CMUP8-[B,ACE]	ALLNOTRD	UPC muon forward	2		12
CMUP9-[B,ACE]	ALLNOTRD	UPC muon semi-forward	2		8
CCUP7-[B,ACE]	CENTNOTRD	UPC central barrel	2		10
C0LSR-ABCE	CENTNOTRD	Calibration: TPC laser	1		
C0TVX-[B,ACE]	ALLNOTRD	Lumi monitoring: 0TVX	2		
CVGO-ABCE	ALLNOTRD	Bgd monitoring: A or C (downscaled)	1	fixed = 0.005%	0.7
Total TPC rate			**50**		**170**

Detector Dead Time



Detector Dead Time: average time of BUSY after valid trigger.

Dead Time depends on:

- Readout time
- Multi-event buffer

Trigger Latency

Different detectors have different latency requirements – 3 trigger levels:

- L0
  - received by detectors 1.2 μs after interaction (generation, propagation and CTP decision)
  - 24 inputs
- L1
  - 6.5 μs after L0
  - 24 inputs
- L2
  - 105.2 μs after L0
  - 12 inputs

Central Trigger Processor

6U VME boards:

BUSY

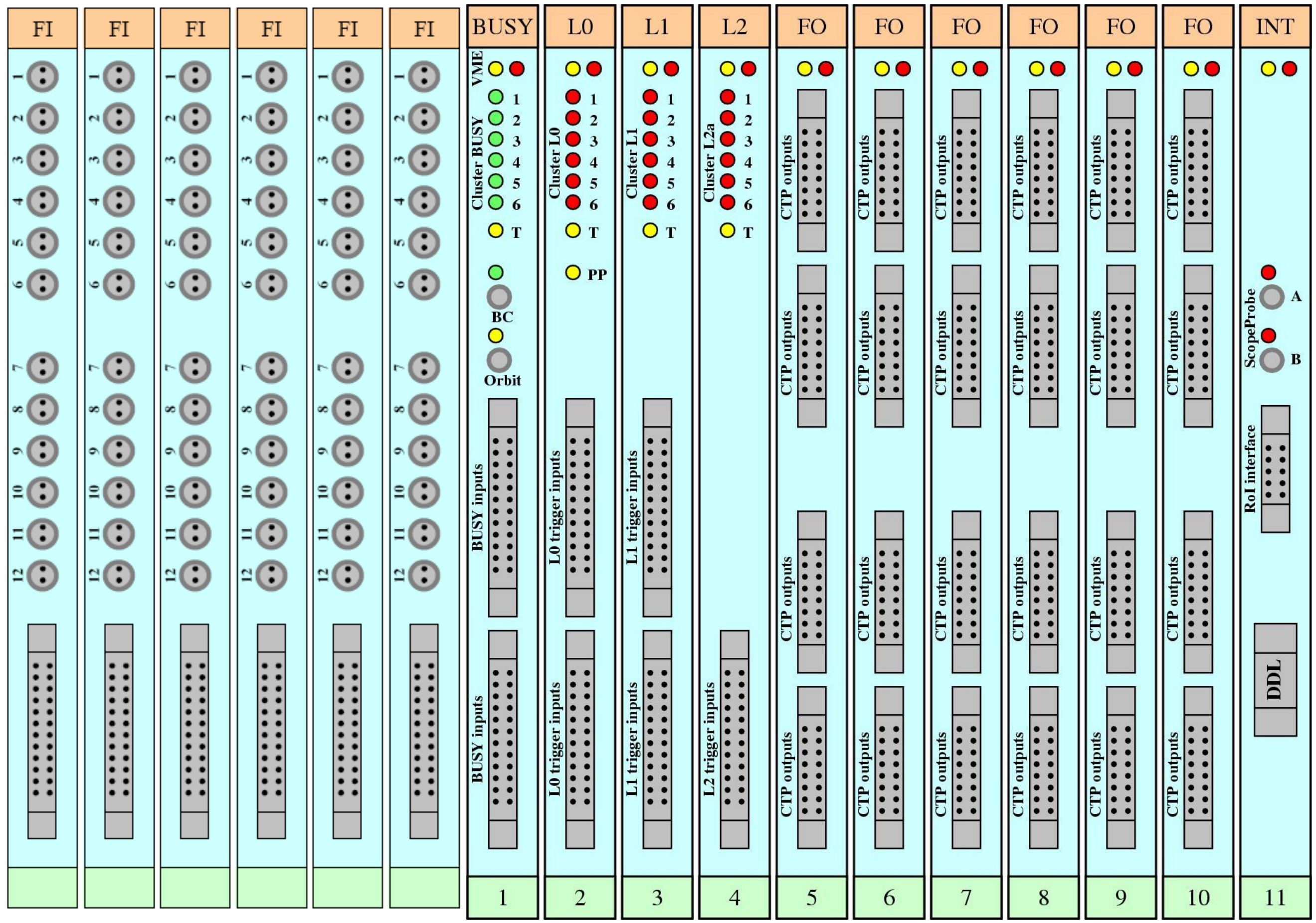
L0

L1

L2

FO

INT



Boards communicate via customised backplane

Trigger Class

Trigger Conditions:

- Logical combination of trigger inputs:
  - Any logical function of first 4 inputs
  - AND of other inputs
- Bunch Crossing (BC) mask:
  - Defines which BC are inspected for interaction in the ORBIT
  - Usually corresponds to LHC filling scheme
- Internal trigger:
  - BC downscale
  - Random

Trigger Cluster:

- Group of detectors to be read out

Trigger Class = Trigger Condition + Trigger Cluster

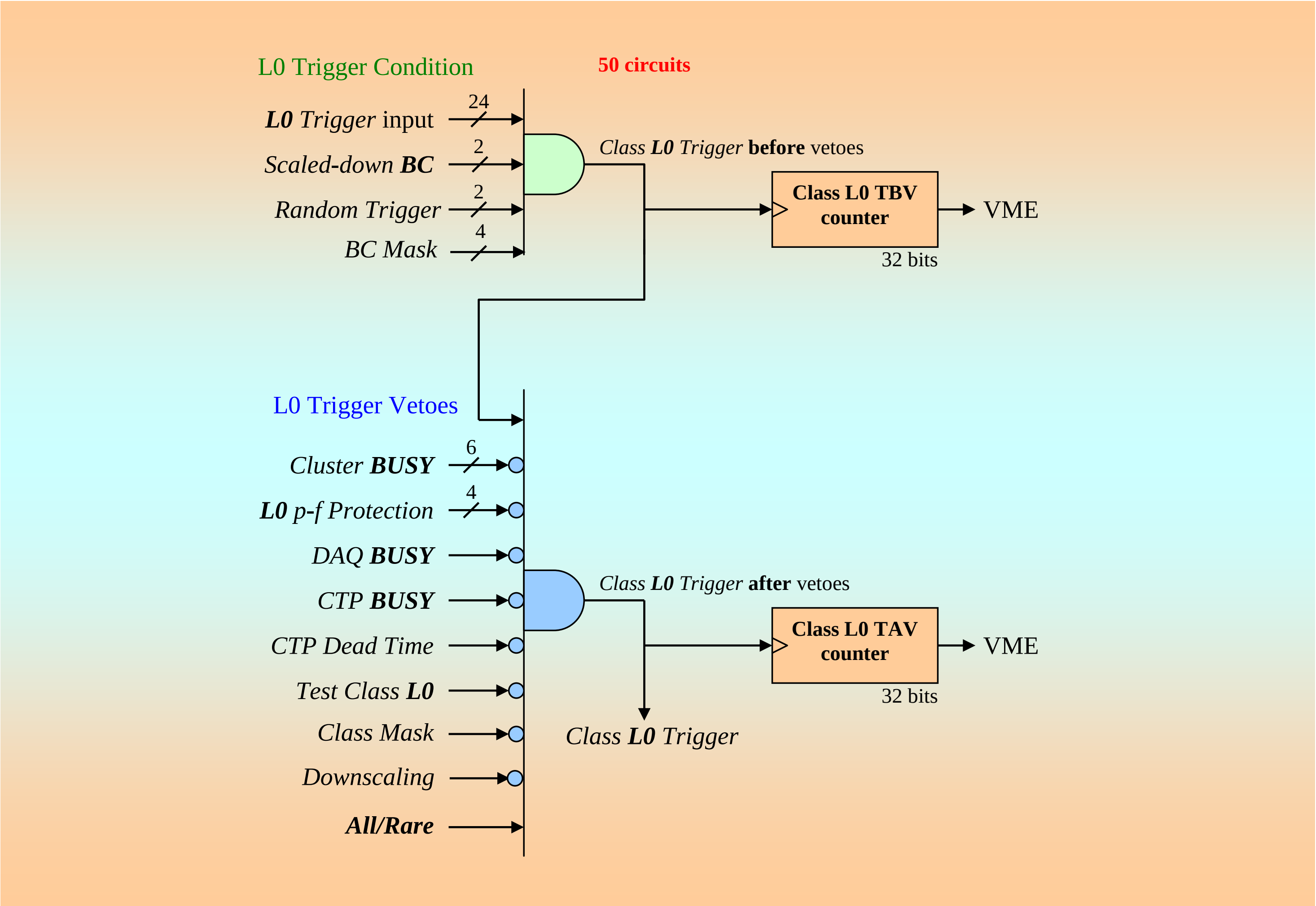
Trigger Vetos

Even if Trigger Condition is true Class can fail:

- Cluster Busy
- CTP Busy
- DAQ Busy
- Downscaling
- CTP dead time

Trigger Class = Trigger Condition + Trigger Cluster +
+ Trigger Vetoes

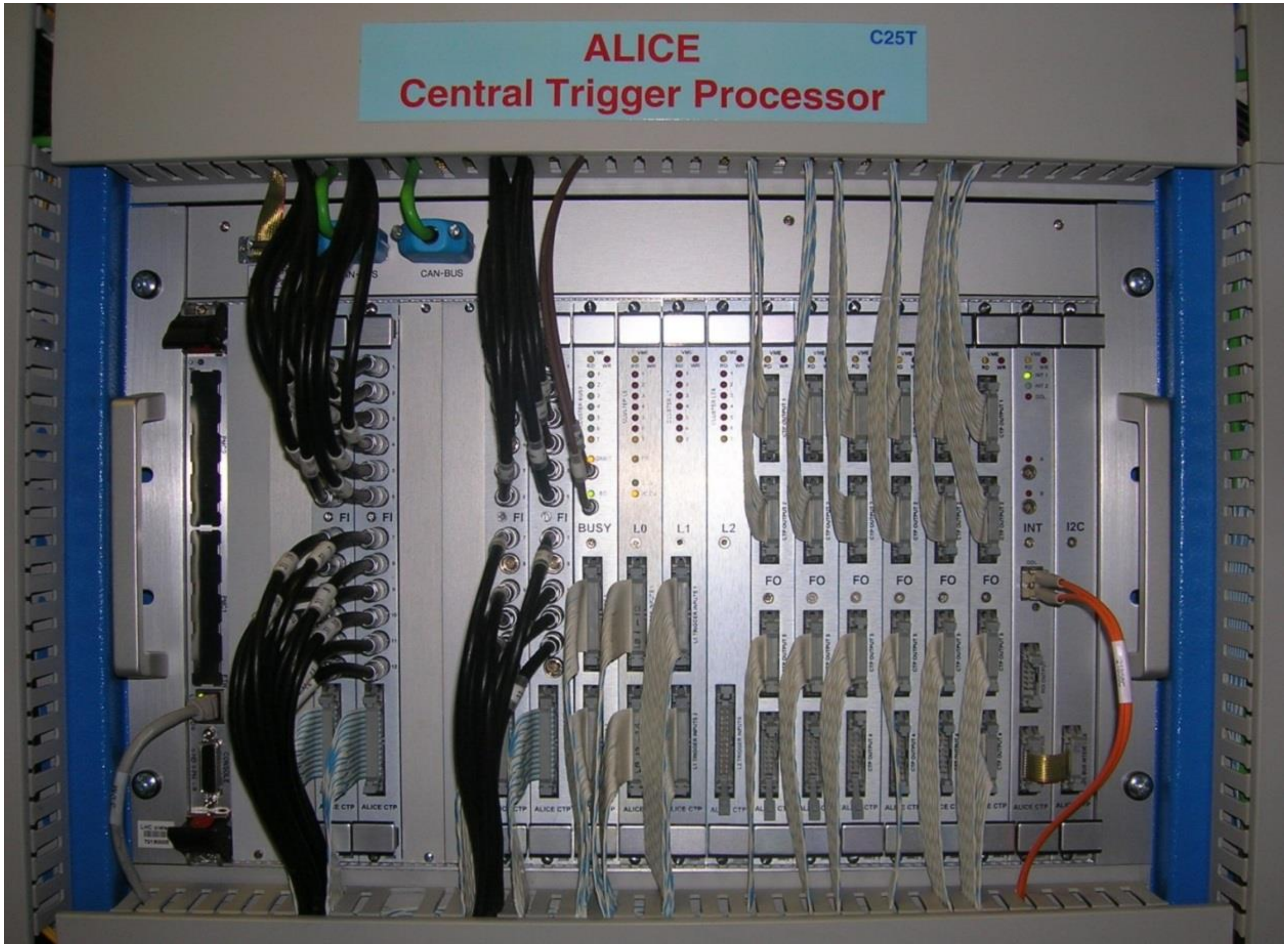
Trigger Class Logic



CTP Summary

- 3 levels
- 50 classes
  - 4 BC mask per class
  - 2 BC and 2 Random internal generators
  - Several types of downscaling
  - Past-future protection
- 24 detectors
- 6 clusters of detectors
- Software/calibration trigger generation

Central Trigger Processor

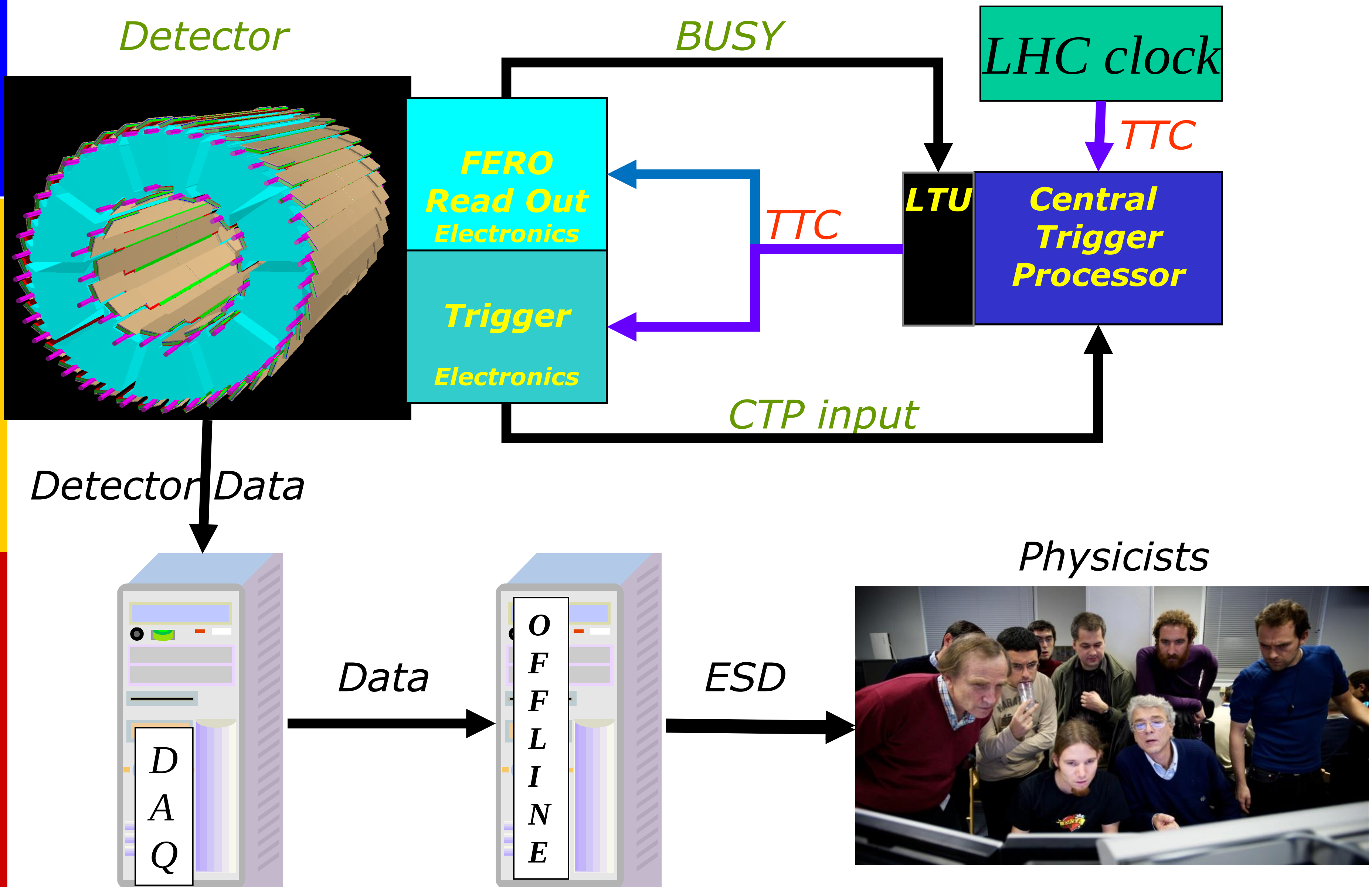


CTP triggers are sent to Local Trigger Units (LTUs) where conversion to output format occurs

Trigger Distribution

- Timing, Trigger and Control system (TTC)
  - LHC standard
  - Distributes clock and triggers
  - Two multiplexed channels A and B
  - Passive optical network
- ALICE trigger protocol
  - L0 – synchronous signal in channel A or LVDS cable
  - L1 – synchronous signal in channel A + asyn message B
  - L1 reject = missing L1
  - L2a/L2r – asynchronous message in B

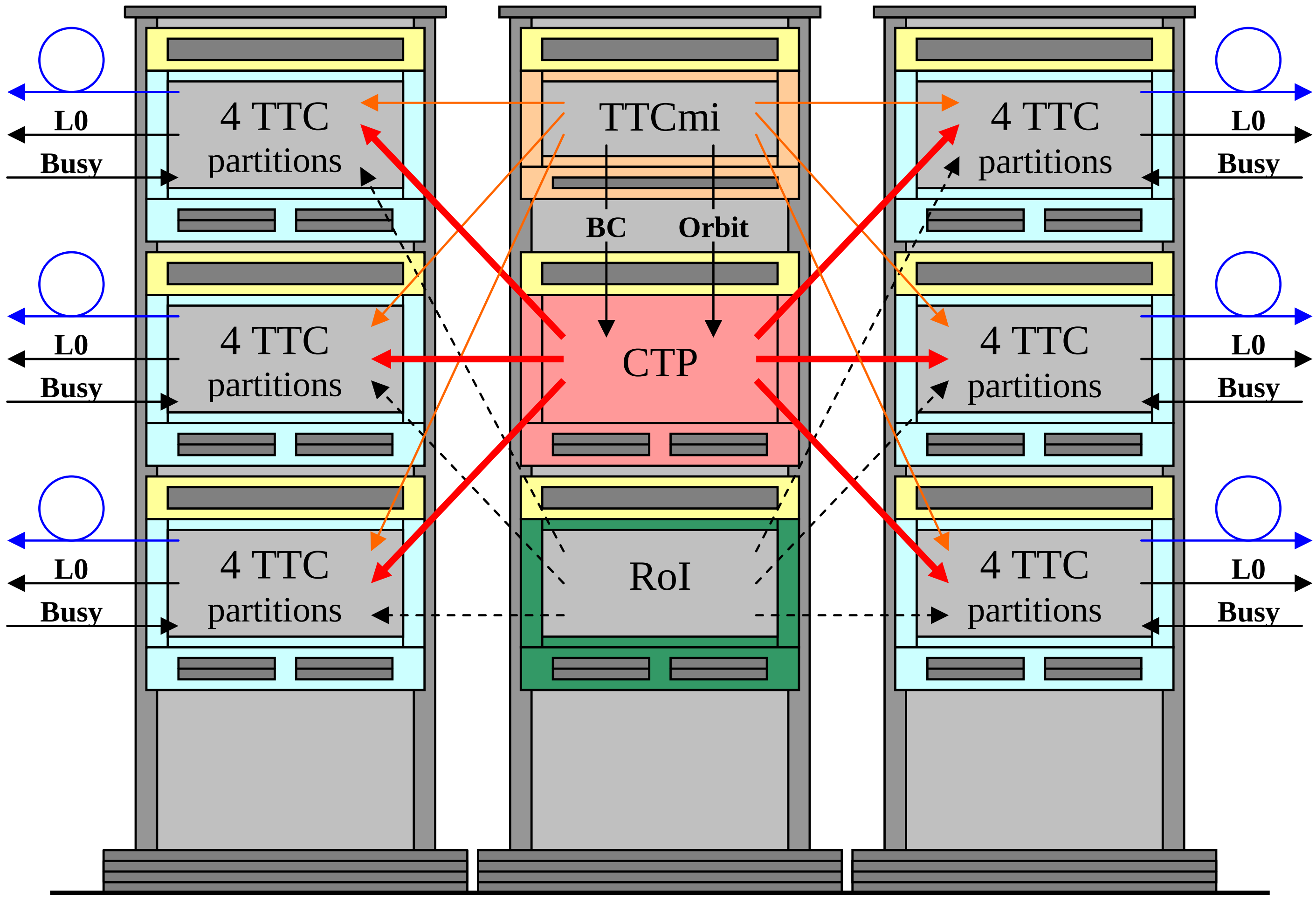
Signal distribution



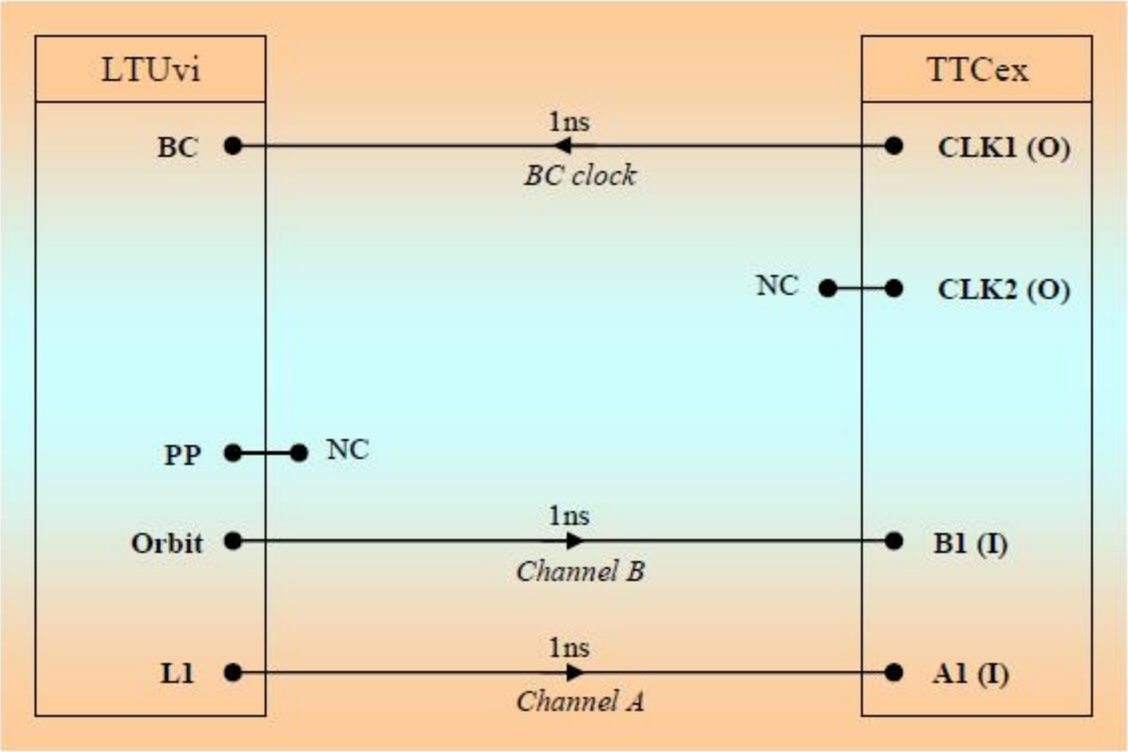
Local Trigger Unit - LTU

- Interface between CTP and Detector
- Global mode
  - conversion of the CTP data messages into the adopted TTC format for the *L1 Message*, the *L2a Message* and the *L2r Word*
- Local mode
  - Emulates full trigger sequences including timing
  - Detector development and debugging

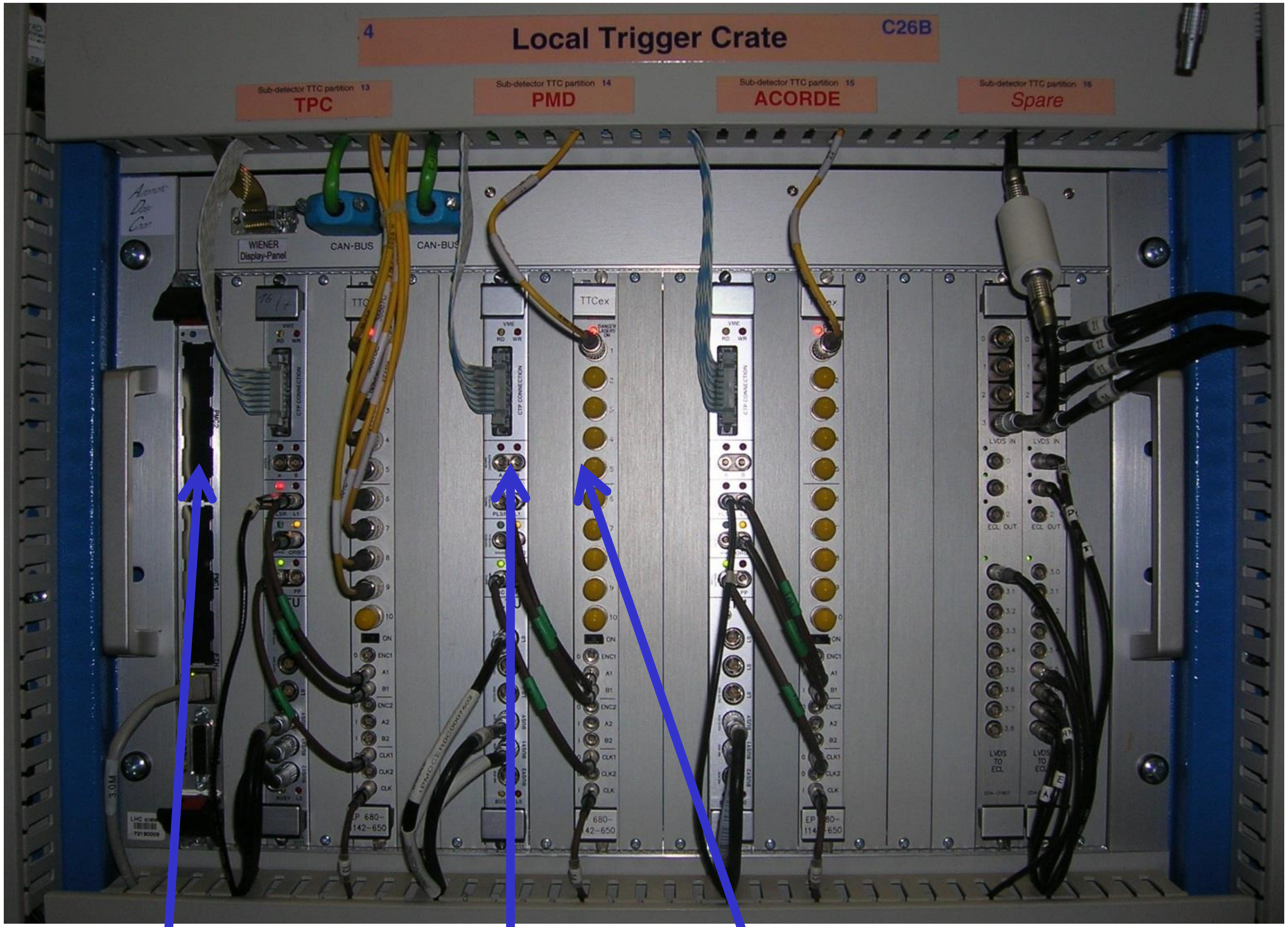
Layout of ALICE trigger system



TTC partition



TTC partition

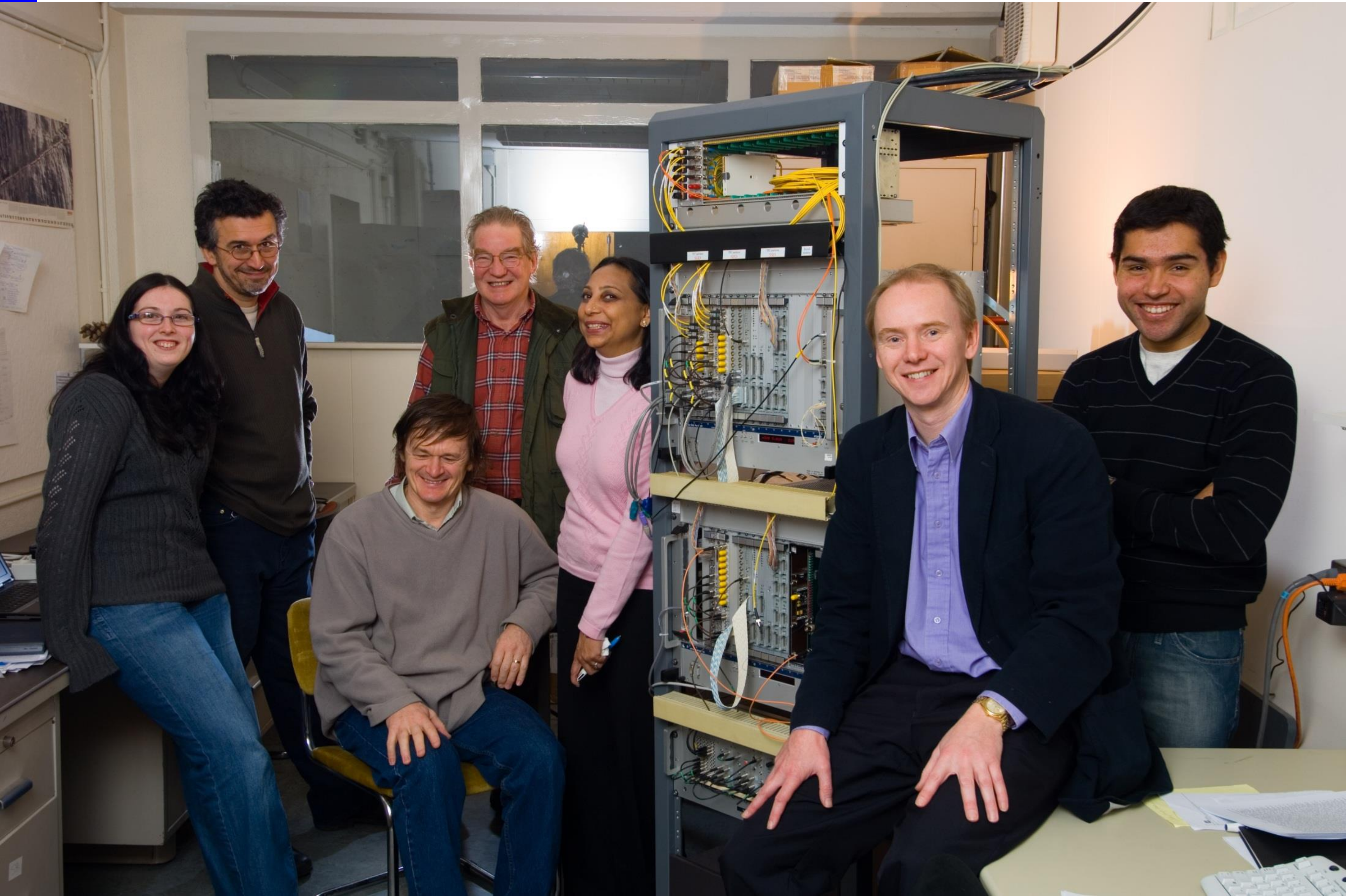


VME CPU

LTU

TTCex

Part of CTP team (~2006)

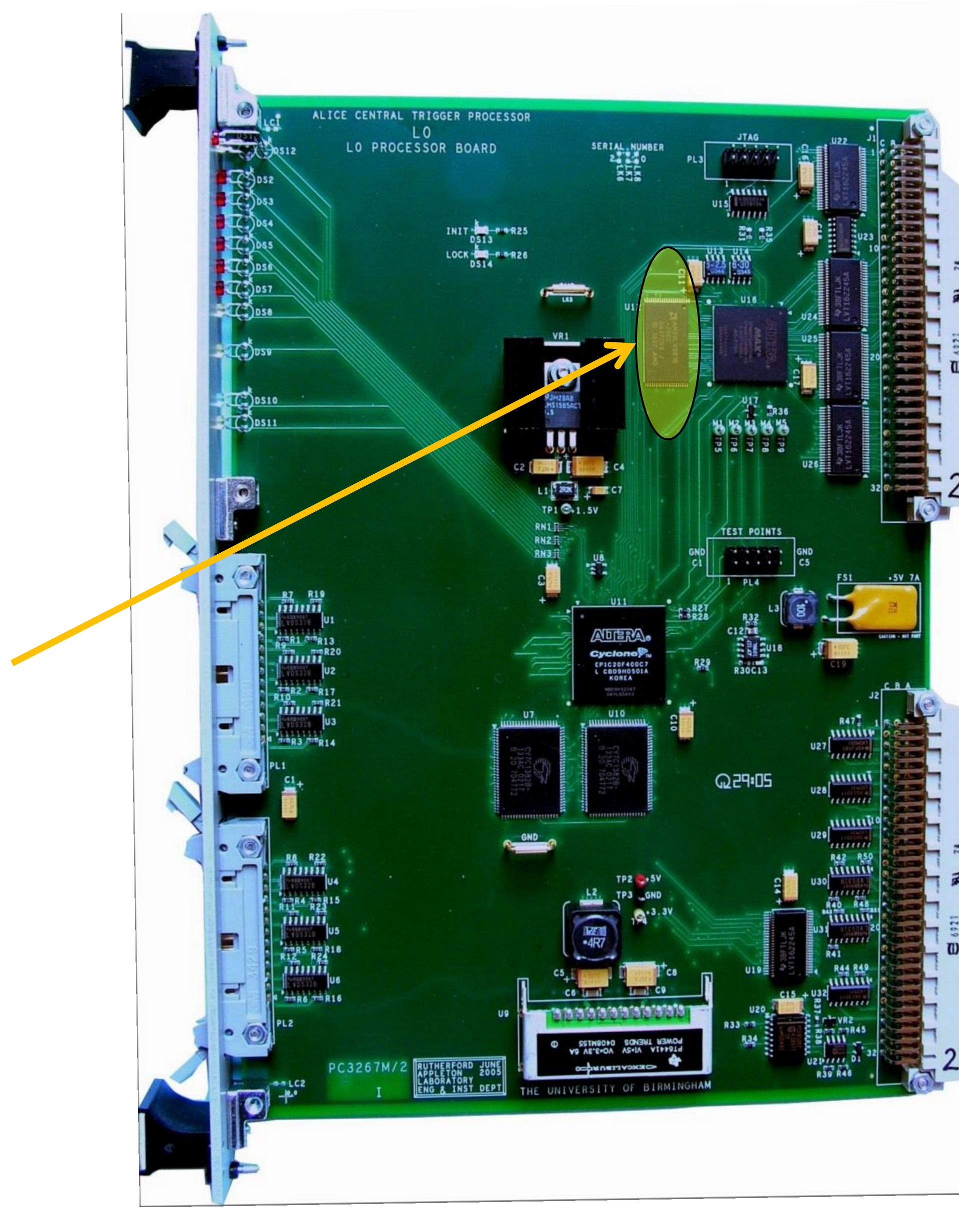


CTP Control and Monitoring

- Configure and control CTP
- Interface to ALICE Experiment Control System (ECS)
- Monitor the correct function of trigger
- Provide debugging facilities when fault occurs

CTP/LTU Board Monitoring

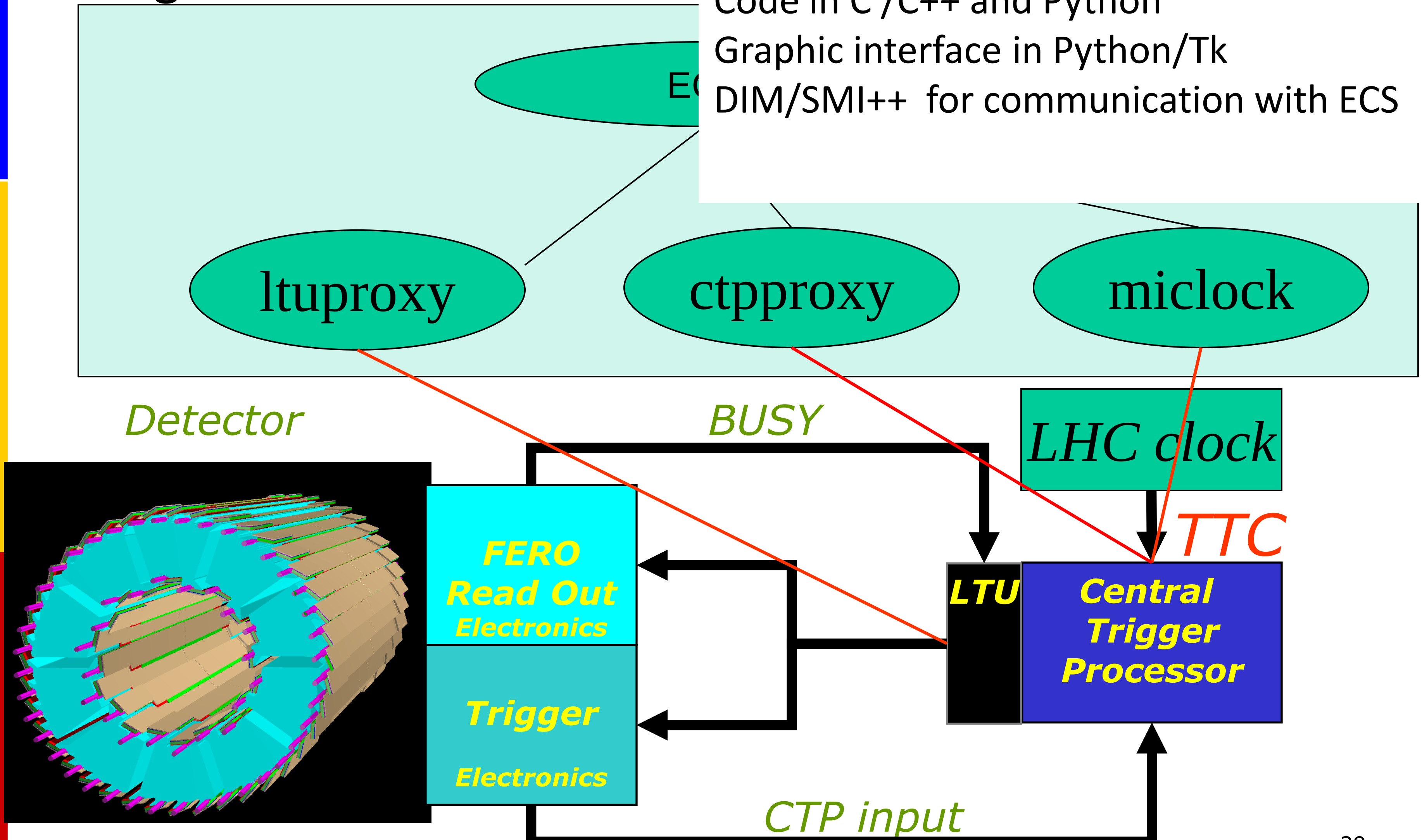
- Counters:
  - CTP ~ 1000 counters
  - LTU ~ 100 countres
  - Read via VME CPU
- Snapshot memory
  - Records 1M of selected signals
  - Monitoring
  - Debugging



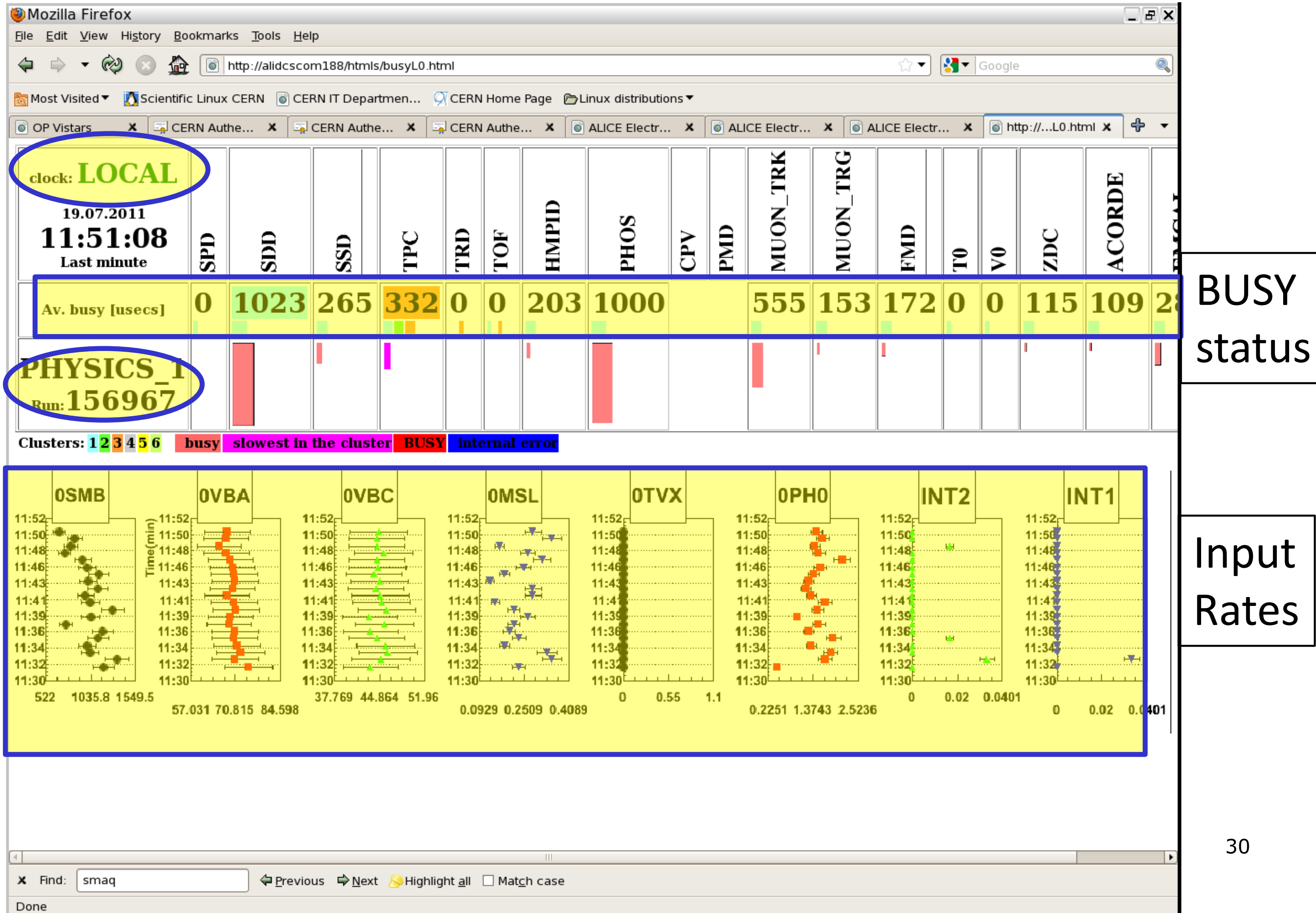
CTP control

Programs

Code in C /C++ and Python
Graphic interface in Python/Tk
DIM/SMI++ for communication with ECS



Global Run Status

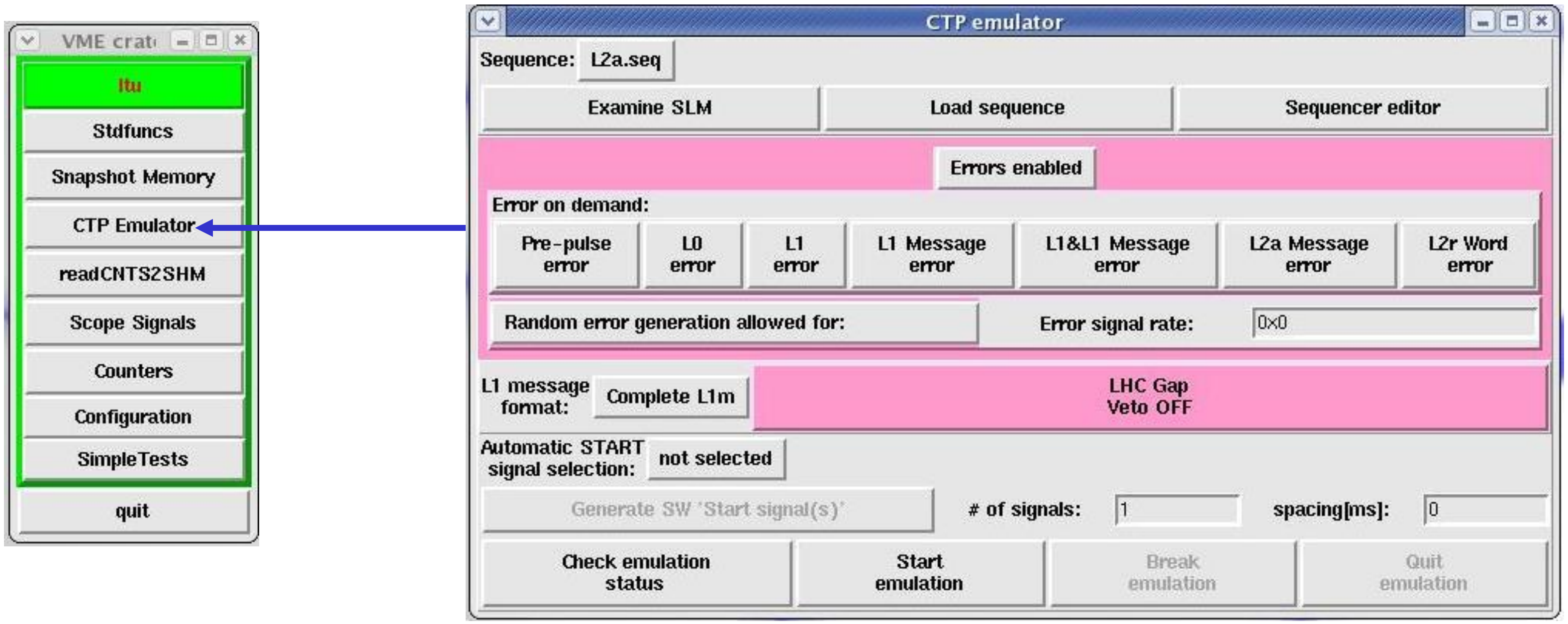


LTU proxy status

Name	Status	Logs
trd	started	log
zdc	started	log
emcal	started	log
tpc	started	log
pmd	started	log
acorde	started	log
sdd	started	log
muon_trk	started	log
muon_trg	started	log
daq	started	log
ssd	started	log
fmd	started	log
t0	started	log
hmpid	started	log
phos	started	log
cpv	started	log
spd	started	log
tof	started	log
v0	started	log

Name	Status	Logs
trd	started	log
zdc	started	log
emcal	started	log
tpc	started	log
pmd	started	log
acorde	started	log
sdd	started	log
muon_trk	started	log
muon_trg	started	log
daq	started	log
ssd	started	log
fmd	started	log
t0	started	log
hmpid	started	log
phos	started	log
cpv	stoped	log
spd	started	log
tof	started	log
v0	started	log

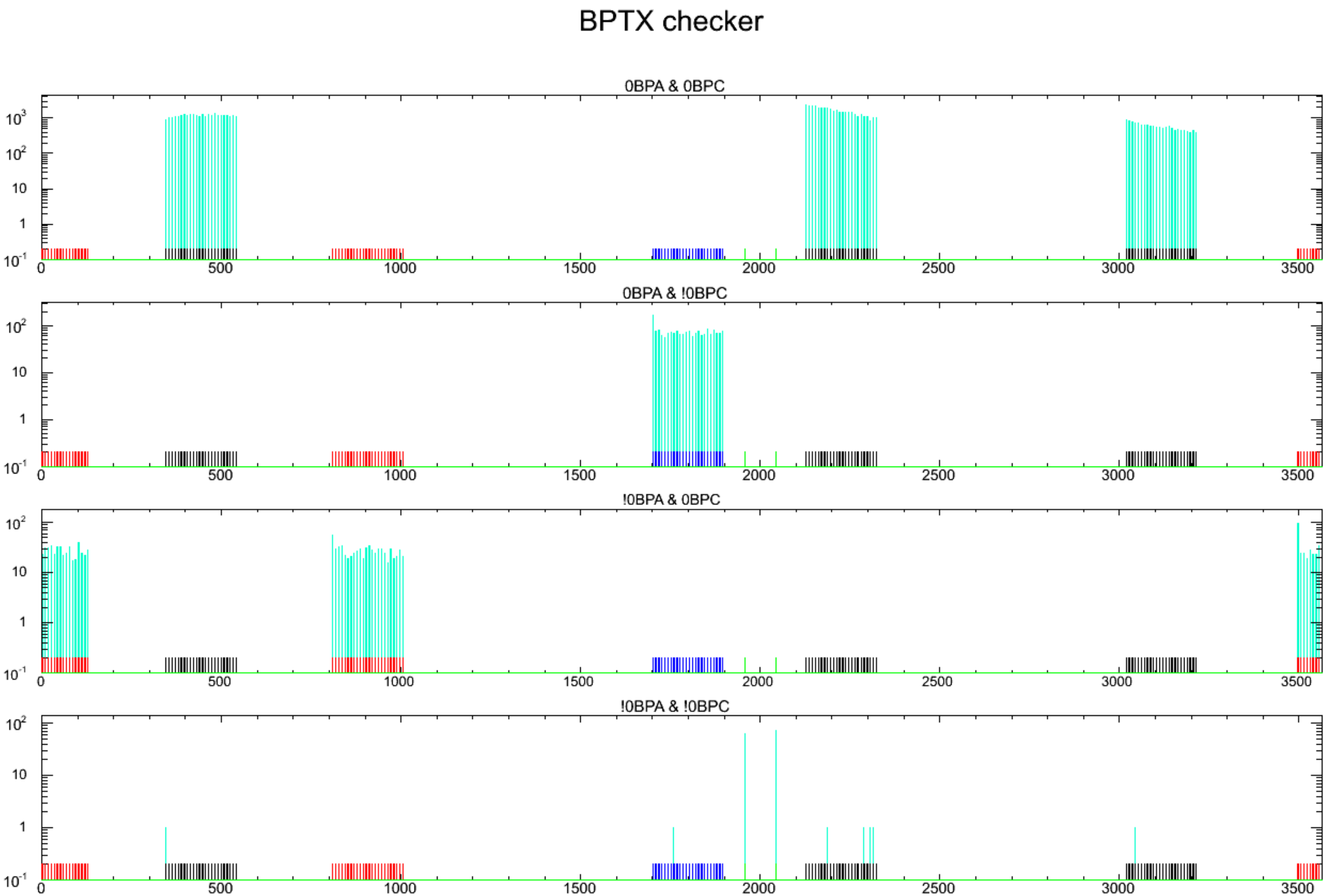
LTU software



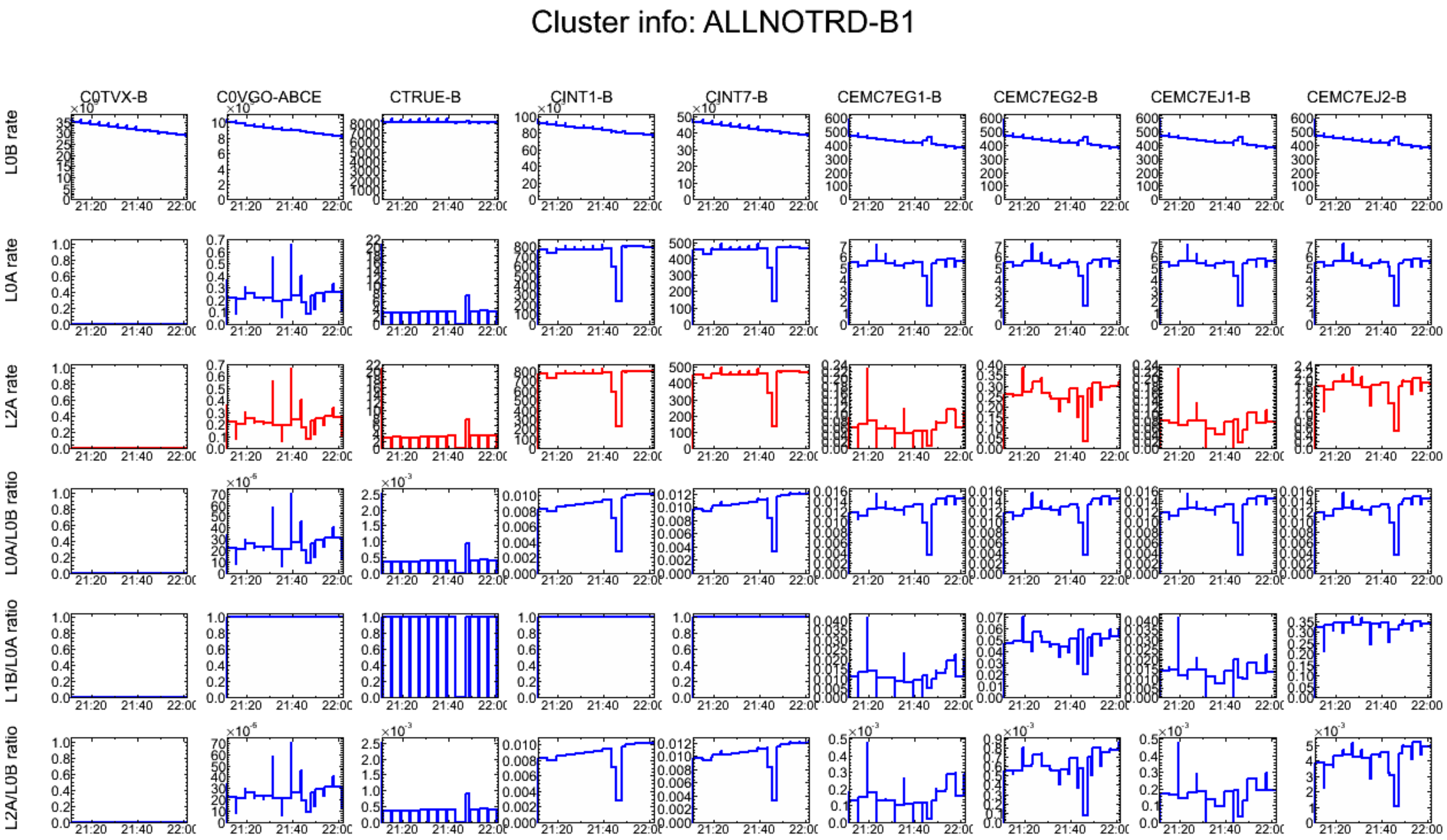
- Sequence execution triggered by **Start signal** derived from BC scaled down, random generator, external pulser or software request
- The LTU board can generate incomplete sequences or different types of errors can be introduced, either randomly or "on demand“ with CTP emulator in LTU software

AFFAIR

A Flexible Fabric and Application Information Recorder



AFFAIR



Cluster info: ALLNOTRD-B1
C0TVX-B
C0VGO-ABCE
CTRUE-B
CINT1-B
CINT7-B
CEMC7EG1-B
CEMC7EG2-B
CEMC7EJ1-B
CEMC7EJ2-B
L0B rate
L0A rate
L2A rate
L0A/L0B ratio
L1B/L0A ratio
L2A/L0B ratio
21:20
21:40
22:00

Summary

CTP performs according to specifications.

ALICE data samples collected:

- November 2010:
  - pp at 7 TeV ~ 17/μb
  - **1st Pb+Pb collisions at 2.76 TeV ~ 4/μb**
- November/December 2011:
  - pp at 7 TeV ~ 2/pb
  - pp at 2.76 TeV ~ 20/nb
  - **2nd Pb+Pb collisions at 2.76 TeV ~80/μb**
- September 2012:
  - pp at 8 TeV ~ 5/pb
  - **Pilot run p Pb ~ 1/μb**
- January/February 2013
  - **p Pb collisions: ~50 /μb (Min Bias) + 30/nb (muons)**

Future Plans

- **2013-2014 – Long Shutdown 1 (LS1)**
  - Completion of detector (TRD, Calorimeters)
  - CTP upgrade (see Marian Krivda's talk tomorrow)
- **2015-2017**
  - 10 x increase in statistics in Pb-Pb at $\sqrt{s}$ =5.5 TeV, i.e $\approx 1nb^{-1}$ to be collected
- **2018 ALICE upgrade – Long Shutdown 2 (LS2)**
  - **High precision measurements of rare probes at low p_T :**
    - **Increase rate capability – continuous readout and new online systems** **(for CTP see MK talk tomorrow)**
    - **Improve vertexing and low p_T tracking – new silicon vertex tracker**
- **2019-2021 (Ar-Ar,p-Pb,Pb-Pb)**
  - $10nb^{-1}$

CTP upgrade after LS1

- New CTP level to improve triggering efficiency of TRD
- 100 classes (currently 50)
- 8+1 clusters
- New L0 board
- Firmware upgrade of all boards

For CTP after LS1 see M. Krivda talk

ALICE upgrade after LS2

- **luminosity upgrade – 50 kHz target minimum-bias rate for Pb–Pb**
- **run ALICE at this high rate, inspecting all events**
- improved vertexing and tracking at low p_T
- preserve particle-identification capability
- new, smaller radius beam pipe
- new inner tracker (ITS) (performance and rate upgrade)
- high-rate upgrade for the readout of the TPC, TRD, TOF, CALs, DAQ-HLT, Muon-Arm and Trigger detectors
- **collect more than 10 nb^{-1} of integrated luminosity**
  - **implies running with heavy ions for a few years after LS3**
- **for core physics programme – factor > 100 increase in statistics**
  - **(maximum readout with present ALICE ~ 500 Hz)**
- **for triggered probes increase in statistics by factor > 10**

For CTP after LS2 see M. Krivda talk

BACK UP

ALICE focus after LS2

Precision measurement of the QGP parameters at $\mu_b = 0$ to fully exploit scientific potential of the LHC – unique in:

- large cross sections for hard probes
- high initial temperature

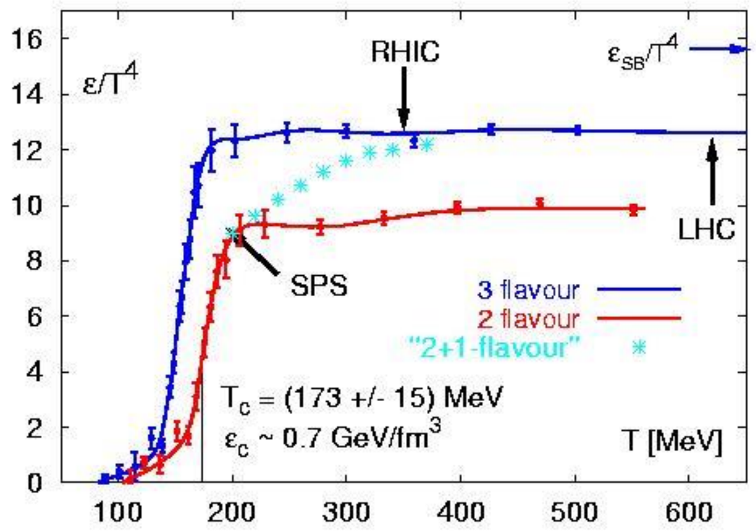
- Main physics topics, uniquely accessible with the ALICE detector:
  - measurement of heavy-flavour transport parameters:
    - study of QGP properties via transport coefficients (η/s, $\hat{q}$)
  - measurement of low-mass and low-p_T di-leptons
    - study of chiral symmetry restoration
    - space-time evolution and equation of state of the QGP
  - J/ψ , ψ', and χ_c states down to zero p_T in wide rapidity range
    - statistical hadronization versus dissociation/recombination

The QCD Phase Transition

The QCD phase transition:

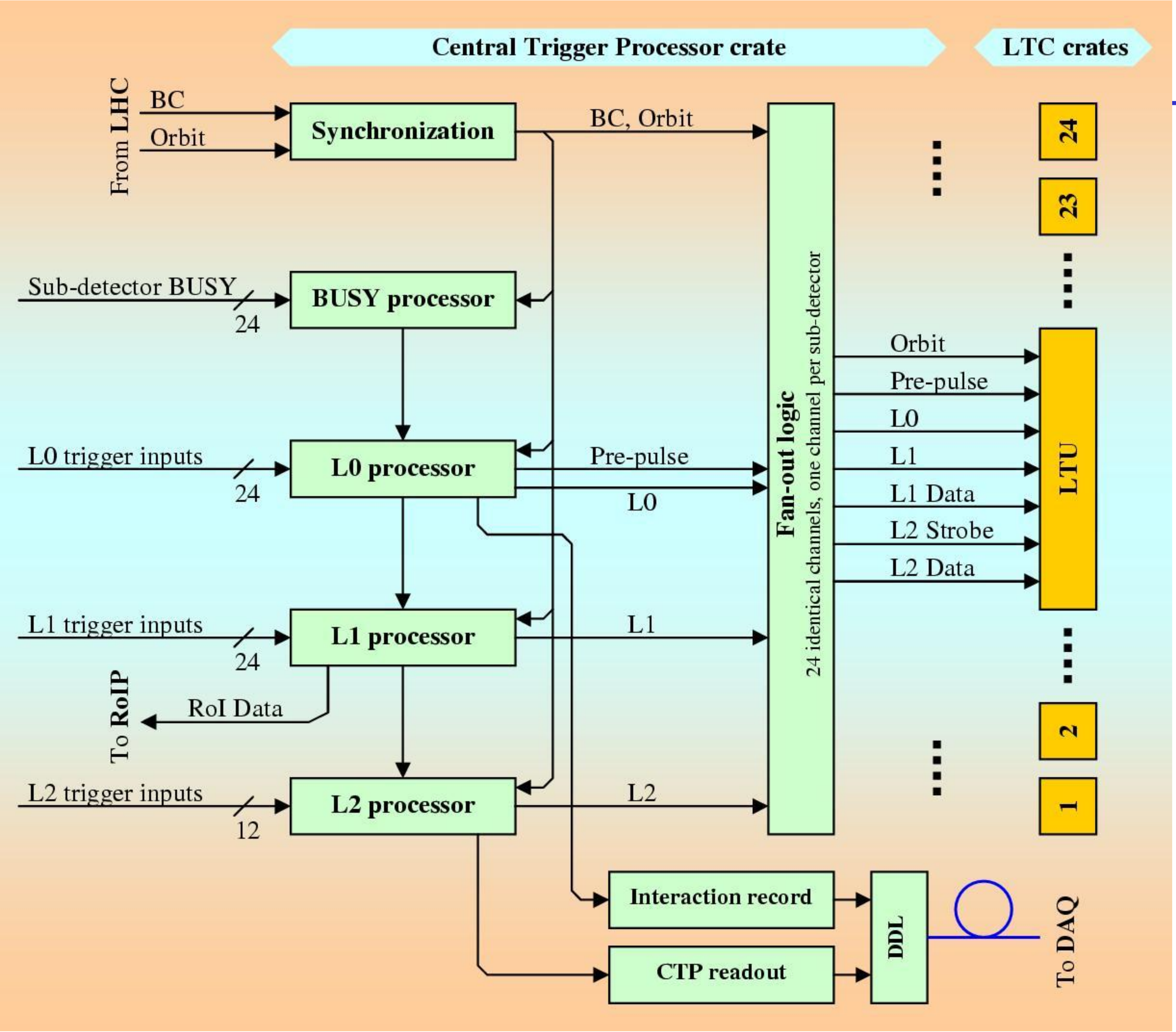
- Cross over for physical quark masses
- Confinement and χ transitions both at T~170 MeV
- QGP is not an ideal gas

Lattice QCD

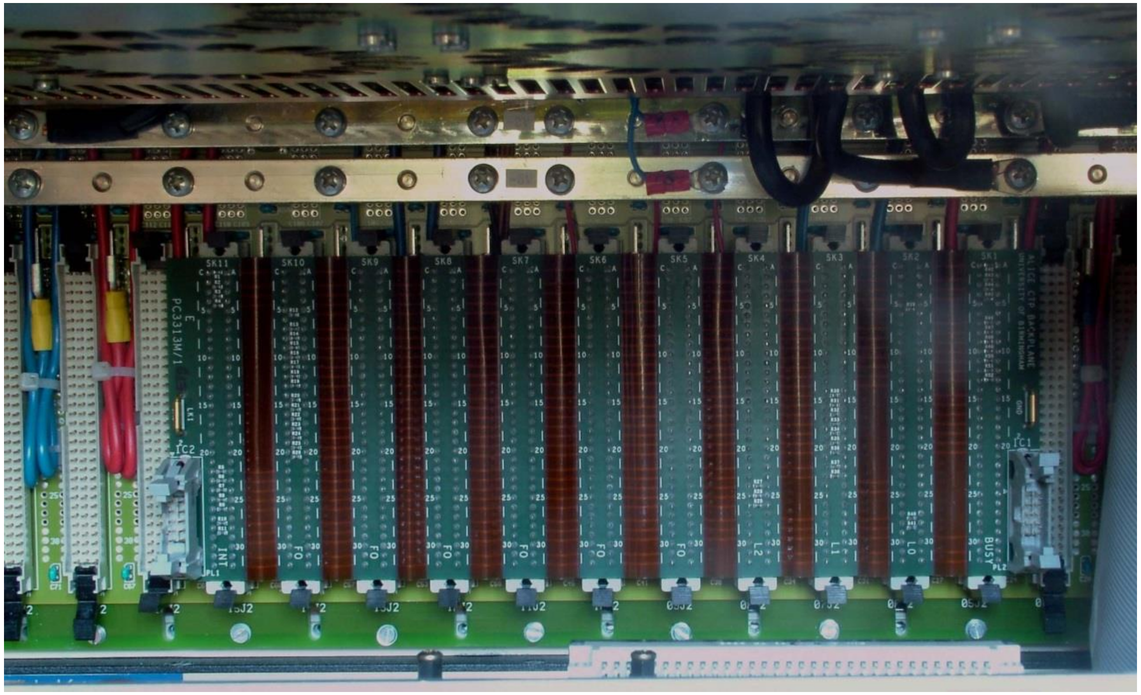


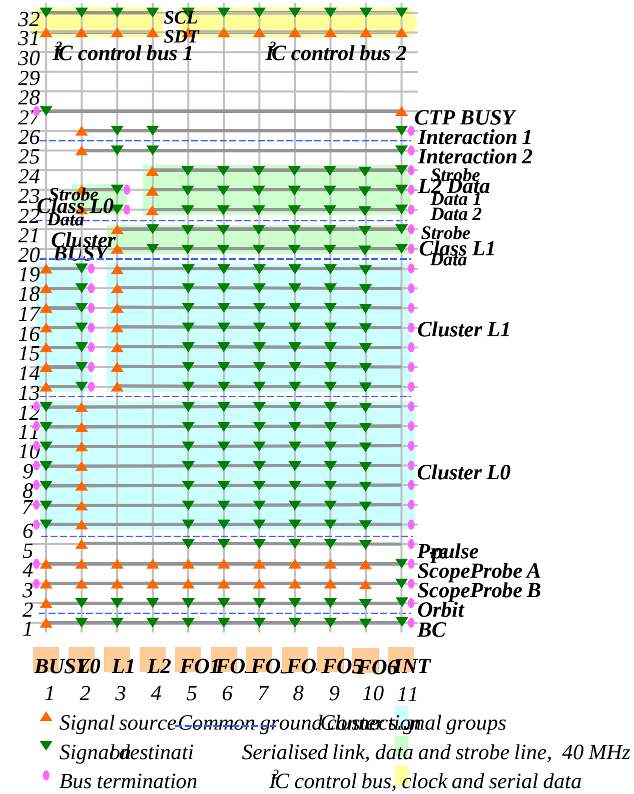
$$p = \frac{\varepsilon}{3} = \left(g_B + \frac{7}{8} g_F \right) \frac{\pi^2 T^4}{90}$$

Heavy Ion collisions study hadronic matter at finite temperature

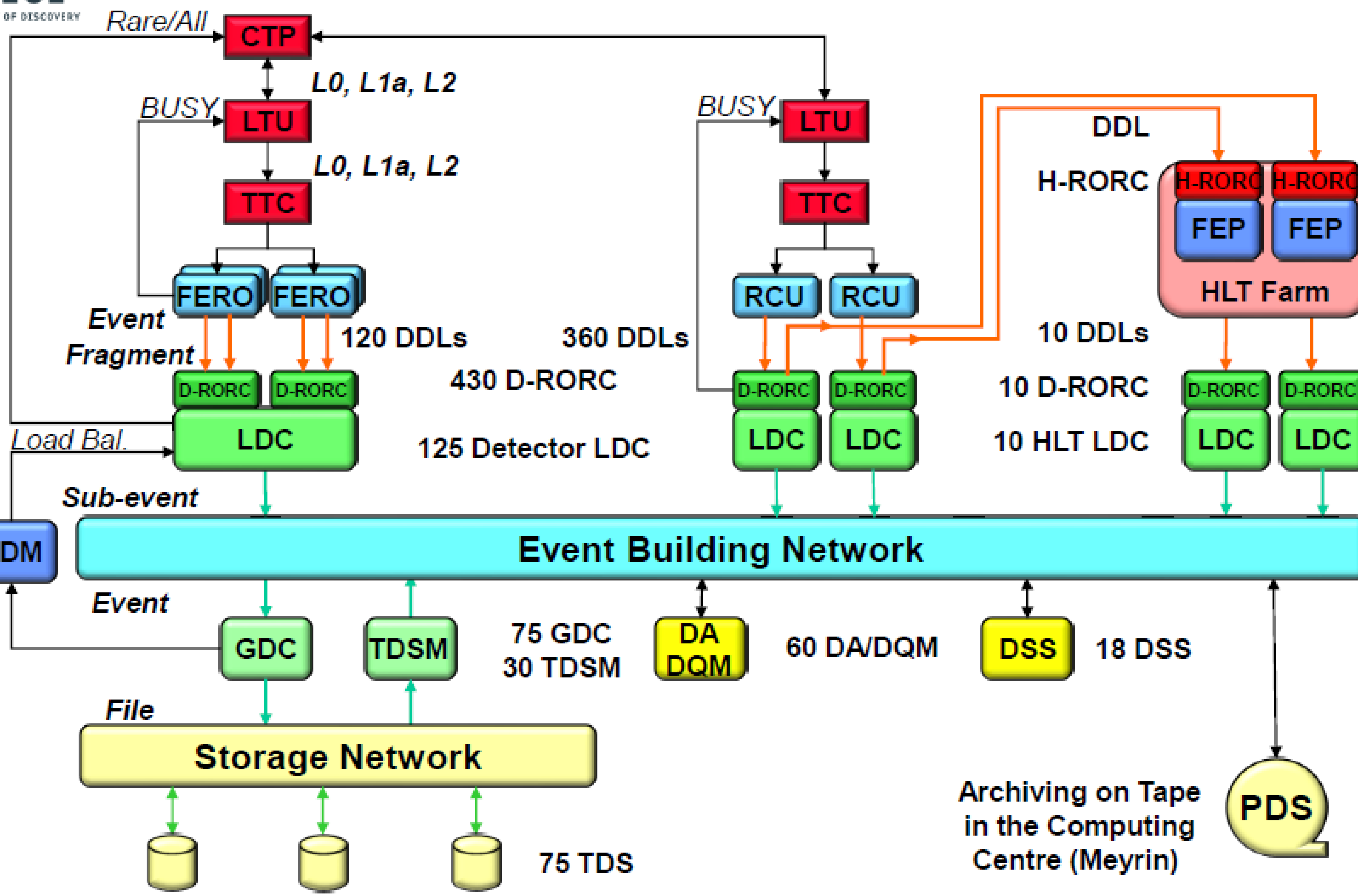

Central Trigger Processor crate
LTC crates
From LHC
BC
Orbit
Synchronization
BC, Orbit
Sub-detector BUSY
24
BUSY processor
L0 trigger inputs
24
L0 processor
Pre-pulse
L0
L1 trigger inputs
24
L1 processor
L1
To RoIP
RoI Data
L2 trigger inputs
12
L2 processor
L2
Fan-out logic
24 identical channels, one channel per sub-detector
Orbit
Pre-pulse
L0
L1
L1 Data
L2 Strobe
L2 Data
LTU
24
23
2
1
Interaction record
CTP readout
DDL
To DAQ

CTP backplane





Present Online Architecture



LHC Basics

- Protons/ions are in bunches
- Bunches are separated
  - 7.5 m in space
  - 25ns in time = 40 MHz
  - LHC clock – 40 MHz
- Interaction Point (IP): crossing of rings
- **ORBIT**
  - 1 full round ~ 89 μs
  - 3564 bunches
- **Bunch Crossing (BC):** crossing of two bunches in IP
- **LHC filling scheme**:
  - how many bunches are injected
  - their position in the ORBIT