The ATLAS Central Trigger Processor and its Phase-2 upgrade

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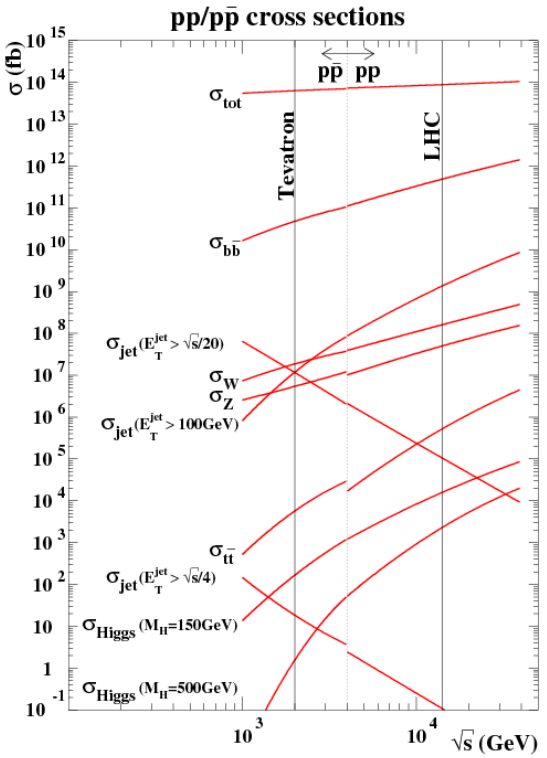
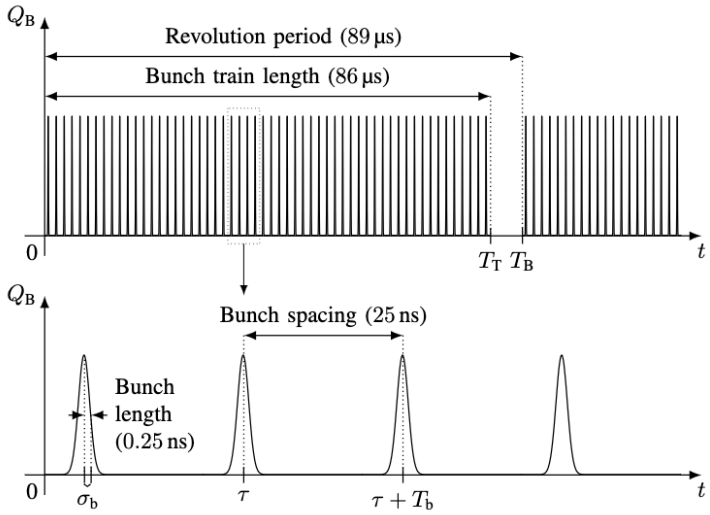
Take-away messages

- Harsh data taking conditions
- ATLAS TDAQ is a sync/async system
- Without the Central Trigger Processor ATLAS does not take data and you can’t do analyses
- Phase-2 Central Trigger will enable the Run-4 ATLAS physics goals

The needle in a haystack

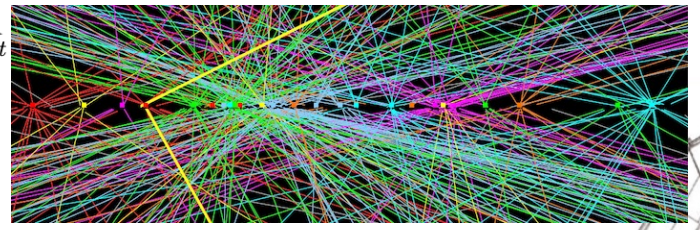


Interesting physics is hidden in a huge background

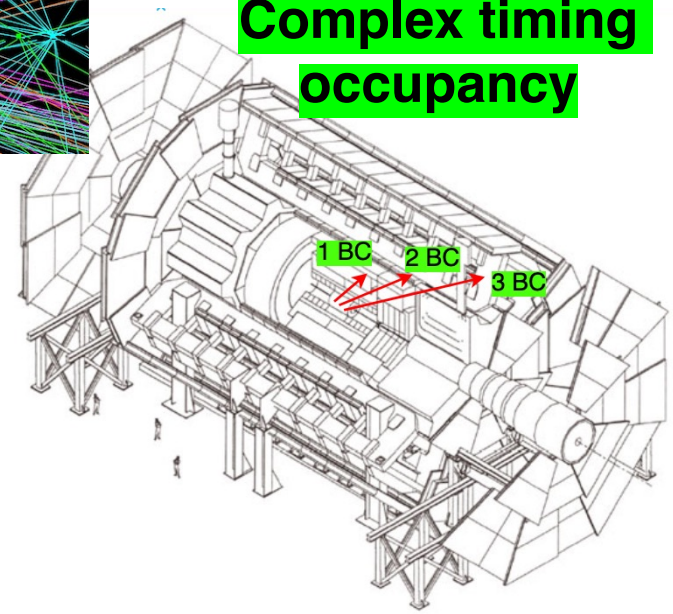


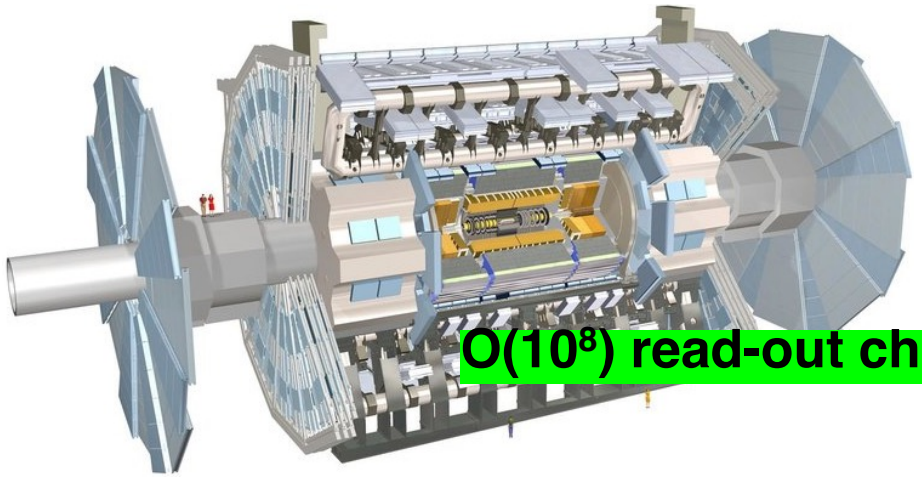
40 MHz Bunch Clock

Run-3 pile-up: < μ > ~ 60



Complex timing occupancy

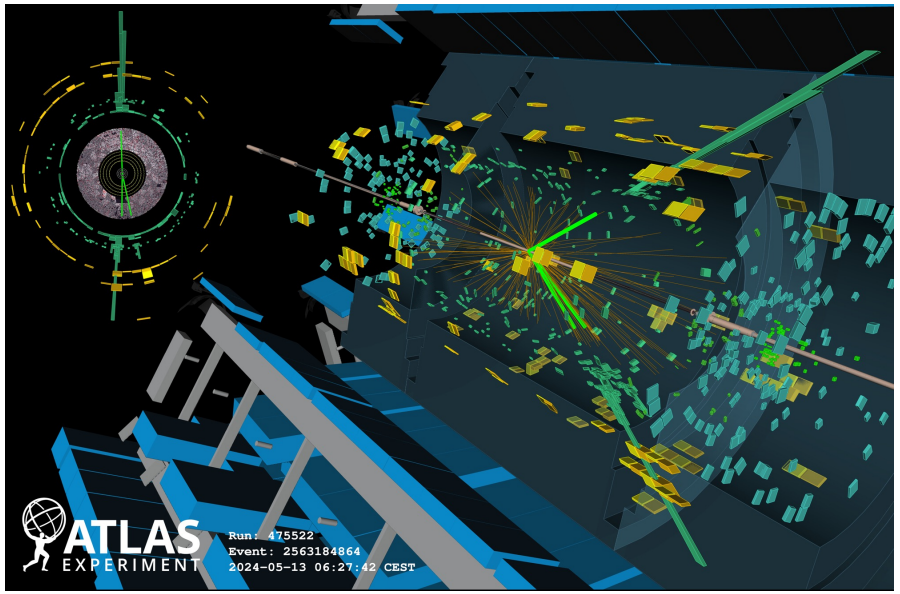


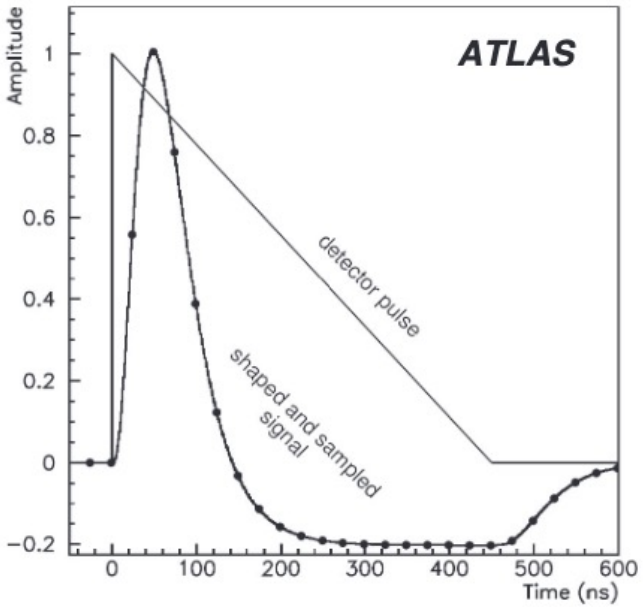


O(10^8) read-out channels

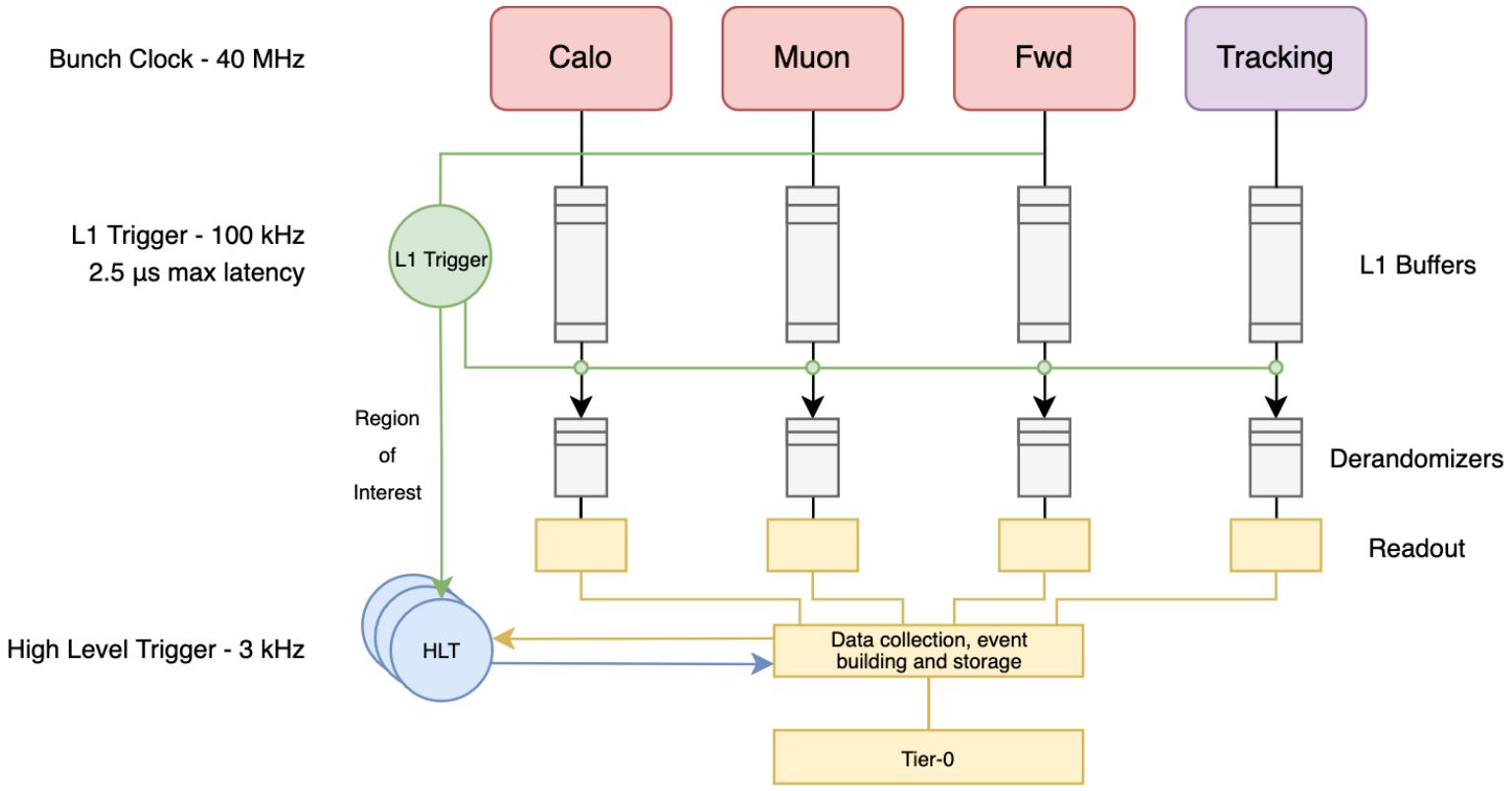
Trigger and data acquisition

1. Front-end data formation (digitisation of analog signals using the beam-synchronous 40 MHz clock)
2. Sub-detector data is stored locally in L1 buffers while waiting for the trigger decision
3. A trigger signal initiates the synchronous readout



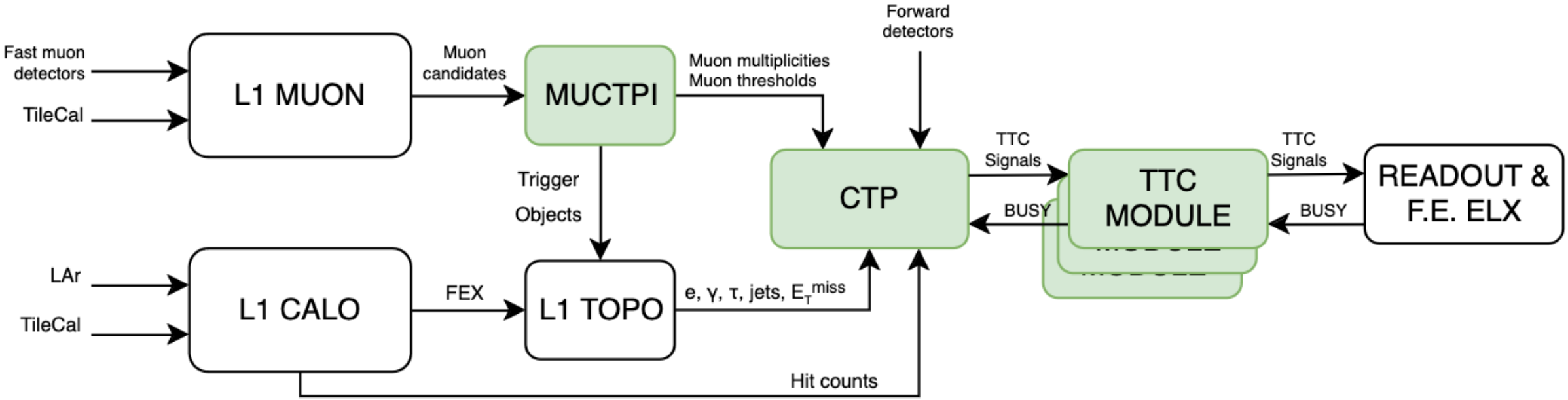


ATLAS Trigger and Data Acquisition (TDAQ)



- Data path and trigger path are different
- Rely on fixed latency from the collision to the reception of the trigger signal at the front-end electronics (mostly signal transmission and pipelined processing)
- Data acquisition becomes completely asynchronous when data is readout, relying on identifiers

L1 Trigger



* Central Trigger system in green

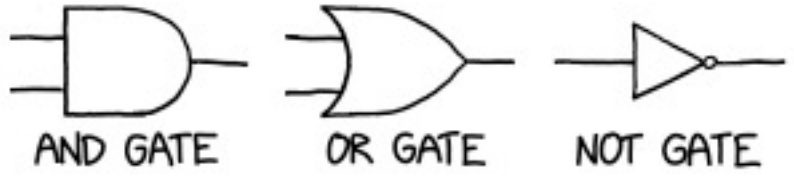
CTP – Central Trigger Processor
MUCTPI – Muon-to-Central Trigger Processor Interface
TTC – Trigger and Timing Control

Translating physics into trigger requirements

Possible triggering objects:

- MU – muon
- EM – electromagnetic
- J – jet
- T – tau/hadron
- XE – missing energy

Object **MULTIPLICITIES** and **THRESHOLDS**



TRIGGER ITEM

512 ITEMS ---> L1 MENU

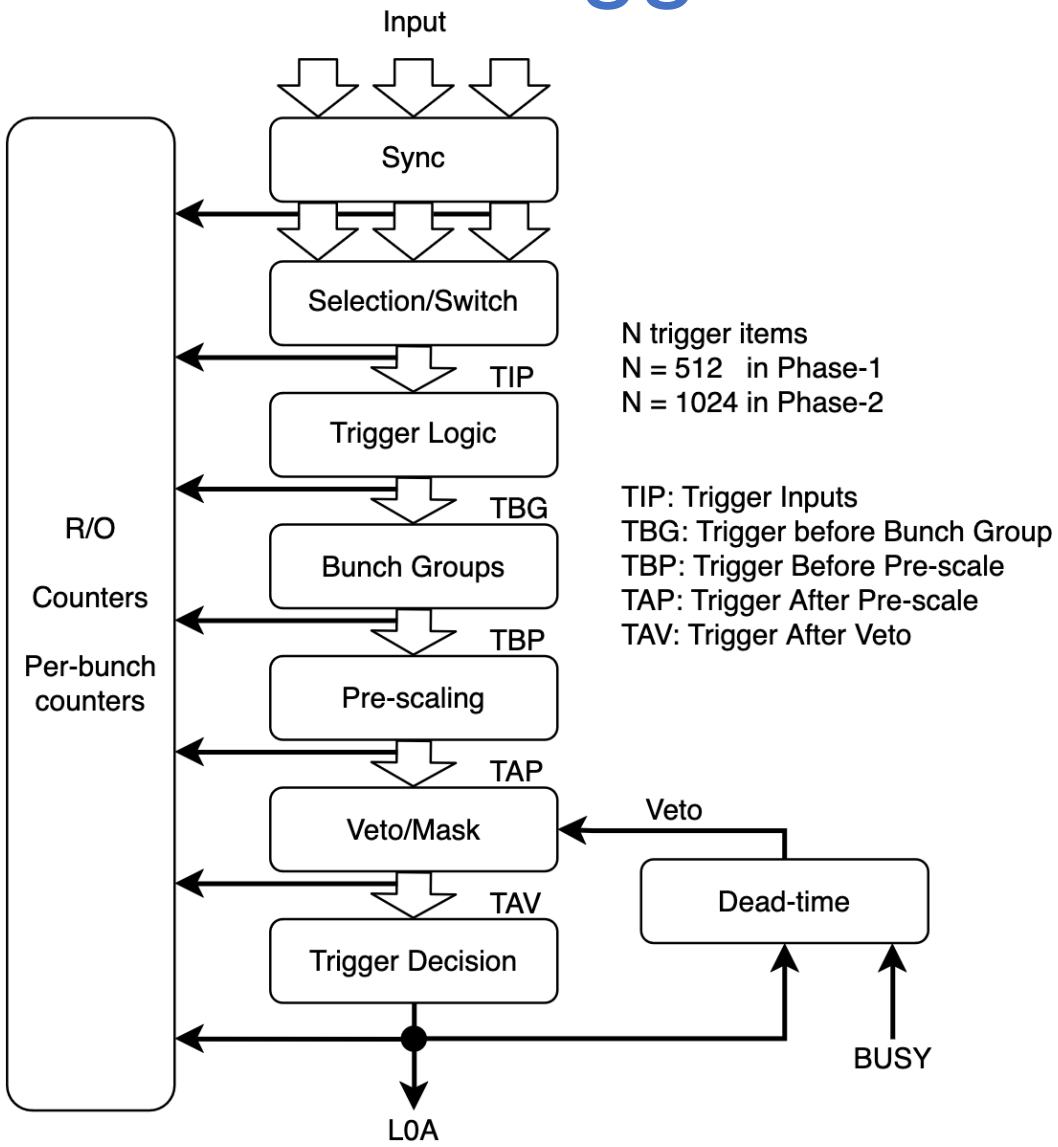
The logical **OR** of all items gives the trigger accept signal

1MU6
2MU6
1EM20 AND XE20
...

Every item is accompanied by a scalar: the prescale.

It is the fraction of events we keep out of all the possible triggering events.

Central Trigger Processor

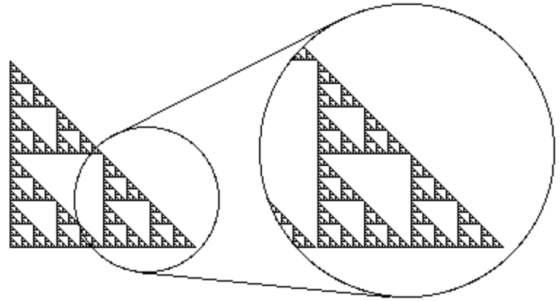


- Receive trigger signals from trigger processors and detectors
- Trigger signal alignment (in steps of 25ns)
- Application of the trigger logic on menu items
- Application of coincidence logic with the beam filling scheme
- Trigger item rate control via programmable rescaling

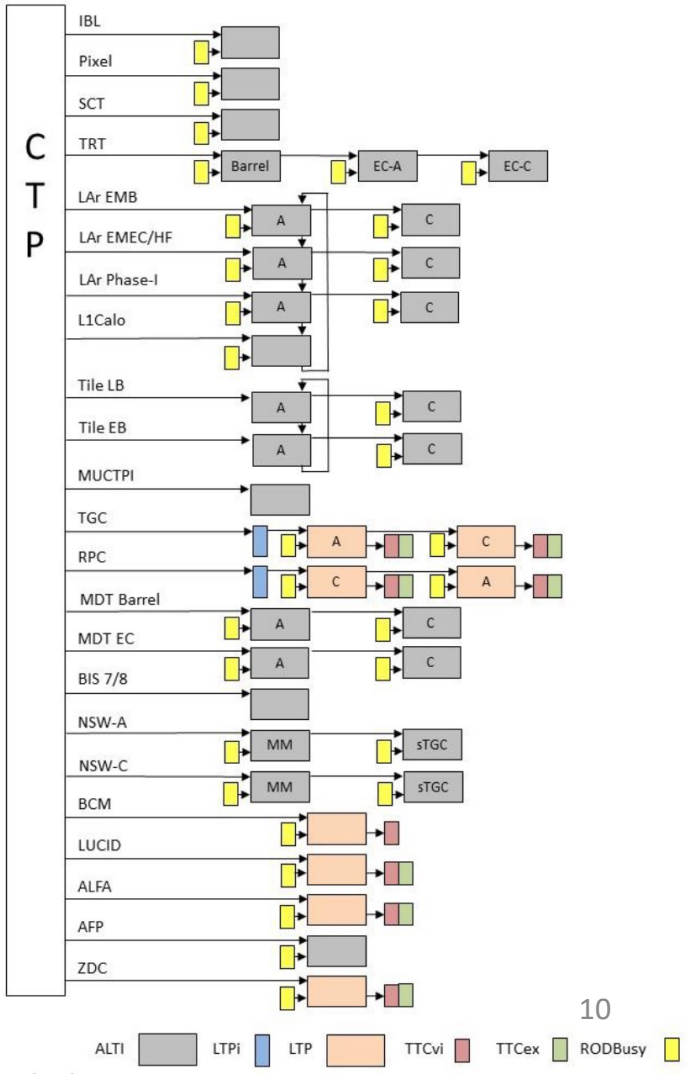
And also:

- Receive LHC timing signals
- Distribution of timing to sub-detectors
- Coherent monitoring of TAP and TAV for luminosity corrections and overall diagnostics
- Trigger data readout for offline reconstruction of the trigger decision

The CTP and ATLAS Partitioning



- The ATLAS detector is partitioned in independent sub-detectors, and each partition has a TTC module
- During physics data taking the sub-detectors partitions are oragnized in a single tree-like structure (ATLAS), where the TTC modules are the leafes and the CTP the root
- During commissioning and tests, each partition can run independently like it is ATLAS, since TTC modules have some CTP functionalities

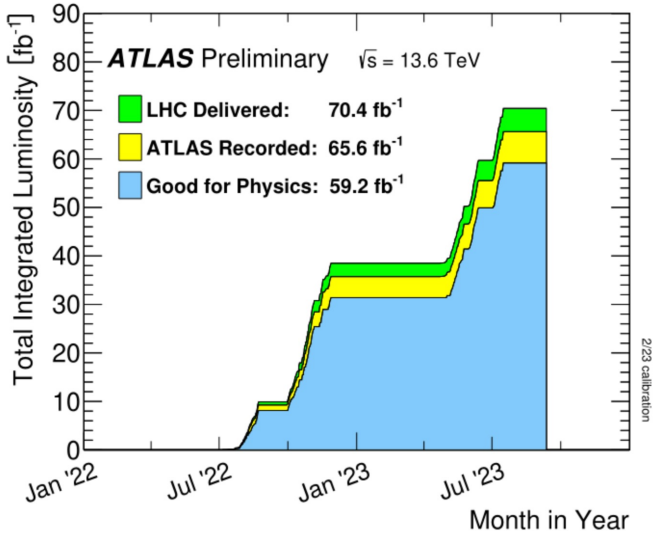


ATLAS data flow control

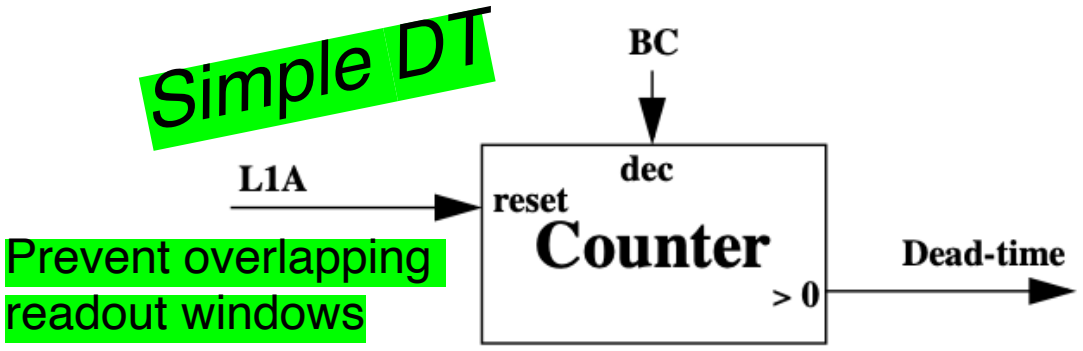
One of the sources of ATLAS inefficiencies is its dead-time (DT)

$$\text{Total DT} = \frac{\text{N of ignored BCs}}{\text{tot N of BCs}}$$

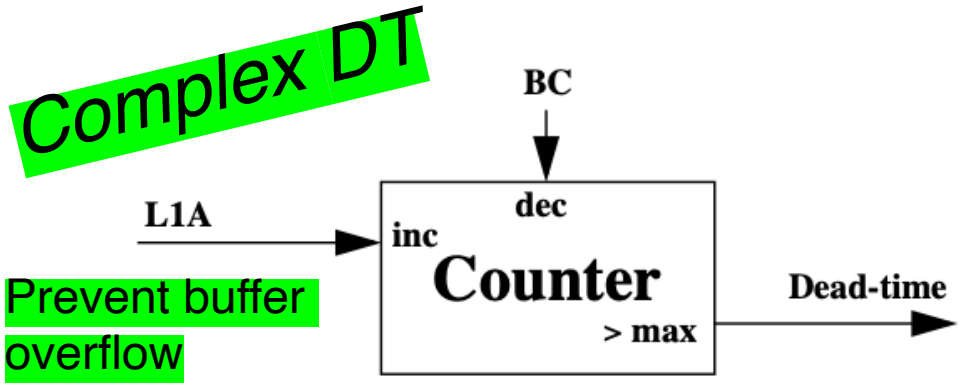
- BUSY ---> Backpressure coming from sub-detector readout
- Prevention ---> Protects front-end buffers from overflowing
- Prescaling ---> Trigger rate control to meet rate requirements



CTP forms the VETO signal (OR of BUSY with preventive dead-time) and uses it to gate the trigger items

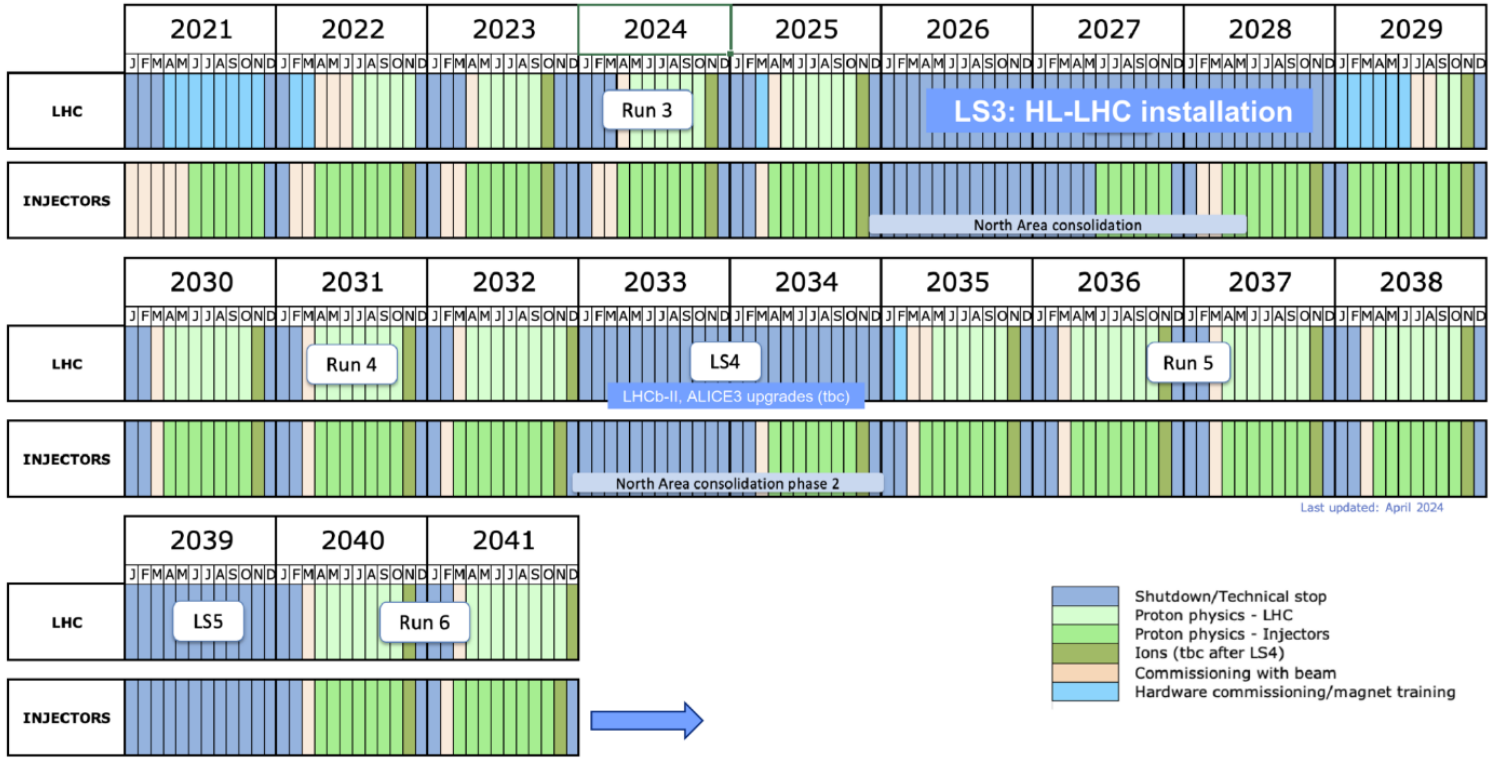


4 BC of dead-time follow one L1A



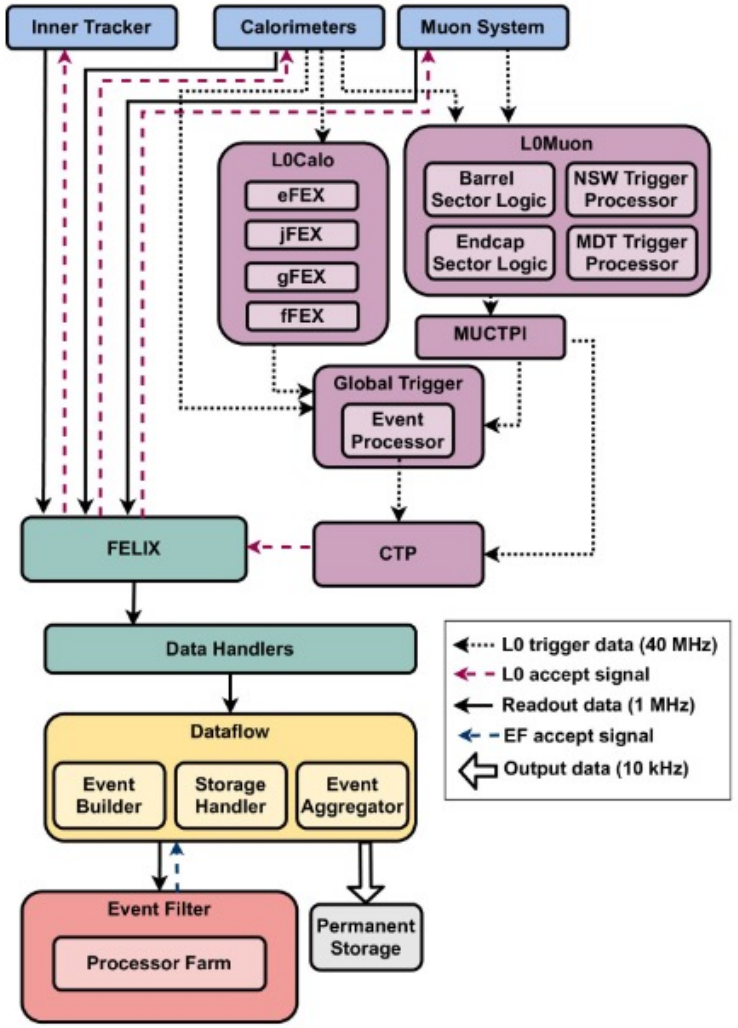
Leaky bucket algorithm

High-Luminosity LHC upgrades



- Instantaneous luminosity increase from 2 10^{34} s^{-1} cm^{-2} to 7.5 10^{34} s^{-1} cm^{-2}
- Pile-up $< \mu >$ from 60 to 200
- Significant upgrades in the ATLAS detector, but in the TDAQ system too!
- **10x Trigger rates to retain Run-4 physics programme**

ATLAS TDAQ Phase-2 upgrade



- **Level-0 trigger * @ 1 MHz**
- Improved High-Level Trigger with full tracking scan @ 150 kHz

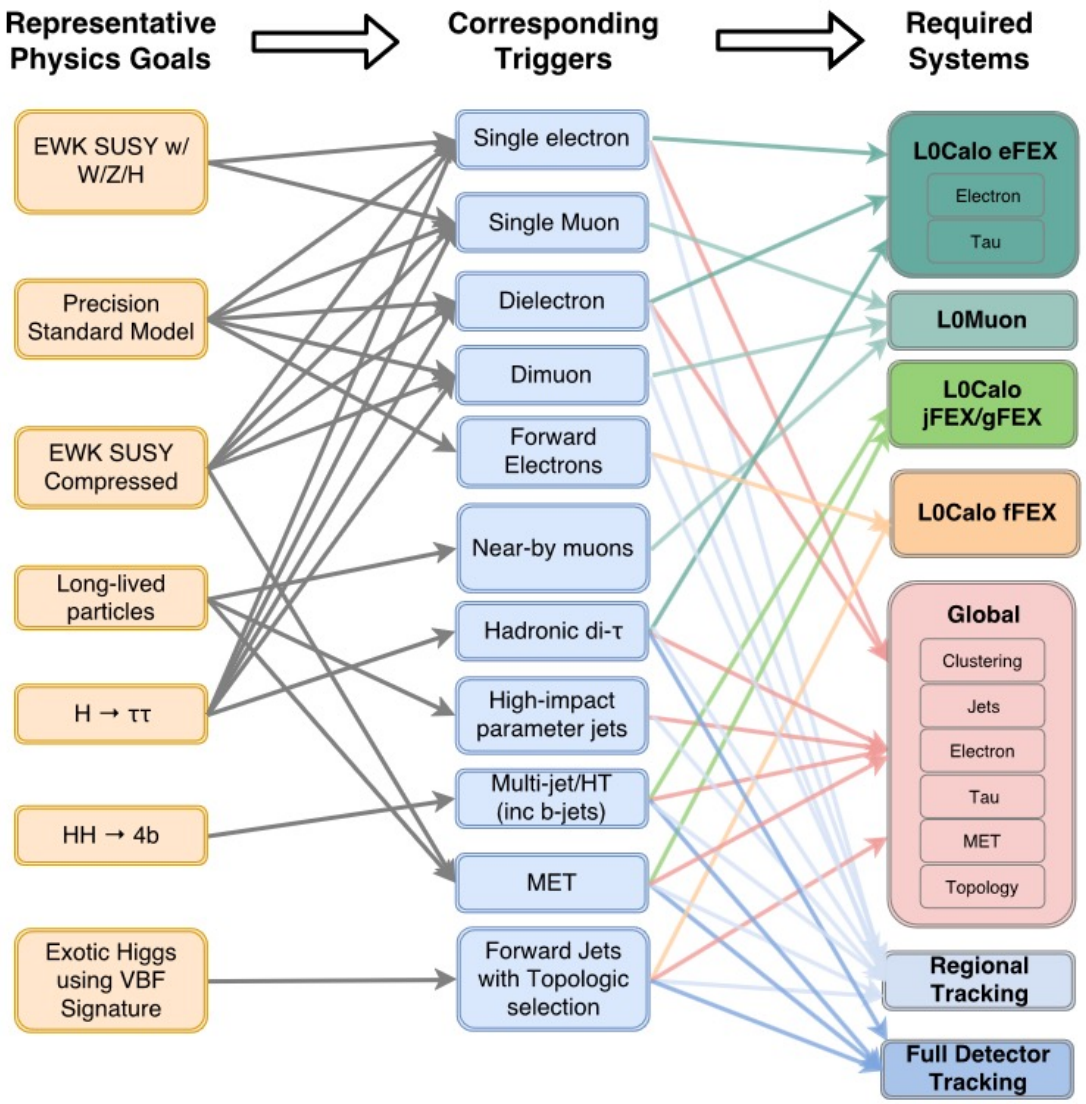
* For Phase-2 the Level-1 trigger nomenclature has been dropped in favor of Level-0

i. **L0 rate @ 1 MHz**

ii. **Fixed L0 latency of 10 μs**

iii. **Maximum DT of 1%**

Phase-2 Physics requirements



Phase-2 CTP will have **1024 trigger items**, improving L0Menu **flexibility** and **selection power**

Phase-2 CTP hardware specs

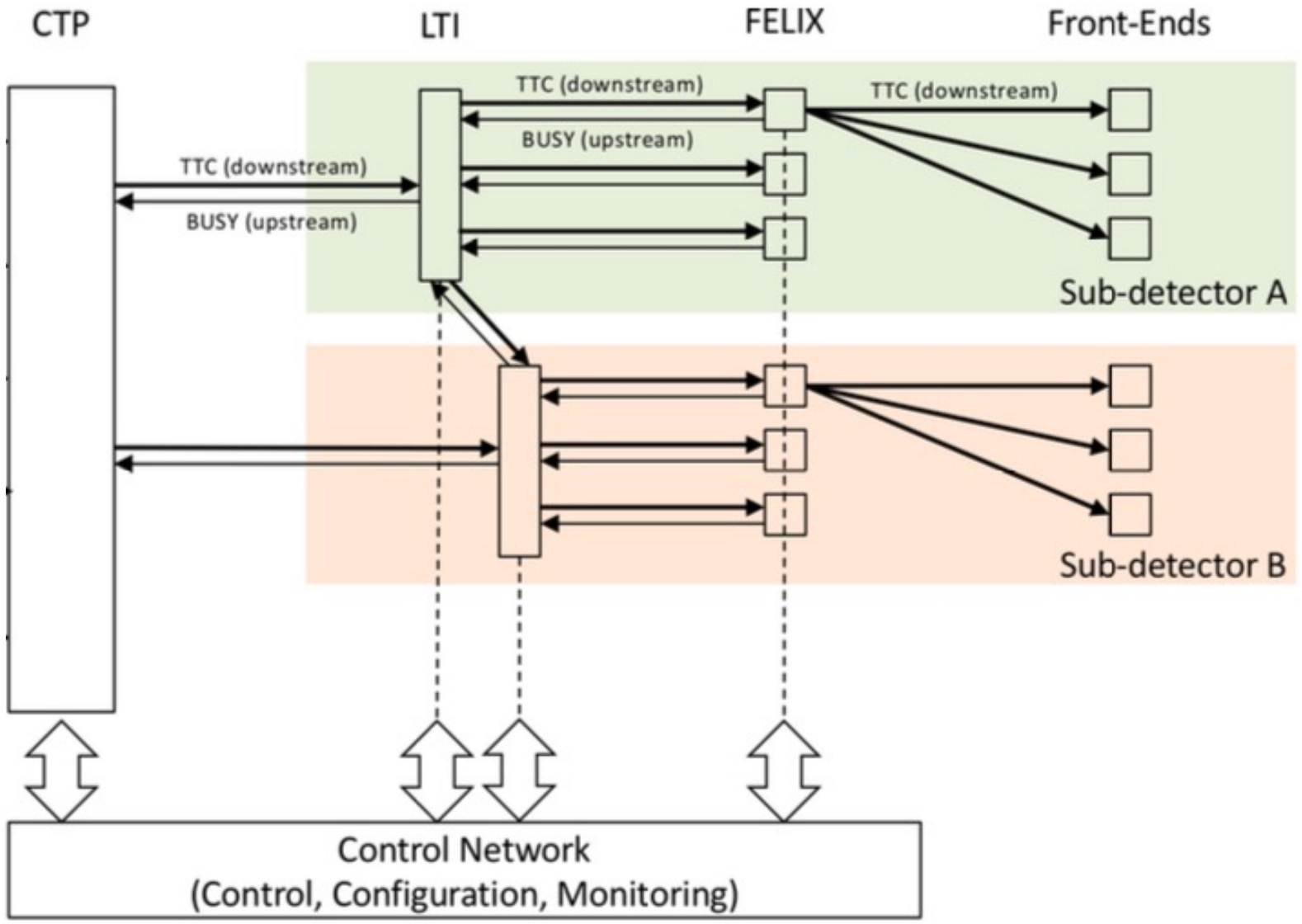
The CTP will be implemented in a single ATCA blade, implementing all the functionalities of:

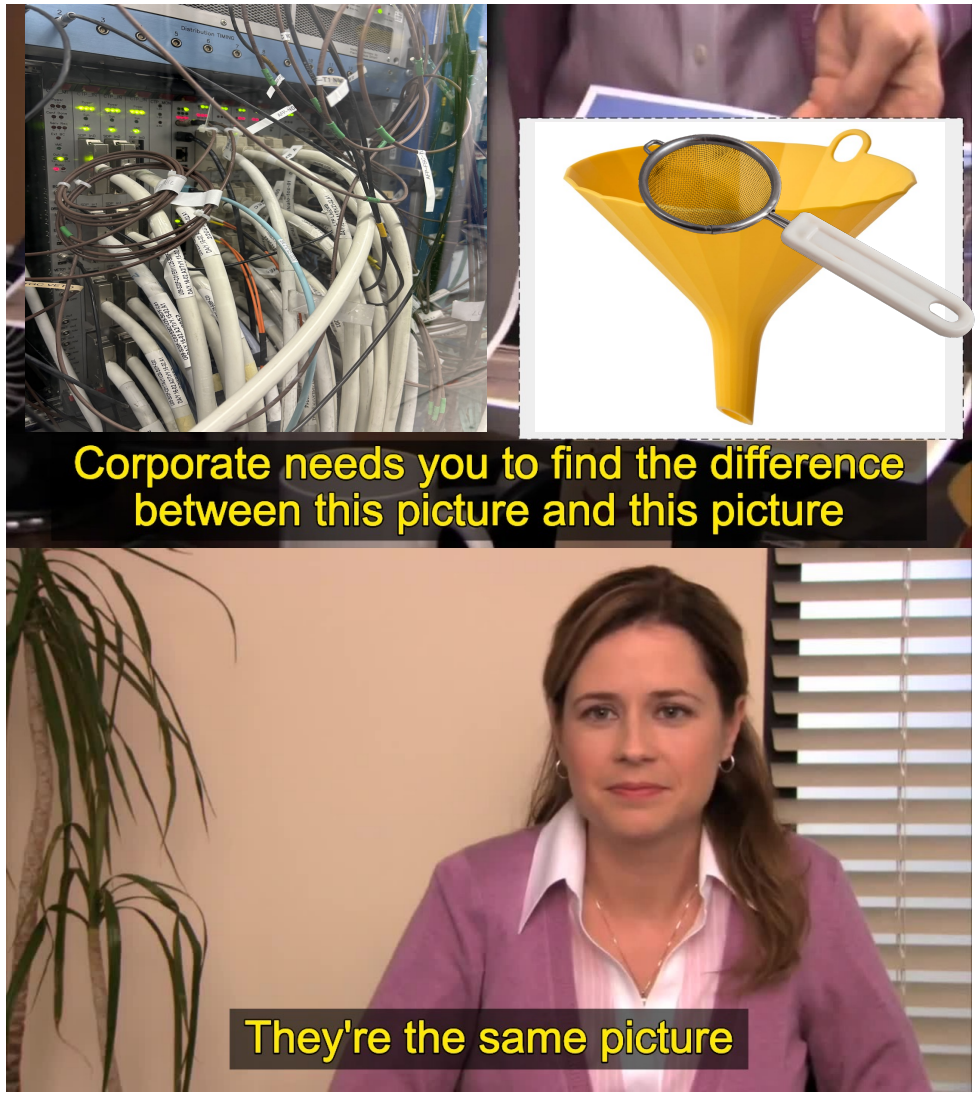
- Machine Interface – receive the BC and Orbit signals from the LHC
- Input module – receive all the inputs in a back-panel
- Core module – form the trigger accept signal and type

The CTP inputs will be based on optical serial inputs, and electrical LEMO connections to receive trigger information from:

- Global Trigger
- MUCTPI
- Forward detectors (electrical)

Phase-2 TTC Distribution





Thank you for your attention!