2004 – 2007 University of Bologna (ITA) PhD student.
SW and FW developer for the ALICE ITS SDD detector.

2007 – now CERN STAFF in the ALICE DAQ group.
SW and FW developer for the ALICE DAQ group (a.k.a. O2/FLP).

RUN2 activities (past):
Software developer of the readout program in ALICE DAQ main system, to collect data from all the detectors and store the information in the PC memory.

FPGA firmware developer for the PCIe readout card (C-RORC).

RUN3 activities (now):
Software and firmware developer for the CRU team.
CRU is the new FPGA PCIe readout card used in ALICE to collect data from the detectors.

Responsible of the detector readout activities in ALICE. Act as main coordinator at CERN between the detectors and the O2/FLP group concerning readout of the detector.

Filippo Costa

TIME:

The Most Precious

RESOURCE


12
1
2
3
4
5
6
7
8
9
10
11


© 2015 Disney


BLAH! BLAH!
BLAH. BLAH!
wikiHow


My Speaking Speedometer
Just right.
Oops, too fast!
Too slow.
twinkl

Dictionary

Search for a word

synchronization

/sɪŋkrənʌɪˈzeɪʃ(ə)n/

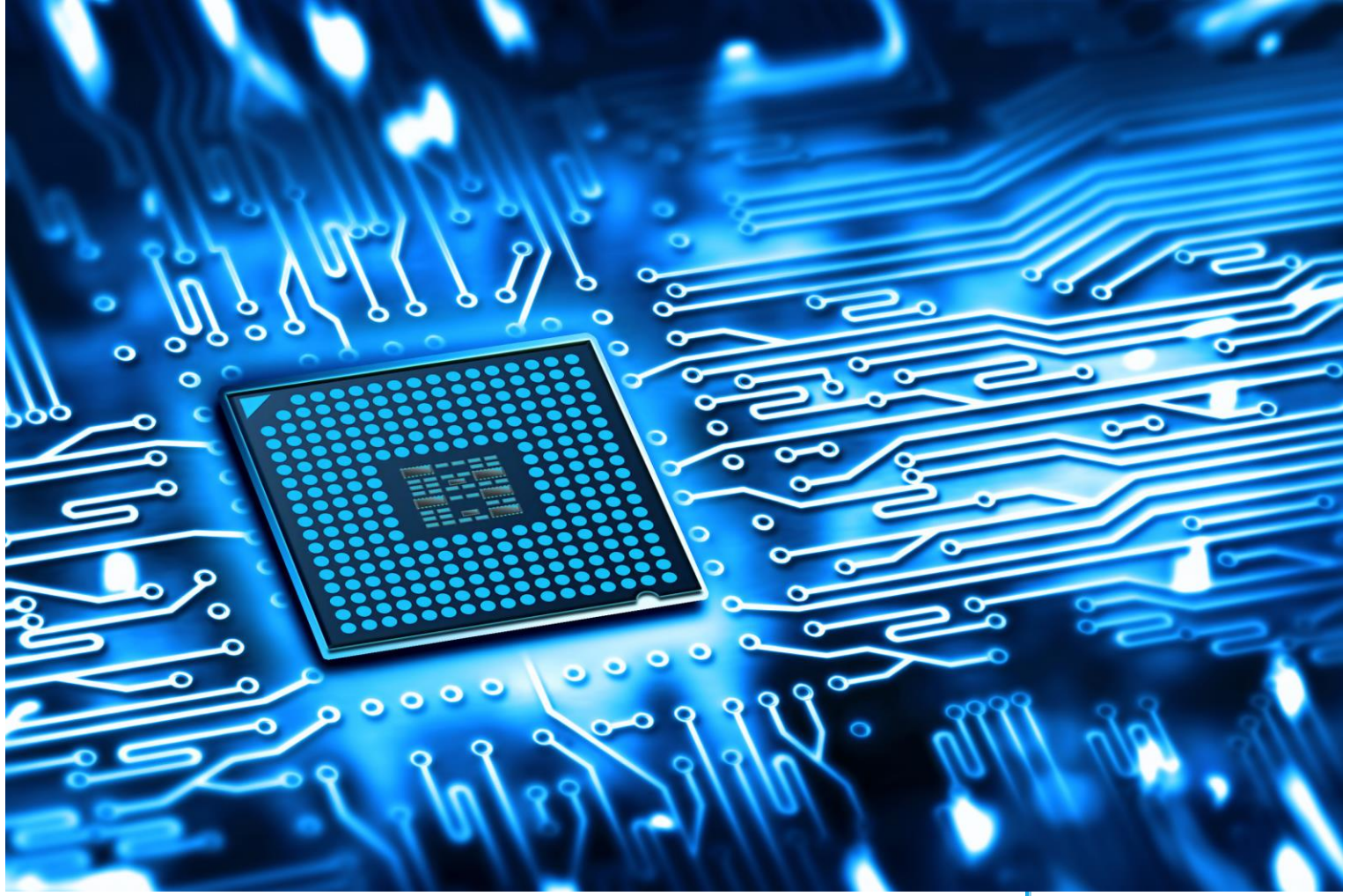
noun

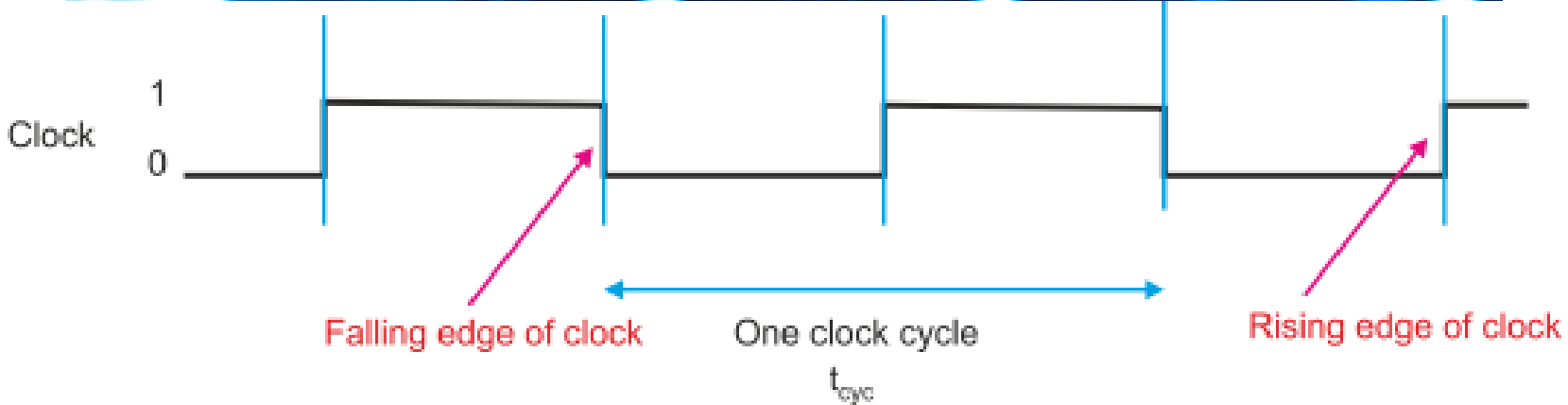
the operation or activity of two or more things at the same time or rate.
"lack of synchronization between the dancers made it look clumsy"

- adjustment of a clock or watch to show the same time as another.
  "clock synchronization between cities"
- COMPUTING
  the action of causing a set of data or files to remain identical in more than one location.
  "folder synchronization allows users on different computers to use shared data sources"

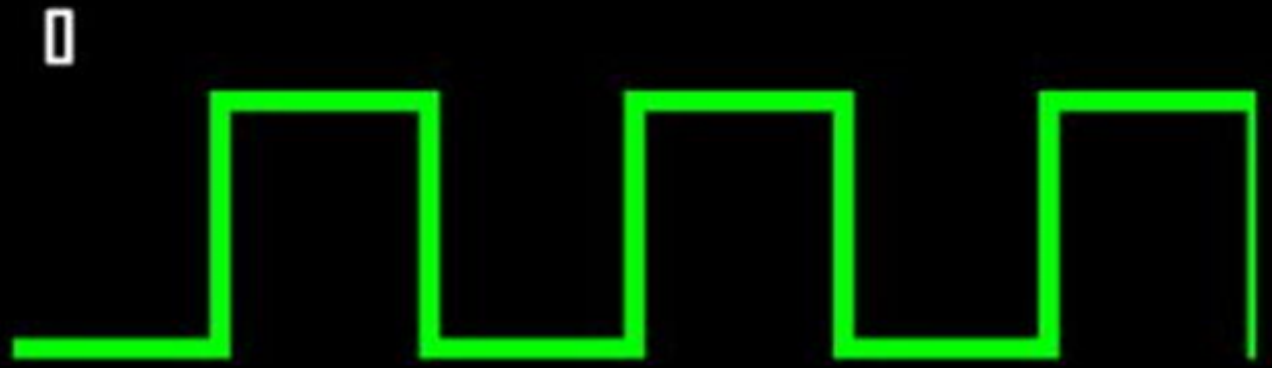
Translations, word origin, and more definitions


NARA, JAPAN
SUBSCRIBE




Clock
1
0
Falling edge of clock
One clock cycle
t_{cyc}
Rising edge of clock

Clock speed



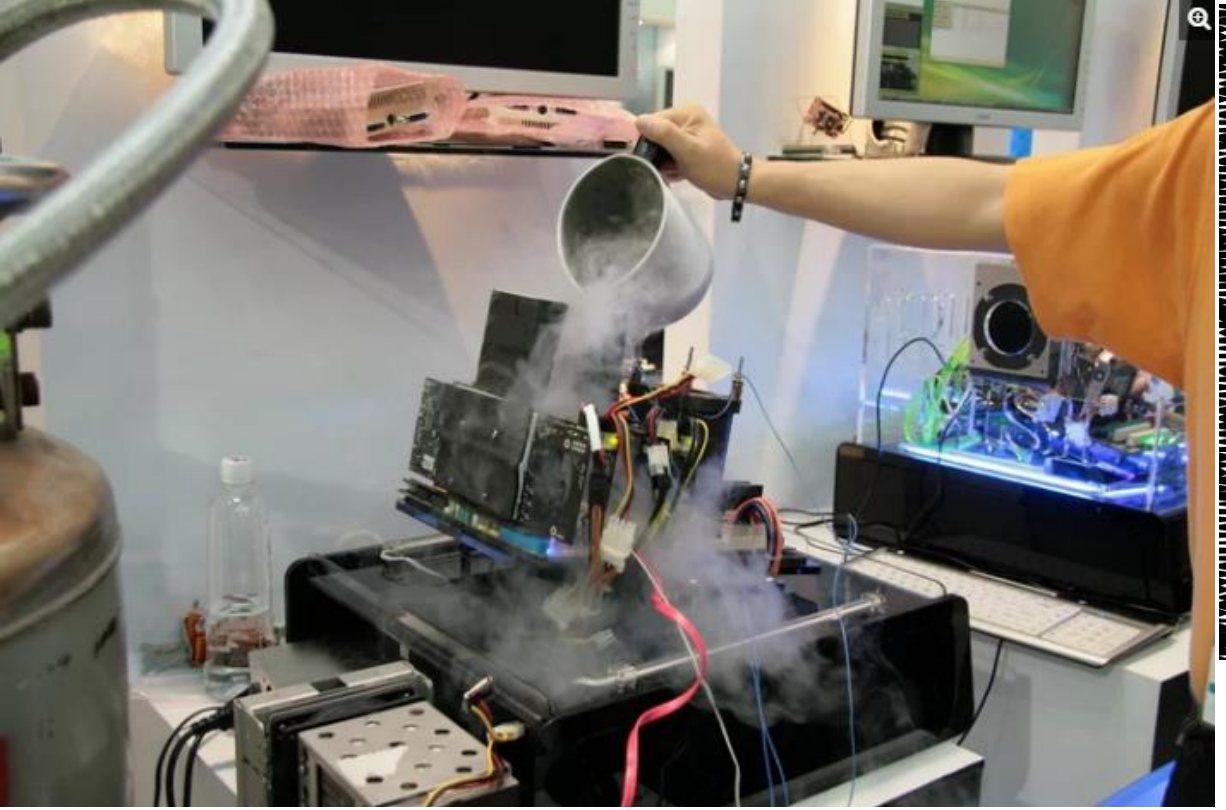
Slow

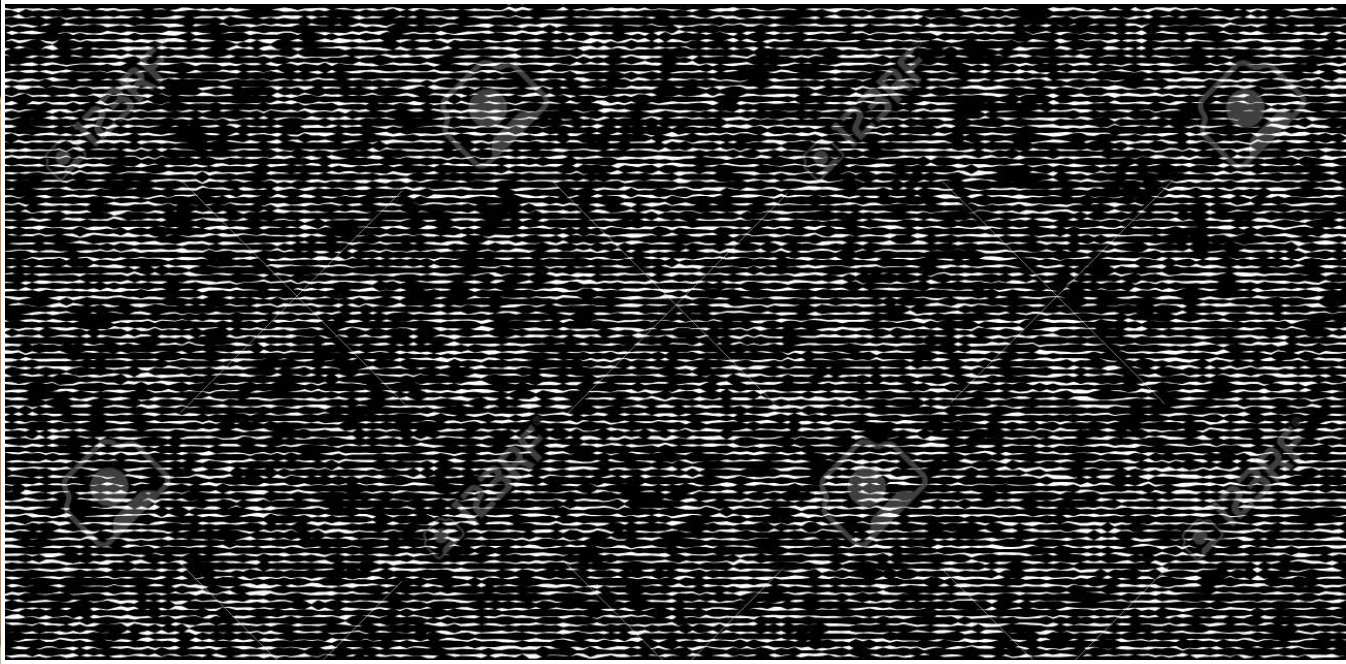
Less cycles per second = **less** instructions processed per second

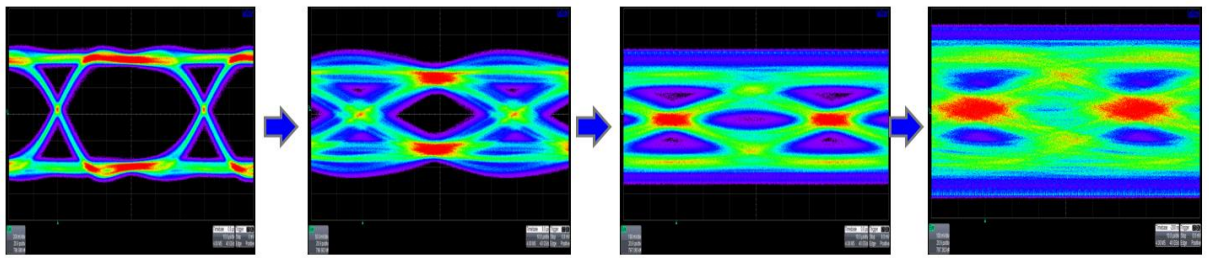
Fast

More cycles per second = **more** instructions processed per second

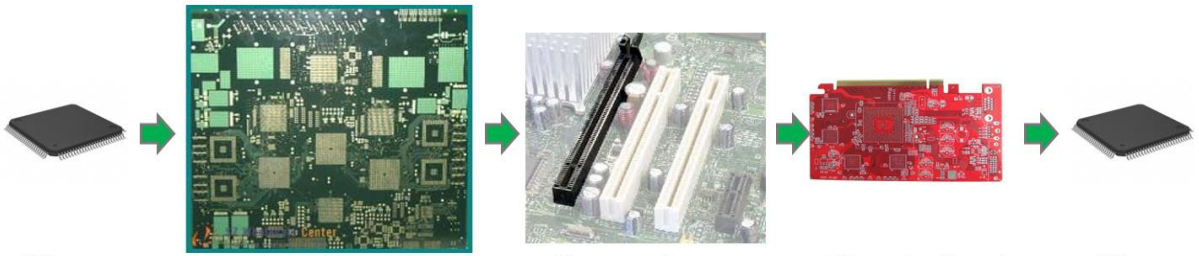
Cycles per second are measured in Hertz (Hz).
A gigahertz (GHz) is 1000 million cycles per second!

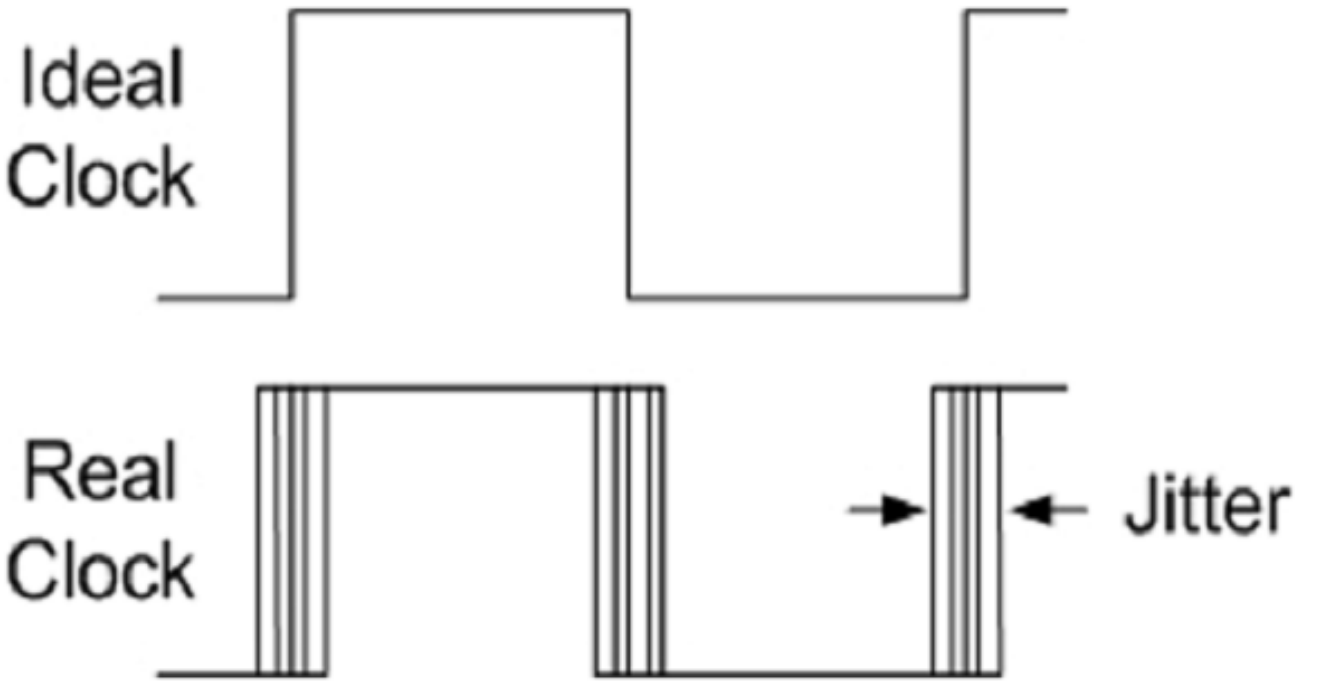


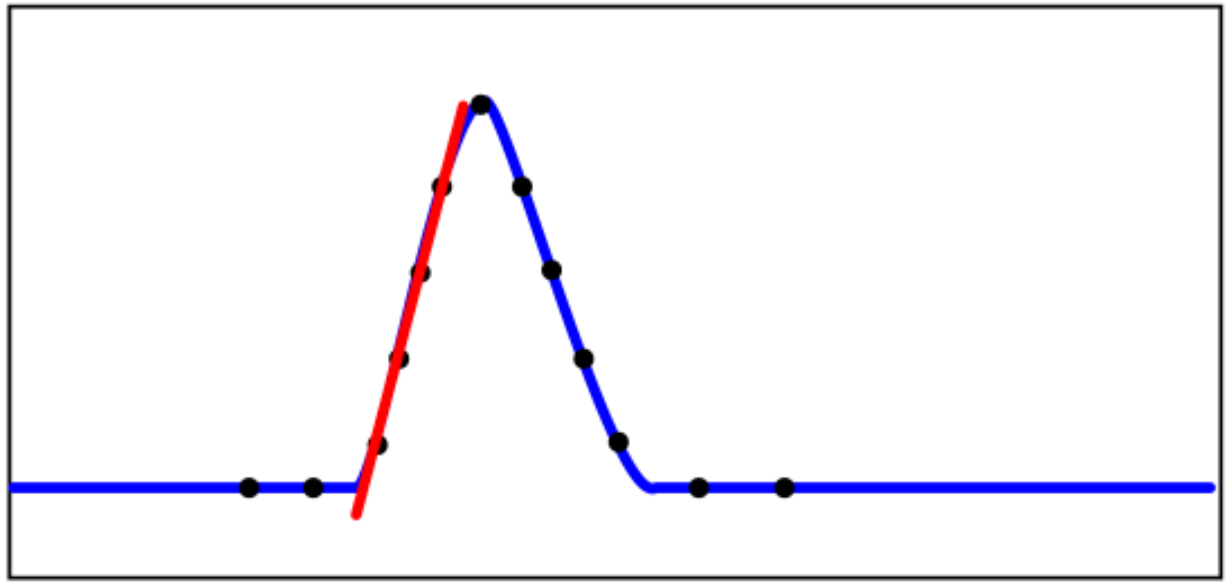




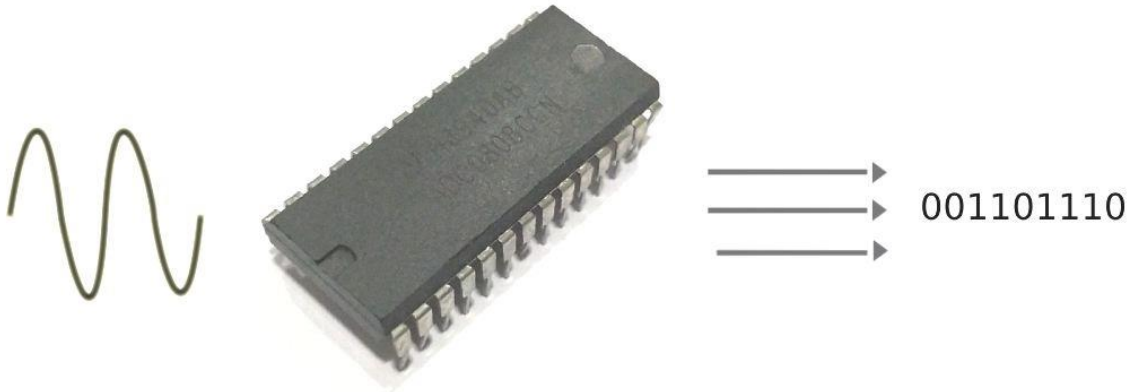
Signal degrades over long transmission path and connectors



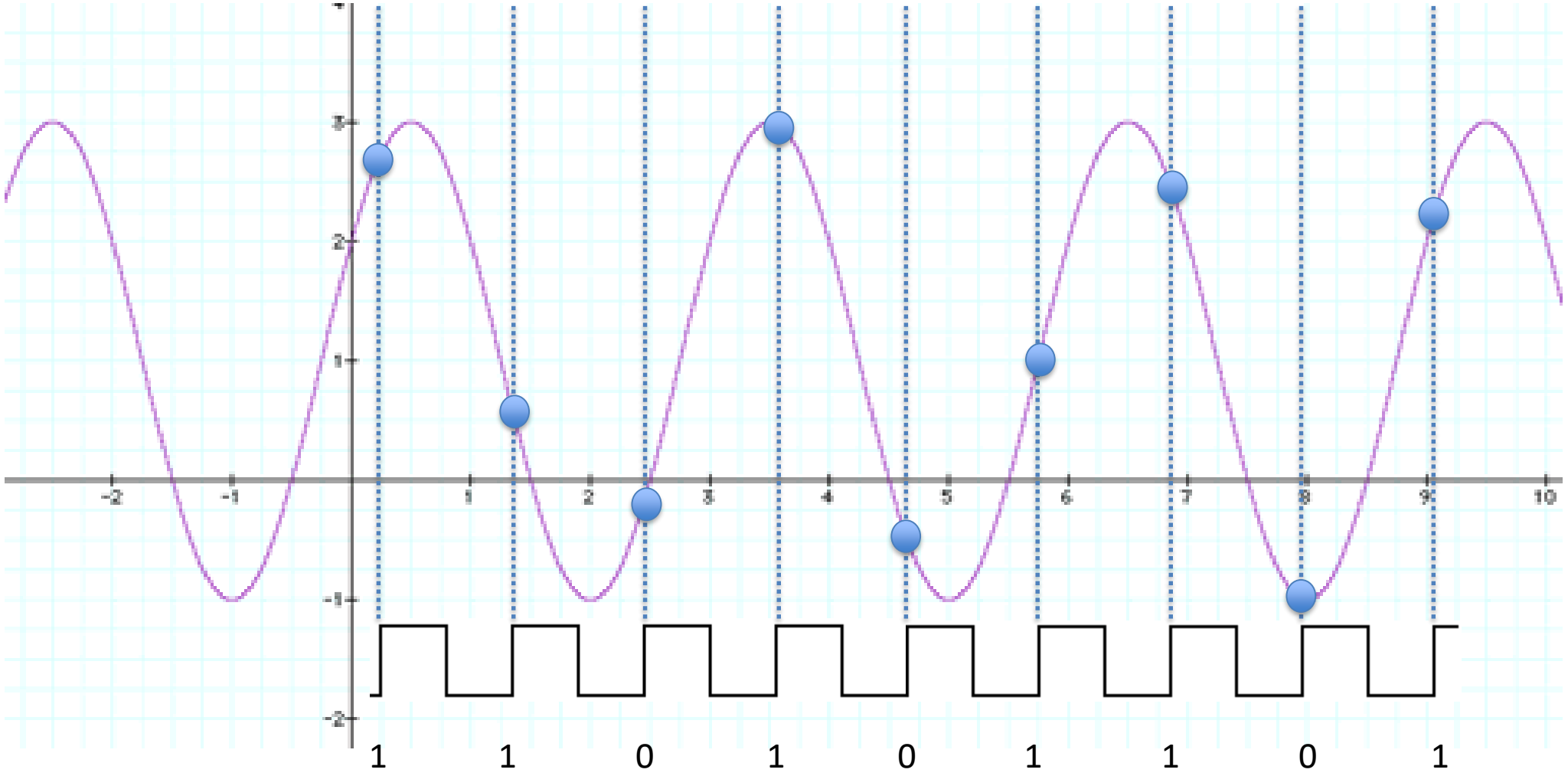




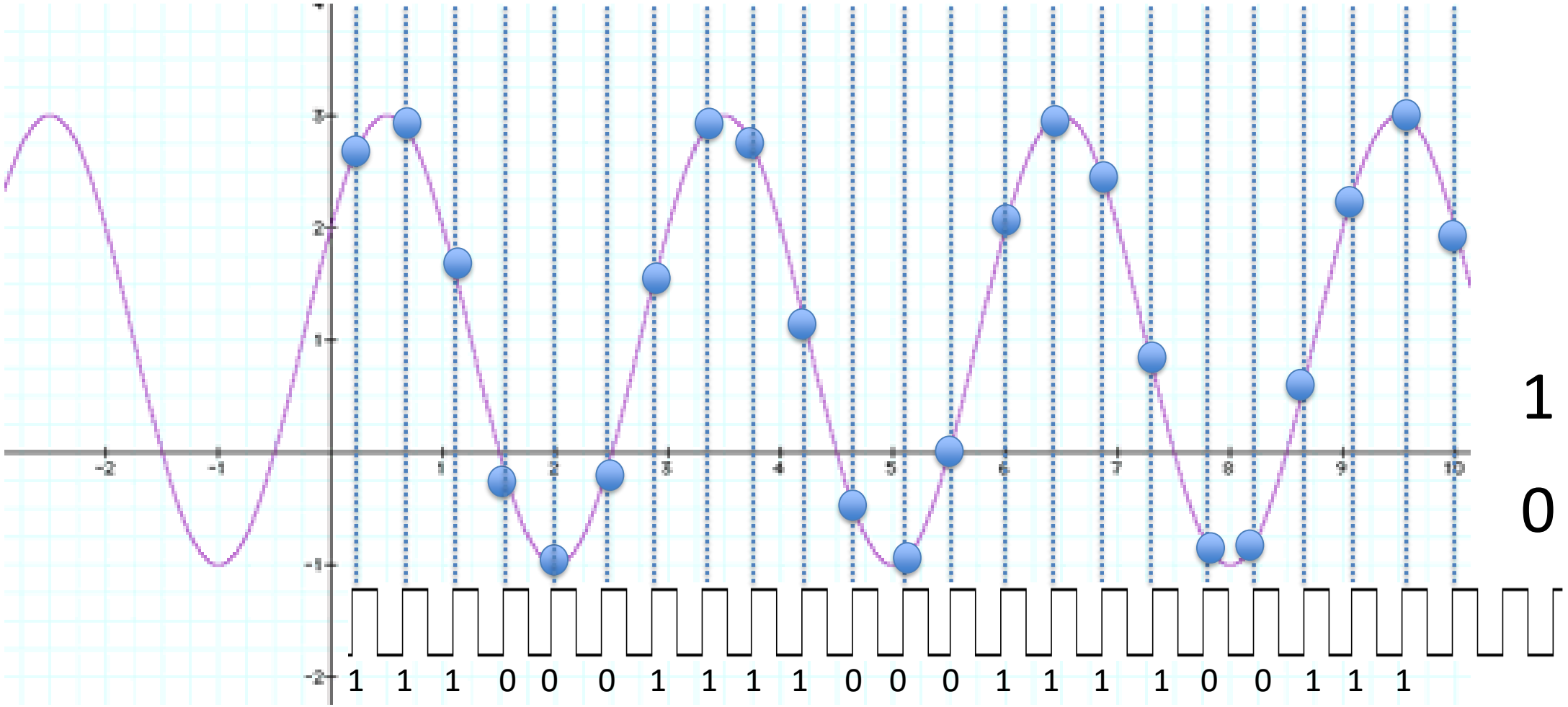
Analog to Digital Converters

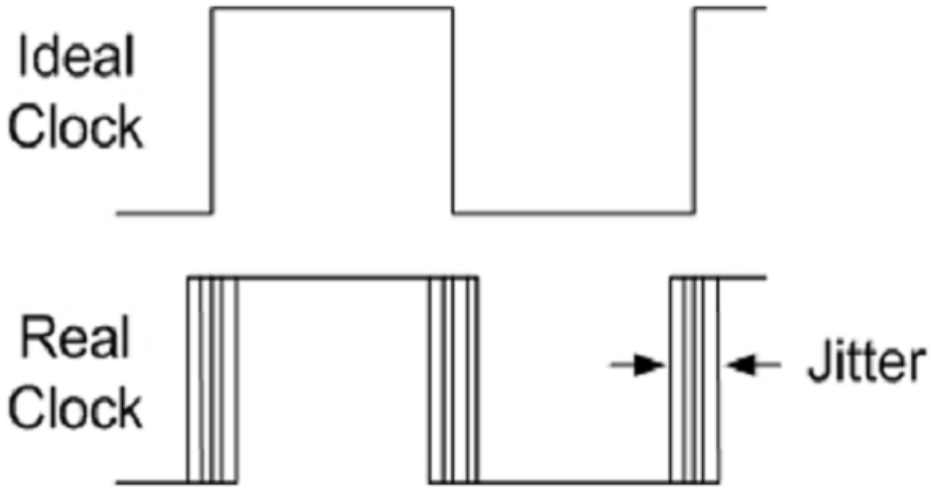


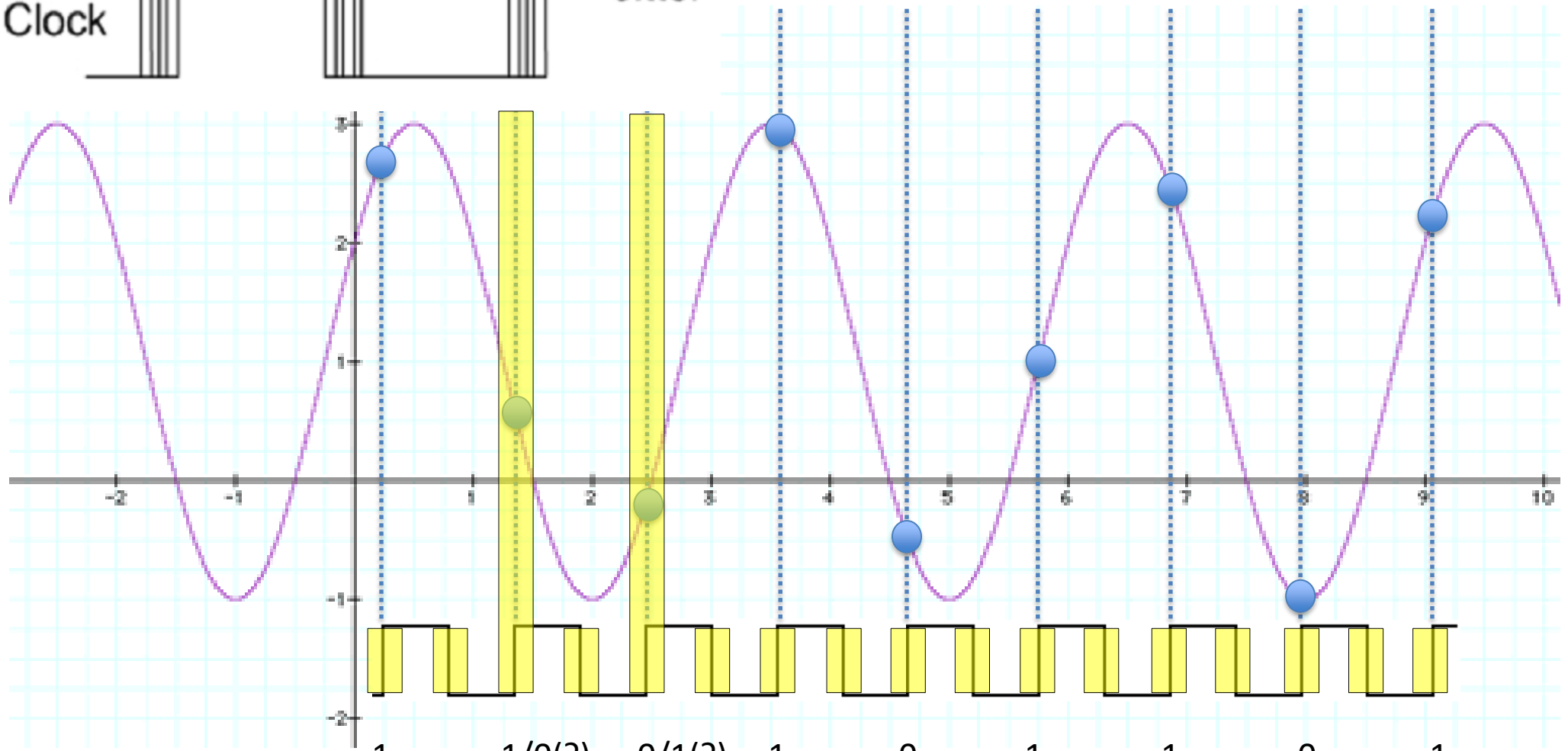
ADC sampling



ADC sampling

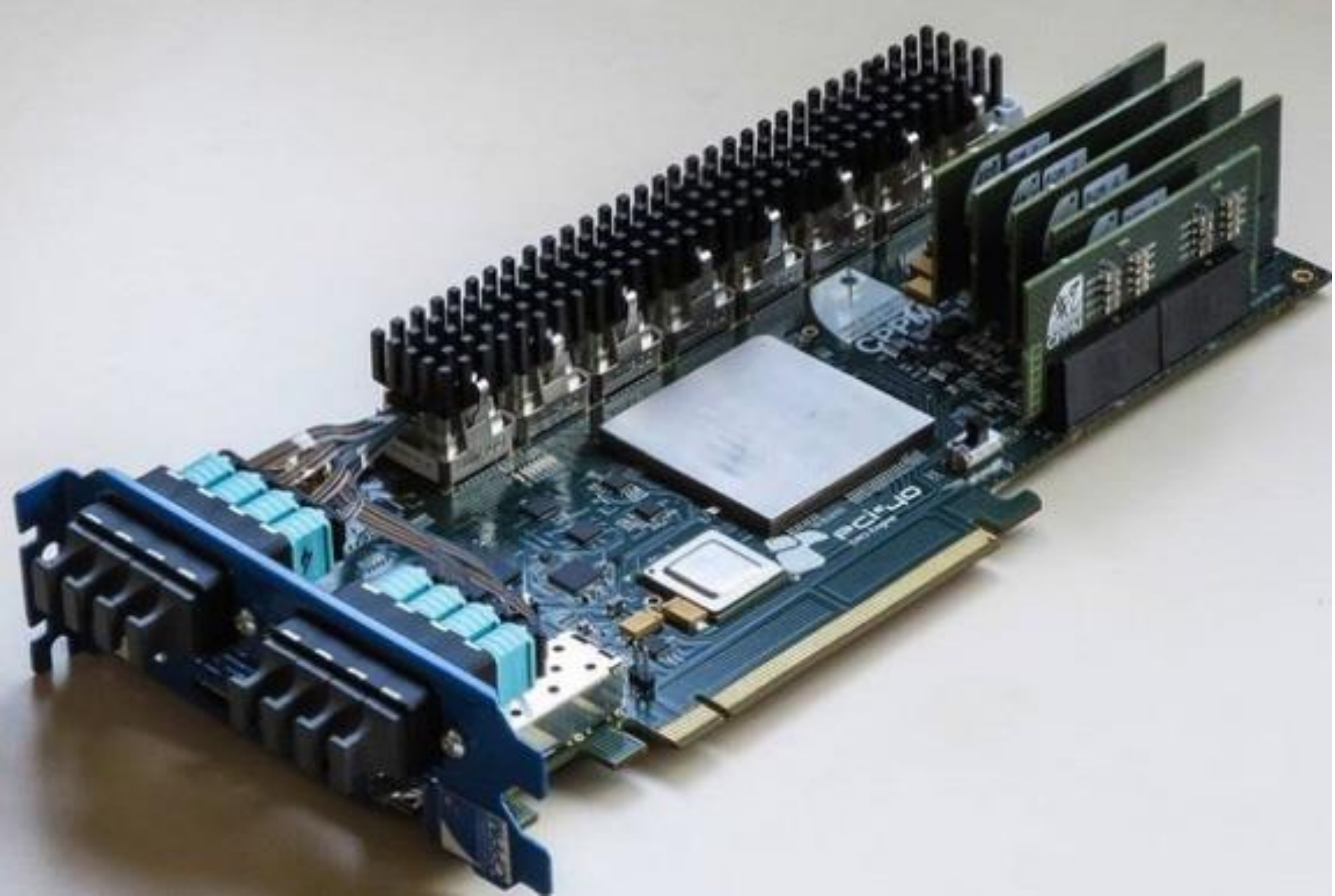


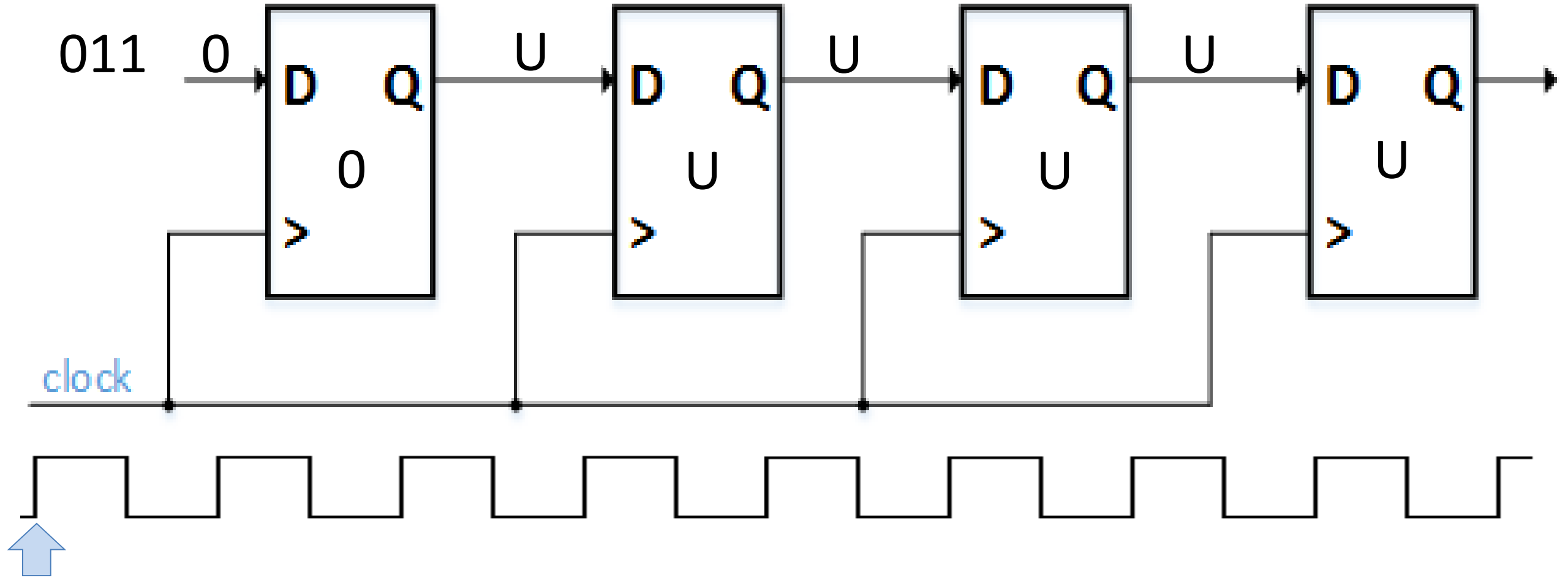


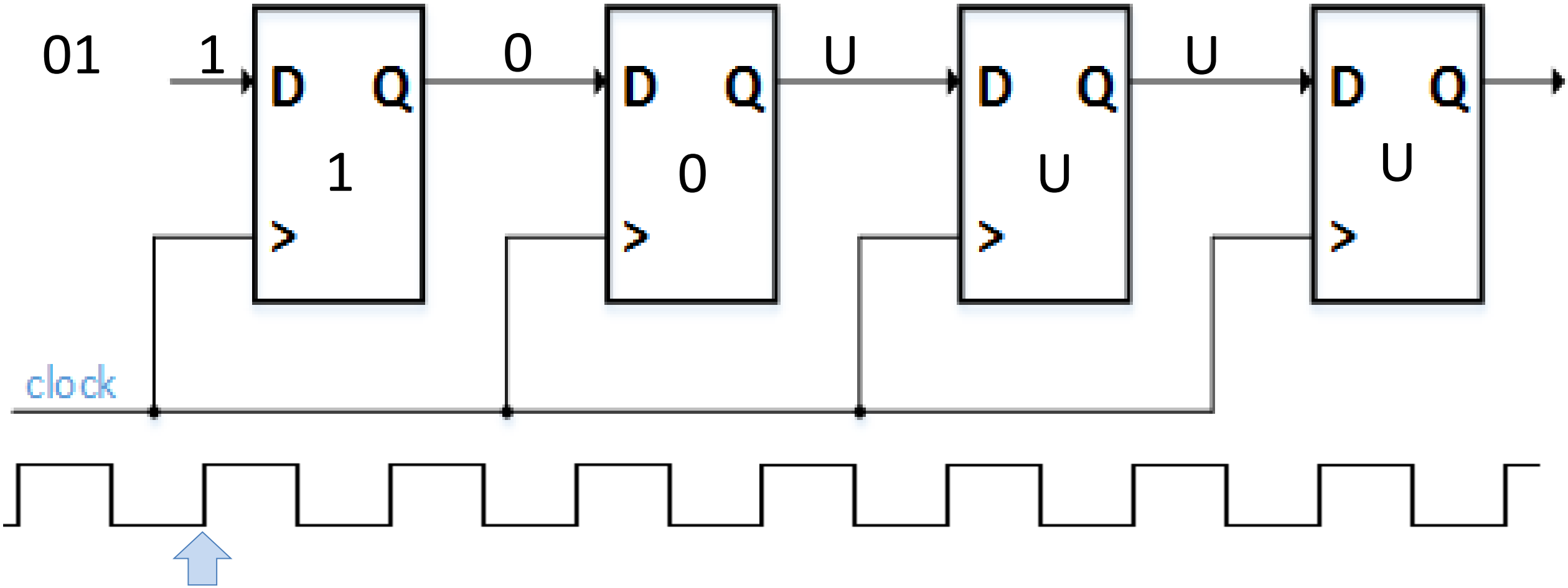


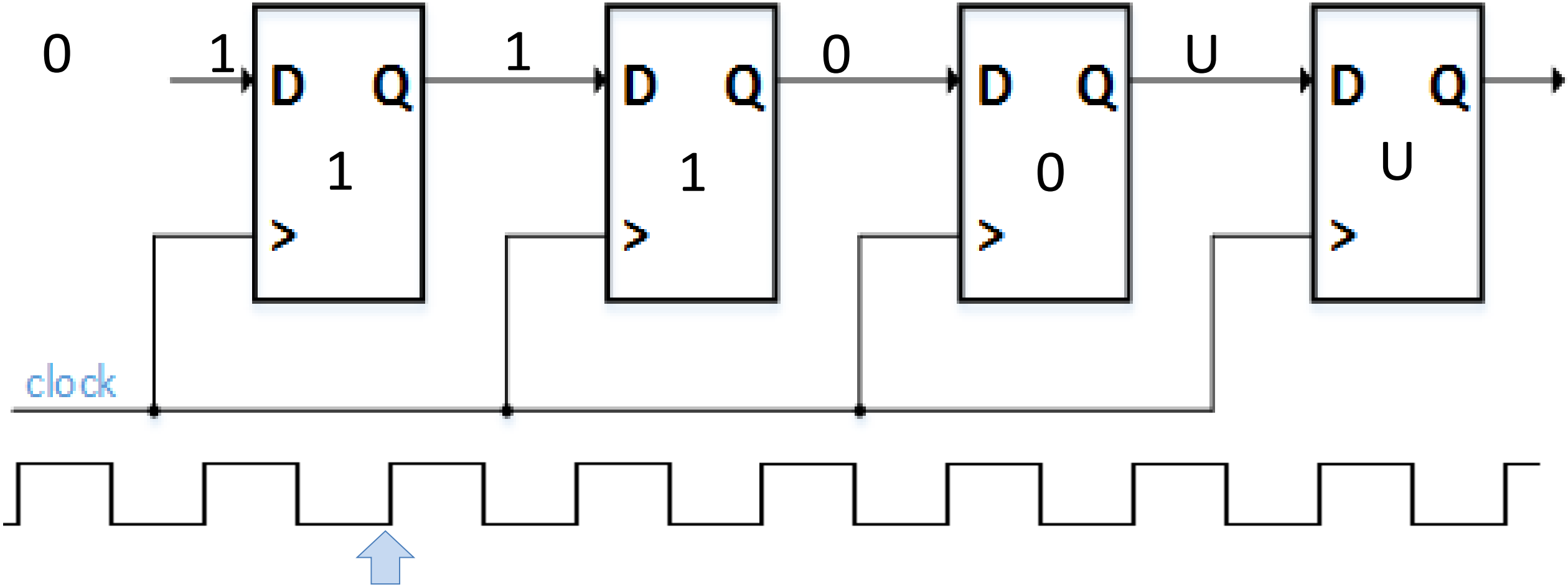
1

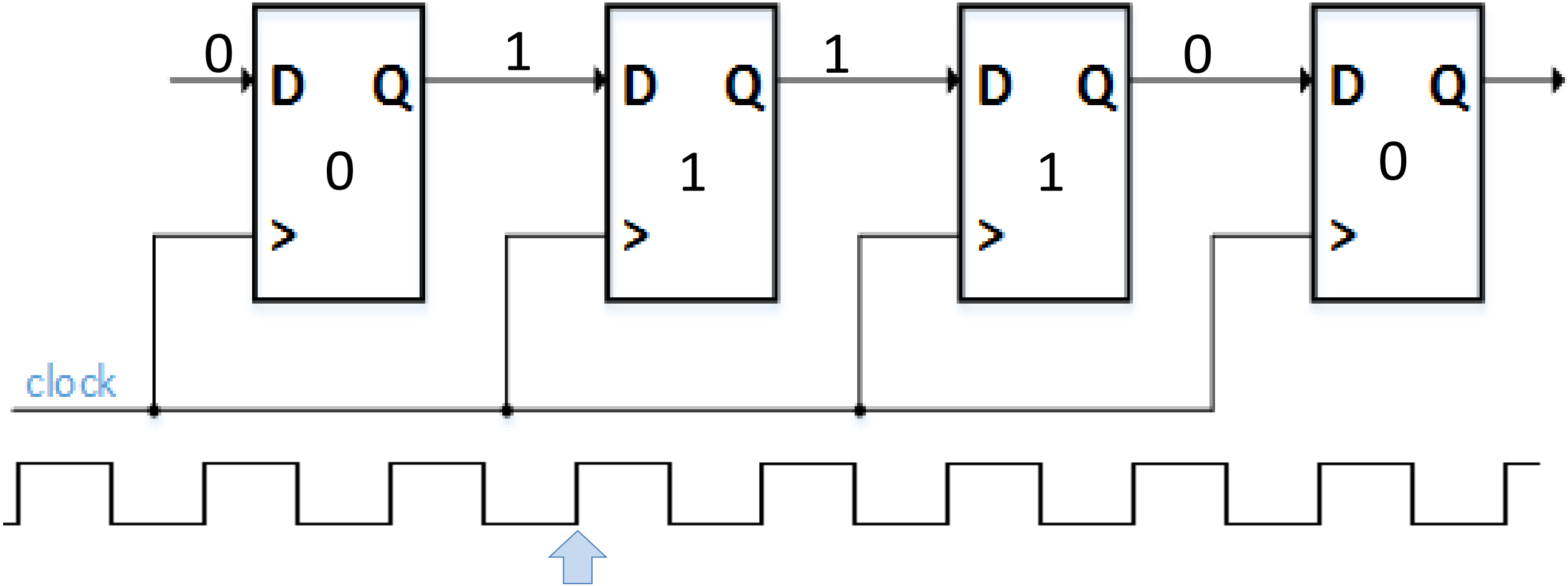
0

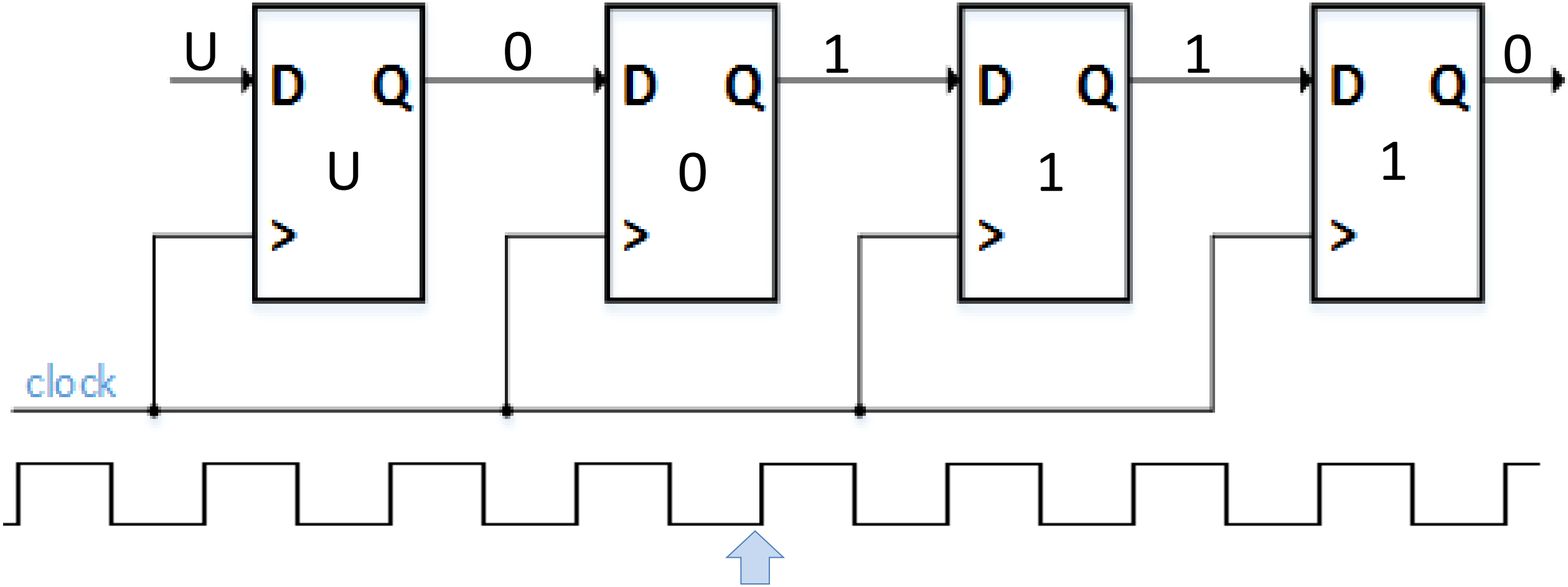


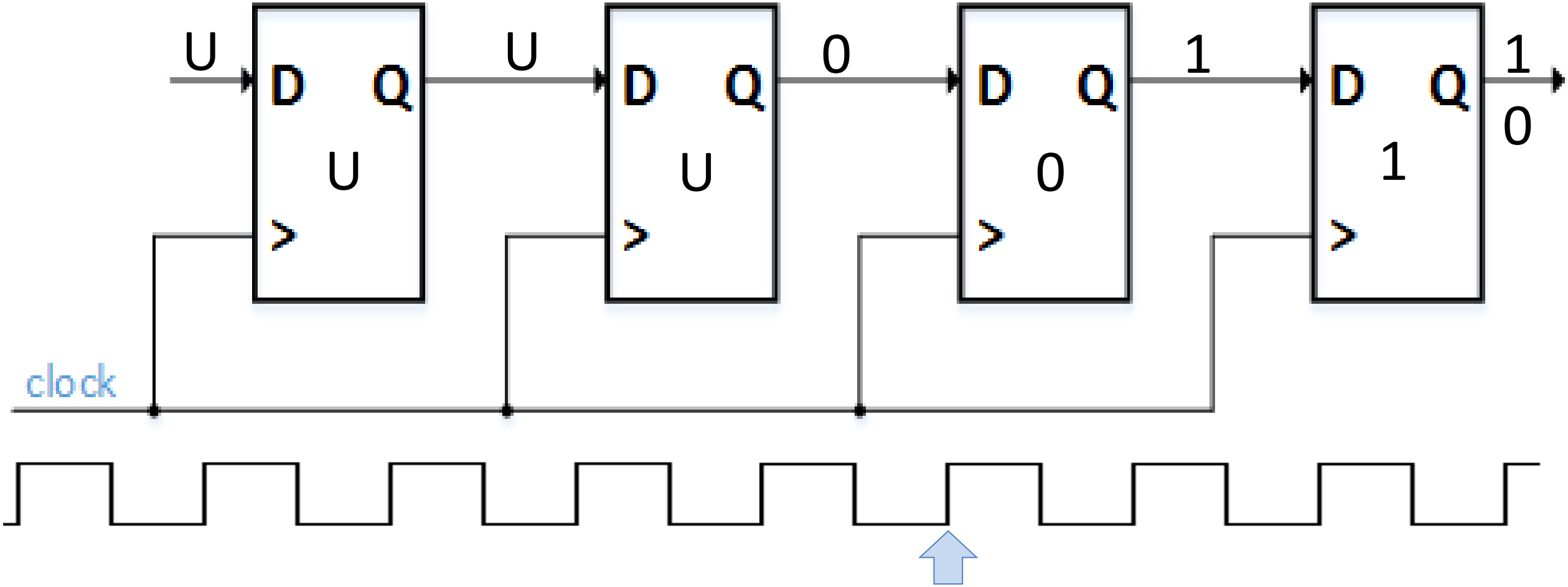

011
0
D
Q
0
>
U
D
Q
U
>
U
D
Q
U
>
U
D
Q
U
>
clock

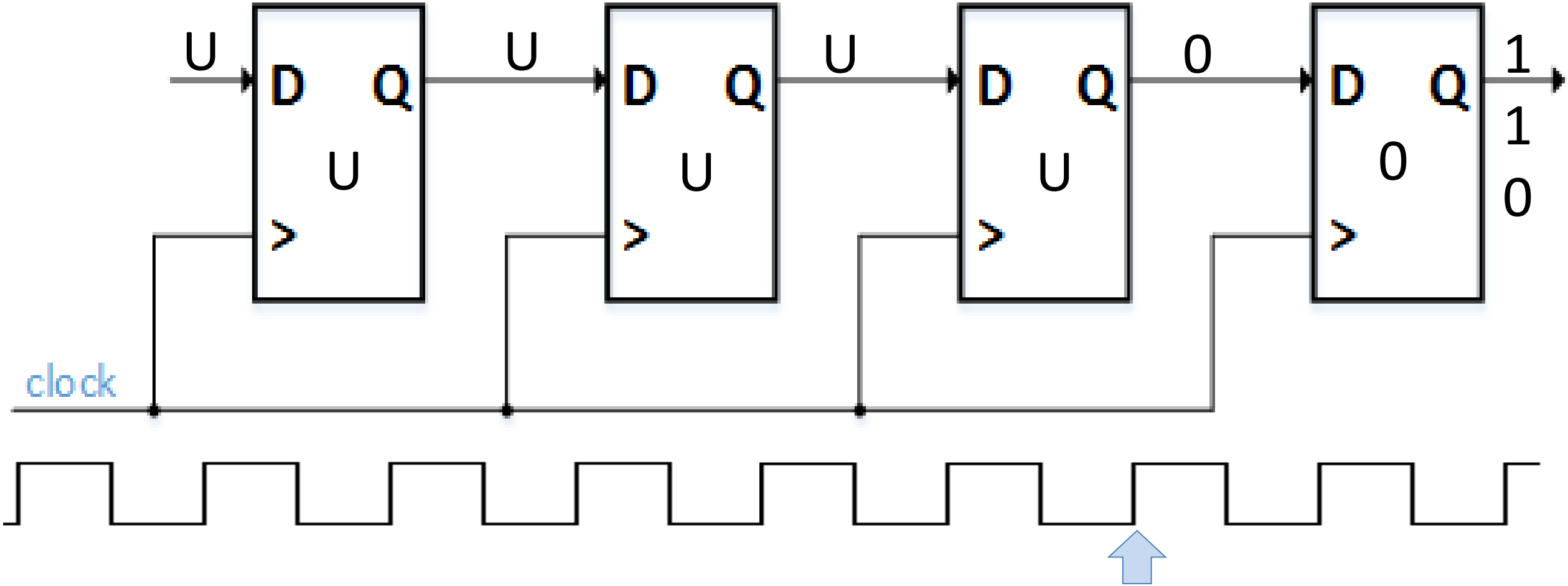

01
1
D
Q
1
>
0
D
Q
0
>
U
D
Q
U
>
U
D
Q
U
>
clock

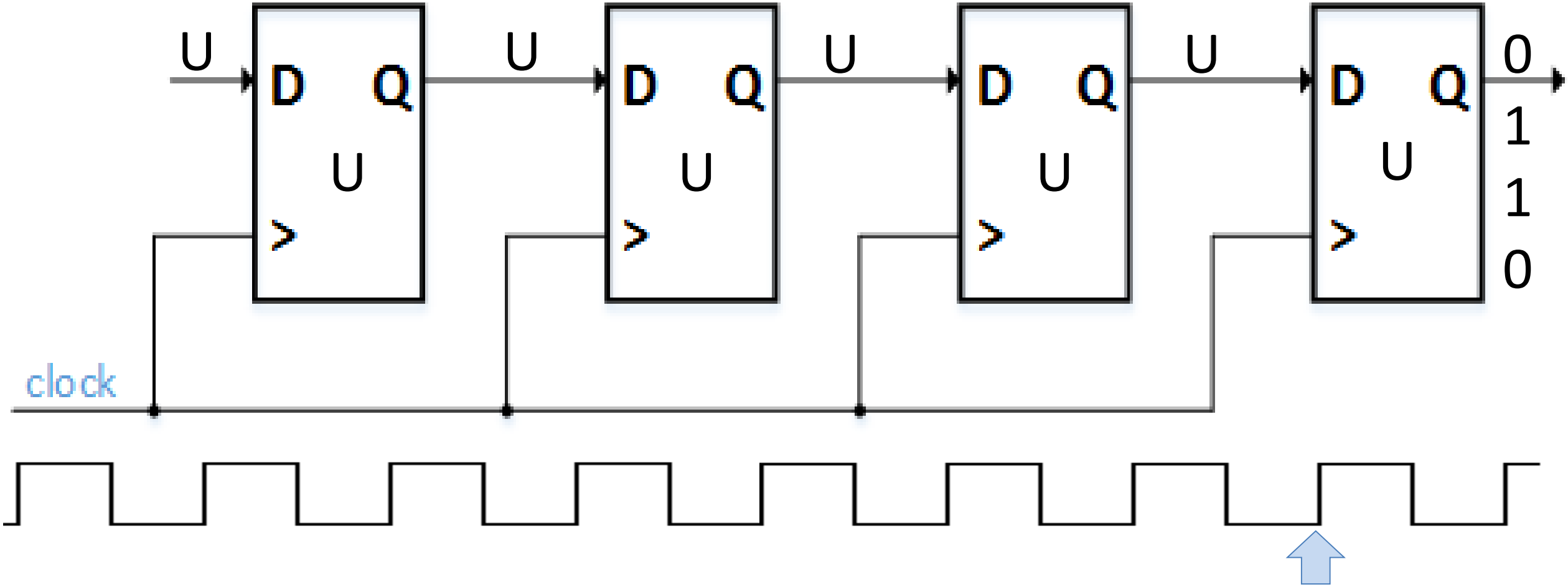

0
1
D
Q
1
>
1
D
Q
1
>
0
D
Q
0
>
U
D
Q
U
>
clock

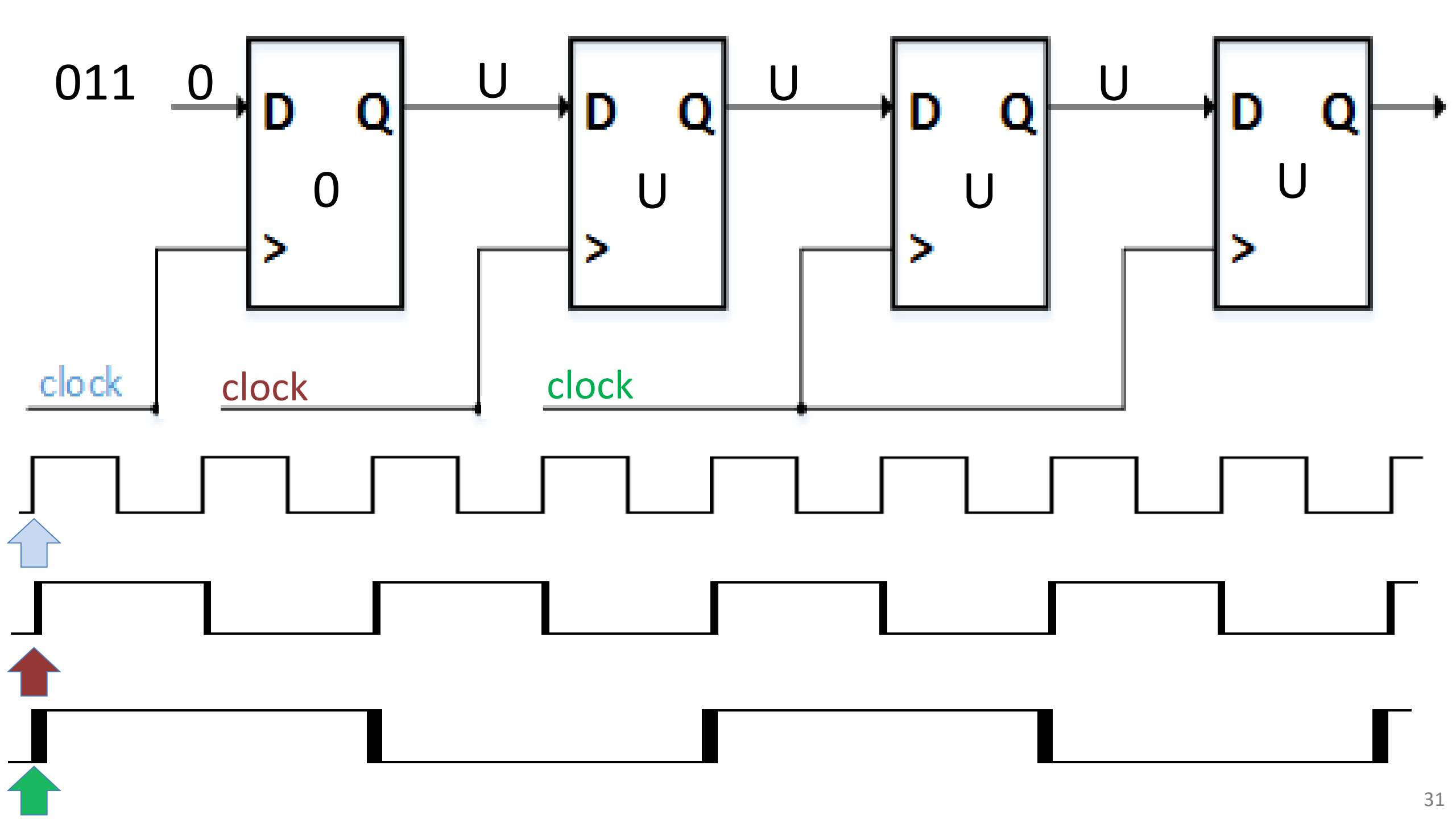

0
D
Q
0
>
1
D
Q
1
>
1
D
Q
1
>
0
D
Q
0
>
clock

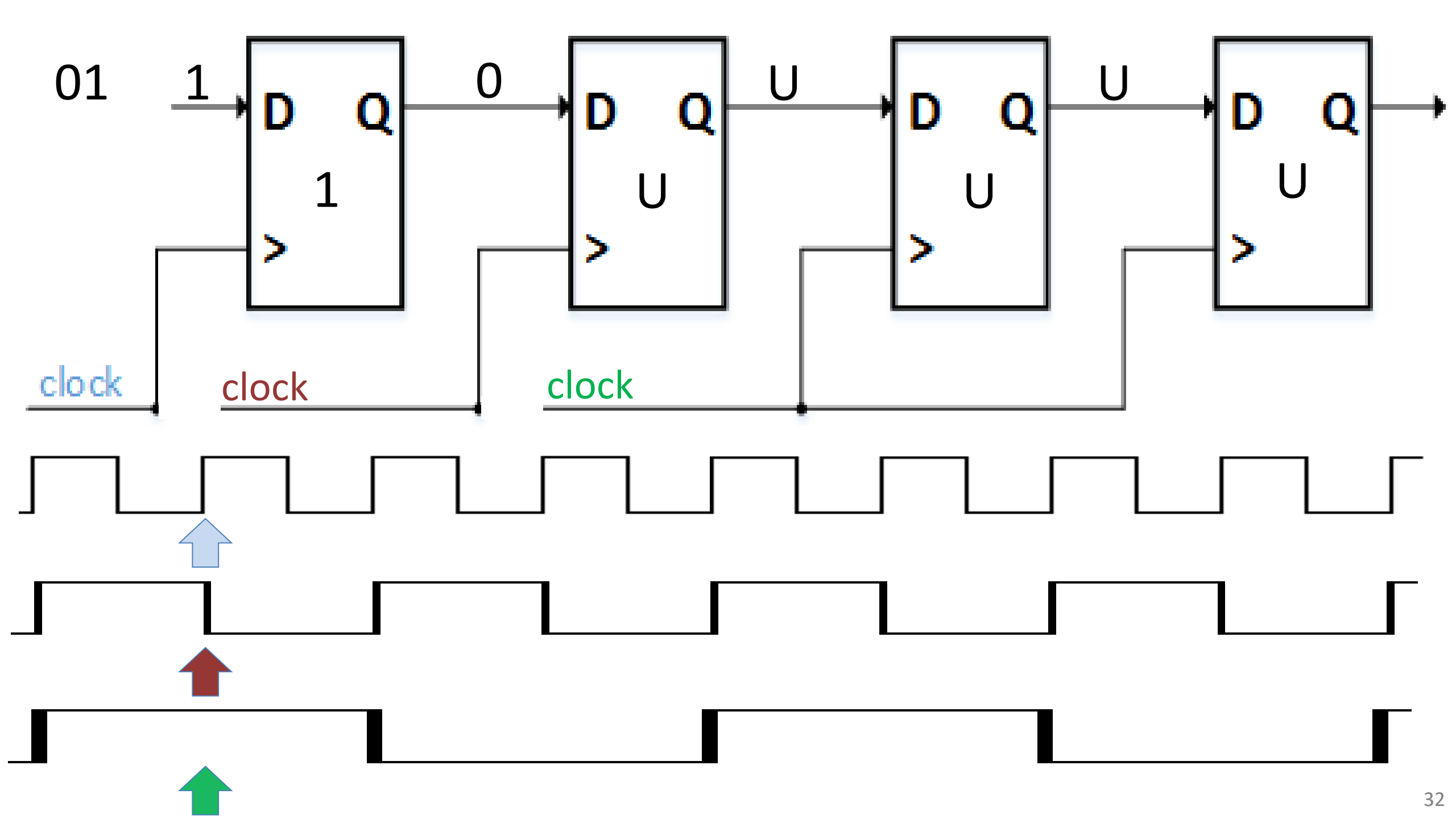

U
D
Q
U
>
0
D
Q
0
>
1
D
Q
1
>
1
D
Q
1
>
0
clock

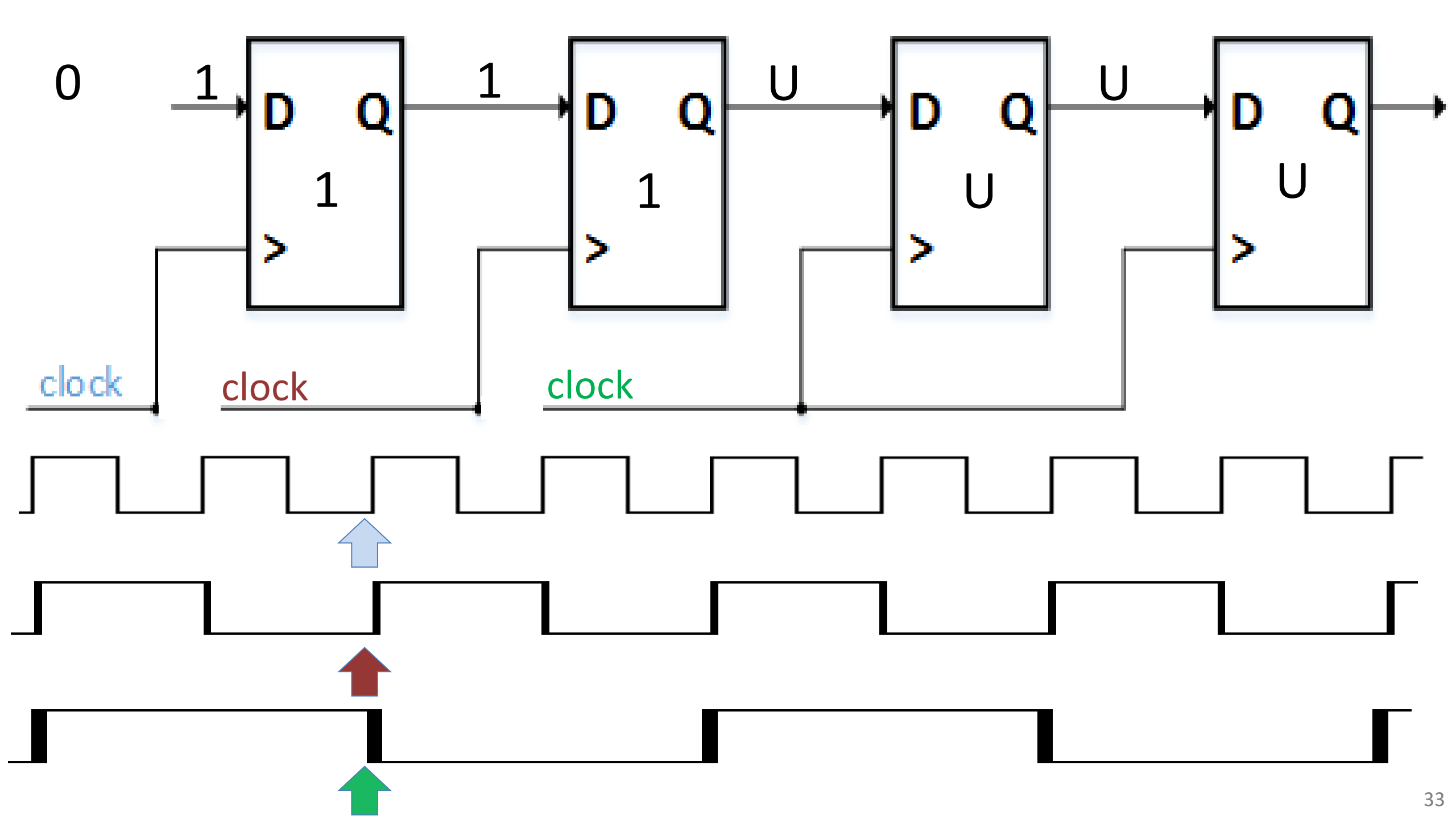

U
D
Q
U
>
U
D
Q
U
>
0
D
Q
0
>
1
D
Q
1
>
1
0
clock

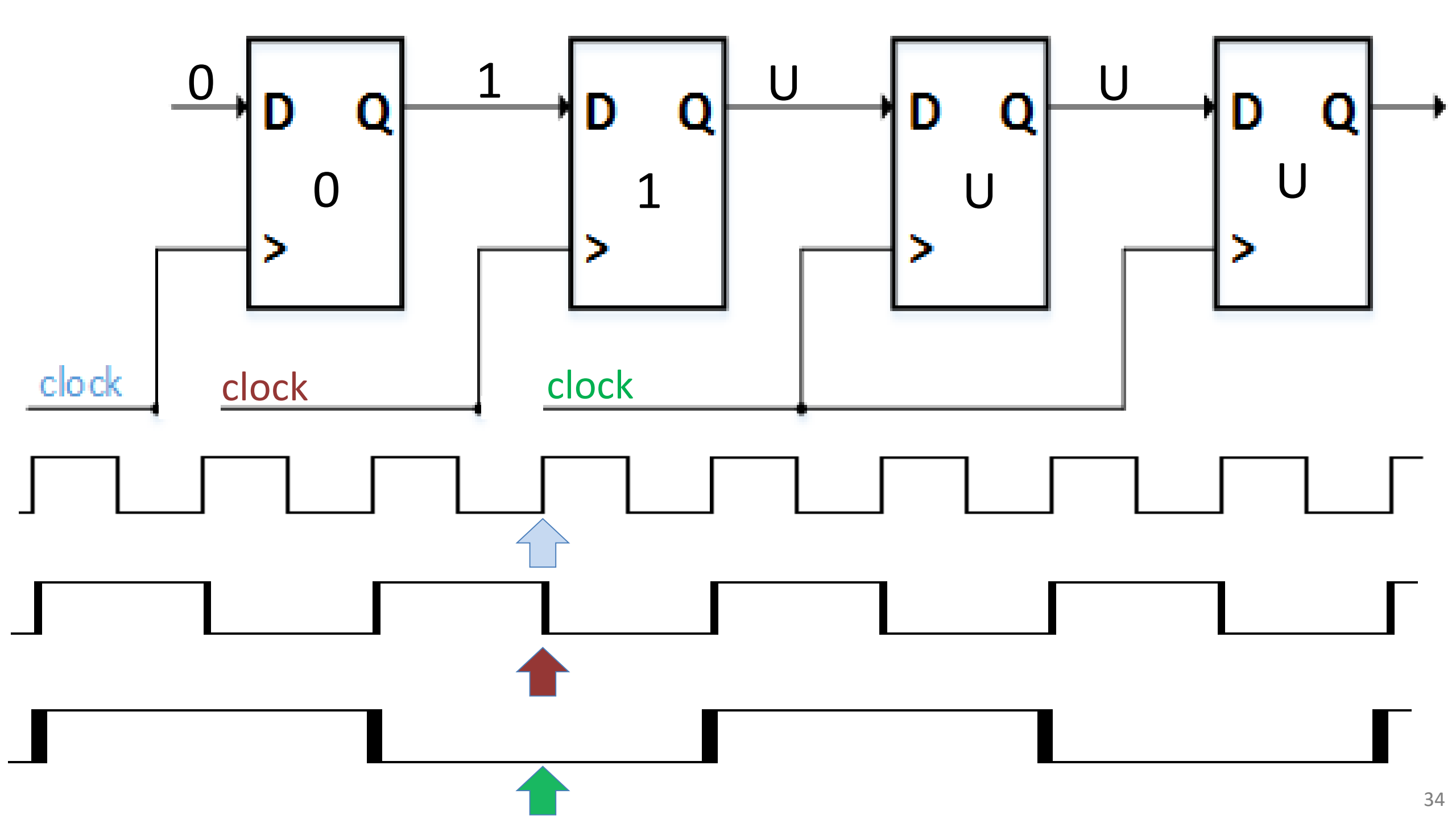

U
D
Q
U
>
U
D
Q
U
>
U
D
Q
U
>
0
D
Q
0
>
1
1
0
clock

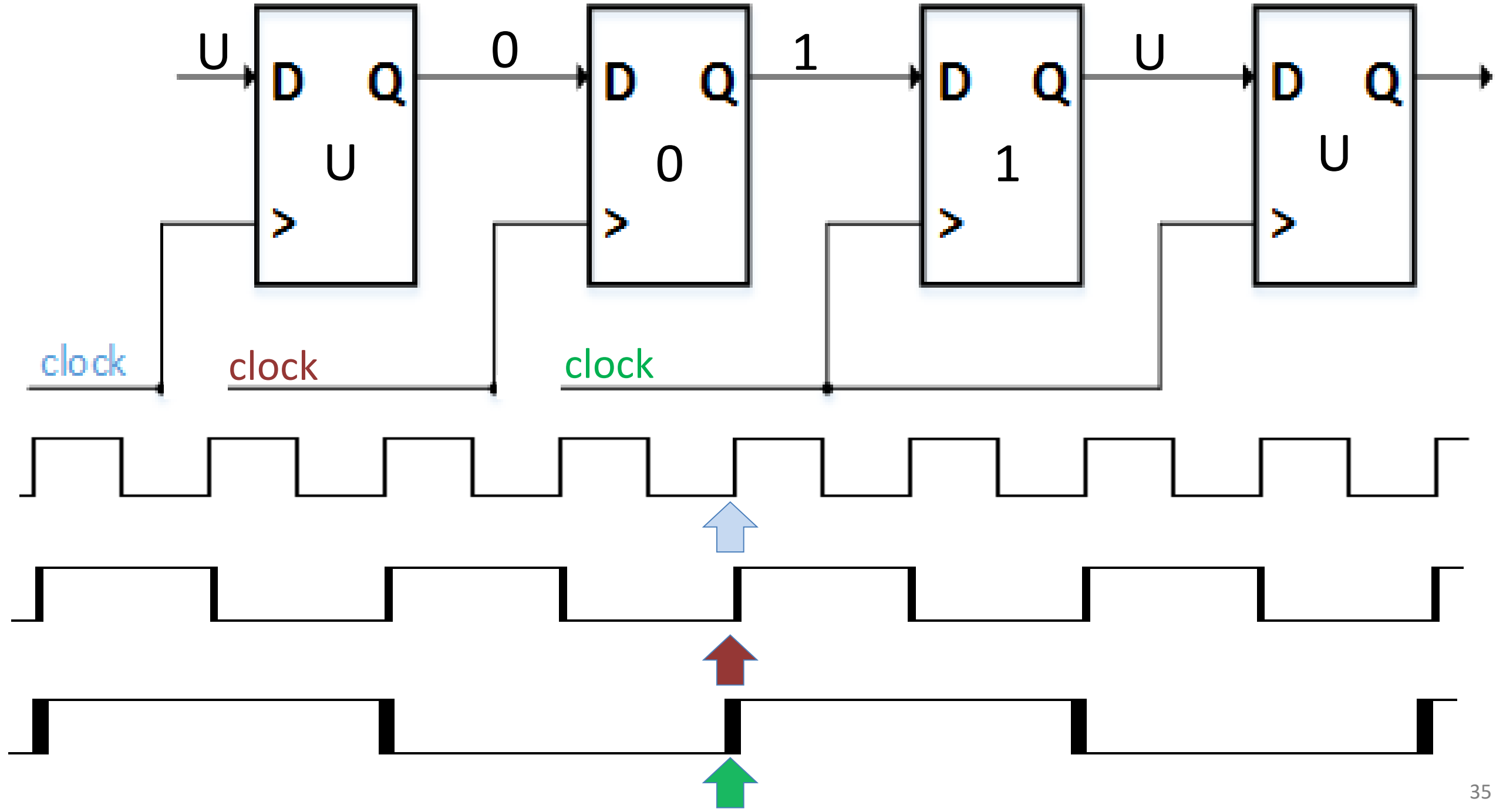

U
D
Q
U
>
U
D
Q
U
>
U
D
Q
U
>
U
D
Q
U
>
0
1
1
0
clock

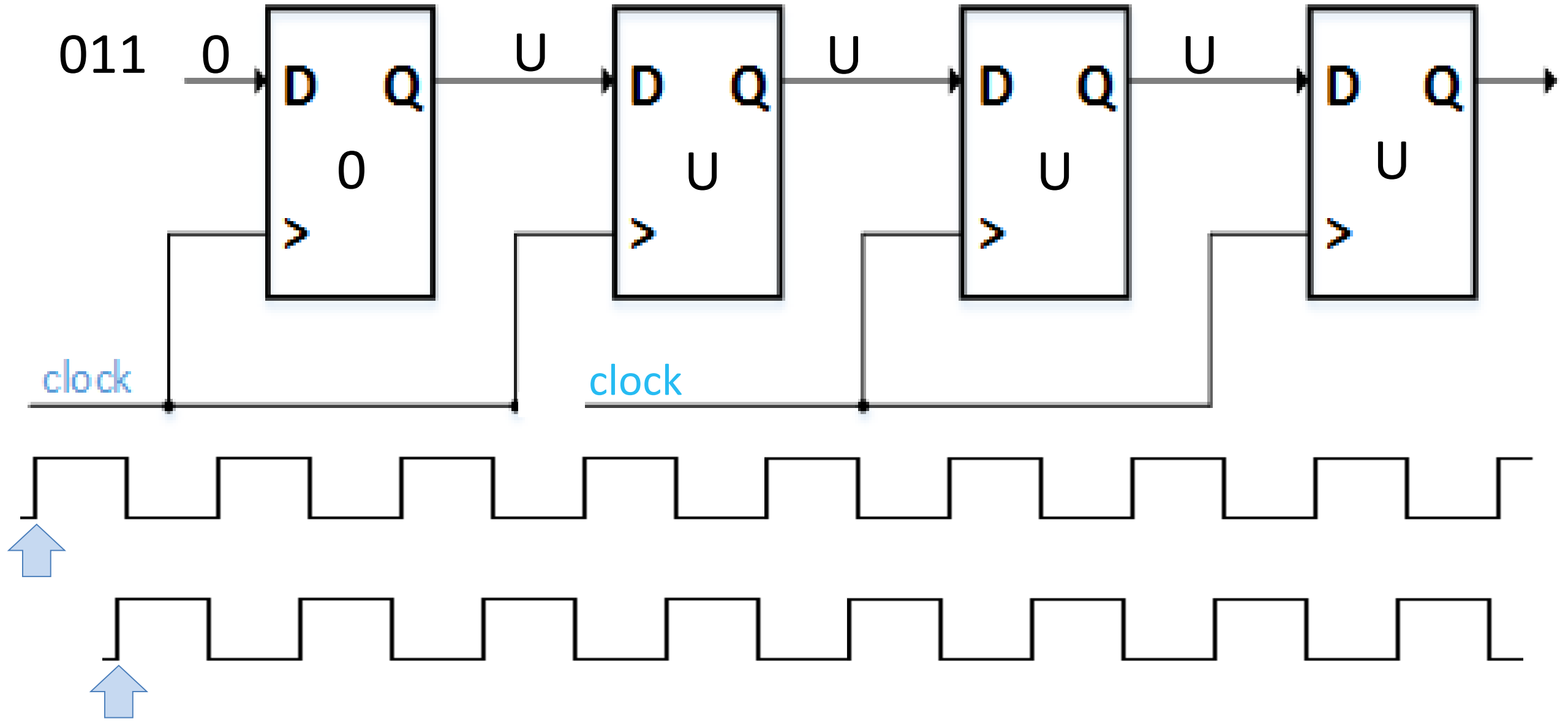

011
0
D
Q
0
>
U
D
Q
U
>
U
D
Q
U
>
U
D
Q
U
>
clock
clock
clock

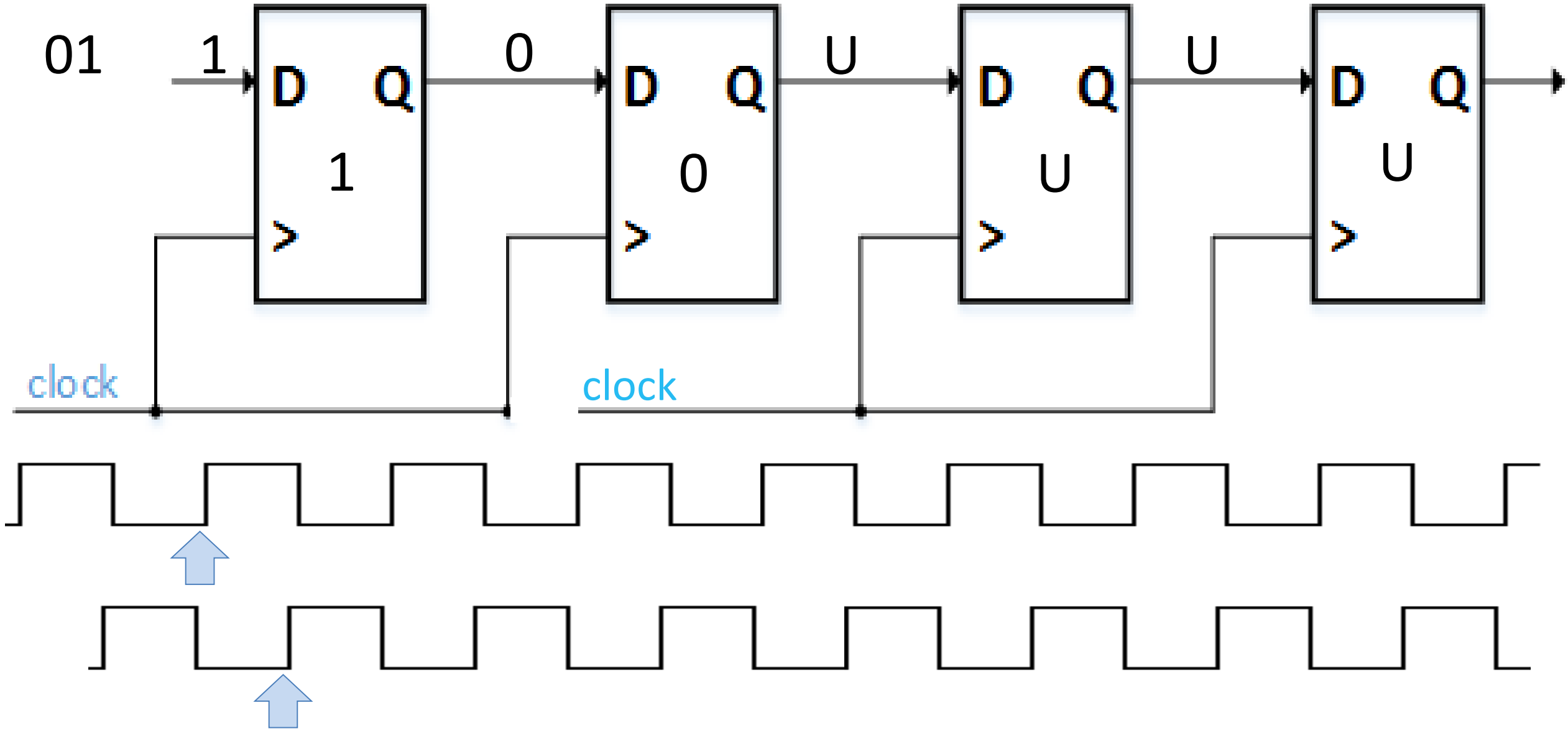

01
1
D
Q
1
>
0
D
Q
U
>
U
D
Q
U
>
U
D
Q
U
>
clock
clock
clock

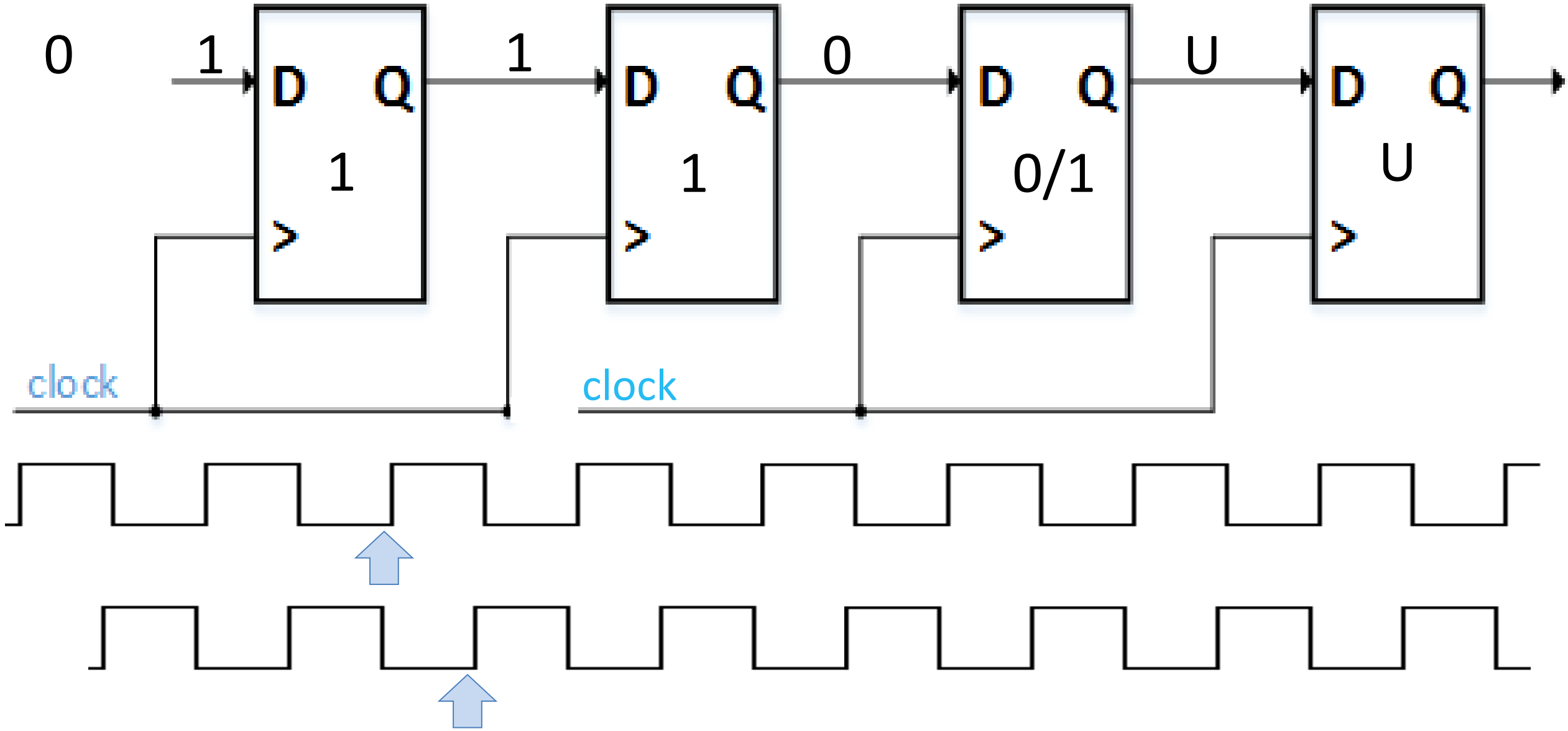

0
1
D
Q
1
>
1
D
Q
1
>
U
D
Q
U
>
U
D
Q
U
>
clock
clock
clock

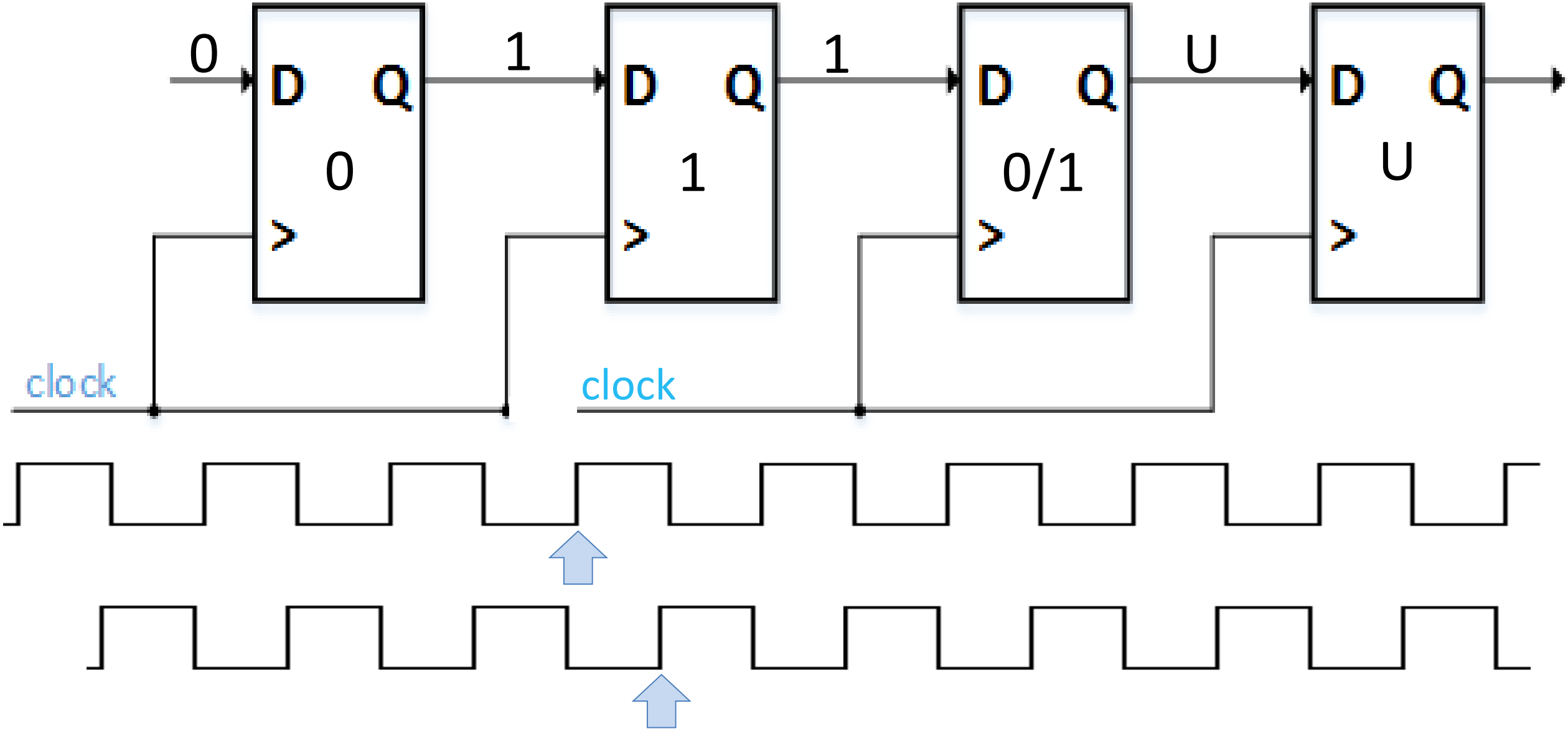

0
D
Q
0
>
1
D
Q
1
>
U
D
Q
U
>
U
D
Q
U
>
clock
clock
clock

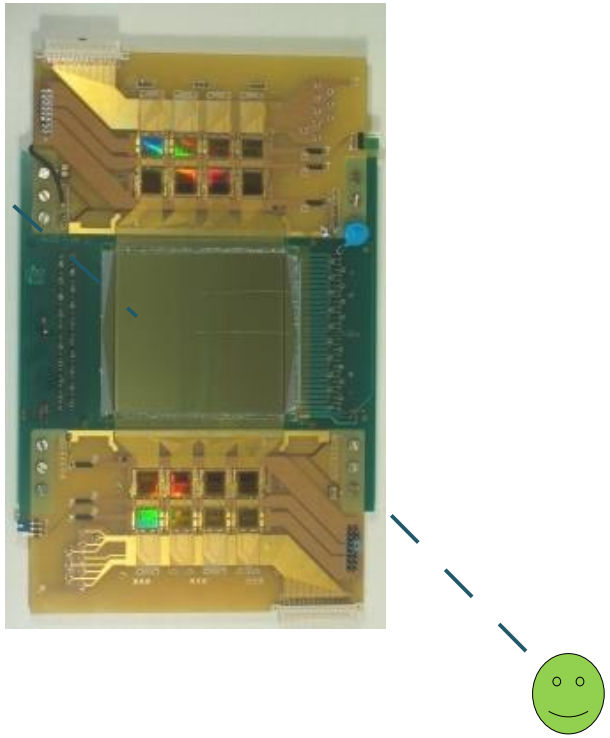

U
D
Q
U
0
D
Q
0
1
D
Q
1
U
D
Q
U
clock
clock
clock

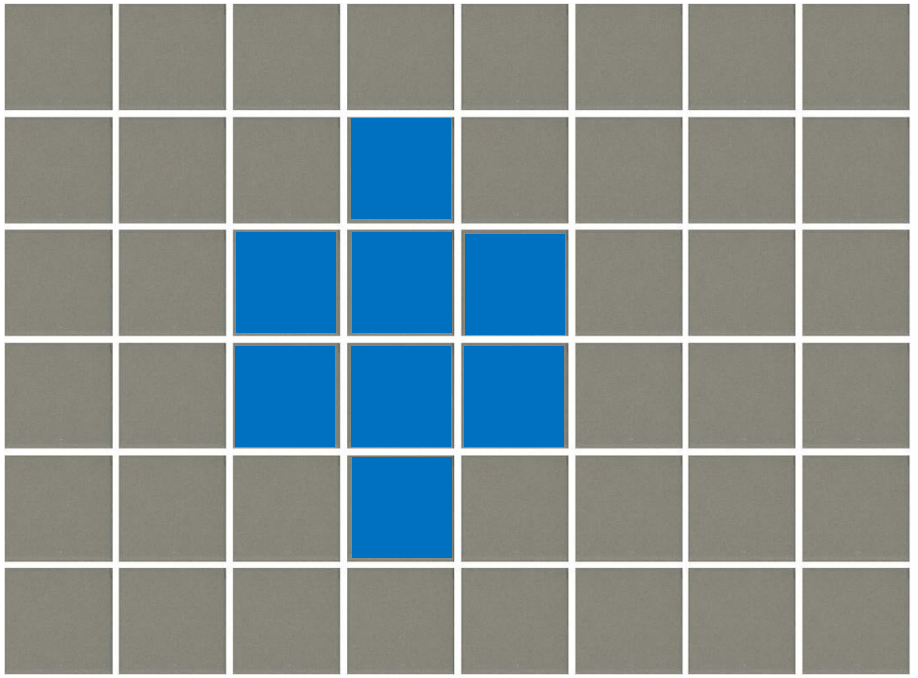

011
0
D
Q
0
>
U
D
Q
U
>
U
D
Q
U
>
U
D
Q
U
>
clock
clock

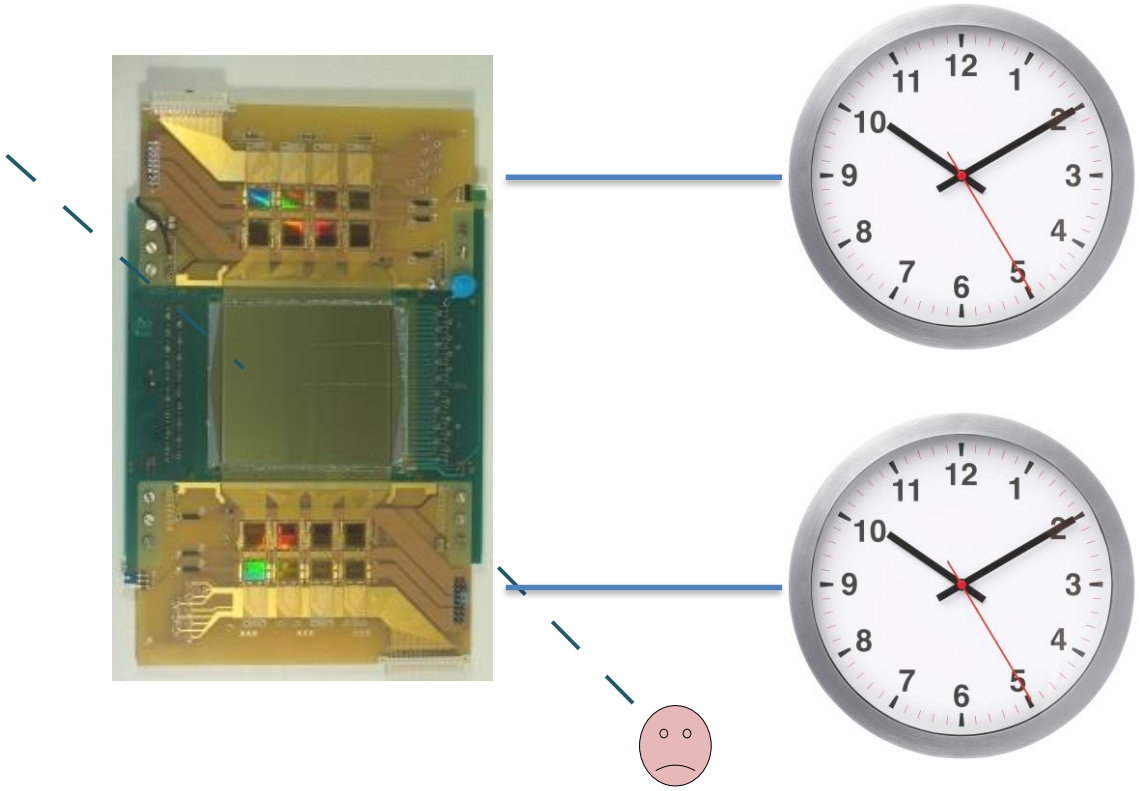

01
1
D
Q
1
>
0
D
Q
0
>
U
D
Q
U
>
U
D
Q
U
>
clock
clock

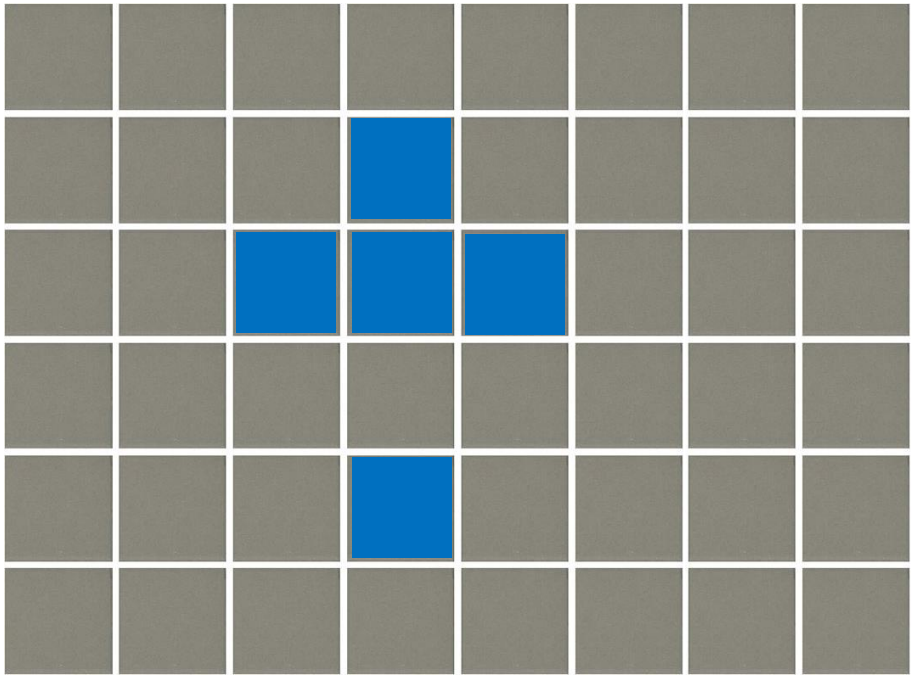

0
1
D
Q
1
>
1
D
Q
1
>
0
D
Q
0/1
>
U
D
Q
U
>
clock
clock

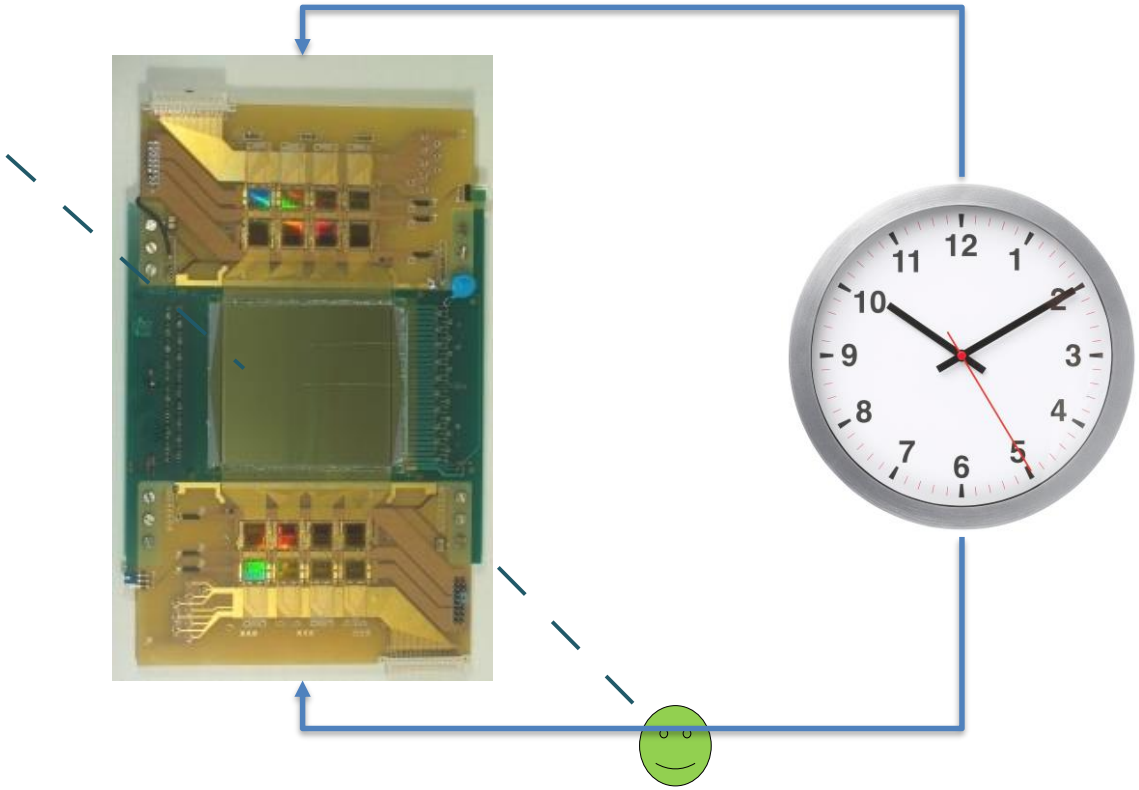

0
D
Q
0
>
1
D
Q
1
>
1
D
Q
0/1
>
U
D
Q
U
>
clock
clock

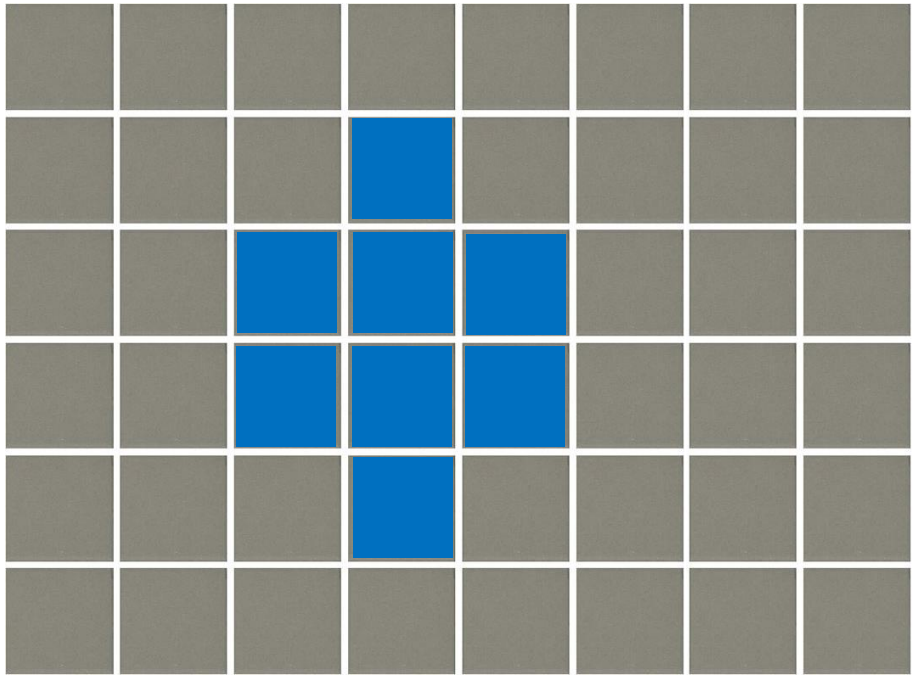


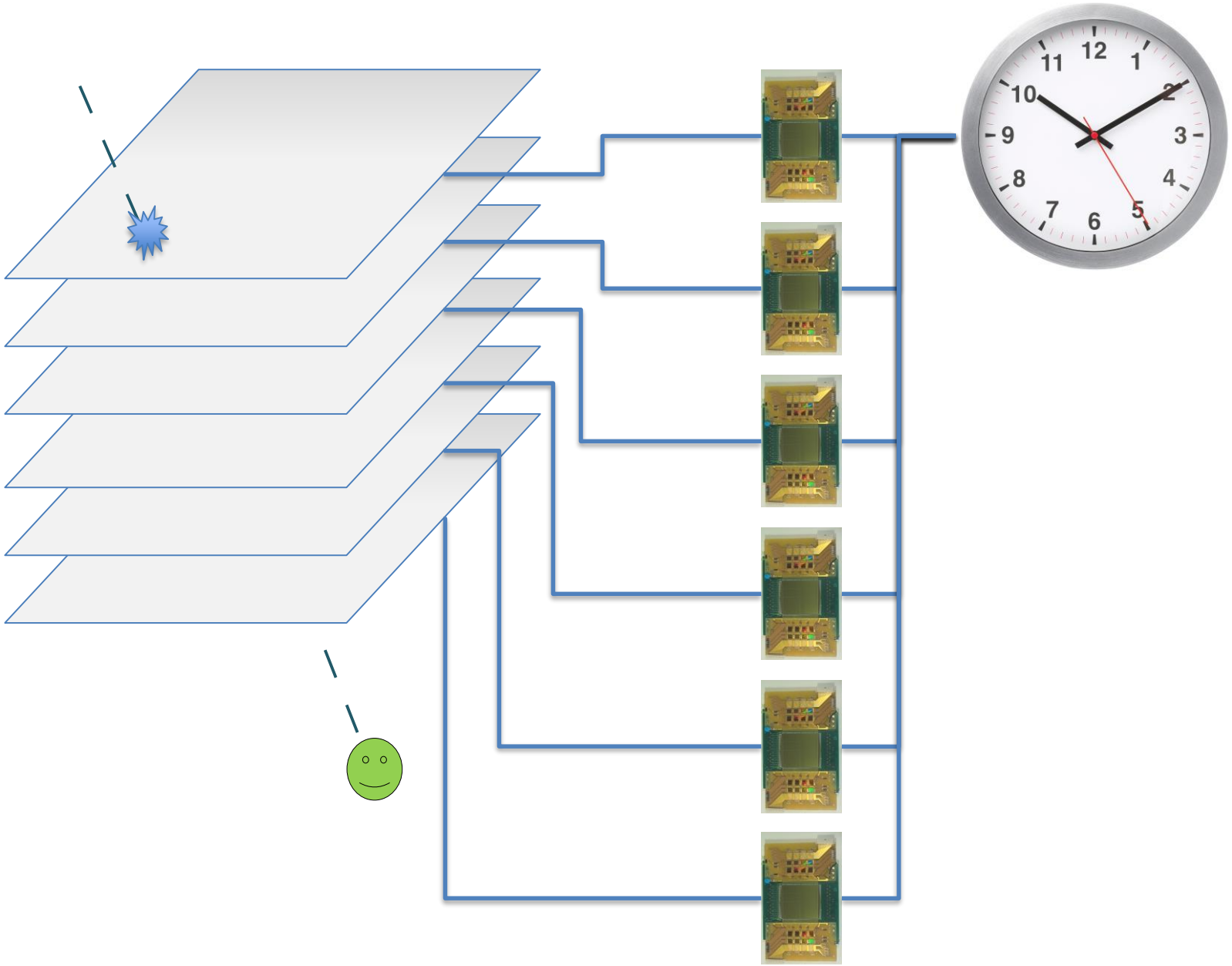


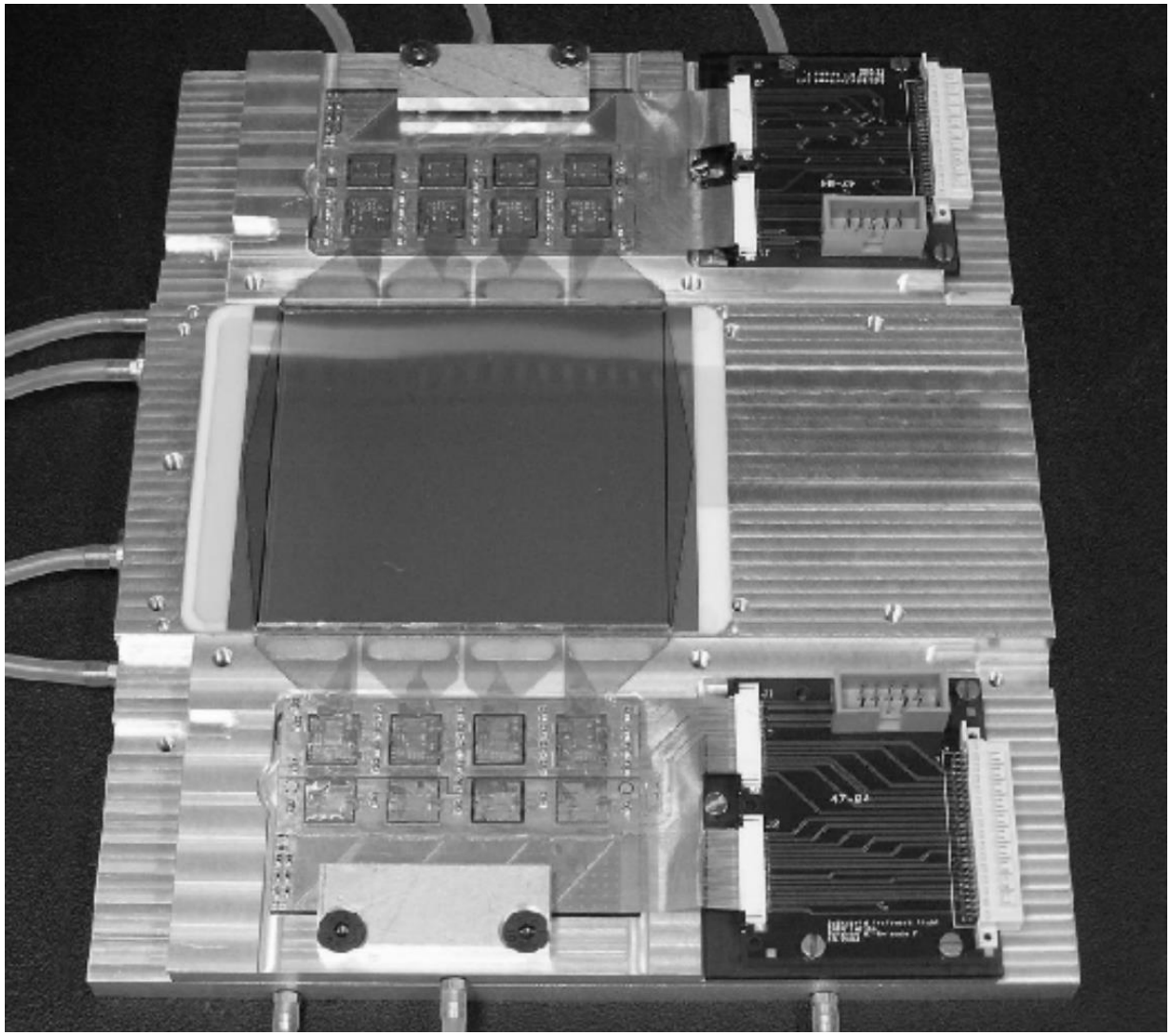


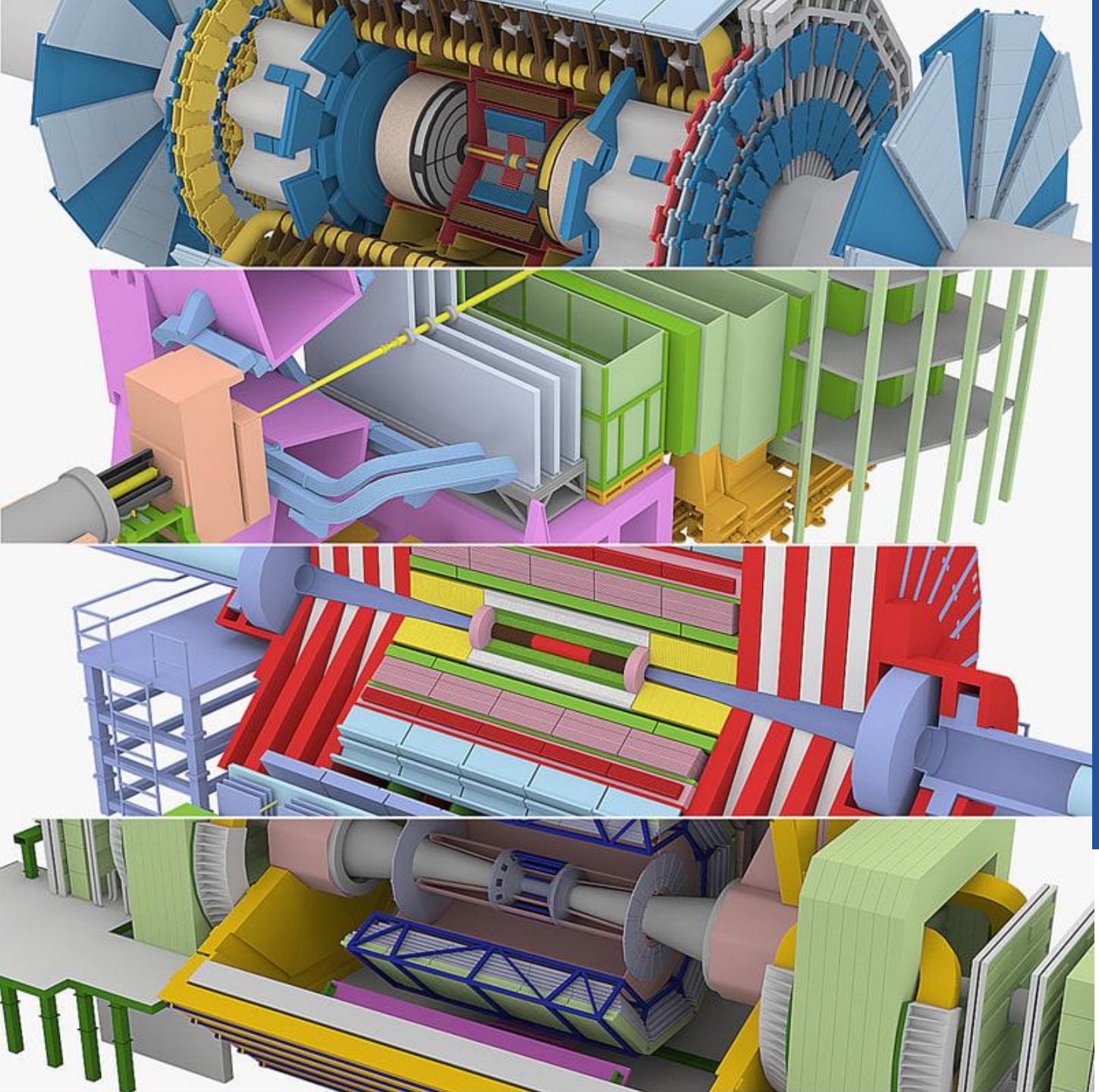


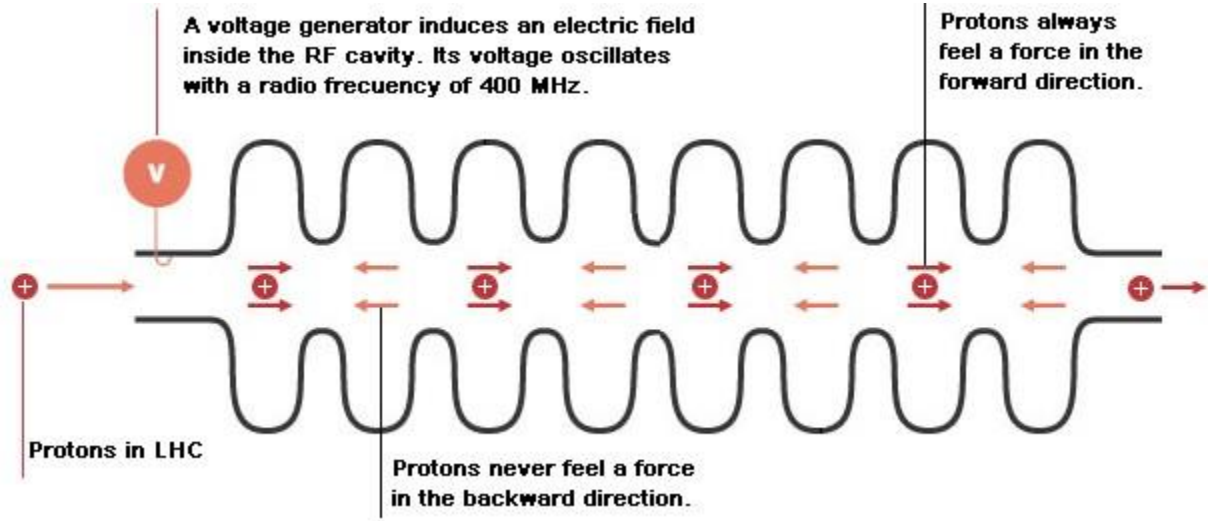

12
1
2
3
4
5
6
7
8
9
10
11

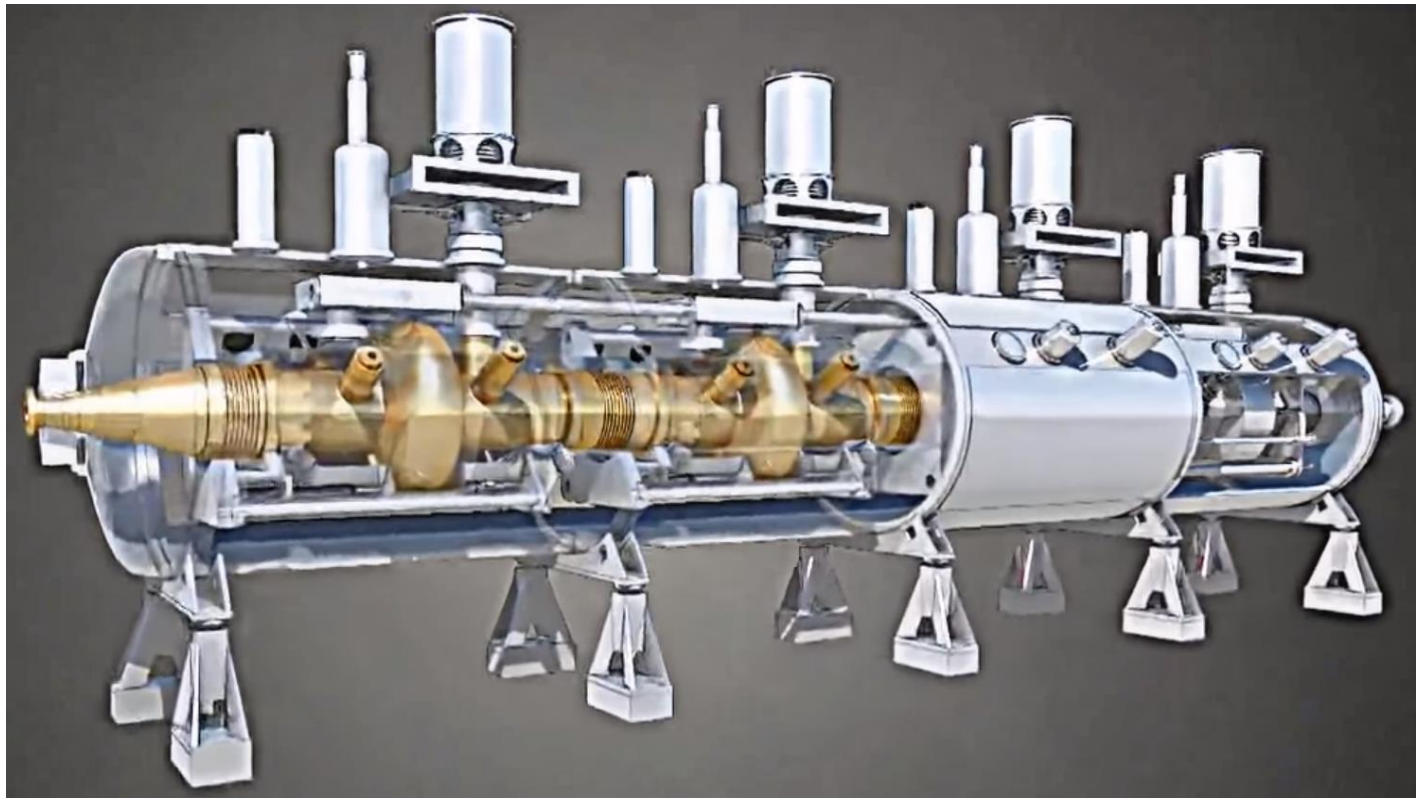


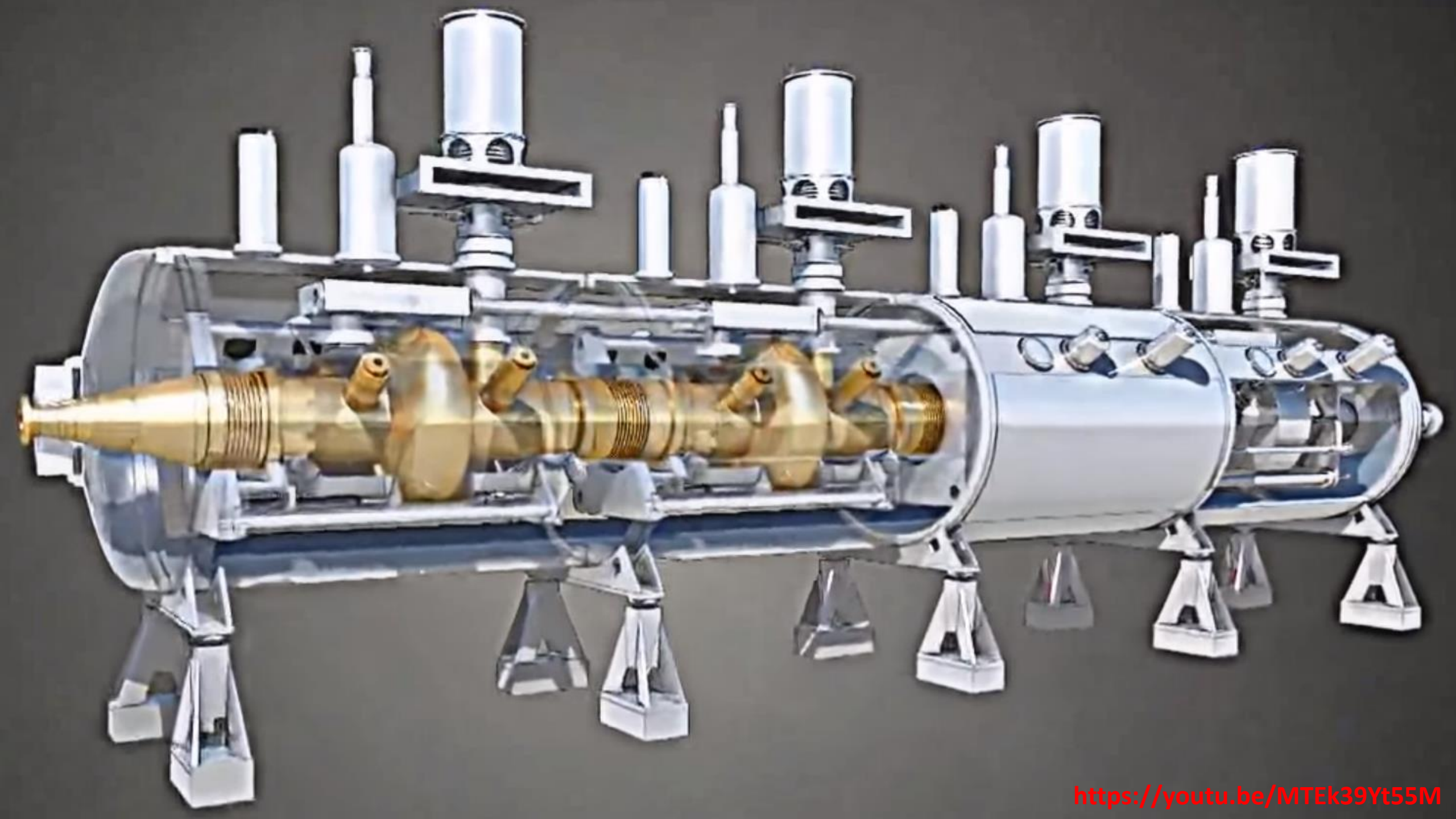

12
1
2
3
4
5
6
7
8
9
10
11

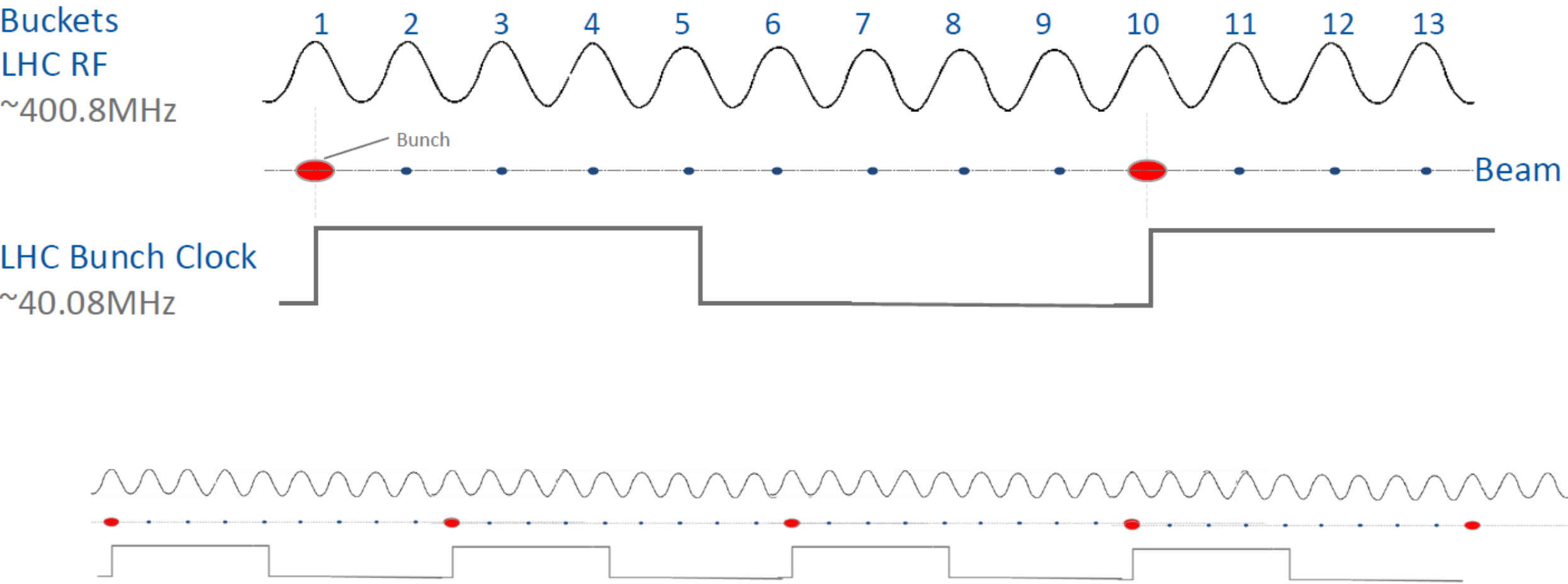


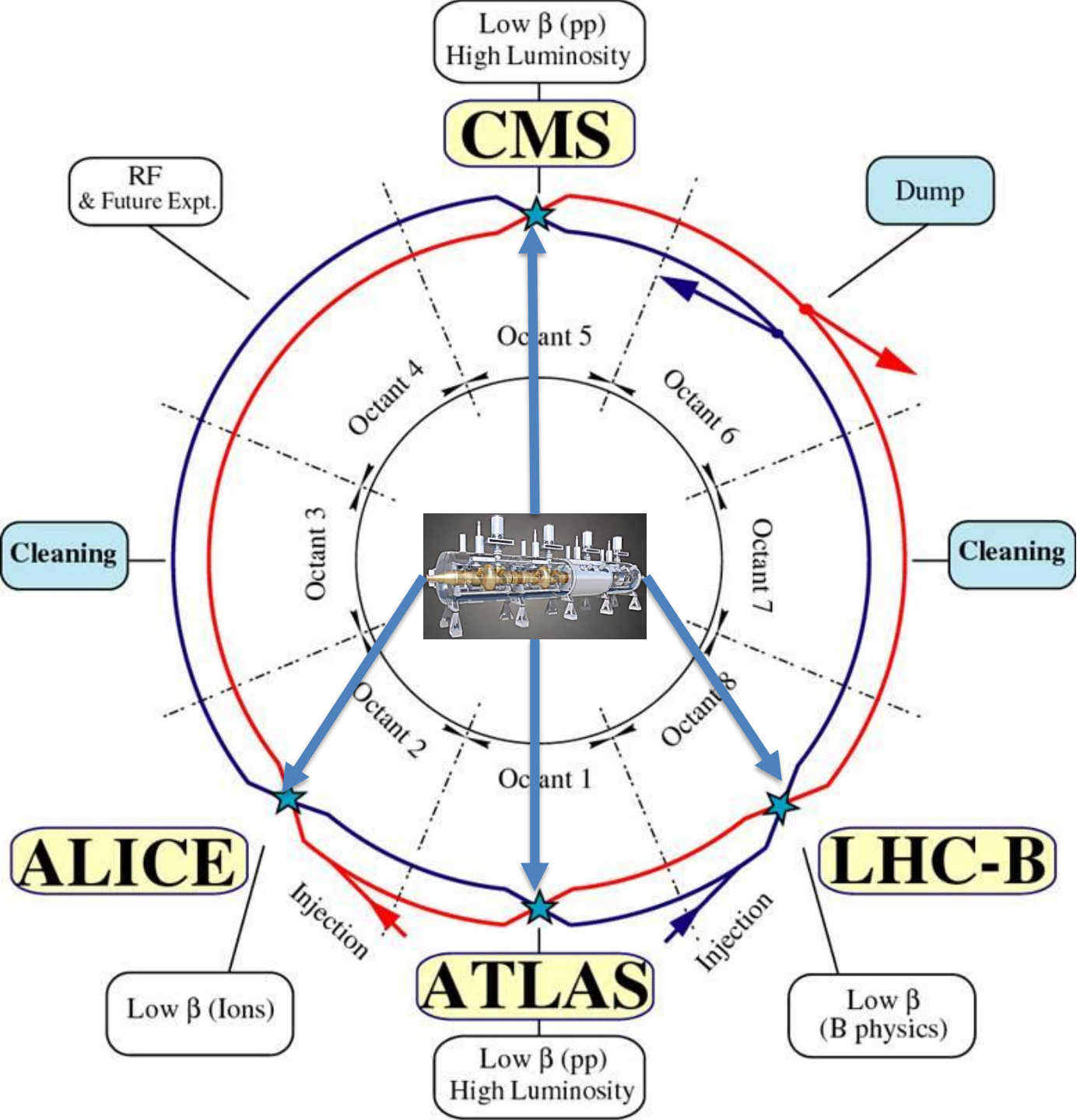



A voltage generator induces an electric field inside the RF cavity. Its voltage oscillates with a radio frecuency of 400 MHz.
Protons always feel a force in the forward direction.
V
Protons in LHC
Protons never feel a force in the backward direction.



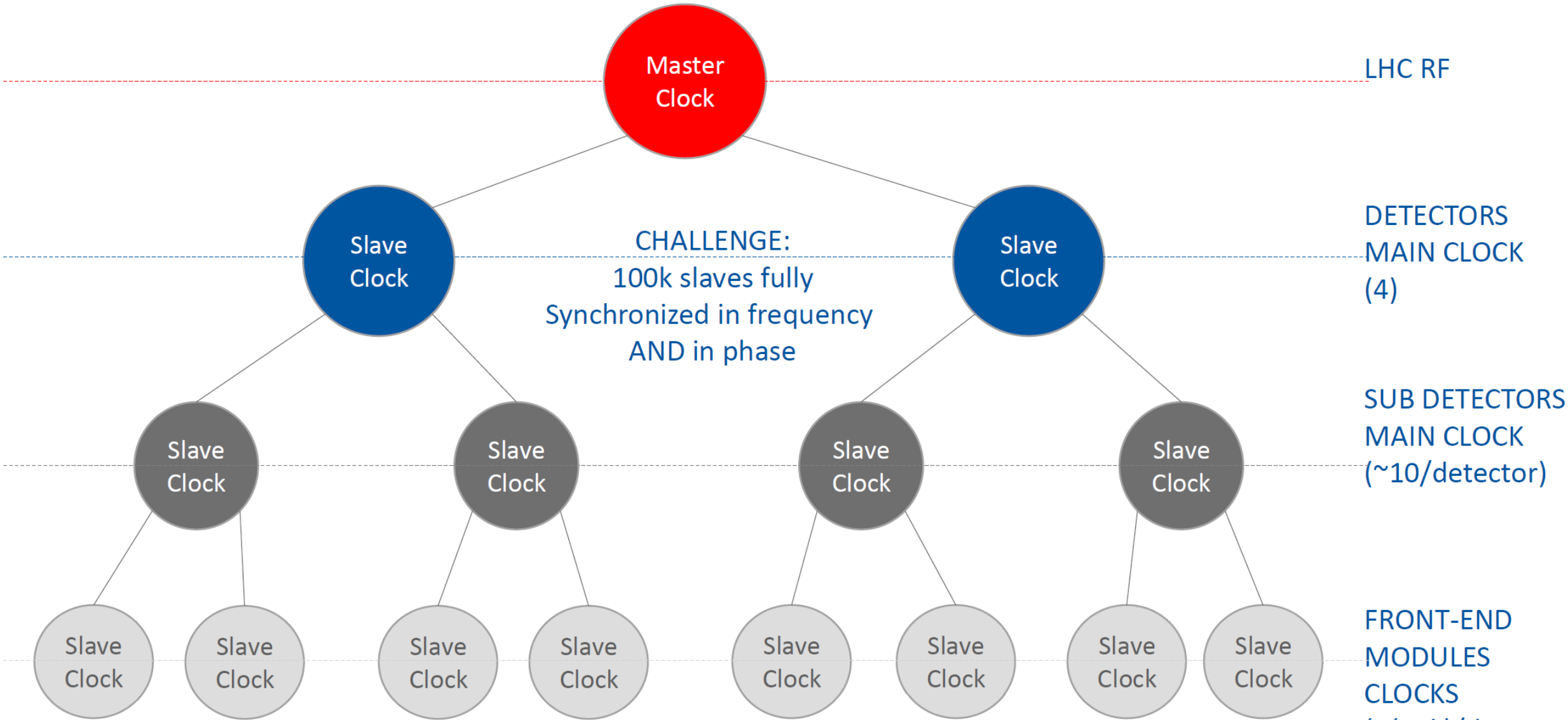

https://youtu.be/MTEk39Yt55M

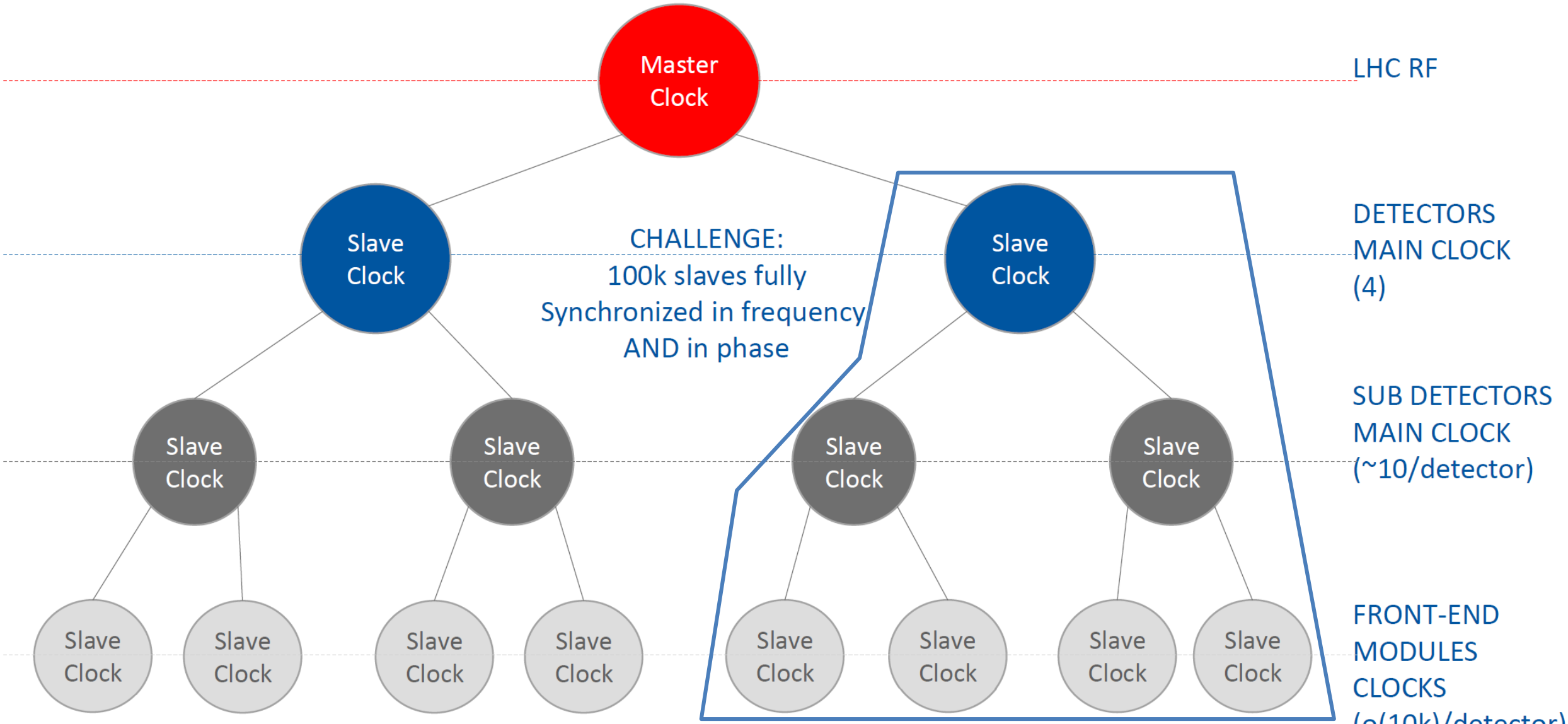

Buckets
LHC RF
~400.8MHz
1
2
3
4
5
6
7
8
9
10
11
12
13
Bunch
Beam
LHC Bunch Clock
~40.08MHz

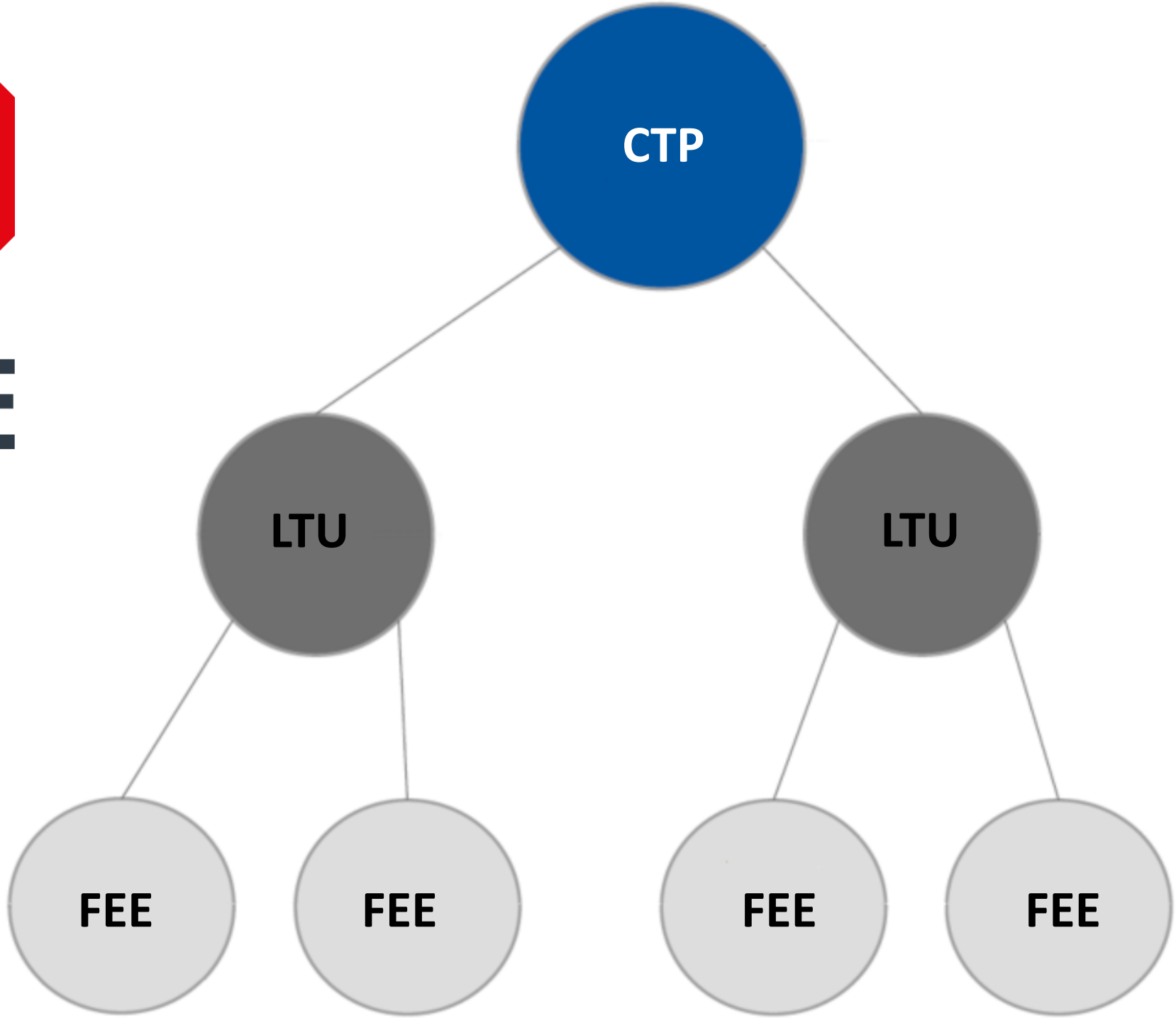


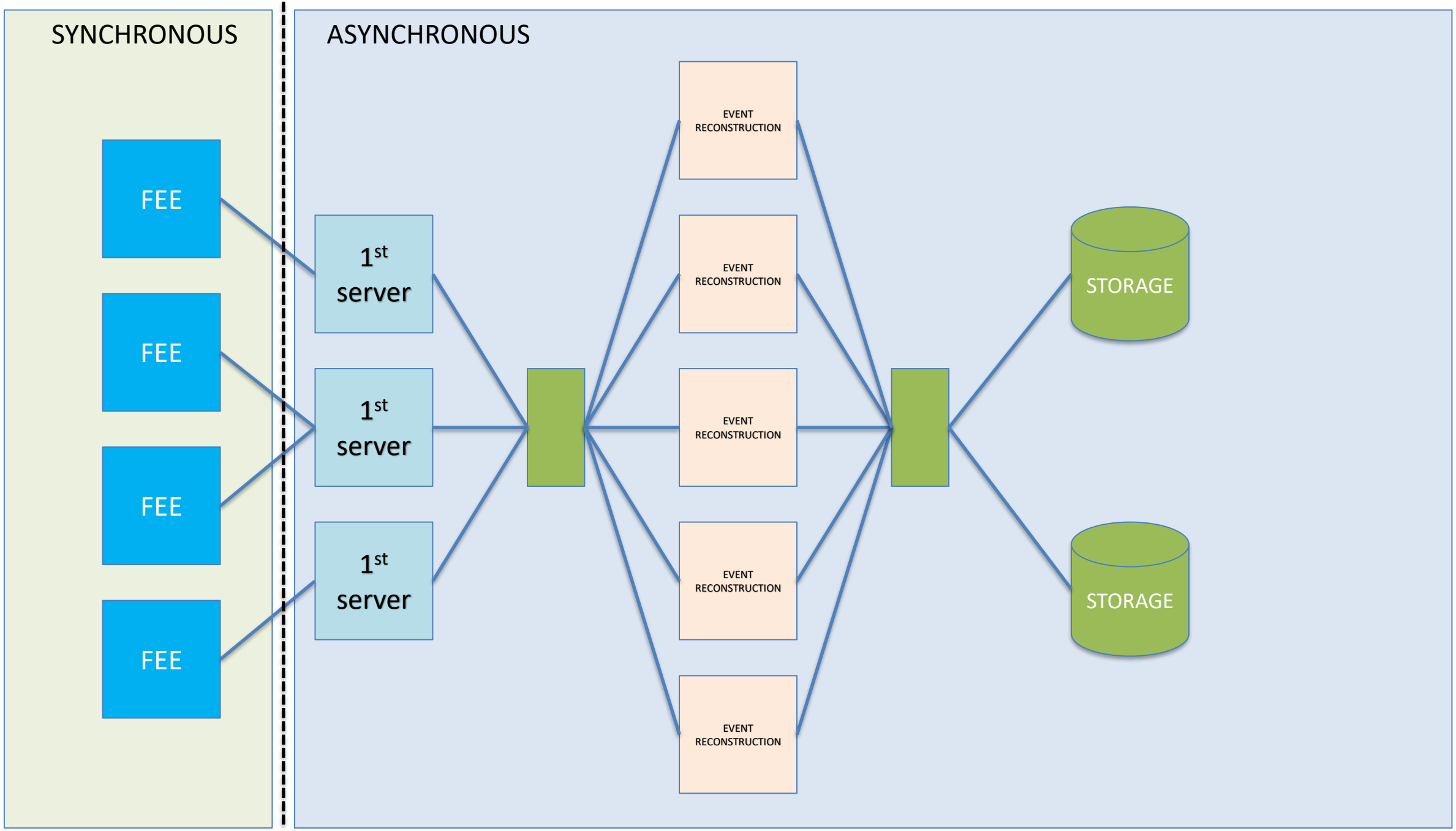
Timing distribution system delivers the **CLOCK** to **ALL** the detectors with

- **accurate and stable frequency**
- **fixed phase**
- **low, fixed and deterministic latency**

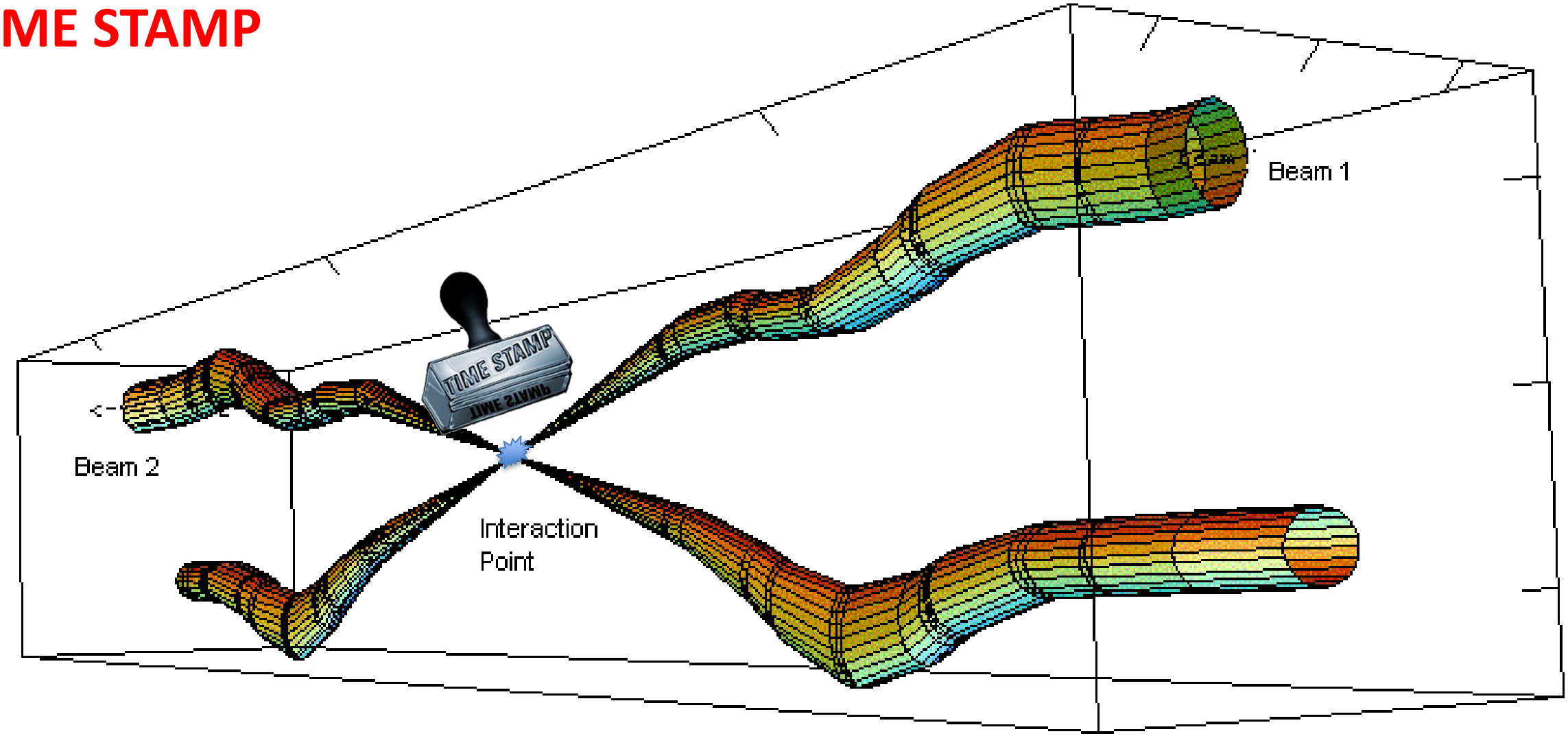

Master Clock
Slave Clock
Slave Clock
CHALLENGE:
100k slaves fully
Synchronized in frequency
AND in phase
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
LHC RF
DETECTORS MAIN CLOCK (4)
SUB DETECTORS MAIN CLOCK (~10/detector)
FRONT-END MODULES CLOCKS (o(10k)/detector)


Master Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
Slave Clock
CHALLENGE:
100k slaves fully
Synchronized in frequency
AND in phase
LHC RF
DETECTORS
MAIN CLOCK
(4)
SUB DETECTORS
MAIN CLOCK
(~10/detector)
FRONT-END
MODULES
CLOCKS
(o(10k)/detector)

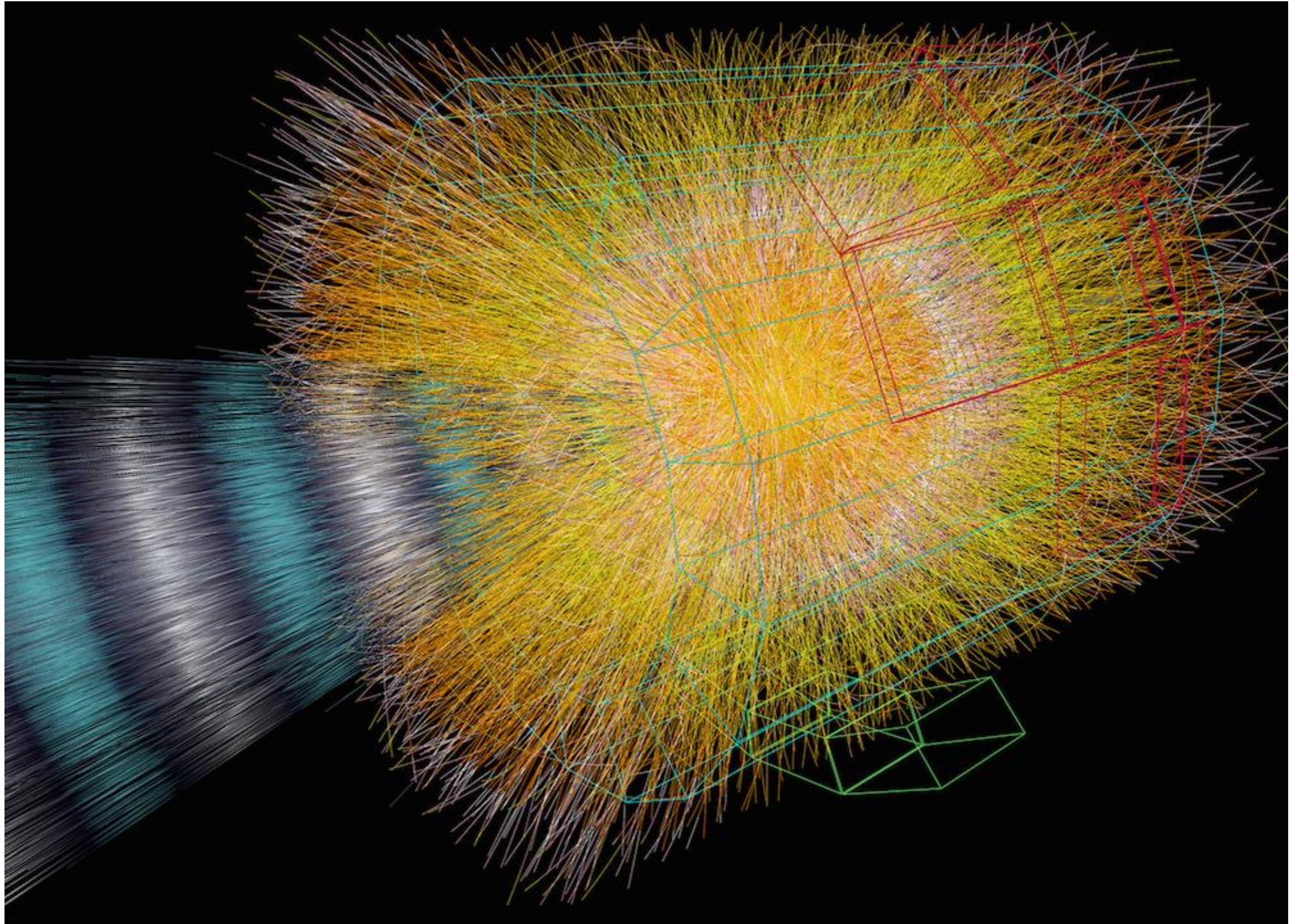

CTP
LTU
LTU
FEE
FEE
FEE
FEE

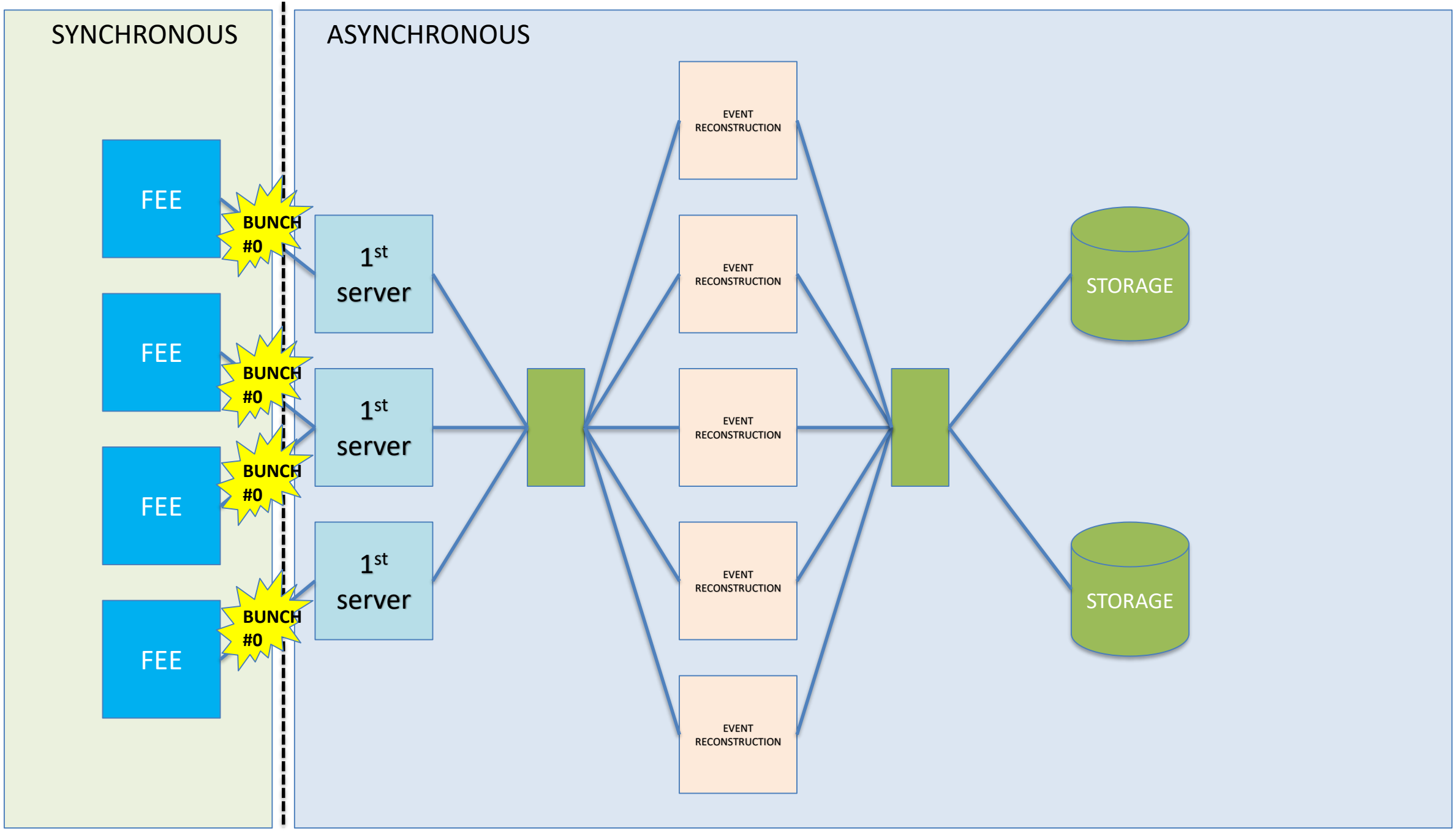

SYNCHRONOUS
ASYNCHRONOUS
FEE
FEE
FEE
FEE
1st server
1st server
1st server
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
STORAGE
STORAGE

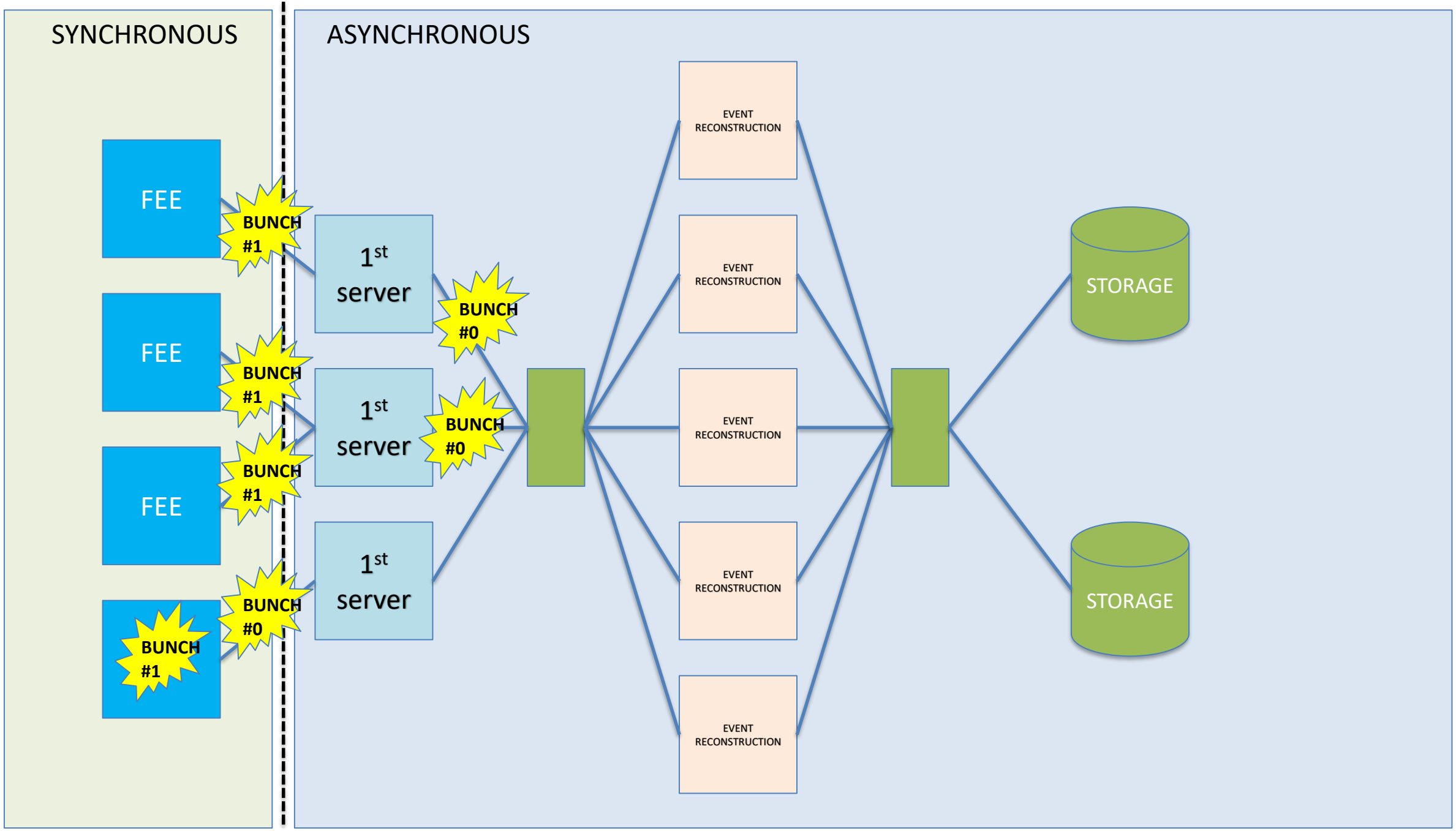
TIME STAMP

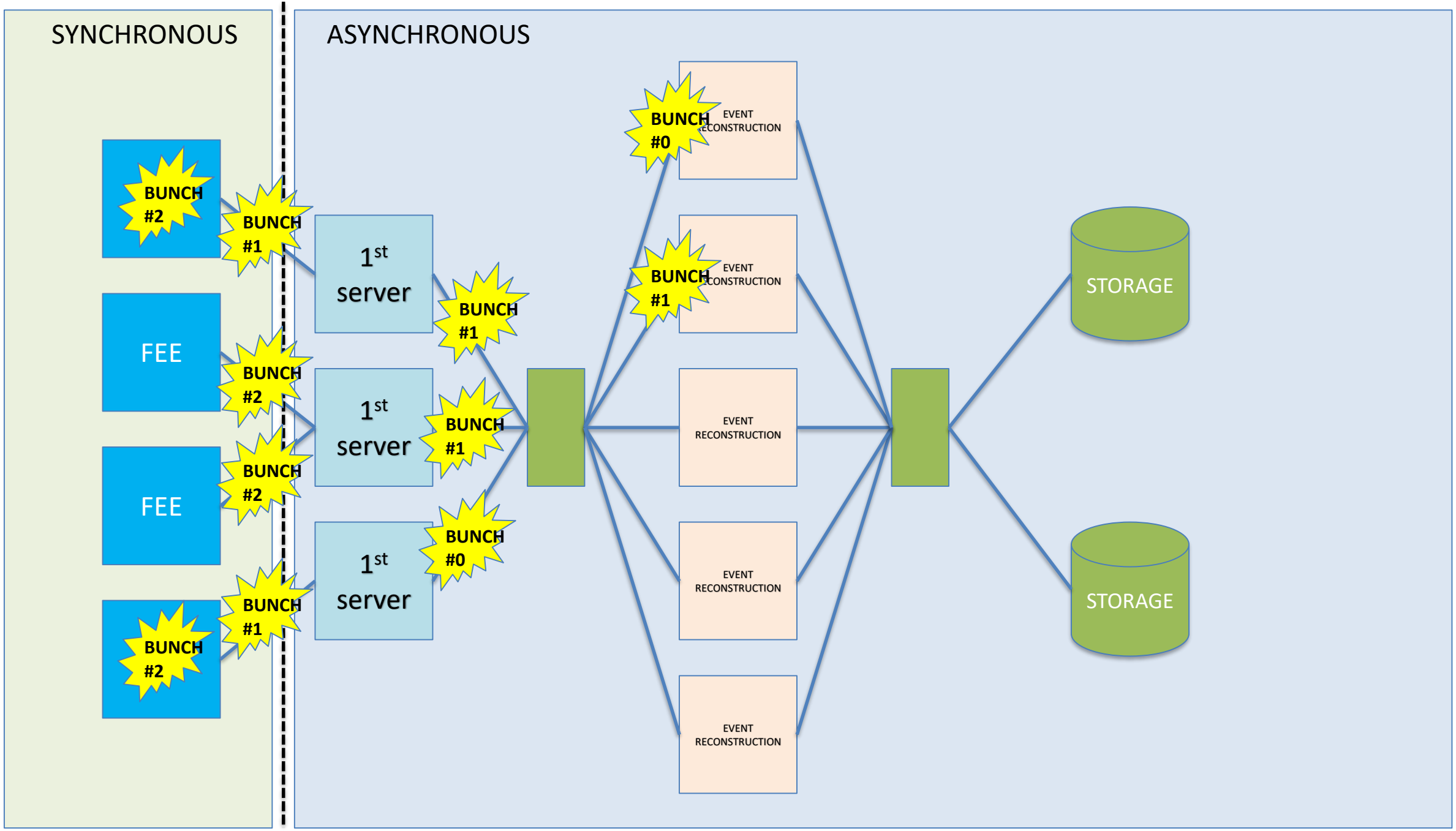


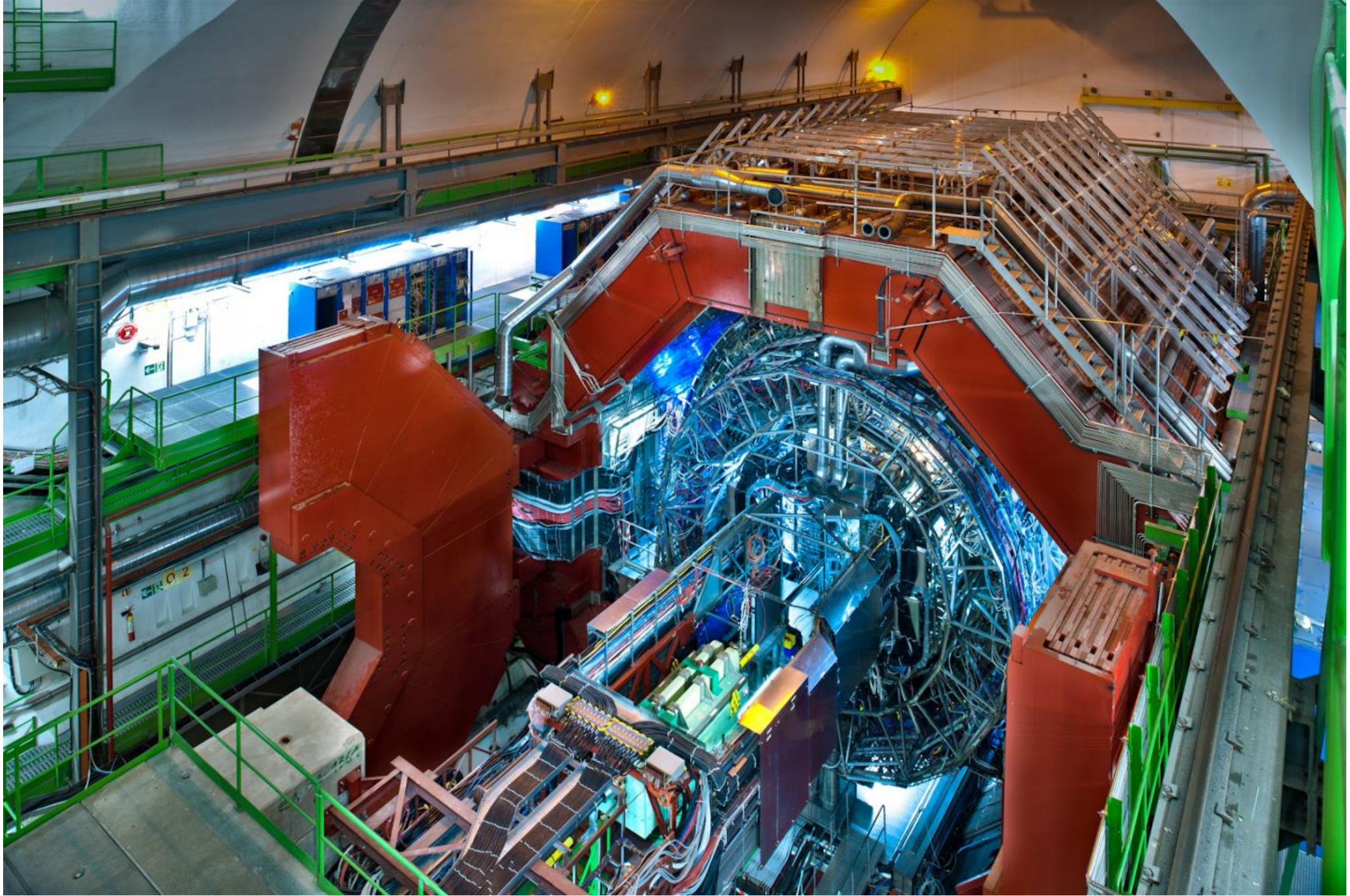
Timing distribution system delivers the **BUNCH CROSSING** and the **ORIBT INFORMATION** to **ALL** the detectors with
accurate and stable frequency
fixed phase with respect to the collisions
low, fixed and deterministic latency




SYNCHRONOUS
ASYNCHRONOUS
FEE
FEE
FEE
FEE
BUNCH #0
BUNCH #0
BUNCH #0
BUNCH #0
1st server
1st server
1st server
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
STORAGE
STORAGE


SYNCHRONOUS
ASYNCHRONOUS
FEE
FEE
FEE
FEE
BUNCH #1
BUNCH #1
BUNCH #1
BUNCH #0
BUNCH #1
1st server
1st server
1st server
BUNCH #0
BUNCH #0
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
STORAGE
STORAGE

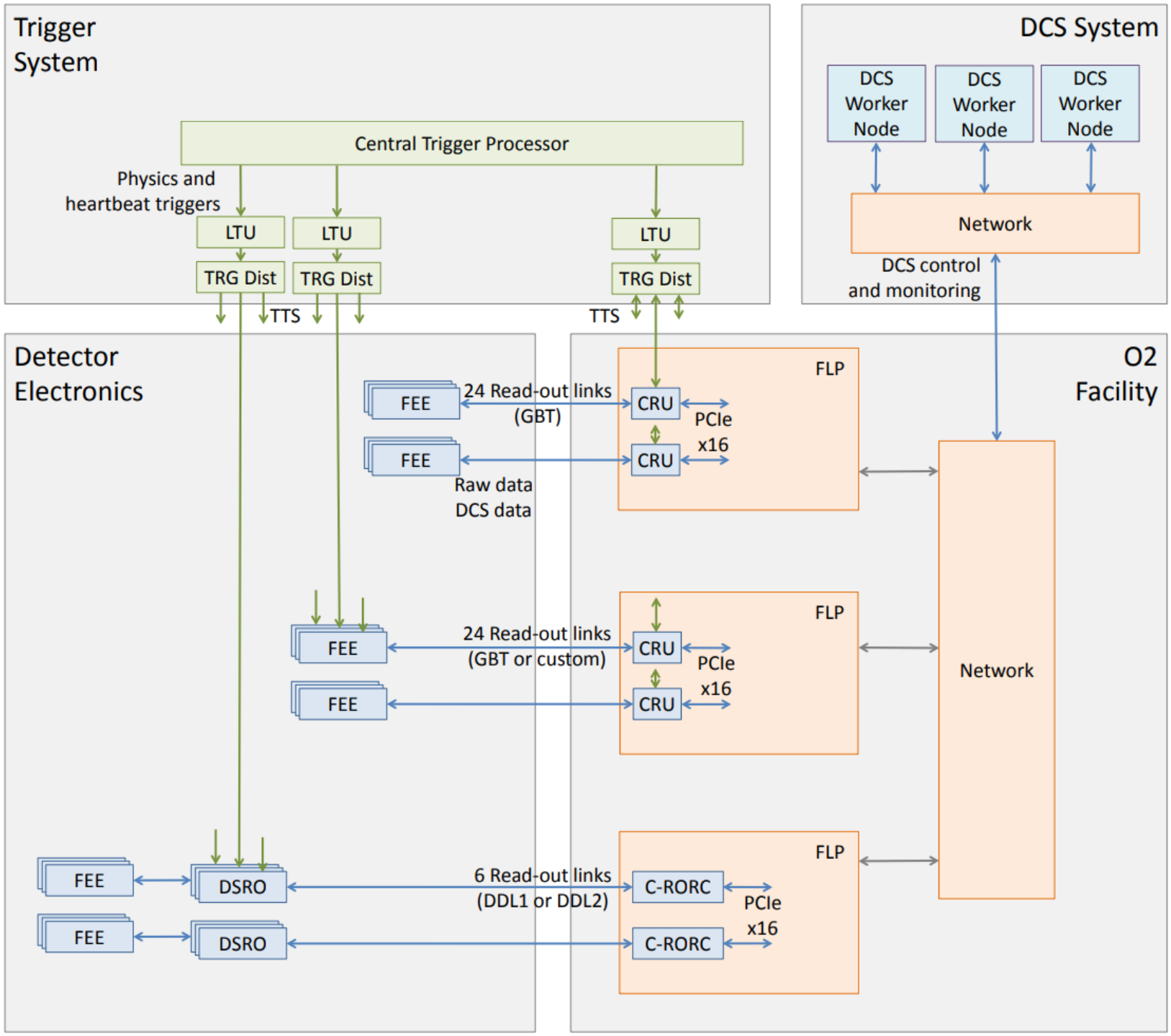

SYNCHRONOUS
ASYNCHRONOUS
BUNCH #2
BUNCH #1
FEE
BUNCH #2
FEE
BUNCH #2
BUNCH #1
1st server
1st server
1st server
BUNCH #1
BUNCH #1
BUNCH #0
BUNCH #0
BUNCH #1
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
EVENT RECONSTRUCTION
STORAGE
STORAGE



ALICE

RUN3 in numbers:

- 3.4 TB/s data from the detectors
- ~10’000 readout links
- ~200 Servers
- 1 CTP
- 14 sub-detectors (14 LTU)
- ~400 clock and timing links



Heart Beat (HB)

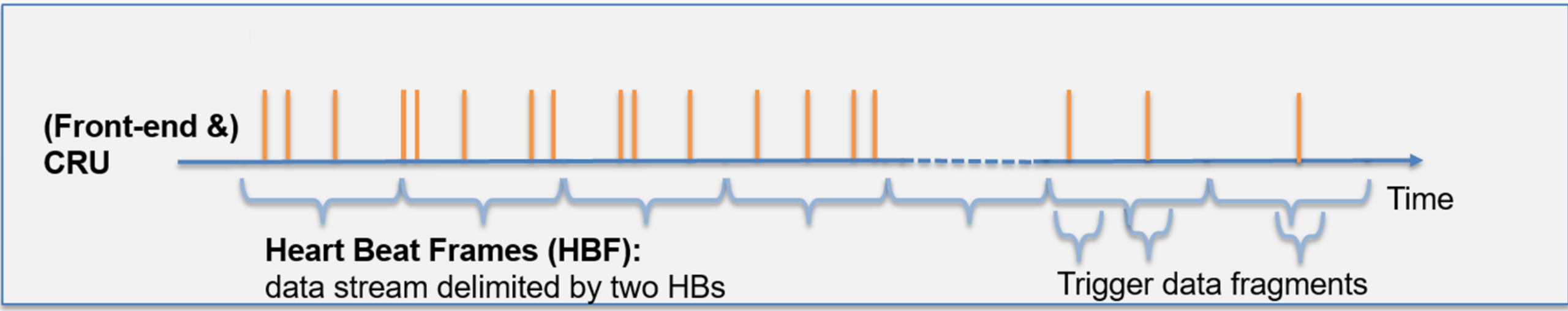
issued in continuous &
triggered modes
to all detectors

Physics trigger

can be sent to upgraded detectors
will be sent to
non-upgraded detectors

HBF and TF rates programmable
Typical values:
- HB: 1 per orbit, 89.4 μs: ~10 kHz
- TF: 1 every ~20 ms: ~50 Hz
- → 1 TF = ~256 HBF

Triggered read-out



Heart Beat (HB)

issued in continuous &
triggered modes
to all detectors

HBF and TF rates programmable
Typical values:
- HB: 1 per orbit, 89.4 μs: ~10 kHz
- TF: 1 every ~20 ms: ~50 Hz
- → 1 TF = ~256 HBF

Continuous read-out

Heart Beat (HB)

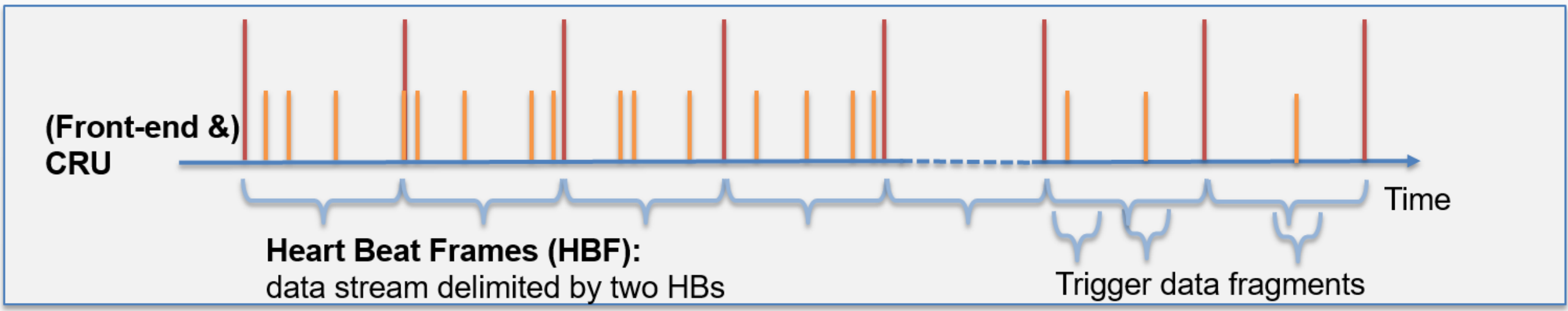
issued in continuous &
triggered modes
to all detectors

Physics trigger

can be sent to upgraded detectors
will be sent to
non-upgraded detectors

HBF and TF rates programmable
Typical values:
- HB: 1 per orbit, 89.4 μs: ~10 kHz
- TF: 1 every ~20 ms: ~50 Hz
- → 1 TF = ~256 HBF

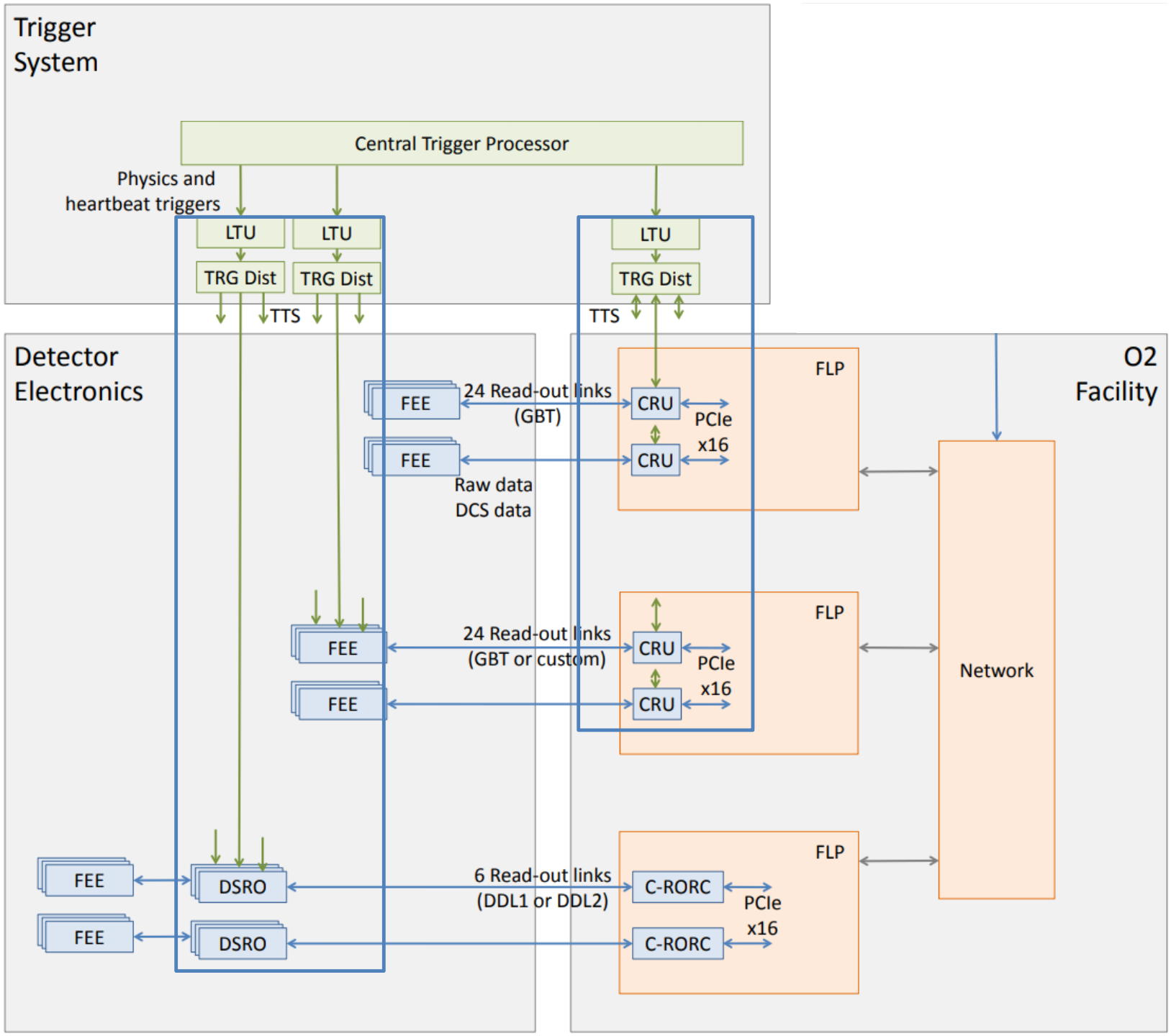
Triggered read-out

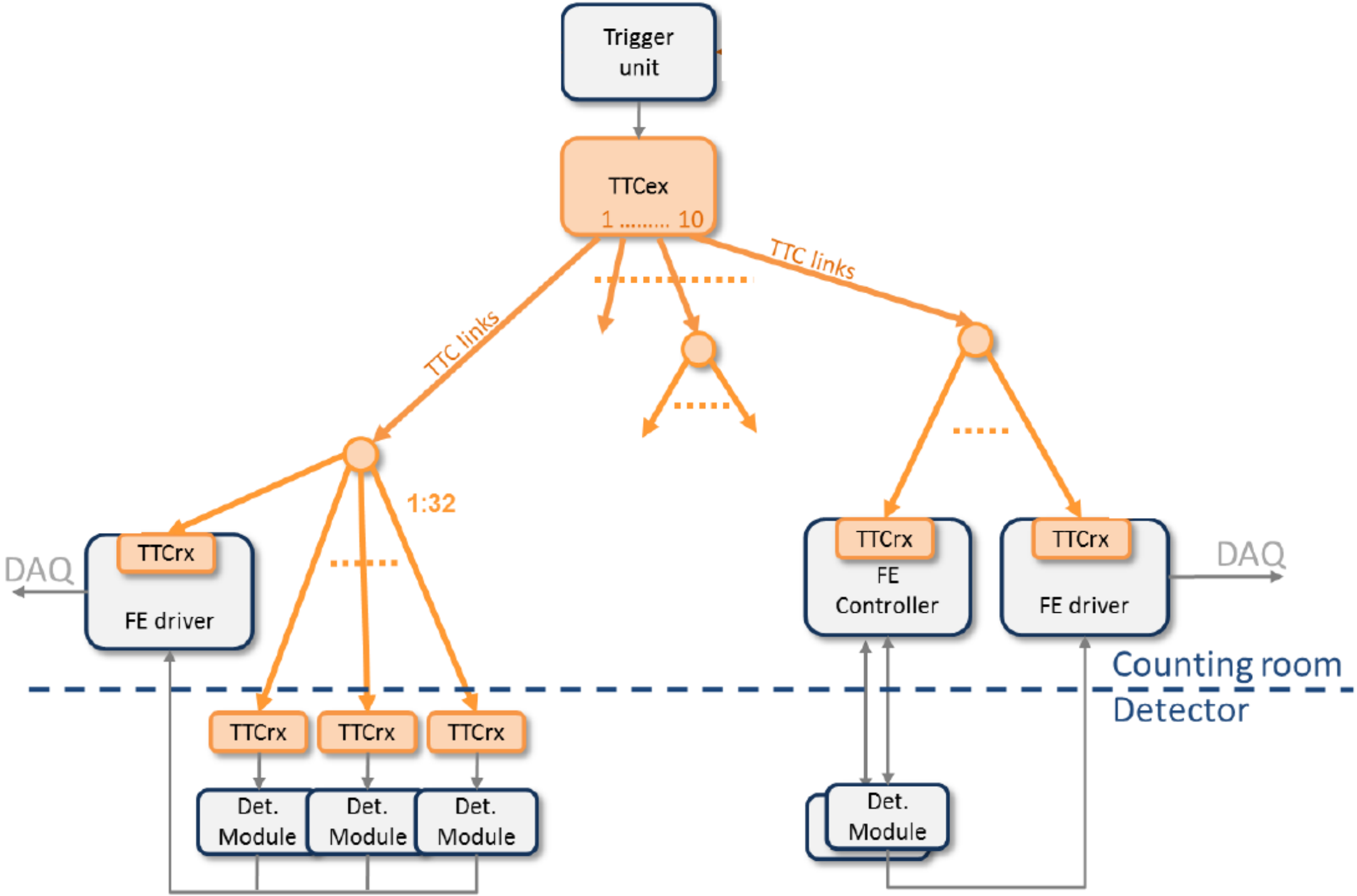


ALICE

RUN3 in numbers:

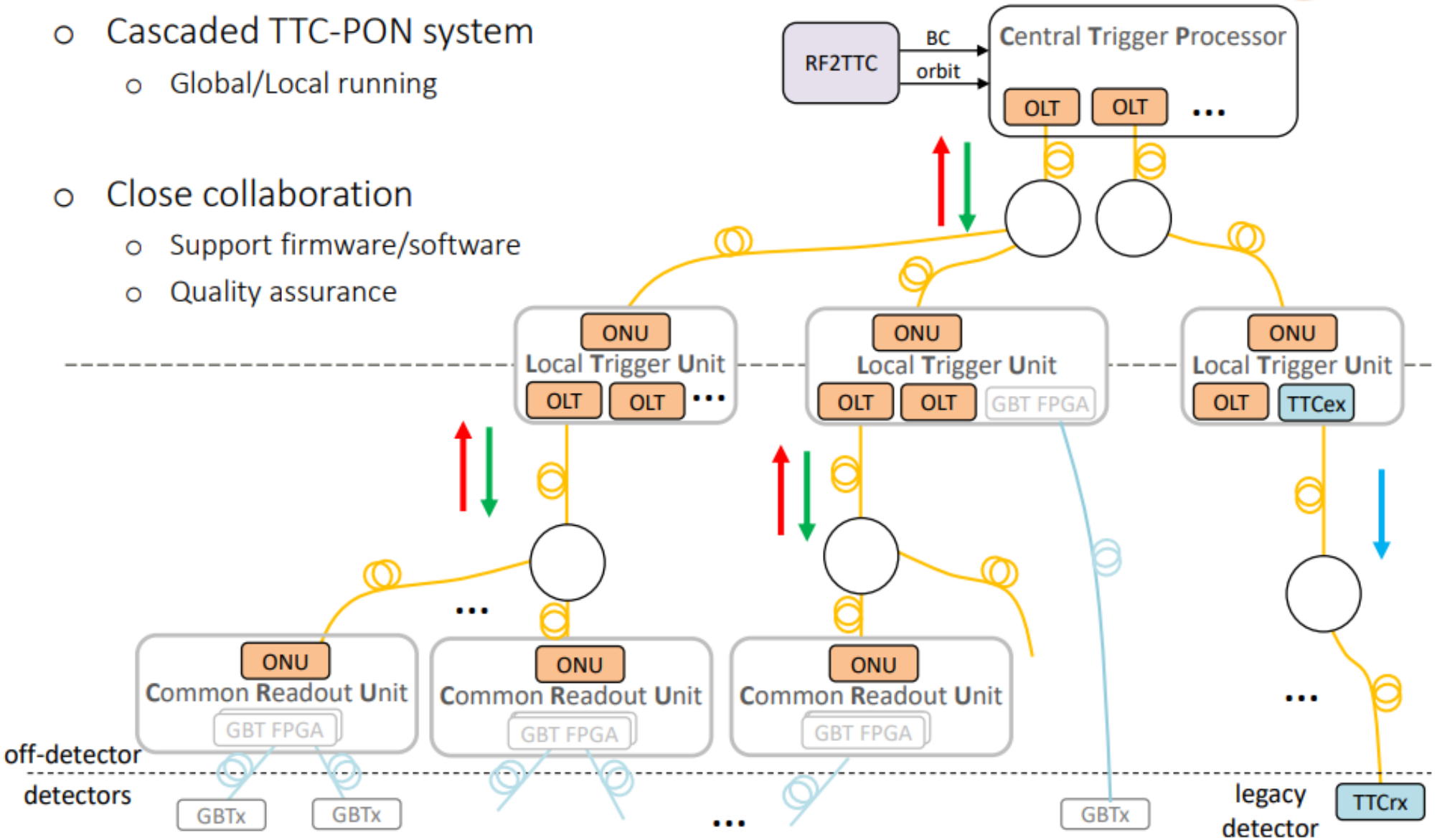
- 3.4 TB/s data from the detectors
- ~10’000 readout links
- ~200 Servers
- 1 CTP
- 14 sub-detectors (14 LTU)
- ~400 clock and timing links



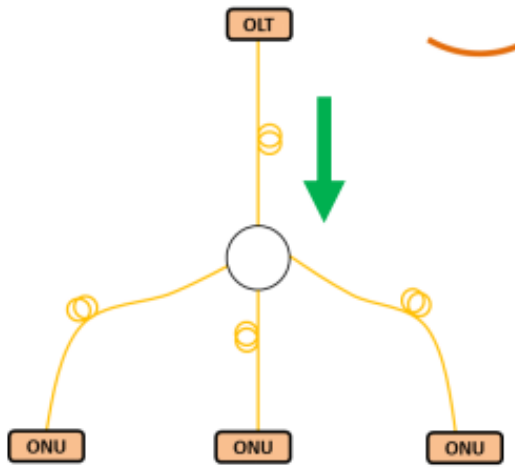

Trigger unit
TTCex
1 10
TTC links
TTC links
1:32
DAQ
TTCrx
FE driver
TTCrx
FE Controller
TTCrx
FE driver
DAQ
Counting room
Detector
TTCrx
TTCrx
TTCrx
Det. Module
Det. Module
Det. Module
Det. Module

TTC-PON / ALICE phase-1 flavour

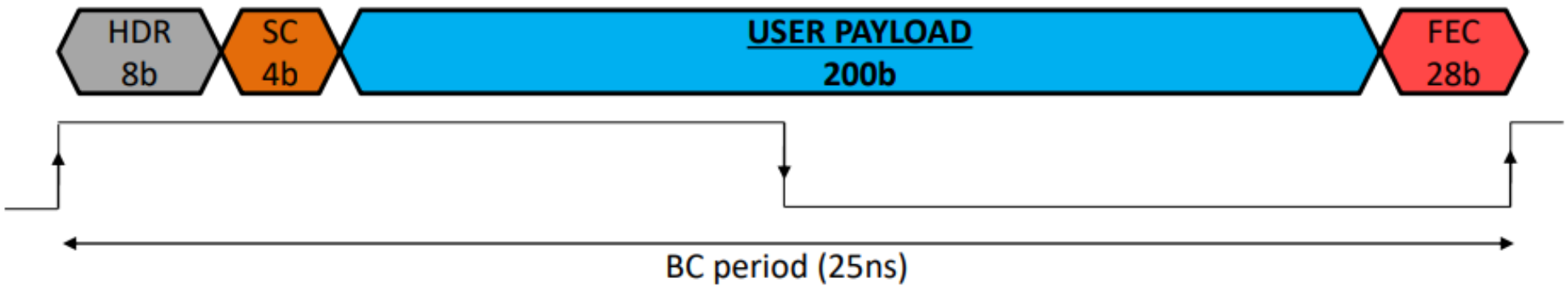
- Cascaded TTC-PON system
  - Global/Local running
- Close collaboration
  - Support firmware/software
  - Quality assurance



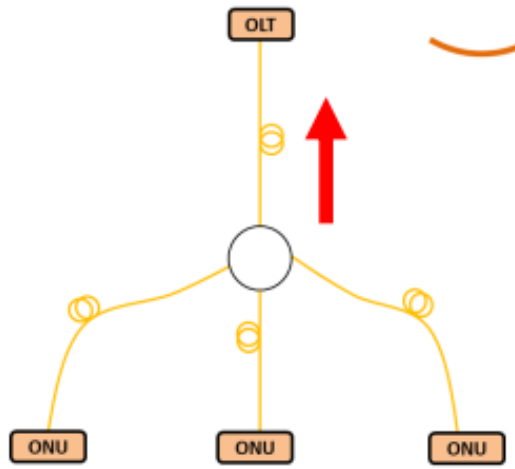
TTC-PON: downstream



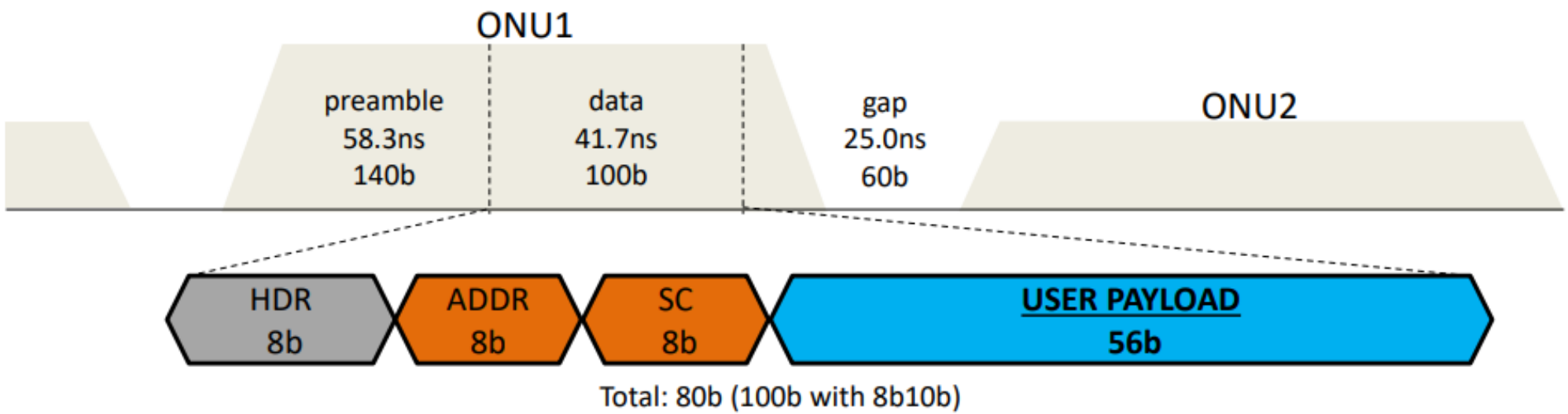
- OLT → ONUs (broadcast)
- 9.6Gb/s line-rate (1577nm)
- Low and fixed latency
- FEC (forward error correction)
  - 2x BCH(120,106) – double random error correcting code
  - 88.3% efficiency, ~3dB coding gain
- SC (slow control)
  - System control/monitoring (FEC and CRC-7 protected)
- **High User Bandwidth (200b per BC – 8Gb/s)**



TTC-PON: upstream



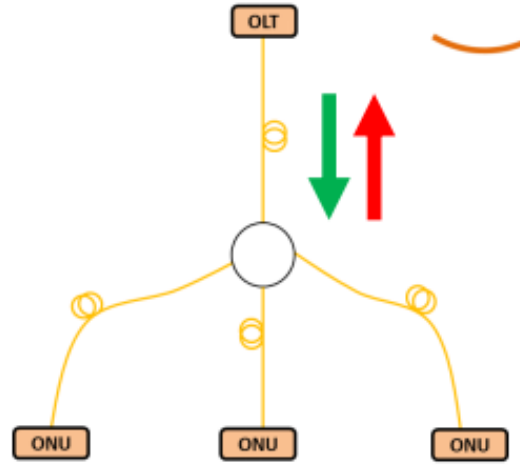
- ONUs → OLT (TDMA)
- 2.4Gb/s line-rate (1270nm)
- Synchronized to downstream
- 8b10b encoded
- Total burst length: 125ns (100ns burst + 25ns gap)
- **Waiting time (BUSY latency): 125ns x Number ONUs (8us for 64 ONUs)**
- **User bandwidth: 448Mb/s x (1 / Number ONUs)**

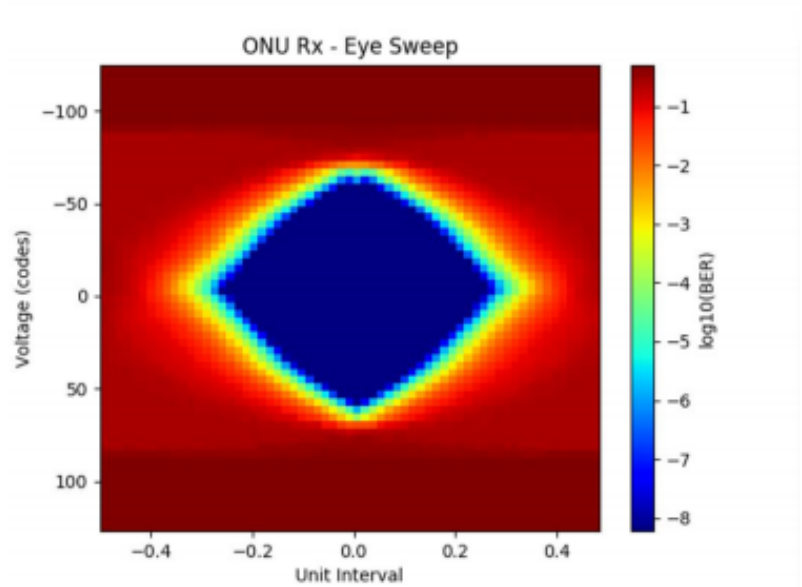


TTC-PON: system features

- Examples of **online** features:
  - Downstream Error Monitoring
    - FEC single error correction
    - FEC double error correction
    - SC-CRC error detection
  - Downstream Eye Scan
    - So far for Xilinx (Kintex7, Kintex Ultrascale)
  - Upstream Error Monitoring
    - 8b10b error detection
  - Among others (see https://indico.cern.ch/event/608587/contributions/2614195/)

severity





WHAT WE HAVE LEARNT

Well … YOU should tell ME

THANK YOU FOR LISTENING

REFERENCE (a few)

TIMING ISOTDAQ 2019
https://indico.cern.ch/event/739424/contributions/3052203/attachments/1673759/2987166/Timing_for_isotDAQ_2019.pdf

LHC RF
https://home.cern/science/engineering/accelerating-radiofrequency-cavities

Clock distribution @ CERN
https://indico.cern.ch/event/202454/attachments/304791/425754/TTCClockdistribution6.pdf

CERN TTC
http://ttc.web.cern.ch/TTC/intro.html

CERN TTC-PON
https://indico.cern.ch/event/681247/contributions/2929040/attachments/1638696/2615583/TTC-PON_ACES2018_EMendes_24_04_18.pdf

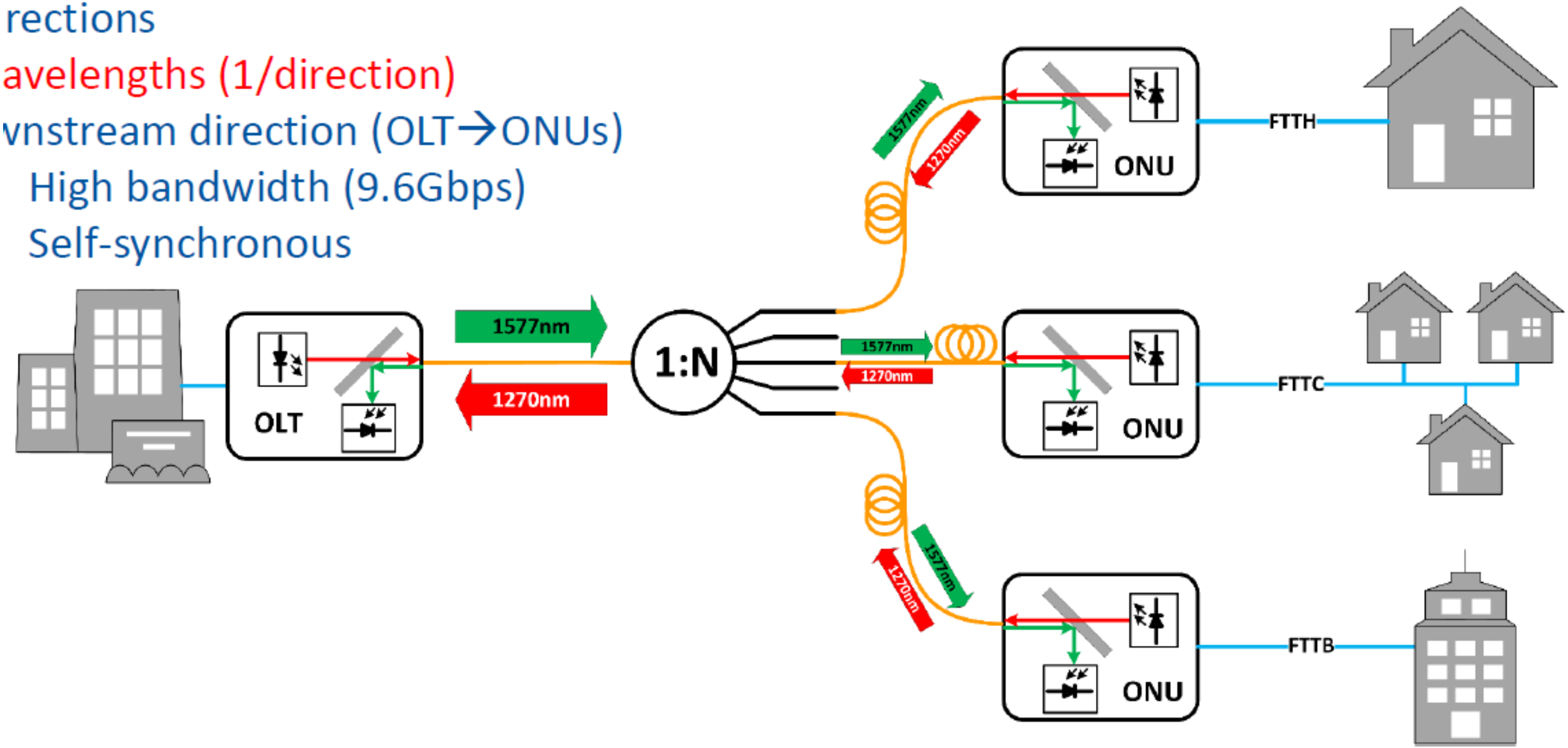
rections

avelengths (1/direction)

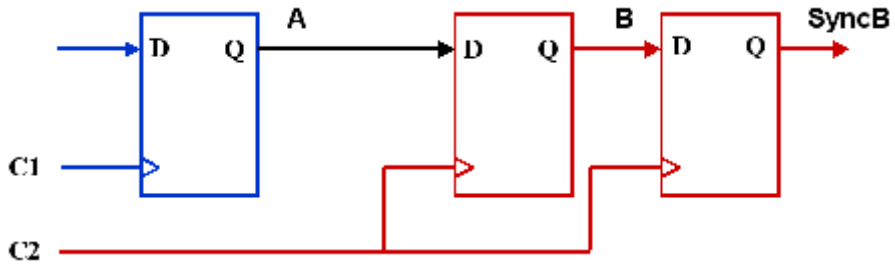
vnstream direction (OLT→ONUs)

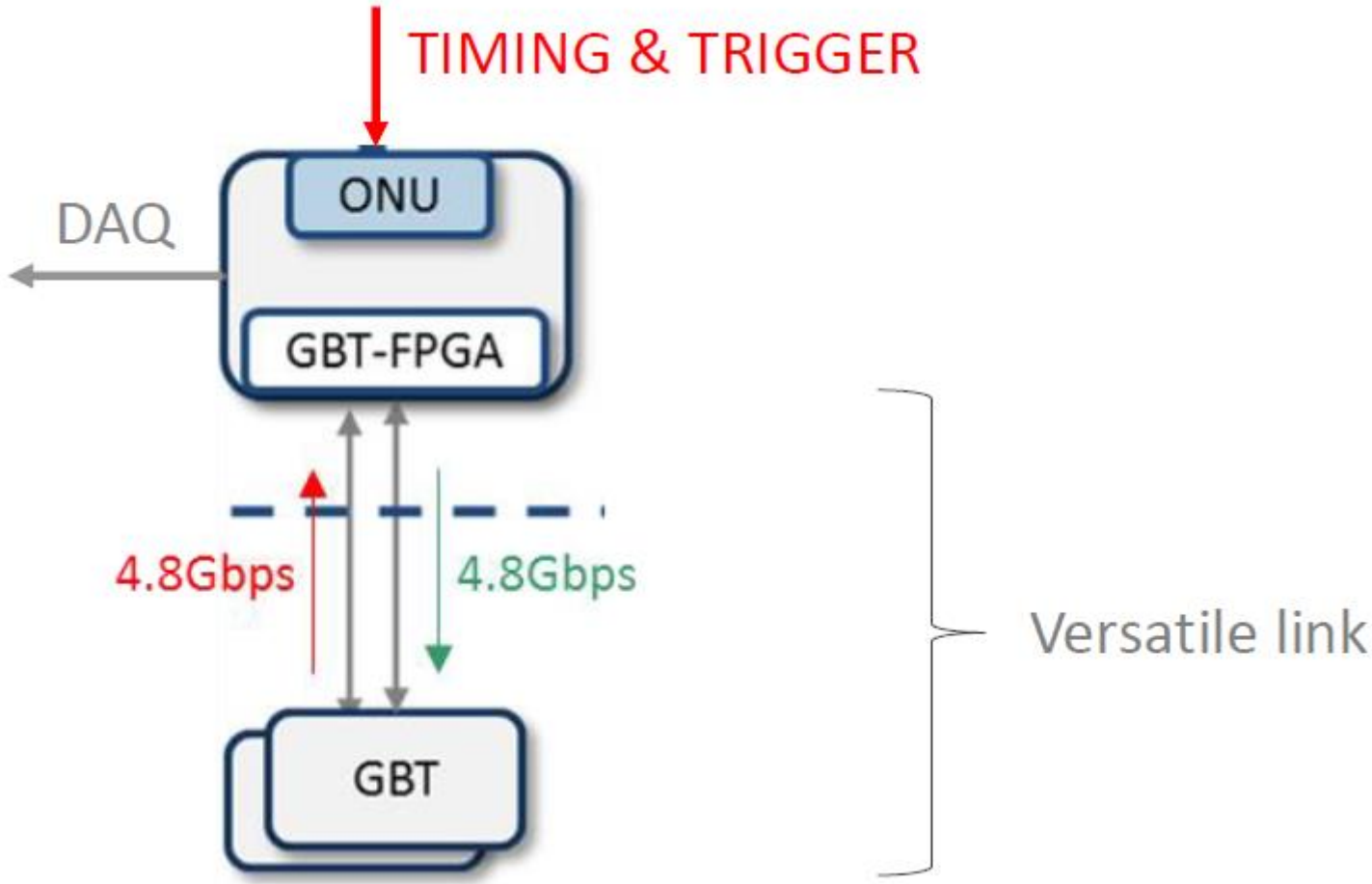
High bandwidth (9.6Gbps)

Self-synchronous



SYNCHRONIZATION in electronics




TIMING & TRIGGER
ONU
DAQ
GBT-FPGA
4.8Gbps
4.8Gbps
GBT
Versatile link