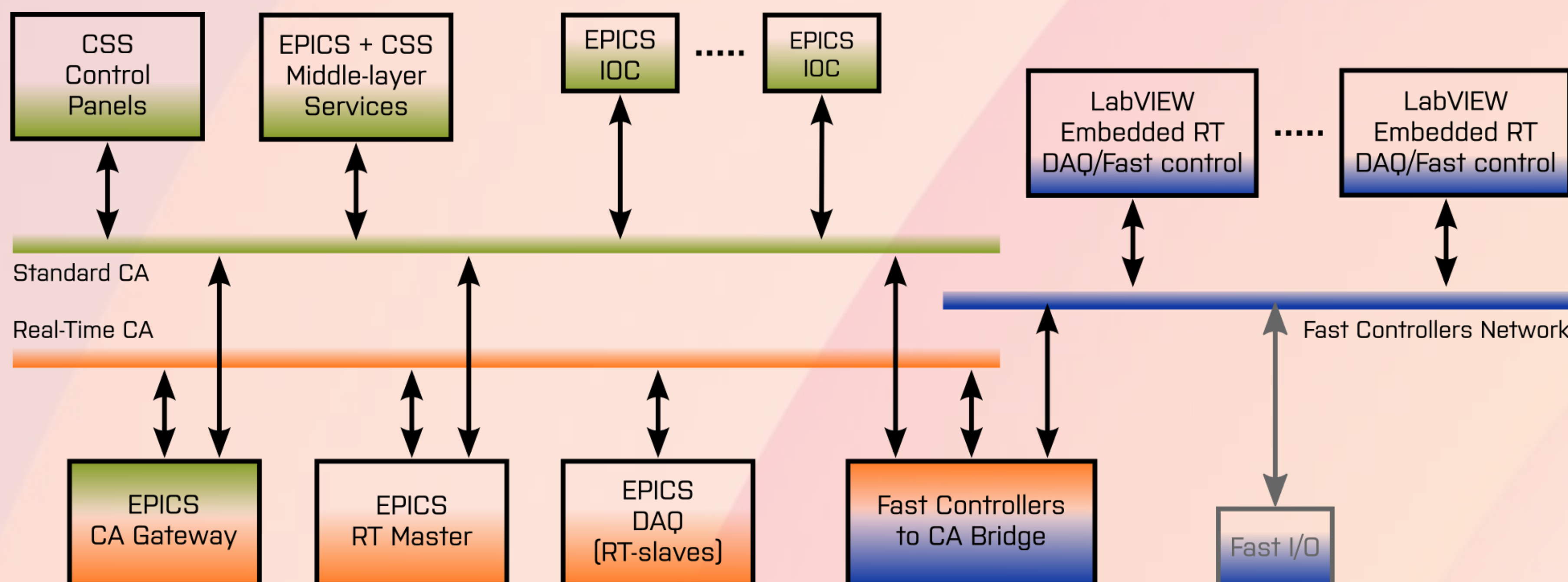# High Repetition Rate Laser Beamline Control System

Extreme Light Infrastructure – ELI Beamlines Czech Republic

Four laser beamlines L1 – L4; Six experiment sites E1 – E6; Pulse distribution switch-yard
up to ≈10 PW; down to ≈20 fs pulses; 10 Hz to 1 kHz repetition rate; secondary sources

L1 Control System – prototyped since 2012 at IoP sites

Threefold architecture proposed:
- EPICS v3 servers (CA) amended with CSS panels, archiver, alarm handler, etc.
- LabVIEW Real-Time targets within Fast Controllers Network
  - still being considered; might include fast I/O
- Real-Time CA intended as a gateway and as medium speed I/O network
  - suggested to use Xenomai RTnet & extended EPICS CA

Diagram boxes:
- CSS Control Panels
- EPICS + CSS Middle-layer Services
- EPICS IOC ..... EPICS IOC
- LabVIEW Embedded RT DAQ/Fast control ..... LabVIEW Embedded RT DAQ/Fast control
- Standard CA
- Real-Time CA
- Fast Controllers Network
- EPICS CA Gateway
- EPICS RT Master
- EPICS DAQ (RT-slaves)
- Fast Controllers to CA Bridge
- Fast I/O
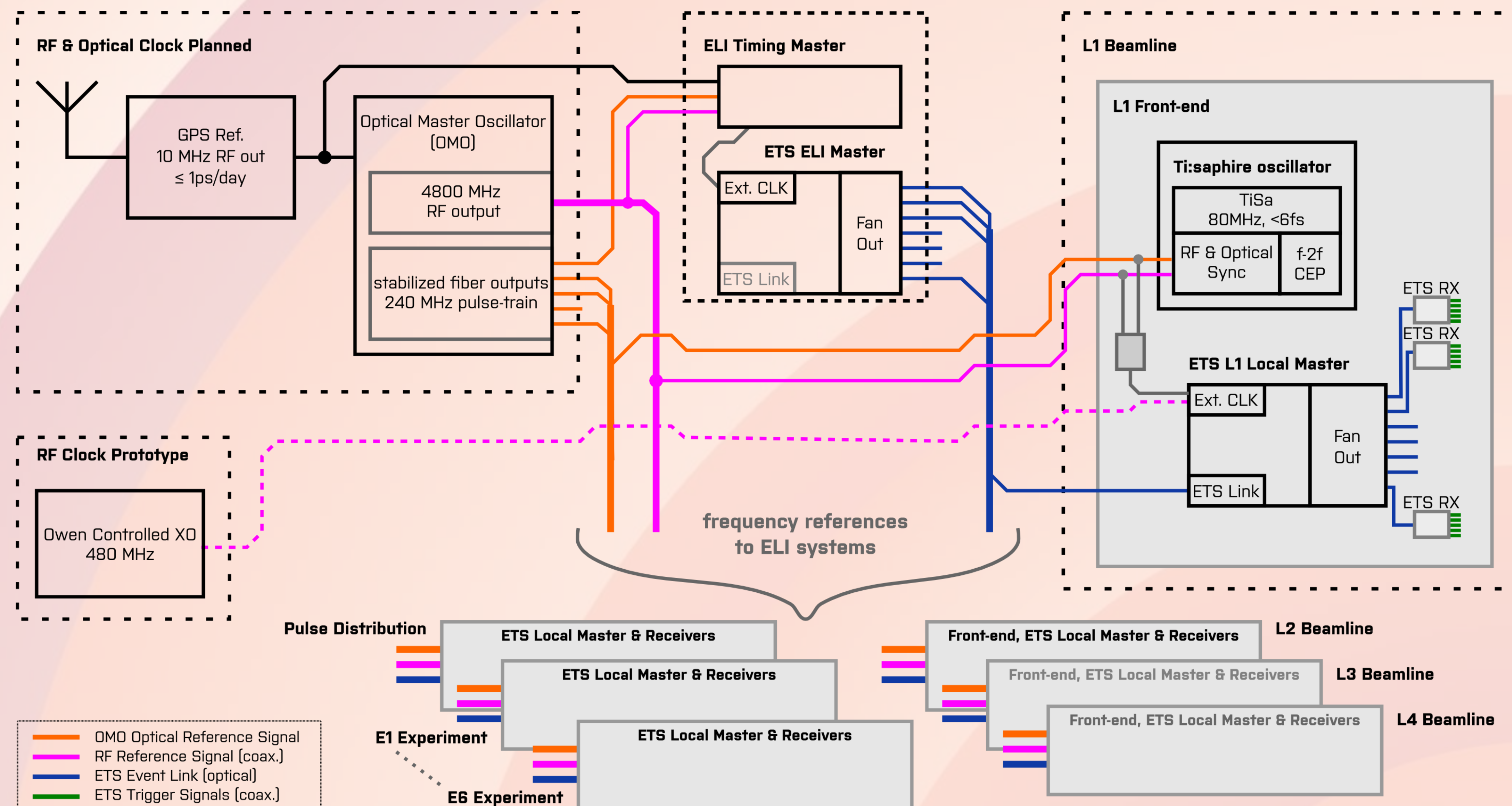
L1 Control System is dealing with
- 1 kHz beamline pulse repetition rate (internally up to 100 kHz)
  - fast control loops, e.g.: ps jitter stabilization at 1 kHz
- Pico- and femto-second duration laser pulses
  - fast photodiodes and GSa/s acquisition
- COTS equipment for diagnostics
- Low rate and 1000 fps rate cameras
- Pulse picking & beam modulation
  - using <15 ps RMS jitter triggers from ETS

L1 Control System is being prototyped with
- Ethernet for backbone & field bus
- Slow controllers use PICMG 1.3 form factor PCs for Ethernet & serial devices
- Fast controllers use PXIe for high-speed I/O, fast-loops and COTS equipment

Timing & Frequency Synchronization
- Optical references for 10 fs locking
  - Optical Master Oscillator (OMO) with <25 fs jitter in 1k–10MHz bandwidth
  - Stabilized fibers for beamline and experiment Front-ends
- RF high-frequency low jitter clock – complementary
- Electronic Timing System (ETS) for <15 ps jitter triggers
  - Master/Receivers using distributed optical link
  - Local masters to manage different timing domains
  - Remote receivers to have physical outputs – triggers
  - Synchronous and event-driven timing
  - Absolute time scale, sub-ms time-stamps and pulse-numbering
  - A prototype is being used in operation (Micro-Research Finland, Hytec)
    - has a minimal setup of ≈25 triggers
    - is interfaced by EPICS v3 and CSS

Timing diagram labels:
- RF & Optical Clock Planned
- GPS Ref. 10 MHz RF out ≤ 1ps/day
- Optical Master Oscillator (OMO)
- 4800 MHz RF output
- stabilized fiber outputs 240 MHz pulse-train
- ELI Timing Master
- ETS ELI Master
- Ext. CLK
- Fan Out
- ETS Link
- L1 Beamline
- L1 Front-end
- Ti:saphire oscillator
- TiSa 80MHz, <6fs
- RF & Optical Sync
- f-2f CEP
- ETS L1 Local Master
- ETS RX
- RF Clock Prototype
- Owen Controlled XO 480 MHz
- frequency references to ELI systems
- Pulse Distribution
- ETS Local Master & Receivers
- E1 Experiment
- E6 Experiment
- Front-end, ETS Local Master & Receivers
- L2 Beamline
- L3 Beamline
- L4 Beamline

Legend:
- OMO Optical Reference Signal
- RF Reference Signal (coax.)
- ETS Event Link (optical)
- ETS Trigger Signals (coax.)

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