Grand slow control design including monitor and interlock

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Using this opportunity, I tried to make a comprehensive (not fully filled) list of relevant items of accomplished work and things yet to be done

Coverage

- **Run control**
- **Slow control systems**
- **Monitoring**
- **Communication to accelerator**
- **Interlock**
- **Inter-process(or) communication**
- **Network**
- **Database and logging**
- **Operation**
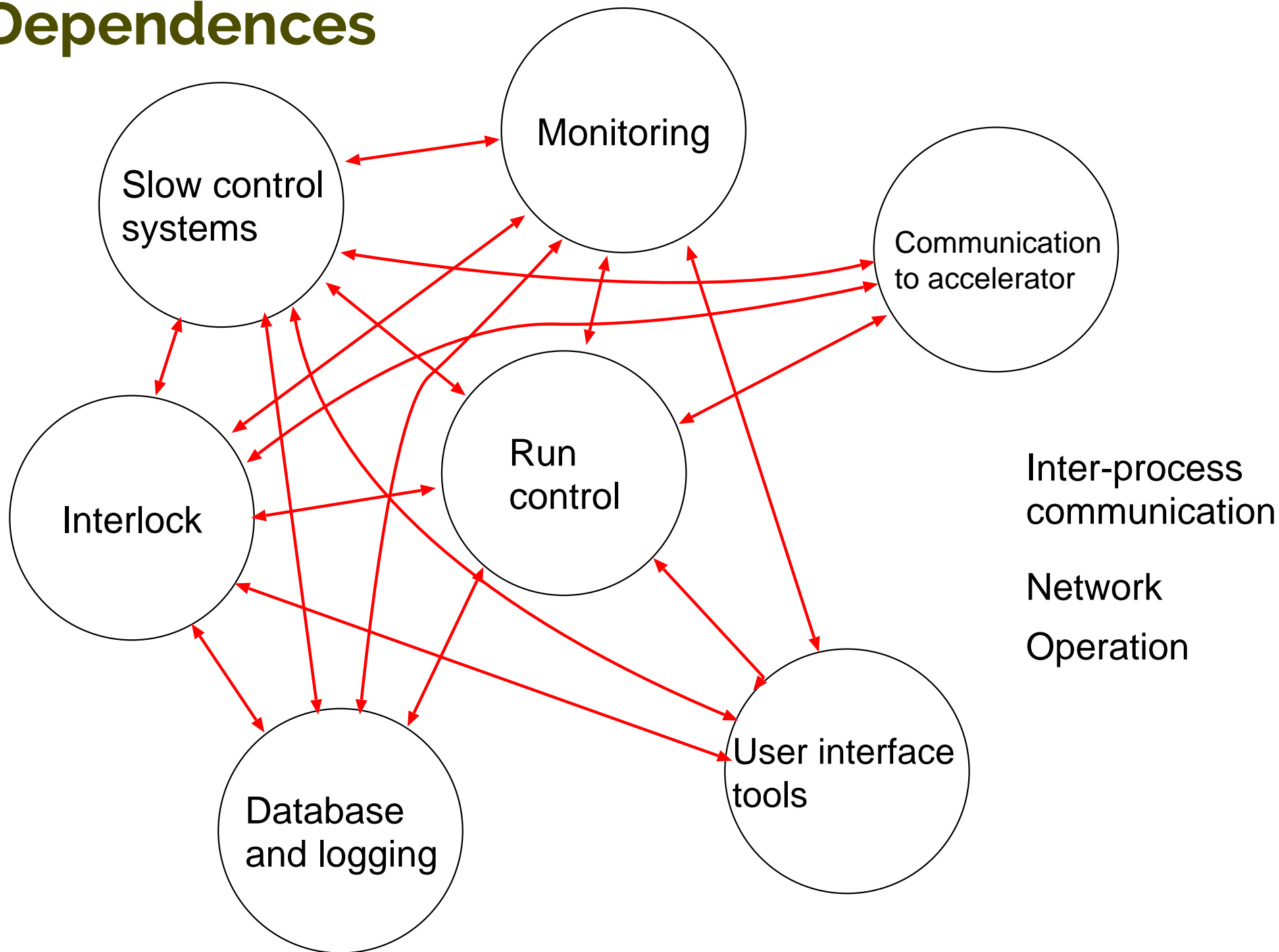- **User interface tools**

Mission
- Take healthy data
- Keep detector safe
- Minimize downtime

Run control
- Run control command system
- Configuration procedure
- Run state and transition
- Run type
- Local run
- Error and recovery handling

Slow control systems
- HV power supplies and control
- LV power supplies and control
- Cooling system

Monitoring
- Environmental sensors
- Gas system
- Solenoid
- Radiation monitors
- Data logger

Communication with accelerator
- Run start handshake procedure
- Info from accelerator
- Feedback to accelerator

Interlock
- Hardwired interlock
- PLC
- Alarm panel
- Reading out hardwired-only signals

Inter-process communication
- NSM2
- EPICS
- Logical structure
- Naming conventions

Network
- Network topology
- Network devices
- Security
- Remote access / Login server
- User account

Database and logging
- Configuration database
- Log messages
- Archiver
- Retrieving data from database

Operation
- Control room
- Shifters and experts
- Electric logbook
- Mail-based reporting system
- Cold startup procedure
- Supervising process

User interface tools
- CSS as a unified GUI tool
- Screen layout
- Color codes

A bit more in detail

Dependences

Slow control systems

Monitoring

Communication to accelerator

Interlock

Run control

Database and logging

User interface tools

Inter-process communication

Network

Operation

Run control

- **Run control command system**

  🙂 Tree structure: Master run control → Detector run control → …

- **Configuration procedure**

  🙂 Developed as a part of the run state transition

- **Run state and transition**

  🙂 States and Transitions are defined, and discussed in detail

  🙂 Coupled to the power supply states, heavily for SVD and PXD

- **Run type**

  🚧 Physics run, calibration run, …(need more discussion)

- **Local run**

  🚧 Discussion has been started

- **Error and recovery handling**

  🚧 Work in progress…

Slow control systems

- **HV power supplies and control**
  - 🙂 NSM2 based control system for outer detectors
  - 🙂 EPICS based control system for PXD, SVD

- **LV power supplies and control**
  - 🙂 Part of the run control transition for PXD, SVD
  - 🙂 LV control system in progress for TOP
  - 🚧 No monitor for others (?)

- **Cooling system**
  - 🙂 PXD CO2 cooling is a complex system to be controlled via EPICS
  - 🚧 No need of remote control for other cooling systems?

Monitoring

- **Environmental sensors**
  - Temperature, humidity, water leak, gas leak, …
  - TOP, KLM temperature monitor through Belle2link
  - Common water leak sensor proposed by TOP group

- **Gas system / cooling system**
  - Computer-readable monitor for gas flow / water flow

- **Solenoid**
  - Current and B-field, quench signal

- **Radiation monitors**
  - Part of beast II

- **Data logger**
  - Yokogawa MW100, Keysight 34980A

Communication with accelerator

- ● **Run start handshake procedure**
  - ✔ Matching between beam fill / abort cycle and PS rampup/down and run start/stop cycles
  - ✔ Hardwired signals for handshake, more information through EPICS

- ● **Info from accelerator**
  - ✔ EPICS CA gateway (b2skbgate) already in use for Beast phase I
  - ✔ Selected SuperKEKB info is readable (readonly) from b2epics
  - ✔ Provided PVs are listed in GATEWAY.pvlist in MDI Wiki

- ● **Feedback to accelerator**
  - ✔ The same EPICS gateway
  - ✔ Selected Belle II (beast) info is readable from SuperKEKB network
  - 🚧 Luminosity, HV, and many other information

Interlock

- **Hardwired interlock**

  - Interlock systems within each detector

- **PLC**

  - Yokogawa FA-M3V, OMRON ZEN

- **Alarm panel**

  - Hardware panel in B3 producing alarm sound

  - Software version to be available too

- **Reading out hardwired-only signals**

  - Some singals were not available in computer readable form in Belle and it was very inconvenient — this situation must be avoided

Inter-process communication

- **NSM2**

  ✔ Framework for outer detector run and PS control

- **EPICS**

  ✔ Framework for VXD detector run and PS control, KEKB interface

- **Logical structure**

  ✔ EPICS-NSM2 gateway makes it almost seamless to communicate between NSM2 systems and EPICS systems

  ✔ It is not real mixture of NSM2 and EPICS, closely related systems are using the same framework

- **Naming conventions**

  🚧 Need to define and provide a comprehensive list

Network

- **Network topology**
  - Two segments: b2nsm/b2epics for slow control / daqnet for others
  - Private networks behind these networks (COPPER, Beast, PXD, …)

- **Network devices**
  - Mostly SL[567] Linux, special devices using something else
  - No Windows directly connected to daqnet (hide in private net)

- **Security**
  - Don't consider daqnet is safe! (recently KEK linac private network was affected by a ransomware)

- **Remote access / Login server**
  - bdaq as the single entry point / b2stone as the single proxy point

- **User account**
  - centralized by bdaq LDAP service / avoid shared password

Database and logging

- **Configuration database**

  - Work in progress

- **Log messages**

  - Work in progress

- **Archiver**

  - Need to set up a central CSS archiver

- **Retrieving data from database**

  - Besides the use within DAQ netwokr, a copy is needed in the KEKCC environment (no direct access from KEKCC)

Operation

- **Control room**
  - Design in progress

- **Electric logbook**
  - elog has been used by TOP and DESY beamtest
  - Not yet in serious use at KEK

- **Mail-based reporting system**
  - ML based error reporting using bpost is working (for Beast II)
  - Individual mail using bpost and registered email for bdaq account

- **Shifters and experts / Cold startup procedure**
  - Yet to be defined

- **Supervising process**
  - Mechanism to quickly detect dead host, dead system processes, ...

User interface tools

- **CSS as a unified GUI tool**

  - Main graphical UIs are now based on CSS

- **Screen layout**

  - NSM2 based UI has its nice look-and-feel

  - VXD UI has another nice look-and-feel

  - They are not similar, need an effort to make them closer

- **Color codes**

  - No written definition, but reasonably unified based on some common sense

Detector based list 1

- **PXD**
  - Complex HV system with many voltage with proper sequence
  - Complex CO_2 cooling system redesigned with EPICS
  - LVPS integrated with DHH
  - Temperature / humidity / water leak sensors

- **SVD**
  - Positive and negative HV and LV system, control by EPICS

- **CDC**
  - LVPS, HVPS, gas, water are in operation
  - HV system based on NSM2
  - FEE (RECBE) temperature and voltage via Belle2link
  - Temperature / humidity / gas leak / water leak by central monitor
  - LVPS, gas flow / water flow yet to be implemented
  - Very little parameter configuration parameters through Belle2link

Detector list 2

- **TOP**

  - LVPS, HVPS, interlock are in operation

  - CAEN HVPS via TCP/IP control by a NSM2-based control

  - Wiener LVPS via SNMP to be controlled by NSM2

  - Temperature/humiditity/voltage/currents via Belle2link

  - Very long configuration sequence with Belle2link and python script

- **ARICH**

  - HV control via NSM2

  - Parameter configuration with Belle2link and NSM2

- **ECL**

  - Parameter configuration with Belle2link is ready

- **KLM**

  - HV control UI developed for Java interface, to be updated for CSS

Conclusion

- **Not much effort has been made for the grand slow control design, but it's about time to do so** (target date: BPAC in October)

- **Plan is to make a Wiki entry with this structure and fill the items with more details** (and with names)

- **Any feedback?**

Backup (2016.6 B2GM slides)
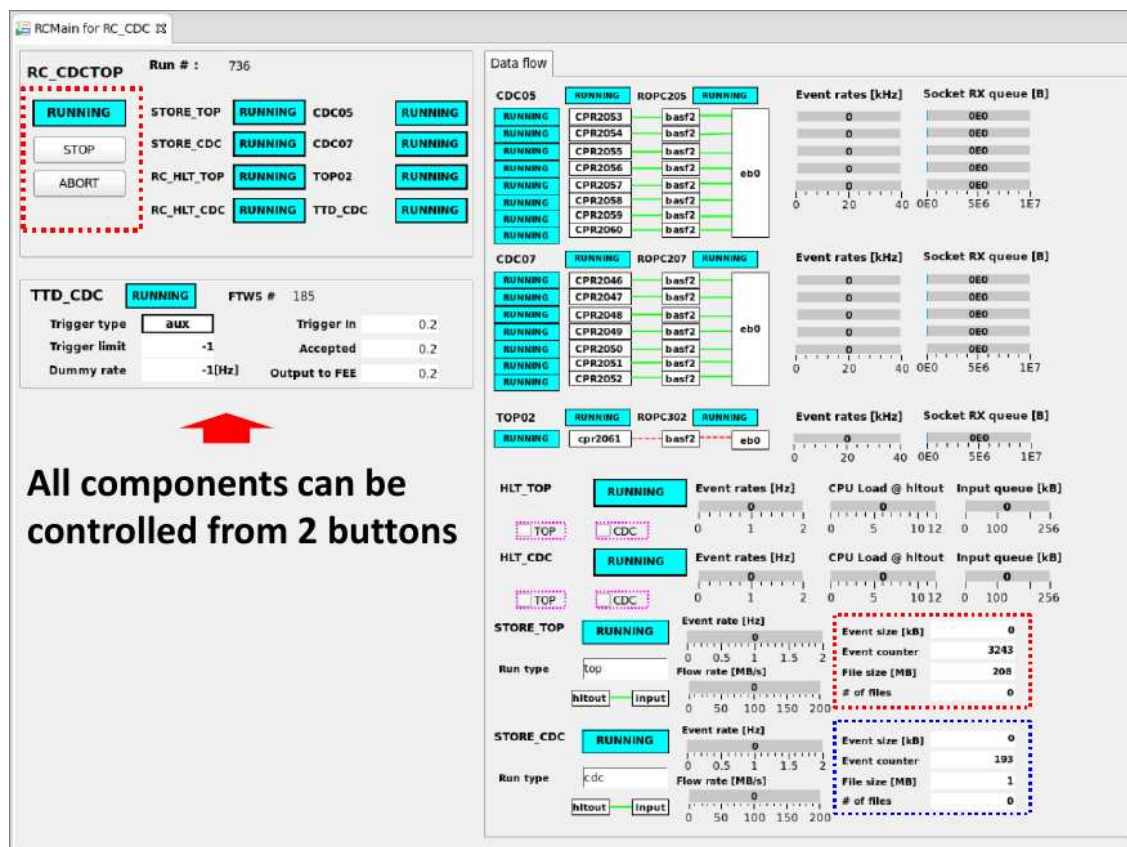
Run/Slow control in operation

- **Full run control and slow control are in operation for CRT at KEK, test beam at DESY**

  - Both NSM2 based systems and EPICS based systems are working

  - Complex readout chain is under control from UI

- **All user interface is now operated under unified CSS environment** 🙂
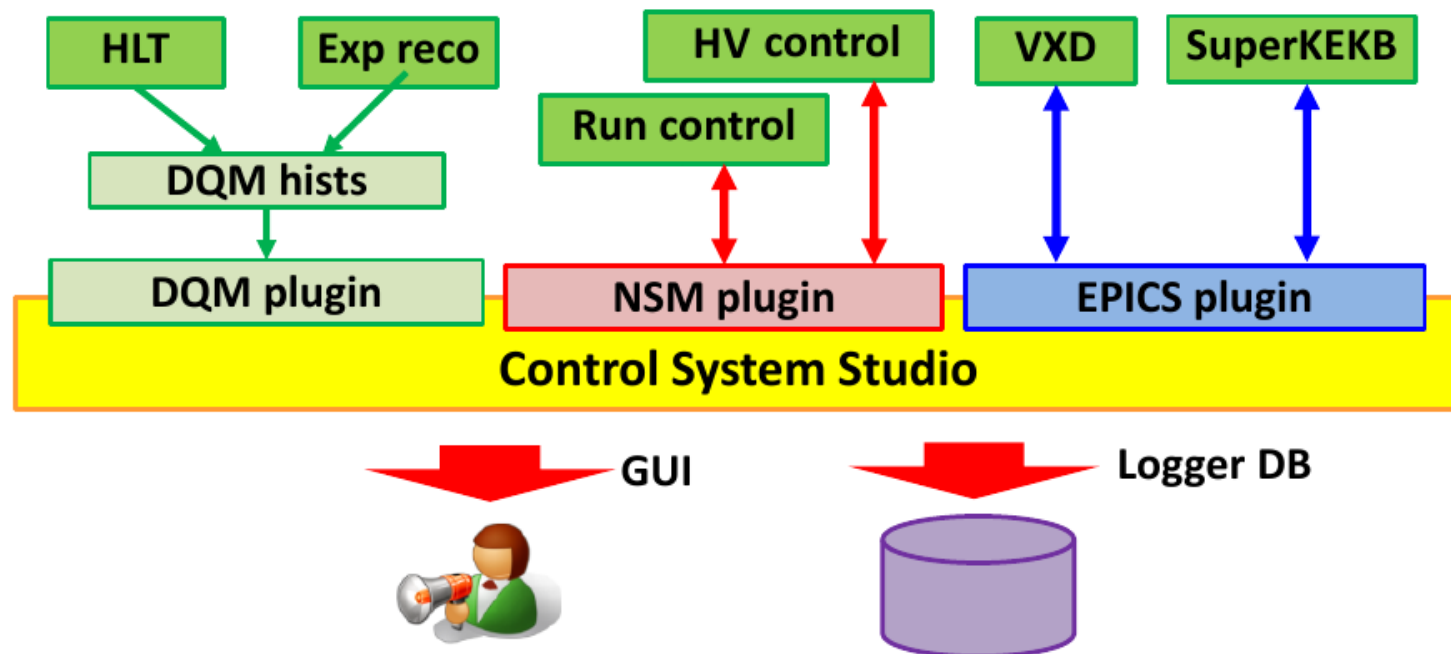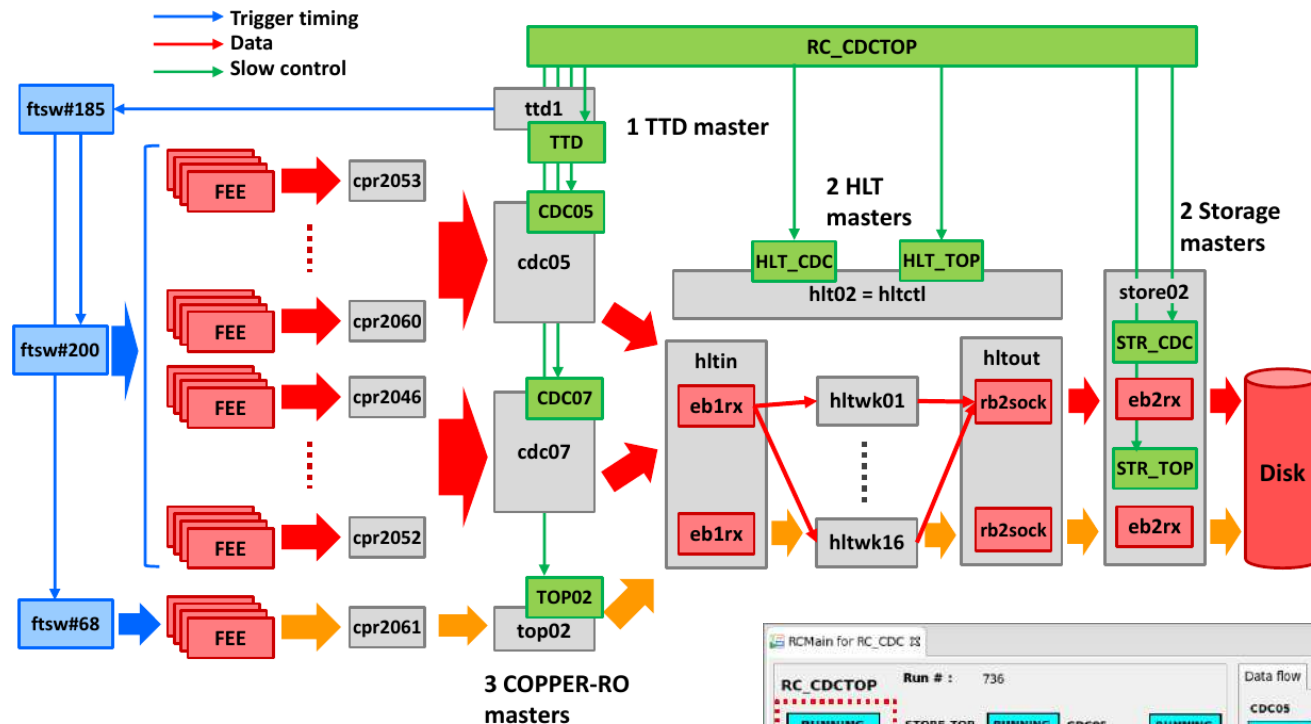
TOP+CDC Run Control

- This level of complex system can be controlled from a single UI panel

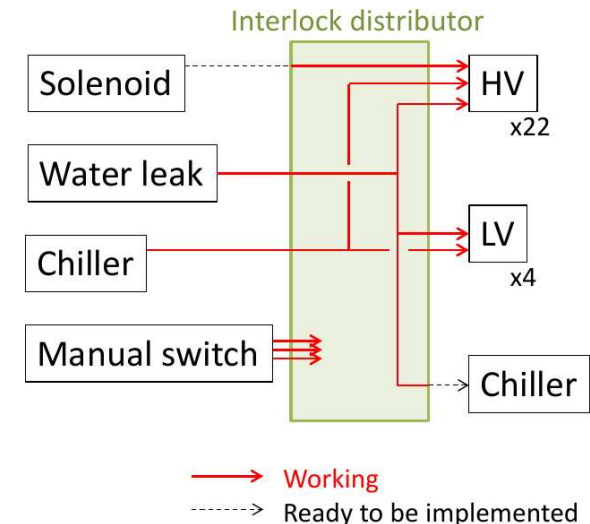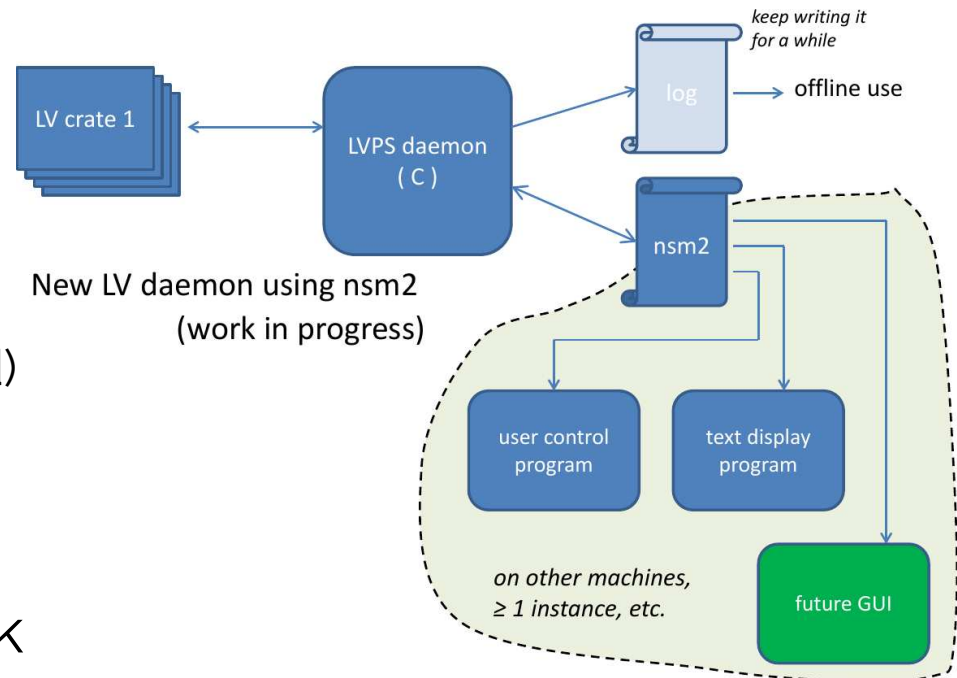- Operation of the system discussed in the talk by Yamada-san

Also at DESY beamtest

- EPICS based VXD run control and NSM2 based SVD-COPPER and back-end DAQ system are nicely controlled from a signle Run Control (Details in Konno-san's talk)
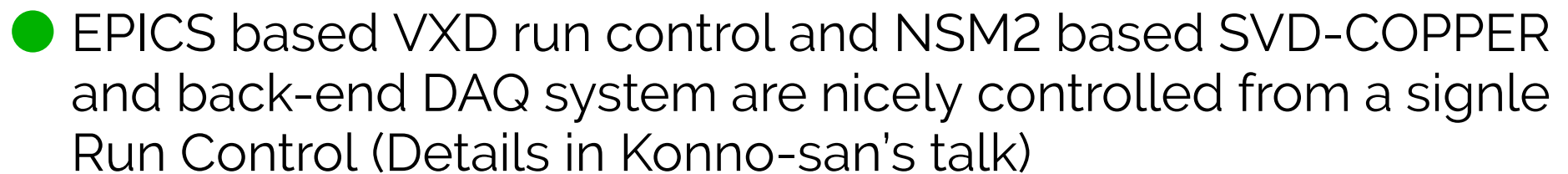
TOP slow control

- LVPS, HVPS, interlock are in operation

- HV control is based on ARICH system developed by Konno + Yonenaga

  (no GUI yet but to be straightforward)

- LV control is in operation

  (GUI should be similar to HVPS)

- Info collected from Belle2link is needed

- Same water leak sensor to be used in the other place of the detector

New LV daemon using nsm2 (work in progress)

LV crate 1 → LVPS daemon (C) → log (keep writing it for a while) → offline use

nsm2 → user control program, text display program, future GUI

on other machines, ≥ 1 instance, etc.

FR-ADセンサ(耐熱難燃タイプ)
120℃までの耐熱性があり、難燃繊維です。

TOP enclosure

IDS

CDC-SC

Water leak sensor

Interlock distributor

Solenoid, Water leak, Chiller, Manual switch → HV (x22), LV (x4), Chiller

→ Working
⤏ Ready to be implemented

Look-and-feel unification

- UI for both outer detector and VXD are now constructed using CSS

- Parallel efforts, outer detectors at KEK and VXD in Europe

- All run control systems and HVPS control systems follow the agreed state transitions

- State names and color codes are agreed and unified

- Current look-and-feel are somewhat diverted, but this is not because of the underlining layer (NSM2 or EPICS)

- All building blocks are now ready, and unification of look-and-feel has to be started

- Next milestone: TRG/DAQ workshop in September

No more java-based UI

BKLM+EKLM HV slow control

- BKLM+EKLM HV power supply control software has been implemented by XiaoLong Wang; GUI uses the DAQ group's java interface *(now declared obsolete?)*

- Control each crate separately.

- Software interlock is functional.
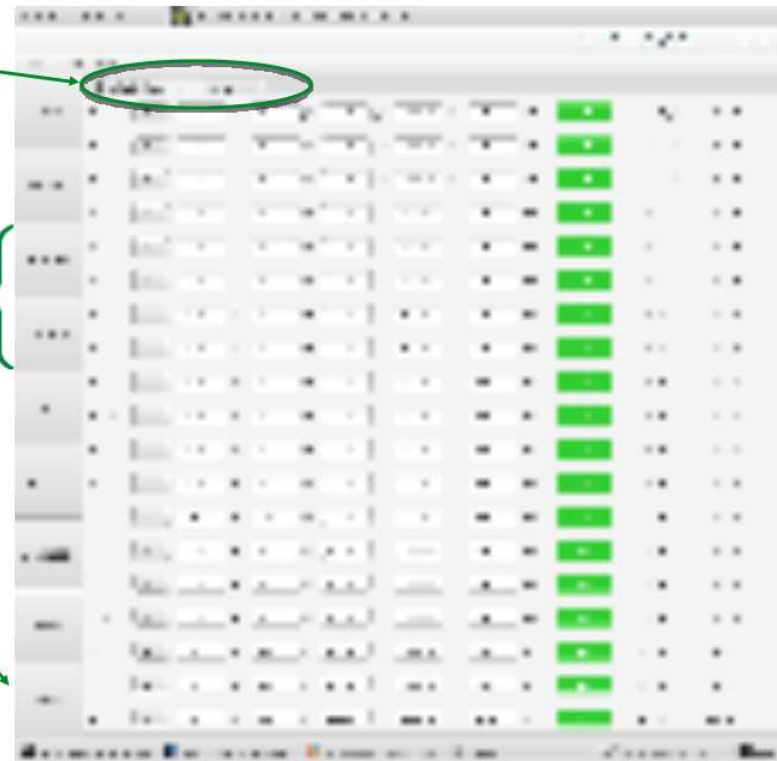
I'm sorry, but yes, it is obsoleted…

Network in Tsukuba hall

● Physically parallel two networks in Tsukuba hall

  ● **b2epics / b2nsm network** — exclusively used for slow control purpose, to avoid unexpected traffic spike

  ● **daqnet** — to login the host from bdaq, run file download, security patches or file backup, traffic spike is permitted

  ● EECL montior (uSOP) group brought in 16 network devices with 32 network ports, now nicely organized and commissioned

● **bdaq** as the login server, **b2stone** as a proxy server

● To be done

  ● bdaq hardware will be updated during summer break

  ● Sending emails from daqnet to internet…

Security of daqnet

- LDAP based user login

  - $\sim$ 100 user accounts were created

  - Shared account has been prepared and used (b2top, b2trg, etc)

  - Shared account is not for login from/to bdaq, just to run programs

  - Shared account login within local private network is allowed

- **Please apply security patches to your PCs**

  - I'm serious. I was asked at a KEK security management committee meeting

- No direct connection of Windows to daqnet / b2epics

  - Windows in E-hut has to be in a private network
    (e.g., diamond luminosity monitor group)

Network access to KEK

From a host at Uni HD with 1GBit/s uplink, measured at the same time, repeated over several weeks with essentially identical results, symmetrical:

- KEK CC (via sshcc2, repeated several times)

```
$ dd if=/dev/urandom bs=4096 count=100000 | ssh
login.cc.kek.jp "cat > /dev/null"
409600000 bytes (410 MB, 391 MiB) copied, 52,4464 s, 7,8 MB/s
409600000 bytes (410 MB, 391 MiB) copied, 51,2012 s, 8,0 MB/s
409600000 bytes (410 MB, 391 MiB) copied, 52,9946 s, 7,7 MB/s
409600000 bytes (410 MB, 391 MiB) copied, 51,3338 s, 8,0 MB/s
```

- bdaq via VPN

```
409600000 bytes (410 MB, 391 MiB) copied, 1325,27 s, 309 kB/s
```

- Difference: **factor of 24**!

- It is unclear if the limit is already in the VPN, or between VPN endpoint and bdaq.

- This bandwidth is hardly sufficient for remote control rooms.

● After the security incident, KEK-VPN was chosen as the access method

● Need something like previous bpost: a new login server is in preparation

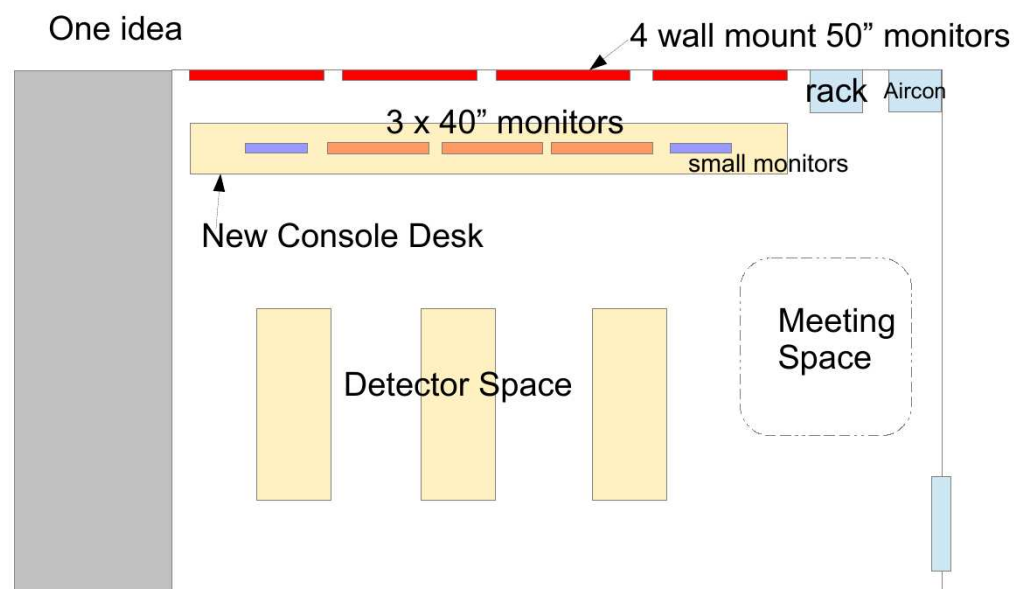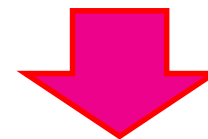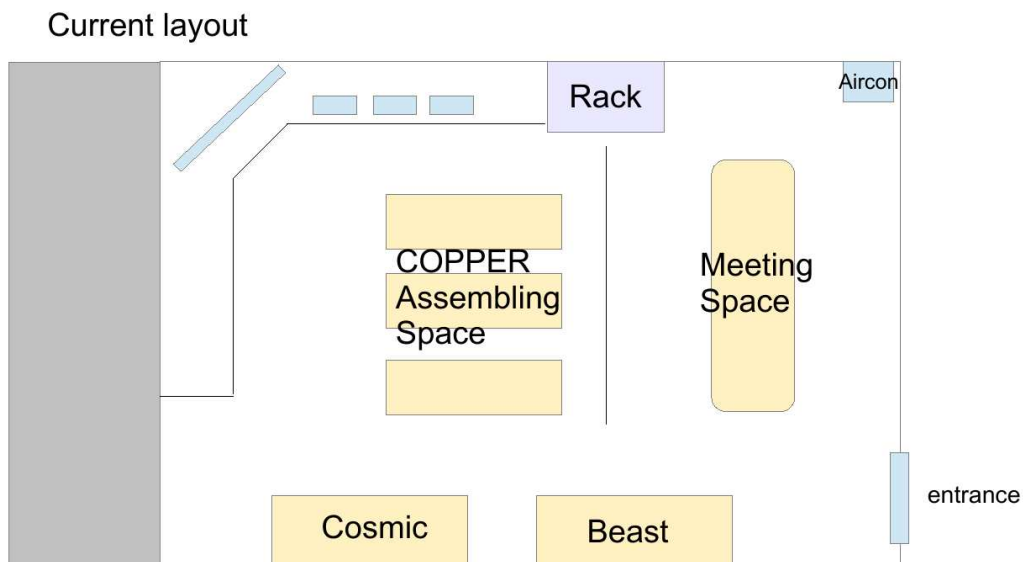● Triple factor authentication: public key + password + (Yubikey or Google authenticator)

Yubikey

YubiKey NEO
★★★★⯨ 198
$50.00 ✓Prime

YubiKey 4
★★★★⯨ 41
$40.00 ✓Prime

YubiKey NEO-n
★★★★⯨ 38
$65.54

FIDO U2F Security Key
★★★★☆ 255
$17.99 ✓Prime

YubiKey 4 Nano
★★★★⯨ 22
$50.00 ✓Prime

- Yubikey is a simple device to attach in USB to generate one-time pass-word

- Costs about 50 USD, already tested and working fine for me (I have a Yubikey-4 and Yubikey NEO-n)

- Google authenticator will be a cost-free alternative solution, but not tested yet

- Details to be announced soon

Control room

- Finally COPPER assembling space and company space can be freed, to turn the room into a control room (We have cleaned the room a lot to prepare for the G7 visit)

- Plan is to replace all desks and provide large 40-inch 4K monitors

- Idea to be converged until the September TRG/DAQ-WS, and actual work to be done afterwards

Current layout

Rack

Aircon

COPPER Assembling Space

Meeting Space

Cosmic

Beast

entrance

One idea

4 wall mount 50" monitors

rack Aircon

3 x 40" monitors

small monitors

New Console Desk

Detector Space

Meeting Space

Missing things

- Need more introductory documents
  - Although the running systems are running fine, very little info available for a new comer to start

- Unification of UIs

- Naming scheme has been discussed earlier, need to finalize

- Centralized archiver is not available yet, urgently needed
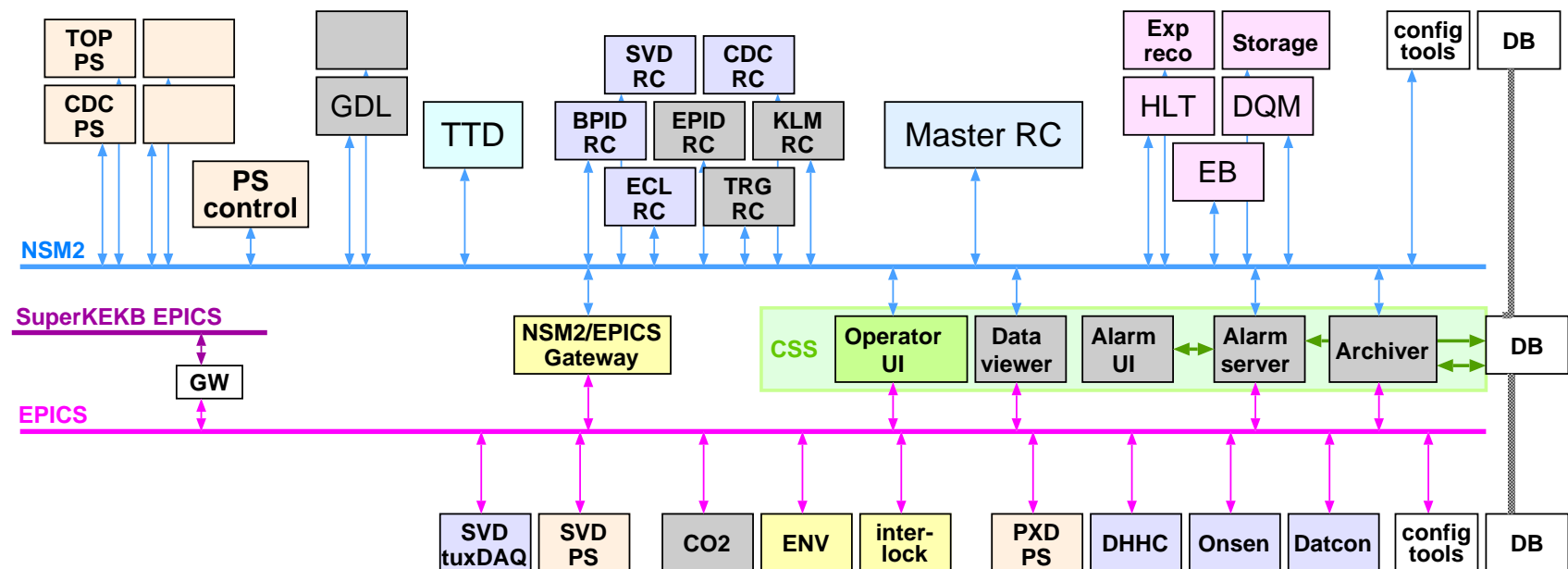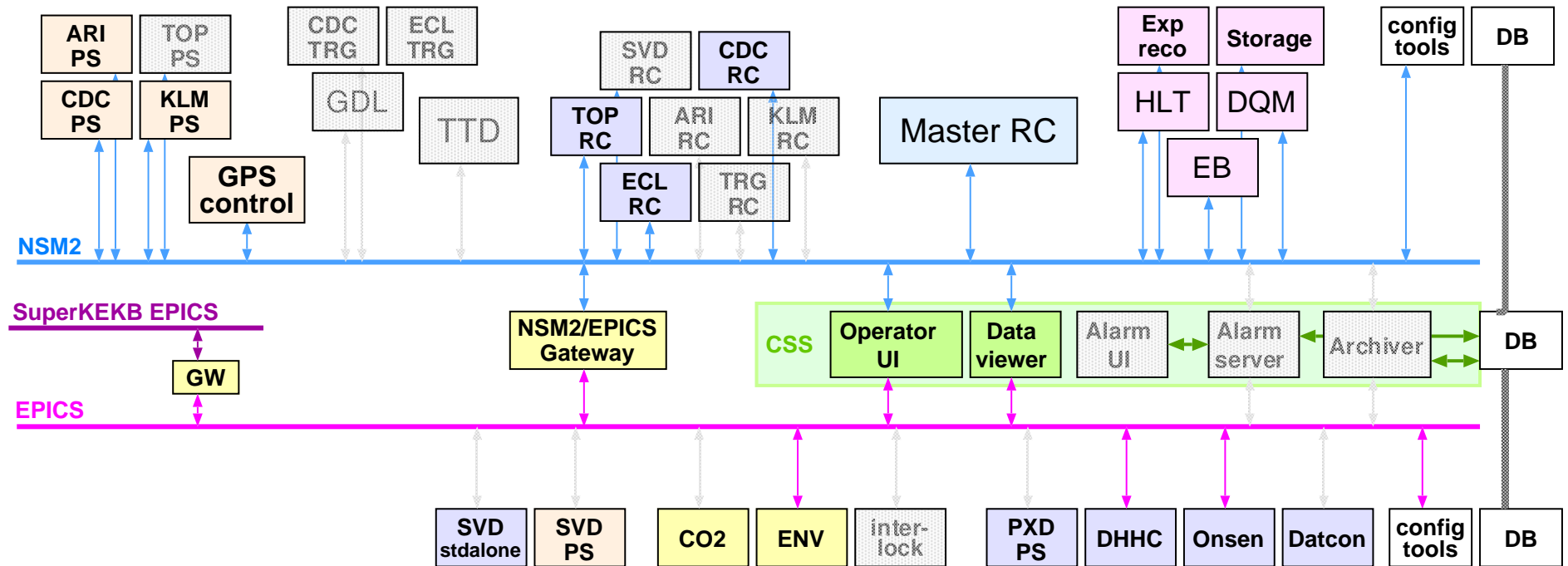
Backup (2016.2 BPAC slides)

Task of Slow Control
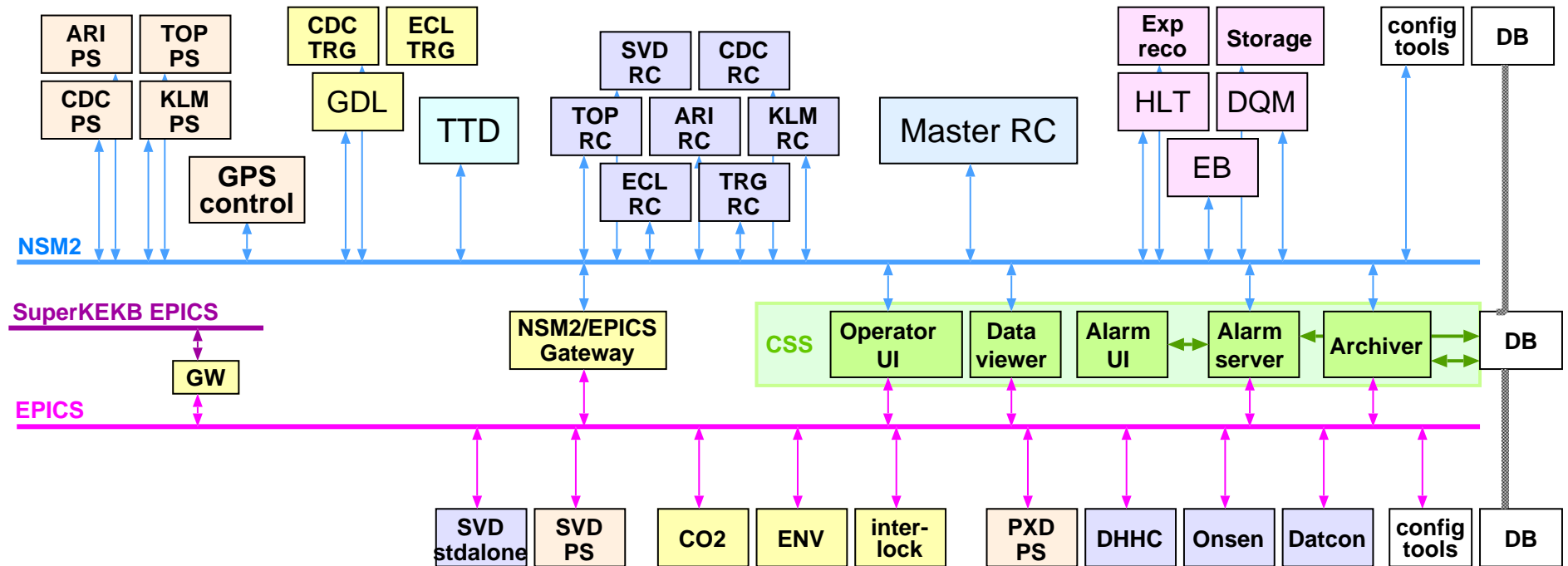
(1) Smooth operation of the DAQ system when beam is ready

(2) Safe operation of the detector

(3) Shifter-friendly interface to operate with minimal training

(4) Expert-friendly interface to quickly solve problems if any

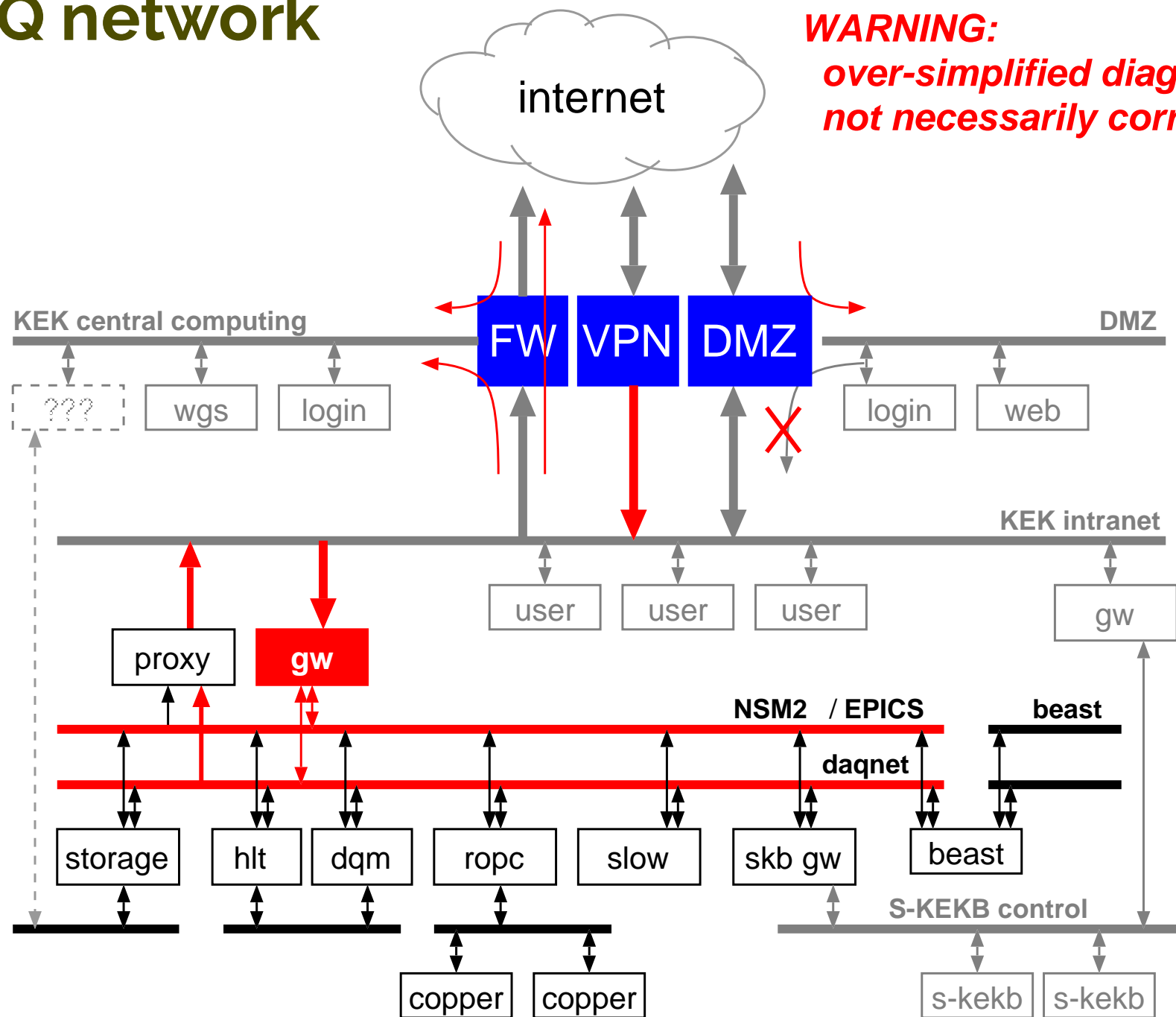**(5)** Logging all trends and events for later analysis / diagnosis

Commissioning Slow Control (outline)

(1) Already many are under control of NSM2 or EPICS

(2) CSS based UI is there

(3) Comissioned system at KEK are getting connected

(4) Many off-site development efforts also on-going

DAQ network

How to use/manage/secure network

⚠️ **34** readout-PCs, **210** COPPERs (all SL5), many HLT cores, …(DAQ group)

⚠️ **Slow control and other PCs (detector groups)**

✔️ Single entry point, single sign-up with LDAP

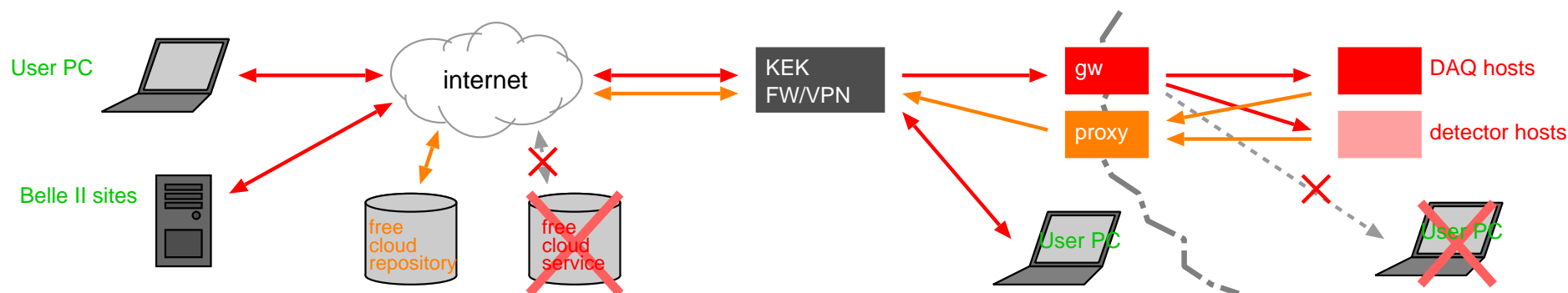✔️ Every user has his/her own account, **no shared remote-login**

🚧 Trying to get rid of shared password inside daqnet

🚧 Trying to get rid of Windows on daqnet

🚧 Accounts in beast networks are a bit caotic now, to be sorted out

⚠️ **One-way path to enter daqnet, more restricted to get out**

🚧 Challenges to make status visible from internet

EPICS (CA) gateways

- **Loose connection between Belle II and SuperKEKB for safety**
  - **SuperKEKB PVs transferred into b2epics** (list maintained by us)
  - **b2epics PVs transferred into SuperKEKB** (List maintained by them)
  - All PV transfer between SuperKEKB and Belle II are **readonly**

- **Beast EPICS network is less loosely coupled**
  - beast shift terminal (OPI) on daqnet/b2epics **in operation**
  - beast PVs transfered into b2epics (and then to SuperKEKB)
 - An other terminal in SuperKEKB operator room in preparation, based on transferred PVs **(readonly)**
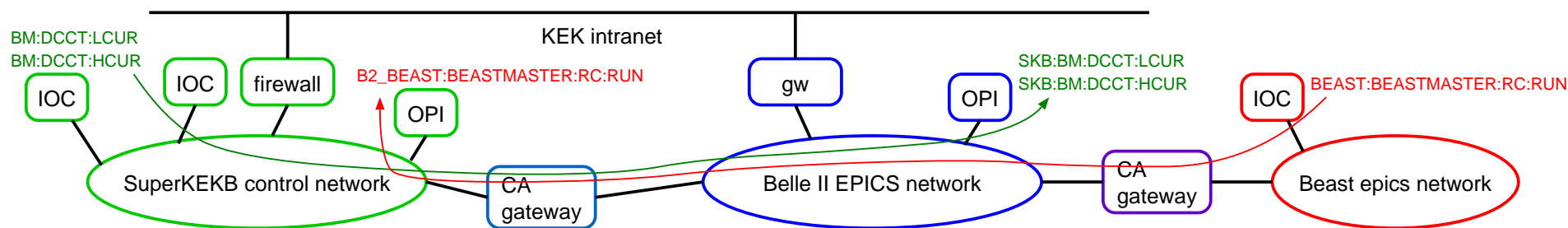
CRT setup for ECL+KLM

- **NSM2 based** control

- Barrel ECL is **fully** installed (36 Belle2links, 18 COPPERs)

- KLM is still partial system (waiting for Belle2link fibers)

- **KLM power supply** under control (ECL is always ON)

- ECL has an **external PC** for Shaper-DSP configuration

- Otherwise FEEs are configured through **Belle2link**

- **ECL trigger** partially installed, always generating trigger (no control yet)

- KLM trigger is still ad-hoc

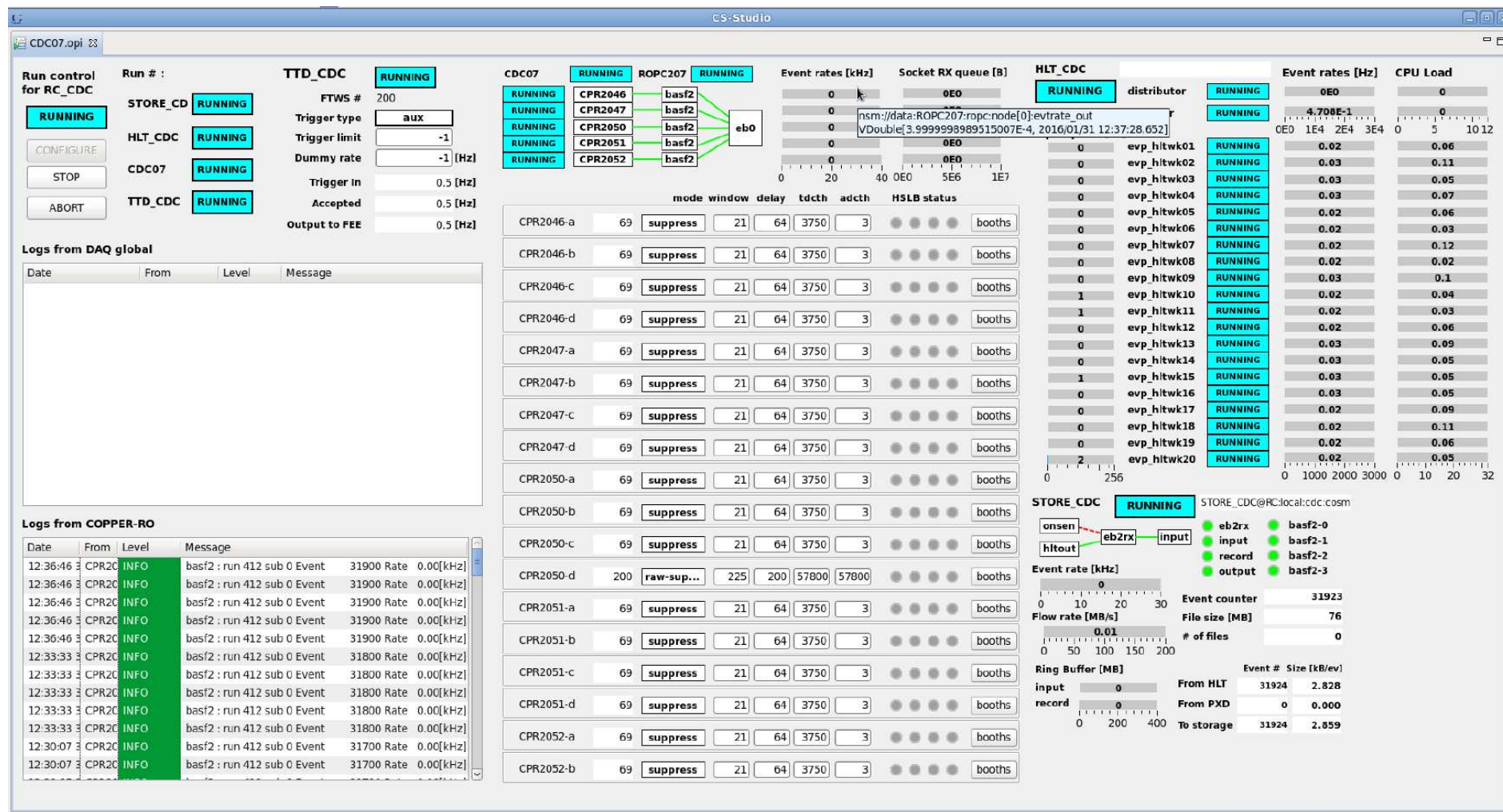- ECL+KLM data taking tested, but still separately used most-of-time
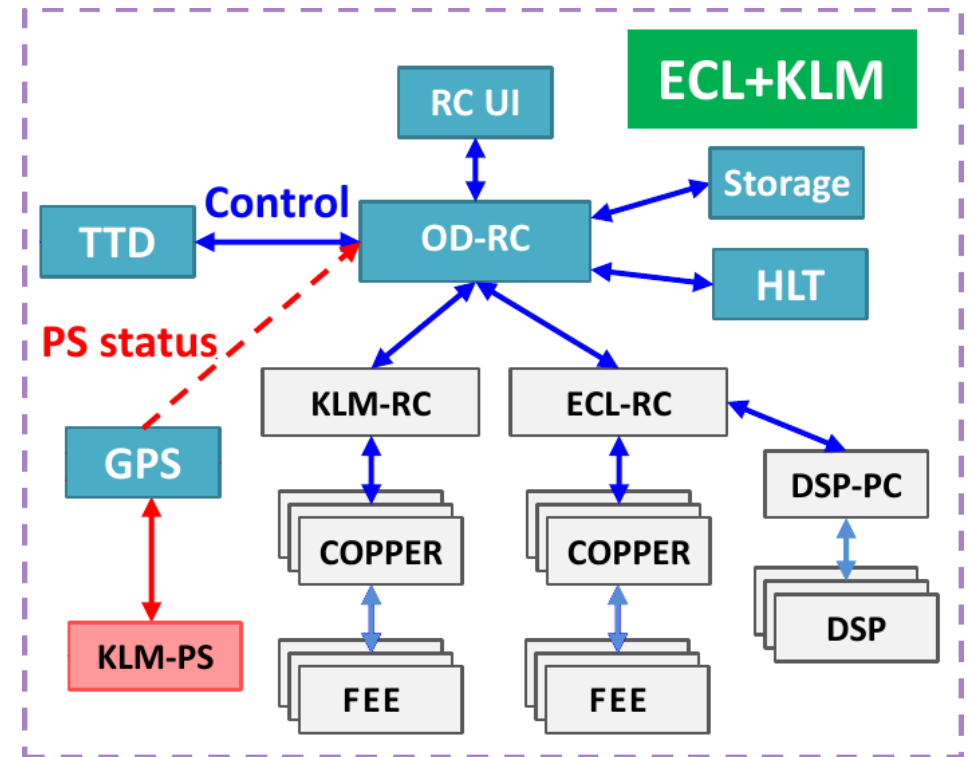
CRT setup for 2-ring-circus
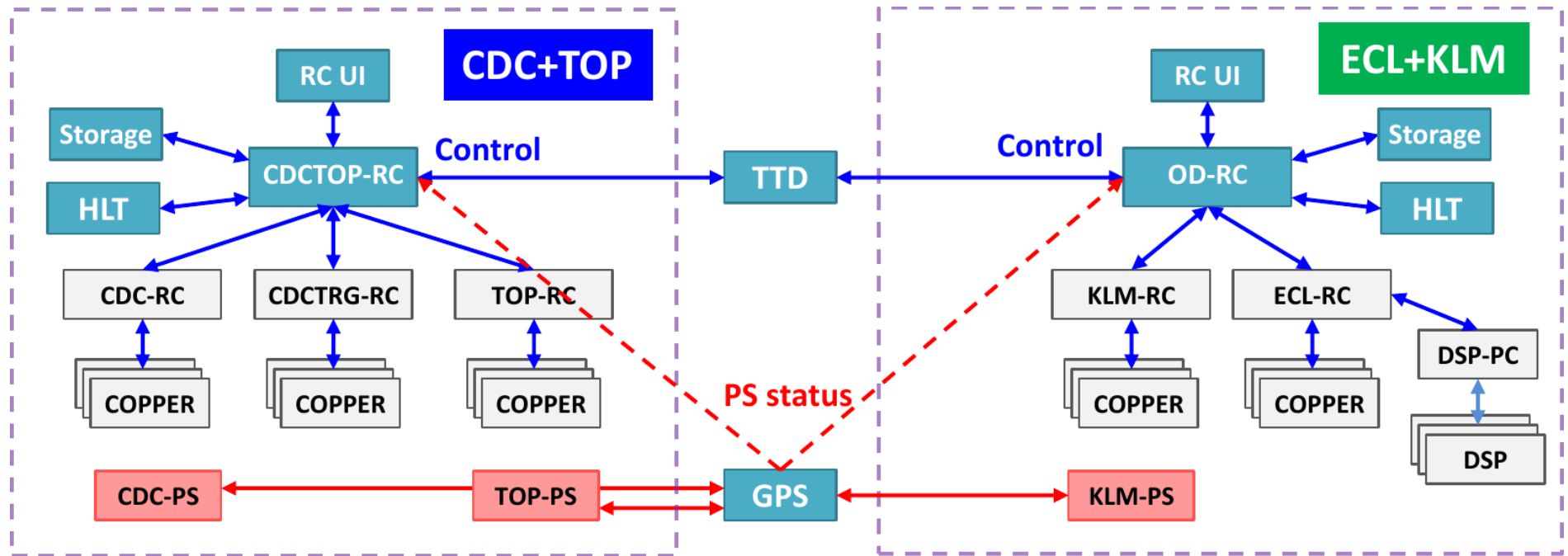
- **No major problem to double the control system**

- **Global Power Supply** and **Trigger Timing Distribution** are shared

- **Separate shift account in preparation**

  (mis-operation is happening, especially when command-line interface is used)
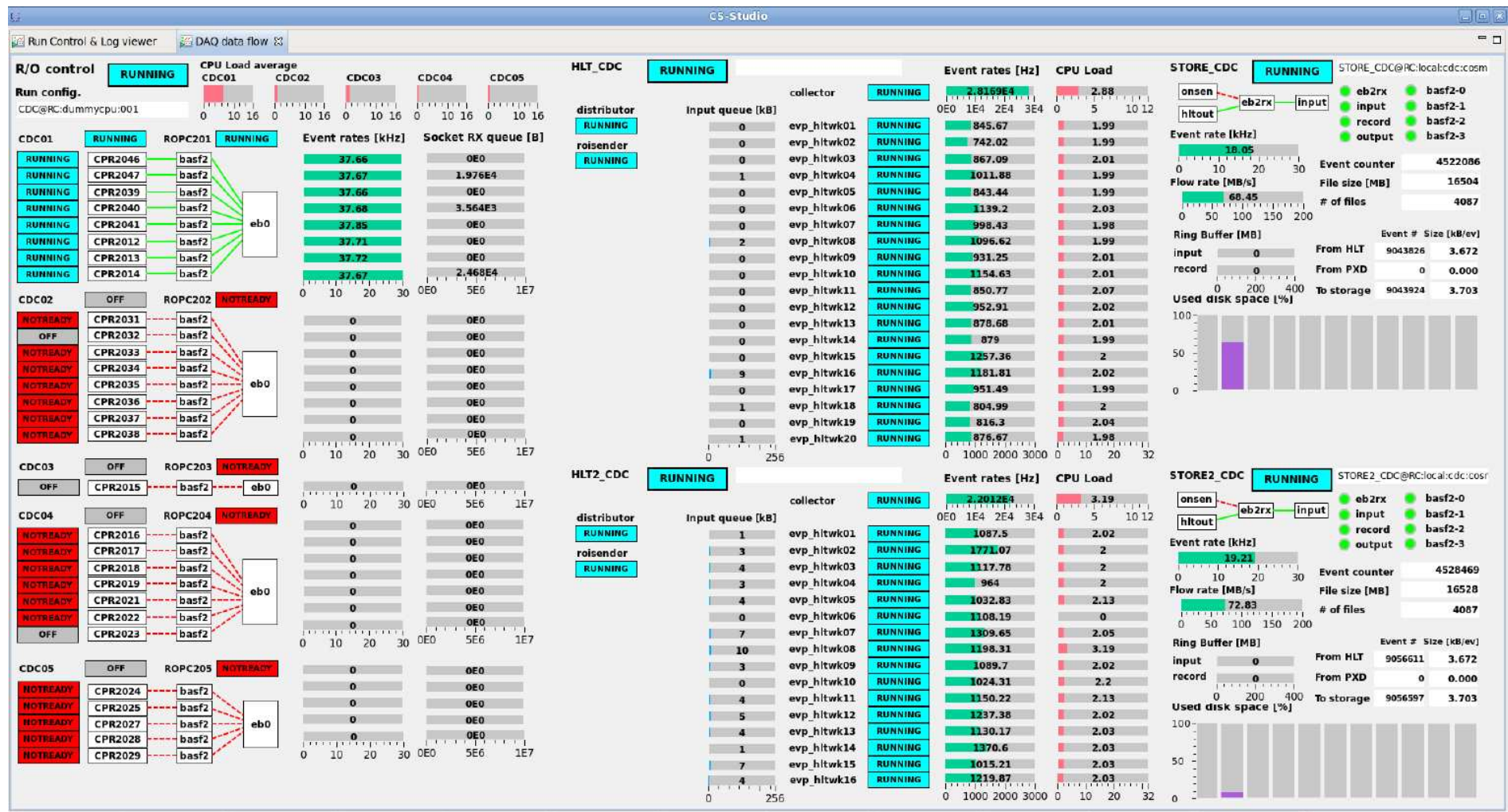
Run control UI

● Running under CSS for NSM2 based systems (COPPER, HLT, ...)

● In this example, all 18 Belle2links of CDC test setup are shown, Multi-layer UI is needed for a further complex system

Data flow monitor

- This kind of panel is useful to identify where the dataflow get stuck
- More info are needed, e.g., Belle2link and COPPER FIFO status

Power Supply Control

(Java-based UI for KLM)

- Similar HV Power Supply (PS) hardware for CDC, ARICH, TOP and KLM

- HV can be applied independent of DAQ — FEE just do not get signals, but useful to debug the system when HV is inhibited

(CSS based UI)

- Common PS control framework

- Already in use for the installed KLM system, operated from Virginia Tech

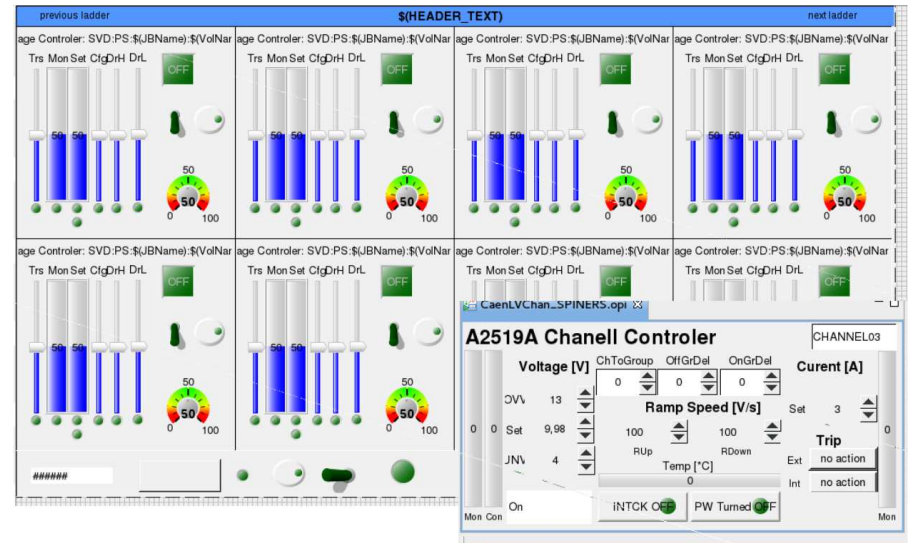- Configuration edit panel and data browser to monitor the values
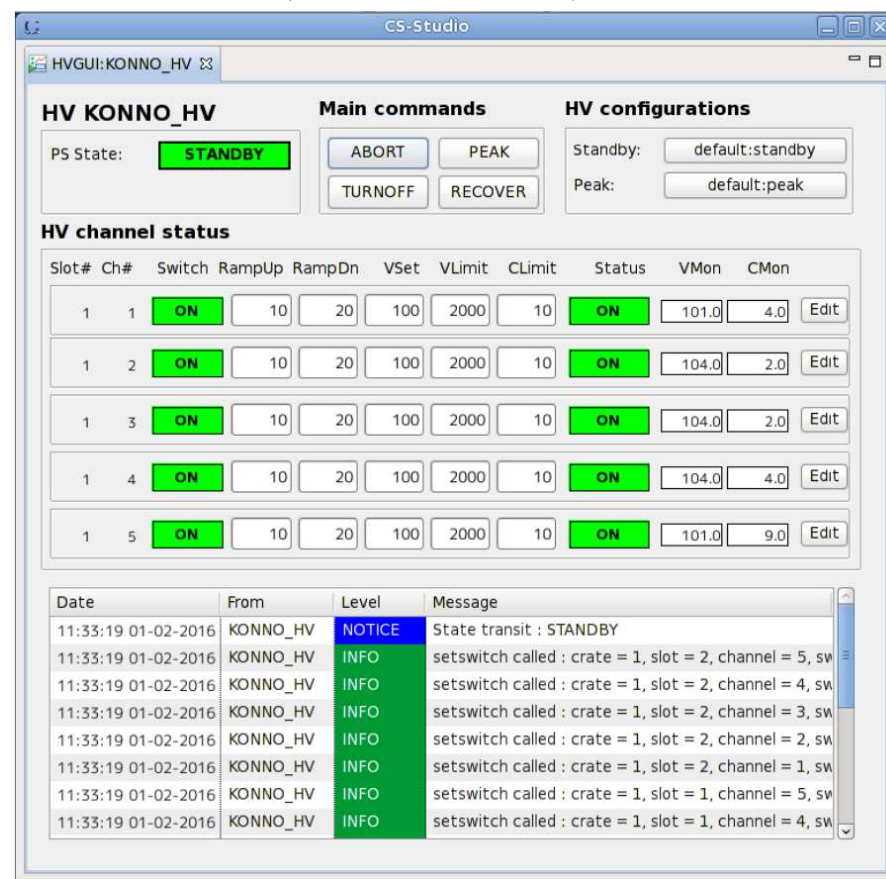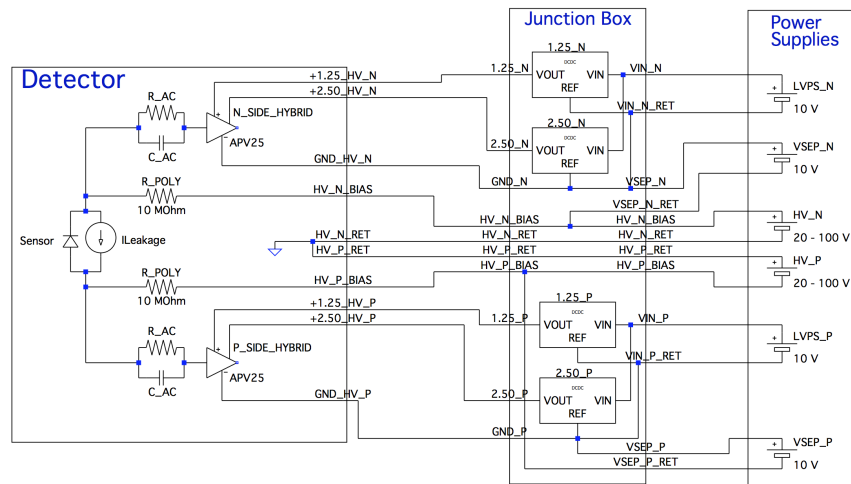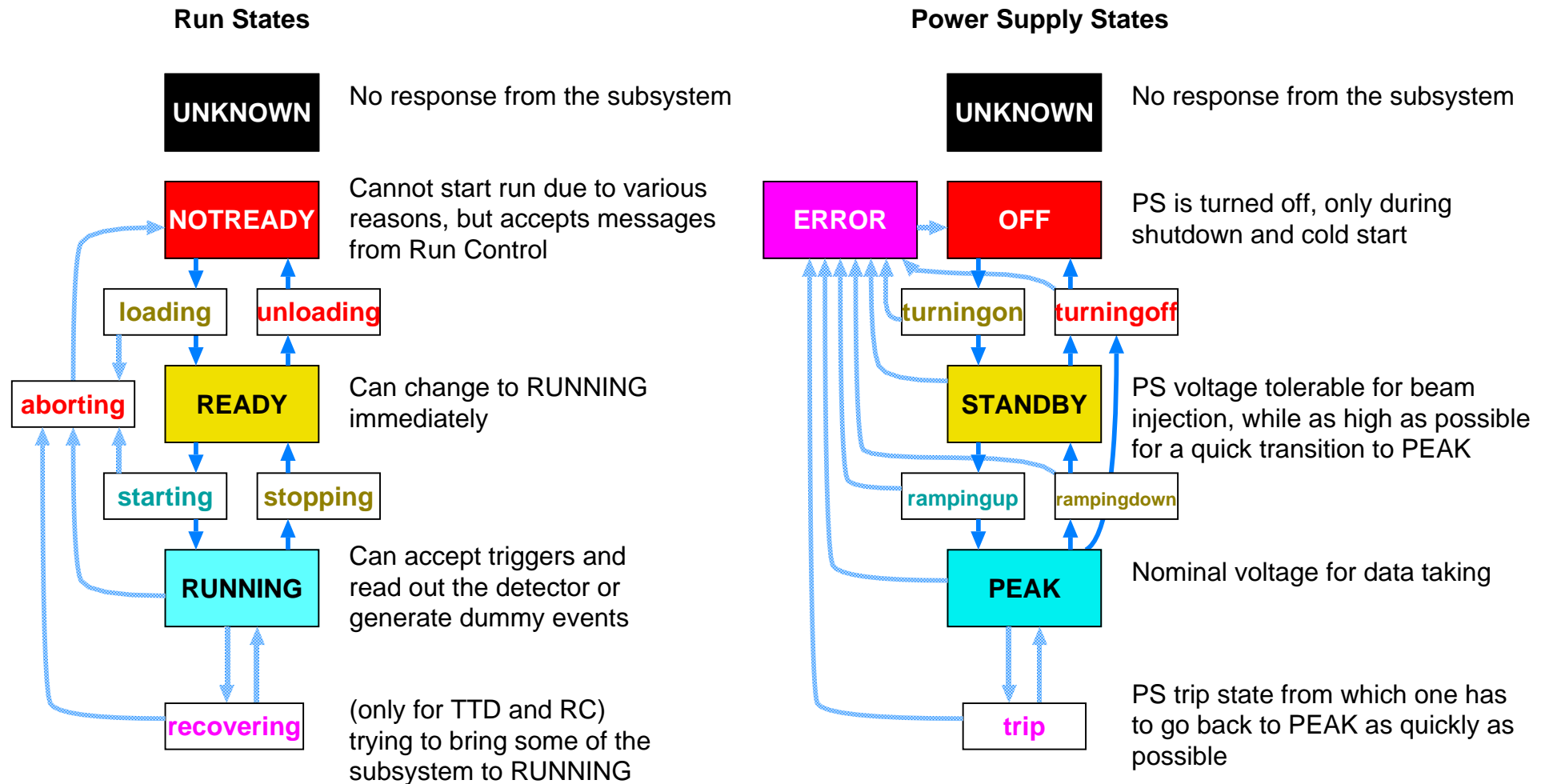
PS Control for SVD

- Complex power-up sequence to float low voltage w.r.t. GND

- First version of GUI is in preparation

- All implemented in EPICS, integration test scheduled this month, to be fully functional for the DESY beam-test in April

- (Look-and-feel unification is the next step)

Run and PS state diagram

Run States

UNKNOWN — No response from the subsystem

NOTREADY — Cannot start run due to various reasons, but accepts messages from Run Control

loading / unloading

aborting

READY — Can change to RUNNING immediately

starting / stopping

RUNNING — Can accept triggers and read out the detector or generate dummy events

recovering — (only for TTD and RC) trying to bring some of the subsystem to RUNNING

Power Supply States

UNKNOWN — No response from the subsystem

ERROR

OFF — PS is turned off, only during shutdown and cold start

turningon / turningoff

STANDBY — PS voltage tolerable for beam injection, while as high as possible for a quick transition to PEAK

rampingup / rampingdown

PEAK — Nominal voltage for data taking

trip — PS trip state from which one has to go back to PEAK as quickly as possible

● 3 main states for Run Control × 3 main states for PS control

● Names of intermediate states are also defined, almost final…

PS States for VXD

- On-detector electronics (APV25, DHP, ...) power supplies have to be dynamically configured in addition to the HV of sensors

- Mapping the Run/PS state in 3x3 matrix to the PS/sensor/DAQ states

	OFF	STANDBY	PEAK
NOTREADY	DHH configured DAQ off	ASICs+DHH ready DEPFETs not powered DAQ off	Frontend sending data DAQ off
READY	DHH configured DAQ links established	ASICs+DHH ready DEPFETs not powered DAQ links established	Frontend sending data DAQ links established
RUNNING	DHH configured DAQ processing triggers, ROIs. **DHH sends dummy data**	ASICs+DHH ready DEPFETs not powered DAQ processing triggers, ROIs. **DHP sends dummy data**	Frontend sending data. DAQ processing triggers, ROIs.

Similar mapping in preparation for SVD

Environment Monitor

- **E-hut and around the detector**
    - Central system based on commercial logger
    - Up and running since 2014 October
    - Alarm and interlock is in operation
    - Persistent archive is not ready yet (final CSS archiver host has not been set up), but to be ready soon
    (more to be covered in the next talk)

- **Barrel ECL** — similar independent commercial logger
- **Endcap ECL** — uSOP (single board processor) + SPI-based temperature/humidity sensor
- **Others** — parasite to the central logger and/or readout through Belle2link
- **SVD+PXD** — fully integrated into EPICS

Summary

⚠️ **Progress since last BPAC**

✅ Network and computing infrastructure reinforced

✅ CSS now integrates NSM2 and EPICS based systems

✅ Already relying on the control system

⚠️ **Urgently needed:**

🚧 CSS archiver

🚧 Trigger Timing Distrution (adhoc version exist)

🚧 Trigger systems

🚧 Fix of Belle2link for FEE configuration and monitor

😊 **Steady progress upon newly gained experiences to come**