Detector control system / Slow control: Overview of KLM HV control

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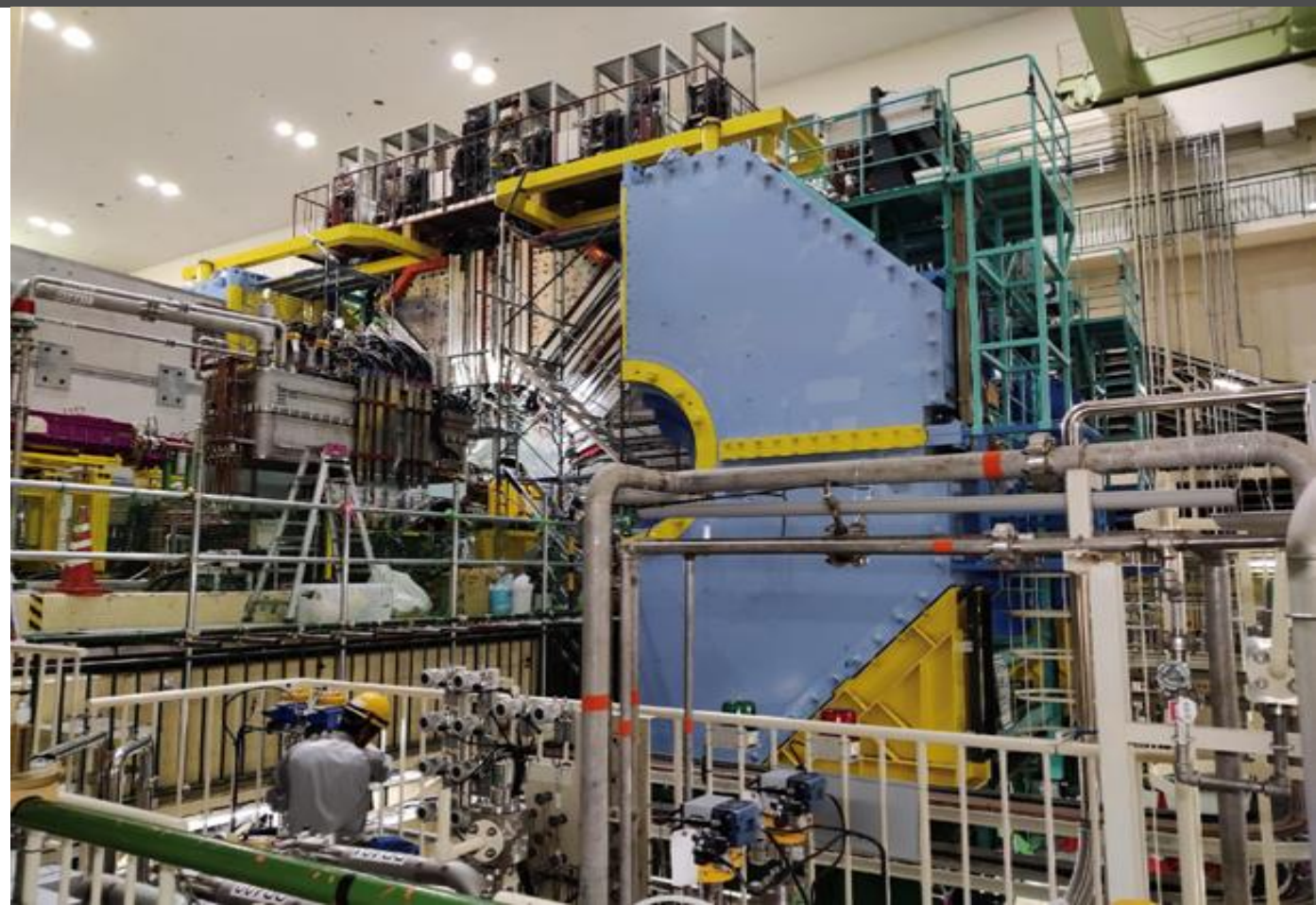
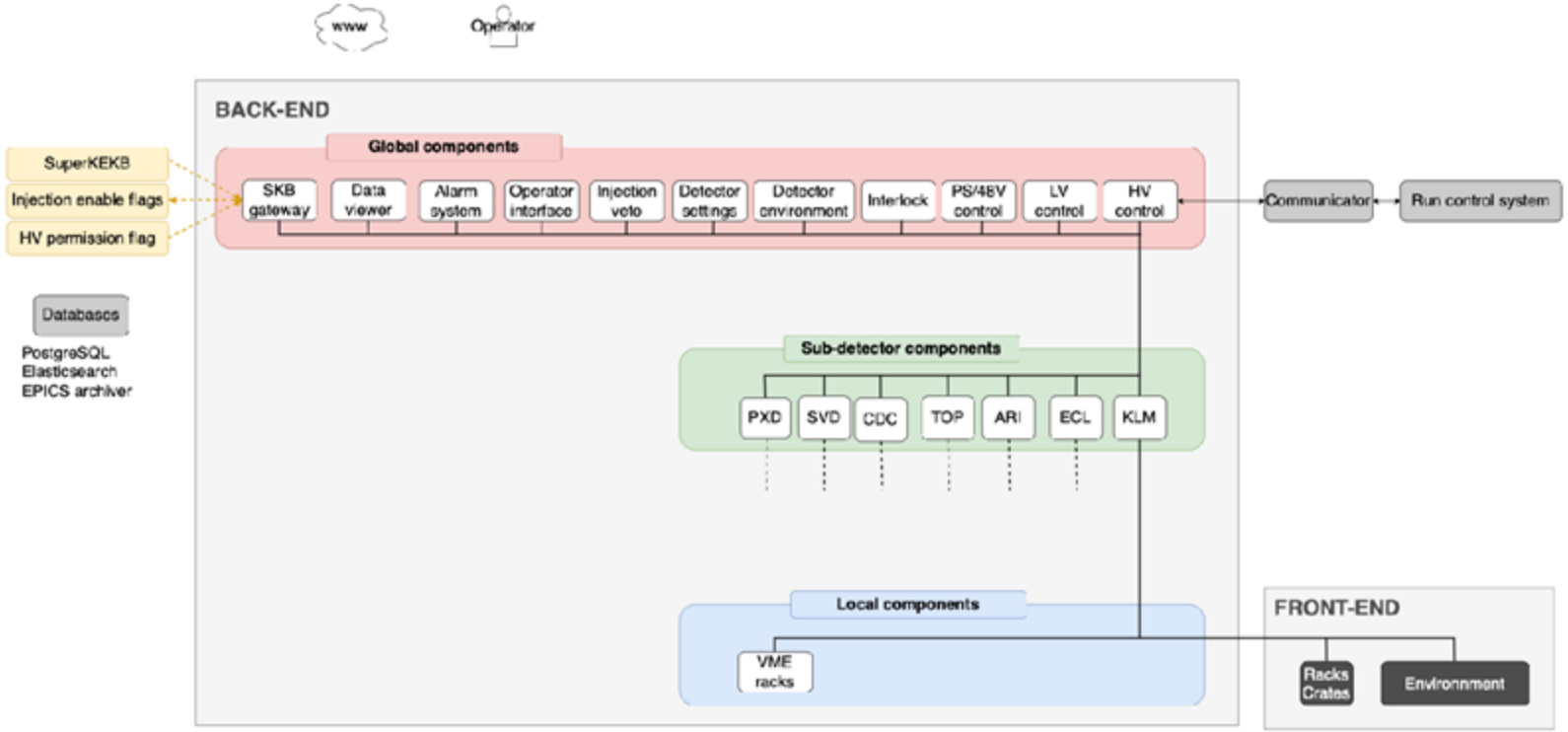
2025 US Belle II Summer Workshop

UNIVERSITY OF LOUISVILLE.



Introduction



➢ Detector Control System Courtesy:Kunigo-san @ KEK

- Derived from a common word: Industrial Control System
- To take data, sub-detector front end needs to be configured and initialized, and during data taking, also requires monitoring detector conditions like temperature, gas, and voltage. These operations are collectively referred to as **slow control**.
- and now the management of these detector-wide operations falls under the **DCS** group.

Targets of the DCS

- **jobs related to detector control**
  - **High voltage control**
  - **Low voltage control**

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  - V-threshold
  - masking
  - interface to the database

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- **detector environment**
  - **thermal monitoring**
  - **gas monitoring**
  - **chiller**, etc

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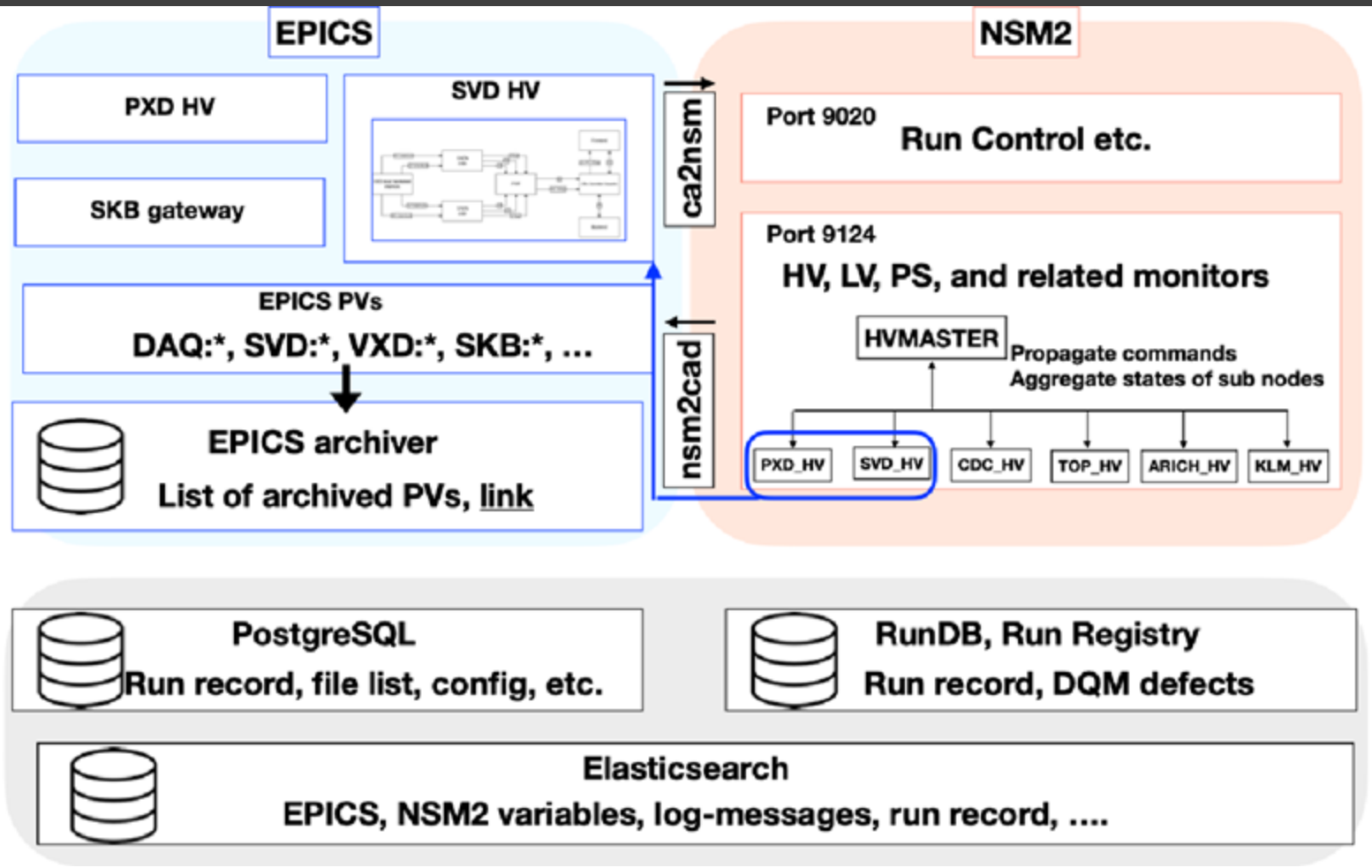
- **detector safety**
  - **HV permission (ARO)**
  - **interlock**
  - **cabling**, etc

B2NSM and B2EPICS



A gateway server (**daqnet**) links the two networks, allowing NSM2 daemons and EPICS IOCs to inter-operated.
– Operators control both networks via a single interface (e.g., Phoebus GUI).

Ref:[Trigger slow control system of the Belle II experiment]

HV control, permission, & ARO flag

- To have hand-shake between accelerator operations (SuperKEKB) and detector operations (Belle II), a mutual agreement is done based on SuperKEKB Injection status and Belle II HV Status for safe and smooth operations.

Current Scheme

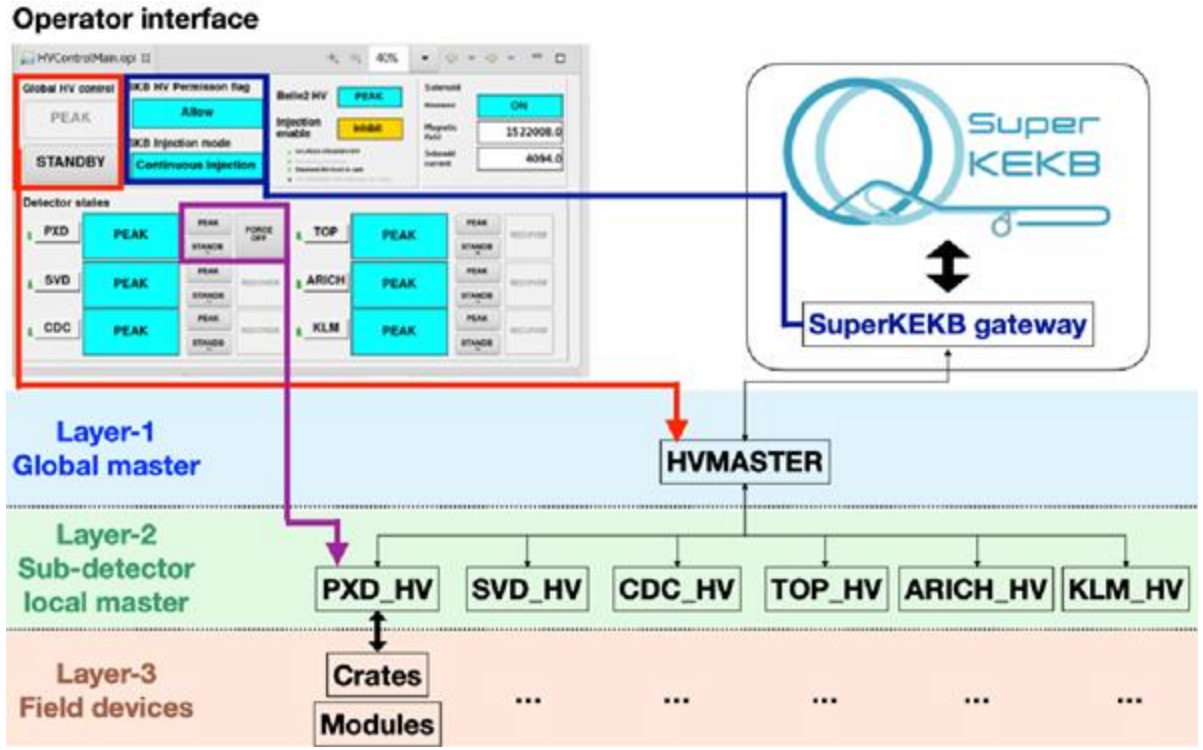
Beam Injection Signal

HV permission → Injection Enable — moderate and calm

HV permission → Injection Enable

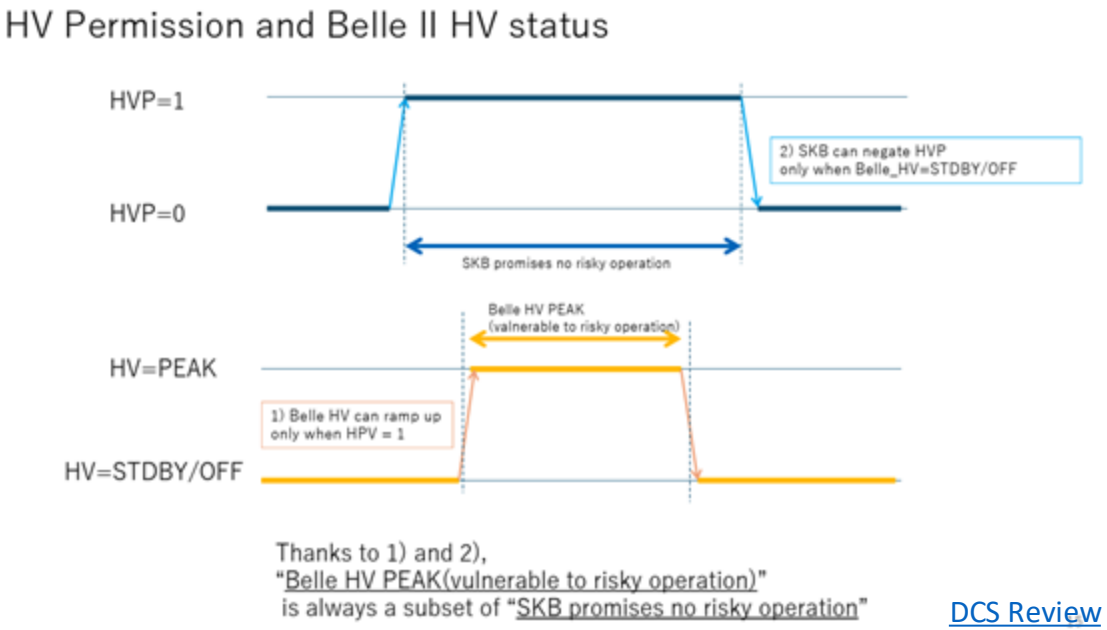
HV permission → Normal Enable — wild and dangerous

The global Belle II HV status is defined in HVMASTER, a module that takes into account the HV status of all sub-detectors.

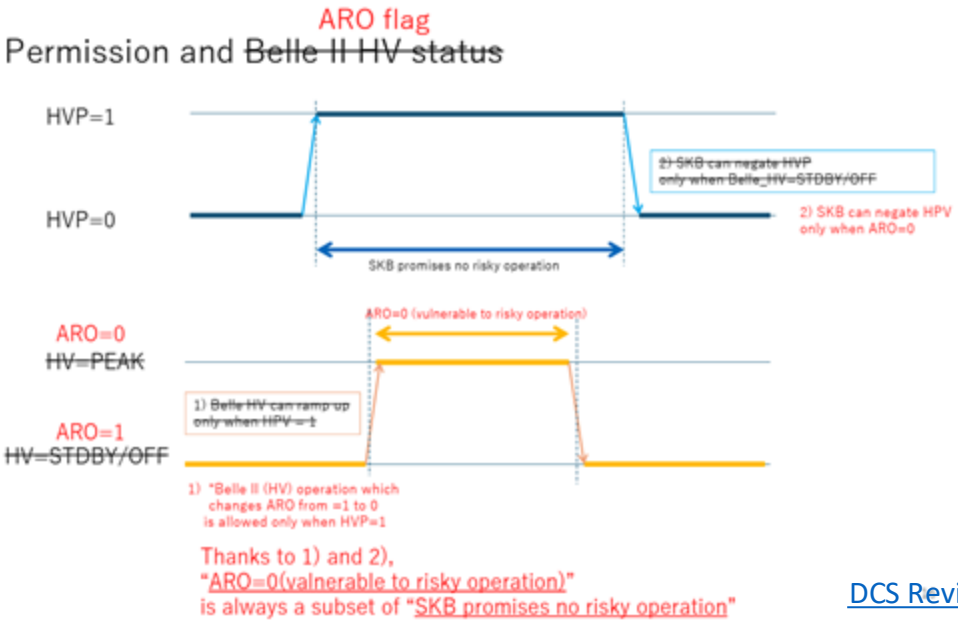


New Scheme: In the new system, **each subsystem can define its own injection enable signals** regardless of its HV status, based on its vulnerability to beam injections.

HV control, permission, & ARO flag



DCS Review

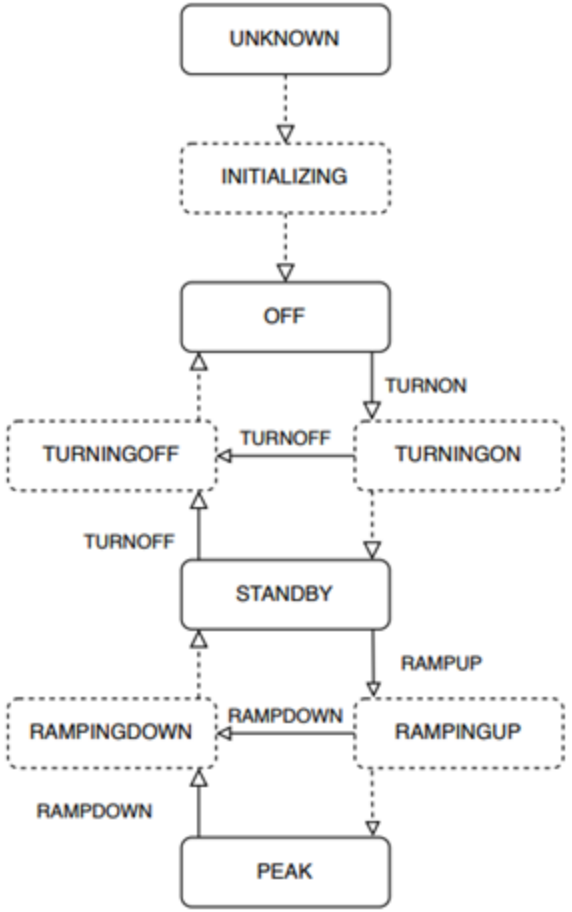


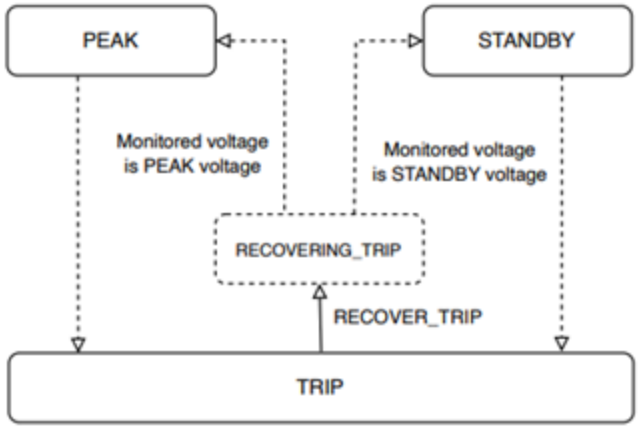
DCS Review

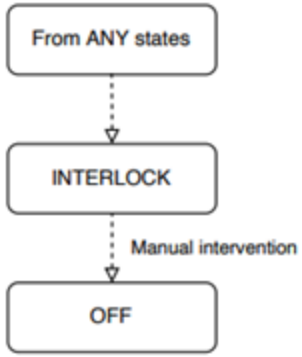
Current Status: Feedback and review of each sub-system scheme is in progress

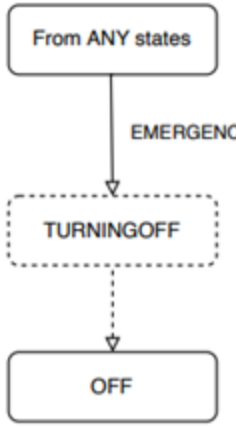
HV states and transitions

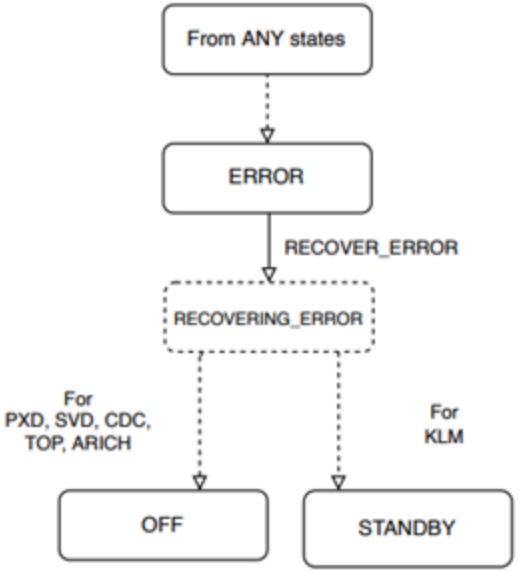
- Stable states
  - OFF
  - STANDBY
  - PEAK
- Transition states
  - TRANSITION
  - RAMPINGUP
  - RAMPINGDOWN
  - RECOVERING
  - TRUNINGON
  - TURNINGOFF
- Error states
  - ERROR
  - TRIP
  - INTERLOCK
  - MASKED











All states are defined in the source code here.

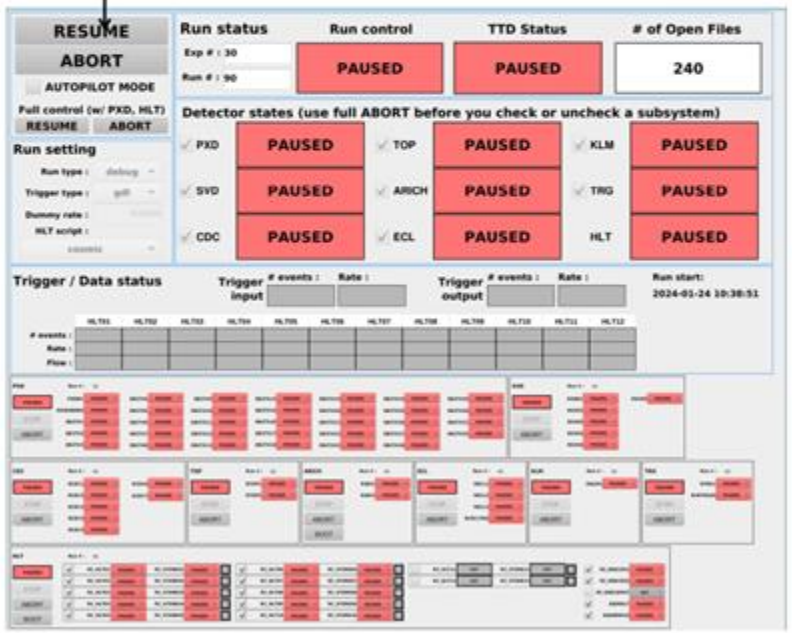
Monitoring by CR shifters

- ❑ To check the any errors are indicated in the HV control panel, in case of any error follow the RECOVERY procedures.
- ❑ To check if any interlock signals are indicated in the interlock panel.
- ❑ To check the mattermost chat notifications.

[Belle II Shifter Operation Manual]

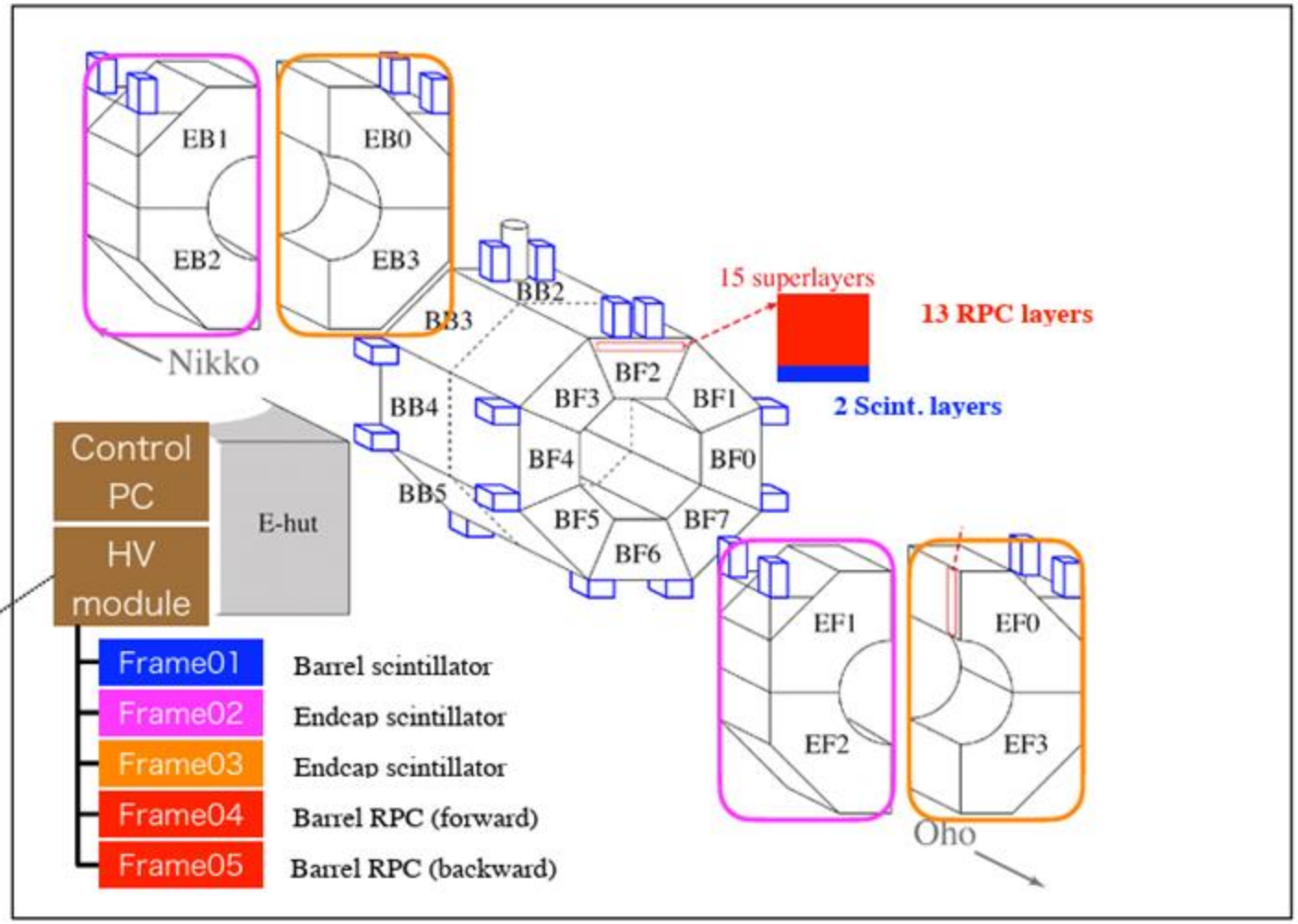
HV error states

- When HV goes to "ERROR", "TRIP", "INTERLOCK" or "UNKNOWN", the data taking is "PAUSED" in the RC panel. Do not "STOP" the current run.
  - ➢ "ERROR" and "TRIP" can be fixed by clicking the "RECOVER" button in the HV panel.
  - ➢ "INTERLOCK" and "UNKNOWN" need to be fixed by the subsystem experts.
- When the error state is gone, you can "**RESUME**" the run.



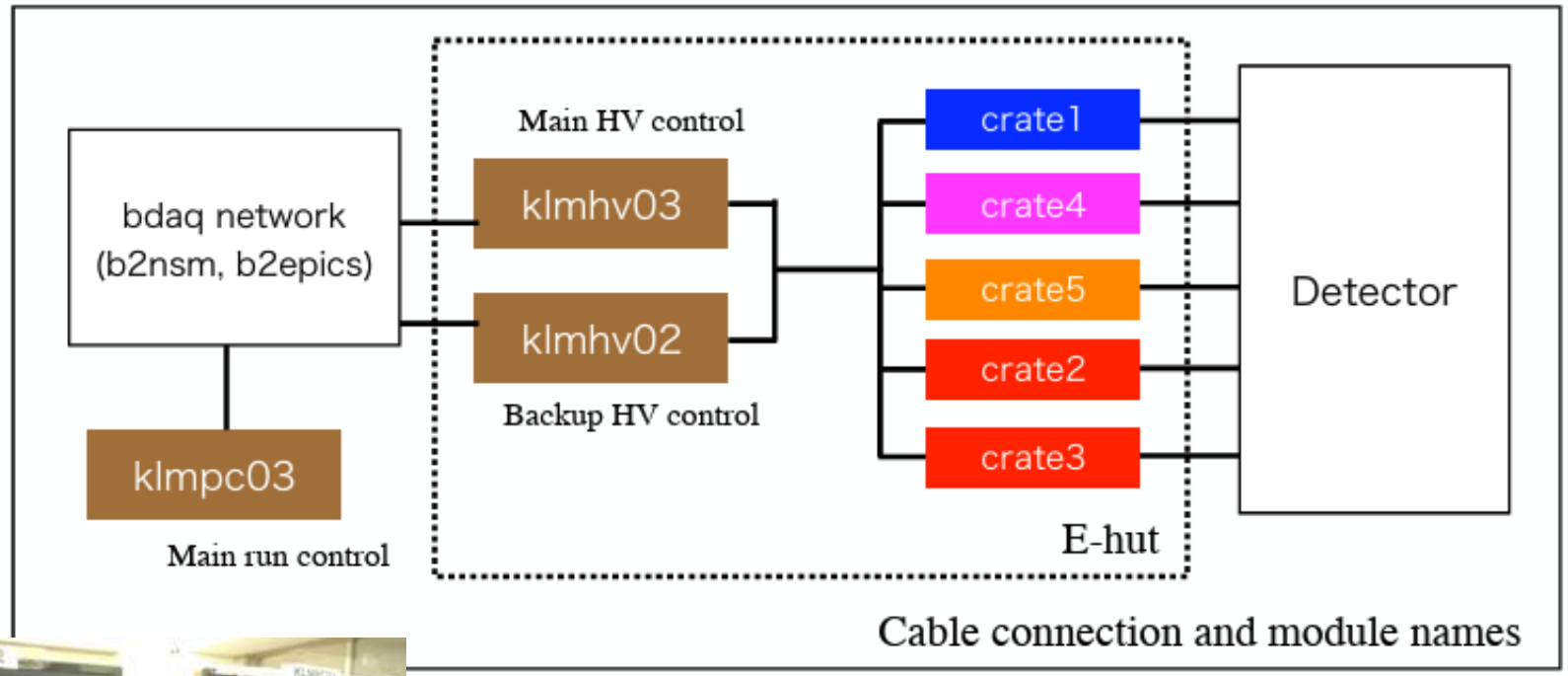
KLM HV control

- B/E-KLM need HV for operation. Scintillators need 75V, and RPCs need 8.2kV (-3.5kV & +4.7kV).
- There are 5 CAEN HV mainframes in E-hut. Each of them provides HV to KLM sectors.



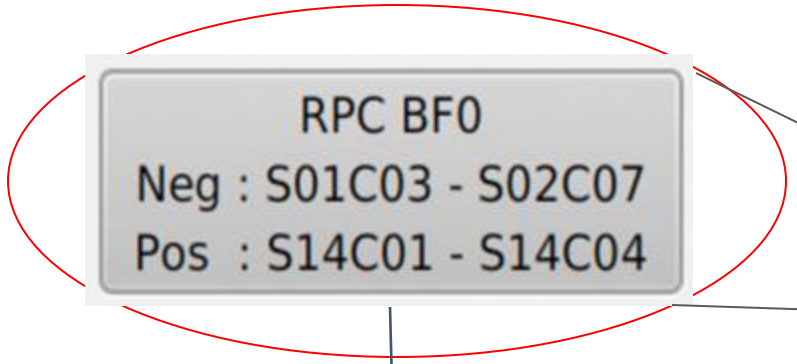
KLM HV Components

- All KLM HV components are in E-hut.
  - There are two HV control PC named klmhv03 and klmhv02.
  - They are controlled by the run control PC named klmpc03 via bdaq network.
  - In both HV PCs, same scripts are running and switching time is ~10 minutes.

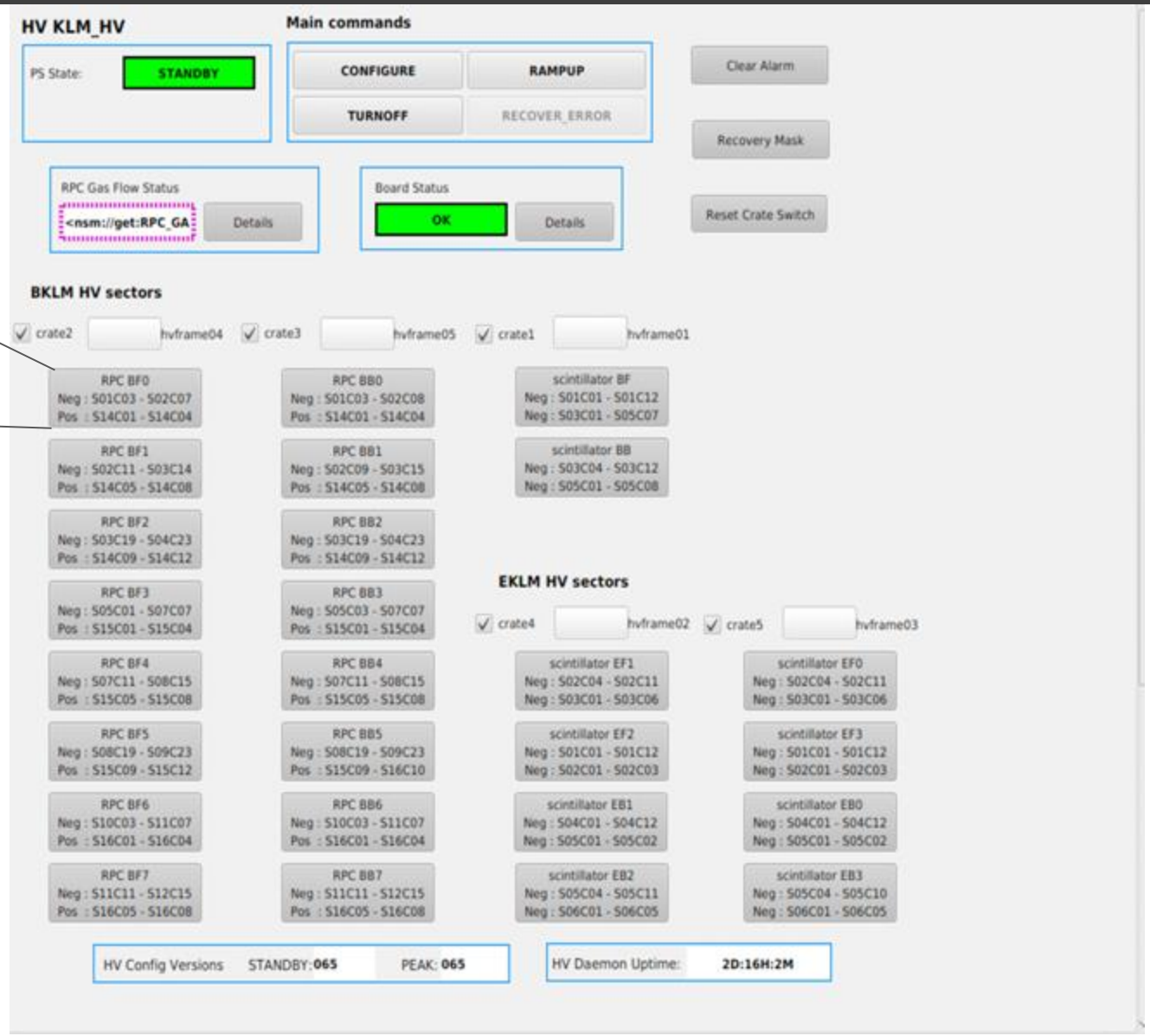


- During Run operations all task are managed through these PCs and a remote shifter can make access through bdaq account.

KLM HV GUI

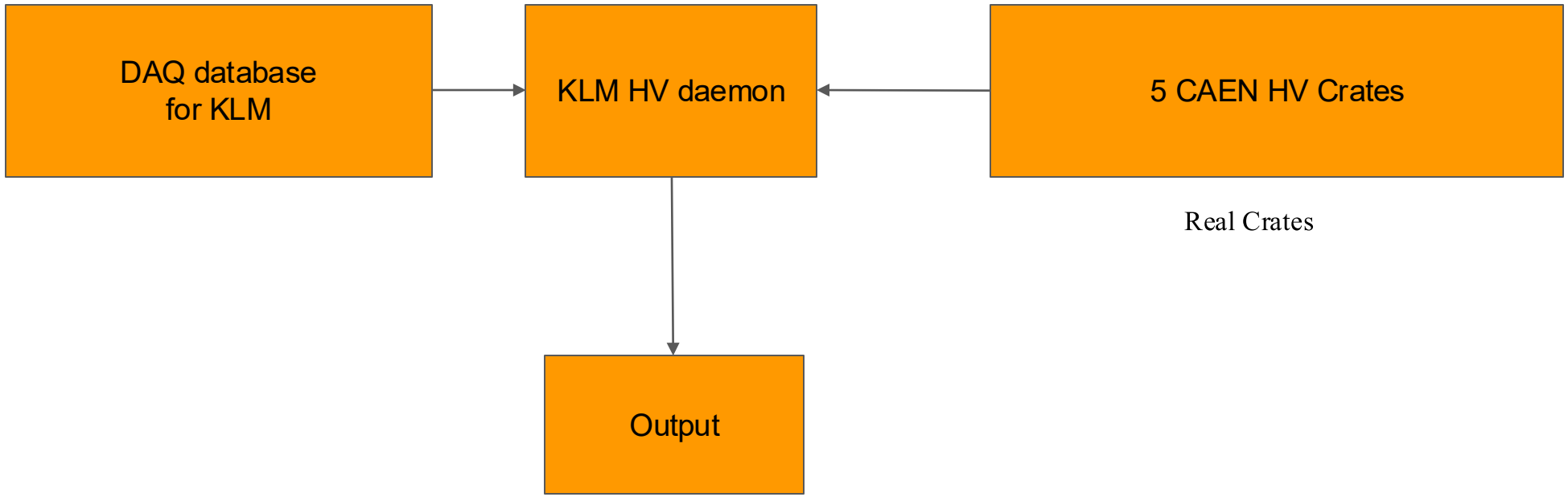

RPC BF0
Neg : S01C03 - S02C07
Pos : S14C01 - S14C04


Slot Ch Switch RampUp RampDn VSet VLimit CLimit Status VMon CMon
1 3 ON 30 30 2700 3500 80 RAMPUP 540.0 25.0
1 4 ON 30 30 2700 3500 80 RAMPUP 540.0 25.0
1 5 ON 30 30 2700 3500 80 RAMPUP 540.0 25.0
1 6 ON 30 30 2700 3500 80 RAMPUP 540.0 25.0
1 7 ON 30 30 2700 3500 80 RAMPUP 540.0 25.0
1 8 ON 30 30 2700 3500 80 RAMPUP 540.0 25.0
1 9 ON 30 30 2700 3500 80 RAMPUP 540.0 25.0


HV KLM_HV
PS State: STANDBY
Main commands
CONFIGURE
RAMPUP
TURNOFF
RECOVER_ERROR
Clear Alarm
Recovery Mask
Reset Crate Switch
RPC Gas Flow Status
<nsm://get:RPC_GA
Details
Board Status
OK
Details
BKLM HV sectors
crate2 hvframe04 crate3 hvframe05 crate1 hvframe01
RPC BF0 Neg : S01C03 - S02C07 Pos : S14C01 - S14C04
RPC BB0 Neg : S01C03 - S02C08 Pos : S14C01 - S14C04
scintillator BF Neg : S01C01 - S01C12 Neg : S03C01 - S05C07
RPC BF1 Neg : S02C11 - S03C14 Pos : S14C05 - S14C08
RPC BB1 Neg : S02C09 - S03C15 Pos : S14C05 - S14C08
scintillator BB Neg : S03C04 - S03C12 Neg : S05C01 - S05C08
RPC BF2 Neg : S03C19 - S04C23 Pos : S14C09 - S14C12
RPC BB2 Neg : S03C19 - S04C23 Pos : S14C09 - S14C12
RPC BF3 Neg : S05C01 - S07C07 Pos : S15C01 - S15C04
RPC BB3 Neg : S05C03 - S07C07 Pos : S15C01 - S15C04
EKLM HV sectors
crate4 hvframe02 crate5 hvframe03
RPC BF4 Neg : S07C11 - S08C15 Pos : S15C05 - S15C08
RPC BB4 Neg : S07C11 - S08C15 Pos : S15C05 - S15C08
scintillator EF1 Neg : S02C04 - S02C11 Neg : S03C01 - S03C06
scintillator EF0 Neg : S02C04 - S02C11 Neg : S03C01 - S03C06
RPC BF5 Neg : S08C19 - S09C23 Pos : S15C09 - S15C12
RPC BB5 Neg : S08C19 - S09C23 Pos : S15C09 - S16C10
scintillator EF2 Neg : S01C01 - S01C12 Neg : S02C01 - S02C03
scintillator EF3 Neg : S01C01 - S01C12 Neg : S02C01 - S02C03
RPC BF6 Neg : S10C03 - S11C07 Pos : S16C01 - S16C04
RPC BB6 Neg : S10C03 - S11C07 Pos : S16C01 - S16C04
scintillator EB1 Neg : S04C01 - S04C12 Neg : S05C01 - S05C02
scintillator EB0 Neg : S04C01 - S04C12 Neg : S05C01 - S05C02
RPC BF7 Neg : S11C11 - S12C15 Pos : S16C05 - S16C08
RPC BB7 Neg : S11C11 - S12C15 Pos : S16C05 - S16C08
scintillator EB2 Neg : S05C04 - S05C11 Neg : S06C01 - S06C05
scintillator EB3 Neg : S05C04 - S05C10 Neg : S06C01 - S06C05
HV Config Versions STANDBY: 065 PEAK: 065
HV Daemon Uptime: 2D:16H:2M

KLM HV Test Bench

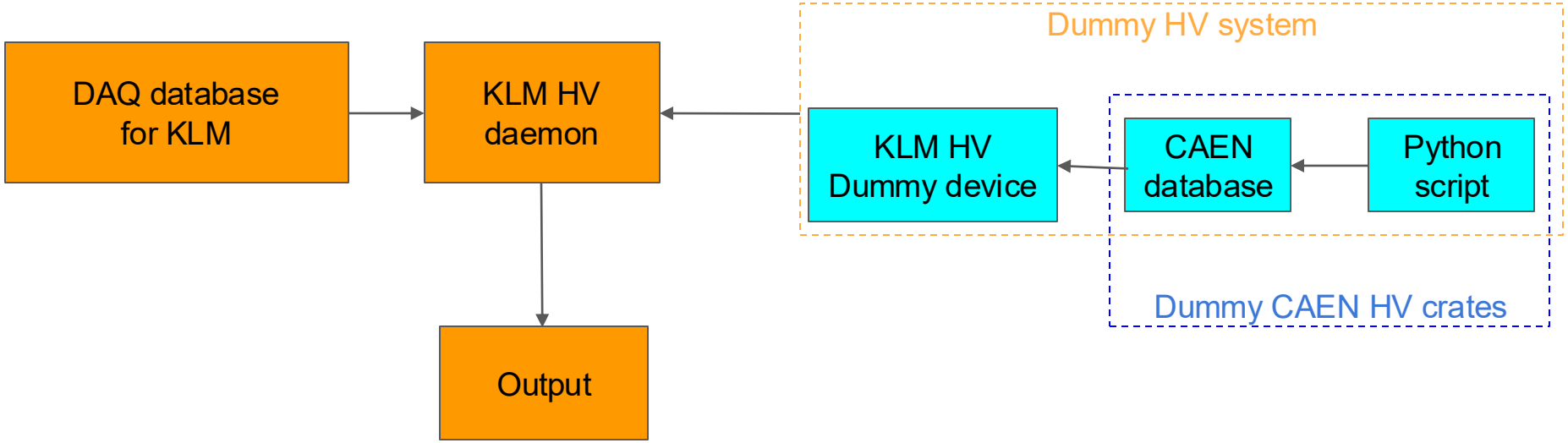
Real System



Real Crates

KLM HV Test Bench

- A **CAEN HV crate simulator** was developed by the UofL group to address issues in KLM HV control.
  - The **daq_slc** setup was successfully installed and compiled on a standalone PC (not connected to DAQNet or B2NSM)
  - A dedicated DAQ database was prepared and configured to support the KLM HV daemon.
  - Details:
    - A **Python script** interfaces with the CAEN database to mimic basic HV crate behavior.
    - It simulates key HV states: **RAMPING UP, RAMPING DOWN, ON, OFF**.
    - The simulator can be extended to include various error message scenarios.

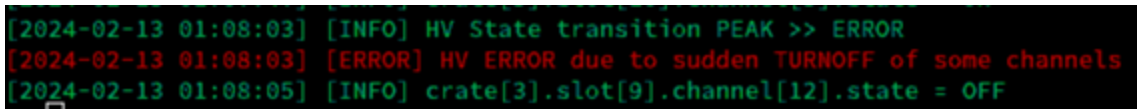


Main Advantage: Allows testing and validation of HV control scripts before deploying them to the real KLM system, improving reliability and reducing downtime.

Recent Issues

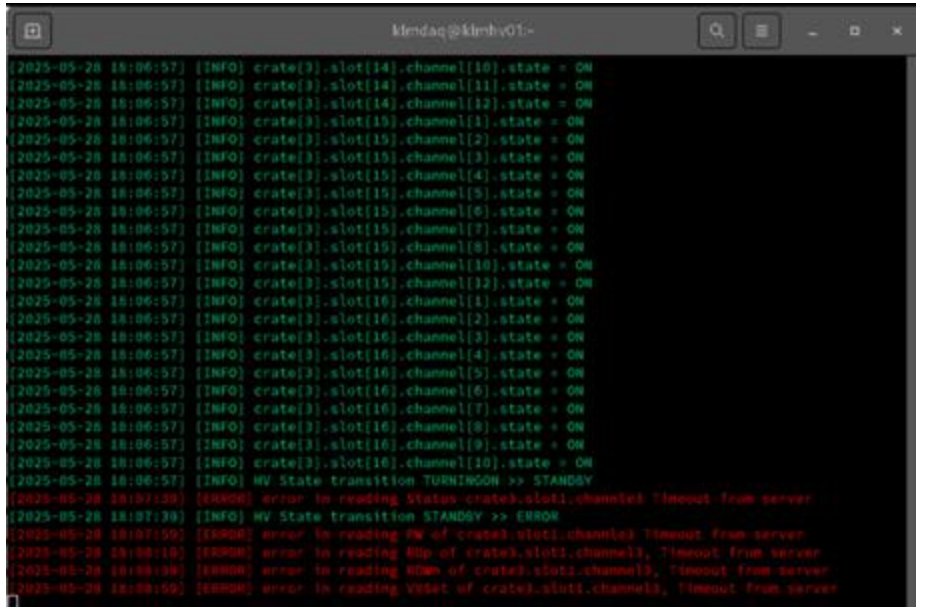
- KLM HV Sudden turn off
  - Certain negative KLM HV modules randomly turn off without entering RAMPDOWN or TRIP states, causing the corresponding positive modules to OVP trip.
  - First observed on Jan 24, 2024 (Crate 3, Slot 15), with similar incidents later seen across other slots of Crate 3.
  - The firmware of the crate 3 has already been changed. But, the problem is still existing.

  - Temporary fix:
    - The HV daemon is now modified to detect this behavior, if it occurs during STANDBY/PEAK, it enters ERROR state, recoverable via RECOVER_ERROR → STANDBY.

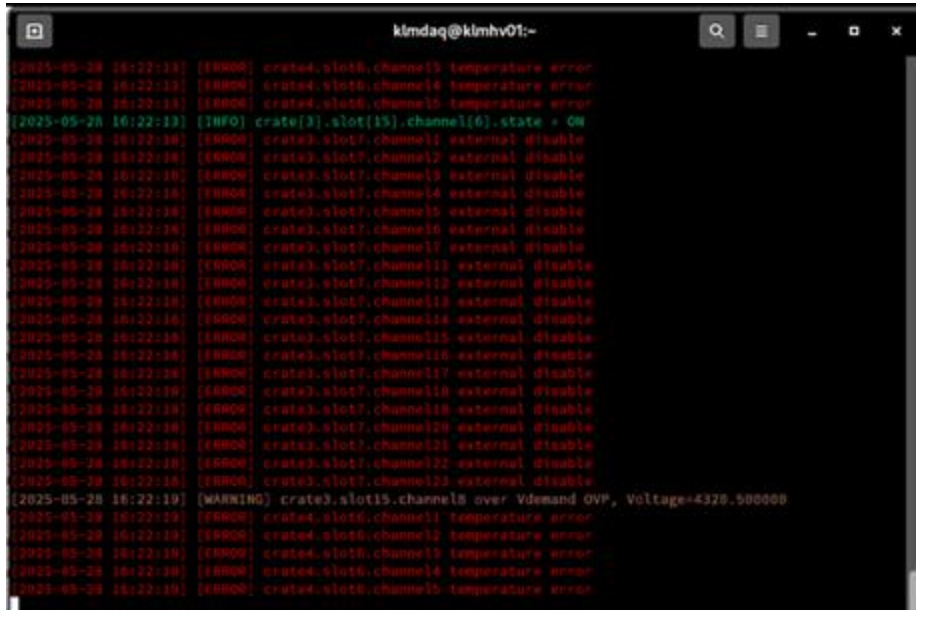


Recent Issues

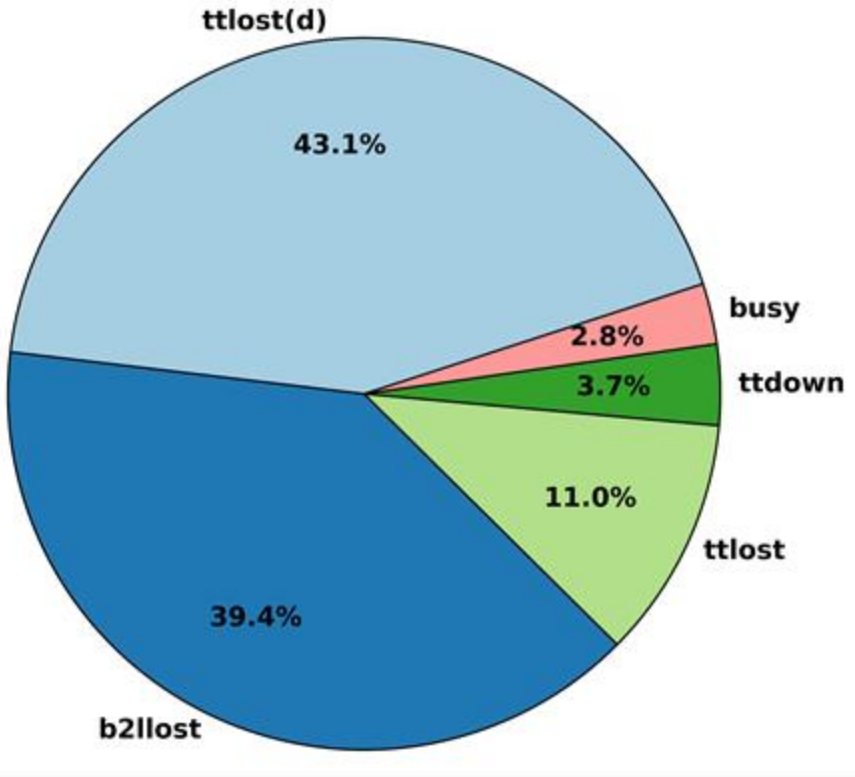
- Issue with UNKNOWN state
  - Caused by B2NSM network failures leading to unresponsive CAEN HV API, leaving KLM HV stuck in its last known state.
  - Issue was often missed by shifters, despite being logged, due to delayed API responses.
  - Fix: Now, the system triggers an ERROR signal within 25 seconds to promptly flag the issue.



- Mixed Error & Interlock state issue
  - Occasionally, scintillator crates show ERROR while RPC crates show INTERLOCK, causing the KLM HV state to oscillate between the two.
  - To fix this, ERROR and soft TRIP signals are suppressed when INTERLOCK is active.
  - Fix: The solution has been successfully tested using dummy interlock signals on the real system, ensuring a stable INTERLOCK-only status.



KLM Errors



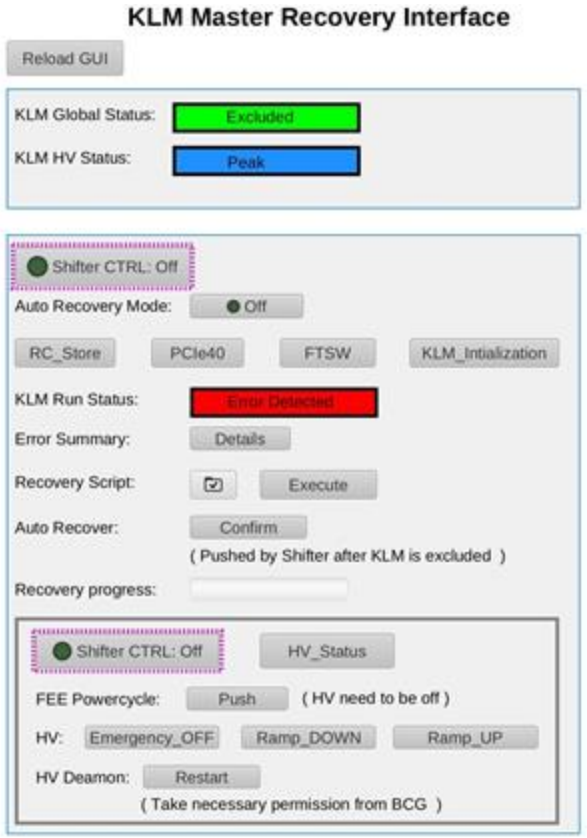
Error distributions in 2024.

- These errors fall into two main categories:
  - **HV errors** (e.g., sudden turn-offs, unknown/error states in HV crates), and
  - **DAQ errors** (e.g., link issues, FEE errors, tag/time mismatches).

- The most frequent causes of these errors are:
  1. `TTLOST` and `TTDOWN`: These occur due to miscommunication between the DC and the FTSW.
  2. `B2LLOST` and `B2LDOWN`: These arise from miscommunication between the DC and the PCIe40.

Future Plans

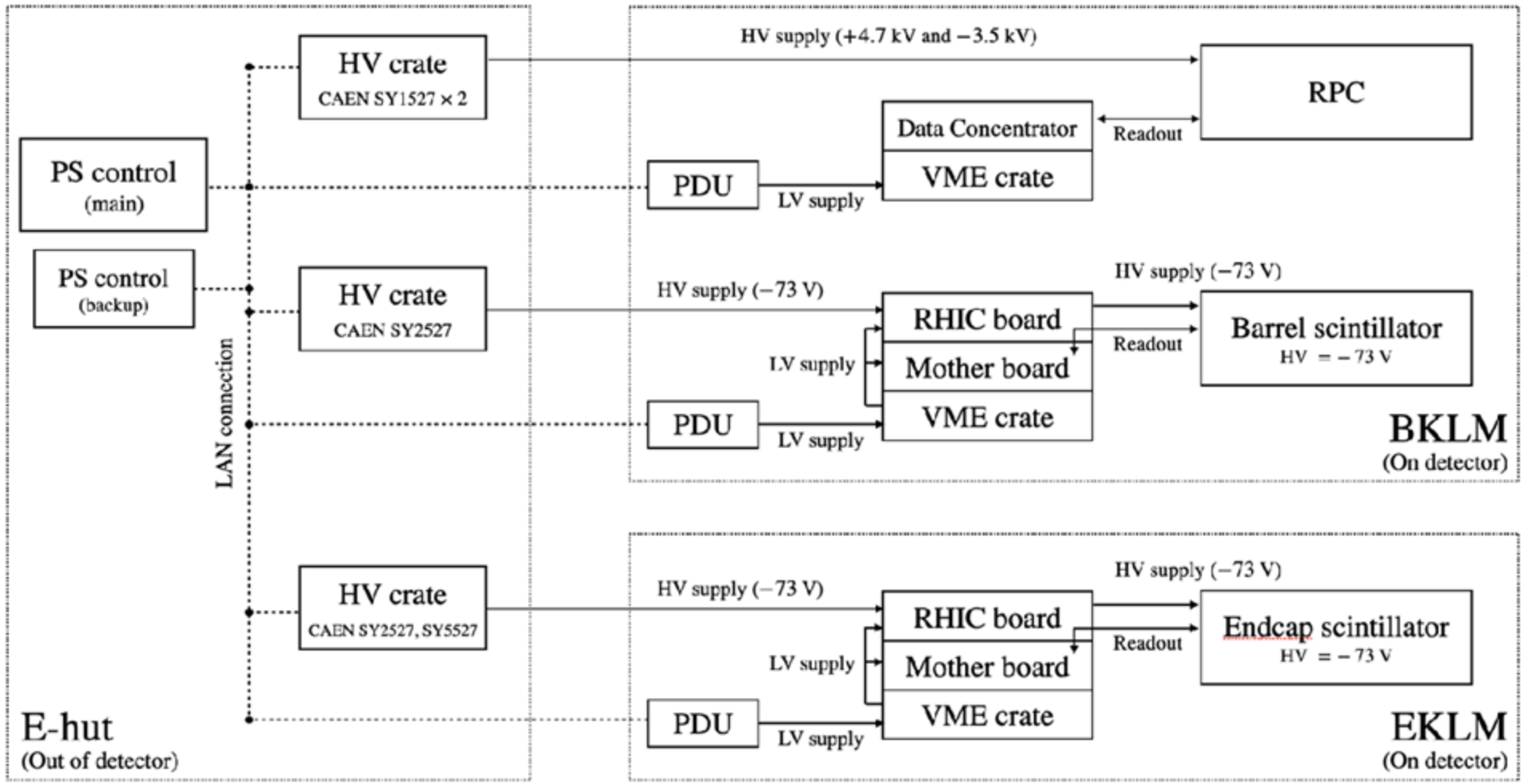
- Master recovery GUI



- Low voltage monitoring
  - Monitor stability of ±12V low voltage power supply to KLM FEE

Backup

KLM Power supply



KLM CAEN HV Database

crate	slot	ch	pw	v0set	vmon	imon	i0set	rup	rdwn	svmax	status
2	11	20	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
5	4	3	1	73.000000	73.000000	25.0	180.000000	5.000000	5.000000	100.000000	1
3	5	6	0	0.000000	20	3.5	80.000000	30.000000	30.000000	3500.000000	0
3	9	22	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
3	10	4	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
2	5	5	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
1	5	5	1	73.000000	73.000000	25.0	180.000000	5.000000	5.000000	100.000000	1
3	8	1	0	2700.000000	20	3.5	80.000000	30.000000	30.000000	3500.000000	0
5	5	6	1	73.000000	73.000000	25.0	180.000000	5.000000	5.000000	100.000000	1
3	10	3	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
2	5	9	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
3	11	7	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
1	5	6	1	73.000000	73.000000	25.0	180.000000	5.000000	5.000000	100.000000	1
2	9	12	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
3	8	20	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
2	8	7	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
3	9	16	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
2	5	17	0	0.000000	20	3.5	80.000000	30.000000	30.000000	3500.000000	0
3	9	15	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
1	5	4	1	73.000000	73.000000	25.0	180.000000	5.000000	5.000000	100.000000	1
2	9	15	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
2	10	22	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
3	9	19	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
3	5	21	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
3	9	4	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
2	10	7	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
3	7	22	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
1	3	1	1	73.000000	73.000000	25.0	180.000000	5.000000	5.000000	100.000000	1
3	10	8	1	2700.000000	2700.000000	25.0	80.000000	30.000000	30.000000	3500.000000	1
2	15	7	1	3900.000000	3900.000000	25.0	200.000000	30.000000	30.000000	6000.000000	1

A PostgreSQL database has been prepared, which contains detailed information about the KLM HV crates.

Thanks to D. Biswas & S. Patra