Error recovery and machine state restore challenges

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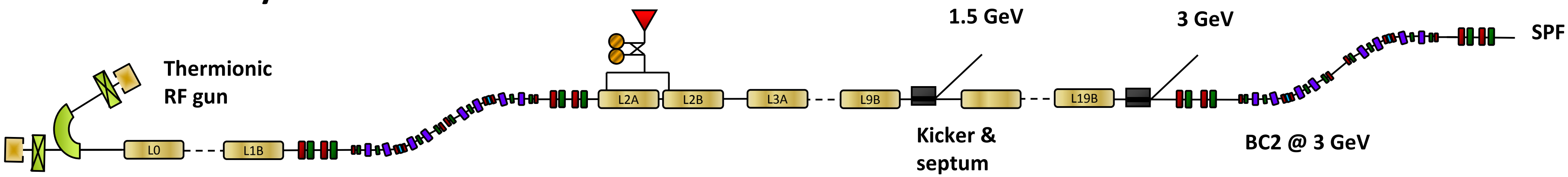
MAX IV

Outline

- Discovering the error
  - Available diagnostics
  - Notification systems
  - Alarms
- Tracing the cause
- Recovering from the error
- Preventative measures

Linac, available beam diagnostics



Item	Purpose
Charge transformers	Bunch charge measurement
Faraday cups	Bunch charge measurement (destructive)
Stripline BPMs	Position measurement
Bunch length monitor (THz detectors)	*Bunch length*
Scrapers	Tuneable particle energy filter (located in dispersive region)
YAG screens	Transverse beam profile imaging (destructive)
Oscilloscopes	Bunch charge profile measurement RF measurements

R3, available beam diagnostics

Item	Purpose
Diagnostic beamline B302B (vis SR) Diagnostic beamline B320B (vis SR)	*Bunch length measurement* *Filling pattern measurement (low priority)* Transverse beam imaging
Extra BPM head after septum	Tune measurement, pickup Bunch-by-bunch feedback Injection angle tuning
Beam Position Monitors (200 LB+)	Position measurement (single pass, post-mortem, 10 Hz and 10 kHz data) FOFB Pinger experiments Orbit interlocks …
Hor/ver excitation striplines	Tune measurement, excitation *Transverse bunch-by-bunch feedback* Filling pattern
Longitudinal kicker	*Longitudinal bunch-by-bunch feedback*
NPCT	Current, lifetime
Pulsed magnet, horizontal	Pinger experiments Tune measurement Injection
Pulsed magnet, vertical	Pinger experiments Tune measurement
Scrapers	Lifetime studies
Screen	Transfer line diagnostic Injection diagnostic

Notification systems

- Current generic control system applications:
  - State grid: shows TANGO device states for hardware
  - Synoptic: shows TANGO device states for hardware
  - PANIC: shows active alarms and warnings, relies on PyAlarm
- Other:
  - Control room phone: carried by on-duty operator. Receives SMS alarms, relies on PyAlarm (currently disabled after huge phone bill was racked up during maintenance shift)

Notification systems, alarms

- MPS interlocks are exposed to TANGO via PLC tags
- Virtual TANGO devices are created for a number of simple equipment connected to the PLC, such as thermocouples, flow switches, etc.
- Internal equipment interlocks must be read from the hardware by the TANGO device:
  - Examples are power supplies (DANFYSIK, Itest, PolyAmp), transmitters, etc.
  - TANGO device that registers interlock changes state to ALARM
  - Generic system not yet in place to ensure all devices that enter ALARM state are registered in alarm log database
- PyAlarm TANGO devices reads attributes of other devices, evaluates conditions, and takes actions.
  - Enters external interlocks, alarm data into the alarm log database
  - Dispatches e-mails, text messages, etc.
- TANGO devices that are interlocked or exceed alarm levels change TANGO state to ALARM → becomes visible in the state grid or synoptic.

Notification systems, alarms

- Determining the order of alarms / interlock happens via time stamping
- Hardware clocks (timing system, servers, etc.) synchronize via NTP → expected absolute time clock accuracies of 1 ms.
- Aim is to time stamp as close to the source as possible
  - Timing system timestamping accuracy very good
  - PLC system timestamping accuracy dependent on program cycle time, which can add 10 ms of delay in the case of R3.
  - TANGO devices that receive alarm information without time stamps add their own time stamp (taking the system time)

Notification systems, infrastructure

Boundary between cooling supplier (ML4) and the accelerators runs through the water cooling circuits for magnets, power supplies, cabinets, vacuum chambers, RF, etc. Heat exchanger and pumps are on ML4 side.

Access to the building automation system needed to quickly identify problem source, in order to define actions

Tracing the source

- Current generic control system applications:
  - Kibana alarm log: automatic log of historical alarms and warnings, relies on PyAlarm
  - Electronic log book: manual entries, discipline needed
  - Archiving:
    - TANGO HDB
    - 100 Hz fast archiver for certain hardware
- KITS library of diagnostic routines:
  - Usually run after Monday maintenance
  - Focussed on control system rather than hardware
  - Currently little used by operators, physicists.
- Subsystem specific post-mortem:
  - Libera Brilliance+ BPM post-mortem buffers
  - LLRF fast data logger
- Future systems:
  - Event classification and logging (partial beam loss, lifetime drop, etc.)

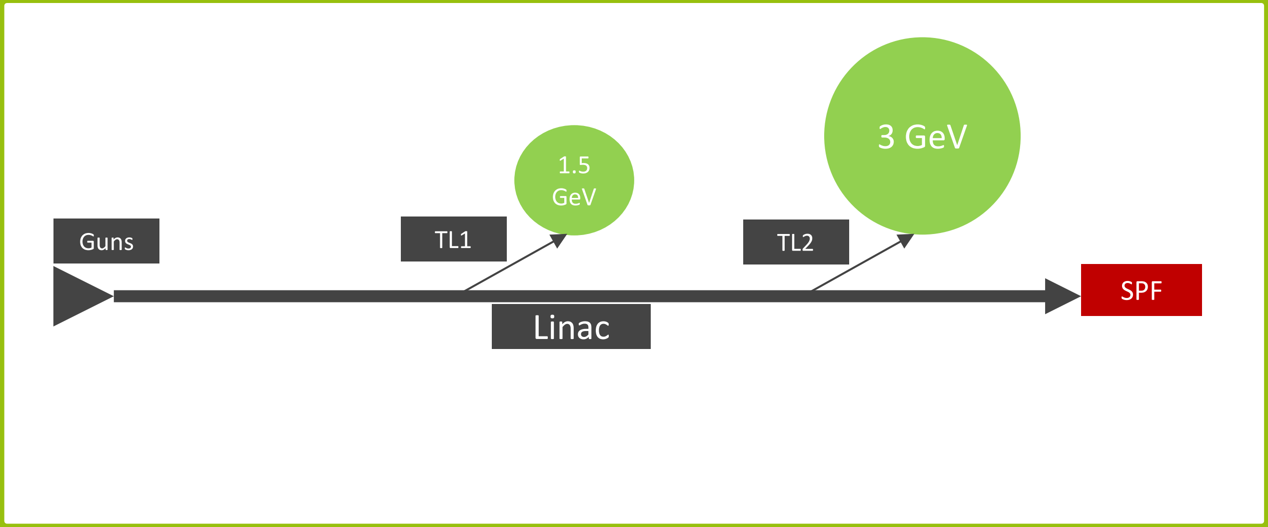
Recovering / machine state restore

- Need to get back to a specific state (usually standby state)
- How to achieve this is dependent on the error → identification and classification of error needed
- Recovery time consumption ideally as low as possible.
  - BLACK-OUTS: recovery time (greatly) improved by ensuring all systems able to automatically restart when power returns.
  - Subsystem recovery: aim to reduce long recovery times
  - Interventions/maintenance tends to occasionally introduce issues
  - Testing procedures and diagnostic routines
  - Re-use of subsystem test procedures used during installation
- Support systems
  - *Snapshot application*
  - Auto-startup routines (sequenced loading of snapshots, etc.)

Linac Error recovery

To reduce as much as possible the number of defects and shortened the error time of Linac, we have been working on the following items:

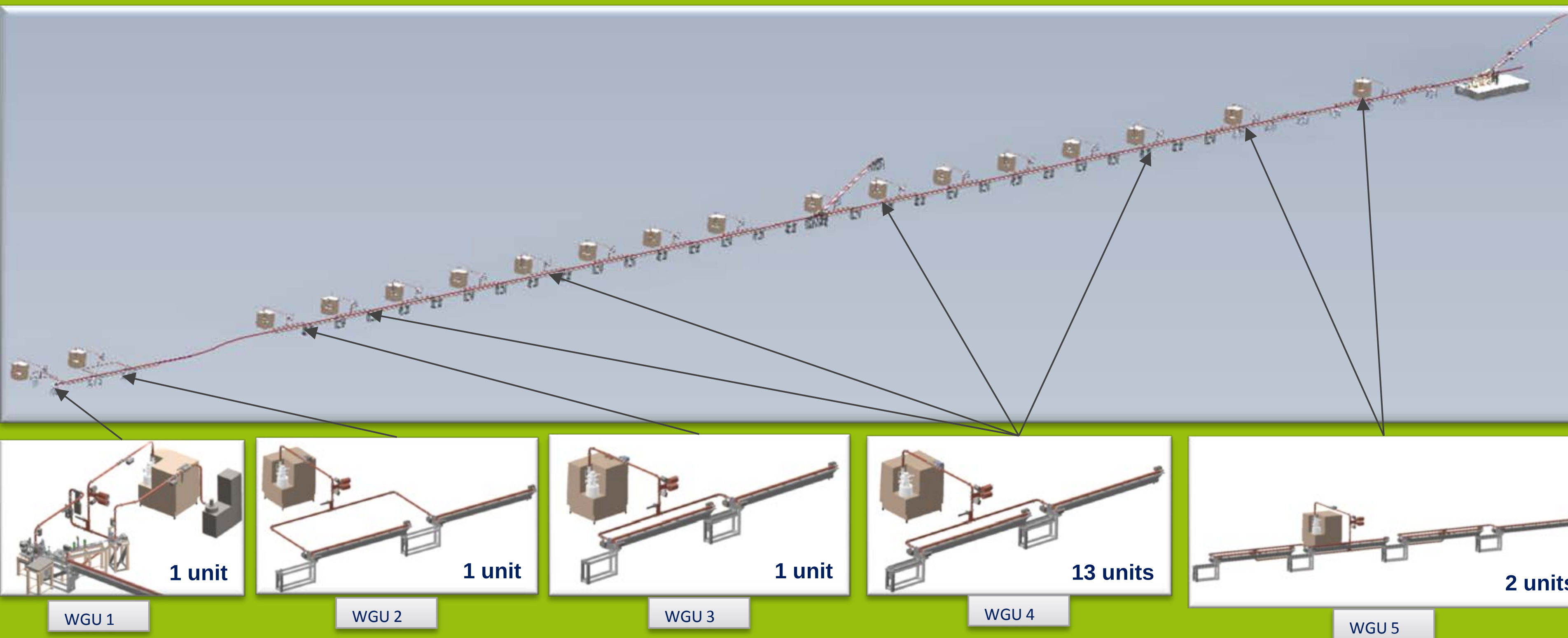
- The RF power and Accelerator technique used in our Linac (S-band) it's one of the most reliable techniques can be applied for time being and several years in the future
- Modularity was one of our priority on this project, it help on easily and inexpensive installation and maintenance and easier on error recovery.
- As simply as possible and sufficient complicated to fulfill successfully the duties taken over.
- Sufficient redundancy of RF Power and of gradient acceleration



We are working intensively to increase the Linac RF Power redundancy with more than 10%; and improving the distribution of the acceleration gradient along the entire length of the LINAC.

Improving RF Power Redundancy

LINAC is build on modules: 5 different models for 18 modules



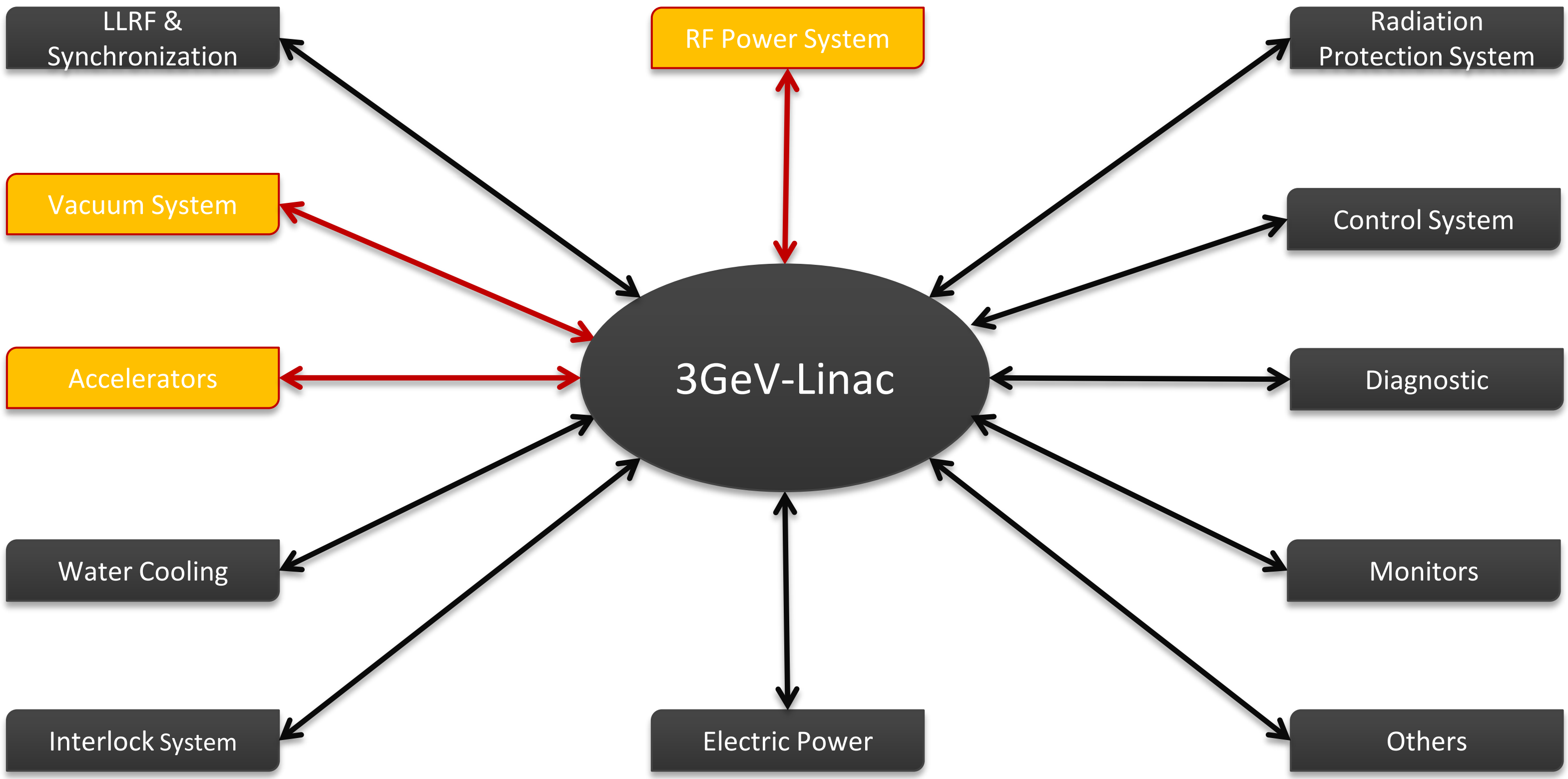
- 19 pcs: RF power units
- 18 pcs: SLED
- 2 pcs: RF guns
- 39 pcs: Linac structuer

→

- 21 pcs: RF power units
- 20 pcs: SLED
- 2 pcs: RF guns
- 39 pcs: Linac structuer

Linac Error recovery

Subsystems made to have successful 3 MeV Linac running at the same time each of them is a potential **source of error**



The most common defect that occurs during Linac running is high voltage sparking in vacuum area exposed on High RF Power, and to recover it, requires time and qualified personal on duty. More affected by this interlock are:

– RF power – Vacuum –Accelerators Systems

We think that, if the control system take over to recover this error, it will be very important contribution to shorten the recovery time and also eliminates human errors

Preventative measures

Encompasses decisions on maintenance frequency and spare parts, focus of resources to increase system robustness, etc.

Not possible to fully automate

Current aim is to eventually provide support for human decision making:

- Automated event classification and logging
- Standardized report generation
- Collecting statistics
- ...?

Suggestions welcome!