RF Control interlocks correlation in EPICS/CSS based on White Rabbit Technology

Post-mortem analysis and first results in LIPAC accelerator The innovative IFMIF

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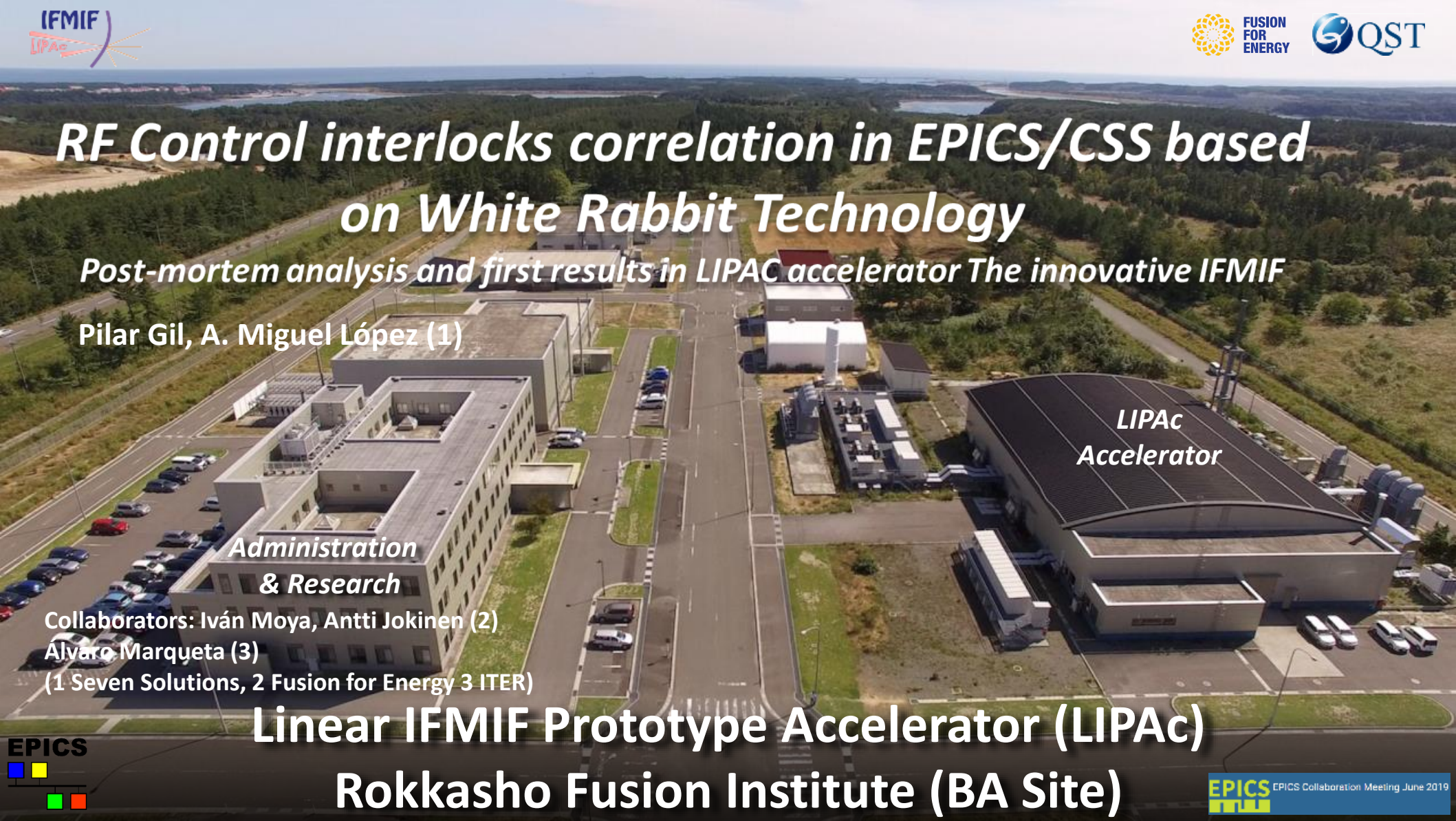

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Linear IFMIF Prototype Accelerator (LIPAc)
Rokkasho Fusion Institute (BA Site)

EPICS Collaboration Meeting June 2019

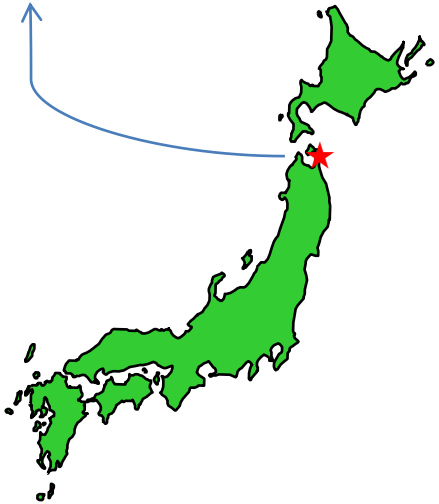
1. **General overview of LIPAc**
2. General overview of White Rabbit
3. LIPAc and Interlocks
4. Historical Interlocks
5. Future Developments

Disclaimer: The present work has been performed in the framework of the LIPAc project through the Broader Approach Agreement. The content of this presentation has been carried out under the on-going framework contract F4E-OFC-0935 between F4E and Seven Solutions.
Views and opinions expressed herein do not necessarily reflect those of Fusion for Energy or the involved Parties.

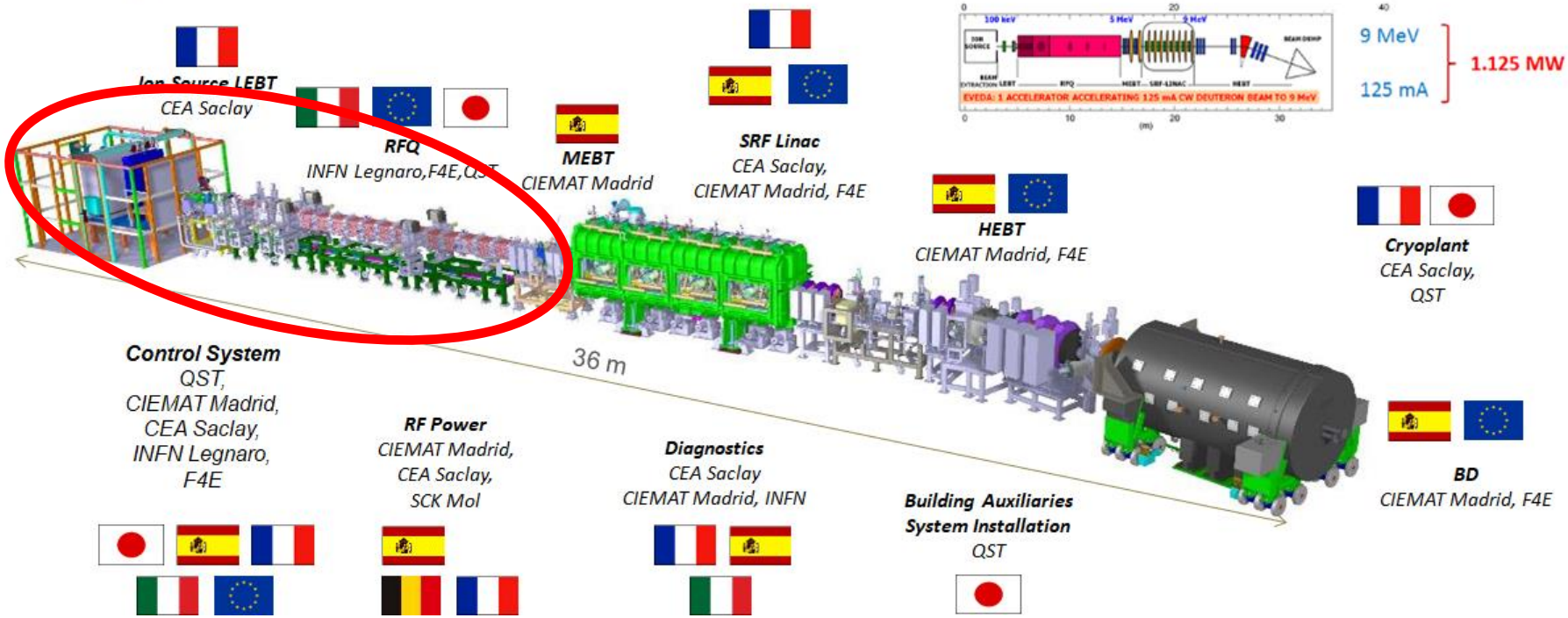
LIPAc (Linear **IFMIF** Particle Accelerator)

International Fusion Materials Irradiation Facility

Rokkasho, Aomori, Japan

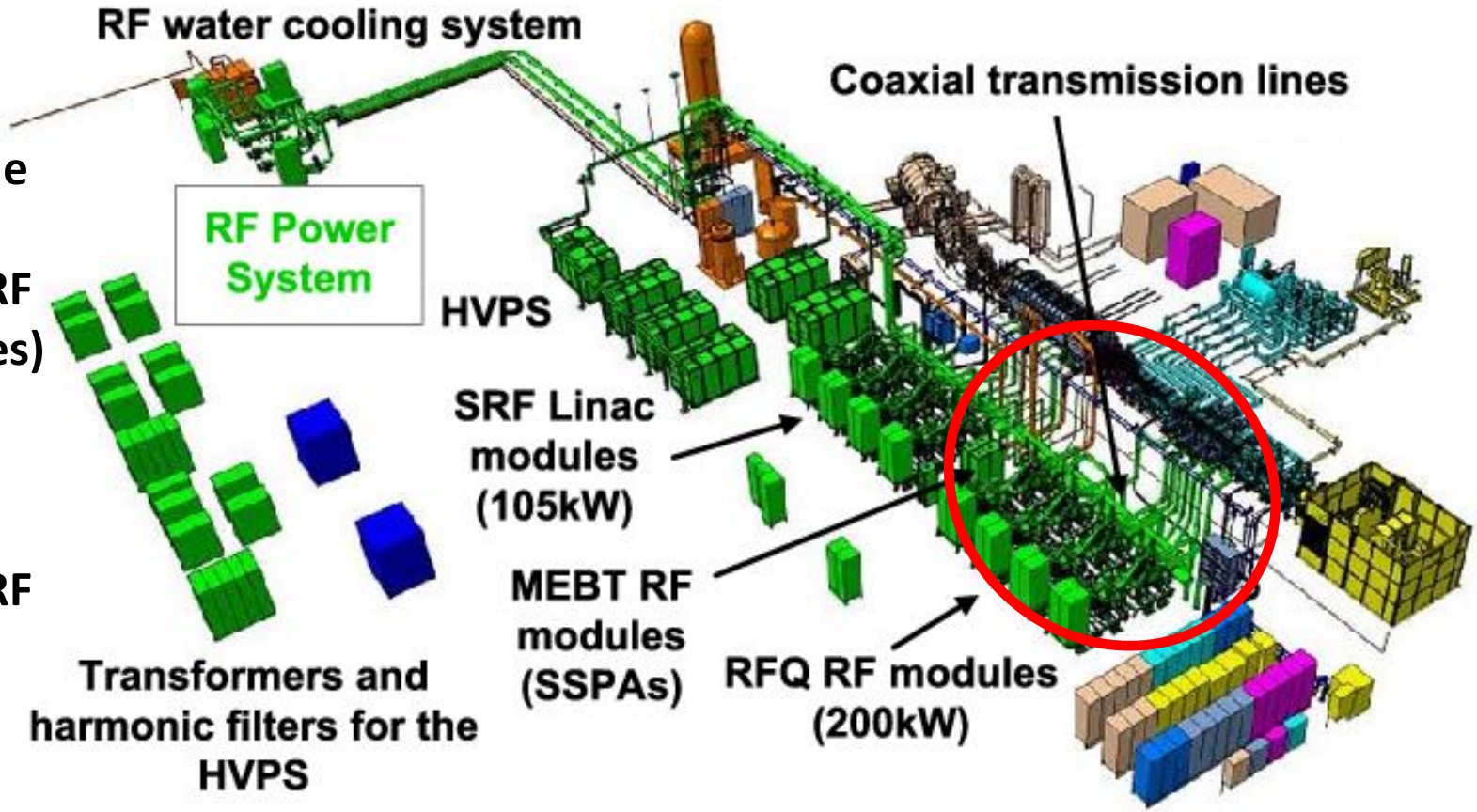


Japan-Europe scientific collaboration



1. General overview of LIPAc

- **8x RF Chains for the RFQ Cavity, controlled by 4 LLRF (1 Master + 7 Slaves)**
- **2x RF Chains for 2 independent Buncher Cavities, controlled by 1 LLRF**



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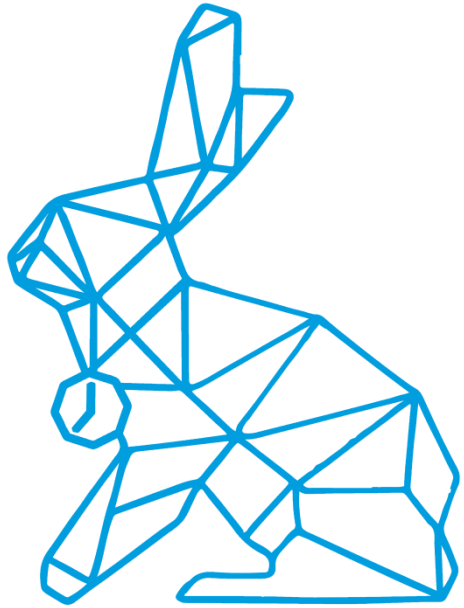
White Rabbit?…A*n extension of Ethernet.*

- It was born at CERN for time and frequency dissemination up to 1000 nodes
- Ultra-synchronization: **Sync-E & PTP (IEEE-1588v2)**
  - Sub-nanosecond time accuracy
  - Clock RMS jitter ~2 ps (1Hz – 1MHz)
- Accurate timestamps
- Thousand of nodes: compatible with standard Eth. nodes
- Distance range over 80 km
- Robustness & redundancy
- Self-calibration over long distances

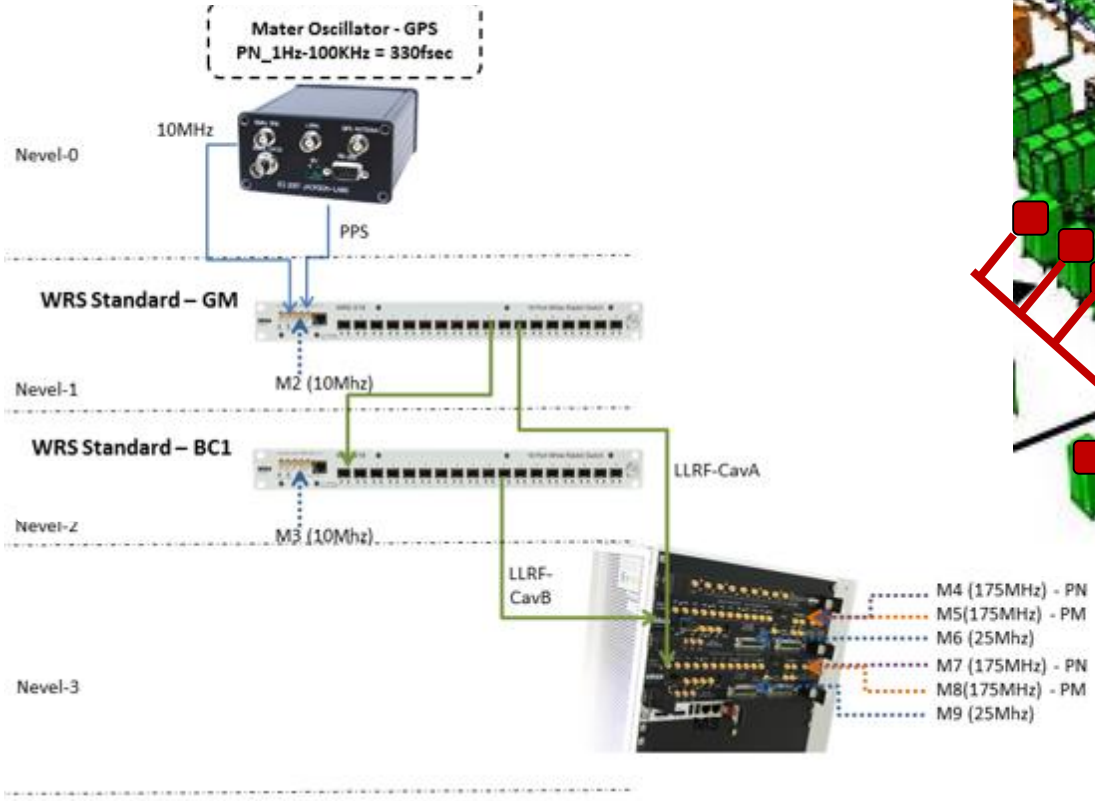


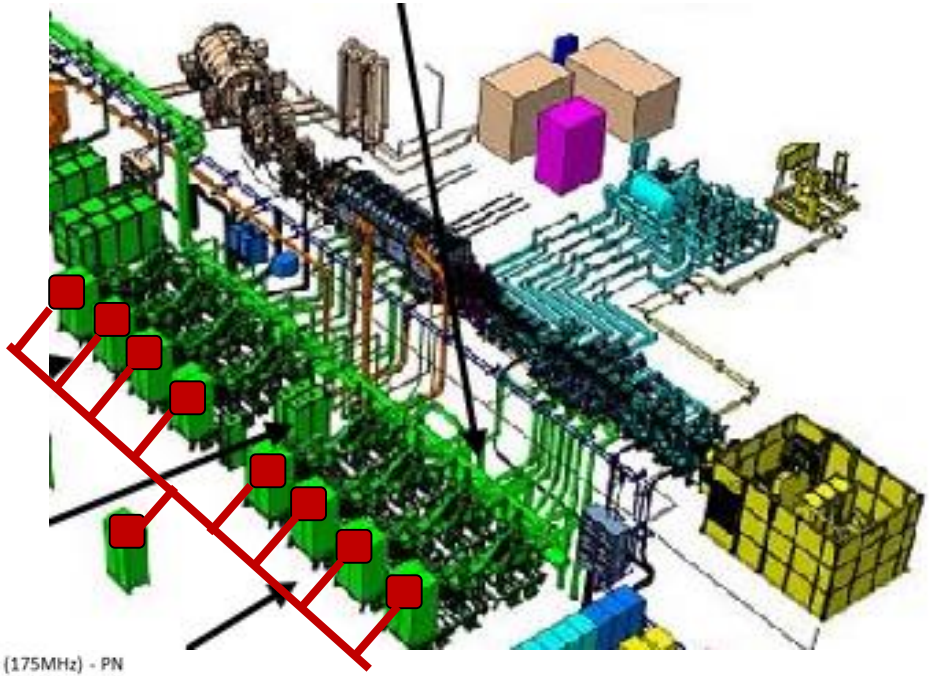
White Rabbit in LIPAc

- **First** Low Level RF based on White Rabbit
- **Frequency distribution** in different locations with synchronized phase, data logging and fast interlock system
- **Clock distribution: Sub-nanosecond** timestamping through the beam line → Same notion of time in all the modules → Monitoring and post-mortem analysis are correlated between LLRFs

2. General overview of White Rabbit

RF and clock distribution system:





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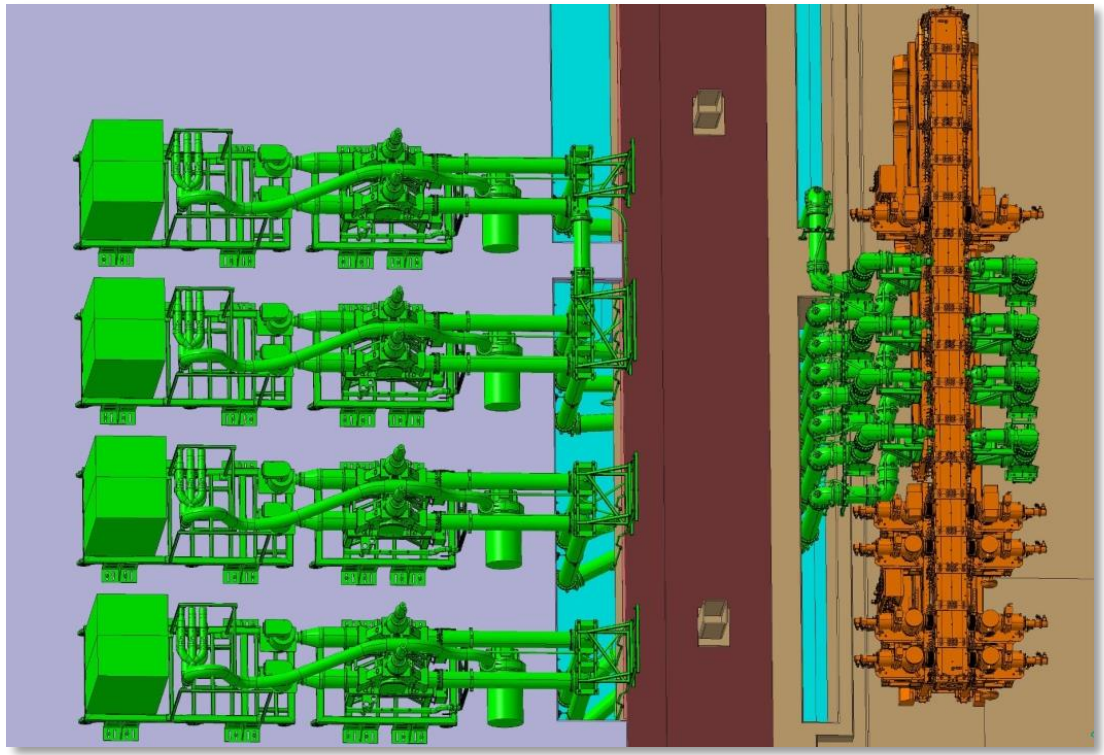
RF System for RFQ

LLRF 4	Cav. 4B (Slv) Cav. 4A (Slv)
LLRF 3	Cav. 3B (Slv) Cav. 3A (Slv)
LLRF 2	Cav. 2B (Slv) Cav. 2A (Slv)
LLRF 1	Cav. 1B (Slv) Cav. 1A (Mst)

RF Area

Vault



Why WR Based Interlock Correlation?

- In LIPAc there are many dependent RF modules and an interlock situation in one of them usually propagates the interlock to other modules (i.e. Reflected power peaks)
- When a module triggers an interlock is difficult to detect which one has been the first → Difficult to detect where is the problem!!
- Conditioning time reduction!!

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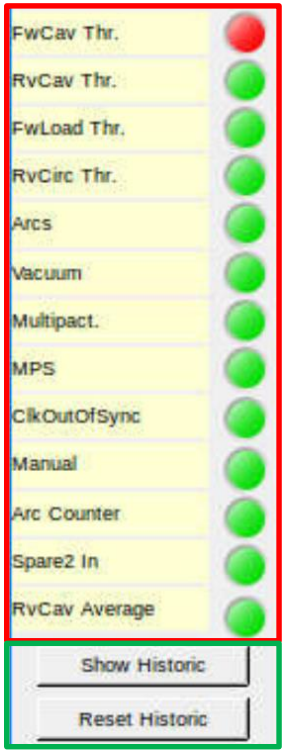
4. Historical interlocks

- WR and EPICS provide a common sense on time in all the LLRF included in the system → All PVs are correlated!!
- EPICS PV and CSS-BOY GUI used for displaying the historical of interlocks
- Waveforms are used for saving interlocks and timestamps →
  PV data available for analysis and archiving purposes
- Interlock historic data is also used for post-mortem analysis
- Provide an easy and visual way to show the sorted interlock occurrence in one or between multiples RF Modules/Chains

Individual Historic



Actual interlock status

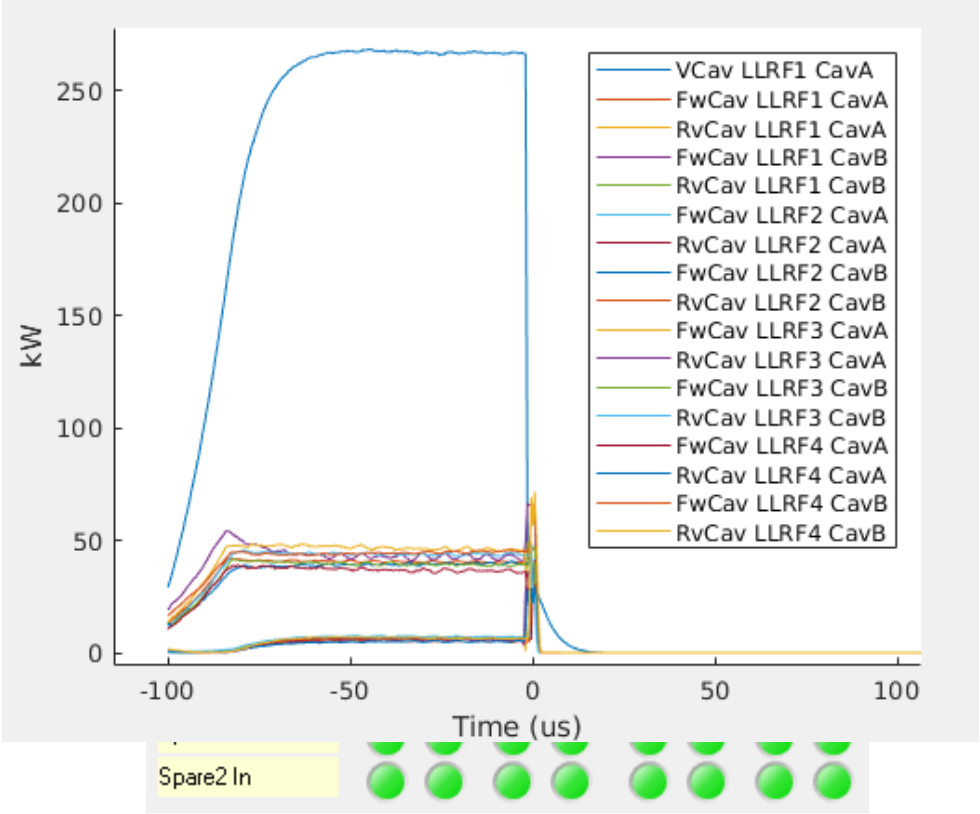
Detects the occurrence of interlocks with nanosecond precision!!!

Timestamp Activation	Timestamp Deactivation	Status	Interlock
13:20:43 (282,377,520 ns)			LLRF1_CavA:TxReady
	13:21:10 (615,001,570 ns)		LLRF1_CavA:TxReady
13:21:10 (615,004,110 ns)			LLRF1_CavA:FwCav
13:21:10 (615,004,120 ns)			LLRF1_CavA:FIM

Enables the view of the Historic of interlocks

4. Historical interlocks

- Easy to detect which Module/Chain has been the first one triggering an interlock
- The accuracy provided is better as the one provided in the EPICS PVs timestamp
- Data are integrated in the Post-mortem information → Correlated event occurrence



Results/Improvements in LIPAc

- Detection of recurrent problems/misconfigurations in the circulators
- Problems detected on the pre-amplifiers
- Creation of an statistics database which
- Improvement of the LLRFs increasing its robustness

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5. Future Developments

- Integration of WR time into the PV timestamp instead of using the host time (NTP)

- Machine learning for detection of critical points

- Server system status warnings using Telegram! → Easy to monitor the alarms in the system from anywhere

5. Future Developments

Thanks for your attention!!

Any questions??