Multi-BOR system with IDROGEN

experiment

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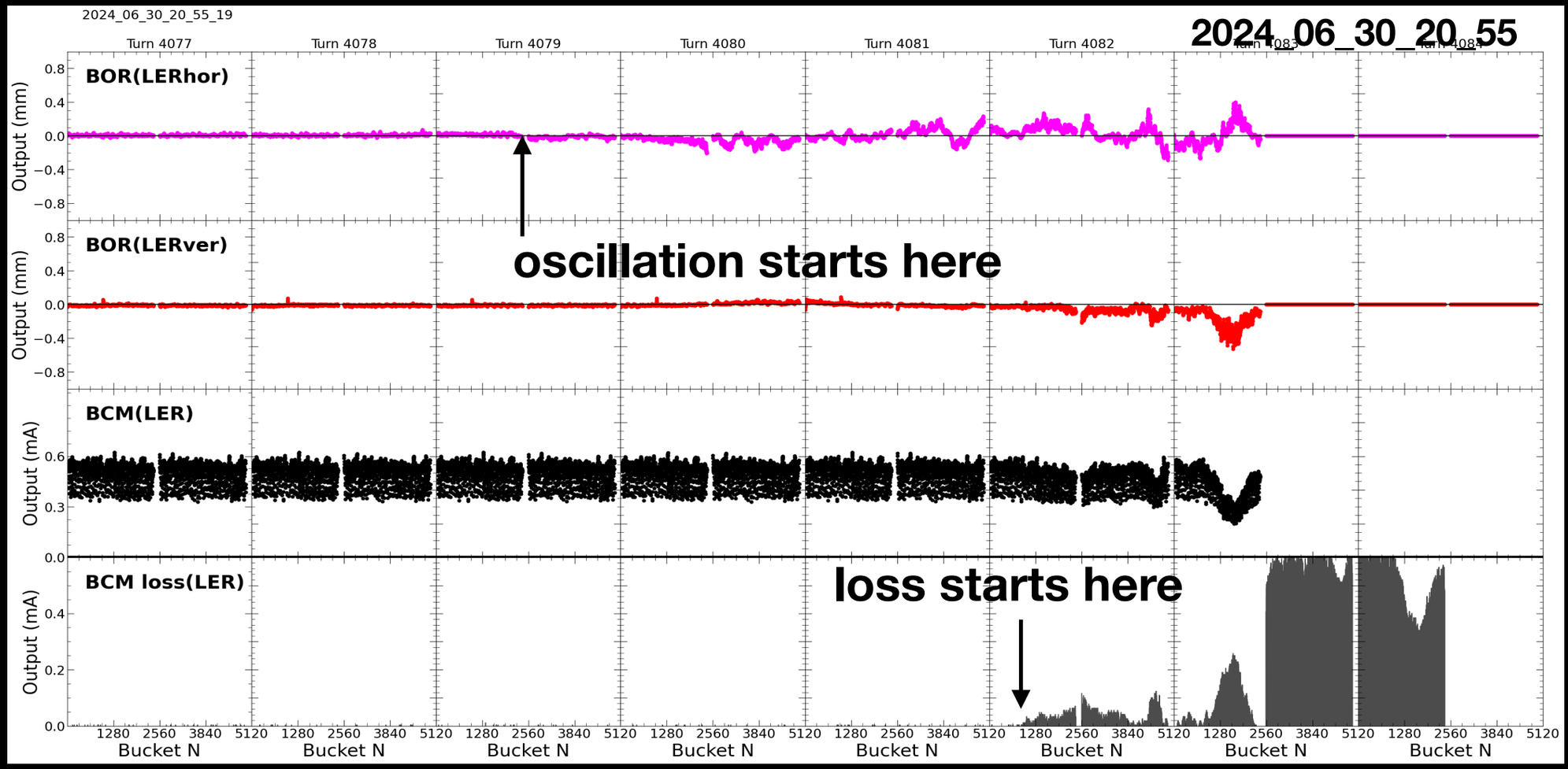
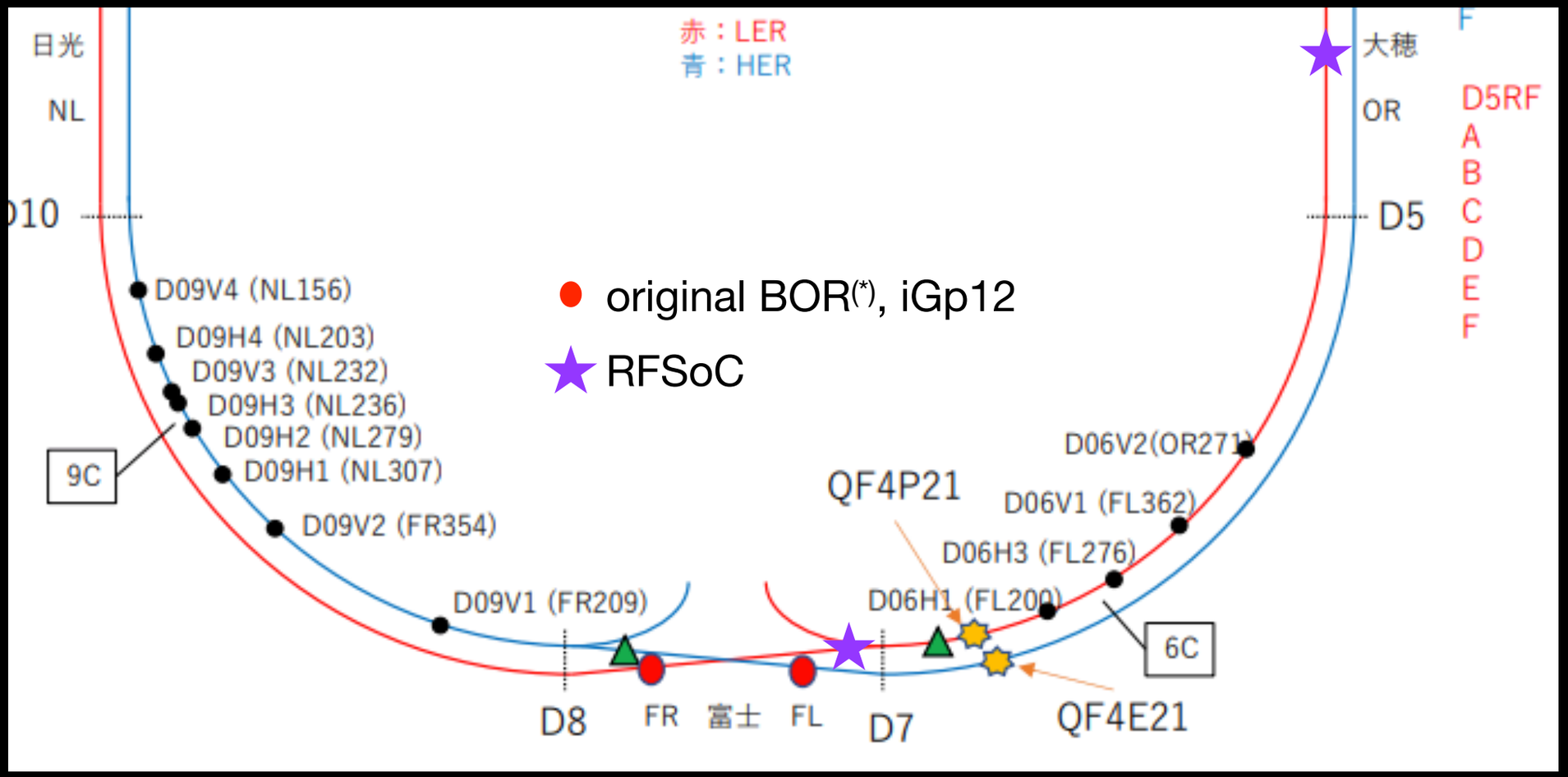
Beam Loss vs Oscillation



Beam oscillations typically begin a few turns before the actual beam loss. This early onset of oscillation provides an opportunity to diagnose the beam in advance.

Existing BOR systems



(*) https://www.pasj.jp/web_publish/pasj2016/proceedings/PDF/TUOM/TUOM06.pdf

BOR, originally installed as a bunch feedback monitor, has proven to be very useful for SBL study. During LS1, additional BORs were added to futher monitor the beam.

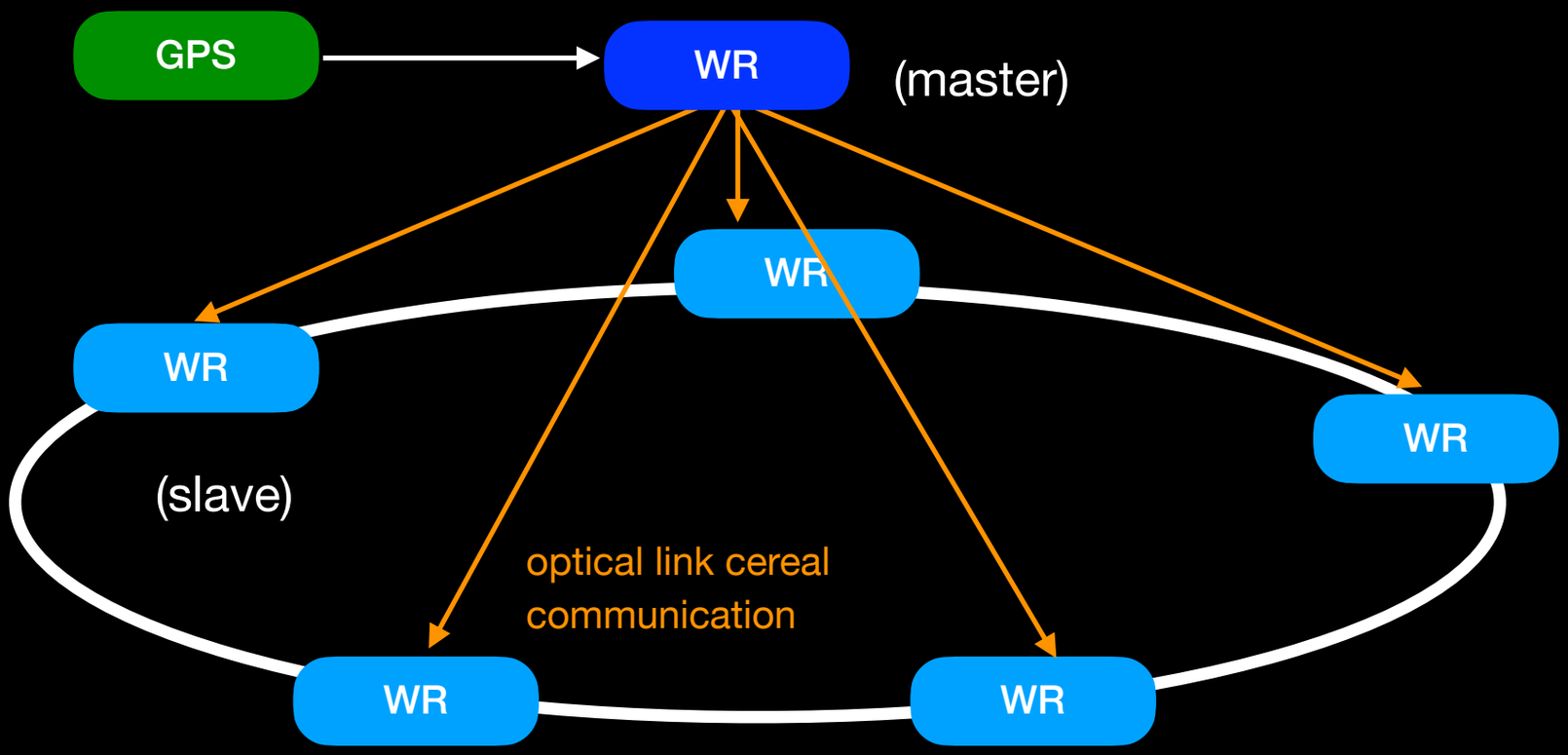
Current Limitations:

- BORs are available only at limited locations, which restricts coverage. A multi-BOR system is needed to monitor the entire ring
- No time synchronization capability, or synchronization is too complex.
- Common reference other than beam abort needed for on-time diagnostics
- The current sampling rate may not be sufficient for all applications.

Unified system is desired with the capability of taking sufficient amount of data → **Multi-BOR system with IDROGEN**

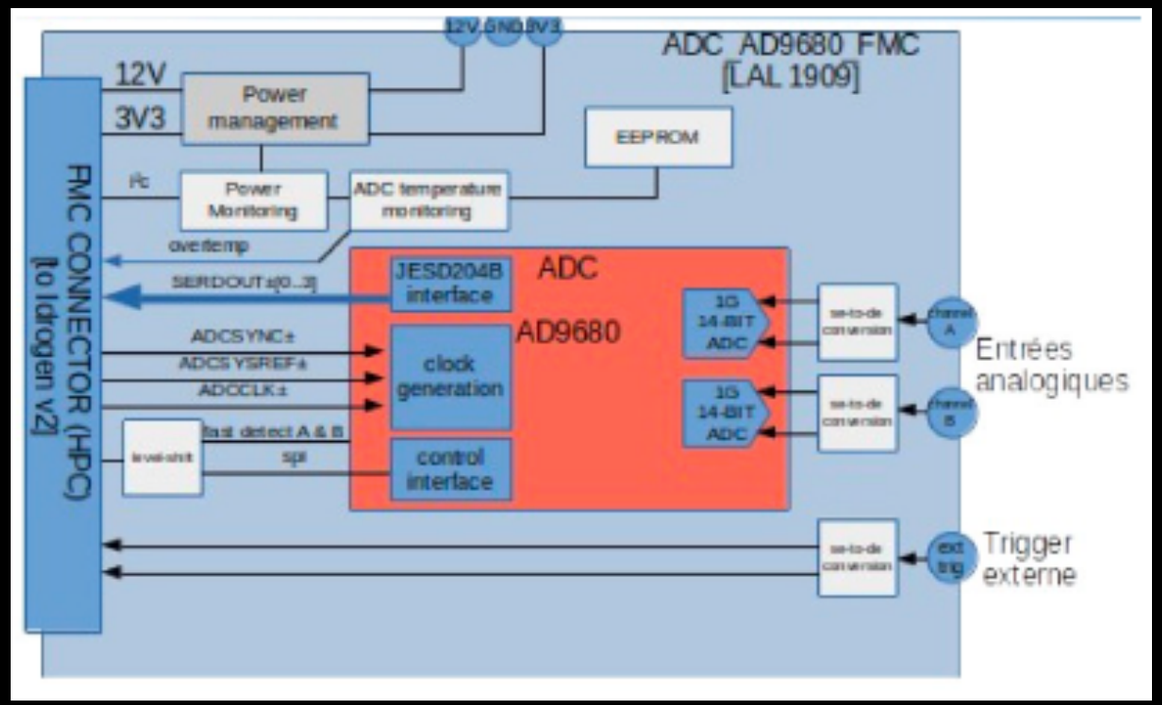
Multi-BOR system with IDROGEN

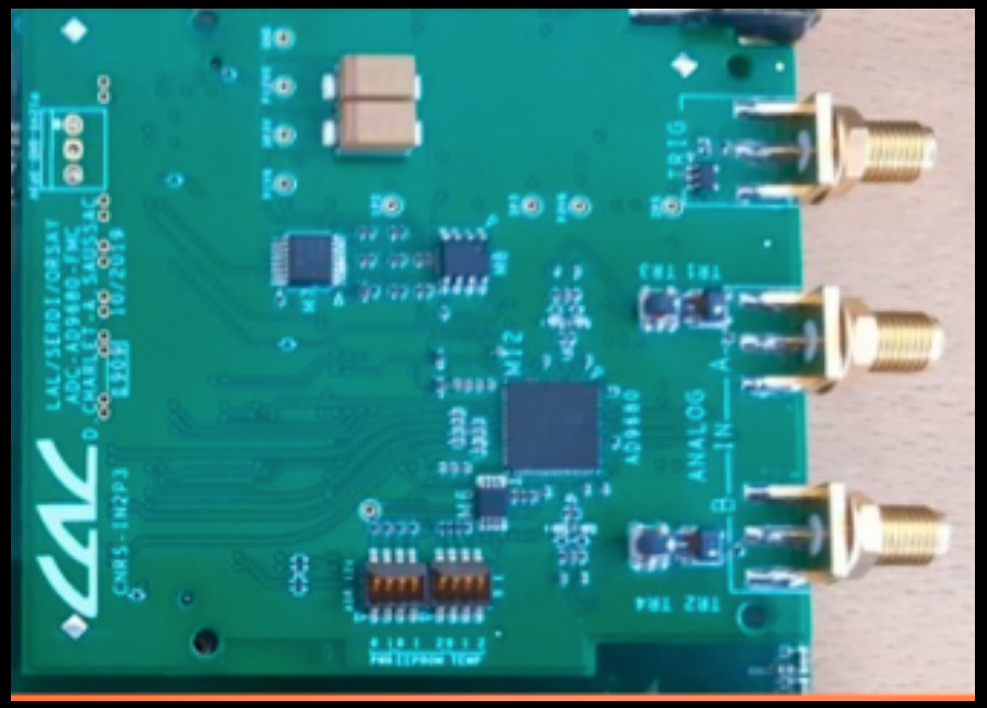
IDROGEN board (developed at IJCLab) with **White Rabbit (WR) PTP** enables high-precision synchronization (<100 ps) and connects directly to an **ADC FMC card** for high-resolution data acquisition.



The data is then transferred to a **readout PC via PCIe** using optical links.

ADC FMC card





- The **ADC FMC Card (ADC 9680)** features **2 channels**, **14-bit**, **500 MS/s**, and a **2GHz bandwidth**.
- The card supports an **external trigger input** and is synchronized with **White Rabbit** for precise timing.
- Continuous data readout is performed using **PCIe with DMA**.

Other considerations for BOR

BPM selection:

- Consider chamber diameter and signal strength (64 mm for Fuji FB BPM, 90 mm for other locations)
- Flexible selection based on COD and DC offset mitigation.

→ Design new circuits to handle DC offset from BPMs and prevent narrowband detector reflection from affecting CCC

Number of BORs:

- At least 3 BORs are required to determine the betatron phase and its sign. Adding more BORs reduces degeneracy (from 44 to 11 with 5 BORs)

Equipments:

- Tronbone delays, N-type signal splitters, SMA cables, low-pass filters, 180° hybrid circuits, single-end amplifiers, LEMO cables, LAN cables, etc

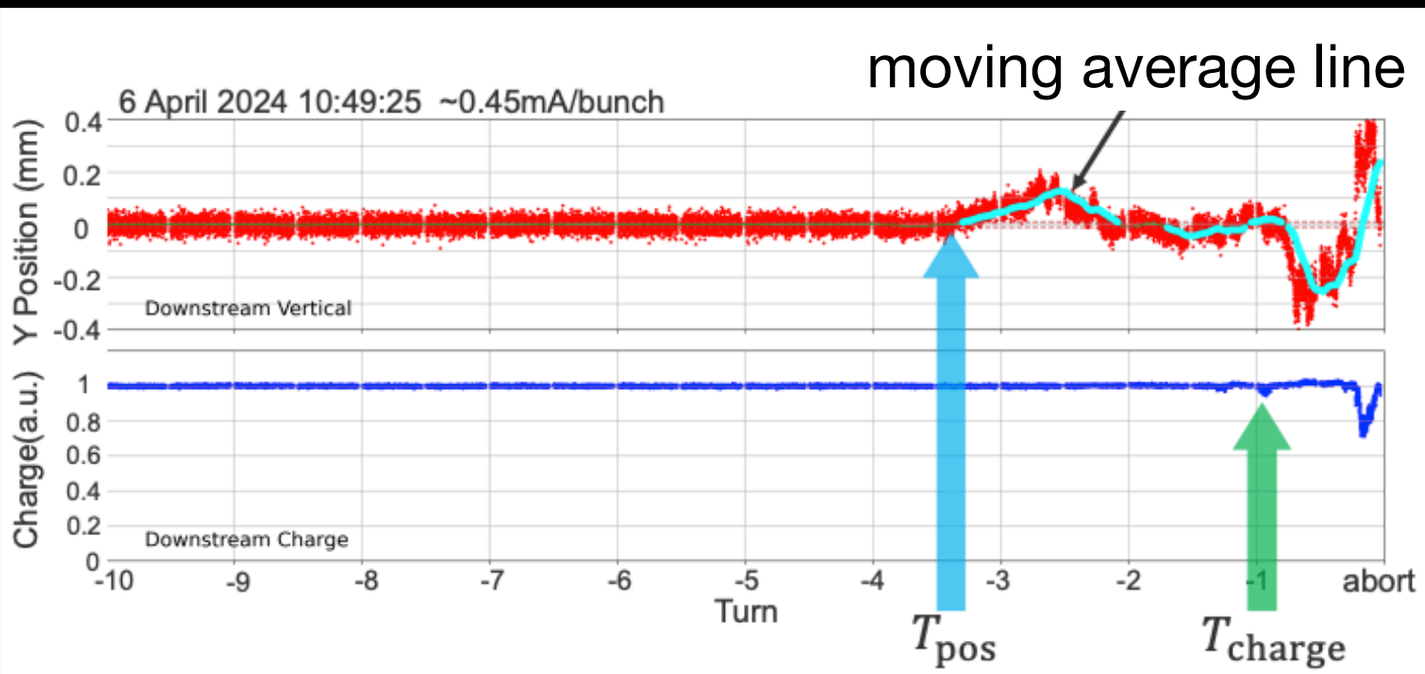
R&D / Commissioning plans

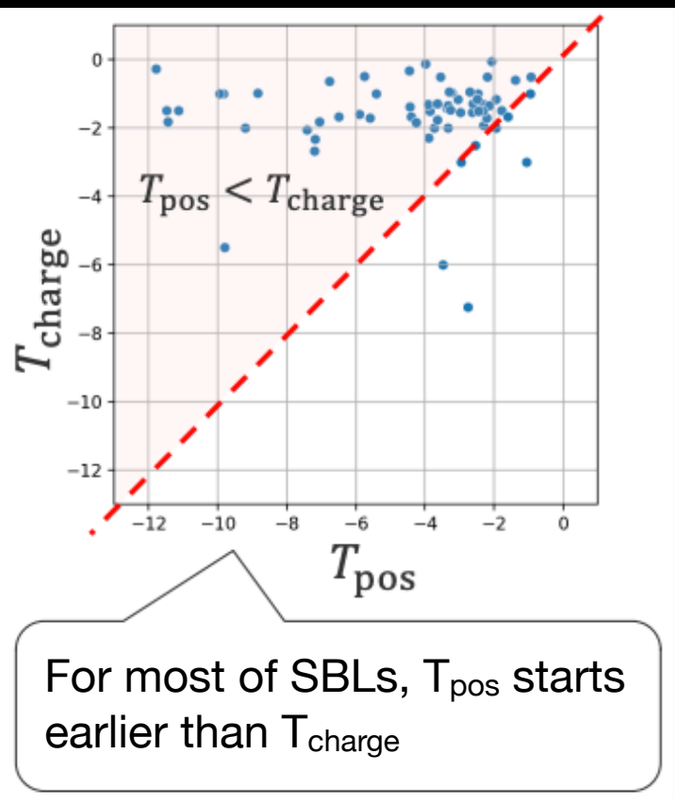
2025	IDROGEN+PCIe Readout Chain Test at UH
	Multi-BOR system Commissioning at ATF/FUJI
2026	Full-Scale Commissioning at SuperKEKB
	Oscillation Data Analysis for SBL/injection study

It will be a collaborative effort with experts from KEK.

Multi-BOR data analysis

R. Nomaru





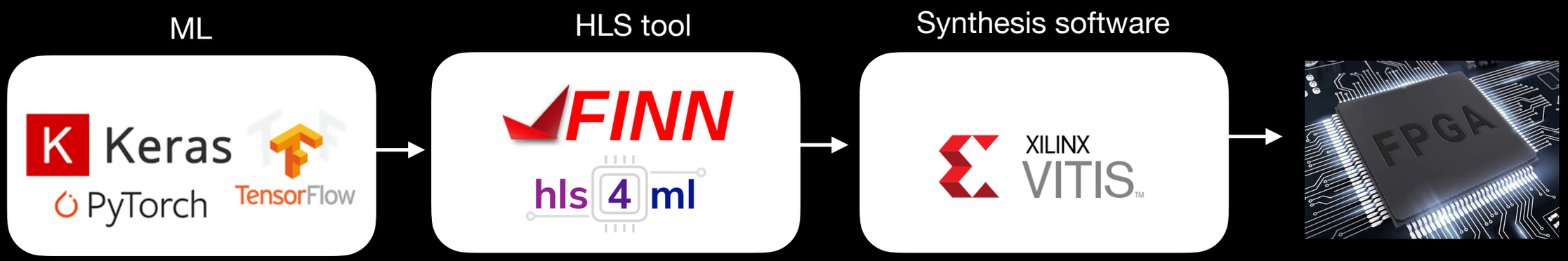
T_{pos}: moving average line over 0.01 mm
T_{charge}: > 5% charge loss

- Ongoing efforts focus on data analysis from an RFSoC, characterizing SBL events. This can be expanded with multi-BOR data.
- Non SBL data can be also analyzed (e.g. injection study).
- Ultimately the oscillation petterns can be categorized and used for oscillation-based beam aborts.

Ultra-fast Beam Abort

Develop a real-time system that detects anomalous oscillation pertterns early and issues an ultra-fast beam abort to prevent beam loss.

- Train a Neural Network (NN) using pattern-analyzed oscillation data,
- Optimize the NN algorithm with HLS tools (pruning, quantization, etc)
- Implement it on an FPGA and perform on-time data analysis with low latency for rapid abort decision-making.



Summary

- BOR can detect oscillations earlier than beam loss, making it crucial for ealy beam diagnostics.

- The multi-BOR system with IDROGEN offers enhanced beam monitoring with White Rabbit for precise synchronization, and the ADC FMC card enables high-resolution, synchronized data acquisition.

- Using analyzed oscillation dta, we aim to build ML algorithms to achieve an Ultra-fast Beam Abort system.

Thank you!

Backup