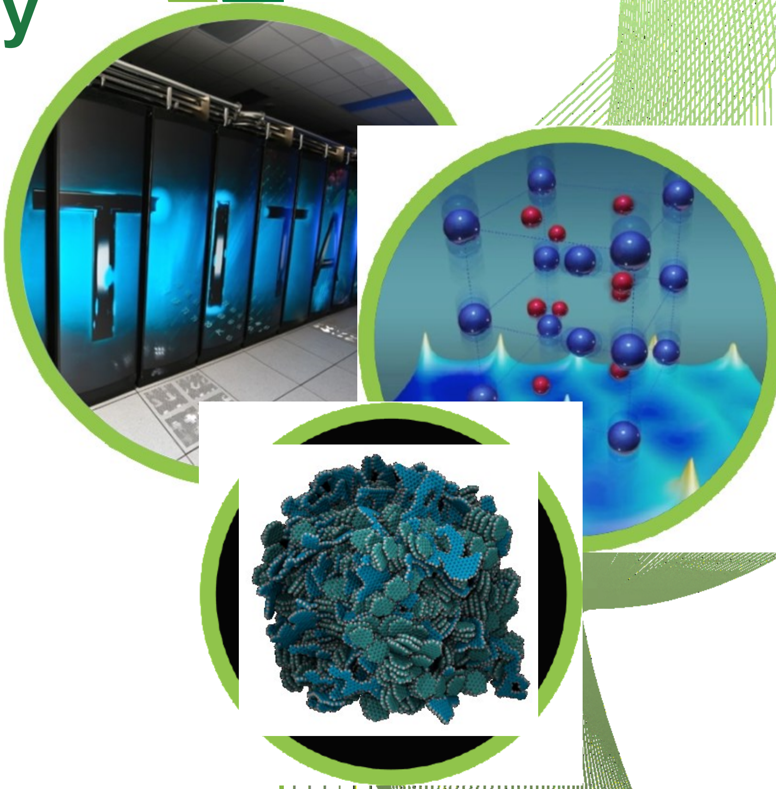
Configurable Crossbar Switch for Deterministic, Low-latency Inter-blade Communications in a MicroTCA Platform



Eric Breeding

Spallation Neutron Source
Oak Ridge National Laboratory

Presented to

6th MicroTCA Workshop for Industry and Research

December 7, 2017
DESY, Hamburg

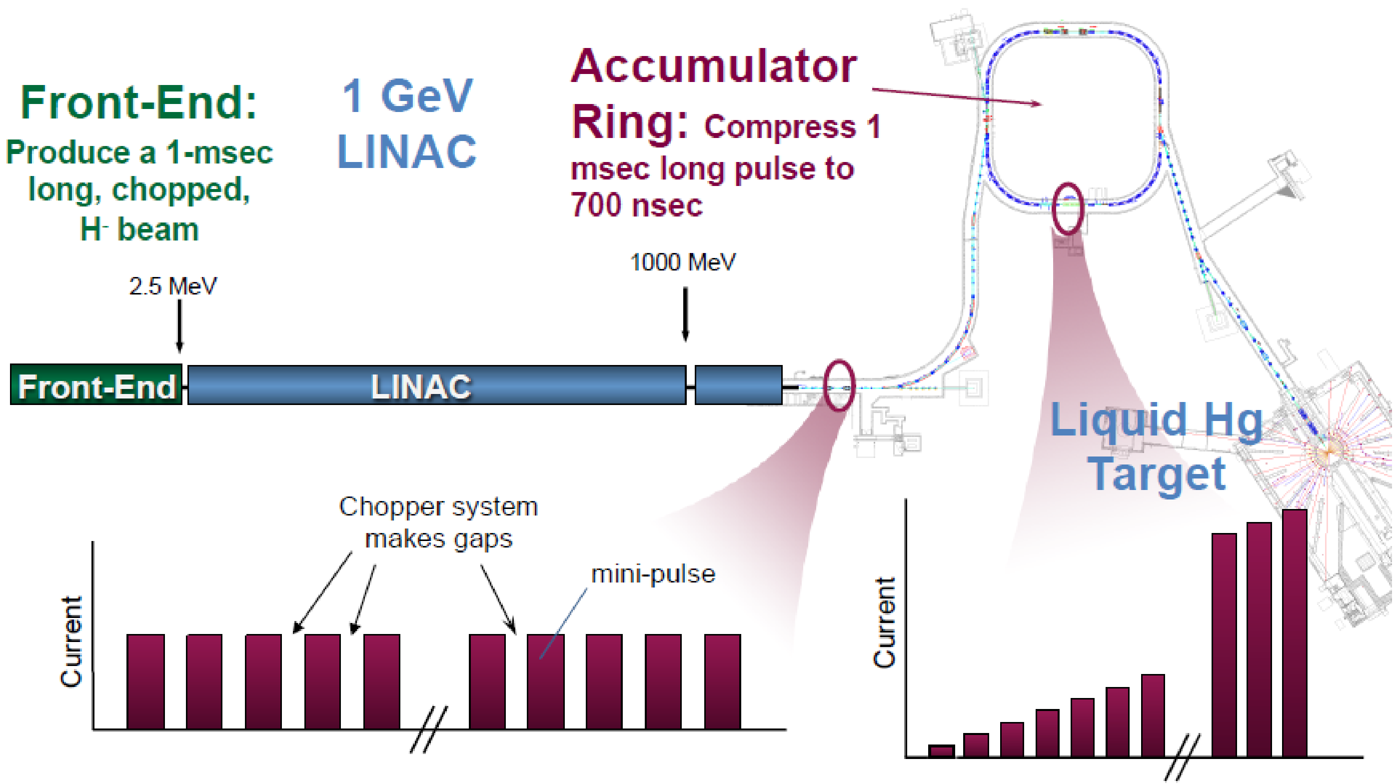
Outline of Presentation

- Introduction to the Spallation Neutron Source (SNS)
- SNS Fast Protection System (FPS)
  - Purpose
  - Architecture
- Crossbar Overview
- Concluding Remarks
- Appendix: MicroTCA Development at SNS

The Spallation Neutron Source (SNS) Provides the Most Intense Pulsed Neutron Beams in the World for Scientific R&D

- Operational since 2007, but built with “1990s” electronics
- Obsolescence is driving new developments at SNS

SNS Accelerator Complex

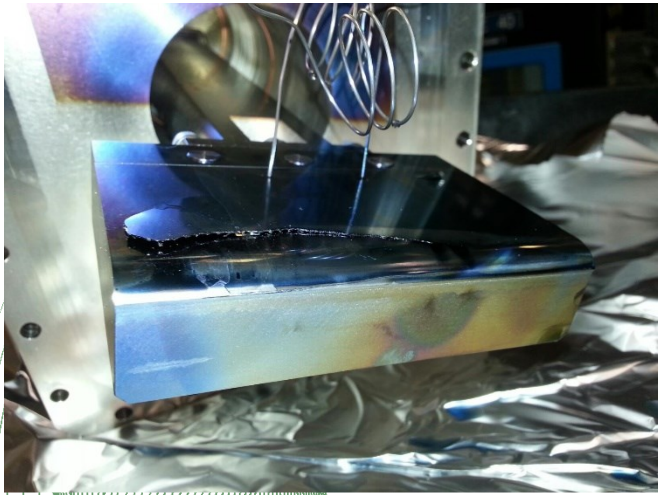


Production Run Parameters:

- Peak current: 38 mA
- Repetition rate: 60 Hz
- Macro-pulse length: 0.85 – 0.975 ms
- Average power: 1.2 – 1.4 MW

High Beam Power Is Accompanied by Significant Hazards

- Hazards
  - Uncontrolled energy release (beam loss)
  - hardware systems failure
- Threats
  - physical damage
  - radio-activation
- Mitigation
  - monitor systems for problems - magnets, RF, Vacuum, etc…
  - "quickly" terminate beam production when a problem (fault) occurs



MEBT Chopper Target Rupture: FY2014

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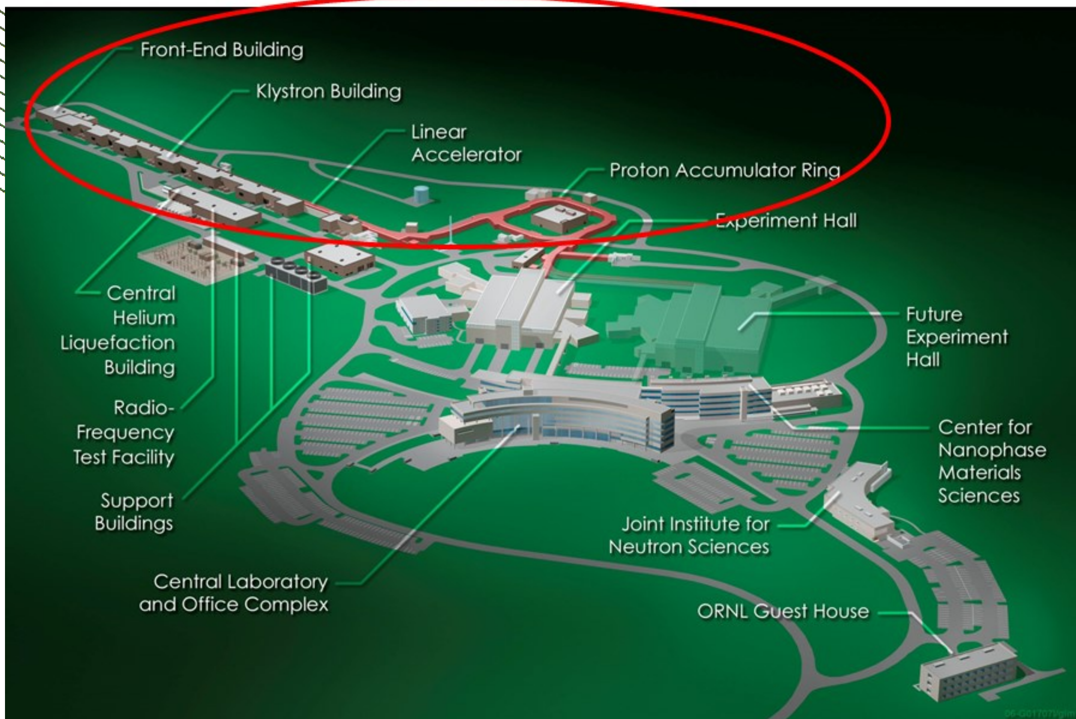
Example of a Fault-causing Occurrence

Raccoon in 13 kV switchgear. 15 % of FY 2010 AC systems downtime (4 hours). Allegedly tastes like chicken.

Photo and remark courtesy of John Galambos: JAS14 (USPAS), Long Beach CA

FPS Purpose: Mitigate Hazards that Threaten Accelerator Components



- FPS monitors more than 1000 sensors covering a large area
- FPS terminates beam generation if a qualified fault occurs
- Response to a detected fault must be less than **20 usec**

FPS must be a system with: (1) a fast response time
(2) a reliable (deterministic) response time

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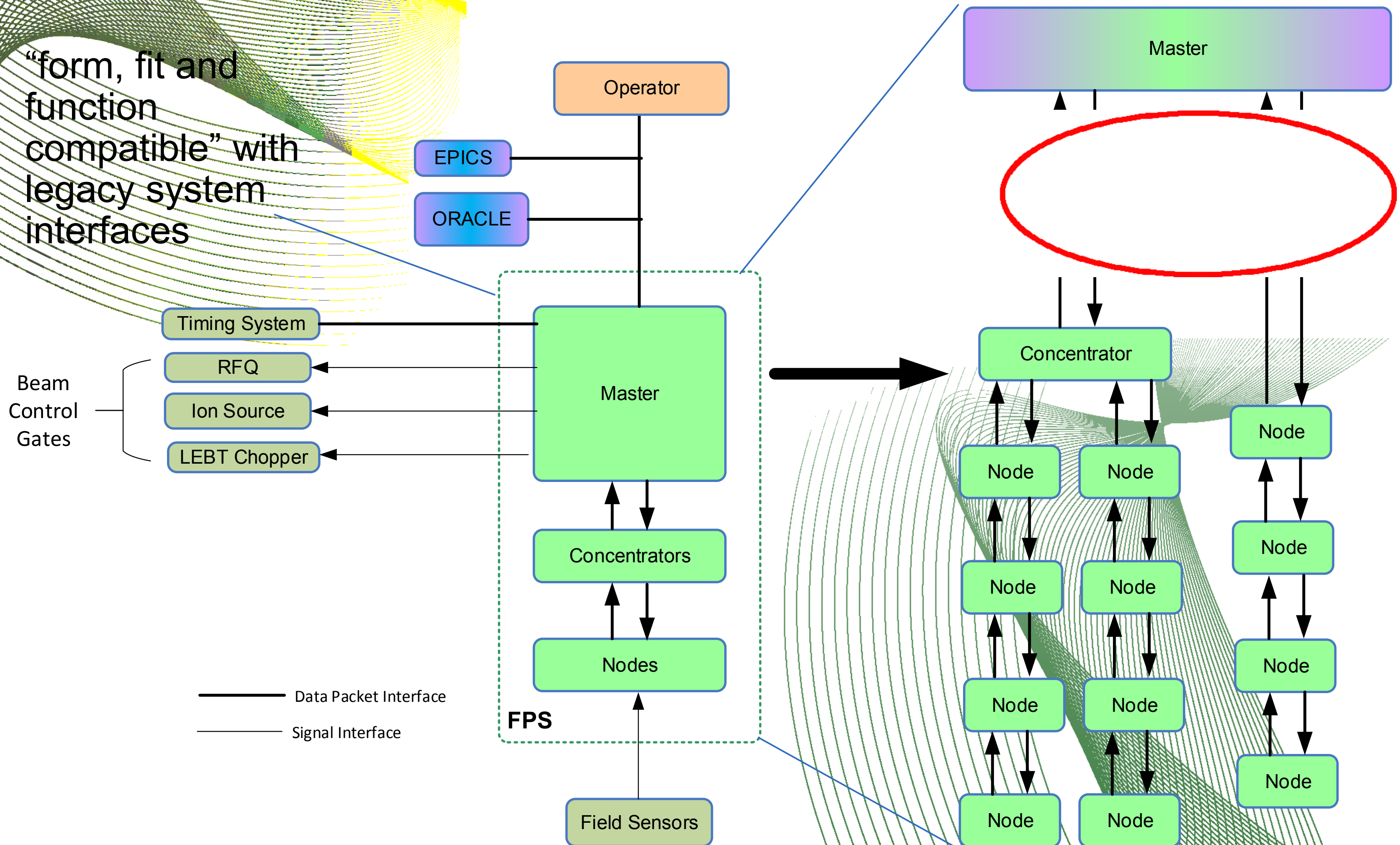
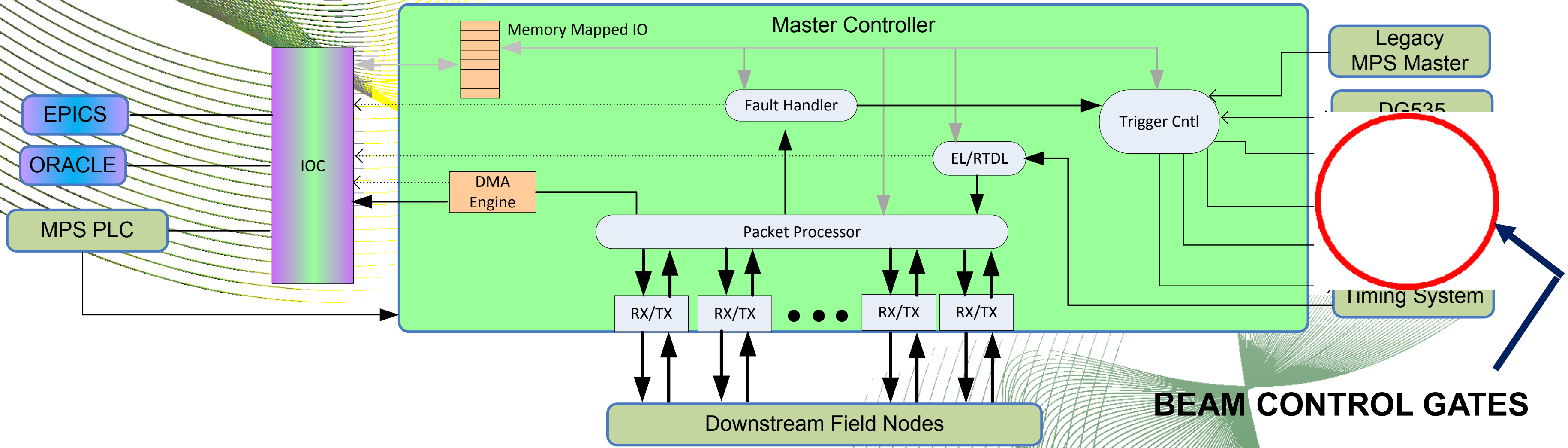
New FPS: Low-latency, Distributed Architecture

"form, fit and function compatible" with legacy system interfaces

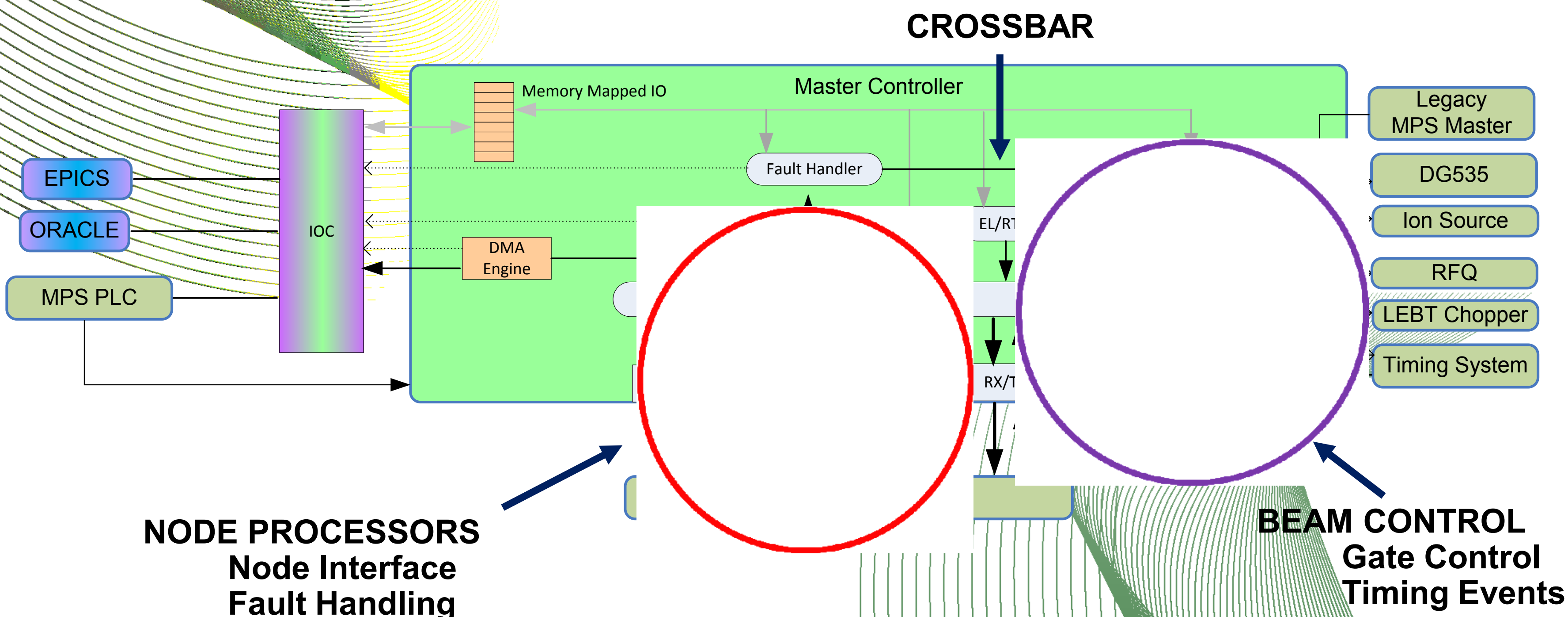


Master Controller Is the Principal Subsystem of the FPS



- Master controller uses gates to control the beam generation. It terminates beam if:
  - a qualified fault condition is received from downstream node
  - beam power exceeds the operating envelope
  - beam power exceeds that allowed for a particular machine mode.

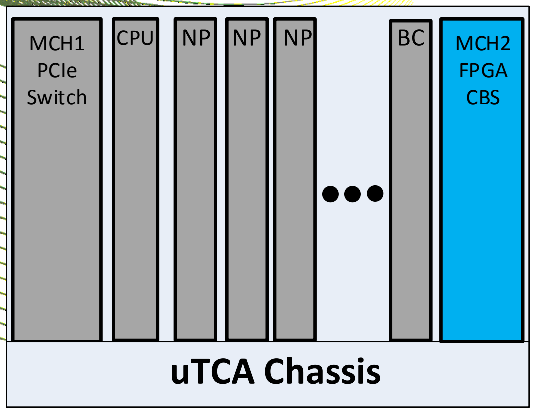
Master Controller Functionality Maps to Three Types of (uTCA) Modules



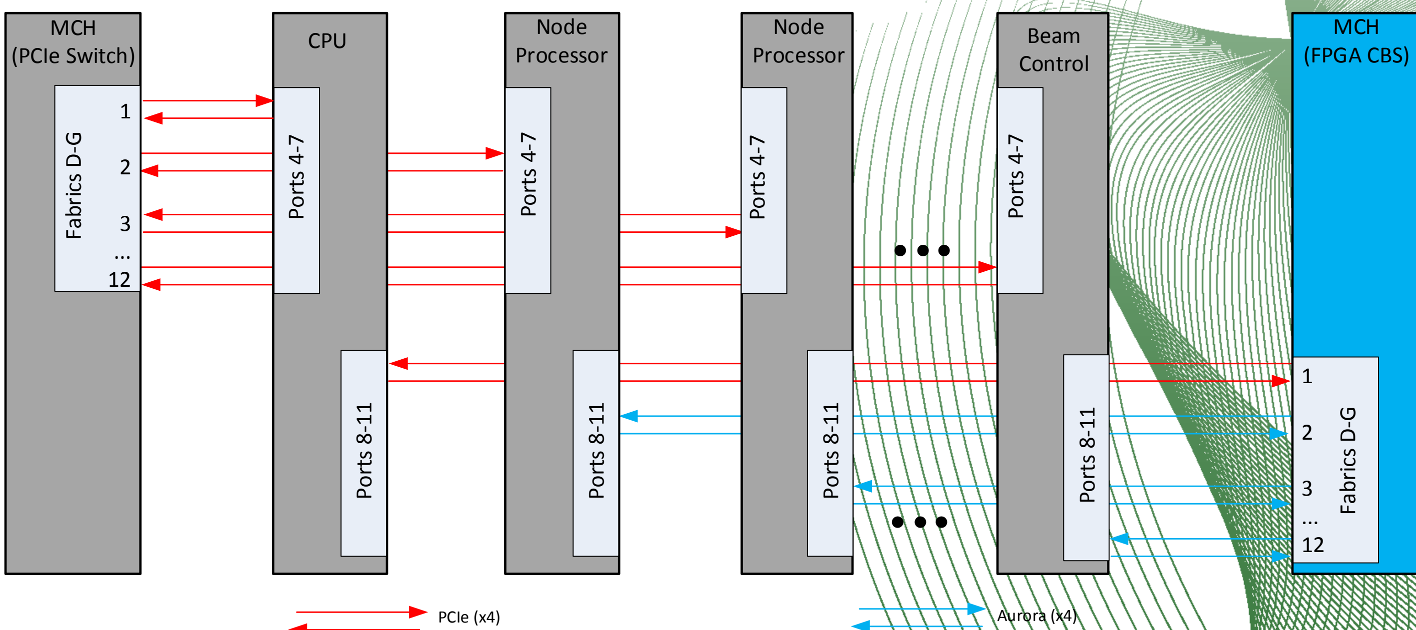
- Why do we need a Crossbar?

ALL NODES NEED "SIMULTANEOUS" ACCESS TO BEAM CONTROLLER and TIMING INFORMATION

Master Controller: MicroTCA Platform with a Special MCH



AMC:
- MCH1: PCIe Switch
- CPU: Processor, Intel Core i7 (Linux)
- NP: Node Processor (up to 10)
- BC: Beam Control
- MCH2: FPGA Crossbar (CBS)



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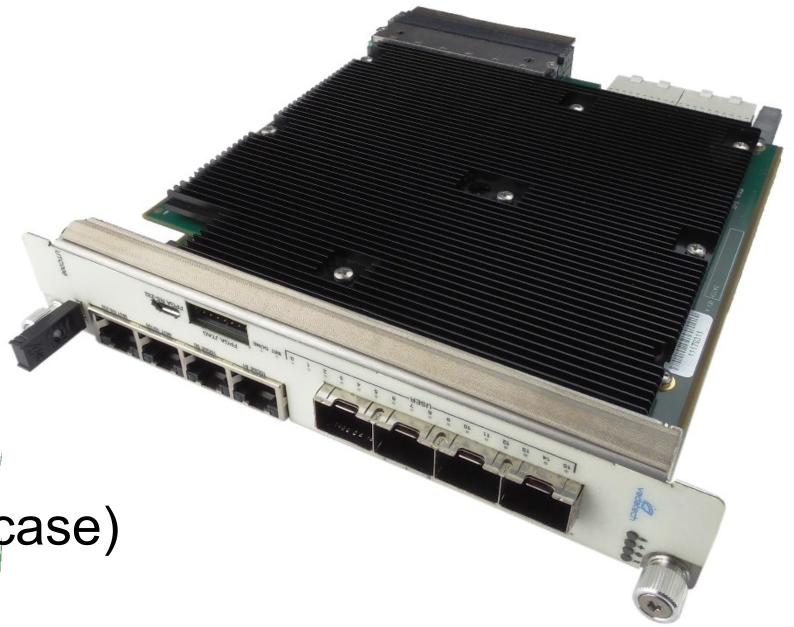
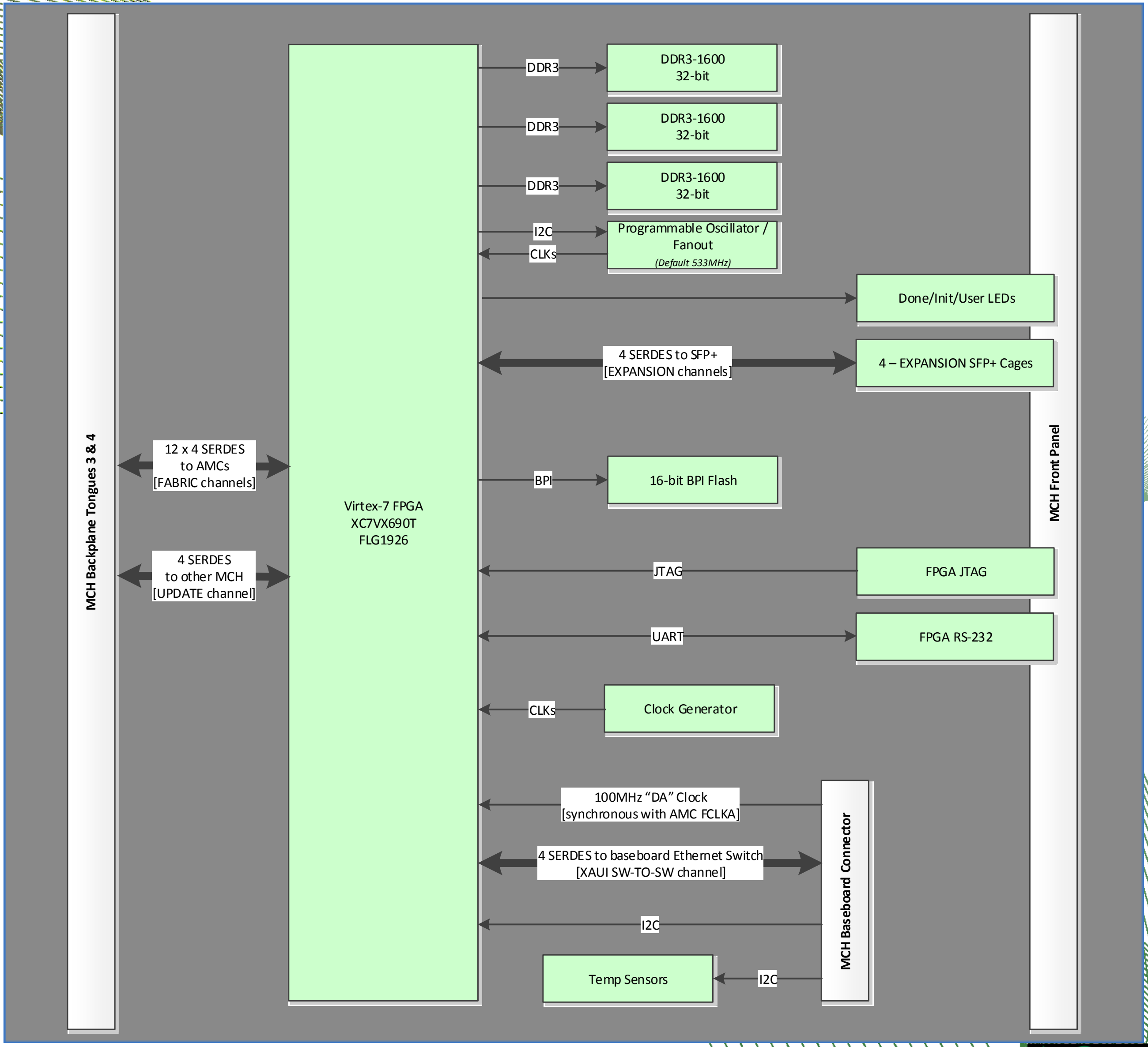
FPGA CBS: Configurable MCH for User-defined Protocols for Interfacing AMC Modules

- Vadatech UTC006-100-000-000
  - Xilinx Virtex-7 FPGA (XC7V690T)
  - 12 ports x 4 (lanes/ port)
  - 4 SFP+ on Front-panel
  - 3 GB DDR
  - 48 GB/s Aggregate BW (ORNL use case)

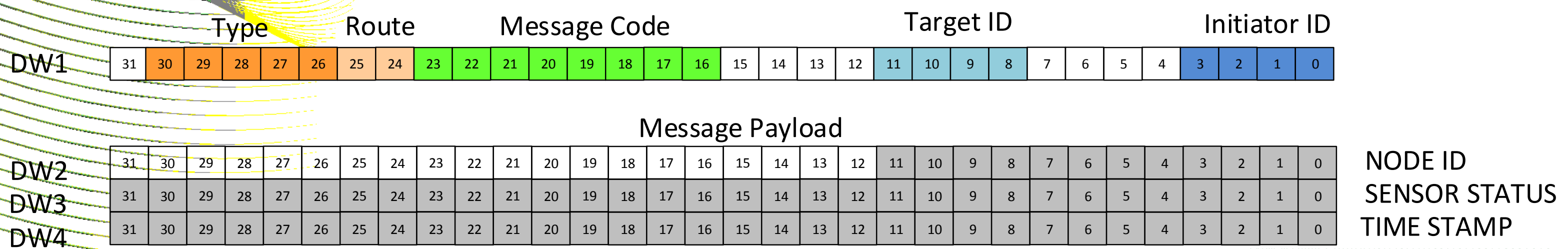


Vadatech UTC006-100 Block Diagram



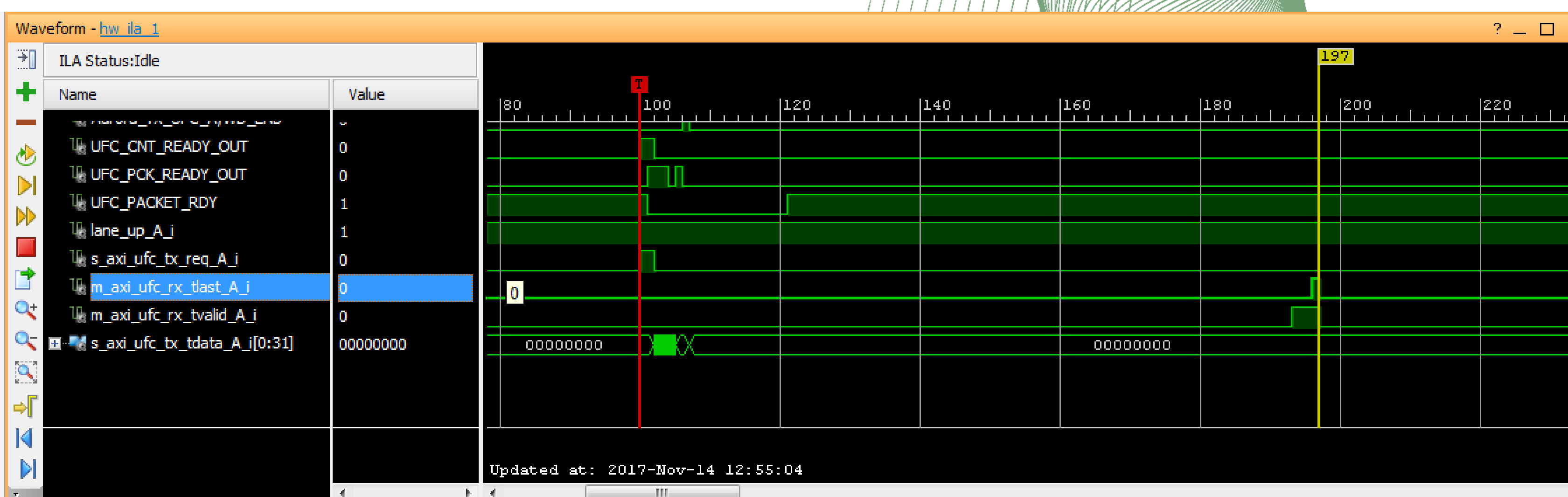
Aurora 8B/10B Protocol Provides Deterministic Performance for Fault Messages

- User Flow Control (UFC): 16-byte message



- Latency:

97 x (~6.4 ns) = ~ 620 ns



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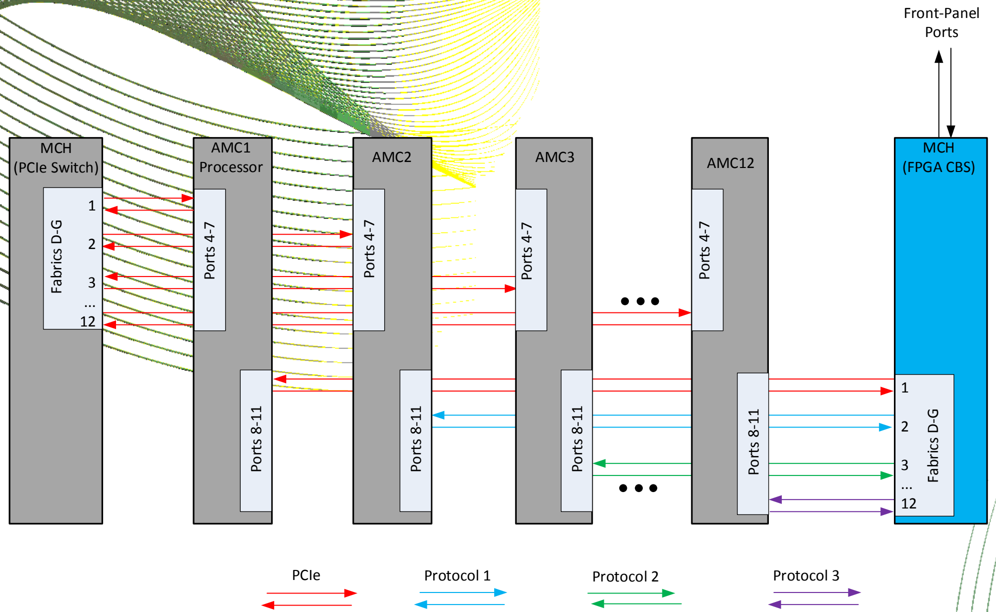
FPGA CBS Represents a Significant Breakthrough in Inter-blade Communications



- Point-to-point (P2P)
  - Any slot to any slot
  - Standard backplane
  - Low latency
  - Carrier-to-carrier
  - Multi-protocol
- "Intelligent" Switching
  - "Many-to-one"
  - "One-to-many"
  - Data reduction

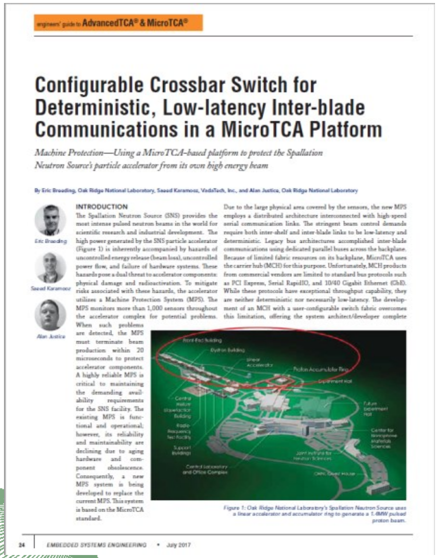
	Type					Route		Message Code								Target ID Mask												Initiator ID			
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Message Payload

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

For More Information…

- Embedded Systems Magazine, July 2017
  - http://eecatalog.com/atca/2017/07/17/configurable-crossbar-switch-for-deterministic-low-latency-inter-blade-communications-in-a-microtca-platform/
- Contact: Eric Breeding (breedingj@ornl.gov)
- www.vadatech.com



engineers' guide to AdvancedTCA® & MicroTCA®

Configurable Crossbar Switch for Deterministic, Low-latency Inter-blade Communications in a MicroTCA Platform

Machine Protection—Using a MicroTCA-based platform to protect the Spallation Neutron Source's particle accelerator from its own high energy beam

By Eric Breeding, Oak Ridge National Laboratory, Saeed Karamooz, VadaTech, Inc., and Alan Justice, Oak Ridge National Laboratory

Eric Breeding

Saeed Karamooz

Alan Justice

INTRODUCTION

The Spallation Neutron Source (SNS) provides the most intense pulsed neutron beams in the world for scientific research and industrial development. The high power generated by the SNS particle accelerator (Figure 1) is inherently accompanied by hazards of uncontrolled energy release (beam loss), uncontrolled power flow, and failure of hardware systems. These hazards pose a dual threat to accelerator components: physical damage and radioactivation. To mitigate risks associated with these hazards, the accelerator utilizes a Machine Protection System (MPS). The MPS monitors more than 1,000 sensors throughout the accelerator complex for potential problems. When such problems are detected, the MPS must terminate beam production within 20 microseconds to protect accelerator components. A highly reliable MPS is critical to maintaining the demanding availability requirements for the SNS facility. The existing MPS is functional and operational; however, its reliability and maintainability are declining due to aging hardware and component obsolescence. Consequently, a new MPS system is being developed to replace the current MPS. This system is based on the MicroTCA standard.

Due to the large physical area covered by the sensors, the new MPS employs a distributed architecture interconnected with high-speed serial communication links. The stringent beam control demands require both inter-shelf and inter-blade links to be low-latency and deterministic. Legacy bus architectures accomplished inter-blade communications using dedicated parallel buses across the backplane. Because of limited fabric resources on its backplane, MicroTCA uses the carrier hub (MCH) for this purpose. Unfortunately, MCH products from commercial vendors are limited to standard bus protocols such as PCI Express, Serial RapidIO, and 10/40 Gigabit Ethernet (GbE). While these protocols have exceptional throughput capability, they are neither deterministic nor necessarily low-latency. The development of an MCH with a user-configurable switch fabric overcomes this limitation, offering the system architect/developer complete

Figure 1: Oak Ridge National Laboratory's Spallation Neutron Source uses a linear accelerator and accumulator ring to generate a 1.4MW pulsed proton beam.

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Appendix

Additional MicroTCA Development at SNS

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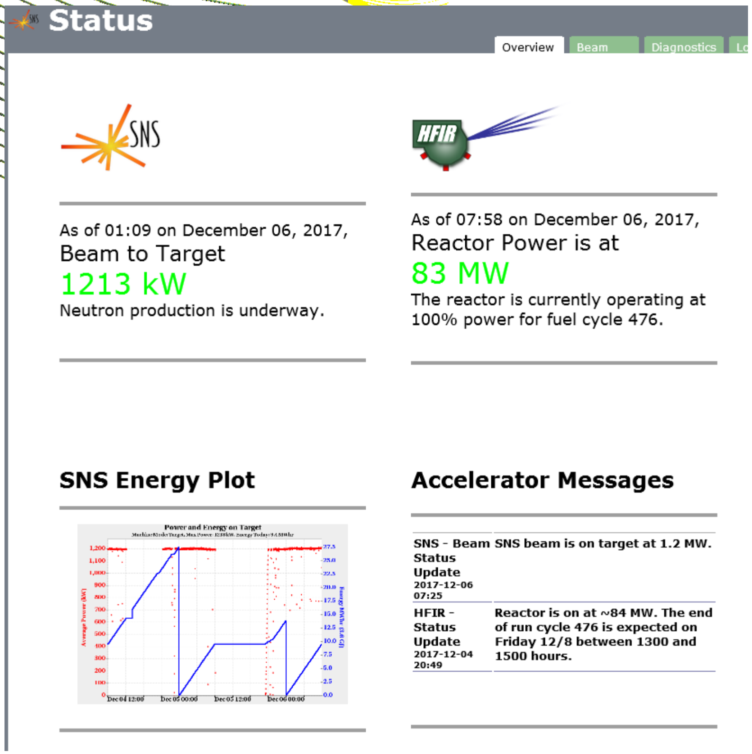
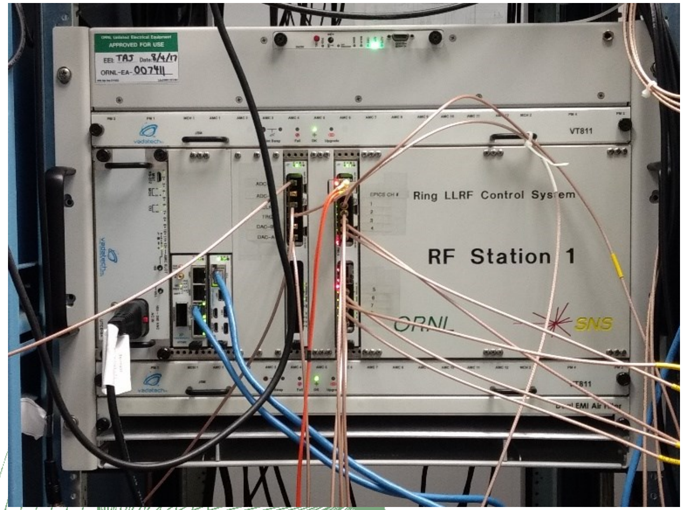
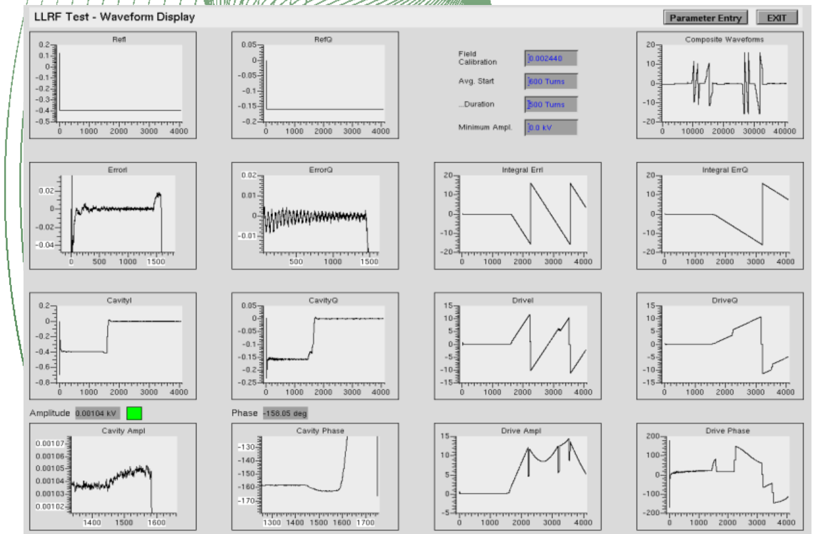
New MicroTCA Ring LLRF System Deployed for Neutron Production (October 2017)







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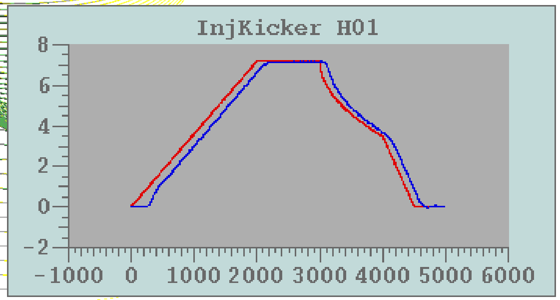
Development of MicroTCA Injection Kicker Waveform Monitor Nearing Completion



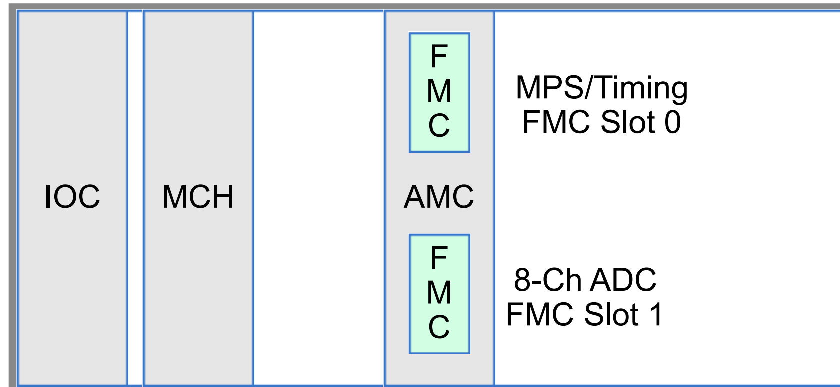
LeCroy Scope GT&FS

LeCroy Scope Diagnostic

LeCroy Scope WFM

LeCroy Scope Diagnostic

LeCroy Scope WFM



Single Card Solution:

- 8-Channel ADC (2.5 MSPS)
- Single Link interface
- 12 user-defined interrupts
- Dual-channel DMA

Thank you for your attention!

Questions?