Electronics for Fast Vertex Position Measurement

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DOE SBIR Phase II
Award DE-SC0001675
Introduction

Company background
Vertex position measurement
Phase II project
Plans and questions
Company background ...

Founded 1994

- Focus on high performance data acquisition electronics
- Other work includes video data processing and wireless sensor networks
- 2 full-time engineers: Lloyd Bridges, William Burton; 1 nuclear physicist: Larry Gadeken

Collaboration since 2001:

- Rice University: Ted Nussbaum, Geary Eppley, Bill Llope, Frank Geurts, Jay Roberts
- University of Texas at Austin: Jo Schambach
Turnkey design, test & production capability:

- System design
- Circuit design, printed circuit design
- Microprocessor firmware, FPGA firmware, networking
- System integration
- Fully equipped electronics laboratory
- Experience, vendor relationships, infrastructure and production management systems (inventory, ordering, BOM, change order, automated test, etc.) for medium scale manufacturing and test.
STAR TOF electronics: A Successful Phase I/II/III project

- Barrel Time-of-Flight Detector in the STAR experiment at RHIC/BNL
- **Enables event-by-event particle identification**
- Time-to-digital converters: 23,000 channels; 20 ps timing resolution
- ~2100 circuit cards
- Global clock distribution, large scale data transfer, CAN bus instrument control
- In-situ firmware updates to embedded microcontroller and fpga devices
- More than 1B events recorded since full installation in RHIC run 10
- Exceeded goal of 100 ps total resolution in central Au-Au collisions
Company background ...

New application: Muon TOF Detector

- New STAR subsystem
- MRPC TOF detector behind solenoid steel
- Approximately 3000 TOF channels
- Off-the-shelf reuse of SBIR data acquisition technology (TDIG and TCPU boards)
- No new R&D funds
Motivation:

• The *vertex position* is the collision point in a particle interaction.
• A vertex position trigger selects centrally located events.
• More precise vertex triggers improve data quality.
• Small detectors such as the Heavy Flavor Tracker require a vertex trigger accurate enough to capture events occurring in their volume.

• Current STAR vertex position accuracy is 5 cm (full energy Au-Au) and worse for lower energies and for p-p.
• Our design objective is 1 cm vertex position accuracy.
• Currently, significant amounts of data are rejected *after* capture, storage and analysis. If the distribution tails are cut away at the trigger, the entire experiment run becomes much more efficient.
Vertex position distribution in STAR
Vertex Position Measurement ...

Requirements:

• 1 cm position accuracy
• Real-time offset and slewing correction (calibration tables)
• Continuous data rate of 10 Mhz (STAR trigger rate)
• 500 ns latency
• Interface to STAR trigger
Vertex Position Measurement ...

Time-of-Flight vertex position measurement

Position $\approx \frac{c}{2} (t_1 - t_2)$
Architecture

- Modular
- Developing both TDC and interpolated ADC approaches to reduce risk
- Real time data capture and processing in FPGA
  - Time interval measurement relative to experiment clock
  - Time slewing and baseline corrections (table driven)
- Signal averaging across channels
- Flexible output: GigE, PCIe x 4, custom daughtercard
Phase II Project ...

2\textsuperscript{nd} Generation prototypes: modular architecture
Gen 2 ADC (3 Gsps, 8 bits) with FPGA card
ADC: 3.3” x 4.3”   FPGA: 5.4” x 4.3”
Phase II Project ...

Preliminary data with ADC2/FPGA2:
2.8 Gsps (357 ps), 8 bits  source is 15 Mhz sine from HP function generator
Phase II Project ...

Preliminary data with ADC2/FPGA2:
2.8 Gsps (357 ps), 8 bits

DG535 negative pulse (0 to –400 mV)
Nominal width = 3 ns

DG535 negative pulse (0 to –400 mV)
Nominal width = 5 ns
Phase II Project ...

2x Gen 2 TDCs with FPGA board
Phase II Project ...

Low jitter discriminator

10 GHz clock synthesizer w/ dividers
Phase II Project ... first prototypes

Gen 1 ADC (1.5 Gsps, 8 bits)
4.5” x 2.3”

Gen 1 TDC (50 ps design)
Cosmic test setup
Plans and questions

Applications for this technology:

• STAR trigger
• time-of-flight mass spectrometers
• scintillation-based neutron detectors
• time-of-flight positron emission tomographic imaging systems
• time-resolved confocal microscopy
• LIDAR - three dimensional imaging
• LIDAR - precision machining equipment
• Transit-time ultrasonic flow meters
• remote environmental sensing (flourescence spectroscopy)
Plans and questions ...

Deliverables:

- Project report
- 20 timing channels for Vertex position measurement, compatible with existing vertex position detector and STAR trigger
- Firmware modifications for other STAR triggers

Milestones:

- Complete hardware performance test (Jan 2012)
- Adapt to QT form factor (May 2012)
- System test (August 2012)
- Production delivery (October 2012)
Plans and questions ...

Thanks to DOE Nuclear Physics

Where else can NP use high performance timing and pulse processing electronics?

Other questions?