Electronics for Fast Vertex Position Measurement

Blue Sky Electronics, LLC

Lloyd Bridges, President (PI)

Houston, Texas

713 880 1108

lloyd@blueskyelectronics.com

DOE SBIR Phase II

Award DE-SC0001675

Blue Sky Electronics

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

Company background …

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.

Company background …

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**

  e.g. "Observation of the antimatter helium-4 nucleus," STAR Collaboration, H. Agakishiev et al., Nature 473, 353 (2011).
- 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

Blue Sky Electronics

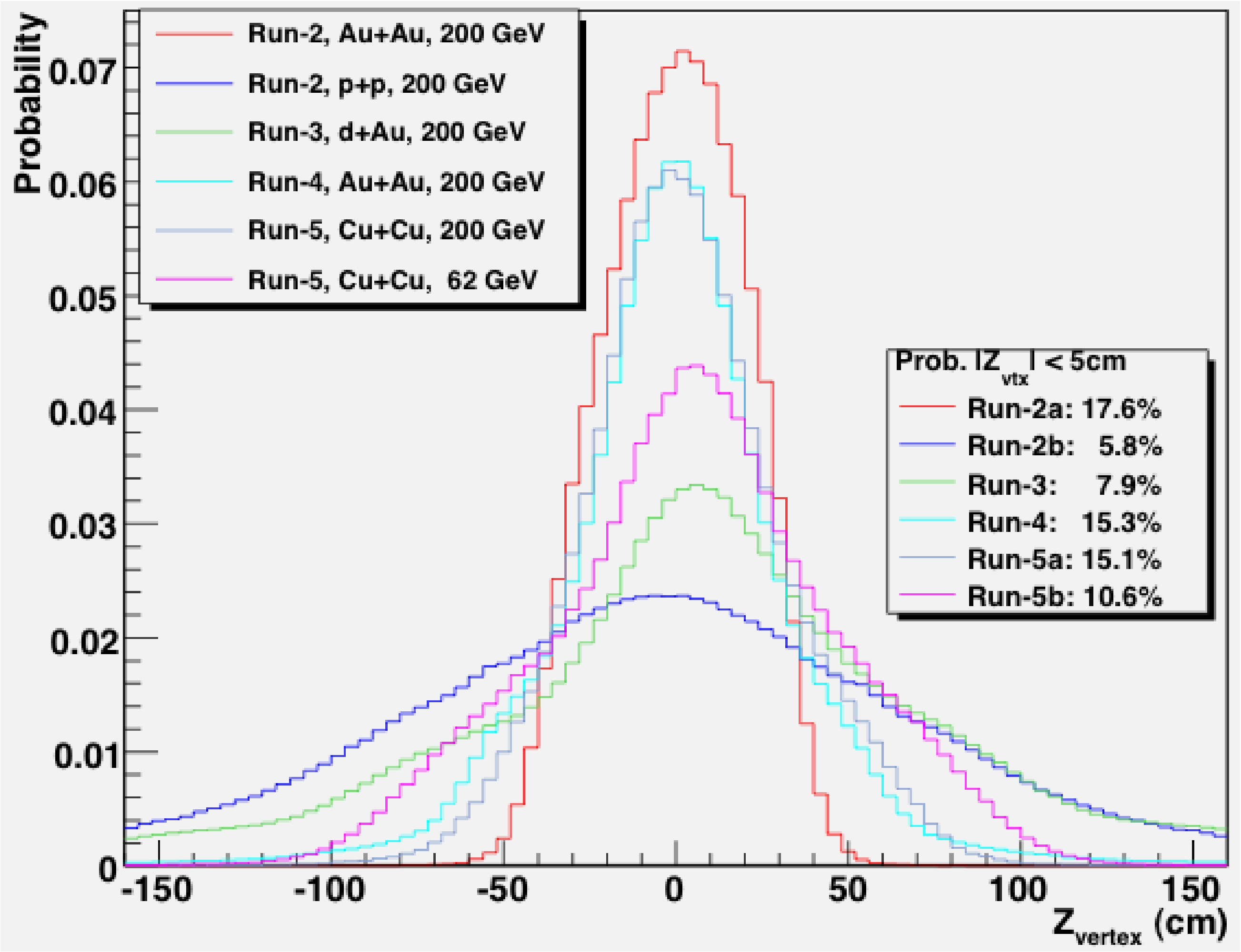
Vertex Position Measurement

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 Measurement



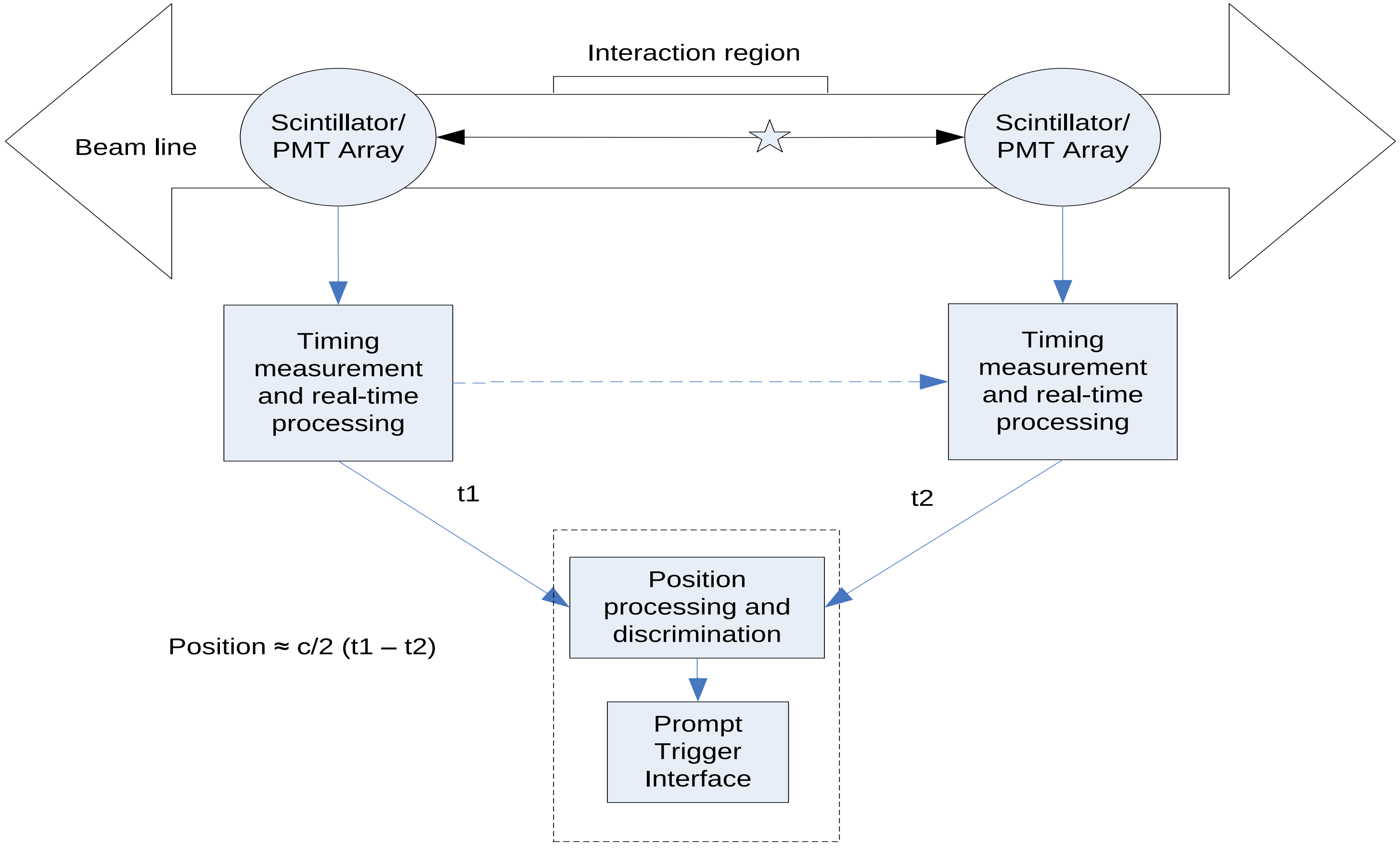
Vertex position distribution in STAR

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 …



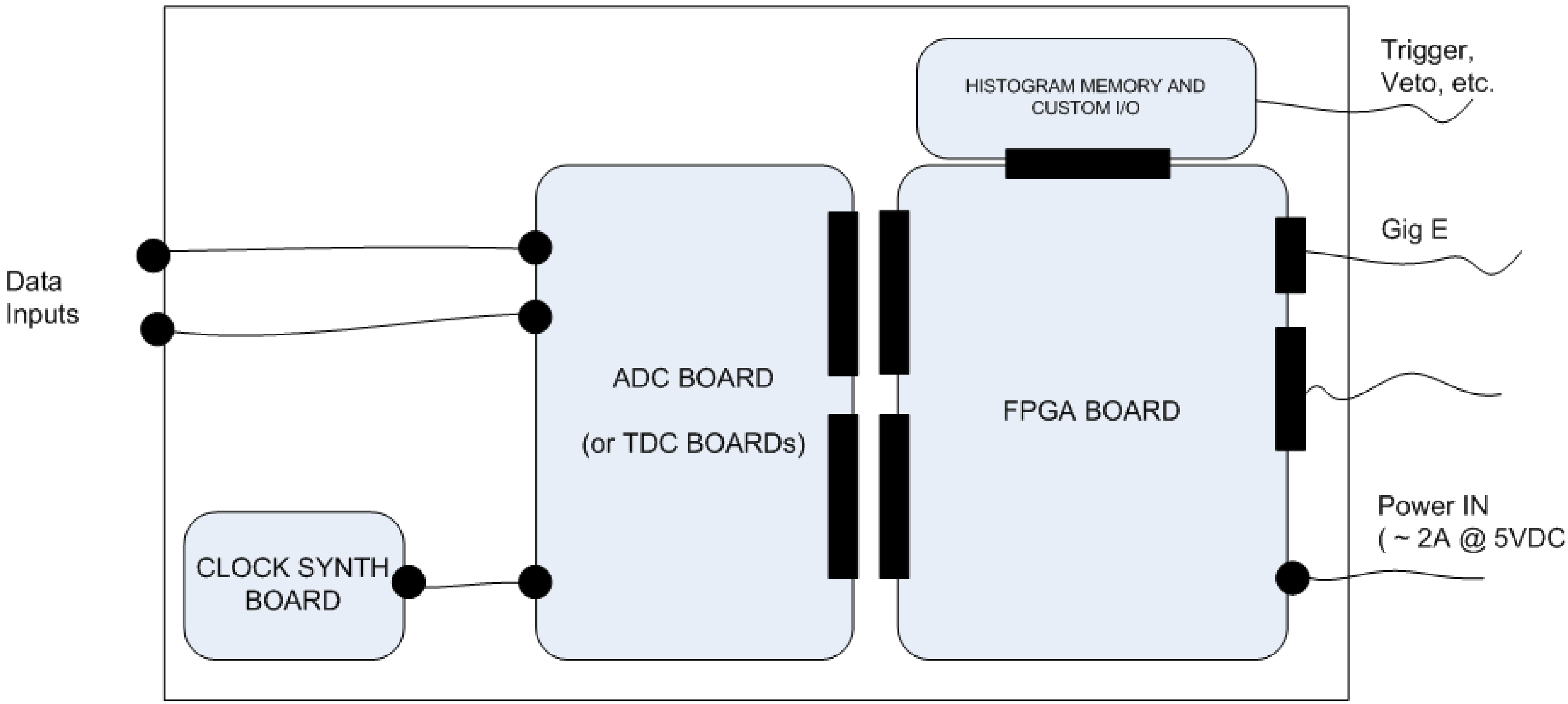
Time-of-Flight vertex position measurement

Phase II Project …

Architecture

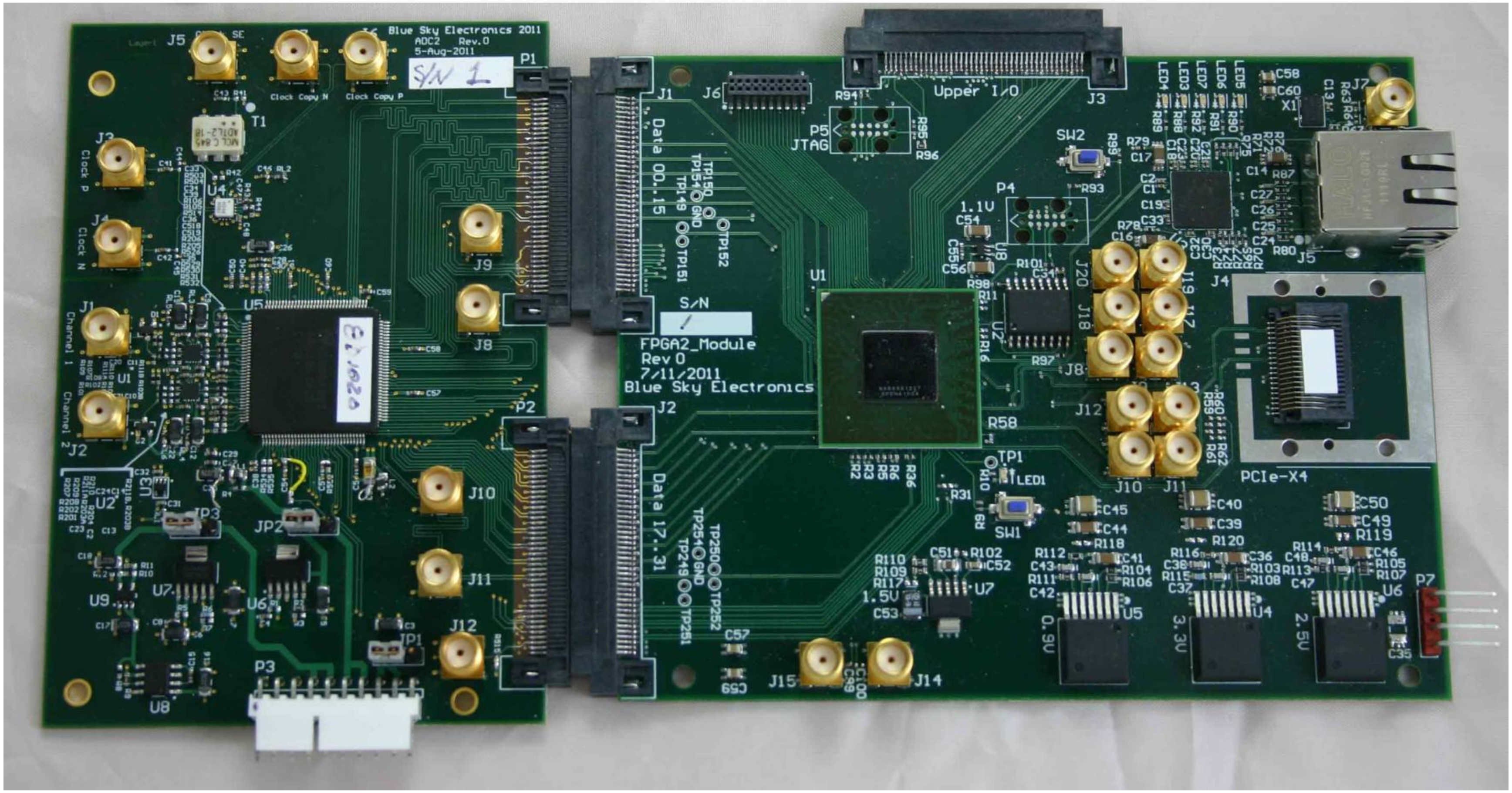
- Modular
- Developing both TDC and interpolated ADC approaches to reduce risk
- Real time data capture and processing in FPGA
  - Time interval measurement relative to experiment clock
  - Time slewing and baseline corrections (table driven)
  - Signal averaging across channels
- Flexible output: GigE,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

Phase II Project …



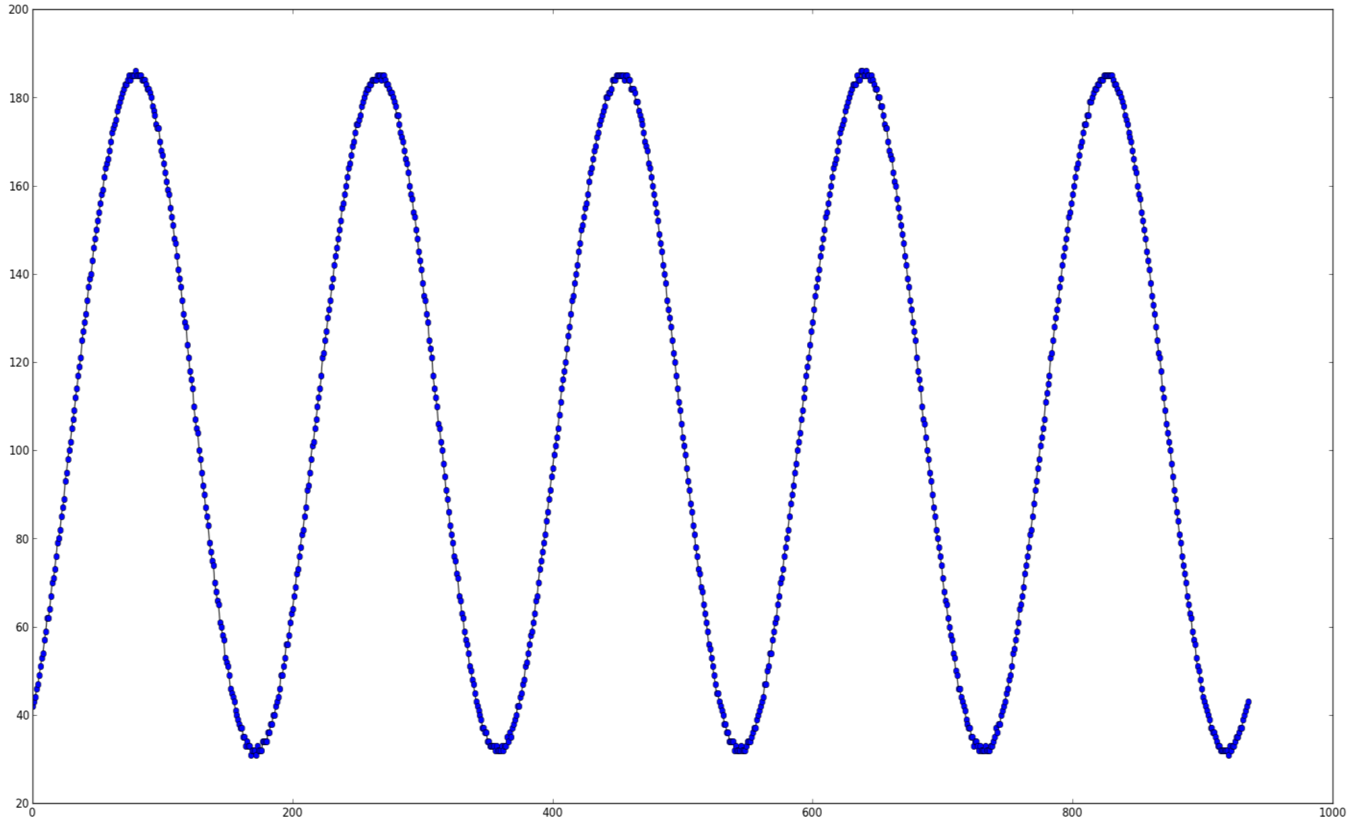
2nd Generation prototypes: modular architecture

Phase II Project …



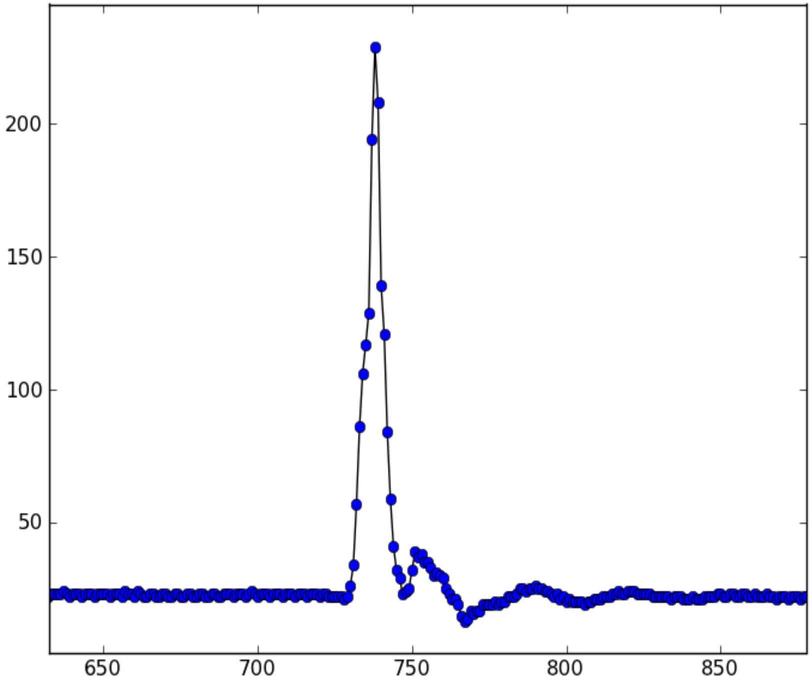
Gen 2 ADC (3 Gsps, 8 bits) with FPGA card
ADC: 3.3" x 4.3"   FPGA: 5.4" x 4.3"

Phase II Project …

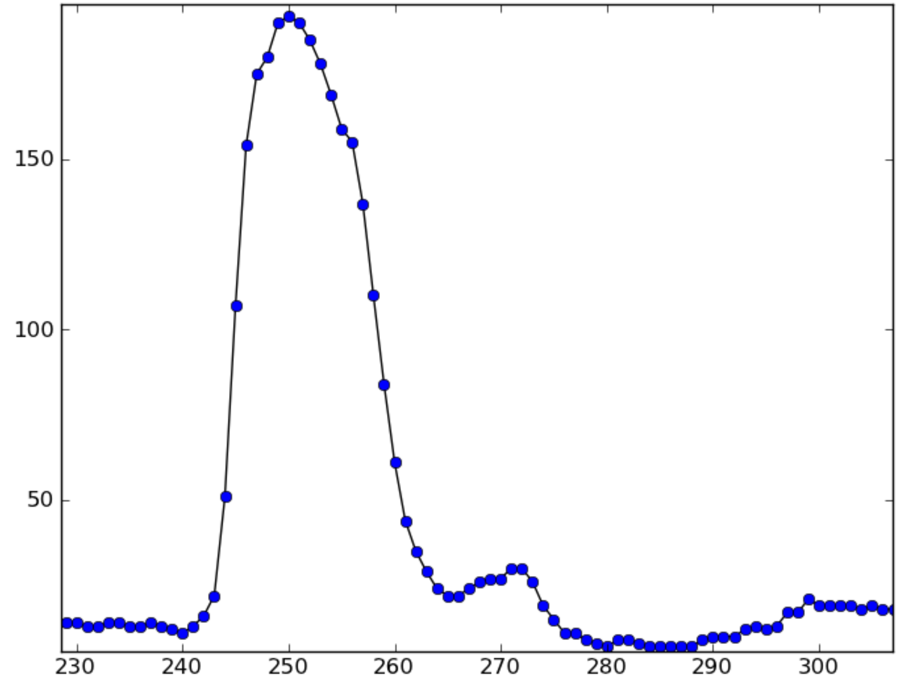


Preliminary data with ADC2/FPGA2:
2.8 Gsps (357 ps), 8 bits   source is 15 Mhz sine from HP function generator

Phase II Project …



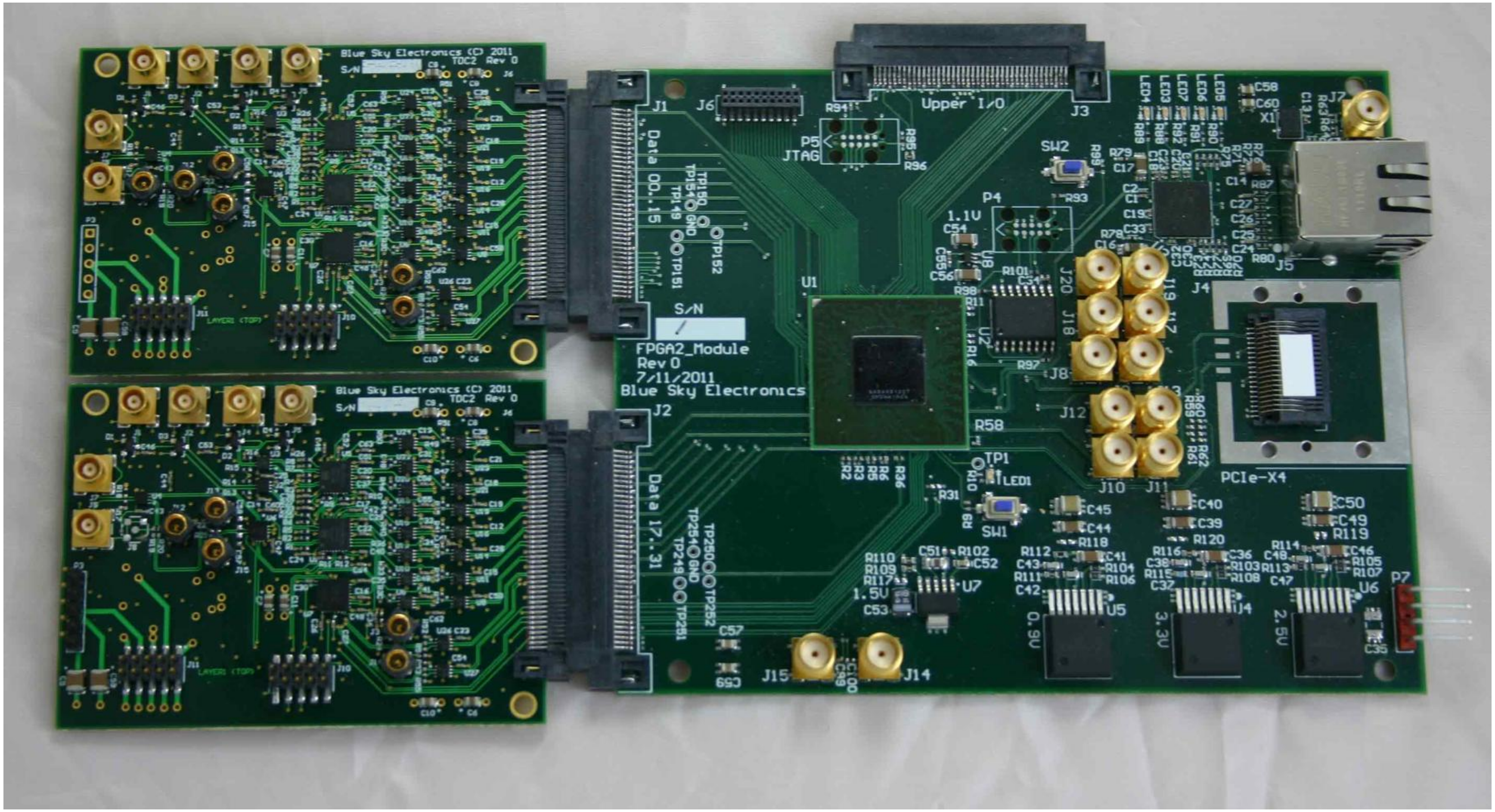
DG535 negative pulse (0 to – 400 mV)
Nominal width = 3 ns



DG535 negative pulse (0 to – 400 mV)
Nominal width = 5 ns

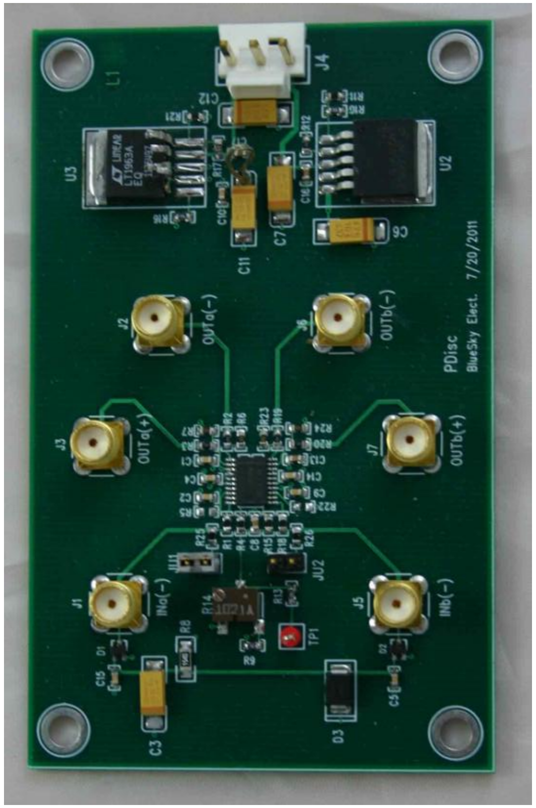
Preliminary data with ADC2/FPGA2:
2.8 Gsps (357 ps), 8 bits

Phase II Project …

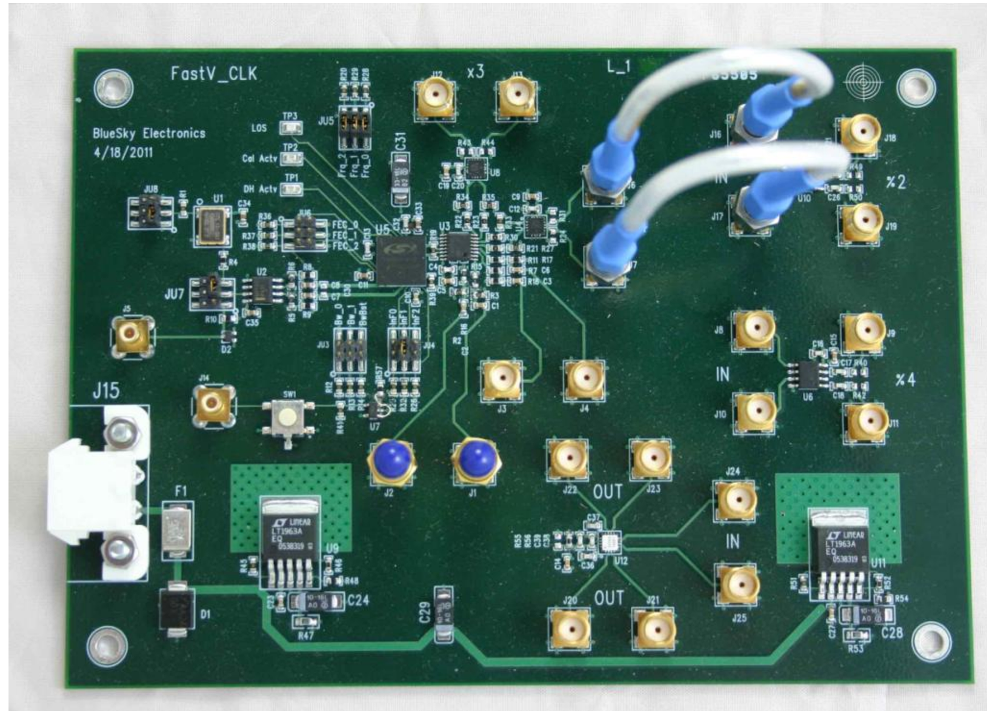


2x Gen 2 TDCs with FPGA board

Phase II Project …

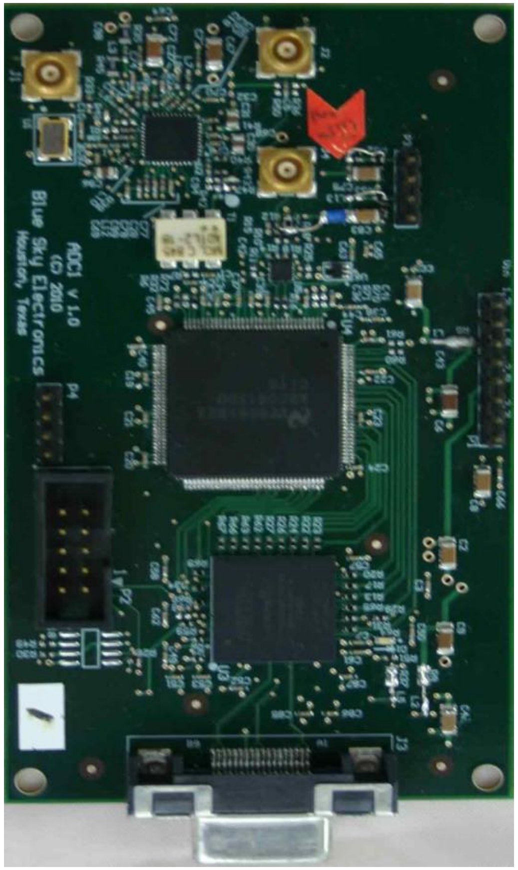


Low jitter discriminator

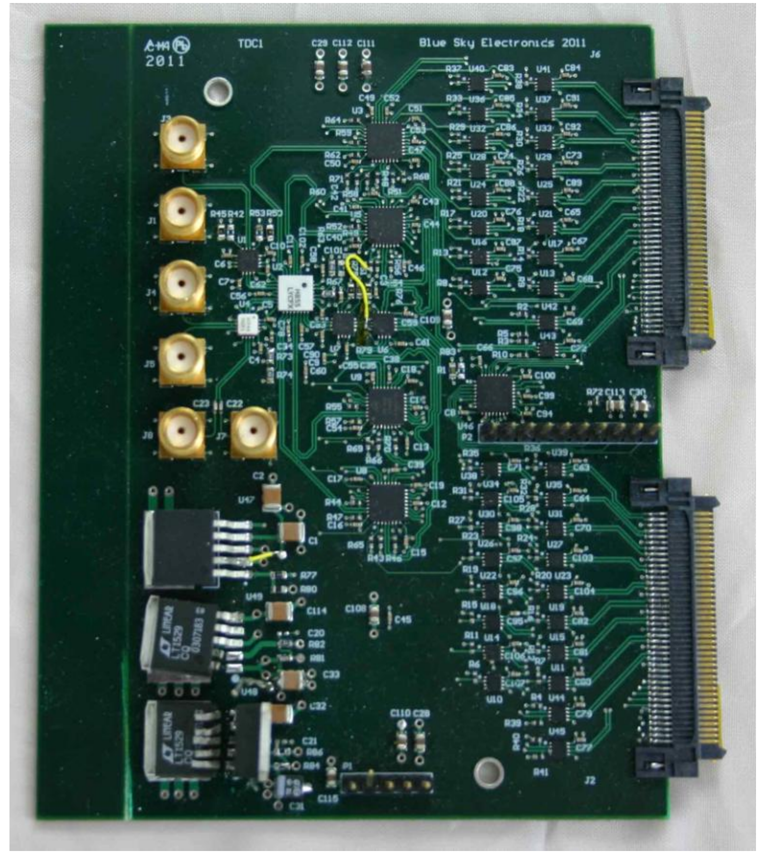


10 GHz clock synthesizer w/ dividers

Phase II Project … first prototypes

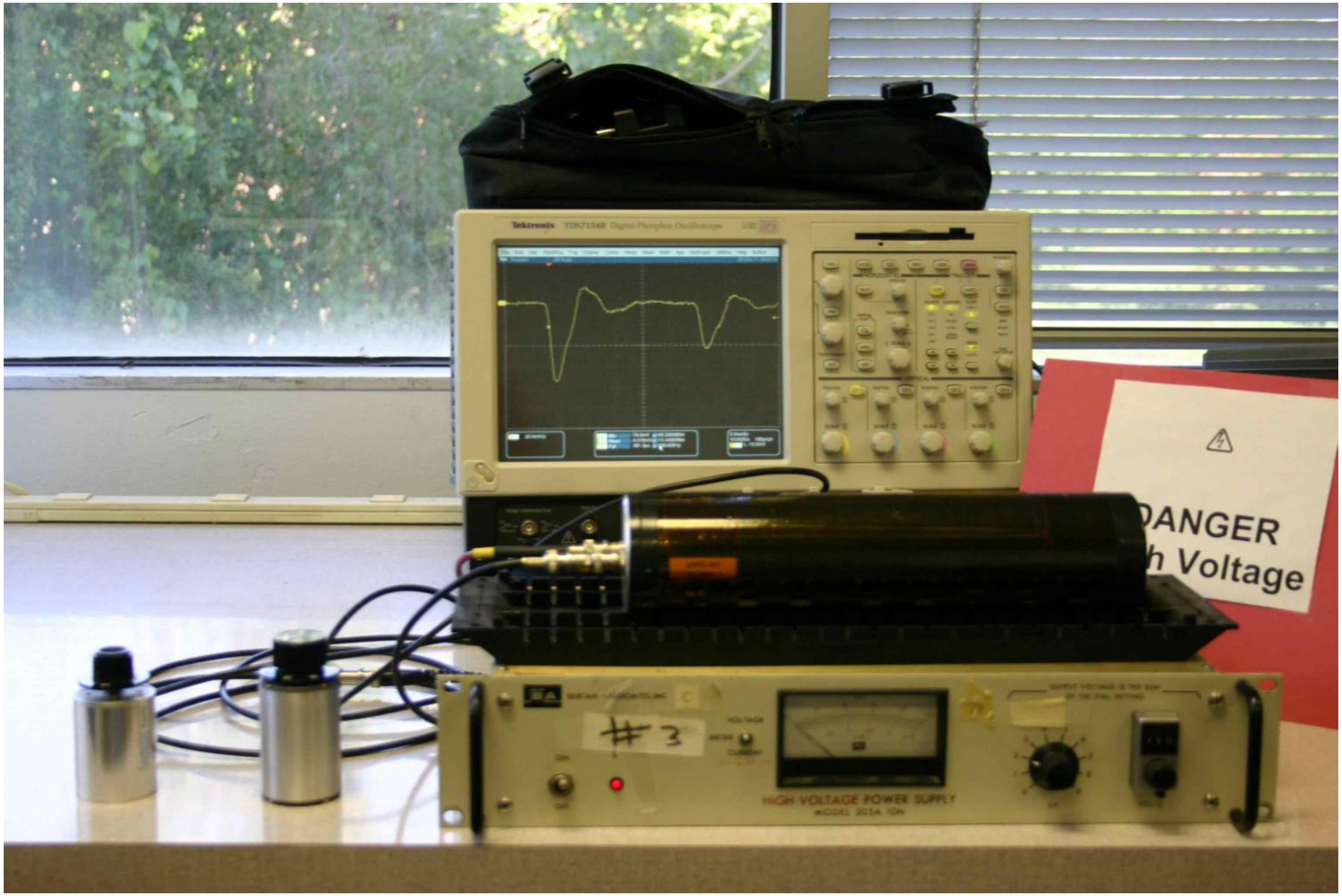


Gen 1 ADC (1.5 Gsps, 8 bits)
4.5” x 2.3”



Gen 1 TDC (50 ps design)

Phase II Project …



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?