# HCAL R&D

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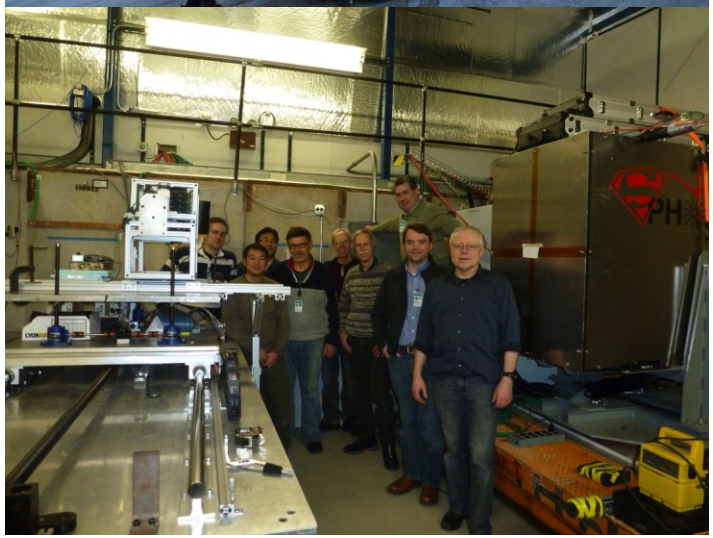
# Initial sPHENIX prototyping goals

- Proof of principle in beam of
  - Tilted plate hadronic calorimeter
  - SPACAL or optical accordion electromagnetic calorimeter
  - SiPM readout
  - Waveform digitizers
  - Light output and collection

# Fermilab T-1044

- HCAL a major component of beam test February 5-25, 2014
- Two segment tilted plate, 4x4
- EMCAL
- 8 WLS fibers optically coupled to one SiPM
- Preamp/shaper capable of temperature compensation
- 60 MHz waveform digitizer 12 bit bipolar



# Lessons of v0 prototype

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- The tilted plates are pretty straightforward to stack
- We can get enough light from the tile and WLS fiber
- The on-detector electronics is quite robust
- Waveform digitizing with 10 m cables worked really well
- LED pulser system very good for health checks
- **Validated Monte Carlo simulation**

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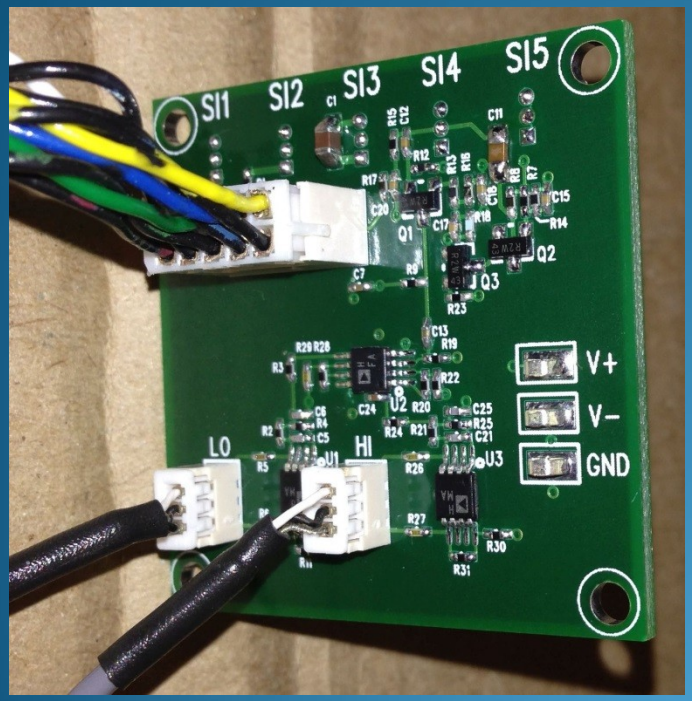
- Handling lots of delicate fibers is not so easy
- Be more careful with channeliing; tilt angle needs to be carefully chosen (4-cross, 5-cross)
- Calibration
- Should have exercised temperature compensation
- Should have had second round after 1-2 months of digesting data

# Applying the lessons

- Based on experience from T-1044, we switched gears and pressed forward on the design (mechanics, light collection, electronics) and simulation to back it up which has resulted in the design that we are trying to optimize now.
- Beam test results will be discussed by Liang
- Development has continued with efforts in
  - Improved preamps and cabling
  - Design of a second (final?) generation digitizer with trigger capability
  - Light collection and sensors

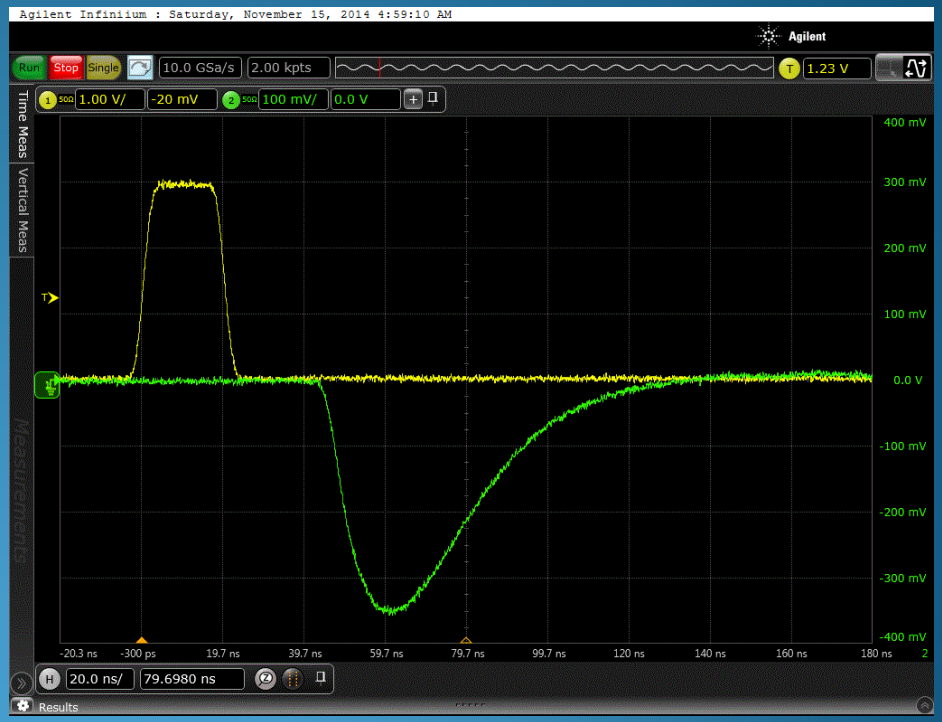
# First Look at New Hcal Preamp

Dual-gain Common-Base Amp



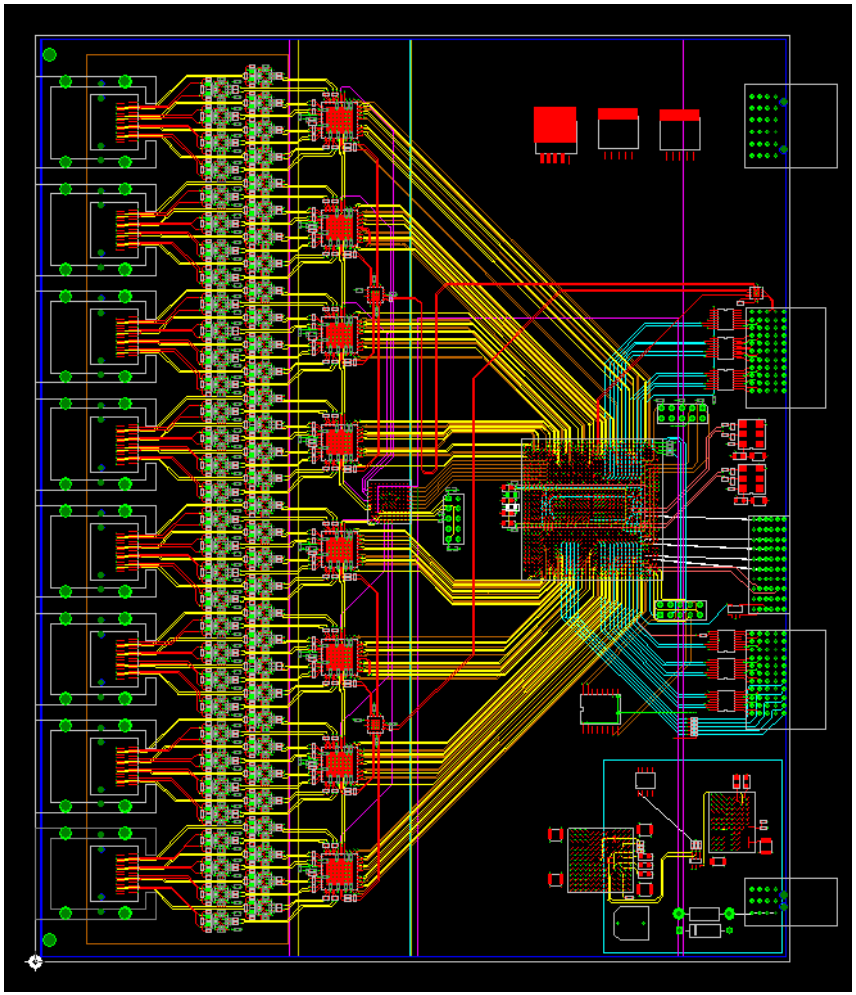

Onboard charge injector 4pf X 8V = 32pC

(Low gain channel shown)



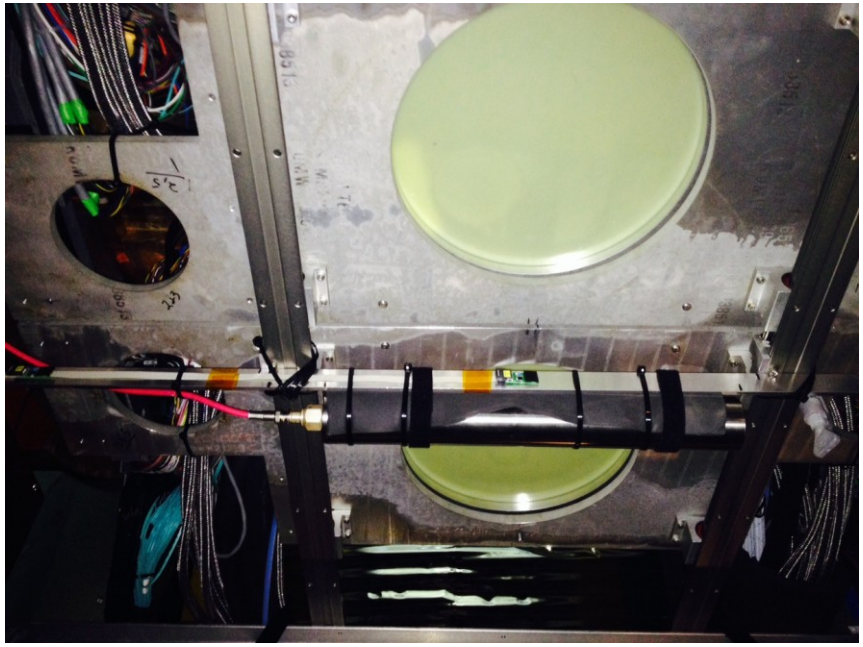
# Digitizer

- Next digitizer is being developed at Nevis by Cheng-Yi Chi and Bill Sippach
- 64 channel 60 MHz 14 bit COTS ADC system
- Layout far along, prototypes ~summer
- Cable choice under study



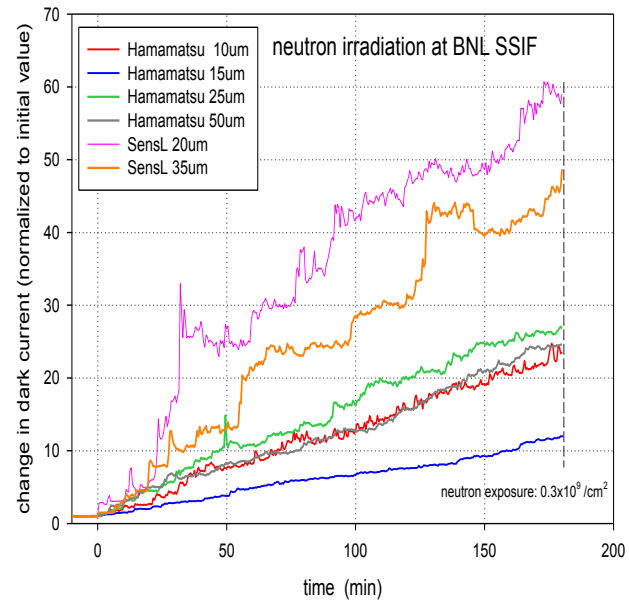
# Radiation damage study

- SiPM's are vulnerable to radiation damage from MeV neutrons
- Test in PHENIX IR in Run 14
- Sean Stoll and Craig Woody have tested a variety of devices with neutrons



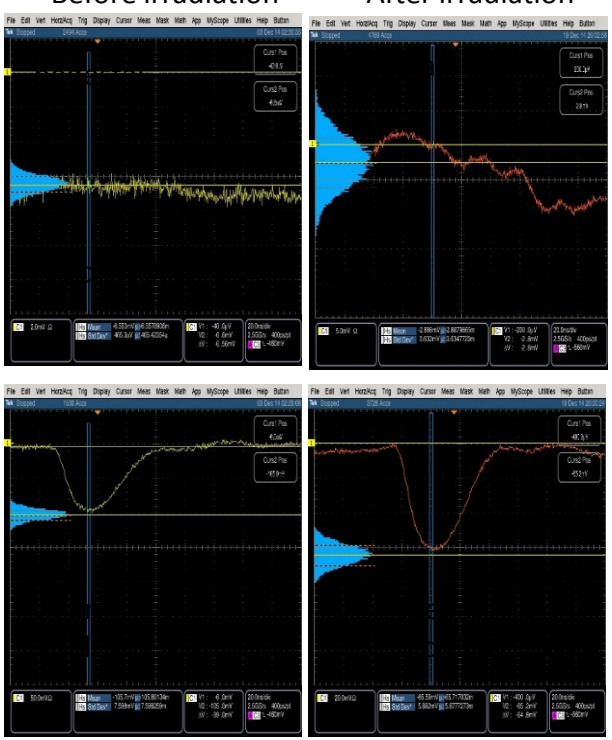
# SiPM Radiation Damage Studies

- All devices measured showed an increase in dark current with increasing neutron exposure
- Devices also showed a decrease in dynamic range
- Radiation damage increased dark/pedestal noise, but signals were still readable even after $7 \times 10^{10}$ neutrons/cm$^2$

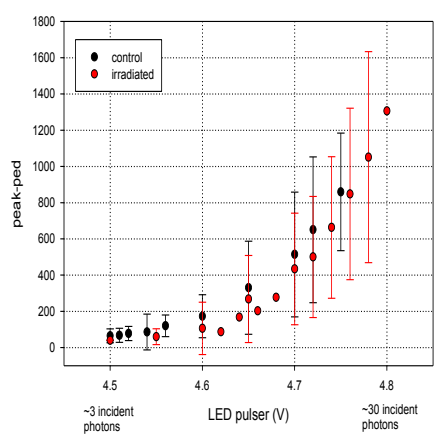


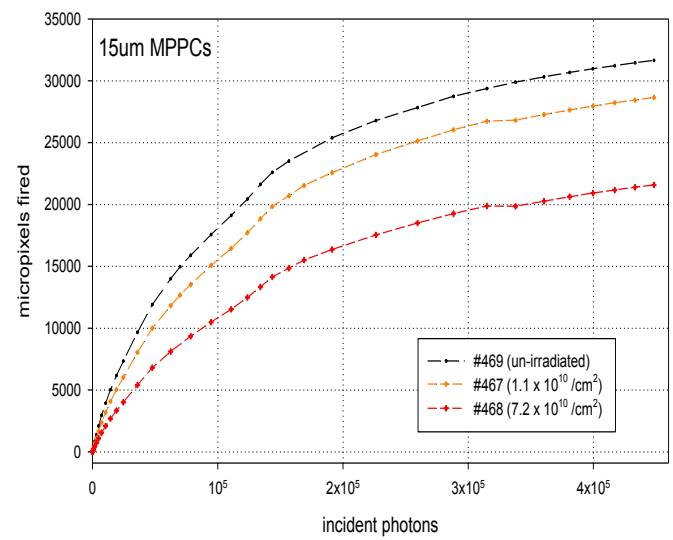

Before irradiation

After irradiation



Hamamatsu S12572-025P
Signal integrity at low light levels, irradiated and control device.
(0.3 x10$^9$ neutrons/cm$^2$)




Sean Stoll

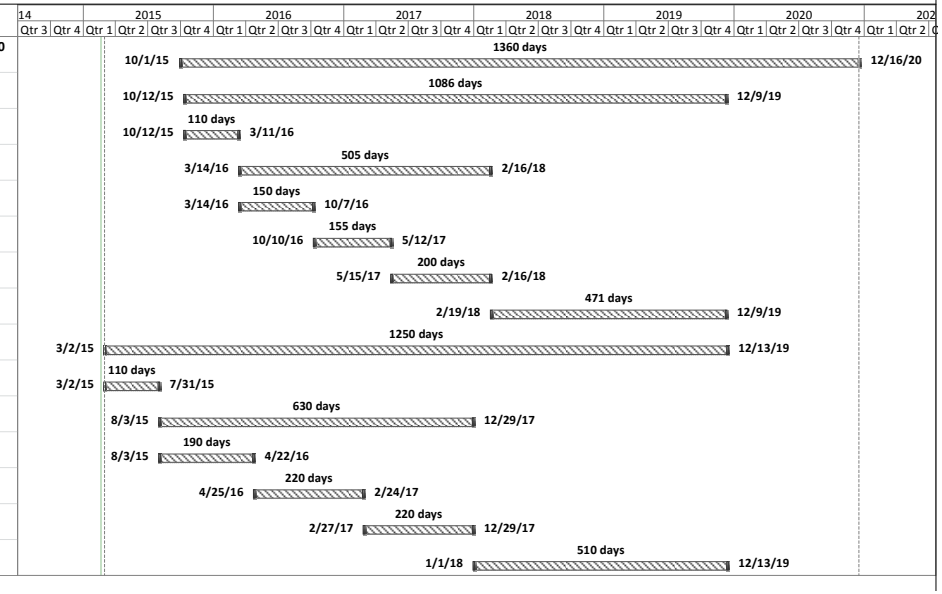
# Prototypes in the project plan

- We have three rounds of prototypes in the project plan
  - **V1** mid-rapidity detector that could be beam-tested
  - **V2** “high” rapidity detector that could be beam tested
  - **Pre-production module** full size, demonstrates mechanical assembly and handling; partially populated with scintillator tiles

# Plans for prototyping

sPHENIX PROJECT SCHEDULE — Preliminary

| ID | Task Mode | WBS | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|---|
| 1 | | 1.6.1 | HCAL management | 1360 days | Thu 10/1/15 | Wed 12/16/20 |
| 4 | | 1.6.2 | Inner HCAL | 1086 days | Mon 10/12/15 | Mon 12/9/19 |
| 5 | | 1.6.2.1 | Inner HCAL design | 110 days | Mon 10/12/15 | Fri 3/11/16 |
| 19 | | 1.6.2.2 | Inner HCAL prototype | 505 days | Mon 3/14/16 | Fri 2/16/18 |
| 20 | | 1.6.2.2.1 | Inner HCAL prototype v1 | 150 days | Mon 3/14/16 | Fri 10/7/16 |
| 29 | | 1.6.2.2.2 | Inner HCAL prototype v2 | 155 days | Mon 10/10/16 | Fri 5/12/17 |
| 38 | | 1.6.2.2.3 | Inner HCAL preproduction prototype | 200 days | Mon 5/15/17 | Fri 2/16/18 |
| 48 | | 1.6.2.3 | Inner HCAL production | 471 days | Mon 2/19/18 | Mon 12/9/19 |
| 71 | | 1.6.3 | Outer HCAL | 1250 days | Mon 3/2/15 | Fri 12/13/19 |
| 72 | | 1.6.3.1 | Outer HCAL Conceptual design | 110 days | Mon 3/2/15 | Fri 7/31/15 |
| 86 | | 1.6.3.2 | Outer HCAL prototype | 630 days | Mon 8/3/15 | Fri 12/29/17 |
| 87 | | 1.6.3.2.1 | Outer HCAL prototype v1 | 190 days | Mon 8/3/15 | Fri 4/22/16 |
| 96 | | 1.6.3.2.2 | Outer HCAL prototype v2 | 220 days | Mon 4/25/16 | Fri 2/24/17 |
| 105 | | 1.6.3.2.3 | Outer HCAL preproduction prototype | 220 days | Mon 2/27/17 | Fri 12/29/17 |
| 115 | | 1.6.3.3 | Outer HCAL production | 510 days | Mon 1/1/18 | Fri 12/13/19 |



# Program Development funding

- Program Development funding for “Novel Hadronic Calorimeter with Tilted Plate Absorbers for the sPHENIX Detector” was approved on Friday for FY15-16 development which we will advance our plans

| | |
|---|---|
| Design components of full scale HCAL prototype module | January-July 2015 |
| Bench test and prototype HCAL components | January-July 2015 |
| Fabrication of full scale HCAL prototype module | August 2015-January 2016 |
| Testing of HCAL prototype (bench and beam tests) | February 2016-December 2016 |

# Prototype beam testing

- Another round of beam tests with nearly final mechanics and readout is necessary
- Requires EMCAL as well as Inner and Outer HCAL prototypes
- A beam test ~April 2016 at FTBF is our target
- Design of that prototype aims to be as close to the mechanics of the sPHENIX as possible
  - Mechanical design ~summer 2015

# Summary

- We have already had a very active and productive R&D program in calorimeter, sensor, and electronics development
- Successful beam test, many lessons learned
- Program Development funding will continue the rapid forward progress