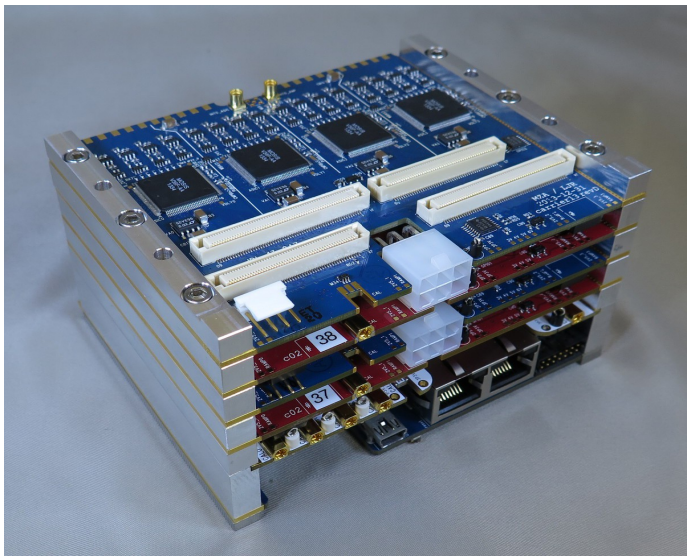
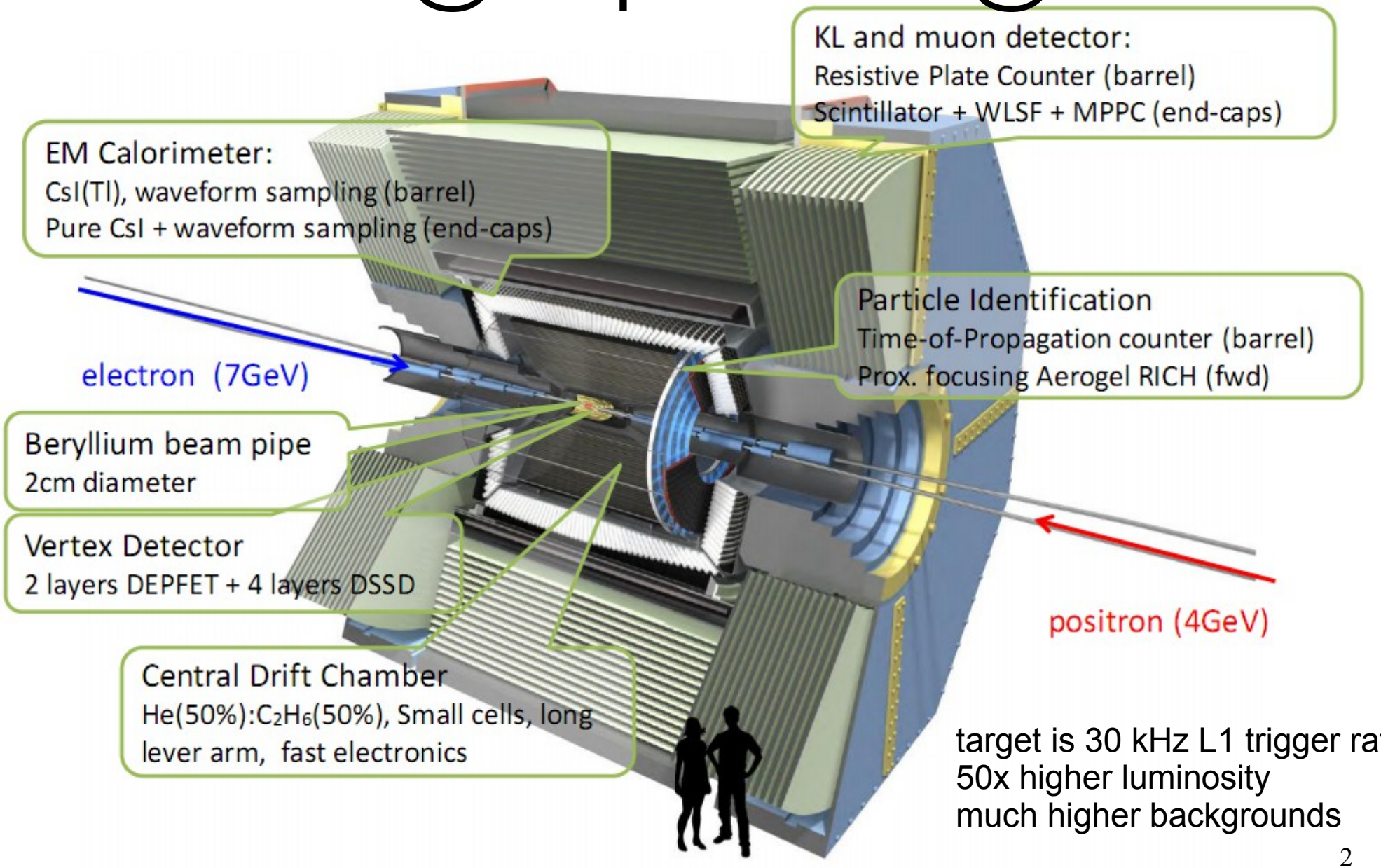
128 channel waveform sampling digitizer/readout in the TOP counter for the Belle II upgrade

University of Hawai`i
SLAC
Indiana University
Nagoya University
PNNL
University of South Carolina
University of Pittsburgh
KEK

on behalf of:
the Belle II bPID/TOP group

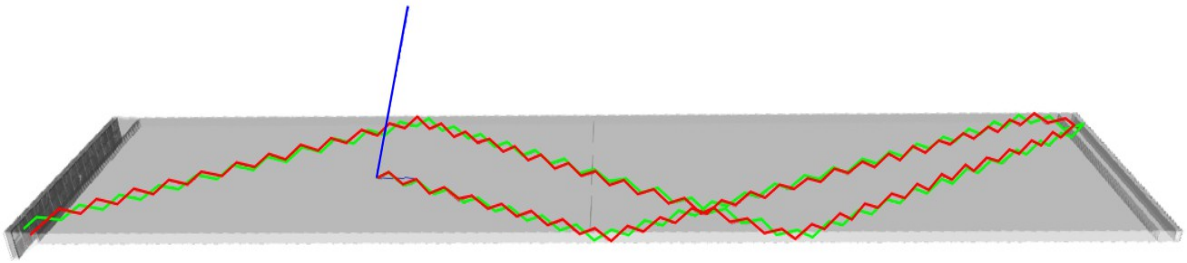


Belle II @ SuperKEKb @ KEK

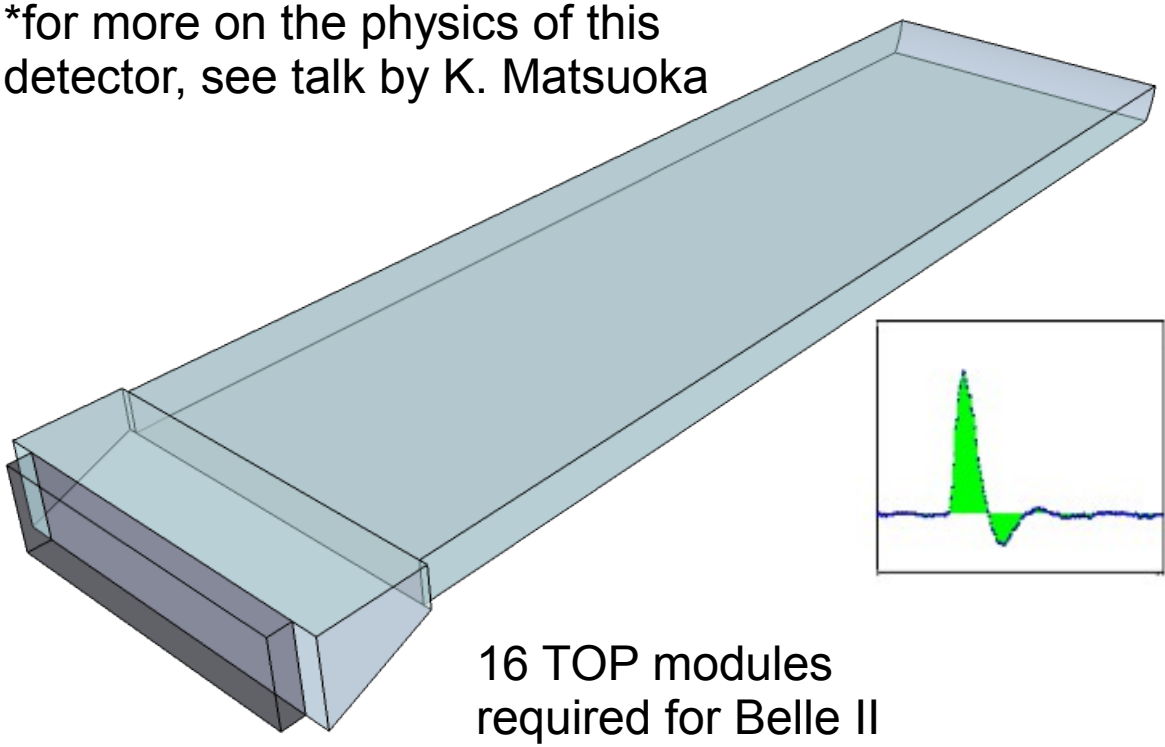


target is 30 kHz L1 trigger rate
50x higher luminosity
much higher backgrounds

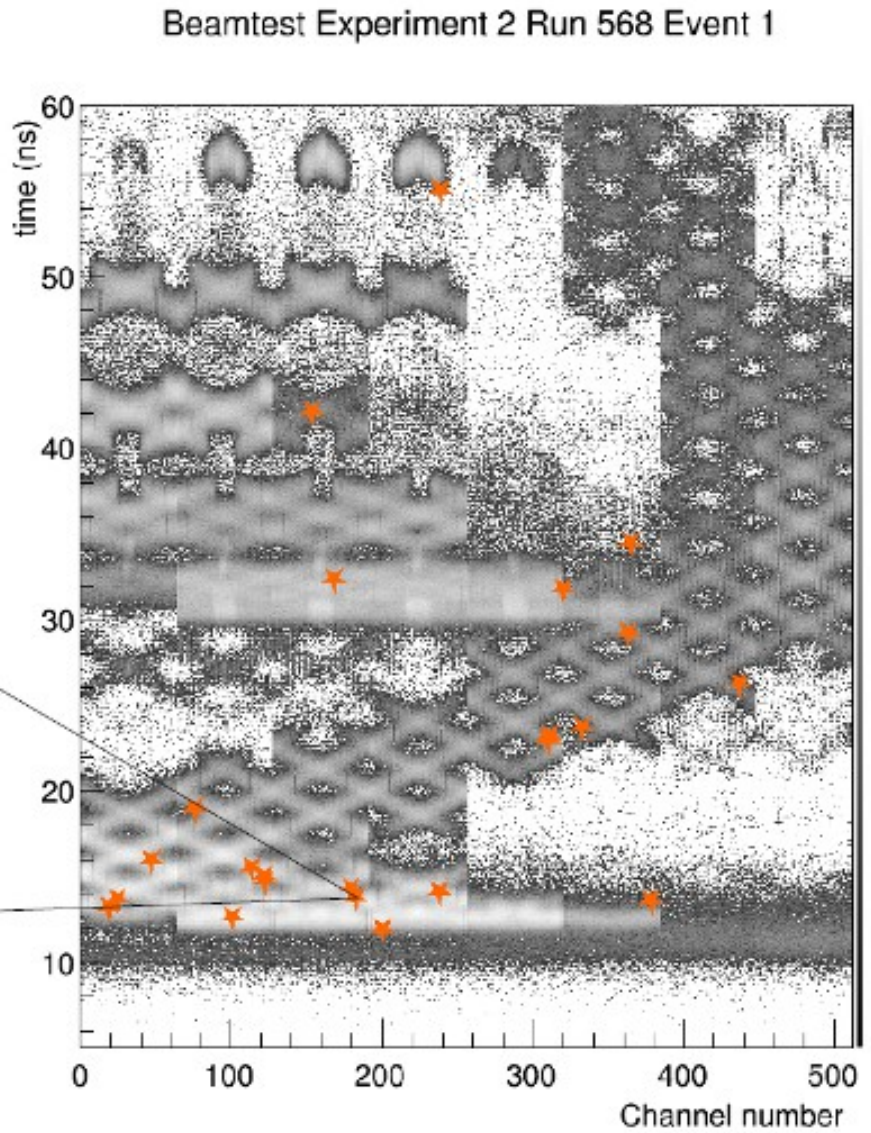
Time-Of-Propagation (TOP) counter: Cherenkov PID based on PDFs



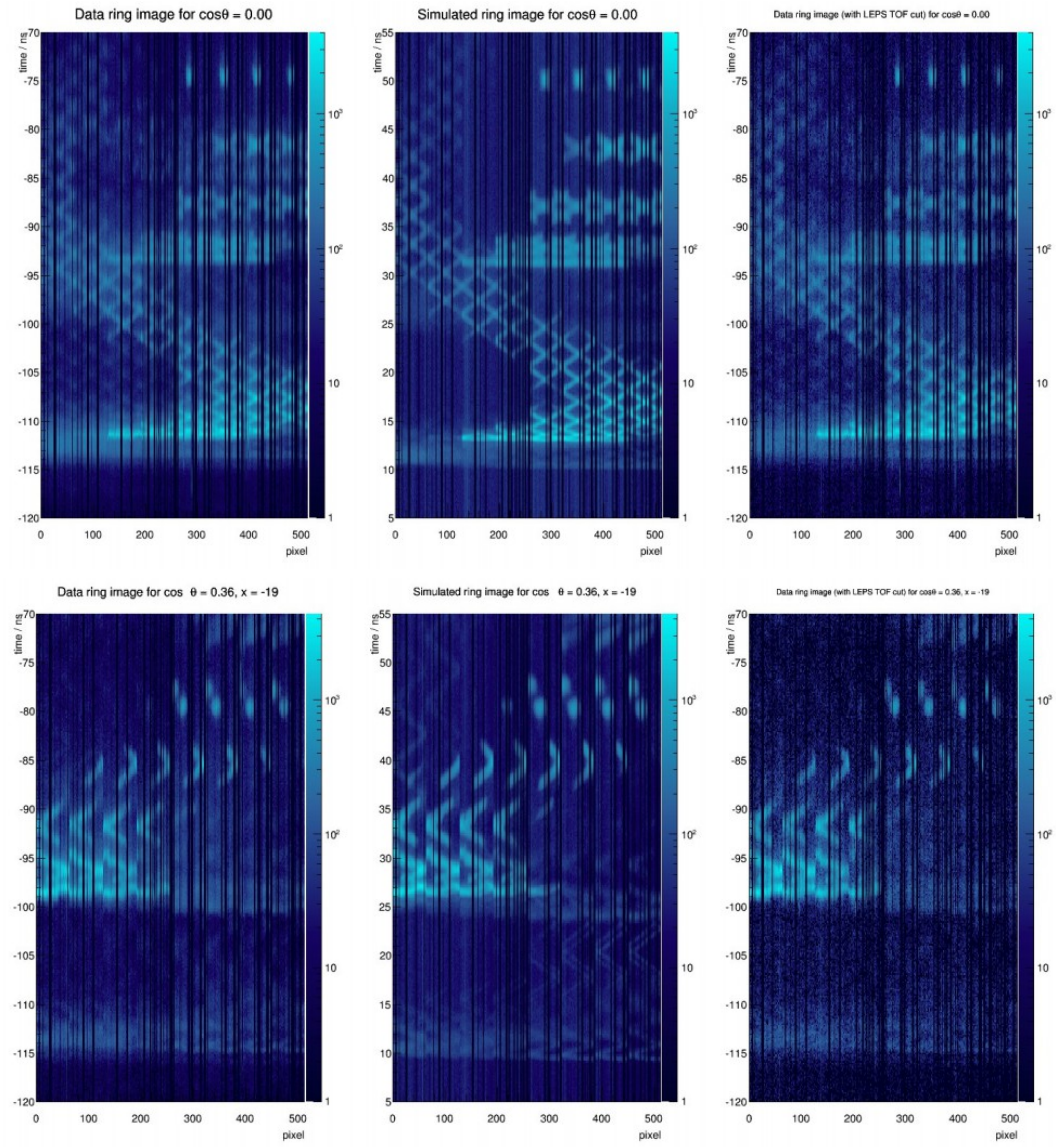
*for more on the physics of this detector, see talk by K. Matsuoka



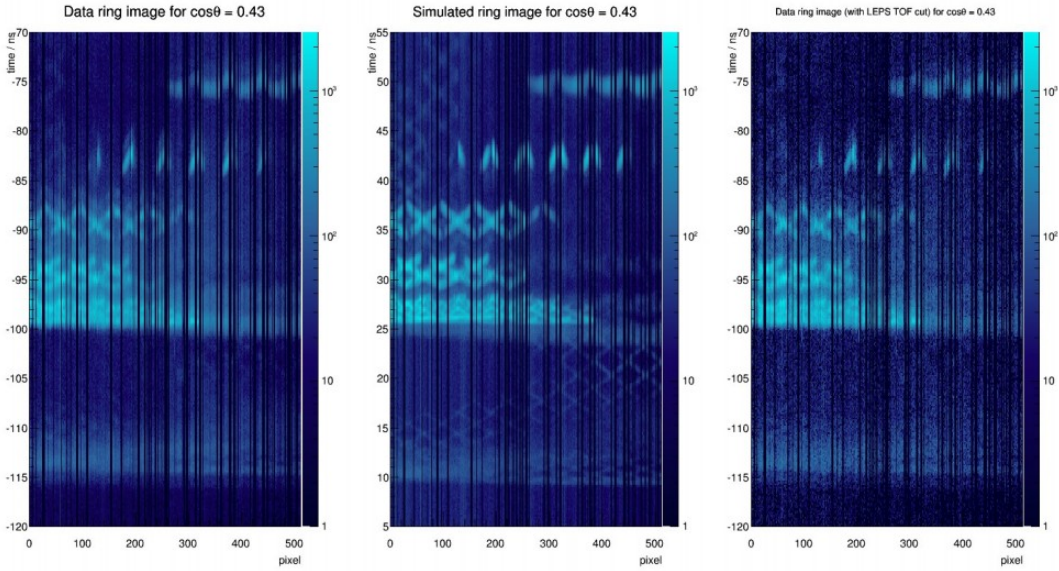
16 TOP modules required for Belle II



folded ring images from SPring-8 / LEPS



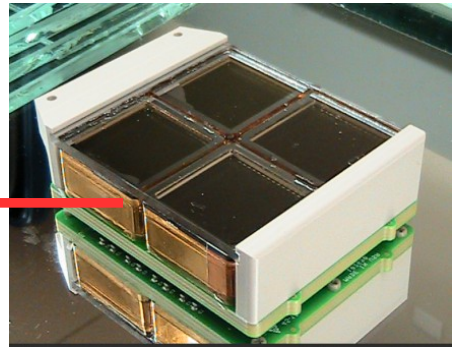
data from previous prototype:
IRS3B ASIC
low gain from single-stage discrete amplifier
timing resolution ~95 ps
80% efficient



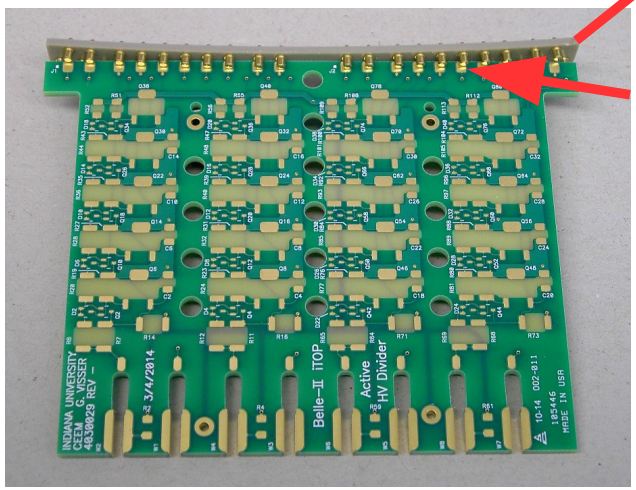
vertical bands are due to
dead channels (90/512)

current prototype front-end electronics

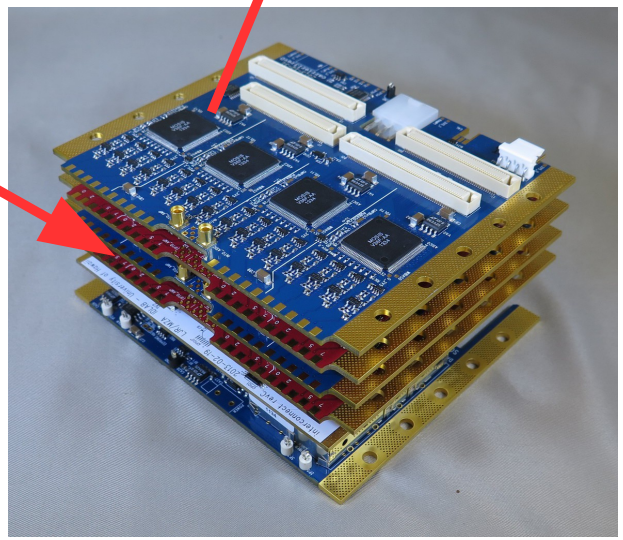
- IRS3C ASIC
- higher gain from single-stage discrete amplifiers
- nearly same form-factor as production boardstack
  - includes pogo pin PMT interface

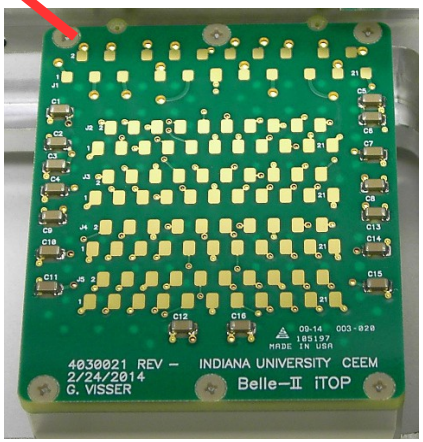


*for more on MCP-PMTs, see talk by T. Yonekura



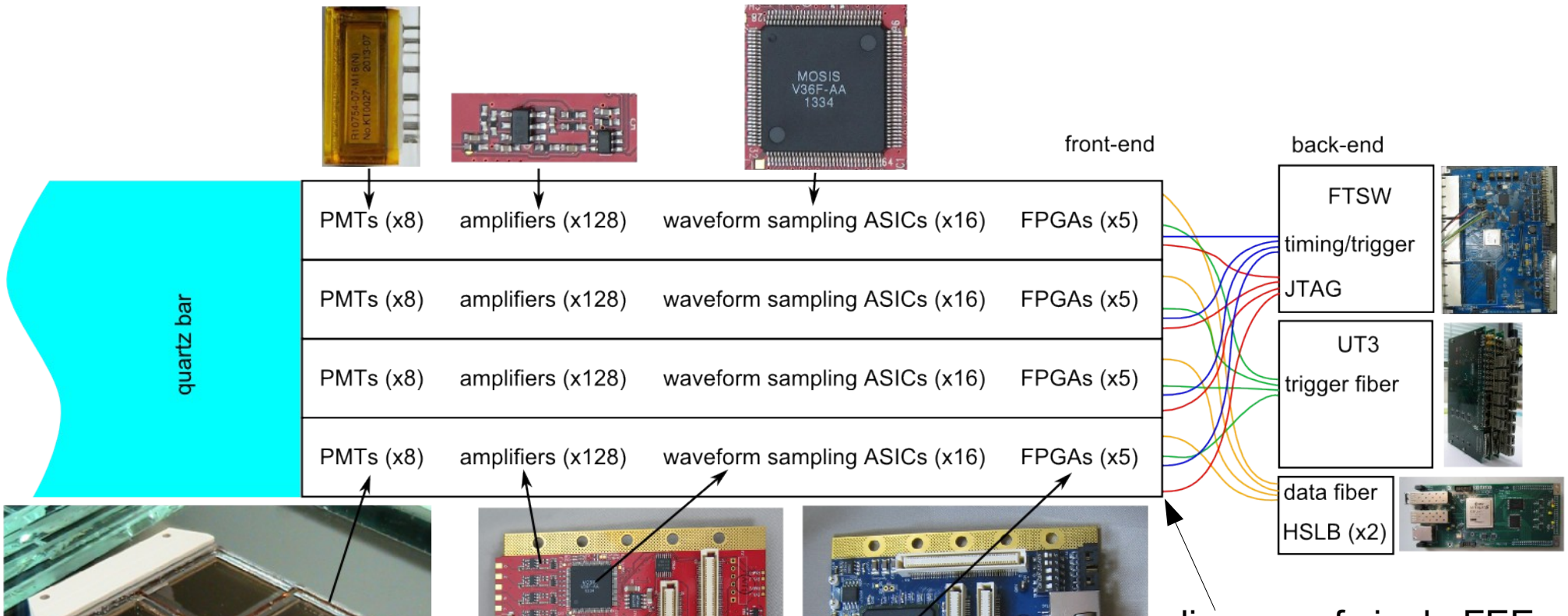
spring-loaded "pogo" pins

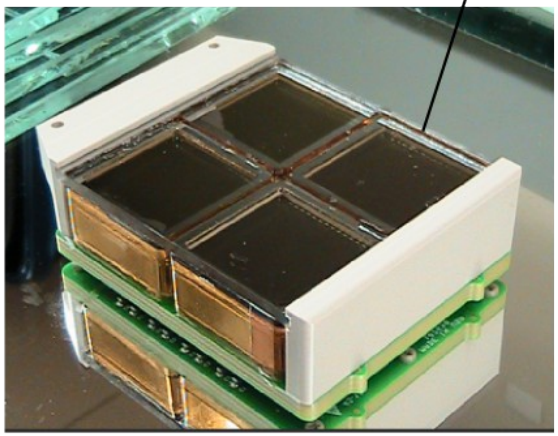


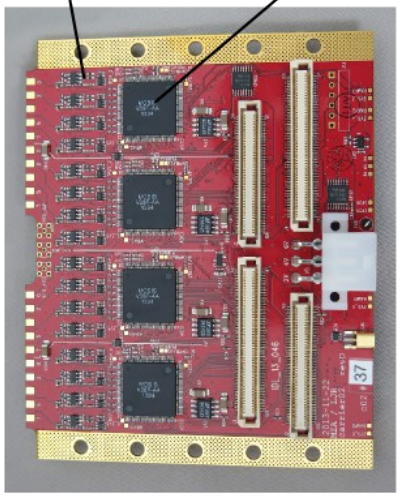


pogo pin landing pads

FEE+DAQ for production TOP module







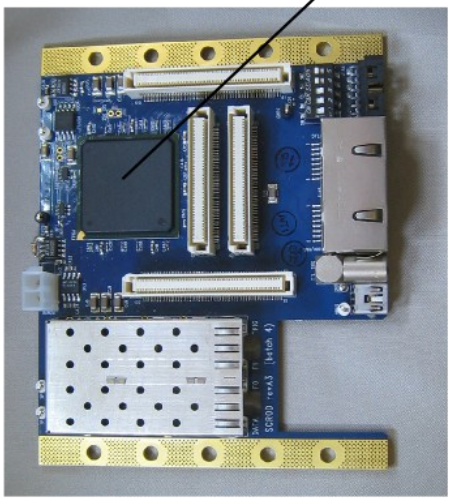


diagram of single FEE module on following page

*pictures are from current prototype of electronics

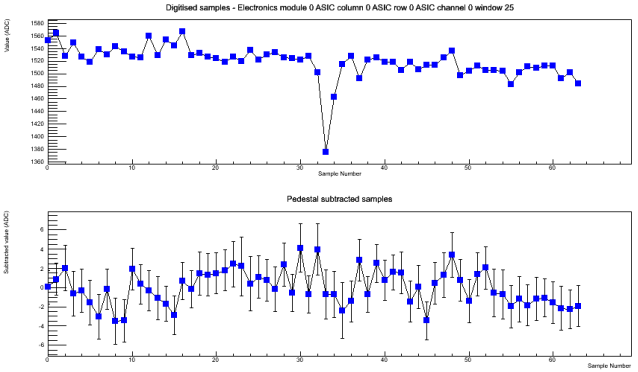
calibration steps
(to aid online feature extraction and zero-suppression)

1. Subtract storage cell pedestal
2. Linearity correction
3. Individual sample time offset correction

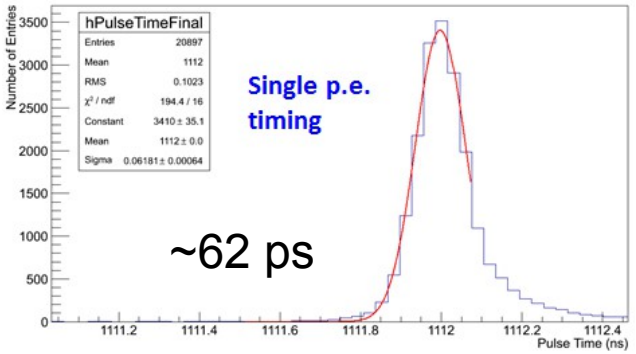
*these data are from IRS3B with higher gain from single-stage discrete amplifier with 96% efficiency

Three sets of calibration constants required:

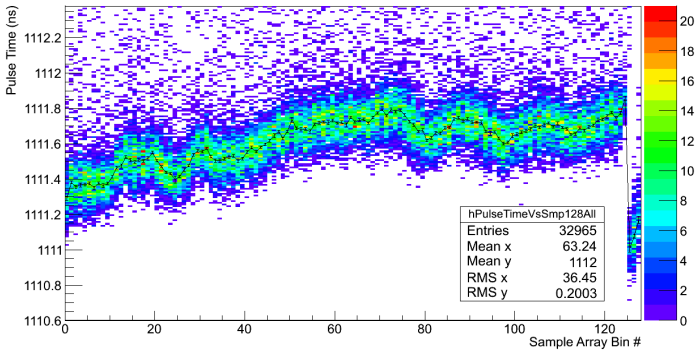
- **Sample pedestal values**
  - (262144 samples/ASIC)
- **Sample time widths**
  - (128 values per ASIC)
- **Timewalk correction**
  - (~20 values per ASIC)



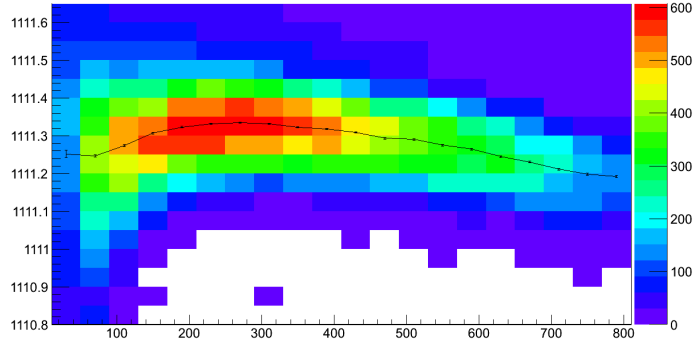
after calibration:



Pulse Time Vs Sample Array Bin # (used to measure Sample-DTs)



Pulse Time Vs Height (timewalk correction)



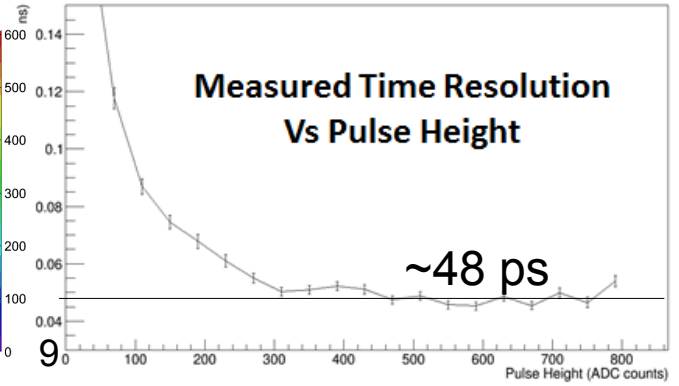
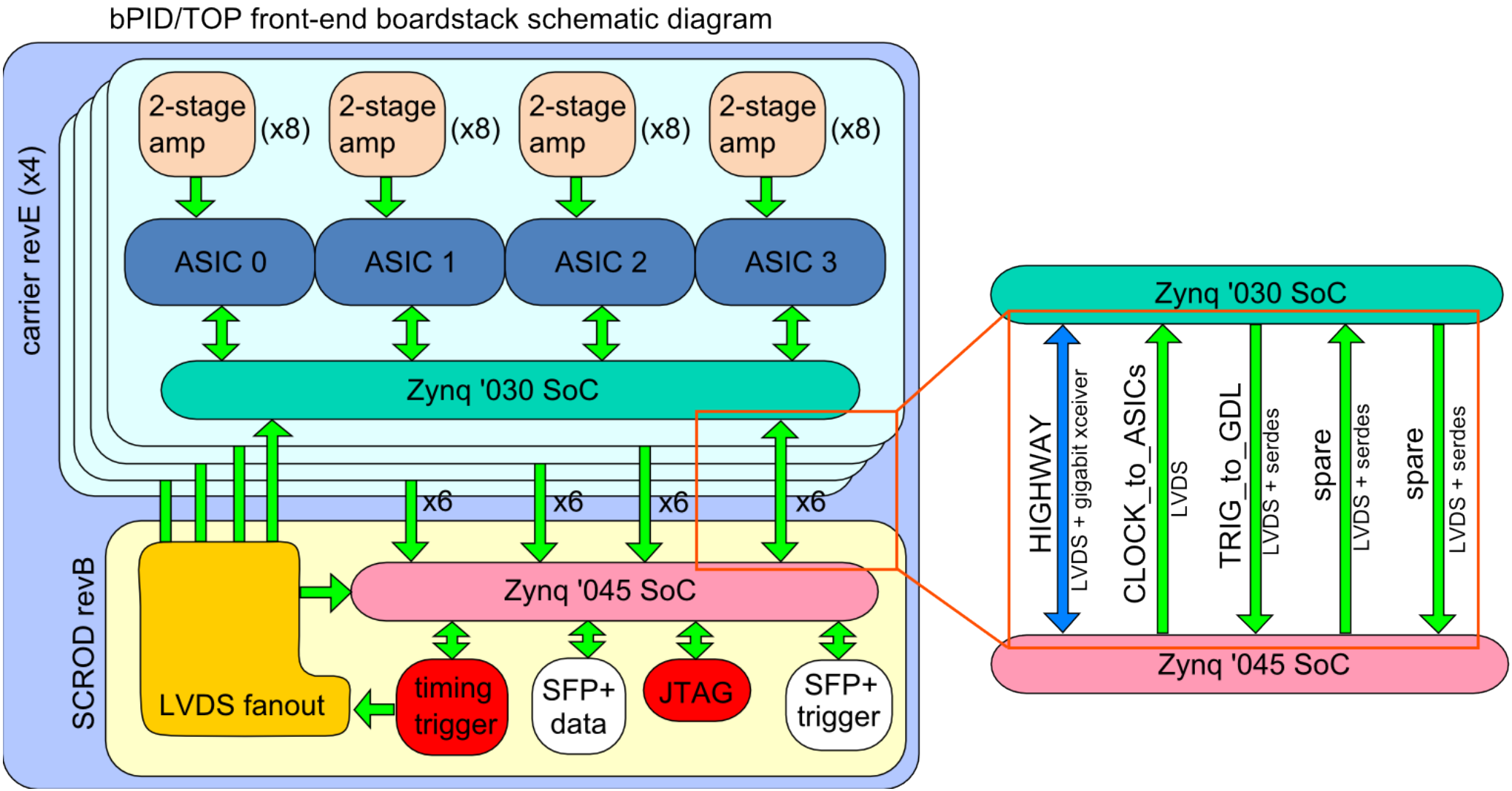
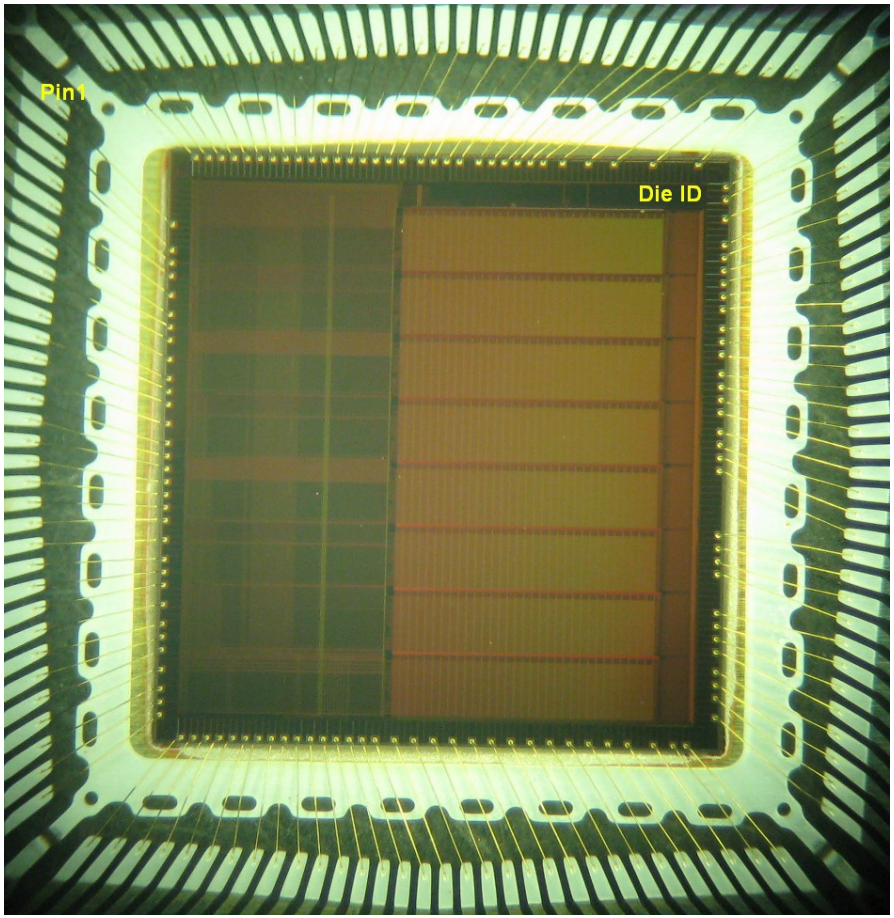


diagram of production front-end

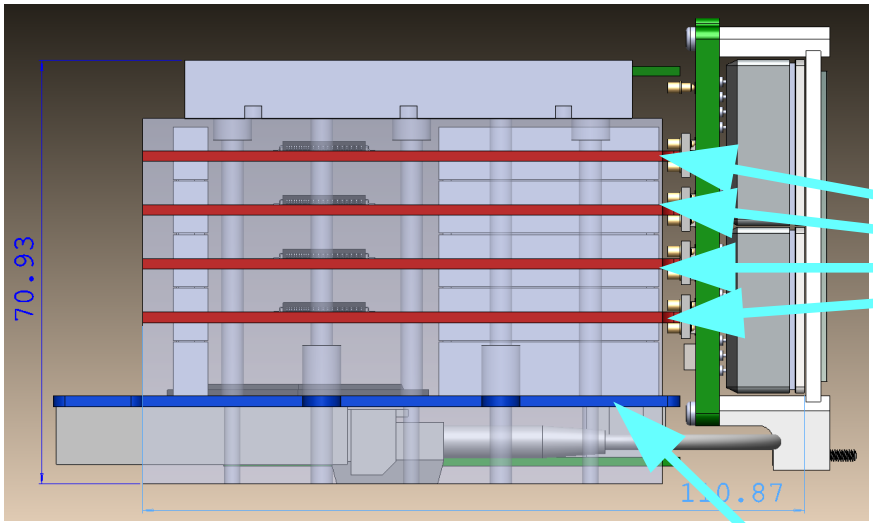


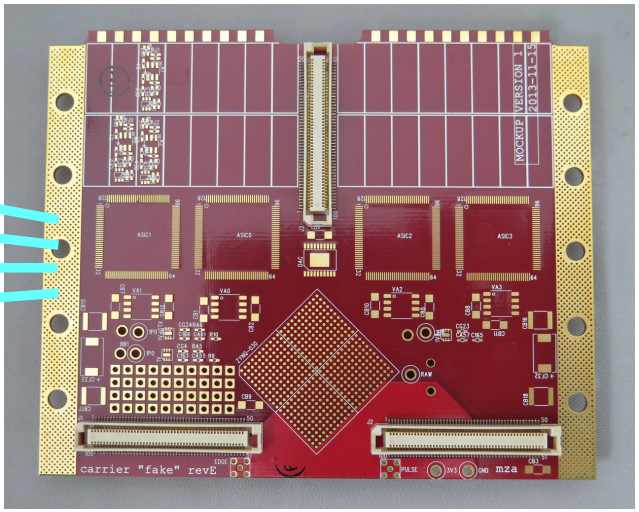
production ASIC (IRSX)

- 8 channels
- 128-sample Switched-Capacitor Array (SCA)
  - up to 4 GSa/s
- trimDAC for each sample in timing generator
  - to remove nonlinearities from time base
- 2-stage (analog) transfer to deep storage array (32,768 samples deep)
  - in principle allows deadtimeless readout
- trigger bit output
  - sent to global decision logic for Belle II
- 12-bit Wilkinson conversion of 8*64 samples
- serial readout over LVDS pair
- TSMC 0.25 um via MOSIS engineering run
- packaged in TQFP-128A

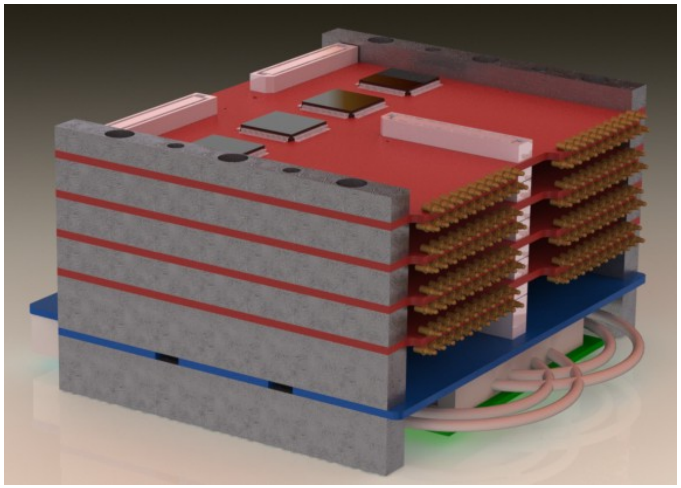


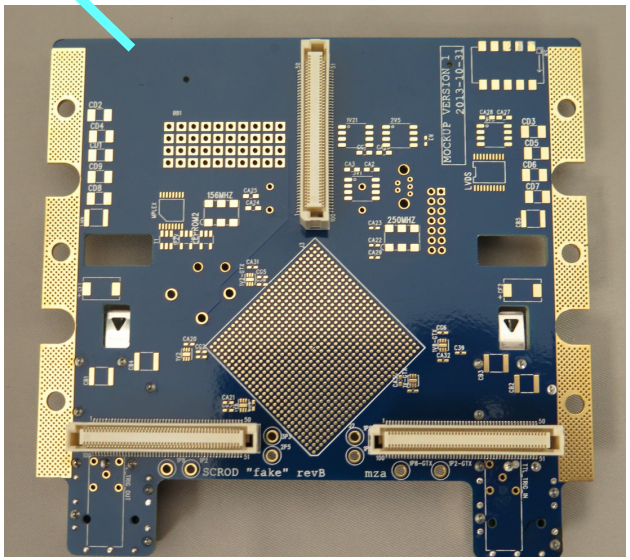
production “boardstack” design



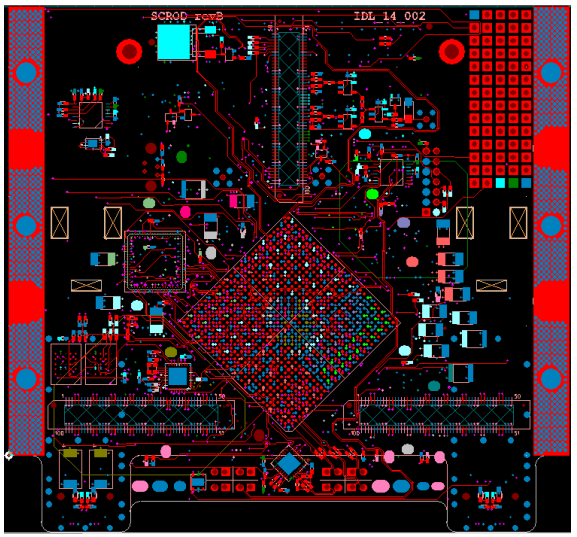


carrier (mockup)





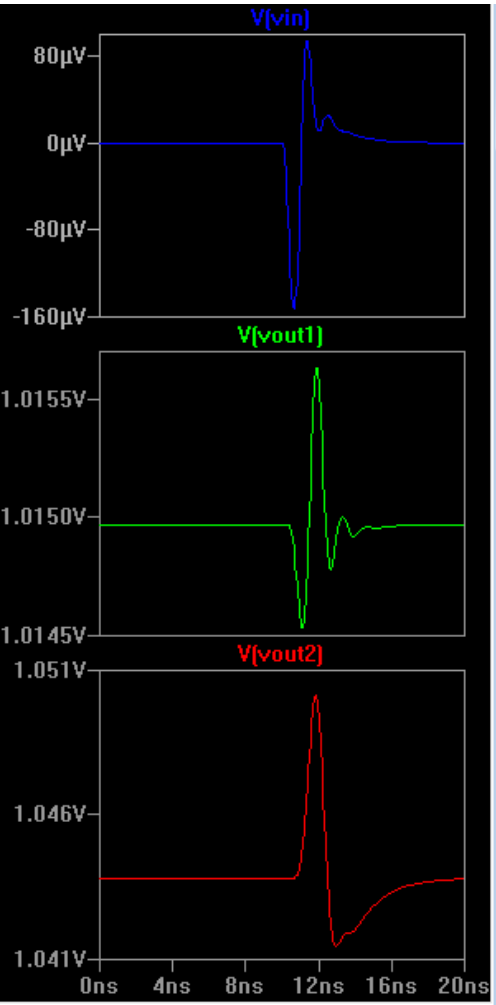
SCROD (mockup)

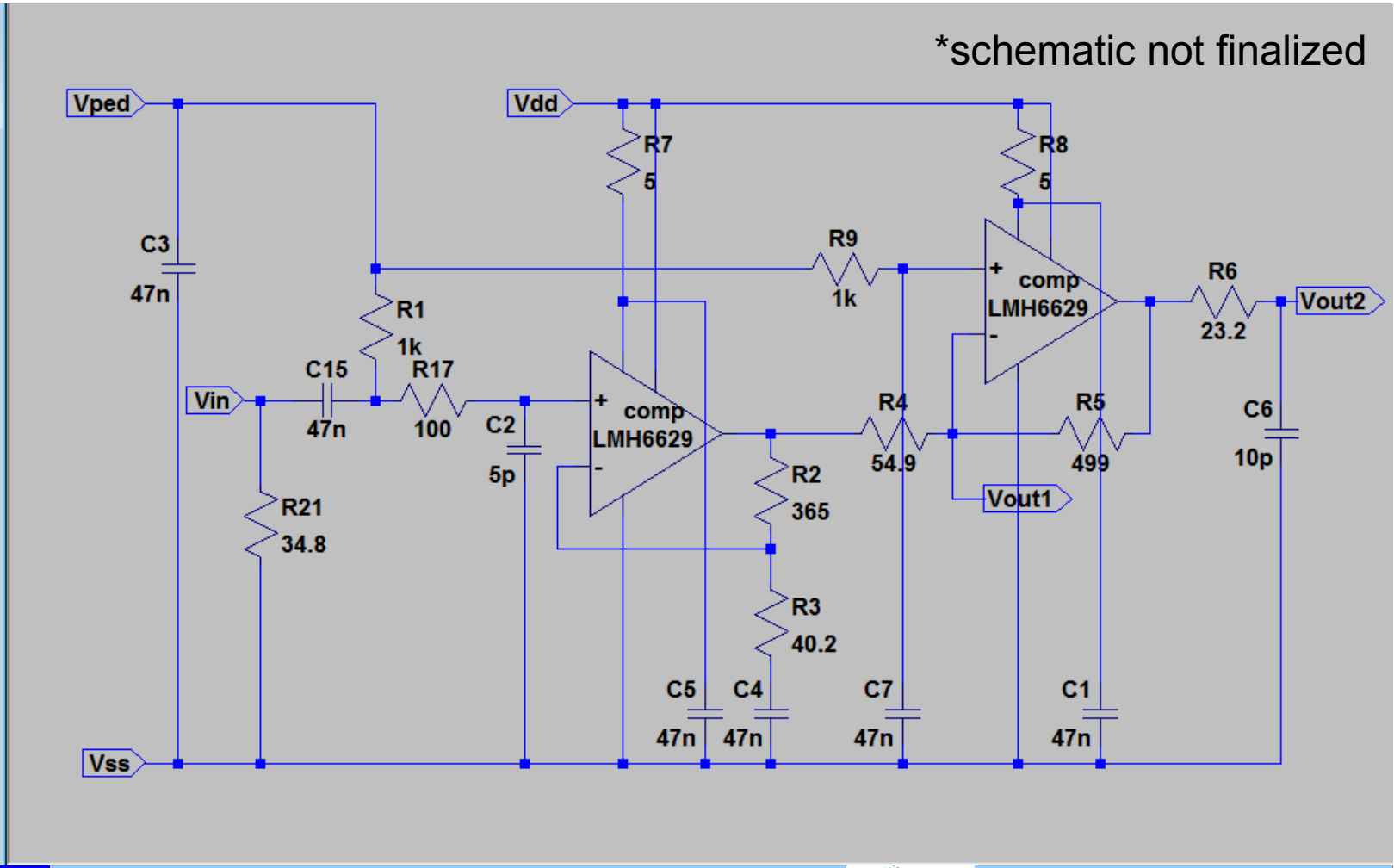


SCROD revB

two-stage amplifier

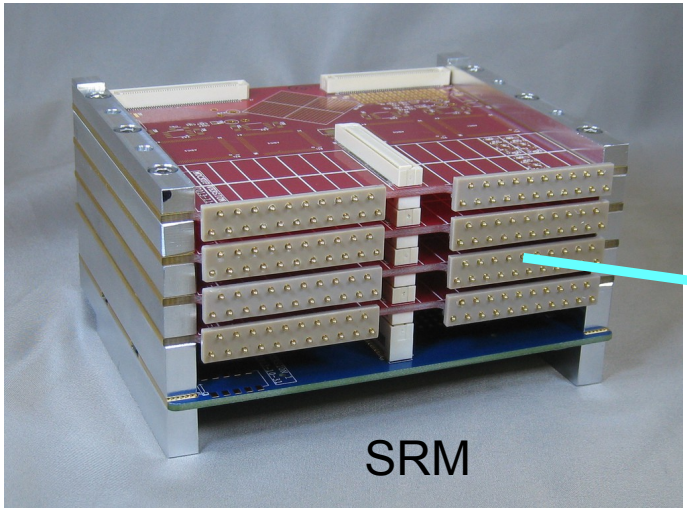
- needed to run MCP-PMTs at 5x10^5 gain

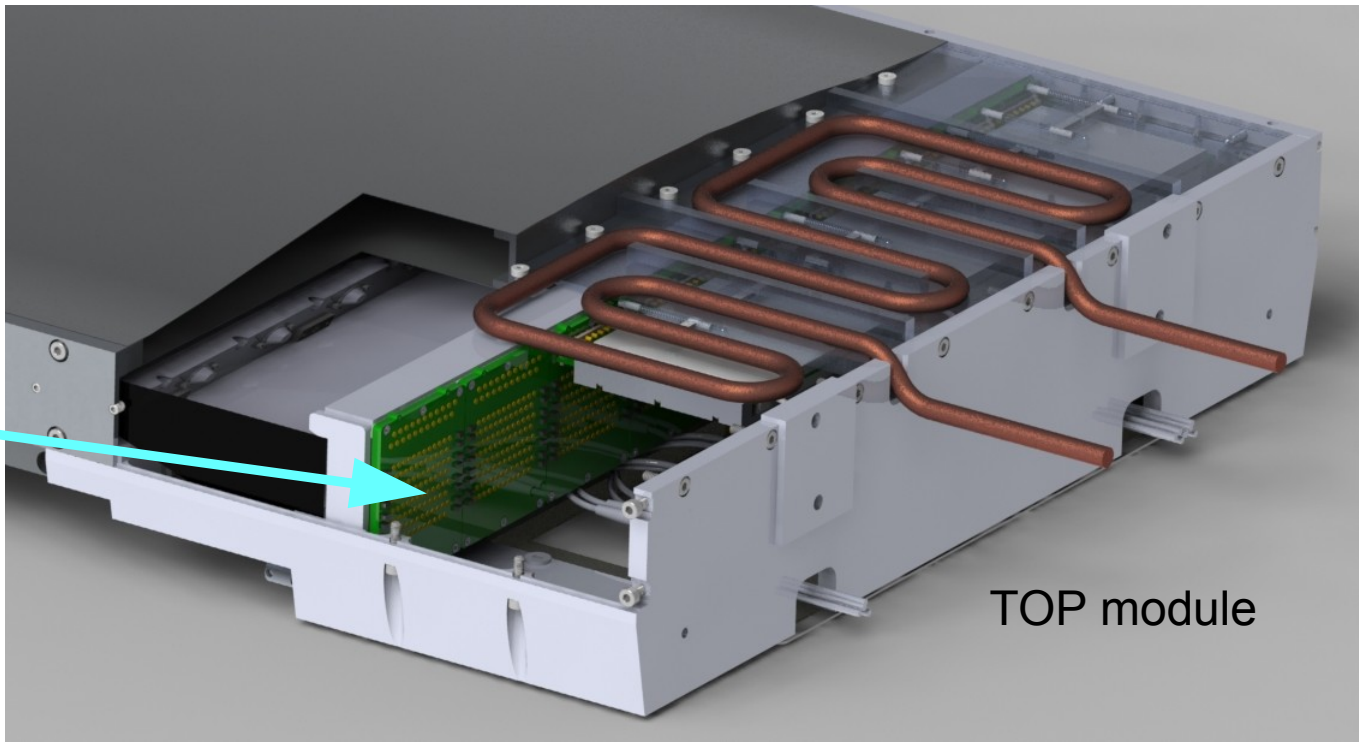




power draw / cooling

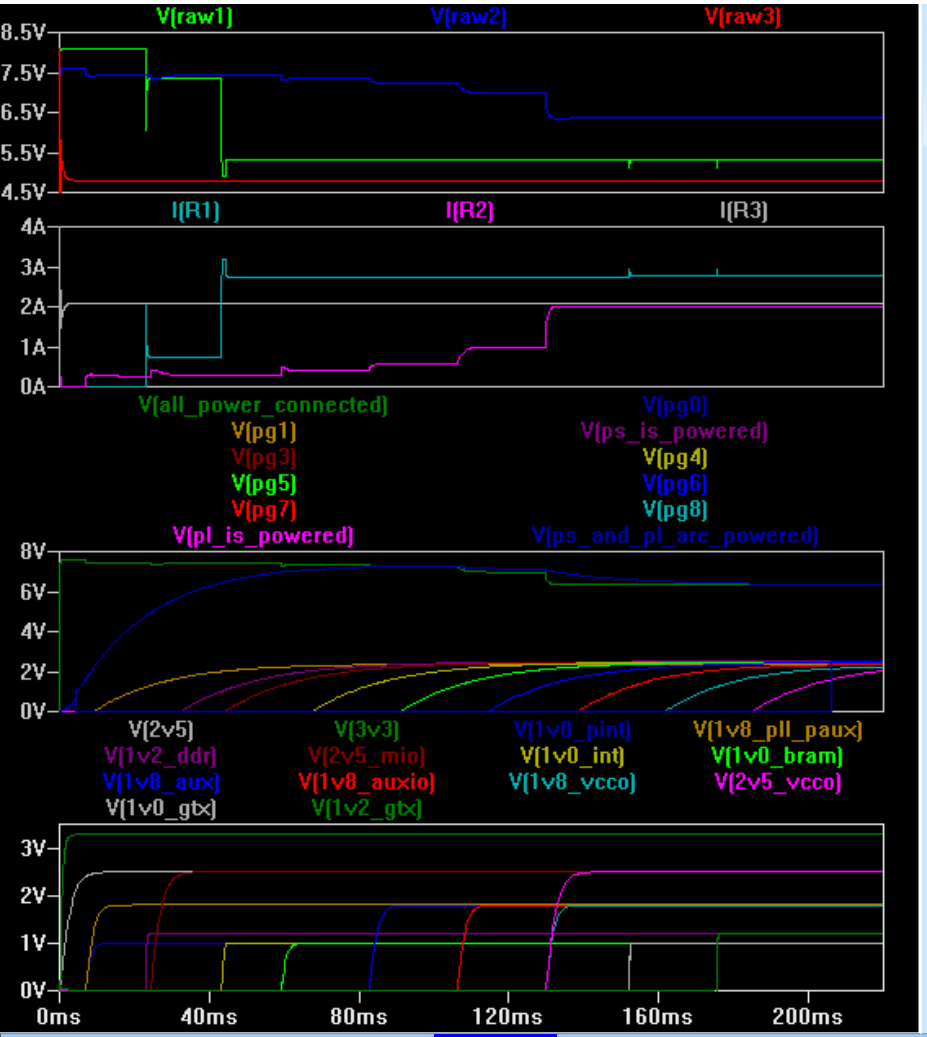
- expected power draw for each production SRM: 50-78 W
- 200-312 W per TOP module

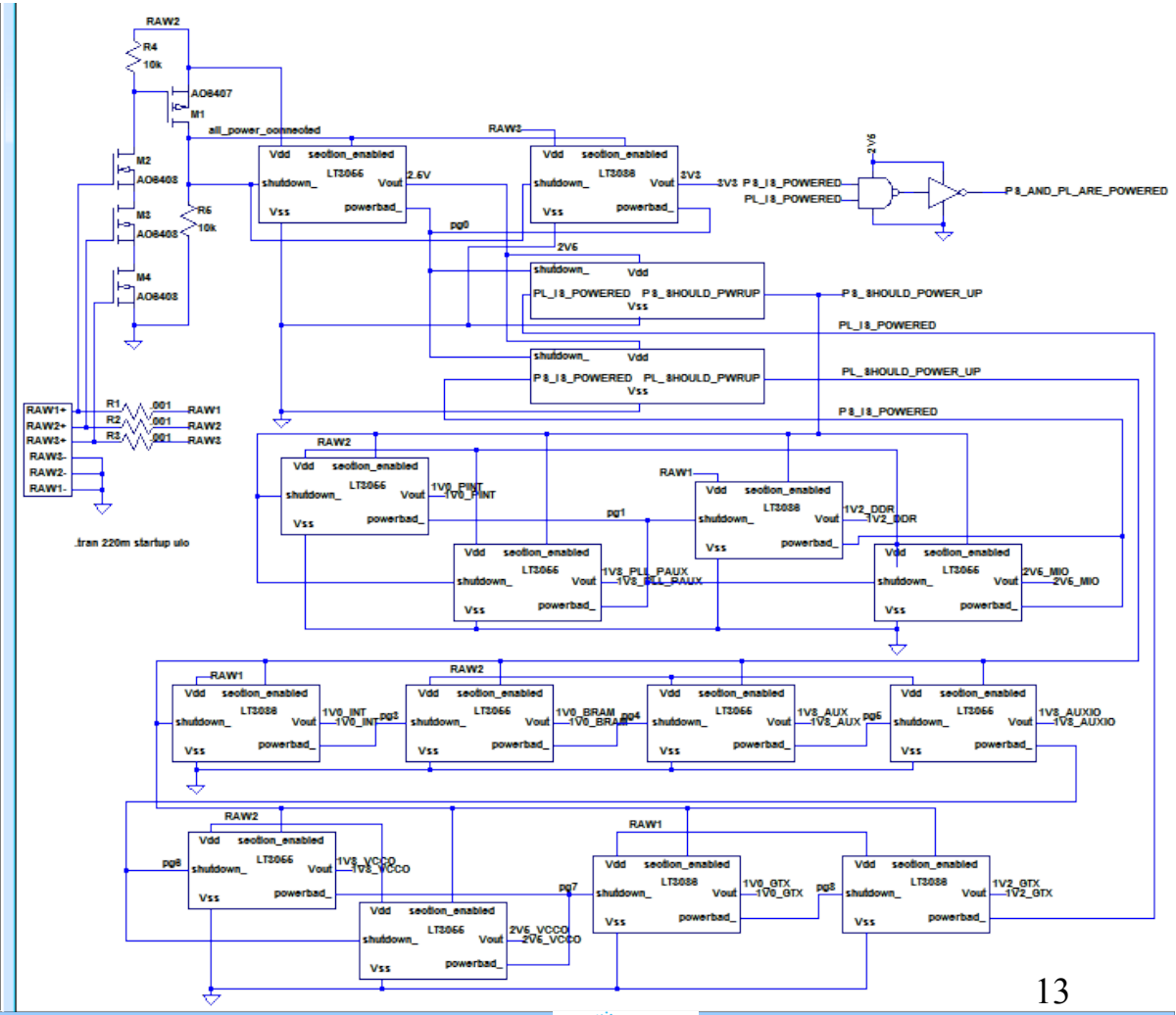




power-supply sequencing

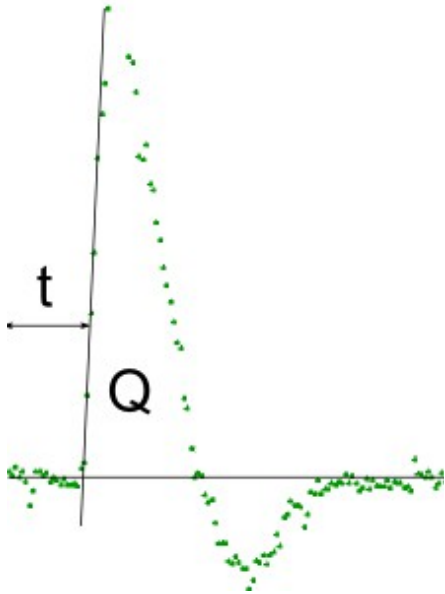
- 10 stages (per board; daisy-chained up boardstack)
  - reduces peak system inrush current





outstanding issues

- service space is extremely constrained
  - LV, HV, fiber optics, timing/trigger, JTAG links
  - cooling pipes
- must extract Q, t from waveforms in FPGA in real time to be sent to downstream DAQ system
  - processing done by dual ARM cores on each FPGA (with help from programmable logic)
  - need to get data down from ~100 bytes per hit to ~10 bytes per hit



status / plans

- took previous prototype electronics to beam test at SPring-8/LEPS (~95 ps; 80% efficient)
- continue to evaluate electronics in bench tests (~62 ps; 96% efficient)
- working on production board designs now:
  - will evaluate next few months thereafter
  - will go into production near end of this Summer
- cosmic-ray test for each TOP module this Fall
- installation into detector to commence next year