AFP Technical Review
ToF Electronics

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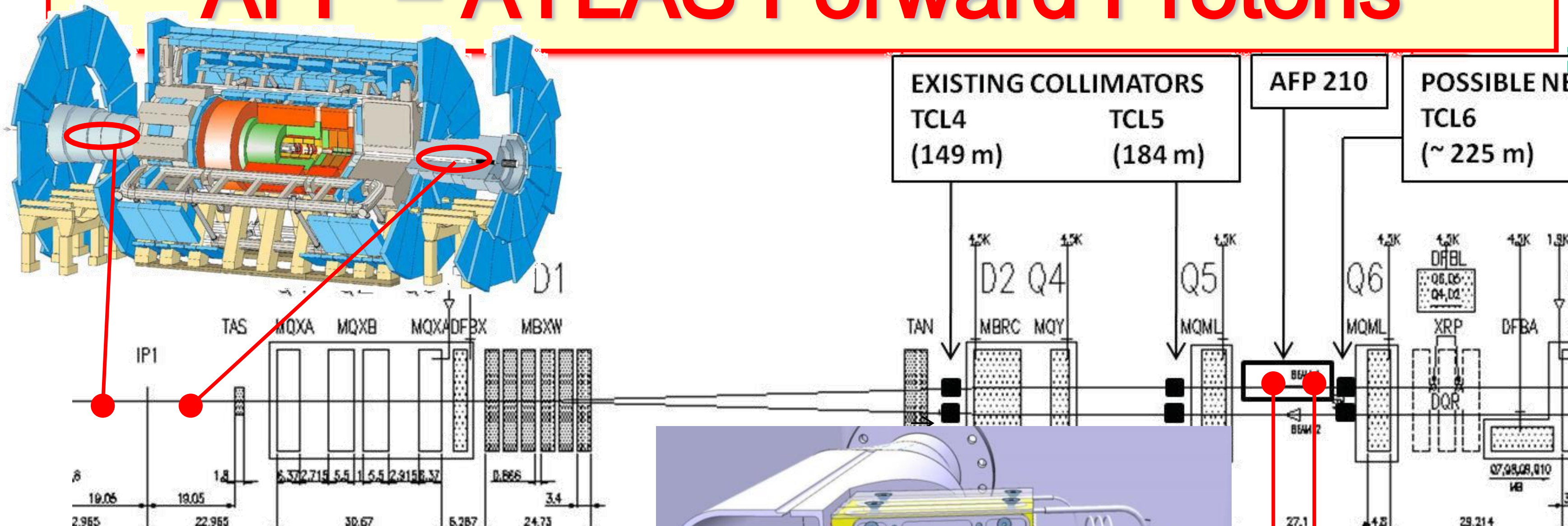
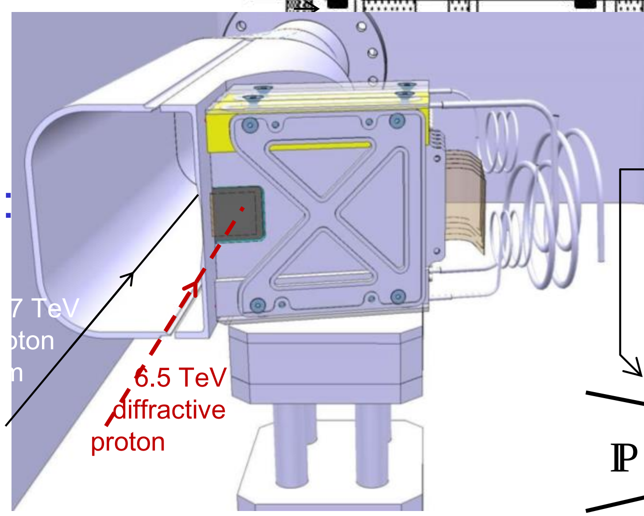
for the AFP QToF Institutes:

U Texas at Arlington, Stony Brook U, U Alberta at Edmonton
U New Mexico, Oklahoma SU

AFP – ATLAS Forward Protons



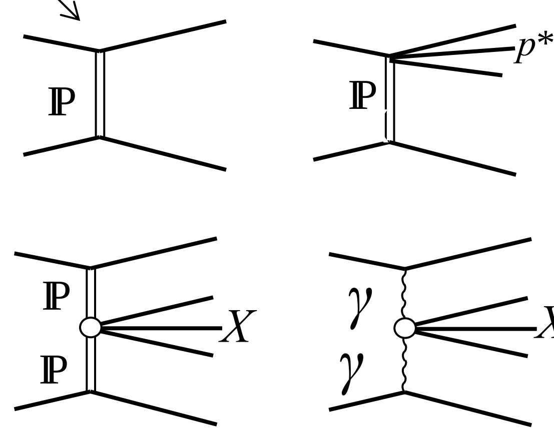


Forward Proton Detectors (AFP):

– detect/measure protons going down the beam pipe

e.g. For $pp \to pXp$: $M_X = \sqrt{s\xi_1\xi_2}$

where s=14 TeV, ξ fractional proton energy loss



Time of Flight:

Time **difference** between protons from **same** interaction arriving in the **two** AFP arms: $z_{vtx} = c(t_L - t_R)/2$

➔ $\sigma_z = (c/\sqrt{2}) \times \sigma_t \sim 2$ mm ➔ $\sigma_t \sim 10$ ps

Use to reject pileup background

Electronics – Goals & Constraints

- preserve timing resolution of the detector: <20 ps/channel
  - **multiple** measurements/proton ➔ <10 ps/proton
  - need multiplicity also for rejection of spurious background rejection!
  - trade multiplicity for resolution: 4 measurements of 20 ps ≃ 10 ps
- provide fast ξ-bin trigger; transverse deflection $x \propto \xi$
  - data rate up to 1 MHz/channel
- radiation-hardness or tolerance
  - fluence/dose estimate for 100 fb^{-1} (1 yr @ 10^{34} $cm^{-2}s^{-1}$)

estimates for 100 fb^{-1}	5 cm from beam @214 m	Tunnel floor @214 m	RR13 @beam level
Electronics exposed:	PA-a	PA-b, Trigger	CFD, HPTDC, Clock
High-Energy hadrons	$5{\cdot}10^{12}/cm^2$	$10^{10}/cm^2$	$5{\cdot}10^{9}$–$10^{8}/cm^2$
1 MeV-equiv. neutrons	$5{\cdot}10^{11}/cm^2$	$5{\cdot}10^{10}/cm^2$	$10^{9}/cm^2$
Integrated dose	5000 Gy	50 – 10 Gy	1 – 0.1 Gy

(1 Gy = 100 rad)

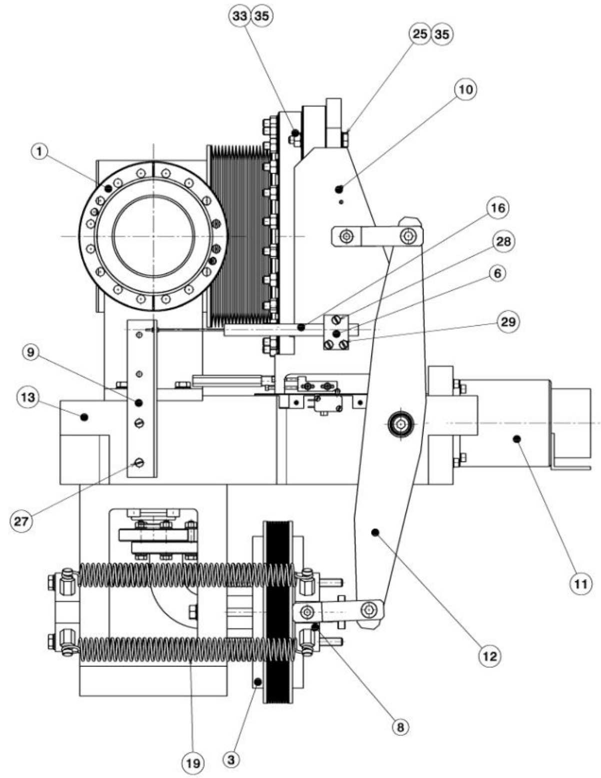
Fast Timing Electronics

Two methods to deal with pulse-height variations:

1. CFD + TDC …
2. Sampling of the (leading edge of the) pulse and time-walk correction

– see slides by J-F Genat, and many others at this workshop!

- AFP Baseline: CFD + HPTDC
  - – see Jim Pinfold ‘s talk
- AFP Electronics R&D: SAMPIC



Pulse Shape and Gain Requirements

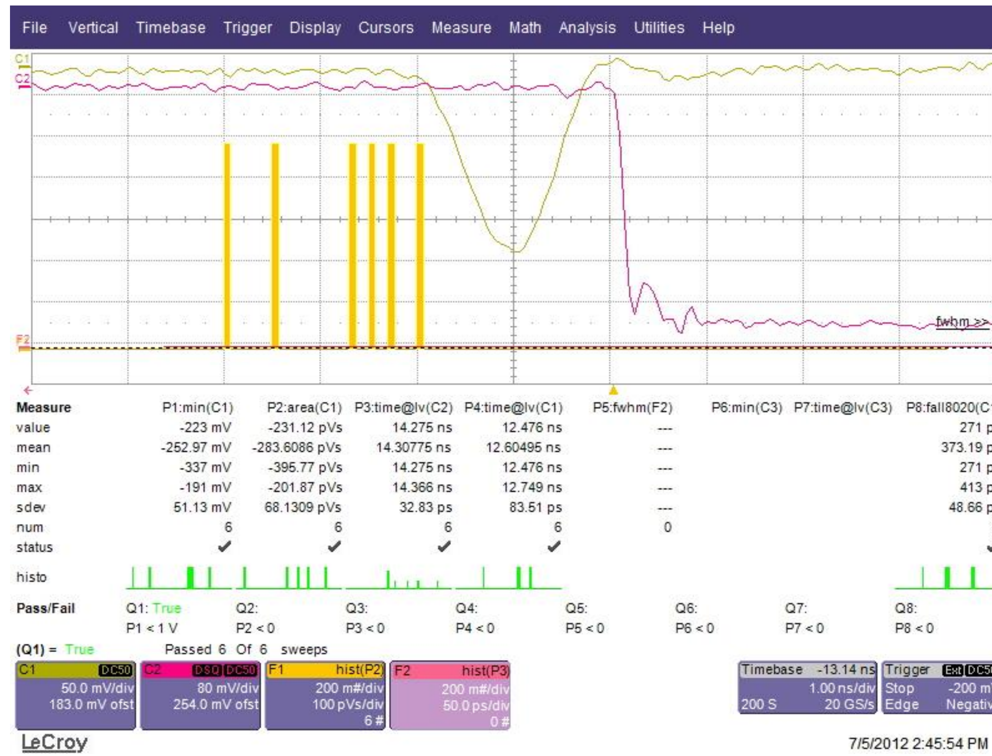
Pulse shape from UTA Laser-Lab testing (25µm pore) :

- Gaussian, FWHM ~700 ps (t_{rise}~300 ps)
- Minimum pulse height at 2 pe, G=1E5: V_{peak}~2 mV (~30 fC in 50 Ω)

Trigger: needs ~100 fC

CFD needs: 250 – 1500 mV

- 2 mV ➔ 200 mV: 40 dB
- PMT pixel variation: ~6 dB
- PMT ageing: ~6 dB



➢ Need ~50 dB gain

- 2 or 4 (inverting) stages of ~20 dB each

Irradiation of AFP Electronics

estimates for 100 fb^{-1} (need update!)	5 cm from beam @214 m	Tunnel floor @214 m	RR13 @beam level
Electronics exposed:	PA-a	PA-b, Trigger	CFD, HPTDC, Clock
High-Energy hadrons	$5\cdot10^{12}/cm^2$	$10^{10}/cm^2$	$5\cdot10^{9}$–$10^{8}/cm^2$
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Integrated dose	5000 Gy	50 – 10 Gy	1 – 0.1 Gy

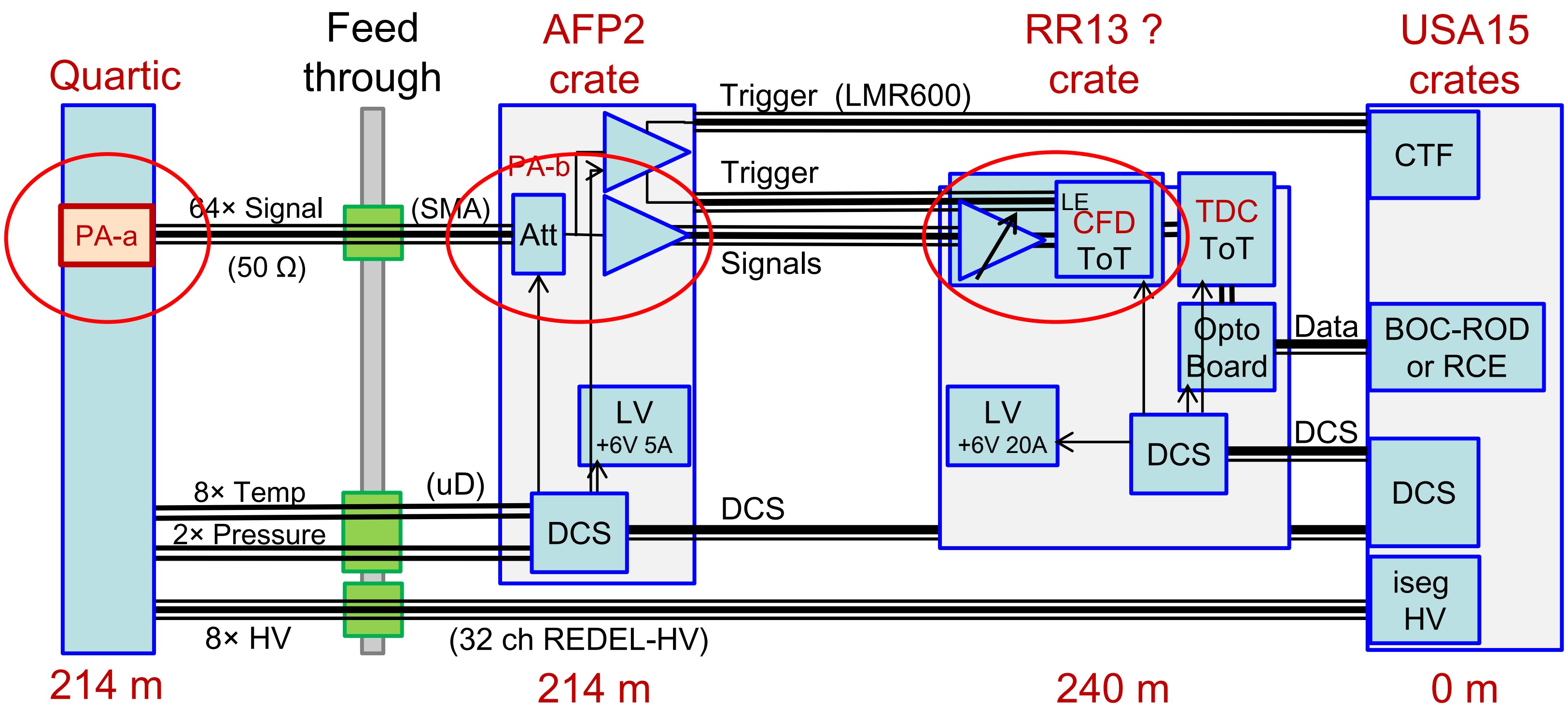
1. HiRad protocol:
   – Neutrons or HE protons: 10^{12} – 10^{13} /cm^2; γ: 1 – 10 kGy.
2. MedRad protocol:
   – Neutrons or HE protons: 10^{11} – 10^{12} /cm^2; γ: 10 – 1 kGy.

- PA-a chips (PSA4-5043+): HiRad
- PA-b boards & trigger: MedRad
- NINO chips (trigger): MedRad
- CFD daughter boards: MedRad
- HPTDC chips: MedRad

Cfr. ALFA radiation dose LHC Run1 measured over 2010–2013 (~30 fb^{-1}): ~20-30 Gy in each pot (≥10 cm from beam)
See: K.Hiller, S.Jakobsen, S.Franz, ALFA General Meeting, Cracow, June 5-7, 201.

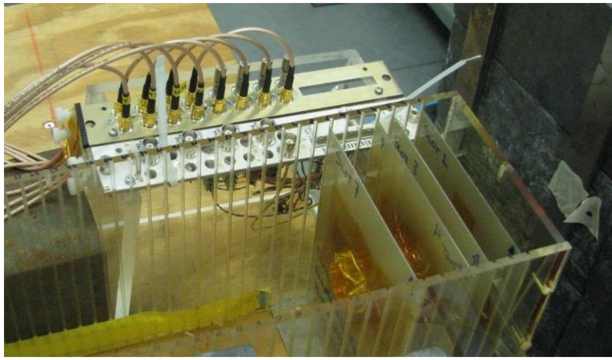
Irradiation – Sep 2013

Irradiated at LANL Sept 2013; S. Seidel *et al.* (UNM), K. Gray (UTA):

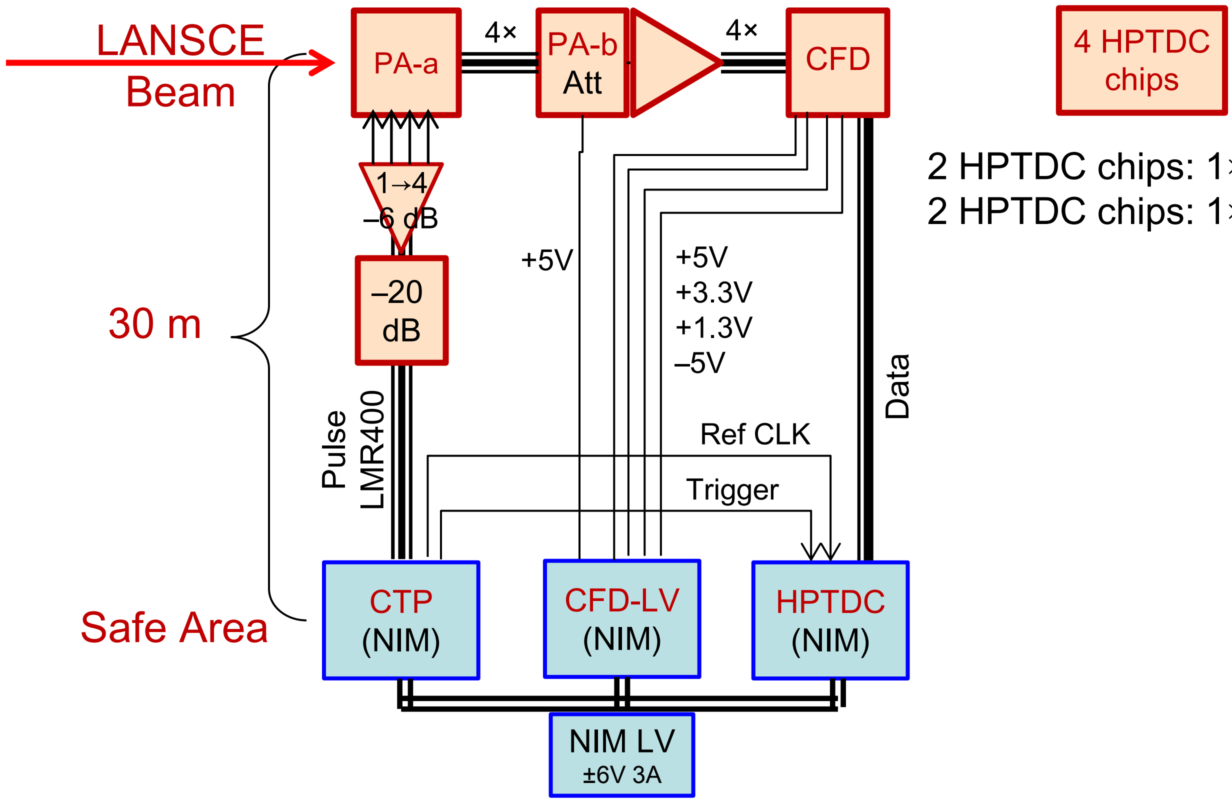


800 MeV p, ~7 cm from direct beam; *passive*

– dose: 6.5-8.7×10^{12} p/cm^2, 2.3-3.1 kGy
– for 100 fb^{-1}: ~expected for PA-a; ~50× expected for PA-b and CFD
– devices are all operational after irradiation!



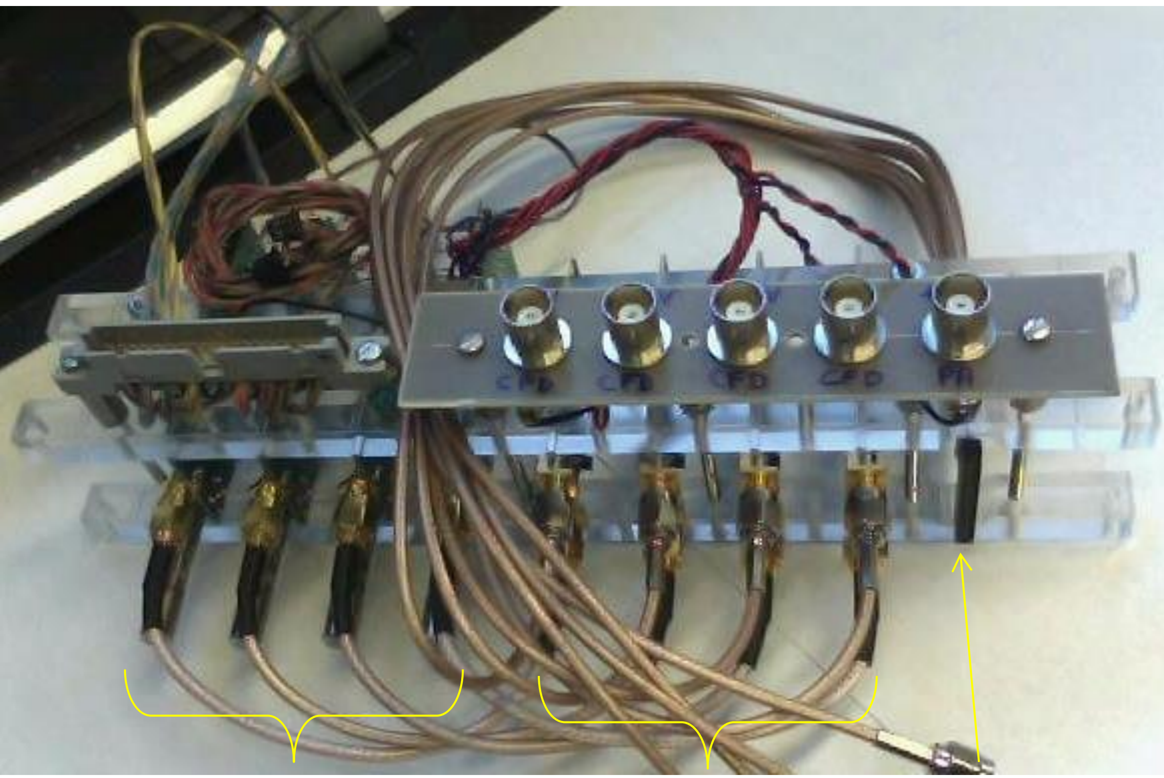
Irradiation @ LANSCE – Jan 2014



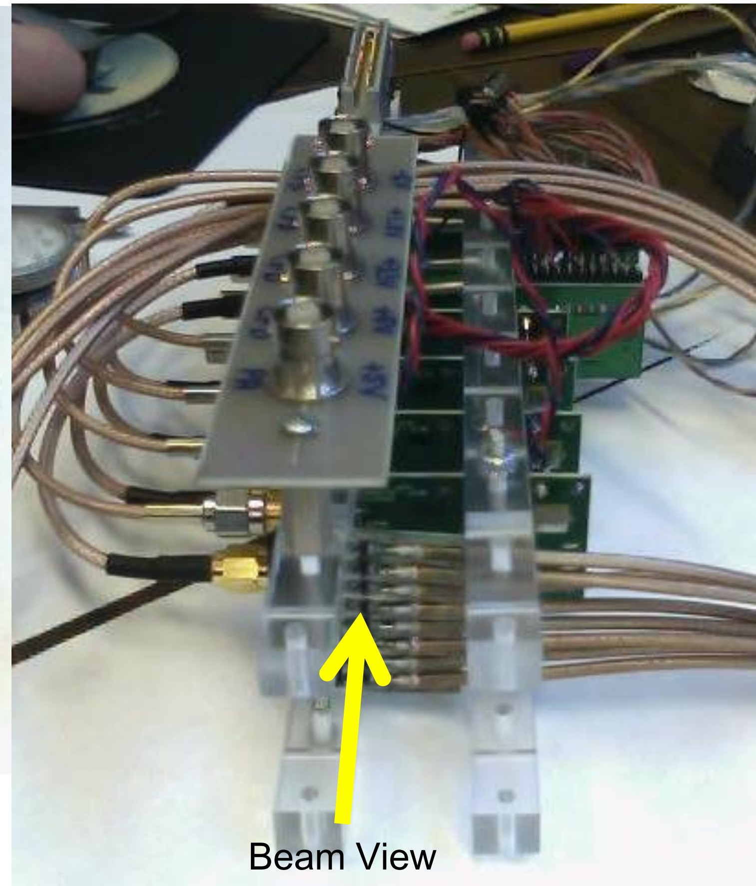
2 HPTDC chips: 1×10^{12} p/cm^2
2 HPTDC chips: 1×10^{13} p/cm^2

4-Channel Electronics Setup

- Jan 31- Feb 2 irradiation at LANSCE
- Protocol:
  - Active irradiation
  - up to 1.0×10^{13} p/cm^2, in 10 steps of 1×10^{12} p/cm^2
  - i.e. 10 pulses of 10^{11} protons per step



CFD PA-b PA-a



January 31- Feb 2 Irradiation

People: Tim Hoffman (UTA); Sally Seidel, Martin Hoeferkamp (UNM)

Protocol: Active irradiation – keep voltages on!

- up to 1.0×10^{13} p/cm^2, in 10 ‘steps’ of 1×10^{12} p/cm^2; **verify operation** before & after each step.
- i.e. 1 ‘step’ equals ~10 pulses of 10^{11} protons/pulse, 1 Hz, ~1 cm Ø

Early results:

- HPTDC readout did not work (cable too short) ➔ 2 Channels were monitored on scope; all 4 channels were powered throughout the run.
- Irradiation up to 5.0×10^{13} p/cm^2
- 2 monitored channels were still operating at the end of the run

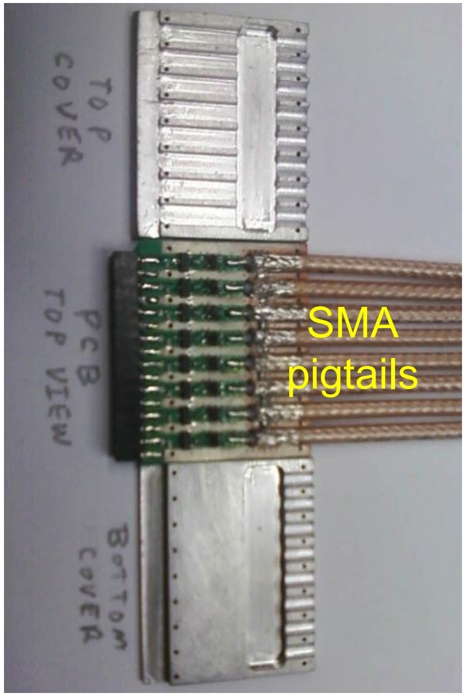
Next:

- Wait for cool-off and return of parts (<2 months)
- Pre-Amps, CFDs: Re-test performance and compare with non-irradiated parts
- HPTDC chips: mount on HPTDC board and check operation

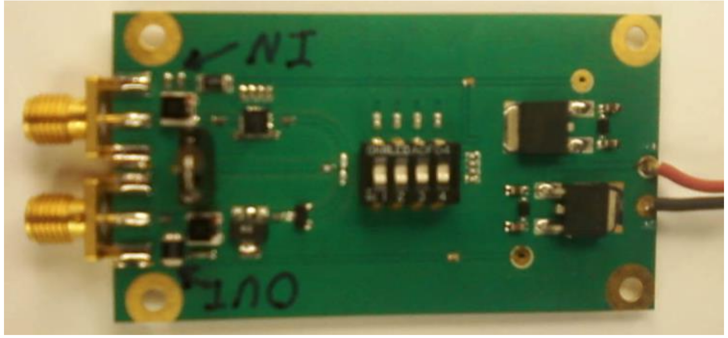
Fast ToF Electronics: we have …

Proven designs & prototype 8-ch modules for:

- Preamp on PMT (PA-a) (4×8 channels)
- 2nd stage variable-gain amp on tunnel floor (PA-b) (2×8 channels)
- Constant Fraction Discriminator (CFD) (3×8 channels)
- High-Precision Time to Digital Converter (HPTDC) (3 12-ch modules)

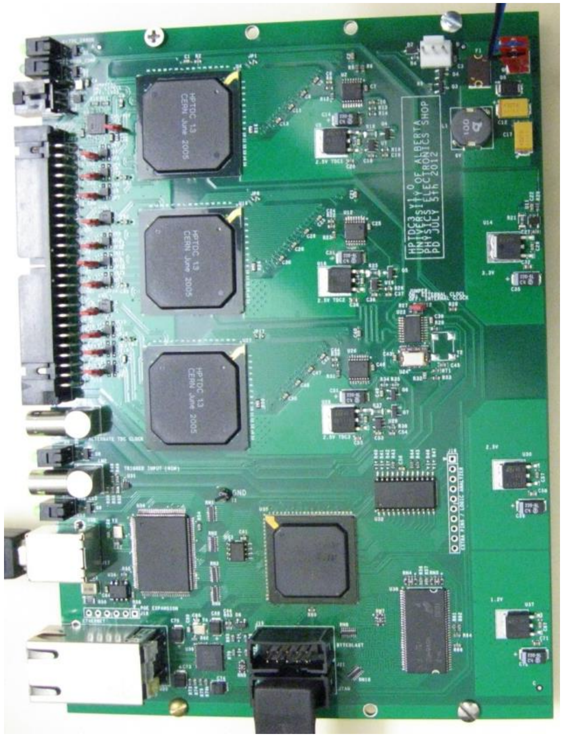


8-Channel Preamplifier (PA-a)



PA-b 1st Prototype

Alberta CFD Daughter Board



Alberta HPTDC Board

Have **design** for:

- Trigger pick-off and Multiplicity Trigger board (based on NINO chip)

Preamp/amp reflections

20 ns/div; need to reduce “ringing”, tail, and reflection @ 20 ns

Reflection:

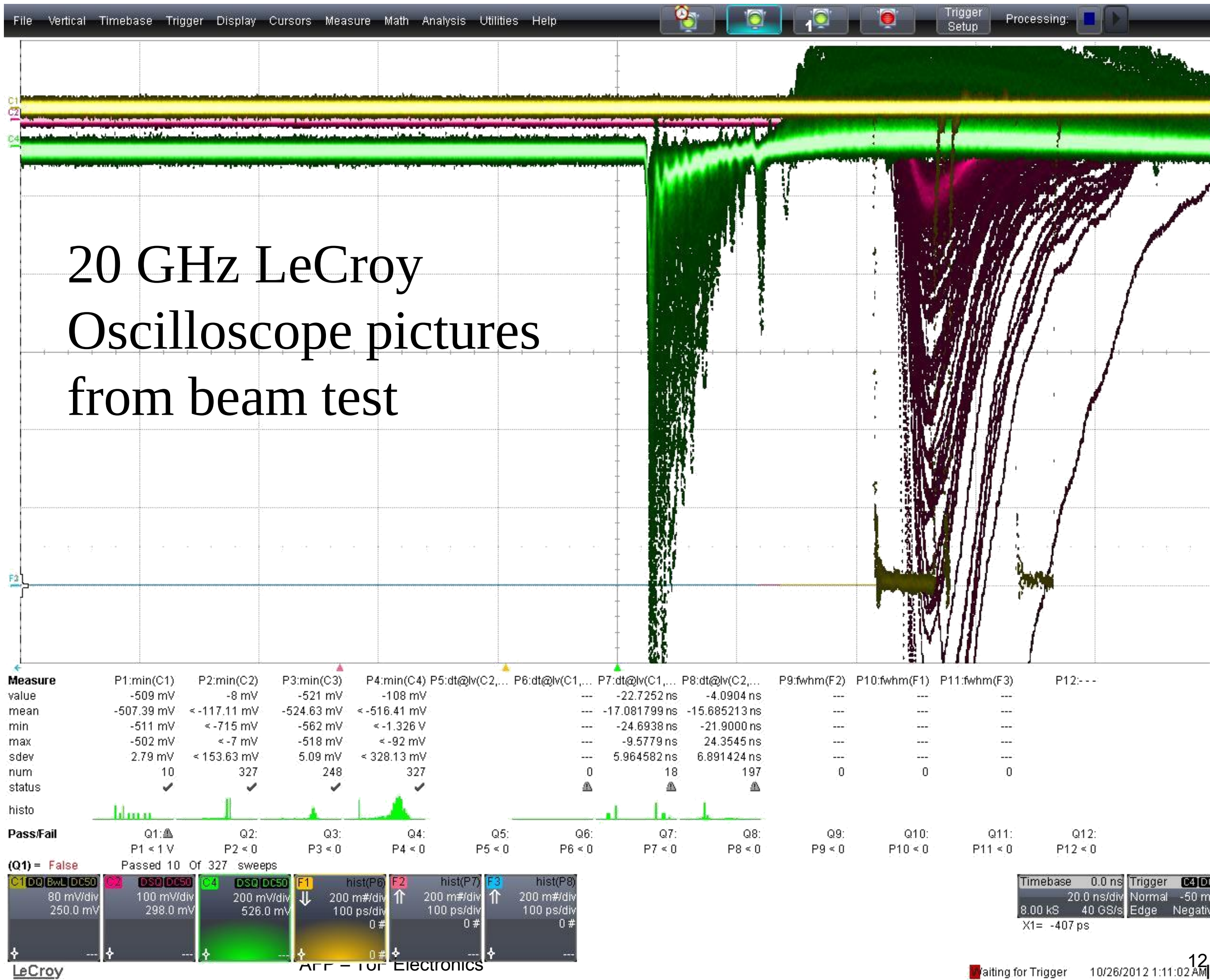
– Understood: caused by mismatch of PA-b traces …

➢ Re-do PA-b PCB

1 ns ringing:

– unclear, not seen with test pulses …

– PMT?

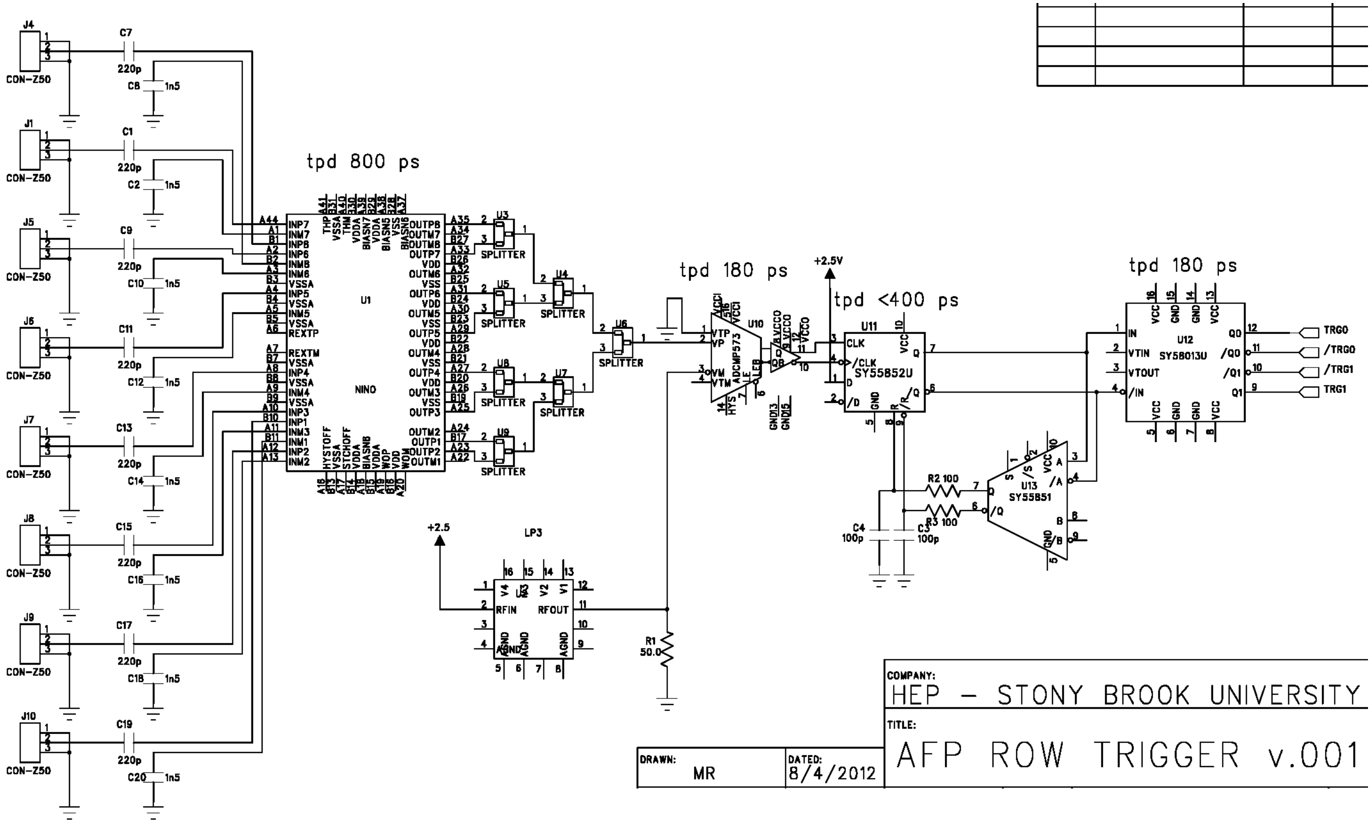


20 GHz LeCroy Oscilloscope pictures from beam test

To Do: Trigger – Stony Brook

on PA-b motherboard; uses signal pick-offs from PA-b

- to be simulated with final layout and prototyped
- Output driver: to be designed …



Trigger Schematic

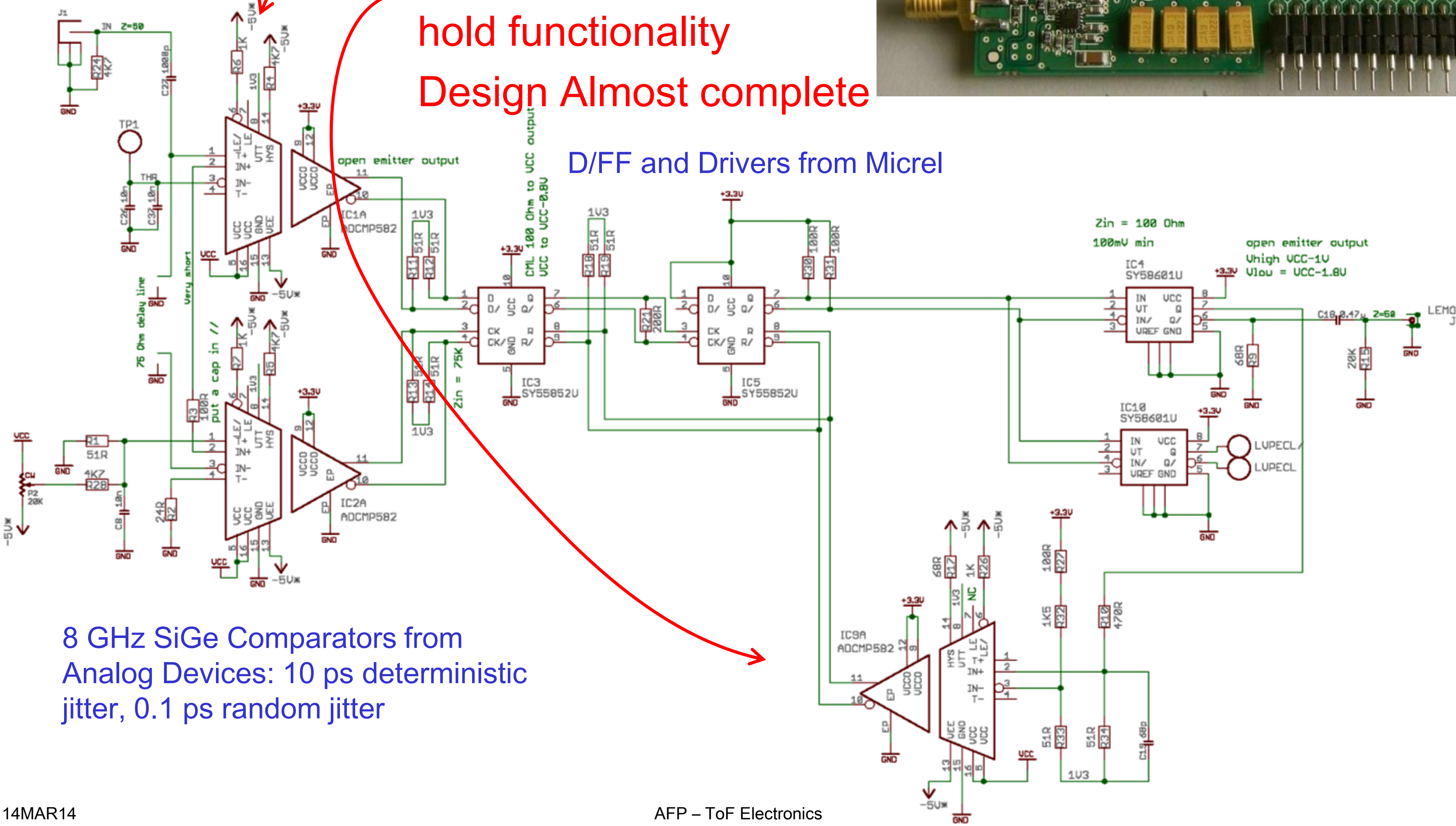
To Do: Modify CFD – U Alberta

add "Latch Enable"

add Time-over-Threshold functionality

Design Almost complete

D/FF and Drivers from Micrel



8 GHz SiGe Comparators from Analog Devices: 10 ps deterministic jitter, 0.1 ps random jitter

Status Fast ToF Electronics: To Do …

- Fast, ultra-stable, long-distance reference clock (U Texas at Arlington)
  - prototype working: ~5 ps jitter
  - Clock fanout: to be designed & built: (U New Mexico)
- Trigger (Stony Brook):
  - build prototype (Design almost complete)
  - Radiation testing
  - AFP trigger interface with CTF
- Modification of CFD (Alberta):
  - add Time-over-Threshold functionality (Design almost complete)
  - build prototype
- Modification of HPTDC (Alberta):
  - Rad-tolerant design
  - add ToT functionality (Design almost complete)
  - build prototype
  - Radiation testing
- Readout:
  - Opto board (2 pc ordered)
  - RCE Interface (SLAC/SBU) used for IBL tests
- DCS (?)