Topics

• **RF Detection of UHE Neutrinos**
  – Antarctic Impulsive Transient Antenna
  – IceRay (IceCube Radio)

• **Low momentum Precision Vertexer**
  – Super B-factory pixel vertex detector
  – ILC vertex detector

• **High Precision Timing**
  – High rate Particle Identification
  – Time-resolved laser ablation

6GSa/s

~11ps
The ANITA Concept

Ice RF clarity: 1.2 km(!) attenuation length

- Effective “telescope” aperture:
  - \(~250 \text{ km}^3 \text{ sr} @ 10^{18.5} \text{ eV}\)
  - \(~10^4 @ \text{ km}^3 \text{ sr} 10^{19} \text{ eV}\)

(Area of Antarctica ~ area of Moon)
A demanding Application

- RF Transient (impulsive) Events (200-1200 MHz)
- Completely solar powered (tight demands on power, few hundred W total)
- 324 chan. @ 2.6GSa/s

Antarctic Impulsive Transient Antenna (ANITA)
Major Hurdles – these ν are elusive

• No commercial waveform recorder solution (power/resolution)

• $3\sigma$ thermal noise fluctuations occur at MHz rates (need ~2.3σ)

• Without being able to record or trigger efficiently, there is no experiment
STRAW2 Chip

- 16 Channels of 256 deep SCA buckets
- Optimized for RF input Microstrip 50Ω
- Target input Bandwidth: >700MHz
- Record length: 128-256ns
- Die: ~2.5mm²

Self-Triggered Recorder Analog Waveform (STRAW)

- On-chip ADC: 12-bit, >2MSPS
- Sampling Rate: 1-3GSa/s (adj.)
- Sampling Rates >~4GSa/s possible w/ 0.25μm process
- External option: MUXed Analog out
- Self-Triggering:
  - LL and HL (adj.) for each channel
  - Multiplicity trigger for LL hits

DACs
ADC
8192 analog storage cells
8192 analog storage cells
A long, winding road…

“I’ve noticed a disturbing pattern Alice, the solution is always the LAST thing you try”

Dilbert’s pointy-haired boss
Strategy: Divide and Conquer

- Split signal: 1 path to trigger, 1 for digitizer
- Use multiple frequency bands for trigger
- Digitizer runs ONLY when triggered to save power
Large Analog Bandwidth Recorder and Digitizer with Ordered Readout [LABRADOR]

- Common STOP acquisition
- 3.2 x 2.9 mm
- Conversion in 31μs (all 2340 samples)
- Data transfer takes 80μs
- Ready for next event in <150μs

- Switched Capacitor Array (SCA)
- Massively parallel ADC array
- Similar to other WFS ASICs

8+1 chan. * 256+4 samples

Random access:

Straight Shot RF inputs

analog bandwidth
9 x 260 samples = 2340 storage cells

LABRADOR(3) architecture

Convert all 2340 samples in parallel, transfer out on common 12-bit data bus

256 + 4 “tail” samples
Wilkinson ADC

- No missing codes
- Linearity as good as can make ramp
- Can bracket range of interest

12-bit ADC

- Excellent linearity
- Basically as good as can make current source/comparator
- Comparator ~0.4 – 2.1V; 133MHz GCC max (~31us)
Pedestal and Pedestal Stability

**Pedestal Distribution**

- AC coupled input

<table>
<thead>
<tr>
<th>Pedestal (ADC counts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
</tr>
<tr>
<td>1100</td>
</tr>
<tr>
<td>1200</td>
</tr>
<tr>
<td>1300</td>
</tr>
<tr>
<td>1400</td>
</tr>
</tbody>
</table>

**Pedestal Stability**

- $\Delta T = 17^\circ C$ ($\delta t \sim 24$ hours)
- $\sim 0.052$ mV/C

**SURF #5**
LABRADOR Sampling Speed

- XOR Look-ahead logic (sample on rising/falling edge)
- Sampling rates up to 4 GSa/s with voltage overdrive

![Graph showing sampling frequency vs. frequency-adjusted voltage (ROVDD) with points and lines indicating data points and trend lines. The graph has a red box highlighting the sampling frequency of 2.6 GSa/s.]
Sampling Rate Temperature Dependence

\[ \chi^2 / \text{ndf} = 1124 / 159 \]

\[ p_0 = 31.65 \pm 0.00 \]

\[ p_1 = -0.05437 \pm 0.00005 \]
LABRADOR (SURF board) Noise

- 10 real bits (1.3V/1.3mV noise)

(2.5V VDD, rails smaller)
Bandwidth Limitations (LAB1 example)

\[ f_{3dB} = \frac{1}{2\pi ZC} \]

LAB3 → move \( R_{\text{term}} \) to front

- For 1.2GHz, \( C \ll 2pF \) (NB input protection diode \( \sim 10pF \))
- Minimize \( C \), \( (C_{\text{drain}} \) not negligible \( \times 260 \))
Bandwidth Evaluation

**Transient Impulse**

FFT Difference $f_{3dB} \sim 1.2$GHz

Labrador with input filter

**Signal Power [dBm]**

- RF pulse
- LAB3

**FFT difference**

-3dB
Response for RF Signals

- 2.6 GSa/s, peak fit (@ board-level noise interference)

Linearity scan

\[ y = 6808.7e^{-0.1229x} \]
\[ R^2 = 0.9983 \]
Cross-talk Amplitude

- Qualitative agreement obtained in SPICE
Cross-talk Phase

- Qualitative agreement obtained in SPICE
Timing Calibration Constants

- $T_0 \neq T_1 \neq \frac{1}{2} T$
- Separate wrap time constants
- Need to determine Phase 0, 1 interleaving
- In general every $\Delta t_0, \Delta t_1$ different
Timing Calibrations (1)

Square Wave Period -- Phase 0

Wrap Offset -- Phase 0 to 1

Entries: 1213
Mean: 1.411
RMS: 0.136
$\chi^2$/ndf: 37.250 / 16
Constant: 178.953 ± 6.277
Mean: 1.416 ± 0.004
Sigma: 0.131 ± 0.003

Entries: 920
Mean: 13.675
RMS: 0.198
$\chi^2$/ndf: 50.396 / 41
Constant: 58.250 ± 2.486
Mean: 13.681 ± 0.006
Sigma: 0.179 ± 0.005

Period (samples)

High-low != Low-high

Wrap-around time difference
Timing Calibrations (2)

600MHz Clock

\(~34 \text{ ps RMS}\)

384.6ps nom.

Bin-by-bin

Bin width in Calibration File [ps]
MC study of Calibration Technique

\[ \sqrt{34^2 - 28^2} \]
\[ \approx 19.3 \text{ ps} \]

Estimated Limit
Timing vs Angle (with Impulse Calibration Radio Signal)

TX Up by 1.56 m

Vertical Angle Dependency

Jiwoo Nam
UC Irvine

TX Down

Face to TX

Horizontal Angle Dependency

Off by 1 Antenna

Impulse signal from Ground Calibration TX

dt\_expected = t1\_expected - t2\_expected

dt = dt\_observation - dt\_expected

expected time delay

\chi^2 / \text{ndf} = 22.1 / 6
\text{Constant} = 227.6 \pm 12.3
\text{Mean} = 1.434 \pm 0.094
\text{Sigma} = 0.07609 \pm 0.00229
Calibration with Realistic Signals

- Ice 80m thick and messy

Ground pulser

Bore hole pulser

Dipole
Validation data: borehole pulser

- RF Impulses from borehole antenna at Williams field
- Detected at payload out to 300-400 km, consistent with expected sensitivity
- Allows trigger & pointing calibration
Flies in space – all components heat sunk

(SURF = Sampling Unit for RF)
(TURF = Trigger Unit for RF)
After full calibration – 250 km downrange

A. Romero-Wolf
ANITA as a neutrino telescope
-- Initial Guesstimates

• Pulse-phase interferometer (150ps timing) gives intrinsic resolution of $<1^\circ$ elevation by $\sim1^\circ$ azimuth for arrival direction of radio pulse

• Neutrino direction constrained to $\sim<2^\circ$ in elevation by earth absorption, and by $\sim3-5^\circ$ in azimuth by polarization angle
Event Resolution – Borehole Pulser Reconstruction

- Better than design specification
- $< < 1$ degree inclination angle
- $< 1$ degree azimuth
- Likely to be physics (not electronics) limited

[J. Nam – UCI]
High Speed sampling – Other Applications

PMT pulse comparison

- 2 GSa/s, 1GHz ABW Tektronics Scope
- 2.56 GSa/s LAB

<table>
<thead>
<tr>
<th></th>
<th>LABRADOR</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling speed</td>
<td>1-3.7 GSa/s</td>
<td>2 GSa/s</td>
</tr>
<tr>
<td>Bits/ENOBs</td>
<td>12/9-10</td>
<td>8/7.4</td>
</tr>
<tr>
<td>Power/Chan.</td>
<td>&lt;= 0.05W</td>
<td>5-10W</td>
</tr>
<tr>
<td>Cost/Ch.</td>
<td>$10</td>
<td>&gt; 1k$</td>
</tr>
</tbody>
</table>
KEKB Upgrade Scenario

- $L_{\text{peak}}$ (cm$^{-2}$s$^{-1}$) $1.6 \times 10^{34}$, $467$ fb$^{-1}$
- $L_{\text{int}}$ $5 \times 10^{34}$, $1$ ab$^{-1}$
- $L_{\text{peak}}$ (cm$^{-2}$s$^{-1}$) $5 \times 10^{35}$, $10$ ab$^{-1}$

**Crab cavity**

14 months shutdown

**Super-KEKB** (major upgrade)

10 /ab comes on the horizon!

3x10$^9$ BB /year!! & also $\tau^+\tau^-$

**Projection of KEKB Luminosity**

- 2000
- 2002
- 2004
- 2006
- 2008
- 2010
- 2012
- 2014

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10

**Integrated Luminosity (ab)**

- 44 /ab/mo
- 52 /ab/mo
- 450 /fb/mo.
Requirements for the detector

Issues

- **Higher background (×20-50)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate (×10)**
  - higher rate trigger, DAQ and computing
- **Require special features**
  - low $p\mu$ identification $\leftarrow$ s$\mu$μ recon. eff.
  - hermeticity $\leftarrow$ ν “reconstruction”
Occupancy in Silicon Vertex Detector

152M $B\bar{B}$ pairs with SVD1
+ ~550M $B\bar{B}$ pairs with SVD2

Present: layer 1 of SVD
~10% occupancy / 200 Krad.yr$^{-1}$

Upgrade: $L \sim 1.7 \times 10^{34} \rightarrow L \sim 5 \times 10^{35}$ cm$^{-2}$s$^{-1}$

Background increase typ. X20-50, w/large uncertainties → Occupancy / dose

Conventional solutions (Si strips) do not work
Pixel Occupancy Scaling

- **Work from following assumptions:**
  - Super-B canonical x20 background increase
    - Assume 10% Layer 1 occupancy as “current”
    - Strip area (L1) = 85mm x 50μm = 4.25M μm²
  - Pixel spatial reduction:
    - Pixel area = 22.5μm x 22.5μm = 506 μm²
    - Reduction factor ~8400
    - Low E γ, reduced cross-section (~3% active thickness)
  - Pixel temporal loss:
    - 0.8μs SVD vs. 10μs PVD (could be improved)
    - Increase factor ~ 12.5
  - Grand total:
    - 10% * 20 * 8400⁻¹ * 12.5
    - Can expect ~ 0.3% occupancy (no ghosting)
Monolithic Active Pixel Sensor

**Current DSSD**

**MAPS**

**Key Features:**

- Thin
  - reduced multiple-scattering, \( \gamma \) conversion, background \( \gamma \) target
- NO bump bonding – fine pitch possible (8000x reduction)
- Standard CMOS process “System on Chip” possible

Because of large Capacitance, need Thick DSSDs -- APS can be VERY Thin
Continuous Acquisition Pixel (CAP)

Pixel Array: Column select – ganged row read

Array of 132x48 pixels

High-speed
analog
& storage

Low power – only significant draw at readout edge
Cont. Acq. Pixels (CAP) 1 Prototype

**CAP1: simple 3-transistor cell**

Pixel size:

22.5 μm x 22.5 μm

CAPs sample tested: all detectors (>15) function.

Source follower buffering of collected charge

Restores potential to collection electrode

132col*48row ~6 Kpixels

NIM A541:166-171 (2005)
Correlated Double Sampling (CDS)

Frame 1 - Frame 2 =

- Leakage current Correction

~fA leakage current (typ)
~18fA for hottest pixel shown

Hit candidate!
Mechanical alignment

~1mm x 3mm “rice grain”

Initial Det. /Det. correlations

Det.3 vs. Det.1
Det.3 vs. Det.2
Det.3 vs. Det.4

Improved correlations

L1 L2 L3 L4
beam

In X
Hit resolution measurement

Residuals for 4GeV/c pions: 
- <11μm (in both planes)
CAP2 – Pipelined operation

3-transistor cell in each cell
132x48 = 6336 channels
50688 samples

10μs frame acquisition speed achieved!

**CAP3**: Full-size Detector Test/Lessons learned

- 928 x 128 pixels = 118,784
- ~4.3M transistors
- 21 mm
- 20.88 mm
- >93% active without active edge processing

Laser scan bench

Laser spot (backside illumination)

- Noise:
  - Near end: 25 e-
  - Far end: 20 e-

- 1.1 e- per ADC count

- RMS x: 25.61
- RMS y: 24.09
CAP3: Laser Scan
Noise (ENC): Summary of MAPS

Noise Comparison

Equiv. Noise Charge [e-]

Total Number of Storage Cells

Unfortunately signal size
Fixed and small
SNR: Summary of Efforts

Comparison of Signal-to-Noise

SNR

CAP1  CAP2  CAP3  APS_LBL  MIMOSA I  MIMOSA II  p13umAmps  Nwell13um  MIMOSA8  Apsel 1  RAL_HEPAPS
CMOS Pixel Back-thinning (Battaglia et al LBL)

Program of back-thinning of diced chips using grinding process by APTEK;

Thinned over 15 chips, yield of functional chips ~90%, Process reliable down to 40 μm. Measured thickness of chips:

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>550 ± 0.5</td>
</tr>
<tr>
<td>“50 μm”</td>
<td>50 ± 7</td>
</tr>
<tr>
<td>“40 μm”</td>
<td>41 ± 6</td>
</tr>
</tbody>
</table>

Study change in charge collection and S/N before/after back-thinning: MIMOSA 5 sensors (1 M pixels, 17 μm, 18x18 mm² surface, AMS 0.6)

Feasibility of Back-thinning CMOS sensors demonstrated

**55Fe**
Determine chip gain and S/N for 5.9 keV X rays

**1.5 GeV e⁻ beam**
Determine S/N and cluster size for m.i.p.

![Graphs showing charge collection and S/N improvement before and after back-thinning.](attachment:image.png)
Readout Rate: Summary of Efforts

Fraction of Needed Readout Rate

SNR: thicker Detector

Readout Rate: true CMOS readout
**CAP4: 3 architectures in AMS 0.35um Opto**

- **Four different architectures**
  - Wilkinson Ramp transfer encoding
  - Mostly NMOS space-time encoding scheme (modest charge collection loss)
  - CMOS space-time encoding scheme (large collection efficiency loss)

- **Evaluations**
  - Speed
  - Uniformity
  - Evaluate space-time technique

- **Will apply lessons learned**
  - Next SOI run (CAP6/LCAP1)
OKI 0.15um SOI

- **Best of both worlds**
  - High resistivity, fully depleted detector (large signal)
  - Excellent deep submicron CMOS

- **Wafer bonding**
  - No bump bonding interconnects
  - Very low collection electrode capacitance

- **Rad hardness**
  - SOI known to be rad-hard
CAP5

- 108 x 34 pixels total structure (28.7 μm by 32.5 μm)
- 6 row testing structures introduced
- Use of CMOS circuits for all structures

Electrodenoise

\[ v_{noise} = \sqrt{\frac{kT}{C}} \]

\[ v_{noise\_Electrode} = 0.822 mV \]

\[ \Delta V = \frac{\Delta Q(1\mu s)}{C} = 0.151 V \]
CAP5: 2nd iteration in OKI 0.15um SOI

- **First submission**
  - Promise of better S, same N → better SNR
  - Many other groups (FNAL/BNL & LBL) subsequently join

- **Second submission**
  - 4x larger die
  - Study process spread
  - Evaluate space-time correlation

- **Will apply lessons learned**
  - Next SOI run (0.2um)
  - Thin devices to be proven
An IceCube UHE Radio Augmentation

- GZK neutrinos ($10^{17-19.5}$ eV), at lowest possible cost
  - Surface or shallow submerged array (60 or $\sim20$, costs similar?)
  - sparse, give up resolution for volume
- Hybrid events with IceCube
  - Primary vertex calorimetry in radio, HE muon or tau secondary in IceCube
Surface Station geometry
“mini ANITA” in ice

- Propose 12+2 antennas
  - 6 V pol 6 Hpol
  - Discones for Vpol
  - Batwings for Hpol
  - 5 m circle
  - 2.5m depth below gnd screen
  - Stacked in pairs for vertical resolution

- 15m Cu mesh ground screen
- DAQ & receivers in shielded boxes ~1.5m depth just above screen
- Also:
  - 1 monitor antenna above screen, but ~1m deep still
  - Pulser bicone at ~15m away, in 24” augered hole, 2.5-3m deep

24” diam holes
OK for both antennas
Station trigger multiplicity: IceRay

- At lower energies (<10^{18} eV), single station triggers dominate
  - ~10% 2-station hits for 10^{17}eV
  - ~60% by 3 x 10^{18}eV

- Higher energies, multiple stations triggers are common
  - Good stereo reconstruction on a subset of GZK neutrino events

- Actual 2^{nd} station hits will be higher if all stations are latched on each trigger
  - Can look deeper into noise

[P. Gorham – UH]
Particle ID – subthreshold detection

- Charged/neutral current & flavor ID enhanced with subthreshold samples
- Coincidence with optical (lower E threshold [PeV])
- Phased array – can push well down into the noise
- Challenge: for multi-k antenna array, multi-Terasamples/s
SuperB Barrel PID Upgrade

~1mm pos. resolution: 200 Ch/counter
*180 counters = 36,000 channels

~5mm pos. resolution: 40 Ch/counter
*200 counters = 1440 channels
Multi-hit (hidden cost) >1440 channels

~few mm x few mm: few kCh/counter
*~100 counters: few 100k channels
Buffered LABRADOR (BLAB1) ASIC

- 64k samples deep
- Multi-MSa/s to Multi-GSa/s
- 12-64us to form Global trigger
- Depth can be expanded

3mm x 2.8mm, TSMC 0.25um
Buffered LABRADOR (BLAB1) ASIC

- 10 real bits of dynamic range

Measured Noise

1.4mV measured noise

1.8V dynamic range

Table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCK w/ CMPBIAS</td>
<td>200 kohm</td>
</tr>
<tr>
<td>Entries</td>
<td>1024</td>
</tr>
<tr>
<td>Mean</td>
<td>1.452</td>
</tr>
<tr>
<td>RMS</td>
<td>0.1373</td>
</tr>
<tr>
<td>Constant</td>
<td>181.6 ± 7.6</td>
</tr>
<tr>
<td>Mean</td>
<td>1.446 ± 0.004</td>
</tr>
<tr>
<td>Sigma</td>
<td>0.1316 ± 0.0037</td>
</tr>
</tbody>
</table>
BLAB1 Analog Bandwidth

- A few fixes (lower power, higher BW)
- BLAB2 [when find support]

-3dB ~300MHz
BLAB1 Sampling Speed

Can store 13us at 5GSa/s (before wrapping around)

Single sample: 200/SQRT(12) ~ 58ps

But, have Complete Waveform Information
125MHz sine wave

Voltage (mV)

Pre-calibration

6GSa/s

time (ns)
Typical single p.e. signal [Burle]

Due to higher bandwidth, "warts" of signal appear.

Overshoot/ringing
Calibration (1)

400MHz sine wave

6GSa/s

Linear variation across chip
Due to IR drop in feed voltage (can be improved)

Storage Cell Number

| Cycle interval | | |
|----------------|----------------|
| Entries        | 470            |
| Mean           | 253.4          |
| Meany          | 2.482          |
| RMS            | 137            |
| RMSy           | 0.04398        |
After basic linearity and bin-by-bin correction
~11ps intrinsic (~8ps possible)

Extracted Period [ns]
~30ns pulse pair

6GSa/s

~27ps for two edges
~20ps for each edge

~40ps for PMT like Signals (working on algorithm)
Temperature Dependence

Sample aperature (172ps = 5.8GSa/s)

0.2%/degree C (can correct)

Matches SPICE simulation

y = 0.4378x + 160.84
R^2 = 0.9991
Interleaved Operation

**LARC ASIC:**
64 chan @ 5 GSa/s = 384GSa/s

⇒ Streak camera type applications – ps timing

- Single shot!
- uncalibrated
- room for improvement
- push BW higher
f-DI RC Array Concept

Many k Photodetector channels

SBIR Phase 2 to develop 1k channel (Si-APD) readout
Summary

Exciting ASIC developments enabling next generation HEP and Astroparticle Experiments

- Tera-ton GZK neutrino detector
- Pixel detector for Super-B and ILC
- Time resolved single photon detection (deep storage, PET, LIBS)
Back-up slides
ANITA flight path

- 35 days, 3.5 orbits
- Anomalous Polar Vortex conditions
- Stayed much further “west” than average
- In view of stations (Pole & MCM) ~30% of time

About 8.2M Triggered Events logged
Flight sensitivity snapshot (preliminary)

- ANITA sensitivity floor defined by thermal (kT) noise from ice + sky
- Thermal noise floor seen throughout most of flight—but punctuated by station & satellite noise
- Significant fraction (>40%) of time with pristine conditions

$T \approx 50K$ (Sun+Gal. Center)
$
\overline{T}_{\text{ant}} \approx 200K
$

- $T$ anti-correlated to altitude:
  - higher altitude at higher sun angle
  - sun+GC higher $\Rightarrow$ farther off main antenna beam
ANITA Level 1 – 3 of 8 Antenna

Plot of Frequency versus Signal Power to the Tunnel Diode input for SHORTv2.

- Input Signal Power to Tunnel Diode (dBm)
- Frequency (MHz)

Filters:
- Y pol
- H pol
- LCP
- RCP

- 8 Trigger bits to Global Trigger

- Filter Banding [MHz]
  - f_c = 156, BW = 113
  - f_c = 402, BW = 177
  - f_c = 618, BW = 277
  - f_c = 913, BW = 433

Legend:
- RF/CM frequency Output Curve
- SHORTv2 Low Filter
- SHORTv2 Mid #1 Filter
- SHORTv2 Mid #2 Filter
- SHORTv2 High Filter
Diode detector Response

$2.3\sigma \approx 3.9 \frac{P}{\langle P \rangle}$

Tunnel Diode Output Single Channel Trigger Rate

Needs amplification!
ANITA local trigger

- Multi-band triggering essential to ANITA sensitivity
- Methods proven by FORTE, GLUE experiments
- Exploits statistical properties of thermal noise vs. linear polarization for signal
- Signal: most or all bands;
  noise: random
- all 8 shown here -- 3 of 8 is found to be enough
SURF High Occupancy RF Trig (SHORT)

For each band:

Tunnel diode + Amps

Filter banding (both sides)

Tunnel Diodes

SHORT

thresh

To 3-of-8 logic

On SURF
Threshold Scan

Notes:

1. Due to Stuck-on detect circuit
2. Deadtime for 1/f !< 12ns
3. Threshold zero is arbitrary
Some Channel-channel variation

Ch. 9

Ch. 11
Test Set-up

- RF Pulser
- Combine pulse signal onto thermal noise (300K)
- 4x RFCM = 4 Antennas (32 channels)
- SHORT boards (in boxes)
- SHORT Signal cables
Single-band efficiency

![Graph showing the relationship between Single Band Trigger Efficiency [%] and Threshold Voltage [mV]. The graph displays a sharp decline in efficiency as the threshold voltage increases.]
Single-band efficiencies

Ch. 9

Ch. 11
Efficiency versus Singles Rate

SNR ~ 4.1 +/- 0.2 σ

12ns discrim. width

Singles Trigger Rate [MHz]

1MHz

2MHz

SurfV3 Board 0
Entries 500
Mean 11.81
Meany 86.08
RMS 7.562
RMSy 23.33
Efficiency versus Singles Rate

Ch. 9

Ch. 11
Trigger Reduction

Raw Signals

Level-1
Antenna
3-of-8

Level-2
Cluster
2-of-5

Level-3
Phi
2-of-2

Prioritizer
(+compress)

Few events/min TDRSS

Few kHz
@ 36kBy/evt
= 36-72Mby/s

5-10Hz
@ 36kBy/evt
= 180-360kBy/s

To disk

100-200kHz
@ 36kBy/evt
= 3.6-7.2Gby/s

80 RF channels
@ 1.5By * 2.6GSa/s
= 312 Gbytes/s
Viewing Impulsive Events with ANITA Viewer
T-486 [Ice!]
ANITA on the End Station A beamline (June 2006)

- 32 QR horns
- 4 discones
- 4 bicones
- 8 monitor antennas
- 72 (288) channels RF digitizer & 256 channels trigger (self-triggered)
- Ethernet/LOS Tx only
The ANITA Payload

- VETO antennas
- GPS antennas + TDRSS & Iridium antennas
- CSBF omni-directional solar array
- Two 8 Seavey horn clusters
- Battery enclosure
- ANITA electronics
- 16 Seavey horn cluster
- ANITA omni-directional PV array
- SIP
1. 1st measurement of the Askaryan Effect in Ice
2. Calibration of the ANITA experiment with 28.5 GeV electrons
3. EM shower max ~ 2m inside 7 tonne ice target
4. Examine effects of surface roughness
5. 1 week of live-time
**Askaryan effect in ice**

- Impulses are band-limited, highly polarized, as expected

- Very strong--need 20dB ‘pads’ on inputs--signals are +95dB compared to Antarctic neutrino signals, since we are much closer
Life in Payload Bay 1

• Barely fit out door
• Room dropped 45C in 30 s
• 4-5 hours to recharge
• Go outside to warm up
Key Instrument pieces

- CSBF
- CIP
- Battery box
- Instrument box
RF Coherence vs. energy & frequency

- Much wider energy range covered than previously: 1PeV up to 10 EeV
- Coherence (quadratic rise of pulse power with shower energy) observed over 8 orders of magnitude in radio pulse power
- Differs from actual EeV showers only in leading interactions ==> radio emission almost unaffected
Sealing the DRM

Antennas

ROBUST

TRACR

DOM-MB

Metal Plate

DRM electronics

Surface Test

Metal can / w' electronics
CAP5

BINARY READ OUT

Per row:

X[j]

External Pipeline (length set by trigger latency):

At trigger latency time, A&B = 1 @ X[j]
CAP5

1 pixel simulation

6 pixel simulation

Voltage (V) Vs Voltage (mV)

Phase 1

Phase 2

Phase 3

Phase 4

Pixel

vthreshold

LeftOut

RightOut

LeftOut

RightOut
Vacuum MCP-PMT Issues

- lower Q.E., fill factor
- High voltage operation, longevity
- High density packing
- Magnetic field effects
- Irreducible Manufacturing Costs

How to get to a large system?

- SBIR with LightSpin Technologies
  - Proprietary Solid-State MCP demonstrator (1 x 1024)
  - No HV, high Q.E. (200 – 900nm!!)
  - Lower dark count rate than Si-PM
  - Mate with BLAB variant, determine timing resolution