Instrumentation Development Laboratory: An Introduction

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For the gang
May 2004
Announcements

• **Introductions:**
  – Introductions during/and at the end

• **Facilities**
  – Going to be crowded – Physics expanding

• **Answering phone**
  – Instr. Dev. Lab “ID Lab”
  – If nearest person, please answer
  – If person not available, please offer to take a message
Main Projects

Accelerator based:
Precision Measurement

Non-accelerator:
Highest energies

Search for new physics:
Cutting-edge of exploring our universe
Why are we here?

People have long asked,

"What is the world made of?"

and

"What holds it together?"

See Previous Talk Posted on Web Page
For further background
And everything between...
Belle Experiment at KEK

- Tsukuba Science City
  - About 60km from Tokyo/airport
Belle Experiment at KEK

• KEK:
  – Kou-Enerugii butsuri-gaku Kenkyuu-jyou (now even longer)
KEK-B Accelerator
World’s highest Luminosity Collider!!

Daily luminosity: still increasing!

Exceeded $10^{34}$
A Holy Grail for Accelerator Physicists

Can repeat in 10 days what it took CLEO 10 years of hard work to measure
Belle Experiment at KEK

- Belle isn’t an acronym:
  - Beauty in French – studying b quarks
    (also called bottom)
The **Belle** Collaboration

*A World-Wide Activity Involving ~50 Institutions*

- SVD Group
  - Frankfurt
  - U. Hawaii
  - Kanagawa U.
  - KEK
  - Krakow INP
  - U. Melbourne
  - National Taiwan U.
  - Niigata U.
  - Osaka U.
  - Princeton U.
  - U. Sydney
  - Tohoku U.
  - U. Tokyo
  - Tokyo Inst. Tech.
  - Tokyo Metropolitan U.
  - U. Tsukuba
  - Vienna

- **~300 members**
Detector

Belle Detector

- SC solenoid
  - 1.5T
- CsI(Tl) $16X_0$
- TOF counter
- 8GeV $e^-$
- 3.5GeV $e^+$
- Aerogel Cherenkov cnt. $n=1.015\sim1.030$
- Tracking $+dE/dx$
- small cell + He/C$_2$H$_5$
- Si vtx. det.
  - 3 lyr. DSSD
- $\mu/K_L$ detection
  - 14/15 lyr. RPC+Fe

Instrumentation Dev. Lab Meeting – May, 2004
Example Event

Rare decay: $B^0 \rightarrow \pi^+\pi^-$
Many Important Results!

• Discovery (w/BaBar) of CP-violation in the B-system
  – Expected, but large and clean
  – CP-violation in Kaon system tiny

• Recent first observation in $B \rightarrow \pi \pi$
  – Detector working well, but already starting to think of the future
  – Incremental Detector improvements
  – Seriously higher luminosity needed to probe non Standard-model effects – upgrade of accelerator and detector

>90 papers in last 2+ years & more pending
Belle Mission

• Observation of CP violation in B decays
  – Achieved in 2001
• Observation of direct CP violation in B decays and other parameters of CKM matrix
  – by 2006 with the gradual improvement of KEKB
• Explore New Physics beyond the Standard Model
  – off-diagonal elements (e.g. study of SUSY breaking)
  – need much higher luminosity

Our Focus Now
Occupancy issues

Pixel for $R < 3\text{cm}$
Pipeline for $R < 10\text{cm}$

Trigger simulation study desirable

Large ambiguity even with dedicated simulation. Need to be conservative.
IR upgrade

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Proper-time difference ($\Delta t$)

$e^-$: 8.0 GeV
$e^+$: 3.5 GeV

$\Upsilon(4S)$
$\beta\gamma \sim 0.425$

$\Delta z \simeq c \beta\gamma \tau_B \sim 200 \, \mu m$

Flavor tag

$\Delta z = \frac{\Delta z}{c \beta\gamma} \cdot \Delta t$

Resolution
CAP1/2 Prototypes

- TSMC 0.35\(\mu\)m Process
  - High speed framing:
    - Target 10\(\mu\)s latency
  - Pipelined readout
  - "slow" RO resolution ~ 2\(\mu\)m
  - CAP2: mini-pipeline in each cell
  - 132x48 (22.5\(\mu\)m\(^2\) pixels)
  - MIMOSA expectation ~ 2\(\mu\)m
Prototype Test Bench

Jim’s the guy

Marlon Testing

Larry, Marlon & Gary to beam test at KEK on Friday
High Luminosity!

At $L = 10^{35}$ cm$^{-2}$/s:
- Pipelined readout:
  128k channels equiv., 40MHz x 2bytes

  **10 Tera-bytes per second!**
  (10,000 CDs per second)

  →

  Global Decision logic trigger: 10kHz
- FIFO: 128k channels equiv., 16 bytes

  **20 Giga-bytes per second!**
  (200 GbE links)

  ← COPPER, online Farm

  **200 Mega-bytes per second!**
  (max. data rate to tape)
Common Electronics

- COPPER (CCommon Pipelined Platform for Electronics Readout)
- Card ~ crate – aid in data reduction
- On board data reduction

(Bin is Working On)
CuEval FINESSE

- Front-end INstrumentation Entity for Sub-detector Specific Electronics

- 480 Mbps USB2.0
- Dual 128kB RAM
- COPPER Interface

Hardware “ready” – Bin working on firmware
2004 Hawaii FINESSE Efforts

- CuEval2

- HPTDC

- STRAW3/LABRADOR

- COPPER platform deployment
The Flux Problem

- At $E > 10^{21}$...
- Life is tough

$$\iiint d\rho d\phi d\theta$$

$r, \phi, \theta$
Antarctic Impulsive Transient Antenna (ANITA)

- **ANITA Goal**: Pathfinding mission for GZK neutrinos
- **NASA SR&T funded since October 2002, upgraded to SMEX recently, launch in 2006**
ANITA concept

Antarctic Ice at $f<1\text{GHz}, T<-20\text{C}$:

- Lossless RF transmission
- Minimal scattering
- Largest homogenous, RF-transmissive solid mass in the world
ANITA-lite (prototype)

RF test flight in Dec–Jan 2004 equipment to Texas in July

Jim, Mary & David assy.
ANITA-lite as-built Configuration

Electronics integration into pressure housing

Antenna arrangement

Instrument housing under TIGER

Housing, hard drive, veto antenna

Redundant fast-recovery USB harddrive (8GB)

A team effort! Hawaii dominated
Launch!

Jason’s 2nd successful launch
Online Data via Satellite

Nice job Ped!
The Game

- Significant signal power at large frequencies
- No commercial solution – too much power/cost
- All noise all the time (thermal noise limit)
STRAW\textsuperscript{2} Chip

Self-Triggered Recorder Analog Waveform (STRAW)

16 Channels of 256 deep SCA buckets

Optimized for RF input Microstrip 50\,\Omega

Target input Bandwidth: >700MHz

Record length: 128-256\,ns

Die: \sim2.5\,mm\textsuperscript{2}

DACs

ADC

8192 analog storage cells

Self-Triggering:
- LL and HL (adj.) for each channel
- Multiplicity trigger for LL hits

On-chip ADC:
12-bit, >2\,MSPS

Sampling Rate:
1-3\,GSa/s (adj.)

Sampling Rates
\sim8\,GSa/s possible w/ 0.25\,\mu m process

External option:
MUXed Analog out

Under Test
DALI Rev. B Evaluation

Delay lines for interleaved sampling

STRAW2 chips

Uncalib.

Team effort: Jim, Larry, Mavourneen; Tina, Ped
Updated August ’03 Baseline
RFCeval – 0th order prototype

Quick Reference:

• RFCeval == Radio Freq Comp evaluation board
• STRAW == Self-Triggered Recorder for Analog Waveforms
• LABRADOR == Large Analog Bandwidth Recorder And Digitizer with Ordered Readout

• Bryan – servo-loop/trigger studies
Bandwidth Limitation Analysis

Simulate Waveform Acquisition

Jing will study

Value from transient analysis

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Cosmic-ray Radio Testbed

Testbed goals:
- Detect first Askaryan signals of cosmic origin
  - Use (rare) multi-TeV muon or single hadron showers
  - Scintillation counter trigger provides particle tag
  - 48 channel digitization via time-multiplexing
- Development of large-scale DAQ needed for full-scale detector
  - ~200 total antenna signals present

Operational since early 8/03
- Data analysis tried...

DALI upgrade – a team effort
Antenna testing and development

- Anechoic test chamber
- Up to 400 lb embedded salt stack

- PCB antenna development
  - Muon test chamber
  - SLAC T460
Horn Antenna Prototype

Dan Yi
Natural Salt Domes: Potential PeV-EeV Neutrino Detectors

- Natural salt can be extremely low RF loss:
  - as radio clear as Antarctic ice
  - ~2.4 times as dense

- typical salt dome: 50-100 km$^3$ water equivalent in top ~3km

Qeshm Island, Hormuz strait, Iran, 7km diameter salt dome

Caprock visible from space

Isacksen salt dome, Elf Ringnes Island, Canada 8 by 5km
GEISER Success

- Gigabit Ethernet Instrumentation for SalSA Electronic Readout
- David, Laine and Chaopin
- Prototype of real system – what better way to gain experience
  - Much better than some bogus R&D (Research and Disposal)
  - It works, prototype for SalSA

Chaopin, Arttu, Marko and Tero
Working on Upgrade for Prototype Deployment – Dec 2004
Documentation

• With so much going on – critical to document

• Marcus has done a great job, scope has expanded → Yihong

• Have expanded the “People” section to include bios and work experience

  • This can be a very nice pointer to work experience in your future

  • I routinely get asked for recommendations and it is useful to have something in the public domain

http://www.phys.hawaii.edu/~idlab
Publications

- Many of the projects are of great interest to outside groups
- GEISER paper draft available – 3x IEEE NSS papers 2004 - Rome
- Continually getting reminded to publish this stuff

Excellent opportunity:

- This can be a very nice pointer to work experience in your future
- If interested in an academic career, such publications are invaluable
- With students coming and going, a natural way to provide continuity for ongoing efforts
- DALIREVB, STRAW, and LABRADOR papers
- RF pocket pulser (Larry)
Cross-Training

- Thanks!
- Lab Interaction
  - Encourage you to learn about what each other working on
  - Very useful to be able to share ideas
- Lab Basic Training
  - General Lab procedures (notebook, documentation)
  - Electronics (handling, reading schematics, parts id)
  - Soldering and hand wiring
  - Computer usage
  - Clean room (wire-bonding, materials handling)

I will be away May 28 – June 18:
If stuck on a project, good time to receive additional training and learn new tools and skills
Preview of Coming Attractions

- **Ongoing projects**
  - Student Opportunities!! Tell your friends
  - **Success depends on you**

- **Other opportunities**
  - Jr./Sr. research projects [e.g. GEISER]
  - Directed study
  - Publications (NIM/IEEE articles for CAP, GEISER, STRAW2...)
  - Board/firmware/chip design (this summer)
  - Many designs in queue; CDF, COW, MTS2, SalSA, and pixel chips
    - Design, layout, simulation and test opportunities

Thoughts on how to improve things always welcome
Back-up slides