BTeV Detector Elements and Front End Electronics
(a quick review)

David Christian
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The BTeV Detectors

- Silicon pixels
- Forward tracker = straw chambers and silicon strip detectors
- Muon chambers
- RICH photo detectors
- Electromagnetic calorimeter

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David Christian p2
Cross Section of a Muon Tube

3/8" (~9.5mm) Diameter Stainless steel Tube filled with Gas.

Small diameter (30µ) gold-plated Tungsten wire Biased at +HV.

Charged particle leaves a Trail of ionized gas; electrons drift to wire... cause an avalanche (gain ~few x 10⁴). Smallest signal ~ few x 10⁵ e⁻.

~300 Ω

~100 kΩ

To amplifier

+HV

(Optional termination)
Muon chambers: ~80K channels

Front-end = U. Penn. ASD (ASDQ designed for CDF COT) “Amplifier Shaper Discriminator”

Latch/zero suppression/r/o not yet defined? --- proposal says serialization is at the octant level.
A close up of prototype muon tubes.

Each station contains 4 views with 2 (offset by ½ diam) tubes per view.
We've performed some tests on a new improved plank. The stainless tubes are soldered in, the endplates are “tight” in an EMI sense, the tubes are terminated, our amplifying and discriminating electronics (which is a card using the 3 ASDQ's from the COT electronics at CDF) are shielded, and our readout is done using simple twisted flat.
4mm diameter Straw tube filled with Gas (Inside of tube is aluminized – & has a protective overcoat)

Charged particle leaves a Trail of ionized gas; electrons drift to wire… cause an avalanche (gain ~few x 10^4)

Leading edge timing can be Used to infer distance of closest Approach to sense wire (TDC)

Small diameter (20µ) gold-plated Tungsten wire Biased at +HV.

Pulse response

To amplifier

~300 Ω

~100 kΩ

Cross Section of a Straw Tube

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Straw Chamber – Baseline Design

- Wire readout at both ends
  (glass bead at center)
- 3 layers per view
- 3 views per station
- >66000 straws in total

ATLAS TRT straw cutter
Straws:

Development effort recently reorganized.

Proposal calls for use of U.Penn. ASD, but does not specify which one. Choices include ASDQ, made for CDF COT in Maxim Cp, & ASDBLR, planned for ATLAS TRT – being prototyped in DMILL.

Requirement for TDC is “easy,” but no existing TDC can be read out fast enough for BTeV.
Silicon Strip Detectors

• Near the beam pipe, the density of tracks is too high for straws to handle (occupancy, radiation damage)

• Central 24 cm x 24 cm (OR MORE???) will be covered with SSD’s (central hole for the beam pipe)

• 100 µm pitch ➔ No problem with high occupancy (40x straw tube segmentation)
Silicon Strip Detectors
(side view)

~300µ thick n-type Si
(very high resistivity)

n+ (contact)

p+ implant (back-biased pn junction)

Polysilicon resistor used to bias strips

Glass layer

To amplifier

GND

Metal

Charged particle creates ~24000 e-hole pairs; holes drift to p+ strips, electrons to n-side.

+V (up to ~500V)
Silicon Strips:

Front end chip: to be designed & fabricated by Milano. baseline = AC coupled single sided sensors binary readout as similar to pixel r/o chain as possible.
Hybrid pixel detectors

- Sensors & readout “bump bonded” to one another
- Principle of operation is similar to SSD’s – same signal (less noise)

![Diagram of Readout chip and Sensor]

FPIX1 bonded to ATLAS test sensor

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FPIX2 Roadmap

- 0.25µ CMOS
  - (5 metal [6 possible], 2.5V)

- Design for 2 vendors ("lowest common denominator" design rules):
  - "CERN" – Very favorable contract, but problems with US Gov. restrictions
  - Taiwan Semiconductor Manufacturing Corp (TSMC) – Available through MOSIS

- **PreFPIX2-T (1999)** TSMC 0.25µ CMOS
  - New analog front end, with new leakage current compensation strategy
  - 8 comparators per cell (3-bit FADC); no EOC logic included
  - Array size = 2 x 160
  - Bench tests (radiation exposure)

- **PreFPIX2-I (2000)** “CERN” 0.25µ CMOS
  - Same front end
  - Complete “core” – including new, simplified EOC & R/O (self-triggered only)
  - Array size = 18 x 32
  - Bench tests

- **PreFPIX2-T2 (2000)** TSMC 0.25µ CMOS (submitted; due back in early December)
  - New programming interface
  - Internal DAC’s – no external currents required; only external voltages are 2.5V & ground.
  - Array size = 18 x 64

- **FPIX2 (2001)** 0.25µ CMOS - Final BTeV R/O chip!!??
A charged particle traveling faster than the speed of light in a medium (e.g. a gas) emits light at a characteristic angle (an electromagnetic shock wave) --- This is Cerenkov light.

Light rays focused into a ring at the image plane of the mirror – ring radius is a function of the Cerenkov angle.
Baseline Cerenkov Photodetector = Hybrid Photo Diode:
vacuum device consisting of:
• photocathode on inside of vacuum window
• 20 KVolt accelerating potential
• silicon pad detector in vacuum
• signal = \( 1 \gamma \rightarrow 1 \text{e}^- \rightarrow \)
  \( (20,000 \text{ eV}/3.62 \text{ eV per e-h pair}) \) – charge loss \( \approx 5000 \text{ e}^- \)

Baseline = DEP HPD w/163 channels per tube
(front end chips outside of vacuum).
The BTeV Electromagnetic Calorimeter

Lead tungstate crystal:
- Very dense (showers don’t spread – allows high segmentation)
- Radiation hard
- Fast scintillator

Electromagnetic shower:
\[ \gamma \rightarrow e^+e^-; e^-N \rightarrow e^-\gamma N; \gamma e^- \rightarrow \gamma e^-; \ldots \]
Each electron deposits energy in the crystal, some of which is transformed into scintillation light & detected by the photo multiplier tube.

~10 pe’s per MeV (incident) into a 2” pmt

Traditional (low gain) base (voltage divider)
EMCAL

~24K Lead-tungstate crystals coupled to PMT’s QIE’s located outside of high rad area

Don’t know where zero-suppression occurs.
Possible commonality:

- Pixels/SSD’s: Chip control, I/O specs
- Straws/Muon: ASD’s
- RICH/Muon: Latches, zero suppression method
- More???