R&D of Scintillating Fibers for Intermediate Tracking and Bunch Id

OUTLINE

- Brief outline of the problem
- Current status, progress
- Future plans

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Effects of Bunch Overlap

NLC/JLC Bunch Structure:

(not to scale!!) 192 bunches

- Many bunches per train
- Trains at 100–120 Hz, msec between trains
- 1.4 nsec spacing between bunches
- High luminosity per bunch

\[ \mathcal{L}_{\text{bunch}} \sim 1.0 \text{ fb}^{-1} \]

Problem: Physics process with largest cross section gives largest contribution to event-event overlap

- Multiple bunch collisions within the integration time of detector components (same luminous region in z, slightly out-of-time depending on bunch)
- E.g., hadronic two-photon events overlapping with physics events of interest. Have studied in past effects of overlap on Higgs topologies with missing energy (e.g., via WW fusion)
- Multiple interactions in single bunch (but not spread out in z like at Tevatron!)
- Hadrons from \( gg \) interactions of the beamstrahlung photons
Bunch Id via Track Timing

- Scintillating fiber tracker, $\Delta t \sim 1$ nsec system wide should be possible, resolve single bunches, R&D on appropriateness as external device for timing
  
  "Strawman" for L detector:
  Two axial layers, two 3 degree stereo layers
  Half-length of 29.5 cm, average radius of 48 cm
  (mounted on inside of inner support structure of TPC)
  ~15,000 channels [or in a silicon detector]

- Single-hit resolution of 80–100 μm, has been checked using Bruce S.'s LCDTRK code that extra material does not degrade impact parameter resolution
detector simulations, adding 0.7% $X_0$ at this radius; extra material, but more measurement points

almost a "wash"; at least no degradation (same is true for impact parameter resolution)

For 0.835 mm diameter fibers, tweaking for getting more light (for better time resolution, see later) increase to 1.00 mm diameter fiber: 18% degradation in momentum resolution at $p_T$ of 1 GeV compared to no intermediate tracker (more material, fewer measurement points, reduced single point resolution)

To do: check having only two axial layers to reduce material, also effects on pattern recognition
- Largest effects on channels involving invisible energy and missing mass
  - e.g., measurement of WW-fusion production cross section: $\mathcal{B}(\mathcal{W}h)$:

  ![Graph showing comparison of simulated data and events with overlapping events](image)

  - Potentially large relative systematic effect (use same templates, 2.0% effect) if background level not known well,

  - Contributions $\sim 60\%$ charged particles, $\sim 40\%$ neutrals for $\cos(\theta) < 0.97$ cut

  Changes depending on forward tracking and forward calorimetry,
  - want timing in forward region too

  - TPC still has decent timing (Ron: track-vertex mismatch in $z$, to 1–2 nsec) integrates over a few bunches.

  Maximum impact of above overlapping multiple events with Poisson distribution still need to be done (also, JLC CDC, time stamp to 3 nsec) (silicon drift)

Combine with scifi
People

- Indiana University
  
  RvK (faculty),
  50% postdoc (other 50% D0),
  existing IU postdoc, new starting Fall 2003
  Keith Turpin (undergrad)

- University Notre Dame

  Mike Hildreth (faculty),
  Other ND expertise: Randy Ruchti (faculty)
  Mitch Wayne (faculty),
  Jadzia Warchol (research scientist),
  Barry Baumbaugh (engineer)

- Fermilab

  Alan Bross (staff physicist)

Funds

- Received as part of DoE supplemental grant to our usual operating grant
  (Spring 2003, funds available 1 May in account)
End on view of scintillating fiber ribbon

- 0.835 mm diameter multiclad polystyrene fibers, 1% PTP flourer and 1500 ppm 3HF wavelength shifter

- Curved 256-fiber ribbon (shown, used in D0 fiber tracker), curved 128-fiber ribbon, flat 128-fiber ribbon (make additional for testing different fibers)

Mates with clear fiber matching connector
Visible Light Photon Counter

- Solid state photomultiplier
- Gains of ~40–50,000
- Quantum efficiency ~80%
- ...but needs to be run at LHe temperatures (< 10 K), cryostat:
Carbon Fiber Cylinder for sci. fiber ribbon mounting

Plans for hardware modifications & orders started

Also piggyback on to existing effort at FNAL to use fast timing info for z position measurement in D0 fiber tracker

MCMII & "Trip Chip", TAC and discriminators, suggest ~2 nsec resolution reading out only one end, modify to readout both ends

Event display, Mayorov, former IU postdoc
- Also, resurrecting simpler X-ray source test setup used in previous timing studies

Engineering started on replacing with faster preamp electronics
- Generate photons throughout scintillating fiber, ray-trace down the fiber and clear fiber

- Photons generated with an exponential time distribution corresponding to scintillator/wavelength decay time

- Photon yield Poissonian, corresponding to scintillator/wavelength shifter characteristics, includes attenuation length down fibers

- Time difference between first detected photon at each end (including clear fiber); i.e., includes quantum efficiency (80% for VLPC)
- Time dispersion due to different path lengths not dominant (since higher-order modes attenuate away faster)

- Depends more on light decay time and no. photoelectrons
All with $\bar{t}_{dec} = 8 \text{ nsec}$ (DØ fibers, $\bar{t}_{dec} = 8.2 \pm 0.2 \text{ nsec} \text{ [Bross]})$.

- **Increase**
  - Increased light yield of scint./shifter combo
  - Shorter (clear) fiber runs

All with mean no. photons = 10
More Light

- Shorter clear fiber runs
- VLPC's require large physical cryostats
- multi-anode PMT's (closer in) instead? trying a 4 x 4 Hamamatsu PMT, also evaluate 64-anode PMT (but lower Q.E.)

Brighter, faster fibers

- Notre Dame & Fermilab on SBIR and STTR projects collaborating with Ludlum Corp. and Penn to produce new dyes with larger light-yields and faster decay times
- Being fabricated into 0.8 and 1.0 mm diameter fibers, use for testing and comparison to MC predictions
Summary

- Started on hardware setups for tests
- MC timing simulation predictions have been made to compare to results
- Need to return to impact of track timing on physics studies; help and others welcome!

Future (following years)

- R&D for integration with a TPC / silicon detector
- Collaboration with calorimeter groups? (e.g., silicon/tungsten calorimeter, time resolution of ~10 nsec...) Embedding of scintillator fibers into calorimeter systems – precise timing of neutral clusters also