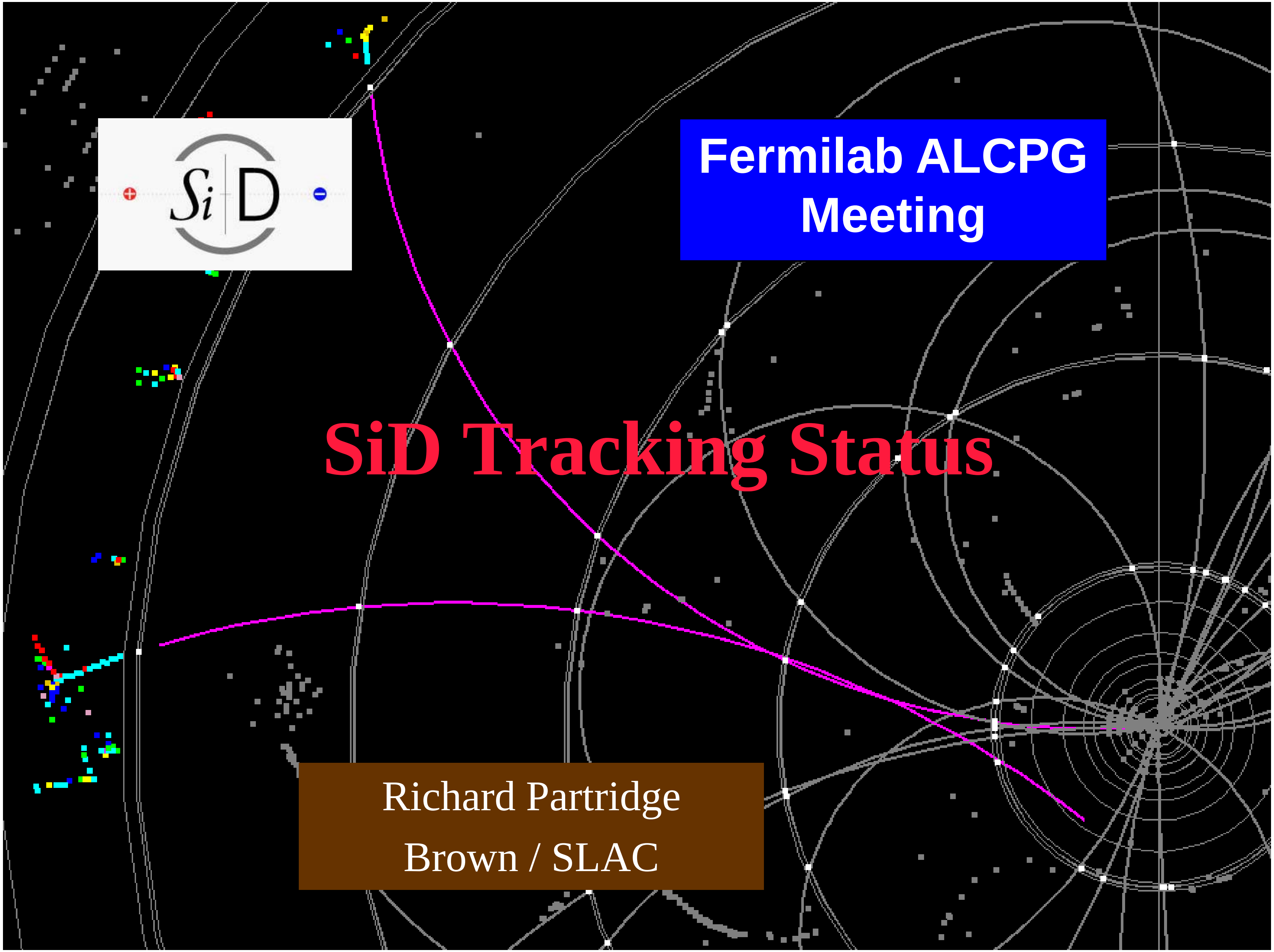
Fermilab ALCPG Meeting

SiD Tracking Status

Richard Partridge
Brown / SLAC

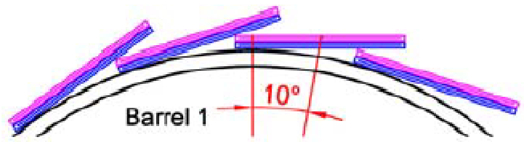


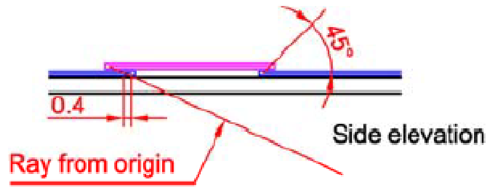
Overview

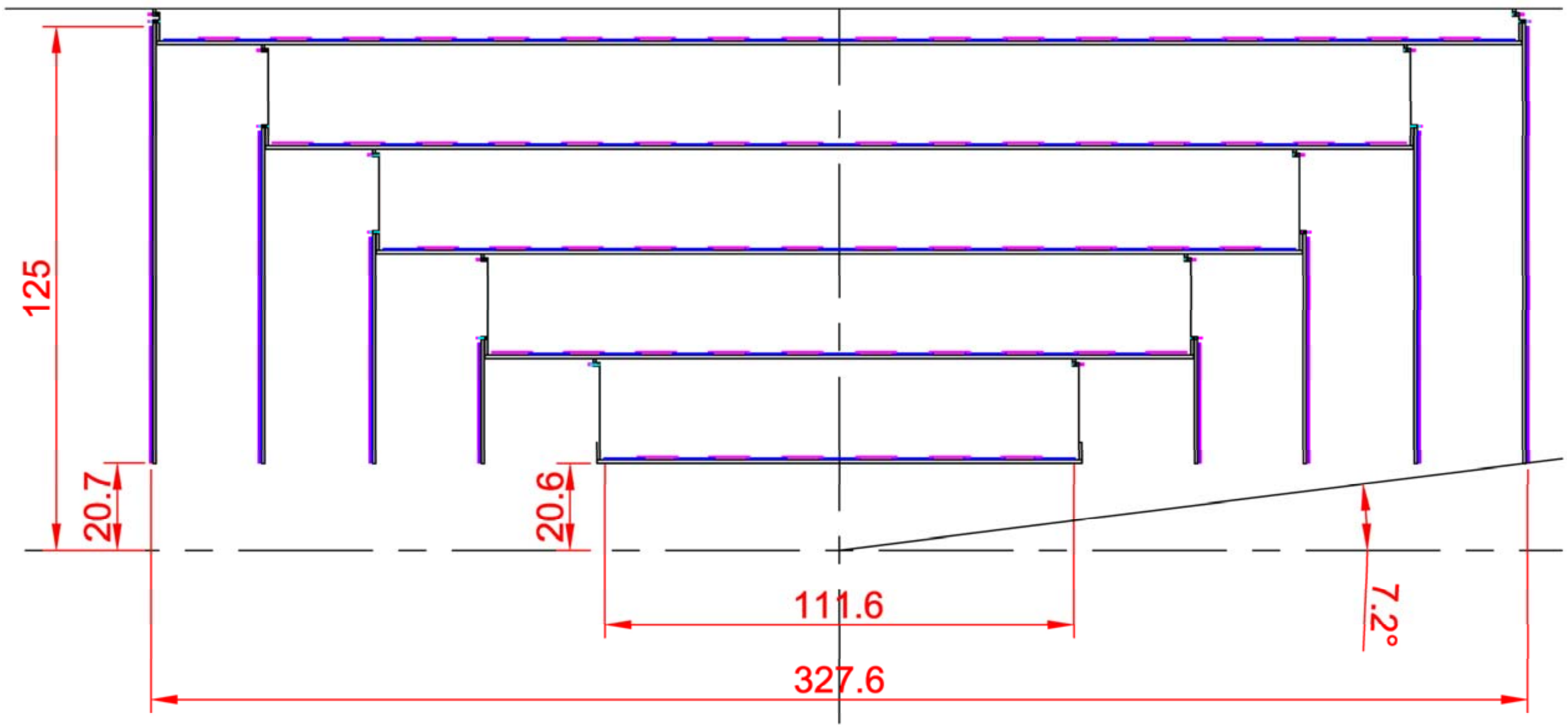
- An all-silicon tracker is a distinguishing feature for SiD
  - Silicon pixel vertex detector
  - Silicon strip outer tracker
- Many advantages to our choice
  - Superior momentum resolution where it matters (i.e., high p_T)
  - Low occupancy, excellent 2-hit resolution allows efficient tracking in dense jets
  - Single bunch timing minimizes effect of machine backgrounds
  - Si strips $\Rightarrow$ compact tracker $\Rightarrow$ 5T field $\Rightarrow$ reduced VTX inner radius
  - Highly integrated tracker design with excellent forward tracking capabilities
  - Mature and proven technology
- …and a few areas where brand X may have an advantage
  - A TPC will probably be better at finding tracks from K_S / Λ decays and kinks
  - A gaseous tracker will probably have less material in the central tracking volume
  - TPC provides particle ID at low momentum
  - Does any of this really matter for the ILC physics program?

Baseline Tracker Layout

- 5 barrel layers of axial strips
- 4 forward disks / end with stereo strips
- Pin-wheel design with z overlaps
- Carbon fiber/rohacell support cylinders/disks

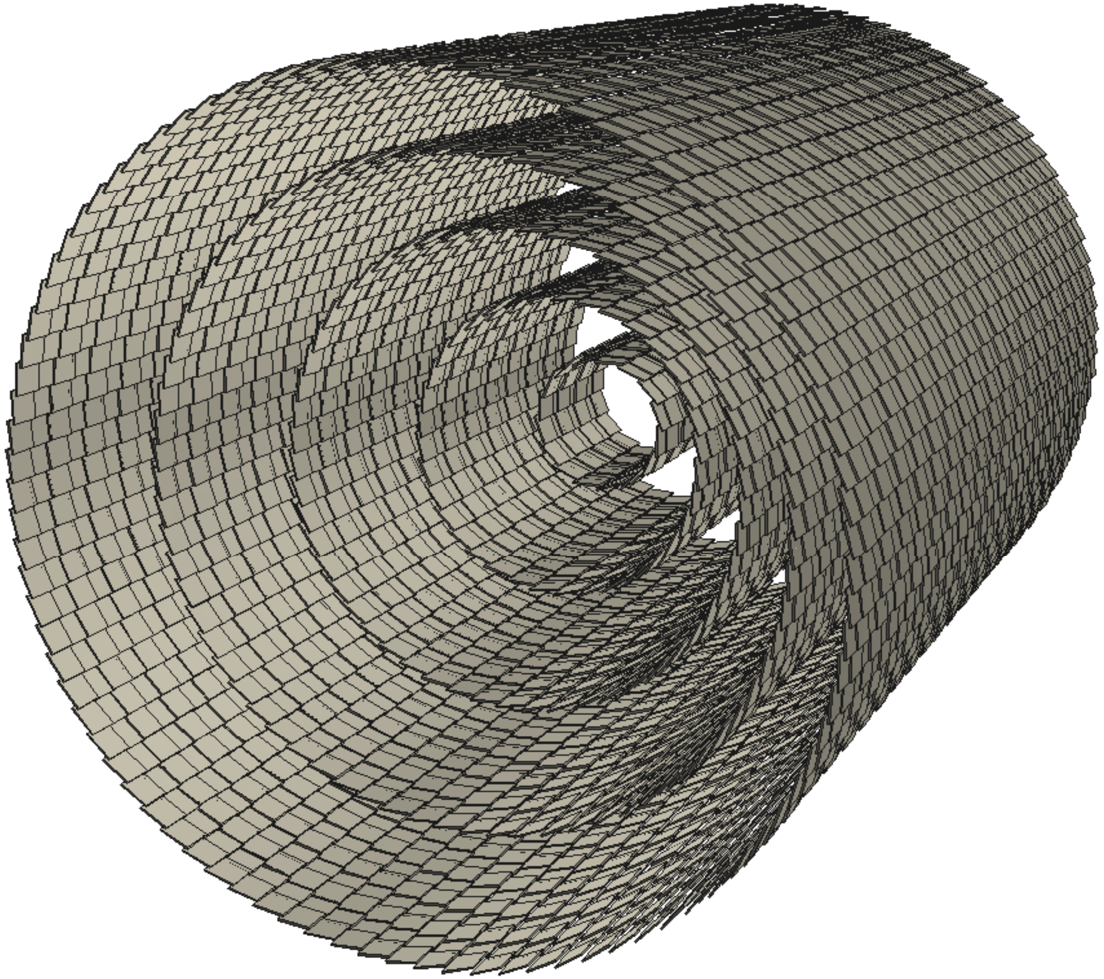






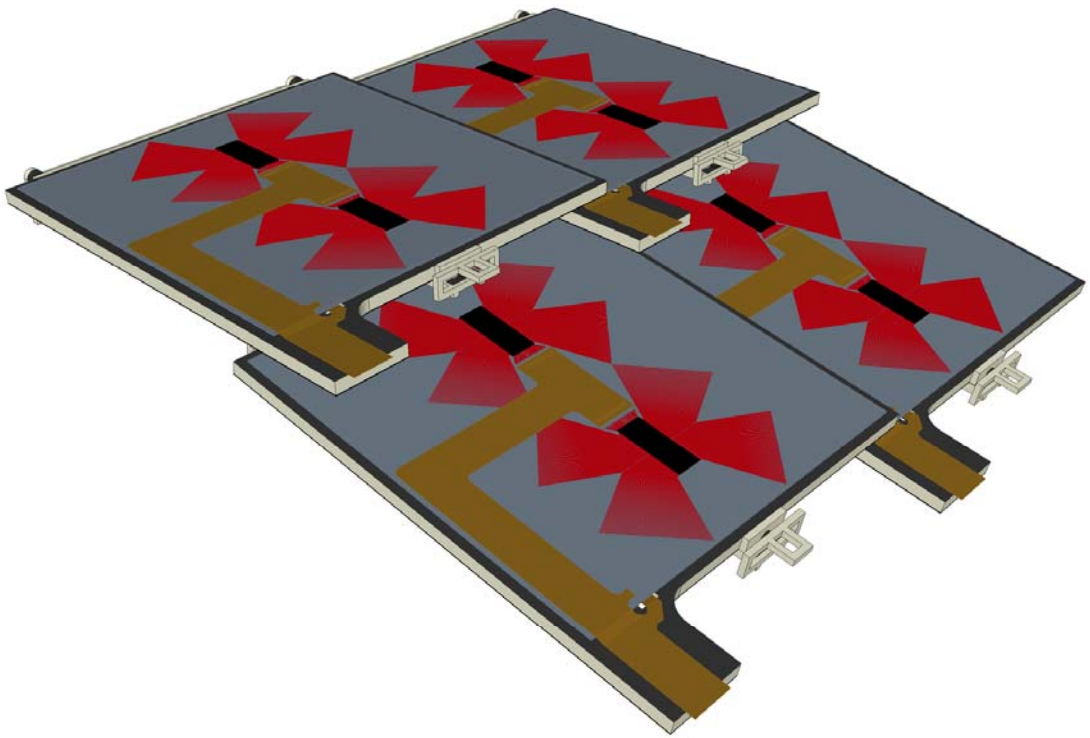
Another Perspective

Barrel tracker layout in GEANT simulation



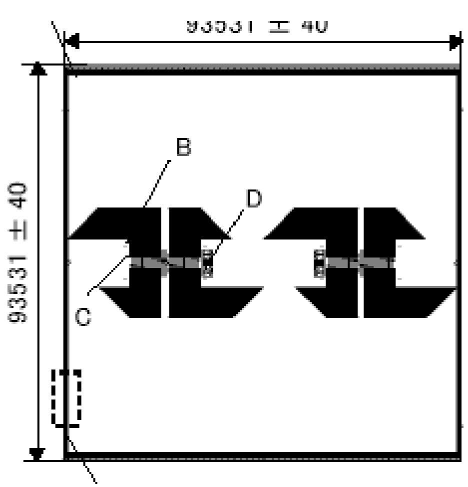
Tracker Module Design

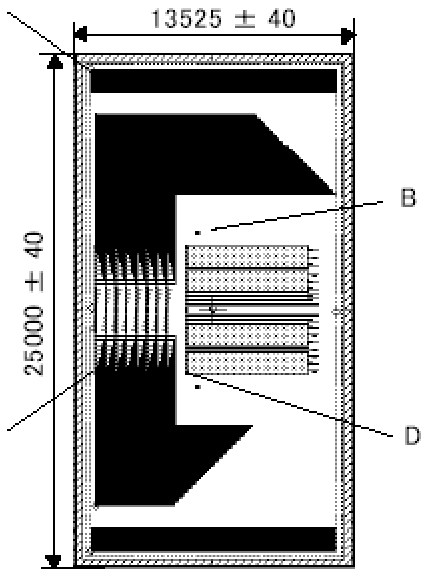
- Highly modular design
- Each module has 1 or 2 sensors mounted on a support frame
- Each sensor is readout independently
- Modules overlap to eliminate projective cracks
- Modules clip into holders mounted on support structure

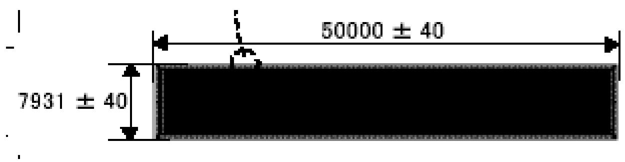


Sensor Submission

- A prototype sensor has been submitted to Hamamatsu
  - 25 μm strip pitch, 50 μm readout pitch
  - Double metal layer routes strips to readout chip that is bump bonded to sensor
  - Double metal layer also used to route power and readout traces to chip
- Submission also includes two test structures
  - Small sensor for testing power / data routing using prototype readout chips
  - DC coupled sensor using charge division to measure longitudinal coordinate

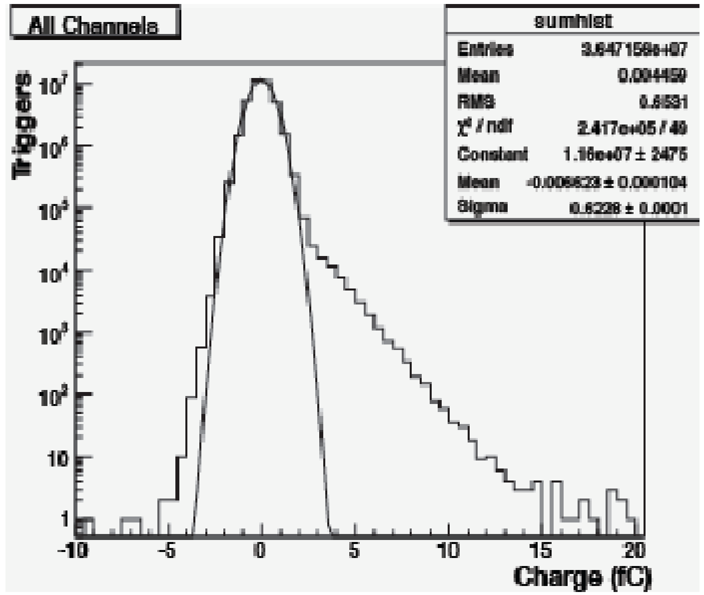


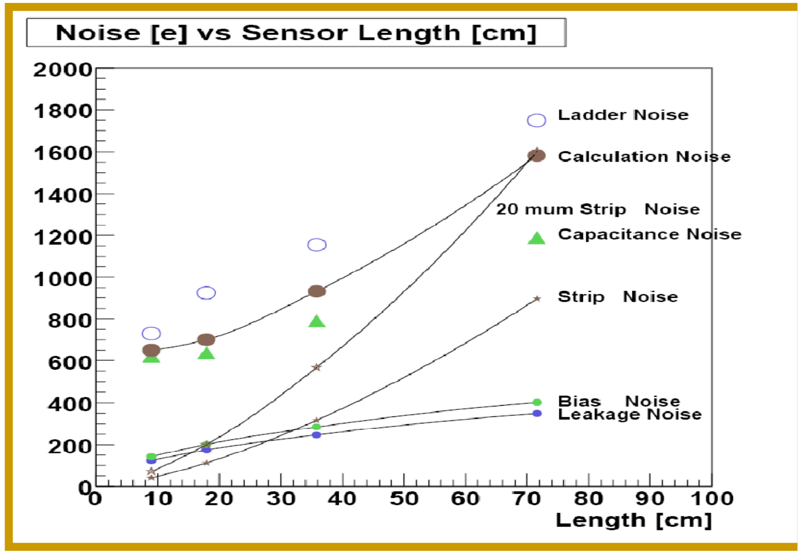




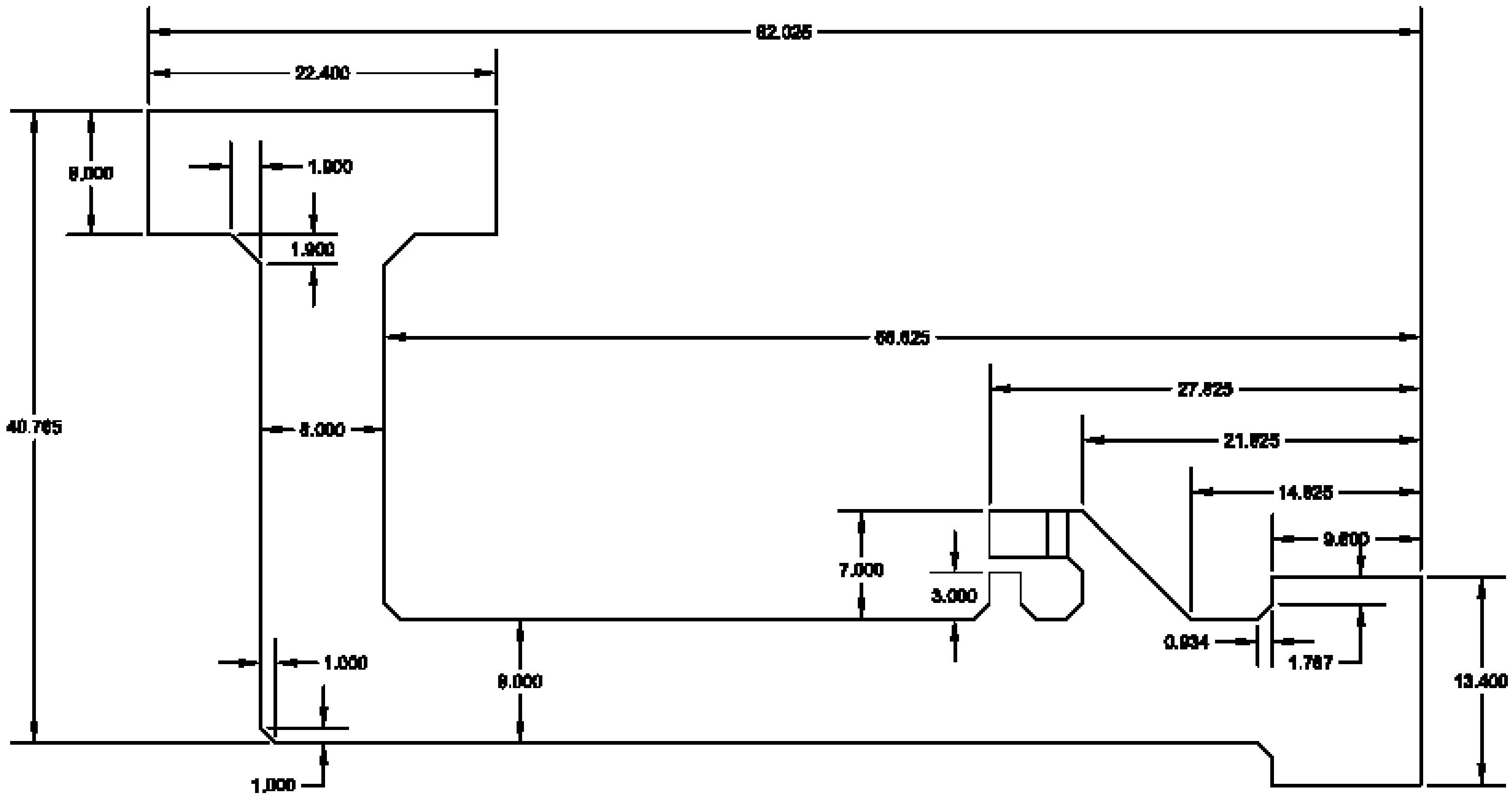
Readout Chip

- Baseline readout chip is KPiX
  - 1024 channel chip planned
  - 4 analog buffers./ channel
  - Same chip as calorimeter readout?
- Recent KPiX beam test
  - KPiX wire bonded to CDF L00 Sensor
  - Exposed to electrons at SLAC ESA
  - Charged particle signal observed
- LSTFE-2 (Santa Cruz)
  - First version showed good noise performance
  - Time over threshold readout chip
- Deep submicron chip (Paris)
  - Considerable success in developing prototype readout chip in 0.09 µm process
  - The future is getting smaller…





Pigtail Cable Design (U. New Mexico)



Power Delivery Issues

- These need to be investigated!!
- Need to switch ~10kA on / off @ 5 Hz for power cycling
- Large Lorentz forces on conductors
- Net force on tracker must be 0, but potential for substantial internal forces and torques
  - Forces are not static – power cycling will generate impulses at 5 Hz
  - Will these forces / torques cause the tracker to vibrate?
- How do we bring power in?
  - Probably don’t want to bring in 10kA at 2.5 V
  - Serial powering of multiple readout chips?
  - Capacitive DC-DC converter for each readout chip?
- These issues need to be investigated!!
  - Good opportunity for someone who wants to take on a SiD tracking project

Alignment and Position Monitoring

- For ~10,000 sensors, there are ~60,000 alignment constants
  - Track based alignment is probably the only method that will meet our goal of 7 μm hit position resolution
  - Scale of problem overwhelms usual matrix inversion algorithms
  - New algorithms have been developed for CMS – need to learn about this!
- Track-based alignment requires detector positions to be stable or well monitored over long intervals
- Problem has a number of different aspects
  - Relative alignment of sensors in a tracker barrels / disks
  - Relative position between barrel / disk layers
  - Relative position between tracker and vertex detector
  - Relative position of tracking systems relative to beam spot
  - Reproducibility of positioning during push-pull operation
- Likely there is not a single solution to all problems

Beam and non-Beam Testing

- Need to test critical aspects of SiD tracker design
- Some expected tests include:
  - Noise / cross-talk / performance of double metal design
  - Verification of hit position resolution
  - Electrical and mechanical aspects of power pulsing in 5T field
  - Mechanical properties of prototype support structures
- Beijing tracking review recommended a large bore solenoid for beam testing to be shared between the silicon and TPC groups
  - If this was free, that would be great!
  - If expensive, then we need to identify our true magnet needs
    - Do we really need a big bore?
    - What tests are best done in beam? What are best done optically?
- What sort of system/slice tests are needed for the detector EDR?
- What tests are needed to make technology choices?

Simulations

- Lots of progress in developing full tracking simulations
- Immediate goal is to deliver a first tracking package that can be used by non-experts
  - Likely to have some level of cheating in first pass (for example, in pattern recognition)
  - As infrastructure advances, increase fidelity of simulation
  - Output – namely track objects – will remain the same so we don't break user code based on top of the tracking package
- Two approaches to segmentation
  - Virtual segmentation of disks and cylinders allows quick exploration of the parameter space
  - Full segmentation into planar sensors allows more thorough and detailed studies
  - Likely that both will be important

Tracking R&D Summary

System	Work Package	Institutions
Mechanical	Mechanical Support Design	Fermilab, SLAC, Washington
	Module Design	Fermilab, SLAC
	Frequency Scanning Interferometry	Michigan
Sensor	Double Metal Sensor	Fermilab, SLAC, Tokyo
	Thin Silicon	Purdue
	Sensor Characterization and Testing	New Mexico, SLAC
Readout	KPiX Readout	Davis, Oregon, SLAC
	Time Over Threshold Readout	Santa Cruz
	Charge Division Readout	Brown, Santa Cruz
Cable	Tracker KPiX Cable	New Mexico, SLAC
Simulation	Simulation Infrastructure	Fermilab, Kansas State, Oregon, SLAC
	Vertex Seeded Tracking	Brown, Colorado, Fermilab, Oregon, Santa Cruz
	Stand Alone Tracking	Fermilab, Santa Cruz, SLAC
	Calorimeter Assisted Tracking	Kansas State (Bonn)
	Fitting and Resolution	Oregon, Santa Cruz, SLAC

Tracking Perspective for the LOI

- We like to see the LOI as a mile post along the road to an EDR
- Certainly it is important to put out a compelling LOI
- Nevertheless, the long term goal is producing the EDR
- Minimize dead-end efforts that divert us from the overall objective of getting ready for the EDR
- Describe the SiD tracker technology choice, design, R&D status, and simulated performance as obtained with the tools being developed for an EDR

Towards the LOI

- Technology choice: silicon
- Motivated layout of the detector
  - General layout
    - Description of detector geometry, including number and locations of barrel and forward tracking layers
    - Average number of measurement planes intersected by infinite momentum particle as function of angle
    - Material budget as function of angle
  - Particle densities for background and physics processes
    - Motivates technology choice in certain regions: pixels versus strips
  - Segmentation and tiling
    - Longitudinal segmentation in barrel
    - Tiling in forward region
    - Occupancies (averaged over full layer and peak occupancy in jet core)
  - Detailed detector description
    - Describe baseline design and possible alternatives
    - Sensors, readout, modules, mechanical supports, cables, alignment, power, etc.
    - Some of this may need to be in a supplementary document

Performance Characterization – Step 1

- Characterization of performance using traditional metrics
  - Momentum resolution as function of p_T and angle
  - Impact parameter resolution as function of p_T and angle
  - Track finding efficiency as function of p_T and angle
    - Isolated tracks as function of angle
    - Inside jet cores: Z-> qqbar @ 500 GeV as function of angle
    - K_S efficiency
  - Fake rate as function of angle and momentum
- Goal is to have all infrastructure in place by SiD Workshop planned for Jan. '08 with a first pass at characterization of detector performance

Performance Characterization – Step 2

- Move towards benchmark physics processes: develop the metrics that measures physics performance
  - Physics will apply a non-uniform weighting to the traditional metrics
    - Inefficiency at high momentum more critical than at low momentum
  - Weighting may depend on physics
    - For example, leptonic ZH heavily weights momentum resolution Characterization of performance using physics benchmark processes
- Some potential tracking benchmark processes
  - ZH missing mass distribution
  - $H \to \mu\mu$ mass resolution
  - b/c tagging efficiency in Higgs decays
  - Acollinearity of forward Bhabhas (luminosity spectrum)
  - Long-lived charged particles (e.g., GM SUSY)
  - Need some good ideas for forward benchmarks

Design Optimization

- Optimize the design using traditional metrics and / or physics benchmarks as appropriate
  - Effect of adding a 6th layer / 5th disk
  - Effect of >0 barrel stereo layers
  - Determine weak spots in the mechanical design and re-optimize
- Optimize integrated detector performance
  - What is needed for good PFA performance?
    - Impact of long-lived secondaries
    - Impact of inefficiency and fakes
    - Impact of material
- In parallel
  - Continue working out in more detail and optimizing the design
  - Continue a vigorous R&D program to meet requirements for an EDR

For More Information on SiD Tracking

- See Tim Nelson's talk in the ALCPG plenary session
- A reasonably current report was prepared for the Beijing Review:
  - http://www-sid.slac.stanford.edu/Documents/Tracking_review.pdf
- Get on the SiD tracking mailing list
  - Send email to Marcel (demarteau@fnal.gov) or myself (richp@slac.stanford.edu) and we will add you to the list
- Attend the SiD tracking /vertexing meeting
  - Friday, 11 AM Fermilab time

Conclusions

- The SiD Tracking effort is founded on a few key principles
  - Take full advantage of the superb hit resolution, two-track separation, design flexibility, and timing properties offered by silicon strip detectors to provide robust tracking capability that meets the ILC physics goals
  - Aggressively work to minimize the material in the tracking volume
  - Optimize the tracker as one element of an integrated detector design
- A comprehensive R&D program has been put in place to perform the R&D required to succeed in this effort
  - This program is unlikely to be static, as historically we have benefited by the rapid pace of advances in semiconductor manufacturing technology
- The LOI is an important milestone for SiD Tracking
  - Goal is an optimized design based on full simulation of both traditional metrics and physics benchmarks