Status of Tracking

- What has been accomplished?
- What needs to be accomplished?

SiD meeting

ALCPG and ILC Workshop
Snowmass, August 2005

Rich Partridge, Marcel Demarteau

for the Tracking Group

Tracking Group

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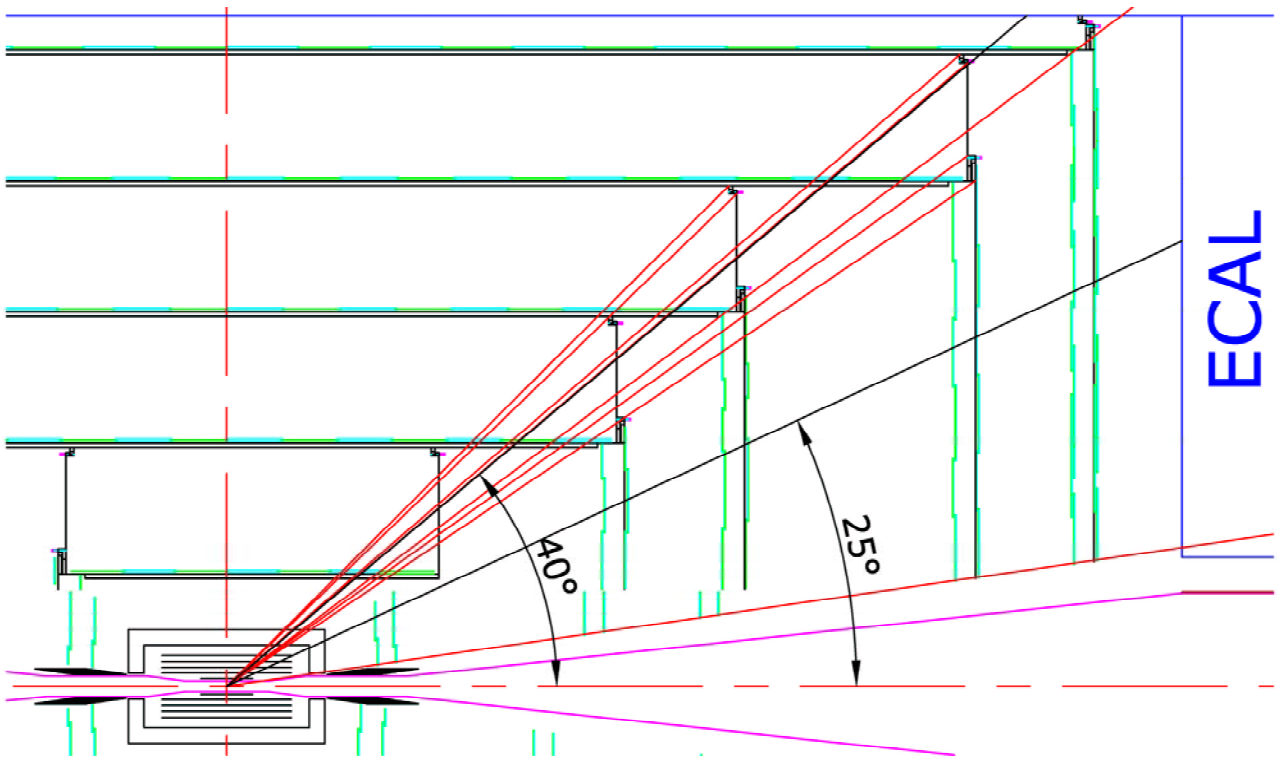
1. Argonne
2. Brown University
3. Caltech
4. Fermilab
5. Kansas State University
6. LPNHE Université de Paris 6/IN2P3-CNRS
7. Oxford University
8. Rutherford Appleton Laboratory
9. SLAC
10. UCSC
11. University of Colorado
12. University of Oregon

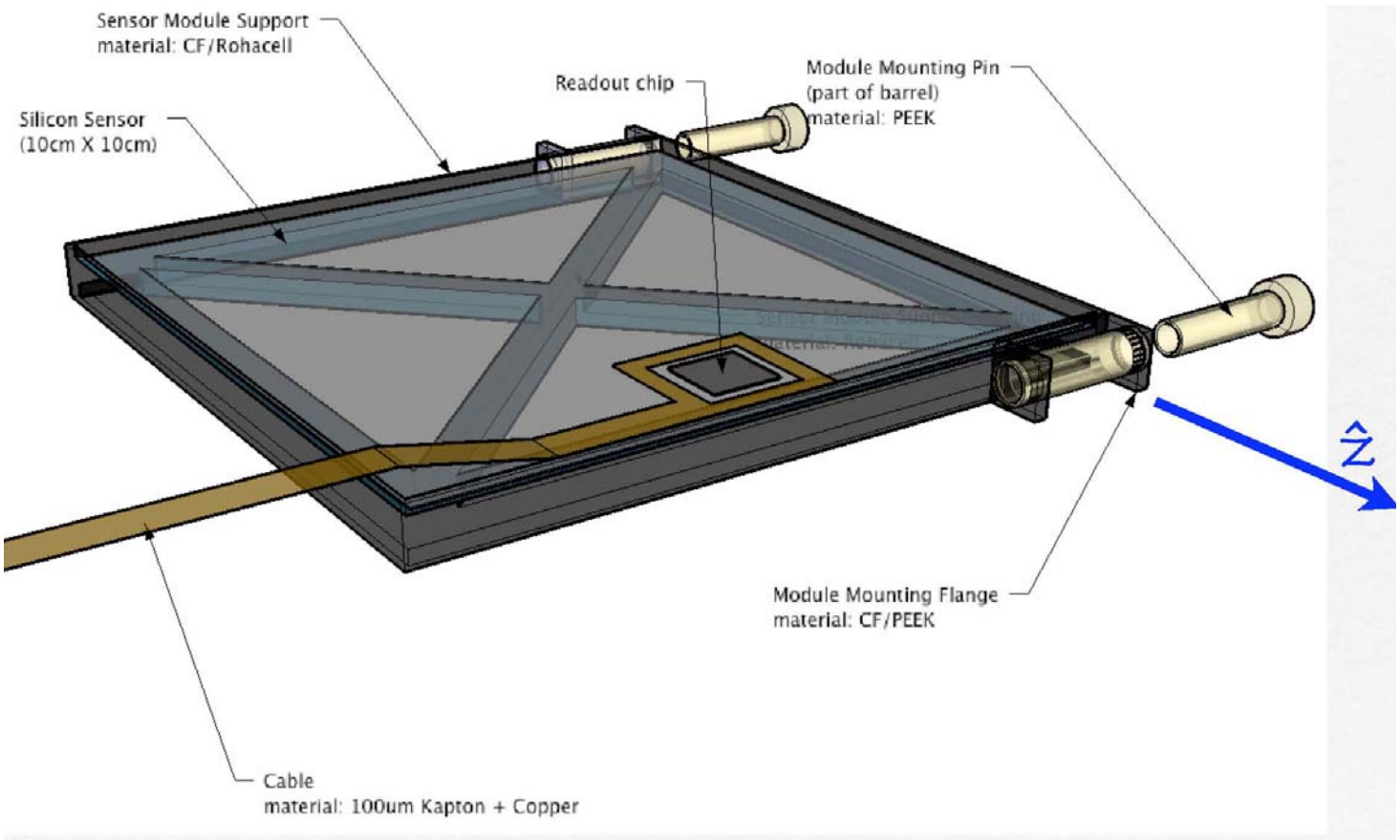
Geometry

- Over the course of last year developed a rather complete design for the outer tracker
- Barrels
  - Five barrels, measure Phi only
  - Eighty-fold phi segmentation
  - 10 cm z segmentation
  - Barrel lengths increase with radius
- Disks
  - Five double-disks per end
  - Measure R and Phi
  - varying R segmentation
  - Disk radii increase with Z



Module Design

- Module design for mounting on continuous carbon-fiber support cylinders



- Multi-sensor ladders also being considered

Dead Material Model

- Also first pass realistic modeling of dead material

Component	Material	X_0(mm)	Thickness(mm)	Coverage	Average Thickness (mm)	Average #X_0(%)
L1 Circuit Board	G10	194	3.0	0.13	0.39	0.20
L1 Circuit Board	Copper	14	0.2	0.13	0.026	0.19
L2 Circuit Board	G10	194	3.0	0.26	0.78	0.40
L2 Circuit Board	Copper	14	0.2	0.26	0.052	0.37
L3 Circuit Board	G10	194	3.0	0.27	0.81	0.41
L3 Circuit Board	Copper	14	0.2	0.27	0.054	0.39
L4 Circuit Board	G10	194	3.0	0.50	1.5	0.77
L4 Circuit Board	Copper	14	0.2	0.50	0.1	0.71
L5 Circuit Board	G10	194	3.0	9.7	29	15.0
L5 Circuit Board	Copper	14	0.2	9.7	1.94	13.8

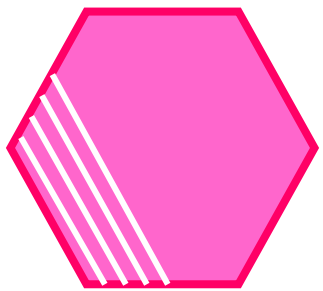
  - At outer layer, high fraction of X_0 due to very limited space at outer barrel
- The limitation was to get the simulation going in the slic framework
  - Statement from collaborator February 2005:
    "... a dramatic need for simulation studies for optimizing / comparing detector designs & performances"

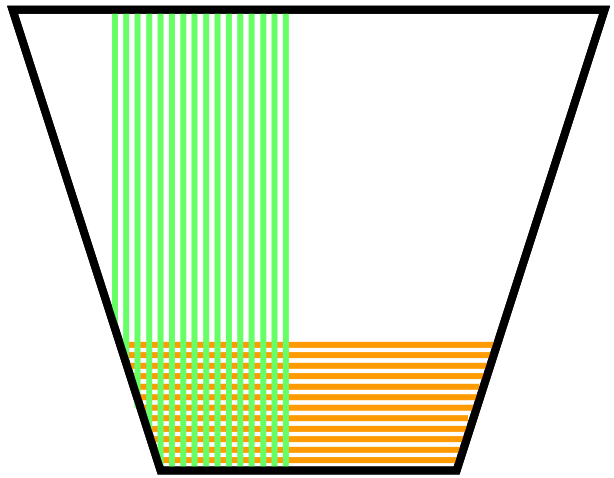
Simulation

- Simulation effort has made considerable progress
  - Event generation: many event samples are available
    - Full SM samples available at 500, 1000 GeV
      - mumu, qqbar, tautau, WW, ZZ, Zgamma, ttbar, ZH(120), ZH(140), lccosmo
    - “single” particle events of increasing complexity covering various regions of phase space.
  - Baseline geometry frozen and available in xml files
    - Various geometries available (2mrad, 20mrad, 4 Tesla, scint. HCAL)
    - Geometry defined at run-time
    - provides full description of current design with modeling of the dead material
  - Detector response:
    - Geant4 hits provided in the lcsim framework
    - Detector response to be implemented by user
  - Readout segmentation:
    - Readout segmentation to be implemented by user in event reconstruction stage
      - adds additional level of flexibility in studying detector variants.
    - Example: detector tiling, pixel size, strip pitch/orientation, etc.

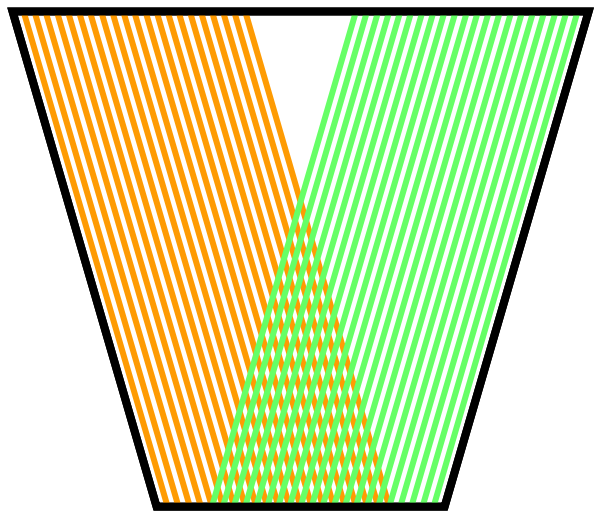
Tiling Disks

- Code exists to tile forward disks with wedges
- Allows one to construct a tiling of a disk with just a few input parameters:
  - number of annuli
  - number of wedges per annulus
  - inner radii of annuli
  - outer radii of annuli
  - phi offset of wedges in annulus
  - strip pitch
  - orientation of strips
- Alternate geometries possible
  - Hexagonal structures





Large Angle Stereo



Shallow Angle Stereo

Fermilab Computing Farm

- All simulation code with all libraries are now, since last week, also available at Fermilab on the computing farm
  - Farm shared between the various divisions
  - Since this has happened recently, not much experience with it
- Machine running at ilcsim.fnal.gov
- Data files available at /prj/btev01/ilc
- Full Fermilab GRID infrastructure will also be available
- If interested, please contact Lynn Garren (garren@fnal.gov)

Hits

- SimTrackerHit (Geant4 simulation)
  - True position and time
  - Energy deposited
  - Link to MC Particle
  - Link to momentum

detector resolution

- Tracker hit
  - Pulse formation in Si
  - Charge sharing between strips
  - Readout configuration, capacitance
  - Digitization and Clustering

- VXD has package to convert hits into realistic CCD pixel hits
  - MC SimHits -> PH's, charge sharing -> Readout, Clusters, -> Hits ($x \pm \delta x$)
- UCSC has developed long-shaping-time for Si strip simulation
  - MC SimHits -> PH's charge sharing -> Readout, Clusters, -> Hits ($x \pm \delta x$)

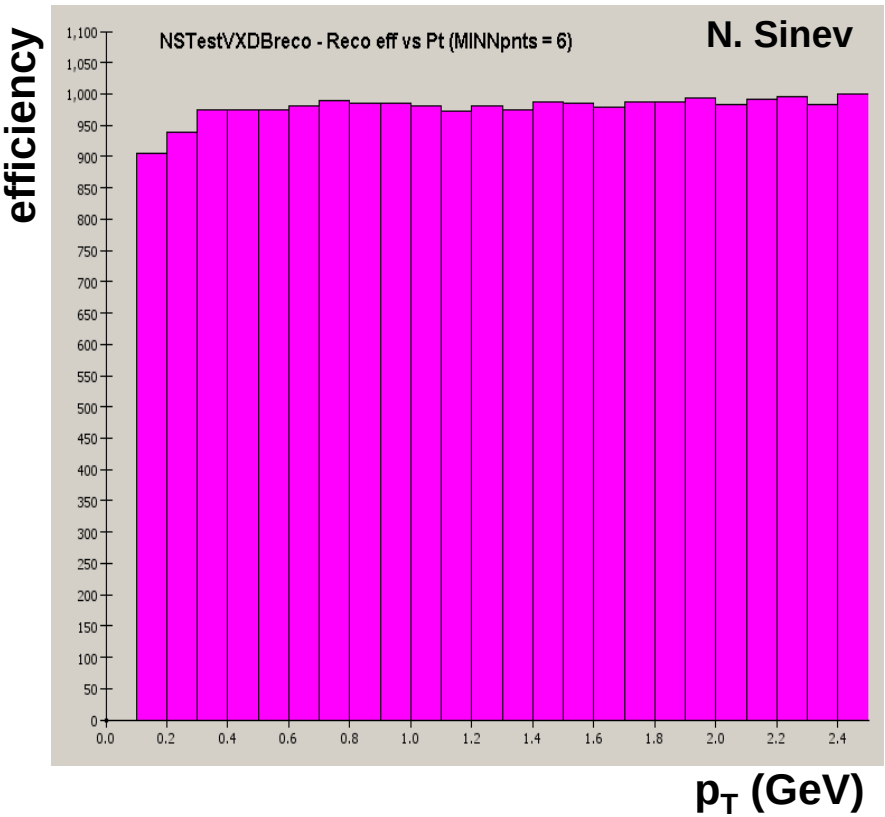
- However, both packages are in the 'old' hep.lcd framework and need to be ported to org.lcsim
- All simulation results to date have been obtained in the hep.lcd framework

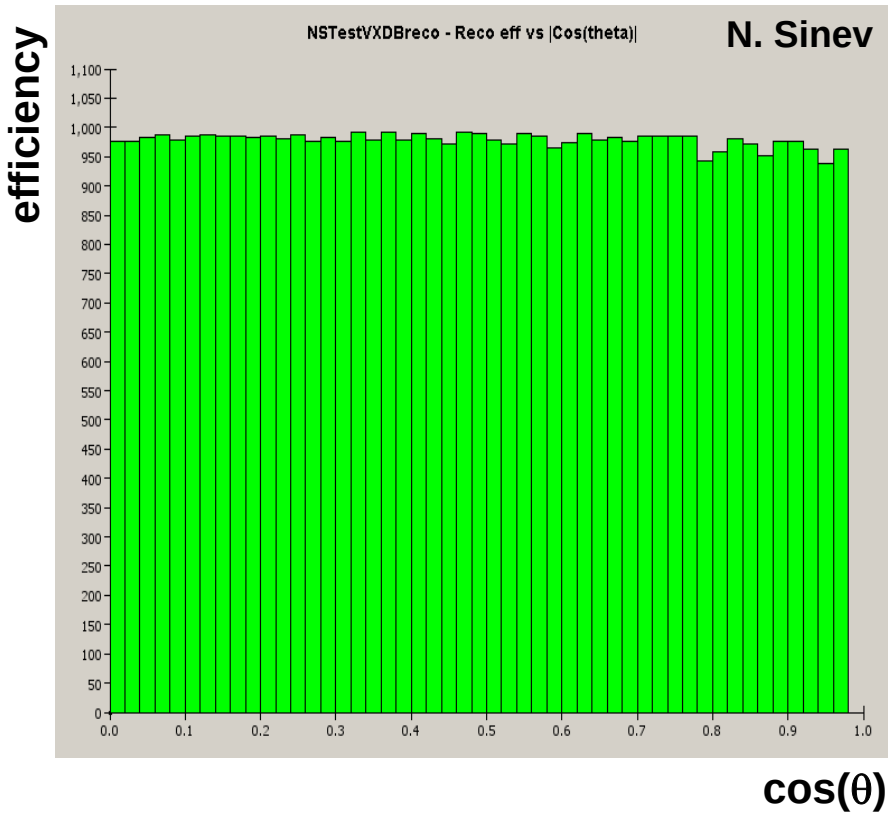
Tracking Studies

- Tracking “inside-out”: based on VXD, adding hits from outer tracker
  - Try all combinations of layer-based hit triplets as pattern recognition base
    - 3 points define track parameters
    - Add additional VXD hits
    - Add additional outer tracker hits
      - Barrel: hits are attached to track based on phi of the strip. z position is only checked to be within strip segment length (10 cm in SiD)
      - Endcap: even layers are assumed to measure only phi, while odd layers are measuring radius
  - Final track accepted when:
    - number of associated hits ≥ 6
    - number of hits shared between tracks at most 1 (VXD) + 1 (OT)
    - Track points close to IP

Tracking Efficiency

- Results from ttbar events at √s = 500 GeV, with full ccd detector resolution applied everywhere
- Track reconstruction efficiency versus p_T and cos(θ)

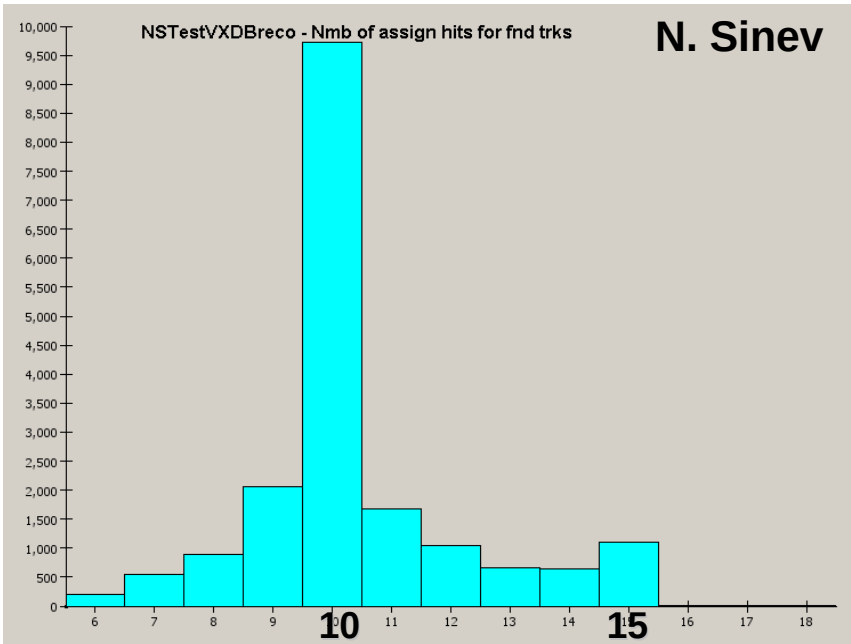




- Average efficiency of about 97%

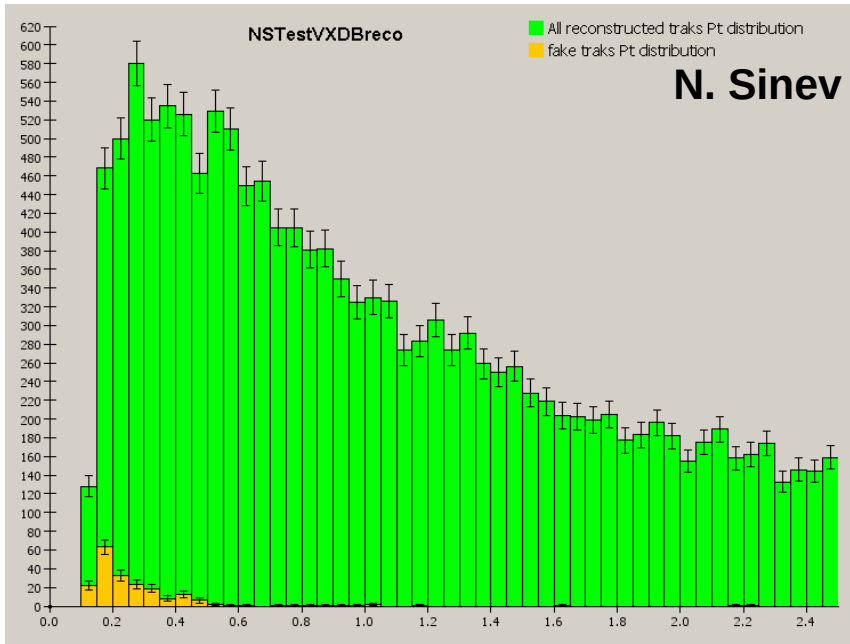
Track Quality

- Number of hits on track



- Forward region: 5 VXD + 10 end disks
- Central region: 5 VXD + 5 Barrel layers

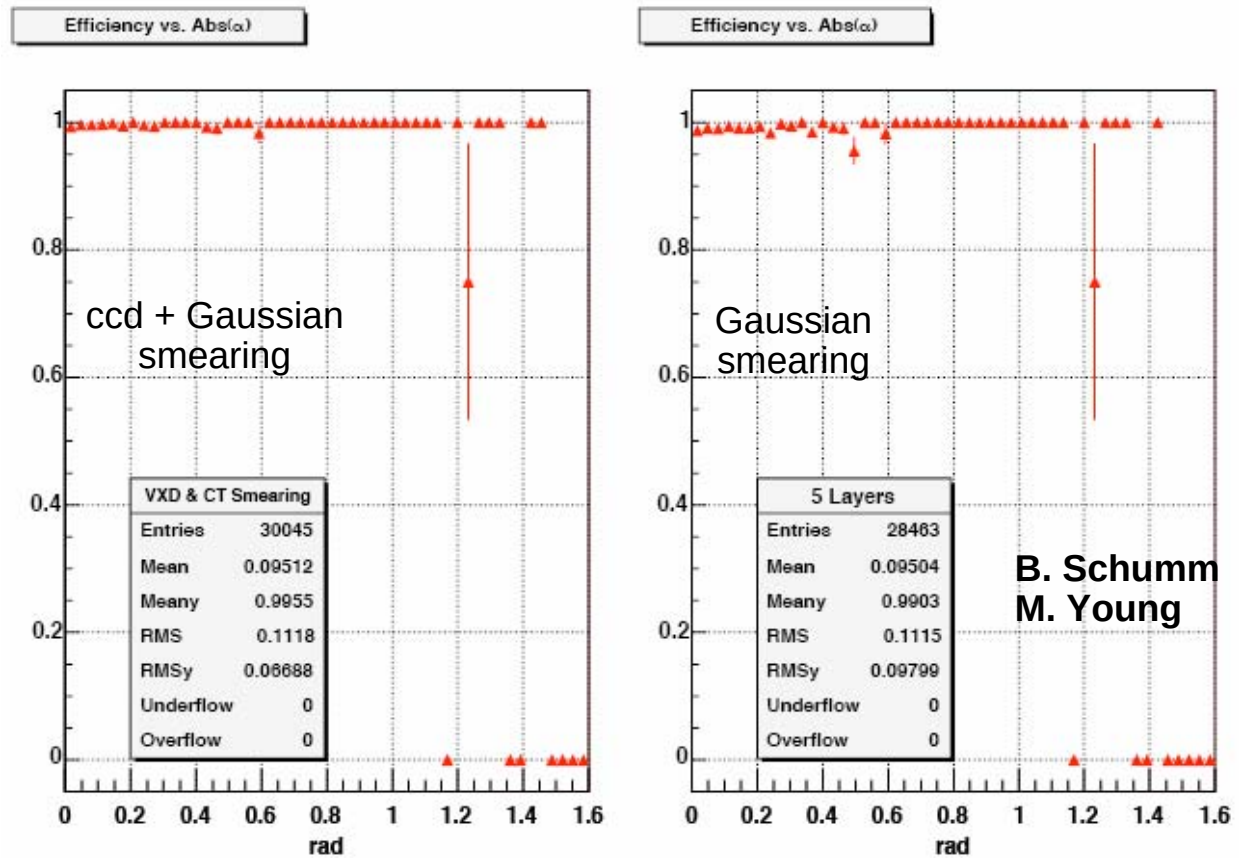
- p_T distribution of fake tracks



- Fake rate is about 1%
- Peaked at low p_T and
- predominantly in the forward region

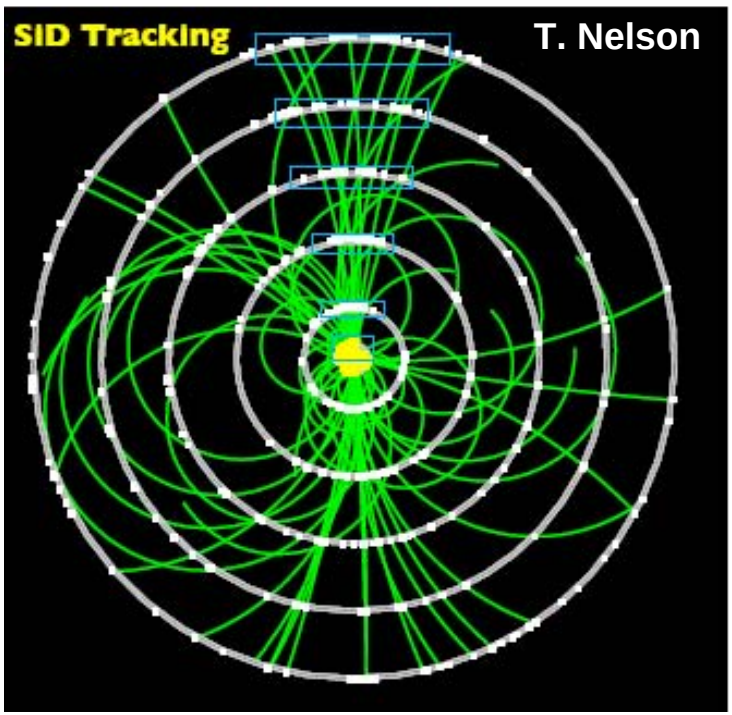
Tracking Efficiency

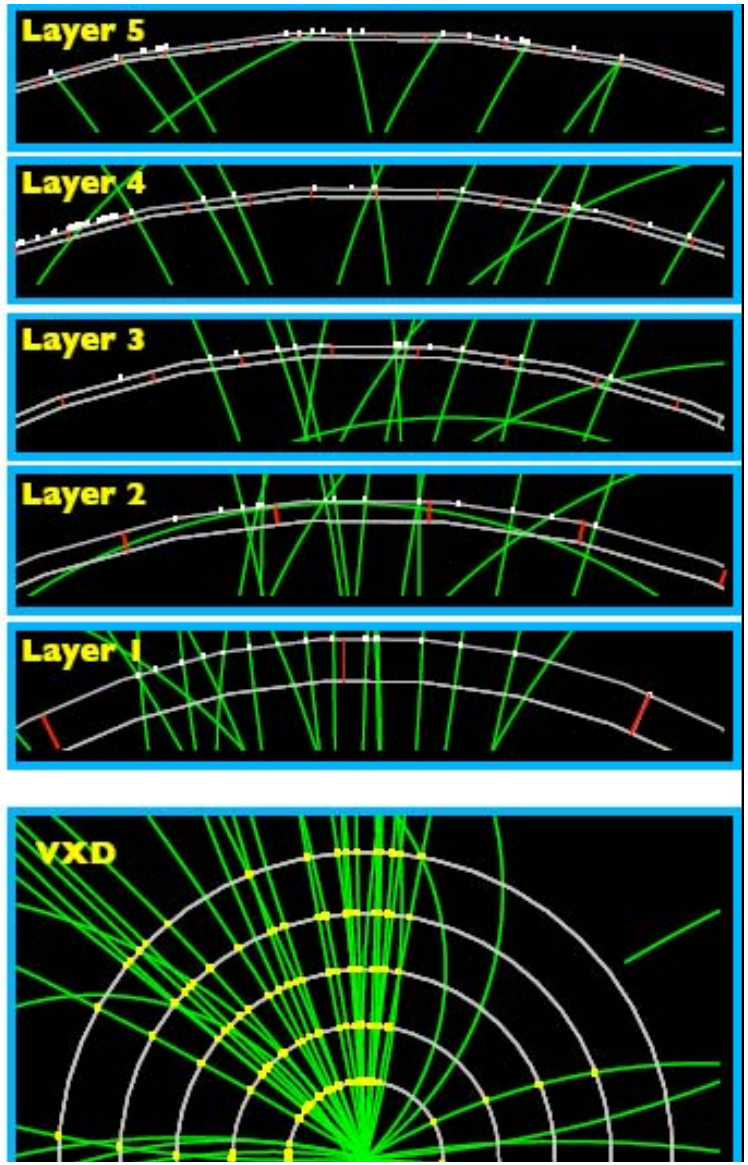
- Another study: Results from qq-bar and μμ events at √s = 500 GeV
  - Events limited to central region only
  - Hit smearing applied and realistic ccd simulation
  - For qq-bar events:
    - Determine Thrust axis, define track angle with respect to Thrust axis, α



Tracking Robustness

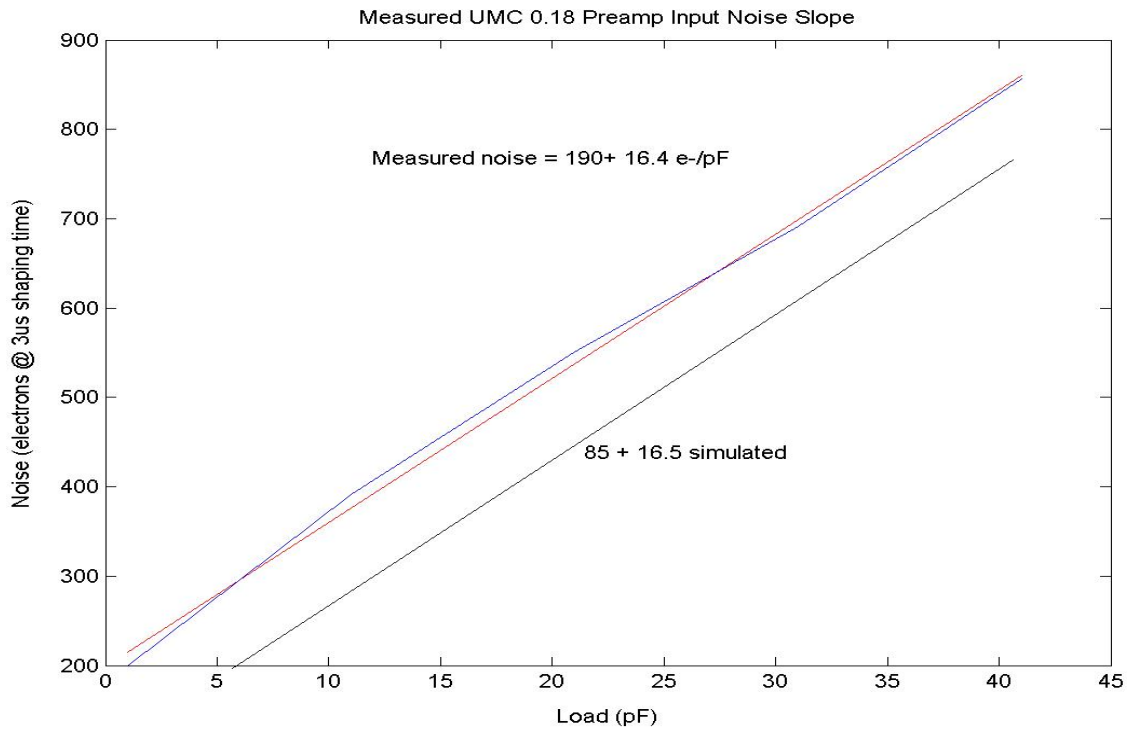
- Comparing with simulated tracks illustrates high efficiency and purity
- *Backgrounds?*





Tracker Readout

- Both Paris and UCSC are developing elements of prototype Si ROC for long shaping time.
- Paris bench tests performed over the spring:



@ 3μs shaping time

ENC = 190 e^- + 16.4 * C/pF

ENC = 85 e^- + 16.5 * C/pF

expected from simulation

- Dependence of noise as function of capacitive load exactly as expected

Status

- First pass mechanical design complete; electrical work on long shaping-time readout progressing
- A lot of work done by the simulation group to complete the lcio framework for the tracker and to provide data samples in various machine and detector configurations
- First steps taken at simulating the tracker in the lcio framework
- However:
  - Many tools still need to be developed
    - Porting tools from the lcd.hep framework to the lcio.org framework
    - Model of electronics readout, digitization of hits; Clustering
    - Pattern recognition for outer tracker
    - ……
  - The tracker needs to be “quantified”
    - What is the occupancy, track finding efficiency, momentum resolution, reconstruction of photon conversions, K_s reconstruction efficiency……
  - Tools need to be developed to “quantify” the physics performance
    - How well can the benchmark processes be reconstructed
    - Involves integration of all detectors, notably calorimeter
  - Optimize the geometry and study detector variants
- How do we balance Geant4 simulations with fast simulations?

Tasks to be done

- Port Nick's digitization code to org.lcsim
- Port Nick's pattern recognition and tracking code to org.lcsim
- Extend Nick's Fitter to include endcap layers
- Port Bruce's strip digitization code to org.lcsim
- Update Bruce's strip digitization code for short ladders
- Develop clustering algorithm for strip tracker
- Develop stand-alone outer tracker pattern recognition and track finder
- Determine z segmentation in barrel
- How many layers are sufficient for robust tracking?
- Do we need stereo readout in the barrel?
- Determine technology for forward region
- Quantify VXD tracking efficiency when backgrounds are added
- Quantify tracking performance in dense jets
- Study of occupancies as a function of various disk-tiling geometries
- Quantify number of ghost hits for various geometries
- Quantify fake track rate
- Stand-alone tracking studies for outer tracker
- K_S reconstruction
- Quantify p_T-resolution, notably in the forward region
- Uniformity of the magnetic field
- Physics benchmark process simulation
- ……

Goals for Snowmass

- Make list as complete as possible
- Prioritize the items on the list
- Recruit people and assign tasks
- Get started ...

- Tracking/Vertexing group meets in CLUB in the Silvertree hotel