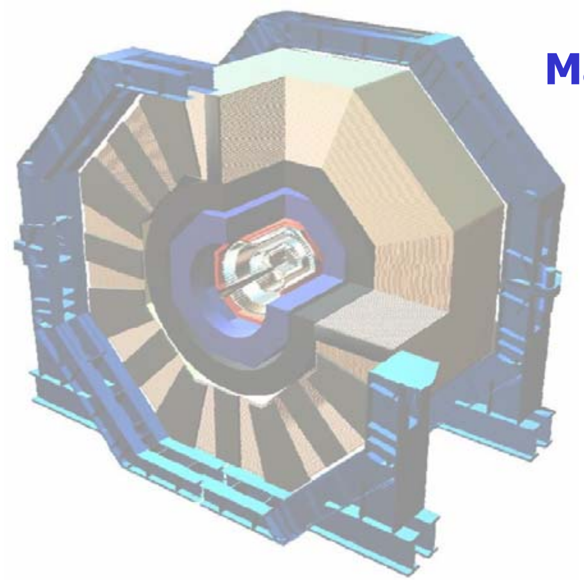
Status of Tracking
Design, Performance and R&D

SiD Workshop

Marcel Demarteau, Richard Partridge
Fermilab



For the SiD Tracking Group

SLAC
Oct. 27, 2006

Tracking Group

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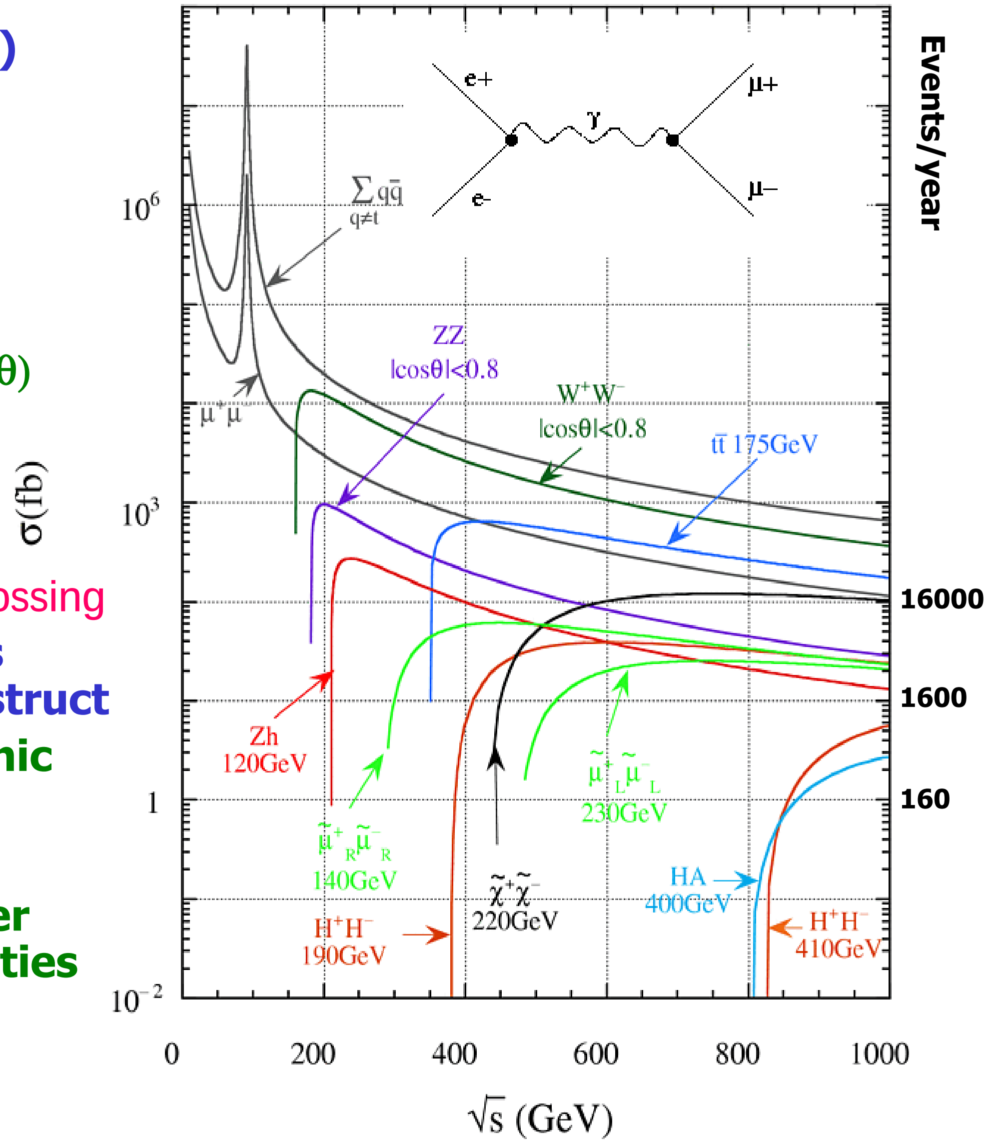
1. Argonne
2. Brown University
3. Caltech
4. Fermilab
5. Kansas State University
6. LPNHE Université de Paris 6/IN2P3-CNRS
7. Oxford University
8. Rutherford Appleton Laboratory
9. SLAC
10. UCSC
11. University of Colorado
12. University of New Mexico
13. University of Oregon

apologies to those we forgot

ILC Physics Characteristics

- **Machine design luminosity**
  $\mathcal{L}$ = 2 x 10^{34} $cm^{-2}s^{-1}$ ($\sqrt{s}$ = 500 GeV)
- **Processes through s-channel spin-1 exchange: $\sigma \sim 1/s$**
  - **Cross sections relatively democratic**
  - **Cross sections are small**
  - **Angular distribution: $(1 + \cos^2\theta)$**
    - Premium on forward region
    - Hermetic detectors
  - **Relatively large backgrounds**
    - 100k e^+e^- - pairs per bunch crossing
- **W and Z bosons in all decay modes become the main objects to reconstruct**
  - **Discriminate W and Z in hadronic decay mode**
- **Highly polarized e^- beam: ~ 80%**
  - **To employ discriminating power requires running at both polarities**

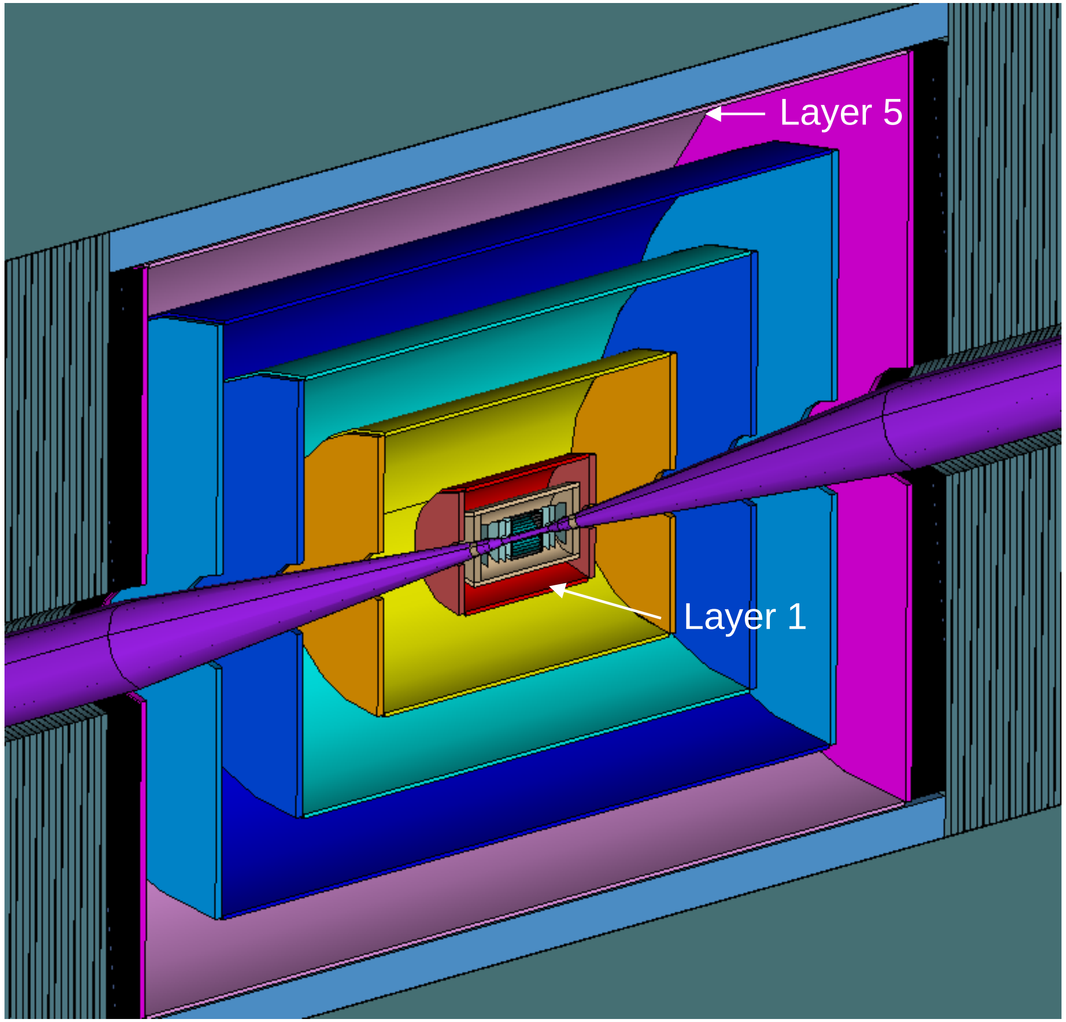
- **Every event counts !**



ILC year: 50% machine duty cycle
50% overall detection efficiency

Tracker Baseline

- **5-Layer silicon strip outer tracker, covering R_{in} = 22 cm to R_{out} = 122 cm, to accurately measure the momentum of charged particles**

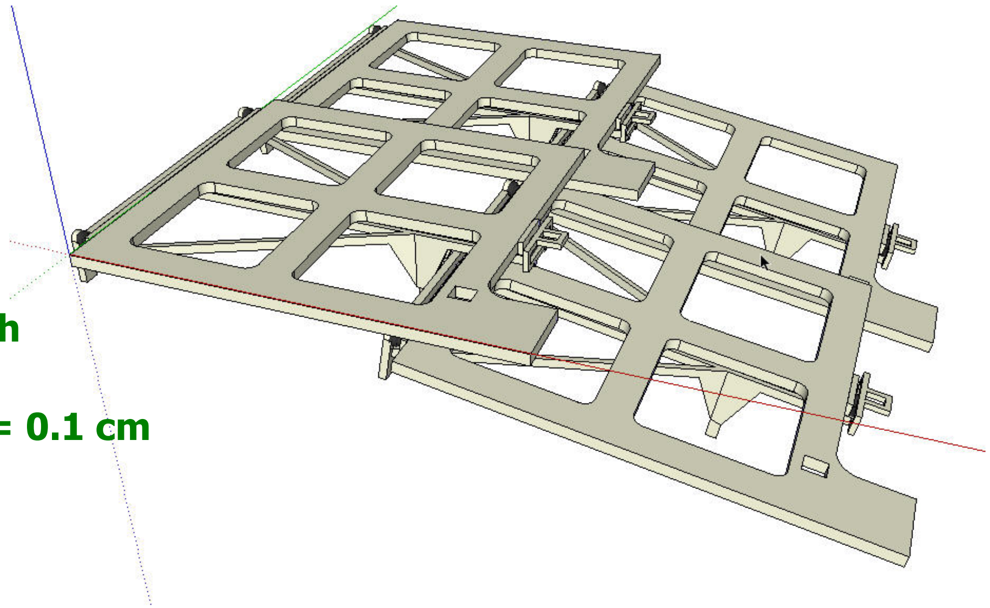


- **Support**
  - **Double-walled CF cylinders**
  - **Allows full azimuthal and longitudinal coverage**
- **Barrels**
  - **Five barrels, measure Phi only**
  - **Varying phi segmentation**
  - **10 cm z segmentation**
  - **Barrel lengths increase with radius**
- **Disks**
  - **Four double-disks per end**
  - **Measure R and Phi**
  - **Varying R segmentation**
  - **Disk radii increase with Z**

Module Design

Tim Nelson

- **Mounting clip**
  - CF-filled PEEK or Torlon with custom Si_3N_4 inserts
- **Mounting strip**
  - 30% CF-filled Torlon (or PEEK), CTE = Si + 3×10-6 /°K
  - 0.125" Si_3N_4 balls, insert-molded
- **Support frame**
  - 0.125" Rohacell foam sheet
  - Two 60-60-60, 0.009" thick, high-modulus CF sheets
  - 50% void - CF under chip
- **Overall design**
  - Boxes are square
    - Outer dimensions:
      0.3 cm x 9.65 cm x 9.65 cm
    - Sensor active dimensions:
      9.2 cm x 9.2 cm
  - Sensors positioned mid-way through the thickness of a box
  - Closest separation between boxes = 0.1 cm

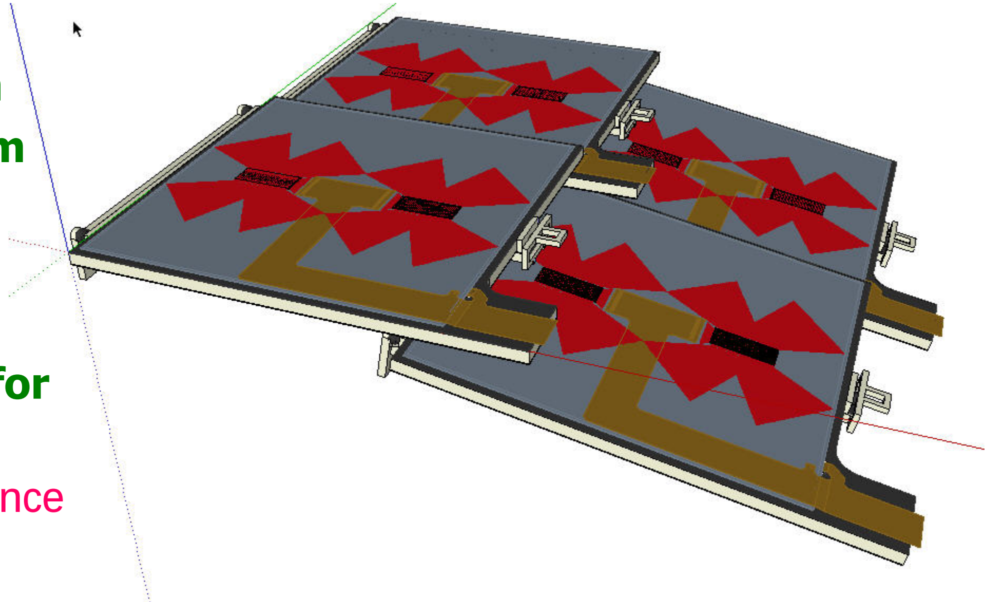


- **Design needs a review**
  - Mass budget is ~0.5%X_0 (0.8%X_0 with support barrels)

Sensor Design

Tim Nelson

- **Readout does not employ a hybrid**
- **Sensor design uses bump-bonded readout chip**
  - **Sensor size 93.5mm x 93.5mm**
  - **Strip/Readout pitch 25 / 50 μm**
  - **Number of RO (IM) strips 1840 (3679)**
    - Need two readout chips
  - **Double metal layer optimized for strip geometry**
    - Minimize capacitance and balance with trace resistance
  - **S/N goal of 25**



- **Sensor design needs formal review and sign-off**

- **University of New Mexico approached for cable design**

Sensor Specifications

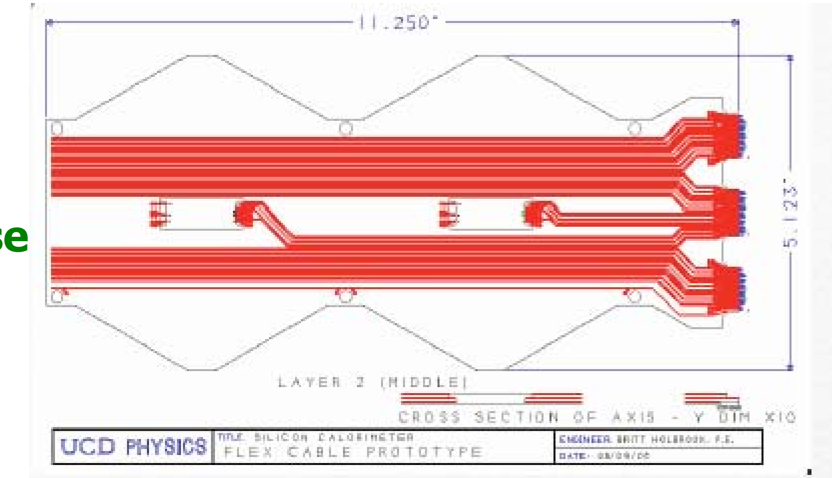
Tim Nelson

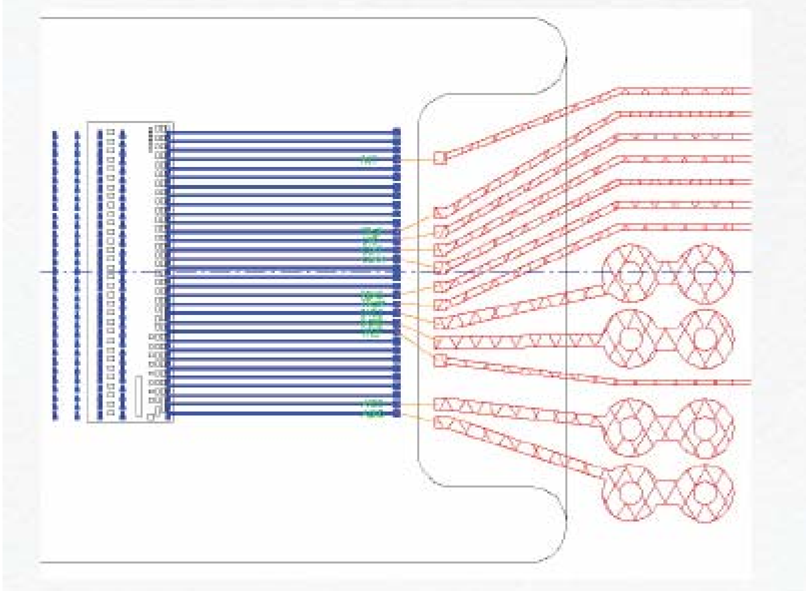
- **First pass at wafer and sensor specifications, acceptance criteria and definition of measurements at manufacturer**
  - **Needs revision**
- **Expect to place an order with HPK this calendar year**

Parameter	Value
Overall Dimensions	93.531mm×93.531mm
Active Area	92.031mm×92.031mm
Strip pitch	25 μm
Readout pitch	50 μm
Number of strips	3679
Number of readout strips	1840
Depletion voltage	60V< V_{dep} <100V
Depletion voltage uniformity	< 20%
Biasing scheme	poly resistors along both edges
Poly resistor value	4.5 ± 0.5MΩ
Implant strip width	8 μm
Implant depth	> 1μm
Doping of Implant	$> 1 \times 10^{14}$ ions/cm^3
Width of Al sense strips	7 to 8 μm
Width of Al readout traces (double-metal)	3 to 4 μm
Thickness of Al traces (all)	> 1μm
Resistivity of Al sense strips	< 30Ω/cm
Resistivity of Al readout traces (double-metal)	< 60Ω/cm
Thickness of insulating layer between metal layers	3 μm
Coupling capacitor value	> 10 pf/cm
Passivation	SiO_2 0.5-1.0μm thick
Width of unpassivated regions along bias ring	$\geq$ 200μm
Junction breakdown	> 200 V
Micro-discharge breakdown	> 150 V
Coupling capacitor breakdown	> 100 V
Total detector current at 150V	< 20μ A
Interstrip capacitance	< 1.2 pf/cm
Non-working strips	< 20 strips detector

Sensor Readout

- **kPiX chip**
  - **KPiX3-64, most recent chip**
    - Is being bench tested
    - Plan to bond to a sensor?
  - **Next version, KPiX4-64, will include nearest-neighbor logic for tracker use**



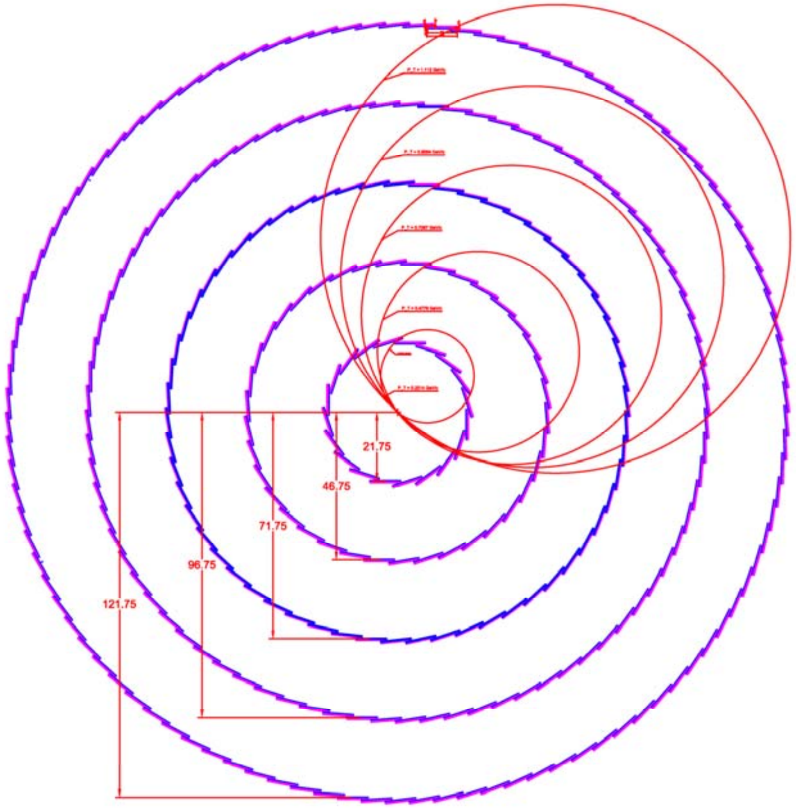


- **Readout cable**
  - **Design progressing for calorimeter**
  - **Expression of interest from University of New Mexico to work on cable design**
  - **Design not started**

Tracker Design Update

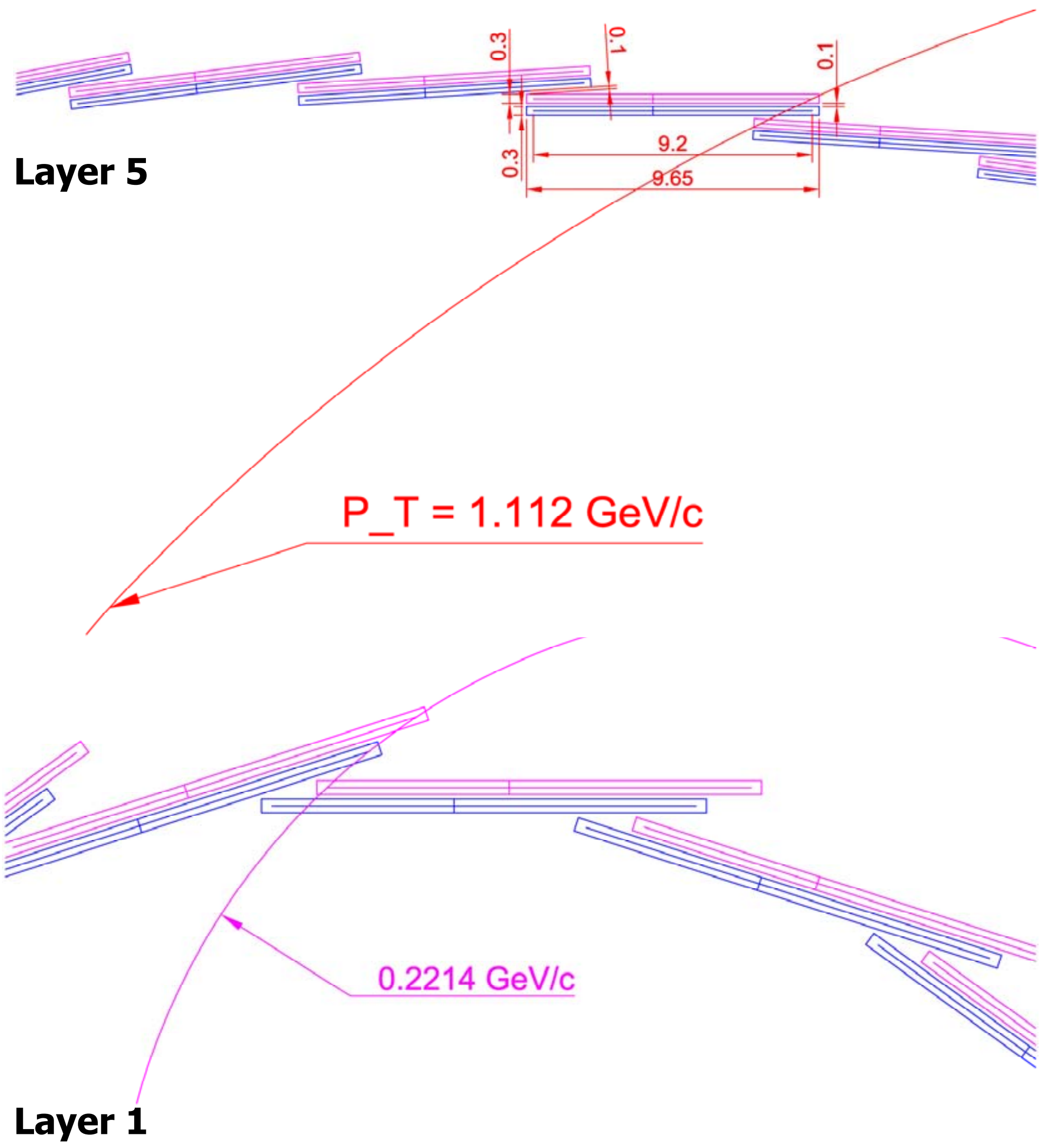
Bill Cooper

- **May ’06 design has been updated to reflect module design**
  - **Lengths of the outer tracker barrels have been adjusted so that material is less directly aligned with trajectories from the origin**
  - **An initial attempt has been made at an arrangement for sensor boxes of the outer tracker barrels**



Layer	# Phi	# Z	Rot. Angle	R (cm)	P_T (GeV/c)
1A	20	7	10.12°	21.75	
1B	20	6	9.94°	22.15	0.221
2A	38	9	7.03°	46.75	
2B	38	10	6.97°	47.15	0.478
3A	58	13	6.60°	71.75	
3B	58	12	6.57°	72.15	0.710
4A	80	15	6.60°	96.75	
4B	80	16	6.58°	97.15	0.906
5A	102	19	6.58°	121.75	
5B	102	18	6.56°	122.15	1.112

Module Tiling



- **Each sensor is positioned mid-way through the thickness of a box**
- **Box thickness 0.3 cm to limit the gaps between sensors**
- **A- and B-layer boxes have been aligned; might simplify box mounts**

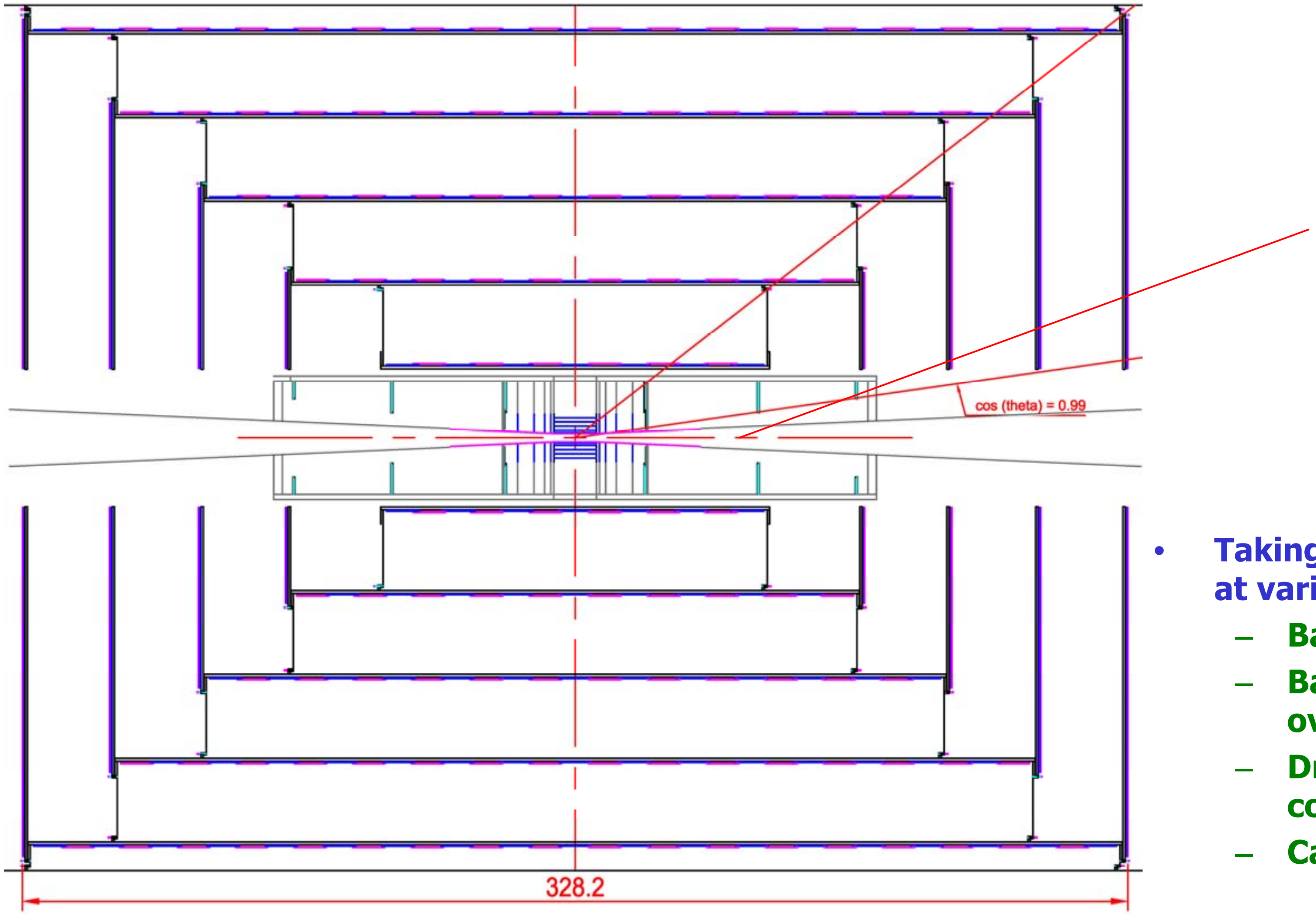
- **Offsetting B-layer boxes with respect to A-layer boxes to be considered**
  - **improves the low PT cut-off for the A-layer, but not the B-layer**
  - **Offsetting slightly could make rotation angles of the two sub-layers identical**

Bill Cooper

RZ View

Bill Cooper

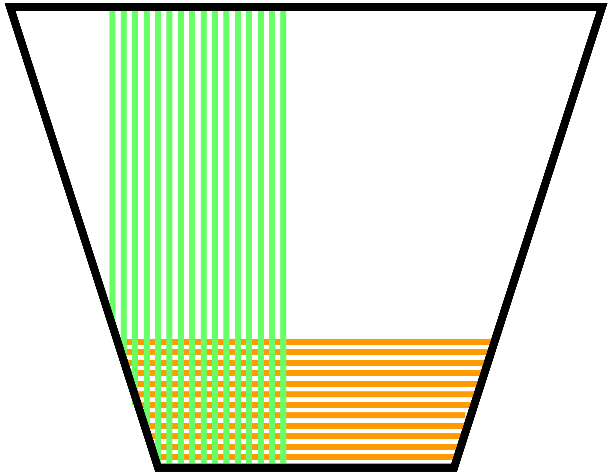
- Pointing material has been spread out



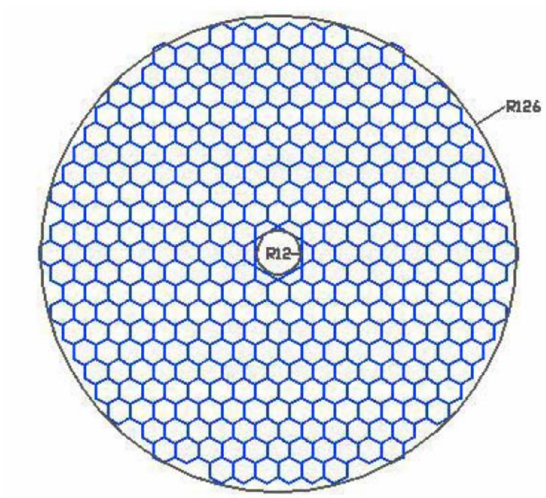
- Taking a close look at various details
  - Barrel 5 mounts
  - Barrel-disk overlap
  - Dry gas connections
  - Cable paths

Forward Disks

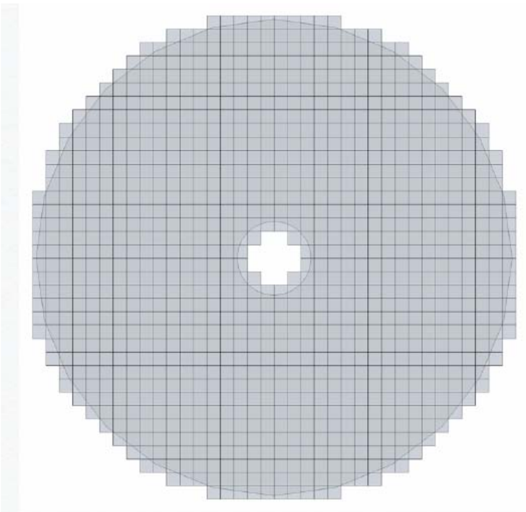
- **Forward disks**
  - **Currently, disks represented by 4 planes with a plane-to-plane separation of 0.2 cm.**
  - **But, no tiling concept exists**
  - **Dedicated one tracking meeting to a discussion of various tiling concepts without conclusion**
- **We need to initiate a study that addresses the tiling**



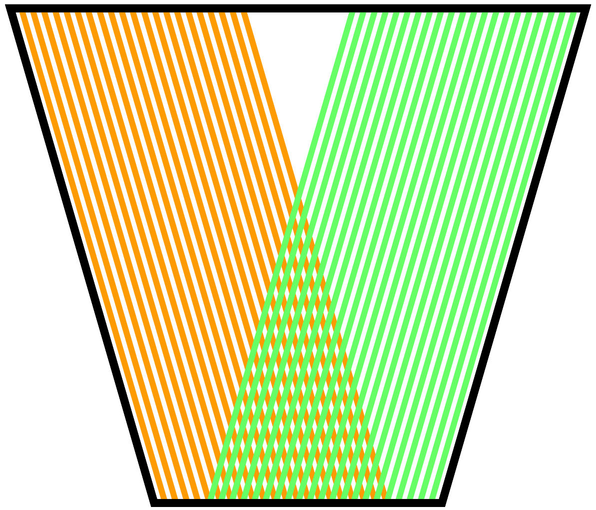
Large Angle Stereo



hexagonal



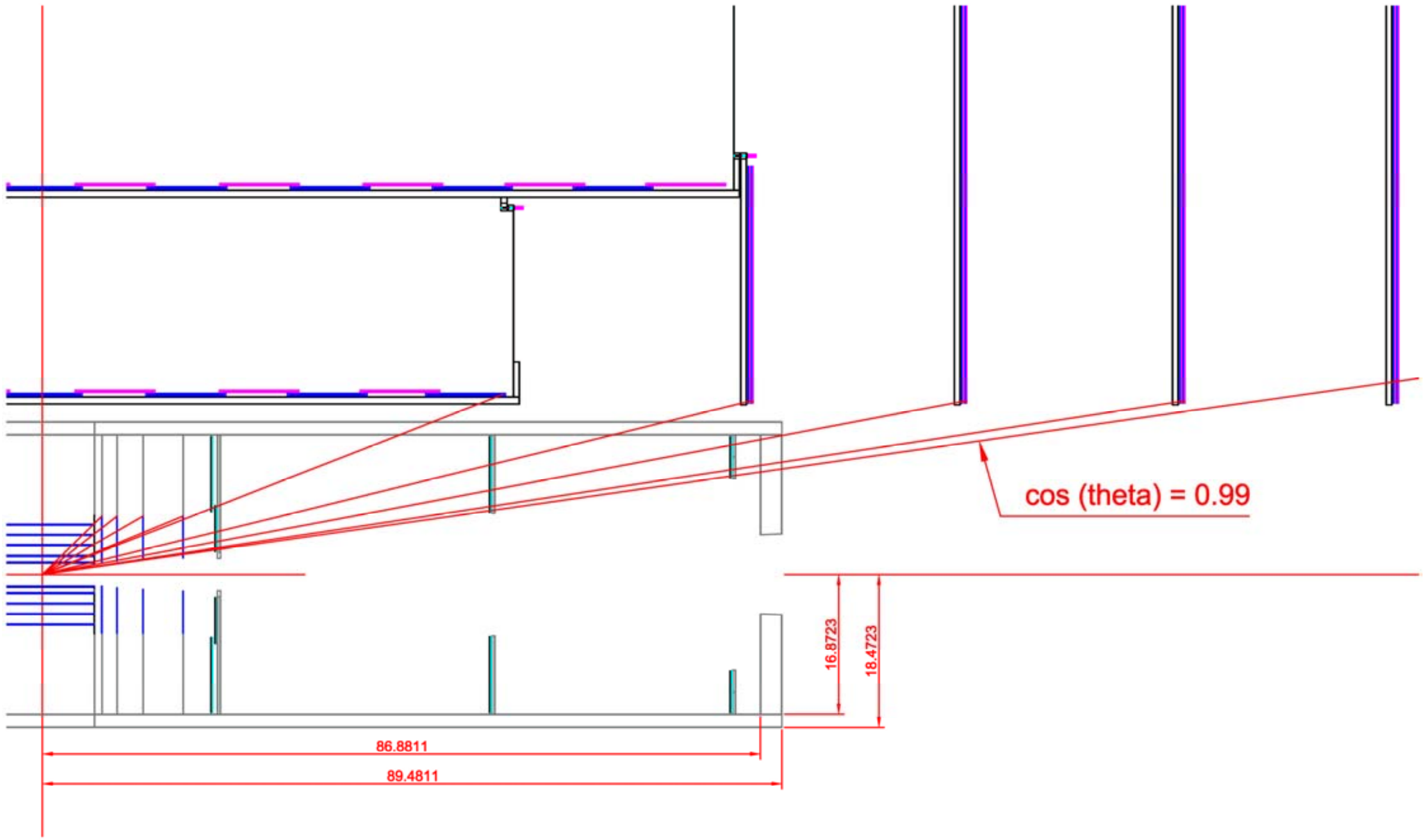
square



Shallow Angle Stereo

Small Angle Tracker Region

- **The baseline has three small area disks in the small angle tracker – vertex detector overlap region**
  - **Small area disks within radius of 20 cm**
  - **The first three outer tracker disks do not reach cos (theta) = 0.99, but forward disks in the VXD region do**
- **We have no quantitative measure of this region**

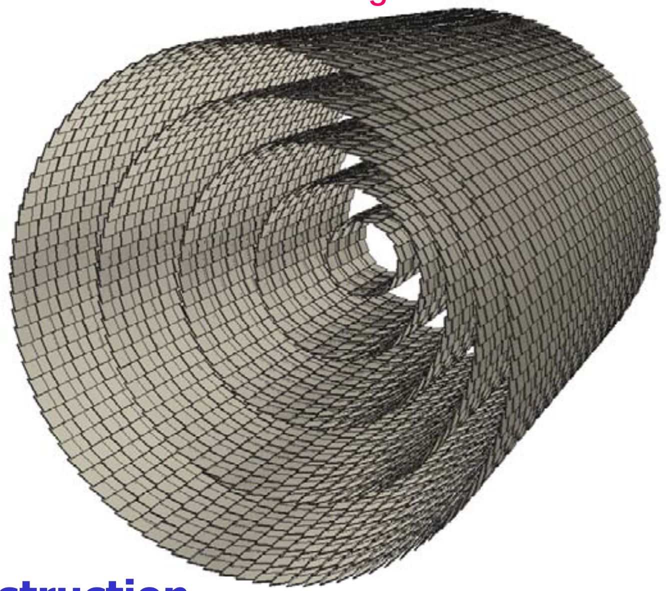


Bill Cooper

More Realistic Simulation

Jeremy McCormic
Tim Nelson

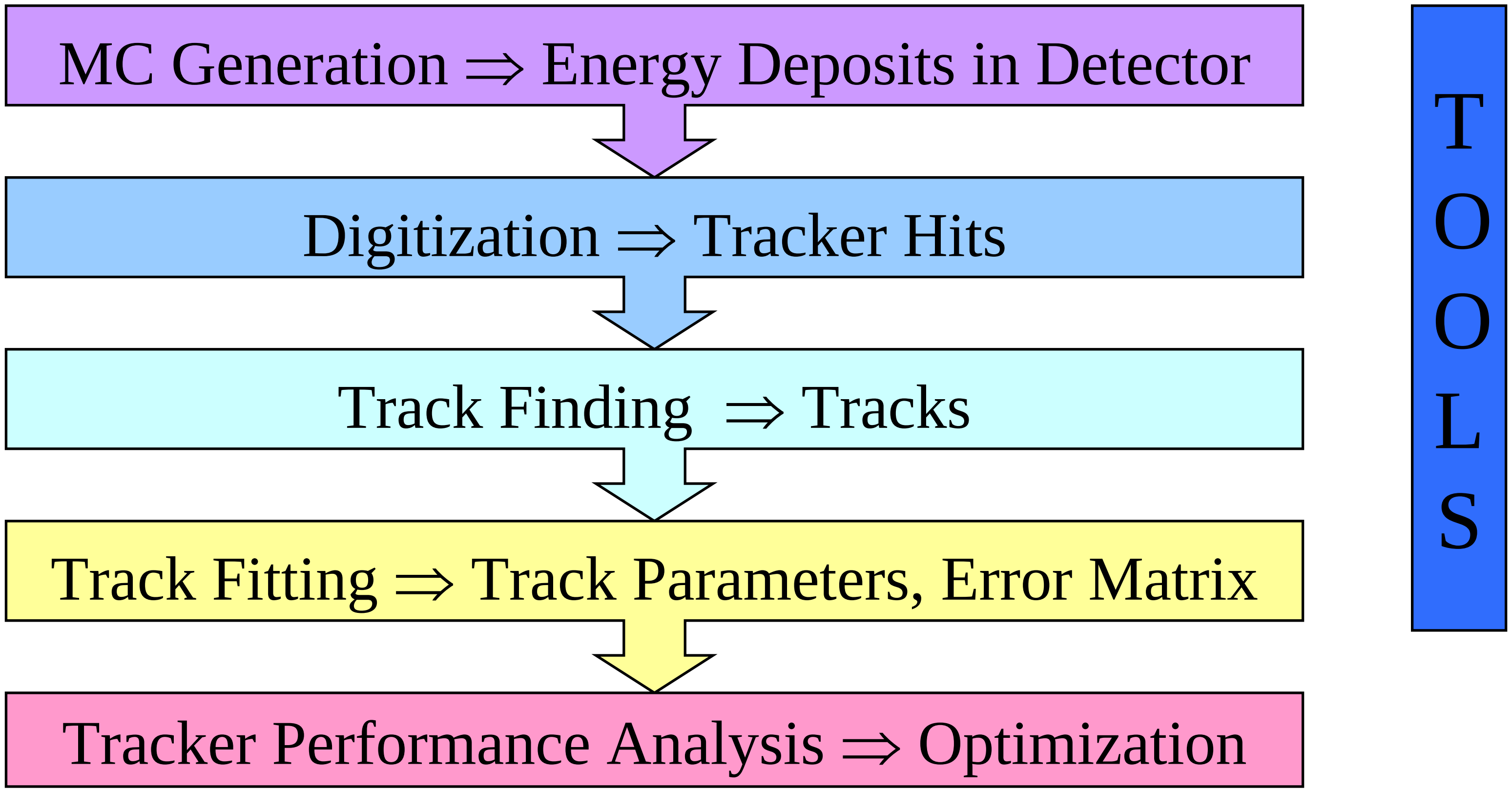
- **Geometry**
  - **Moving from a cylindrical geometry in the Monte Carlo to a planar geometry**
    - Realistic z-segmentation with overlap; End cap regions not yet done
  - **Allows for**
    - Track finding/fitting constraints provided by z-segmentation and stereo angle
    - Ghosting in double-sided layers (esp. forward)
    - Realistic modeling of occupancies (esp. forward)
    - Lorentz angle studies with sensor tilt
    - Clustering issues
    - Efficiency studies of cracks between phi/z overlaps



- **Associated software well underway**
  - **Hit encoder and decoder**
    - barrel/endcap flag
    - layer number
    - number of module in phi layout
    - number of module (sensor) in z layout
- **Integrating New Geometry into Tracking Reconstruction**
  - **Sensitive volumes create TrackerHits using sistripsim code**
  - **Allows for immediate use of existing tools with new geometry**
  - **Considering more advanced tools**
- **Geometry needs to be reconciled with Bill's updated geometry**

Tracking Simulation

- **Tracking simulation is a multi-layered effort**



From Rich's Vancouver talk

Software

- **Hit Digitization**
  - **Detector hits are not created during GEANT simulation**
    - Allows readout segmentation to be changed without re-running GEANT
  - **Hit formation (Nick Sinev (ccd), Tim Nelson (strips))**
    - Charge deposition
      - Turn energy deposits into charge on nearby strips
      - Include Lorentz angle, diffusion, capacitive coupling, noise
    - Readout Segmentation and Clustering
      - Map strip charges onto the readout segmentation
      - Sum charges when multiple particles produces charge on the same strip
      - Find clusters of strips and form “TrackerHit” with hit position and error
- **Track Finding**
  - **Conformal Mapping (Norm Graf)**
    - Conformal mapping of circular trajectory to a straight line
    - Current package works from 3D hits – needs strip digitization + ghosting
    - Results presented in tracking meetings for forward tracking
  - **Vertex Seeded Tracking (Fred Blanc, Rich Partridge, Steve Wagner)**
    - Find track seed in vertex tracker and pick up hits in outer tracker
    - Results presented in tracking meetings using MC truth for vertex seeds
  - **Calorimeter Seeded Tracking (Dima Onoprienko, Eckhard von Törne)**
    - Find MIP stubs in calorimeter and pick up hits in outer tracker
    - Can be used to find long-lived secondaries (K_S, Λ, etc.)
  - **Stand-alone Outer Tracking (Bruce Schumm, Tim Nelson)**
    - Find track candidates using outer barrel tracker

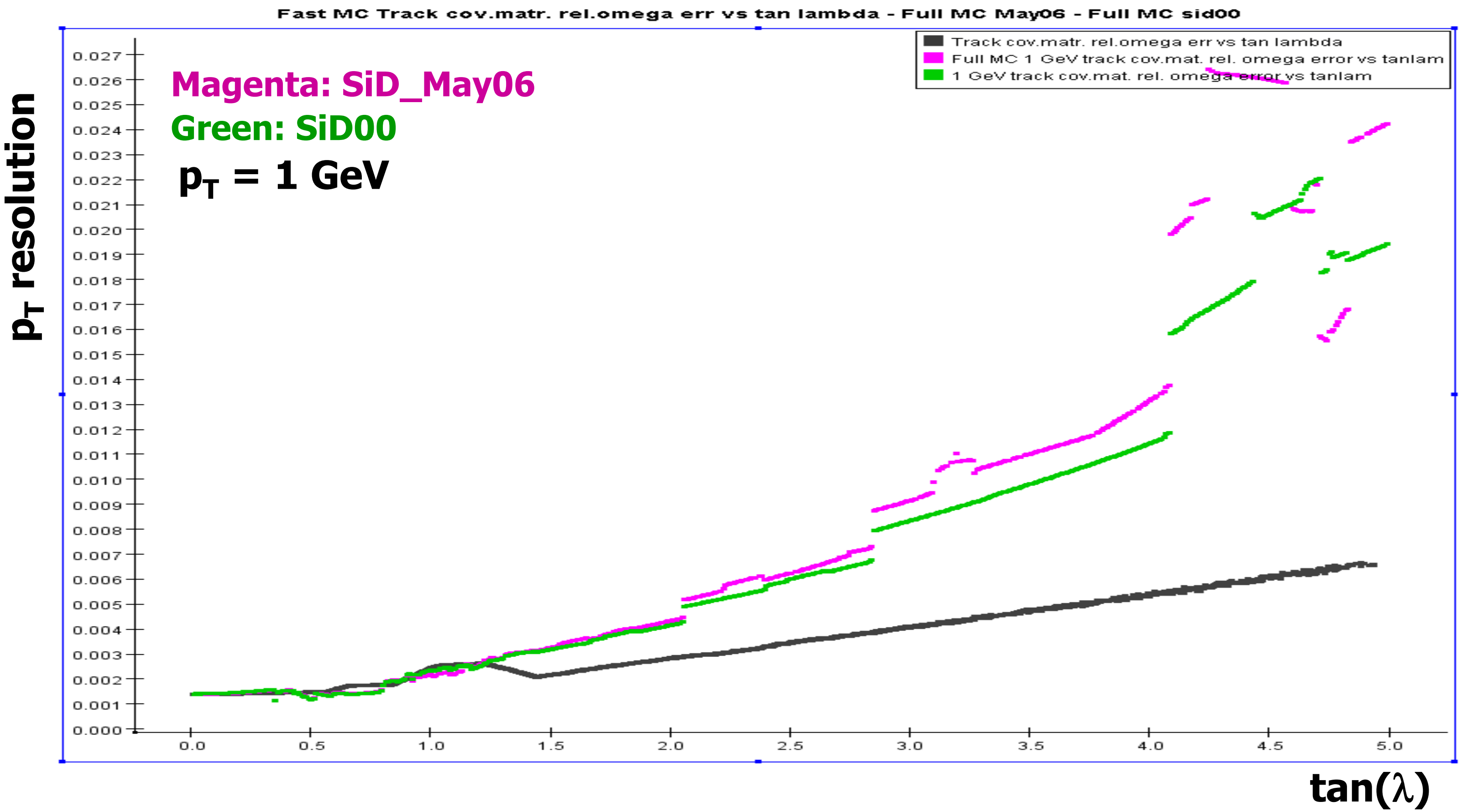
Software

- **Track Fitting**
  - **Weight Matrix (Nick Sinev)**
    - Performs a χ^2 fit of hits to a helix including multiple scattering correlations
  - **Kalman Filter (Fred Blanc, Norman Graf)**
    - Uses Kalman Filter to adapt trajectory for observed multiple scattering

Tracking Performance

Nick Sinev

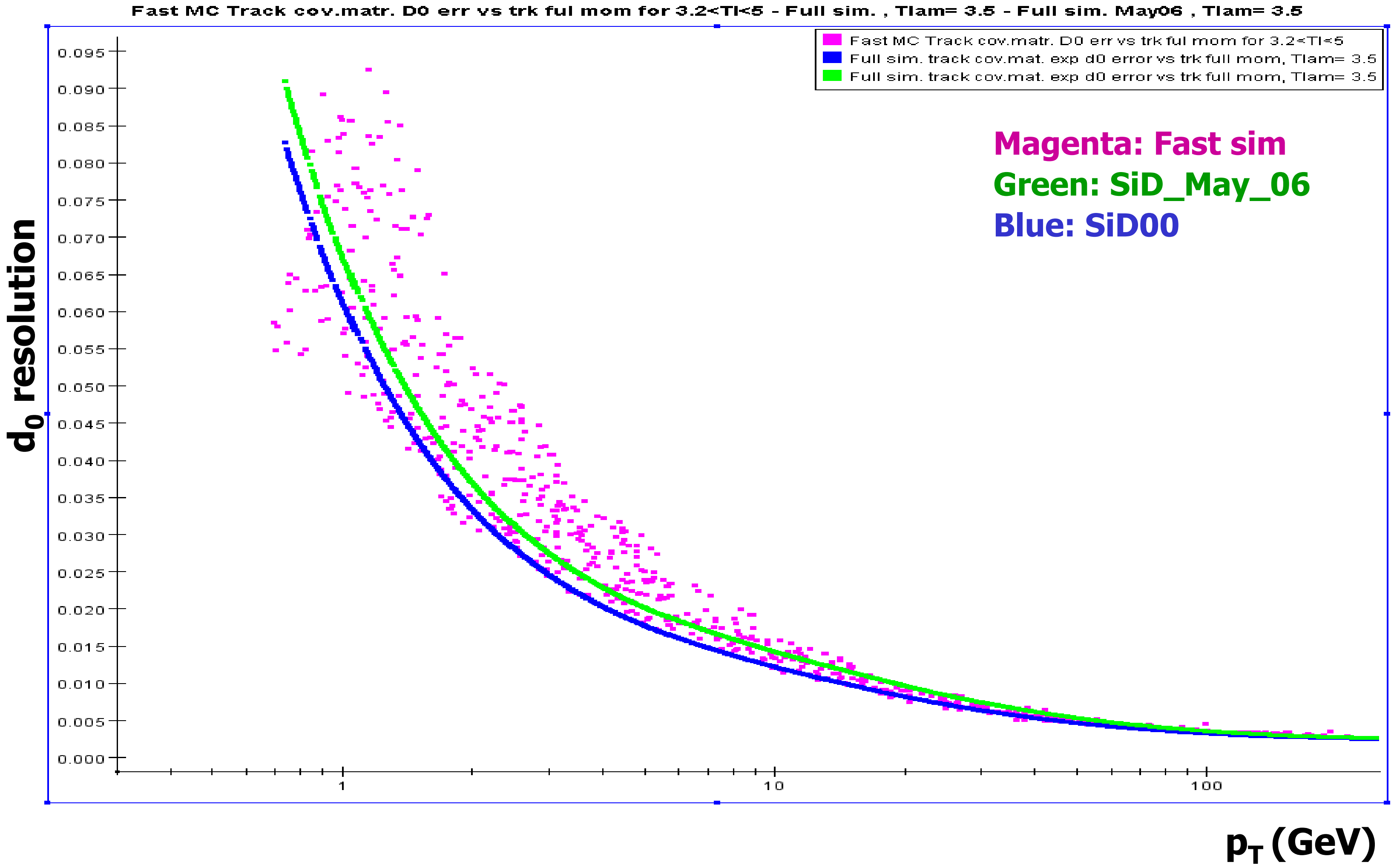
- Developing tools which allow to study effects of detector design on tracking resolutions with full detector simulation
- Current studies limited to weight matrix fitter; need to extend to Kalman fitter



Tracking Performance

Nick Sinev

- **2d-Impact parameter resolution versus momentum**



Summary

- **Good progress given the limited resources**
- **Geometry now well defined and suitable for detailed studies**
- **All the tools are slowly becoming available to do full tracking studies**
- **We have to move from tool development to**
  - **utilizing tools**
  - **confronting them with physics benchmarking processes**
  - **optimizing the detector design**

- **The group is gaining momentum, we should try to sustain that**

- **Exploit all areas where there is a possibility for collaboration**