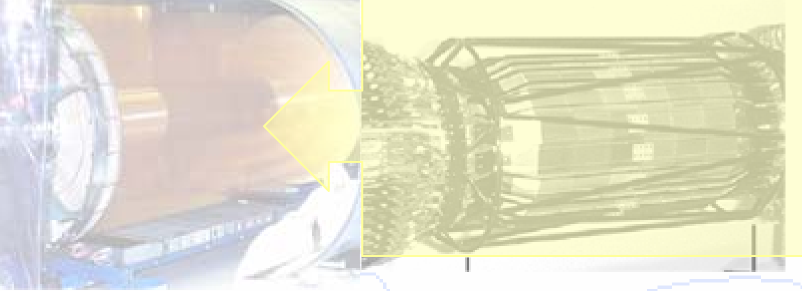
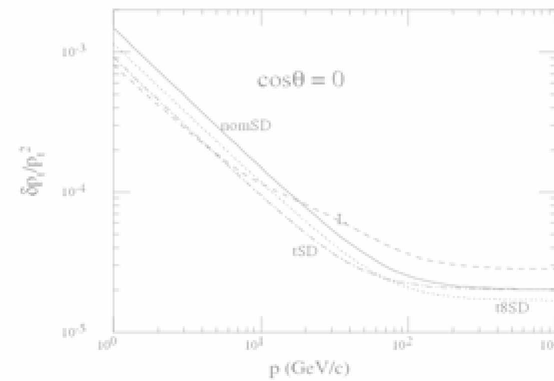


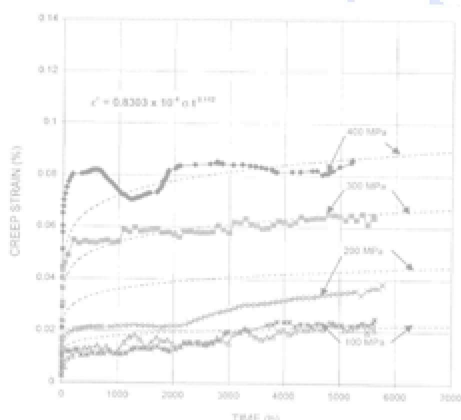


Low-Mass Tracker Support

for the ILC

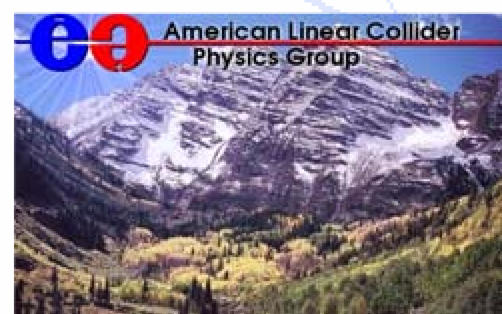
International Linear Collider

2005 International Linear Collider Physics and Detector Workshop
and Second ILC Accelerator Workshop



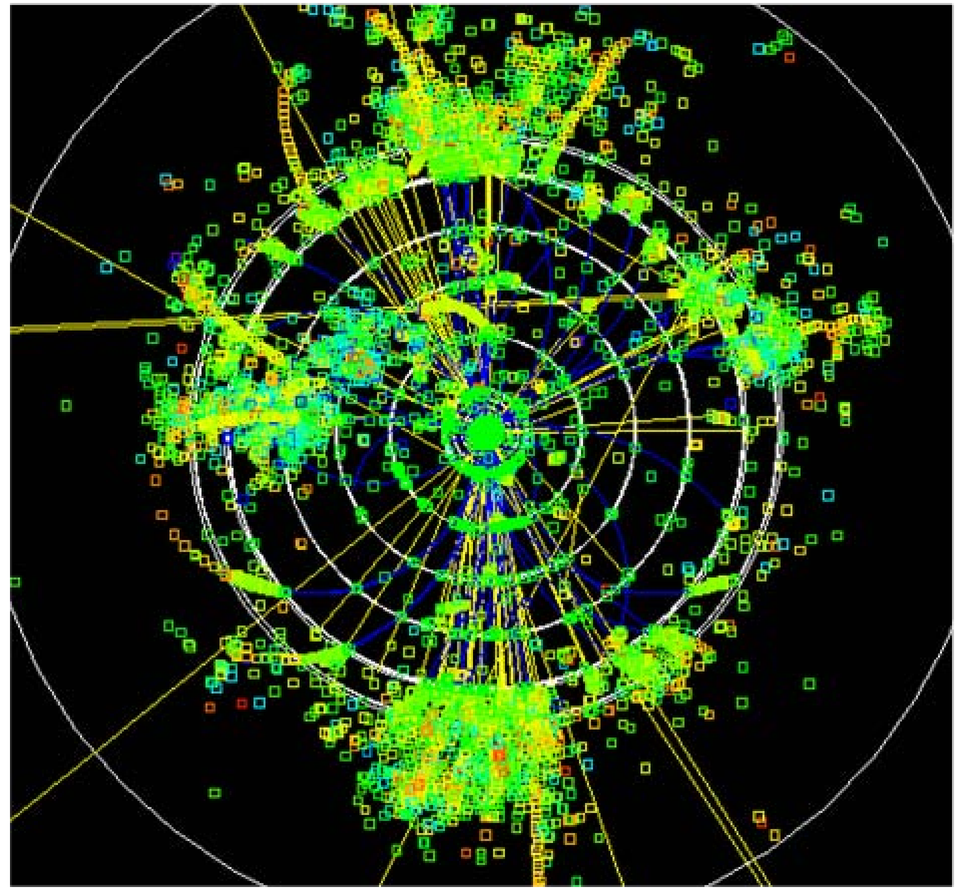
J. Albert

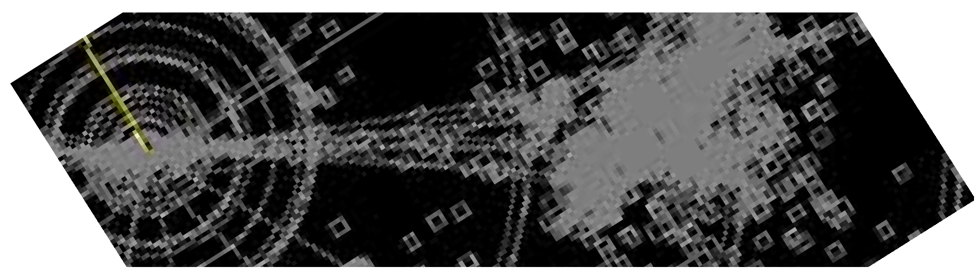
Aug. 23, 2005



Overview

- The tightly-packed jet structure of ILC events poses a challenge for separate reconstruction of charged tracks, however…
- Individual track reconstruction required for "particle flow" jet energy resolution improvement.
- Even small amounts of multiple scattering can easily confuse particle tracks in such tightly-packed jets.





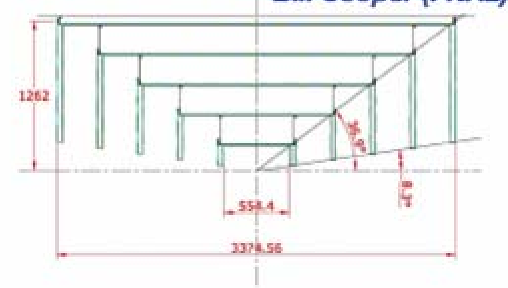
- Reduce amount of material in tracker! (Without sacrificing resolution, increasing noise…!)
- How? A **carbon fiber filament-based tension support structure**.

Philosophy: Always Change as *Little as Possible!*

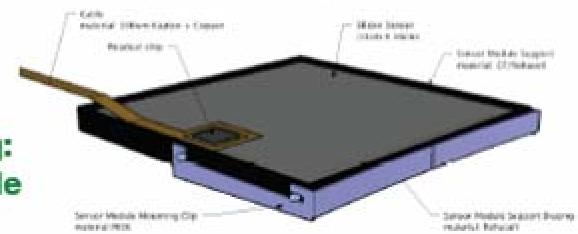
- Small module design allows for simple, robust readout.
- Simplified manufacturing, replaceability.

Alternative: Small Modules

Bill Cooper (FNAL)

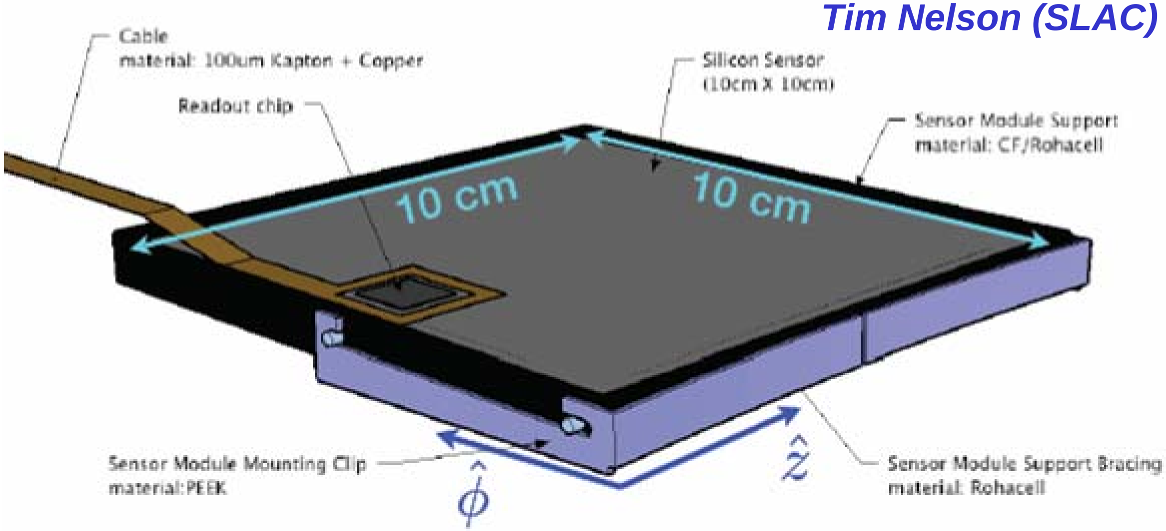


- *Shift responsibility for rigid/robust support onto underlying structure:* Nested, closed carbon-fiber / Rohacell cylinders (a la D0 CFT, Atlas SCT)
- *Tile cylinders with small, simple modules, each with own readout*
  - Very high S/N (~20)
  - …embly
  - …on/handling:
  - …nent possible



Short Module Design

Tim Nelson (SLAC)



- **Don't change a good design !!!**
- But what about the <u>barrel cylinders</u>? Do we *really need all that inactive material*?? ...

Material Budget (Default)

Component	Material	X_0(mm)	Thickness(mm)	Coverage	Average Thickness (mm)	Average $\#X_0$(%)
Inner skin	CF	242	0.25	1.0	0.25	0.103
Core	Rohacell	13800	13	1.0	13	0.0942
Outer skin	CF	242	0.25	1.0	0.25	0.103
Total	—	—	—	—	—	0.300

Table 2: Material summary for barrel support cylinders.

Component	Material	X_0(mm)	Thickness(mm)	Coverage	Average Thickness (mm)	Average $\#X_0$(%)
Mounting Clip	PEEK	287	1.0	0.2	0.2	0.070
Frame	CF	242	4	0.04	0.16	0.066
Bracing	Rohacell	13800	4	0.35	1.4	0.010
Adhesive	Epoxy	290	0.5	0.35	0.175	0.060
Sensor	Silicon	93.6	0.3	1.0	0.3	0.321
Chip	Silicon	93.6	0.3	0.016	0.0048	0.005
Total	—	—	—	—	—	0.532

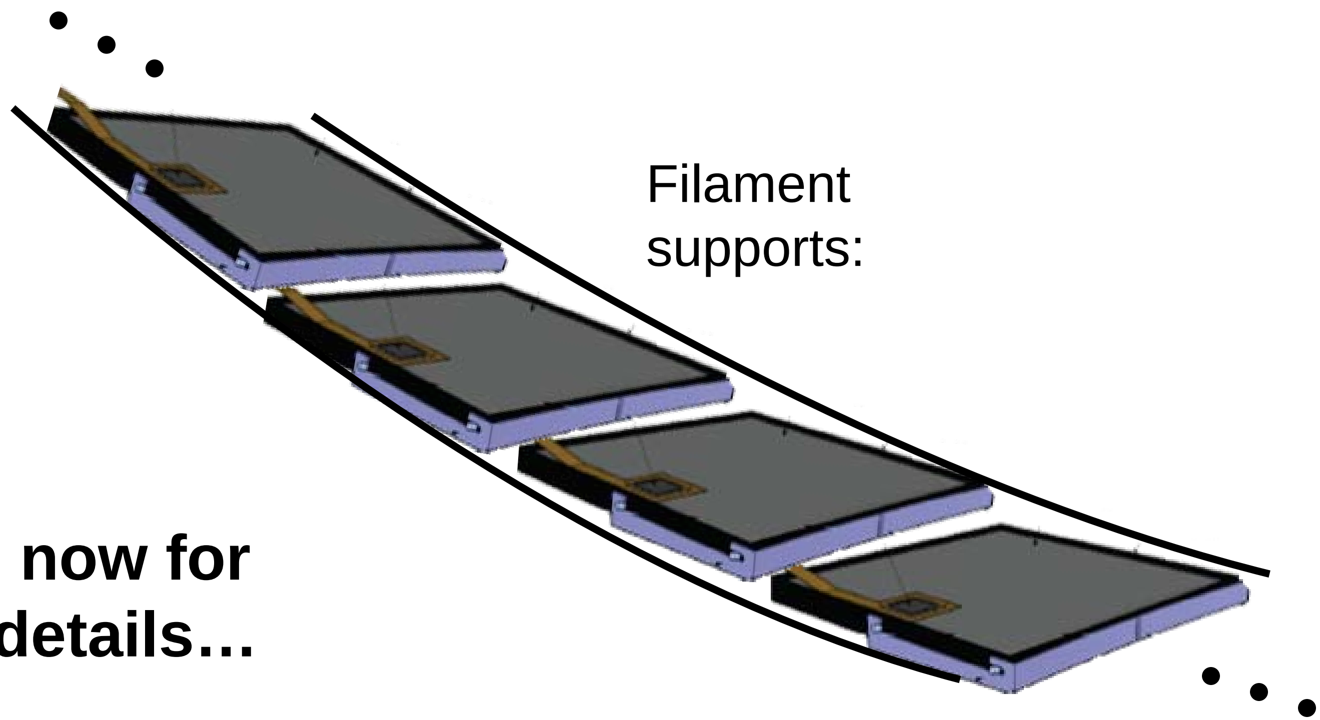
Table 3: Material summary for barrel silicon modules. Materials are listed roughly in inside-out order, and are applied to the outside of all cylinders.

Tim's SiD Tracker Material v.0.21

- Barrel supports are **only 36% of total material** – *however, that assumes we end up using 300 um silicon.*
- If we go to, for example, 150 um, the barrels are then **50%**. And if we perchance go lower than that … we're basically all inactive support.
- Cylindrical barrels also do not support the Lorentz angle of modules – thus additional material may be necessary for such support…

Basic Concept

- Place modules between thin carbon fiber filaments.
- Filaments, under tension, support the modules.
- Services & readout supported, alongside the modules, by the filaments.
- Vastly reduces support structure.
- Filaments easily oriented for appropriate Lorentz angle.



And now for the details…

Filaments

- Carbon fiber provides very high yield strength, low creep with low mass / Z.
- Optimization of filament properties:
  - ✓ Sag must not increase over time.
  - ✓ Sag must be "small"…
  - ✓ **Must be calibratable at all points *and times* to << 7 um (nominal resolution).**
  - ✓ Must have safety factor for creep (above), C.F. yield strength (obviously).
  - ✓ Must have safety factor for major shaking / earth movement.
  - ✓ Vibration properties must be both small and fully calibratable.

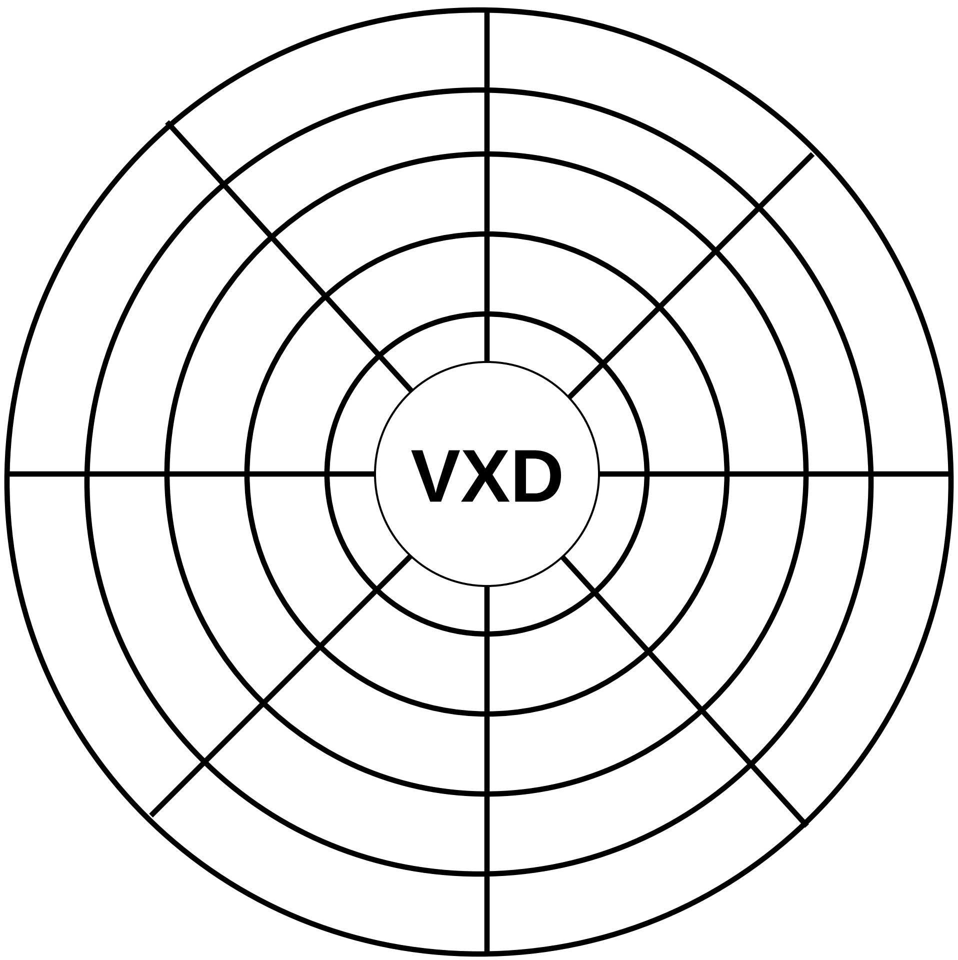
Carbon Fiber General Properties

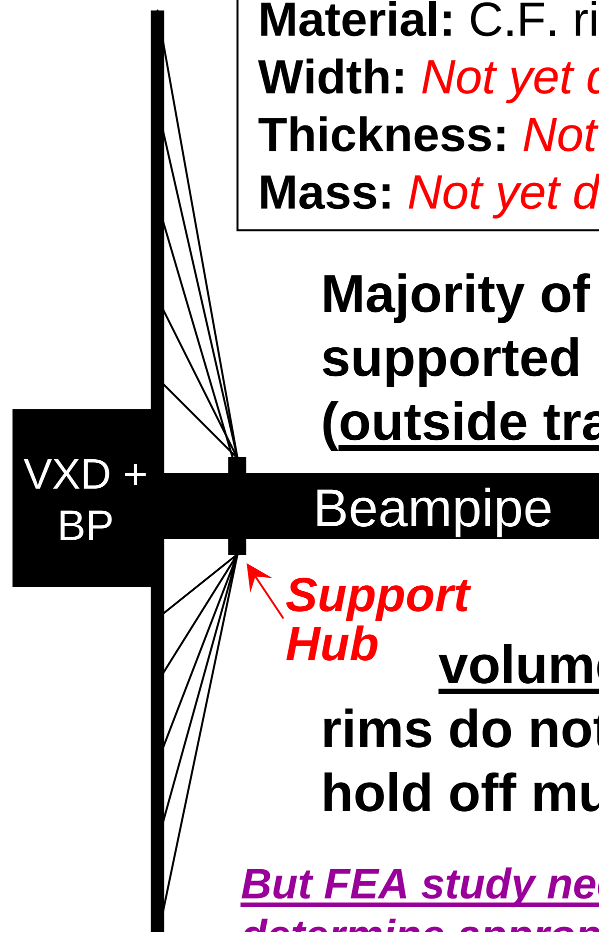
Yield strength: 6.9×10^8 Pa
Young's modulus: 2.4×10^{11} Pa
Density: 1.8×10^3 kg m^{-3}
Thermal C.E.: $1\text{-}3 \times 10^{-6}$ K^{-1} (match Si)
Specific heat: 7.1×10^2 J kg^{-1} K^{-1}

Material: 0-90º crossply C.F. matrix
Width: 2 mm
Thickness: 250 um
Tension: 5 N (= 1×10^7 Pa)
Mass (incl. modules): 0.19 kg (L5)
Sagitta: 6.9 mm (L5 = max)

End Supports

- End supports must also be low mass, but able to hold tension of support filaments.
- Use old idea from Al Odian (SLAC – *& perhaps others*): ***bicycle-wheel***:





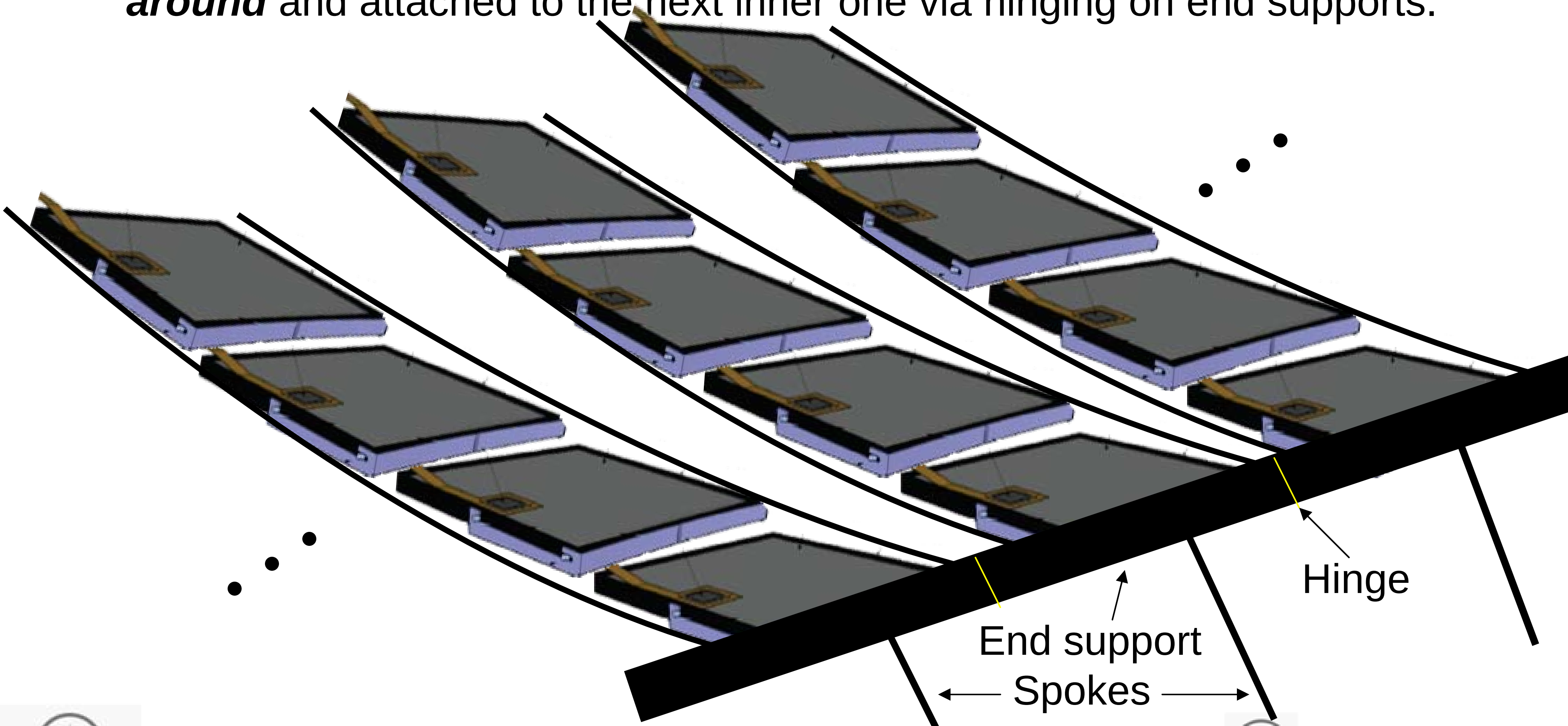
Material: C.F. rims, spokes
Width: *Not yet determined*
Thickness: *Not yet determined*
Mass: *Not yet determined*

Majority of tension supported by hub (<u>outside tracking volume</u>) so support rims do not need to hold off much tension!

<u>But FEA study needed to really determine appropriate dimensions…</u>

Assembly

- Assembly could be done more simply by having layers be **separable**.
- Module insertion onto filament frame structure done **flat** on a filament frame stand. (Also good for cosmic tests.)
- Then, on final assembly, each layer (very carefully, mechanically) ***wrapped around*** and attached to the next inner one via hinging on end supports.



Deflections / Alignment

- The filaments will nominally take the shape of an "elastic catenary," a function that's well-known from structural engineering in cable structures.

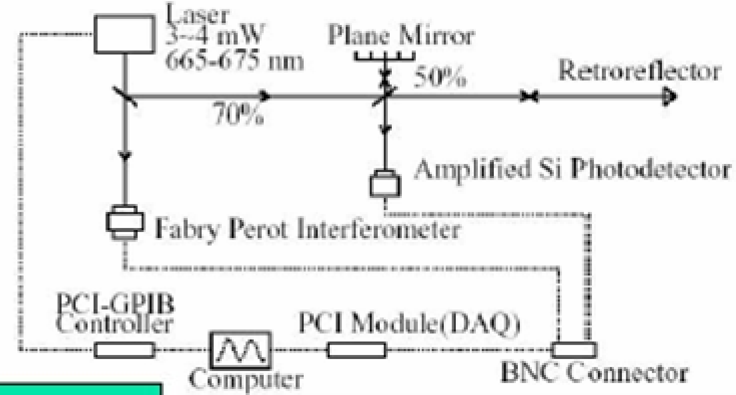
- However, very clearly each module will require exact calibration of its position and Euler angles, to provide a proper bootstrap point for track-based calibration.

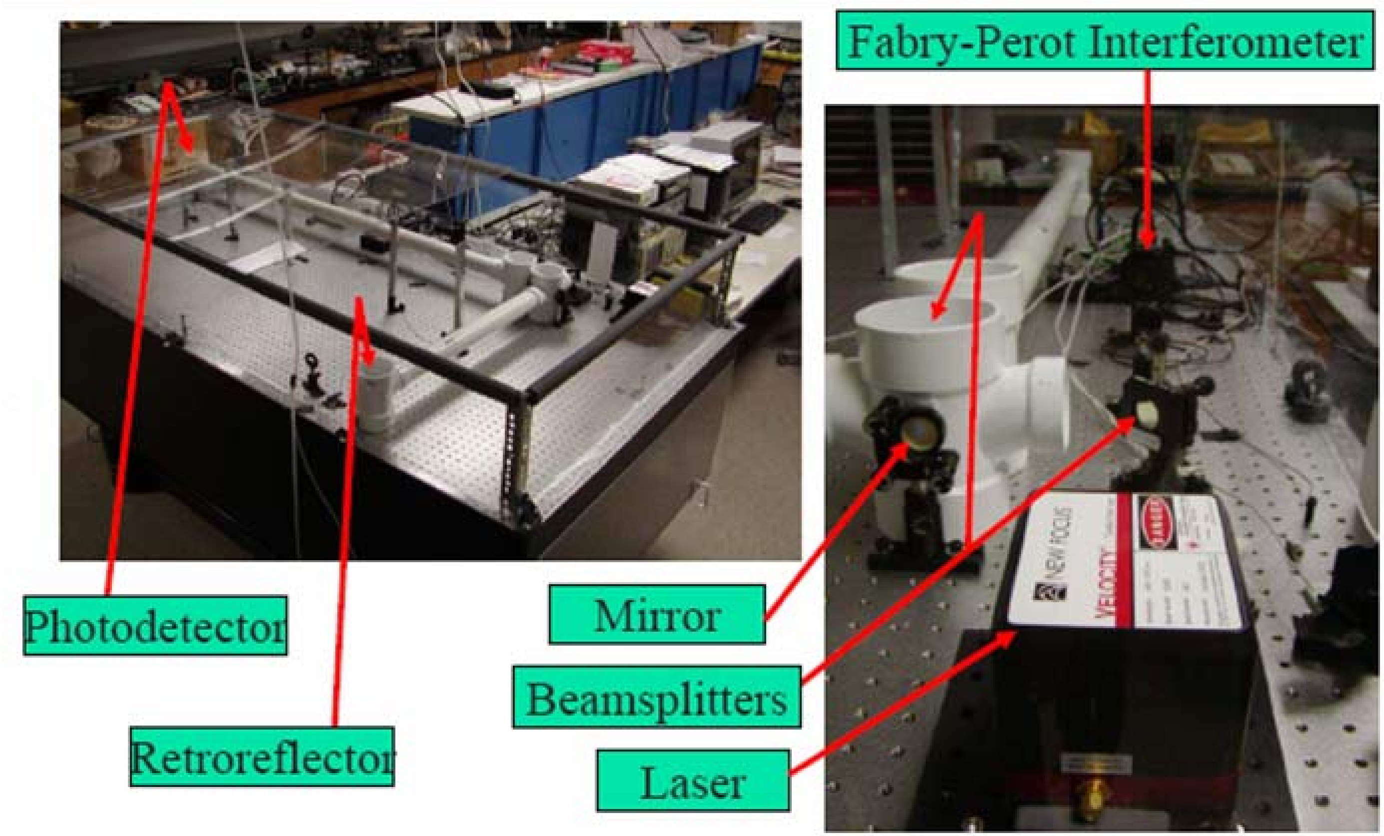
- Furthermore, a highly precise position calibration must be done **in real time**, due to vibrations from microphonics, etc. (Particle tracks will be largely unhelpful for such a real-time calibration.)

- Fortunately, technology for real-time calibration of each module's position is being developed and largely available…

FSI Alignment (UMichigan)

- The UMichigan group (Haijun Yang, Sven Nyberg, Keith Riles) developed an FSI laser alignment system that is *extremely well-suited* to a support structure with potential vibrations and motivation to determine position in real time.

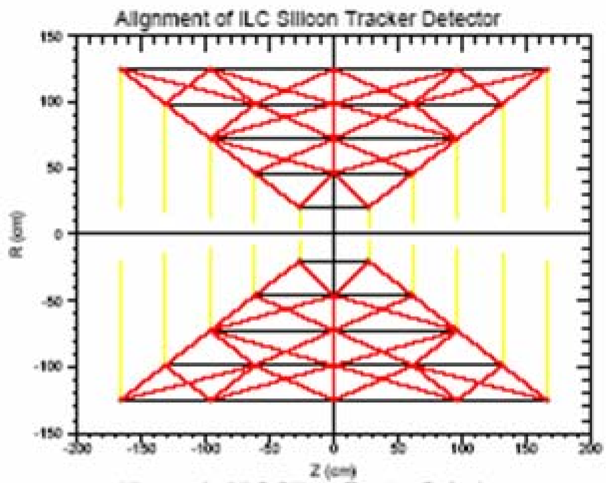


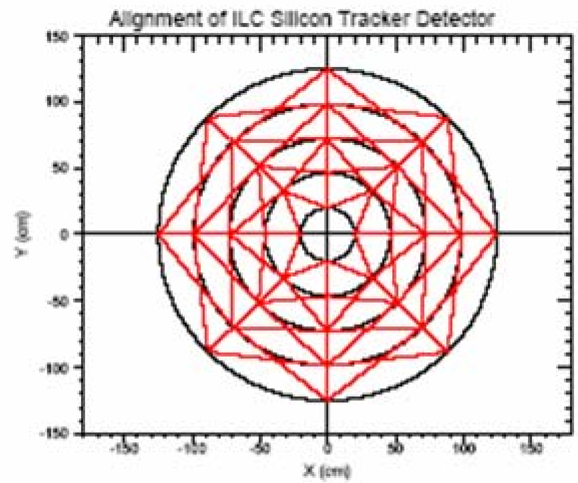


- FSI alignment will also be in use for ATLAS SCT (Oxford group + others).

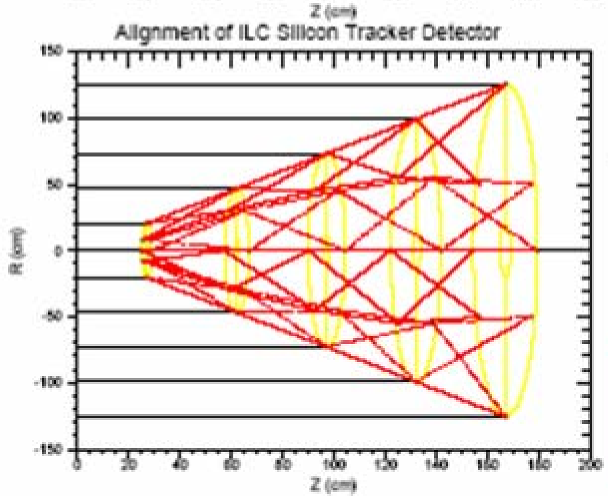
- So there will be additional prior working experience with not-completely-rigid silicon.

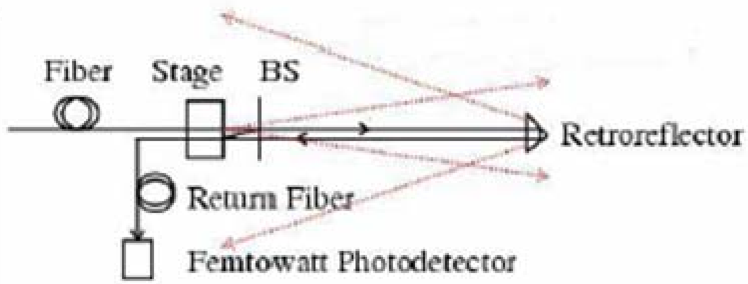
FSI Alignment (UMichigan)





- Small retroreflectors on modules allow measurement of **individual absolute position and vibrations**.





→Measurable range

$f_{vib} = 0.1 \sim 100$ Hz,

$amp_{vib} =$ few nm $\sim 0.4\ \mu m$

752 point-to-point distance measurements

* Measured vibration

$f_{vib} = 1.025 \pm 0.002$ Hz,

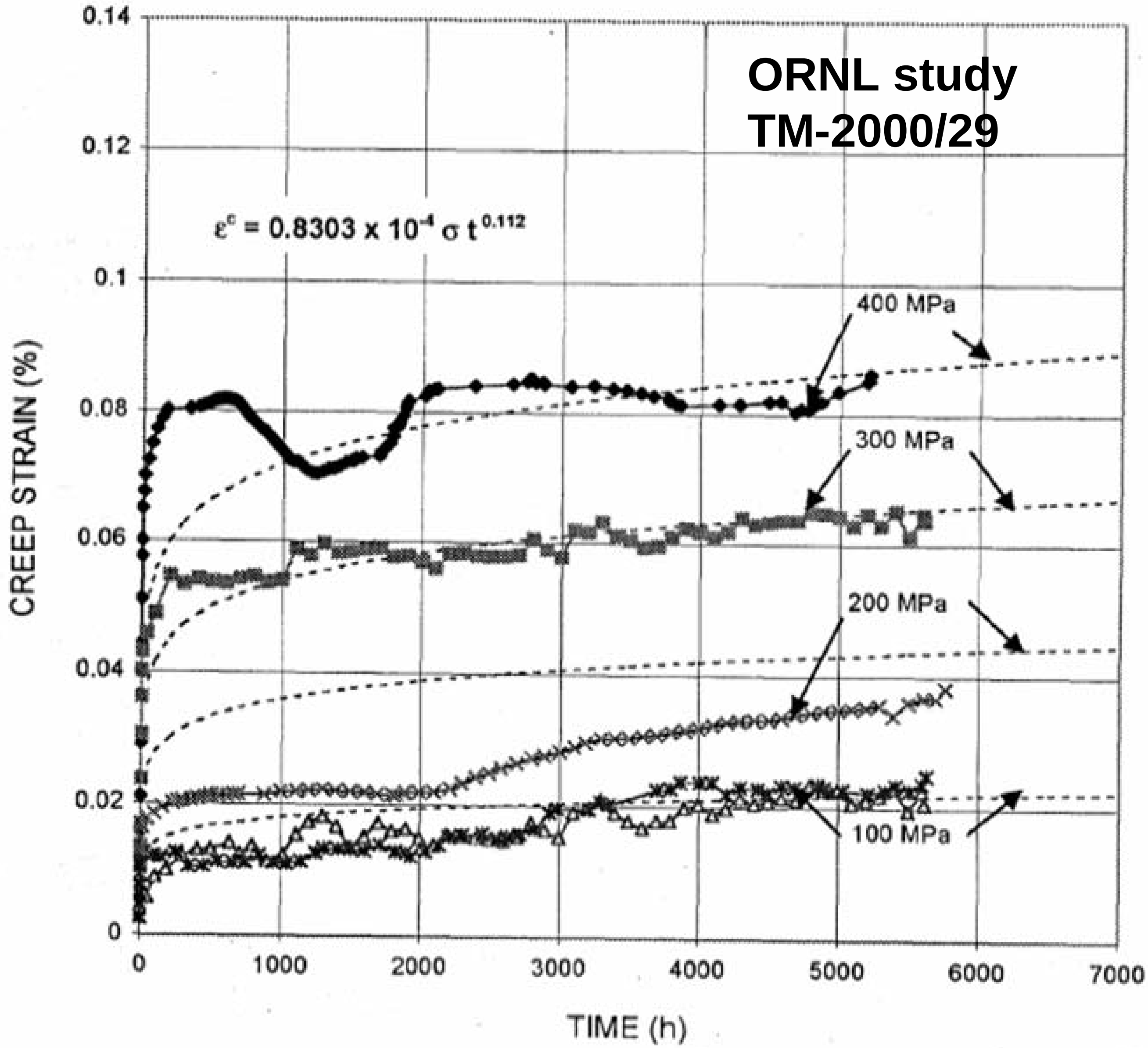
$amp_{vib} = 9.3 \pm 0.3$ nanometers

!!!

- Using the UMich FSI technology under development, the vibrations in a **filament-based structure** can be **extremely precisely** calibrated ***in real time***.

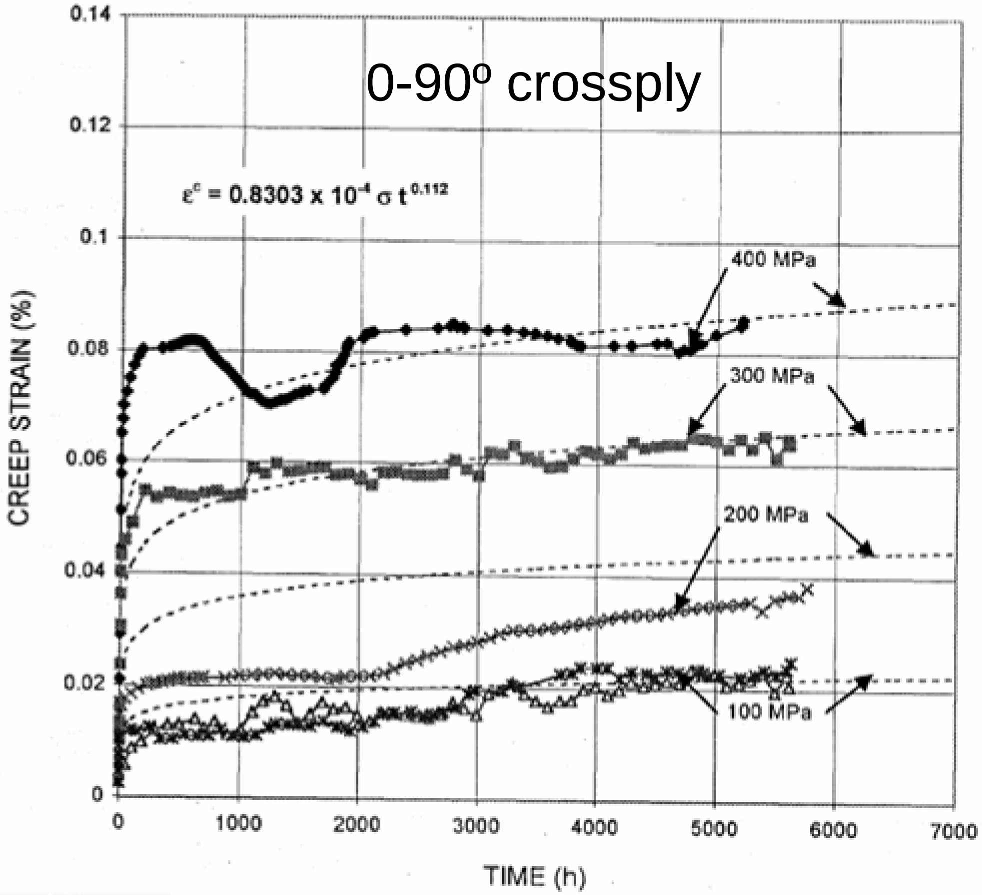
Filament Creep

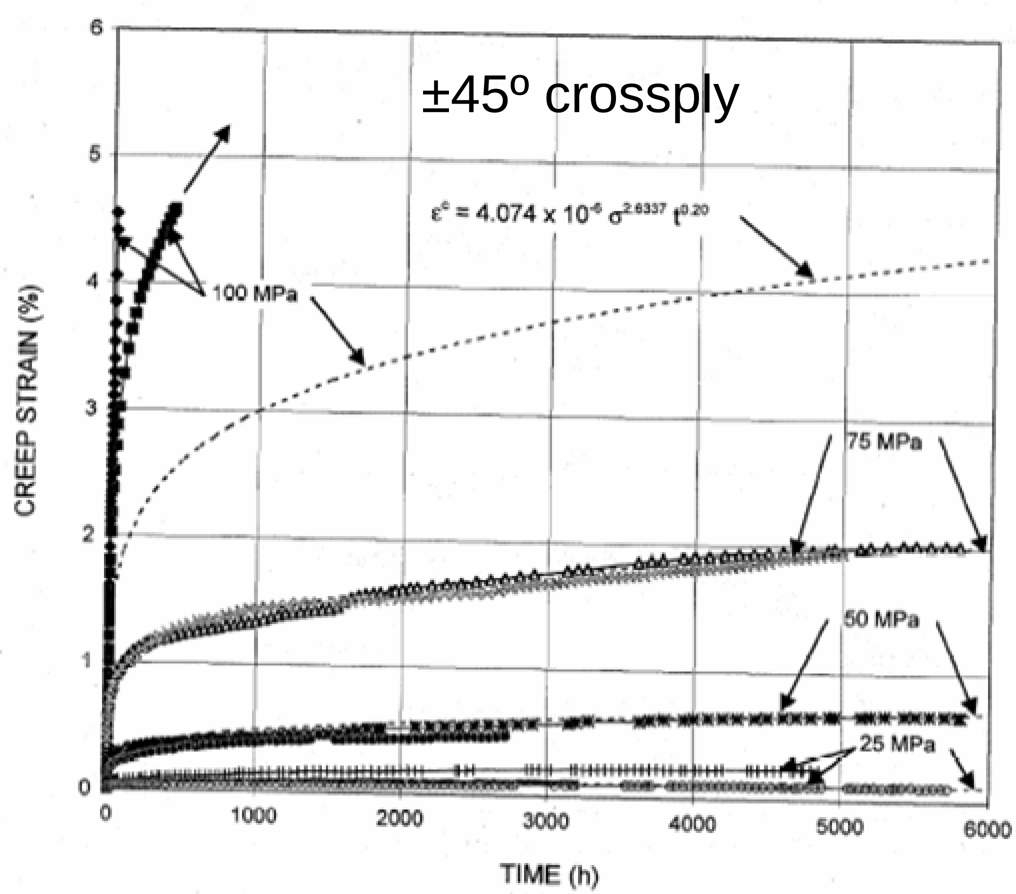
- Yield strength = 691 MPa *is not limiting factor*.
- One is more strongly limited by **creep of fibers** over time.
- ORNL reference study of C.F. creep and other properties provides resource.
- C.F. has relatively low creep, nevertheless to assure insignificant creep, we must keep below **~10 MPa**.



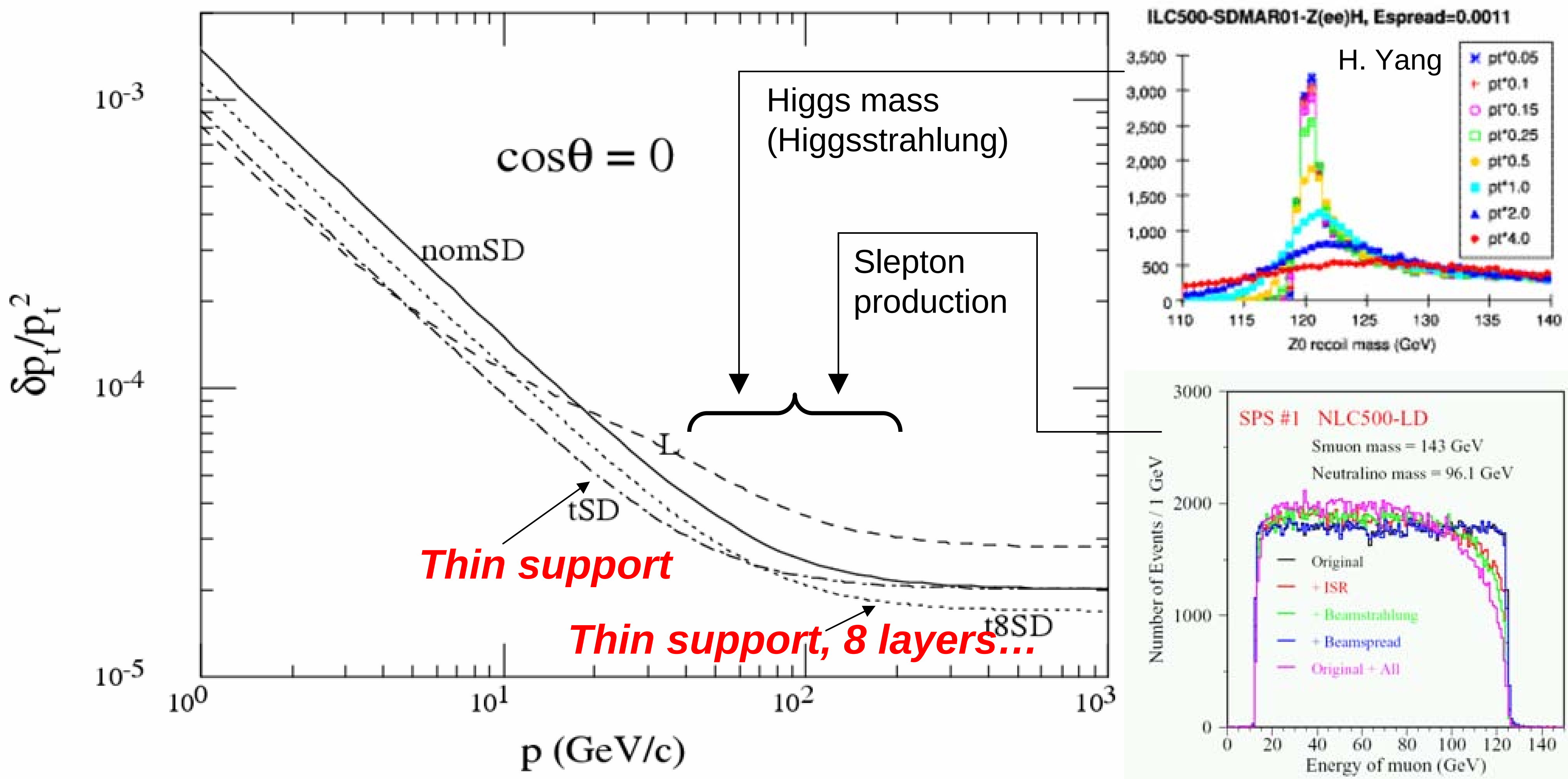
Filament Creep

- But one must be sure to ***buy the correct fiber orientation*** in C.F. matrix (0-90º crossply)!!
- Otherwise creep strain can rise by factor of ~400 !!!!! (±45º crossply).
- But by keeping tension below measurable strain levels *(& real-time alignment),* creep becomes not a major issue.





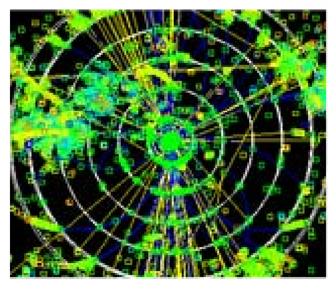
Performance

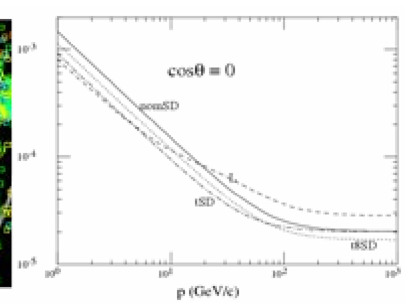


- Done using Bruce Schumm's LCDTrk. Clearly needs full org.lcdsim simulation!!!
- Resolution improves in region of interest.
- Benefit *not just* to charged particle mass peak resol'n… Less scattering ⇒ less **tails** ⇒ **less confusion in particle flow** ⇒ should **improve jet energy resolution** as well…

Conclusions

- In tightly-packed jets, minimizing multiple scattering will be critical for robust pattern recognition and individual track reconstruction for particle flow.
- Replacing barrels with filaments eliminates a large fraction of the inactive material in the tracker.
- This becomes especially important if we reduce the thickness of the silicon from present 300 um. Otherwise we are just dominated by inactive barrels.
- Works in the general direction of Bruce Schumm's goal of a combination of gas and silicon detectors (or at least a combination of a wire chamber and a silicon detector) – **without the comparatively major redesign issues**. Just barrels $\rightarrow$ filaments.
- ***Clearly*** needs a ***lot of work***: **full simulation**, FEA study, test setup (!!)





- There is certainly sufficient time for these studies, though, and at least in my opinion the benefit of this logical implementation should be worth the effort, do you agree?