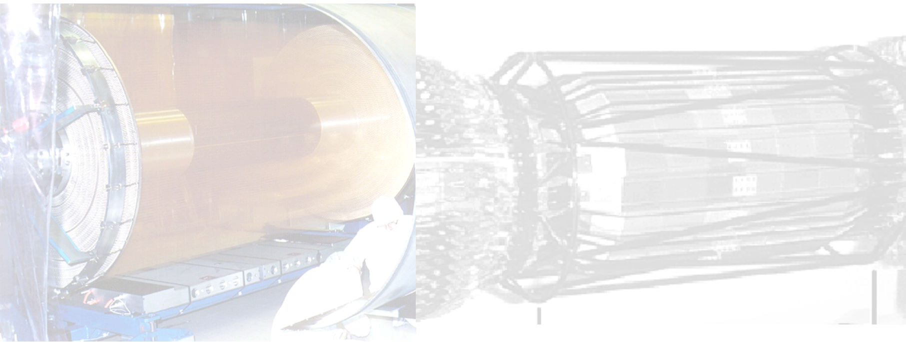



# Low-Mass Layer 0 Support Ideas

## for SuperB Silicon





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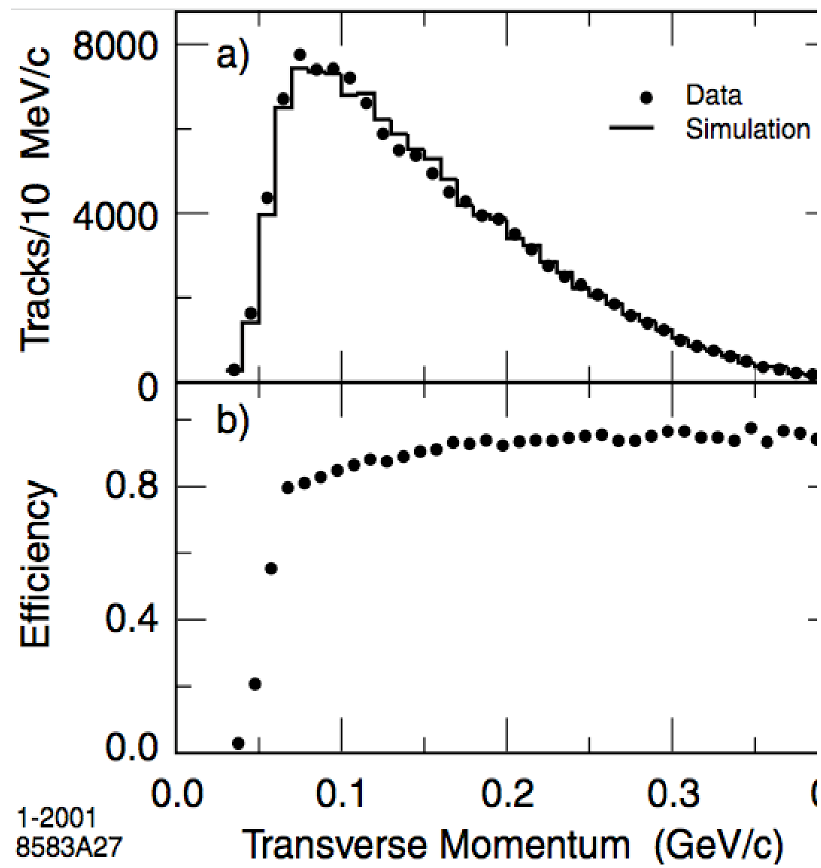
Daresbury Laboratory

# Overview

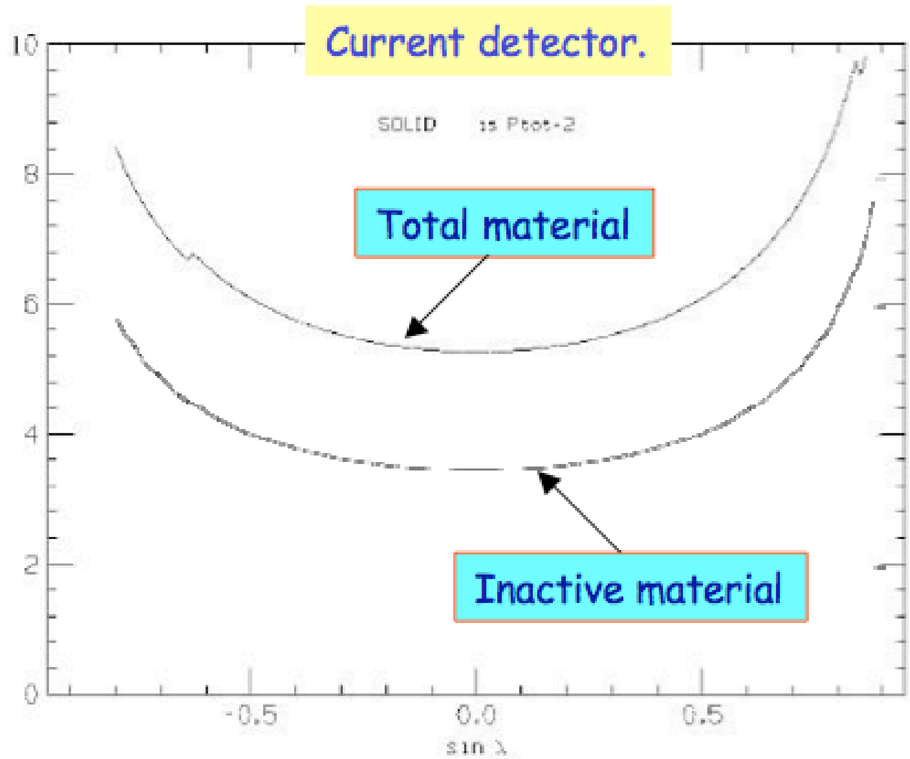
- A large fraction of SuperB physics will involve some slow tracks (e.g. Breco sample, hadronic tag analyses using *D**, etc.)
- Even small amounts of multiple scattering worsens slow pion (and other slow track) ***efficiency***, ***acceptance***, $\Delta$m resolution. This is primarily an issue for the innermost layers (& beampipe).

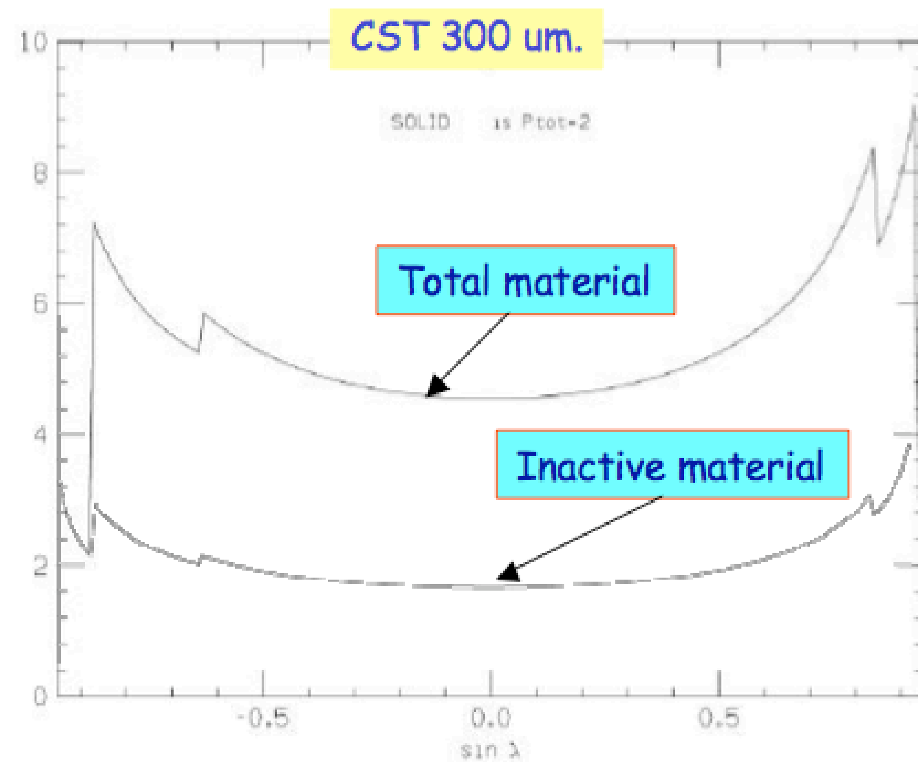
➢ Make sure layer 0 has as little material as possible! (Without sacrificing resolution, increasing noise…!)

➢ How? One way is to use a **carbon fiber filament-based tension support structure**.



# Material Budget



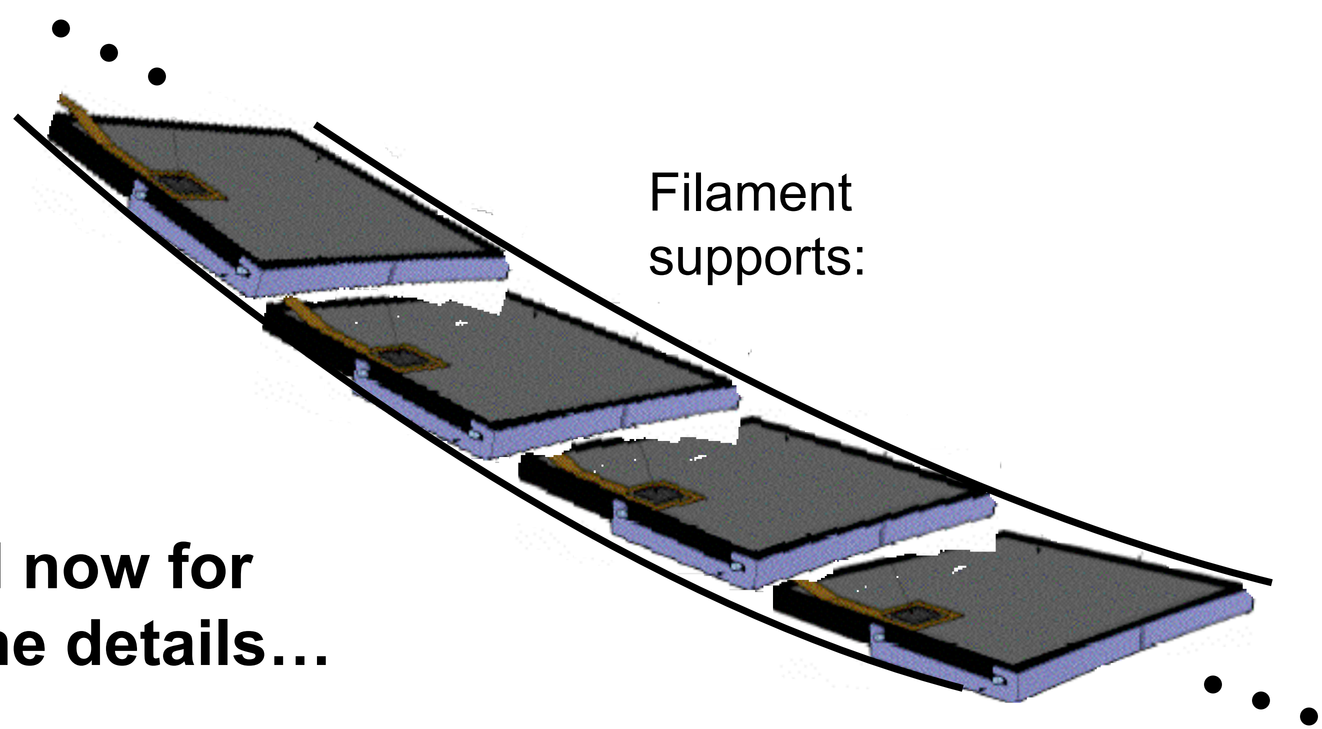




*From F. Forti*

- Inactive material dominates, unless support tube is removed.
- Even if support tube is removed, if layer 0 uses **thinner than 300 um silicon** (likely), then inactive material will *vastly* dominate that layer if a similar support structure to the present rigid frame is used there.

# 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 some 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 << 10 um (approximate 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.

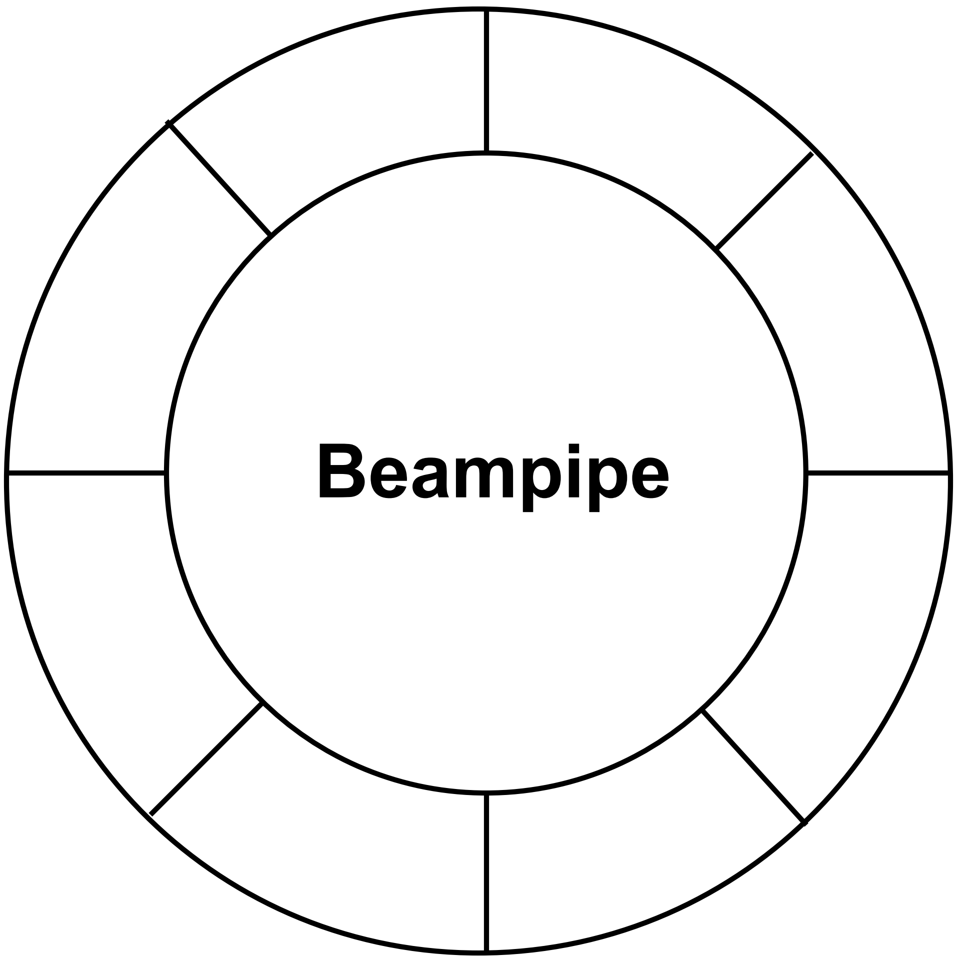
**Carbon Fiber General Properties**

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

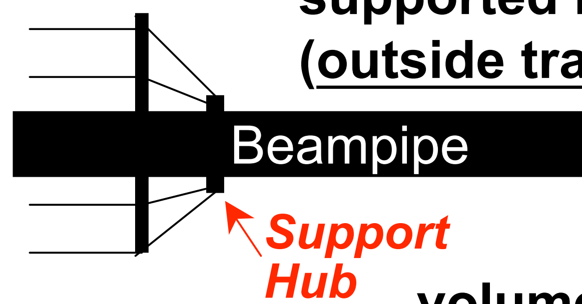
**Material:** 0-90º crossply C.F. matrix
**Width:** 2 mm
**Thickness:** 250 um
**Tension:** 5 N (= $1 \times 10^7$ Pa)
**Mass (incl. modules):** 0.19 kg (L5)
**Sagitta:** 6.9 mm (L5 = max)

# End Supports

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




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

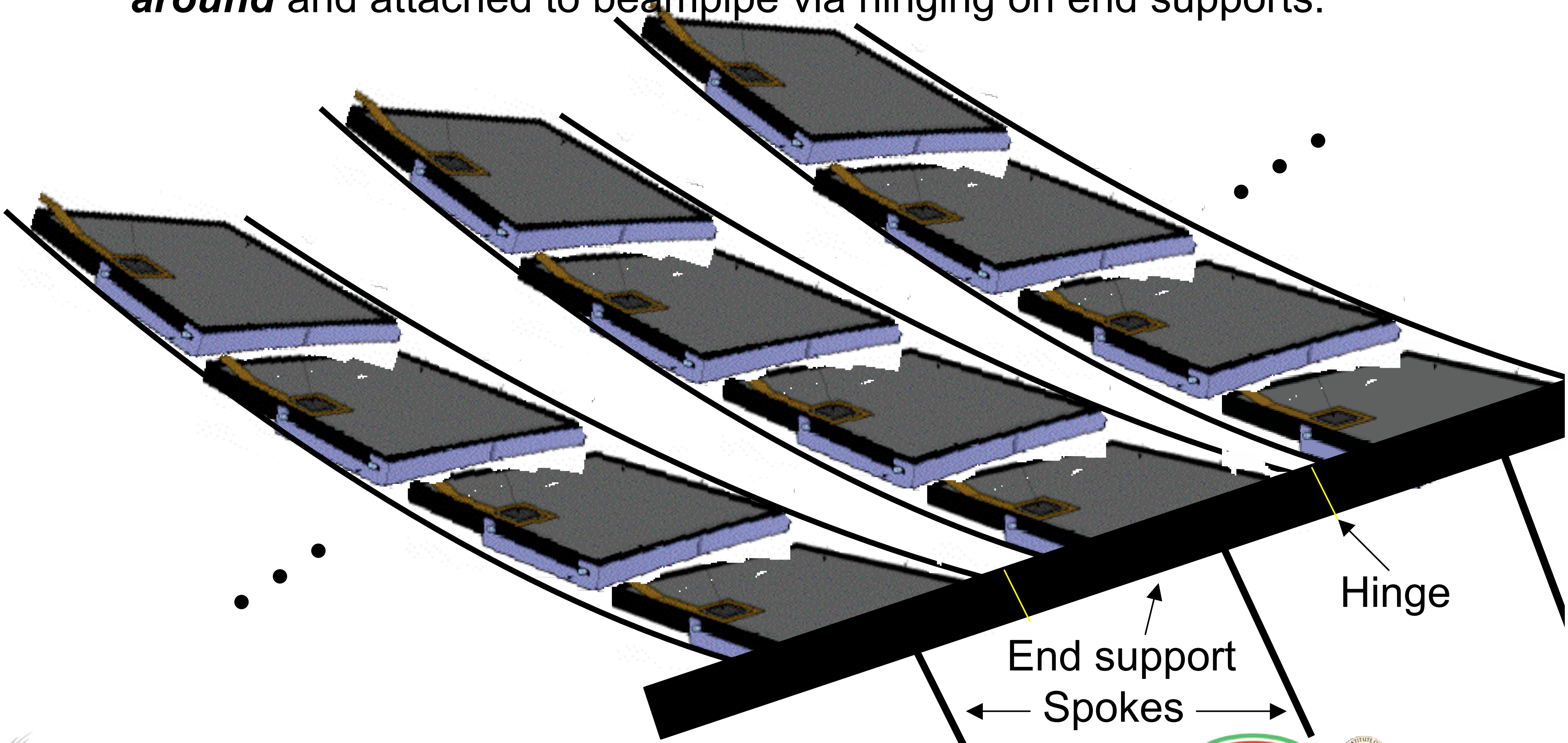



**Majority of tension supported by hub (outside tracking volume) so support rims do not need to hold off much tension!**

***But FEA study needed to really determine appropriate dimensions…***

# Assembly

- Assembly could be done more simply by having a hinged end support.
- Module insertion onto filament frame structure done **flat** on a filament frame stand. (Also good for cosmic tests.)
- Then, on final assembly, layer 0 (very carefully, mechanically) ***wrapped around*** and attached to beampipe via hinging on end supports.

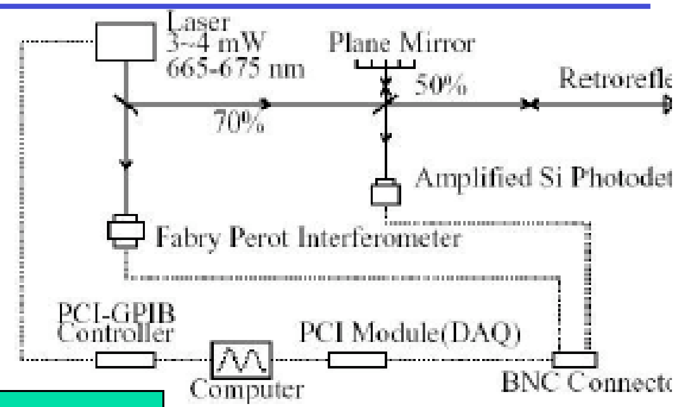


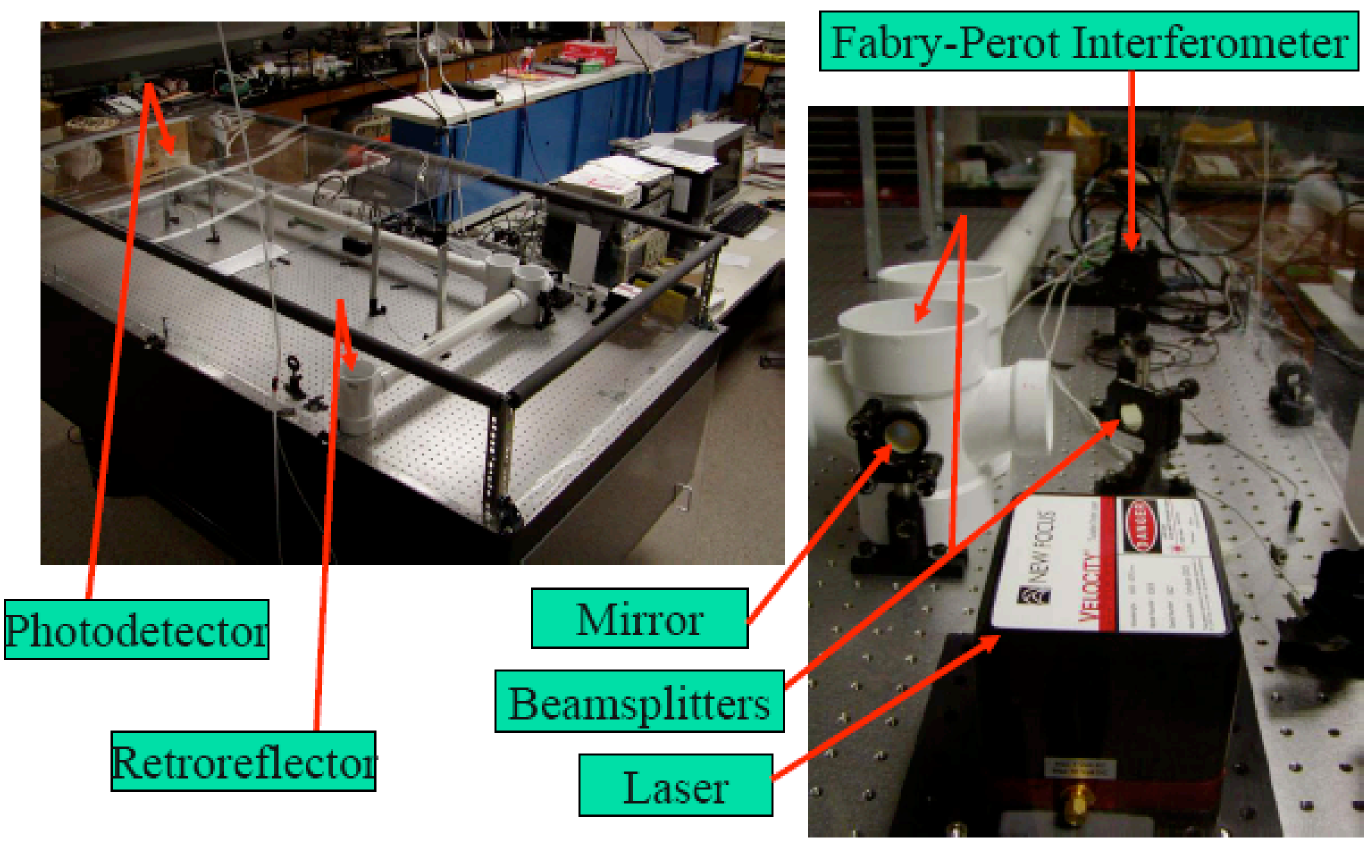
# Deflections / Alignment

- 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 for position of individual silicon modules is being developed and largely available…

# FSI Alignment (UMichigan)

- The UMichigan ILC 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.

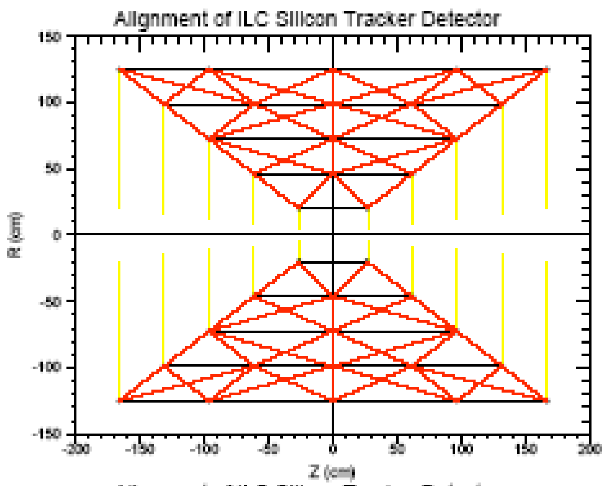


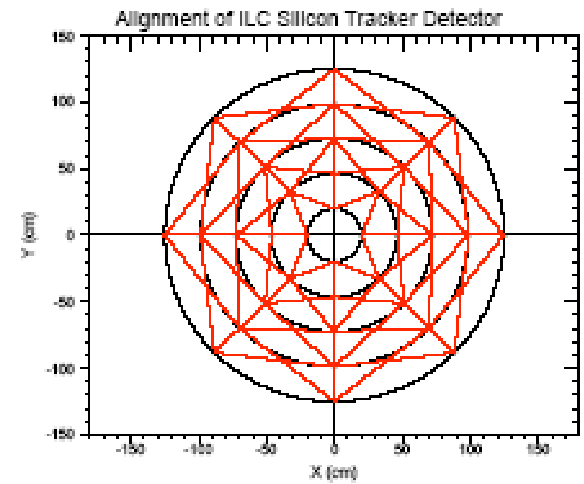




- FSI alignment will also be in use for ATLAS SCT (Oxford group + others).

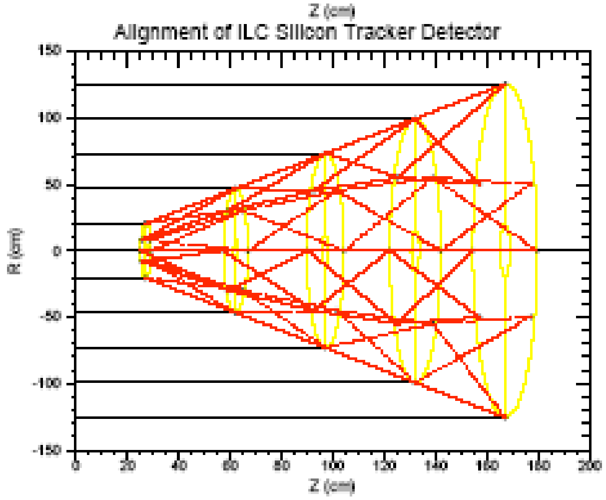
- So there will be additional prior working experience with not-completely-rigid silicon.

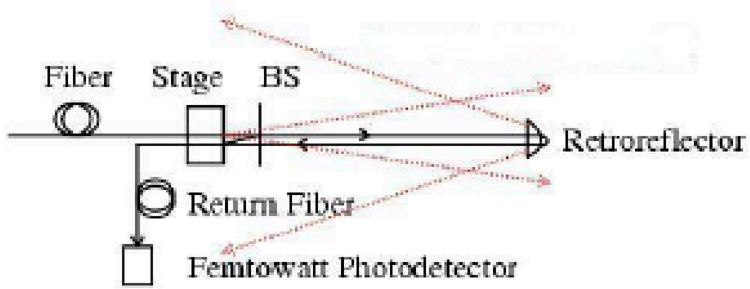
# FSI Alignment (UMichigan)




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




→Measurable range

$f_{vib}$ = 0.1 ~ 100 Hz,

$amp_{vib}$ = few nm ~ 0.4 μm

752 point-to-point distance measurements

* Measured vibration

$f_{vib}$ = 1.025 ± 0.002 Hz,

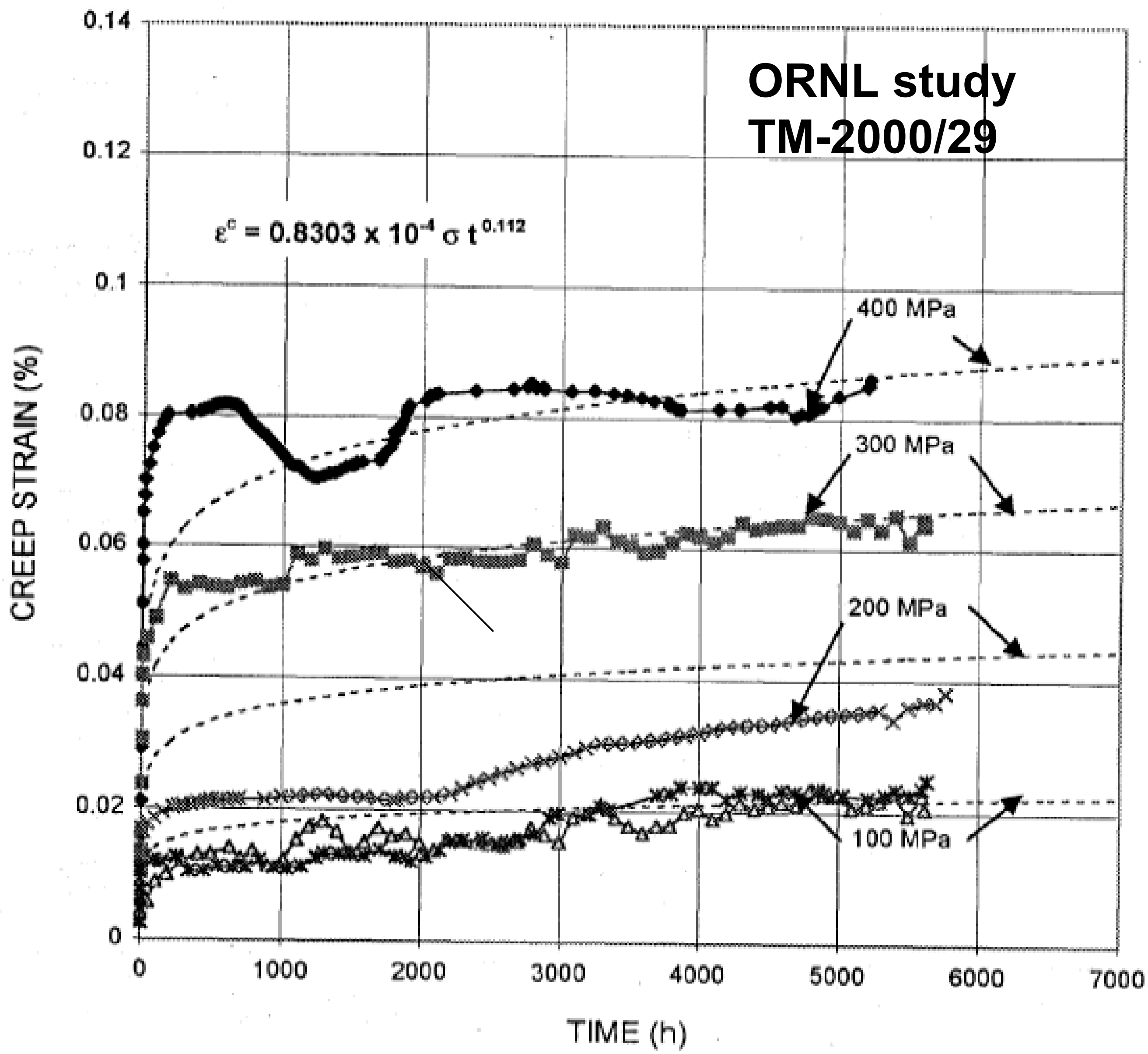
$amp_{vib}$ = 9.3 ± 0.3 nanometers

!!!

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

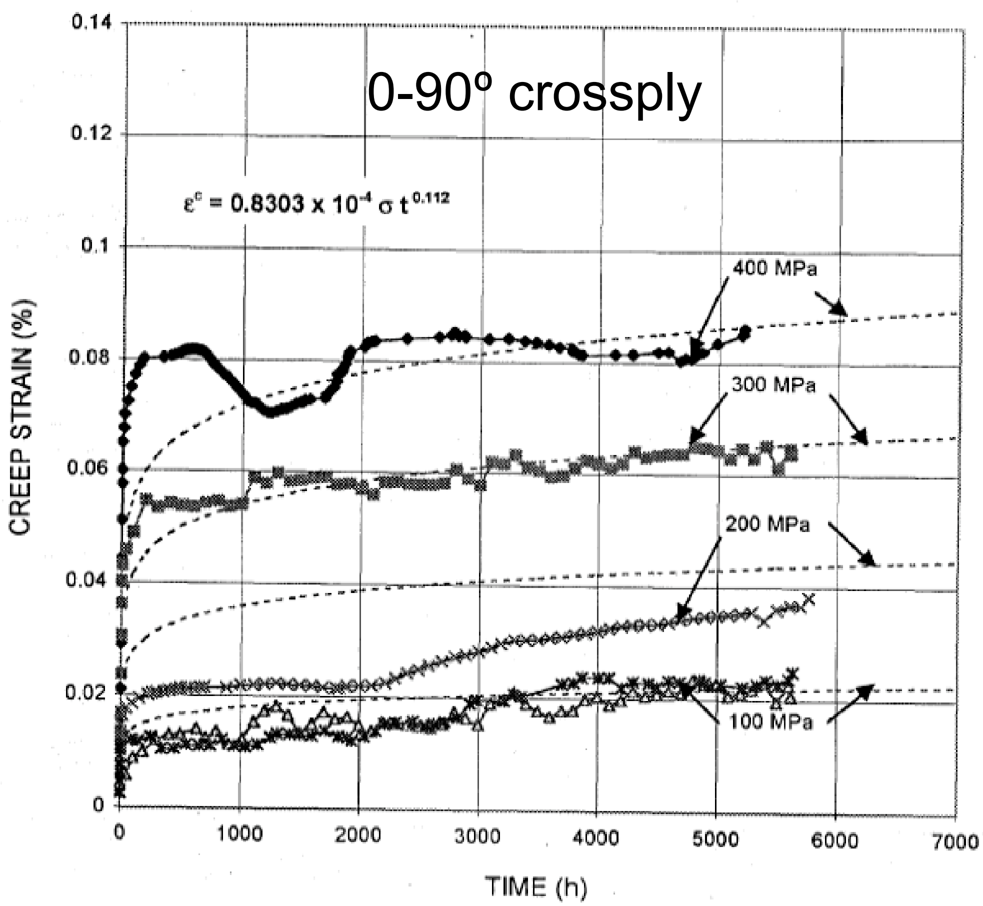
# Filament Creep

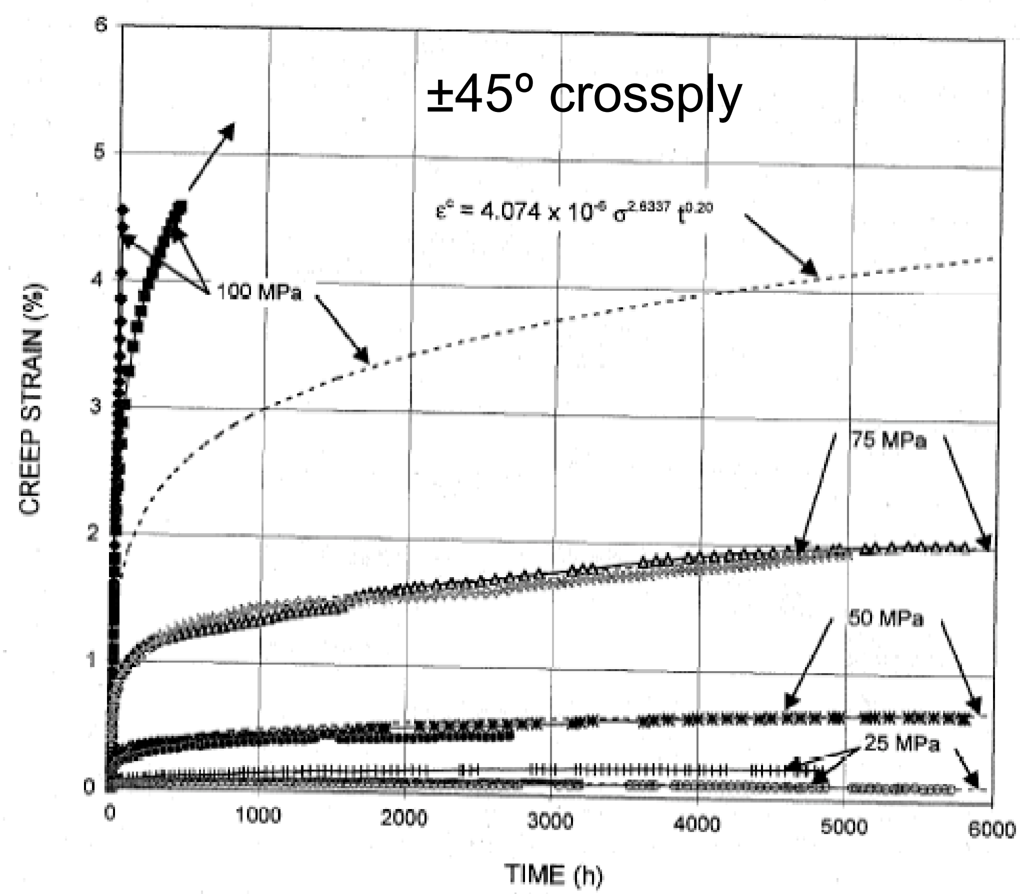
- Yield strength = 691 MPa *is not limiting factor*.
- One is more strongly limited by **creep of fibers** over time.
- ORNL reference study of C.F. creep and other properties provides resource.
- C.F. has relatively low creep, nevertheless to assure insignificant creep, we must keep below **~10 MPa**.



# Filament Creep

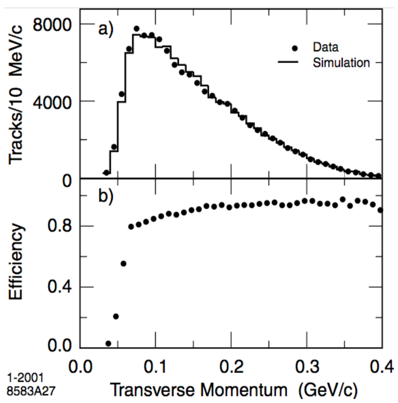
- But one must be sure to ***buy the correct fiber orientation*** in C.F. matrix (0-90º crossply)!!
- Otherwise creep strain can rise by factor of ~400 !!!!! (±45º crossply).
- But by keeping tension below measurable strain levels *(& real-time alignment),* creep becomes not a major issue.

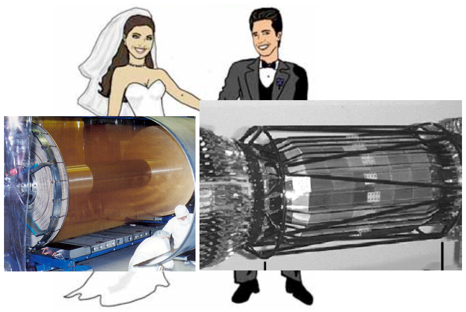


# Conclusions

- For low $p_T$ tracks at SuperB, minimizing material will be critical for high acceptance and efficiency (as well as good momentum resolution).
- Replacing a support frame with filaments would eliminate the vast majority of the inactive material in layer 0.
- ***Clearly* needs a *lot of work*: full simulation**, FEA study, test setup (!!)



- Note that this is potentially useful for ILC silicon detectors as well, so deserves further study IMO…