BCAL R&D

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The role of the BCAL

- Neutral (photon) calorimeter (primary)
- Charged particle detector and PID via ToF measurements (primary)
- Limited track reconstruction via relative timing information and read-out segmentation (secondary)
- Additional input into charged PID likelihood analyses with dE/dx and total energy information (secondary)

Performance parameters

- **Performance Objectives**
  - **Energy resolution $\sigma(E)/E \leq (0.05 + 0.05/\sqrt{E})$ with E in GeV**
    - Depends on SciFi/Pb sampling ratio
    - Depends on Radiation Length
    - Depends on #P.E.'s and intrinsic PMT resolution
  - **Timing Resolution $\sigma(t) \leq (150 + 50/\sqrt{E})$; $\sigma \approx 200$ ps**
    - Depends on #P.E.'s (number of SciFi's read out per PMT that have recorded "hits")
    - Depends on intrinsic PMT resolution and rise time

Progress Report

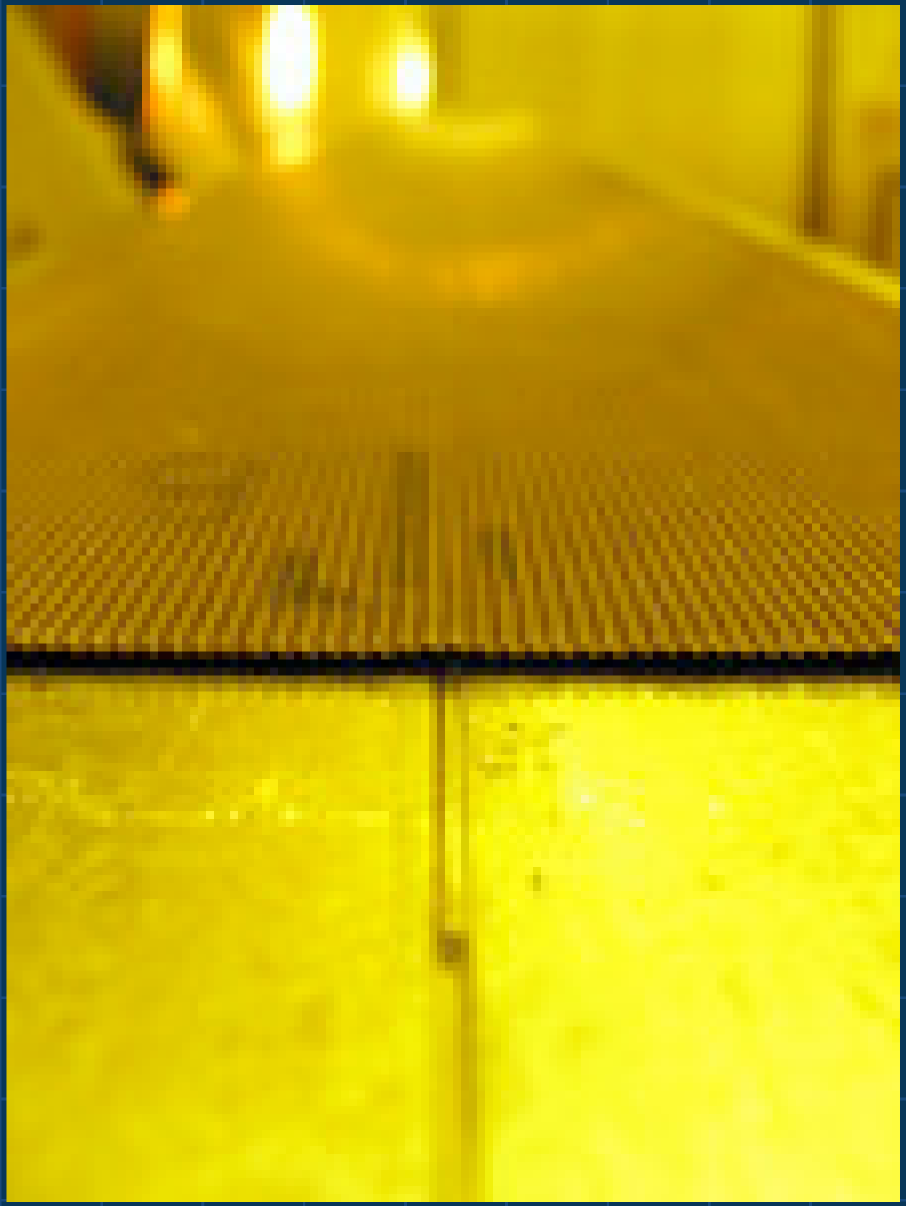
- **Module-1 construction R&D is completed**
  - Length is 400 cm after machining and polishing
  - Height is 23.3 cm (~16Xo) of Pb/SciFi/Epoxy matrix
  - Used almost 80 km of SciFi's
  - Took 5-6 persons a month to complete
  - Used five gallons of BICRON 600 epoxy
  - Construction & machining was done at CSR/UofA
- **Cosmic ray tests will be done at the UofR**
- **SiPM readout progress and in-beam tests**

Some Pictures Now

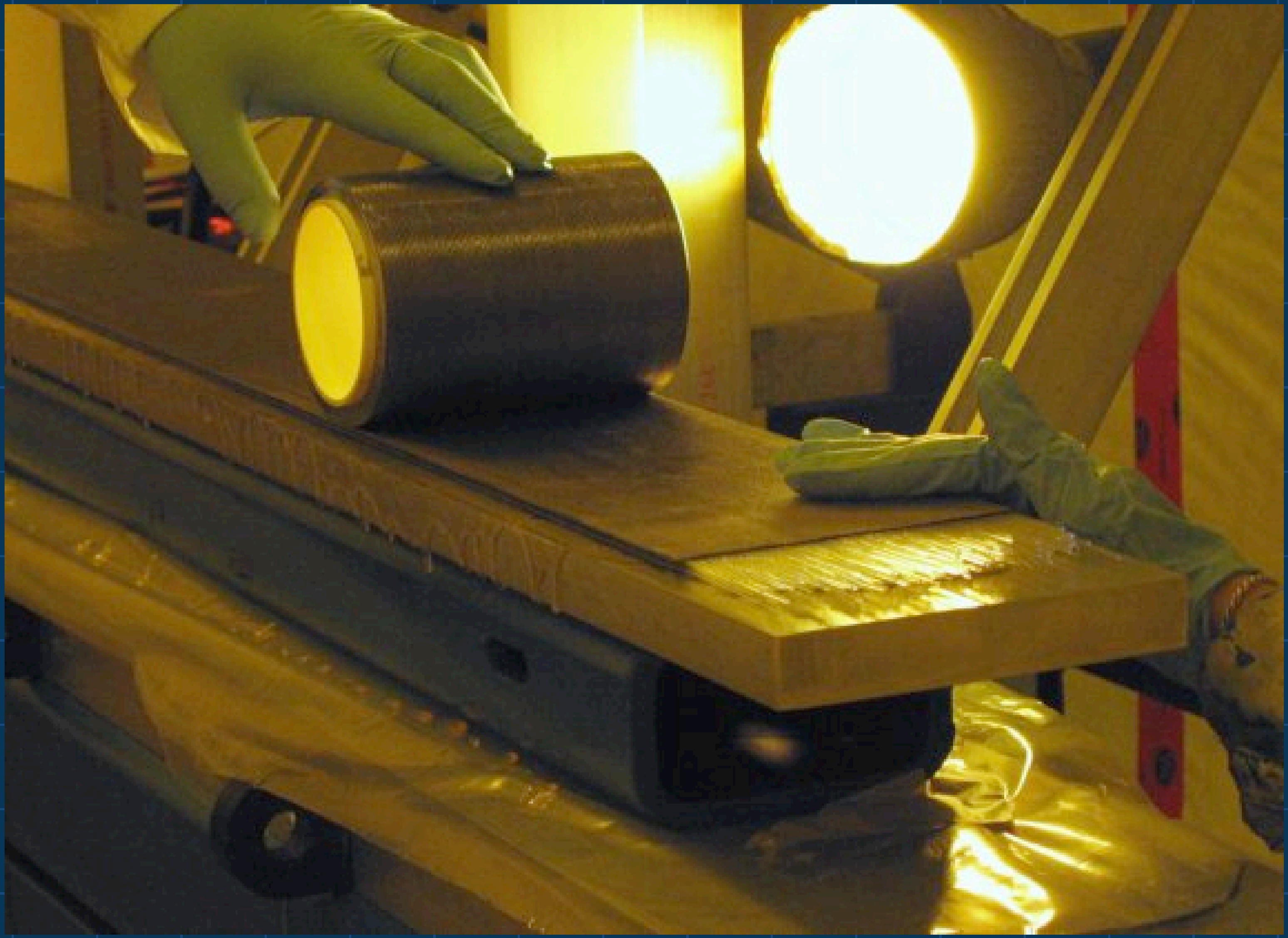
Details are shown in the training video

In the Beginning….

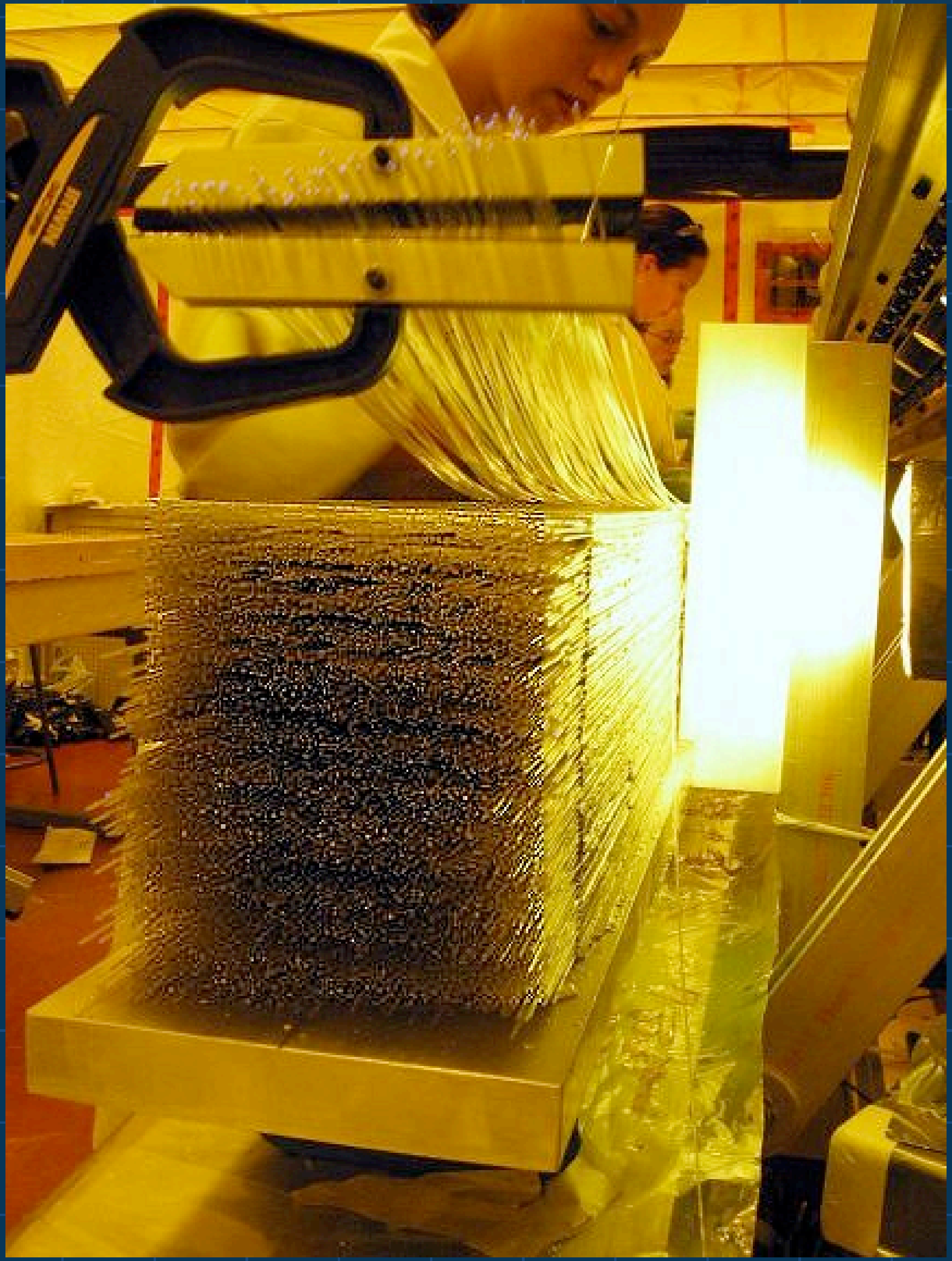
A Critical Operation



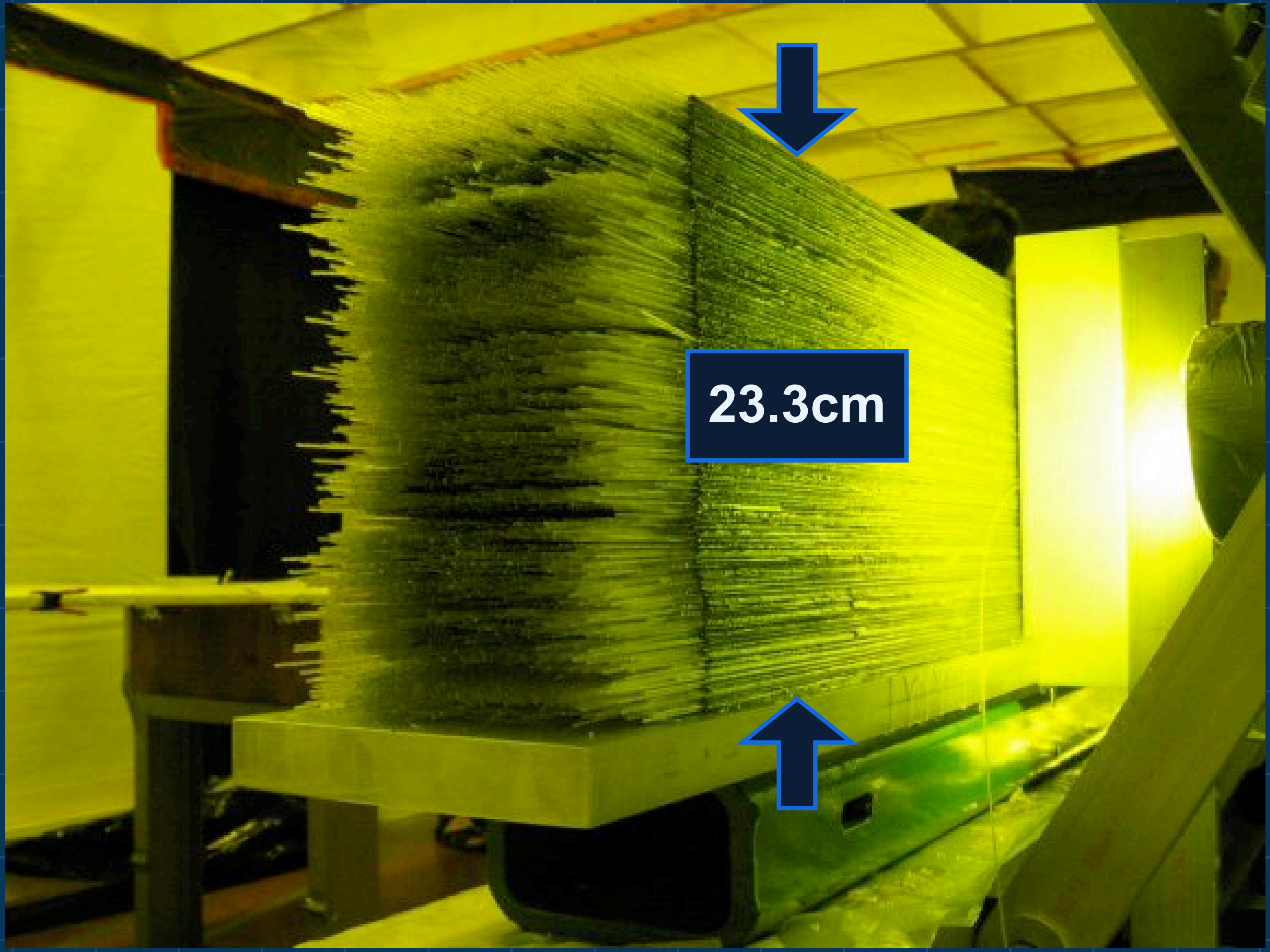
Adding layers of Lead



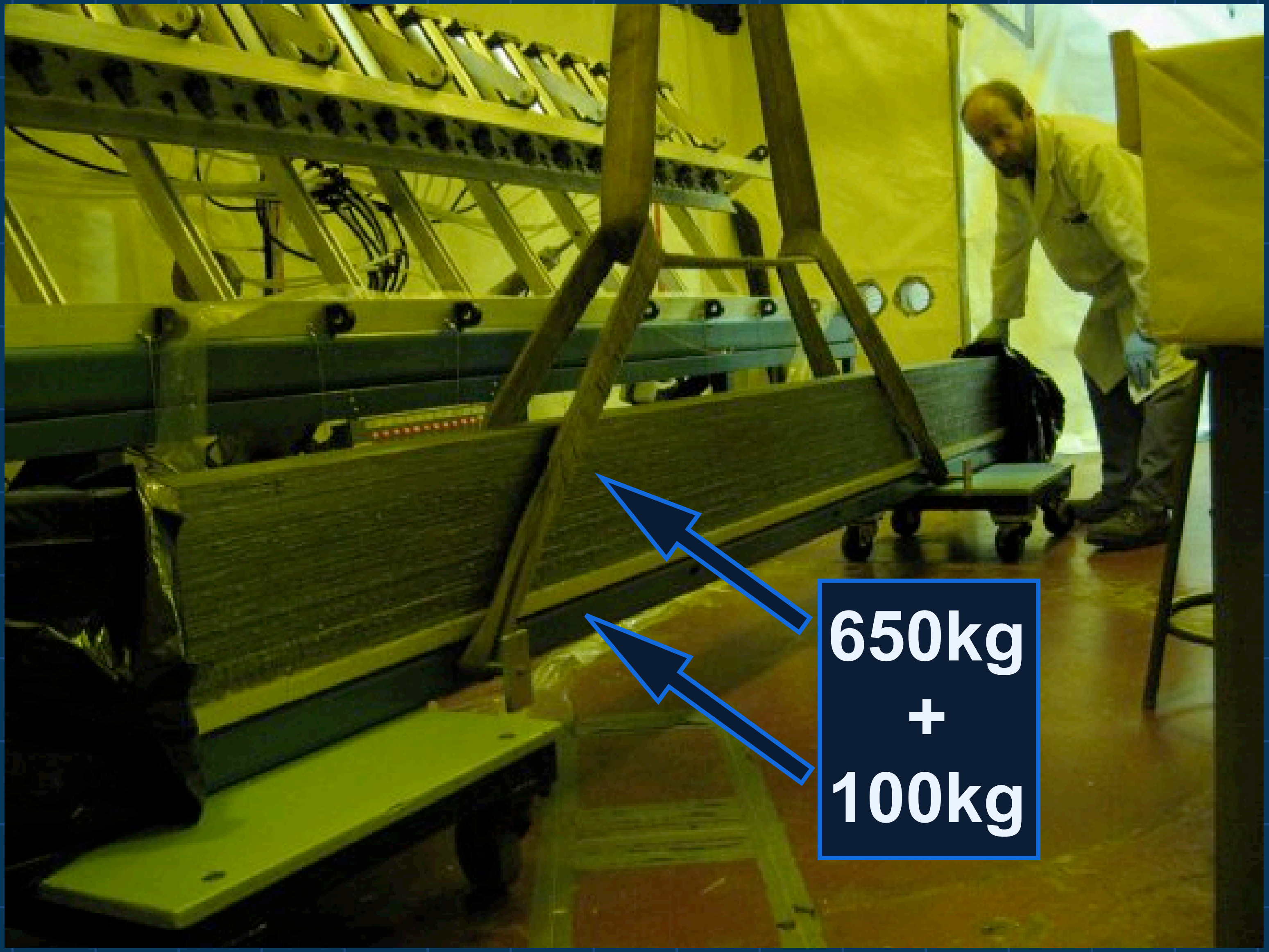
96 SciFi's per layer



Module-1 Fully Grown

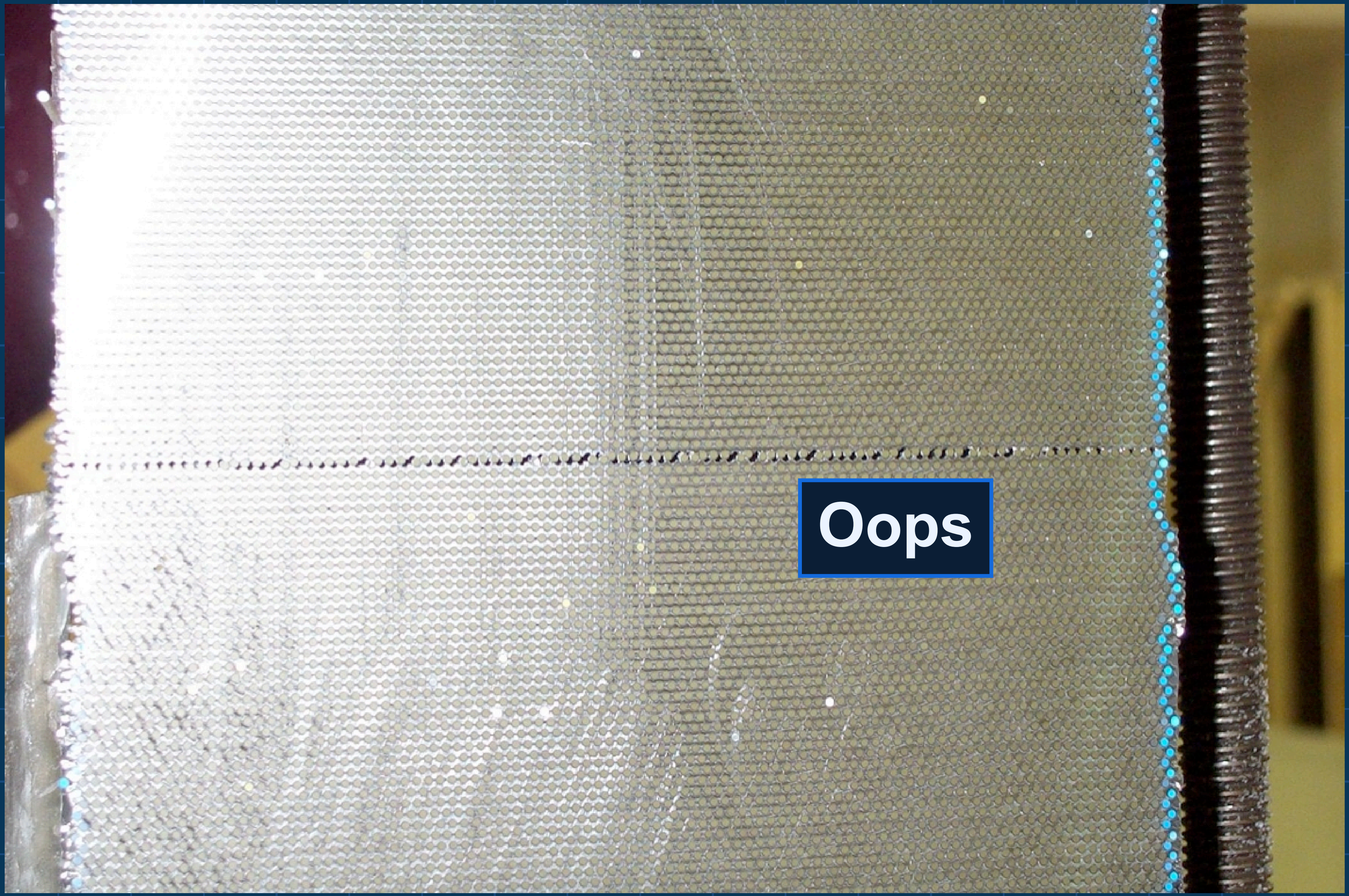


Module-1 hoisted for machining



Triming off the fiber ends

Face Machined (first pass)

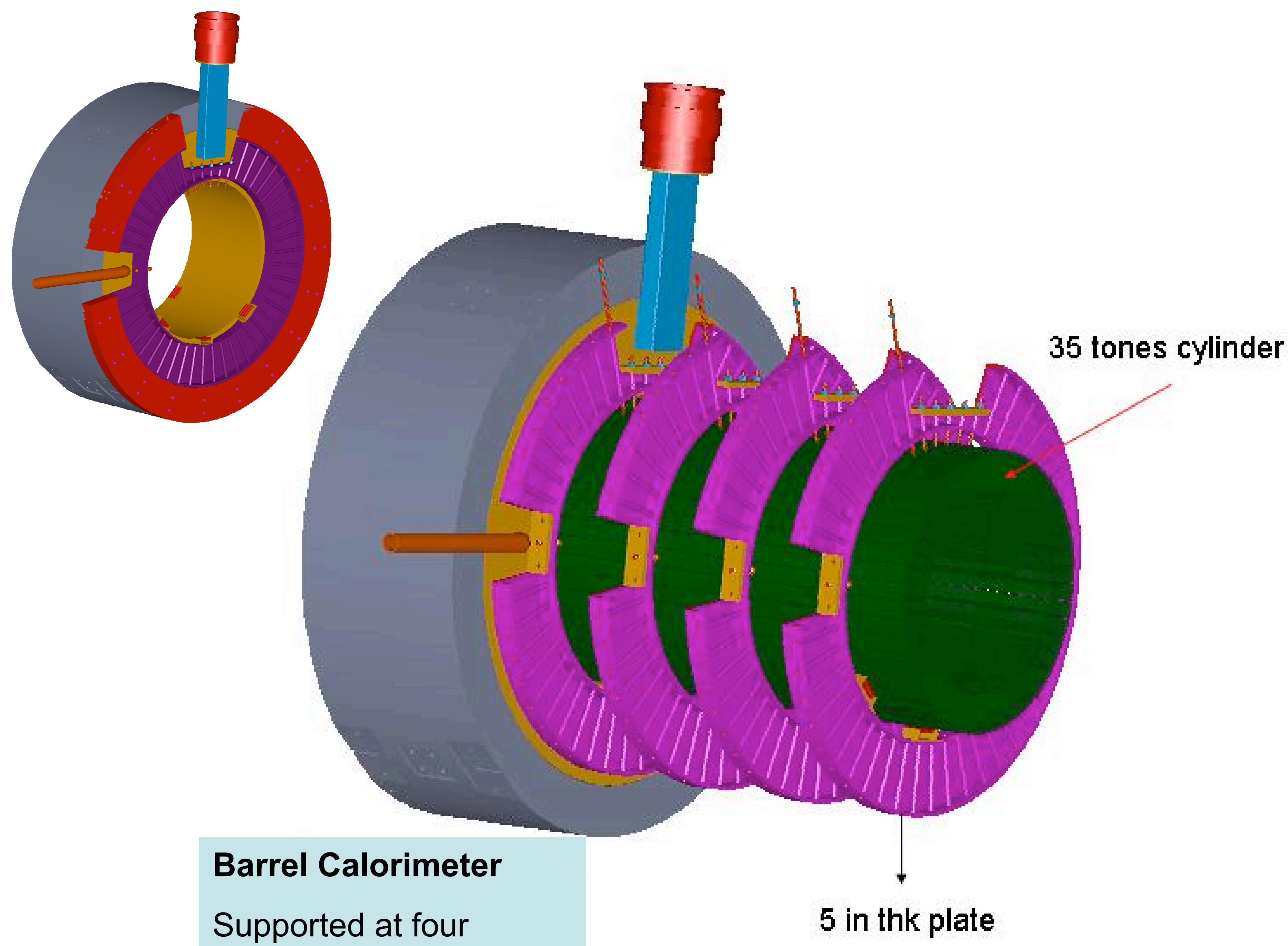


Ready for transport

Conclusions for physical construction of BCAL

- Construction techniques and infrastructure are in place and process can start when funds become available
- 1 mm Ø of SciFi is an optimum balance between performance, construction quality and costs
- Performance ∝ SciFi/Pb⊗light collection properties⊗scintillator properties
- Costs ∝ SciFi length⊗SciFi diameter
- These are non-linear functions!

Insertion of BCAL



Barrel Calorimeter

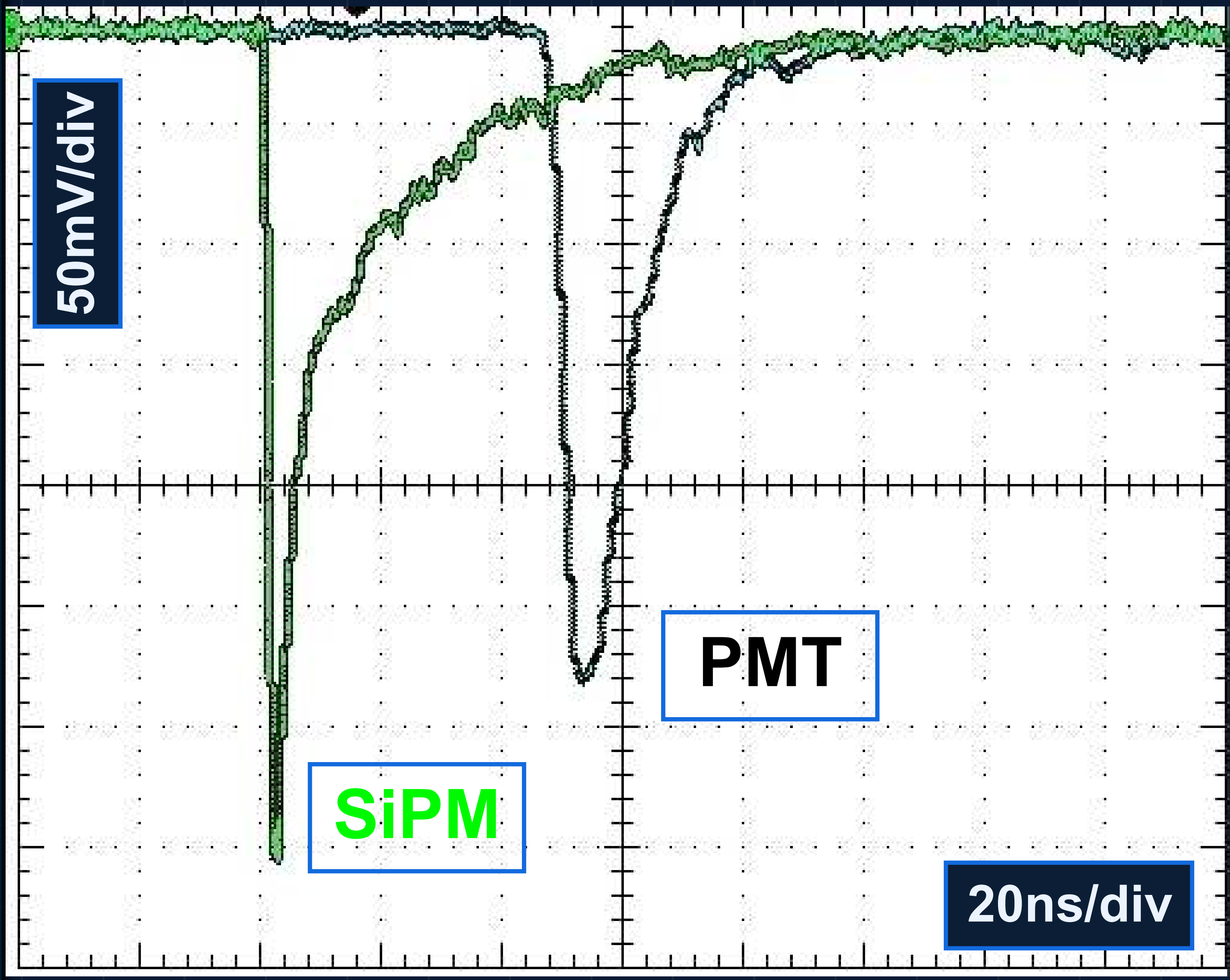
Supported at four locations

Read-Out R&D

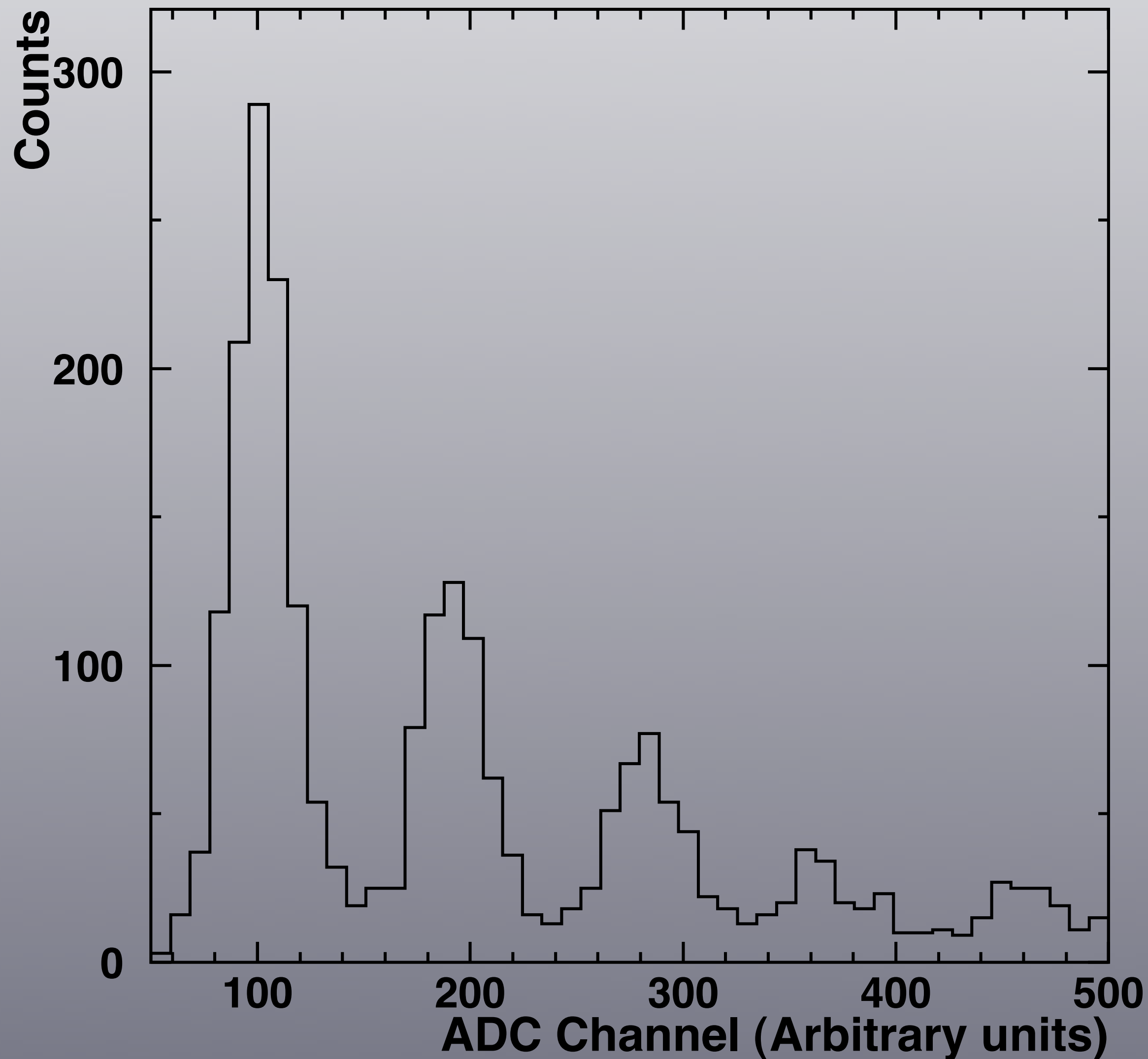
- 60 SiPM's have been obtained from CPTA
- Results so far have been very promising
- Pulse rise time and energy resolution are excellent and gain is almost as good as vacuum PMT's
- Significant R&D is required to determine the optimum SiPM-to-SciFi coupling to obtain the required timing and energy resolutions with the minimum number of SiPM's

SiPM vs. Burle 8575

- **SiPM flashed with Optitron NR-1A**
- **PMT: BURLE 8575 under identical conditions, at 2kV**



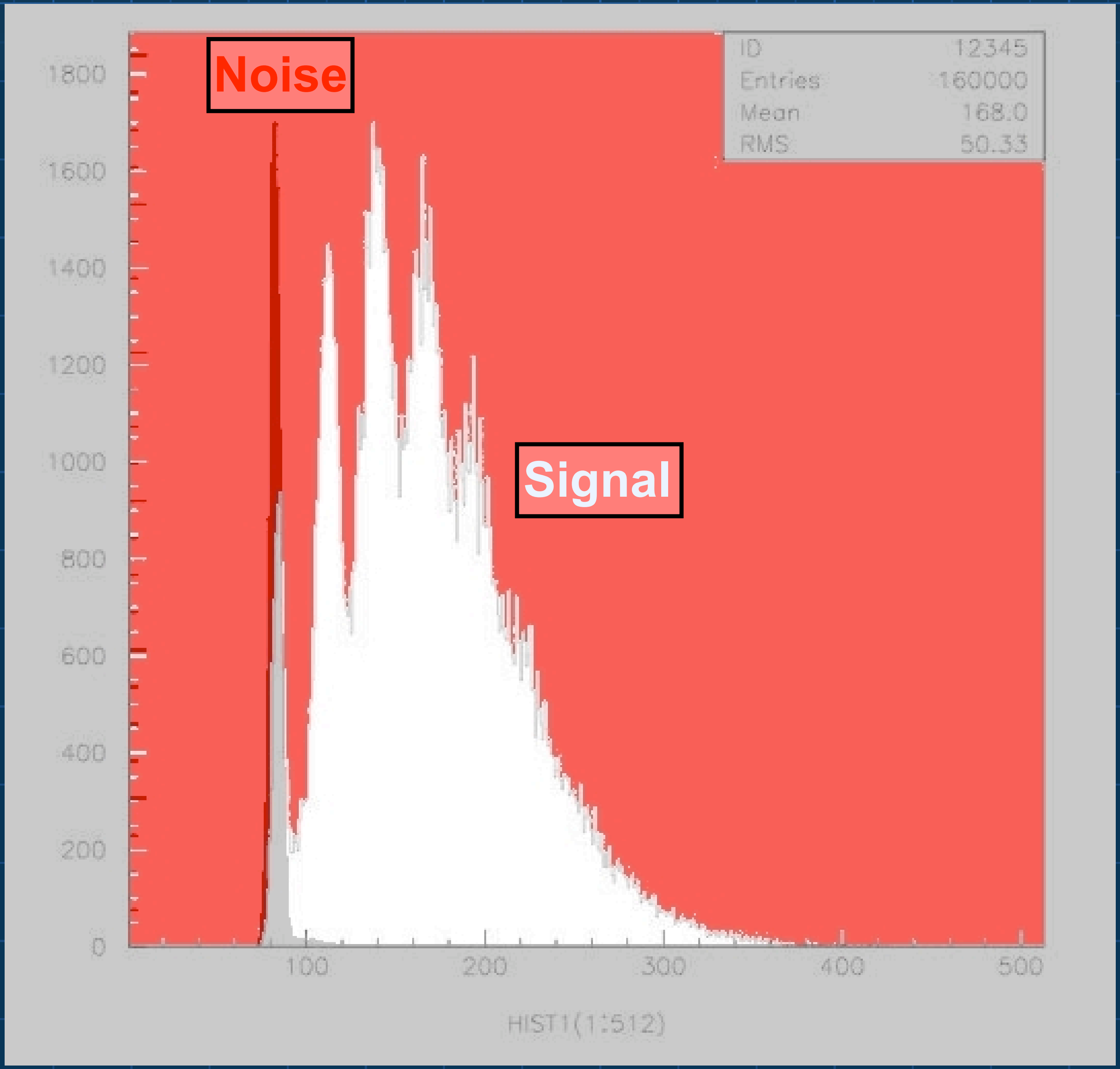
SiPM and SciFi with source



SiPM's and dark rates

- SiPM's are noisier than vacuum PMT's
- "Effective" noise levels depend on noise amplitude. Most vacuum PMT's have very high dark rates at the 1-5 mV levels, also known as electronic noise (well below 1 P.E. levels)
- Some brands of SiPM's have much higher noise rates and currents than others

CPTA with SciFi and LED



What does it all mean?

- The correlated “noise” rate is shown to be negligible when compared to real events in the ADC spectra at 100 kHz, since the LED was triggered at that rate
- The noise amplitude is below one P.E. level
- Each SiPM - in a matrix of 10-20 coupled devices viewing the same BCAL area - will be discriminated at that level to prevent noise triggering the TDC’s and causing amplitude resolution effects

Matching SiPM's to SciFi's

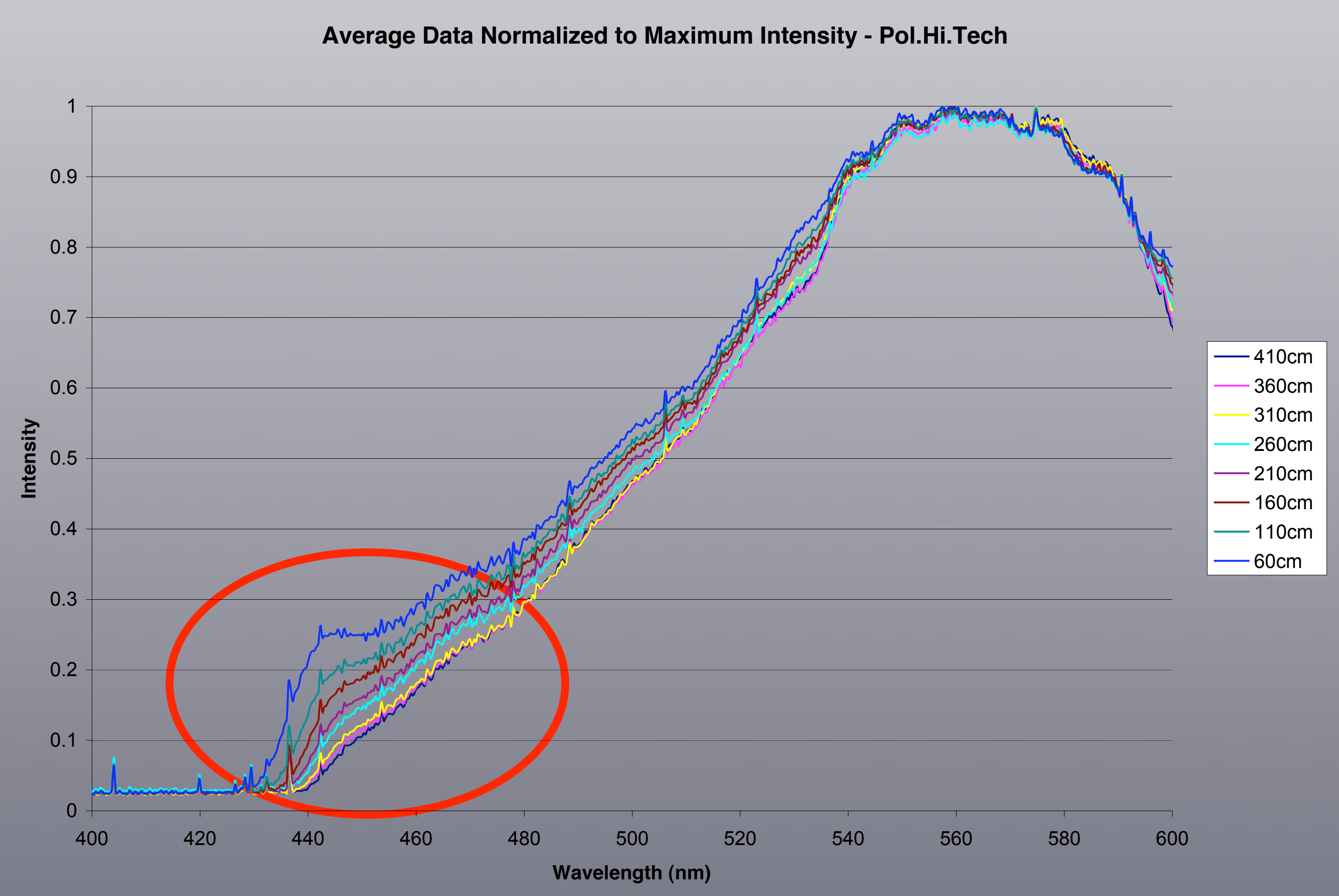
- "Standard" SiPM's have higher Q.E. in the λ≈500–600 nm range (Y–G)
- "Standard" (blue) SciFi's have peak emission in the λ≈410–450 nm. However, for lengths > 50 cm, the light surviving is mostly Y–G
- We need to model and test - with beam and/or cosmic rays - the optimum way to collect the light onto the SiPM's

Scintillating light transmission in long blue SciFi

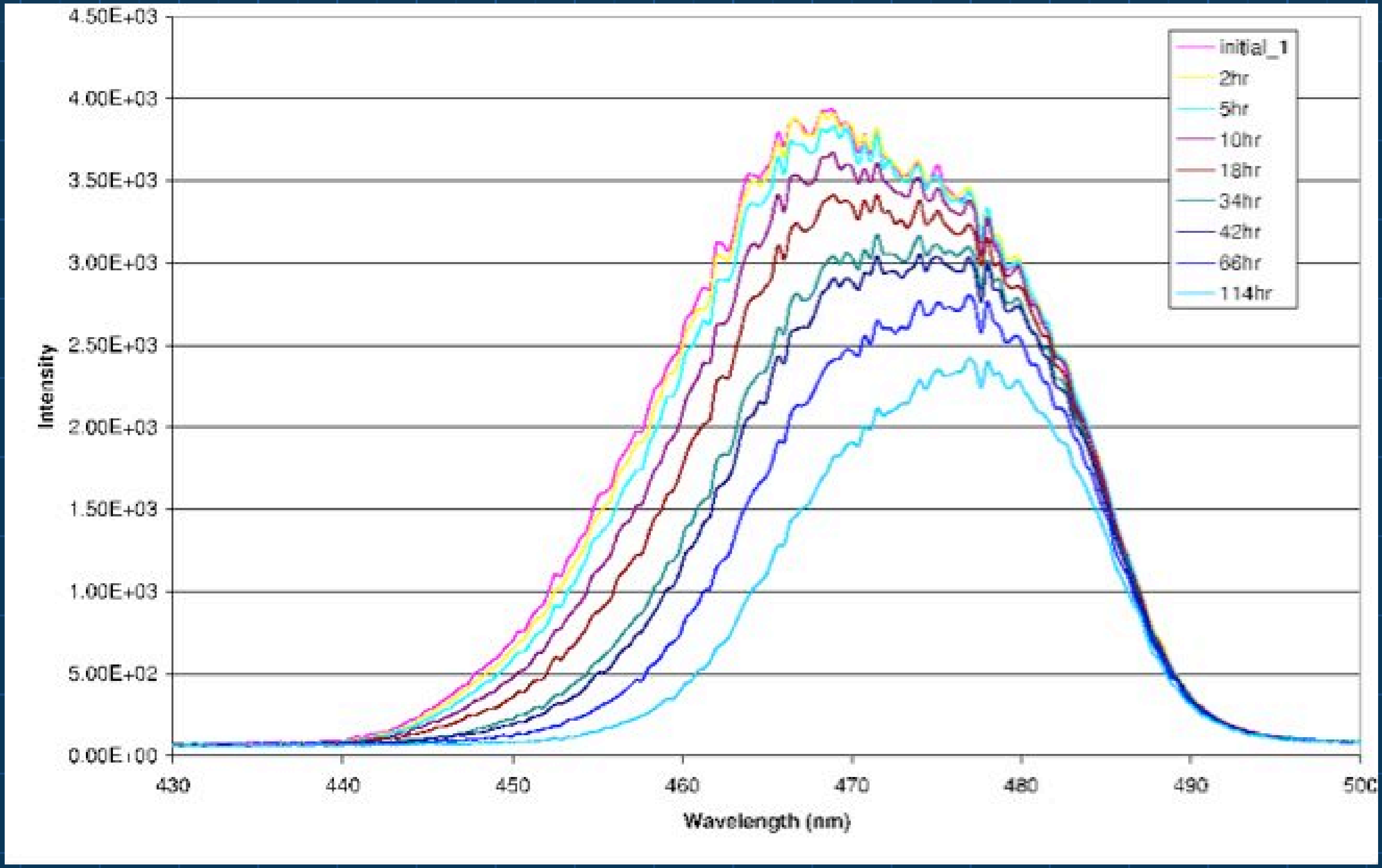
- Source: Ocean Optics 380 nm LED
- SciFi: PoliHiTech double-clad 1 mm ∅
- Transmission spectra have also been obtained as a function of fiber length
- Blue ➧ Yellow–Green

Spectral response as a function of SciFi length

- **Source:380 nm LED**
- **Spectrometer: Ocean Optics**
- **One SciFi (PolhiTech) fiber used for all measurements**



UV-exposure tests of fibers



Controlled exposure to fluorescent lighting; LED 470nm, transmission spectrum

Alternative solutions?

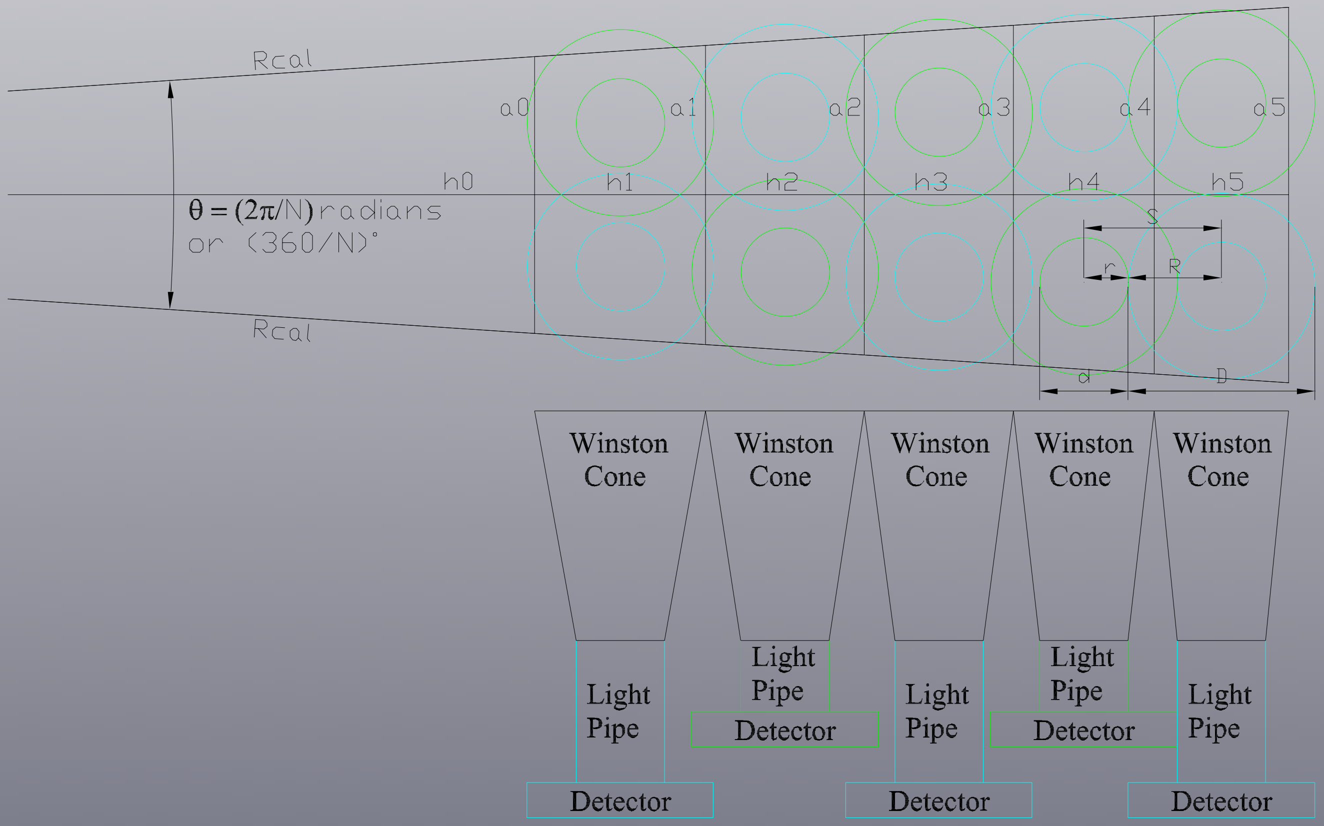
- Matching Green SciFi to SiPM may provide certain benefits, such as longer attenuation length and better spectral match to SiPM's
- Fast Green SciFi is now available (BCF-20, peak emission @ 490 nm, decay time=2.7 ns, 1/e length > 3.5 m). Hybrid Green and Blue SciFi BCAL is also an option
- Cost may be a problem but construction of a 5 cm high and 4m long test module may become necessary to test actual performance against the one obtained from blue SciFi

What if SiPM's prove problematic?

- Coupling of several SiPM's to a finite area of SciFi's remains to be modeled and a prototype needs to be constructed for testing
- Coupling of a number of SiPM's as one matrix will be a new development
- All has to fit within tight physical constraints
- Conventional vacuum PMT's - with long clear fibers as light guides - remain as a fall back position if all else fails

Gedanken Geometries

- **48 azimuthal slices**
- **5x2 readout segments per slice**
- **1000-5000 channels**



Conclusions

- Read-out to be decided by end of 2005
- This will also lead to final decision on the type of SciFi, Green, Blue or Hybrid
- Delivery of SciFi's and their sorting, inspecting and bundling them is very time consuming and can be done before even construction funding is released.
- Similarly for the delivery and preparation of the Pb sheets

Back up material

⇓

Cost Projections (Materials) per Module (I)

- SciFi (80 km @ $0.65/m): $52,000
- BICRON 600 epoxy (5 gallons @ $600/gal): $3,000
- Lead: $2,000
- Consumables (industrial epoxy, gloves, brushes, paper and cloth wipes, alcohol, etc., etc.): $1,000
- Al plate and steel support channel: $2,500 (includes labour)

Cost Projections (Materials) per Module (II)

- 10x2 sets of 15 coupled (matrices) of SiPM's ($55 per SiPM): **$16,500**
- Electronics (bases + discriminator chips) for above: **$4,000** (includes labour)
- 20 sets of SciFi-to-SiPM (matrix) light guides and Winston cones + 15 light collection fibers per set: **$4,000** (includes labour)
- Shipping crate: **$1,000** (includes labour)

Cost Projections (Equipment)

- New swaging machine: $20,000 (includes labour)
- Second press-frame: $15,000 (includes labour)
- Fiber handling and sorting table with Cu (grounded) table top cover: $1,500
- “Clean room” to house two presses and one main SciFi table with A/C (filtered) and temperature and humidity controls. Estimated cost: $20,000 (includes labour)

Cost Projections for BCAL (Materials + Equipment)

☛All these numbers are preliminary☚

- Total Materials Cost: $4,128,000
- Total Equipment Cost: $56,500
- Sub-Total Materials+Equipment (includes some labour, as indicated): $4,184,500

Labour Time Estimates for Module Construction

- Each module requires 2.5 man-months to complete - assuming eight hours per day (unskilled labour, e.g. 5 students)
- Cutting and swaging ≈200 sheets require approximately 10 man-days per module (unskilled labour, e.g. 2 students)
- Labour and milling machine charges for machining each module to final dimensions are approximately $2,800 (machinist rates)

Construction Labour Costs

- 2.5 x $1,500/month x 48 = **$180,000** for the construction of 48 modules
- 24 man-months x $1,500/month = **$36,000** for Pb sheet cutting and swaging
- Machining and polishing = **$134,400**
- Total labour costs for BCAL construction: **$350,400** reflects UofR+UofA labour **only**
- A large fraction can be contributed from Canadian funding sources but we will require early delivery of material (Pb and SciFi's) as long lead items to stretch the funding cycles

Total BCAL Costs (best estimate at this stage)

☂ **$4,534,900 ± 15%** ☂