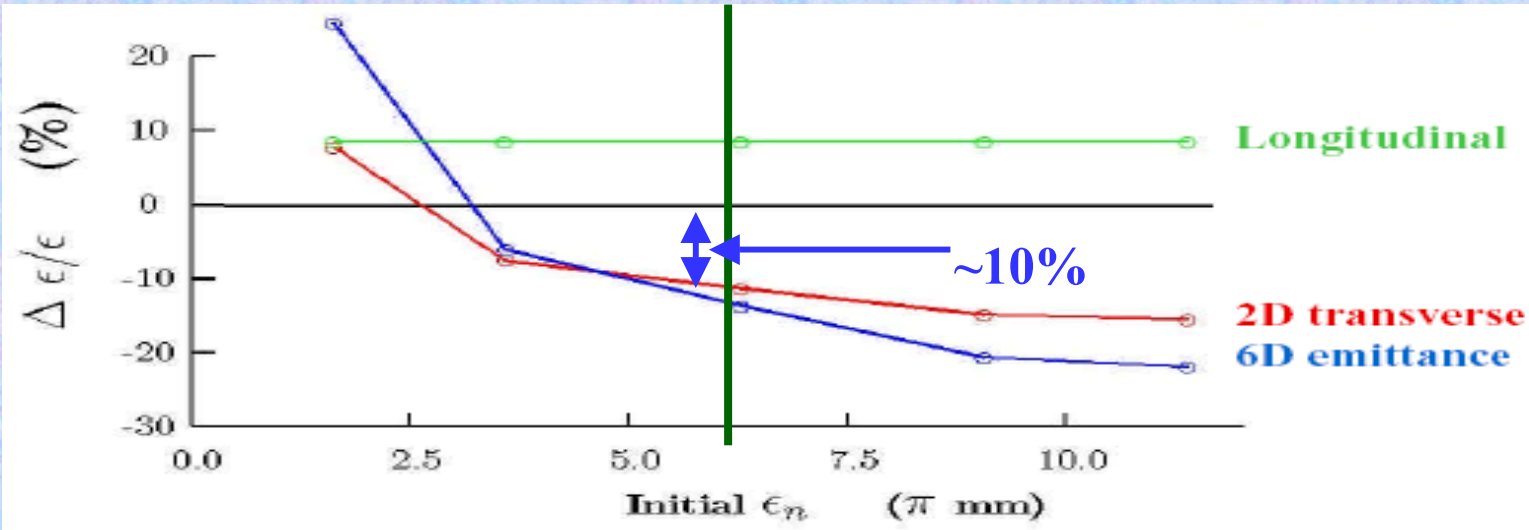
A Scintillating Fibre Tracker for MICE

Malcolm Ellis, on behalf of the
MICE Sci-Fi group
DPF Meeting
Riverside, August 2004

MICE – Muon Ionisation Cooling Experiment

- Design, build, commission and operate a realistic section of cooling channel.
- Measure its performance in a variety of modes of operation and beam conditions.



$$\Rightarrow \sigma\left(\frac{\Delta\varepsilon}{\varepsilon_{in}}\right) << 0.1 \qquad \text{Goal} : \sigma\left(\frac{\Delta\varepsilon}{\varepsilon_{in}}\right) = 0.001$$

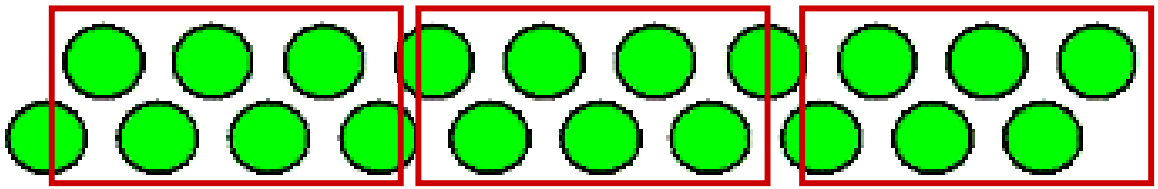
MICE Tracker

- MICE requires an accurate measurement of the position and momentum of a muon beam, in the presence of a high background from RF cavities.
- Solution is scintillating fibres, read out with Visible Light Photon Counters (VLPCs).
- Two identical trackers are required, one to measure the muon beam going into the cooling channel, and the second to measure the outgoing beam.

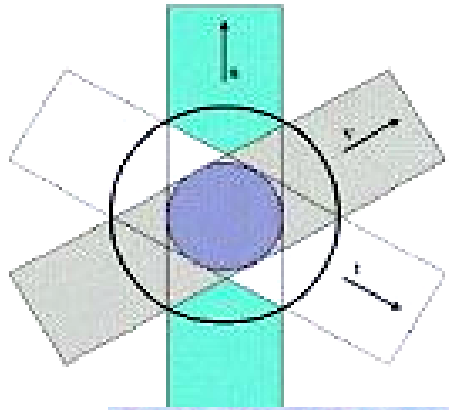
Sci-Fi Group

- Japan:
  - KEK, Osaka University
- United Kingdom:
  - Brunel, Edinburgh, Imperial College London, Liverpool
- United States of America:
  - FNAL, IIT, Riverside, UCLA

Tracker Design



a)



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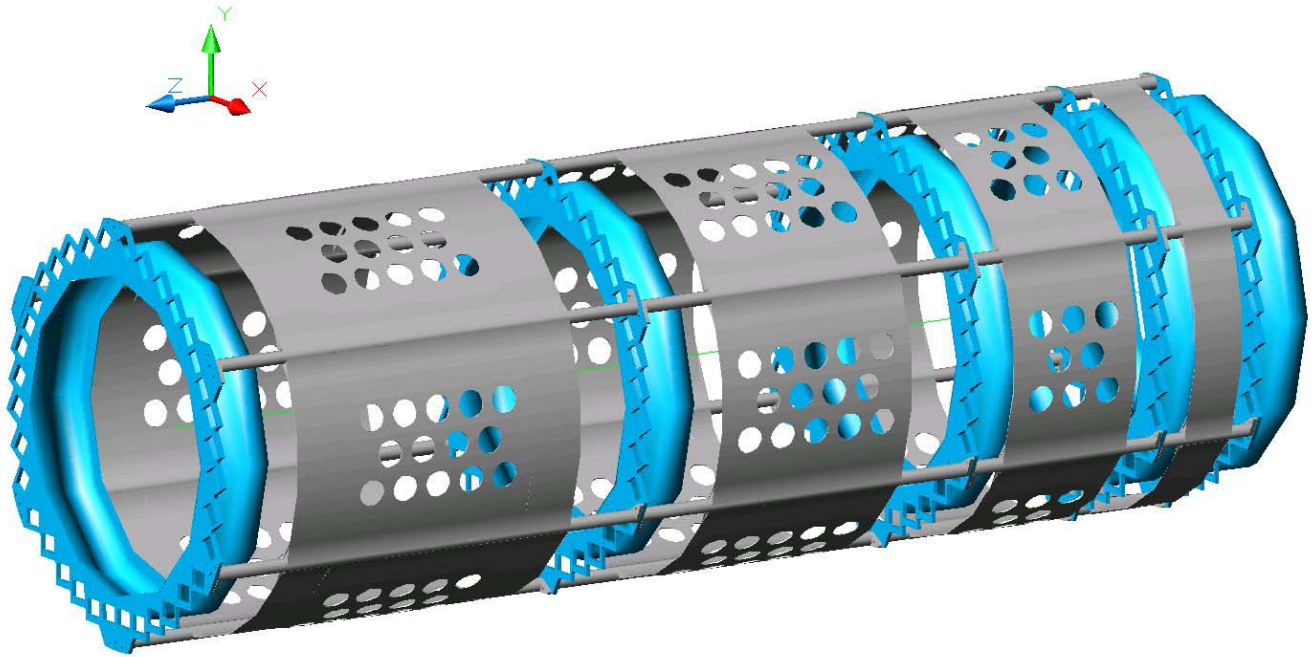
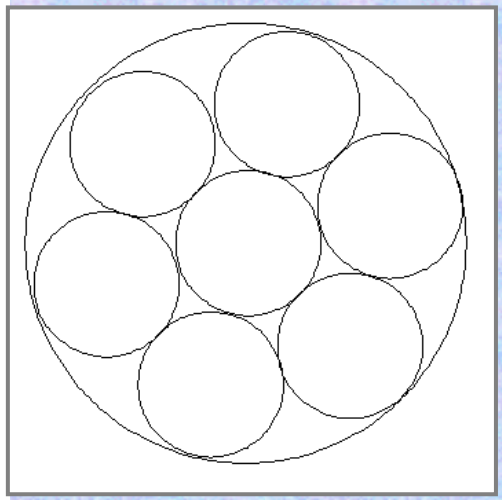


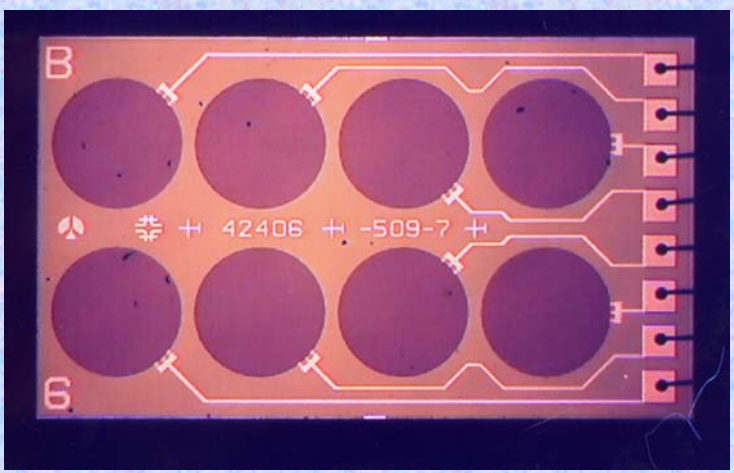


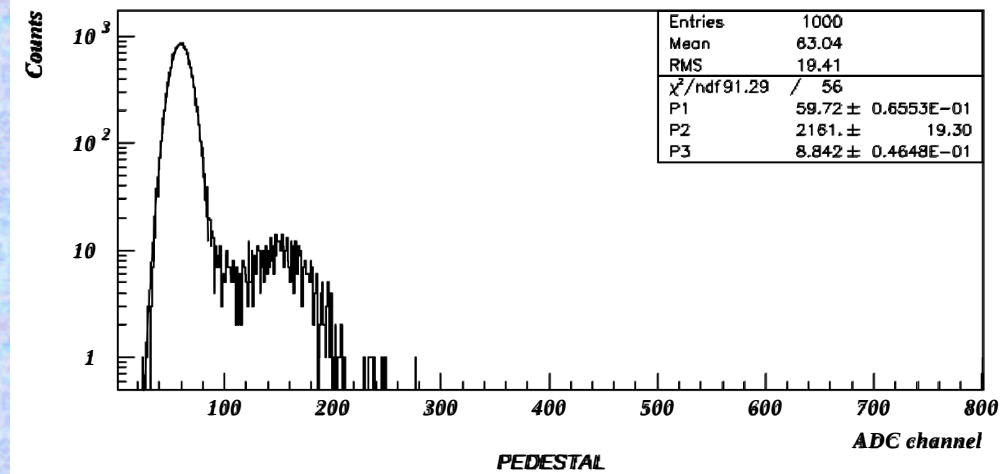
Scintillating Fibre

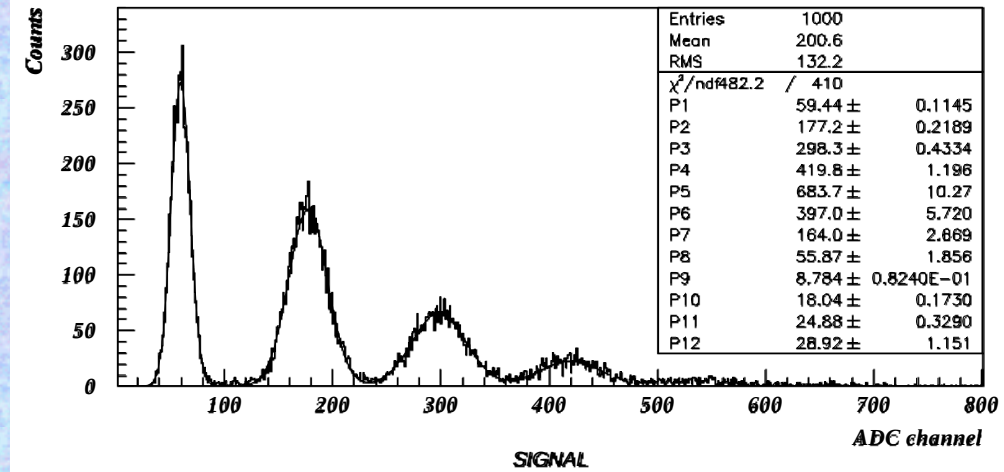
- Fibre supplied by Kurary.
- 350 micron diameter, double clad fibre.
- Second layer increases light trapping efficiency by ~70%
- Polystyrene core is doped with 1% p-terphenyl (PTP) and various concentrations of 3-hydroxyflavone (3HF).
- Output light is in the yellow-green part of the spectrum, peak emission at 530 nm.
- Emission spectrum matches the response of VLPCs.

VLPCs

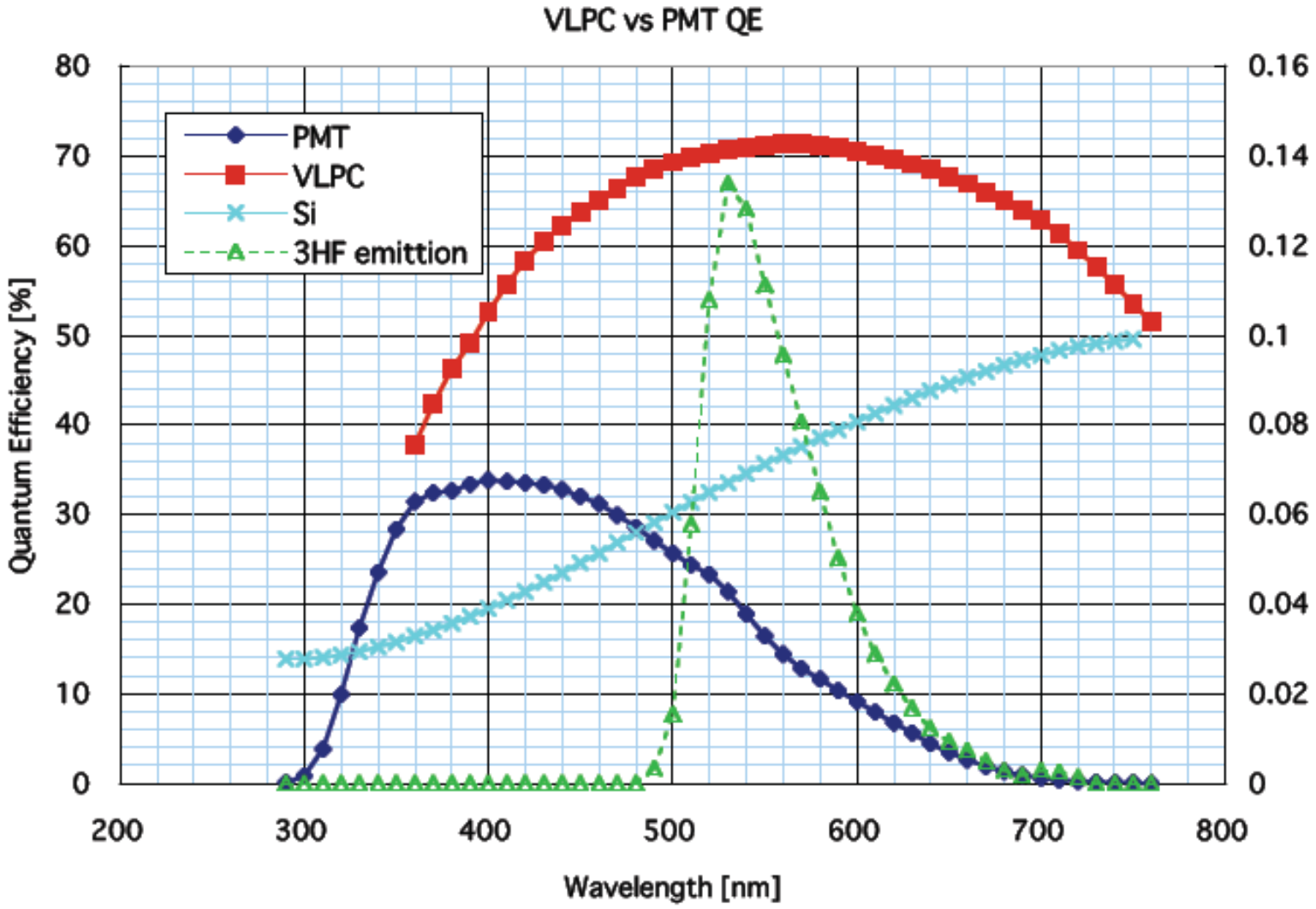
- Visible Light Photon Counters – cryogenic APD system operating at 9K.
- Combine high QE (~80%) with low noise and high rate (40 MHz) capability.







3HF output vs. VLPC response

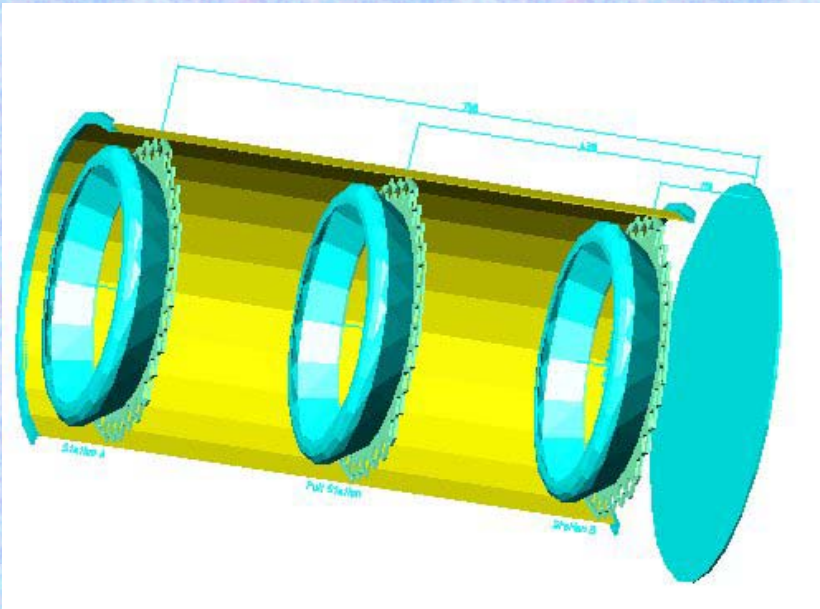


Prototype

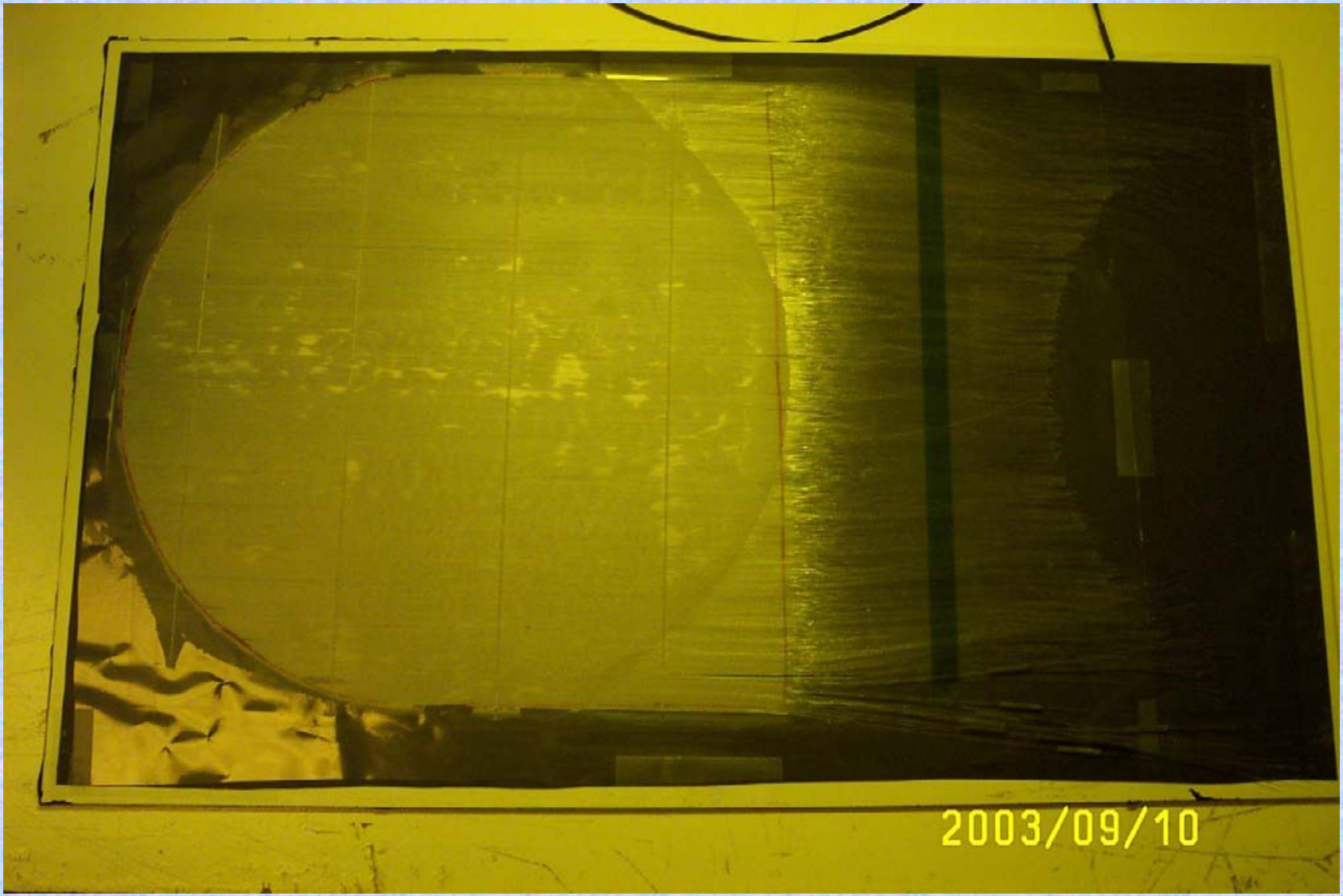
- Prototype was built in September 2003 in order to test the Scintillating Fibre design.
- Fibre was ordered from Kurary in Japan.
- Ribbons of fibre were produced at FNAL and shipped to the UK.
- Individual fibres were bundled into groups of 7, planes were aligned, bundles placed into connectors, etc, at Imperial College.
- Stations were shipped back to FNAL, where the complete tracker was assembled.

Prototype Design

- 3 Stations (originally only 1 was planned).
- Only 1 station had all 3 views, the other two had two views (total 7 planes).
- Different concentrations of 3HF used to study light yield.



Prototype Construction

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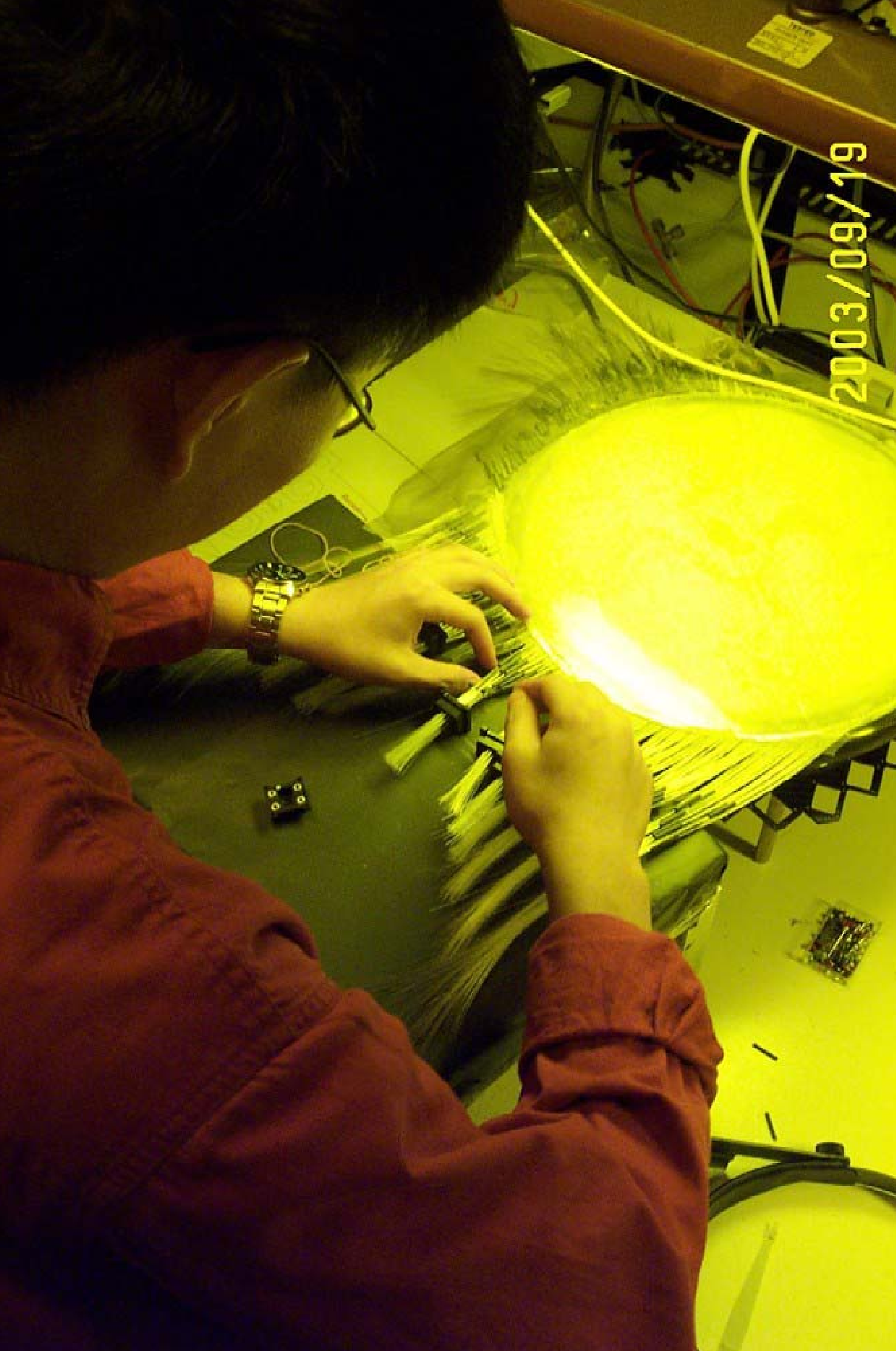
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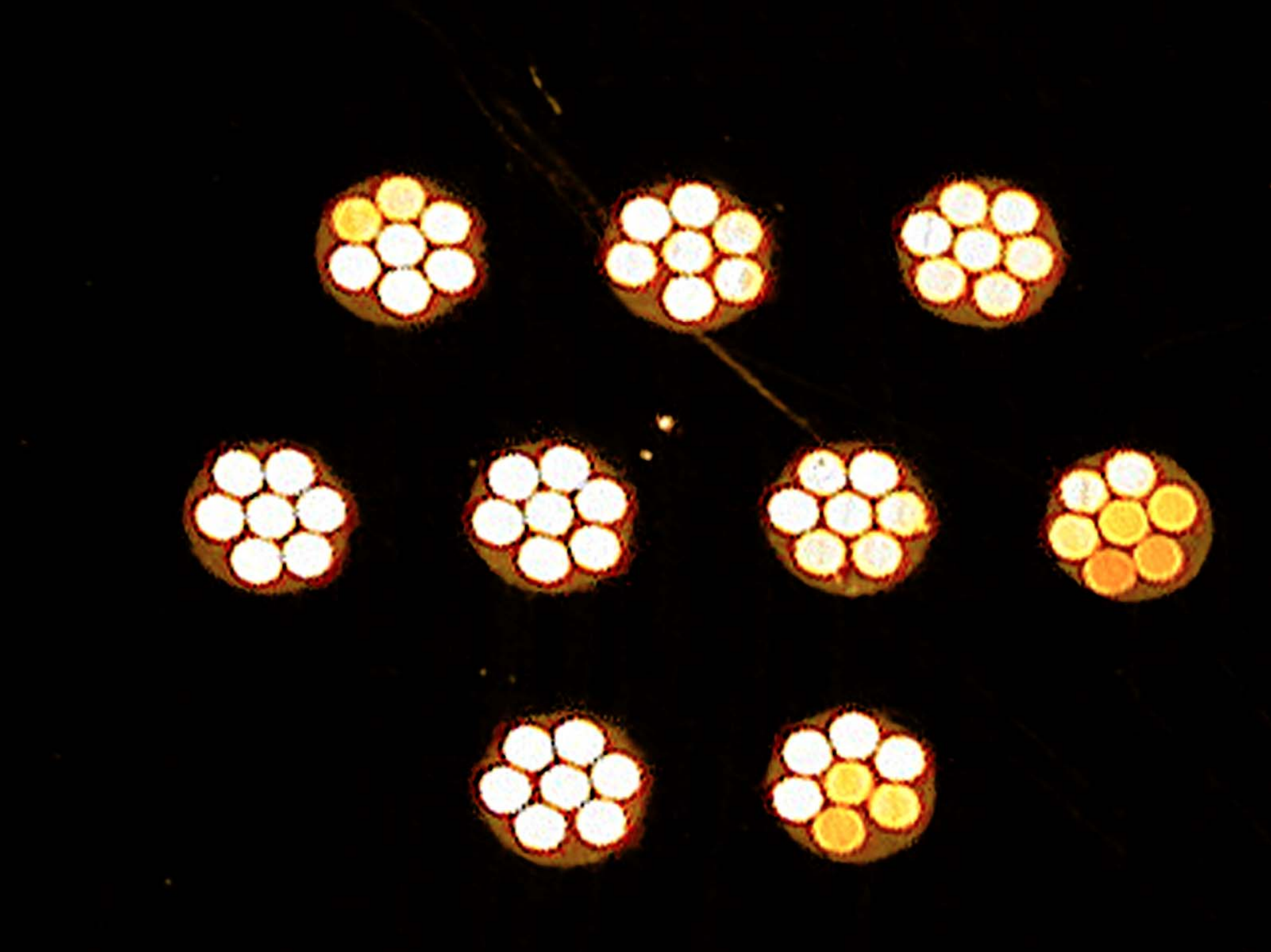

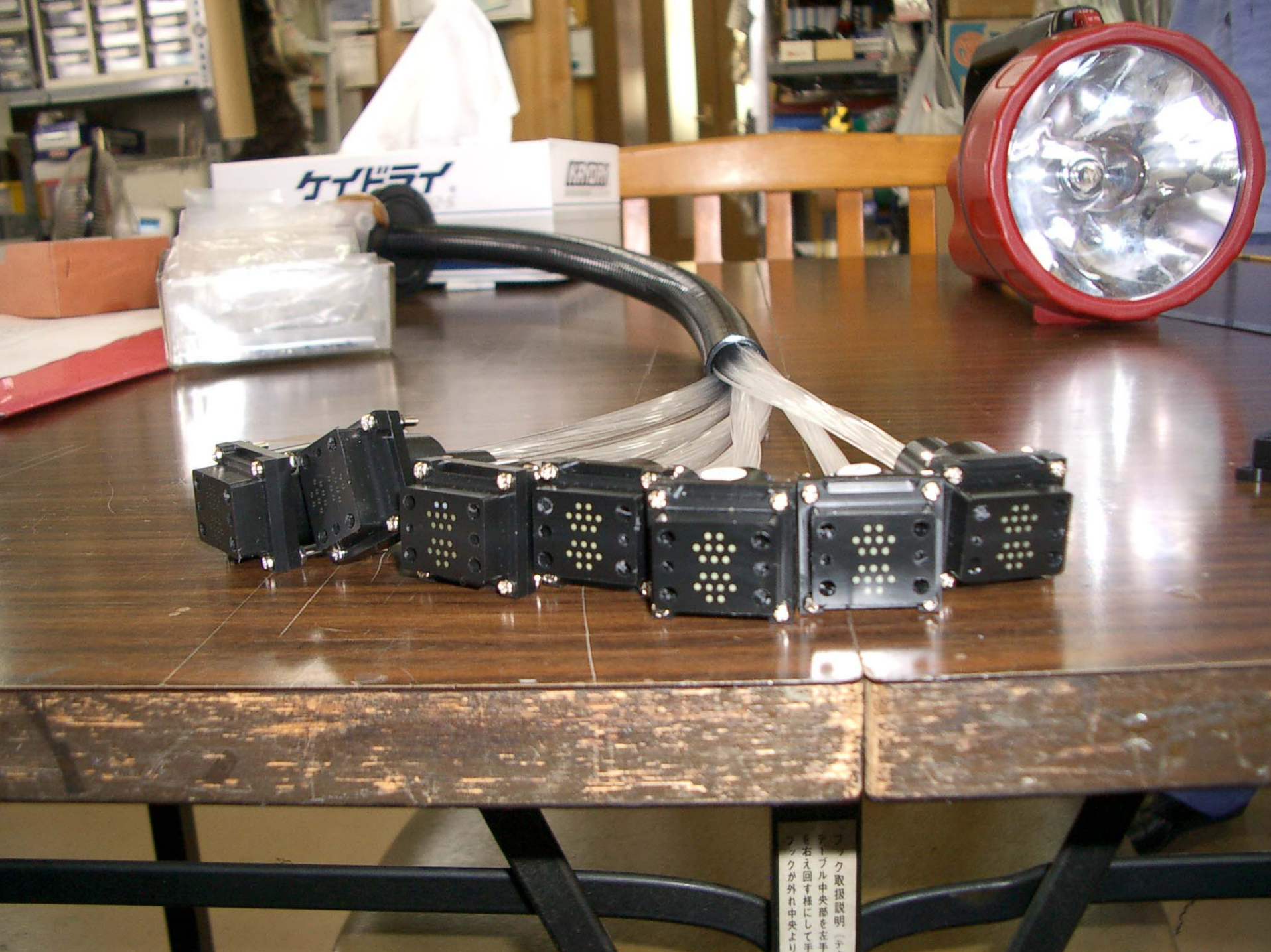
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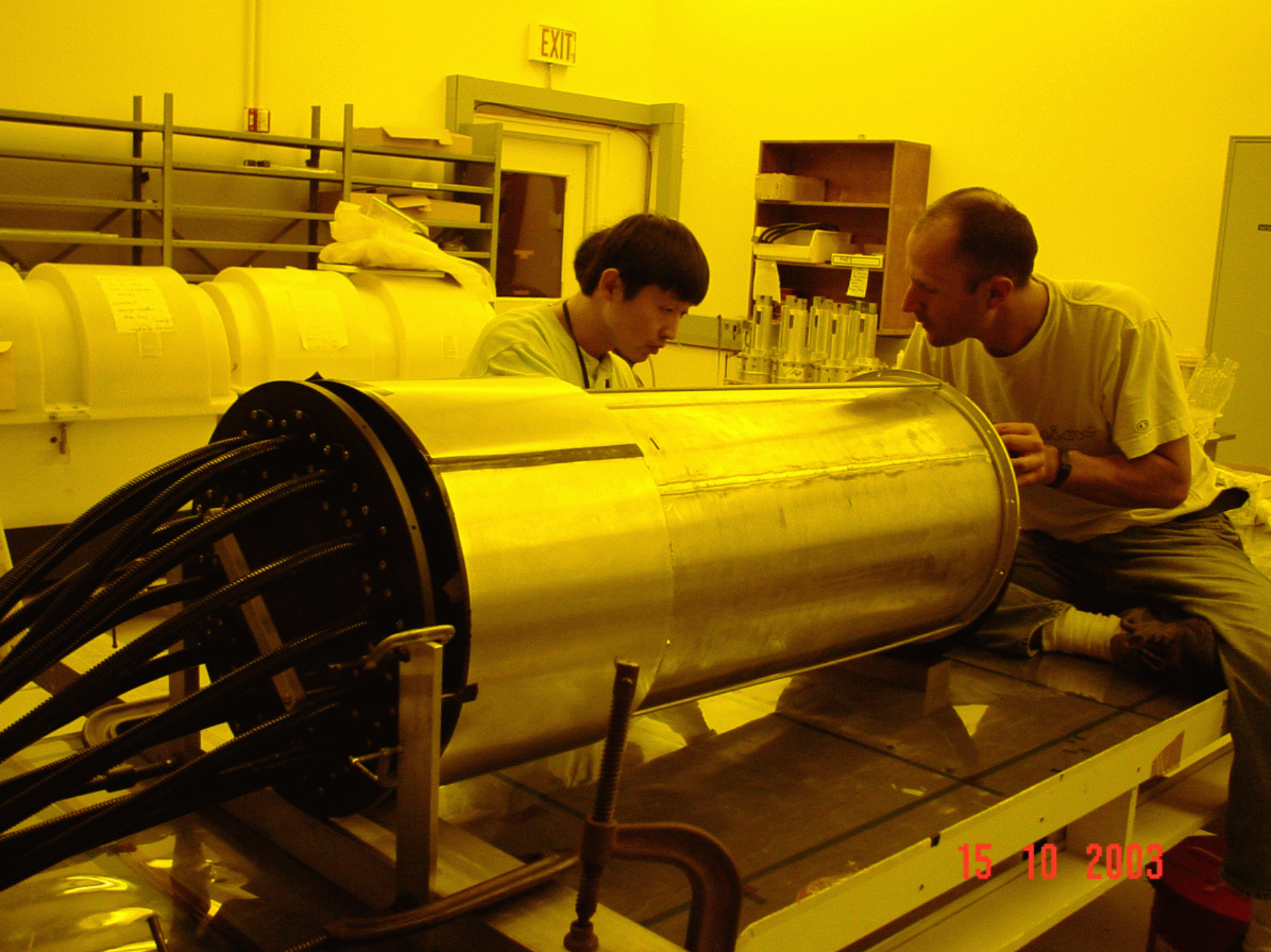
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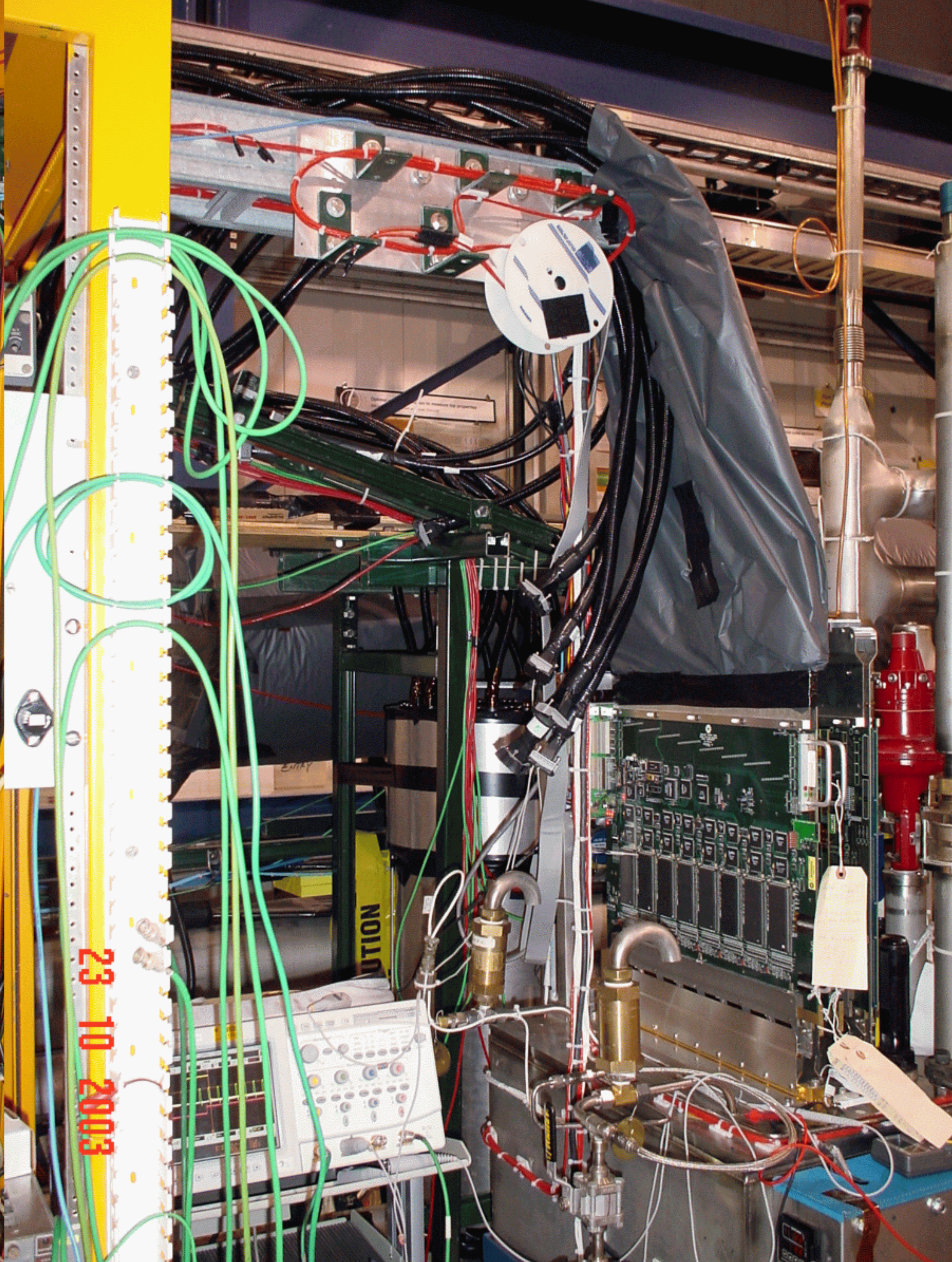
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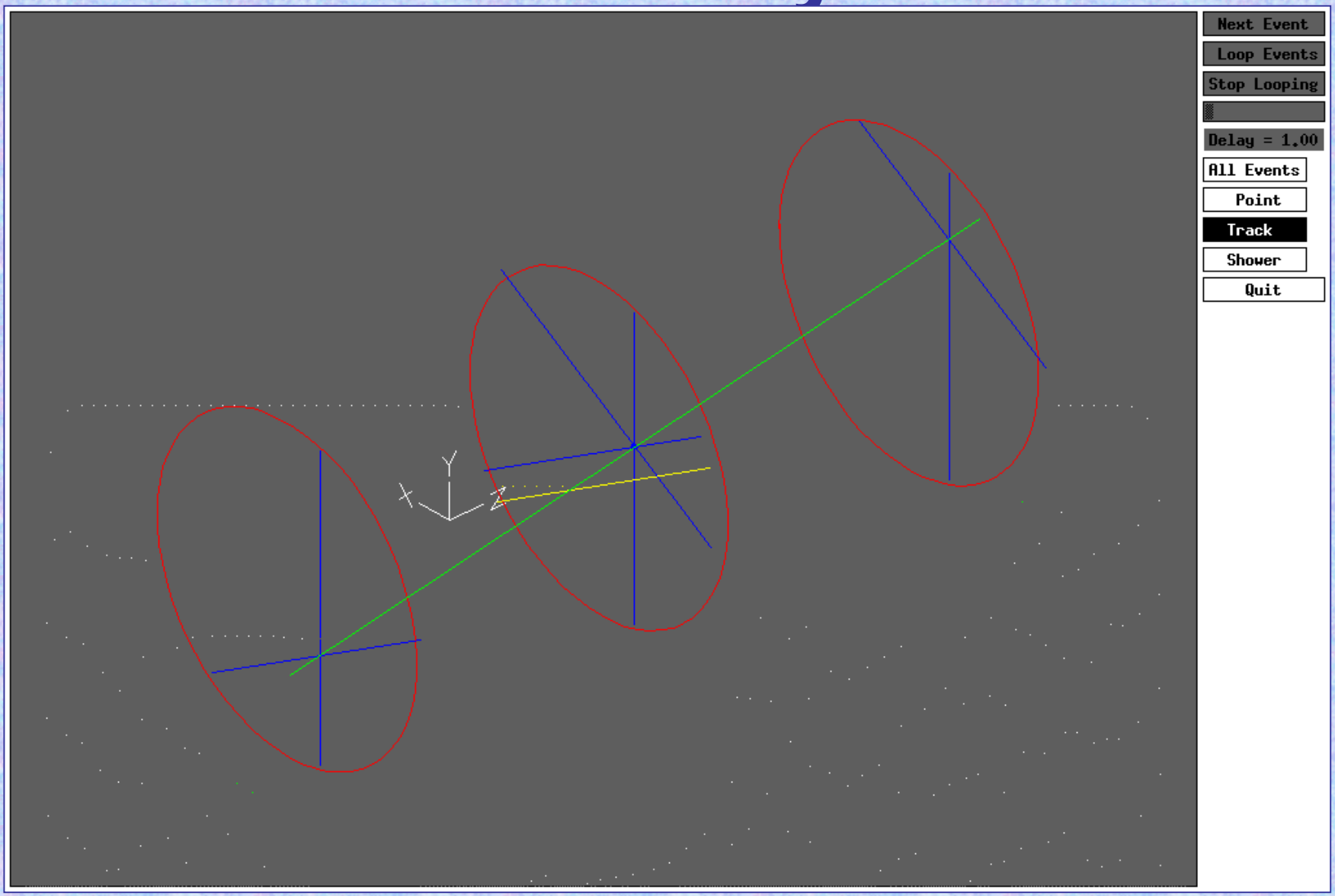
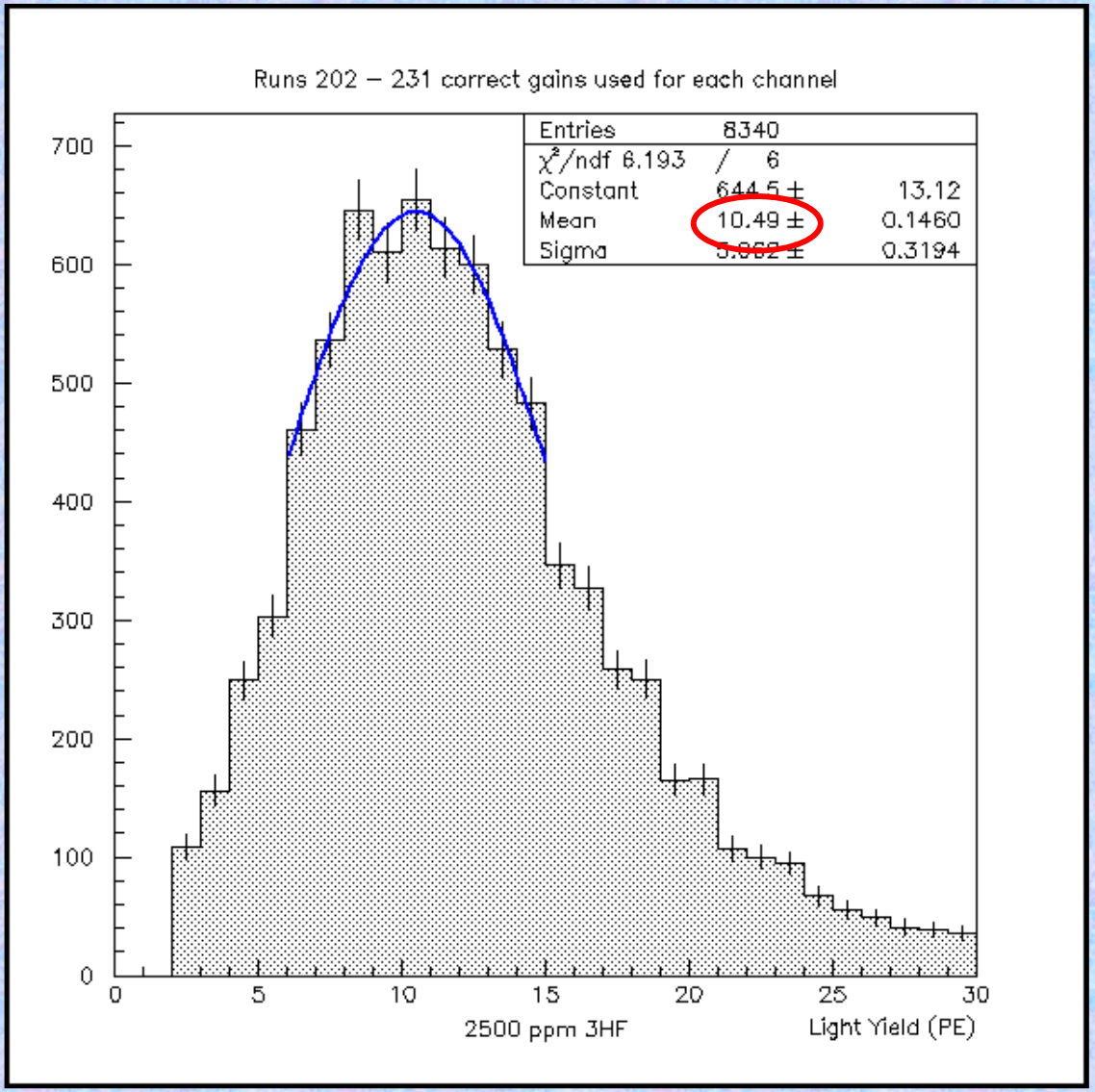
Cosmic Ray Data

- Two periods of data-taking:
  - October 2003
  - March 2004
- Simple cosmic-ray trigger.
- Data analysed to measure tracking resolution, light yield, single plane efficiency, dead channel rate...
- Results now fed into MICE simulation (G4MICE) in order to optimise design.

A Cosmic Ray Track



Light Yield: 2500 ppm 3HF



Prototype Results

- Most probable light yield: 10 – 10.5 p.e.
  - Expectation based on D0 experience ~10
- Resolution: 442 ± 4 (stat) ± 27 (syst) μm
  - Expectation from fibre geometry: 424 – 465 μm (single fibre bunch or two fibre bunch)
- Single Plane Efficiency: (99.7 ± 0.2)%
  - Poisson expectation for 10 p.e. signal 99.7%
- Dead channels: 0.2% (two channels)
  - 0.25% assumed in G4MICE simulation based on D0 experience

Further Work

- Improved design and QA procedures have been produced based on this experience.
- A 4th station will be built soon in order to test the new design and procedures.
- Currently planning to use all 4 stations in a test beam at KEK, to confirm pattern recognition performance and momentum resolution.
- Start producing the full trackers for MICE…