Scintillating Fiber Tracker

Prototype and Simulation

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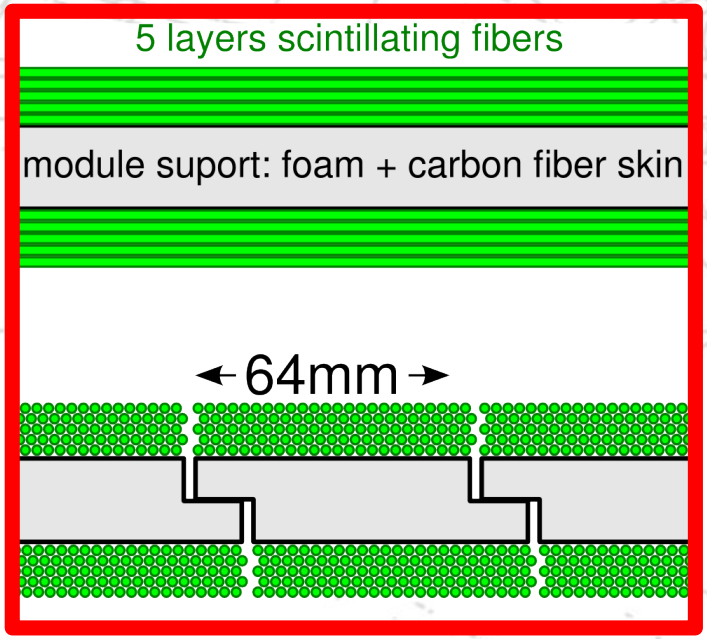
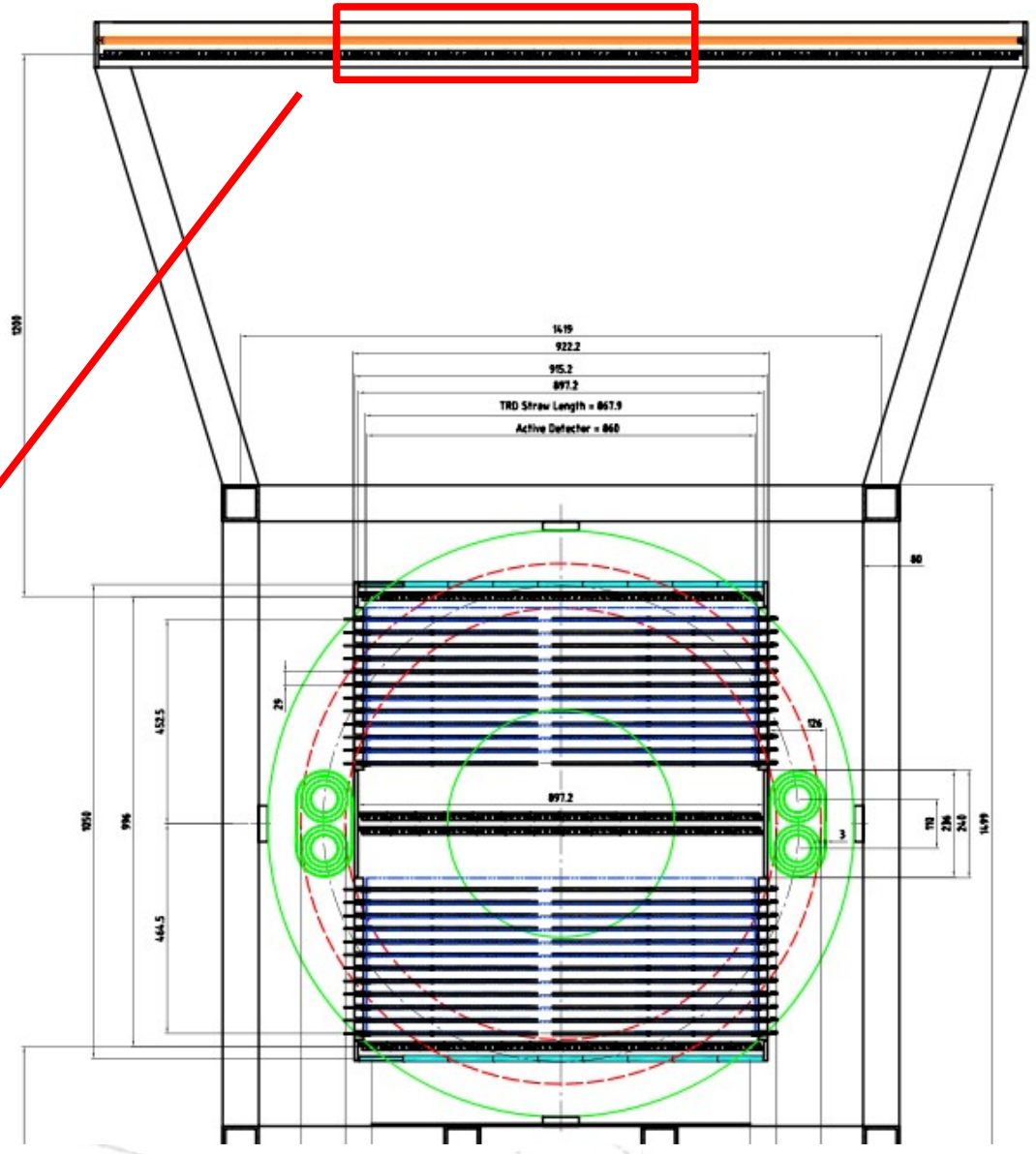
PEBS Meeting 2009-02-28

The PEBS Outer Tracker

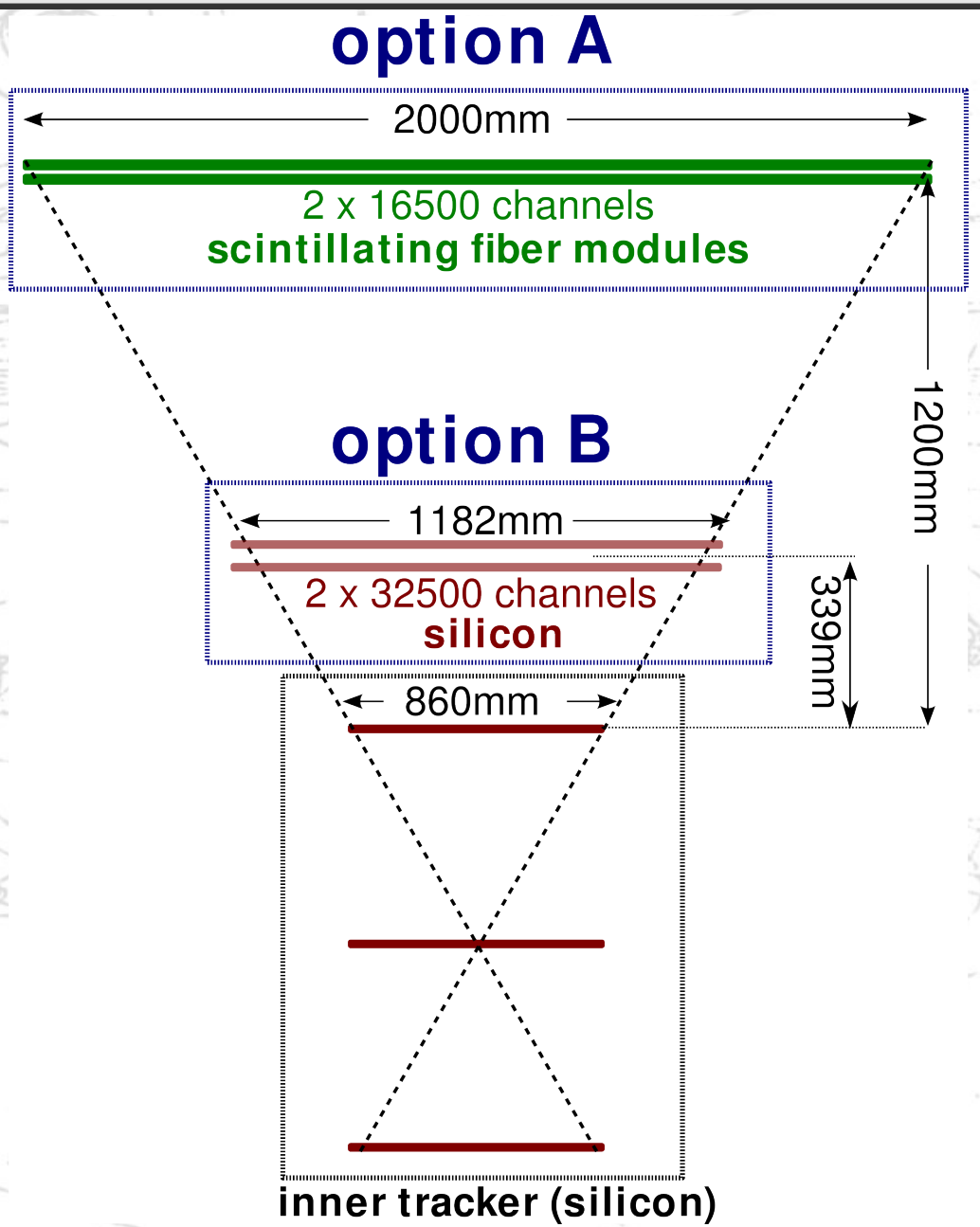
- *50µm resolution targeted*
- *2m module length*
- *2 x 32 modules*
- *512 channels per module*
- *80W power consumption*



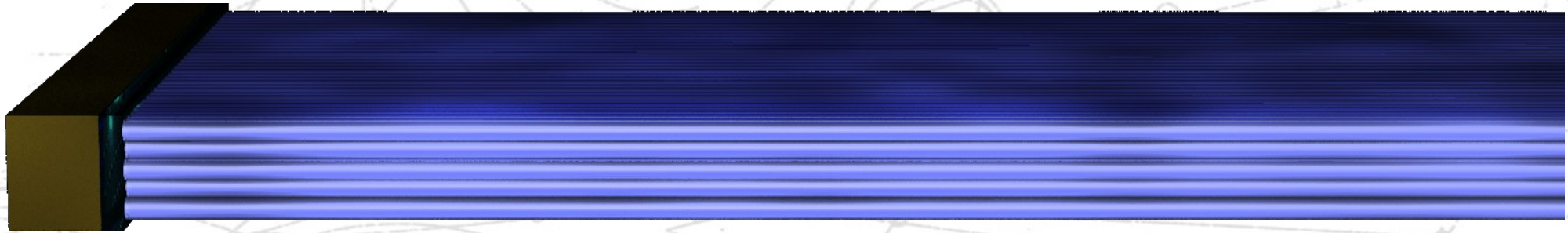


Outer Tracker Options

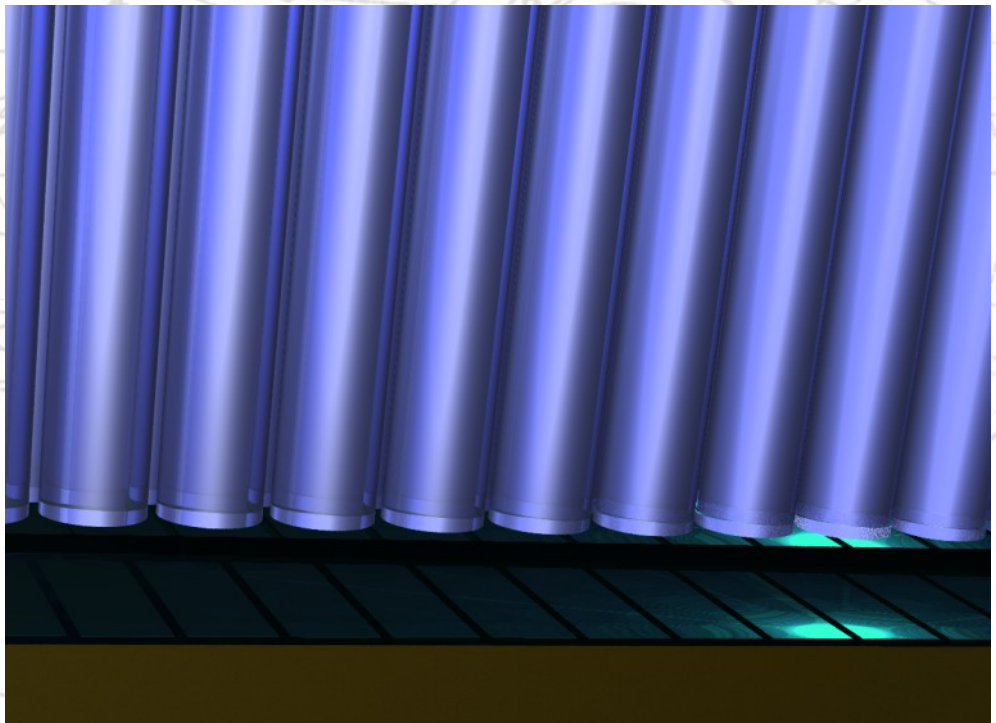
- *fiber tracker*
  - **50µm / sqrt(2) in two coordinates**
  - **~33000 channels**
  - **2m x 2m**
  - **2 points in 3D => particle direction**
- *silicon tracker*
  - **10µm in two coordinates**
  - **~65000 channels**
  - **1.2m x 1.2m**
  - **only 1 point in 3D**
- *preference for fibers from SRD?*



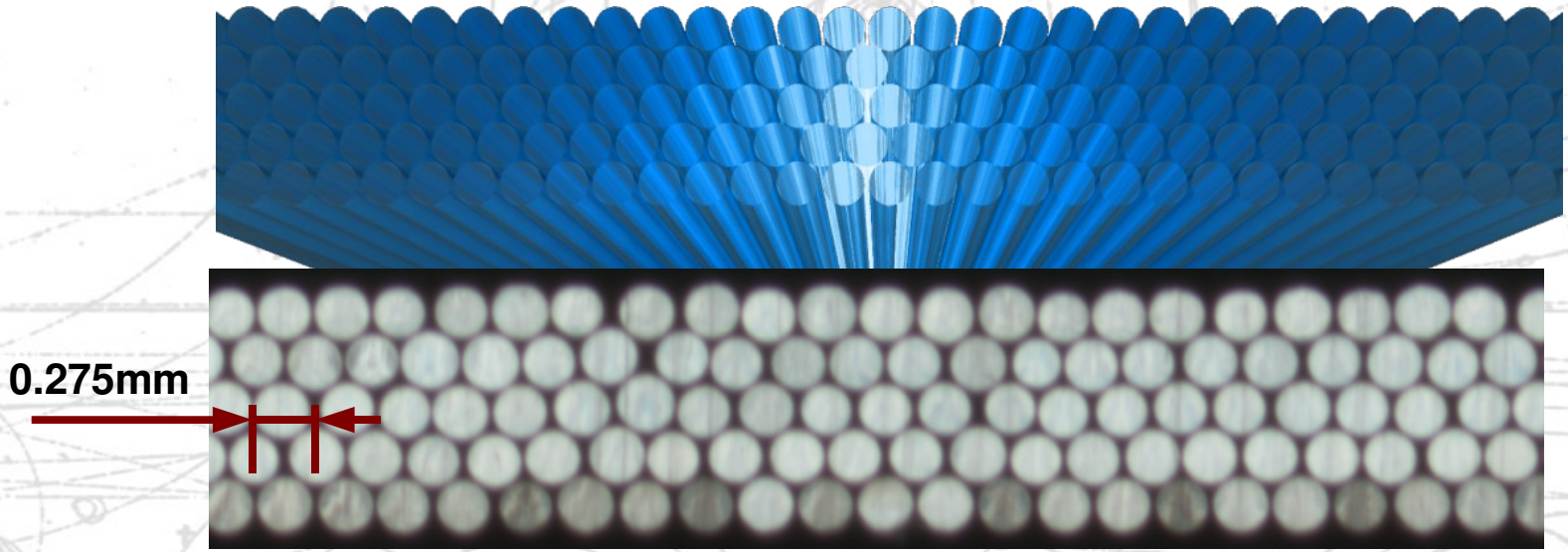
A Scintillating Fiber Tracker



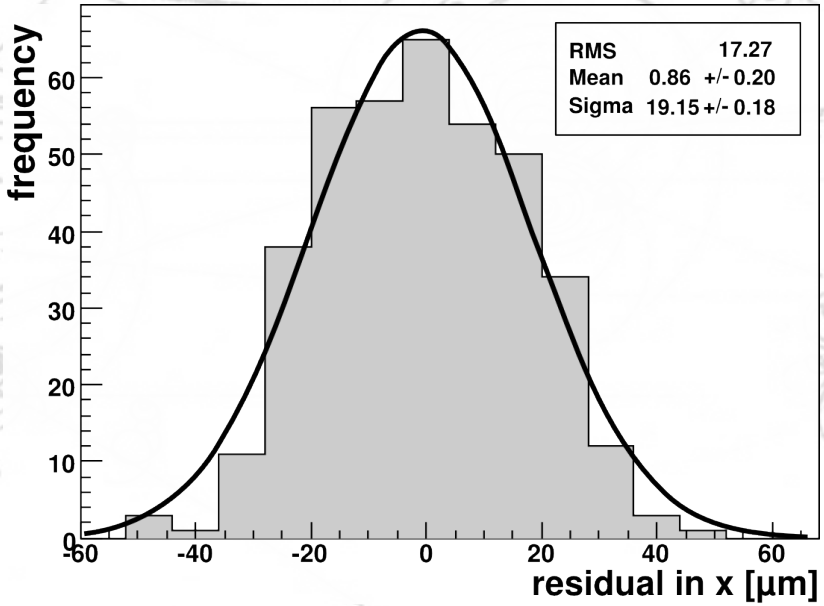
- *scintillating fiber trackers*
  - **typical resolutions >100µm**
  - **limited by method of fiber readout**
- *what resolutions can be achieved using SiPM Arrays?*



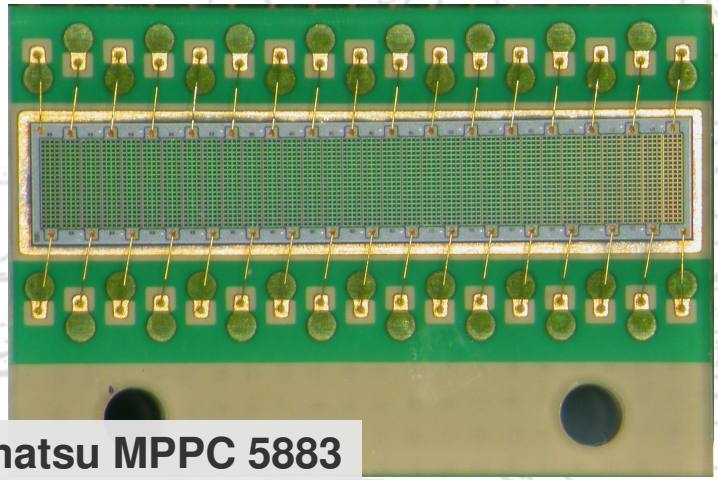
Prototype Fiber Ribbon



- *250µm fiber diameter*
- *275µm fiber pitch*
- *precision < 20µm RMS for for fiber placement in ribbon of 5 layers*

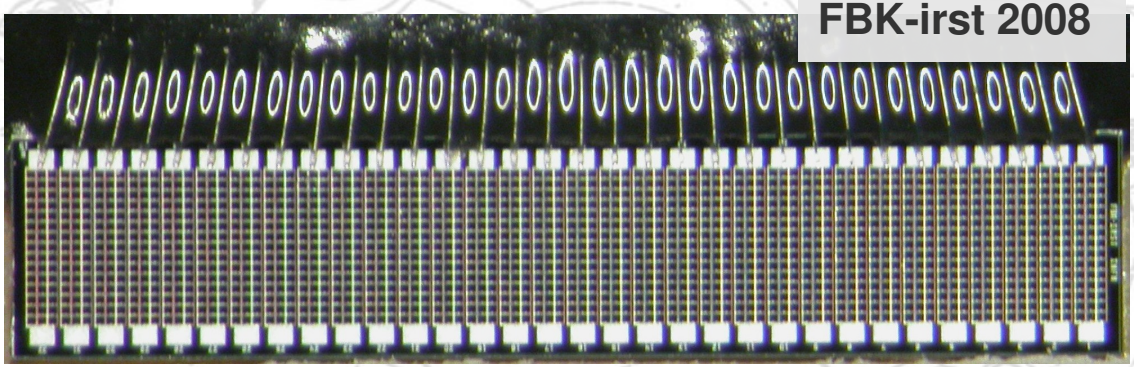


Available SiPM Arrays

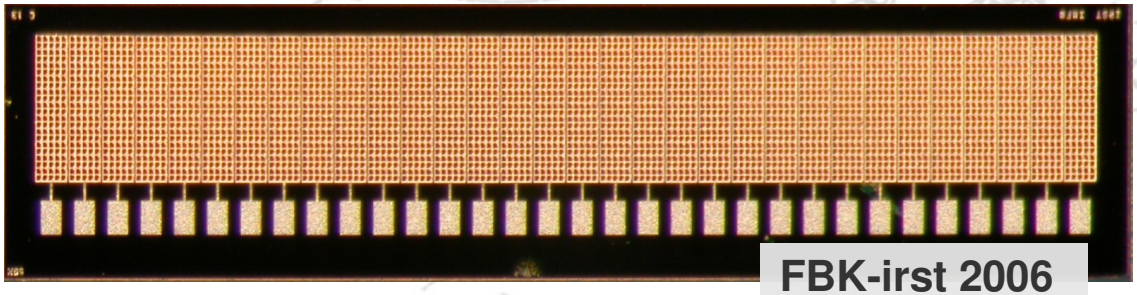


Hamamatsu MPPC 5883

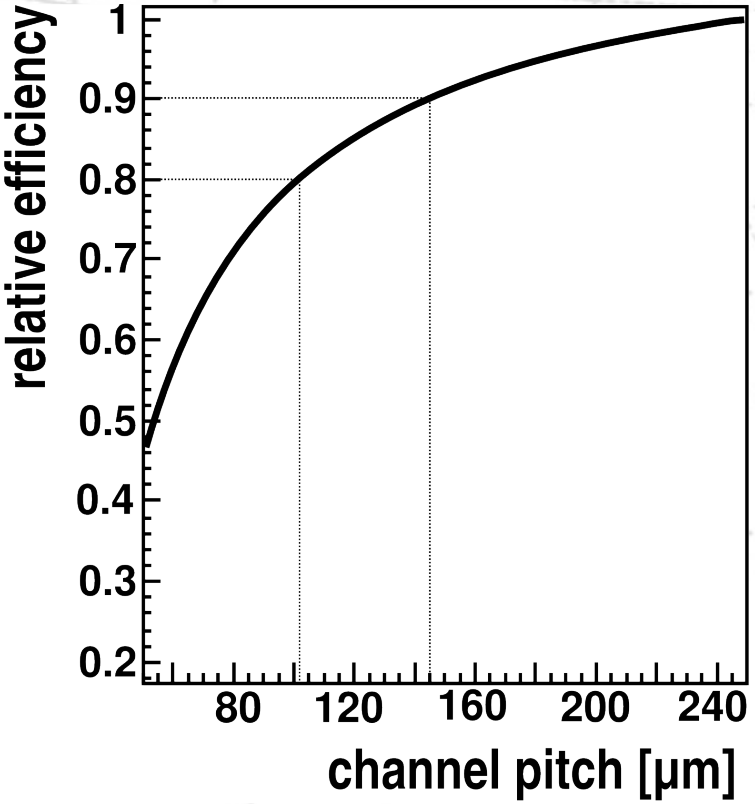
- *Photon efficiency > 50%*
- *250µm channel pitch*
- *more on SiPM Arrays in Roman's talk*



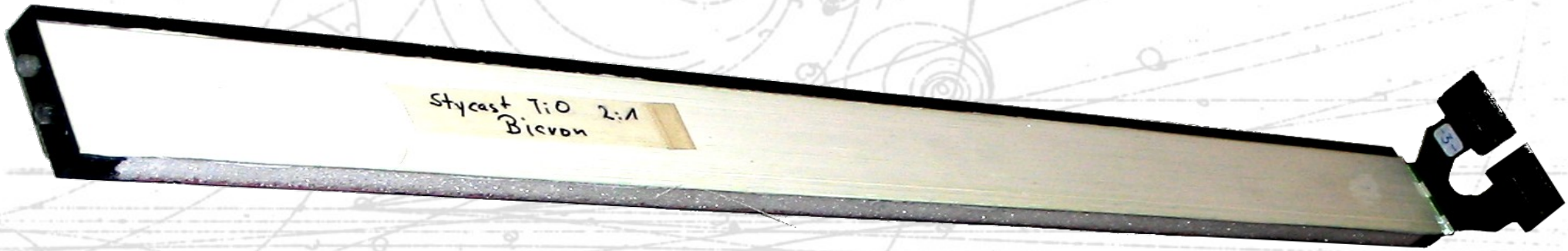
FBK-irst 2008



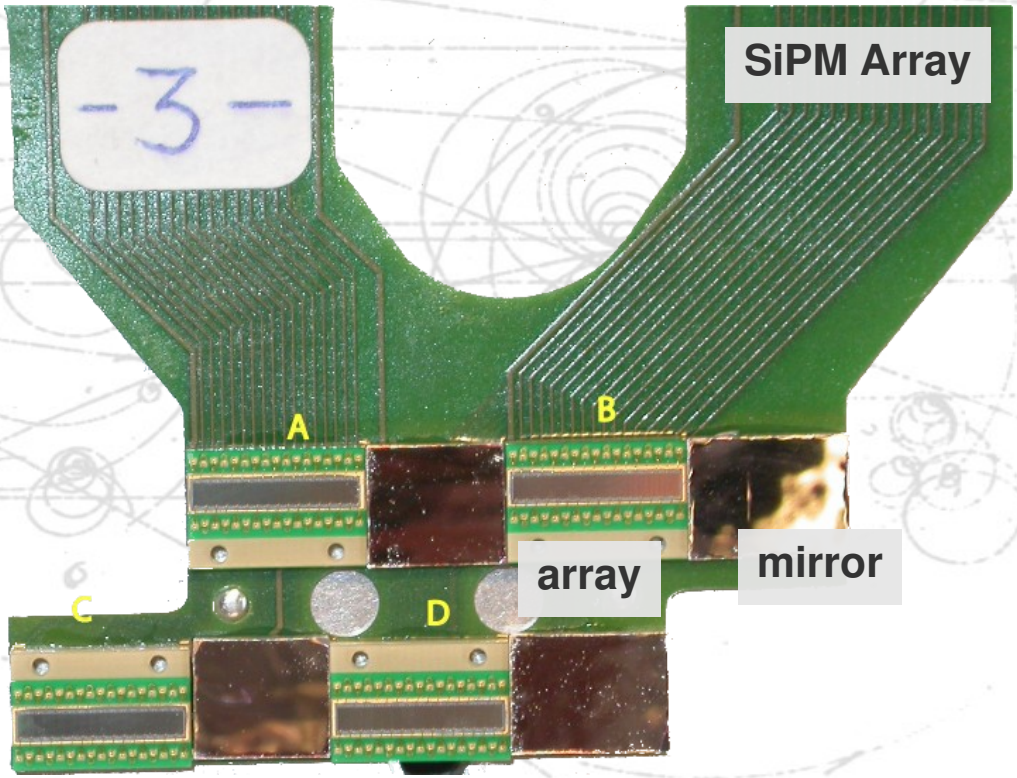
FBK-irst 2006



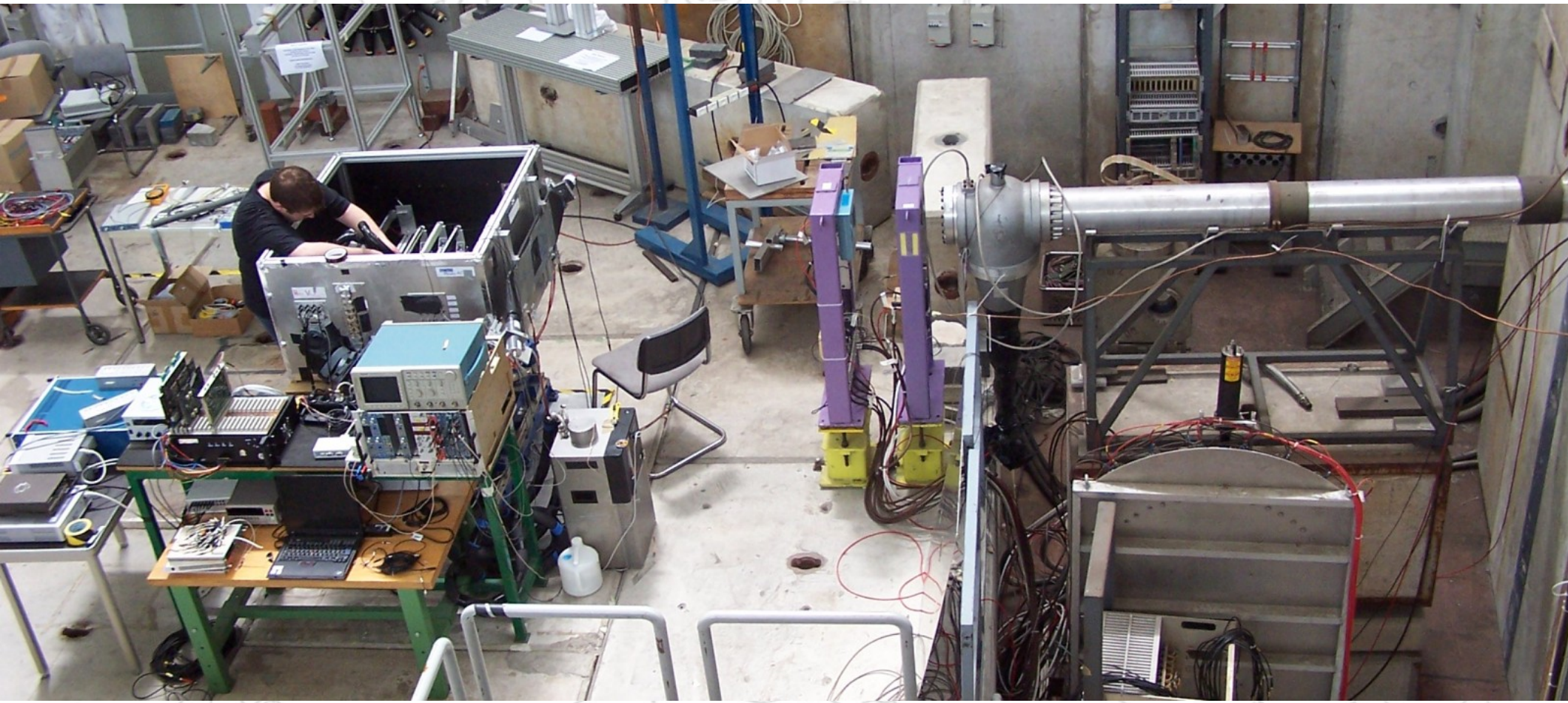
Fiber Module Prototype



- *prototype from beamtest*
  - **measured spatial resolution**
  - **measured light yield**

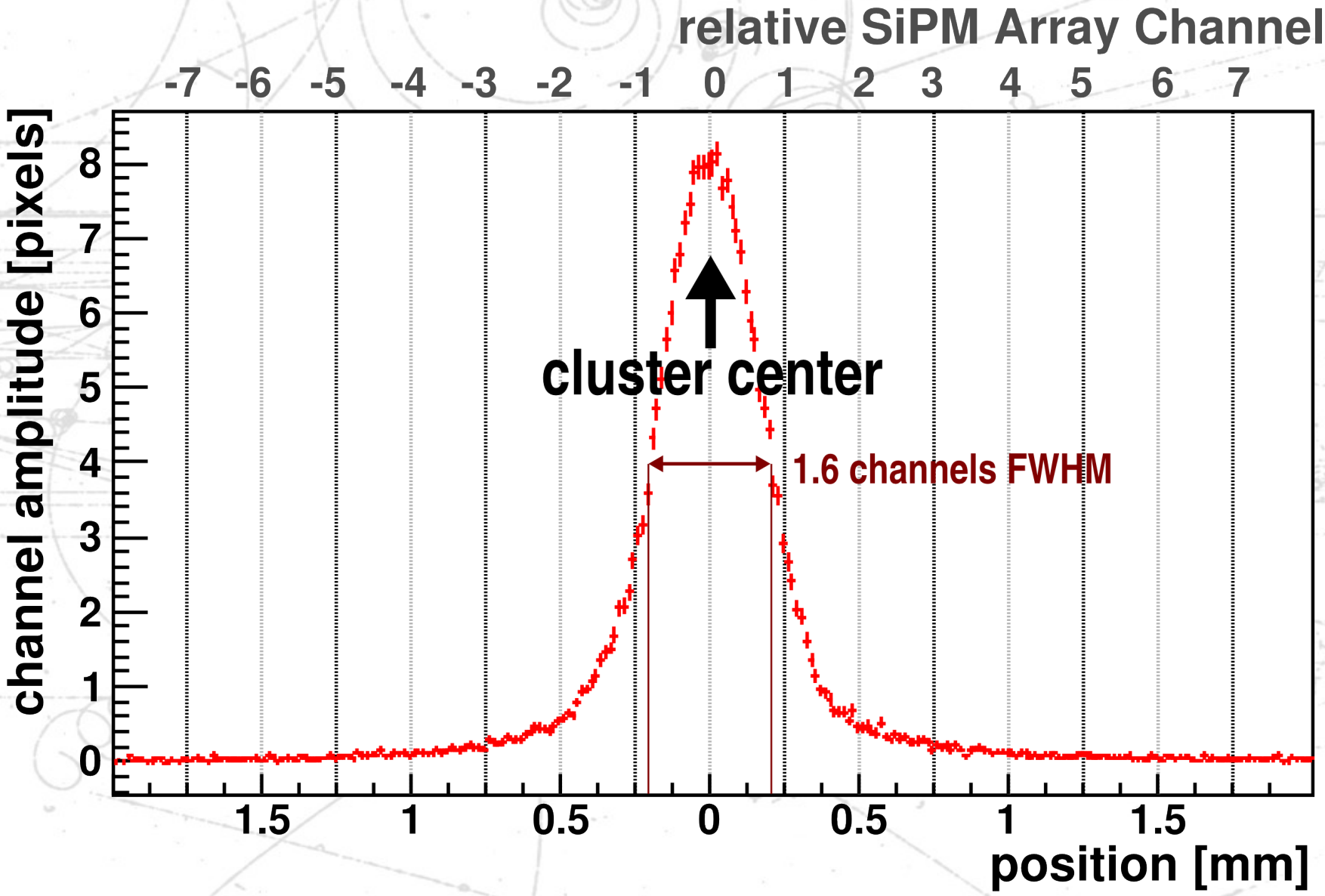


Test of Prototype



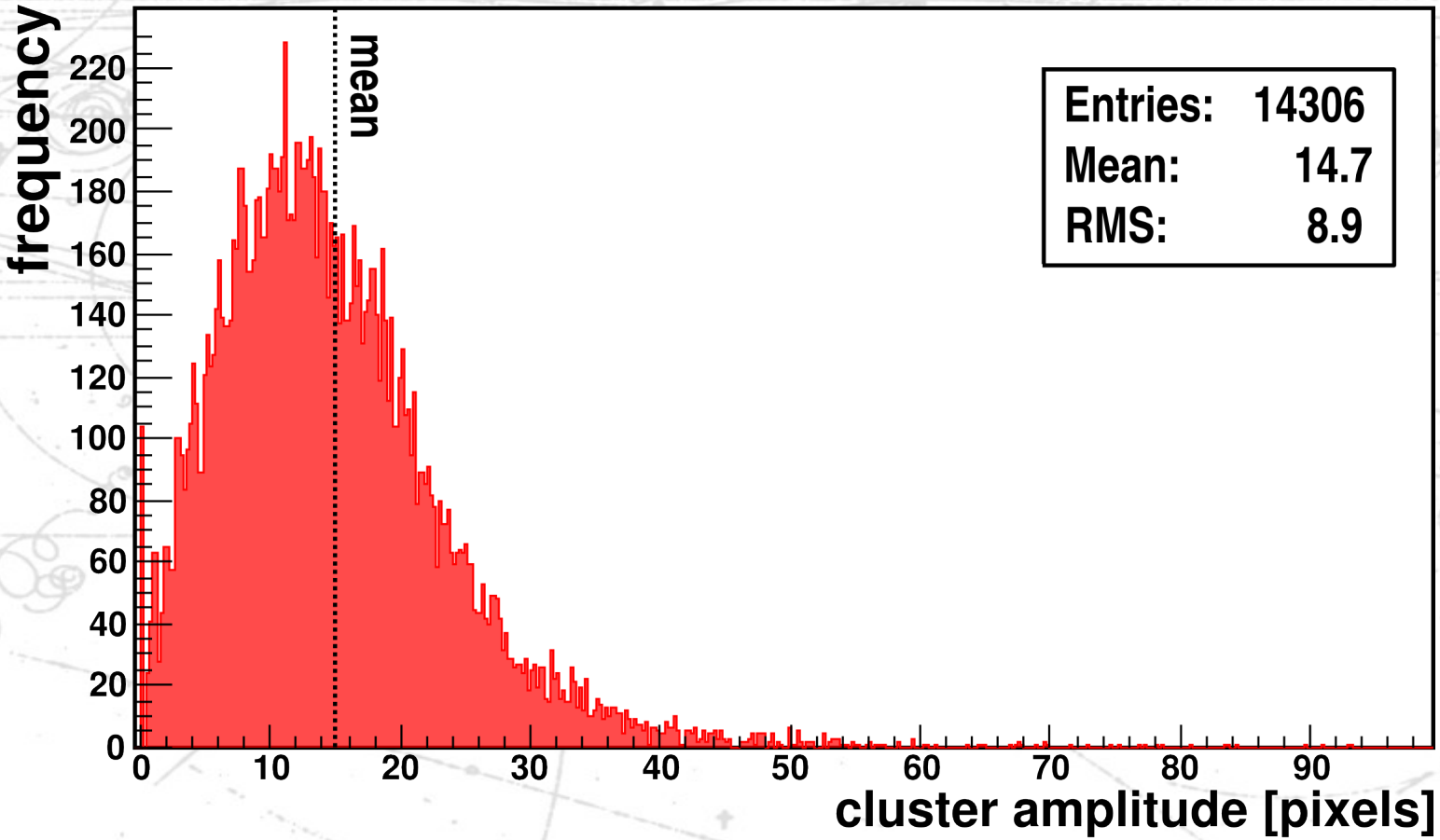
- *CERN PS, 10 GeV beam (protons & pions)*

Signal Cluster Shape

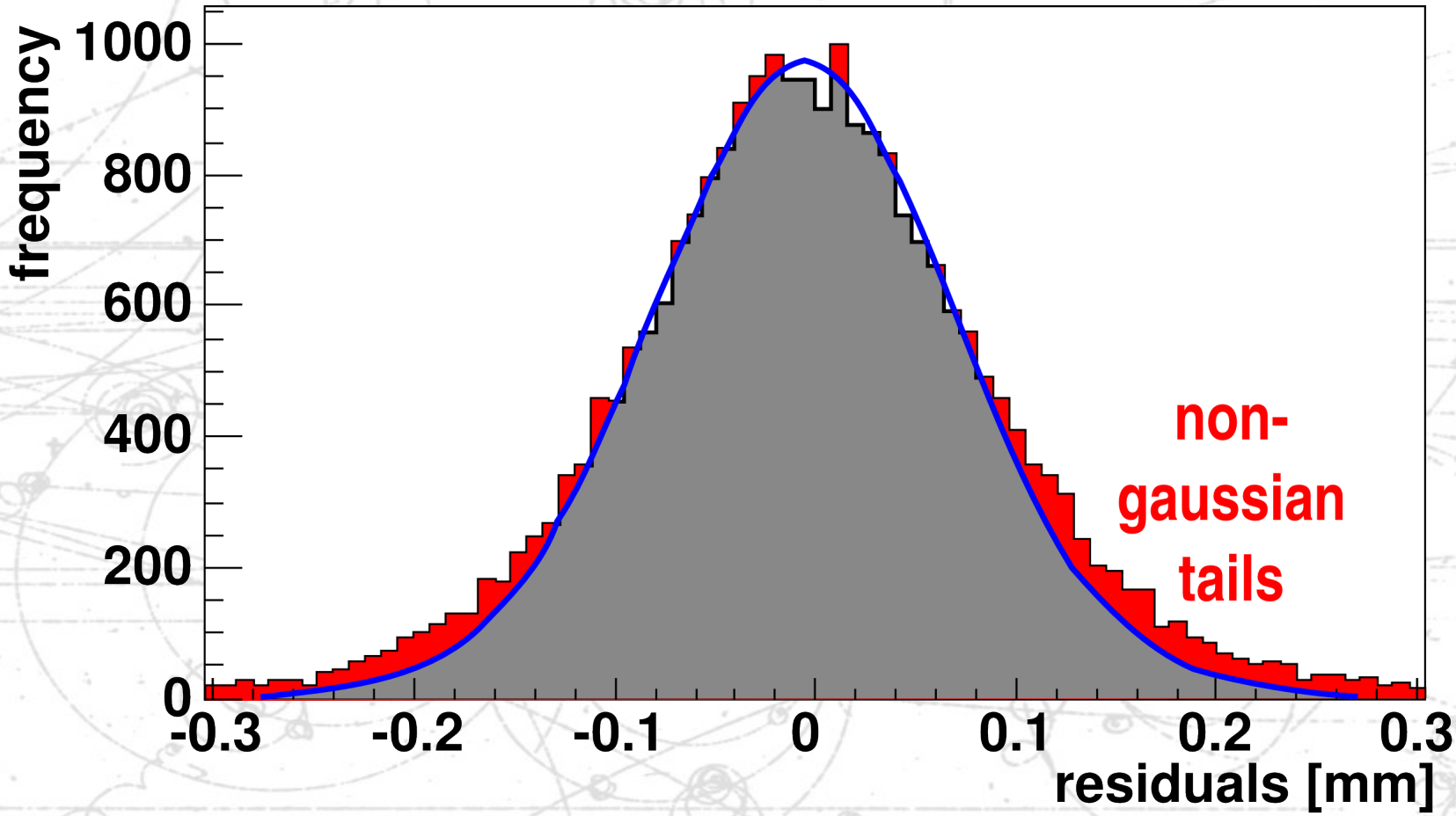


Mean Cluster Amplitude

- *average signal cluster amplitude: 14.7 pixels*
  - **approximately 10 detected photons + crosstalk**
  - **particle detected with efficiency > 99%**



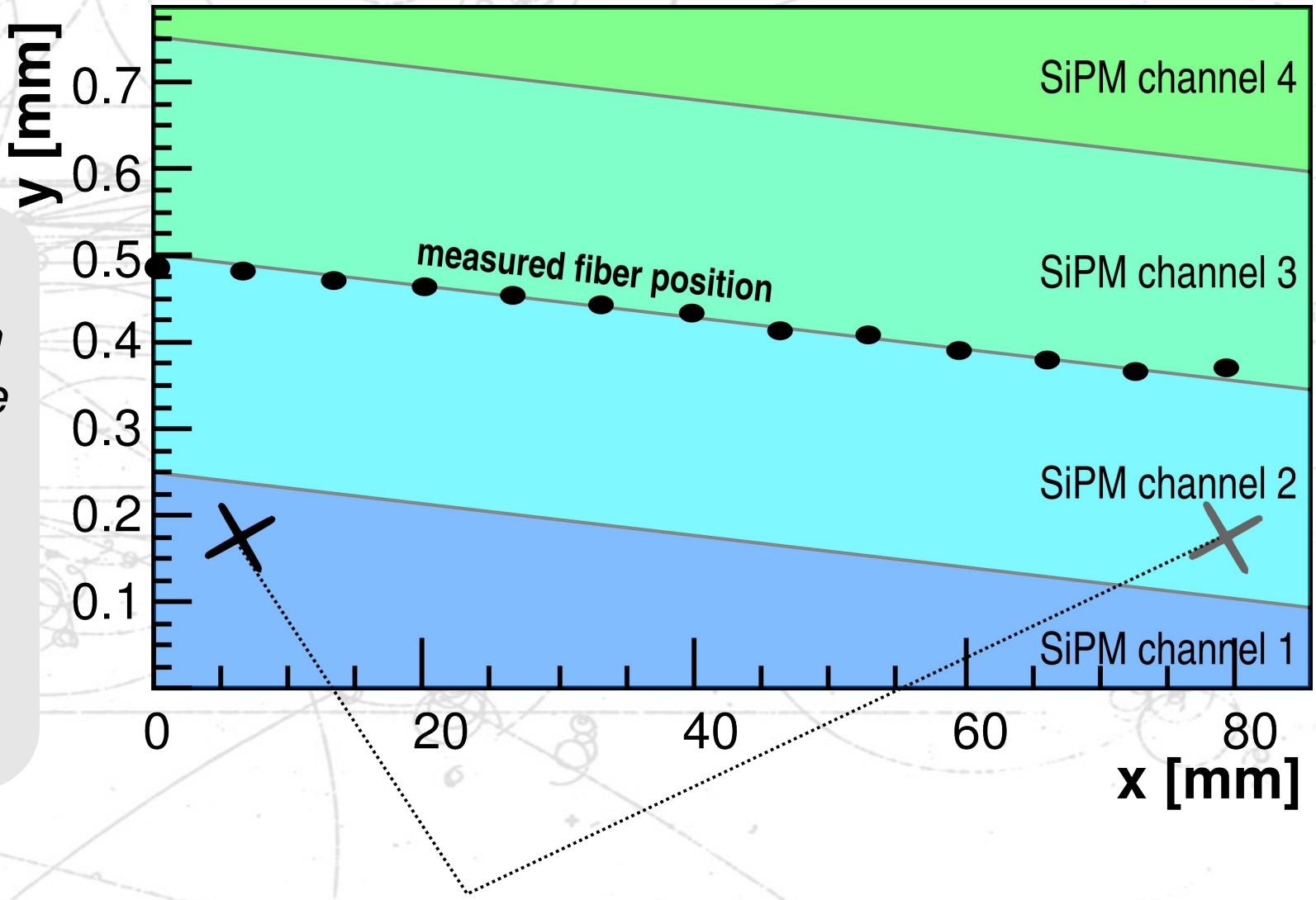
Track Residuals



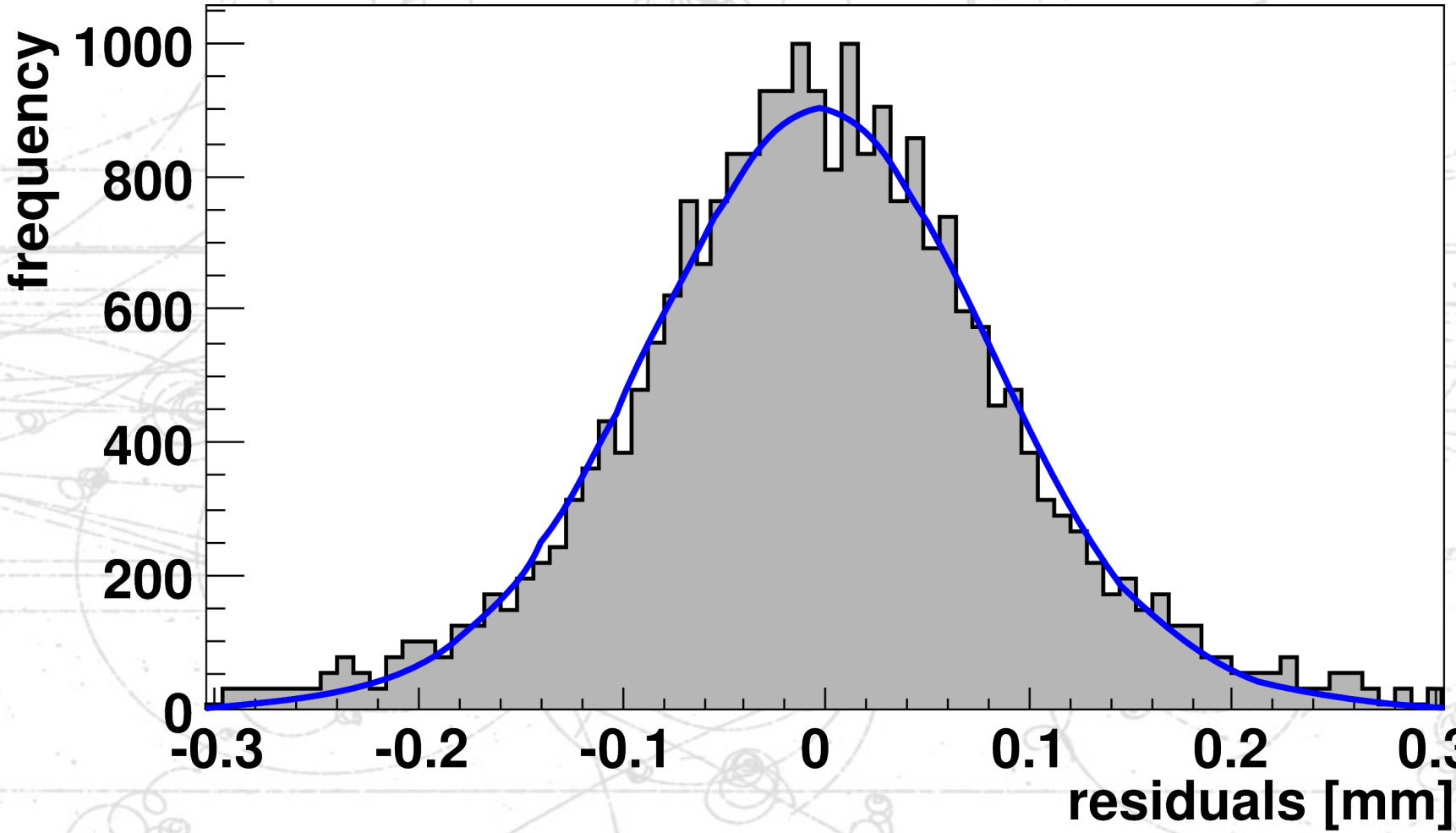
- *σ≈80μm fitting only central region of peak*
- *σ=95μm±6μm fitting distribution with double-gaussian*

Failed Track Reconstruction

- *ambiguous x-coordinate from beam telescope*
- *spatial resolution of fiber module was under-estimated*

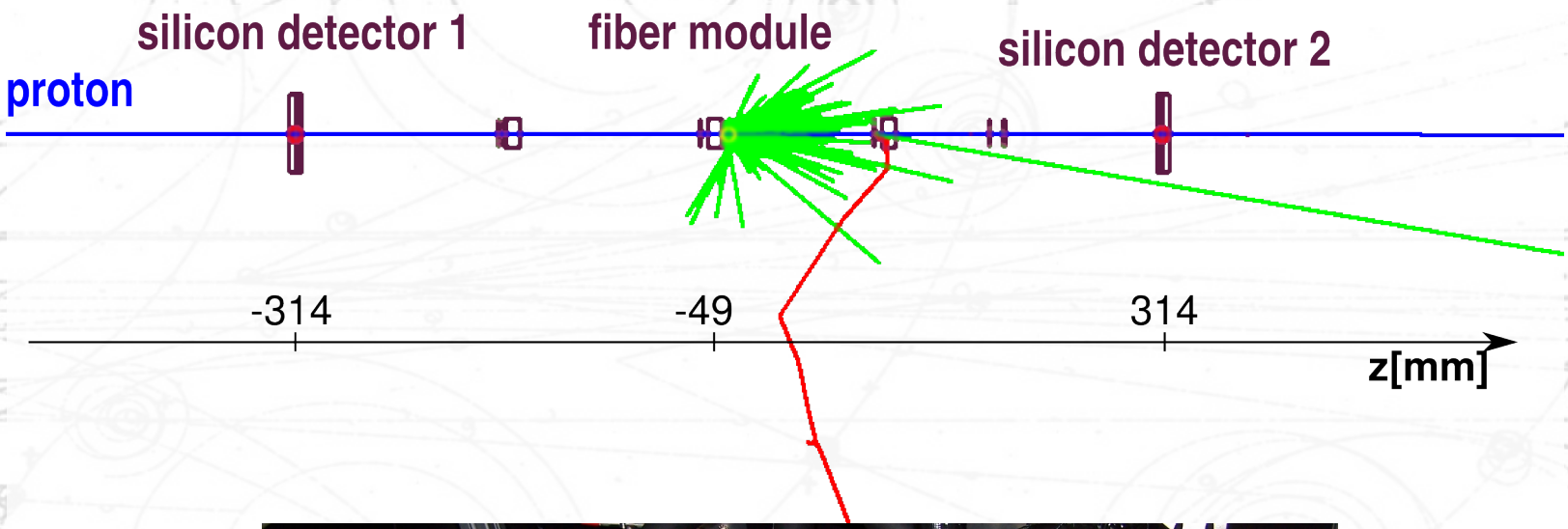


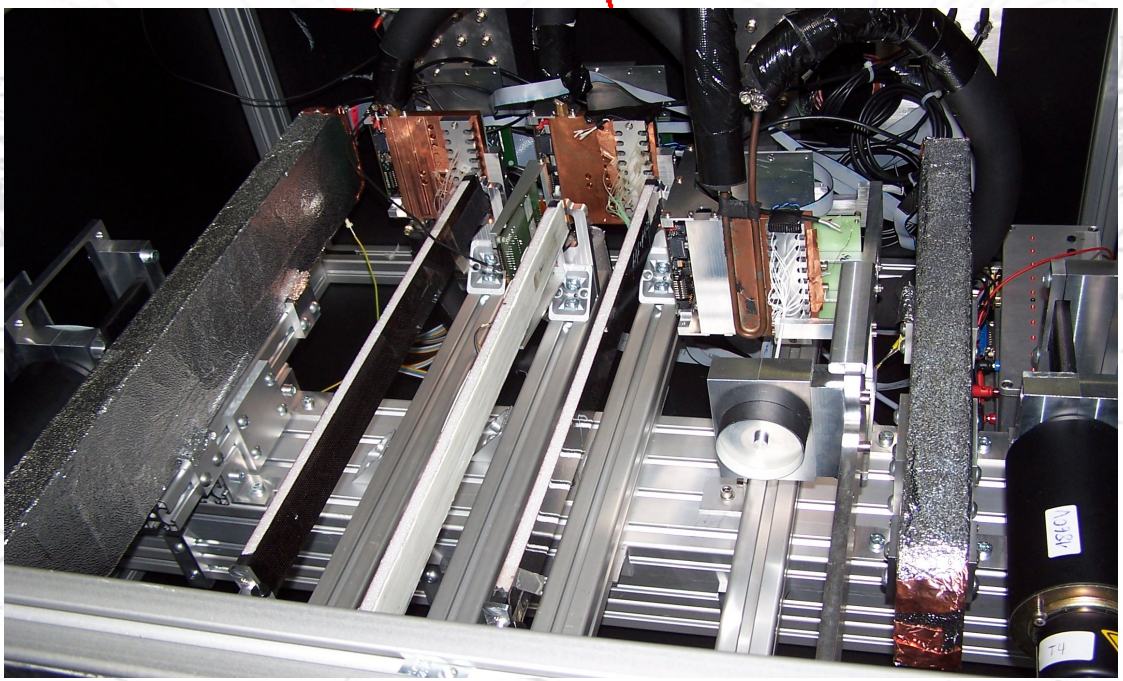
Track Residuals



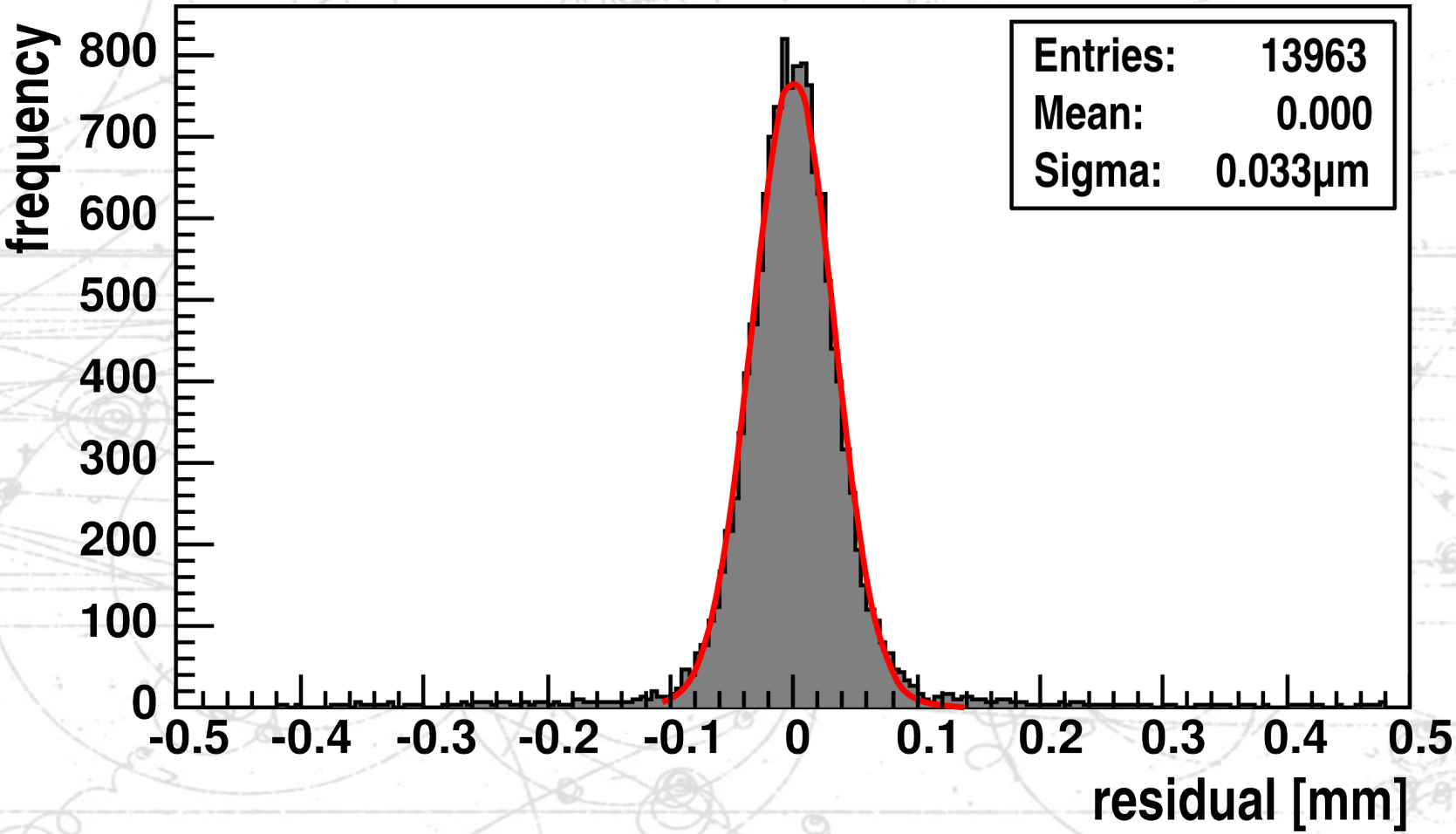
- *σ=82μm ± 1μm fitting distribution with simple gaussian*
  - **χ^2 / ndof = 1.02**

Beam Telescope Resolution



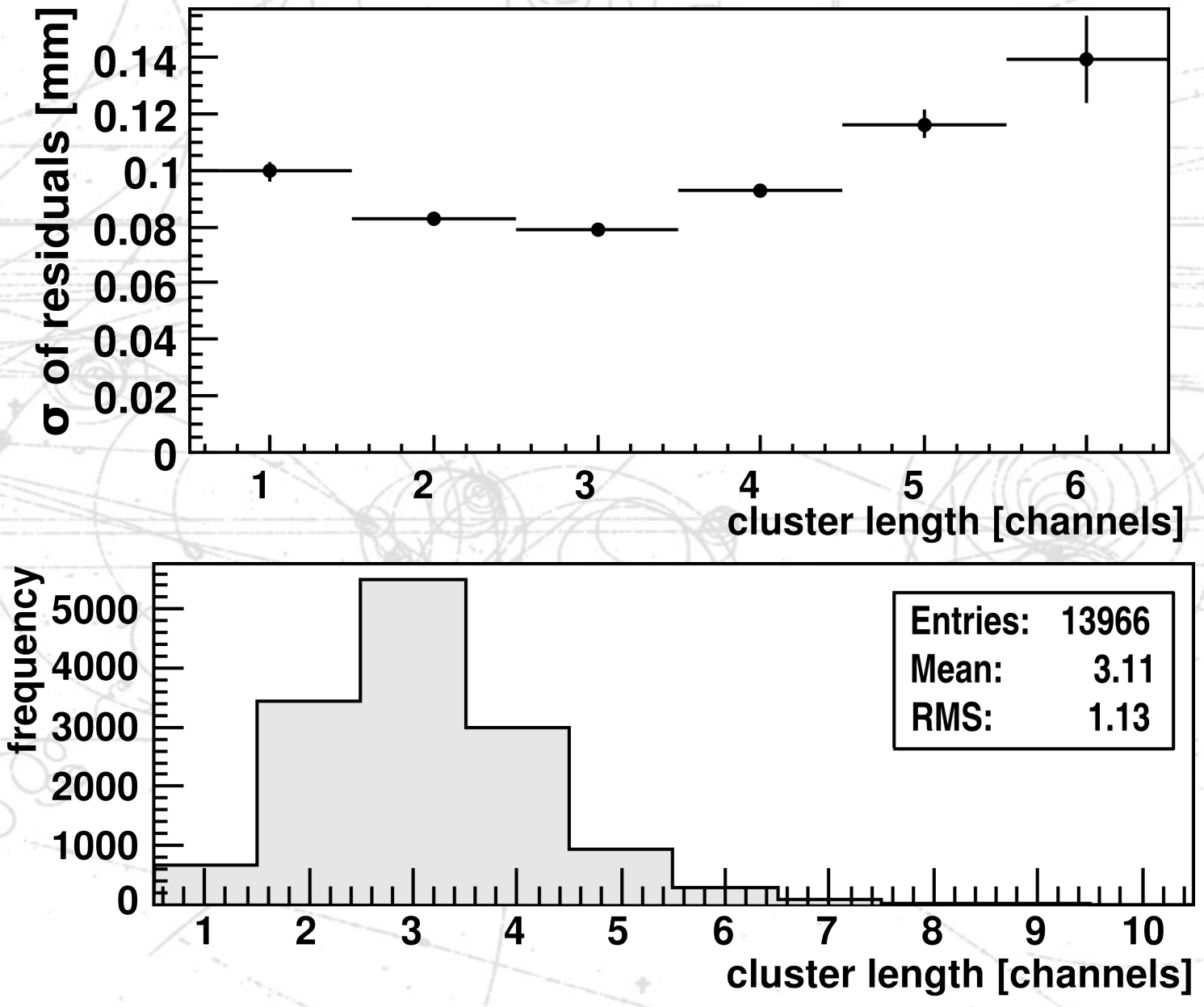


Beam Telescope Resolution



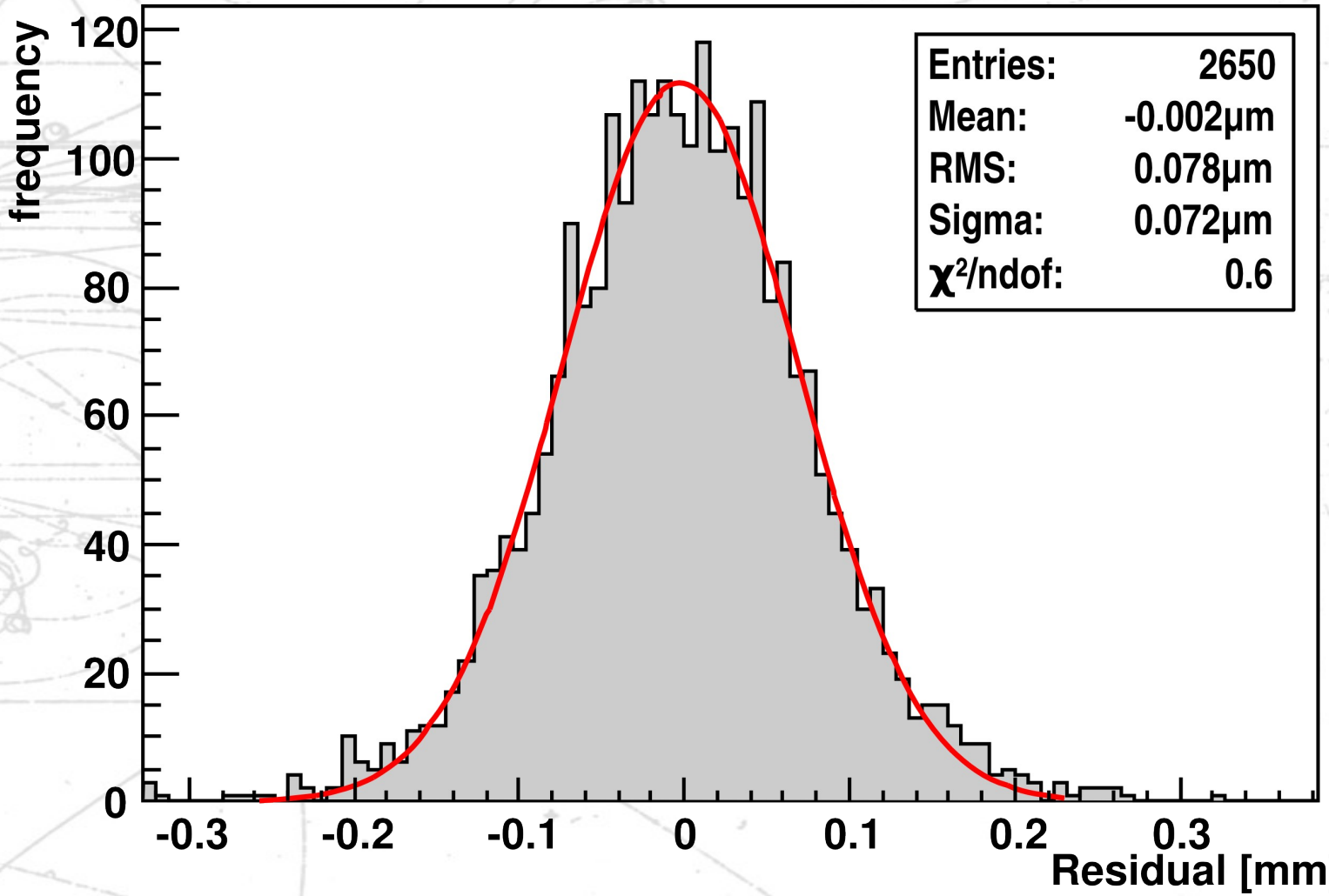
- *spatial resolution of fiber module is 75µm ± 2µm*
  - **using effective beam telescope resolution of 33µm**

Mean Signal Cluster Length



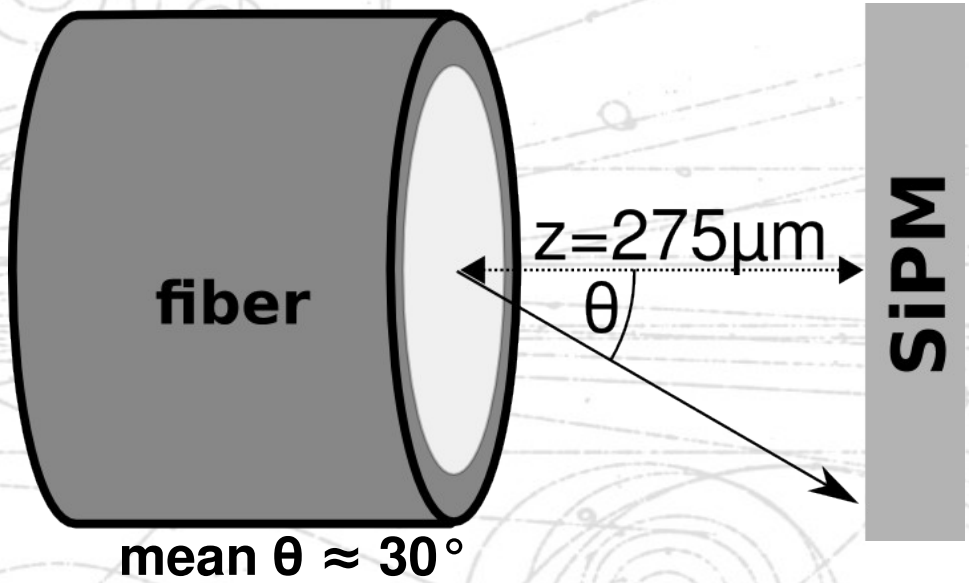
Selecting Short Clusters

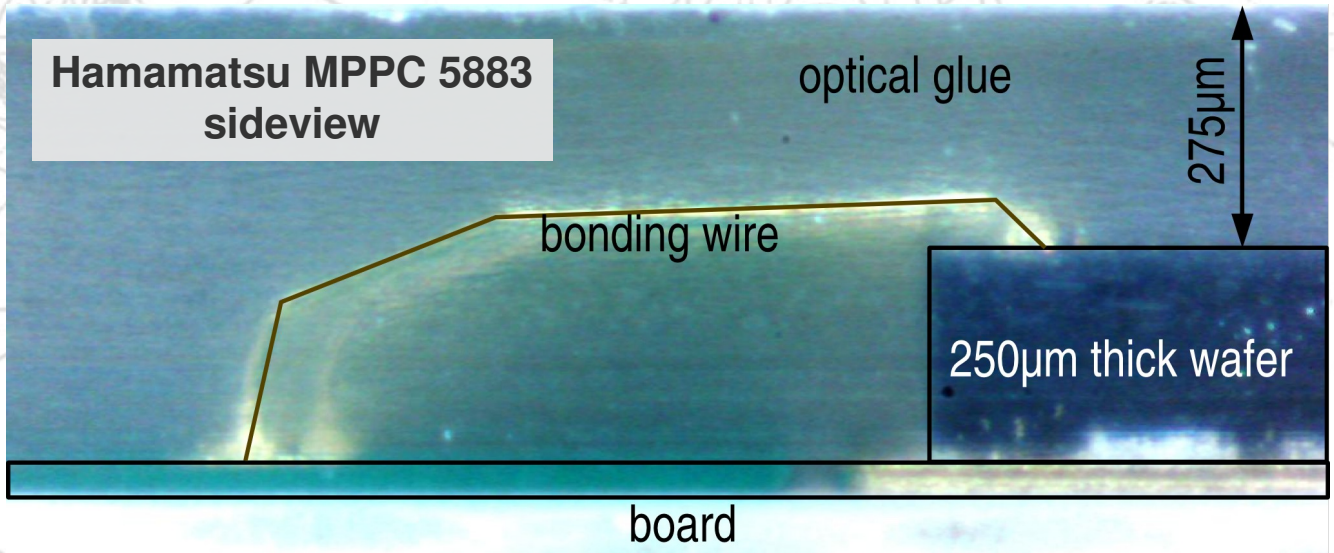
- *64µm spatial resolution for short clusters*
  - **65% efficiency**



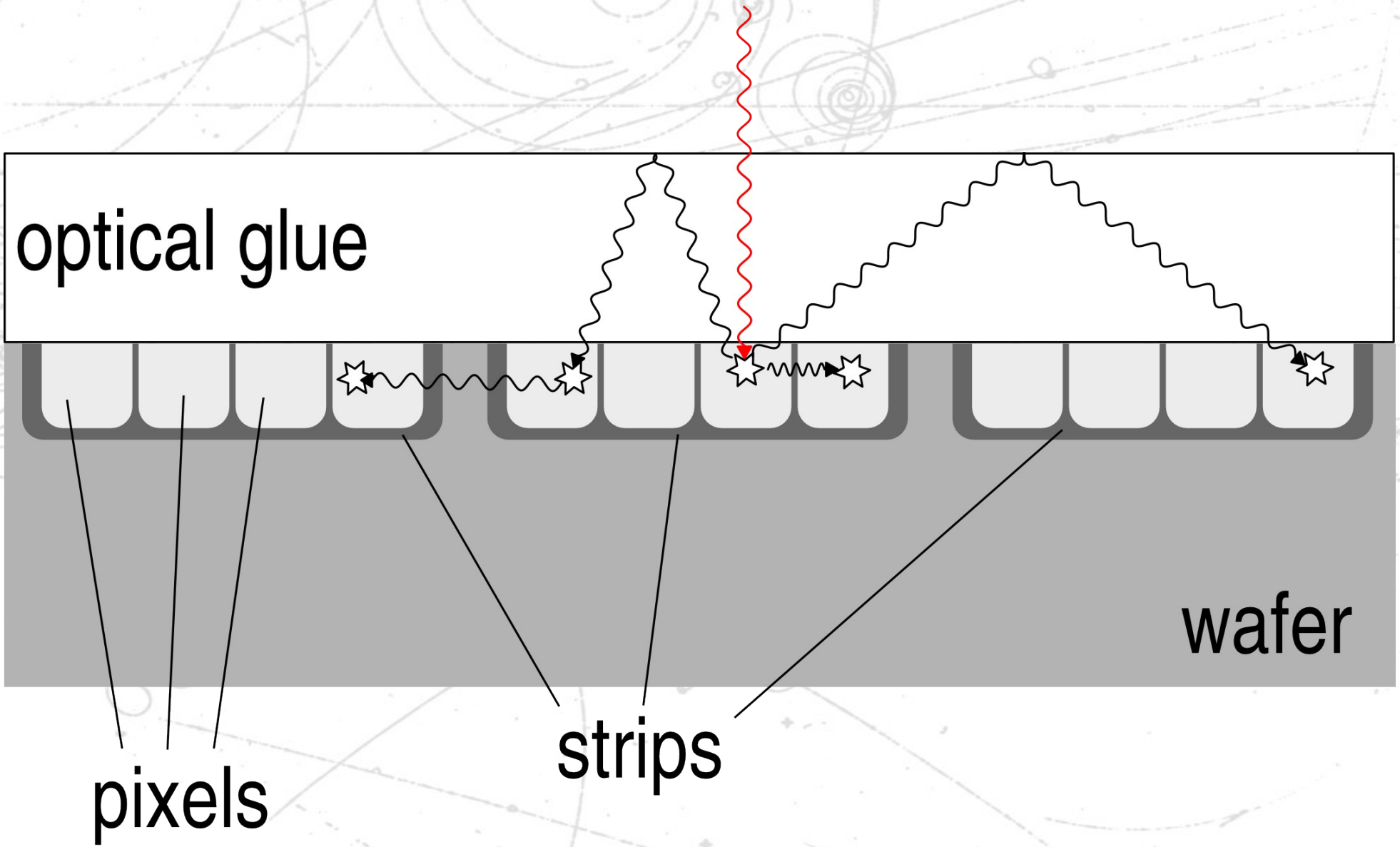
Optical Glue On MPPC 5883

- *optical glue layer on top of Hamamatsu MPPC 5883 defines fiber-SiPM-gap*

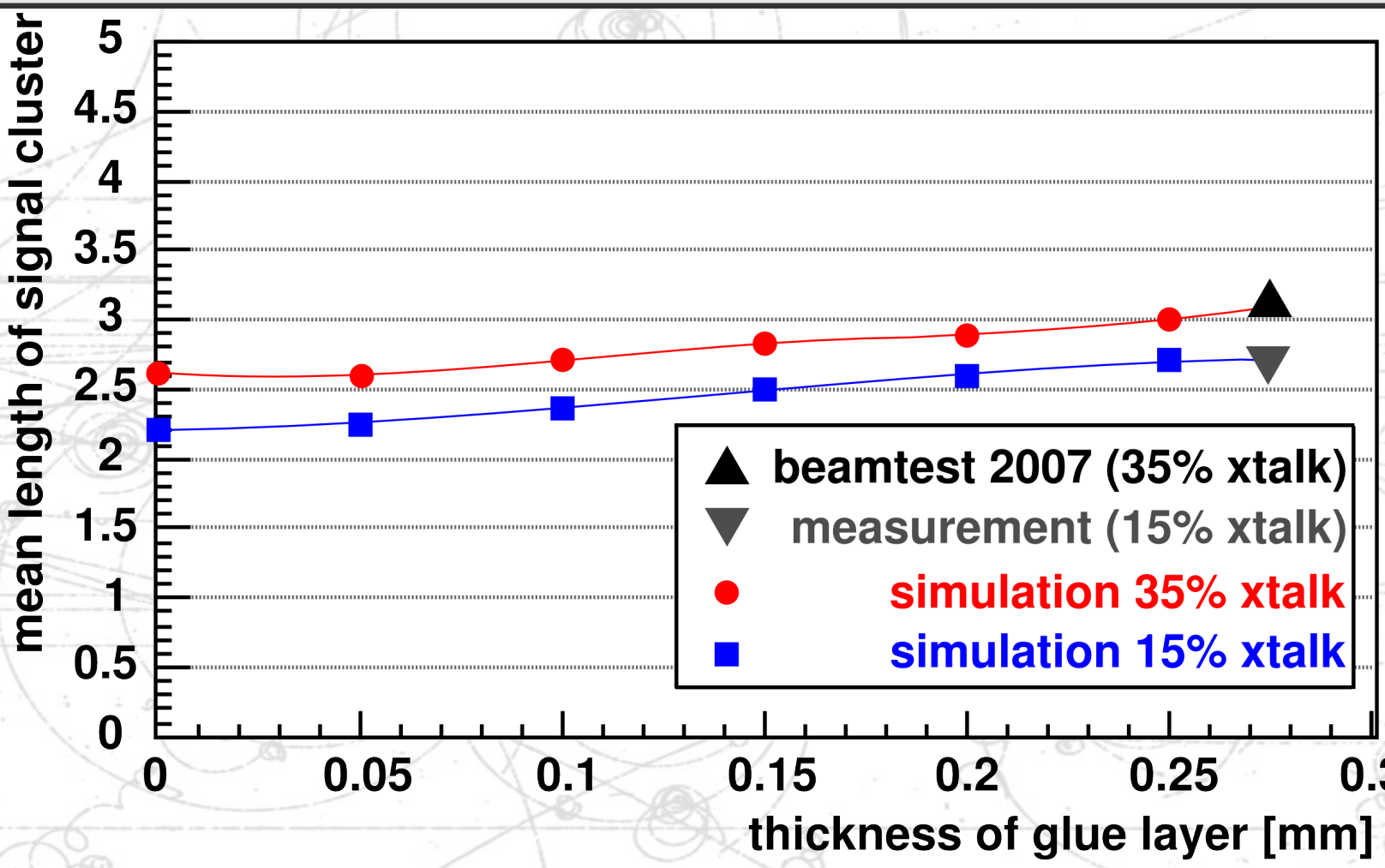




Crosstalk Between SiPM Strips

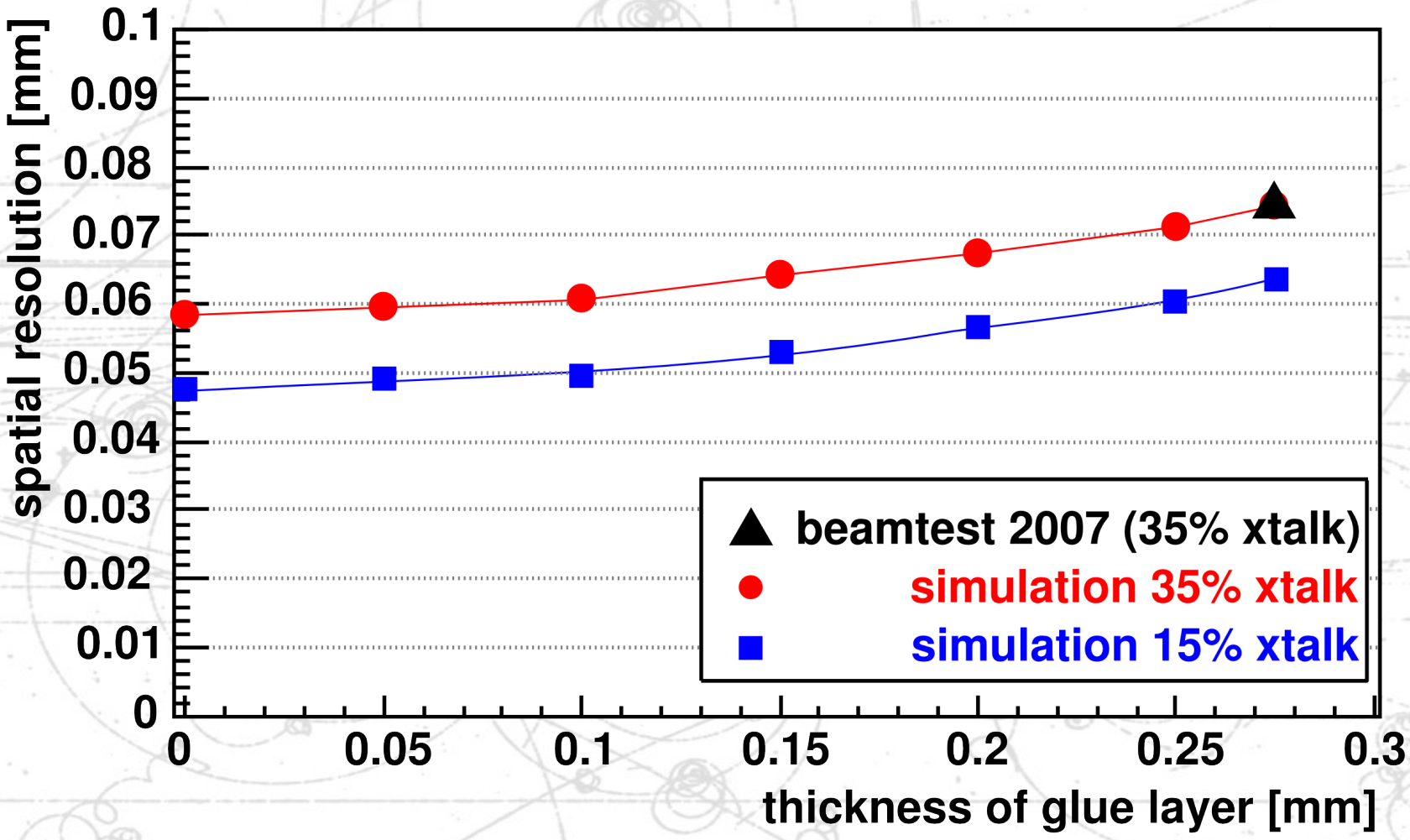


Reduction Of Cluster Length



- *lower crosstalk achieved by adjusting operation voltage without much impact on photon detection efficiency (=> Roman)*

Expected Resolution

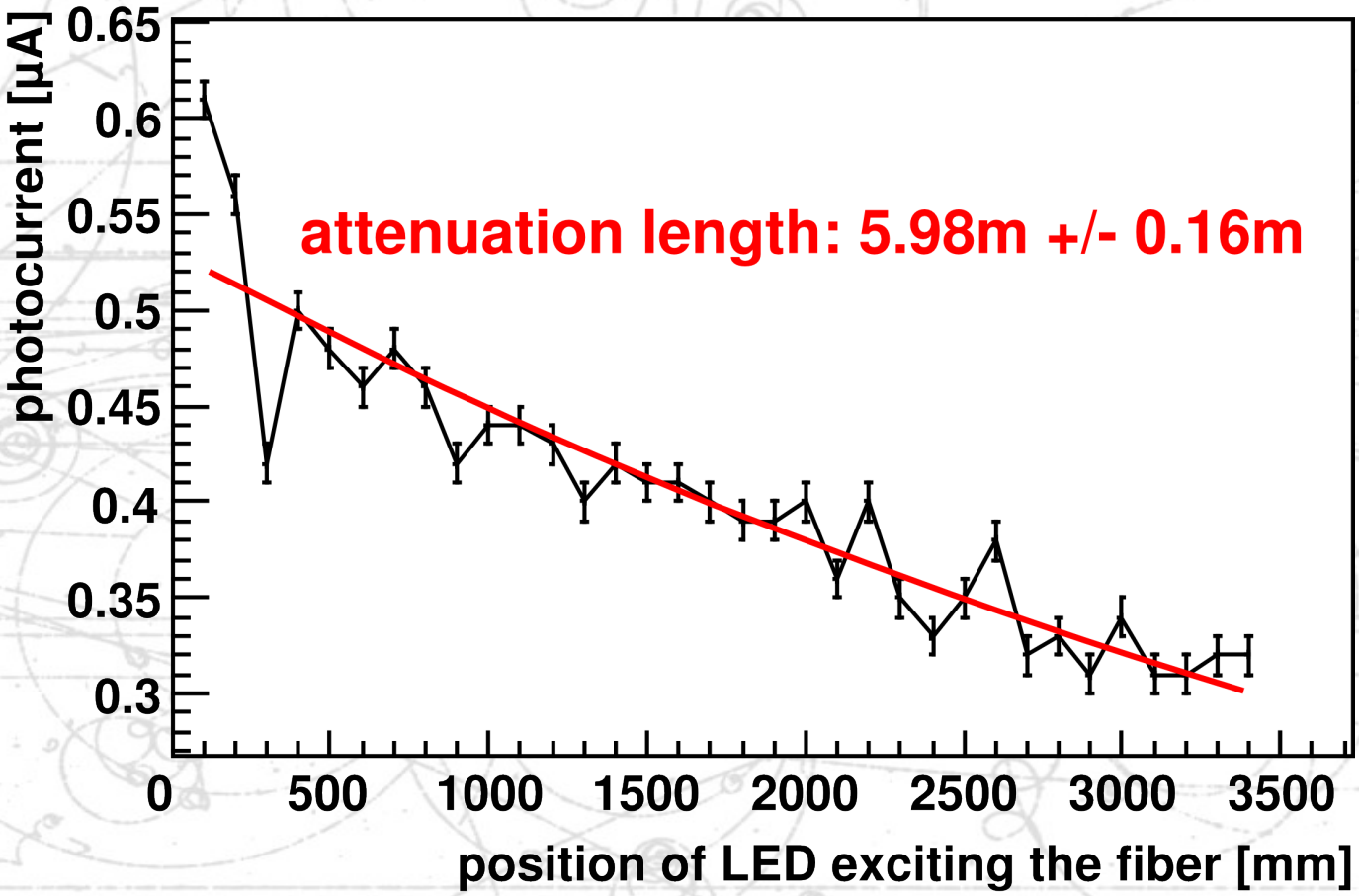


- *Hamamatsu proposed design for SiPM with reduced glue layer (<0.1mm)*

Summary & Conclusion

- *We already achieved a resolution of 64µm +/- 3µm*
- *We can build a scintillating fiber tracker with 50µm single point resolution*
- *We need to test whether we can retain that resolution at a module length of 2m*

Fiber Attenuation Length

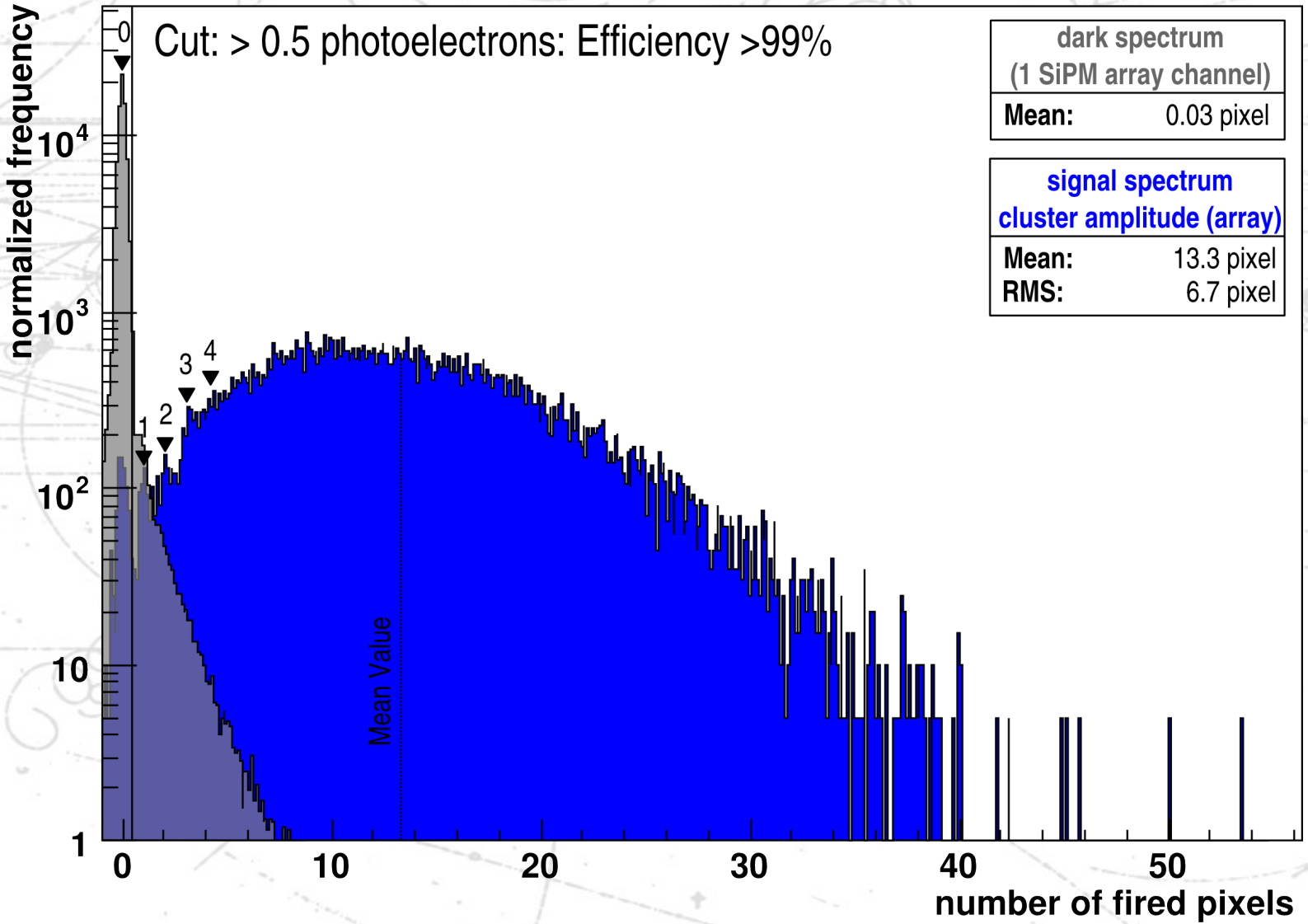


- *attenuation length of fiber sample: 6m*
- *specification (Kuraray): > 3.5m*

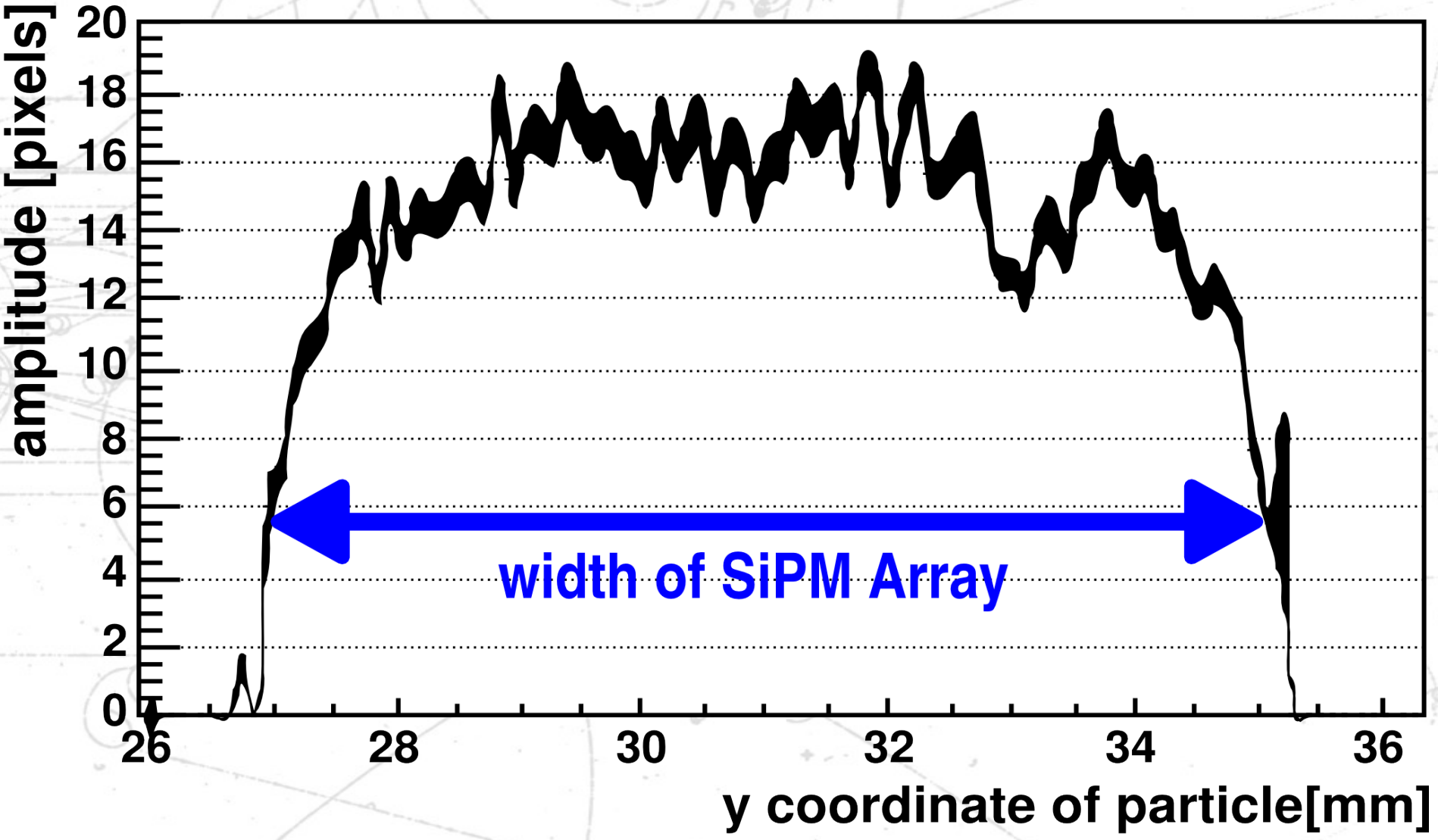
Amplitude (Cluster Center)

Signal Plot Hamamatsu MPPC 5883 + Kuraray Fiber

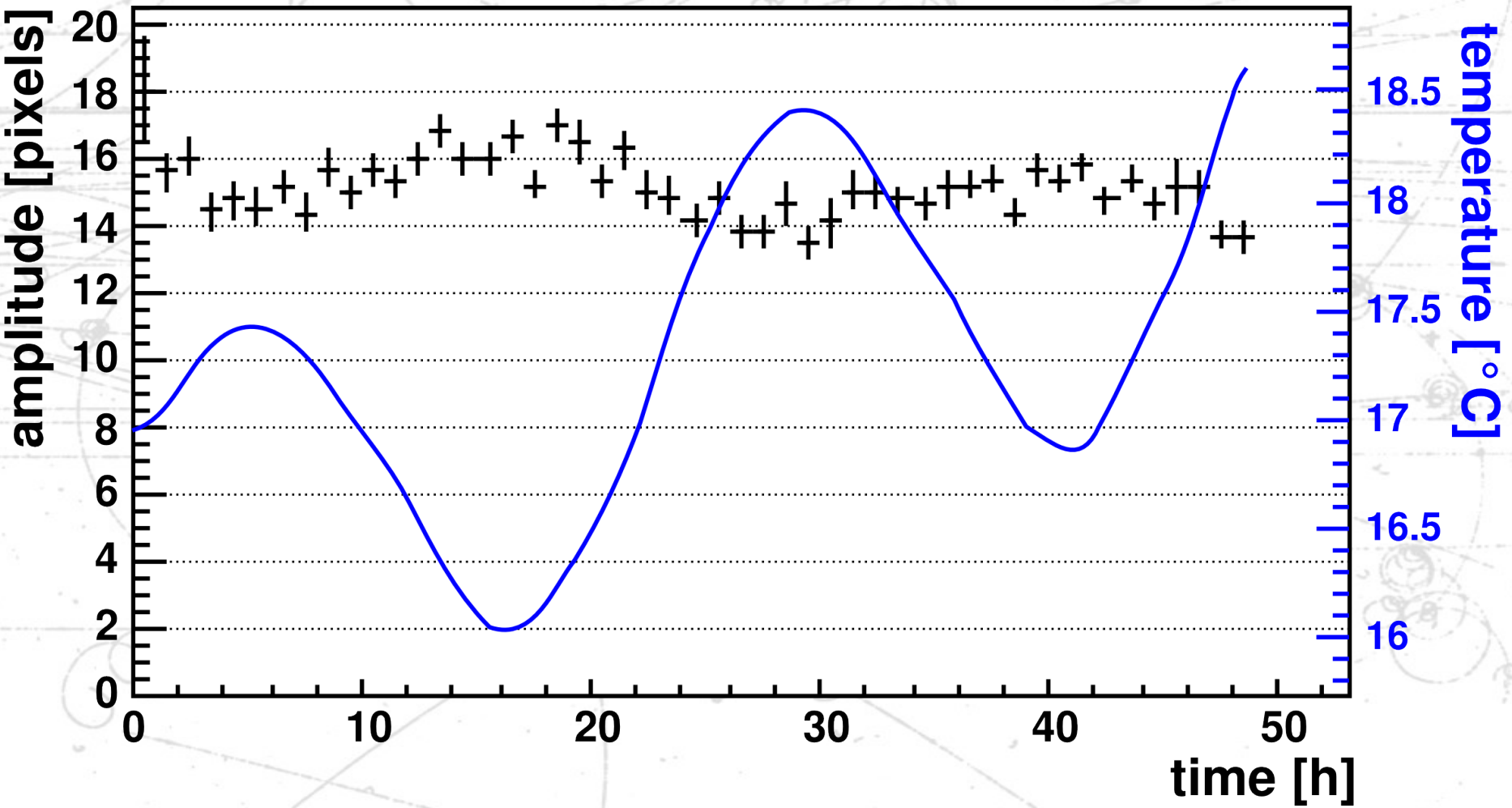
(central region => complete cluster amplitude contained)



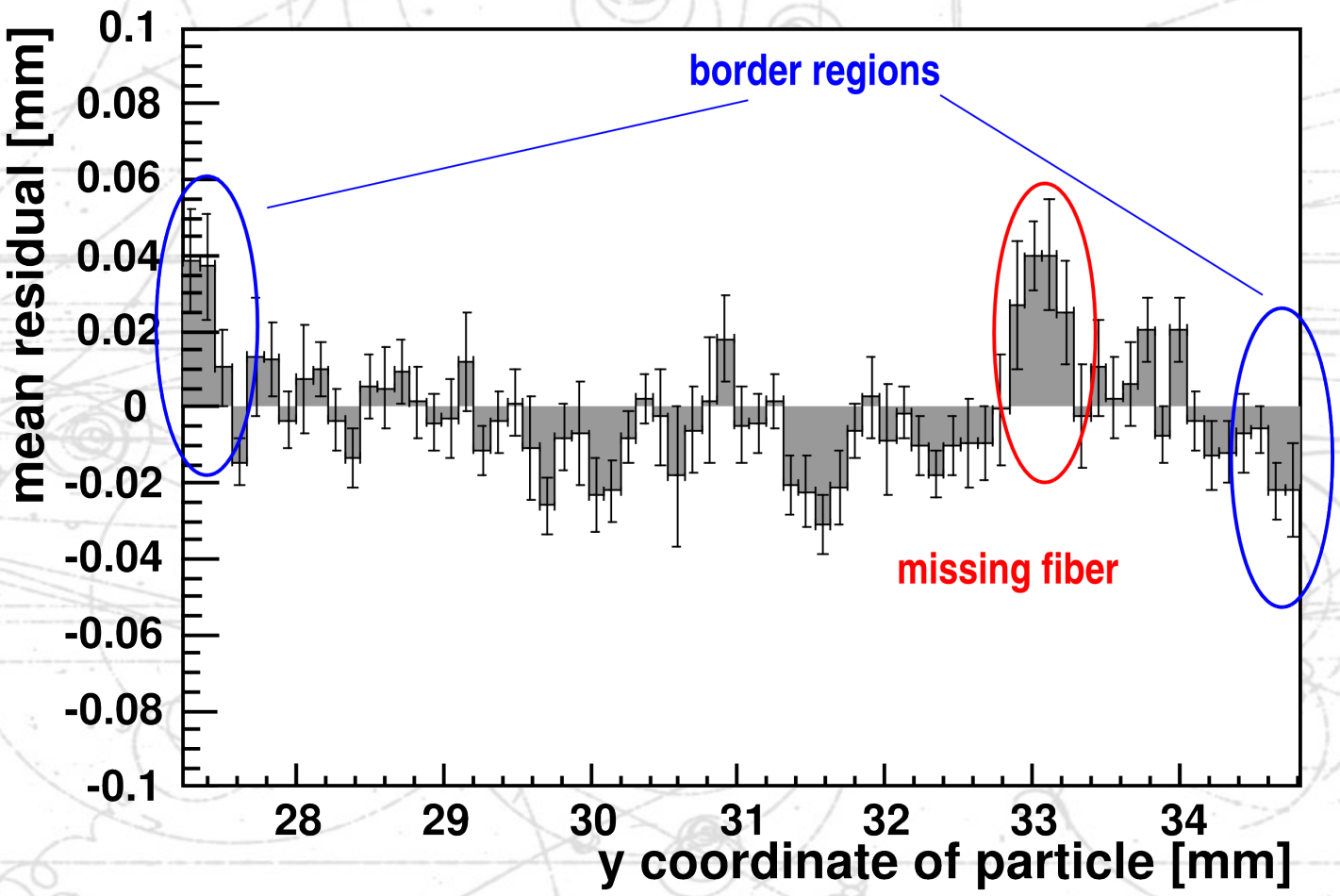
Mean Cluster Amplitude

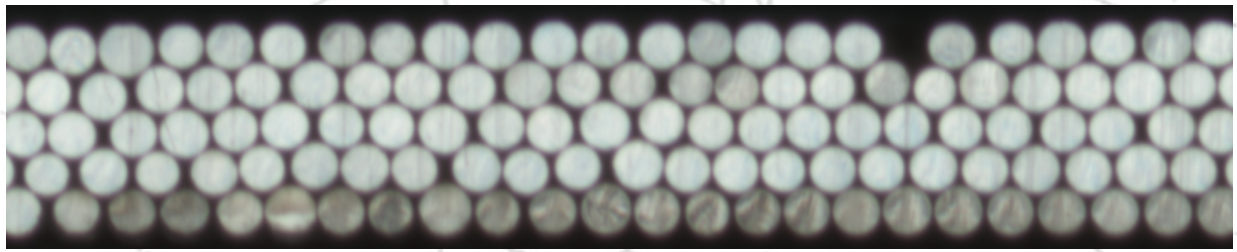


Mean Cluster Amplitude

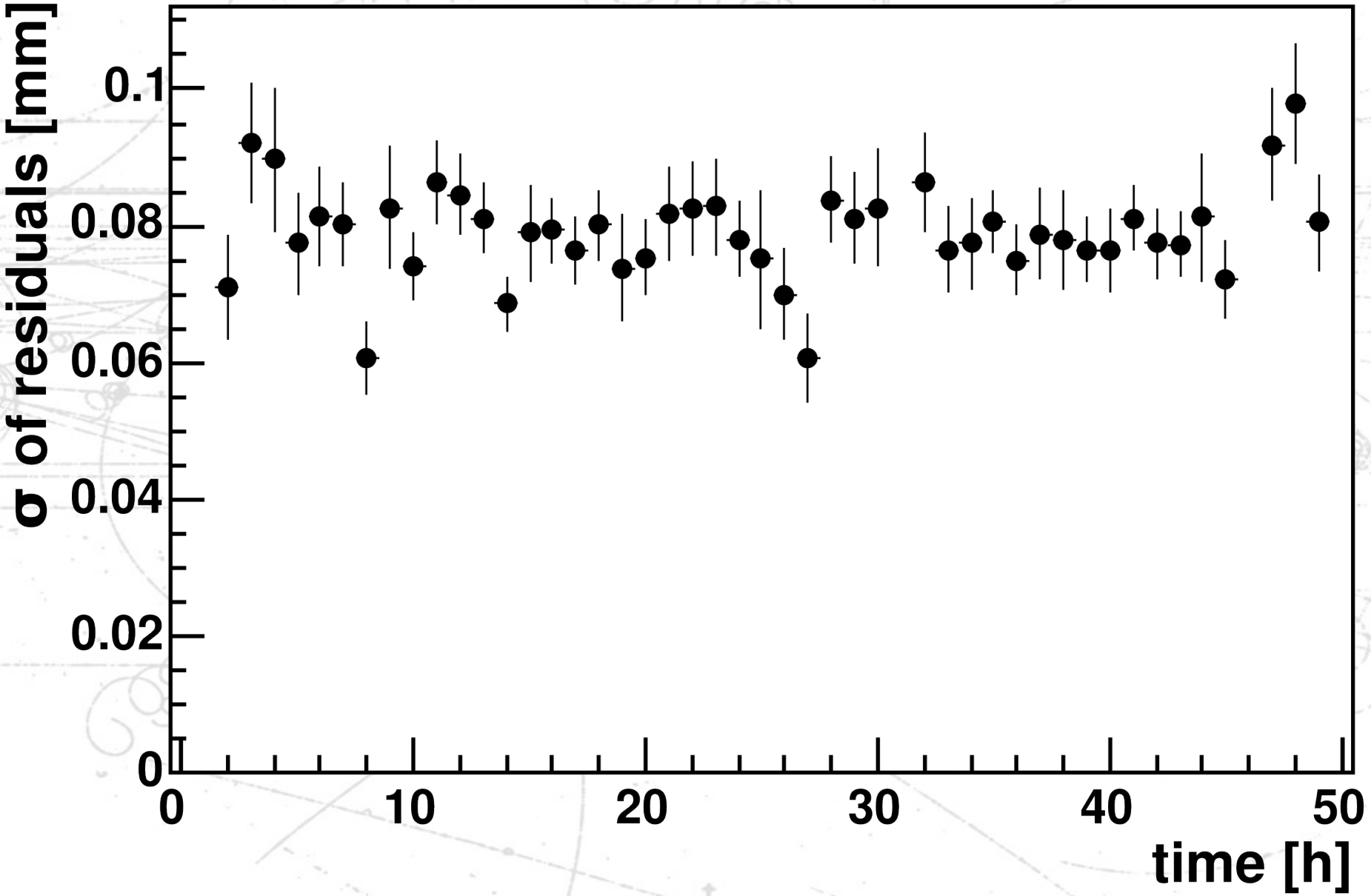


Defects In Prototype

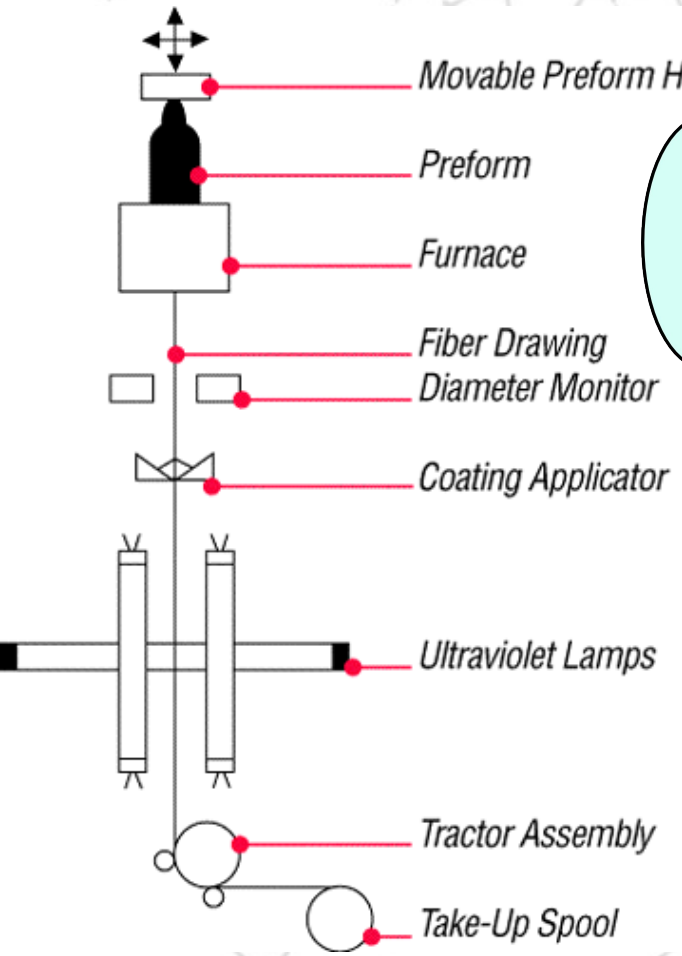




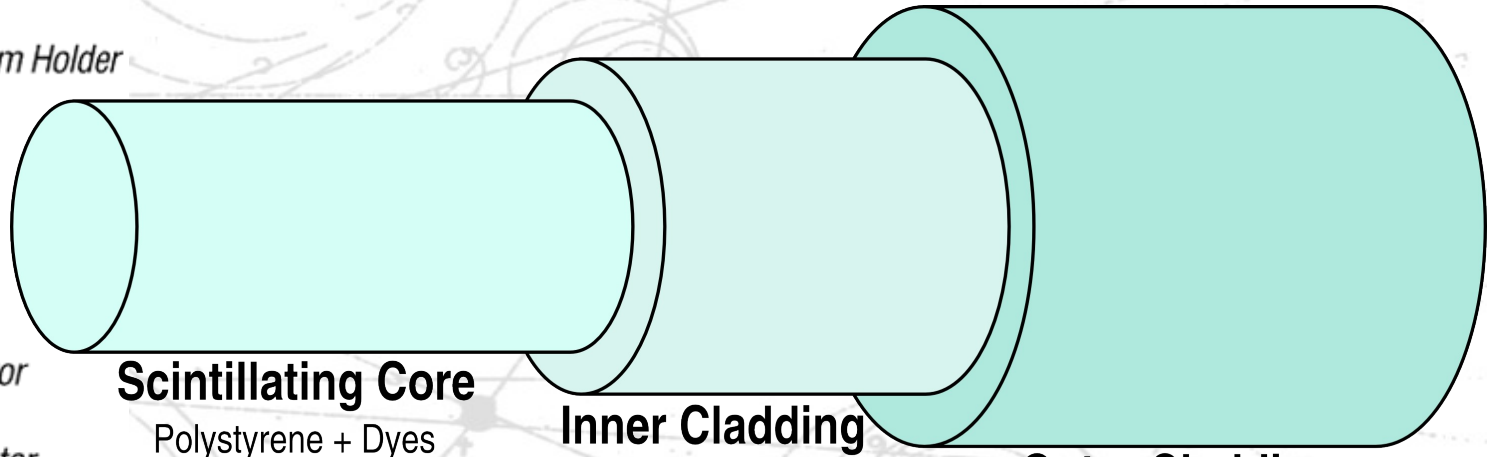
Track Residuals Over Time



Scintillating Fibers



www.corningfiber.com



Scintillating Core
Polystyrene + Dyes
n = 1.59
thickness ~ 230μm

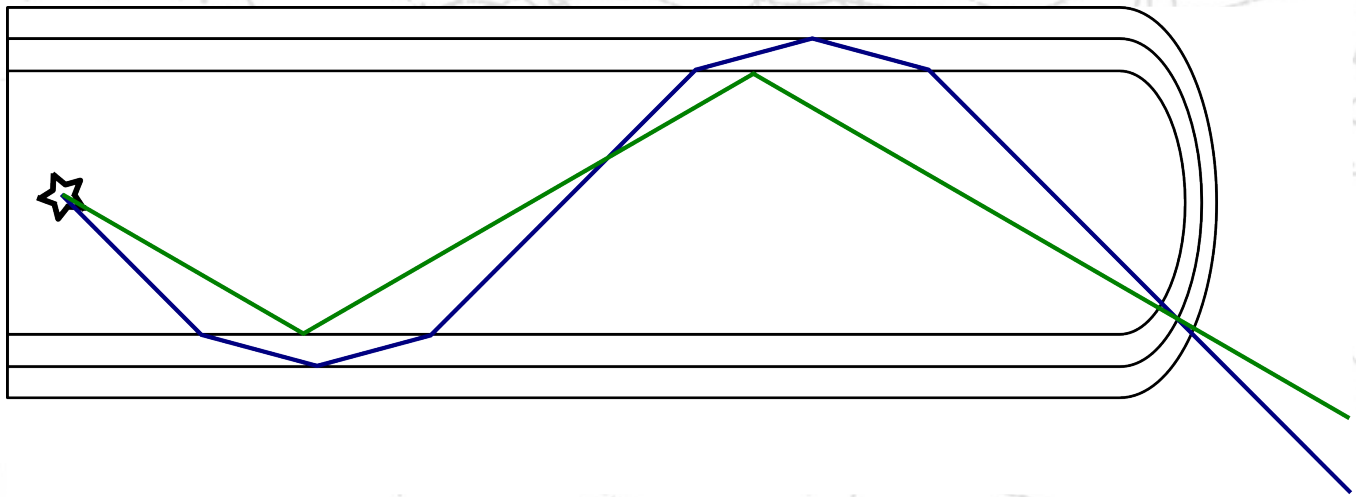
Inner Cladding
PMMA
n = 1.49
thickness ~ 10μm

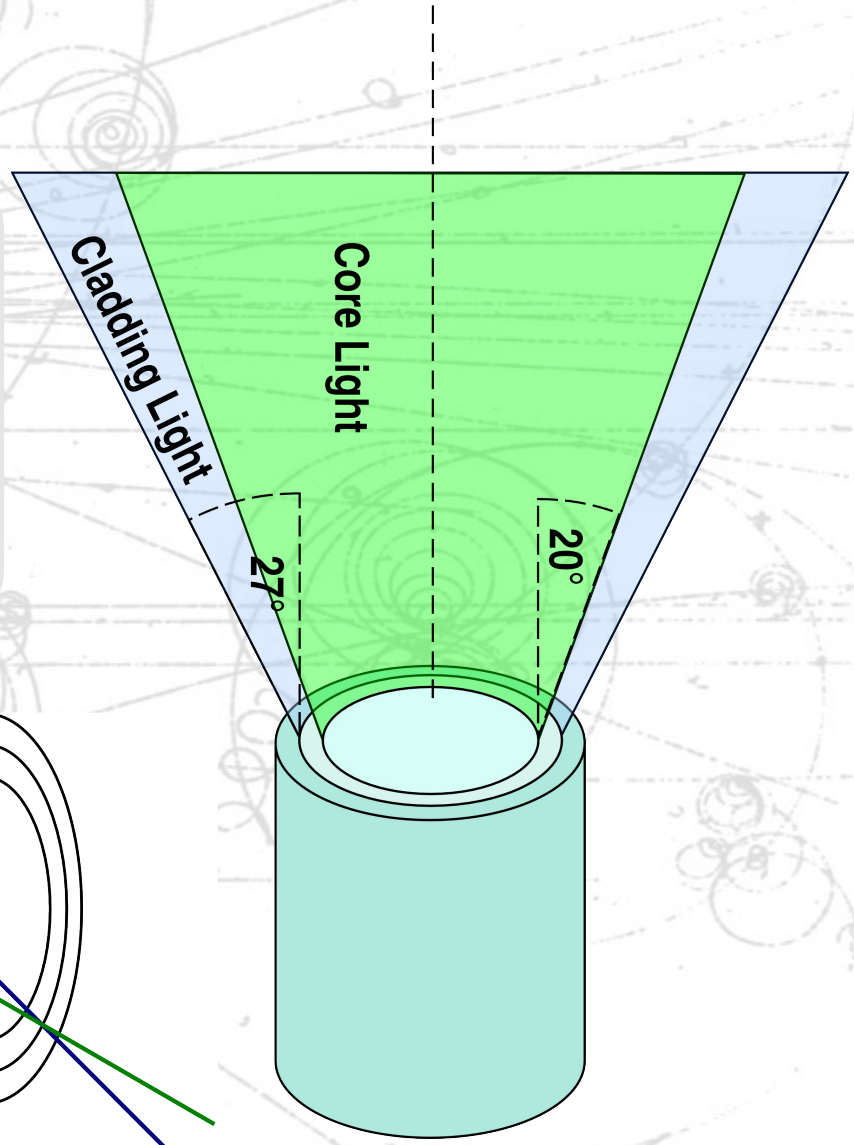
Outer Cladding
Fluorinated PMMA
n = 1.42
thickness ~ 10μm

- *Fibers are produced in drawing process*
  - **good diameter control**
  - **not so good control over concentricity of claddings**
  - **short attenuation length for cladding light**

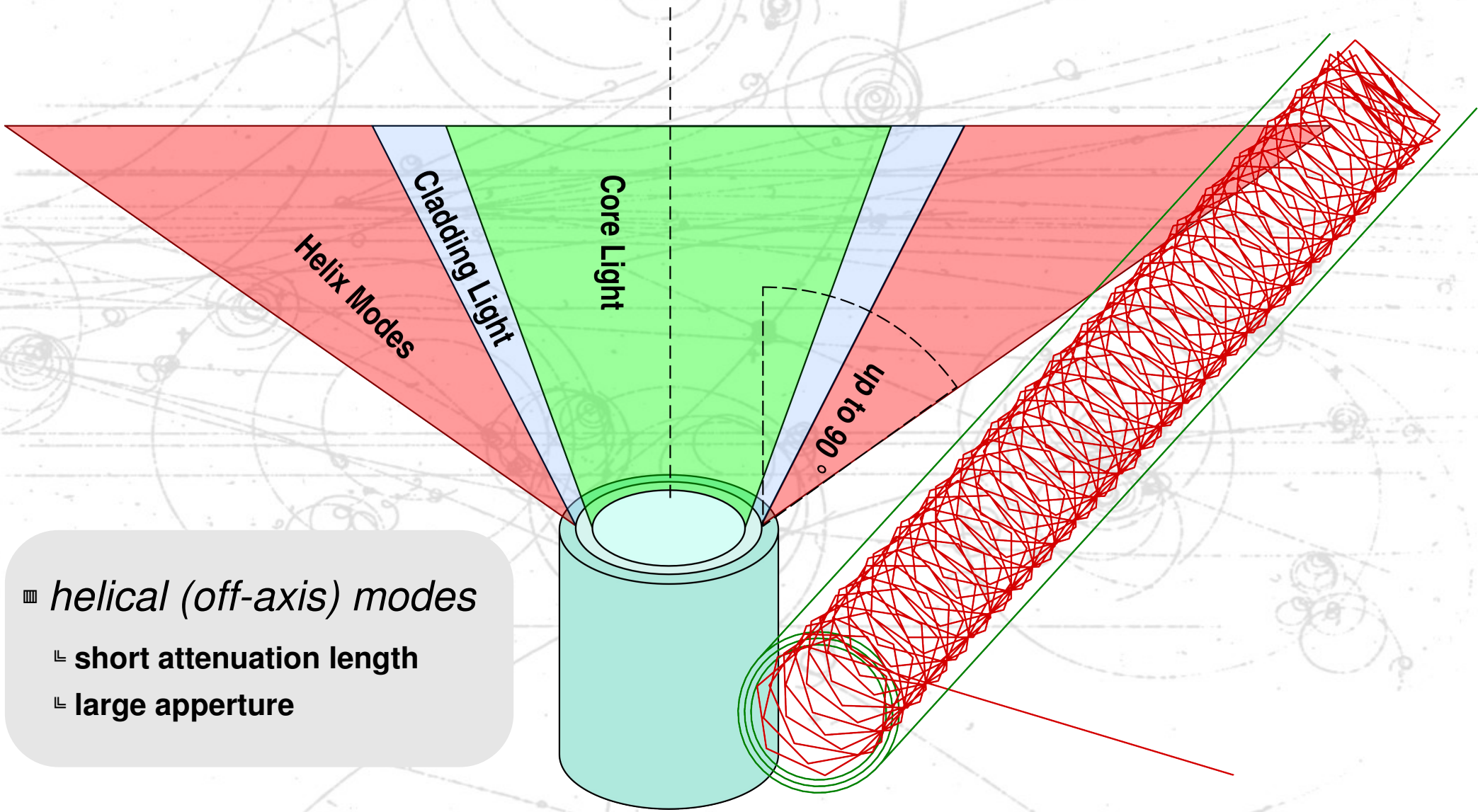
Light Collection In Fibers

- *light trapping by total reflection*
  - **light inside fiber core has long attenuation length (several meters)**
  - **light inside cladding has short attenuation length due to poorer quality of cladding surface**



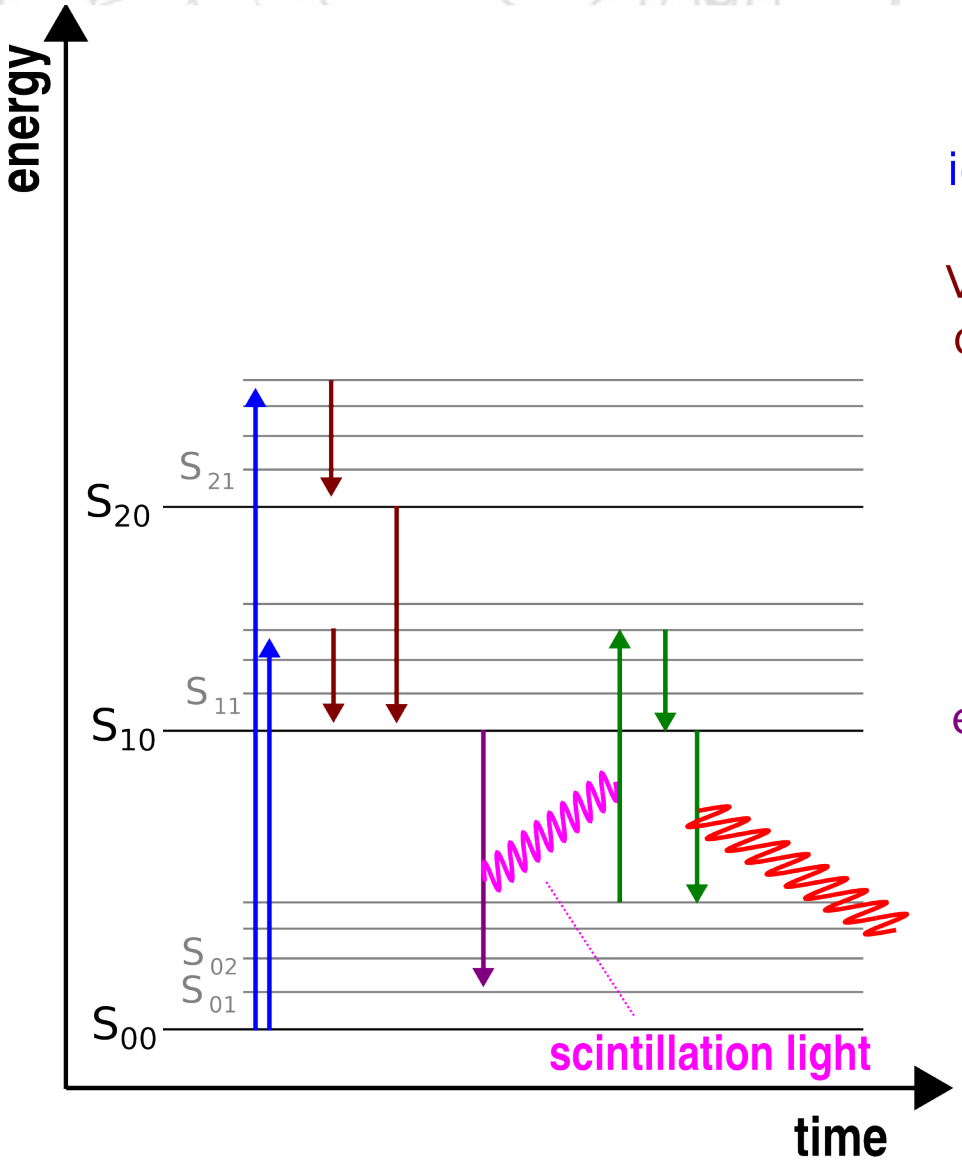


Helical Modes



- *helical (off-axis) modes*
  - **short attenuation length**
  - **large apperture**

Self-Excitation In Scintillators



Excitation by ionizing particle

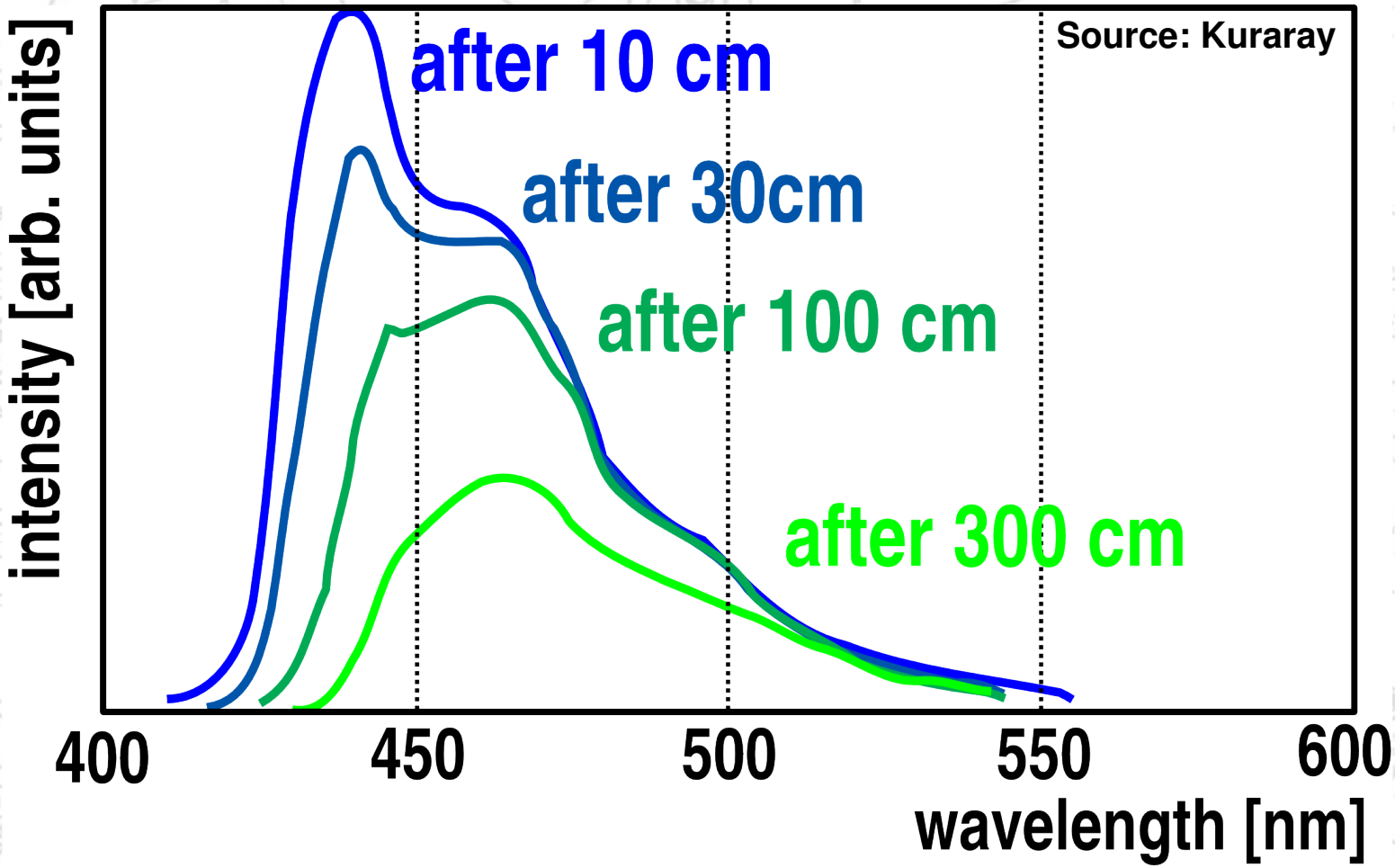
Vibrational energy dissipates quickly via phonons

Degradation to S_{10}

S_{10} decays under emission of photon

possible reabsorbtion of scintillation light and reemission

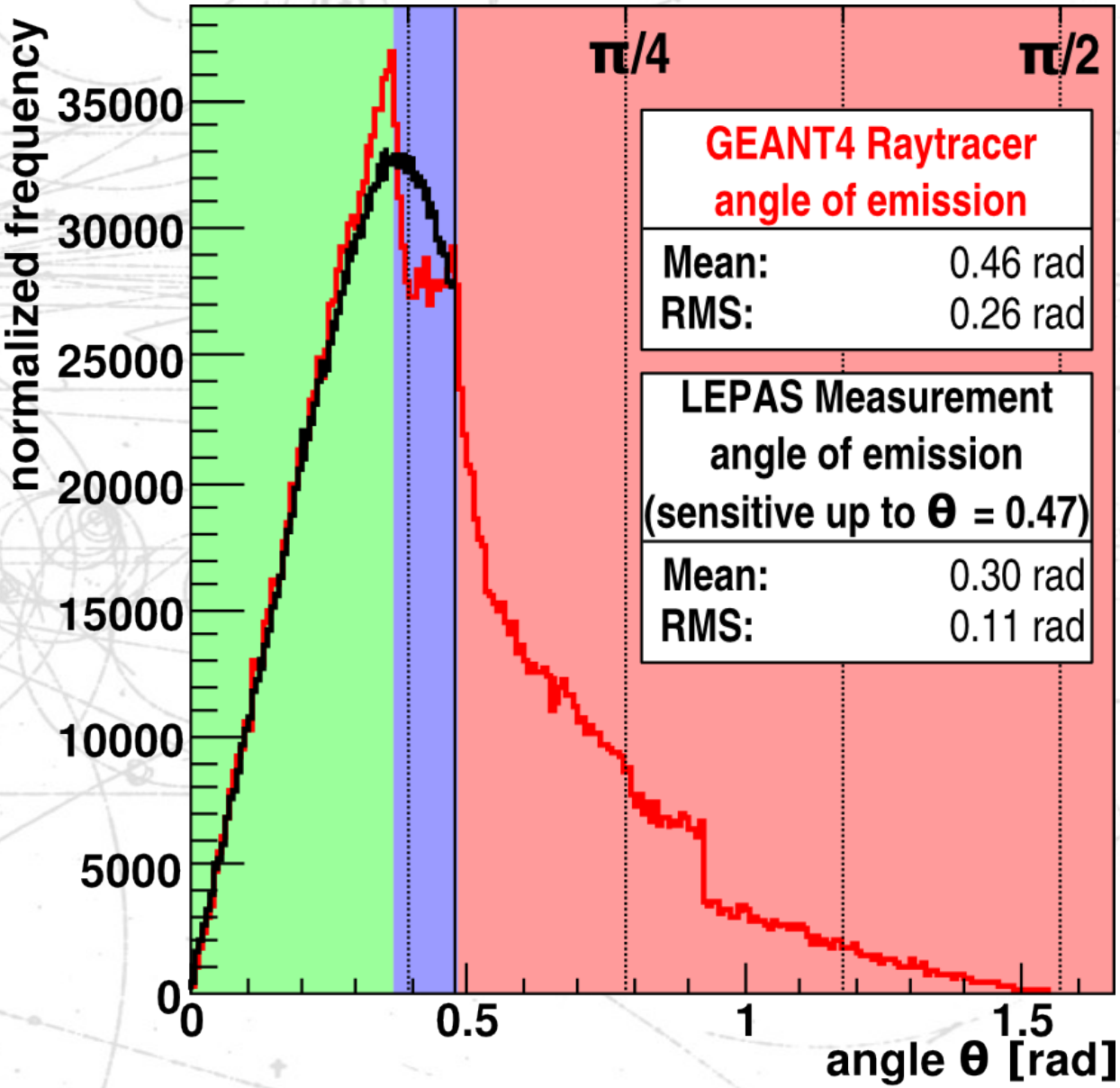
SCSF-81M Wavelength Shift



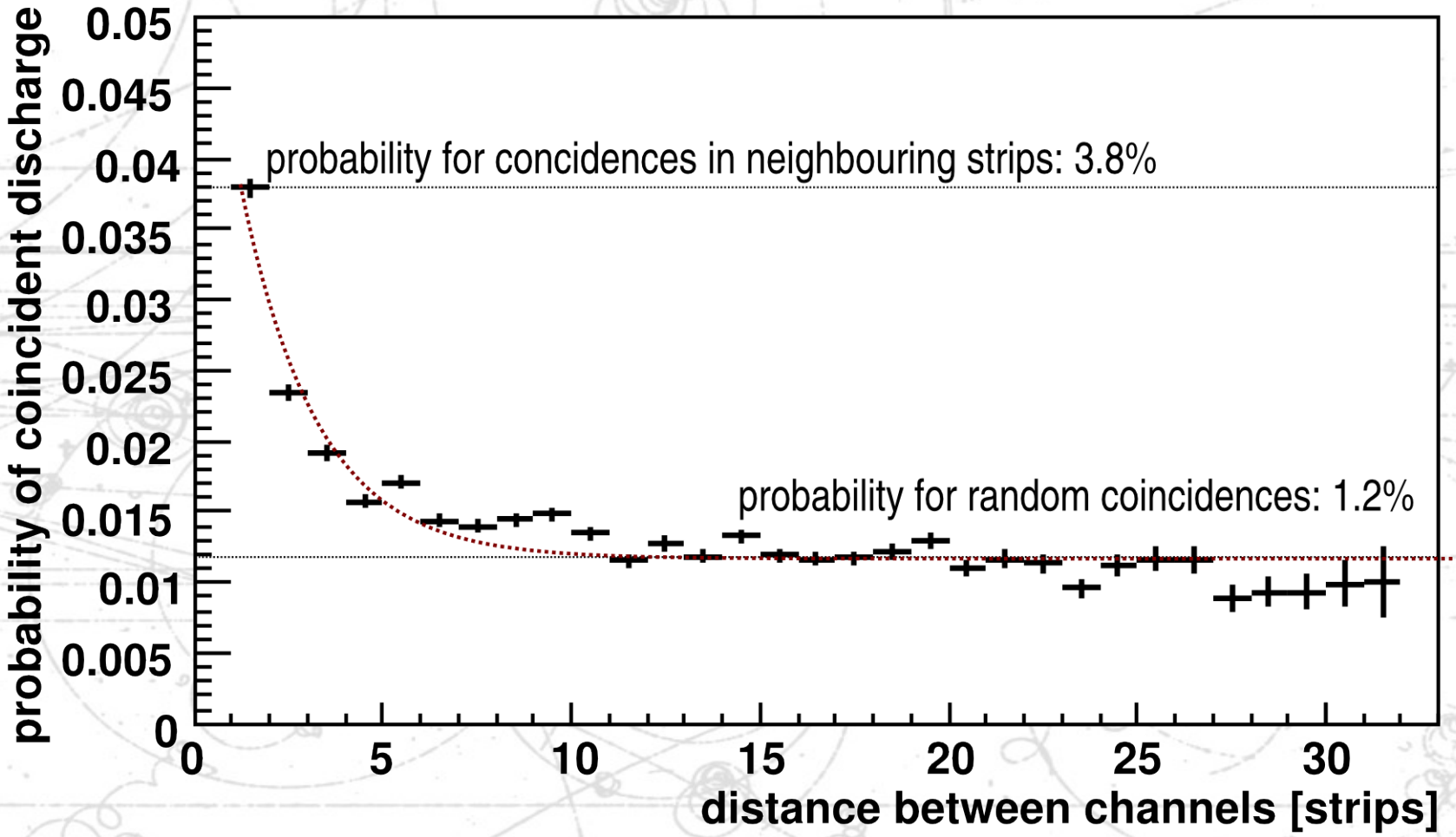
- *effect of self-excitation in Kuraray SCSF-81M fibers*

Angle Of Emission From Fiber

- *lost core light is constantly exciting cladding modes and helix modes*

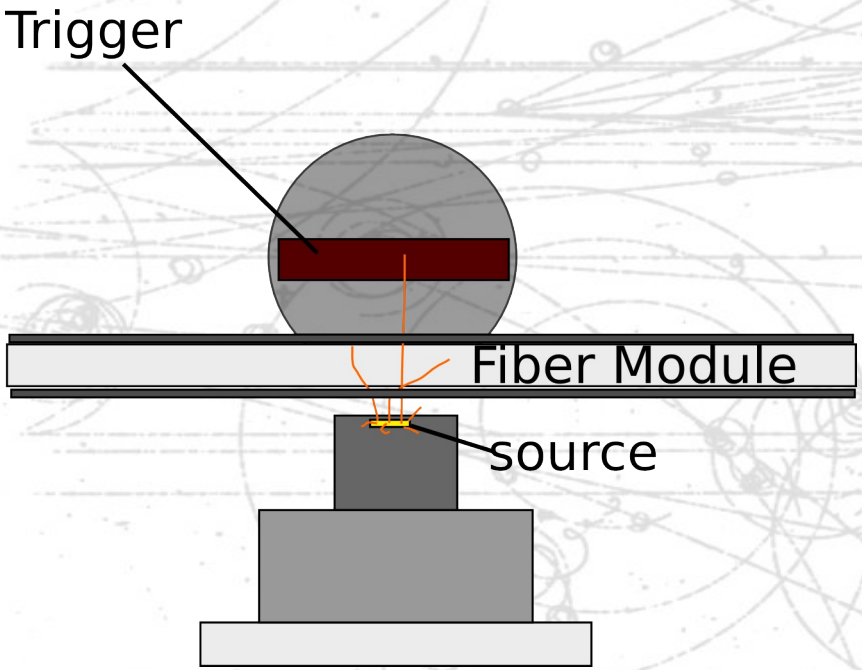


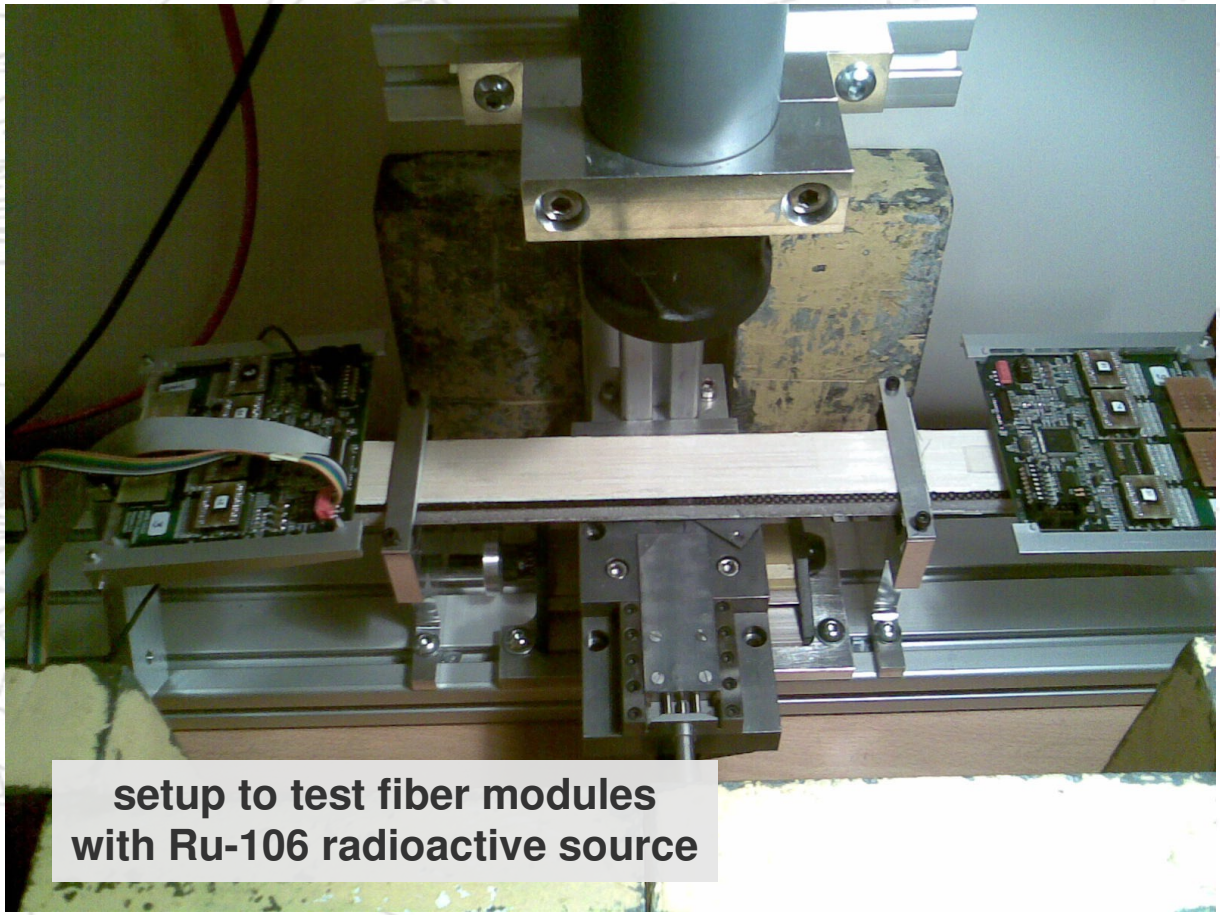
Crosstalk During Beamtest



- *35% crosstalk between pixels of the same strip*
- *2.6% crosstalk probability between neighbouring strips*

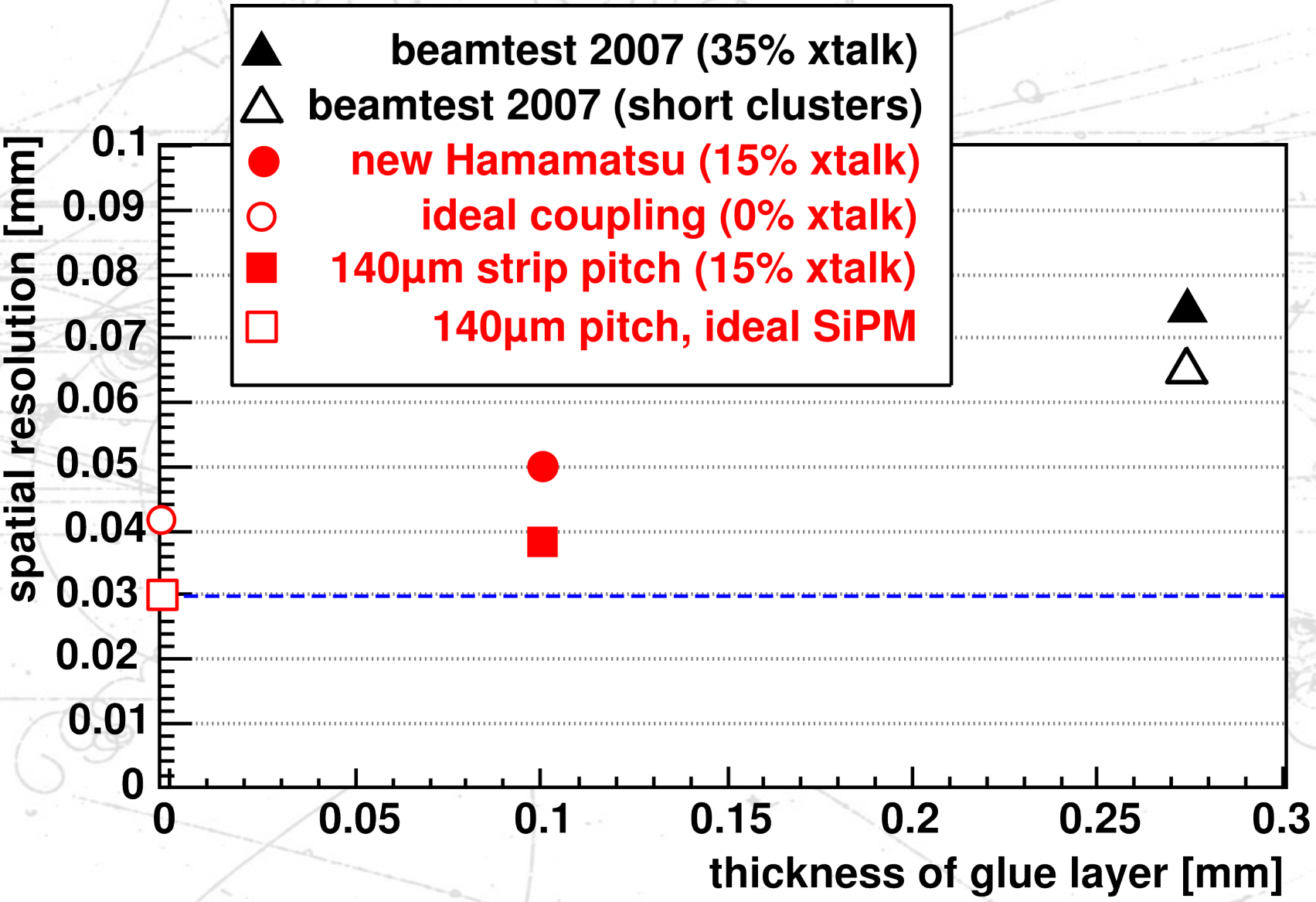
Module Test Setup



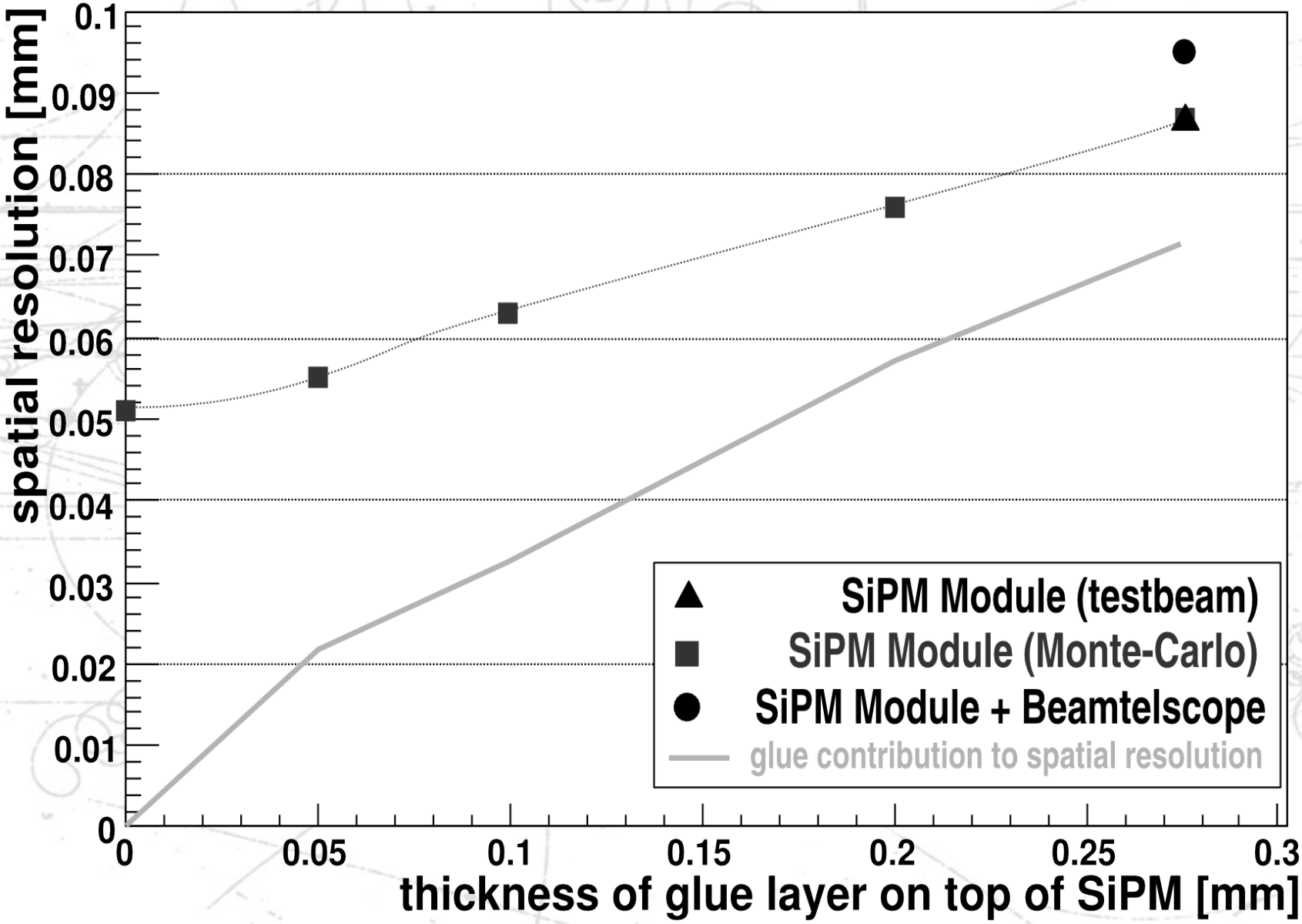
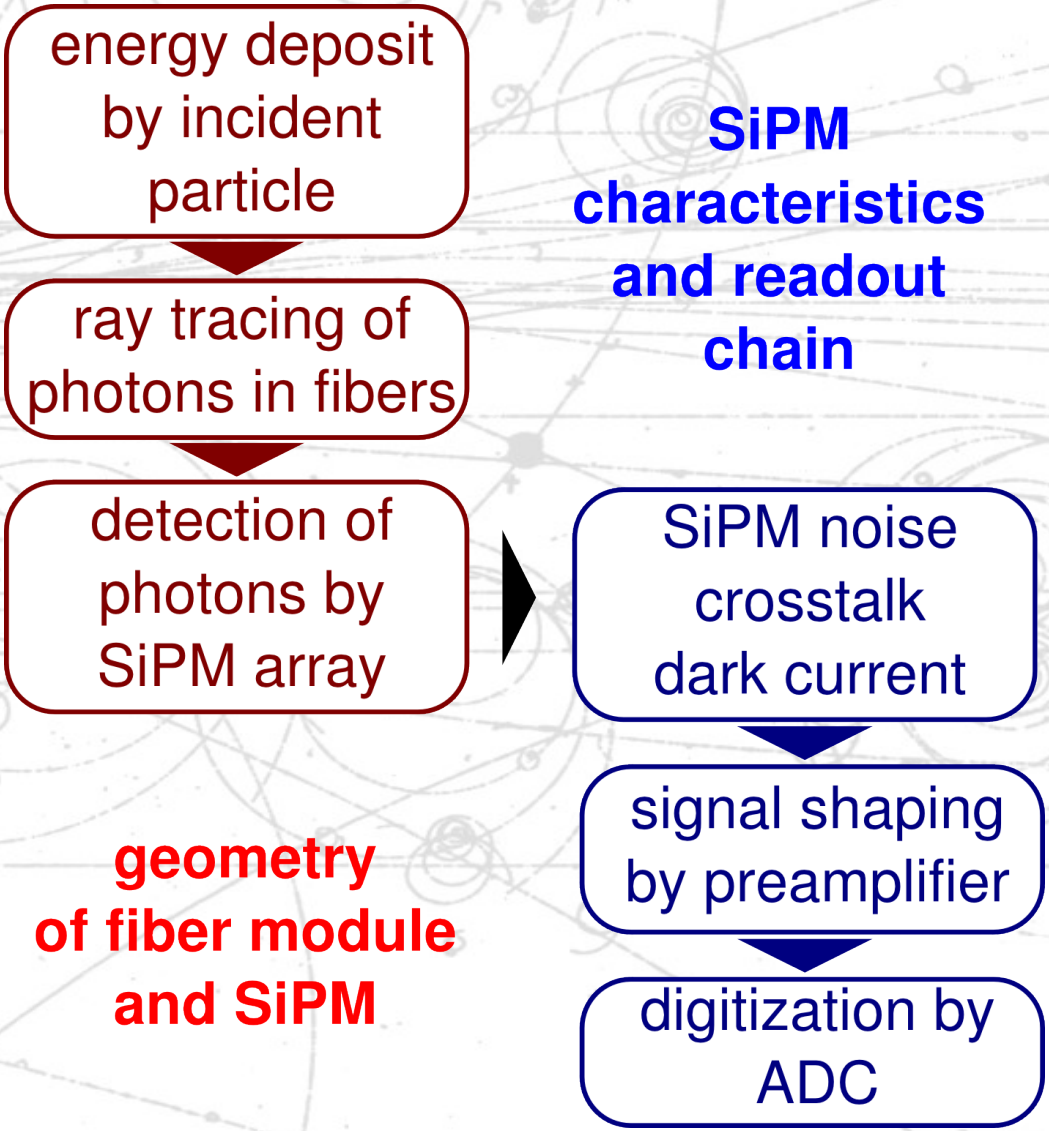


setup to test fiber modules
with Ru-106 radioactive source

Pushing The Limits



Expected Resolution (old)



GEANT4 based Simulation