GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung

RWTH AACHEN UNIVERSITY

# SciFi – A Scintillating Fibre Detektor for the LHCb Experiment

## Production, Quality Assurance, Beam Tests

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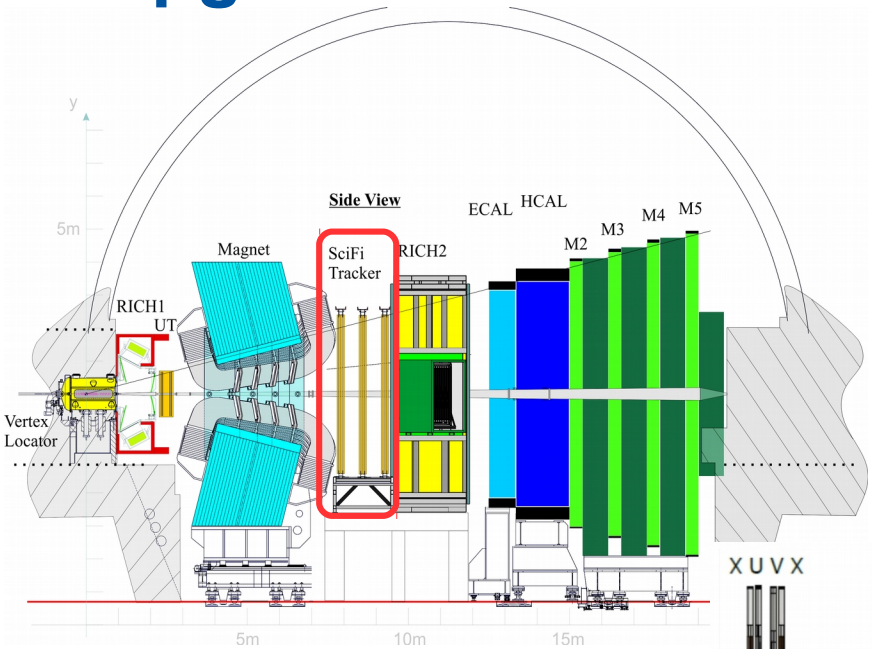
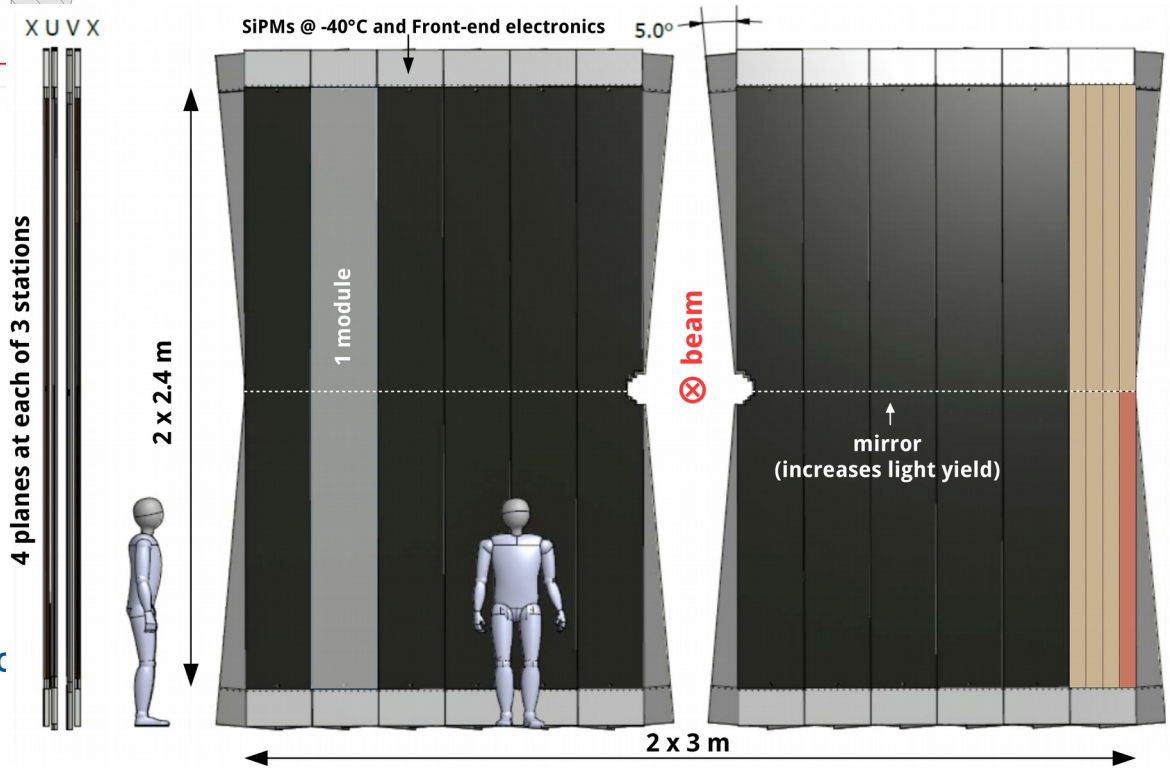
# Upgrade of LHC / LHCb

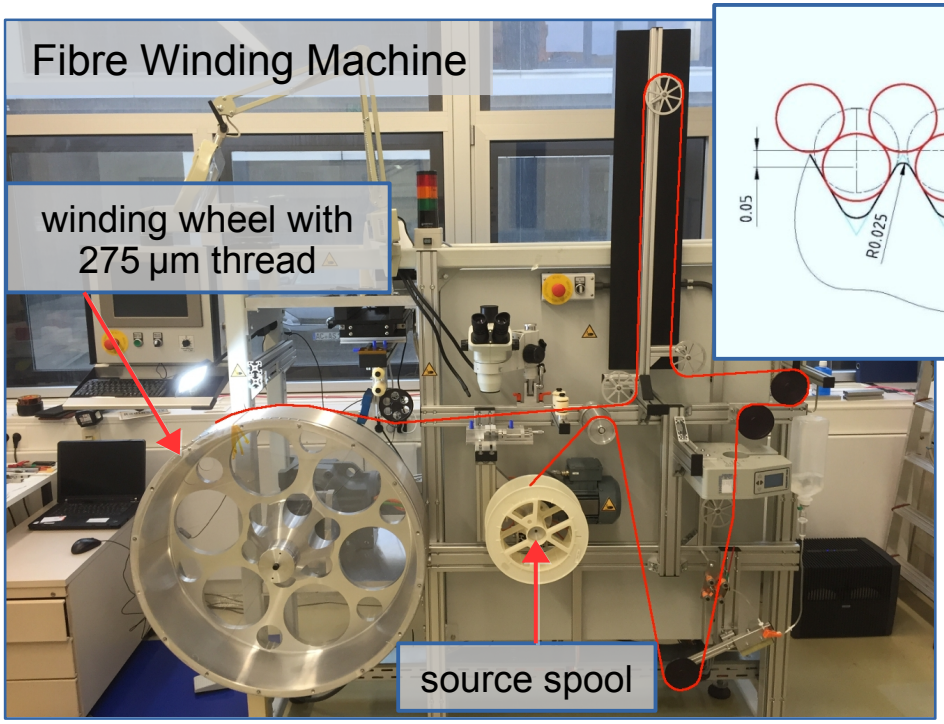


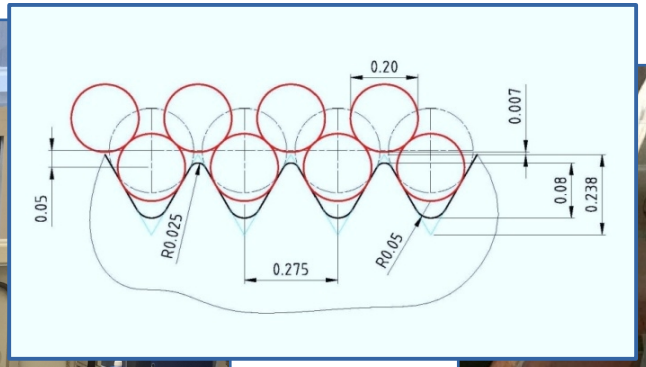

- Active material: **double-clad plastic scintillating fibres**, 2.4m long
- Mats of 6 fibre layers
- **1024 mats** (+spares) in total, over **8000km of fibres**
- Readout: cooled SiPMs arrays (single photon counters)

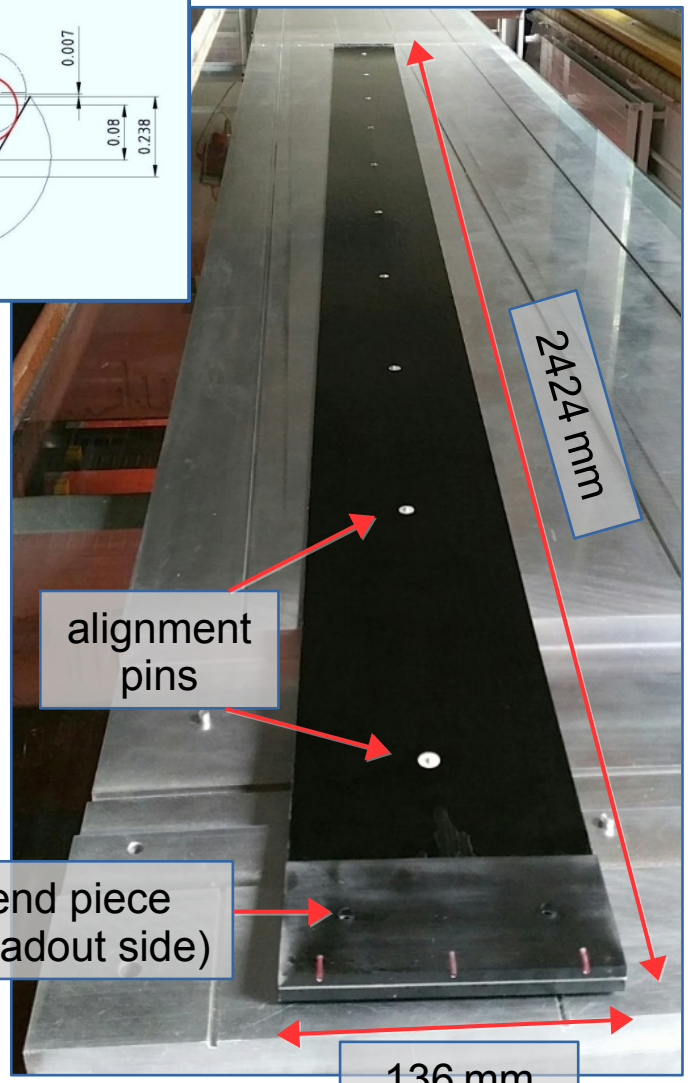
- Replacing downstream tracker with **SciFi** Tracker
  - → **Sci**ntillating **Fi**bres (Ø250 µm) with silicon photomultiplier (SiPM) readout
  - → **<100 µm** spatial resolution
  - → 320 m² area



# Fibre Mat Production



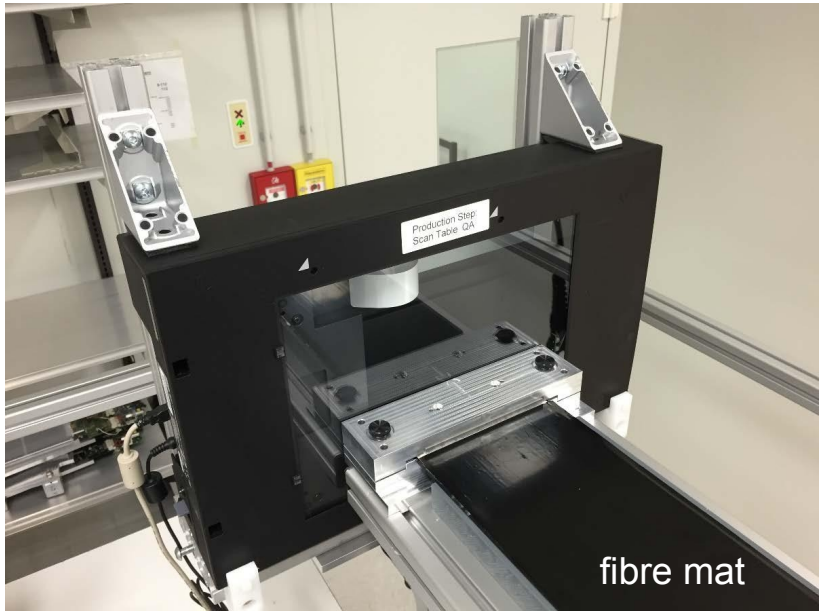



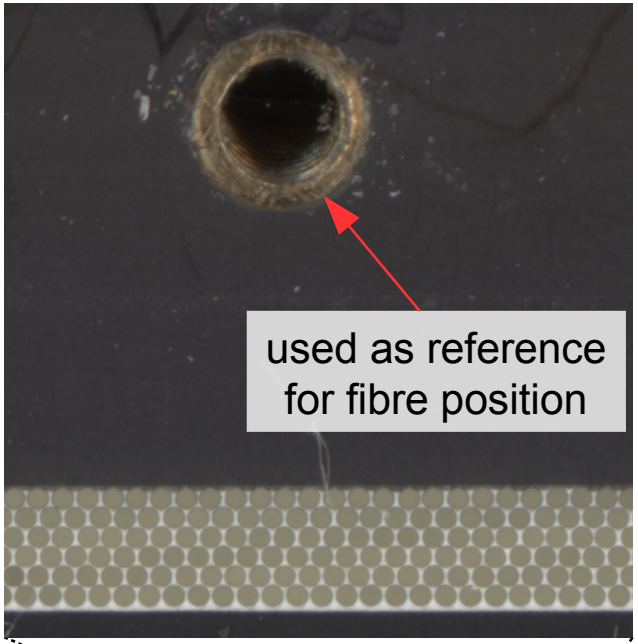



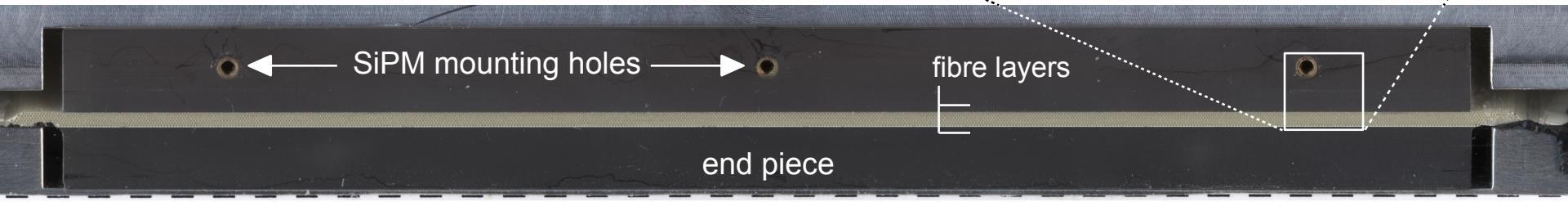

- Black foil casting for stability, protection, and light tightness
- Plastic end pieces for attaching readout and mirror
- End faces cut with diamond tool for optimal coupling to readout / mirror

# Quality Assurance
## Optical Survey

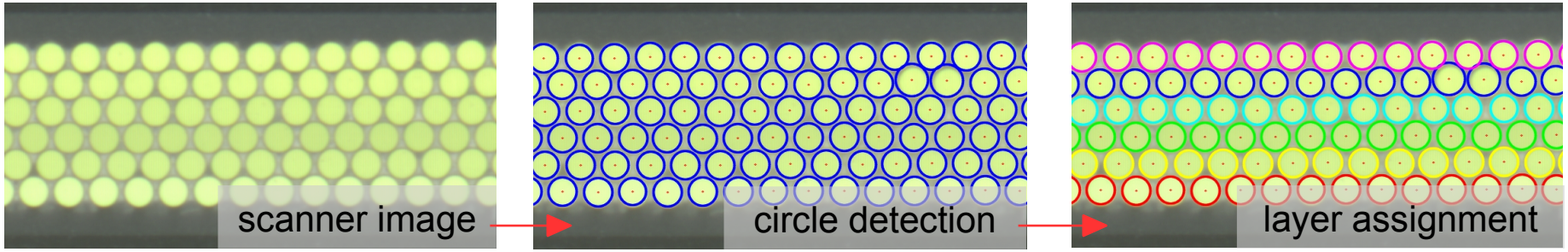
- Mats scanned with **2.5 µm pixel pitch**
- Circle detection algorithm finds fibre positions and assigns layers
- Surveys irregularities, missing fibres
- Shows cracks and overall layer shape



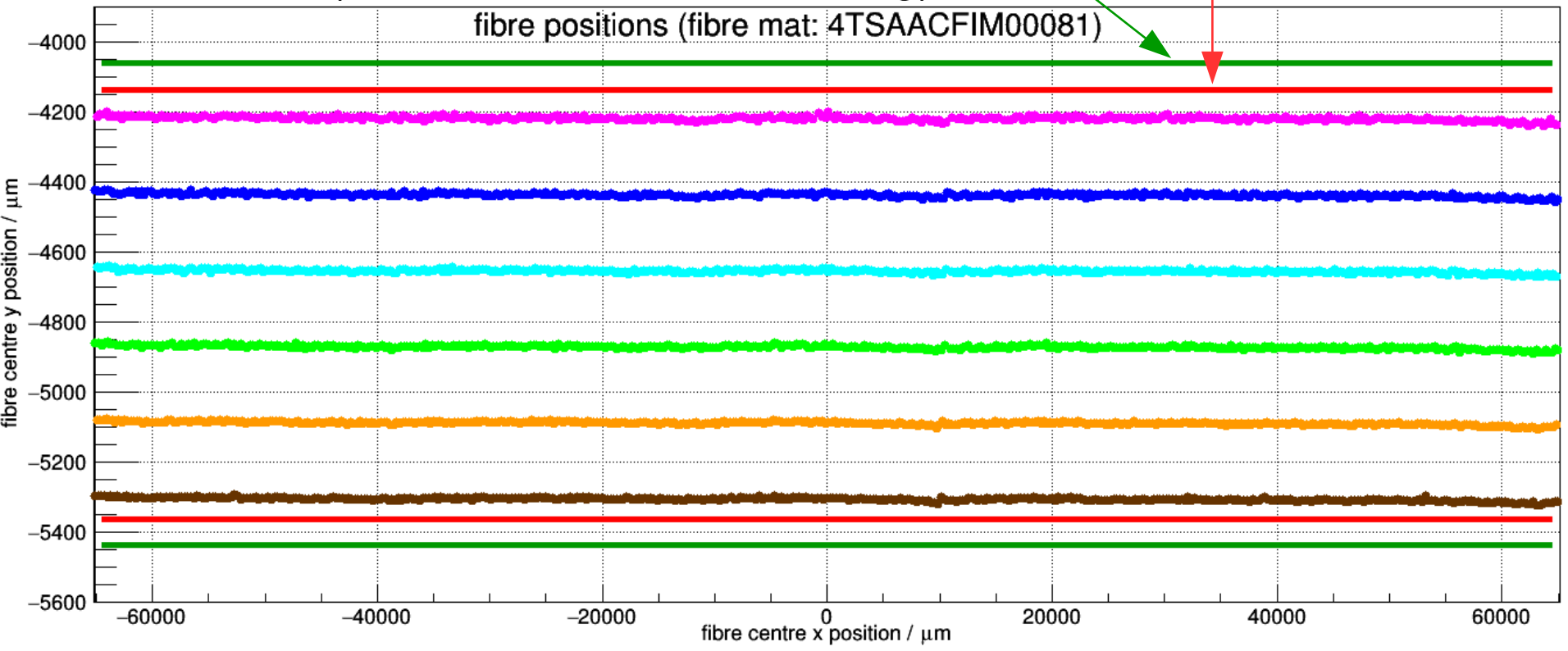



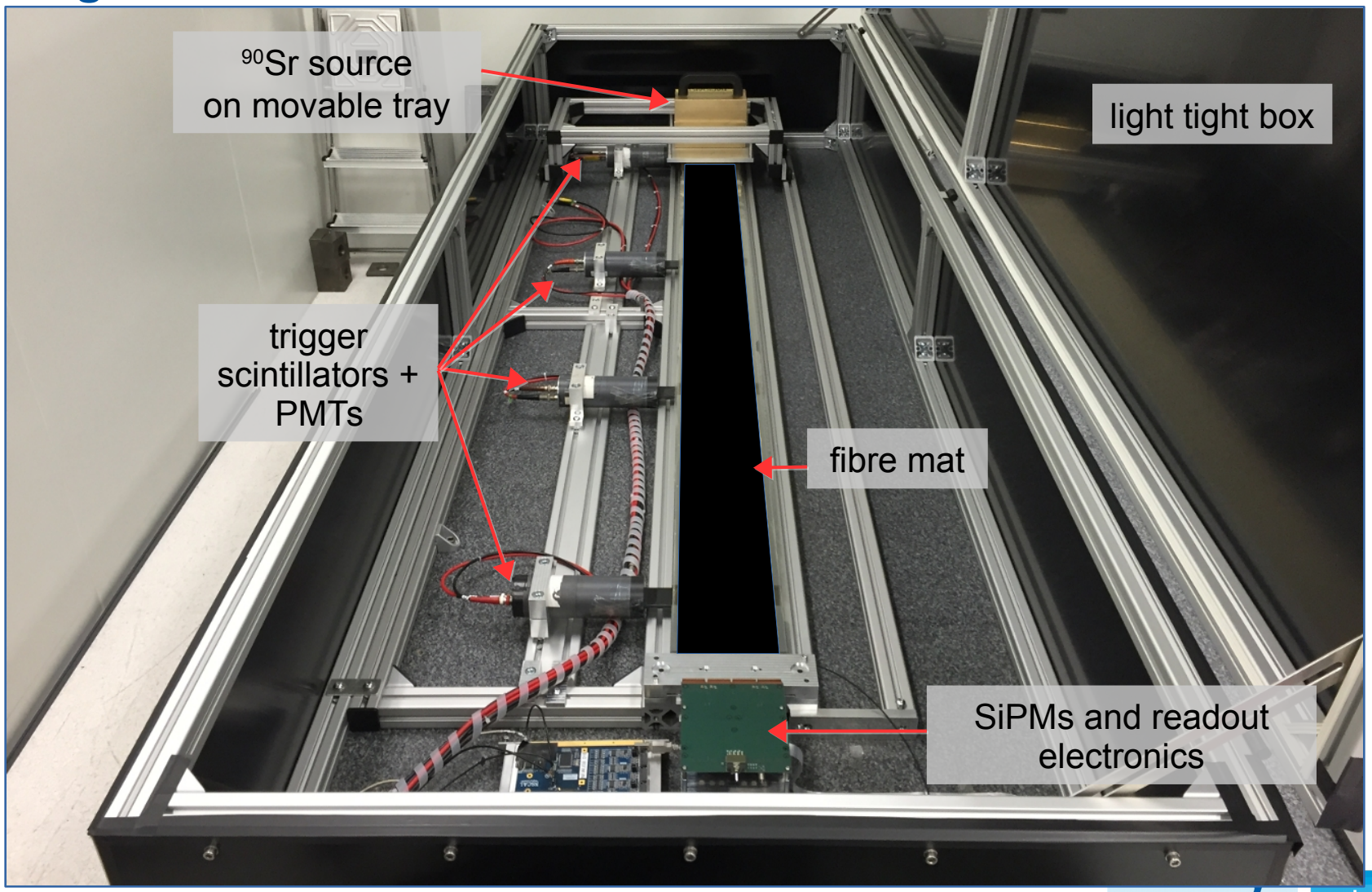
# Quality Assurance
## Optical Survey




- Fibres have to stay inside **active area of SiPM** with **75 µm to spare** on each side (tolerances for SiPM mounting)

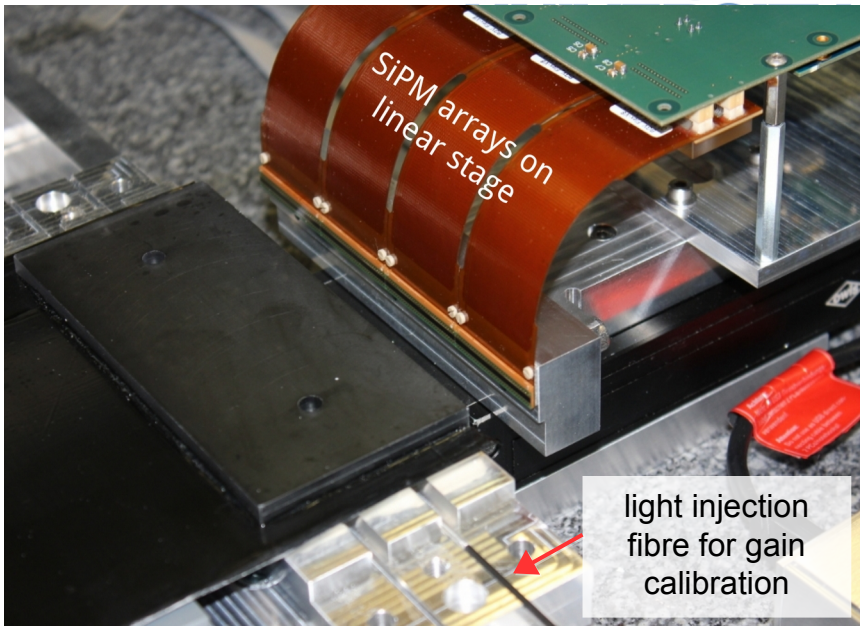


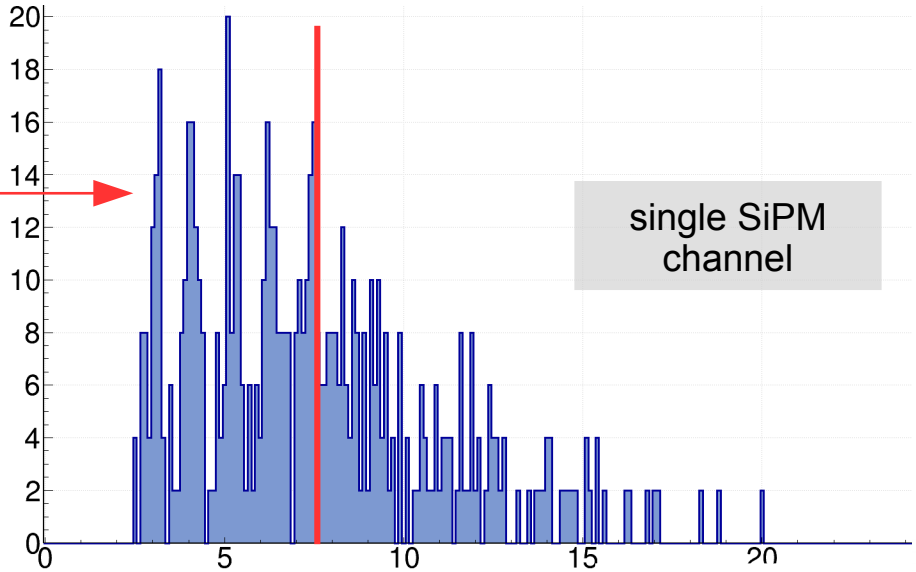
# Quality Assurance
## Light Yield Measurement



# Quality Assurance
## Light Yield Measurement

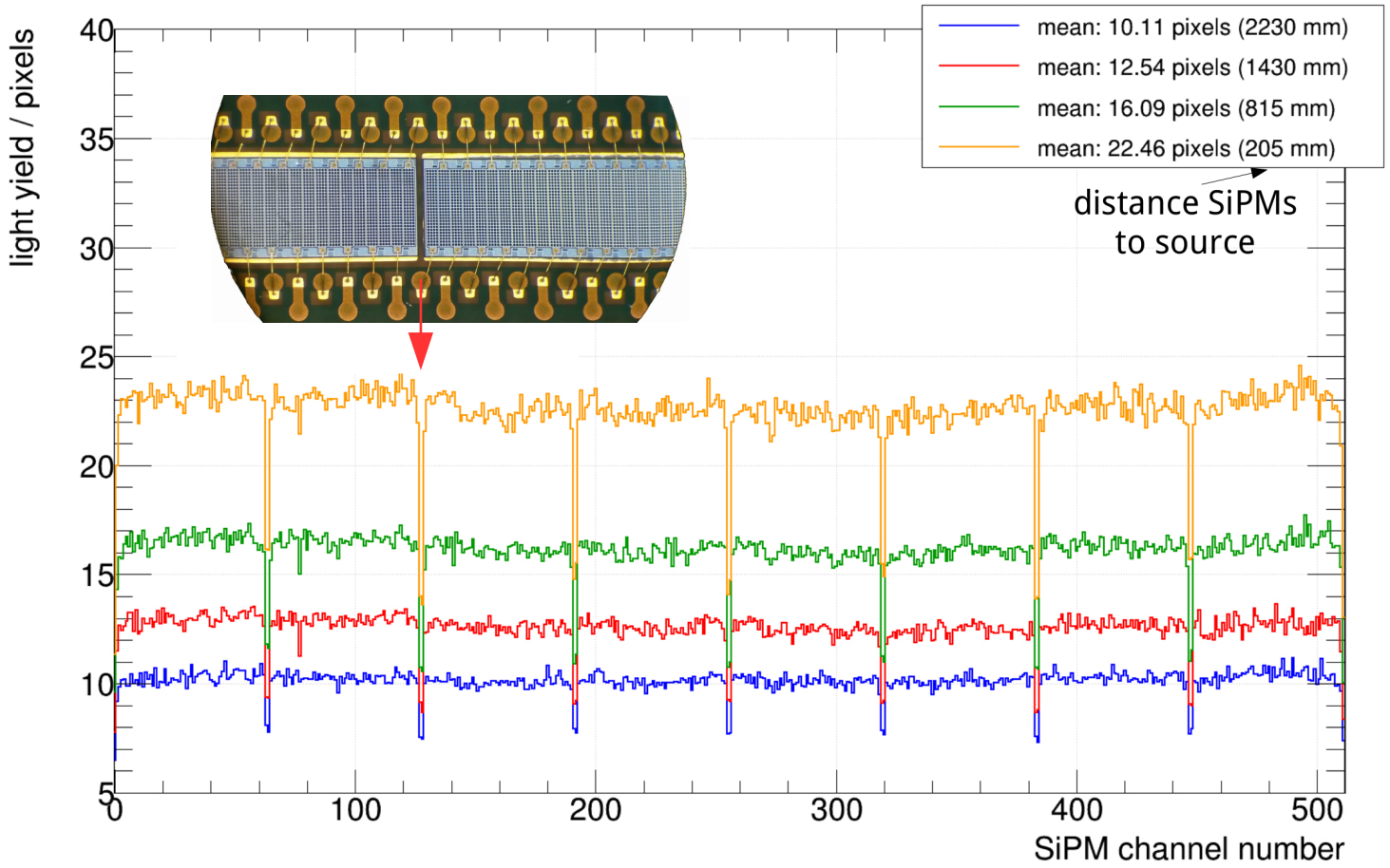
- **~2 MeV electrons** from $^{90}$Sr point source (**13 Mbq**) induces light in mat
- Provides light yield measurements at 4 **positions** of the source
- Read-out with 4 SiPM arrays
  - → 4x128 = 512 channels
  - → gain of each channel automatically determined before every measurement
- mean SiPM signal over 500k events = light yield (per channel)
- 4 measurement positions to identify damages inside mat



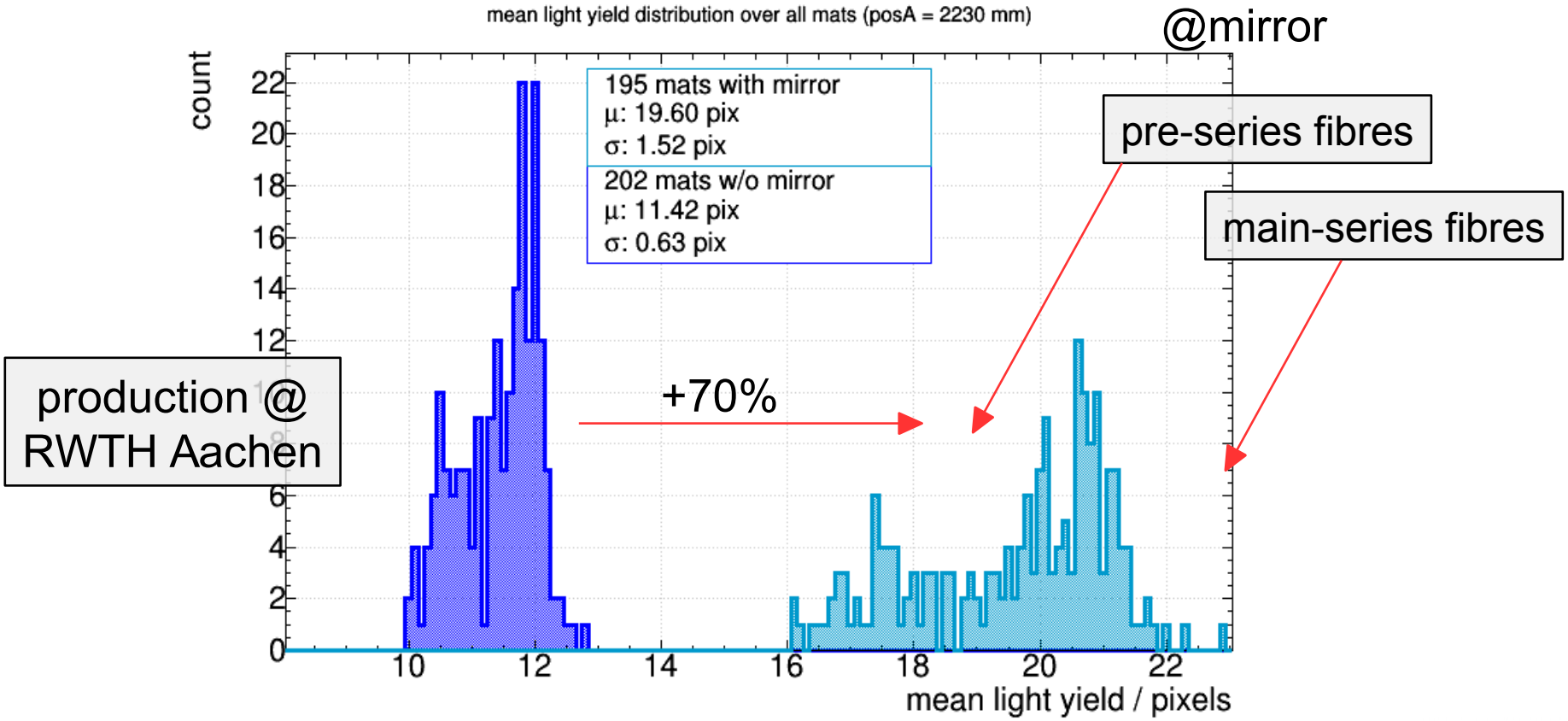
# Quality Assurance
## Light Yield Measurement

- Plot light yield for each channel → **light yield profiles**
- Cracks in the mats or other problems show up as slopes in the light yield profiles



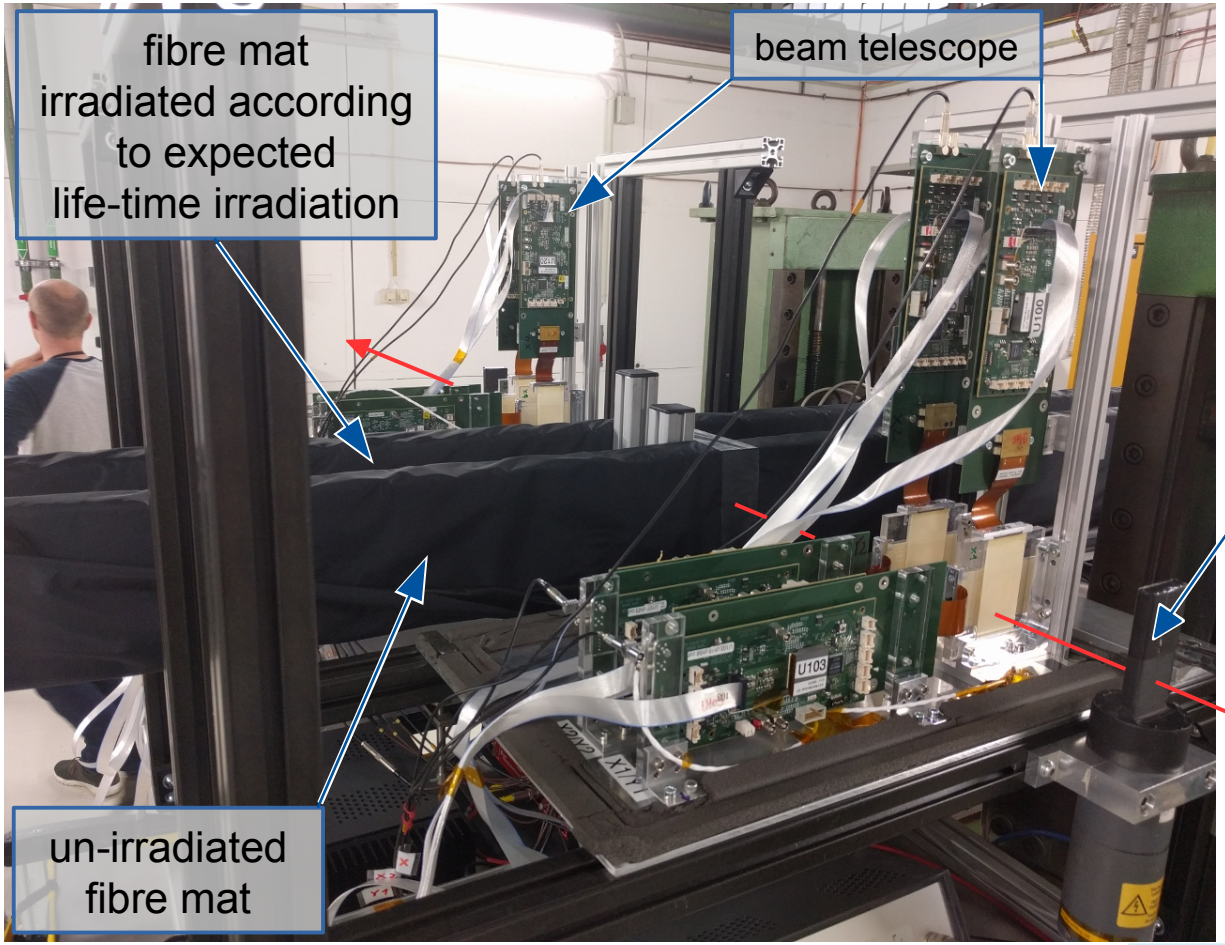
# Quality Assurance
## Light Yield Measurement

- Mats are measured with and without mirror to study mirror efficiency
- Statistics over all produced mats help classify each mat
- Mean light yield of **19.60 pixels** with mirror



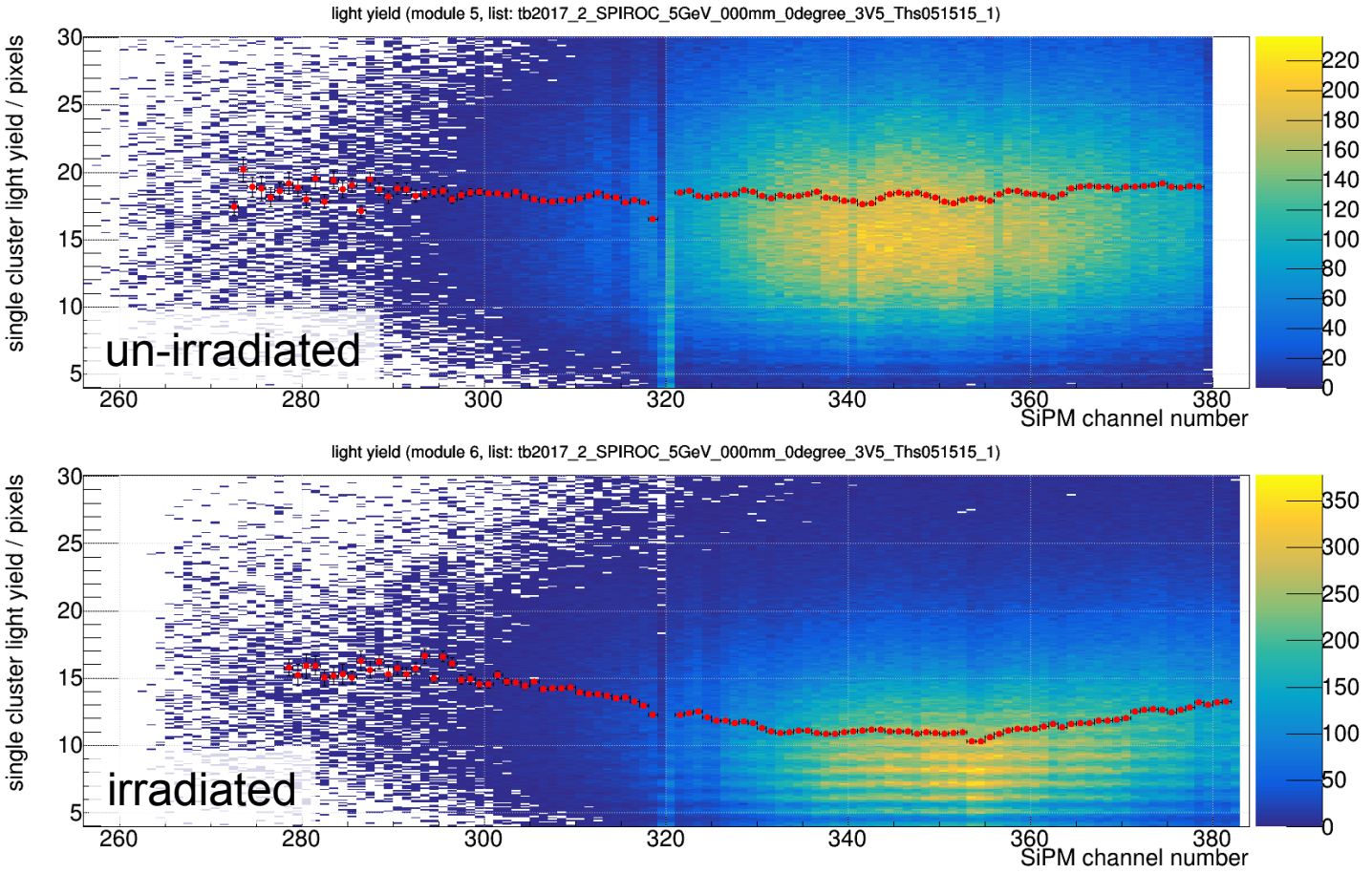
# Beam Tests

- Beam tests are conducted at CERN and DESY to study perfomance of fibre mats and read-out electronics (light yield, efficiency, resolution, irradiation studies...)



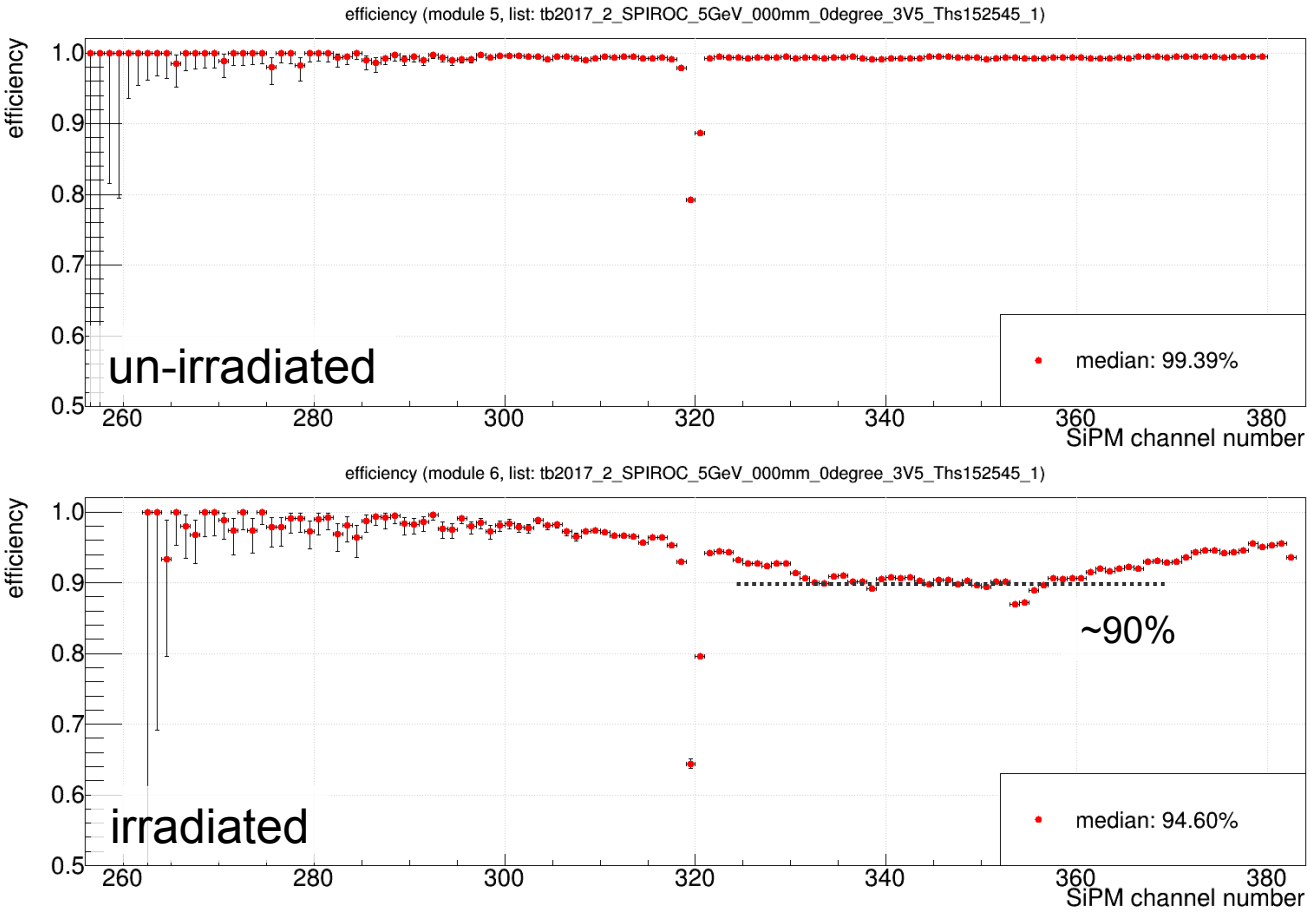
# Beam Tests
## Light Yield

- Measured at mirror
- SPIROC readout
- 1 GeV electron beam
- **~18.5 pixels** in un-irradiated mat, **~10 pixels** in most irradiated area
- ~40% light loss confirms irradiation simulations



# Beam Tests
## Single Hit Efficiency

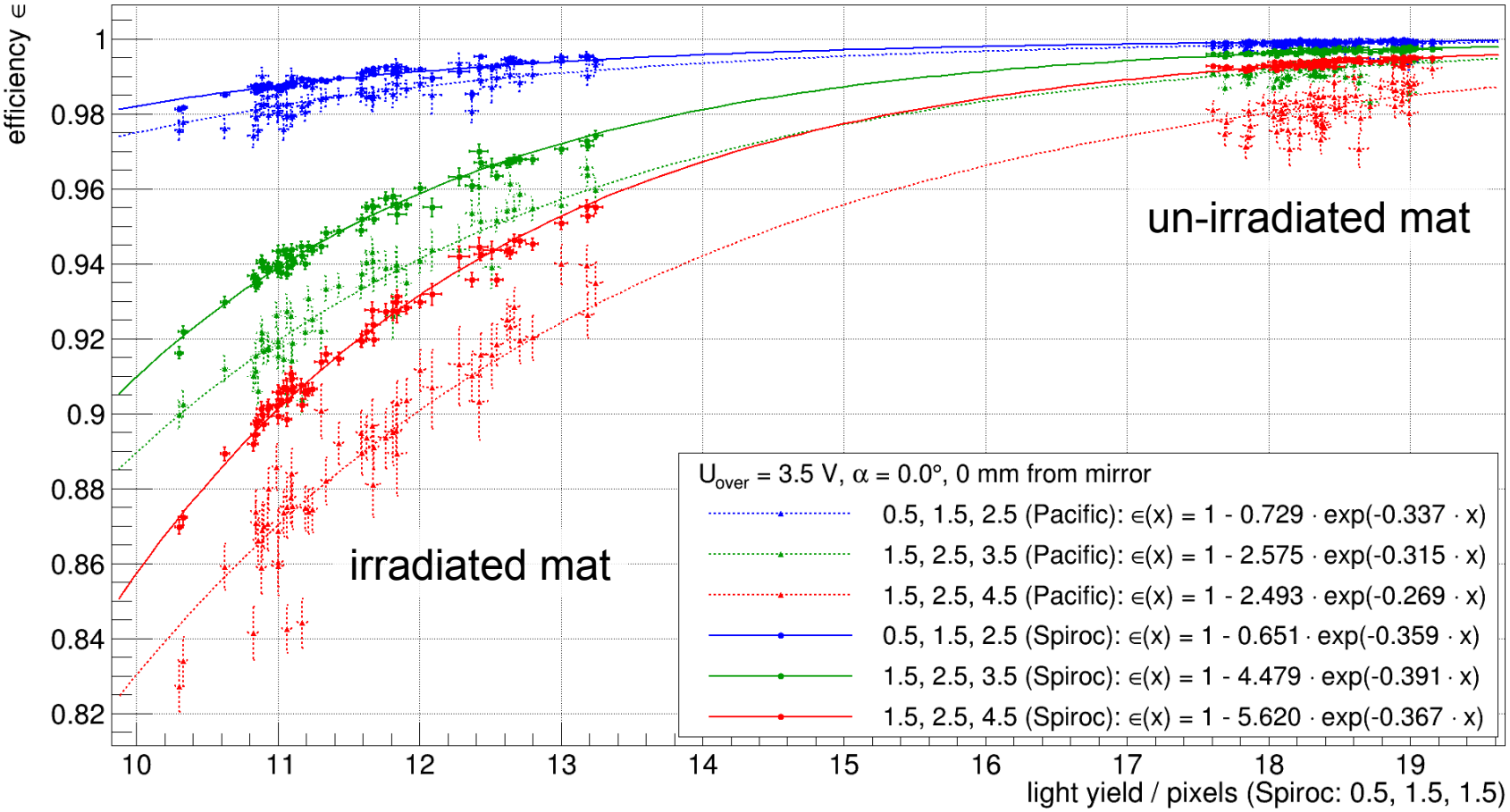
- Measured at mirror
- SPIROC readout
- 1 GeV electron beam
- **~100%** in un-irradiated mat, **~90 %** in most irradiated area



# Beam Tests

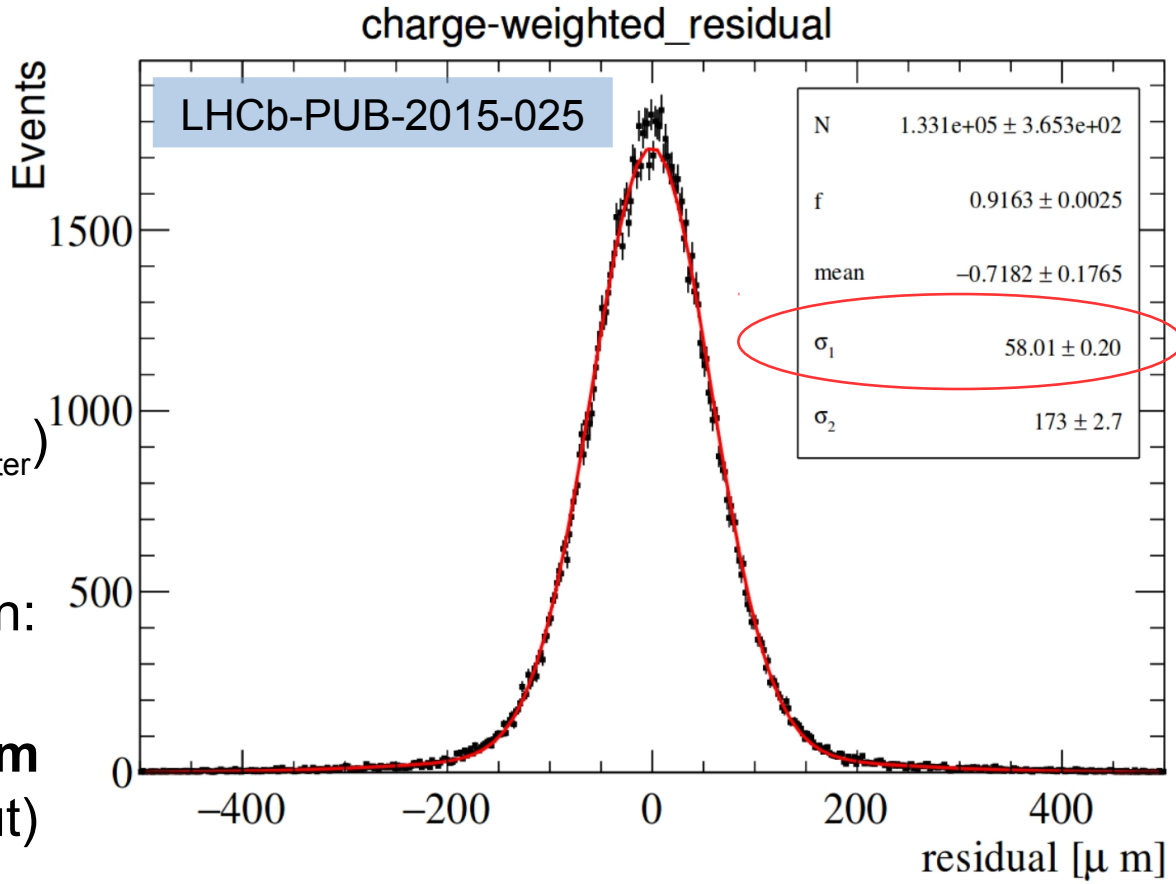
## Single Hit Efficiency vs. Light Yield

- Different readout chips: SPIROC (200ns shaping time) and PACIFIC (25ns)
- Tested several threshold settings



# Beam Tests
## Resolution

- Measured at mirror
- SPIROC readout
- 180 GeV pion beam
- Fitted double Gaussian onto residuals ($x_{track} - x_{cluster}$)
- Central sigma: **60 µm**
- Beam telescope resolution: **30 µm**
  - → SciFi resolution: **50 µm** (with SPIROC readout)



# Status & Outlook

- Serial production started in June ‘16 and running at all **four production** sites
  - → Mats wound so far: **700**
  - → Current production rate: **5 - 9 mats / week / site**
  - → Production finished in **Q1 2018**
- QA test stands allow for fast and easy measurements of fibre mat quality
  - → Mean light yield of mats (at RWTH Aachen): **19.60 pixels (99.5% single hit efficiency)**
- Beam tests confirm performance of the tracker
  - → Spatial resolution of **50 µm** with SPIROC readout
  - → Single hit efficiency of six layer mats **close to 100%**