Production of Scintillating Fiber Modules for high resolution tracking devices

TIPP 2014, Amsterdam, 5th June 2014

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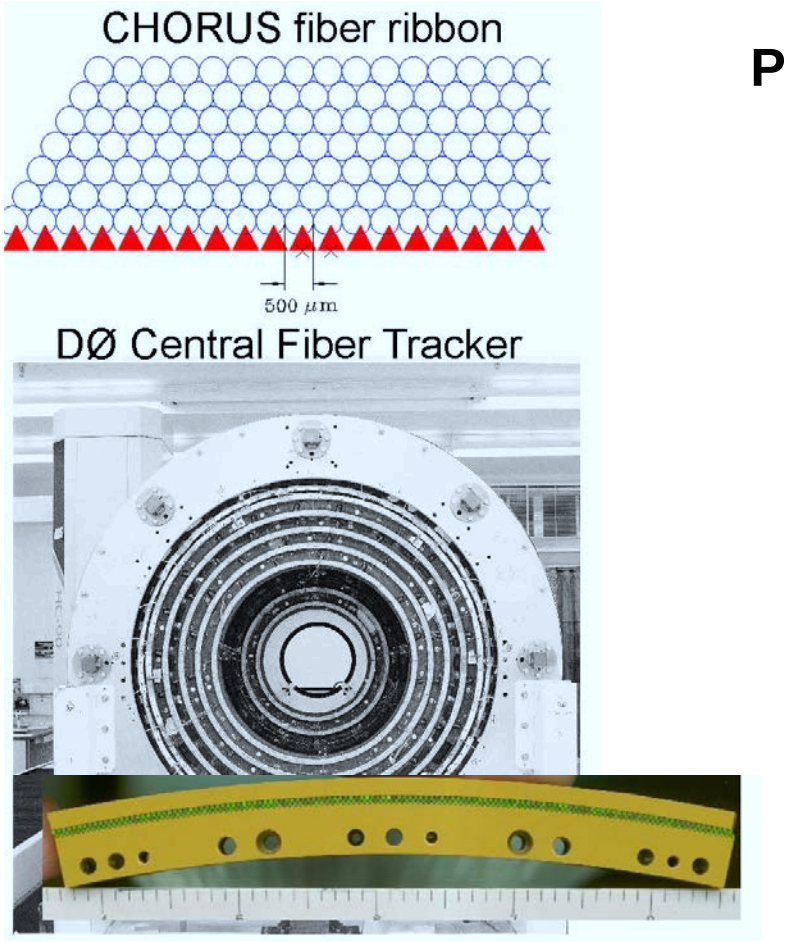
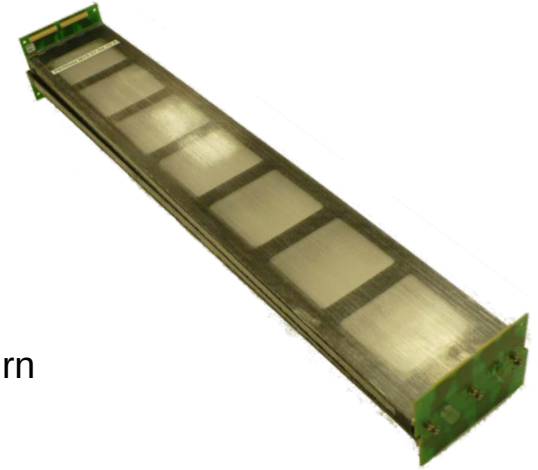
Scintillating fiber tracker





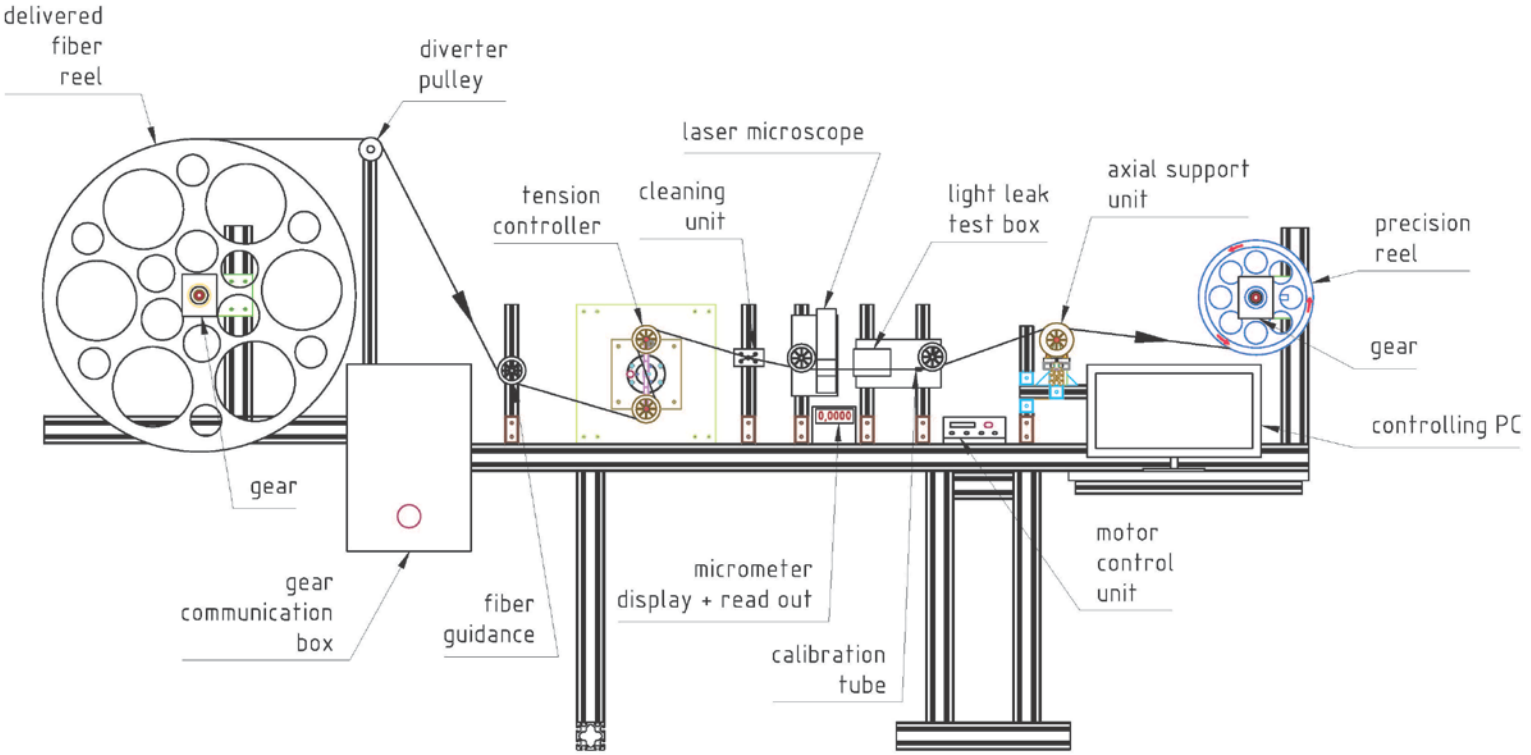
Previous Scintillating Fiber Tracker

- CHORUS, UA2
  - Ø=500µm fibers, 7 layers, image itensifiers, CCD camera
  - ~150µm spatial resolution
  - requires ~10kV HV
- E835, DØ
  - Ø=835µm fibers, 2 layers, VLPCs
  - ~100µm spatial resolution
  - VLPCs operated at cryogenic temperatures

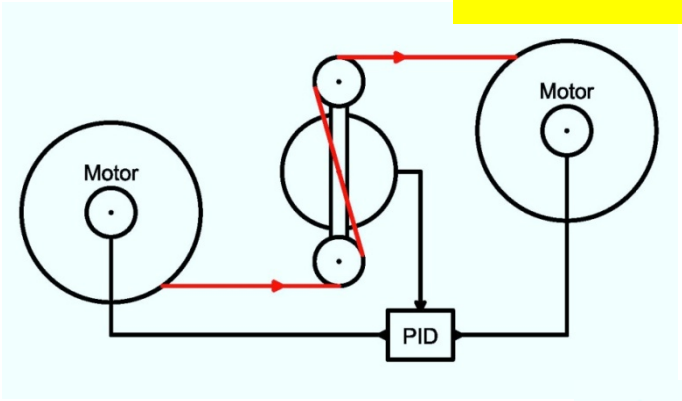
Our Goal: spatial resolution < 50 µm

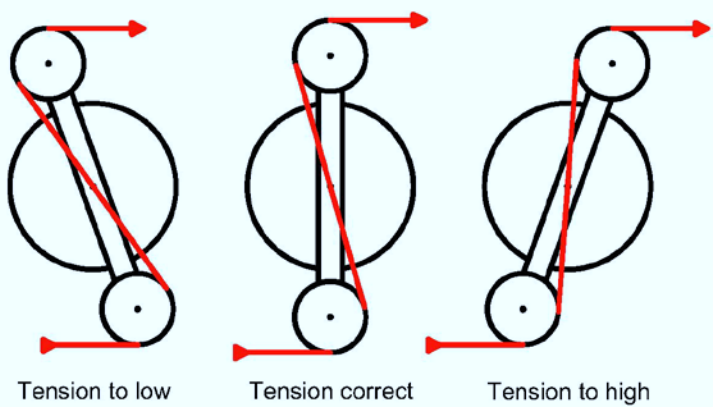
→ Scintillating fibers Ø 250 µm and SiPM readout

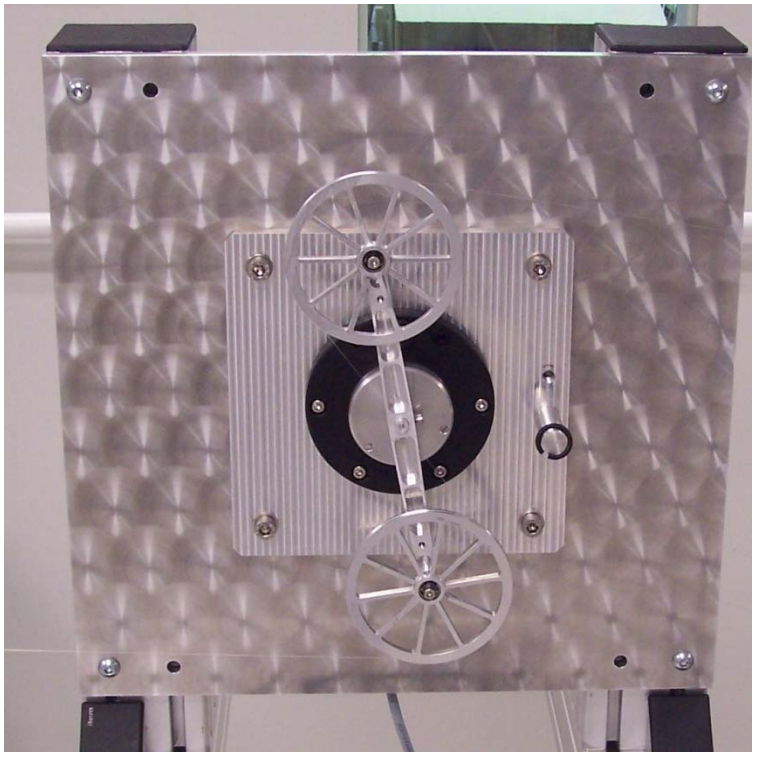
Rewind fiber stand: From producer spool to production spool



Rewind fiber stand: Tension Control Unit







Purpose: Keep fiber tension constant during rewinding process

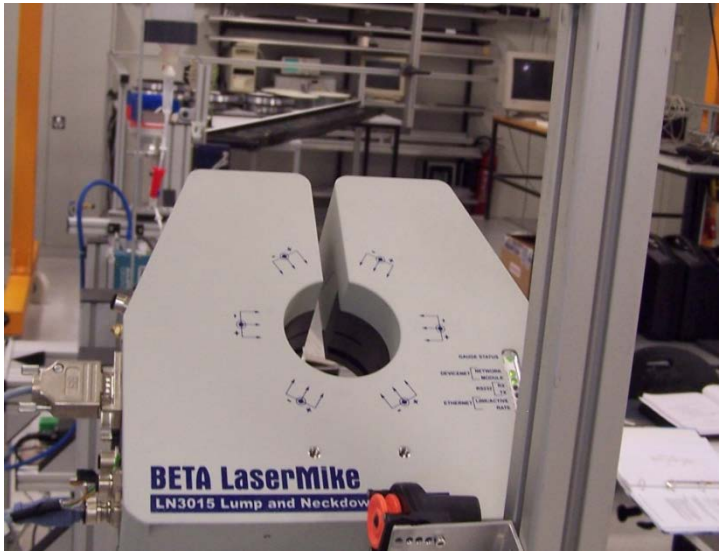
Consists of two-armed lever (pivot mounted in the center) with a pulley at each end

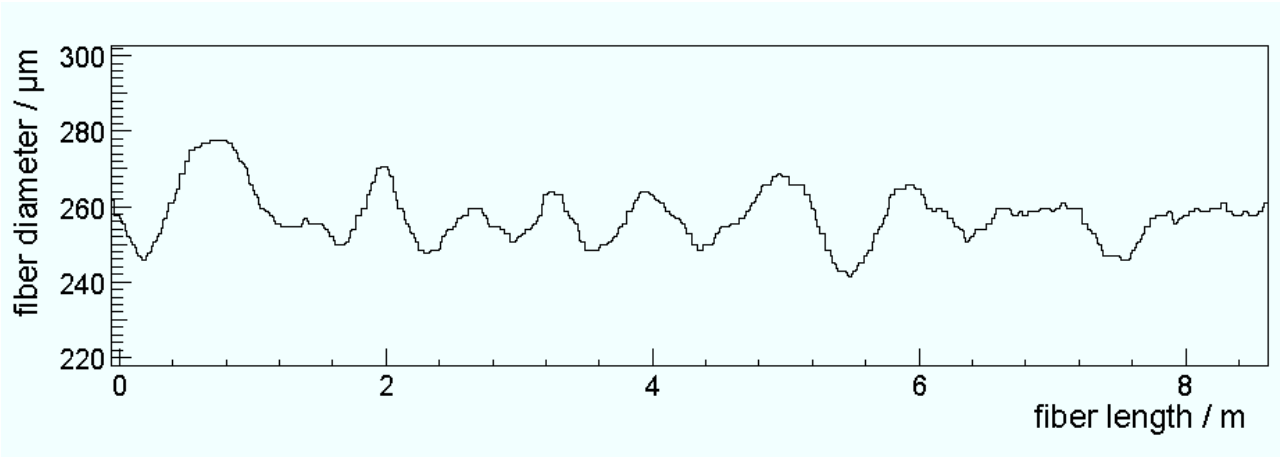
Lever is kept in vertical position due to compensation of fiber tension by a spiral spring at pivot

Variation in tension → Loss of vertical orientation → angular change is measured

→ signal to speed control of take-off and take-up reel motors ; Pull strength of 0.4 to 0.5 N

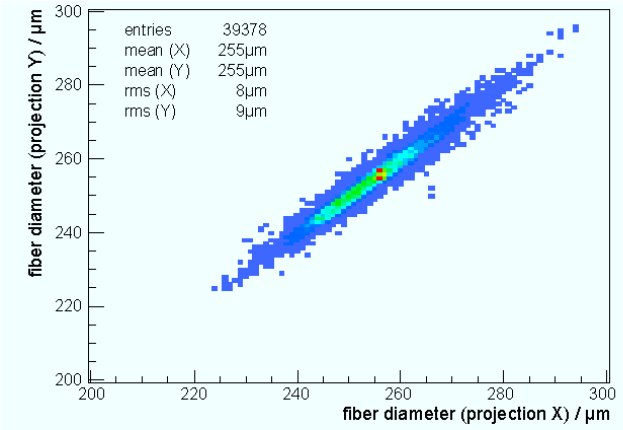
Fiber Diameter Measurement via Laser Micrometer



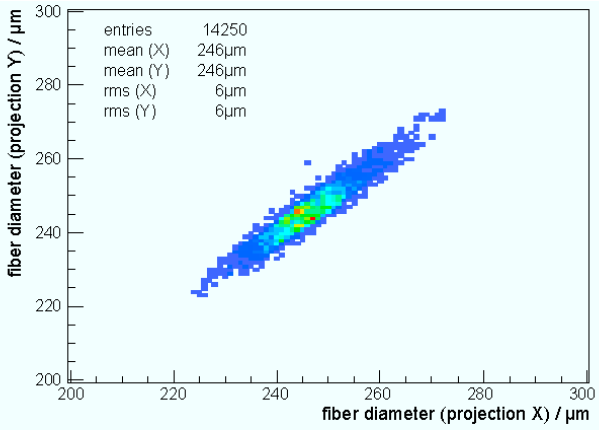


Fiber diameter variation of SCSF81M fiber

with Zumbach ODAC 15XY-J



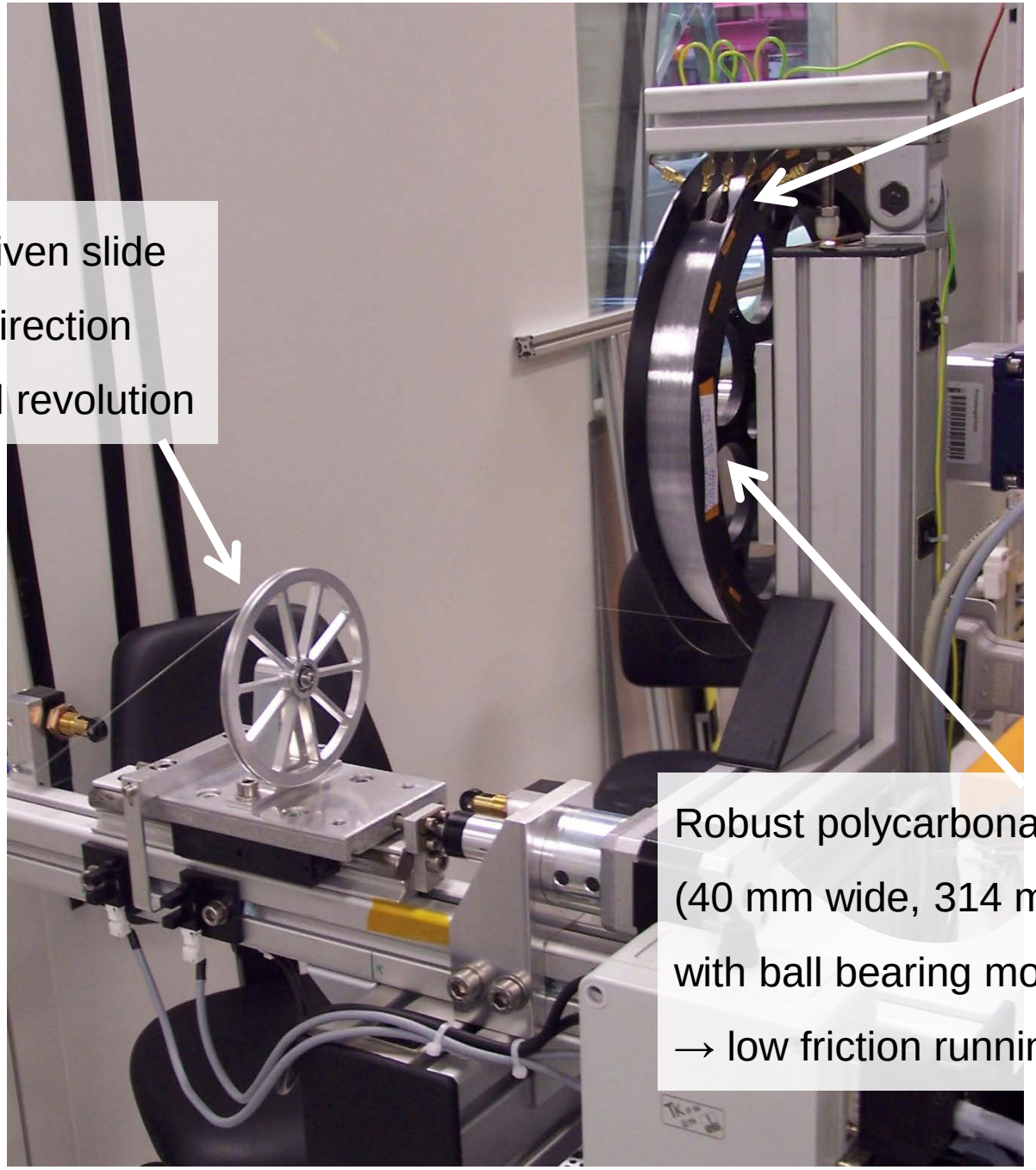
(a) The measured diameter of 850 m of Kuraray SCSF81M fiber. Correlation factor $r = 0.98$.



(b) The measured diameter of 400 m of Kuraray SCSF78MJ fiber. Correlation factor $r = 0.93$.

Fiber diameter measured with Zumbach ODAC 15XY-J

Rewind fiber stand: Re-Reeling Unit



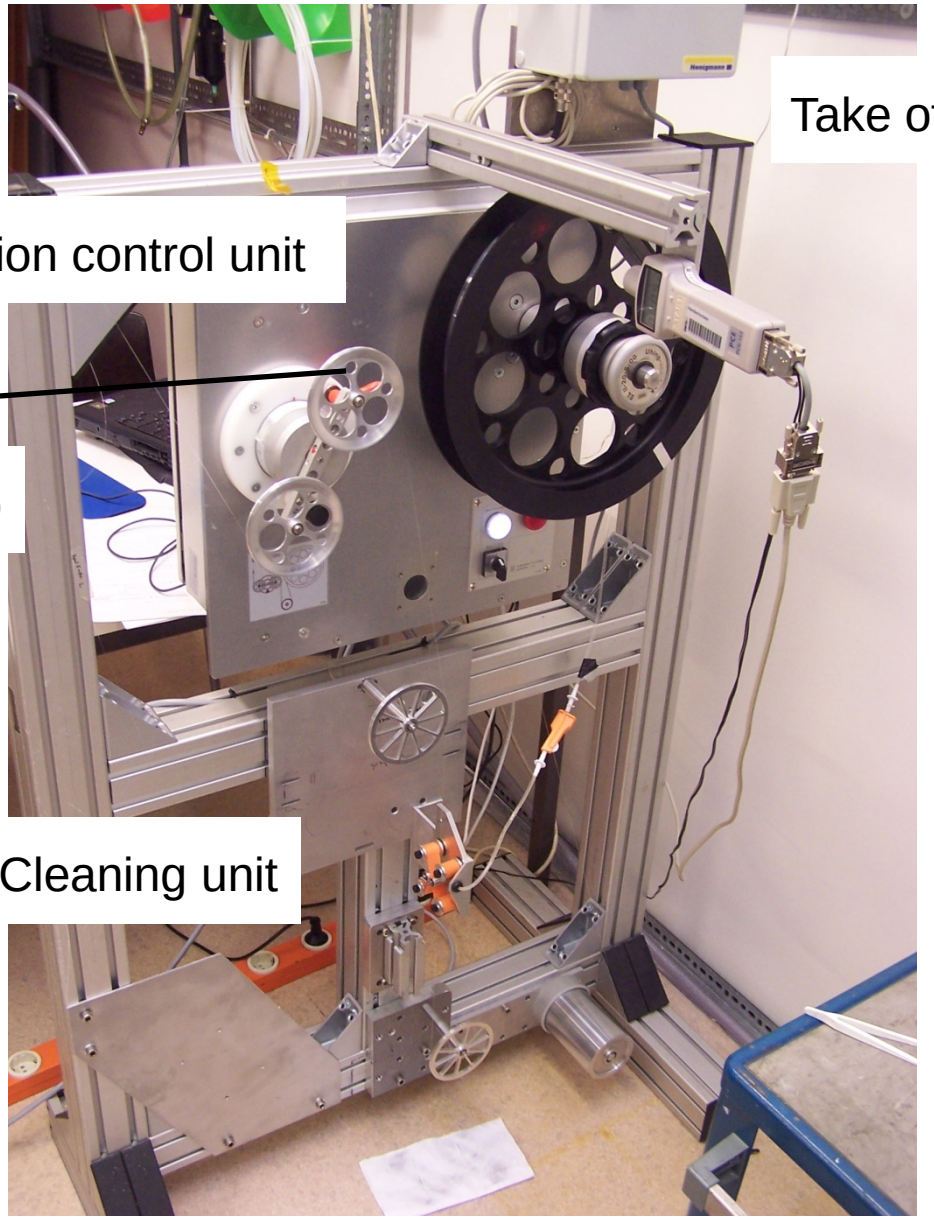
Brushes against
electrostatic charging

Pulley on motor driven slide
is moved in axial direction
by 250 µm per reel revolution

Robust polycarbonate reels
(40 mm wide, 314 mm winding diameter)
with ball bearing mounting on axle
→ low friction running; driven by a motor

Production of Scintillating Fiber Mats: Winding stand

Fiber wound upon cylindrical winding hub layer by layer



Measurements:

Tension

Position of winding reel

Clock signal of tachometer

→ counting turns of take off reel

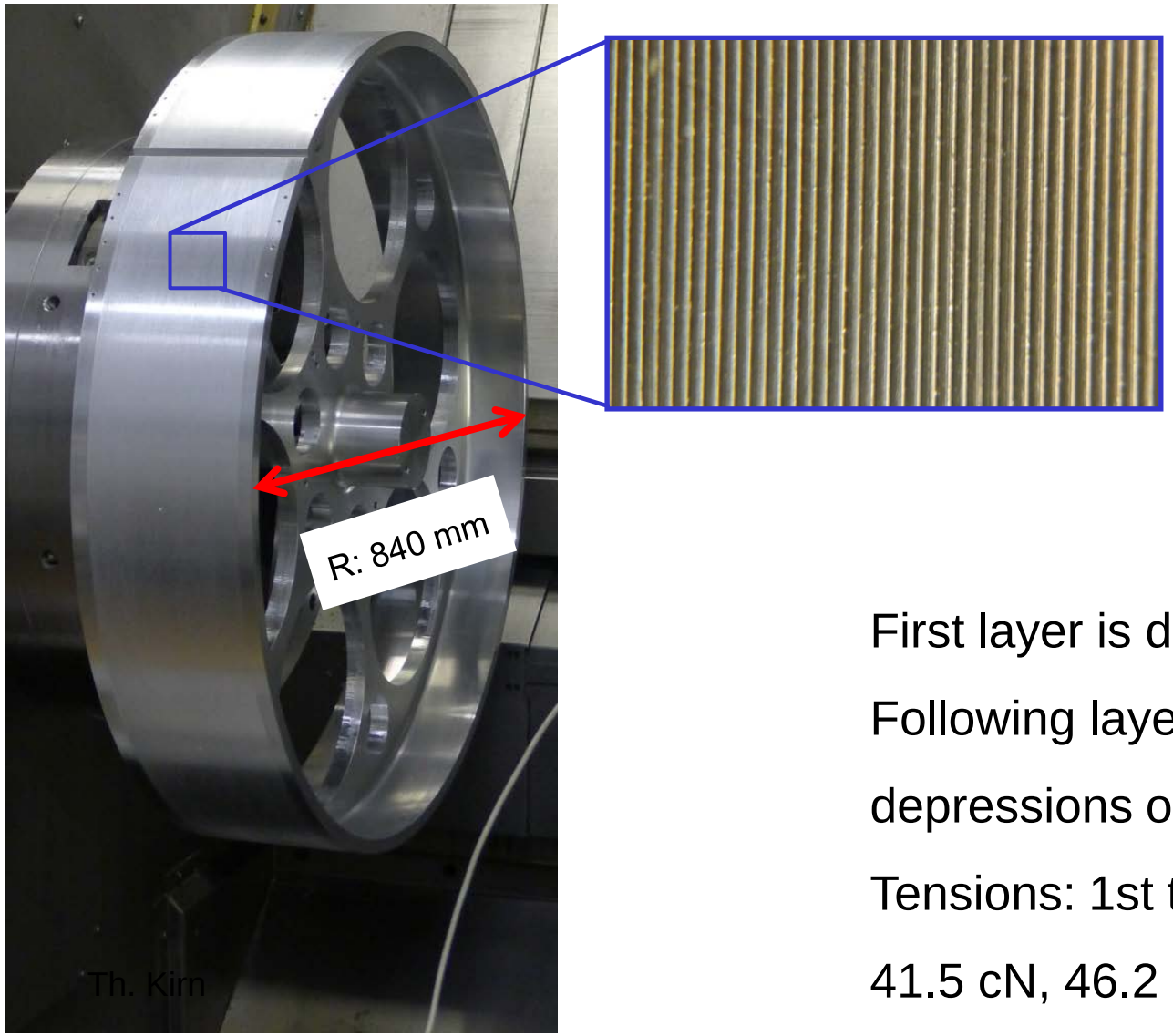
Production of Scintillating Fiber Mats: Winding hub

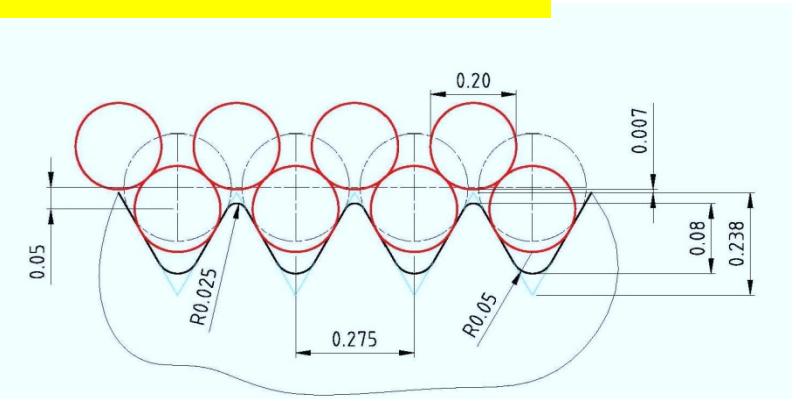
Winding hub:

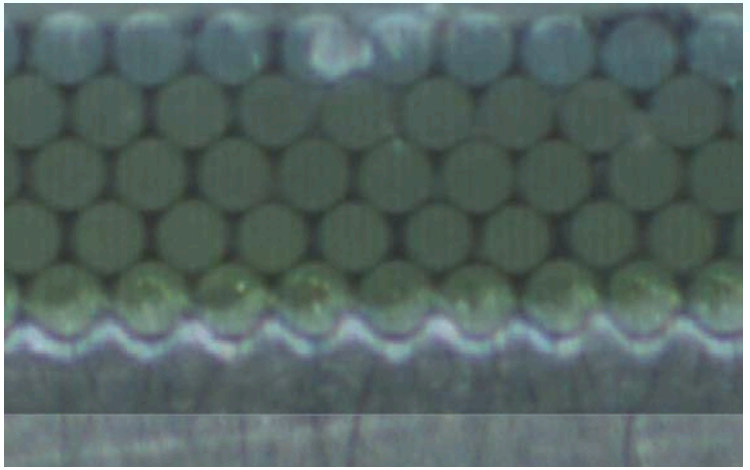
Radius: 300mm 840 mm

Width : 65mm 130 mm

Fiber mats length: 860mm 2650 mm,







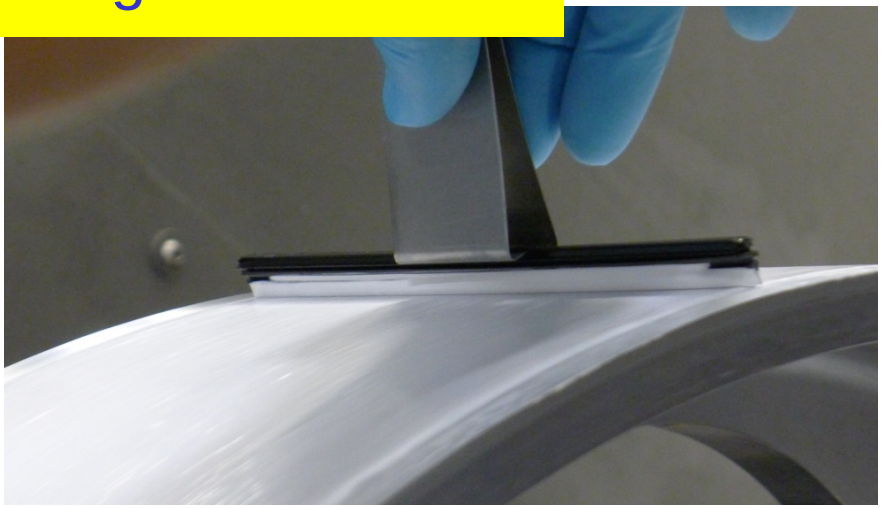
First layer is directly wound onto hub

Following layers are wound into groove-like depressions of preceding layers

Tensions: 1st to 5th layer:

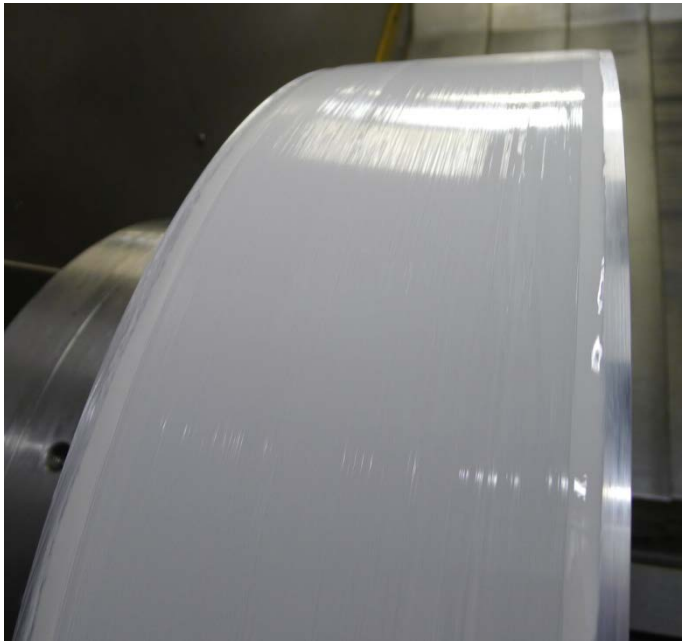
41.5 cN, 46.2 cN, 51.0 cN, 55.8 cN, 60.4 cN

Production of Scintillating Fiber Mats

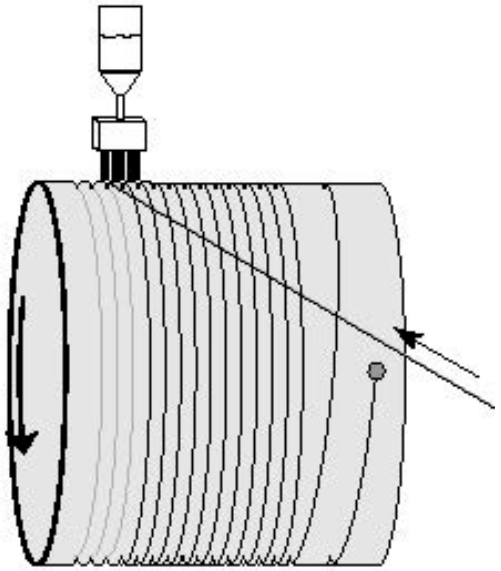


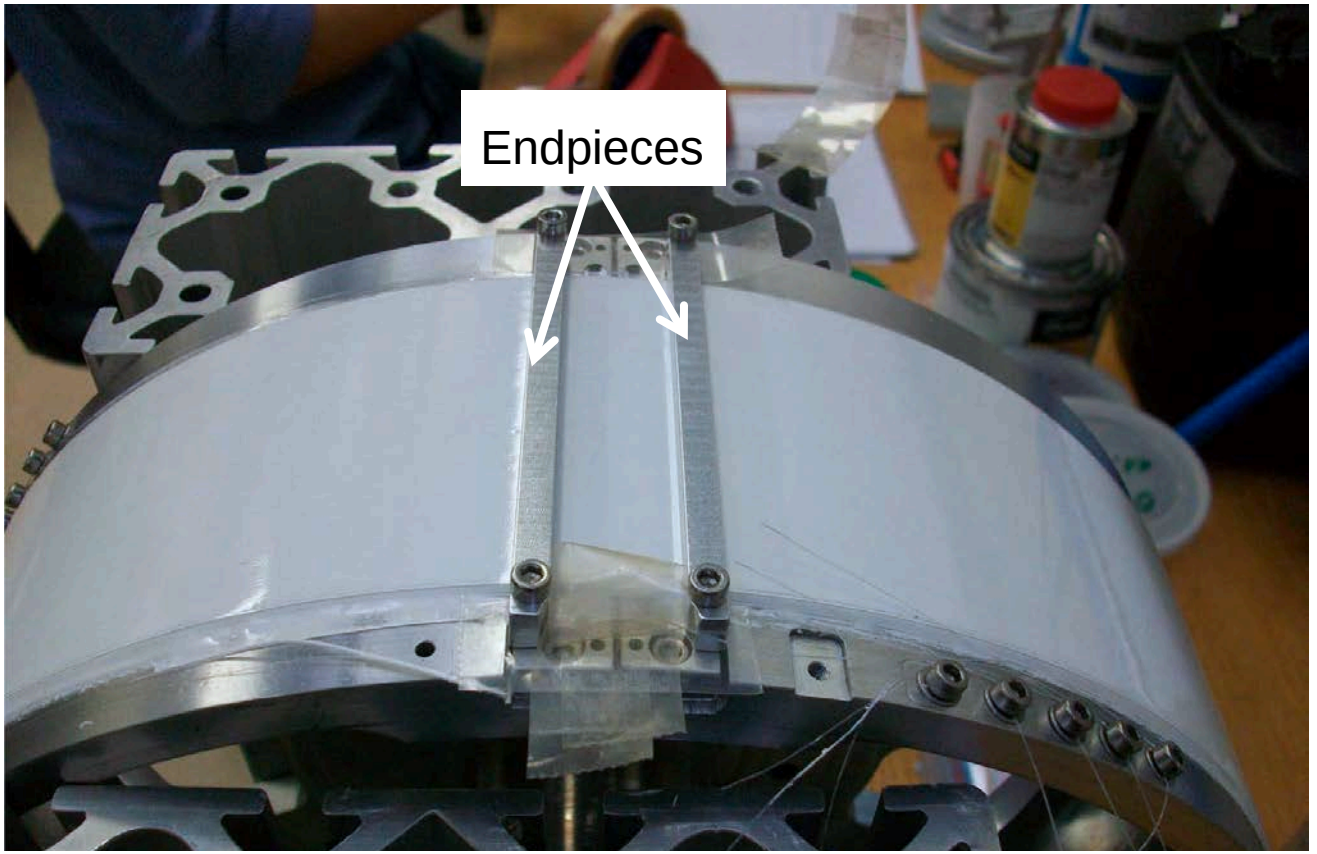
Glue: Epotec 301 + 25% TiO2 (optional)

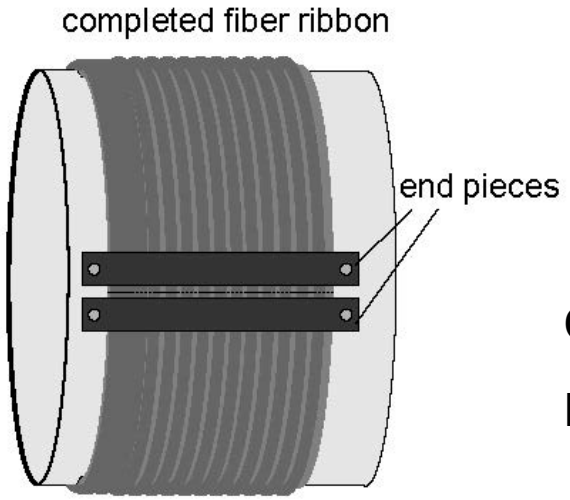
→ Minimization of crosstalk between adjacent fibers



Winding of fiber mats







Glue curing over night,

Endpiece mounting→ screwed together and glued to fibers,

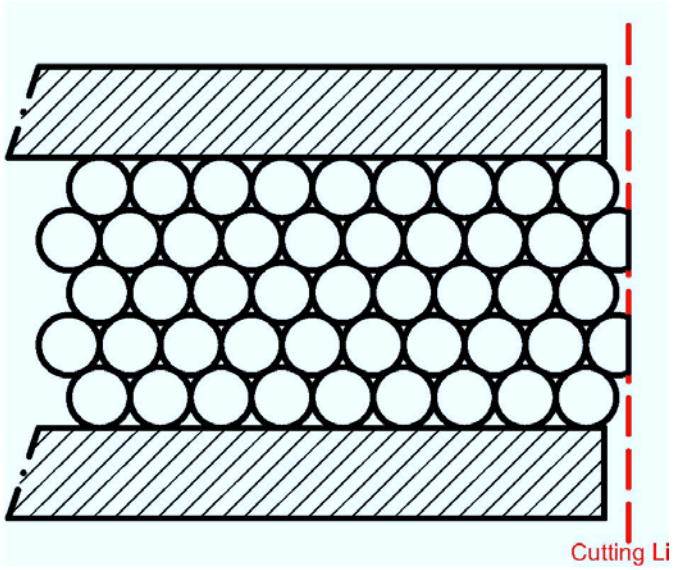
cured over night

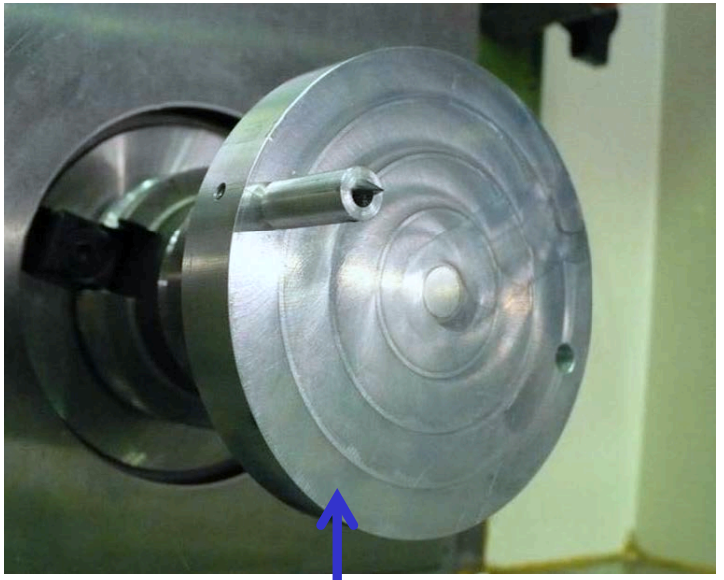
Fiber mat cut in between endpieces

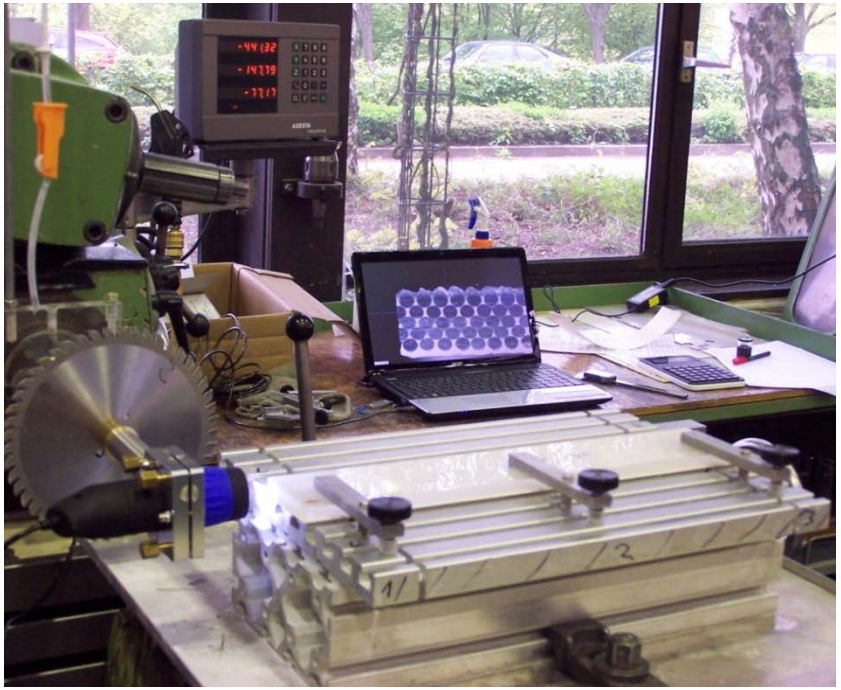
Mat released from former and straightend

Production of Scintillating Fiber Mats: Unforming

Cutting of Fiber Mats: Length and Width







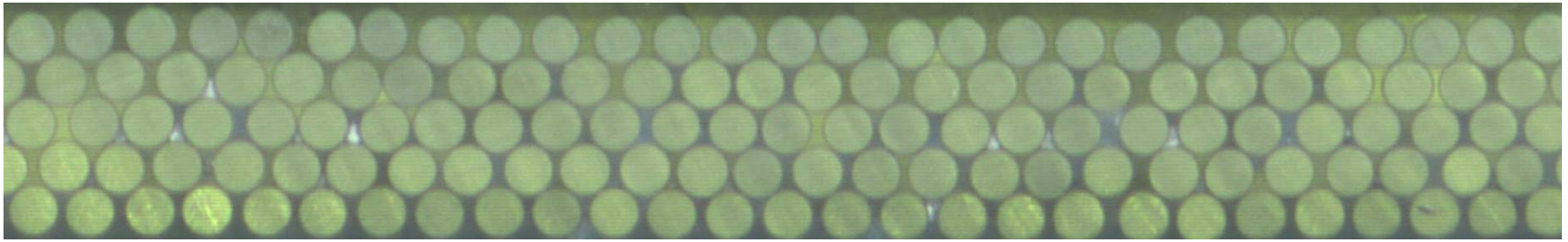
- Milling with high speed one point cutter (polycrystalline diamond, needs water cooling) or
- alternatively with a carbide blade (no water cooling needed)

→ fibers @ edge of mat tend to peel off

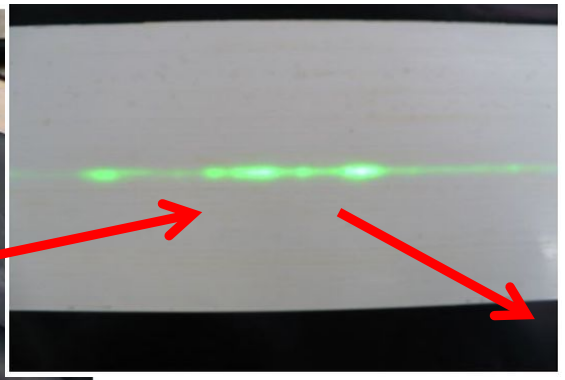
→ to avoid damage of fiber cladding

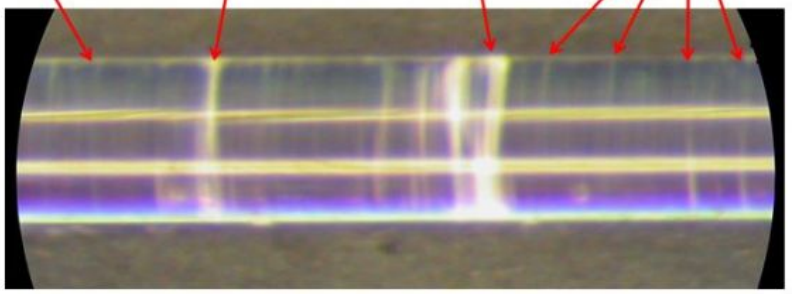
Optical Quality Control before mounting on module support

- Illuminate fiber mat on one end with a lamp
- Scanner records opposite end → darkness as sign for damaged fibers



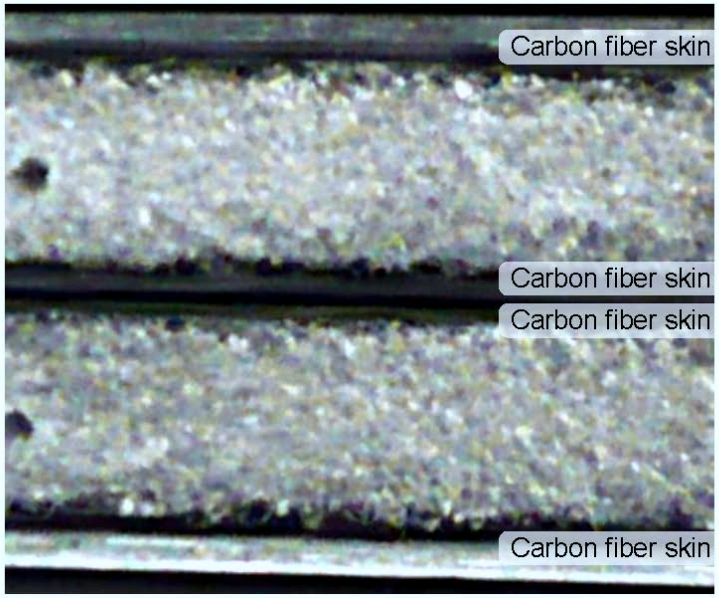
- Illuminate fiber mat on one end with a green laser → light leaks due to contraction of core material



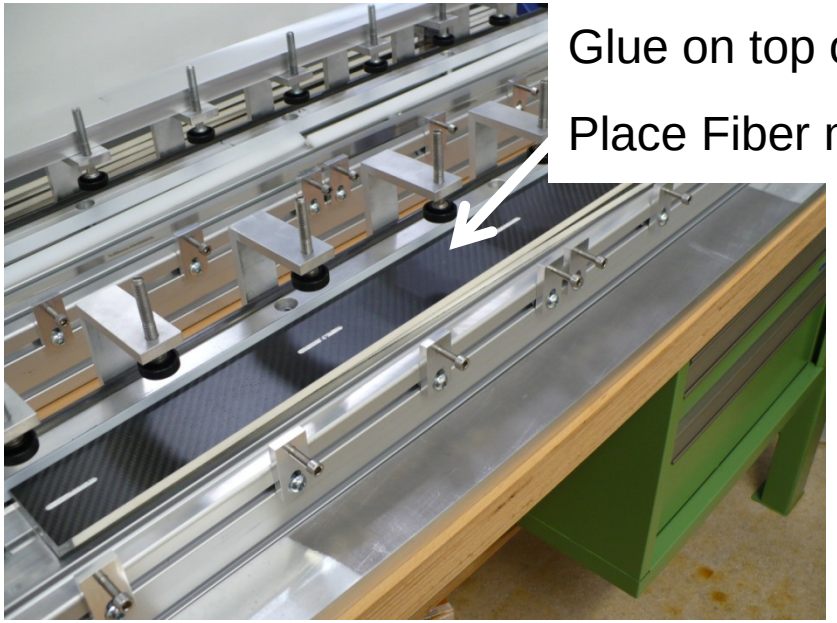


Scintillating Fiber Detector Modules: Module Support

- CFC module carrier
  - fiber ribbons on top & bottom
  - 2 stereo angle
  - 1.1% X0
- front faces: polycarbonate endpieces

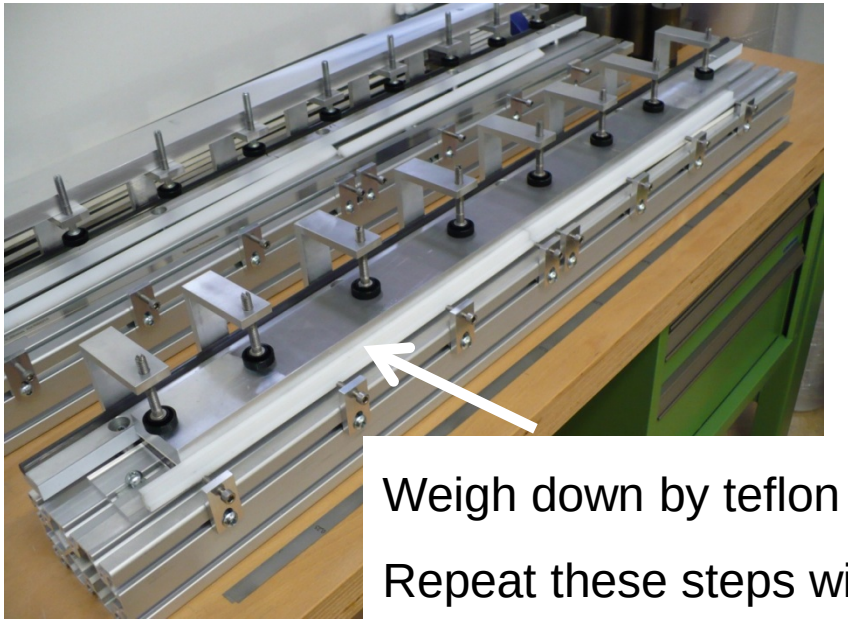


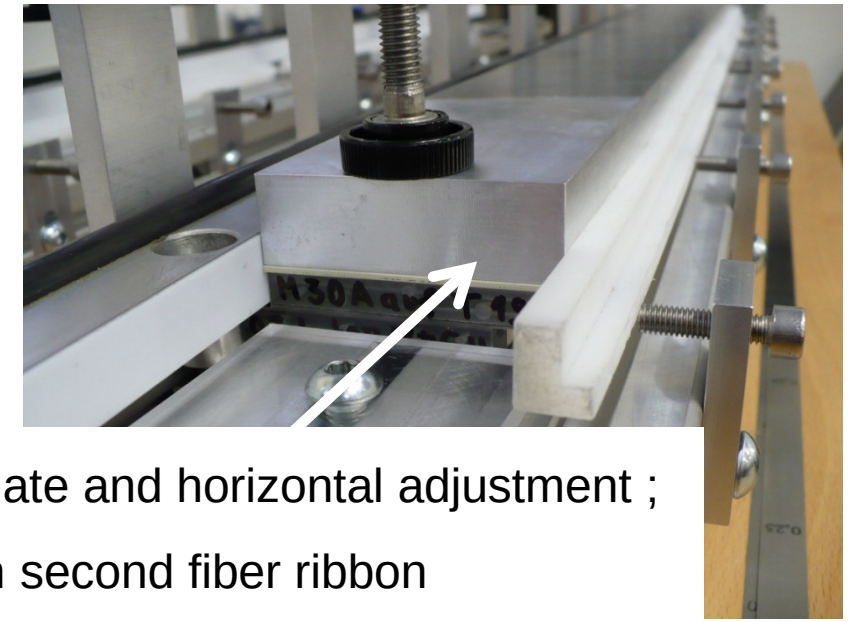
Scintillating Fiber Detector Modules: Fiber Mat glued to Module Support



Glue on top of support

Place Fiber mat on support

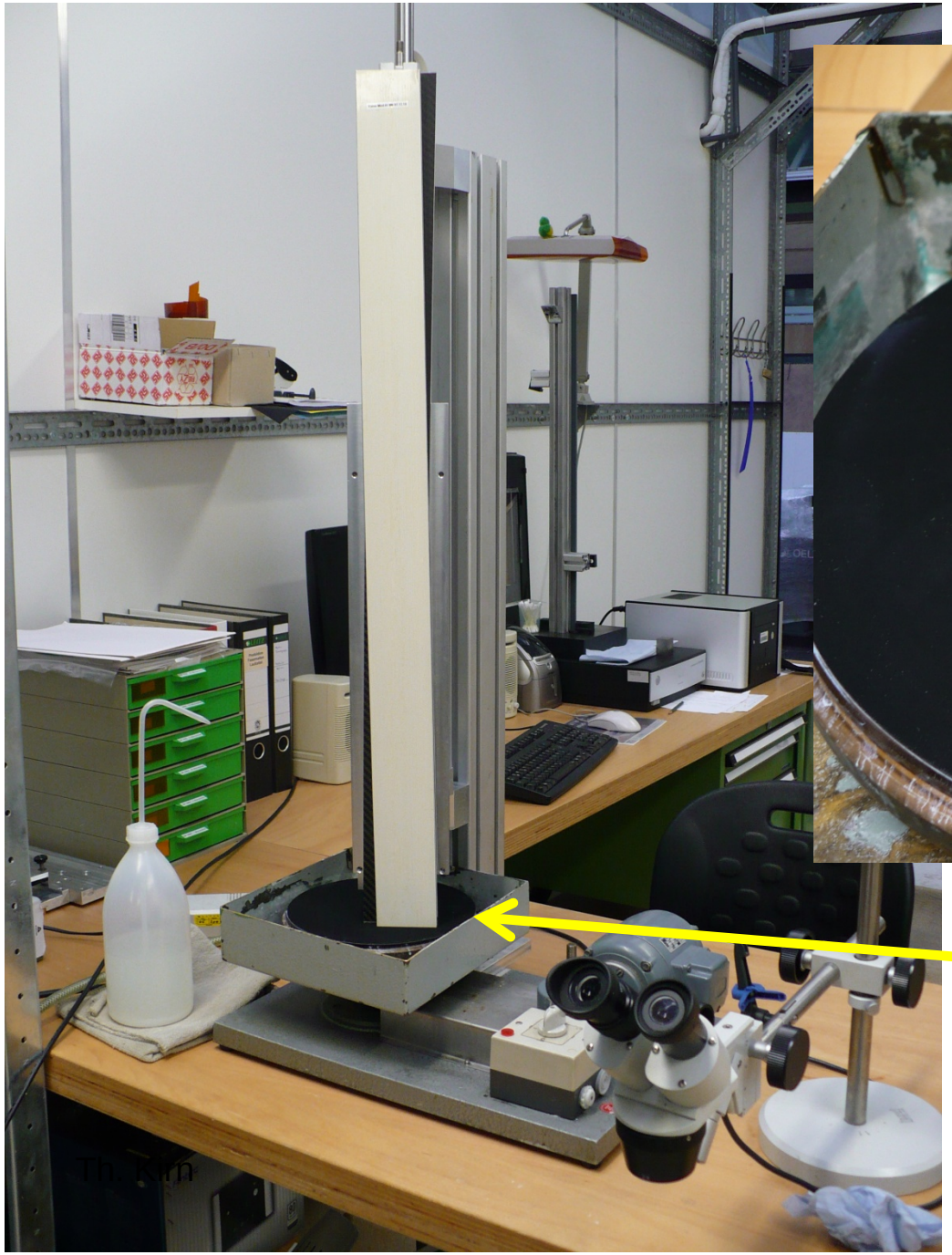


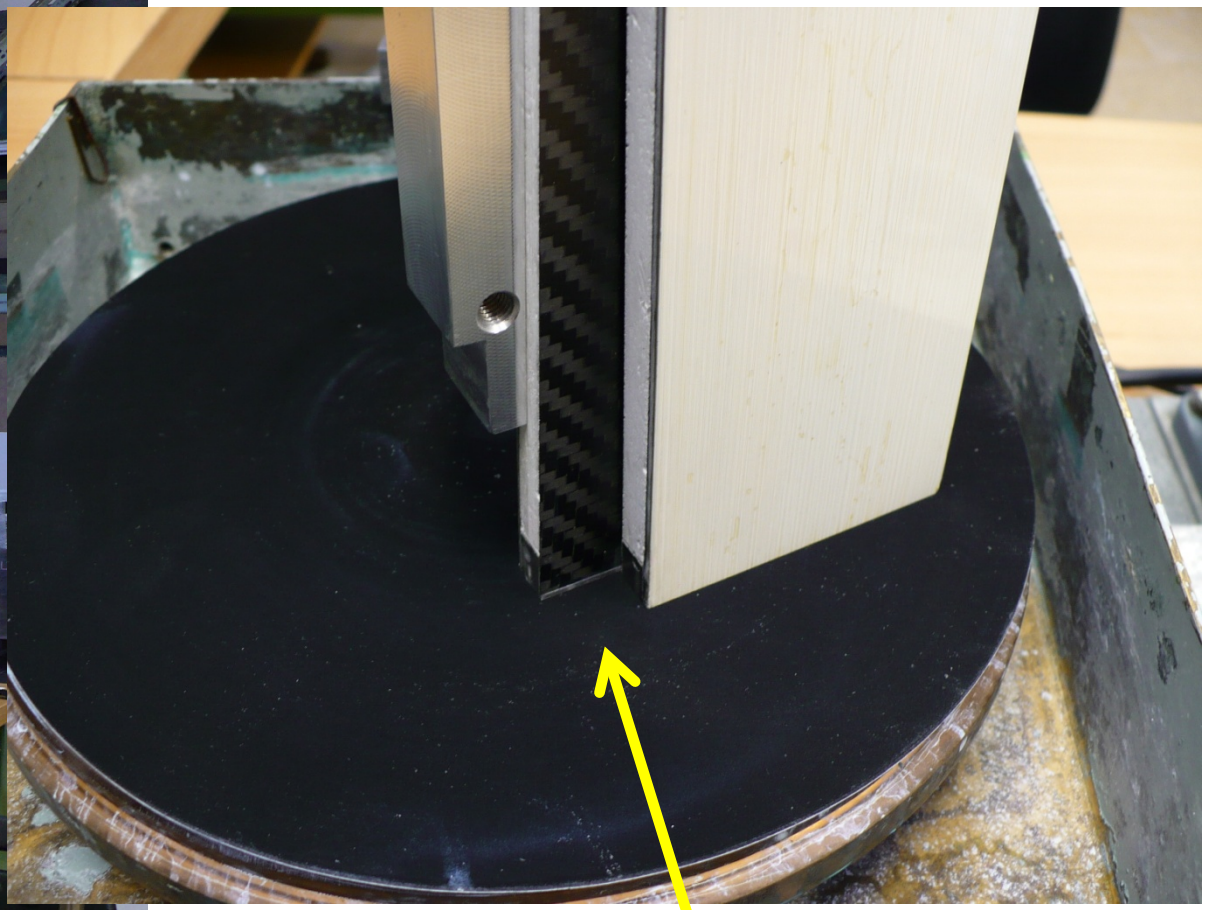


Weigh down by teflon plate and horizontal adjustment ;

Repeat these steps with second fiber ribbon

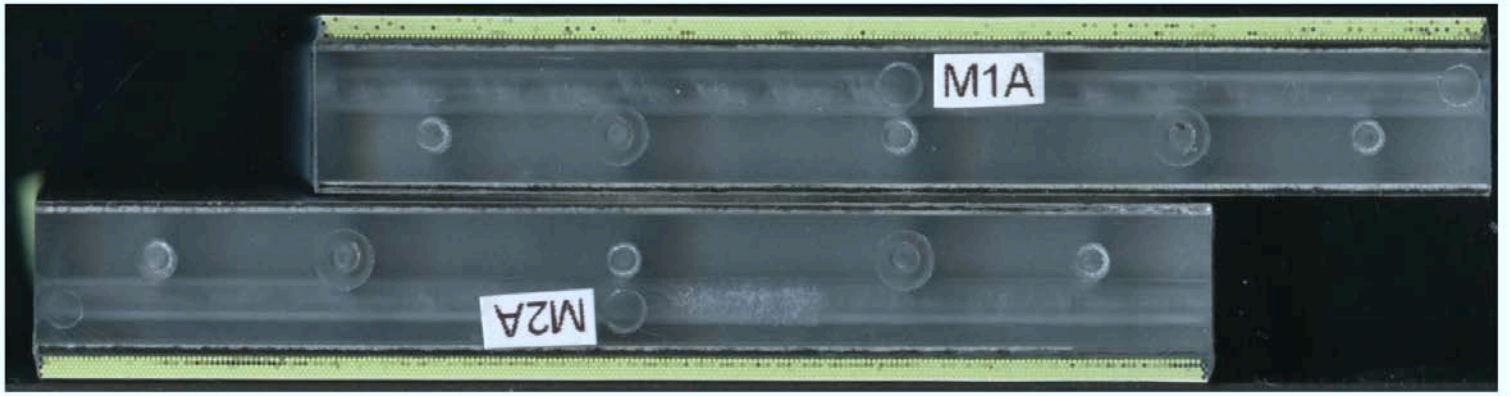
Scintillating Fiber Detector Modules: End faces polished (optional)



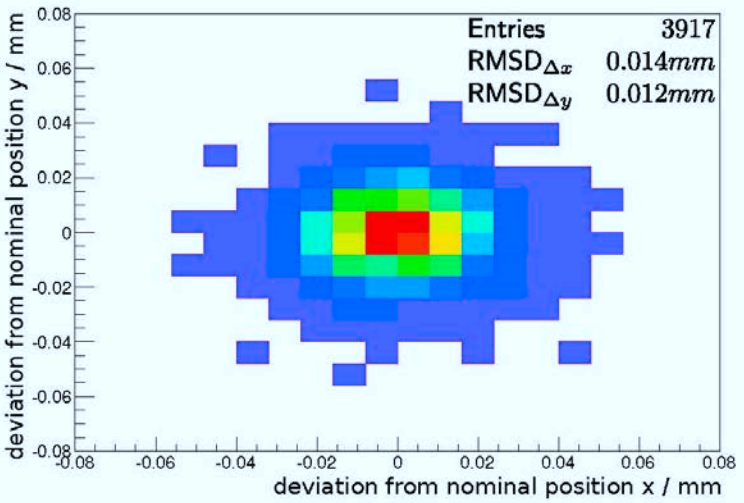


Polished by a surface grinding machine

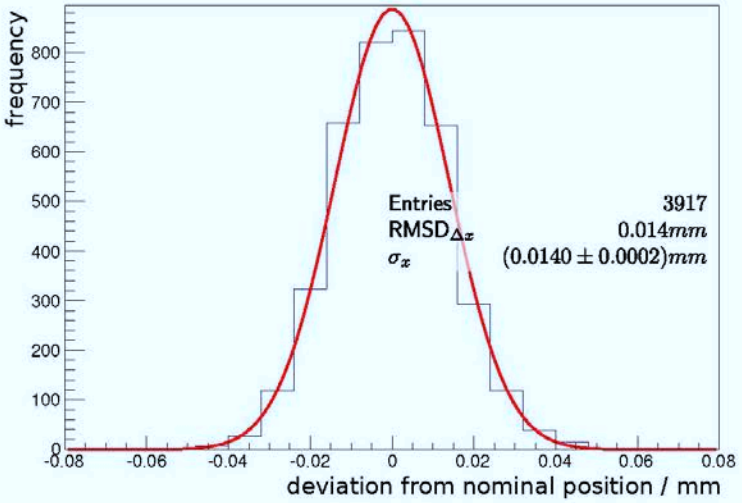
Scintillating Fiber Detector Modules: Optical quality control



(a) A scan of a module from 2011 with illumination at the remote fiber end.



(b) Deviations from nominal positions in 2D

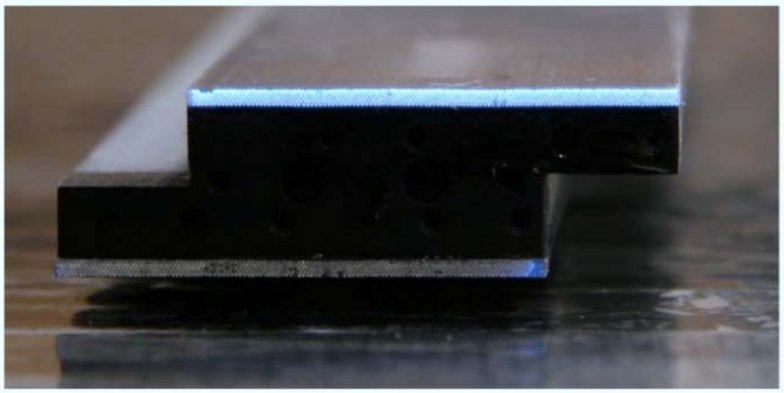


(c) Projected deviations from nominal positions

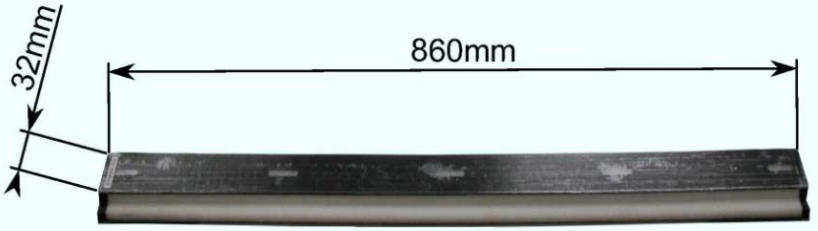
Figure 3.18: The mechanical precision achieved for modules produced in 2011

Scintillating Fiber Detector Modules: Prototypes

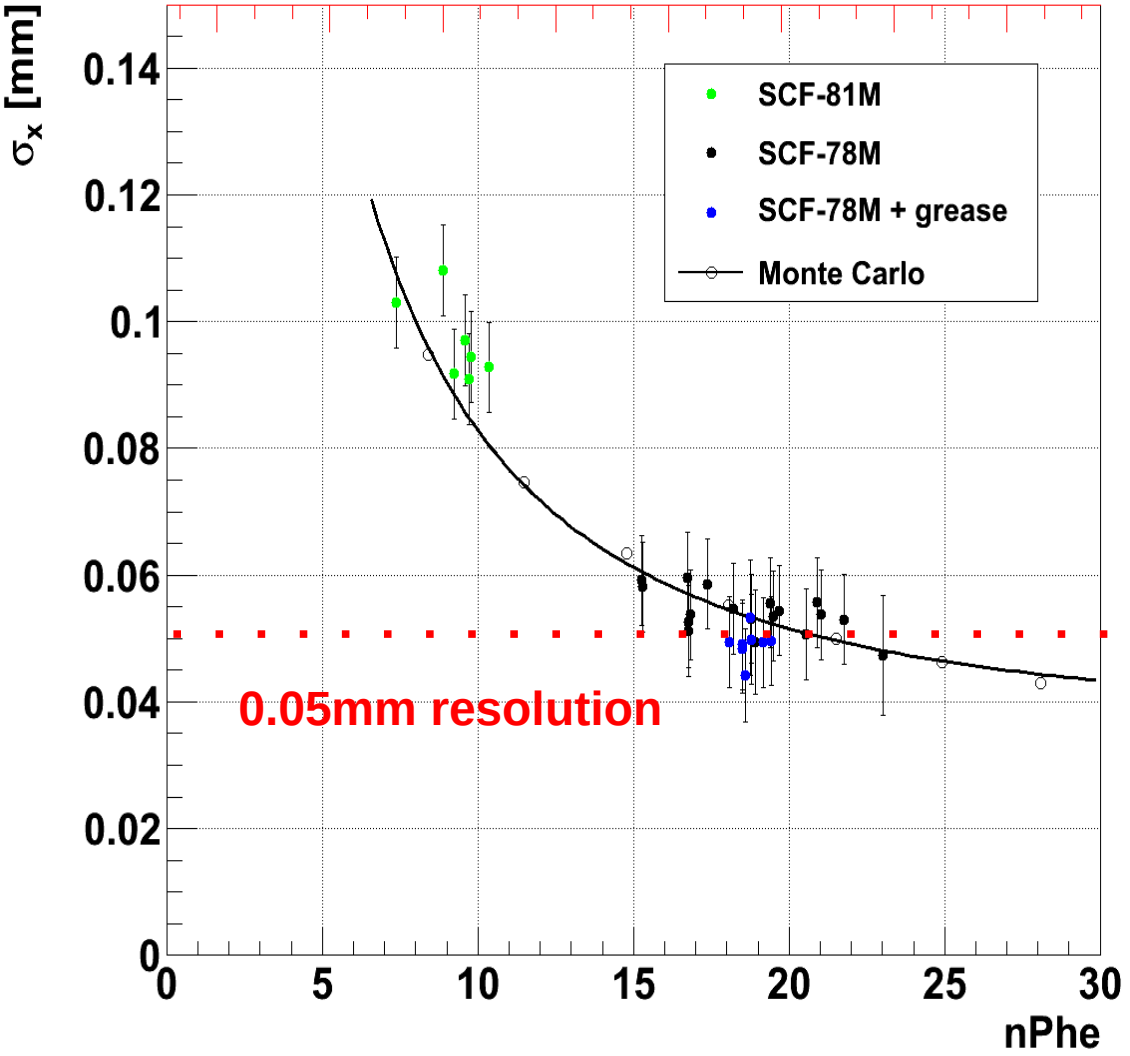
Prototypes with length: 860 mm and width 32 mm or 64 mm



(a) Front view of fiber module.



(b) Full view of fiber module.



PERDaix SciFi tracker

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2010: Perdaix SciFi tracker: Length: 400 mm, width: 64 mm

See NIM A 695 (2012) 91-95

4 double layers of scintillating fiber tracker

- 10 stereo modules

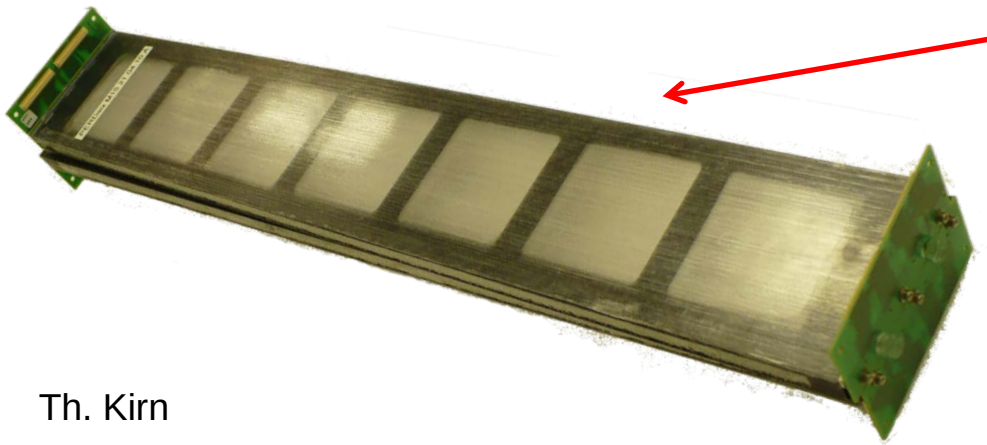
  → 20 fiber ribbons

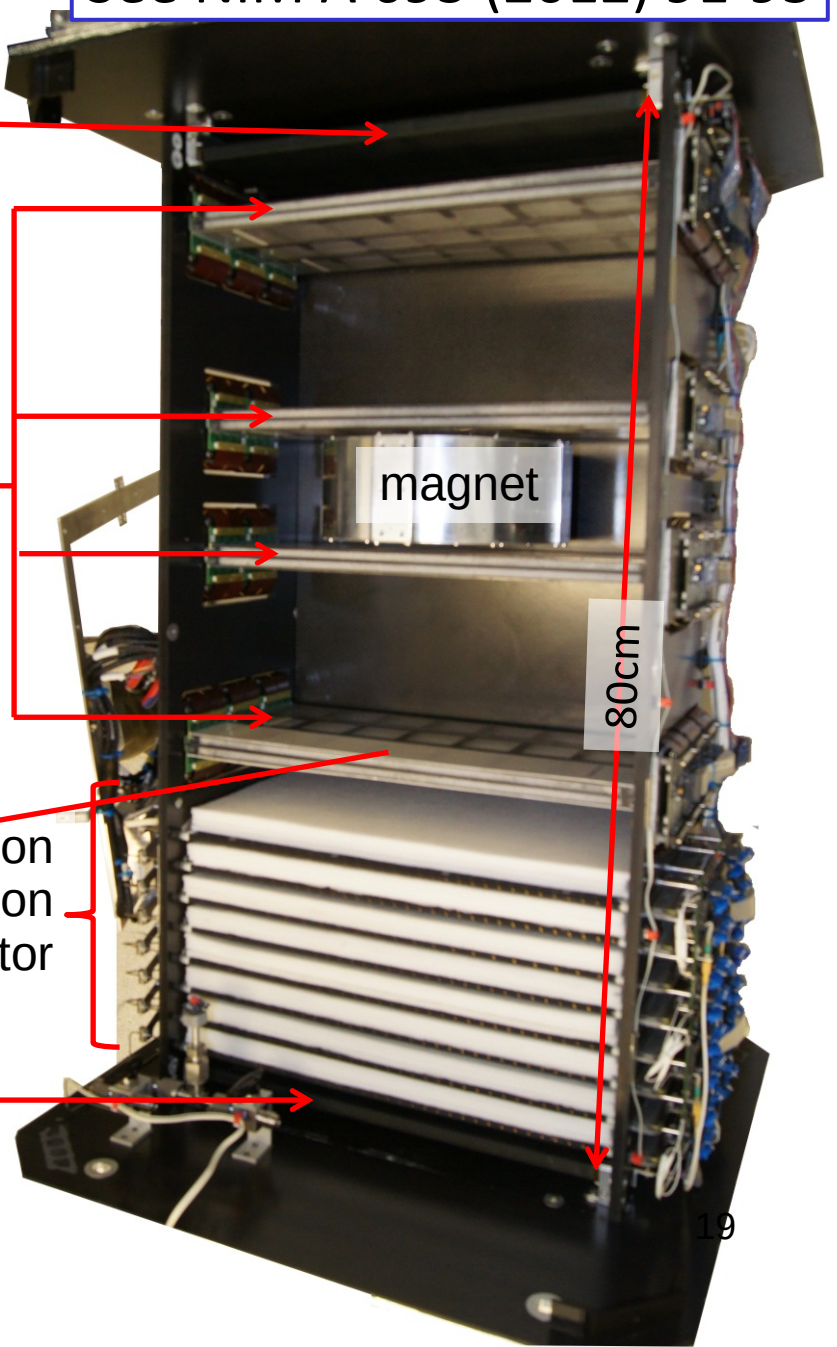
  → 160 SiPM arrays

  → 5120 channels

- two ribbons made of 5x256 250µm thick scintillating fibers mounted on Rohacell foam/Carbon fiber support structure (ladder structure for material saving

  → 1,1 % X0 per module)





PERDaix SciFi tracker

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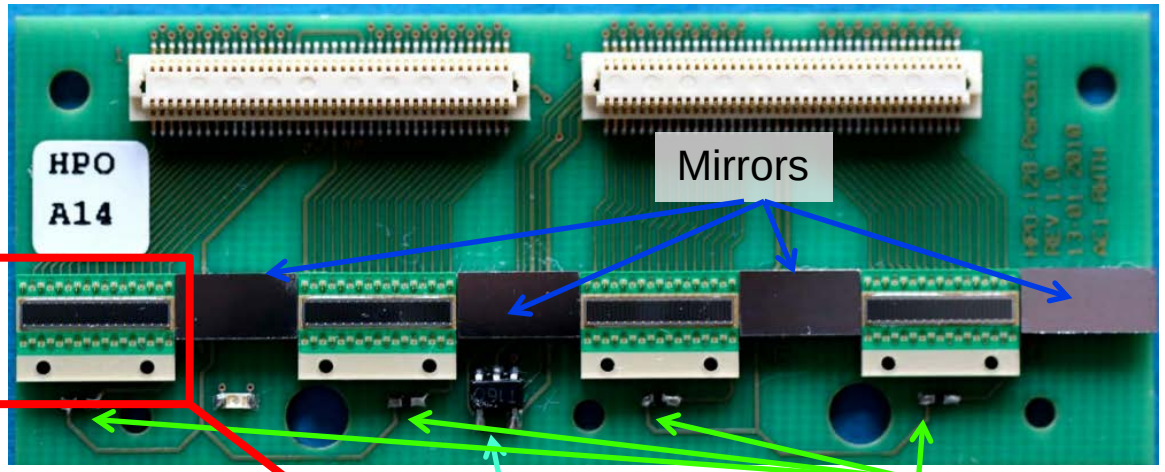
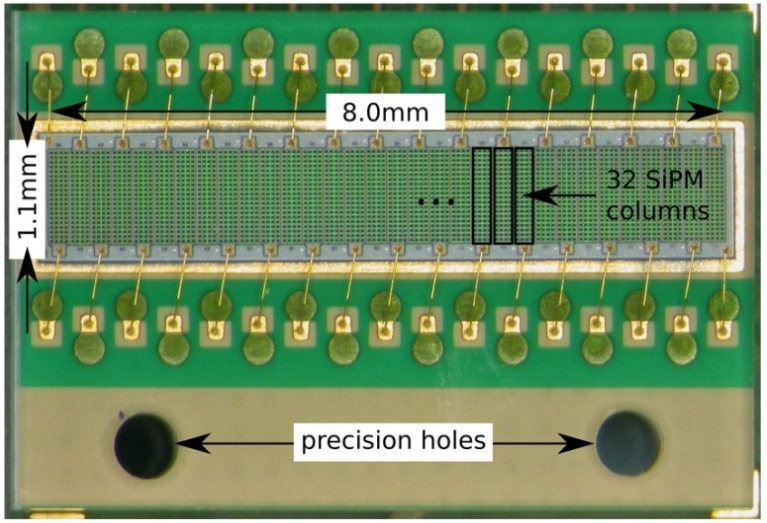
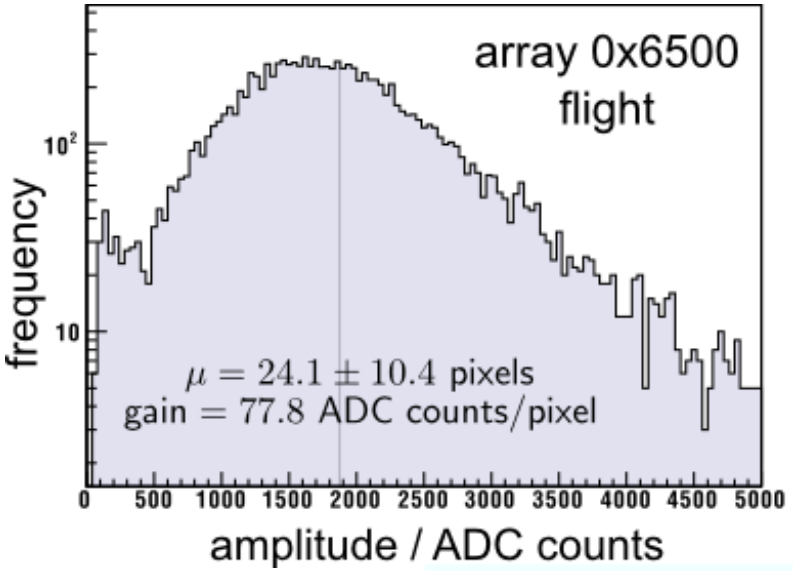
- CFC module carrier
  - fiber ribbons on top & bottom
  - 1 stereo angle
  - 1.1% X0
- Kuraray SCSF-78MJ fibers
  - (250 6) µm fiber diameter
  - $\lambda_{Emission}$ = 450nm
  - 5 fiber layers per ribbon
  - Each layer with 256 fibers

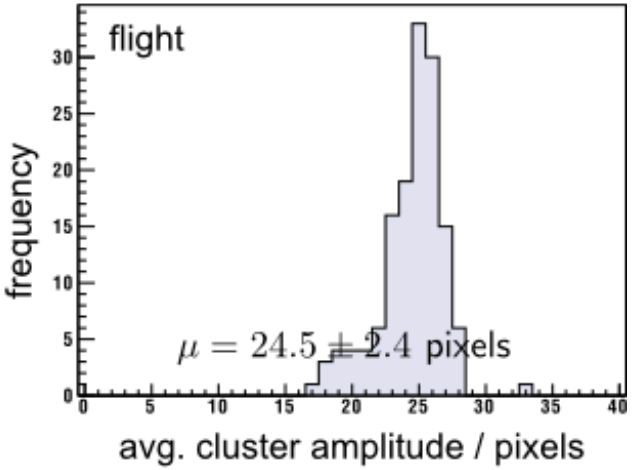


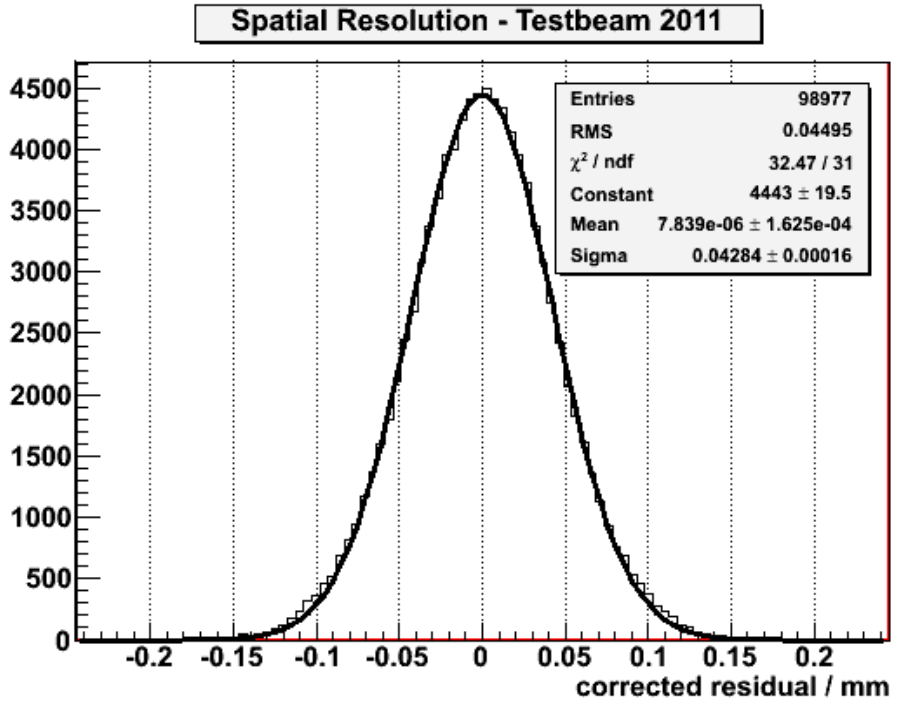


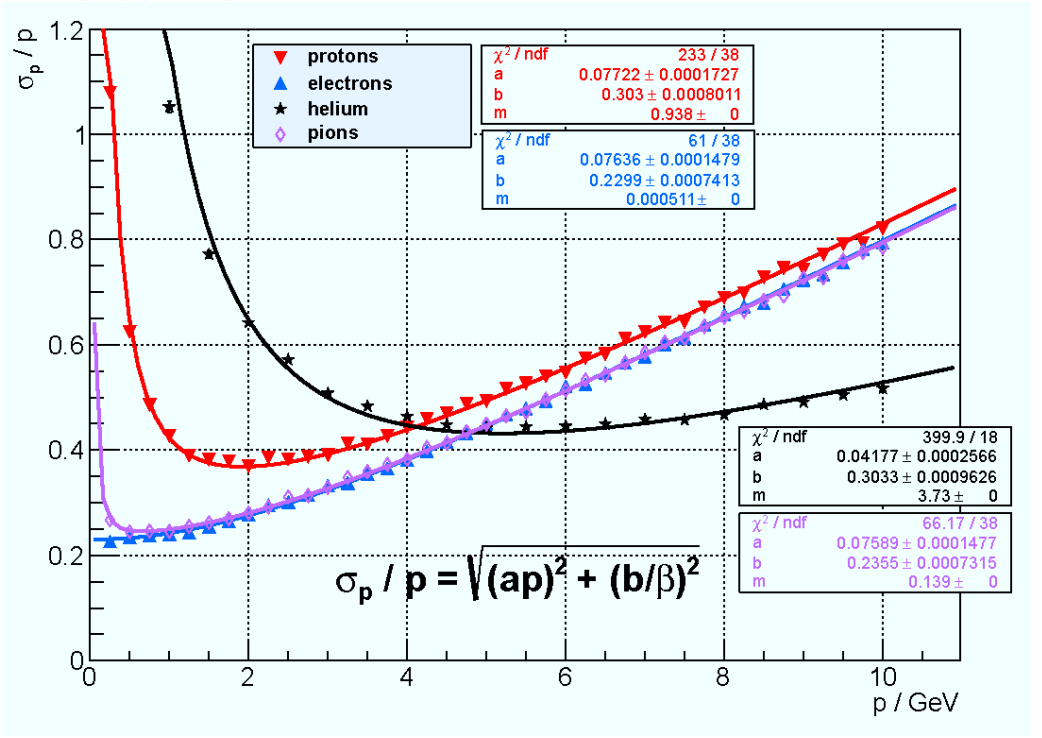
32 channel MPPC 5883 arrays:
- 0.25mm channel pitch
- 80 pixels (dynamic range)
- U_{bias} = 70V
- PDE 50%, Gain 10^6
- Pixel Crosstalk 30%
- Dark count ~200kHz/channel

PERDaix SciFi tracker



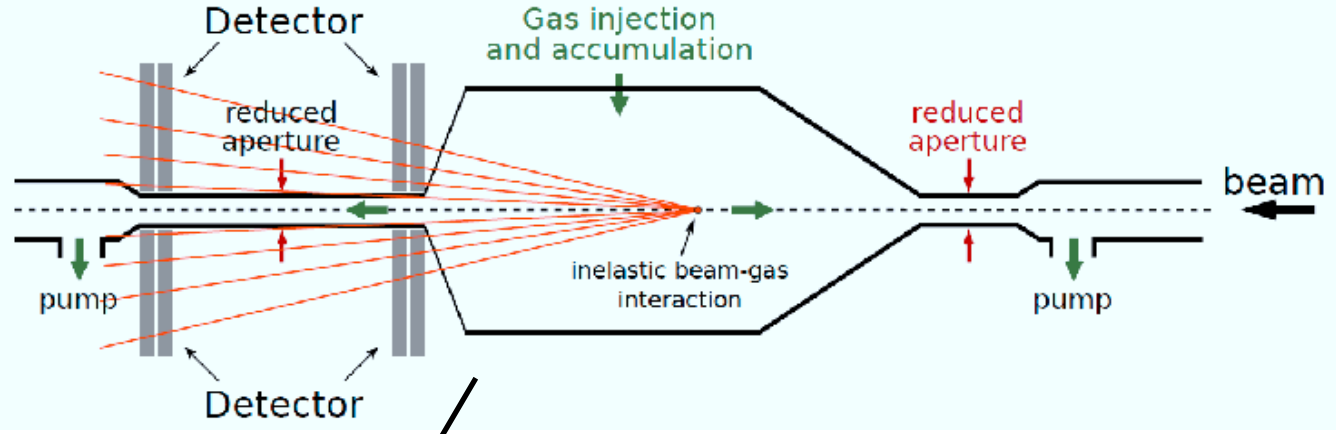




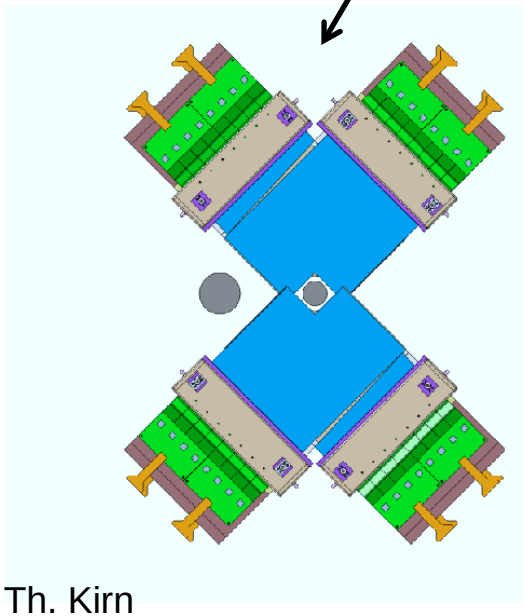


Beam Gas Vertex (BGV) Monitor

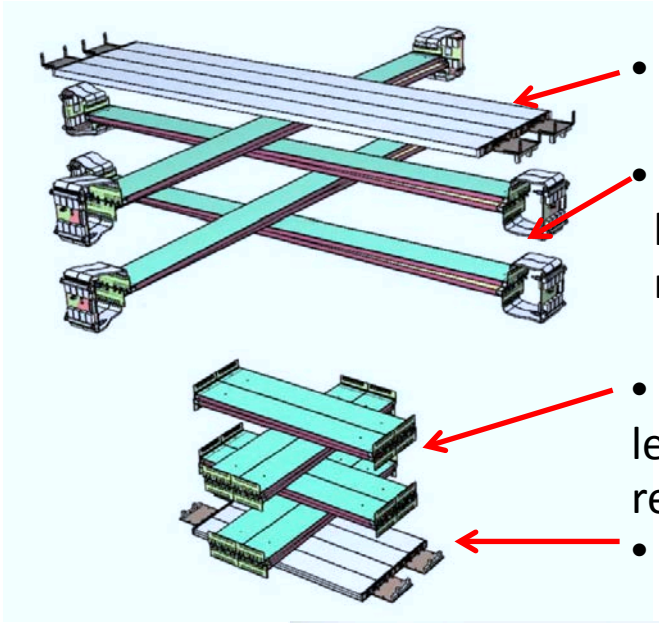
- For measuring the transverse beam profile
- Each vertex (inelastic beam-gas interaction) produces a number of particles
- Tracking detectors measure the charged particle trajectories and determine precisely the vertex position
- Gas target generates the needed rate of beam-gas interactions



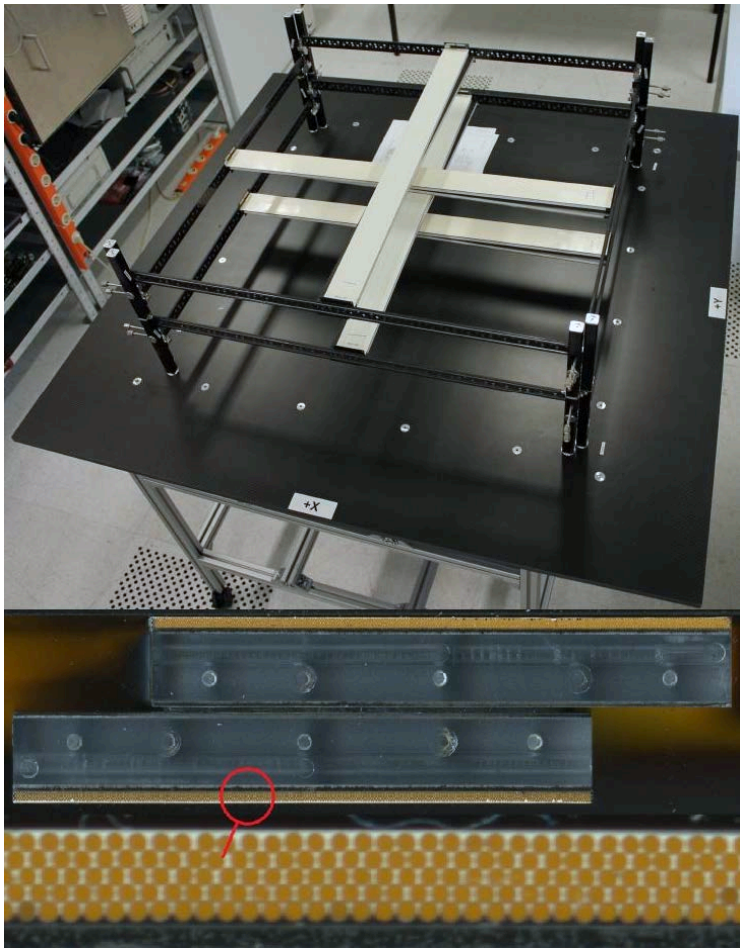
See talk C. Barschel:
Beam profile measurements based on modern vertex detectors and beam-gas interactions

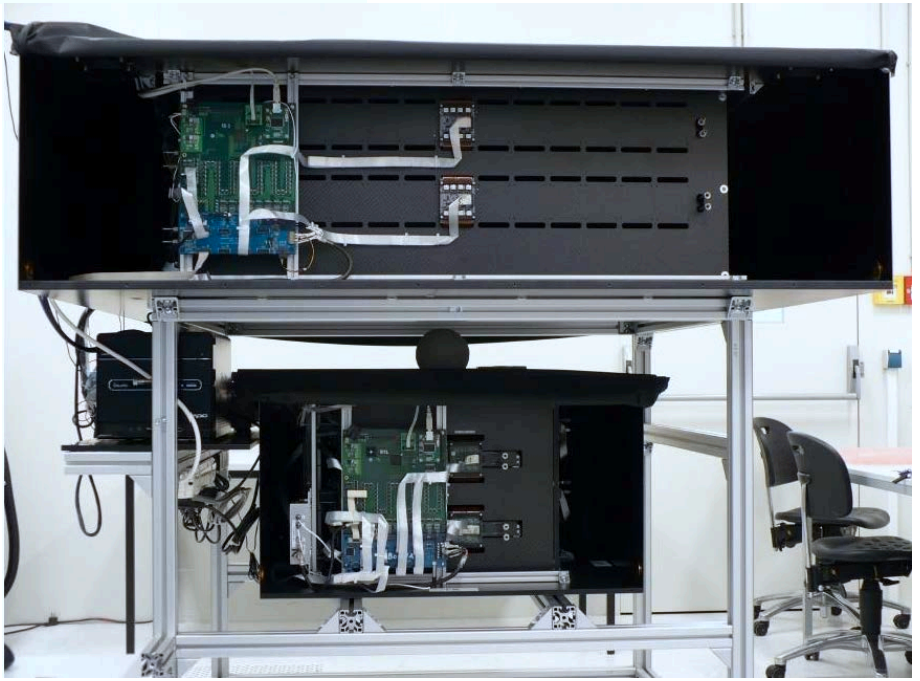


Scintillating Fiber Detector Modules: Muontomograph

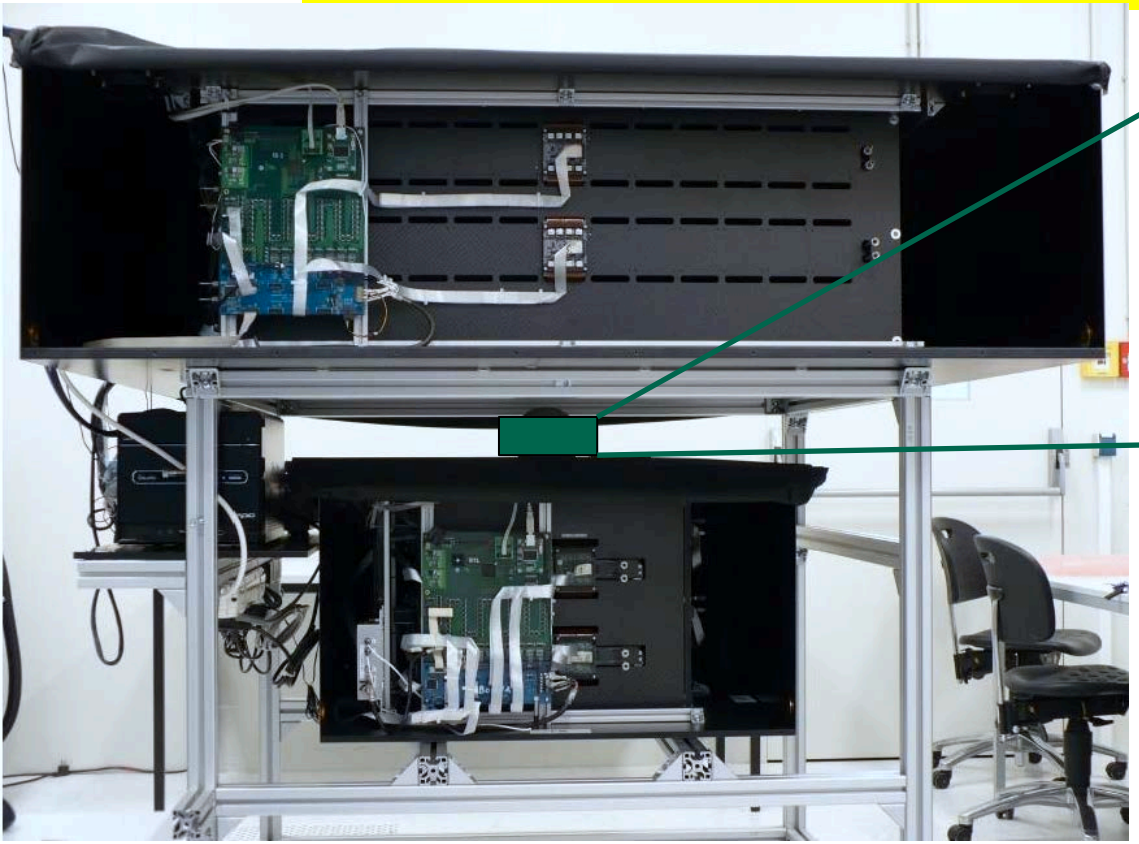


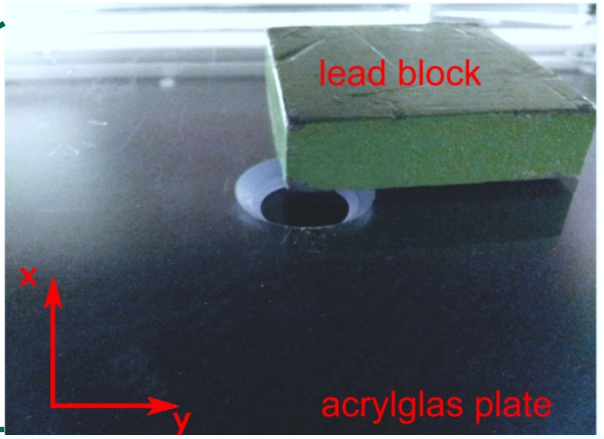
- Upper ToF System
- Upper SciFi mats
  length 860 mm, width 64 mm
  readout with SiPM arrays
- Lower SciFi mats
  length 400 mm, width 64 mm
  readout with SiPM arrays
- Lower ToF System

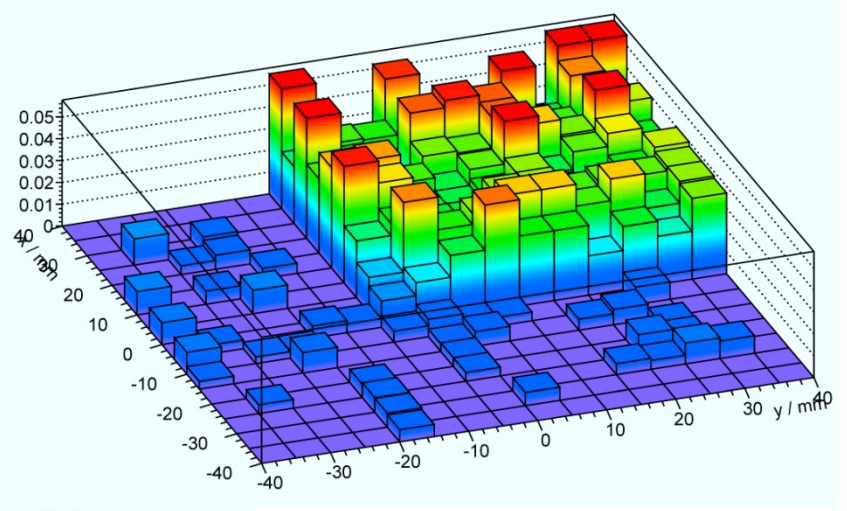




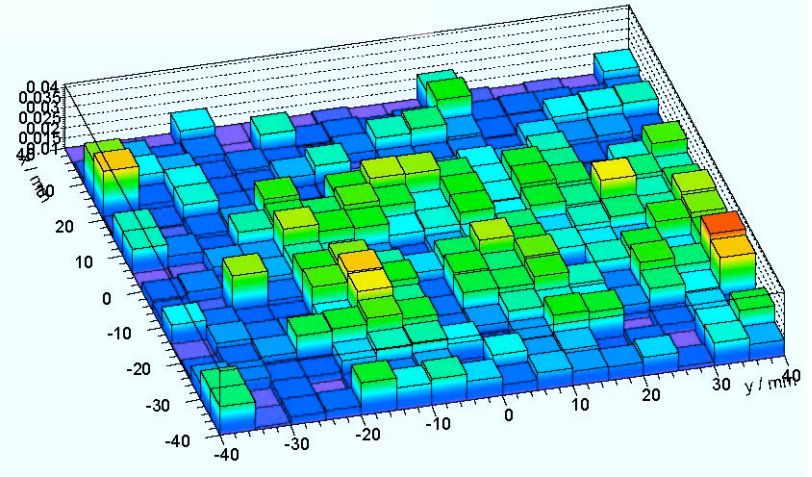
Scintillating Fiber Detector Modules: Muontomograph



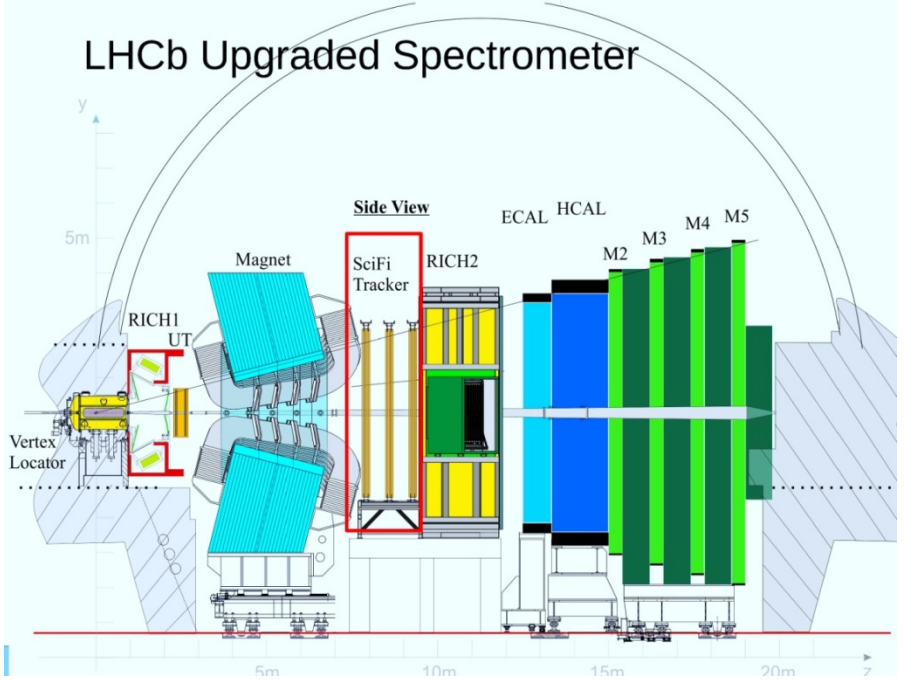


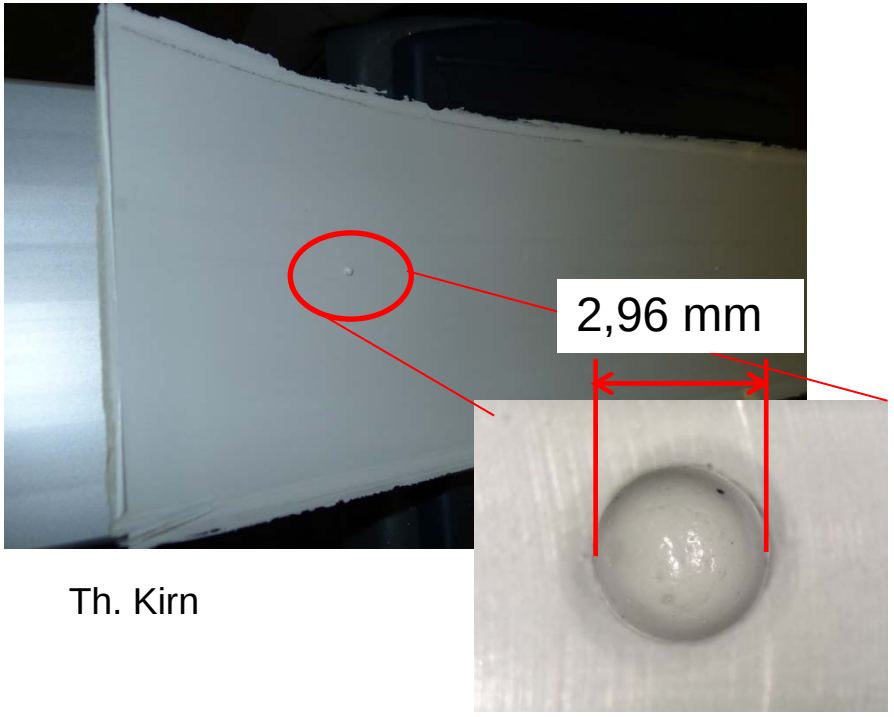


Cement block with RWTH symbol made out of tin:



Scintillating Fiber Detector Modules: LHCb Upgrade





See talk B. D. Leverington:
The Scintillating Fibre Tracker for the LHCb Upgrade

See talk M. Deckenhoff:
Scintillating Fibre and Radiation Damage Studies for the LHCb Upgrade

See talk Z. Xhu:
Silicon Photomultipliers for the LHCb Upgrade Scintillating Fibre Tracker

See Poster R. Ekelhof
Detector Module Design, Construction and Performance for the LHCb SciFi Tracker