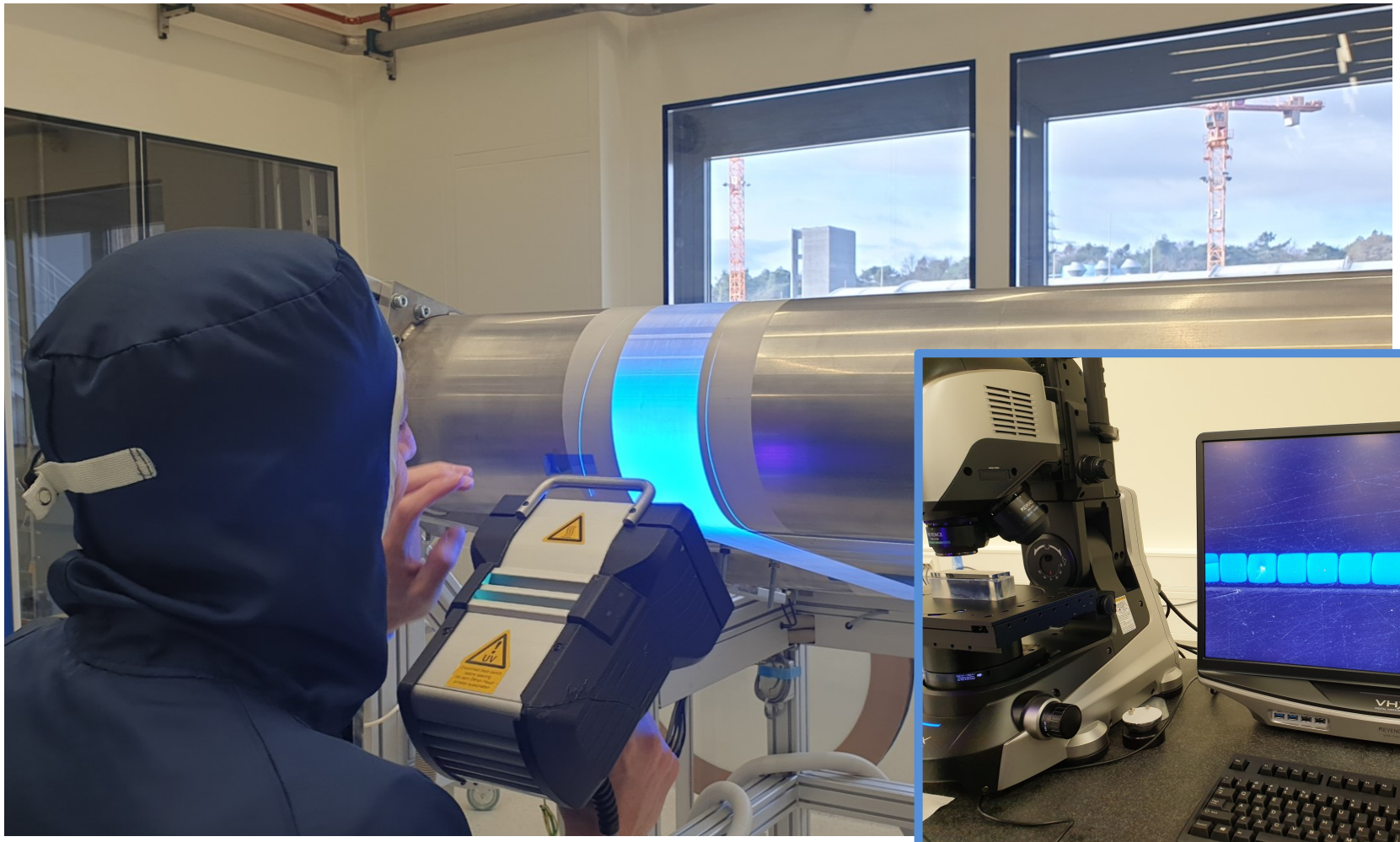
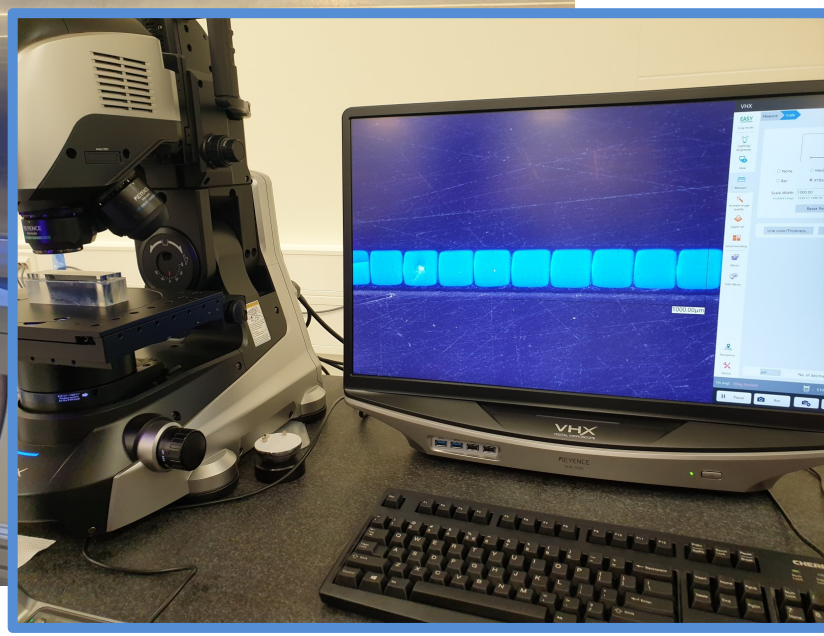
Scintillating Fiber Tracker

4d Tracking at High Rate with High Dynamic Range



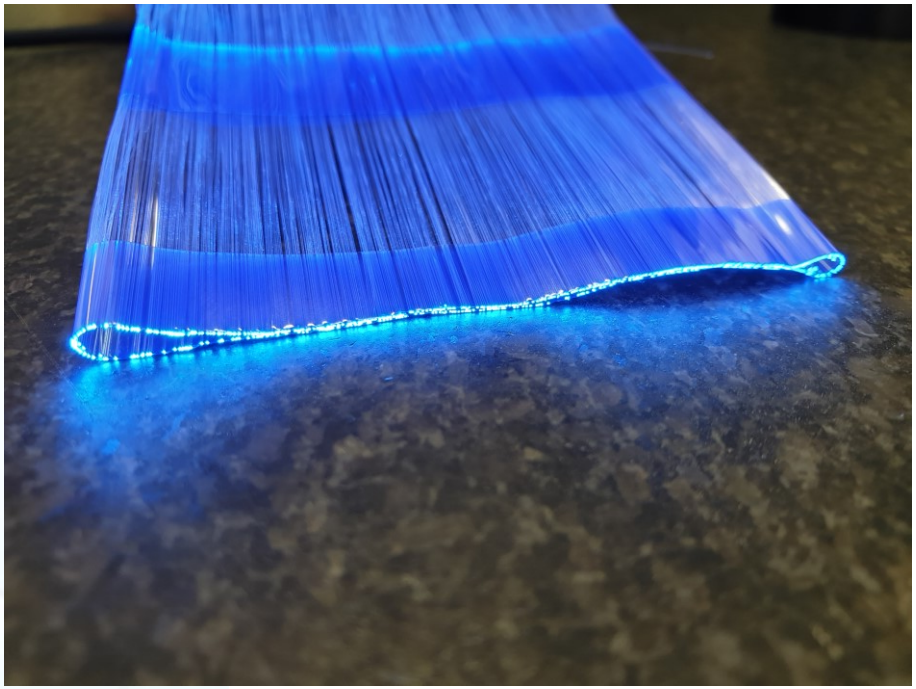


HELMHOLTZ SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

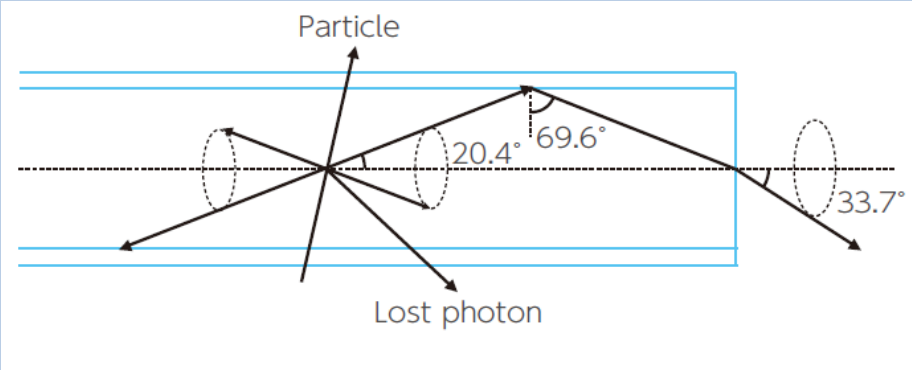
Google
Kellogg's
Nutrition™
FIBER
TRACKER
SEE HOW YOUR FOOD CHOICES CONTRIBUTE TO
YOUR FIBER INTAKE FOR THE DAY!

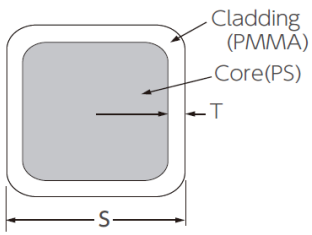
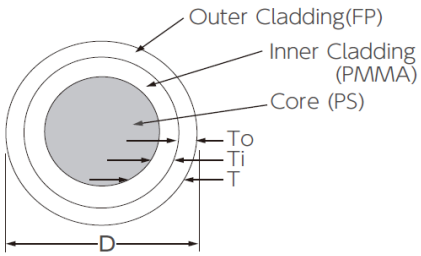
Google

scintillating



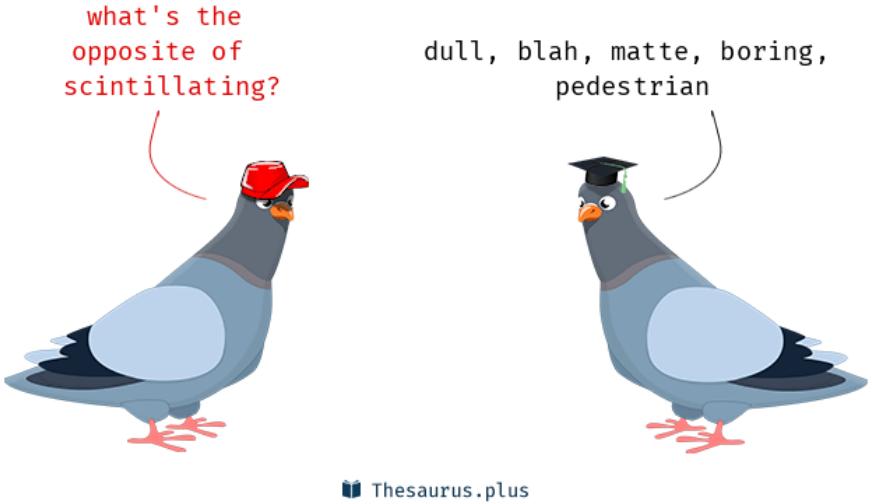
Scintillating Fiber – What is it?



Single Cladding	Multi-Cladding (M)
	
Cladding Thickness : T=2% of S Numerical Aperture : NA=0.55 Trapping Efficiency : 4.2%	Cladding Thickness[2] : T=2%(To)+2%(Ti) =4% of D Numerical Aperture : NA=0.72 Trapping Efficiency : 5.4%

The scintillating fibers have two roles:

1. act as scintillator
(scintillating dye is expected to be radiation hard)
2. transport the light to the PM (Si / MA)
(attenuation length is an issue , radiation hardness)



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Not a new technology

THE REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 31, NUMBER 10 OCTOBER, 1960

Some Considerations on Luminescent Fiber Chambers and Intensifier Screens

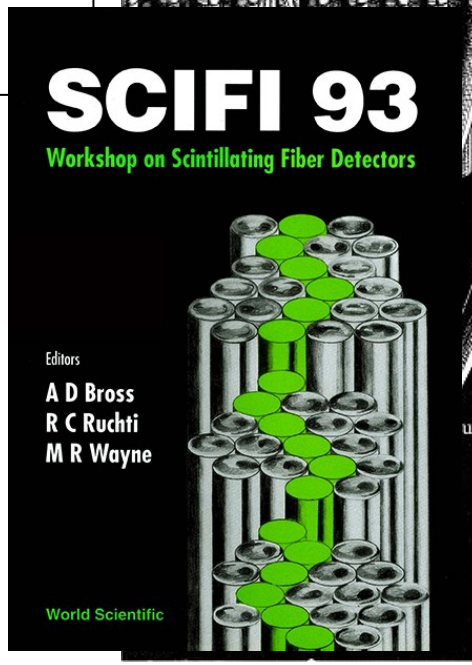
L. Reiffel and N. S. Kapany
Physics Division, Armour Research Foundation, Chicago 16, Illinois
(Received April 21, 1960; and in final form, June 1, 1960)

Many examples from the past

ELSEVIER Nuclear Instruments and Methods in Physics Research A 402 (1998) 67–74

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

A large-area scintillating fibre detector for relativistic heavy ions



what are other words for scintillating?

sparkling, glittering, clever, dazzling, witty, glinting, gleaming, effervescent, brilliant, twinkling

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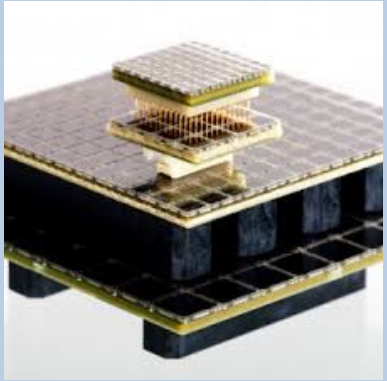
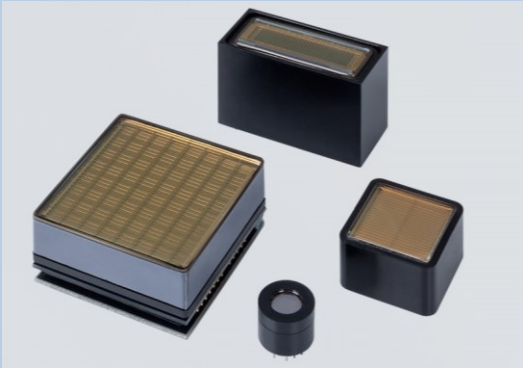
But still needed!

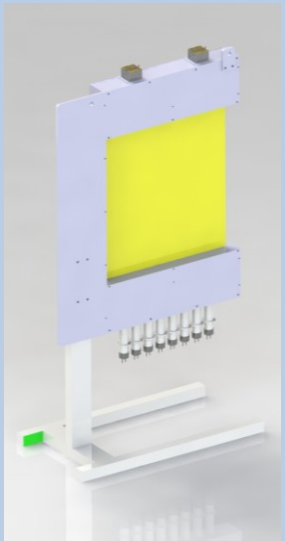
- production @ DL started in 2011 by J. Hehner
- revived mid 2017

fast detectors
→ 4d tracking

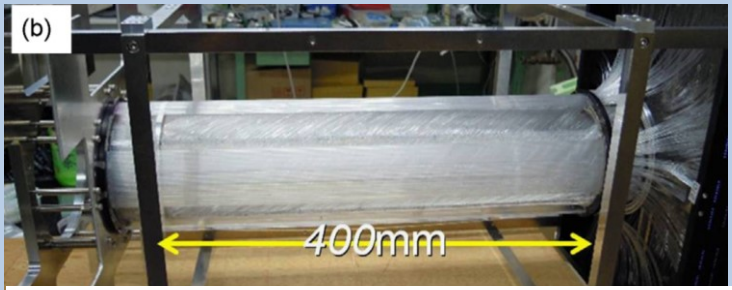
SiPM / MultiAnode photodetectors



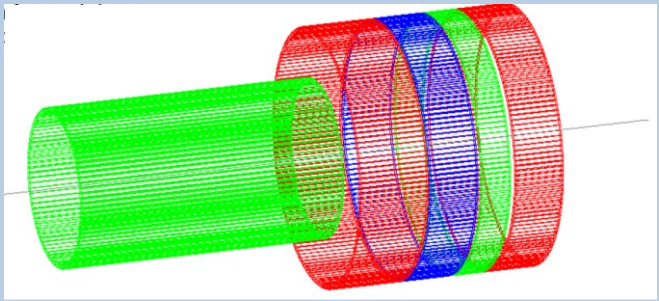




flexible geometry: various detector shapes are possible (plane, cylindrical, cuts, etc...)



Nuclear Instruments and Methods in Physics Research A 787 (2015) 193–196



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Prospects for future applications

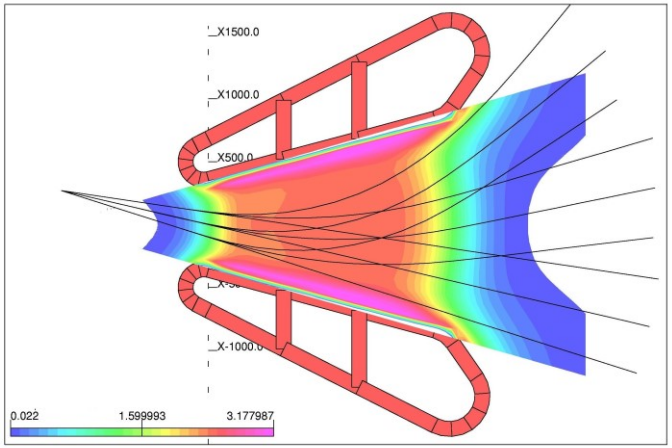
Two kinds of position detectors

1) tracking detectors (event-by-event)
   - R3B
   - SuperFRS
   - AsyEOS II (Krakow Barrel [KRAB])
   - WASA

2) Beam Profile Monitors („integrated“)

„Therapy“ -> QBERT colab. with SuperFRS
-> prototype for HIT

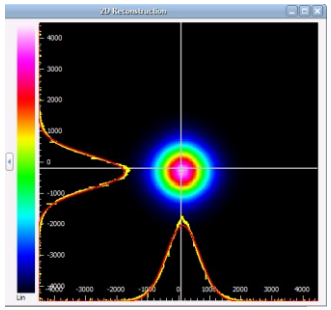
4D tracking (space and time!)

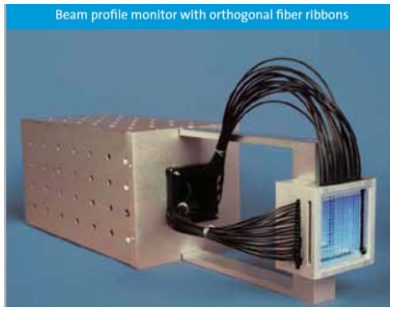


“Market Suvey”

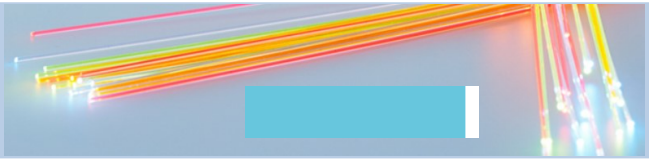
SAINT-GOBAIN CRYSTALS

Types of Fiber Assemblies Available
- Single ribbons 300mm x 3200mm
- Multilayered ribbons up to 4 layers





PSF is a type of plastic optical fiber developed as a radiation-detecting material



https://twiki.cern.ch/twiki/bin/view/LHCb/FibreMatsModules

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Fiber Tracker

Fibre quality control (RWTH, Aachen)

Drum from Kuraray

Tension control

Cleaning (dust)

Measurement of fiber diameter and light leak

Drum ready for production

Data base for traceability

Similar setup is running at Dortmund TU.

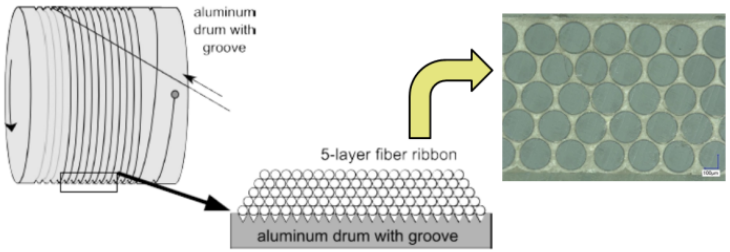
(picture by B.Leverington)

12 June 2014 SciFi Tracker First SHiP Workshop, Zurich 14

SciFi ribbon fabrication method

2 steps:

- Fibre rewinding from a large Kuraray cardboard (Ø 1000 mm) drum to a smaller (Ø300 mm) plastic one, fibre quality control during rewinding.
- Winding process allows production of 5(6)-layer fibre ribbon using the EpoTec epoxy glue impregnated with TiO_2 bonding

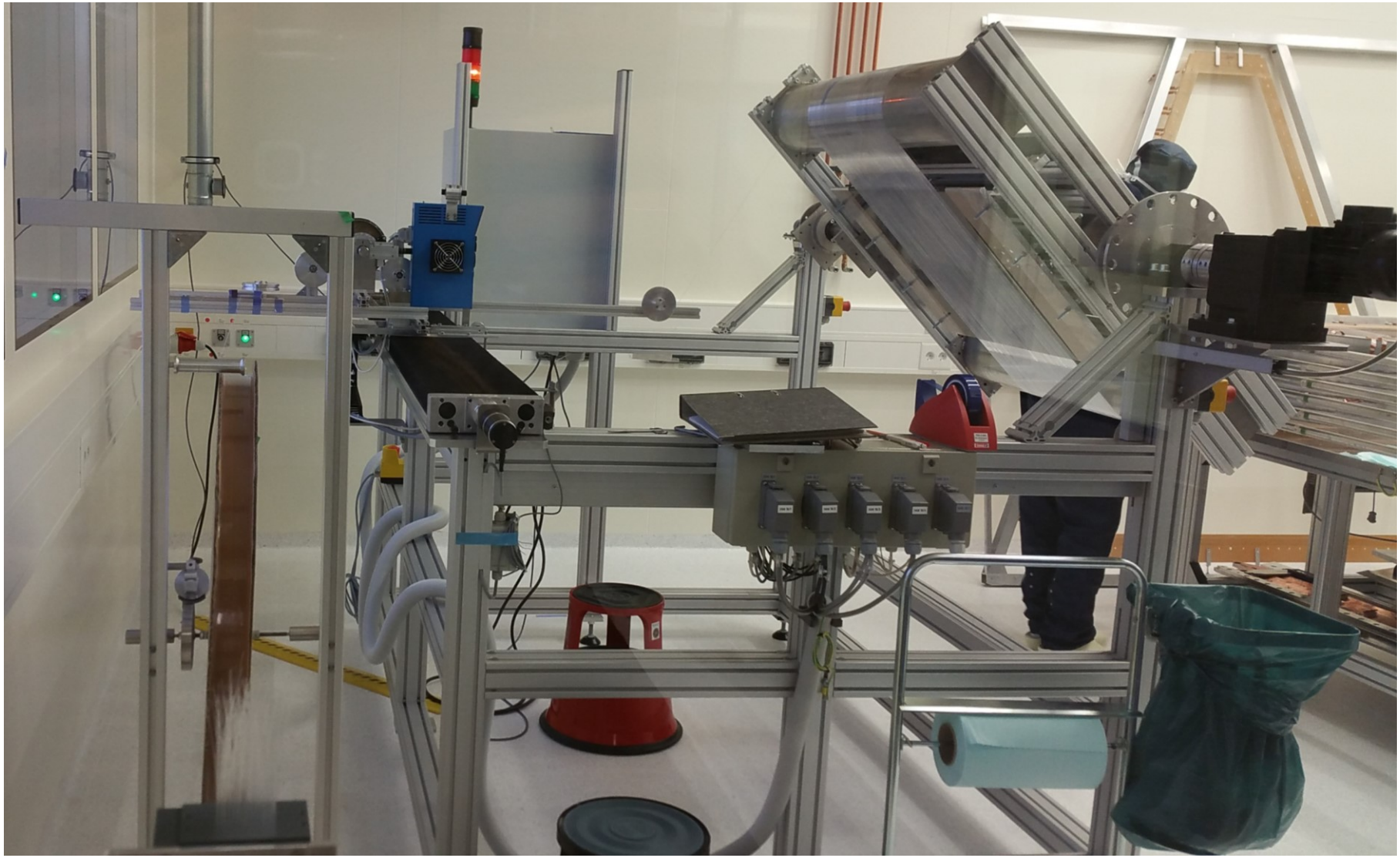


12 June 2014 SciFi Tracker First SHiP Workshop, Zurich 13

Differences of our "productions" to LHCb one

- very flexibel:
  - size
  - shape
  - fiber type
  - number of layers
- glue not applied to complete fiber

Infrastructure @ [redacted] -



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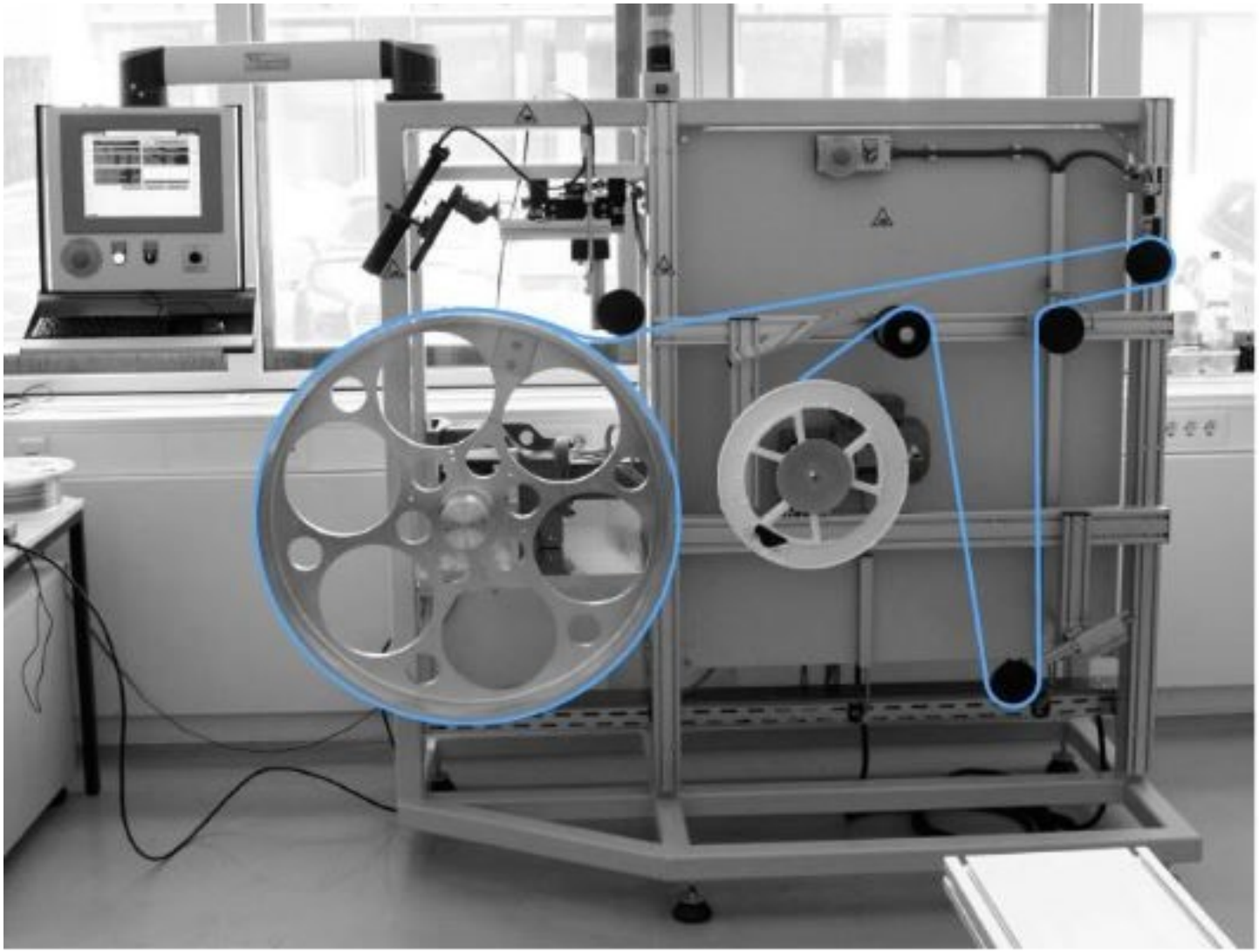
Infrastructure @ [redacted] -



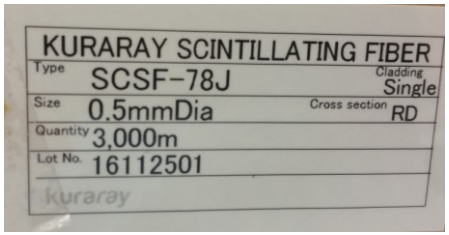
At the moment a fully automatic winding is unfortunately not possible

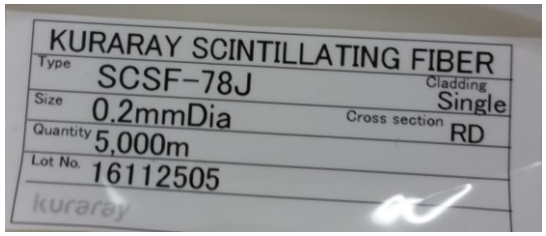
Fiber Tracker One Example

Material used:

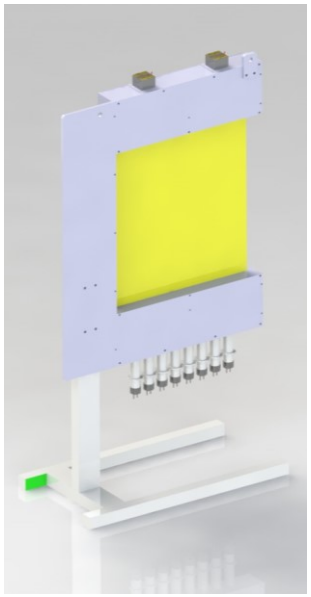
- 10mu Pokalon foil
- EPO-TEK 301-2 glue
- Kuraray Fiber
- Araldite 2018
- QSil 216 for light coupling
- Hamamatsu H9500 MAPMT
- Hamamatsu PMT R9779 (NeuLAND)

main criteria material budget and its homogenity





operated in vauum	yes	
Maximum active area	50 x 50	cm2
Maximum allowed length in beam direction	10	cm
Position resolution	200	mu
Positioning	/	
Time resolution	/	
Maximum rate capability	1	1 MHz/ch
Dynamic range	p - U	



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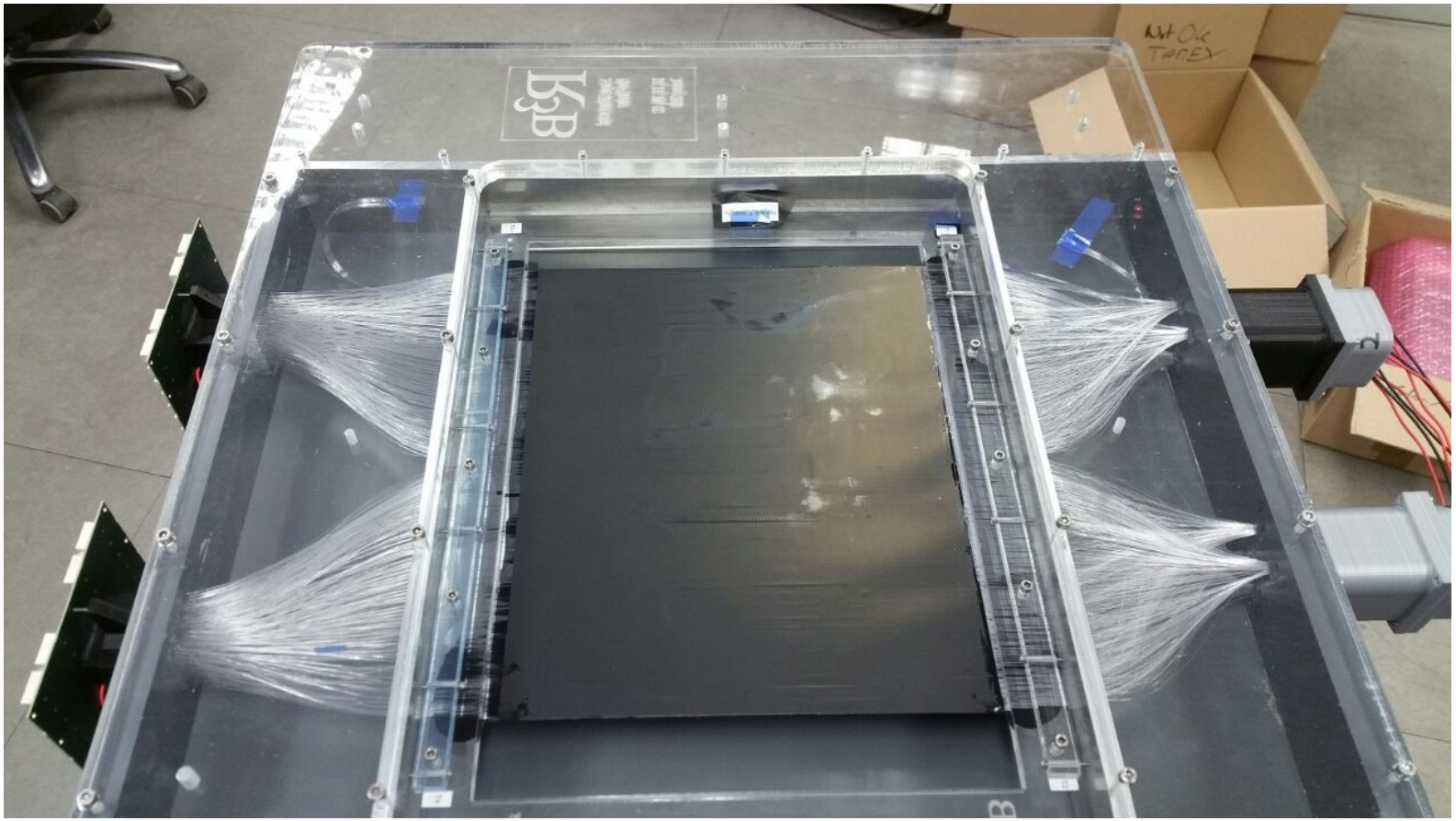
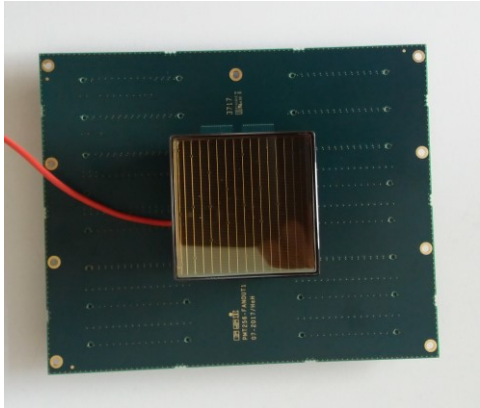
Fiber Tracker Example: Fiber4

- 0.2 mm thick and round plastic-scintillator fibers.
- 2048 fibers, total dimension of the detector 30 x 40 cm^2.
- 4 fibers bundled to one anode of MAPMT
- 4 single PMT on the other side to distinguish the fibers.



Fiber Readout (Prototype)

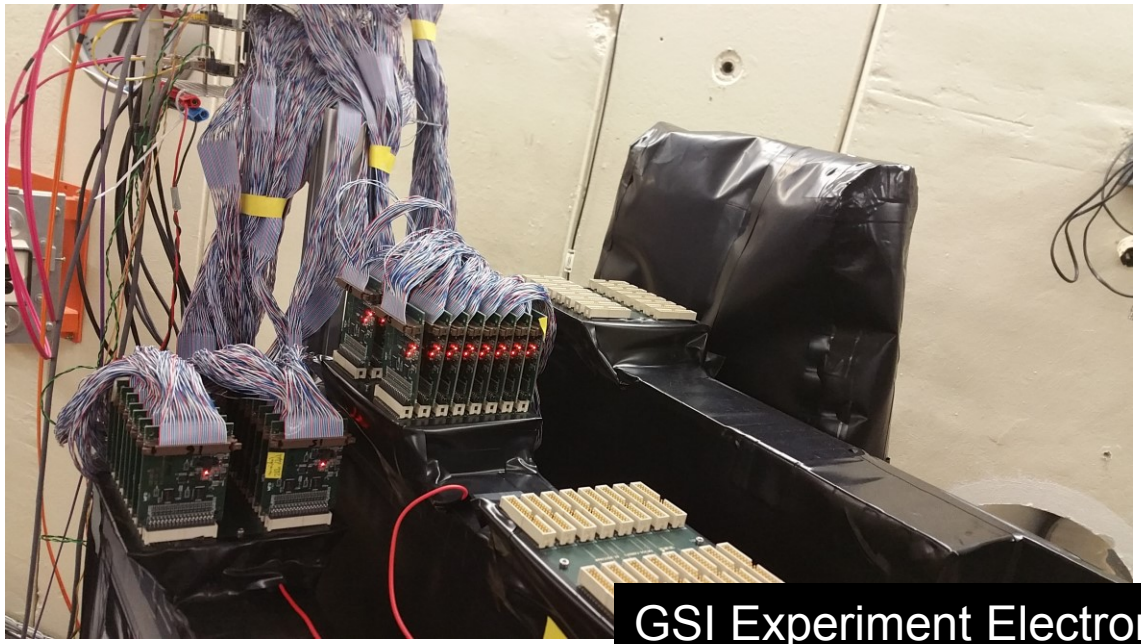
- Hamamatsu H9500 (H13700) MAPMTs
- 16 “PADI boards” and 2 “Clock-TDC” boards for 1 MAPMT

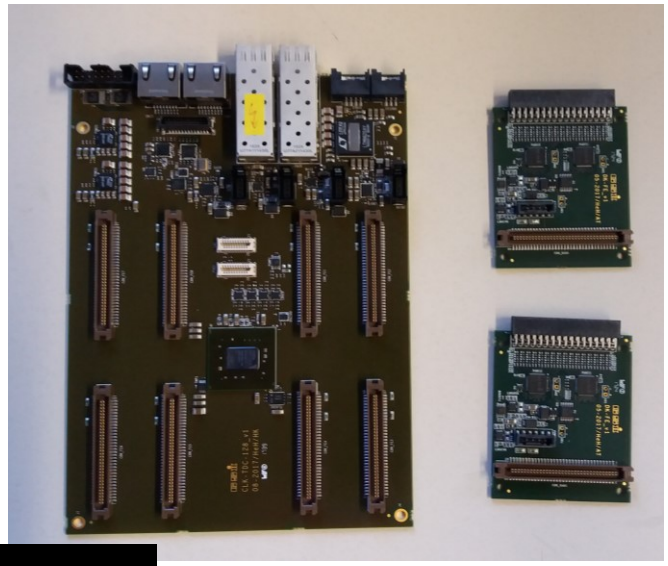


Clock-TDC (128 channel FPGA TDC, 250 ps rms leading edge and ToT multi hit TDC) Xilinx Kintex 7

PADI, an Ultrafast Preamplifier - Discriminator ASIC

IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 61, NO. 2, APRIL 2014





GSI Experiment Electronic (EE)

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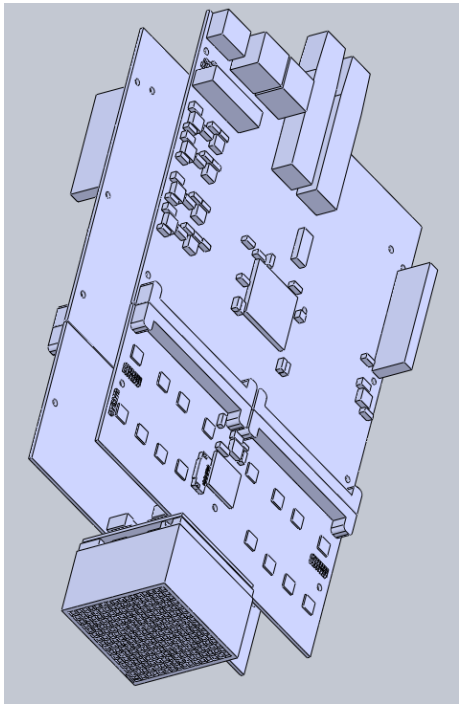
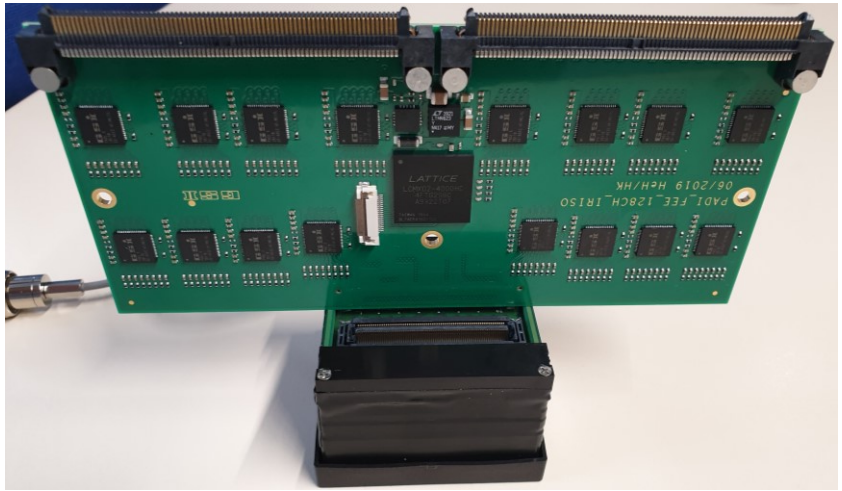
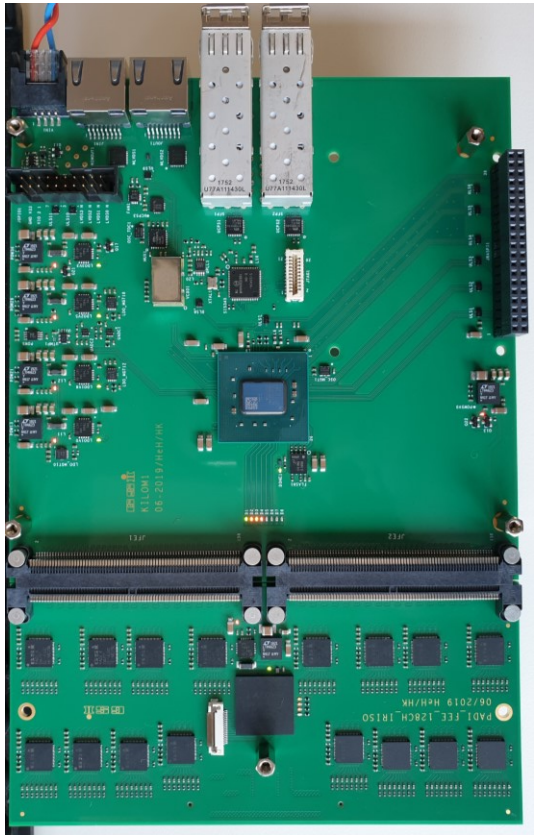
Fiber Readout (KILOM)

FANOUT+16 PADI FEEs (+Cables) + ClockTDC

One compact Module







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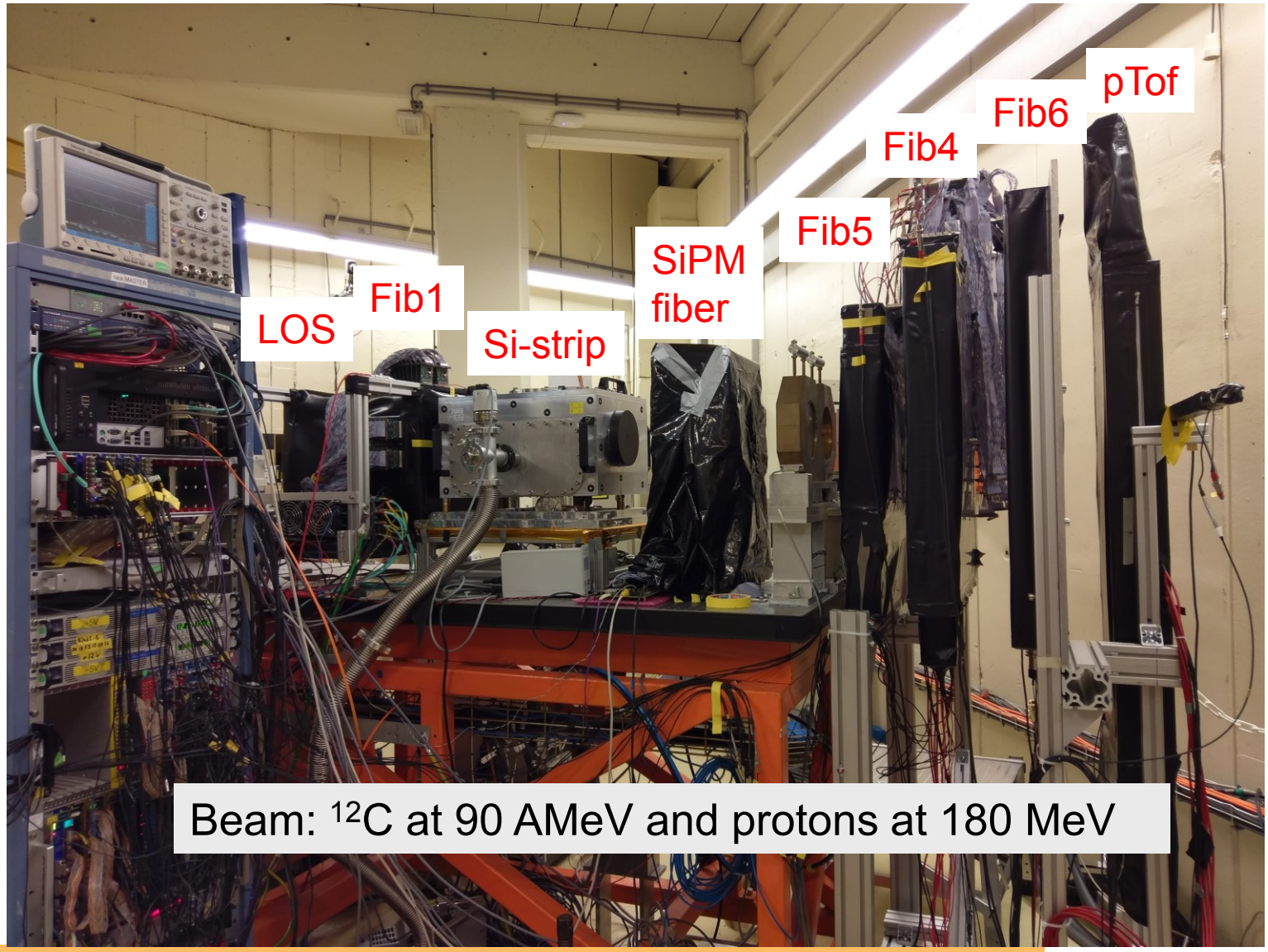
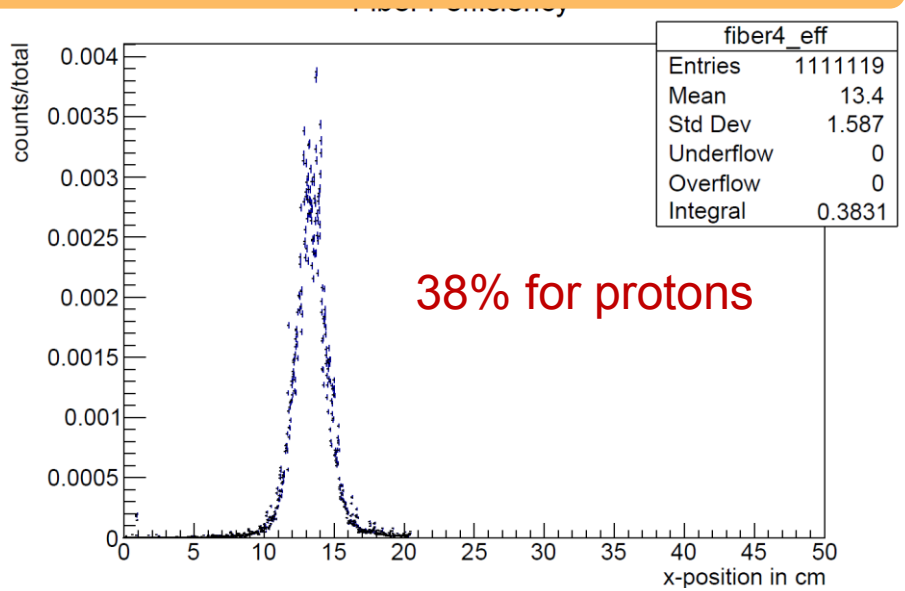
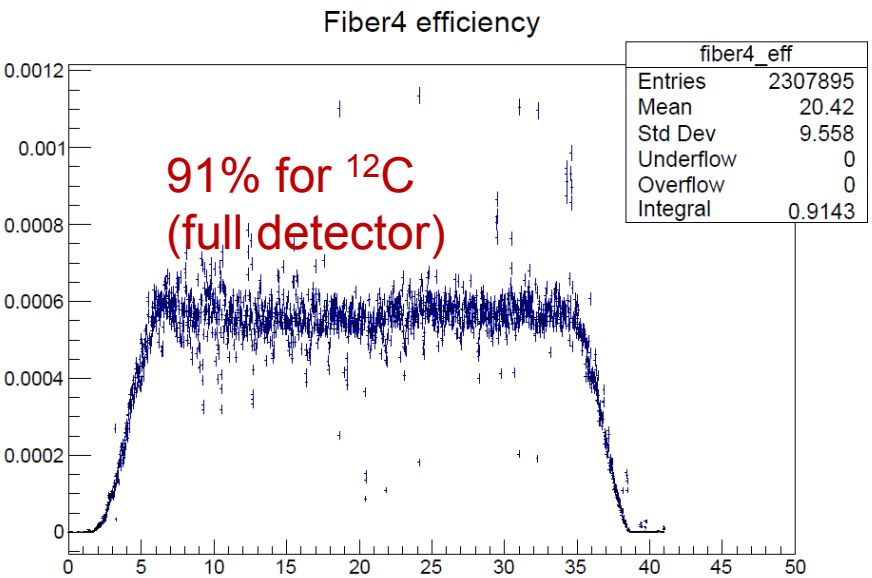
Test Beam @ KVI

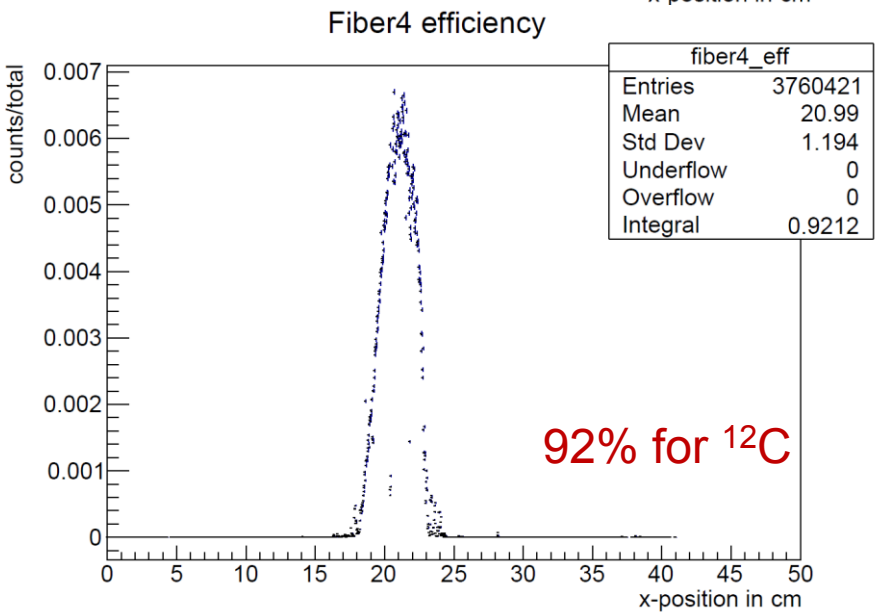


Fiber4 efficiency

Fiber efficiency is 92 % for ^{12}C beam and 38 % for protons

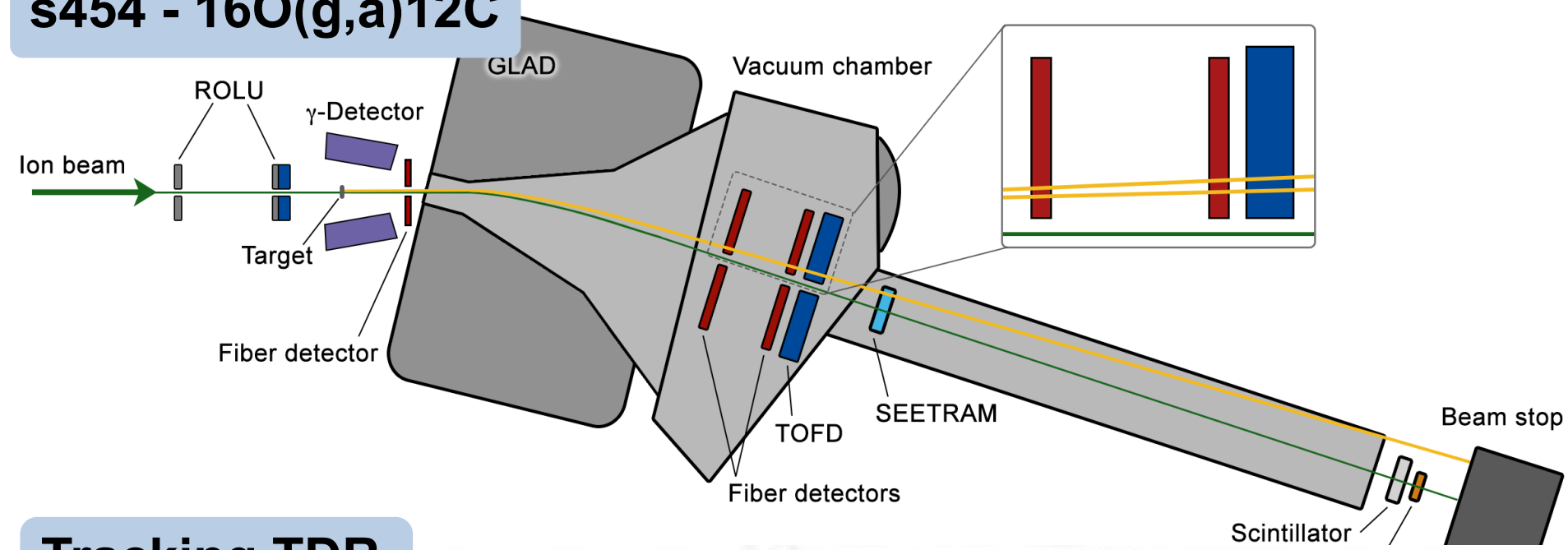




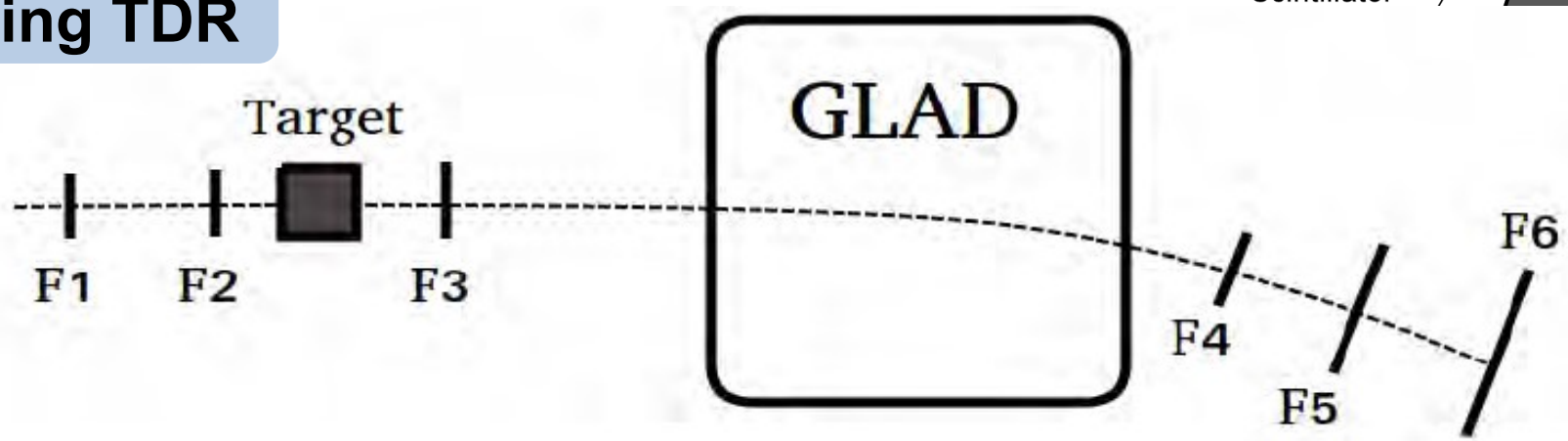


R3B - Setup

s454 - 16O(g,a)12C



Tracking TDR



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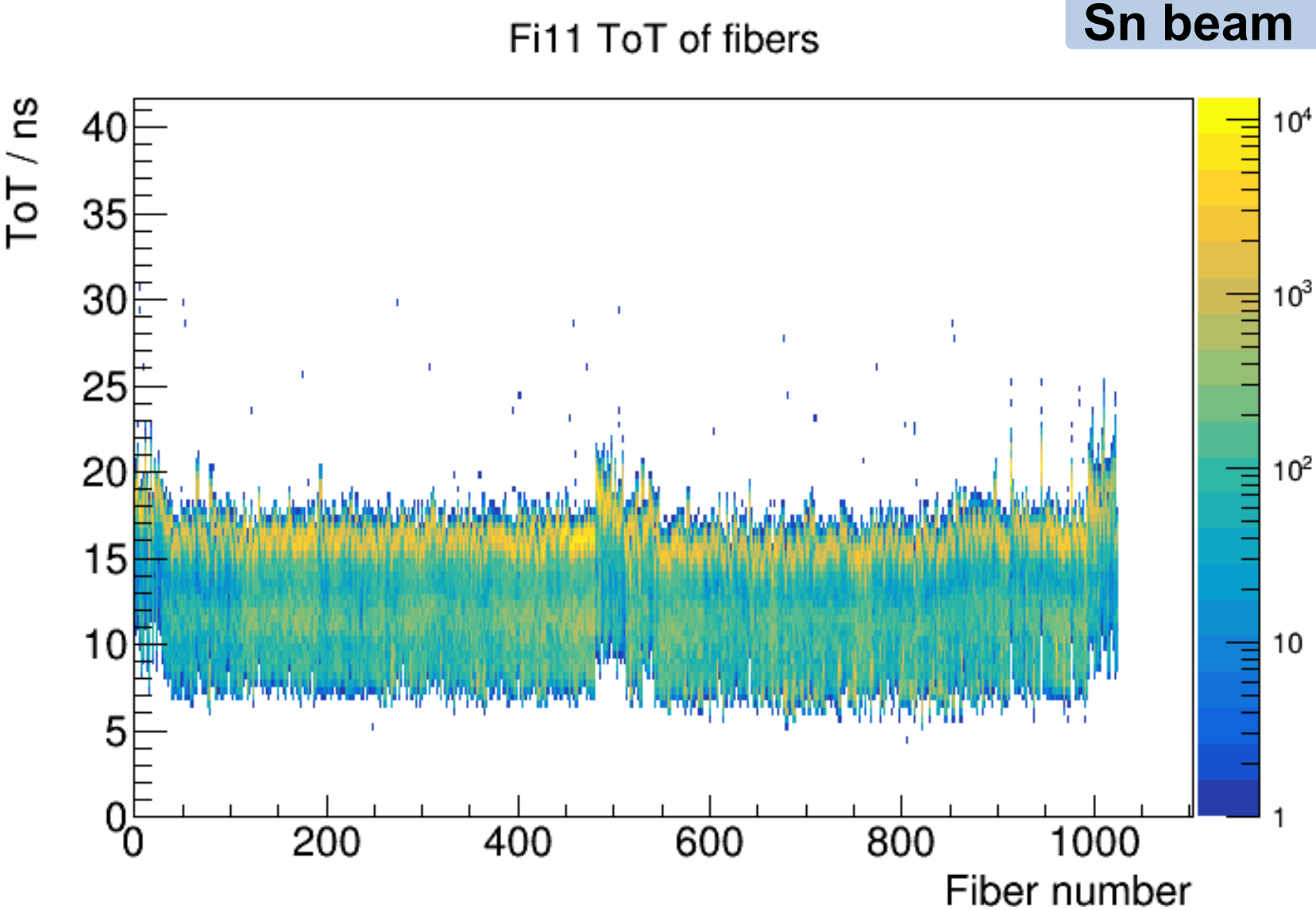
R3B - Setup:

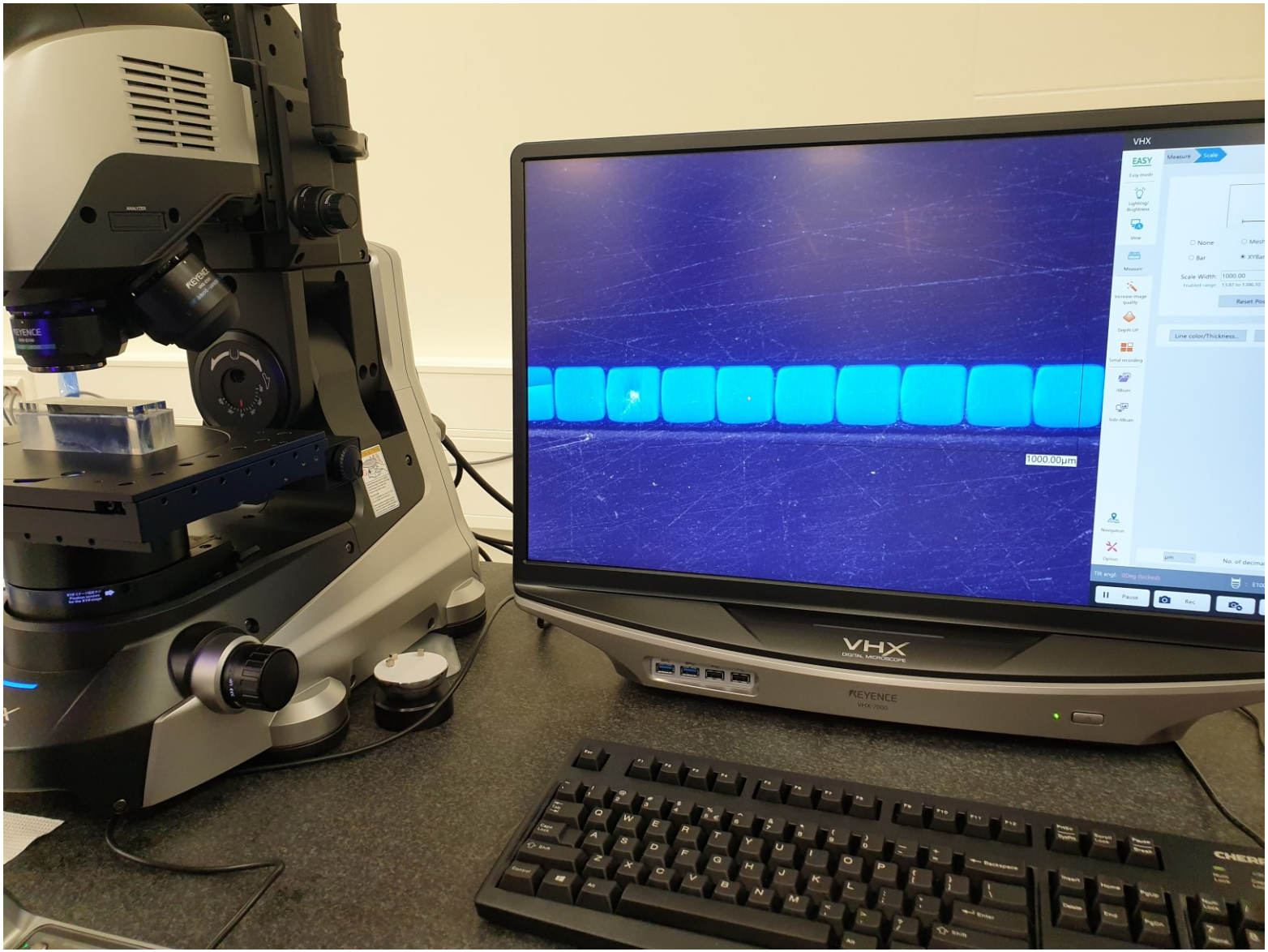
s454 - 16O(g,a)12C

R3B - s473 prelimary „Analysis“

Sn beam



Quality Assurance - optical inspection: Fiber Ribbon



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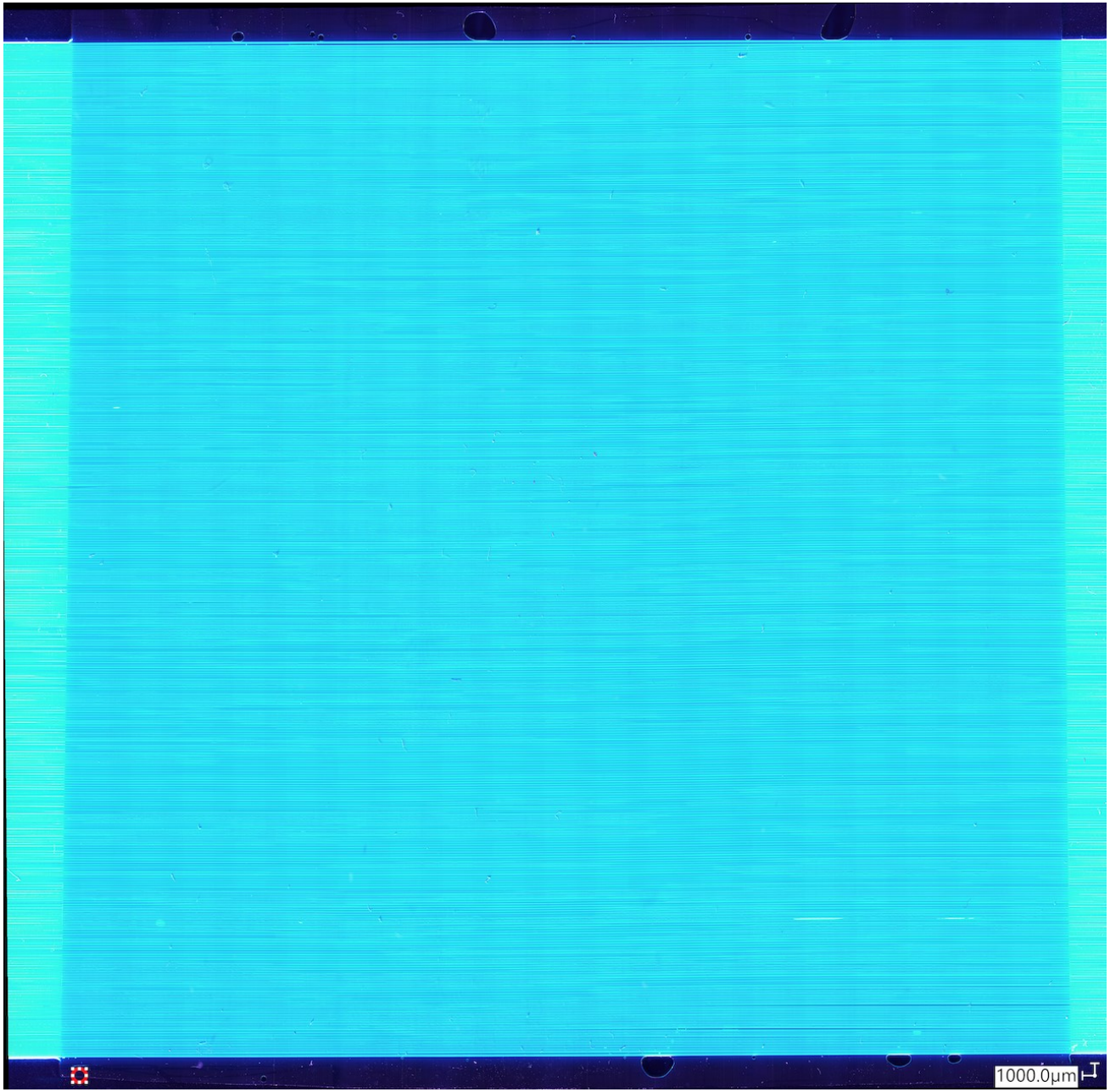
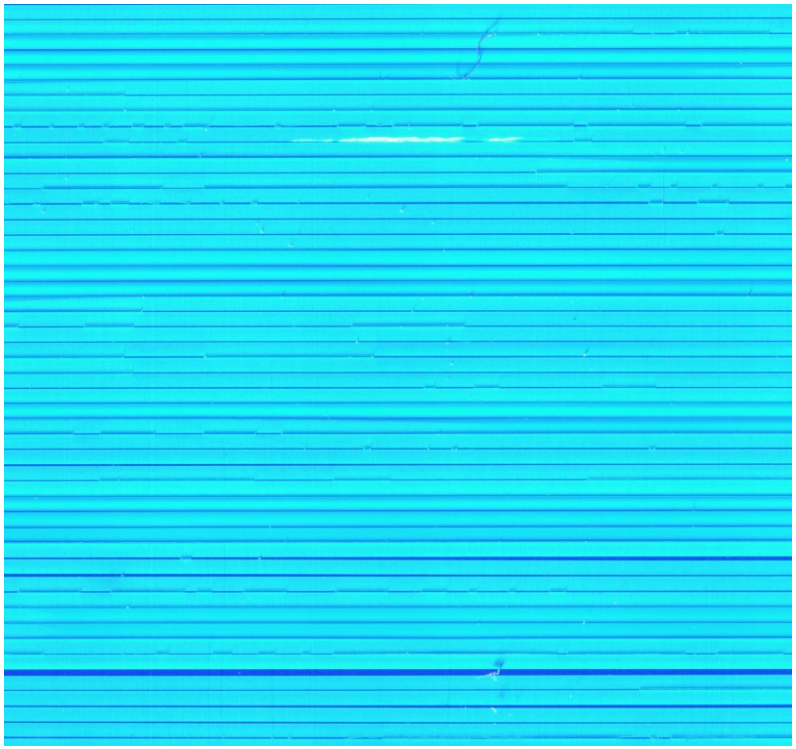
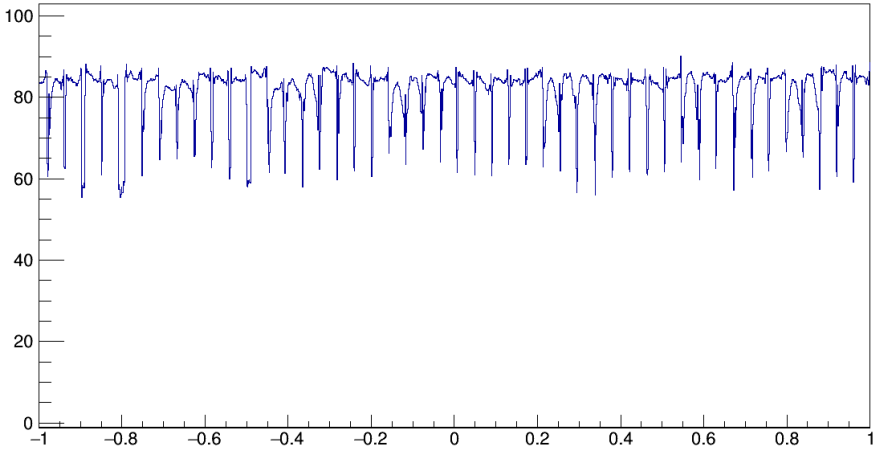
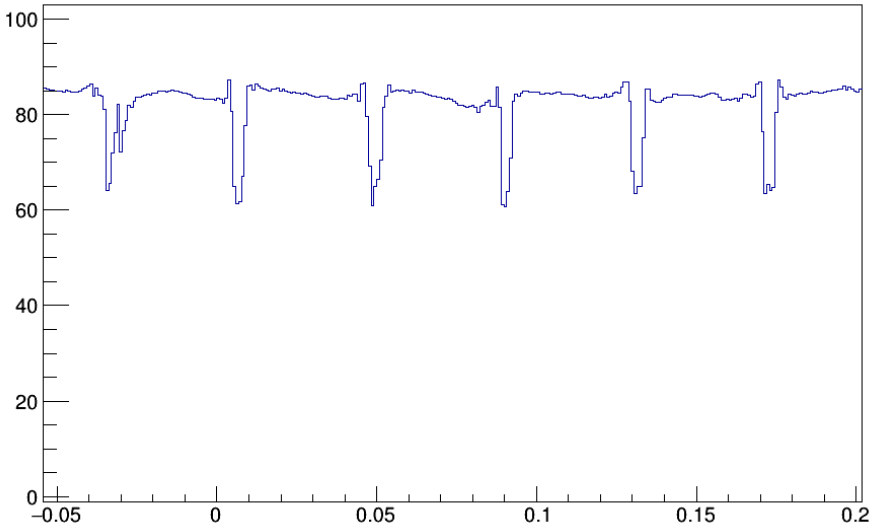


HELMHOLTZ SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

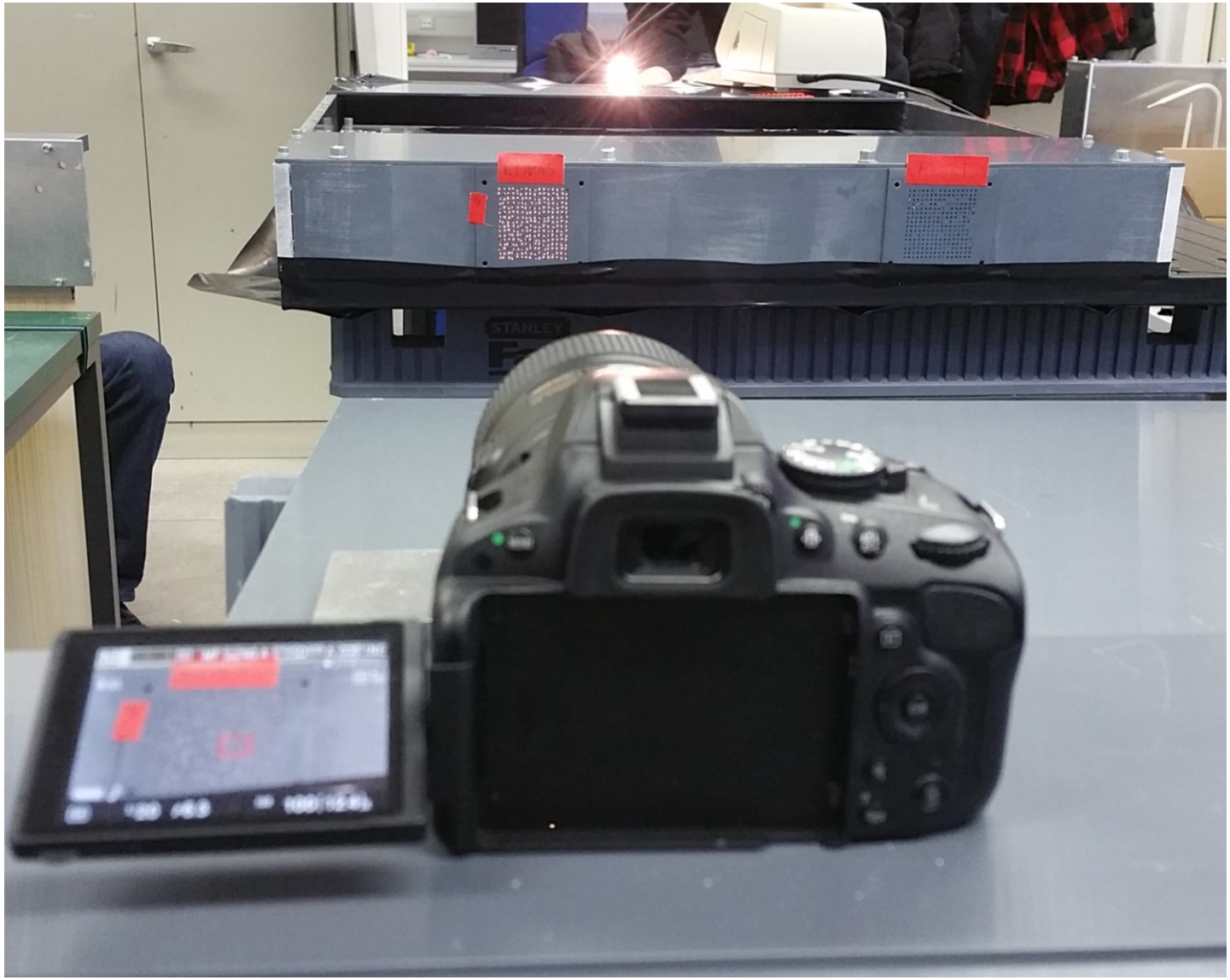


1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1 −0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8 1
0.9
0.8
0.7
0.6
0.5
0.4


100
80
60
40
20
0
−1 −0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8 1


100
80
60
40
20
0
−0.05 0 0.05 0.1 0.15 0.2

Quality Assurance - optical inspection: Fiber Mask



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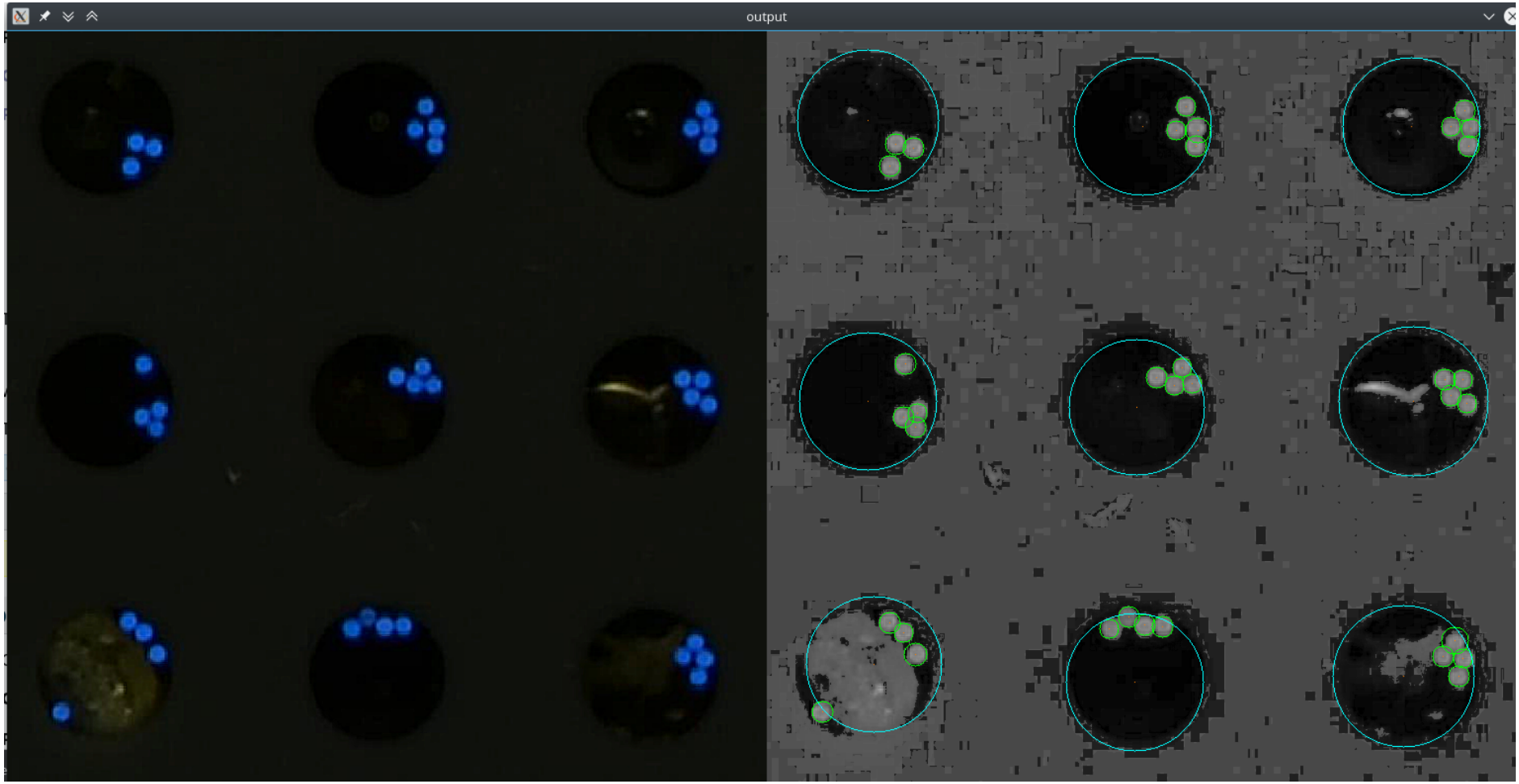
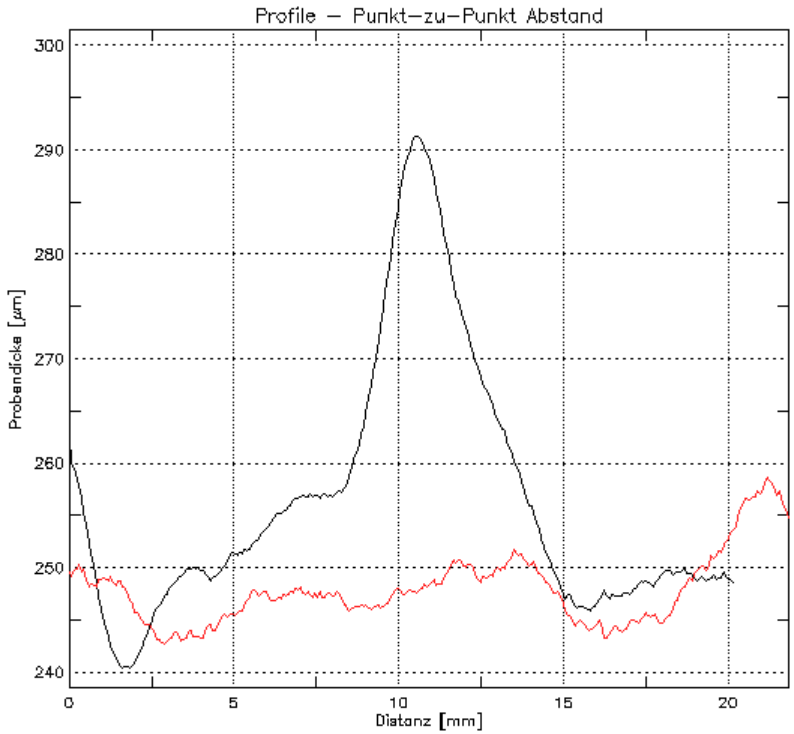
Quality Assurance - optical inspection: Fiber Mask

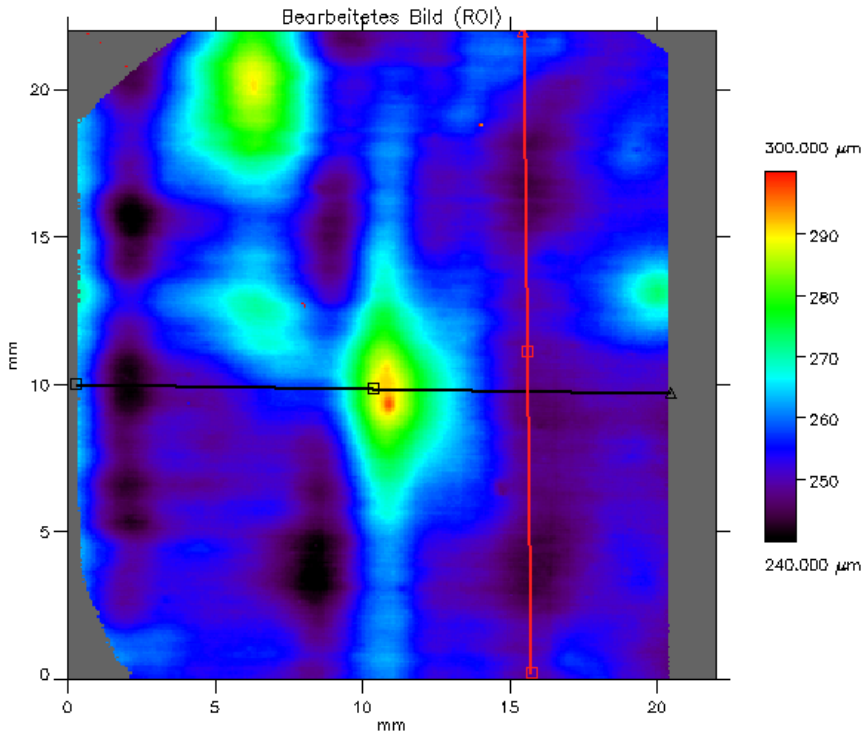


Quality Assurance

Thickness measurement @ Target- Lab
Chromatic aberration

	in µm
Mittelwert	**255**
Minumum	239
Maximum	648
Standardabweichung	**9**





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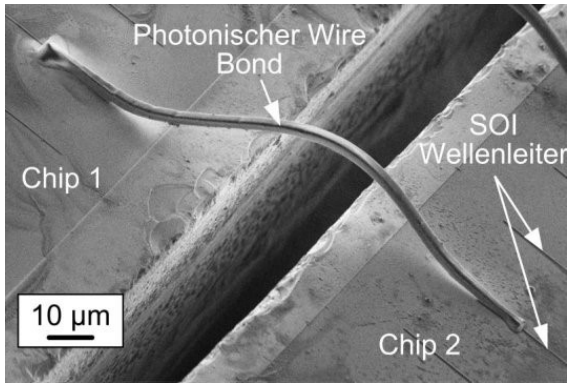
Summary

single layer planar detectors can be produced ‚fast‘ 200mu/500mu; square/round up to 50x50 cm2



Outlook

- Establish QA
- optimize infrastructure
- SiPMs readout
- investigate rad. hardness
- investigate outgasing
- learn from optical fibers
  - ‚optical wire bonding‘
  - V groove chips

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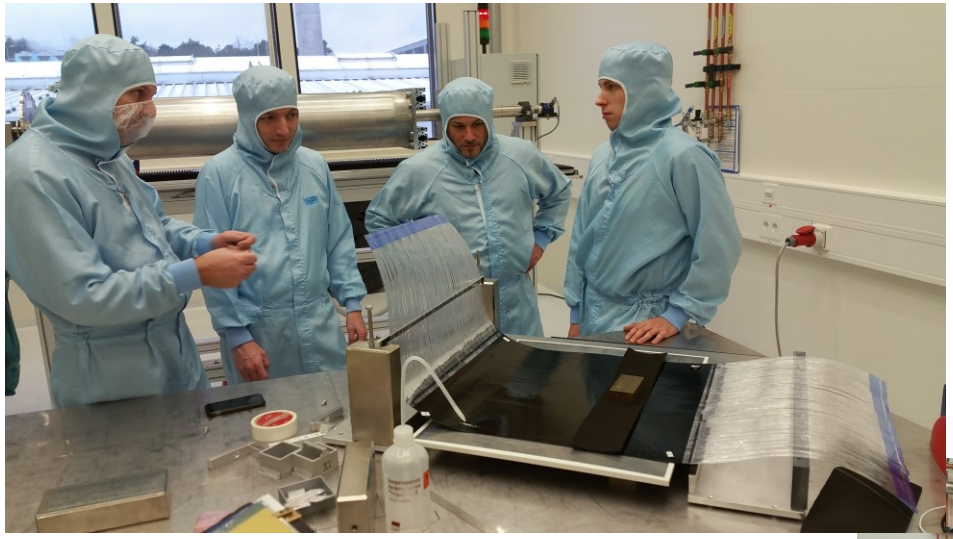
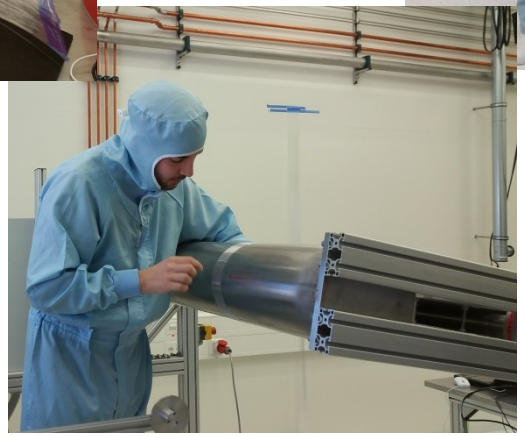
Working - Group

DL:	Jörg Hehner, Christoph Caesar
EE:	Henning Heggen, Nik Kurz
R3B:	Deniz Savran, Michael Heil, Daniel Körper, Bastian Löher, Kathrin Göbel





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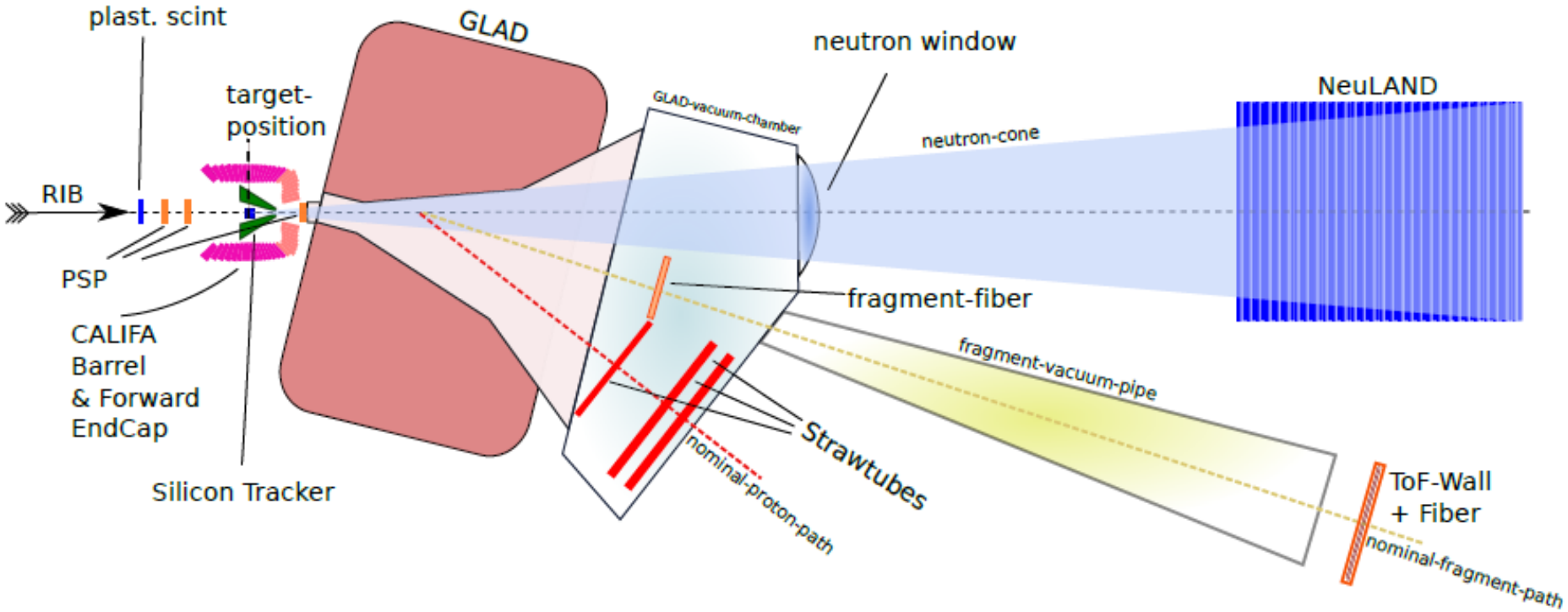
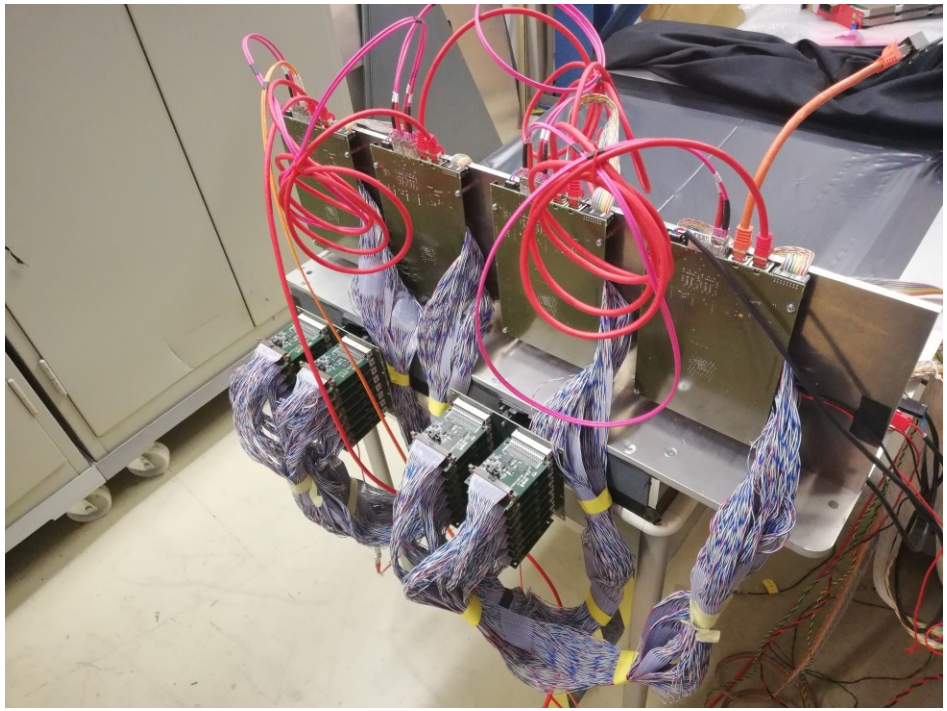
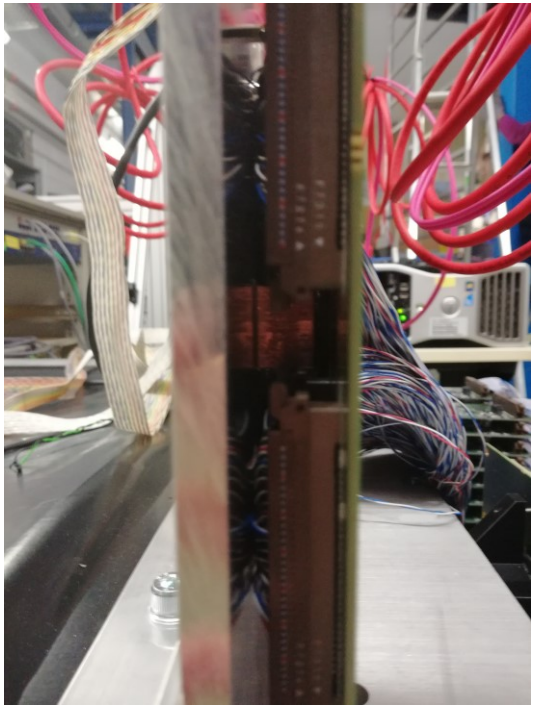
R3B - Setup


plast. scint
GLAD
neutron window
target-
position
GLAD-vacuum-chamber
NeuLAND
neutron-cone
RIB
PSP
fragment-fiber
CALIFA
Barrel
& Forward
EndCap
fragment-vacuum-pipe
Strawtubes
nominal-proton-path
Silicon Tracker
ToF-Wall
+ Fiber
nominal-fragment-path

Tests in vacuum

- PADI boards tested in vacuum without cooling.
- Clock TDC gets too hot without cooling.
- FPGA is hottest part on PCB. Passive cooling with copper block pressed against Alu board is sufficient.
- Full system has been tested!





detector outgassing is mainly due to the glue that fixes the fibers

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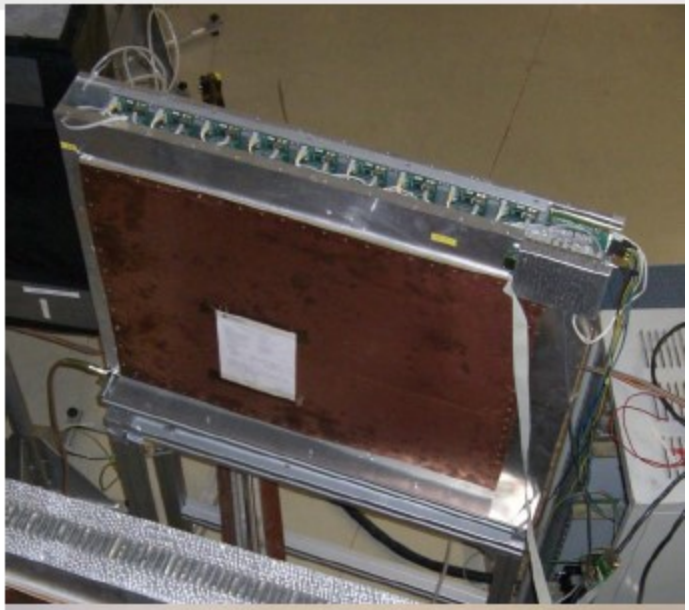
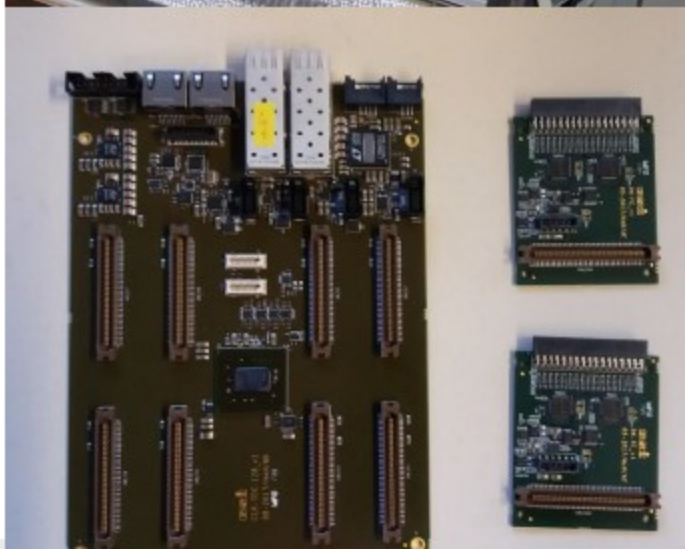
PDCs and clock TDC electronics

- A new read-out based on PADI and clock-TDC has been designed by the GSI electronics department (Nikolaus Kurz, Henning Heggen, Shizu Minami).
- The PADI is suited for small signal amplitudes of the PDCs (> 3 mV) .
- The clock frequency is 250 MHz with 8 phases (later maybe 16 phases).
- First tests show that times and ToTs can be measured with an RMS of 200-320 ps.





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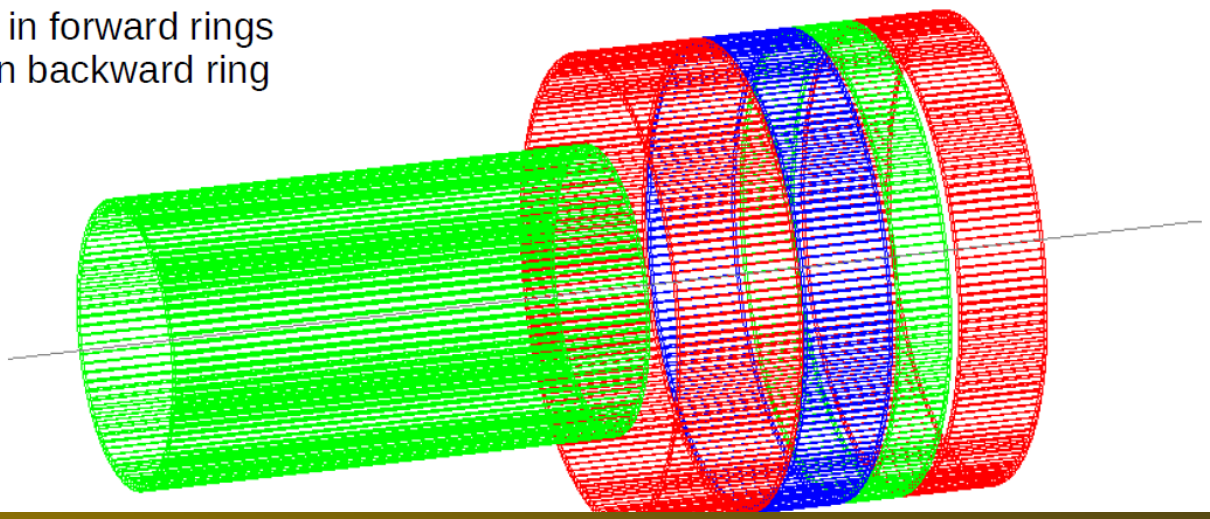
KRAkow Barrel (KRAB)

Trigger/Reaction Plane detector around the target:

- 5 rings of 4x4 mm^2 fast scintillating fibers (e.g. BCF-20) read out by SiPMs
- covers angles from 30° to 165°,
- segmentation assures more or less uniform count rates for Au+Au at 1 AGeV,
- geometrical efficiency ~95%
- ~10% of charged particles involved in multihits,
- ~5% multihit probability
- sufficiently large for radioactive beams
- sufficiently small and lightweight not to disturb neutrons
- min radius - 6 cm,
- max radius - 12 cm
- length 43 cm
- 180 segments in forward rings
- 90 segments in backward ring
- 810 channels



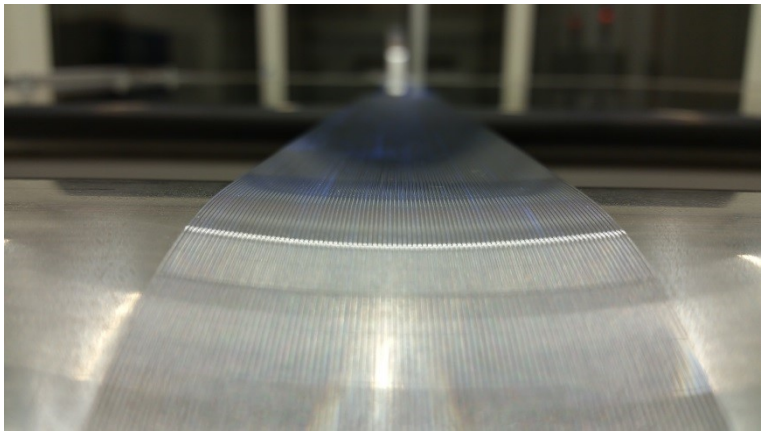
NUSYM17, GANIL
Caen, 4-7.09.2017

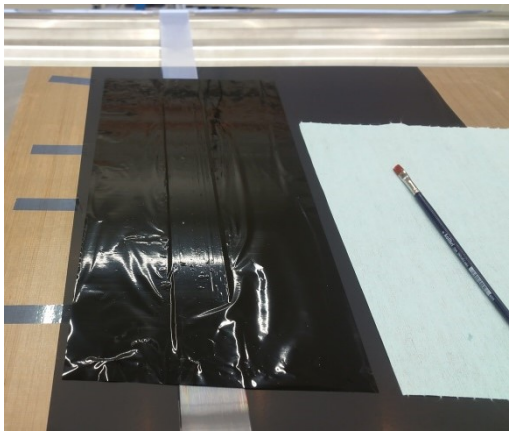
Work supported by Polish Ministry of Science and Higher Education, grant No. DPN/N108/GSI/2009 and by Polish National Science Center, contract Nos. UMO-2013/10/M/ST2/00624, UMO-2013/09/B/ST2/04064

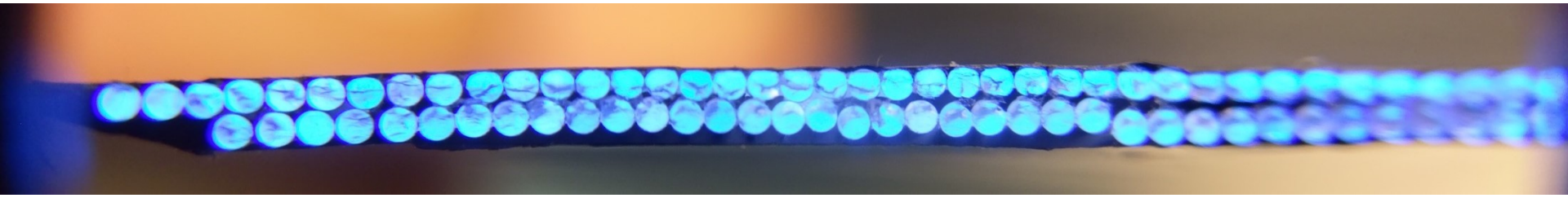
Jerzy Łukasik
IFJ PAN Kraków, Poland

test with 2 layers on frame

- placing fibers by hand seems in general feasible (costs a lot of time)
- gluing procedure not fully fixed yet
- fibers seem to be not well aligned in mat, although they are on the ‚roll'.







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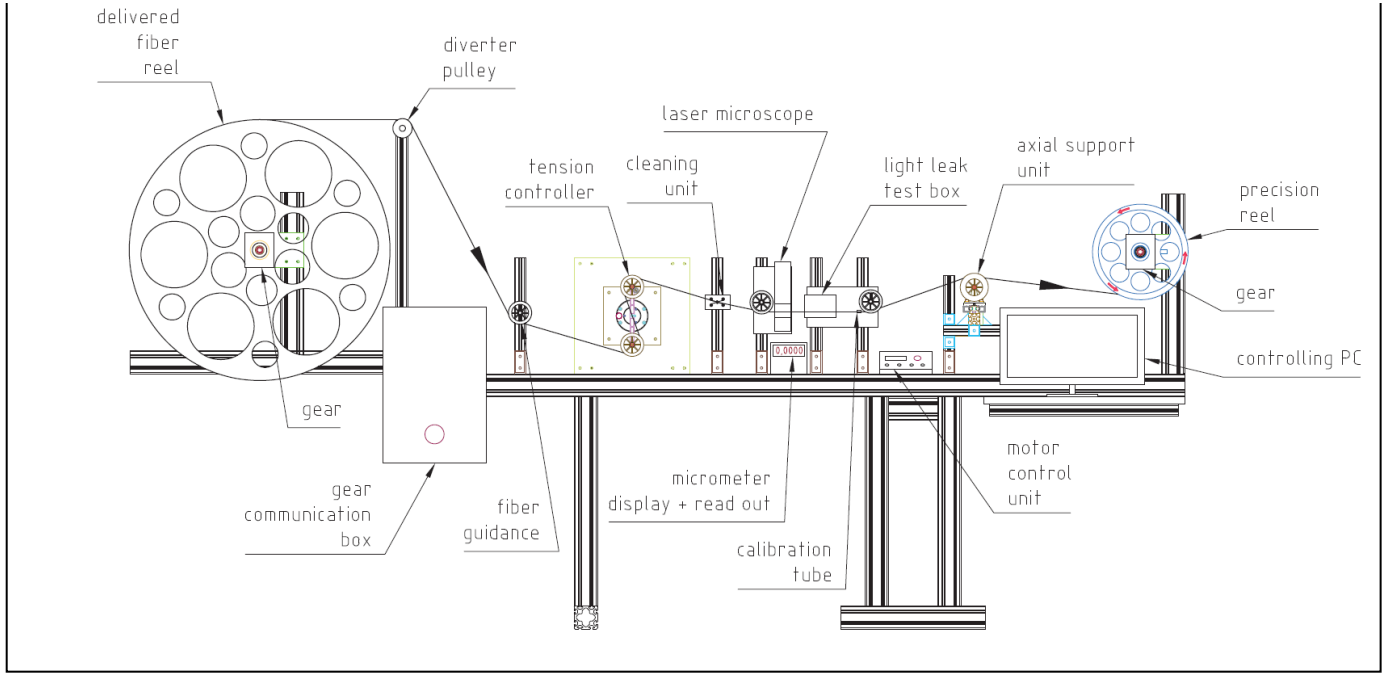


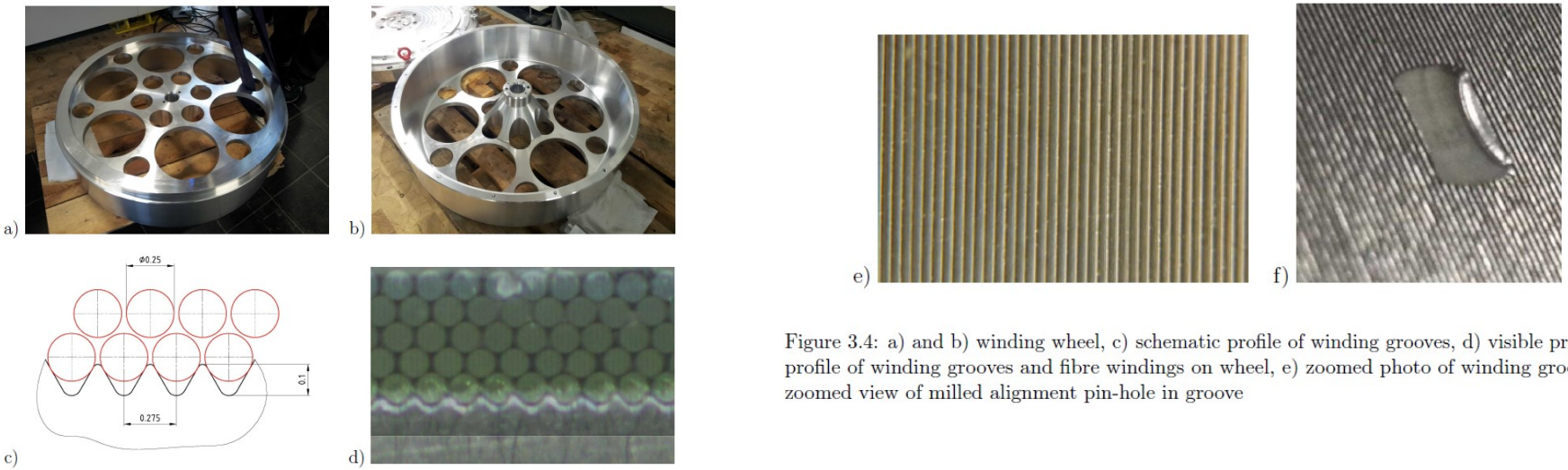
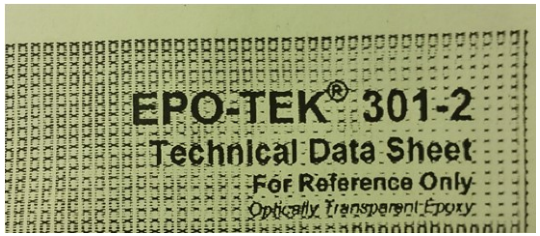


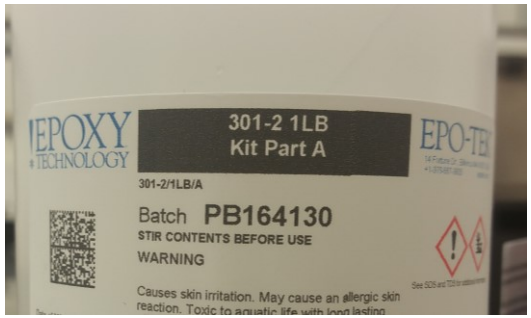
Figure 3.4: a) and b) winding wheel, c) schematic profile of winding grooves, d) visible produced profile of winding grooves and fibre windings on wheel, e) zoomed photo of winding grooves, f) zoomed view of milled alignment pin-hole in groove

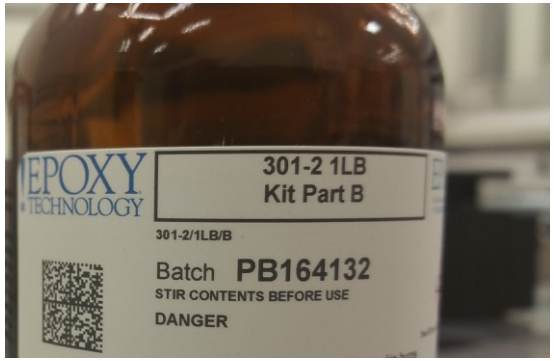
EPO-TEK® 301 Advantages & Suggested Application Notes:

- Semiconductor: optical glob top or underfill; adhesion to common wafer passivation, solder mask and flex circuits; compatible with LED die, Si, GaAs.
- PCB: general potting and protection over FR4, flex, or ceramic PCBs.
- Fiber Optic:
  - Adhesive for glass and plastic fibers; wicking into fiber bundles used in patch cords, endoscopes or sensor devices; adhesive/seal/encapsulant used for fiber packaging and components; transmission of IR up to 2500 nm; terminating fibers into ferrules; fiber coupling and splicing.
- Opto-electronic:
  - LCD/LED adhesive for laminating glass layers; adhesion to PET plastic; general potting, encapsulation, and protection; spectral transmission in VIS and IR light; adhesive/encapsulant for VCSEL's packaged devices; resisting yellowing per ASTM D1925; adhesive for precision optics including lens, prism, beam splitter cubes, mirrors, and diodes, found in medical, university, or research communities.
- NASA approved, low outgassing epoxy - http://outgassing.nasa.gov/

The used glue is a two component epoxy glue (Epotek Epoxy 301-2). So in this step the resin and hardener of the epoxy plus titanium dioxide (20% by weight) are needed. This glue is non outgassing and has a potting time of 8 h. For measuring the right amount of each component scales and syringes are used. To guarantee a smooth mixing of the three components a special mixing machine under vacuum is assumed. Afterwards, the mixer has to be cleaned with isopropanol.





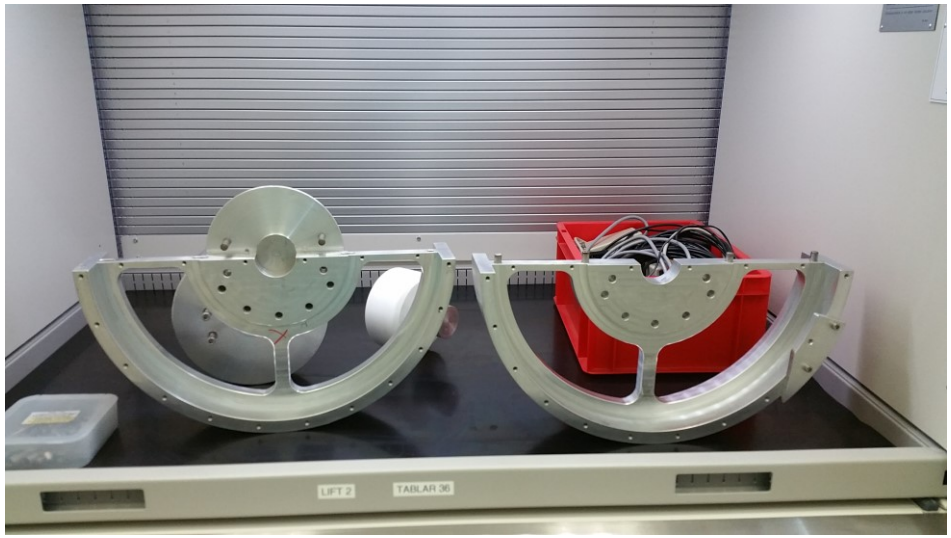


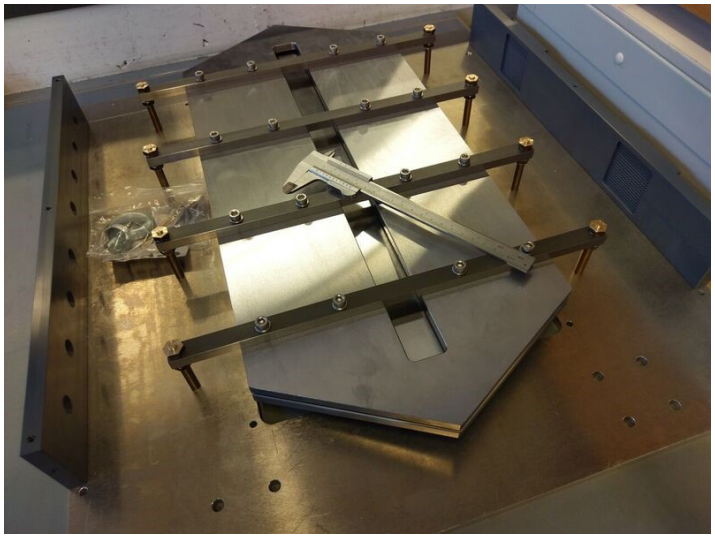
Titanium only as EMA!?

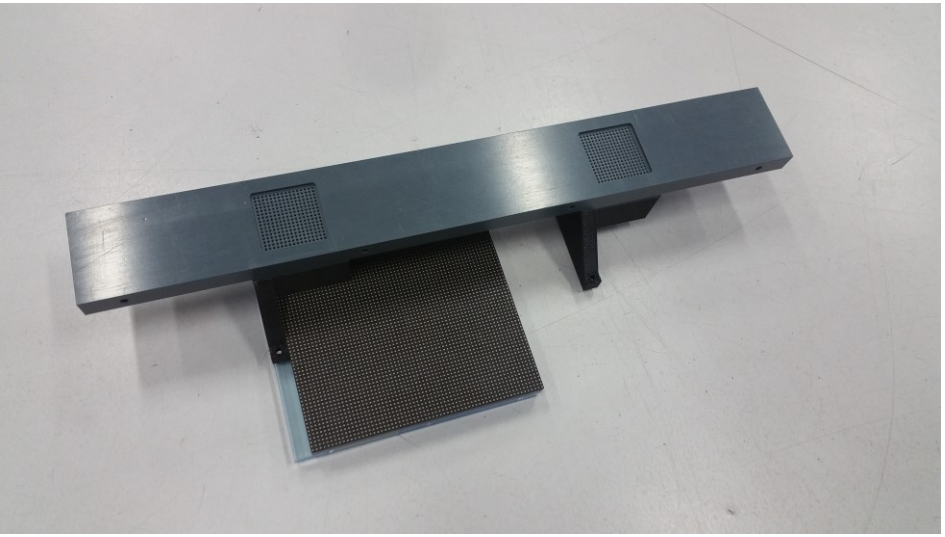
EMA (Extra Mural Absorber) – White or black coatings may be applied to the outer fiber surface primarily to eliminate crosstalk among closely packed fibers. Our coatings are typically 10 to 15 microns thick.An EMA coating decreases the overall signal intensity obtained from a fiber, irrespective of its length. This effect is greatest with black EMA, as well as with short fibers. The coating can interfere with useful light-piping in the cladding. Black EMA applied at the near end of fibers can be used to flatten out position dependent response. White EMA is used in the construction of short fiber imaging bundles.

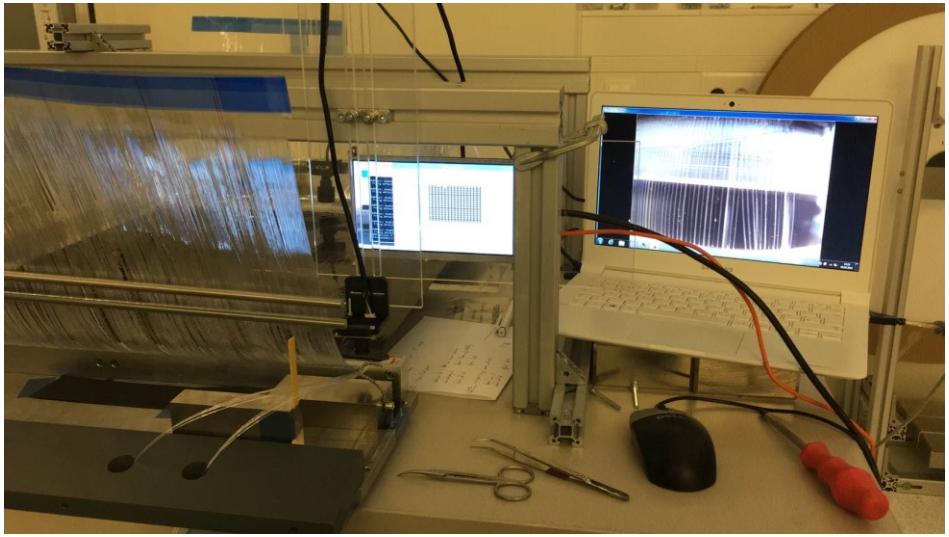
10mu Pokalon Folie
Polycarbonat (PC) mit Leit-Russ Füllung von Lofo:

Das Material Pokalon, das in der Vergangenheit durch die Firma Lofo High Tech Films GmbH angeboten wurde, ist zukünftig über die Dr. Dietrich Müller GmbH zu beziehen.









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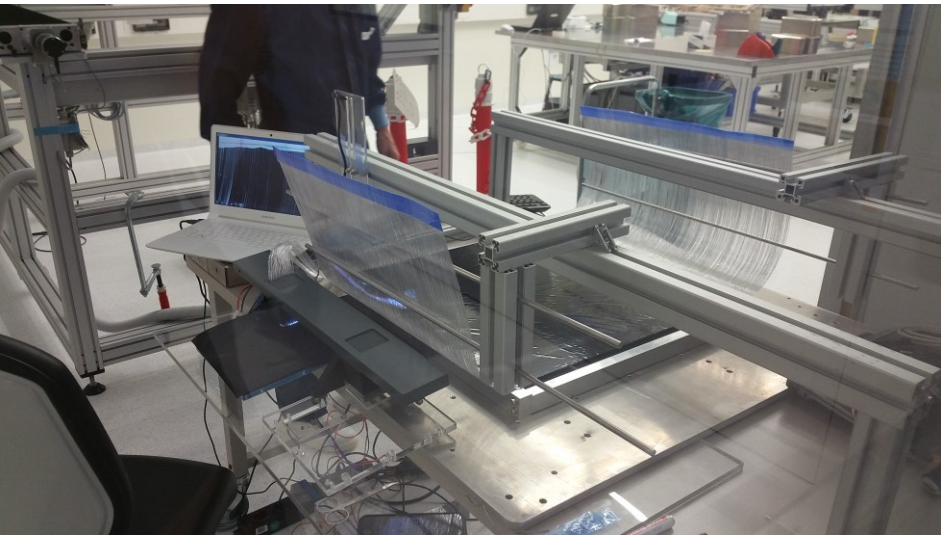

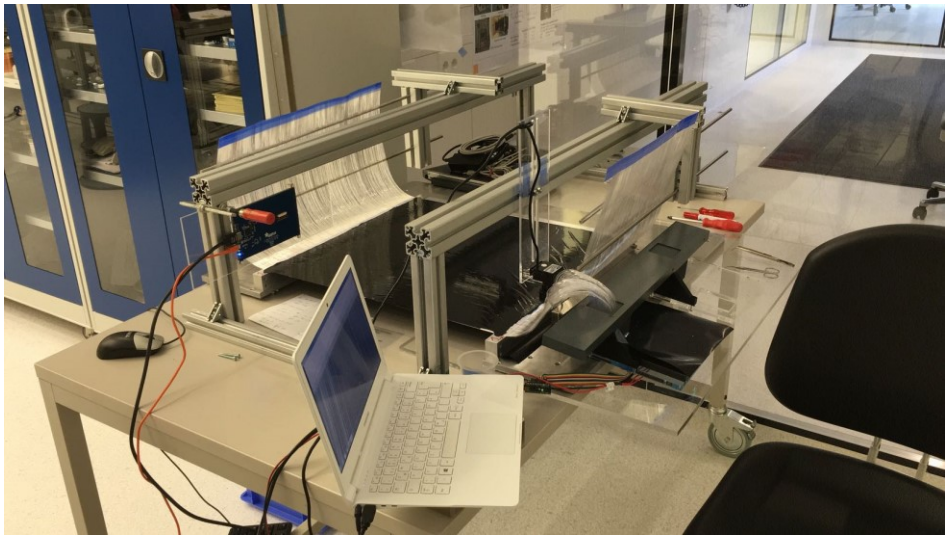

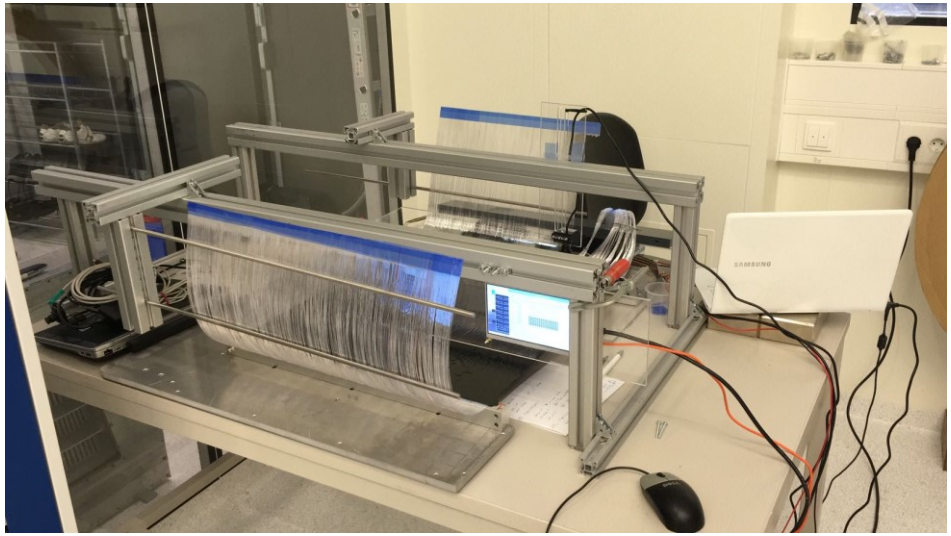

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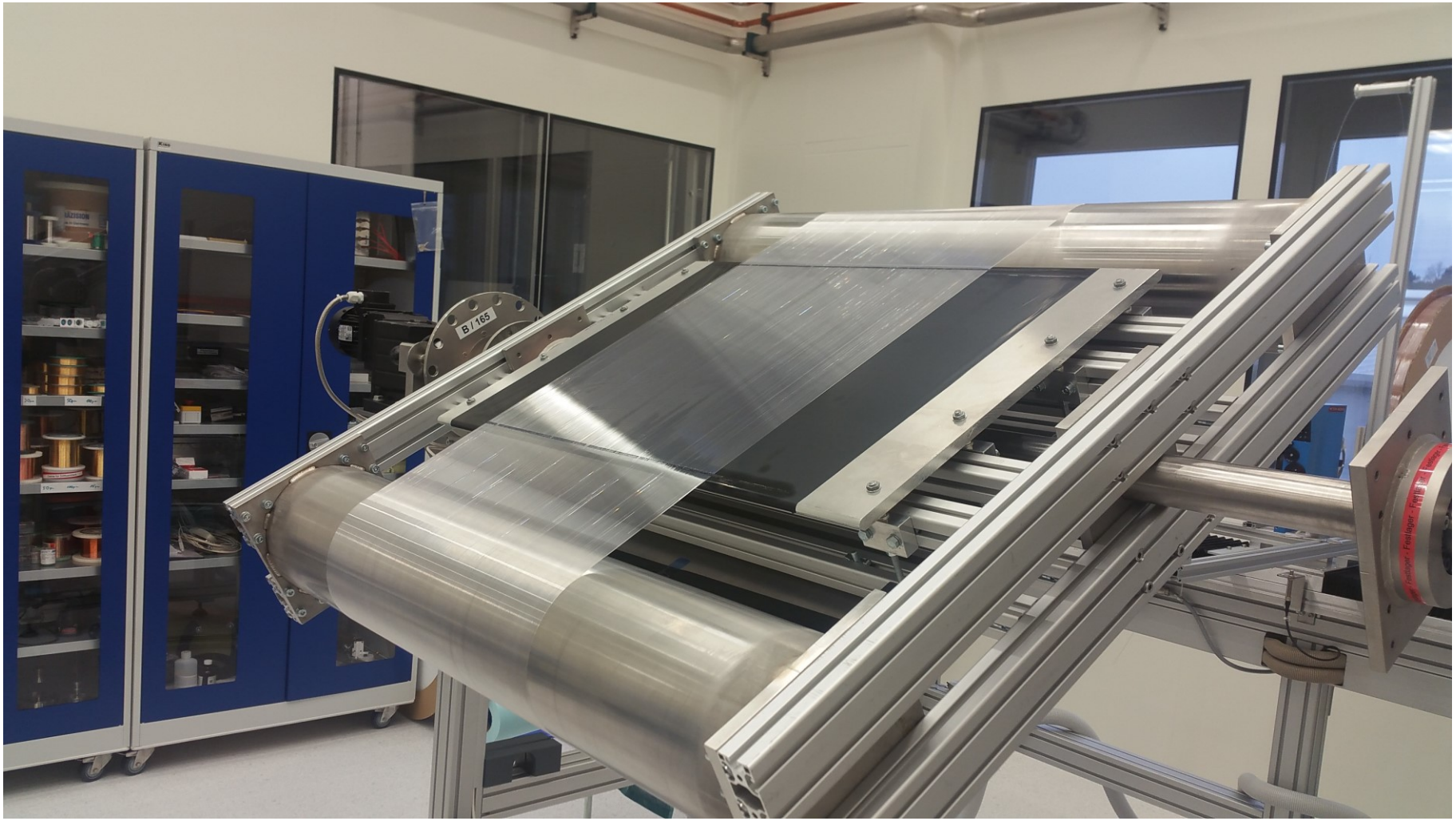

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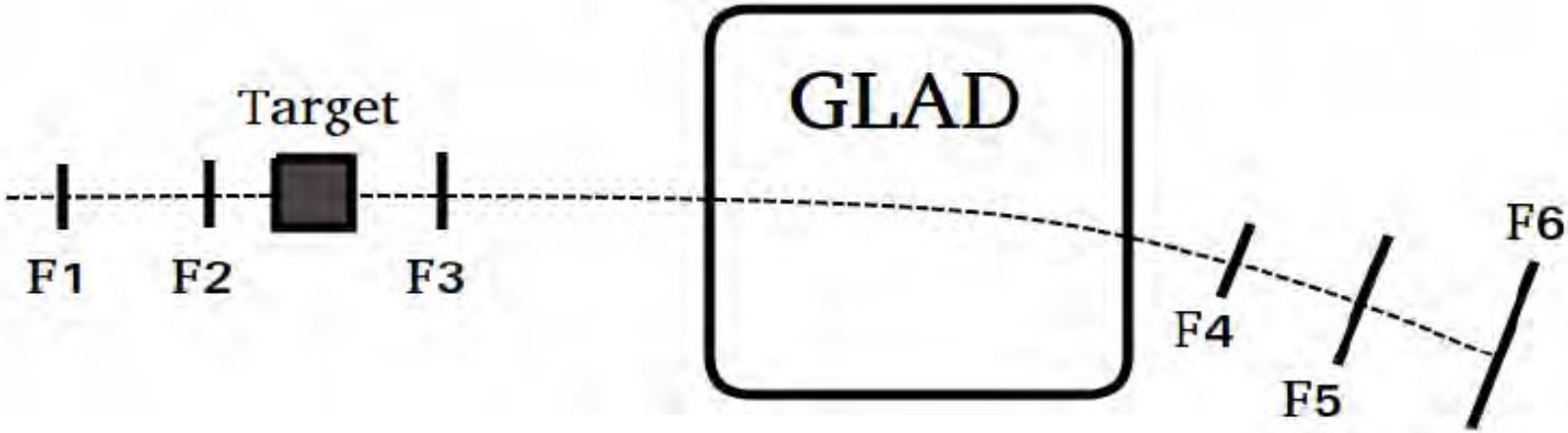
R3B - Setup 2019

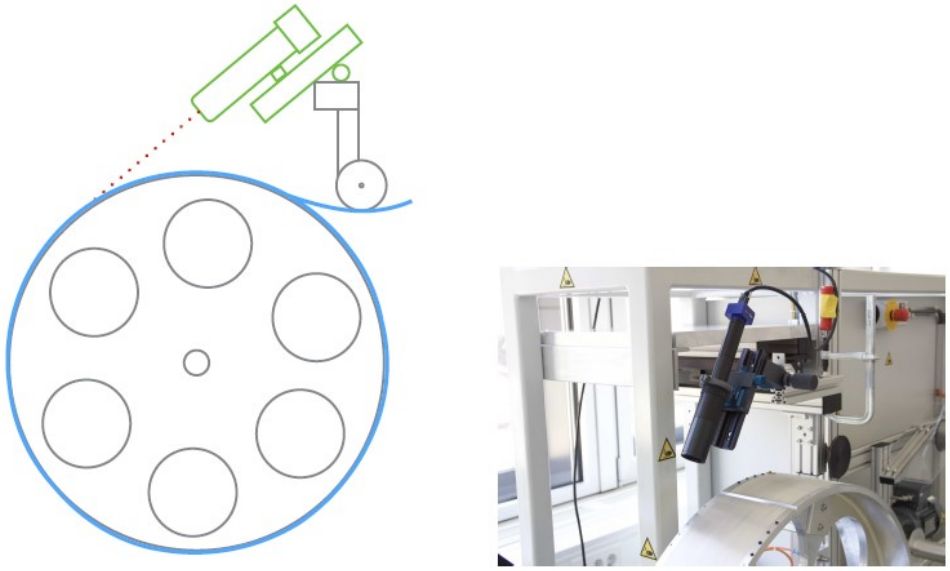
- Fiber1+2: 5 x 5 cm², 2 x 256 quadratic 210 µm fibers.
- Fiber3: 10 x 10 cm², 2 x 512 quadratic 200 µm fibers (in progress).
- Fiber4: 30 x 40 cm², 2048 round 200 µm fibers.
- Fiber5: 25 x 40 cm², 2048 quadratic 200 µm fibers.
- Fiber6: 50 x 50 cm², 1024 round 500 µm fibers.
- 3 Old GFIs: 50 x 50 cm², 512 quadratic 1 mm fibers.



- Fiber Tracker (side remark)

(a) (b)

Figure 3.38: Two different defects which can occur during the winding process. In (a) the current fibre jumped in the wrong threat and leave an empty space. (b) shows a fibre lying in the wrong layer.



(a) (b)

Figure 3.39: Left: Scheme of the camera setup on the winding maschine. The camera (green) will be placed on the same slide as the positioning spool and look tangential on the wheel. Right: Camera setup mounted on the winding machine.