A Scintillator Fiber detector as a tracker for the EIC ZDC (a very preliminary idea)

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Motivation

Yulia's presentation May 11th 2020:

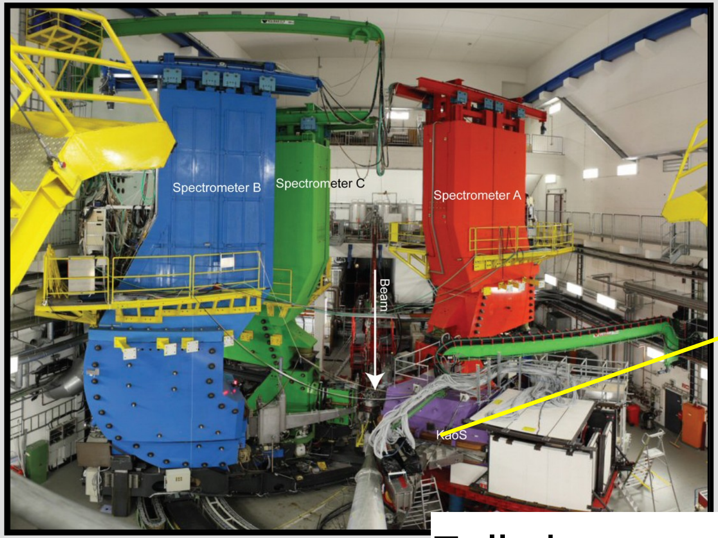
- For $\Lambda \rightarrow p + \pi^{-}$ protons could be detected efficiently, but we need trackers in opposite direction (charge) => on the path to ZDC

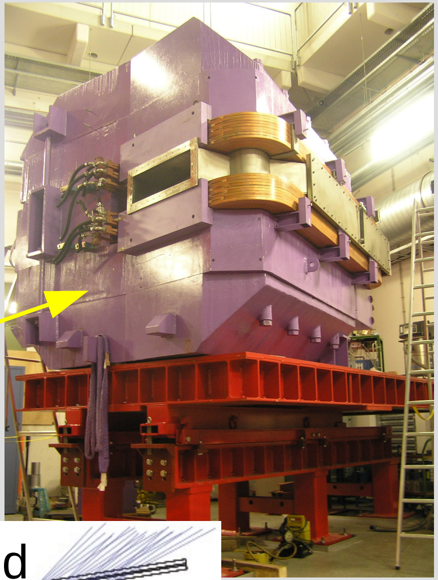
In general the tendency nowadays is the use of GEMs or silicon trackers (it was suggested in the conclusions but it is expensive R&D)

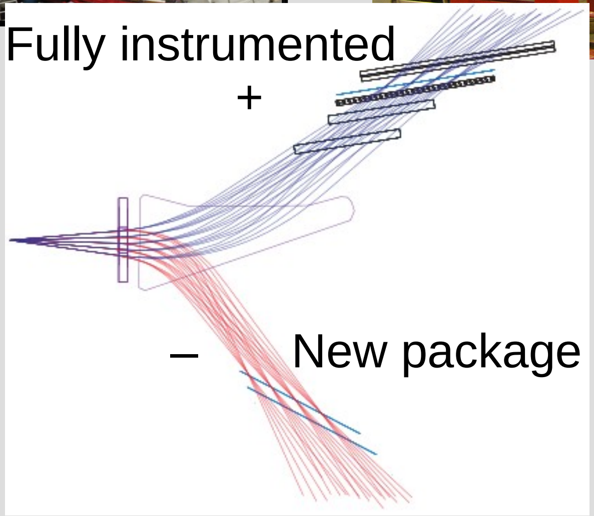
In my PhD I designed a plastic scintillator fiber detector for electron tracking (but just one dimension) for its use in the KaoS experiment at Mainz.

After a brief discussion with Yulia by email, she encouraged me to present a couple of slides to the collaboration.

The Mainz scintillator fiber detector

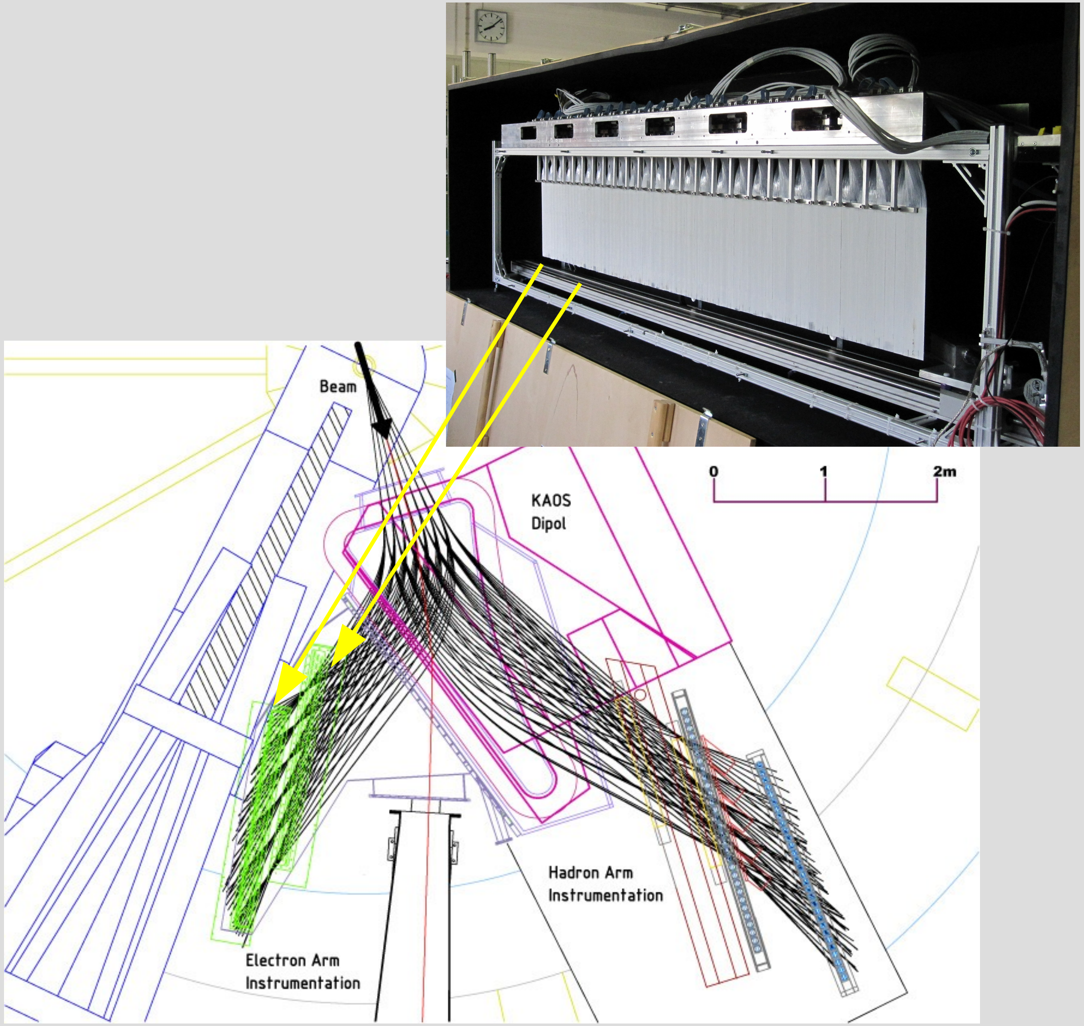






- KaoS is a magnetic spectrometer, used previously at GSI.
- In 2003 it was moved to the three spectrometers hall at the MAMI accelerator facility in Mainz.
- It was planned to be used as a double side spectrometer in the electroproduction of hypernuclei program.
- It was necessary the instrumentation of the electron side at very forward angles which must accomplish the following requirements:
  - High count capability
  - Good position resolution
  - Good timing information

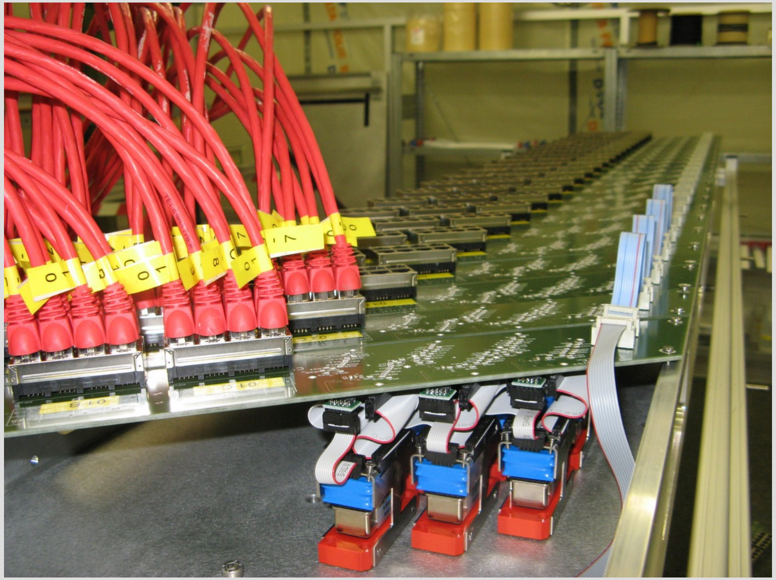
The Mainz scintillator fiber detector



<u>Scintillator fiber array with multianode photomultiplier readout</u>

The fiber detector summarizes:

✔Two scintillator fiber planes of 1.9 m length x 442 mm (297 mm “active”) height
✔72 modules per plane 2304 channels
✔18432 scintillating fibers assembled



Details I

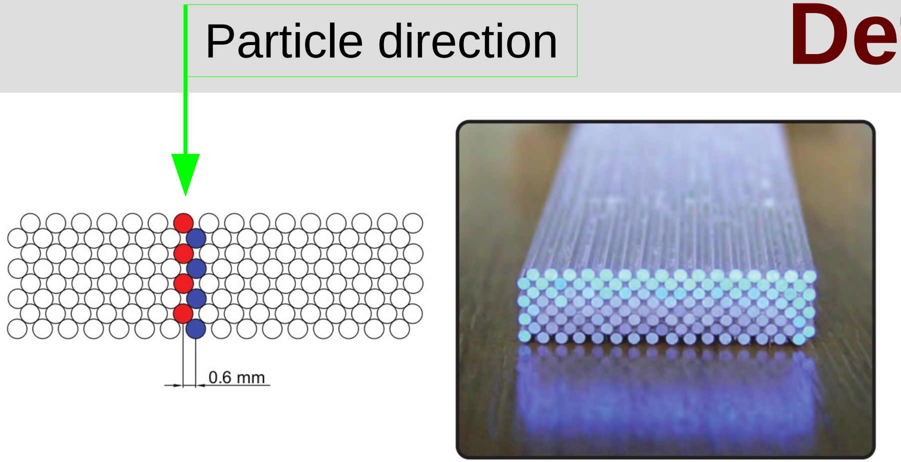


Figure 3.21: Left. Scheme of the fiber arrangement of 0°. Columns of the same color represent a single readout channel. The pitch between between each column is of 0.6 mm. Right. Photograph of the bundle arrangement.

First prototypes design used a 0deg layout, which was beam tested.

This slanted version was choose for the final version in order to reduce the multiplicity

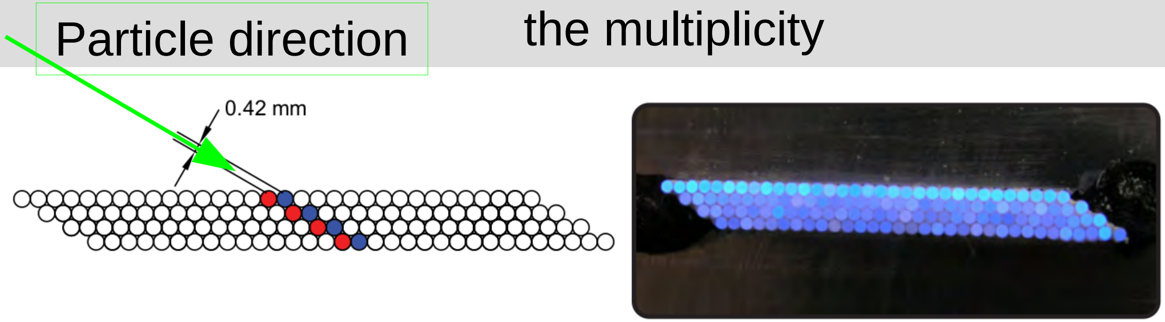
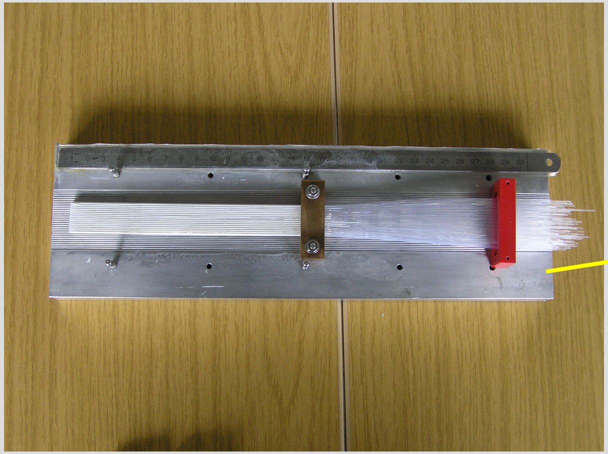
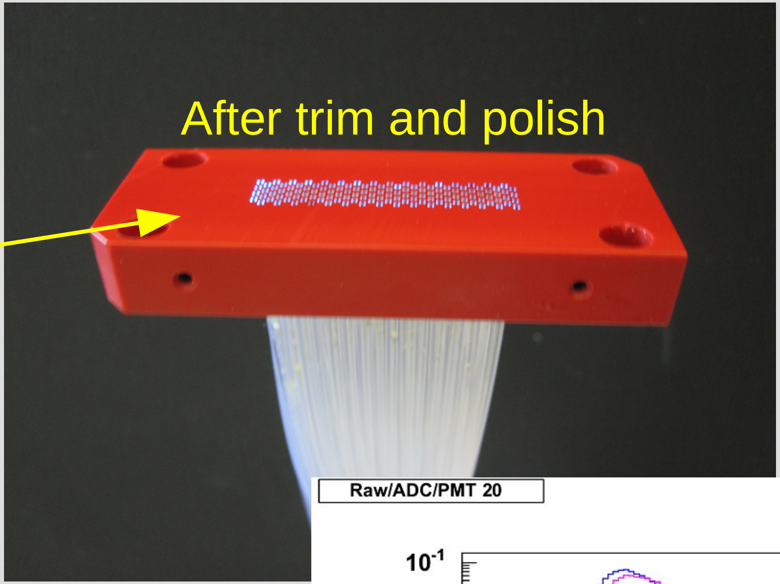


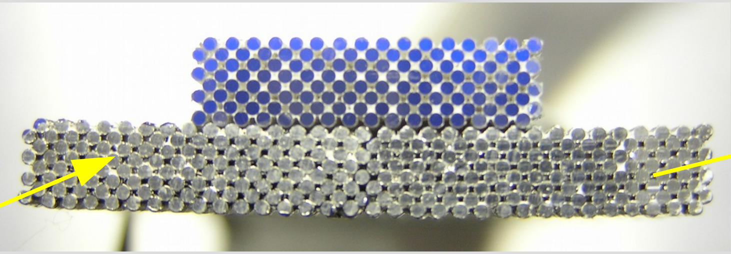
Figure 3.23: Left. Scheme of the fiber arrangement of $\phi = 60°$. Columns of the same color represent a single readout channel. Right. Photograph of the bundle arrangement.

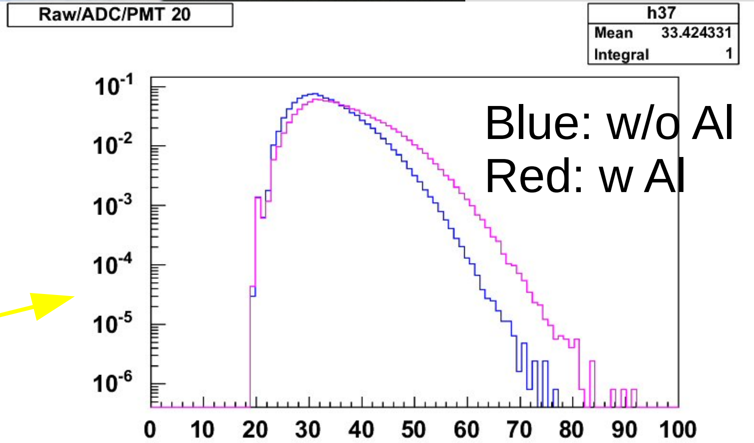
Details II





End side
with
vaporized
aluminum

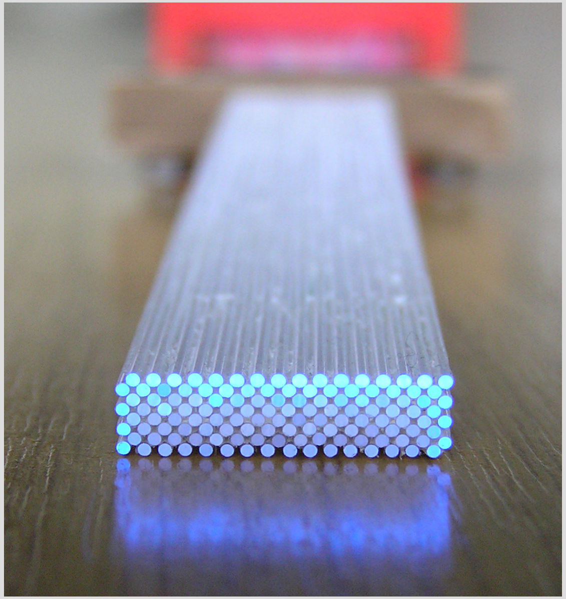




Increase of ~14% of light output

Details III

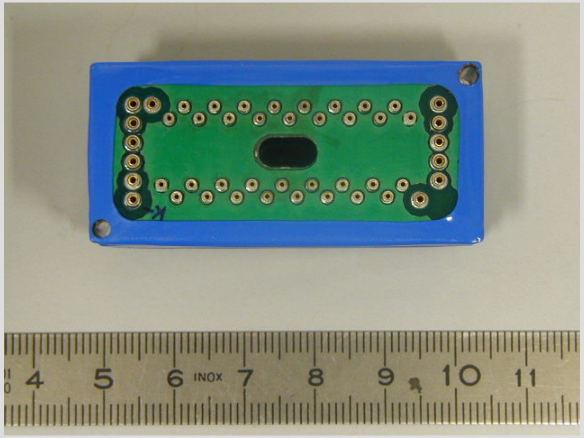
Kuraray SCSF-78M Double cladding, Ø0.83mm

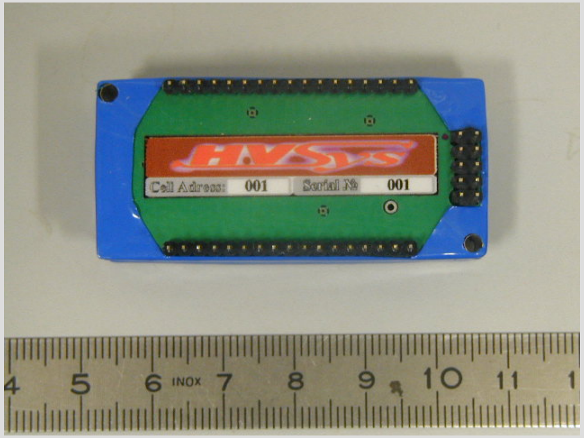


One module consists of 128 fibers (4 fibers/PMT channel), glued with acrylic paint.

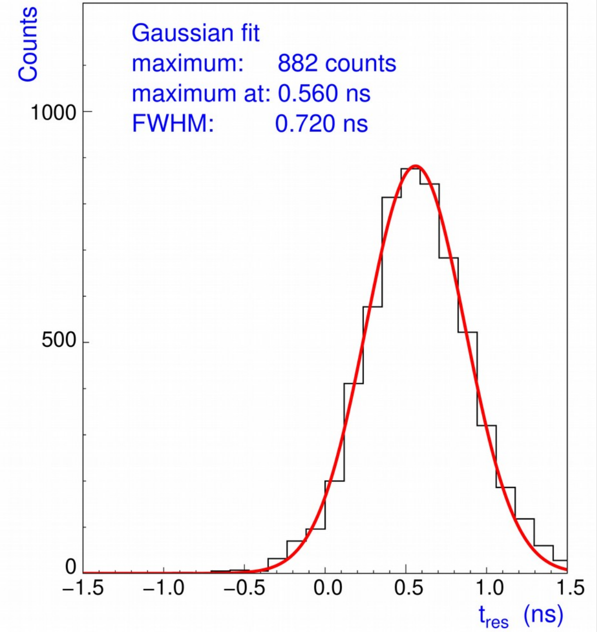
Hamamatsu H7259K 32 channels linear array

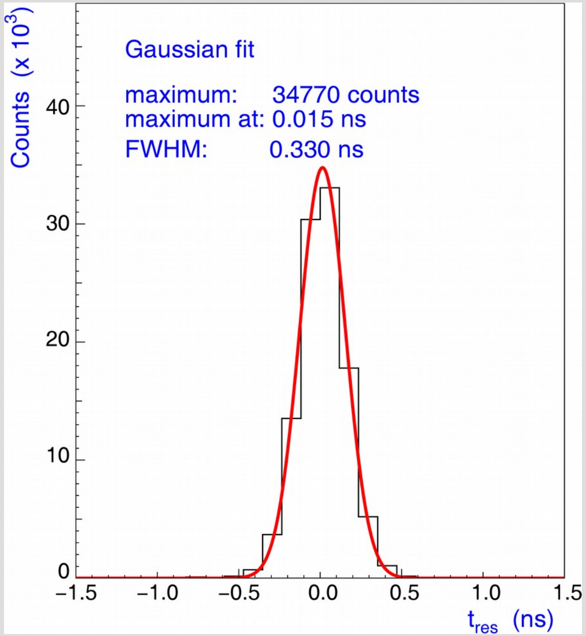
Each mPMT powered by a C-W voltage multiplier base.
Power is provided by flat cable (no need of stiff HV cables)

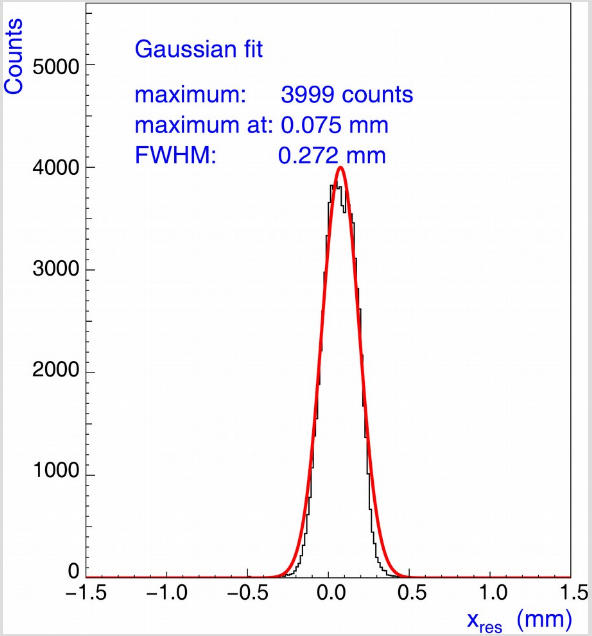




Test beam at GSI



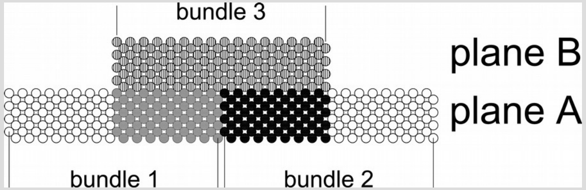




Some numbers from 2007 GSI beam test (cocktail beam π^+/p/d protons at 1GeV/c) and C beam of 2 AGeV energy:

- Residual of t_A-t_B FWHM = 720ps (cocktail) → 510ps single plane,
  330ps (carbon) → 220ps single plane

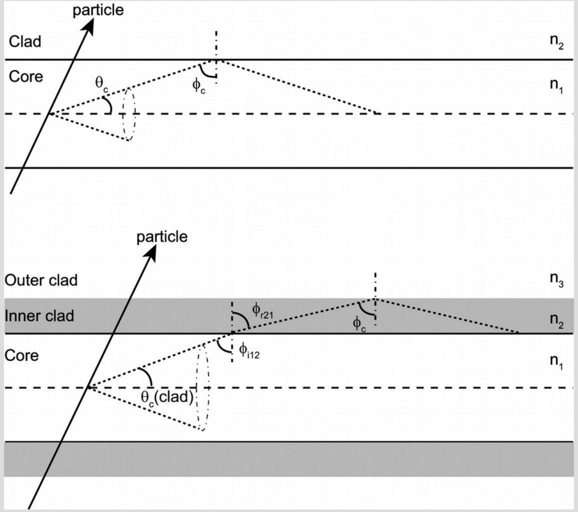
- Residual track position X_A-X_B FWHM ~0.27mm (carbon)



P. Achenbach, C. Ayerbe Gayoso, J. Bernauer, R. Bohm, M. Distler, et al., “In-beam tests of scintillating fibre detectors at MAMI and at GSI,” Nucl.Instrum.Meth.,vol. A593, pp. 353–360, 2008.

Some numbers

- Each 0deg bundle is ~1.9cm width and ~0.5 cm thick
  - $X/X_0 \approx 1.2\%$ (mostly polystyrene X_0=43.79 g/cm²)
- Trapping efficiency of one multicladding fiber → 5.3%
- Kuraray (Japan) price 7.5km of fiber:
  - ~1.6M¥ (2009) → ~15k$ (rate 2020)
- For ZDC, cover 60x60 cm² (two planes X-Y)
  - Assuming similar layout (4 fiber/channel):
    - 60 cm/1.9cm/bundle = 32 bundles → 32x128 fibers = 4096 fibers
    - 4096 x (60 cm + 20 cm) ~3.3 km of fiber/plane
    - 1024 readout channels/plane
- Readout + associated electronics (discriminator+TDC)
  - Readout could be APDs, silicon photomultipliers, even multianode PMTs



Final remarks

- A scintillator fiber detector is a non-expensive tracker, with high detection capabilities.
- The Mainz SciFi detector has a total length of ~45cm
  - 30cm detection area + 15 cm for support purposes.
  - The use of MaPMT forces the use of 32ch bundles.
  - The detector was just attached in one side.
- A tracker for the ZDC could be attached at both sides (one with the readout and the other clamped).
- Depending on the chosen readout, the bundle could be assembled with more channels
  - Removing the inaccuracies in the transition bundle to bundle
  - This is more dependable of the design of the construction tools

- **I presented the layout used in my PhD, the number of layers, the layout of the arrangement, the diameter, even the shape of them (round or square), is a matter of simulation/test for the best performance at the ZDC.**