Distortion measurements from analysis of patterned cathode photoelectrons

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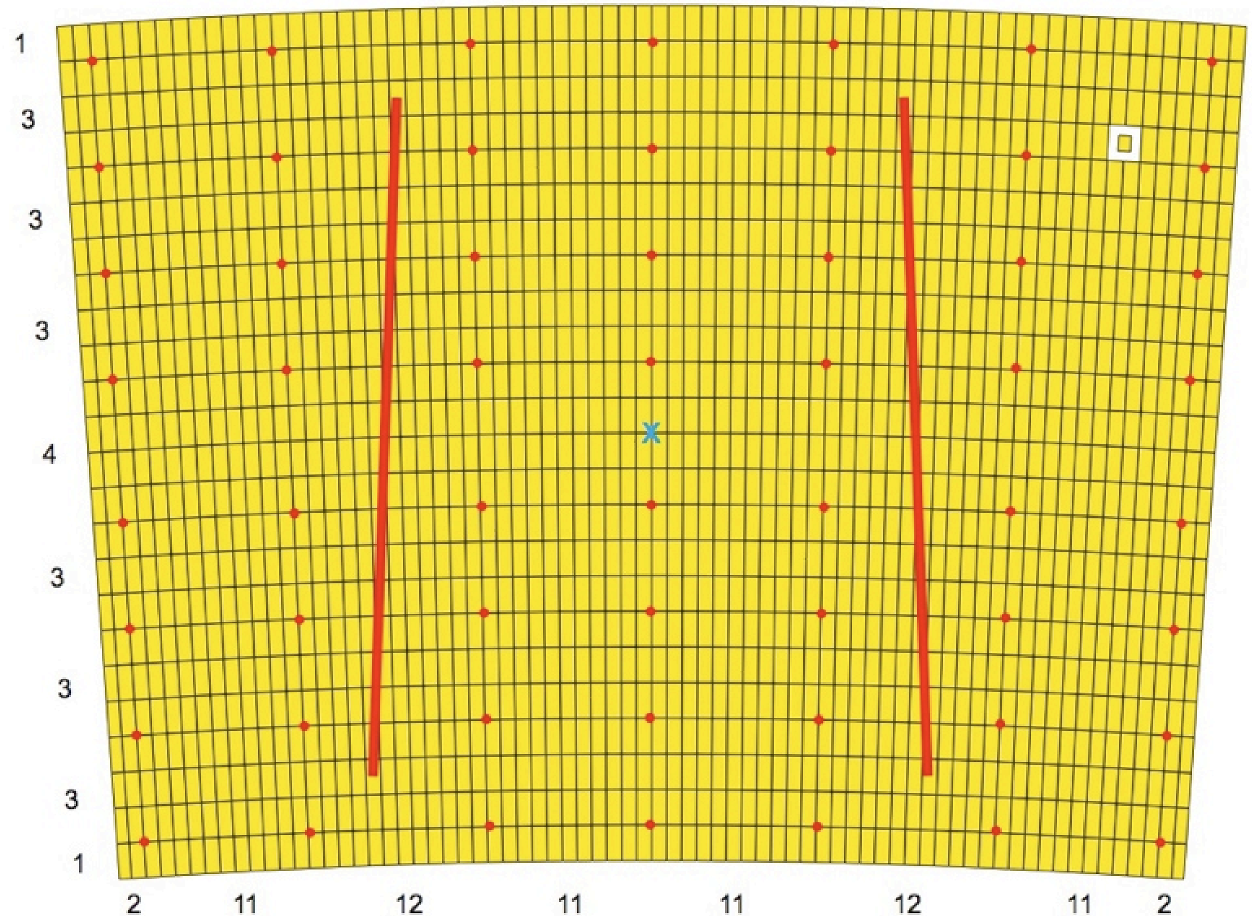
Overview

- Non-constant magnetic field in the solenoid, along with electric inhomogeneities, creates distortions in the apparent position of tracks in a TPC
- To best correct these distortions, a measurement of electron clouds originating at known locations is performed
- Electron clouds can be created through photoelectric effect on a pattern with low work function
- Positions of electron clouds can be reconstructed in MarlinTPC to give magnitude/direction of distortions
- Photoelectric reconstructions can also be used to easily calculate drift velocity and diffusion (longitudinal and transverse)

Origin of electron clouds - patterned cathode

- Al has a lower work function than Cu → incident light will cause photoemission from Al pattern at longer wavelength than Cu
- Pattern can be Al tape glued to cathode (T2K) or special cathode with Al substrate (ILC)
- Applying tape labour-intensive and manual, drilling through Cu is automated and guarantees that surveying is accurate



ILC Micromegas detector shown with sample Al pattern overlaid

Light path/energy

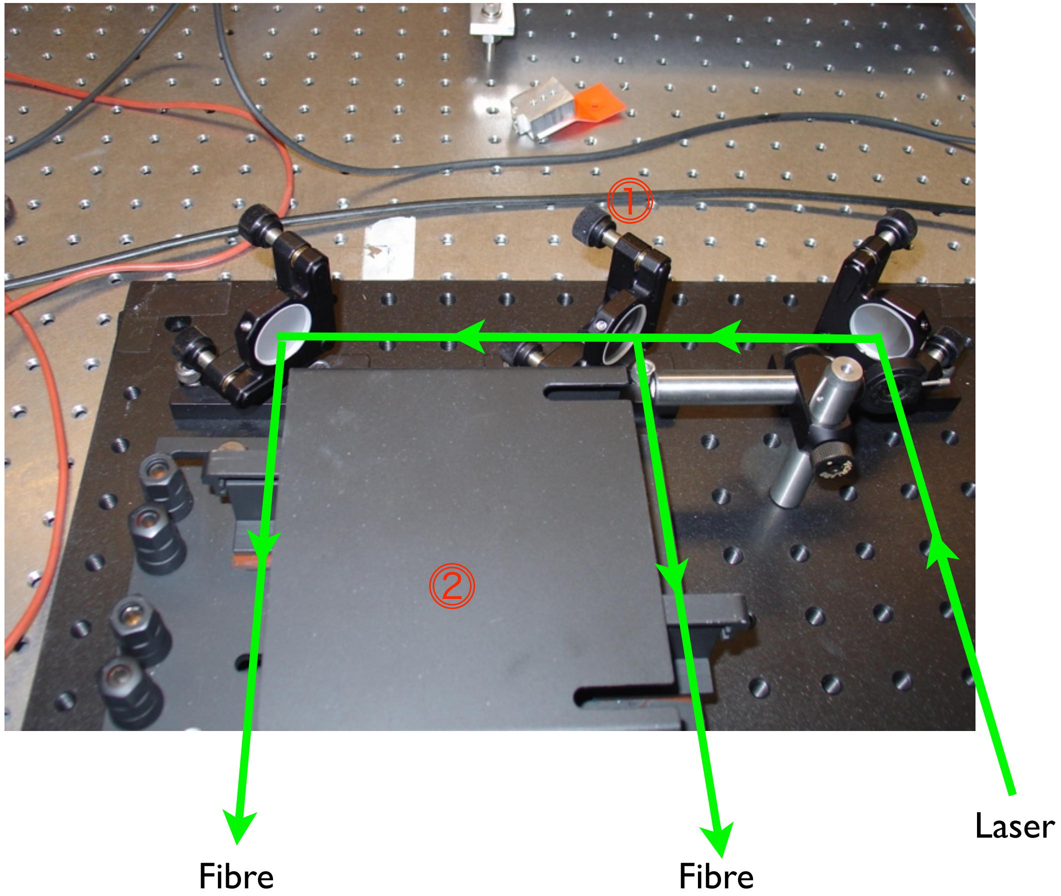
- UV light for photoemission is from a pulsed Nd:YAG laser flashing at 266nm and ~2 Hz. Pulses last 7ns, with pulse energy $\mathcal{O}$(100μJ)
- Light is focussed onto the face of one or more optic fibres. Power loss ~50% from necessity of maintaining low energy density
- Energy lost through fibres at ~350dB/km - energy remaining after 1.3m of fibre is ~30% original: $\mathcal{O}$(10μJ)
- Once fibre enters TPC, light passes through a pair of lenses which attempt to shine light through gas at unvarying intensity. Light is estimated to strike cathode at $\mathcal{O}$(10nJ).

Light transmission - optic fibres

- Light transmission through optic fibres is highly variable. Dependent on:
  - Polishing quality - polish must be performed manually. Expertise and improvements in technique have resulted in 100% improvement in transmission
  - Energy required for sufficient intensity on cathode causes gradual damage & transmission to optic fibres. Effects are non-linear with pulse repetition rate
  - Fibre-fibre coupling results in loss of ~5% energy, strongly dependent on polish quality
- We can control light intensity for each fibre by modifying beam diameter as it enters a fibre

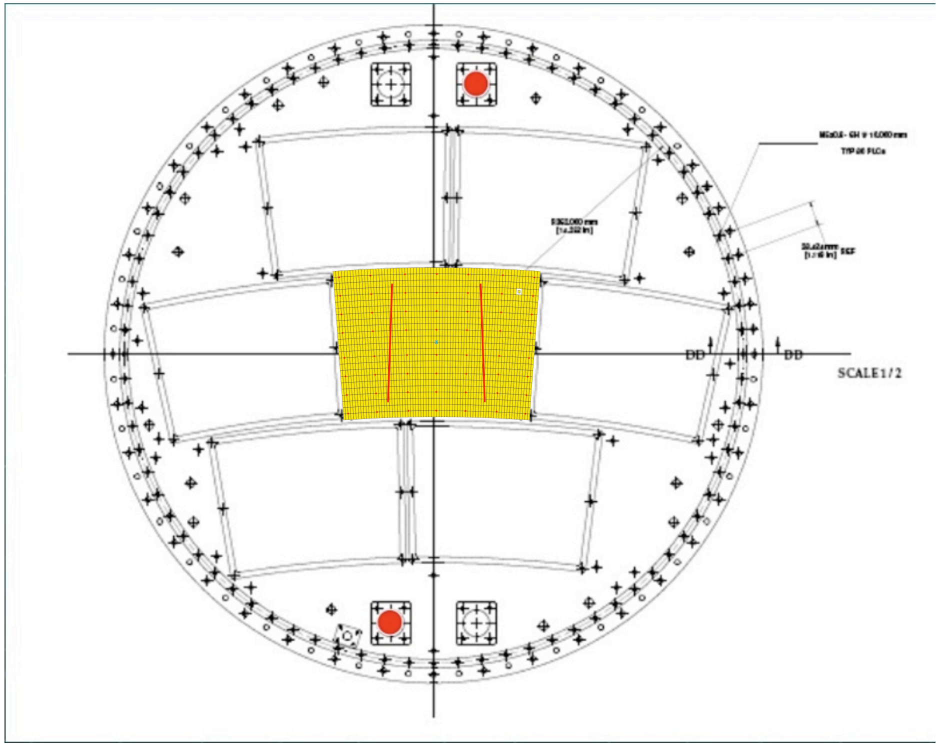
Implementation of multiple fibres

- Multiple laser inputs used to maintain consistent intensity and allow input to multiple regions of the TPC
- Method used can depend on TPC design:
  - ILC: beamsplitter (1) divides beam into two fibres: can flash into TPC simultaneously
  - T2K: ladder of fibres allows laser to flash into one TPC region at a time



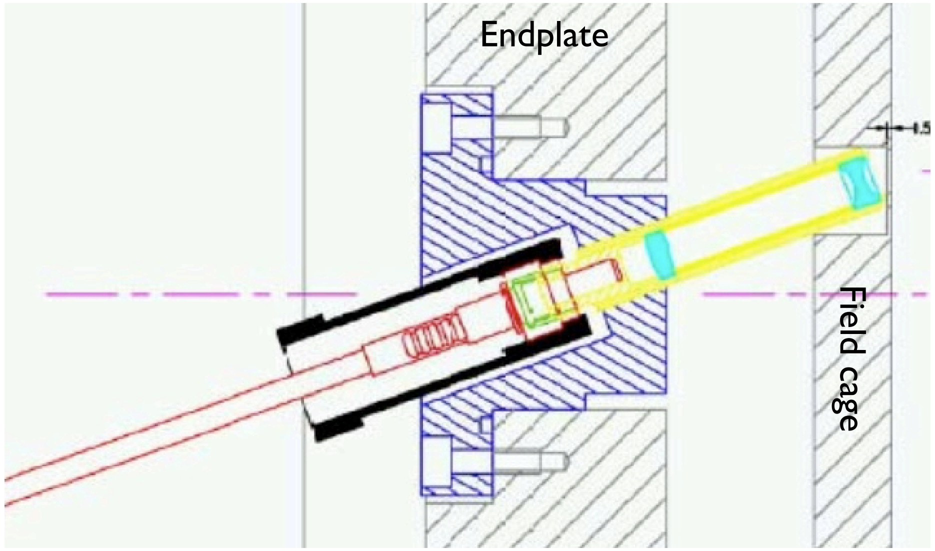
- Beam-blocking device (2) allows either beam to be used individually to test light profile of each fibre

Fibre - drift volume feedthrough (LC-TPC)



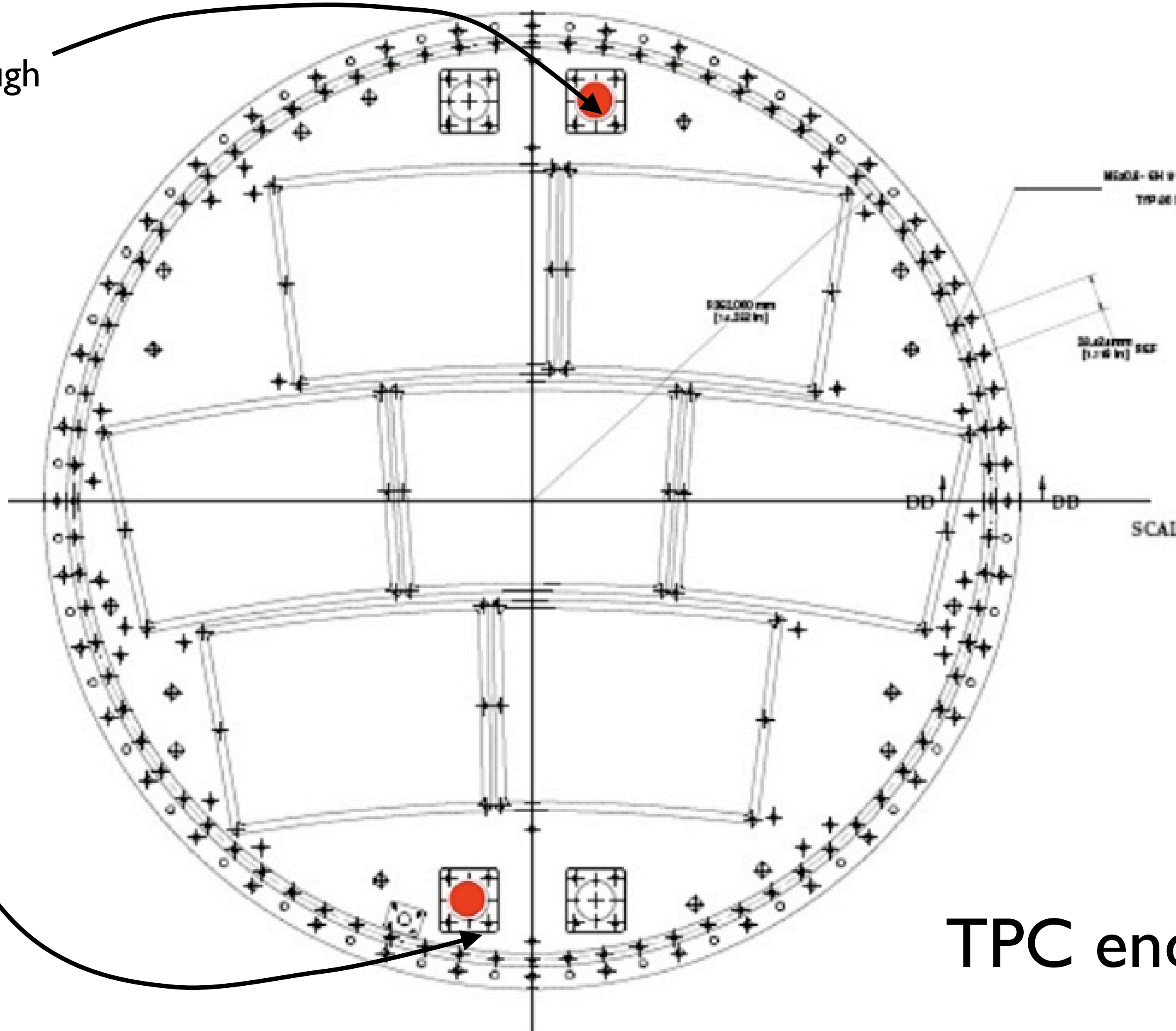
- Fibres will enter TPC at points marked in red
- Allow us to maintain consistent energy across centre readout plane

- Feedthroughs have been constructed so beam axis is 20° to endplate
- Beam axis (greatest light intensity) will reach cathode near centre; superposition of beams will provide constant energy density



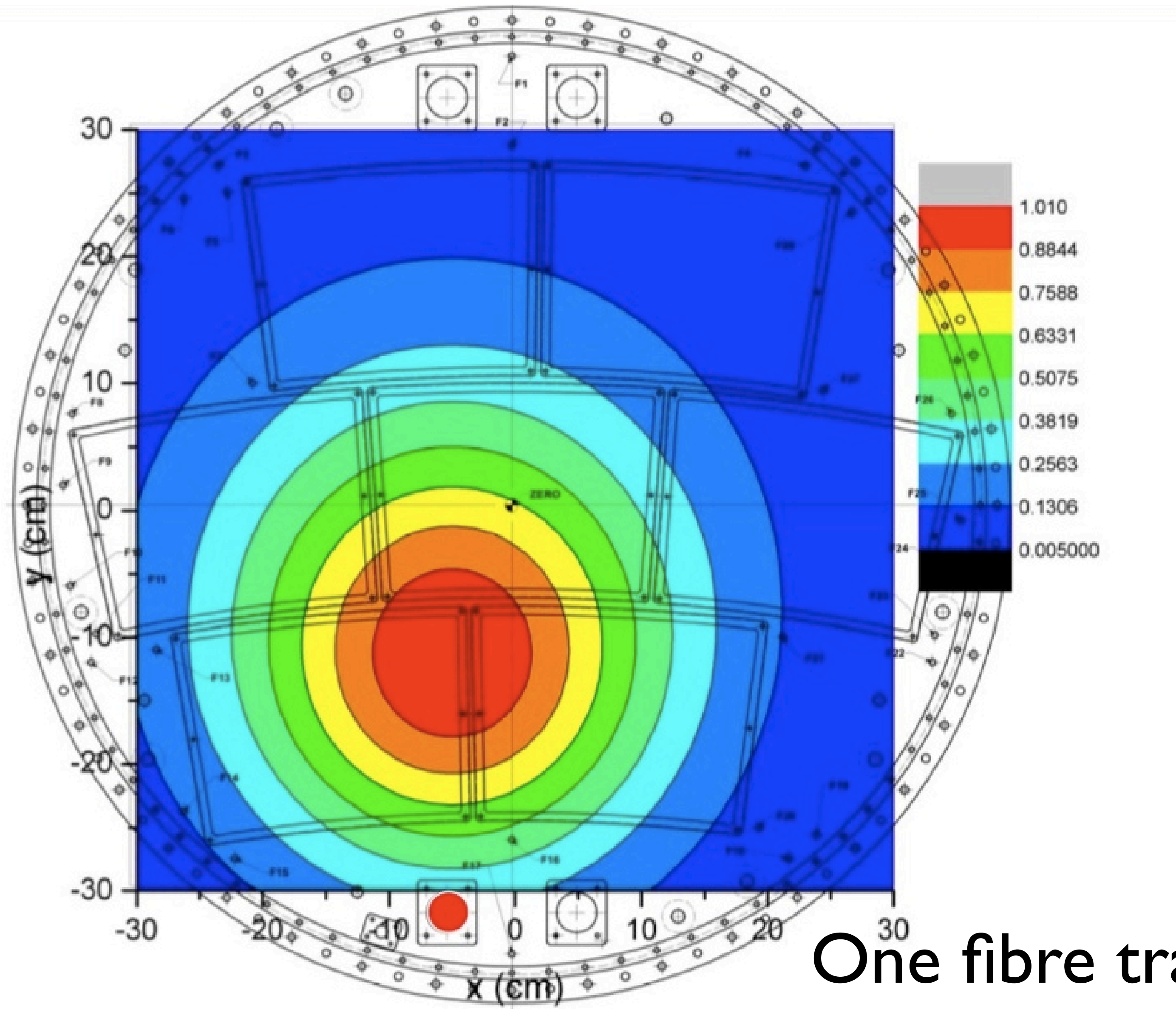
Fibre - drift volume feedthrough

Fibre feedthrough



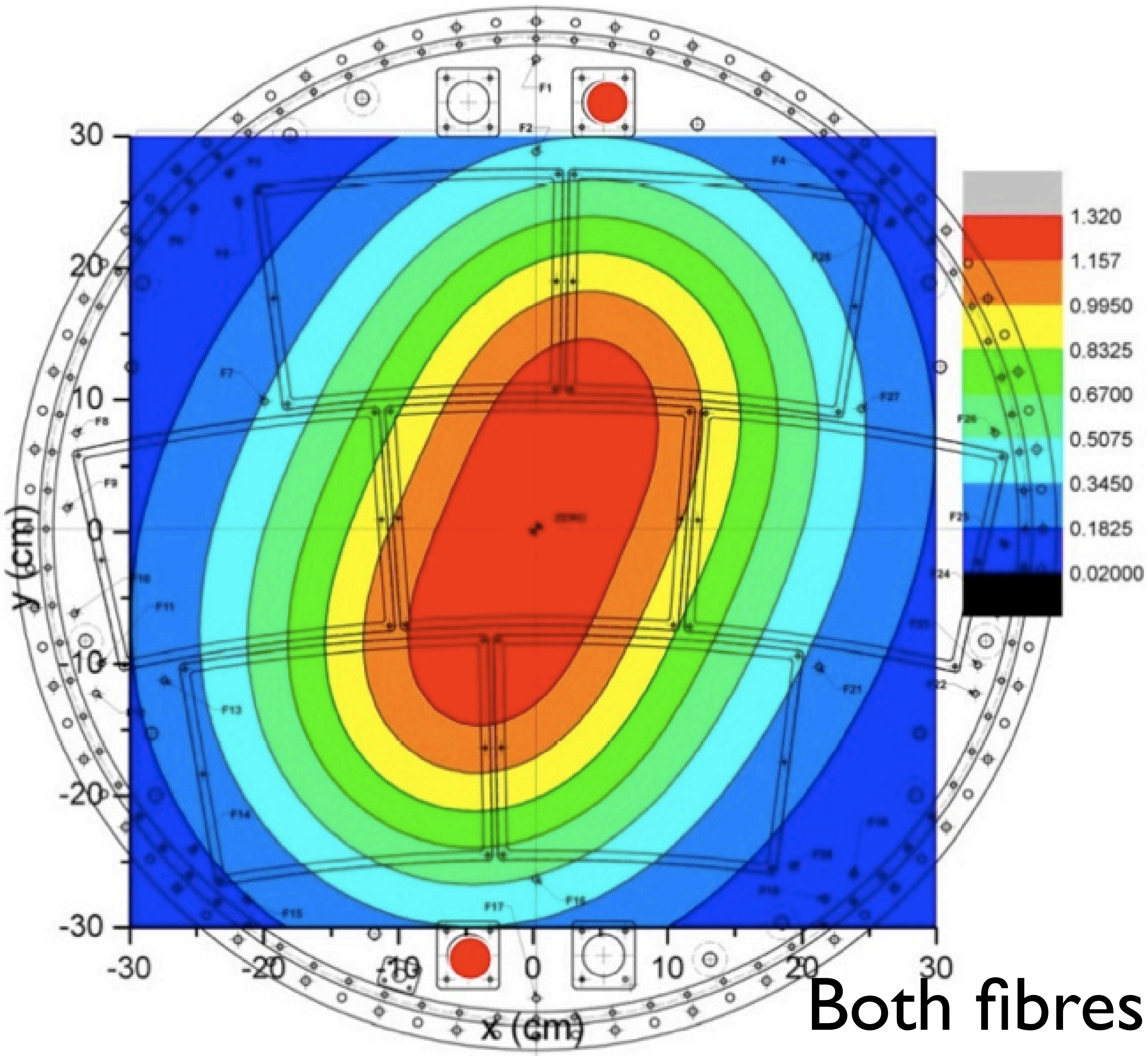
TPC endplate

Fibre - drift volume feedthrough



One fibre transmitting

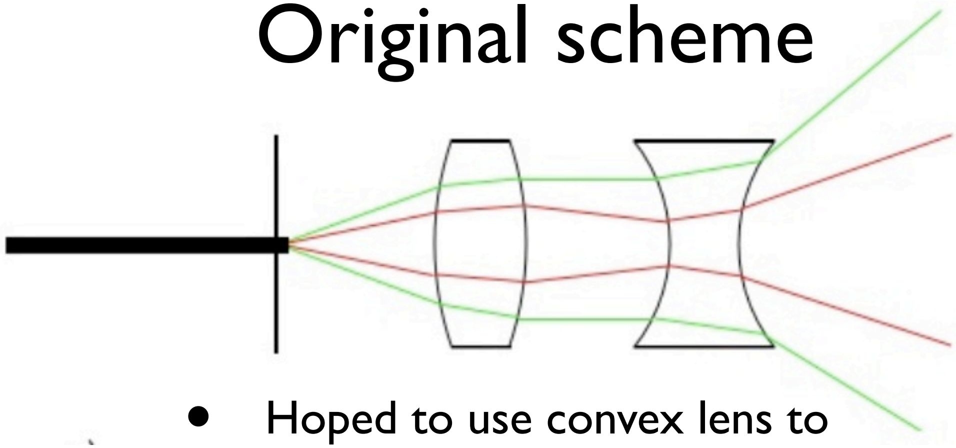
Fibre - drift volume feedthrough



Both fibres transmitting

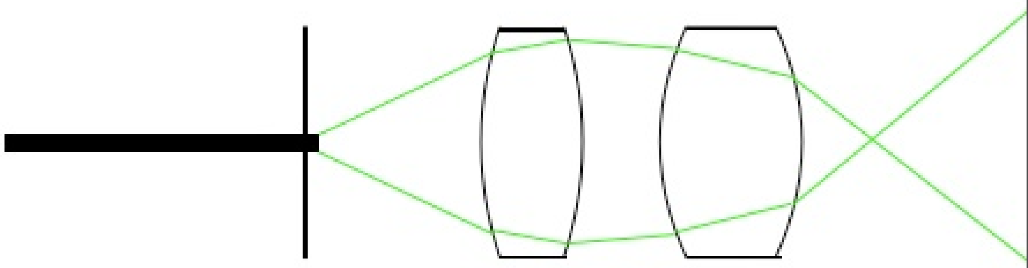
Light defocussing

Original scheme



- Hoped to use convex lens to collimate beam and concave to spread beam a known amount
  - Not successful. Focal length of convex lens successfully collimated badly-polished fibre (green lines).
  - Well-polished fibres have lower NA, and concave lens is less successful

Current scheme

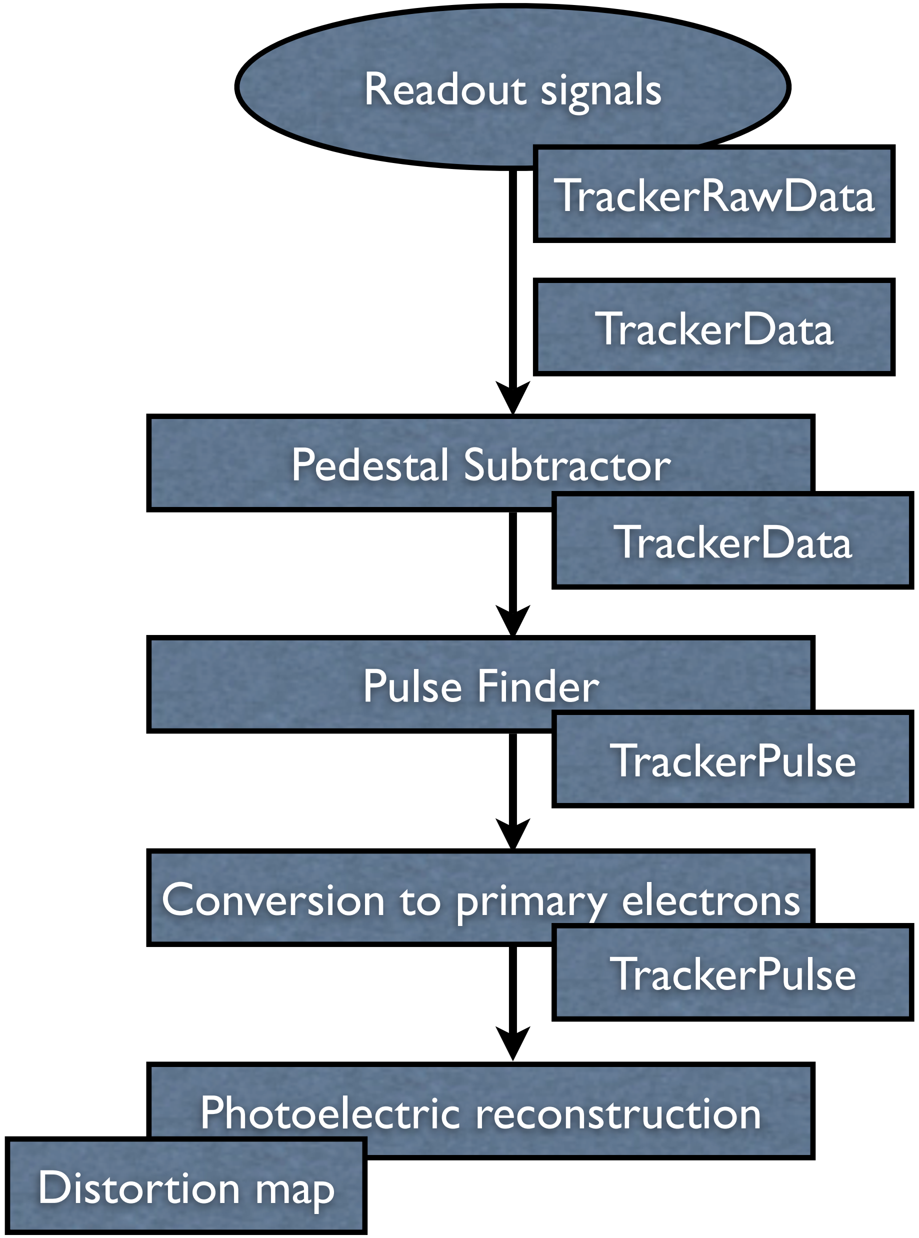


- A pair of convex lenses solves reduced defocussing of concave lens
- Focal point of beam in this system allows a much smaller hole in field cage
  - If necessary, shorter focal lengths could be used at the cost of losing small field cage hole

- Either design has a fundamental limit on defocussing (~45°) because of lens size

Reconstruction of distortions

- Calculation of distortions is performed by a MarlinTPC processor
  - Positions of dots and lines read from a text file and matched to hits;
  - change in width of electron cloud from lines gives transverse diffusion;
  - geometric centre of clouds from dots calculated, resulting distortion vectors are printed to an lcio collection.



Conclusions

- Laser flashing into a TPC volume at low energy creates photoelectron clouds off an Al pattern on cathode
- Electron clouds are measured with normal electronics (GEM or micromegas, etc..
- A MarlinTPC processor dedicated to this reconstructs distortions from the pulses created by these electron clouds
- The system has good potential in many different uses: calculating distortions, drift velocity, diffusion, gain
- Calibration system has already been given extensive testing in T2K LP and Module 0

Appendix

- Very difficult to determine rate of damage (solarization) except in the experiment
- At 50Hz, ~50% loss in transmission can be seen in 300k pulses
- While laser is not flashing, transmission increases again
  - Lower pulse repetition rate gives fibre time to repair between flashes; reduces heating

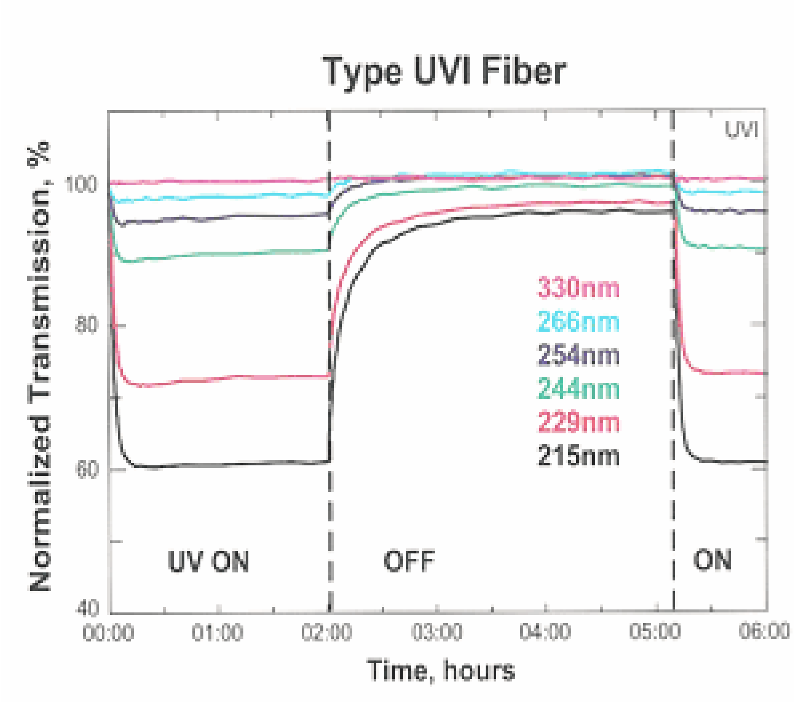
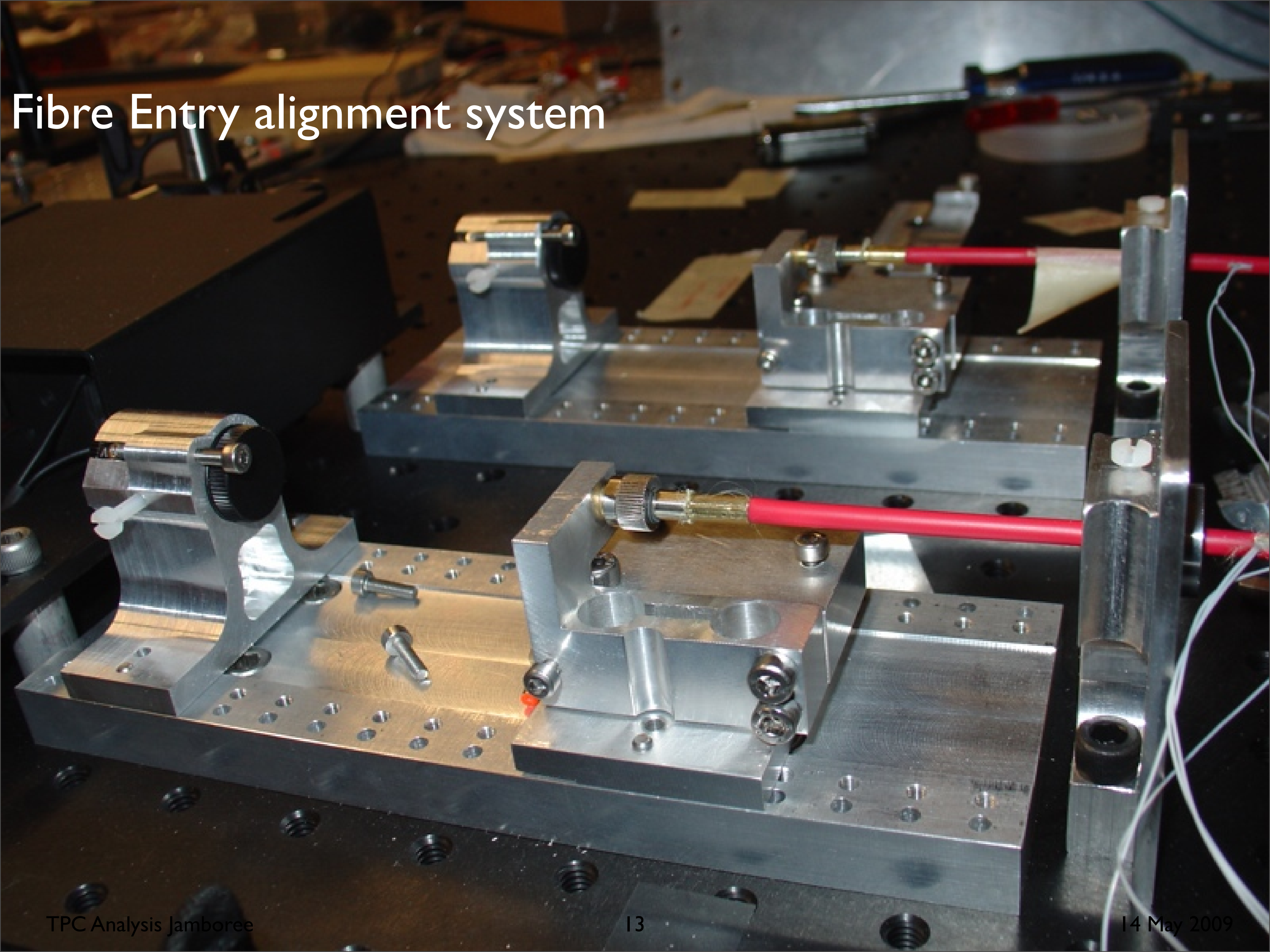


Image source: Polymicro Technologies

Fibre Entry alignment system



T2K LP