Creation of patterned-cathode photoelectrons and TPC distortion analysis

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Introduction

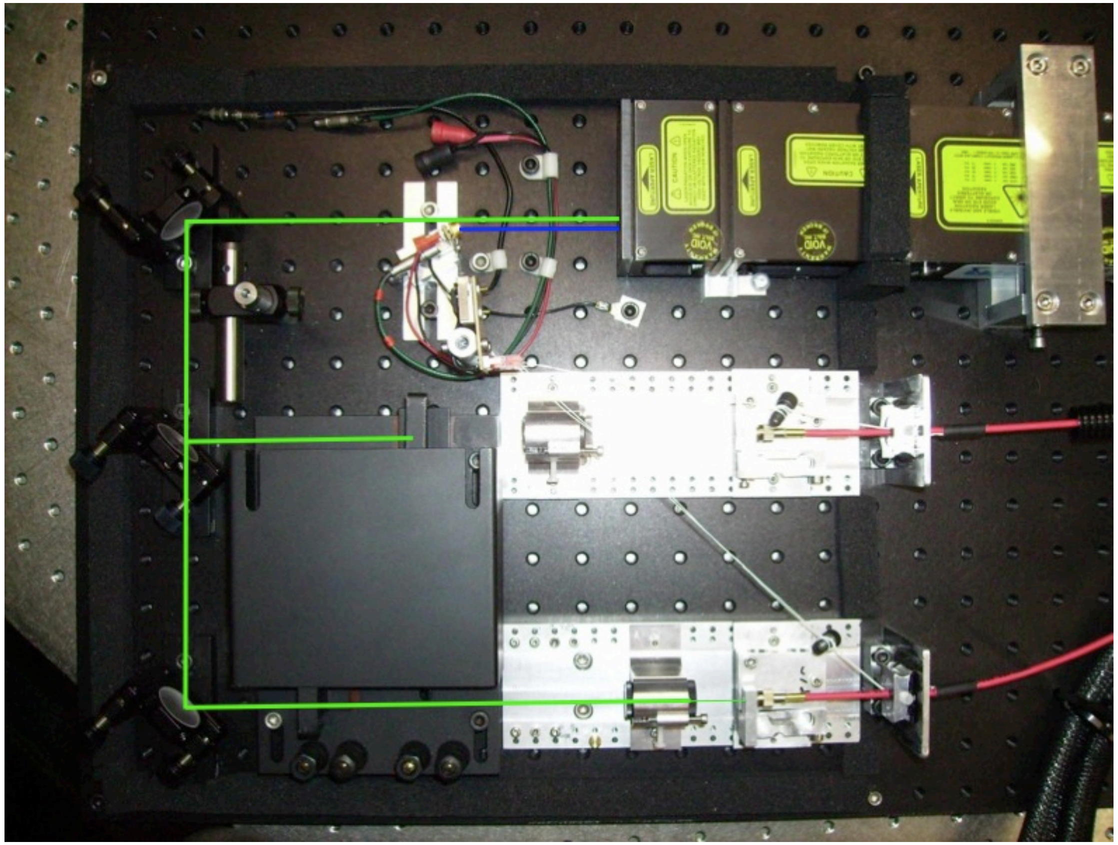
- Inhomogeneities in the electric and magnetic fields inside a TPC create distortions in the positions of tracks.
- These distortions can be quantified by analysing the positions of hits create from electron sources at known locations
- Photoelectrons from the flash of a UV laser incident on the cathode

Overview

1. Design of the laser system
2. Analysis of photoelectric data

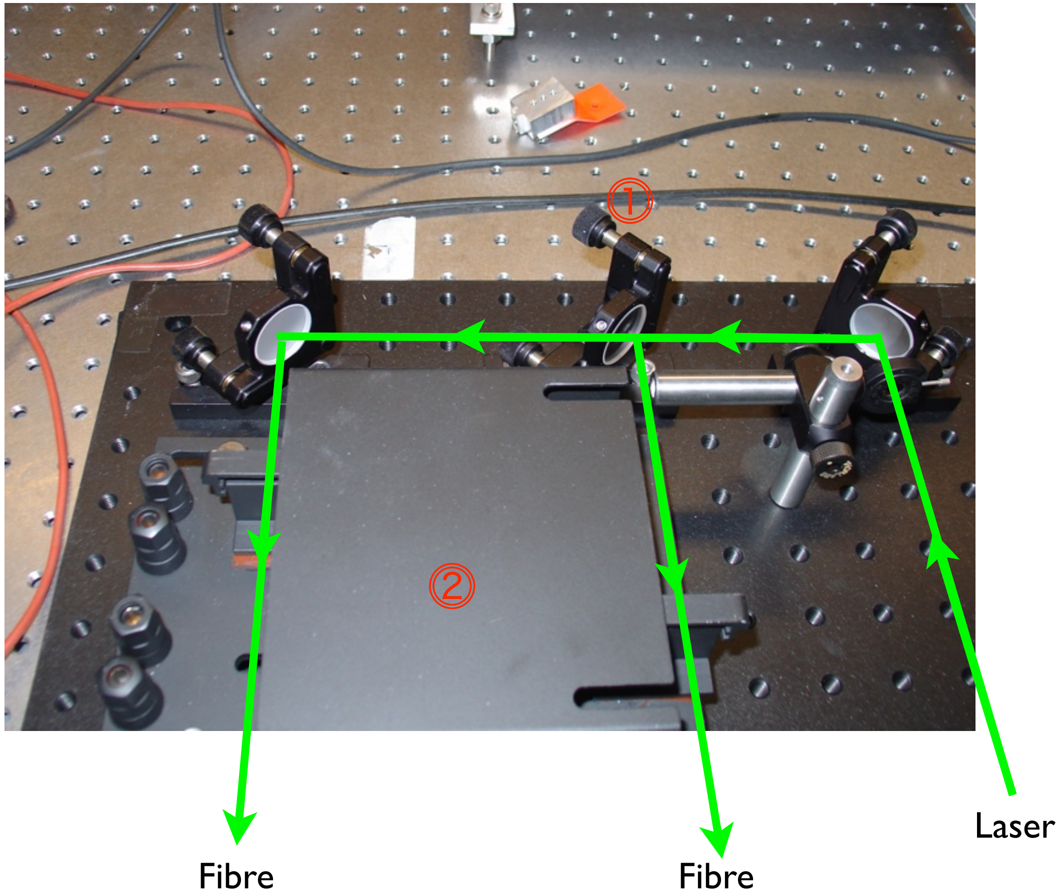
Light source & path

- Source: 266nm (frequency-quadrupled) Nd:YAG pulsed laser, repeating at 1-20Hz
- Longer-wavelength light is intercepted by a photodiode, creating an analog trigger signal synchronous with the laser pulse
- Path: light travels to one or more lenses that focus light onto fibre-optic cables, which transmit the light to lens systems on the TPC endplate.



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

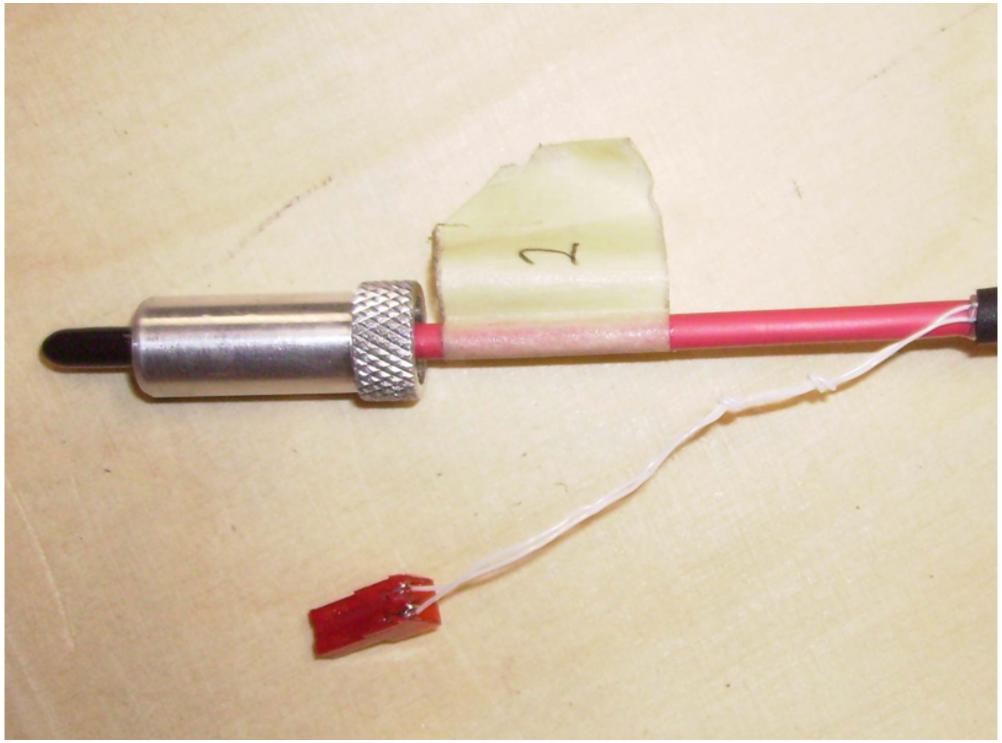


- Beam-blocking device (2) allows either beam to be used individually to test light profile of each fibre

Fibre optics

- Fibre optic cables are single-mode fibres with a 800μm-diameter core surrounded by a 60μm cladding, in a sheath of kevlar fibres and a plastic furcation tube for protection

- Red connector is part of the laser's interlock sytsem, to ensure the fibre cannot be disconnected or cut.



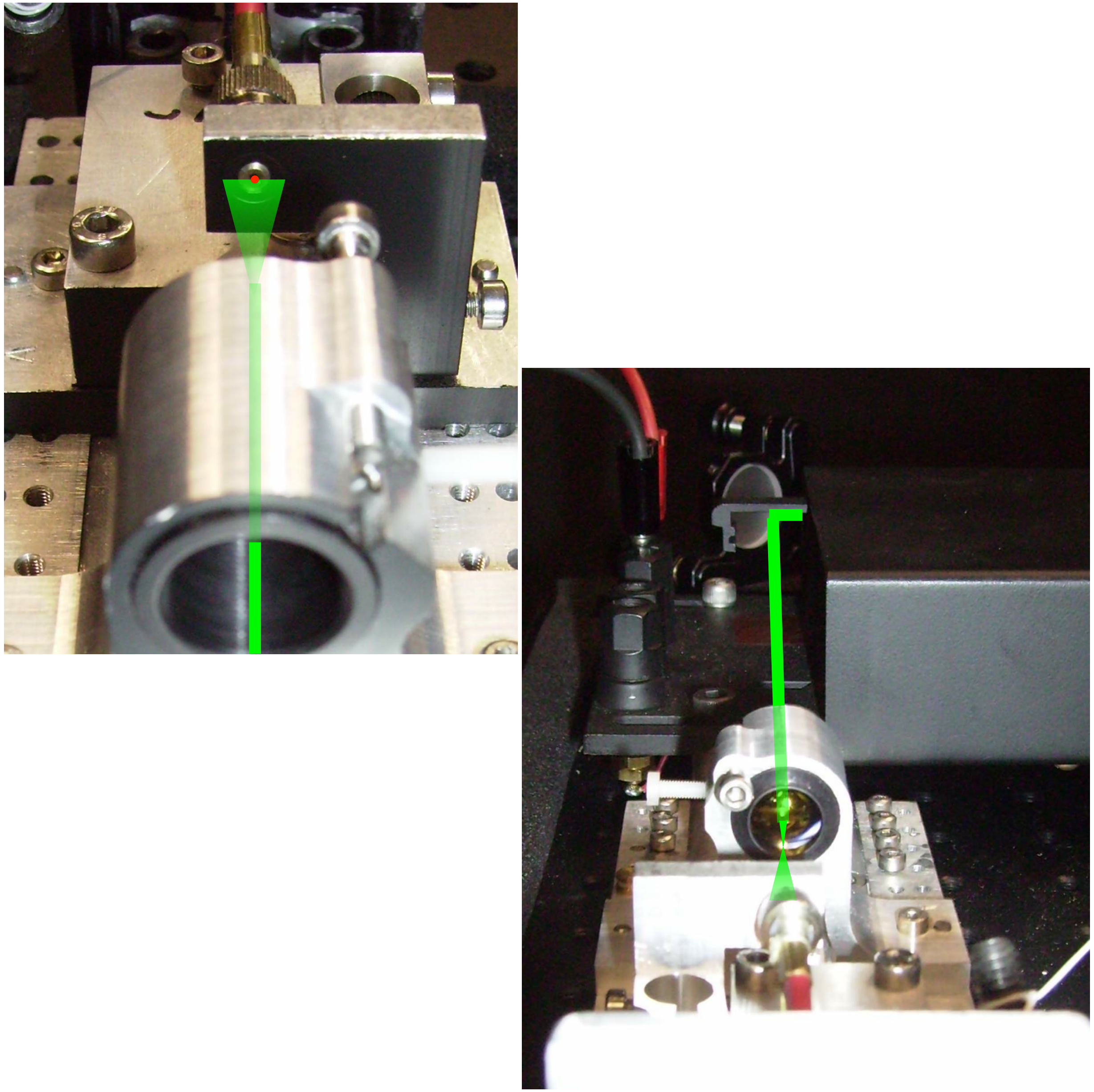
Light transmission - optic fibres

- 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

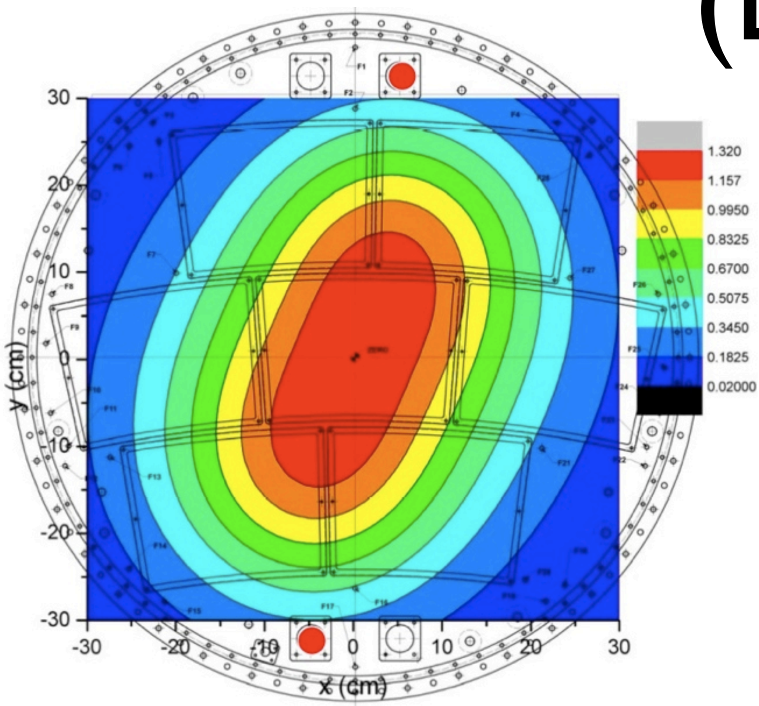
Optics: input

- Fibres are unfortunately very sensitive to high-intensity light (high energy densities cause instantaneous damage)

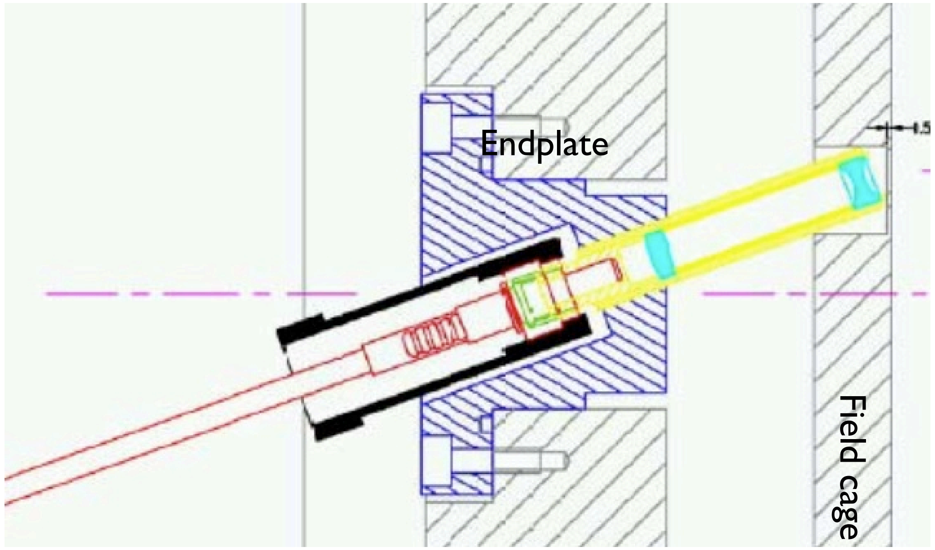
- A lens that would nominally be used to focus the light onto the fibre is actually used to defocus and reduce energy density



Fibre - drift volume feedthrough (LC-TPC)



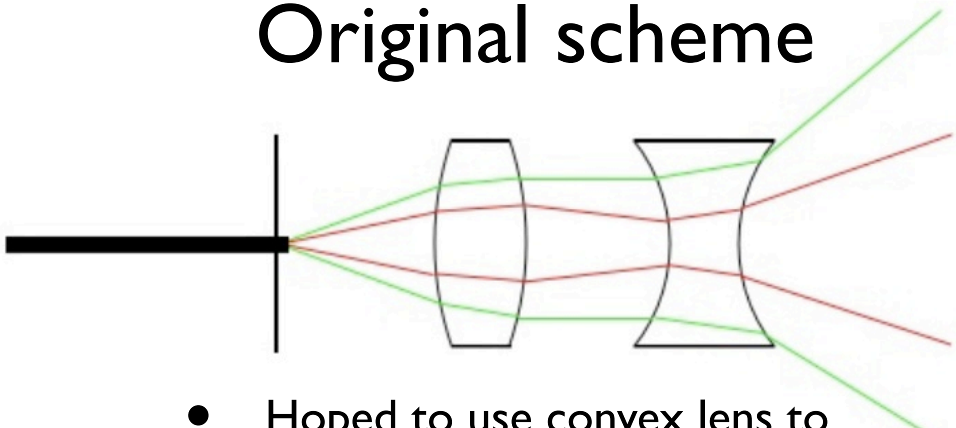
- Feedthroughs have been constructed so beam axis is 20° to endplate
- Beam axis (greatest light intensity) will reach cathode near centre; superposition of beams will provide constant energy density



- Fibres will enter TPC at points marked in red
- T2K laser system has three feedthroughs/drift volume: 4 modules/fibre

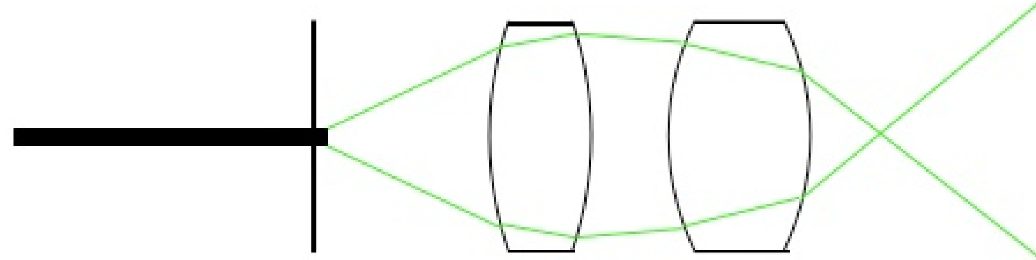
Optics: output

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

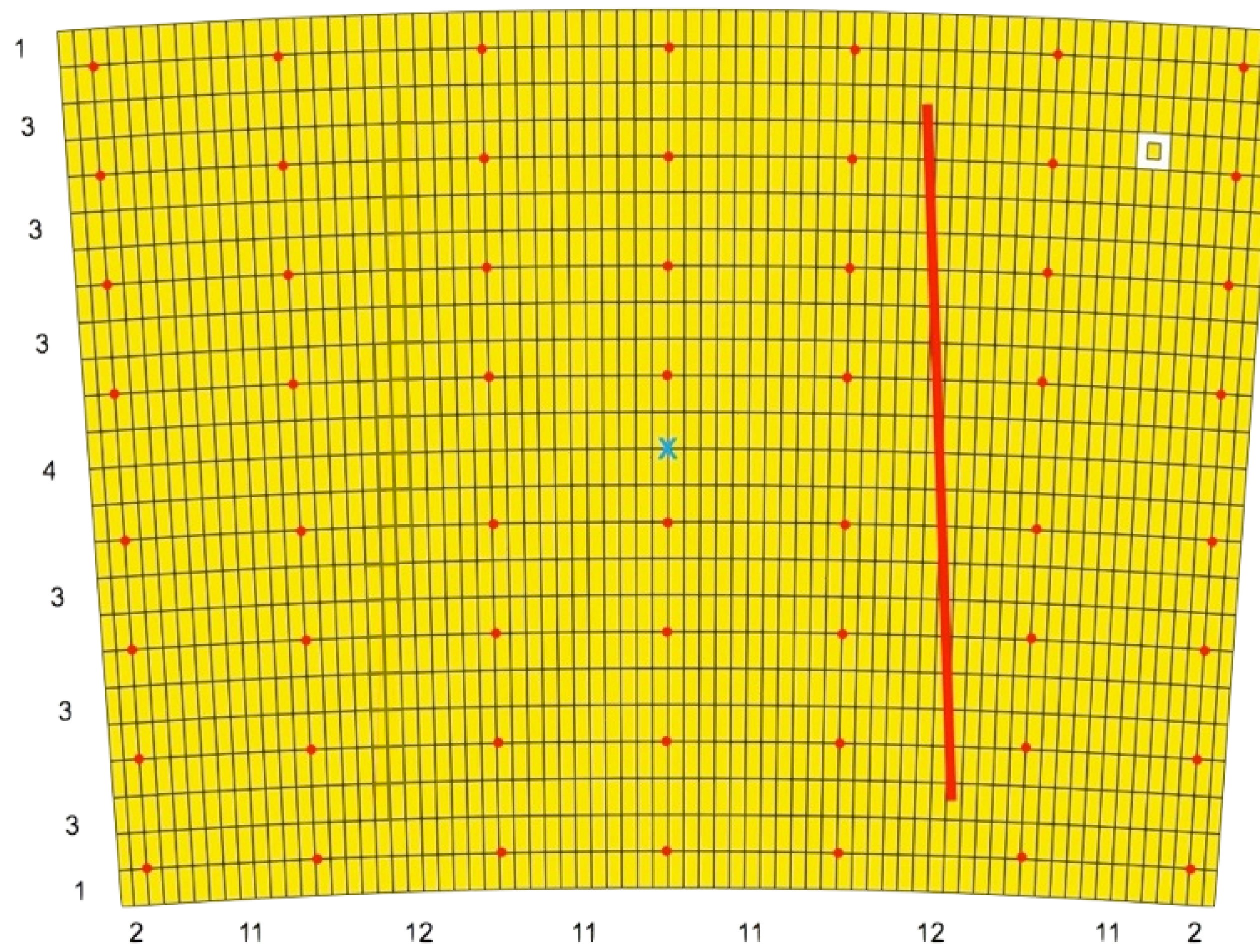
- Either design has a fundamental limit on defocussing (~45°) because of lens size

Origin of electron clouds - patterned cathode

- Al has a lower work function than Cu → incident light will cause photoemission from Al pattern at a longer wavelength than Cu

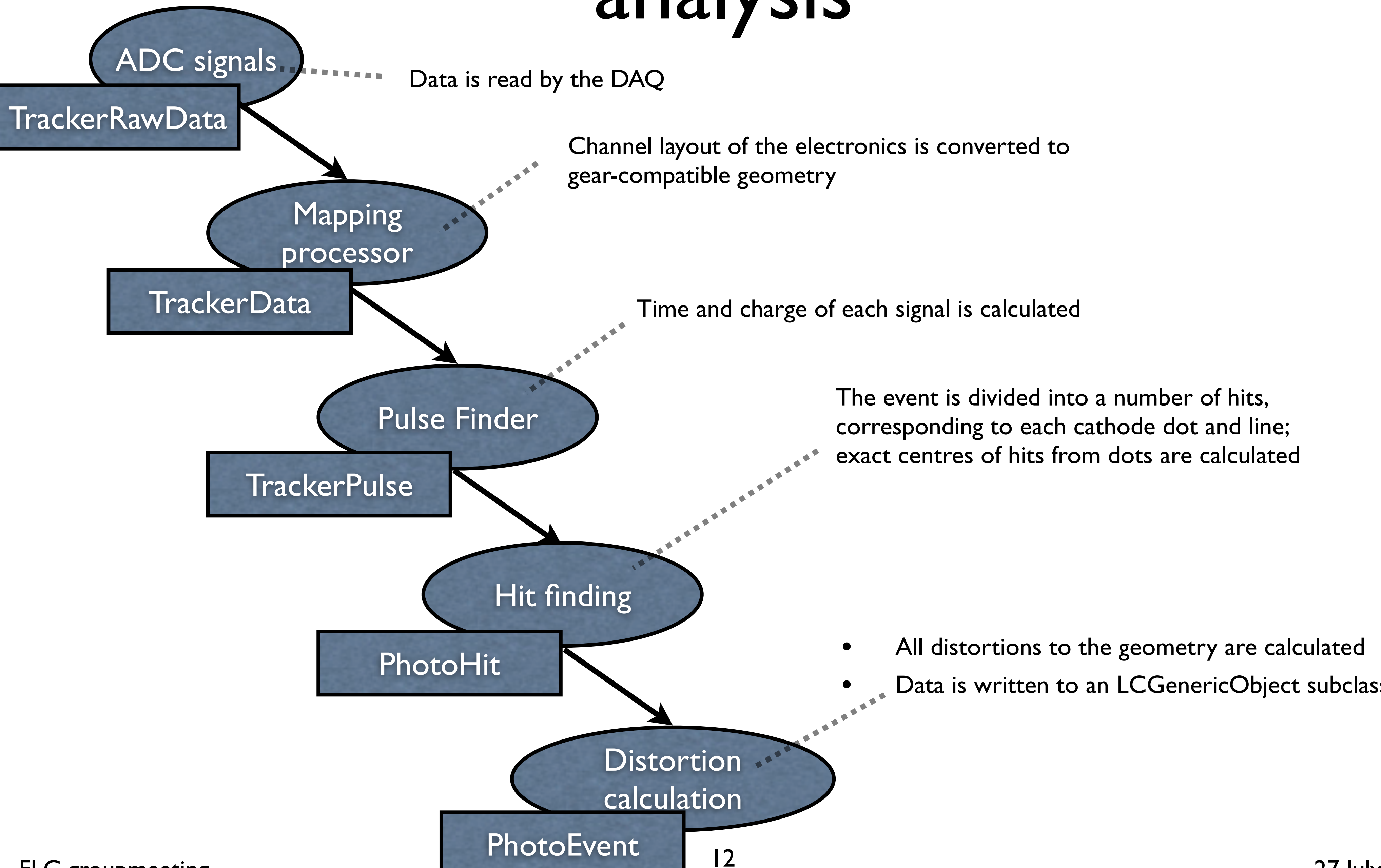
- Pattern can be Al tape glued to cathode (T2K) or special cathode with Al substrate (ILC)

- Applying tape labour-intensive and manual, drilling through Cu is automated



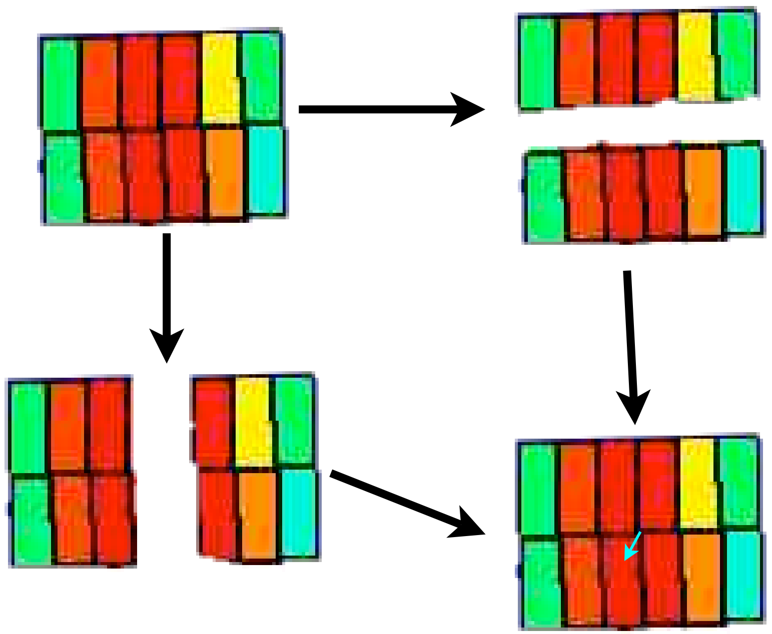
Saclay Micromegas geometry shown with the Al pattern overlaid

Reconstruction & distortion analysis



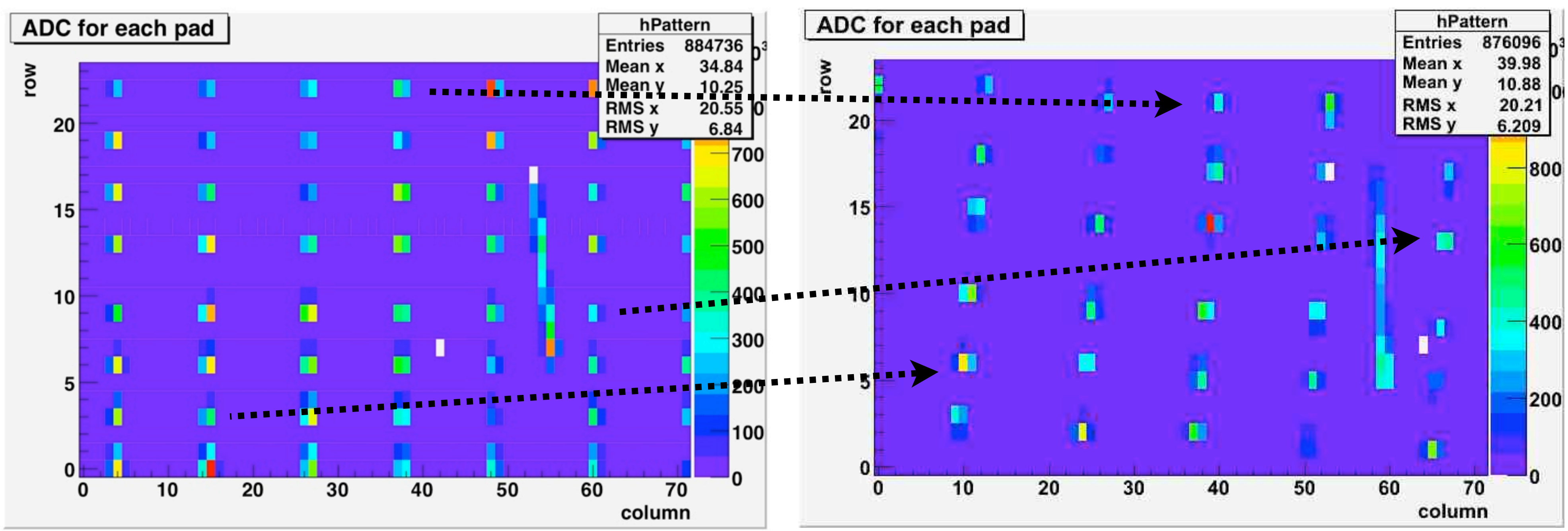
Hit finding

- Each hit is divided into quadrants
- Inverse error function is applied to the fraction of change on the top/bottom and left/right pairs
- Resultant distance from the boundary in each calculation gives the centre of the hit
- Once hits are matched to cathode dots, a map is obtained of distortions at each point in the TPC



Global distortions

- Distortions also occur globally, especially at long drift distances in the PCMAG:
  - A rotation in the module can be found from the angle of the line
  - Scaling can be found from the length of the line
  - A displacement in the module can be calculated from the averaged positions of several widely-separated dots



Other data

- In addition, transverse diffusion can be calculated from the width of the line
- Drift velocity is easy to calculate because all electrons were generated at the cathode in a short time
- Gain can be calculated through analysis of hits with low charge
- When all distortions have been calculated, they are written to an LCGenericObject subclass to be used in analysing tracks or averaged to monitor for changes in TPC conditions