Measuring distortions in a TPC with photoelectrons

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Introduction

- A controlled and reproducible ionization pattern can be very useful to understand and monitor electron transport in a TPC:
  - drift velocity
  - diffusion
  - gain
  - distortions arising from
    - electric field, magnetic field non-uniformities
    - positive ions
Using photoelectrons

- To produce photoelectrons for this purpose, place on the central cathode a pattern of metal with a lower workfunction.
  - Flashing the central cathode with a light pulse of the right wavelength will produce photoelectrons only from the metal pattern.
  - Precise survey of metal pattern allows for absolute measurements of distortions.

- This technique is used in the STAR TPC and will be used in the T2K TPCs.
Correcting distortions

- For the test pattern to be useful to help empirically correct distortions (arising because of imprecise knowledge of the fields, or from positive ions) then it is important to consider the ambiguities in solving the inverse problem:
  - given the known positions of the test-pattern, and images from the device, determine the displacements
Ambiguities

- **Issue 1:** diffusion constant must be known to calculate spatial coordinates from the observed charge distribution
  - use line patterns (not aligned with pad boundaries) to determine diffusion constant
- **Issue 2:** lines alone are not enough:
Ambiguities

- Having lines in other directions resolves ambiguity, but only near crossing point

- crossing points more difficult to analyze
T2K TPC test pattern

- A set of circular dots will be used, along with a few line patterns for diffusion

One MM module:
- 36 x 34 cm$^2$
- 1728 pads
  - 10 x 7 mm$^2$
- 4 mm wide strips
- 4 mm radius dots
Prototype test for T2K

- A test system was installed in the T2K-Canada prototype field cage during its initial construction in 2005

- The pattern consists of lines only
  - thin aluminum tape applied manually
    - 2-4 mm wide
  - two contrast materials for central cathode:
    - bare copper
    - carbon loaded kapton (STAR design)

- The UV light is provided by a 266 nm laser
  - acquired just a few months ago (same model as used in our DESY ILC TPC tests in 2004)
System design

- Test with CW UV
- Test with red laser in field cage
First events

Ar CO₂ (90:10)
Typical pulses:

on strip

off strip – current through protection resistors change GEM potential

electronics off

100 ns time bins

Electronics off

Electronics off

Electronics off
First events

- Observed images appear by eye to match the strip pattern
Movie of 10 sequential events
Analysis of laser tracks

- Segments of pads are analyzed separately, using standard jtpc methods

- Run 732 – 4000 pulses in ~ 1 hour
Track parameters

- For one strip...

- 732 z0L1

- 732 x0L1

- 732 tanL1

- 732 phiL1
Drift velocity calibration

- Simple, precise
  - first run – drift velocity is changing by 0.2% over a period of 1 hour
Other monitoring for the same run

- Diffusion and amplitude vs time

![Graphs showing diffusion and amplitude vs time.](image)

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**Absolute gain**

- The variation in collected charge in a row from 1 strip in repeated pulses is Poisson
  - variance $\propto$ amplitude
  - gives absolute gain estimate
Measuring distortions

- Fit tracks to upper and lower modules separately, except for 2 short tracks
  - gives 14 measurements
  - note: no survey done

- compare to specified strip locations

x0 coordinate measured on this centre line
Track x₀ – specified strip x₀

- Displacements are small!
  - apart from one, all are within 0.5 mm
Track angle – strip angle

- upper mod: tracks within 2 mrad of spec.
- lower mod: rotation seen – to be studied

![Graph showing track angle vs true x0 coordinate (mm)]
Intentional field distortions

- The TPC was operated with intentionally incorrect field cage voltages to verify sensitivity to field distortions:

  - Voltage on the last strip of the field cage (field low) was changed by 10% (about 250V)
Nominal field low
Field low +10%
Nominal field low
Field low –10%
Considerations for the ILC TPC

- A combination of dots and nearly radial lines on the central cathode (azimuthal displacements most critical)
  - dots of diameter 2 mm would allow displacements to be measured to a precision of 50 $\mu$m from a single laser pulse
- laser ports will require some gaps in readout
Uniformity of light, electronics gain

- The light intensity needs to be relatively uniform across each dot – to not cause a significant shift in the charge centroid
  - similarly the relative gain in neighbouring pads sampling charge from a dot needs to be known

- example:
  - dot diameter: 2 mm (1D \( \sigma = 0.5 \text{ mm} \))
  - light intensity (or relative gain) differs on two sides of dot by 3%
  - shift is:
  \[
  \delta \hat{\mu} = \sqrt{2\pi \sigma \delta f} \approx 40 \text{ \( \mu \text{m} \)}
  \]
Possible locations for installing on LP1

- Two fibre ports
  - separate pulsing checks that light variation across dots not affecting measurements
- light directed towards centre points on cathode
Summary

- Reproducible patterns of photoelectrons can be conveniently produced by pulsing UV on the central cathode

- Proof of principle test completed
  - very good contrast between aluminum and copper
    - no need for carbon loaded kapton on central cathode
  - laser data easy to use to monitor drift velocity, diffusion, and possibly gain
  - system gives essential information to understand distortions

- Would be useful to install in LP1
Displacements of tracks

- 10 mm displacements seen at outer edges, no effect at centre, roughly linear