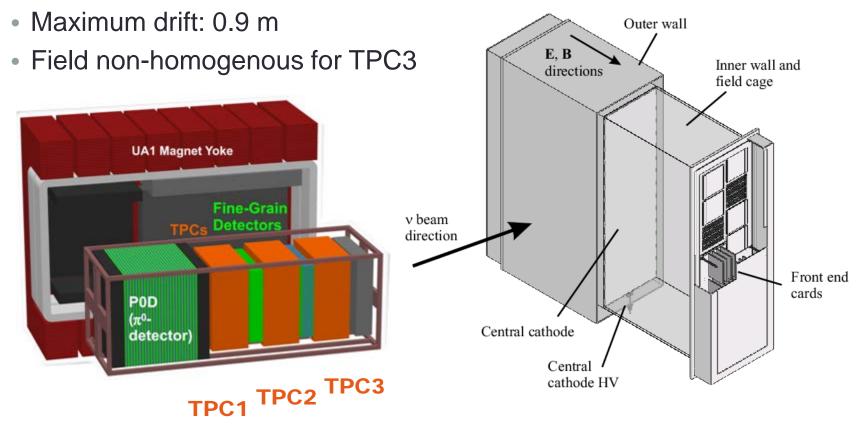


# T2K TPC For Laser Calibration

D. Karlen / U. Victoria & TRIUMF LCTPC Collaboration Workshop March 26, 2012

# T2K TPC design

- Detectors designed to fit inside UA1 magnet volume
  - Each TPC approx: 2.5 m x 2.5 m x 1 m

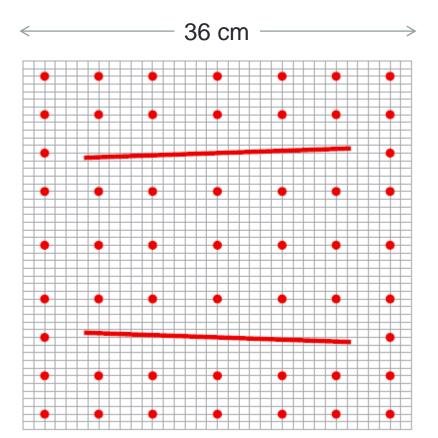


# TPC laser calibration system

- Illuminate the central cathode with pulses of UV light
  - Use 266 nm laser and 18 quartz fibers (mechanical mux.)
- Aluminum features emit more photoelectrons than copper
  - Nominal setting: 2 pe/mm<sup>2</sup> for aluminum, 0.03 pe/mm<sup>2</sup> for copper
- Calibration capabilities:
  - **Time domain**: drift velocity, relative time offsets between separate readout modules, shifts in timing offsets
  - Gain calibration: use Poisson nature of photoelectron emission to estimate absolute gain of system and relative gains
  - Field distortions: measure displacements of photoelectrons transverse to drift direction, due to non-homogenous B field

#### Aluminum pattern

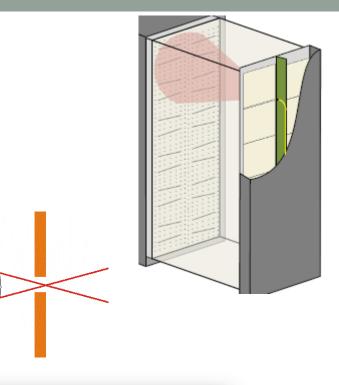
- Common pattern for each readout module
  - 8 mm diameter dots and 4 mm wide strips
  - 7 mm x 10 mm pads
- Points much more useful than lines of ionization to understand field distortions
  - particularly for T2K as there is no "preferred" track orientation, unlike ILC where tracks originate from a fixed point



# Bringing in the light

 Focused through ~1 mm hole in module frame





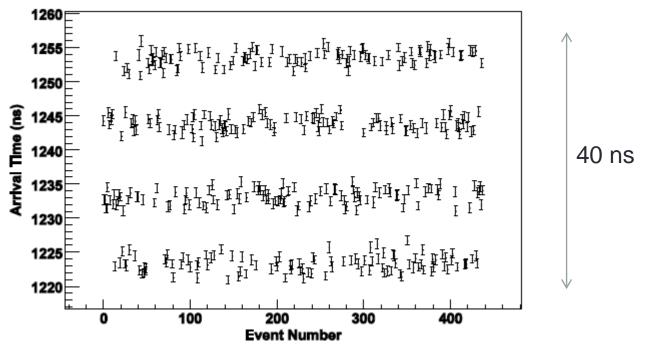
5

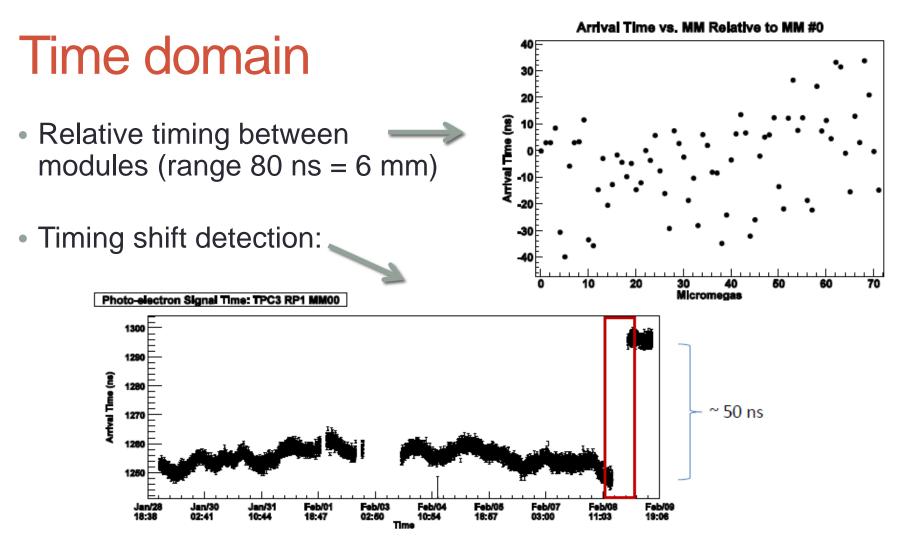


# Operational Experience

# Time domain

- Digitization: 25 MHz (40 ns samples) 12 bit
- Arrival time for single calibration pulse:  $\sigma$  ~ 1 ns
- Used to discover/fix random event-event phase shifts
  - 25 MHz clock derived from 100 MHz clock 4 phases





 Drift velocity monitoring done with mini-TPC connected into gas system (in continuous operation)

# Field distortions

• Goal: account for field distortions so that systematic uncertainty on the momentum scale is:  $\delta\left(\frac{1}{p_t}\right) < 0.02 \text{ GeV}^{-1}$ 

• Note: momentum resolution is  $\sigma\left(\frac{1}{p_t}\right) \cong 0.1 \text{ GeV}^{-1}$ 

• Sagitta:  $s = \kappa L^2/8$   $\frac{1}{p_t} = \frac{\kappa}{0.3 B} = \frac{8}{0.3 B L^2} s$ 

•  $\kappa = 1/radius$  of curvature, L = track length

• T2K: B = 0.2 T, L = 0.8 m  $\rightarrow \frac{1}{p_t} = 0.25 s$  [GeV, mm]

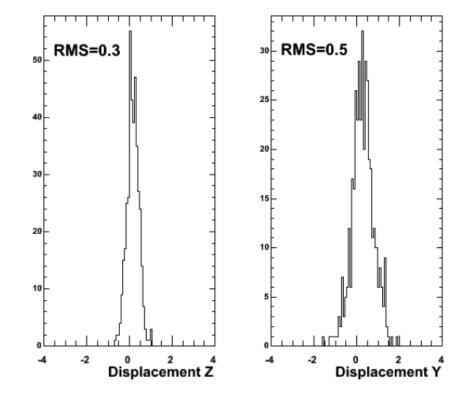
distortions need to be understood at level of 0.1 mm

• LCTPC: B = 3.5 T, L = 1.8 m  $\rightarrow \frac{1}{p_t} = 0.002 s$  [GeV, mm] • ILD goal\*:  $\delta\left(\frac{1}{p_t}\right) < 2 \times 10^{-5} \text{ GeV}^{-1} \rightarrow \delta(s) < 0.01 \text{ mm}$ 

\* not sure what number to use here

## Field distortion measurements

- B-field mapped prior to installation of detectors
  - special purpose apparatus built by CERN technical group
  - precision goal: transverse field components known to 1-2 Gauss
- Measure displacement of calibration dots centres when B field is turned on
  - Compare with the expected displacements from B-field map
  - Difference between two: empirical correction and uncertainty
  - 100 flashes  $\rightarrow \sigma \sim 0.04$  mm



#### **TPC3** distortions

 Lines show displacements (x 20) for dots on one readout plane (aspect ratio not preserved) (maximum few mm)

simulated from field map

measured

-	_	_	- m-			1 million 1								
· · ·	-		-										-	
-	-	_		_			-	-	-	_	_	. A.		
		-	-	-	-	-		_		~	~	· •		
-					_	_							<b>*</b>	
	-	-		<b>B</b>	-	<b>B</b>	-	-	-	-			+	
-	_							- N	N					
-	-	-	-				*	•	•	•	*	*	<b>*</b>	
÷.					- N.							· · · ·	- C.	
-	-	-	-	_	-	1	•	· ·	<b>r</b>	<u> </u>	~	_		
× .					T	r	÷					- F		
۰.	-	•	*	+	<u>*</u>	P	<u>6</u>	-	-	<b>P</b>		-	- a	
		-	-	÷.	÷	in the second	- C	- C						
÷.	2	2	÷.		5	- m	_	_	~				~	
Υ.		· · ·	· · ·	~		~	~	, <u>-</u>	100	10 March 10		-		
							í er	Sec. 1		1				
		<b>3</b>	<b>7</b>	<b>**</b>		1.00	- C	- C	- C			-	_	
- P	· · · ·	~	· · · ·	_	~		-	-	~	_	_			
-	_	_	· · ·	· · ·	1.00	·		·		-	-			
<i></i>	_		_		~	_		~	~		_	_	_	
s						<u>_</u>	-				- a -	- a-	-	
					<b>B</b>	- C P	- Contra - C	_	_			_		
<u>.</u>						C	-							
~	_						- C C C C C C C C.	~	~	_	_		~	
~	~	~	~	_	-	-	- <u>-</u>	- <b>-</b> -	- e -	1 an	~		- <u>-</u>	
÷	_	_	_	<u></u>	- <u>-</u>	1. Al		e	1		<u></u>	~~.	~~ ~	
					- C - C - C - C - C - C - C - C - C - C	1 m -			_					
<u> </u>		_	_	_	_		<u>_</u>		~					
~	_	-	_	_	-	1000		-			~ _	~ _		
<b></b>	<b>.</b>	-	-	-	(D)	- m	1 m -					- <b>-</b>		
-	_	_	-		~	_		~	_	_	_	~~	_	
- <b>1</b>	-	-	<u></u>	<u></u>		<u></u>	_				ر ہو ۔ ~	مرجر ال	_	
·					- C	18 a - 18	1 - C - C - C - C - C - C - C - C - C -		1.1	1	1	×		
- 22			_			- C		<u>_</u>						
~	~	~	~	~	_	- C	- C		_		-	<u></u>		
<u>_</u>	_m	<u></u>	<u></u>	· · · ·	~~ ·		- Carlos - C	-	-	-	· _ /		100	
		- C.	1 A A		1 a - 1	C	100	1-	1	100	1	-	1	
· .	-	- Carlo	- Carlo	1 Car	- Car	6.		-						
e	-		-	_	~		1.5	~~ ·	11	11	11	100	10	
~					- C	100		~	10		- A -	~~~/	- /a -	
	~		~	<b>.</b>		5 m		-	1			11		
		- C -	- C -		-	1	- Sec. 1	5 C	- C		100	1 1	12	
	_	× .	~	, m				~	~	~	<i>+</i>	- + 1	11	
· .	-				- C	- C		6	100	1	/_	- <u>/</u>	//	
÷ .	~	_	~		~	~	~	~	100	- P	100	11	11	
~						100	· · ·	·	-	- C -	10	· / - '	· / -	
·						1 C - 1			~	1	12	C T =	15	
<u> </u>	_						100		· · · ·	- C -			15	
e	_		_				100	, <b>-</b>		<b>7</b>	<b>7</b>	1.2	158	
× .	~	~	-	-	× 1		1 m	1 m	( p	/œ	/œ	/œ	510	
	<b>*</b>	<b>2</b>	<b>2</b>		100	1 m		1-	1-	1	1/-	14	14	
<b>m</b>		- C -	· · · ·		- C	- 10 M		1	· 7	12	11	12	17	
<u> </u>	_	_				- C	· · · ·		- 27		- 17	10	10	
-	-	~	-		~	~	19 A				1	~ ~ ~	100	
lder a anarrene e rearrant a arranger r arranger i arranger ta arranger ta arranger	the rest and some star and that the rest rest and that the	If the same are also and all all all are and are and the II	the face was and and that will the wire the will fill the	If for other and and the destruction and the second of the	A law me vie will be all the vie vie vie and the	Marian and and and and and and and and and a	III HIMMAN AND STATISTICAL AND	II THE ARE AND	In the series of the source of the total the series and the the	In several way we want to be the the the the several of the	· •	1 <b>-</b>	14	
					-	r .		5				- r	- 0°	
and the second s	<u>, 19</u>	<u>, en</u>	<u>, 20</u>	, <u>100</u>	ge-	pr-	· · ·	, <b>1</b>	- m	1.00	1.00	100	- CT -	
<u> </u>	- C					- C		100	1		- C -	1.	- Y -	
	-	_	-	-	-	- E	1	<u> </u>	2	<u>م</u>	1 m	- C2	02	
~		_	~	~	~		- <b>1</b>	- C		- C			1 C C C C C C C C C C C C C C C C C C C	
_ <b>_</b>	_	<u>_</u>	_	<u>_</u>	-	· P					-	·	14	
-	-				1 m	1 m	- Car	6	1	<u>_</u>	<u> </u>	<u> </u>	K	
	-	-			- C	1	_	-		- 2	- 12	· •		
	_	-	-			-	_			19	- <del>1</del>	· · ·	11	
									100	- <u></u>	· · ·	100		
-	_	-		~			-	100		-		100	- X	
	-	-			100	- C	-				· · ·	· · ·		
	_	_	_	_	_	-		~	~	~	_	<u>_</u>	100	
-			-		_		-		-	100	1	100	1-	
	_	_	_	_	_	_	-	_	_	_	-	1	-	
						_		-	-					
	_	-	-	_	-						_	_	1	
-													-	
-		_						_	_	_	_	_	-	
								-		-	-		-	
										_	II IN YOU AND AND AN AND AND AND AND AND AND AND	-		

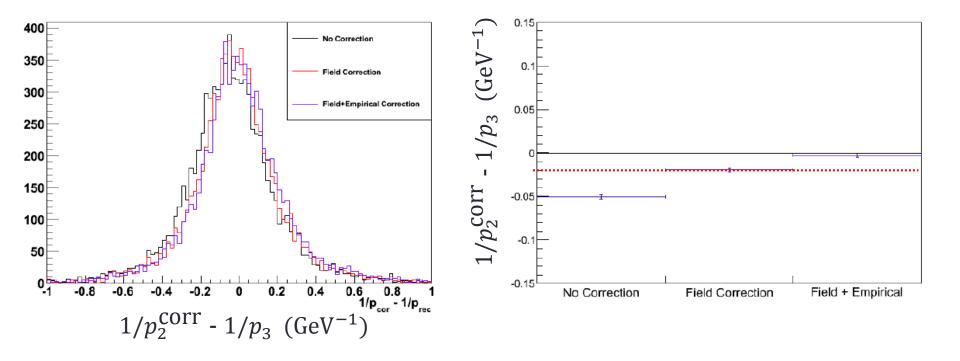
	-	-			- C								
<u>-</u>	-				<u> </u>	<u> </u>	_	-	_		_	_	_
-						-		-	_	-		-	_
_	_				_		-		-	_		_	-
							-						*
-	-	-		<b>1</b>	<b>a</b>	<b>11</b>	-		-	-			-
													- <b>5</b>
•	-	-		<b>.</b>	<b>.</b>	<u></u>	_					~	
-						-	-	<b>a</b>	-		-		-
	-	-	-	-	-	<b>Cb</b>	-		-				
-	-	-	-	-	~	-							_
		-	-				-	÷			_		_
-	-	-	-	-	-		-	-	-		-		-
-		-	-	-	-	500 C	-	~	-	-	-	-	-
-											- C	- C.	-
			+	+		÷.	-	-				_	~
_	_	_	-			-							_
	-	-	-	-			-		~		-	-	-
										-	-	_	- C
	-12	-	-	-	-	-	-			_		_	_
•						÷	- m					-	·
	-						_	-	-	-	_	~	
-		_	-	_	_	-							_
		-	-	-	-		-		-	_	_	_	-
-	-		-	-	-	-	æ	-					
-	-	-	-		per la	-	-	-	_		- Contra 1	·	_
						<b>2</b> 2-					-		
-	-	-	-	-	-	-	-		-	_	-	-	
-	-									-			_
-	-	-	-	-				- A - A - A - A - A - A - A - A - A - A			~	-	
									- C	- C			-
	-	-				- <b>-</b> -	-			-		~	~
-							-		-		1000		
	-	-	-	-	-	-						_	
-	-	-	-	-	-	-	-			- C - L - L	- C - C - C	· · ·	~~
-	-	-	-	_	-						_		
-	-	-					<b>1</b>	100	1 m m			1 2 3	
-	-	-	-	-	-	<b>P</b>	- 12	<u></u>	- Carl		· · · ·	1	1
-												1	
	-			-	100				- 7			100	~
							-				- C	- C - C - C	19
	-	-	-	-	<u>مە</u>	<u>م</u>		÷.	er -		-		10
								· · ·	- F			1	1
-	-	-	-	-	× .	<b>T</b>	- <b>T</b>	<b>T</b>				~	
-						an 1997 -	_	-		- <u>-</u>	- C_		1-
-			~	- C	-	-	T	<b>T</b>			~		
	-		-			*	-					1	100
-	-	-	-		-	<b>T</b>	- <b>P</b>		<b>P</b>		<b>7</b>	<b>7</b>	100
-	100 A	-		-	-	-		÷	<b>b</b>	6a -	App 1	A.	10
-	-	-	-	-	100 C		÷	-	<u> </u>	<u> </u>	4	14	
-								T	-	T		- Z	- T
_	-	-	-	_	-	2		- <b>T</b>	7	7		17	
				-									19
-	-	-					-	-	-		-	-	- Ar
													· · · ·
-	-		-	-		- <b>-</b>			<b>T</b>				~
-						-	-	~	÷	÷	_	. <u>.</u>	1 A A A A A A A A A A A A A A A A A A A
	-	-	-	-	~	~	-	· ·	· ·	- <i>r</i>	· Τ	- 7	r
-	_	-	-	-		-	-						9
							-	<b>*</b>	*		<b>T</b>	-	- Fer
ldi h a aisseace e scenare e bitactes a lapstedi e areaceac e esc	the sets the test of the test of a sets the test of the sets of the set	· · · · · · · · · · · · · · · · · · ·	•• ••• •••• ••• •••• •••• ••• •••• •••• ••••		<b>.</b>	ата и актория и закатала и списта в каталия и наплати и на на и и и и и и и и и и и и и и и	$\left( \left( \left$	It has been and going that that are been not show and in	le car and the bill ter day are seen one man are to	to see that the tall the discovered and the talk of ta	The second second way a visit of the bill and second	- A	÷ .
-		-	-	-	~	*	÷.	÷	÷			<u> </u>	~
						<u>.</u>	_	-	-		<b>T</b>		τ.
	-	~	~	-	-	-		-		<b>.</b>	7		÷
			-	- C	-		-						2
	-	*	-	÷	~	~	+		-		+	+	÷.
		-											
-	-	-	-	-	-	-	-	-	-	-	т	7	7
							-	-	-	-	-	<u> </u>	· .
-		-	-	-	-	-	-	-		<b>*</b>		~	1
-	-	-	-	_	-	_	-						×
		-			-			-	-	-	~	~	-
							-		-	-	<u> </u>		

# **Observations**

- Displacements follow similar pattern as simulation
  - initially not the case: field map had sign error on transverse components
- Displacements smaller than expected, using  $\omega \tau$  as determined from the ratio of transverse diffusion with and without magnetic field ( $\omega \tau = 0.42$ )

# Fitting with field distortions

- Likelihood fit to ionization pattern on pads modified to account for displacements of drifting ionization
- Check with data: using μ<sup>-</sup> that pass through TPC2 and TPC3 (and account for energy loss in FGD2)



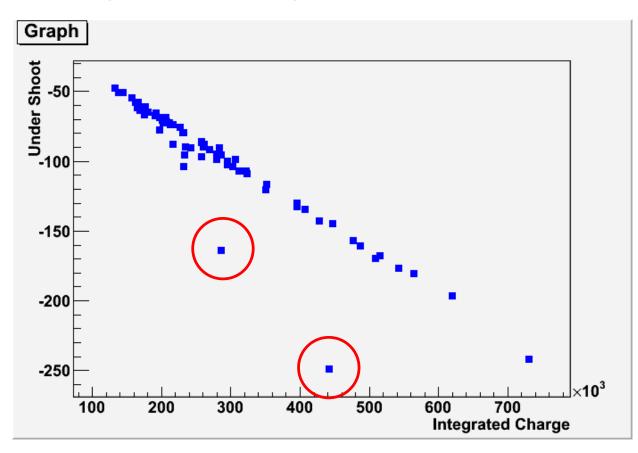
# **Unplanned** application

• The electrons arrive at readout plane all at once

- higher instantaneous charge than from ionizing tracks (not parallel to the tracking plane, less charge overall)
- a burst of charge passing through a micromegas (and to a lesser extent, a GEM) momentarily reduces the electric potential
- a signal of inverted polarity is observed on all pads of equal amplitude (somewhat masked on pads that collect charge)
- the amplitude depends on the capacitive coupling between the pads and the amplification structure
- Measurement of the undershoot is a check of the overall capacitance between mesh and pads.
- Plot on next page, shows 2 of 72 modules unusual capacitance
  - one of which had a HV filter failure
  - the HV filter of the other was replaced, just in case

# **Unplanned application**

- undershoot: negative pulse on region without AI
- integrated charge: total charge collected from AI features



# Summary

- Photoelectron calibration system an important tool to understand subtle timing issues and distortions in electron transport in the T2K TPCs
- Issues:
  - laser (Quantel/Big Sky) power degrades by a several % over the period of week running
    - requiring several returns to manufacturer for repair
    - not present for all data collection periods
  - significant effort required to design and laser transport system
    - multiplexer
    - fibres than have modest minimum bending radius)
  - needs to be included early in design stage of LCTPC

# **Backup Slides**

#### Gain

- Use variance of repeated laser shots
- Not presently used for gain calib

