Test results of ANL Photodetectors

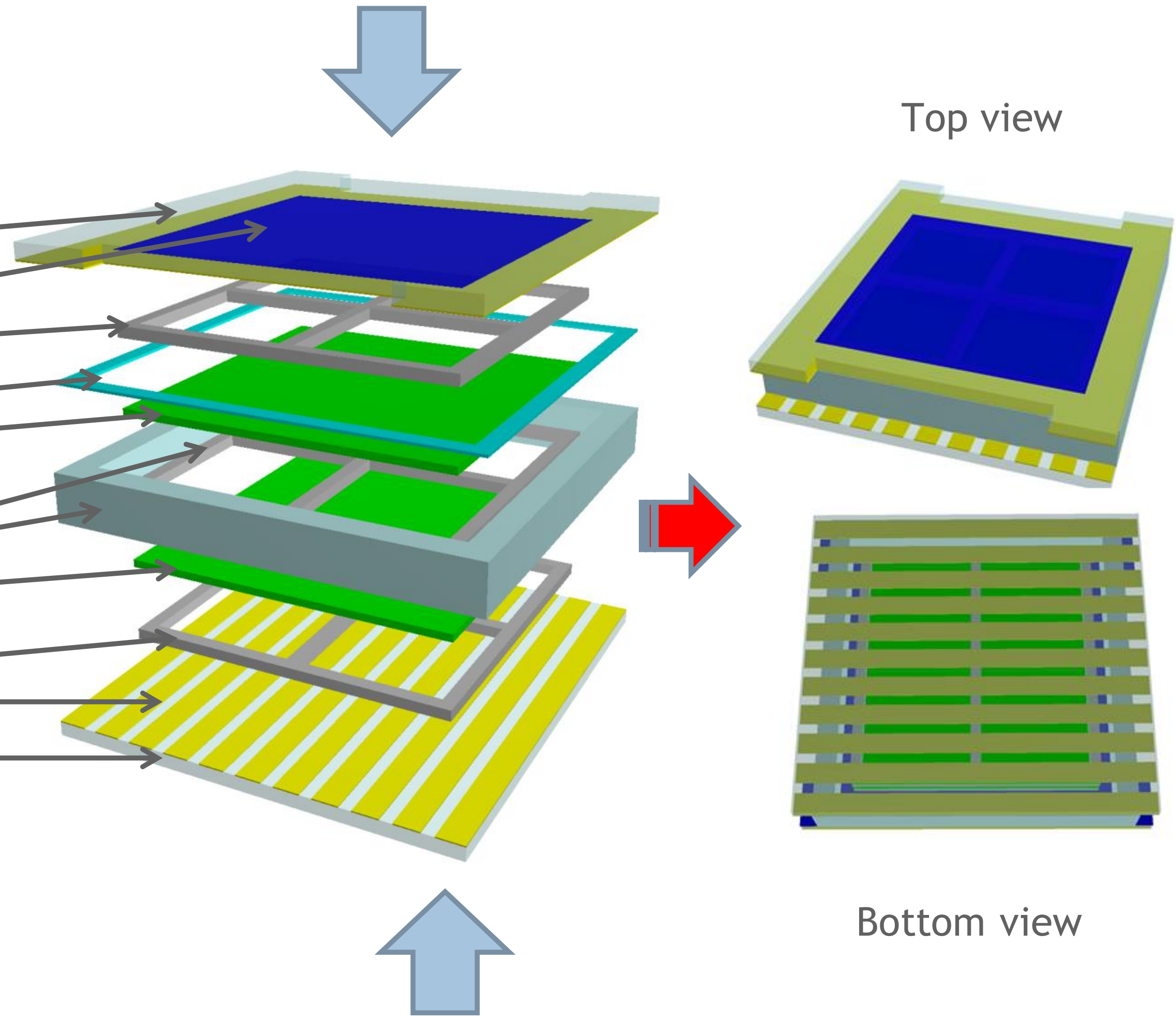
Jingbo Wang
Argonne National Laboratory, Lemont, IL
wjingbo@anl.gov

Outline

- **ANL 6cm photodetector**
- **Laser test facility @ANL-HEP**
- **Test result**
  - Typical waveform
  - Analysis approach
  - Test at high light level
  - Test in single Photoelectron mode
- **Ion feedback**
- **Summary and future plan**

ANL 6cm photodetector

- Top Window
- Photocathode
- Top Grid Spacer
- Indium wire
- Top MCP
- Middle Grid Spacer
- Side wall
- Bottom MCP
- Bottom Grid Spacer
- Anode Strips
- Bottom Window



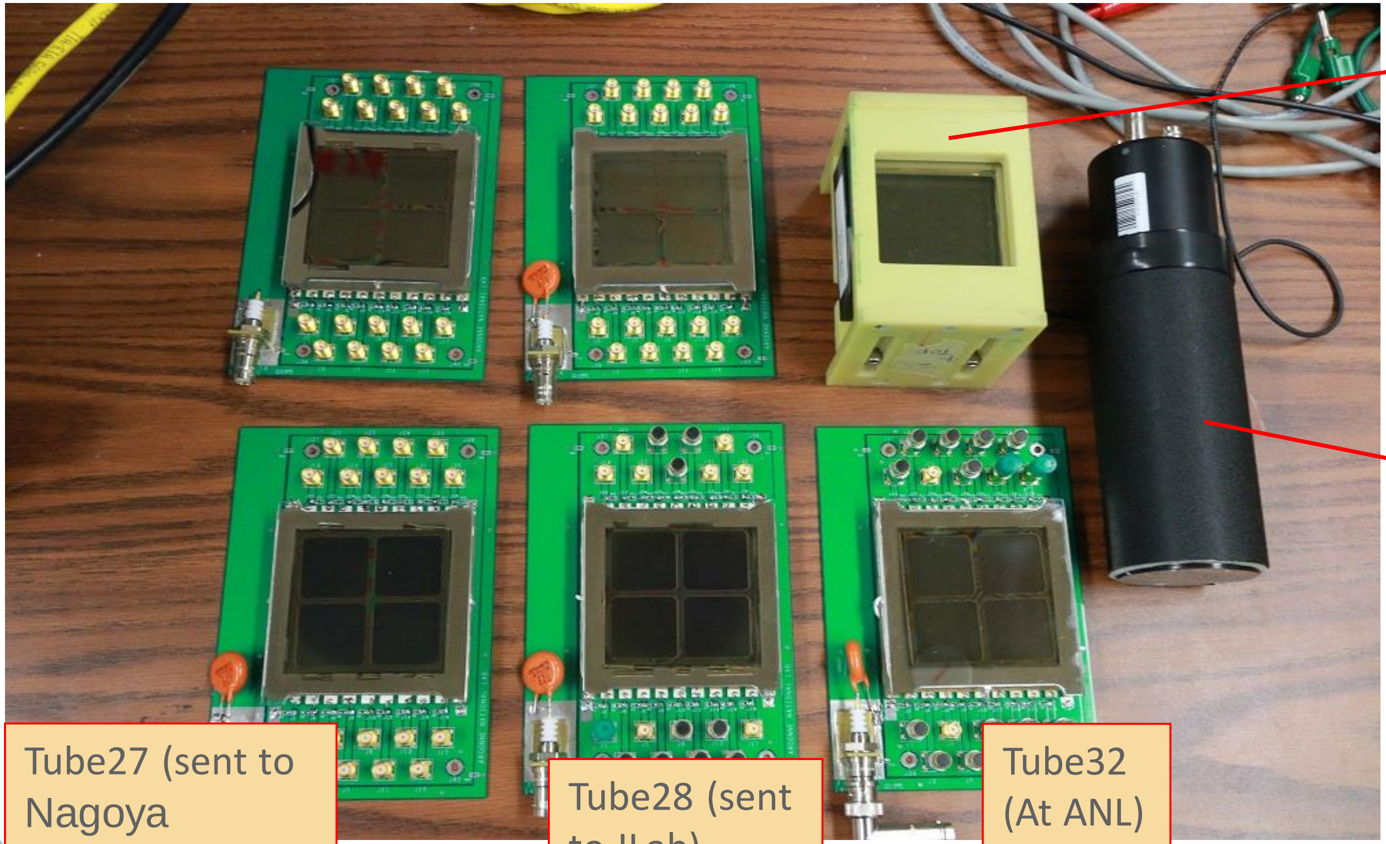
Recent production status

- Tube#20 was the first functional device
- Tube#27 is the first long-lived device

Serial #	#27	#28	#29	#30	#31	#32
Date	09/17/14	09/24/14	09/26/14	10/01/14	10/08/14	15/10/14
Type	Full tile	Full tile	Cathode only	Full tile	Full tile	Full tile
Seal	Good	Good	/	Good	Good	Good
MCP	Gen I	Gen II	/	Gen II	Gen I + Gen II	Gen II
Getter	Old, Good	New, Good	Old	Old, bad activation	New, bad activation	New, Good
σ_{tts}	~27 ps	~20 ps	/	Cloudy area: 28 ps Clear area: 35 ps	/	~16 ps
σ_{diff}	~9 ps	~ 7 ps	/	11 ps 23 ps	/	~6 ps
Life time	>10 weeks	>9 weeks	Dead, bad seal	Signal unstable on 1st day, arced at 2kV on 2nd day	Amplitude up to 1V on 1st day, mV level on 2nd day, arced at 80V on 3rd day	>7 weeks

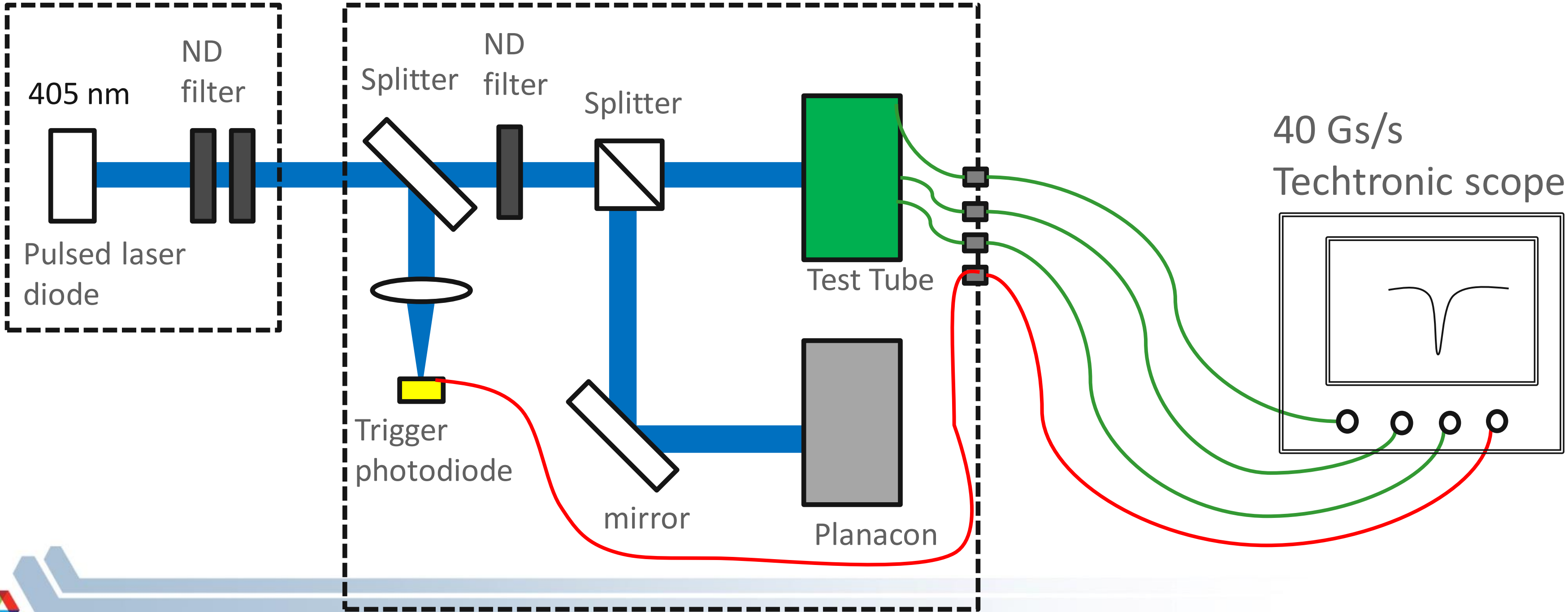
Testing tubes

- Burle Quantacon and Planacon MCP-PMT as reference detectors
- Tube27, Tube28 and Tube32 tested with a blue laser @ANL-HEP

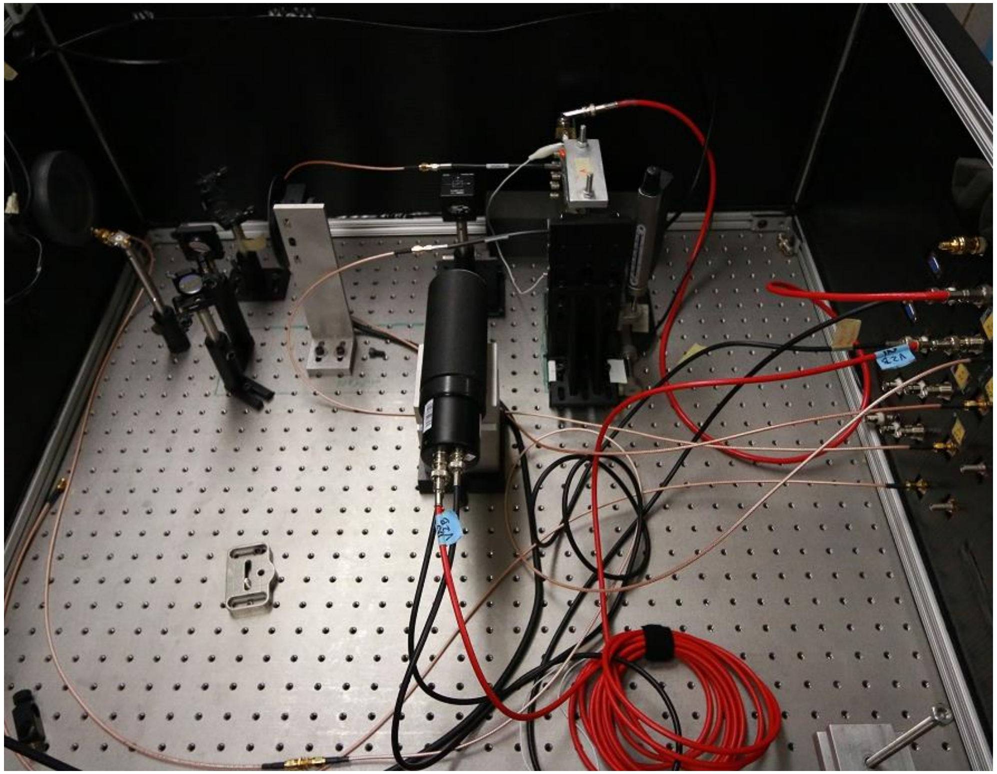


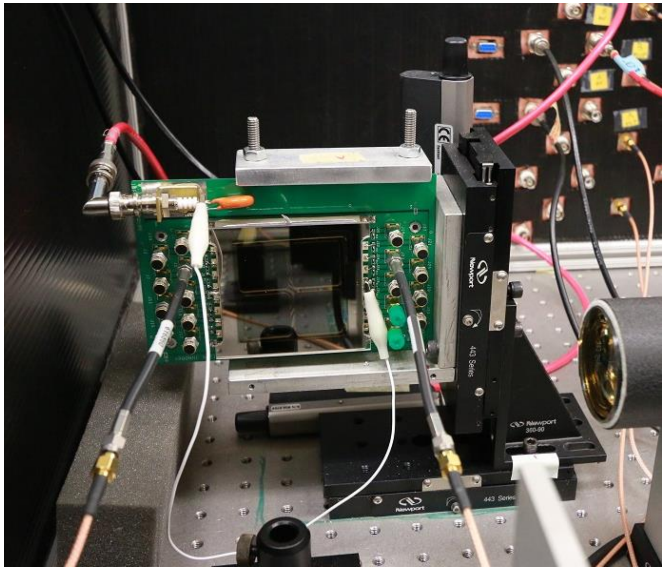
Laser facility @ANL-HEP

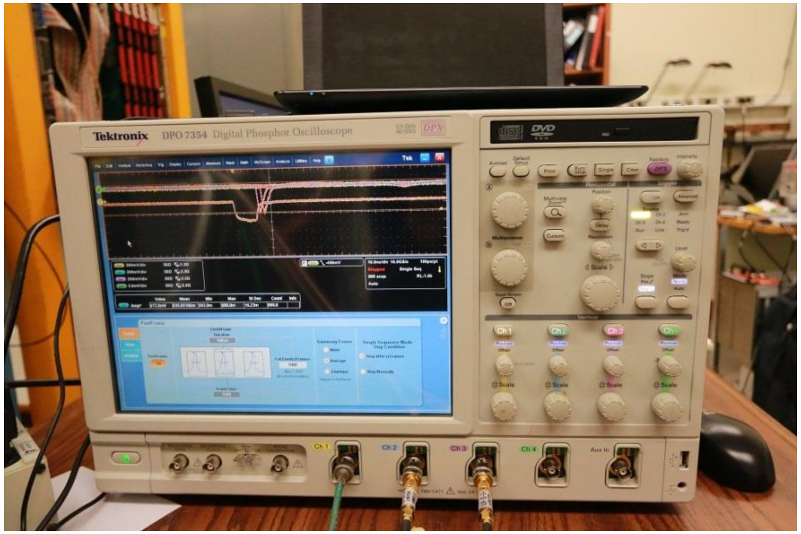
- Wavelength: 405 nm
- Pulse duration: ~70 ps, significant at low light level
- Pulse frequency: 2 Hz - 10 MHz
- Beam size: 1-2 mm
- Start time: Photodiode (<3 ps); laser pulse ($\sigma = {\sigma_{max}}/{\sqrt{N}}$)
- Readout: Oscilloscope, 40 Gs/s (10 Gs/s per channel); Camac system
- Slow controls: Motor driver in x and y directions, um level precision



Laser facility @ANL-HEP

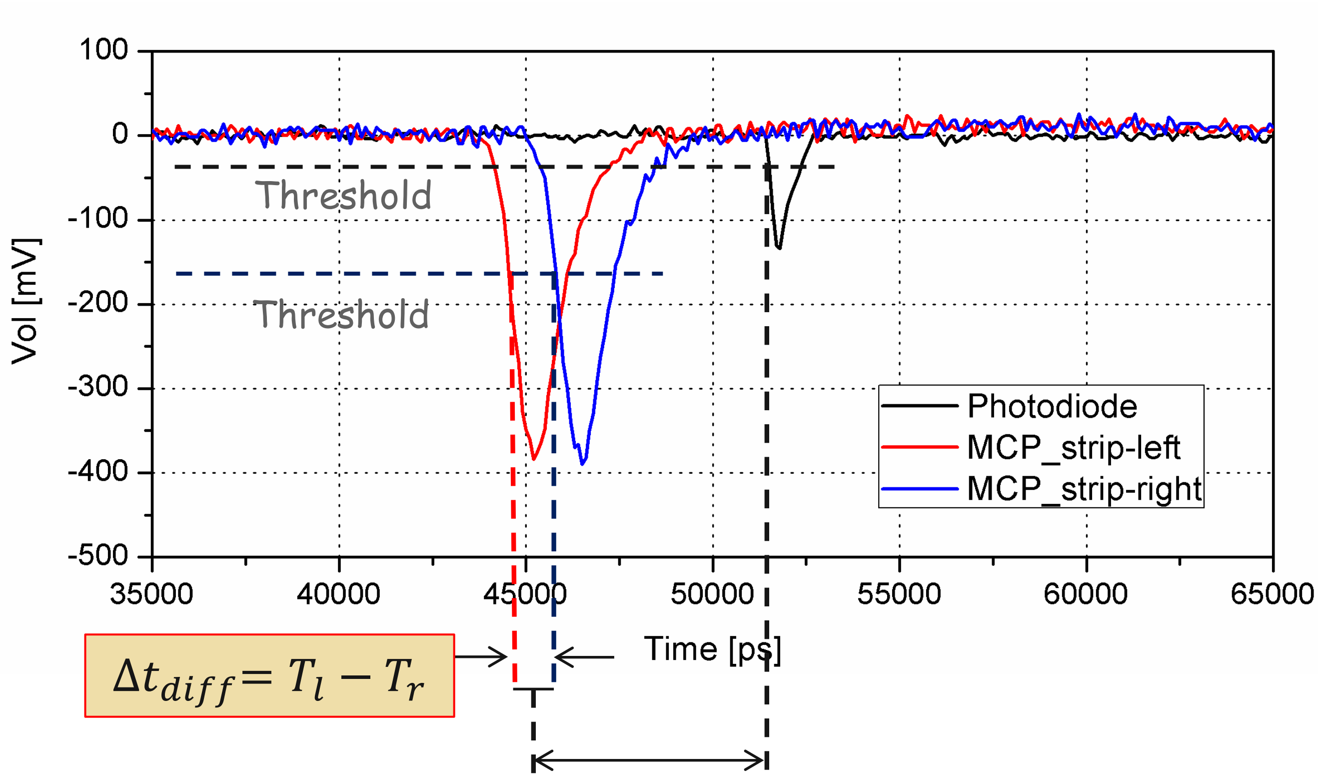






Typical MCP signal

- MCP signal rise time: ~0.7 ns
- MCP signal fall time: ~2.1 ns
- Photodiode signal rise time: ~0.3 ns



$$\Delta t_{diff} = T_l - T_r$$

$$\Delta t_{transit} = T_{MCP} - T_{Photodiode}$$

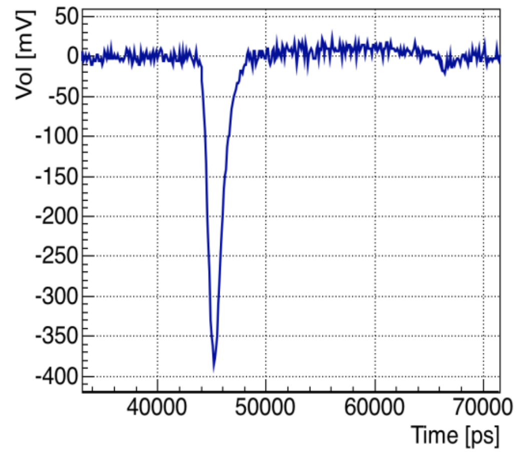
$\boldsymbol{\sigma}(\Delta t_{transit})$: Transit time spread (TTS) resolution

$\boldsymbol{\sigma}(\Delta t_{diff})$: Differential transit time spread resolution

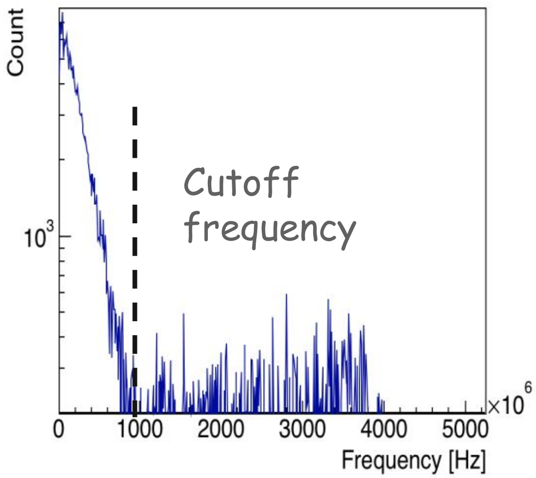
Waveform Analysis approach

1. Record digitized waveforms
2. Fast Fourier Transformation (FFT)
3. Low pass frequency filter
4. Constant Fraction Discriminator (CFD)
5. Obtain timing form Spline Fit
6. Time-Amplitude slewing correction

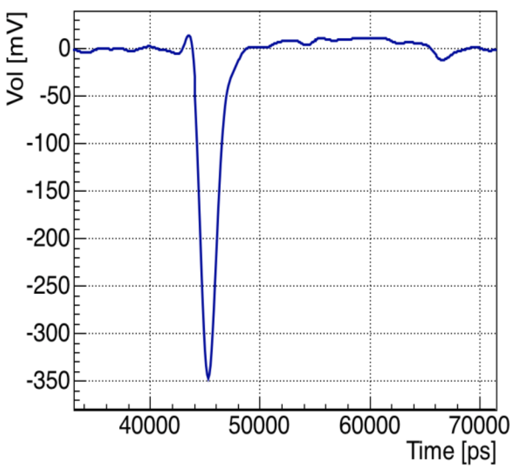
(1) Raw MCP waveform



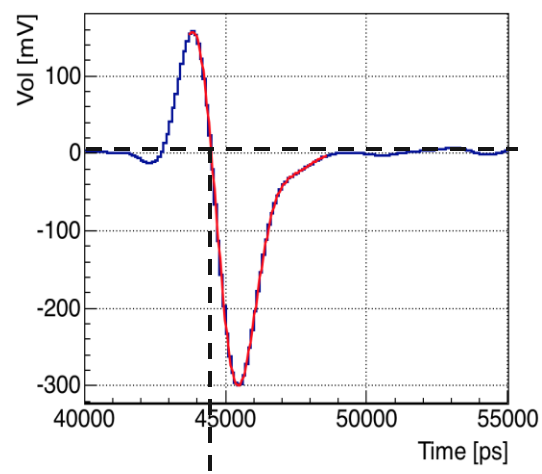
(2) Frequency spectrum



(3) Filtered MCP waveform



(4), (5) Standard CFD



Timing

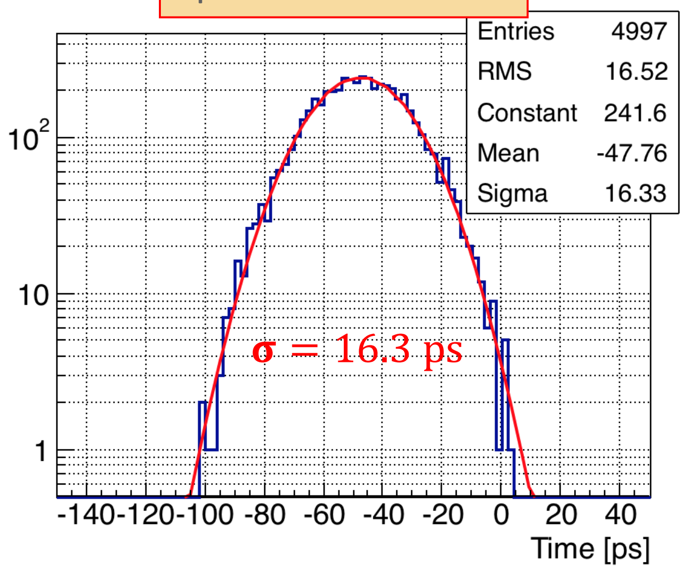
Test at high light level (Npe~300)

Typical timing distribution

Many effects contribute to the overall time resolution

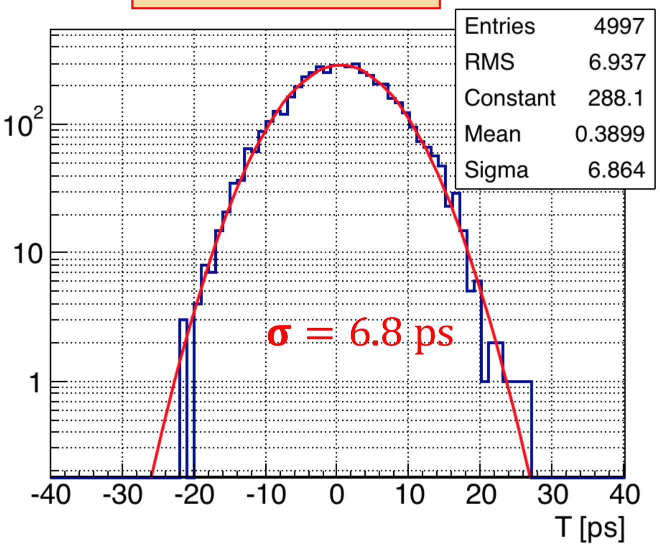
- Jitter of the reference detector
- Jitter from the readout system
- MCP intrinsic time resolution
- CFD time slewing as a function of the pulse amplitude

Transit time spread resolution



Differential time resolution

Npe ~ 300

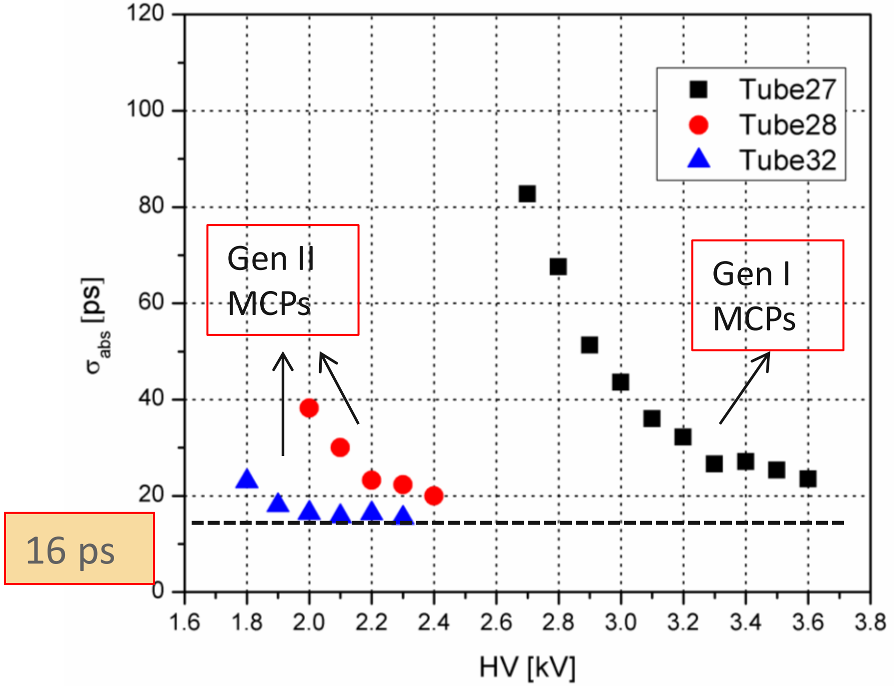


Test at high light level (Npe~300)

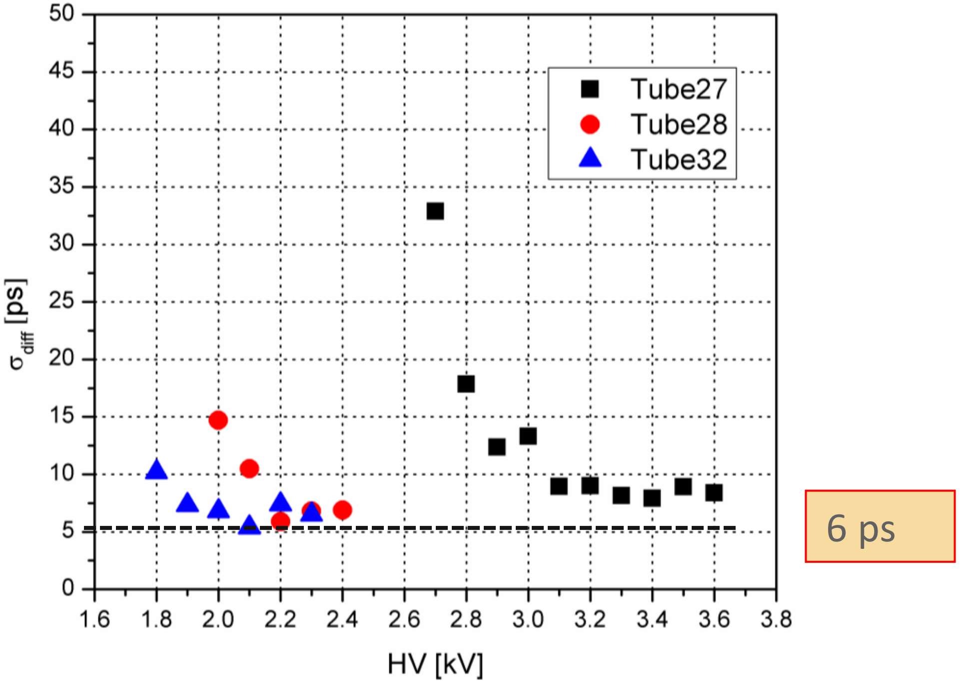
HV scan

- Tube27: Gen-I MCPs
- Tube28: Gen-II MCPs, resistance well matched
- Tube32: Gen-II MCPs, resistance not well matched.

TTS resolution



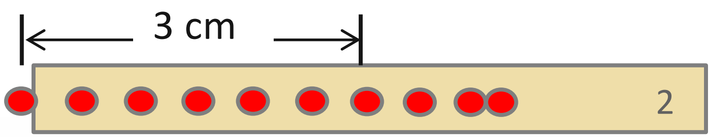
Differential time resolution

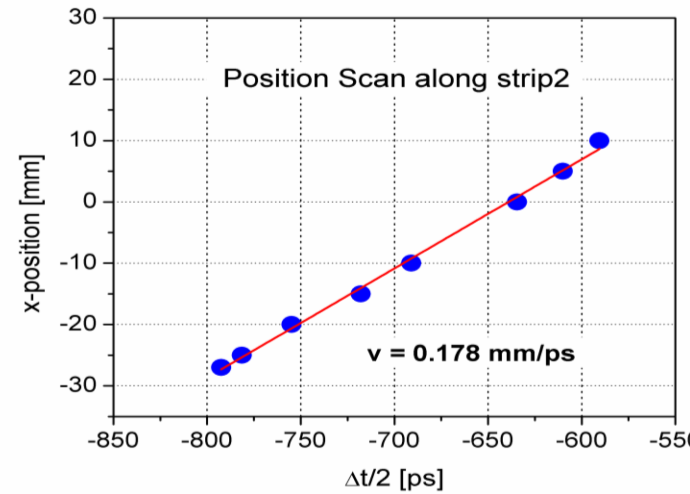


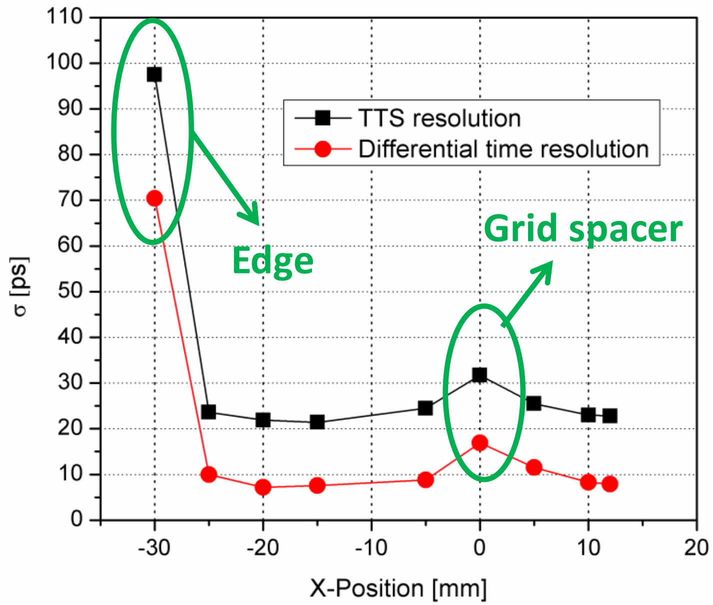
Test at high light level (Npe~300)

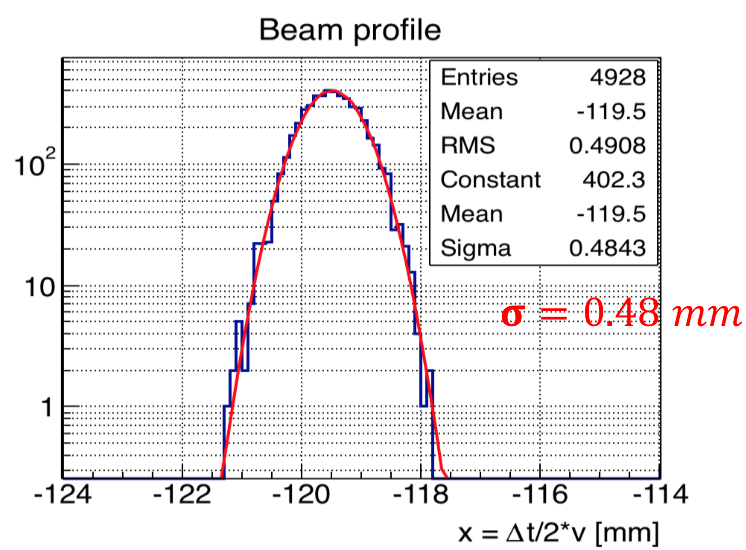
Position scan for Tube#28

- Signal transmission speed: 178 um/ps
- position resolution: < 0.5 mm





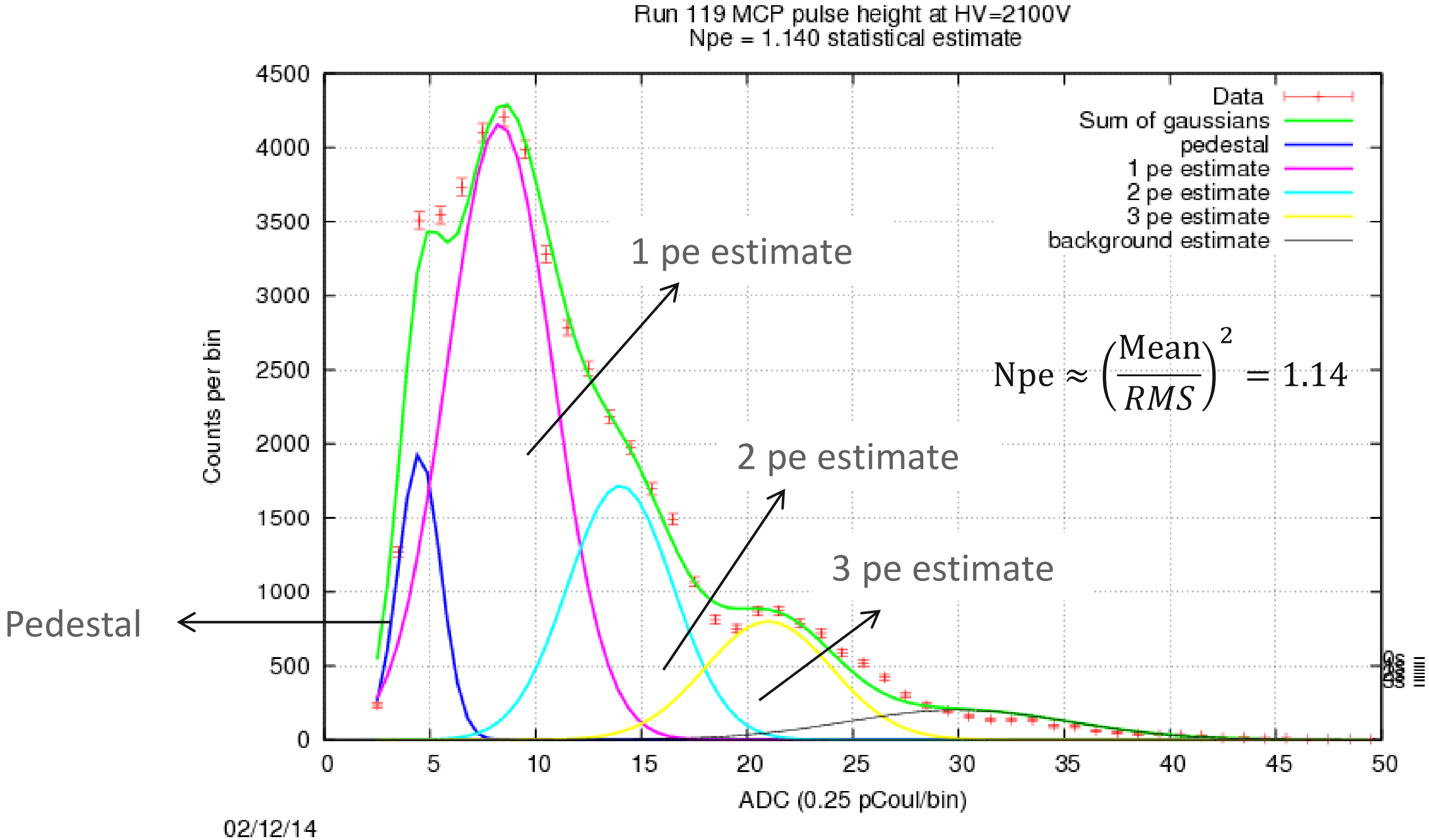




- Need to be repeated in single photoelectron mode

Test in single PE mode (Npe ≤1)

Charge distribution of Tube#32



Measured in Camac system, by Edward May

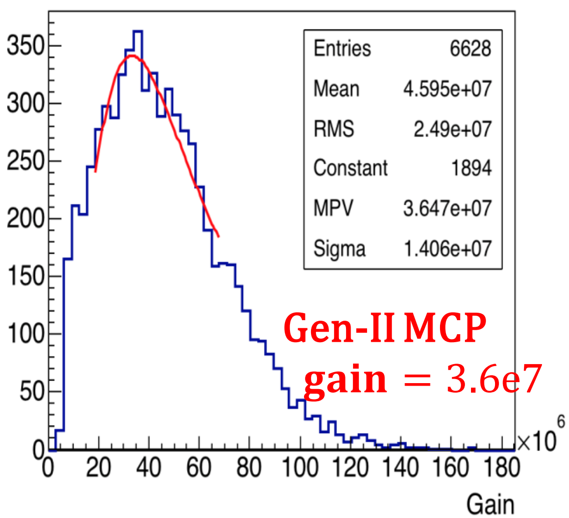
Test in single PE mode (Npe ≤1)

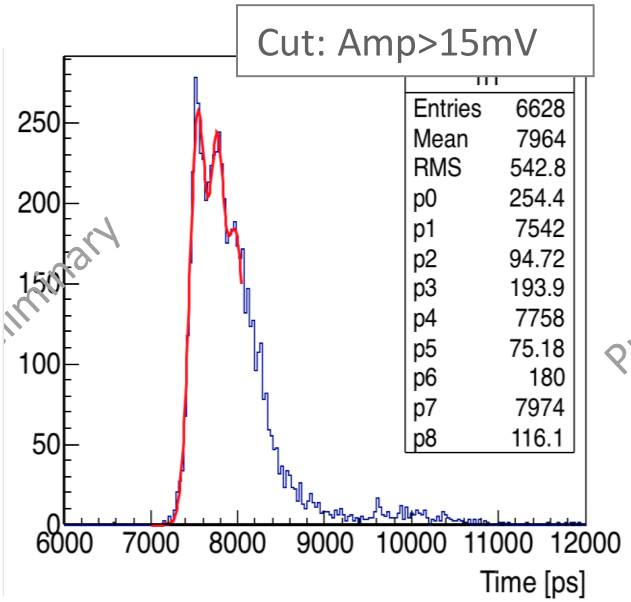
TTS resolution of Tube#28

Old test 5 weeks ago.
Tube#28 has been sent to Jefferson Lab

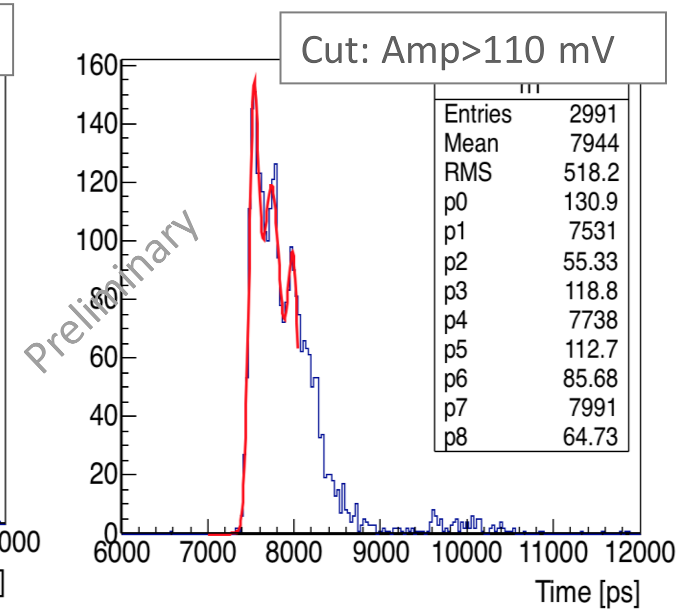
Analysis method:

- Laser sub-structure: 200 ps Relaxation oscillation ??
- The overall time jitter value is inferred from the standard deviation of the first Gaussian at the main peak.
- The single PE TTS resolution is better than 95 ps





$\sigma_{overall} = 94.7\ ps$



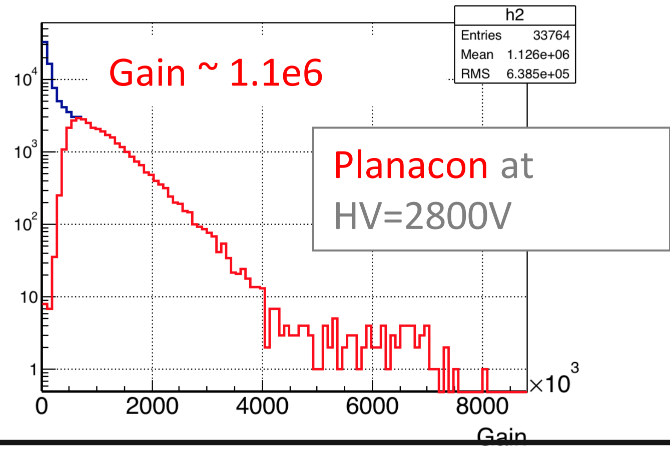
$\sigma_{overall} = 55.3\ ps$

Test in single PE mode (Npe ≤1)

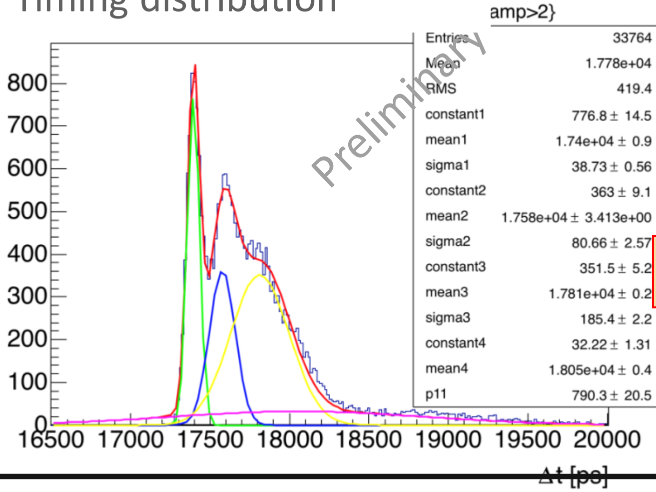
Recent test

TTS resolution of Planacon and Tube#32

Gain distribution

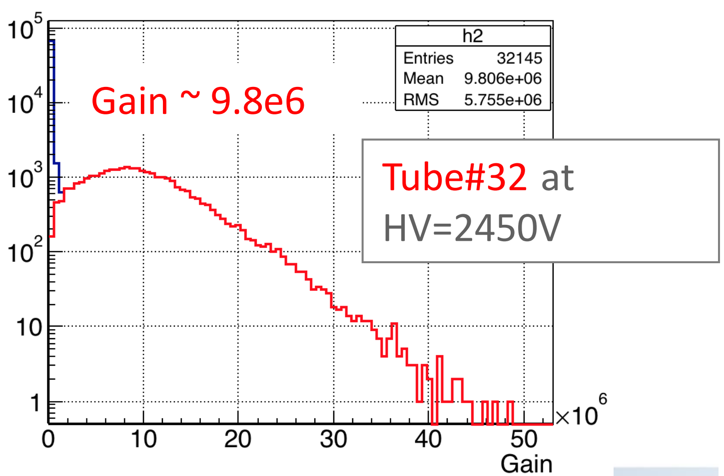


Timing distribution

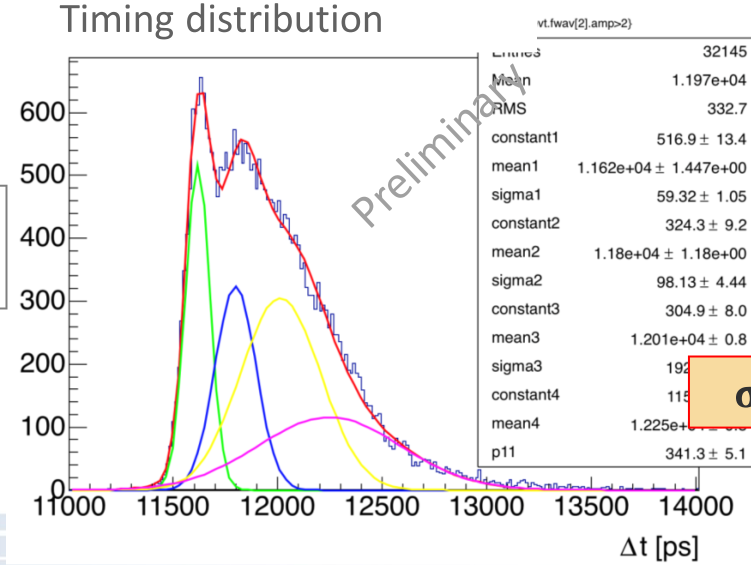


$\sigma = 38.7\ ps$

Gain distribution



Timing distribution

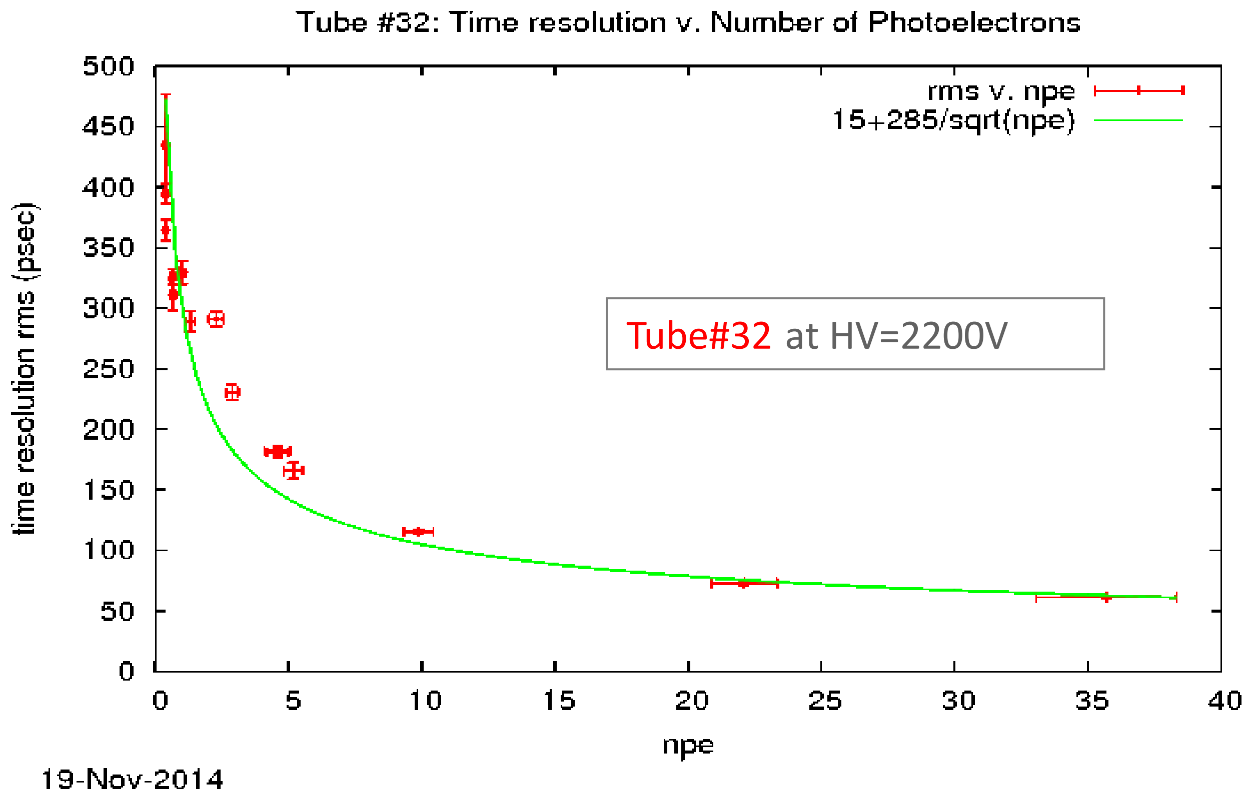


$\sigma = 59.3\ ps$

Test in single PE mode (Npe ≤1)

Measured in Camac system, by Edward May

TTS resolution RMS VS Npe for Tube#32



First result measured by Camac system

Need to do a detailed waveform analysis on laser sub-structure

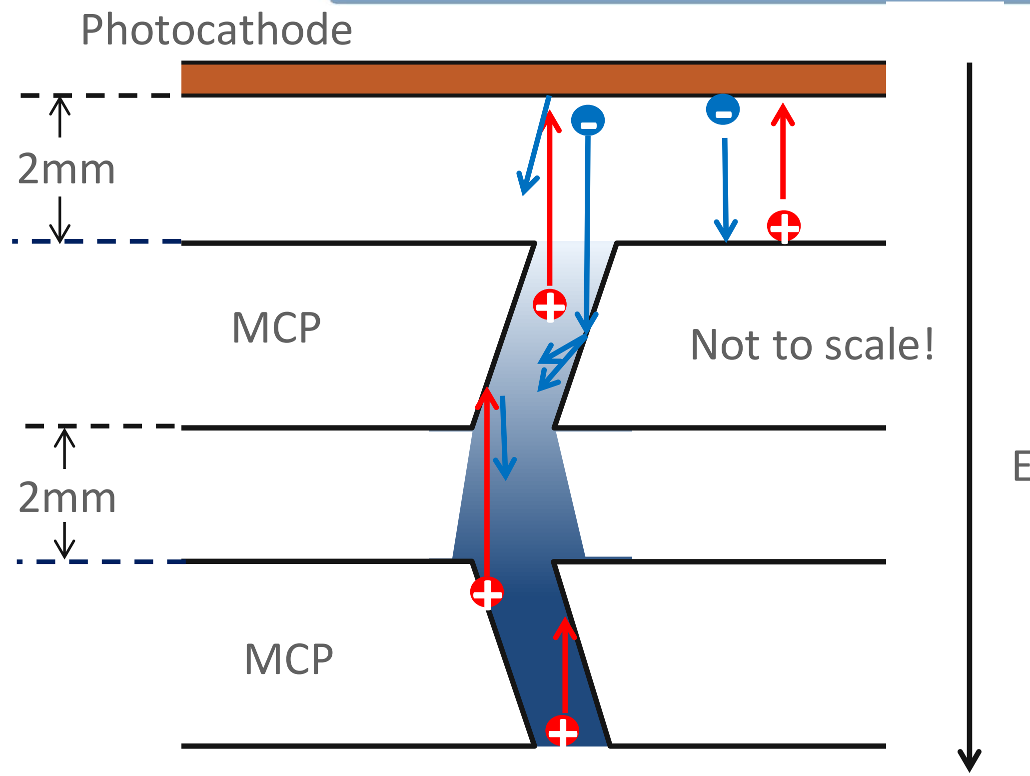
Limitations

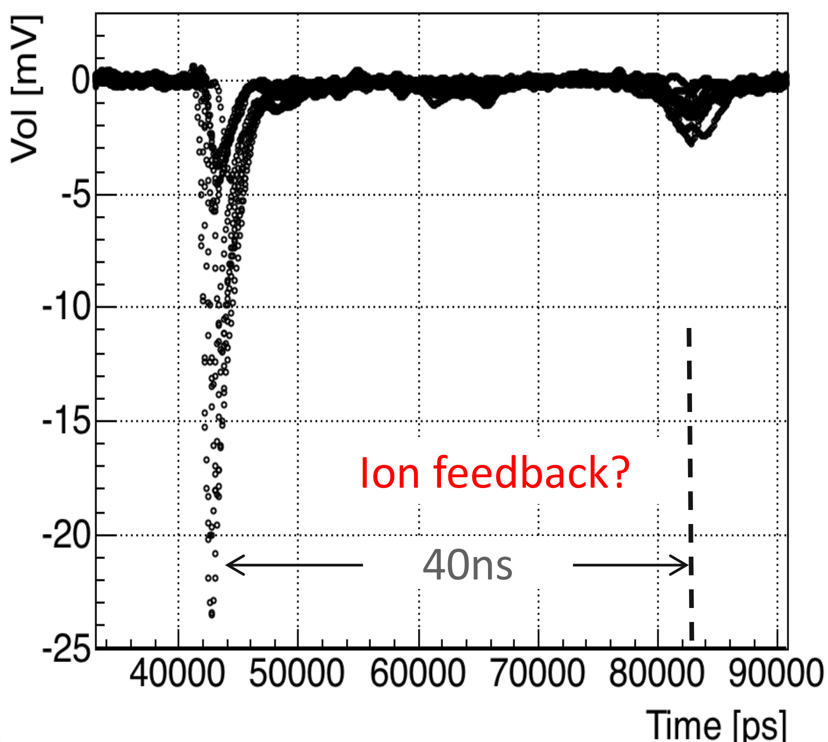
- Laser Pulse duration: 70 - 100 ps (σ_{max} = 30 - 42 ps, $\sigma_{mean} = {}^{\sigma_{max}}/_{\sqrt{N}}$).
- Laser sub-structure in timing

Ion feedback

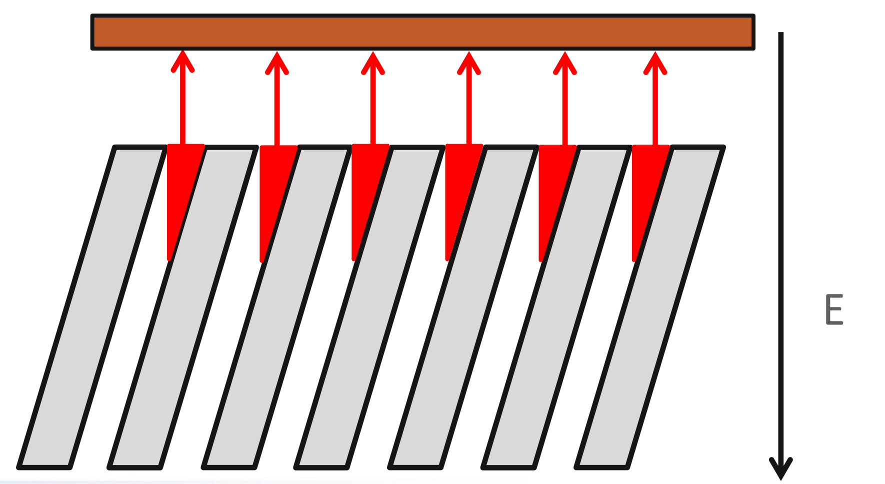
Possible reasons:

- Signal transmission
- Dark pulse (dark rate very low)
- Ion feedback (a few ns to 100 ns)





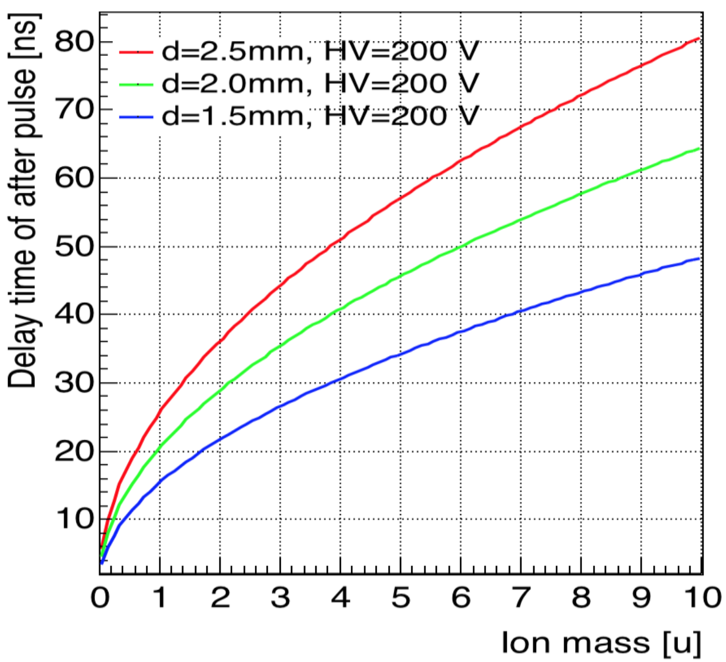
Bias angle: 8 deg



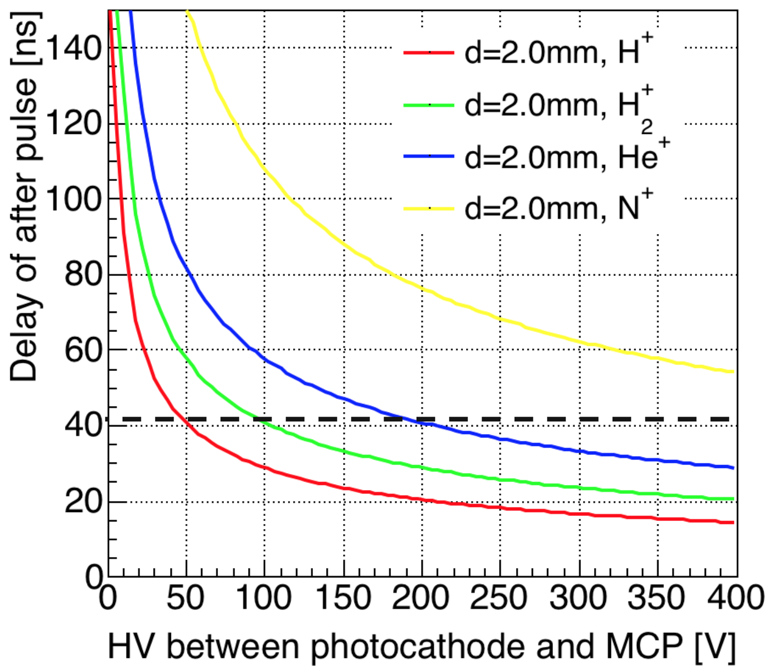
Ion feedback

- To confirm ion feedback effect, a systematic HV scan is helpful
- We need a better understanding of the residual gas in the tile processing system, and the outgas species.

Delay VS Ion mass



Delay VS HV



Not sure if 40 ns after pulse if from ion feedback

Summary

- Three successful devices: Tube#27, Tube#28, Tube#32
- Performance at high light level:
  - TTS resolution is ~16 ps
  - differential time resolution is ~7 ps
  - position resolution < 0.5 mm
- Performance in single PE mode:
  - Gain: 10^6 - 10^7
  - TTS resolution: 60 ps
- We have encountered two problems:
  1) Need a better understanding of the laser sub-structure
  2) Not sure if 40 ns after pulse is from ion feedback

Future plan

- Test at ANL-APS laser facility (100 fs pulse)
- Ion feedback study
- Optimize the detector structure

Thanks for your attention