PLANACON MCP-PMT for use in Ultra-High Speed Applications

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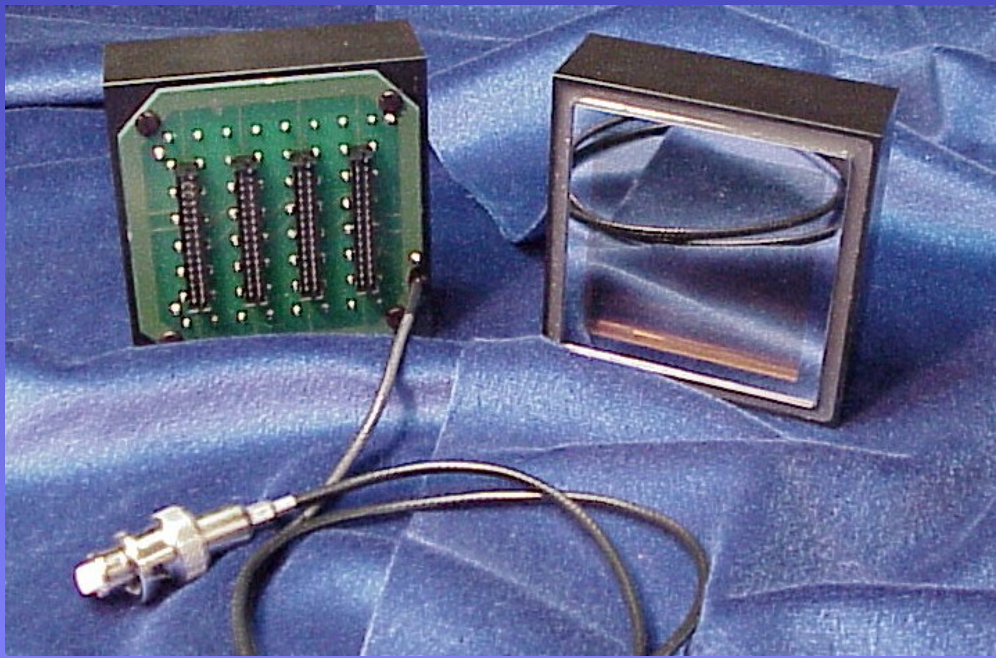
10 Picosecond Timing Workshop
28 April 2006

Planacon™ MCP-PMTs

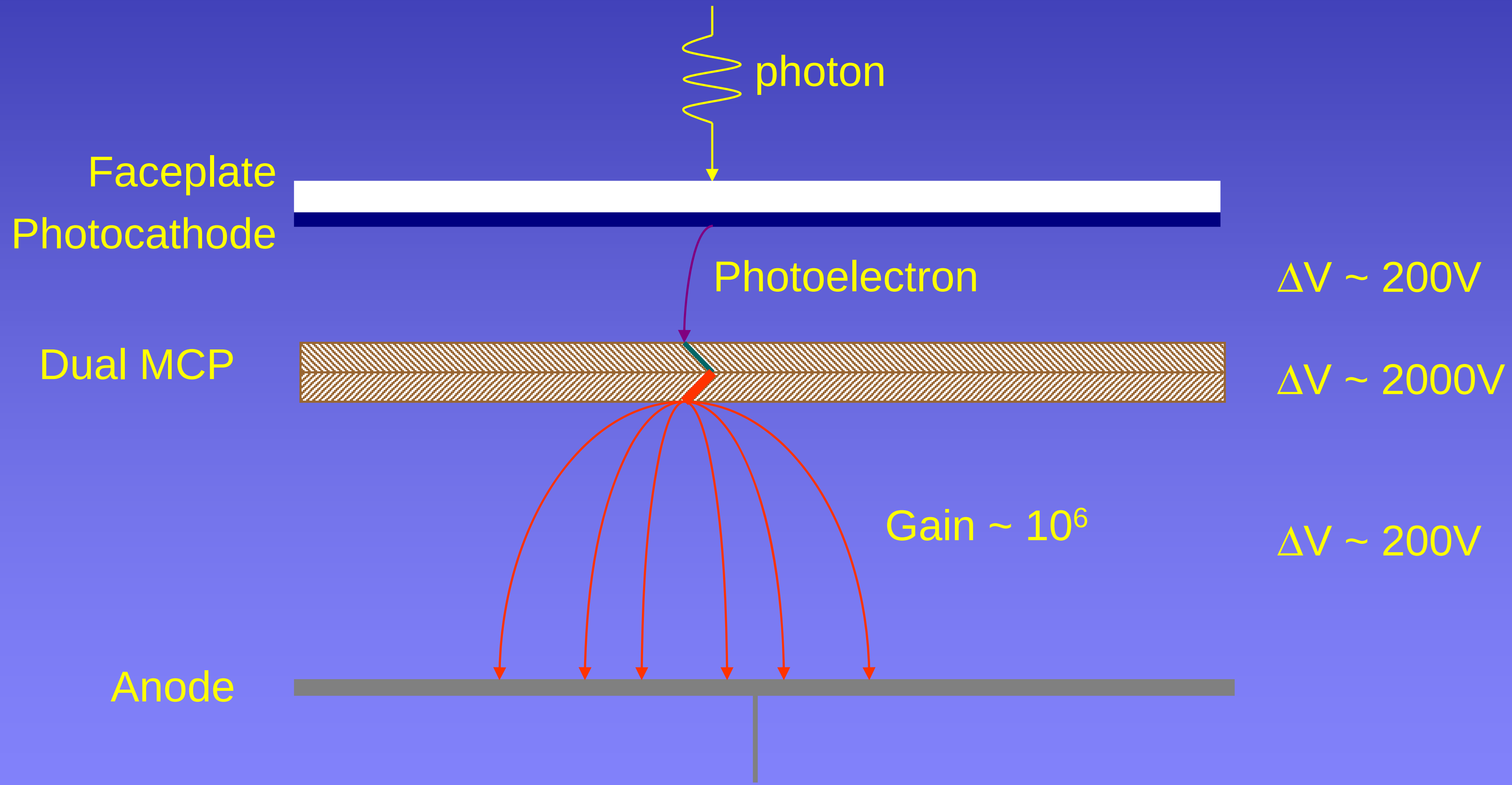
- Two inch *square flat* PMT with dual MCP multiplier.
- Anodes, 2x2, 8x8 and 32 x 32 configurations.
- Improved Open Area Ratio device now available
- Bi-alkali cathode on quartz faceplate.
- *Easily tiled, low profile, excellent time resolution, excellent uniformity*.



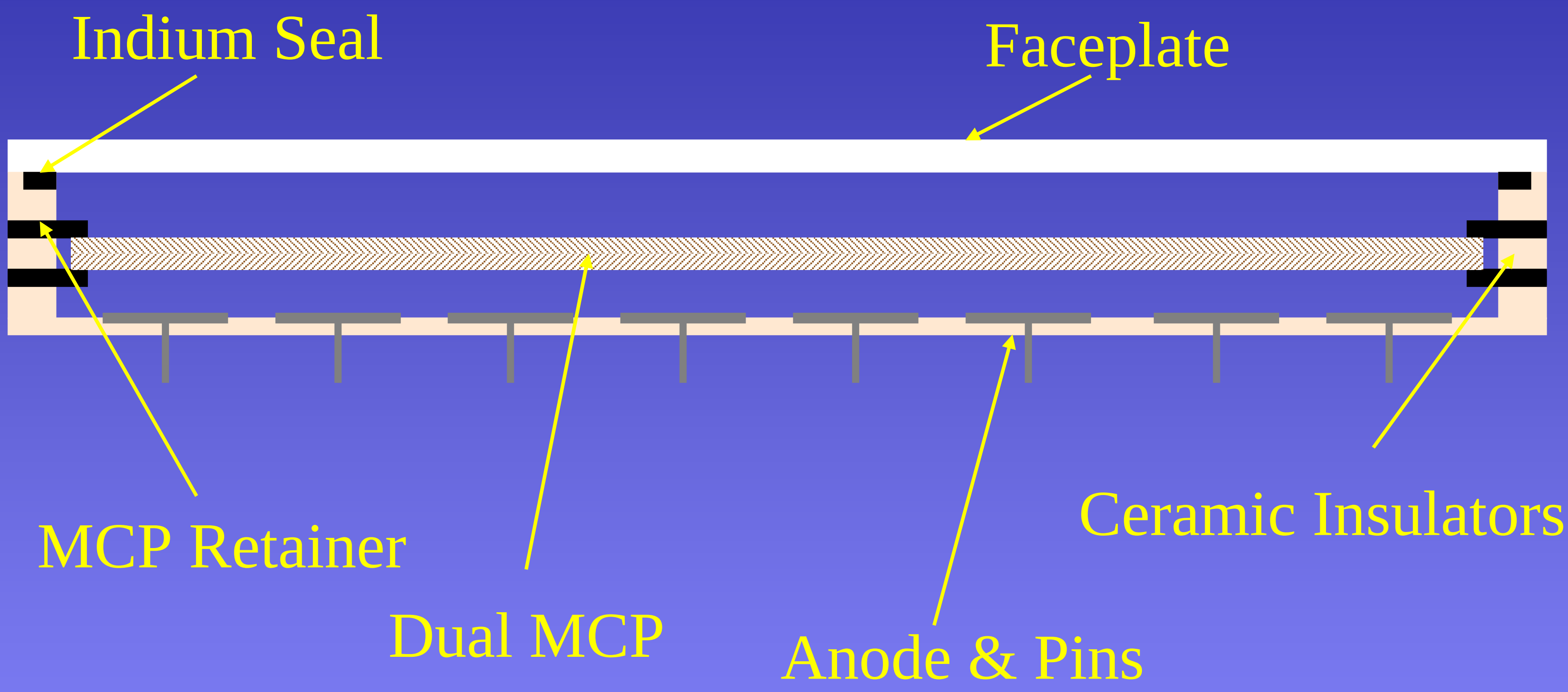
PLANACON Family

- 50mm Square family of MCP based PMTs
  - 8500X – 4 anode
  - 8501X – 64 anode
  - 8502X – 1024 anode
- New improved Active Area Variants available with 86% active area, 85002/85012/85022
- 64 anode PMT available with integrated Anger-logic readout
- Gated High Voltage Power Supply available

MCP-PMT Operation



MCP-PMT Construction



- Spacing between faceplate and MCP and MCP and anode can be varied for different applications
- Anode can be easily modified

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Timing Limitations

- Detected Quantum Efficiency (DQE)
  - Photocathode QE
  - Collection efficiency
  - Secondary emission factor of first strike
- Electron optics and amplification
  - Cathode – MCP Gap and Voltage
  - Pore-size, L:D, and voltage of MCP
  - MCP-Anode Gap and Voltage
- Signal extraction

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Detected Quantum Efficiency

DQE Component	Current	Next Gen	Limit
QE @ 420nm	20%	28%	32%
Open Area of MCP	50%	70%	80%
First Strike	85%	90%	95%
DQE for Timing	8.5%	17.6%	24.3%
Multi-photon TTS improvement	1.0	.69	.59

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DQE Efforts

- Photocathode QE
  - Developing new cathode recipe for transfer system based on nuclear medicine bi-alkali which has 35% QE
- Collection efficiency
  - 10 micron pore improves open area to ~60%
  - Over-etching of glass can increase this to 70%
  - Funneled pores can increase this to > 80%
- Secondary yield
  - Current yield is 2.3 – 3.0
  - Deposition of enhancement films such as MgO_2 can improve this to 5.0 or higher

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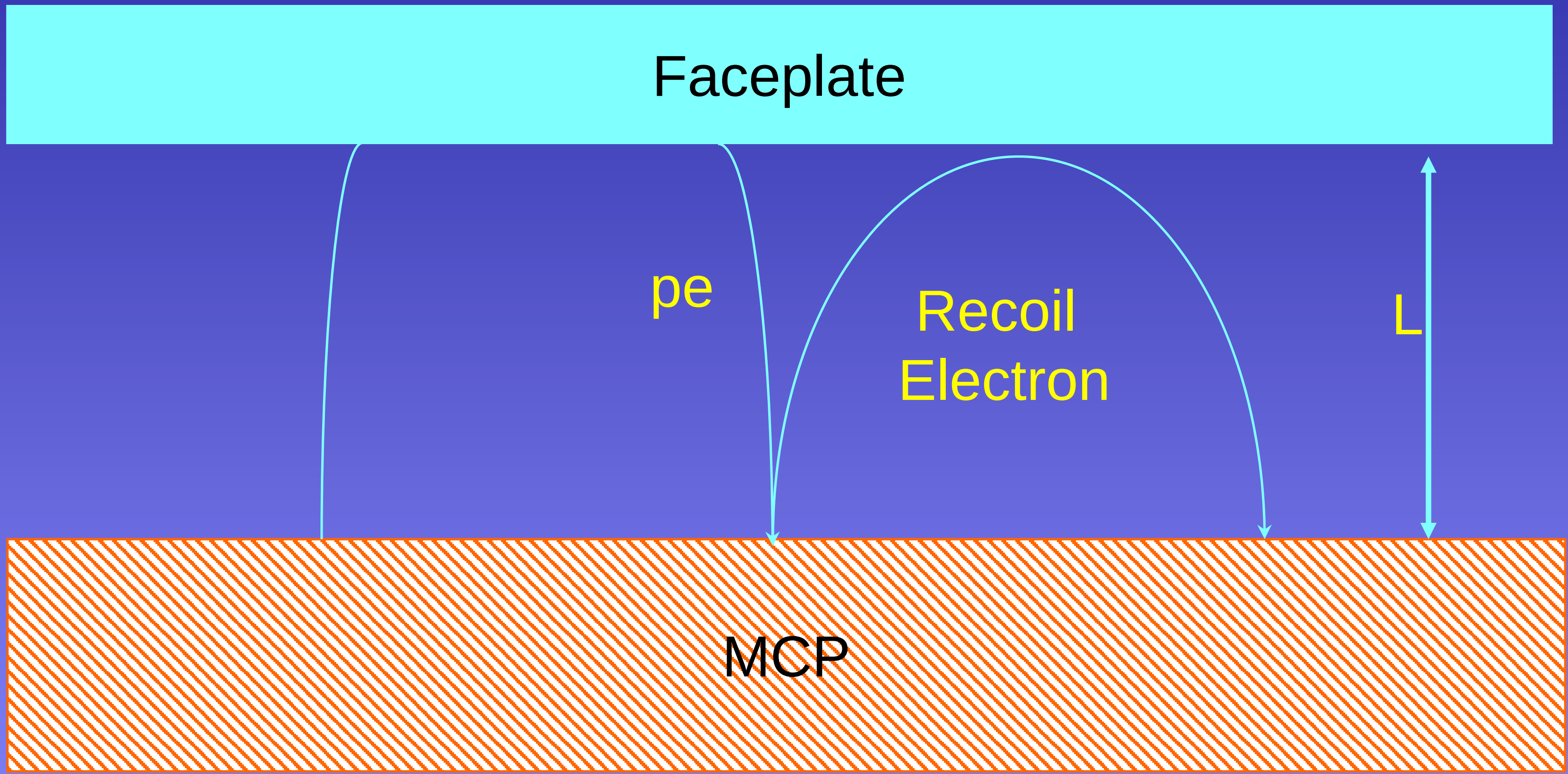
Cathode-MCP Gap

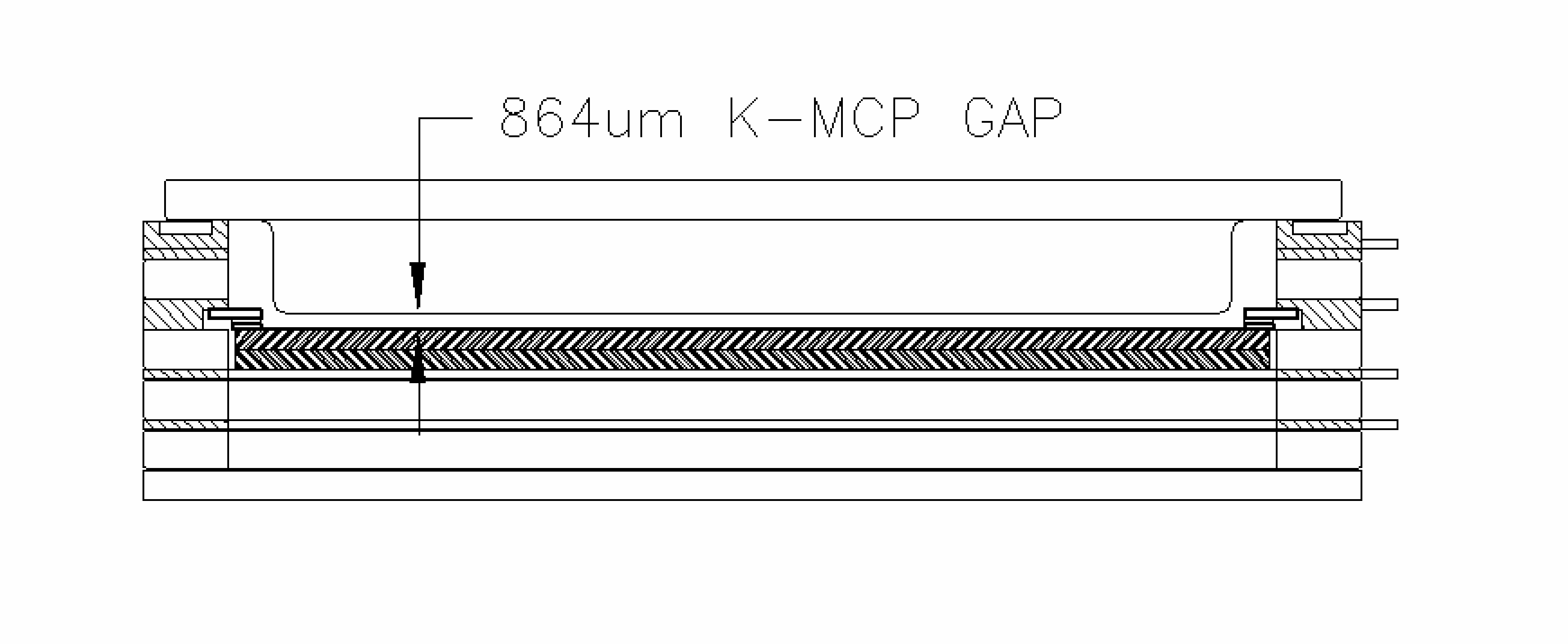
- Limitations
  - Recoil electrons (cause long TT shoulder)
    - Decreased DQE for leading edge timing measurements
    - Decrease imaging capabilities
  - Transit time (Variations in p.e. velocity)
    - Dominated by transverse momentum of the photoelectrons
    - Becomes worse at higher photon energies
- Counter-measures
  - Reduce physical gap
    - Significant reduction in transit time, reducing effects of transverse momentum
  - Increase voltage
    - Higher acceleration reduces transit time and effects of transverse momentum

Recoil Electrons



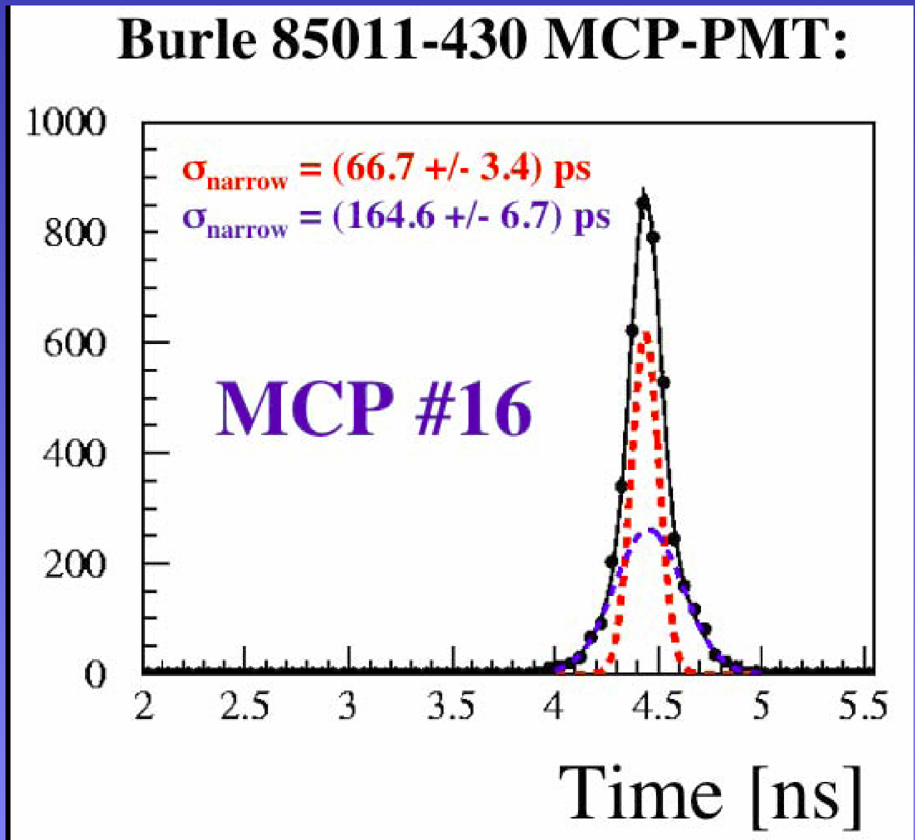
- Scattered electrons can travel a maximum of 2L from initial strike
- Produces a TTS shoulder
- Reduces the DQE for direct detection

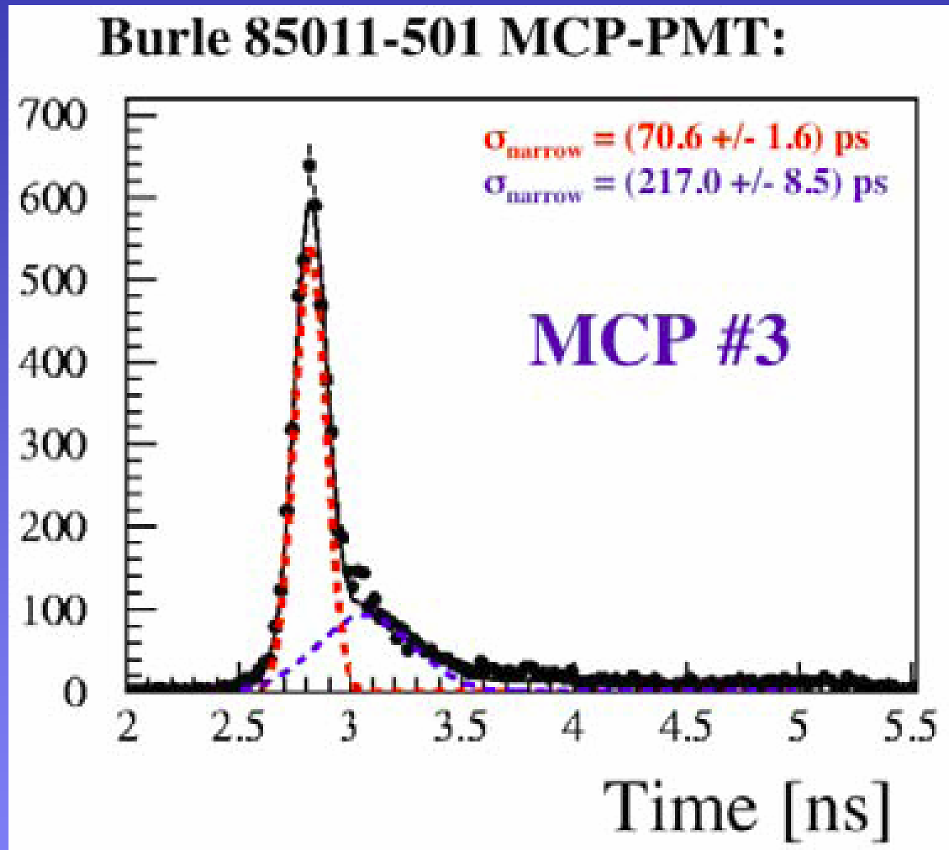
85011 430 Drop Faceplate



- Cathode – MCP gap is decreased from to ~0.85mm
- Photocathode active area is reduced to 47mm from 50mm

Effect of Reduced PC-MCP Gap



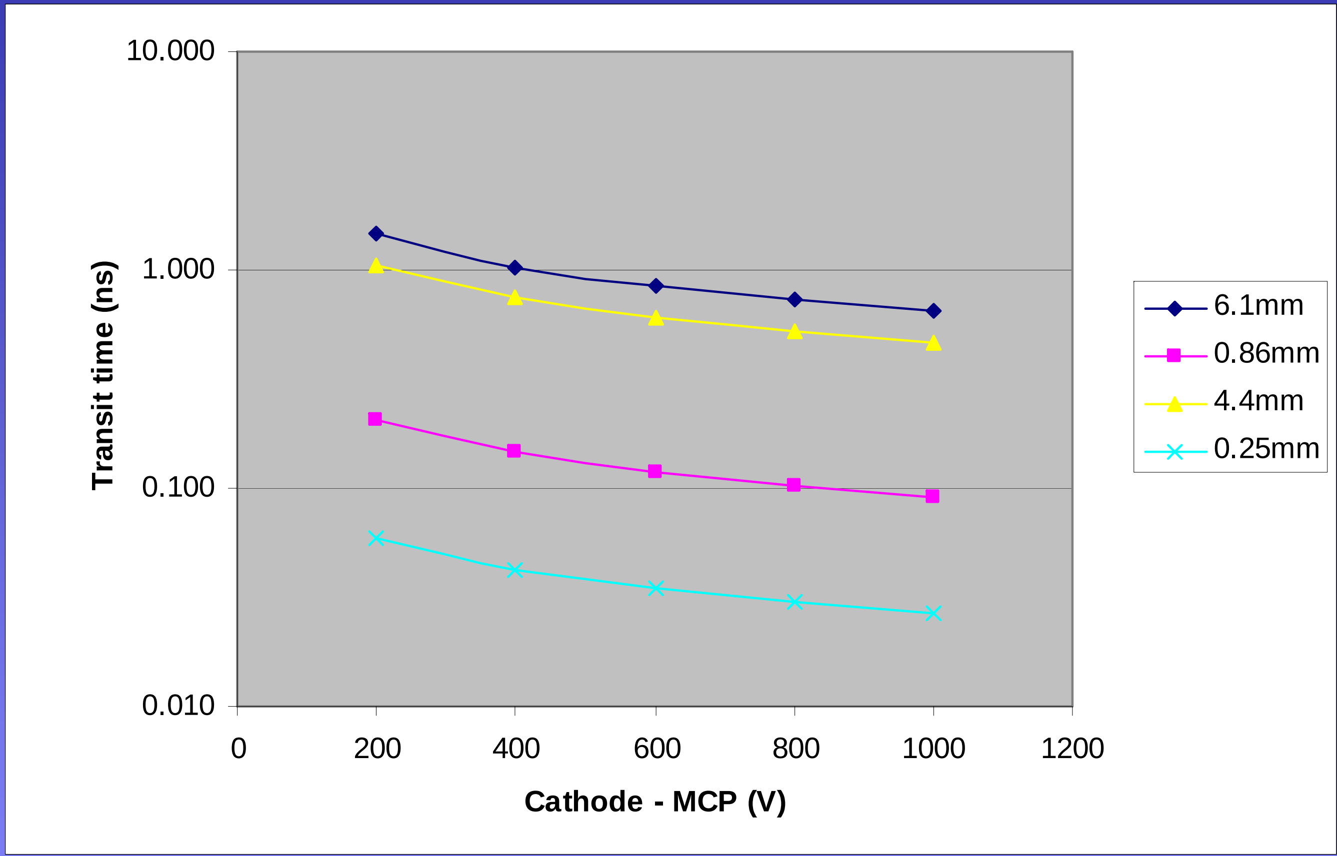


C. Field, T. Hadig, David W.G.S. Leith, G. Mazaheri, B. Ratcliff J. Schwiening, J. Uher,+ and J. Va'vra*

Development of Photon Detectors for a Fast Focusing DIRC

5th International workshop on Ring Imaging Cherenkov Counters (RICH 2004), 11/30/2004-12/5/2004, Playa del Carmen, Mexico

Cathode – MCP Transit Time

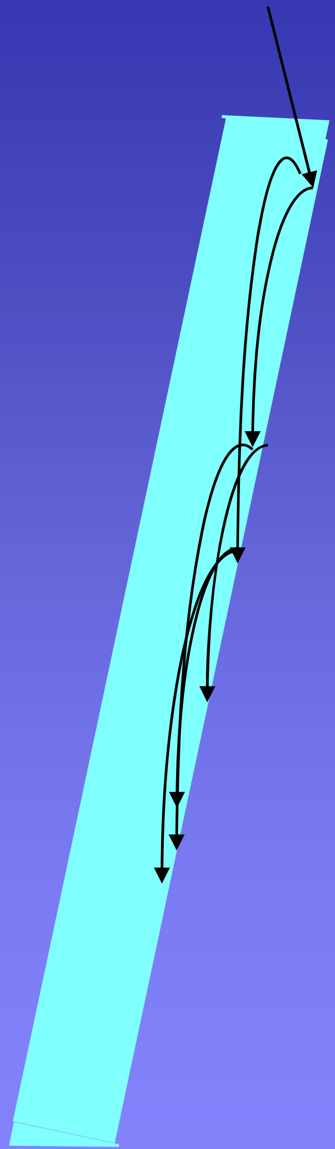


- Increased voltage or decreased gap can drastically reduce the transit time, and therefore transit time spread

MCP Contributions

- MCP amplification is responsible for anode rise-time
  - Secondary electron trajectories result in variations in time between strikes.
- Pore-size
  - Reduced pore size decreases thickness for the same amplification, reducing transit time
  - L:D sets the gain assuming same applied field
  - Want small pore size, minimum L:D and high field
  - Bias angle increases transit time and amplification, can reduce L:D and increase bias to keep timing properties the same but improve lifetime

Amplification in Pore



- Typical secondary yield is 2
- For 40:1 L:D there are typically 10 strikes (2^{10} ~ 10^3 gain single plate)
- Number of strikes depends on velocity of individual secondary electrons

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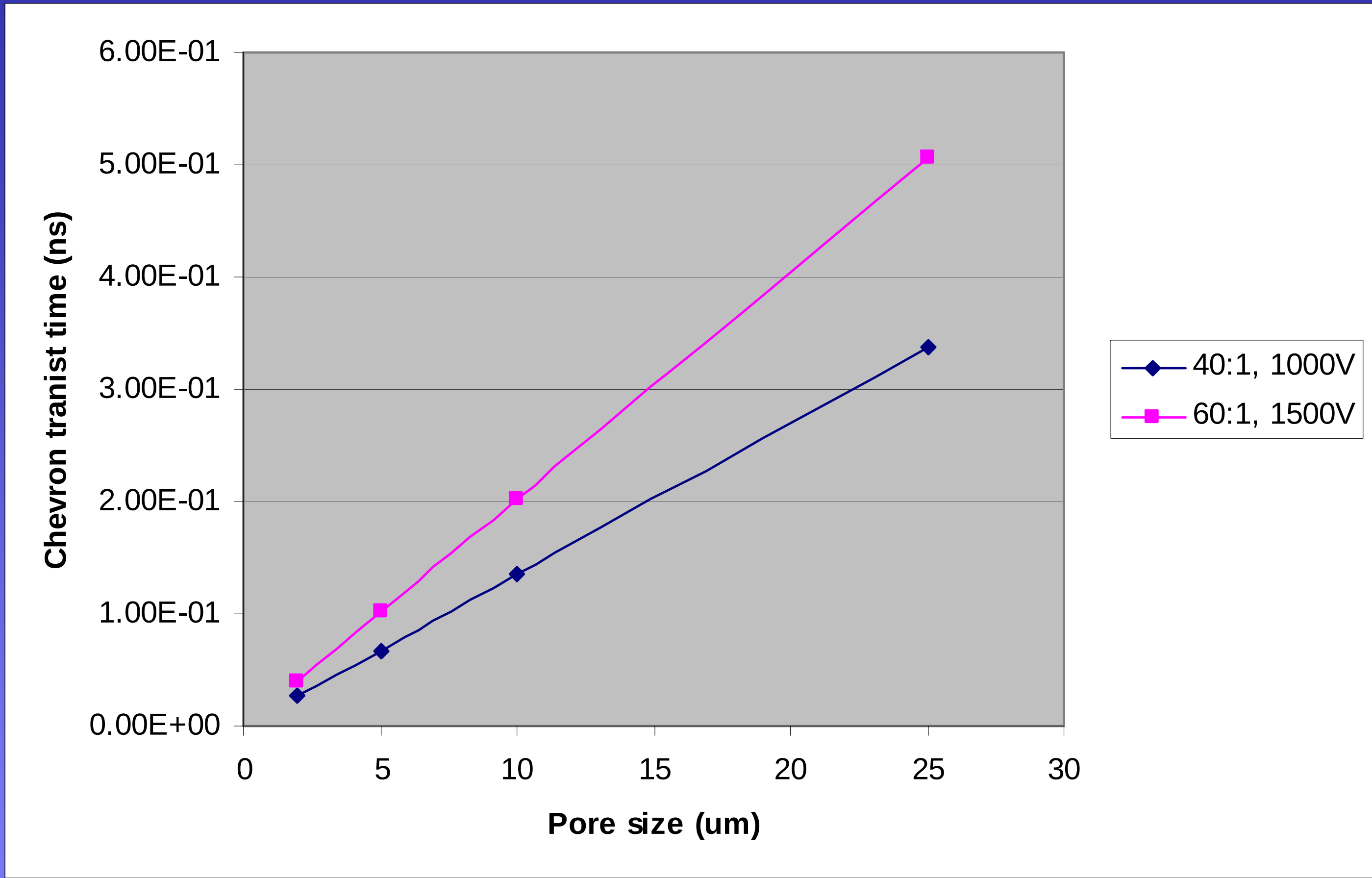
MCP Transit Time



- Transit time assumes 10 strike in 40:1 L:D with 1000V applied per plate, Chevron configuration, cold secondary electrons

Anode-MCP Gap

- Limitations
  - Transit time (Variations in secondary electron velocities)
    - Dominated by location of origination in MCP
    - Also affected by transverse momentum
  - Capacitance and Inductance between the two electrodes
    - Can effect signal quality at the anode
- Counter-measures
  - Reduce physical gap
    - Significant reduction in transit time, reducing effects of transverse momentum
  - Increase voltage
    - Higher acceleration reduces transit time and effects of transverse momentum
  - Provide a ground plane or pattern on the anode
  - Reduce resistance of MCP-Out electrode

Other Considerations

- Current limitations
  - Have received MCPs with 300uA strip current, achieve 30uA linear operation
  - Can increase to 60uA with electrode change
- Lifetime
  - Capital investment in better electron scrub system
  - Recent modifications to the process which increases lifetime, measurements in process
  - Increased bias angle up to 19 degrees
  - Gating of Cathode during periods of no data collection
- Anode configuration
  - Can modify electrode pattern on anodes to include ground plane or ground pattern for improved signal extraction

Future Directions

- Improved DQE
- Improved average anode current (50 – 100 uA)
- Improved lifetime
- Step faceplate to optimize timing
- Reduce anode-MCP gap to investigate effect on signal integrity and TTS
- MCP input treatment to optimize DQE and reduce recoiling effect (increased Open Area and high yield coating)
- New anode configurations with integral ground plane or ground pattern to improve

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