MCP-PMT status

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• BURLE MCP-PMT characteristics
• Bench tests overview
• Operation in magnetic field
• Cherenkov angle resolution and number of photons per ring
• Detector layout
• Long term stability - aging
• Summary
BURLE MCP-PMT Characteristics

Model 85015/A1 (80511):
- multi-anode PMT with two MCP steps - chevron configuration
- $10 \mu m$ (25 $\mu m$) pores
- bialkali photocathode
- gain ~ $0.6 \times 10^6$
- open area ratio ~ 70 % (60 %)
- box dimensions ~ 59 mm (71 mm) square
- 64 (8x8) anode pads
- pitch ~ 6.5 mm, gap ~ 0.5 mm
- active area fraction ~ 80 % (52 %)
- excellent timing < 40 ps - single photon
- window thickness 1.5 mm (2 mm)
- K-MCP 4.4 mm (6.1 mm)
- MCP-A 3.7 mm (5.2 mm)
Scanning setup

Outside dark box:
- PiLas diode laser system EIG1000D (ALS)
- 404nm (635nm) laser head (ALS)
- filters (0.3%, 12.5%, 25%)
- optical fiber coupler (focusing)

- optical fiber (single mode, ~4µm core)

Inside dark box mounted on 3D stage:
- optical fiber coupler (expanding)
- semitransparent plate
- reference PMT (Hamamatsu H5783P)
- focusing lens (spot size $\sigma \sim 10\mu$m)
- Laser rate 2kHz (~DAQ rate)
- Amplifier: 350MHz (<1ns rise time)
- Discriminator: leading edge, 300MHz
- TDC: 25ps LSB ($\sigma \sim 11$ps)
- QDC: dual range 800pC, 200pC
- HV 2400V
Photon detection

Parameters used:
- $U = 200 \text{ V}$
- $l = 6 \text{ mm (K-MCP)}$
- $E_0 = 1 \text{ eV}$
- $m_e = 511 \text{ keV/c}^2$
- $e_0 = 1.6 \times 10^{-19} \text{ As}$

Photo-electron:
- $d_{0,max} \sim 0.8 \text{ mm}$
- $t_0 \sim 1.4 \text{ ns}$
- $\Delta t_0 \sim 100 \text{ ps}$

Backscattering:
- $d_{1,max} \sim 12 \text{ mm}$
- $t_{1,max} \sim 2.8 \text{ ns}$

Internal-reflection
Excellent timing

- corrected TDC distributions for all pads (4 ch. MCP-PMT)

- prompt signal ~ 70%
- short delay ~ 20%
- ~ 10% uniform distribution
Charge sharing

- slice of the counting rate distribution including the central areas of 8 pads (single channels - colored, all channels - black)

Single channel response:
- uniform over pad area
- extends beyond pad area due to charge sharing

Count rates - all channels:
- charge sharing at pad boundaries
- Number of detected signals vs. $x$
- Long tails - photoelectron backscattering
Internal reflection

- displacement of secondary image consistent with reflection from MCP surface
- impact on position resolution and timing resolution

single channel response for photon incidence angles of 0° and 45° (logarithmic scale)
Tests in magnetic field

- B up to 1.5 T
- Light source - laser:
  - Wavelength 439 nm
  - Spot size < 0.5 mm
  - Pulse timing 90 ps (FWHM)

Signal detection:
- Amplification x5 (PMT amp) x200
  - ORTEC FTA820A → passive splitter:
    - → LE discriminator (PHILIPS 708)
    - → TDC (Kaizu works KC3781A)
    - → ADC (LeCroy 2249A)
Tests in magnetic field: ADC vs B

- HV = 2400 V
- B = 0 T

- HV = 2500 V
- B = 1.5 T
Tests in magnetic field: ADC vs B

Gain as a function of magnetic field for different operation voltages.
Tests in magnetic field: ADC vs B

Gain as a function of applied voltage for different magnetic fields.
Tests in magnetic field: charge sharing

Number of detected hits on individual channels as a function of light spot position.

- HV = 2400 V
- B = 0 T
- HV = 2500 V
- B = 1.5 T
Number of detected hits on all channels as a function of light spot position.

- $HV = 2400 \, V$
- $B = 0 \, T$

- $HV = 2500 \, V$
- $B = 1.5 \, T$
Beam test 2004

Tested in pion beam at KEK in combination with multi-anode PMTs

- 25 µm pores, effective area ∼ 52%
- aerogel 2+2 cm, 1.046, 1.056

- $\sigma_\theta \sim 13$ mrad (single cluster)
- number of clusters per track $N \sim 4.5$
- $\sigma_\theta \sim 6$ mrad (per track)
- $\rightarrow \sim 4 \sigma$ π/K separation at 4 GeV/c

- 10 µm pores required for 1.5T
- use new package with improved effective area
- aging study should be done
Cherenkov angle resolution

- charge sharing at the edges of the pads and backscattering affects the resolution
- in magnetic field this effects will be minimized and resolution will improve

$$\sigma_\theta : 17.6 \text{ mrad} \rightarrow <15 \text{ mrad}$$
Number of detected hits per ring

- $N_{ph} / \text{track} = \sim 1.8$ - estimated from number of events with no hit
- acceptance $\sim 13\%$
- number of hits per full ring $\sim 14$
- close packed MCP-PMTs $\sim 11$ (@ 80% effective area - new package)
- inner radius \( \sim 420 \) mm
- outer radius \( \sim 1145 \) mm
- detector area \( \sim 3.5 \) m\(^2\)

- inner limit: currently by acceptance
- outer limit: available space and overlap with TOP
- sensor size 59 mm square
- minimum gap 0.2 mm
- Number of MCP-PMTs and covered area fraction

<table>
<thead>
<tr>
<th>ring</th>
<th># PMTs</th>
<th>fraction</th>
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<tbody>
<tr>
<td>1</td>
<td>48</td>
<td>86%</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
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<td>88%</td>
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<td>4</td>
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<td>6</td>
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<tr>
<td>11</td>
<td>114</td>
<td>95%</td>
</tr>
<tr>
<td>all</td>
<td>876</td>
<td>91%</td>
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</table>

Total number <1000 and rough estimate for price < 4M€ (uper limit)
Number of detected photons and resolution per track

Extrapolation from beam test:
- $\sigma \sim 15$ mrad (single hit)
- number of hits per track $N \sim 11$

Additional geometrical loss due to tiling:
- coverage $\sim 90\% \rightarrow N \sim 10$

Cherenkov angle resolution per track:
- $\sigma \sim 4.7$ mrad (per track)

$\rightarrow \sim 5 \sigma \pi/K$ separation at 4 GeV/c
Several discussions with Emile Schyns, Group Product, Manager, Micro Channel Plates (final a good lead to the company)

Current performance (no Al protection layer): $\rightarrow$ 50% drop of efficiency after 10-15C/tube = 350-540mC/cm$^2$

Expect $\sim$ 10 mC/cm$^2$/year on ARICH (scaling the TOP estimate)

Summer 08: move production to Europe, expect to improve the ageing by a factor $> 5$ (use a different scrubbing technique, deep UV $\rightarrow$ electrons)

$\rightarrow$ Ageing most probably not a problem but need to be tested!
Additional feature: RICH+TOF

Make use of fast photon detectors: measure time-of-flight with Cherenkov photons from PMT window and aerogel

- Cherenkov photons from the window can be used to positively identify particles below the threshold in aerogel

Beam test:
- 50ps per single photon (~20ps per track)
- ~35ps per track
Summary and plan

• BURLE MCP-PMTs have been tested on the bench, in the beam and in the magnetic field → stable operation and very performance

• The Cherenkov angle resolution and yield are in good agreement with expectations

• Possible TOF extension ← excellent timing

To do list:
• Aging test
• Readout electronics
• Timing resolution in magnetic field
• Photon detection efficiency
Photon detector has to operate in magnetic field of 1.5T

One of the candidates - BURLE 85011 MCP-PMT:

- multi-anode PMT with two MCP steps
- 25 μm pores
- bialkali photocathode
- gain \( \sim 0.6 \times 10^6 \)
- collection efficiency \( \sim 60\% \)
- box dimensions \( \sim 71\text{mm square} \)
- 64(8x8) anode pads
- pitch \( \sim 6.45\text{mm, gap} \sim 0.5\text{mm} \)
- active area fraction \( \sim 52\% \)
**BENCH TEST SETUP**

**LIGHT SOURCE:**
- light source is blue LED (470nm) focused by microscope to ~ 30 µm
- position of the light source is computer controlled in steps of 12.5 µm

**READOUT ELECTRONICS:**
- signals from anodes are amplified and discriminated by ASD8 boards
- digital signals are converted to ECL levels and fed to VME counters

**ASD8 BOARDS:**
- used in the HERA-B RICH
- 16 channels (2 x ASD8 chips)

**ASD8 (8 channel amplifier, shaper and discriminator) data:**
- ENC ~ 900 + 70/pF
- shaping time ~ 10ns
- sensitivity ~ 2.5mV/fC
POSITION DEPENDENT SINGLE PHOTON COUNTING

count rates - all channels:
- charge sharing at pad boundaries

single channel response:
- uniform over pad area
- extends beyond pad area due to charge sharing
**CHARGE-SHARING**

- variation of the counting rate at the corner of four pads
- single photon detected by 1, 2, 3 or 4 channels

**5mm x 5mm, 2300 V**

- slice of the counting rate distribution including the central areas of 8 pads (single channels - colored, all channels - black)
Charge sharing

- comparison of the charge sharing effect for red (635 nm, left) and blue (405 nm, right) laser
- single channel response for photon incidence angles of 0° and 45° (logarithmic scale)
INTERNAL REFLECTIONS

- relative intensities of main peak, first and second reflections are 0.92, 0.07 and 0.01 respectively
- displacement of secondary image consistent with reflection from MCP surface

- impact on position resolution (+10% @18°)
- impact on timing resolution $\Delta t \sim 40$ps
**Beam Test Setup**

- Pion beam 0.5 GeV/c - 4 GeV/c
- Two MWPCs for tracking
- Same front end electronics (ASD8) as bench tests
- Digital signals read out by VME TDCs
- Different aerogel samples used

**Light-shield box**

- **RICH 1**
  - Flat-panel PMT (H8500) array
  - 20 cm

- **RICH 2**
  - Aerogel radiator
  - Cherenkov photons
  - 20 cm
  - MCP - PMT & Multi-anode PMT (R5900-M16) array

**Aerogel:**
- Focusing conf.
  - \(n_1 \approx 1.046, 2\) cm
  - \(n_2 \approx 1.056, 2\) cm
MCP-PMT mounted together with an array of 12(6x2) R5900-M16(Hamamatsu) PMTs at 30mm pitch

R5900-M16 characteristics:
- bialcali photocathode
- 16 (4x4) pads, pitch 4.5mm
- active area fraction ~ 36%
- collection efficiency ~ 75%
MCP-PMT: Cherenkov ring & HV scan

- accumulated rings on MCP-PMT and M16 PMTs

- HV scan: number of clusters in Cherenkov ring as a function of high voltage applied to MCP-PMT
- number of clusters reaches plateau at ~ 2200V
## Table of sensor properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximity focusing RICH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with aerogel radiator</td>
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</tbody>
</table>

- proximity focusing RICH with aerogel radiator
BENCH TEST SETUP - ELECTRONICS

VME
- VMEEMM master module
- Caen V830 32 CHANNEL SCALER
- Caen V830 32 CHANNEL SCALER
- Caen V262 I/O REGISTER
- Caen V288 CAEN NET CONTROLLER

NIM
- Caen V7470 High Voltage power supply
- Caen N93B dual timer

VME
- PCI/ISA NET CARD
- PC Windows 2000 LABWindows CVI

ISEL CNC controller
- KEITHLEY 220 current source
- CNC position table
- Microscope with LED

HAMEG HM7044
- BURLE 85011501 Multi channel plate PMT
- ASD8

16 channel data cables

Low voltage supply

THR
simple simulation:
- generating Cherenkov photons
- counting number of hit pads
- counting number of clusters within the 8x8 channel areas

11 pads
7 clusters