New Fast Shower Max Detector Based on MCP as an Active Element

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Fast timing in calorimeters

• Starting point in exploring precision timing in calorimeters
  o Secondary emitter material as active element in a sandwich type calorimeter

• Secondary particles from EM shower are detected by MCP
  o Signal is proportional to the number of secondaries \( \rightarrow \) energy of parent
  o Most of secondary particles are low energy \( \rightarrow \) MCP very efficient
  o MCP are intrinsically very fast \( \rightarrow \) calorimeter with very fast timing
Radiation resistant and fast SM detector

Experimental setup

• We performed an experiment in the FNAL MTest area with electron and proton beams (Nov 2013 and Jan 2014):
  o “Development of a new fast shower maximum detector based on micro channel plates photomultipliers (MCP-PMT) as an active element”, A. Ronzhin, S. Los, E. Ramberg, M. Spiropulu, A. Apresyan, S. Xie, H. Kim, A. Zatserklyaniy; submitted to NIM A

• Two types of MCP-PMTs used
  o 2 units of Photek 240 (PK A/B)
  o 1 unit of Photonis (PH)

• DAQ is composed of 2 DRS4 waveform digitizer units
  o attenuated input signals from one DRS4 to cover the full dynamic range
  o triggered on scintillator counters
  o Cherenkov radiator used to select electron events
Photek 240 and Photonis MCP-PMT

- **Photek**
  - 10 µm pore size, 41mm aperture, PC-MCP distance ~5mm, rise time~60 ps, SPTR~40 ps

- **Photonis**
  - 25 µm pore size, 60x60mm² sensitive area, rise time~300 ps, SPTR~120 ps, much cheaper than Photek
Test beam setup

- Primary proton beam: 120 GeV/c
- Secondary beam of positrons: 12 and 32 GeV/c
- Vary several parameters of the setup
  - Change lead thickness
  - Add quartz radiators in front of PH
  - Plastic scintillator in front of PKB
Event selection and analysis

• Assign a time stamp to each event
  o Mean value of Gauss fit to the pulse at maximum

• Event selection to eliminate abnormal pulses
  o Large signals above 500 mV were rejected because they saturated the DRS4 inputs.
  o Pulses with an irregular peak profile were rejected
  o Selected the pulses with larger than 20 mV amplitude for analysis.

• For Photonis linear dependence of the $\Delta T$ is observed
  o Perform a time correction for each event on the measured amplitude.
Characterization of the setup

• Electronic time resolution
  o Measure time difference of a split signal from one Photek into same DRS4
  o Slightly different for two units: 4.8 and 6.7 ps
  o New DRS4 calibration can achieve ~1-2 ps
    • S. Ritt: https://indico.cern.ch/event/306859/session/3/contribution/10

• TOF time resolution for protons
  o Resolution for the two Photek 240 placed in line was found to be ~16 ps

Photek 240 signal recorded by a DRS4 during 120 GeV/c protons run passing through the input window.
Measurements with $e^+$ beam

- Measure the dependence of the *signal amplitude* and *time resolution* on the *lead thickness*, and Cherenkov by varying the *quartz thickness*.

Photonis, 12 GeV, 2 mm of quartz, input window, 10 mm of lead

Photonis, 12 GeV, 5.5 mm of quartz, 10 mm of lead

Photonis 12 GeV, 9 mm of quartz, 10 mm of lead
Measurements with e$^+$ beam

- Shower particles are detected both through Cherenkov (in the entry window) AND direct interaction with the MCP.
  - Significant component from direct detection of the secondary emission
- ~70% of the MCP-PMT response is due to the secondary emission and 30% is due to Cherenkov light in the 2 mm thick input window.
Time resolution and secondary emission

- **Time resolution** 20-30 ps achieved in beam for shower arrival.

- **No significant difference in TR** at 12 GeV vs 32 GeV beams.
  - No big TR changes for different lead thickness in these measurements.
Conclusion

• Time resolution of 20-30 ps achieved in test beam for shower arrival

• Photek and Photonis MCP-PMT are compared
  o Photek has better timing parameters: smaller pore size (10 vs 25 µm), better anode timing uniformity, Photonis comparable performance

• Further test beams planned in near future
  o Explore MCP w/o photocathode to directly measure the secondaries

• A sandwich type calorimeter based on MCP as active layers is possible to build
  o Progress in LAPPD project