Fermilab / U. Chicago / Argonne Collaborative Initiative on Ultra Fast Timing Detectors

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Fermilab
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With:

(ANL) Karen Byrum, Gary Drake, Bob Wagner

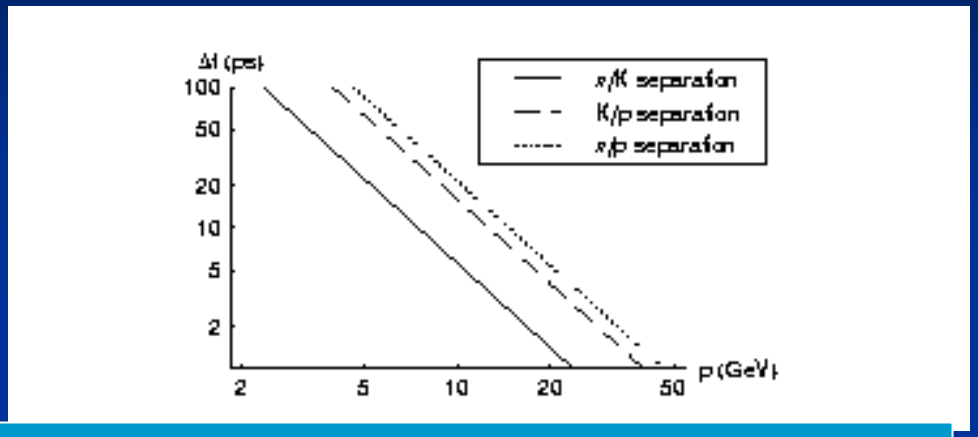
(UC) Henry Frisch, Harold Sanders, Fukun Tang

(FNAL) Mike Albrow, Anatoly Ronzhin

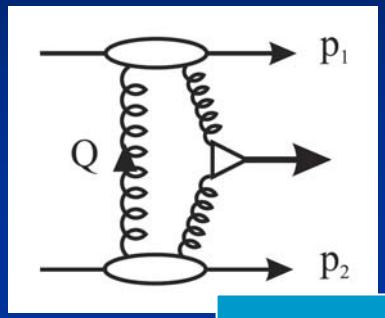
OUTLINE

- Motivation & Synergies in fast timing R&D
- MCP Best Fast Timing Measurements
- U. Chicago Engineering
- Argonne Engineering/Laser Test Stand
- Fermilab Meson Test Beam Facility
- Work on SiPM's

Applications in Particle Physics, Astrophysics, PET, OTHER

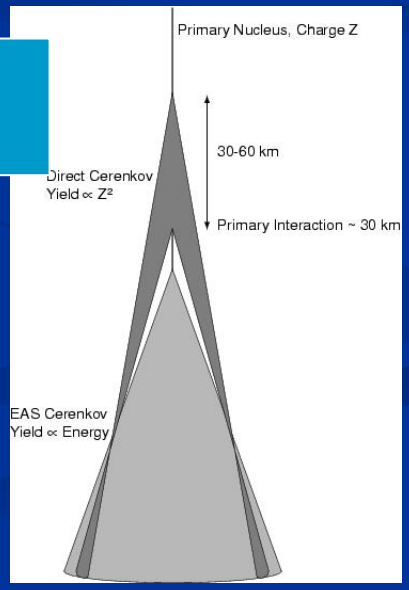


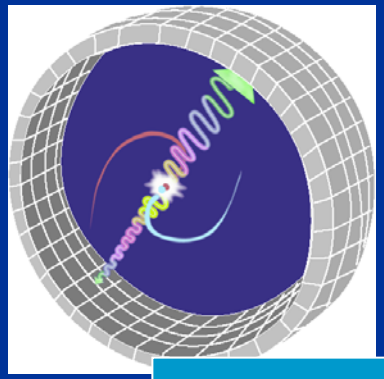
Particle ID – LHC upgrades, ILC, Flavor Physics



LHC – Forward Proton Tagging

Cosmic rays - Direct Cerenkov radiation

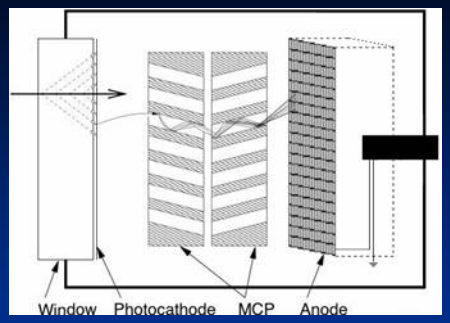




PET

Muon Colliders

Fast Timing Collaboration



Engineers: J.Anderson [1], G.Drake [1], J.F. Genat [4], H.Sanders [6], F.Tang [6], L.Zhou [6]
Physicists: K.Byrum [1], H.Frisch [6], P. Le Du [4], B.Moses [3], E.Ramberg [2], C.Royon [4], J. Va'Vra [5], R. Wagner [1]
Radiologists: C.Chen [7], C.Kao [7], Q.Xie [7]
Students: O.Biris [7], C.Ertley [1,6], D. Herbst [6], J.Lin [7], S. Wilbur [6], D. Yu [6]

Argonne National Laboratory [1], Fermi National Laboratory [2], Lawrence Berkeley Laboratory [3], Saclay Institute, France [4], Stanford Laboratory Accelerator Facility [5], University of Chicago Enrico Fermi Institute [6], University of Chicago, Radiology Department [7]

Goal: Development of Large-Area time-of-arrival systems

HEP $\sigma \sim 1$ps PET $\sigma \sim 30$ps

Includes:

- 3-D modeling of photo-optical devices
- Laser Facility to characterize/compare performance
- Design and construction of ultra-fast (200GHz) electronics.
- End-to-end simulation of large systems
- Development of Library of SiPM & MCP pulses
- Studies in FNAL Test Beam
- Real-time processing for PET

Micro Channel Plate Photo Multiplier Tube (MCP/PMT) are Tool of Choice

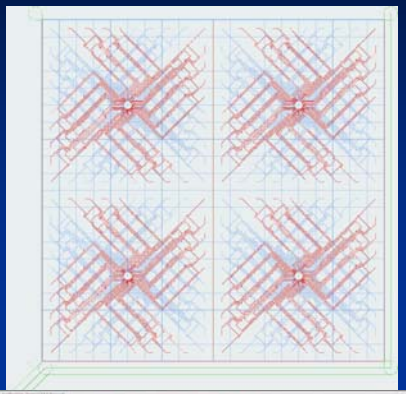
- Jerry Va'Vra SLAC (Presented at Chicago Sep 2007)
  - Upper Limit on MCP-PMT resolution: $\sigma_{MCP\text{-}PMT} \sim 4.5$ps

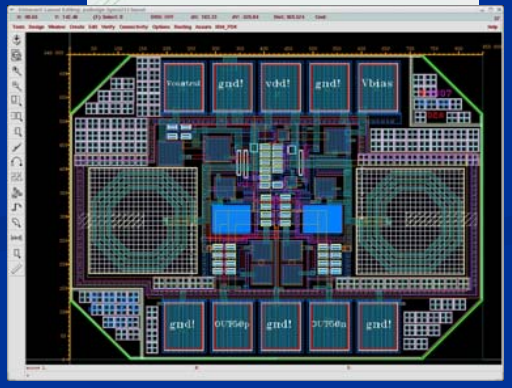
Photonis MCP-PMT 85012-501
(64 pixels, ground all pads except one)

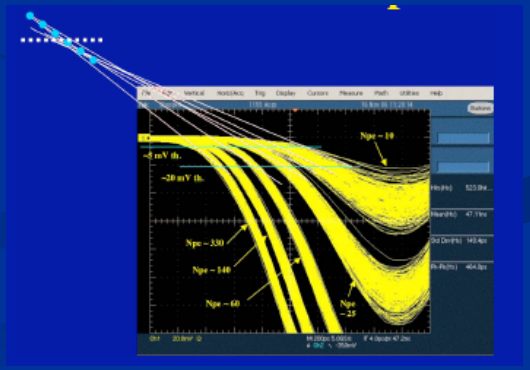
- Takayoshi Ohshima of University of Nagoya (Presented at SLAC Apr 2006)
  - Reached a $\sigma_{MCP\text{-}PMT} \sim 6.2$ps in beam test
  - Used 2 identical Hamamatsu detectors in beam
  - Beam measured with 1 cm quartz radiator (Npe ~50)

U.Chicago Engineering Highlights

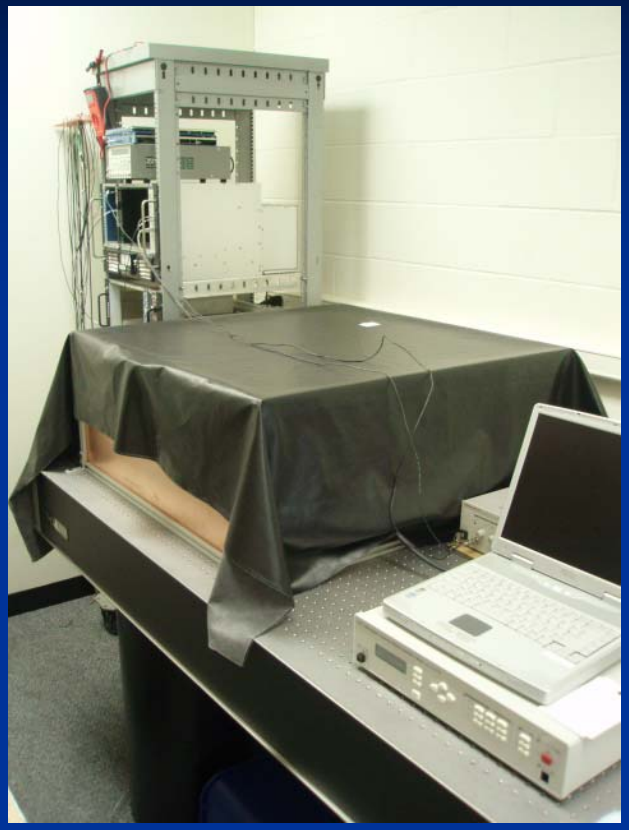
- Development of equal-time anode structure for PMT's
- Designed Voltage Control Oscillator using IBM 0.13um SiGe BiCMOS8HP
- More challenging - Time Stretcher chip (including ultra low timing jitter/walk discriminator & dual-slope ramping time stretching circuits etc.)
  - From simulations, accuracy not good enough (5-10 psecs)
  - Power concerns
- NEW: Invented 2 new schemes - a) Multi-threshold comparators, b) 50 GHz 64-channel waveform sampling. Both schemes give energy and leading edge time.
- Current plan: Save waveform and use multiple thresholds to digitize. Use CMOS
  - Dec meeting at UChicago with UChicago, ANL, Saclay, LBL & Hawaii, IBM and Photonis





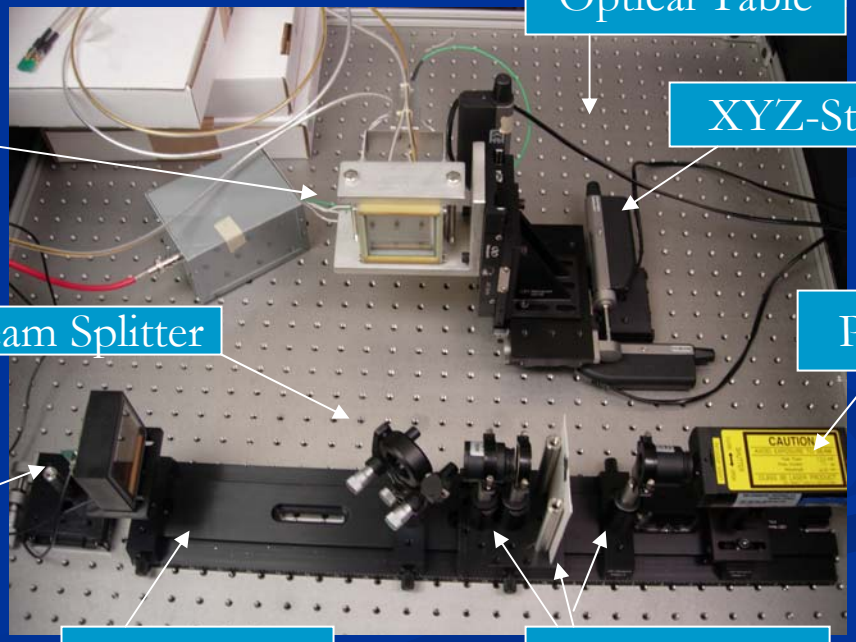


Argonne's Laser Timing Lab



Hamamatsu PLP-10 Laser (Controller w/a laser diode head) 405 & 635nm head.

Pulse to pulse jitter < 10psec (Manufacture Specifications)



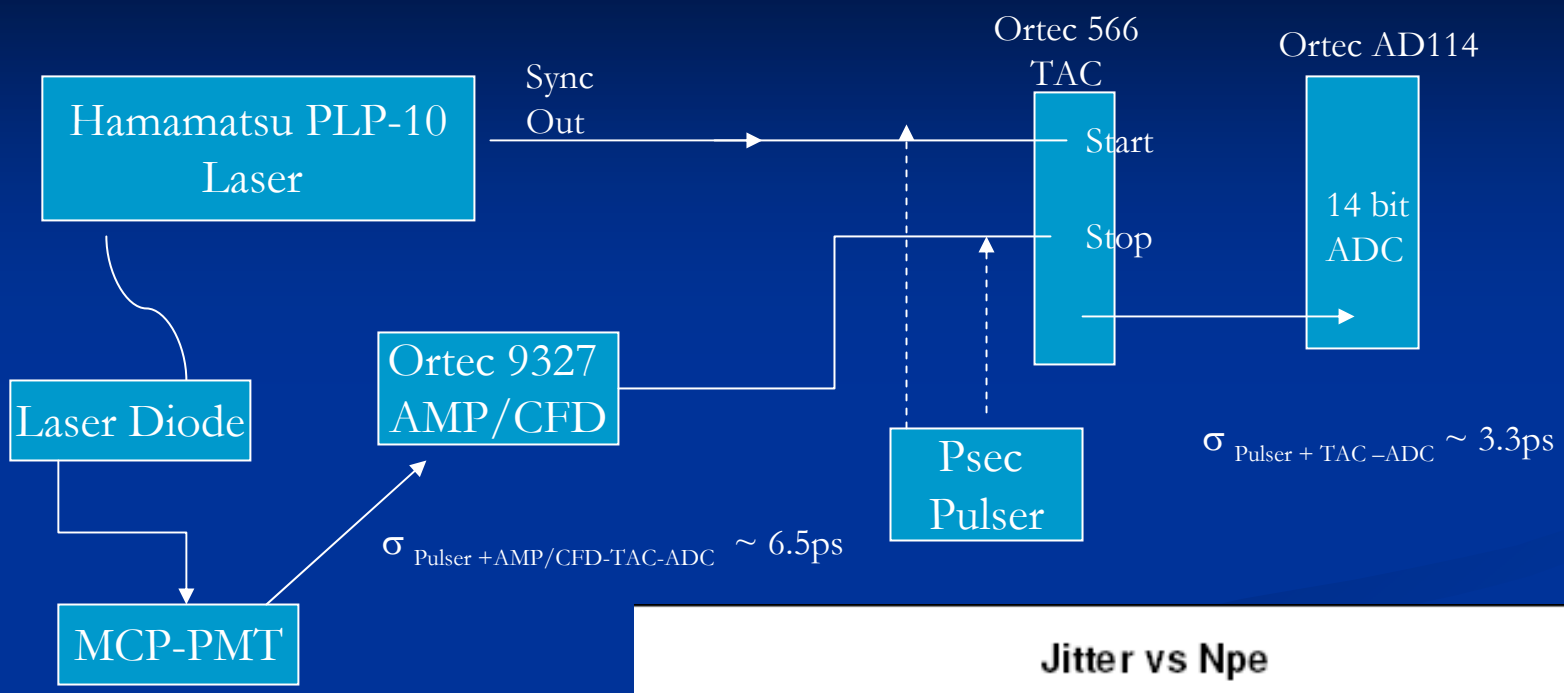
DAQ: Camac CC-USB processor connected to laptop running linux

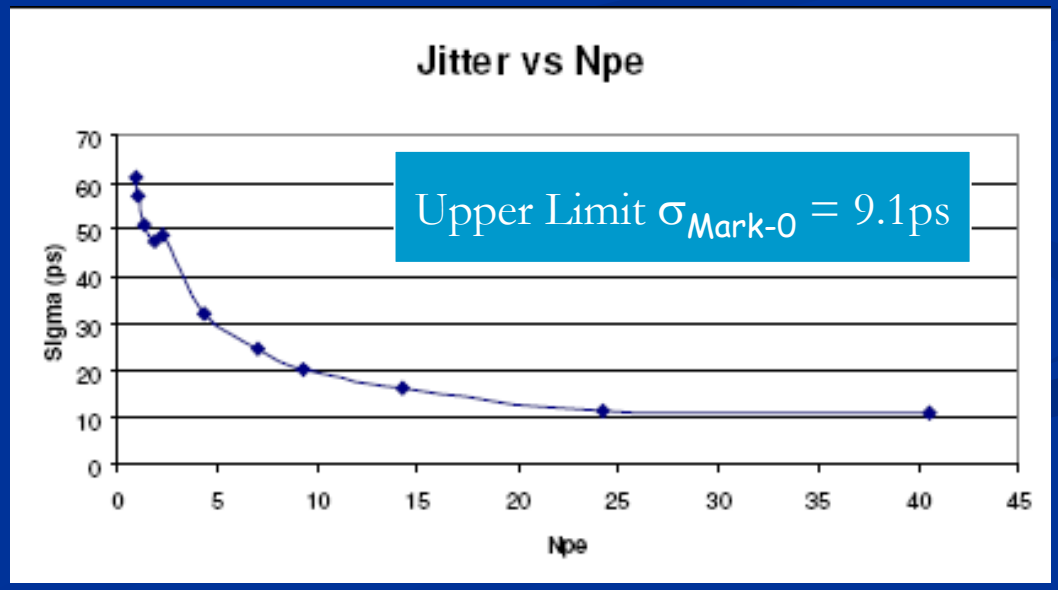
Ortec 9306,9307,9327

Ortec 566 TAC

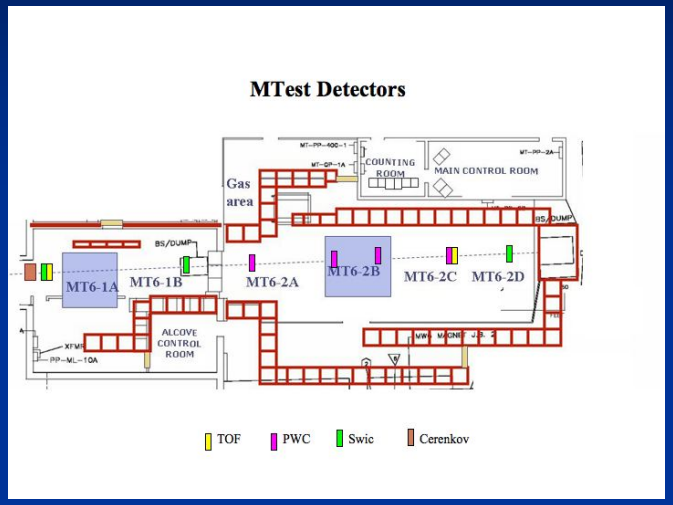
Ortec AD114

Timing Resolution with PLP-10 Laser

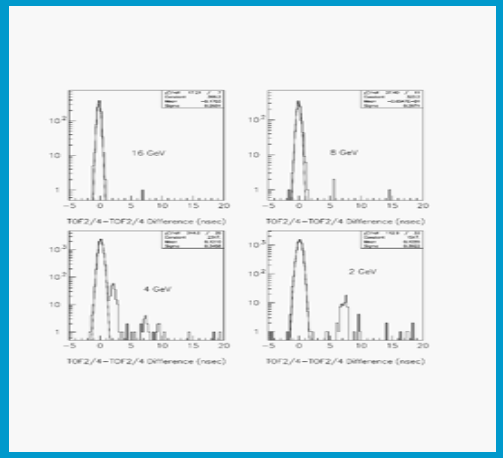




Fermilab's Meson Test Beam Facility



- Time-of-flight system limited to below 2 GeV
- Two counters of 20 mm scintillator & 4 PMT's
- Best resolution of 160 psec



T958: Fast Timing Detectors at Fermilab test beam

UTA (**Brandt**), Alberta (Pinfold),
Louvain (Piotrzkowski), FNAL (Albrow)

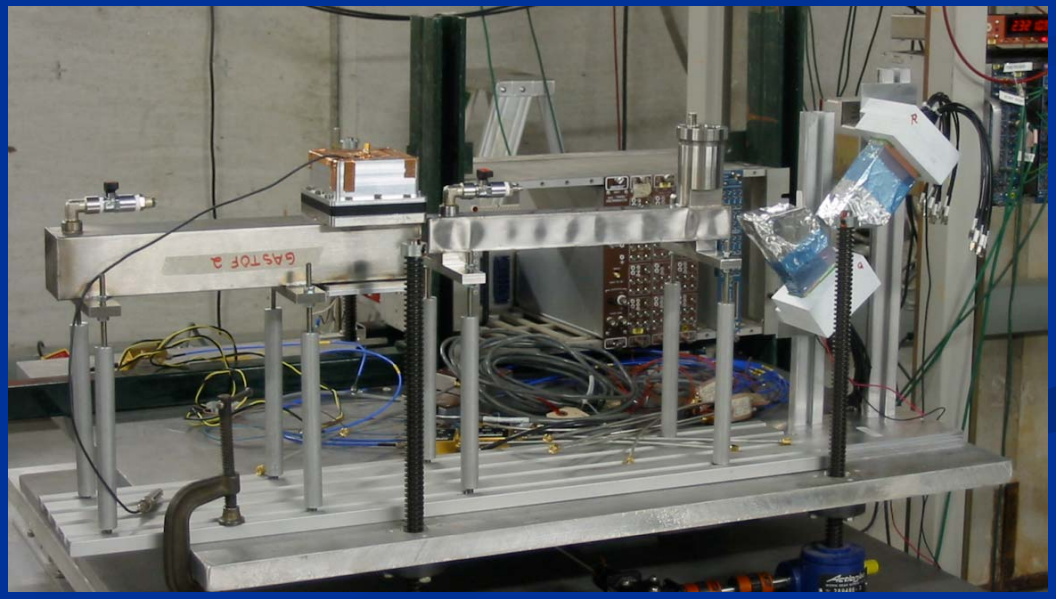
Physics Motivation: **FP420 an R&D program to investigate feasibility of double proton tagging at 420m as a means to discover new physics/measure properties of new physics at LHC**

Goal of R&D: **Develop a fast time-of-flight detector <20 psec for pile-up rejection (determine using timing of protons whether they originate from hard scattering vertex)**

Two detectors tested:

GASTOF (~40 psec)
QUARTIC (~60 psec) -->

Both use MCP/PMTs

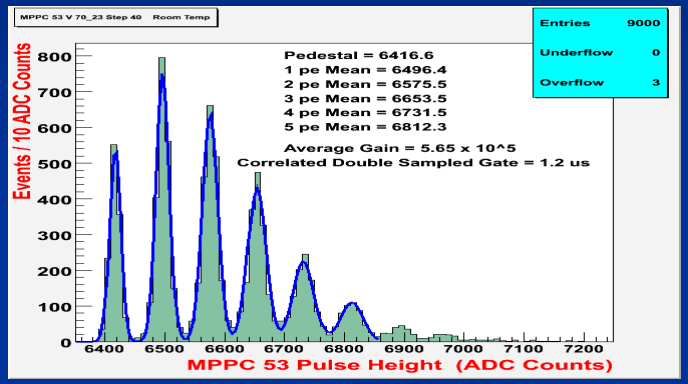


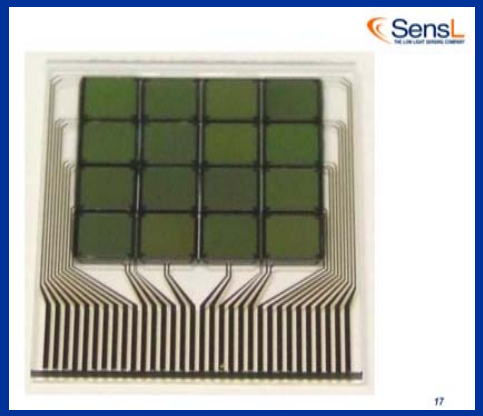
Research on SiPM Timing

SiPM Key Properties

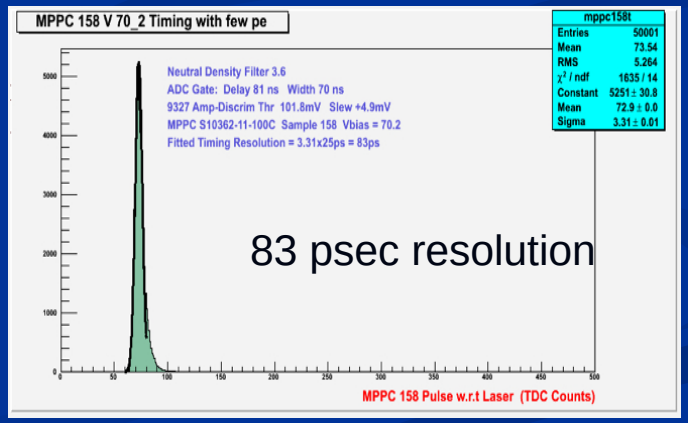
- Sensitive to single photons
- Resolvable p.e. peaks
- High intrinsic gain (>10^5)
- Low operating voltage
- Insensitive to magnetic fields

Bob Wagner has tested timing properties of a Hamamatsu SiPM:





Fermilab has purchased new SiPM array from SensL for timing tests



Future Efforts

- Grant will support:
  - Continued engineering at U.Chicago and ANL in support of development of MCP/PMT technology and ultra-fast timing electronics
  - Fermilab to start on the path to a significantly better TOF system for the test beam
  - Purchase of amplifiers, MCP/PMT's, oscilloscopes for group use.
  - World-wide collaborative efforts