Forward TOF

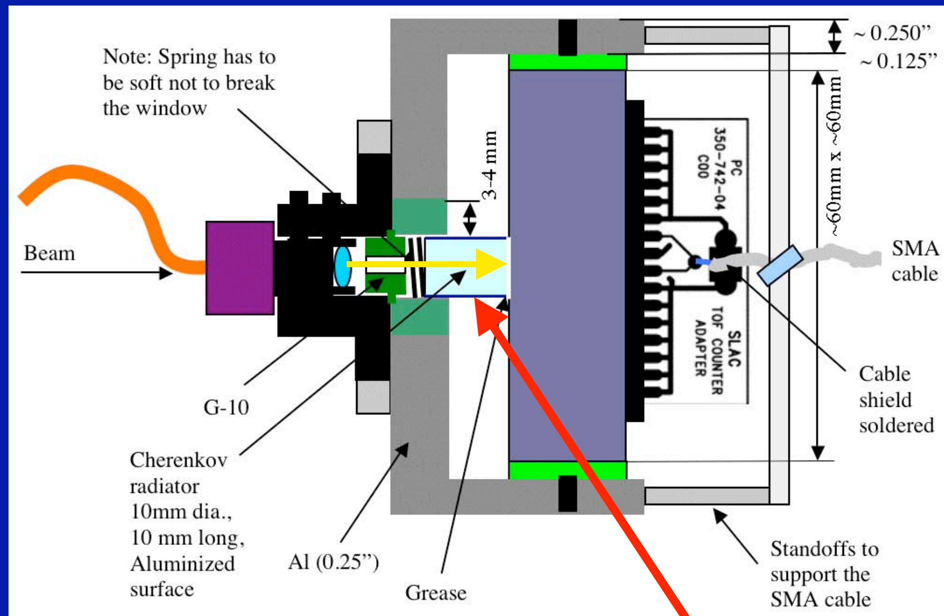
J. Va'vra, SLAC

Light travels 300μm in one ps

Content of this talk

- **SLAC & Fermi lab beam test results**
- **Initial aging tests**
- **Upcoming tests in the cosmic ray telescope**
- **Options for the SuperB TOF application**
- **Comment on operation in magnetic field & aging**

SLAC TOF counter prototype



Cylindrical radiator coated with Al on its sides

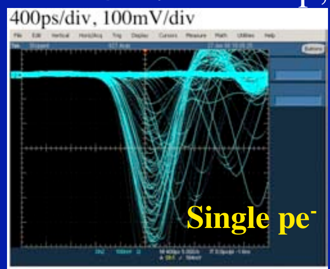
- **Cherenkov light for ultra-fast response.**
- **Burle/Photonis MCP-PMTs with 10 µm MCP holes.**
- **Short together 4 pads to get a signal; all the rest of pads grounded.**
- **A 10mm-long, 10mm dia, quartz radiator, Al-coating on cylinder sides: (a) Fermilab test: good coating by Photonis, (b) SLAC test: poor coating.**
- **Calculation using all known efficiencies: Npe ~ 30.**
- **Calibration of the Fermilab beam test: Npe ~ 45 ± 10.**

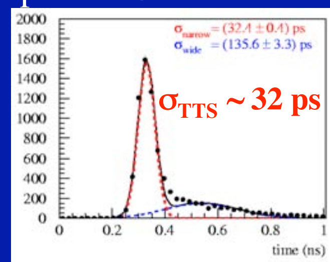
My best σ_{TTS} was achieved with slower electronics

J.Va'vra et al., Nucl.Instr.&Meth. A 572 (2007) 459–462, and my log books 3 & 6, 2006 & 2008

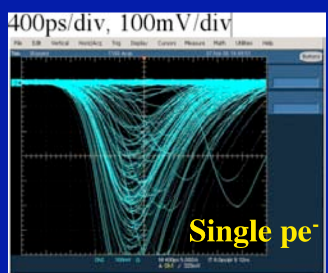
1) ~ 300 MHz BW electronics:

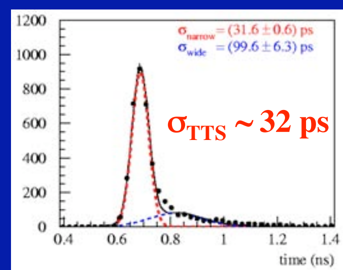
HPK C5594-44 amp, Phillips 715 CFD:



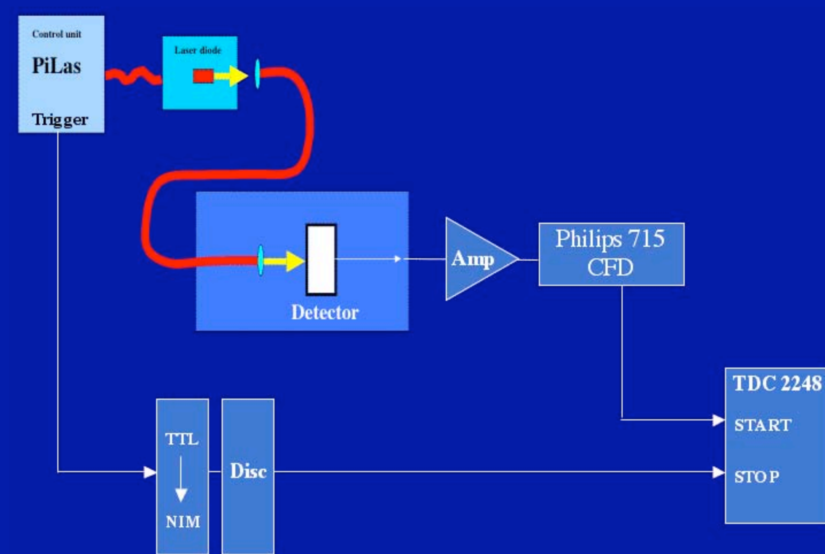


Ortec VT-120 amp.+6dB, Phillips 715 CFD :





- Photonis Planacon, S/N 11180401
- 10 µm MCP hole diameter
- 2.8 kV
- Single pe sensitivity



- Slow down amplifiers by a long cable between Amp & CFD (optimum was found to be ~20ns).

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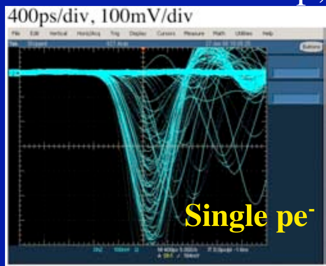

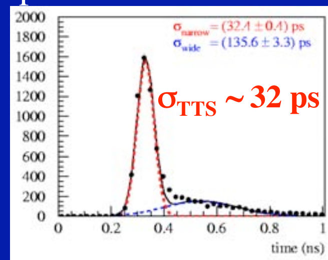

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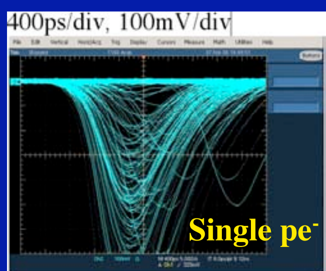
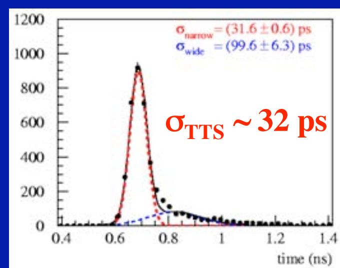
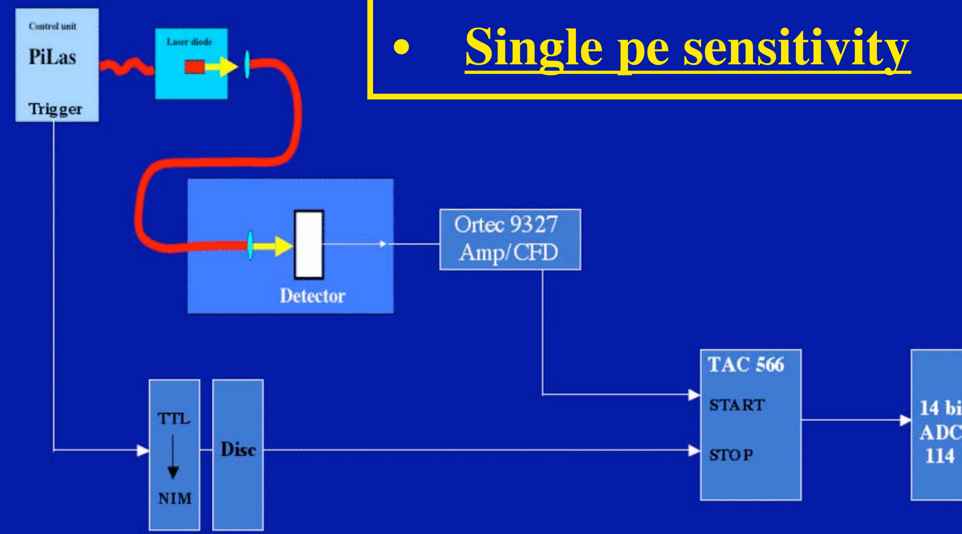




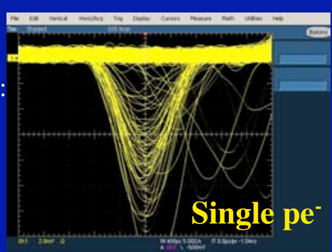


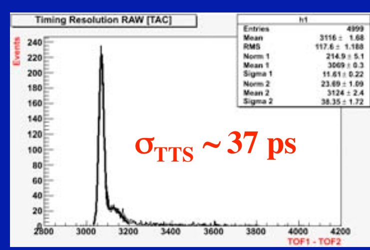
- **Slow down amplifiers by a long cable between Amp & CFD** (optimum was found to be ~20ns).

2) ~ 1 GHz BW electronics:

Ortec 9327CFD, TAC566, ADC114:

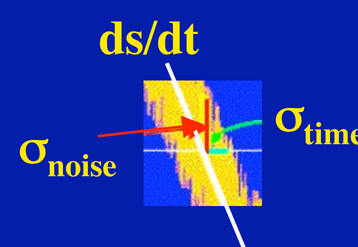
CFD monitor:





- **CFD timing:**

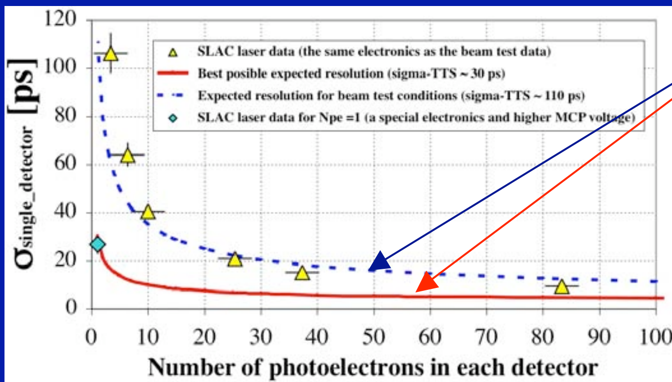
$$\sigma_{time} = \sigma_{noise} / (ds/dt)_{zero\ crossing\ point}$$



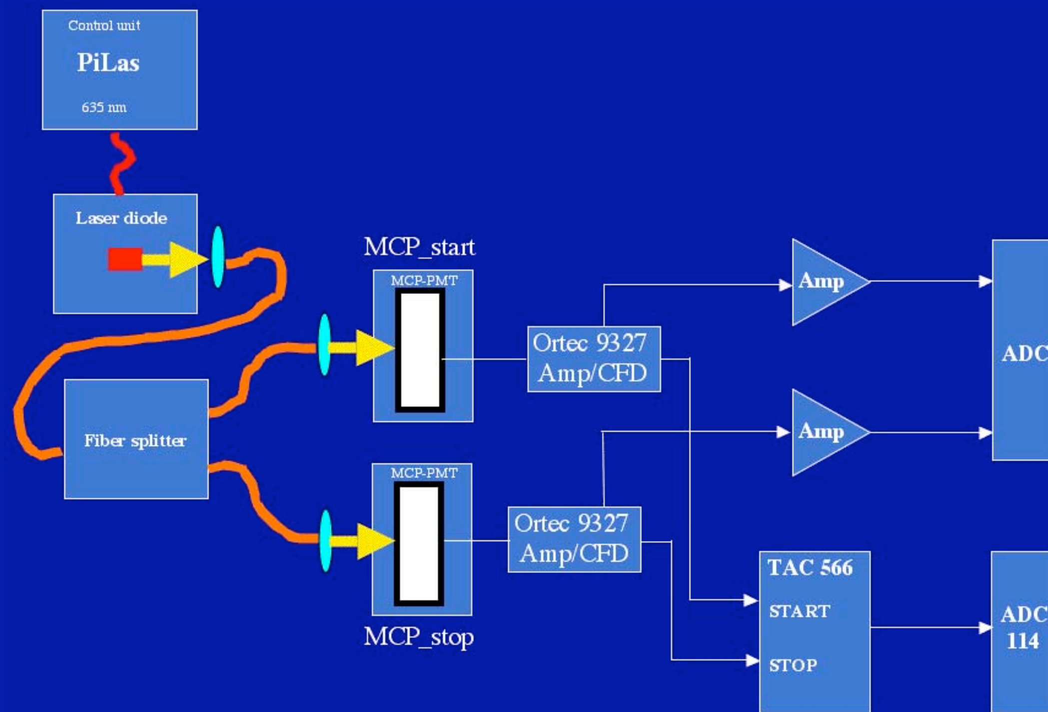
σ_{TTS} with beam test electronics & at low gain

J.Va'vra et al., Nucl.Instr.&Meth. A 595 (2008) 270-273

Nominal MCP voltages, G ~2x10[4]**:**



$$\sigma \sim \sqrt{[\sigma^2_{MCP\text{-}PMT} + \sigma^2_{Laser} + \sigma^2_{Electronics} + \ldots]} =$$
$$= \sqrt{[\sigma_{TTS}/\sqrt{N_{pe}})^2} + \sqrt{((FWHM/2.35)/\sqrt{N_{pe}})^2 + (4.2\ ps)^2\ ]}$$



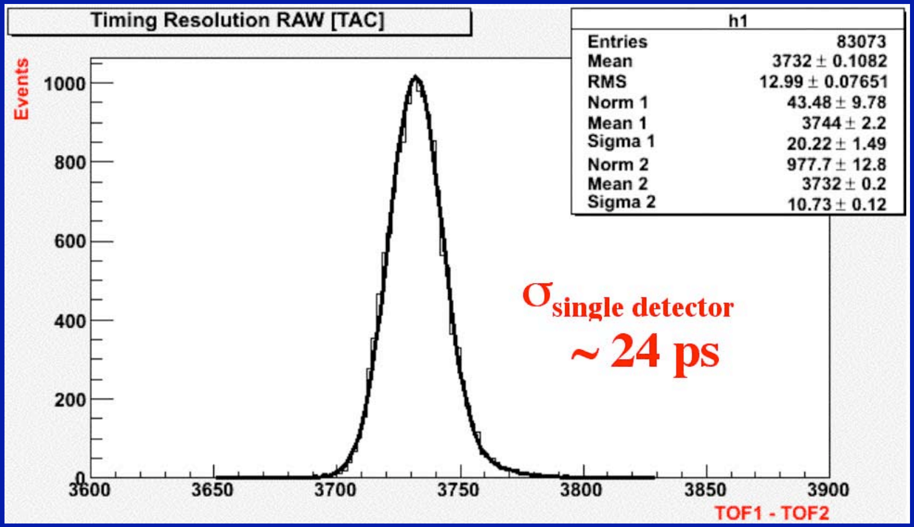
- **Photonis Planacon**, S/N 11180401 & 7300714
- **10 µm MCP hole diameter**
- **2.2 kV & 2.0 kV on MCP-PMTs**
- **Not sensitive to single pe, instead, linear for Npe ~ 30-50**

- **The same electronics as in the test beam - Ortec electronics (9327CFD, TAC566, ADC114)**
- **Extrapolating to Npe = 1, one obtains much worse σ_{TTS} ~ 110 ps.**

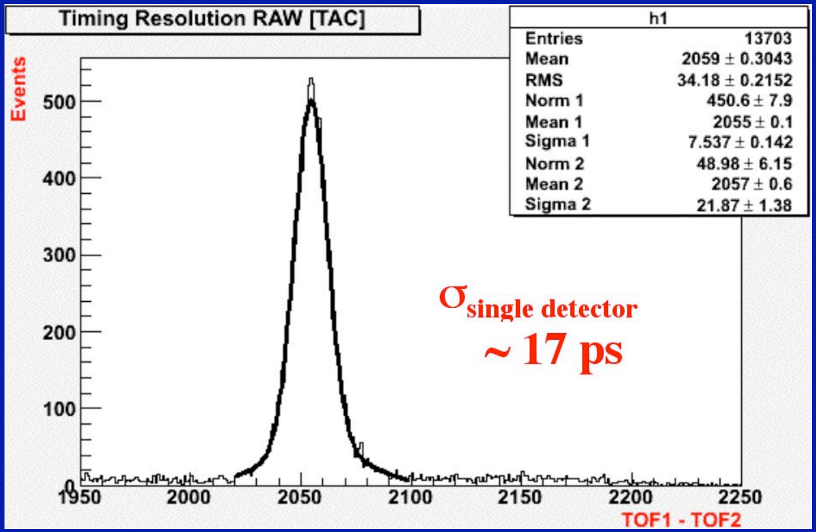
Beam tests at SLAC and Fermilab

J. Va'vra, D.W.G.S. Leith, B. Ratcliff, E. Ramberg, M. Albrow, A. Ronzhin, H. Frisch, T. Natoli, E. May, K. Byrum,
"Beam test of a TOF detector prototype" , to be published in NIM.

SLAC beam test, 10 GeV e^+:



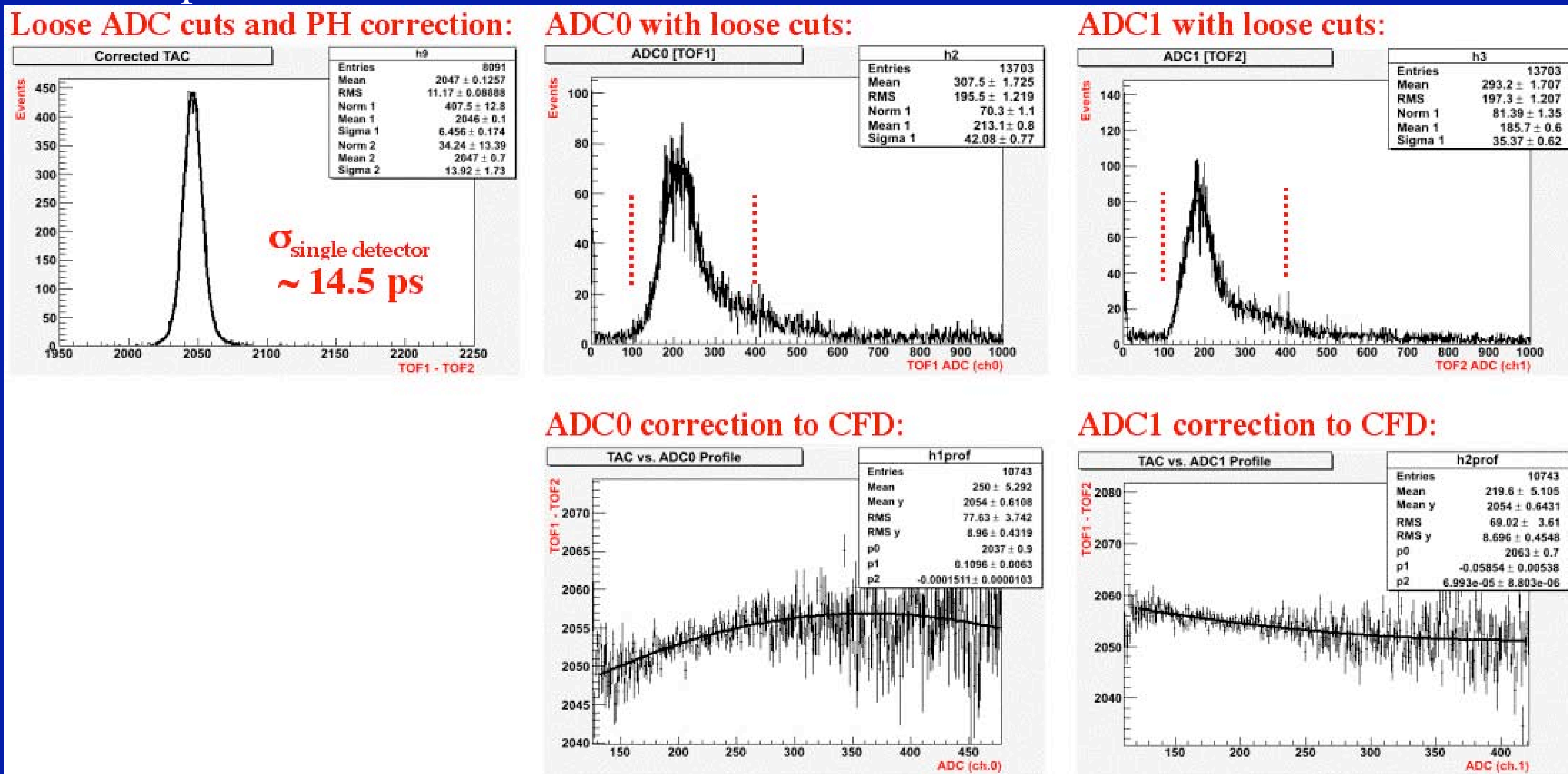
Fermilab beam test, 120 GeV p:



- **Take all events - no ADC cuts.**
- **No ADC correction to CFD timing.**
- **<u>Difference between two tests</u>: use a new quartz radiator with a new aluminum coating in the in Fermilab test (coated by Photonis).**

Beam test at Fermilab

120 GeV protons:

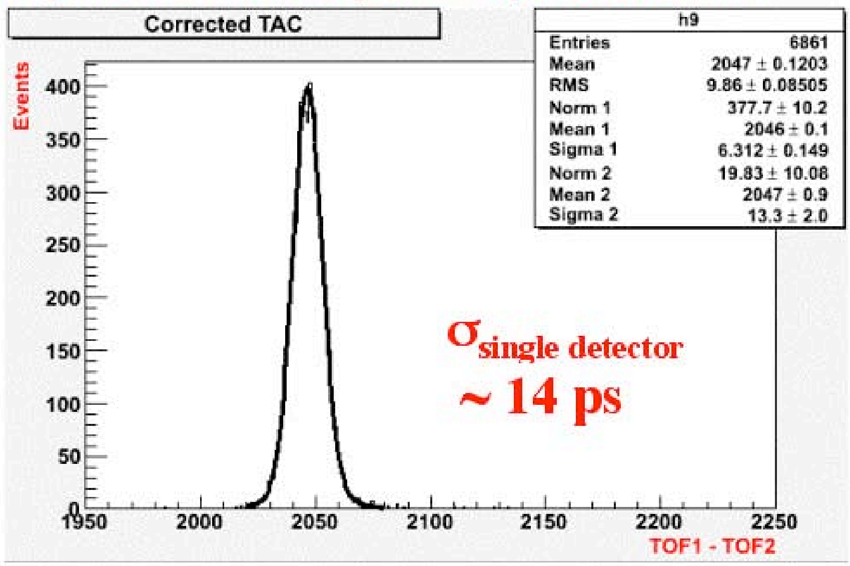


- **ADC correction to CFD timing & <u>loose</u> ADC cuts**

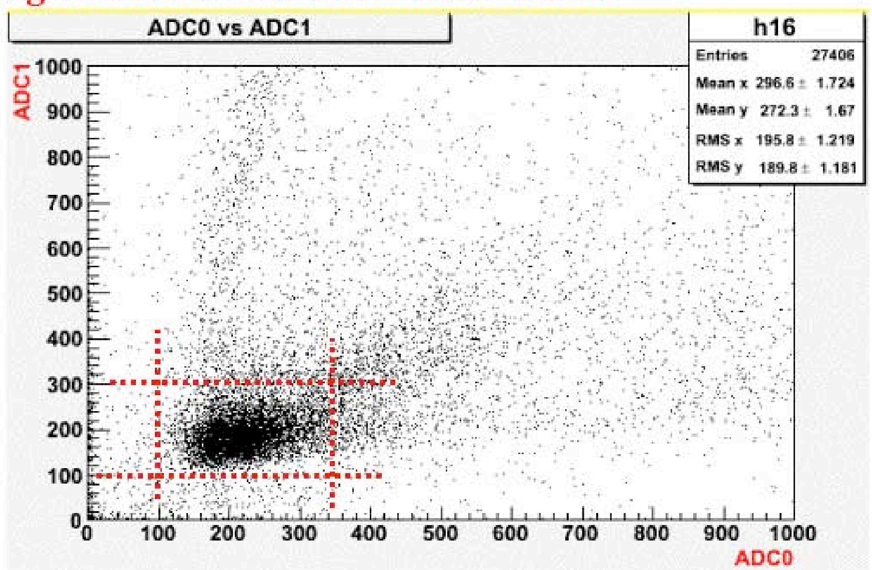
Beam test at Fermilab

120 GeV p:

Tight ADC cuts and pulse height correction:



Tight ADC cuts to eliminate doubles:



- **ADC correction to CFD timing & <u>tighter</u> ADC cuts**

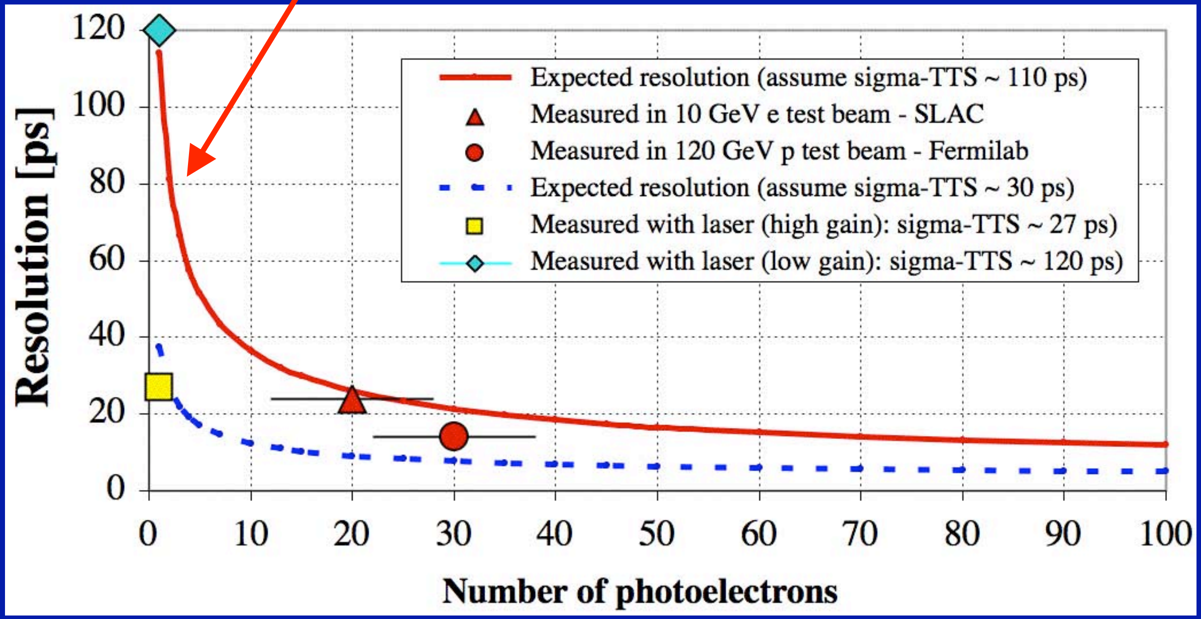
Are the results consistent with expectations ?

$\sigma \sim \sqrt{[\sigma^2_{MCP-PMT} + \sigma^2_{Radiator} + \sigma^2_{Pad\ broadening} + \sigma^2_{Electronics} + \ldots]} =$

$= \sqrt{[(\sigma_{TTS}/\sqrt{N_{pe}})^2 + (((12000\mu m/\cos\Theta_C)/(300\mu m/ps)/n_{group})/\sqrt{(12Npe)})^2 +}$

$+ ((6000\mu m/300\mu m/ps)/\sqrt{(12Npe)})^2 + (4.7\ ps)^2\ ]$

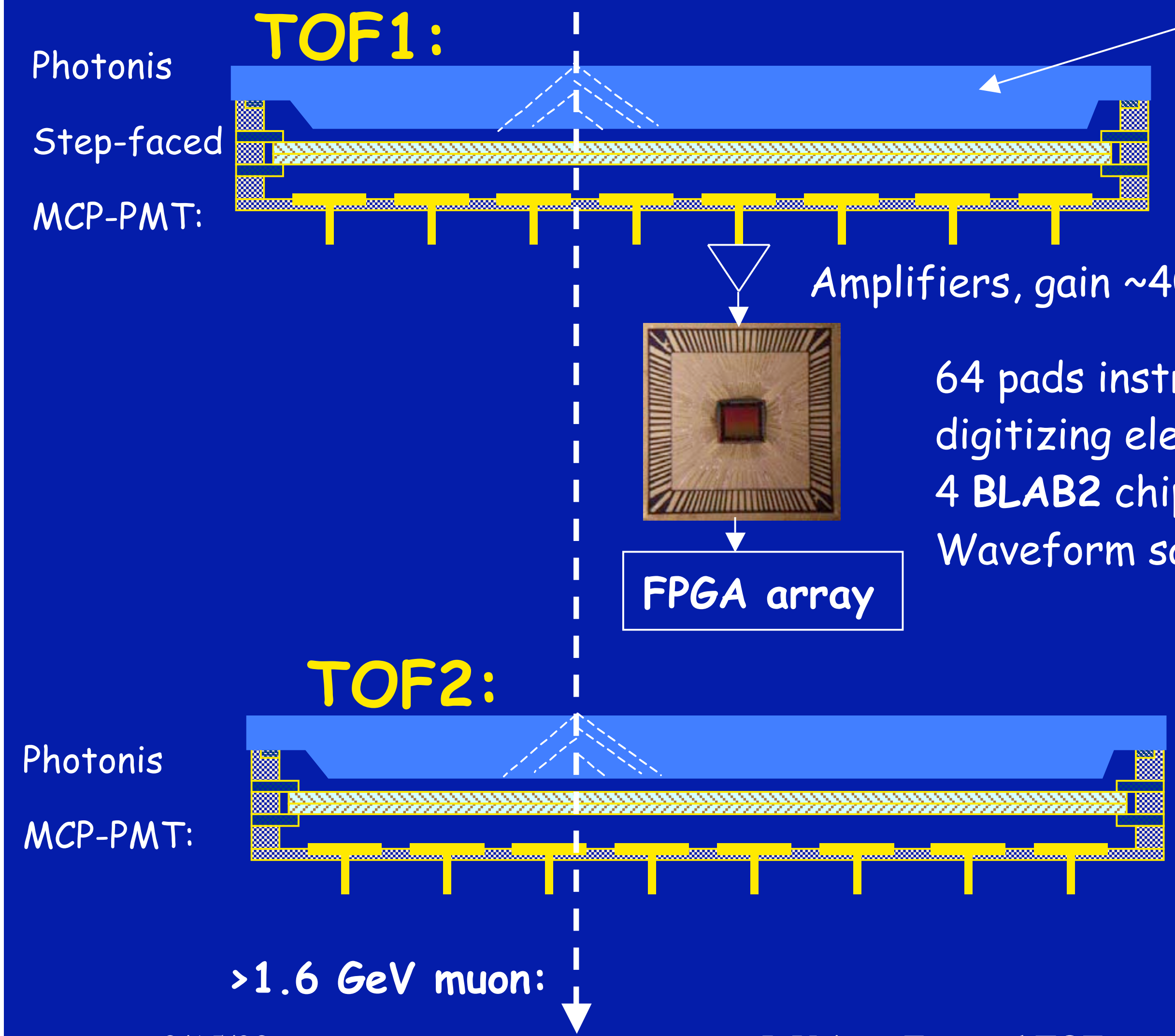
For Npe = 30, contributions from each term: 22 ps 2.1 ps 1.1 ps 4.7 ps



- **Calculation for Fermi lab test: Npe ~ 30.**
- **Calibration measurement for Fermi lab test: Npe (ave of TOF1 & TOF2) ~ 45 ± 10.**
- **Hard to improve the resolution by adding photoelectrons (slowly varying function).**
- **<u>How do we jump to blue curve ?</u>**

Option #1

Initial test of the TOF detector in the cosmic ray telescope or beam



64 pads instrumented with a waveform digitizing electronics,
4 **BLAB2** chip / MCP-PMT,
Waveform sampling rate: ~2 GSa/s

Note:
This solution requires a full single pe sensitivity => high gain operation

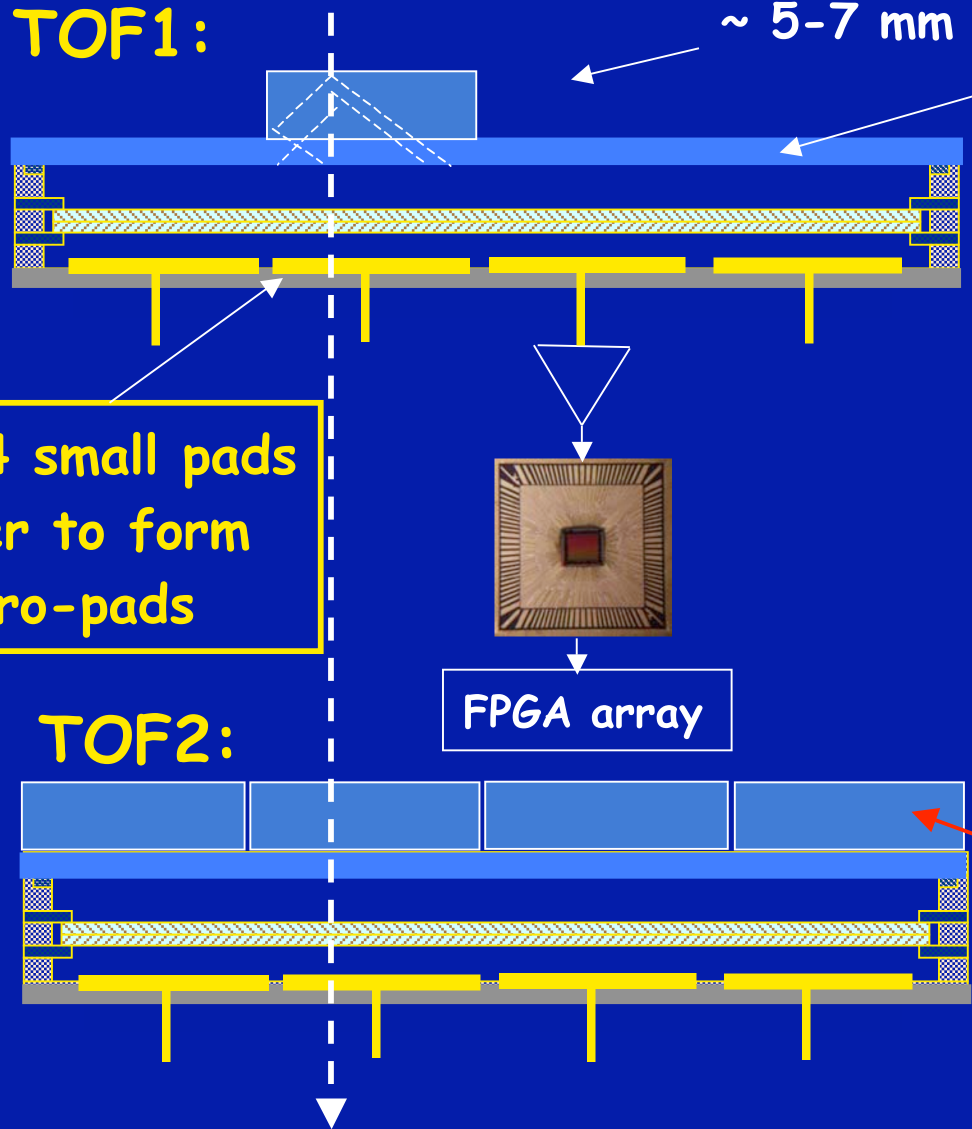
Option #2

Better alternative: run at lower gain

TOF1:

~ 5-7 mm thick quartz radiator cube

~ 2 mm window



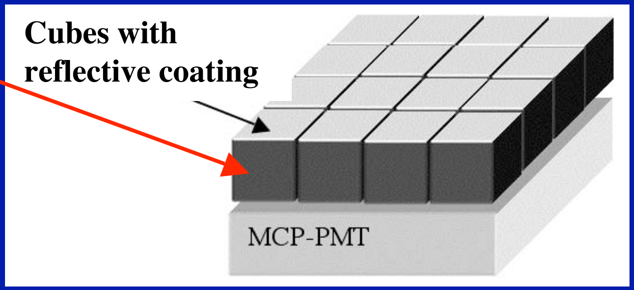
Short 4 small pads together to form 16 macro-pads

Want to run MCP at low gain of ~2-5x10^4.
Arguments for it:
- smaller aging
- good results in beam

TOF2:

Photonis MCP-PMT:

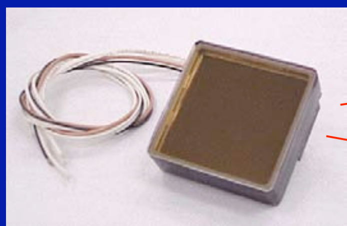
Cubes are light concentrators

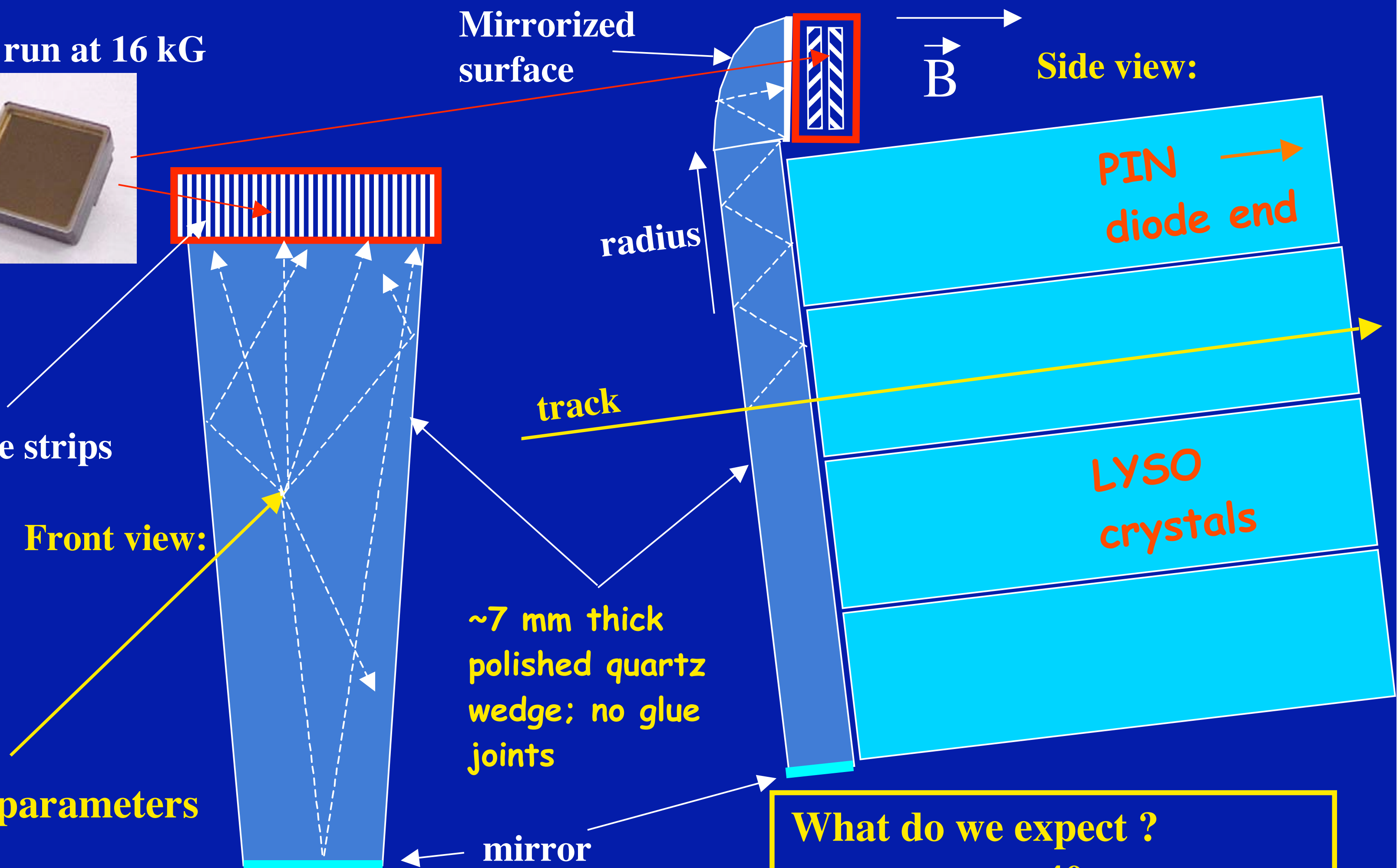


Option #3

“DIRC-like” Forward TOF detector ?

MCP needs to run at 16 kG





Need track parameters

A photon will be accepted if:

$\Sigma(TOP_i^{measured} - TOP_i^{expected}) < Cut$

What do we expect ?

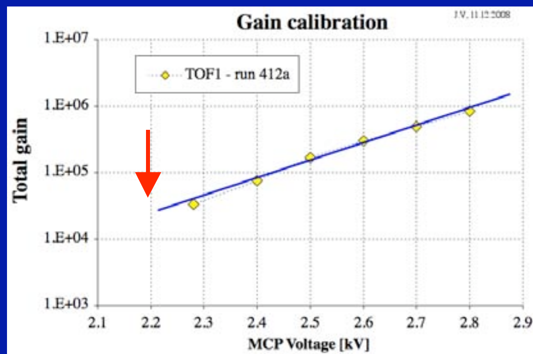
- $\sigma_{TTS} \leq 40$ ps
- Npe ≥ 5 pe’s on ave.

=> $\sigma \sim \sigma_{TTS}/\sqrt{Npe} \leq 18$ps

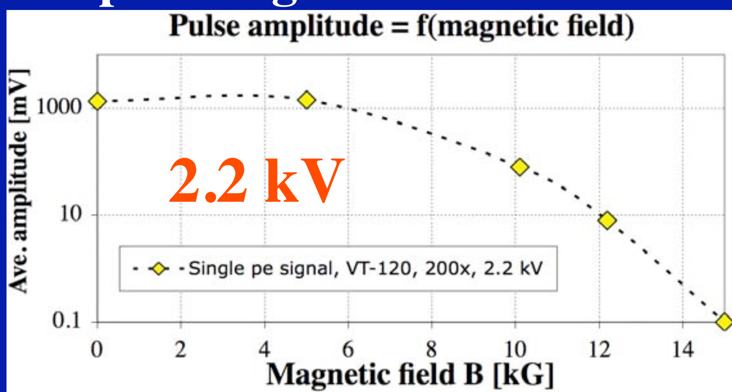
Is an MCP-PMT with 10 μm holes going to work at 16 kG ?

J.V., log book 3

Gain at B = 0kG:

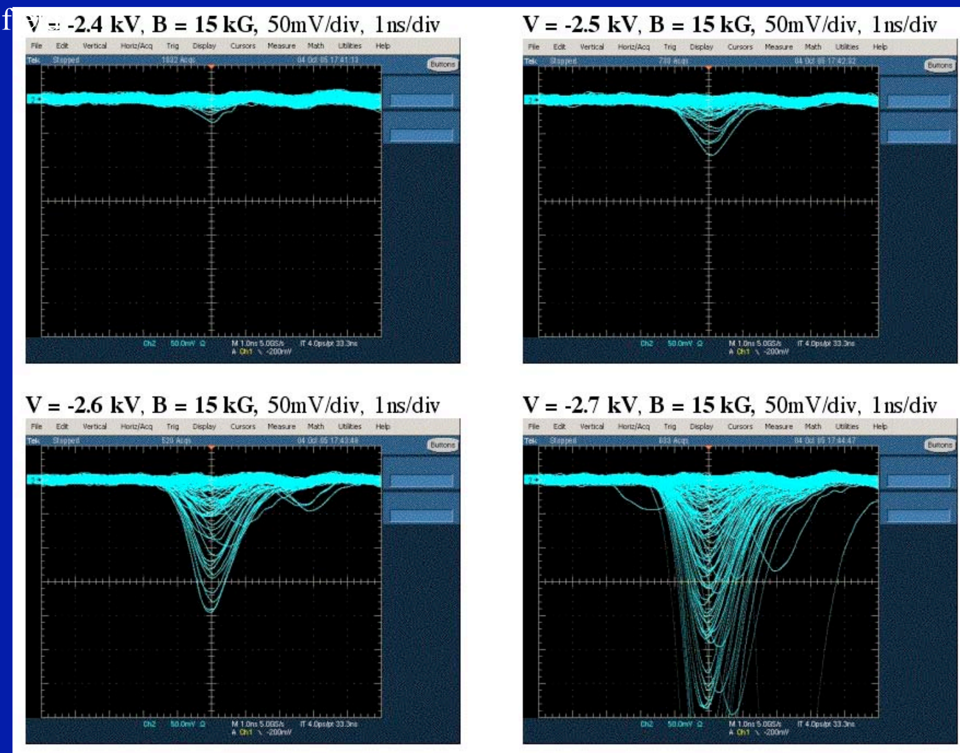


Amplitude goes to ~0 at 15 kG:



Single pe's:

Ortec VT120A amp., 200x gain, MCP face perpendicular to magnetic f



- **My estimate: one has to run MCP voltage ~ 400V higher at 16 kG !!**
- **Will this work in a large system ?**
- **Should one go to smaller hole diameter ?**

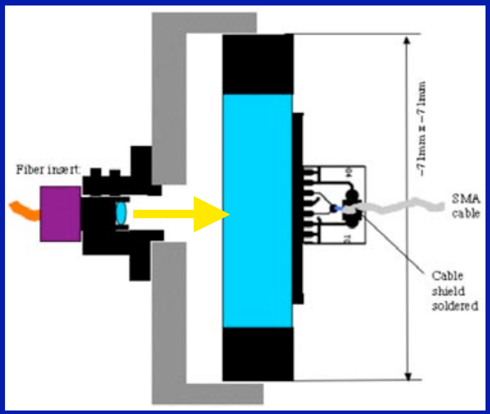
Photonis MCP-PMT QE aging at low gain mode

J.V., Log book 6, 2008

Photonis quotes a limit for the Planacon of a ~40% QE efficiency loss and ~10% gain loss after a total anode charge of ~400 mC/cm^2 ~ ~4mC/mm^2 (a quote from P. Hink).

Aging test done with a laser diode:

MCP with 25 µm holes:



S/N 09130303

Laser diode needs to be temp. stabilized and one has to use a reference PMT to correct for temperature-dependent light yield changes !

Aging test conditions:

Each laser pulse Q ~ one track equivalent
Similar settings as in the Fermilab test
Voltages set not to be sensitive to single pe's.
Low gain operation (G ~ 2-3 x 10^4)
Npe ~ 50 pe / pulse in this test
Irradiated spot size: ~ 1 mm^2
Laser rate: 20 kHz / 1 mm^2
Total # of track hits: ~ 3.5 x 10^{10} / mm^2 / run
(Total charge: ~ 7x10^3 mC/mm^2 / run)

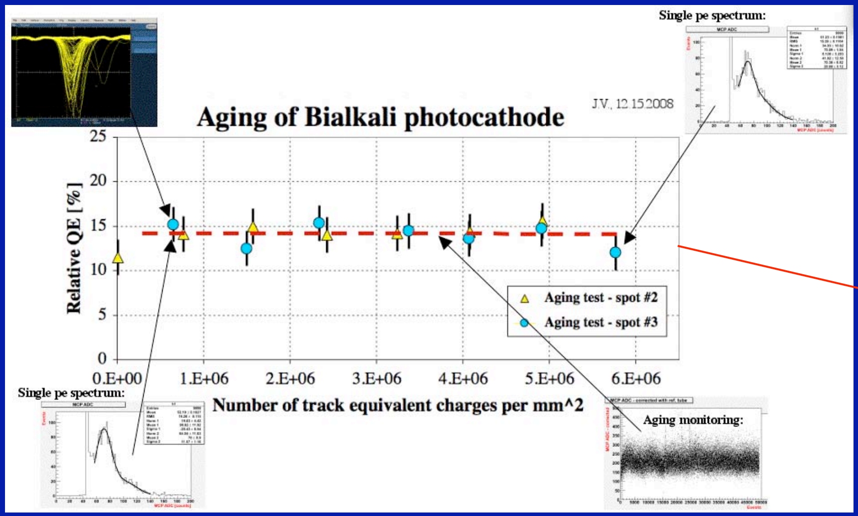
SuperB worst expectation:

Track rate in the forward region:
~ 2 kHz / cm^2 ~ 6.3x10^9/mm^2/10 years

Photonis MCP-PMT QE aging at low gain mode

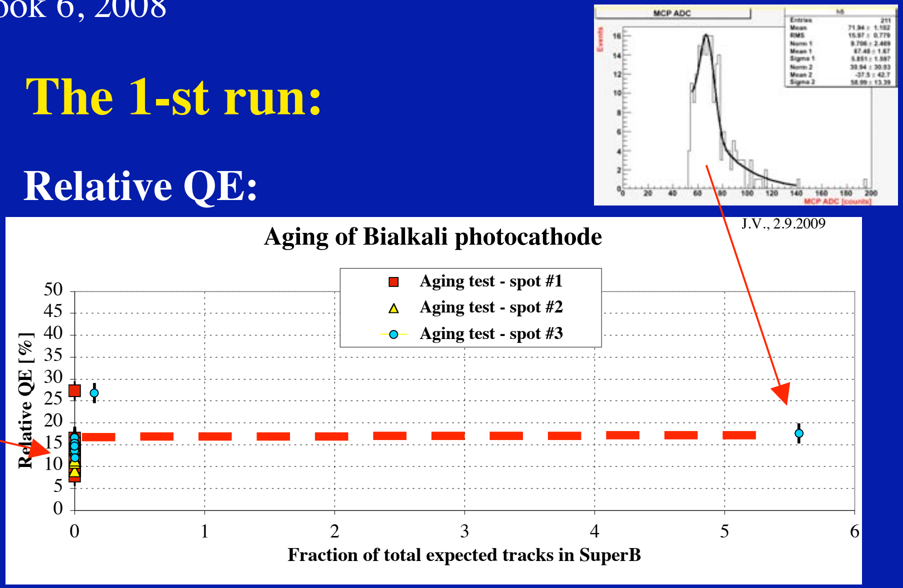
J.V., Log book 6, 2008

Intended method:

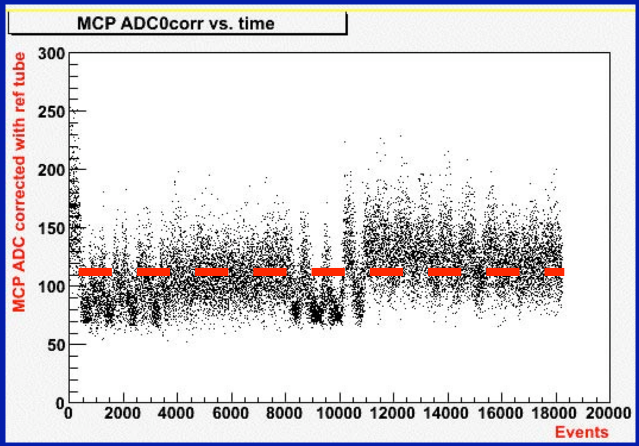


The 1-st run:

Relative QE:



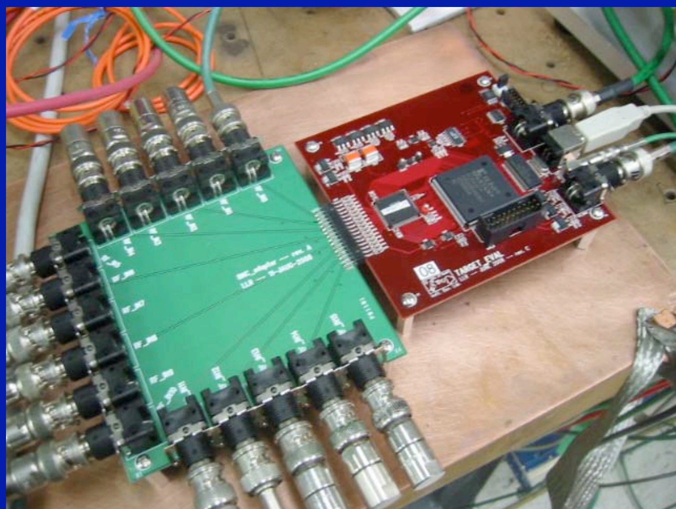
MCP-PMT gain during the same interval:

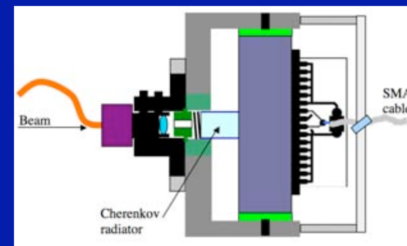


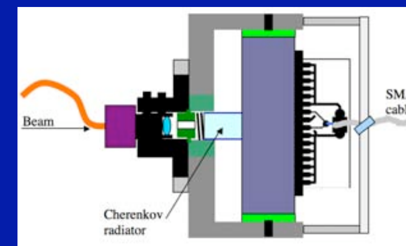
At the moment I do not see any aging effect under a low gain condition and for this particular setup !

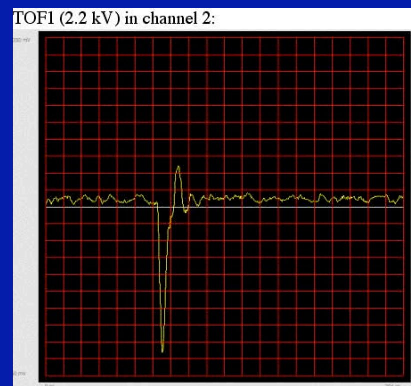
Target chip & TOF counter bench tests with the laser

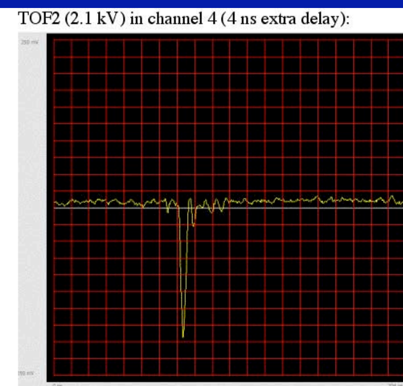
TARGET chip was developed by G. Varner











- **"Oscilloscope-like" software running on my MAC**
- **Pulses from a Photonis MCP-PMT (a pair of counters used in the Fermi lab test beam)**
- **Light source: PiLas laser diode**
- **HPK amplifier with a gain of 63x**
- **Maximum sampling speed: 2.5 GSa/s**
- **Two TOF counters in tandem, collected some events and will try to develop a strategy for waveform-based timing between two MCP-PMTs, and compare them to earlier Ortec 9327 CFD results.**
- Acknowledgement for help to: G. Varner, Larry Ruckman, Andrew Wong