

# Study of small plastic scintillator tiles for the EM calorimeter at JLC

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# Outline

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- Introduction
- Compatibility of scintillators, WLS fibers, and PMTs.
- Bench test
- Future plan

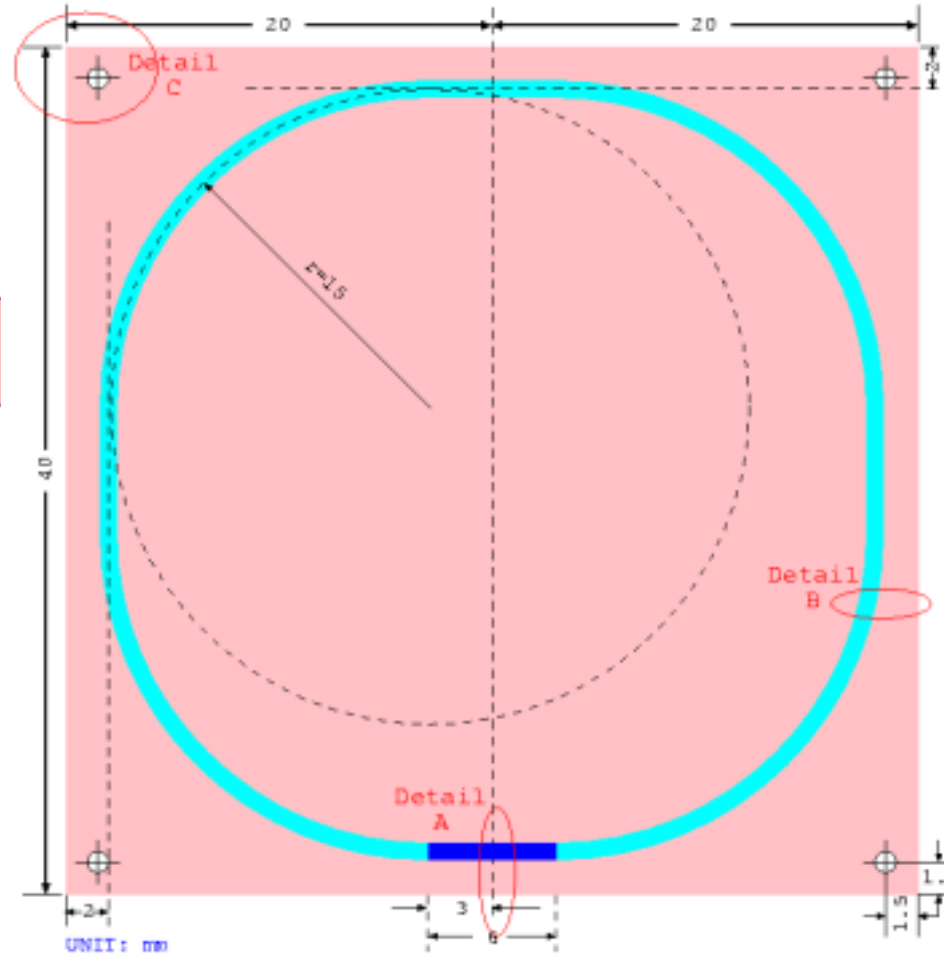
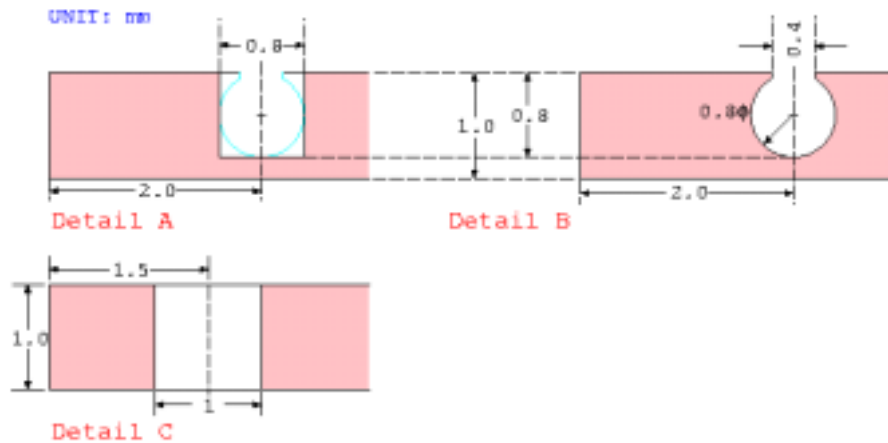


# Introduction

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- A good calorimeter is important for JLC
  - Baseline EMC design in ACFA Report (KEK Report 2001-11):
    - Compensated sampling calorimeter
      - (4mm Lead + 1mm Scintillator)
    - Tile/fiber technique
    - Transverse cell size = 4cm × 4cm
- ⇒ We are studying this small (4cm × 4cm × 1mm) tile calorimeter system.

# Small Tile Calorimeter Design



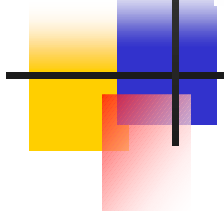


# Compatibility of Scintillators, Fibers & PMTs

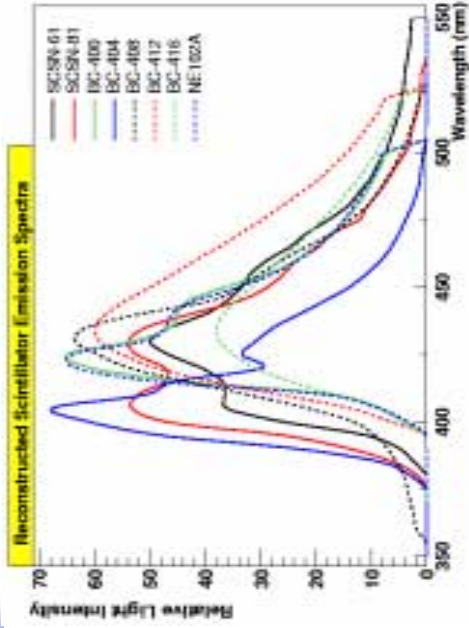
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- We want to know which combinations of plastic scintillator, wavelength shifting (WLS) fibers, and PMT would give better light yield
- Data used were reconstructed from manufacturer's data sheets
- Materials Considered
  - Plastic Scintillators
    - Kuraray -- SCSN-61, SCSN-81
    - Bicron -- BC-400, BC-404, BC-408, BC-412, BC-416
    - OKEN/NE Technology – NE107A
  - WLS Fibers
    - Kuraray – Y-7, Y-8, Y-9, Y-10, Y-11
  - PMTs
    - Hamamatsu – H6568 (multi-anode), H7422-40

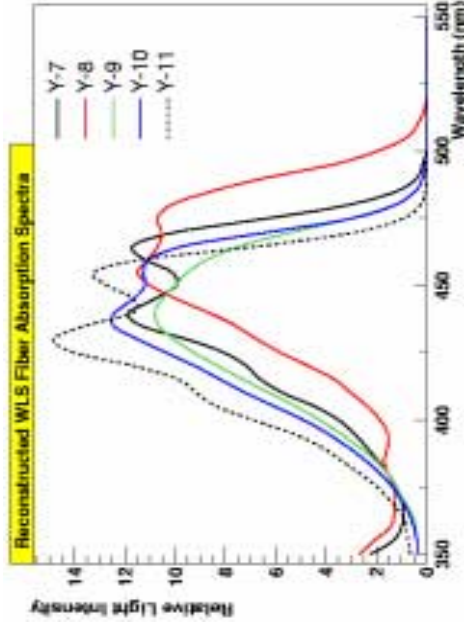
# Reconstructed Spectra



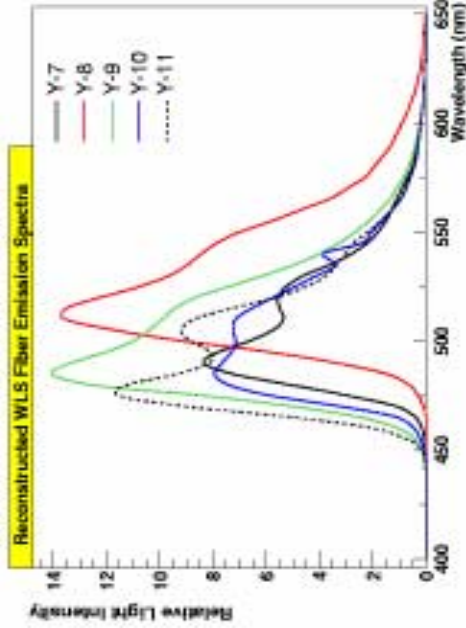
Scintillator Emission



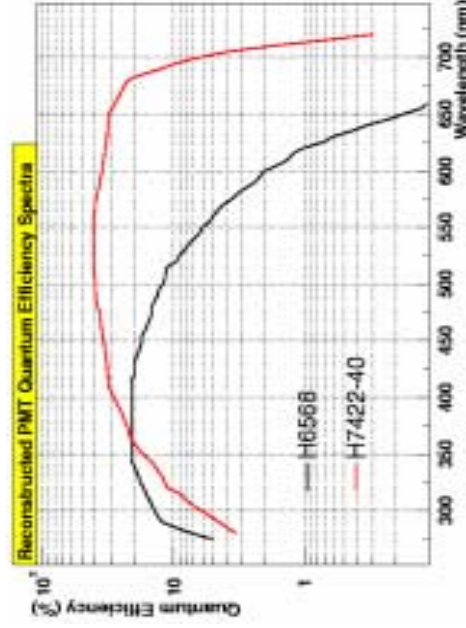
Fiber Absorption



Fiber Emission



PMT Quantum Efficiency



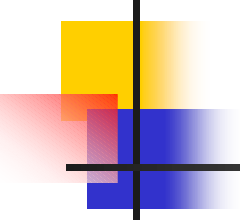


# Compatibility Calculation Method

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- Scintillator & Fiber Compatibility
  - $S(\lambda)$  = scint. emission,  $F_a(\lambda)$  = fiber absorption
  - $\alpha = \int S(\lambda) \cdot F_a(\lambda) d\lambda$
- Fiber & PMT Compatibility
  - $F_e(\lambda)$  = fiber emission,  $P(\lambda)$  = PMT quant. eff.
  - $\omega = \int F_e(\lambda) \cdot P(\lambda) d\lambda$
- Total Compatibility
  - $\alpha \cdot \omega$

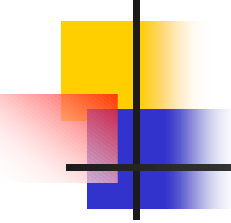
# Normalized Results (H6568 PMT)



BC-412+Y-11+H6568: 1.00	SCSN-81+Y-10+H6568: 0.550
SCSN-61+Y-11+H6568: 0.939	NE102A+Y-10+H6568: 0.549
BC-408+Y-11+H6568: 0.936	BC-400+Y-10+H6568: 0.548
BC-412+Y-9+H6568: 0.919	BC-412+Y-7+H6568: 0.543
SCSN-81+Y-11+H6568: 0.842	BC-408+Y-8+H6568: 0.539
NE102A+Y-11+H6568: 0.840	SCSN-81+Y-8+H6568: 0.518
BC-400+Y-11+H6568: 0.839	BC-400+Y-8+H6568: 0.510
BC-408+Y-9+H6568: 0.825	NE102A+Y-8+H6568: 0.509
SCSN-61+Y-9+H6568: 0.810	SCSN-61+Y-8+H6568: 0.504
NE102A+Y-9+H6568: 0.749	BC-408+Y-7+H6568: 0.463
BC-400+Y-9+H6568: 0.748	BC-416+Y-8+H6568: 0.452
SCSN-81+Y-9+H6568: 0.746	SCSN-61+Y-7+H6568: 0.446
BC-412+Y-8+H6568: 0.713	BC-416+Y-10+H6568: 0.430
BC-404+Y-11+H6568: 0.680	SCSN-81+Y-7+H6568: 0.425
BC-412+Y-10+H6568: 0.678	NE102A+Y-7+H6568: 0.422
BC-416+Y-11+H6568: 0.633	BC-400+Y-7+H6568: 0.421
BC-408+Y-10+H6568: 0.607	BC-404+Y-10+H6568: 0.410
SCSN-61+Y-10+H6568: 0.596	BC-416+Y-7+H6568: 0.344
BC-416+Y-9+H6568: 0.582	BC-404+Y-7+H6568: 0.291
BC-404+Y-9+H6568: 0.559	BC-404+Y-8+H6568: 0.289



# Norm. Results (H7422-40 PMT)



BC-412+Y-8+H7422-40: 1.00	BC-408+Y-10+H7422-40: 0.652
BC-412+Y-11+H7422-40: 0.994	SCSN-61+Y-10+H7422-40: 0.641
BC-412+Y-9+H7422-40: 0.962	BC-416+Y-8+H7422-40: 0.633
SCSN-61+Y-11+H7422-40: 0.934	BC-416+Y-11+H7422-40: 0.630
BC-408+Y-11+H7422-40: 0.931	BC-416+Y-9+H7422-40: 0.609
BC-408+Y-9+H7422-40: 0.863	BC-412+Y-7+H7422-40: 0.606
SCSN-61+Y-9+H7422-40: 0.848	SCSN-81+Y-10+H7422-40: 0.591
SCSN-81+Y-11+H7422-40: 0.837	NE102A+Y-10+H7422-40: 0.590
NE102A+Y-11+H7422-40: 0.836	BC-400+Y-10+H7422-40: 0.590
BC-400+Y-11+H7422-40: 0.835	BC-404+Y-9+H7422-40: 0.585
NE102A+Y-9+H7422-40: 0.784	BC-408+Y-7+H7422-40: 0.517
BC-400+Y-9+H7422-40: 0.783	SCSN-61+Y-7+H7422-40: 0.499
SCSN-81+Y-9+H7422-40: 0.781	SCSN-81+Y-7+H7422-40: 0.475
BC-408+Y-8+H7422-40: 0.756	NE102A+Y-7+H7422-40: 0.471
BC-412+Y-10+H7422-40: 0.729	BC-400+Y-7+H7422-40: 0.471
SCSN-81+Y-8+H7422-40: 0.727	BC-416+Y-10+H7422-40: 0.462
BC-400+Y-8+H7422-40: 0.715	BC-404+Y-10+H7422-40: 0.441
NE102A+Y-8+H7422-40: 0.714	BC-404+Y-8+H7422-40: 0.405
SCSN-61+Y-8+H7422-40: 0.707	BC-416+Y-7+H7422-40: 0.384
BC-404+Y-11+H7422-40: 0.676	BC-404+Y-7+H7422-40: 0.323

# Normalized Results (All PMTs)

H7422-40		H6568	
BC-412+Y-8: 1.00	BC-408+Y-10: 0.652	BC-412+Y-11: 0.301	SCSN-81+Y-10: 0.165
BC-412+Y-11: 0.994	SCSN-61+Y-10: 0.641	SCSN-61+Y-11: 0.282	NE102A+Y-10: 0.165
BC-412+Y-9: 0.962	BC-416+Y-8: 0.633	BC-408+Y-11: 0.282	BC-400+Y-10: 0.165
SCSN-61+Y-11: 0.934	BC-416+Y-11: 0.630	BC-412+Y-9: 0.276	BC-412+Y-7: 0.163
BC-408+Y-11: 0.931	BC-416+Y-9: 0.609	SCSN-81+Y-11: 0.253	BC-408+Y-8: 0.162
BC-408+Y-9: 0.863	BC-412+Y-7: 0.606	NE102A+Y-11: 0.253	SCSN-81+Y-8: 0.156
SCSN-61+Y-9: 0.848	SCSN-81+Y-10: 0.591	BC-400+Y-11: 0.252	BC-400+Y-8: 0.153
SCSN-81+Y-11: 0.837	NE102A+Y-10: 0.590	BC-408+Y-9: 0.248	NE102A+Y-8: 0.153
NE102A+Y-11: 0.836	BC-400+Y-10: 0.590	SCSN-61+Y-9: 0.244	SCSN-61+Y-8: 0.152
BC-400+Y-11: 0.835	BC-404+Y-9: 0.585	NE102A+Y-9: 0.225	BC-408+Y-7: 0.140
NE102A+Y-9: 0.784	BC-408+Y-7: 0.517	BC-400+Y-9: 0.225	BC-416+Y-8: 0.136
BC-400+Y-9: 0.783	SCSN-61+Y-7: 0.499	SCSN-81+Y-9: 0.224	SCSN-61+Y-7: 0.134
SCSN-81+Y-9: 0.781	SCSN-81+Y-7: 0.475	BC-412+Y-8: 0.215	BC-416+Y-10: 0.129
BC-408+Y-8: 0.756	NE102A+Y-7: 0.471	BC-404+Y-11: 0.204	SCSN-81+Y-7: 0.128
BC-412+Y-10: 0.729	BC-400+Y-7: 0.471	BC-412+Y-10: 0.204	NE102A+Y-7: 0.127
SCSN-81+Y-8: 0.727	BC-416+Y-10: 0.462	BC-416+Y-11: 0.190	BC-400+Y-7: 0.127
BC-400+Y-8: 0.715	BC-404+Y-10: 0.441	BC-408+Y-10: 0.183	BC-404+Y-10: 0.123
NE102A+Y-8: 0.714	BC-404+Y-8: 0.405	SCSN-61+Y-10: 0.179	BC-416+Y-7: 0.103
SCSN-61+Y-8: 0.707	BC-416+Y-7: 0.384	BC-416+Y-9: 0.175	BC-404+Y-7: 0.087
BC-404+Y-11: 0.676	BC-404+Y-7: 0.323	BC-404+Y-9: 0.168	BC-404+Y-8: 0.087



# Calculation Result

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- Best combination using H6568 PMT is
  - BC-412 + Y-11 + H6568
- Best combination with H6568 gives only 30% of the best combination with H7422-40 PMT
  - BC-412 + Y-8 + H7422-40
- However, for beam test, we plan to use H6568 PMT

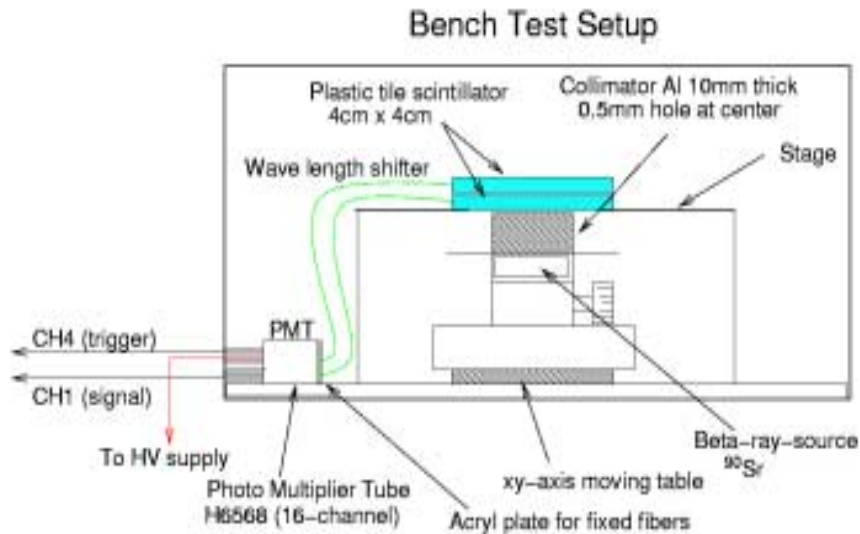


# Bench Test

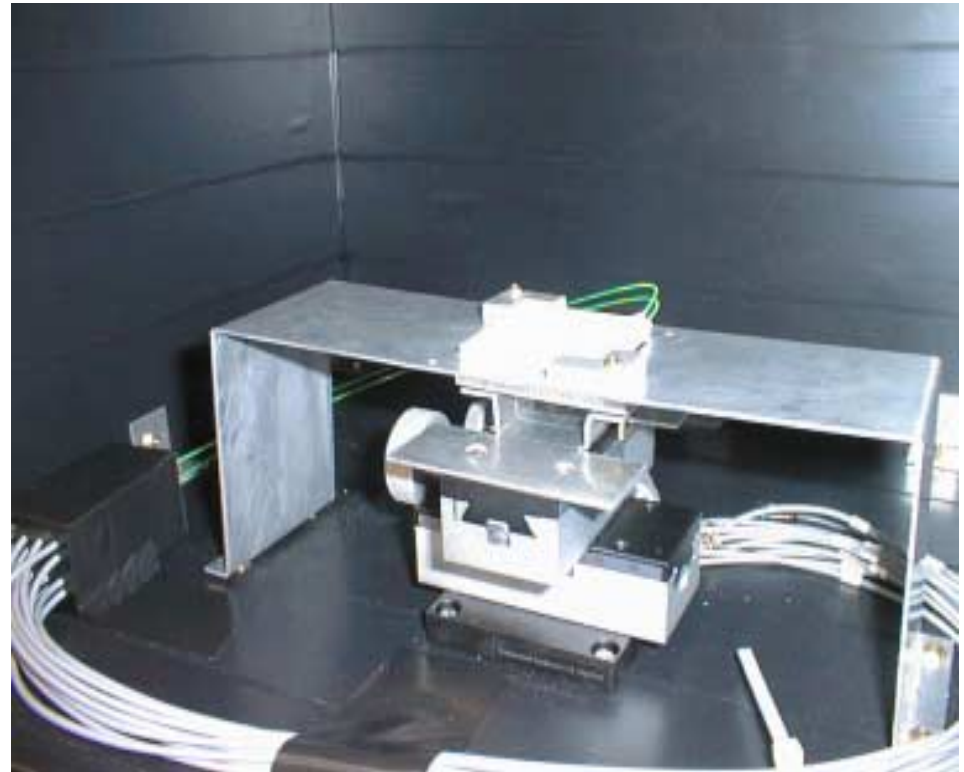
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- We use: NE107A scintillator, Y-7 (400ppm) WLS fiber, H6568 PMT
- Tile design and construction
  - Tile cut by Kyoei Engineering (Shibata City, Niigata Prefecture, Japan)
  - Edges painted with white reflective paint
  - Fiber inserted by hand
  - Total fiber length = 50cm
  - Whole tile is wrapped with a white reflective tape

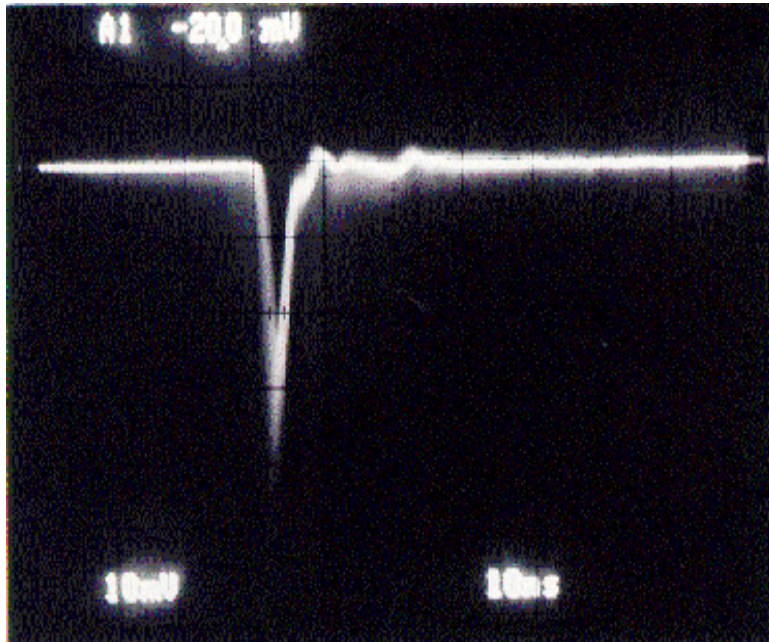
# Bench Test Experimental Setup



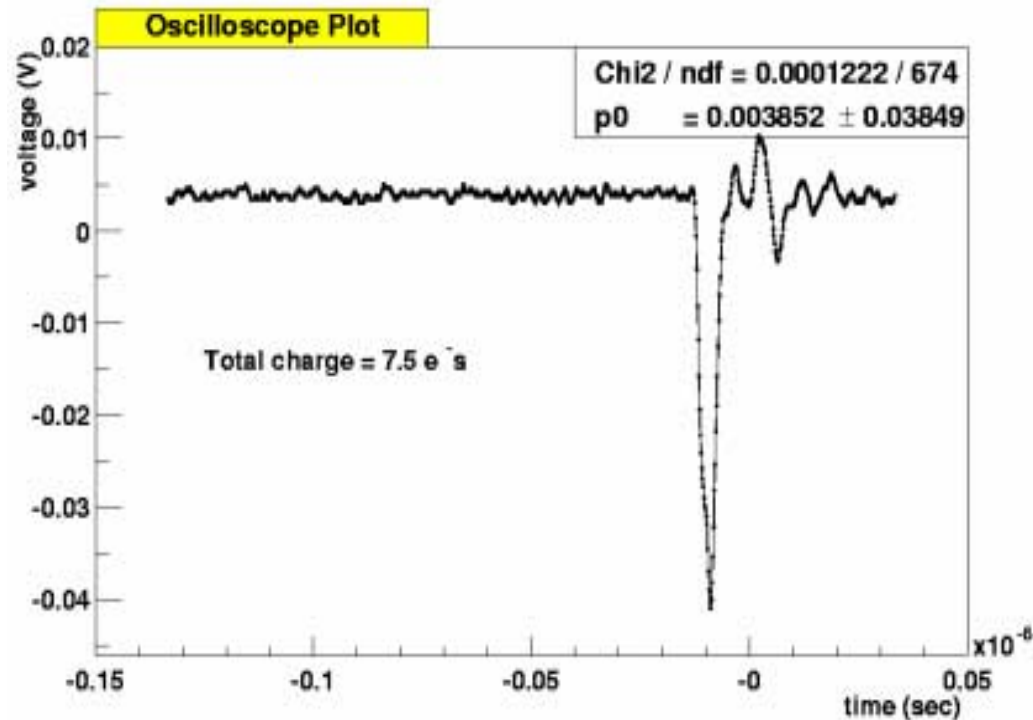
PMT Operating Voltage: -800 V



# Oscilloscope Signal

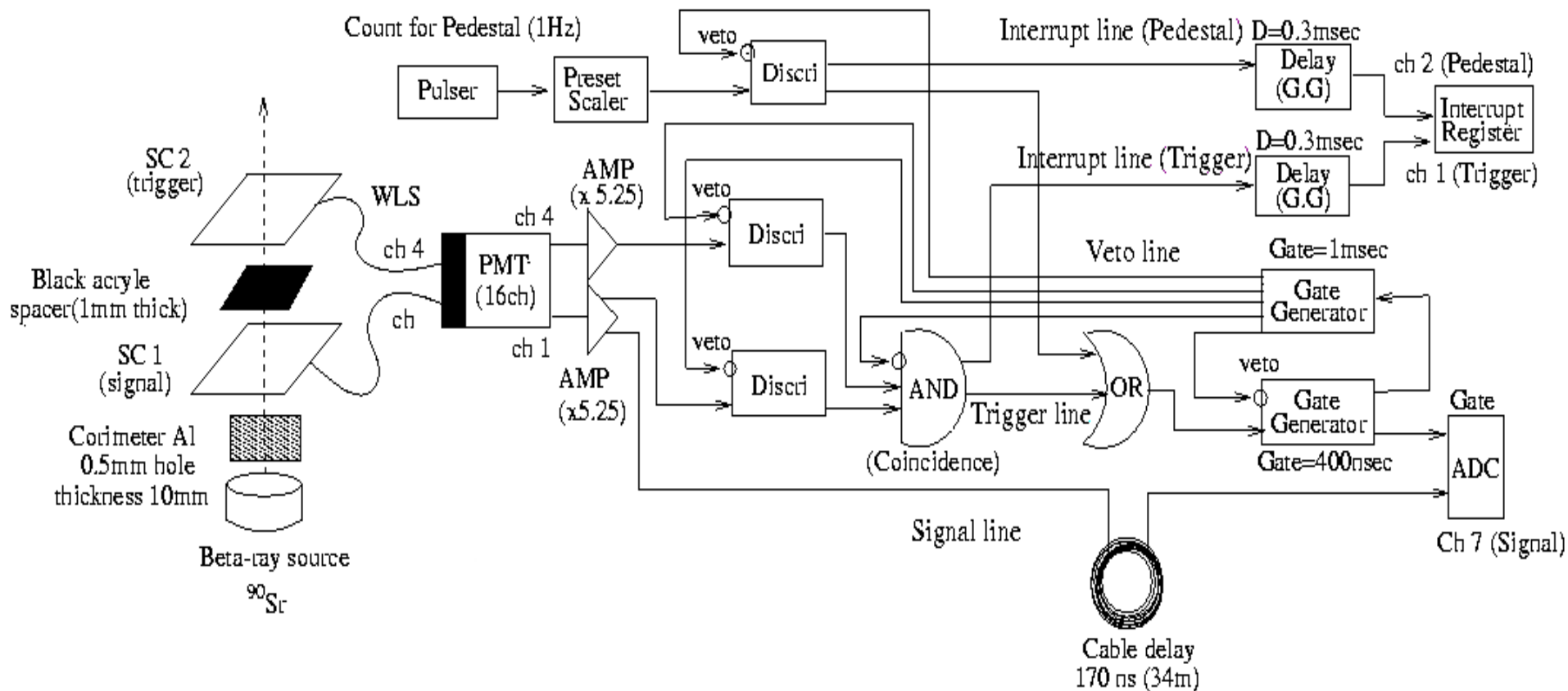


First observed signal

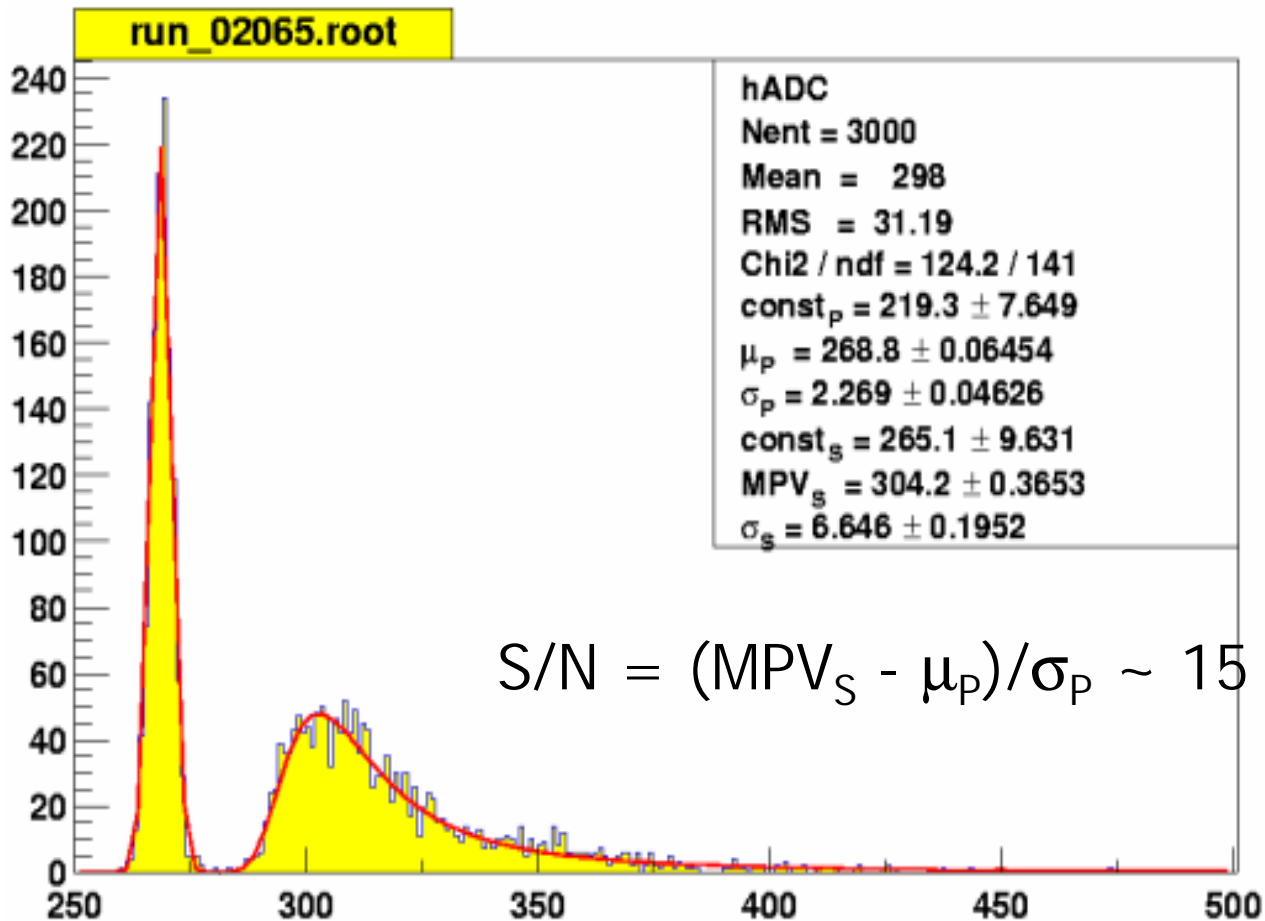


Data from digital oscilloscope  
Typical integrated yield:  
About 5-7 photoelectrons

# ADC Measurement Logic



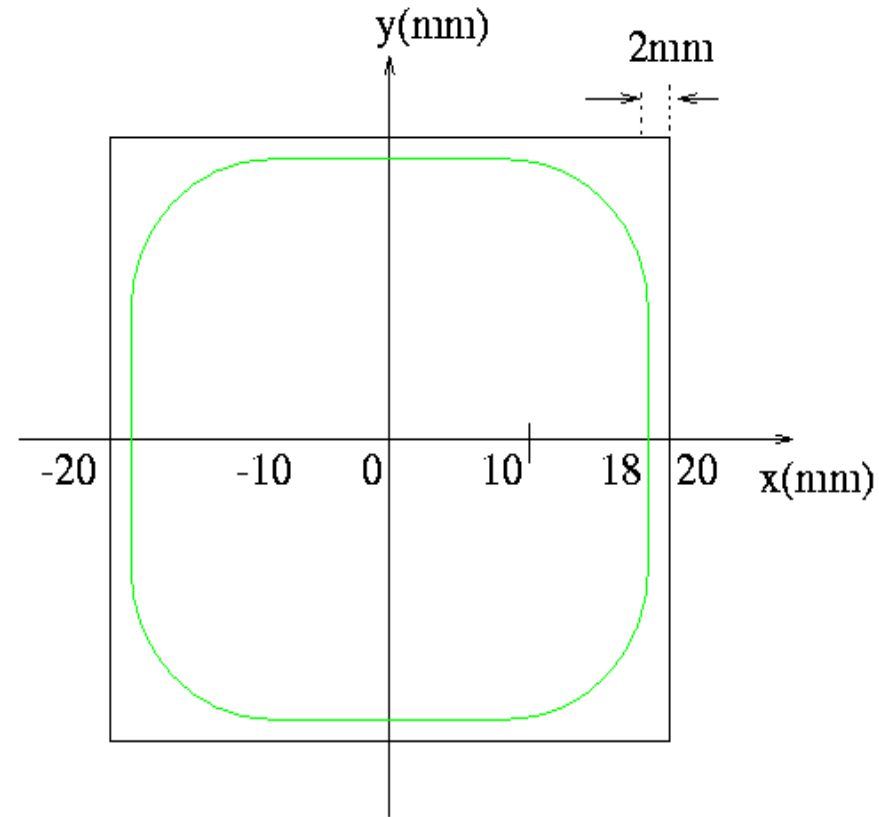
# ADC Count Distribution



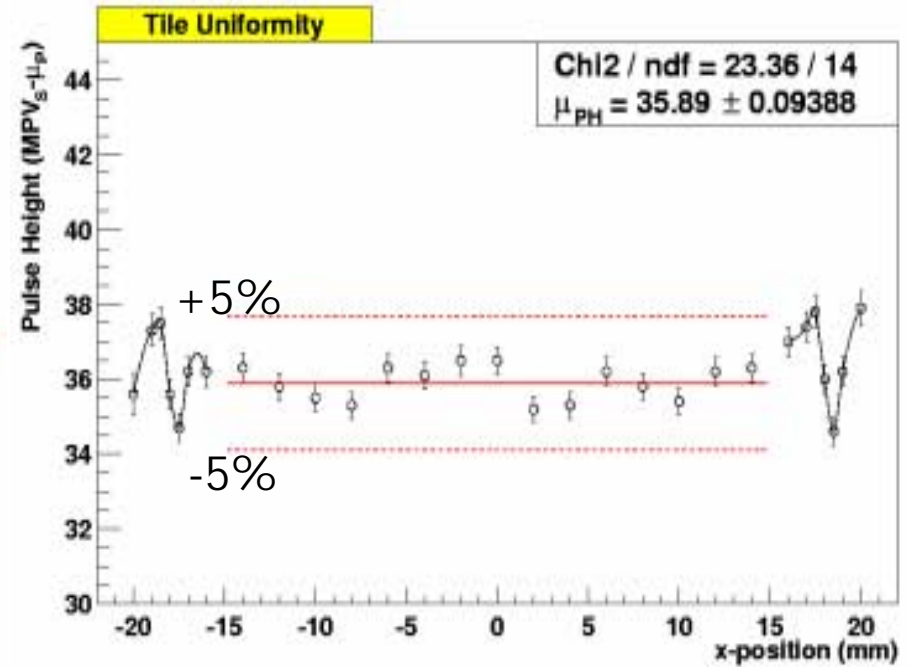
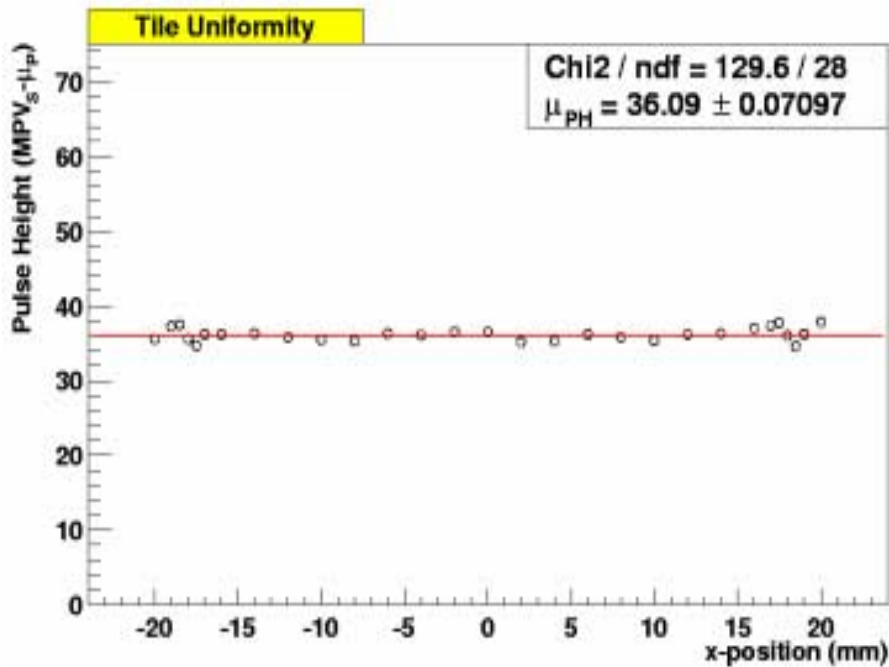


# Uniformity test

- We measured x-axis uniformity
  - x-points: ( $\pm$ ) 0, 2, 4, 6, 8, 10, 12, 14, 16, 17, 17.5, 18, 18.5, 19, 20 mm
  - fiber at  $\pm 18$ mm
  - fiber exits at +18mm

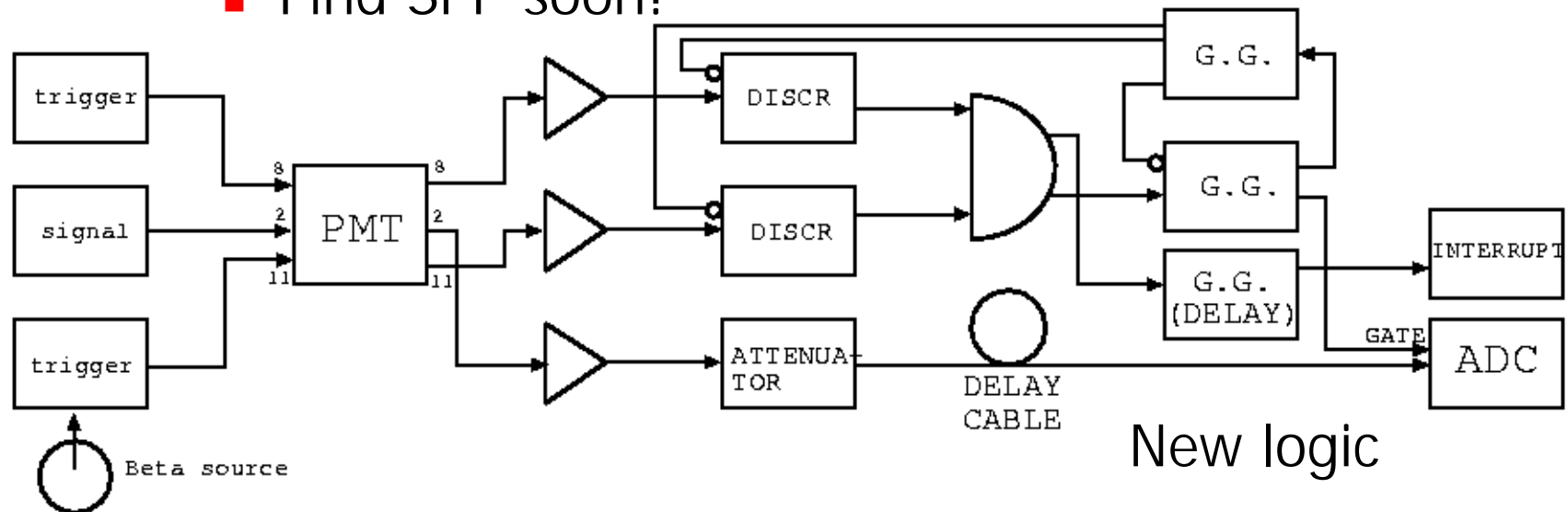


# Uniformity test (Early results)

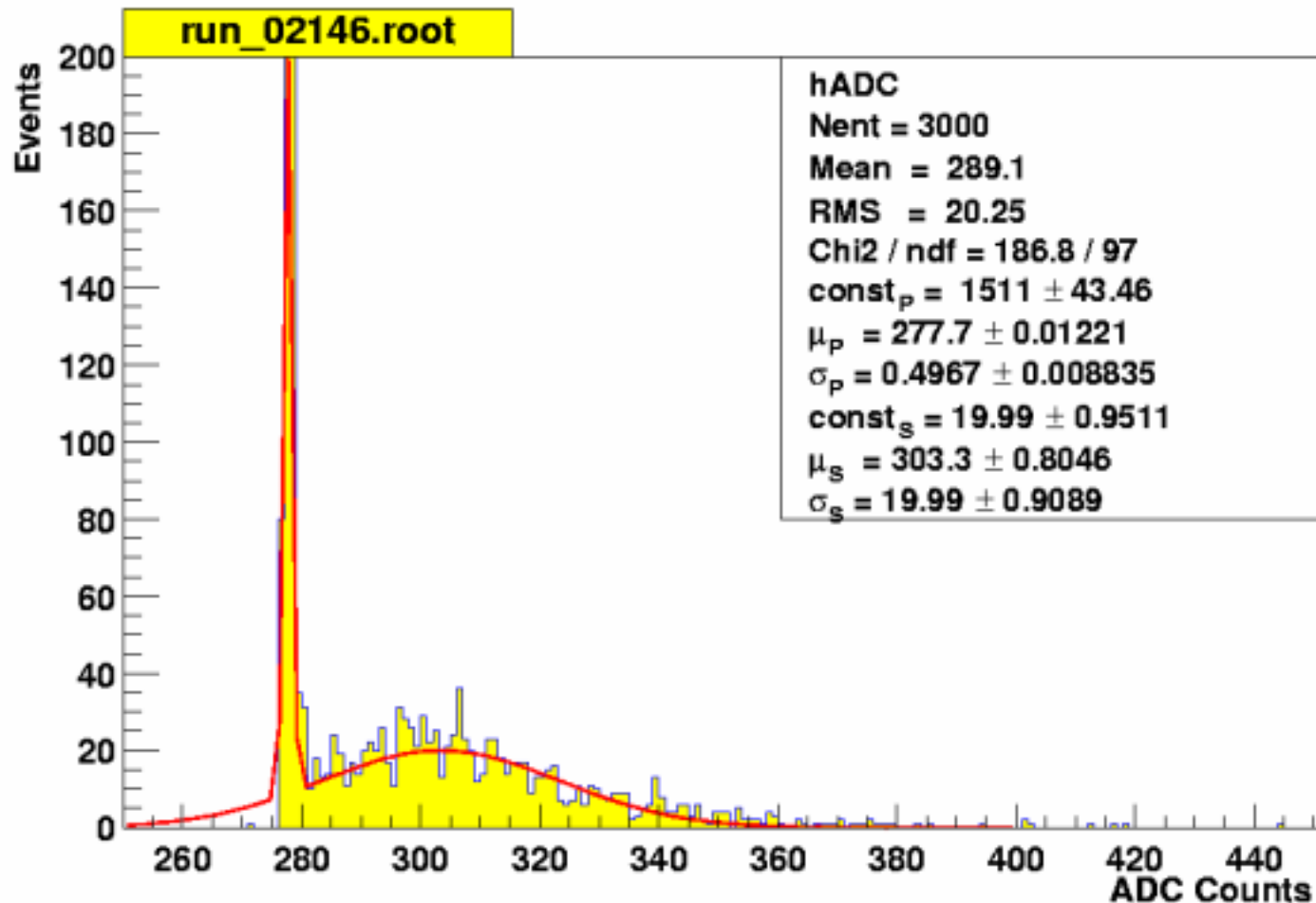


# Light Yield (?)

- Determine light yield (no. of photo- $e$ -s)
  - Change ADC measurement logic
    - Previous logic excluded 0 p.e. events
  - Find single photon peak by inserting light filter between fiber & PMT
  - Find SPP soon!



# ADC Count Distribution (new logic)





# Future plan

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- Find single photon peak
- Re-do uniformity test with new logic
- Get ready for beam test