Photodetector Studies for Polarimetry

Christian Helebrant

DESY

Workshop on Polarization and Energy Measurements
Zeuthen
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Overview

ILC Polarimetry

Cherenkov Detector Layouts

Test Bench

Linearity Measurements

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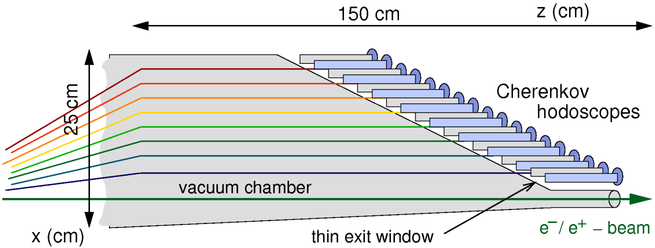
Cherenkov Detector Layouts

Test Bench

Linearity Measurements

Polarimetry at ILC



- crucial process: detection of Compton scattered electrons via Cherenkov radiation
- aim at precision of $\mathrm{d}P/P \approx 0.25$ %
- limited mainly by linearity of detector (stat. errors small; experience from other polarimeters)
- Which photodetector (PD) and hodoscope layout fulfills the requirements?

  esp.: linear in a range from 1 to several 1000 photoelectrons

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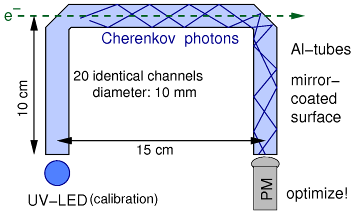
Layout 1

Gas tubes

- cross section ≈ 1 cm^2
- filled with C_4F_{10}
- high Cherenkov threshold (some MeV)

conventional PMT

- well-known technology
- large variety of different designs
- high sensitivity (to mechanical stress, magnetic fields, bright light etc)



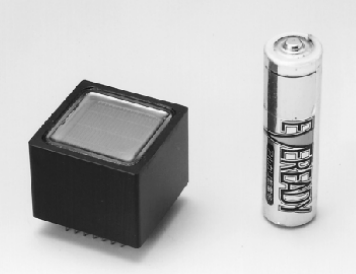
Layout 2

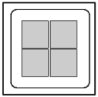
Gas tubes

same as before

Multi-Anode PM

- fast
- compact
- fits gas tube cross section perfectly
- anodes can be read out seperately
- crosstalk?

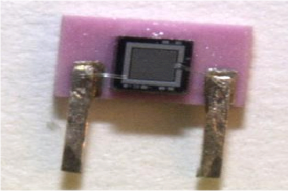


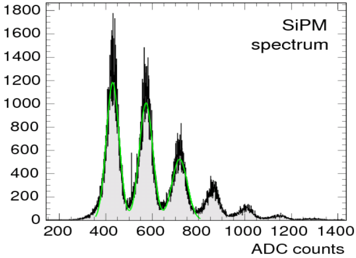
	4 Channel (2 × 2) Multianode
Anode Type	
Multianode PMT	R5900U-M4 Series
Multianode PMT Assembly (Built-in Voltage Divider Circuit)	—
Effective Area (per Channel)	8.9 mm × 8.9 mm
Anode Pulse Rise Time (per Channel)	1.2 ns
Cross-talk	2 %

Layout 3

SiPM

- novel technology (little field experience)
- tiny ($\approx 1 - 10$ mm^2)
  $\Rightarrow$ higher spacial resolution
  $\Rightarrow$ better dP/P
- great single photon detection capabilities
- very robust
- performance is sensitive to temperature changes





Layout 3

Quartz fibers

- low Cherenkov threshold (keV)
- background radiation?

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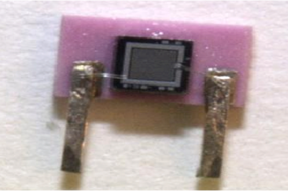

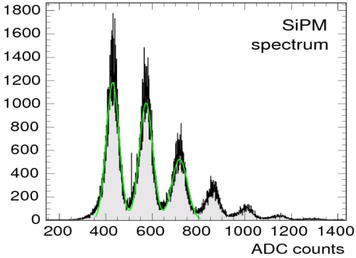

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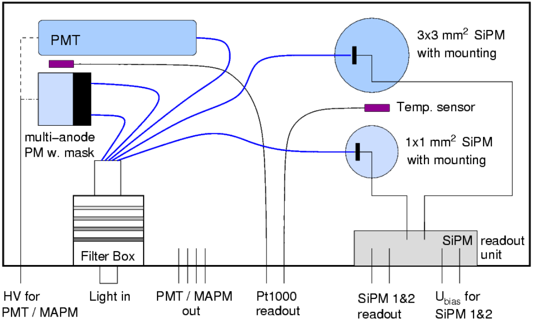
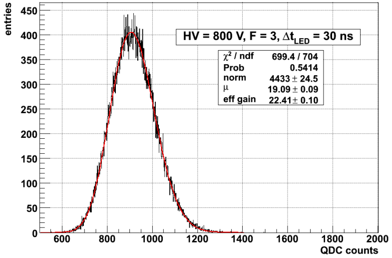


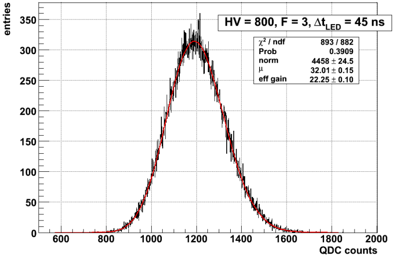
- light tight box (with light fibers, optical filters, mountings for different PD types, ...)
- blue LED (470 nm) with function generator
- VME-DAQ (incl. double range 12-bit QDC, 200 and 25 fC LSB)
- PDs: conventional PMT, 2x2-MAPM, several SiPMs (400 - 3600 pixels)

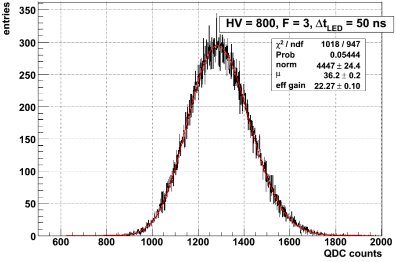
Measurements

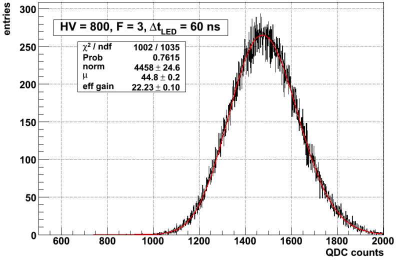
- test of different methods to determine linearity
- using a 2x2-MAPM
- one million single measurements
- fit results with a modified Possion function
- determine number of incident photoelectrons from fit

Fit Results

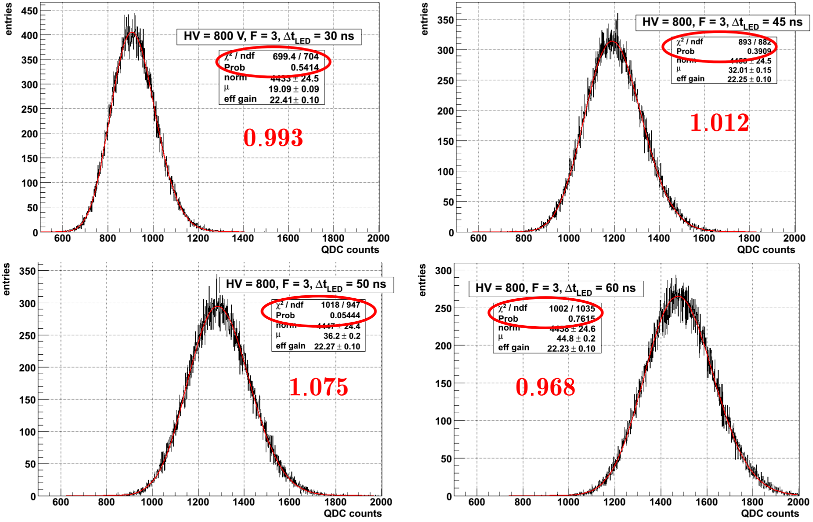

entries
HV = 800 V, F = 3, Δt_LED = 30 ns
χ² / ndf 699.4 / 704
Prob 0.5414
norm 4433 ± 24.5
μ 19.09 ± 0.09
eff gain 22.41 ± 0.10
QDC counts


entries
HV = 800, F = 3, Δt_LED = 45 ns
χ² / ndf 893 / 882
Prob 0.3909
norm 4458 ± 24.5
μ 32.01 ± 0.15
eff gain 22.25 ± 0.10
QDC counts


entries
HV = 800, F = 3, Δt_LED = 50 ns
χ² / ndf 1018 / 947
Prob 0.05444
norm 4447 ± 24.4
μ 36.2 ± 0.2
eff gain 22.27 ± 0.10
QDC counts


entries
HV = 800, F = 3, Δt_LED = 60 ns
χ² / ndf 1002 / 1035
Prob 0.7615
norm 4458 ± 24.6
μ 44.8 ± 0.2
eff gain 22.23 ± 0.10
QDC counts

Fit Results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μ 32.01 ± 0.15
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1.012
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1.075
HV = 800, F = 3, Δt_LED = 60 ns
χ² / ndf 1002 / 1035
Prob 0.7615
μ 44.8 ± 0.2
eff gain 22.23 ± 0.10
0.968
entries
QDC counts

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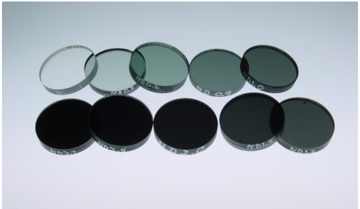
Methods to Determine Linearity of Photodetectors I

Optical filters

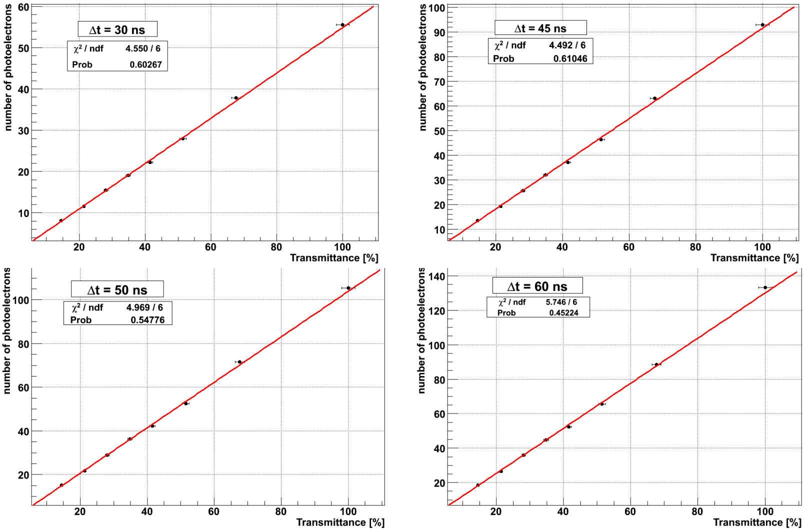
- calibrated filters
- most common method
- 3 filters used: 8 series of measurements



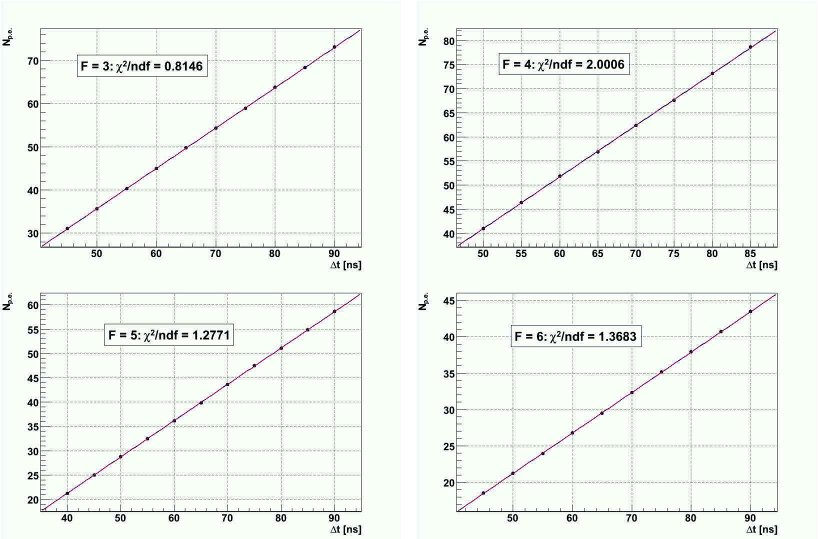
LED pulse length

- vary length of **rectangle** pulse
- ensures linear variation of amount of light on photo cathode
- $\Delta t = 25, 30, ..., 100$ ns

Method 1: optical fibers

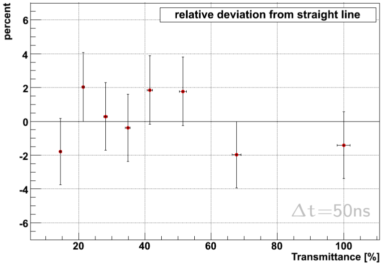


Method 2: LED pulse length

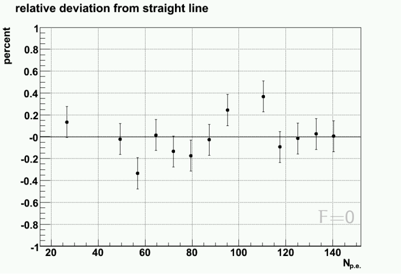


Deviation from Straight Line

different filters; fixed pulse length



different pulse lengths; fixed filter



- filter method: limited by errors due to insufficient knowledge of transmittance
- pulse length: statistical errors ($\approx 0.15\%$) too high
  $\Rightarrow$ more single measurements needed

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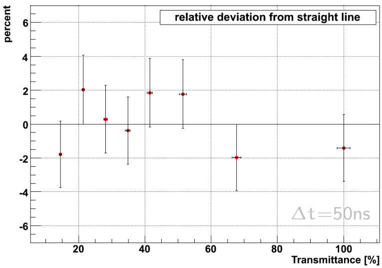

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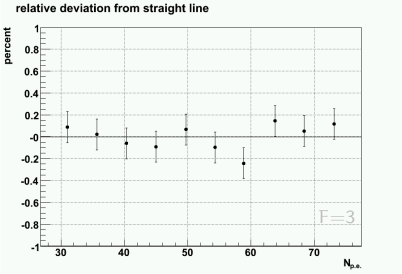

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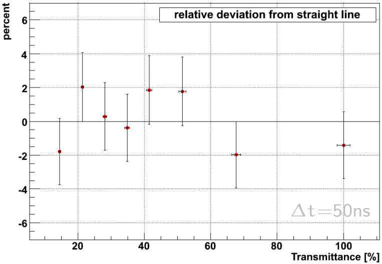

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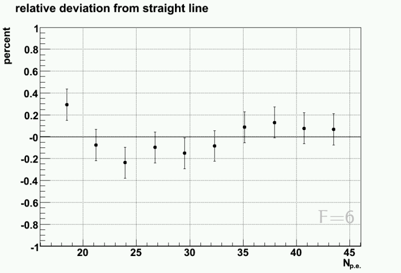
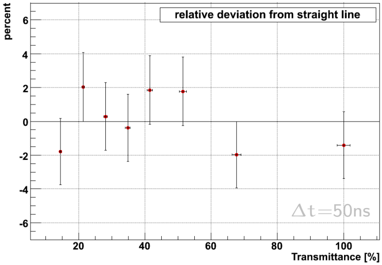


- filter method: limited by errors due to insufficient knowledge of transmittance
- pulse length: statistical errors (≈ 0.15%) too high
  ⇒ more single measurements needed

Deviation from Straight Line

different filters; fixed pulse length



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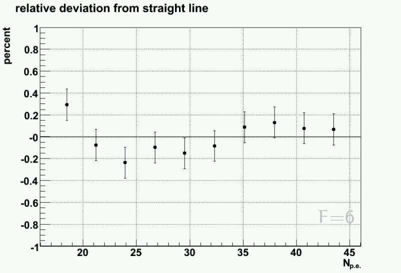

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- How much statistics needed to be sensitive to non-linearities of $\approx 0.1\%$? Monte Carlo studies are ongoing

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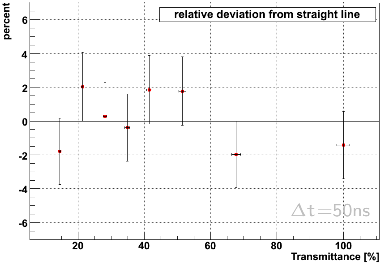

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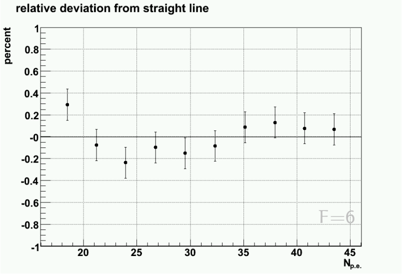

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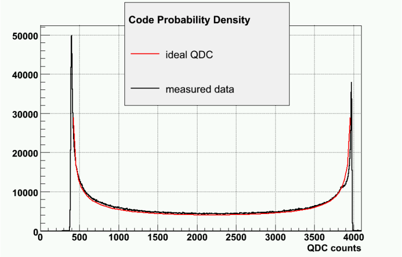
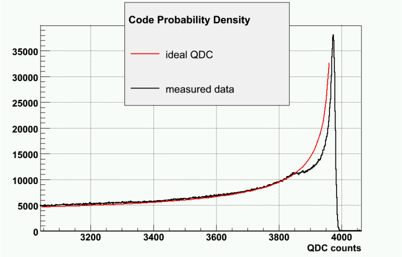
- How much non-linearity is introduced by QDC?

QDC Non-Linearity

Histogram Testing Method

- FSR sine wave input (10 Hz)
  no sawtooth to avoid artefacts from function generator
- short random gate (50 ns) triggered by noise
- 25 million samples
- code probability density $P(i) = N/\pi \cdot \sqrt{(A/2)^2 - (i - (A/2))^2}$
- input: $A \cdot \sin(\omega x) + A/2$, A=FSR, N=25 million

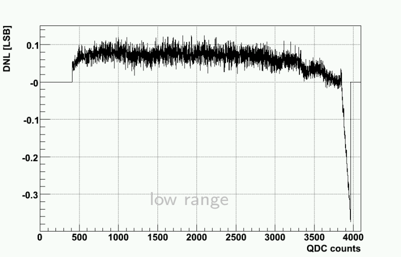


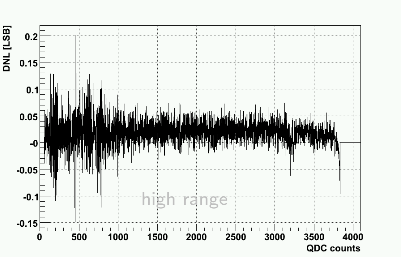


Histogram Testing Method

DNL

- ratio of measured and ideal distribution is equal to code bin width $\longrightarrow$ **DNL**
- differential non-linearity: deviation from ideal bin width (1 LSB)
- looks good below 3800 QDC counts

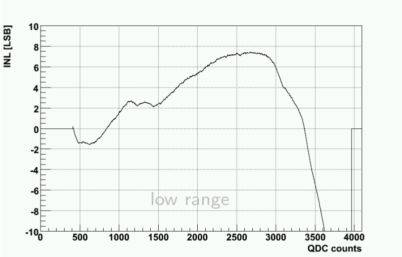


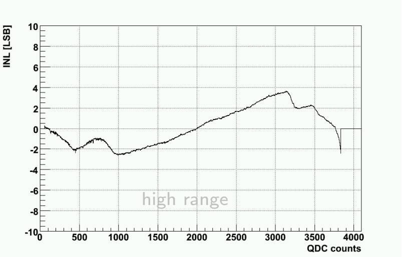


Histogram Testing Method

INL

- summing up yields **INL**
  (+ correction of gain and offset to be 1 and 0 respectively)
- integral non-linearity
- $\approx 0.1\%$ of FSR (as stated in manual)

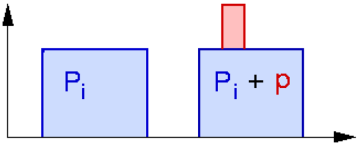




Methods to Determine Linearity of Photodetectors II

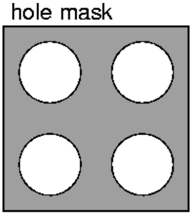
Double pulse

- two different LED pulses
  $P_i \gg p$
- record $Q(P_i)$ und $Q(P_i + p)$
- vary P_i
- **differential** non-linearity
- not realized yet



Mask

- four-holed mask on PD
- measure LED pulse for each hole seperately and for all together
- $\text{DNL} = \frac{\sum_{i=1}^{4} Q(P_i)}{Q(P_0)} - 1$
- first measurements done



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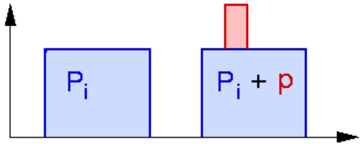

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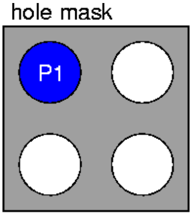

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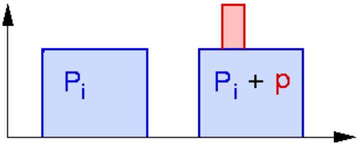

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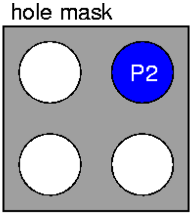

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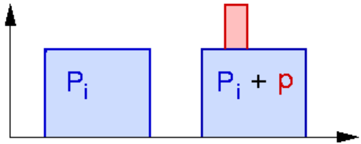

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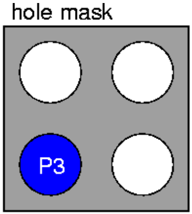

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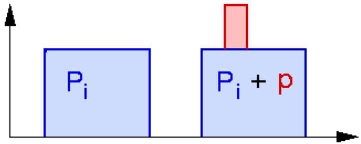

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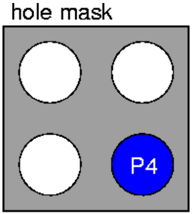

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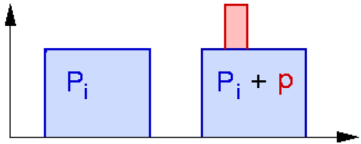

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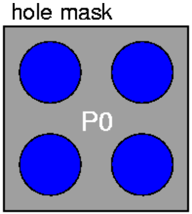

Summary and Outlook

Summary

- **linearity** of photodetectors in Cherenkov hodoscope is crucial requirement for precise polarimetry at ILC
- test bench for PD studies has been set up
- different methods of linearity measurement tested with MAPM
- analysis of results is ongoing

Summary and Outlook

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Outlook

- Monte Carlo studies on statistics and fit method
- repeat measurements with sufficient statistics
- study of further PDs
- test PDs in simulated ILC bunch train