# Minimizing the non-linearity of Compton photon detector

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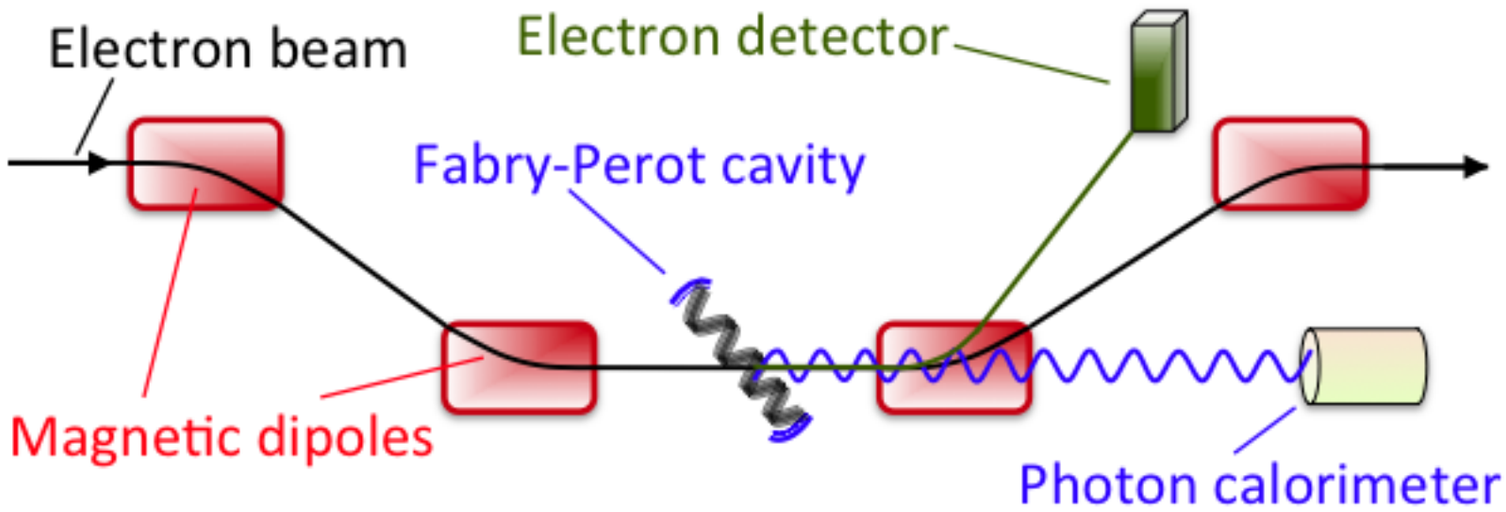
# outline

- Hall A Compton polarimeter
- Compton scattering
- linearity testing method - finite difference
- how to improve PMT base

# Hall A Compton polarimeter



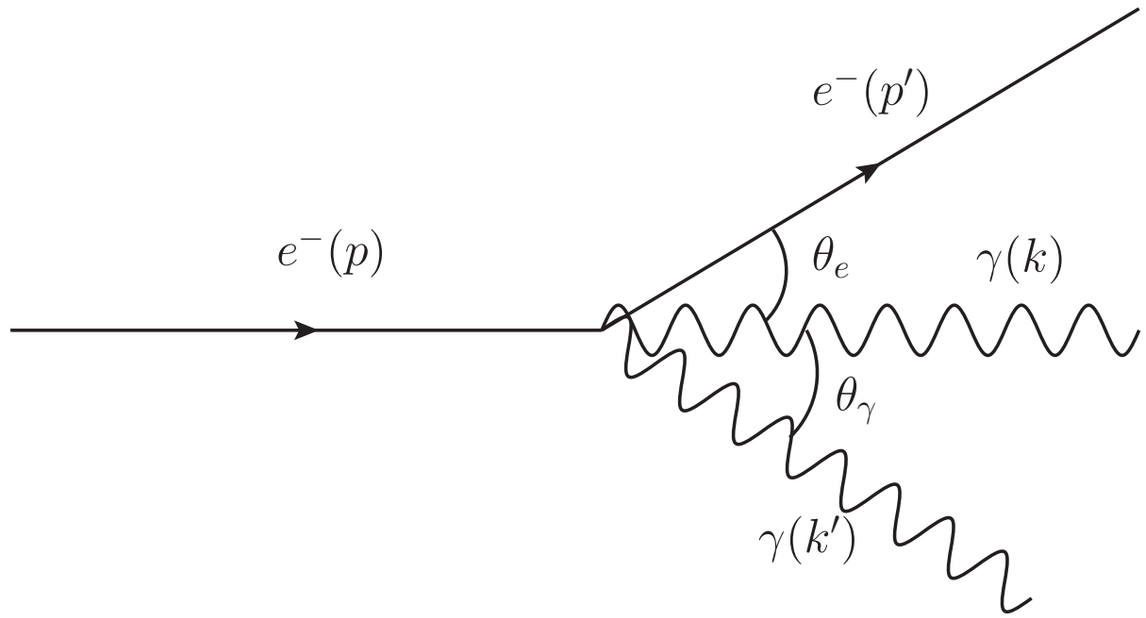

- purpose of Compton polarimeter:
  measure the polarization of the electron beam

$$A_{exp} = P_e P_\gamma < A_l >$$

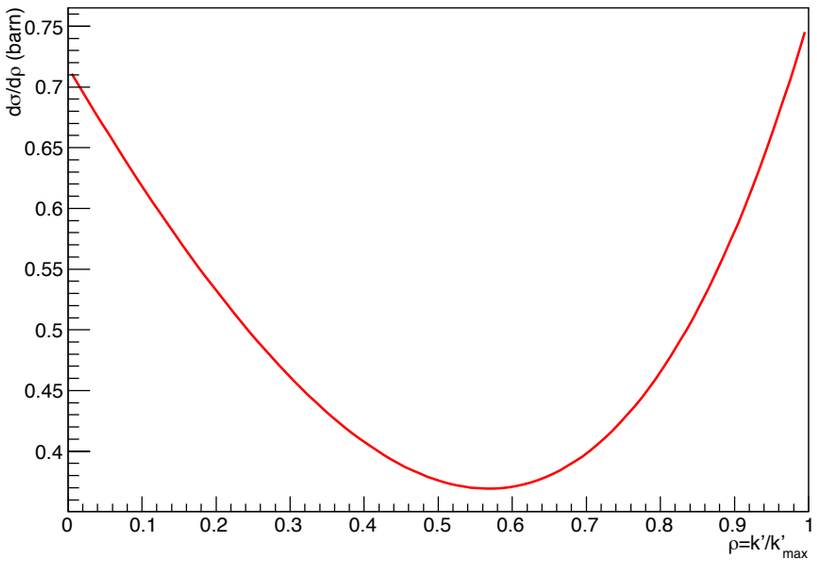
# features of Compton polarimeter

- energy of electron E=1-11GeV
- photon energy k=2.33eV (green light λ=532nm)
- k’max=3.1GeV

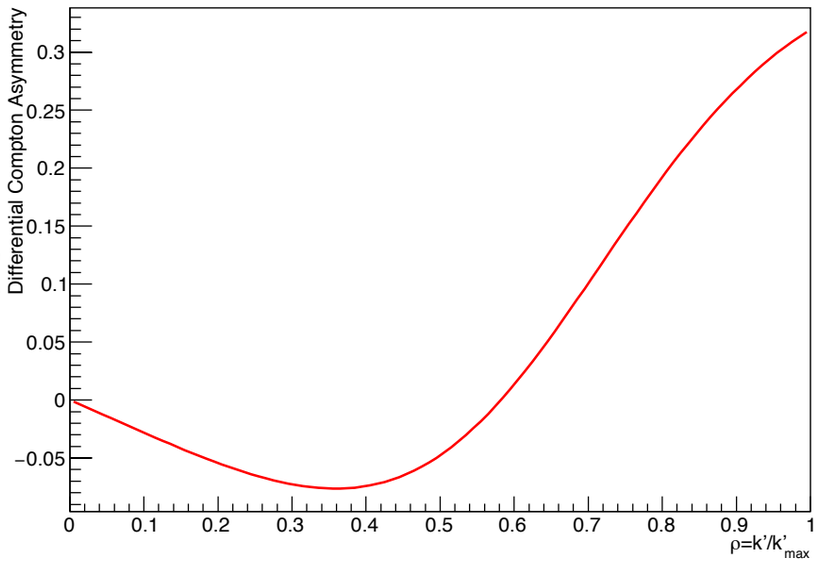
# Compton scattering



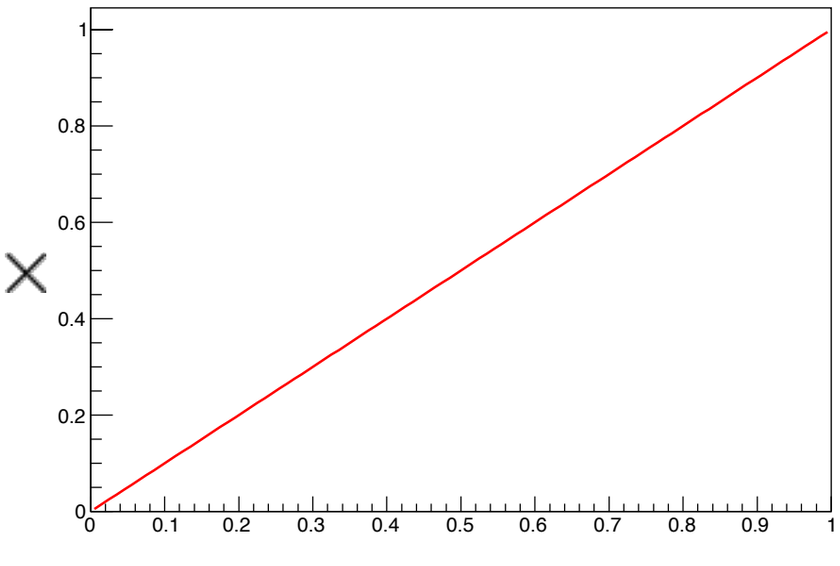
# energy-weighted Compton integrated asymmetry




×




×



unpolarized Compton scattering cross-section

Compton scattering asymmetry

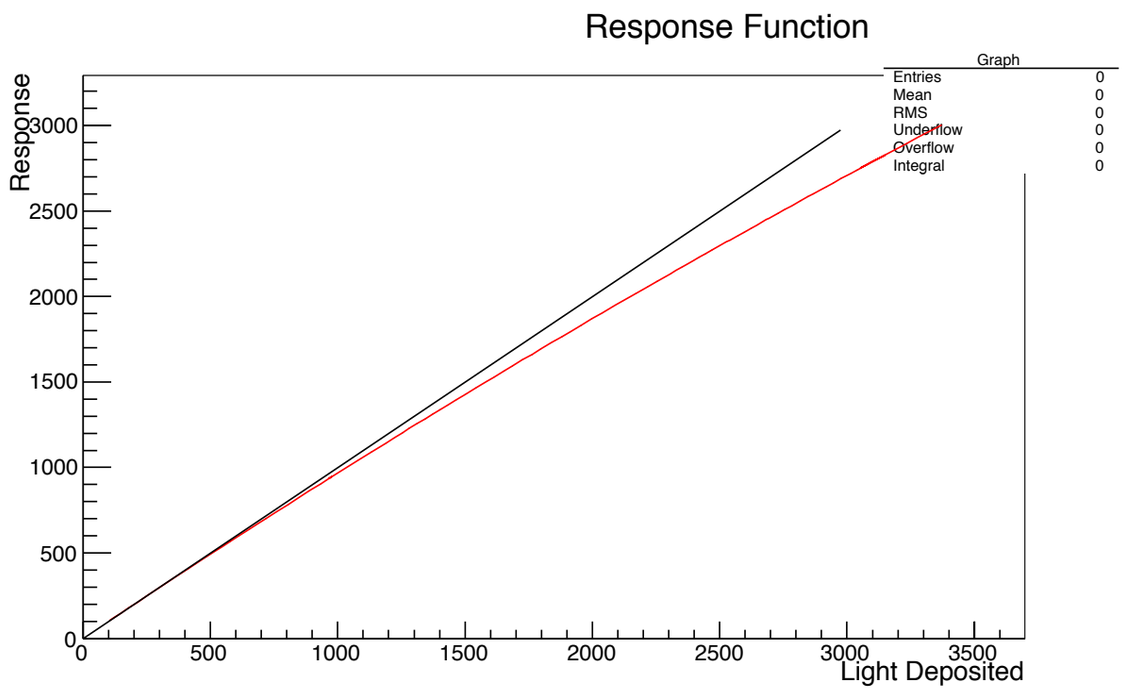
energy-weighted

$$< A_l >_W = \frac{E^+_{tot} - E^-_{tot}}{E^+_{tot} + E^-_{tot}} = \frac{\int d\rho E(\rho) A_l(\rho) \frac{d\sigma}{d\rho}(\rho)}{\int d\rho E(\rho) \frac{d\sigma}{d\rho}(\rho)}$$

$$< A_l >_W = 0.130339$$

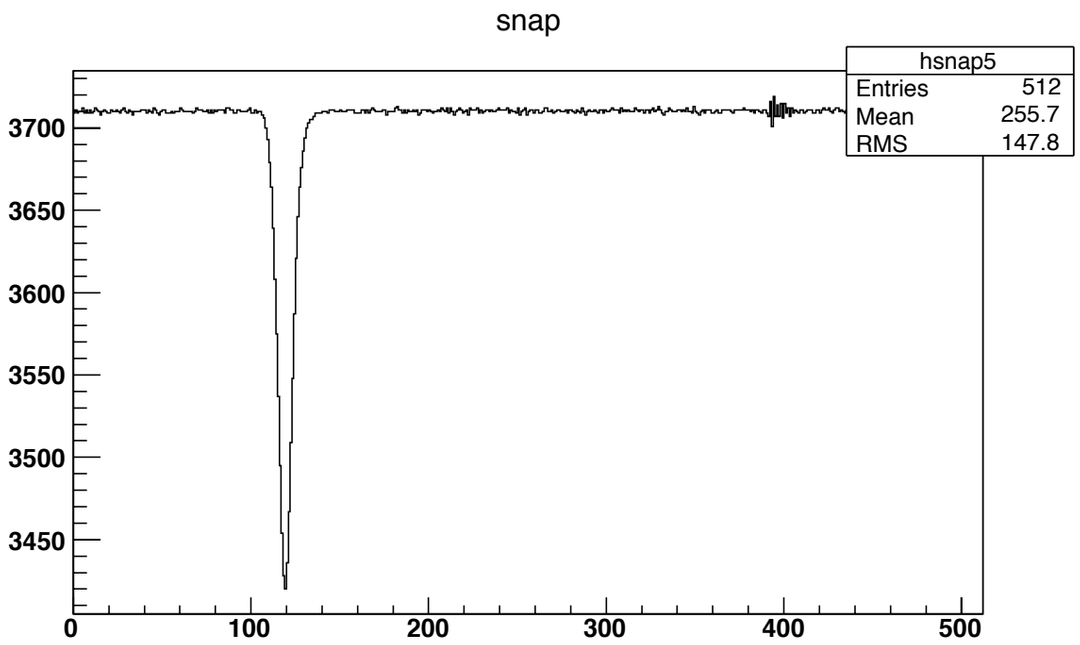
# non-linearity and true response

$$\frac{response}{R_0} = (\frac{I}{I_0}) + \alpha(\frac{I}{I_0})^2 + \beta(\frac{I}{I_0})^3$$

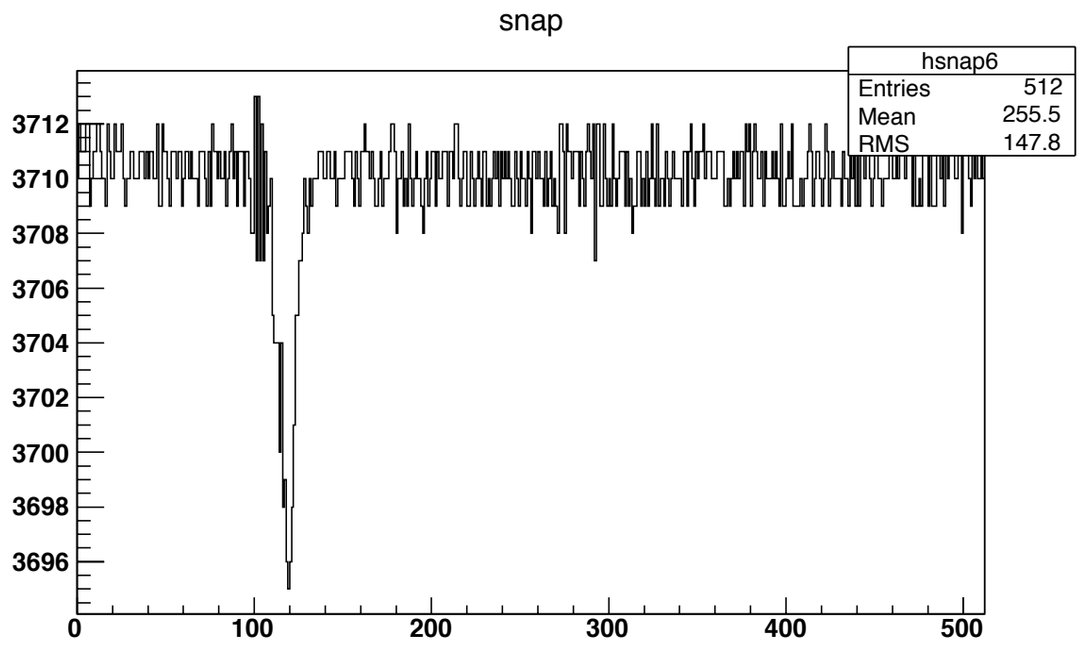



black: straight line
red: true response

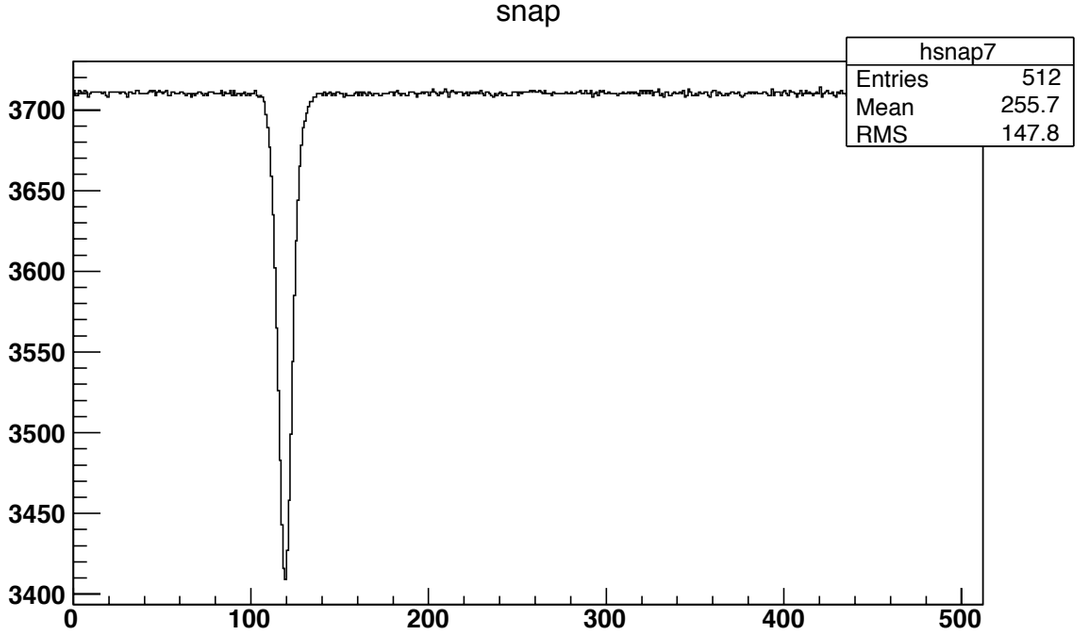
# linearity testing



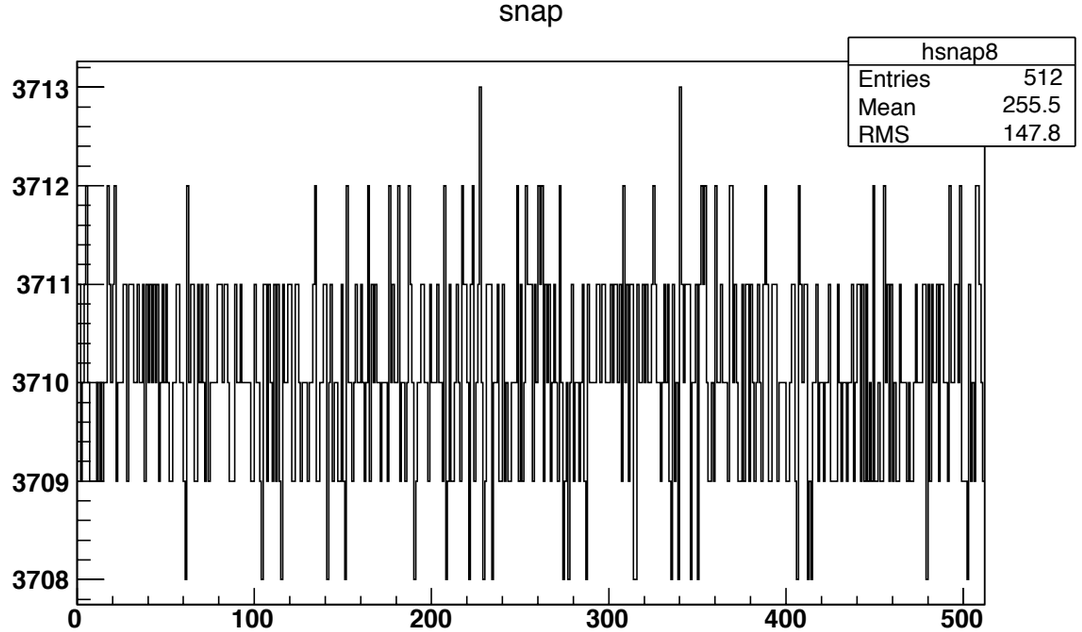

variable




delta



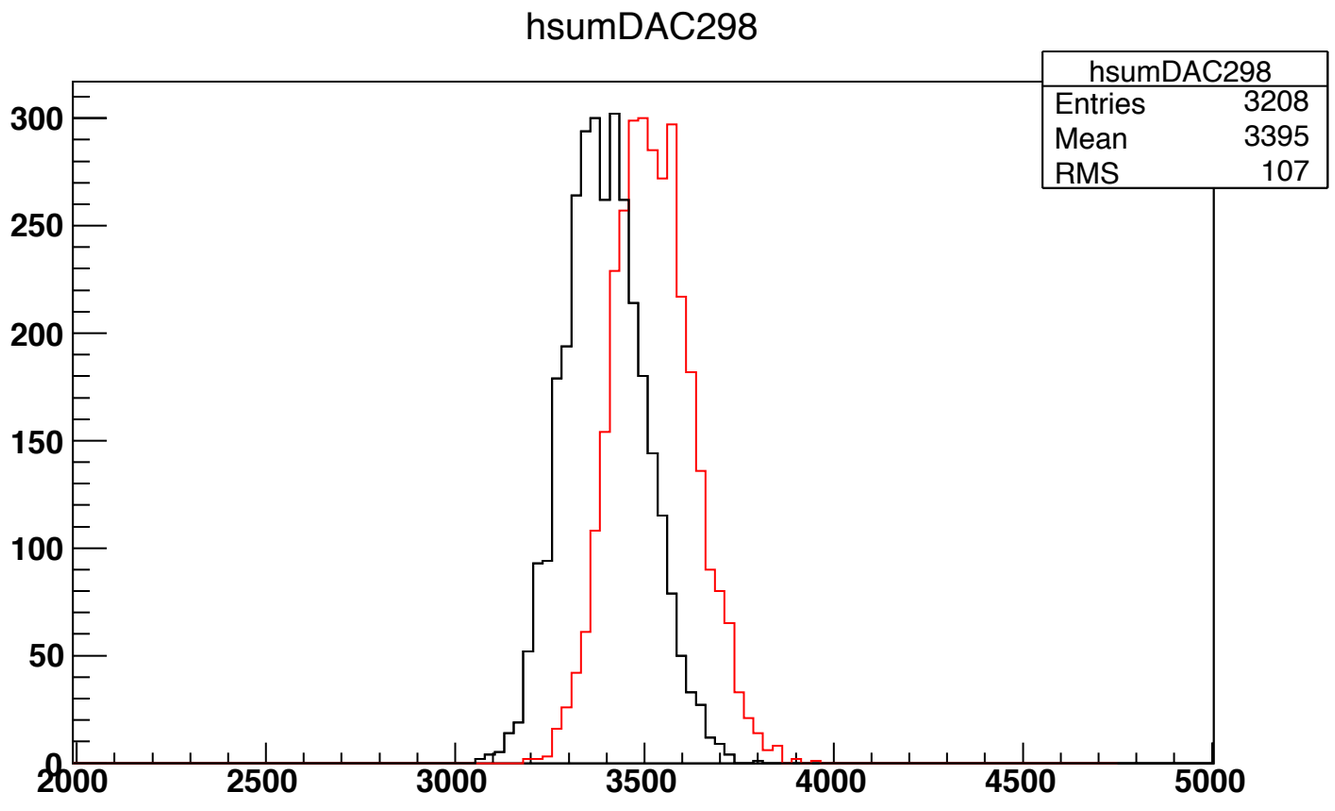

variable+delta




none

# linearity testing

- finite difference method y(x)=f(x+δ)-f(x)

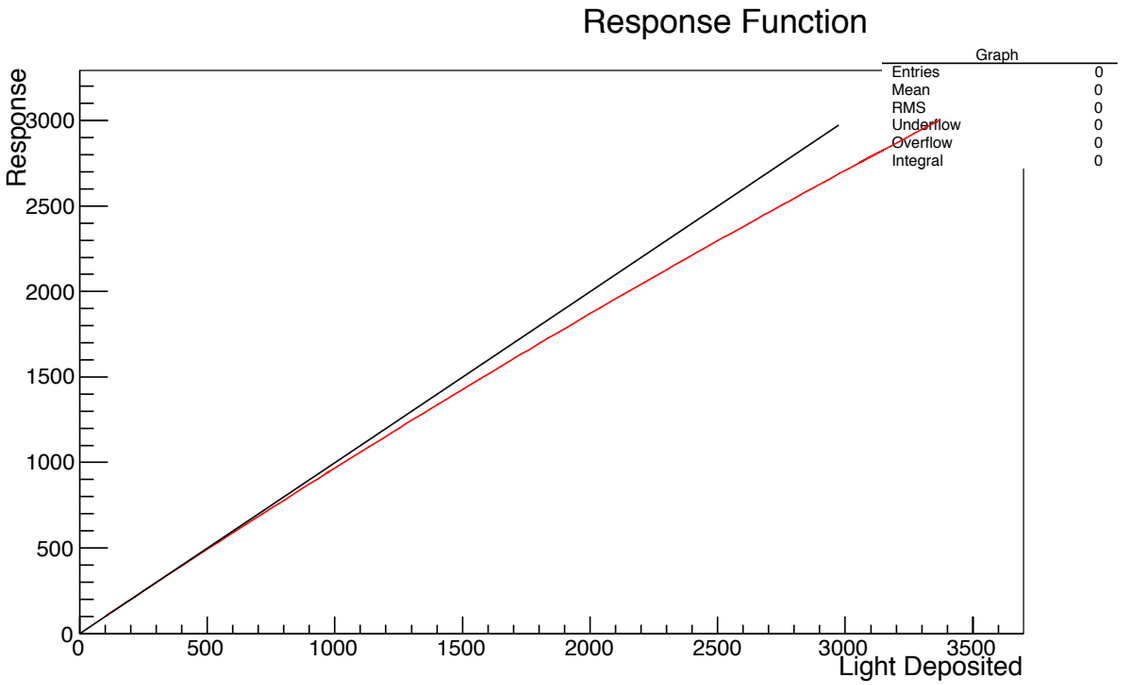


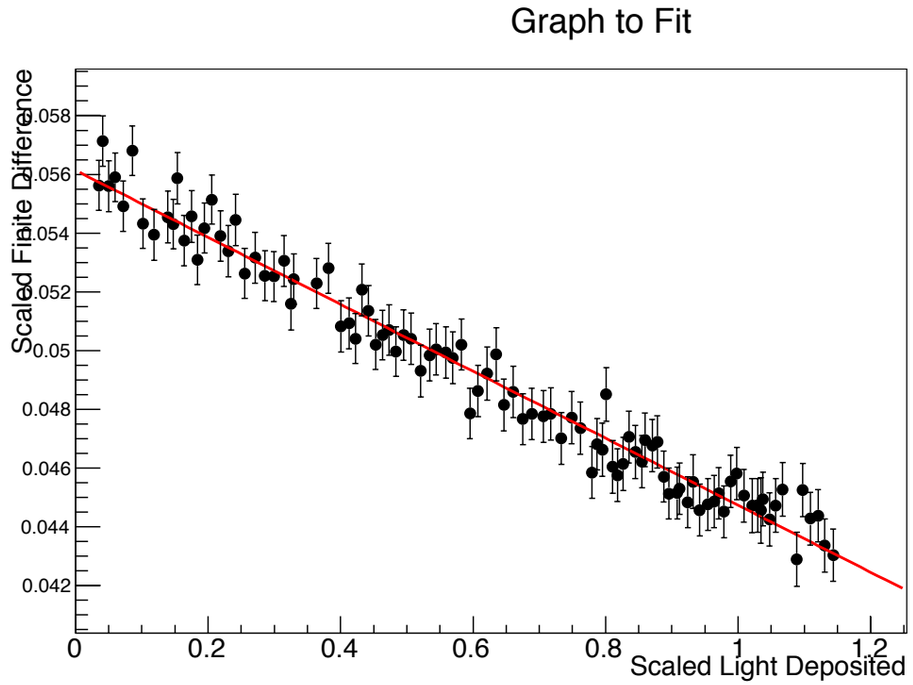

black: variable

red: variable+delta

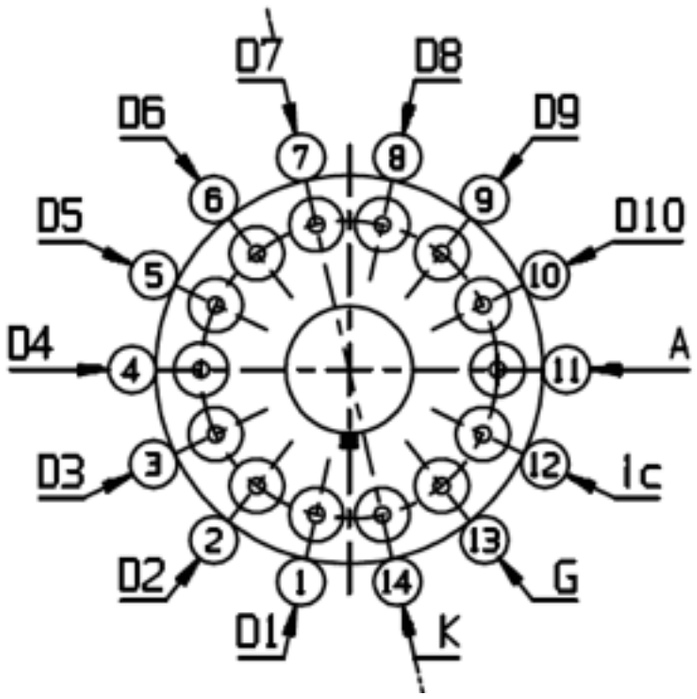
# non-linearity and true response

$$\frac{response}{R_0} = (\frac{I}{I_0}) + \alpha(\frac{I}{I_0})^2 + \beta(\frac{I}{I_0})^3$$



# xp2412b PMT base



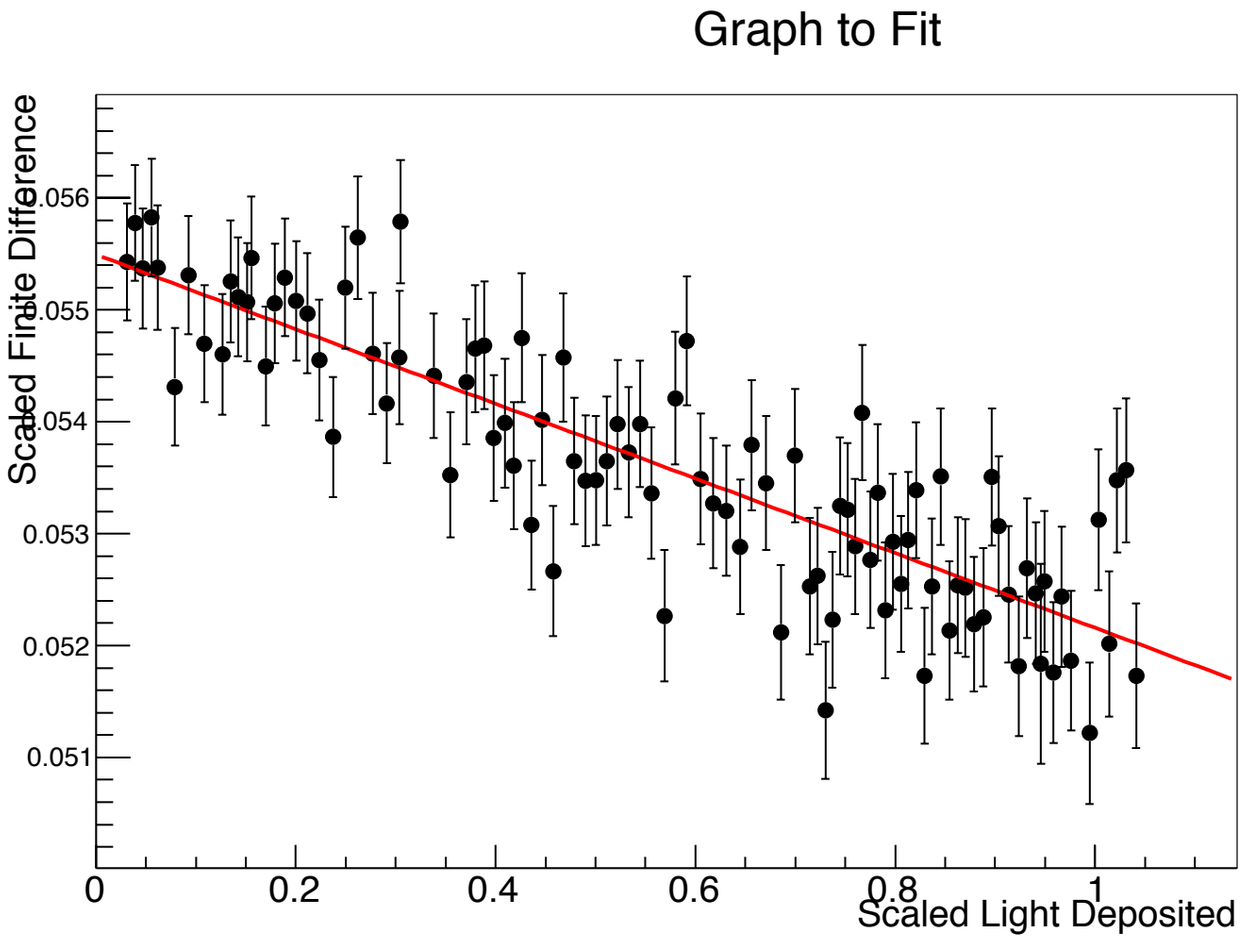

K:cathode
A:anode
G:focusing electrode
D:dynode

- original voltage chain design

| K | G | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | D10 | A | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | 1.5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | (total : 12) |

# changing the base

- the non-linearity of original base
  K 2 1 1 1 1 1 1 1 1 1 1 1




non-linearity=-3.01%

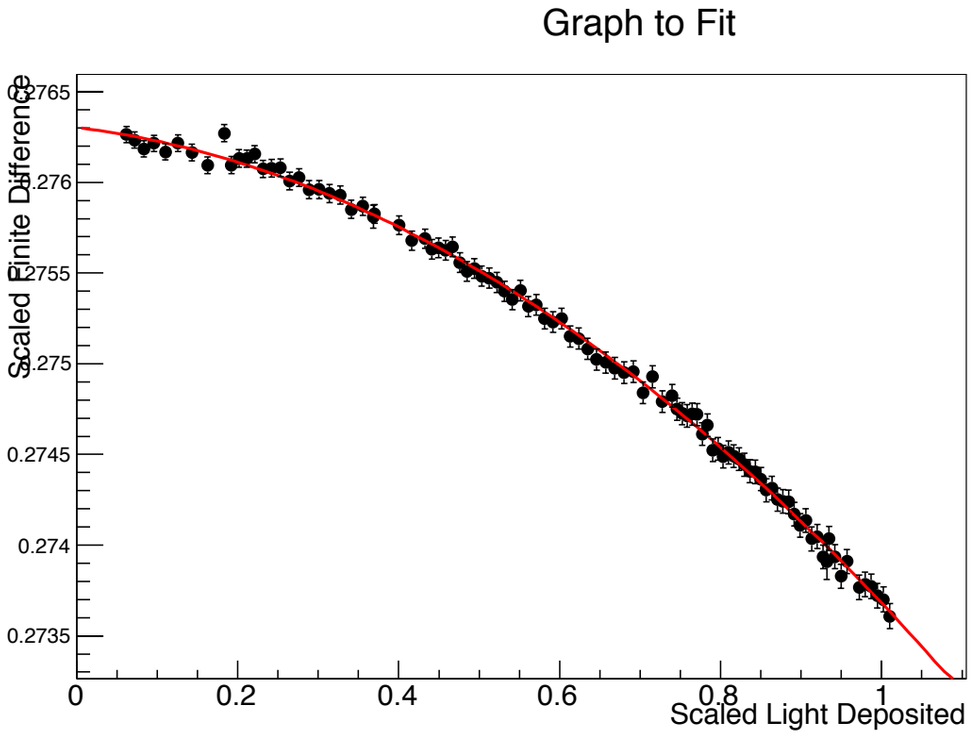
$< A_l >_W = 0.129299$

| tapered base | non-linearity |
|---|---|
| K 2 1 1…1 1 1 1 Ground | -3.01% |
| K 2 1 1…1 2 3 2 Ground | -1.27% |
| K 2 1 1…1.5 2 3 2 Ground | -1.46% |
| K ZZ 1 1…1.5 2 4 3 Ground | -0.433% |
| K ZZ 1 1…1.5 2 4 4 Ground | -0.481% |
| K ZZ 1 1…1.5 2 5 4 Ground | -0.227% |
| K ZZ 1 1…1.5 2 5 ZZ’ Ground | -0.343% |

ZZ, ZZ’ : Zener diodes

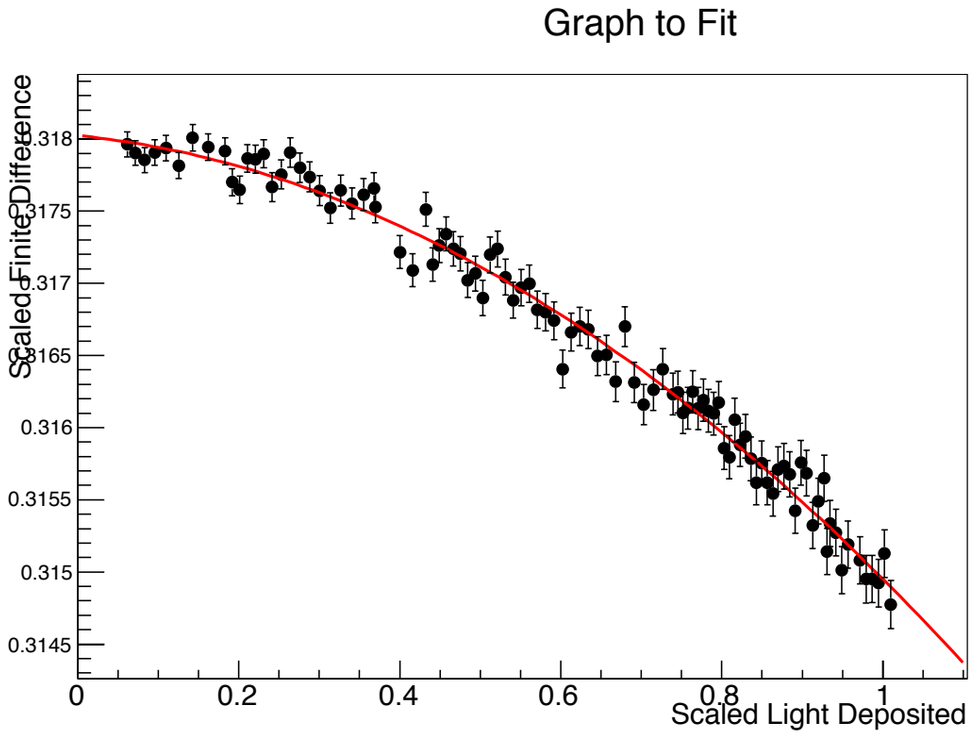
# with background

## voltage chain
## ZZ 1 1... 1.5 2 5 4




non-linearity=-0.245%

## voltage chain
## ZZ 1 1... 1.5 2 5 ZZ’




non-linearity=-0.226%

# result

- $< A_l >_W = \frac{\int d\rho E(\rho) A_l(\rho) \frac{d\sigma}{d\rho}(\rho)}{\int d\rho E(\rho) \frac{d\sigma}{d\rho}(\rho)}$
- If the base has linear response, Compton integrated asymmetry $< A_l >_W$ =0.130339.
- Starting with manufacturer's default setting, $< A_l >_W$ =0.129299.
- After optimizing PMT base, $< A_l >_W$ =0.130181, which is an improvement of ~6x.