Jefferson Lab High-B Facility

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for the DIRC Collaboration

EIC PID Consortium Meeting, 20 April 2015

High-B Sensor-Testing Facility

Motivation: **DIRC configuration with readout inside a solenoid magnet. PMTs operate inside a 3-T field.**

Purpose: **Gain evaluation of small photon sensors in magnetic fields.**

Goal: **Determine design characteristics, suitable for DIRC readout.**

High-B Sensor-Testing Facility

Jefferson Lab Support

- Laboratory Space, Equipment
- Personnel
  - Data Acquisition Installation and Maintenance
  - Supperconducting Magnet Cooling, Refilling, and Maintenance
  - Detector Lab support: engineering

University Contributions

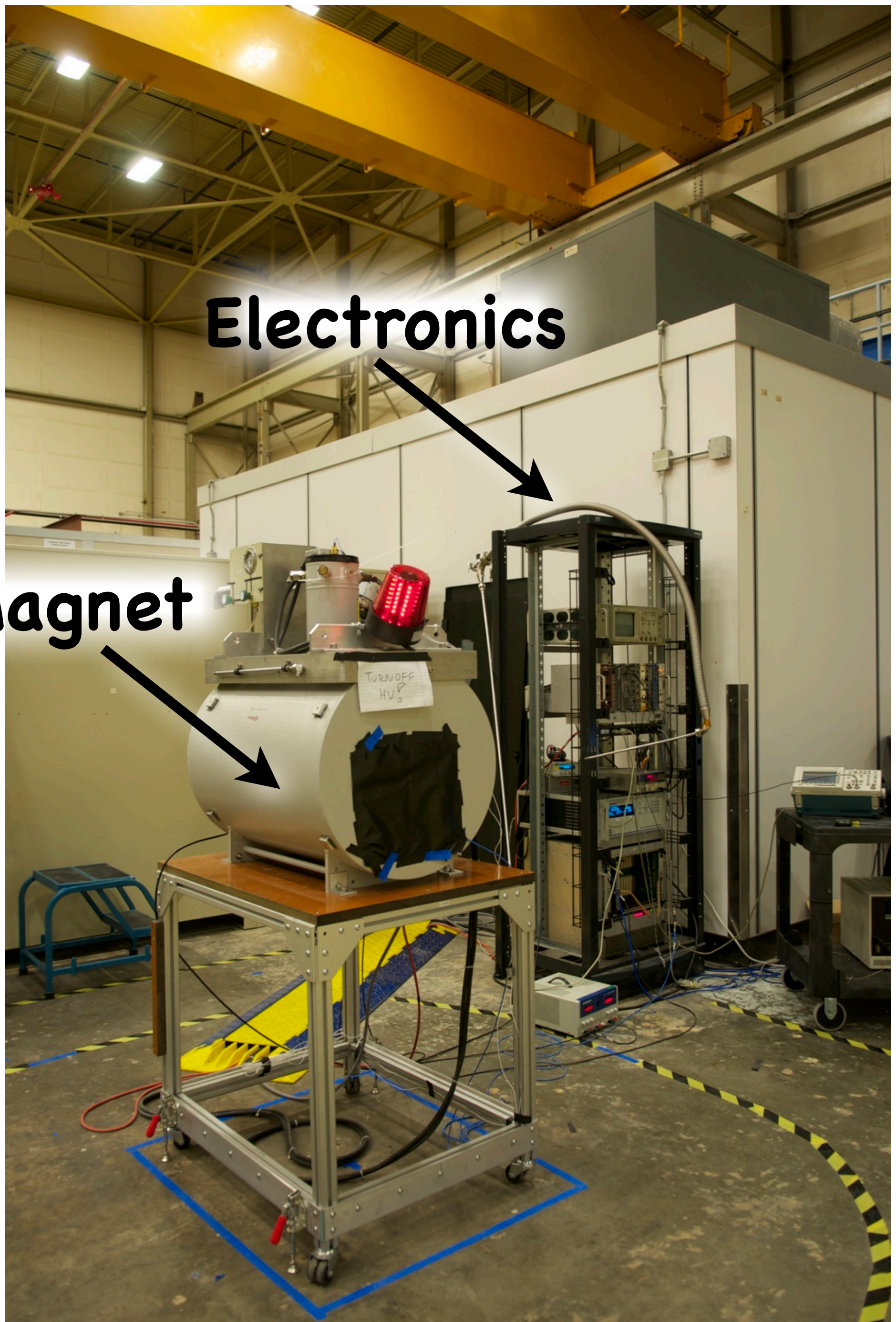
- Personnel
  - University of South Carolina: faculty, graduate and undergraduate students
  - Old Dominion University: postdoctoral fellow(s), graduate student

Jefferson Lab
Thomas Jefferson National Accelerator Facility

UNIVERSITY OF SOUTH CAROLINA

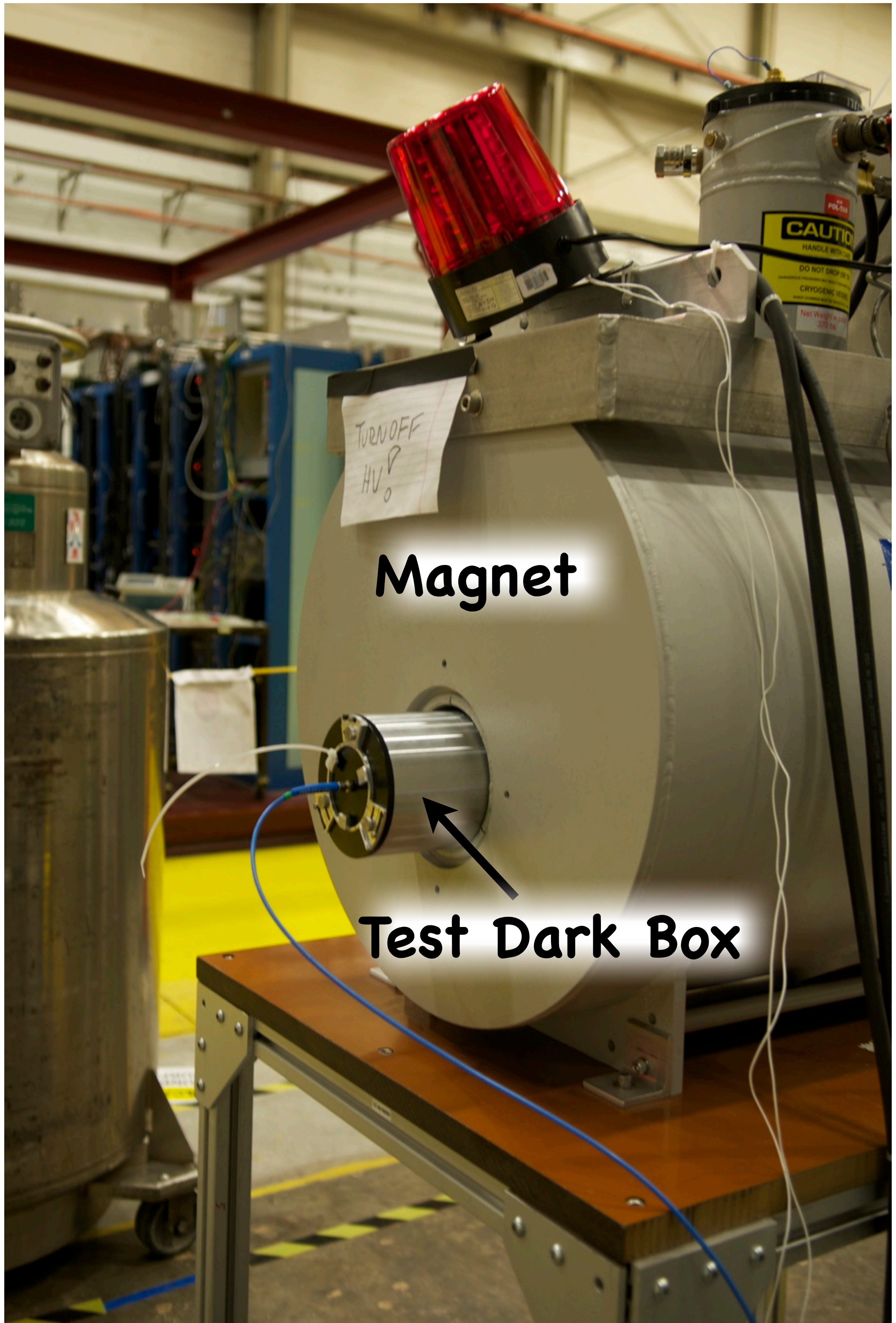
OLD DOMINION UNIVERSITY
IDEA FUSION

High-B Sensor-Testing Facility



- Commissioning: July/August 2014
- Data taking: November 2014
- People: JLab: P. Nadel-Turonski, C. Zorn; USC: Y. Ilieva, T. Cao, E. Bringley; ODU: K. Park, G. Kalicy, L. Allison; UVA: V. Sulkosky

Major Components



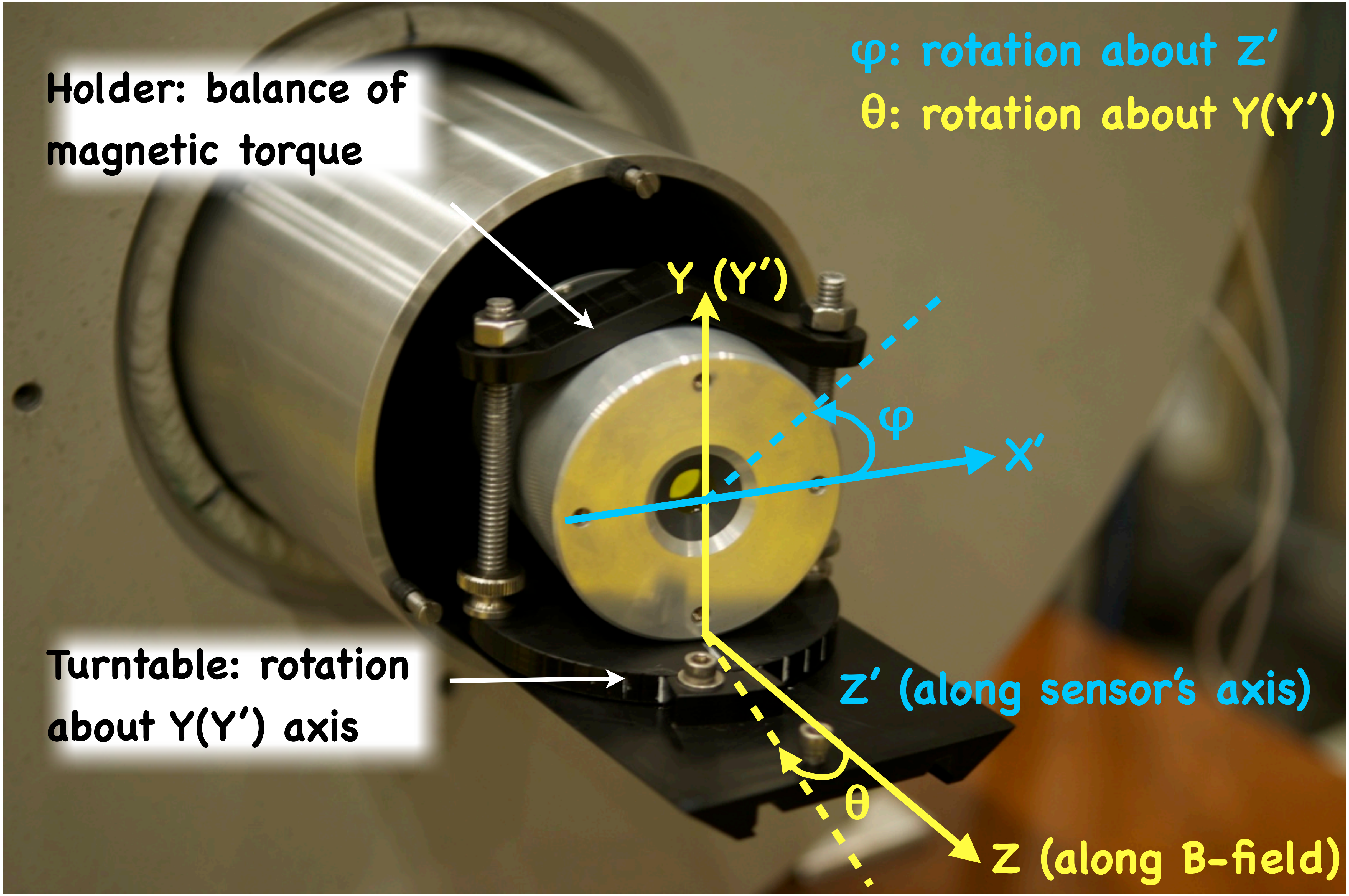
Magnet:

- superconducting solenoid
- max. field: 5.1 T at 82.8 A
- 12.7-cm (5-inch) diameter warm bore
- length of bore: 76.2 cm (30 inch)
- central field inhomogeneity: $\leq 5\times10^{-5}$ over a cylindrical volume of a diameter of 1.5 cm and length of 5 cm

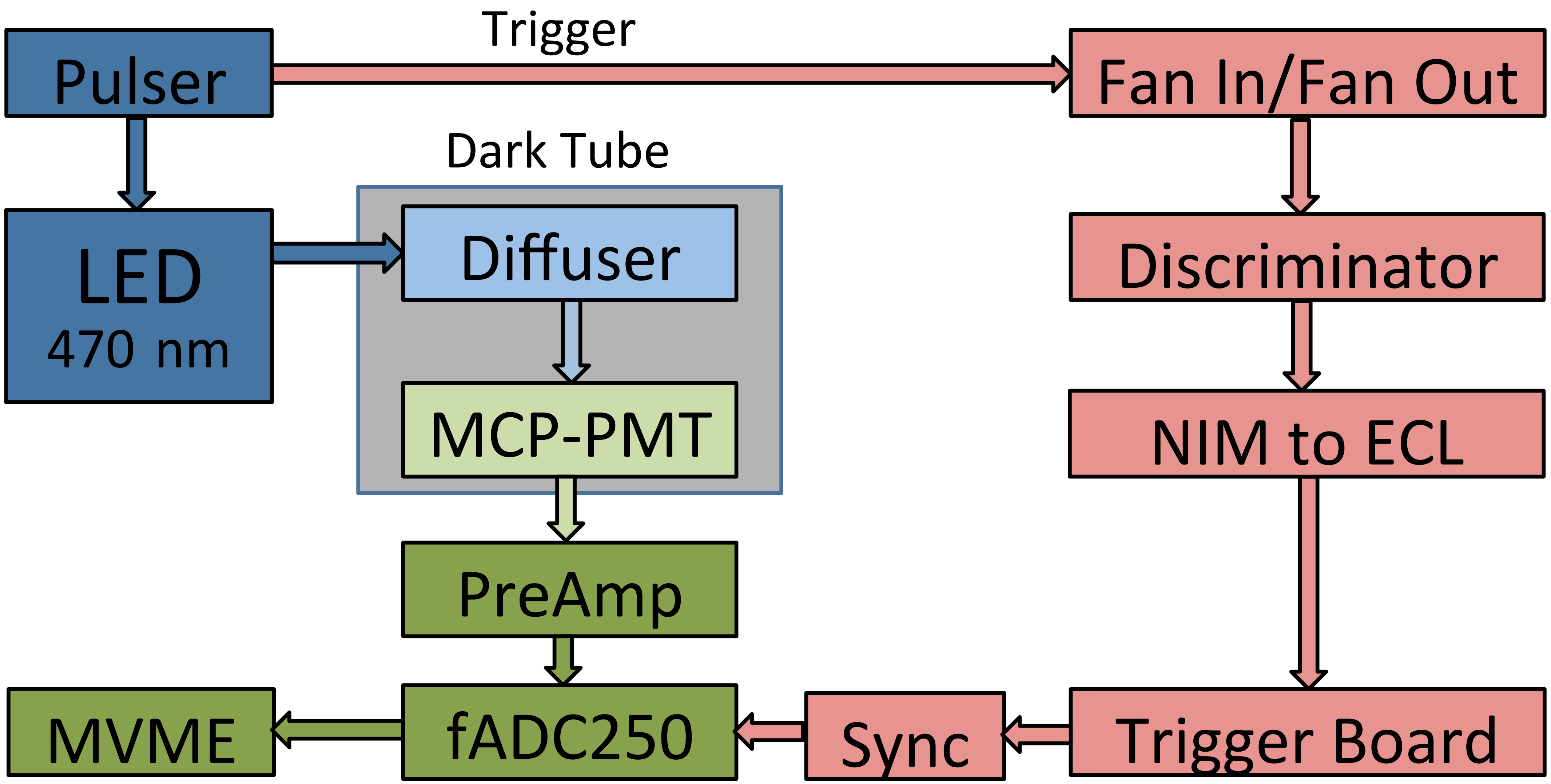
Test Box:

- non-magnetic, light-tight
- cylindrical shape: $d_{in} \sim 4.5$ inch, $L \sim 18$ inch
- allows for rotation of sensors
- LED light source

Sensor Orientation Capabilities



Major Components

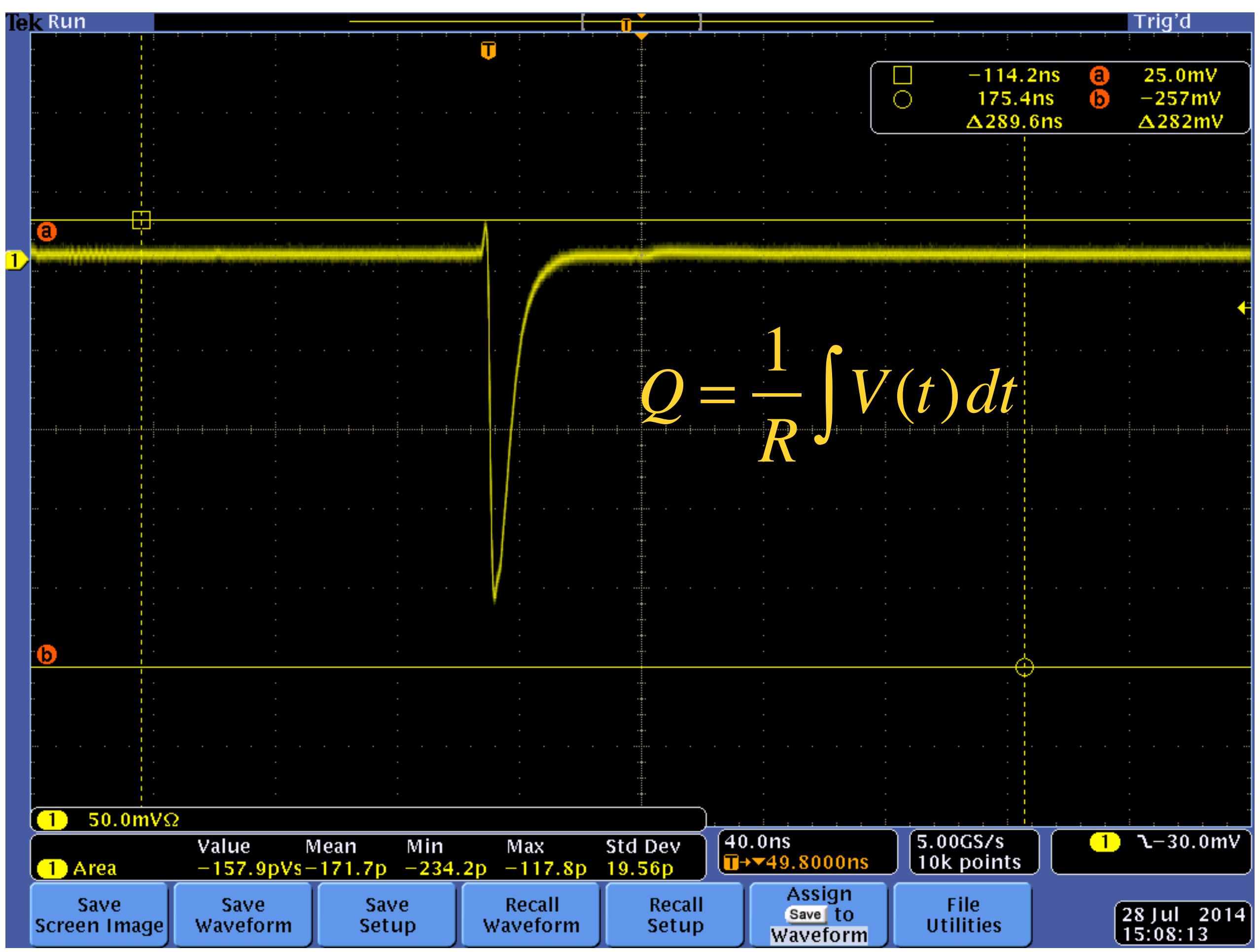


fADC Calibration

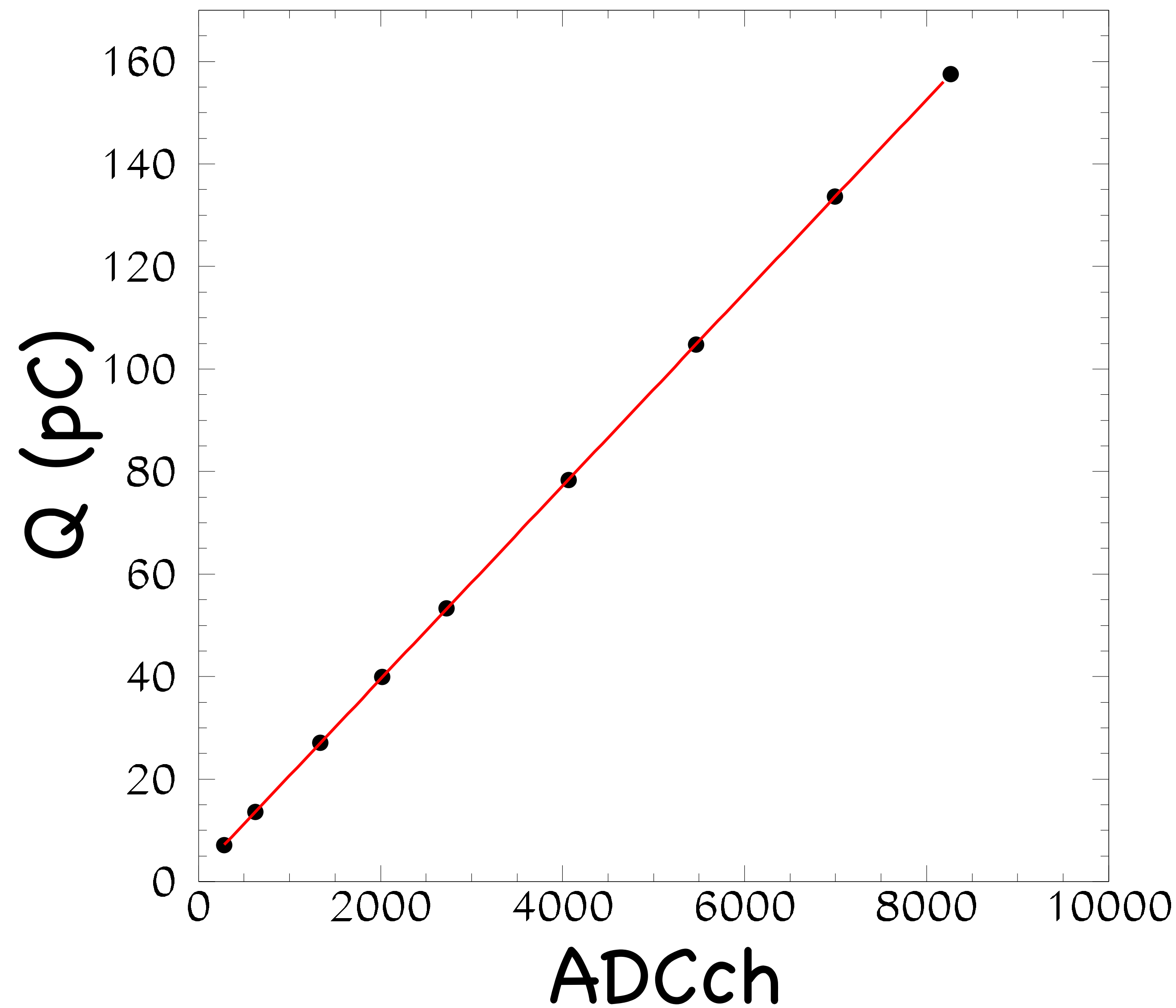
Charge Generator PS7120
Q(t)

→

fADC250
ADCch

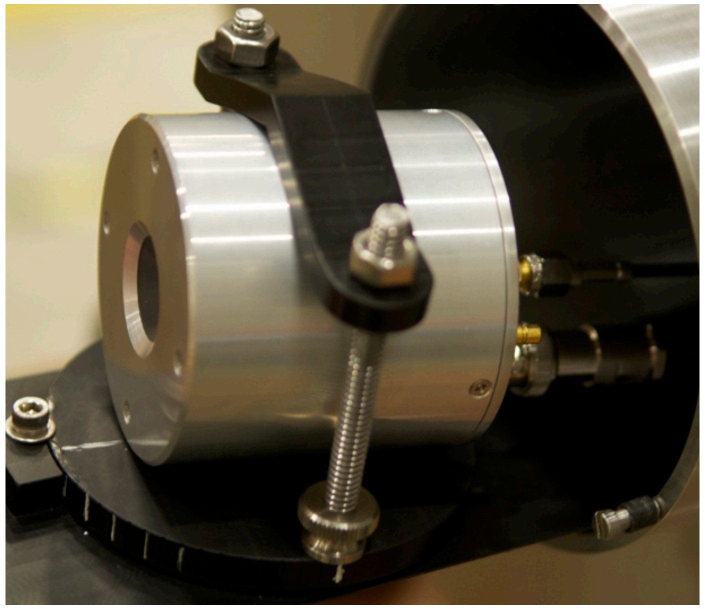


$$Q = (1.9 \pm 1.2) + (0.01883 \pm 0.00039) \cdot \mathrm{ADCch}$$



Commissioning and First Run

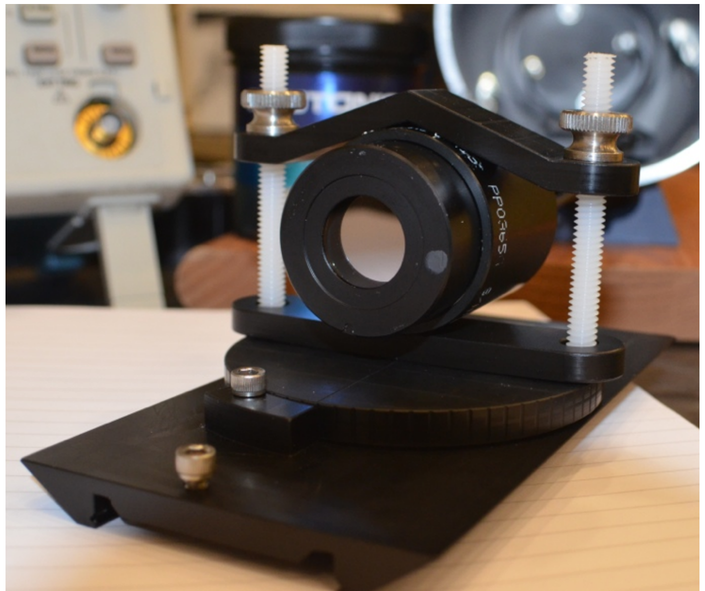
- **ADC:** 19.1±0.2 fC/ADCch
- **Data** collected
  - **Photek PMT210**: B = (0, 5) T; θ = (0°, 30°, 180°); φ=0°, 90°, 135°
  - **Photek PMT240**: B = (0, 2) T; θ = 0°; φ=0°
  - **Photonis PP0365G**: B = (0, 3) T; θ = (0°, 30°, 180°); φ=0°, 90°, 135°



pore size: 3 μm, 10 μm

gain: ~10^6

QE: 15%



pore size: 6 μm

gain: ~10^5

QE: 18%

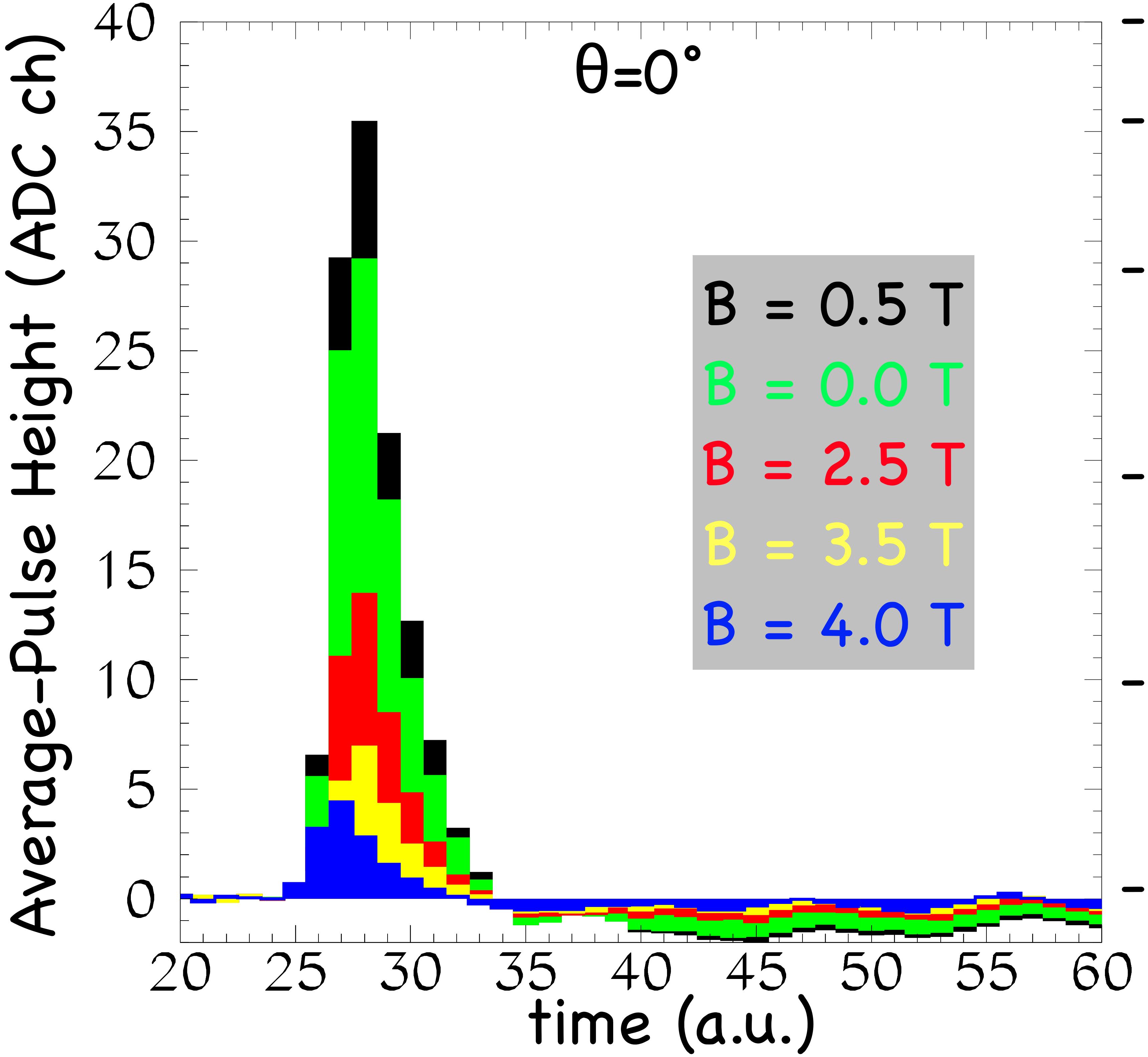
MCP-PMT Data Analysis

Methods:

A. At each setting, evaluate the total charge collected on the anode. Map total collected charge as a function of setting.
   a. sensitive to fluctuations in the light input
   b. must renormalize data at different θ to a reference setting (0 T, 0°)
   c. somewhat sensitive to pick-up noise
   d. quantity simple to evaluate, no fits involved

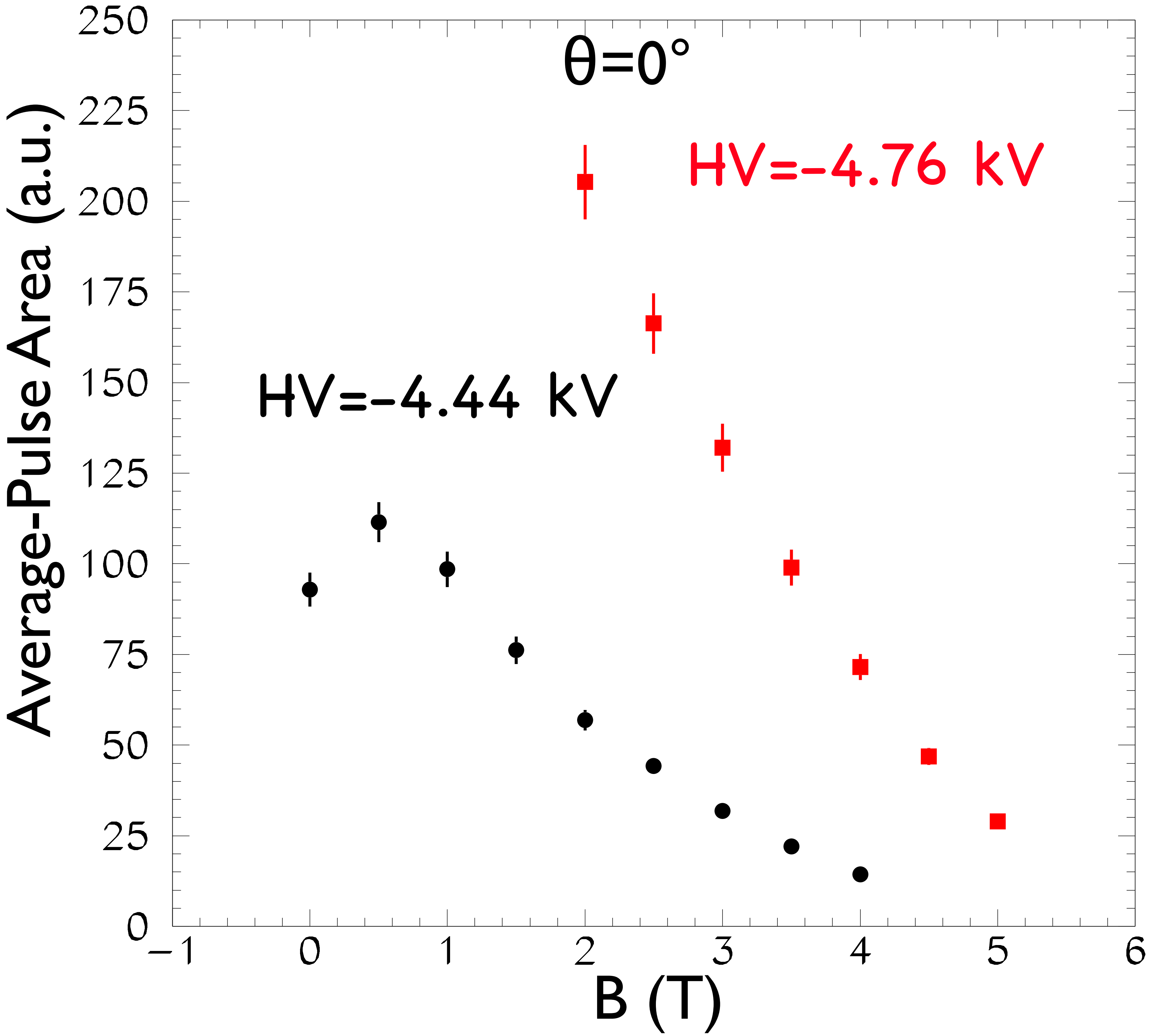
B. At each setting, determine the absolute gain of the PMT. Map the absolute/relative gain as a function of setting.
   a. independent on light-input fluctuations
   b. no need for renormalization
   c. sensitive to fit function, initial values of fit parameters
   d. sensitive to interval of integration of signal

Method A



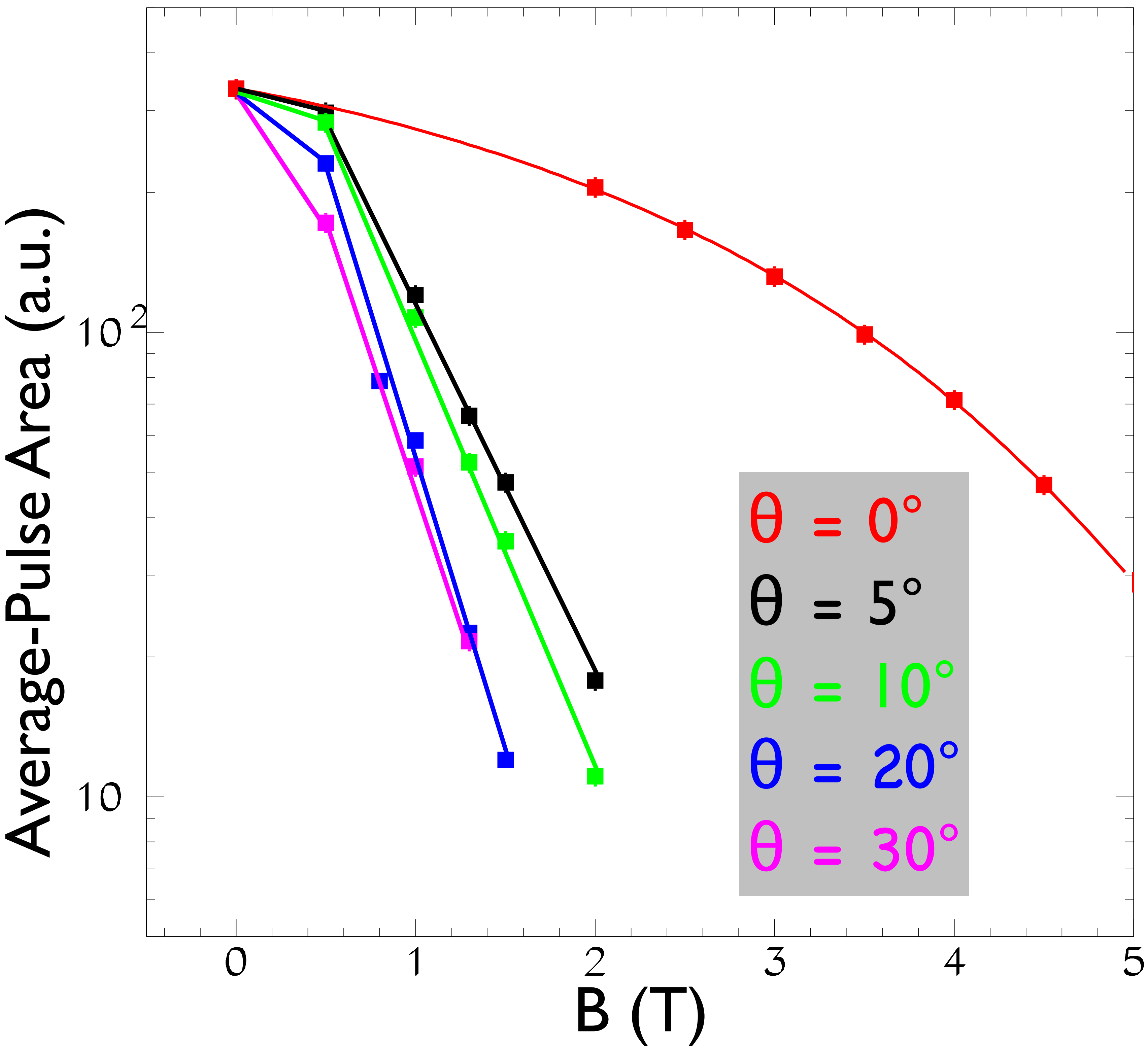
- Photek PMT210
- signal height is averaged over all events in the run
- average pedestal is subtracted from pulse height at each time
- all positive pulse-heights are added in a sum (Average-Pulse Area)
- increasing the field from 0. to 0.5 T leads to an increased gain
- above 0.5 T the signal amplitude continuosly deacreses

Results: Method A



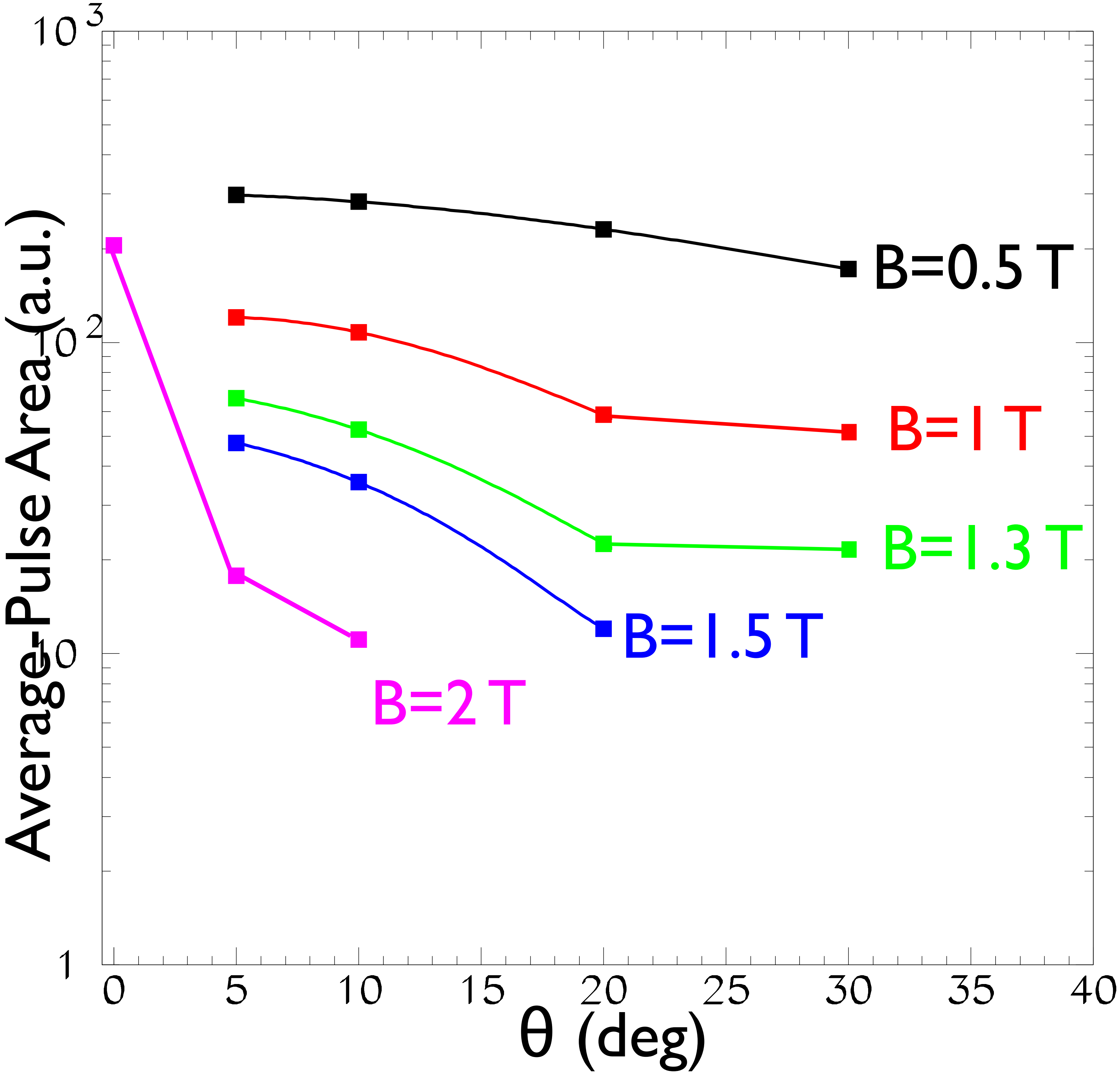
- Photek PMT210
- max. high voltage: -4.8 kV
- 5% uncertainty shown: dominated by variations in reproducibility of the same data point.
- nearly 20% increase of charge output at 0.5 T relative to 0 T
- about a factor of 6 decrease of signal between 0 T and 4 T (-4.44 kV)
- operating the sensor at nearly maximum high voltage extends the range of applied field to 5 T

Results: Method A



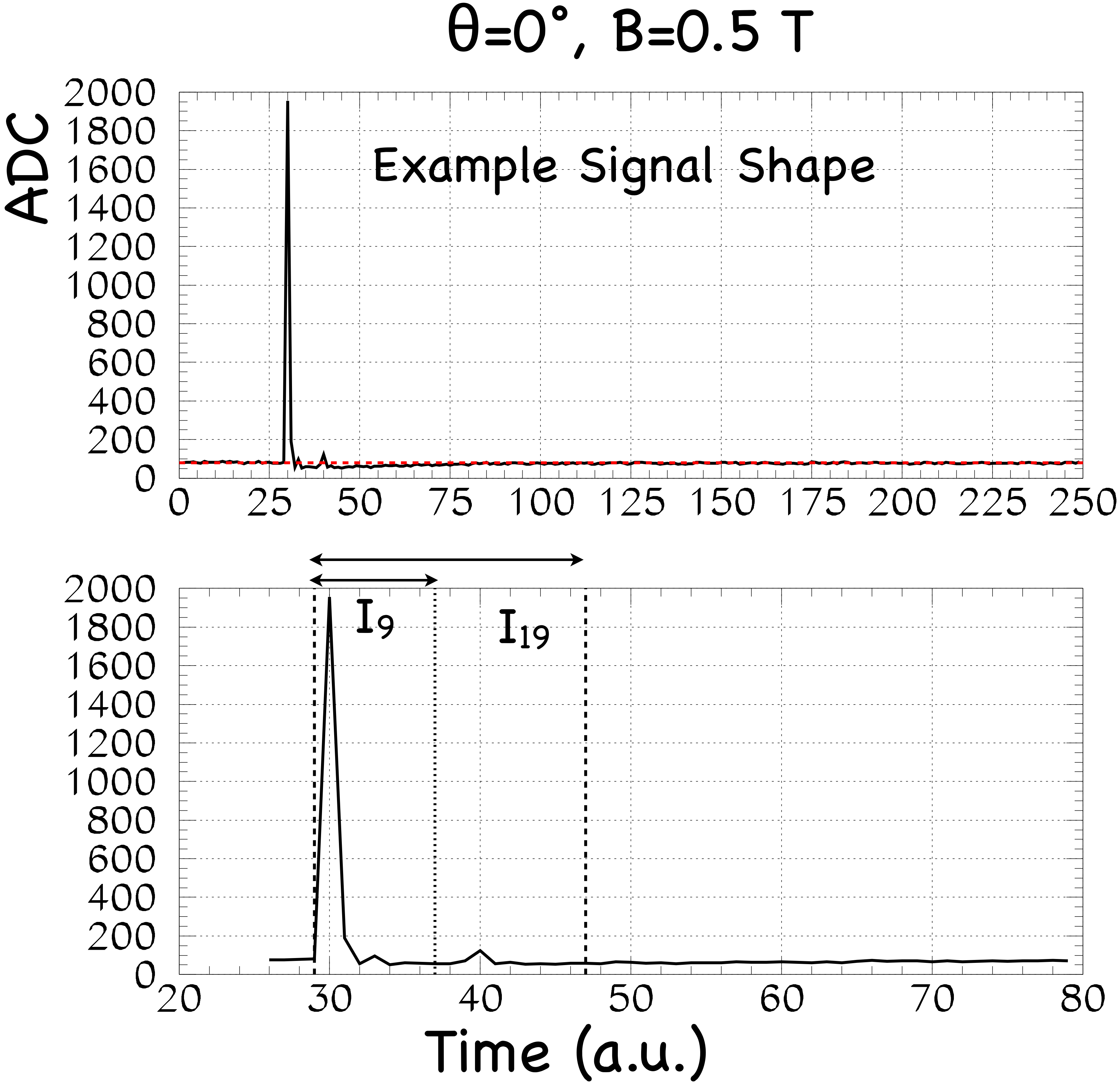
- Photek PMT210
- operating voltage: -4.76 kV
- data at θ>0° are normalized to the nominal point at 0 T and 0° to compensate for different light input to photocathode
- θ = 0°: polynomial decrease of signal as B increases
- θ > 0°: above 0.5 T exponential decrease of signal as B increases
- preliminary and not shown: no significant dependence of signal on φ

Results: Method A



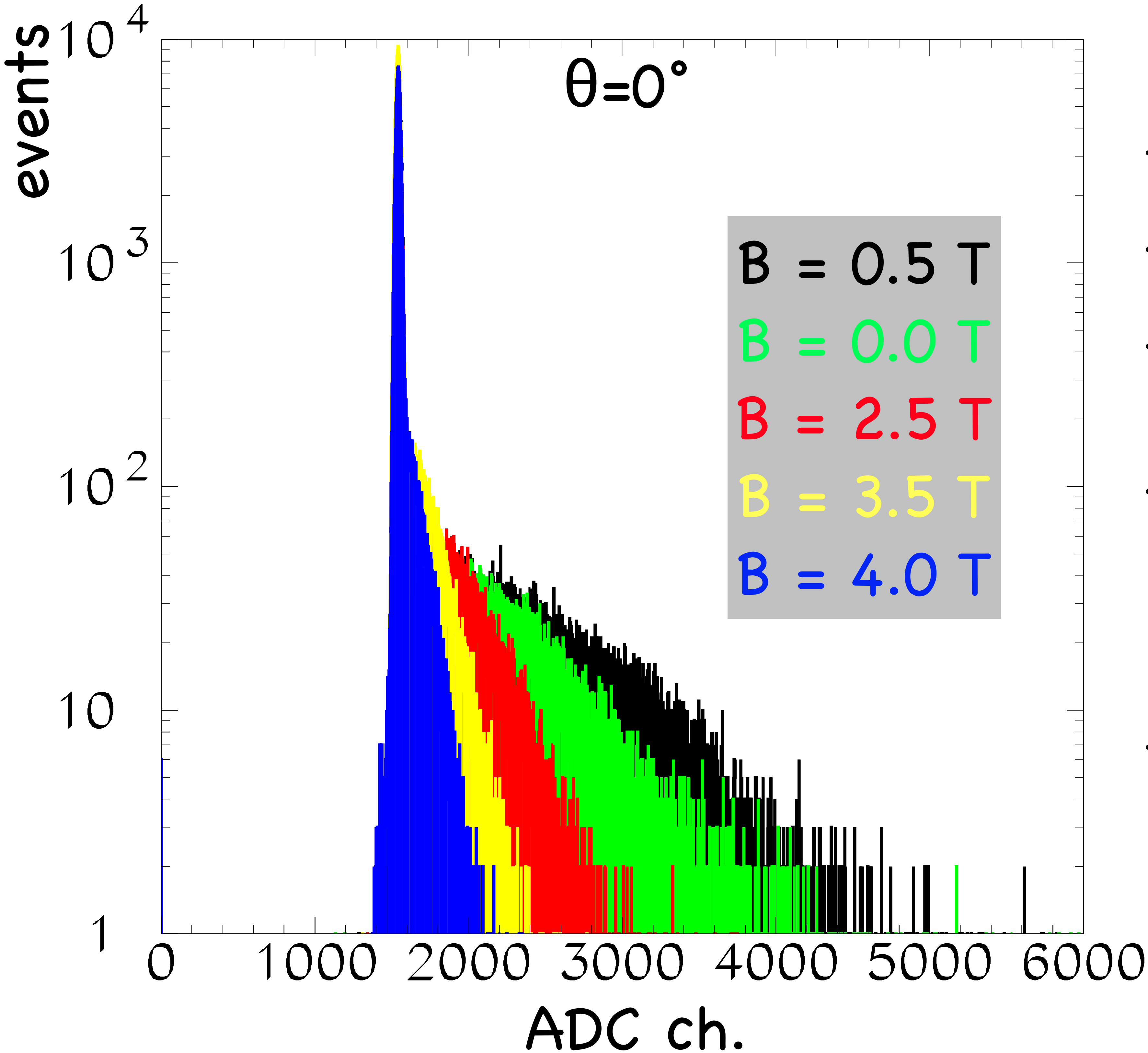
- Photek PMT210
- operating voltage: -4.76 kV
- Data at 0° only at 2 T for this voltage
- 2 T: signal decrease by about 10 from 0° to 5°
- as θ increases above 5°, signal decreases slowly. Rate of decrease increases as B incrases

Method B



- high voltage: -4.4 kV
- narrow peak with a very long tail
- max. ADC value at sample s_{max} = 30
- $I_9 = \sum_{i=s\max-1}^{s\max+7} ADC_i$
- $I_{19} = \sum_{i=s\max-1}^{s\max+17} ADC_i$

Results: Method B



- Photek PMT210
- high voltage: -4.4 kV
- pedestal peak at about 1530 ch
- gain can be extracted from fits to spectra to identify position of single-photoelectron peak
- analysis of spectra is ongoing

Method B: Fitting Function

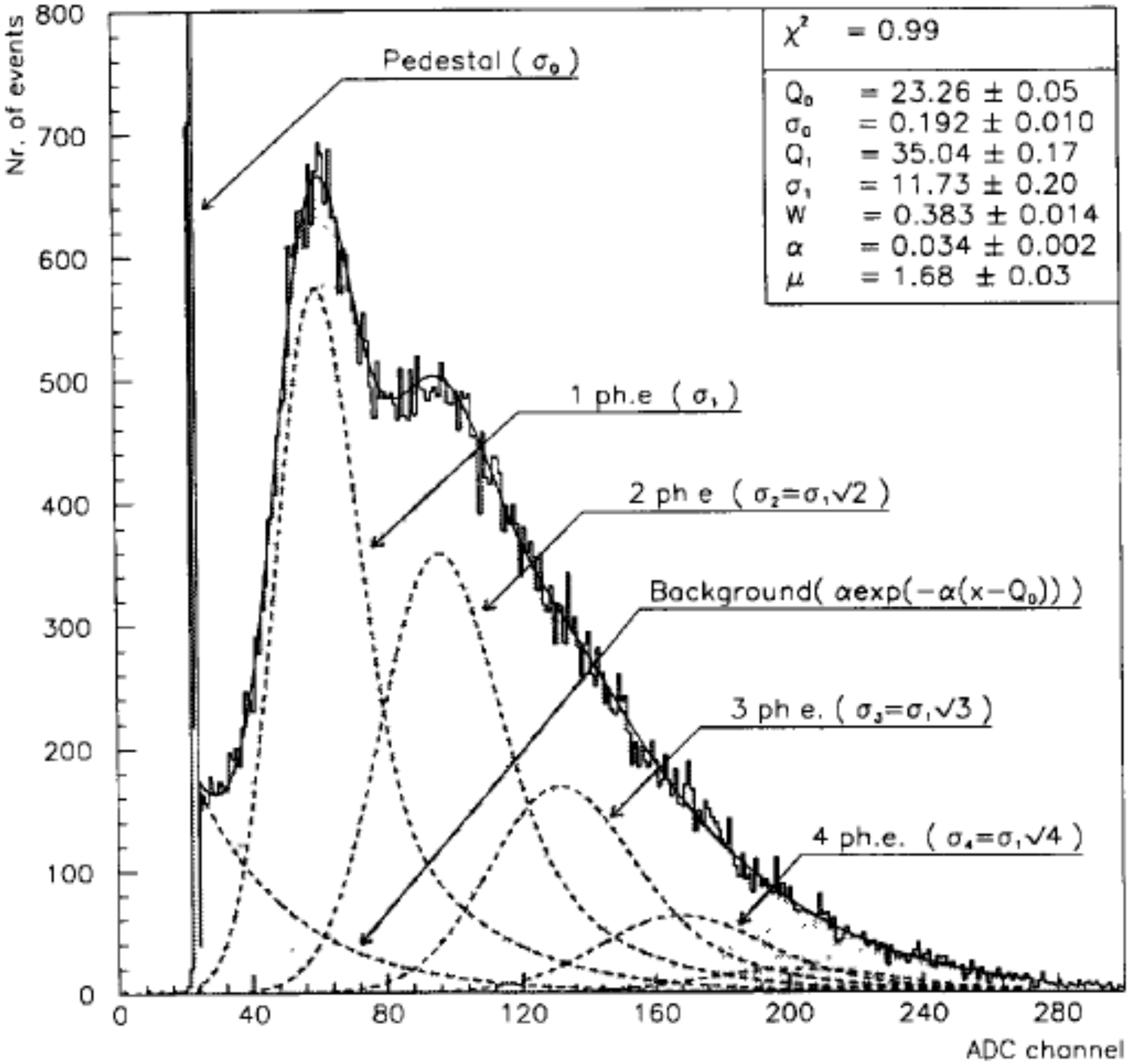


Fig. 2. Typical deconvoluted LED spectrum (EMI-9814B photomultiplier).

$$S_{Real}(x) = \int S_{Ideal}(x')B(x-x')dx' = \sum_{n=0}^{\infty} \frac{\mu^n e^{-\mu}}{n!} * \left[(1-w)G_n(x-Q_o) + wI_{G_n\otimes E}(x-Q_o)\right],$$

$$I_{G_n\otimes E}(x-Q_o) = \int_{Q_o}^{x} G_n(x'-Q_o)\alpha\exp[-\alpha(x-x')]dx$$

$$= \frac{\alpha}{2} exp[-\alpha(x-Q_n-\alpha{\sigma_n}^2)]$$

$$* \left[\mathrm{erf}\left(\frac{|Q_0-Q_n-\alpha{\sigma_n}^2|}{\sigma_n\sqrt{2}}\right) + sign(x-Q_n-\alpha{\sigma_n}^2) * \mathrm{erf}\left(\frac{|x-Q_n-\alpha{\sigma_n}^2|}{\sigma_n\sqrt{2}}\right)\right]$$

$$Q_n = Q_o + nQ_1$$

$$\sigma_n = \sqrt{{\sigma_o}^2 + {\sigma_n}^2} \approx \begin{cases} \sigma_n = 0, n = 0 \\ \sigma_n = \sqrt{n}\sigma_o, n > 0 \end{cases}$$

$$Q = \frac{f}{A} \cdot Q_1$$

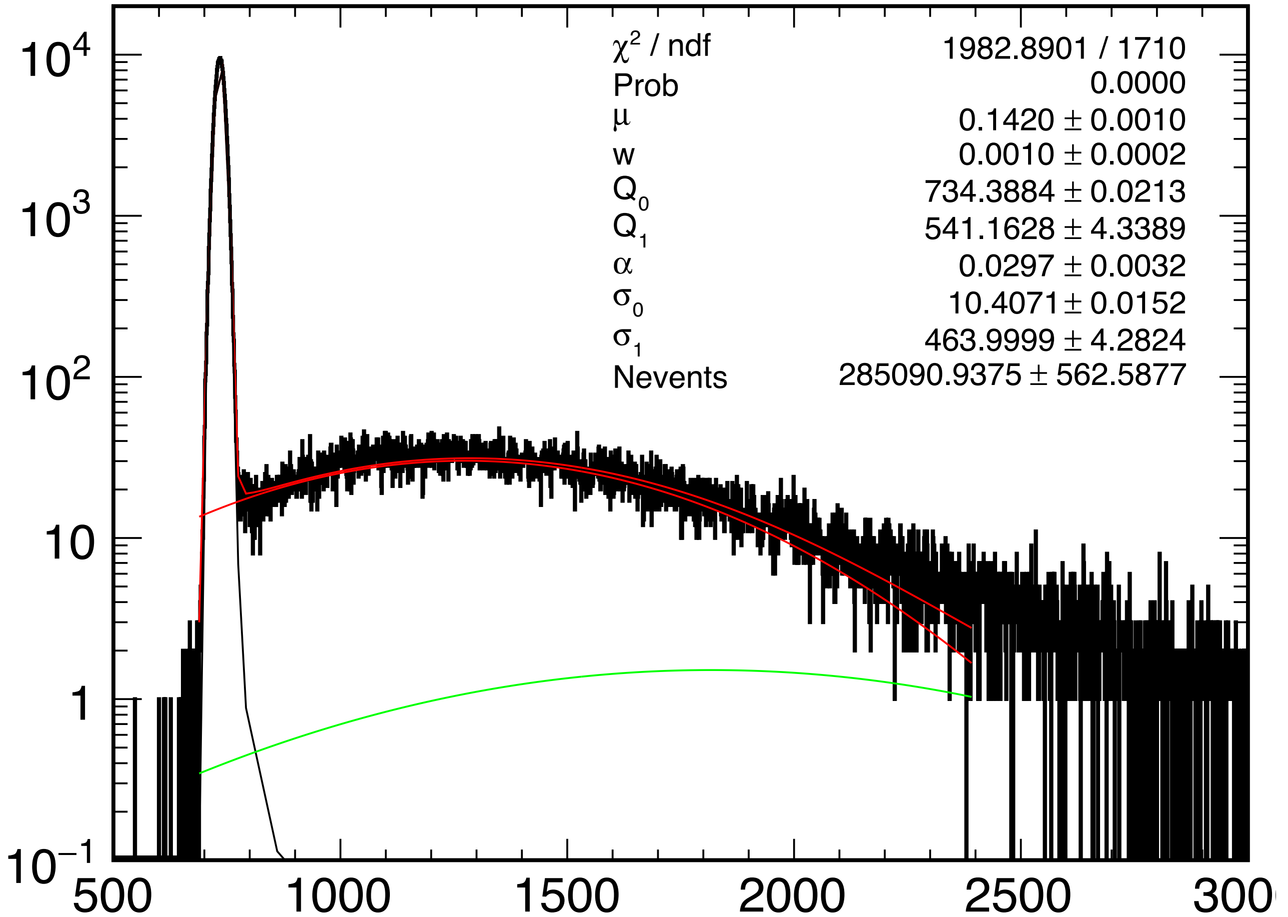
$$G = \frac{Q}{q \cdot N_{phe}} = \frac{f}{A \cdot q} Q_1$$

Q_1 : position of single phe peak above the pedestal Q_0

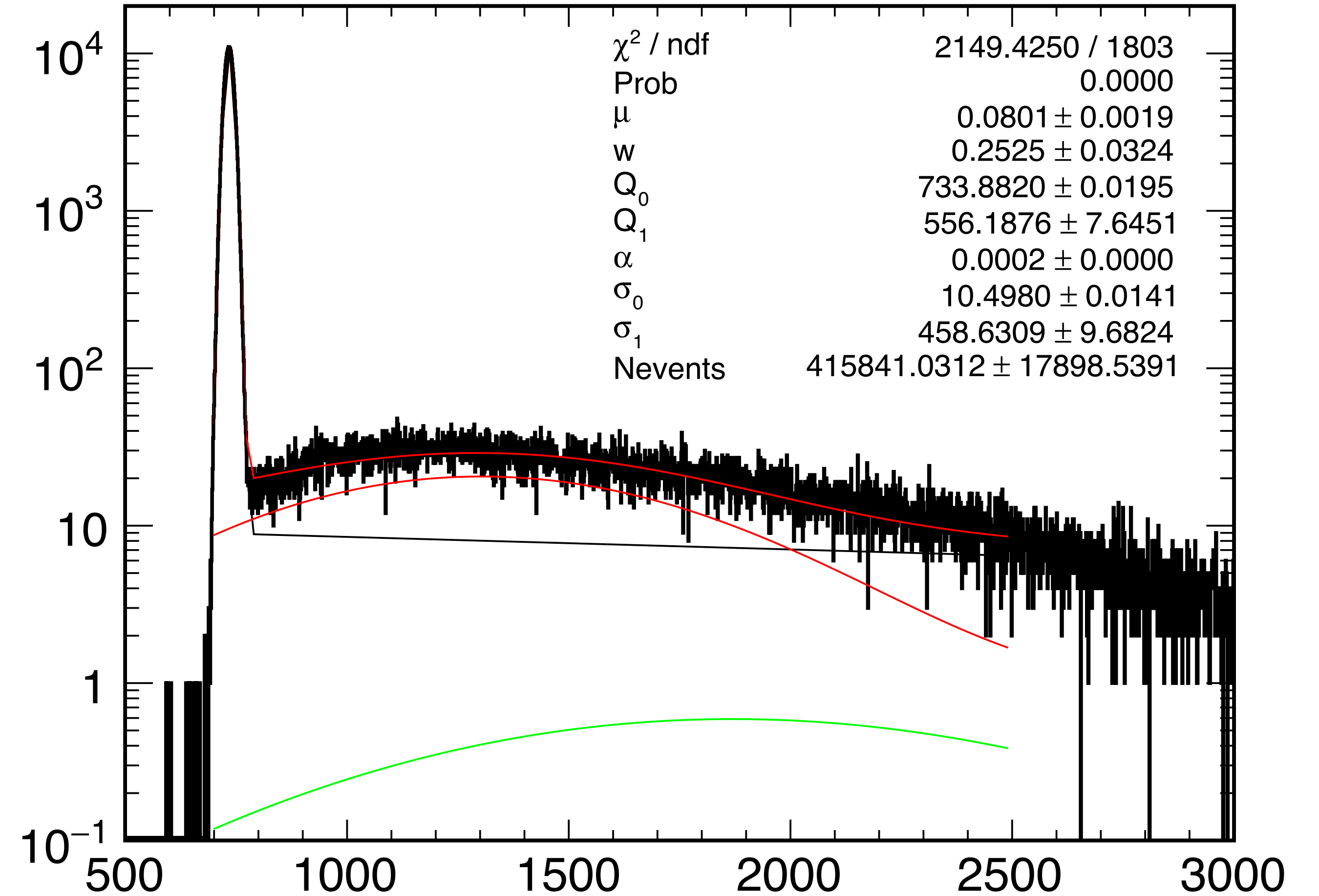
E.H. Bellamy et al. *Nucl. Instr. and Meth in Phys . Res. A* 339 (1994) 468-476

Method B: Example Fits, I_9

$\theta=0°$, $B=0.$ T

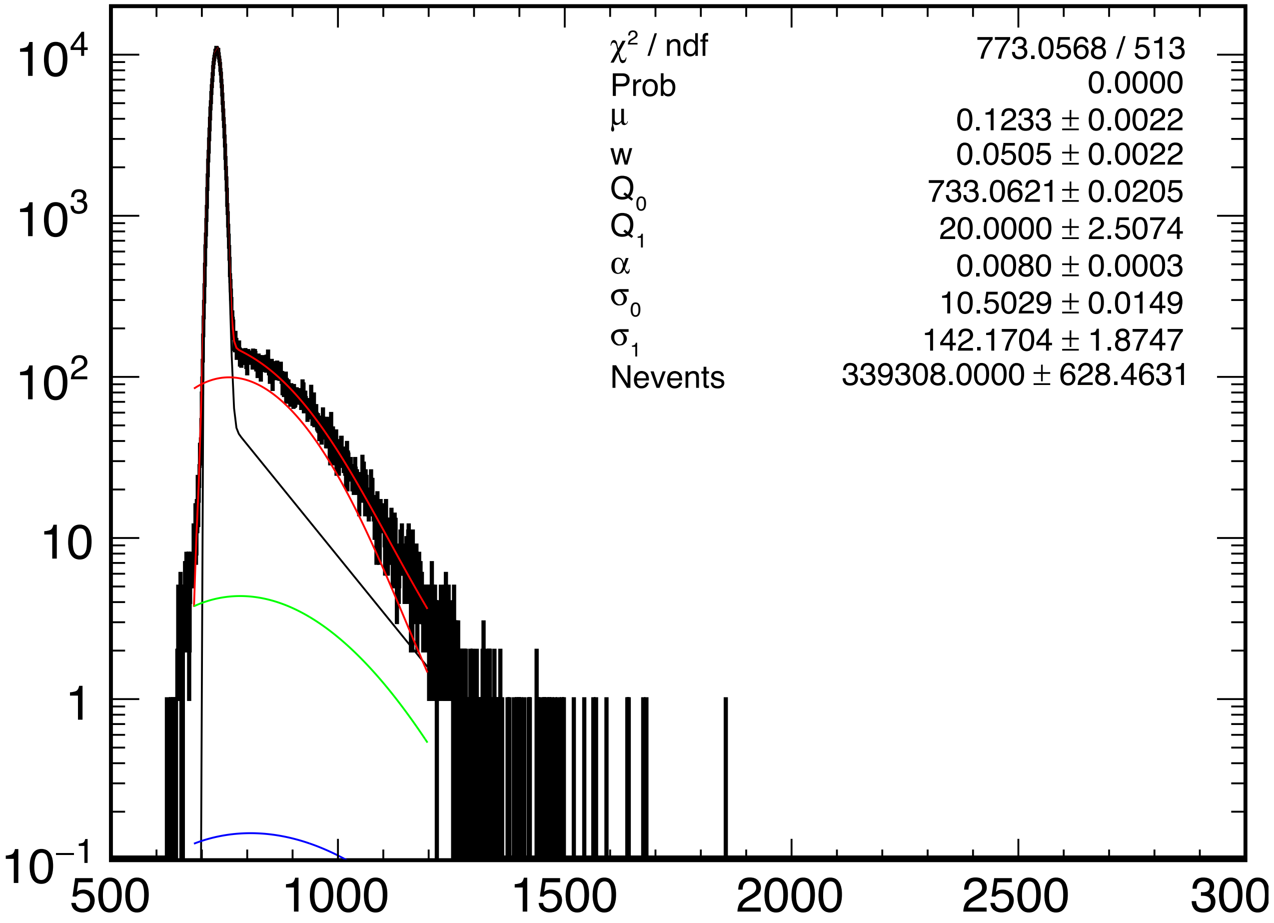


$\theta=0°$, $B=0.5$ T

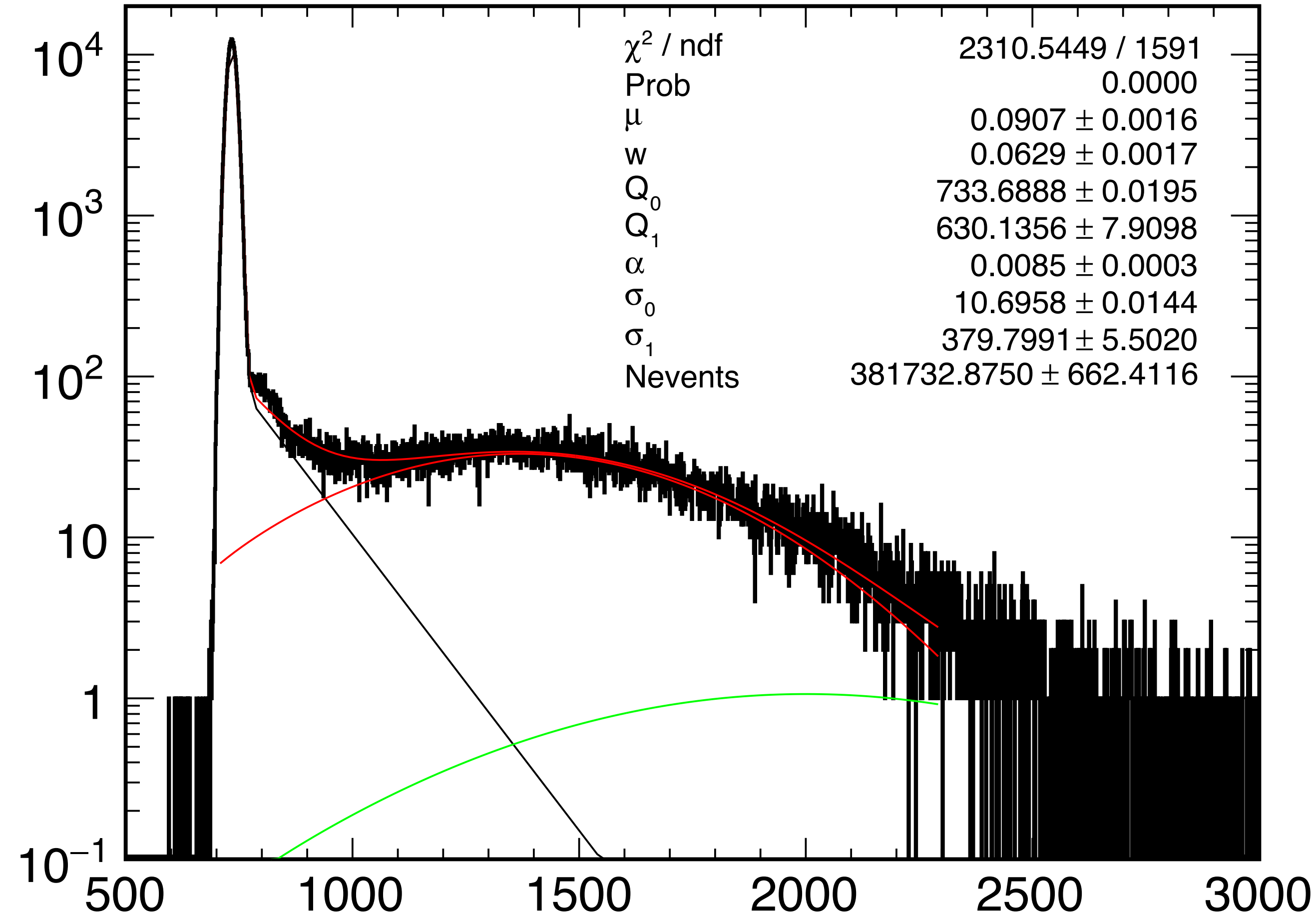


Method B: Example Fits, I_9

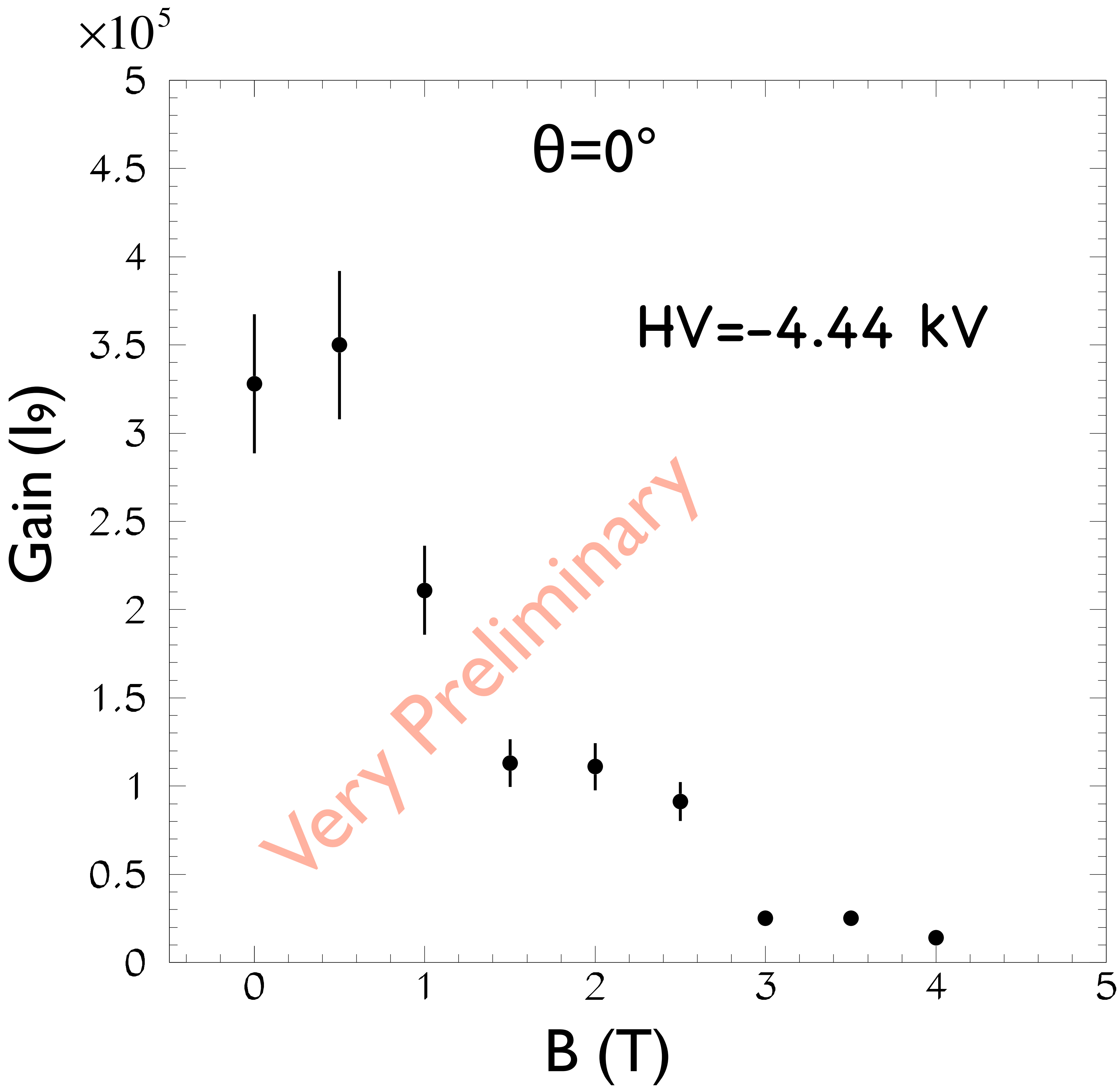
θ=0°, B=4. T, HV=-4.44 kV



θ=0°, B=4 T, HV=-4.76 kV



Method B: Gain Evaluation



- Photek PMT210
- 12% uncertainty shown: 7% due to variations in reproducibility of the same data point; 10% due to fit-response variability.
- maximum performance at 0.5 T reproduced
- about a factor of 20 decrease of signal between 0 T and 4 T

Summary

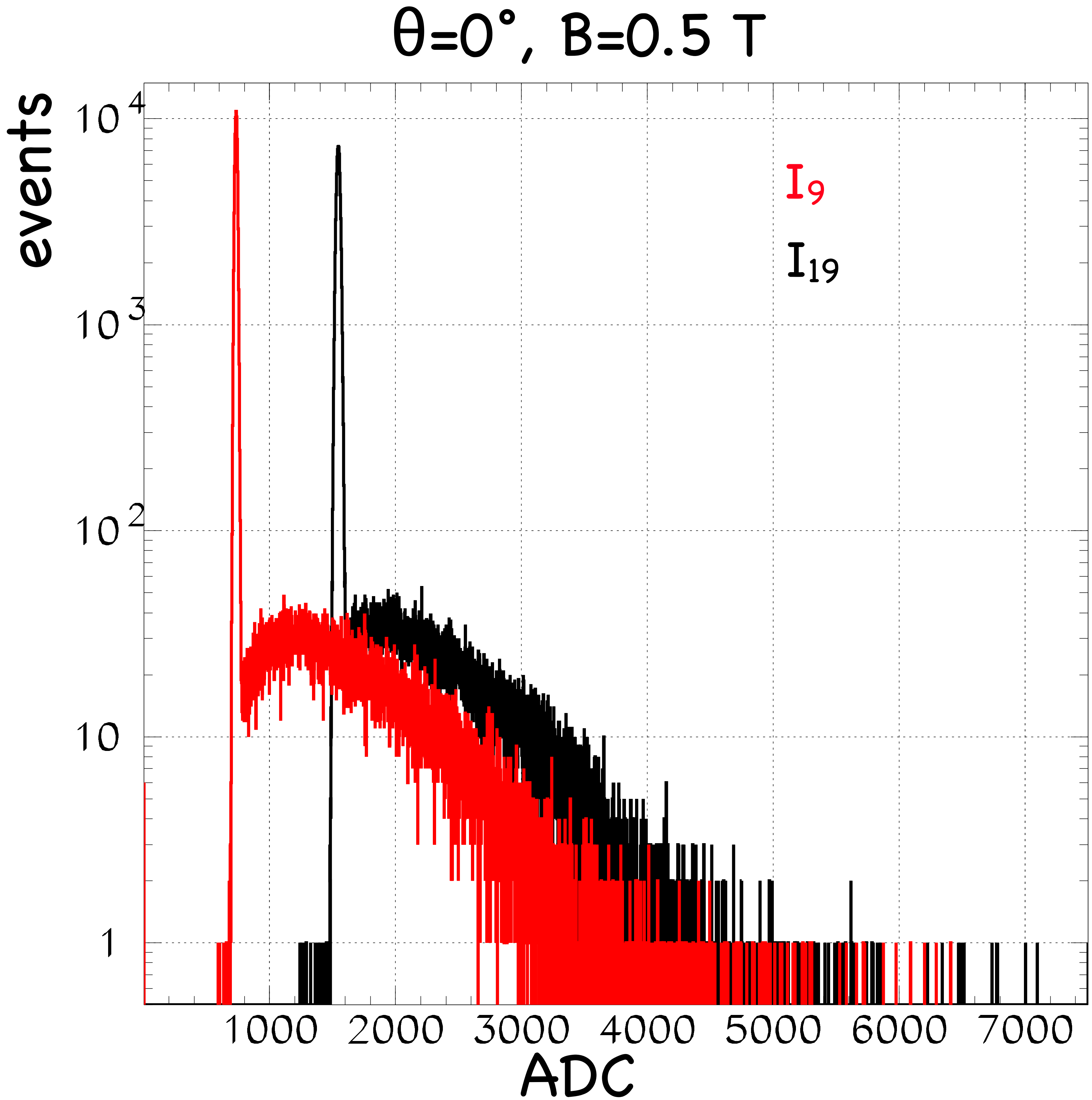
- Sensor Testing Facility Established: gain evaluation up to 5 T
- Rotational capabilities for small sensors
- Single-Anode sensors (Photek PMT 240 and 210, Photonis PP0365G) evaluated in 2014
  - Photek PMT210: excellent performance up to 5 T at θ=0°.
  - Photek PMT240: indication for magnetization effects
  - Photonis PP0365G: excellent performance up to 3 T
- First Measurements indicate that smaller-pore size sensors have better immunity to magnetic fields.

Current Status

- Strong Interest from Manufacturers
  - Follow-up measurements of PMT210: independent control of cathode—plate, across plates, and last-plate—anode HVs.
  - Planacon sensors (25 μm and 10 μm) on loan from Photonis.
- Downtime until July 2015
  - upgrade of dark-box endcaps (HV independent control)
  - implementation of a reference PMT (pulser monitor)
  - implementation of QDC (alternative means for charge integration)
  - replacement of HV units

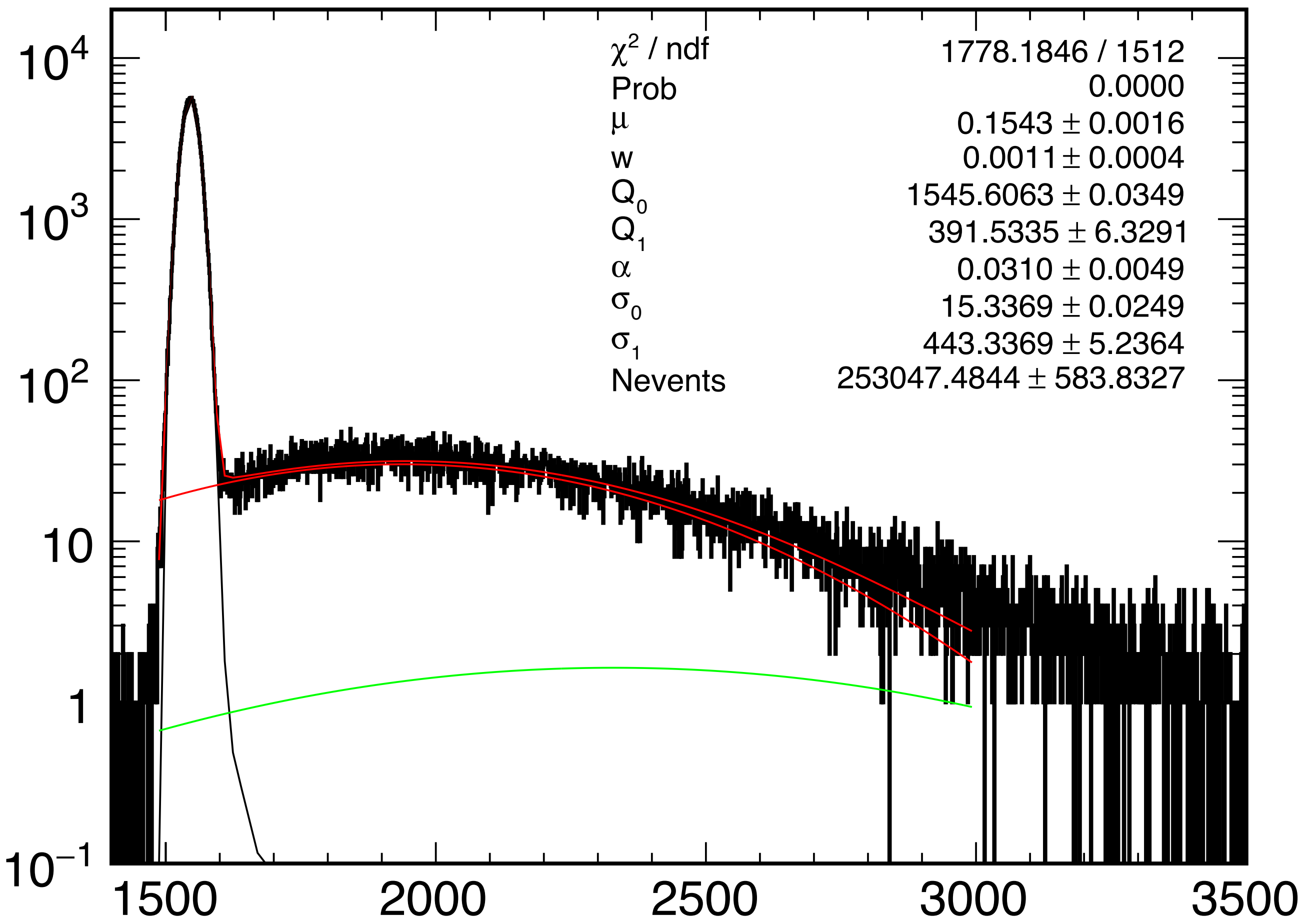
The END

Method B: I_9 and I_{19}



Method B: Example Fits, I_{19}

θ=0°, B=0. T



θ=0°, B=0.5 T