High-B Facility Update

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EIC PID Workshop, 9 - 10 July 2019

Photon Sensor Parameters for EIC PID Cherenkov Detectors

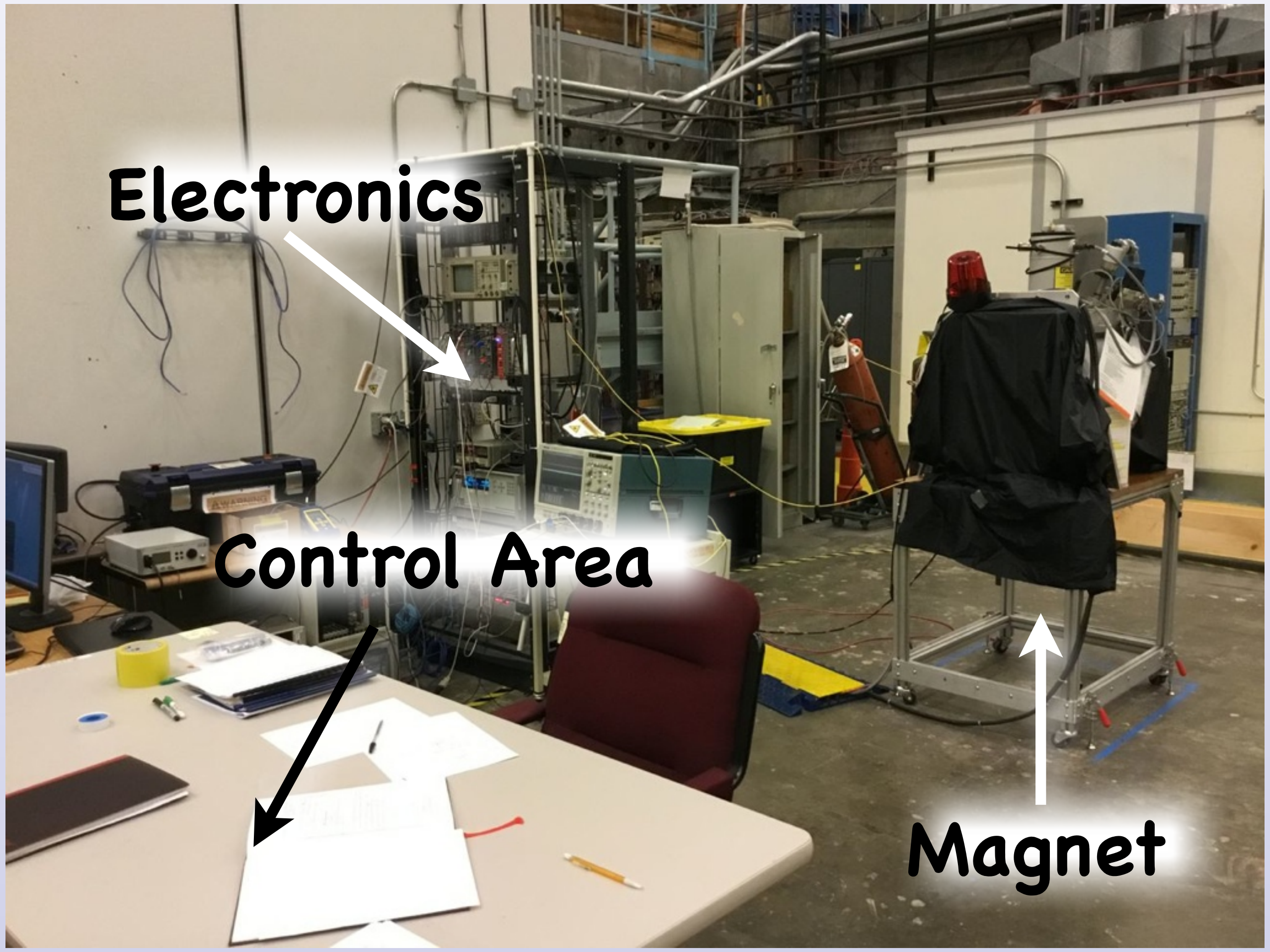
Parameter	DIRC	mRICH	dRICH
Gain	~10^6	~10^6	~10^6
Timing Resolution	≤ 100 ps	≤ 800 ps	≤ 800 ps
Pixel Size	2–3 mm	≤3 mm	≤ 3 mm
Dark Noise	≤ 1kHz/cm^2	≤ 5MHz/cm^2	≤ 5MHz/cm^2
Radiation Hardness	Yes[14]	Yes[14]	Yes[14]
Single-photon mode operation?	Yes	Yes	Yes
Magnetic-field immunity?	Yes (1.5–3 T)	Yes (1.5–3 T)	Yes (1.5–3 T)
Photon Detection Efficiency	≥ 20%	≥ 20%	≥ 20%

Goals

- to identify the limitations of current MCP-PMT design and operational parameters for High-B operations;
- tentative: to achieve optimization of these for successful application in DIRC in the high magnetic field of the central detector at EIC.

Facility Capabilities

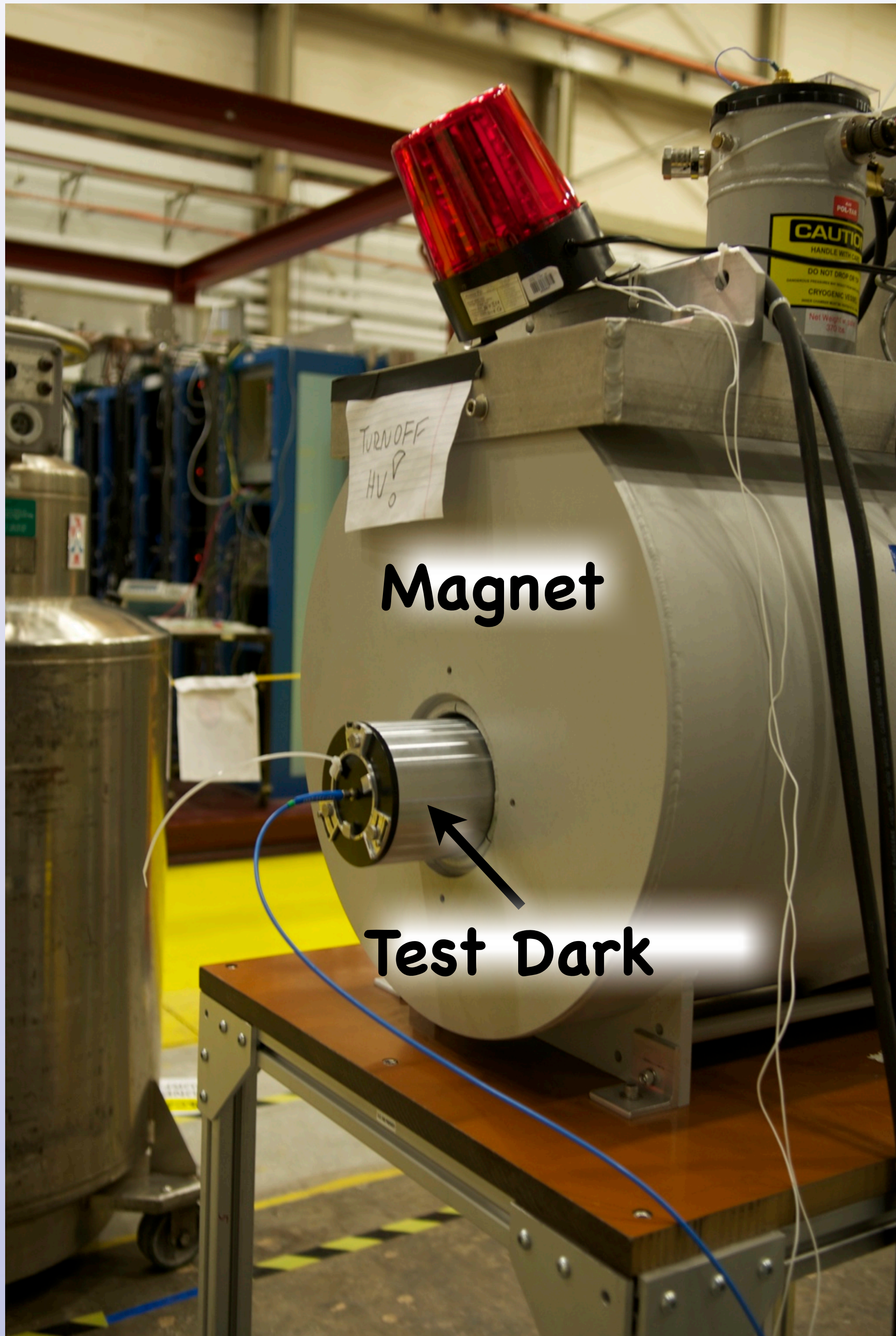
Overview



- Purpose: Evaluation of small-PMT gain, efficiency and timing resolution in B fields
- Commissioned in July/August 2014
- Data taking: November 2014
- People: SB: P. Nadel-Turonski, JLab: C. Zorn, J. McKisson; CU: G. Kalicy, USC: Y. Ilieva, E. Bringley, C. Barber, J. Rapoport, A. Rowland, B. Tumeo; UNH: T. Cao, IU: C.

Facility Capabilities

Major Components



Magnet:

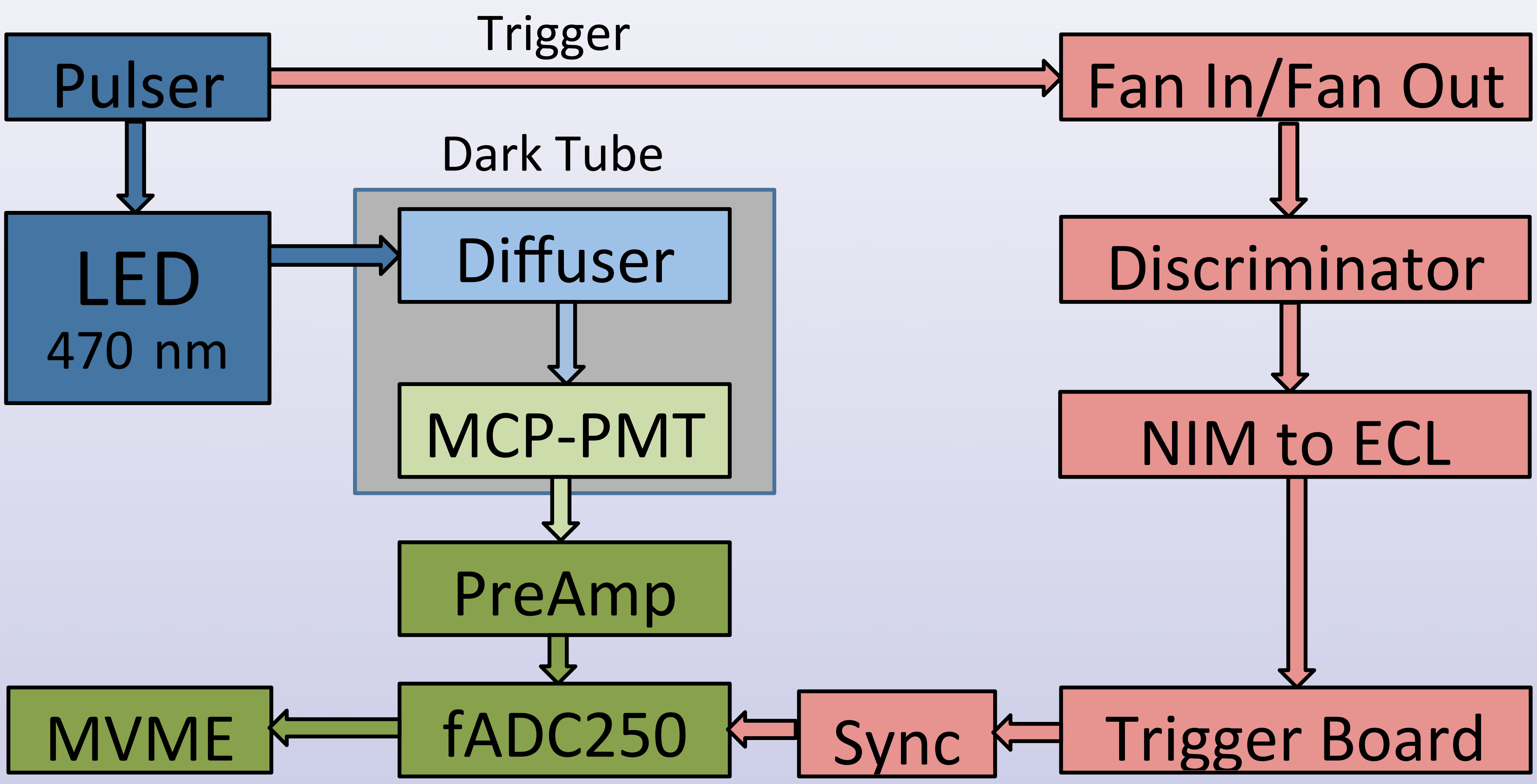
- superconducting solenoid
- max. field: 5.1 T at 82.8 A
- 12.7-cm (5-inch) diameter warm bore
- length of bore: 76.2 cm (30 inch)
- central field inhomogeneity: $\leq 5\times10^{-5}$ over a cylindrical volume of a diameter of 1.5 cm and length of 5 cm

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, 470 nm

Facility Capabilities

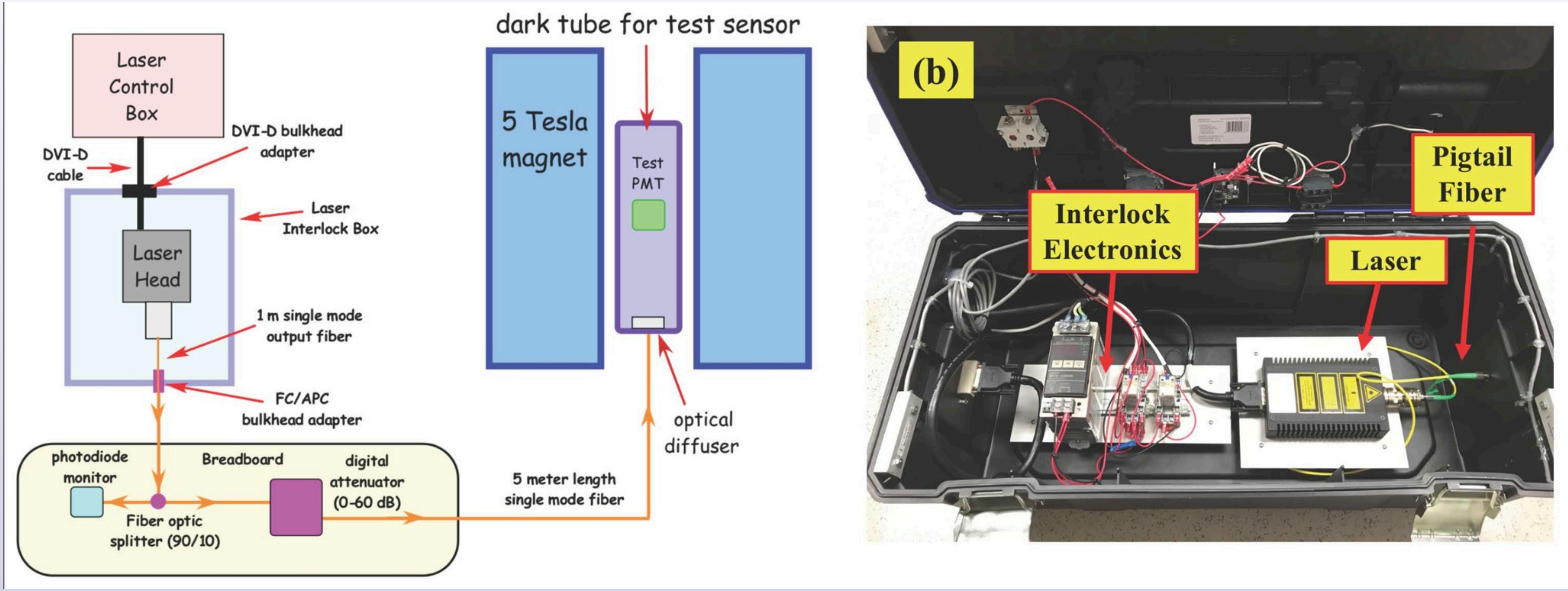
Major components



19.1 ± 0.2 fC/ADCch

Facility Capabilities

Major components



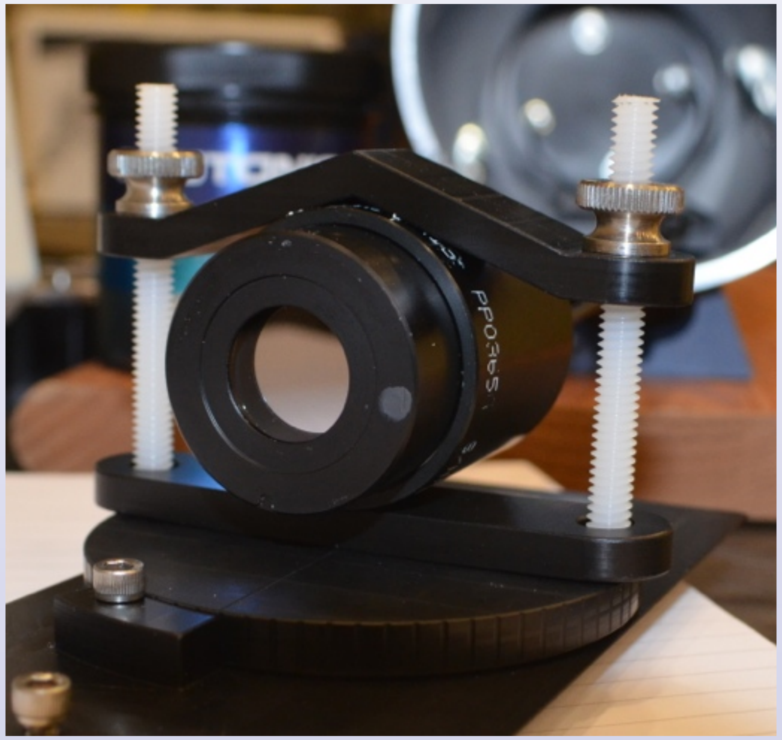
A **picosecond laser** added in **Summer 2018** (procured by ODU)

Laser setup (JLab Detector Group)

Laser safety system (JLab electronics Group)

Gain Characterization of Single-Anode MCP PMTs

Photonis PP0365G

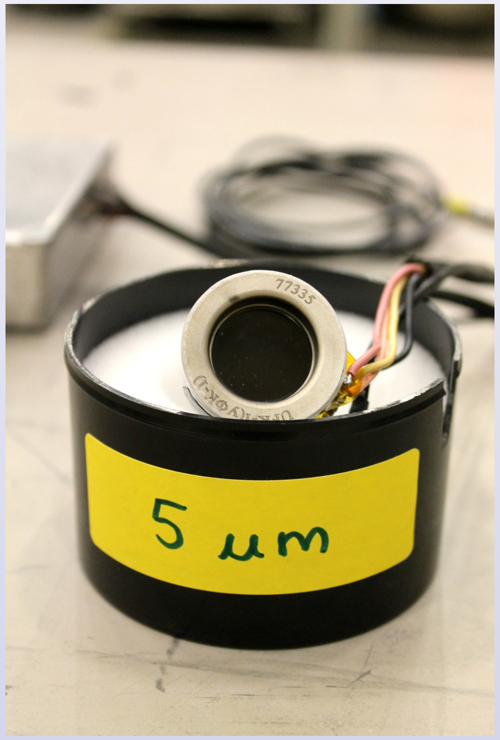


pore size: 6 μm
max. gain: ~10^5
QE: 18% at 470 nm

Photek PMT210, PMT240

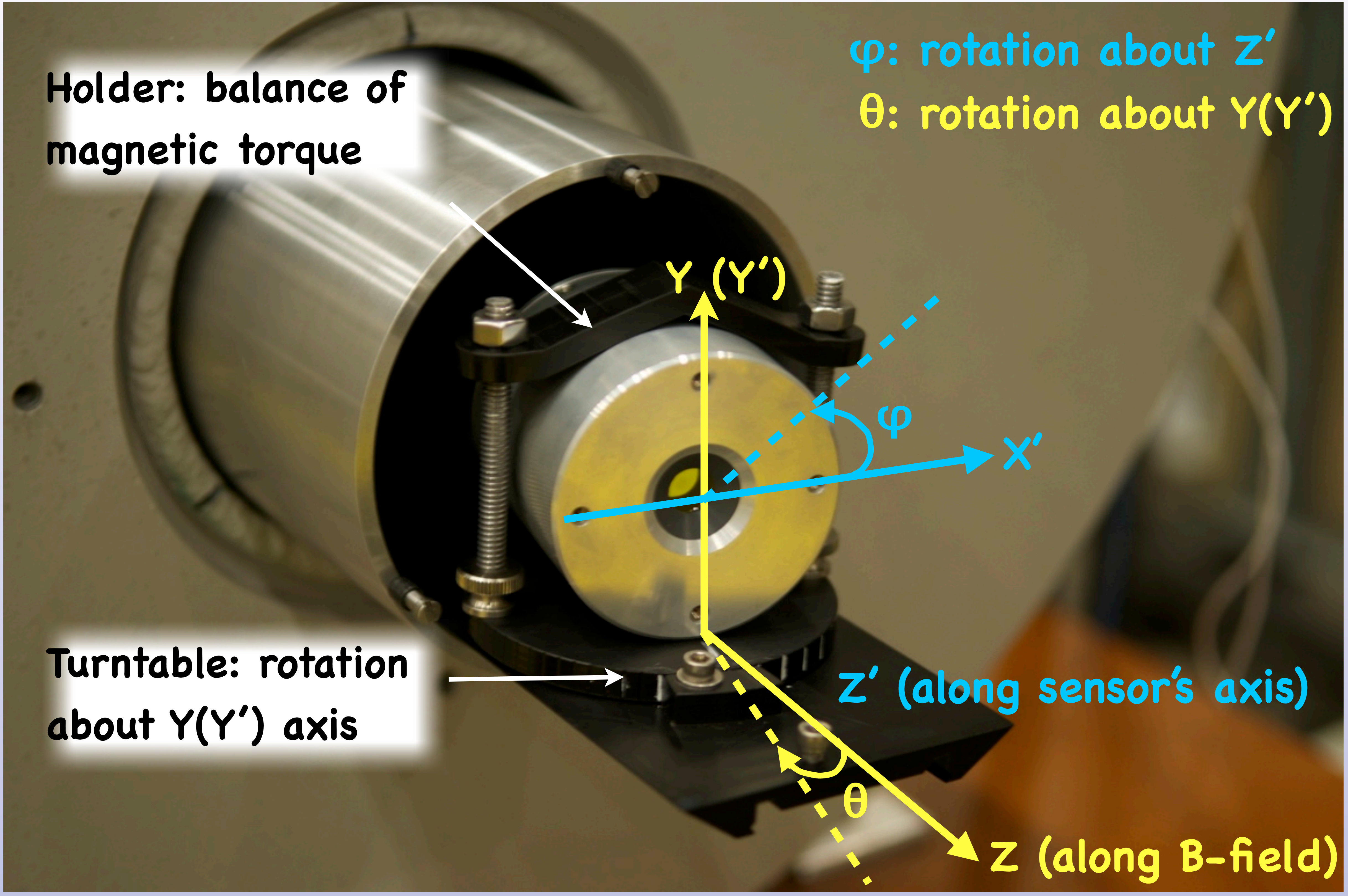
pore size: 3 μm, 10 μm
max. gain: 10^6
QE: 15% at 470 nm

Katod



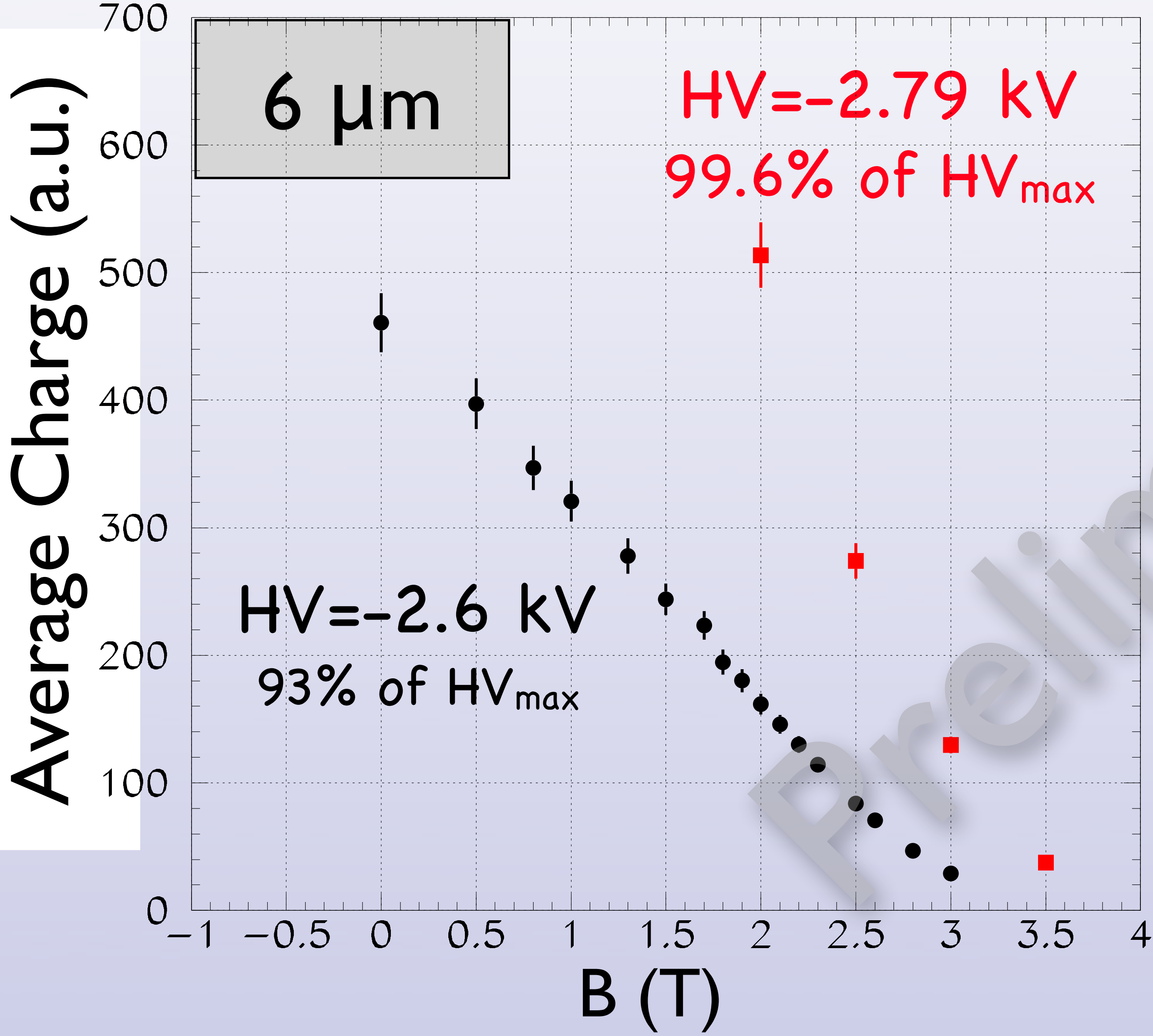
pore size: 3 μm, 5 μm
gain: 10^6
QE: 20%

Sensor Orientation Capabilities

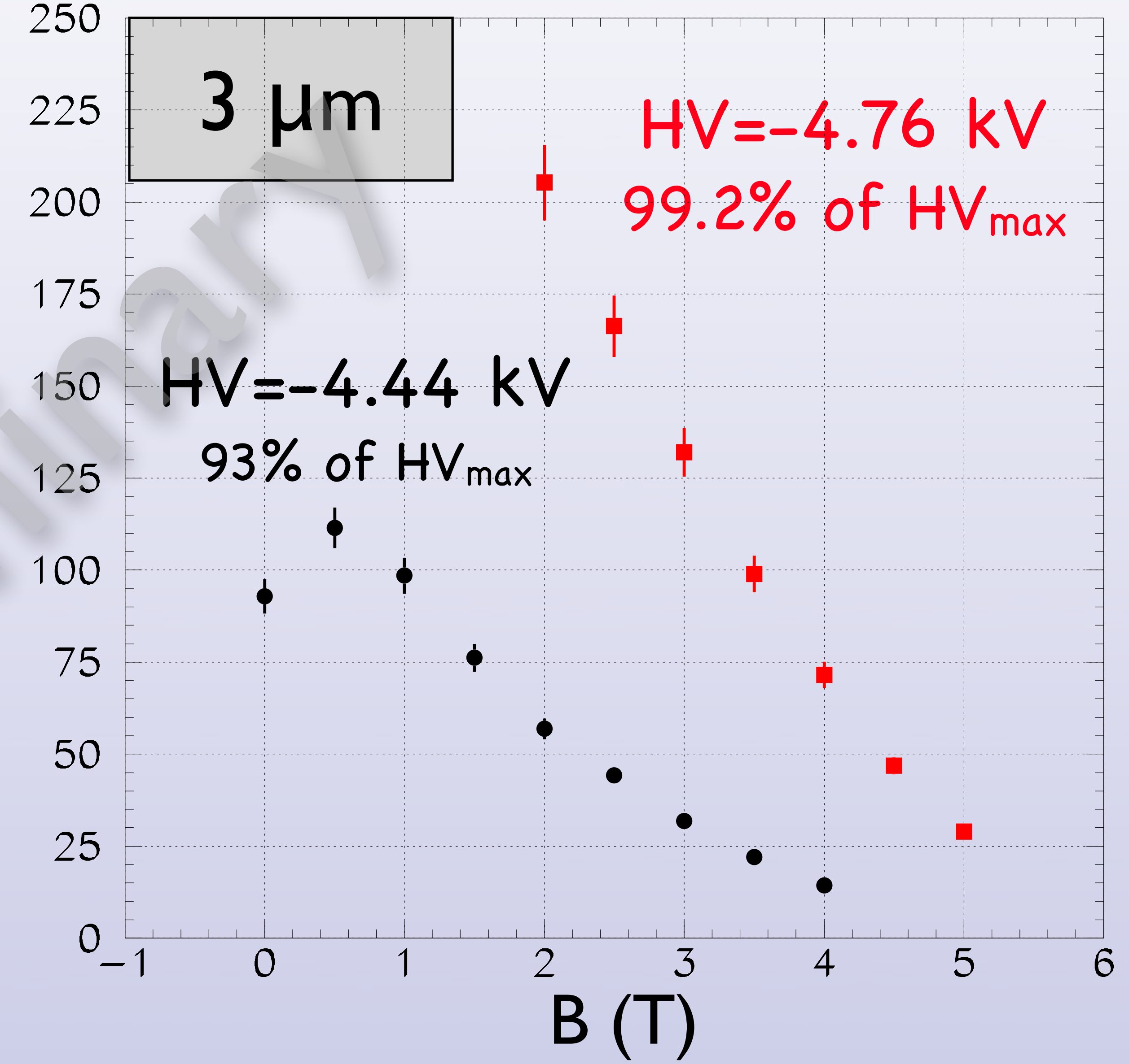


Gain Characterization of Single-Anode MCP PMTs

Results at 0 deg



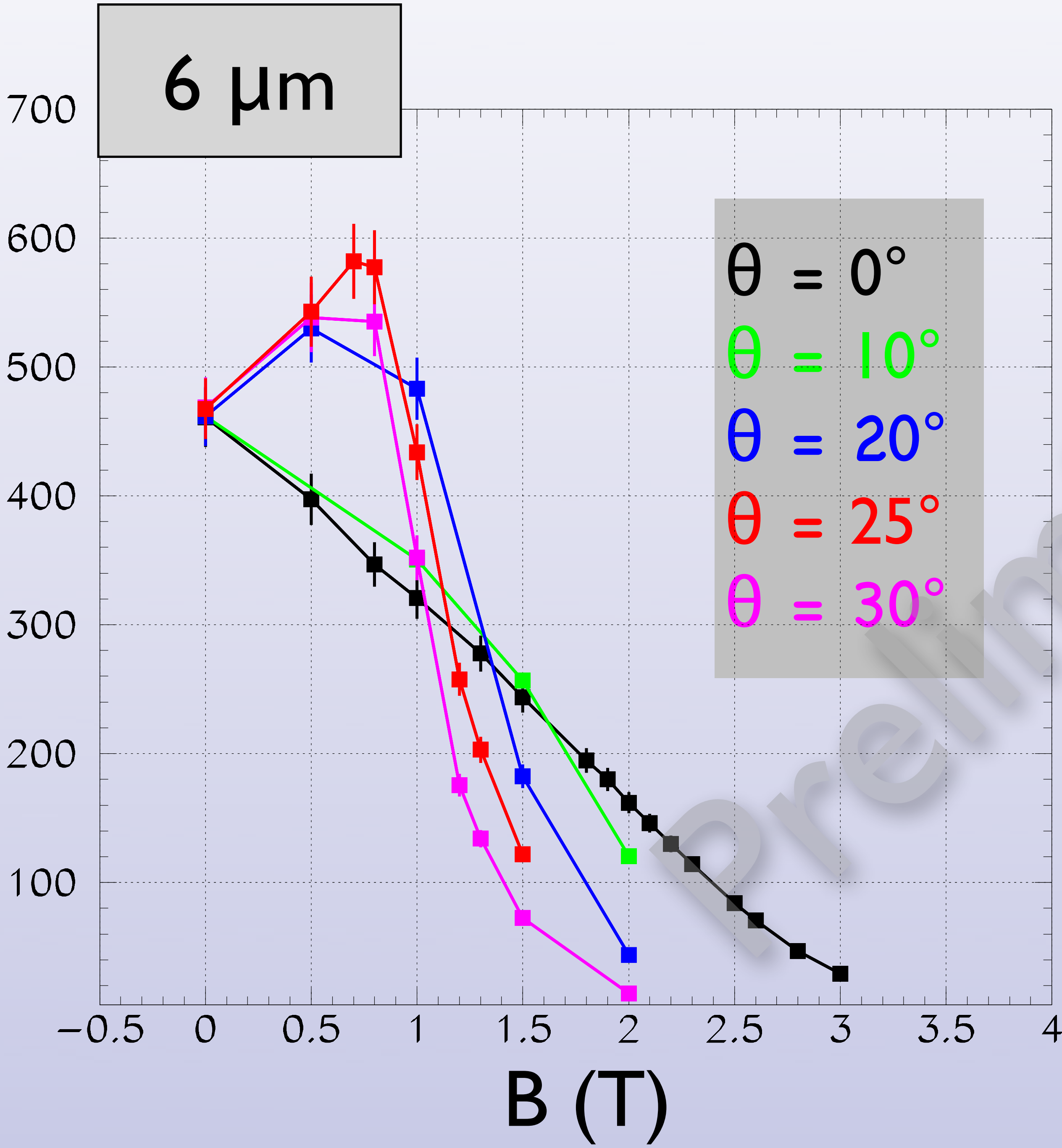
- about a factor of 15 decrease of signal between 0 T and 3 T (-2.6 kV)
- 5% preliminary uncertainty

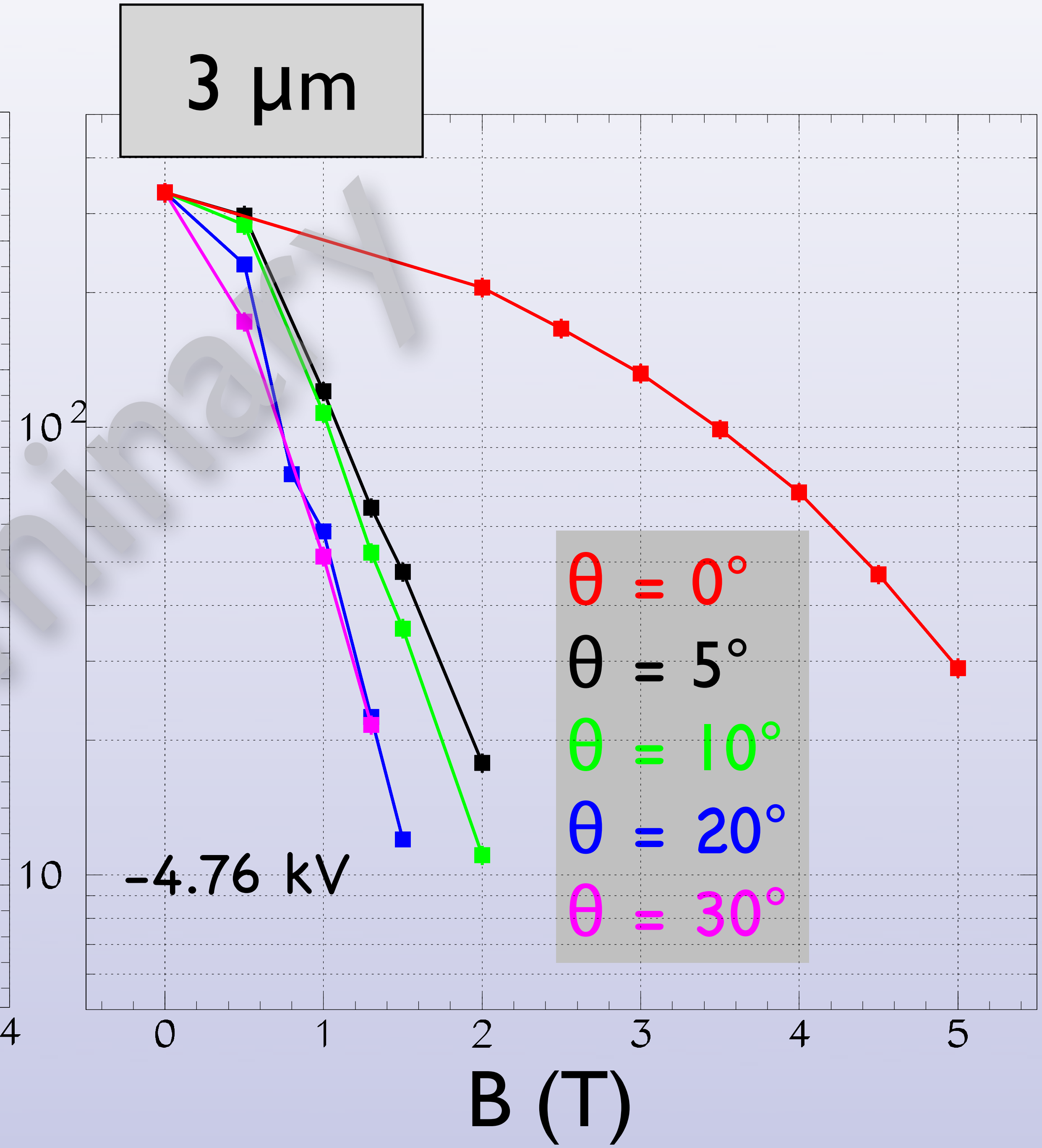


- about a factor of 6 decrease of signal between 0 T and 4 T (-4.44 kV)
- 5% preliminary uncertainty

Gain Characterization of Single-Anode MCP PMTs

Results at other angles

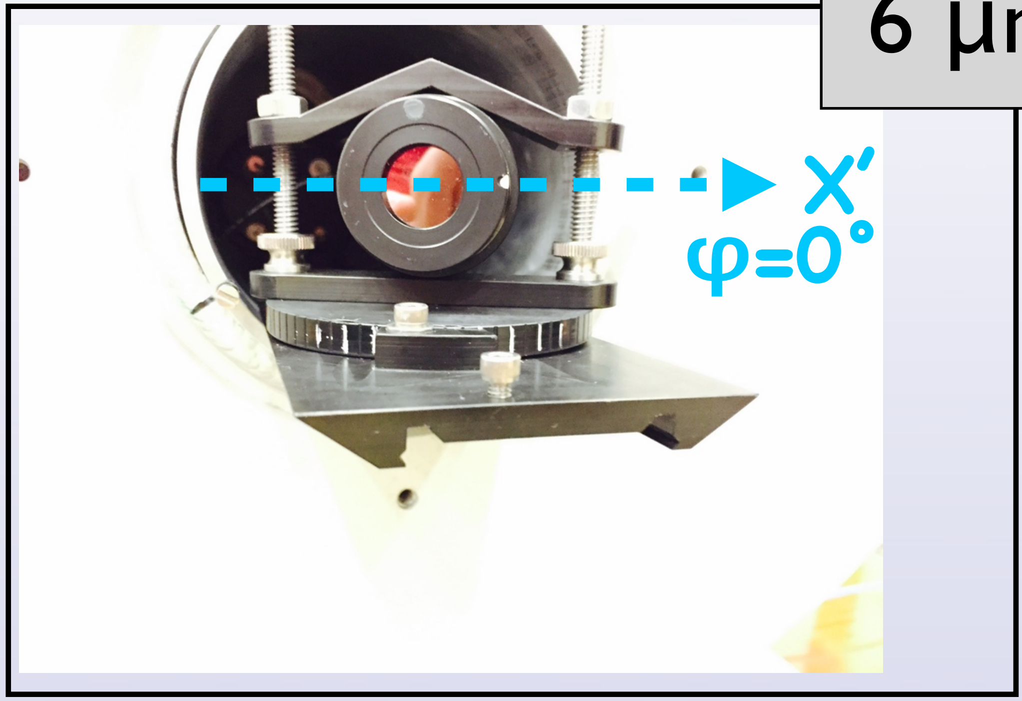


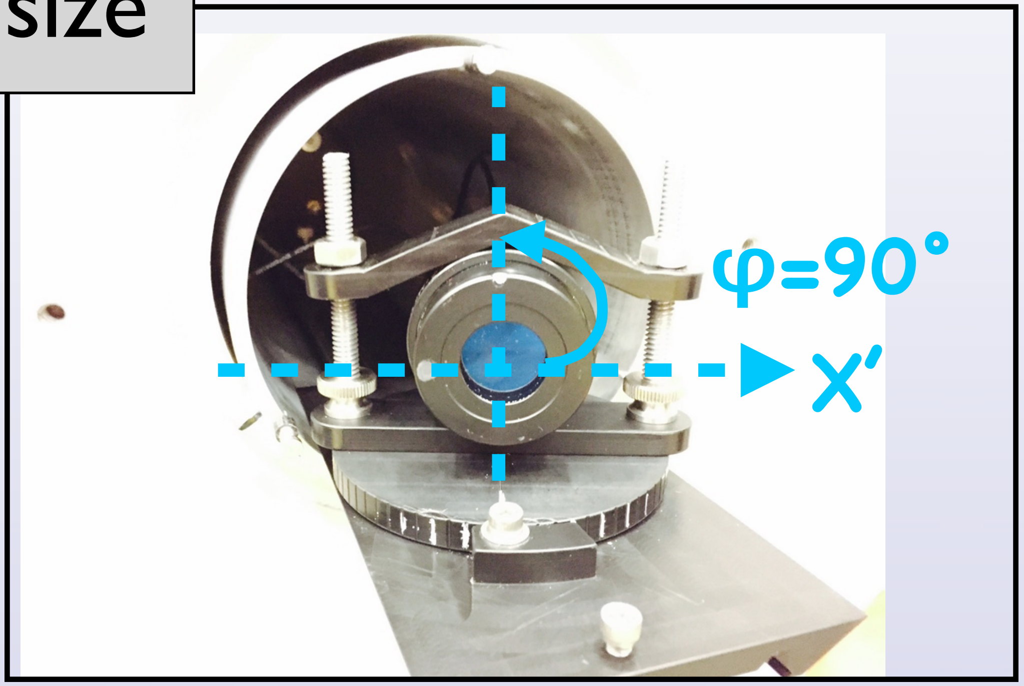


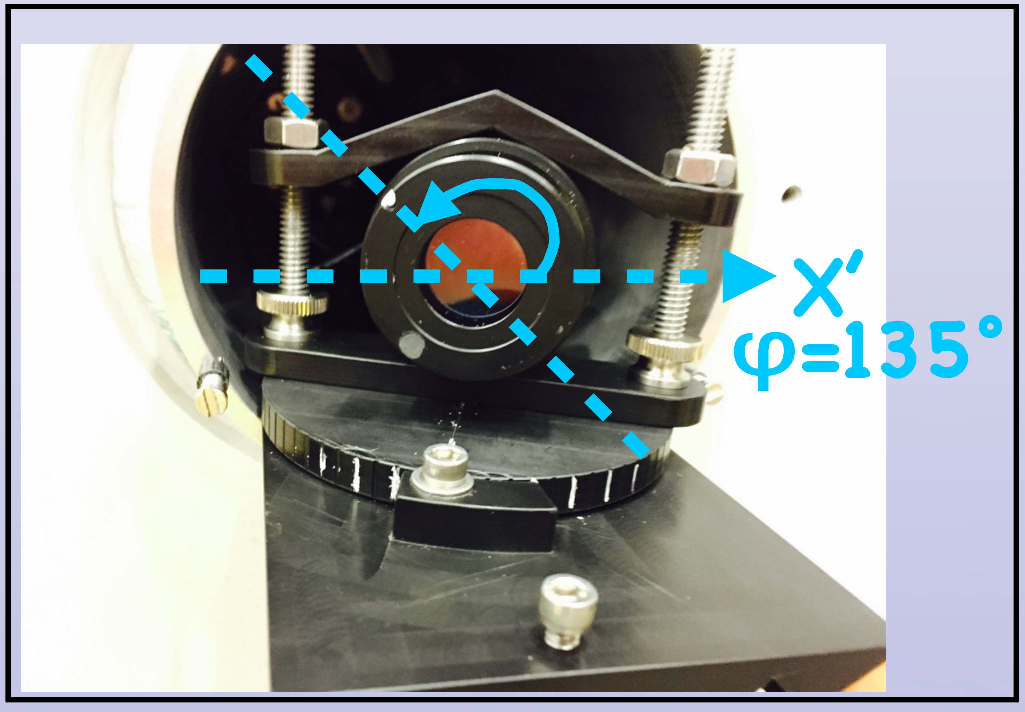
Gain Characterization of Single-Anode MCP PMTs

Studies of Azimuthal Angle Dependence

6 µm pore size

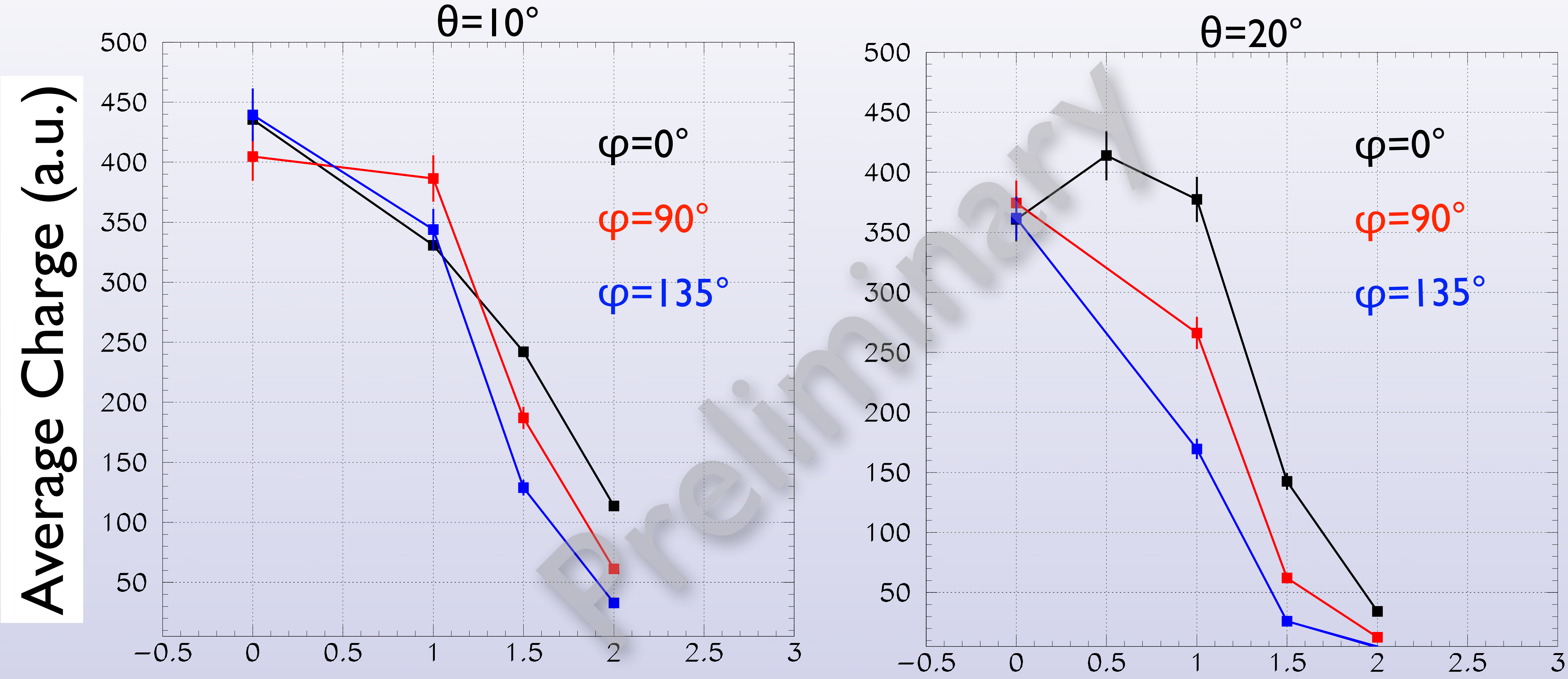






Gain Characterization of Single-Anode MCP PMTs

Studies of Azimuthal Angle Dependence



- operating voltage: -2.6 kV
- no normalization applied
- overall data suggest that the total collected charge depends on the φ angle, especially above 1 T
- the φ dependence is strongly correlated with θ

Gain Characterization of Single-Anode MCP PMTs

Overview

- Smaller pore size yields better gain performance in B-fields

  3 μm: about a factor of 6 decrease of signal from 0 T to 4 T.

  - 6 μm: about a factor of 15 decrease of signal from 0 T to 3 T.

- B-field gain performance varies among different types of sensors

  Shape of gain B-field dependence at various polar angles strongly depends on the sensor.

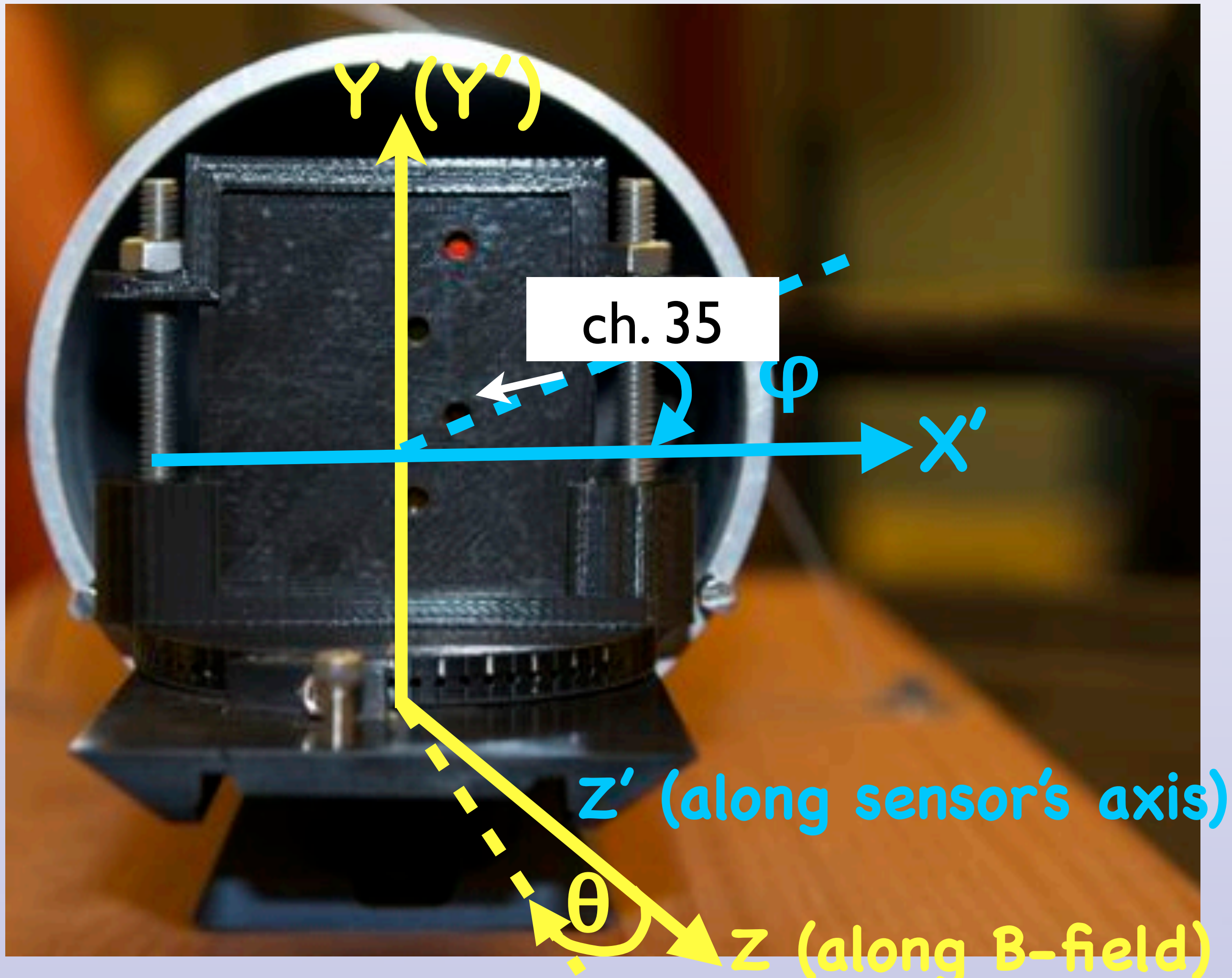
  Azimuthal dependence strongly correlated with polar angle.

  Overall, reasonable performance up to 2 T.

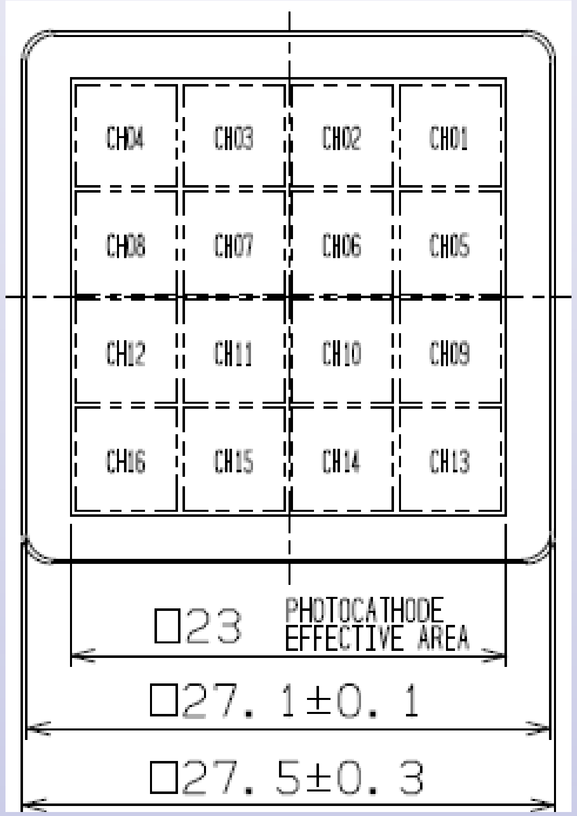
- Design optimizations needed if the orientation of the sensors relative to the field varies significantly.

Gain Characterization of Multi-Anode MCP PMTs

Photonis XP85112, 10 μm pore size



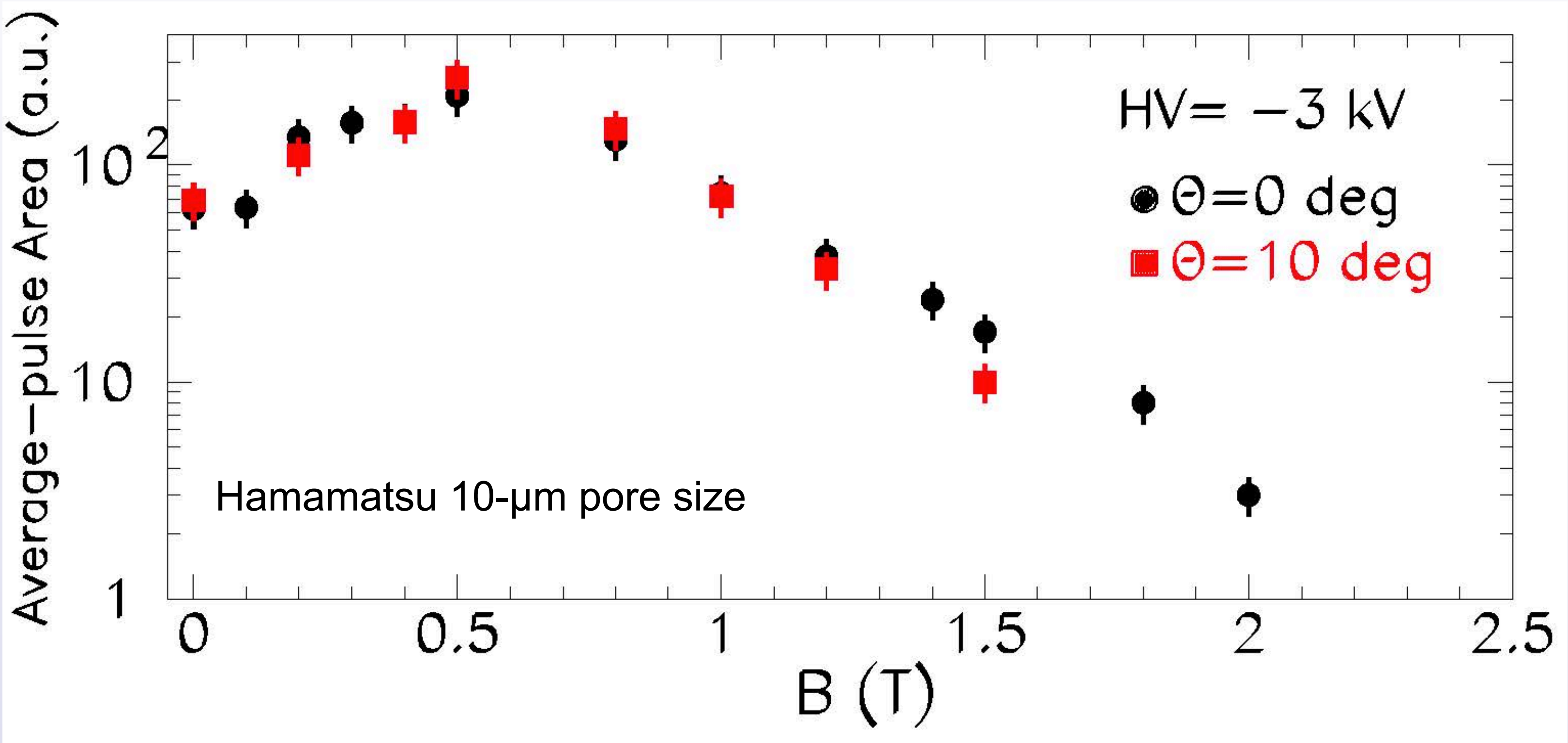
Hamamatsu R10754-07-M16X 10 μm pore size

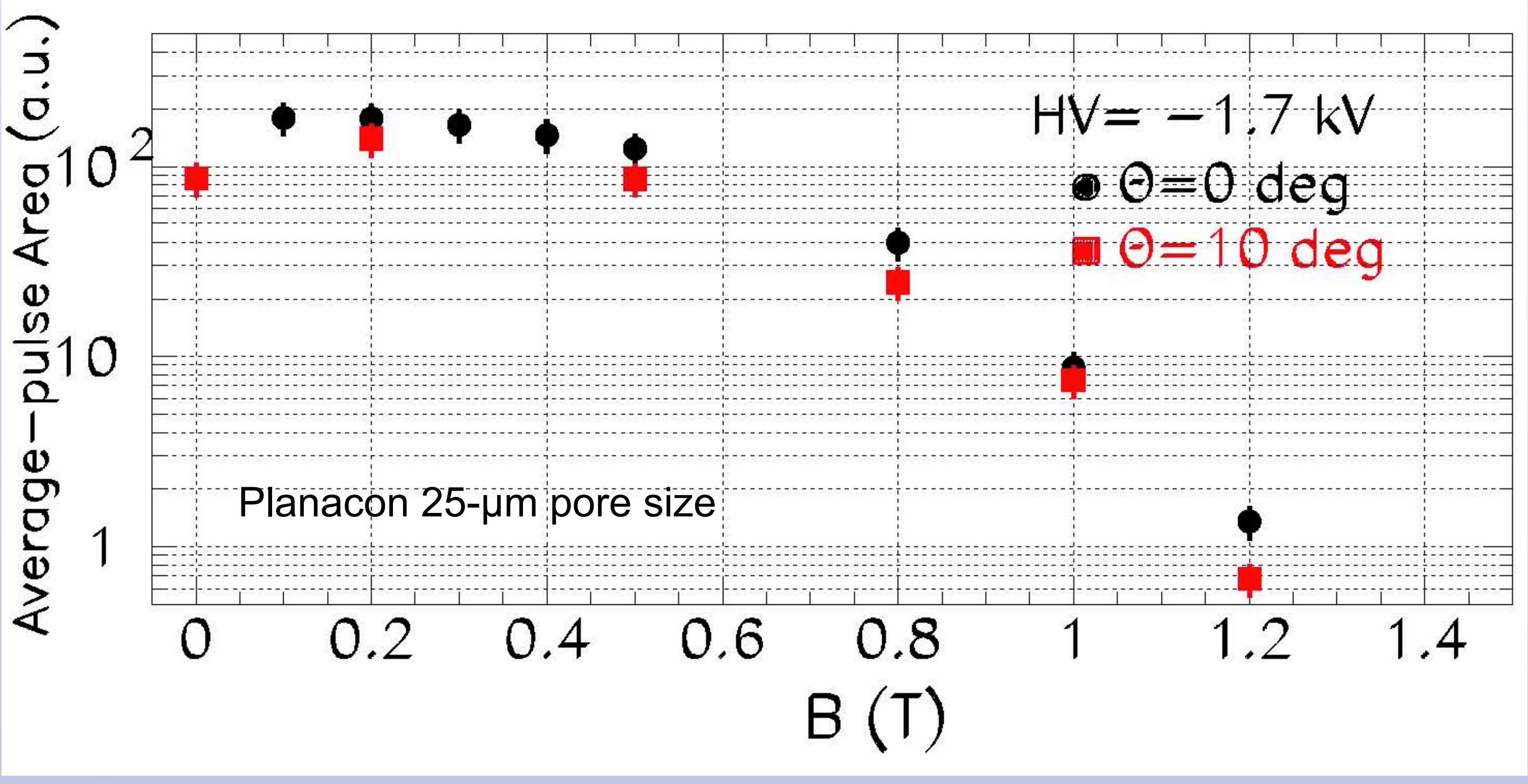


Photonis XP85012, 25 μm pore size

Gain Characterization of Multi-Anode MCP PMTs

Results



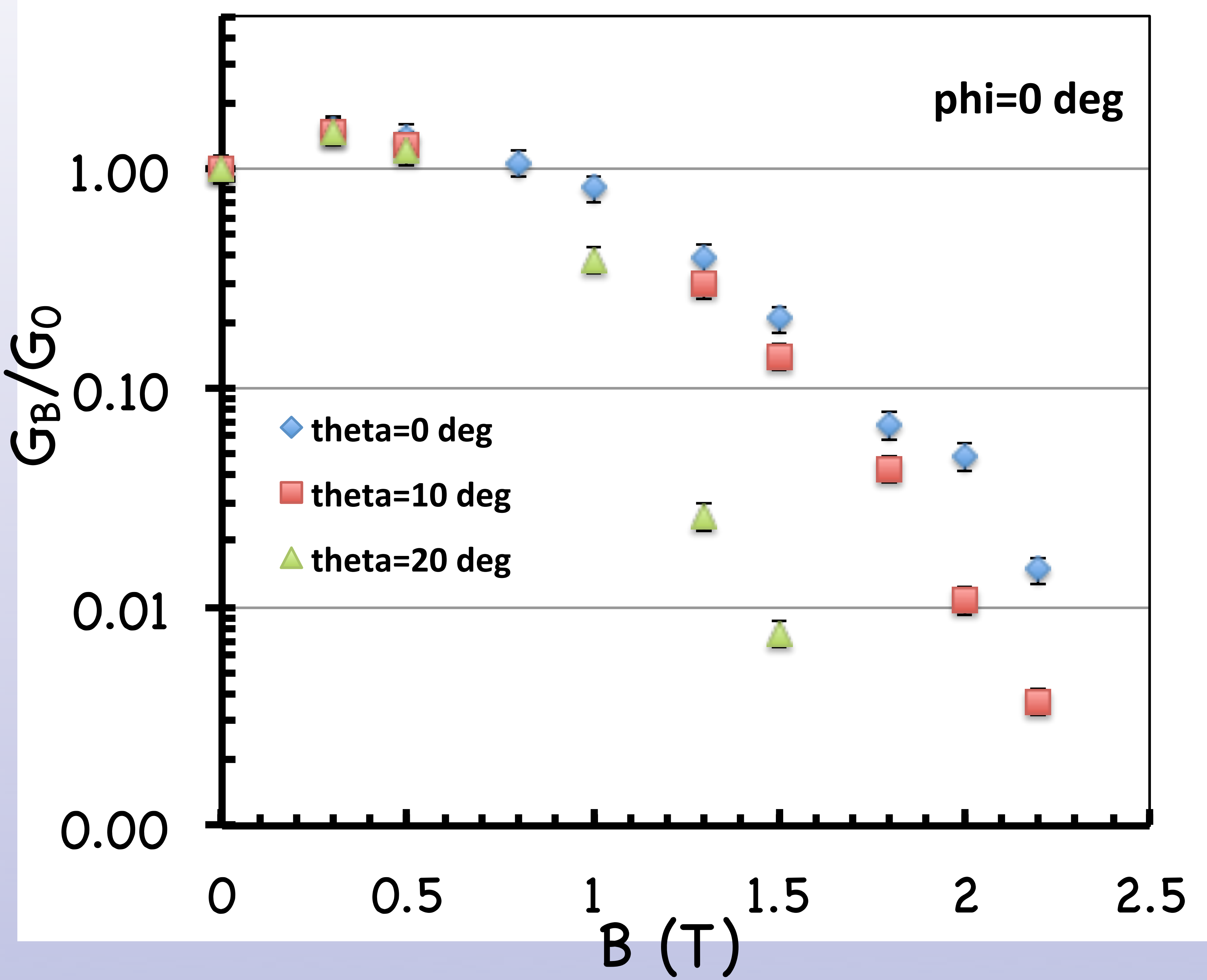


- Measurements performed at 96% of maximum allowed high voltage.
- 10-μm sensor
  - Can be operated up to about 2 T at standard orientation.
  - Can be operated up to about 1.5 T at larger angles.
- 25-μm sensor
  - At both orientations sensor can be operated up to about 1.2 T
  - Main objective of measurements is to negotiate 10-μm sensor on loan from Photonis.

Gain Characterization of Multi-Anode MCP PMTs

Results

Photonis XP85112



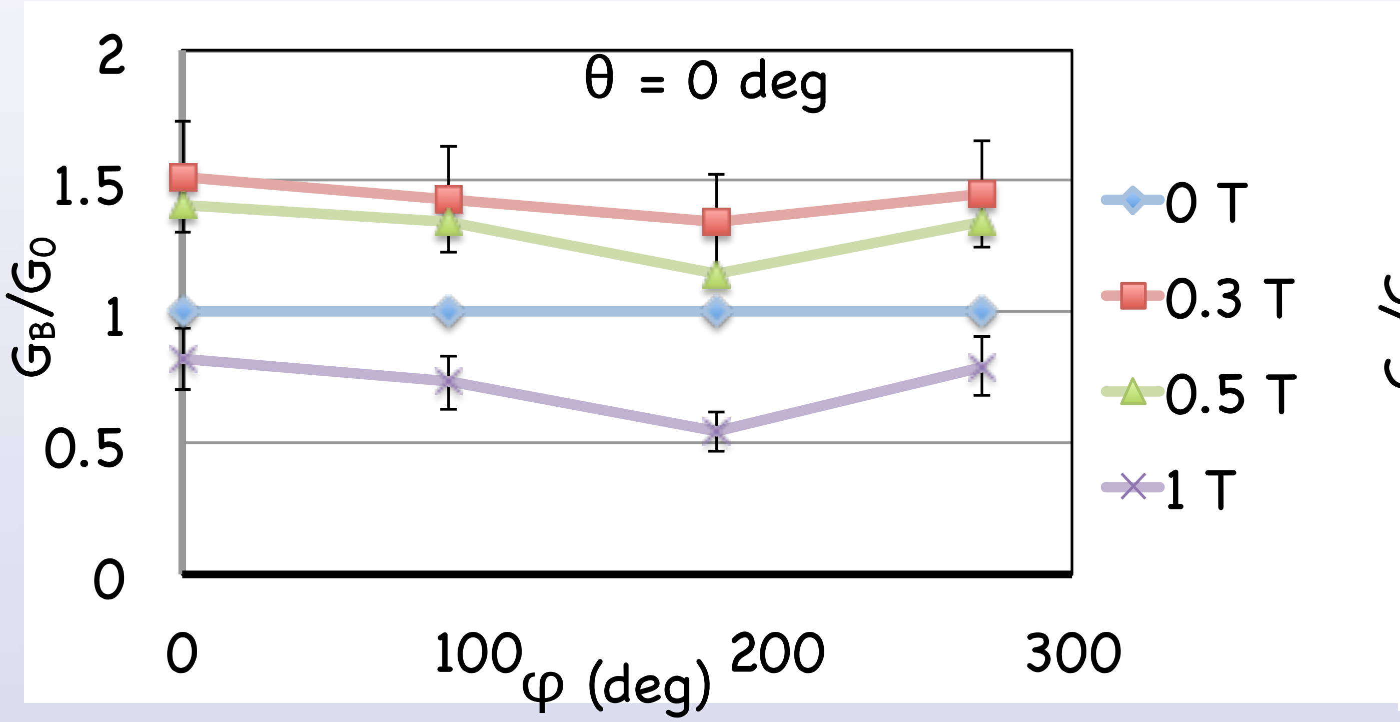
- Measurements performed at 96% of maximum allowed high voltage.
- Data
  - Maximum gain at 0.3 T.
  - B_{max} = 2.2 T.
  - Value of B_{max} strongly depends on orientation.
  - The larger the polar angle, the lower B_{max}.

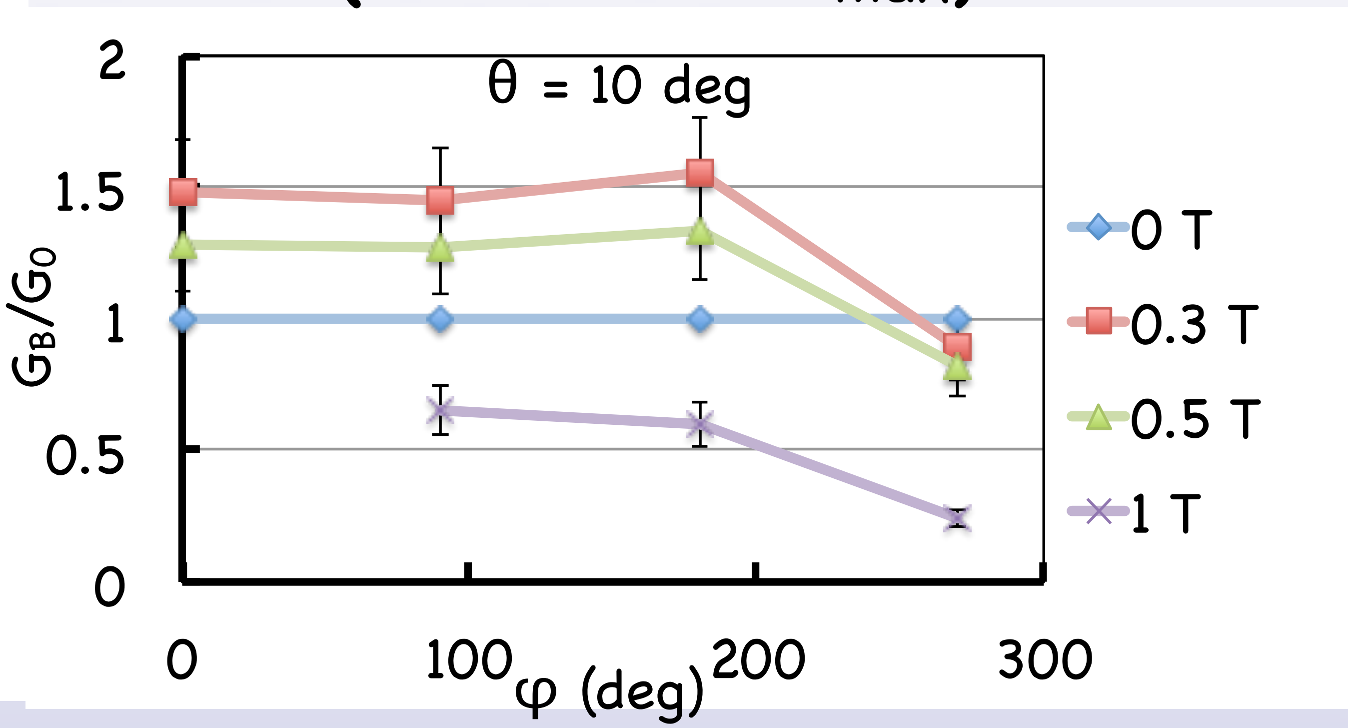
Gain Characterization of Multi-Anode MCP PMTs

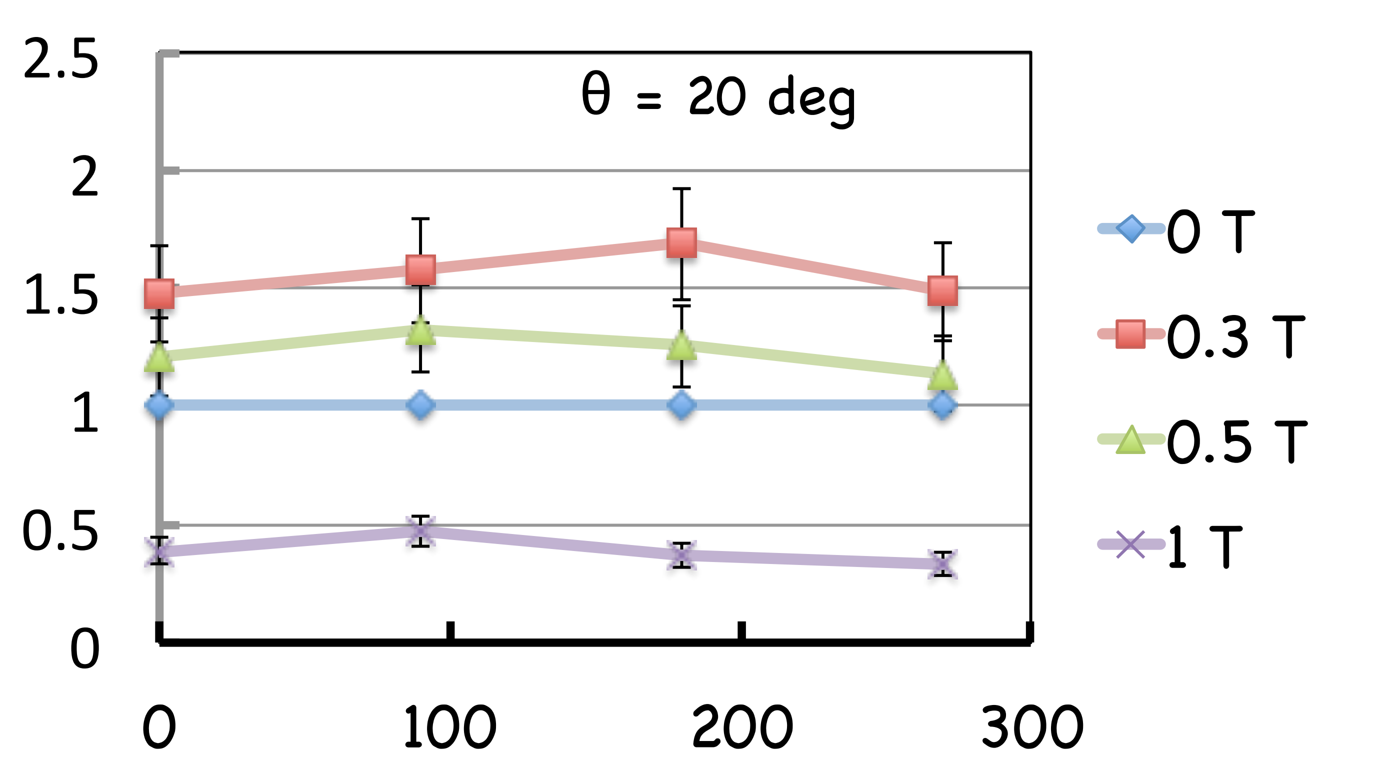
Results

Photonis XP85112

HV=-2.7 kV (96% of HV_{max})





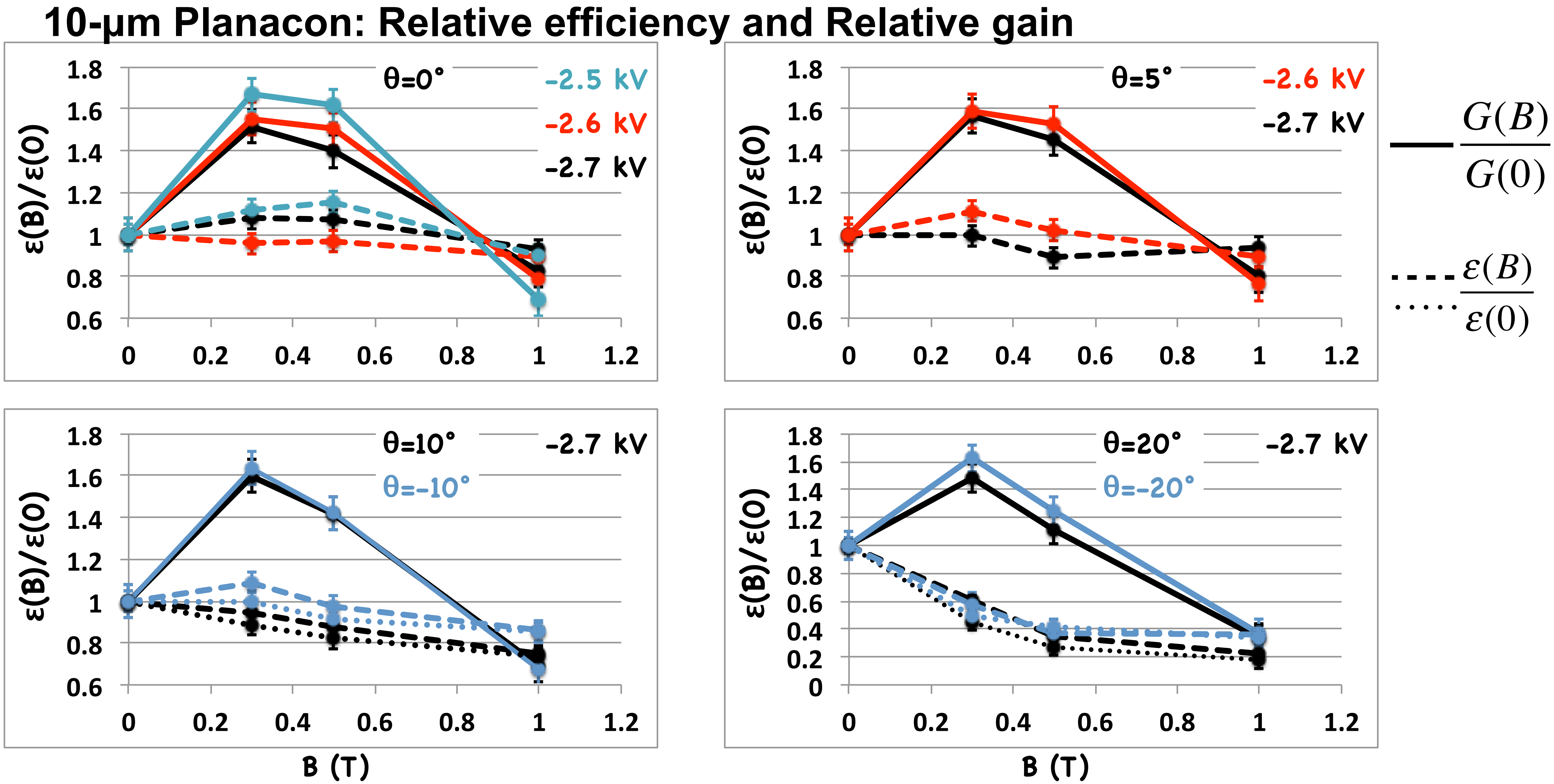


Azimuthal-angle dependence is correlated with the polar angle

- θ = 0° – minimum at φ = 180°
- θ = 10° – minimum at φ = 270°
- θ = 20° – no characteristic features

Gain Characterization of Multi-Anode MCP PMTs

Results

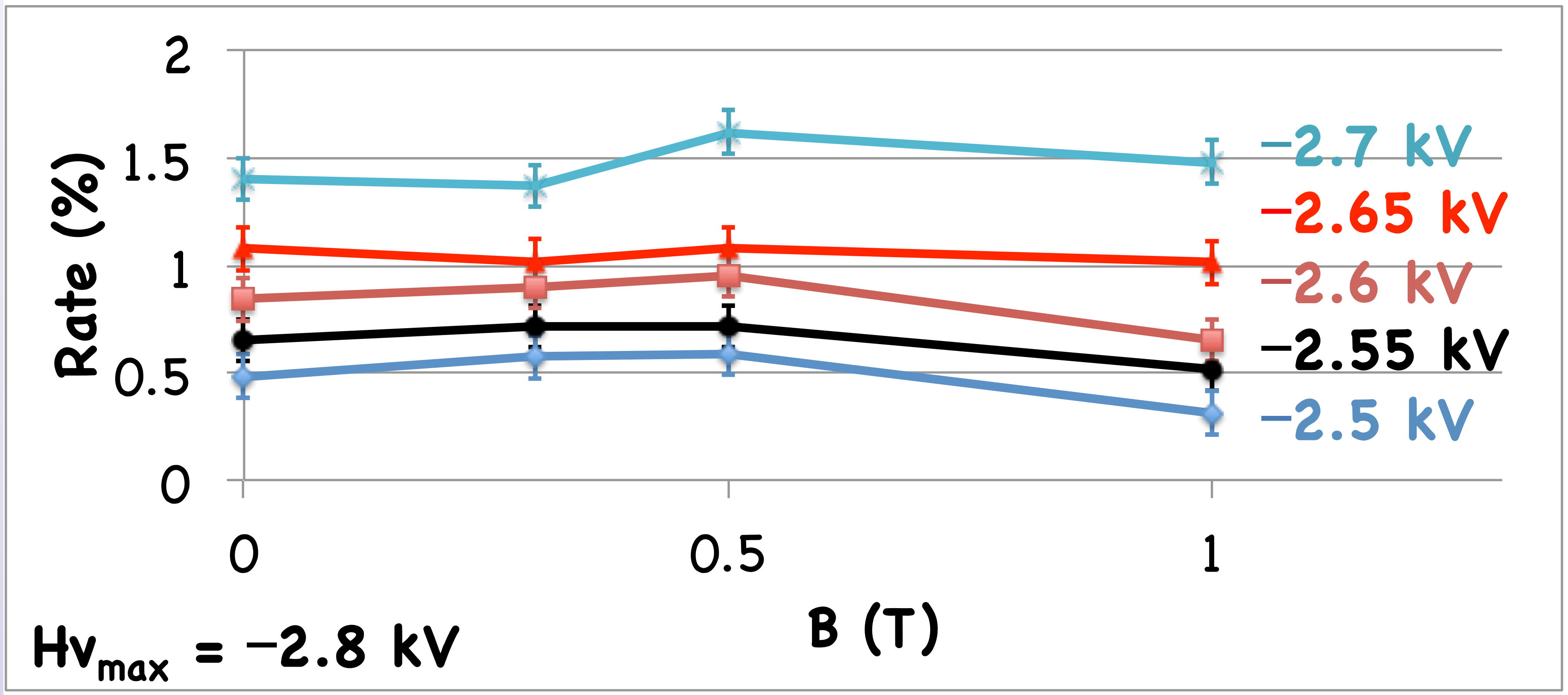


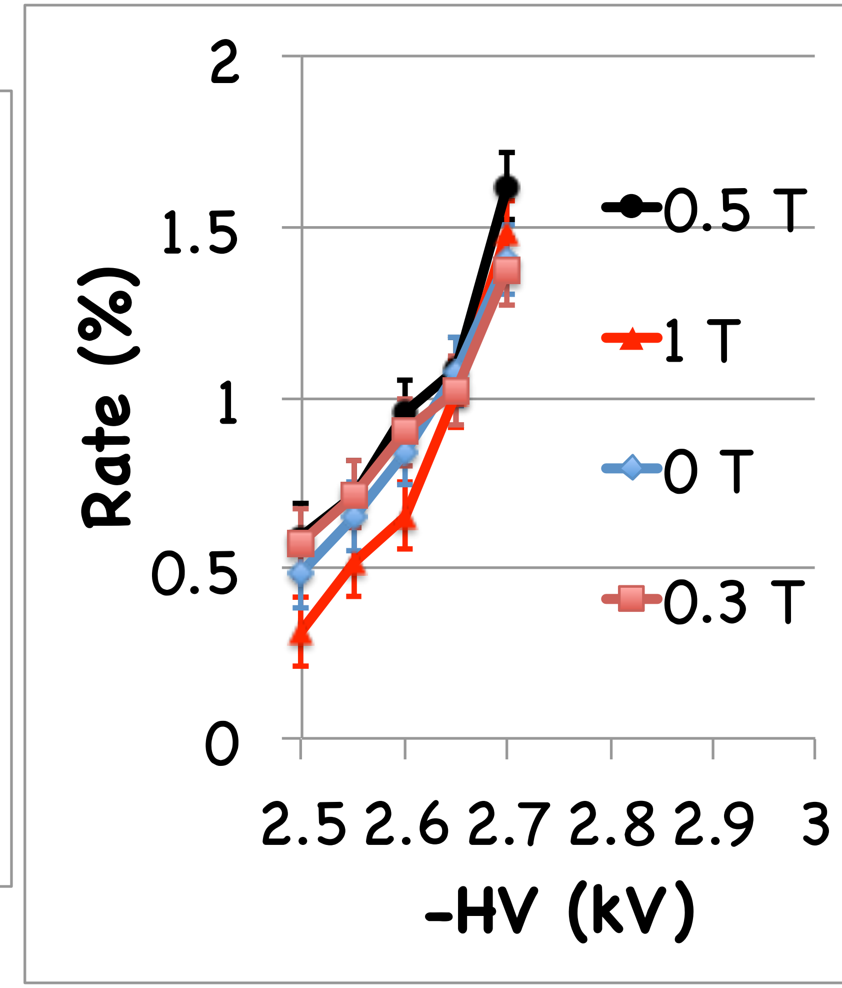
- Efficiency: $\varepsilon = N_{1phe}/N_{ped.}$
- At θ=20° between the sensor and the B-field axes, the efficiency drops continuosly as B increases even though the gain shows a maximum at 0.3 T.
- An increase of $HV_{photocathode\text{-}MCP1}$ by 200 V (close to maximum allowed) recovers only about 13% of the efficiency (θ=20°).

Gain Characterization of Multi-Anode MCP PMTs

Results

10-μm Planacon: Ion Feedback





$\Delta = Rate(A_{thr}=\text{Pedestal}) - Rate(A_{thr}=233)$. $\bar{\Delta} = 0.13$. Reported above: $Rate(A_{thr}=233) + \bar{\Delta}$

- At all voltages the ion rate is below 2%.
- Results suggest that ion-feedback is primarily driven by HV.
- Ion-feedback rate dependence on B-field magnitude is relatively weak.

Short Term Plan

Analysis of 2019 Data

- Study the effect of different amplifiers and amplifications on derived gain and efficiency curves.
- 2019 data seem to confirm low efficiency at 20deg - plan how to study this in the future.
- Re-evaluate efficiency estimates with same method as used for ion-feedback rates.

FY20 Plans

- Procure a 32x32 10-μm pore size Planacon XP85122.
- Install a high-resolution TDC (CAEN V 1290-N) and perform timing-resolution measurements.
- Study effect of different readout solutions on gain and efficiency curves (signal cables, preamplifier).

Long Term Plan

- Study new 10-μm pore size Photek sensor.
- Perform timing tests with a CAEN 3-ps resolution TDC - have an alternative readout to SiREAD-type of solution for tests.
- Study gain, timing and efficiencies, for different amplifiers and amplifications.
- Prepare for large-scale characterization of MCP PMTs for DIRC prototype using planned SiREAD readout (share resources at JLab with INFN-Ferrara, ANL LAPPD project)
  - cross talk
  - uniformity
  - gain, timing, efficiency per channel