Sensors in High-B Fields

Goal

Identify an adequate readout sensor for the DIRC detector that can operate in the 3-T magnetic field of the solenoid.

Requirements

Position resolution (accommodate 1 mrad required detector resolution)
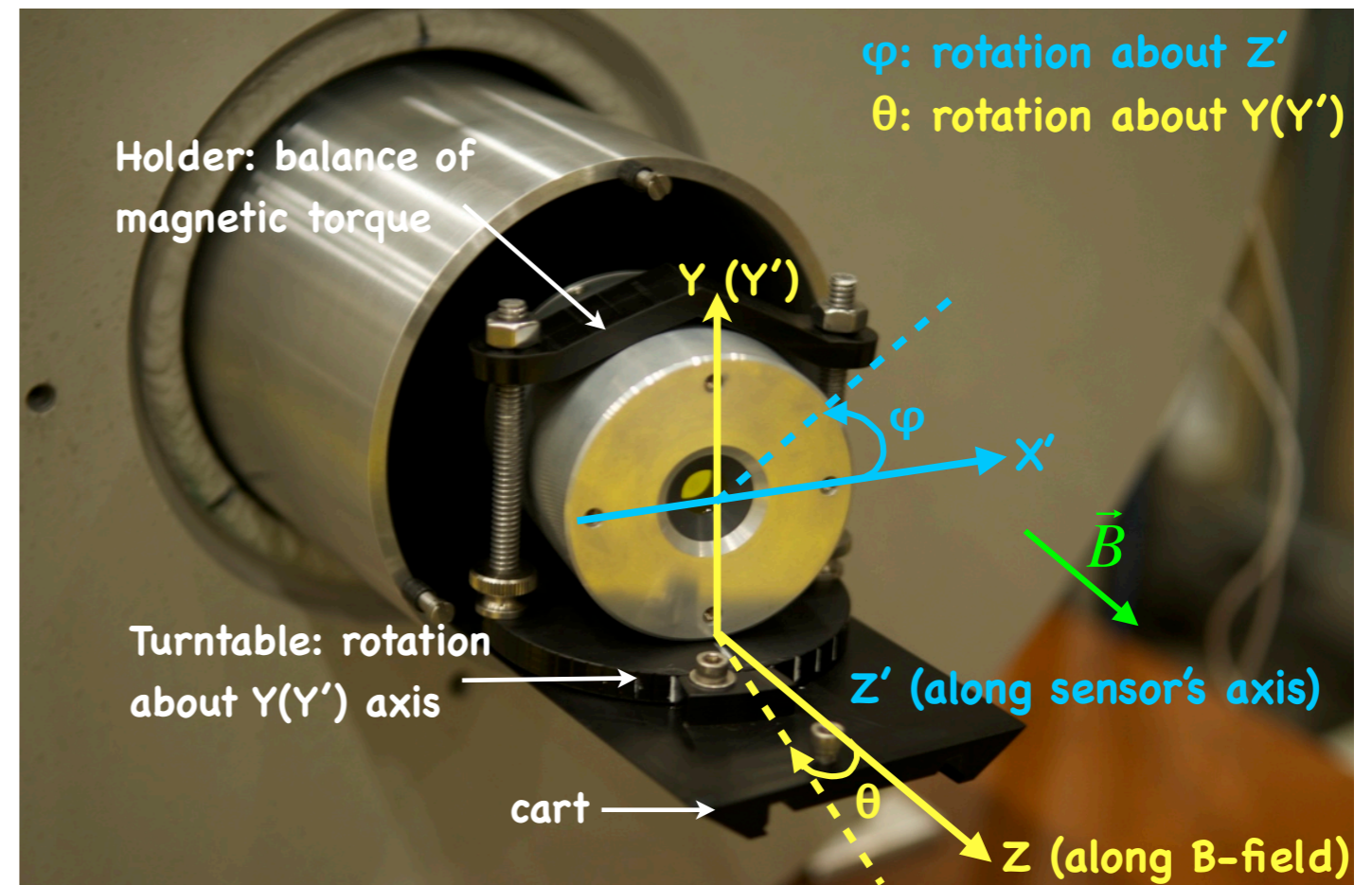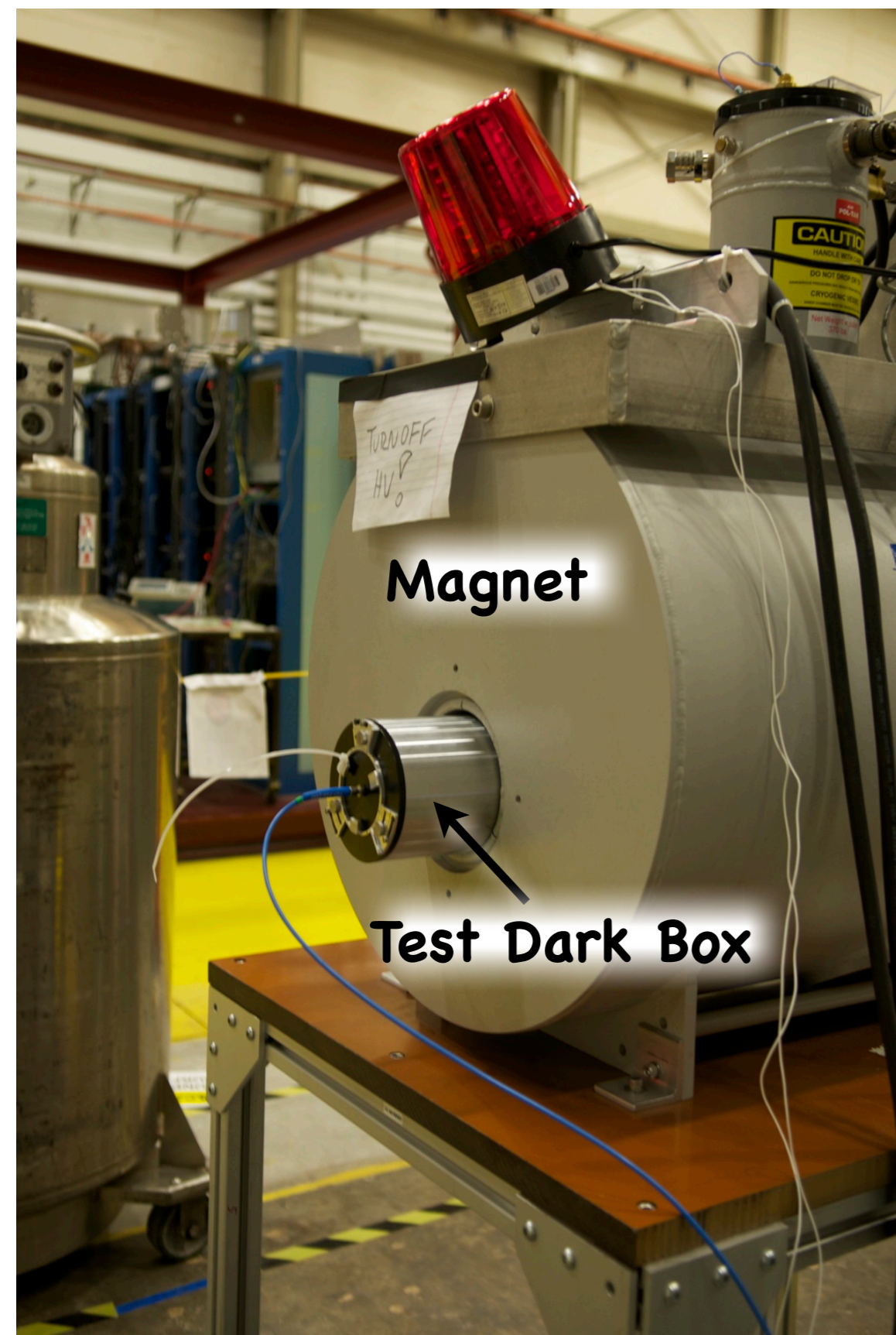
Timing resolution: < 100 ps

Gain: adequate for single-photon mode operation (500,000 - 1,000,000)

Gain: adequate high-B performance (small range of variation about nominal)
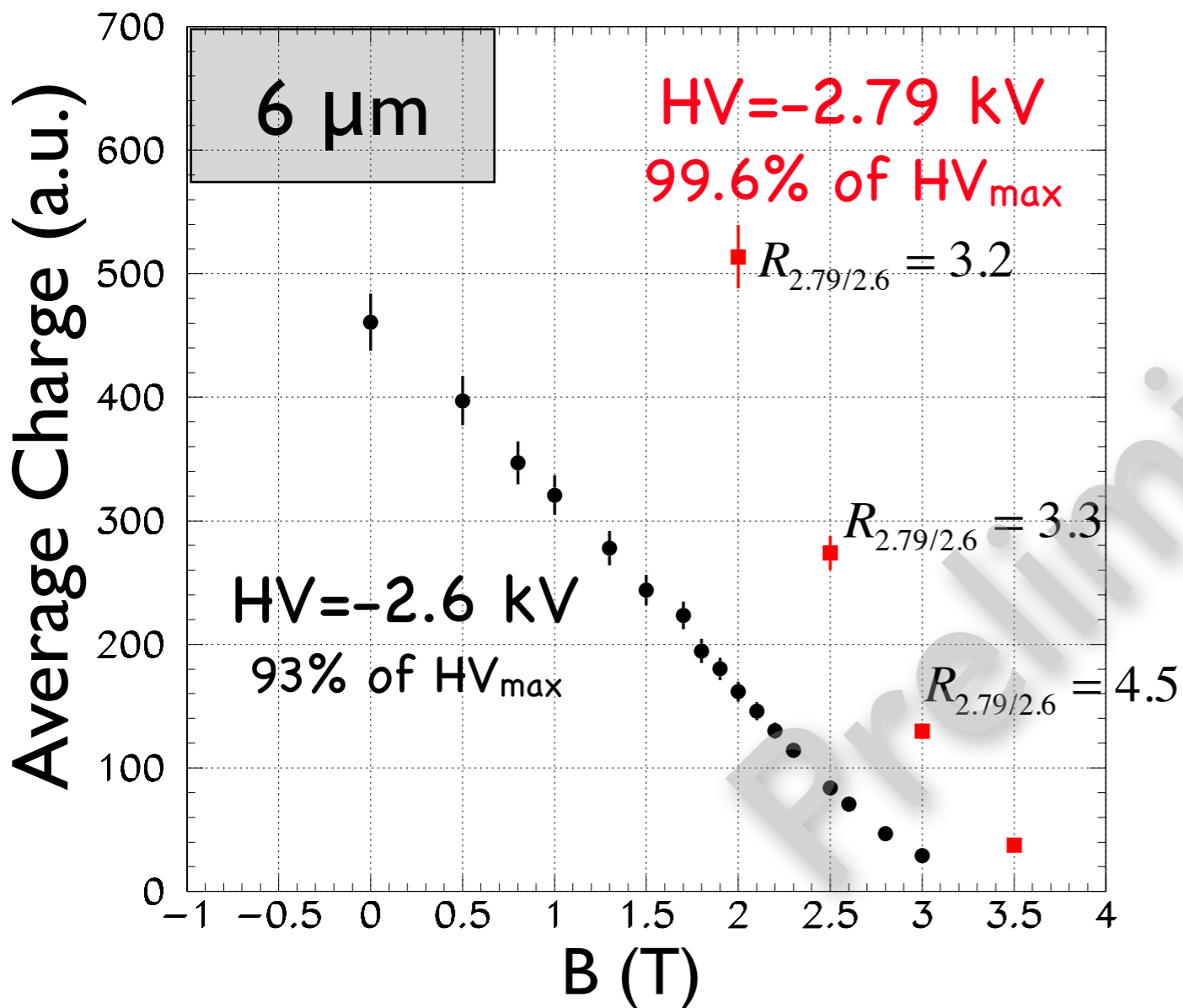
Low Noise

Setup

Magnet

Test Dark Box

φ: rotation about Z′
θ: rotation about Y(Y′)

Holder: balance of magnetic torque

Y (Y′)

φ

X′

$\vec{B}$

Turntable: rotation about Y(Y′) axis

Z′ (along sensor's axis)

cart

θ

Z (along B-field)

Features:

- superconducting solenoid

- max. field: 5.1 T at 82.8 A

- non-magnetic light-tight box

- pulser-driven LED source: 470 nm

Results: θ=0°

6 μm

HV=−2.79 kV
99.6% of HV_{max}

$R_{2.79/2.6} = 3.2$

$R_{2.79/2.6} = 3.3$

HV=−2.6 kV
93% of HV_{max}

$R_{2.79/2.6} = 4.5$

Average Charge (a.u.)

B (T)

3 μm

HV=−4.76 kV
99.2% of HV_{max}

$R_{4.76/4.44} = 3.75$

HV=−4.44 kV
93% of HV_{max}

$R_{4.76/4.44} = 4.48$

$R_{4.76/4.44} = 4.97$

B (T)

Preliminary

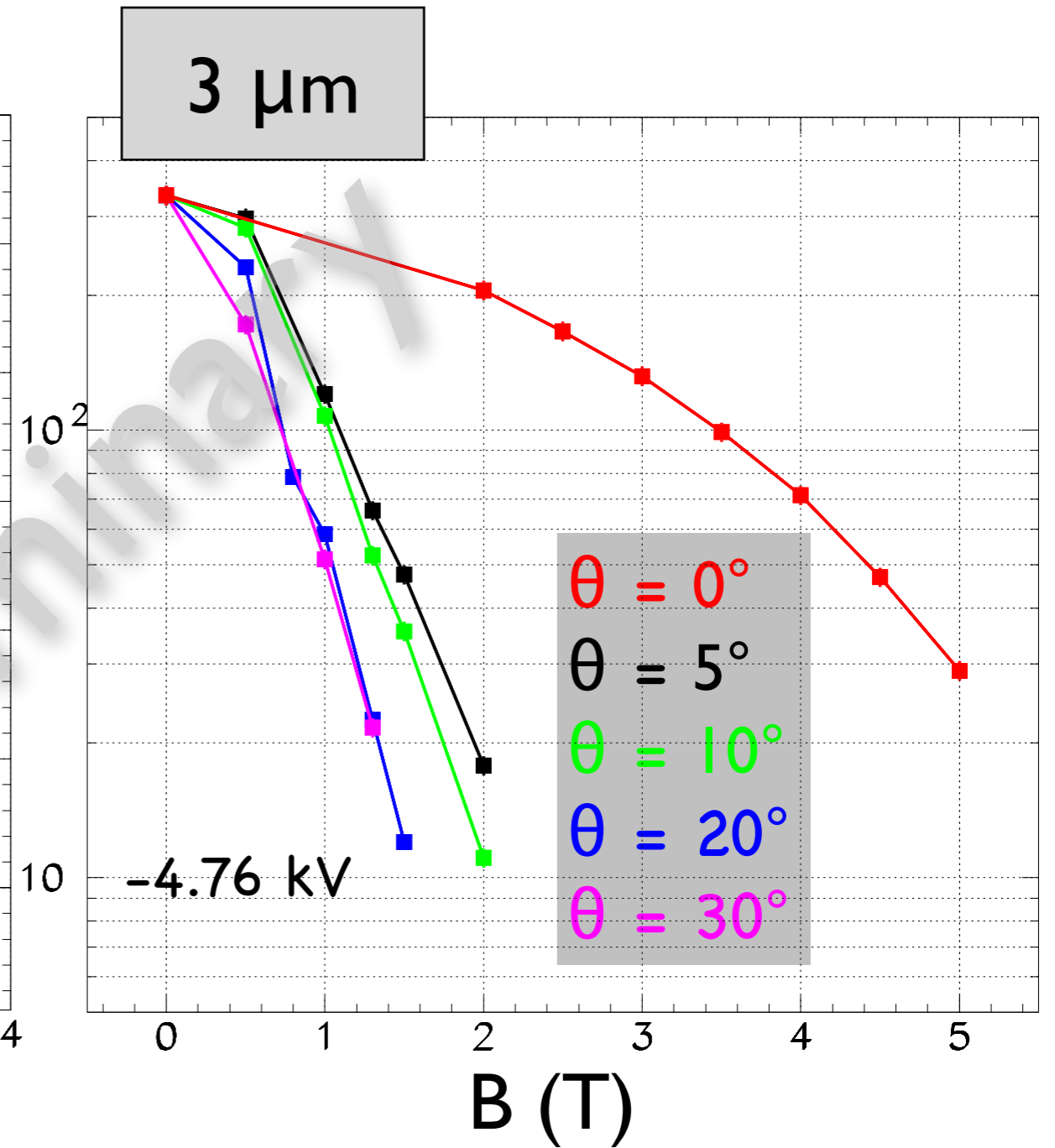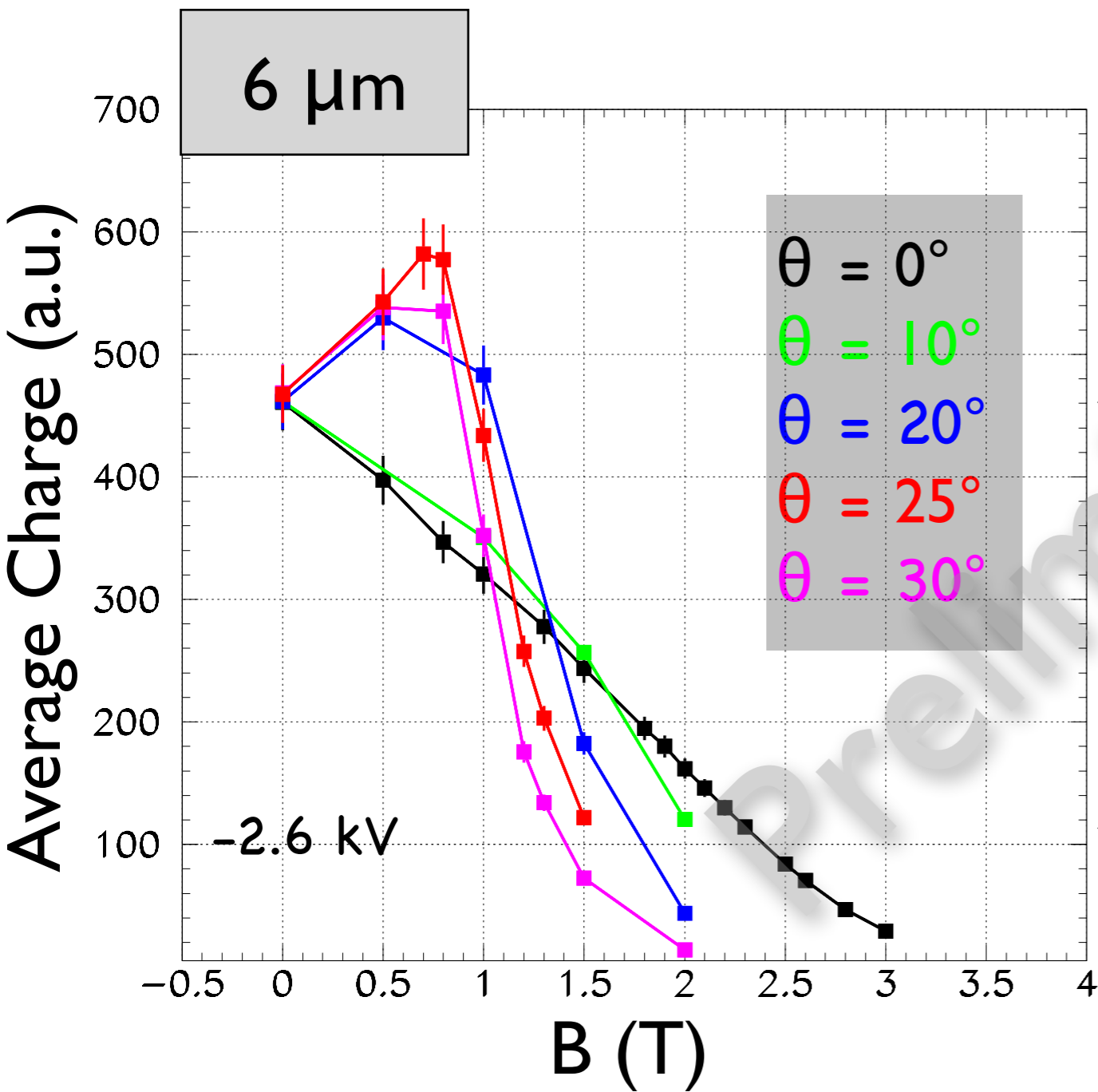- about a factor of 15 decrease of signal between 0 T and 3 T (−2.6 kV)
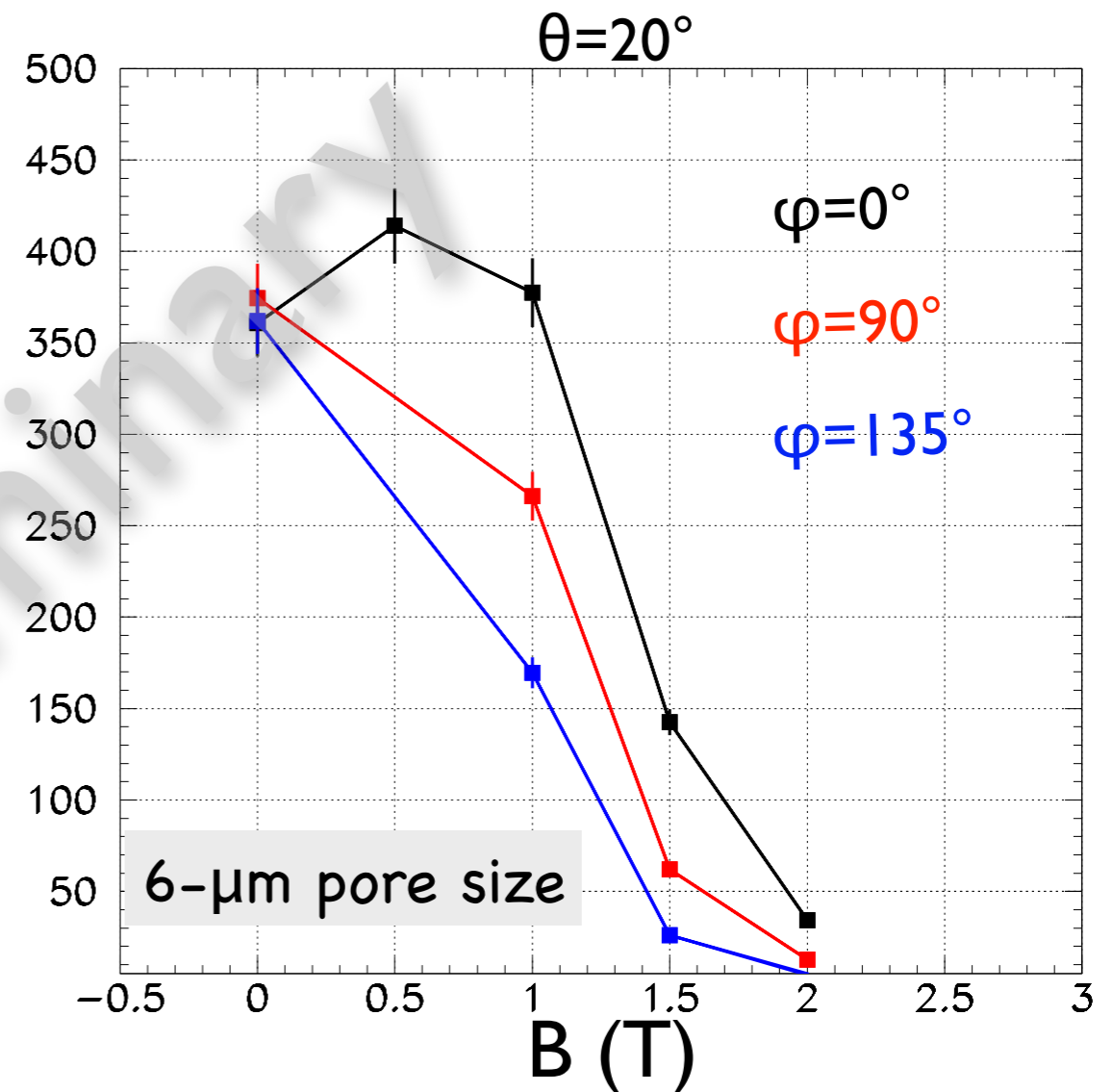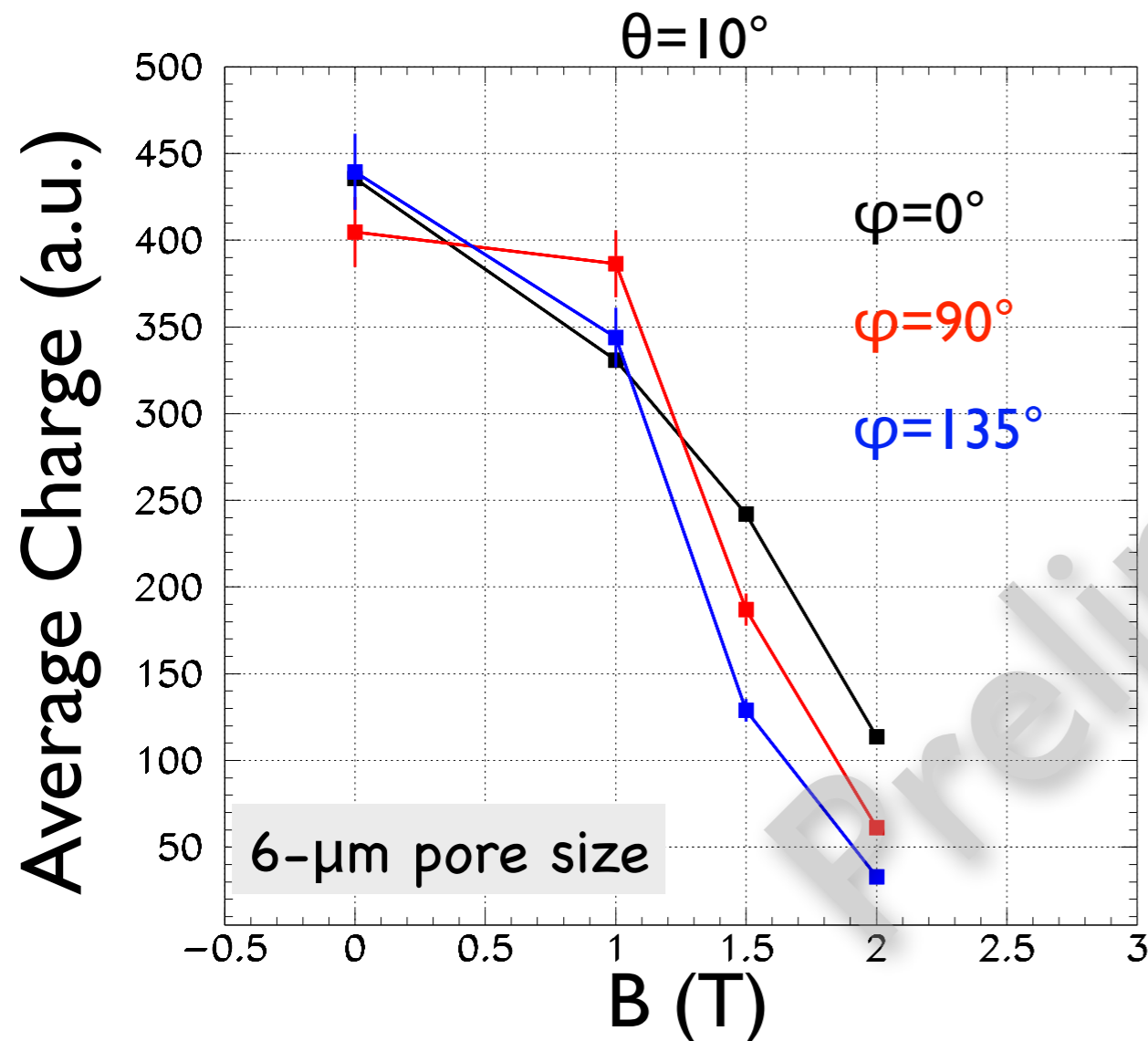
- 5% preliminary uncertainty
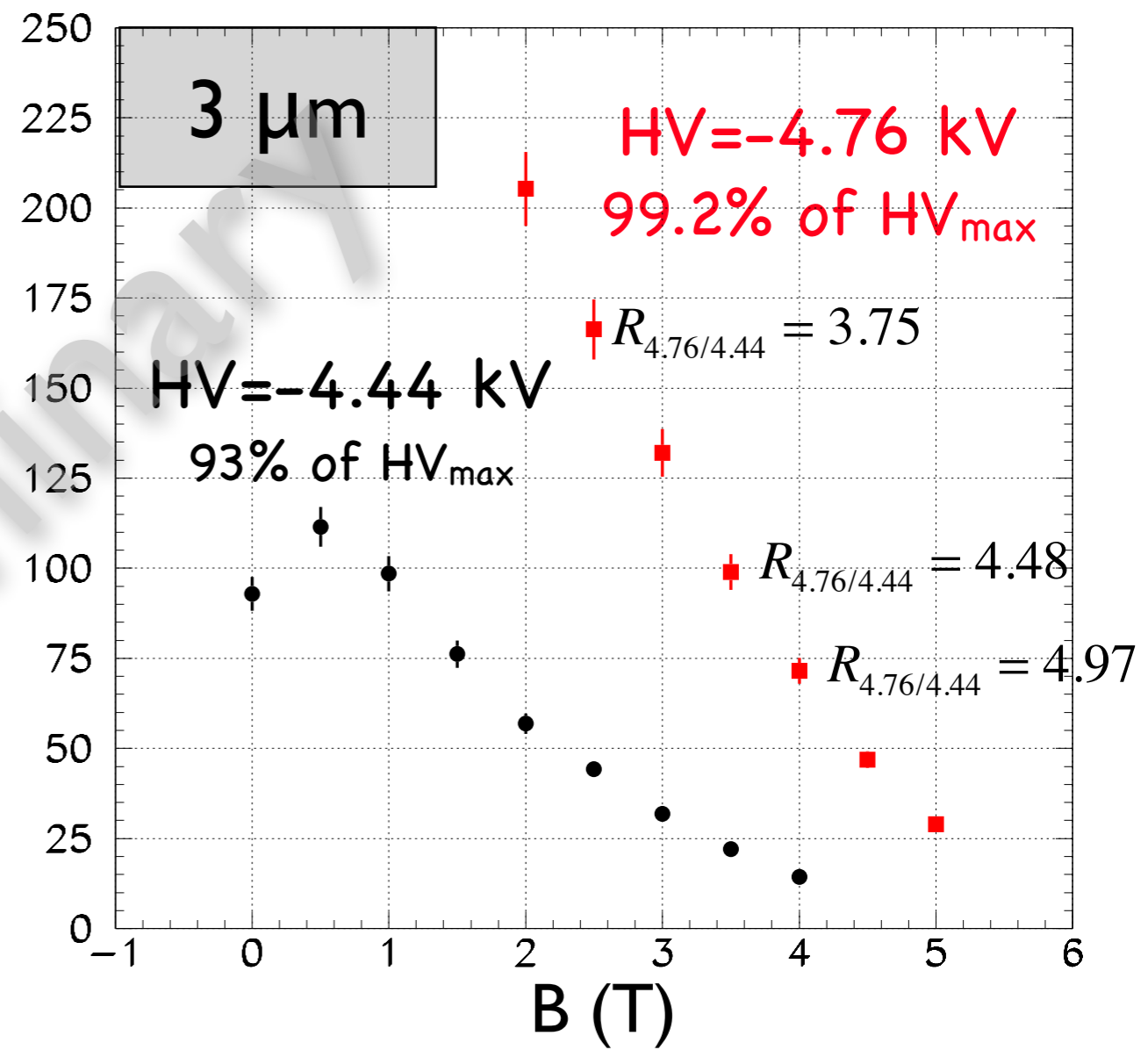
- about a factor of 6 decrease of signal between 0 T and 4 T (−4.44 kV)

- 5% preliminary uncertainty

Results: Other Angles

Results: Azimuthal Angles

- 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

Voltage Divider

Photek PMT210
Voltage Divider setup

Cathode to MCP voltage
Jumper chooses 180 or 200 V
No jumper ➔ 220 V

MCP to anode voltage
Two jumpers – choice of total resistance
Jumper shorts out a resister
In photo – R = 4 + 1 = 5 MΩ
This is "0101" configuration
There is fixed 14 MΩ in series
So R(total) = 14 + 5 = 19 MΩ
Note: this choice will affect MCP voltage
Refer to spreadsheet for details

Method

θ=0°

B = 0. T
B = 0.5 T
B = 1.0 T
B = 2.0 T
B = 3.0 T
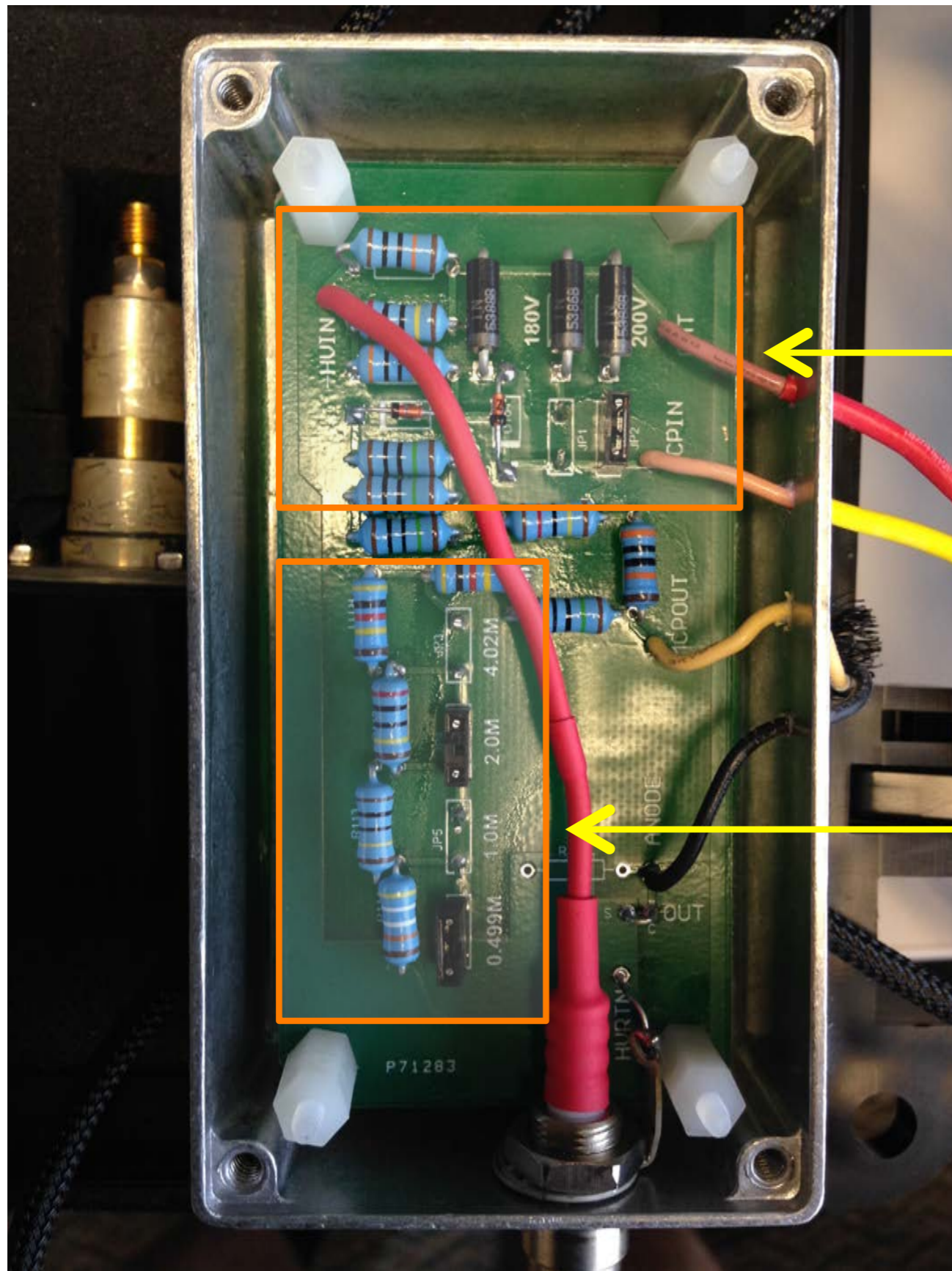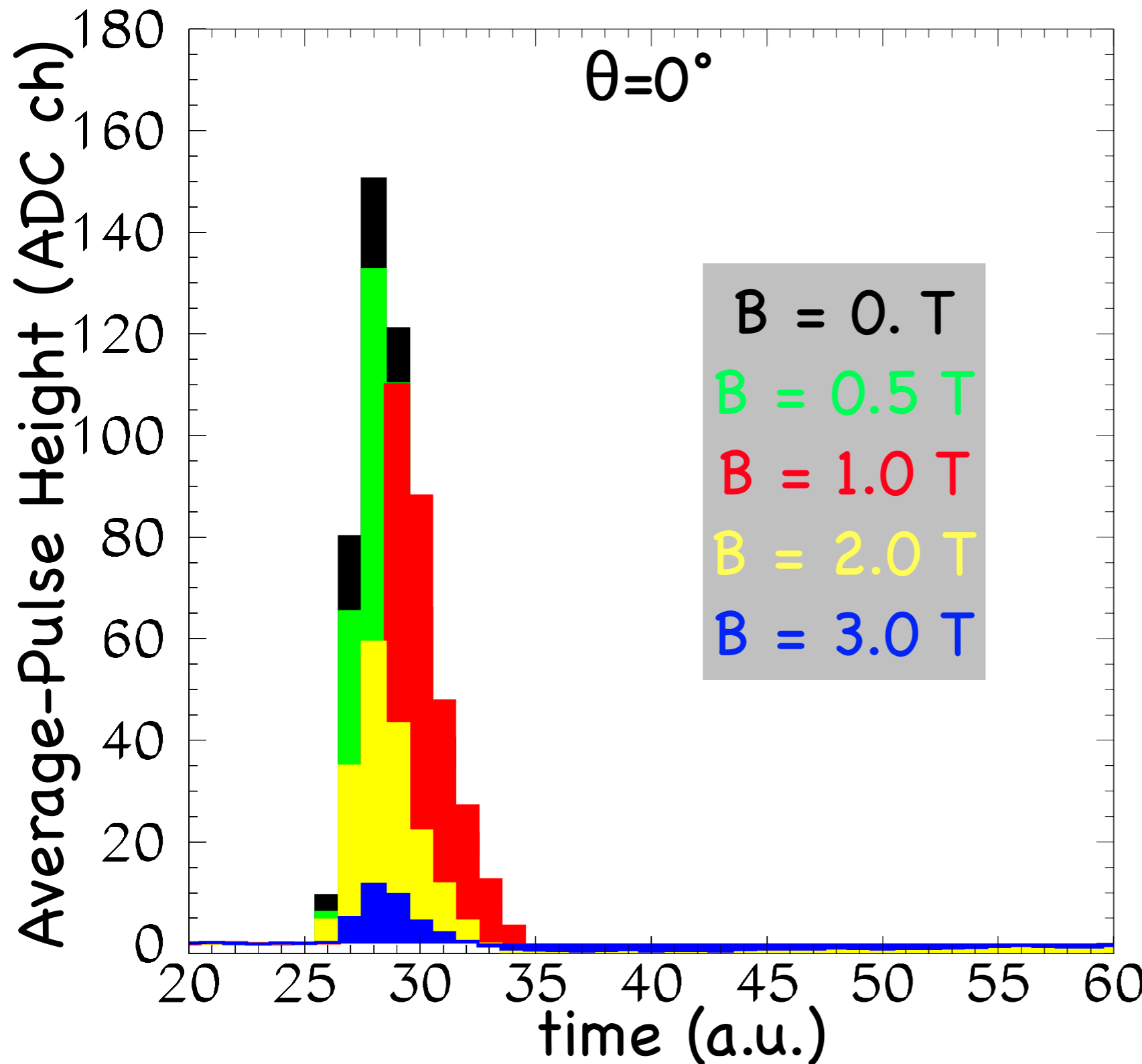
Average-Pulse Height

- 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)

Average Collected Charge

- for each event: ADC values added up in area of peak

- pedestal subtracted from sum

- average charge proportional to sum averaged over all

Latest Results
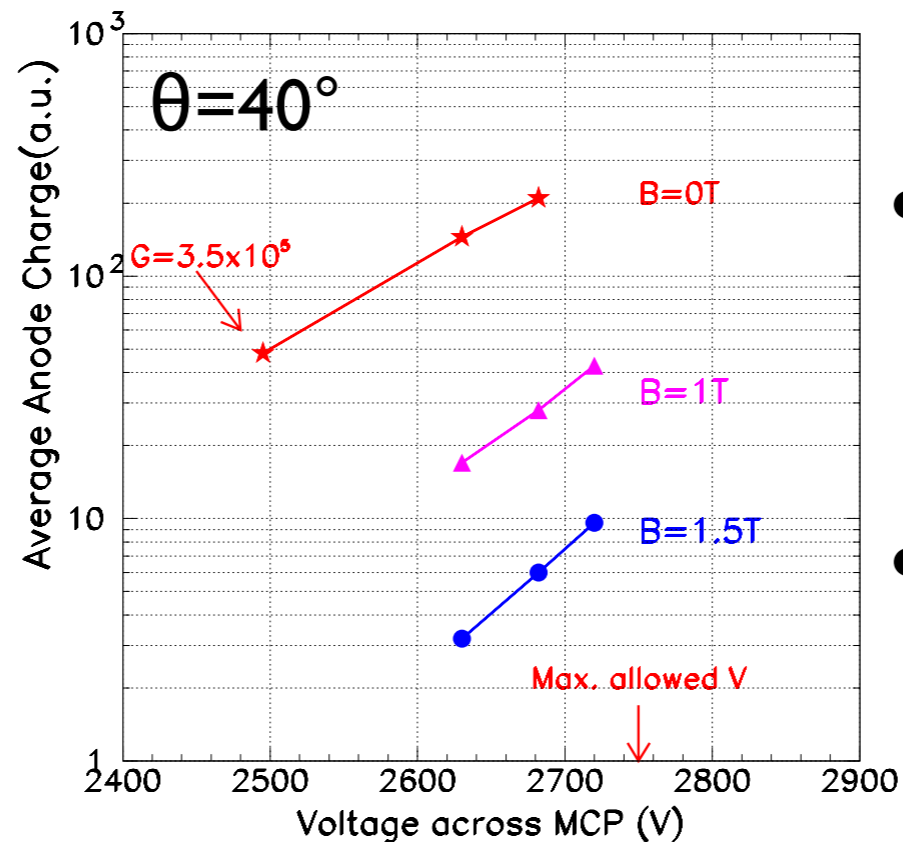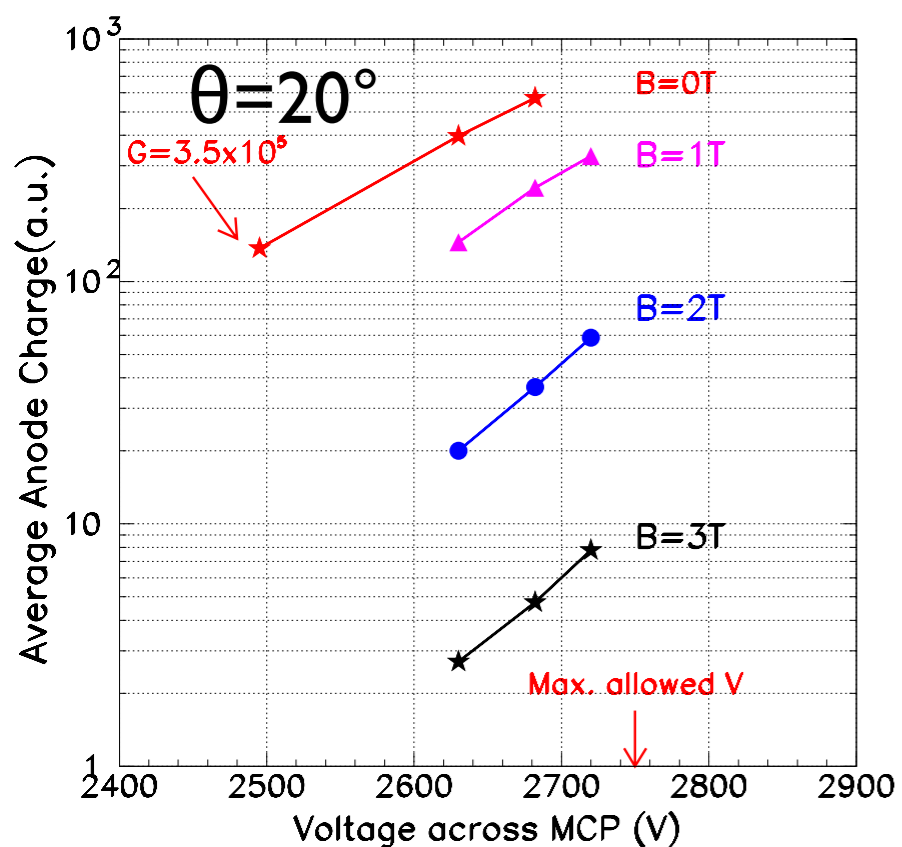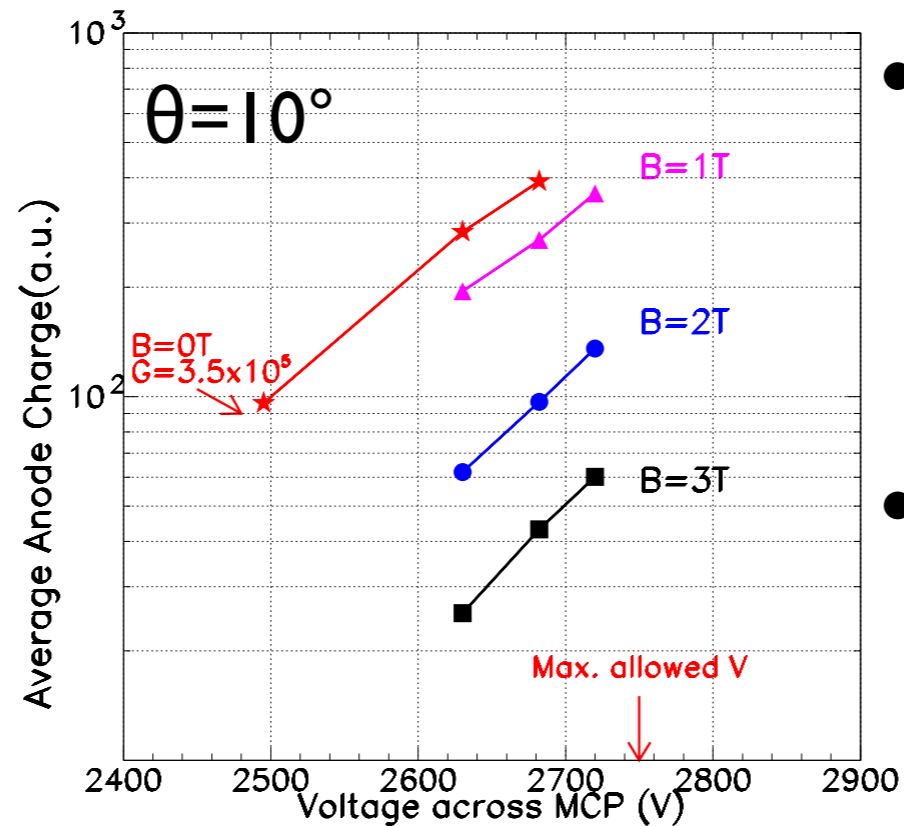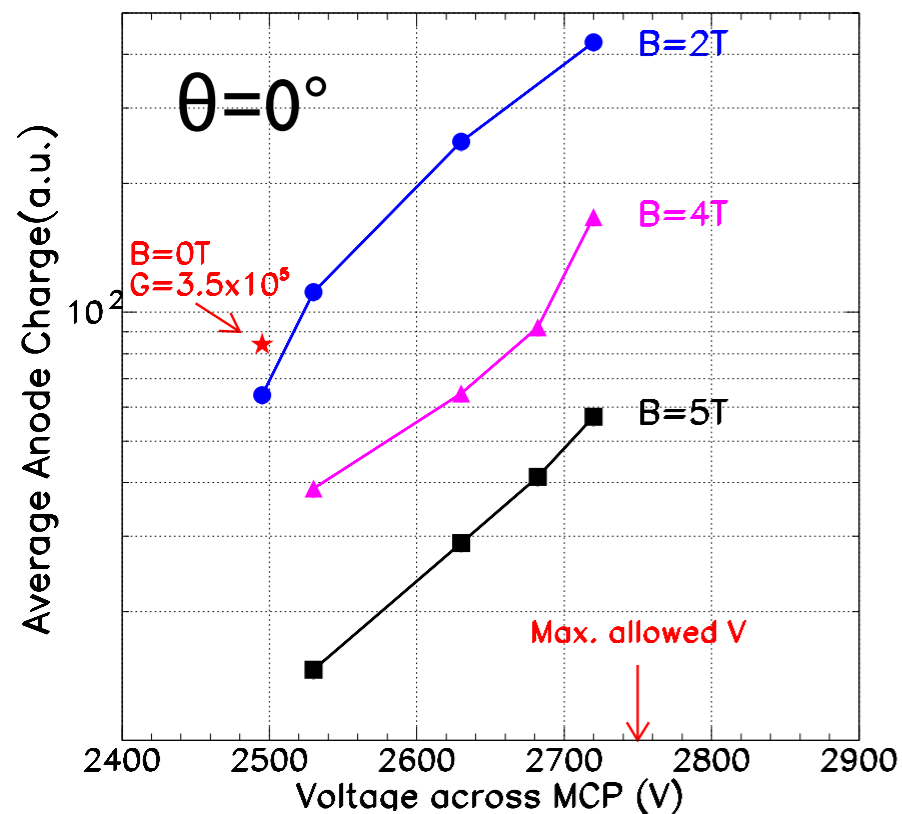
- Increasing the potential difference across the channel plates can help to recover the loss in gain due to the magnetic field.

- Gain recovery is strongly correlated with the angle between the MCP and field axes: the larger the angle, the more limited is the range of fields where the sensor can be operated at the same gate.

- At 0 deg, increasing $V_{cathode-MCP}$ and $V_{MCP-anode}$ above their nominal values does not seem to affect the gain performance.

- Additional optimizations for gain recovery need to be implemented if the orientation of the sensor relative to the field varies significantly.

Summary

- Single-anode MCP PMTs shows that 3-µm pore-size sensor has a better B-field immunity than a 6-µm sensor.

- The gain depends significantly on sensor orientation relative to B-field and the type of the sensor (Photek vs Photonis tested).

- Gain recovery is strongly correlated with the angle between the MCP and field axes: the larger the angle, the more limited is the range of fields where the sensor can be operated at the same gate.

- Overall, other optimizations for gain recovery need to be implemented if the orientation of the sensor relative to the field varies significantly.

Outlook

- Evaluate commercial multi-anode MCP-PMTs with 10-mum pore size up to 5 T (Hamamatsu, Photonis). Previous tests show good operation up to about 1.5 T.

- Evaluate the independent effect of custom voltage distribution on gain of multi-anode sensors (universal HV divider under development)

- Evaluate timing resolution up to 5 T.

- Study MCP PMT design in a simulation with the goal of identifying a set of parameters and its limitations for optimal performance in B-fields.

- Consider other solutions.