



# Photodiode Calibrations

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# HRPPD QA Setup

- Reference photodiode is used to correct for the fluctuation of the light source
- Each test station across the pfRICH working group will receive a photodiode calibrated at BNL

HRPPD QA setup

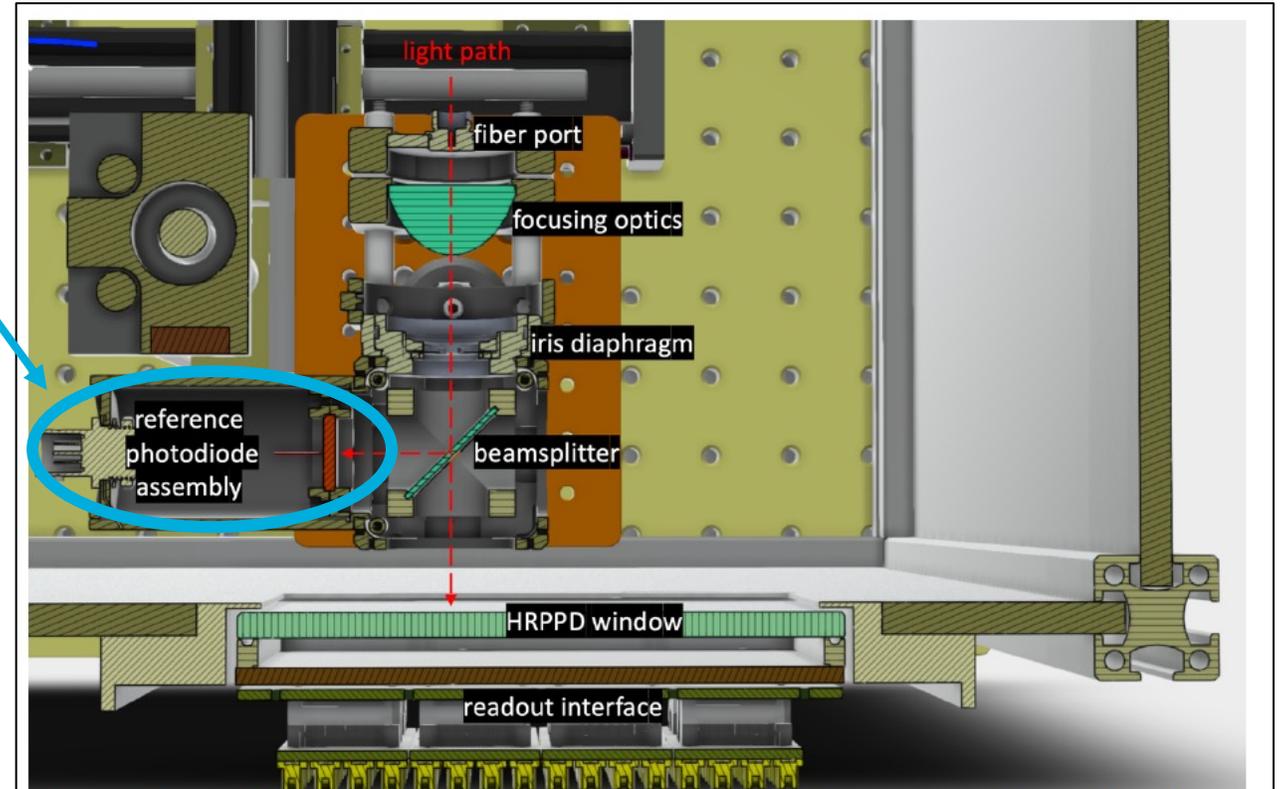


Figure 2 A crosscut of the optical head (top view), with a focusing lens, a beamsplitter and a reference photodiode mounted on a movable table. An HRPPD assembly with a 4x4 array of small 16ch MCX interface boards is seen at the bottom of the picture, mounted on a side wall.

# Photodiode Calibration Setup at BNL

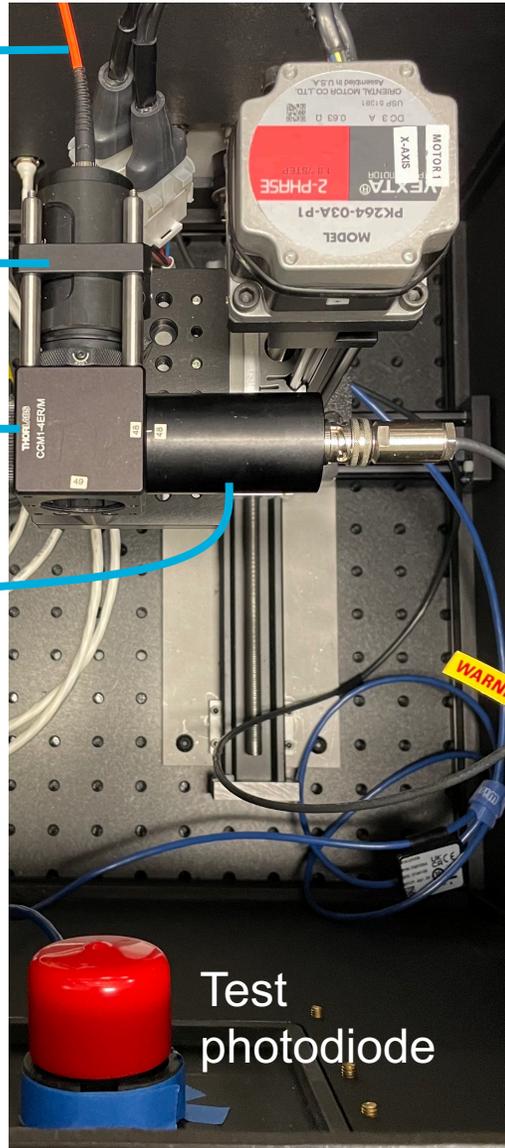
Optical fiber  
d = 600  $\mu$ m

Light source  
guide

splitter

Reference  
photodiode

Test  
photodiode



Monochromator  
(200-800nm)



- Reference photodiode is used to normalize the light source brightness/photon flux
- The beam spot diameter is adjustable by varying the distance between the splitter and the test photodiode
- Tested beam spot diameter: 2mm, 3mm, 4mm
- 5 test photodiodes:  
Incom (no filter), 3134199, **3174603, 3174609, 3174611**

New batch



Keithley  
Picoammeters



# List of Measurements

1. Re-measure beam spot diameter vs z position  
Using different optical fibers with a much larger cross-section than in Chandra's measurements (See slides 7 & 8 in

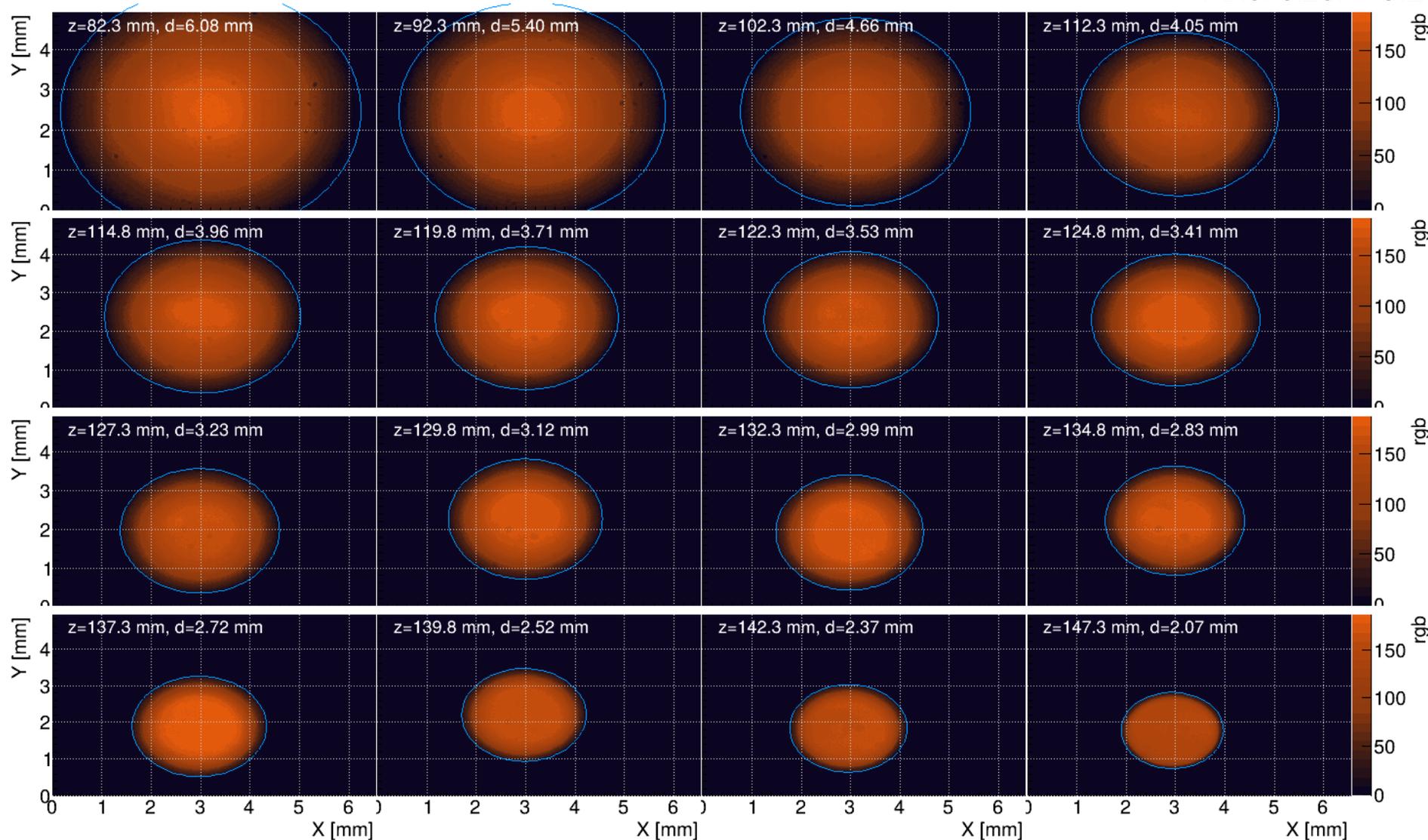
[https://docs.google.com/presentation/d/1NNZsdpOuSrckKHss6LG\\_6CzQKibnOS5YaUBtKrX26IU/edit?slide=id.g3733b31733c\\_0\\_18#slide=id.g3733b31733c\\_0\\_18](https://docs.google.com/presentation/d/1NNZsdpOuSrckKHss6LG_6CzQKibnOS5YaUBtKrX26IU/edit?slide=id.g3733b31733c_0_18#slide=id.g3733b31733c_0_18))

2. Dark currents
3. Wavelength scan: compare power vs wavelength measured between different photodiodes → calibrations
4. Power vs beam spot diameter
5. Power vs brightness: linearity
6. XY scan: uniformity

# Beam Spot Diameter Measurement

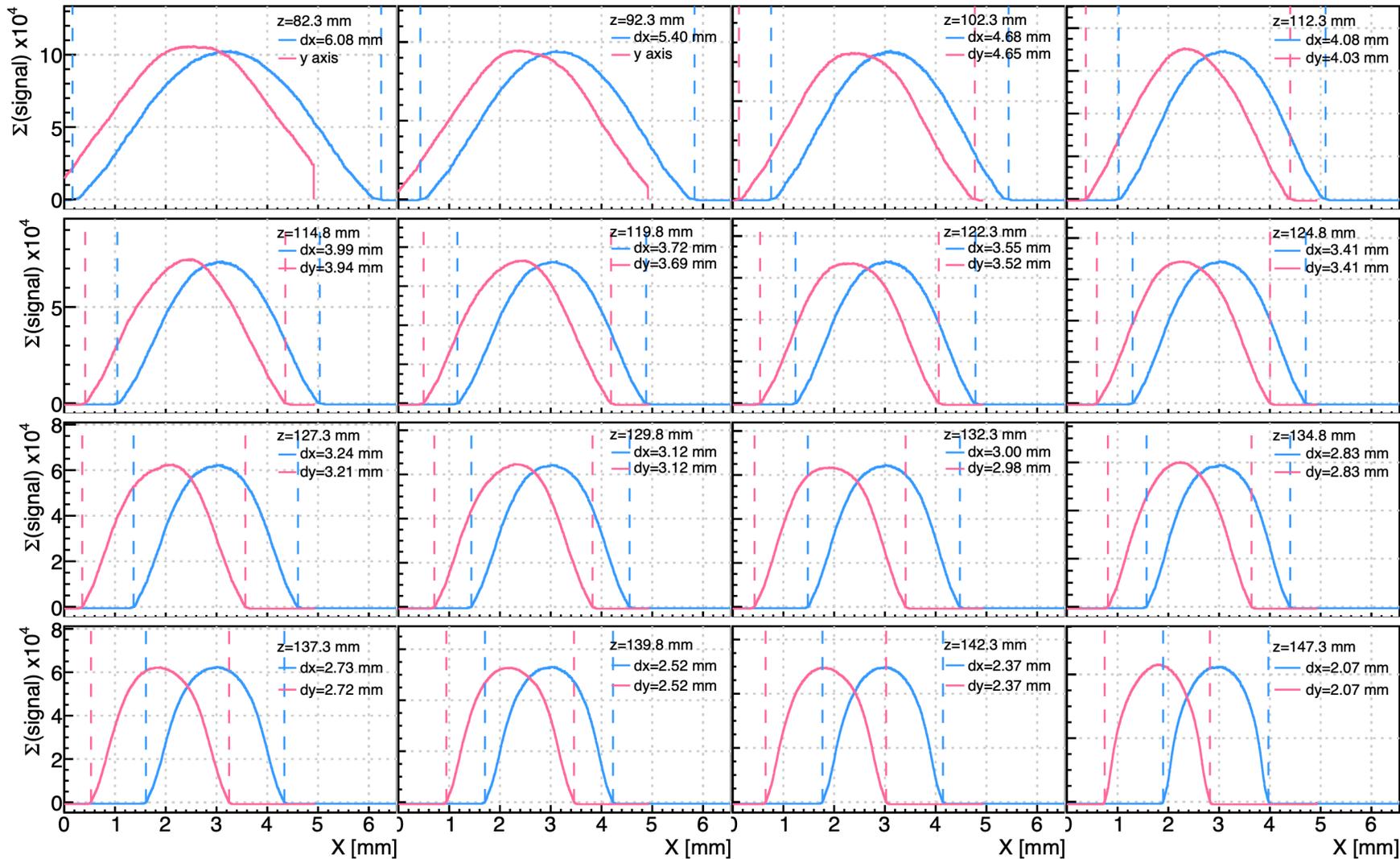
# Red Signal 2D Distribution

- AmScope MD310b-BS
- Camera sensor size  $\sim 6.55 \times 4.92 \text{ mm}^2$
- Pixel size =  $3.2 \mu\text{m}$



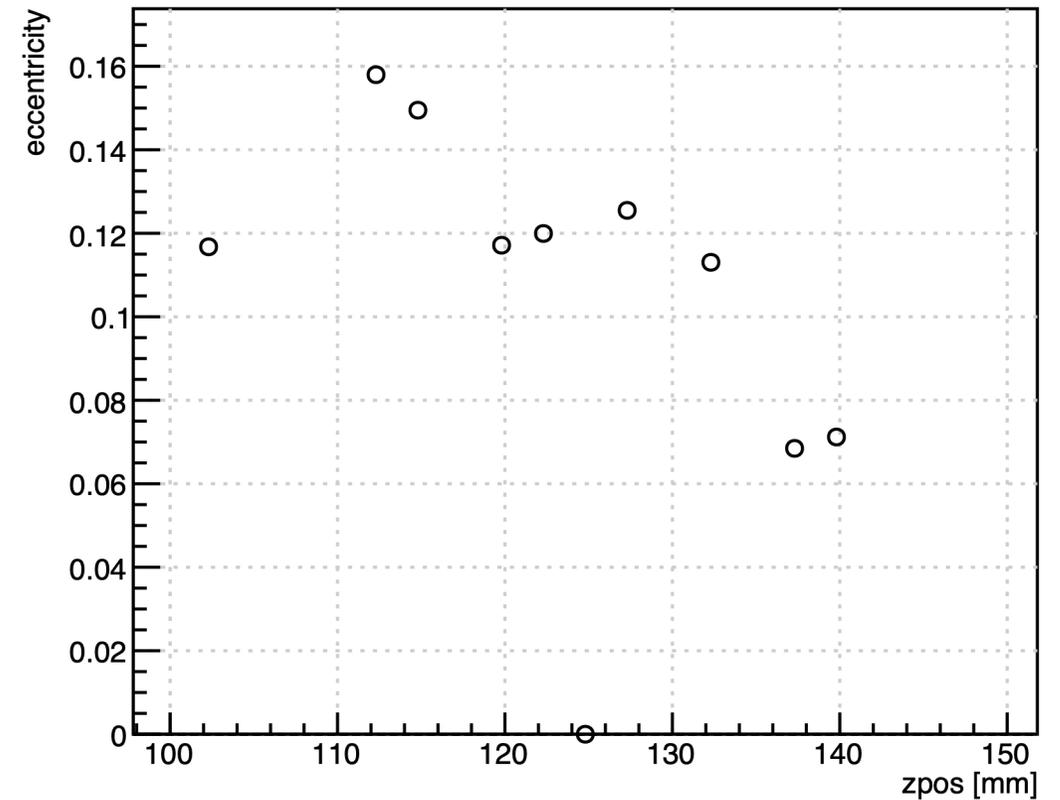
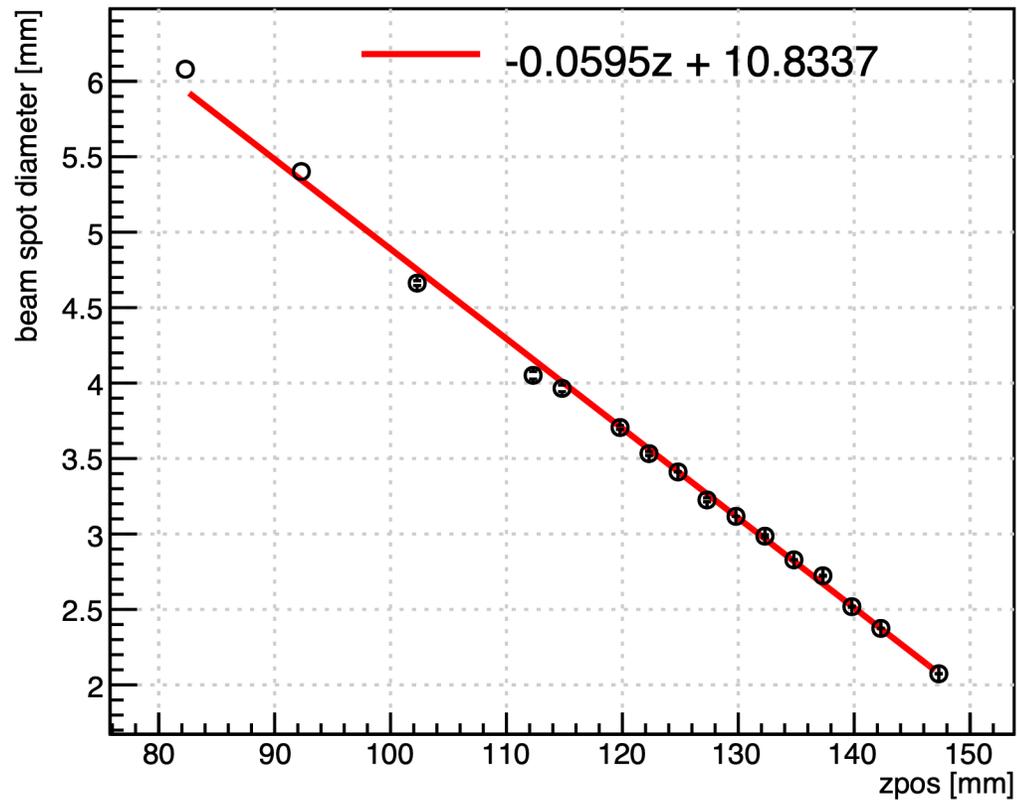
- Light source wavelength =  $600 \text{ nm}$
- z is the position of the motor that move the optical components
- The colored axis is not equivalent to brightness

# Red Signal 1D Distribution



- The dashed lines, which show the edge of the circle, are defined by the first and the last bins with a positive signal
- Diameter =  $(dx+dy)/2$
- Error is the rms
- For the larger image that exceeds the y-range of the camera sensor, diameter = dx, and error=0

# Beam Spot Diameter/Eccentricity vs Z Position



$$z = -\frac{D - 10.8337}{0.0595}$$

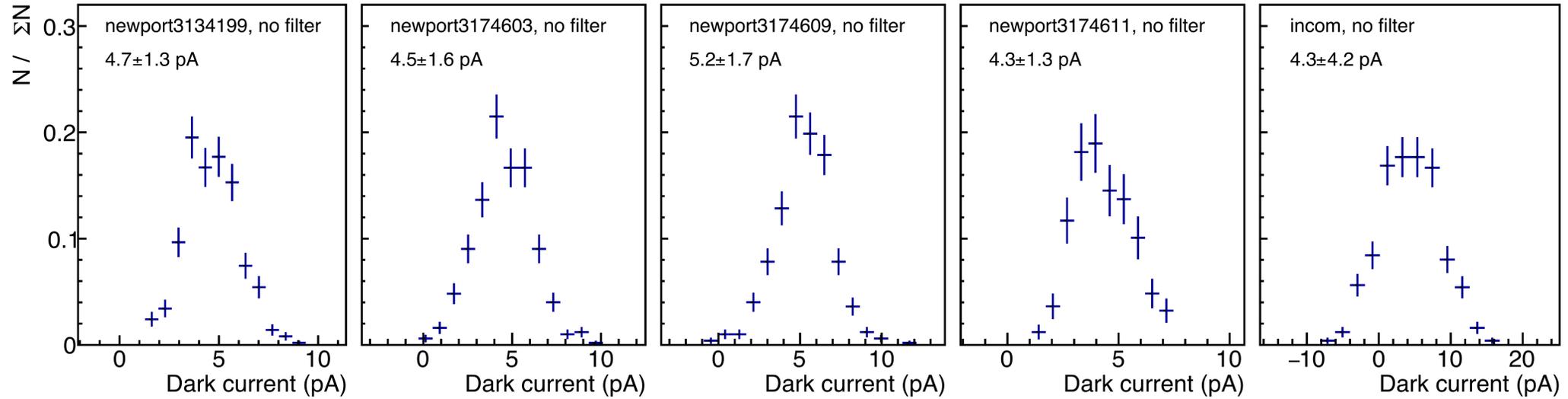
$$x = 93.0170 + 0.123z - 1.83$$

$$y = 78.2873 + 6.2 \times 10^{-3}z - 0.9$$

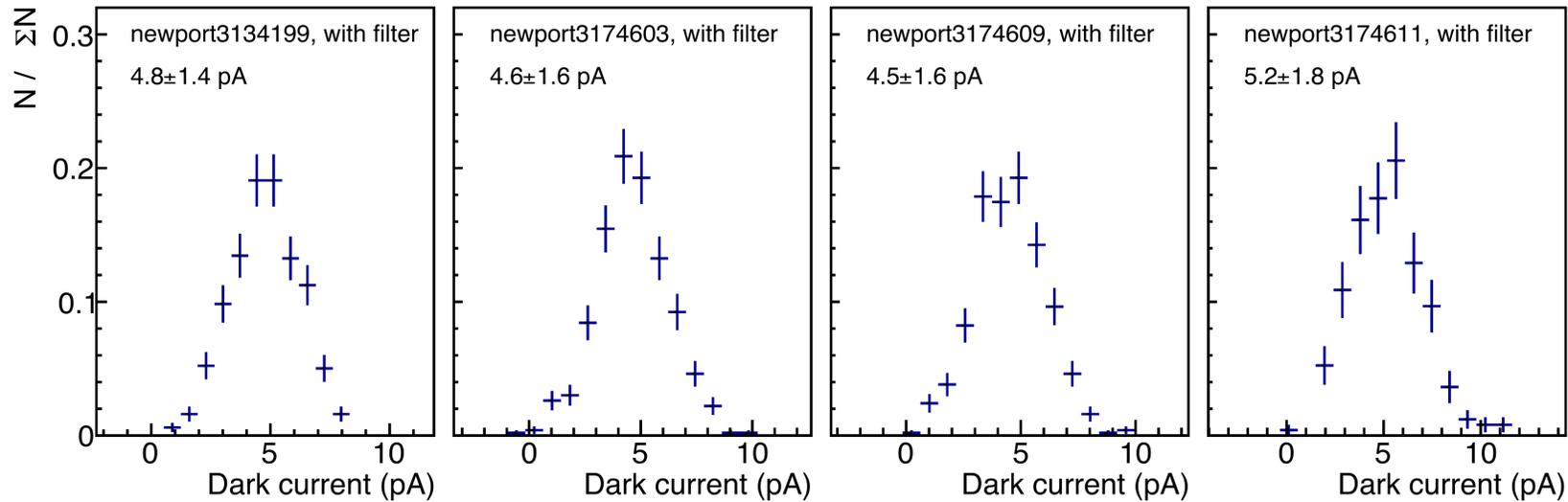
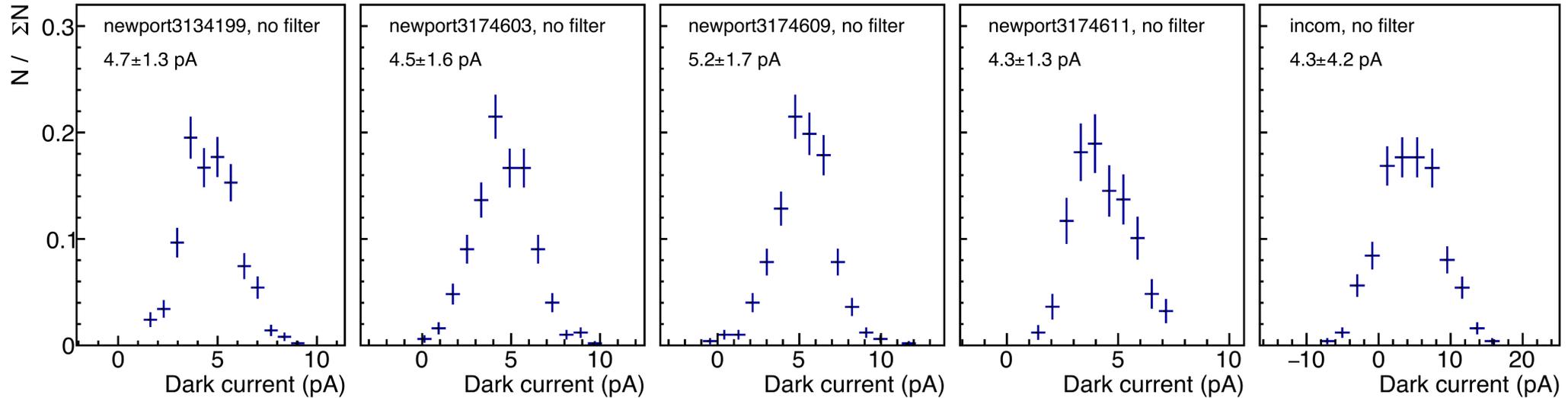
# Dark Currents

# Dark Current

500 measurements per photodiode

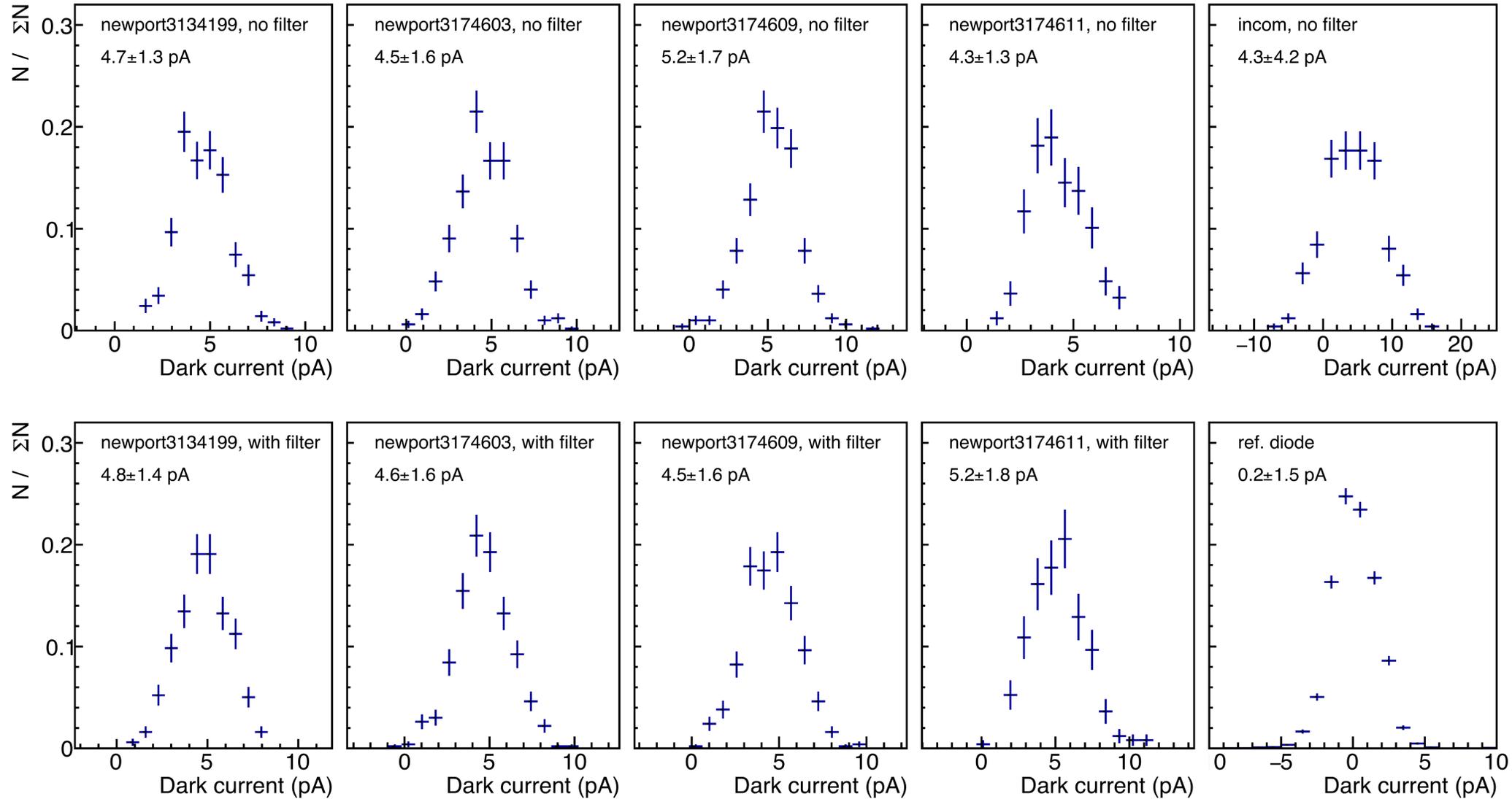


# Dark Current



Dark currents are consistent with and without filters  
→ Electronics noise?

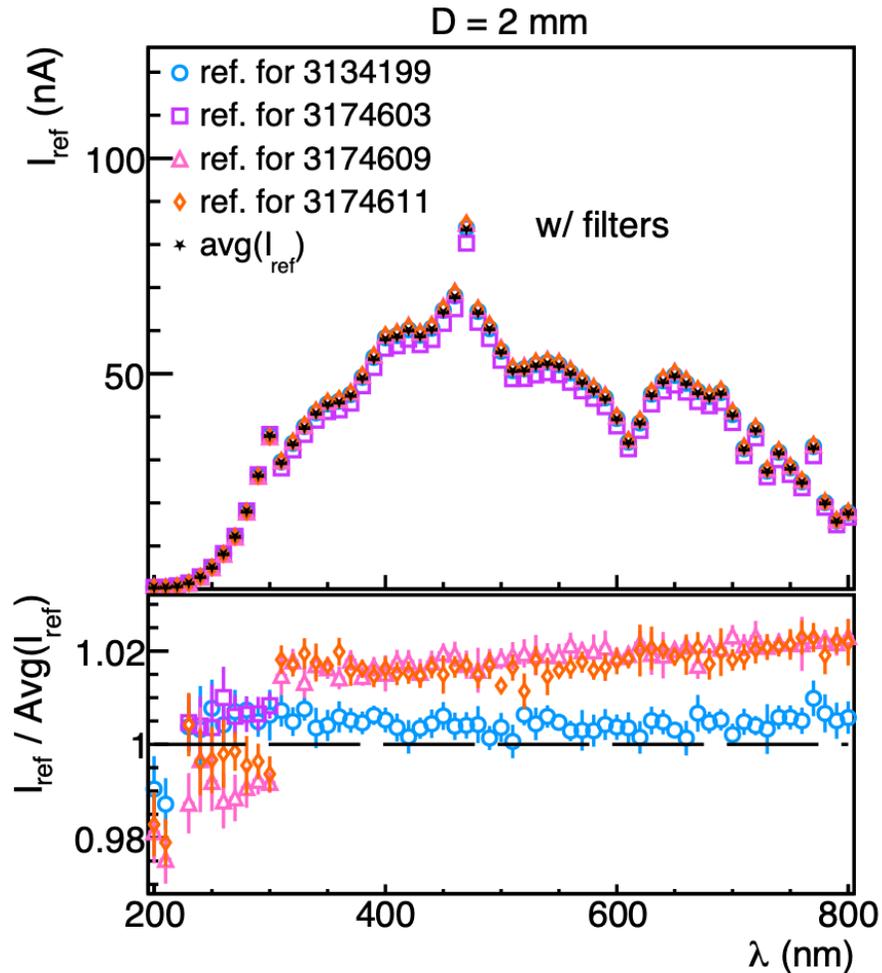
# Dark Current



# Power vs Wavelength

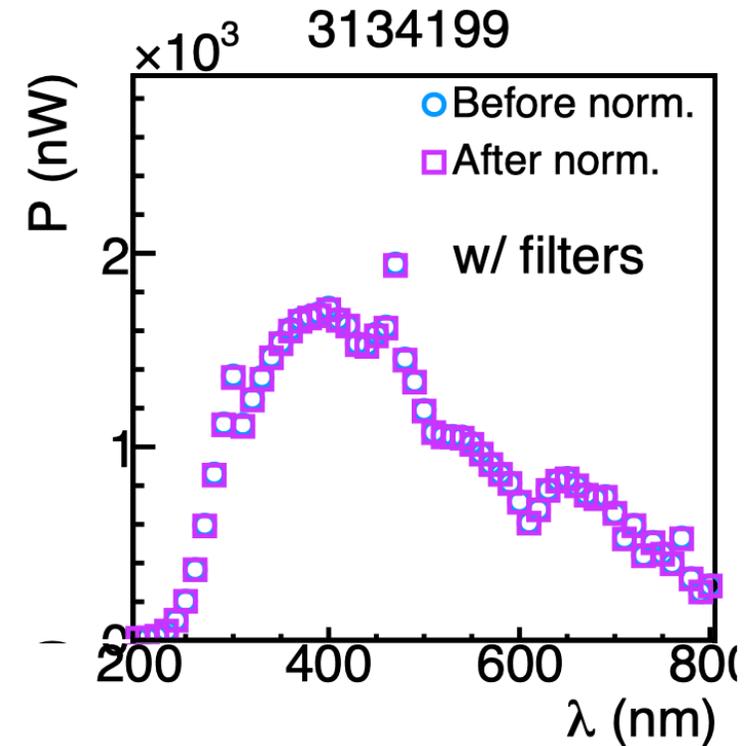
# Normalization using the Reference Diode

Reference diode current in wavelength scan



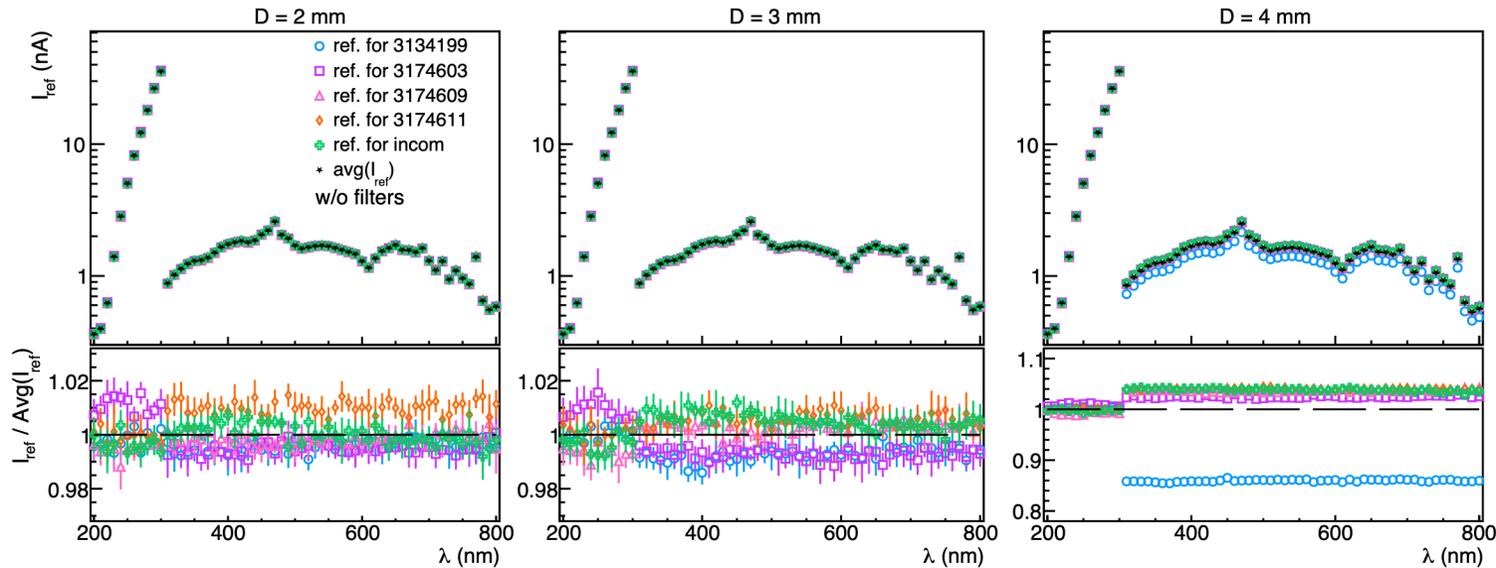
Test diode power before/after normalization

$$p^{norm} = P \times \frac{\text{Avg}(I_{ref})}{I_{ref}}$$

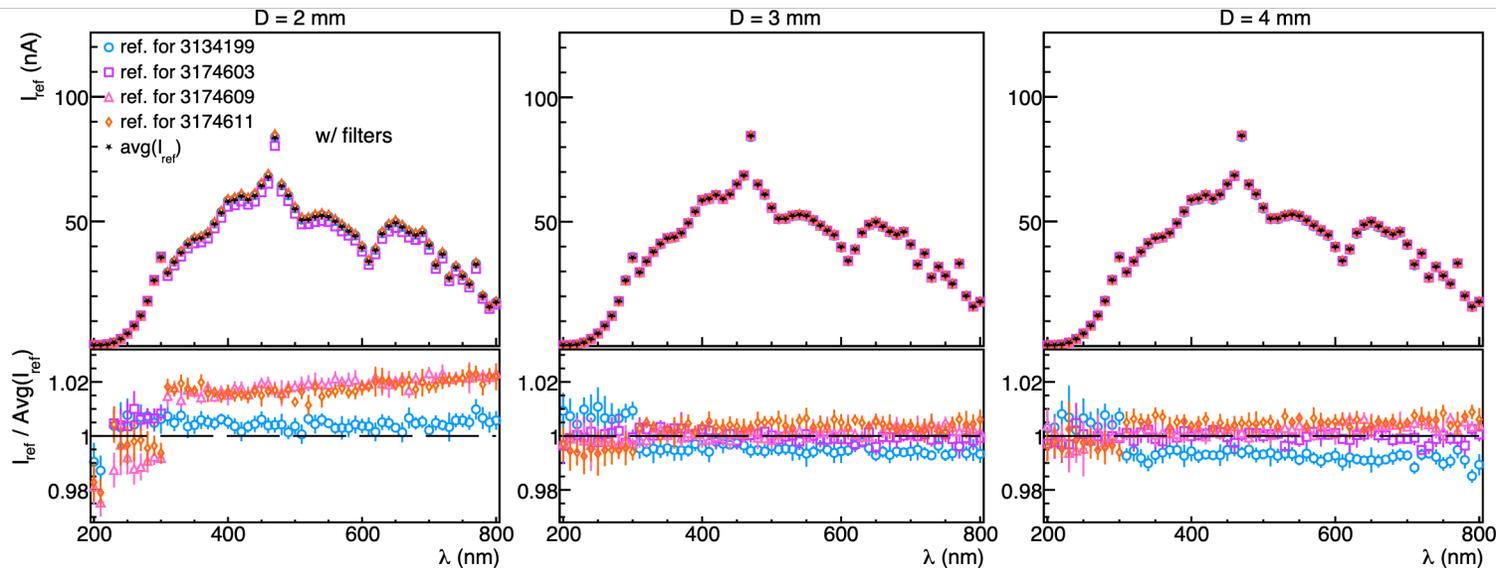


# Normalization from the Reference Diode

No filter

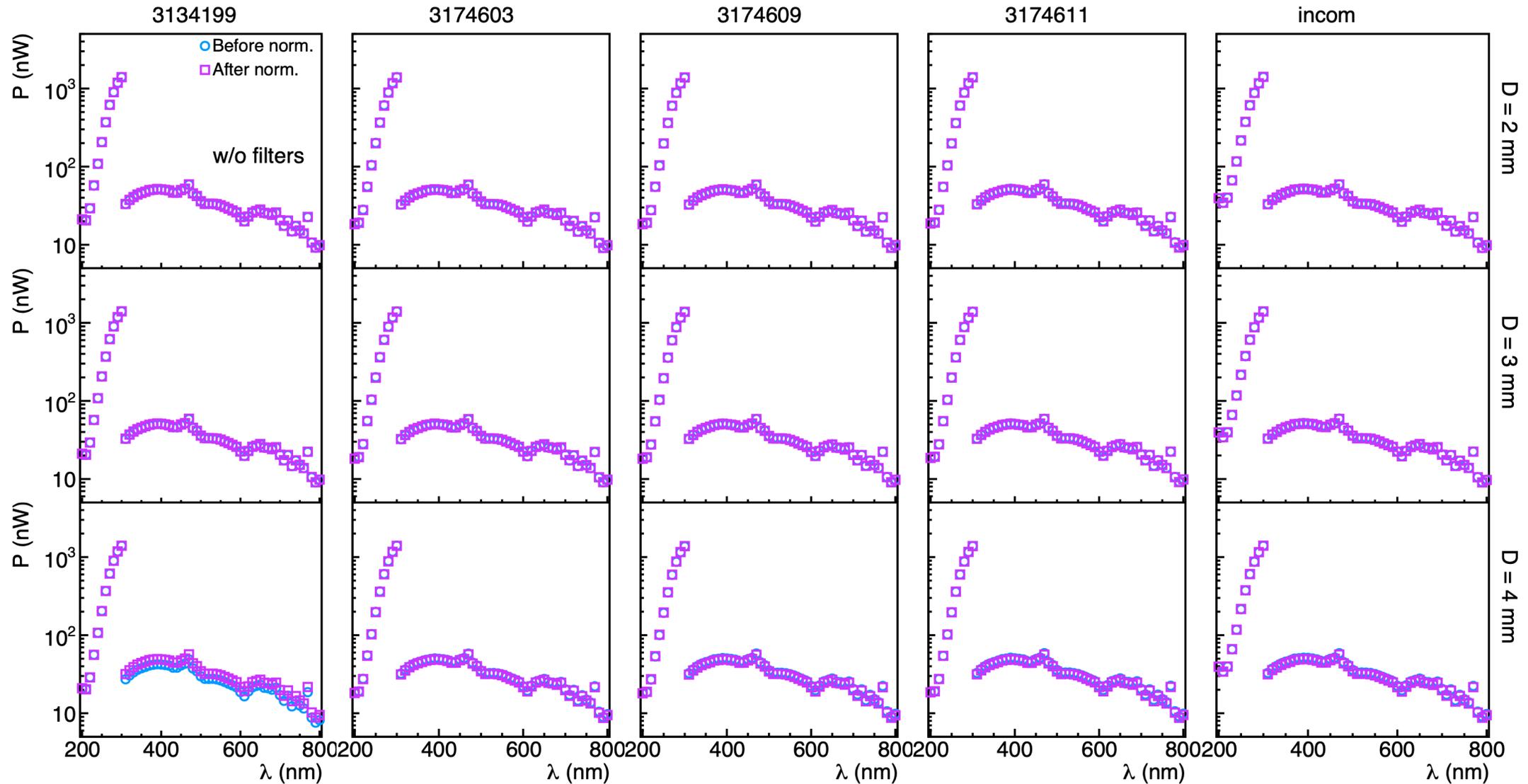


with filter

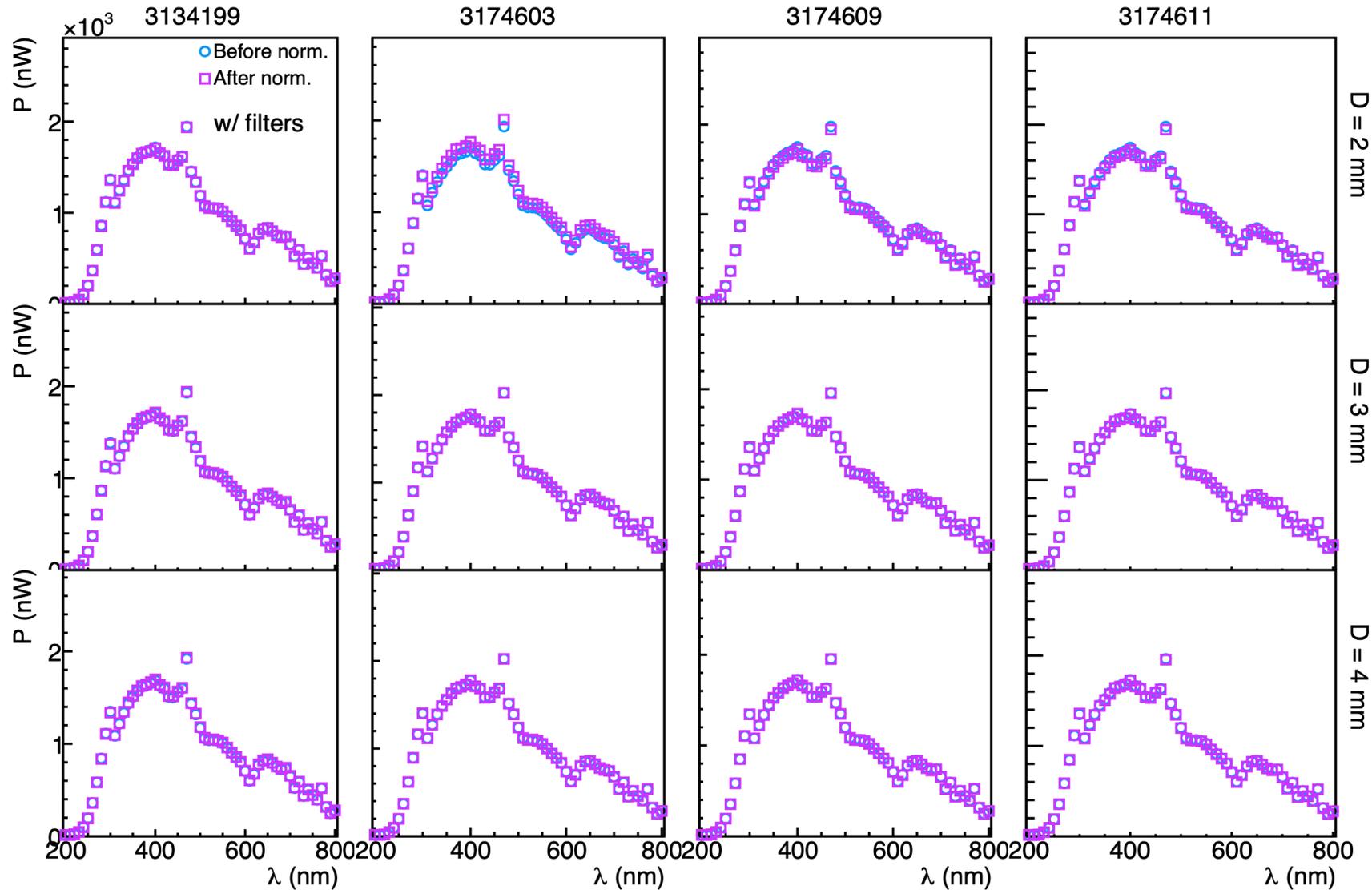


- Slit of the monochromator was adjusted back and forth, thus the changes in reference diode currents between measurements
- The disconnection at 300nm: manual increase of brightness
- **No filter** measurements: Close the monochromator slit all the way down  
Excessive brightness leads to exceeding the measurement range of the Keithley's
- **W/ filter** measurements: Slit opens halfway  
inadequate brightness leads to worsen fluctuation of the measurements

# Power vs Wavelength, No Filter

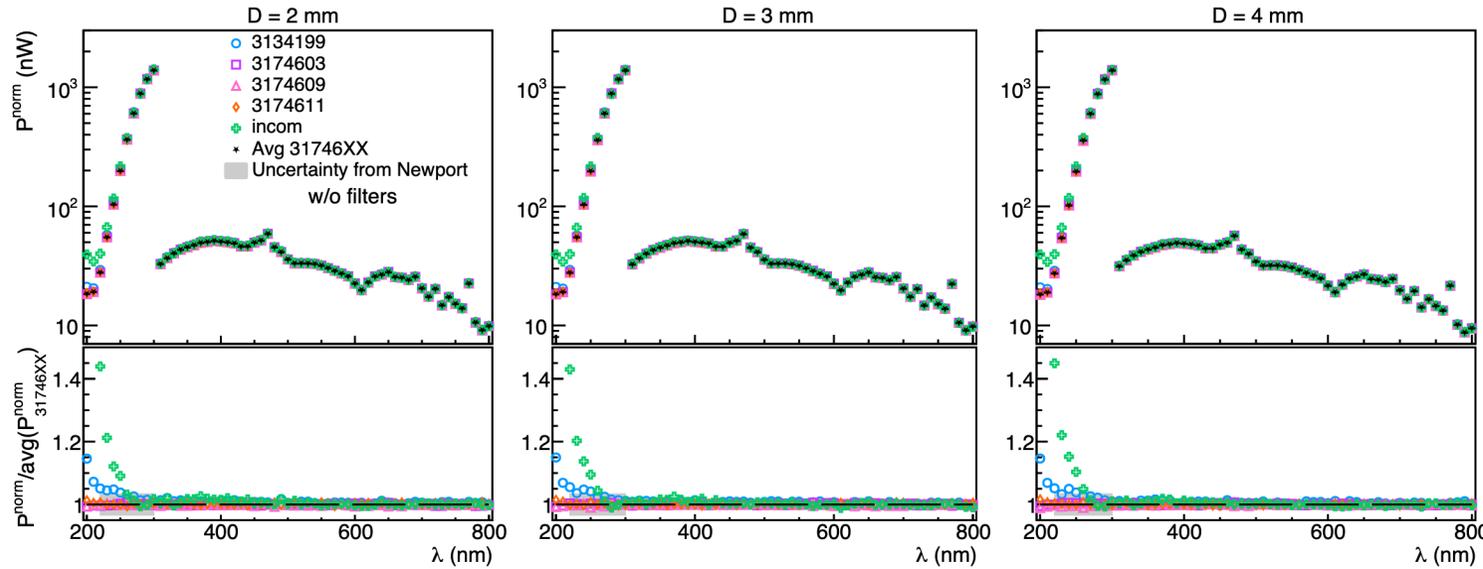


# Power vs Wavelength, with Filter

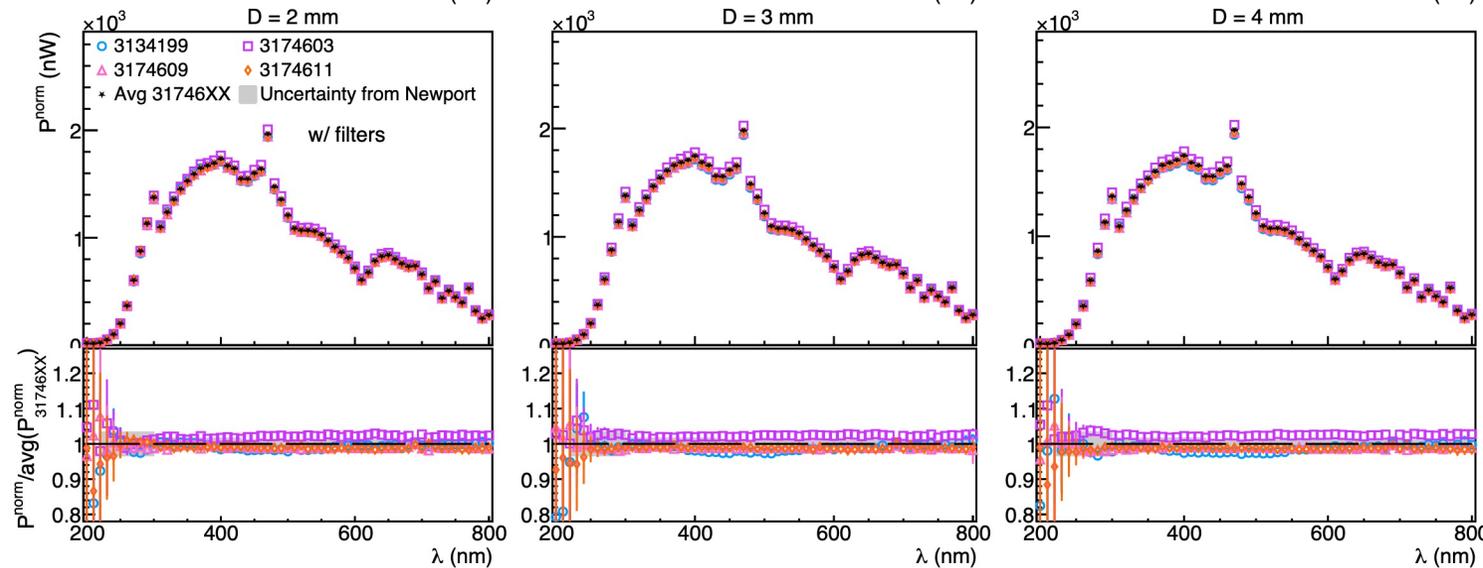


# $P(\lambda)$ Comparisons, No Filter

No filter



with filter



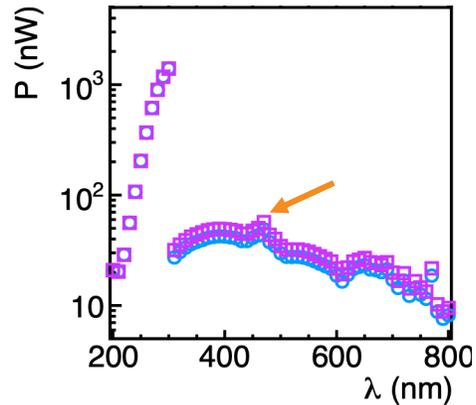
<250 nm: disagreements between the new-batch diodes and the old diodes

>250 nm:

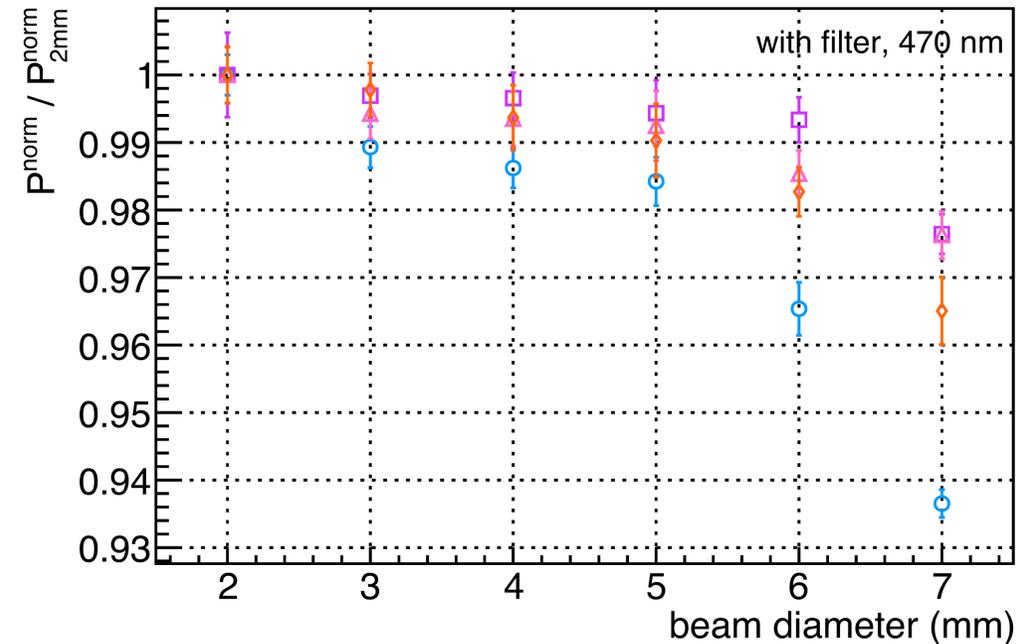
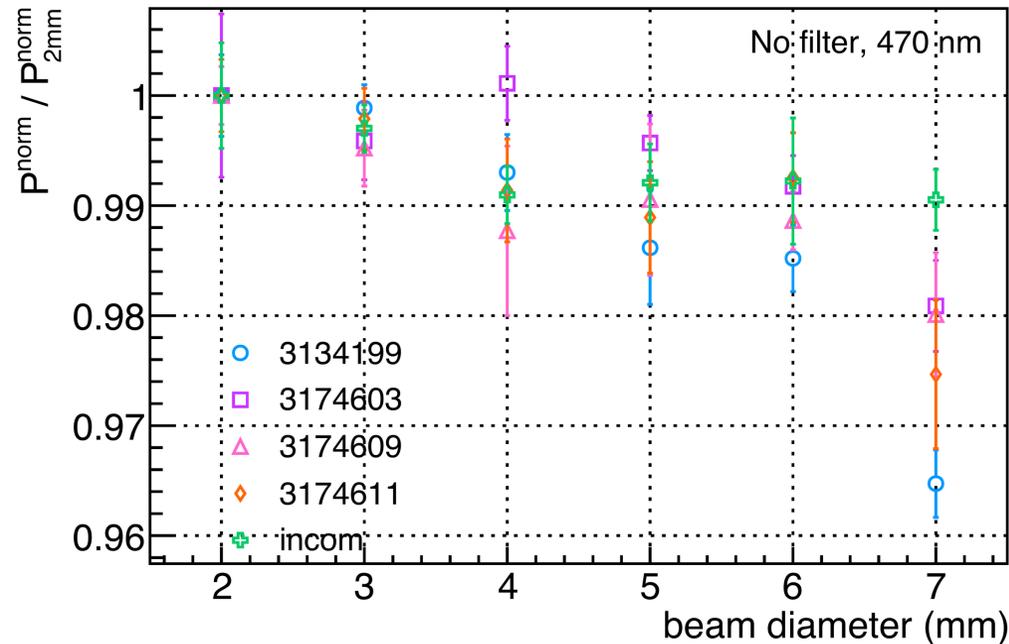
- good agreements among all diodes without the filters
- 3174603 is ~2% off than the rest of the diodes with the filter on

# Power vs Beam Spot Size

# Power vs Beam Spot, Pointing toward the Center



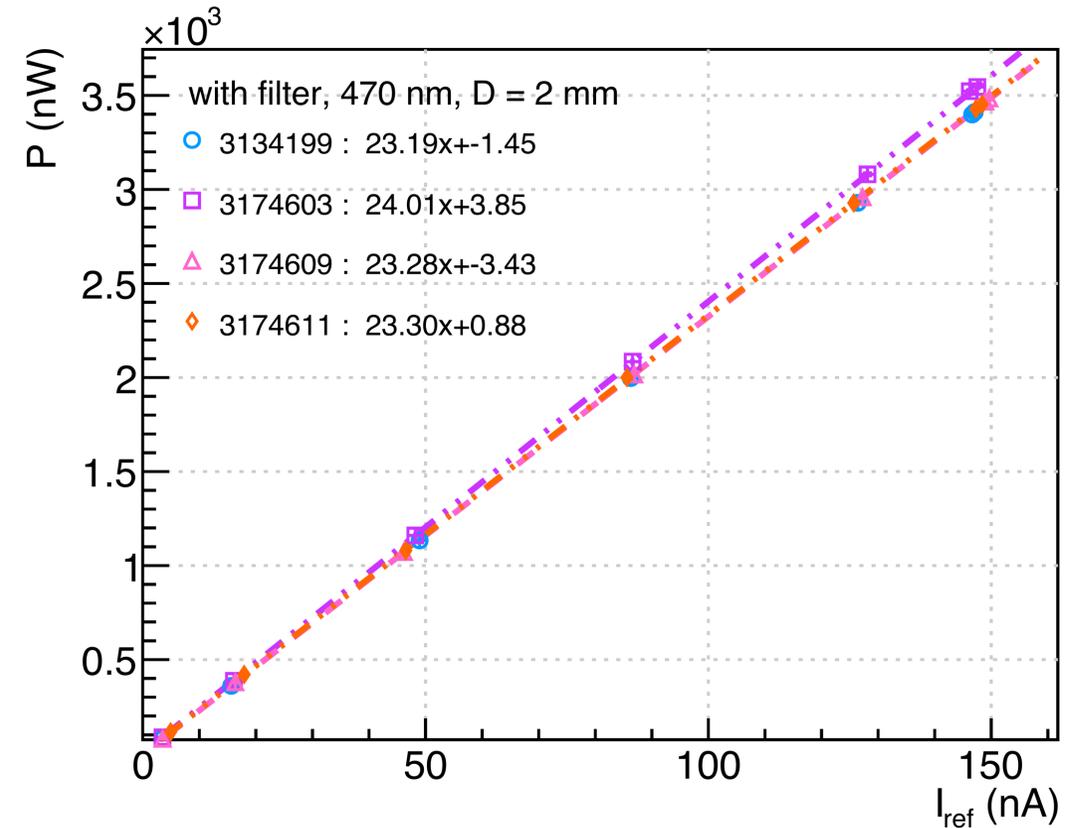
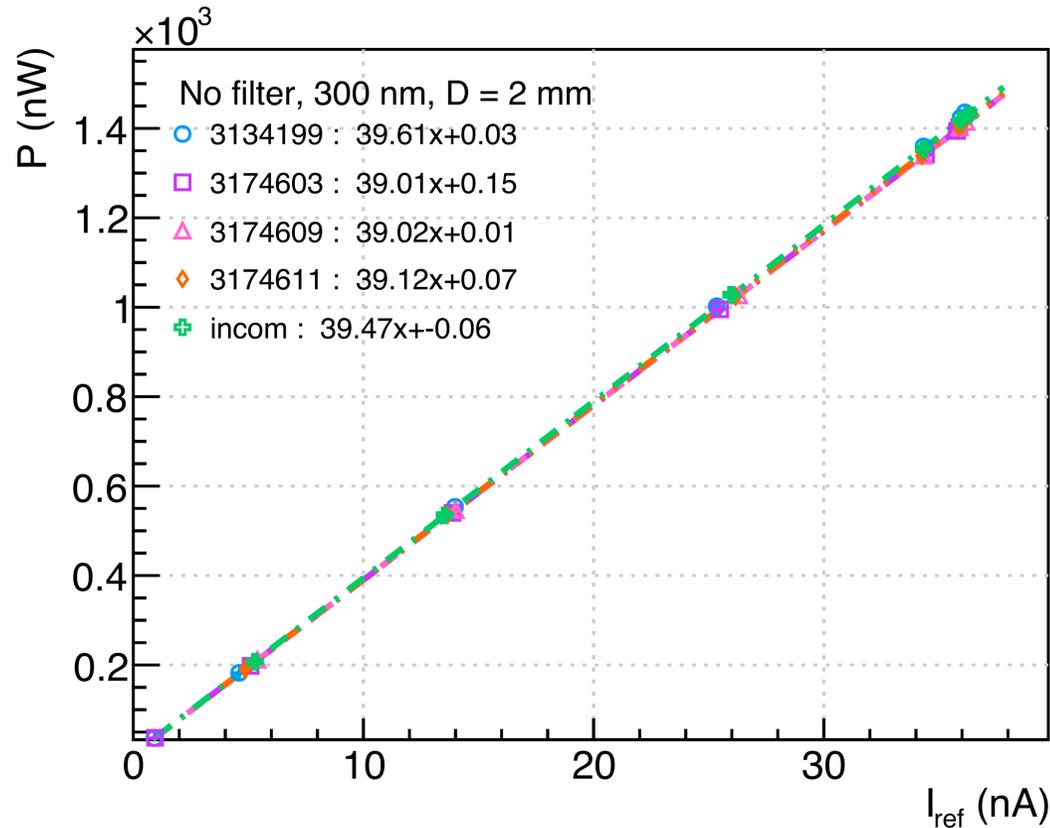
- Taking the normalized power at  $\lambda = 470$  nm from the power vs wavelength measurements
- Power drops by about 2% as beam spot increases from 2 mm to 5 mm



# Brightness Scan -- Linearity

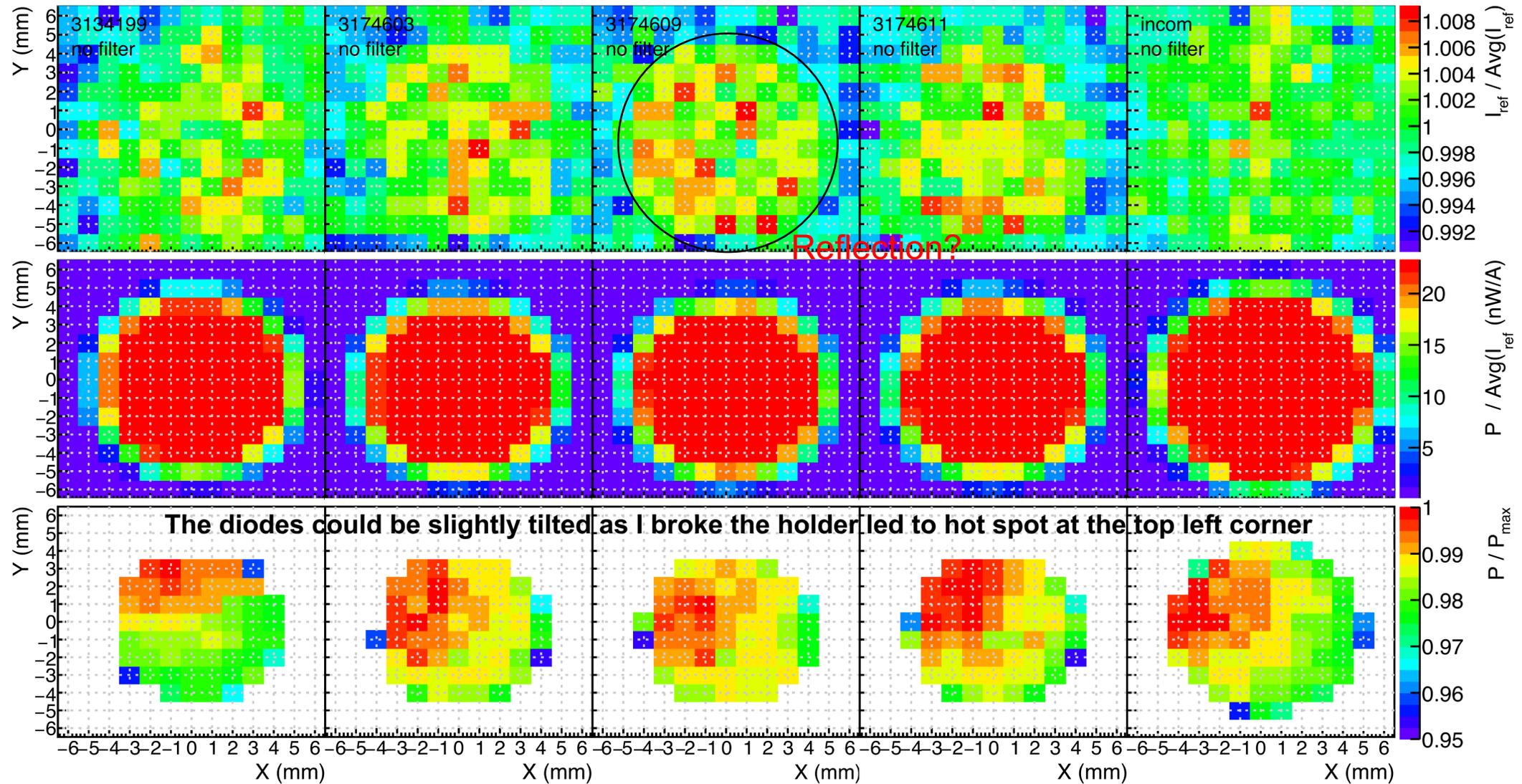
# Power vs Reference Diode Current

The power rises faster without the filters

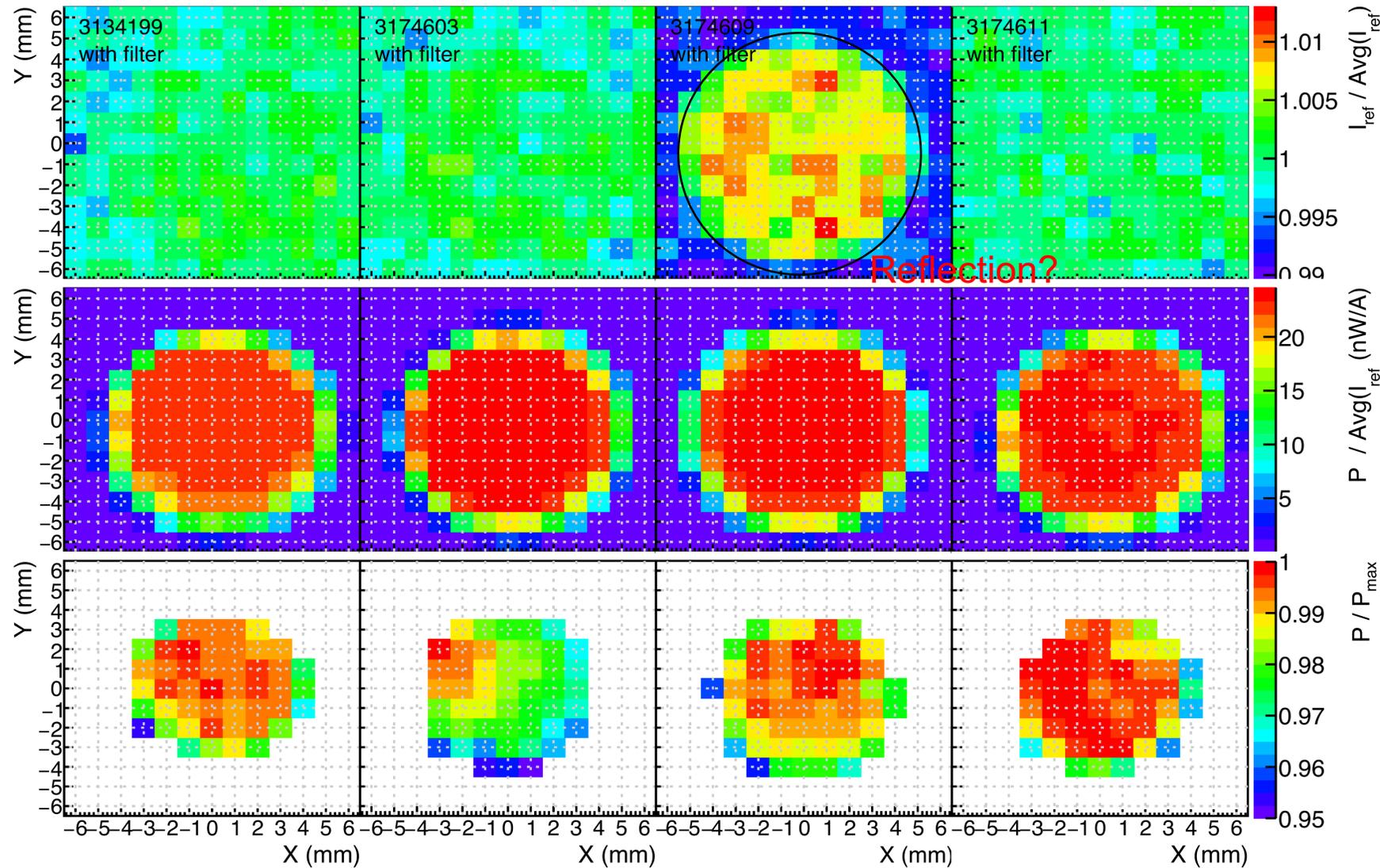


# XY Scan -- Uniformity

# XY Scan, Beam Spot=2mm, $\lambda = 470$ nm, No Filter



# XY Scan, Beam Spot=2mm, $\lambda = 470$ nm, with Filter



Even if there are reflections reaches the reference diode, the effects of reflection is small (<3%)

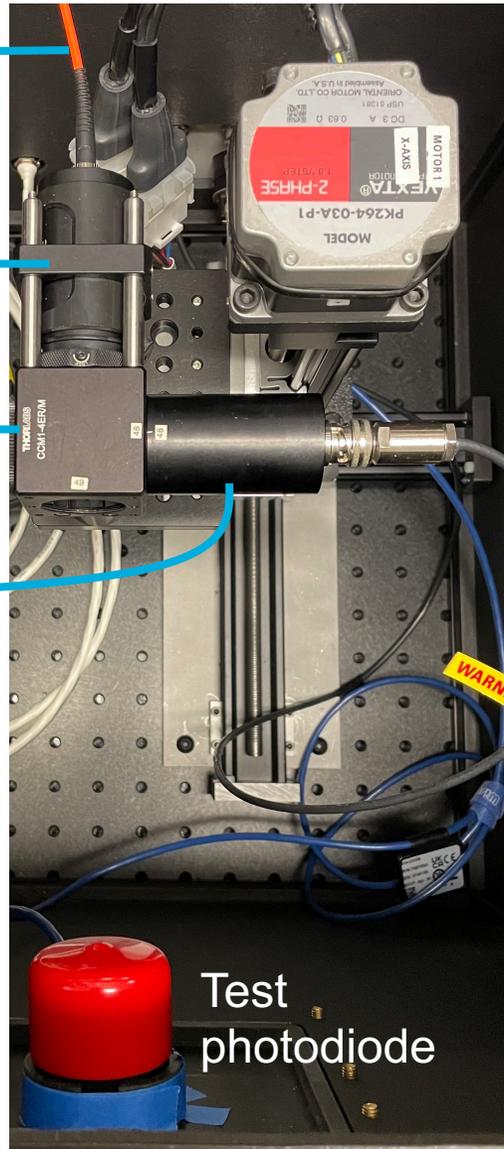
# Reference Diode Photocurrent with ND Filters

Optical fiber  
 $d = 600 \mu\text{m}$

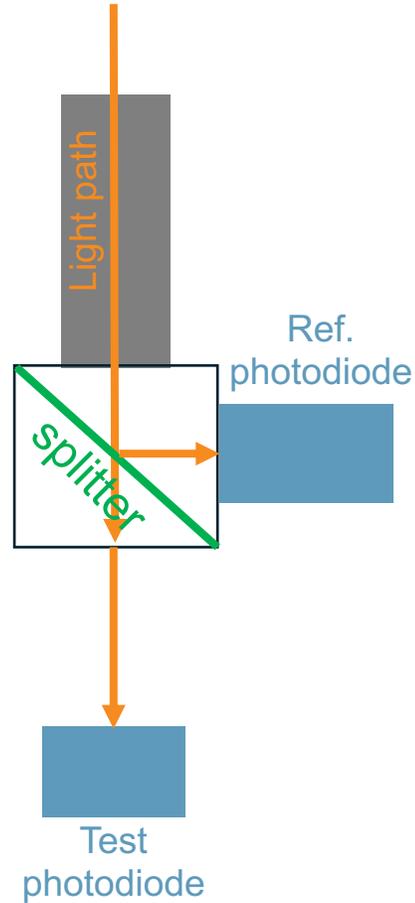
Light source  
guide

splitter

Reference  
photodiode



Monochromator  
(200-800nm)



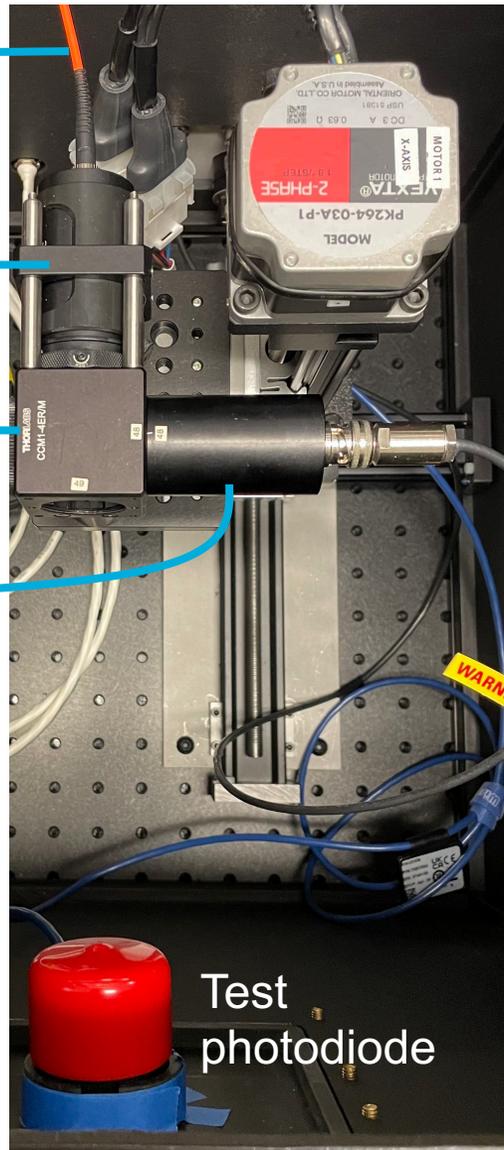
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Optical fiber  
 $d = 600 \mu\text{m}$

Light source  
guide

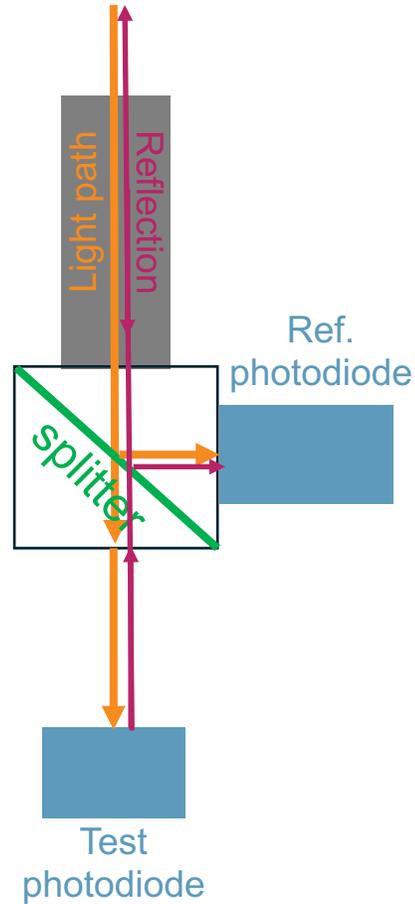
splitter

Reference  
photodiode



Test  
photodiode

Monochromator  
(200-800nm)



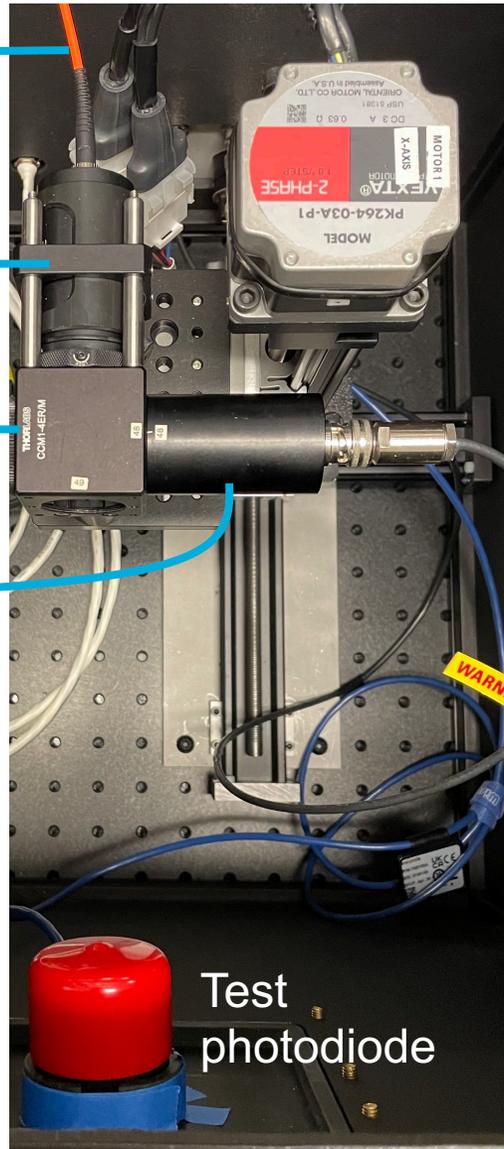
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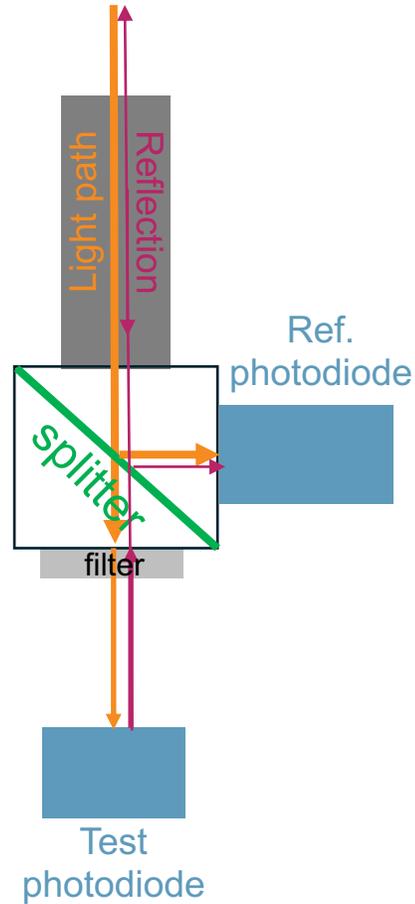
Light source  
guide

splitter

Reference  
photodiode



Monochromator  
(200-800nm)



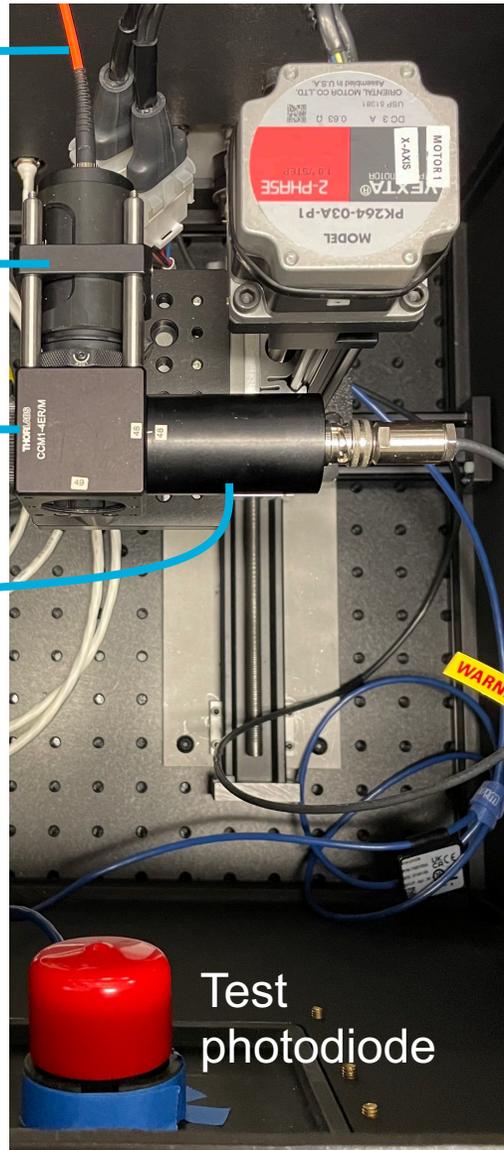
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Optical fiber  
d = 600  $\mu\text{m}$

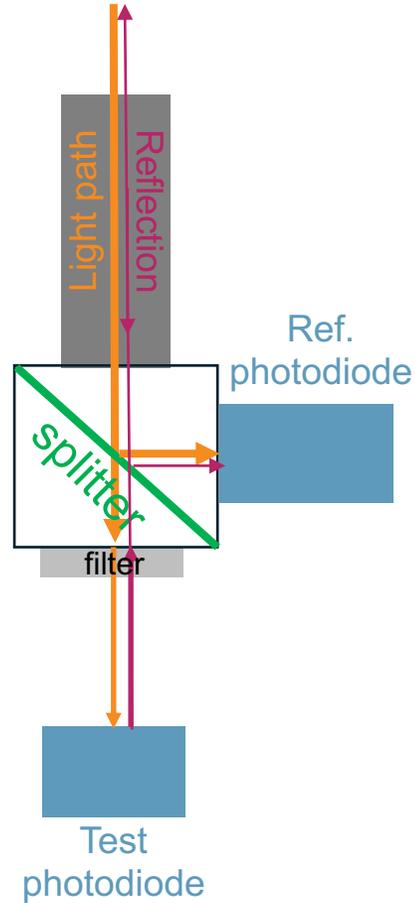
Light source  
guide

splitter

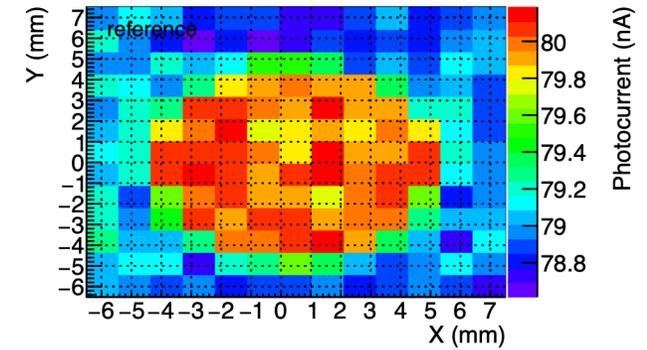
Reference  
photodiode



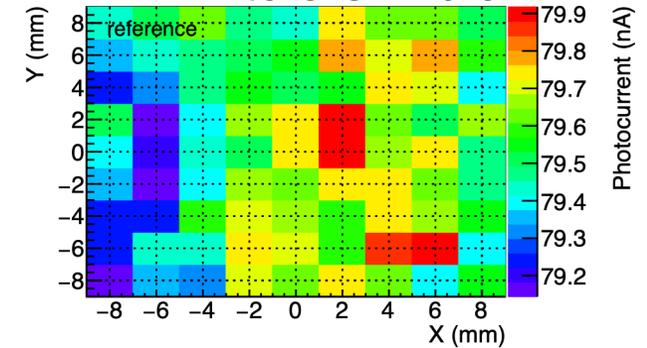
Monochromator  
(200-800nm)



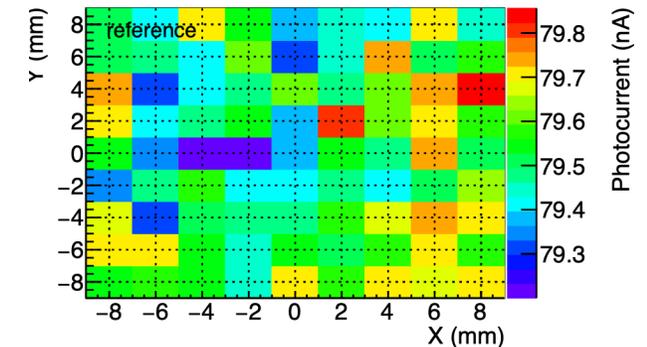
No ND filters



ND filters OD=0.5



ND filters OD=1.0



# Summary

## $P(\lambda)$ at the center

- The new batch of photodiodes (31746XX) without the filters shows high consistency, with differences below 5%
- 3174603 shows disagreement with the rest of the photodiodes when filters are installed
- The older photodiodes (Incom & 3134199) exhibit larger variation (>10%) compared to the new batch at wavelengths below 250 nm

## Power vs beam spot size

- A small drop (~2%) in power is observed as the beam spot diameter increases from 2 mm to 5 mm

## Brightness

- The test diodes power is proportional to the reference diode current and thus the brightness of the light source
- The power rises faster without the filters

## XY scan, $\lambda = 470$ nm

- Only a few percents of fluctuation in the central region
- The Incom photodiode has a slightly larger active area (approximately 1–2 mm larger in diameter)
- ND filter could be used to reduce reflections