

# Canadian HK Photosensor and Calibration Work

Thomas Lindner | TRIUMF  
HK-EU Meeting | Dec 2013

# Outline of talk

Canadian-HK people working on two separate HK PMT projects:

- PMTs with enhanced photon traps.
- PMT Test Facility
  - This is actually a mixed T2K/HK project.

Most of the slides/content are stolen from  
Firat Nurozler (Co-op student) and Hiro Tanaka

# PMTs with photon traps; aka enhanced PMT

- The idea: use a 12" PMT with a photon trap for HK, instead of 20" PMT.
- The hope: that an enhanced 12" PMT will provide equal/better photon collection at a lower cost.
- Test idea using GEANT4 simulation.

# Possible HK PMT Configurations

## Super-K Style PMT

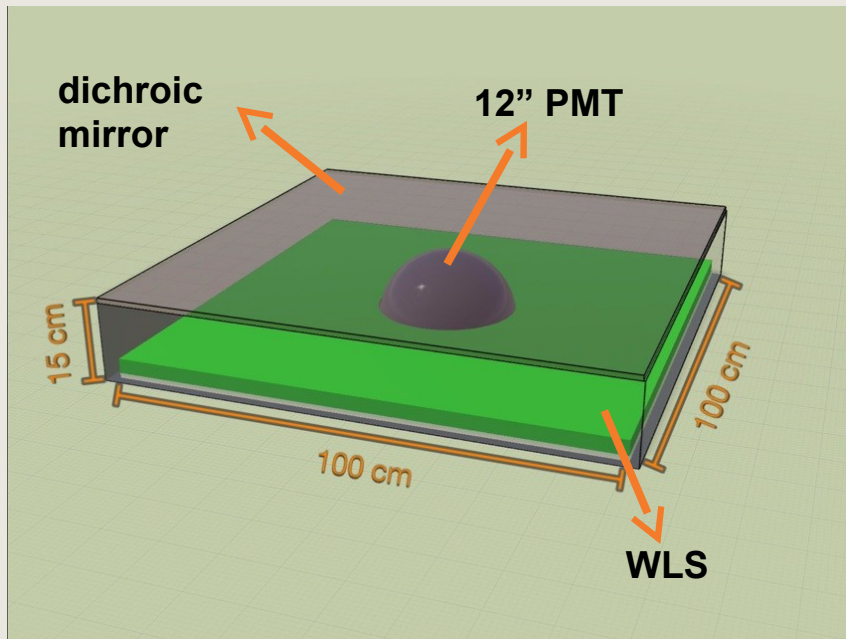
- 20-inch PMT
- Photon collection depends on PMT size.

## PMT with Photon Trap

- 12-inch PMT (cost efficient)
- PMT-missing photons are collected.
- Components:
  - Dichroic mirror
  - Broadband mirror
  - Wavelength shifter plate
- Simulated five configurations using Geant4.

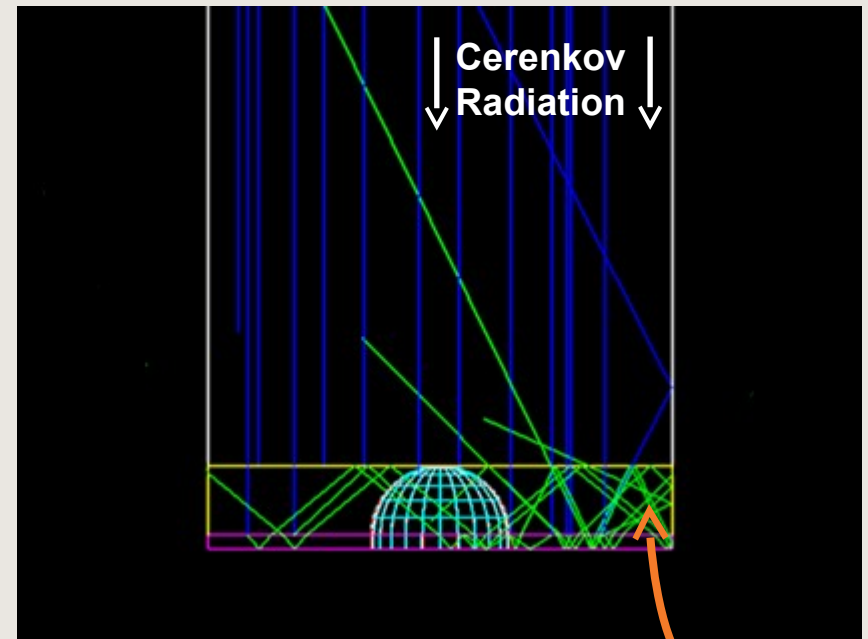
# Enhanced photon traps

## 3D Model



Trap: 12-inch PMT  
 3-cm-thick blue-to-green WLS plate  
 Dichroic mirror + broadband mirror

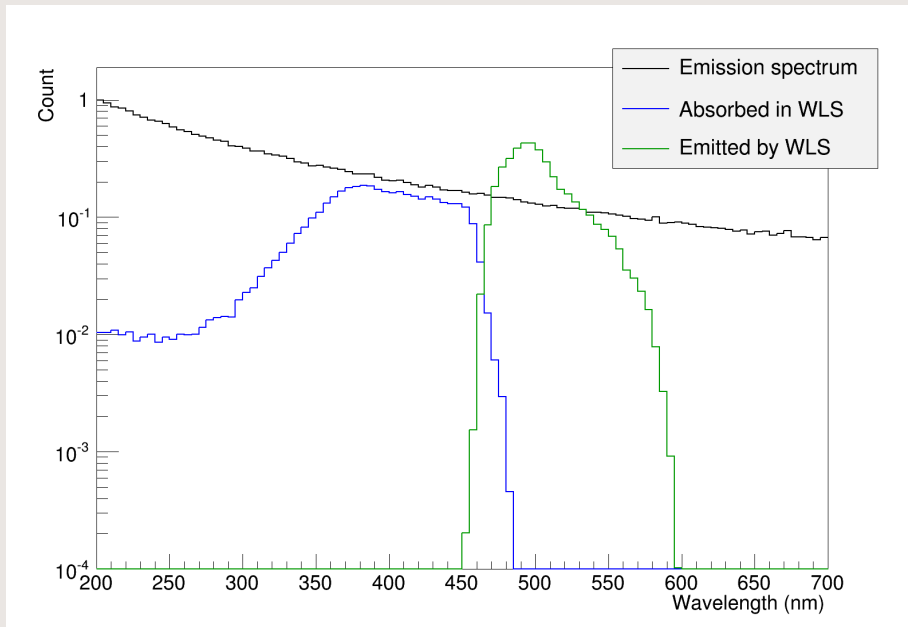
## Geant4 Visualization



F. Nurozler

# WLS and Dichroic Mirror Properties

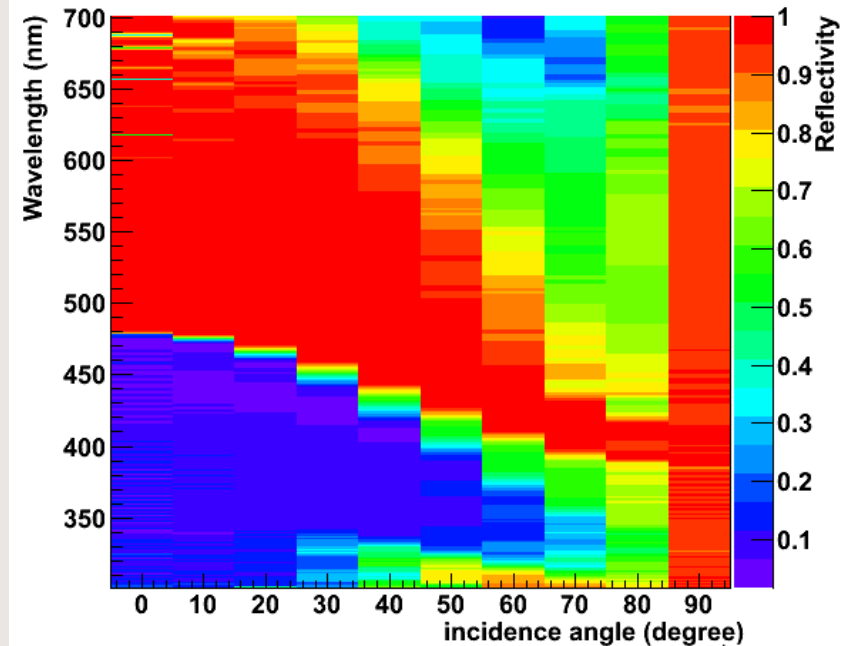
## WLS Optical Spectra



F. Nurozler

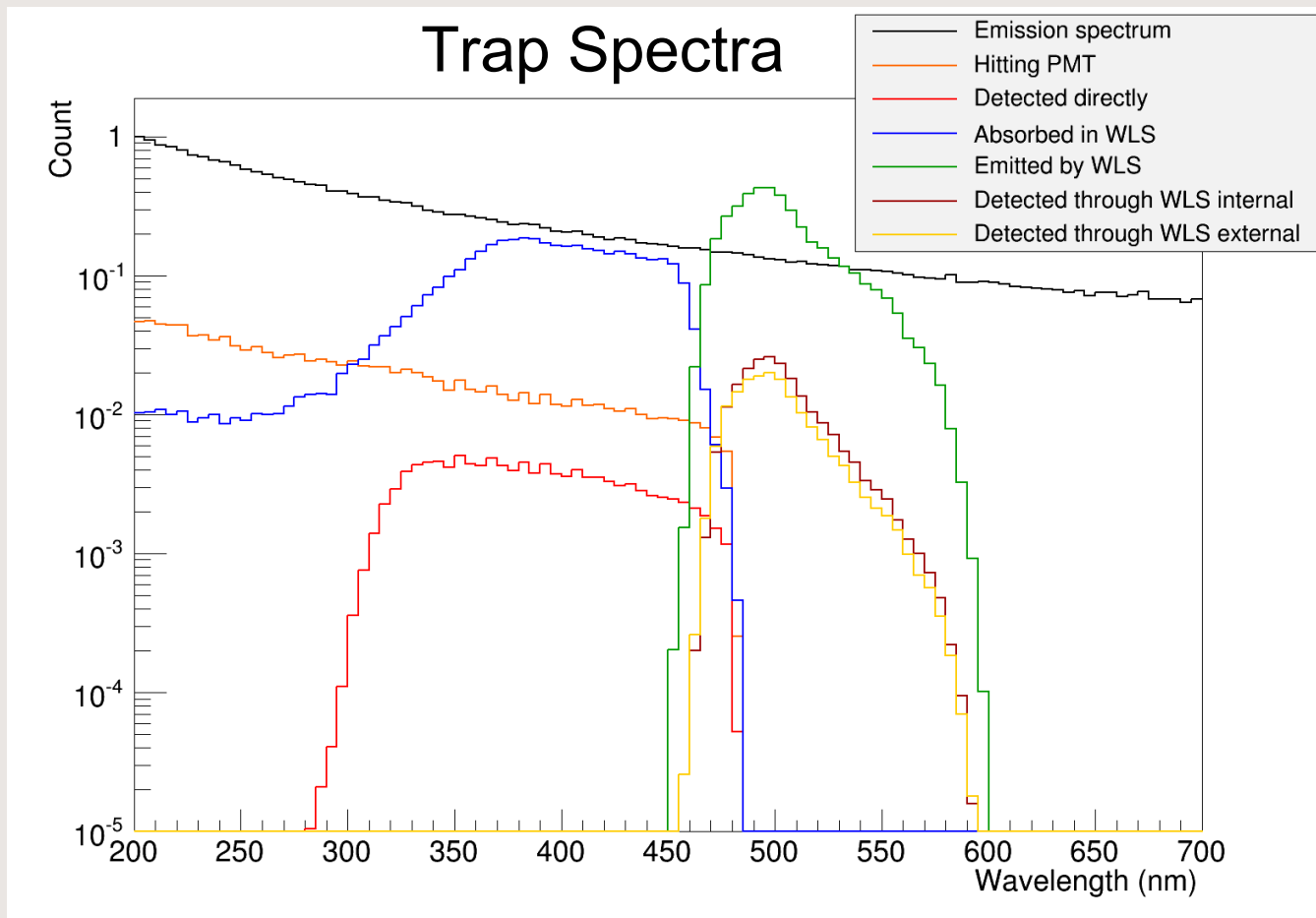
Saint-Gobain BC482A

## Dichroic Mirror Reflectivity



Iridian Spectral Technologies,  
custom dichroic mirror

# Trap Performance



**Internal:**  
No interaction  
with dichroic  
mirror.

**External:**  
Secondary  
photon  
reflected from  
dichroic mirror  
before hitting  
PMT.

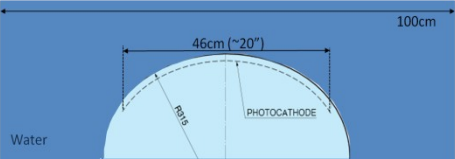


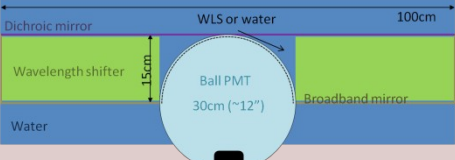
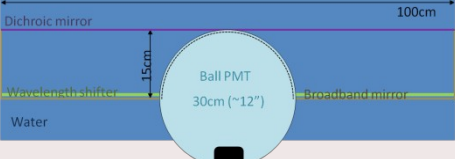
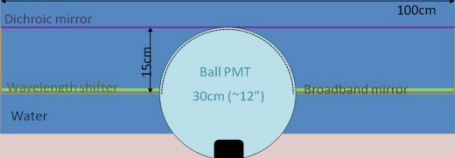
Trap: 12-inch PMT

3-cm-thick blue-to-green WLS plate

Dichroic mirror + broadband mirror

F. Nurozler

# Photon Collection Performance of 100 cm Traps

Configuration		Primary	Internal	External	Int+Ext	Total
20" PMT (SK)		1*	0	0	0	1
12" PMT + 3cm WLS + side mirrors		0.43	0.38	0	0.38	<b>0.81</b>
12" PMT + 3cm WLS + side & back mirrors + WLS dichroic mirror		0.42	0.43	0.13	0.56	<b>0.98</b>
12" PMT + 15cm WLS + side & back mirrors + dichroic mirror		0.34	0.56	0.47	1.03	<b>1.37</b>
12" PMT + 3cm WLS + side & back mirrors + dichroic mirror		0.34	0.44	0.35	0.79	<b>1.13</b>
12" PMT + 5mm WLS + side & back mirrors + dichroic mirror		0.35	0.21	0.41	0.62	<b>0.97</b>

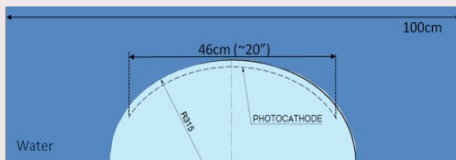
\*All values are normalized by the 20-inch PMT collection efficiency.

# Photon Collection Performance of 100 cm Traps

Configuration

Primary Internal External Int+Ext Total

20" PMT (SK)



1\*

0

0

0

1

12" PMT + 3cm WLS  
+ side mirrors



0.43

0.38

0

0.38

**0.81**

12" PMT + 3cm WLS  
+ side & back mirrors  
+ WLS dichroic mirror



0.34

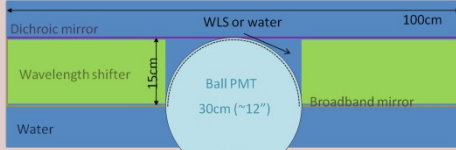
0.56

0.47

1.03

**1.37**

12" PMT + 15cm WLS  
+ side & back mirrors  
+ dichroic mirror



0.34

0.44

0.35

0.79

**1.13**

12" PMT + 3cm WLS  
+ side & back mirrors  
+ dichroic mirror



0.35

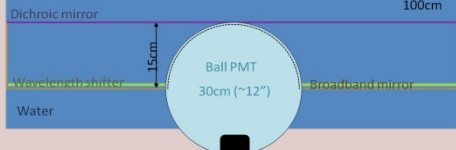
0.21

0.41

0.62

**0.97**

12" PMT + 5mm WLS  
+ side & back mirrors  
+ dichroic mirror



Can achieve better light collection with enhanced PMT compared to standard PMT.

\*All values are normalized by the 20-inch PMT collection efficiency.

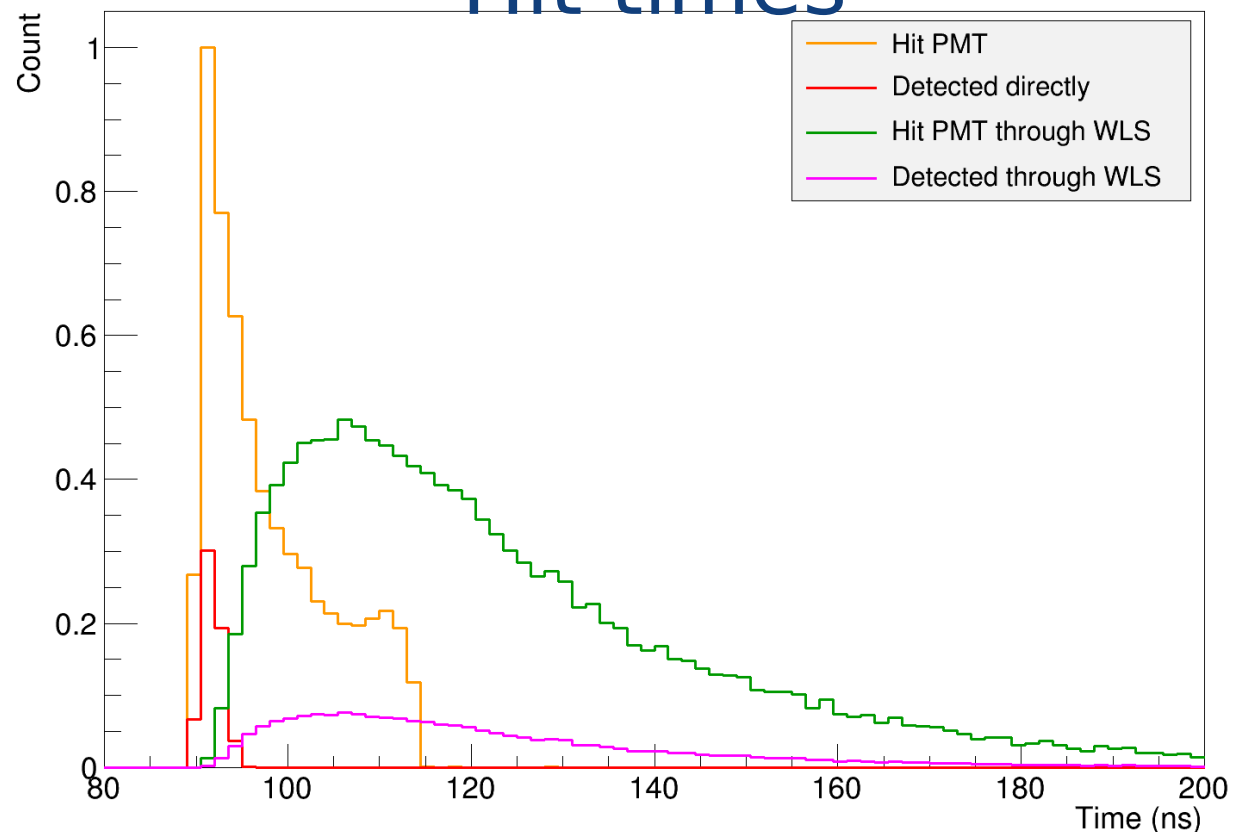
# Time of photons from trap

- But we find a big problem: the time of the photons from the trap are substantially delayed compared to the direct.
- Will seriously degrade the HK timing resolution.

Presumably not acceptable for HK.

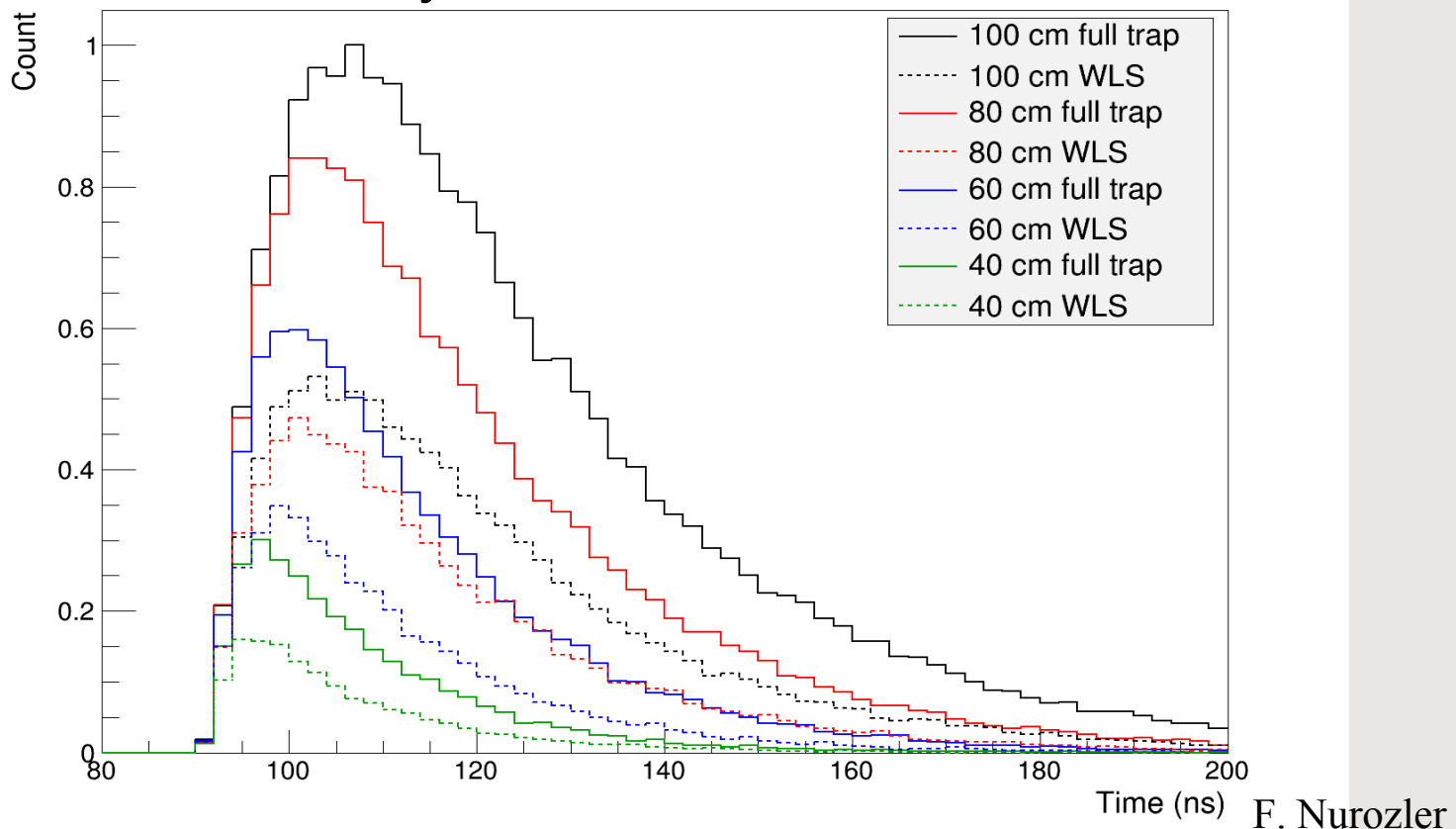
## Hit times

F. Nurozler



# Hit Time: Trap Size Analysis

## Secondary Detection Time vs. Size



**Full Trap:** 12-inch PMT  
3-cm-thick WLS plate  
Dichroic mirror + broadband mirror

**WLS:** 12-inch PMT  
3-cm-thick WLS plate  
broadband mirror plated WLS sides

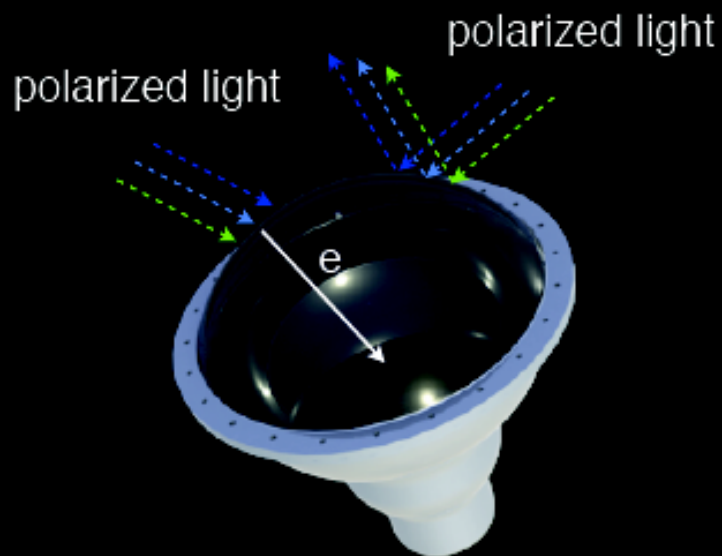
# Conclusion: photon-trap

- Degraded time resolution probably not acceptable for HK inner detector completely.
- But could still consider adding additional enhanced PMTs to the baseline 20" PMTs; increasing photo-cathode coverage for a marginal additional cost.
- Also consider enhanced PMTs in HK outer detector.

## Future Plans

- The trap concept needs physical verification using full HK simulations; help appreciated.
- Cost analysis required.
- Investigating other dichroic mirrors and WLSs.

# PMT test facility (PTF)



- Study response of R3600 20" PMT to light across (in water):
  - wavelengths (330-550 nm)
  - incident angles to surface
  - locations on the PMT
  - polarization
- Light reflected from the PMT affects response of other PMTs (in water)
- Study reflectivity of R3600 20" PMT across same parameter space,

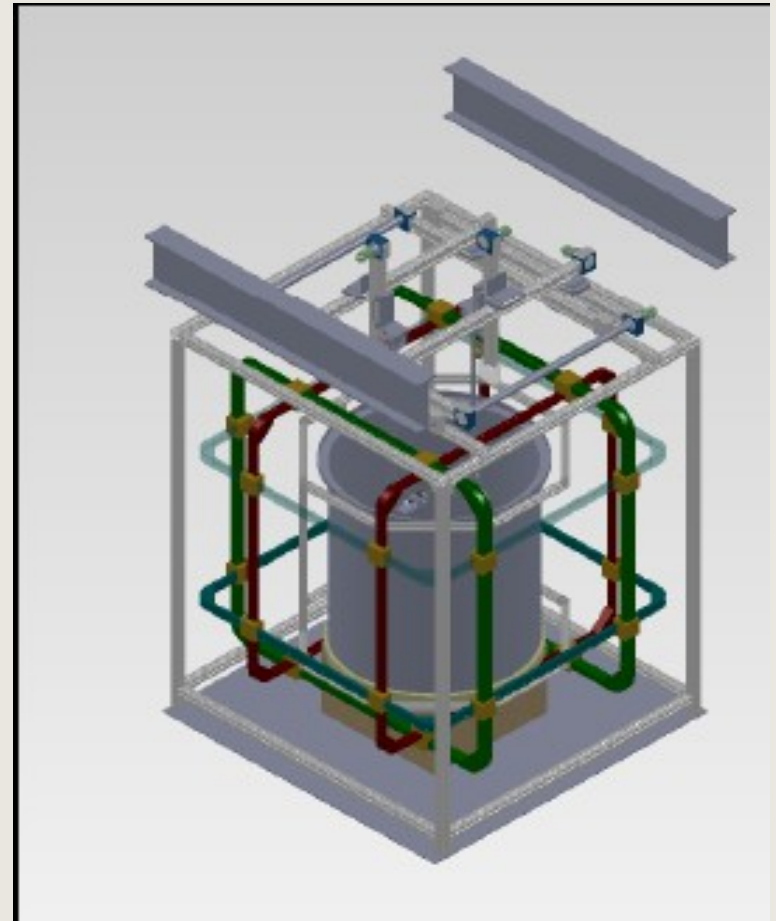
# PMT Test Facility (PTF) @ TRIUMF

## Requirements:

- The primary requirements of the PTF:
  - House and operate a 20" R3600 PMT in water
  - Shield the PMT from stray magnetic fields ( $<100$  mG)
  - Direct collimated, polarized monochromatic light at a large range of relevant wavelengths (300-500 nm) at any point of the PMT photocathode surface at all inward incident angles.
  - Detect light reflected from the PMT at any outward incident angle and at all source wavelengths.

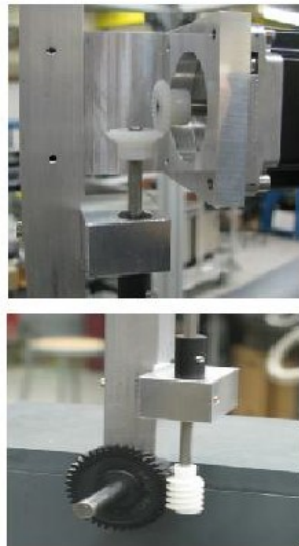
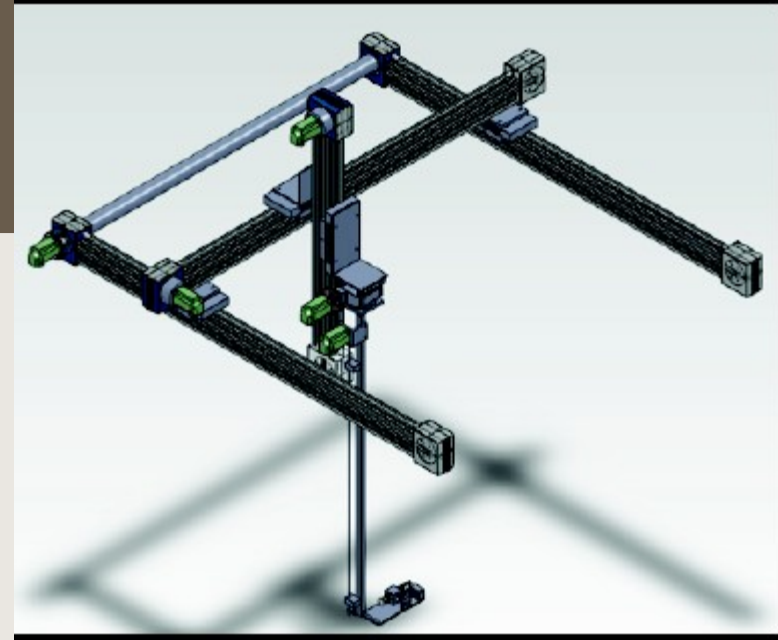
# PTF: Overall setup

- Pair of optical heads: each head has a laser fibre and a measurement PMT.
  - Each optical head can either fire laser light at 20" PMT or measure reflected light.
- Two gantries with 5D control of optical heads (3 translation, 2 rotation axes).
- Active/Passive magnet shielding.
- Water tank and circulation system.



# TRIMPTF: Positioning Gantries

- 3D translation along belt drive system from Rexroth components.
- 2 rotation axes; tilt motor must be out of water -> use worm gear to tilt optical head at end of long arm.
- Two gantries identical, but rotated around Z axis.

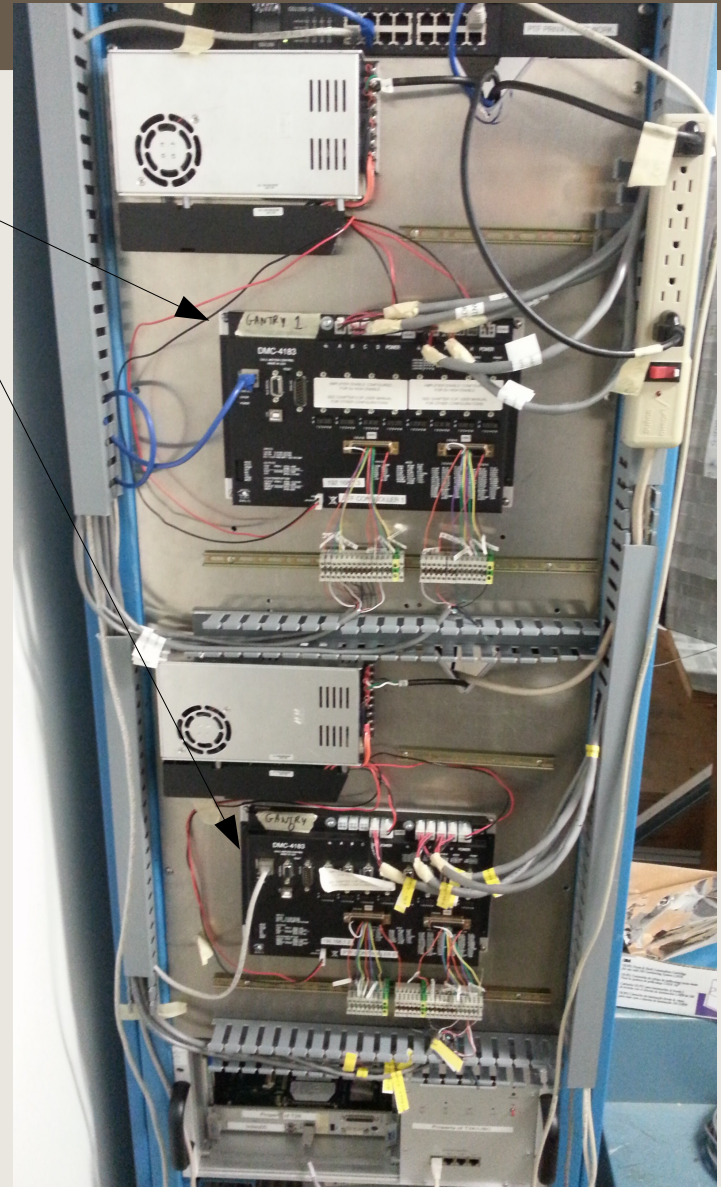


HK Photosensor/Calibration



# PTF: Motor Control

- Motors driven by Galil controllers
- controllers implement hardware limit switches.
- MIDAS DAQ; front-end programs communicate over TCP/IP with Galils.



### PTF Gantry Movement Control

**Gantry Status**

- Gantry is stopped.
- Gantry is not initialized.
- Last move was completed.
- Current Gantry Position:
  - X = 0 m
  - Y = 0 m
  - Z = 0 m
  - Rotate = 0 deg
  - Tilt = 0 deg
- Current Gantry Destination:
  - X = -0.35 m
  - Y = 0 m
  - Z = 0 m
  - Rotate = 0 deg
  - Tilt = 0 deg
- Phidget Measurements:
  - Tilt = -1.736 deg
  - MagField = 0.169 0.089 1.124

**Gantry Control**

Stop Gantry Now!

feMove is not active

Reinitialize Gantry Move Gantry

Destination:

X	
Y	
Z	
Rotate	
Tilt	

**MIDAS Messages**

- Fri Dec 13 11:42:11 2013 [feMotor01.INFO] DigitalOut2 request CB 10
- Fri Dec 13 11:42:11 2013 [feMotor01.INFO] DigitalOut2 request CB 11
- Fri Dec 13 11:42:11 2013 [feMotor01.INFO] DigitalOut2 request CB 12
- Fri Dec 13 11:43:07 2013 [feMotor00.INFO] Move of Z axis to 500000.000000 will take max 2085 seconds
- Fri Dec 13 11:43:07 2013 [feMotor00.INFO] Move command = CN -1,1,1,0,ACH=16022,DCH=5000,SPH=240,PRH=50000,SH 16,80 H
- Fri Dec 13 11:43:34 2013 [feMotor01.INFO] Move of Z axis to 500000.000000 will take max 2085 seconds
- Fri Dec 13 11:43:34 2013 [feMotor01.INFO] Move command = CN -1,1,1,0,ACC=16022,DCC=5000,SPC=240,PRC=50000,SH C-80 C
- Fri Dec 13 11:45:07 2013 [Logger.INFO] Client 'feMove' on buffer 'SYSMSG' removed by cm\_watchdog because process pid 3938 does not exist
- Fri Dec 13 11:45:08 2013 [feMotor00.INFO] Client 'feMove' on buffer 'SYSTEM' removed by cm\_watchdog because process pid 3938 does not exist
- Fri Dec 13 11:45:27 2013 [feMotor00.INFO] Program feMotor00 on host midpf01 stopped
- Fri Dec 13 11:45:29 2013 [feMotor01.INFO] Program feMotor01 on host midpf01 stopped
- Fri Dec 13 11:45:32 2013 [midpf01.ERROR] [midas.c:9088:rpe\_client\_connect.ERROR] cannot connect to host 'midpf01.triumf.ca', port 46802: connect() returned -1, errno 111 (Connection refused)
- Fri Dec 13 11:45:32 2013 [midpf01.ERROR] [midas.c:5513:cm\_shutdown.ERROR] Cannot connect to client 'feMove' on host 'midpf01.triumf.ca', port 46802
- Fri Dec 13 11:45:32 2013 [midpf01.ERROR] [midas.c:5516:cm\_shutdown.ERROR] Killing and Deleting client 'feMove' pid 3938
- Fri Dec 13 11:46:07 2013 [feSCAN.INFO] Client 'feMove' (PID 3938) on database 'ODB' removed by cm\_watchdog (idle 60.3s, TO 60s)

MIDAS motor control page

# PTF: Second Gantry

- Milestone last week with first movement of second gantry.
- Example videos here:  
[http://ladd00.triumf.ca/~lindner/ptf/ptf\\_2gantries\\_2.mp4](http://ladd00.triumf.ca/~lindner/ptf/ptf_2gantries_2.mp4)
- Also working on an improved optical housing.
- Optical housing has
  - Fibre and collimator for laser light.
  - Two PMTs; one for monitoring laser, other for measuring reflected light.
  - Tilt angle measurement.

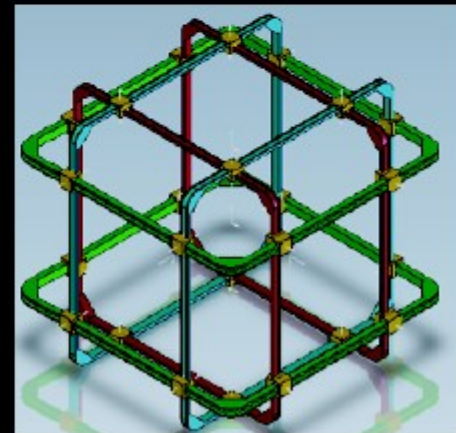
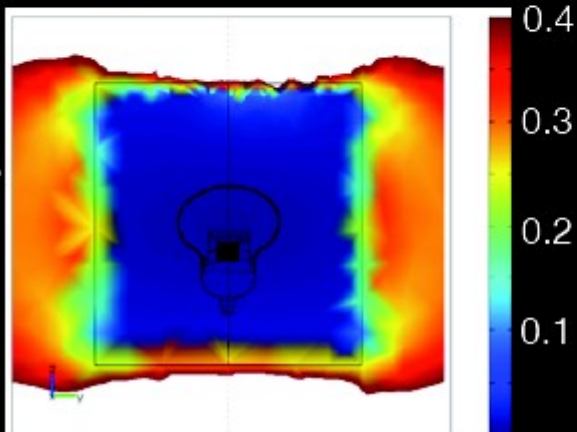


# Magnetic Shielding



- water tank (Barr plastics):
  - 360 gallon (48" diameter x 50.75 " height)
  - high density black polyethylene tank
- Magnetic shielding is via
  - active cancellation (Helmholtz coils)
  - passive shielding (GIRON)
  - FEM analysis:  $< 10$  mG in relevant regions

S. Tobayama



# PTF Status Summary

- Lots of new help with project (Shimpei, Corina Nantais, Sophie Berkman, Mark Scott, Tom Feusels), lots of progress recently.
- Basic gantry movement now working; needs full commissioning and collision avoidance code.
- Starting to fully test Helmholtz coils and passive shielding.
- Light-tightening room.
- Water circulation: components bought, but still lots of work.
- Should be able to start some real tests of small PMTs and black-sheets within first half of 2014.

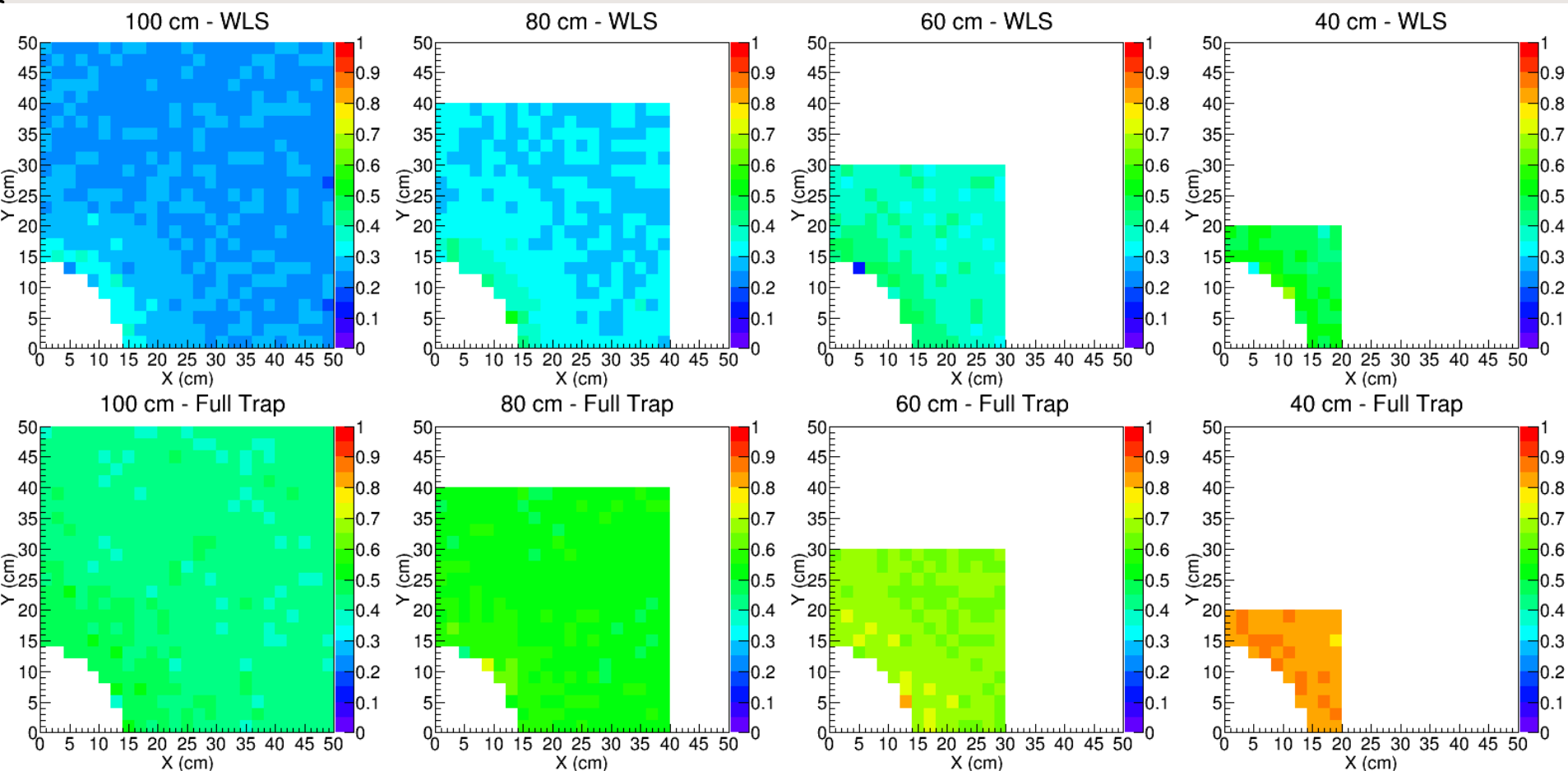
# Conclusions

- Mixed results regarding PMTs with photon traps: some possibilities remain, but timing resolution is a major problem.
- PMT Test Facility has made a lot of progress recently. Hope to have first real results this year.
- Other work as well: UBC student working with TRIUMF engineers on ideas for HK manipulator arm.

# Backups

## Trap Size Analysis: Secondary Collection Efficiency

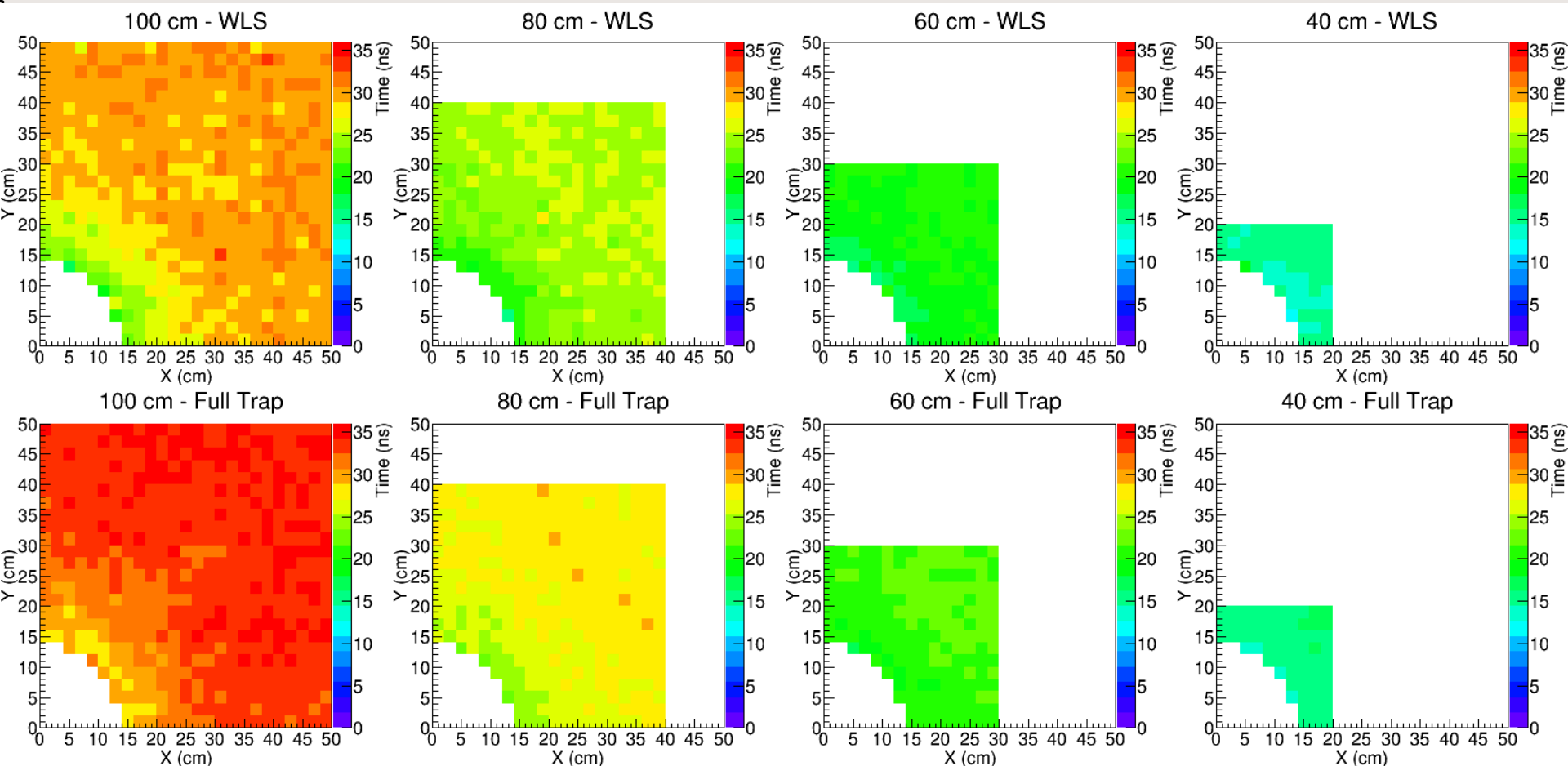
**WLS:** 12-inch PMT with 3-cm-thick WLS plate



**Full trap:** 12-inch PMT, 3-cm-thick WLS with dichroic mirror trap.

## Trap Size Analysis: Secondary Detection Time Delay

**WLS:** 12-inch PMT with 3-cm-thick WLS plate



**Full trap:** 12-inch PMT, 3-cm-thick WLS with dichroic mirror trap.

# Passive Magnet Shielding

GIRON

