WCSim mPMT Simulations & 2R ID using CNN

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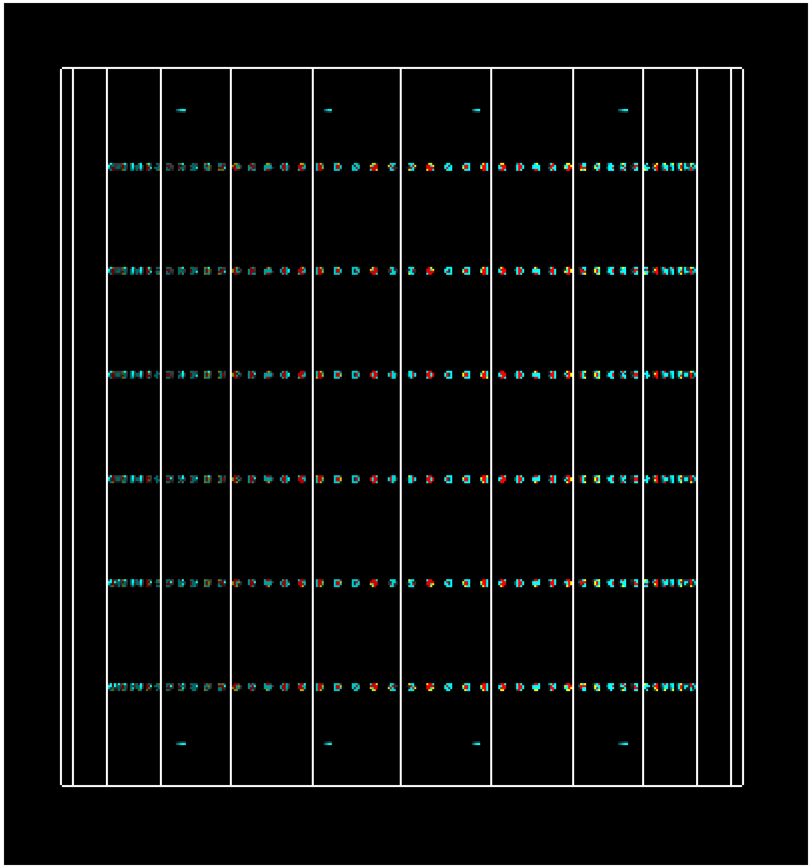
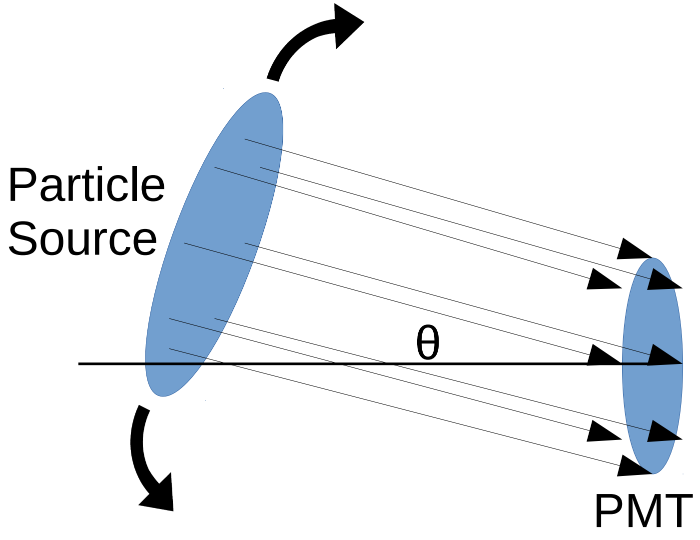
Overview

- Simulate (m)PMTs in WCSim
- Compare performance with/without reflectors
- Look at angular response
- Make sure mPMTs are working as expected



Simulations

- Quantum and collection efficiencies turned off
- Dark noise turned off
- Circular source of optical photons
  - 400 nm wavelength
  - 1 meter from (m)PMT
  - 1,000,000 events
- 10 angles simulated beteween 0° and 75°

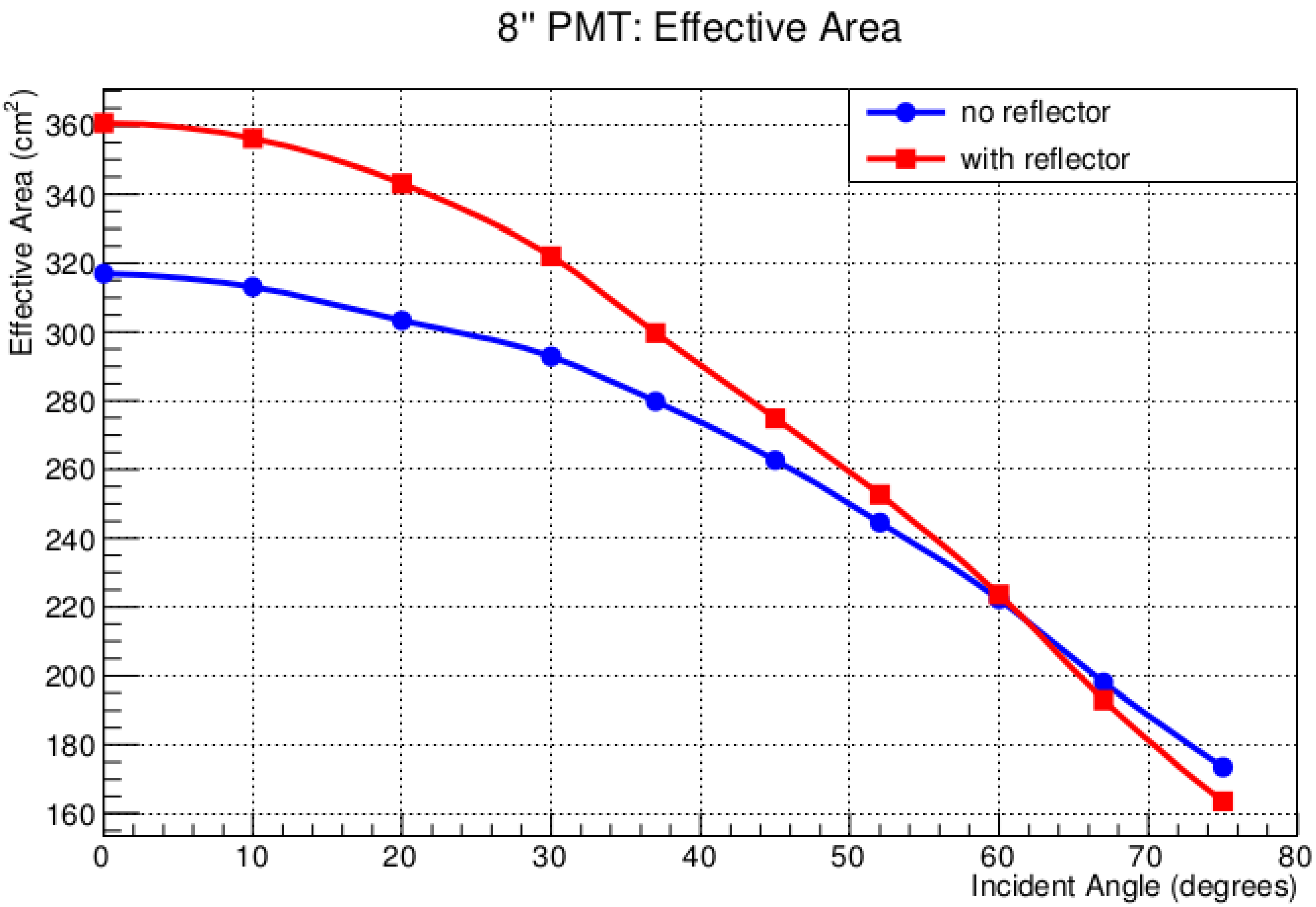


$$\text{Effective Area} = \frac{NHits}{NEvents} \times \pi r^2$$

where r is the radius of the photon source

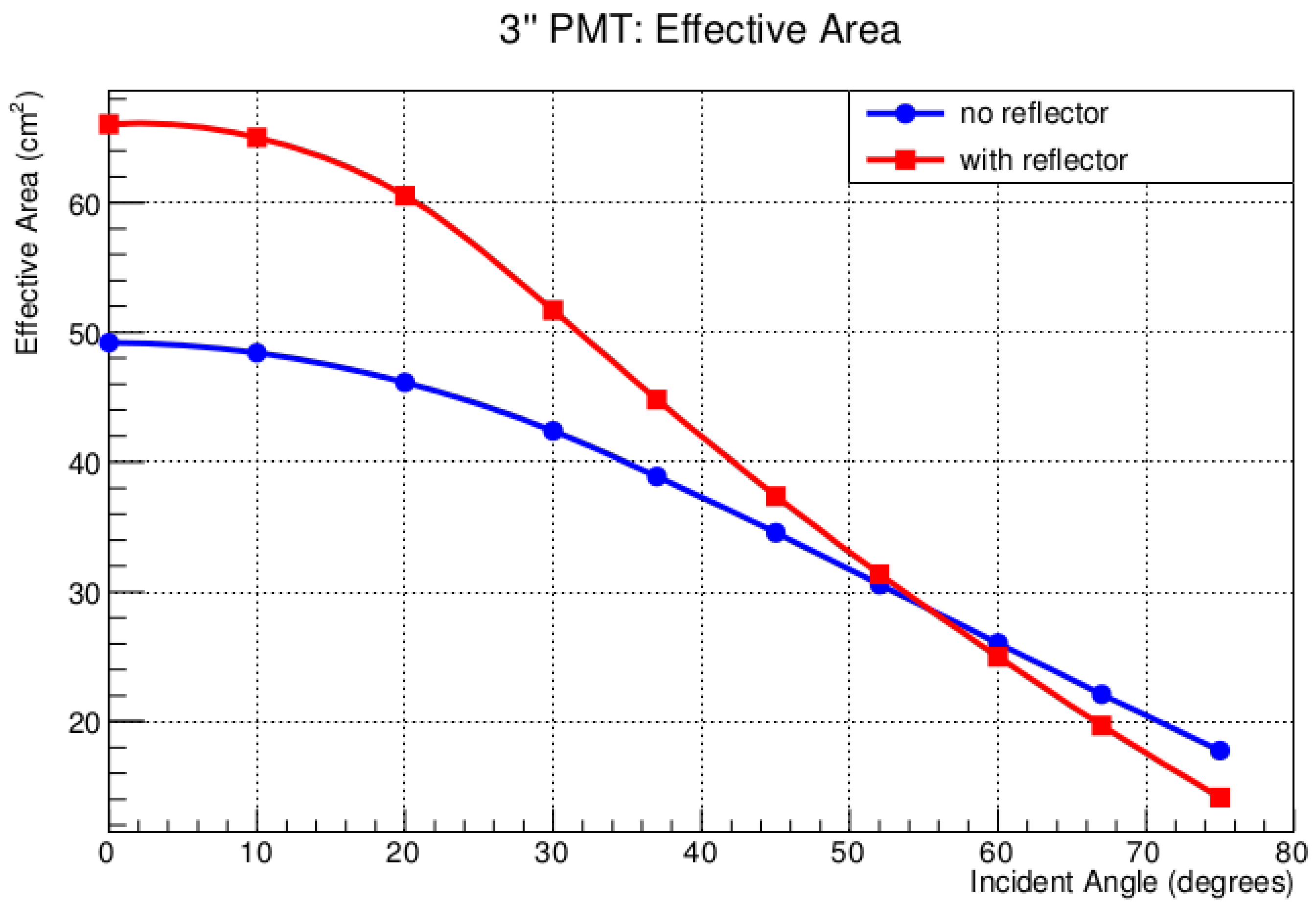
8" PMT

- Single 8" PMT
- 7.5 mm refelctor height
- 45° reflector angle
- Effective area as expected at 0° incident angle



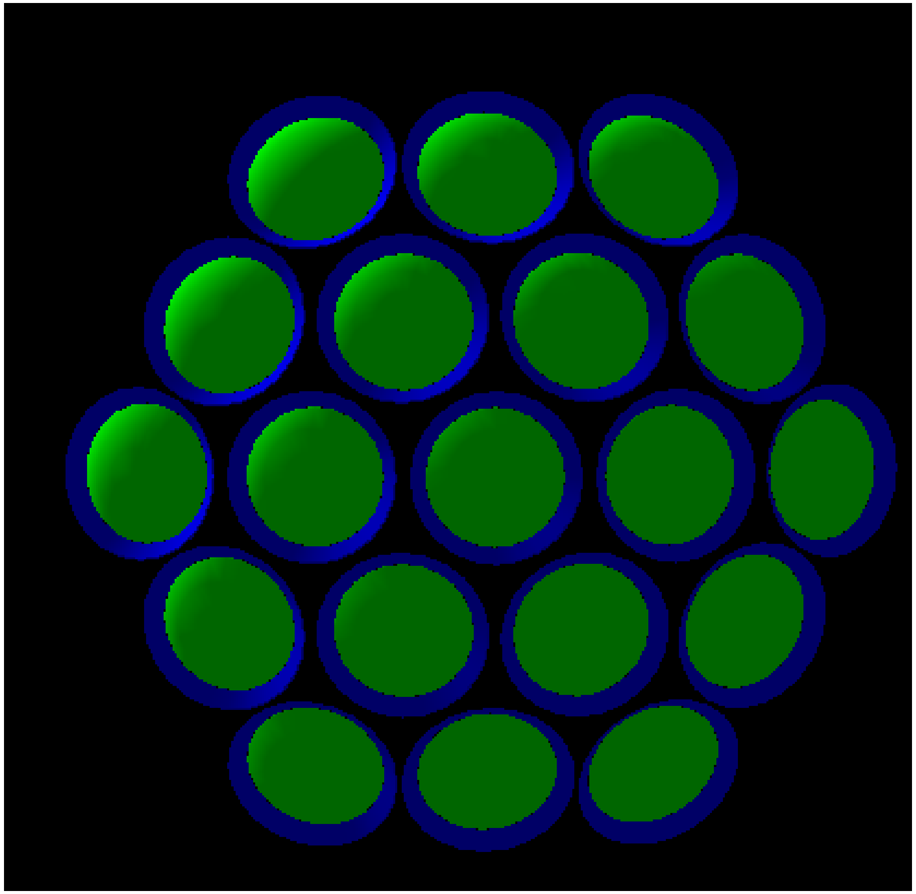
3" PMT

- Single 3" PMT
- 7.5 mm refelctor height
- 45° reflector angle
- Effective area as expected at 0° incident angle



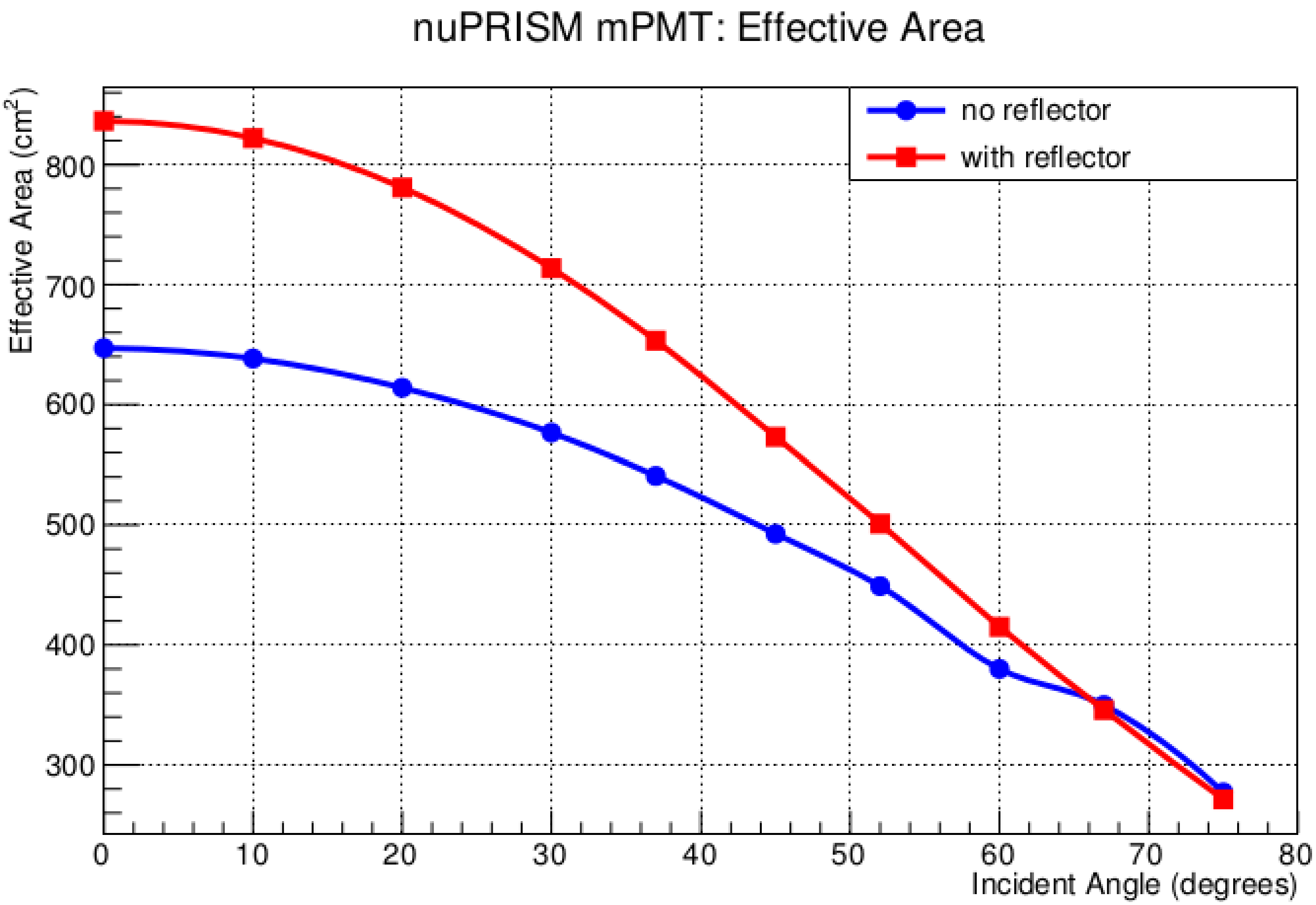
NuPRISM mPMT

- mPMT with 19 PMTs
  - 1 PMT in 0th row (0°)
  - 6 PMTs in 1st row (18°)
  - 6 PMTs in 2nd row (31.2°)
  - 6 PMTs in 3rd row (36°)
- 7.5 mm reflector height
- 45° reflector angle
- With acrylic vessel and SilGel



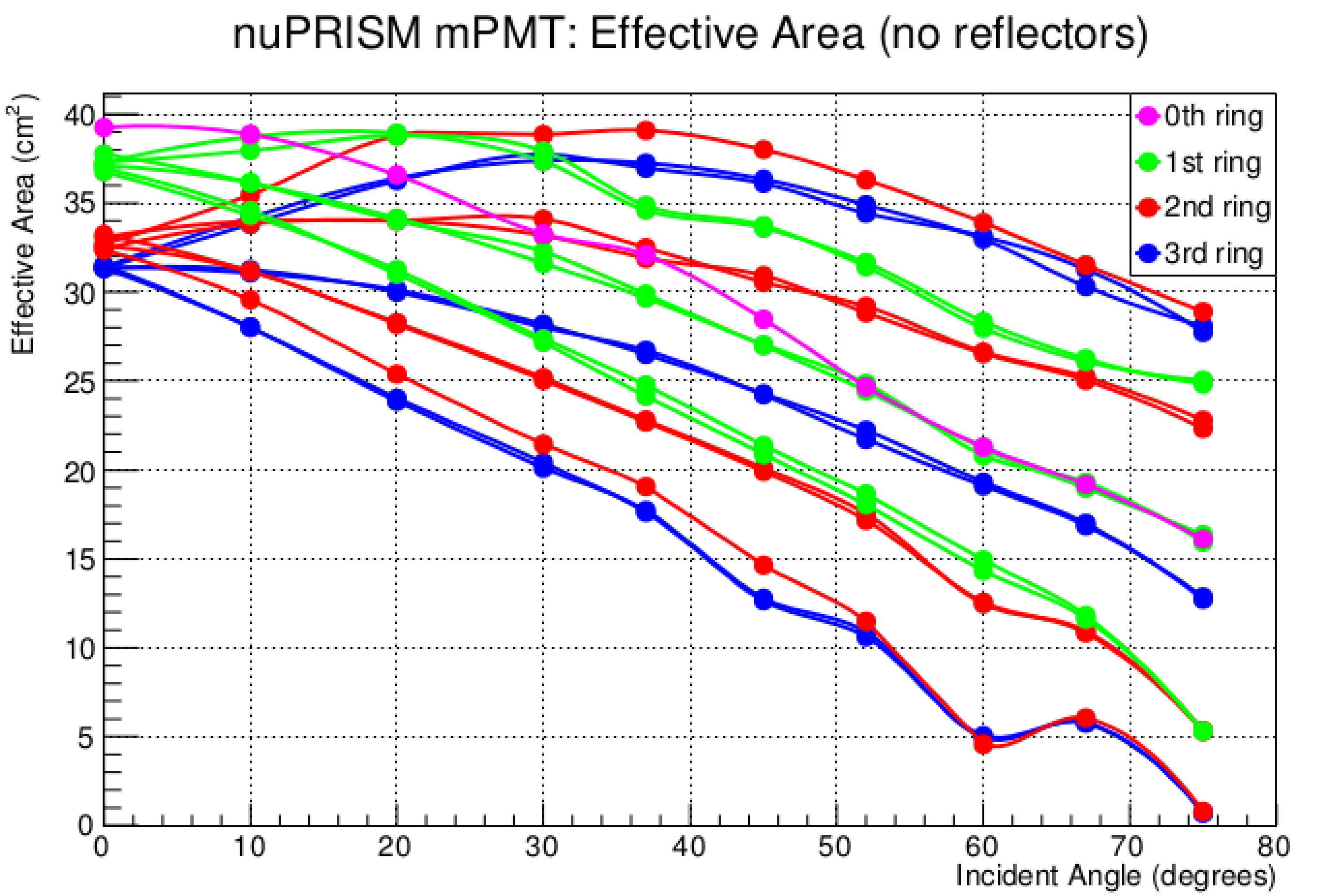
NuPRISM mPMT

- Effective area lower than expected
- naively expect ~800 cm^2 at 0° incident angle without reflectors based on 3'' PMT effective areas
  - expect lower area due to acrylic vessel + SilGel, but not that much lower



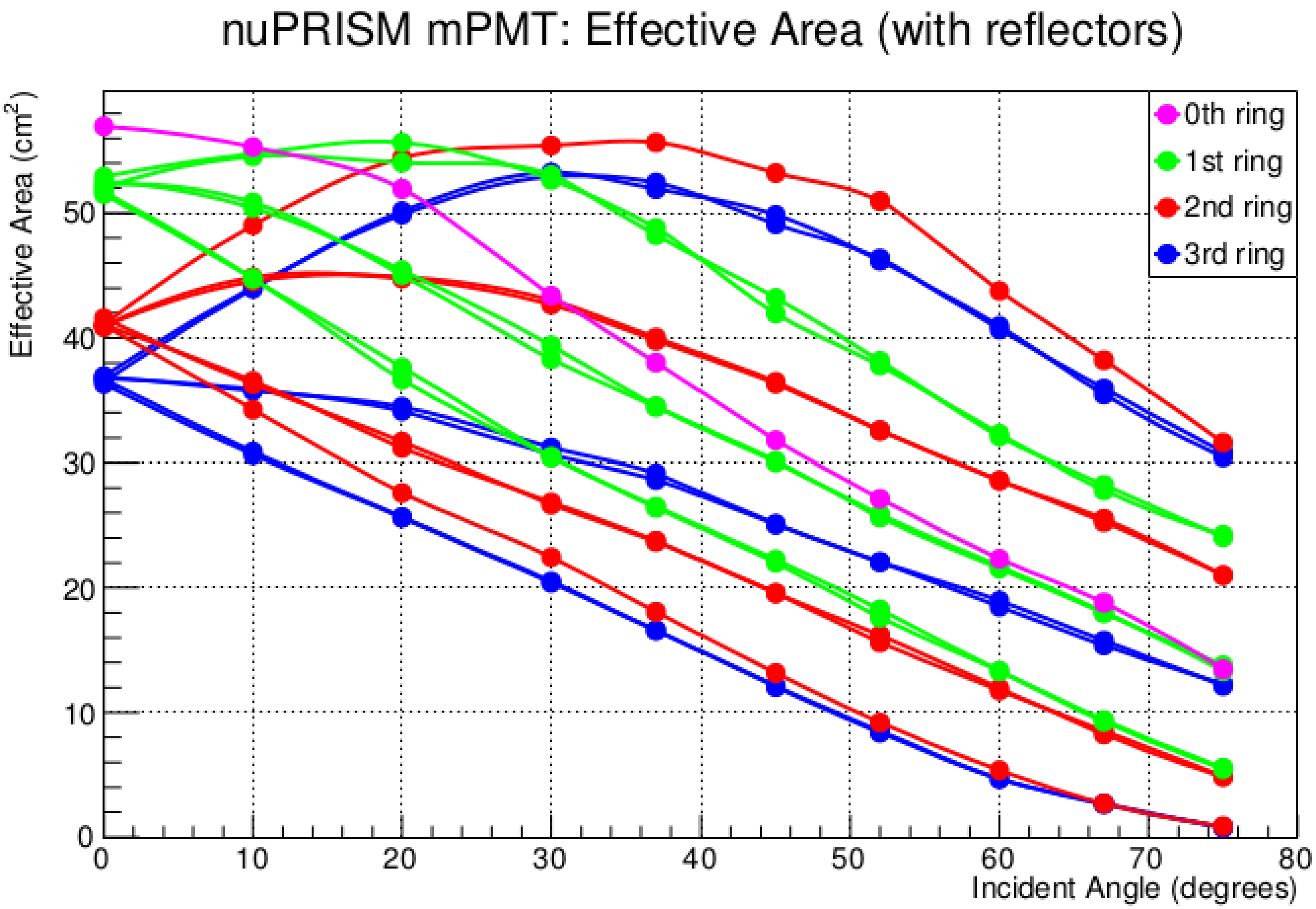
Individual PMTs (no reflectors)

- Look at effective area of each 3" PMT in the mPMT
  - no reflector case shown here
- Magenta line: only get 40 cm^2
  - expect 50 cm^2 at 0° based on single 3" PMT simulation
- Not due to Acrylic/Silgel
  - replaced materials with water, got same result



Individual PMTs (with reflectors)

- See same behaviour with reflectors as well
  - expect ~66 cm^2 at 0°



Normal Event (debug mode)

```
 Photon at Boundary!
 thePrePV:  WCBarrel
 thePostPV: WCBarrelCell
 Old Momentum Direction: (-1,0,0)
 Old Polarization:       (0,0.257658,-0.966236)
 *** SameMaterial ***
 Photon at Boundary!
 thePrePV:  WCBarrelCell
 thePostPV: WCBarrelCellBlackSheet
 Old Momentum Direction: (-1,0,0)
 Old Polarization:       (0,0.257658,-0.966236)
 New Momentum Direction: (-1,0,0)
 New Polarization:       (0,0.257658,-0.966236)
 *** Absorption ***
WCSimWCDigitizerSKI::DigitizeHits START WCHCPMT->entries() = 0
WCSimWCDigitizerSKI::DigitizeHits END DigiStore->entries() 0
WCSimWCTriggerBase::AlgNDigits. Number of entries in input digit collection: 0
Found 0 NDigit triggers
 Filling Root Event
 RAW HITS
ngates =  0
```

Event of Interest

```
 Photon at Boundary!
 thePrePV:  WCBarrel
 thePostPV: WCBarrelCell
 Old Momentum Direction: (-1,0,0)
 Old Polarization:       (0,0.877152,0.480214)
 *** SameMaterial ***
 Photon at Boundary!
 thePrePV:  WCBarrelCell
 thePostPV: WCMultiPMT
 Old Momentum Direction: (-1,0,0)
 Old Polarization:       (0,0.877152,0.480214)
 *** SameMaterial ***
 Photon at Boundary!
 thePrePV:  WCMultiPMT
 thePostPV: WCPMT_vessel
 Old Momentum Direction: (-1,0,0)
 Old Polarization:       (0,0.877152,0.480214)
 New Momentum Direction: (-0.996284,0.0599589,0.0618264)
 New Polarization:       (0.0823095,0.874175,0.478584)
 *** FresnelRefraction ***
 Photon at Boundary!
 thePrePV:  WCPMT_vessel
 thePostPV: WCPMT_container
 Old Momentum Direction: (-0.996284,0.0599589,0.0618264)
 Old Polarization:       (0.0823095,0.874175,0.478584)
 New Momentum Direction: (-0.999477,0.0225055,0.0232065)
 New Polarization:       (0.0308986,0.876103,0.481133)
 *** FresnelRefraction ***
WCSimWCDigitizerSKI::DigitizeHits START WCHCPMT->entries() = 0
WCSimWCDigitizerSKI::DigitizeHits END DigiStore->entries() 0
WCSimWCTriggerBase::AlgNDigits. Number of entries in input digit collection: 0
Found 0 NDigit triggers
 Filling Root Event
 RAW HITS
ngates =  0
```

No absorption!

40 occurences in mPMT simulation of 1000 events
- almost always ends in WCPMT_container

only 2 occurences in 3'' PMT simulation of 1000 events
- neither ends in WCPMT_container

Other Work: Convolutional Neural Networks

- Getting familiar with TensorFlow
- Replicate Theo's results using his SKalgorithm package for 1 ring e/μ ID
- Down the road: apply to 2 rings (eπ)