Solution(s) for improving the overall photo-detection efficiency

F. Retière, P. Gumplinger

TRIUMF

TRIUMF

Motivations

- 20% photo-coverage with ~30% quantum efficiency is not that good
  - Can we do better than that at low cost?
- Benefits
  - Low energy reach
  - Better resolution?
- To be avoided: increase background light

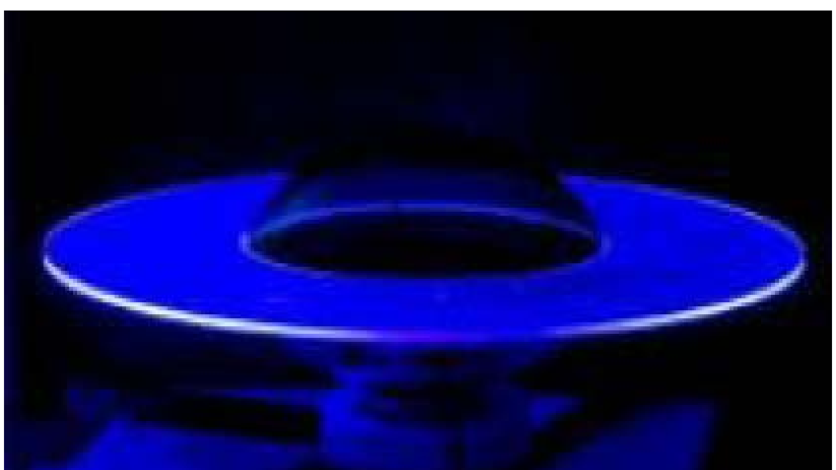
TRIUMF

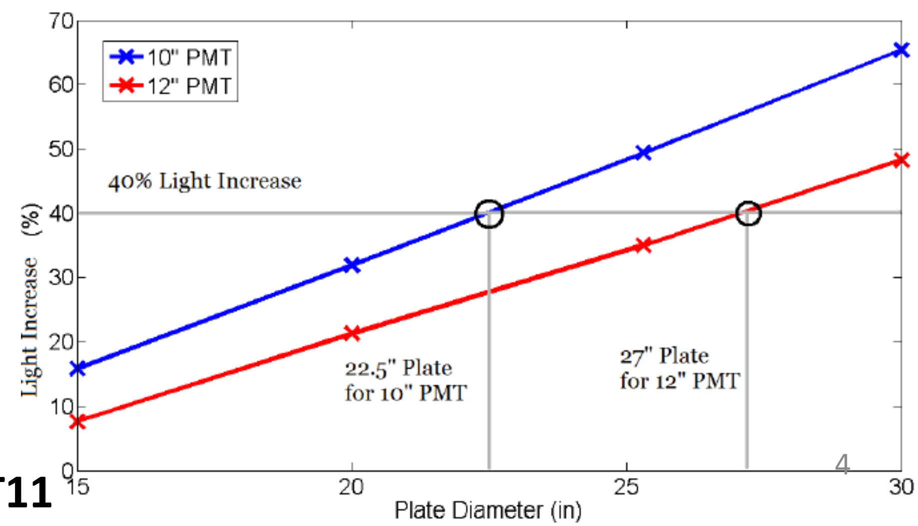
Solutions

- Guide the photo-electrons using E-Field
  - 20” PMT may already as big as it gets
  - Cylindrical PMT + scintillator proposed for PINGU?
    - Lets talk over coffee
- Guide the photons
  - Light concentrators (mirror) not so efficient and strong angular dependence
  - Wavelength shifter
    - The “only” purpose of wavelength shifting material is to allow to trap light in the material
    - Compelling if decent efficiency can be achieved

LBNE R&D: "Mexican hat" wavelength shifter

- Pros
  - Up to 40% gain in light collection
  - Does not require additional PMT
  - Preserve prompt light
- Cons
  - Some light reemitted in water
    - may worsen position reconstruction
  - Water index of refraction limit trapping efficiency
  - Delayed photo-electron from WLS

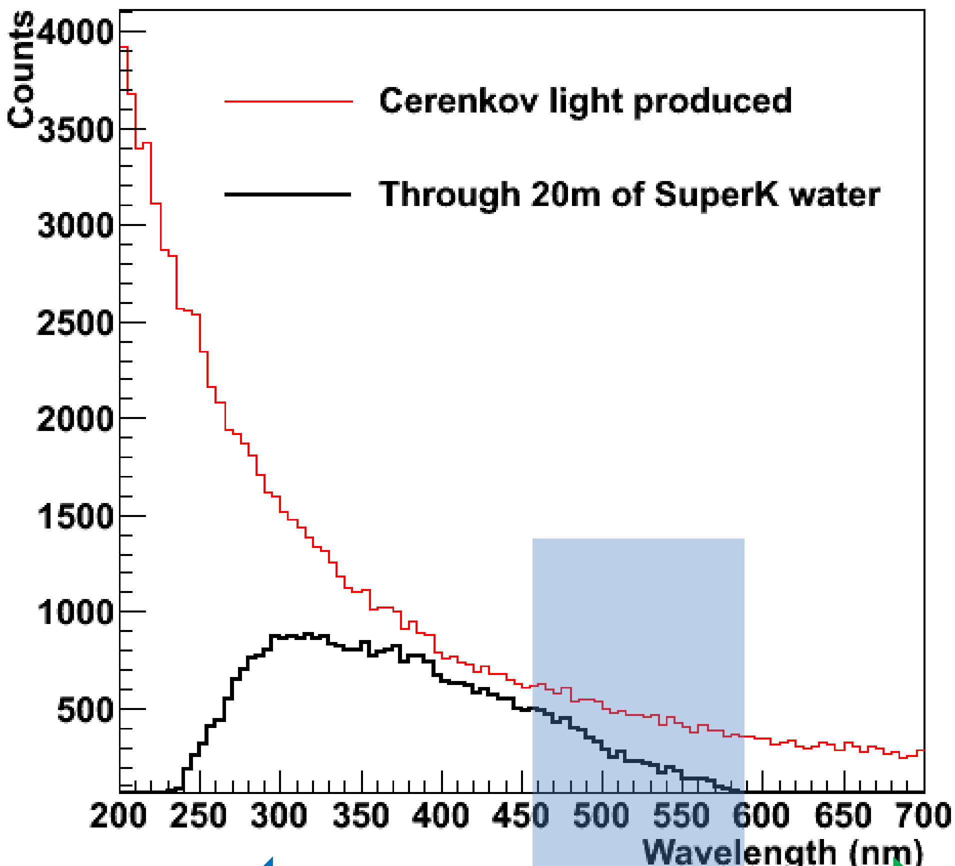


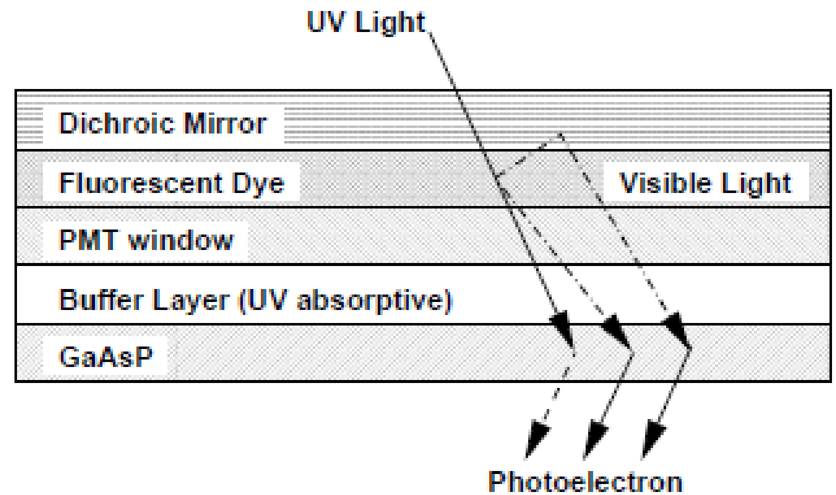


N Buchanan, W. Johnston, ANT11

TRIUMF

Using dichroic mirror/filter to minimize the cons





28th International Cosmic Ray Conference — 857

Study on Wavelength Shifters and Multilayer Half-Mirror for High-QE PMT

Masahiro Takeda[1], Tetsuya Aoyama[1], Toshikazu Ebisuzaki[1], Yoshiya Kawasaki[1], Naoto Sakaki[1], Hirohiko M.Shimizu[1], Yoshiyuki Takahashi[2], Yoshiyuki Takizawa[1], Haruhiko Tsunoda[3], Tatsuo Wada[1]

(1) RIKEN, Hirosawa, Wako, Saitama 351-0198, Japan

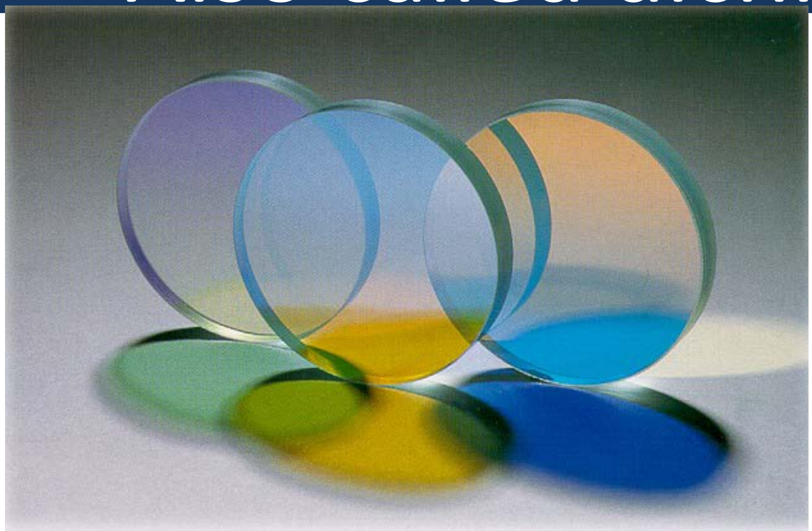
(2) Department of Physics, University of Alabama in Huntsville, Huntsville, AL 35899, USA

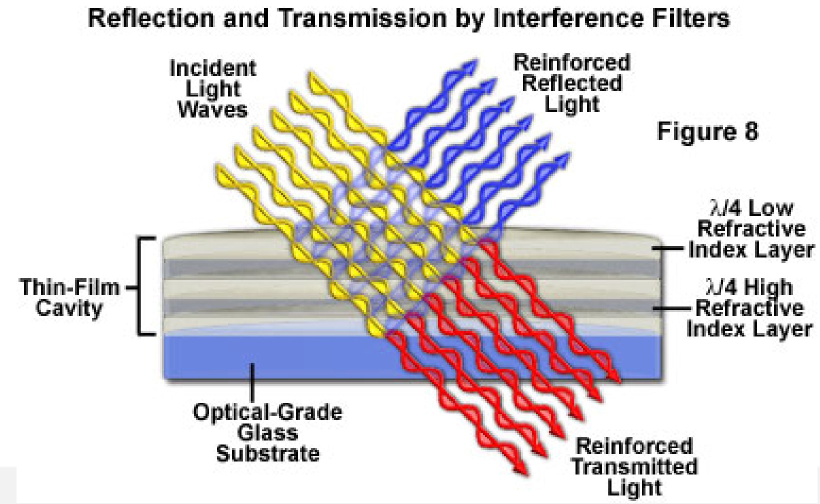
(3) Core Technology Center, Nikon Corporation, Kanagawa 228-0828, Japan

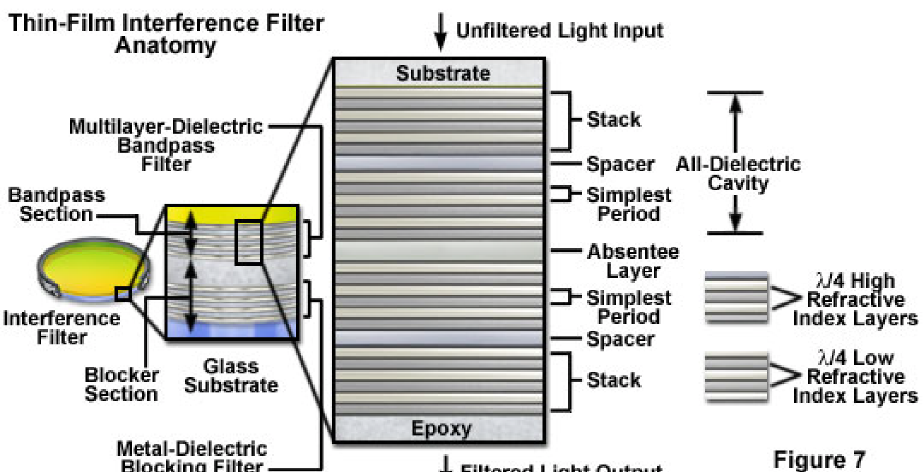
Absorb
Minimize reflection

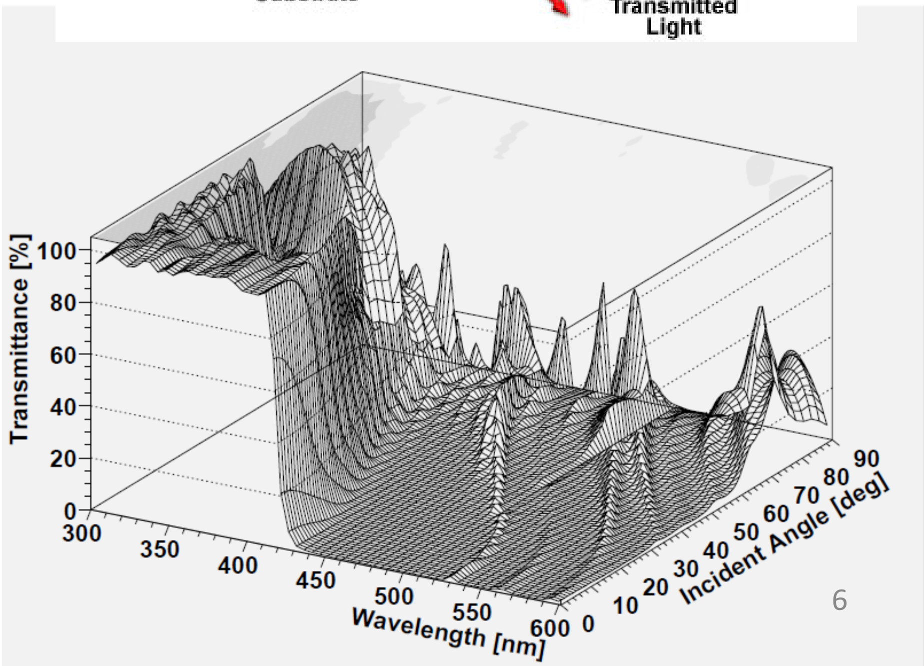
Reemit
Reflect

How interference filters work
Also called dichroic filters/mirrors



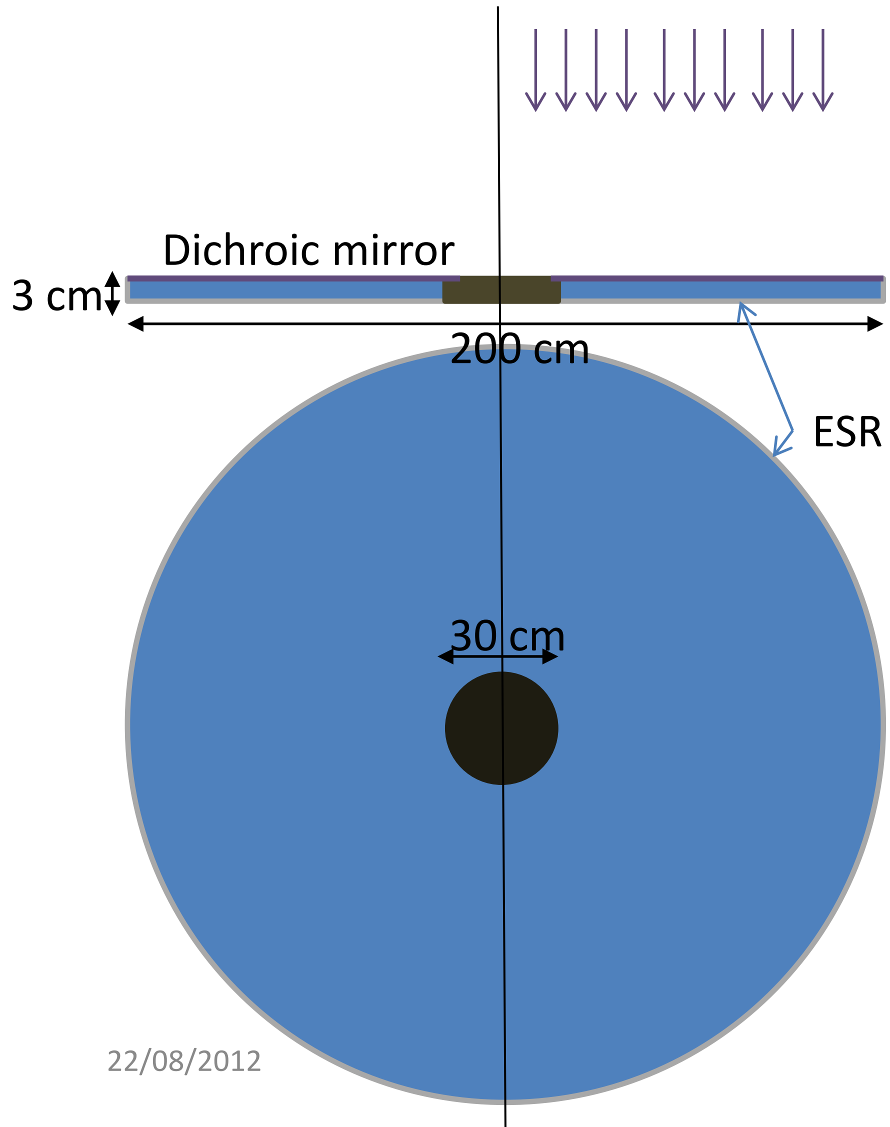






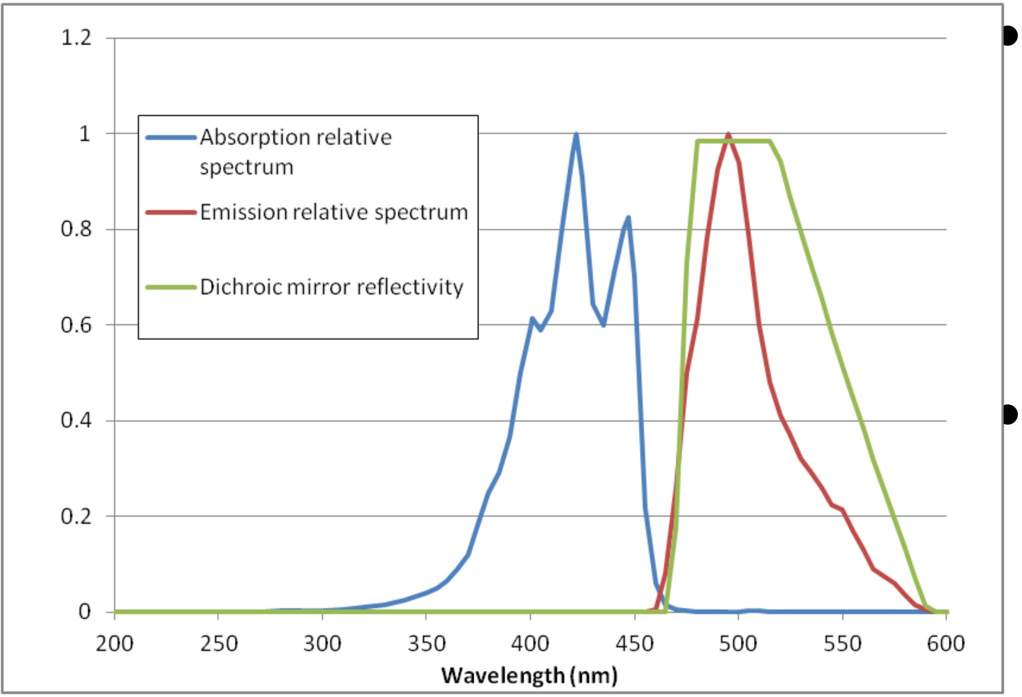
TRIUMF

Exercise with GEANT4



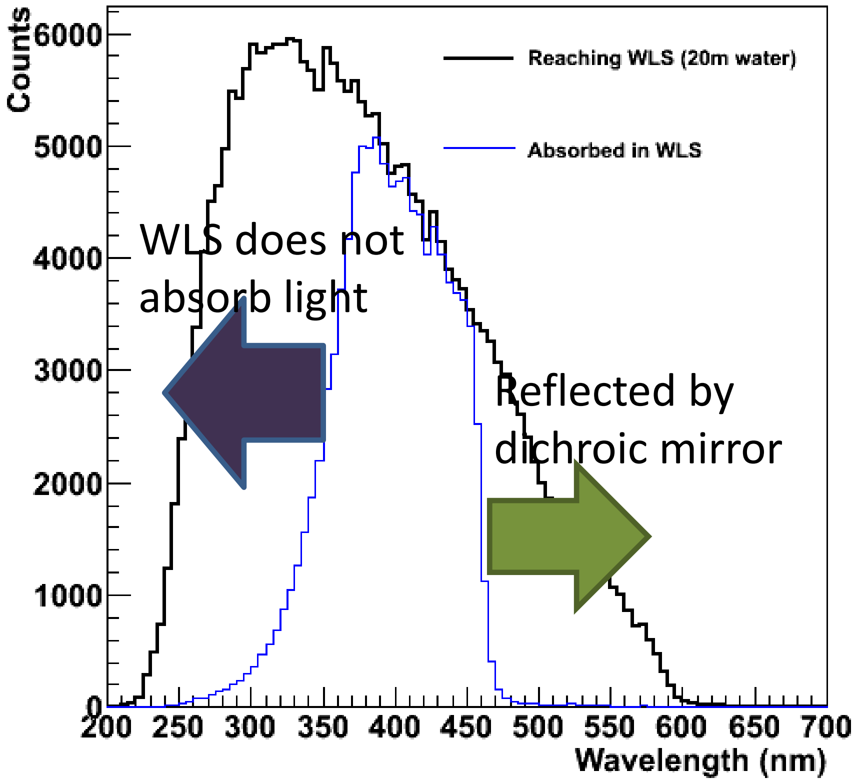
- Dichroic mirror
  - 98.5 reflectivity between
  - 98.5 otherwise
- WLS
  - BC484A
  - 3 cm thick, 2 m diameter
  - Back and side covered with 98.5% reflectivity specular reflector (3M ESR)
- Photo-detector
  - 30 cm diameter disk
    - ~12” PMT
    - 20” PMT could be used but photo-cathode coverage would have to be expanded

Simulation assumptions



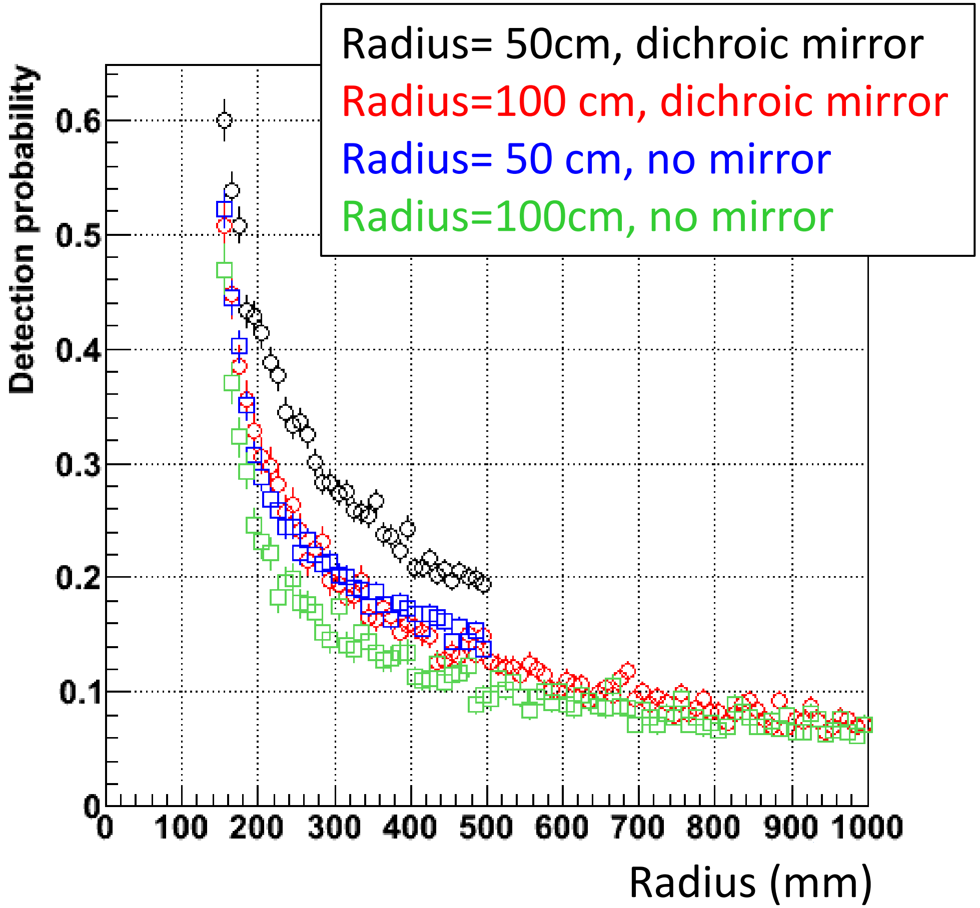
- Wavelength shifter BC482A blue to green shifter
  - Misses a lot of UV light
- Simple dichroic filter simulations
  - Still some issues in GEANT
  - No angular dependence

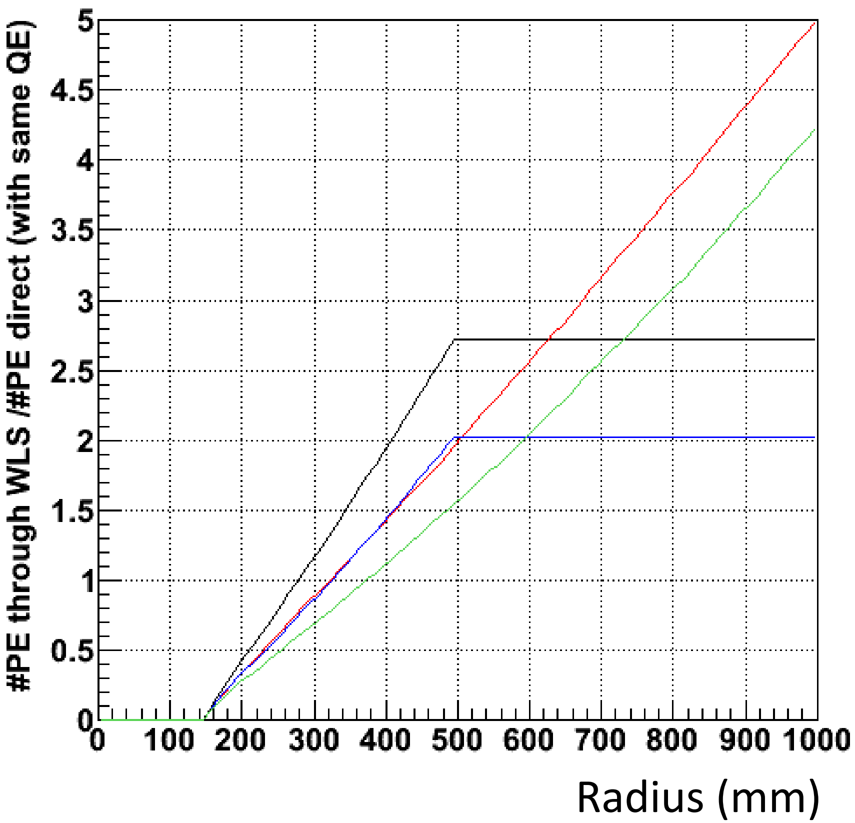
Light absorption



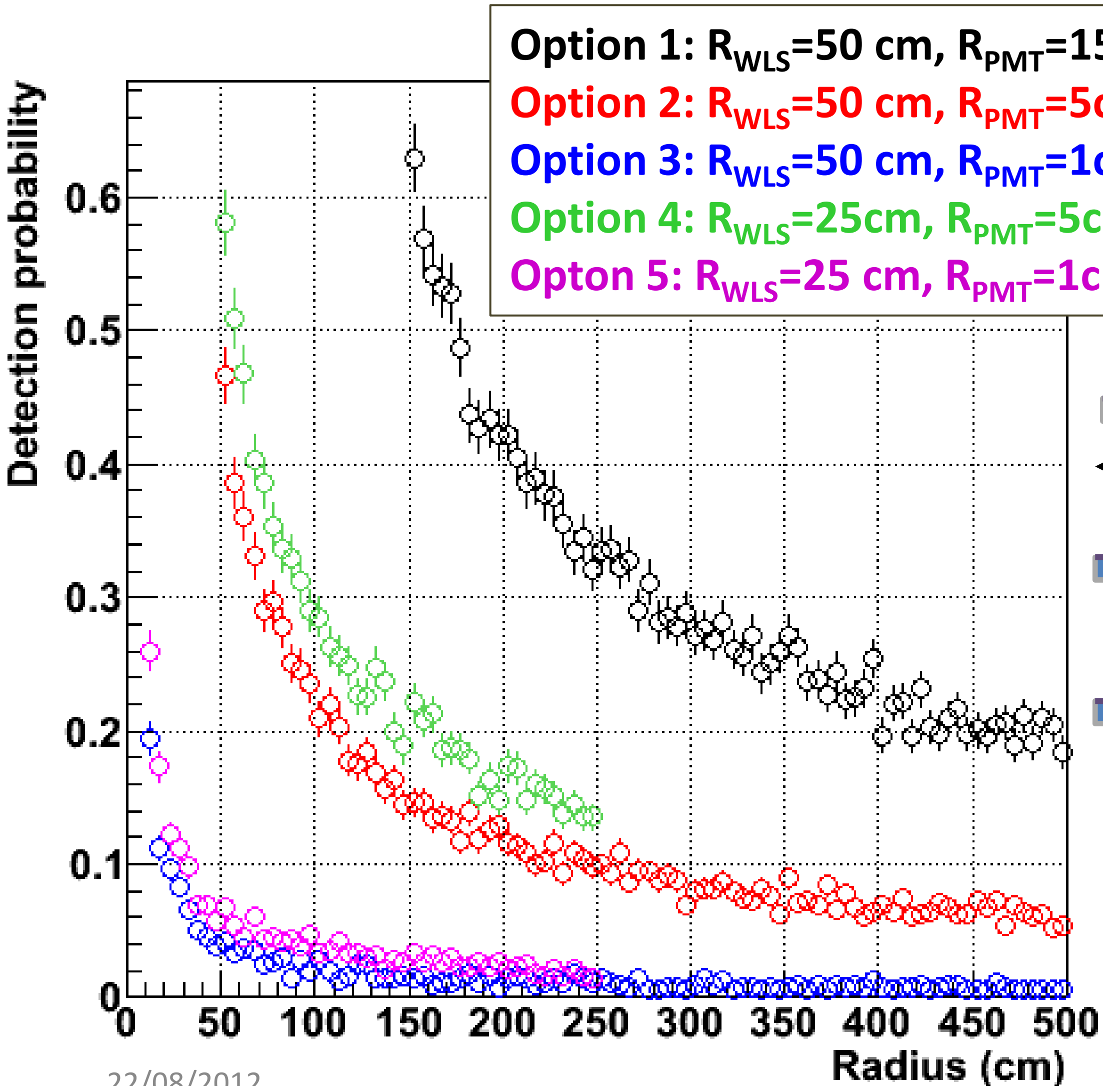
- BC482A absorbs about 25% of the Cerenkov light
  - Non absorbed light would be reflected with a broadband back mirror
    - Best would be to expand the range of absorbed and reemitted light
  - Need to absorb more light in wavelength shifter or use a dichroic mirror on the back side as well
- Not much we can do about Cerenkov light reflected by dichroic mirror
  - Push WLS emission to > 600nm?

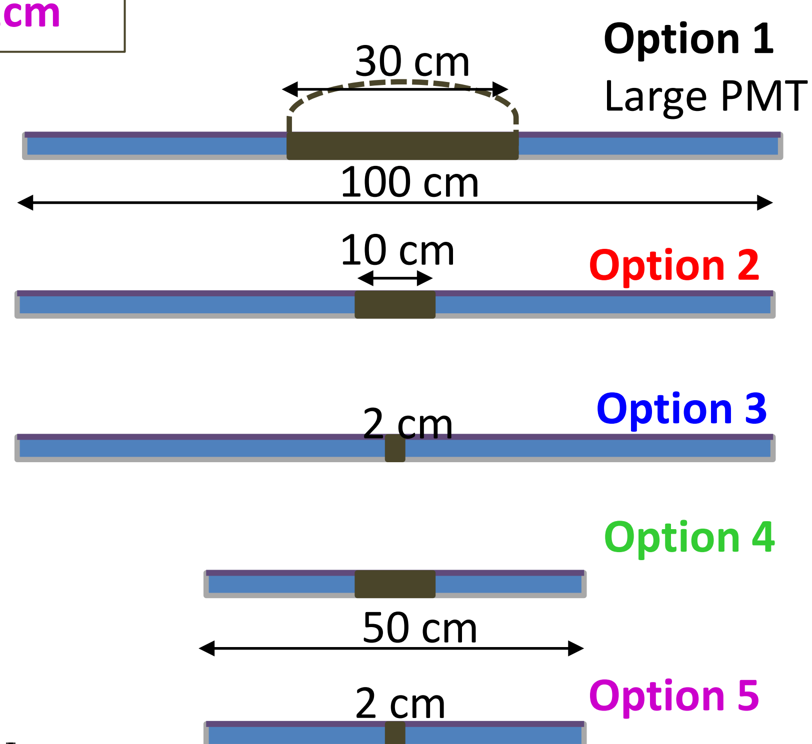
Wavelength shifted light detection





Standalone solution aka not using the large PMT





Conclusions

- Promising solution: more than x2 photons detected
  - Re-use large area PMT
    - Need photo-cathode coverage on the side
  - Use dichroic mirrors
    - Enhance WLS light collection efficiency
    - Strongly suppress reemission of light into the water
    - Limit reflection of light back into the water
  - Improving wavelength shifters would make this solution even better
    - Faster decay time constant
    - Increase light absorption below 350 nm
    - Push re-emitted light spectrum to red (>600 nm)
- Solution with disk/sheet + small PMT not so good
- Alternate solutions
  - Cylindrical PMT
  - Detect WLS light with small PMT on the back side with Winston cone

TRIUMF

To do

- Material research
  - Optimize dichroic filter
    - Achieve > 95% transmission for Cerenkov light
    - Achieve > 95% reflectivity for wavelength shifted light
    - Investigate how to direct deposition on wavelength shifter
    - Tune according to the index of refractions at boundaries (n=1.33 and n=1.59)
  - Optimize wavelength shifter
    - Extend the absorption range below 400 nm
    - Lower decay constant (below 1ns would be ideal)
    - With interference filter, high index of refraction not required
- Optimization for Hyper-K
  - One kind or two kinds of PMTs?
  - Geometry for optimum light collection
  - Investigate physics impact of enhanced light collection and possible random light background
    - Full simulations
  - Mechanical and electrical integration
- It would be best to setup a mini-collaboration to tackle these goals
  - And need contacts with industry, e.g:
    - ELJEN + spectral-products in US
    - Kuraray + Nikon in Japan

Thank you