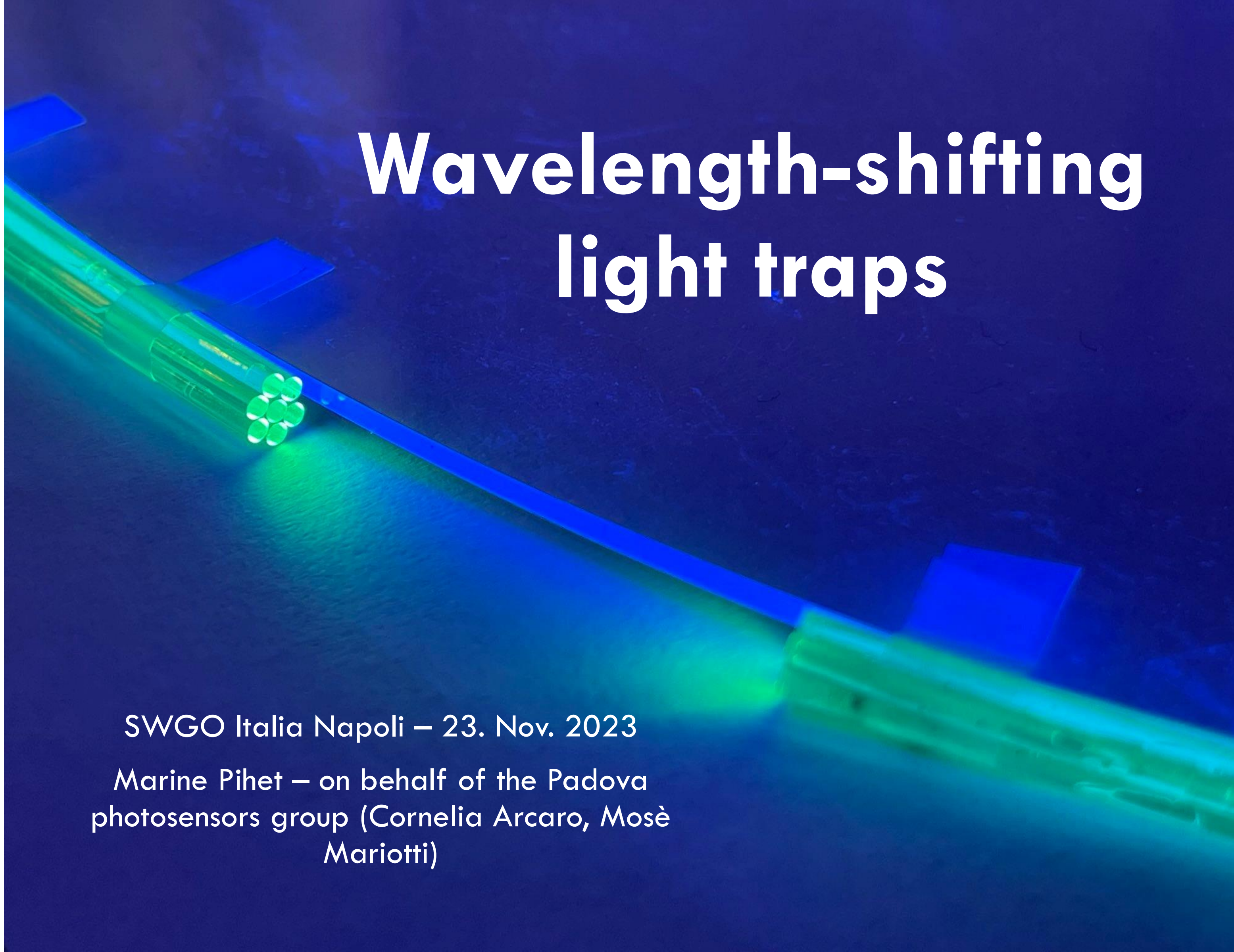
SWGO
The Southern Wide-field Gamma-ray Observatory



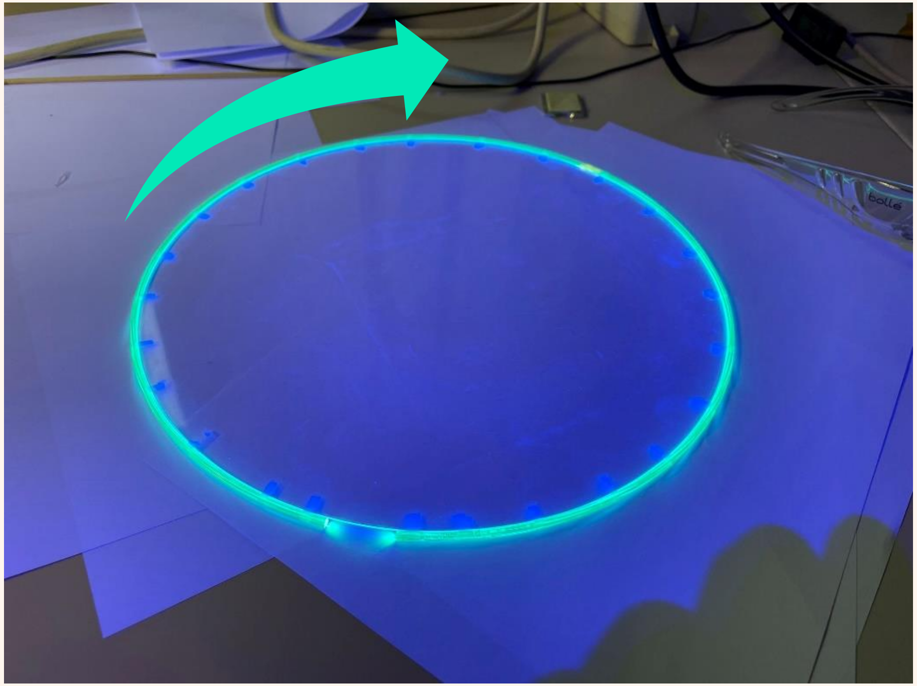
Wavelength-shifting light traps

SWGO Italia Napoli – 23. Nov. 2023

Marine Pihet – on behalf of the Padova photosensors group (Cornelia Arcaro, Mosè Mariotti)

Following the green fiber of the talk

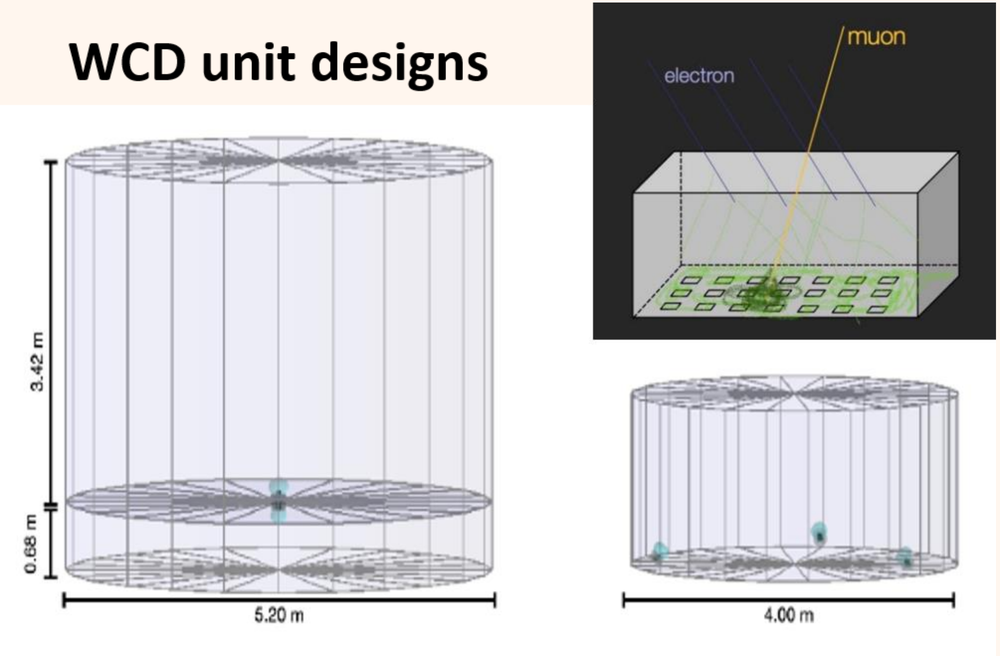
- Motivation
- Components
- Concept
- Measurement setup
- Results
- Summary



Motivation

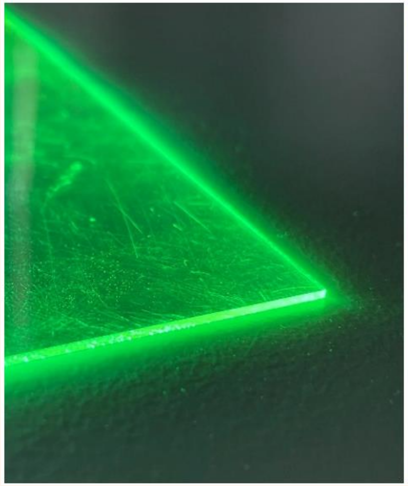
- Single-layer tanks with arrays of light traps
- Reduce cost
- Large light-collecting surfaces
- Good g/h separation
- Potentially useful technology for future experiments
- Requirement for light traps: low cost and sufficient efficiency

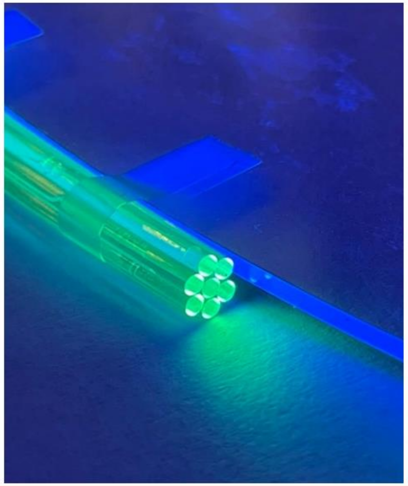
WCD unit designs

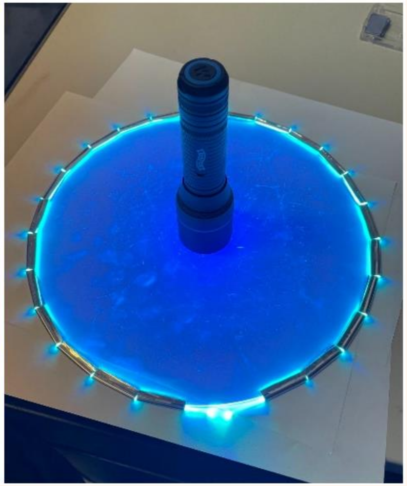


Components – WLS materials

- WLS disks and paint from Eljen Technology (USA) , fibers from Kuraray (Japan)
- Refraction index: ~ 1.6
- Doped with molecules that absorb and isotropically re-emit light in a different wavelength

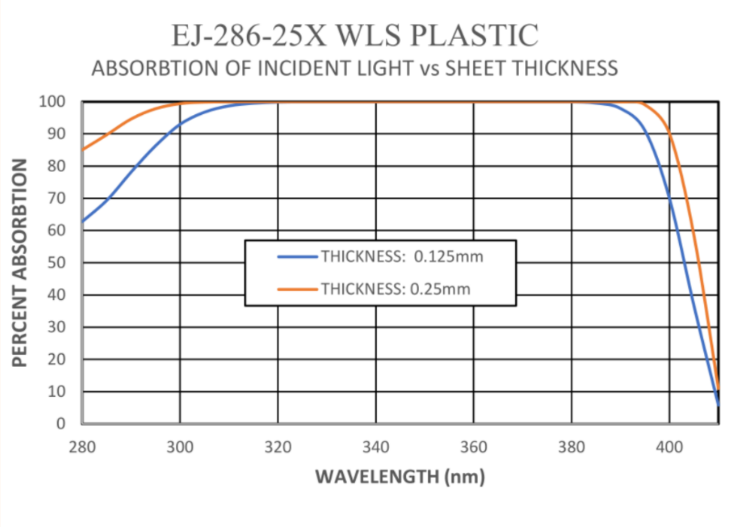


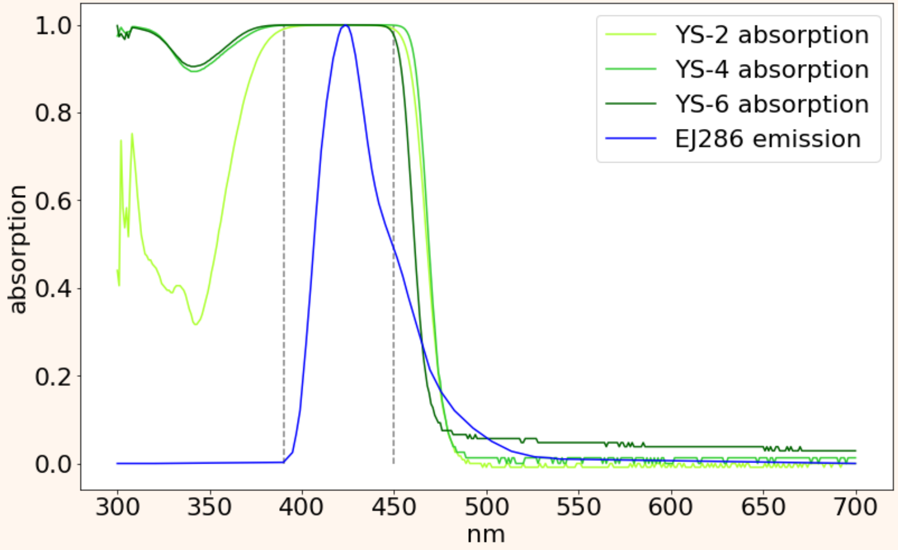




Components – WLS materials

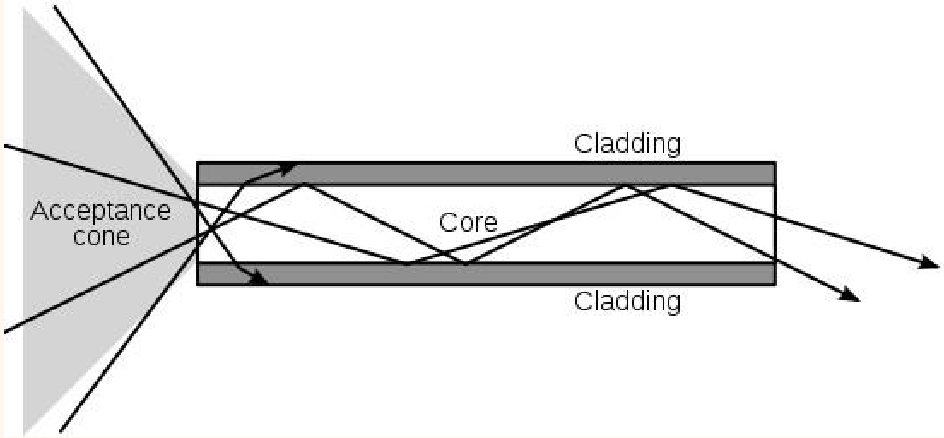
	EJ-282	EJ-286	YS-2	YS-4	YS-6
Absorption peak (nm)	390	355	422	420	414
Emission peak (nm)	481	425	474	470	462
Decay time (ns)	1.9	1.2	3.2	1.4	1.3



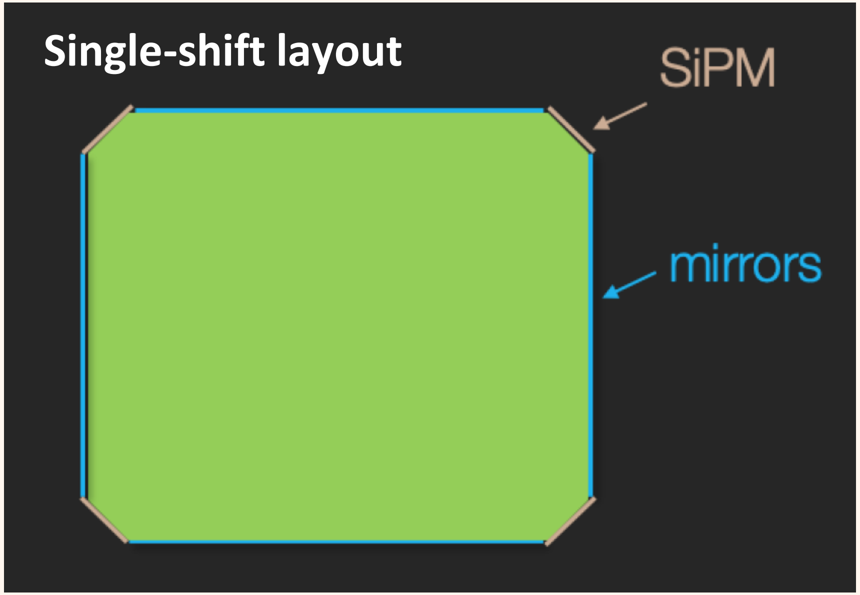


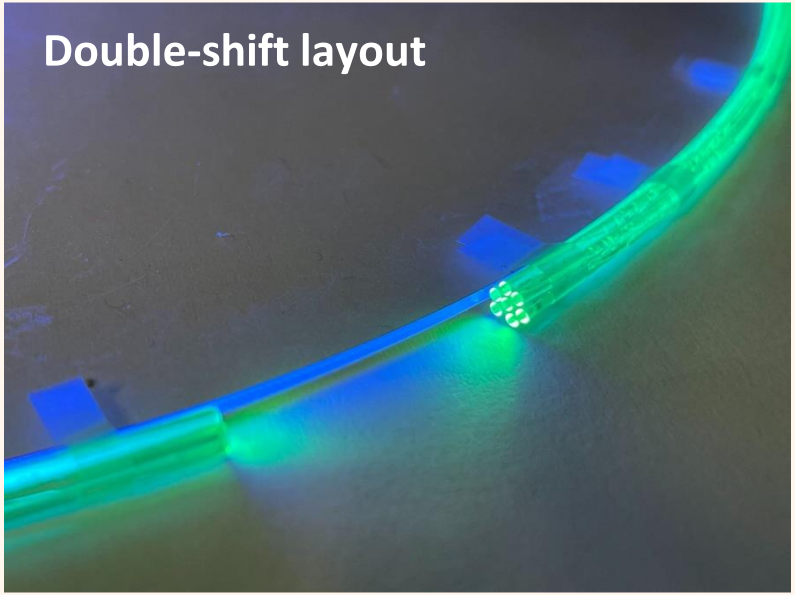
Concept – Light trapping

- Absorption and isotropic re-emission inside WLS
- Trapping of large percentage of light through total internal reflection and guidance towards borders of disk/end of fibers
- Possible geometries: disk or tube
- $\varepsilon = \sqrt{1 - \left(\frac{n_2}{n_1}\right)^2}$ for disk (n_1: refraction index of WLS material, n_2: refraction index of surrounding medium)
- $\varepsilon = 1 - \frac{n_2}{n_1}$ for tube
- Trapping efficiencies:
  - 77% (disk in air)
  - 54% (disk in water)
  - 37% (tube in air)
  - 16% (tube in water)



Concept – single and double shift





Measurement setup

- High definition oscilloscope
- Black container for dark environment
- Hamamatsu SiPMs and preamplifiers to measure indirect and direct intensities
- UV pulsed LED with tunable intensity (376 nm emission)
- Few small custom designed pieces

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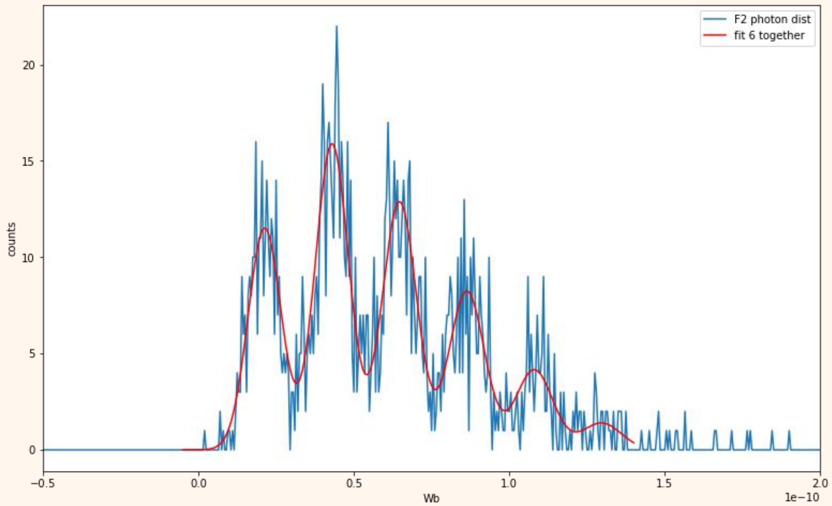
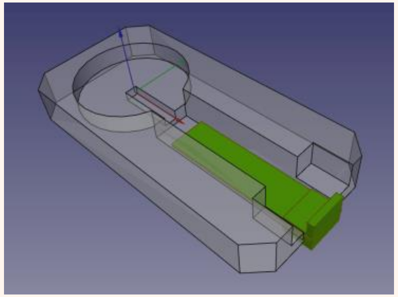
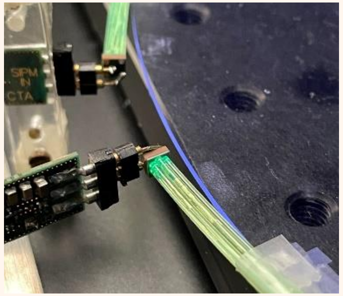
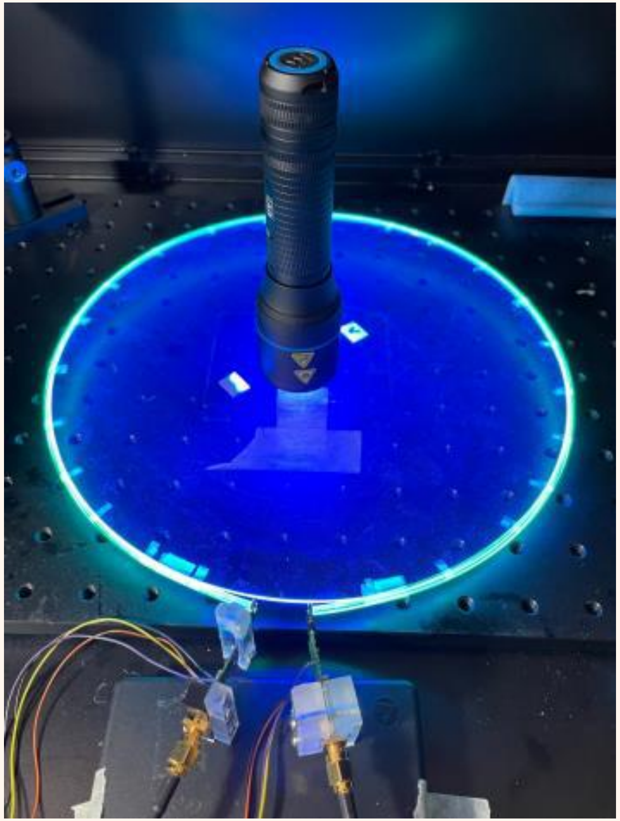
Measurement setup





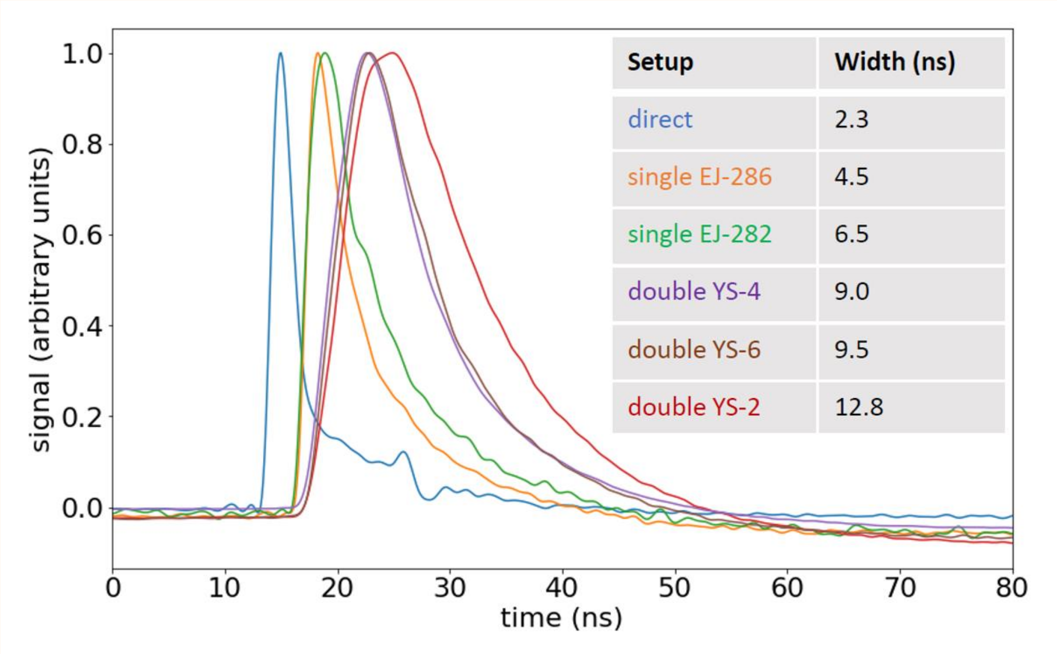




Results – Detection efficiency

- Single-shift design:
  - Theoretical UL for a partial efficiency (only including the effects of absorption, re-emission and trapping but not reflection and detection by the SiPM): 71 % (air) and 50 % (water)
  - Mean of repeated measurements in air: (69.2 ± 2.5) %
- Double-shift design:
  - Theoretical ULs for the overall efficiency, depending on fiber type and number of fibers: from 17 % to 20 % (air) and from 5 % to 6 % (water)
  - Maximum measured efficiency of 3 % (for double-shift layout with 7 YS-2 fibers, optical coupling (OC) between fiber and SiPM and reflecting foil around the fibers)
- Crosscheck of efficiencies with Landau distributions of different setups

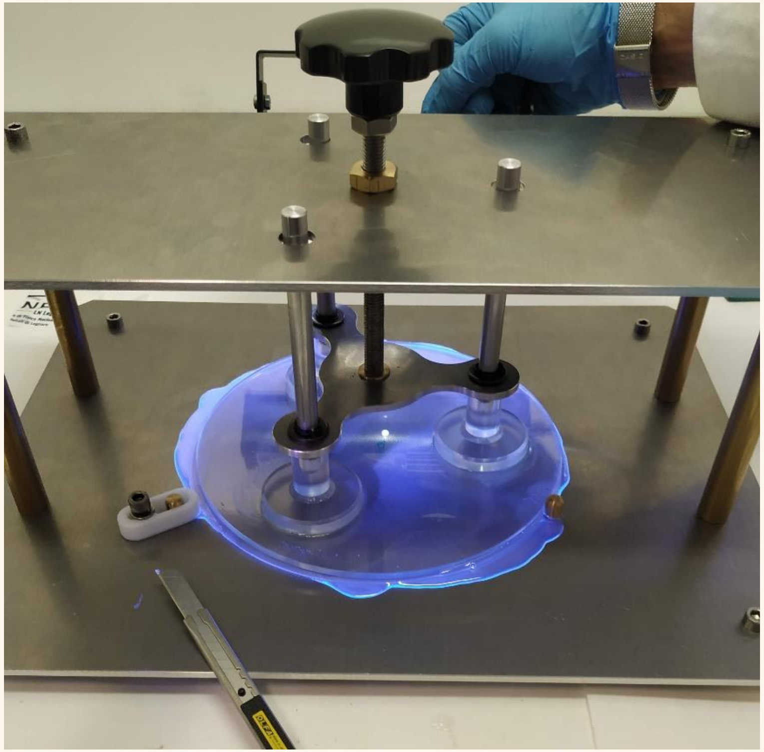
Results – Temporal performance



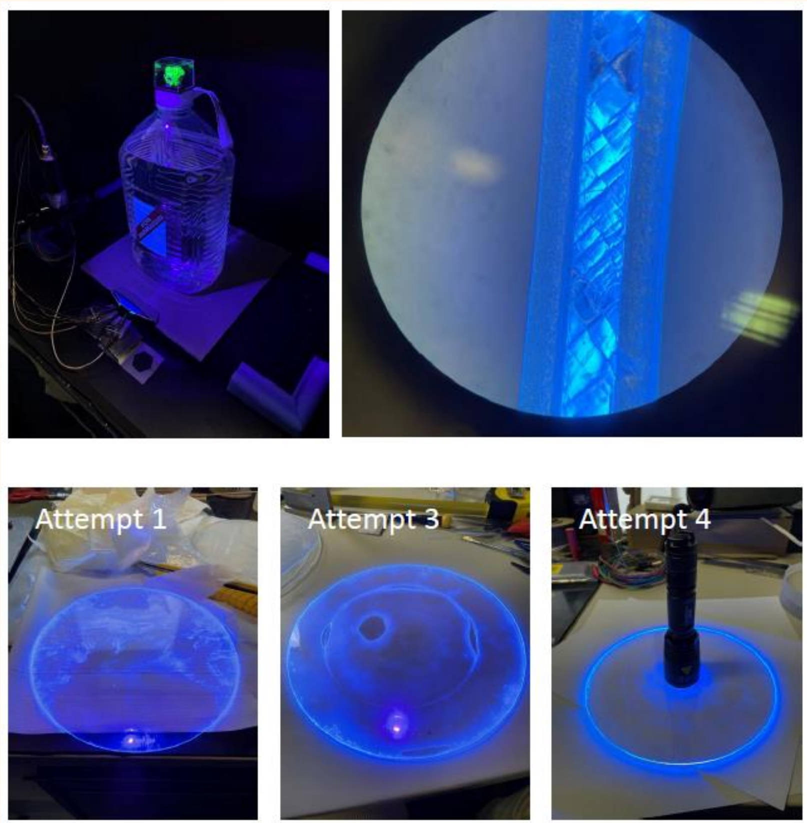
- Temporal response of few ns
- 2-10 times less performant than typical PMTs
- Double-shift pulse longer because decay times of disk and fiber add up
- Light traveling times due to geometry insignificant
- Expect to reduce uncertainty using the mean of signal arrival times of an array in one WCD unit

Results – WLS sandwich

- Idea: use liquid WLS material (paint) and UV transparent plexiglas to build a sandwich light trap
- Repeated tests using custom made sandwich maker
- Best result so far:
  - → Almost no bubbles
  - → Good amount of paint, but not enough for total absorption
  - → Thickness of paint layer not homogeneous enough

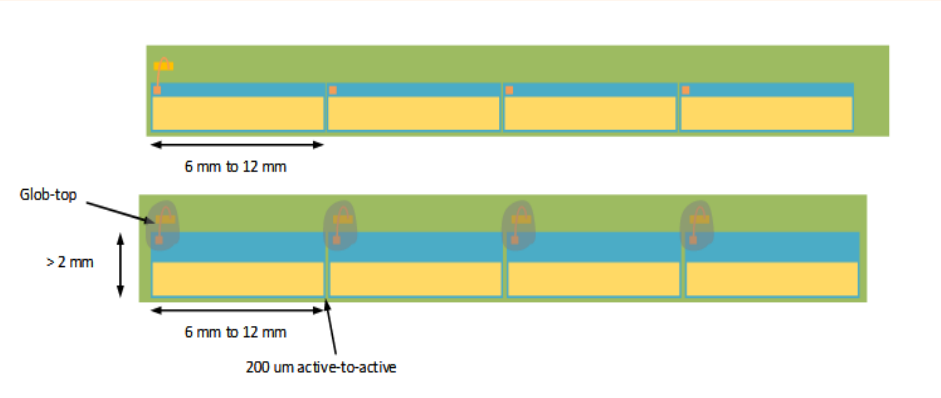


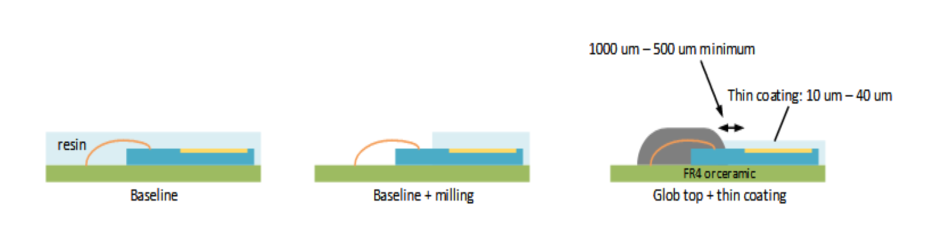
Results – WLS sandwich



- Tests for polishing of border (paint not flat as can be seen under the microscope)
- Tests with (fluorescent) beta source, trying to get a signal of Cherenkov light using a water bottle

Ongoing work and outlook





- Development of electronics for coincidence treatment of signals
- Measurement of cosmic-ray events and attempt to measure real Cherenkov light (also to avoid external source and make relative measurements between setups using directly cosmic rays)
- Ordered new pulsed UV laser and SiPM matches from FBK (both arriving during next year)

Summary

- Construction of light traps with wavelength-shifting materials in single-shift or double-shift layout
- Estimates of efficiency (~ 10 %) and temporal resolution (~ 5 ns) clearly favor the single-shift layout
- Ordered production of thin SiPM matches at FBK and ongoing work on electronics
- HAP note: https://www.swgo.org/SWGOWiki/lib/exe/fetch.php?media=detector_wg:hap-23-009-light_traps.pdf

Thank you!

References

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- HAP note: https://www.swgo.org/SWGOWiki/lib/exe/fetch.php?media=detector_wg:hap-23-009-light_traps.pdf
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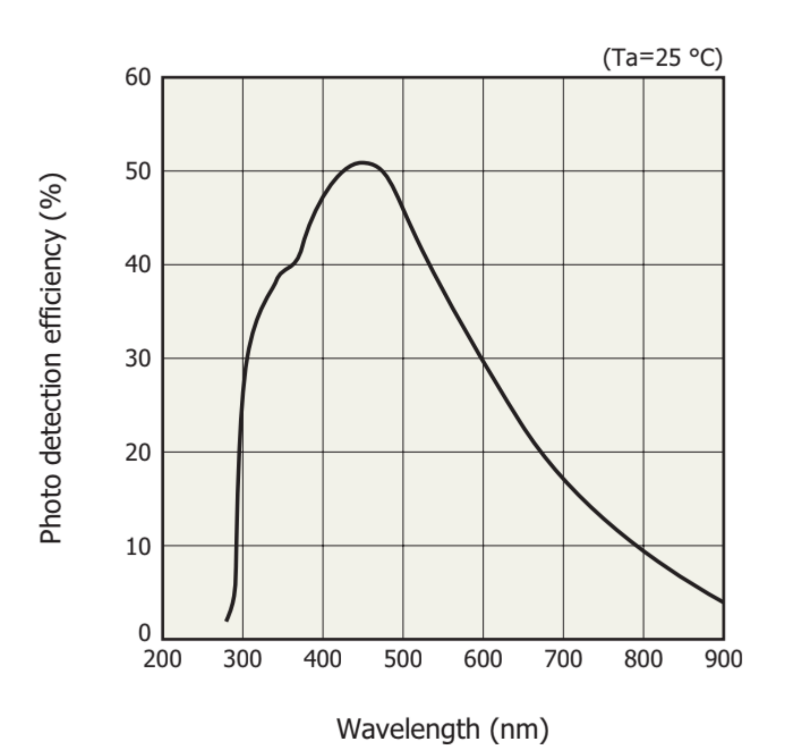
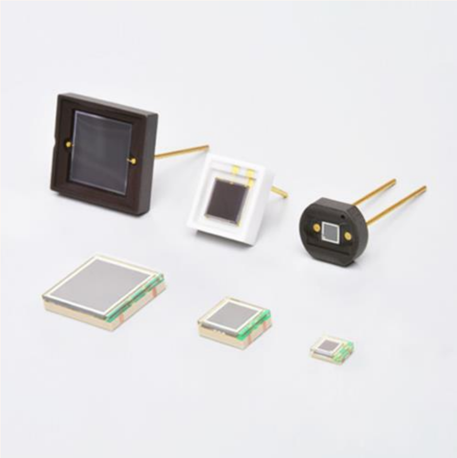
Backup

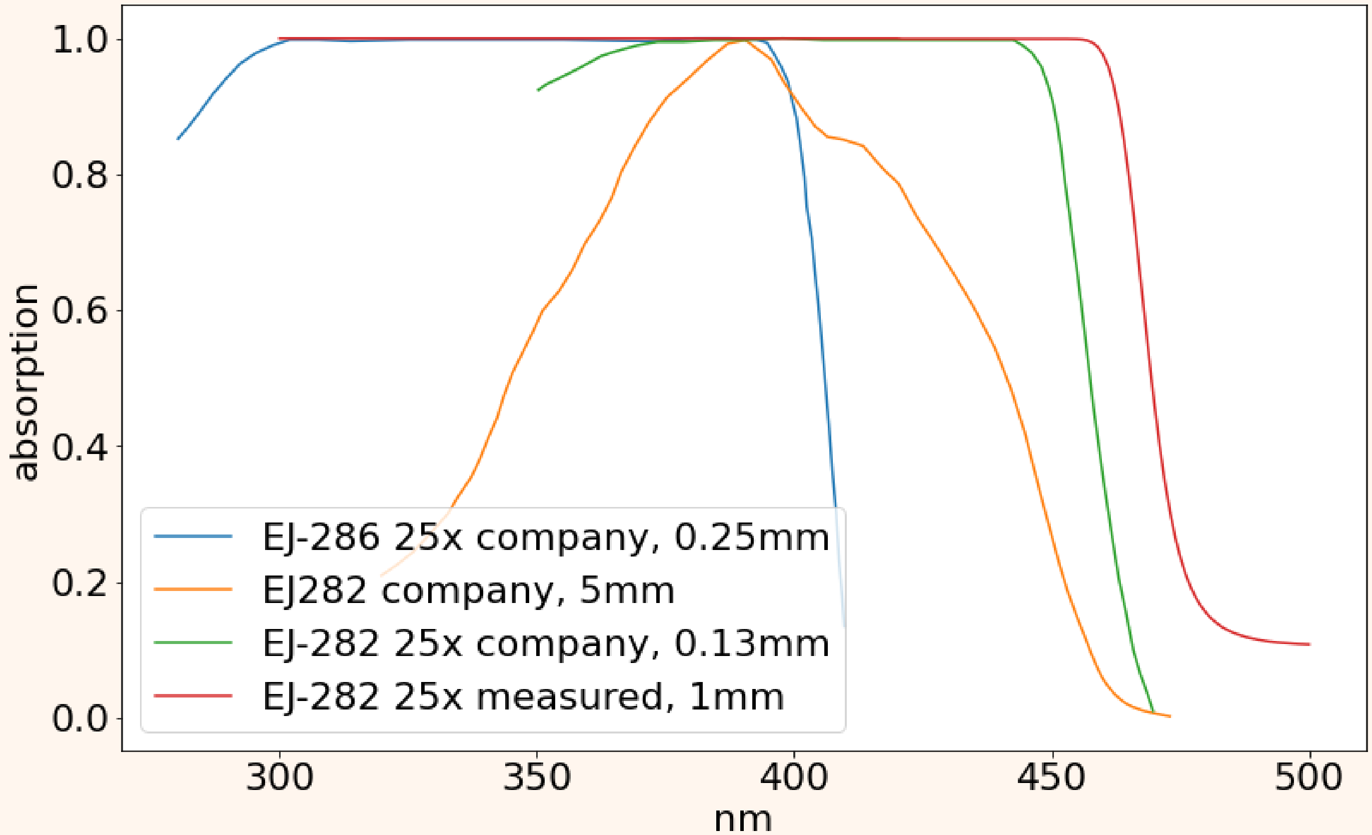
Components – SiPMs



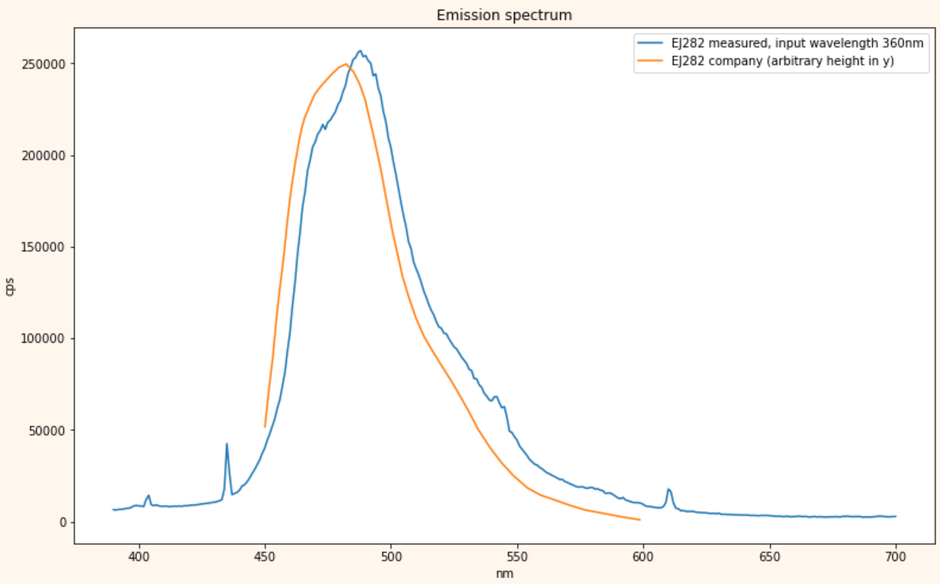
- Hamamatsu SiPMs (MPPCs S14160/S14161 series)
- Size: 3x3 mm^2
- High photon detection efficiency @300 nm – 600 nm

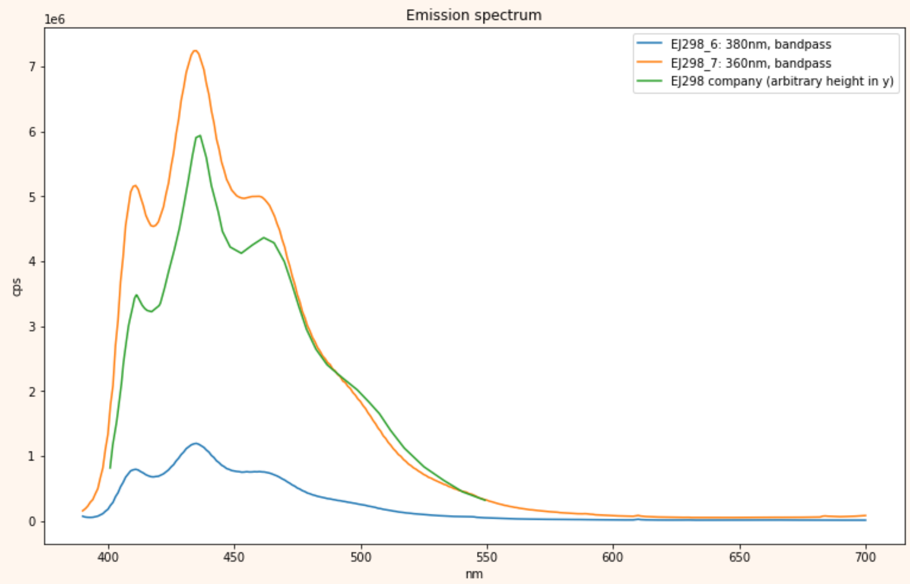


Absorption spectra

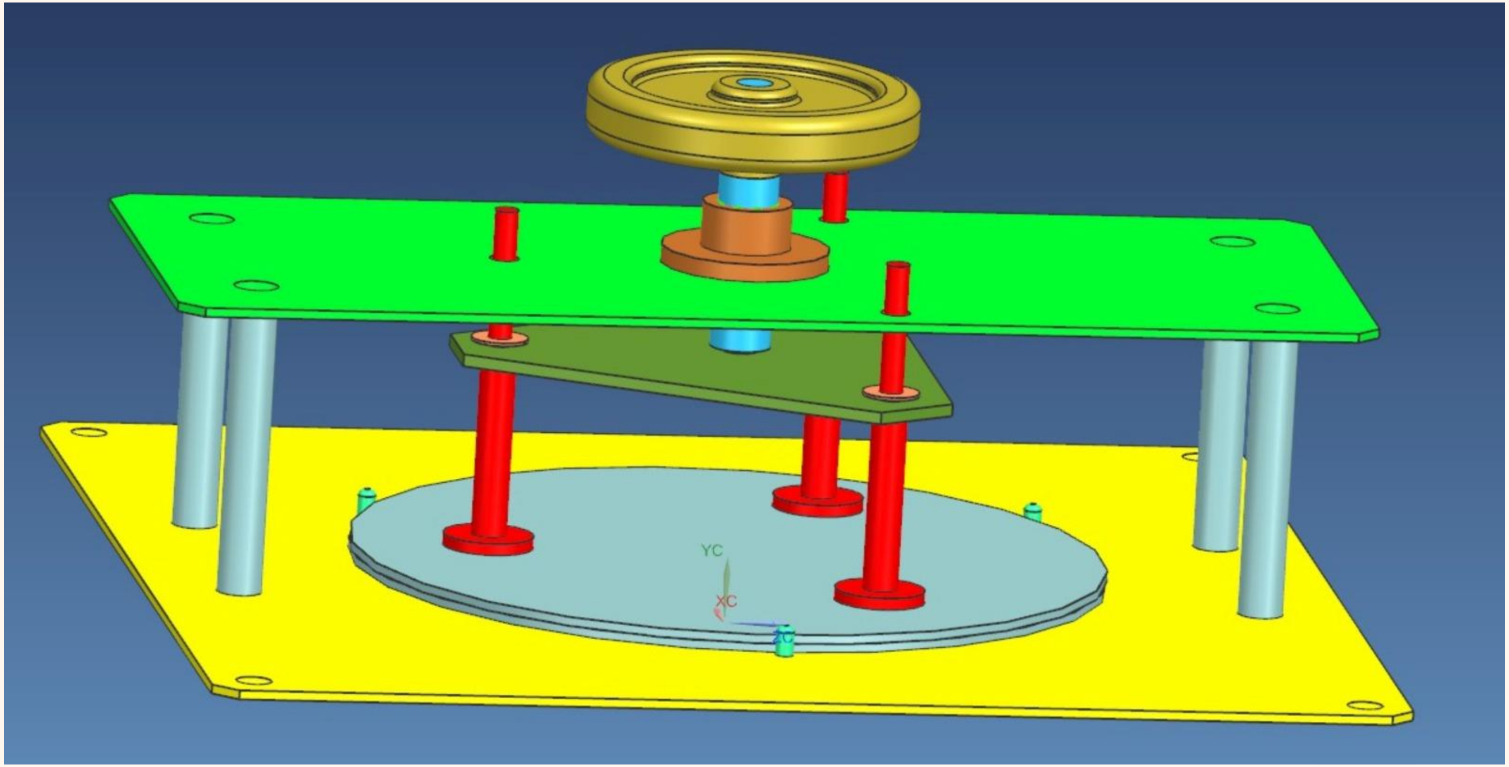


Emission spectra of EJ282 and EJ298





Sandwich Maker



Reflecting foil reflectivity