WCTE water system

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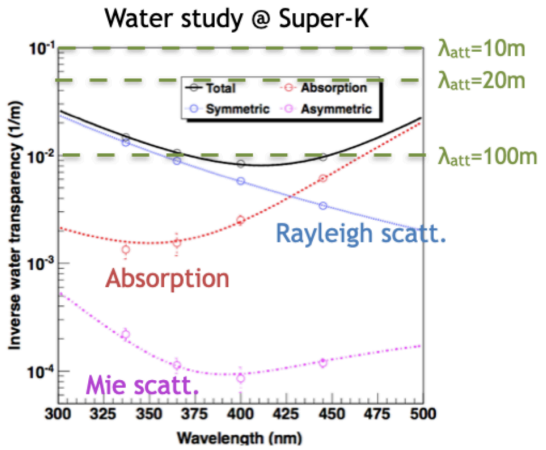
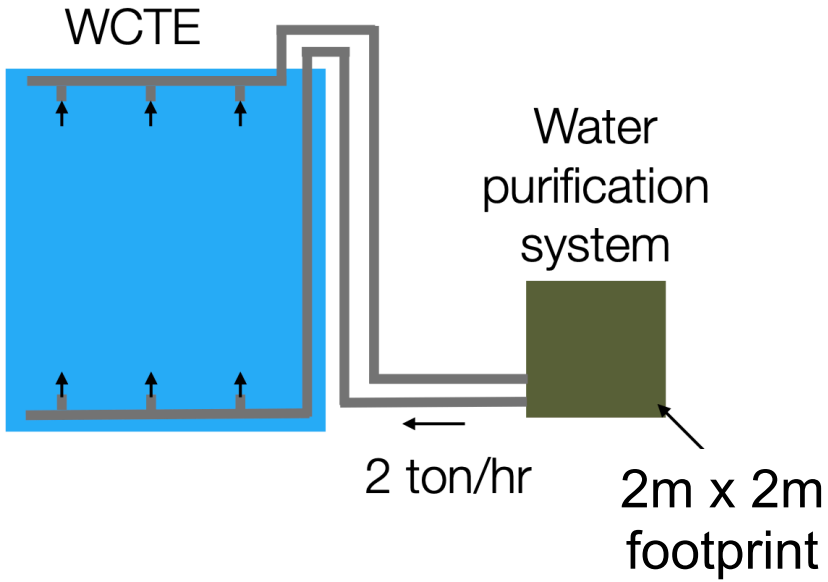
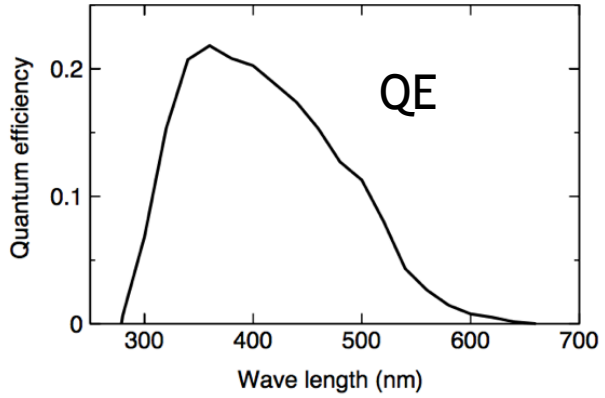
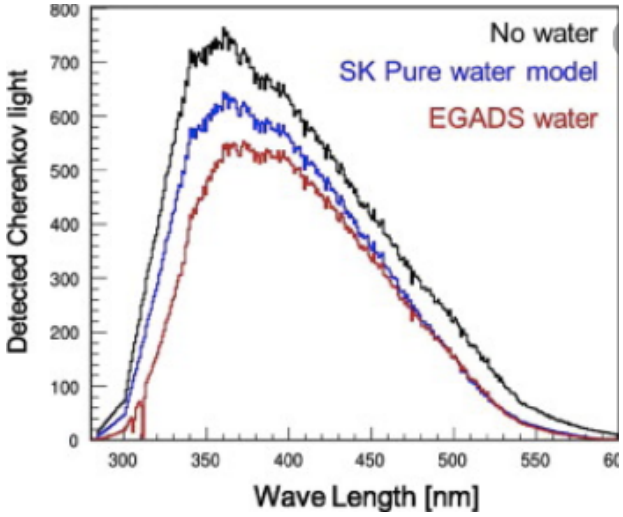
@ WCTE workshop





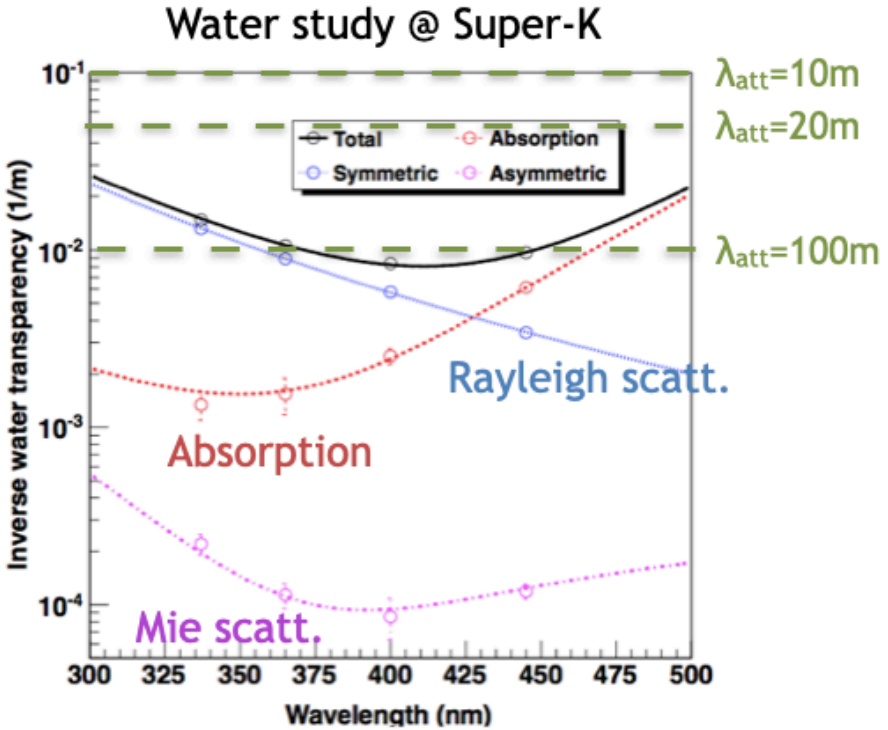




- Cherenkov light yield ~ $1/\lambda^2$
  - More Cherenkov light at shorter wave length
- Light detection efficiency
  - Quantum efficiency of PMT peaks at ~400nm
- Detected Cherenkov light is 320-500nm
  - Peak is 350-400nm
  - some suppression of light below 400nm with Gd

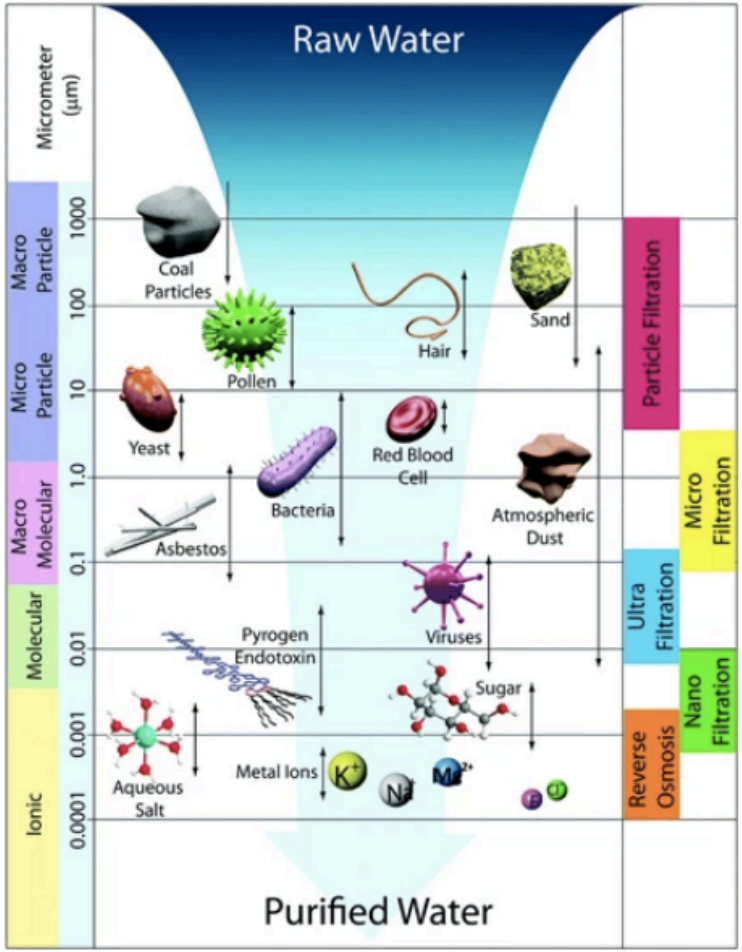
Light attenuation in SK water Cherenkov

- Attenuation at λ > 450nm due to
  - Water absorption: $\lambda_{att} > 50$m
    - negligible for WCTE with 4m diam.
- Attenuation at λ < 400nm due to
  - Rayleigh scattering: $\lambda_{att} > 50$m
    - negligible for WCTE with 4m diam.
  - Absorption by dissolved impurities
    - Removed by molecular and ion filters
      - Reverse Osmosis, Ion exchanger, degasser
      - Gd ions need to be kept for Gd run
- Mie scattering
  - bacteria, dust, and other particles
    - removed by the water filtering (Microfilter)
  - negligible for SK but could be the main cause in WCTE

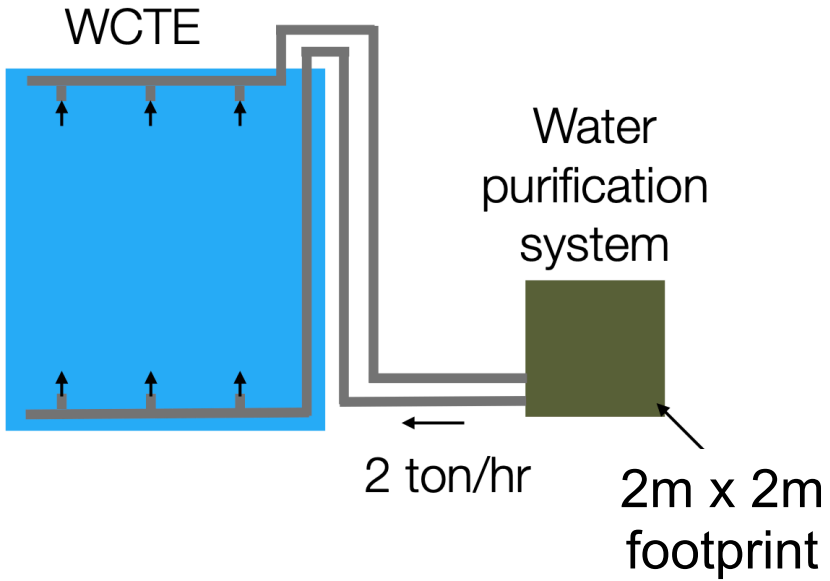


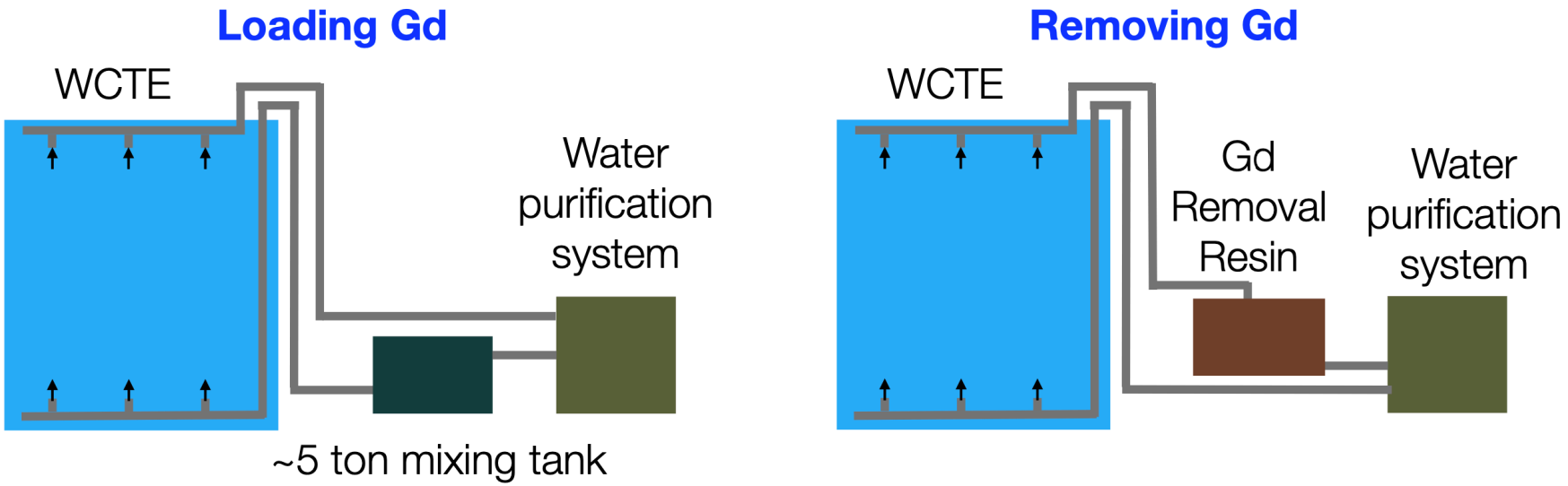
SuperK full water purification system

- Activated carbon filter
  - adsorption of chlorin, organic material, etc.
- Membrane particle filter
  - Microfilter(MF), Ultrafilter(UF), Nanofilter(NF)
    - different pore sizes
- Reverse Osmosis (RO)
  - filter metal ions
- Ion exchanger resin
  - cation (+) and anion (-) exchange
- Membrane degasser
  - remove dissolved CO_2 (food for bacteria)
- UV sterilizer and Chiller
  - suppress the growth of bacteria



- Initially use deionized water
  - pure water with ions removed
  - potentially available at CERN
    - used for magnet cooling
- Water purification system
  - Micro/nano and carbon filters
    - remove Mie scatt. particles
  - UV sterilizer, chiller, degasser
    - suppress bacteria growth
  - Ion exchanger and RO?
    - interfere with Gd loading
    - either not using them or use special resin
      - see the later discussion

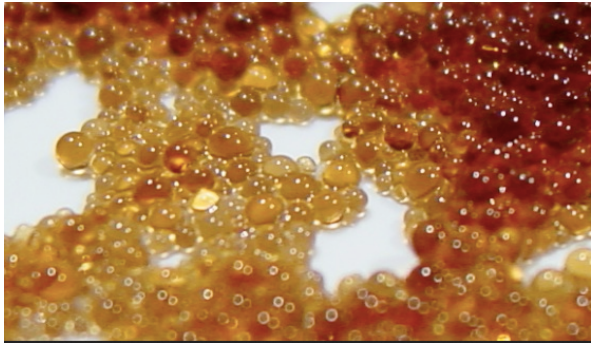


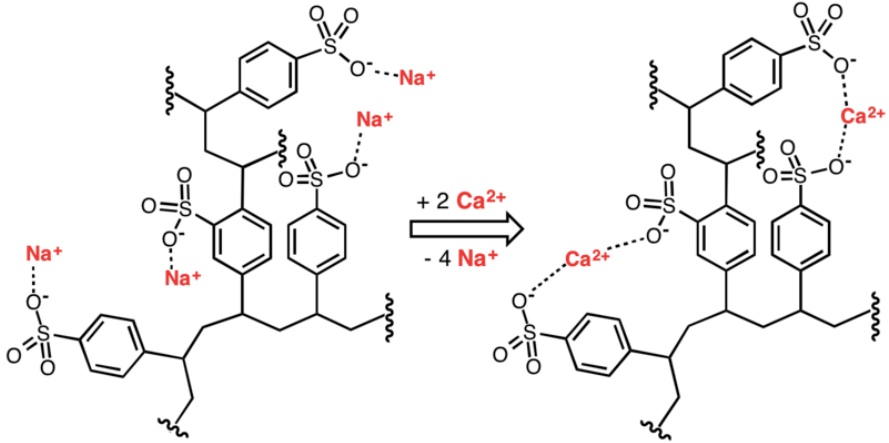


- $Gd_2(SO_4)_3$ mixed in the mixing tank
  - WCTE: 0.2% x 50ton x $70/kg = $7k
- Gd removal by cation resin in the water line
  - more expensive than $Gd_2(SO_4)_3$ itself

Gd removal by ion exchanger resin

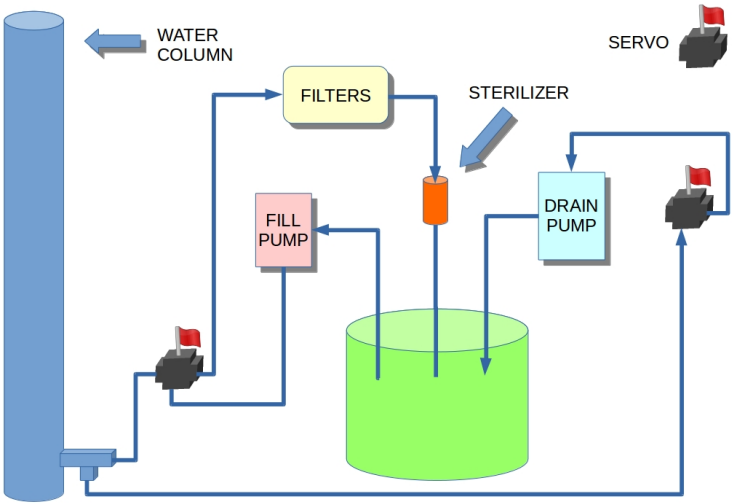
- Water softening cation resin
  - simple & effective emergency Gd remover
  - SK (50kton water), WCTE (50ton)
- For circulation, Gd need to be maintained
  - special ion exchanger resin (expensive)
  - Or we may do without ion exchanger

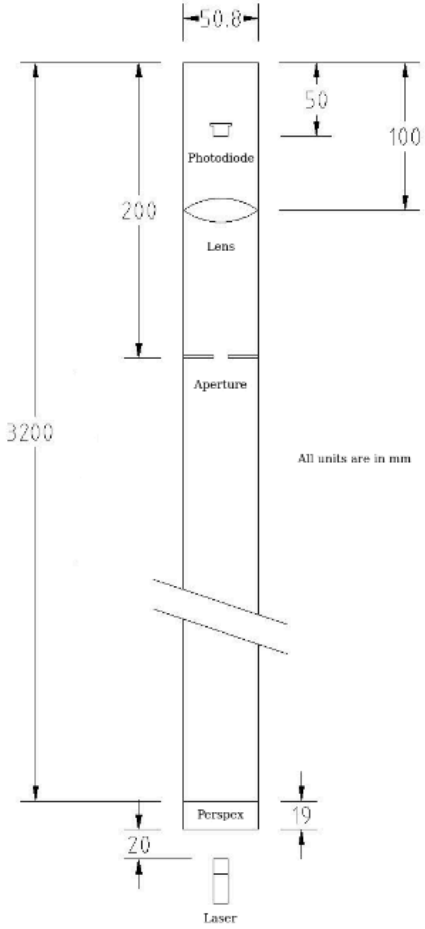




Simple water purification for CHIPS: arXiv:1610.06957

- Water filtering on pit water only with
  - 1µm carbon filter
  - 0.2µm microfilter
  - UV sterilizer
  - no filtering on metal ions at all
- Water column for attenuation length study

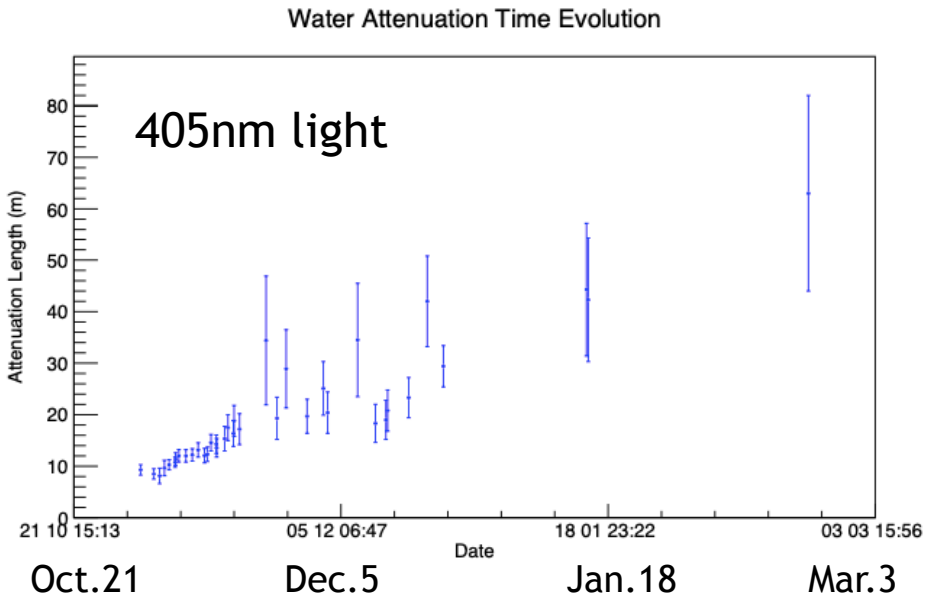




Simple water purification for CHIPS: arXiv:1610.06957

Raw pit water circulated only with carbon filter, microfilter, and UV

In WCTE, we will start by ultra-pure water with ions and gas removed



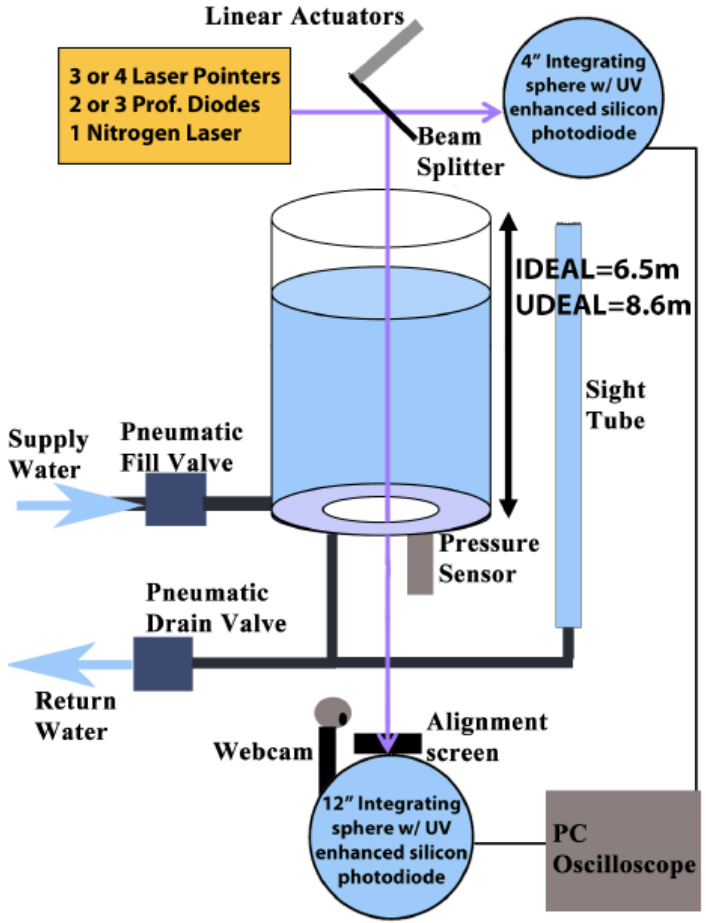
- Attenuation length reach 50m @ 405nm
  - 4 months after starting from raw pit water
  - even with fully dissolved ions and gas

- Comments by Nakajima-san
  - 50m exceeds the requirement (λ_{att}>20m)
    - resolution is limited by 3m column: error is large but still very promising
  - Degradation is expected below λ=400nm
    - important to study in the Cherenkov peak region of 350-400nm
  - Study was done in an empty water tank
    - need to study with detector components
      - emanation? corrosion by metal ions?
  - Systematic R&D study is needed (no data!)
    - Light attenuation study with ions in presence

Water transmission monitor: UDEAL/IDEAL (UC Irvine group)

- UDEAL water transmission detector
  - laser light is injected from the top of the water colum
  - integrating sphere with photodiode at the bottom to measure the light
  - Changing the water hight in the column to change the light path length in the water

- Similar system is needed for the WCTE water system
  - excellent graduate students project
    - systematic study of water quality
    - low cost detector to build
      - require careful 1% level measurement
    - physics simulation studies



Summary

- Water purification is needed for good light transmission in water Cherenkov
  - Active carbon filter adsorption for Cl and organic materials
  - Particle filters (MF, UF, NF) for small particles and molecules
  - Reverse Osmosis (RO) and Ion exchange resin catch ions
  - Membrane degasser removes dissolved gas, in particular CO_2 (food for bacteria)
  - UV lamp will suppress bacteria growth
- Simple filters (carbon, MF) and UV lamp may be enough for WCTE water circulation
  - The size of WCTE is small and may not require ion removal during the circulation
  - Start with ultra-pure (deionized) water at CERN
  - If this works, it is simple, economical and works with Gd loaded water
- Encouraging result from CHIPS study showing that simple filters worked @ 405nm
  - systematic R&D required to study water transparency with dissolved ions
  - SK (Irvine) UDEAL system provides good example for the transparency measurement
    - WCTE will be an excellent platform to test long term stability with real detector
- Looking for a group who will lead this important and important project