NPS Calorimeter Prototype:
Status 30 January 2014

Ongoing studies:

- We are still trying to locate the HV dividers assembled last year by V. Popov (with the intent to use these for the prototype). One of the dividers, and one PMT R4125, was taken by RadCon, and is in the bunker (still hot)..
- We are looking for different sets of Blue and IR LRDs for the monitoring and curing systems.
- We have ordered Nichia (blue) and two sets of high intensity IR LEDs.
- We are trying to find drivers for the LED (pulsed and continuous modes)
- We looked for methods and a possible device to measure the absolute intensity of the LEDs (number of photons per second), since we need to know absolute power of light source for monitoring and curing, and be able to measure light intensity delivered to each module.

The number of emitted photons can be calculated with known power of LED
The photon energy is: $E_\gamma = h\nu = hc/\lambda$***, where h = 6.62606896×10^{-34} J·s Plank's constant, c = 299792458 m/s speed of light, and λ is a photon wavelength.***
This gives for photon energy: $E_\gamma = 19.864\times10^{-17}/|\lambda|$ J (if λ taken in nm). (Example, photons with λ=488 nm have an energy $E_\gamma=4.07\times10^{-19}$ J).
If the LED power is P_{LED} = 1.0 W (1W = 1 J/s), then within time t=1s it will emit energy $E_{LED} = P_{LED}\times t$ = 1 J.
The number of emitted photons would be $N_\gamma = E_{LED}/E_\gamma$ ***. (For the E =1.0 J number of emitted photons: $N_\gamma = (1/19.864)\times\lambda\times10^{17}=5.03\times\lambda\times10^{15}$ (λ in nm)***
If a monochromatic LED with a wavelength λ=1000 nm has a power of P=100 mW, the number of emitted photons per second would be dN_γ/dt = 0.1×5.03×1000×1015 = 5.03×10^{17} γ/s.

We found one instrument - CAS140 from Konica-Minolta- that would be perfect to measure the absolute light intensity
With CIE adapter this devise can perform direct and high accuracy measurement of optical parameters of LEDs, fibers, splitters and mixers. But it is expensive (~$100 k)


LED-436 luminous intensity measurement adapter


LED-811 test sockets for high-power LEDs

The design of the prototype will require a final decision for the monitoring and curing systems. We are skeptic about IR curing, which is promising but difficult, so we need to try and test this approach. Hence, we will develop both, blue and IR, curing systems for the tests.

The worry about in-situ IR curing (with PMTs HV On condition, which is a main the benefit of IR) is the small but quantitatively unknown quantum efficiency of the PMT at wavelength of λ~900 nm. Even if small, effective curing will require a very large IR light intensity of ~10^{17} γ/sec. A phototube, even with a very low QE at this wavelength, could be completely damaged at such a high intensity IR light. It is possible that the use of special IR-cut foils (spectral filters) will help, but all this must be carefully examined and tested, one of the goals of the prototype.

There are further technical problems related to monitoring and curing:

- Since, the first stage of NPS calorimeter is perhaps a combination of ~600 PbWO4 blocks (from PrimEx) and 208 PbF2 blocks (from Hall A DVCS), the design of the NPS calorimeter must be optimized to be acceptable for the assembled PbWO4 PrimEx blocks.
- This complicates (or perhaps excludes) a connection of the monitoring fibers from the back without unwrapping of the PrimEx blocks and disconnecting the PMT. (Note, Primex blocks are optically coupled with R4125 PMTs by glue and are wrapped in Al foil and Tedlar paper).
- If we stick to the PrimEx design of the blocks, then we need to combine curing in situ and monitoring system from the front side. (Note, in PrimEx and other similar calorimeters, fibers for monitoring were attached to the blocks from the front by special plastic pads).

Our proposal is to mechanically combine the monitoring and curing systems in the prototype.

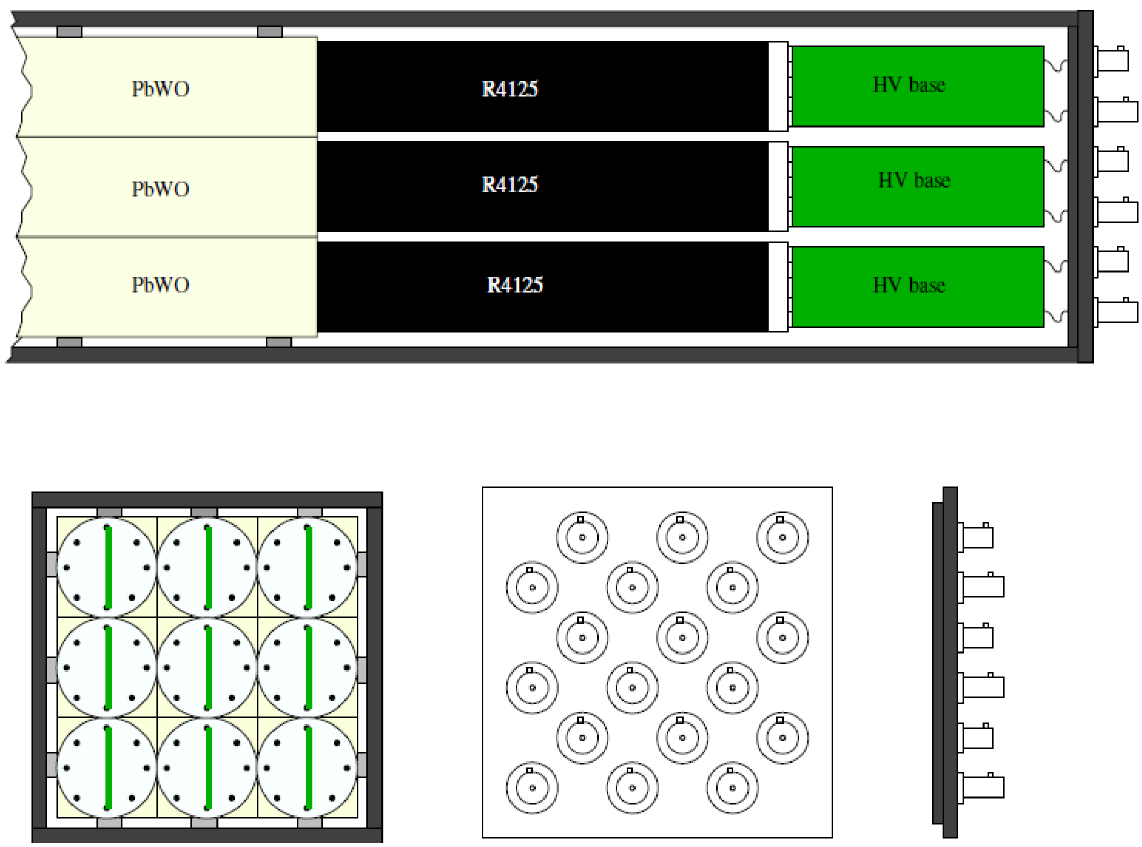
For monitoring we will use Blue light (~450-480 nm), which will be delivered from the splitter to each PbWO block by a ~200 μ diameter quartz fiber.

For the tests we plan to make two versions of such a combined (monitoring + curing) system:

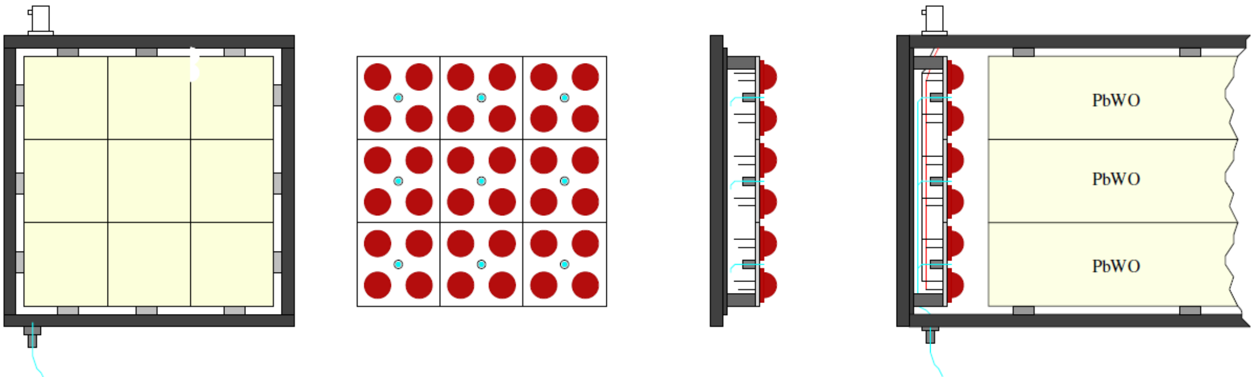
In the first version, the curing will be performed with a matrix of 4 ultra-bright Blue LEDs per block (with intensity about 10^16 photons/sec per block);

In the second version, the curing system would be a clone of first one, but with a matrix of 4 ultra-bright Infra-Red LEDs per block (with intensity about 5×10^17 photons/sec per block).

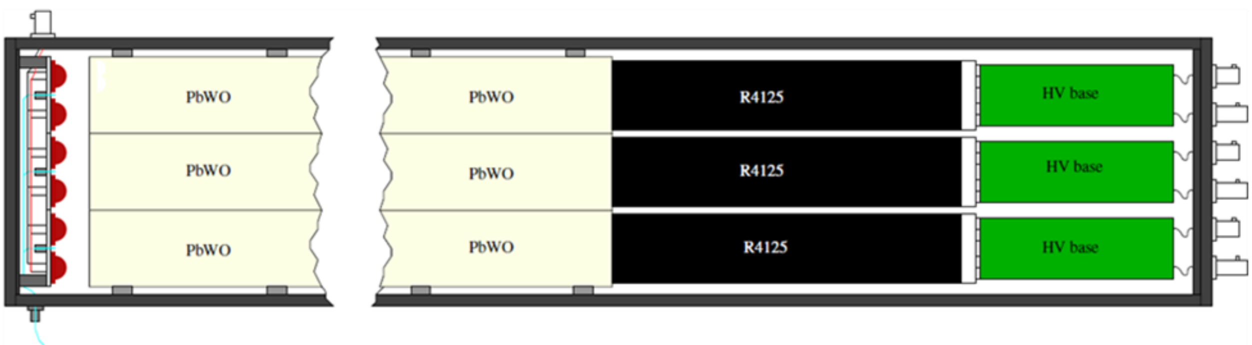
Simple drawings (not to scale and not engineering drawings) illustrate our present idea of construction of the prototype. We will do more advanced drawings and detailed drawings (acceptable for the JLab machine shop) after we have taken into account all comments and advise, as well as folding in the actual physical dimensions of the components (blocks, PMTs, LEDs, fibers and so on).



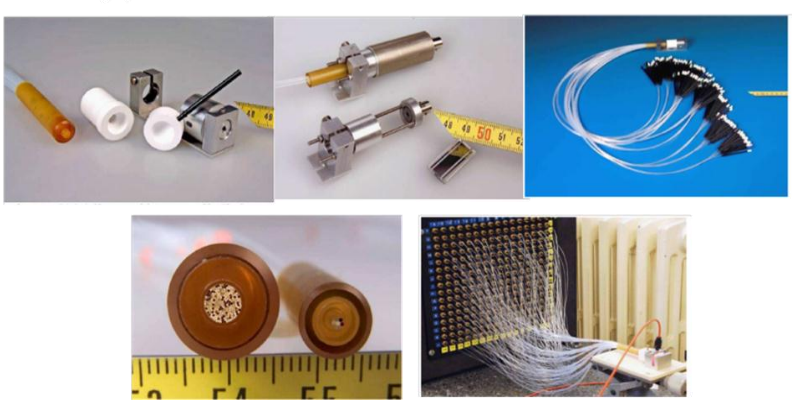
Sketch of a side and back view of the prototype. (Second half, where PMTs, dividers and connectors are located)



Sketch of a side and front view of the prototype. (First half, where LEDs, fibers and connectors are located)



Schematic side view of the full assembled prototype.



Many details and technical solutions of light monitoring system can be adopted from calorimeter PANDA, PrimEx, ATLAS and CMS. (Here are show details from the CMS.)

List of proposed activities and studies before final assembly of the Prototype:

- Engineering design of the prototype “temperature-controlled box” (acceptable for fabrication in JLab machine shop);
- Try to locate one or two PbWO blocks (even if with some mechanical damage) to measure the transmittance;
- Ask JLab RadCon group to radiate one of these blocks up to a 0.1-0.5 Mrad dose;
- Measurement of light transmission efficiencies (in the range 200-1000 nm with step 10 nm) of the new $PbWO_4$ blocks (after delivery);
- Look for the possibility to get one 2.0 cm x2.0 cm PbWO module from PrimEx (or elsewhere), or alternatively just make a mechanical copy to study all aspects for connection of fibers from light monitoring system.
- Assemble and test of the HV (active) dividers for the R4125 PMTs;
- Gain and relative quantum efficiency measurements of the PMTs;
- Development and assembly of drivers (pulse and continuous mode) for the blue and IR LEDs;
- Efficiency and intensity studies for the samples of Blue and Infra-Red LEDs;
- Test sensitivity of the PMT’s to IR light and measurements of anode current;
- Study of possibilities using IR cutoff filters (films) to reduce IR light impact;
- Develop necessary hardware and software for tests;
- Estimation (measurement) of the absolute number of photons from the LED’s;
- Design and preparation of a Blue-LEDs matrix, and light mixer/integrator and splitters for monitoring system;
- Measurement of the output light intensity from the mixer and individual fibers;
- Design and preparation of IR and Blue LEDs matrix for curing (in all cases we need to have a blue LED version as backup);
- Design, fabrication of the prototype “temperature controlled box”;
- Assembly and test of the light monitoring system;
- Assembly and test of the curing system (both, blue and IR variants);
- Assembly of the prototype with both curing and monitoring systems;
- Laboratory test of the prototype (with LED and cosmic);

Current status:

- 10 blocks of $PbWO_4$ crystals have been ordered (~$15 k) in December 2013, the delivery from SICAS is expected before summer 2014;
- 10 phototubes Hamamatsu R4125 have been ordered in January 2014 ($5 k);
- Working on prototype design;
- Working to collect all parts for high voltage bases developed and assembled by V. Popov;
- We have ordered samples of Nichia Blue and two different types of IR LEDs;
- Looking for the other types of blue and IR LEDs and their drivers;
- Looking for the Photodiode for the intensity measurements of blue/IR LEDs.