NPS Calorimeter Prototype:
Status 27 March 2014

Ongoing activities

PMT and HV Dividers

- 10 Hamamatsu R4125 PMTs for the prototype have been delivered.
- R4125 PMT HV dividers:
  - HV divider boards have been delivered on 19 March (despite some administrative delays). Now we have all components and boards for the R4125 HV dividers.
  - Received the schematics and board drawing for the HV divider from Vladimir Popov. This information is needed for assembling of the R4125 PMT dividers.
  - We agreed with the JLab electronic group (Chris Cuevas) that they will assemble the R4125 PMT HV dividers. The boards are surface mounting and electronic components are very small, and so require professional and special tools for their installation. All needed parts, boards and schematics have been given to the electronics group and the assembly has started.
  - Still looking for the PMT R4125 and dividers taken in 2013 by collaborators for the various tests. On 07 March I sent another email to FIU (Pete and Joerg) asking them to return one PMT R4125 with divider. Pete and Joerg replied and hopefully will send the PMT soon.

LEDs and testing

- The Hamamatsu Photodiode S2281 has been delivered. This photodiode is effective in the wavelength range 200-1100 nm. We are planning to measure the LED's absolute intensity using Carl Zorn's setup in ARC.
- Recently we have ordered additional new samples of LEDs:
  - Infrared LEDs: Vishay TSAL7400, with $\lambda \sim 940$ nm, Osram LD271, $\lambda \sim 940$ nm and Osram SFH4547, $\lambda \sim 950$ nm
  - Blue, $\lambda \sim 460$-470 nm, RL5-B5515 and RL5-B4630

  We already have on hand one type of blue LED (SLA580BCT3F) and two types of Infrared LEDs (OSRAM SFH4233 and LD274-3).

LED initial test results

- Carl Zorn has a test setup running and already took some initial data for the NIR LED (LD-274-3).

- At a distance of ~3 cm, where the LED fully illuminates the calibrated photodiode (with an effective area of 100.0 mm^2) the energy output is equivalent to **2 x 10^{16} photons per second** (for area 100 mm^2 or 2 x 10^{16} γ/s/cm^2) .
- Note, the wavelength of LD-274-3 LED is λ=950 nm (peak).
- Using this number as an average to estimate energy of the photons:

$$E_\gamma = h\times\nu = h\times c/\lambda = (6.63\times10^{-34}\ m^2\cdot kg/s\times3\times10^8\ m/s)/(950\times10^{-9}\ m) =$$
$$= 0.0209\times10^{-17}\ m^2\cdot kg/s^2 \Rightarrow \mathbf{1.31\ eV}$$

($1\ J = 1\ kg\cdot m^2/s^2 = 6.24\times10^{18}\ eV$; $1\ eV = 1.602\times10^{-19}\ J$).

- Such flux of photons $N_\gamma = 2 \times 10^{16}$ will deposit power of energy

$$P_\gamma = N_\gamma\times E_\gamma = 2 \times 10^{16}\times1.31 = 2.62\times10^{16}\ eV/sec \approx$$
$$\approx 2.62\times10^{16}\times1.602\times10^{-19}\ J/s \approx \mathbf{4.2\ mW\ per\ cm^2}$$

(at a mean wavelength of 950 nm and at the nominal maximum current of 100 mA driving the LED, as listed in the Osram data sheet).

- Data obtained by Carl show that the output is almost linear with driving current. Beyond 60 mA, the output begins to curve slightly indicating the onset of saturation.
- We are planning to perform more detailed measurements to see how powerful these different LEDs are and to select the optimal one for the prototype.

<u>PbWO4 and PbF2 Crystals</u>

- Recently Arshak did transmission measurements for one $PbWO_4$ crystal using Carl Zorn's setup in the ARC. This was mostly for training purposes to get familiar with the setup.
- Next he made transmission measurements for an actual PbF_2 crystal, which we will use in NPS calorimeter. Charles provided one PbF_2 crystal from HA/DVCS for this measurement. Transverse and longitudinal transmittance measurements were made for this PbF_2 crystal.
- Also asked Ashot for an actual PrimEx crystal for the transmission measurements, but he said this will not be possible. PrimEx ended up using all crystals except from very few of them which had been left in EEL building after the experiment. When the EEL area was cleaned up after the PrimEx experiment they lost all spare parts, including the crystals.

The prototype design consideration (use Al or Cu for the frame ?)

- Several aspects have be considered to choose material for the frame:
  - **Weight:** Assume that for the construction of prototype frame we will use Al or Cu sheets with a thickness of 1.0 cm. The frame will be assembled from 6 pieces, four side plates with a dimensions of 42.0 cm × 8.0 cm, one back and one frontal plate, with roughly equal dimensions of 8.0 cm × 8.0 cm. With ~1.0 cm thickness, the total weight of the prototype frame would be $(4\times42.0\times8.0\times1.0)\times\rho + (2\times8.0\times8.0)\times\rho = 1472\times\rho$. This will yield total weight of ***≈13 kg for Cu, and ≈4 kg for Al***. (Note weight of 9 crystals with PMTs and dividers would be ~1 kg.
  - **Estimated Price for machining** of the prototype frame in JLab:
    - ~$1,000 for the Cu + ~$1,000 for job ➔ ~$2,000
    - ~$800 for the Al + ~$800 for job ➔ ~$1,600
  - **Thermal properties**: Copper has a higher thermal conductivity than aluminum, but aluminum is able to radiate the heat into the air better than copper because of its lower density.
  - **Residual radiation activity**: I could not find experimental data for photon/electron induced residual activities. Calculated counting rates for samples of Al and Cu irradiated by fast protons/neutrons show that residual activity of the Cu is a factor of ~4 higher than that of Al. In addition, the cooling time after irradiation for Al is about 10 times shorter than for Cu.
- **Conclusion:** Aluminum is weight and to some extent cost effective. It has lower residual activity and shorter cooling time after radiation, but worse thermal properties. Since thermal properties are important for the prototype studies we will **use Cu for the construction of the prototype frame.**
- Machine shop required more detailed drawings to start fabrication. We need to finalize type of the connector for the LEDs and connection system of the fibers for delivery light from the monitoring system to blocks.

Common light source in the monitoring system for the $PbWO_4$ and PbF_2:

- One of the open question was "*could we use same primary light source for the hybrid calorimeter consisting of $PbWO_4$ and PbF_2 blocks*" ?
  - Comparison of Transmittance efficiency curves show that $PbWO_4$ and PbF_2 crystals transparencies are very different in the short

wavelength region (λ~250-350 nm), but for both type of crystals the transparency is reached to its maximum value above λ~400 nm)

Conclusion ➔ the blue light with a wavelength ~470 nm should be acceptable for both types of crystals as a common light source for the monitoring system

The output pulse timing and shape for $PbWO_4$ and PbF_2 crystals

- Alternative version of the NPS calorimeter will combine $PbWO_4$ and PbF_2 crystals. For $PbWO_4$ crystal the light generation mechanism is pre-dominantly scintillation light, while it is pure Cherenkov for PbF_2. As we have discussed on 06 March meeting, these will require special studies:
- The output signal timing properties and pulse shape are different then it may require a different digital filtering for the $PbWO_4$ and PbF_2.
- In addition, the active bases used for R4125 PMTs will change the shape of signals from the $PbWO_4$. It is necessary to take this into account,

The proposed activities in near future

There are several jobs which can and needs to be done before construction of the calorimeter prototype. Moreover, some of them are necessary to finalize the design of the prototype and direction our future activities. The list of these jobs include:

- Assembling of the high voltage dividers for the PMTs
- Test divider and be sure that they are in a good shape and no any mistake
- Preparation of Carl's equipments for LED studies
- Measurement absolute intensity of the LED's (what we have at present)
- Study of Quantum efficiency of the R4125 in the region of λ>800 nm
- Study the timing properties and shape of the signals generated by blue LED in $PbWO_4$ crystal when using active high voltage divider (with amplifier)
- Transmission measurements of the PbF_2 and $PbWO_4$ crystals.