NPS Light Monitoring System

Because of its high density and fast decay time, the lead-tungstate ($PbWO_4$) crystal is chosen to construct calorimeter of the Neutral Particle Spectrometer (NPS). This type of crystal, however, still suffers from non-negligible radiation damage. Studies show that the scintillation mechanism in $PbWO_4$ is not affected by radiation, and the loss of light output is due to only absorption caused by radiation. A light monitoring system will measure variations of the transmittance of crystals in the course of experiment and provide calibration in situ.

The light monitoring system will be used to control stability of the detector, degradation of the crystals due to accumulated radiation dose and define condition when curing of the crystals is needed. It will periodically inject light into detector modules between the real events during data taking or during special calibration runs with a frequency ~10-20 Hz.

Note that we can't use the front of the Calorimeter for monitoring system, since most of the radiation damage is occurred in the first 2-3 cm of the front of the crystal, and monitoring of this damage does not give full information about crystal condition.

Main Components of the Light Monitoring System.

The main components of the Light Monitoring System (LMS) are:

- Light source: Nitrogen Laser (LN203C, LN120C or ORIEL Instruments, λ~337 nm, pulse width ~300-600 ps, energy/pulse ~300 μJ, max. rate ~50 Hz, estimated cost ~10 k. Good candidate for lase is Quantronix Tisapphire which are used in CMS. This laser have λ=440 nm, practically no need for WLS, puse energy is ~1 mJ, puls width 25-30 ns.)
- Wave Length Shifter (bis-MSB, G2, BC482 or NE172 type, estimated cost ~0.5 k)
- Filter wheels with remote control system (FW102C, need two, estimated cost 2×1100 ≈ 2.2 k, including programmable filter sequences)
- Set of neutral density filters (ND) (1:2, 1:4, 1:5, 1:10, 1:100, 1:1000, estimated cost ~100-300/each or ~2.0 k for full set)
- Mixing box (Integrating sphere, 4 inch diameter, estimated cost ~2.0 k)
- Light distribution system (ten 12 legged1:12 Primary splitters, silica fiber of ~200 μm in diameter, each leg with CT connector and 3 m long, estimated cost 12×450 ≈ 5.5 k, and ten 100 legged 1:100 Secondary splitters without connector and ~3.5 m long silica fibers of core diameter ~200 μm, estimated cost 10×1000 ≈ 10 k)
- Reference detectors (High-speed silicone Photodiode, estimated cost ~0.1 k, and 2 Hamamatsu R4125 PMTs, estimated cost ~0.9 k)
- Am^{241} α-source within YAP (3×300 ≈ 1 k)
- Optical fibers (~40 m long with core diameter 1 mm, of PCS1000 or HPSUV1000 type silica fiber, estimated cost ~25 $/m, and ~3,000 m PCS200 or PHSUV200 type silica fiber with core diameter ~200 μm, estimated cost ~1 $/m) ➔ total ~4 k
- Laser box (Al box to house laser, WLS, PIN photo-diode with electronics and filter wheels, needs to be designed and fabricated, estimated cost ~5 k)
- Optical fiber connectors (50 connectors, ST or SMA type, estimated cost 50×20≈ 1 k)
- Fiber optic & ST connector termination and polishing kit (estimated cost ~0.5 k)
- Laser safety goggles (estimated price ~150 $)

Schematic sketch of the NPS calorimeter light monitoring system is shown in Fig.1.

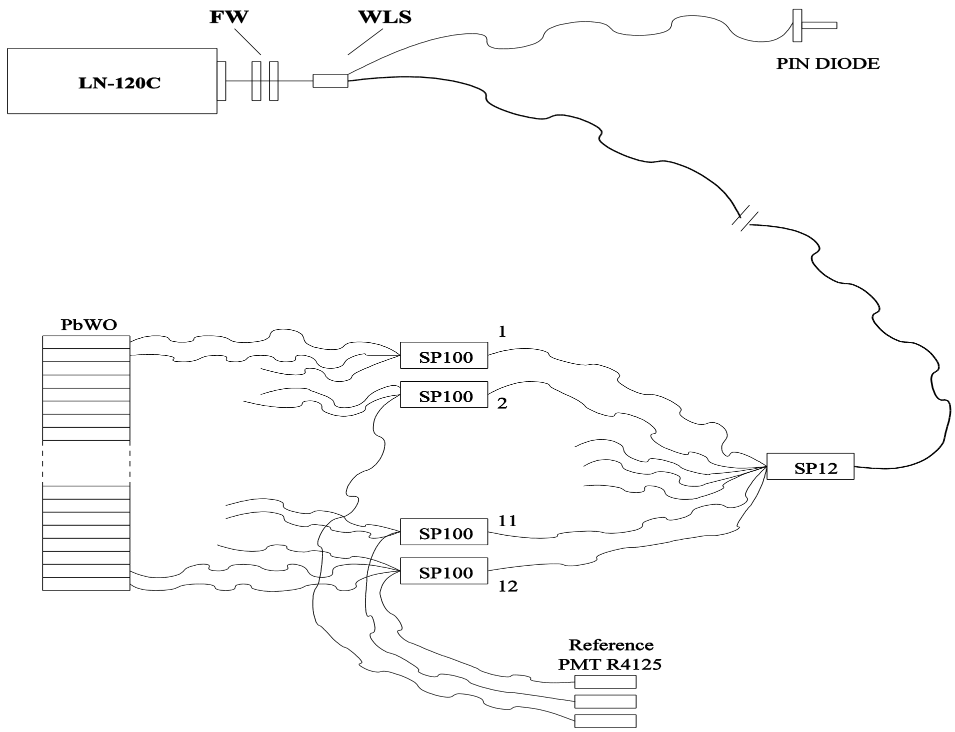

Fig. 1 Schematic view of NPS calorimeter light monitoring system

It would be modified version for 1000 channels of PrimEx monitoring system shown in Fig. 2.

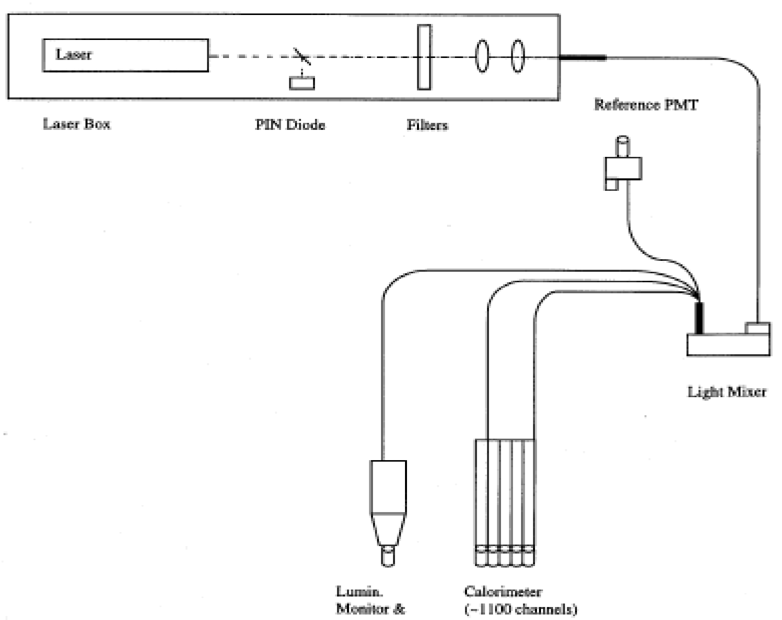

Fig.2 Schematic view of PrimEx laser base gain monitoring system (adopted from PrimEx CDR)

More details of components of light monitoring system are presented below.

1. Light source:

The light source will be nitrogen laser. The intense UV light (337 nm) from the laser first will be converted to blue light (~420-440 nm) in order to match the spectral sensitivity of the phototubes and be near the $PbWO_4$ scintillation emission peak.
The laser wavelength is short enough (~300 ps) to excite the scintillator. Hence, the final shape of the signal will be determined by the WLS and properties of light integrating sphere and splitters. Nitrogen laser would be located in the rear small room of the Hall C counting house, or in the experimental area but accessible for maintenance during running periods.

The light source also can be a set of super bright LEDs (for instance, NICHINA Super Bright Blue LED, NSPB500AS, price ~4-5$/each). In this case need to develop and construct electronics to power LEDs.

2. Wave Length Shifter:

The light shifter would be 3-5 mm thick, ~ 2×2 cm^2 in cross section rectangular bar of WLS (bis-MSB or BBQ type), or 20-50 mm long piece of fiber, ~5-8 mm in diameter of the same type material.
Note that the laser beam spot size is about 2×3 mm^2, and that its position may walk with time by 1-2 mm. Covering the laser beam spot with a WLS of such dimensions will minimize dependence of light output on beam position.

3. Filter wheel:

Two motor driven filter wheels (6 positions for 01" optics) with a set of neutral density filters will be used to change remotely the light intensity in a wide range (from 2:1 to 1000:1) when needed for calibration of the detector, or for checking all the spectrometric and electronic channels.

4. Neutral density filters

A neutral density ND filter (of glass material) reduces light intensity uniformly in a wavelength range. The filters are denoted as ND2 (attenuation factor 2, giving 50% of input light intensity), ND4 (25%), ND8 (12.5%) etc, operate in wide wavelength range (from 400 nm to 2000 nm). They are available from THORLABS, Newport, OPHIR and ORIEL.

5. Mixing box

For the light mixing the integrating sphere with a diameter ~4 inches can be used. This need to mix light from several sources (if in addition to laser LED system will be used). Inside surface of integrating sphere must be coated with broadband stable coating PTFE and BaSO4 (available from Newport or other companies of optical family).
Note, the bigger diameter (6 inches or more) will increase the light signal tail. As reported by PrimEx collaboration, with 6 inch diameter integrated sphere they got light signal tail of ~200 nsec, and switched to 4 inch sphere to reach acceptable timing.

6. Light distribution system (or splitter system):

The laser light pulses are directed to individual crystals via a multilevel optical-fiber distribution system (primary and secondary). At least two different types of splitters will be needed. The first type is to split light from the primary fiber (1 mm diameter) into 12 outputs. This 1:12 splitter is denoted SP12. The second type of splitters will be needed to split each signal from the primary splitter into 100 channels. This 1:100 splitter is denoted SP100. The main requirements to these splitters are: low light loss (better than 50%) and uniformity between output channels (within 10-15%). The total attenuation of the light distribution system must be possibly low to generate signal in each individual module equivalent to particle with energy ~0.5-1 GeV.

7. Reference detector:

Two sets of reference detectors will be used in this system.
The first one is to monitor variation of the laser light intensity. This reference detector will be P/N photodiode with an amplifier, and will be located in the laser box.
The second reference detector system will be located near the main detector and will be used to monitor light intensity from the outputs of the splitters. This will consist of 2-3 PMTs with a radioactive α-source Am^{241} on a scintillating YAP crystal. The system will be well shielded from radiation.
The light pulse from each secondary splitter will be transported to the reference PMTs via fiber cables, and the bundle of these fibers will be fed to these PMTs..

8. Optical fibers:

Taking into account radiation condition of the detector only silica-glass fibers with the highest radiation hardness can be used near the detector.
The light from the laser will fed via ~20 m long (SpectTran, PCS1000 or HPSUV1000 type silica/quartz fiber with a hard polymer cladding and polymer jacketing, 1 mm core diameter) to the primary light distribution box SP12 near the calorimeter. A second fiber of the same type will be mounted after a laser beam splitter and will be used to trigger start detectors of the magnetic spectrometer (most likely S1 and S2 hodoscope-planes of the HMS).
We propose to deliver light from the first distribution box to a secondary splitter (which will be allocated inside the detector box) by ~10-15 m long, ~1mm diameter PCS100 type silica fiber.
The light from the primary fiber first will be split 1:12 in the primary splitter SP12, then in turn each output signal from the primary splitter will be split 1:100 in the secondary splitters SP100, and output fibers will deliver light to each module of the calorimeter (one fiber per block).
The fibers from the secondary splitters to the individual blocks would be ~3 m long, ~200-300 μm in core diameter, PCS200 or HPSUV200 type quartz fibers.
We need to find out how connect individual optical fibers to the back of a crystal near PMT in order to deliver light pulses from the monitoring system. Need to look closely for a simple way to modify the PrimEx and PbF2 blocks to attach fibers.

9. Optical fiber connectors/adapters:

Need ~50 ST or SMA type optical fiber connector & adapter pare to connect main fiber with laser box, fiber with primary splitter, and outputs of primary splitter to secondary splitters for assembly of the splitters.

10. Laser box:

The laser, two filter wheels with neutral density filters, a wave-length shifter and a PIN diode will be housed in a separate, electrically well shielded box in a radiation safe area. For safety reasons this box must have electrical protection to block laser power whenever it will be opened.

11. Optical fiber polishing kits
This kit is needed to mount/glue optical connectors and polish fibers whenever needed.

12. Laser safety goggles (from StellarNet Inc or other optical companies) to performe any work with laser beam optics.

Many details and technical solutions of light monitoring system can be found and adopted from well-known calorimeters, such as PANDA, PrimEx, ATLAS and CMS. As an example in Fig.3 shown some details of CMS laser based light monitoring system.

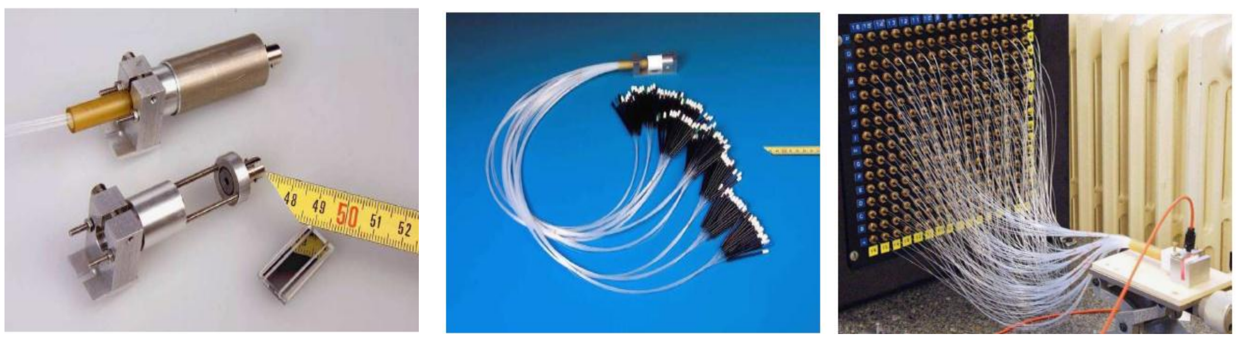

Fig. Some details of CMS calorimeter laser based monitoring system (adopted from M. Anfreville et al., NIM A 594, 2008, p292)