What Temperature is optimal for the NPS ?

1. Approved JLab 12 GeV energy experiments E12-13-007 (P_T in SIDIS); E12-13-010 (DVCS); E12-14-003 (WACS); E12-14-005 (WA exclusive π°) and E12-14-006 (Polarization in WACS) require:

- Energy resolution $\frac{\sigma}{\mathbf{E}} \sim \frac{3\,\%}{\sqrt{\mathbf{E}}}$
- Coordinate resolution $\sigma_{X,Y} \sim \frac{2-3}{\sqrt{\mathbf{E}}}\,\mathbf{mm}$
- Energy range of detected particles (photons) from 300 MeV to 7.4 GeV

2. Let assume NPS will operate at room temperature (at 18°C). Then:

- Light yield is about 15 p.e. per 1 MeV energy deposition (R. Novotny)
- Slow component: ~10% (fraction of LY above 100 ns up to 4 μs)
- Temperature stability: 0.1°C (guarantees a 0.5% resolution stability)
- Spontaneous recovery of radiation damage: from few hours to few days

3. Effects from cooling $PbWO_4$ from T=+18°C down to T=+14°C or 10°C:

- Light Yield per 1 MeV energy deposition will increase and from 15 p.e. to 16.5 p.e. at T=+14°C and 18.5 p.e. at T=10°C (or will increase by ~11% and~23%). Note: from PANDA group studies LY(-25)/LY(+18)~3.5-4.0 or increased by 3% per 1°C (assuming exponential growth of LY with temperature: $LY(T) \approx LY(0°) \times e^{0.03\times(0°-T)} \approx 25\times e^{0.03\times(0°-T)}$).
- Slow component also will increase and will reach 12% at T=14°C and 14% at T=10°C. Note: PANDA group studies show that slow component will increase by ~5% per 1°C.
- Temperature stability: 0.1°C (guarantees a 0.5% resolution stability)
- Speed of spontaneous recovery of radiation damage will go dawn
- Technical difficulties and problems will arise

4. Well known $PbWO_4$ based calorimeter resolutions:

The energy resolution of a calorimeter can be expressed as

$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$, where $a/\sqrt{E}$ is stochastic term related to intrinsic shower fluctuations and photo-electron statistics, b/E is electronic noise term, and c is constant term that includes instrumental effects and mis-calibration.

- PANDA: $\frac{\sigma}{E} = \frac{1.74}{\sqrt{E}} + 0.7$ (at T=+10°C), or 2.45% at 1 GeV.
- PANDA: $\frac{\sigma}{E} = \frac{0.95}{\sqrt{E}} + 0.91$ (at T=-25°C), or 1.86% at 1 GeV.

(Note, from T=+10° to T=-25°C the LY increased by factor of ~3.5 while resolution improved only by 30%, from 2.45% to 1.86%).

- HYCAL: $\frac{\sigma}{\sqrt{E}} = \frac{1.17}{\sqrt{E}} \oplus \frac{1.80}{E} \oplus 1.15$ (at T=+14±0.1°C) or 2.45% at 1 GeV.
- CMS: $\frac{\sigma}{E} = \frac{2.8}{\sqrt{E}} \oplus \frac{0.12}{E} \oplus 0.30$ (at T=+18±0.05°C) or 2.82% at 1 GeV.

5. NPS resolution at energy 300 MeV and T=+18°C, and T=+14°C or 10°C:

- At T=18°C Light Yield is ~15 p.e. per 1 MeV energy deposition, so photons with energy 300 MeV will generate ~4500 p.e.
- At T=+14°C photons of same energy (300 MeV) will generate ~5000 p.e. (~16.5 p.e. per 1 MeV). At T=+10°C same energy (300 MeV) photons will generate ~5500 p.e. (~18.5 p.e. per 1 MeV).
- These numbers and CMS/HYCAL/PANDA data show that even at 300 MeV stochastic term "a/√E ≈1/√n" (n is number of photons) is not a limiting factor for the calorimeter's resolution. The electronic noise ("b"-term), and instrumental effects and calibration ("c"-term) are essential.
- **We think stabilizing the NPS calorimeter at an ambient temperature (T=18±0.5°C) would be quite acceptable for the NPS experiments. This will allow avoid the water condensation problem and related technical complications.**