DISCUSSIONS IN GIESSEN (5-7 October 2015)

Participants: Carlos Munoz-Camacho, Gabriel Charles, TH, Rainer Novotny, Valera Dormenev, Kai Brinkmann, Hans-Georg Zaunick

SIC CRYSTAL TESTS (SEE SPREADSHEET FOR DATA)

- Tested crystals are of type 11 (tapered)
- Early crystals 2009-2011 issue was transmittance at 360 nm. This was found to be a consequence of different orientation of the crystal axis compared to BTCP.
- Crystals from 2012 were more or less ok - still had the T_360nm issue, but this was ignored
- Crystals produced in 2014 had issues with failing transmittance requirements at 360nm, 420 nm, and 620 nm, radiation hardness (absorption coefficient), and sometimes light yield
- Out of the most recent crystals produced in 2015
    - Optical transmittance is problematic. Almost all crystals would fail the >70% requirement at 420 nm and also those at 360 nm and 620 nm
    - Crystals have good light yield and absorption coefficient (dk<<1.1m^-1) - these may be achieved by more doping, but this could also result in more slow component contribution
    - Slow component in these crystals is on order 10%

TESTS OF SIC 2014 CRYSTALS FROM JLAB - AFTER ANNEALING (SPREADSHEET)

- Tested crystals are rectangular
- Annealing increased LY for 2 of the 5 crystals tested
- Longitudinal transmittance doesn't change with exception of crystal #8
- Photospectrometer spectrum for longitudinal transmittance shows increase above theoretical limit for wave lengths >700 nm. This needs to be checked.

CRYTUR PLANS

- Initial tests of the first Crytur produced crystals carried out in Giessen. See Rainer's report from October 2015.
- Discussion about pre-production
    - Rainer expects ~10 rectangular crystals that he could send us after completing his tests. We could use these in combination with SICCAS crystals for a 5x5 prototype for few GeV experiments.
    - About 100 preproduction crystals will be manufactured for PANDA ECAL project. Expected rate is 2/week/oven.
    - ➢ No direct need for preproduction since using the same technology - unless additional/different features are needed.

- Discussion about contract
    - Time scale is about a year. Expectation is that contracts will be drawn up around end of summer/beginning of fall 2016.
    - For contract example see BTCP/Giessen contract
- Discussion about raw materials
    - For all larger orders it is important to coordinate with PANDA about quantities and time lines
    - All available material from BTCP = 8500 crystals (exactly those needed by PANDA)
    - ➢ In principle could produce ~1000 NPS crystals using existing raw materials and in parallel develop new raw materials

CRYSTAL QUALITY CONTROL

- Giessen model for testing BTCP crystals for PANDA ECAL
    1) Measure with ACOS at CERN: decay kinetics, position dependence/homogeneity, geometry with special laser setup
    2) Measure at Giessen: Transmittance, light yield, temperature dependence checking for slow components, irradiation
    - ➢ Main rejection reason was radiation hardness

- Discussion about model for NPS crystals:

    - ➢ **Composition of crystals (Checking 1/50 crystal may be sufficient)**
        - Interesting how much Mo contained in crystals - chemical analysis VSL
        - Some indication of raw materials can also be seen in dk spectrum shape (differences could mean differences in defects or in raw material
        - Purity depends mostly on raw material and not on crystal growth, so since using same raw materials as those analyzed by Rainer in 2013 purity should be of similar quality.
    - ➢ **Geometry and surface quality**
        - *Reject crystals with visible cracks* - would be visible in transmittance spectra
        - *Tolerance in dimensions: 1/10 mm* - machining to should be ok.
        - Measure dimensions using deviation from a reference shape. No special laser setup needed since crystals are rectangular
        - Roughness: no focusing, so no major issue
    - ➢ **Intrinsic Radioactivity (Spot check)**

- Could check LY spectra. If there is a peak at 1.4-1.5 MeV then intrinsic radioactivity relevant. In general, this effect is expected to be small though.
- Peak in LY spectra could also be used for calibration in recovery

- **Transmittance (all crystals)**
  - Longitudinal for general crystal quality check
  - Transverse for crystal homogeneity along 20 cm (wavelength where measure 50% T for a few points along the length of the crystal ad compare the results for these points) - non-uniformities may impact energy/position dependence -> affects constant term

- **Light yield (all crystals)**
  - Should have accuracy of ~1% - goes into energy resolution.
  - Important factors in LY measurements: PMT properties (QE, photocathode size), reflector coverage, and bonding between PMT an crystal.
  - Temperature dependence in measurement: ~1 degree C sufficient - 1-2% in peak position - comparable to 3%/C temperature sensitivity
  - **Reflector**
    - Teflon seems ideal but VM-2000, ESR work as well
    - Important is that the reflector is tightly wrapped around the crystal (if too loose can impact reflectivity) - shrinking tube is a good choice
  - **Temperature Sensitivity (Spot check every 1/50 crystals)**
    - Main source is heat generated by voltage dividers - best to mount crystals in a box and have good air circulation to reduce this effect

- **Decay kinetics (all crystals)**
  - measure the light yield with different integration gates: LY(100ns)/LY(1us)
  - For spot checks can also try to isolate decay components

- **Radiation hardness (all crystals)**
  - Estimate expected integral and dose rate - rate at JLab factor of ~100 higher than PANDA
  - For crystals procured at CRYTUR logistics straightforward - could make measurements and decision on acceptance/rejection within EU (Orsay/Giessen/...)

- For dk requirement require the mean value of dk distribution to be lower to only have the tail of the distribution. For PANDA the mean value is 0.75 m^-1. Advantageous since can put higher resistance crystals in higher radiation locations
- For PANDA dk<1.1m^-1 requirement takes into account uncertainties in measurement (reflections, stability in repeated measurements)
- If want to pursue measurements in Idaho need to make a series of calibration measurements with Giessen. Also consider to irradiate lateral in Idaho for more uniform irradiation.

➢ **Recovery and monitoring**
  - Really need only one wave length. PANDA will use 2 (420 nm and ~500 nm)
  - If need frequent recovery then also need to consider the impact on HV devices - the voltage divider may allow a modification to only switch off a limited number of stages)
  - Monitoring system important for logistics and offline recovery
  - PMT recovery time after shut off ~30 min
  - Combination of recovery and monitoring systems: recovery requires high flux, monitoring system needs light pulses. Since the rate for the latter is lower one could have LEDs for recovery from front and fiber for light monitoring from back
  - Note that radiation behavior of LEDs at high doses and high dose rates may need to be studied. HPS tests suggest that there is an effect on the measurements, but it is not clear if it is due to the crystal or the LED.