**Proposal Time Calibration (Electronics) KM3NeT – Italia 8 towers**

Assumptions :

- TTS and TT Measured on all PMT or on a statistically valuable ensemble of them

- TT and TTS are not measured with FEMs installed on Optical Modules

- Echo\_TX, Echo\_RX, FCM\_Frame\_offshore signals are synchronous and phased with GPS Master clock

**Stage A- Floor Vessel calibration FCM-EFCM @ Vessel integration site**

**1) Measurement of FCM electronics latency**

Instrumentation needed (for 1 test bench):

1 PC

1Terasic board

4 Calibrated fibres (1550 nm) 5m length (+-1 cm), LC/UPC terminated on both sides

1 calibrated (optical loss and fibre length +-1cm) attenuator for 2 LC/LC line connections

[LC TXin 🡪 attenuator 🡪 LC TXout | LC RXin 🡪 attenuator 🡪 LC RXout]

3 time-calibrated lemo cables (same lenght)

1 TDC

1 Open FCM vessel

(auxiliary) 1 thermometer for room temperature

Method:

plug 2 calibrated fibres between RX and TX ports of the optical transceiver (Terasic – EFCM)

and attenuator

plug 2 calibrated fibres between RX and TX ports of the optical transceiver (FCM) and attenuator

plug calibrated lemo cables on Echo\_Tx, Echo\_Rx and FCM\_Frame\_offshore

plug calibrated lemo cables on Scope or TDC

Read FCM temperature

Read Room temperature

Measure RTT (Round Trip Time) = EchoRx –EchoTx

Measure TTFTx(Travel\_Time\_Fibre\_TX) = FCM\_Frame-EchoTx

Measure TTFRx(Travel\_Time\_Fibre\_RX) = EchoRx-FCM\_Frame\_offshore

*Optional: Calculate T\_Lambda contribution of different lambda dispersion / Temperature effects (neglible, few ps)*

Calculate LFCM\_Tx(Latency FCM\_Tx) = TTFTx – T\_LambaTX

Calculate LFCM\_Rx(Latency FCM\_Rx) = TTFRx – T\_LambaRX



**2) Measurement of FCM Vessel optical pig-tails delay**

Instrumentation needed:

1 PC

1Terasic board

2 Calibrated fibers (1550 nm) 5m length (+-1 cm), LC/UPC terminated on both sides

1 calibrated (optical loss and fiber length +-1cm) attenuator for 2 LC/LC line connections

[LC TXin 🡪 attenuator 🡪 LC TXout | LC RXin 🡪 attenuator 🡪 LC RXout]

1 VEOC-simulator Jumper cable (length calibrated-see Appendix 1-) terminated with LC/UPC connectors

3 time-calibrated lemo cables (same length)

1 TDC

1 Open FCM vessel with optical pigtail (OPTG connector installed on FCM vessel)

(auxiliary) 1 thermometer for room temperature

Method:

plug 2 calibrated fibres between RX and TX ports of the optical transceiver (Terasic – EFCM)

and attenuator

plug 2 calibrated fibres between RX and TX ports of the attenuator and jumper cable

plug calibrated lemo cables on Echo\_Tx, Echo\_Rx and FCM\_Frame\_offshore

plug calibrated lemo cables on TDC

Read FCM temperature

Read Room temperature

Measure RTT (Round Trip Time) = EchoRx -EchoTx

Measure TTFTx(Travel\_Time\_Fibre\_TX) = EchoRx- FCM\_Frame

Measure TTFRx(Travel\_Time\_Fibre\_RX) = EchoRx-FCM\_Frame

*Optional: Calculate contribution (T\_Lambda)of different lambda dispersion / Temperature effects (neglible, few ps)*

Calculate Pig\_tail\_Tx\_time:

[ TTFTx (method 2) – TTFTx(method 1) ]

Calculate Pig\_tail\_Tx\_lenght : correct for lamba and temperature effect

Calculate Pig\_tail\_Rx\_time (time):

TTFRx (method 2) – TTFRx(method 1)

Calculate Pig\_tail\_Rx\_lenght : correct for lamba and temperature effect



**Stage B- Floor calibration @ Floor integration site**

**1) Measurement of Floor-OMs electronics latency via triggered laser**

Instrumentation needed:

Floor inside dark box (tabuto)

1 GPS + antenna

1 PC

1Terasic board

4 Calibrated fibers (1550 nm) 5 m length (+-1 cm), LC/UPC terminated on both sides

1 calibrated (optical loss and fibre length +-1cm) attenuator for 2 LC/LC line connections

[LC TXin 🡪 attenuator 🡪 LC TXout | LC RXin 🡪 attenuator 🡪 LC RXout]

1 VEOC-simulator Jumper cable (length calibrated-see Appendix 1-) terminated with LC/UPC connectors

2 LC/UPC-LC/UPC “I” in the dark box “interface frame”

1 TDC

1 (auxiliary) thermometer for room temperature

Specific for laser test:

4 time-calibrated lemo cables

1 Laser Source ultra stable and fast, with external trigger input and synch out

1 calibrated optical splitter 1x8 (6 OMs, 1 spare, 1 LED monitor) all FC/PC connectors

8 calibrated fibres (410 nm) 10 m length, FC/UPC connectors on both sides (laser outputs)

2 calibrated fibres (410 nm) 5 m length, FC/UPC connectors on both sides (laser input)

1 FC/UPC – FC/UPC “I” in the dark box interface

Method:

Dark box set-up (una tantum)

plug 2 calibrated fibres between RX and TX ports of the optical transceiver (Terasic – EFCM)

and attenuator

plug 2 calibrated fibres between RX and TX ports of the attenuator and dark box interface

plug jumper cable fibres to the dark box interface (LC/UPC)

plug time-calibrated lemo cables between Echo\_Tx, Echo\_Rx and TDC

plug time-calibrated lemo cable between Echo\_Tx and blue laser

plug time calibrated lemo cable between Laser\_Synch Out and TDC

Specific for the Laser Test:

plug 1 calibrated fiber (410 nm) 5m between laser and dark box interface

plug 1 calibrated fiber (410 nm) 5m between dark box interface and optical splitter

plug 6 calibrated fibers (410 nm) 10 m between optical splitter outputs and dark box supports facing the OMs

plug 2 spare calibrated fibers (410 nm) 10 m in optical splitter outputs

(optional) plug 1 of the 2 above calibrated fiber to the spare calibrated fiber of LED monitor splitter (next section)

set blue laser to external trigger (Echo\_Tx – 8 kHz) and intensity = 200 x 8 photons (lambda= 407 nm) - Laser stabilises in about 2 h (never change laser amplitude!!!)

1600x0.1 eV/50 ns = 1.6 10^9 eV/s = 3.2\*1.6 10^9 \*10^-19 J/s = 0.2 nW (check…)

Floor set-up (per each floor)

plug VEOC-simulator jumper cable to FCM vessel

Start measurement, save calibration runs

Check stability of RTT during measurement

*Optional: Calculate T\_Lambda contribution of different lambda dispersion / Temperature effects (neglible, few 10 ps)*

From Analysis Measure (check!):

Delta\_T (OM\_1:6) – [T\_triggerline + T\_laser + T 20 m fibre (lamba=407 nm) + T\_splitter] – Start\_Frame\_FCM – [Pig\_tail\_Tx\_time- LFCM\_Tx(Latency FCM\_Tx) – T\_jumper – T\_fibres]

Laser Info:

LNS/CT: Hamamatsu Picosecond light pulser C8898. Internal clock interno, 10 Hz : 100 MHz. Ext trigger:s yncout NIM or TTL.

Head: Peak Power 235 mW - Pulse duration 71 ps - wavelength 406 nm - connector FC/PC

LNF: Picoquant PDL800B



**2) Measurement of Floor-OMs electronics latency via LED Beacon**

Instrumentation needed

Floor inside dark box (tabuto)

1 GPS + antenna

1 PC

1Terasic board

4 Calibrated fibers (1550 nm) 5 m length (+-1 cm), LC/UPC terminated on both sides

1 calibrated (optical loss and fibre length +-1cm) attenuator for 2 LC/LC line connections

[LC TXin 🡪 attenuator 🡪 LC TXout | LC RXin 🡪 attenuator 🡪 LC RXout]

1 VEOC-simulator Jumper cable (length calibrated-see Appendix 1-) terminated with LC/UPC connectors

2 LC/UPC-LC/UPC “I” in the dark box “interface frame”

1 TDC

Specific for LED test:

1 PC [Microsoft Windows XP Professional SP3 (32bit) || Microsoft Windows Vista Business SP2 (32bit) || Microsoft Windows 7 Professional SP1 (32bit/64bit)]; the Hamamatsu driver and software already installed on the machine;

1 calibrated optical splitter 1x8 (6 OMs, 1 spare, 1 laser monitor) all FC/PC connectors

8 calibrated fibres (410 nm) 10 m length, FC/UPC connectors on both sides (LED input)

2 calibrated fibres (410 nm) 5 m length, FC/UPC connectors on both sides (LED output)

1 FC/UPC – FC/UPC “I” in the dark box interface

1 (auxiliary) thermometer for room temperature

1 MPPC module (Hamamatsu);

1 USB cable (with miniB termination) for the connection of the MPPC module to the PC; *[il cavo in dotazione è lungo circa 130 cm; la lunghezza potrebbe essere sufficiente se il dispositivo è posto all’esterno della dark box; viceversa, potrebbe essere necessario un cavo di lunghezza maggiore se il dispositivo è collocato all’interno (o, meglio, due “spezzoni” di cavo, perché la connessione deve “attraversare” il pannello della dark box)]*

1 cable with SMB/ BNC connector (SMB = output of the MPPC Module; BNC = input connector of the TDC); *[troppo generico dire solo “cable”? Anche qui, non specifico la lunghezza del cavo (o la necessità di due “spezzoni” di cavo perché la questione sulla collocazione del sensore è ancora aperta. “xxx” è perche non conosco i dettagli del collegamento con il TDC]*

(G.R.:decidi l’interfaccia con il tabuto -BNC o lemo- , il TDC ha tipicamente connettori BNC. per le lunghezze vedi i disegni che ha messo marco, anche io ancora non le ho definite faro’ un merge tra una lunghezza adatta e una ragionevolmente convertibile in un numero intero di ns)

**Method**

**set-up (una tantum)**

Method:

Dark box set-up (una tantum)

plug 2 calibrated fibres between RX and TX ports of the optical transceiver (Terasic – EFCM)

and attenuator

plug 2 calibrated fibres between RX and TX ports of the attenuator and dark box interface

plug jumper cable fibres to the dark box interface (LC/UPC)

plug time-calibrated lemo cables between Echo\_Tx, Echo\_Rx and TDC

Specific for the LED test

plug 1 calibrated fiber (410 nm) 5m between the MPPC module [a mechanical support has to be devised, facing the MPPC sensor and hosting the fiber connector] and dark box interface

plug 1 calibrated fiber (410 nm) 5m between dark box interface and optical splitter

plug 6 calibrated fibers (410 nm) 10 m between optical splitter outputs and dark box supports facing the LEDs (Noth Pole of the OM)

plug 2 spare calibrated fibers (410 nm) 10 m in optical splitter outputs

(optional) plug 1 of the 2 above calibrated fiber to the spare calibrated fiber of laser splitter (LED monitor)

plug the cable with the SMB/xxx connector between the MPPC module and the TDC;

plug USB cable between the MPPC module and the PC; turn on the Peltier cell for the cooling of the module; set the acquisition parameters;

**set-up (per each floor)**

- plug jumper cable to FCM;

**Start measurement**

- fire one LED per time;

- measure (with the TDC) the time difference between the GPS signal and the rising edge of the digital pulse produced by the MPPC device;

- collect a set of measurements for each LED in order to have a statistically significant sample;

- save calibration runs;

- compute t as the average of values of time differences in the sample;

Check stability of RTT during measurement

*Optional: Calculate contribution (T\_Lambda)of different lambda dispersion / Temperature effects (neglible, few ps)*

**From Analysis Measure:**

Delta\_T (LED\_1:6) – [T\_triggerline + ~~T\_laser~~ + T 20 m fibre (lamba=407 nm) *[quale fibra è questa?]* + T\_splitter] – Start\_Frame\_FCM – [Pig\_tail\_Tx\_time- LFCM\_Tx(Latency FCM\_Tx) – T\_jumper – T\_fibres]

**Stage B – 2**

*[hai il file con l’immagine che hai incluso in questo documento, in modo che io possa modificarlo e provare a produrre uno schema della misura analogo al tuo?]*

**Stage C- Tower calibration @ Tower integration site**

***Scusami ma questo capitolo fallo tu con fabrizio, angelo e mario io ho mille cose da fare e anche io non conosco bene i dettagli della torre integrata***

**1) Measurement of floor-tower optical delay and electronics latency via LED Beacon**

**Instrumentation needed**

Tower packed and covered by black cloth.

- 1 GPS + antenna;

- 1 PC [Microsoft Windows XP Professional SP3 (32bit) || Microsoft Windows Vista Business SP2 (32bit) || Microsoft Windows 7 Professional SP1 (32bit/64bit)]; the Hamamatsu driver and software already installed on the machine;

- 1 Terasic board;

- 2 Calibrated single mode fibers (communication) 5m length (+-1 cm), LC/UPC and FC/PC terminated;

- 2 FC/PC “I-barrell”;

- 1 VEOC-simulator Jumper cable (10 m) with known Tx-RX fibers lengths (+-1 cm), terminated with FC/PC connectors;

- 1 time-calibrated lemo cable;

- 1 FC/PC “I-barrel”;

*[anche nel caso del test di torre non conosco i dettagli del sistema, quindi questo elenco di componenti e la descrizione delle relative connessioni vanno verificati]*

- 1 MPPC module (Hamamatsu);

- 1 USB cable (with miniB termination) for the connection of the MPPC module to the PC; *[il cavo in dotazione è lungo circa 130 cm; la lunghezza dovrebbe essere sufficiente (non essendoci dark box)]*

- 1 cable with SMB/xxx connector (SMB = output of the MPPC Module; xxx = input connector of the TDC); *[Non specifico la lunghezza del cavo. Nel caso del test di torre, senza dark box, la lunghezza dipende dalla configurazione del setup di misura. “xxx” è perché non conosco i dettagli del collegamento con il TDC]*

- TDC *[sbaglio a inserirlo qui? ho notato che finora non l’hai nominato nella lista della strumentazione]*

~~- 1 optical splitter 8x1 (6 OMs, 1 spare, 1 LED monitor)~~

*[stiamo valutando di non utilizzare lo splitter nel caso del test di torre, perché questa scelta implicherebbe realizzare una struttura meccanica ad hoc, acquistare uno splitter 16 X 1 e tutte le relative fibre (calibrate), e realizzare il contatto con i 14 PMT, e tutto questo ha un costo in termini di soldi e tempo (considerando anche i due siti di integrazione). Impulsare un LED alla volta significa spostare di volta in volta il contatto fibra/PMT (invece che allestire tutto insieme all'inizio del set di misura), ma consentirebbe di risparmiare risorse. A mio parere, la prima soluzione (che richiede un investimento maggiore) è vantaggiosa se si pensa di utilizzarla anche per le futuri torri; viceversa nel caso contrario (o nel caso di una progettazione a breve termine del lavoro).]*

- 1 optical fiber (multimode-blue) time calibrated: one termination facing the LED in the North Pole of the Optical Module; the other termination connected to the MPPC module. The mechanical supports have to be devised, one facing the MPPC sensor and hosting the fiber connector; the other one facing the LED and hosting the fiber connector. The connectors at the termination of the fiber should be the same used in the previous test for LED beacon characterization). *[The lenght of the fiber depends on the geometry of the packed tower and on the configuration of the test setup. I guess that 10m should be ok]*

- (auxiliary) 1 thermometer for room temperature

**Method**

**set-up (una tantum)**

- plug jumper cable between dark box interface (FC/PC);

- plug lenght calibrated fibers (10 m) between RX and TX ports of the optical transceivers (Terasic) and dark box interface (FC/PC);

- plug time-calibrated lemo cables between Echo\_Tx, Echo\_Rx and Scope or TDC;

- plug the cable with the SMB/xxx connector between the MPPC module and the TDC;

~~plug time-calibrated lemo cable between Echo\_Tx and blue laser~~

- plug USB cable between the MPPC module and the PC; turn on the Peltier cell for the cooling of the module; set the acquisition parameters;

- plug time-calibrated fiber (10 m, multimode blue, FC/PC) in the MPPC module; the other termination is into the mechanical support that assures the contact with the LED in the Optical Module;

- plug 1 length.calibated fiber to spare lengh calibrated fiber to LED monitor *[come sopra, non ho capito questa storia del LED monitor… immagino sia per avere un qualche riferimento, ma non conosco i dettagli del sistema]*

**set-up (per each floor)**

The tower is packed; one LED per floor (the more easily accessible) is selected.

- plug jumper cable to FCM;

- place the mechanical support hosting the termination of the time-calibrated fiber (10 m, multimode blue, FC/PC) on the Optical Module (facing the selected LED);

- cover the tower with the cloth.

**Start measurement**

- fire the selected LED;

- measure (with the TDC) the time difference between the GPS signal and the rising edge of the digital pulse produced by the MPPC device;

- collect a set of measurements for each LED in order to have a statistically significant sample;

- save calibration runs;

- compute t as the average of values of time differences in the sample;

Check stability of RTT during measurement

Calculate contribution of temperature effects (negligible, few 10ps)

**From Analysis Measure:**

Delta\_T (LED\_1:6) – [T\_triggerline + ~~T\_laser~~ + T 20 m fibre (lamba=407 nm) *[quale fibra è questa?]* + T\_splitter] – Start\_Frame\_FCM – [Pig\_tail\_Tx\_time- LFCM\_Tx(Latency FCM\_Tx) – T\_jumper – T\_fibres]

**Stage C – 1**

*[hai il file con l’immagine che hai incluso in questo documento, in modo che io possa modificarlo e provare a produrre uno schema della misura analogo al tuo?]*

**APPENDIX 1 -Calibration of VEOC Jumper cables**

1 PC

1Terasic board

4 Calibrated fibres (1550 nm) 5m length (+-1 cm), LC/UPC terminated on both sides

1 calibrated (optical loss and fiber length +-1cm) attenuator for 2 LC/LC line connections

[LC TXin 🡪 attenuator 🡪 LC TXout | LC RXin 🡪 attenuator 🡪 LC RXout]

1 VEOC-simulator Jumper cable (to be calibrated) terminated with LC/UPC connectors

1 OPTG bulkhead with 2 fibres (total physical length of the fibres about 20 cm +-1 cm) terminated with LC/UPC connectors

2 LC/UPC-LC/UPC “I”

3 time-calibrated lemo cables

1 TDC

1 Laser Source ultra stable and fast, with ext trigger input ans synch out

1 (auxiliary) thermometer for room temperature

Method:

Measure physical length of two fibres one OPTG (bulkhead)

Step 1

plug 2 calibrated fibres between RX and TX ports of the optical transceiver (Terasic – EFCM)

and attenuator

plug 2 calibrated fibres between RX and TX ports of the attenuator and FCM

plug calibrated lemo cables on Echo\_Tx, Echo\_Rx and FCM\_Frame\_offshore

plug calibrated lemo cables on TDC

Measure RTT (Round Trip Time) = EchoRx –EchoTx

Measure TTFTx(Travel\_Time\_Fibre\_TX) = FCM\_Frame-EchoTx

Measure TTFRx(Travel\_Time\_Fibre\_RX) = EchoRx-FCM\_Frame\_offshore

Step 2

plug 2 calibrated fibres between RX and TX ports of the optical transceiver (Terasic – EFCM)

and attenuator

plug 2 calibrated fibres between RX and TX ports of the attenuator and VEOC Jumper using the 2 LC/UPC-LC/UPC “I”

plug jumper on OPTG bulkhead

plug OPTG bulkhead fibres to RX and TX ports of the optical transceiver (FCM)

%plug calibrated lemo cables on Echo\_Tx, Echo\_Rx and FCM\_Frame\_offshore

%plug calibrated lemo cables on TDC

%use the same TDC thresholds for signals

Measure RTT (Round Trip Time) = EchoRx –EchoTx

Measure TTFTx(Travel\_Time\_Fibre\_TX) = FCM\_Frame-EchoTx

Measure TTFRx(Travel\_Time\_Fibre\_RX) = EchoRx-FCM\_Frame\_offshore

Calculate JUMPER\_Tx\_time:

[ TTFTx (step 2) – TTFTx(step 1) ]

Calculate JUMPER\_Tx\_lenght : correct for lamba and temperature effect and OPTG\_pigtail\_TX\_length

Calculate JUMPER\_Rx\_time (time):

TTFRx (step 2) – TTFRx(step 1)

Calculate JUMPER\_Tx\_lenght : correct for lamba and temperature effect and OPTG\_pigtail\_RX\_length

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