Electron Muon Ranger (EMR) Commissioning and operation

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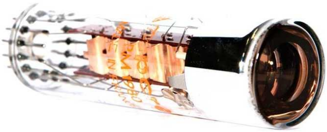
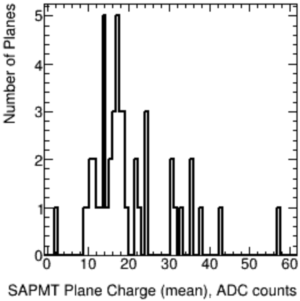
Single Anode PMT replacement (1)

Ageing **Philips XP2972** manufacturer characteristics:

- Useful diameter: Ø 23 mm
- Maximum response: 400 nm
- Sensitivity: ~ 65 μA/lm
- Gain: 3×10^6
- Time spread: ~ 800 ps
- QE: 14.5 %

$\rightarrow$ 30 years old
$\rightarrow$ Degraded photocathode
$\rightarrow$ Reduction of secondary emissions
$\rightarrow$ Gain loss
$\rightarrow$ Spurious pulses



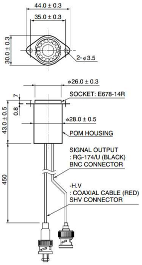


Single-Anode PMT replacement (2)

New **Hamamatsu R6427** manufacturer characteristics:

- Useful diameter: Ø 25 mm
- Maximum response: 420 nm
- Sensitivity: ~ 100 μA/lm
- Gain: 5×10^6
- Time pread: ~ 500 ps
- QE: 24 %

→ 56 PMTs (8 spares)
→ Change done by UniGe technicians at RAL at the beginning of October 2014 (two days work)



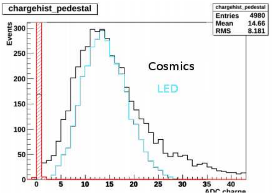
SAPMT selection process

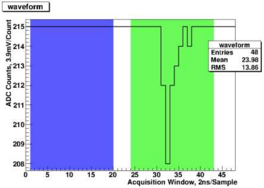
Test bench

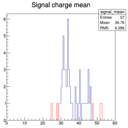
- LED pulser tuned to MIP signal
- light-tight coupling with an SAPMT
- trigger on the pulser
- acquisition of 150000 signals with a 10kHz clock
- Signal integration
- Measurement of the average charge

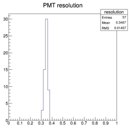
Results

- Much higher gain and efficiency than the Philips SAPMTs
- Rejection of the lowest and highest averages of the sample (8 spares)
- Selection of the 48 SAPMTs with central averages









Comparaison between old and new SAPMTs

Measured mean charge for MIP signals:

- acquisition of 150k MIP-like signals in the range (1100-1900)V
- measurement of the mean charge for each setting

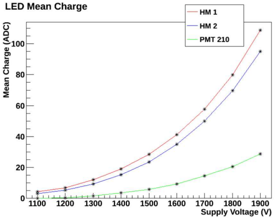
$\rightarrow \overline{Q_{Hm}} \gg \overline{Q_{Ph}}$ over the whole range

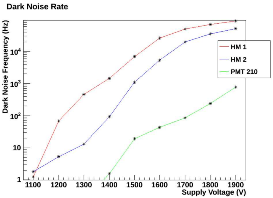
Measured level of dark noise:

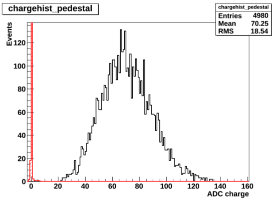
- recording of the DN frequency over 5 minutes in the same range
- measurement of the average DN frequency for each setting

$\rightarrow$ DN 2 orders of magnitude higher for Hamamatsu PMTs

$\rightarrow$ Not to worry, as the DN/Signal separation is ensured







Voltage divider replacement

Old voltage divider developed in house:

- Operating voltage: 1800V
- Nominal current: 700 μA

New **Hamamatsu E2624-14** voltage divider:

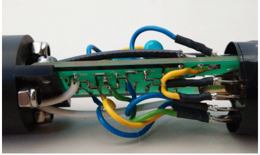
- Operating voltage: 1500V
- Nominal current: 314 μA

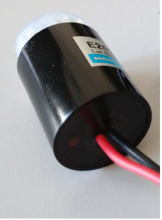
$\rightarrow$ 57 VDs (9 spares)

Selection process:

- Power on HV with the same SAPMT for each VD
- Monitor current and DN

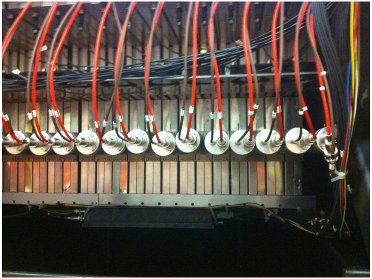
$\rightarrow$ All functional, random selection of 48

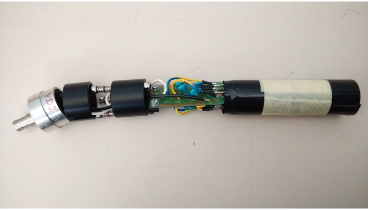




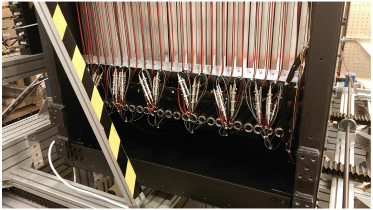
SAPMT implementation

Old set up





New set up



New EMR Elements Installation

New elements:

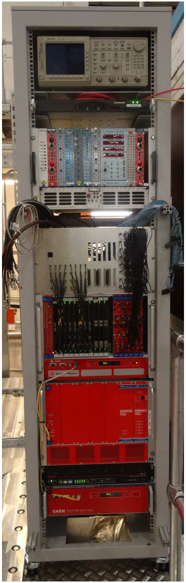
- 47 U rack to replace current one
- AC fan system (back of the rack, top of the rack, EMR box)
- Remote controlled AC power supply
- HVPSU (photomultipliers)
- LVPSU (trigger distribution boards, LED driver, fans)
- New VME (and NIM) crate(s)

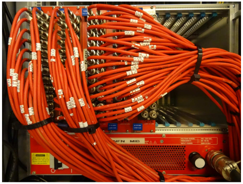
Implementation:

- New design and layout approval (RAL) (✓)
- Installation of remote control switch, connection to grid (RAL) (✓)
- Rack repackaging (UniGe) (✓)
- Cables rewiring (UniGe) (✓)
- Test and commissioning (UniGe) (✗)
  $\rightarrow$ Finalized after the upgrade of the SAPMT

New 47U EMR rack

- Implementation of all the elements in a single rack → Scope, DAQ computer, NIM crate, trigger patch panel, signal patch panel, VME crate, HVPSU, remote controlled switch, LVPSU1, LVPSU2
- Replace the wheels by fixed feet
- Cables rerouted under the platform
- Plexiglas panel to protect the front of the rack
- Shift of the back door to fit the HVPSU
- Positioned at the beam dump

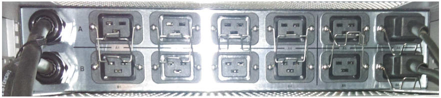




Remote controlled power switch

Specifications of the *WTI VMR-HD4D30-12B C19*:

- Dual 30 Amp In-Feeds
- 12 power outlets (2×LVPSU, HVPSU, VME, NIM, PC, Scope, Ethernet/USB switch, 3×Fans)
- Thorough `ssh`, `telnet` and `html` control (Individual On/Off switches and current monitoring)



Managed Power Controller   Site ID: (undefined)

PLUG	NAME	STATUS	DELAY	DEF	PRI
A1	InfeedA_Outlet1	ON	0.5 S	ON	1
A2	InfeedA_Outlet2	ON	0.5 S	ON	2
A3	InfeedA_Outlet3	ON	0.5 S	ON	3
A4	InfeedA_Outlet4	ON	0.5 S	ON	4
A5	InfeedA_Outlet5	ON	0.5 S	ON	5
A6	InfeedA_Outlet6	ON	0.5 S	ON	6
B1	InfeedB_Outlet1	ON	0.5 S	ON	7
B2	InfeedB_Outlet2	ON	0.5 S	ON	8
B3	InfeedB_Outlet3	ON	0.5 S	ON	9
B4	InfeedB_Outlet4	ON	0.5 S	ON	10
B5	InfeedB_Outlet5	ON	0.5 S	ON	11
B6	InfeedB_Outlet6	ON	0.5 S	ON	12

PARAMETER	VALUE
Current (Line Input A)	3.8A
Voltage (Line Input A)	236V
Power (Line Input A)	896W
Current (Line Input B)	3.6A
Voltage (Line Input B)	235V
Power (Line Input B)	846W
Current (Fuse B1-B2)	---
Current (Fuse B3-B4)	---
Current (Fuse B5-B6)	---
Current (Fuse A1-A2)	---
Current (Fuse A3-A4)	---
Current (Fuse A5-A6)	---
Temperature	78F

Total Plug Current:	7.4A
Total Plug Power:	1742W
CPU Power:	12W
Power Factor:	1.00
Power Efficiency:	100%

High Voltage Power Supply Unit (HVPSU)

Specifications of the *CAEN SY4527*:

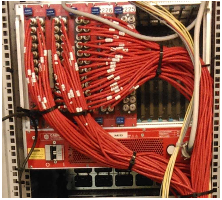
- 2 power supplies (Primary + Booster), 1200W
- Basic version, no control interface on the crate
- 5 HVPS boards (5×24=120 ch., 24 spare ch.)
- 0-2500V HV range, 0-500μA current range
- Thorough `html` ctrl&mon (HiVoCS)

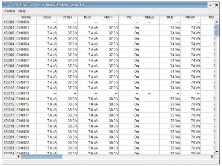
Use of the HVPSU for the EMR:

- 48 MAPMT ch. (700V), 48 SAPMT ch. (1500V)

Issue at this point

- The HV trips constantly, Pierrick investigating





Low Voltage Power Supply Units (LVPSUs)

Specifications of the *CAEN SY8800*:

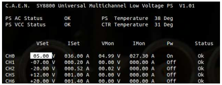
- 1kW power supply
- Thorough local and remote ctrl&mon (`telnet`)

EMR LVPSU 1:

- One 2-7V ch. (Fan-out boards, FEBs A&B, DBBs)
- Two 7-16V ch. (Internal EMR box fans)
- Two 20-28V ch. (LED Driver)

EMR LVPSU 2 (future):

- Three 2-7V ch. (FEBs A, FEBs B, DBBs)



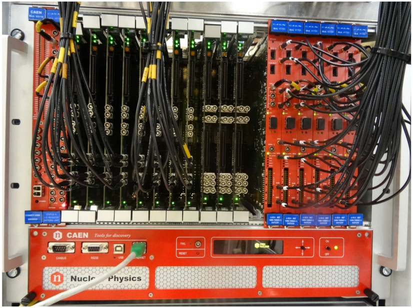
Issue at this point

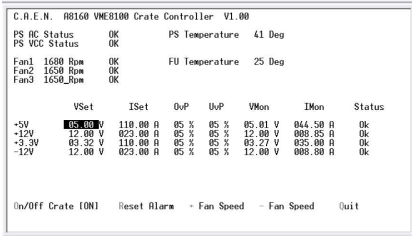
- The 20-28V ch. in LVPSU1 are not working

VME crate

Specifications of the *CAEN VME8100*:

- 21 slot for 6U x 160mm VME modules
  - 1 Ctrl, 1 I/O, 8 VRB, 3 VCB, 6 V1731 (fADC)
- Available with VME64, VME64X
- Short circuit, overvoltage and temperature protection
- Ethernet interface (`telnet`) for remote ctrl&mon





Replacement of the VHDC

Reasons for their replacement:

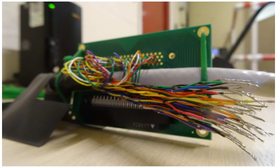
- Upcoming shifts of the EMR location (US then DS)
- Easily damaged flat VHSDC
- Critical part of the EMR to configure the FEBs

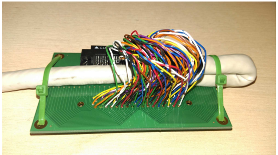
New choice of cables:

- 3M Round, Shielded Jacketed, Disc. Wire Cable
- Interface boards to connect the cables to the VHDCI
- Soldering done at RAL by the EMR group (4 15m cables, 1 spare)

→ Much sturdier cables that can withstand stress

→ One of the cable is malfunctioning, under investigation





Additional Patch pannel

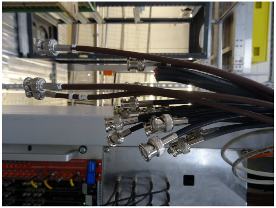
20 BNC feed-through connectors to accommodate the 8 control room signals and 3 EMR control signals:

Control Room

- in Start Of Spill (SOS)
- in Particle Trigger (PT)
- in DAQ Trigger (DAQT)
- in End Of Spill (EOS)
- in Spill Gate (SG)
- out SOS busy (SOSB)
- out DAQT busy (DAQTB)
- out EOS busy (EOSB)

EMR Control

- out Spill Gate (SG)
- out Particle Trigger (PT)
- out LED Trigger (LEDT)



Temperature and humidity sensors

Specifications of the Yocto-Meteo:

- Refresh frequency: 1Hz
- Humidity sensor: (0 - 100) $\pm$ 0.8 %
- Pressure sensor: (500 - 1150) $\pm$ 0.8 mbar
- Temperature sensor: (-40 - 125) $\pm$ 0.2 $^\circ$C
- Libraries for main languages (Cpp, python, etc.)

Purpose for the EMR

- Monitor these variables in the EMR box and the rack
- Study their influence on the electronics

PMT High Voltage Optimization

Situation after the SAPMT change:

- Fully commissioned SAPMTs
- All the Multi-anode PMs set to the same voltage
- The PMTs are non-uniform and their response can vary significantly

→ Need for a high voltage scan

→ Planned after rack and SAPMTs installation, Important

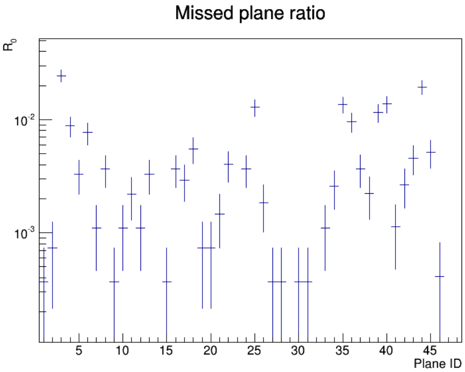


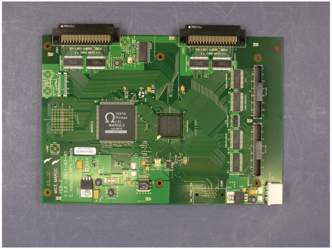
Fig: Probability of given plane to not record a single signal in the MAPMT when a 350 MeV/c muon goes through it. Some of the planes have an efficiency under 99 %; their voltage needs to be adjusted.

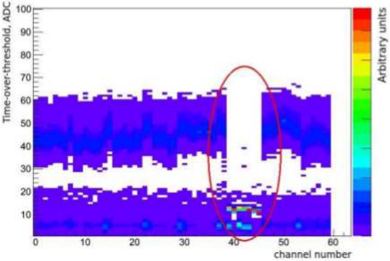
Faulty Front End Boards Investigation

Some of the spare dedicated FEBs exhibit faulty behaviours:

- High levels of noise
- No signal recorded at the right Time over Threshold
- Electronics flaw

→ Needs to be investigated to see at which stage the signal is lost
→ Fixing them will provide much required additional spares
→ 1 month work, Important

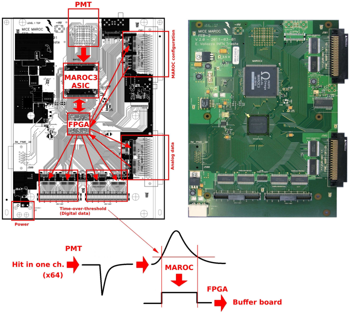




Front End Board ASIC Optimization

The ASIC used in the EMR is a Multi-Anode ReadOut Chip (MAROC):

- 64 inputs/outputs
- Shapes the signal and measures a Time over Threshold
- Fast response
- Tunable pre-amplifier gain up to a factor 4 with 6 % accuracy
- Tunable threshold value



→ Hasn't been studied extensively
→ Study of the threshold influence to increase acceptance
→ Correction of the MAPMT non-uniformity using the pre-amp
→ 2 month work with a test bench at CERN, Secondary

EMR code integration into MAUS

Essential parts of the EMR code to be integrated in MAUS

- `EMRPlaneHits` map modified to accommodate two additional reconEvents (noise + decays) and fill them (✓)
- `EMRMCDigitization` entirely in MAUS (version 2.1) (✓)
- Modication of the **data structure** implemented (✓)
- **Data Processors** adapted (✓)
- New **tests** for the `EMRPlaneHits` and `EMRMCDigitization` (✓)
- `EMRRecon` integrated, needs to be revised (✓)
- **Test** for `EMRRecon` (✗)

→ **Almost completely functional**

EMR DAQ

A few standalone features of the EMR need to be integrated in the DAQ

- Calibration of the fADC pedestal after power cycles (✓)
- MAROC configuration after power cycles (✓)
- 3 distinct modes of DAQ
  - Beam (✓)
  - Cosmic (✗)
  - LED pulser (✗)

Standalone code

- Use LED monitoring to adjust PMT gains (analogue devices are sensitive to environmental changes, B fields, power cycles, etc.) (✗)
- Calibration Run (1 week of cosmic data taking after major hardware updates, finely tuned by LED monitoring) (✓)

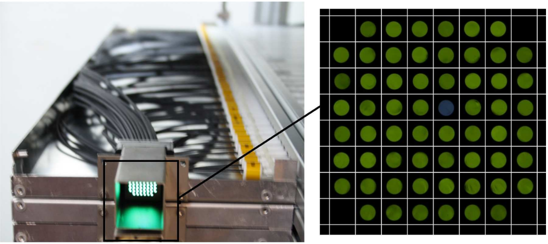
→ **The EMR can be included in every run**

EMR Operations

- Write EMR operation instructions
- Write EMR technical note
  - Cable tags, patch panels map
  - Hardware IDs
  - High Voltage mapping
  - DAQ configurations

  → 1 month work, Important
- Set-up LED monitoring of the PMT gain

  → Stalled by the malfunctioning of LVPSU 1, Important.



EMR status summary

EMR hardware upgrade in progress

- SAPMT updated in commissioned, upcoming MICE-DET-NOTE (✓)
- New 47U rack, network operated power switch → functional (✓)
- New HVPSU → cannot be turned on (✗)
- New LVPSU → faulty channel (✗)
- New CAEN VME crate → functional (✓)
- VHDC replacement → faulty cable (✗)
- New patch panel and environmental sensors → functional (✓)

Future EMR hardware analyses to be conducted

- PMT HV scan, faulty FEB investigation, FEB ASIC optimization (✗)

EMR Software integration in MAUS

- Days away from completion (∼✓)

EMR DAQ and manuals

- EMR conf. operational in DATE, could use a few additions (✓)
- EMR operation instructions and technical note → to be done (✗)