Electron Muon Ranger (EMR)
Plans and Commissioning

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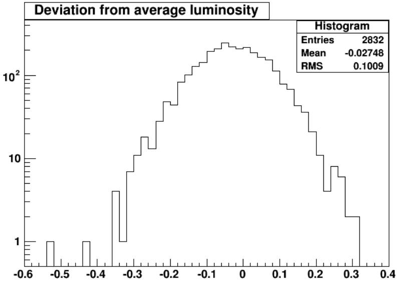
June 26, 2014

Clear Fibre Luminosity

The relative deviation from the average luminosity in the plane is calculated of each of the 2832 channels of the EMR:

$$D_{ij} = \frac{1}{\overline{L}_j}(L_i - \overline{L}_j),$$

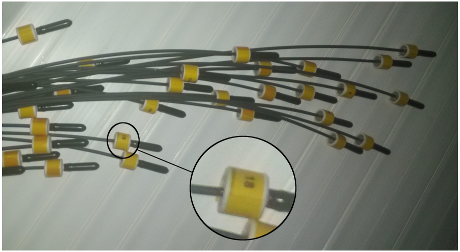
with i the channel ID and j the plane ID ($i \in j$).
→ 95 % of the fibres are within 20% from the average luminosity;
→ All of them are bright enough.

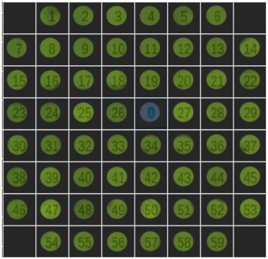


Channel Mismatch Analysis

Several assembly mistakes could cause a mismatch in the EMR:

- swapping two fibres;
- mismatching fibres on the mask;
- electronics short cut.





	1	2	3	4	5	6	
7	8	9	10	11	12	13	14
15	16	17	18	19	20	21	22
23	24	25	26	0	27	28	29
30	31	32	33	34	35	36	37
38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53
	54	55	56	57	58	59	

→ In the following we will try to determine if some on the channels are in fact mismatch using **cosmic muon data**: only type that covers the whole detector.

Mismatch of adjacent channels

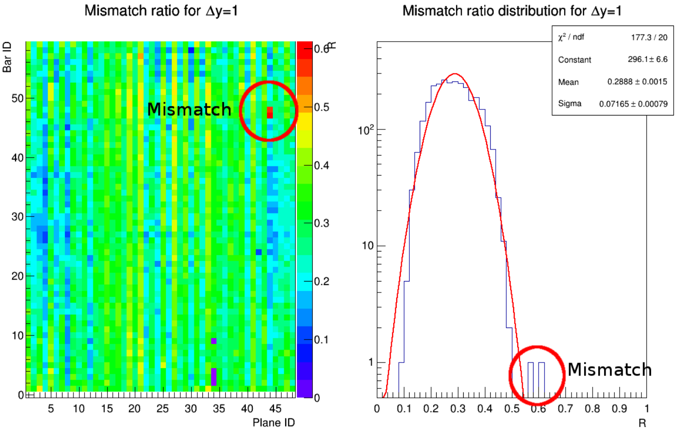


Figure: Clear mismatch between two channels in plane 44 on the left plot

Mismatch of distant channels

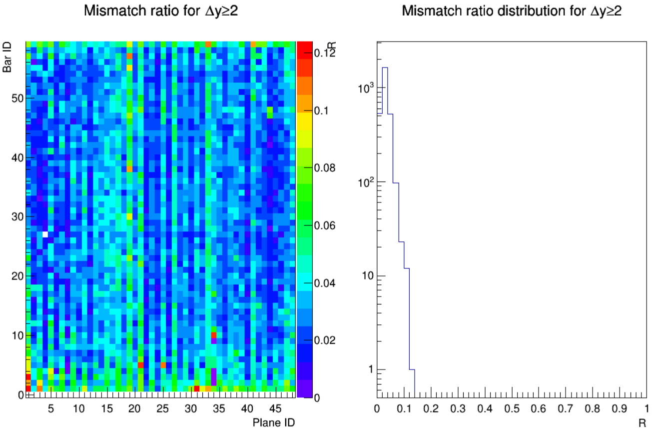


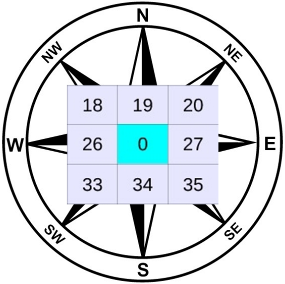
Figure: No mismatched channels farther than 1 bin away from each other

Crosstalk characterization

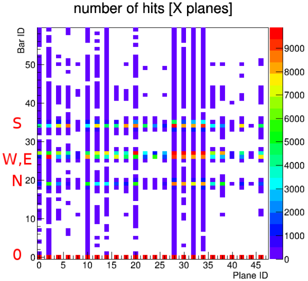
For each plane and each channel surrounding channel 0, we measure two main parameters are measured:

- the **ratio** of the charge measured in that channel and the charge in channel 0, that is $R_Q = Q_i/Q_0$;
- the **rate**, i.e. the percentage of the time an adjacent channel is lit along with channel 0, that is $R_N = N_i/N_0$.

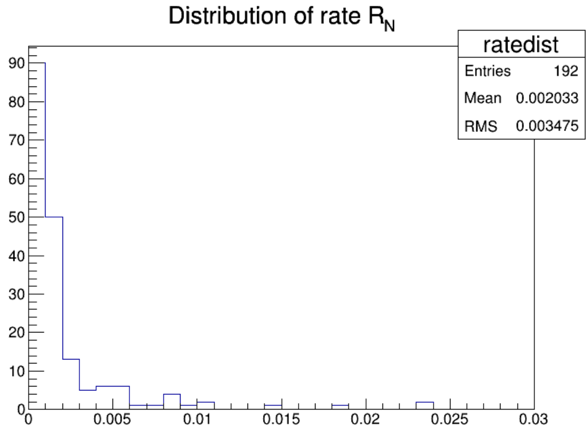
The channels are named after the cardinal points



18	19	20
26	0	27
33	34	35

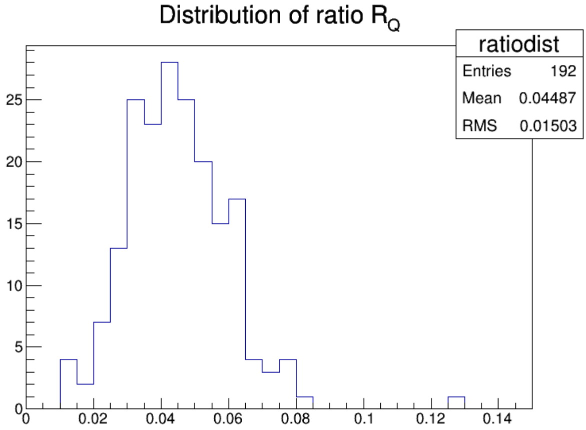


Probability of crosstalk in an adjacent channel **at MIP energy**



→ Most of the time, $R_N < 0.5$ %

Averaged crosstalk charge ratio **if crosstalk there is**



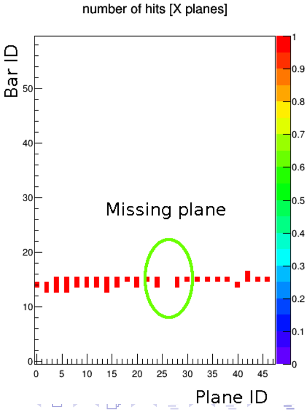
→ The average ratio in terms of charge is $R_Q \simeq 4.5 \pm 1.5$ %

Signal Acquisition Efficiency E_{SA}

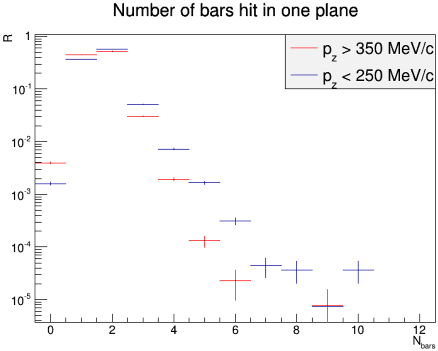
Analysis to determine if signals are lost in the EMR when a particle goes through the EMR. The signal acquisition efficiency E_{SA} is defined as *the probability that at least one hit will be recorded in each plane on the path of a particle*.

Measured quantities:

- distribution of bar multiplicity for different momenta;
- efficiency E_{SA} for each momentum;
- efficiency E_{SA} of individual planes.



Global Efficiency (Beam data)



N	$p_z > 350$ MeV/c	$p_z < 250$ MeV/c
0	0.43 ± 0.02 %	0.16 ± 0.01 %
1	45.25 ± 0.25 %	36.62 ± 0.19 %
2	51.22 ± 0.27 %	57.16 ± 0.26 %
3	2.90 ± 0.05 %	5.13 ± 0.06 %
4	0.18 ± 0.01 %	0.73 ± 0.02 %
5	0.011 ± 0.003 %	0.17 ± 0.01 %
≥ 6	< 0.01 %	< 0.1 %

→ Excellent efficiency, $E = 1 - R_0 \simeq 99.57 \pm 0.02$ %

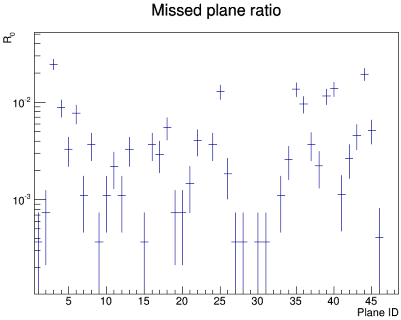
→ High probability of hitting only one bar

→ Higher probability of hitting high number of bars for stopping muons (higher energy deposited in each bar, stopping point very bright)

Single Plane Efficiency

All the MAPM are set to the same High Voltage (700V):

- no high voltage scan has been performed on the MAPM, yet;
- too high a voltage causes undesired hits ($N > 2$);
- too low a voltage misses hits more frequently ($N < 2$).



R_0	N_{planes}
$R_0 > 1\ \%$	6
$.1\ \% < R_0 < 1\ \%$	25
$0 < R_0 < .1\ \%$	11
$R_0 = 0$	6

→ These values are function of the plane specificities.

Hardware Commissioning Summary

MAPM readouts

- All the electronics in the EMR work as designed
- 4 Channels are dead (0.15 % of the bars) in plane 34

Clear fibres luminosity

- 95 % of the fibres are within a 20 % interval off average

Mismatch

- 2 mismatched channels in plane 44

Crosstalk

- Probability of crosstalk : $R_N < 0.5$ %
- Fraction of the initial signal : $R_Q \simeq 4.5 \pm 1.5$ %

Signal Acquisition Efficiency

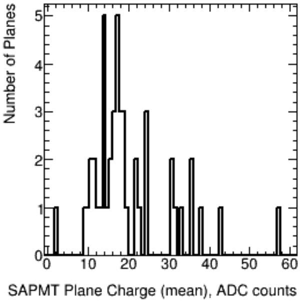
- Excellent global efficiency $E_{SA} = 99.57 \pm 0.02$ %
- High voltage scan required on some of the MAPM

Single Anode PMT replacement (1)

Ageing **Philips XP2972** manufacturer characteristics:

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

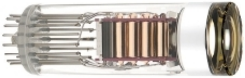
→ 30 years old
→ Degraded photocathode
→ Reduction of secondary emissions
→ Gain loss
→ Spurious pulses



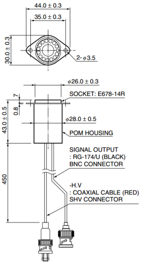
Single-Anode PMT replacement (2)

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 %



New voltage divider
→ 55 PMTs and 55 VDs (7 spares)
→ Characterization tests at CERN in September (noise, dark current, response to MIP like signal)
→ Change done by UniGe technicians at RAL at the beginning of October 2014 (few days work), Necessary



New Control Rack Installation

New elements:

- 47 U rack to replace current one
- AC fan system
- Remote controlled AC power supply
- HVPSU (photomultipliers)
- LVPSU (trigger distribution boards, LED driver, fans)
- New VME and NIM crates

Figure: Remote controlled PSU

Implementation:

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

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 in October after rack and SAPMTs installation, Important

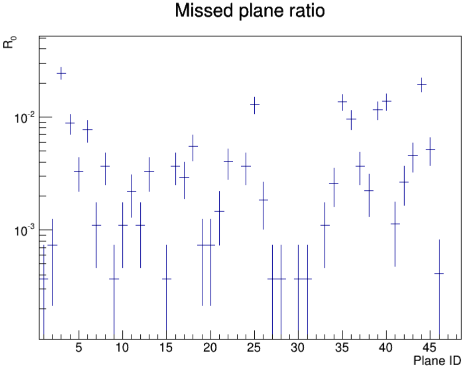
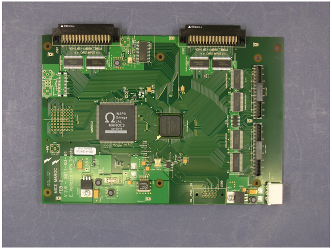


Fig: Probability of given plane to not record a single signal in the MAPMT when a 350 MeV/c muon goes through it. Some of the planes have an efficiency under 99 %; their voltage needs to be adjusted.

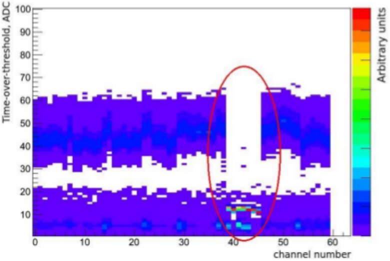
Faulty Front End Boards Investigation



Some of the dedicated FEBs exhibit faulty behaviours:

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

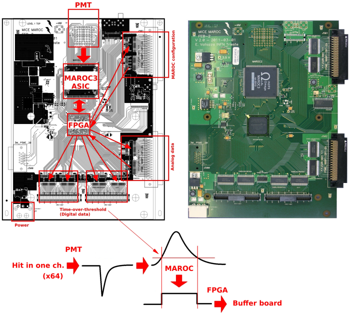
→ Needs to be investigated to see at which stage the signal is lost
→ Fixing them will provide much required additional spares
→ 1 month work, Important



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



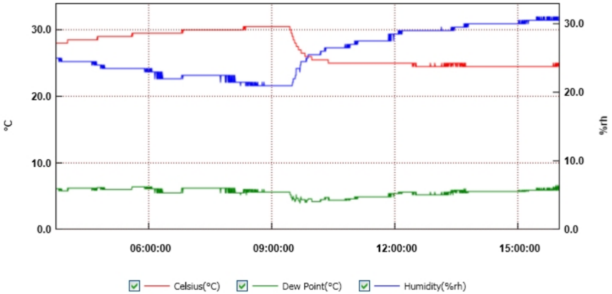
→ Hasn't been studied extensively
→ Study of the threshold influence to increase acceptance
→ Correction of the MAPMT non-uniformity using the pre-amp
→ 2 month work with a test bench at CERN, Secondary

Temperature and Humidity Sensors

Temperature and Humidity sensors are to be installed in the EMR box and the electronics and PSUs rack and should be used to

- Monitor the stability of these variables
- Study the influence they have on the front end electronics (FEBs are known to trip above a certain value of temperature)
- Study the influence of the PMT gain or their readout and adjust their parameters according to the measured values

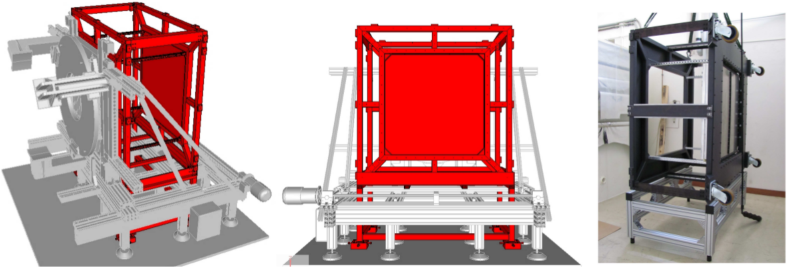
→ Secondary



EMR Frame

- The front panel of the EMR consists of 800kg of steel
- What will be the magnetic field at the level of the EMR?
- Should the structure be reinforced?

→ Necessary



Code integration into MAUS

What has been done:

- **MC Digitization** entirely in MAUS (version 1.1)
- Modication of the **data structure** implemented
- **Data Processors, tests** adapted

What needs to be done:

- Modification of the **EMRPlaneHits** map to accommodate two additional reconEvents (noise+decay particles) and fill them
- Integrate the **reconstruction code** (already exists)

→ functional by the end of summer, Necessary.

Digitization Parameters Study

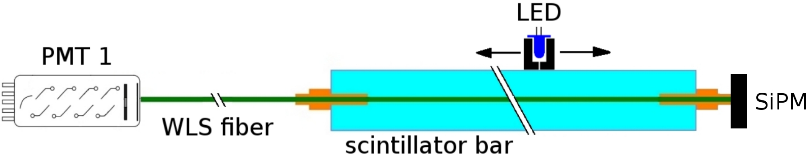
The MC digitization variables are currently based on the data sheets:

- Photoproduction and trapping efficiency in the bars
- Attenuation factors in the fibres
- Quantum Efficiency of the Multi and Single Anode PMTs
- PMT non-uniformity

Studies will be made for the parameters to reflect the detector specificities

- PMT non-uniformity adjusted through calibration
- Light output of the bars with SiPM
- Transport of the light in the fibres with SiPM

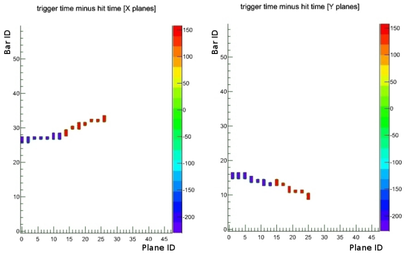
→ 2 months work, Important.

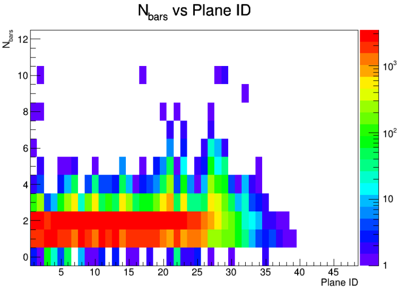


Improve Track Reconstruction

- The coordinate in each plane as a weighted average of the position of the bars hit and their ToT measurements
- Include the triangular geometry in the range measurement
- Redefine the end point of the primary track using bar multiplicity
- New parameters to tag muons (eDep pattern for instance)

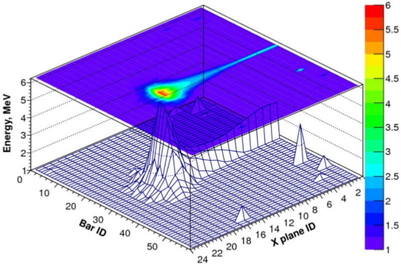
→ 1 month work, Secondary.





Software Advanced Prospects

- Use Monte Carlo digitization as a tool to reconstruct the energy deposition pattern of muons from the measured charge and ToT
  → 1 month work, Secondary.



- Implement multivariate algorithm for particle identification
  → 1 month work, Secondary.

EMR DAQ

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

- Calibration of the fADC pedestal after power cycles (DONE)
- MAROC configuration after power cycles
- Use LED monitoring to adjust PMT gains (analogue devices are sensitive to temperature changed, magnetic fields, power cycles, etc.)
- Calibration Run (3 weeks of cosmic data taking after major hardware updates, finely tuned by LED monitoring)
- 3 distinct modes of DAQ
  - Beam
  - Cosmic
  - LED pulser

→ Possibility to include the EMR in every run, Necessary.

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

→ 1 week work, Important.