Update on the Analysis of 2018 Beamtest Data

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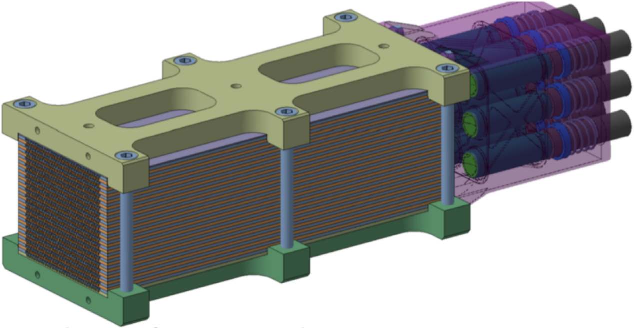
A Quick Brushup - The Absorber

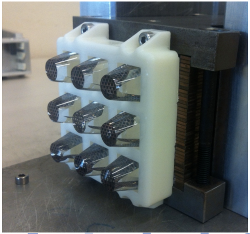
- Absorber made of W/Cu plates



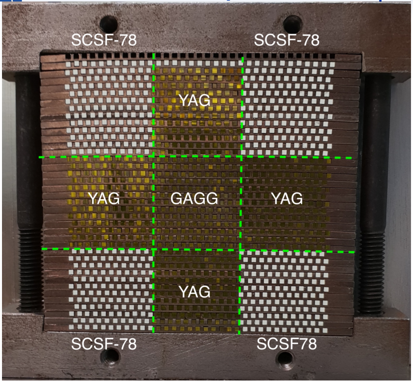
N.Siegrist, H. Gerwig, CERN

- $1.5 \times 60 \times 200$ mm^3 plates
- $1 \times 1 \times 200$ mm^3 grooves carved into each plate

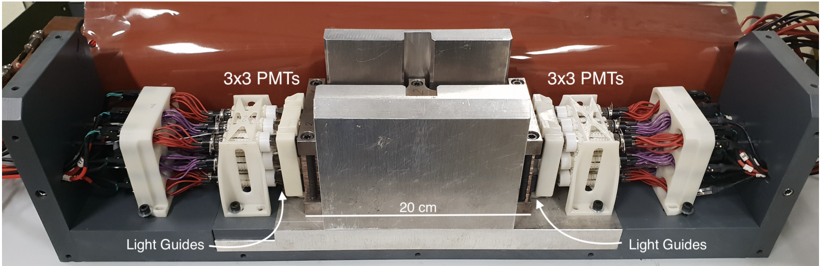
- PMT-Fibers coupling via light guides $\longrightarrow$



A Quick Brushup - 2018 BeamTest Setup



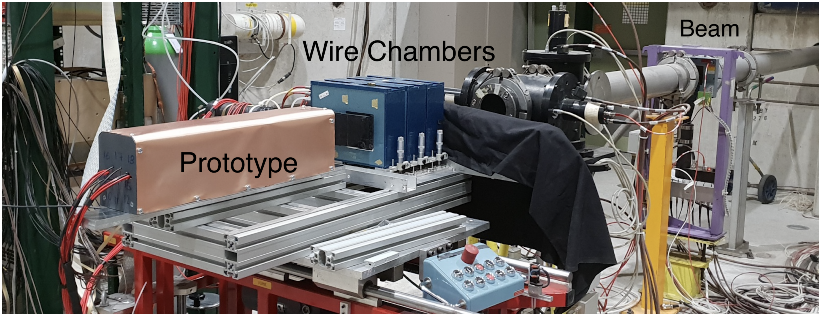
- 549 Plastic fibers → 20 cm long
- 1374 Crystal fibers → 2×10 cm long
  - 278 GaGG Fibers
  - 1096 YAG Fibers
  - 1 end is aluminized ⇒ Front and back sections are isolated.
- PMMA Light guides
- Front and back readout



Configurations Measured

- Beam Particles:
  - Muons 180 GeV
  - Electrons 20 GeV (Only e^- energy available during October)

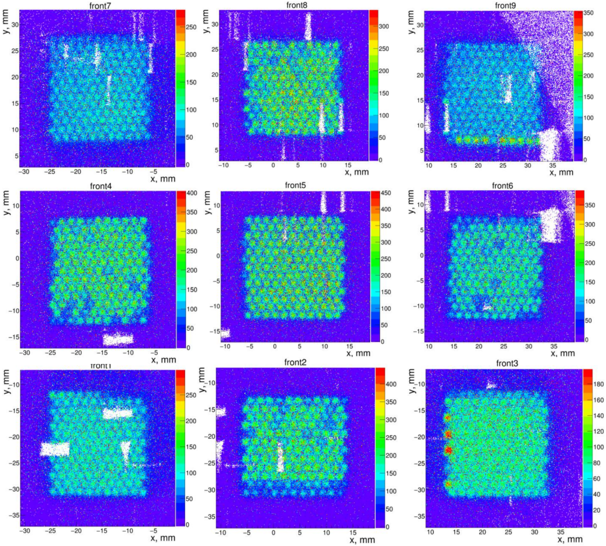
- Tilt Angle:
  - 3° - horizontal plane (azimuthal angle)
  - $3^\circ \oplus 3^\circ$ - horizontal and vertical plane (azimuthal $\oplus$ polar angle)
  - 90° - horizontal plane (perpendicular to the beam) - Muons only
  - 0° - horizontal plane (parallel to the beam) - Muons only



Snapshot of the 3° configuration.

Muons - 0° - Fiber Granularity

- Combining the space information given by the wire chambers and the energy deposition in the prototype when parallel to the beam it was possible to reconstruct the granularity provided by the fibers.

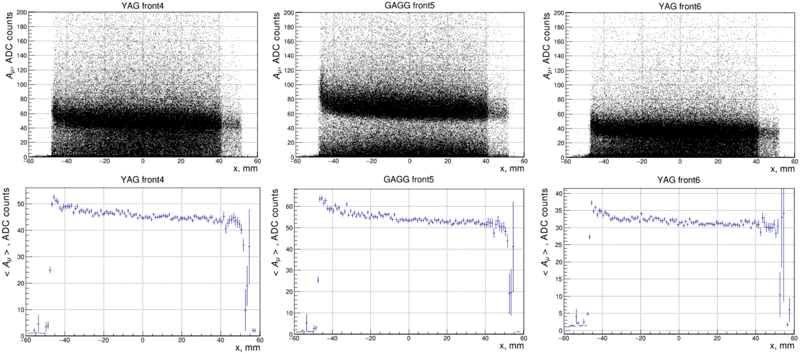


Clearly visible:

- Poorer quality fibers
- Light guides misalignments
- DWC inefficient areas

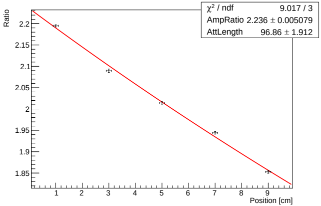
Muons - 90° - Longitudinal Uniformity

- Placing the prototype orthogonally to the beam the longitudinal uniformity can be checked.



- Non uniformities compatible with the measured attenuation length.

$$\langle \lambda_{YAG} \rangle = 95 \text{ cm}$$



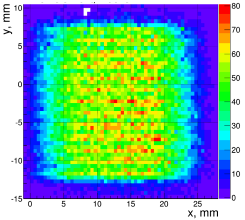
Muons - Tilt Checking

- Exploiting the high penetration of muons it is possible to cross check the true tilt of the module as:

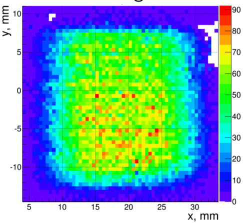
$$\sin\theta = \frac{\langle x^i_{back}\rangle - \langle x^i_{front}\rangle}{z_{back} - z_{front}} \qquad i = 1, 2$$

  - 3° Configuration real tilt $\longrightarrow \theta = (3.4^\circ, 0.1^\circ) \pm 0.5^\circ$

Front signal

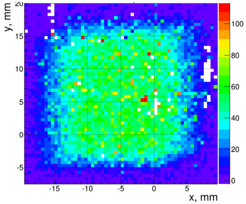


Back signal

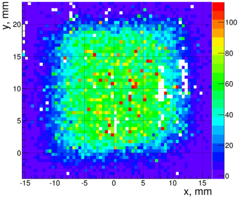


  - $3^\circ \oplus 3^\circ$ Configuration real tilt $\longrightarrow \theta = (3.2^\circ, 2.2^\circ) \pm 0.5^\circ$

Front signal



Back signal



Calibration - I

In order to find the calibration factors C_i to convert from ADC Channels to Energy, the following was performed:

- First a set of crude calibration factors μ_i was found making use of the muons as in:

$$\mu_i = \frac{k}{\langle A_i^{muons} \rangle} \tag{1}$$

$\langle A_i^{\mu} \rangle$ is the mean number of channels generated by the passage of a muon in the channel i and k is a fitting constant.

Calibration - II

- Secondly, a new set C_i was found minimizing the deviations from the known mean energy E_0 (20 GeV) value:

$$\begin{cases} \nabla_c \sum_{ev} [E^{ev} - E_0]^2 = 0 \\ E^{ev} = \sum_i C_i A_i^{ev} \end{cases} \quad (2)$$

Hence:

$$\sum_i \left[\sum_{ev} A_i^{ev} A_j^{ev} \right] C_i = E_0 \sum_{ev} A_j^{ev}$$

Which, defining the following

$$A_j = \sum_{ev} A_j^{ev} \qquad \text{and} \qquad H_{ij} = \sum_{ev} A_i^{ev} A_j^{ev}$$

is, in matrix notation:

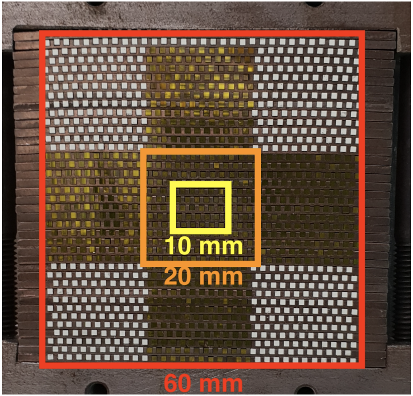
$$C_i = E_0 H_{ij}^{-1} A_j \quad (3)$$

- Leakages must be avoided $\Longrightarrow$ 40×40 mm^2 and 18-22 GeV selection window
- Due to impure beam the procedure is iterate until convergence is reached.
- To help convergence the ratio between front and back calibration factors should be fixed to the muons' factors one:

$$c_i = \frac{\mu_i}{\mu_{i-9}} c_{i-9} \qquad i = 10, ..., 18$$

Energy Resolution - Premises

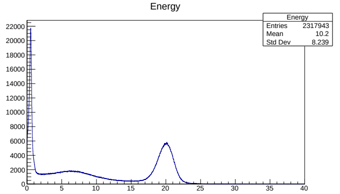
- Track selection was performed offline in order to reduce noise and border effects exploiting data from the 3 wire chambers:
    - Rejection of sparse tracks
      $\Longrightarrow$ **Noise reduction**
    - Selection of centremost tracks
      $\Longrightarrow$ **Border effects reduction**
- 3 different selection windows were chosen making use of the data from the DWC closest to the prototype, as depicted in the figure. $\longrightarrow$



Electrons - 3° - Energy Resolution

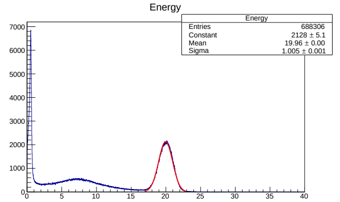
60×60 Square selection

- Resolution: $\frac{\sigma_{RMS}}{\langle E \rangle}|_{17}^{23} = 5.8\ \%$
- Non gaussian peak due to leakages



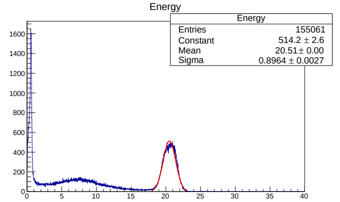
20×20 Square selection

- Resolution: $\frac{\sigma_{RMS}}{\langle E \rangle}|_{17}^{23} = 5.0\%$
- Gaussian fit resolution: $\frac{\sigma}{E_{peak}} = 5.0\%$



10×10 Square selection

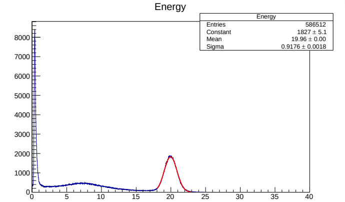
- Resolution: $\frac{\sigma_{RMS}}{\langle E \rangle}|_{17.5}^{23.5} = 4.5\ \%$
- Gaussian fit resolution: $\frac{\sigma}{E_{peak}} = 4.4\%$
- Resolution improves due to better light collection in the center of the guide.



Electrons - 3° ⊕ 3° - Energy Resolution

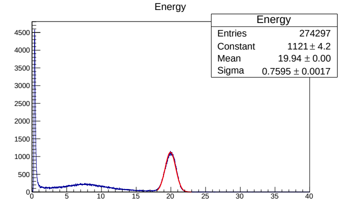
60×60 Square selection

- Resolution: $\frac{\sigma_{RMS}}{\langle E \rangle}\Big|_{17}^{23} = 4.8\ \%$
- Gaussian fit resolution: $\frac{\sigma}{E_{peak}} = 4.6\%$



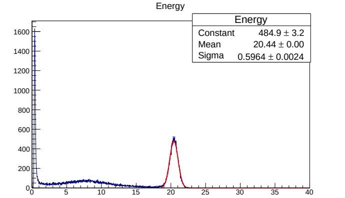
20×20 Square selection

- Resolution: $\frac{\sigma_{RMS}}{\langle E \rangle}\Big|_{17}^{23} = 4.1\%$
- Gaussian fit resolution: $\frac{\sigma}{E_{peak}} = 3.8\%$



10×10 Square selection

- Resolution: $\frac{\sigma_{RMS}}{\langle E \rangle}\Big|_{18}^{23} = 3.1\ \%$
- Gaussian fit resolution: $\frac{\sigma}{E_{peak}} = 2.9\%$
- Resolution improves due to better light collection in the center of the guide.



Electrons - Photoelectrons Yield

Once the detector has been calibrated in energy, is then possible to retrieve the Photoelectrons Yield.

- Each PMT is illuminated by a pulsed monochromatic LED light from which the Poisson statistics provides the intensity of a single photoelectron event and the calibration factor for the i-th channel C^i_{phel}:

$$C^i_{phel} = \frac{1}{A_{1phel,i}} = \frac{\mu_{LED,i}}{\sigma^2_{LED,i}}$$

- Therefore, dividing C^i_{phel} by the ADCChannel-to-Energy C_i calibration factor the photoelectrons yield can be retrieved:

Material	Photoelectrons/MeV	$\pm$
GAGG	9.71	0.22
YAG	6.76	0.16
Plastics	1.15	0.14

- Photoelectron yield hampered non negligibly by the light guides.
  Preliminary simulations show an improvement of a factor of $\sim$4 with air coupling.

Open Questions

- Some matters related to these data still to be discussed before the next beamtest:

1. Montecarlo simulations do not fit the measurements:
   - Beam towards the center of the prototype
   - 3° Energy resolution
     Simulated $= 5.1\%$ Measured $= 4.4\%$
   - $3^\circ \oplus 3^\circ$ Energy resolution
     Simulated $= 4.7\%$ Measured $= 3.0\%$

2. Light guides inefficiency:
   - Non uniformities in light collection ($\sim 10\%$) degrade the energy resolution
   - Poor general efficiency $\longrightarrow$ Looking for alternatives