Tracking *scintillator* for Crilin TB

V. Ciccarella[1], E. Di Meco[3], E. Diociaiuti[3], R. Gargiulo [1 2], I. Sarra [3]

[1]Sapienza University of Rome, [2]INFN Section of Rome-1, [3]INFN Frascati National Laboratories

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SAPIENZA
UNIVERSITÀ DI ROMA

Overview

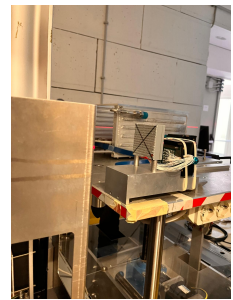
- Selection of 1-e^- events + fiducial regions needed at Crilin TB
- Previous TBs with Si trackers in sinergy with HIKE - not easy syncronization
- New idea: Scintillator + 16 SiPMs on facing-beam side $\rightarrow$ "low-cost" tracking

- EJ-200 3×3 cm^2 plastic scintillator tile with 0.5cm thickness
  - 10^4 photons/MeV light output, 0.9ns rise time and 2.1ns decay time
- 4×4 mm^2 Hamamatsu SiPMs (at 41V) - 50μm pixels $\rightarrow$ 52% PDE
- ESR on beam-facing side and charge sharing for position reconstruction

- Performances tested in LNF-BTF with a 450 MeV e$^-$ beam
  - High efficiency (96%) + MIP counting capability + 150 ps timing
  - $<$ 1 mm spatial resolution in two coordinates

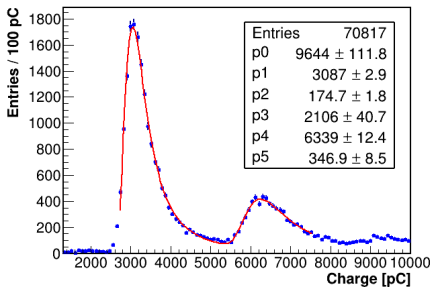
Mechanics and electronics

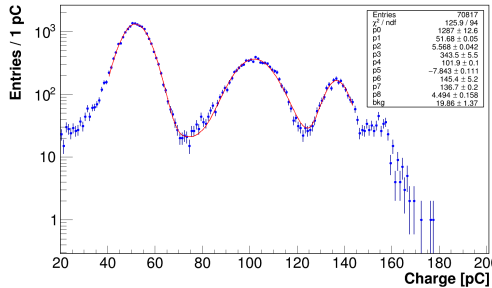
- SiPMs coupled and kept in place with optical glue
- SiPMs connected to Crilin prototype board with wires
- 3D printed box to keep scintillator and wires still
- Assembly mounted on steel block together with the prototype board
- Beam alignment using BTF laser on box diagonals cross



Charge spectrum and total light yield

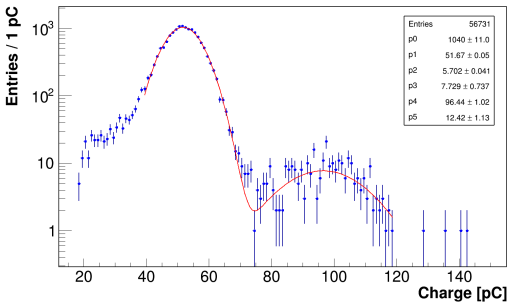
- 1 and 2 particles distinguishable in lead glass and scint. total charge
- 0.23 p.e./pC estimated with 2.7×10^6 SiPM and 10 FEE gain
- Large total p.e./MIP (1MeV deposit) $N \sim 710$
  - Compatible with an $\epsilon \sim 50\%$ light collection efficiency (run at center)
  - $10^4(N_\gamma) \times 28\%(\text{Area ratio}) \times 52\%(\text{PDE}) \times 50\%(\epsilon) \sim 700$

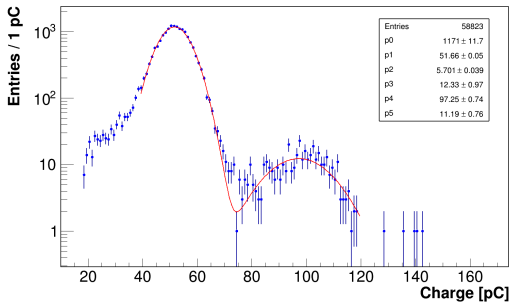




Single particle events ID

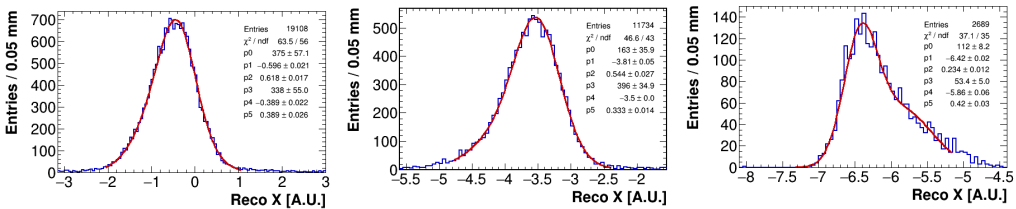
- A simple cut on scint. total charge can reject 2 particle events
  - $Q < 4000$ pC: 83% eff. on 1 MIP - 3% eff. on 2 MIPs (Plot 1)
  - $Q < 5000$ pC: 93% eff. on 1 MIP - 5% eff. on 2 MIPs (Plot 2)
  - Efficiencies found using lead glass as truth (ratio of yields from gaussians)





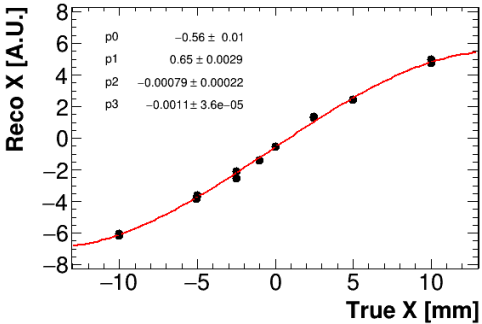
Position reconstruction

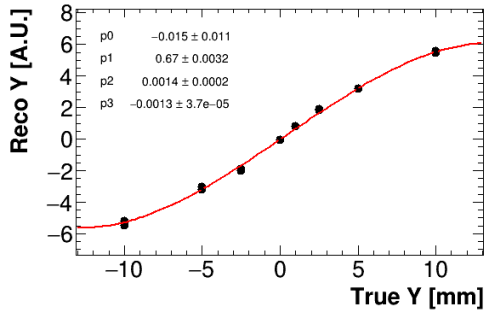
- X and Y reconstr. as the mean of all charges weighted by SiPM positions
- 2 gaussians fit to measure per-run yield, mean and resolution
- Edge effects visible at 1cm from the center
- In figure reconstr. X at 0, 5 and 10 mm from the center along a diagonal



Position calibration

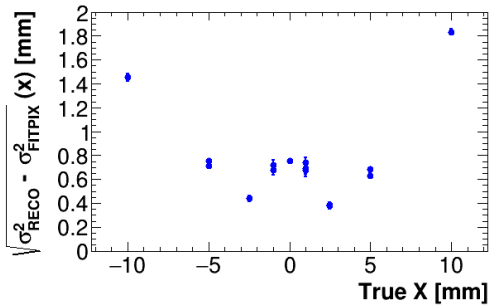
- Cubic function fitted to calibrate X and Y response
- Saturation effect visible at the edges

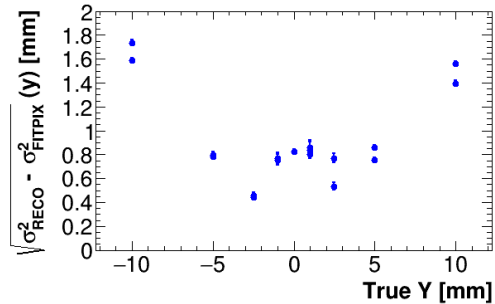




Position resolution

- Beam spot size $\sigma \sim 0.4$mm (from FitPix) subtracted in quadrature
- Resolution found after propagating calibration formula on per-run fitted std. dev.
- Inside a ± 5mm region around the center, 0.5mm$< \sigma_{x,y} < 1$mm
- Best resolutions reached when the beam impinges on a SiPM (highest charge)

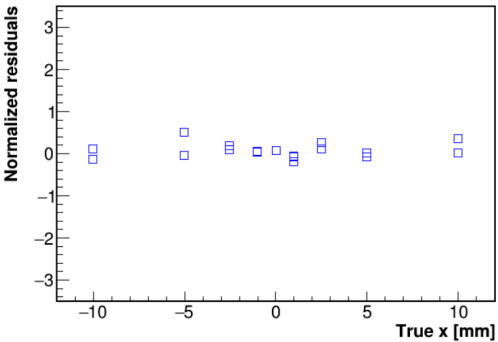


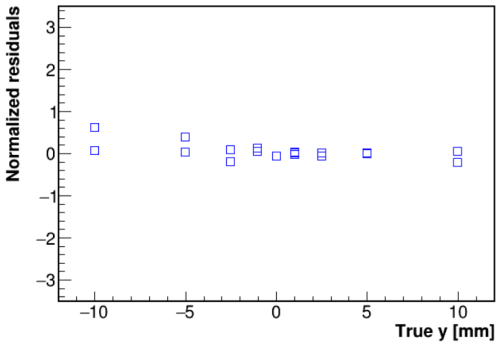


BACKUP

Position residuals

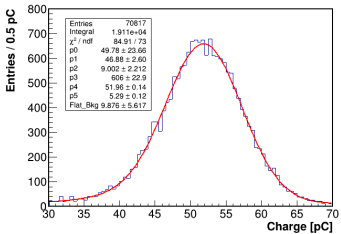
- Normalized position residuals below 1 $\rightarrow$ Position reconstruction under control

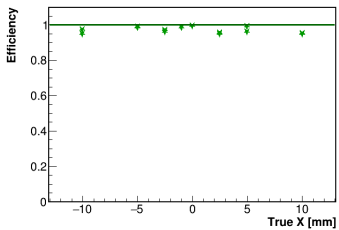


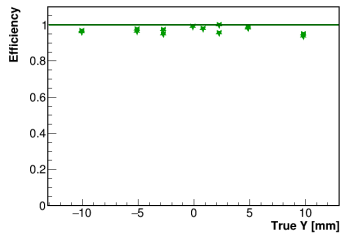


Efficiency

- 2 gaussian + flat bkg fit to lead glass charge in 1-MIP region
- (Cut-and-count / Fit integral) scale factor found from the run at center
- Per-run efficiencies estimated from the fitted number of events
- Efficiencies norm. with per-run lead glass cut-and-count yield, multiplied by global scale factor
- Very high $\sim 96\%$ average efficiencies

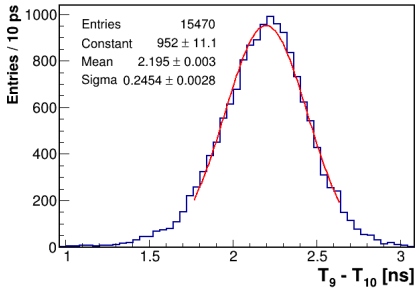






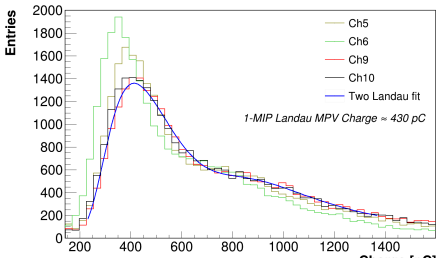
Timing

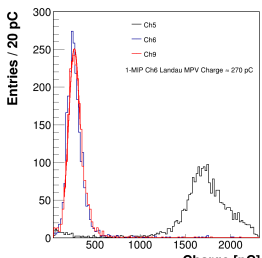
- Timing performances checked with time differences between near channels
- Ch9 and Ch10 (highest charges) from the run at center were used
- Found a $\sigma_{\Delta T} \sim 250$ps, therefore $\sigma_T \sim 170$ps
- σ_T close to ultimate value $\sqrt{\tau_R \tau_D / N_{p.e.}} \sim \sqrt{0.9 * 2.1/100} ns \sim 140$ps
  - see *doi.org/10.1016/j.nima.2018.02.074*

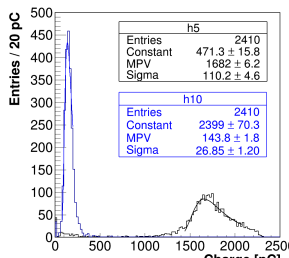


Single channel charge spectra

- From now on, for all runs, cuts on lead glass charge applied (30-70pC $\rightarrow$ 1MIP)
- ~ 430 pC (100 p.e.) MPV on central chs for run at center (4.2mm beam center - SiPM center distance)
- ~ 1700 pC (400 p.e.) for ch5, in a run with the beam pointing at its SiPM
  - ~ 270 pC for ch6 and ch9 (6mm beam-SiPM distance)
  - ~ 140 pC for ch10 (8.5mm beam-SiPM distance)

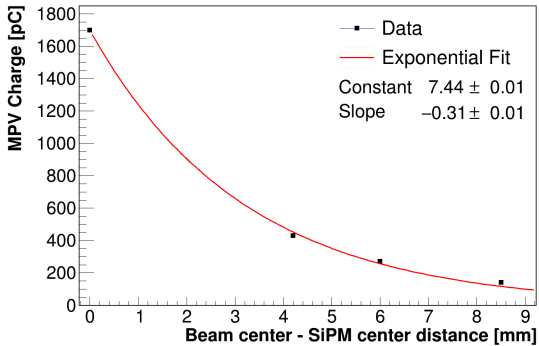






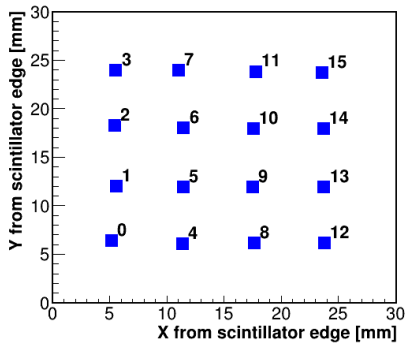
Charge-position dependence

- Last slide data (charge, beam center - SiPM center distance) plotted
- An exponential model for light propagation can be established
- Fitted attenuation length of ~ 3mm



Preliminary operations

- SiPMs positions measured from a well-aligned picture (first slide)
- BTF beam fired on all SiPMS to validate channel map after assembly



Runs summary

- One run per position
- Two diagonals scan at 2.5, 5, 10 mm from the center in each coordinate
- One test run (not reconstructed) at 15mm from the center to see the scintillator edge
- Some runs at 1mm from the center, most of them blinded