An Imaging Calorimeter prototype with WLS fibers and LYSO crystal

L. Lorusso*[a,b], M. Giliberti[a,b], A. Liguori[a,b], F. Loparco[a,b], G. Panzarini[a,b], R. Pillera[a,b], M. N. Mazziotta[a]

a Istituto Nazionale di Fisica Nucleare – Sezione di Bari
b Dipartimento Interateneo di Fisica «M.Merlin» del Politecnico e Università di Bari
* leonarda.lorusso@ba.infn.it

Abstract

We propose an innovative modular detector for the new generation of satellite-borne experiments for sub-GeV gamma rays (PoS ICRC2023 (2024) 956), exploiting WLS fibers coupled to a scintillator crystal and readout with SiPMs.

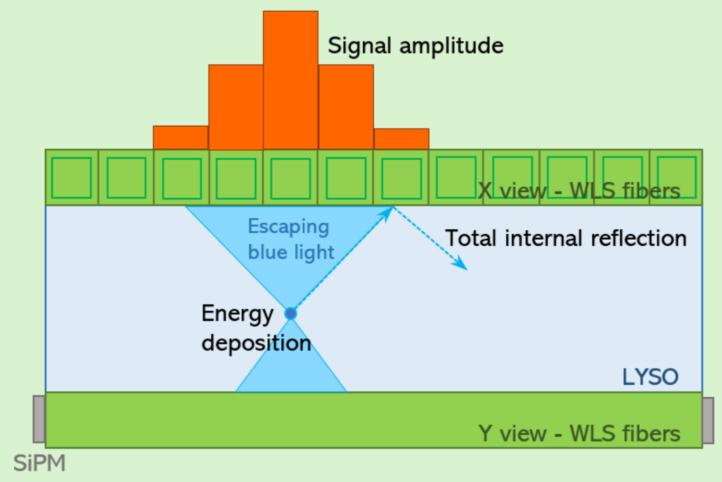
Different prototype configurations were tested in our laboratories with a Sr90 radioactive source and cosmic rays (CRs) to carry out a study of light yield. Preliminary results will be presented.

Detector concept

Single **X-Y module**: 3 mm thick LYSO crystal coupled with two crossed planes of Kuraray Y-11 1 mm square WLS fibers, on its top and bottom faces. The fibers are read-out by a Hamamatsu 128-channels SiPM array S13552.

Principle of operation

Ionizing particles and absorbed gamma rays release an energy deposit (ΔE) into the crystal, producing isotropic blue scintillation light, with a light yield (LY) of 33 photons/keV. WLS fibers within the acceptance cone collect these photons, shift the wavelength towards green, and transport them to the SiPM at their ends.



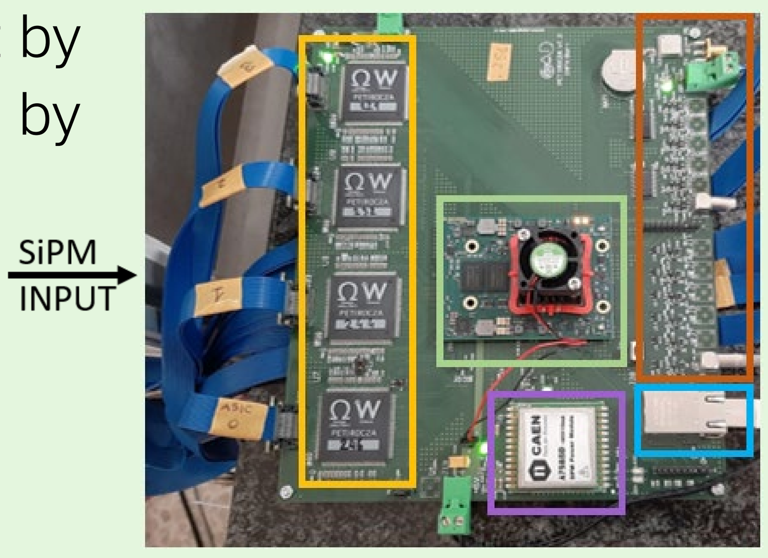
The resulting number of photoelectrons readout by SiPMs coupled to the LYSO (WLS fibers) is given by $N_{pe} = LY \times \Delta E \times f_T \times \varepsilon \times PDE$, where f_T is the fraction of light transmitted by the crystal, ε includes the geometrical acceptance of the SiPMs and in case of WLS fibers the transport efficiency of light to the ends (about 4% for single cladding), and PDE is the SiPM photon detection efficiency.

The configuration with crossed fiber planes allows to evaluate the position of the interaction point in the scintillator crystal.

Read-out system

SiPM signals are read-out by a **custom FEB** designed by INFN Bari, hosting :

- 4 Petiroc 2A ASICs
- Kintex-7 FPGA module
- CAEN A7585D SiPM voltage module
- NIM I/O
- ethernet port

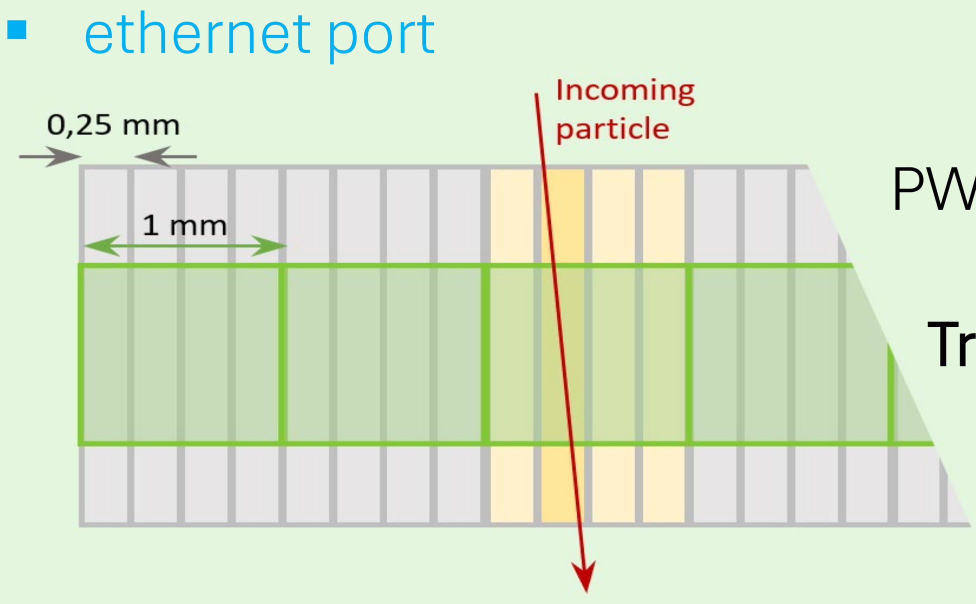


- 32 FE channels
- ADC for charge measurements
- TDC to measure the arrival times
- 32 digital outputs for triggering

- I/O data management
- Trigger
- Coincidence

- SiPM bias voltage regulation up to 80 V

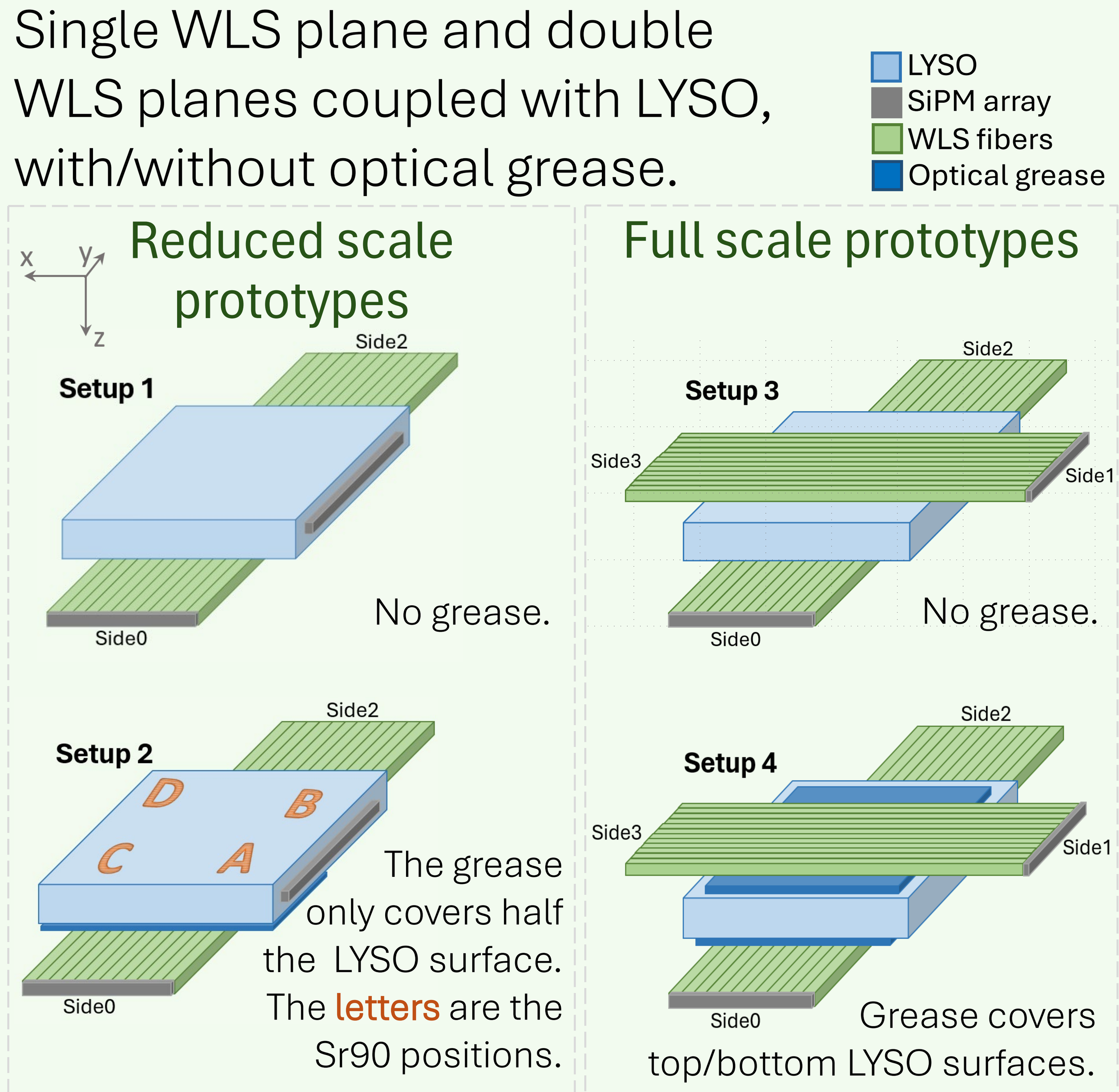
- NIM I/O for external trigger



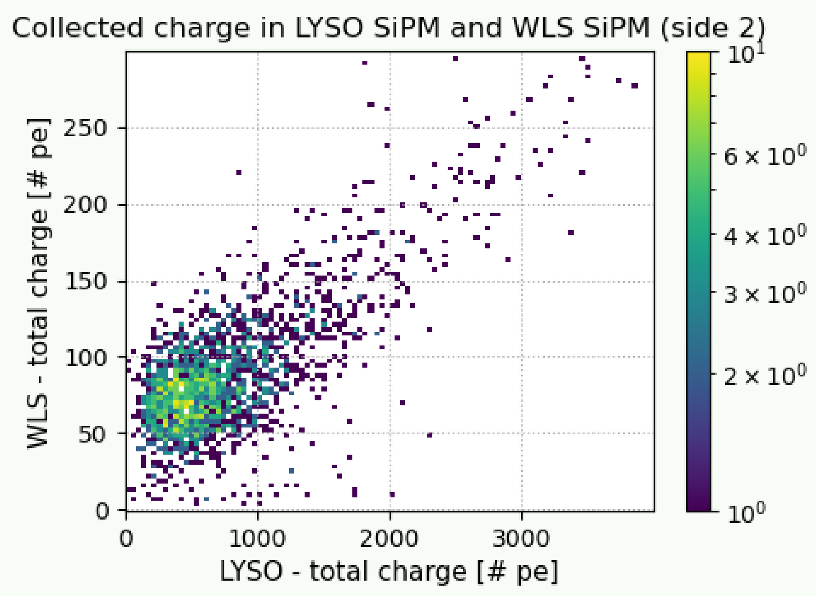
The SiPM is mounted on the top of a PWB. PWB interfaces enable different read-out pitches by OR-ing groups of 4 adjacent channels. **Trigger**: requires the coincidence in a short time window between the signals from at least two different channels at opposite sides.

Measurement setup

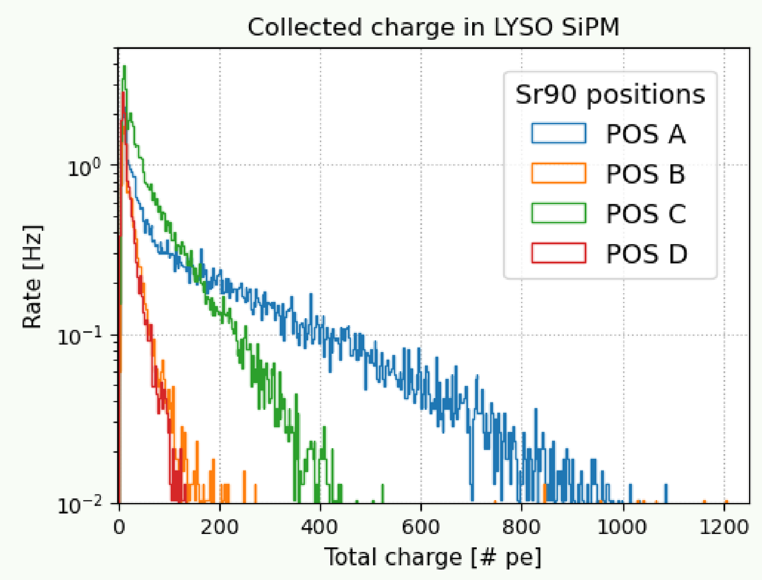
Single WLS plane and double WLS planes coupled with LYSO, with/without optical grease.

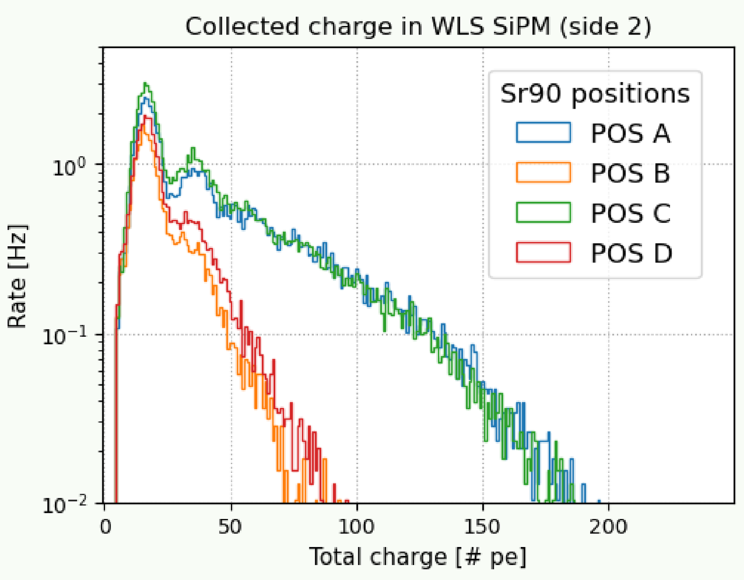


Reduced scale prototype results



Setup1 - CR: the photoelectrons from the SiPMs coupled to WLS and LYSO are correlated and are consistent with expectations: 50-60% for LYSO and 85-90% for WLS.

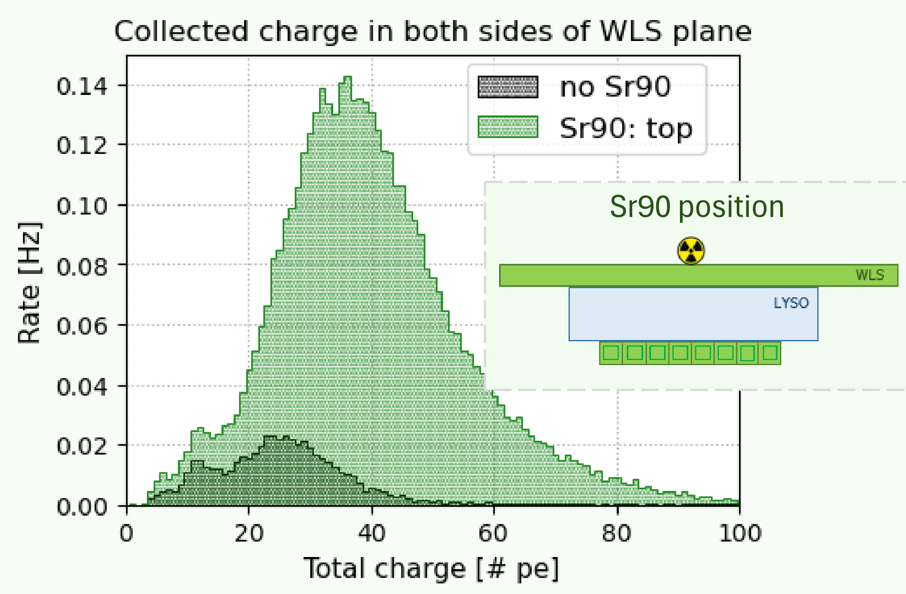


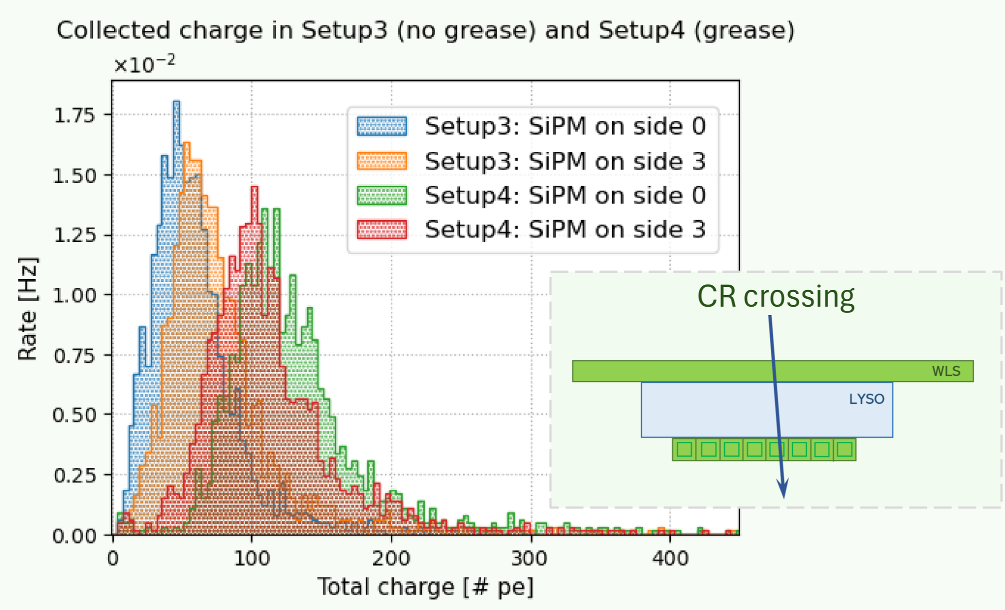


Setup2 – Sr90: the closer the source is to the LYSO SiPM, the higher is the number of photoelectrons, due to the direct light contribution (left plot). The optical grease improves the light collection by SiPMs, as expected due to the better matching of refractive indices.

Full scale prototype results

Setup3 – Sr90: the WLS sides 0 and 2, when the source is placed on the other WLS plane, collect 40 p.e. The black curve shows the contributions of WLS scintillation light and cosmic rays.





Setup3 vs Setup4 - CR: more light is collected in the Setup4 thanks to the optical grease between the WLS fibers and the LYSO crystal.