Flexible setup for the characterization of innovative scintillating nanocrystals

E.Mazzola[1,2], *E.Auffray*[3], *C.Brofferio*[1,2], *S.Capelli*[1,2], *S.Dell'Oro*[1,2], *L.Gironi*[1,2], *C.Gotti*[1,2], *M.Nastasi*[1,2], *M.Salomoni*[1,3], *V.Zabloudil*[3,4]

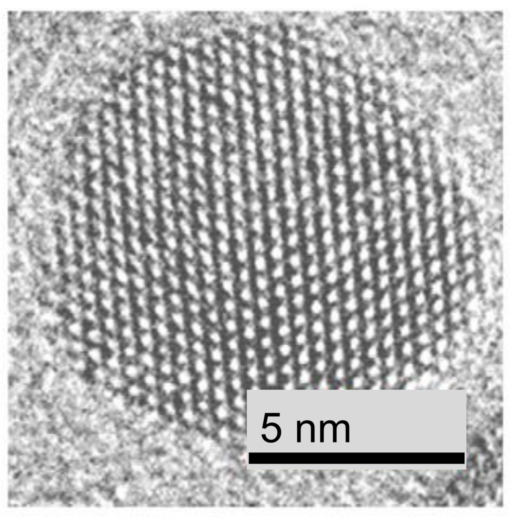
[1]University of Milano-Bicocca, [2]INFN section of Milano-Bicocca, [3]European Organization for Nuclear Research (CERN), [4]Czech Technical University in Prague, Prague.
Corresponding Author Email: e.mazzola@campus.unimib.it

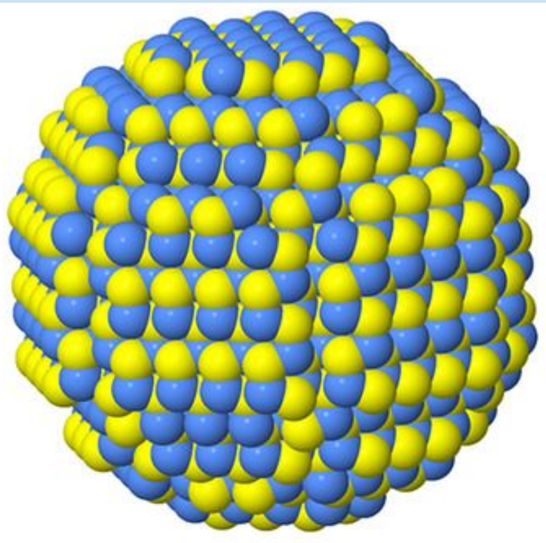
Scintillators

Scintillators → highly effective for the detection of ionising radiation. Easy to use, cost-effective, and stable.

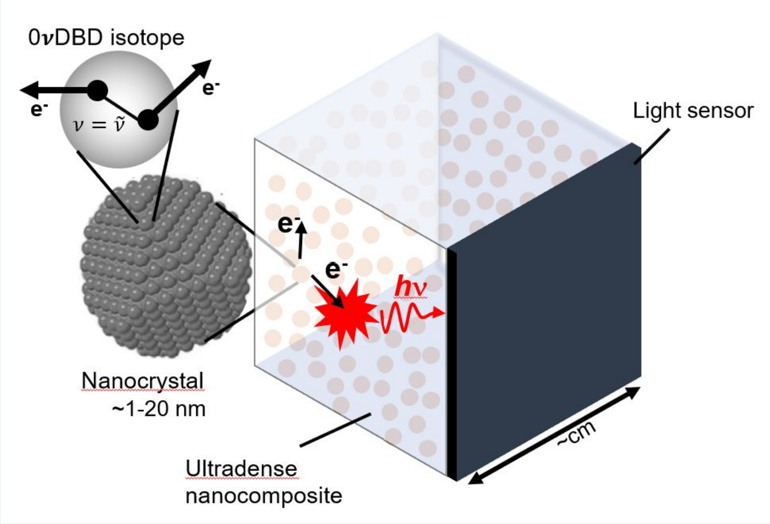
Limitations:

- Inorganic scintillators: dense, moderate decay time and high Light output.
- Organic scintillators: low density and low light yield → low energy resolution.





Nanocomposite (NC) scintillators: bulk matrices with innovative scintillating crystals in the nanometer range → high energy resolution, efficiency, stability, and mass scalability.

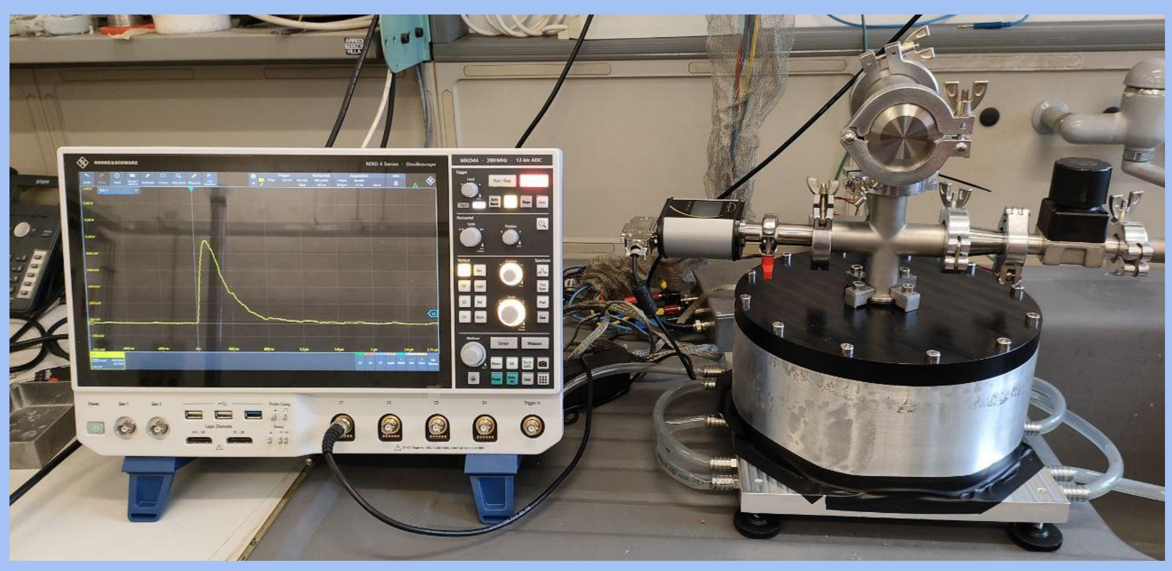


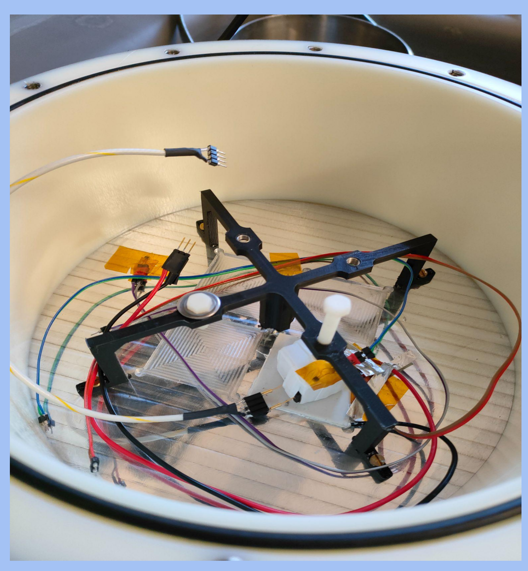
- The **UNICORN project** [1] → developing of NC-scintillator detectors using engineered nanomaterials for radiation detection
- Primary focus → investigating **neutrinoless Double Beta Decay** (0vDBD)
- NCs will be specifically designed to be both the source and the detector for 0vDBD

Custom experimental setup

Vacuum chamber hosting scintillator, light sensors, Peltier cells, and thermometers

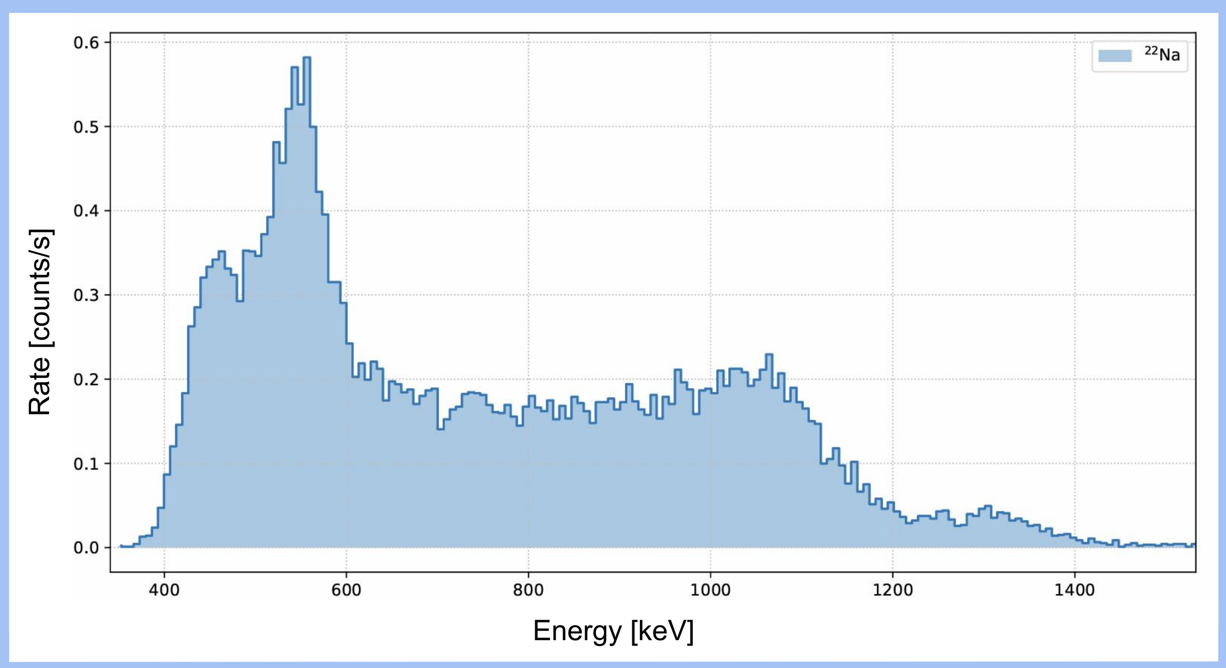
- reduced dark current and counts
- temperature control for thermal stability of the light sensor

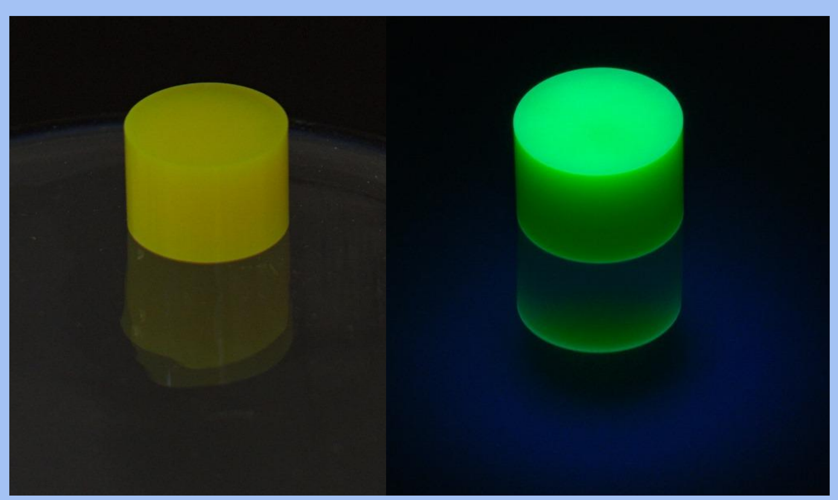




- **Hamamatsu Si photomultipliers (SiPM):** 6x6 mm² photosensitive area and about 10,000 single cells.
- **Alpha, beta, and gamma sources** for light emission excitation, including custom **alpha sources implanted** on the scintillator.
- A **Rohde & Schwarz MXO4** oscilloscope to acquire and store on disk the whole signal waveforms → optimized offline analysis of pulse amplitude and shape.

Set-up test: ^{22}**Na** spectrum with 1 cm^3 **YAG** crystal





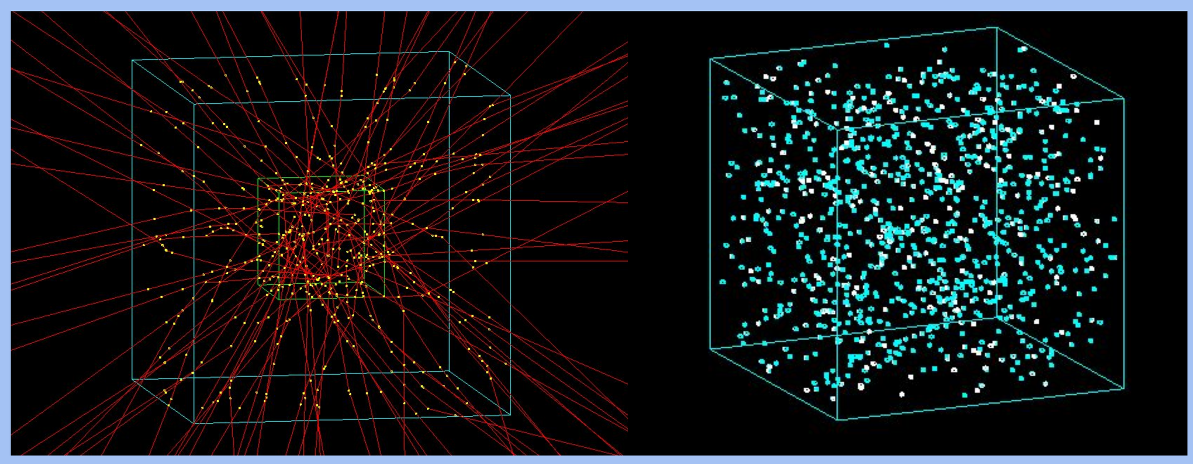
Next step: characterization of nanocomposite compound

- **PS** with **1%** (by weight) of **CdS/CdSe**
- Cylindrical volume of **1,57 cm^3**

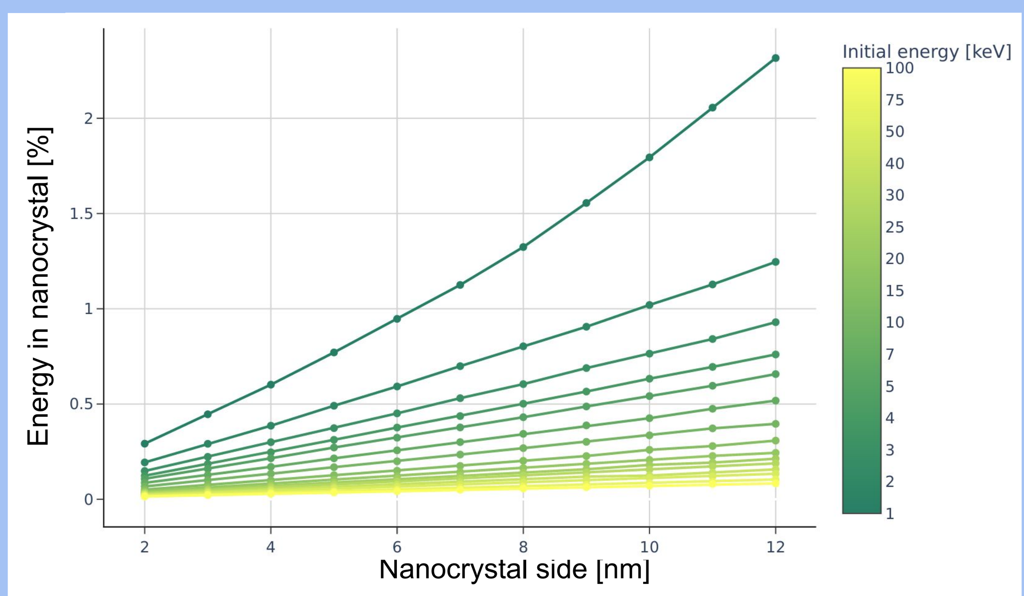
Monte Carlo simulation

Based on GEANT4 toolkit → accurate reproduction of the experimental apparatus.

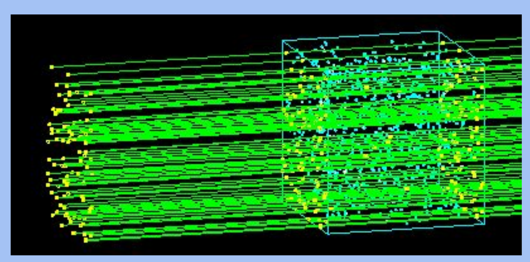
- Possibility to **easily change** position, energy, type of simulated sources, type and dimensions of scintillator.
- Both commonly used inorganic scintillators (BGO, LYSO) and **various types of nanocrystals** ($CsPbBr_3$ and CdS/CdSe) are included.
- NC represented as plastic cube containing one (left) or many (right) nanocrystals, **depicted as** small **cubes**.

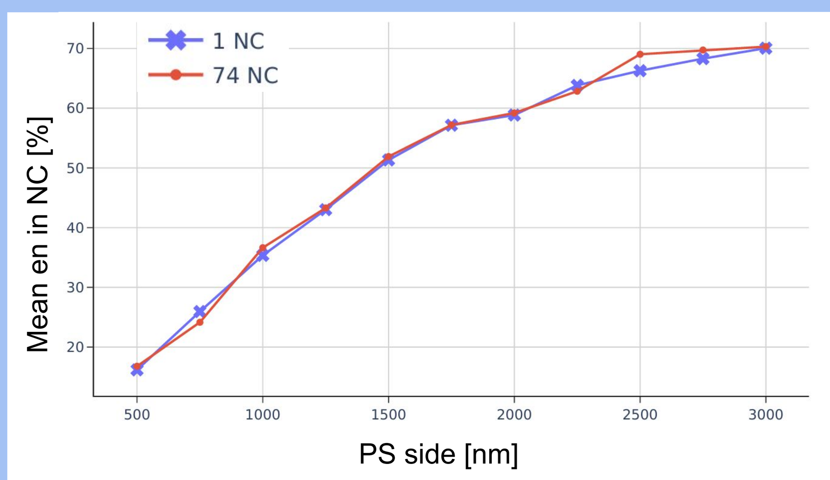


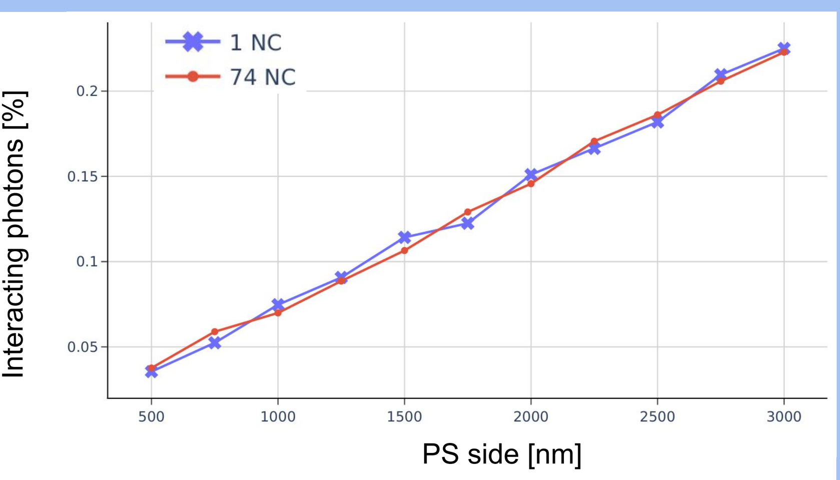
- This geometry is crucial for studying **energy deposition** in individual nanocrystals of **$CsPbBr_3$**
  - Fixed PS dimension: 100 nm per side
  - Variable electron energy (1 -100 keV)
  - Variable nanocrystal sides dimension (2-12 nm in 1 nm steps)



- External 7 keV x-ray source → the energy deposited in **a single big nanocrystal** and **in many smaller nanocrystals** (same total volume of 2000 nm^3) is the same.







References

[1] UNICORN, https://unicorn.altervista.org/
[2] S. Agostinelli et al, Geant4 - a simulation toolkit, Nucl. Instrum. Meth. A 506 (2003) 250-303

Acknowledgements

This work is carried out in the framework of European Pathfinder Open project UNICORN (GA 101098649).