

Plastic scintillators for calorimetry

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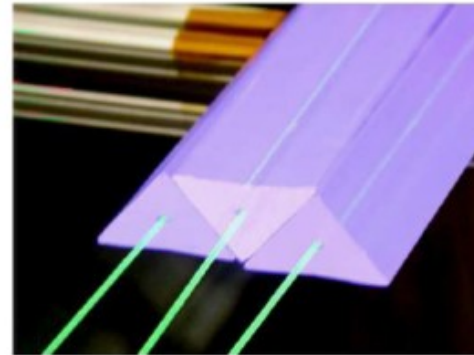
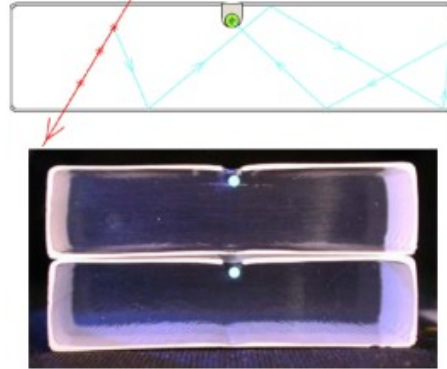
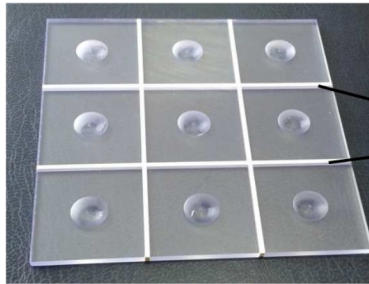
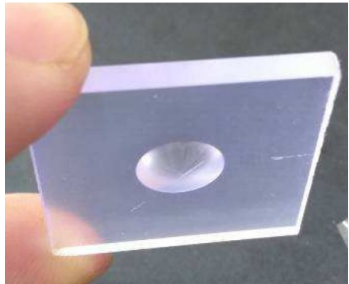
Outline

- Scalability Challenge for Highly Granular Calorimeters
- Adaptation of Manufacturing Technologies for Scintillation Modules.
- Materials Adaptation
- Integration with the Absorber

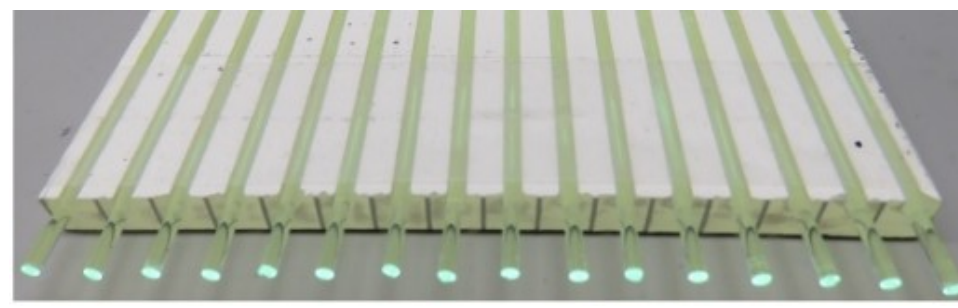
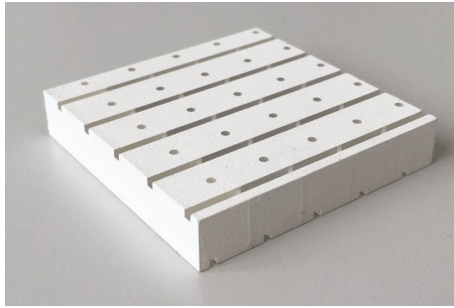
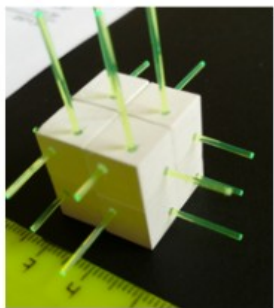
Scintillation Element Designs for Calorimeters

Increasing the Granularity of the Scintillation Volume

CALICE 10.1088/1748-0221/18/11/P11018
MINOS 10.1016/j.nima.2008.08.003 MINERvA 10.1016/j.nima.2013.12.053

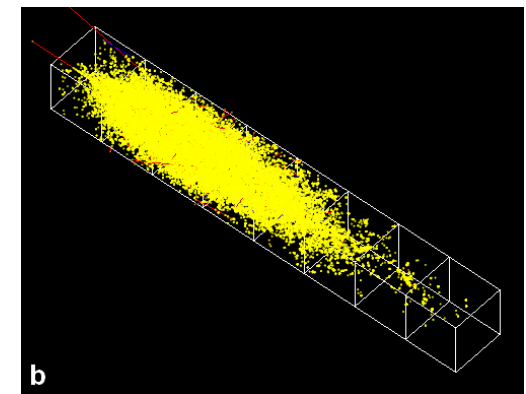
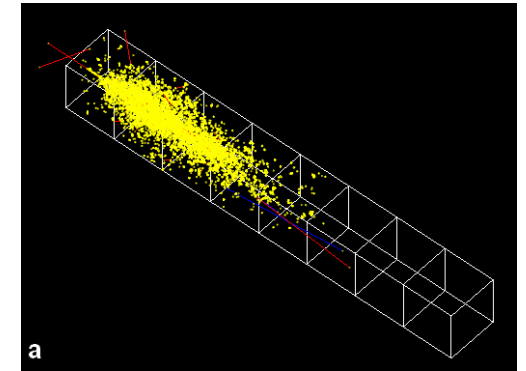


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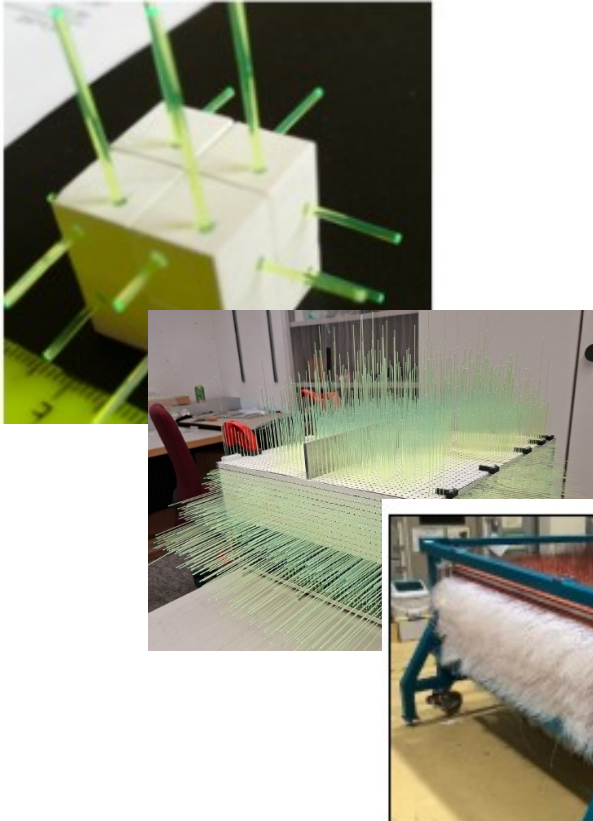
The LHCb Magnet Station:
Scientific and Technical Design Report

Sampling Calorimeters: Combination of Absorber and Active Elements



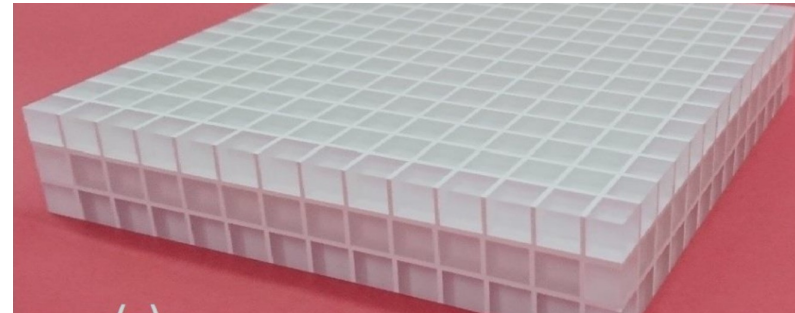
Technology Adaptation

Challenge: More Scintillation Elements Mean More Operations and Greater Process Complexity

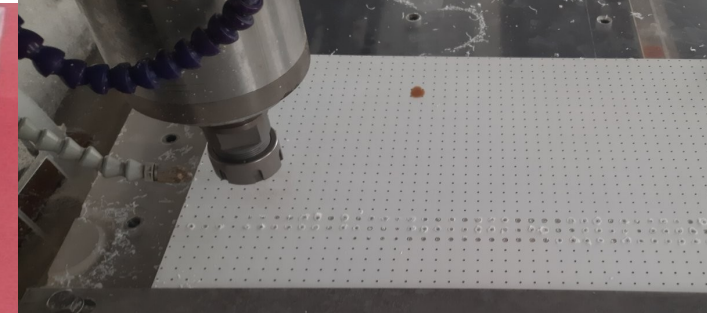


Solution: Shift to Mass Production

Replacement of Individual Element Production with Bonded Panel Fabrication

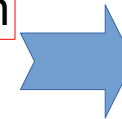


Replacement of Specialized Equipment with General-Purpose Machine Tools



Injection Molding and Extrusion

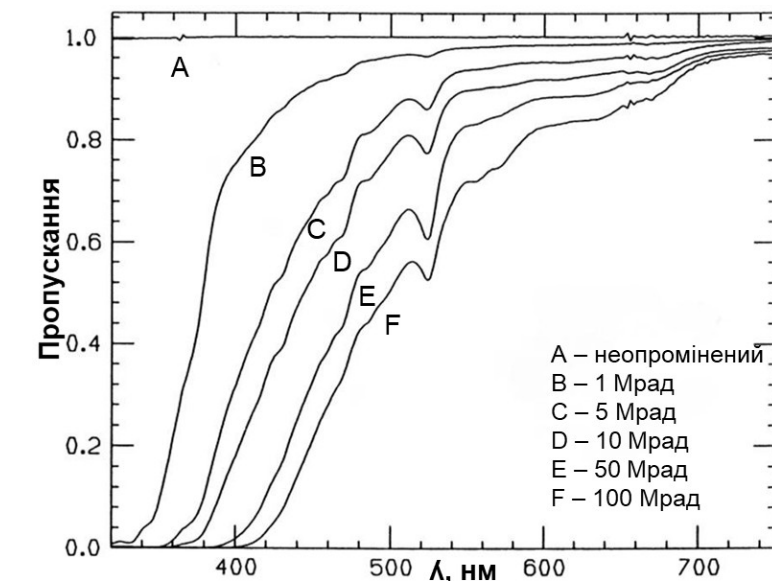
Specialized Equipment



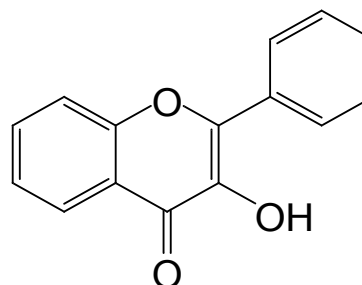
Batch Machining

General-Purpose Machine Tools

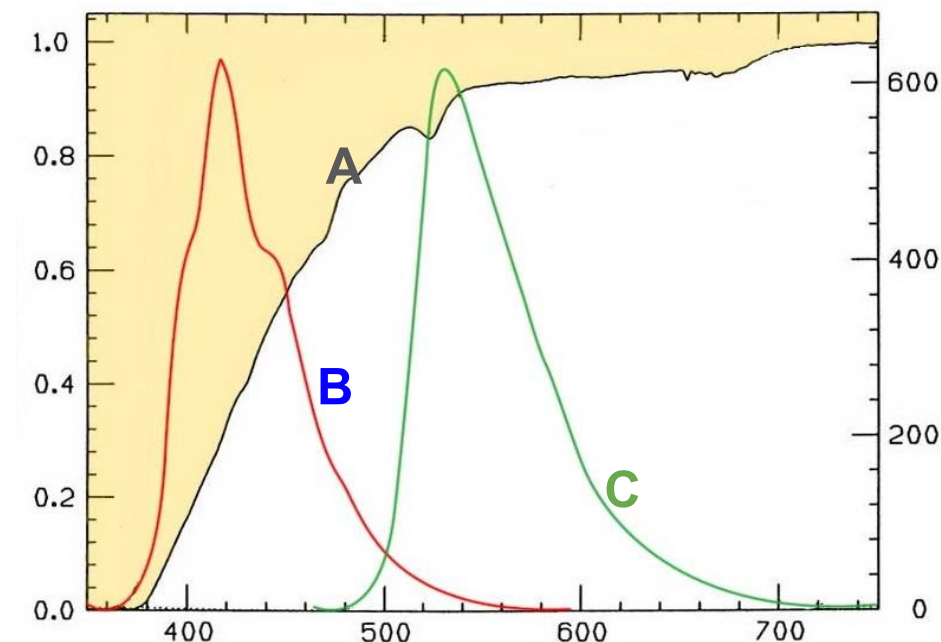
Improving Radiation Hardness by Shifting the Emission Spectrum



PS with 3-HF
 $D_{1/2} = 12$ Mrad



Conventional PS: 5 Mrad

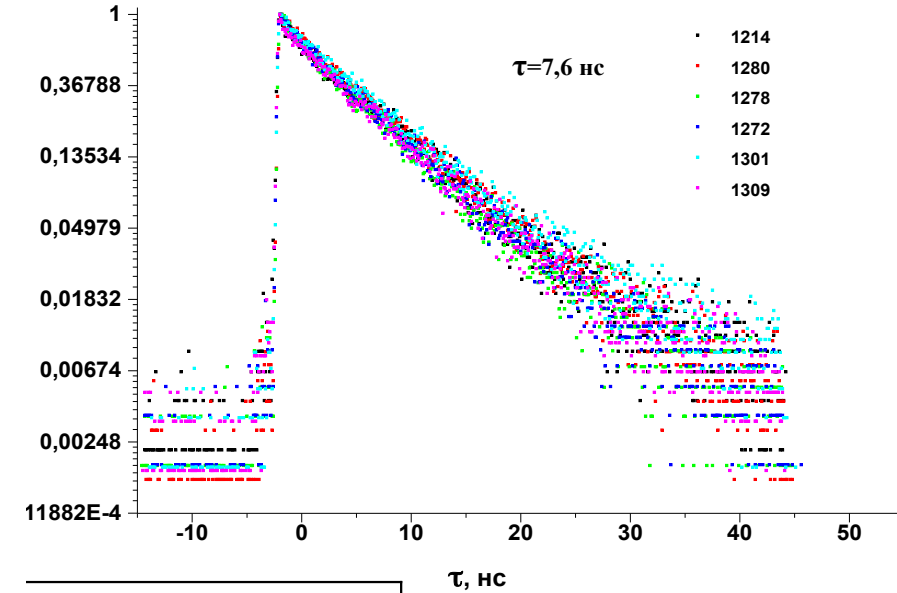
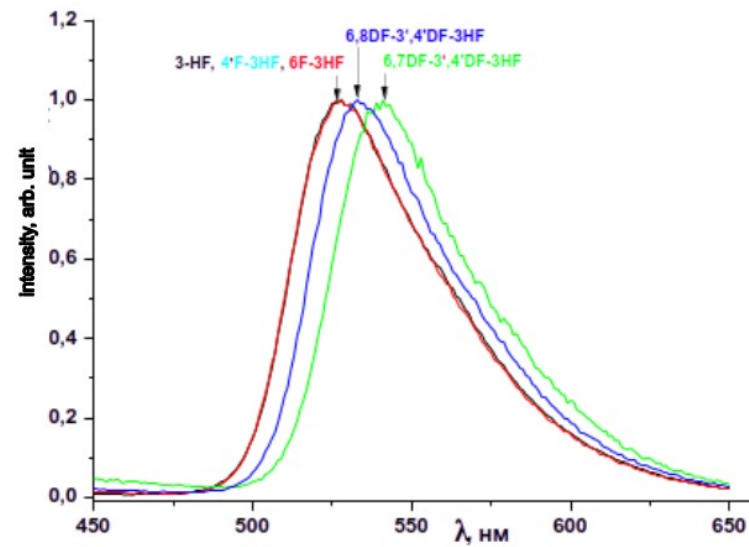
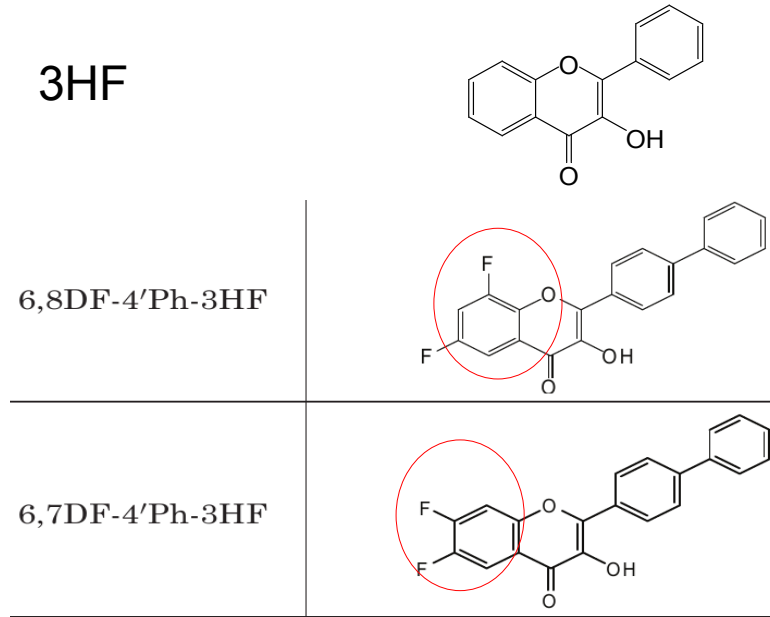


A – Polystyrene transmittance after irradiation to a dose of 10 Mrad;
B – POPOP luminescence;
C – 3-HF luminescence

Polystyrene remains transparent in the green spectral region, but the activator degrades under irradiation.

Further improvement in radiation hardness requires stabilization of the activator.

Radiation Hardness of Scintillators with Fluorinated 3HF Derivatives



Composition of Polystyrene-Based Plastic Scintillators, wt. %	L ₀ , %	L, %
2 3-HF	31,5	20,3
2 4'-F-3HF	30,6	20,9
2 6F4'-F-3HF	30,4	21,4
2 6,7DF-3',4'DF-3HF	28,0	21,4
2 6,8DF-3',4'DF-3HF	20,9	16,1
UPS-923A 2 p-TP + 0,02 POPOP	100	-

Adhesive Compositions

The adhesive composition performs several functions:

- Mechanical bonding
- Scintillation light reflection
- Optical isolation of adjacent elements

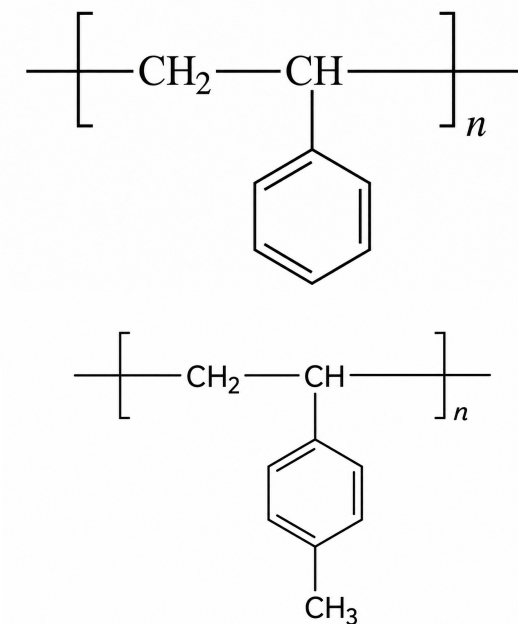
Polysiloxane-based adhesives – unsatisfactory mechanical properties

Acrylic-based adhesives – insufficient radiation resistance

Epoxy resin-based adhesives – composition optimization required

Optimization Parameters

- Adhesion to the scintillator material
- Adhesive polarity
- Adhesive strength
- Thermal expansion mismatch between the adhesive and the scintillator
- Residual stresses



PS and PVT are weakly polar polymers

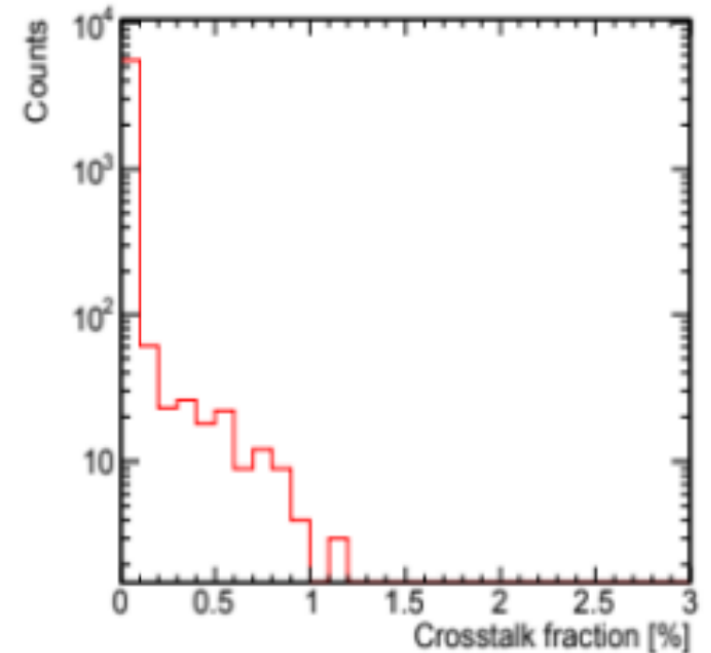
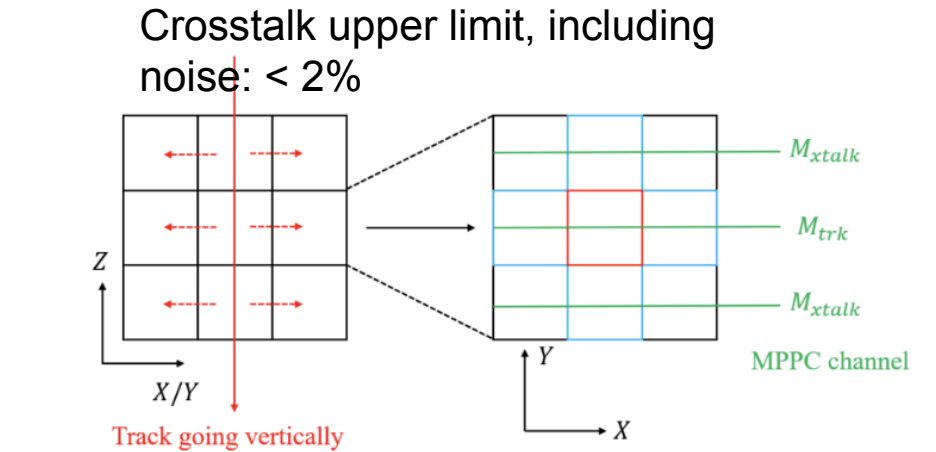
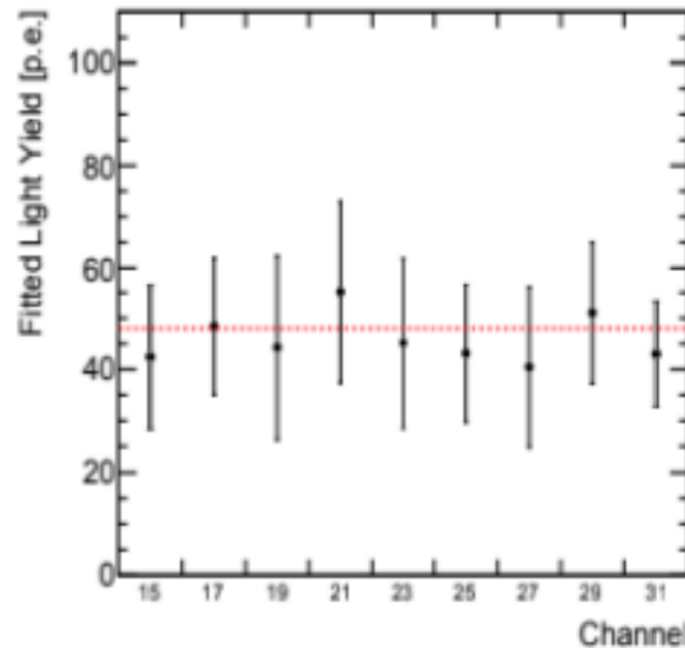
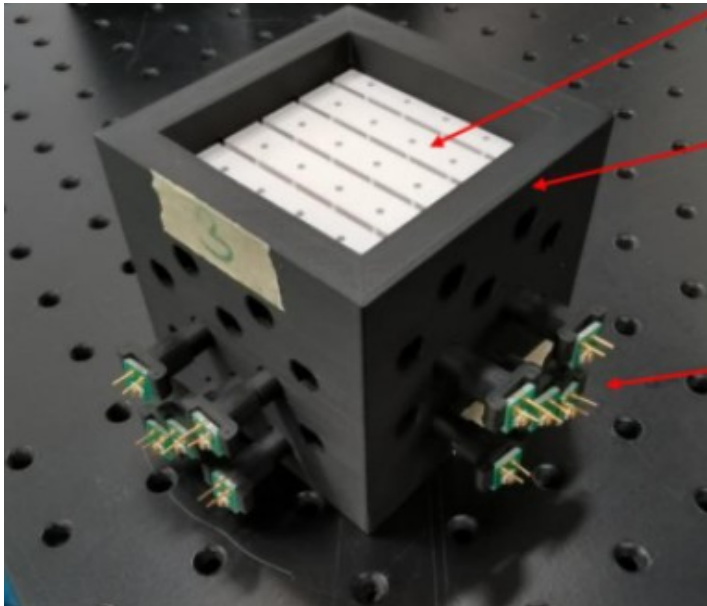
TiO₂-Filled Epoxy Compositions

Readout:

- Kuraray Y11 WLS fiber, Ø1 mm
- Hamamatsu S13360-1350CS MPPC

JINST 17 P10045 10.1088/1748-0221/17/10/P10045

Cosmic-muon light yield: 50 p.e.

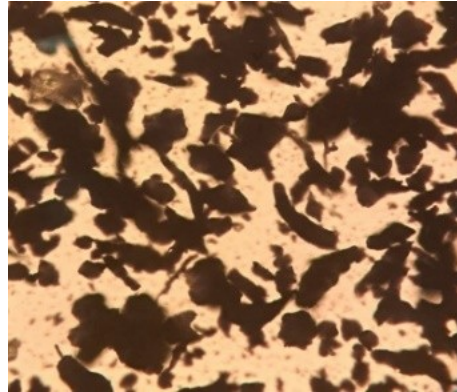


Tungsten-Powder-Based Absorber

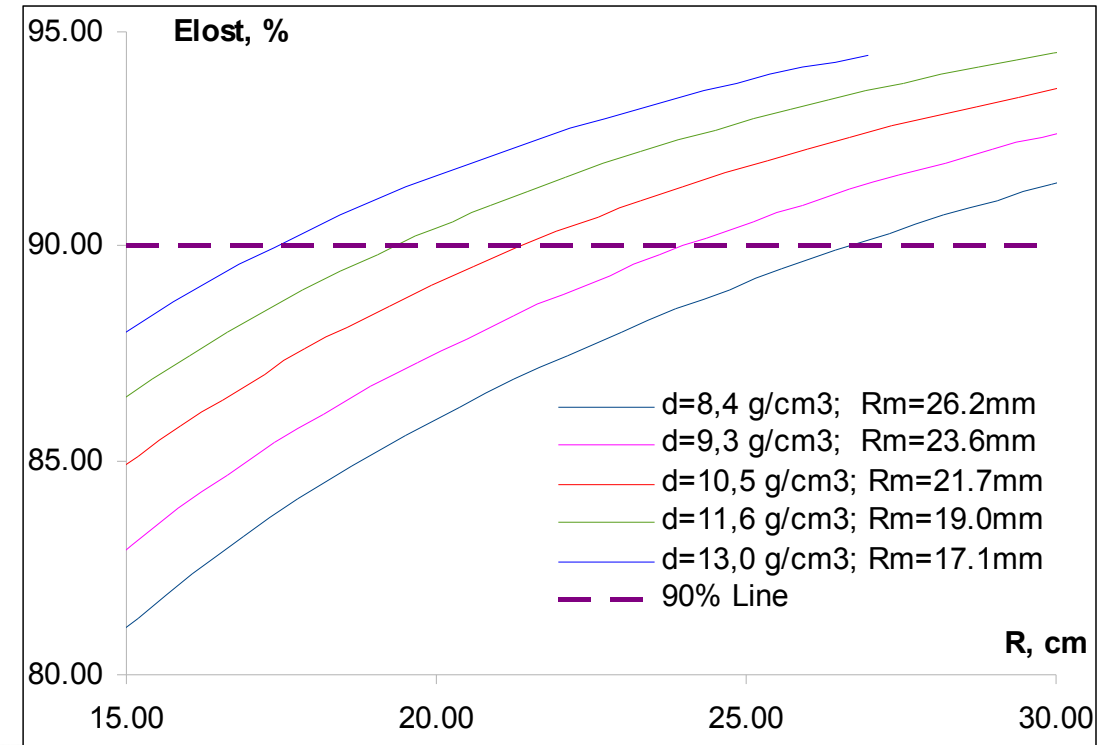
Commercially Available Tungsten Powder



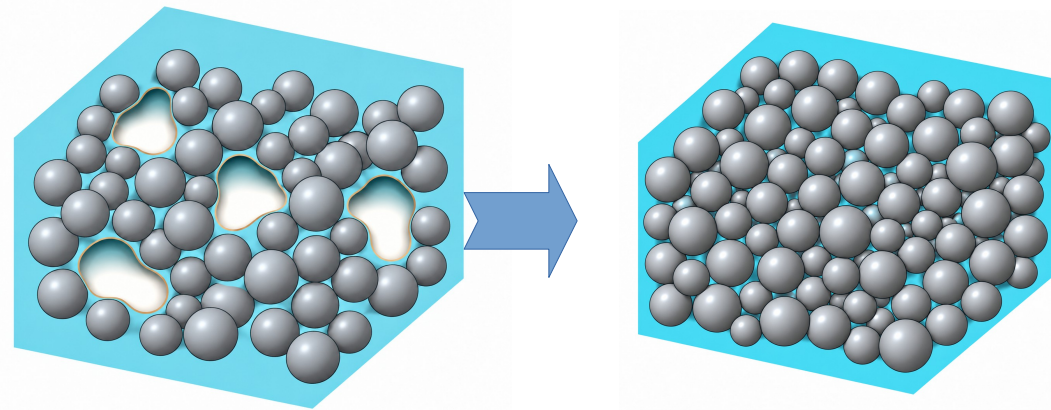
tap density
12,5 - 13,5 g/cm³



tap density
≈ 10 g/cm³



Target density of the finished absorber: not lower than the tapped density of the tungsten filler

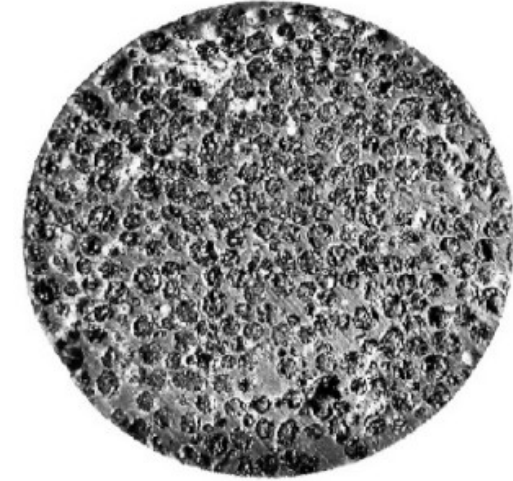
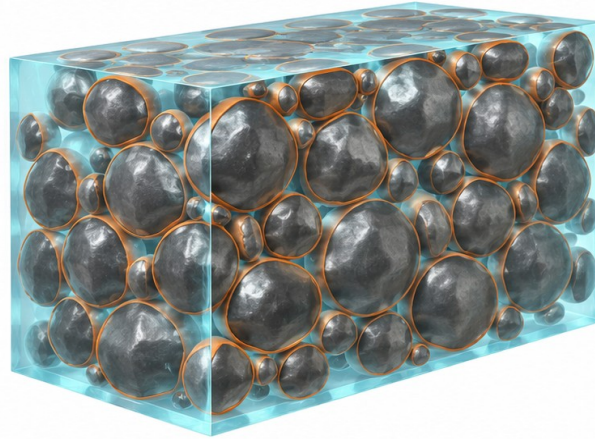


Surface Modification of Tungsten Powder

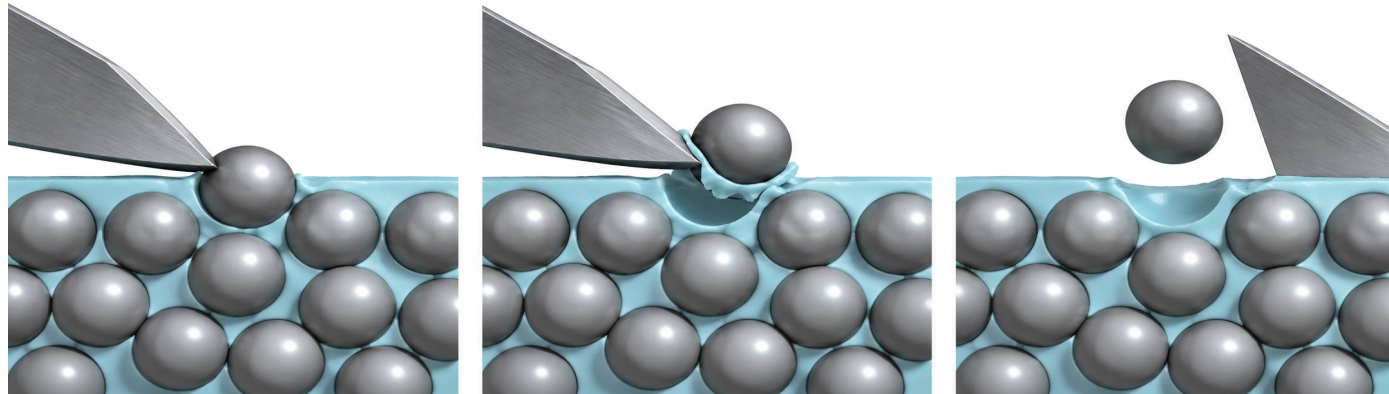
W

Primer

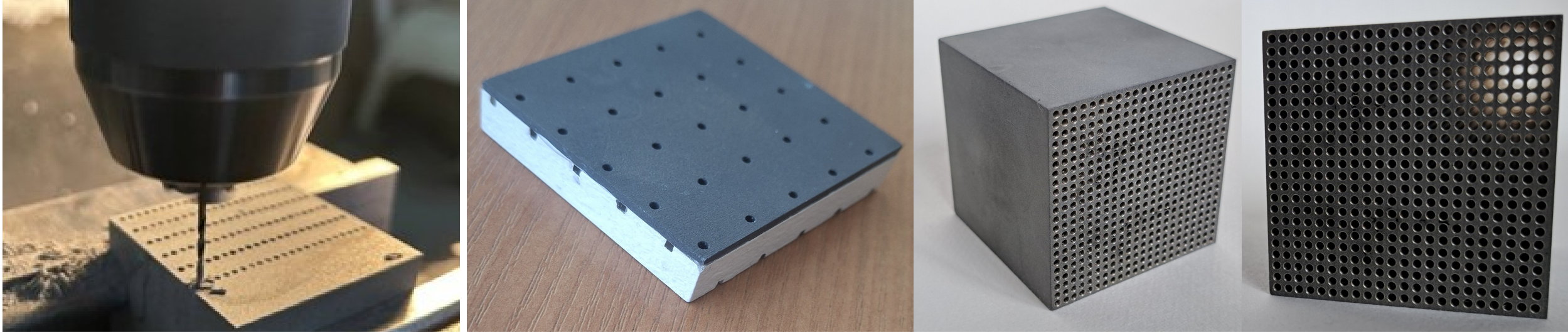
Composite



During machining, tungsten particles are pulled out of the matrix rather than cut.



Absorber with Tungsten Powder

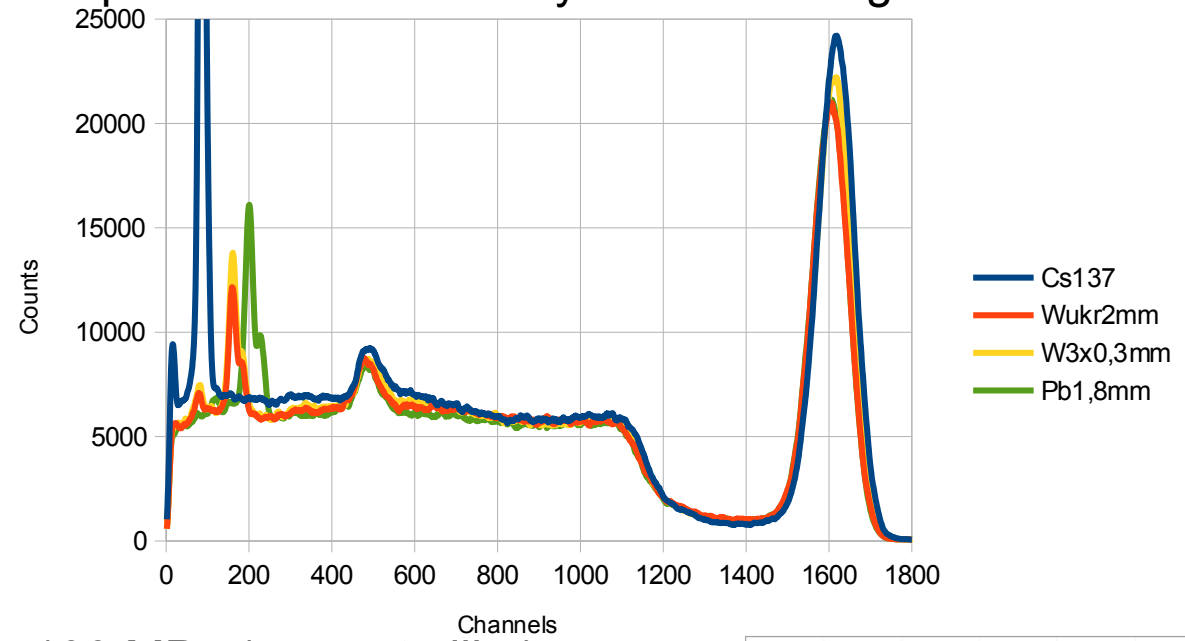
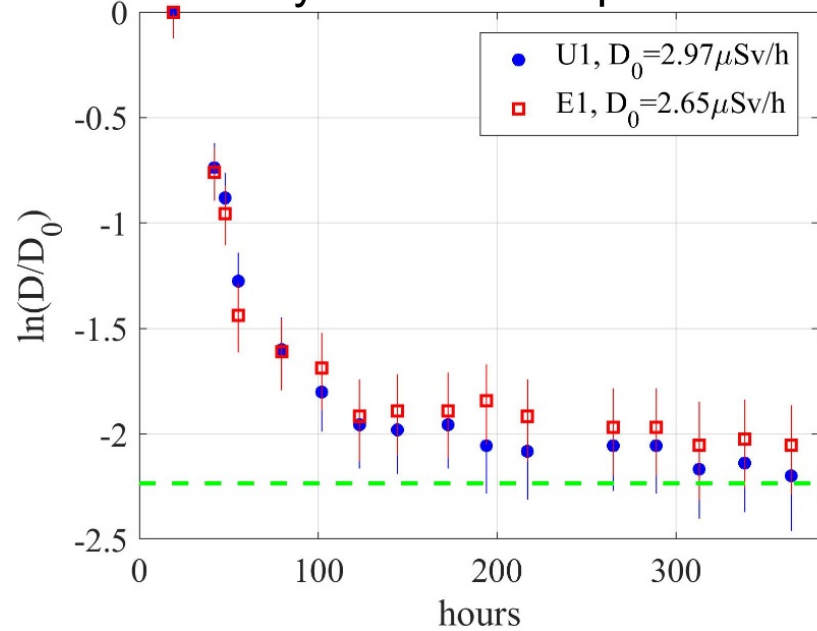


- Absorber density ranges from 10 g/cm^3 for flat particles to 13.5 g/cm^3 for rounded particles.
- Radiation hardness comparable to that of the epoxy resin
- Absorber fabrication does not require high temperatures and involves no toxic processes.
- Use of standard equipment

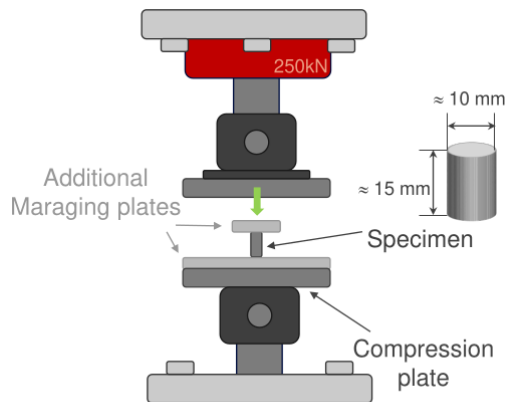
*** This technology developed in cooperation between ISMA, INFN Bologna, IJCLAB and CERN.**

Absorber Characterization

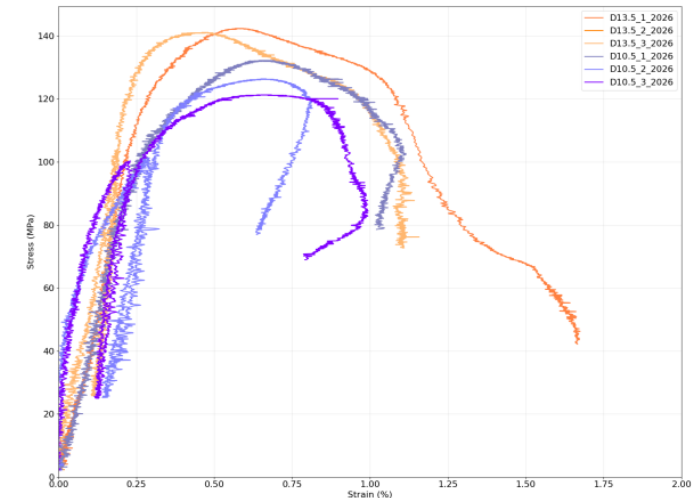
A 2 mm layer of the composite absorber is equivalent to a 1 mm layer of solid tungsten.



Compressive strength 100 MPa (concrete like)



Density	$\sigma_{0.2}$ (MPa)	σ_{UTS} (MPa)	E_{eng} (GPa)	ν
10.5	123.6	129.9	42	0.87
10.5	123.4	124.1	49	0.66
10.5	109.7	118.9	47	0.338
13.5	136.7	140.2	57	0.71
13.5	135.5	136.4	-	-
13.5	138.8	138.8	50	0.57



As conclusion

- Flexible industrial technologies have been developed for the fabrication of scintillation elements for HEP calorimeters without the use of specialized equipment.
- We developed plastic scintillators with fluorinated 3HF derivatives. Their radiation hardness is 2.5 times that of standard plastic scintillators.
- A material and fabrication technology for tungsten-powder-based absorbers have been developed, where a 2 mm layer is equivalent to 1 mm of solid tungsten.

Thank you for your attention.