# The reSPECT project for a flexible and fast total body nuclear imaging diagnoses with high-Z organic scintillators

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- ▶ Use **plastic scintillators** instead of inorganic crystals to profit from their fast signal, ease of manipulation and low cost.
- ▶ Plastic scintillators are not optimised for the detection of gamma rays via photoelectric effect.
- ▶ The idea is to enrich our organic scintillators with high-Z impurities (e.g. Bismuth or Cerium) [1]

[1] Mattiello L;, Patera V.; Belardini A.; Rocco D.; Marafini M.; Organic Scintillator. *Patent WO2023156957A1, 2023.*

## The reSPECT detection system


Rotating detection Ring
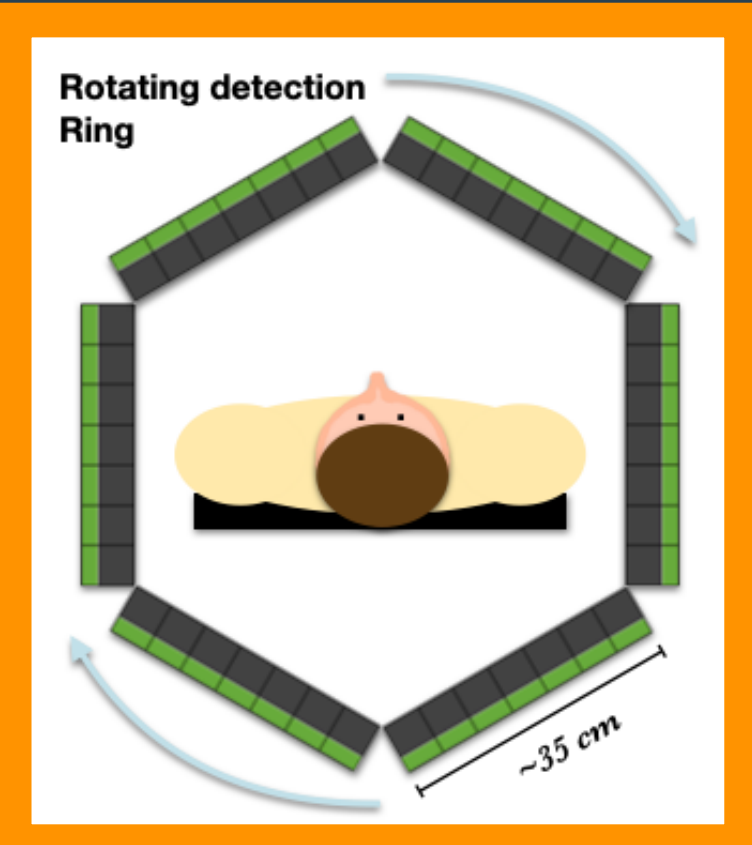
The **reSPECT detection system** will have a modular structure able to revolve around the patient, enabling multi-angle data acquisition.

Each module will consist of a 3D-printed tungsten frame that serves both as a collimator and as a container of the scintillator segments.


MODULE Side View


Scintillator Side View
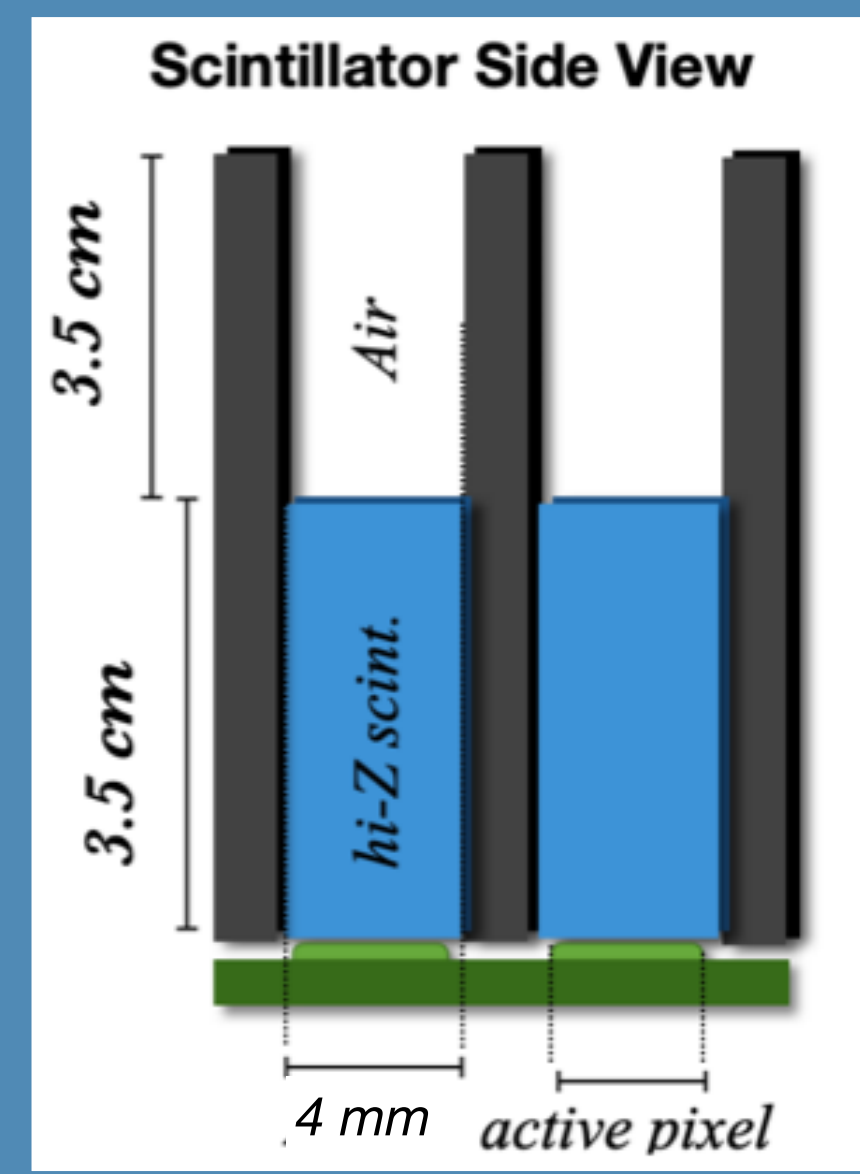
The readout will be performed by SPAD array silicon-based photodetectors arranged in small-size pixels, individually coupled to the scintillator segments. The Polymerisation occurs directly inside the holes.



FPGA matrices will be placed on the back of each module to pre-process the acquired data.
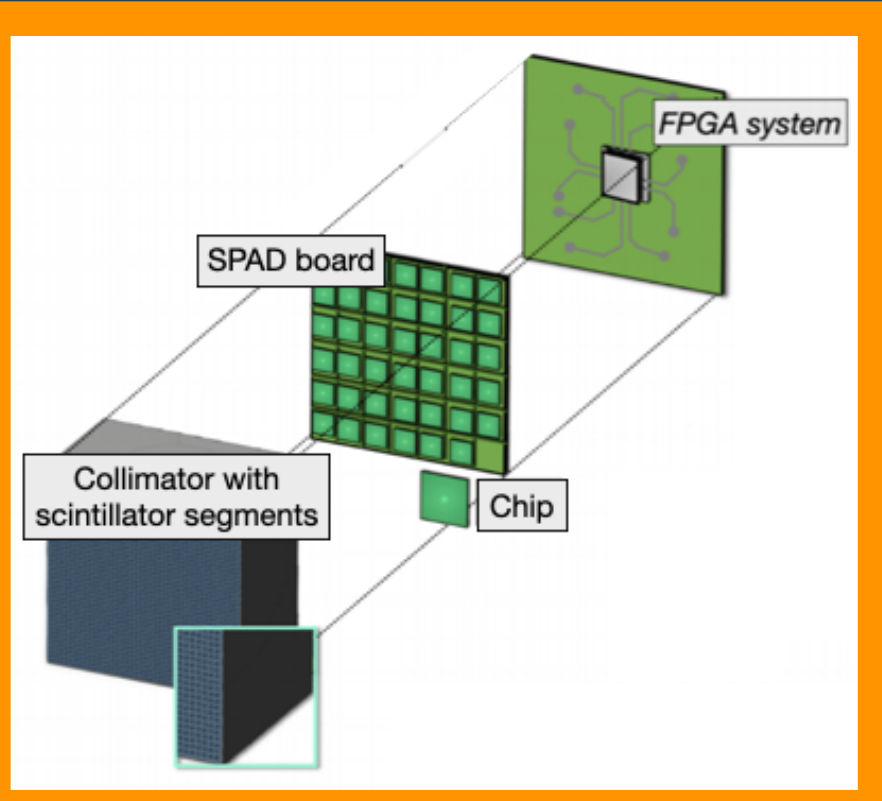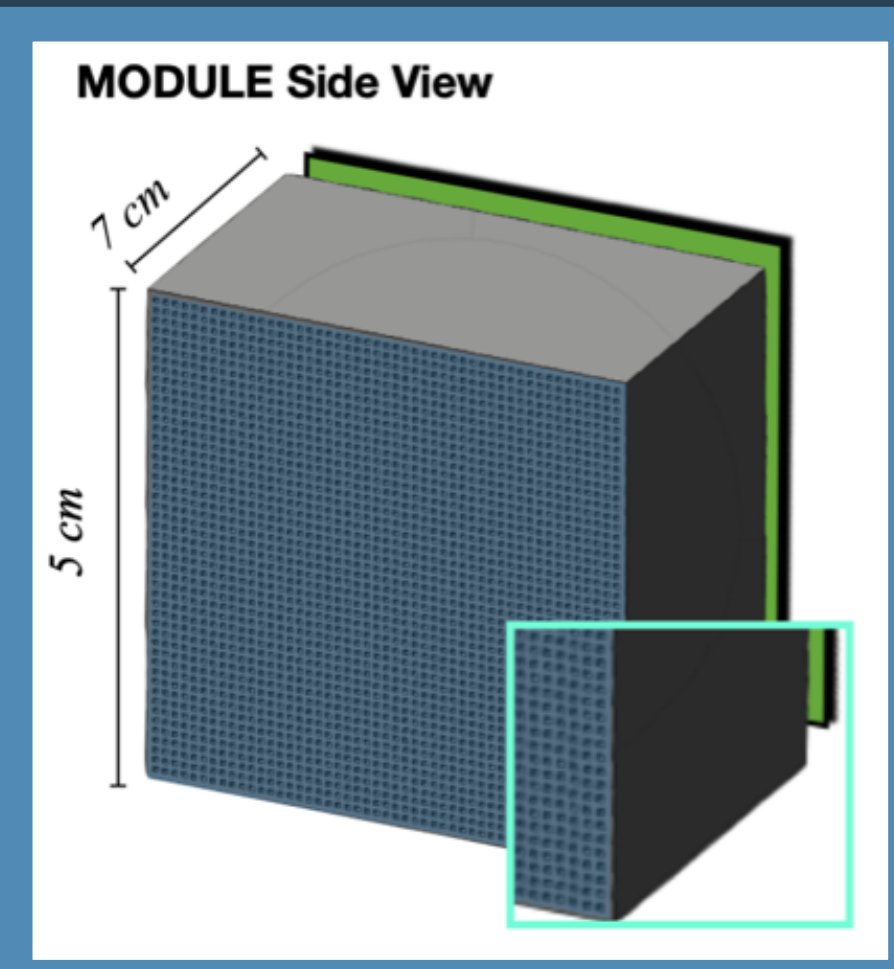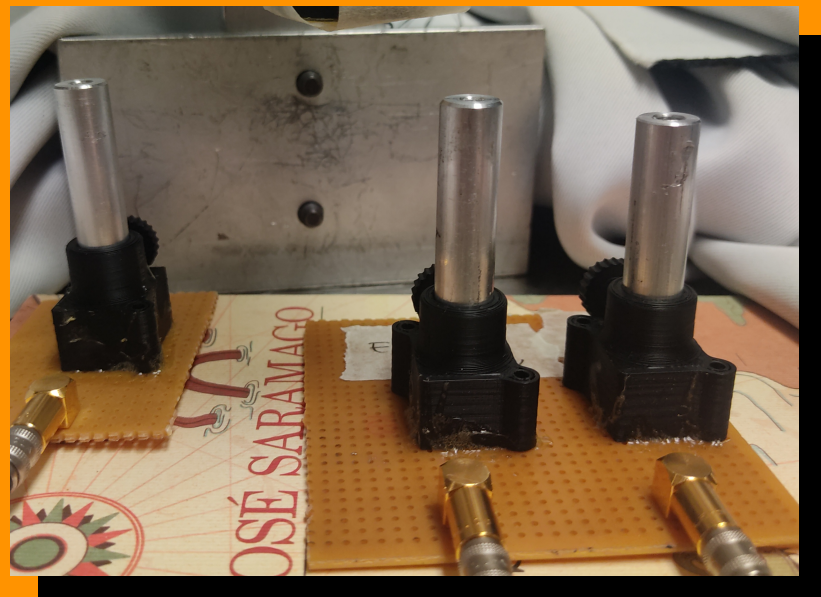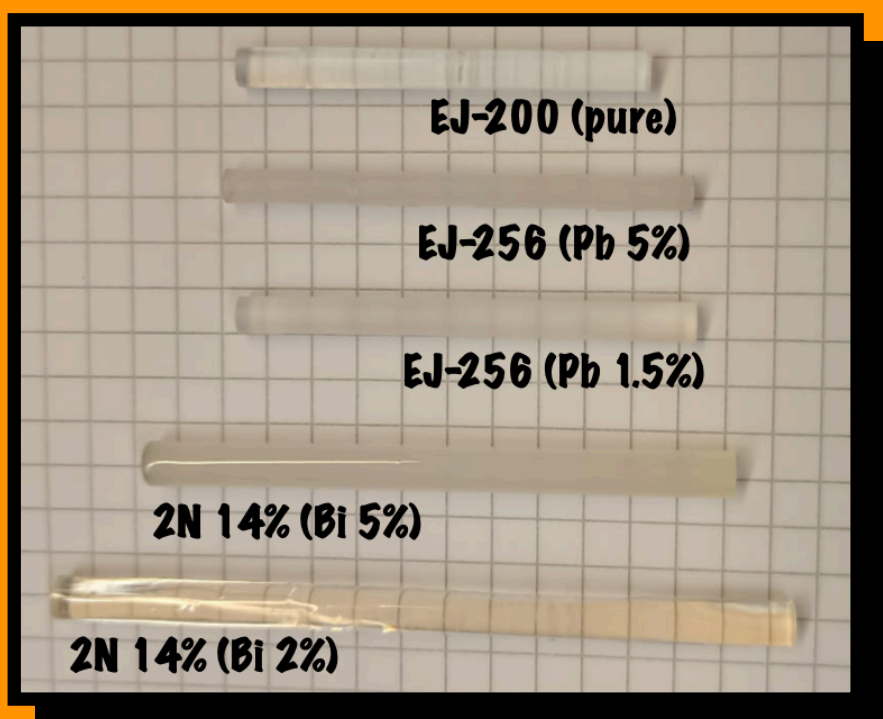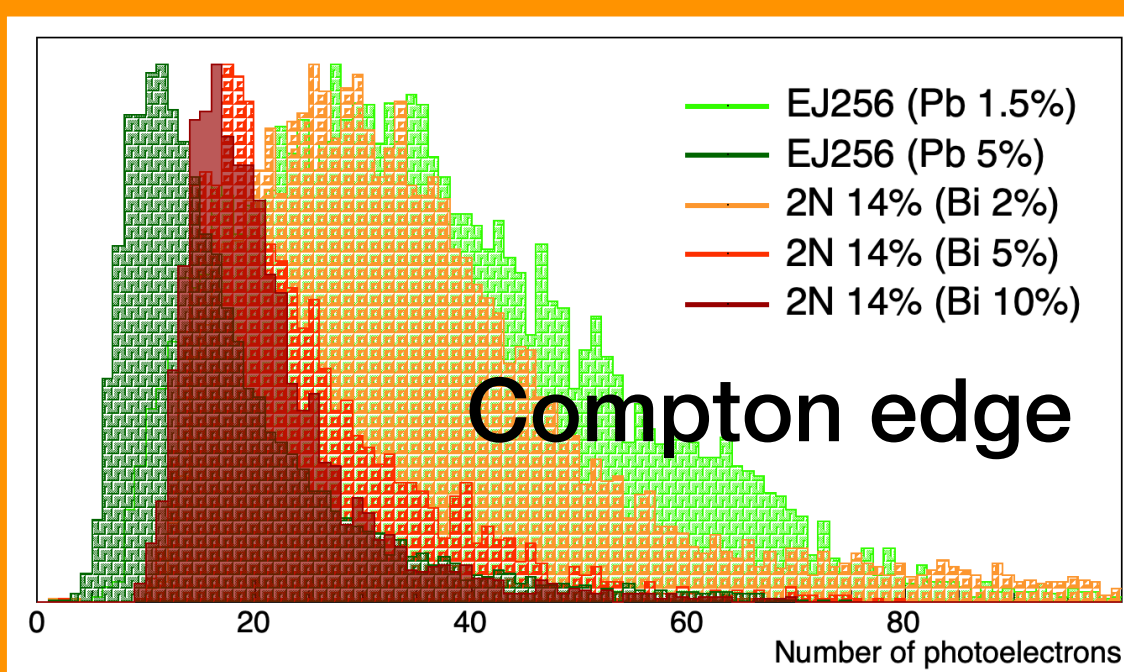
## High-Z plastic scintillators

- ▶ We produced samples of high-Z organic scintillators
- ▶ Transparency turns out to be good up to very high concentrations
- ▶ We performed test with laboratory sources and different readout systems


+ Bi 2%   + Bi 4%   + Bi 10%

PVT matrix
high-Z impurities
(Bismuth 2-10%)

| Sample | Light Output [a.u.] | Ph.el |
|---|---|---|
| New 2% Bi | 100 | + |
| New 4% Bi | 71 | ++ |
| New 10% Bi | 67 | +++ |


- EJ256 (Pb 1.5%)
- EJ256 (Pb 5%)
- 2N 14% (Bi 2%)
- 2N 14% (Bi 5%)
- 2N 14% (Bi 10%)

Compton edge

Number of photoelectrons


EJ-200 (pure)
EJ-256 (Pb 5%)
EJ-256 (Pb 1.5%)
2N 14% (Bi 5%)
2N 14% (Bi 2%)

$^{22}$Na source

Readout with a SiPM

## Expected performances

- ▶ The expected performances of the reSPECT detection system have been obtained through **Monte Carlo simulations.**
- ▶ The simulated scintillators have a **10% Bismuth** concentration.
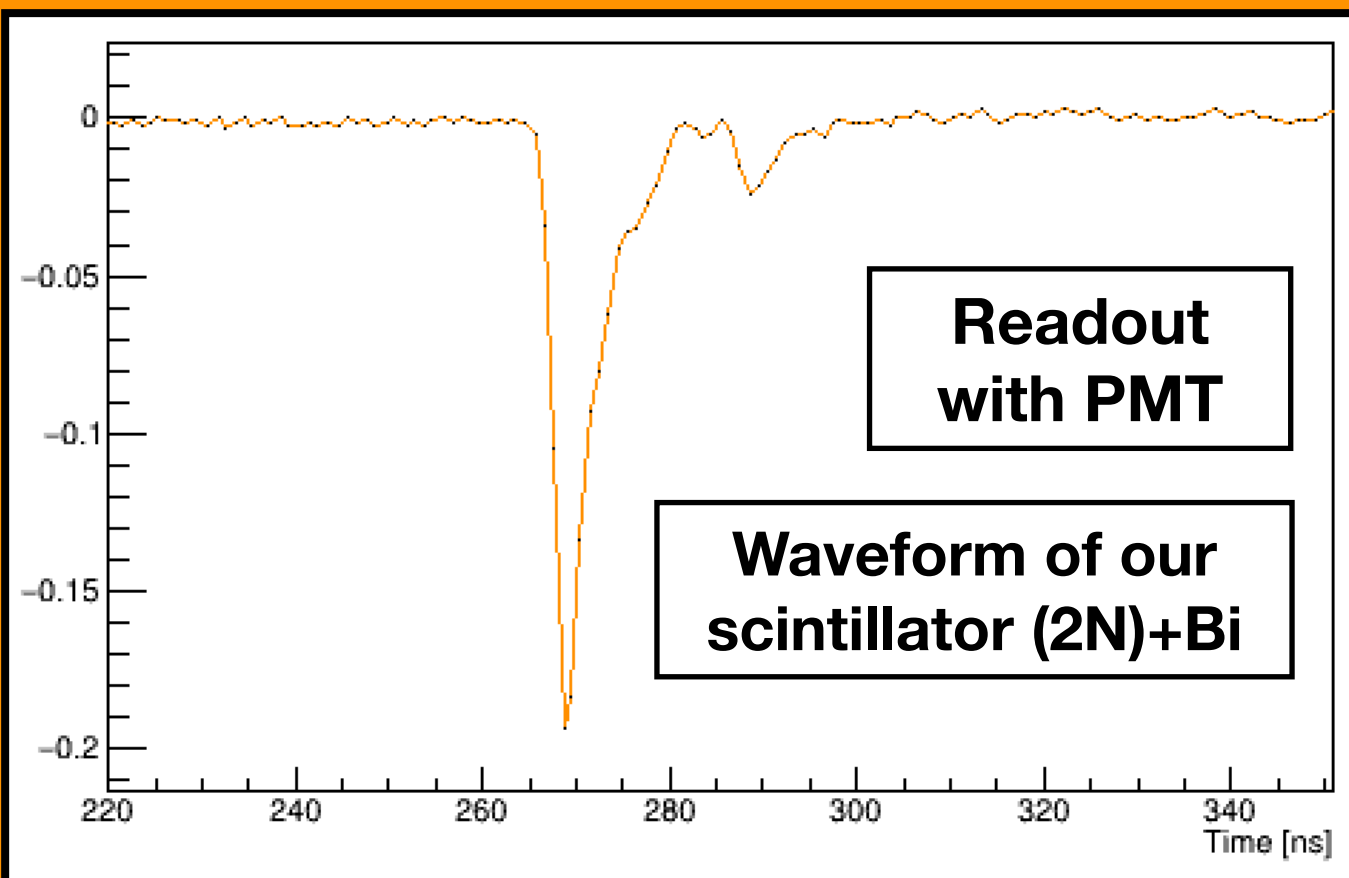- ▶ The reSPECT detection system allows to realize a **total-body SPECT.**

| SPECT DETECTION SYSTEM | SENSITIVITY PER MODULE @140 keV | SYSTEM SPATIAL RESOLUTION (FWHM) @10 cm | DECAY TIME | RATE CAPABILITY | TOTAL COST | MRI COMPLIANCE | RADIOMETABOLIC DOSIMETRY COMPLIANCE |
|---|---|---|---|---|---|---|---|
| Anger Camera (NaI) FoV: 53 x 39 cm² | 170 cpm/µCi | 7.4 mm | 250 ns | 0.25k-3k cps/cm² | $$ | ✗ | ✗ |
| CZT FoV: 39 x 51 cm² | 190 cpm/µCi | 7.6 mm | 350 ns | 30k-700k cps/cm² | $$$ | ✓ | ✗ |
| reSPECT 6 rotating blocks, FoV: 35 x 35 cm² | 184 cpm/µCi (energy cut @80 keV) | 8.9* mm (2 mm pixels) | 2-5 ns | 50M-200M cps/cm² | $ | ✓ | ✓ |

*The spatial resolution can be improved by adjusting the geometrical parameters.

- ▶ We produced samples of high-Z organic scintillators polimerised in TEFLON in order to study the matching with this material
- ▶ Results show a very good collection efficiency and transparency



| Sample | Light Output [a.u.] | Ph.el |
|---|---|---|
| New 0% Bi | 100 | - |
| New 2% Bi | 20 | To do |
| New 10% Bi | Ongoing | To do |


Readout with PMT

Waveform of our scintillator (2N)+Bi

- ▶ The performances of the scintillator prototypes produced have been compared with those of the commercial alternatives (Eljen Technology) in terms of light output and time resolution.
- ▶ The MC simulations showed that a 10% Bismuth concentration is needed to ensure good imaging performances.
- ▶ We realised a 10%-doped sample with promising results: such dopant concentrations are not available on the market.

| Sample | Measured #photoelectrons |
|---|---|
| EJ-256 (Pb | 45 ± 10 |
| EJ-256 (Pb | 14 ± 1 |
| 2N 14% (Bi | 42 ± 3 |
| 2N 14% (Bi | 17 ± 2 |
| 2N 14% (Bi | 21 ± 1 |

Light collection efficiency is crucial in this geometry!

## Timing performances

- ▶ The scintillator exploited and enriched shows also better performances in terms of timing wrt to commercial loaded scintillators.
- ▶ Open possibilities for PET applications.

| Sample | Time Resolution (Statistic Error) |
|---|---|
| EJ-256 (Pb 1.5%) | (360 ± 17) ps |
| EJ-256 (Pb 5%) | (520 ± 31) ps |
| 2N 14% (Bi 2%) | (233 ± 13) ps |
| 2N 14% (Bi 5%) | (278 ± 33) ps |
| 2N 14% (Bi 10%) | (340 ± 46) ps |

## NEXT STEP