Design and development of a miniaturized detector for radionuclide determination in automated flow system

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LaboRA Laboratorio de Radiactividad Ambiental

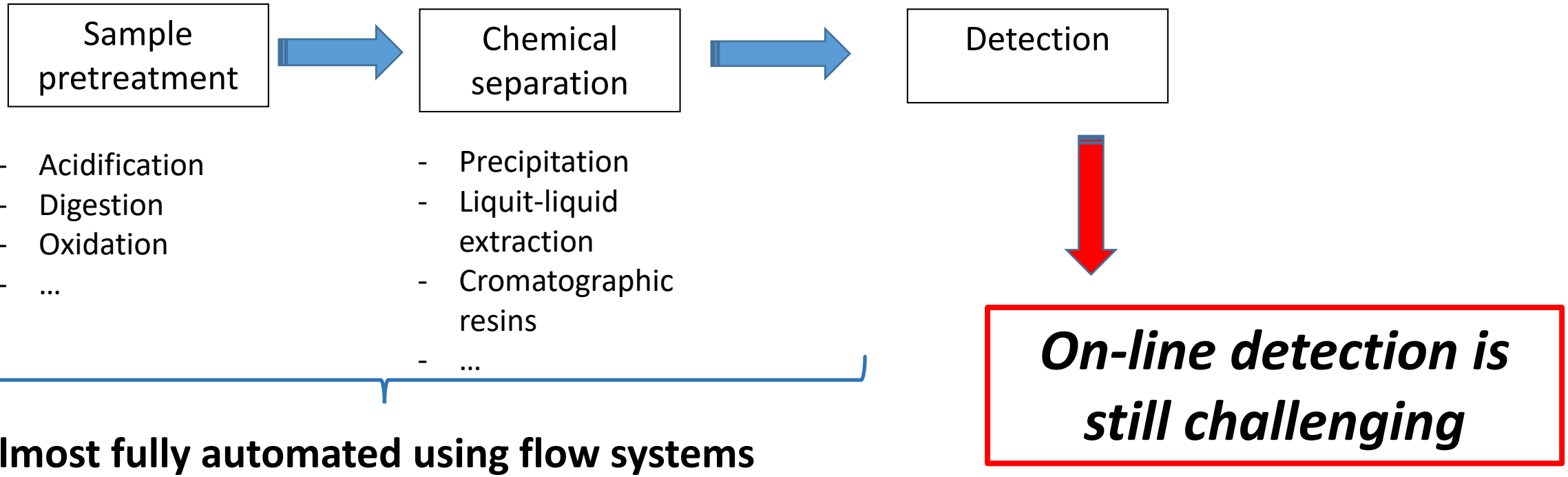
iC Málaga Integrated Circuits

SCIWARE SYSTEMS S.L.

UIB Universitat de les Illes Balears

Radionuclide detection and identification

Radiochemical analysis



Almost fully automated using flow systems

- ❑ Minimal handling of samples and standards, improving the safety of the analyst
- ❑ High reproducibility
- ❑ Decrease in time of analysis, reduction of sample and reagent consumption

On-line detection

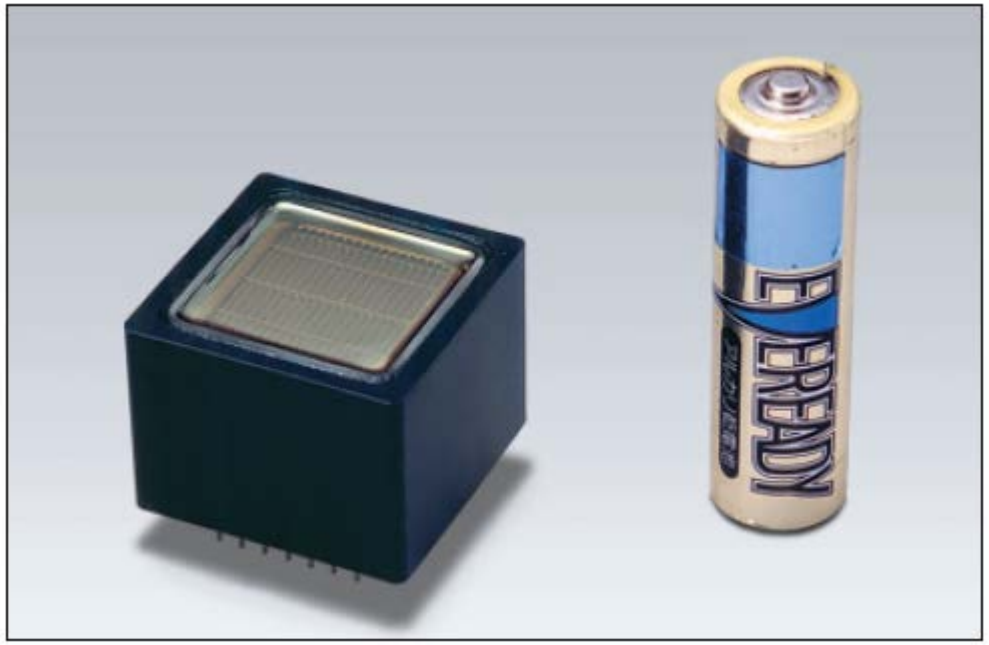
Goal: Design and build a portable detector, easily acoplable to an automated Flow sample preparation system

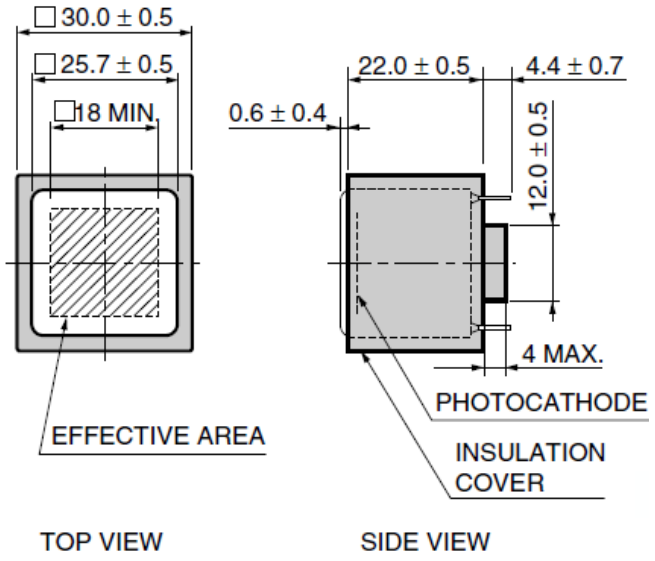
Desired properties:

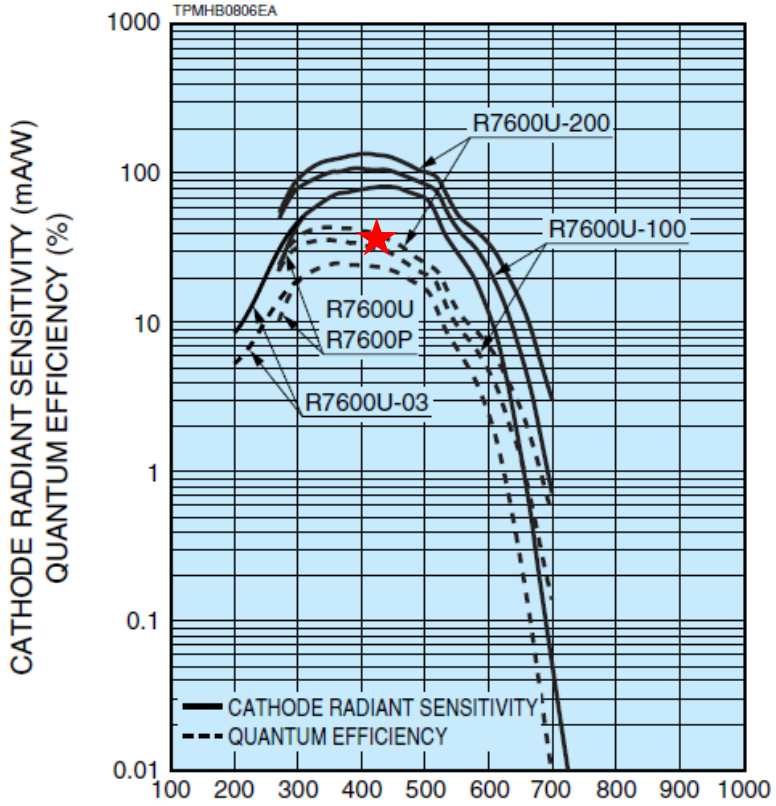
- Small
- Light
- Efficient
- Alpha & beta radiation detection
- Easily tunable to different radionuclide determination

LIQUID SCINTILLATION COUNTING

PMT Selection







Hamamatsu R7600U-200

- Small form factor
- Large detection window, better geometric efficiency.
- Large detection efficiency (35% approx @ 420 nm).

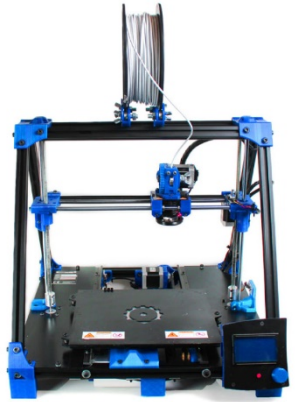
Dark box

Dark and opaque box to integrate different components of the detector (PMT & Scintillation vial) and to isolate them from external light sources.

3D printing design

- ❑ Fast prototype design and manufacture
- ❑ Easy and fast modification of design
- ❑ Usually printed overnight
- ❑ Post-printing treatment: polishing and painting

3D printers & resins



Model: BCN 3D+ (BCN3Dtechnologies)
Technology: FFF – Fused Filament Fabrication
Resolution: 100 – 350 microns
Printing volume: 20.0 x 20.0 x 25.2 cm
Resin: PLA – Polylactic acid

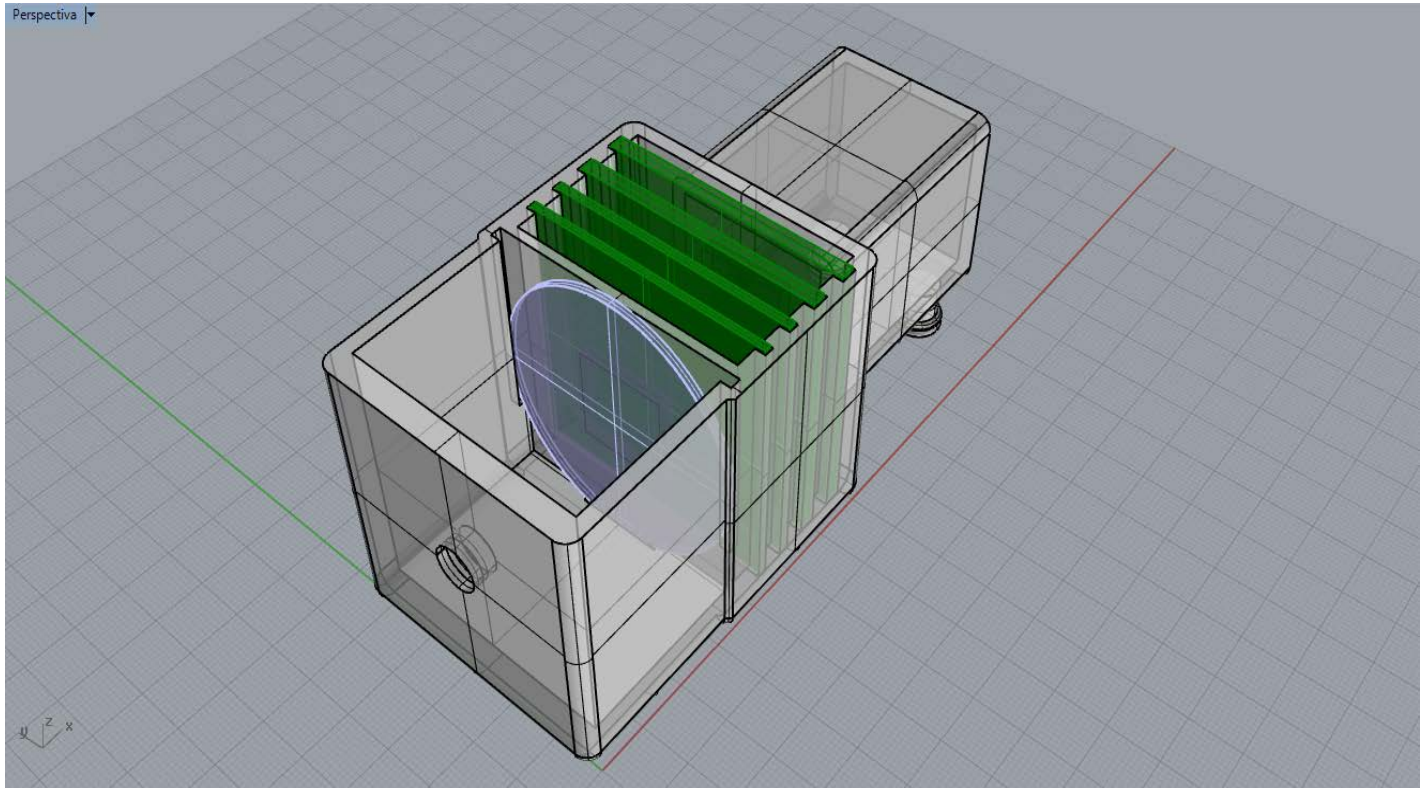
- ❑ Porous
- ❑ Useful to build auxiliar parts of the system, holders and external containers.

Model: Form 1+ (Formlabs)
Technology: (SLA & DLP) Stereolithography and Digital Light Processing
Resolution: 25-100 microns
Printing volume: 12.5 x 12.5 x 16.5 cm
Resin: Methacrylate Photopolymer

- ❑ Non-porous
- ❑ Resistant to acid solutions and other reagents. Useful to build active parts of the flow system.

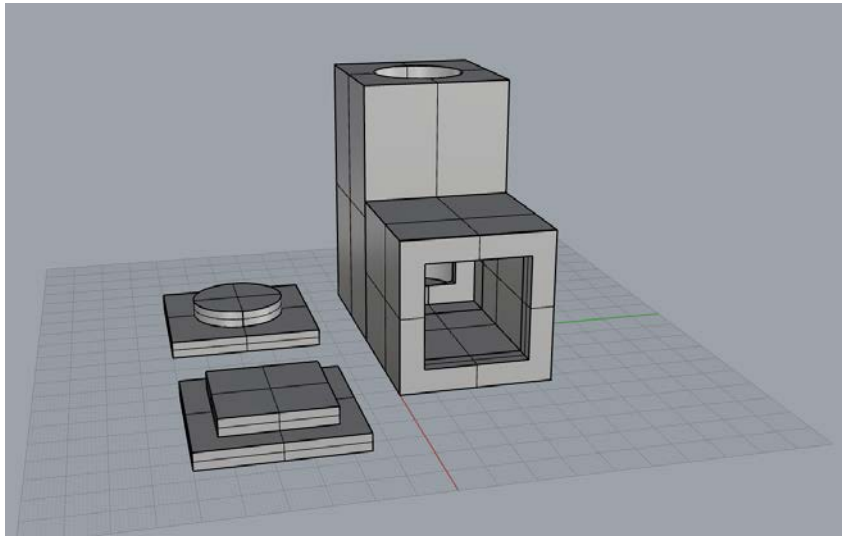
3D-printed dark box (I)

PMT characterization using a 420 nm LED and several Neutral Filters.



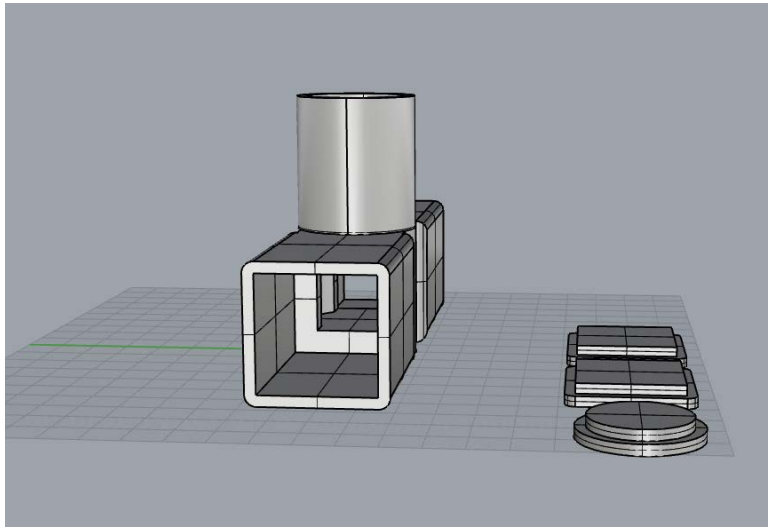
3D-printed dark box (II)

1 PMT



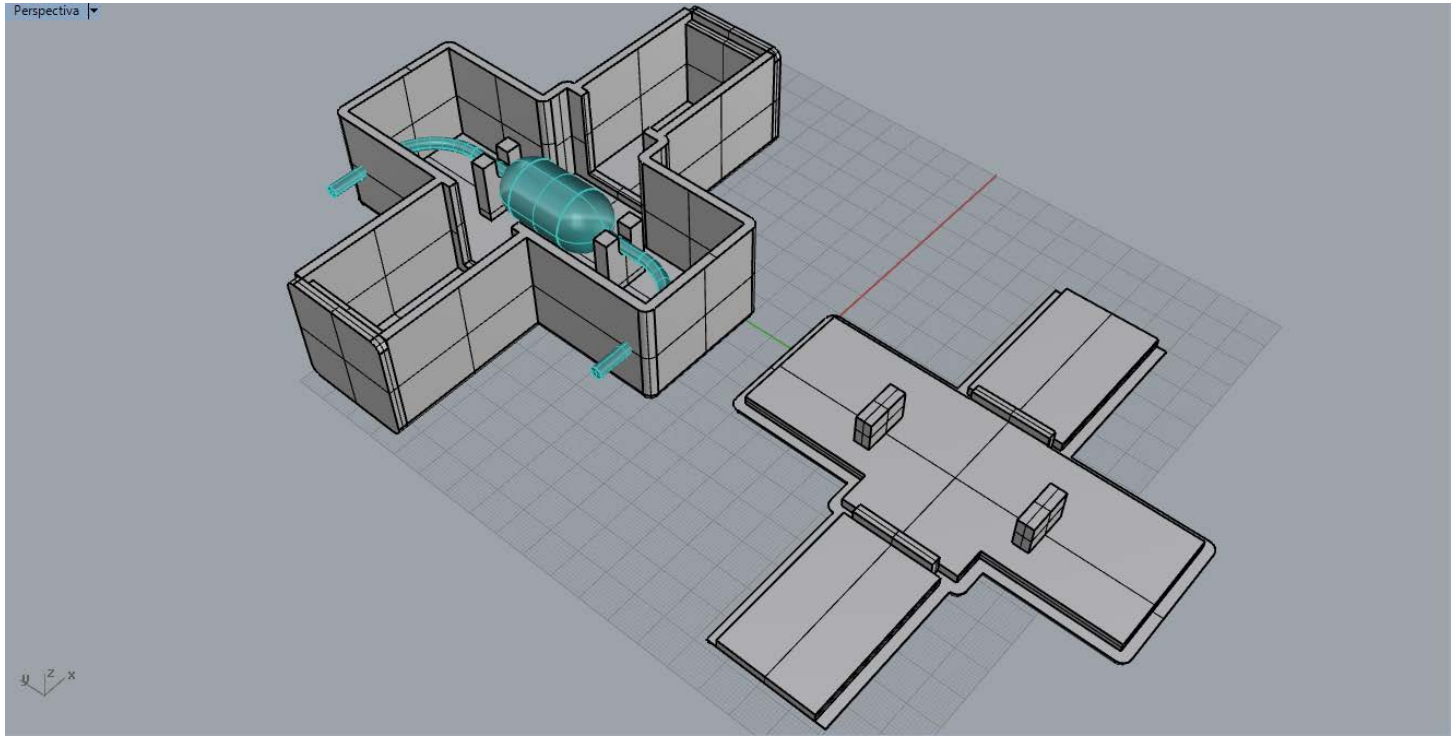
20 ml Scintillation vial

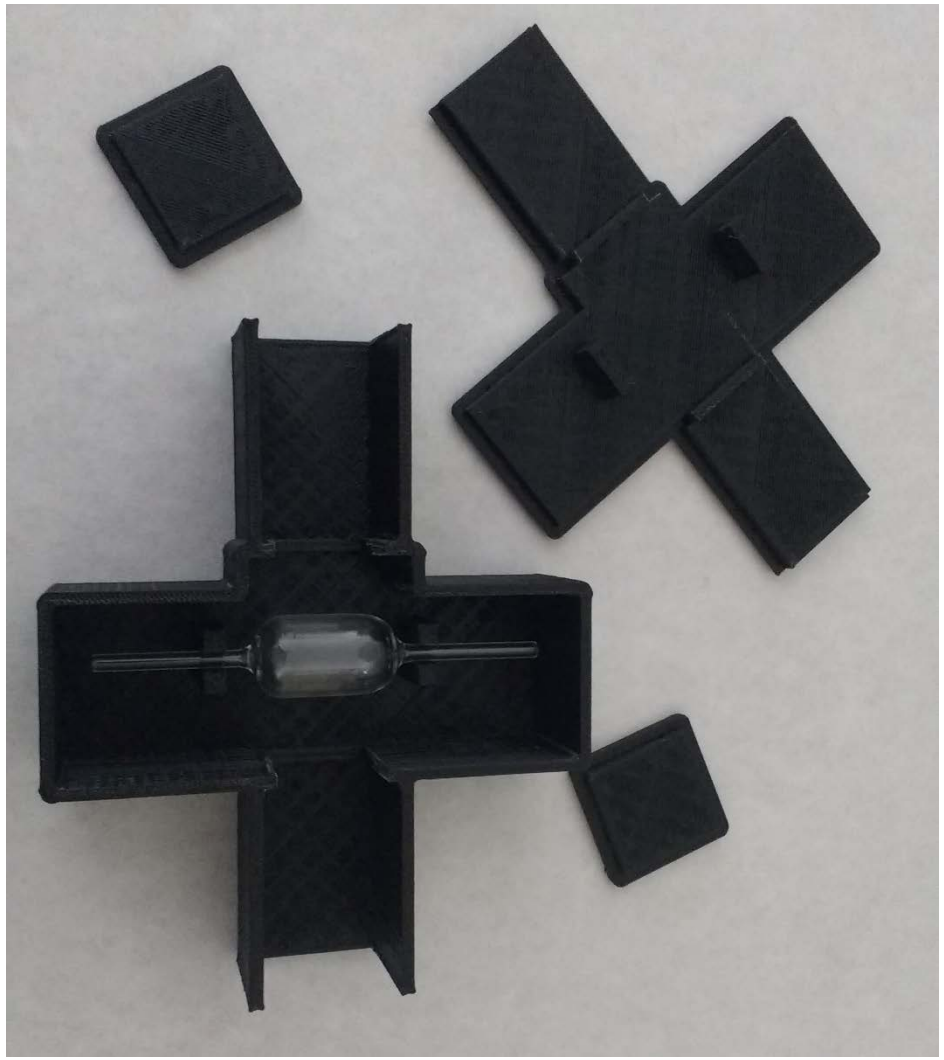
2 PMT



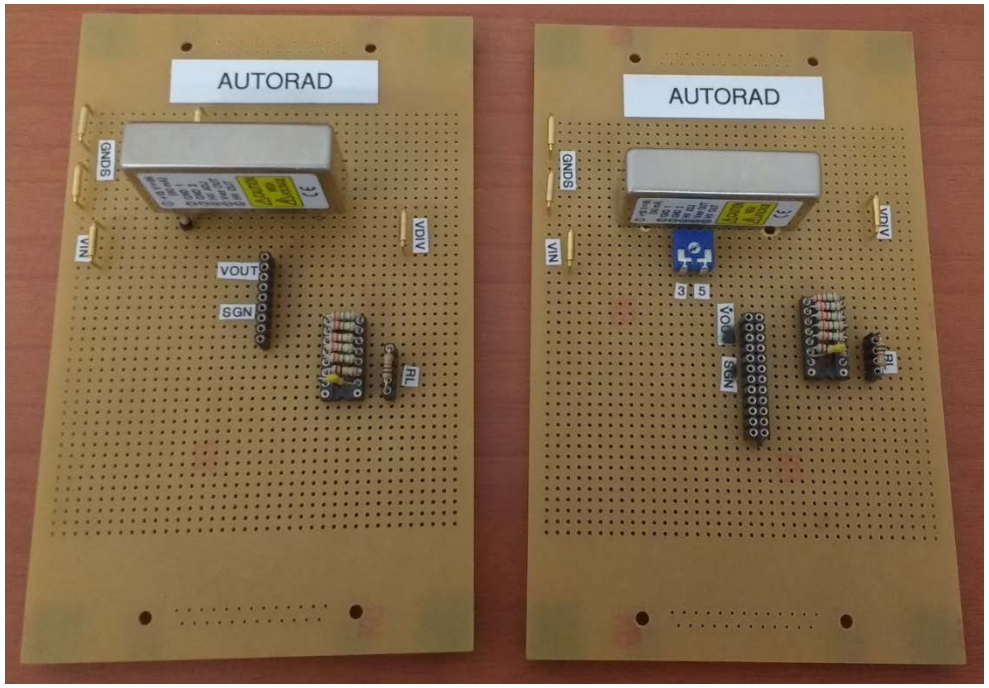
3D-printed dark box (III)

Dark box to hold and integrate PMTs and glass flow counting cell. Aimed to be coupled to the automated flow system.



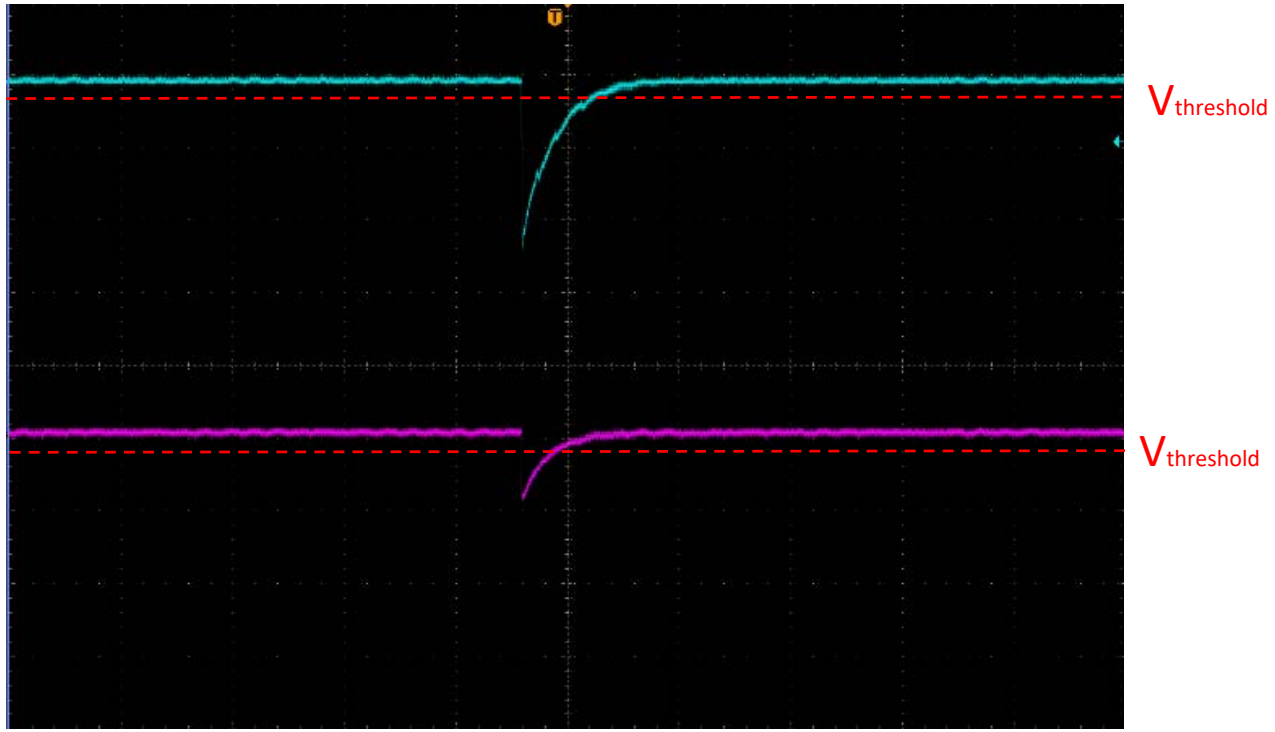


Testing setup



- High voltage power supply: Hamamatsu C4900
- Specific circuit designed to control power supply and signal readout
- Readout performed by Tektronix MDO3024 oscilloscope
- Independent tuning of PMT voltage supply to obtain equivalent gain.

Coincidence counting



- Waveform adquisition and off-line pulse coincidence counting
- $V_{threshold}$ to fire pulse detection signal just above background electrical noise
- Coincidence counting code developed in our laboratory.

Detection efficiency

Beta emitting radionuclides (Sr-90/Y-90)

25-40 %

Testing sample activities: 95 Bq & 190 Bq

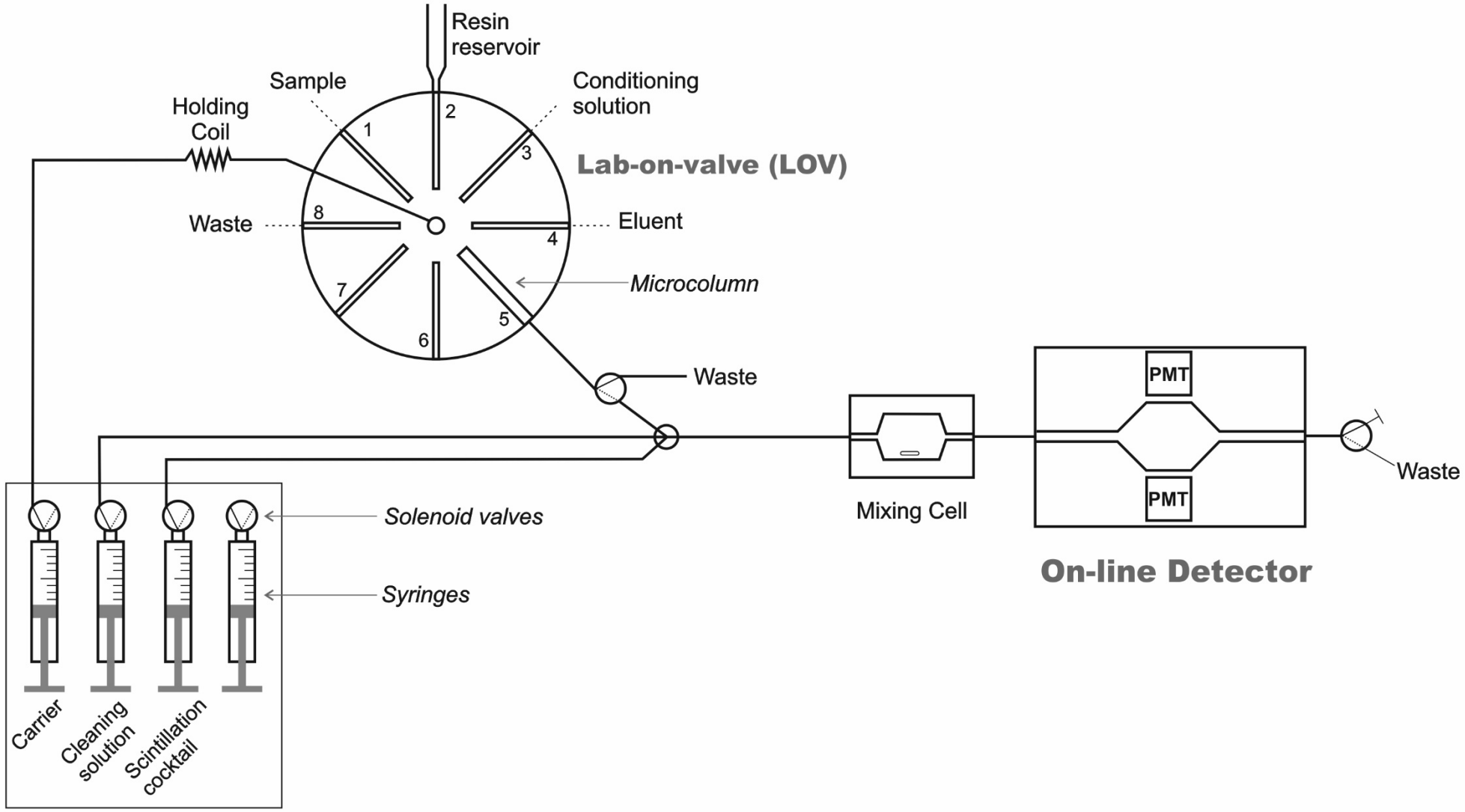
Alpha emitting radionuclides (Am-241)

80-90 %

Testing sample activities: 100 Bq, 200 Bq and 400 Bq

Detection efficiency limited by electronic noise in 1 of the PMT output signals.

Automated separation flow system (Am-241)



Automated separation flow system (Am-241)

Resin: TRU-resin

Conditioning solution: HNO_3 (2 mol L^{-1})

Eluent: HCl 4M

Above 90% recovery with high reproducibility

Cleaning solution: Acetone (80%)

Liquid Scintillation Cocktail: Low viscosity Perkin Elmer Ultima Flow-M (1:2 sample to scintillation liquid ratio)

Tubing: Glass and Polytetrafluoroethylene (PTFE) (∅ 0.8 and 1.5 mm)

Mixing cell: Glass mixing cell via magnet or 3D printed active mixing cell.

LS counting cell: 10 or 20 ml glass cell inside 3D printed module

Signal adquisition and analysis: Tecktronix MDO3024 oscilloscope or ADC with DPP.

Future work (3 months)

- Replacing of damaged HV power supply.
- Analog-to-Digital output conversión with Digital Pulse Processing. On-line event determination (CAEN comercial module)

- Effective coupling of all elements.

Future work (medium-term)

- Additional 3rd PMT (TDCR method)
- Unify computer control of flow system and detection through AutoAnalysis software package (Sciware Systems).