# A novel SiPM-based detector for Time-of-Flight Mass Spectrometry


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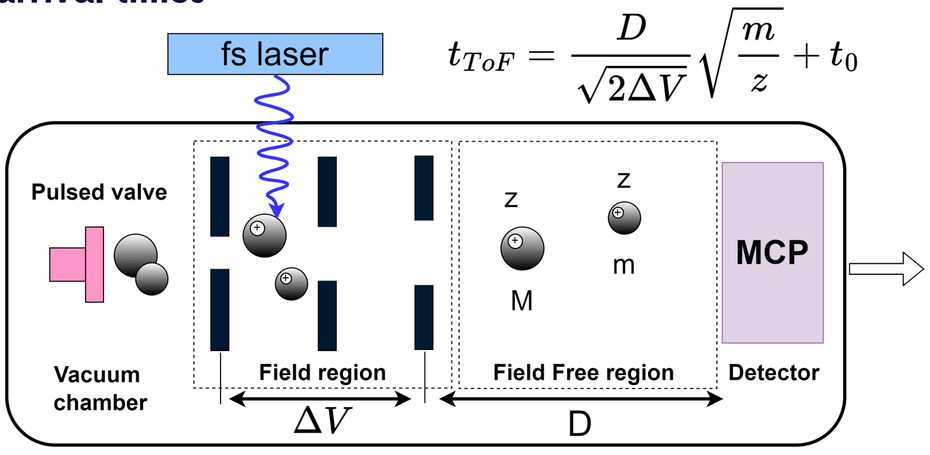
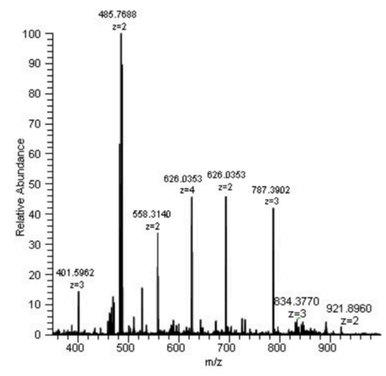
## ToF-MS Spectrometer

**Applications**: personalized medicine , study chemical reaction dynamics, enviromental studies, planetary science, ...

**Molecules** are **dissociated** and **ionized** by **fs laser** --> **ions** are **accelerated** by an **electric field (3-10 kV)** --> **ions** with **larger mas-to-charge ratio** have **longer arrival times**

$$t_{ToF} = \frac{D}{\sqrt{2\Delta V}}\sqrt{\frac{m}{z}} + t_0$$



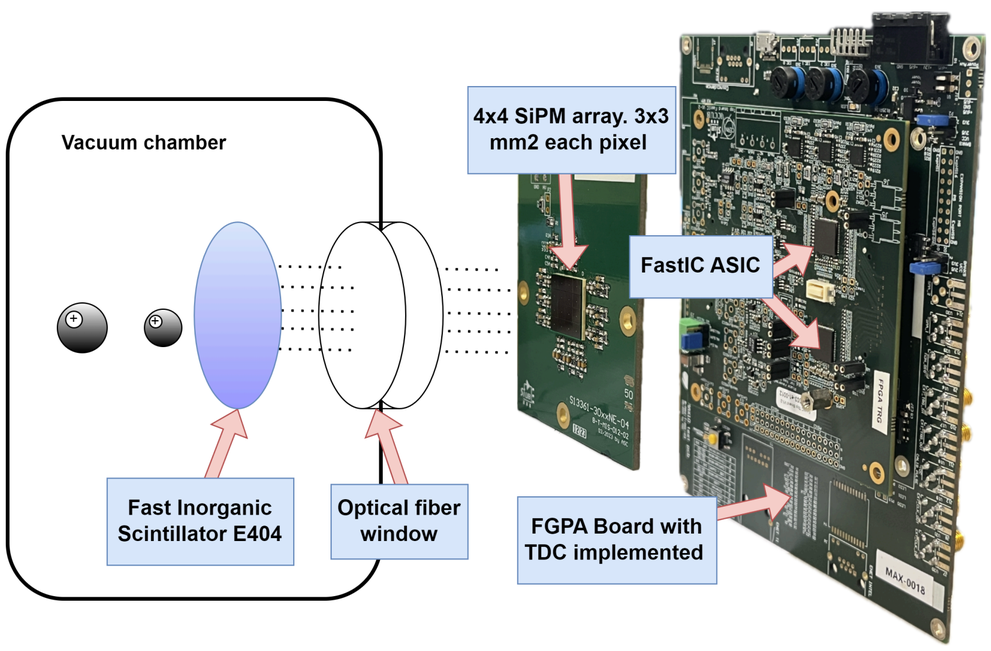




### Limitations of MCP detectors [1]

- **High vacuum conditions** <10^-6 mbar.
- **Fragile**, limiting ion throughput.
- **Gain saturation.**

**Objective**: **study the feasibility of SiPM-based detectors** for **Time-of-Flight Mass Spectrometry**

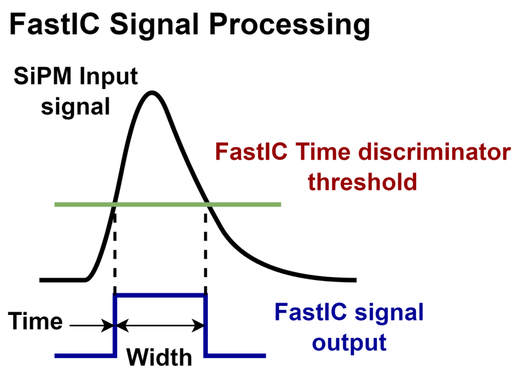
## SiPM+FastIC detector




### Detector chain

- **Fast scintillator :** E404, rise time ~1ns, decay time ~1.5 ns, emission peak [2].
- **SiPM array**: HPK S13360-3050-NE04. 55% PDE at 59V
- **FastIC module**: 2 FastIC ASICs + FPGA time-to-digital converter (TDC). 8 channels per ASIC [3].

**SiPM+FastIC** can detect **single photons** with **high time resolution** (**SPTR FWHM ~200 ps).**



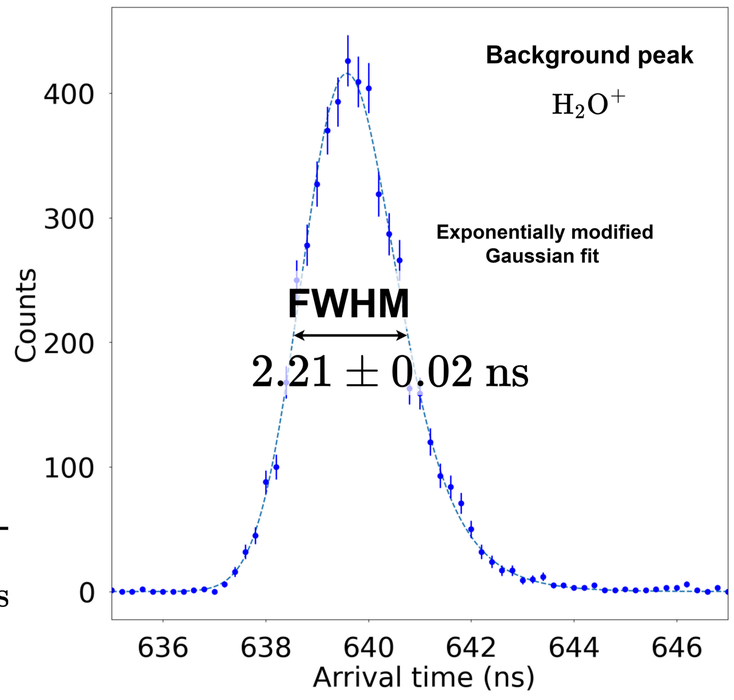

- **FastIC outputs a binary signal: Time** information is **encoded** in its **rising edge** and its **width** is **related** to the **pulse amplitude.**
- **Binary signal** is **digitized** by FPGA **TDC, giving a digital output** (Time and Width).

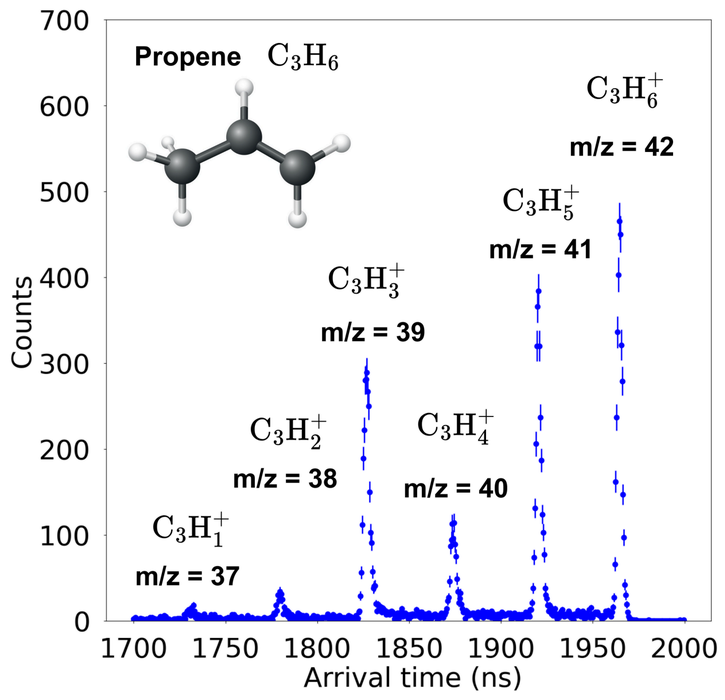
## Testing the detector in Oxford ToF-MS spectrometer

First tests showed us:

- Capability to **detect low energy ions** (3-10 keV).
- Ability to **resolve peaks that differ in one proton**.
- Time **resolution is dominated** by the **spread** in the **ion arrival time** to the detector.

$$\sigma_{TOT} = \sqrt{\sigma^2_{\text{IonDrift}} + \sigma^2_{\text{Scintillator}} + \sigma^2_{\text{SiPM+Electronics}}}$$




## Outlook and references

- **First ToF-MS detector** using a **SiPM array.**
- **Detection without MCPs** sets the road for **compact ToF-MS instruments.**
- The **proposed detector** will **allow 3D (x,y,t) imaging of the fragment ions** with excellent time resolution.
- **Easily scalable to hundreds of pixels**. New FastIC+ will facilitate this due to its integrated TDC, yielding a digital output.


**References**:
[1] J.N.Bull et al., 2014 EJMS
[2] E. Orunesajeo et al, 2021 The Journal of Physical Chemistry.
[3] A.Mariscal-Castilla et al. 2022, PSMR-TBP22.
Futher reading: B. Winter et al. 2016, IJMS. J.W.L. Lee et al 2020, Nature Comms Chemstry