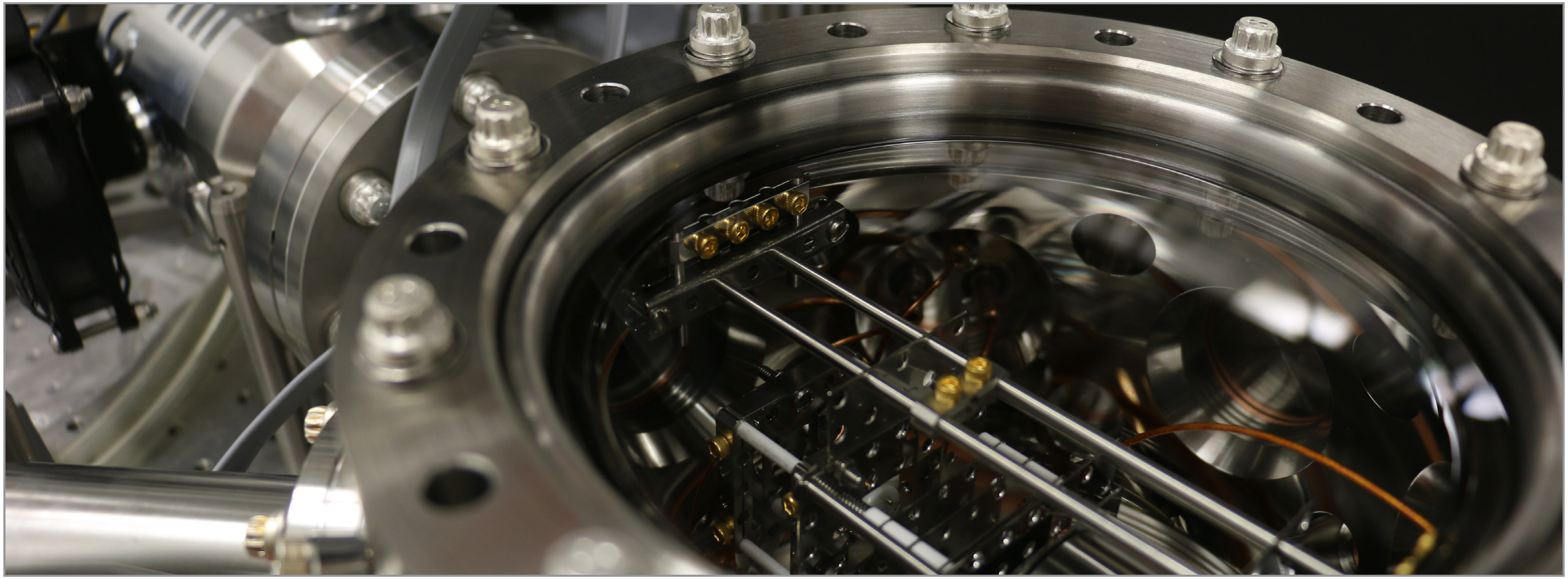
Direct Ion Detection Project Summary



Paul Hockett
femtolab.ca
National Research Council of Canada, Ottawa

project overview

- Technology project.
- 2 years @0.3FTE, ~$20k

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ELSEVIER

Improved direct detection of low-energy ions using a multipixel photon counter coupled with a novel scintillator

Benjamin Winter, Simon J. King, Mark Brouard, Claire Vallance*

Department of Chemistry, University of Oxford, Chemistry Research Laboratory, 12 Mansfield Road, Oxford OX1 3TA, United Kingdom

Aims

- Colleagues at the University of Oxford (UK) have recently developed a new type of “direct” (on-chip) ion detection.
- In collaboration with them, and starting from their current state-of-the-art prototype detectors [Winter et. al., 2016] we would develop and investigate the use of these detectors for high-sensitivity molecular detection applications.
- This work would be a fusion of new technology with our expertise of the fundamentals of molecular detection and instrument design.

Further project progress details at http://femtolab.ca?cat=90

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project overview

- This is an enabling technology for high-pressure (hence portable), rugged and low-cost instruments, and the work so far is a "*stepping stone on the path towards a generic silicon-based ion detector which would remove the need for high voltages and high-vacuum and at the same time greatly reduce detector cost relative to MCP-based detectors.*" [Winter et. al., ibid].
- Early work would be low TRL, make use of existing prototype chips, and involve collaboration with the University of Oxford (UK) and the international PImMS consortium (http://pimms.chem.ox.ac.uk).
- This project builds new collaborations with other research institutions. If successful it paves the way for portable, low-cost and high-efficiency ToF mass spectrometers for use in a range of in-situ detection scenarios, e.g. military, industrial, commercial, environmental…

(1) Gain

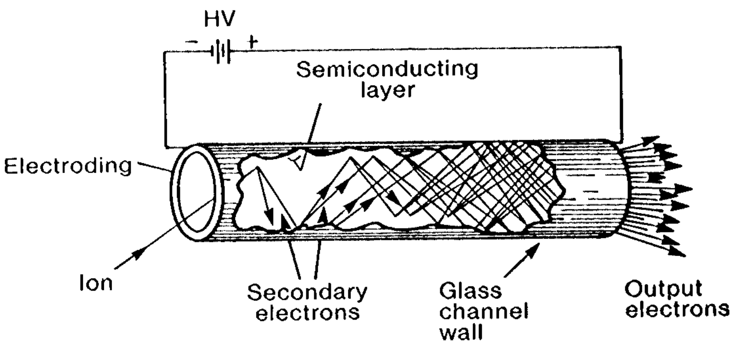


Figure 2-4 Basic Operation

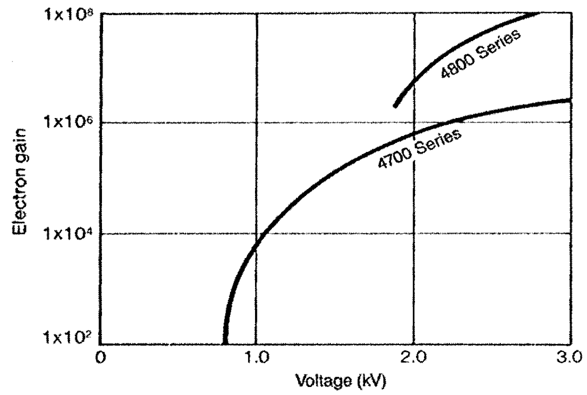
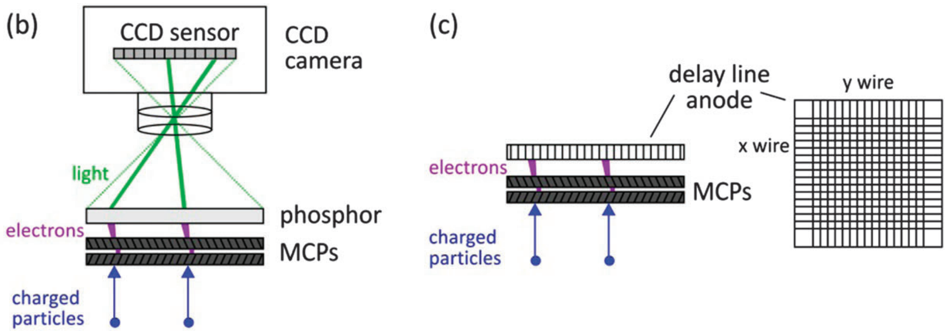
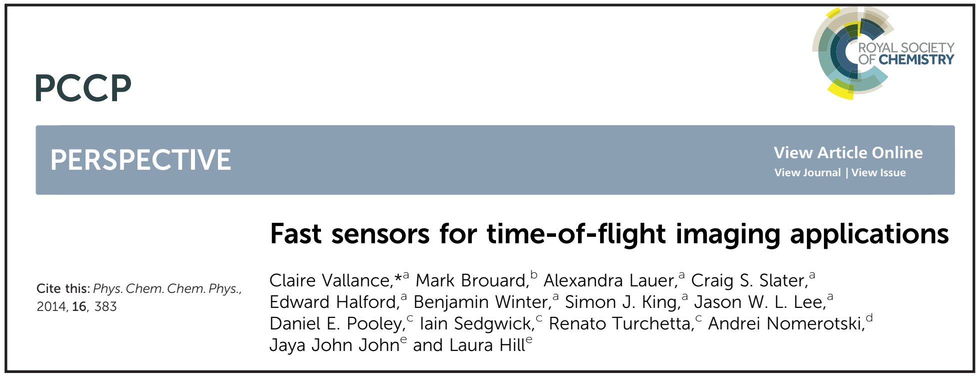


Figure 2-6 Typical Gain Characteristic (4700 and 4800 Series)

Channeltron Handbook (Burle)

(2) Detection

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Fast sensors for time-of-flight imaging applications

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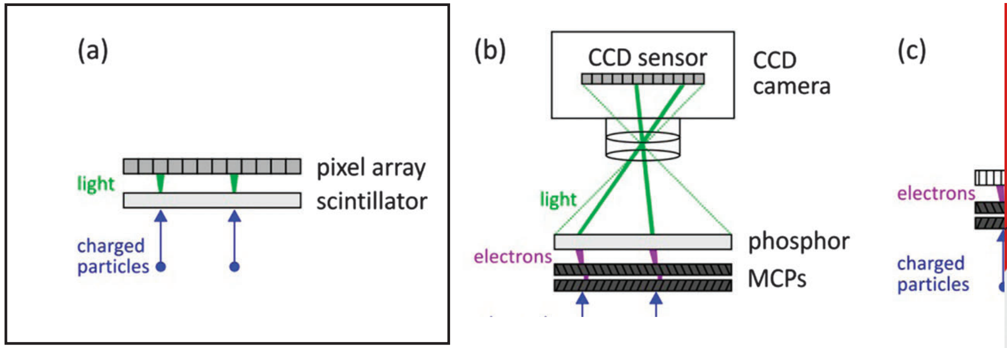
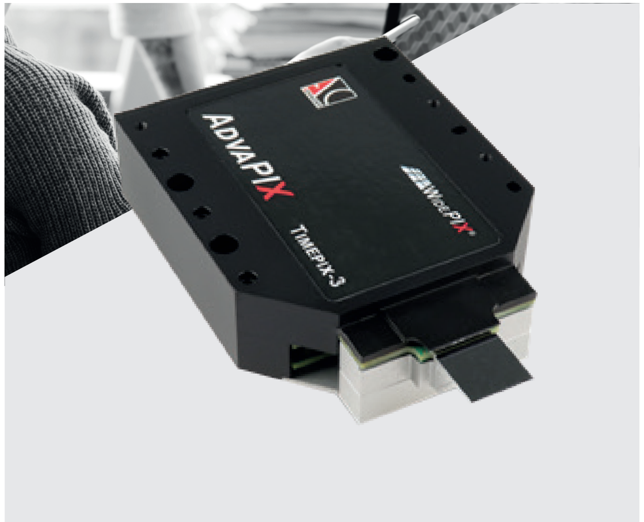
Claire Vallance,*[a] Mark Brouard,[b] Alexandra Lauer,[a] Craig S. Slater,[a] Edward Halford,[a] Benjamin Winter,[a] Simon J. King,[a] Jason W. L. Lee,[a] Daniel E. Pooley,[c] Iain Sedgwick,[c] Renato Turchetta,[c] Andrei Nomerotski,[d] Jaya John John[e] and Laura Hill[e]

Scintillator & sensitive single or array optical detector...?



Advacam AdvaPix3 (with CERN's Timepix chip)



Main Features

• **Readout chip type**	Timepix3
• **Spatial resolution**	256 x256 pixels, 55 µm pitch
• **Time resolution**	1.6 ns
• **Interface**	USB 3.0 (Super-Speed)
• **Power**	External or via second USB 3.0
• **Max. readout speed**	40 million pixels / s
• **Dimensions**	125 x 79 x 25.5 mm
• **Weight**	503g

Hamamatsu multi-pixel photon counter (MPPC)

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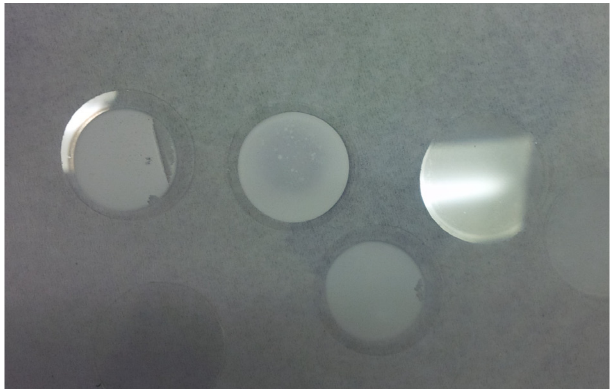
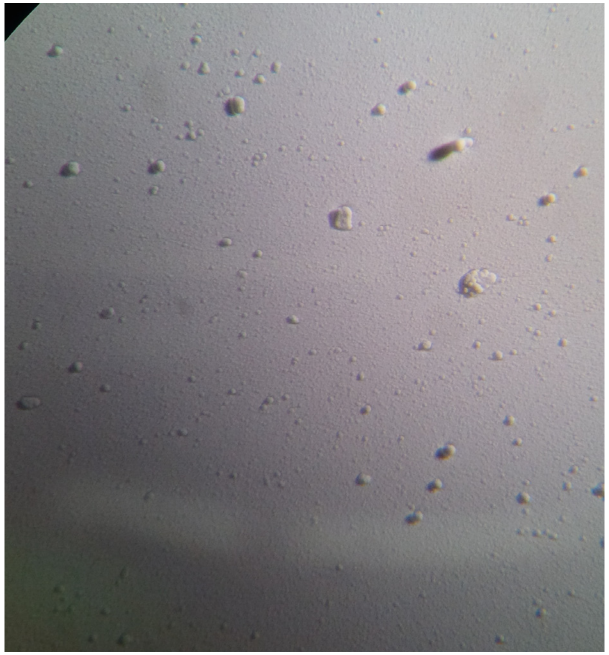
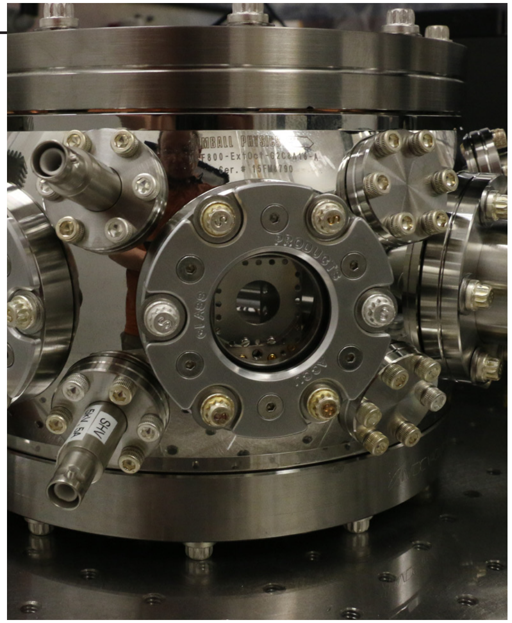
Scintillator screens by vacuum deposition of laser dye.

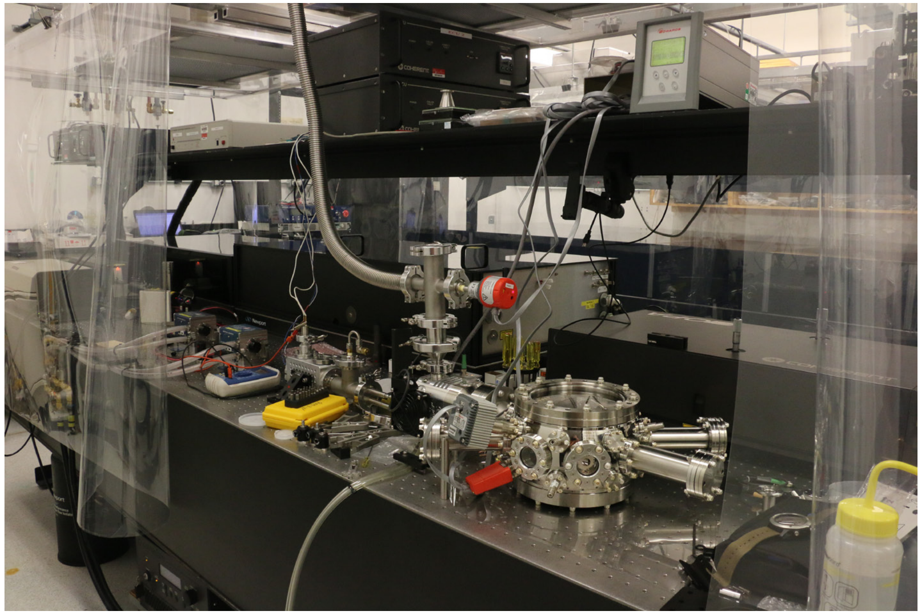


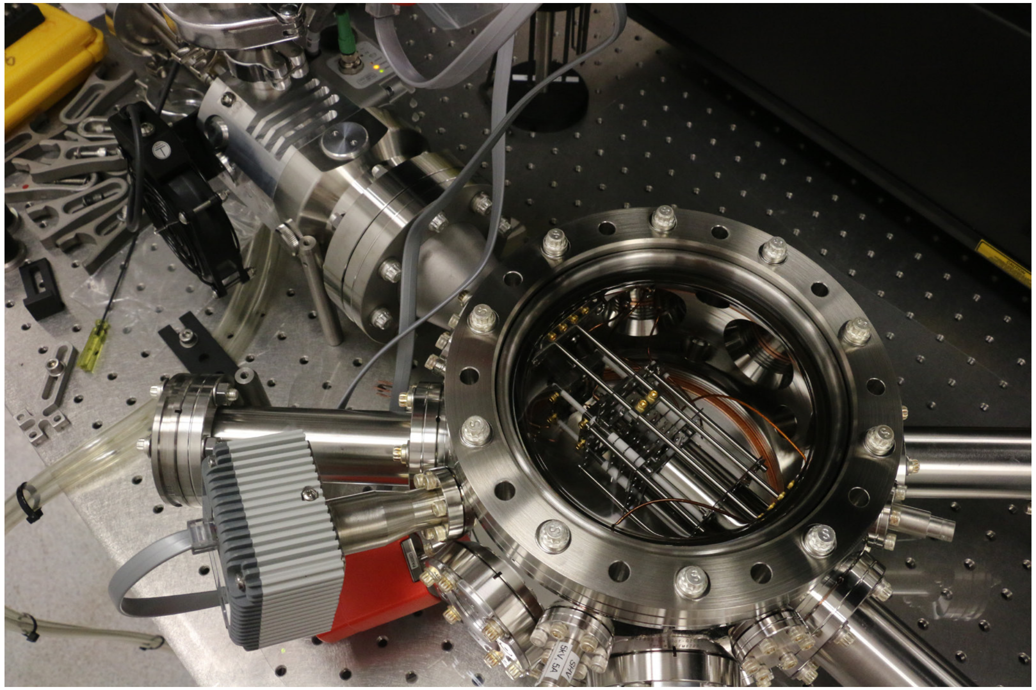


VIRP test chamber



VIRP chamber
- Vaccum Instrument Rapid Prototyping chamber
- Small & efficient
- Test configurations can be constructed and tested on few-hour timescales
- Testing for spectrometer stacks, detectors, new materials... &c &c...





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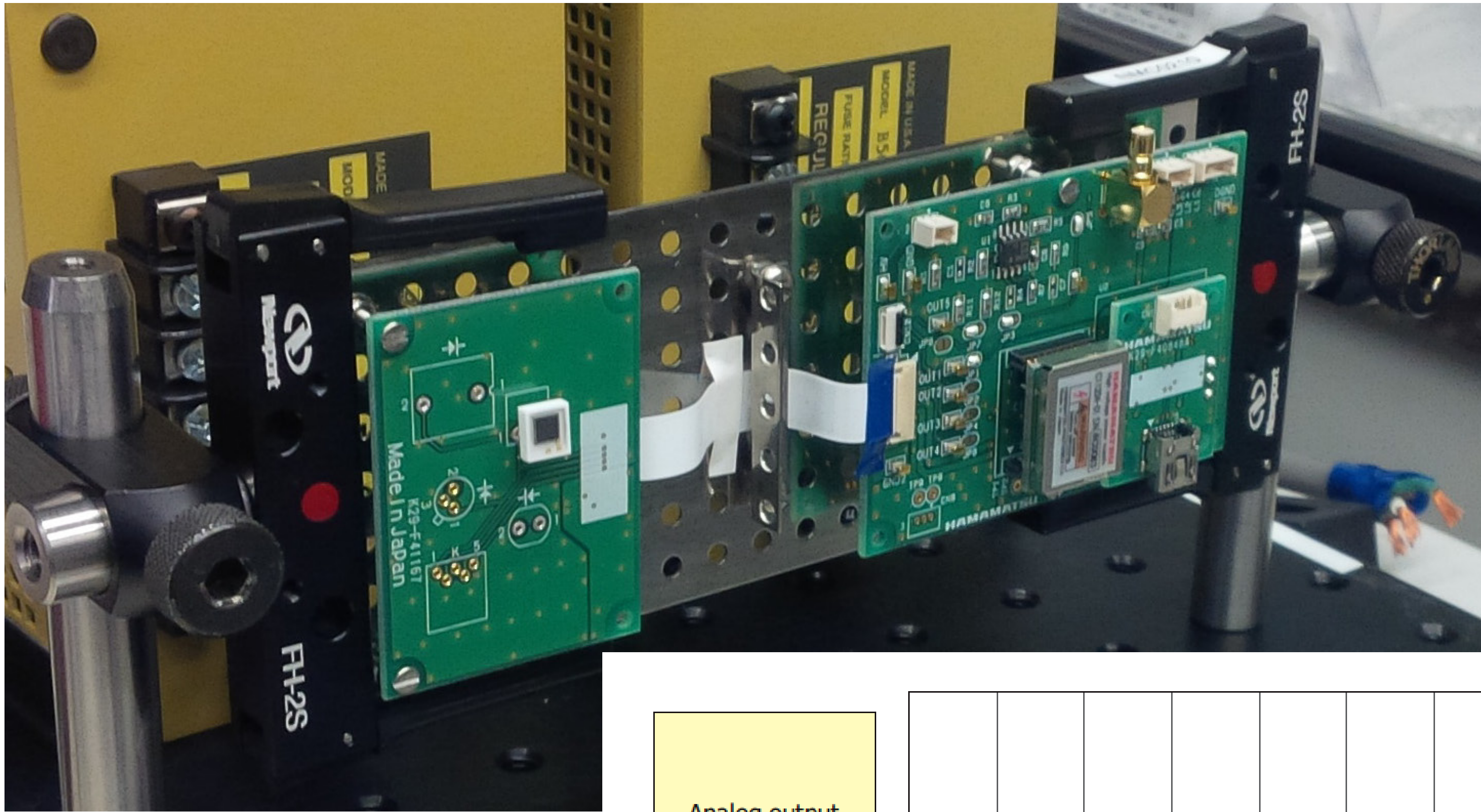
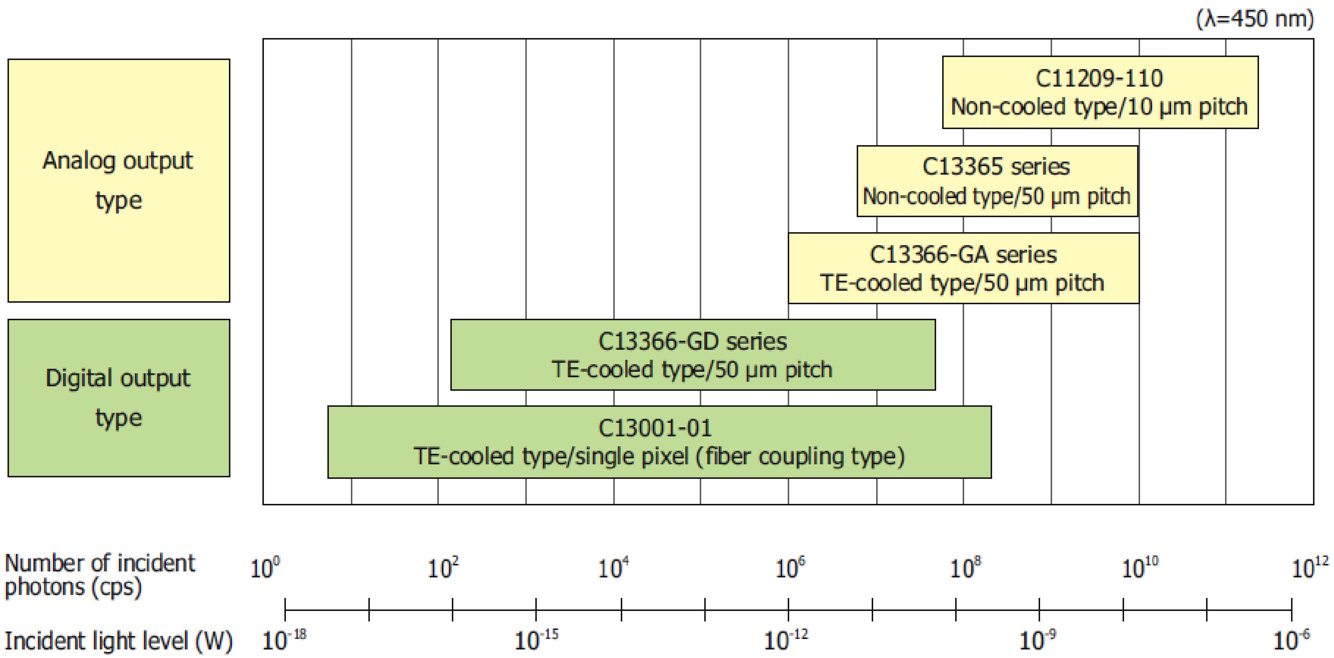
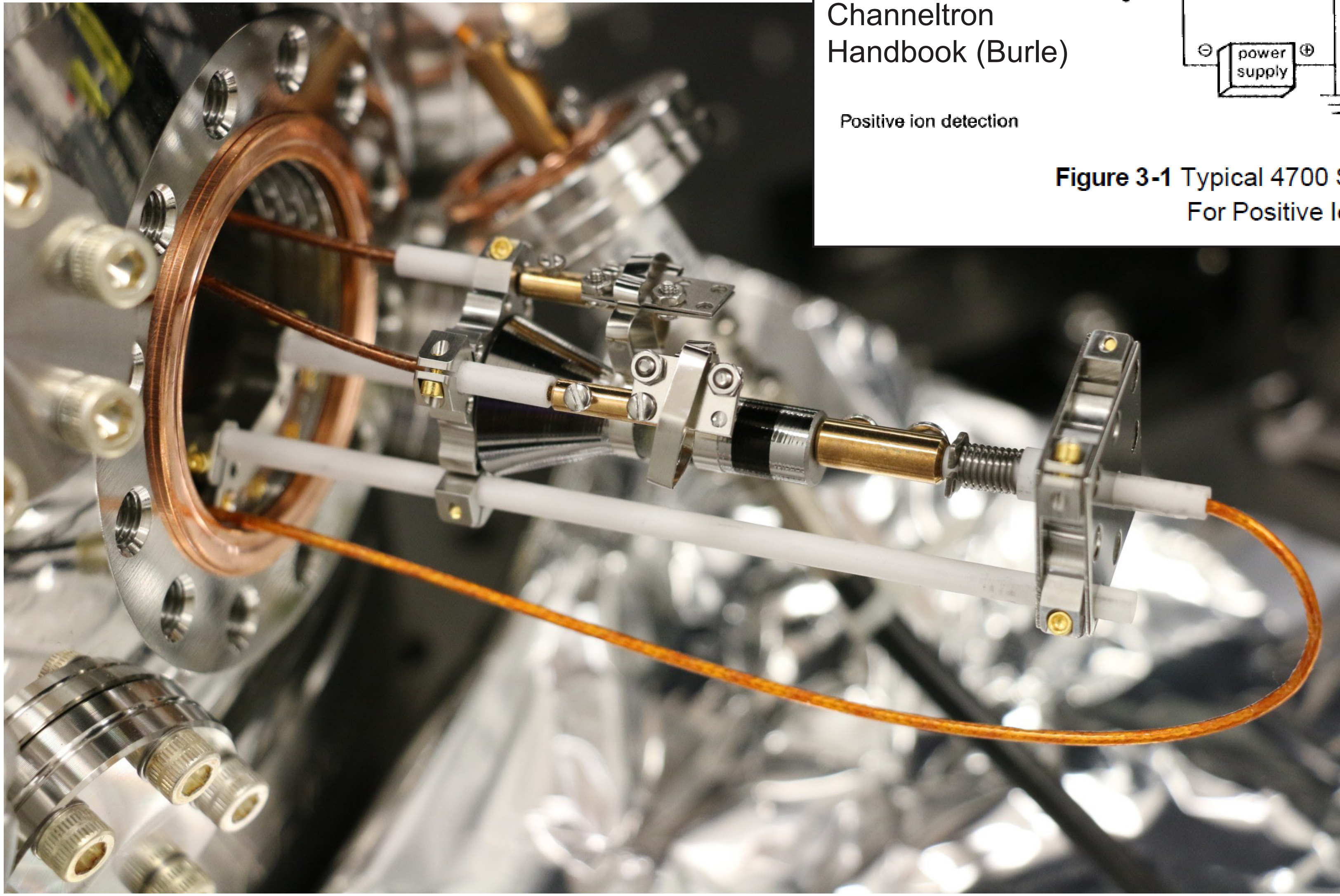
MPPC test board



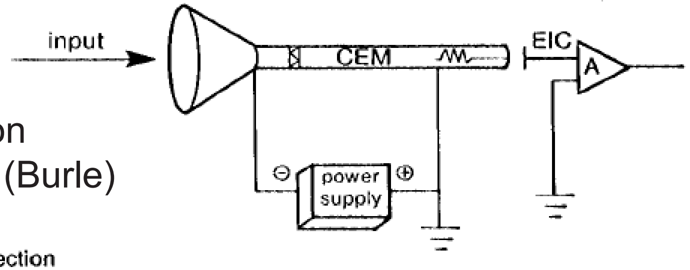


Hamamatsu MPPC catalogue

channeltron



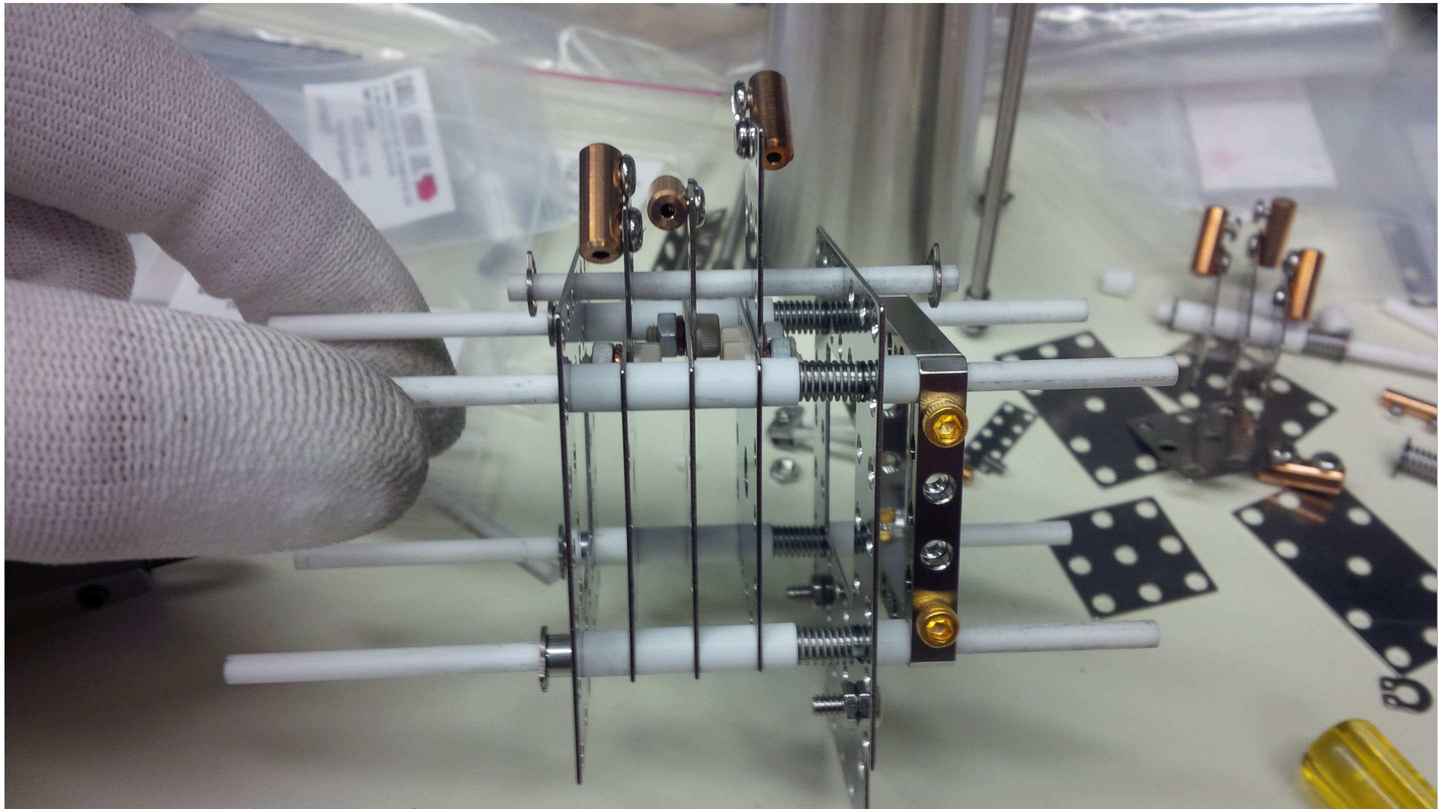
Channeltron
Handbook (Burle)



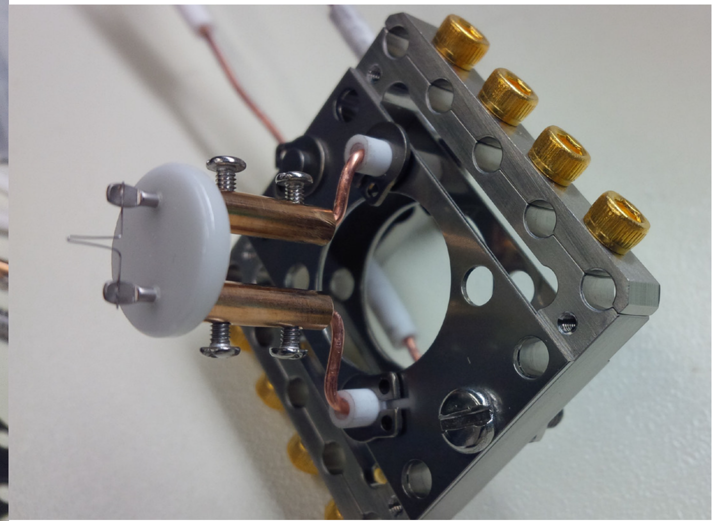
Positive ion detection

Figure 3-1 Typical 4700 Series Connection For Positive Ion Detection

mini ToF



Time-of-flight Spectrometer stack
- Space-focussing Wiley-MacLaren spectrometer
- Minaturized design
- Rugged
- Optimised for low-energy particles



Mini e-beam

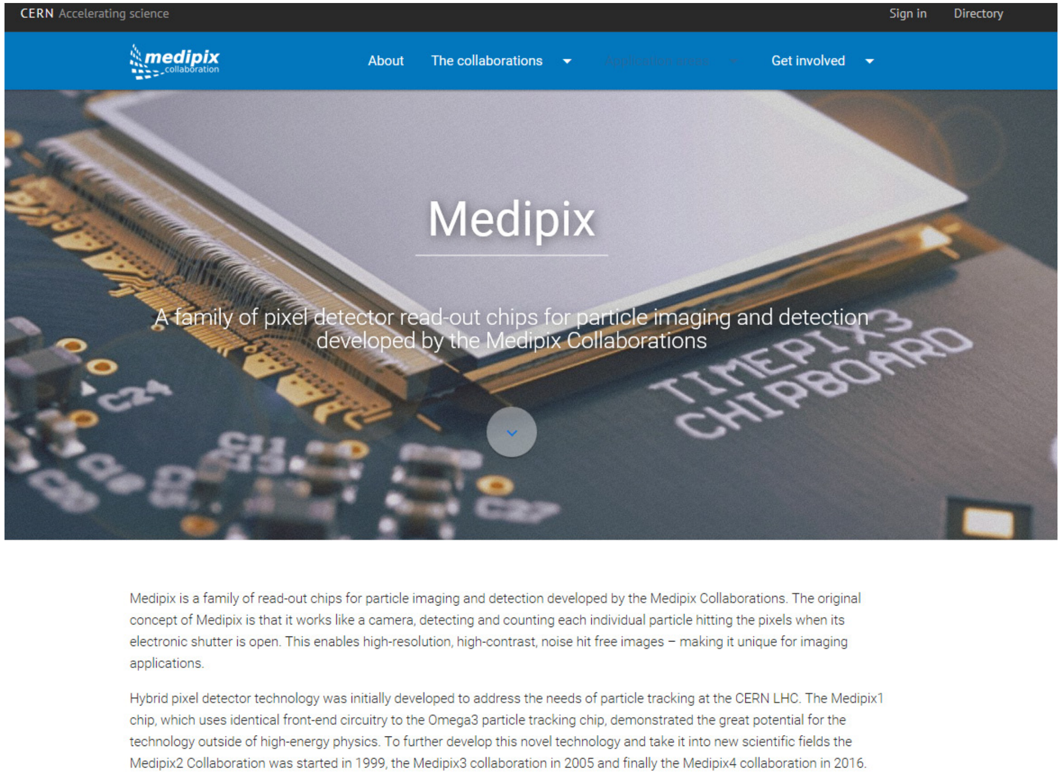
Successes

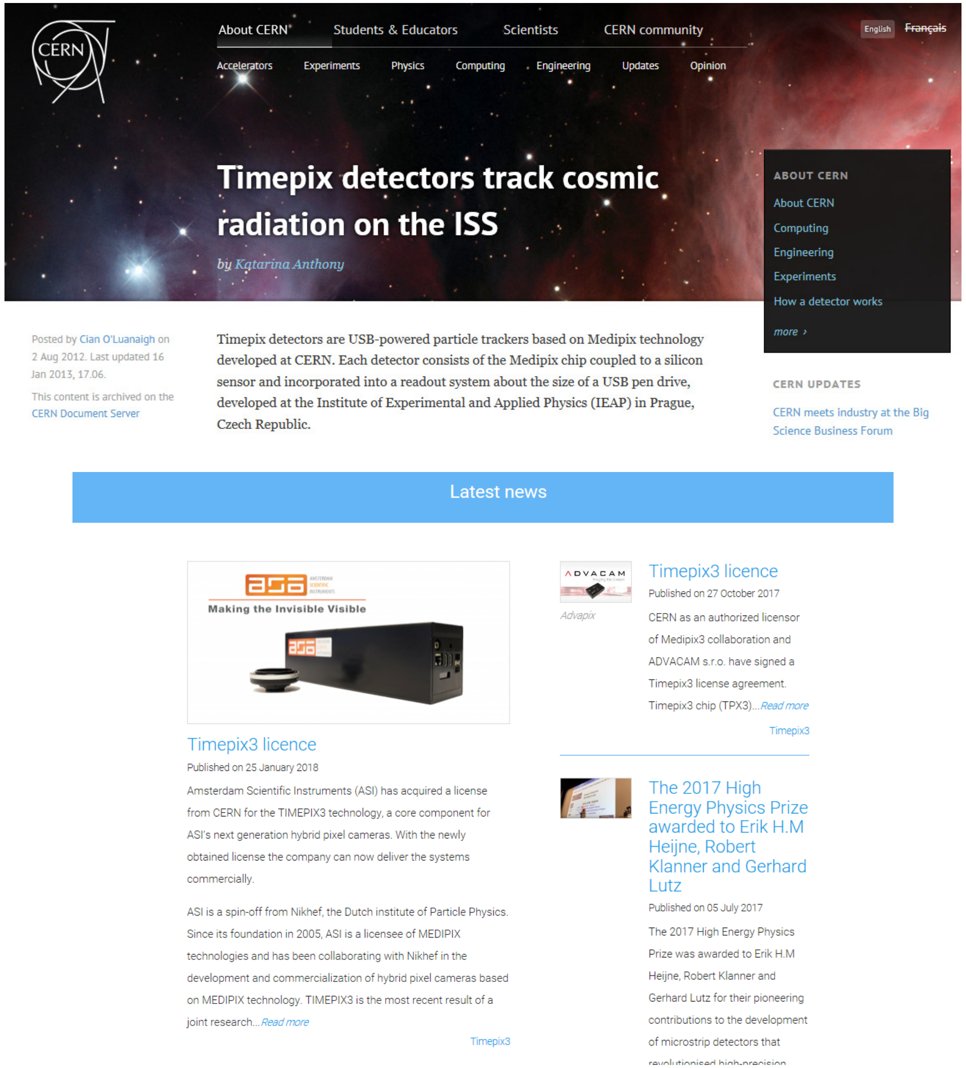
- Entry into new technologies
- Scintillator preparation
- VIRP chamber
- Hardware interfacing, software development
- Prototype operation demonstrated
- PImMS camera also trialled (see later)
- Future directions clear...

Issues & problems

- Tech development requires a lot of person hours
- Full characterisation very time-consuming
- Emerging on-chip detectors from large collaborations (PImMS, CERN) now becoming available...

Large collaborations now have chips commercially available, including “direct” and optical versions. In particular, CERN’s Timepix chip...





... and the PImMS camera from the team at Oxford.
We already gained some experience with PImMS as part of the project.

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Time-resolved multi-mass ion imaging: Femtosecond UV-VUV pump-probe spectroscopy with the PImMS camera

The Journal of Chemical Physics **147**, 013911 (2017); https://doi.org/10.1063/1.4978923

Ruaridh Forbes[1,2], Varun Makhija[2], Kévin Veyrinas[2], Albert Stolow[2,3,4], Jason W. L. Lee[5], Michael Burt[5], Mark Brouard[5], Claire Vallance[5], Iain Wilkinson[4,6], Rune Lausten[4], and Paul Hockett[4]

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The Inner Lives of Molecules

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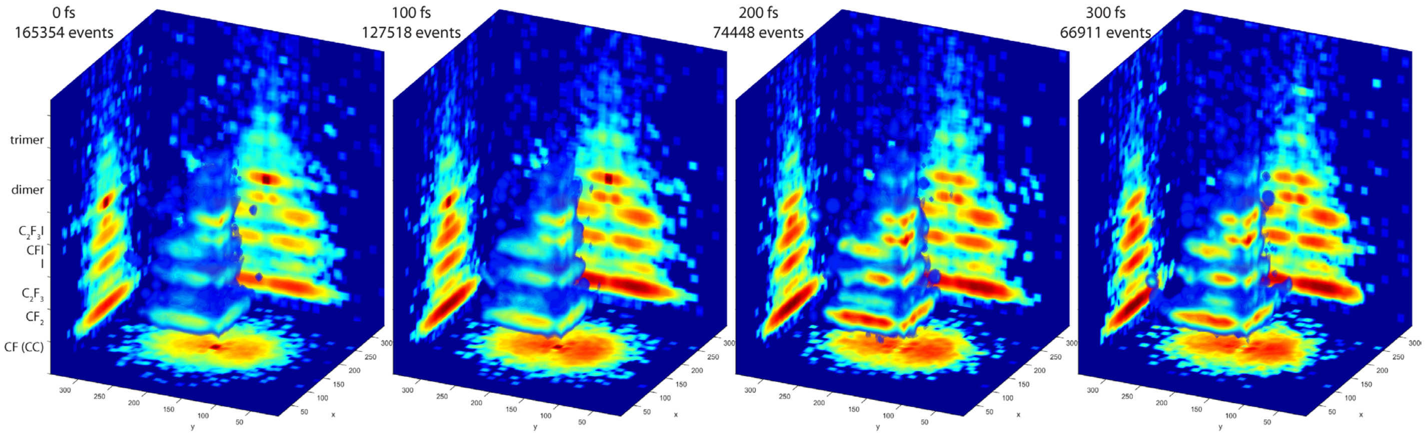
New method takes 3-D images of molecules in action

From the Journal: *The Journal of Chemical Physics*

By AIP News Staff

WASHINGTON, D.C., April 4, 2017 -- Quantum mechanics rules. It dictates how particles and forces interact, and thus how atoms and molecules work -- for example, what happens when a molecule goes from a higher-energy state to a lower-energy one. But beyond the simplest molecules, the details become very complex.

"Quantum mechanics describes how all this stuff works," said Paul Hockett of the National Research Council of Canada. "But as soon as you



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So...

- Current Direct Ion project to wrap-up this year.
- Ideas, expertise and equipment to roll back into our foundational work (investment so far is not shelved!).
- Bridge-building with Oxford (PImMS) and CERN (Timepix)...

...new work, with the new chips, to begin FY2019 or FY2020.