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The Single Photon Air Analyzer
A technology transfer journey

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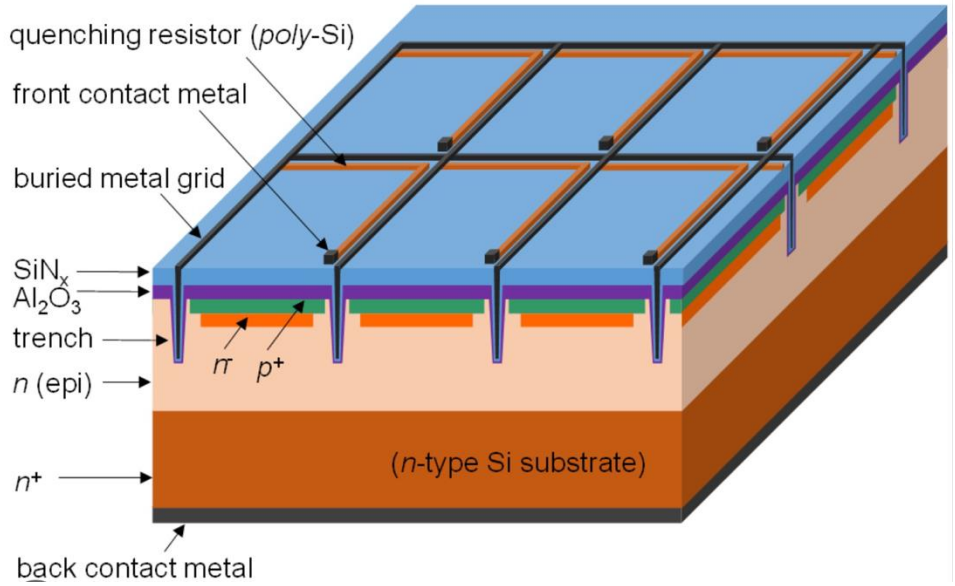
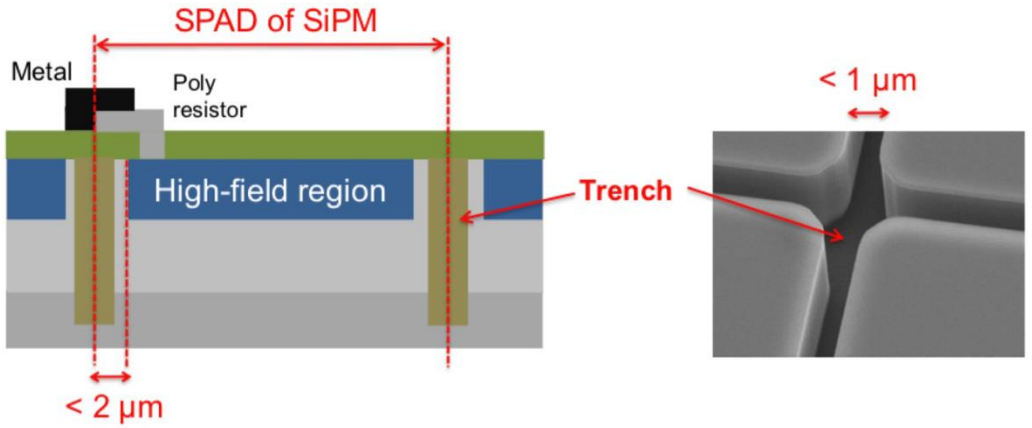
Due to on-going intellectual property issues, I cannot show you every details

Discovery, accelerated

The starting point Single Photon Avalanche Diode Arrays (SiPMs)

- Pros:
  - High gain (~10^6) and single photon separation
  - Excellent time resolution
  - Good granularity
  - Insensitive to magnetic fields; low V operation
  - Compact
  - Radiopure
- Cons:
  - High dark count rate. typ. ~100 kHz/mm^2
  - correlated avalanches (afterpulse, crosstalk) & emits light
  - Very sensitive to neutrons and ionizing particles
- Our journey
  - T2K -> nEXO -> hopefully XLZD





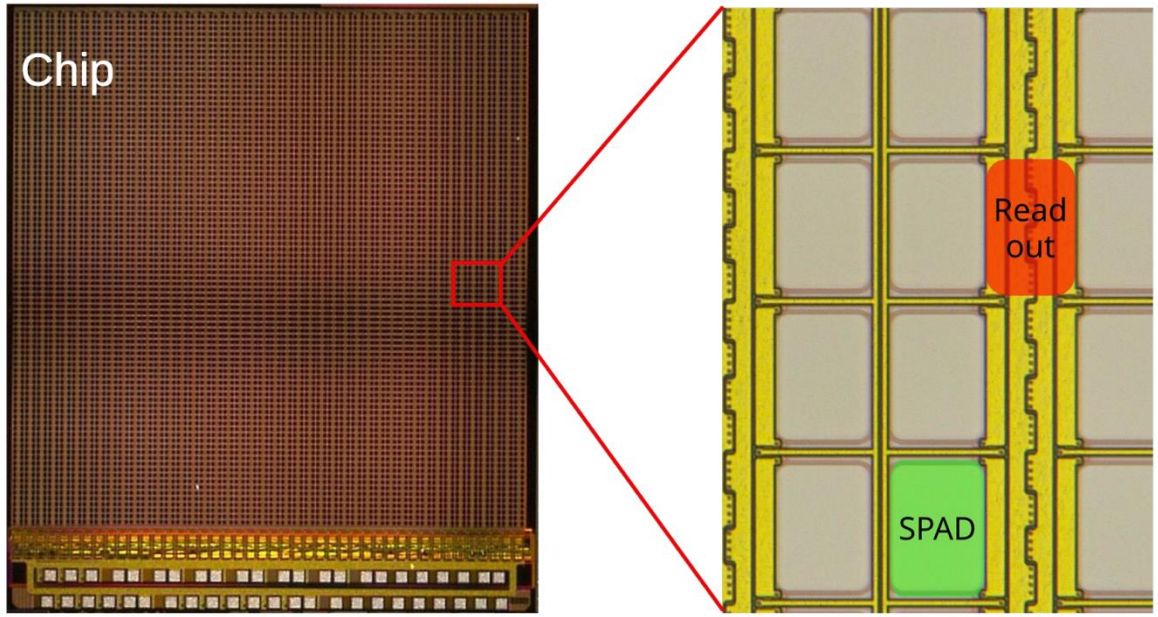
Integrating SPADs in CMOS (aka silicon chip)

- Pros
  - “no” power dissipation when idling
  - Tailor performances to needs. E.g. dynamic range, timing, imaging,…
  - Less complex at system level
  - Lower dark noise by SPAD elimination
- Cons
  - In 2D, some efficiency loss
  - More complex at chip level
  - Mass production not demonstrated (by HEP)

Digital SiPMs for DARWIN

Michael Keller, Peter Fischer, Robert Zimmermann, Michael Ritzert – University of Heidelberg

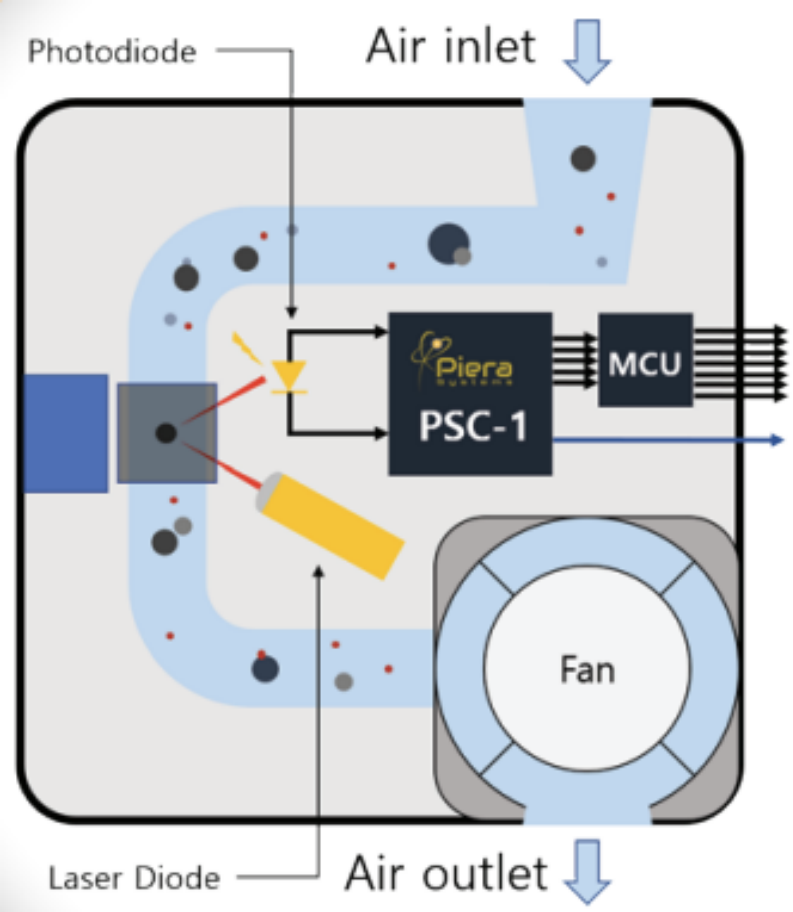
DARWIN Collaboration Meeting 2023 at University of Heidelberg



The world is burning and coastal BC is a disaster waiting to happen

- Can we do more with SPAD than astro-particle?
- Is there anything we can do to prevent catastrophic forest fires?
- Detecting smoke?

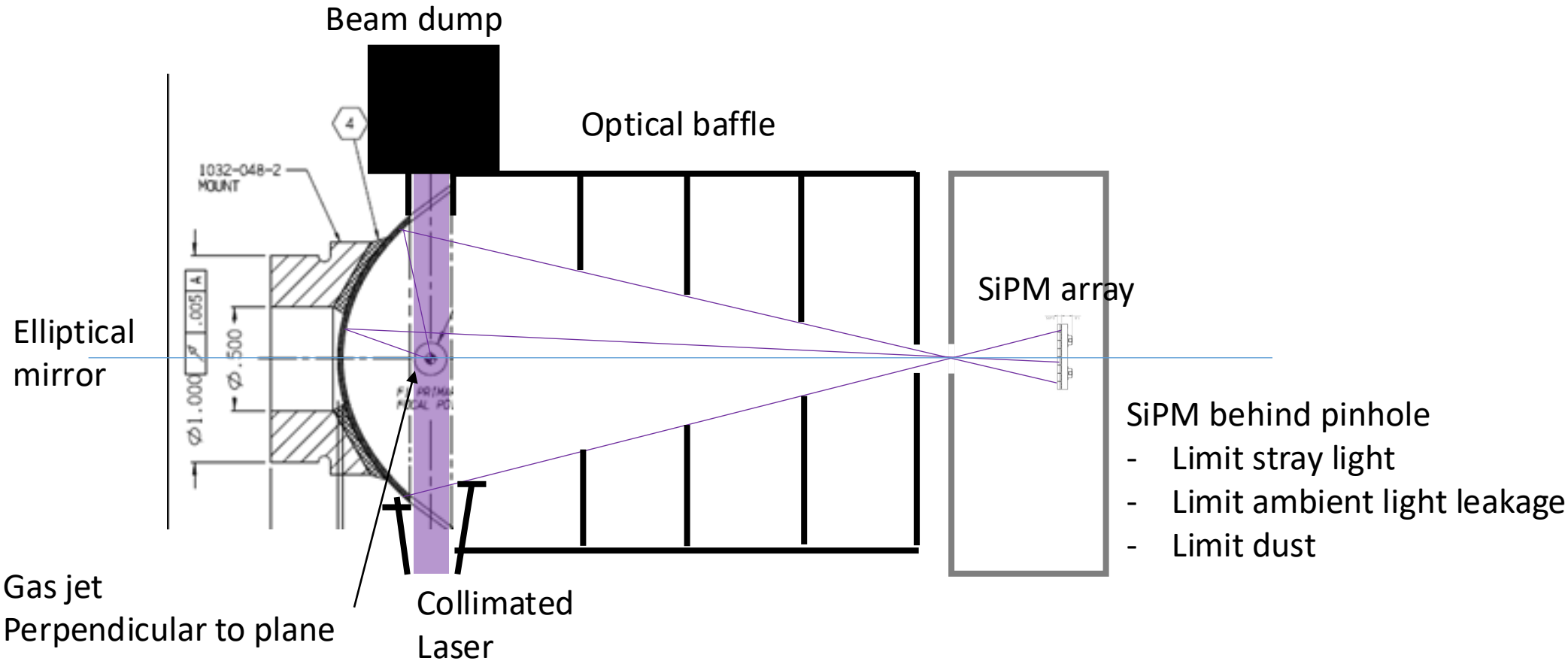
Characterizing smoke by detecting particulate scattering



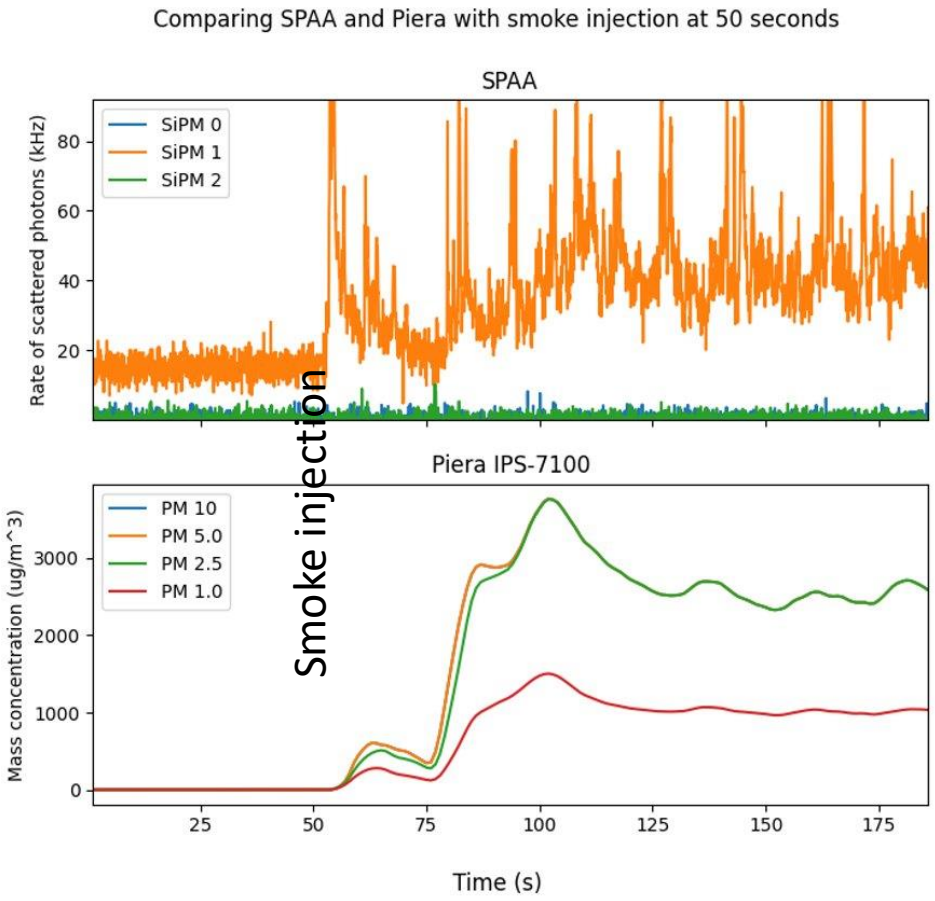
Based on a single photo-diode
Low noise electronics in an ASIC + AI

Designed primarily in Mississauga, ON
80$/unit

The single Photon Air Analyser concept 1 (now obsolete)



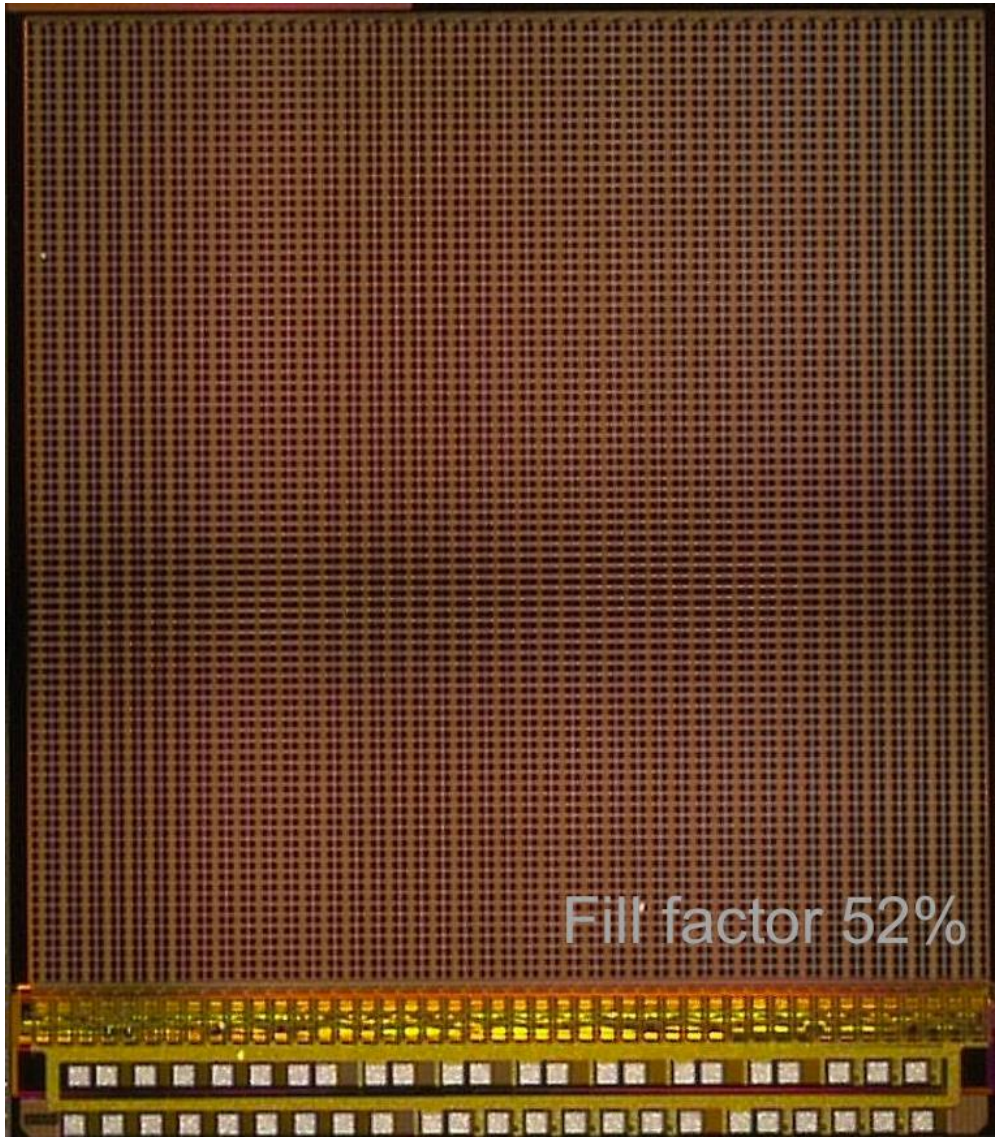
Working concept!



- Demonstrated over the summer 2022
- Photon counting is compelling
- New design coming. Easier to build

Work funded by McDonald Institute seed program and HQP

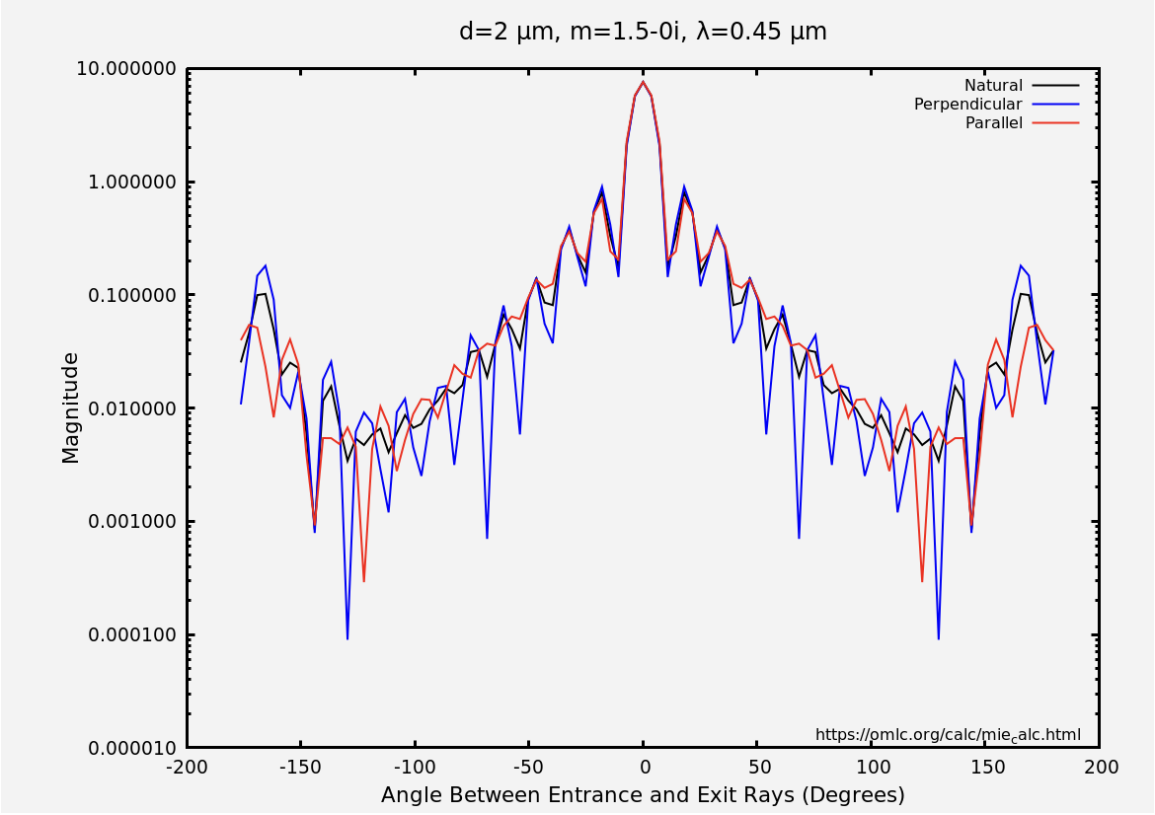
In 2025, we got our hands on Heidelberg IDP chip



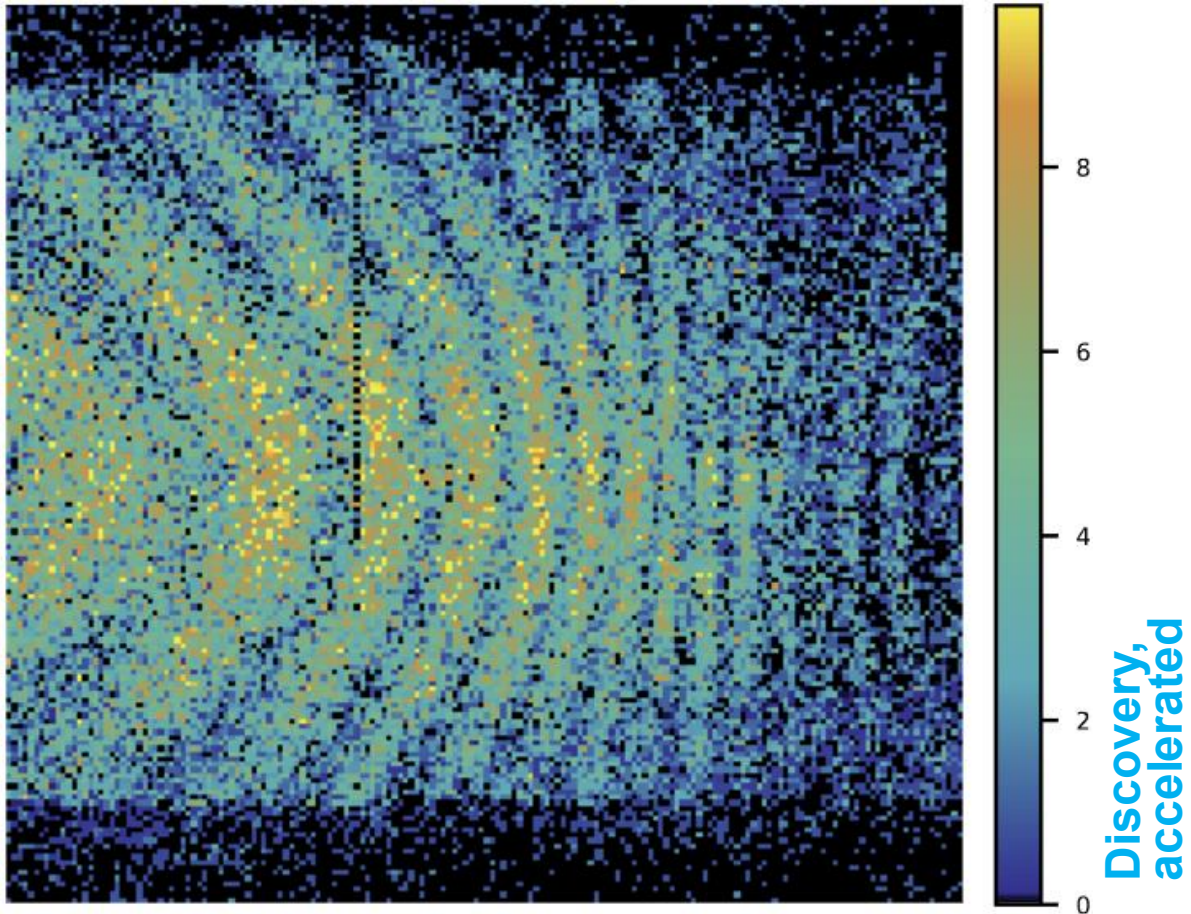
- 10x10 mm^2
- 30x30 pixels instead of 3 pixels before
- 1 bits frame at 8kHz max

And we put it to good use

- Projecting the Mie scattering diffraction pattern onto a plane of a single particle in air



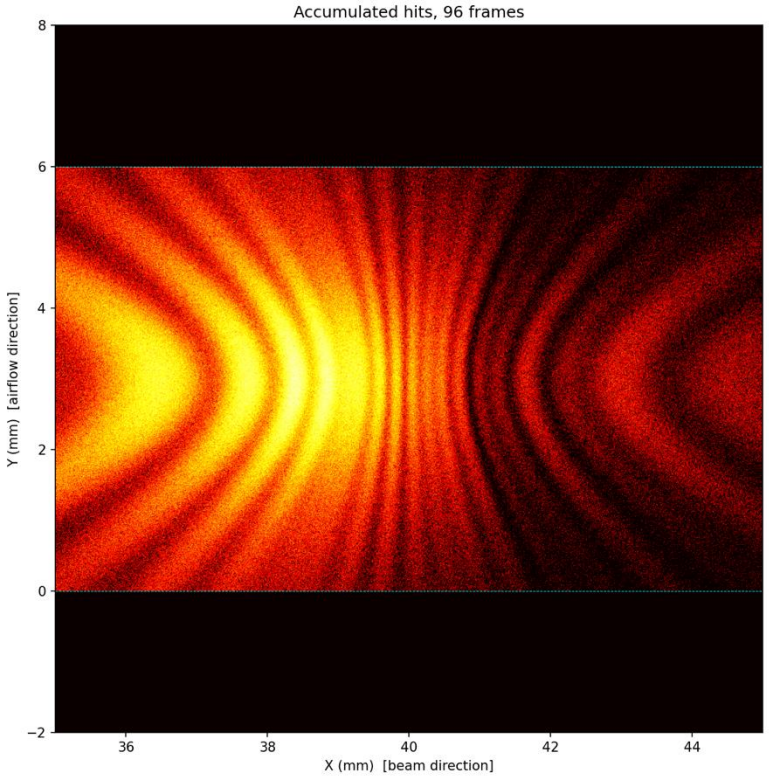
Data imaging a background particle that passed by



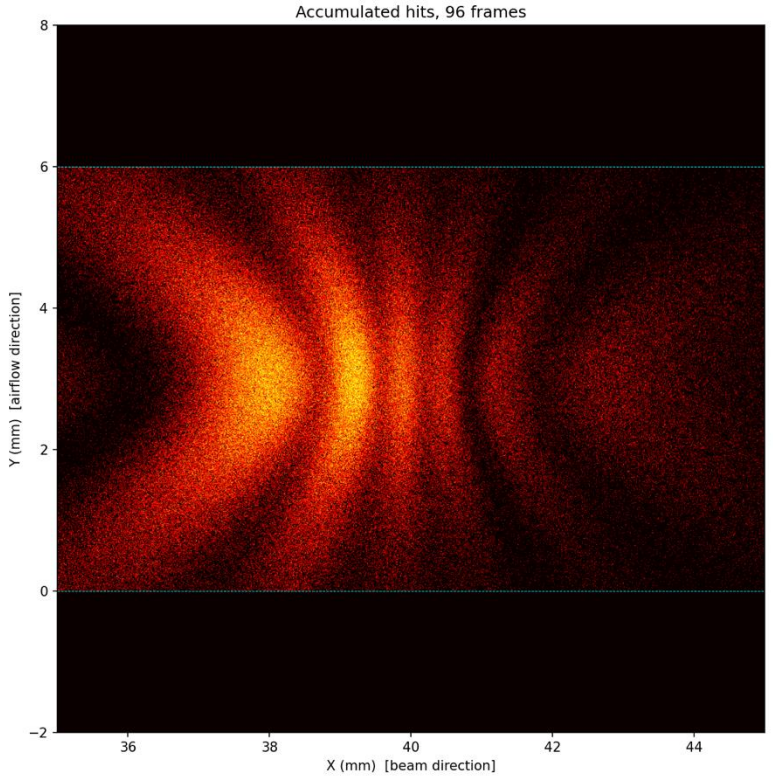
Data and simulation match extremely well

- Simulations (code 100% written by CLAUDE)

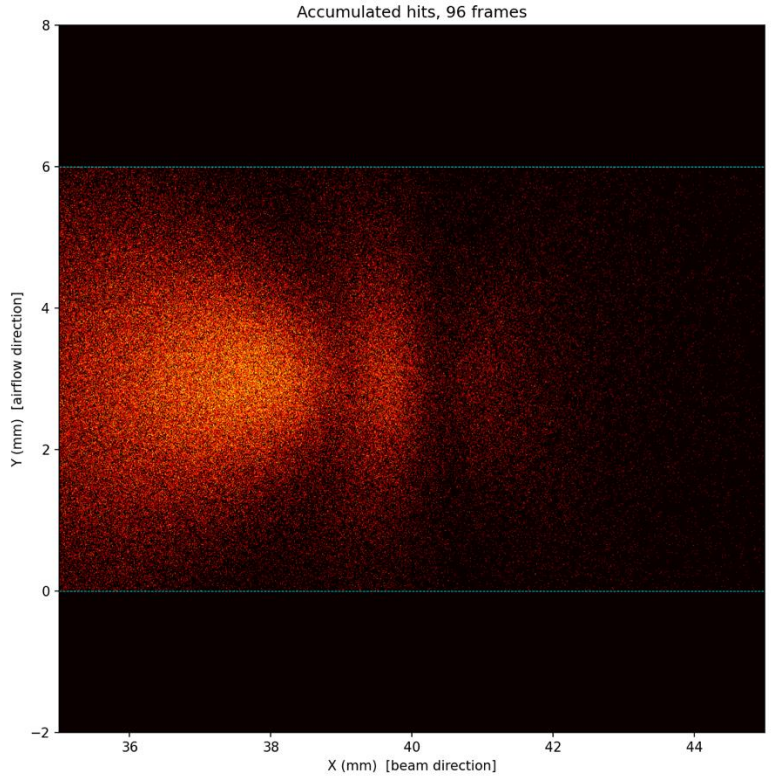
3 um particle



1 um particle



0.5 um particle



We have completed the proof of concept

- We can get a wealth of information about particle in air
- For forest fire the focus is on small particles

Particle	Origin	Size (µm)	Morphology	Refractive index m = n + ik	Effect	In 0.2–10 µm window
Pollen (whole)	Biogenic	10–100	Ornamented sphere	≈1.5 + ~0i	Allergen	Edge — mostly >10 µm
Pollen fragment	Biogenic	0.1–2.5	Irregular	≈1.5 + ~0i	Allergen (asthma)	Yes
Fungal spores	Biogenic	2–10	Ovoid	≈1.5 + ~0.01i	Allergen / pathogen	Yes
Bacteria	Biogenic	0.5–10	Rod / sphere	≈1.38–1.40 + ~0i	Pathogen	Yes
Viruses	Biogenic	0.02–0.3	Sphere	≈1.5	Pathogen	No — sub-0.2 µm
Diesel soot (black C)	Combustion	0.01–1 (aggregates)	Fractal aggregate	≈1.85 + 0.7i	Toxicant / carcinogen	Aggregates yes
Wood / wildfire smoke (brown C)	Combustion	0.05–1	Aggregate / sphere	≈1.55 + 0.003–0.014i	Toxicant	Aged yes, fresh no

Moving forward

- Funding
  - SenseNet is our partners
  - ALLIANCE/MITACS grant being reviewed for demonstration in the field
  - ALLIANCE Quantum for further R&D
  - Working on the business case for private funding
    - The beachhead market may not be forest fire

- Technical work
  - Optimize the optical path
  - Analyze the data on the fly
  - Minimize power usage
  - From table-top sensor to compact sensor to wearable sensor

If everything goes well

- Build new SPAA sensors made with a custom chip by end of 2026
  - X-FAB new foundry also being prototype for XLZD
- Test operation of ~5 SPAA in Spring 2027 in Pacific Spirit park
- Test 20+ SPAA in summer 2027 in Whistler with SenseNet
- Demonstrate performances using test burns in Fall 2027 and Spring 2028
  - Assess the density of sensor needed. The hope is that 1 per km^2 is good enough.
- Install 100+ SPAA in Whistler area for summer 2028 season
- Demonstrate detection and automatic suppression in Fall 2028 and Spring 2029
- Cover the Sea to Sky corridor, North shore to Pemberton for summer 2029 (1000+ SPAA)
  - Move to large scale production in 2029
- Rapidly expand to risk area of BC in 2030 (>10,000 SPAA)
- We need 1,000,000 SPAAs for BC only at 1 SPAA per km^2

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Merci / Thank you

If you are considering applied physics, I am hoping we will start recruiting for this project this Fall

Discovery, accelerated