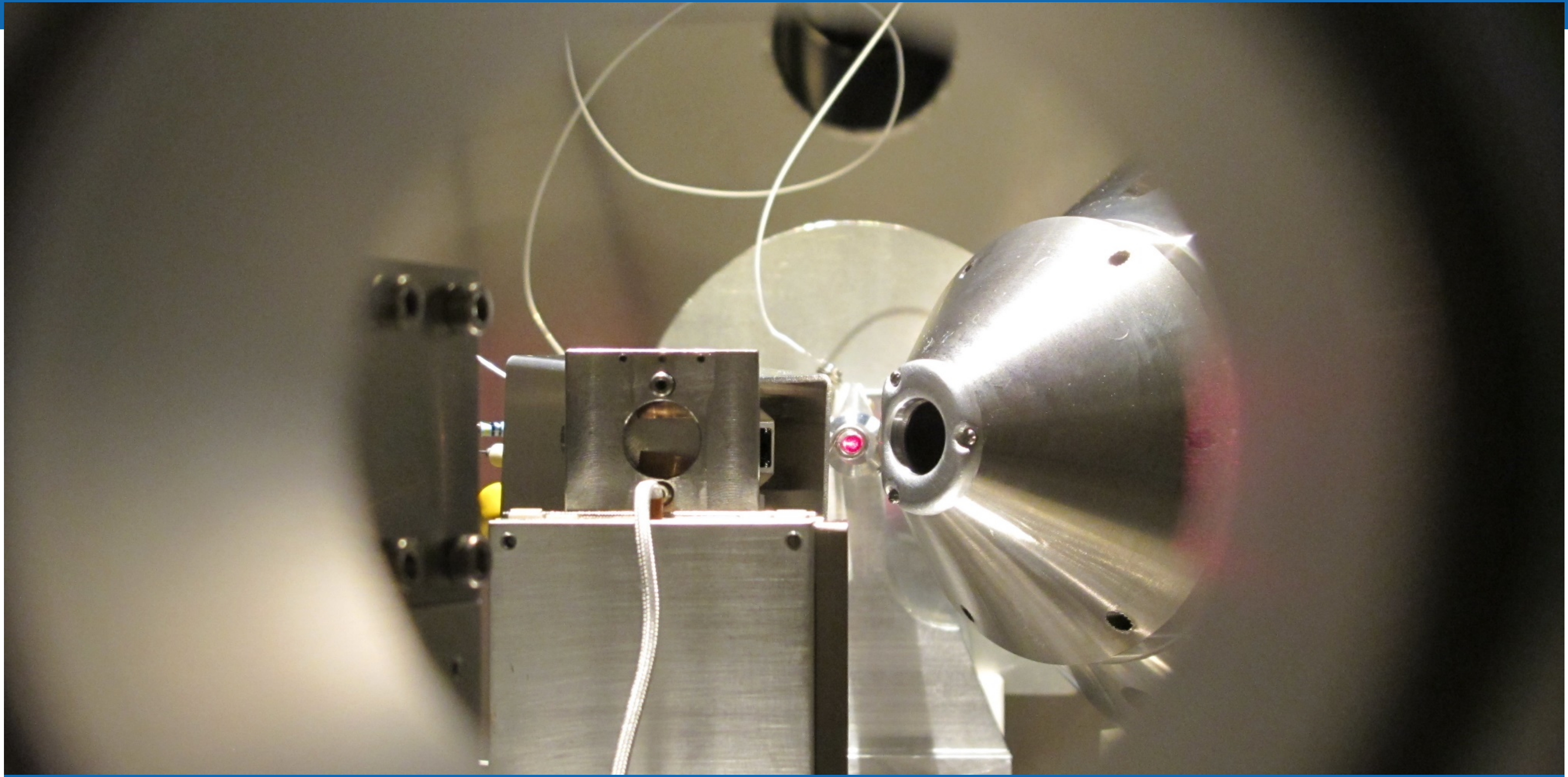


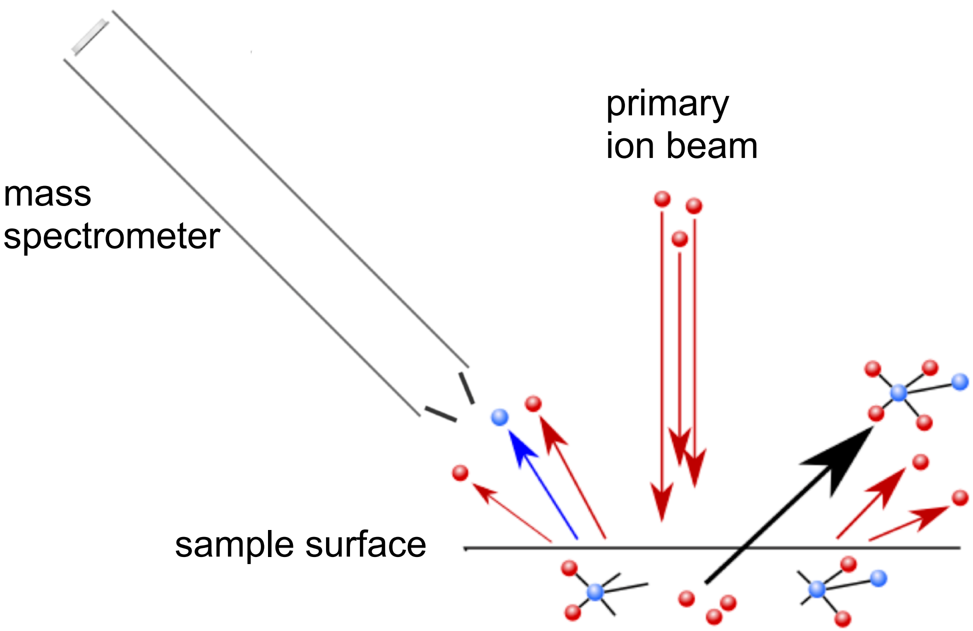
MeV-SIMS with the Capillary Heavy Ion MicroProbe

Klaus-Ulrich Miltenberger, M. Schulte-Borchers, A. M. Müller, M. George, M. Döbeli, H.-A. Synal
Laboratory of Ion Beam Physics, ETH Zürich

SIMS (Secondary Ion Mass Spectrometry)

keV-SIMS for material analysis

collisional, chemical, electronic **sputtering**

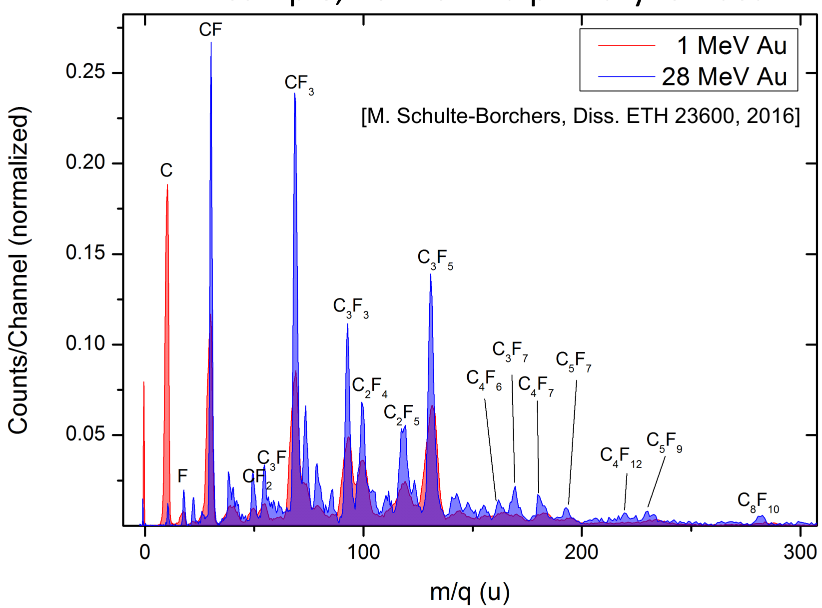


[http://www.cameca.com/instruments-for-research/sims4550.aspx]

Elemental speciation !

MeV-SIMS

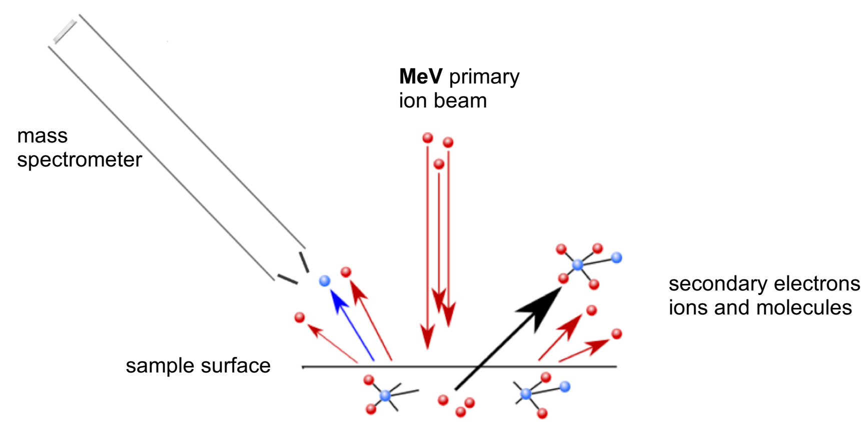
PTFE sample, 28 MeV Au primary ion beam



Improve **molecular yields** /

reduce **fragmentation**:

- **Higher energies** (electronic stopping)
- **Cluster ions** (surface damage)

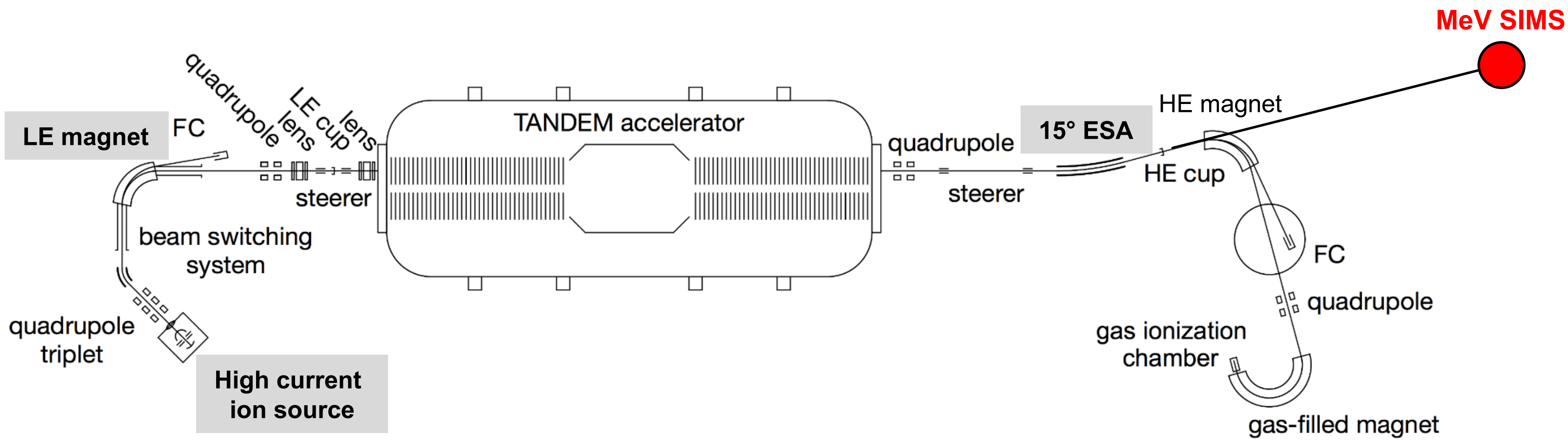


Molecular speciation for chemical

information possible ?

(applications in medicine, biology…)

MeV-SIMS beamline at ETH Zurich



exclusively **electrostatic ion optics** i.e. E/q selection

(except LE magnet with m < 750 u)

heavy (cluster) beams available at low charge states

(from Au @ 75 MeV up to C_{60} @ 15 MeV)

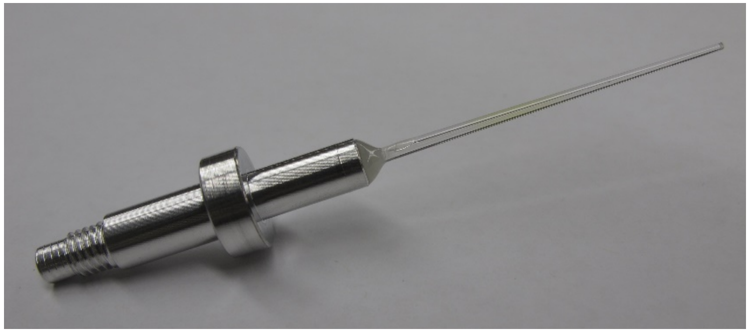
beam pulsing (AMS beamline)

Microprobe for imaging

glass capillary microprobe

beam exit diameter: 0.7 – 20 µm

independent of ion mass and energy

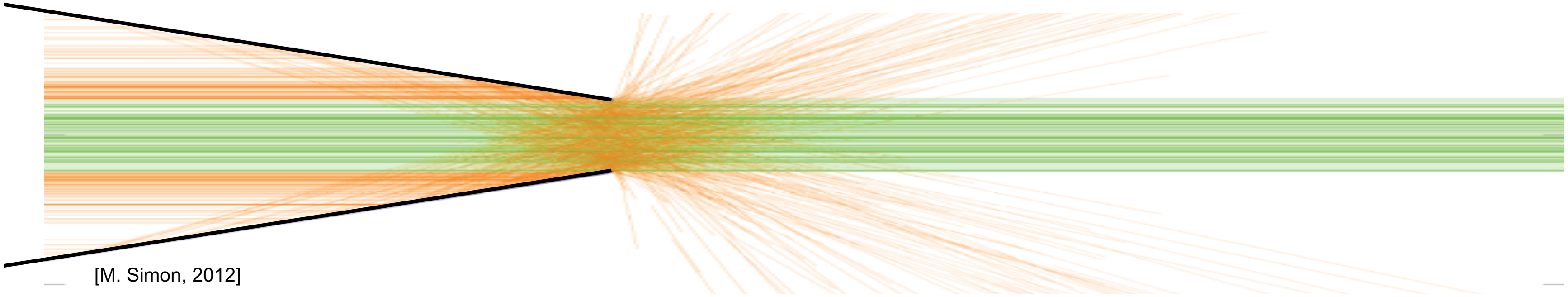


used for PIXE & STIM at ETH Zurich, developed by M. Simon [Diss. ETH No. 21019, 2012]

principle: collimation of parallel beam

divergence < 0.3 mrad

reduction of beam current by a factor of 10^6 - kHz particle rates (fA)



[M. Simon, 2012]

CHIMP (Capillary Heavy Ion MicroProbe)

- **Capillary** microbeam

  collimation independent of ion mass & velocity, imaging

- Almost exclusively **electrostatic ion optical elements**

  heavy **cluster ion beams** available

- **Time-of-Flight spectrometer** with fast signal **digitizer**

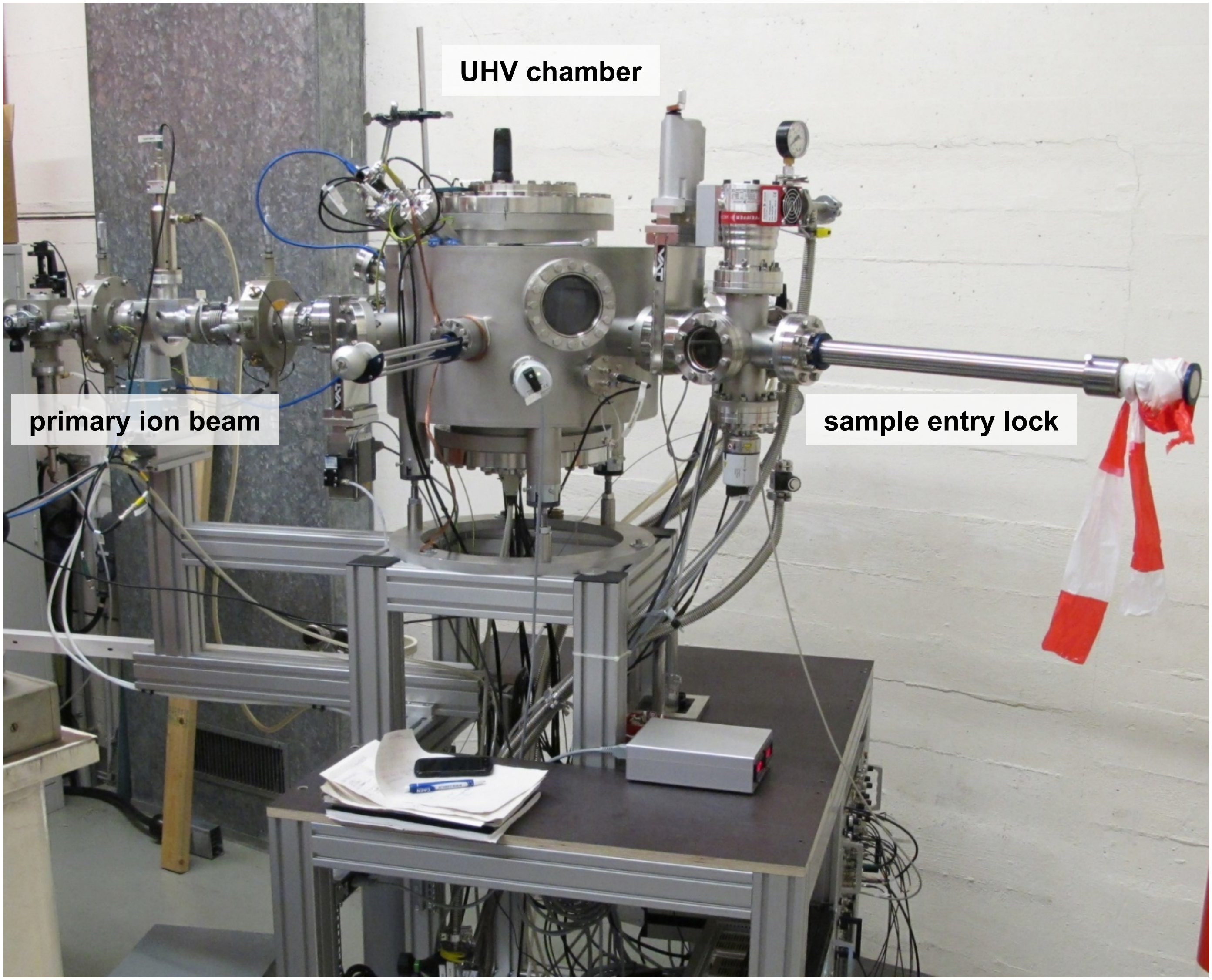
  every event is recorded independently

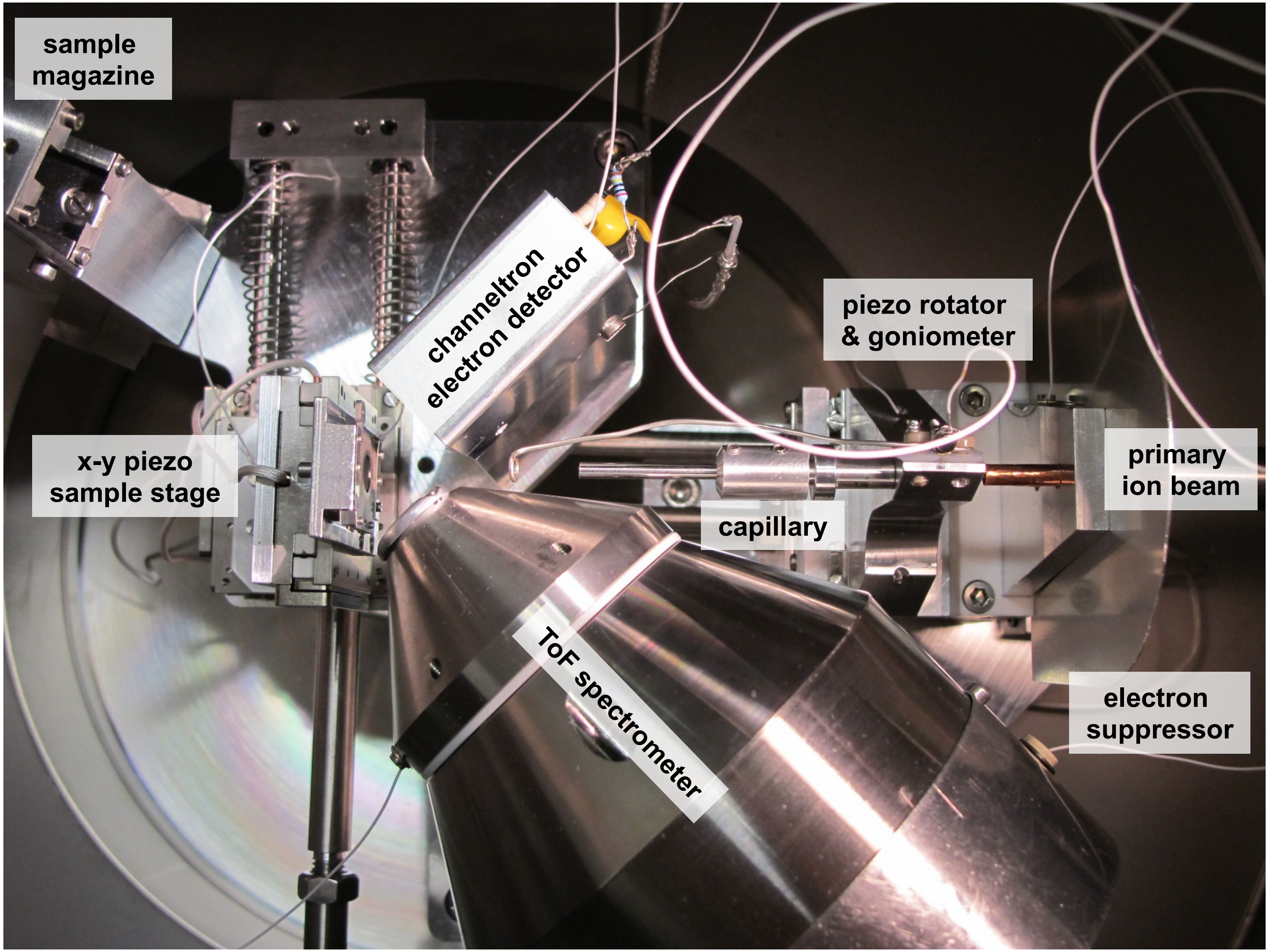
- Several different **ToF start modes** implemented

  secondary electron detector

  gas ionization detector for **transmitted ions** (thin samples)

  primary beam **pulsing**

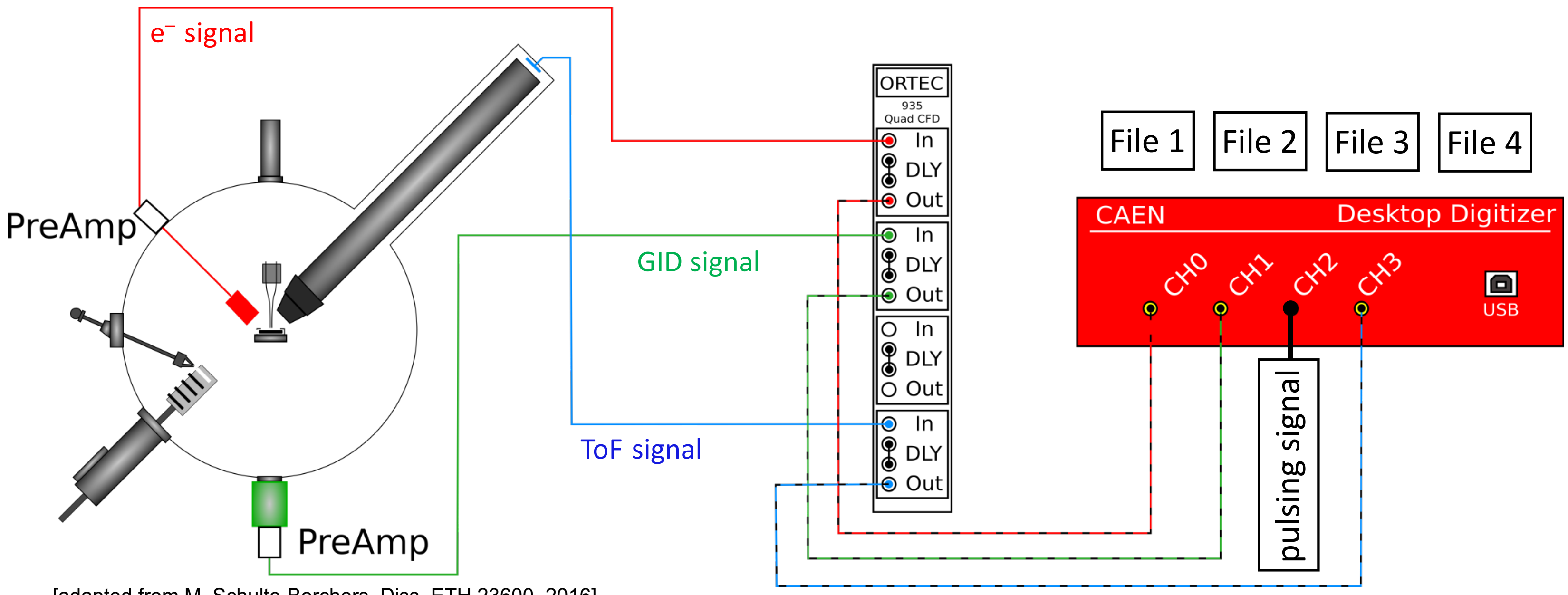

UHV chamber
primary ion beam
sample entry lock


sample magazine
channeltron electron detector
piezo rotator & goniometer
x-y piezo sample stage
primary ion beam
capillary
ToF spectrometer
electron suppressor

ToF data aquisition

3 different ToF start signals & ToF stop signal

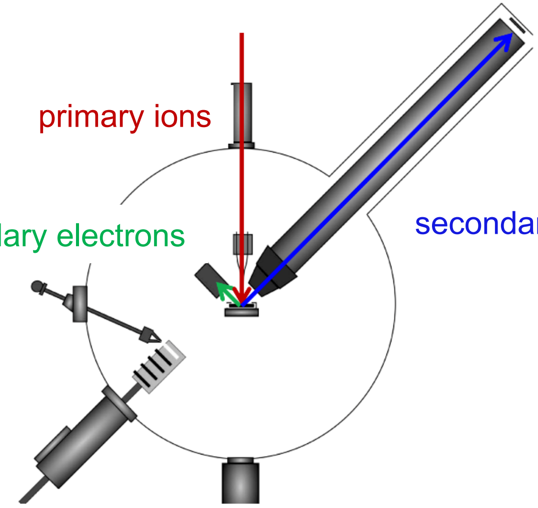
CAEN 4-channel digitizer records time stamps (1 ns resolution) into 4 separate files



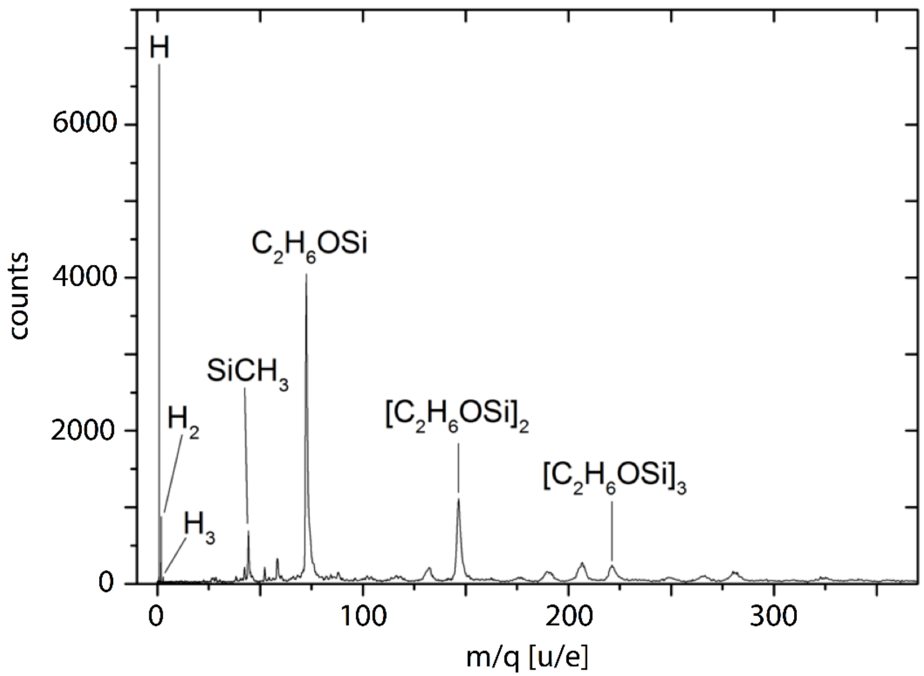
[adapted from M. Schulte-Borchers, Diss. ETH 23600, 2016]

➡ mass spectrum **analysis online** or **offline** by correlation of events

ToF start modes: electron start

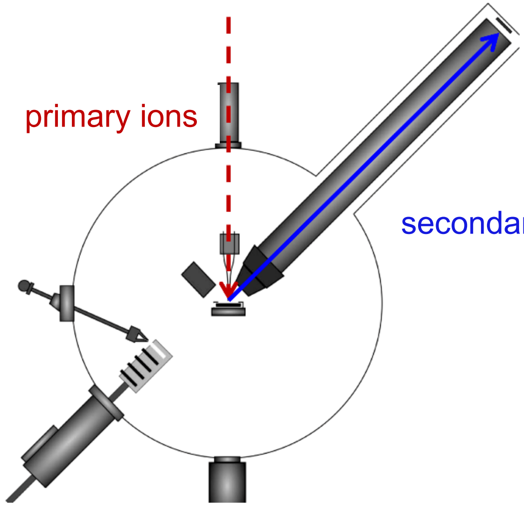


silicone surface, 28 MeV Au primary ion beam

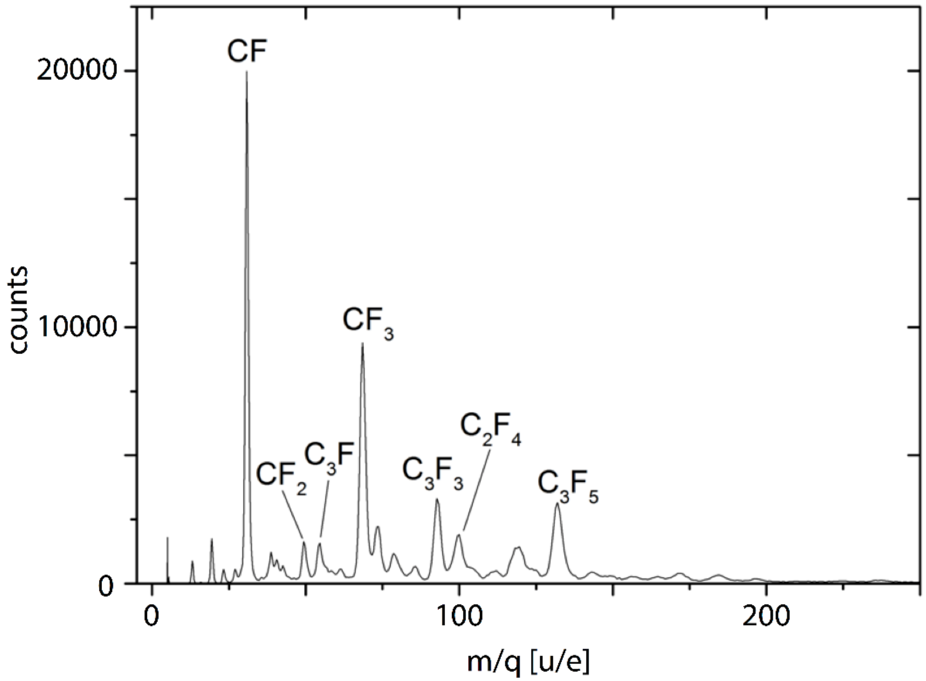


efficiency electron detector	~ 20 %
time resolution electron detector	< 1 ns
time resolution ToF detector	< 8 ns
mass resolution (m/Δm)	60 - 107

ToF start modes: beam pulse start

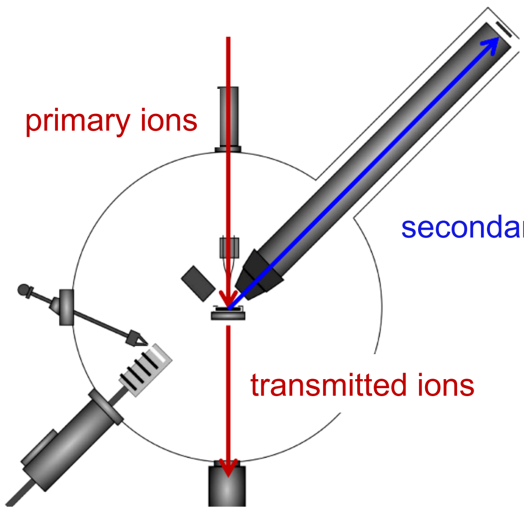


PTFE sample, 28 MeV Au primary ion beam

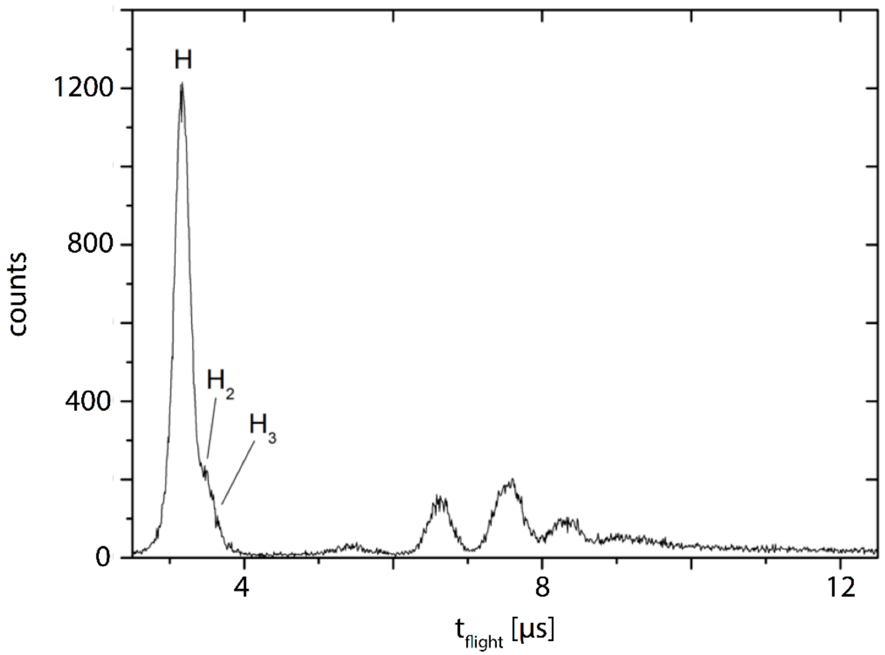


time width beam pulses	56 ns
time resolution ToF detector	< 8 ns
mass resolution (m/Δm)	30 - 45

ToF start modes: transmission start



thin silicon nitride foil, 28 MeV Au primary ion beam



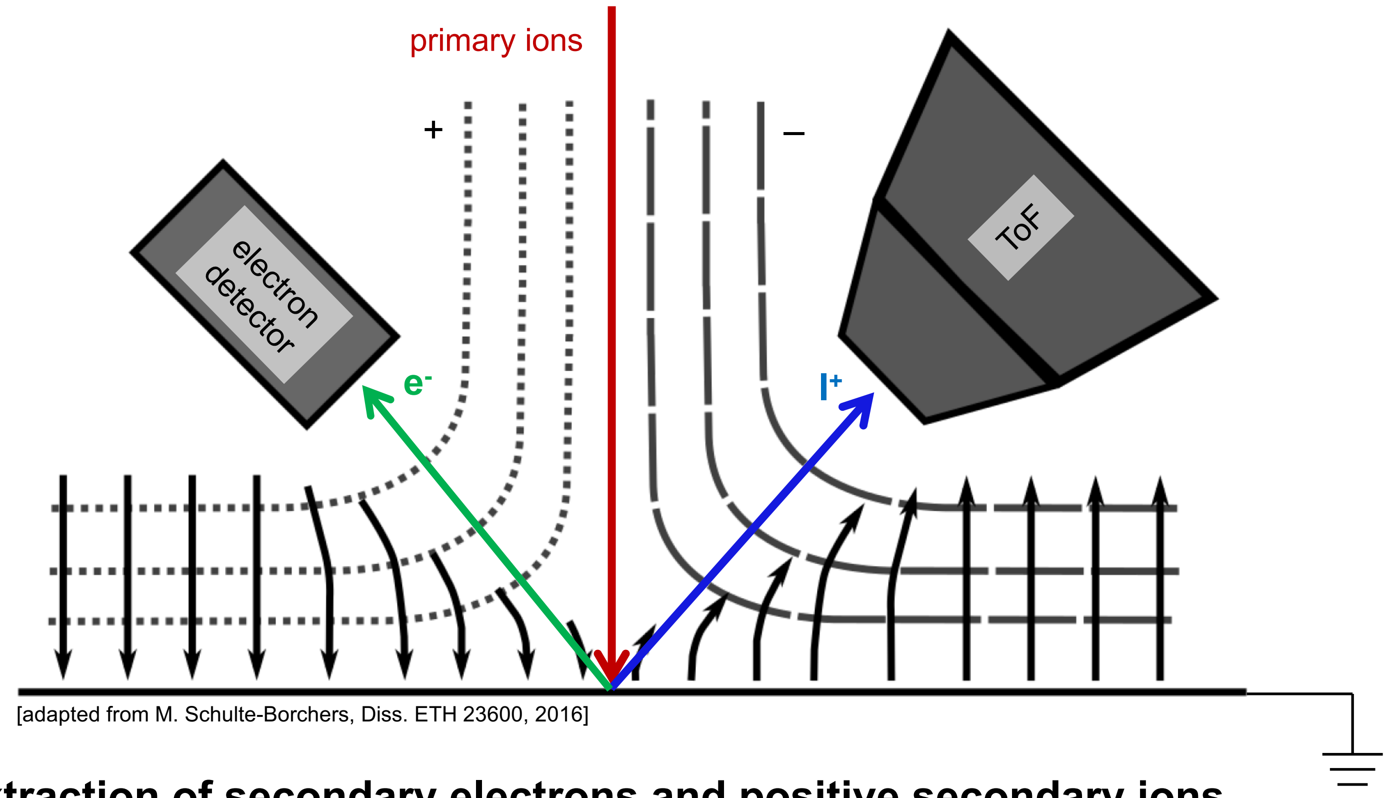
time resolution transmission detector 190 ns

time resolution ToF detector < 8 ns

used for **yield, efficiency measurements:**

efficiency ToF (sec. / inc. ion) 10 – 40 %

Electron start: field configuration



[adapted from M. Schulte-Borchers, Diss. ETH 23600, 2016]

➡ impact on mass resolution

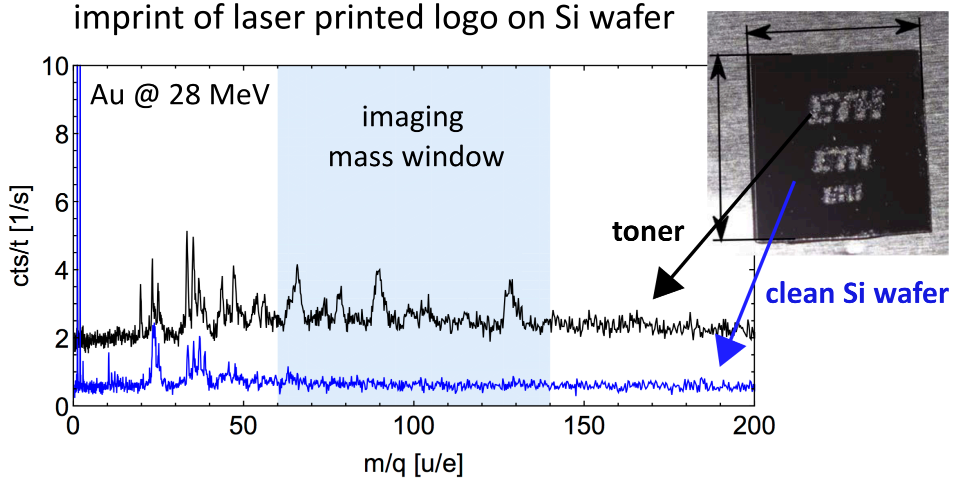
simultaneous extraction of secondary electrons and positive secondary ions

field free region at beam impact point

initial kinetic energy needed for electrons and ions to escape

2D Imaging

imprint of laser printed logo on Si wafer

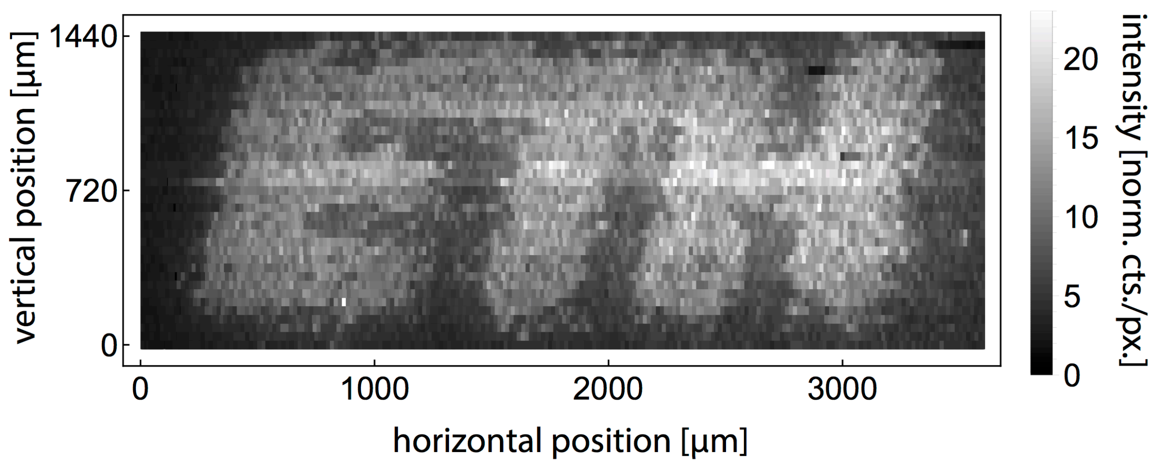


lateral resolution 12 mm

capillary Ø : 7 mm,

working distance 30 mm

collimated beam



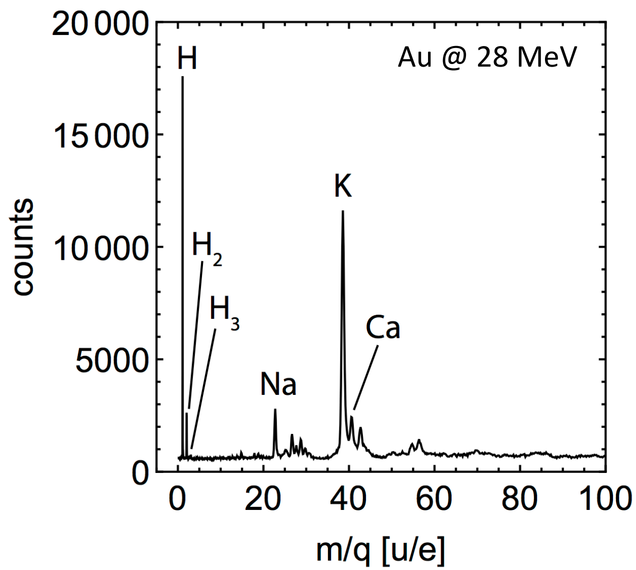
time per pixel 1 sec

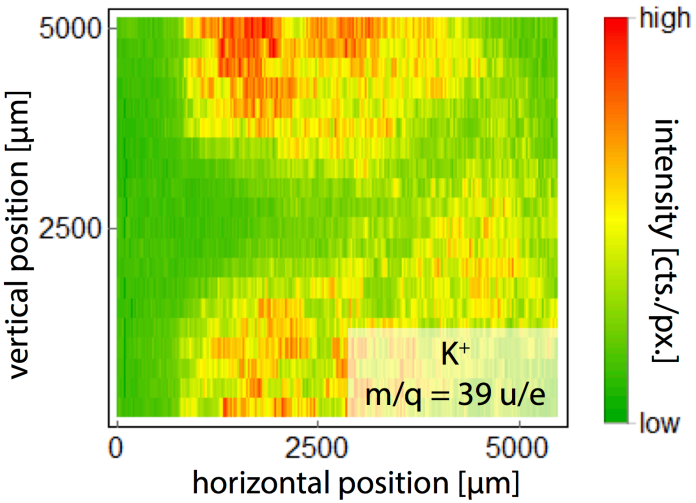
continuous sample movement

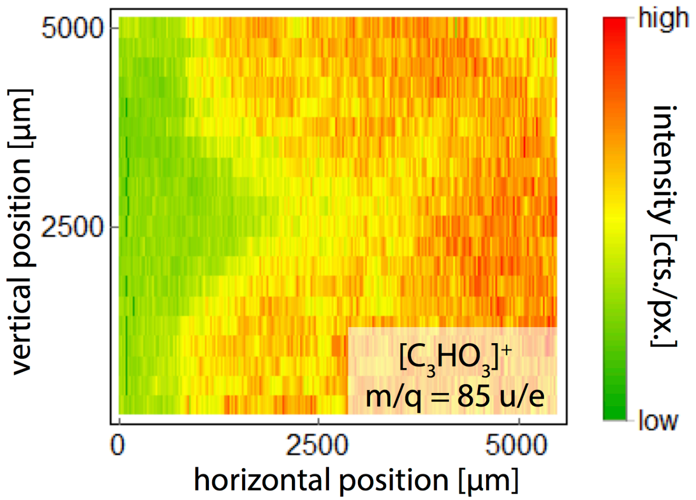
ToF coincidence rate 3 - 6 kHz

2D Imaging

imprint of strawberry
on Si wafer



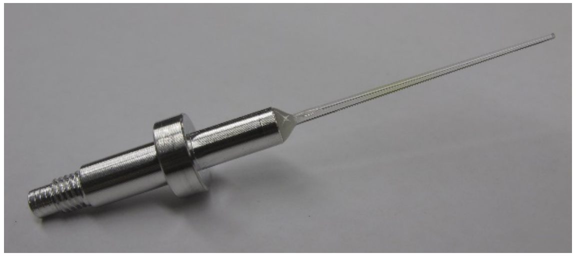




Conclusion

- **MeV-SIMS setup** with **capillary microprobe**

    enables use of heavy primary ion beams at high energies



- ToF mass spectrometer with

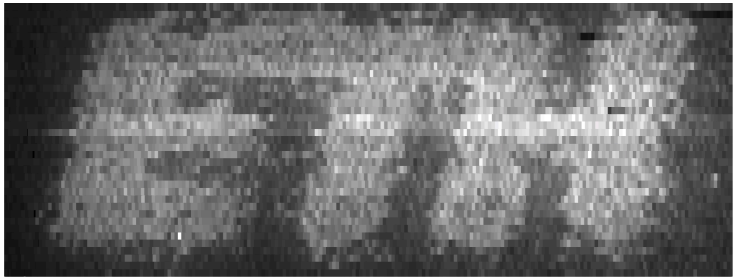
    infinite-stop electron start mode

    no efficiency loss through primary beam pulsing

- **Imaging** by sample scanning

    resolution in the 10 μm range determined

    by capillary outlet diameter



Outlook

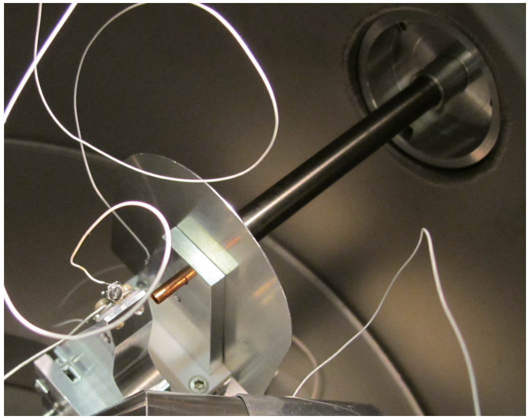
- **Reduce electron background**

  test electron suppressor and

  beam tube screening on HV (already installed)

- **Imaging** with **higher resolution**

  capillary with smaller outlet diameter (already installed)



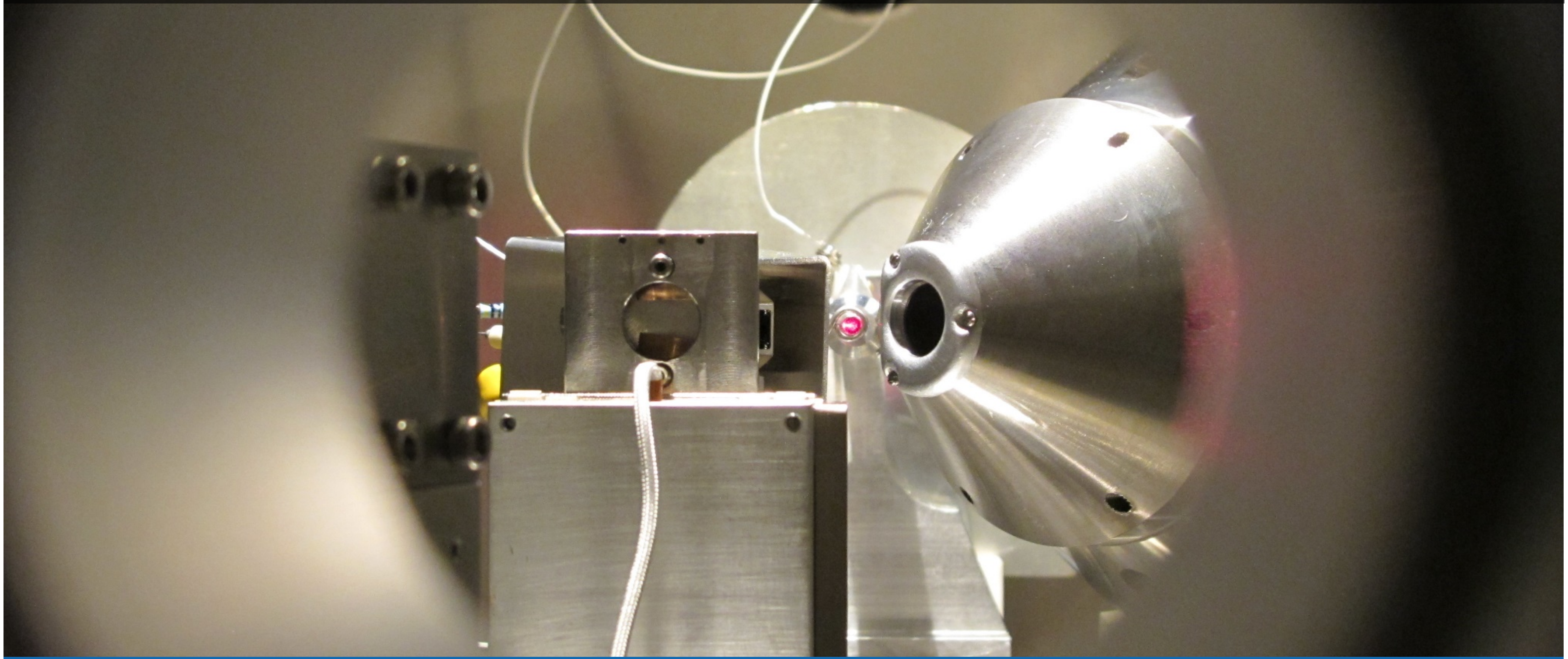
- Advanced **signal** and **peak correlation**

  (work in progress)

- Analyse **sputter yields** and **mechanisms**

  Quantify sputter yields for different primary ions / energies / sample materials, **negative ions**

Thank you for your attention!



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