BIRKELAND CENTRE
FOR SPACE SCIENCE

OBSERVATION of Long laboratory sparks and lightning interaction with aircraft

by Pavlo Kochkin

Research school of Birkeland Centre for Space Science:
Atmospheric Electricity and Hard radiation from Thunderclouds

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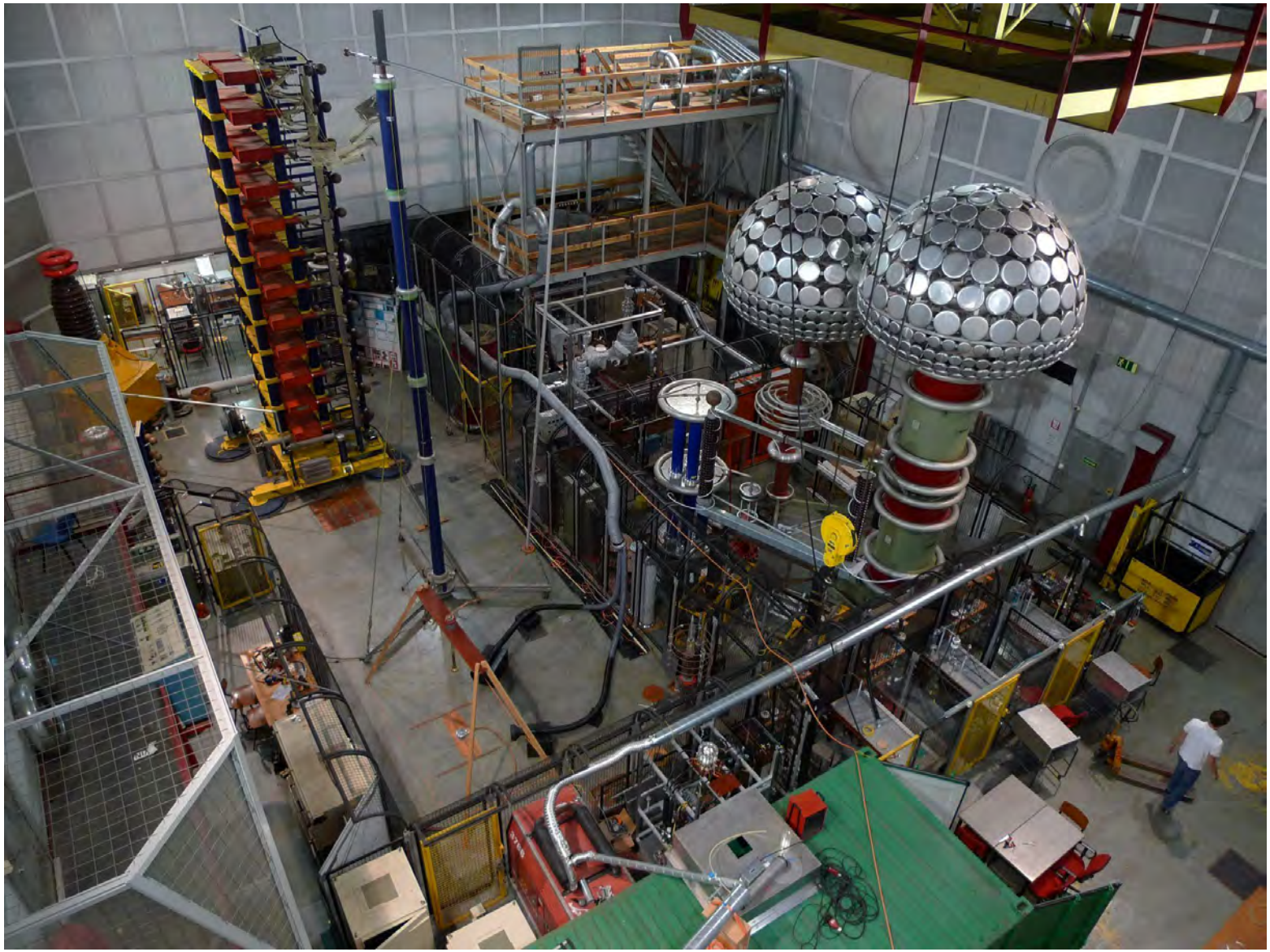
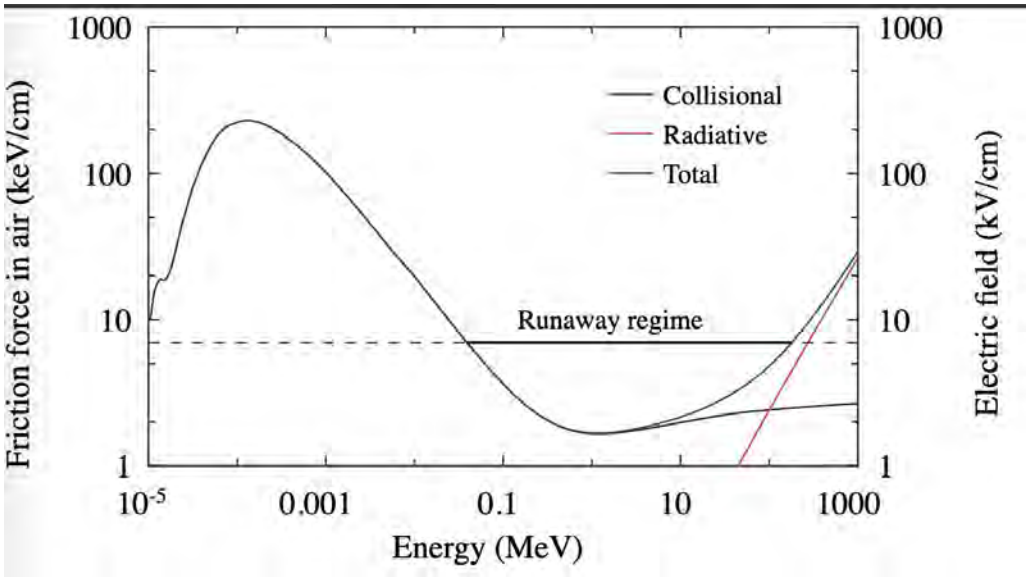


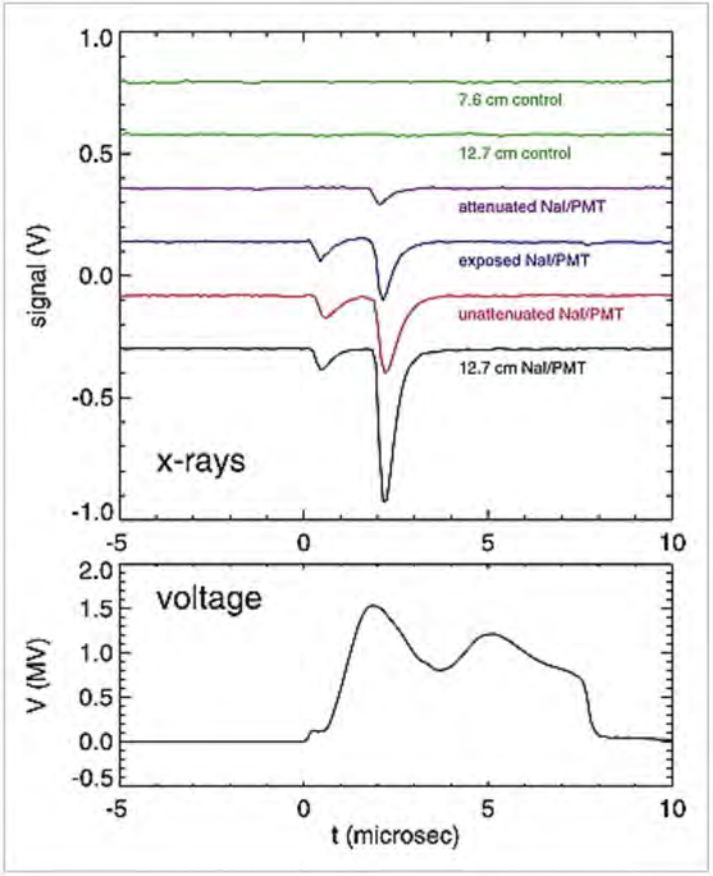
X-ray bursts produced by laboratory sparks in air

J. R. Dwyer ✉, H. K. Rassoul, Z. Saleh, M. A. Uman, J. Jerauld, J. A. Plumer

First published: 22 October 2005 | https://doi.org/10.1029/2005GL024027 | Cited by: 59

- Intensity and spectra are inconsistent with RREA
- Cold runaway breakdown





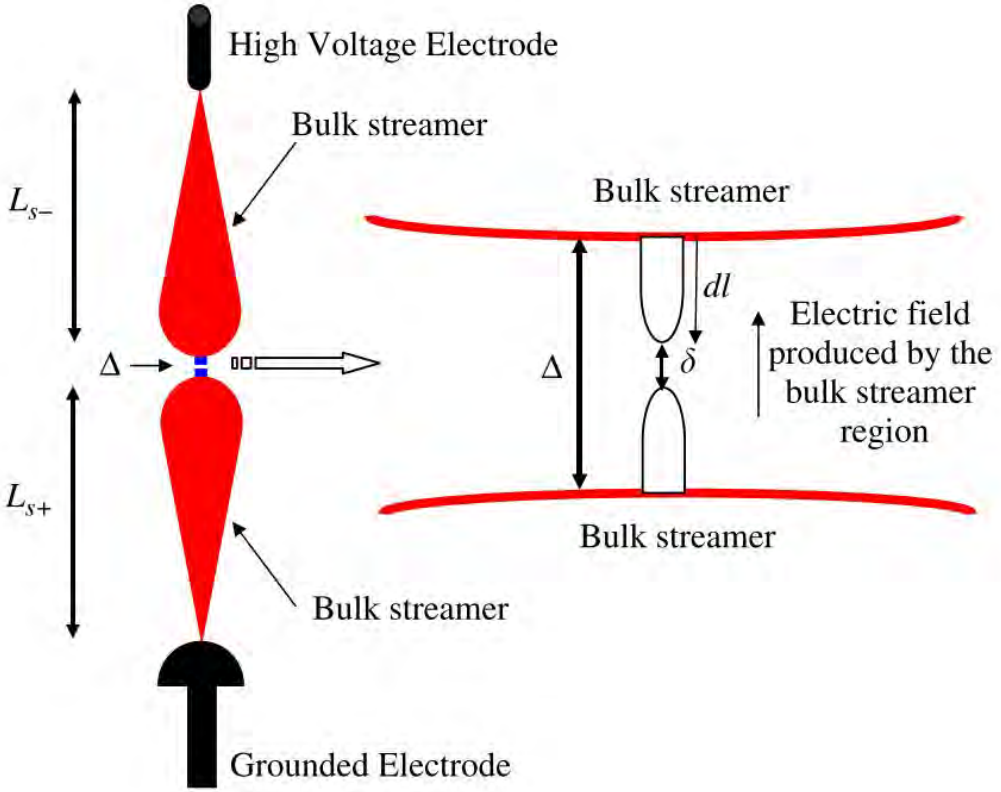
BIRKELAND CENTRE FOR SPACE SCIENCE

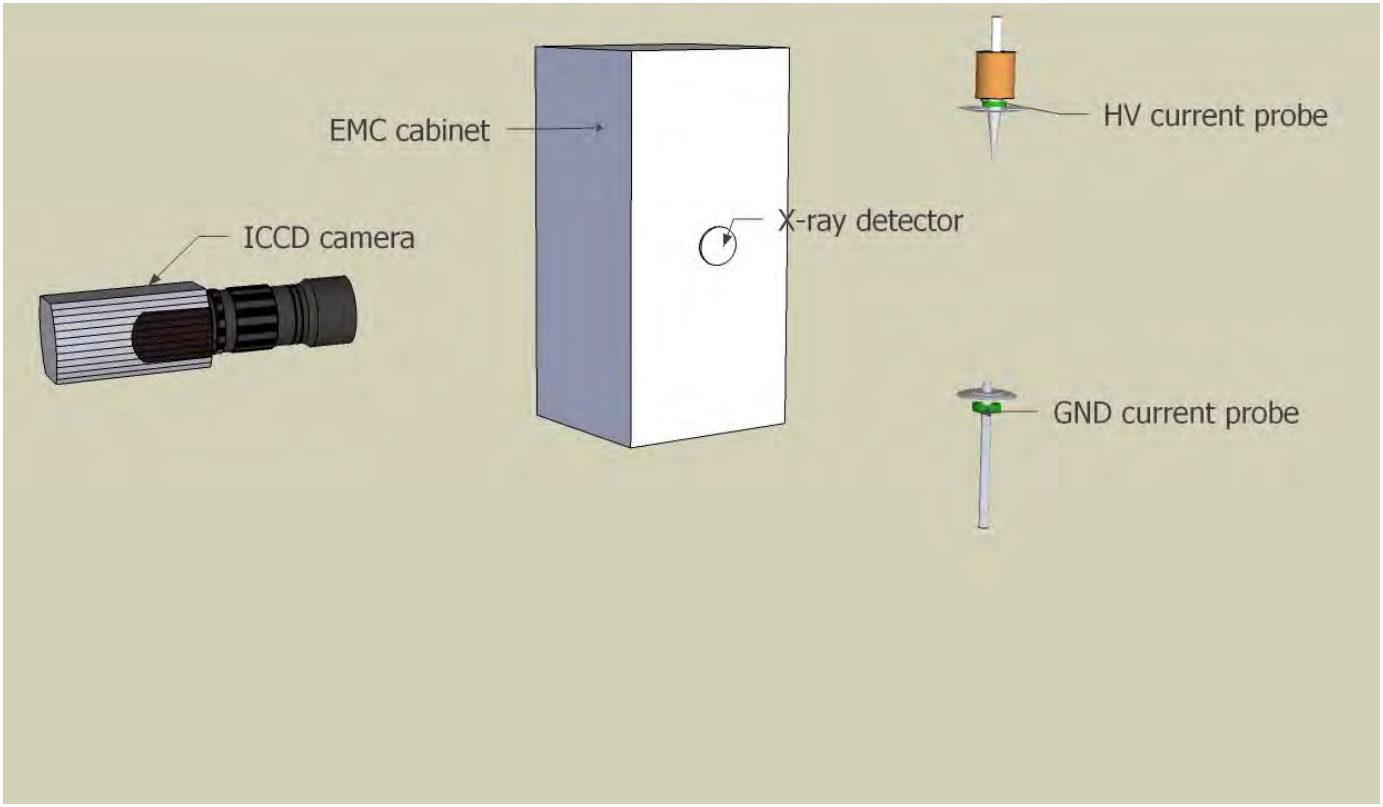
On the possible origin of X-rays in long laboratory sparks

Vernon Cooray [a,*], Liliana Arevalo [a], Mahbubur Rahman [a], Joseph Dwyer [b], Hamid Rassoul [b]

" … *an encounter between two streamer heads in the mid gap region can push the electrons to energies in the range of 200 keV.*"

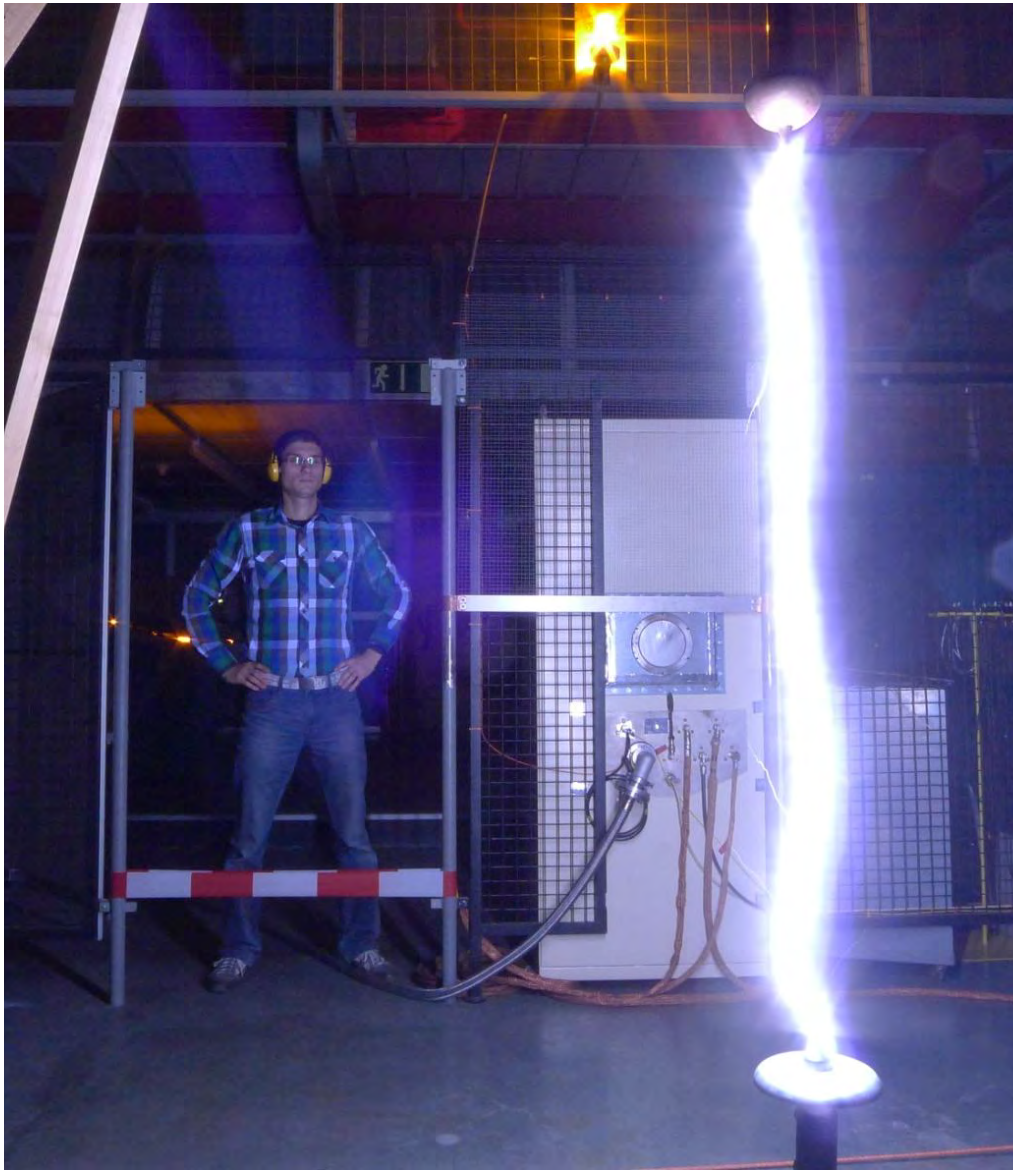
Time resolved photography in simultaneous measurement of X-rays would be able to confirm this prediction.



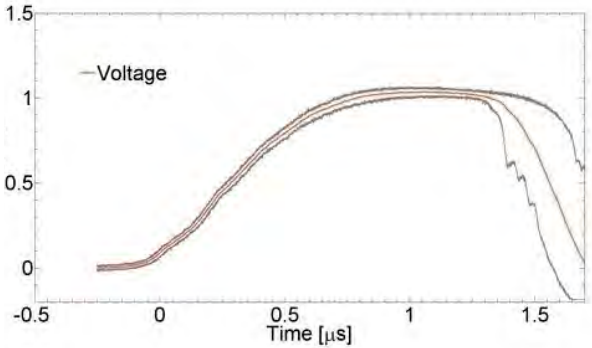


1 MV over 1 meter spark

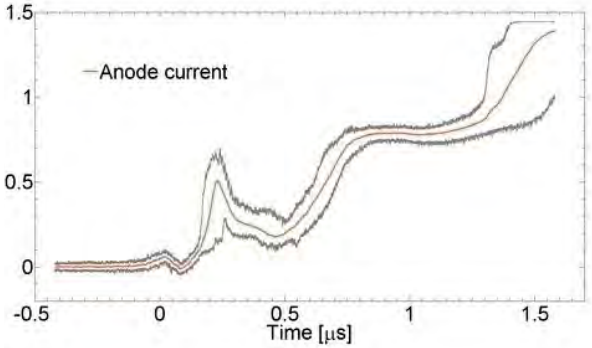
Experimental setup



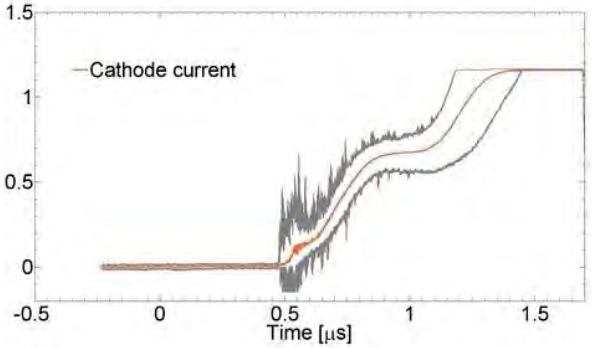
Voltage



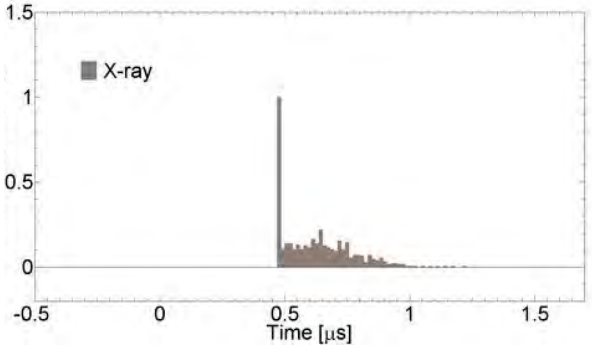
HV current



GND current



X-rays [appearance]



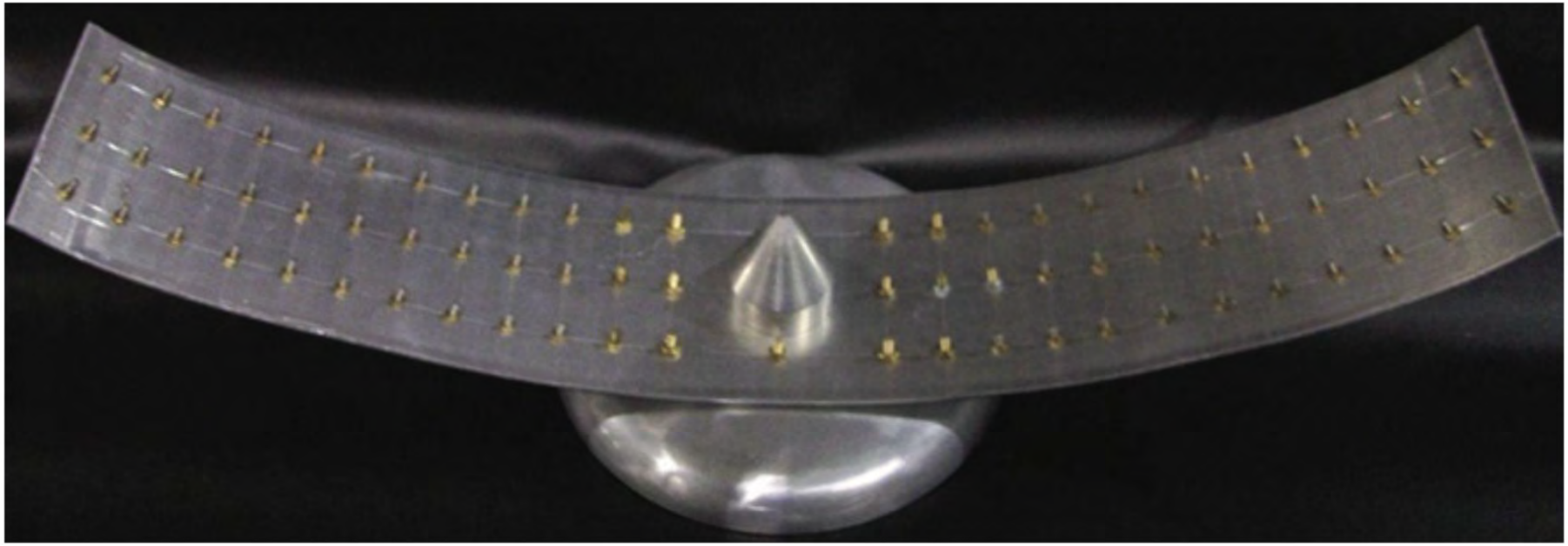
+

HV-electrode

GND-electrode

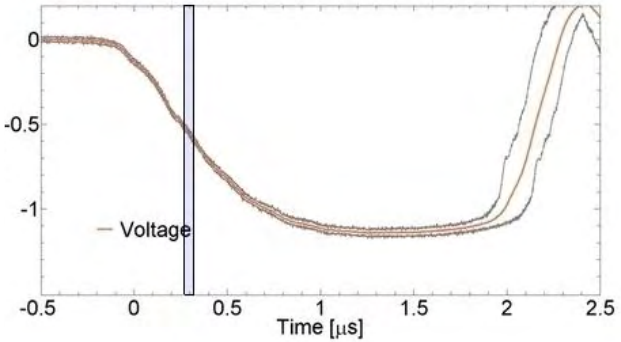
Positive discharge animation https://www.youtube.com/watch?v=1n96IHrKeIw

Paper https://iopscience.iop.org/article/10.1088/0022-3727/45/42/425202/meta



Negative streamers is necessary condition to produce X-rays

Voltage



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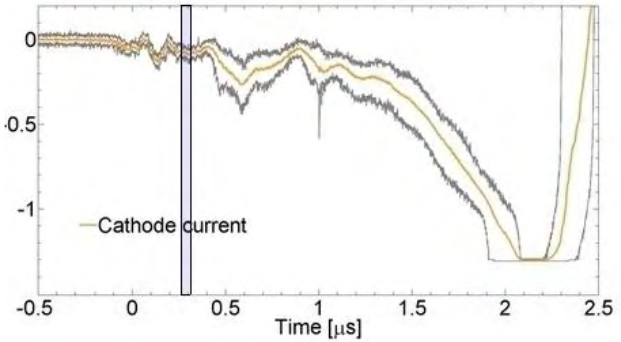

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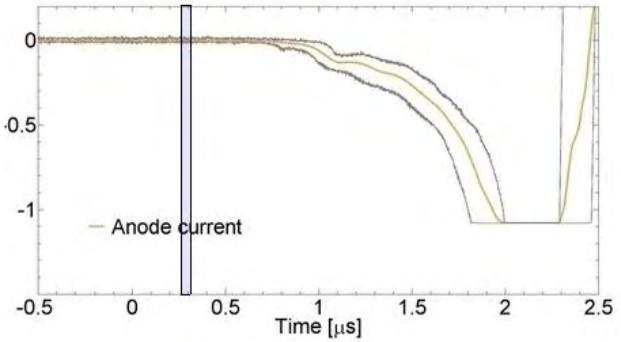
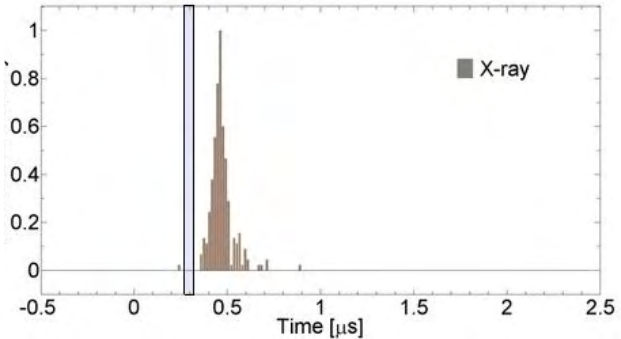


X-rays [appearance]



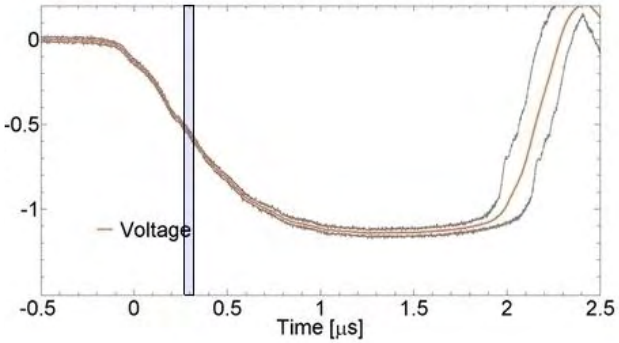
HV-electrode

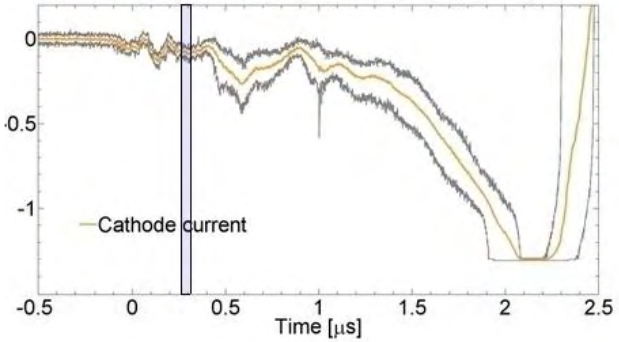
GND-electrode

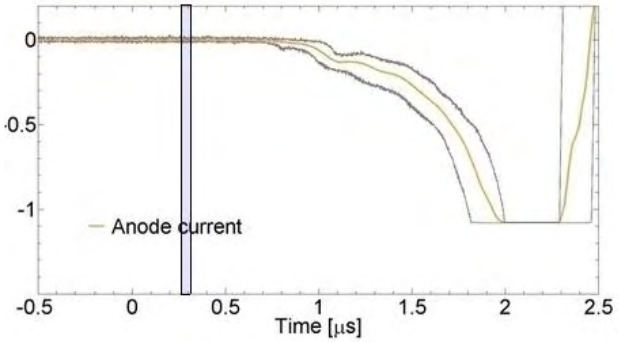
Negative discharge animation https://www.youtube.com/watch?v=2vjElSVaiPo

Papers

1. https://iopscience.iop.org/article/10.1088/0022-3727/48/2/025205
2. https://iopscience.iop.org/article/10.1088/0022-3727/47/14/145203/meta
3. https://iopscience.iop.org/article/10.1088/0022-3727/49/42/425203/meta


Voltage
Time [μs]


Cathode current
Time [μs]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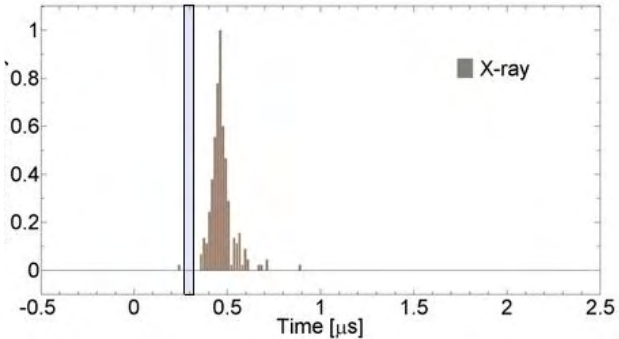
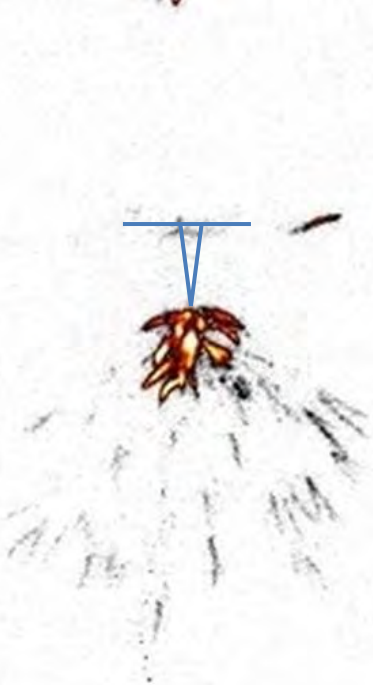
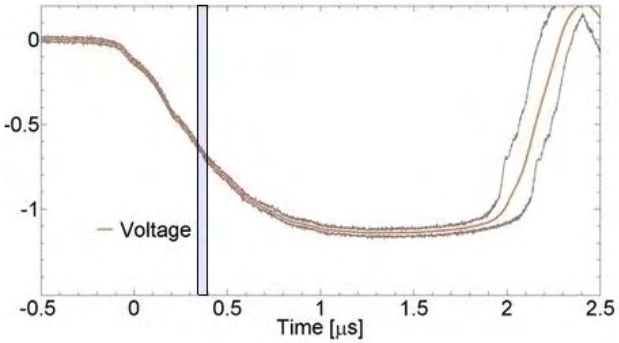

X-ray
Time [μs]

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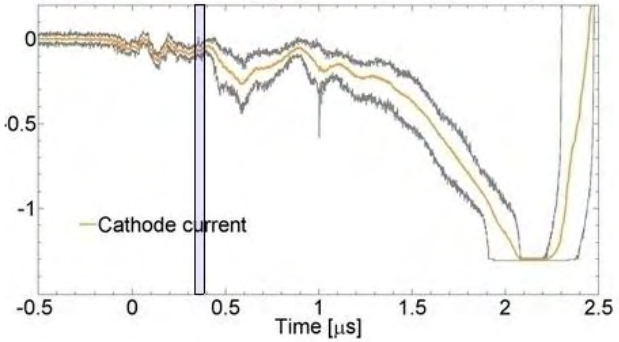
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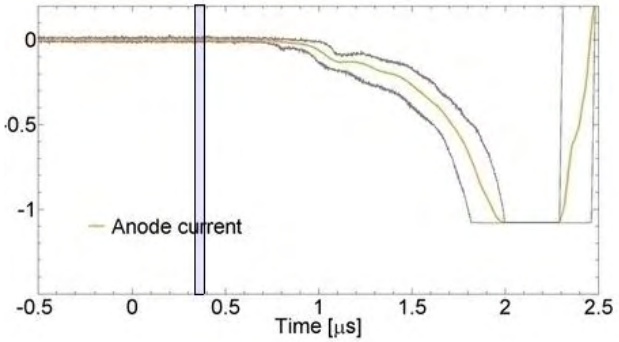
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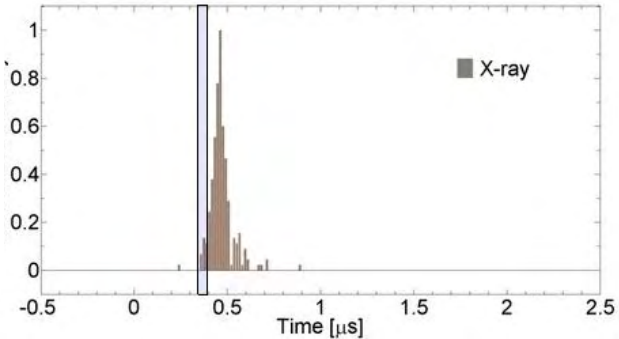
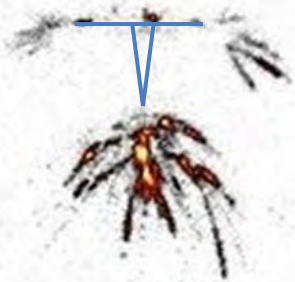
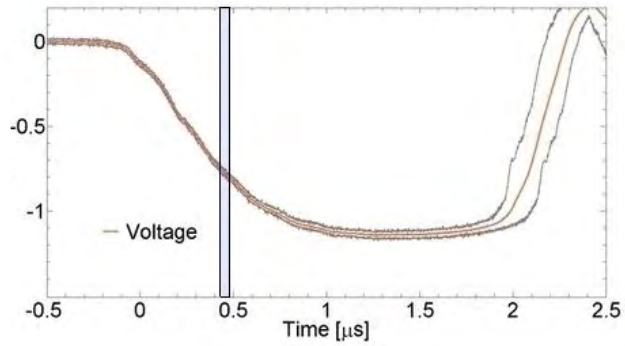

X-ray
Time [μs]

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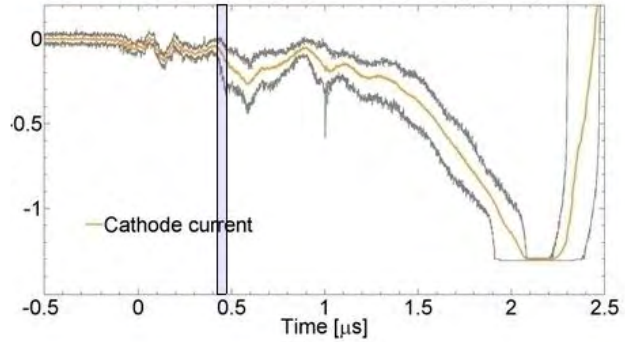
Time [μs]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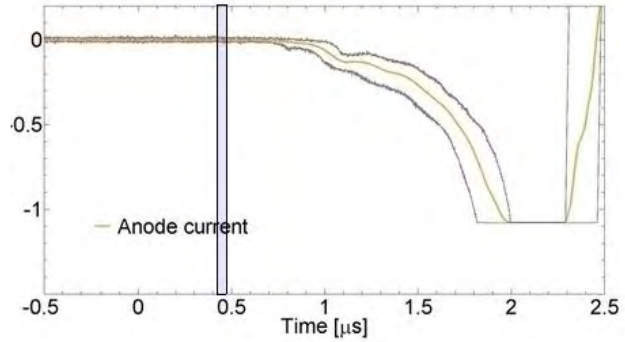
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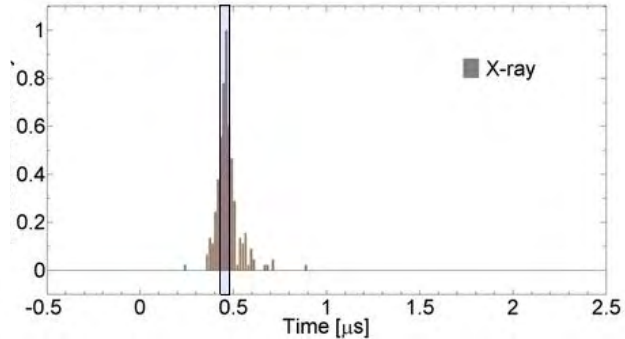
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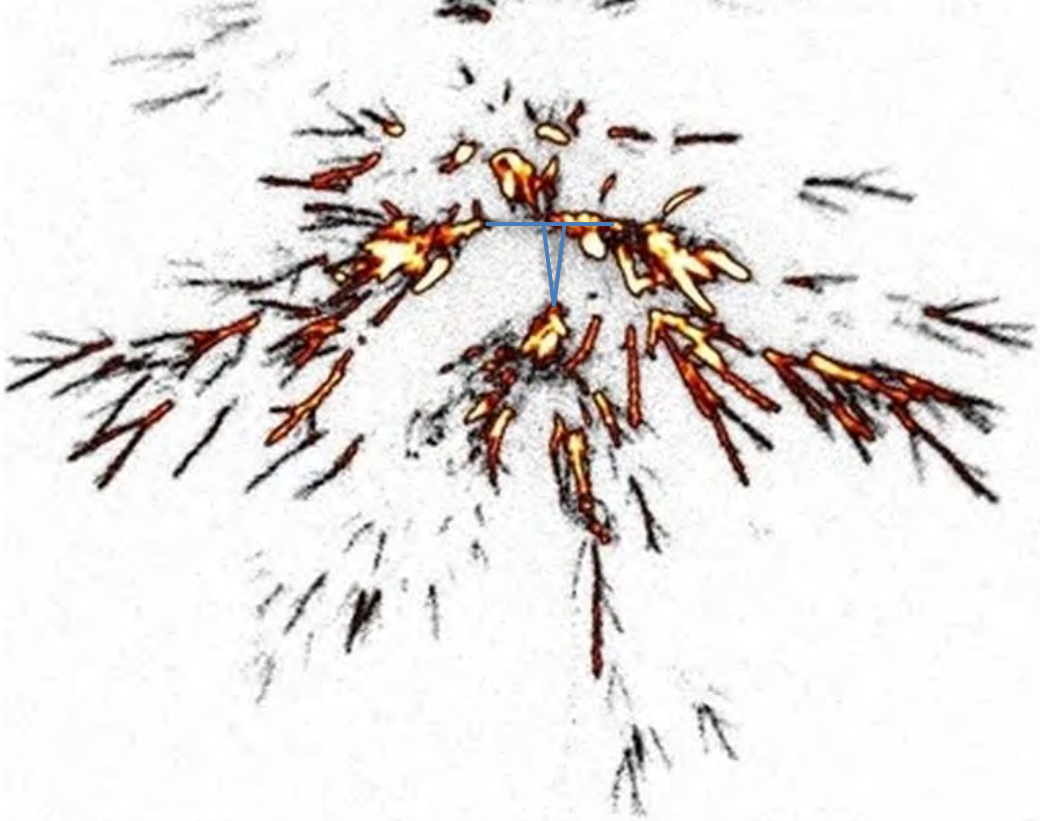

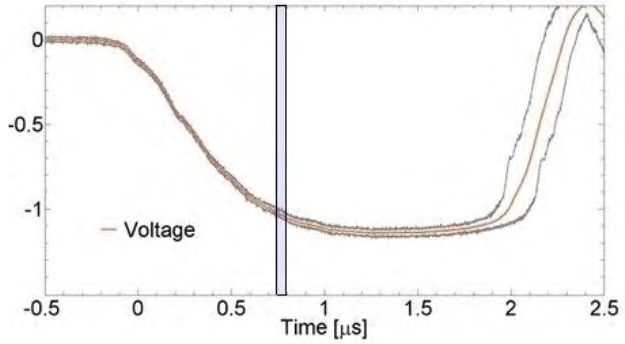
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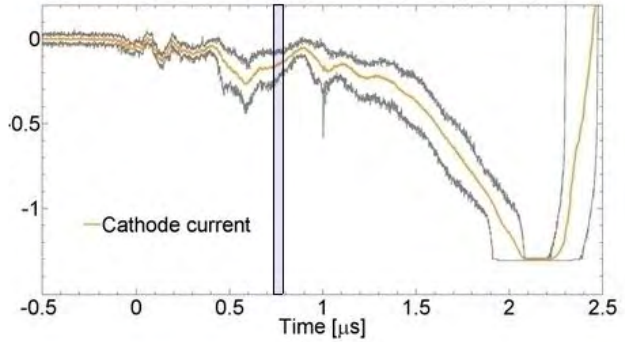
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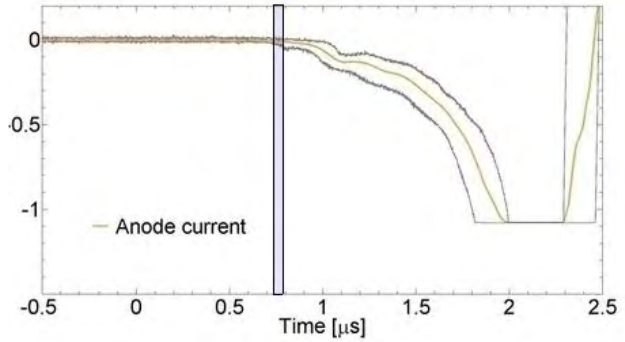
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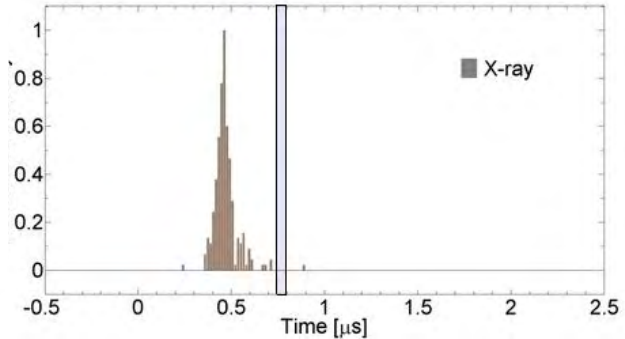
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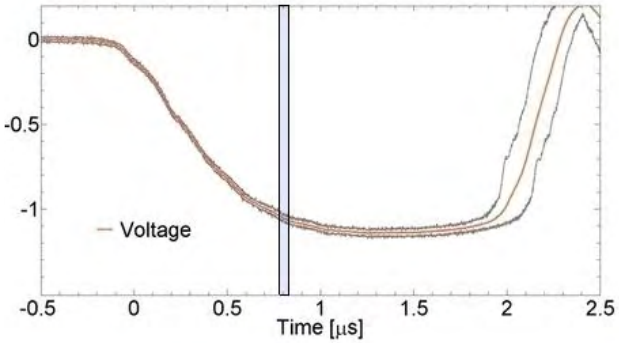
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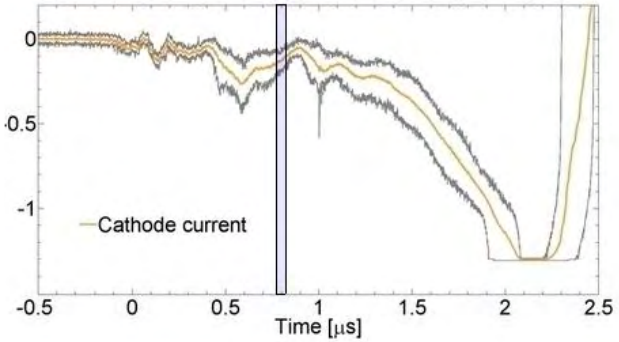
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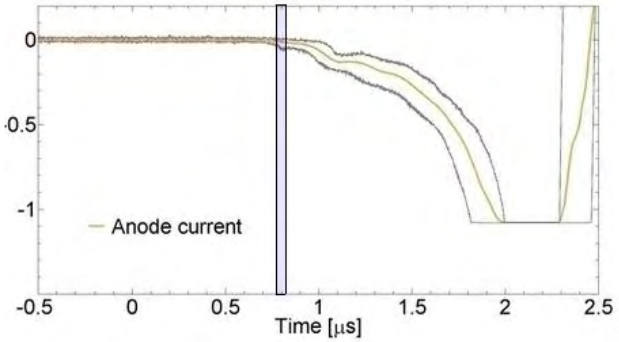
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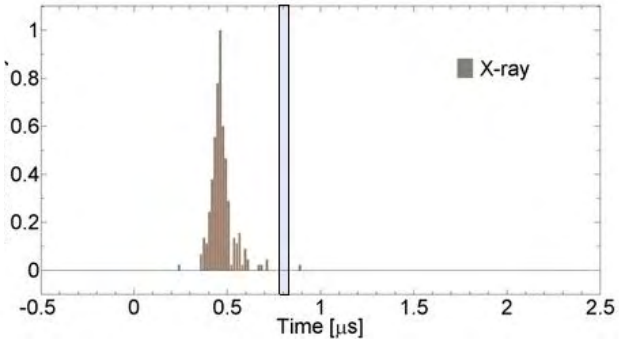
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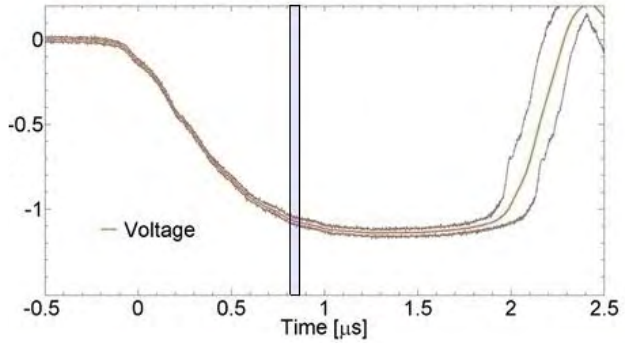
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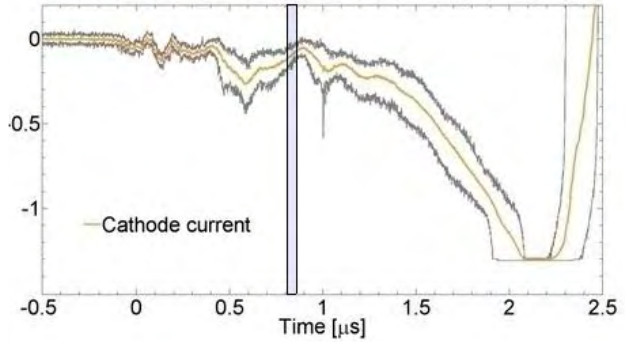
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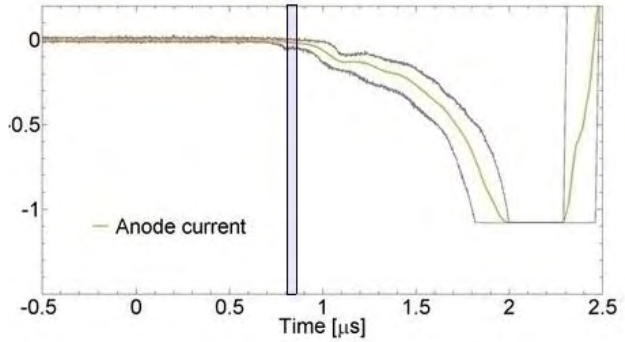
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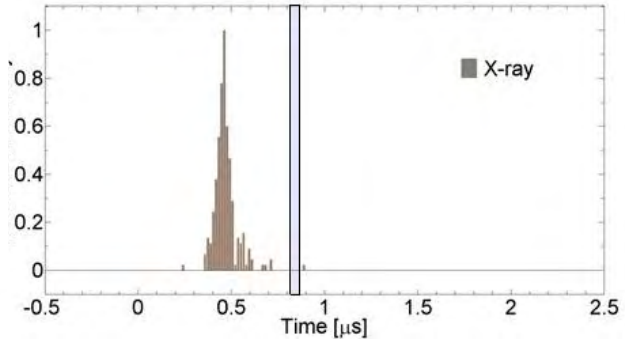
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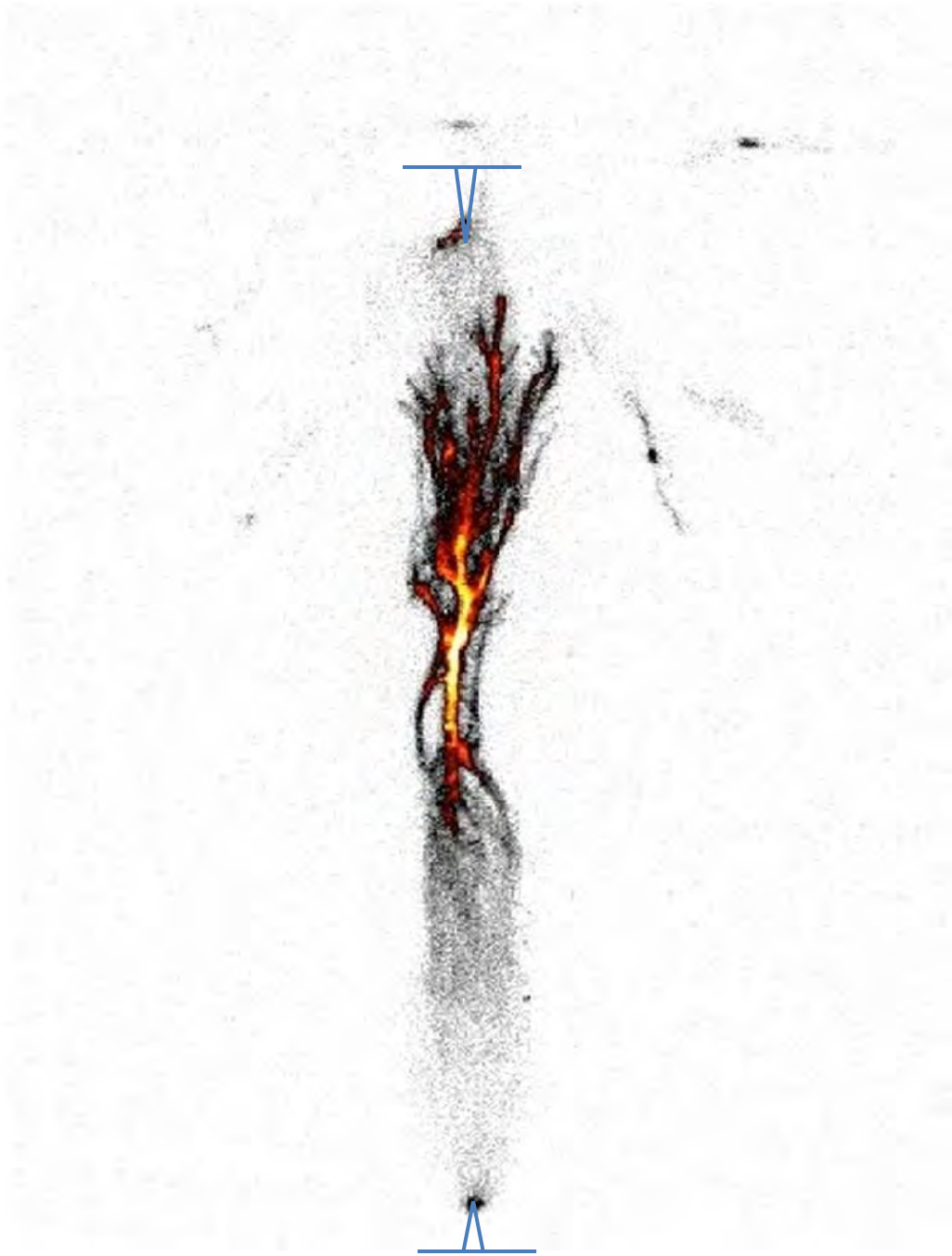

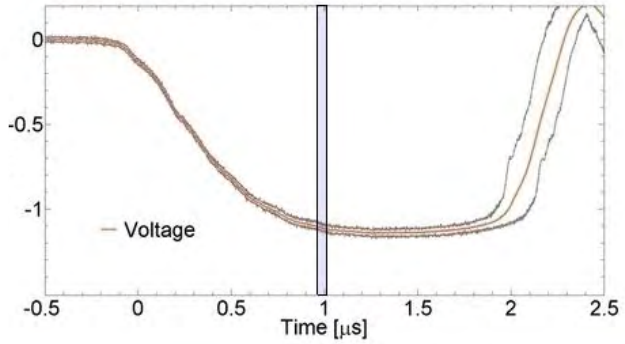
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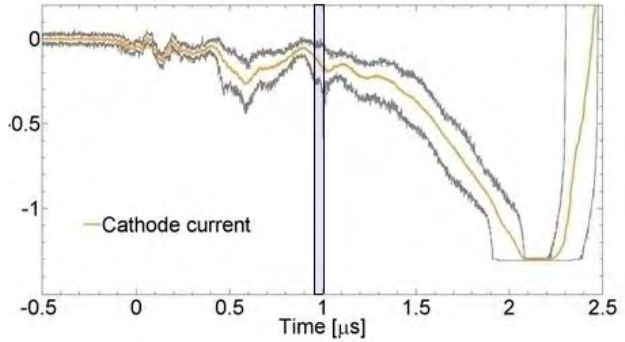
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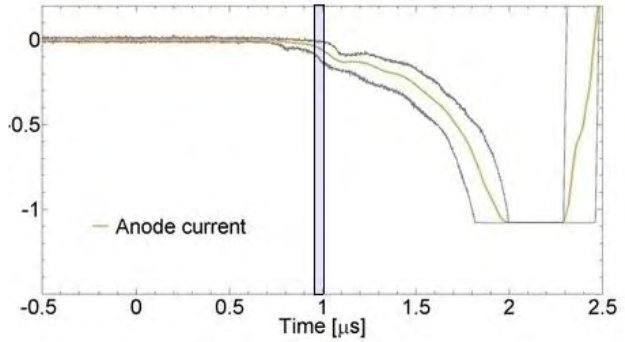
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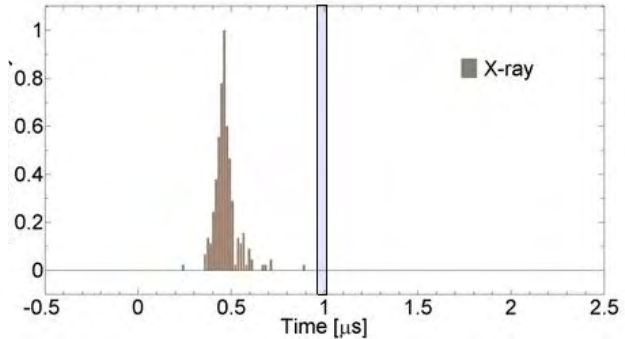
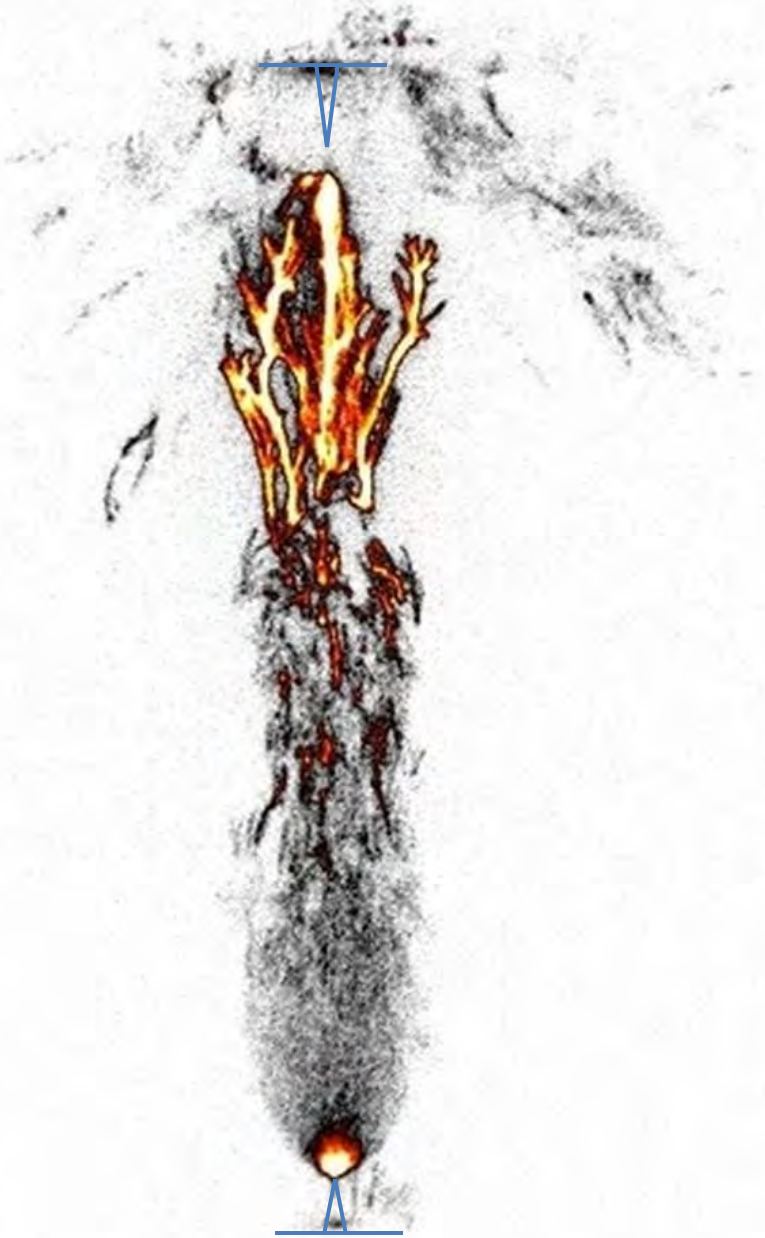
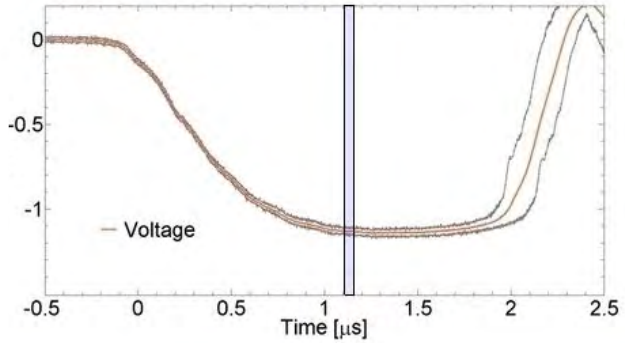

X-ray
Time [μs]

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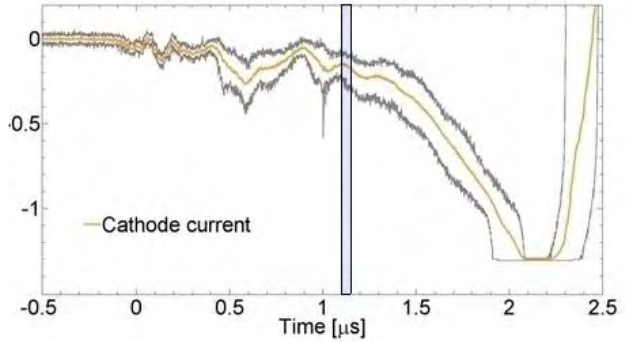
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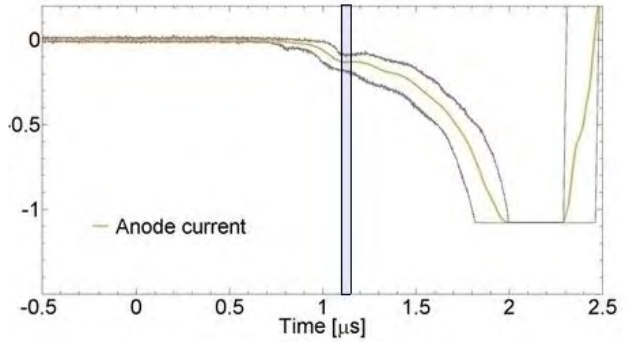
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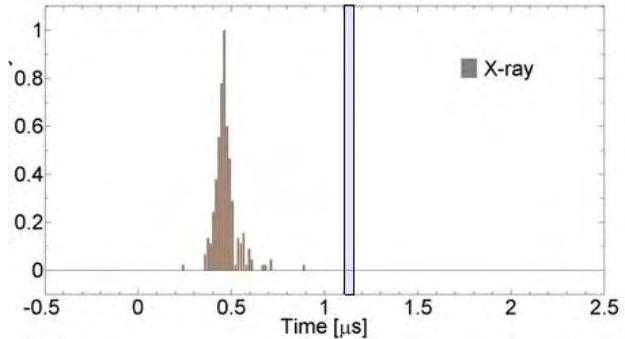
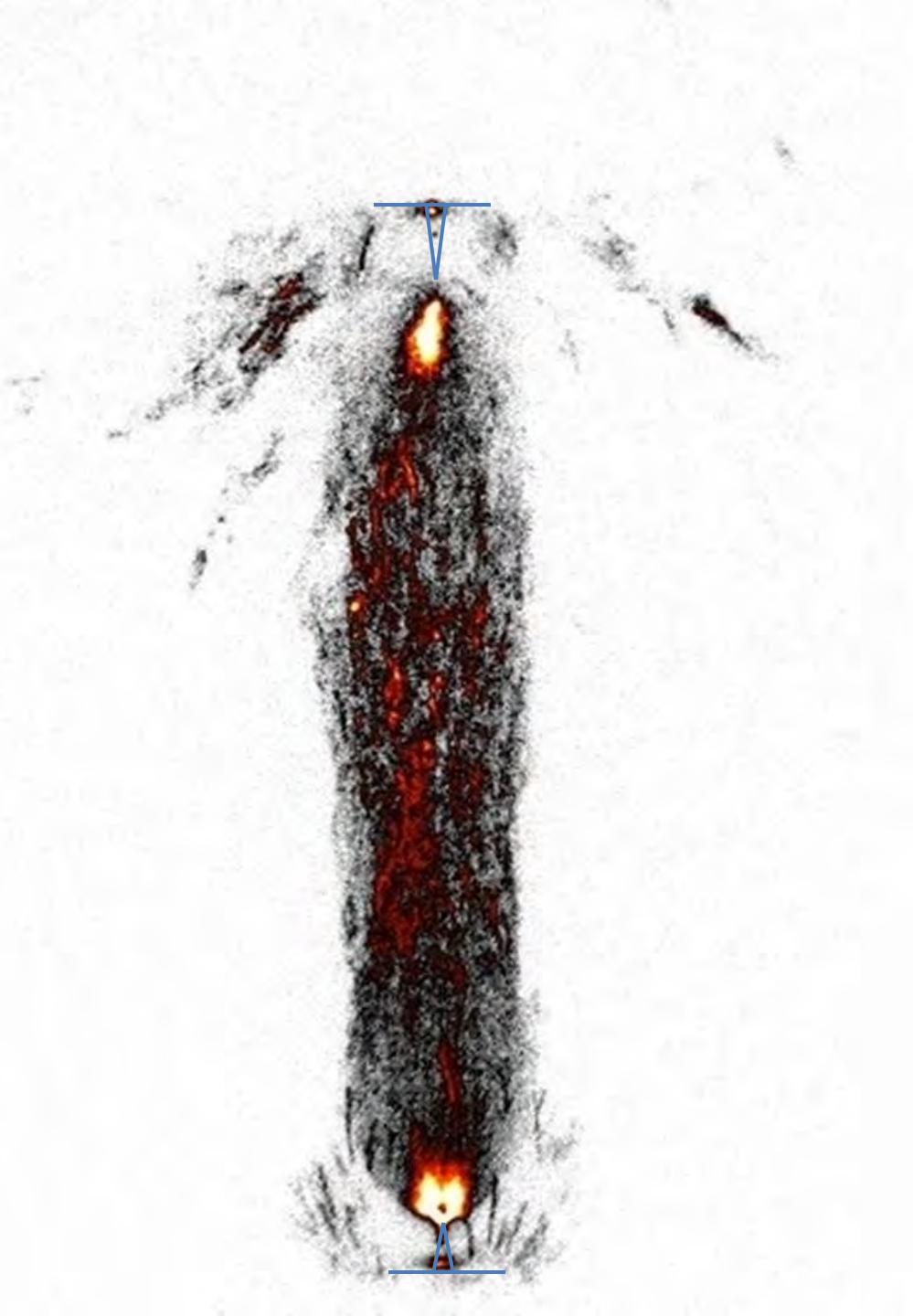
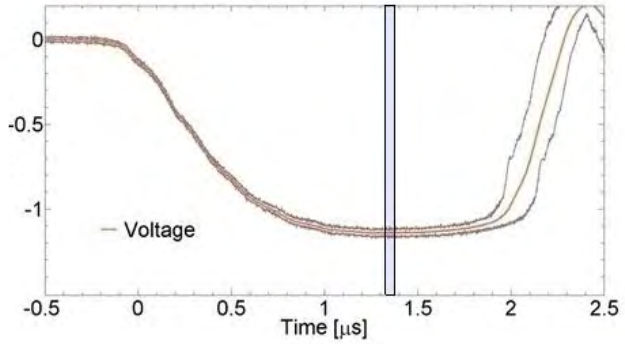

X-ray
Time [μs]

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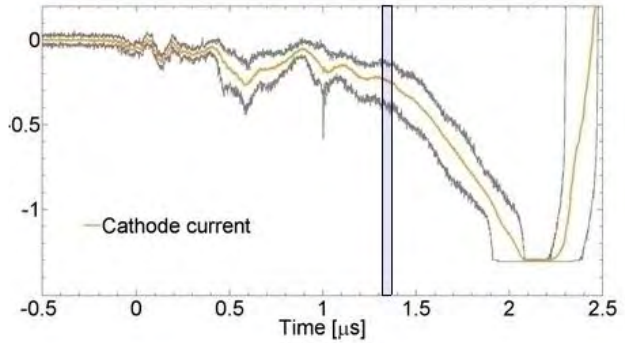
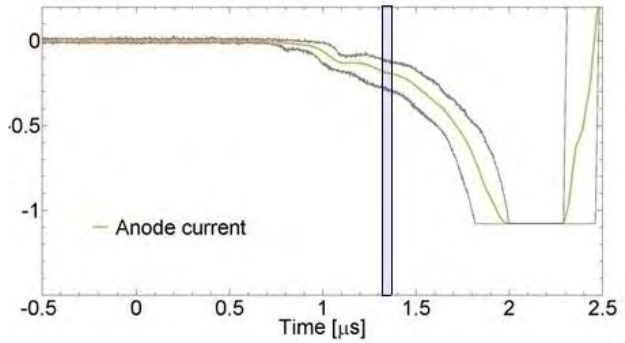
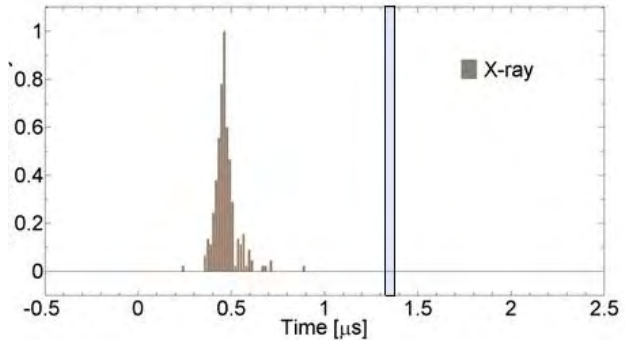
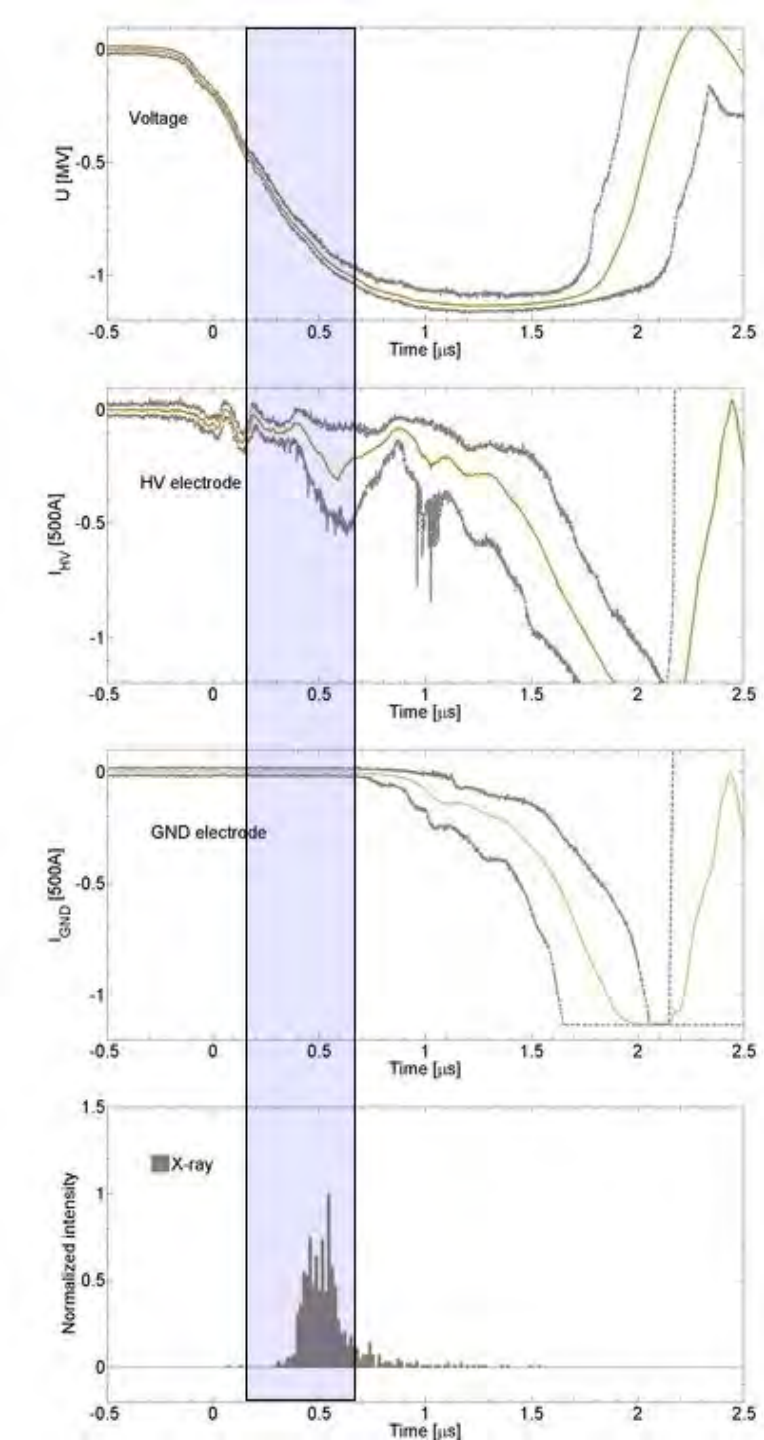
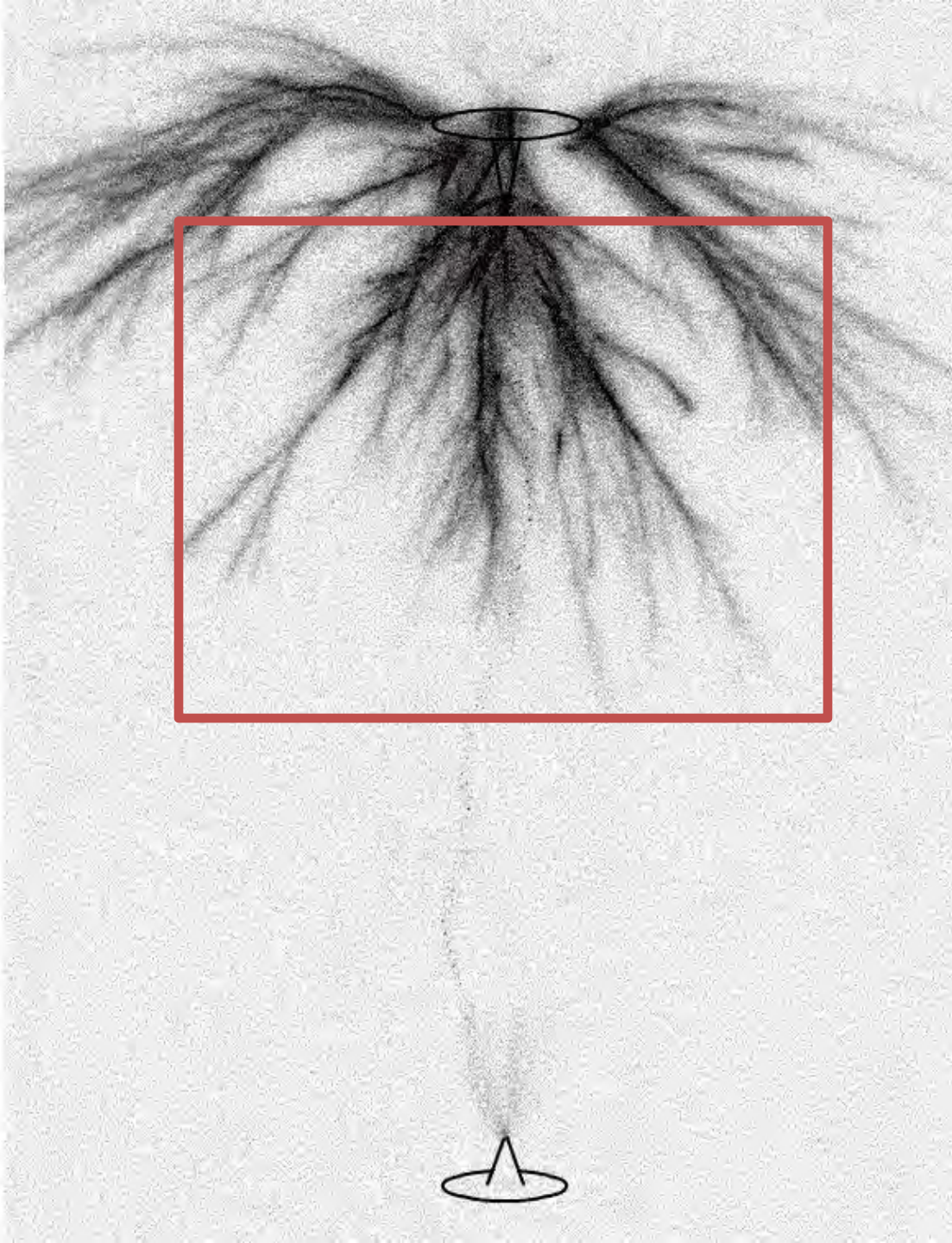
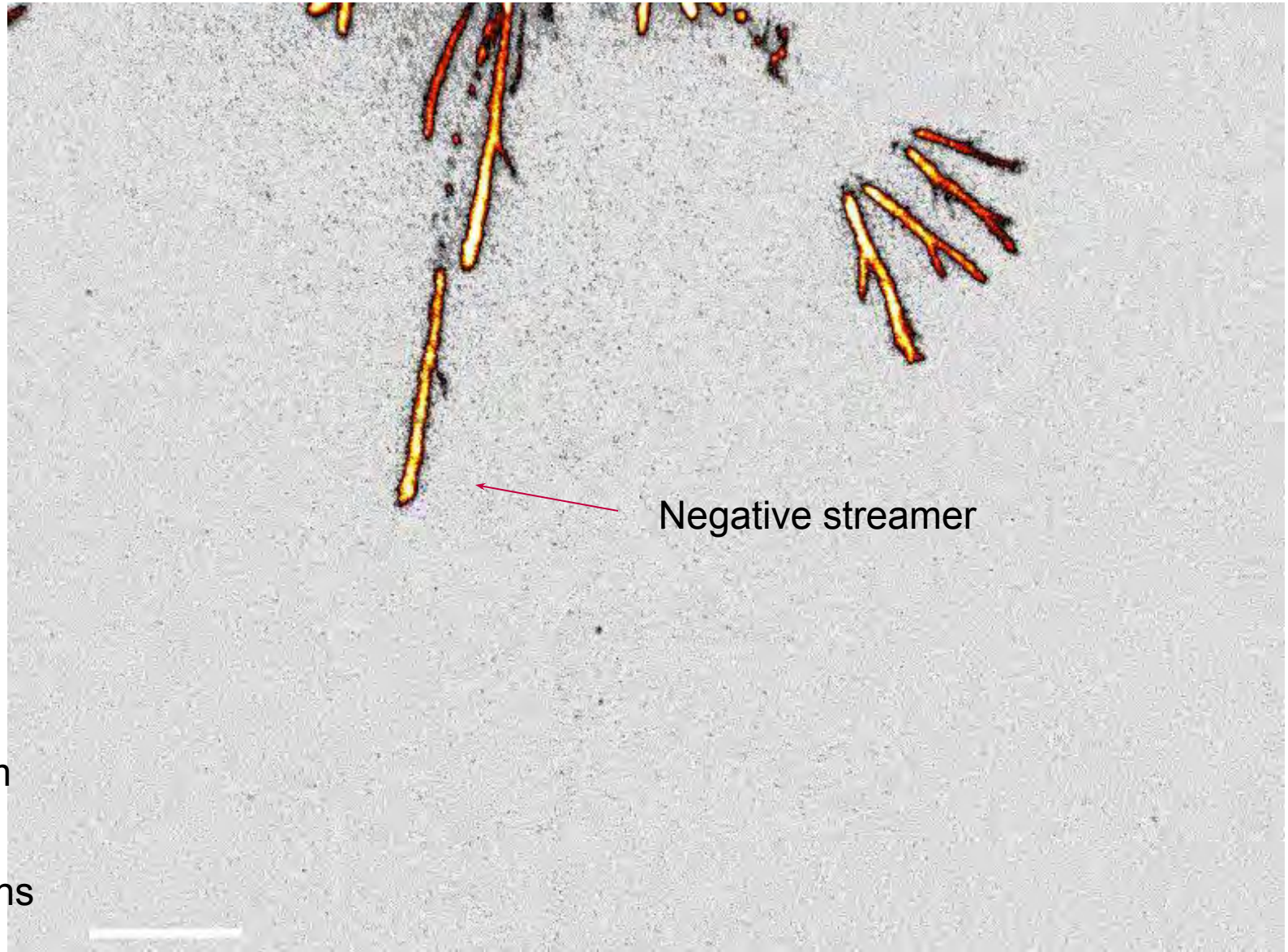

Cathode current
Time [μs]

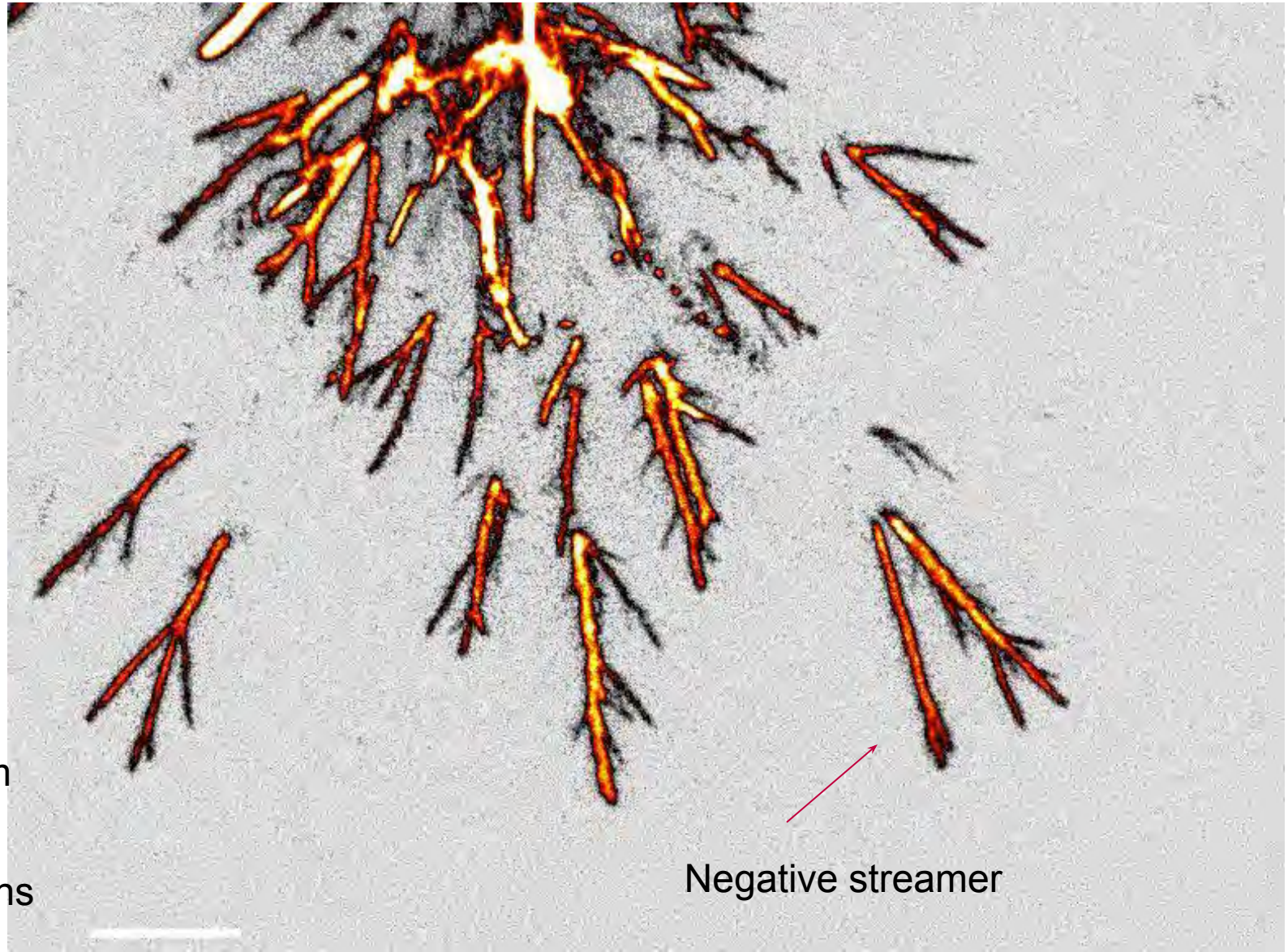

Anode current
Time [μs]

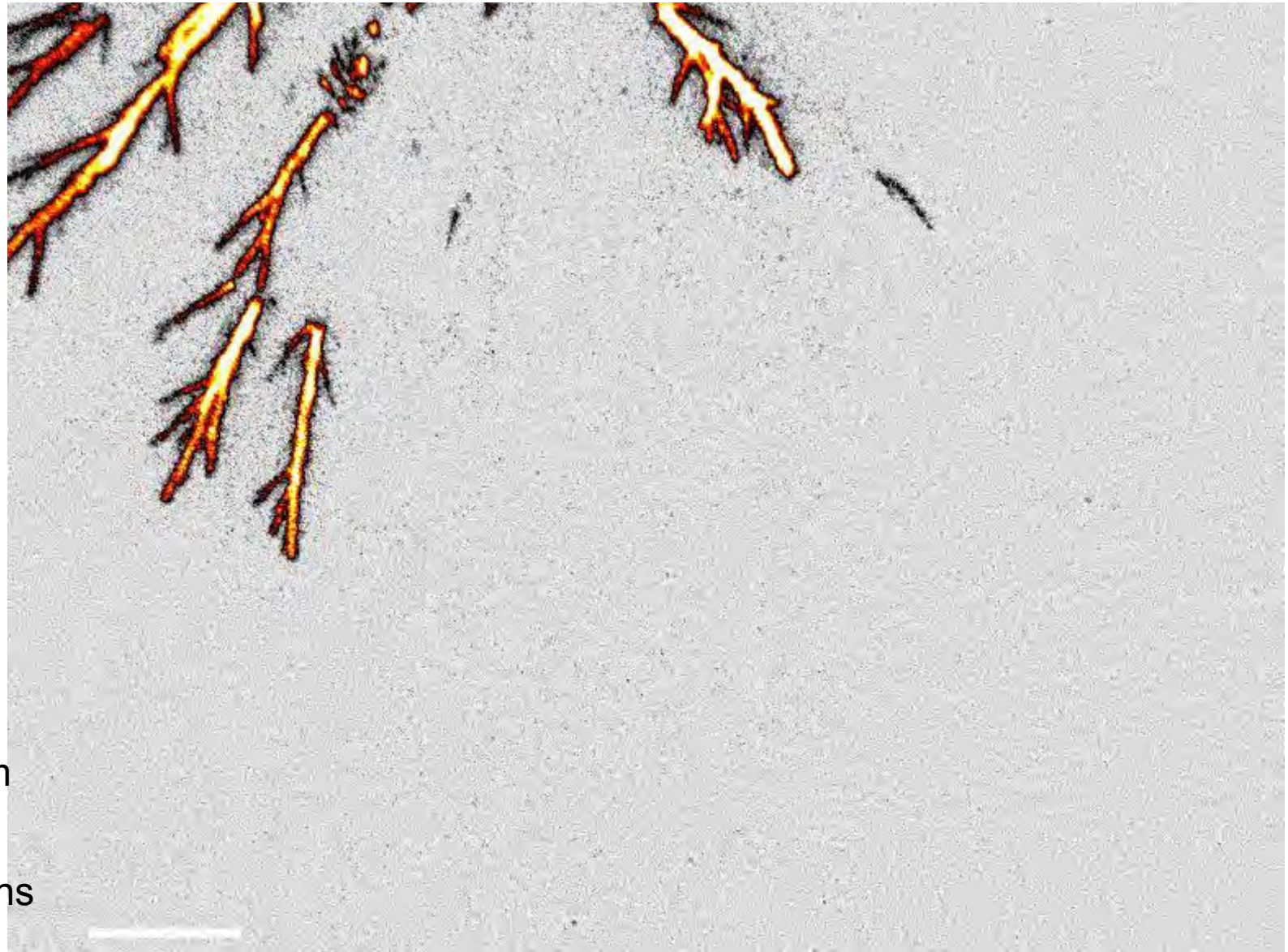

X-ray
Time [μs]

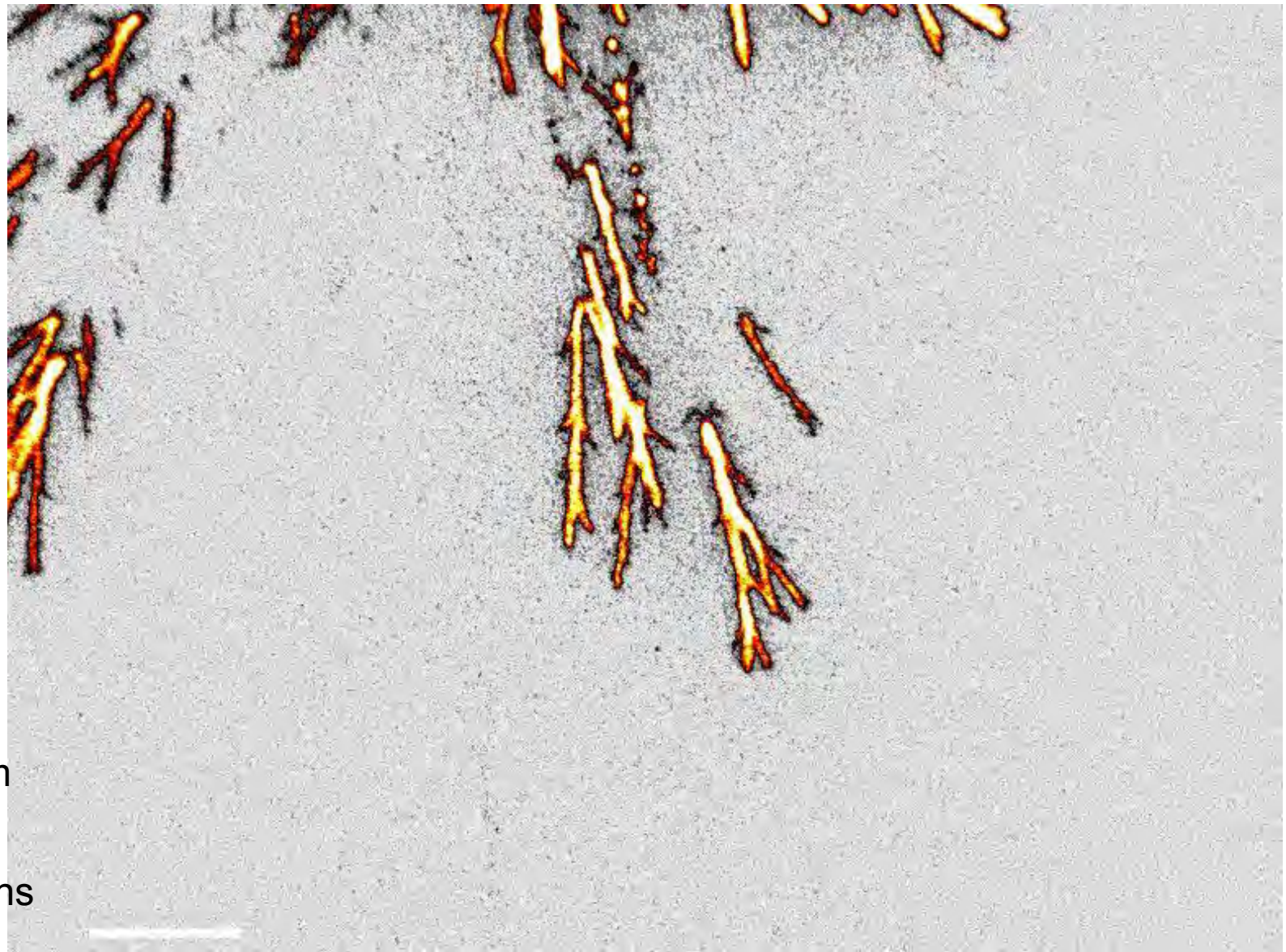

Voltage
U [MV]
Time [μs]
HV electrode
I_{HV} [500A]
Time [μs]
GND electrode
I_{GND} [500A]
Time [μs]
X-ray
Normalized intensity
Time [μs]

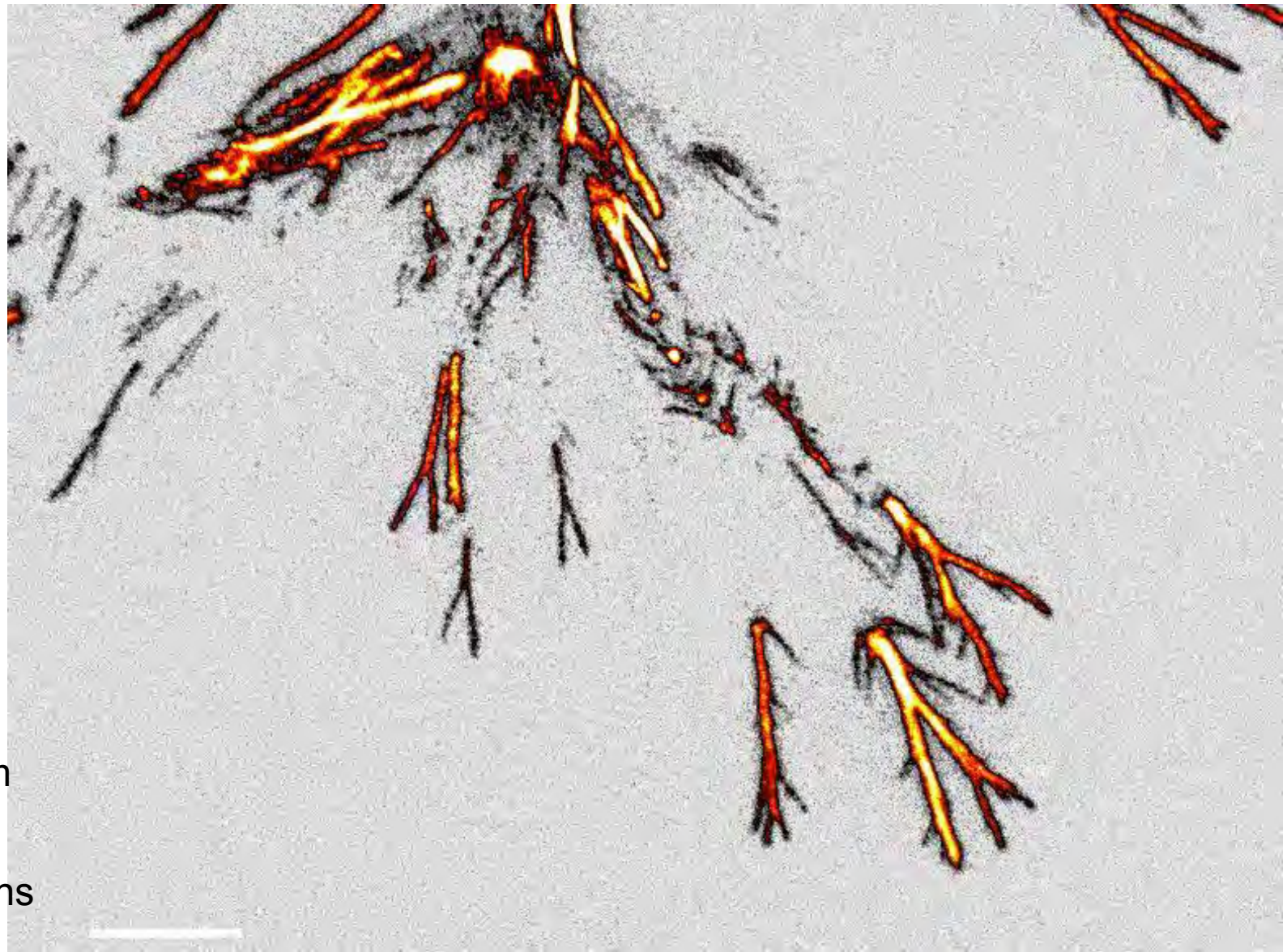


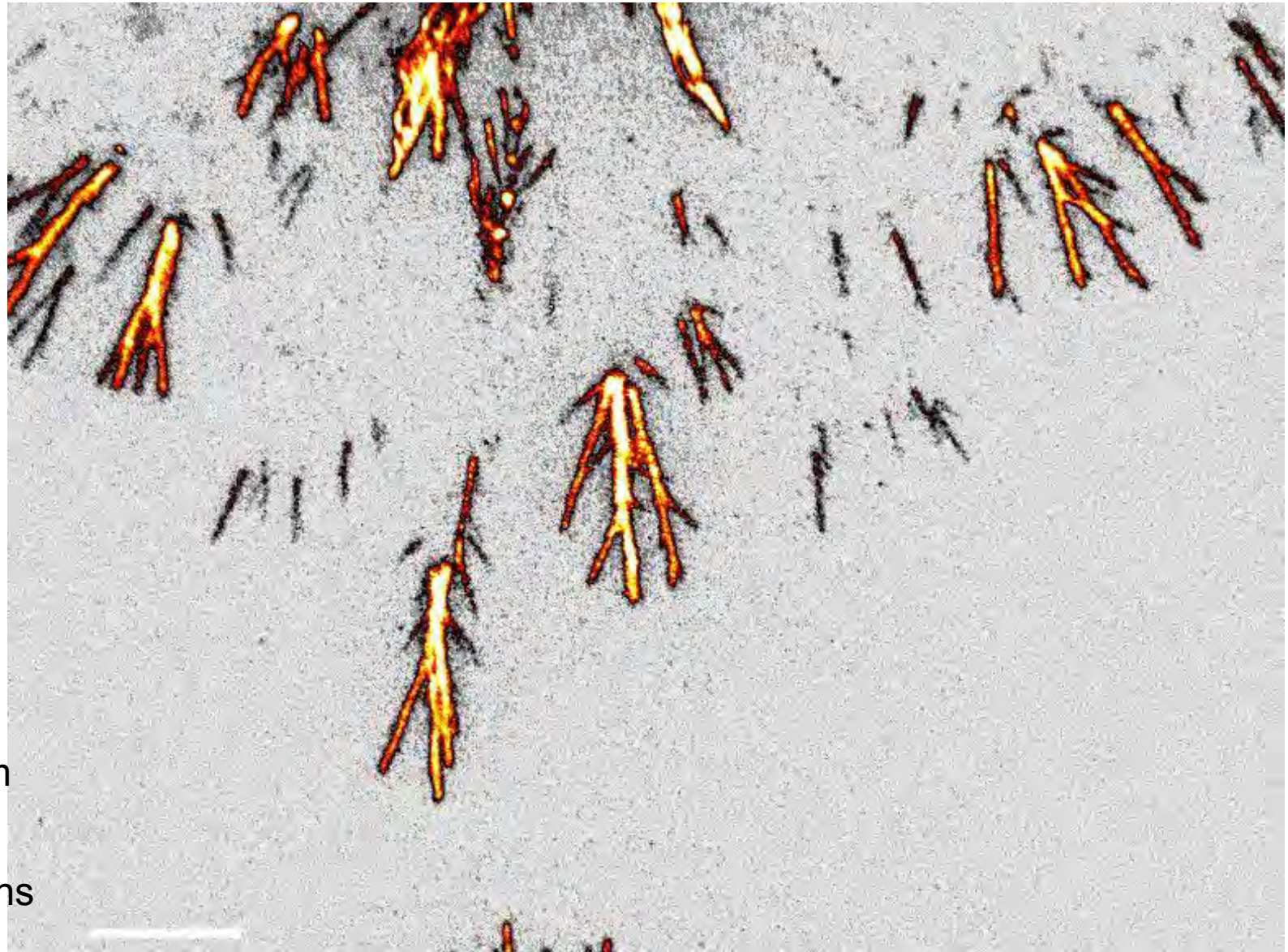

Negative streamer
10 cm
50 ns

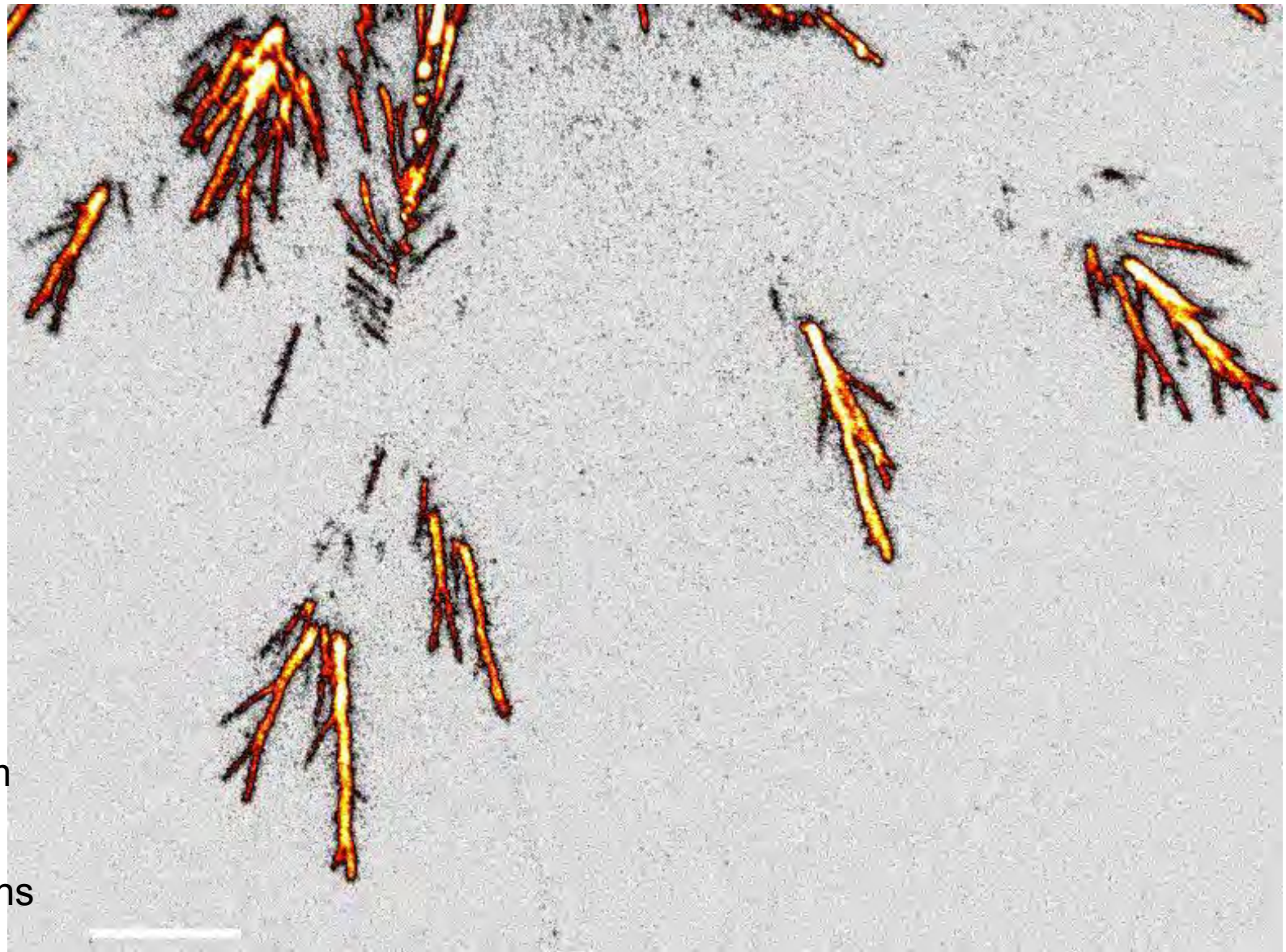

10 cm
50 ns
Negative streamer


10 cm
50 ns

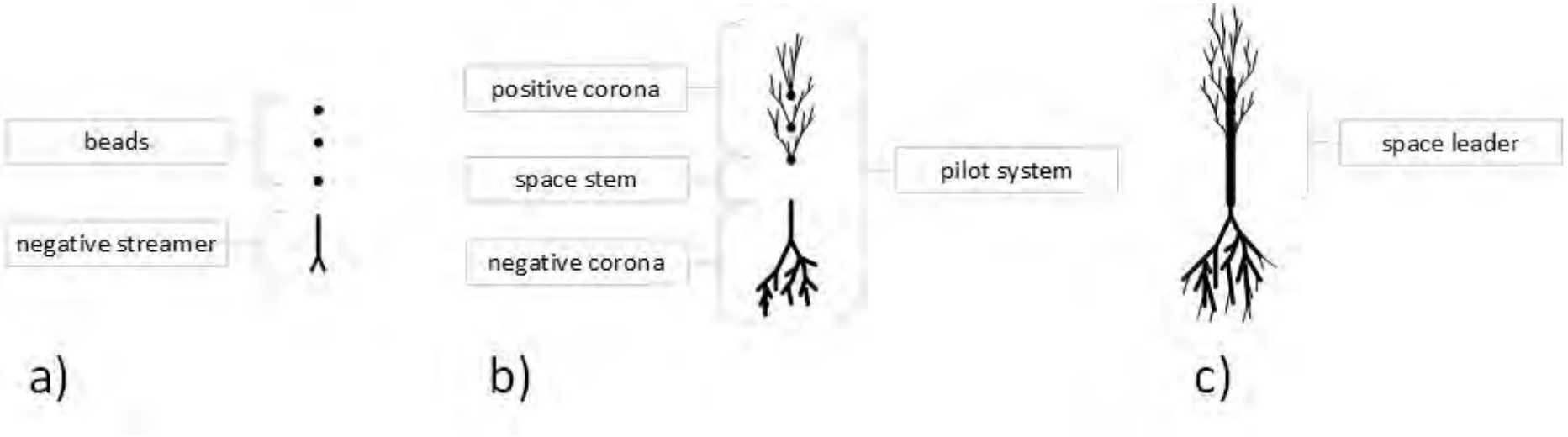

10 cm
50 ns

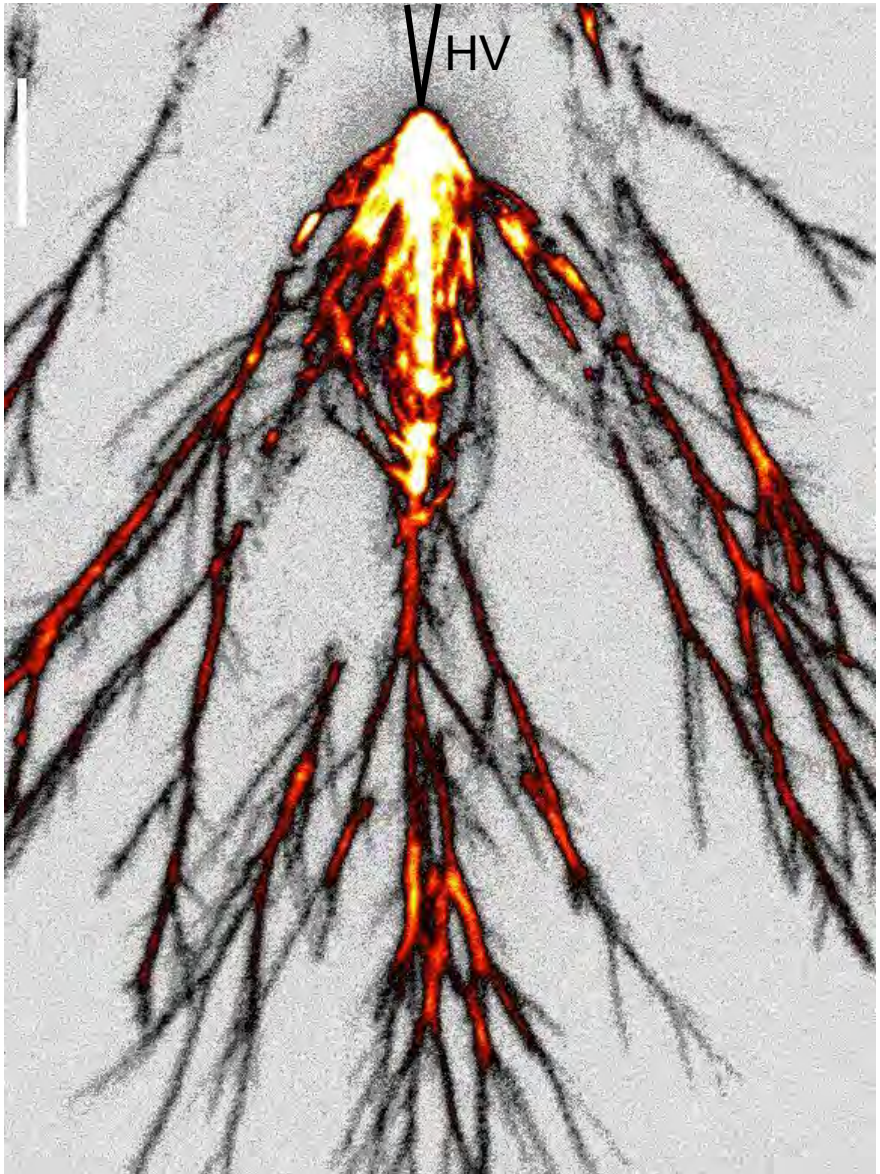

10 cm
50 ns


10 cm
50 ns


10 cm
50 ns

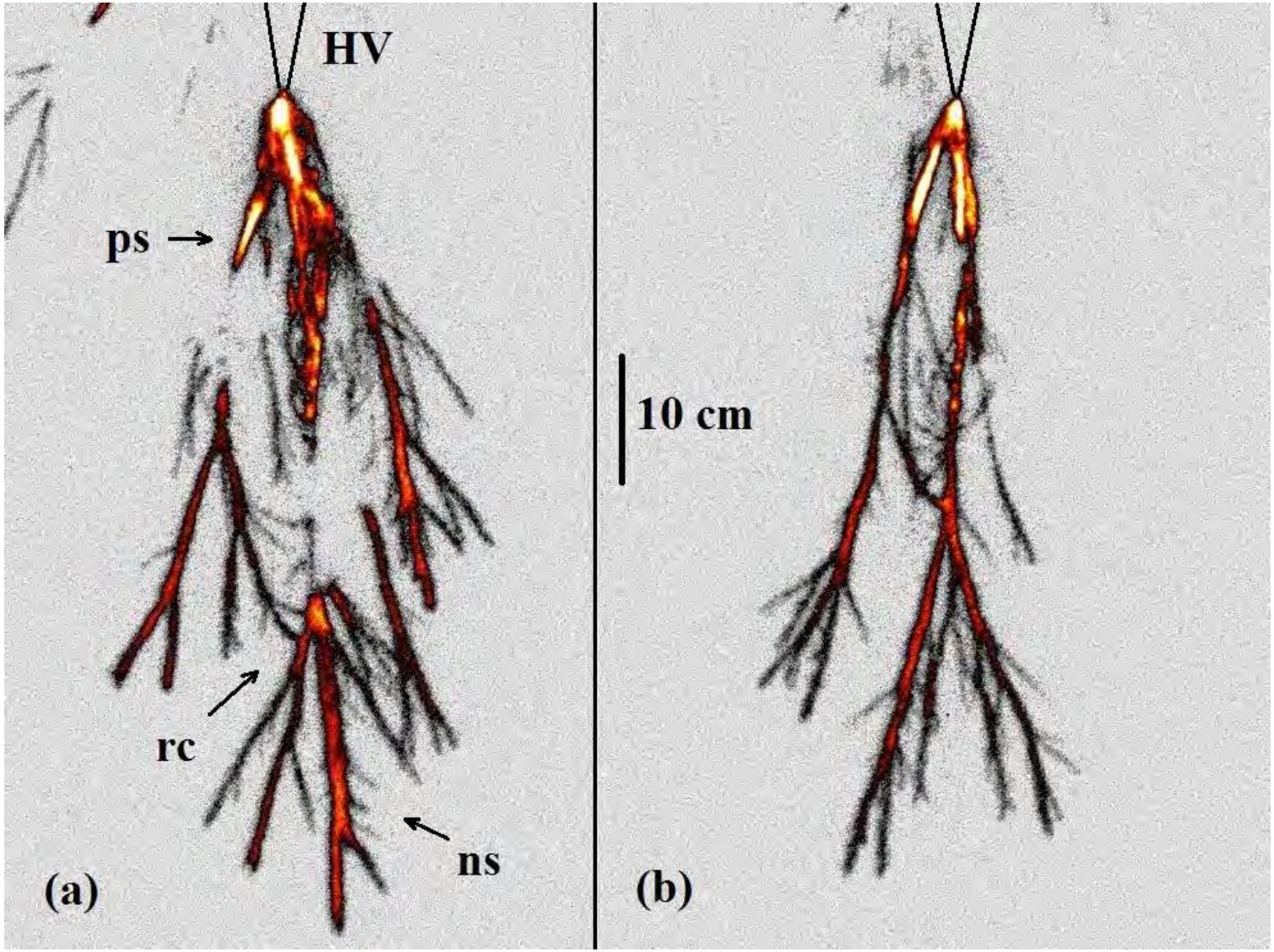
Pilot system development

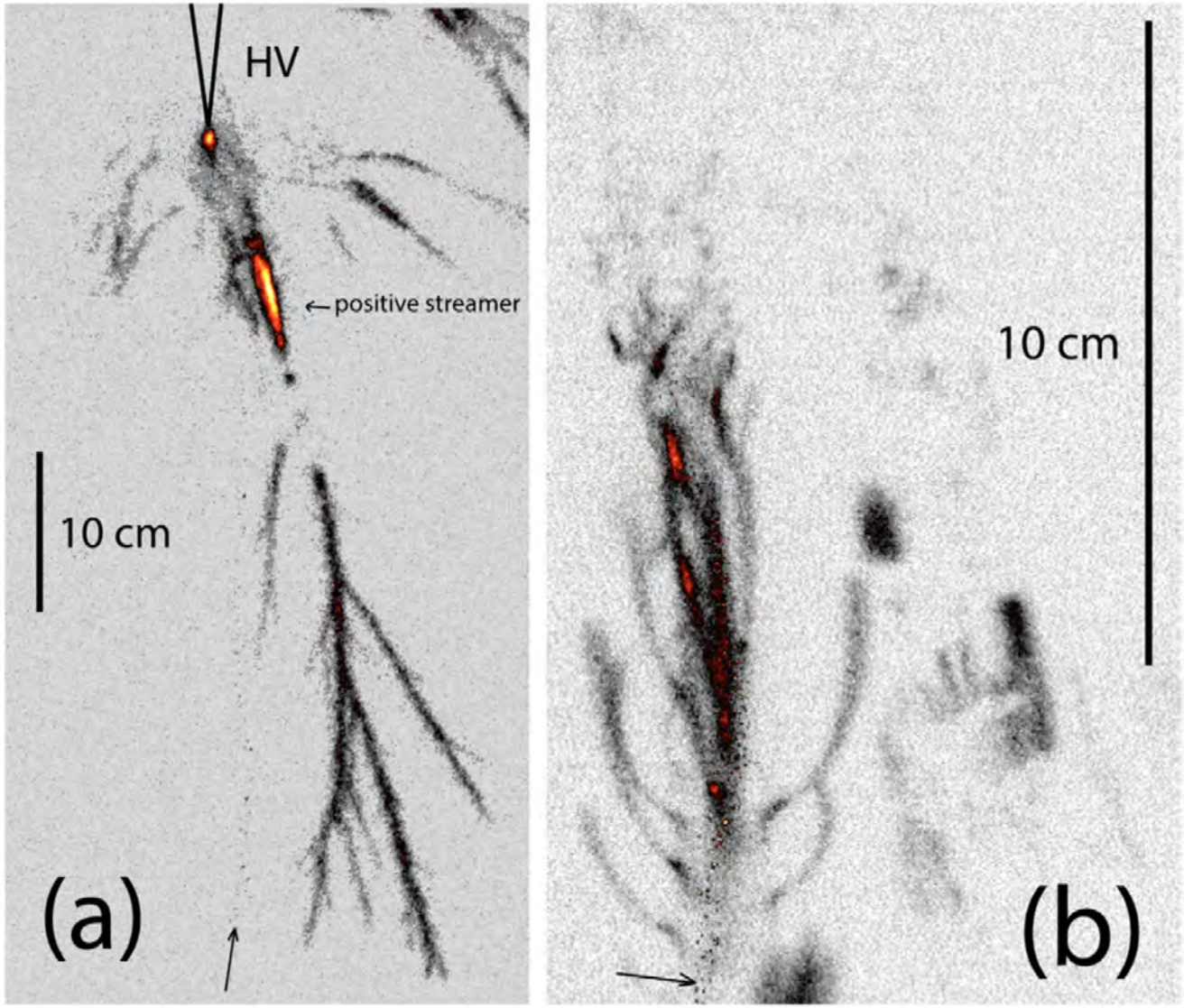


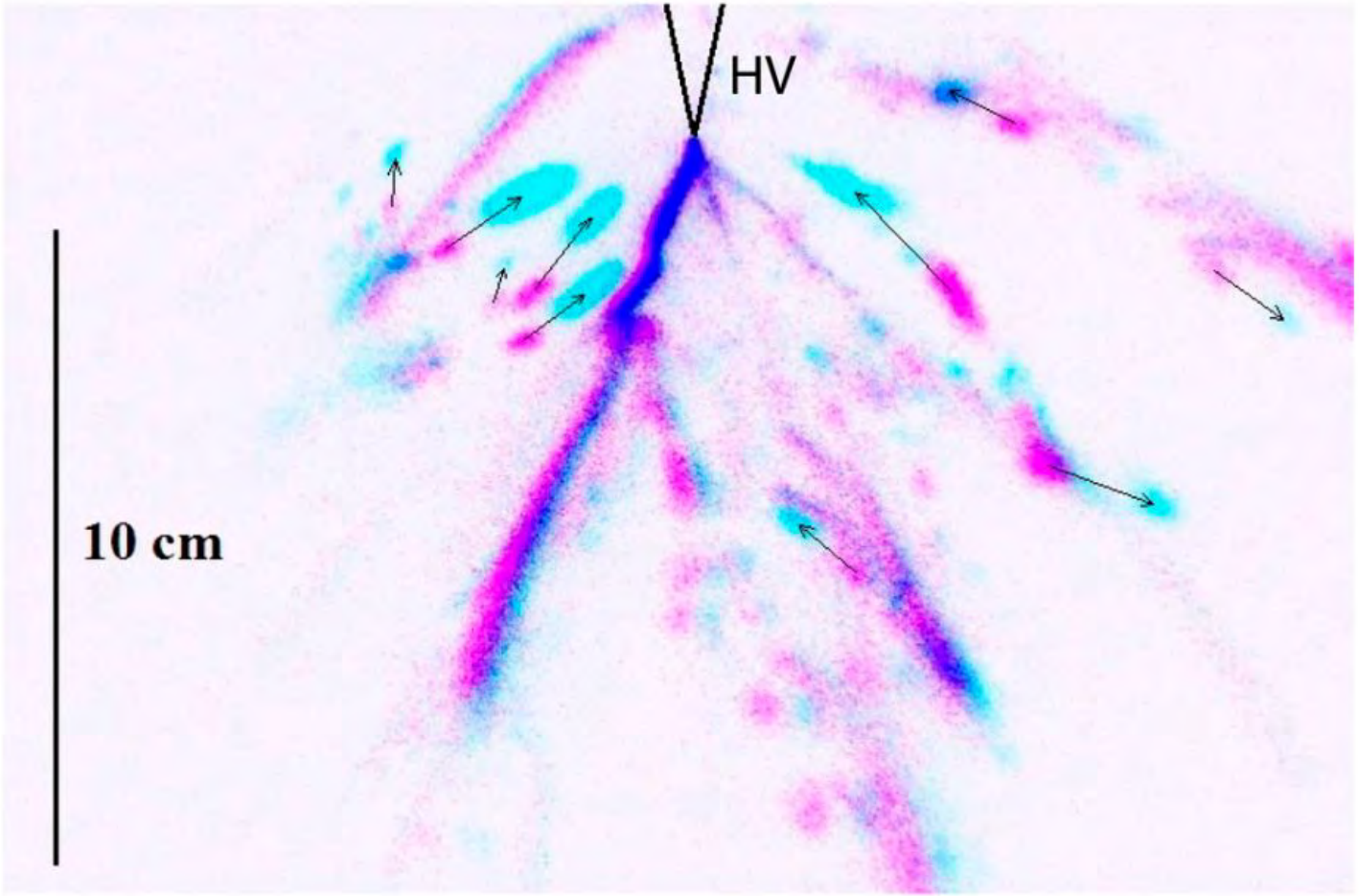


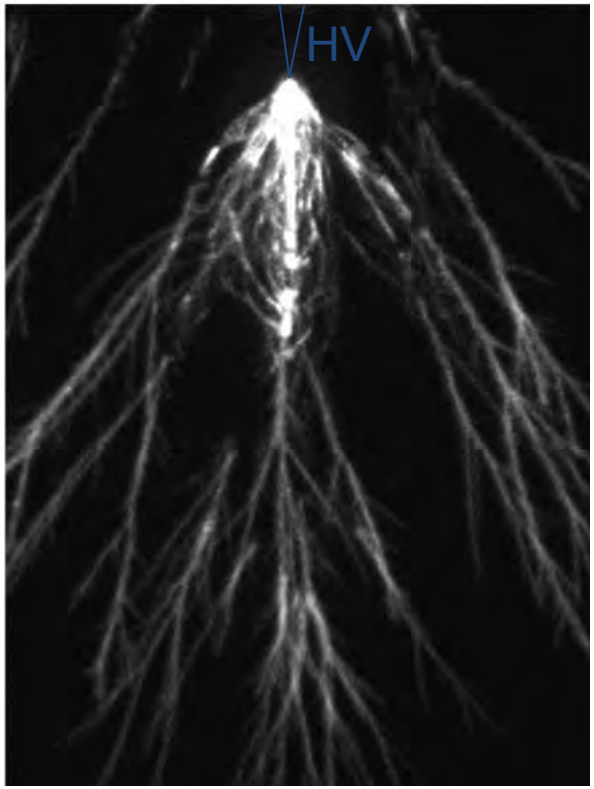
10 cm

100 ns

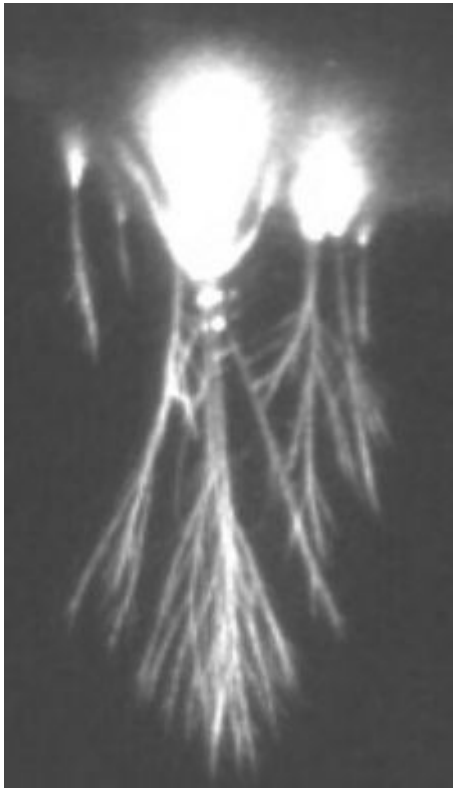

HV
ps
rc
ns
(a)
10 cm
(b)


HV
← positive streamer
10 cm
(a)
10 cm
(b)


HV
10 cm



TU/e, Eindhoven



Steven A. Cummer,
GEOPHYSICAL RESEARCH LETTERS,
VOL. 33, L04104, 2006

PAPER • OPEN ACCESS

Pilot system development in metre-scale laboratory discharge

Pavlo Kochkin[1], Nikolai Lehtinen[1], Alexander (Lex) P J van Deursen[2] and Nikolai Østgaard[1]

Published 22 September 2016 • © 2016 IOP Publishing Ltd
Journal of Physics D: Applied Physics, Volume 49, Number 42

Questions?

- Lightning interaction with aircraft
- Gamma-Ray Glows and positron annihilation observed from aircraft

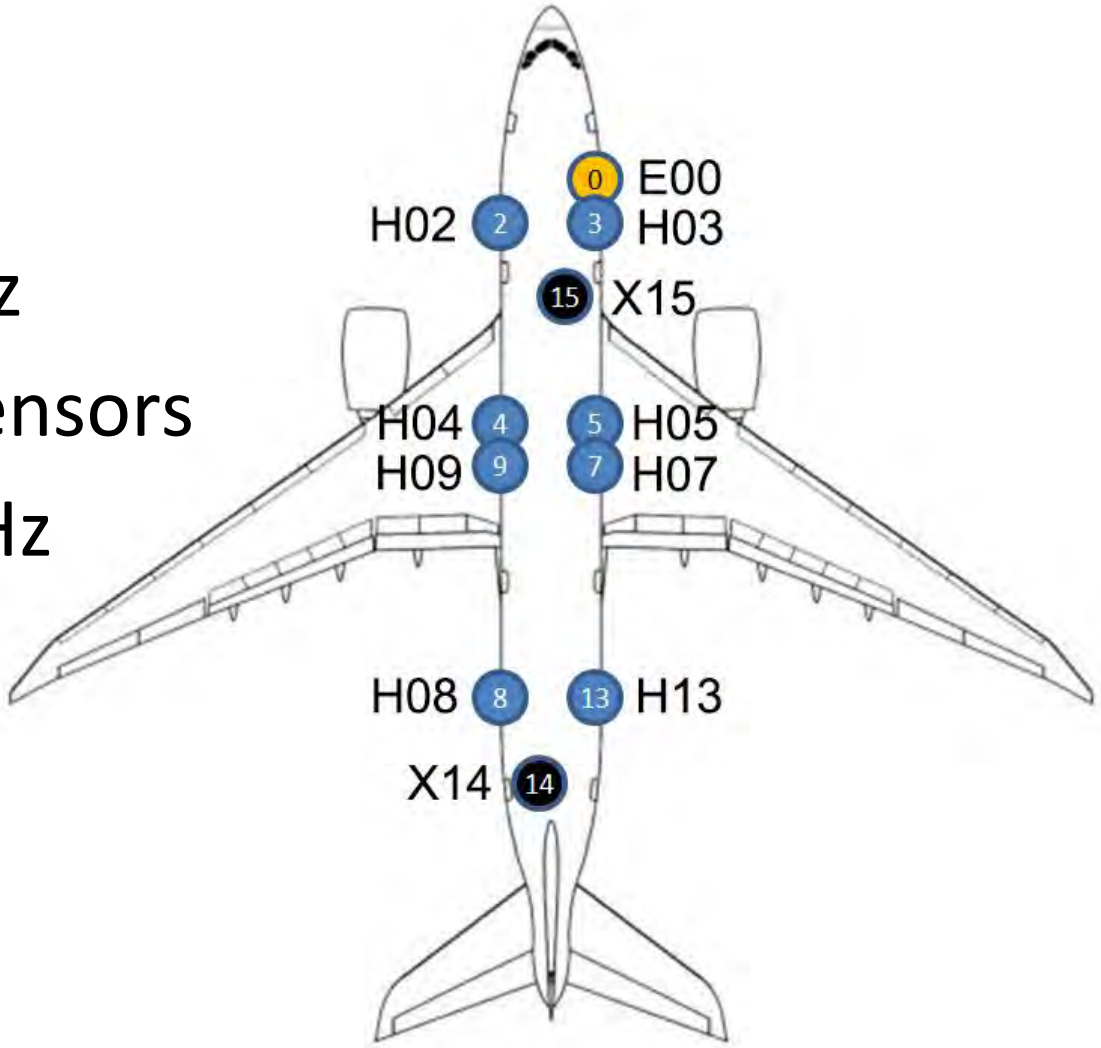
BIRKELAND CENTRE FOR SPACE SCIENCE

- 1 E-field sensor

  10 Hz to 500 kHz
- 8 window H-field sensors

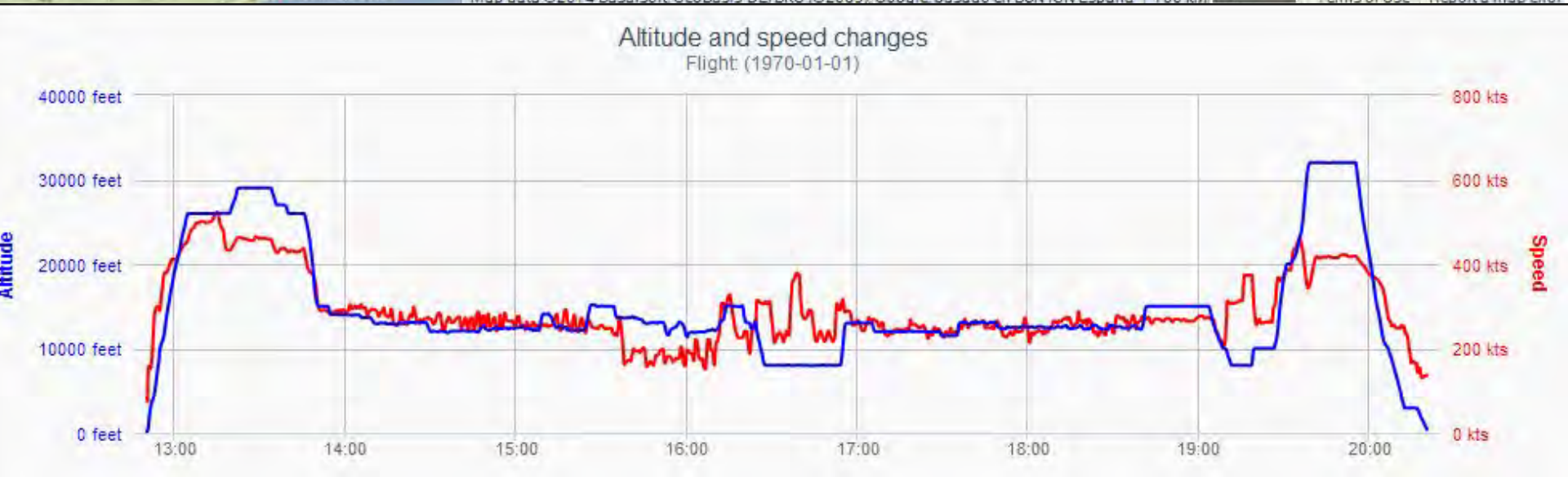
  100 Hz to 10MHz
- 2 X-ray detectors

  0-10 MeV

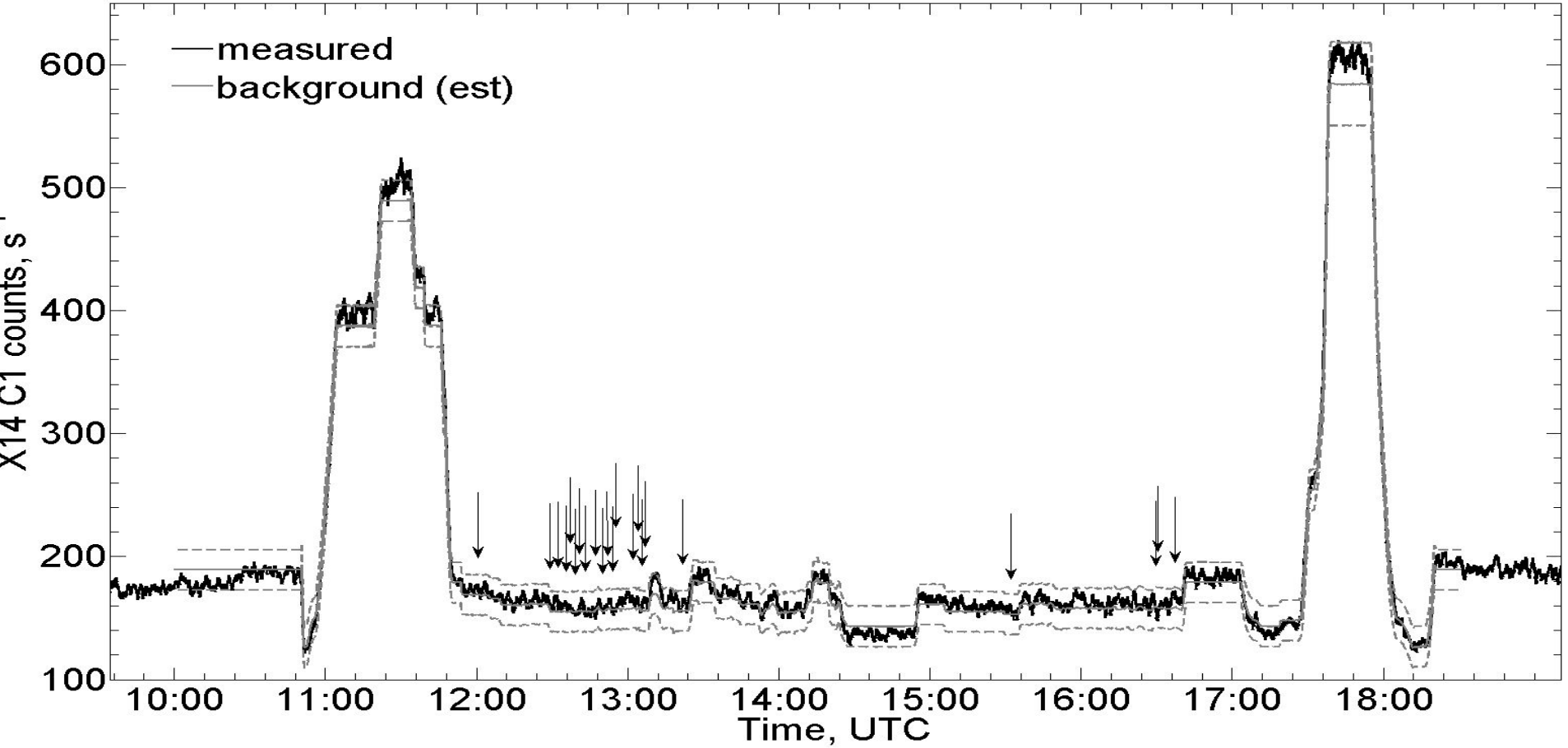


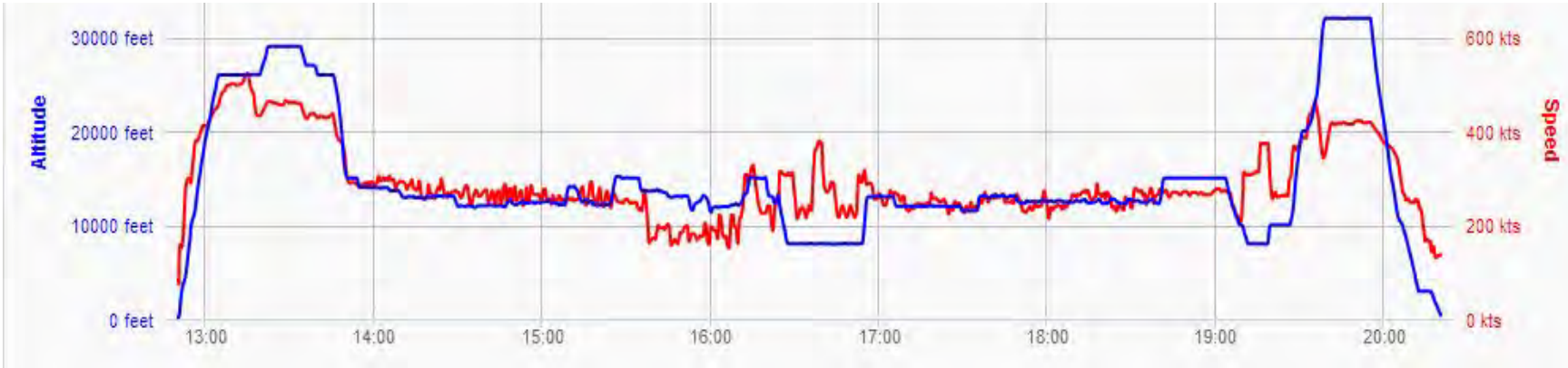
- Continuous (15 ms)
- Triggered (10 ns)

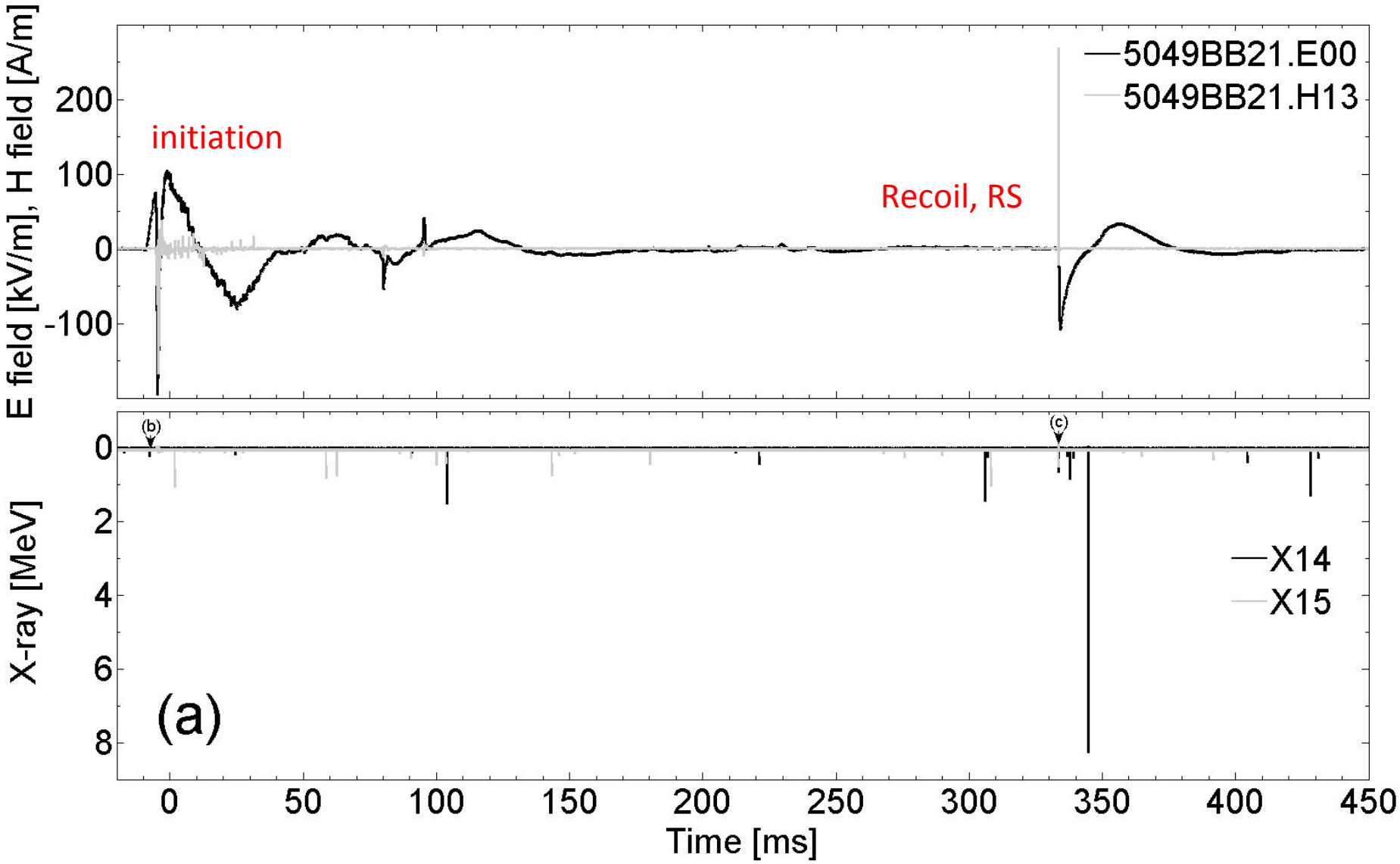

Map
France
Switzerland
Slovenia
Croatia
Italy
Poitiers
Digoin
Lausanne
Maribor
La Rochelle
Bourg-en-Bresse
Geneva
Roanne
Lyon
Zagreb
Milan
Brescia
Venice
Trieste
Rijeka
Sisak
Grenoble
Turin
Verona
Bordeaux
Parc Naturel Régional des Volcans d'Auvergne
Modena
Genoa
Bologna
Agen
Zadar
Knin
Avignon
San Marino
Sarajevo
San Sebastián
Montpellier
Aix-en-Provence
Monaco
Livorno
Florence
Split
Marseille
Fréjus
Toulon
Perpignan
Andorra
Pescara
Terni
Ajaccio
Rome
Zaragoza
Lleida
Sabadell
Adriatic Sea
Foggia
Reus
Barcelona
Latina
Bari
Map data ©2014 Basarsoft, GeoBasis-DE/BKG (©2009), Google, basado en BCN IGN España
100 km
Terms of Use
Report a map error


Altitude and speed changes
Flight: (1970-01-01)
40000 feet
30000 feet
20000 feet
10000 feet
0 feet
Altitude
800 kts
600 kts
400 kts
200 kts
0 kts
Speed
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00

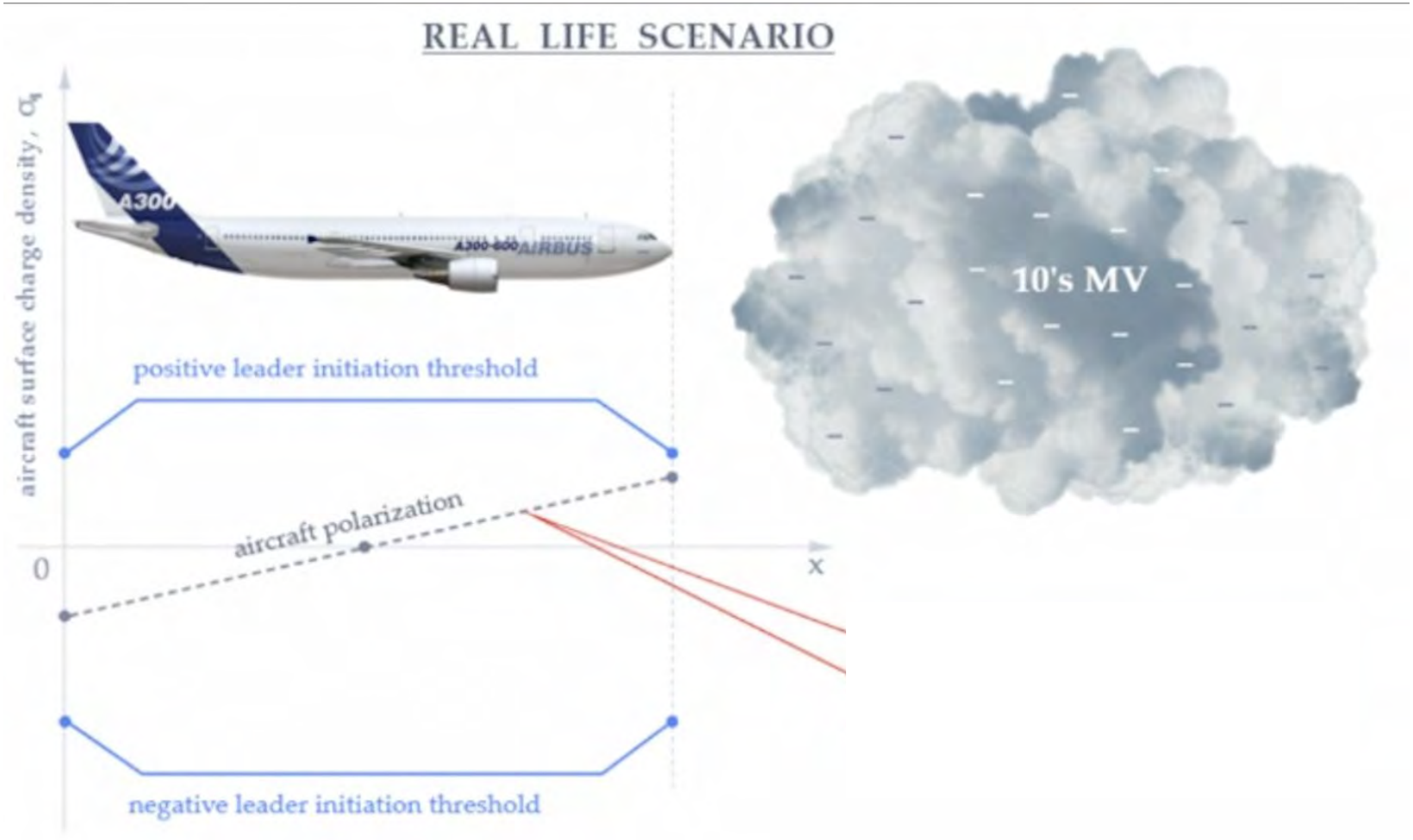
BIRKELAND CENTRE
FOR SPACE SCIENCE



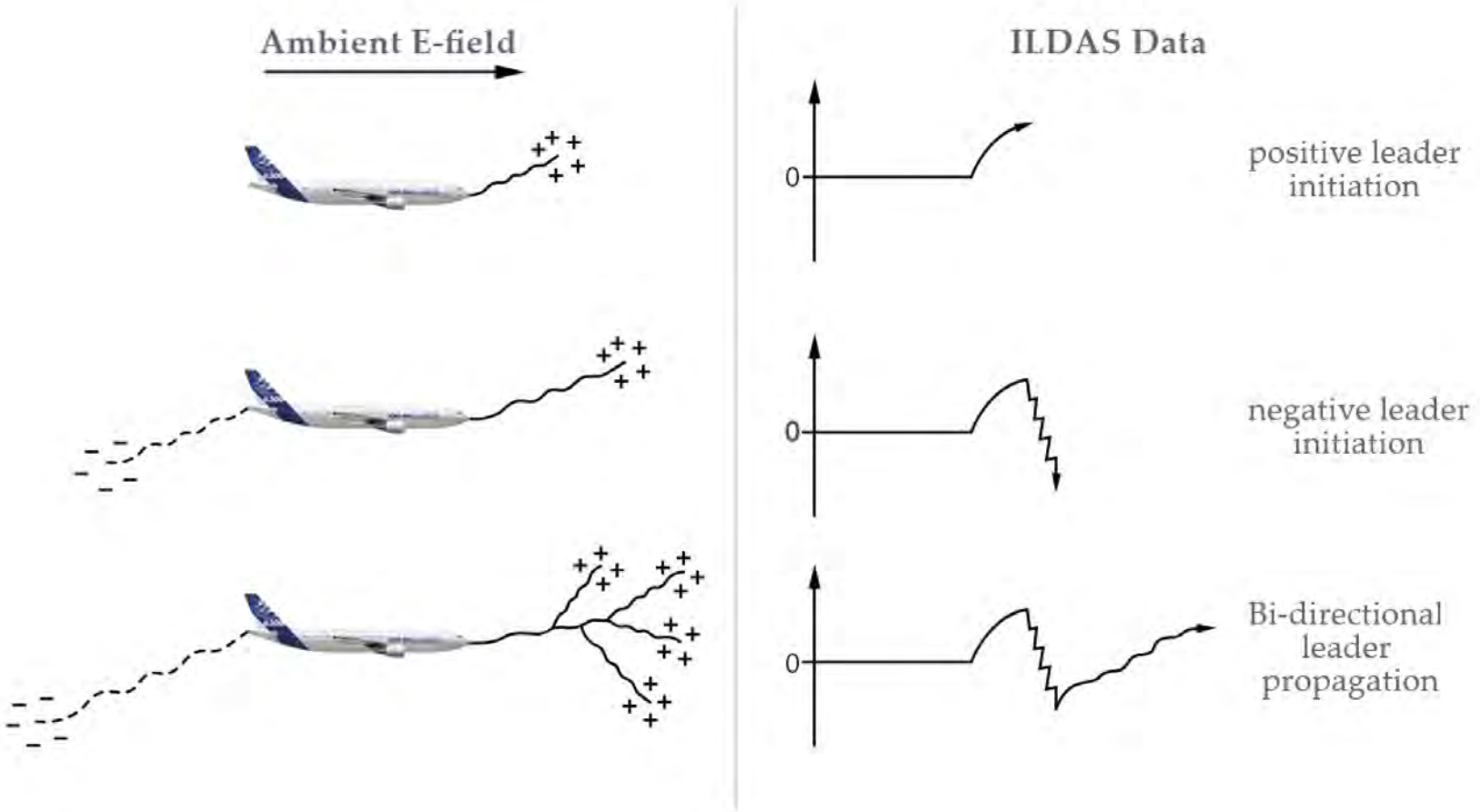


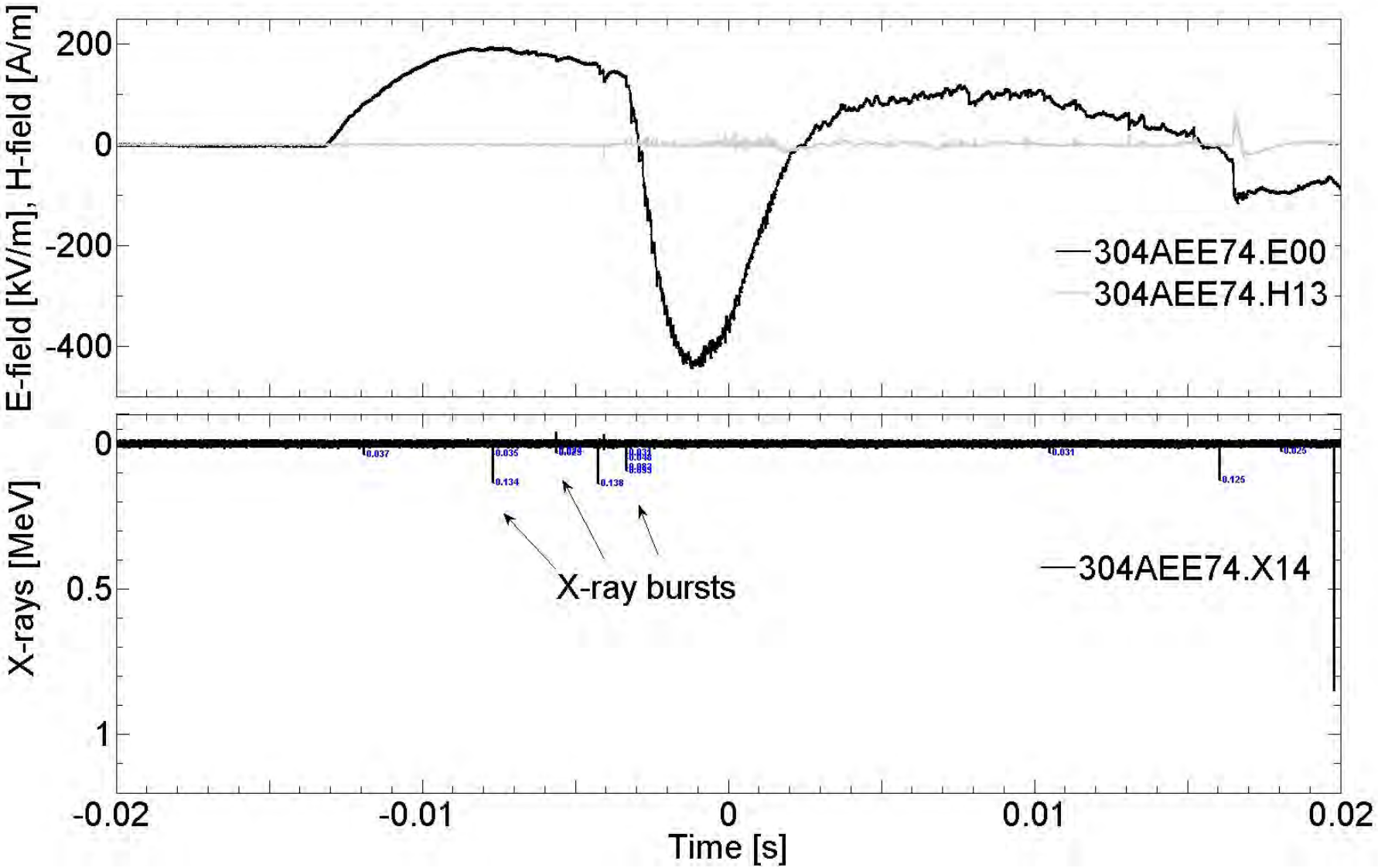

E field [kV/m], H field [A/m]
200
100
0
-100
5049BB21.E00
5049BB21.H13
initiation
Recoil, RS
(b)
(c)
X-ray [MeV]
0
2
4
6
8
X14
X15
(a)
0
50
100
150
200
250
300
350
400
450
Time [ms]

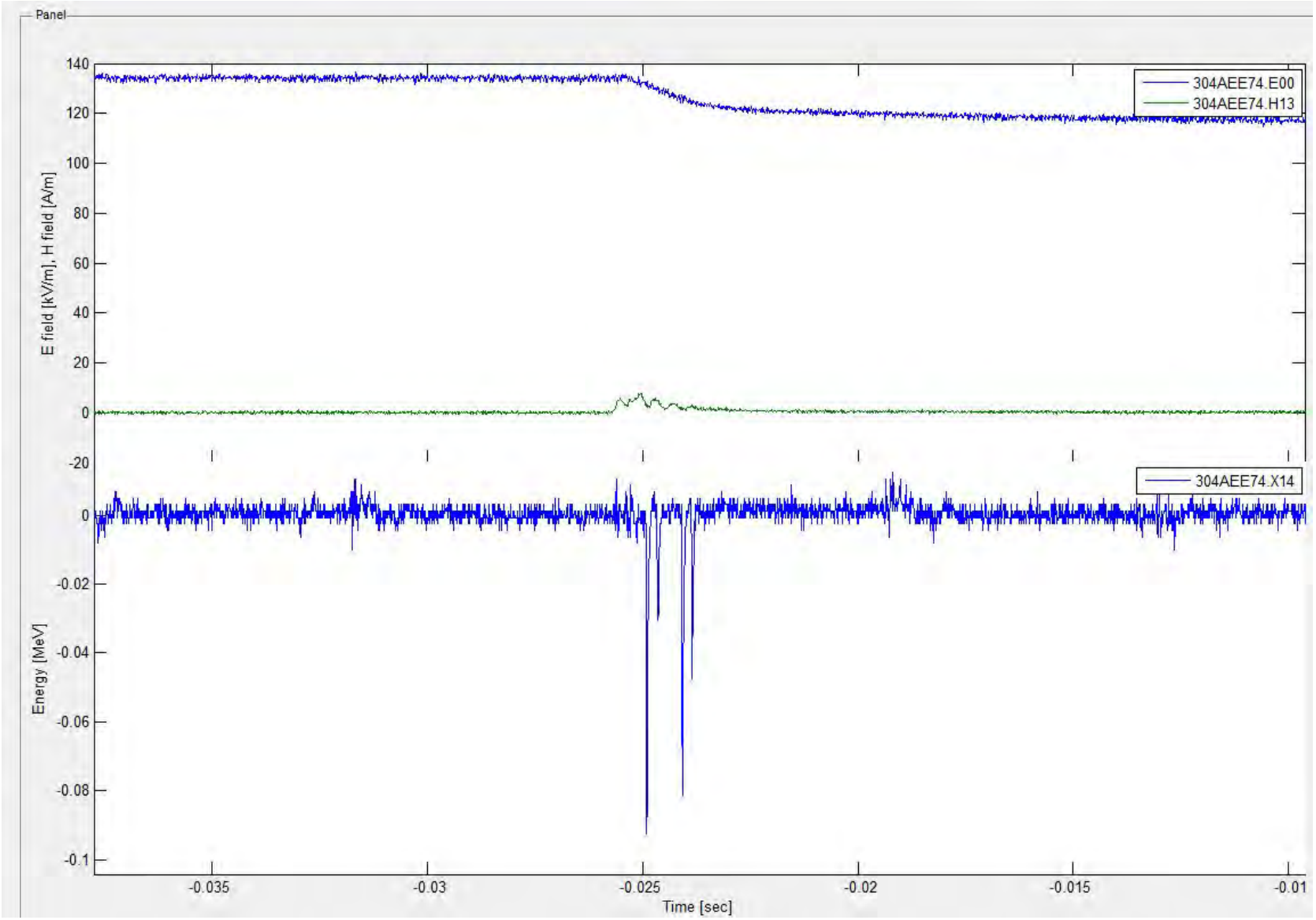
Aircraft-triggered discharge

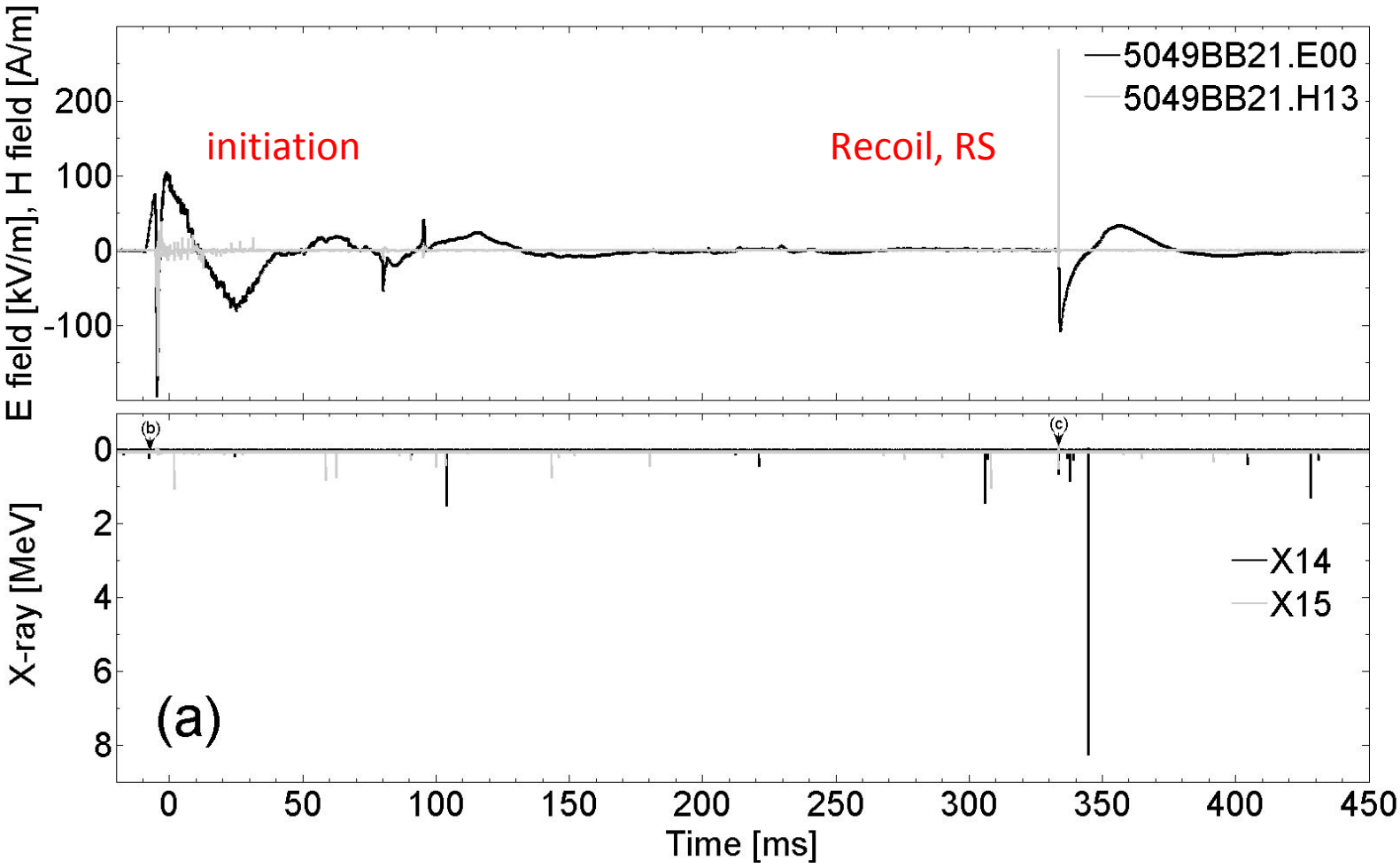


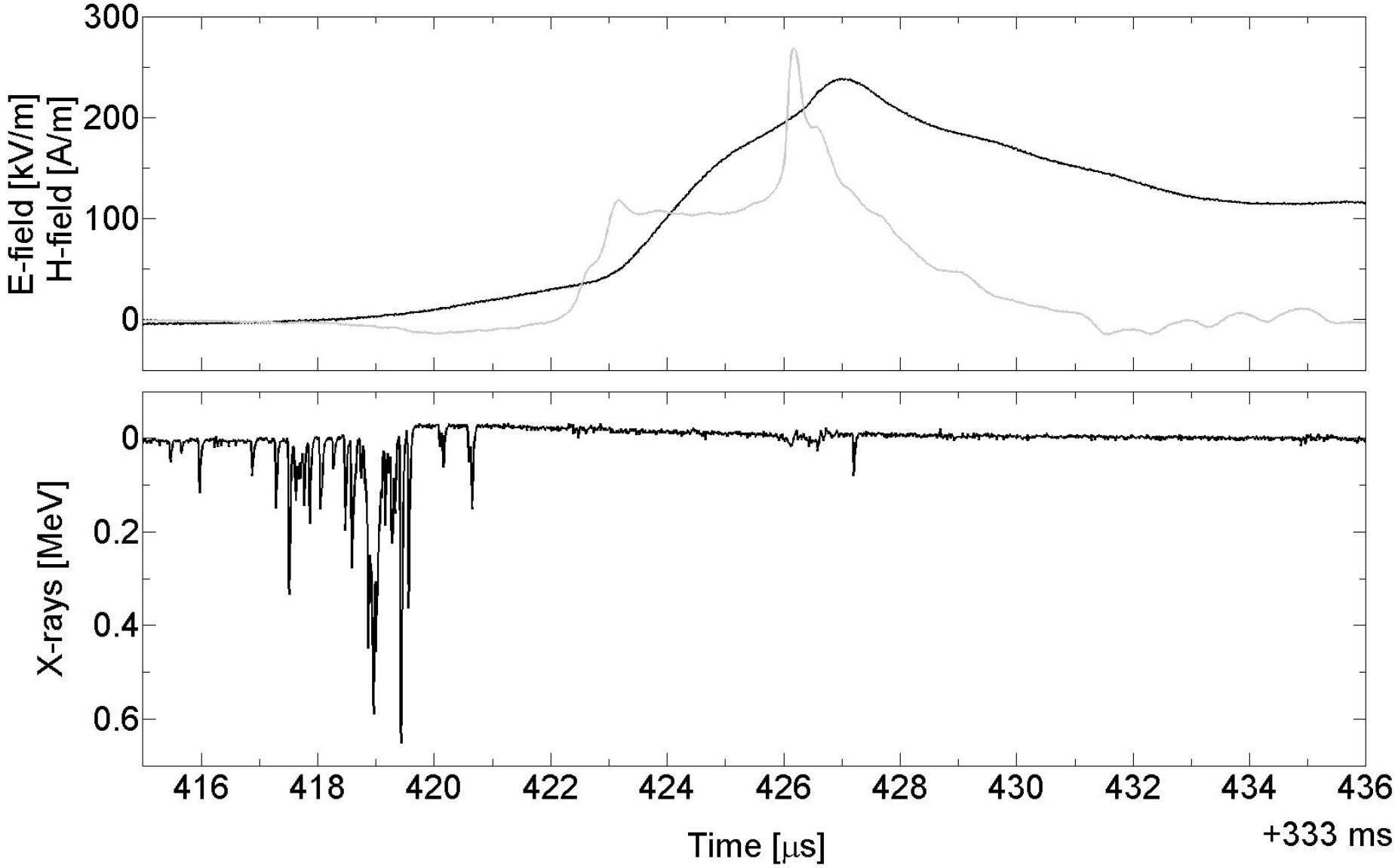
Aircraft-triggered discharge

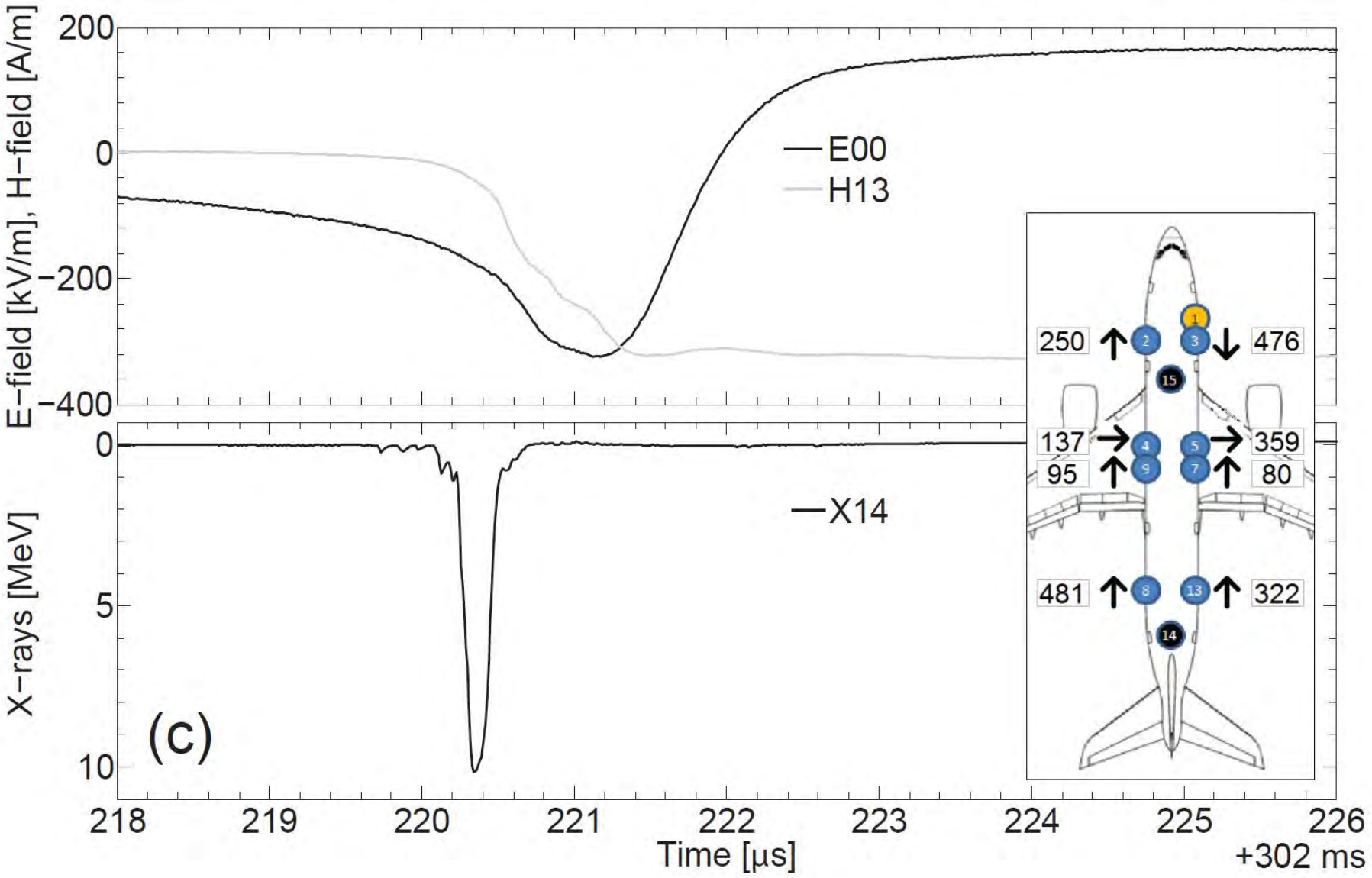


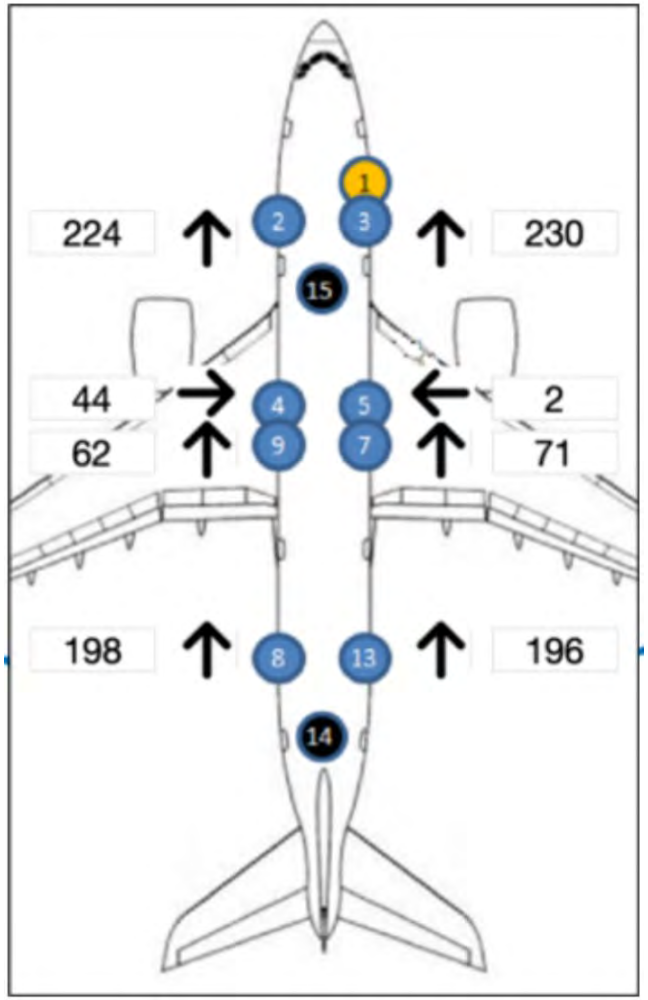

E-field [kV/m], H-field [A/m]
200
0
-200
-400
304AEE74.E00
304AEE74.H13
X-rays [MeV]
0
0.5
1
0.037
0.035
0.134
0.029
0.138
0.031
0.125
0.025
X-ray bursts
304AEE74.X14
-0.02
-0.01
0
0.01
0.02
Time [s]


Panel
304AEE74.E00
304AEE74.H13
304AEE74.X14
E field [kV/m], H field [A/m]
Energy [MeV]
Time [sec]
140
120
100
80
60
40
20
0
-20
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.035
-0.03
-0.025
-0.02
-0.015
-0.01


E field [kV/m], H field [A/m]
200
100
0
-100
initiation
Recoil, RS
5049BB21.E00
5049BB21.H13
(b)
(c)
X-ray [MeV]
0
2
4
6
8
X14
X15
(a)
0
50
100
150
200
250
300
350
400
450
Time [ms]

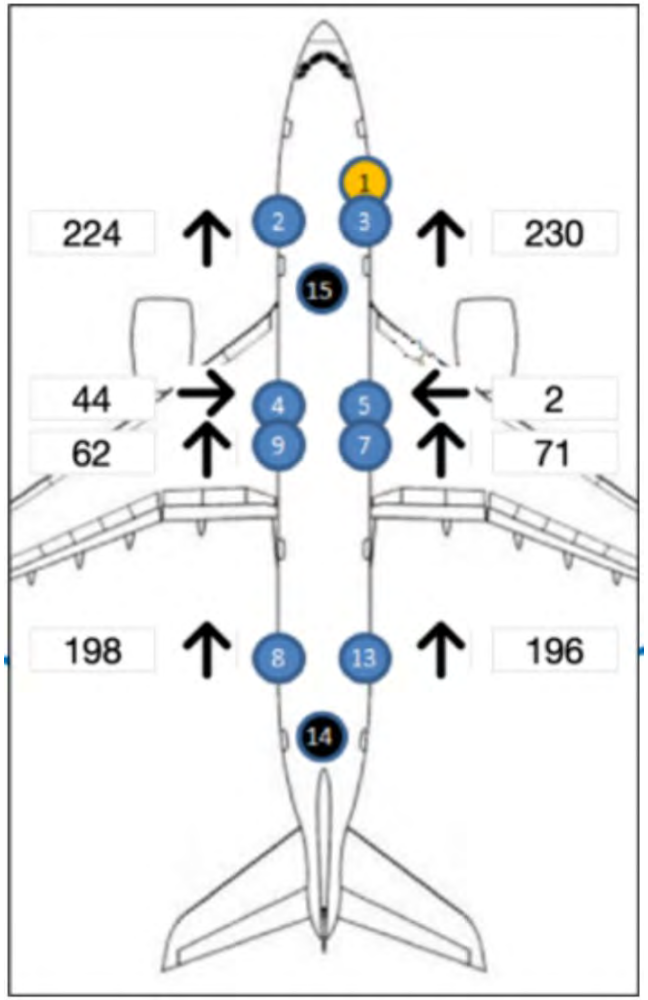

E-field [kV/m]
H-field [A/m]
300
200
100
0
X-rays [MeV]
0
0.2
0.4
0.6
416
418
420
422
424
426
428
430
432
434
436
Time [μs]
+333 ms


E−field [kV/m], H−field [A/m]
200
0
−200
−400
E00
H13
X−rays [MeV]
0
5
10
X14
(c)
218
219
220
221
222
223
224
225
226
Time [µs]
+302 ms
250
476
137
359
95
80
481
322
1
2
3
4
5
7
8
9
13
14
15


1
2
3
224
230
15
44
4
5
2
62
9
7
71
198
8
13
196
14

Aircraft-triggered discharge

BIRKELAND CENTRE FOR SPACE SCIENCE



ILDAS

(c) Presented by Otowa Electric Co., Ltd.

Gamma-Ray Glows and positron annihilation

BIRKELAND CENTRE FOR SPACE SCIENCE

Airborn Lightning Observatory for FEGS and TGFs (**ALOFT, 2017**)

- NASA ER-2, 20 km altitude, Colorado, USA
- X-ray detectors: 3 BGO (15 x 5 x 3.2 cm each)
- Energy range: 0.3 - 40 MeV

- Lightning Mapping Array: COLMA (VHF)

Østgaard N. et al., 2019, Gamma-ray glow observations at 20 km altitude, submitted to JGR

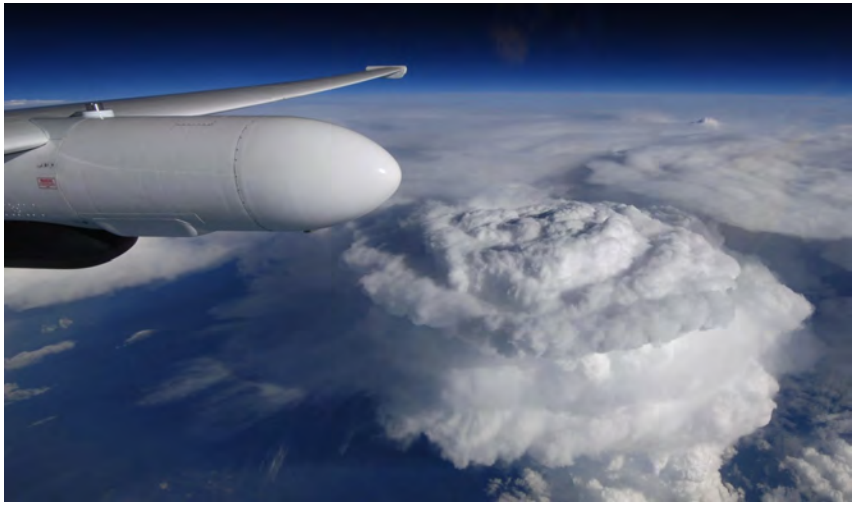
In-flight Lightning Damage Assessment System (**ILDAS, 2016**)

- Airbus A340, 12 km altitude, Darwin, Australia
- X-ray detectors: 2 LaBr3 (4 x 4 cm cylinder)
- Energy range: 0.05 - 10 MeV

- Lightning data: GPATS (hybrid VLF-VHF)

Kochkin P. et al. "In-Flight Observation of Positron Annihilation by ILDAS." *Journal of Geophysical Research: Atmospheres* 123.15 (2018): 8074-8090.

Airborn Lightning Observatory for FEGS and TGFs (**ALOFT, 2017**)



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- Energy range: 0.3 - 40 MeV

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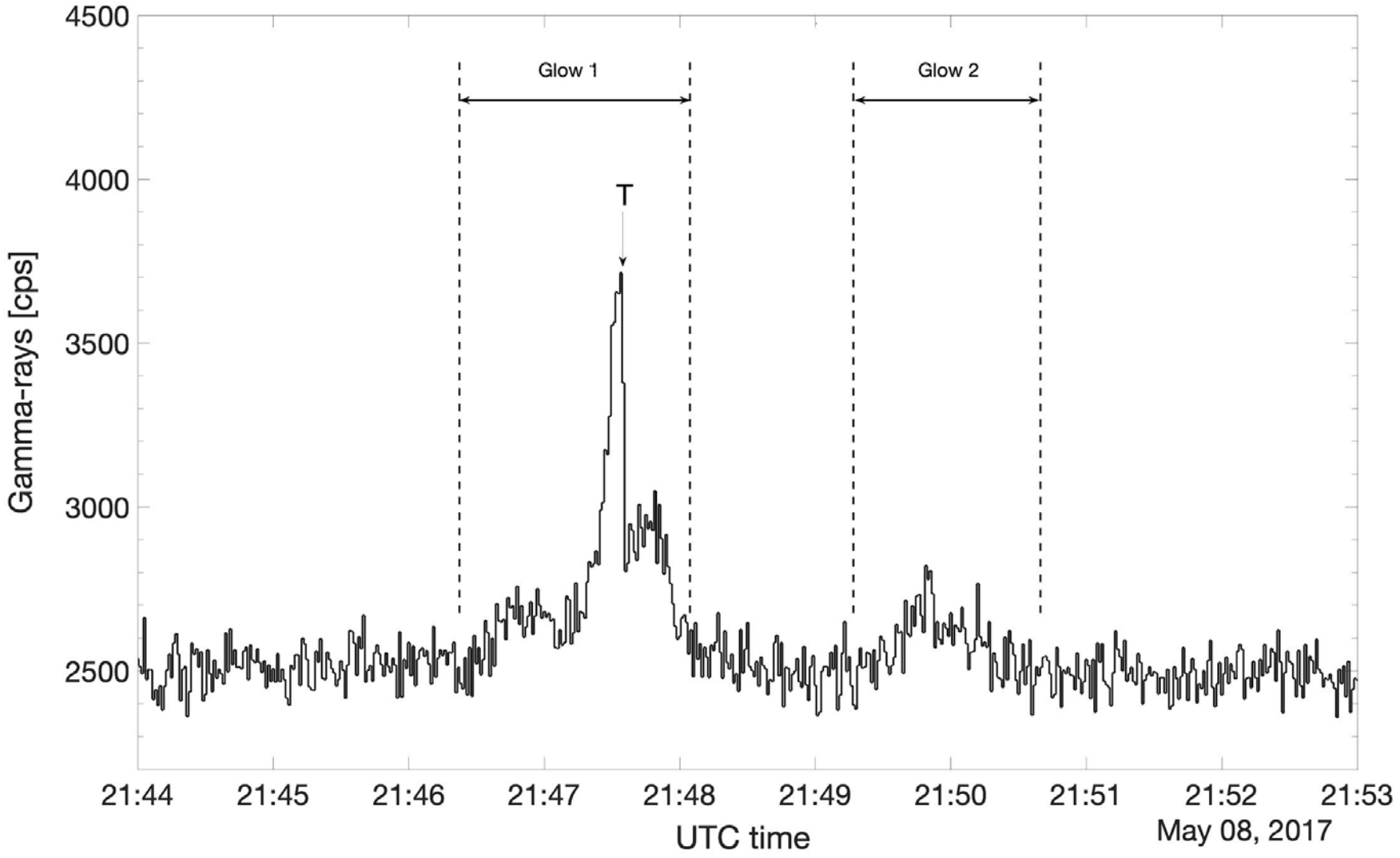
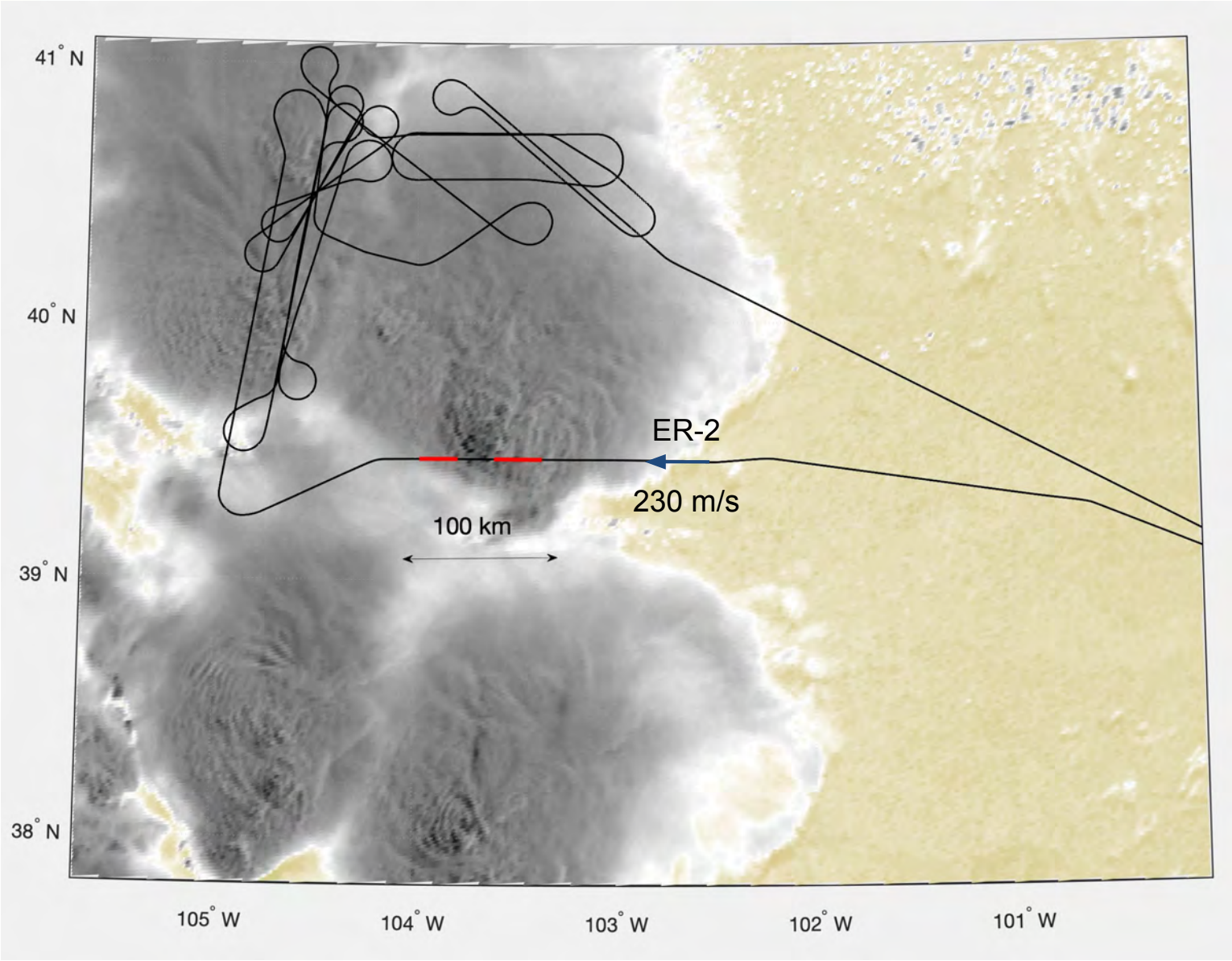
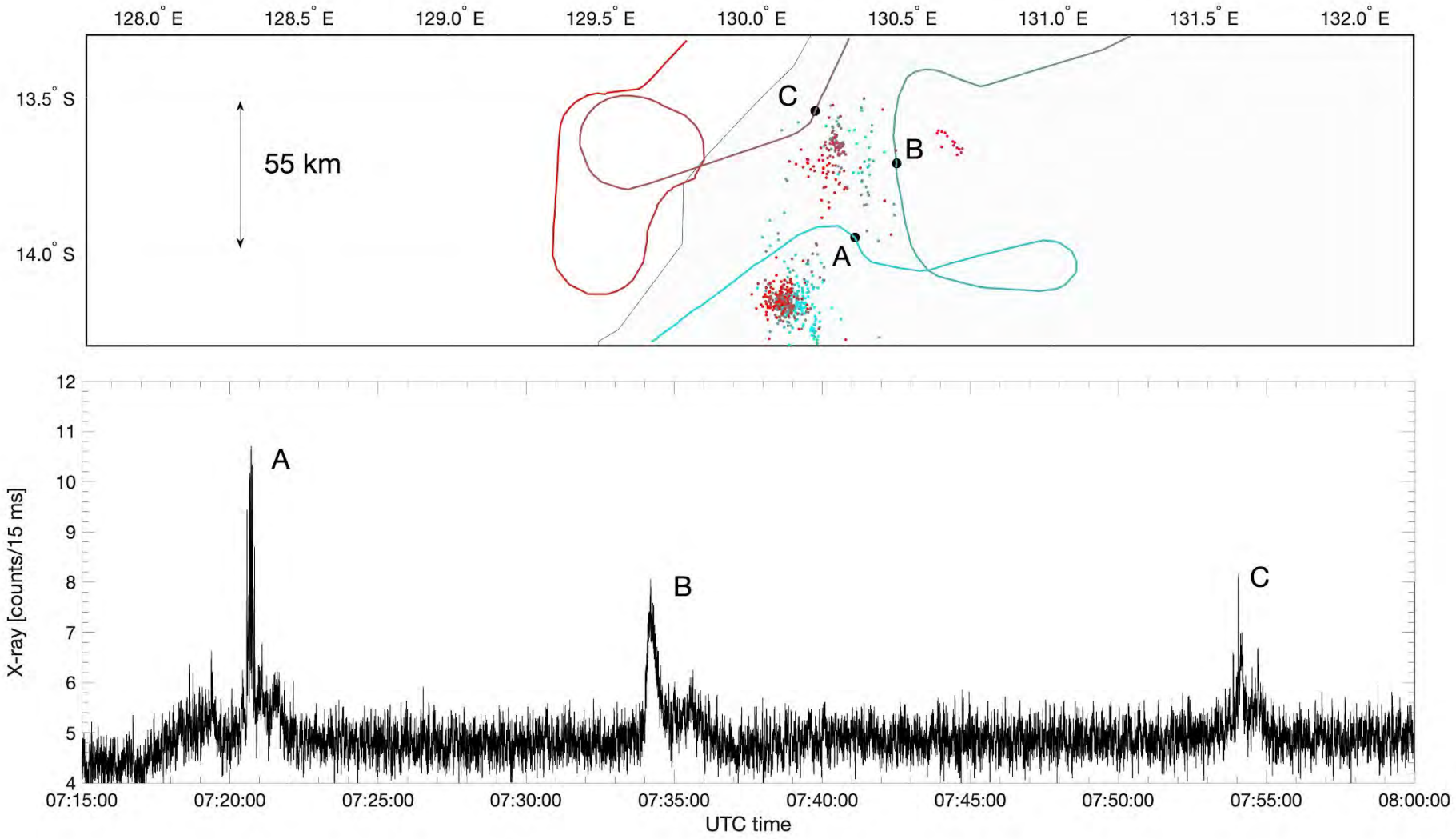

4500
4000
3500
3000
2500
Gamma-rays [cps]
Glow 1
Glow 2
T
21:44
21:45
21:46
21:47
21:48
21:49
21:50
21:51
21:52
21:53
UTC time
May 08, 2017


41° N
40° N
39° N
38° N
105° W
104° W
103° W
102° W
101° W
ER-2
230 m/s
100 km

A thunderstorm near Darwin

BIRKELAND CENTRE FOR SPACE SCIENCE

ILDAS observation



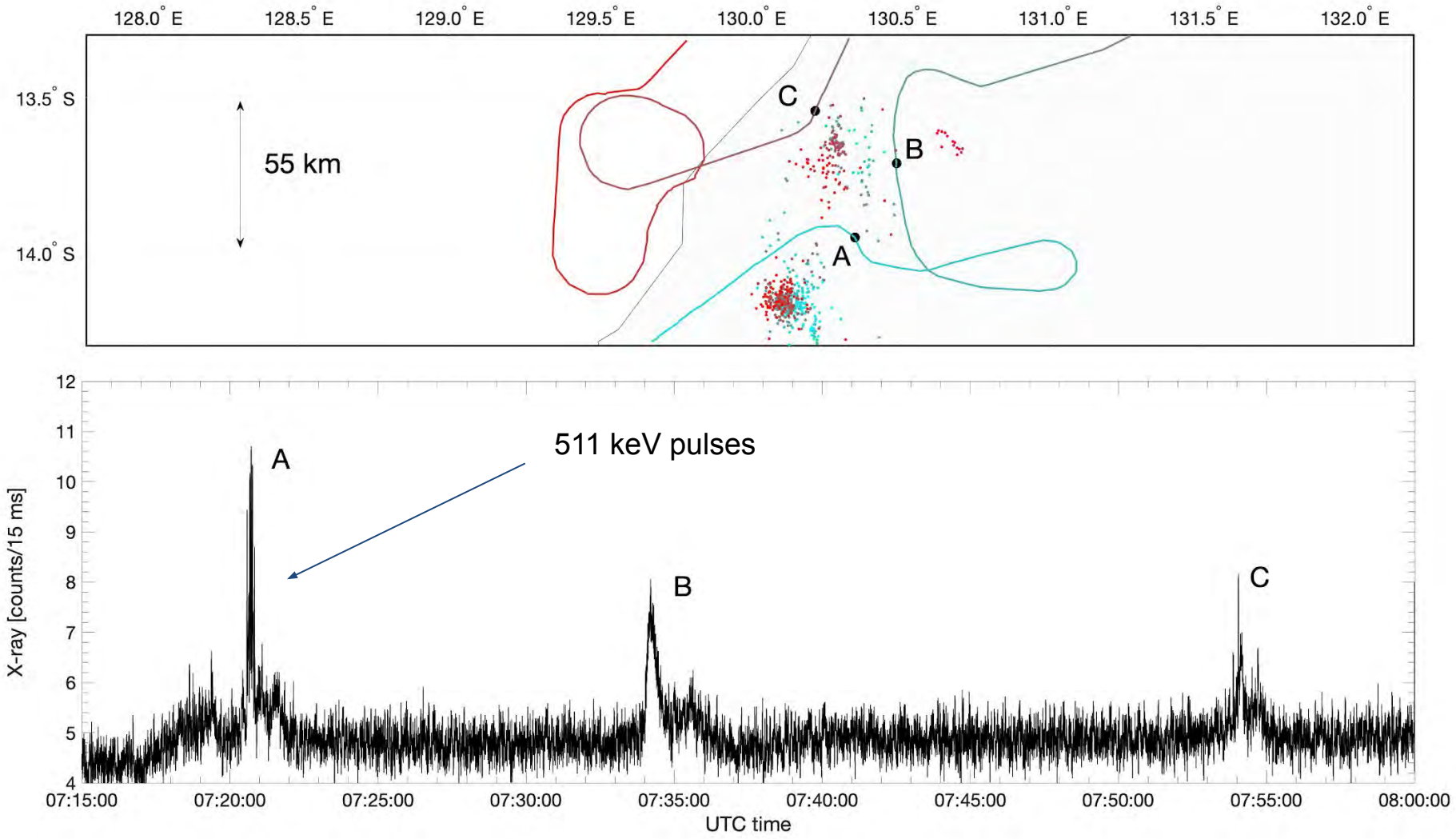
ILDAS animation

1. https://www.youtube.com/watch?v=Q7pMcu4OPj4
2. https://www.youtube.com/watch?v=u6IbpDh5Rwg

ILDAS papers

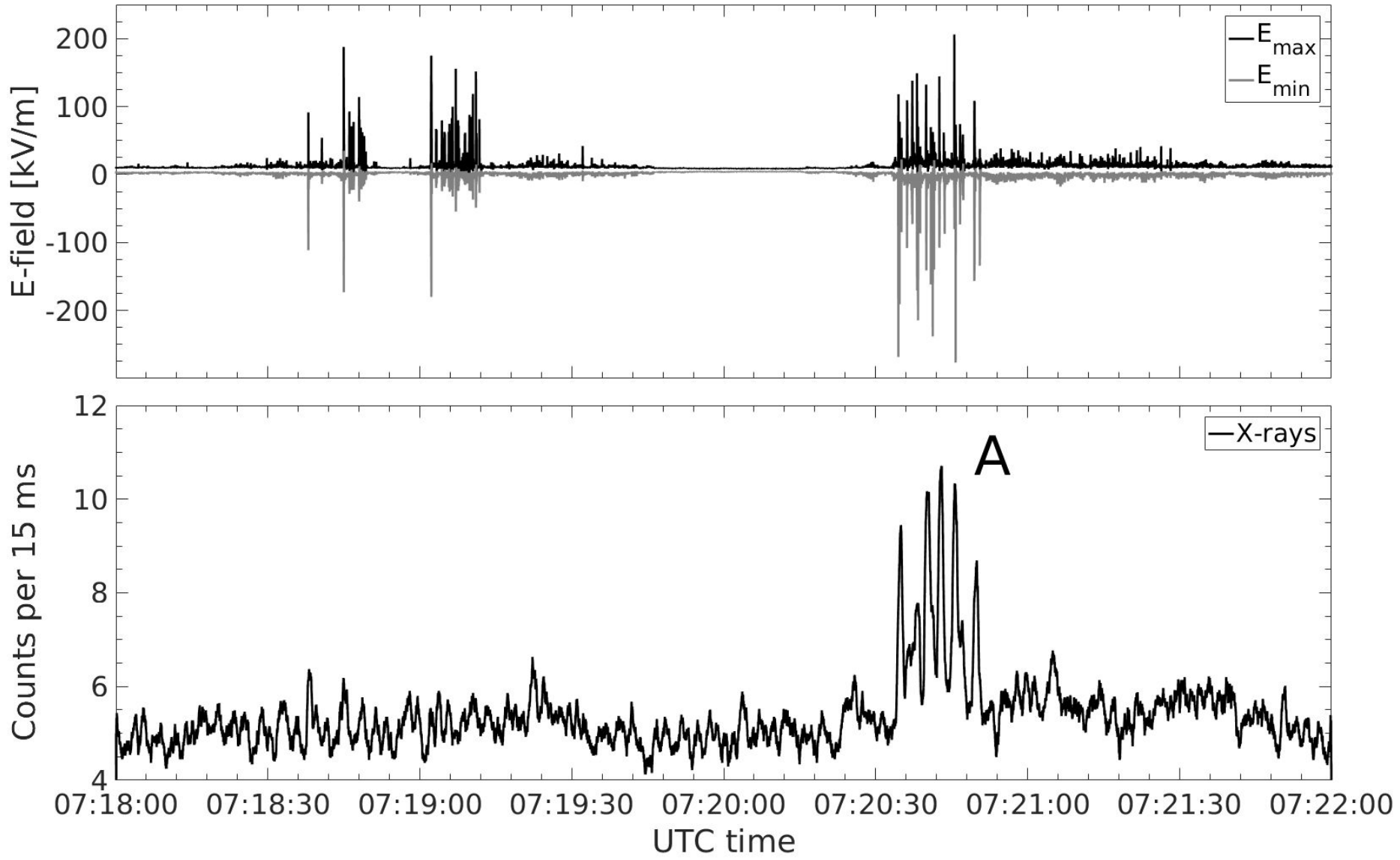
1. https://iopscience.iop.org/article/10.1088/0022-3727/48/42/425202/meta
2. https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2017JD027405
3. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JD028337

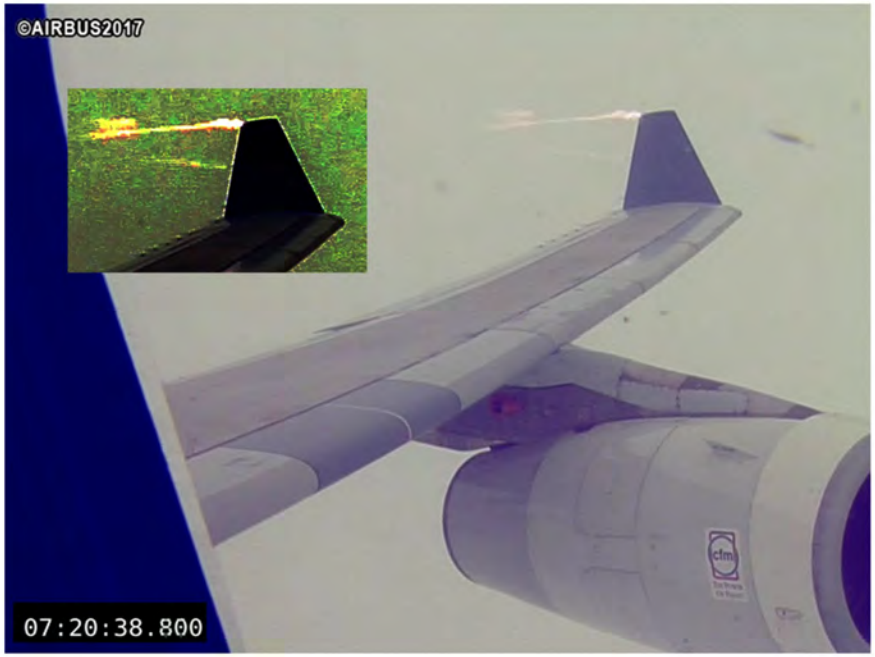
ILDAS observation



511 keV pulses

BIRKELAND CENTRE FOR SPACE SCIENCE





Research Article | Open Access

In-Flight Observation of Positron Annihilation by ILDAS

P. Kochkin, D. Sarria, C. Skeie, A. P. J. van Deursen, A. I. de Boer, M. Bardet, C. Allasia, F. Flourens, N. Østgaard

First published: 23 June 2018 | https://doi.org/10.1029/2018JD028337

It was a ferry flight to Farragut, ID. Enroute there were many scattered thunder showers. As we approached Billings, Montana, the build-up was becoming more and more noticeable. We had severe radio static. Communication was impossible with Billings. To reduce static somewhat I reduced RPM. That was when were struck directly on the nose section. Second of just blank, then a hurried look at gauges, radios, instruments and personnel. The Radio Operator said a ball of flame passed down the isle through the door. The passenger said the ball of flame about the size of a basketball rolled down the isle even with the right wing, out through the fuselage, down the wing and off the tip. After landing at Billings the aircraft was checked completely for any skin damage. None was found, but there was 70 ft. of trailing antenna burned off the radio station spool.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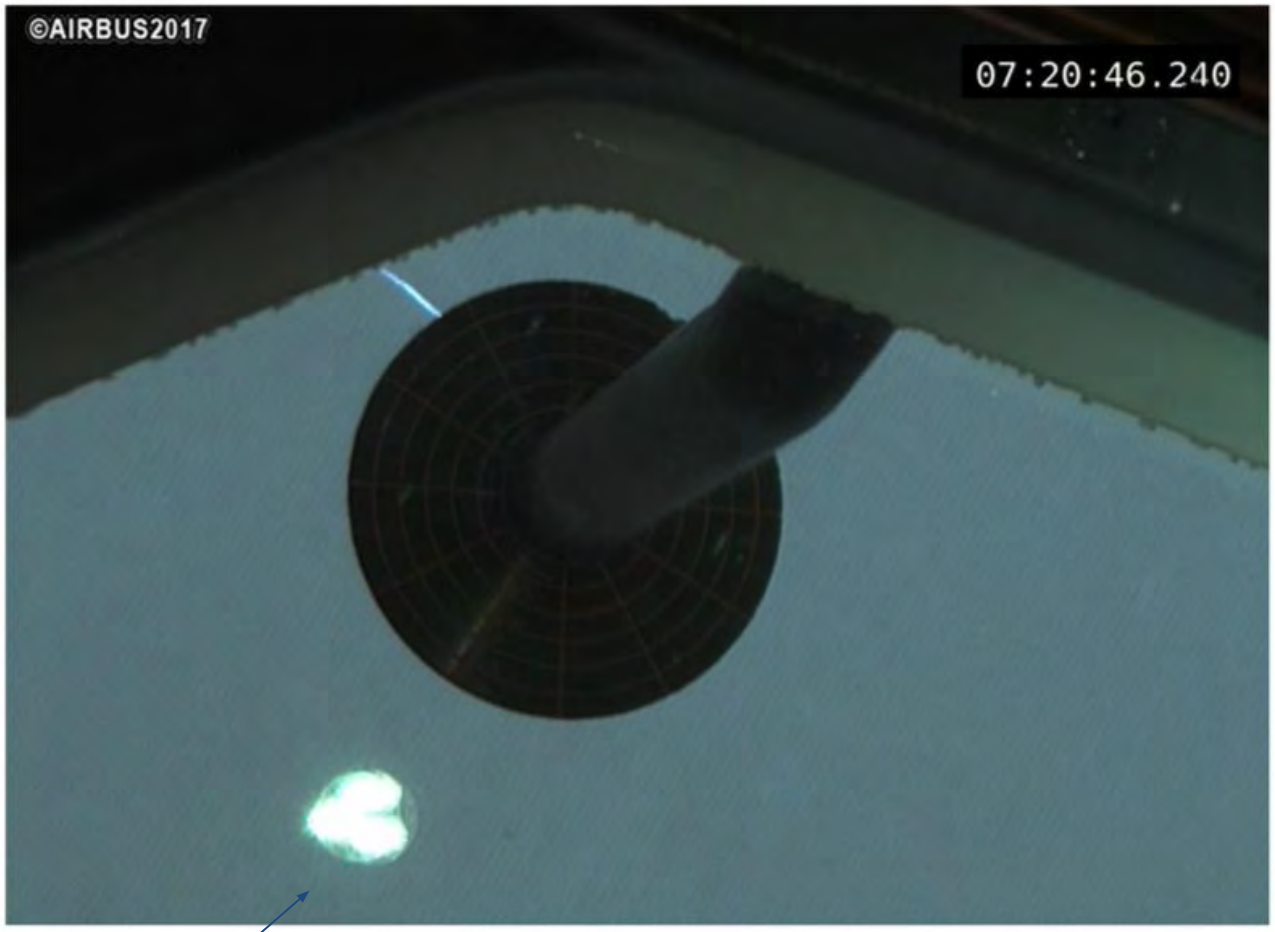
07:20:46.240



LED light reflection