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Filament-induced electric events in thunderstorms

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Collaboration: Langmuir Laboratory of New Mexico Tech & AFRL / DE*

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Outline

- Introduction
- Filamentation of ultrashort lasers
- Real-scale experiments in thunderclouds
- Conclusion & outlook



Lightning control

- On-demand lightning
 - fundamental studies
 - device testing

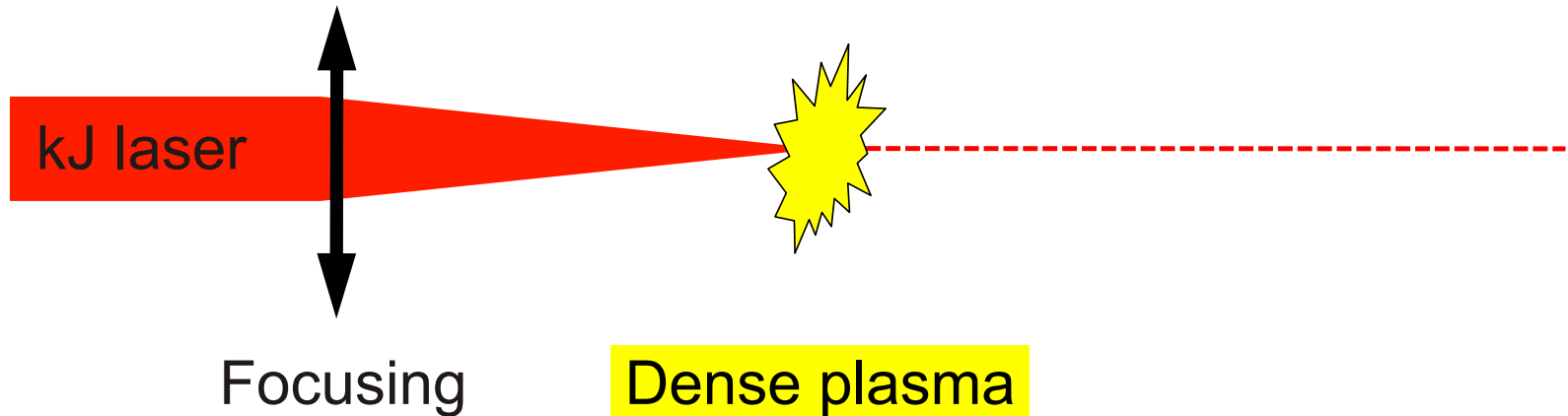
Rockets !

- But...
 - Reaction time ~few s
 - limited amount of rockets
 - no steering

→ Laser control !



Lightning control using « Long » laser pulses



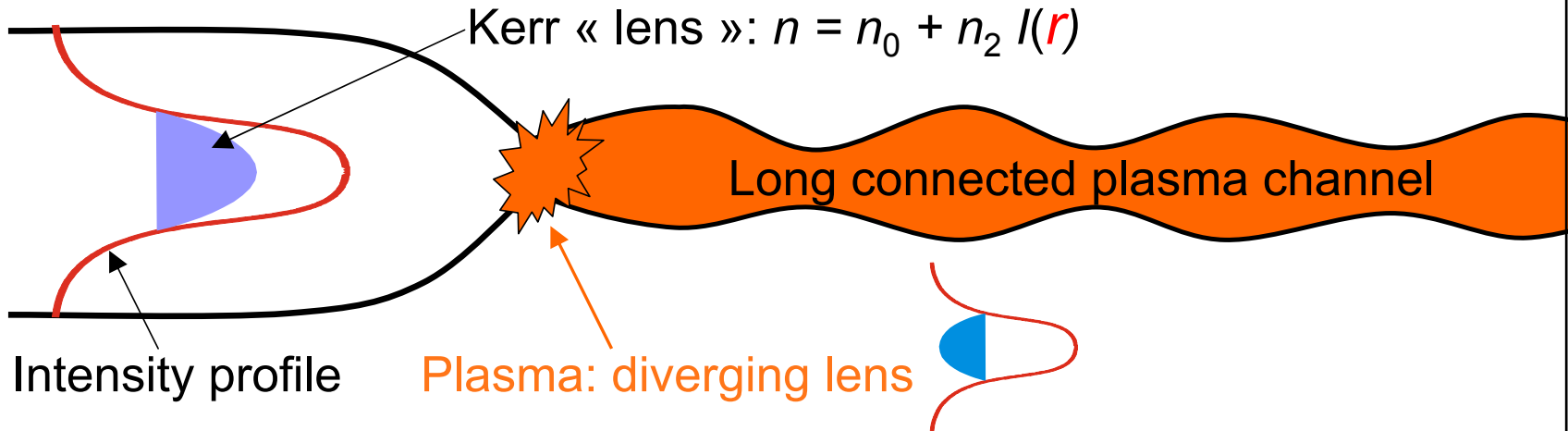
Opaque! Laser blocked !

No long connected plasma channel!
No triggering of lightning

See eg. S. Uchida et al., J. Opt. Technol. **66**, 199 (1999)

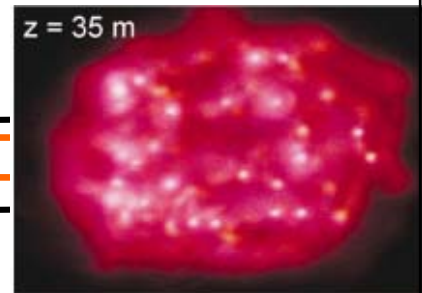
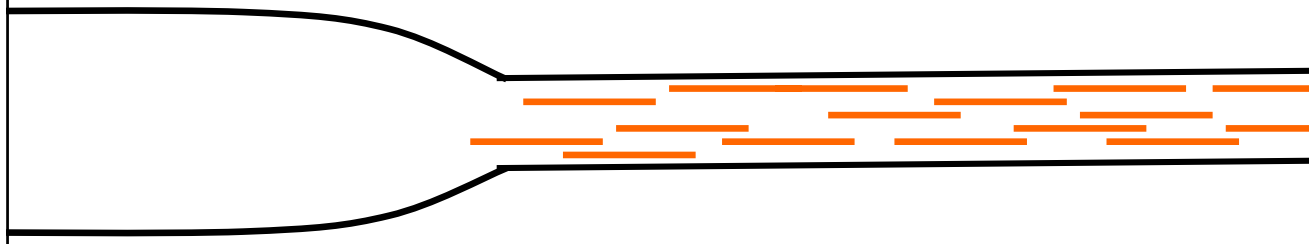


Self-guided propagation of fs lasers: Filamentation



Filament: $\Phi = 100 \mu\text{m}$, $L > 100 \text{ m}$, $I = 10^{14} \text{ W/cm}^2$, $\rho = 10^{15} \text{ cm}^{-3}$

High energy: multiple filamentation





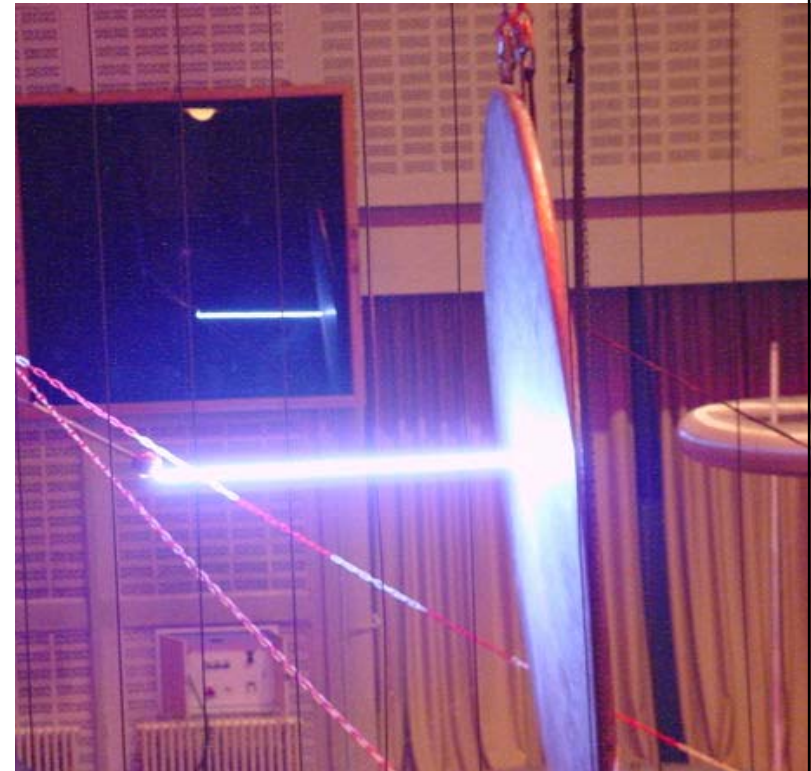
- Non-linear optics in air: Self-guiding
Reviews: Science **301**, 61 (2003); *Opt. Express* **16**, 466 (2008)
- Long-range (km) propagation PRE **69**, 036607 (2004)
- Continuous plasma channel
Weakly ionized APB **71**, 877 (2000)
Conducting: 1 M Ω /m Opt. Lett. **27**, 772 (2002)
10-100 filaments in beam EPJ-AP **20**, 183 (2002)
- Propagate in adverse conditions
Turbulent air APL **91**, 171106 (2007)
Fog, rain PRE **72**, 026611 (2005)
Reduced pressure APB **80**, 785 (2005)

Good candidates for lightning control



Control of high-voltage discharges

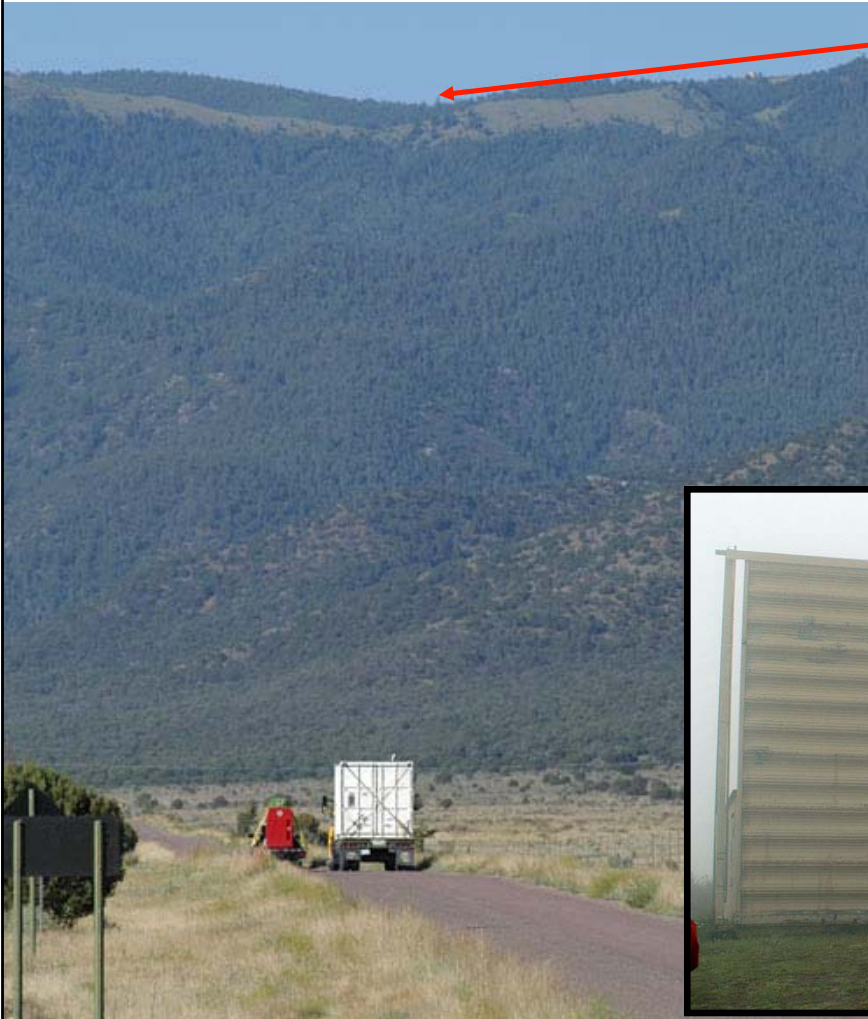
- **Triggering**: $U_{50} \searrow 30\%$
- **Guiding** by filaments
- Scale to real lightning ?
 - Leader-streamer mechanism





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Field campaign (Summer 2004)



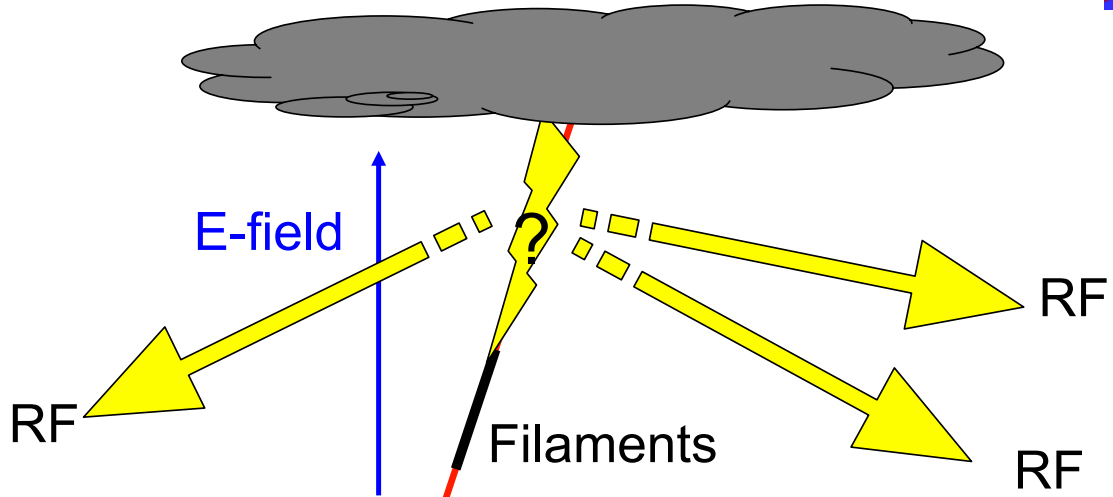
Langmuir Laboratory,
New Mexico Tech
3200 m altitude

Metallic hall: Faraday cage



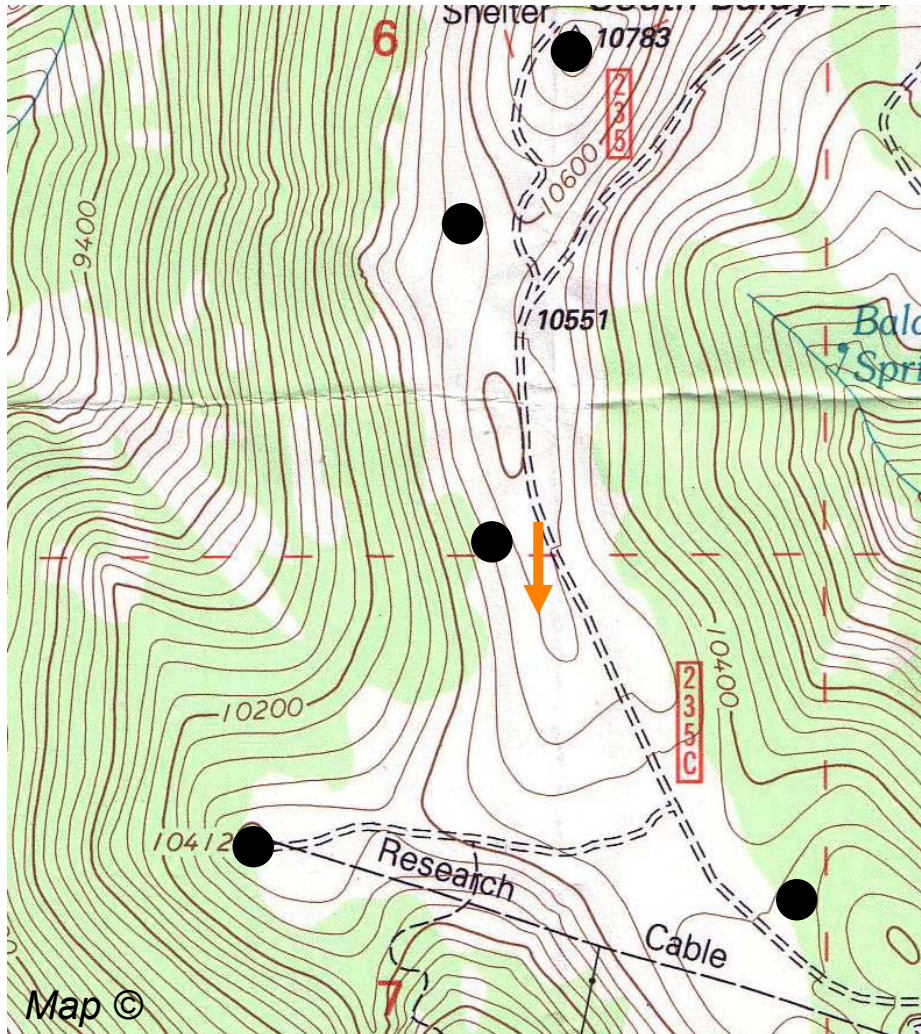


Principle of measurements





Langmuir Laboratory



● RF detectors (LMA)



Laser & filament

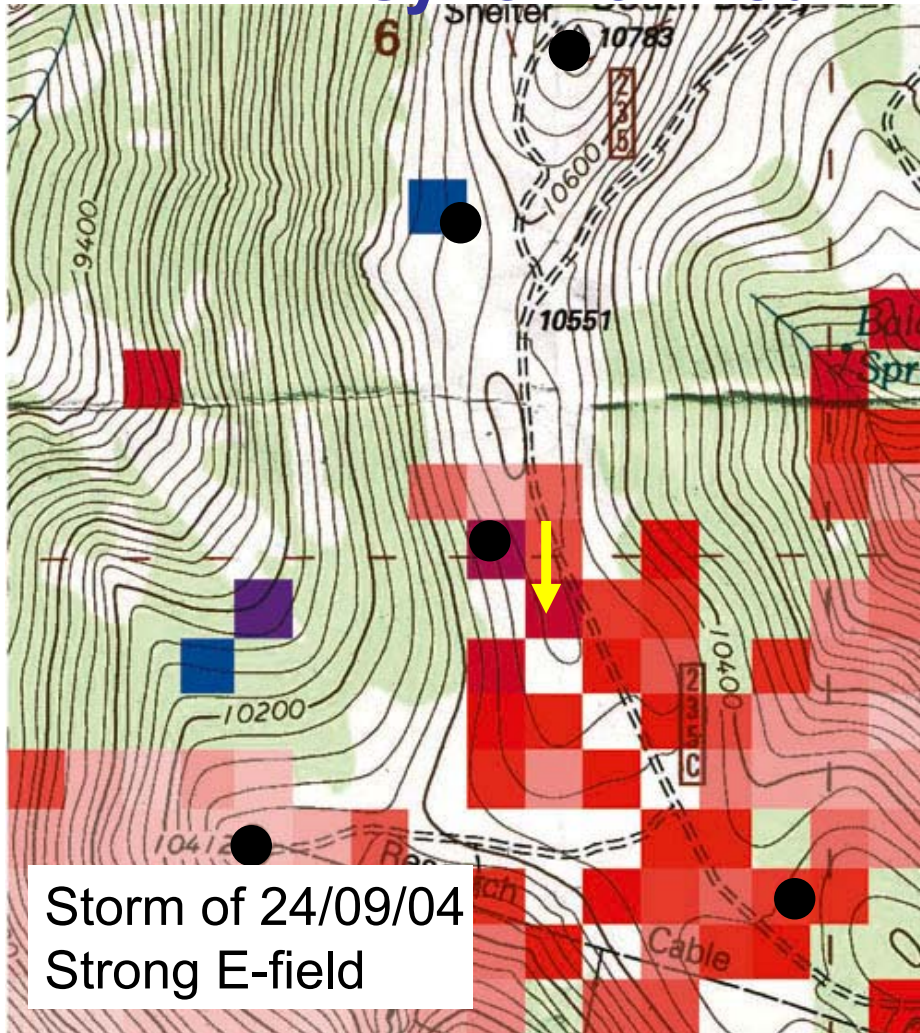
2 useable thunderstorms
0 triggered lightning strike

1 km



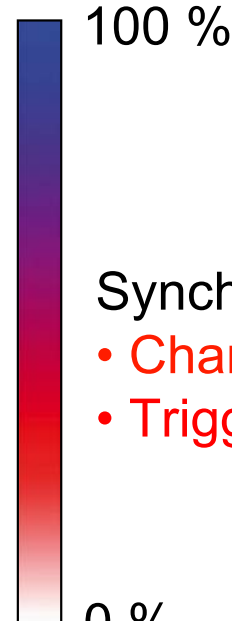


New approach: RF pulses synchronized with the laser



● RF detectors (LMA)

↓ Laser & filament



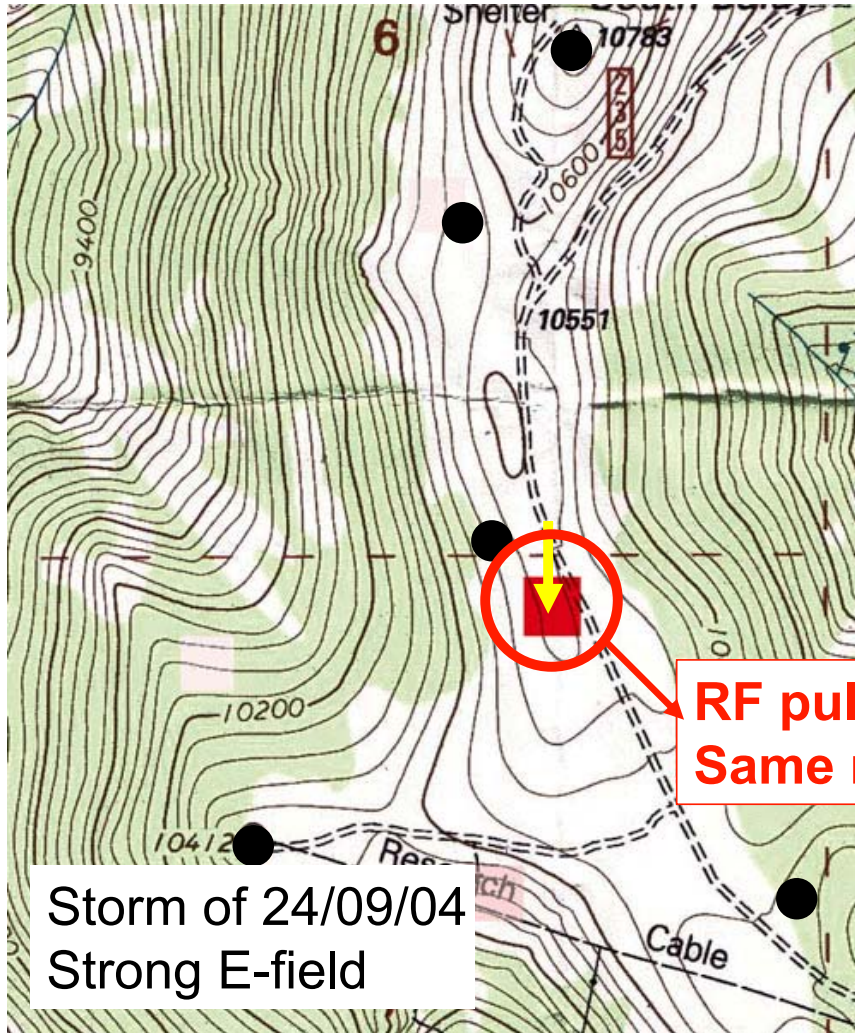
Synchronized pulses:

- Chance?
- Triggered?

1 km

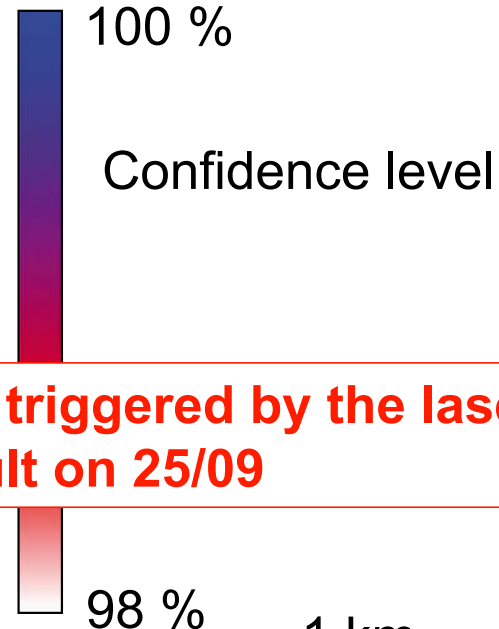


Statistical analysis



● RF detectors (LMA)

↓ Laser & filament



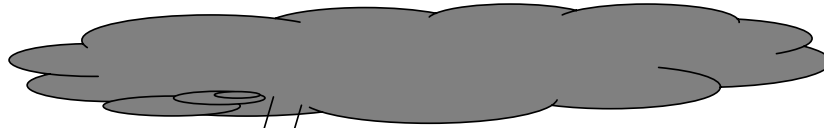
**RF pulses triggered by the laser !
Same result on 25/09**

1 km



Laser-induced corona!

Filamenting
region



Corona discharges at the tip of conductors:
« St Elmo's fires »

- **Optimizing observable** for a next campaign
- **Effect limited by**
 - **Plasma density**
 - **Plasma lifetime:** $\sim \mu\text{s}$
 - **Laser repetition rate:** 10 Hz





Conclusion & outlook

Ultrashort laser filaments

- long, connected **plasma channels**
- **propagate** in the *atmosphere*
- control high-voltage **discharges**
- **trigger** electric events *in thunderstorms*

Next step: improve the plasma...

- ...**density**: Higher laser *pulse energy*
- ...**lifetime**: *Pulse sequences*



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