Lightning and Energetic Radiation

Recent work at the University of Bergen

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University of Bergen, Norway

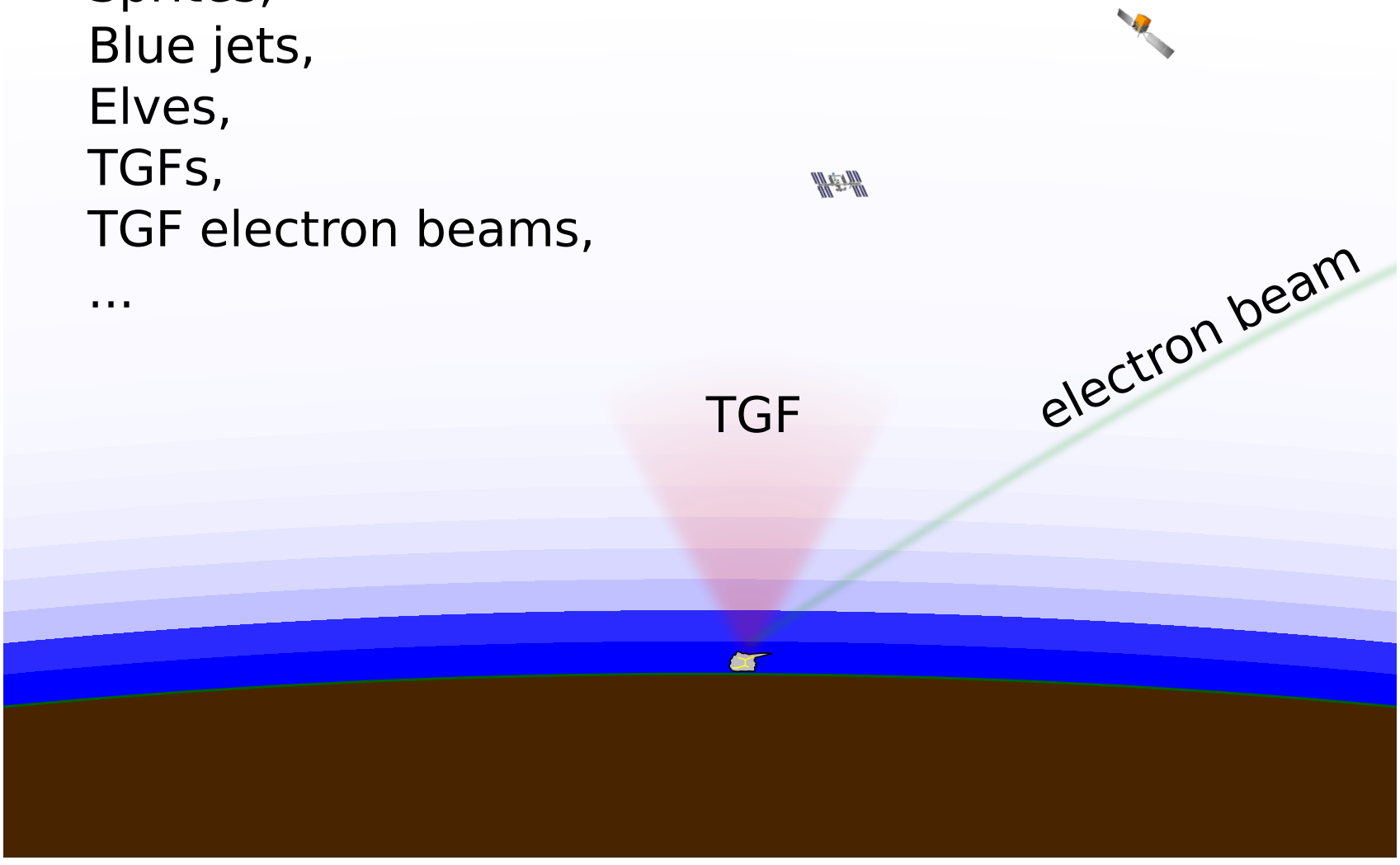
AGILE Workshop, ESRIN, 18 April 2012

Outline

- ASIM
  - Status, progress.
- Data analysis
  - RHESSI data search
  - Spark data analysis
- Modeling
  - RHESSI/Fermi comparison
  - Aircraft/balloon observation modeling
  - Lightning modeling

Context

Lightning,
Sprites,
Blue jets,
Elves,
TGFs,
TGF electron beams,
...



Lightning

lightning in slow-motion

Video credit: Tom Warner

Runaway electron avalanche

RREA animation

Sprites

sprites in slow-motion

Video credit: Steve Cummer

Context

Lightning

- Thousands of deaths/year.
- Billions of USD damage.
- Not really understood.

Lightning as charge motion

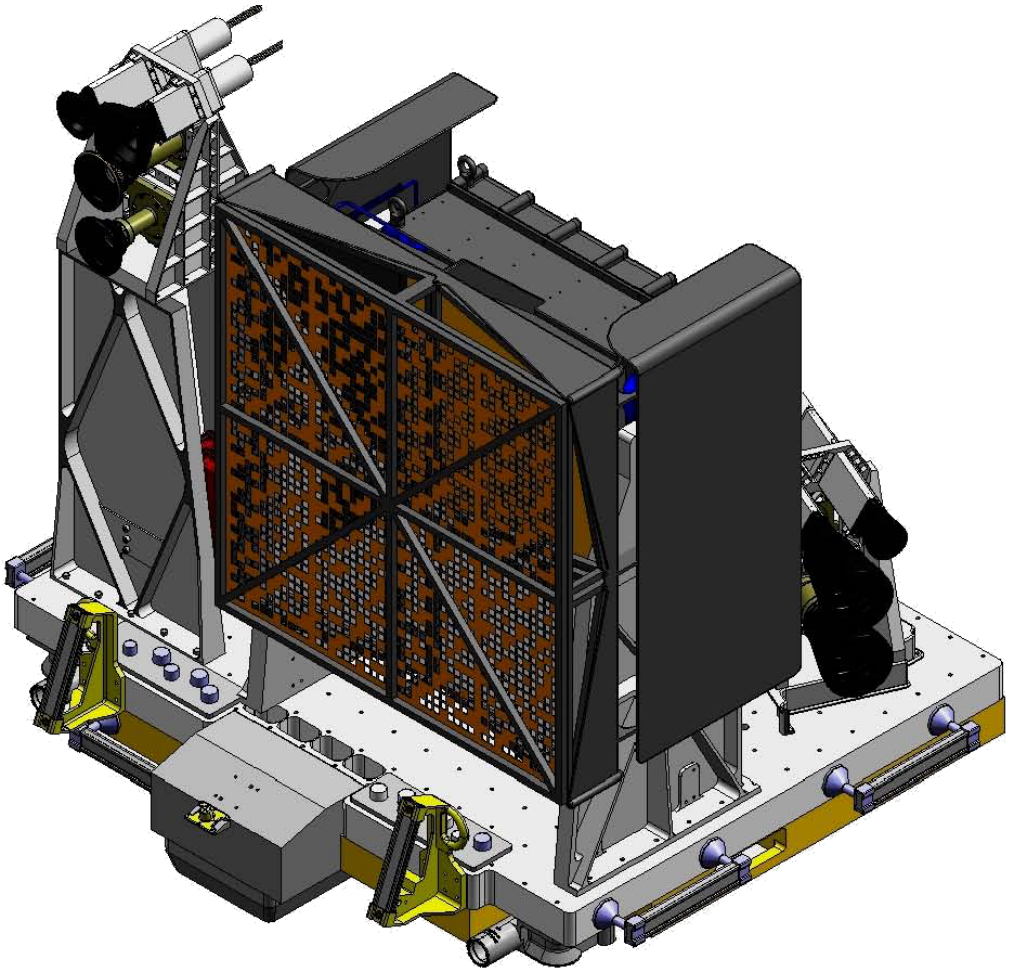
- Large charge motion $\rightarrow$ sprites
- Fast charge motion $\rightarrow$ elves

Lightning as particle accelerator

- Up to 40 MeV? Up to 100 MeV?

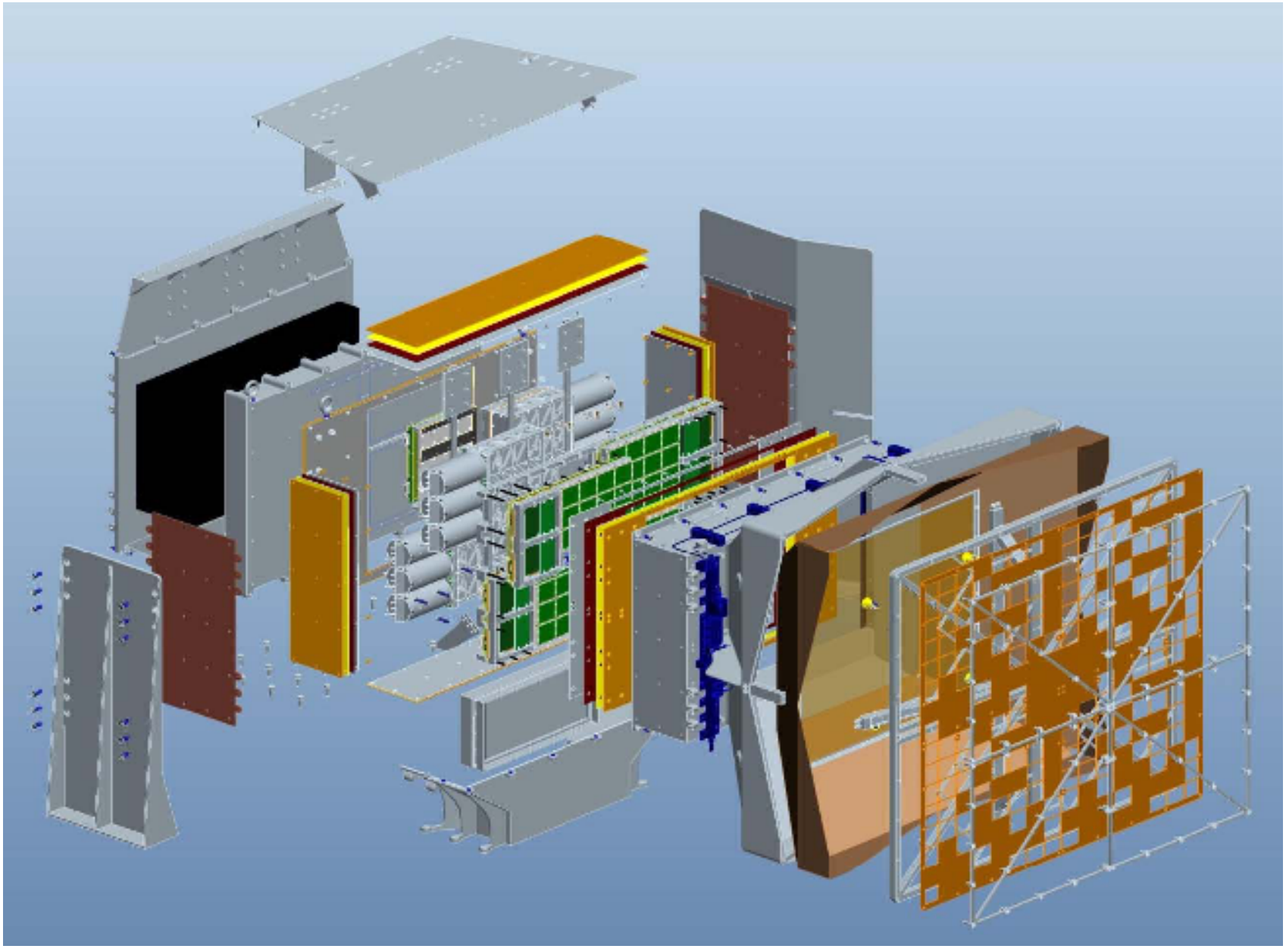
Implications?

ASIM



- MXGS
  - Coded mask
  - CZT low-energy
  - BGO high-energy
- MMIA
  - Photometers
  - Cameras
- ISS/Columbus
- Nadir pointing
- Observe TGFs and lightning

ASIM exploded



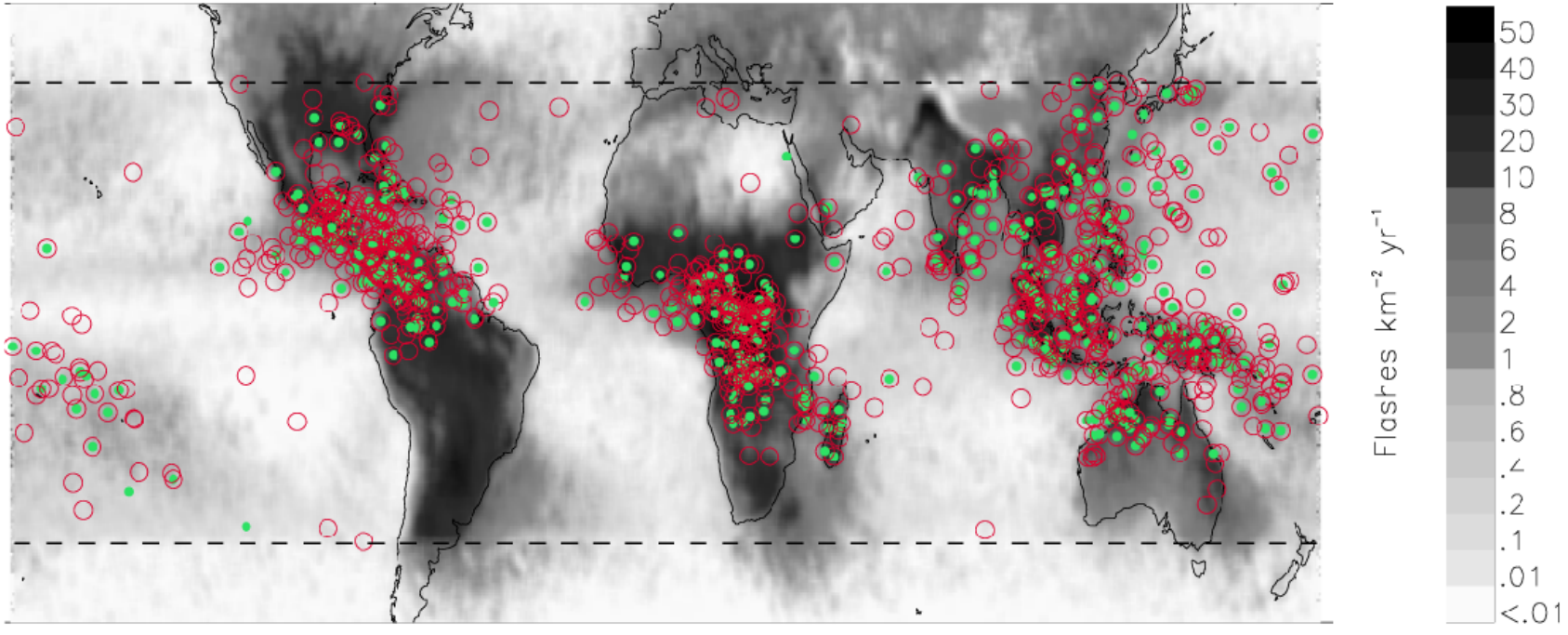
ASIM status

- Passed PDR
- Now phase C
- Working on electronics, final design
- Expected launch “2015”

RHESSI data search

Re-analyze RHESSI data, lower threshold, careful calculations.

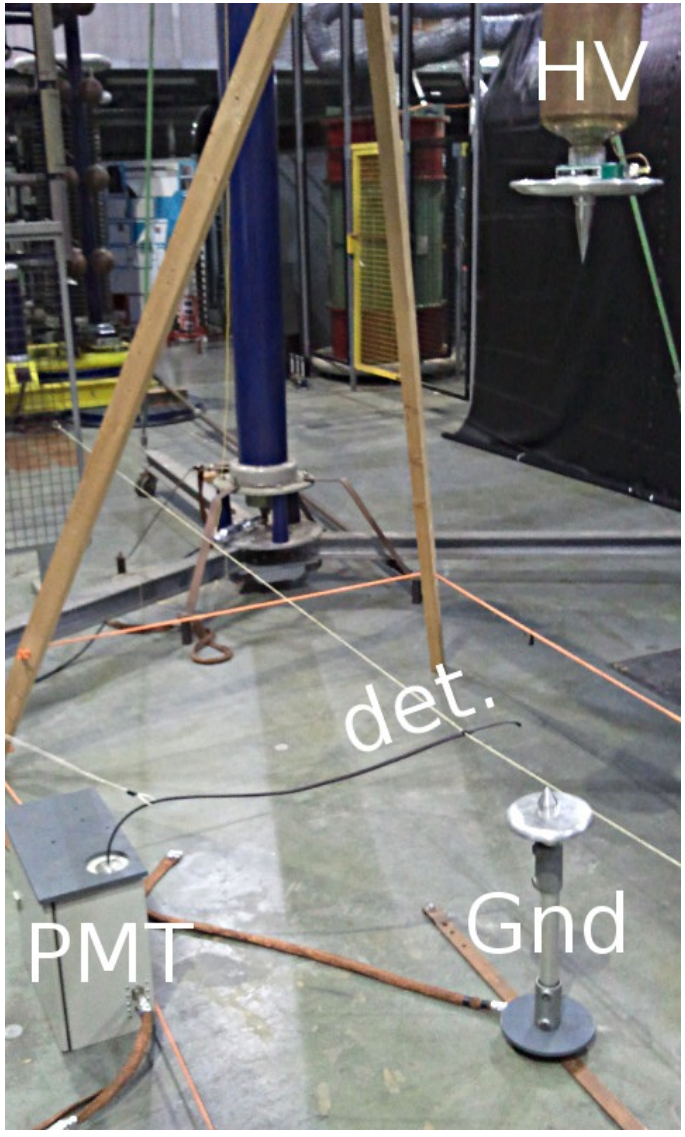
Get $\sim 2\times$ more events, same WWLLN match rate.

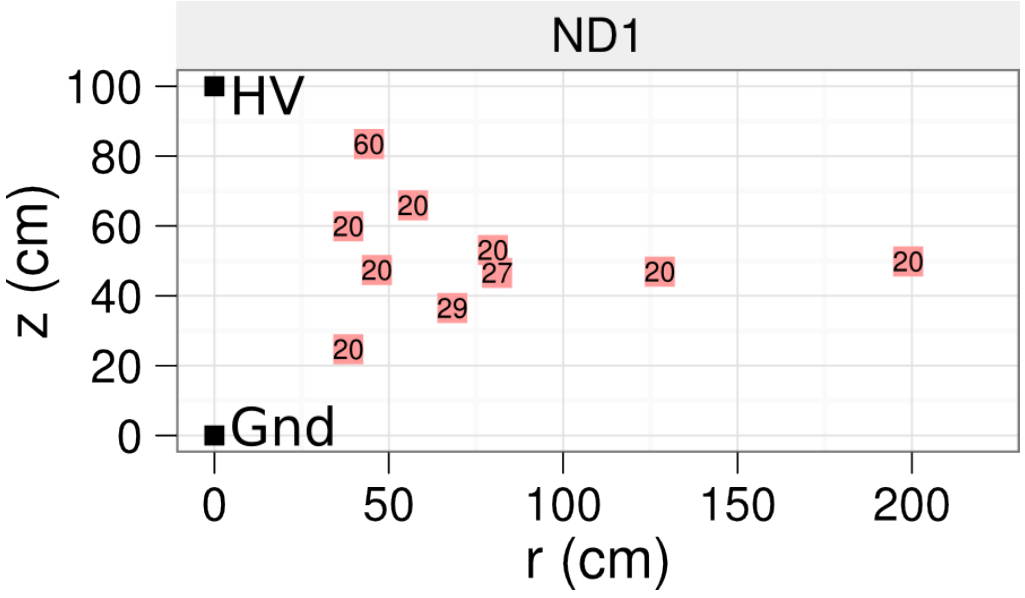


Gjesteland, T., et al. (2012). A new method reveals more TGFs in the RHESSI data. GRL, 39(5), 1-5.

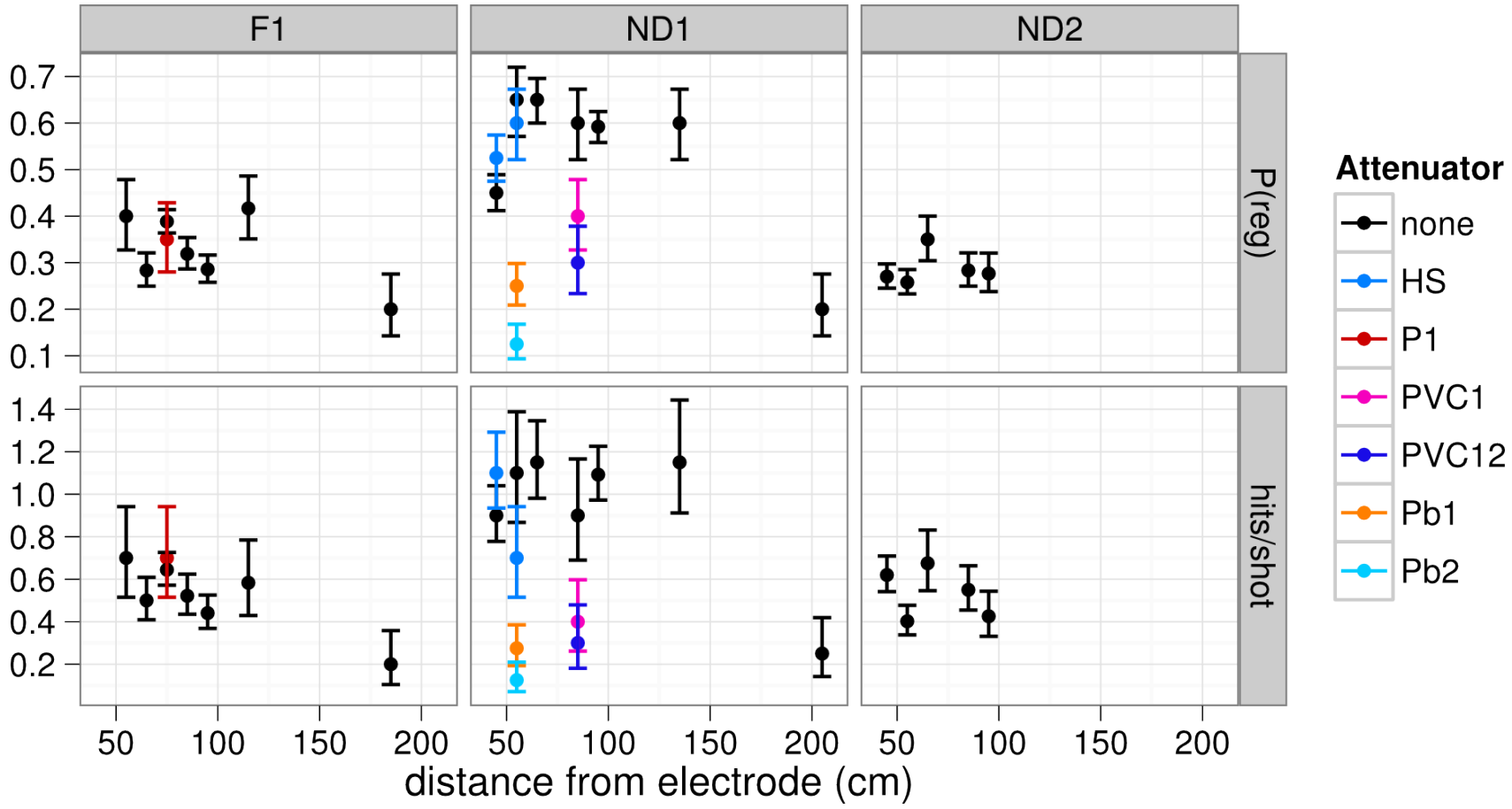
Spark data analysis

- 2 MV Marx generator at TU/e.
- Search for runaway electrons.
- Understand x-ray statistics.
- Plastic scintillators / optical fibers.
- Various positions.
- $\sim$ 900 sparks.





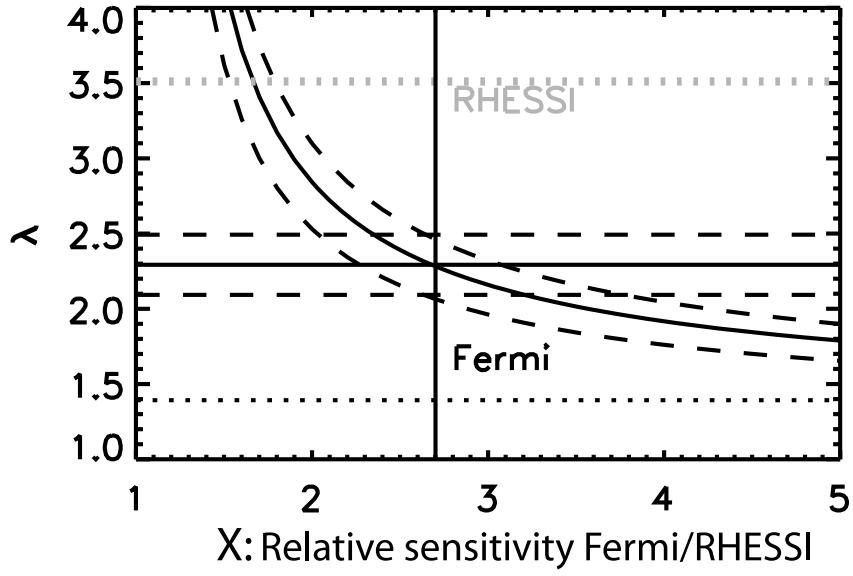
Spark data statistics

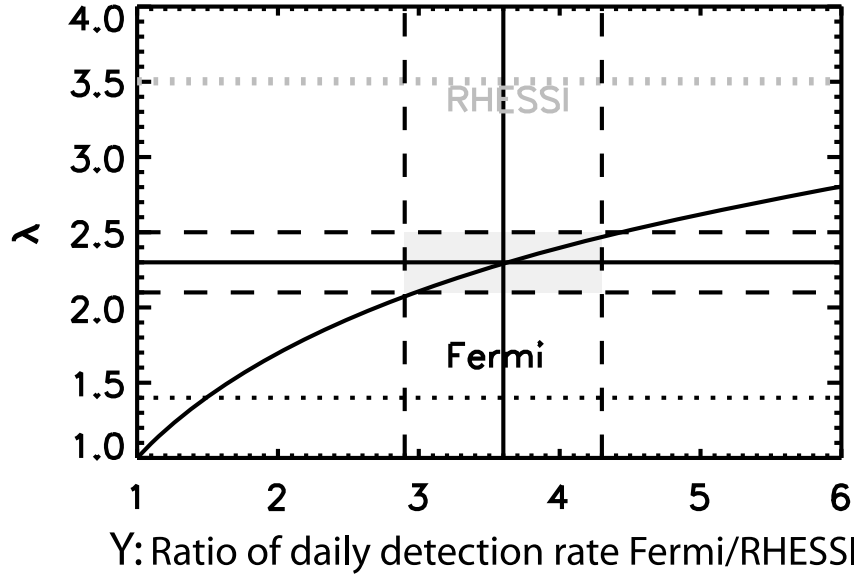


See Carlson et al., European Geophysical Union Conference presentation (next week).

RHESSI/Fermi comparison

- Different dead-time, triggering.
- Different detection thresholds.
- ... compare detection rates.
- Constrain fluence distribution.
- $\rightarrow$ power law, $\lambda \sim 2.3$
- $\rightarrow$ RHESSI dead-time consistent.

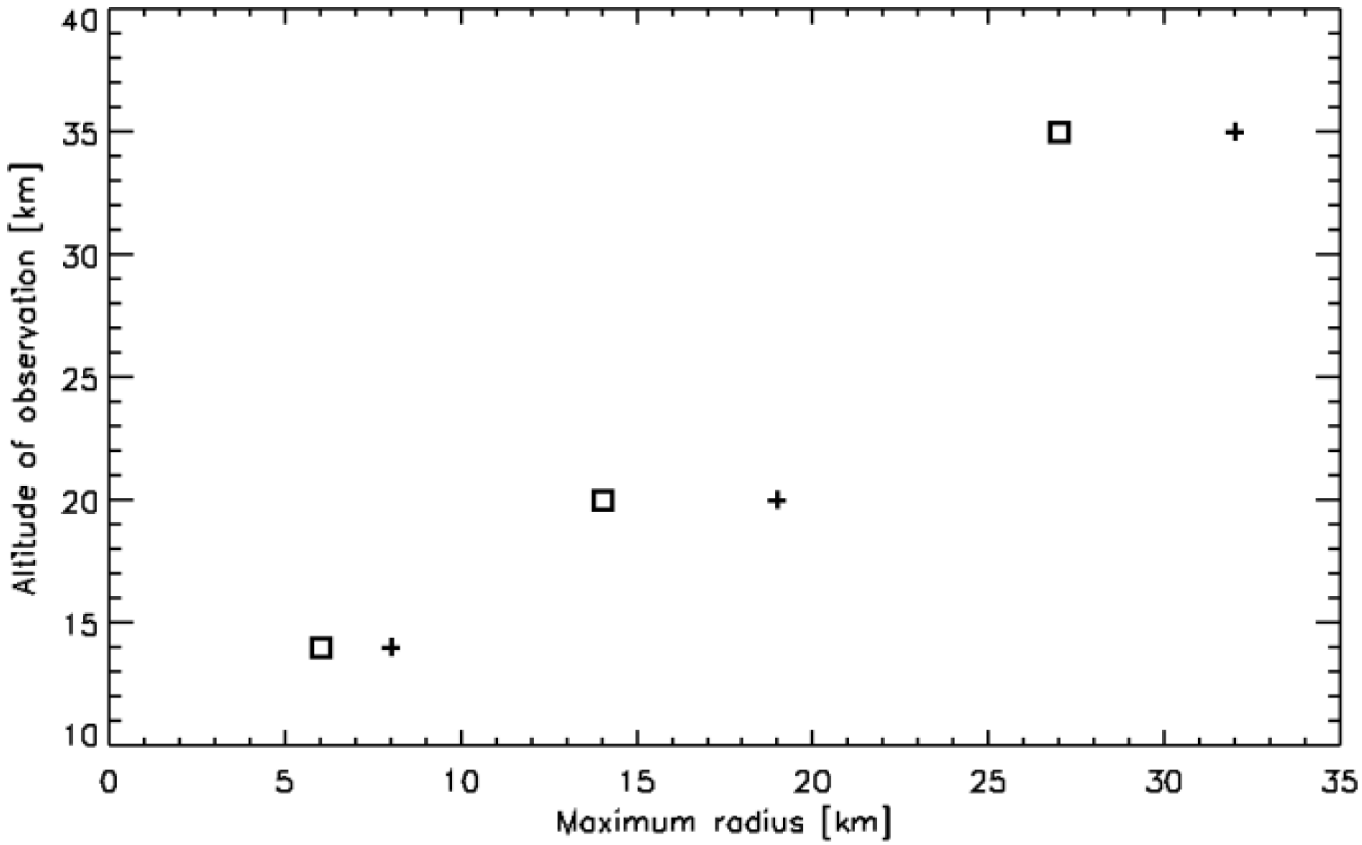




Østgaard, N. et al. (2012). The true fluence distribution of terrestrial gamma flashes at satellite altitude. JGR, 117(A3), 1-8.

Aircraft/balloon observation modeling

- Assume TGF-scale emission.
- Predict aircraft, balloon observations.
- $\rightarrow$ Criteria for campaign design.
- $\rightarrow$ Understand ADELE observations.



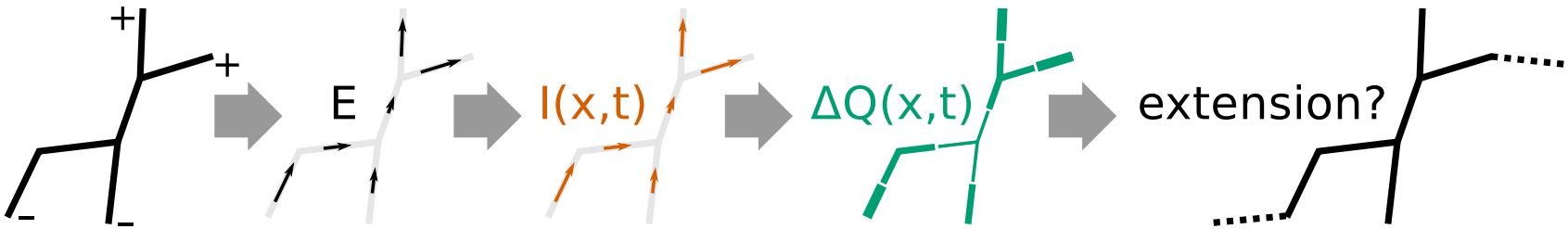
Hansen et al., upcoming.

Lightning modeling – TDFL

Electric field dominates behavior

$$\mathbf{E}(\mathbf{x},t) = \frac{1}{4\pi\epsilon_0}\int d^3x' \left\{ \frac{\hat{\mathbf{R}}}{R^2}\left[\rho(\mathbf{x}',t')\right]_{\text{ret}} + \frac{\hat{\mathbf{R}}}{cR}\left[\frac{\partial\rho(\mathbf{x}',t')}{\partial t}\right]_{\text{ret}} - \frac{1}{c^2R}\left[\frac{\partial\mathbf{J}(\mathbf{x}',t')}{\partial t}\right]_{\text{ret}} \right\}$$

Calculate E-field along channel, determine current.
Currents determine charge evolution.



- Full time-domain evolution, < 1 μs to > 100 ms scale, stochastic extension, unconstrained geometry, adaptive time-stepping, corona sheath, channel property evolution.
- Many parameters (initial conditions, channel properties...)

TDFL movie

sample TDFL simulation

Carlson et al., upcoming.

Et cetera...

- Bremsstrahlung meeting
- Electron beam modeling
- RREA feedback modeling
- New RHESSI data / correlations with lightning
- ...
- Any other ideas? Collaborations?

Thanks!

The UiB TGF group:

Nikolai Østgaard (PI), Thomas Gjesteland, Ragnhild Hansen,
Alexander Skeltved, Øystein Grondahl,
and the ASIM engineering team.