Solar radio bursts from proton-producing flares and CMEs

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9th Workshop
"Solar Influences on the Magnetosphere, Ionosphere and Atmosphere"
30 May–03 June 2017, Sunny Beach, Bulgaria

Introduction

Aim

Comparative study on the ***occurrence*** of radio burst **types II, III and IV** in relation to the solar origin of proton events (flares/CMEs) in ongoing SC24 (**2009–2016**)

Previous work on SC23: ***Miteva et al. (2013), CEAB***

SEPs → (flares/CMEs)→ Radio bursts

Cane et al. (2002); Gopalswamy (2003); Cliver et al. (2004); Cliver & Ling (2007, 2009), Miteva et al. (2013)...

Radio bursts → (flares/CMEs) → SEPs

Kahler (1982); Cliver et al. (2004); Goplaswamy et al. (2008); Winter & Ledbetter (2015); Prakash et al. (2017)...

SEPs – radio bursts

Event selection:

- Composing 'generalized' **proton catalog**

bias-free from satellite/instrument/energy, etc.: cross-correlation (onset time, peak intensity, solar origin) of 5 proton catalogs/3 instruments/7 energy ranges

GOES (2): NOAA list; Papaioanou et al. (2016)

Wind/EPACT (2): list (Miteva et al. 2016)

SOHO/ERNE: SEPServer list (Vainio et al. 2013)

- **Solar origin** identification of protons: **flares & CMEs**

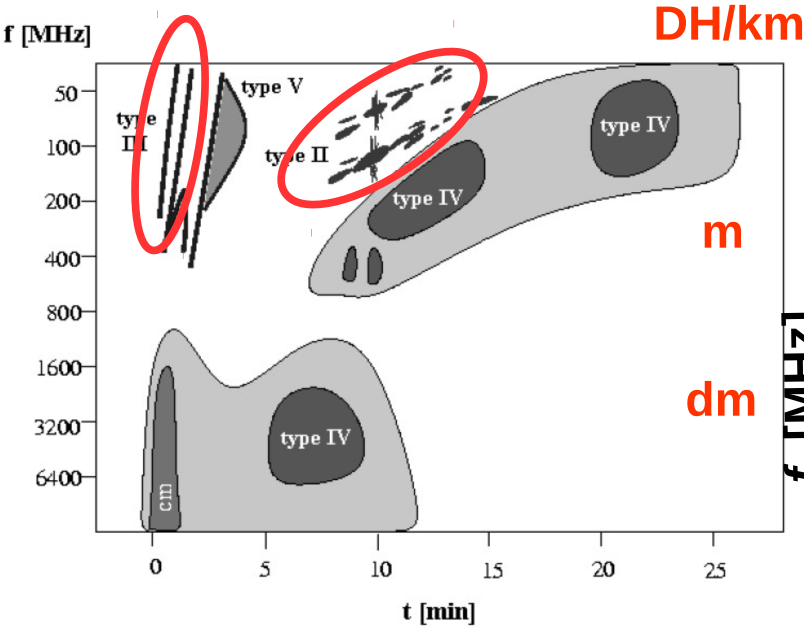
  criteria: time; helio-location; proton profile; IP-type III bursts

- Searching **radio bursts** in the time period: flare onset – CME first appearance

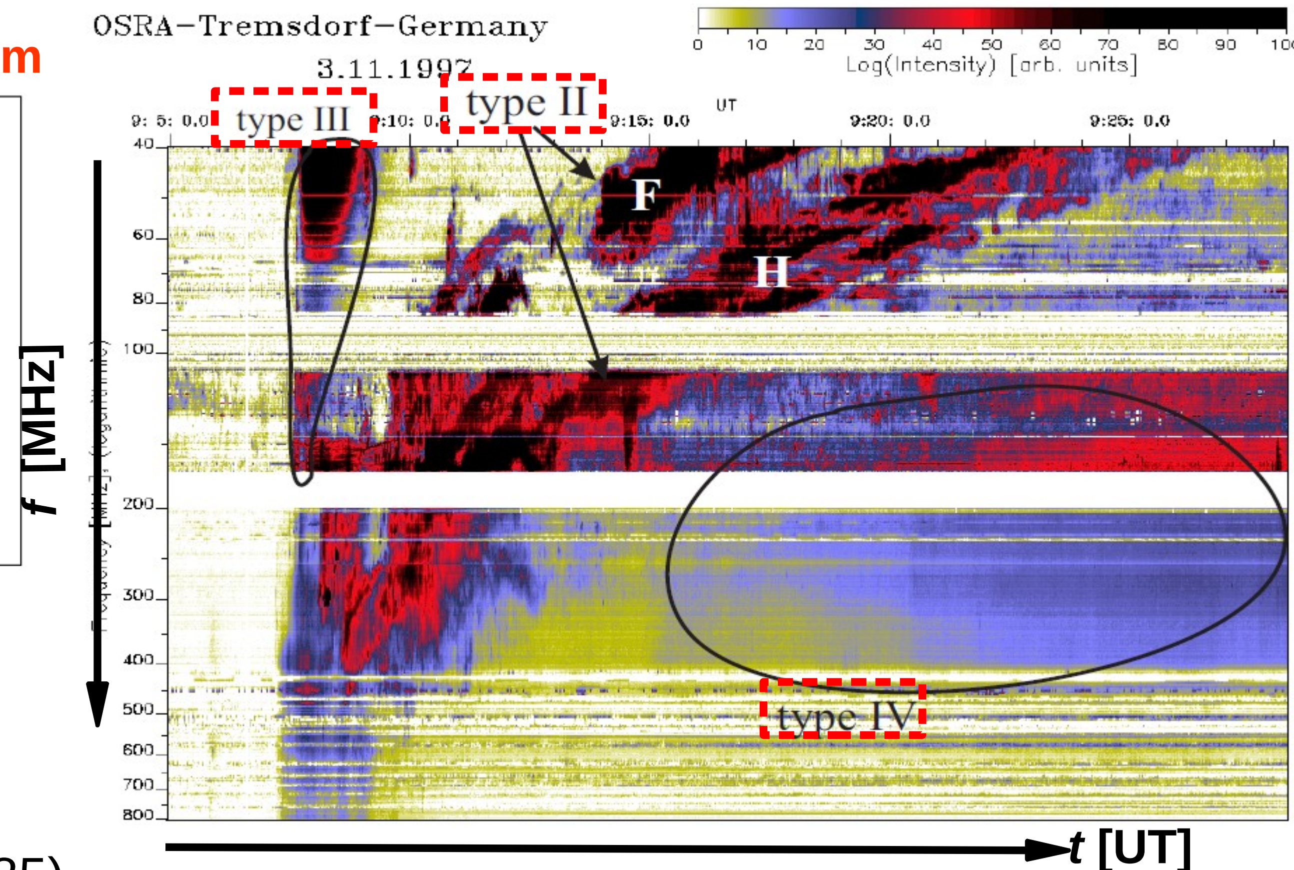
[All proton events from our list have in situ electron signature]

procedure: following Miteva et al. (2017, JASTP in press)

Solar radio bursts: Type II, III & IV



Warmuth & Mann (2005)



Magdalenic (2008)

Type II *(shock wave)*

e.g. Nelson & Melrose (1985)...

Type III *(electron beams)*

e.g. Wild (1950); Melrose (1985); Aschwanden et al. (1995)...

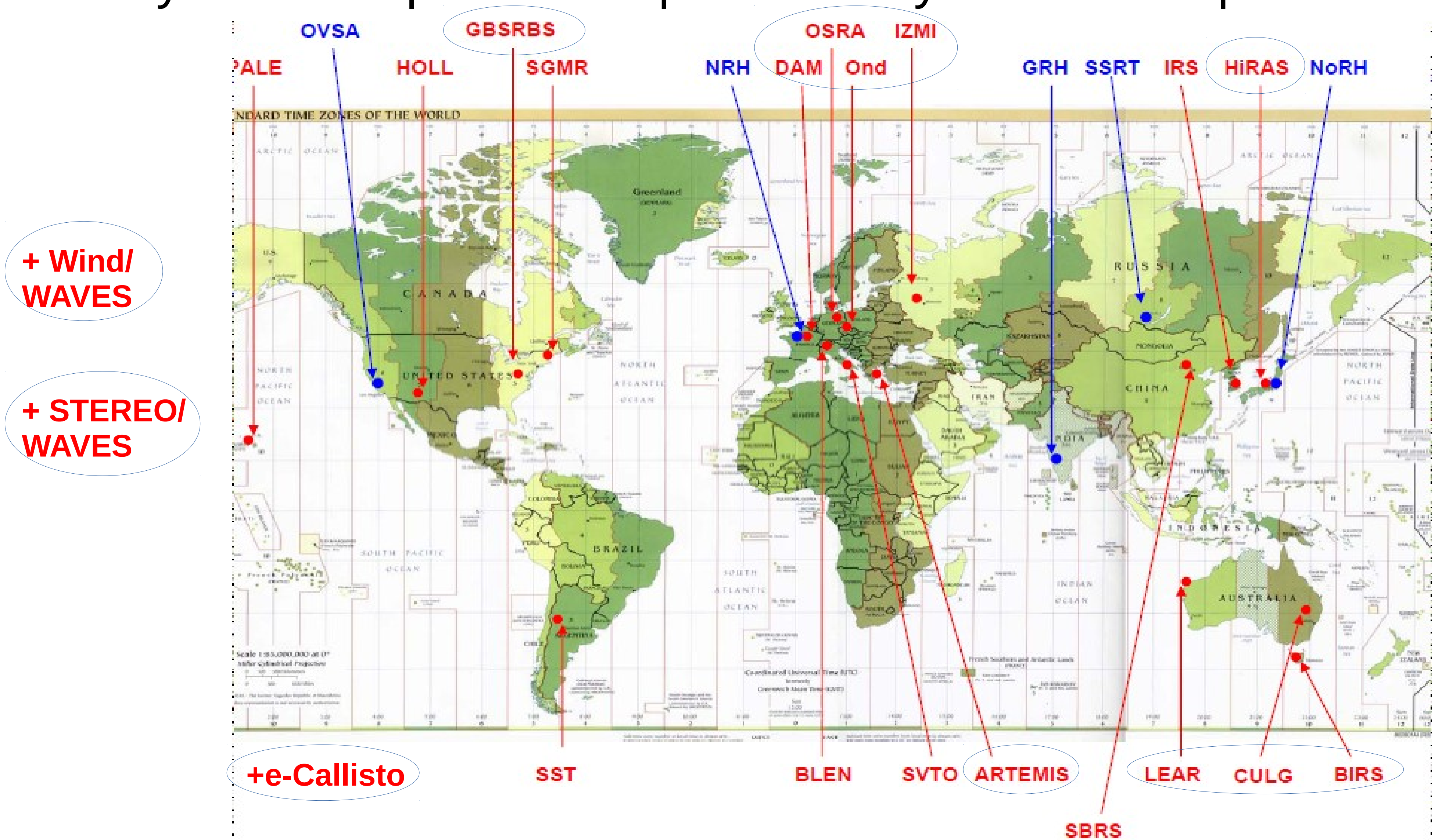
Type IV + continuum *(trapped electrons)*

e.g. Boishchot (1957); Kundu (1982); Stewart (1985)...

Solar radio observatories

Identification of radio burst occurrence

1. by visual inspection of quick-look dynamic radio plots



Solar radio bursts: Type II, III & IV

Identification of radio burst occurrence

2. by collecting information from radio observatory reports

Coverage	Link/Reference
	NOAA
	ftp.ngdc.noaa.gov/STP/space-weather/solar-data/solar-features/solar-radio
1960–2010	/radio-bursts/fixed-frequency-listings/
1967–2011	/radio-bursts/reports/spectral-listings/
2000–2011	/radio-bursts/tables/spectral-sgd/
1996–present	ftp.ngdc.noaa.gov/STP/swpc_products/daily_reports/solar_event_reports/
	Phoenix/e-Callisto
1998–2011	http://soleil.i4ds.ch/solarradio/
	HiRAS
1994–2011	http://sunbase.nict.go.jp/solar/denpa/spe_summary/
	Culgoora/Learmonth
1992–present	http://www.sws.bom.gov.au/World_Data_Centre/1/9
	ARTEMIS (selected events)
1998–2013	http://artemis-iv.phys.uoa.gr/DataBaseForWeb/data_set.htm
	IZMIRAN (selected events)
1996–present	http://www.izmiran.ru/stp/lars/MoreSp.html
	Green bank/Bruny Island (selected events)
2004–2015	http://www.astro.umd.edu/~white/gb/index.shtml
	Wind/WAVES (selected events)
1994–2015	https://solar-radio.gsfc.nasa.gov/wind/data_products.html

Results

I. All proton sample → Type II, III, IV

- visual identification (black-color)
- uncertain (dark-color)
- observatory reports only (light-color)

II. Trends:

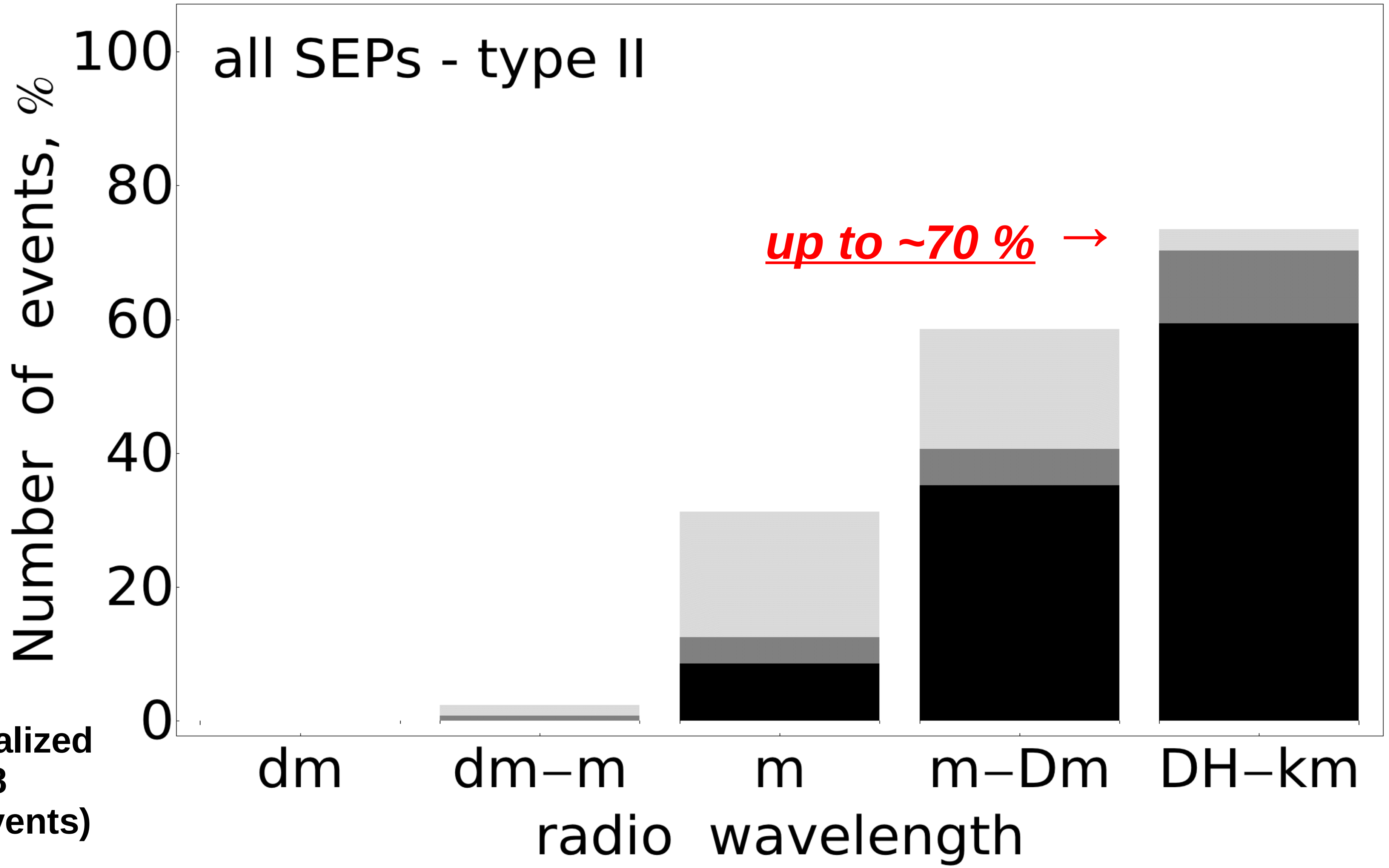
Western vs. Eastern origin of proton events → Type II, III, IV

- according to the AR (flares) and MPA (CMEs)

Strong vs. Weak proton events → Type II, III, IV

- according to the median value of the proton event sample

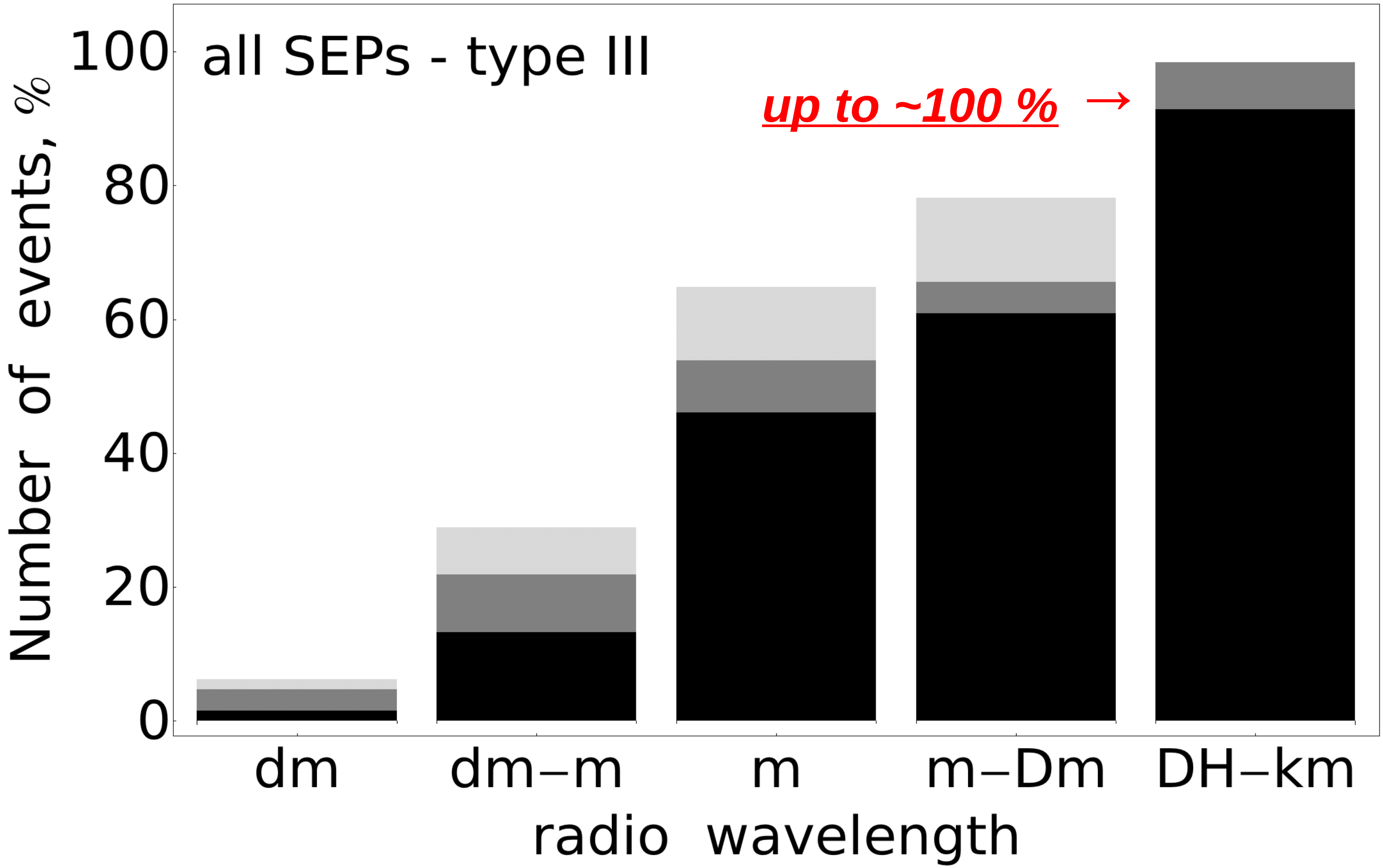
Results: Type II



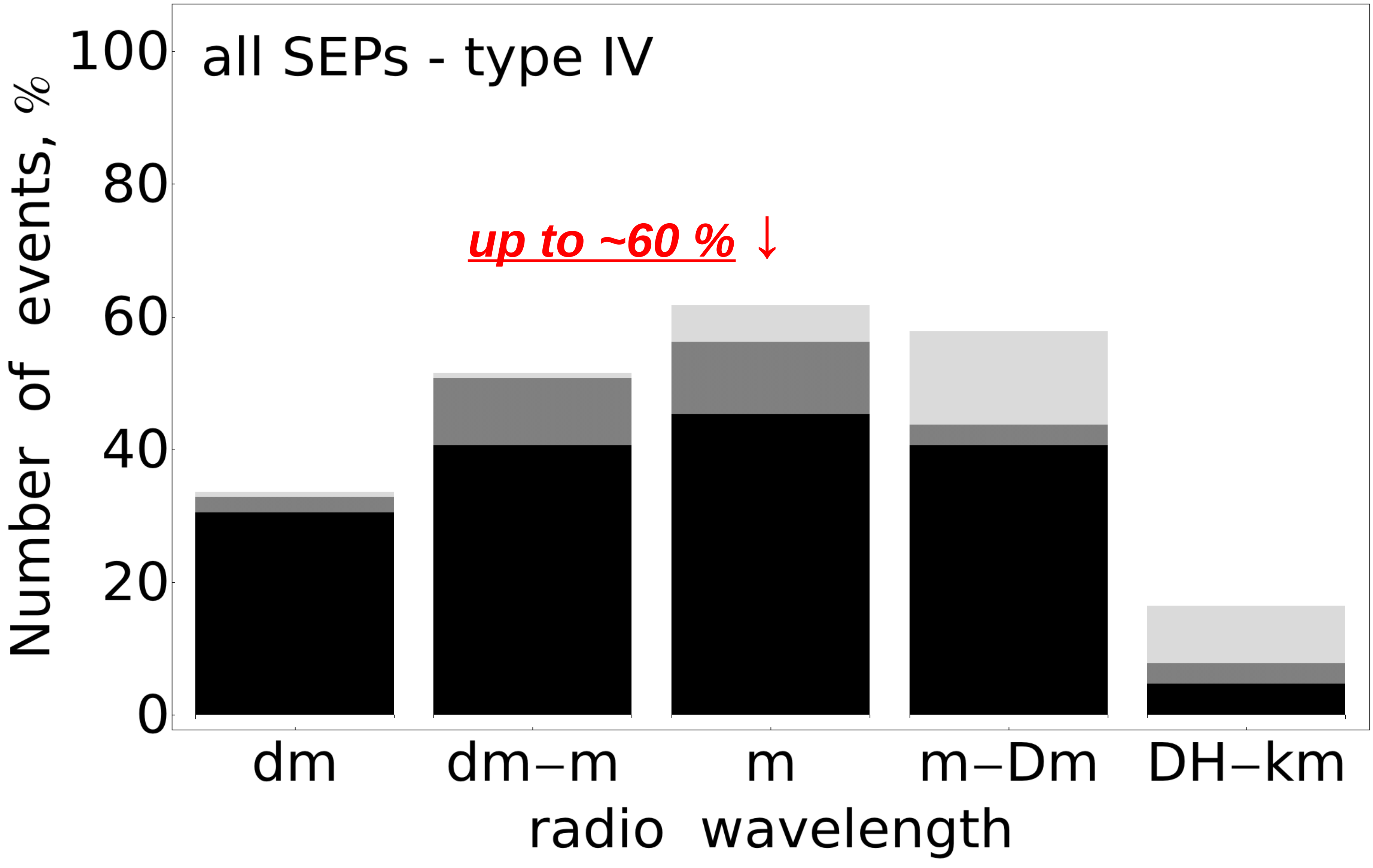
normalized to 128 (all events)

3–1 GHz *1–0.3 GHz* *300–100 MHz* *100–30 MHz* *30–0.01 MHz*

Results: Type III



Results: Type IV



Results: W-to-E longitude

- **No significant difference** (±σ) between radio burst occurrences with origin to the East (27 %) or the West (73 %) (exception: m-Dm type II)

- **Tendencies for stronger flare classes and faster CMEs** for burst occurring in the **East** (exception: type IV)

East: ~M3-X1.5 and ~1100-1300 km/s
West: ~M3-M6   and ~1100-1200 km/s

Results: strong-to-weak protons

- **Tendencies for larger fraction** of radio burst occurrences originating from **strong** (55 %) vs. weak (45 %) **proton events**

- **Tendencies for stronger flare classes and faster CMEs** producing **strong proton sample**

Strong: ~M3-M8 and 1300-1600 km/s
Weak: ~M3 and ≤ 1000 km/s

→Big Flare Syndrome (Kahler 1982) effect?

Future work

1. Solar cycle comparison (first 8 yrs):

SC23 (1997–2004) vs. SC24 (2009–2016)

2. Timing study: delayed radio?

onset of proton events ↔ onset of radio bursts

3. Spectral study: correlation?

proton spectral index ↔ radio spectral index