



# Filament Eruptions Outside of Active Regions as Sources of Large SEP Events



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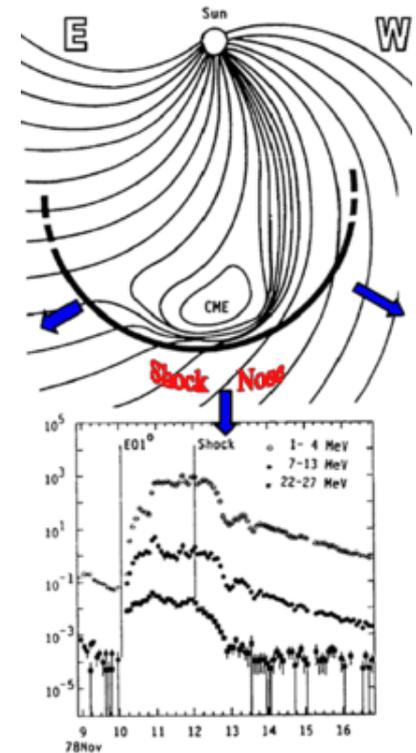
# FILAMENT ERUPTIONS AND LARGE SEP EVENTS



Gradual solar energetic ( $E > 10$  MeV) particle (SEP) events are produced in shocks driven by coronal mass ejections (CMEs).

The CMEs are usually accompanied by large X-ray flares in associated solar active regions (ARs).

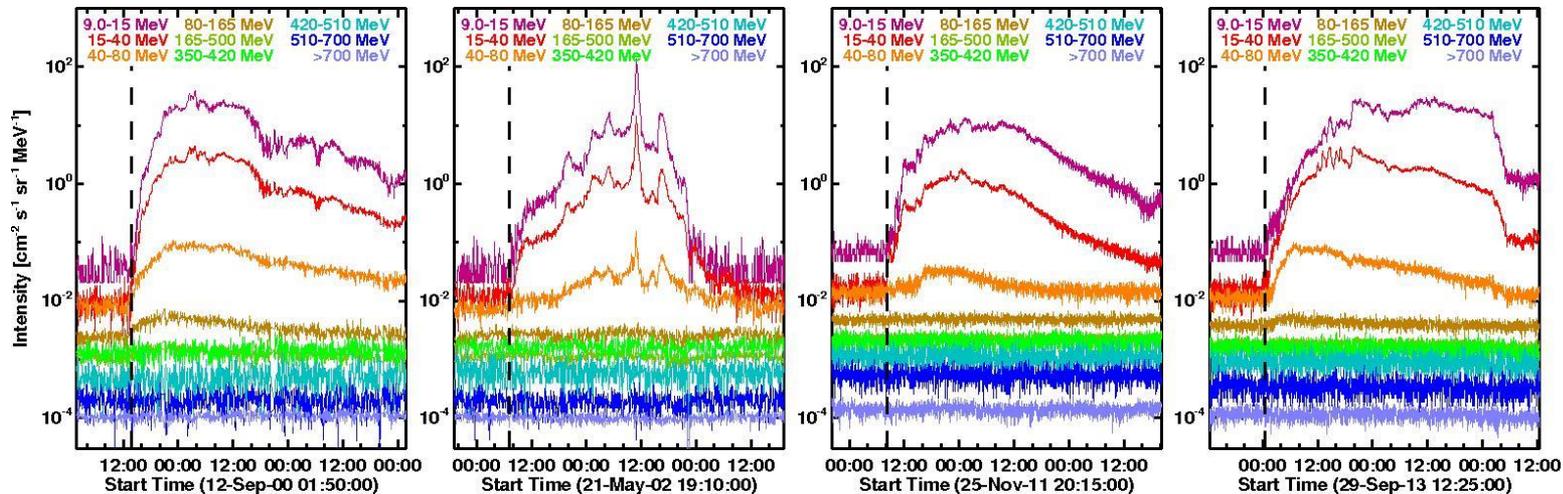
Historically, three cases of SEP events to  $\sim 50$  MeV from filament eruptions (FEs) are known. Faint X-ray signatures from post-eruptive arcades outside any AR defined the solar events.



SEP Dates	Solar Features
1971 December 14	first WL CME, type II, IV bursts
1981 December 5	CME, IP type II burst
1994 April 14	Yohkoh SXT X-ray arcade



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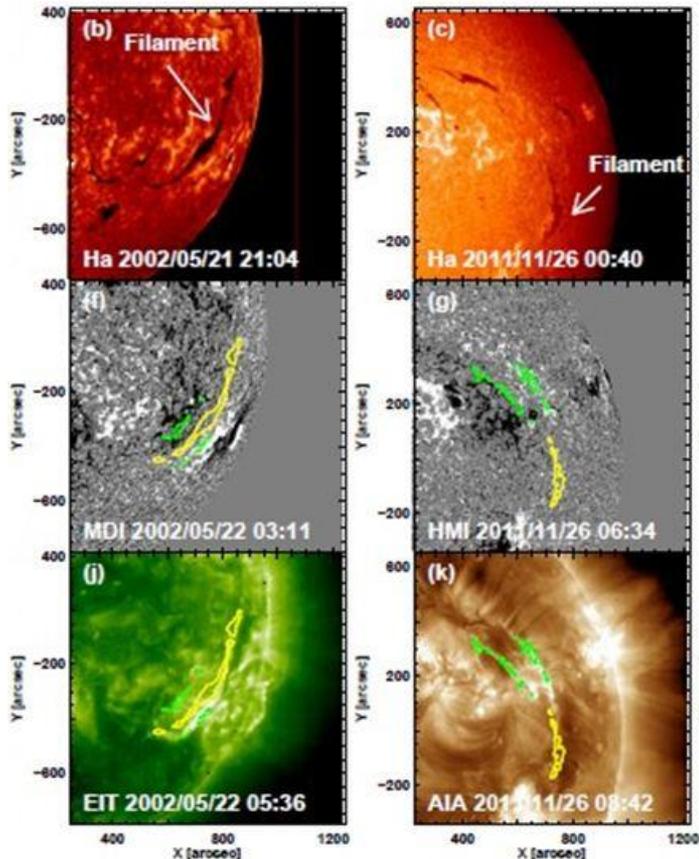


Gopalswamy et al. (2015) have reported four new FE SEP events, all with  $E > 50$  MeV increases. See GOES SEP profiles above.

SEP Date	pfu	Long.	X-ray	CME V
2000 Sept 12	320	W09	M1.0	1550 k/s
2002 May 22	820	W34	C5.0	1494 k/s
2011 Nov 26	80	W49	C1.2	933 k/s
2013 Sep 29	180	W25	C1.1	1025 k/s



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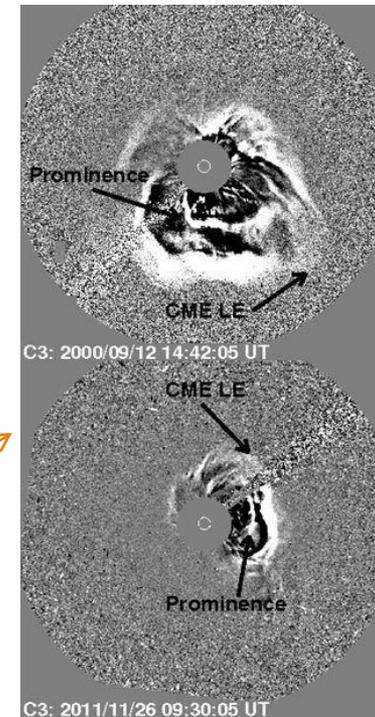
*Top:* pre-event Ha filaments  
*Middle:* filaments on magnetograms  
*Bottom:* EUV post-eruption arcades

Solar source observations:

Filaments (yellow) in large bipolar regions

Extended post-eruption arcades (green)

Prominences trailed CME leading edges.  
 All CMEs were fast ( $\geq 900$  km/s) and wide ( $\geq 60^\circ$ ).  
 DH type II bursts in all four SEP events.



LASCO images of CMEs and eruptive prominences for two SEP events.



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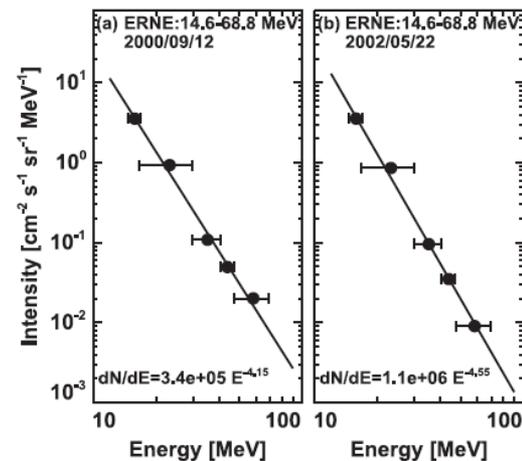


Subsequent searches yielded another 5 candidate FE events listed here.

General event properties:

- Usually magnetically well-connected (W10 – W80)
- Weak metric but strong DH type II bursts and IP shocks observed
- Low CME accelerations
- No polar-crown FE SEP events
- Steep ( $\gamma > 4.0$ ) SEP spectral indices in 15 - 70 MeV range

SEP Date	pfu	Long.	X-ray	CME V
2000 Apr 4	55	W55	C9.7	1188 km/s
2001 Aug 9	17	W14	C3.7	479 km/s
2004 Apr 11	35	W49	C9.6	1645 km/s
2012 Sep 1	59	E42	C8.4	1167 km/s
2014 Nov 1	11	W79	??	740 km/s





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## SUMMARY

SEP events associated with FEs outside of ARs are a small but well-defined class of events.

Difficult to forecast SEPs from weak ( $\leq M1$ ) X-ray emission.

Lower CME accelerations, higher coronal shock formation ( $> 2-3 R_s$ ).

Steep ( $\gamma > 4.0$ ) SEP energy spectra.

Shock-accelerated from fast and wide CMEs.



**ICRC**

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