Classification of Beam-Like Near-Relativistic Solar Electron Events: Implications for Acceleration and Injection

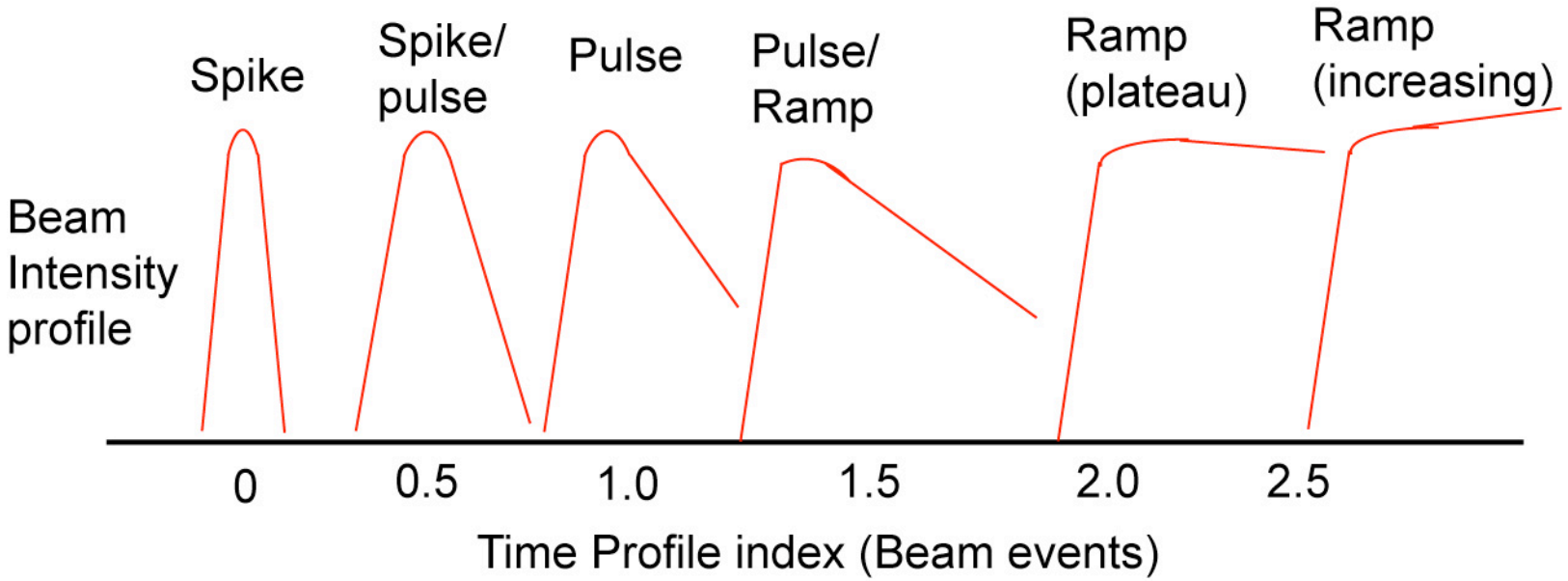
Edmond C. Roelof and Dennis K. Haggerty

Johns Hopkins University/Applied Physics Laboratory
Laurel, MD 20723-6099

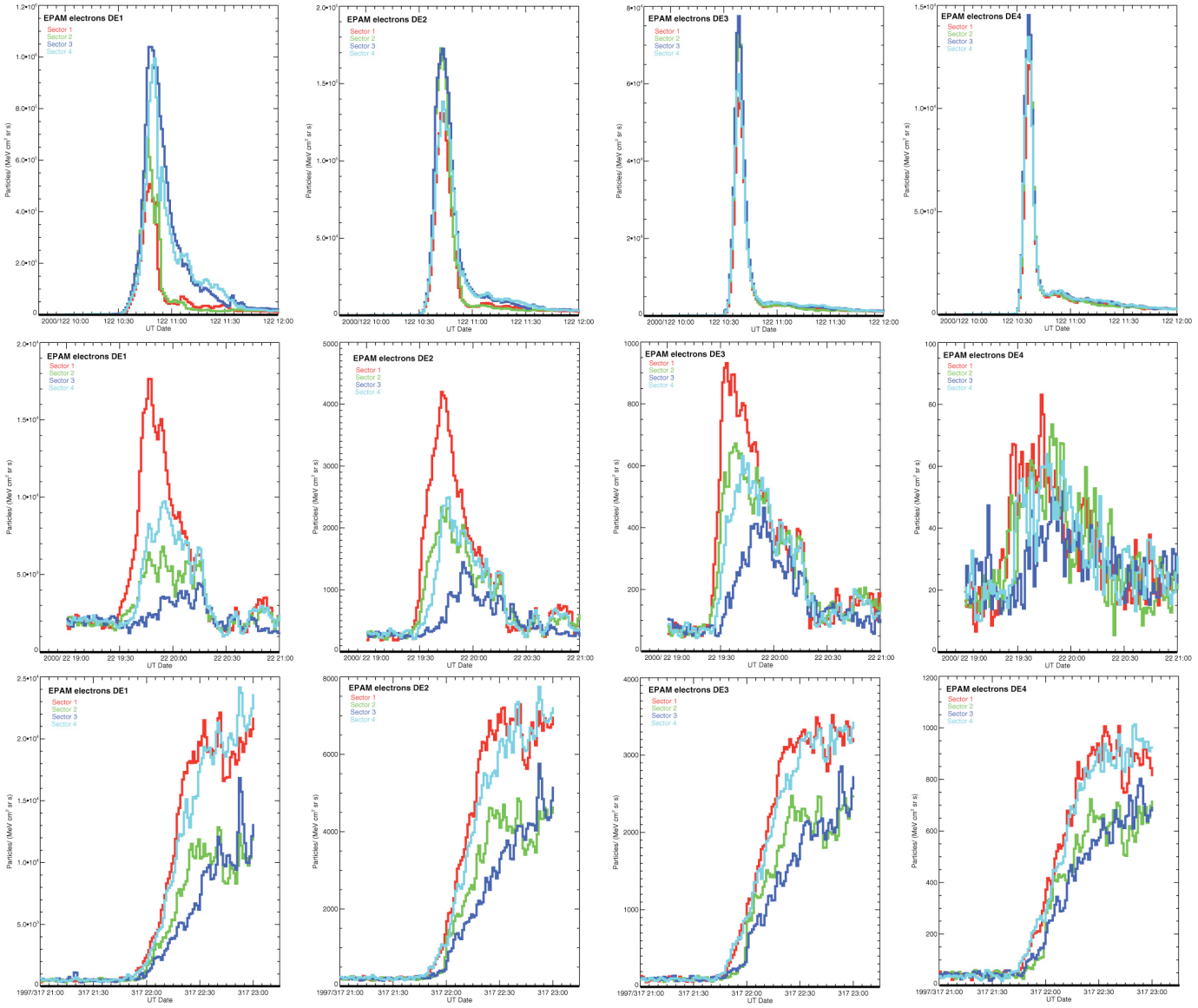
Solar Sources of "Impulsive" SEPs
Berkeley, CA (3 November 2006)

Thanks, Hugh et al.!!!

Numerical Index for Time Profiles of Beam-Like Near-Relativistic Solar Electron Events



Intensity time profile at zero-degree pitch angle within beam ***while anisotropy is still significant*** (solar injection is dominating backscatter from r>1AU)



Spikes: 0.0<index<0.5

Spike type events have symmetrical Gaussian profiles with FWHM < 10 minutes. At 1 AU these events have strong anisotropy throughout their peaks and display a very clear velocity dispersion that implies energy independent injection at the Sun

Pulses: 0.6<index<1.5

Pulse type events have fast rises and slower decays with FWHM ~ 30 minutes. These events are also anisotropic and show velocity dispersion at the maximum similar to the spike events.

Ramps: 1.6<index<2.8

Ramp type events have gradual rises to plateaus lasting < 1 hour. These ramp type events are still very anisotropic and show velocity dispersion.

"Pure" time history indices: 0.0=spike; 1.0=pulse; 2.0=ramp

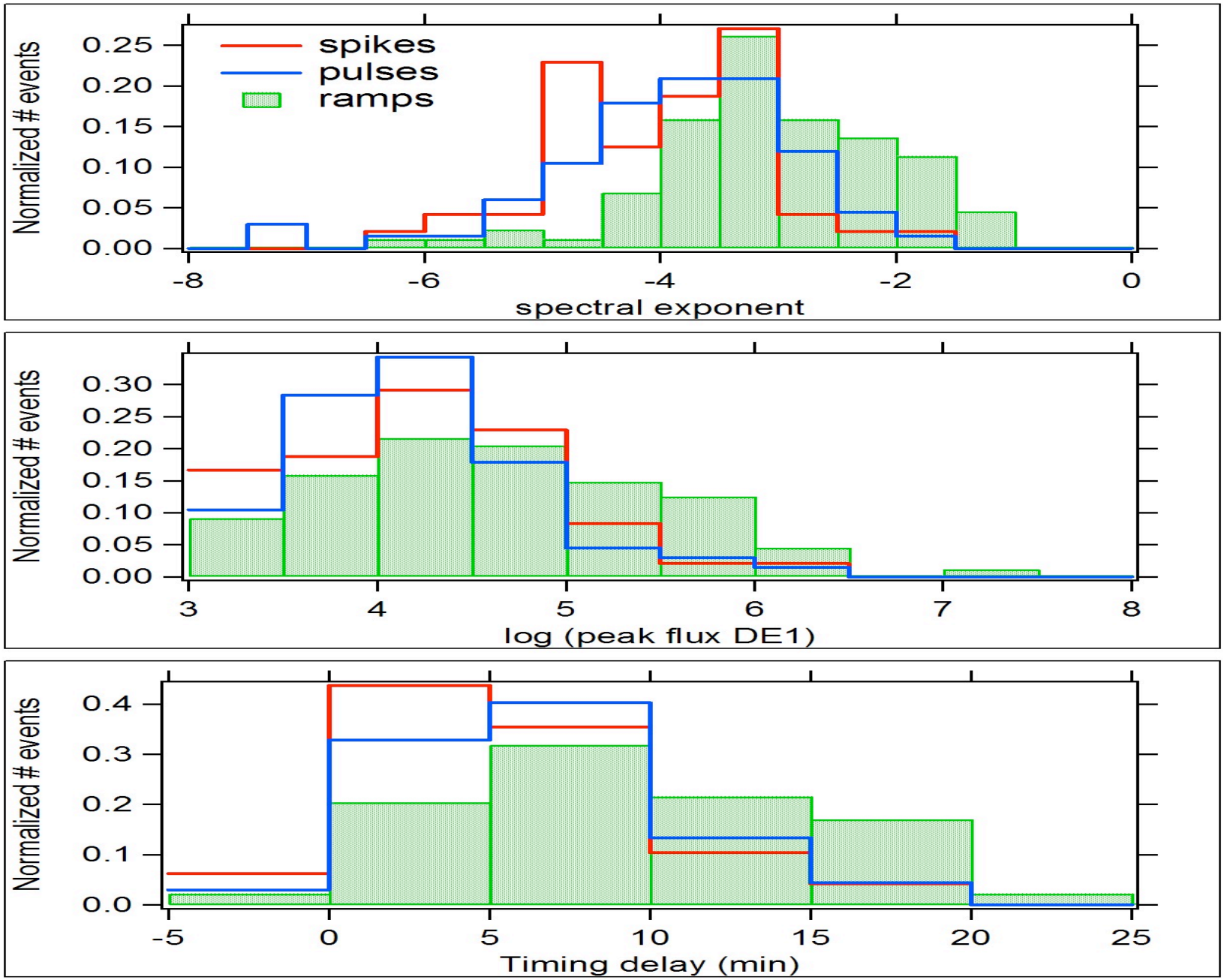
Near-relativistic beam event classification orders:

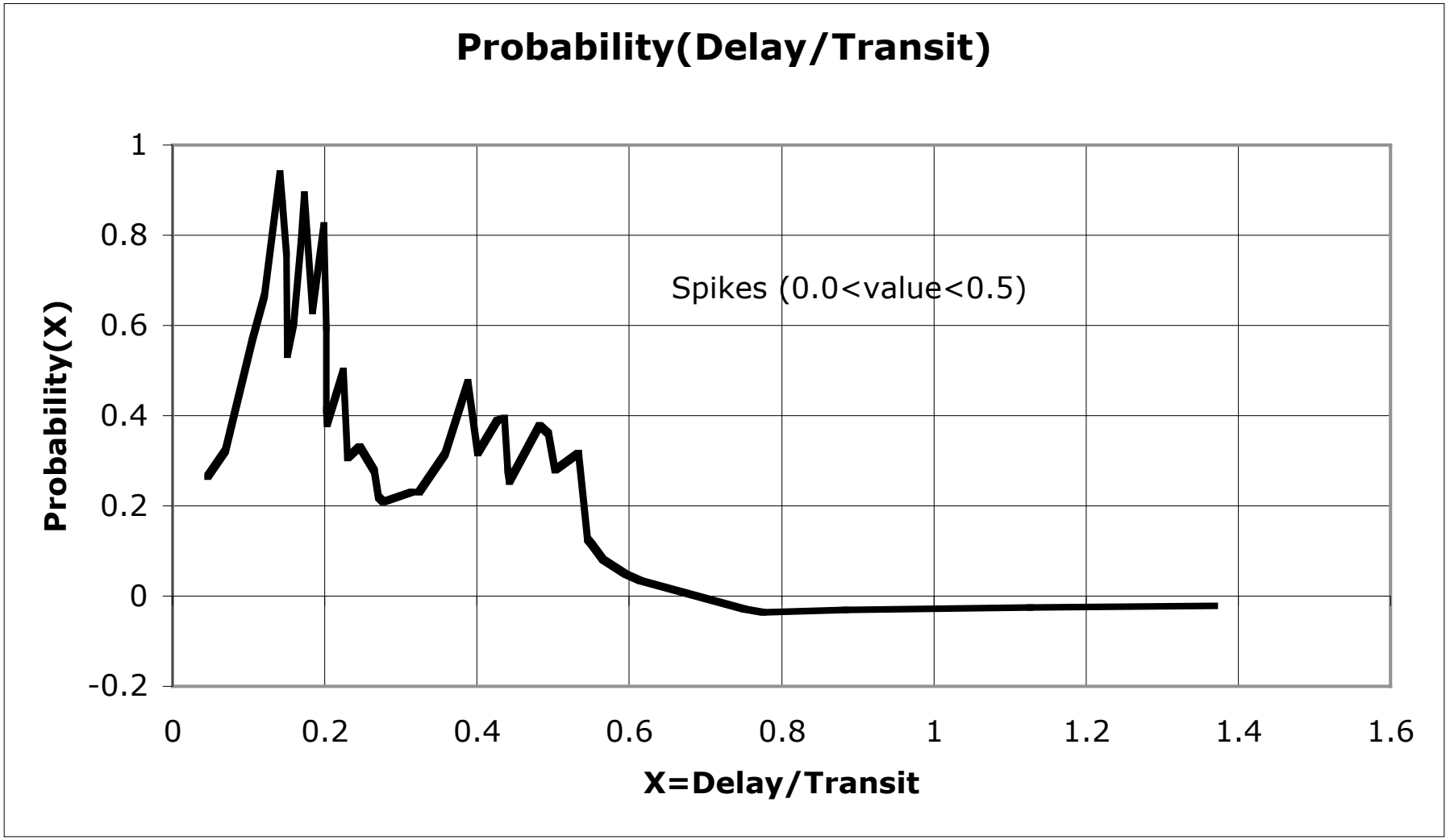
Energy *spectral* index

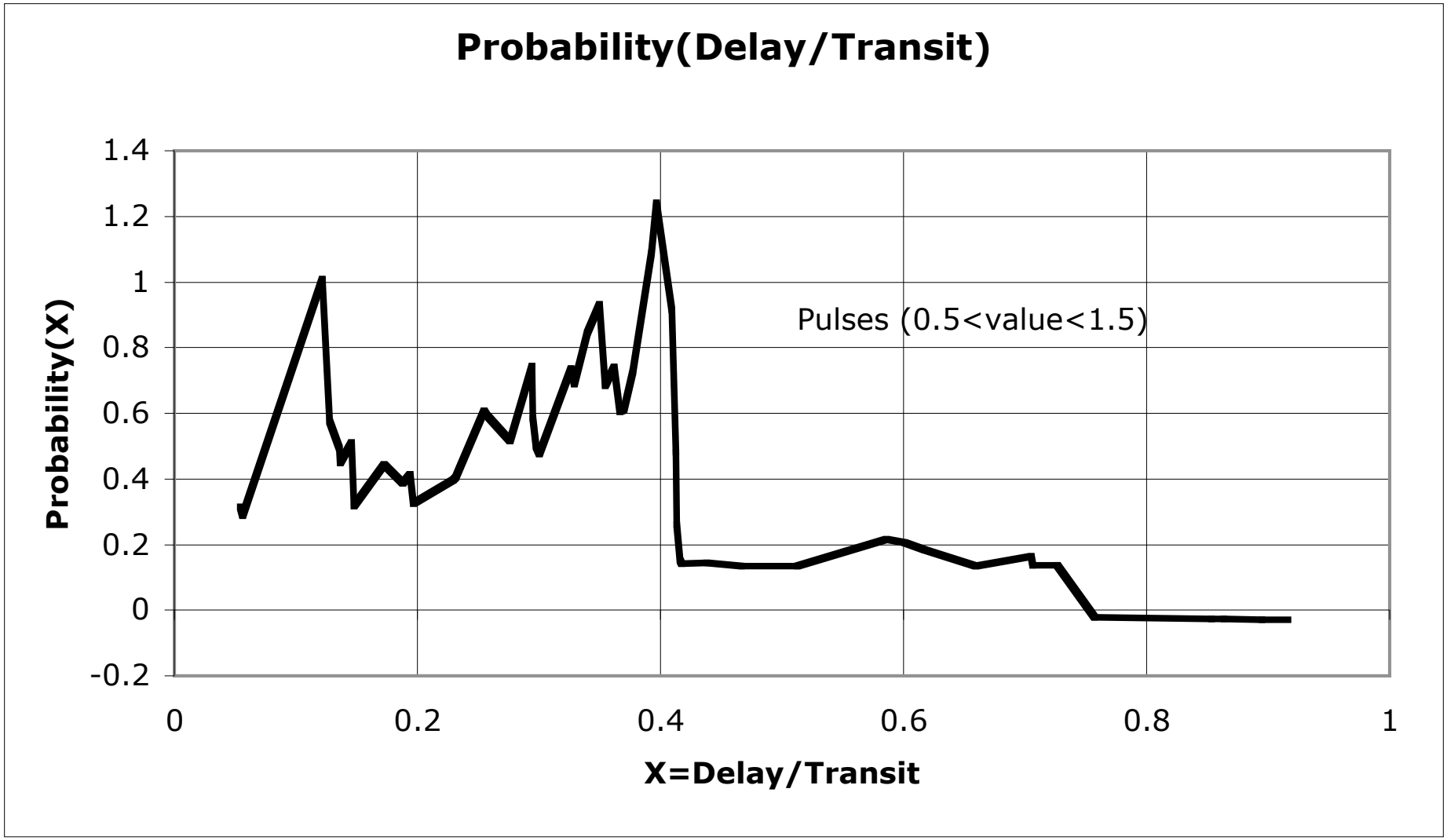
Maximum event *intensity*

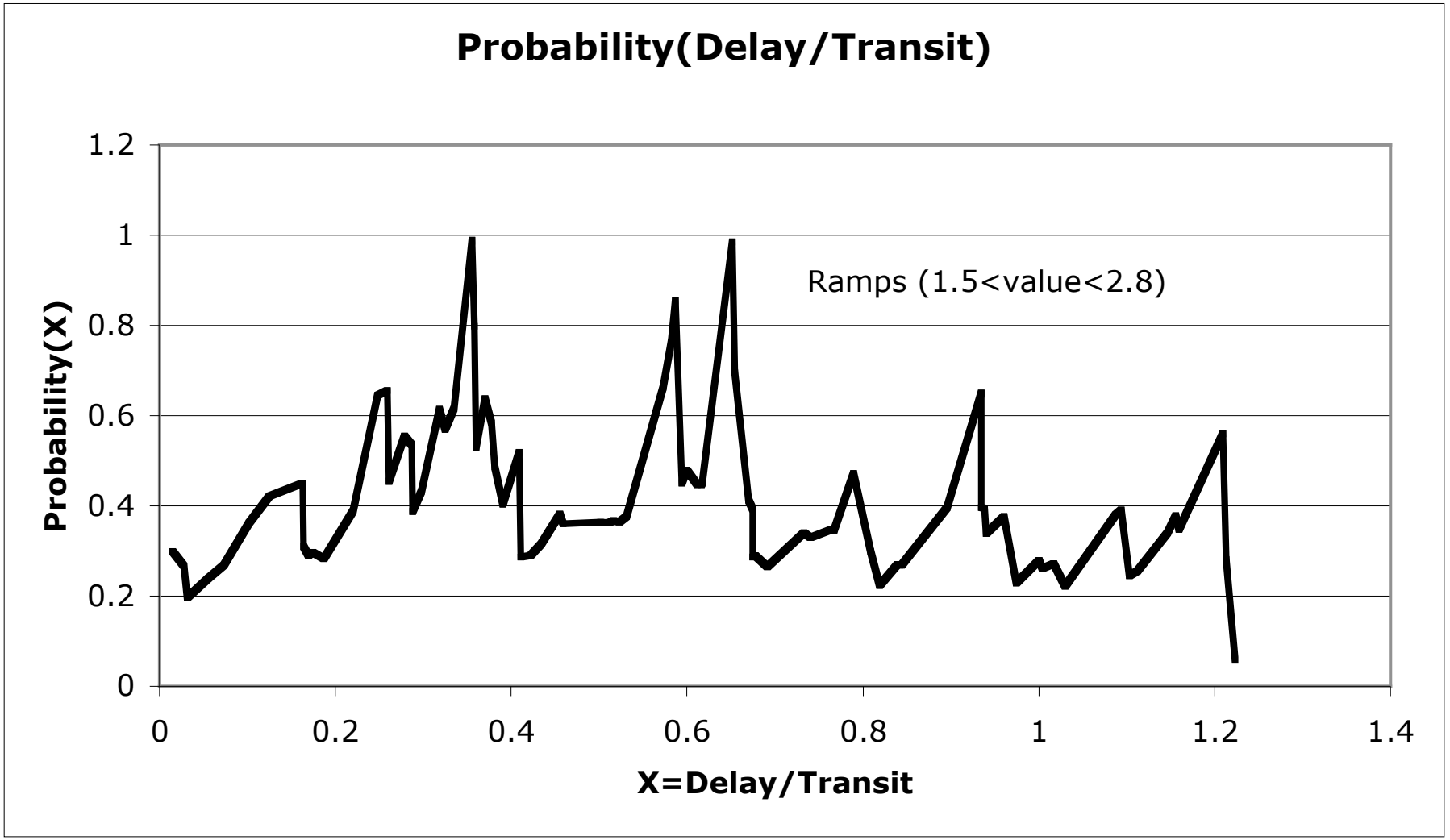
Injection time delays with respect to solar electro-magnetic emissions (14MHz typeIII, H-alpha, microwave burst, *etc.*)

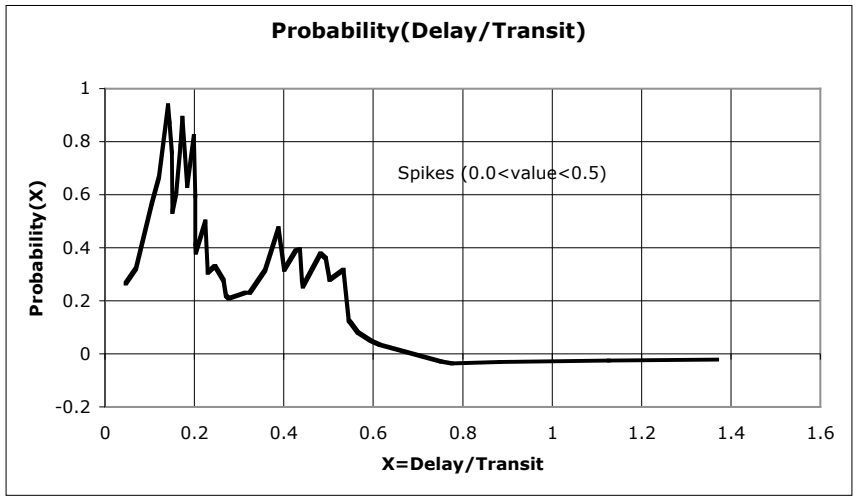
Preliminary: High coronal *injection longitude* w/r associated active region (PFSS model)

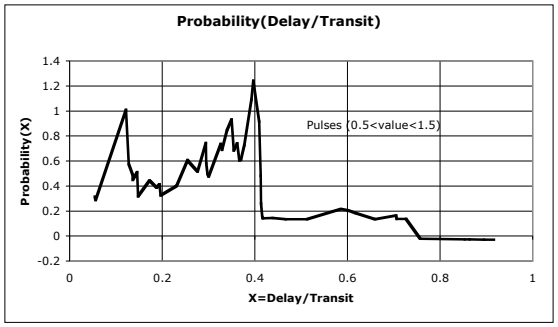

spikes
pulses
ramps
Normalized # events
0.25
0.20
0.15
0.10
0.05
0.00
-8
-6
-4
-2
0
spectral exponent
Normalized # events
0.30
0.25
0.20
0.15
0.10
0.05
0.00
3
4
5
6
7
8
log (peak flux DE1)
Normalized # events
0.4
0.3
0.2
0.1
0.0
-5
0
5
10
15
20
25
Timing delay (min)

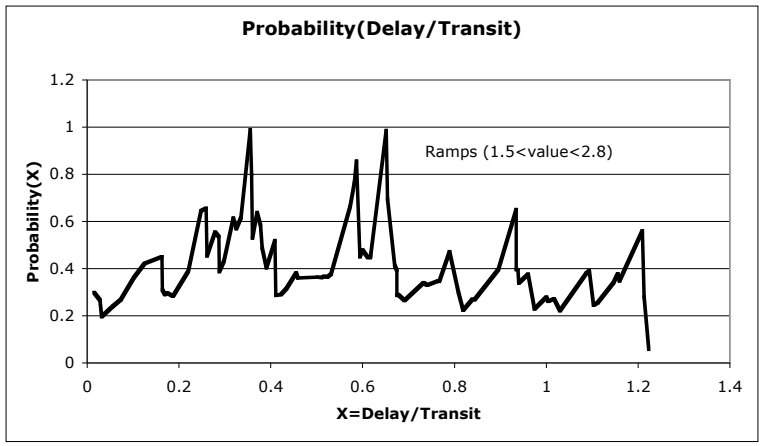

Probability(Delay/Transit)
Probability(X)
1
0.8
0.6
0.4
0.2
0
-0.2
Spikes (0.0<value<0.5)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
X=Delay/Transit


Probability(Delay/Transit)
Probability(X)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
0.2
0.4
0.6
0.8
1
X=Delay/Transit
Pulses (0.5<value<1.5)


Probability(Delay/Transit)
Probability(X)
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
X=Delay/Transit
Ramps (1.5<value<2.8)







Spikes

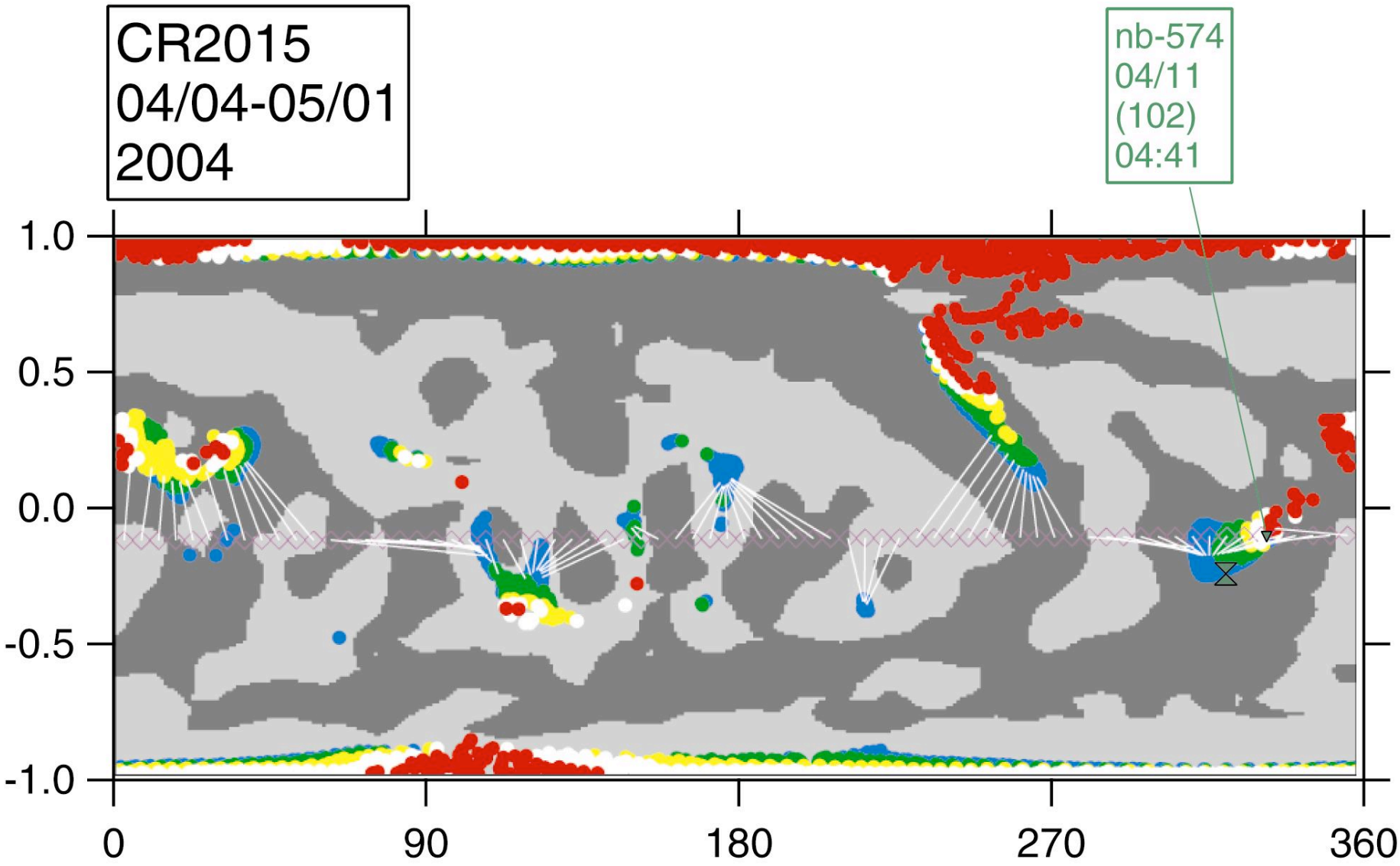
"Pure" spikes cannot have propagation delay (because symmetric time profile)
Near-zero delays expected

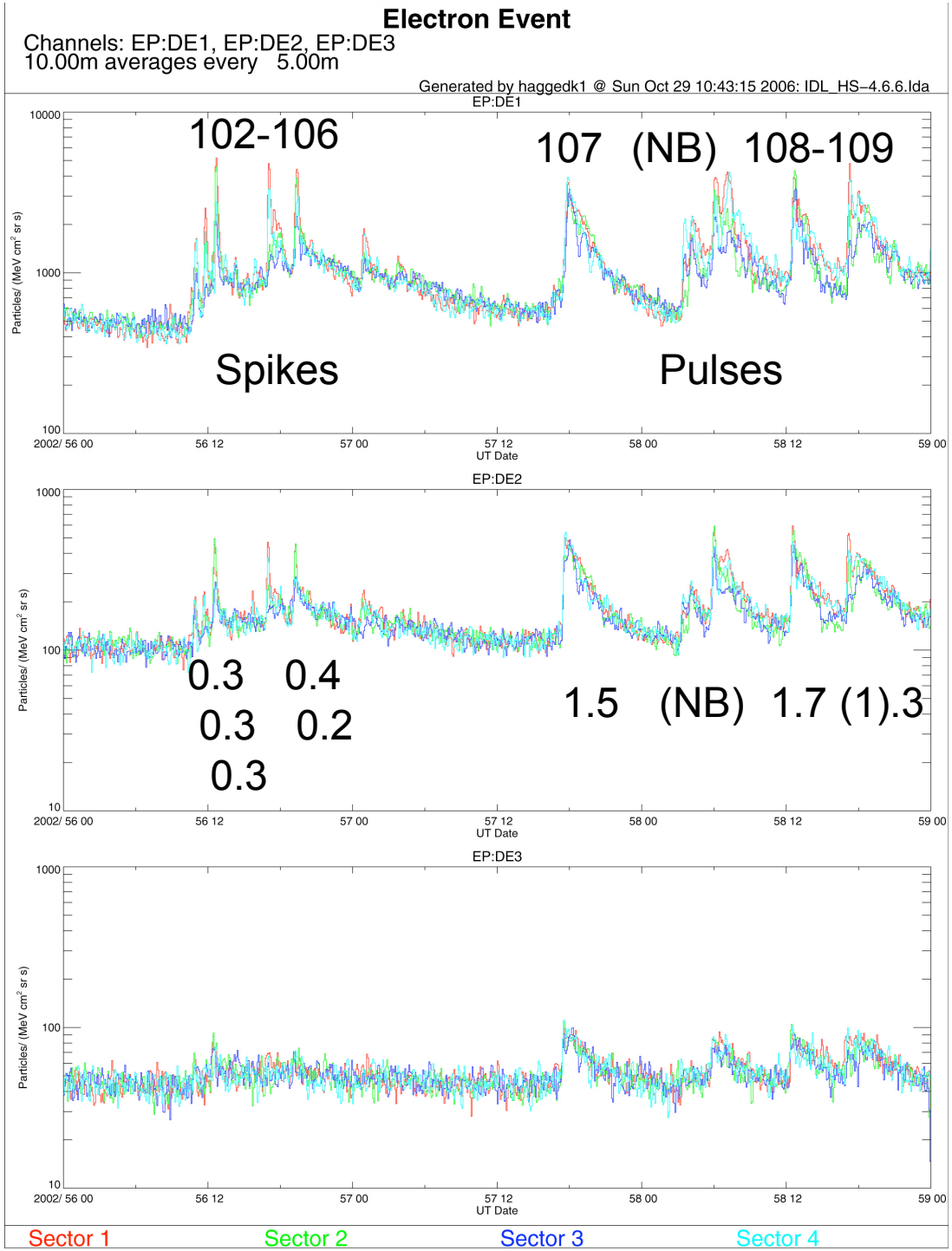
Pulses

Fast rise; slower decay
Delays<0.4 Transit Time (<5 min for 250 keV)
Consistent with small delays

Ramps

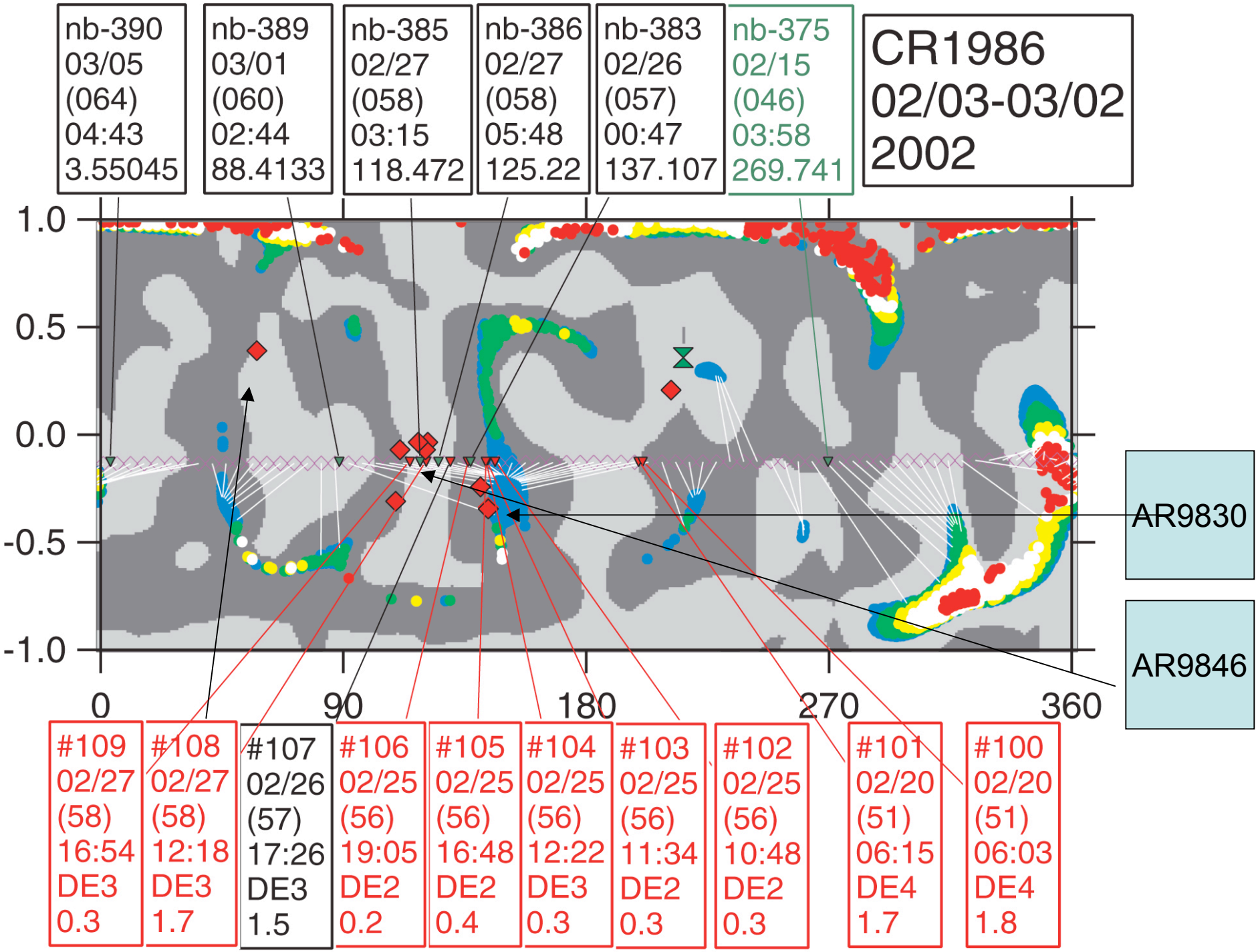
Delays to 1.2xTransit Time (up to 15 min for 250 keV)
Broad range of delays must be coronal (not interplanetary)

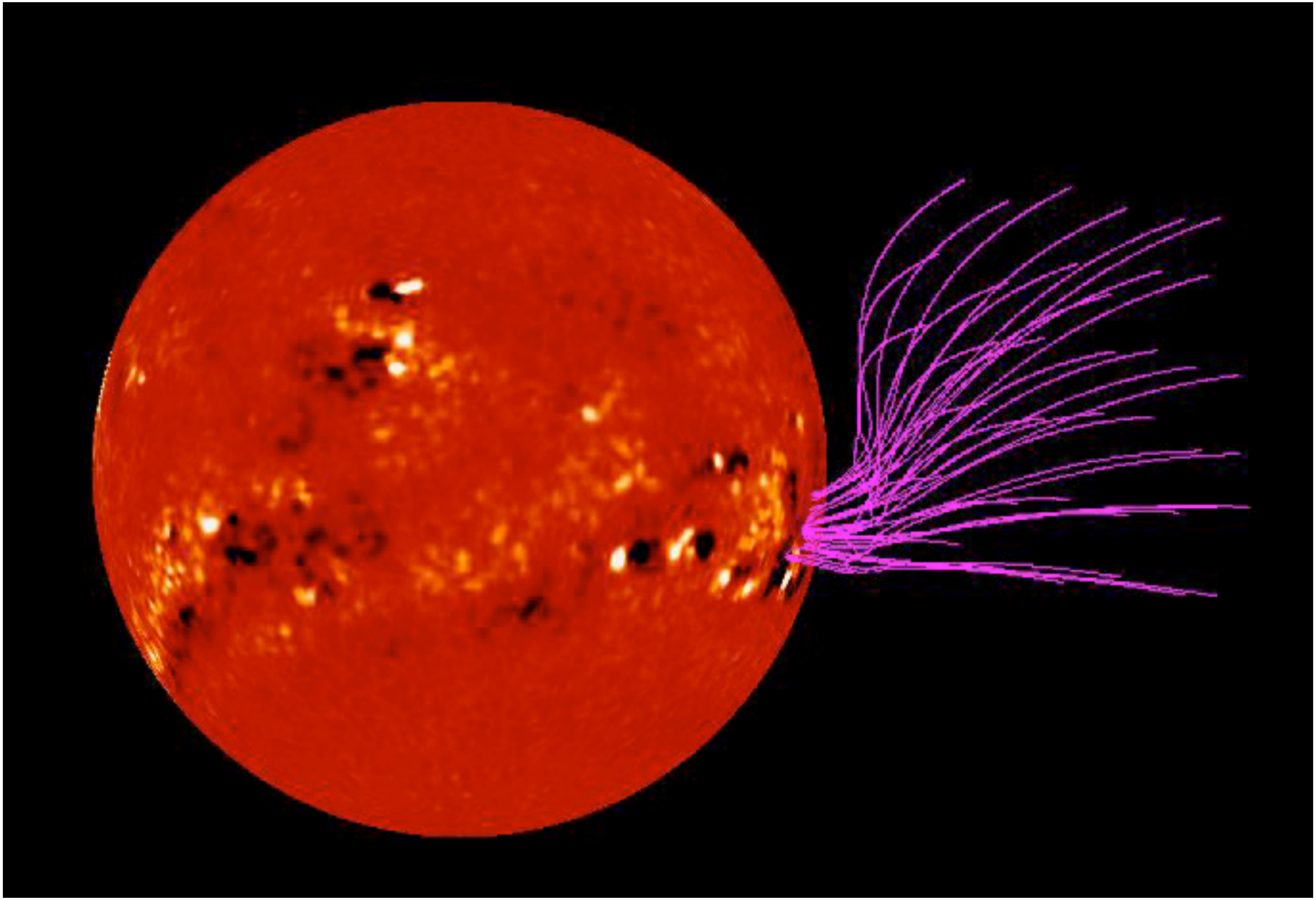

CR2015
04/04-05/01
2004
nb-574
04/11
(102)
04:41
1.0
0.5
0.0
-0.5
-1.0
0
90
180
270
360



Sequence of EPAM electron events
25-27 February 2002

5 Spikes followed by 3 Pulses (and one Non-beam)


nb-390
03/05
(064)
04:43
3.55045
nb-389
03/01
(060)
02:44
88.4133
nb-385
02/27
(058)
03:15
118.472
nb-386
02/27
(058)
05:48
125.22
nb-383
02/26
(057)
00:47
137.107
nb-375
02/15
(046)
03:58
269.741
CR1986
02/03-03/02
2002
1.0
0.5
0.0
-0.5
-1.0
0
90
180
270
360
AR9830
AR9846
#109
02/27
(58)
16:54
DE3
0.3
#108
02/27
(58)
12:18
DE3
1.7
#107
02/26
(57)
17:26
DE3
1.5
#106
02/25
(56)
19:05
DE2
0.2
#105
02/25
(56)
16:48
DE2
0.4
#104
02/25
(56)
12:22
DE3
0.3
#103
02/25
(56)
11:34
DE2
0.3
#102
02/25
(56)
10:48
DE2
0.3
#101
02/20
(51)
06:15
DE4
1.7
#100
02/20
(51)
06:03
DE4
1.8



SolarSoft PFSS 2002/02/25 12:22UT Onset of EPAM beam #104 (spike)

Near-relativistic beam event classification orders:

Energy *spectral* index

Maximum event *intensity*

Injection time delays with respect to solar electro-magnetic emissions (14MHz typeIII, H-alpha, microwave burst, *etc.*)

Preliminary: High coronal *injection longitude* w/r associated active region (PFSS model)