Injection Timing of Solar Impulsive Electrons

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Outline

Two events: **1998 August 29**

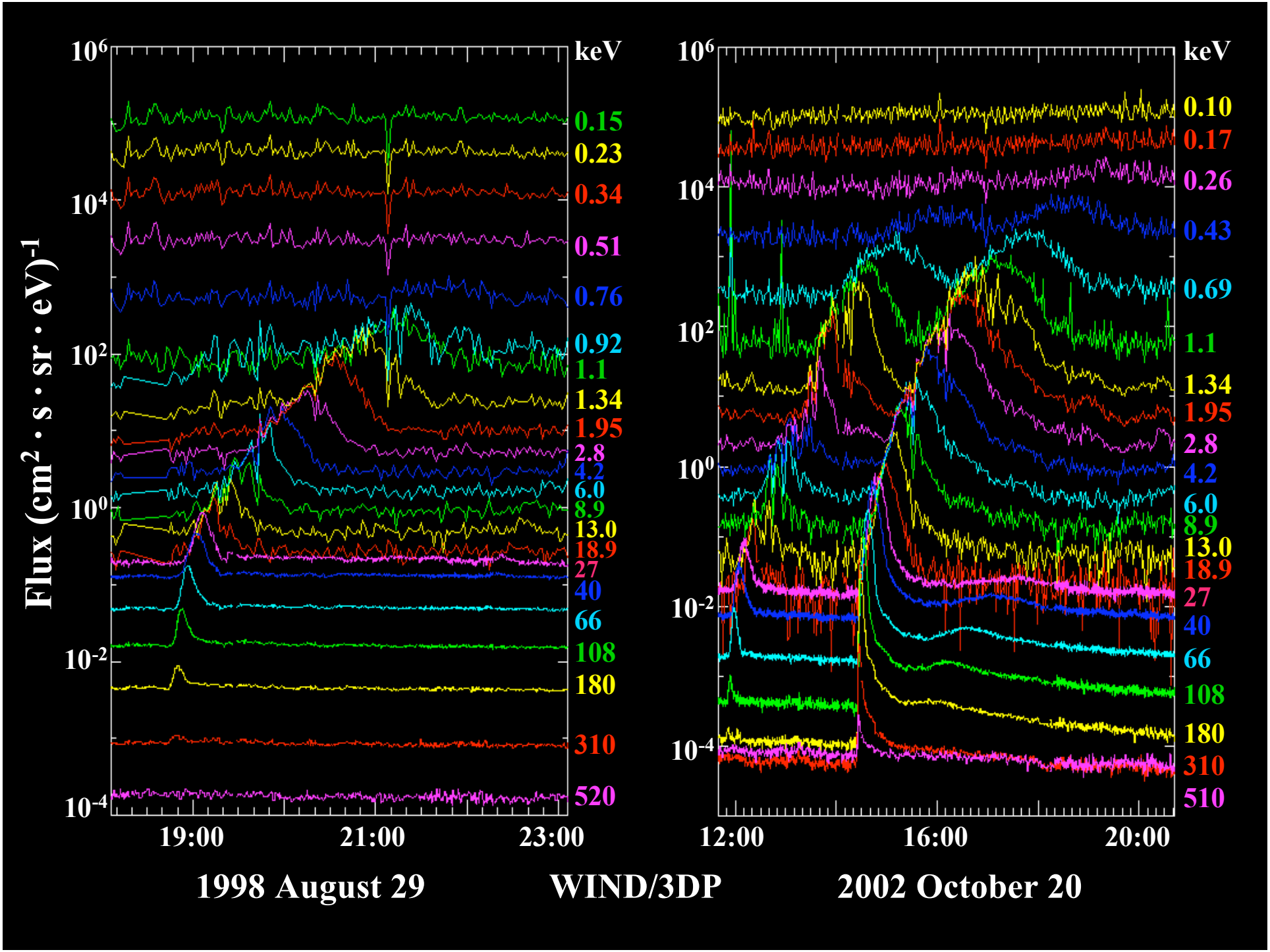
2002 October 20

1 Injection profiles of solar impulsive electrons at the Sun

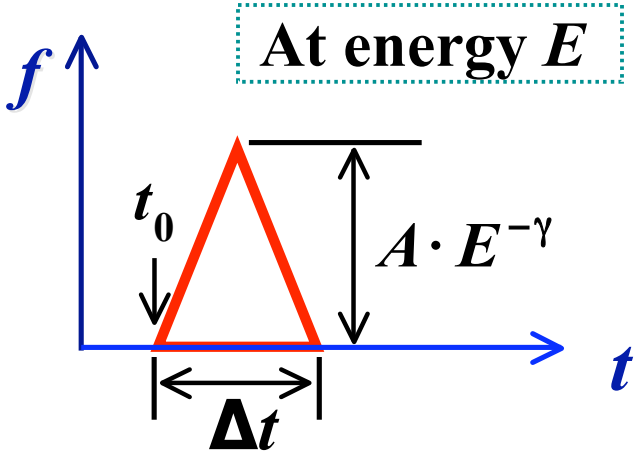
(Triangular injection profiles; scatter-free)

2 Propagation effects in the interplanetary medium

(pitch angle distributions (PAD) at 1 AU)


keV
0.15
0.23
0.34
0.51
0.76
0.92
1.1
1.34
1.95
2.8
4.2
6.0
8.9
13.0
18.9
27
40
66
108
180
310
520
Flux (cm² · s · sr · eV)⁻¹
10⁶
10⁴
10²
10⁰
10⁻²
10⁻⁴
19:00
21:00
23:00
1998 August 29
WIND/3DP
2002 October 20
12:00
16:00
20:00
0.10
0.17
0.26
0.43
0.69
1.1
1.34
1.95
2.8
4.2
6.0
8.9
13.0
18.9
27
40
66
108
180
310
510

1. Injection Profiles



- Triangular fitting:

*** Injection profiles are triangular functions of time**

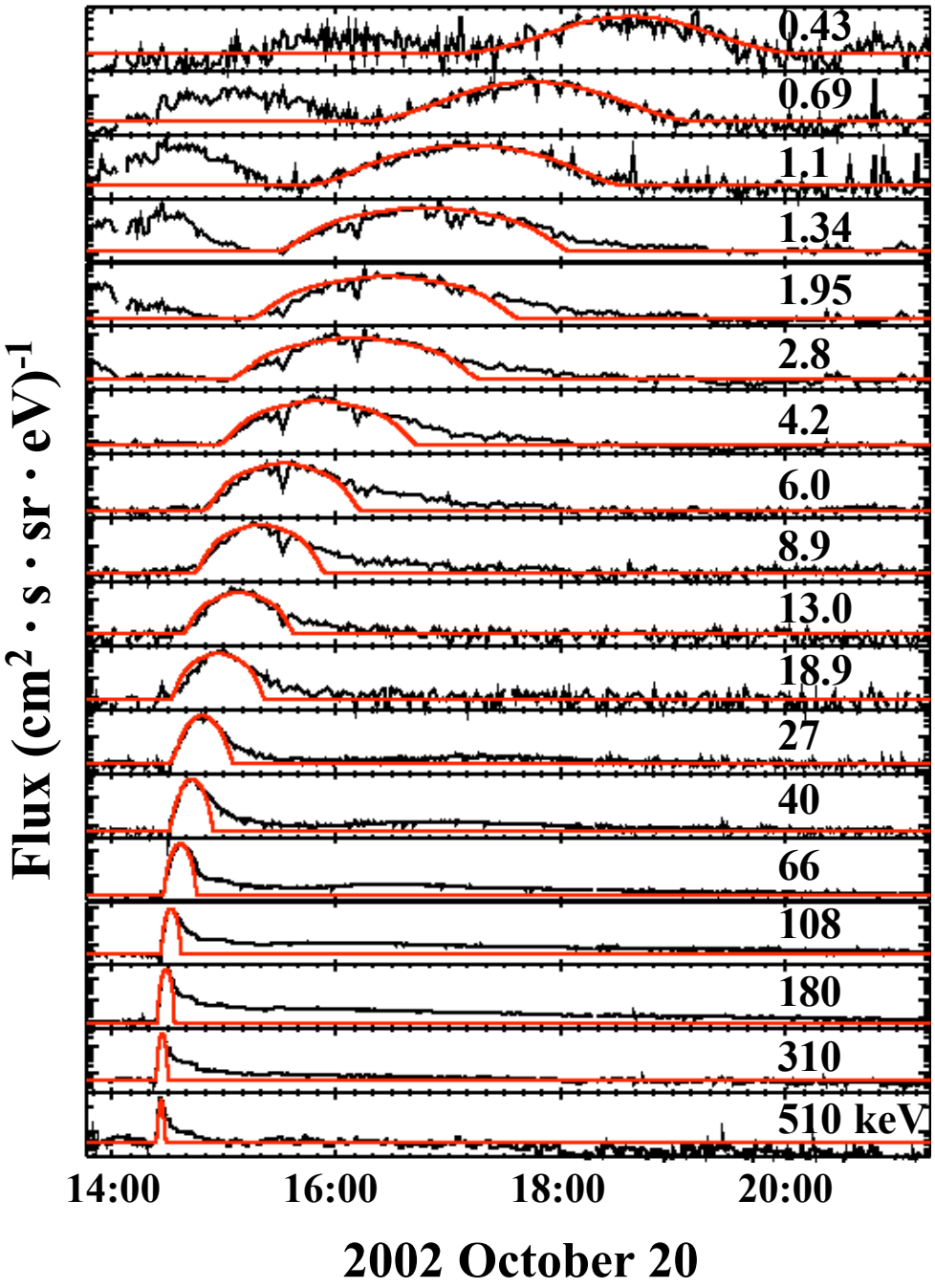
*** Scatter-free propagation**

*** Correct for the bandwidth of each energy bin**

*** Fit the profiles at 1 AU to the observations**

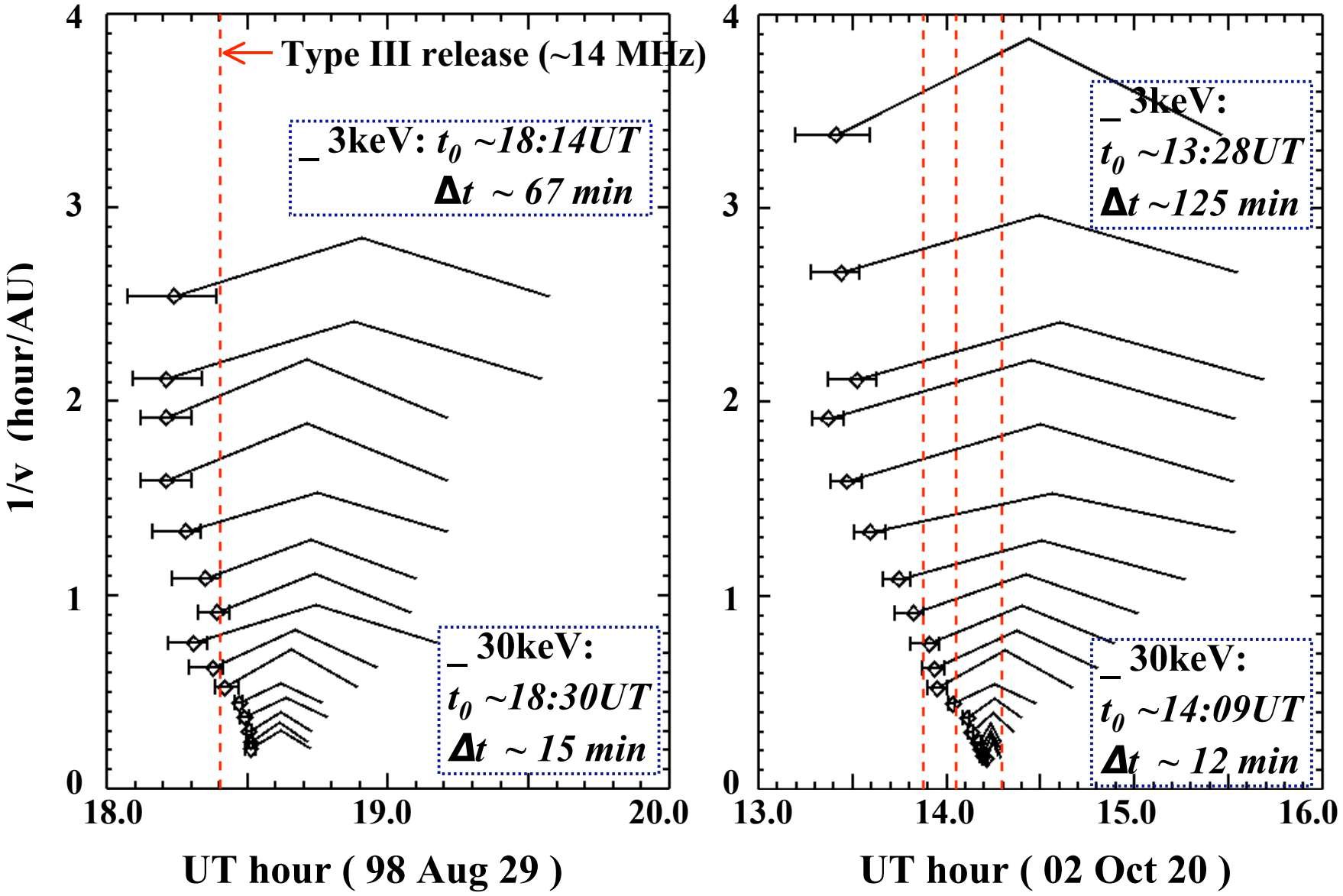
*** Adjust t_{0j} , Δt_j and A_j of injection profiles until get best fits to the rise of in situ time-intensity profiles**

_Observations (black) and fits (red)



Best fits to the rise of observed time profiles

_ Triangular injection profiles at the Sun



_ Injection study Results

1. The 1998 August 29 event:

below ~3 keV : the duration ~ 60 – 80 min

above ~30 keV: the start delayed by 16 ± 7 min

the duration ~ 12 – 18 min (shorter)

2. The 2002 October 20 event:

below ~3 keV : the duration ~ 130 min

above ~30 keV: the start delayed by 41 ± 8 min

the duration ~ 5 – 25 min (shorter)

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Scatter–free ???

2. Propagation Effects

* **Magnetic focusing (adiabatic):**

  magnetic moment $mv_{\perp}^2 / 2B$ **invariant ;**

  B(r) ~ r^{-2}

  ⇨ **reduce the pitch angle**

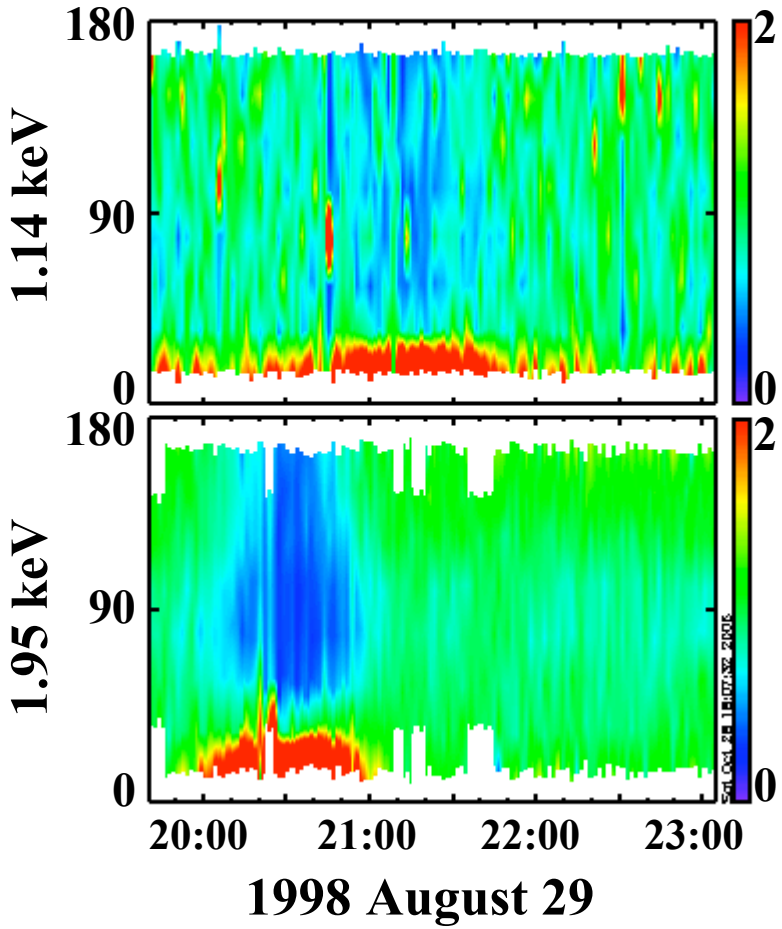
* **Pitch angle scattering:**

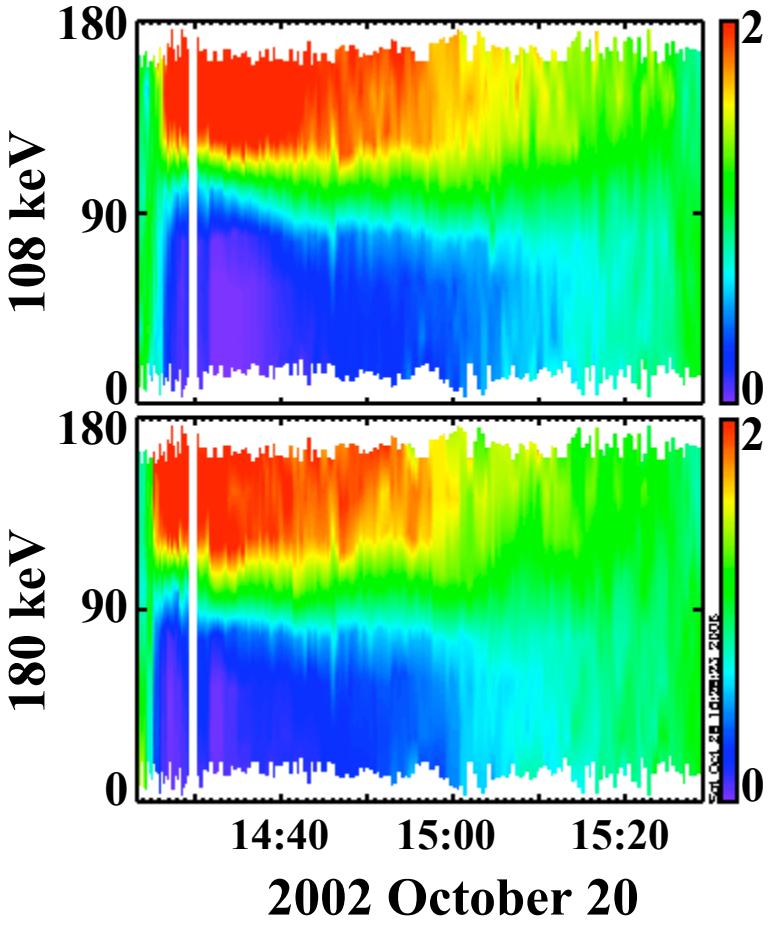
  interact with turbulence in the solar wind,

  scattering in pitch angle

  ⇨ **increase the pitch angle**

Pitch angle distributions at 1 AU

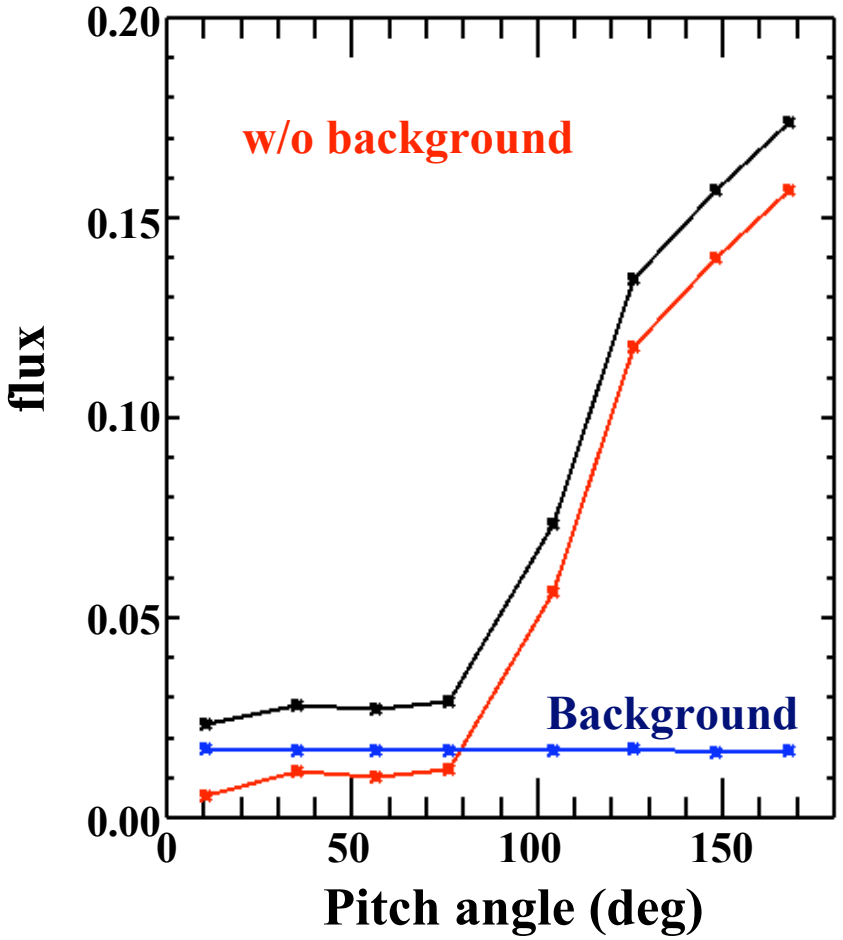


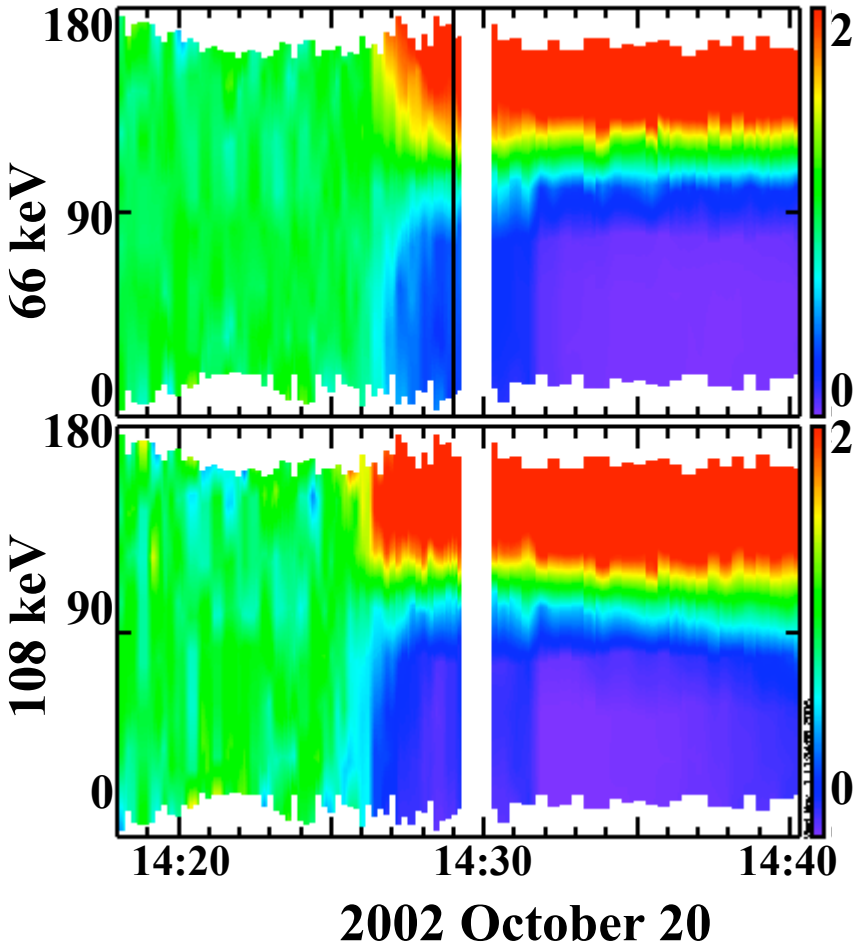


* WIND/3DP : 8 pitch angle bins, resolution of 22.5°

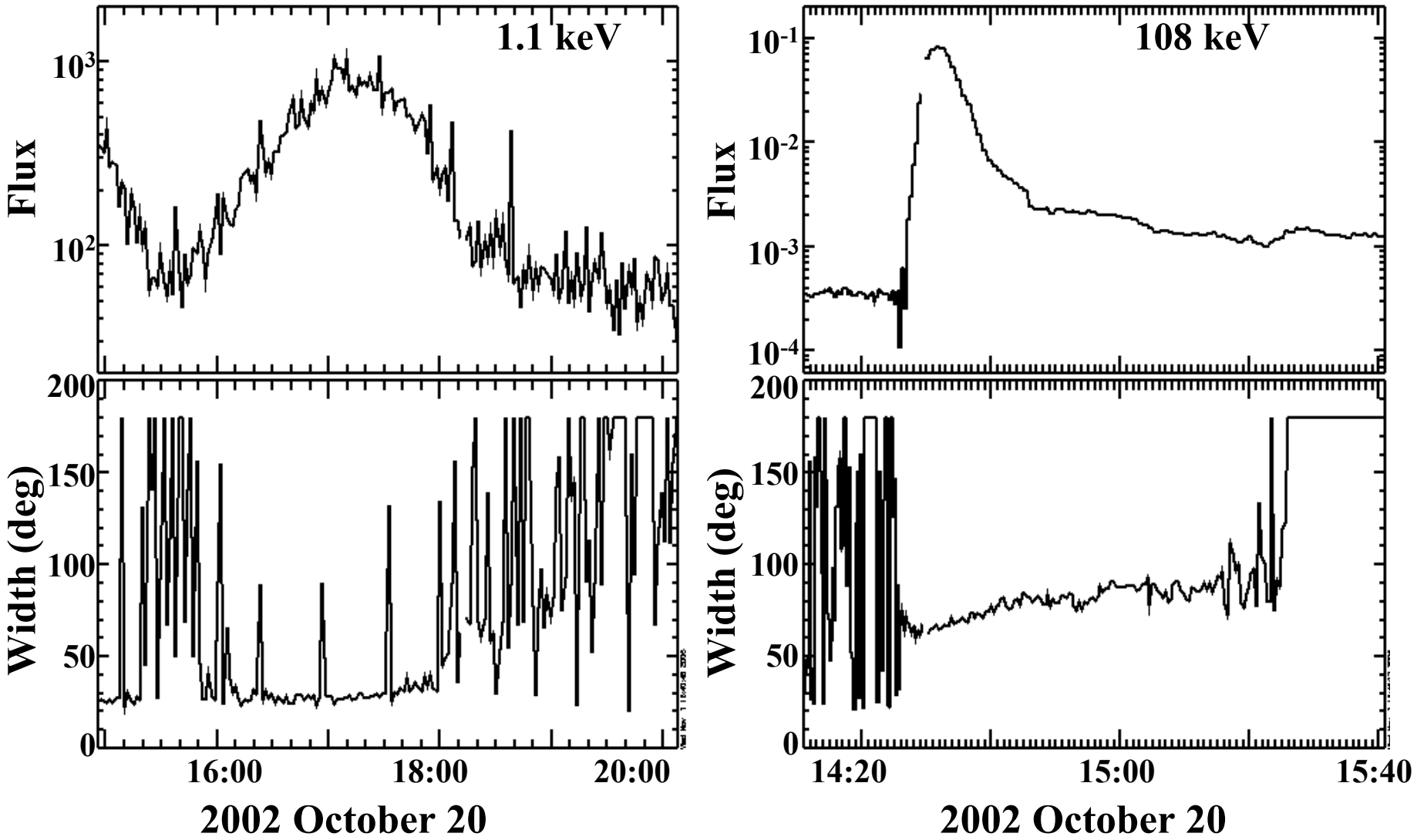
* **Remove the pre-event background;**

calculate the PAD width at half maximum

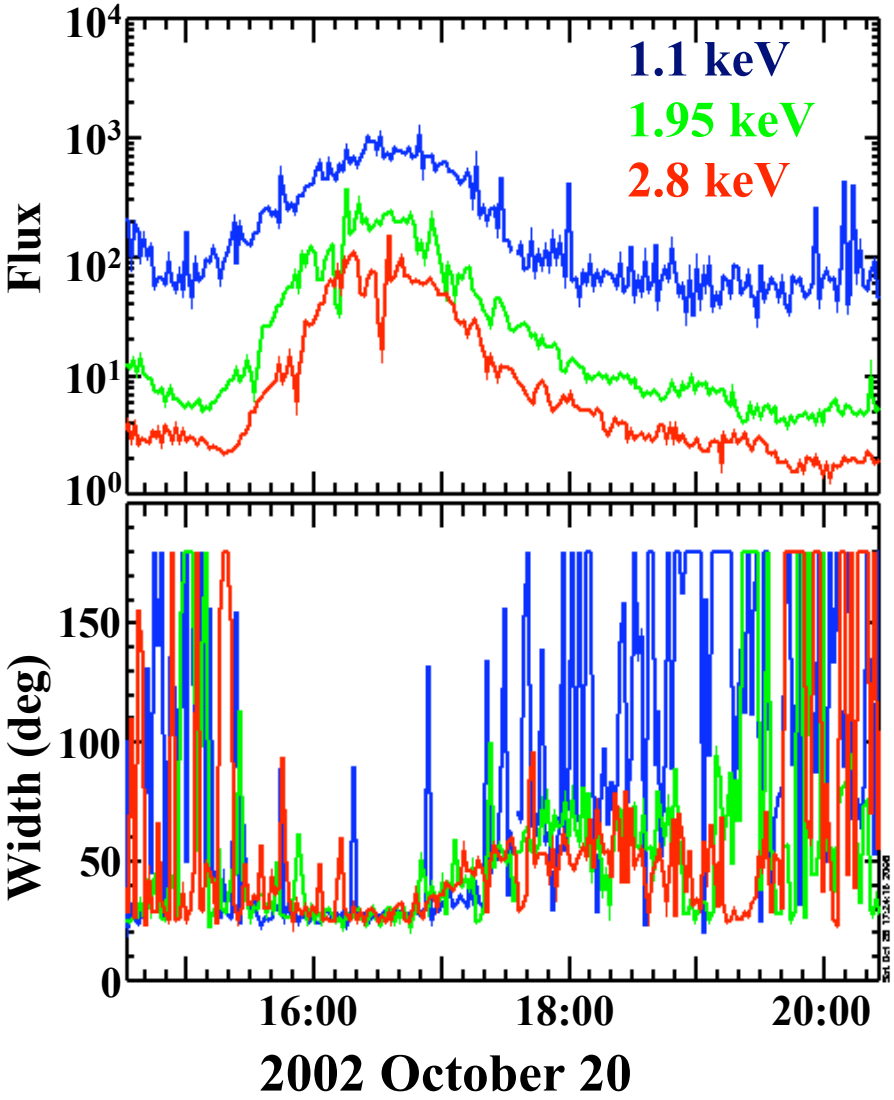


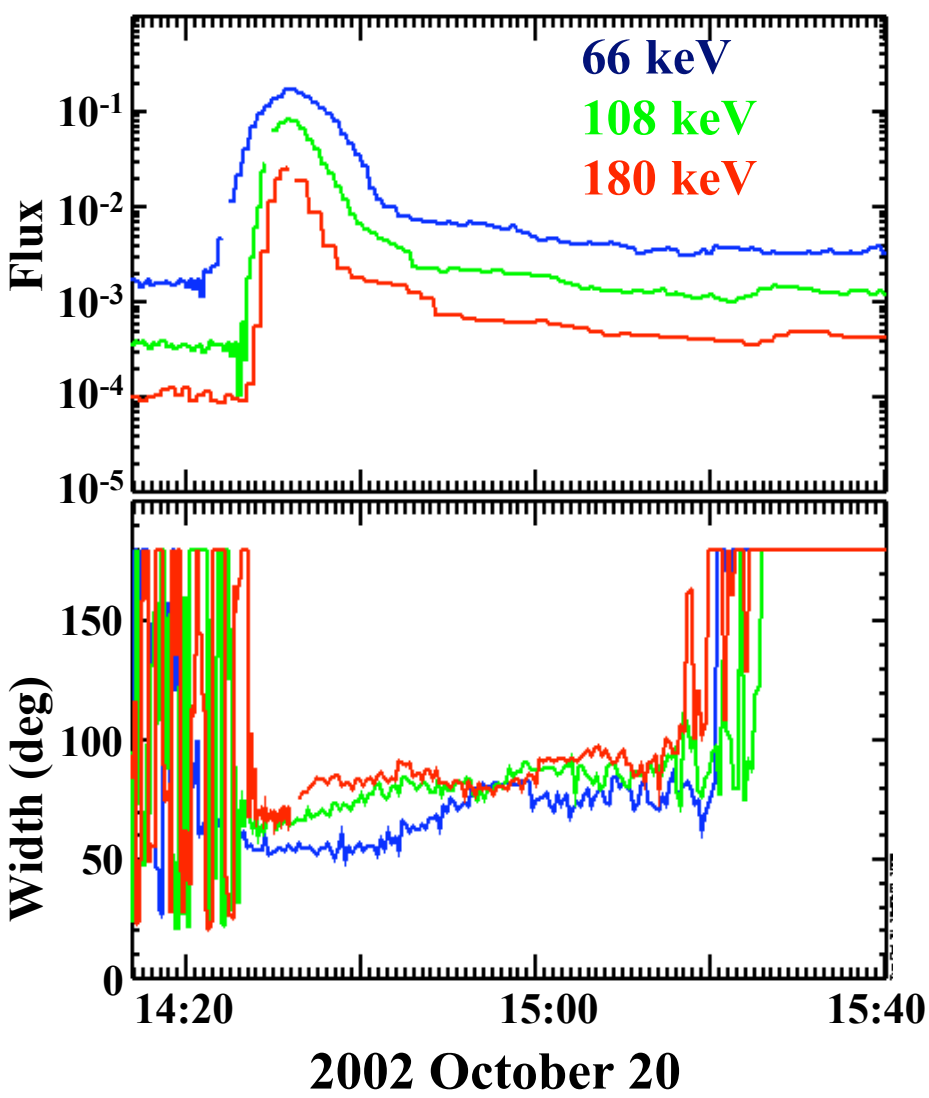


Pitch angle distribution width



After shifting peaks to the same time





_ Results of Pitch angle width Δ_

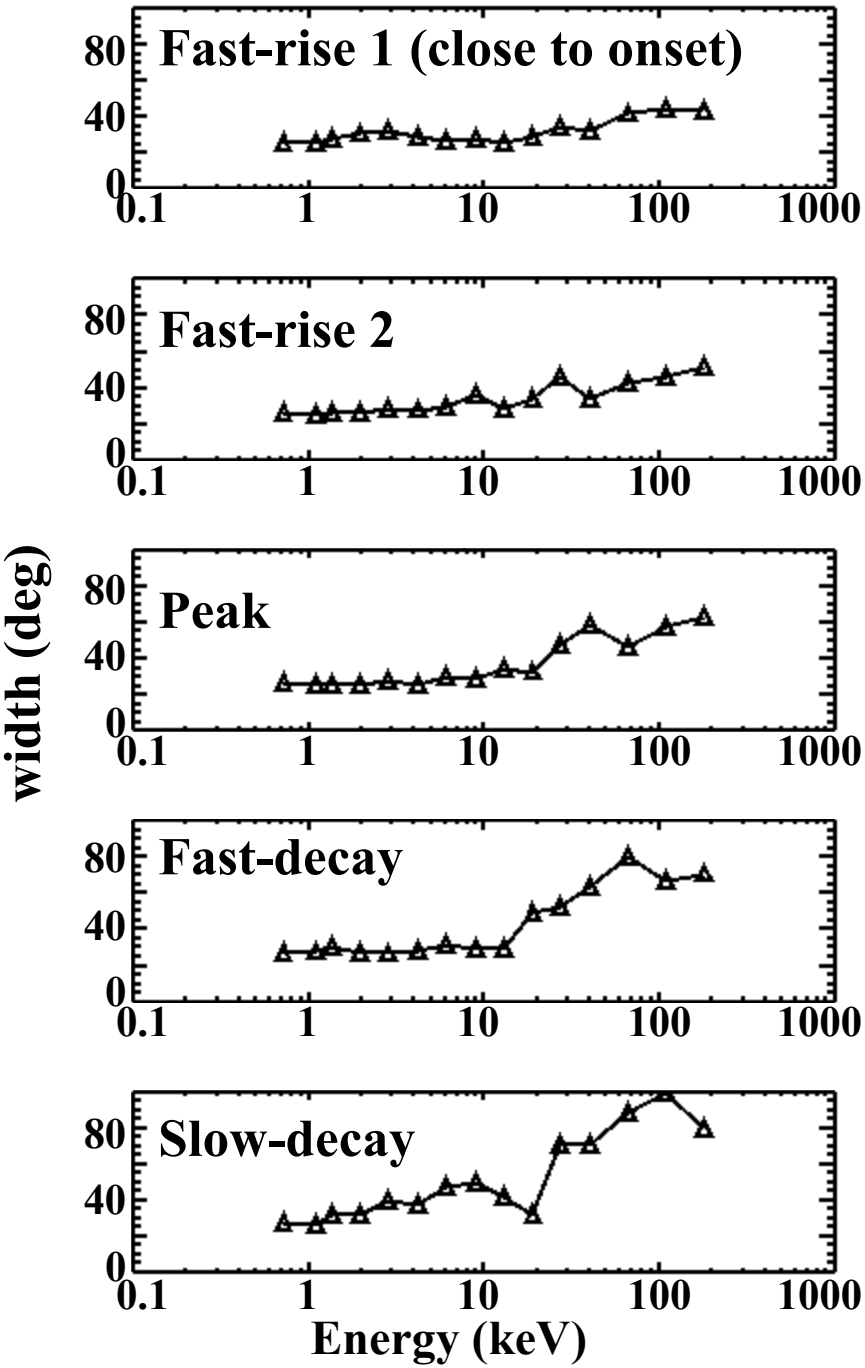
1998 Aug 29 event

* Below ~15-20 keV:

  Δ_ <~30°, constant;

* Above ~15-20 keV:

  Δ_ roughly increases with E and t



_ Results of Pitch angle width Δ_

1998 Aug 29 event

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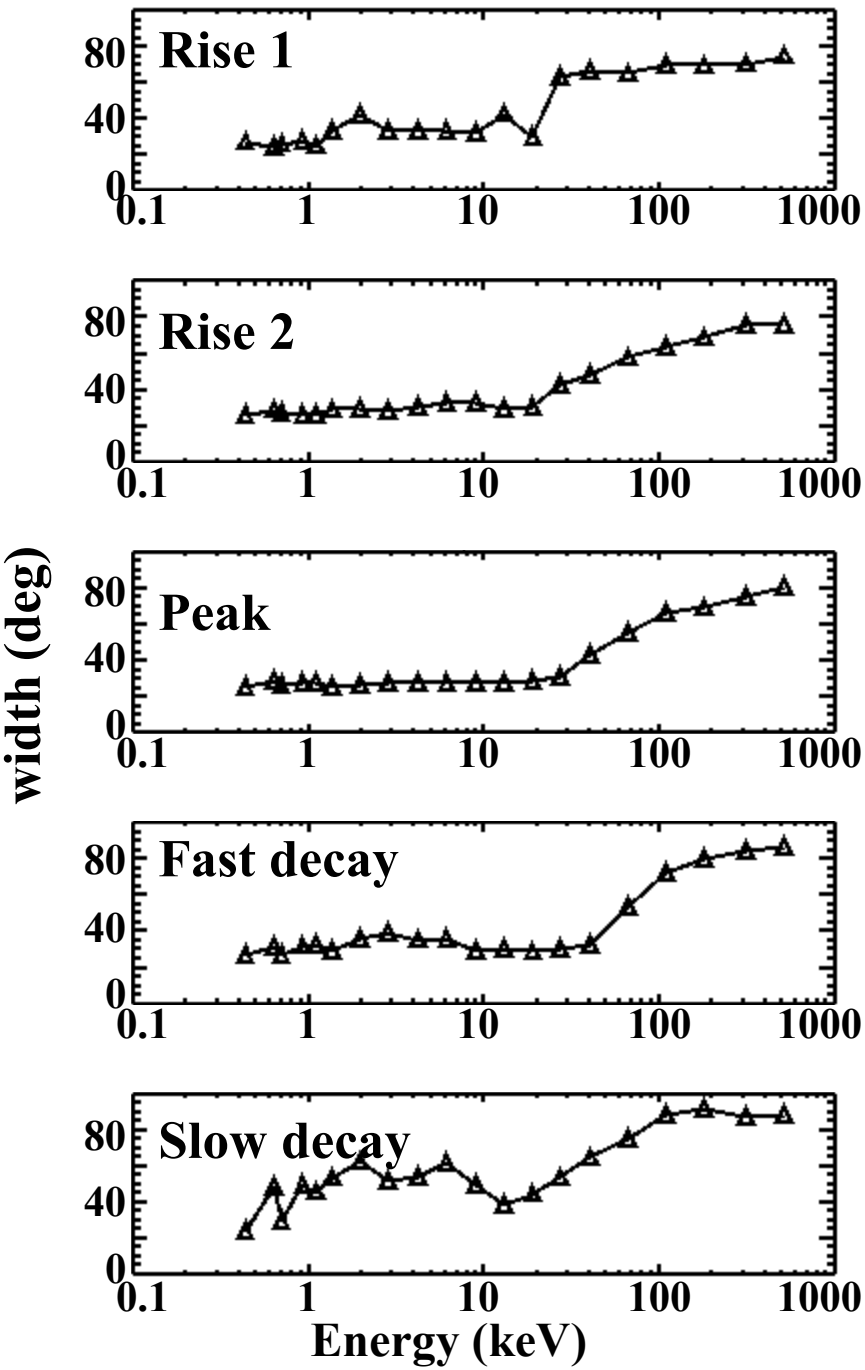
Low-E electrons (scatter-free)

High-E electrons (scattered)



Conclusions

1. Injection study with scatter-free assumption:

The inferred injections of low-E electrons last for ~1-2 hours.

The injection injections of high-E electrons start with a delay of ~10-40 min and last for ~5-10 times shorter

2. Pitch angle width at 1 AU:

Below ~15-20 keV: $\Delta\alpha$ <~30°, constant through fast decay;

Above ~15-20 keV: $\Delta\alpha$ roughly increases with E and t

Low-E electrons (scatter-free); High-E electrons (energy-dependent scattering)

Conclusions

The actual injections of low-E electrons have a duration of ~1-2 hours.

The actual injections of high-E electrons are shorter (<~ 20mins) and delayed.

Low-energy and high-energy electrons are accelerated by different mechanisms, and low-energy electrons may provide a seed population for the acceleration of high-energy electrons