Why should there be "dips" in flare <nVF> spectra?

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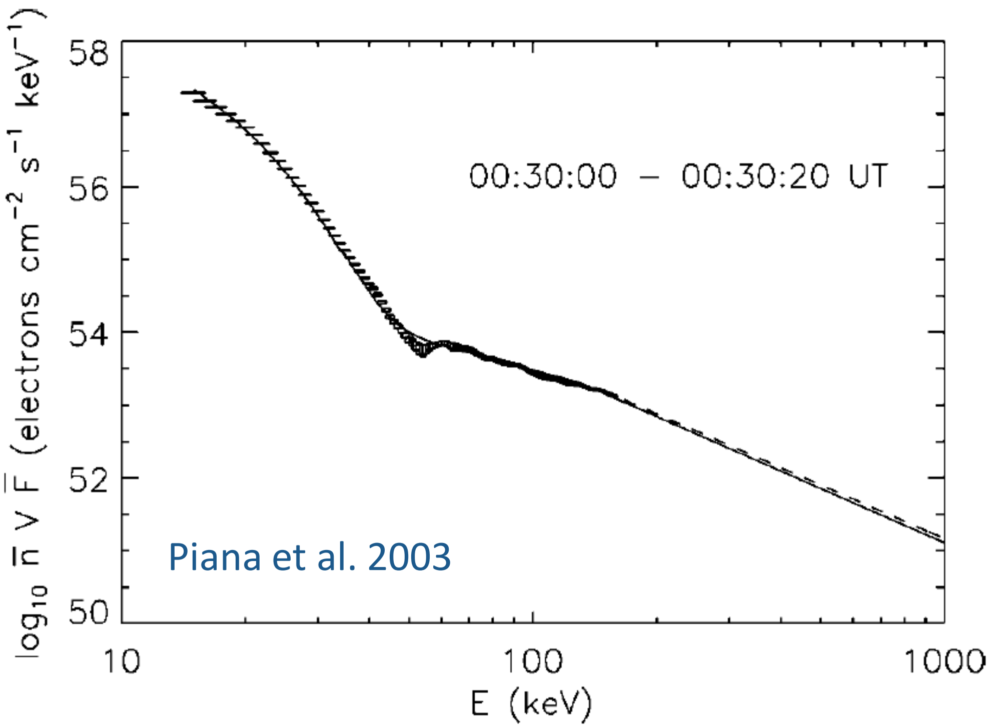
Introduction & Motivation

- **In some flares a local minima or "dip" is found in the mean electron flux spectrum <nVF>**
  - If real, it's very important as indicates presence of low energy cut-off which tells us about the total energy in the accelerated electron population



- Can be removed by albedo correction in some flares (i.e. Piana et al. 2003, Kasparova et al. 2005, Kontar et al. 2008) but still present in others (i.e. Sui et al. 2007)

Something more than thick-target?

- **Dip expected from collisional thick-target on $F(E) \sim E^{-\delta}$ above E_{C}**
  - Coulomb collisions produce +ve slope below break as beam propagates from coronal acceleration site to chromosphere
    - See Emslie's talk

- **But what about response of background plasma?**
  - And non-collisional beam-plasma interaction faster than Coulomb collisions
    - Zheleznyakov & Zaitsev 1970

- **So model the background plasma response in form of electron-beam driven Langmuir wave turbulence**
  - Using self-consistent 1D equations of quasi-linear relaxation
    - Vedenov & Velikhov 1963, Drummond & Pines 1964, Ryutov 1969, Hamilton & Petrosian 1987, Kontar 2001
    - Equations and setup on next slide

Numerical Simulation

$$\frac{\partial f}{\partial t} + v\frac{\partial f}{\partial x} = \frac{4\pi^2 e^2}{m^2}\frac{\partial}{\partial v}\left(\frac{W}{v}\frac{\partial f}{\partial v}\right) + \gamma_{C_f}\frac{\partial}{\partial v}\left(\frac{f}{v^2}\right)$$

$$\frac{\partial W}{\partial t} + \frac{3v_T^2}{v}\frac{\partial W}{\partial x} = \left(\frac{\pi\omega_p}{n}v^2\frac{\partial f}{\partial v} - \gamma_{C_W} - 2\gamma_L\right)W + Sf$$

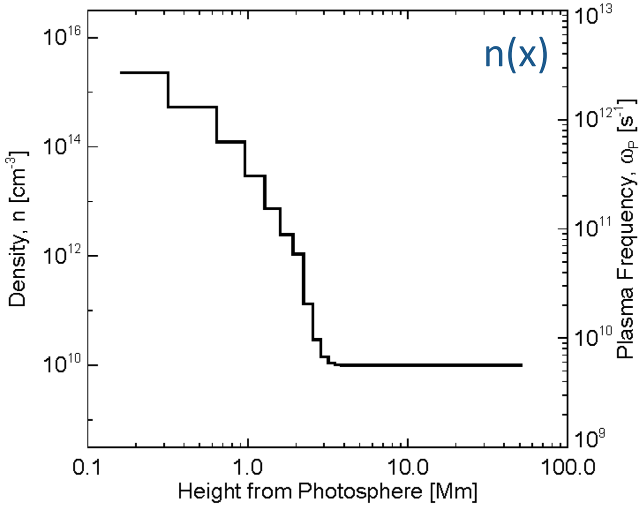
- f(v,x,t) is the electron distribution, W(v,x,t) spectral energy density of the waves
- γ_{Cf} , γ_W are Coulomb collision terms, γ_L Landau damping, S spontaneous emission

- Background plasma density n(x), 10^{10} cm^{-3} in corona, increases in chromosphere

- Initial electron distribution
  - Power-law in velocity (index α), Gaussian in space
  - n_0 beam density

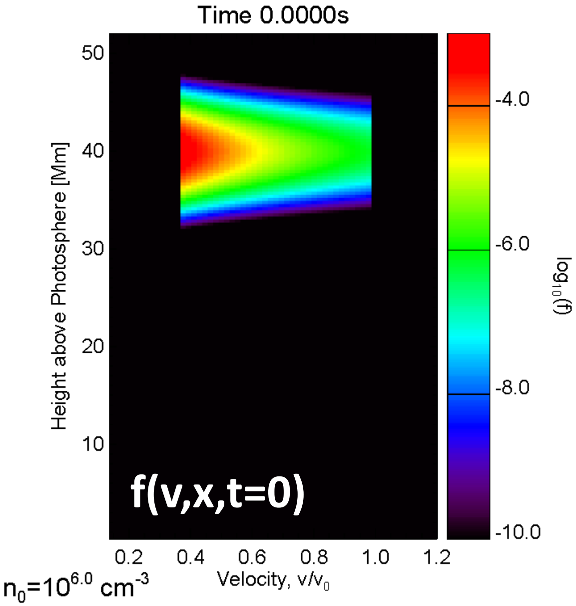
$$f(v,x,t=0) = n_0\frac{(1-\alpha)}{v_C}\left(\frac{v}{v_C}\right)^{-\alpha}\exp\left[\frac{-x^2}{d^2}\right]$$

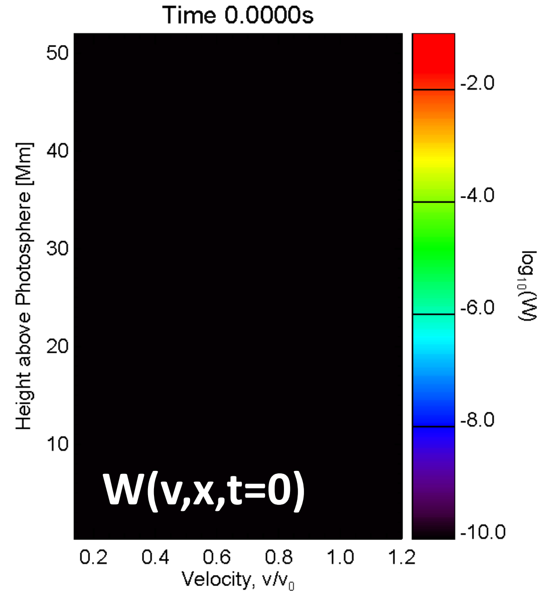
- Initial waves=thermal background $W(v,x,t=0) \approx 0$



Initial Configuration

- **Using modest beam density, microflare like, $n_0=10^6$ cm^{-3}, $N \approx 10^{32}$ electrons**
  - If has an effect for small flares then bigger effect in large





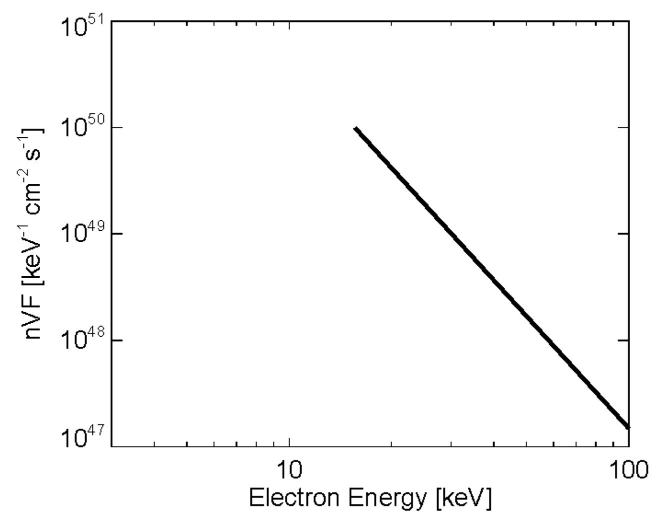
E_C=15 keV,

α=7, => δ=3.5

d=2x10^8 cm

v_0=2x10^{10} cm/s

T=1 MK

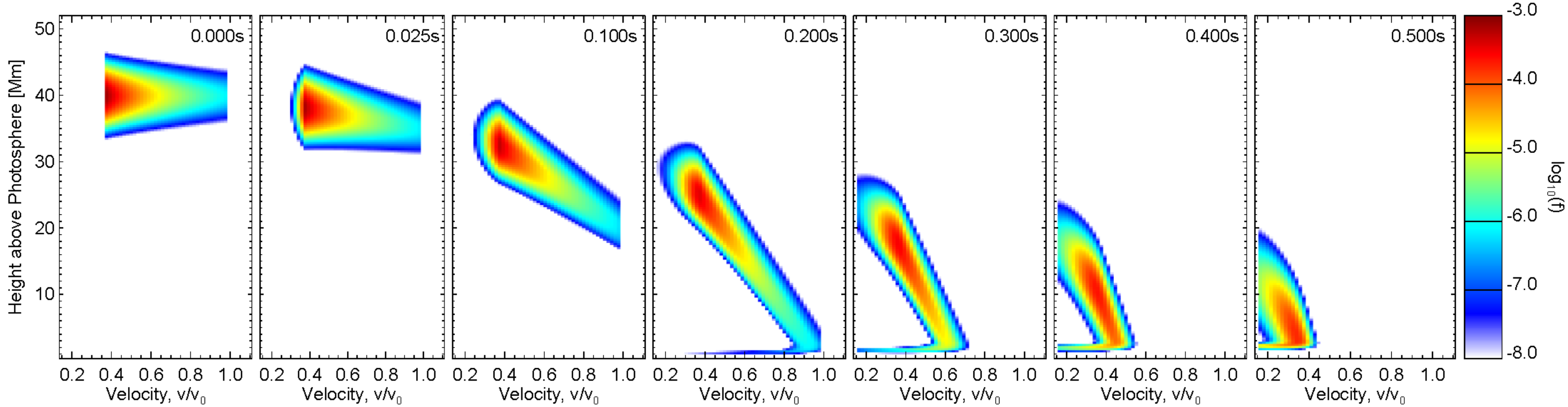


- **Presenting results in terms of <nVF>**
  - $A \approx FWHM^2 = 2.35d^2$

$$\overline{n}V\overline{F}(E,t) = \sum \left[n(x) \frac{f(v,x,t)}{m_e} \right] dx A$$

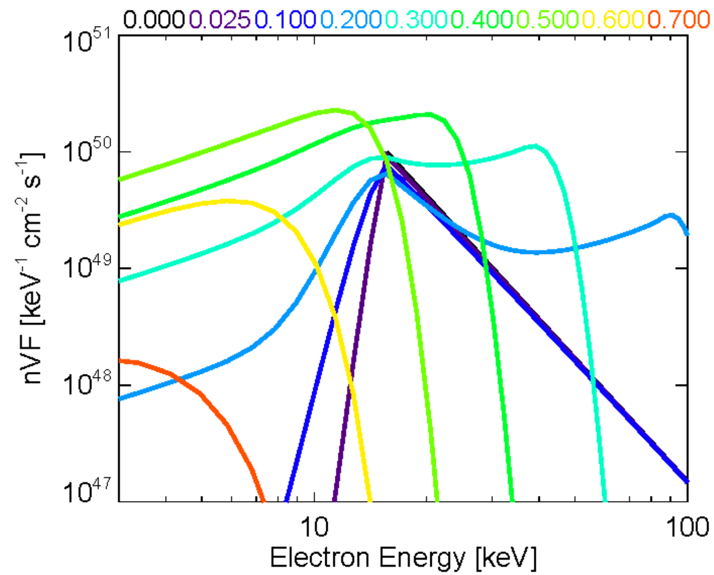
Beam & Coulomb Collisions Only

Beam Only, f(v,x,t)

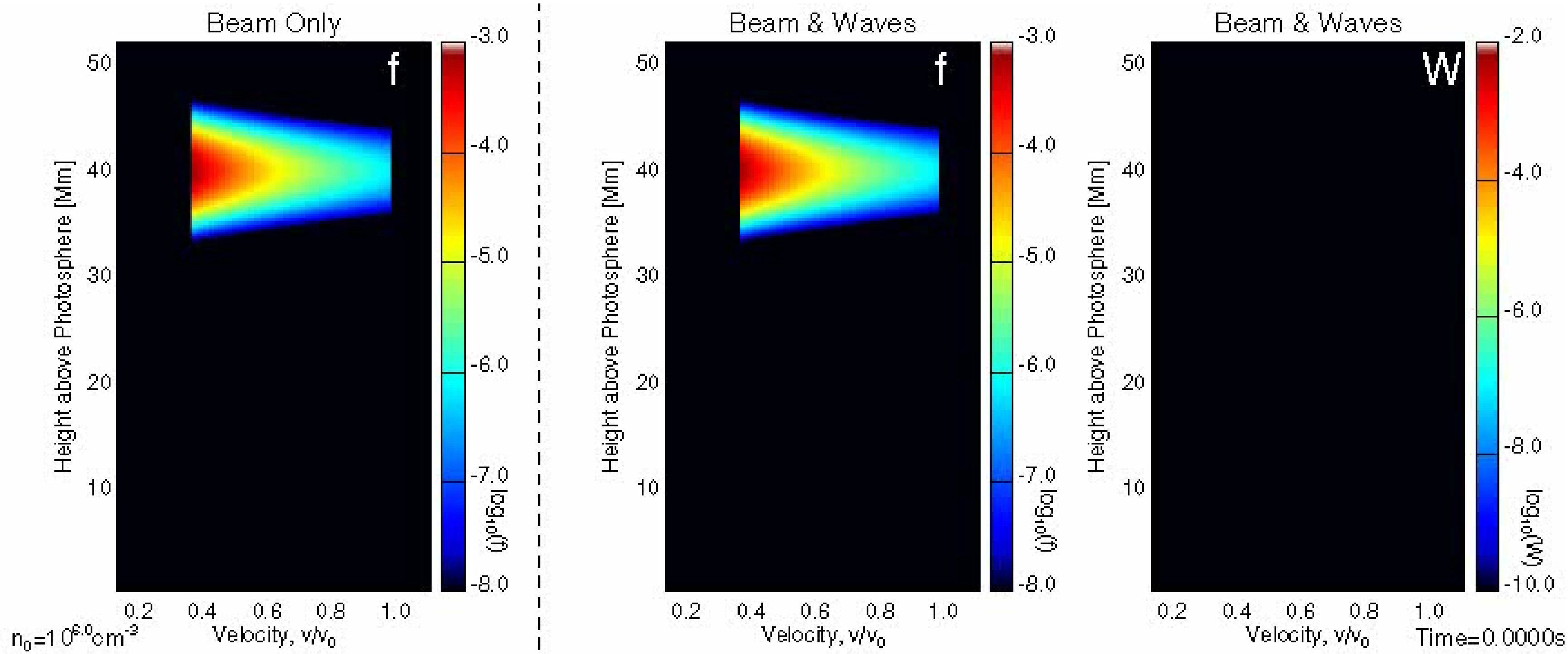


Time →

$$\frac{\partial f}{\partial t} + v\frac{\partial f}{\partial x} = \gamma_{\mathrm{C_f}} \frac{\partial}{\partial v}\left(\frac{f}{v^2}\right)$$



Beam Driven Langmuir Wave Turbulence

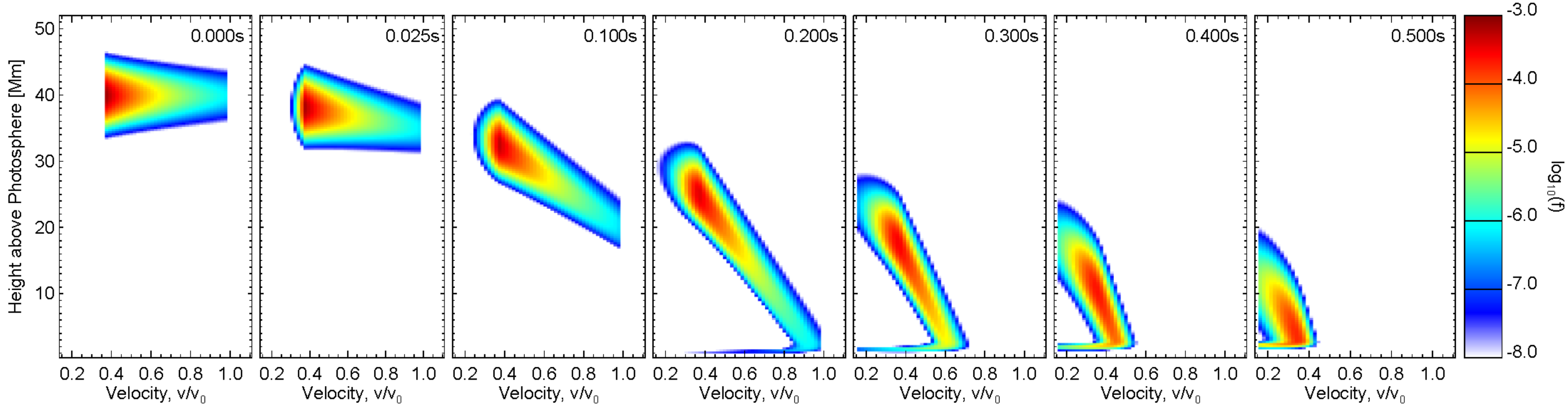


Beam Only,
f(v,x,t)

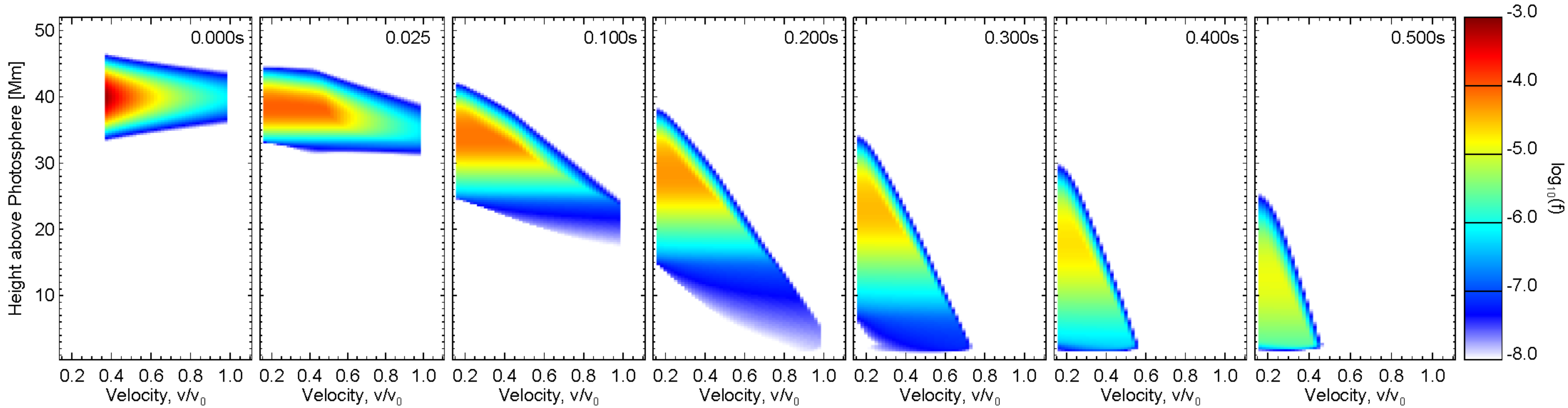
Beam & Waves,
f(v,x,t) & W(v,x,t)

Comparison Beam vs Beam+Waves

Beam Only, f(v,x,t)



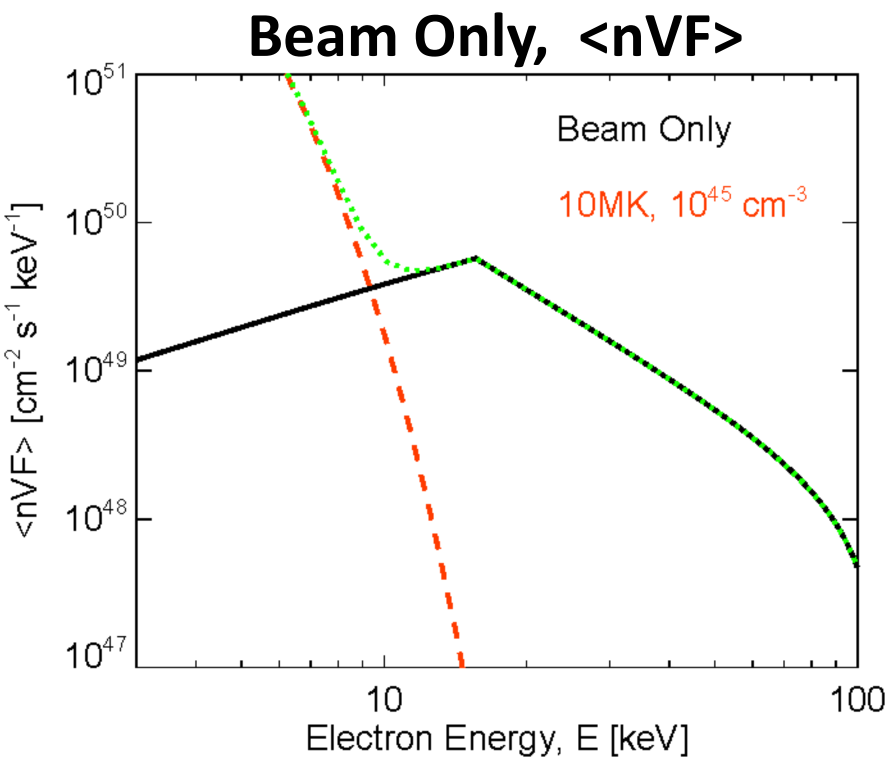
Beam & Waves, f(v,x,t)

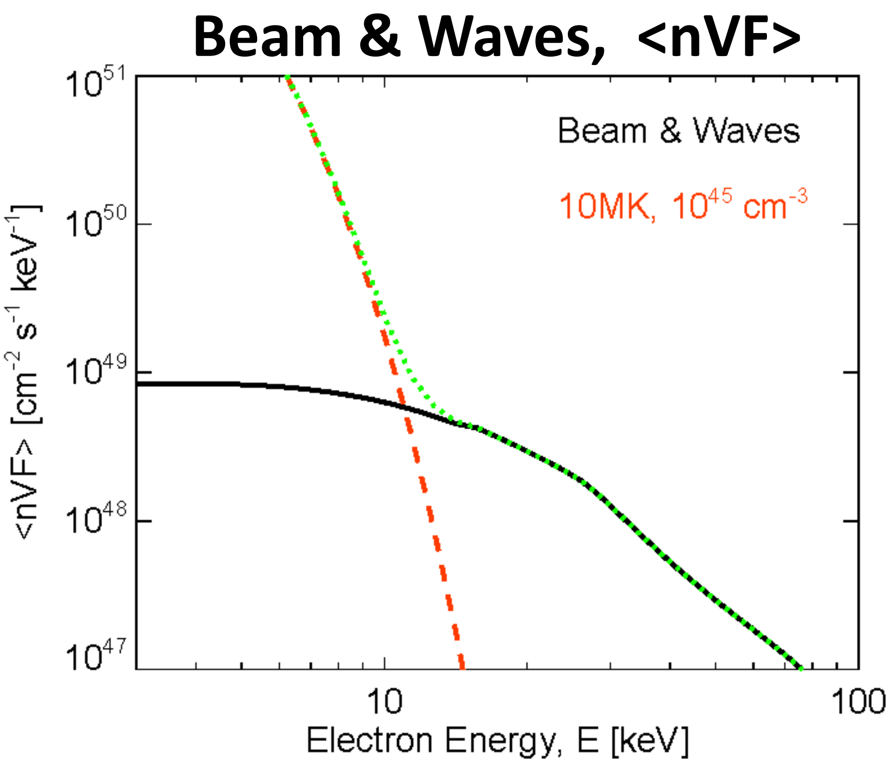


Time

Comparison Beam vs Beam+Waves

- **The resulting time averaged mean electron spectrum <nVF>**
  - Model **Thermal** added to indicate dip or lack thereof in total **<nVF>**





Conclusions

- **Even for a modest flare, wave-particle interactions modify the mean electron flux spectrum**

- **Initial low energy cut-off is quickly flattened out**
  - Low energy cut-off is unlikely to develop/exist ?

- **What does the non-thermal do as it transitions into the thermal distribution?**
  - Flatter transition into thermal distribution?
  - This would reduce the total non-thermal energy