DS-1/Plasma Experiment for Planetary Exploration (PEPE)

PEPE – is a particle spectrometer capable of resolving energy, angle and mass & charge composition of plasma

- electrons (Elc)
- protons (Ions single)
- Ions (composition, M/Q, TOF)

Data coverage: 2001/262-266
Encounter with Comet Borrelly on day 266
Files provided: mission.cat, insthost.cat
datainfo.txt, data_product_def030113.pdf
calib_info.txt, pepe_borelly_ds.cat, pepe_inst.cat

Issues of PEPE's information files

1. Instrumental & calibration parameters are spread through the various catalog files.
2. There is a description on how to generated phase space density (i.e. distribution functions) from the counts and instrumental parameters but the energy factor in the equation should be interpreted as energy per charge.
3. There is no description on the physical (meaningful) quantities that could be determined, formulas or algorithms on how to estimate them.
4. In the calibration file there is an incorrect labeling of Table 2 as detector efficiencies. They are detector solid angles (str).
5. For composition determination, a model dependent approach is suggested for the analysis, but no example are presented.

Instrument Characteristics (PEPE)

	Electrons	Protons/Ions
*Energy Range (120 log-space steps)	8 eV – 31.5 keV	8 eV – 31.5 keV
Energy Resolution (ΔE/E)	0.085	0.046
*Elevation Angle Range(4/8 steps)	-45° - 45°	-45° - 45°
*Azimuthal Angle Range(4/8 steps)	0°-360°	0°-360°
Angular Resolution	256 px@ 5°×22°	128px@ 5°×5°, 32px@ 5°×22°, 96px@ 5°×45°
Mass Range	-	1 – 135 amu
Mass Resolution (M/ΔM)	-	4(MR), 20(HR)
Integration Time (Δτ in ms)	572.4 ms, 28.62 ms	572.4 ms, 28.62 ms

* Telemetry Modes: 50bps, 1kbps

Moments

Phase-Space Density:

$$f_s(\mathrm{v}_i,\theta_j,\phi_k)=\sum_{i,j,k}\frac{C_{i,j,k}}{A\,\Delta\Omega_{j,k}\left(\frac{\Delta \mathrm{v}}{\mathrm{v}}\right)\eta\,\Delta\tau\,\mathrm{v}_i^4}=\sum_{i,j,k}\frac{C_{i,j,k}\,(m_s/q_s)^2}{2\,A\,\Delta\Omega_{j,k}\left(\frac{\Delta E}{E}\right)\eta\,\Delta\tau\,(E_i/q_s)^2}$$

Geometrical Factor (G): $G_{i,j,k} = A\ \Delta\Omega_{j,k}\ (\Delta E/E_i)\ \Delta\tau$
Efficiency : η ($\eta=1$)

Data Products: Moments of the distribution function f:

$$n_s=\int f_s(\vec{\mathrm{v}})\,d^3\vec{\mathrm{v}}=\int f_s(\vec{\mathrm{v}})\,\mathrm{v}^2 d\mathrm{v}\,d\Sigma \quad \leftarrow \textit{Density}$$

$$n_s\vec{U}_s=\int f_s(\vec{\mathrm{v}})\,\vec{\mathrm{v}}\,d^3\vec{\mathrm{v}} \quad \leftarrow \textit{Flux or Velocity}$$

$$\mathbf{P}_s=m_s\int f_s(\vec{\mathrm{v}})(\vec{\mathrm{v}}-\vec{U}_s)(\vec{\mathrm{v}}-\vec{U}_s)\,d^3\vec{\mathrm{v}}=m_s\int f_s(\vec{\mathrm{v}})\,\vec{\mathrm{v}}\vec{\mathrm{v}}\,d^3\vec{\mathrm{v}}-n_s m_s\vec{U}_s\vec{U}_s \quad \leftarrow \textit{Energy density}$$

Electron Moments (ELC)

Electrons in the SW are subsonic & sub-Alfvenic (i.e. $U_e << v_{the}$)

Density:

$$n_s \quad \left(m_s/2\right)^{1/2} \sum_{i,j,k} \frac{C_{i,j,k} \left(\frac{\Delta E_i}{E_i}\right) \Delta\Sigma_{j,k}}{G_{j,k}\,\eta\, E_i^{1/2}}$$

Bulk Velocity:

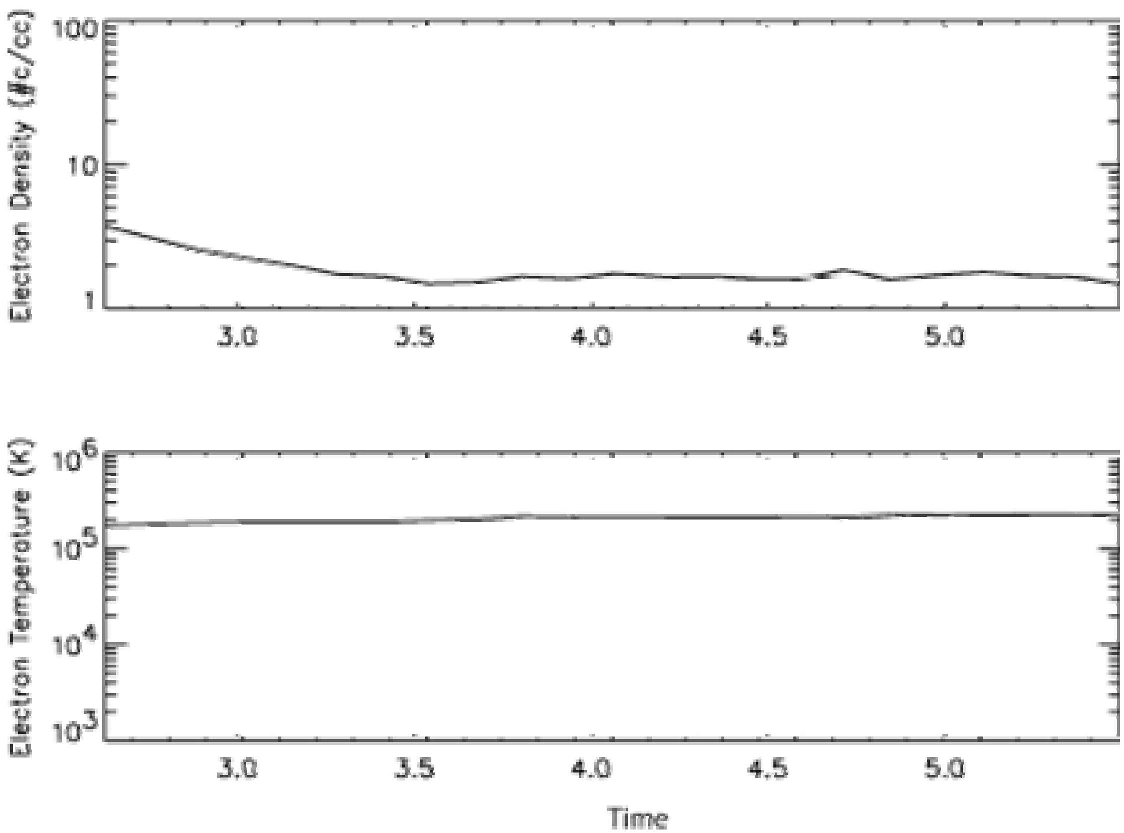
$$\vec{U}_s \quad \frac{1}{n_s} \sum_{i,j,k} \frac{C_{i,j,k}\, \vec{e}_{i,j,k} \left(\frac{\Delta E_i}{E_i}\right) \Delta\Sigma_{j,k}}{G_{j,k}\,\eta}, \quad \vec{e}_{i,j,k} = unit\ vectors$$

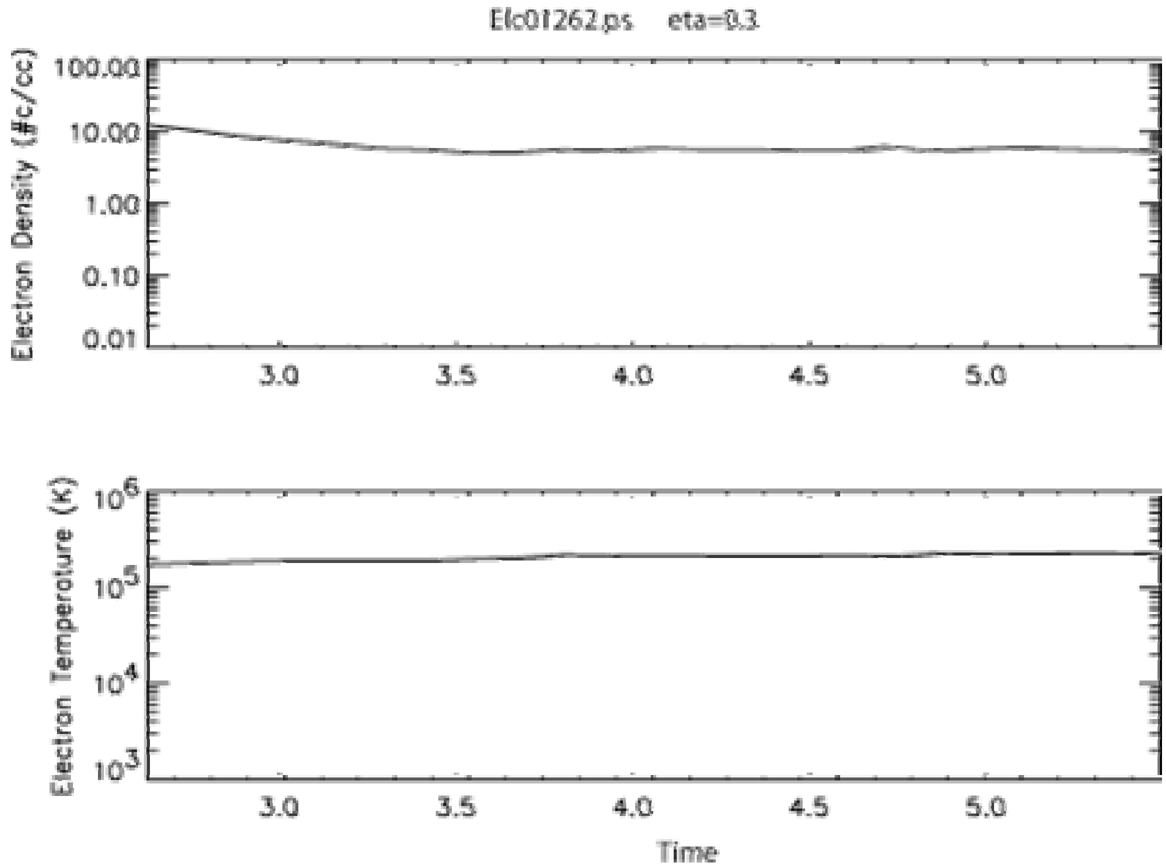
Unit vectors $e_{i,j,k}$ = -(cosϕ^{az} cosθ^{el}, sin θ^{el}, sin ϕ^{az} cosθ^{el}).

Average Energy (Temperature) in the proper frame:

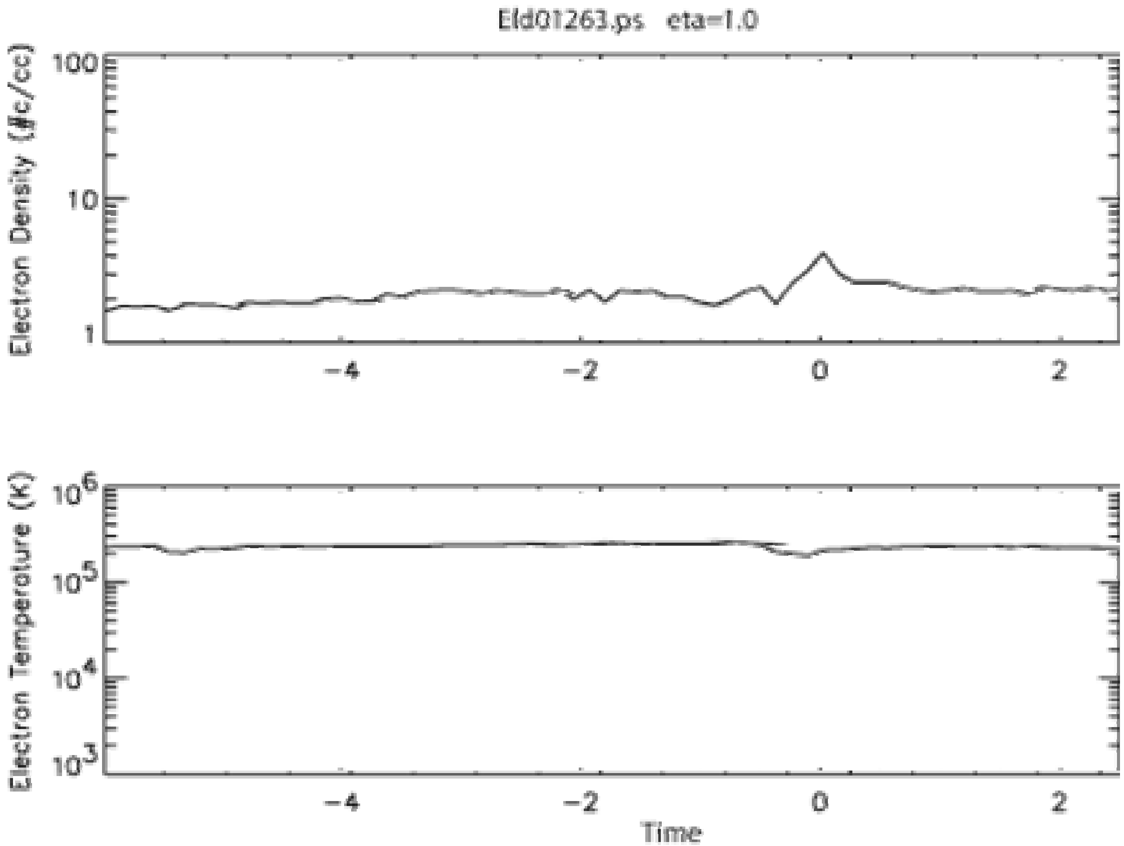
$$\langle \kappa T_s \rangle \quad \frac{2}{3} \frac{\sum_{i,j,k} \frac{C_{i,j,k} \left(\frac{\Delta E_i}{E_i}\right) E_i^{1/2} \Delta\Sigma_{j,k}}{G_{j,k}\,\eta}}{\sum_{i,j,k} \frac{C_{i,j,k} \left(\frac{\Delta E_i}{E_i}\right) E_i^{-1/2} \Delta\Sigma_{j,k}}{G_{j,k}\,\eta}}$$

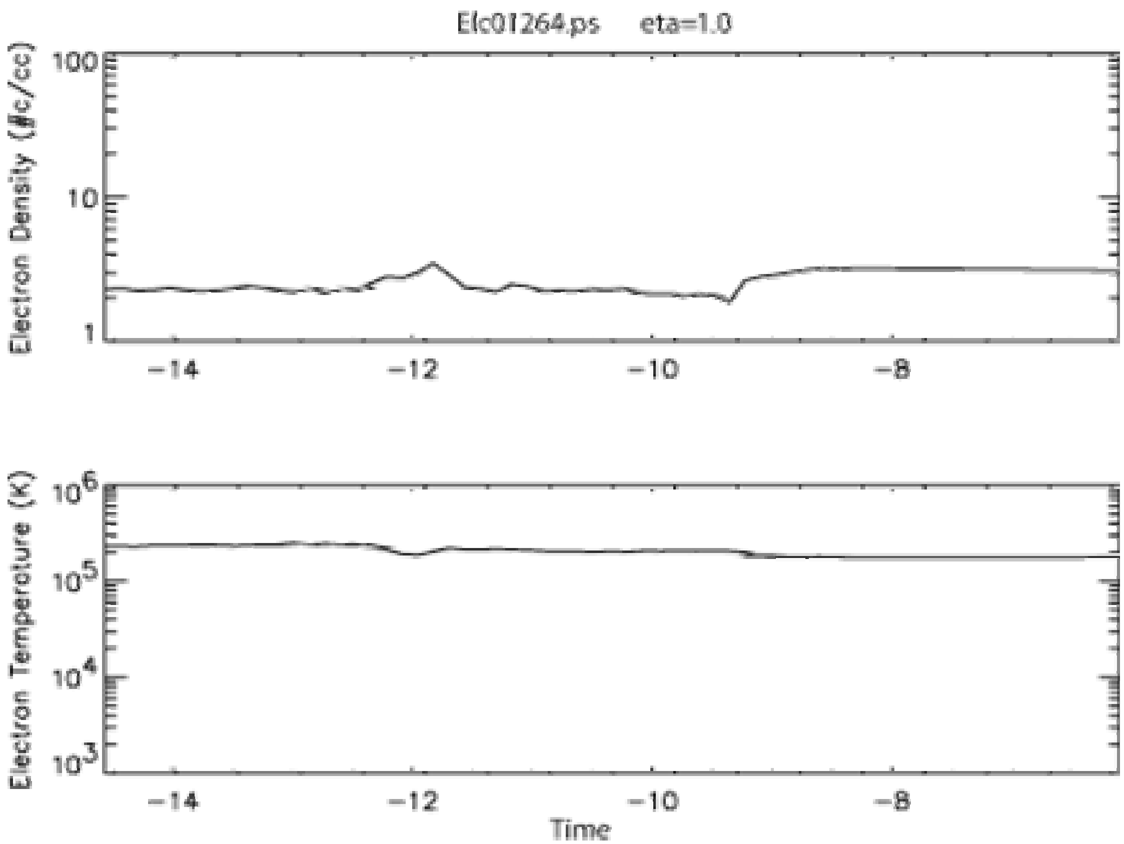
Elc01262.ps   eta=3.



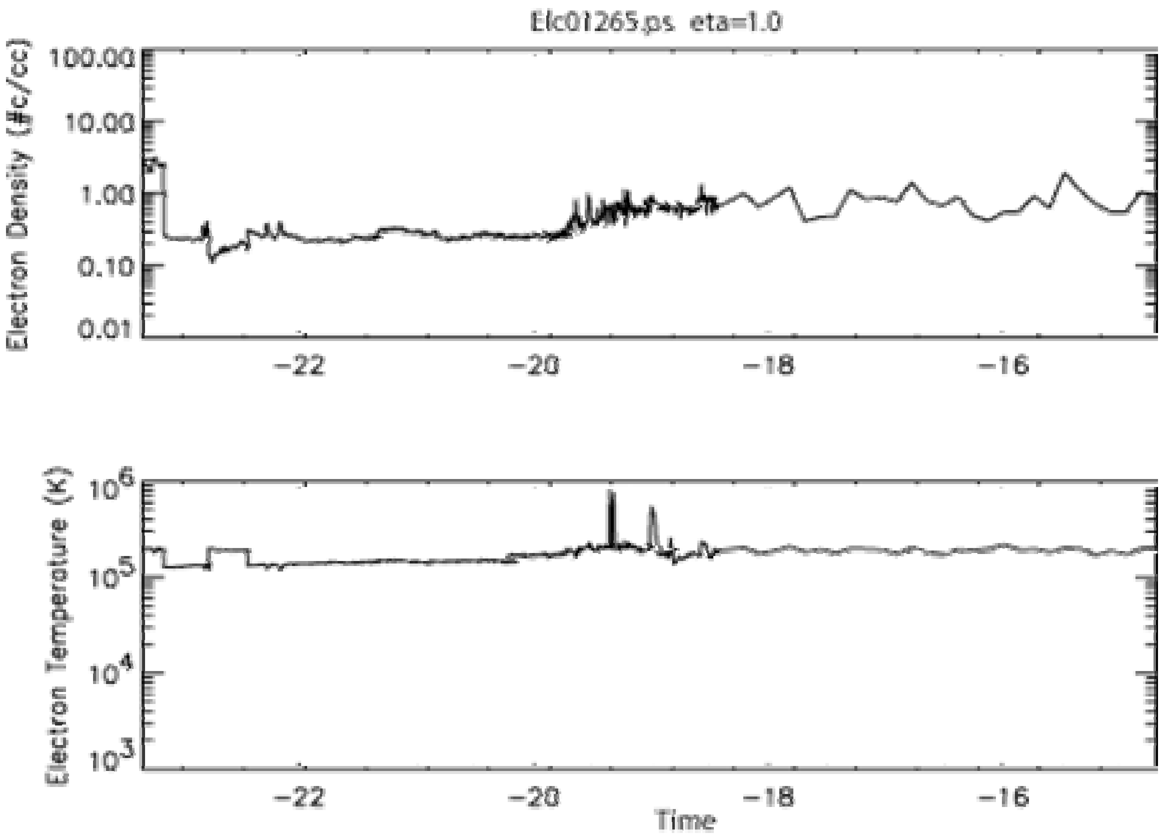


Elc01262.ps eta=0.3
Electron Density (#c/cc)
100.00
10.00
1.00
0.10
0.01
3.0
3.5
4.0
4.5
5.0
Electron Temperature (K)
10^6
10^5
10^4
10^3
3.0
3.5
4.0
4.5
5.0
Time

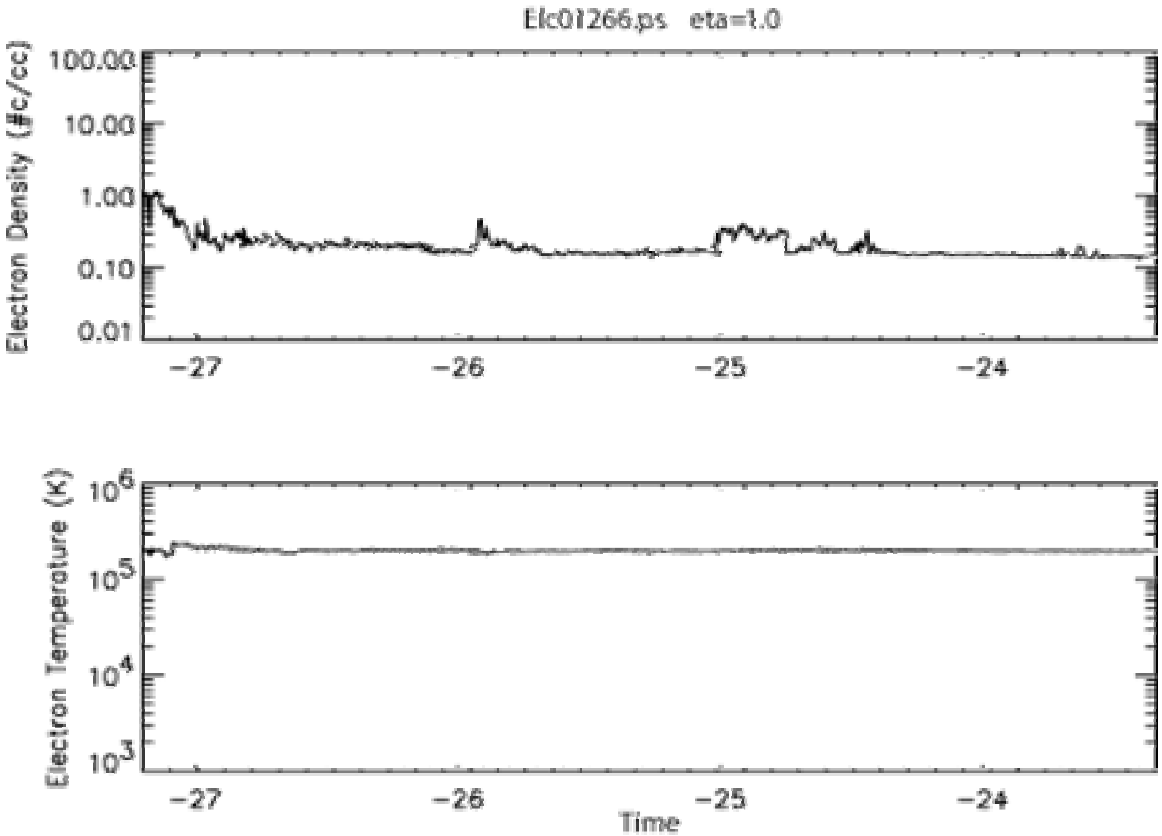

Eld01263.ps eta=1.0
Electron Density (#c/cc)
100
10
1
-4
-2
0
2
Electron Temperature (K)
10^6
10^5
10^4
10^3
-4
-2
0
2
Time



Elc01264.ps eta=1.0
Electron Density (#c/cc)
100
10
1
-14
-12
-10
-8
Electron Temperature (K)
10^6
10^5
10^4
10^3
-14
-12
-10
-8
Time



Elc01265.ps eta=1.0
Electron Density (#c/cc)
100.00
10.00
1.00
0.10
0.01
-22
-20
-18
-16
Electron Temperature (K)
10^6
10^5
10^4
10^3
-22
-20
-18
-16
Time



Elc01266.ps eta=1.0
Electron Density (#c/cc)
100.00
10.00
1.00
0.10
0.01
−27
−26
−25
−24
Electron Temperature (K)
10^6
10^5
10^4
10^3
−27
−26
−25
−24
Time

Electron Issues for Data Validation

- Efficiency factor η for density validation, cross-calibration with other spacecraft electron data to determine η accurately. It may also be angular dependent.
- Spacecraft potential (ϕ_{spc}) corrections (photoelectrons, secondary electrons, etc).
- Electron background (or "glint") counts subtraction.
- Poor angular resolution for other vectorial moment quantities such as: bulk velocity, temperature anisotropy, heat-flux.
- The data files are perhaps easily understood if the counts are formatted in matrix form with dependence on elevation, energy and time for each azimuth.

Proton Moments (Ions single)

Protons in the SW are supersonic & super-Alfvenic (i.e. $U_p >> v_{thp}$)

Density:

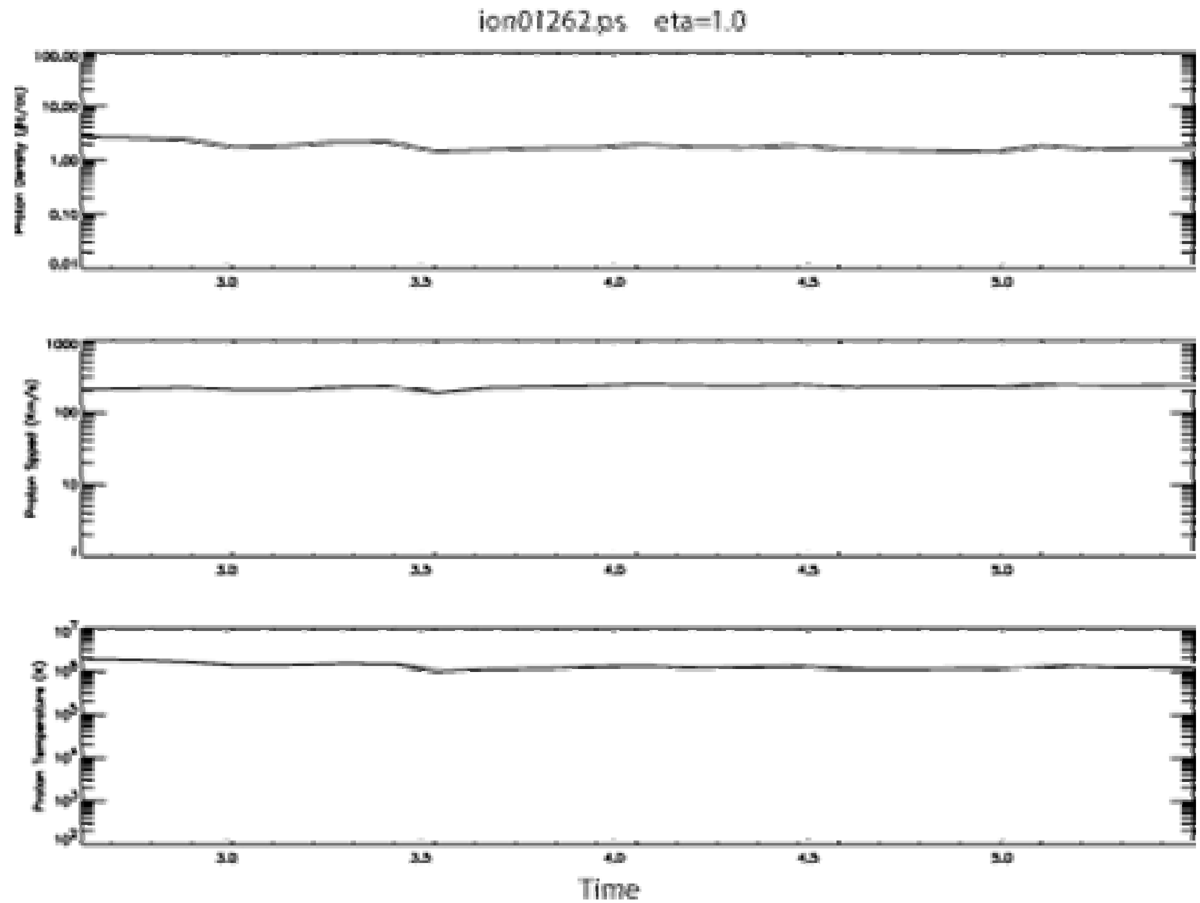
$$n_s \quad (m_s/2)^{1/2} \sum_{i,j,k} \frac{C_{i,j,k} \left(\frac{\Delta E_i}{E_i} \right) \Delta\Sigma_{j,k}}{G_{j,k} \, \eta \, E_i^{1/2}}$$

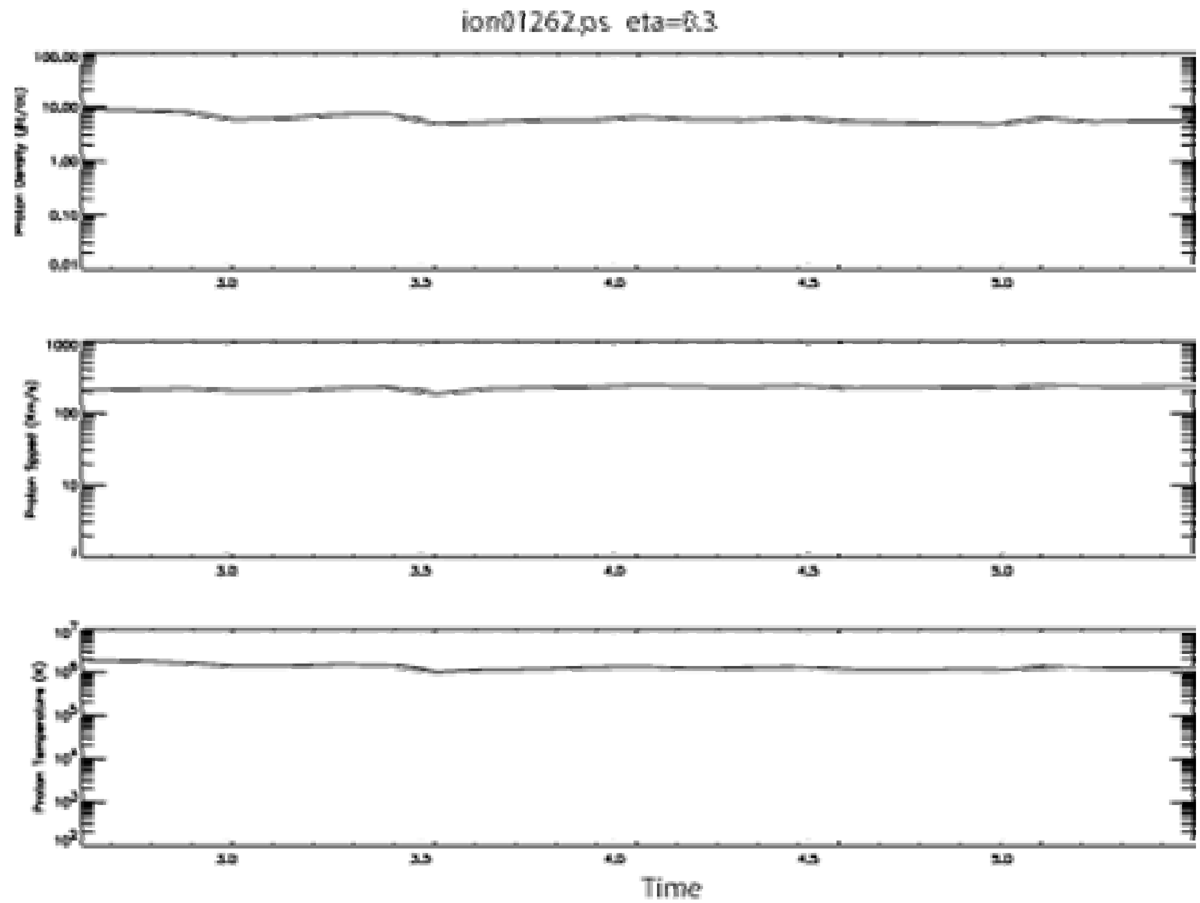
Bulk Velocity:

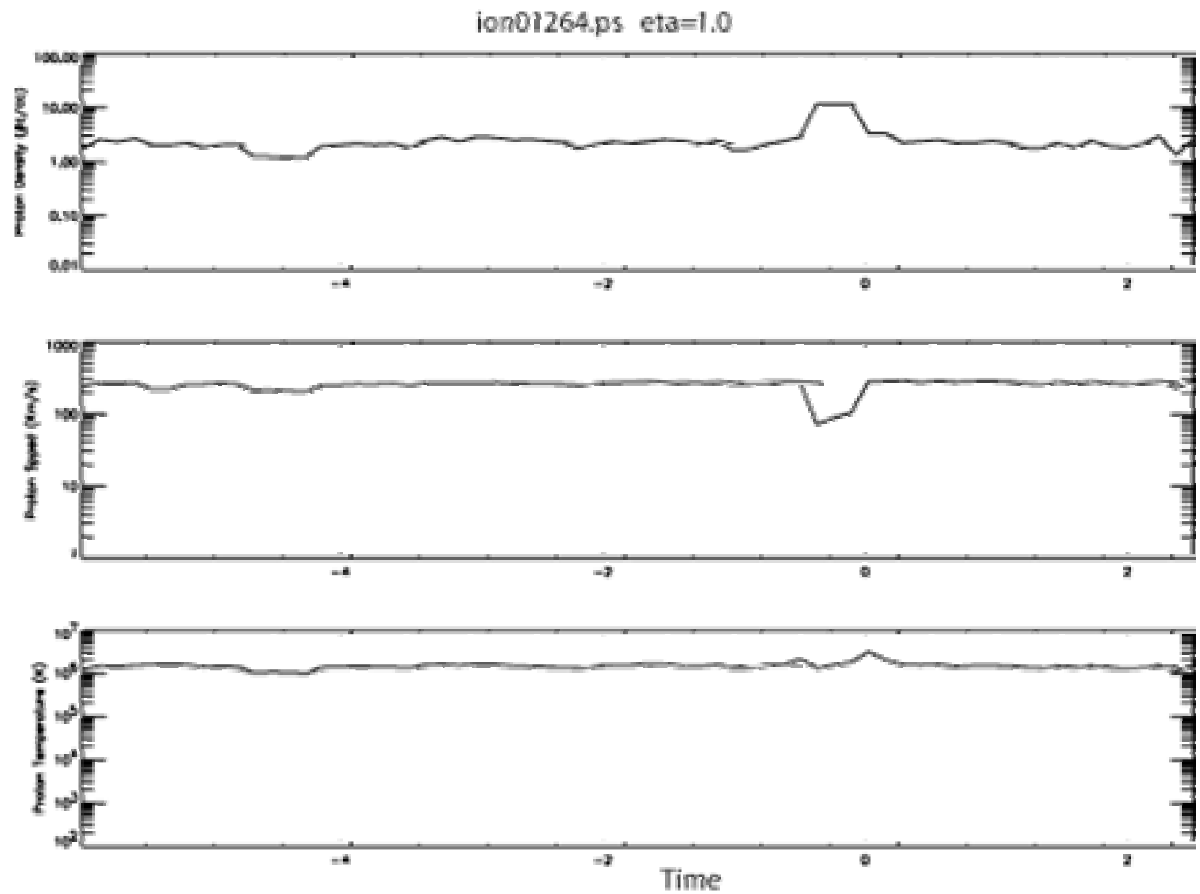
$$\vec{U}_s \quad \frac{1}{n_s} \sum_{i,j,k} \frac{C_{i,j,k} \, \vec{e}_{i,j,k} \left(\frac{\Delta E_i}{E_i} \right) \Delta\Sigma_{j,k}}{G_{j,k} \, \eta}$$

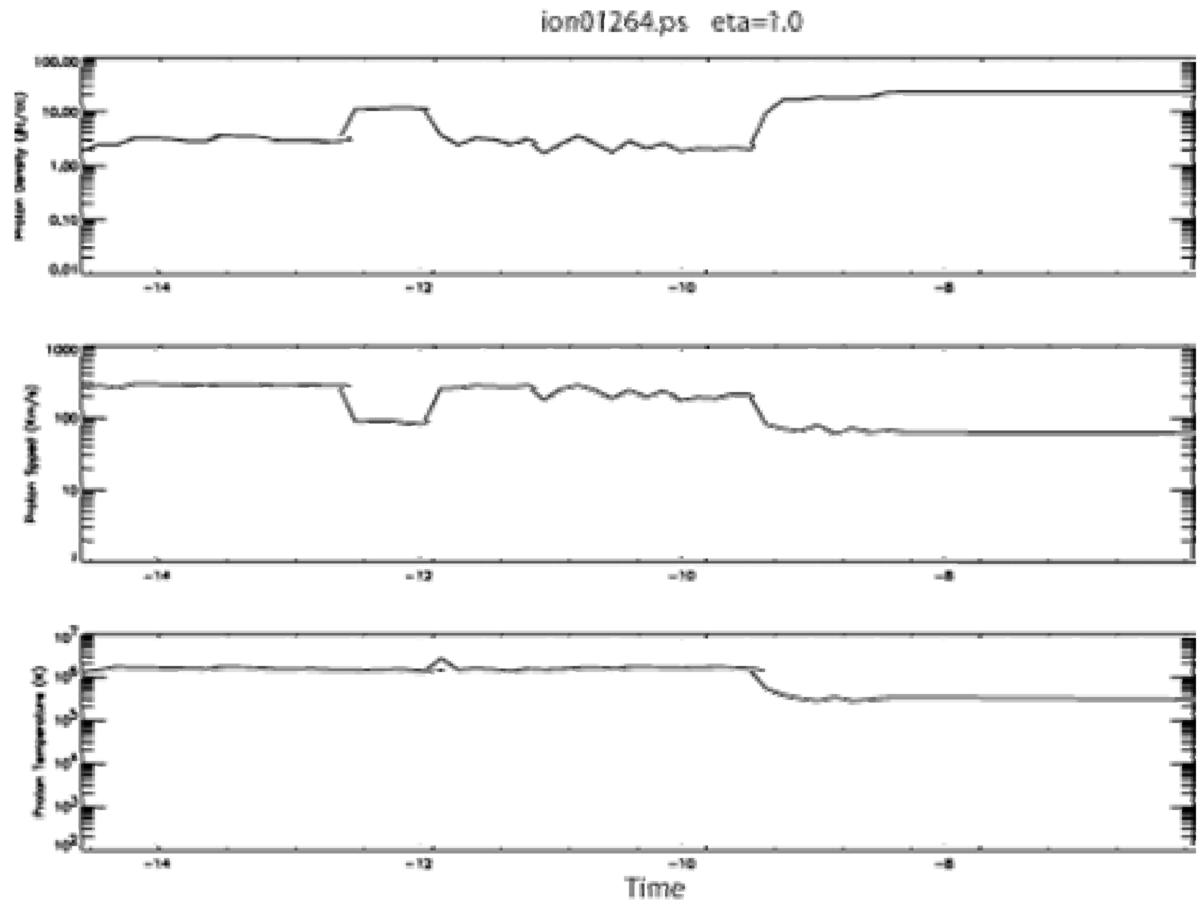
Average Energy (Temperature) in the proper frame:

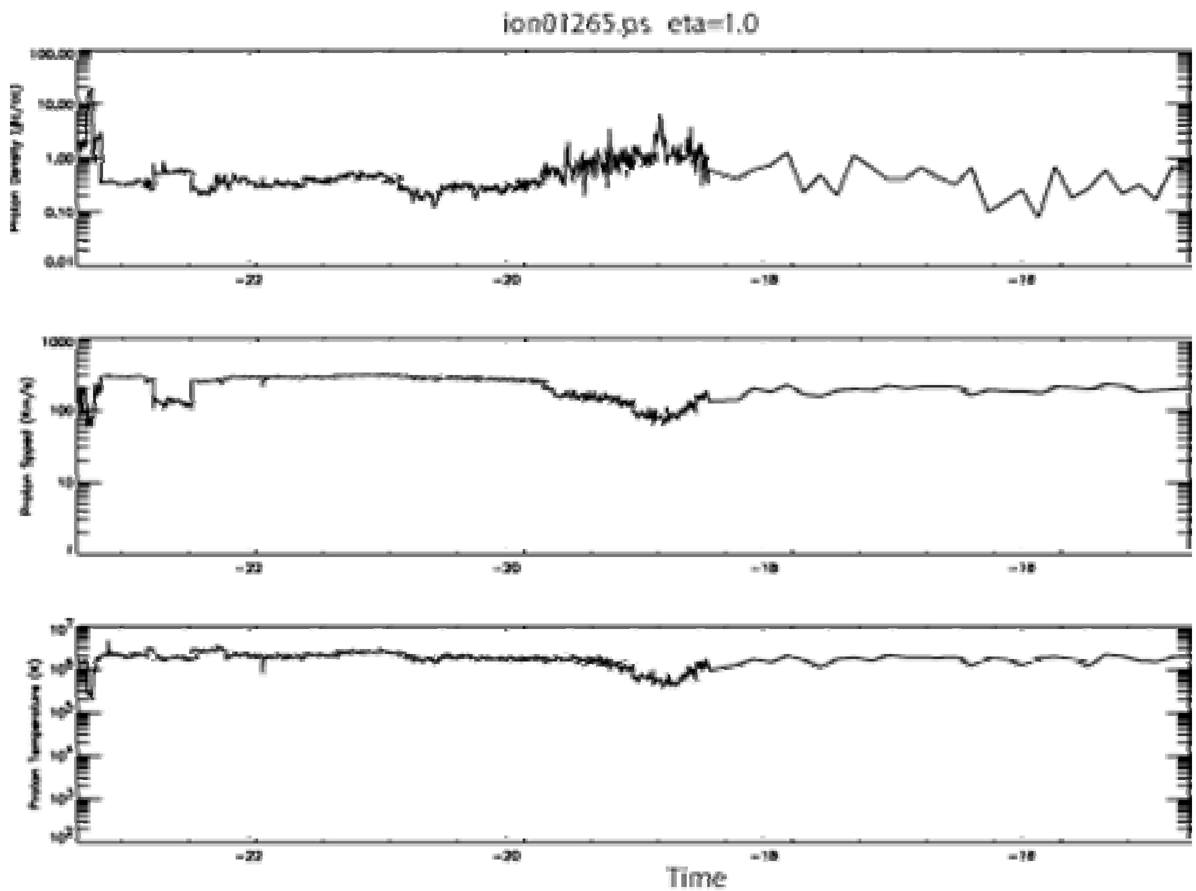
$$\langle \kappa T_s \rangle \quad \frac{2}{3} \left(\frac{\sum_{i,j,k} \frac{C_{i,j,k} \left(\frac{\Delta E_i}{E_i} \right) E_i^{1/2} \Delta\Sigma_{j,k}}{G_{j,k} \, \eta}}{\sum_{i,j,k} \frac{C_{i,j,k} \left(\frac{\Delta E_i}{E_i} \right) E_i^{-1/2} \Delta\Sigma_{j,k}}{G_{j,k} \, \eta}} - m_s U_s^2 \right)$$


ion01262.ps eta=1.0
Proton Density (#/cc)
Proton Speed (km/s)
Proton Temperature (K)
Time


ion01262.ps eta=0.3
100.00
10.00
1.00
0.10
0.01
3.0
3.5
4.0
4.5
5.0
1000
100
10
Time


ion01264.ps eta=1.0
Time


ion01264.ps eta=1.0
100.00
10.00
1.00
0.10
0.01
1000
100
10
1
-14
-12
-10
-8
Time



Proton Issues for Data Validation

• Efficiency factor η for density validation: cross-calibration with other spacecraft proton data to determine η accurately. It may also be angular dependent.
• Proton background counts correction (subtraction).
• To estimate the proton average temperature, it is necessary to subtract out the energy density due to bulk motion, thus an estimate of the proton bulk velocity $\mathbf{U_p}$ is required.
• A possible way to estimate the magnitude of the proton bulk speed is to plot from the M/Q data, the counts (or phase space density) for bin 0 versus energy to obtain the maximum peak.
•Good angular resolution for other vectorial moment quantities such as: bulk velocity, temperature anisotropy, etc.
•The data files are perhaps easily understood if the counts are formatted in matrix form with dependence on elevation, energy and time for each azimuth.

Ion Composition Issues for Data Validation

• Model dependent → p are the unknown parameters to be determined by a minimization (Chi-Squared) method.

$$\chi^2(C_i, E_i; \vec{p}) = \sum_i \frac{\left[C_i^{data} - C_i^{model}(\vec{p})\right]^2}{\sigma_i^2}$$

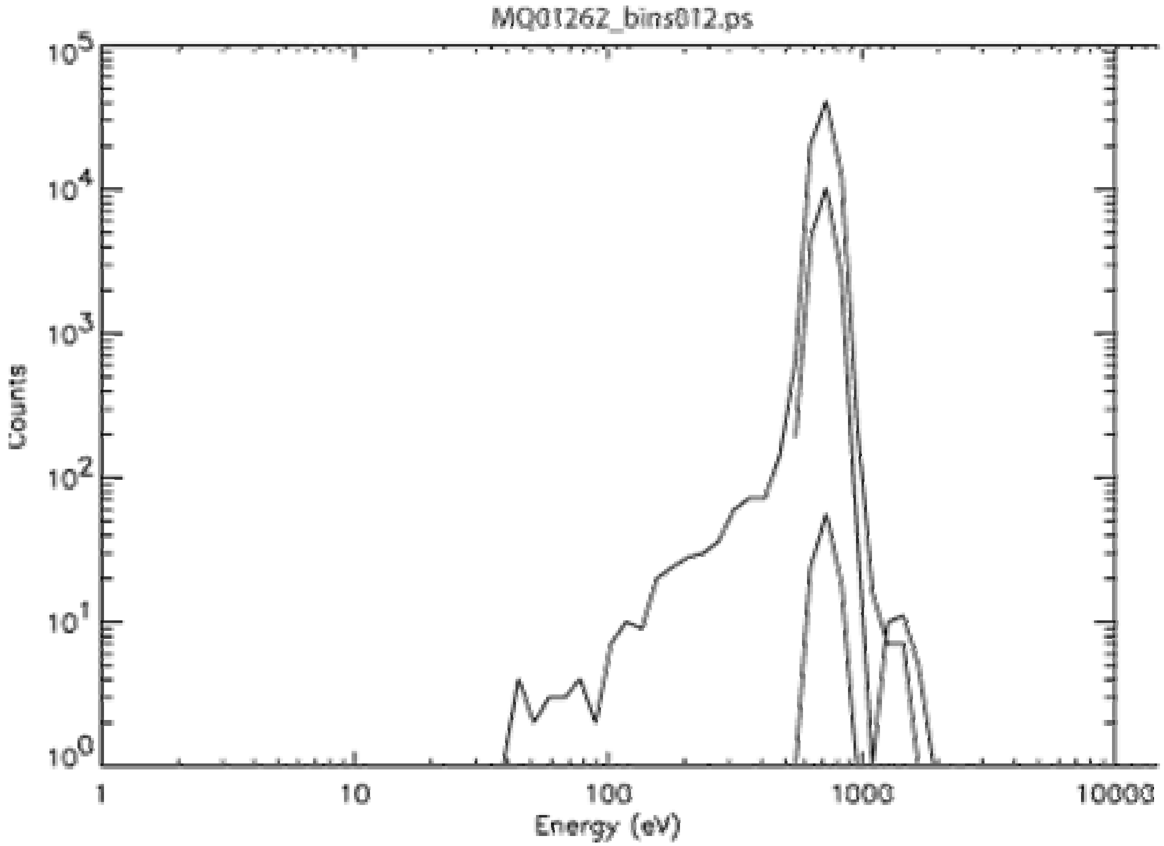
Where the average counts model C^{model} is obtained as follows:

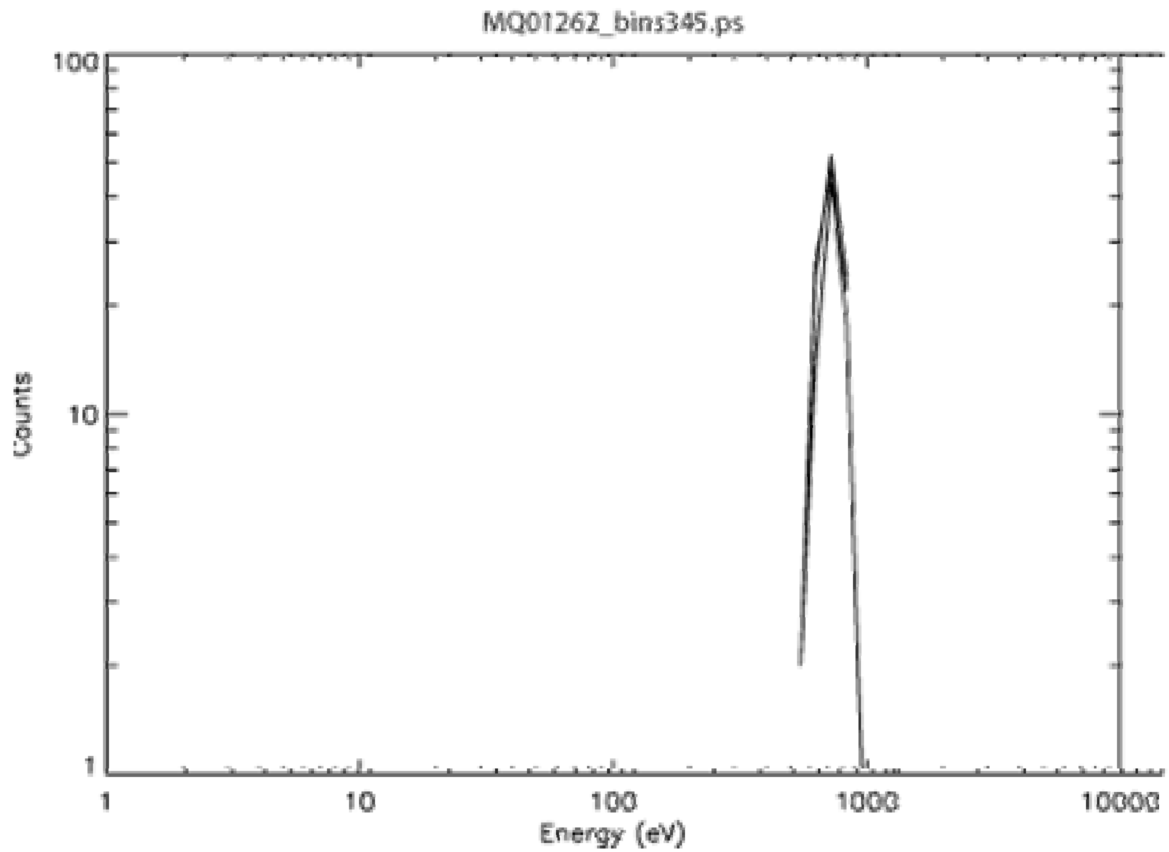
$$\left\langle C_i^{model} \right\rangle = \left\langle 2G\eta\,\Delta\tau\,\left(E_i / q_s\right)^2 \right\rangle \left\langle f_s^{model}\left(E_i\right) \right\rangle / \left(m_s / q_s\right)^2$$

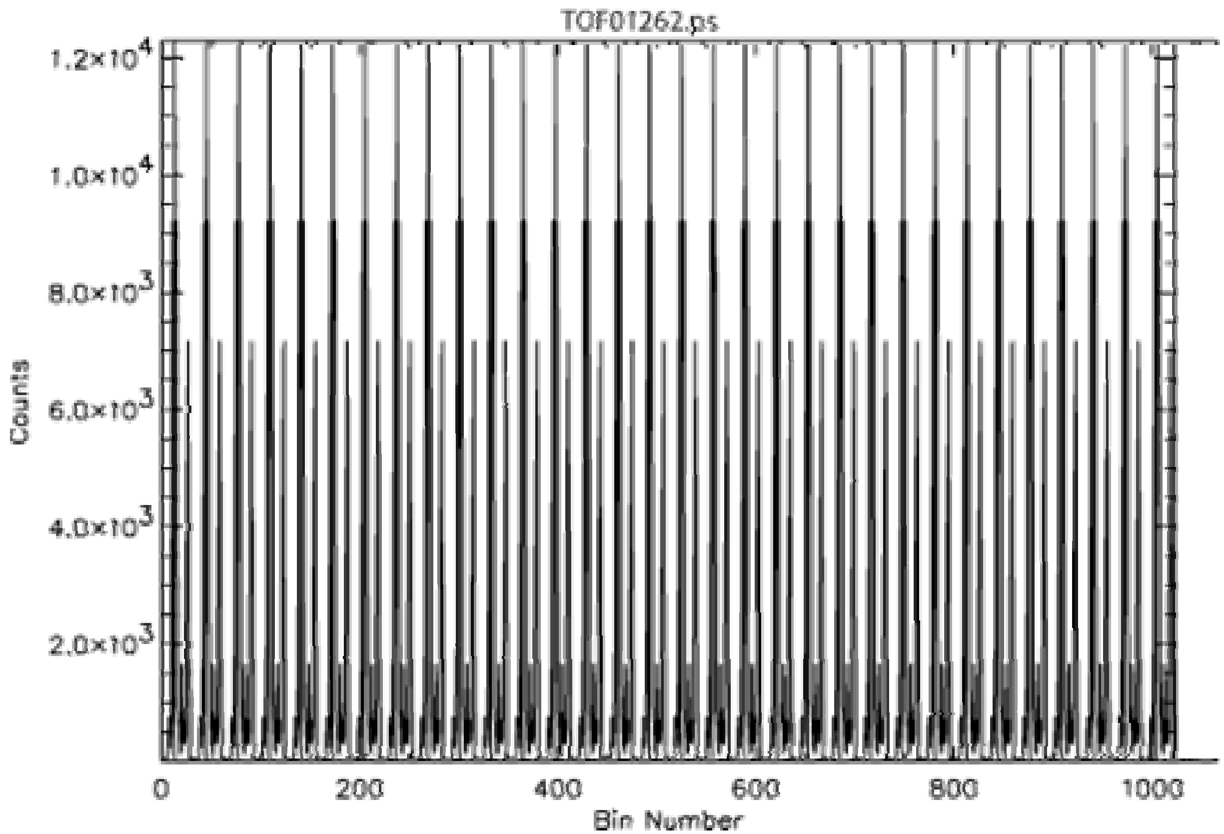
For example: f^{model} can be represented by a Maxwellian distribution

$$f_s^{model}\left(E_i\right) = \frac{n_s}{\pi^{3/2} w_{th}^3} \exp(-\left(\mathrm{v} - U_s\right)^2 / w_{th}^2) = \frac{n_s}{\pi^{3/2} w_{th}^3} \exp(-\Delta E / E_{th})$$

Unknown parameters p → (m_s/q_s, n_s, U_s, w_{th})


MQ01262_bins012.ps
Counts
Energy (eV)
10^5
10^4
10^3
10^2
10^1
10^0
1
10
100
1000
10000


MQ01262_bins345.ps
Counts
Energy (eV)
100
10
1
1
10
100
1000
10000


TOF01262.ps
Counts
1.2×10^4
1.0×10^4
8.0×10^3
6.0×10^3
4.0×10^3
2.0×10^3
0
200
400
600
800
1000
Bin Number