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Low-Energy, LEO Protons in AP9

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Motivation

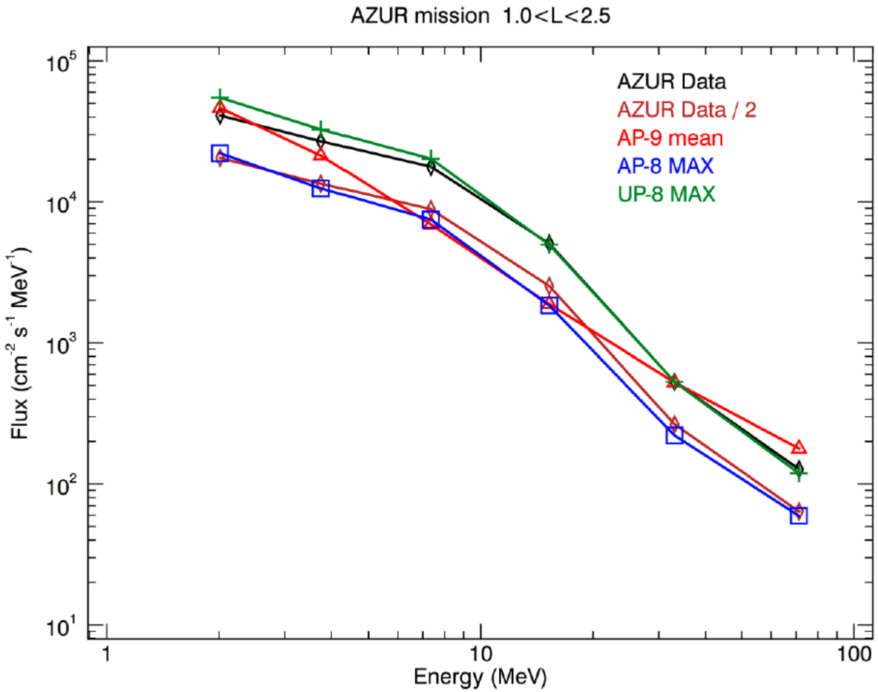
- ESA* performed an independent validation of AE9/AP9.
  - Compared AP9 with data and other models.
  - One conclusion was that AP9 proton fluxes are significantly higher than data and other models, especially for LEO and at low energy (< 10 MeV).
- AE9/AP9 (IRENE) team wanted to determine possible reasons and resolutions.
- This study focuses on the low energy LEO protons.
  - This is a very difficult population to measure.
  - We expect RBSP/RPS to provide the "definitive" measurements for > 50 MeV.

*Heynderickx, D., and P. Truscott, "NARMI Technical Note 2: Validation and Comparison Results," 27 October 2014.

Summary of ESA Findings (Relevant to LEO Protons)

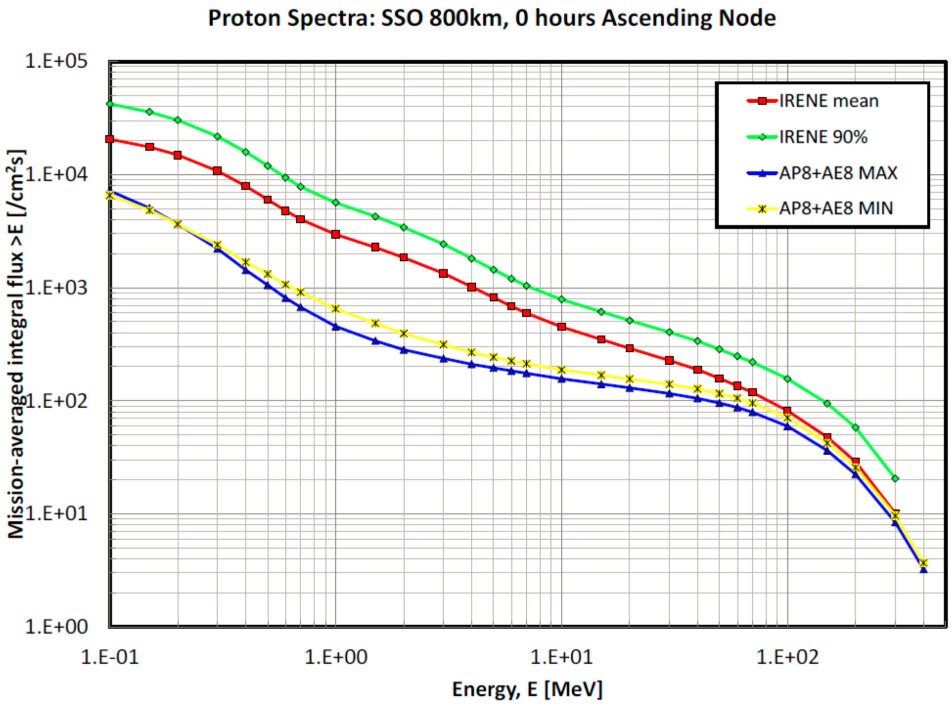
- **AP9 vs. Azur: AP9 mean overestimates except around 10 MeV, spectral shape does not agree with data and other models. Also overestimates extent of SAA region.**
- **AP9 vs. AP8, LEO: For all energies, the proton flux predictions from the AP9 Mean model are greater than the AP8 predictions by almost two orders of magnitude (rising to more than $\times 10^3$ at ~0.1 MeV).**
- **AP9 vs. AP8, GTO: >10 MeV, proton flux predictions from AP9 Mean model are greater than the AP8 predictions by up to ×3. At lower energies, opposite is true (AP8 potentially ×2 those from AP9 Mean). CRRESPRO Active model predicts average proton fluxes closer to AP8 predictions ~>10 MeV, but closely match AP9 Mean model results for lower energies.**

AP9 vs. Azur



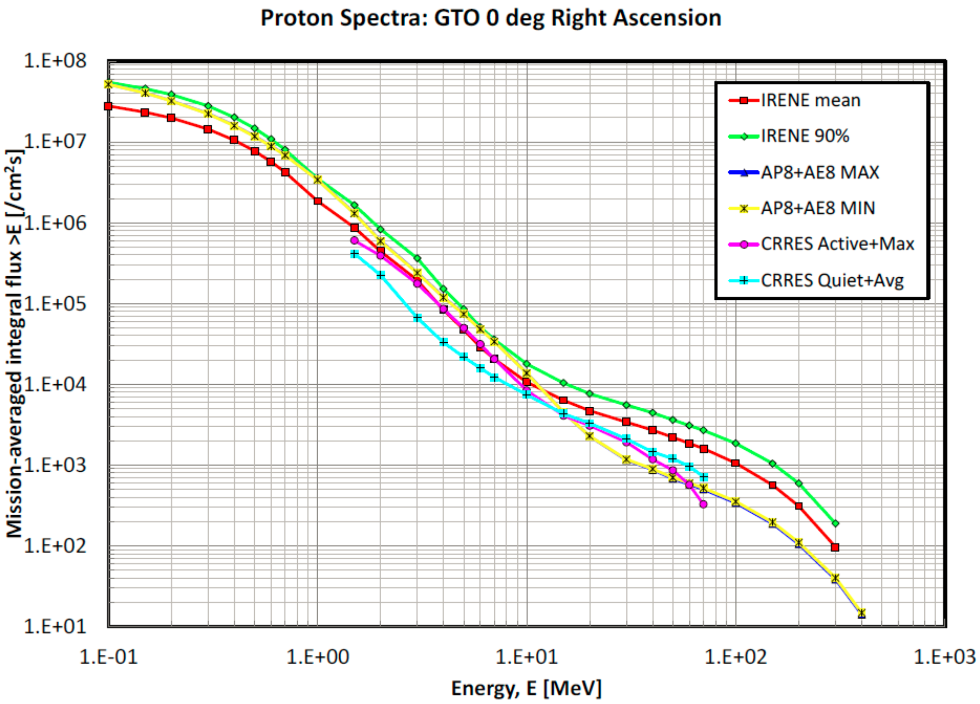
- **This plot compares spectra averaged over the Azur mission (all points for 1.0 < L < 2.5).**
- **AP9 has a different spectral shape.**
- **Note that AP8MAX is based mainly on Azur, so good agreement is expected.**

AP9 vs AP8: LEO



- **This plot compares AP9 with AP8 for a polar LEO orbit.**
- **At 1 MeV, AP9 is up to a factor of 10 higher than AP8.**
- **AP9 is more like a power law for E < 100 MeV.**

AP9 vs. AP8: GTO



- In GTO, AP9 shows harder spectra than AP8.
- AP9 mean is lower than AP8 for E < 10 MeV, higher for E > 10 MeV.
- At 1 MeV, AP9 mean is about a factor of 2 less than AP8.

Analyses Performed

AE9/AP9 Team performed several analyses to investigate reasons for differences:

- **"Binspectra" plots**
  - Plot energy spectra in each AP9 bin for all data sets used.
  - Plot model as well.
  - We have added additional data sets not currently in AP9 (e.g., Azur, S3-3).
  - These show uncertainty of measurements and model in each bin.
- **S3-3 analysis**
  - Flew in 1976 – 1979 (about 6 years after Azur, rising part of solar cycle).
  - 236 x 8048 km x 97.5° orbit; 0.08 – 3.2 MeV.
  - Data formed the basis for a low-energy model by Vampola.
  - Data showed very high fluxes for L < 1.9.
  - Although S3-3 data have not been used directly in AP9, they were included in templates.
  - Analysis focused on identifying potential contamination.
- **TacSat-4 data analysis**
  - Attempt to deduce spectral shape from counts in different CEASE channels.
  - Intent is to determine whether TacSat-4 data is consistent with a spectral shape like Azur.

Summary of Results

- **Binspectra plots**
  - There are often large differences among data sets.
  - Azur is often the odd one out.
  - Agreement among data sets improves above L ≈ 1.5.
- **S3-3**
  - No reason to doubt large fluxes for L < 1.9.
  - May be a transient phenomenon, but fairly stable over 2.8 years of data.
- **TacSat-4 Tests**
  - TacSat-4/CEASE response appears to be inconsistent with Azur spectral shapes.

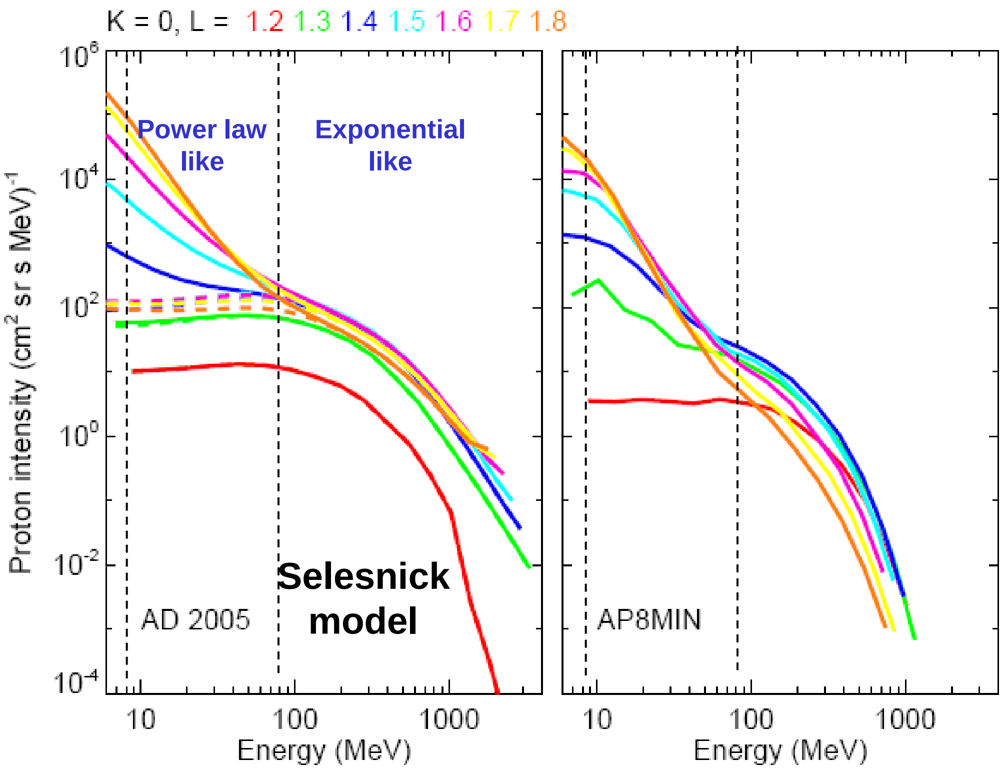
Miscellaneous Points (1)

- ESA comparisons are with AP9 V1.0.
  - AP9 V1.20 differs slightly.
- ESA comparisons with Azur use differential, omnidirectional flux.
  - A more direct comparison would use unidirectional difference fluxes, since Azur data is unidirectional with wide energy bins
  - ESA's conclusions are still valid.
- For E < 10 MeV, AP9 is largely driven by data from CRRES/PROTEL.
  - Much work was performed to remove initial contamination of measurements at E < 10 MeV (including after release of CRRESPRO model).
  - Note that in many cases AP9 fluxes are more like CRRES active data.

Miscellaneous Points (2)

- Measurements of < 10 MeV protons in inner zone are very difficult, primarily due to contamination from penetrating protons.
- The fact that Azur is lower than other data sets indicates that the others could be contaminated (but not beyond a reasonable doubt).
- If 1 – 10 MeV protons in LEO are really as intense as AP9 predicts, would solar arrays be failing faster than observed?
- Analytical models indicate a range of spectral shapes, but these are for energies > 10 MeV (see following charts). Spectrum below 10 MeV could be flat or power law (or something else).

Spectral Shapes: Selesnick et al., 2007



- **This figure from Selesnick et al. shows spectra from model and AP8 at solar minimum.**
- **Both show flat spectra below 100 MeV at low L.**

From Selesnick, et al., *Space Weather*, 5, s04003, doi:10.1029/2006SW00275, 2007.

Spectral Shapes: Blanchard & Hess (1966)

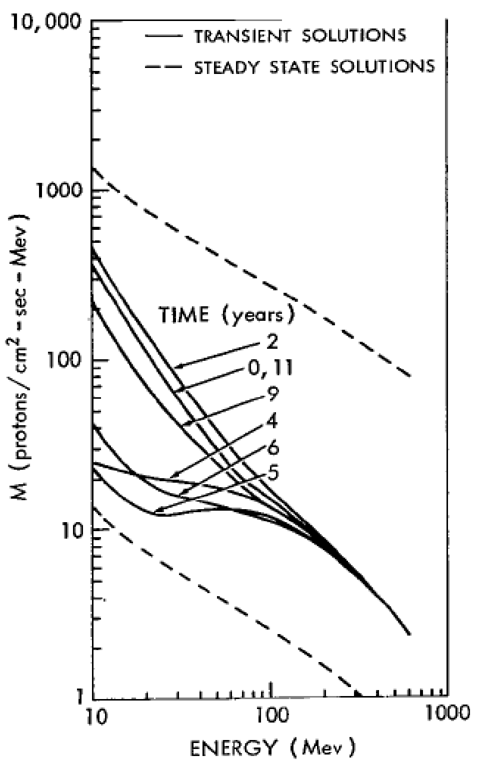


Figure 42—Proton energy spectra at different times in the solar cycle for L = 1.188, B = .1884, h_{min} = 650.

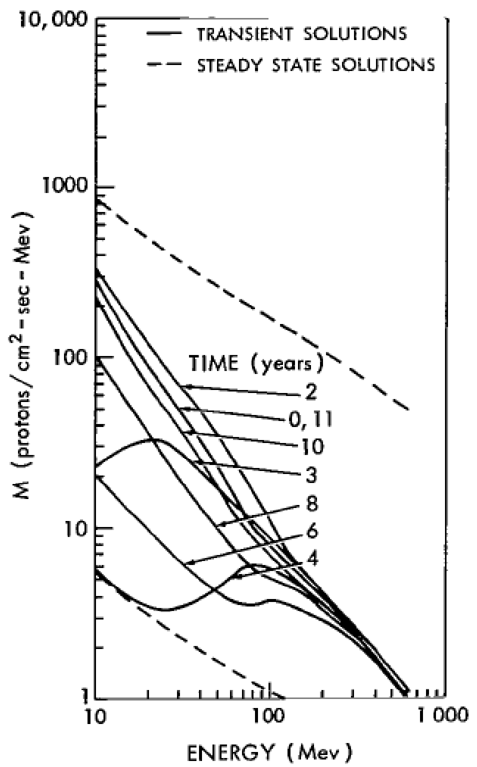


Figure 43—Proton energy spectra at different times in the solar cycle for L = 1.188, B = .193, h_{min} = 580.

- **These figures from Blanchard and Hess show model spectra at low L over the solar cycle.**
- **Here we see some flattening at low energies 3 – 5 years after solar min, power-law at other times.**
- **Note that Blanchard & Hess, Selesnick et al., and other models are all for E > 10 MeV.**
- **Claflin & White (1974) predict relatively flat spectra below 10 MeV.**

Spectral Shapes: Other Data

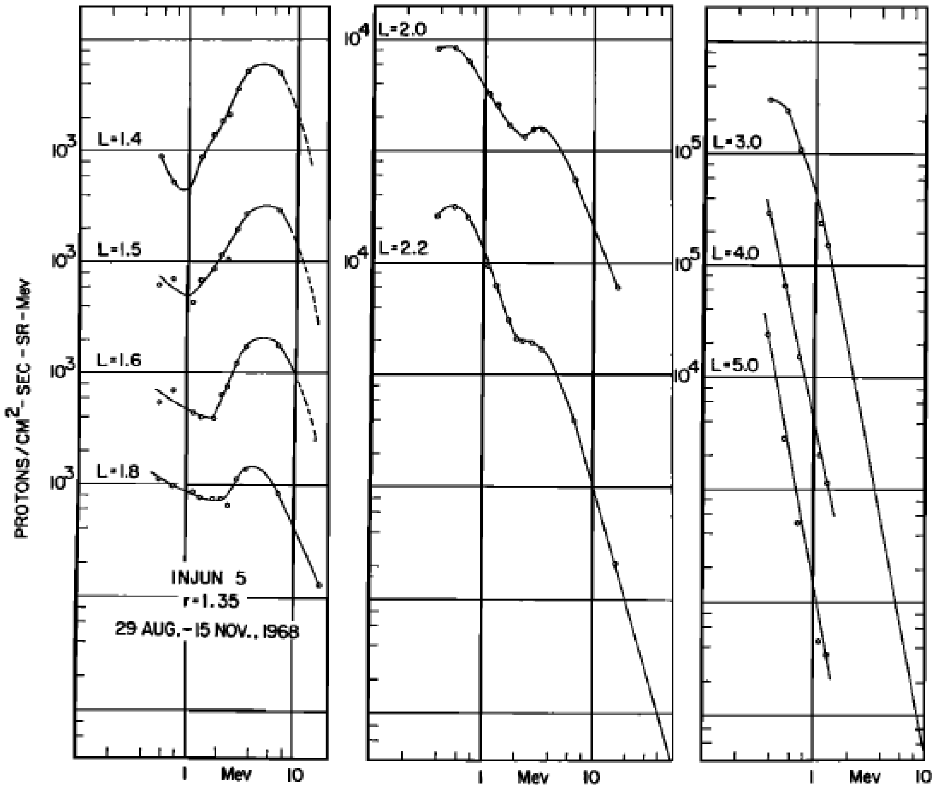


Fig. 2. Experimental proton differential energy spectra at $r = 1.35$ and various L values.

- **Data from Injun 5 in 1968 (Pizzella and Randall, 1971) – about 1 year prior to Azur.**
- **This data was used in AP8.**
- **Note minimum in spectrum for E ≈ 2 MeV at low L.**

Spectral Shapes: AP8 & Older Data

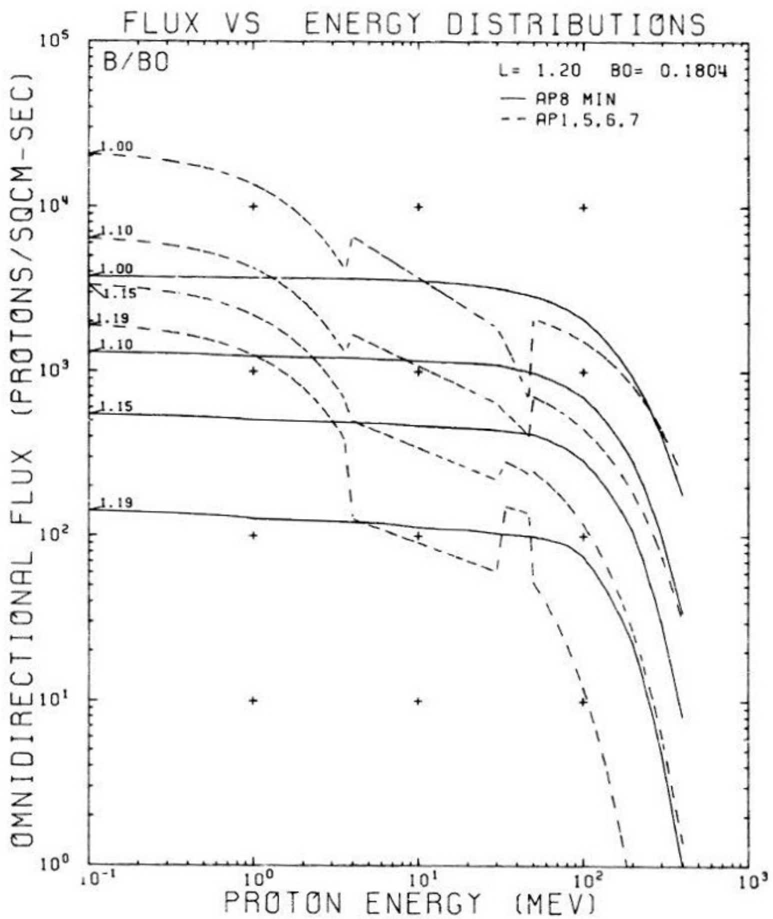


Figure 144. AP8MIN and AP-1, -5, -6, and -7 Flux vs Energy Comparison Plot for L = 1.20 R_E

- This plot from the AP8 report shows the evolution of model spectra at L = 1.2.
- Note that these are integral, omnidirectional fluxes.
- Early model AP-5 did have higher fluxes at lower energies.
  - AP-5 covered 0.1 – 4 MeV, assumed an exponential spectral shape (in integral flux).
- Relay 1 (1963) measured 3 MeV fluxes about 9 x Azur (1970) at L ≈ 1.7.
- Vette probably modified the shape based on Injun 5 and Azur.
- This illustrates the uncertainty and difficulty in developing global models including many data sets and a large energy range.

Other Validation Studies

- **Badavi (*Adv. Space Res.*, 2014) found AP9 agreed better than AP8 w/dosimeter measurements on ISS.**
  - **Presumably, these results are relevant at higher energies (> 40 MeV).**
  - **Results are dependent on transport through complex ISS structure.**

Conclusions (1 of 2)

- **No apparent contamination in S3-3 data.**
  - **Implies that high fluxes at low energies are possible.**
- **Spectral bias in CEASE fluxes not a major issue.**
- **AP9 agrees with many data sets that we trust.**
- **We also trust Azur data.**
- **Most likely hypothesis is that Azur (and Injun 5) and S3-3 represent two different geophysical states.**

Conclusions (2 of 2)

- Including Azur data should bring AP9 fluxes down, unclear how much.
  - Error bars will also change.
- Need to eventually explain the discrepancies and natural variability.

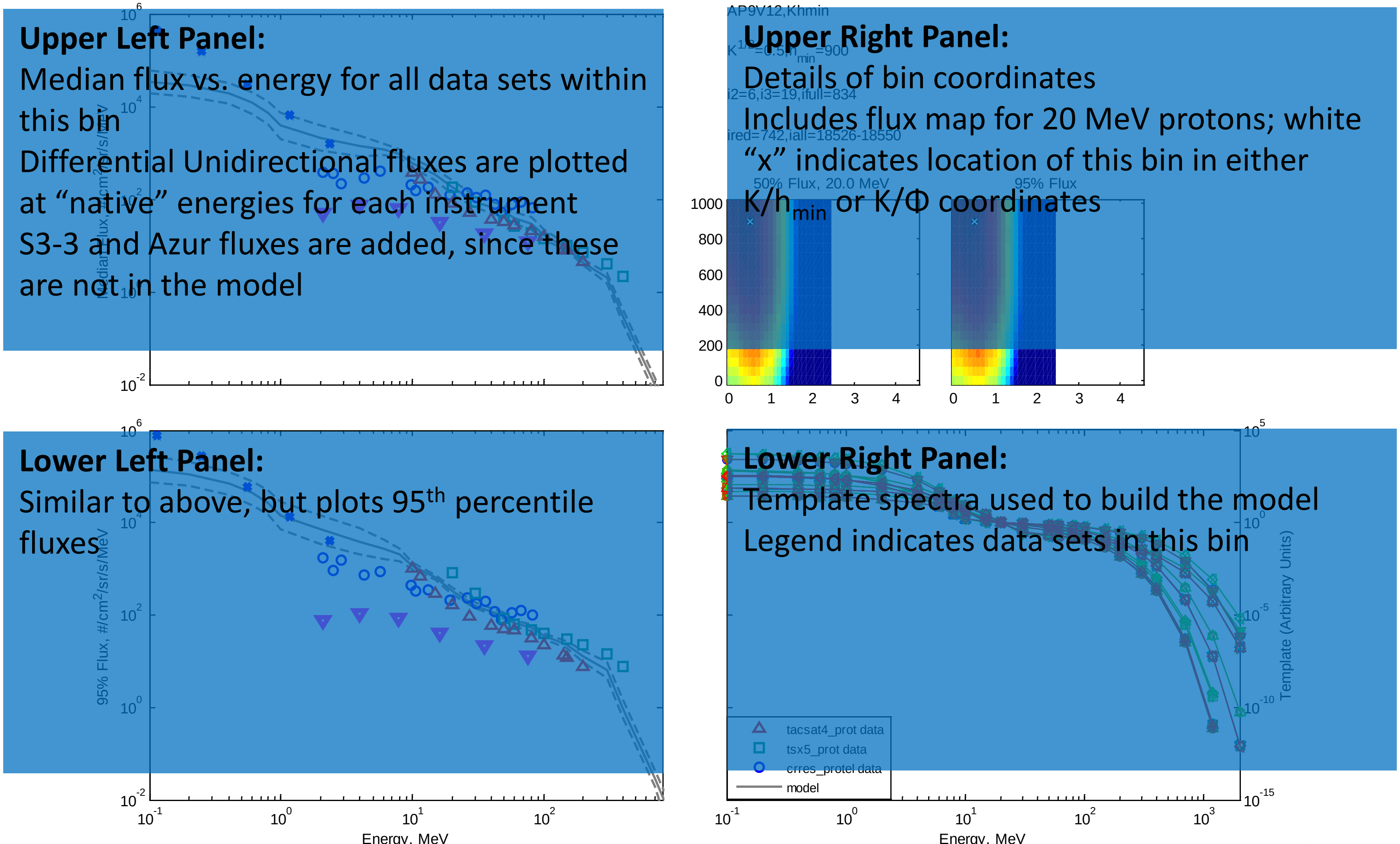
- What does RBSP (e.g., MagEIS) have to say?

Azur and S3-3 Binspectra Plots

Binspectra Plots

- **Part of the "turnkey" process to develop AE9/AP9 flux maps is the generation of "binspectra" plots for diagnostics.**
- **These plot all data sets used within a K/Phi or K/h_{min} bin together with the model flux.**
- **We examined the data in several low altitude bins to show the range of measurements .**
- **We also plotted data from Azur and S3-3.**
- **These plots are from the development of AP9 V1.20, and contain data from TacSat-4/CEASE in addition to the V1.00 data sets.**

Explanation of Binspectra Plots



Upper Left Panel:

Median flux vs. energy for all data sets within this bin

Differential Unidirectional fluxes are plotted at “native” energies for each instrument

S3-3 and Azur fluxes are added, since these are not in the model

Upper Right Panel:

Details of bin coordinates

Includes flux map for 20 MeV protons; white “x” indicates location of this bin in either K/h_{min} or K/Φ coordinates

Lower Left Panel:

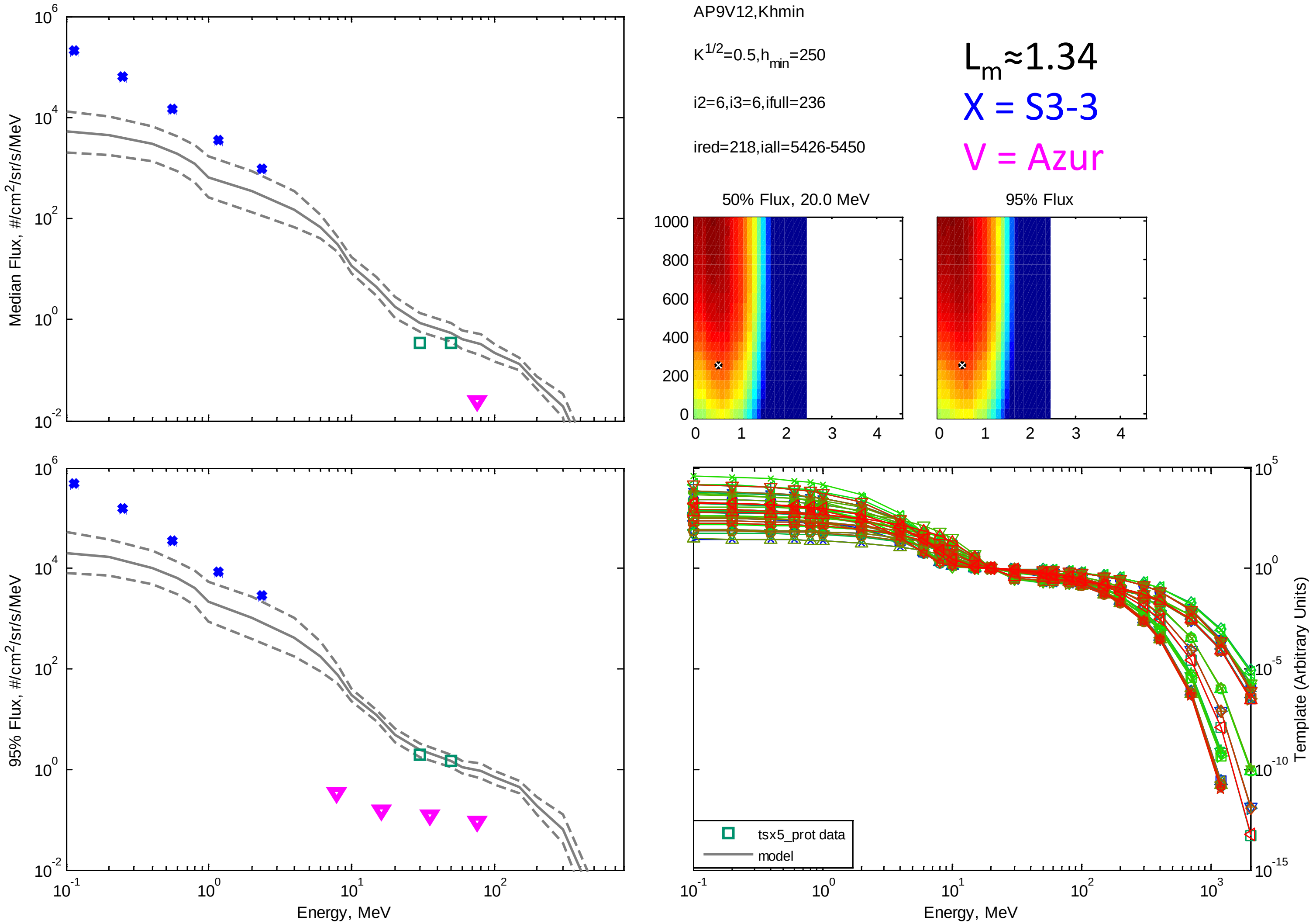
Similar to above, but plots 95th percentile fluxes

Lower Right Panel:

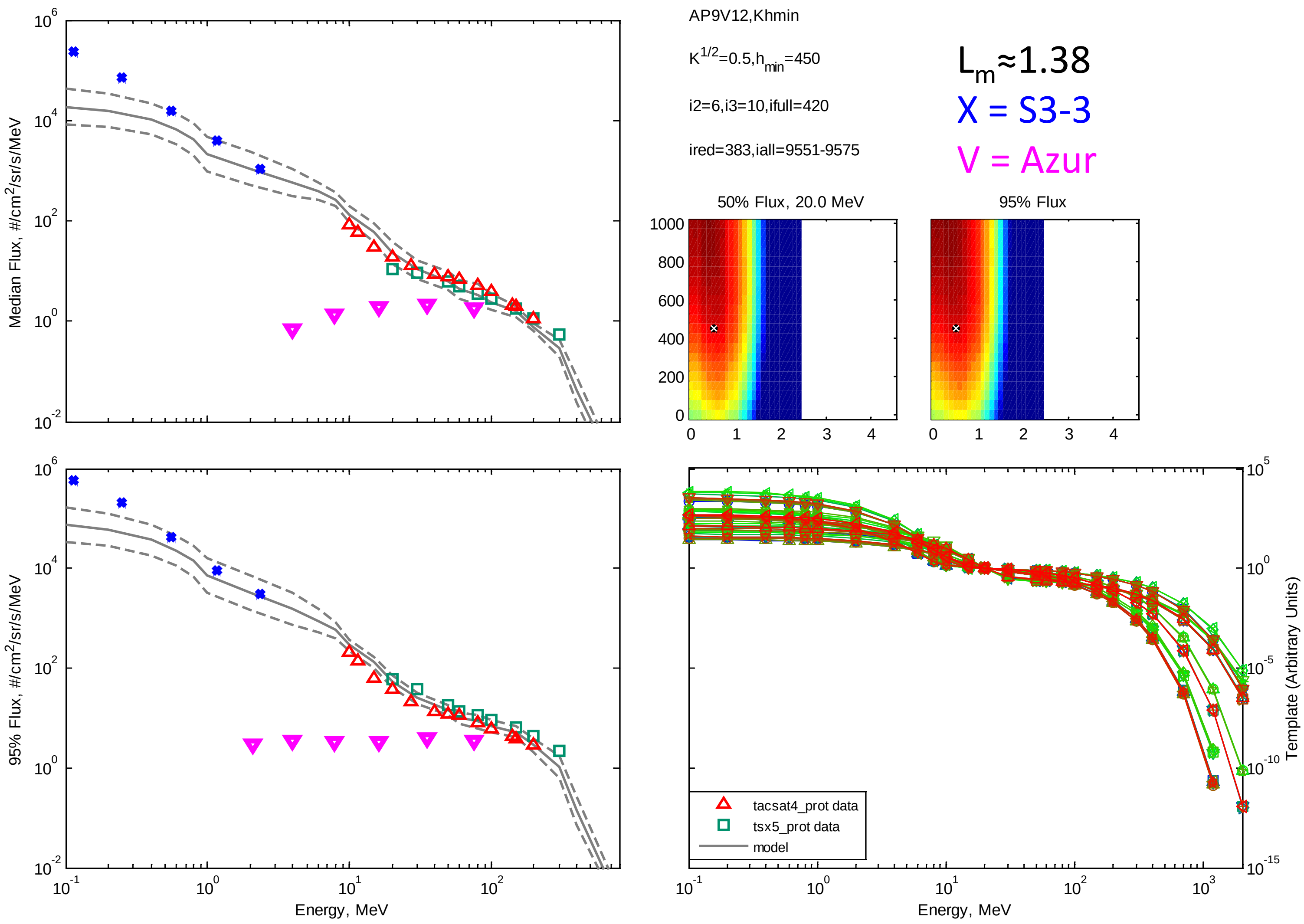
Template spectra used to build the model

Legend indicates data sets in this bin

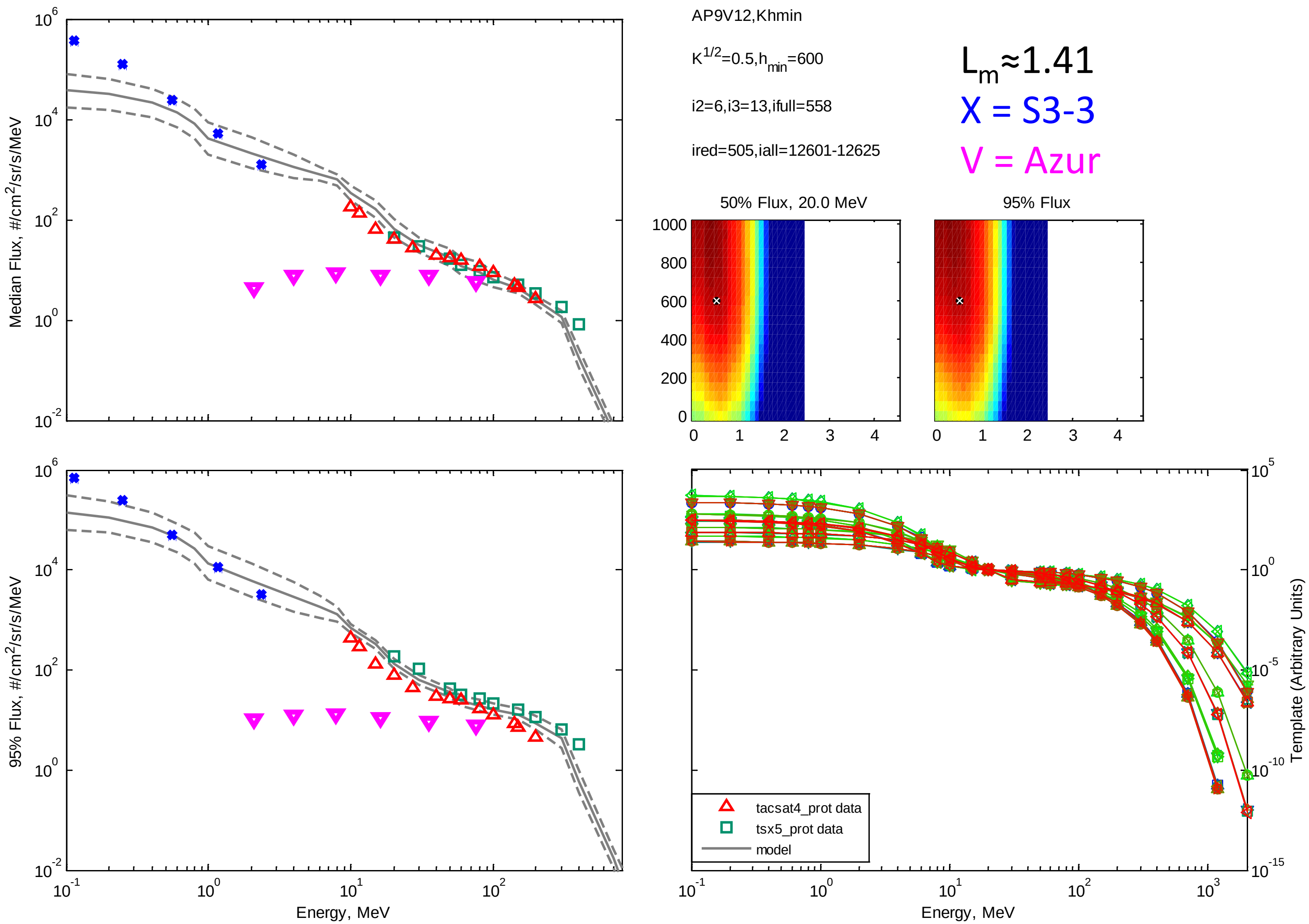
$L_m \approx 1.34, K^{1/2} = 0.5, h_{min}=250$



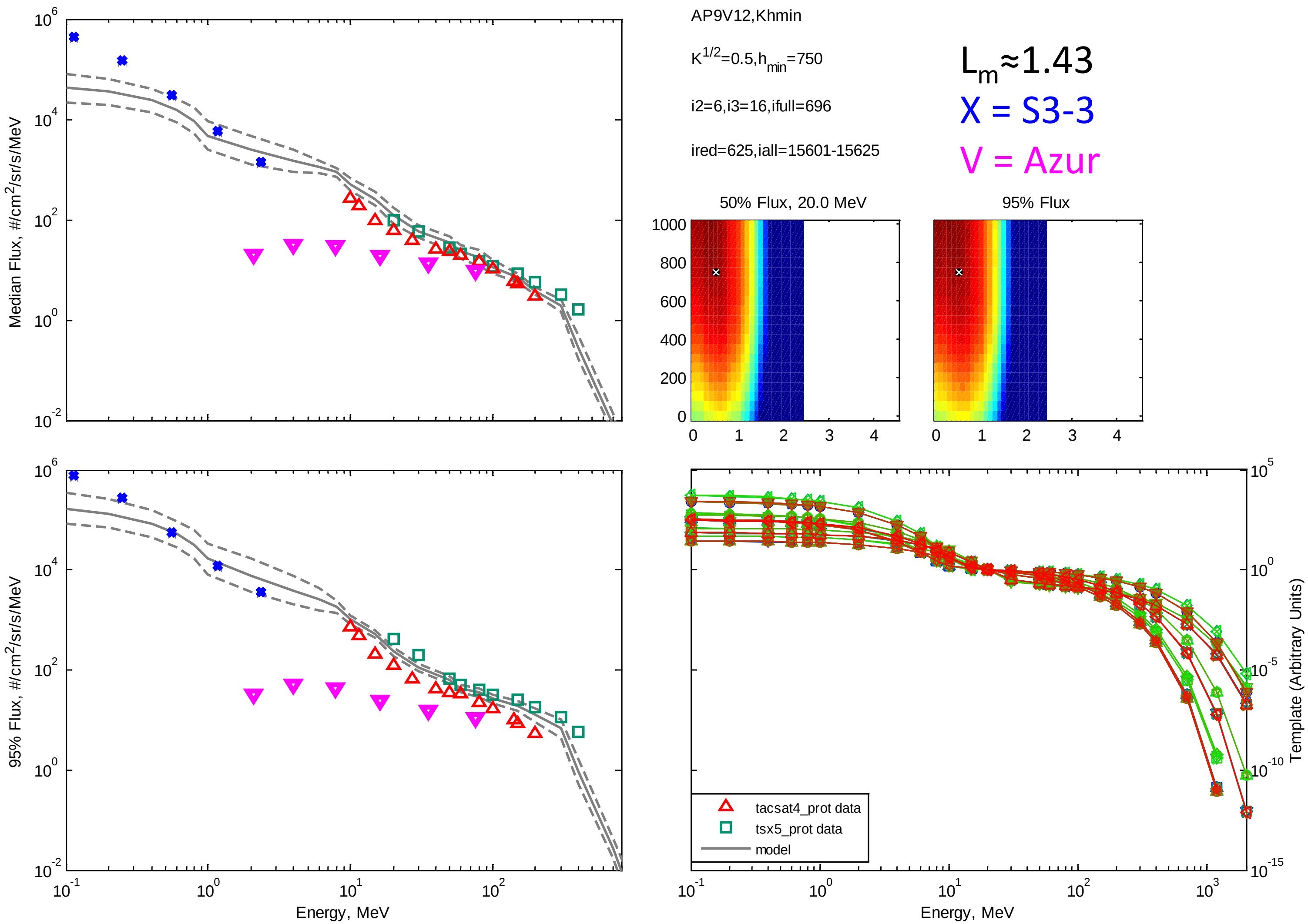
$L_m \approx 1.38$, $K^{1/2} = 0.5$, h_{min}=450



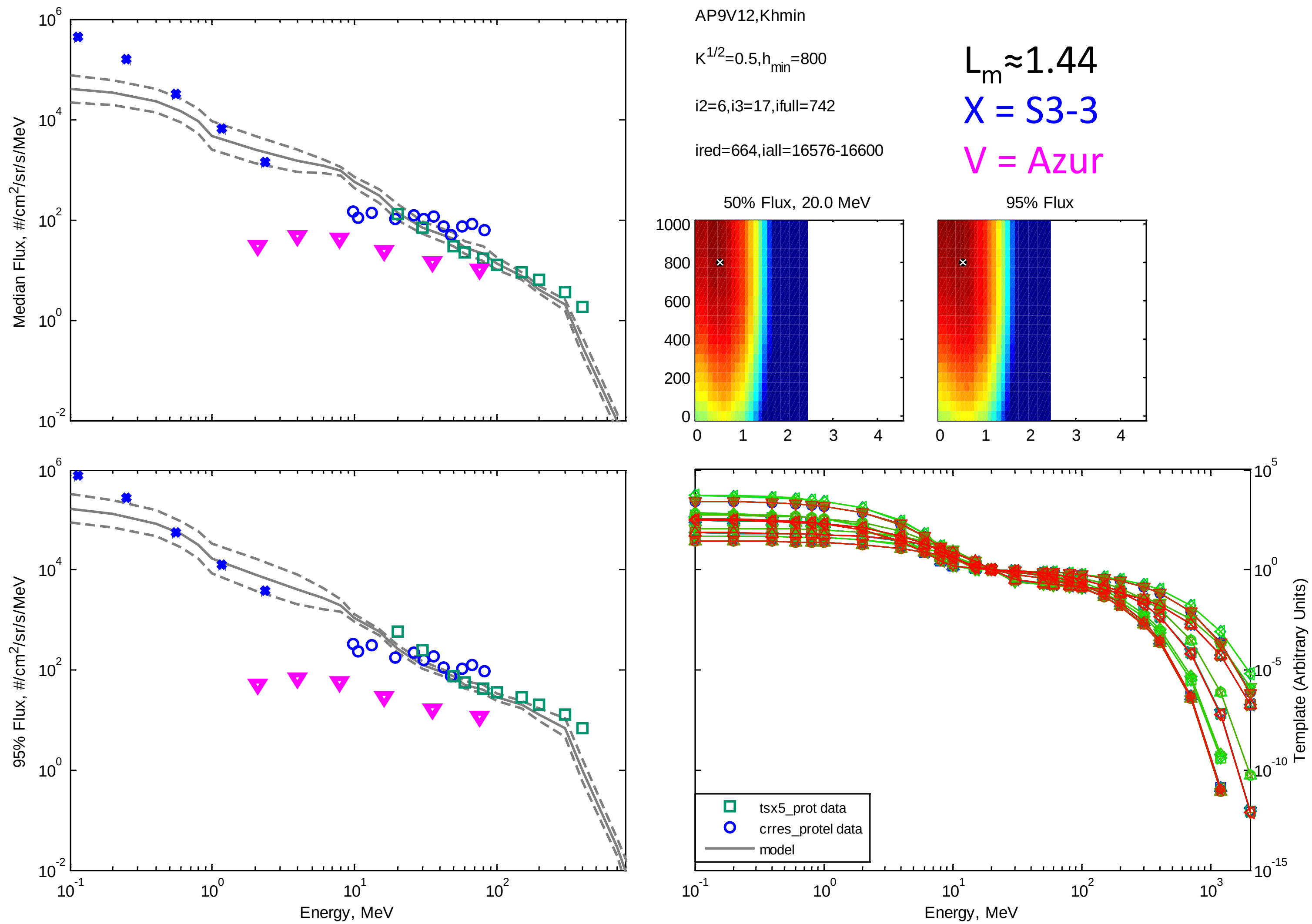
$L_m \approx 1.41, K^{1/2} = 0.5, h_{min}=600$



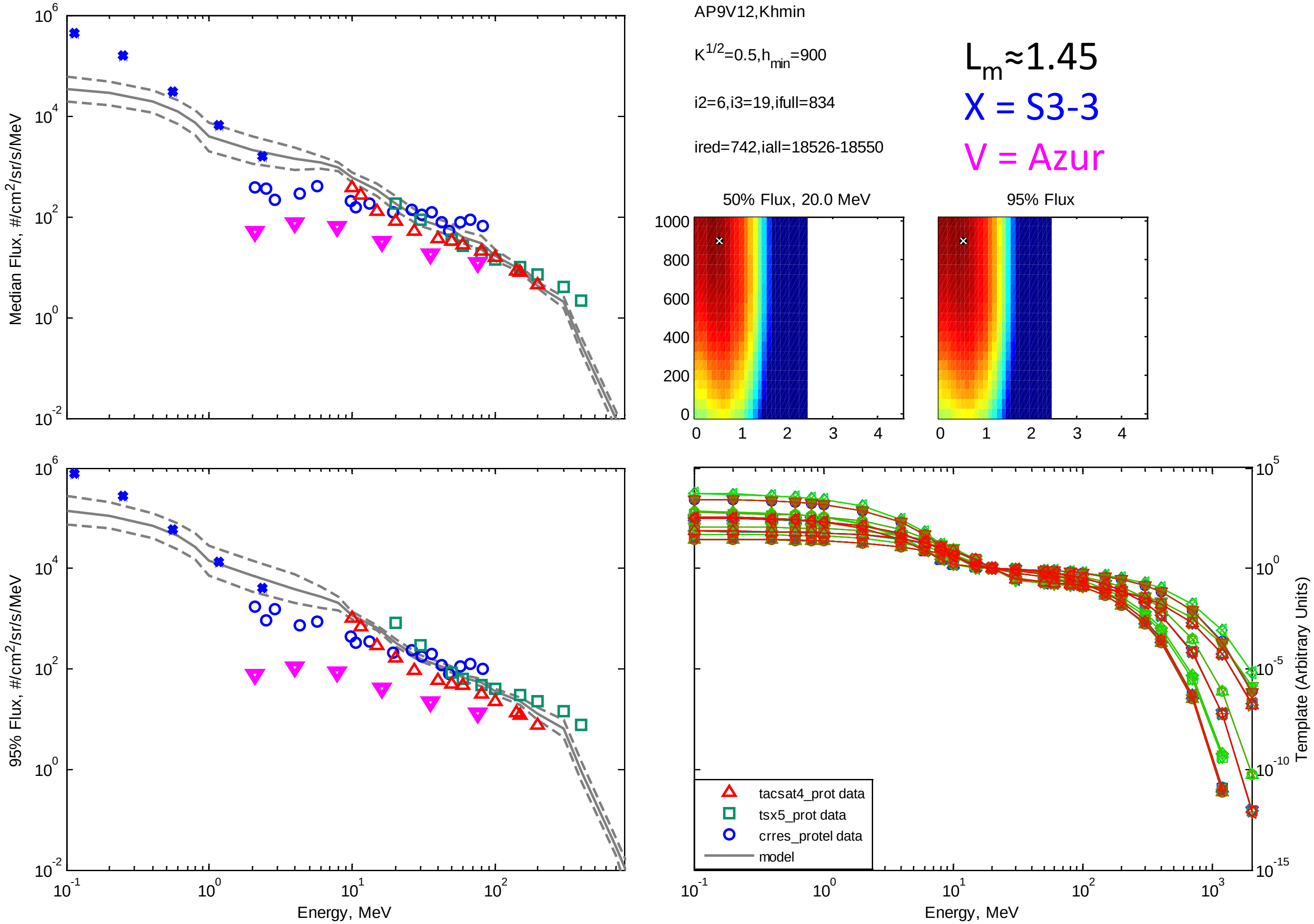
$L_m \approx 1.43$, $K^{1/2} = 0.5$, $h_{min}=750$



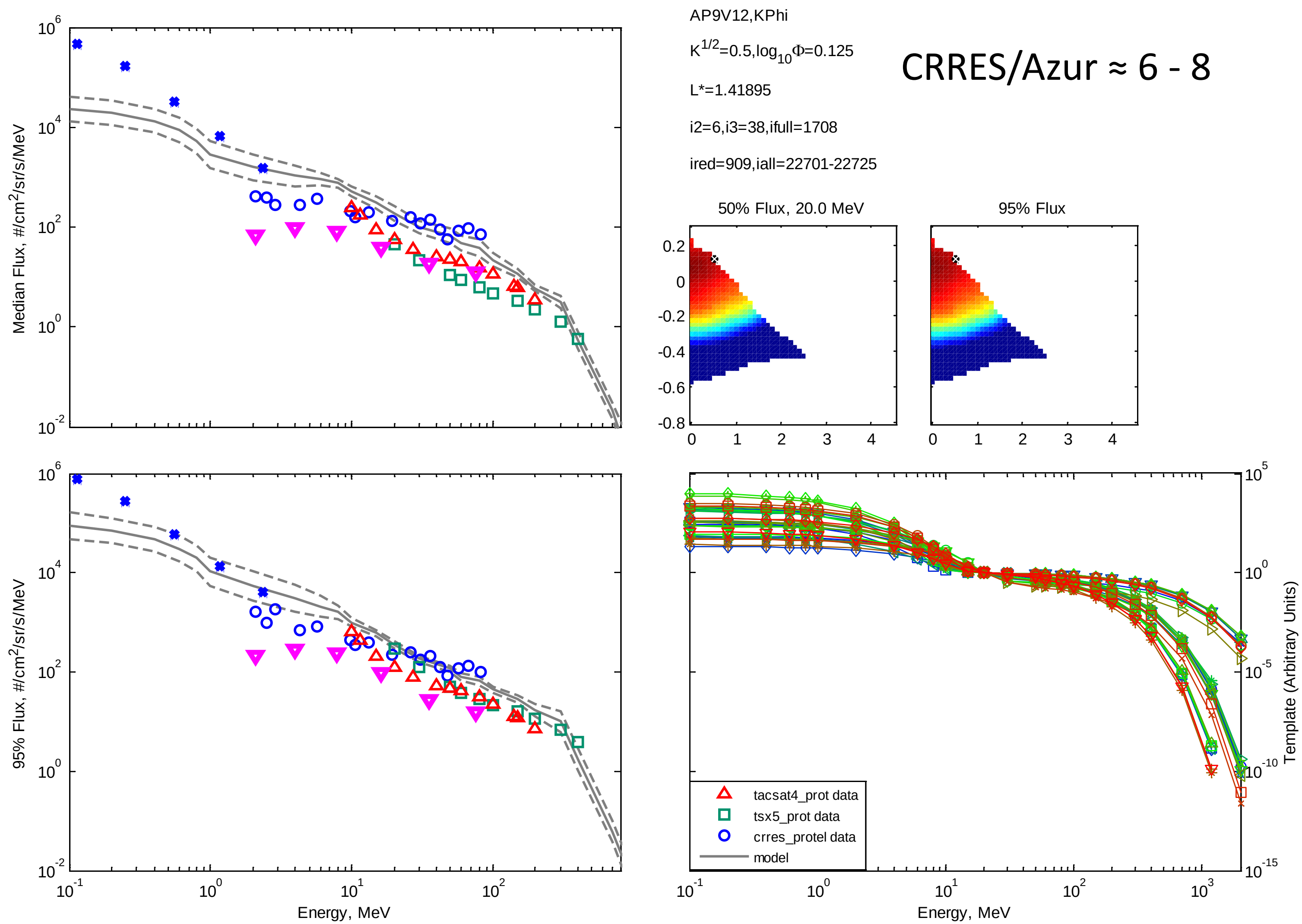
$L_m \approx 1.44, K^{1/2} = 0.5, h_{min}=800$



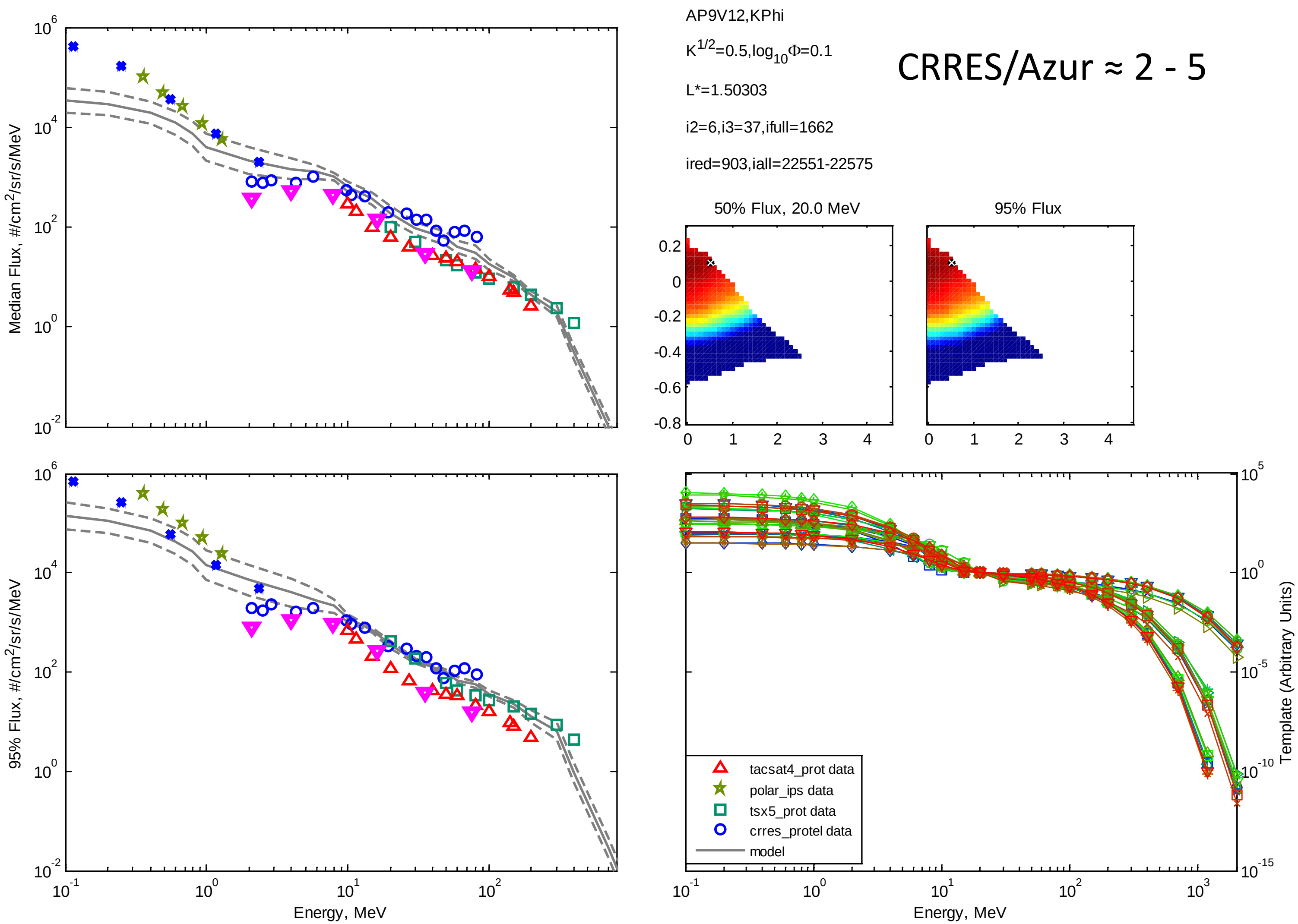
$L_m \approx 1.45, K^{1/2} = 0.5, h_{min}$=900



$L_m \approx 1.419$, $K^{1/2} = 0.5$



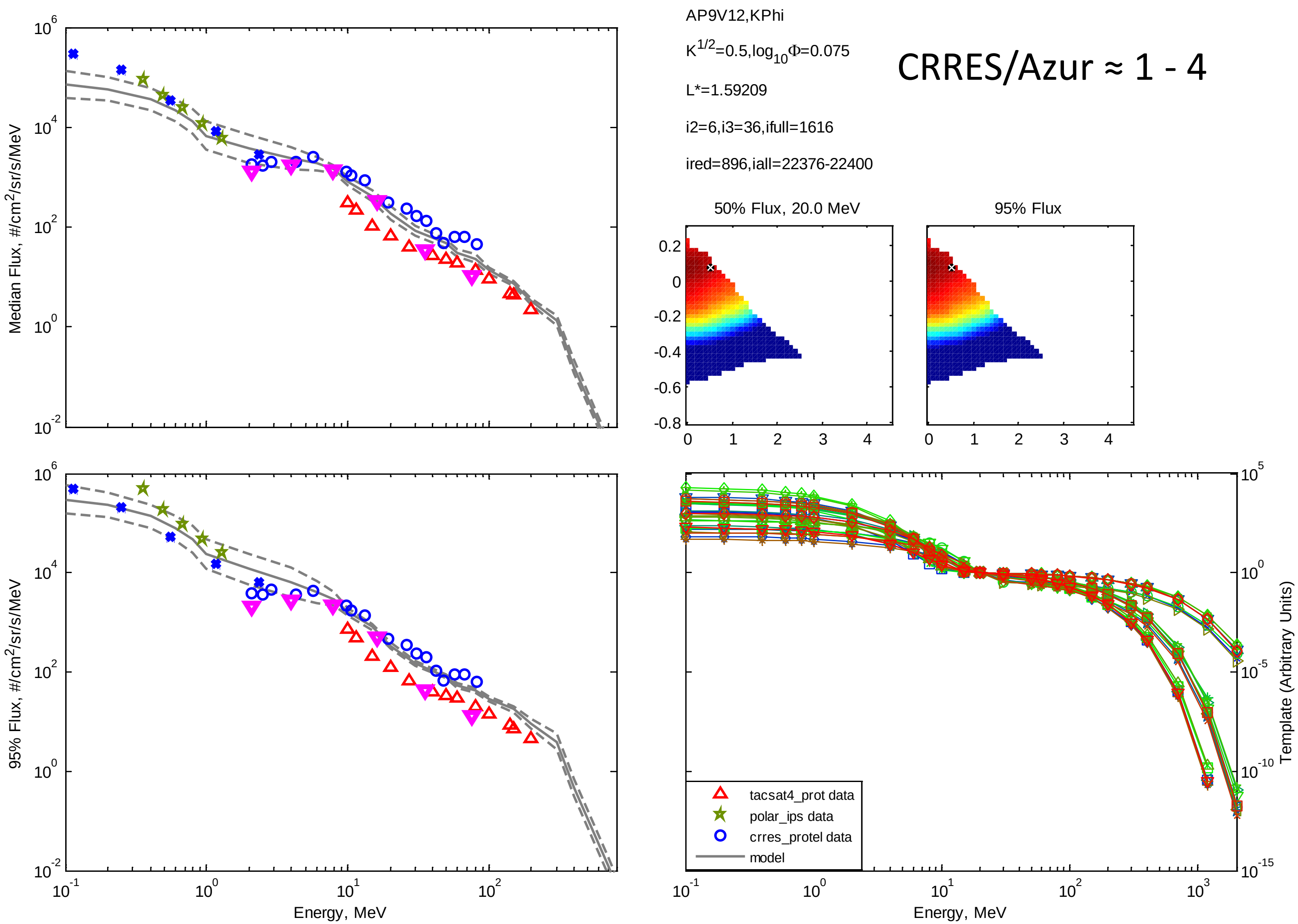
$L_m \approx 1.503$, $K^{1/2} = 0.5$



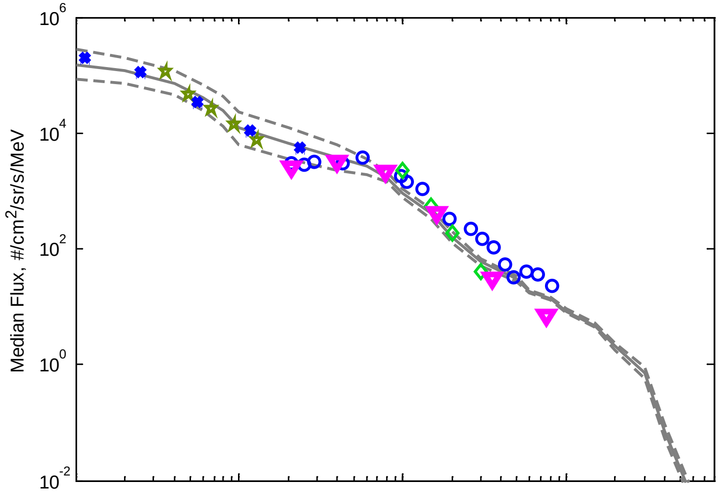
CRRES/Azur ≈ 2 - 5

$L_m \approx 1.592, K^{1/2} = 0.5$

CRRES/Azur ≈ 1 - 4



$L_m \approx 1.686$, $K^{1/2} = 0.5$



AP9V12,KPhi

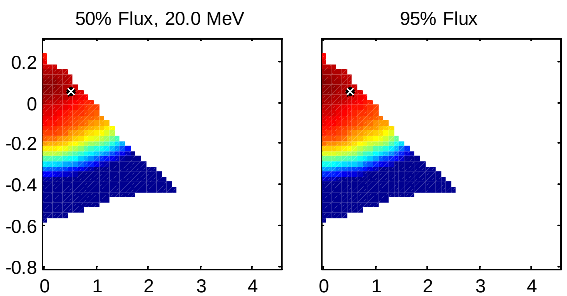
$K^{1/2}$=0.5,$\log_{10}\Phi$=0.05

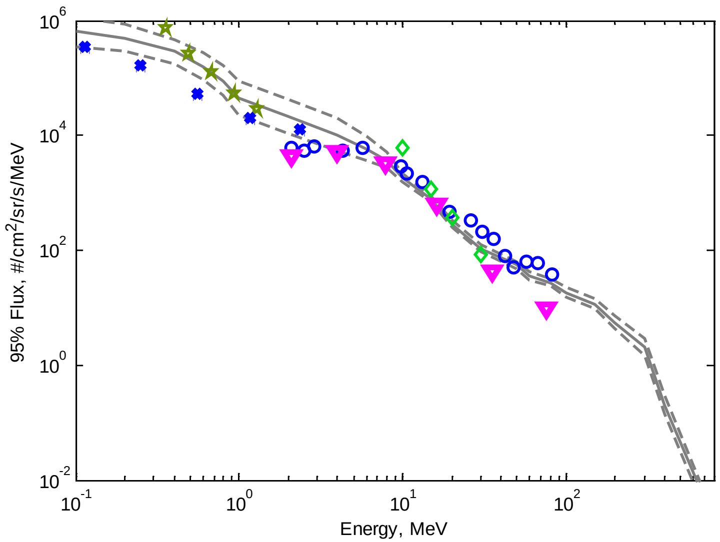
L*=1.68643

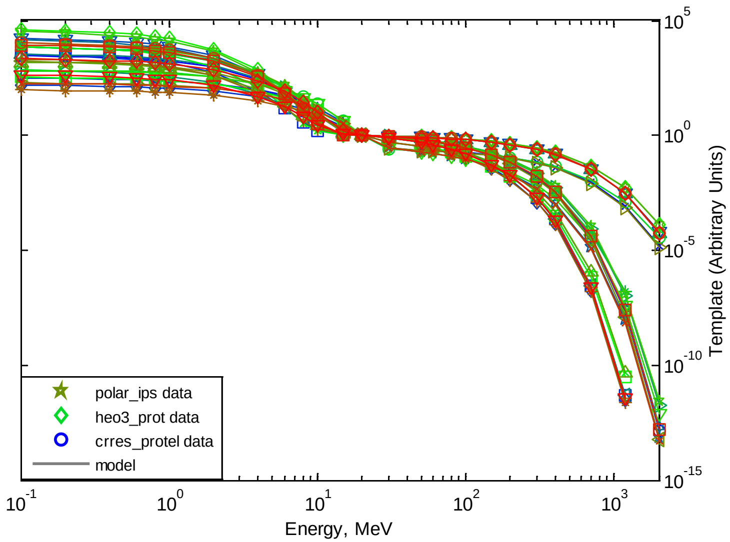
i2=6,i3=35,ifull=1570

ired=888,iall=22176-22200

CRRES/Azur ≈ 1 - 3

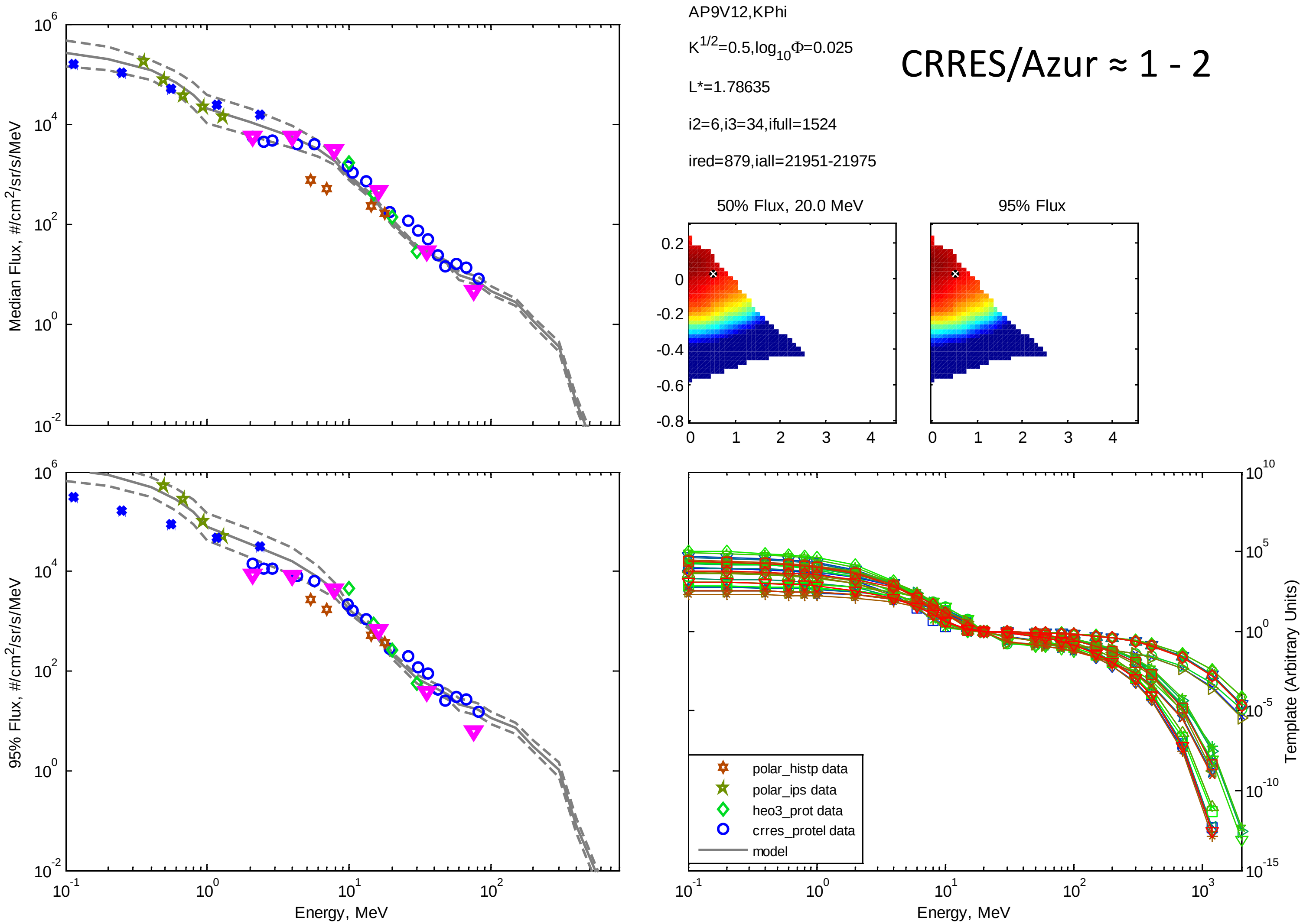






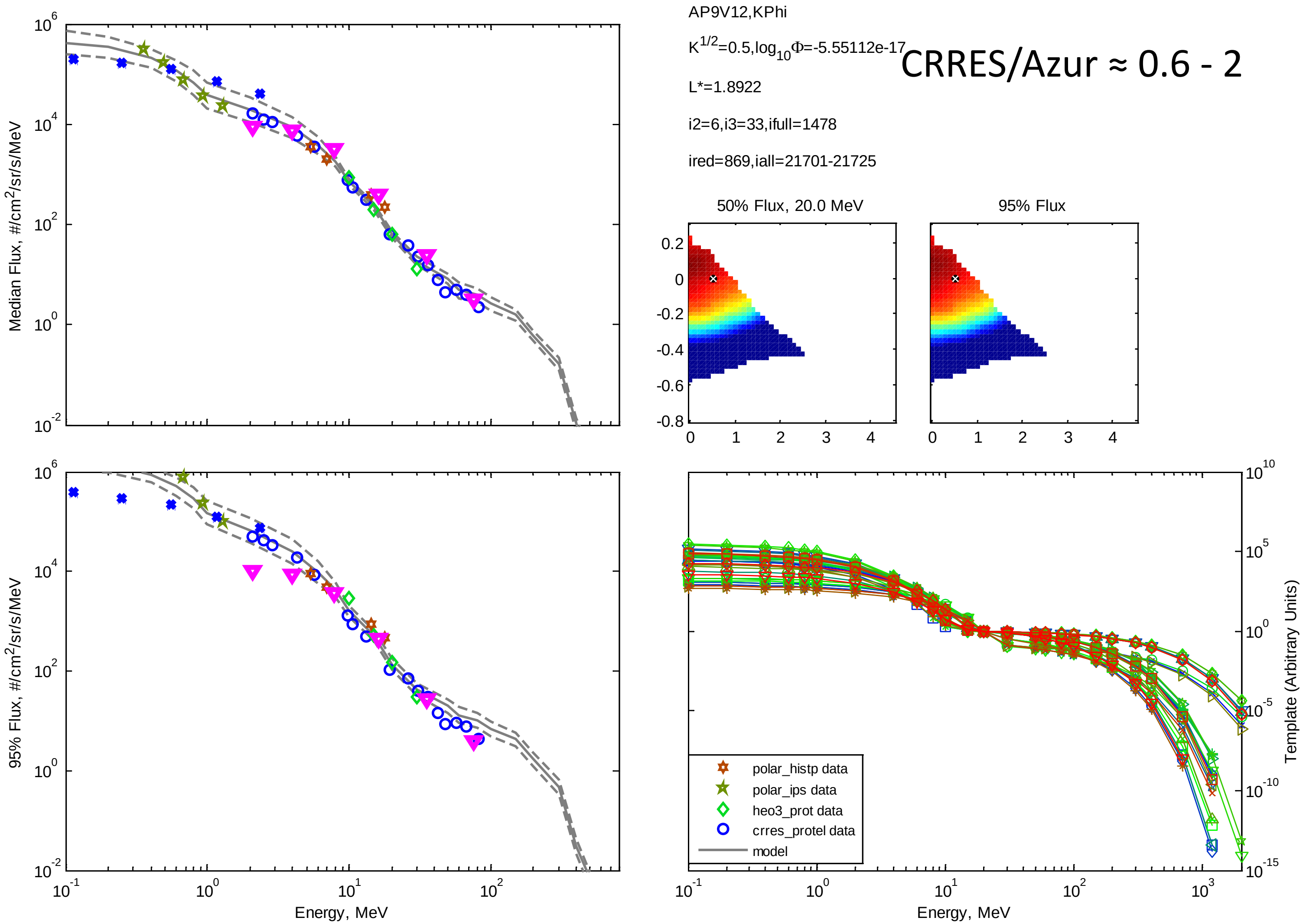
$L_m \approx 1.786, K^{1/2} = 0.5$

CRRES/Azur ≈ 1 - 2

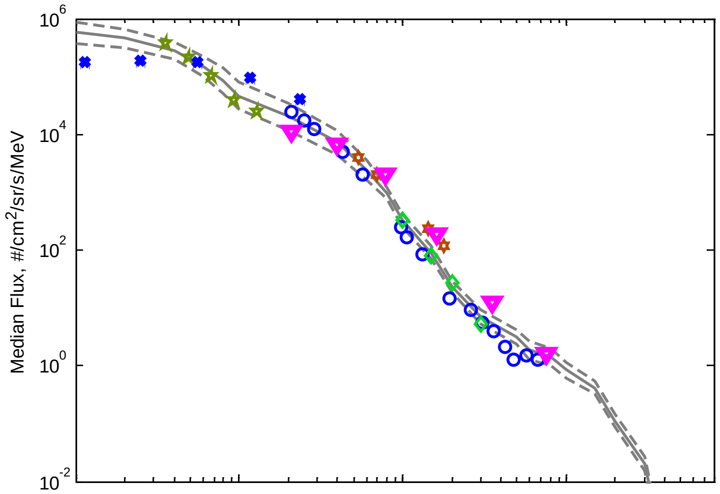


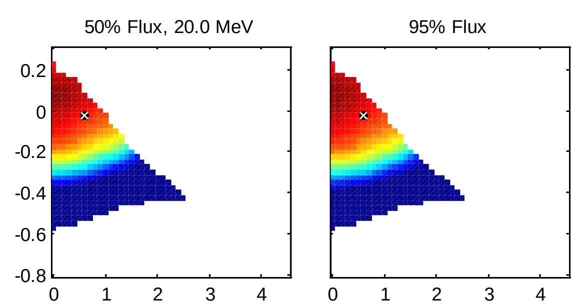
$L_m \approx 1.892, K^{1/2} = 0.5$

CRRES/Azur ≈ 0.6 - 2



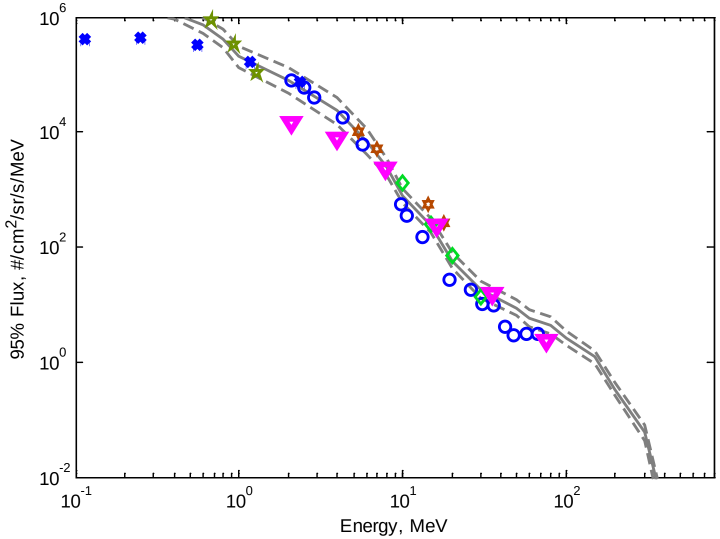
$L_m \approx 2.004, K^{1/2} = 0.6$

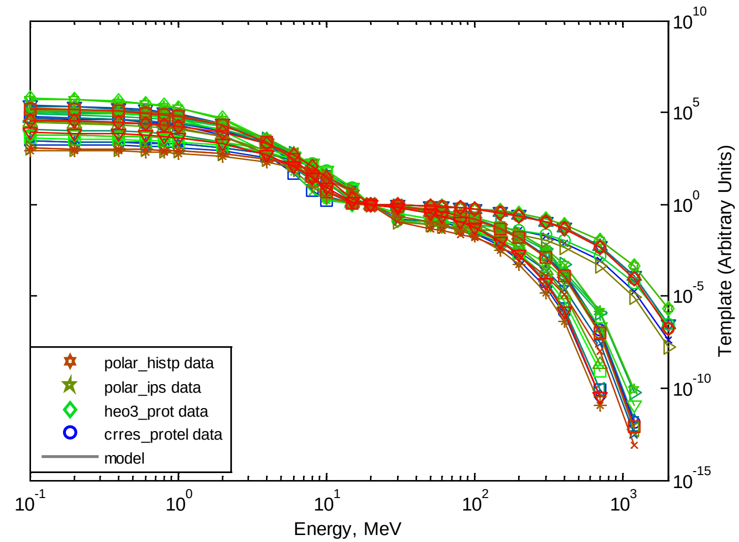




CRRES/Azur ≈ 0.5 – 2

Note, $K^{1/2}$=0.6





Observations

- Comparisons are only made for $K^{1/2} \approx 0.5$.
- Above $L \approx 1.6$ ($\log_{10}\Phi \approx 0.075$), all datasets are pretty consistent (at least at $K^{1/2} = 0.5$).
- However, starting from L=2 down to L=1.44, difference between Azur and CRRES increases steadily; i.e., Azur sees steeper gradients even well beyond our K/h_{min} grid.
- Major differences in spectra throughout K/h_{min} grid.
- S3-3 data are not used in AP9 in any of these bins.
  - S3-3 is not included at all in AP9 K/h_{min} grid (but it is included implicitly through templates).
- S3-3 fluxes barely decrease at all with decreasing h_{min}.
  - This is consistent with Vampola's paper.
- Below $L \approx 1.8$, both Azur and CRRES show a peak at ≈ 5-8 MeV; S3-3 (and Polar) show increasing flux with decreasing energy.
- Much smaller difference between 50th & 95th percentiles for Azur than for other datasets.
  - Short time period for Azur.

S3-3 Analysis

Motivation

- **AP9 predicts much larger fluxes of low energy (< 10 MeV) protons than AP8 at low altitudes.**
- **AP8 MAX is based almost entirely on data from Azur.**
  - **Flew in 1969 – 1970 (0.3 years near solar maximum): very short time span.**
  - **1.5 – 104 MeV in 7 channels ($\Delta E/E_{mid} \approx 0.7$).**
  - **Very clean data set, low altitude measurements at 90° pitch angle.**
- **AP9 is based mainly on CRRES PROTEL below 10 MeV.**
  - **Flew in 1990 – 1991 (1.3 years near solar maximum): short time span.**
  - **1 – 100 MeV in 24 channels ($\Delta E/E_{mid} \approx 0.2$).**
  - **Much data for low L is based on high-altitude pitch angle resolved measurements.**
- **AP9 implicitly uses data from S3-3 via templates.**
- **Vampola published a model based on S3-3; low-altitude fluxes were much higher than AP8.**
- **We want to determine if S3-3 data can be believed.**

S3-3

- Operational July 1976 – April 1979 (2.7 years near solar minimum & increasing phase)
- 8000 x 250 km x 97.5°
- Spin stabilized (~ 3 rpm)
- Proton telescope:
  - 6.05° aperture half-angle
  - 0.08 – 3.2 MeV in 5 channels ($\Delta E/E_{mid} \approx 0.7$)
  - Views through aperture of magnetic electron spectrometer; magnetic chamber prevented any electrons with energies below 20 MeV from impinging on the detectors.
- Vampola developed a model based on S3-3 data (Vampola, A.L., Low Energy Inner Zone Protons Revisited, in *Workshop on the Earth's Trapped Particle Environment: Conf. Proc. 383*, American Institute of Physics, Woodbury, New York: AIP Press, 1996, pp. 81-86.)

Points from Vampola's Paper

- "There have been many low energy proton sensors flown at low altitude on satellites during the last three decades, but essentially none of the data was analyzed in the portion of the inner zone where the energetic protons constitute a tremendous background problem."
- "No published data for protons between 100 keV and 3 MeV between L=1.3 and L=1.65 were found. Other investigators said that they avoided this region because of the difficulty of removing the penetrating proton contamination from their data."
- For S3-3:
  - Penetrating protons present a background problem for 1.25 < L < 1.75.
  - Beyond L = 2.1, backgrounds in the proton telescope are not significant.
  - Dead-time corrections are required.
- "For the present study, a statistical analysis was made of residual, uncorrected effects in the data. All bounce-loss-cone data from the entire data base was used. The assumption was made that any counts which occurred while the instrument aperture was viewing in the downward loss cone were due to background effects such as cosmic rays and penetrating protons."
- "The on-board data processing was very effective for eliminating contamination from the Jperp (90° ± 5°) data. The residual penetrating proton contamination in the Jperp count rate in the heart of the inner zone was less than the statistical variations associated with the true counts." (NOTE, on-board data processing is not described in the paper.)

Figures from Vampola's Paper

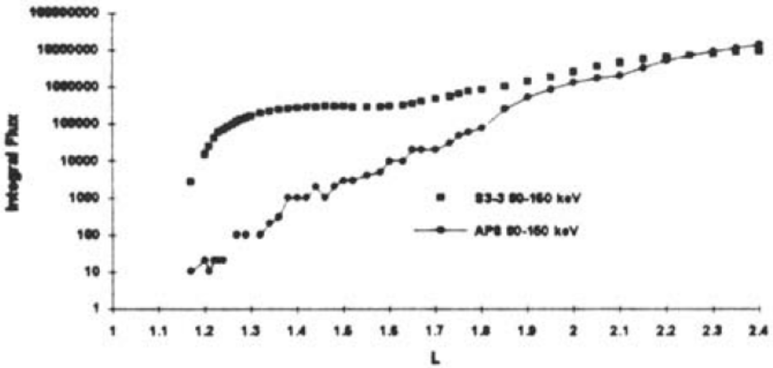


Figure 6. Comparison of S3-3 80-150 keV flux intensities with the AP8MAX model in the inner zone.

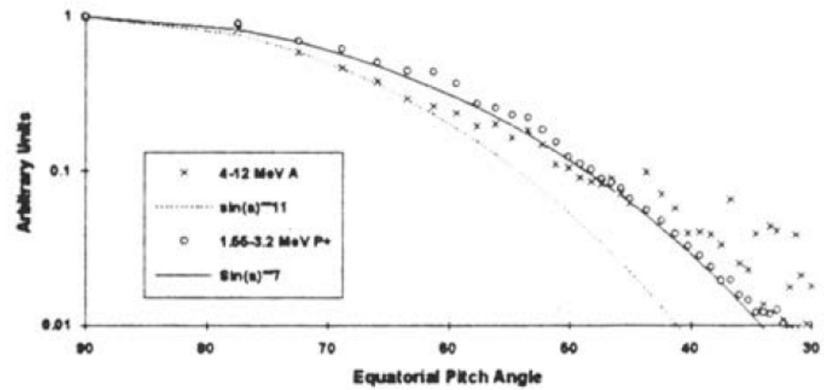


Figure 7. S3-3 Equatorial pitch-angles at L=1.85

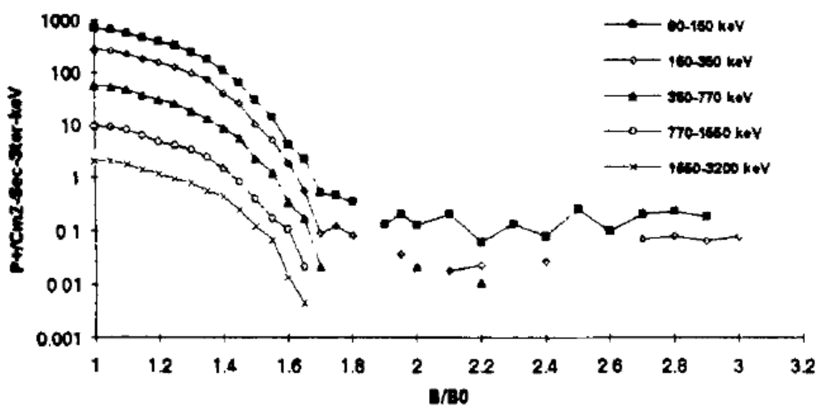


Figure 8. S3-3 proton equatorial pitch angle distributions at L=1.30.

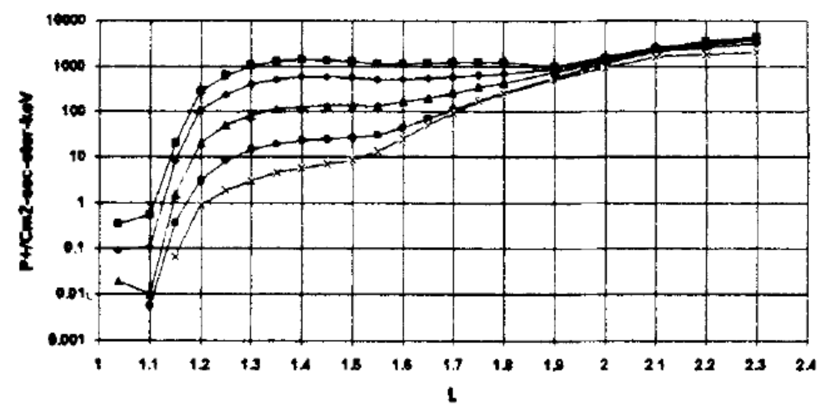


Figure 9. Average inner zone equatorial Jperp proton fluxes measured on S3-3. Squares, diamonds, triangles, circles and "X"s are respectively the 80-150 keV, 150-350 keV, 350-770 keV, 770-1550 keV, and 1.55-3.2 MeV channels. No smoothing has been done.

Procedure

- **Compare our data with Vampola's paper.**
  - **Make sure we're working with the same data and doing the same processing.**
- **Evaluate any potential contamination from penetrating protons or other.**

Figure 8

- **Figure 8. Equatorial PADs at L=1.3 (digitized)**

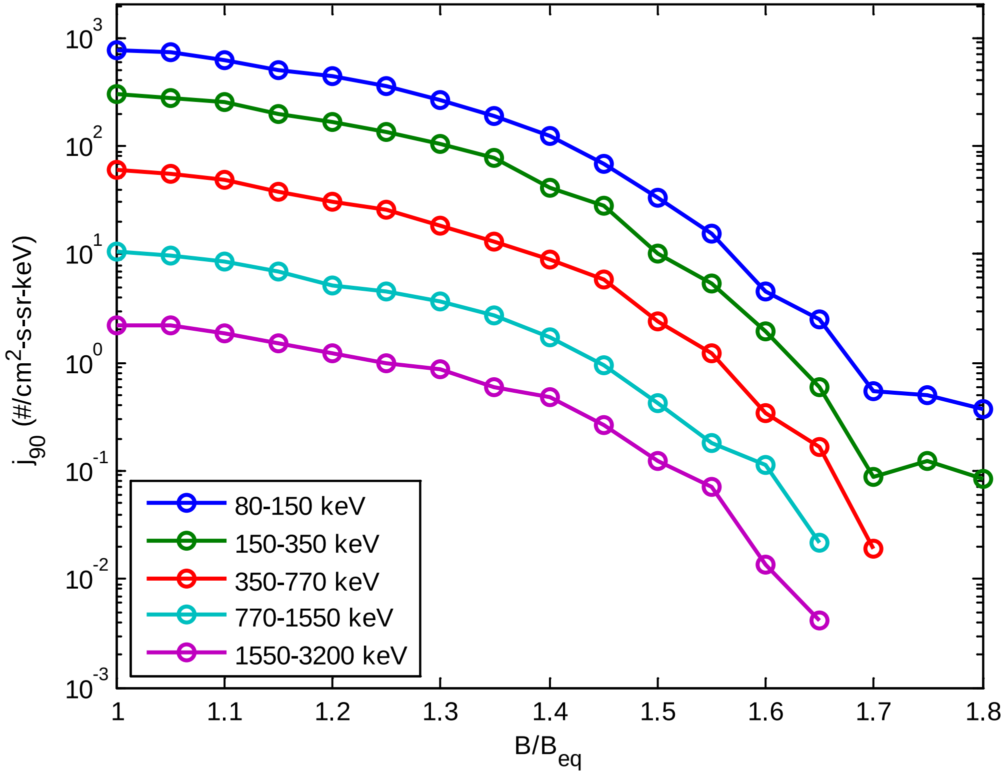
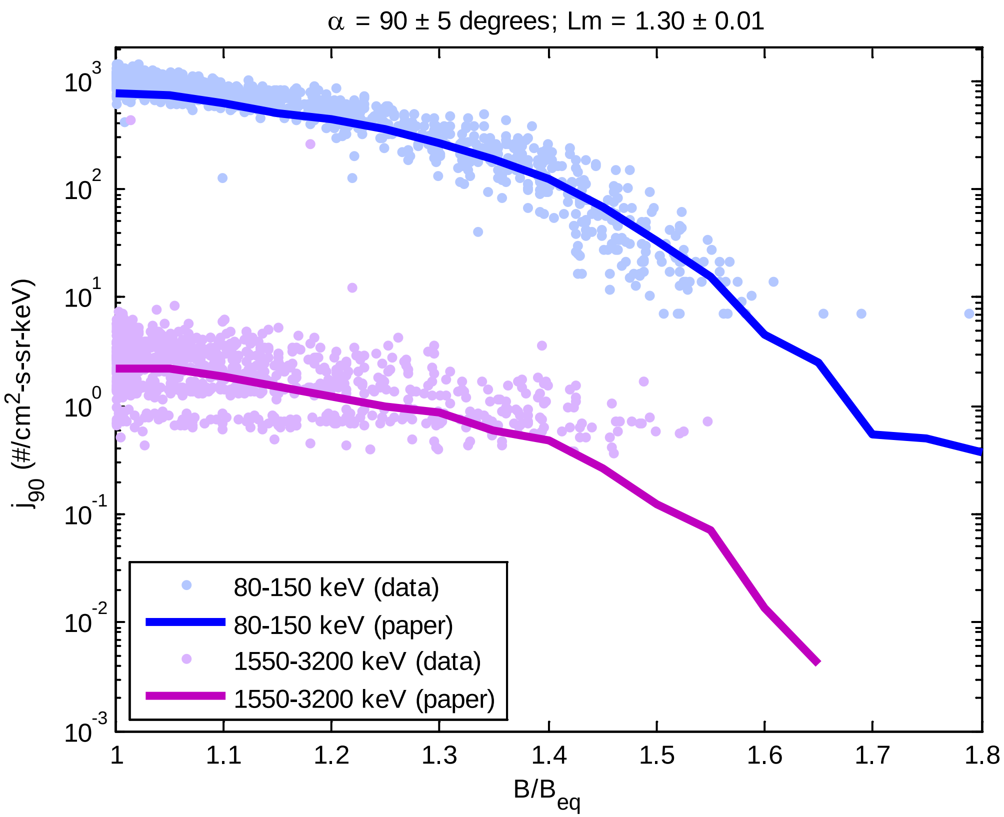


Figure 8 and data

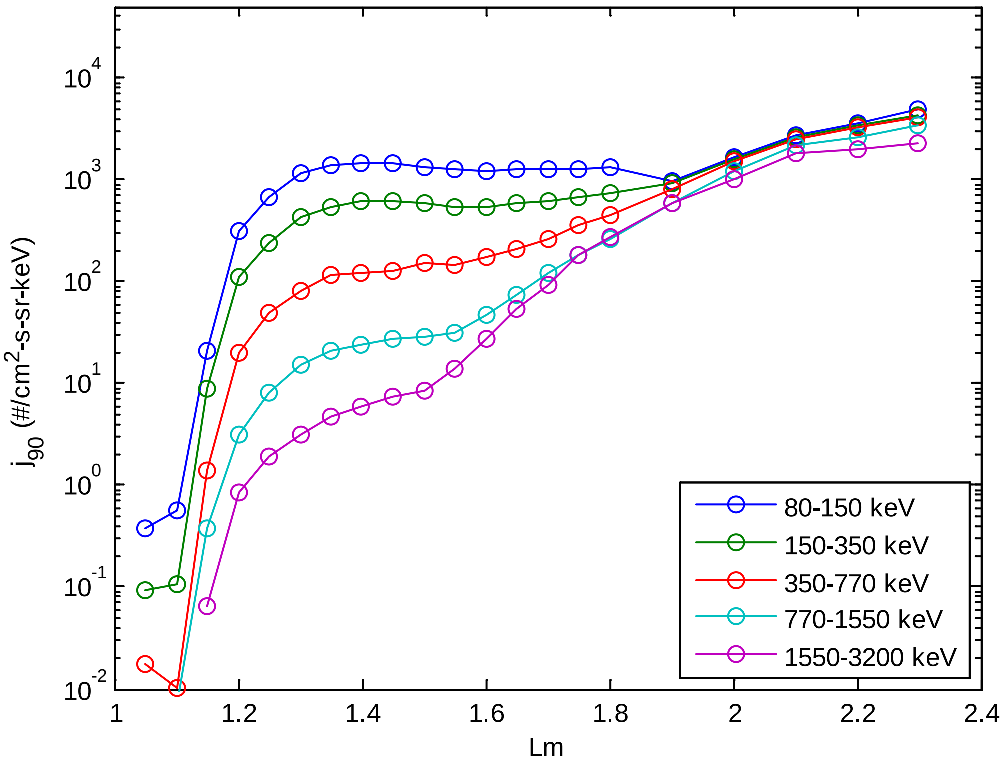
- **Figure 8: Data compared to digitized**



- **Our data agree with Vampola's figure quantitatively, but not qualitatively.**
- **Vampola's seem to go down to lower fluxes and extend to higher B/B_{eq} values.**

Figure 9

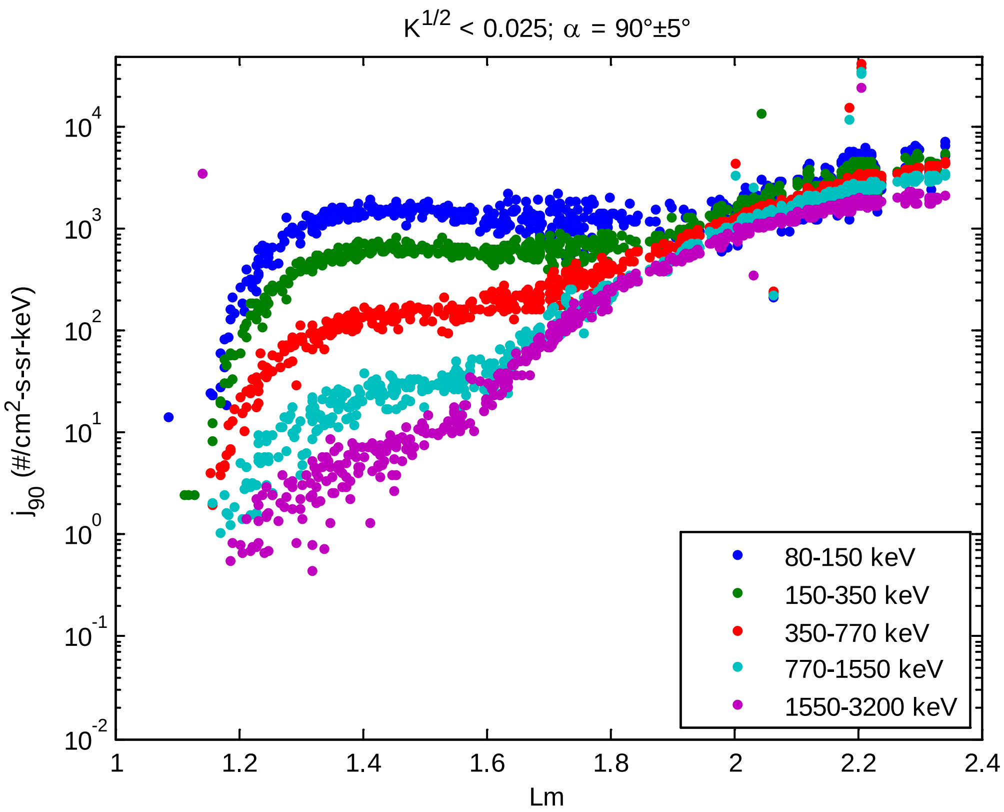
- **Figure 9. Equatorial jperp fluxes (digitized)**



- **Note that flux spectra are quite flat for L > 1.9.**
- **At lower L, there appears to be an additional population of protons with energy < 5 MeV or so.**
  - **Plateau for 1.4 < L < 1.9.**
  - **Steep drop-off at lower L.**
- **This population could be contamination from high energy protons, but it seems unlikely.**
  - **100 MeV protons peak around L=1.5, and drop off quickly on either side.**

Data for Figure 9

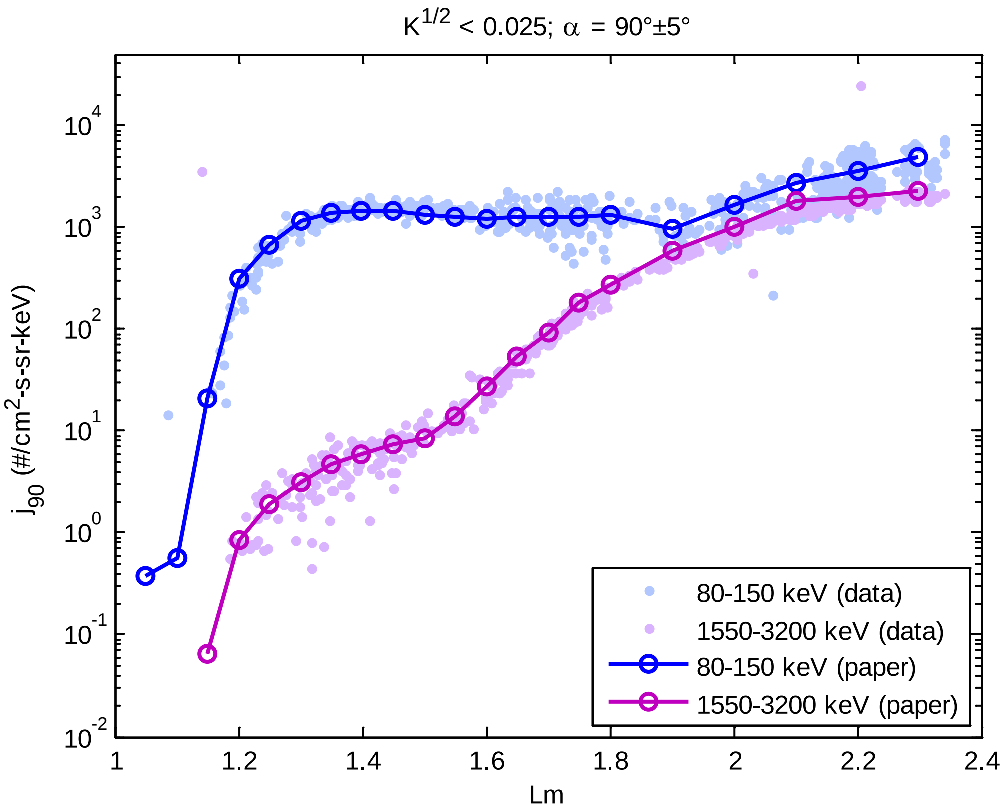
- **Figure 9 (data)**



- **Same as previous slide, but using the data set we have.**

Figure 9 and data

- **Figure 9 (data compared to paper)**

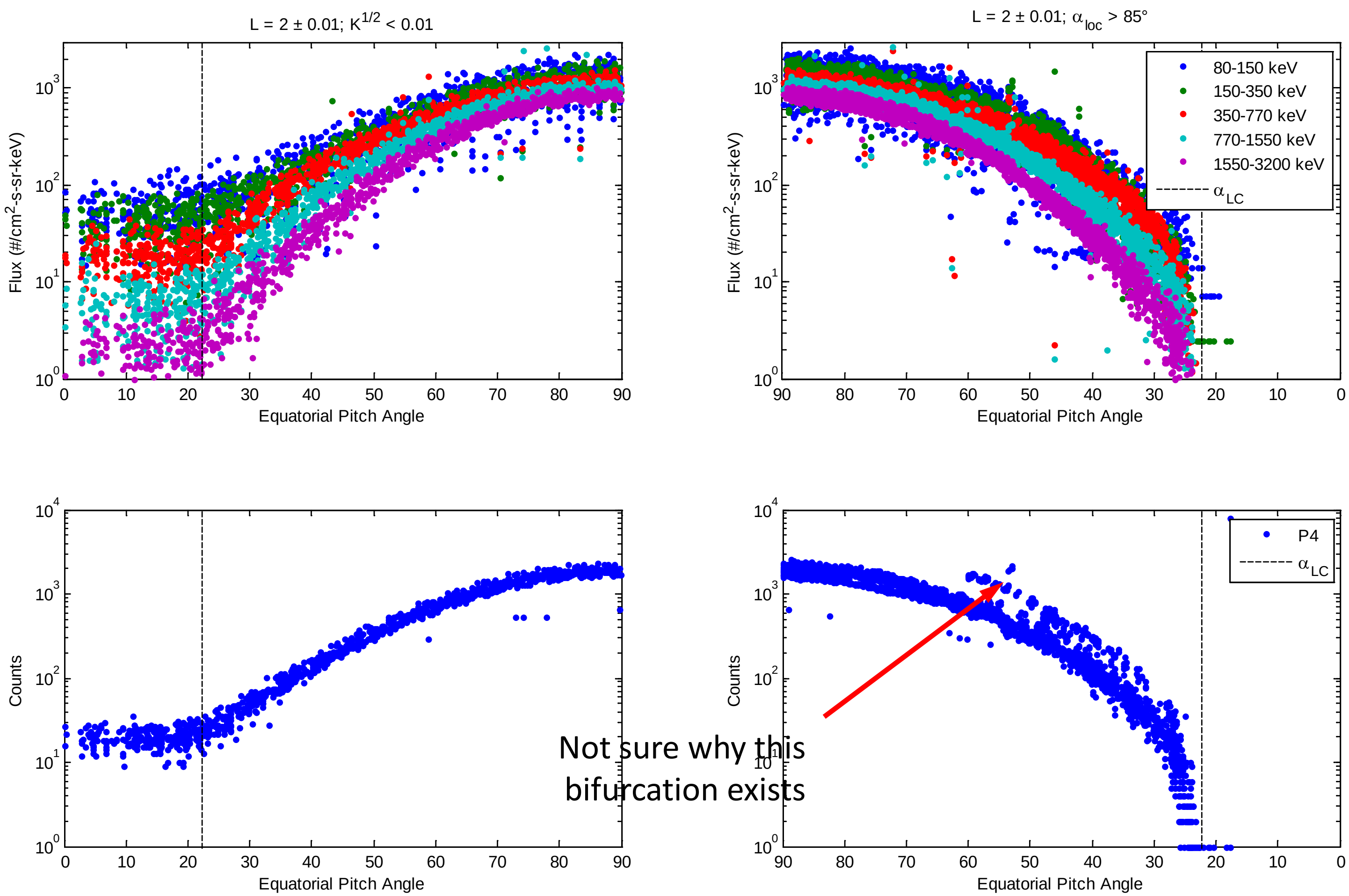


- **Combining previous 2 slides for 2 energies.**
- **Again, our data agree with Vampola's figure.**
- **Vampola's data again go to lower flux values than ours, but here the difference is less pronounced than in Fig. 8.**

Pitch Angle Distributions

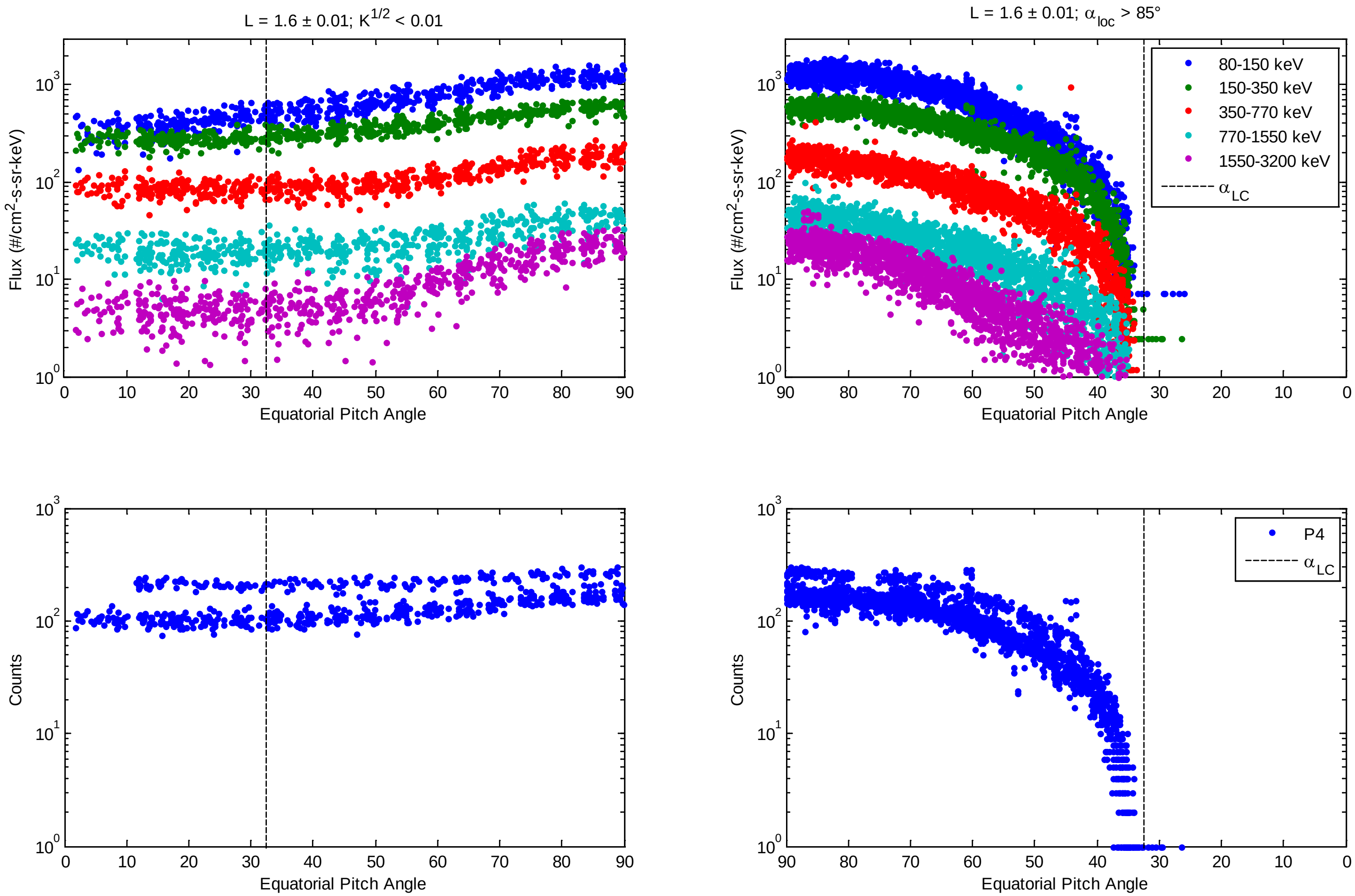
- The following charts show equatorial pitch angle distributions measured two ways:
  - Measured near the equator, pitch angle determined by the pitch angle of the detector axis (left panel).
  - Using j_{perp} measurements, equatorial pitch angle determined using B/B_{min} (right panel).
- Top panels show fluxes in the 5 energy channels.
- Also shown in bottom panels are PADs of raw counts in P4 channel (nominally > 150 keV).
- Dashed vertical line indicates loss cone for each L (using AP9 data).
- Plots show PADs at several L values.

PADs: L=2.0

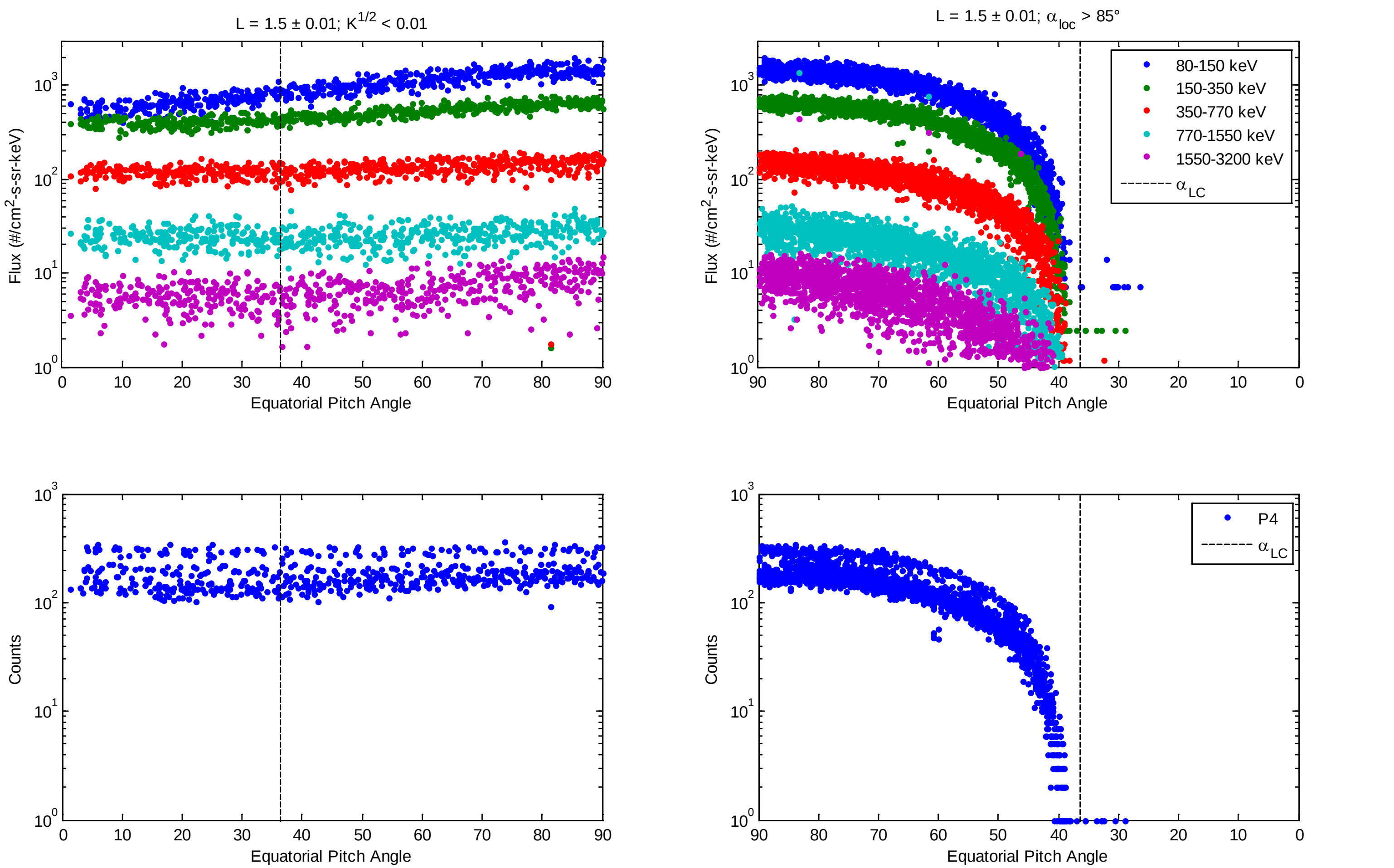


Not sure why this bifurcation exists

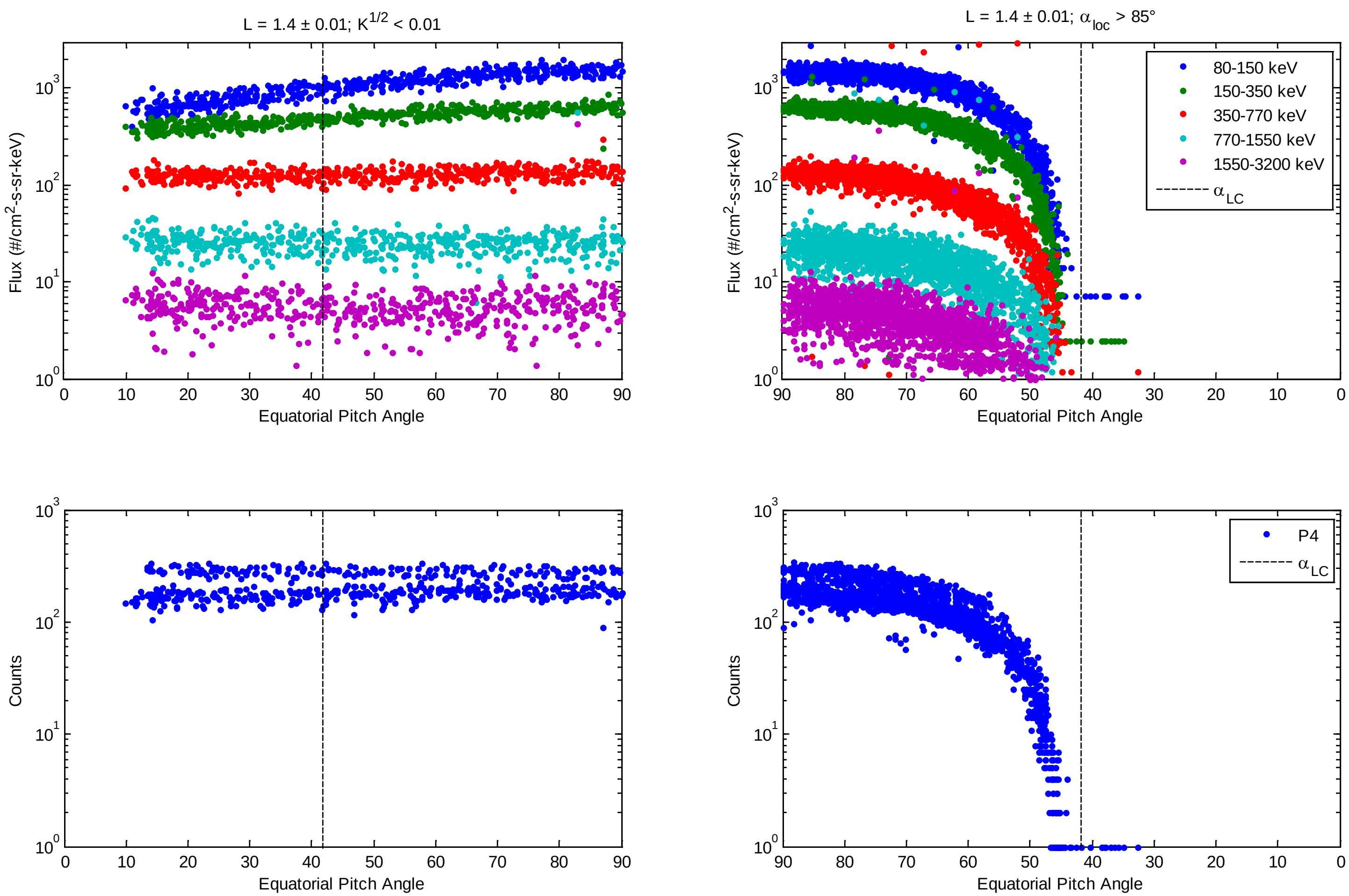
PADs: L=1.6


L = 1.6 ± 0.01; K^1/2 < 0.01
L = 1.6 ± 0.01; α loc > 85°
Flux (#/cm2-s-sr-keV)
Counts
Equatorial Pitch Angle
80-150 keV
150-350 keV
350-770 keV
770-1550 keV
1550-3200 keV
α LC
P4

PADs: L=1.5

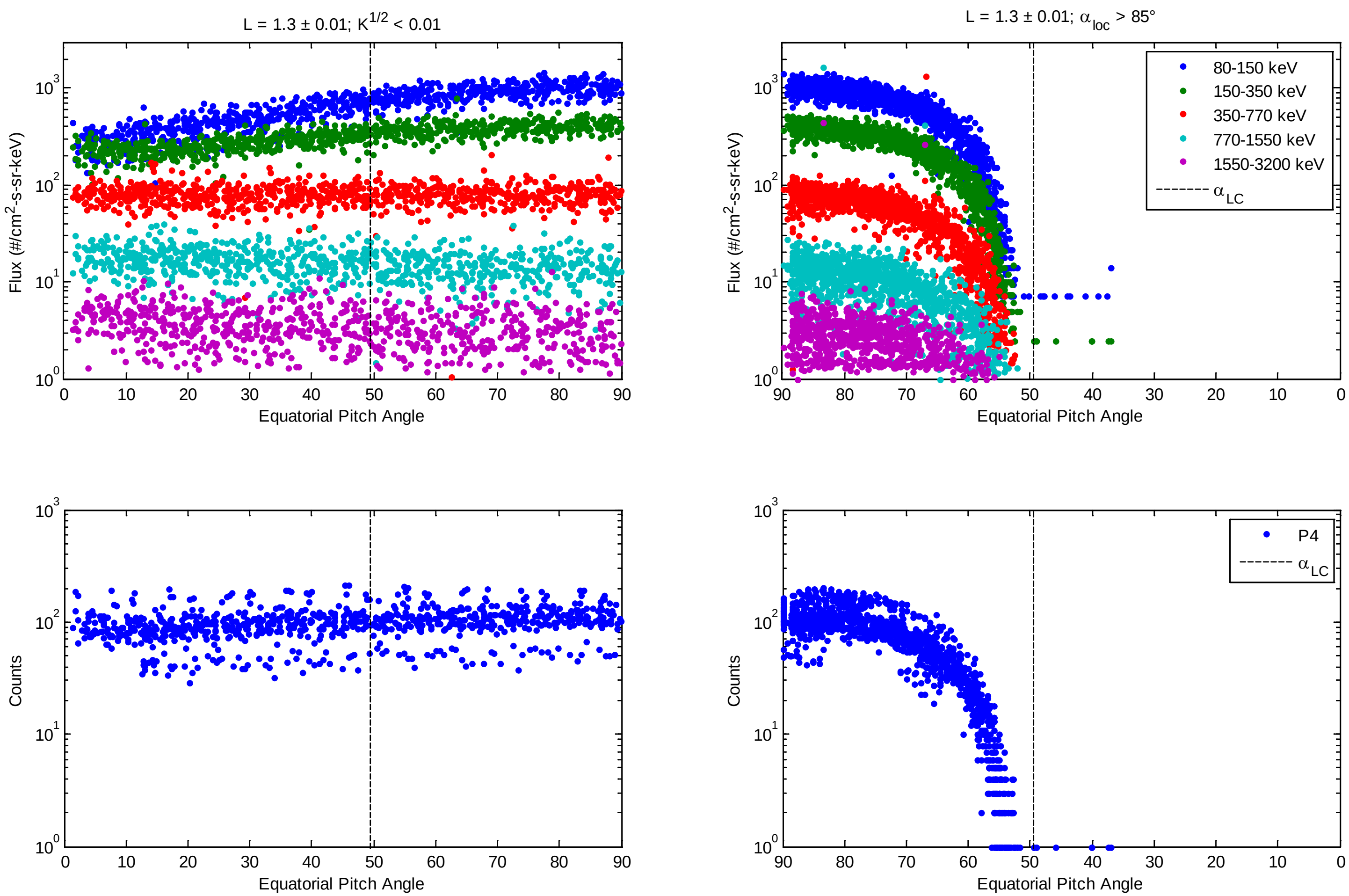

L = 1.5 ± 0.01; $K^{1/2}$ < 0.01
L = 1.5 ± 0.01; α_{loc} > 85°
Flux (#/cm^2-s-sr-keV)
Counts
Equatorial Pitch Angle
80-150 keV
150-350 keV
350-770 keV
770-1550 keV
1550-3200 keV
α_{LC}
P4

PADs: L=1.4



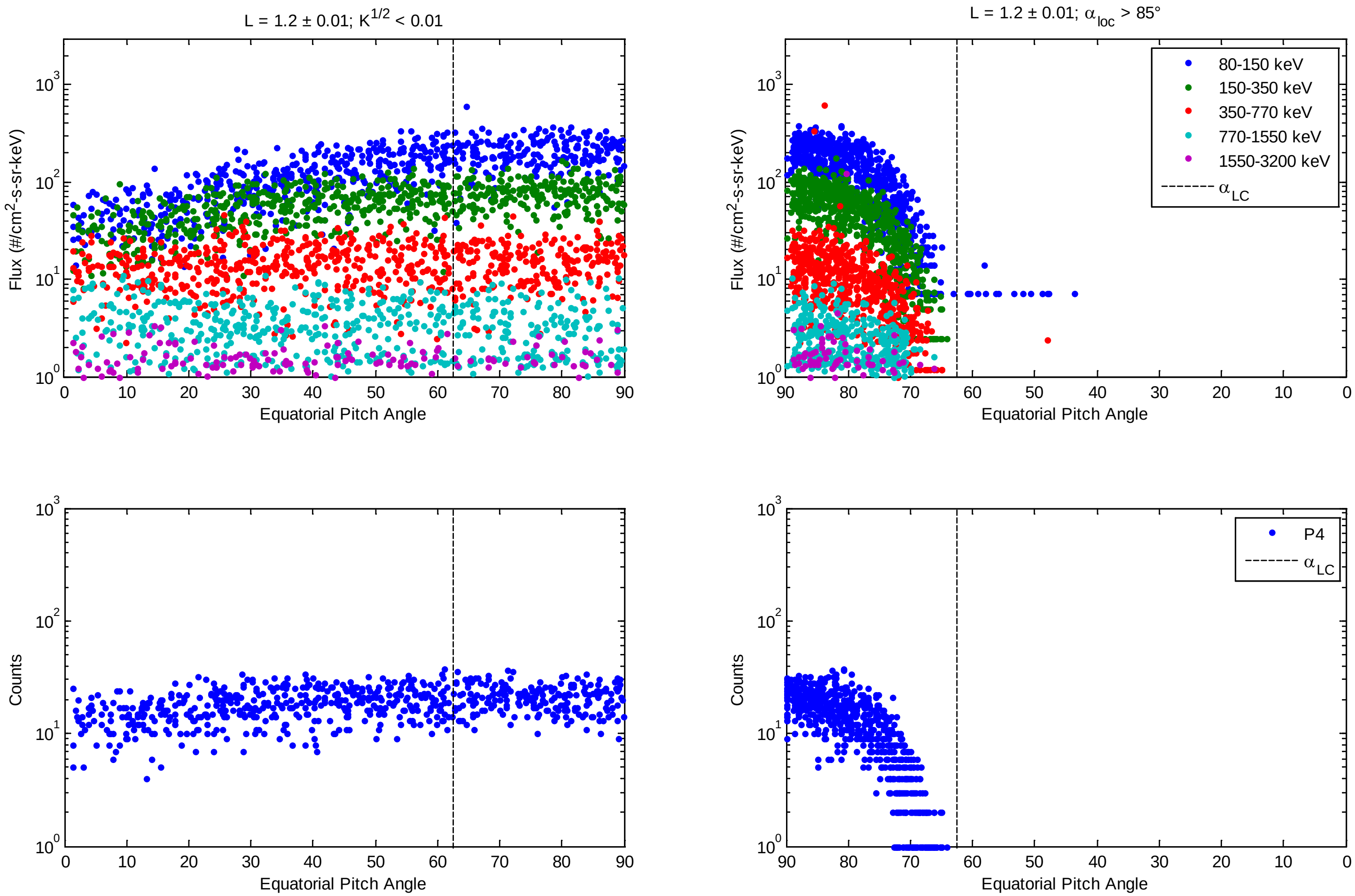
L = 1.4 ± 0.01; K^1/2 < 0.01
L = 1.4 ± 0.01; α_loc > 85°
Flux (#/cm2-s-sr-keV)
Equatorial Pitch Angle
Counts
80-150 keV
150-350 keV
350-770 keV
770-1550 keV
1550-3200 keV
α_LC
P4

PADs: L=1.3



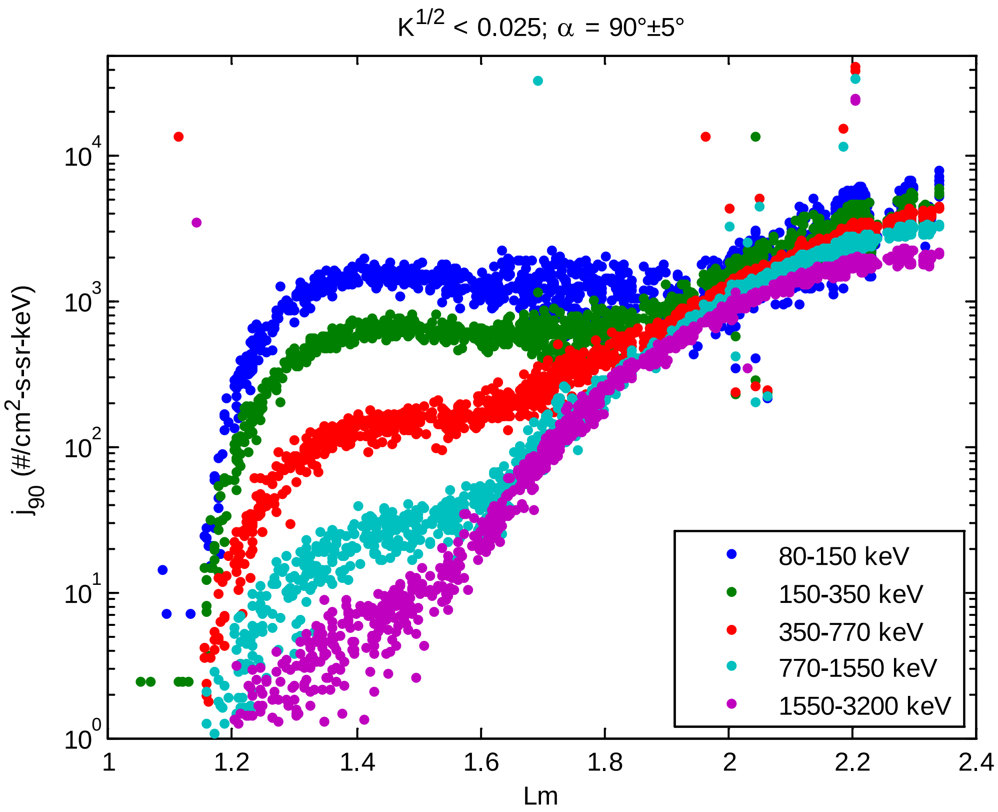
L = 1.3 ± 0.01; K^1/2 < 0.01
L = 1.3 ± 0.01; α_loc > 85°
Flux (#/cm²-s-sr-keV)
Counts
Equatorial Pitch Angle
80-150 keV
150-350 keV
350-770 keV
770-1550 keV
1550-3200 keV
α_LC
P4

PADs: L=1.2



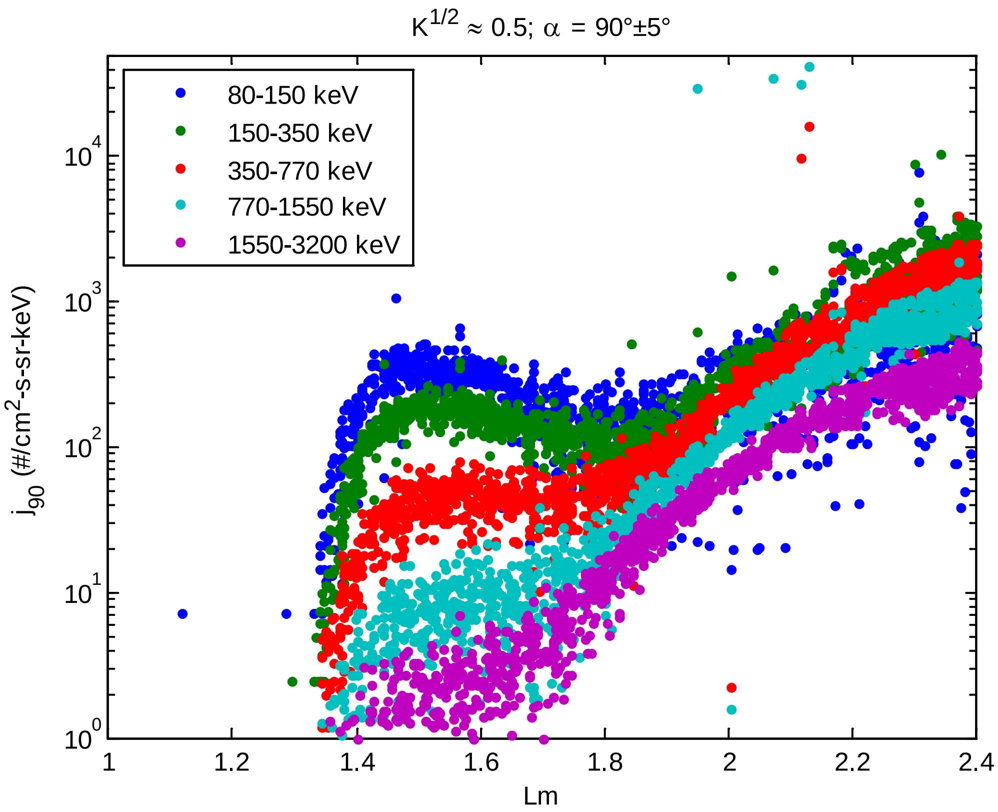
L = 1.2 ± 0.01; K^1/2 < 0.01
L = 1.2 ± 0.01; α_loc > 85°
Flux (#/cm²-s-sr-keV)
Equatorial Pitch Angle
Counts
80-150 keV
150-350 keV
350-770 keV
770-1550 keV
1550-3200 keV
α_LC
P4

Variation with K (1 of 2)



Re-plot of Vampola's Figure 9; compare with next slide for K dependence.

Variation with K (2 of 2)



Same as previous slide, but for K = 0.5 (B/B_{min} ≈ 1.6 - 2).

Here, fluxes do appear to peak around L=1.5.

Summary

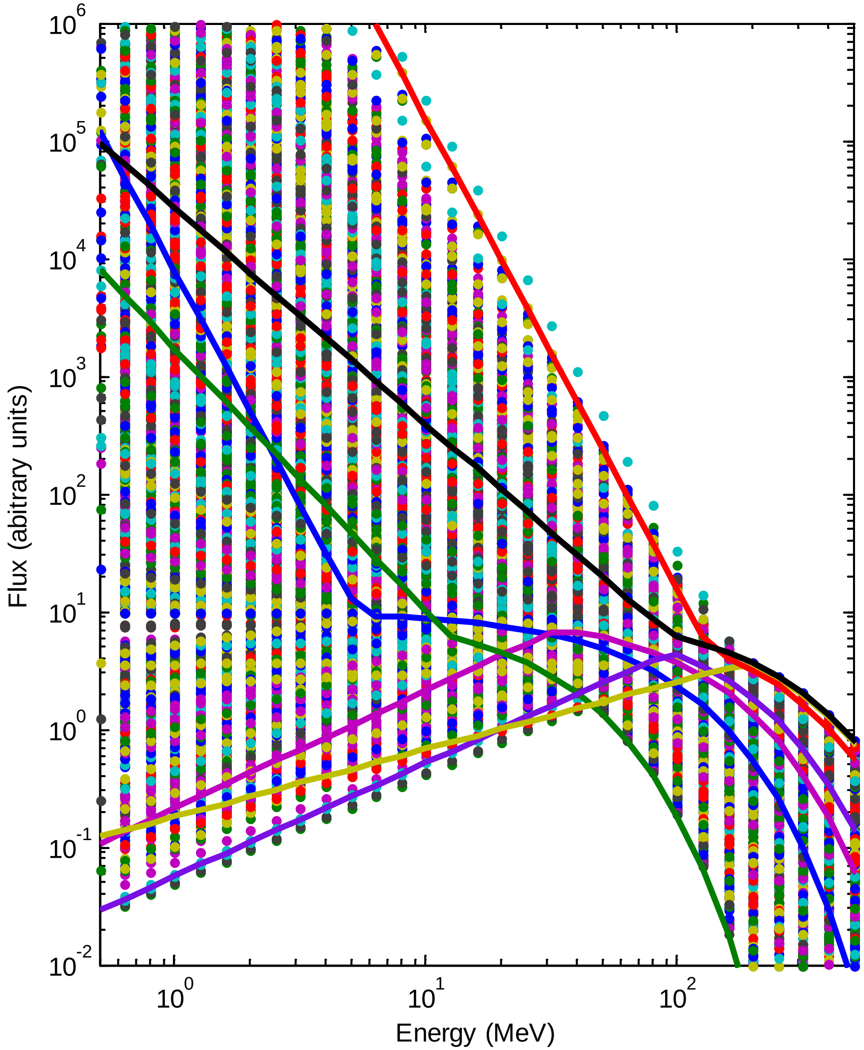
- Able to duplicate most features of figures in Vampola paper.
  - Our data and processing give the same fluxes as Vampola's
  - Data in Vampola's figures go to lower fluxes and B/B_{eq} (or L) values than ours. Not sure why.
- PADs measured from equator show strong contamination from penetrating protons below L=2.0, as evidenced by nearly flat PADs.
- PADs determined from jperp data seem clean.
  - Measured loss cone is consistently larger than analytical loss cone. Not sure why, or how significant this is.
- L profiles do not seem to be consistent with contamination.
- Large fluxes for L < 1.9 appear to be real. These may be a transient phenomenon but are fairly stable over the 2.8 years of data.

TacSat-4 CEASE Data Analysis

TacSat-4/CEASE Tests

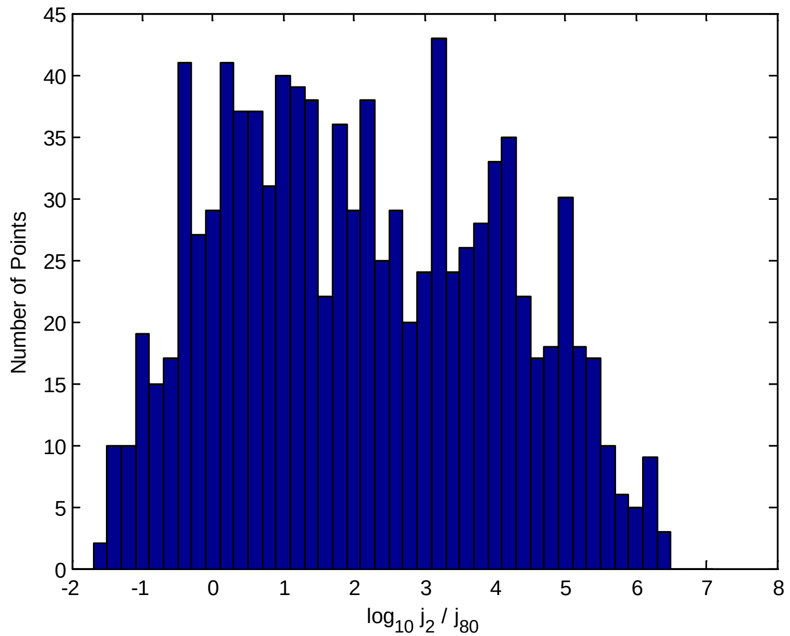
- **Problem: ESA study shows AP9 fluxes at low energy, low altitude much higher than Azur data, AP8 model, and others.**
  - **In particular, there are significant differences between Azur spectral shape and data sets used in AP9.**
- **AP9 makes extensive use of fluxes obtained through spectral inversion (CEASE in particular). These require assumptions about spectral shape.**
- **Objective: determine if CEASE count rates (not inverted) can distinguish between a "flat" (e.g., exponential) spectrum (like Azur) and a power-law + exponential spectrum.**
- **Procedure:**
  - **Generate a set of spectra with a wide range of spectral shapes.**
  - **Integrate spectrum with isotropic response functions to determine counts in each CEASE channel.**
  - **Determine if ratios of counts in different channels can distinguish spectral shapes.**
  - **As an additional test, compare count ratios expected from Azur spectra to those actually obtained.**

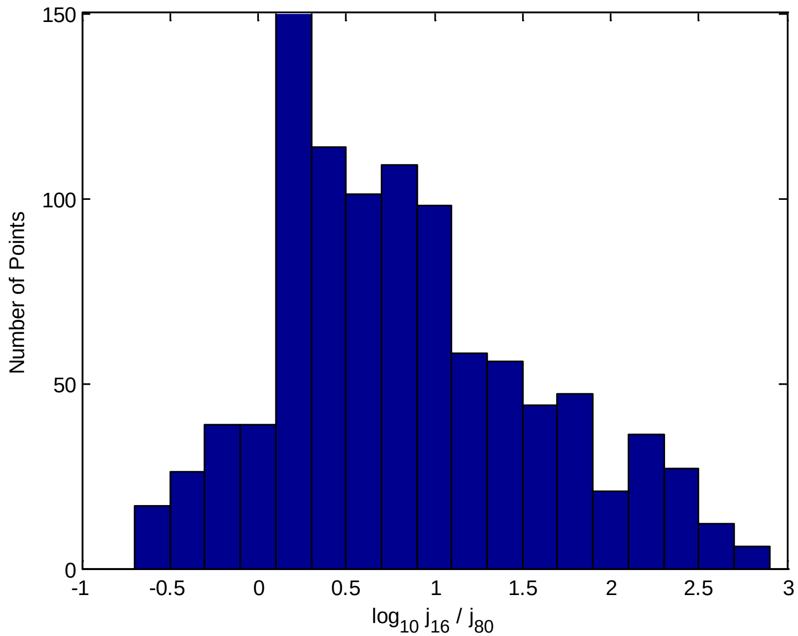
Input spectra



- **Assumed power-law with exponential tail.**
- **Spectral parameters (PL exponent γ, exponential energy E_0, break energy E_{break}) varied randomly to obtain a wide variety of spectral shapes ranging from peaked to essentially flat to steep power-law.**
- **Solid lines show several “representative” spectra.**
- **Not all of these spectra are likely to be seen or even physically reasonable.**

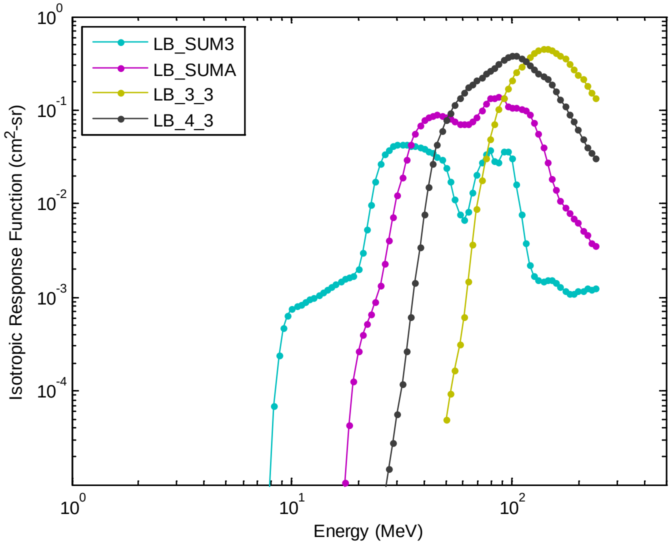
Histograms of Flux Ratios

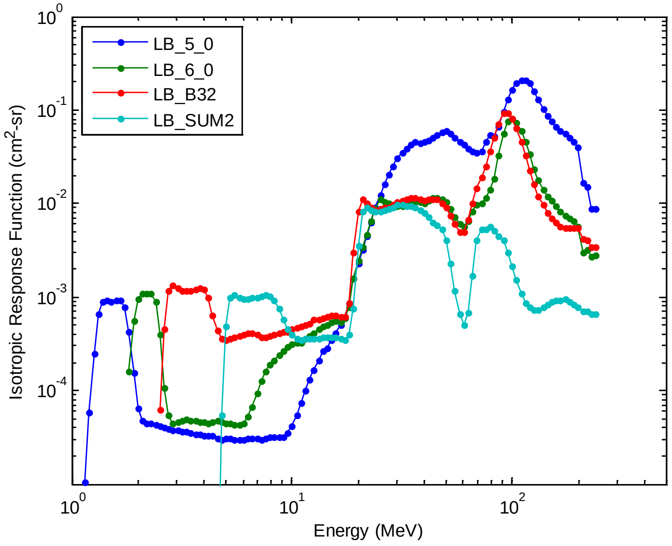




- We selected two indicators of spectral shape: the ratio of flux at 2 MeV and at 16 MeV to the flux at 80 MeV. These three energies are close to channel center energies for Azur.
- A flux ratio of 1 or less indicates a “flat” or “peaked” spectrum similar to some Azur spectra.
- These two plots show histograms of the ratios for the random spectra generated.

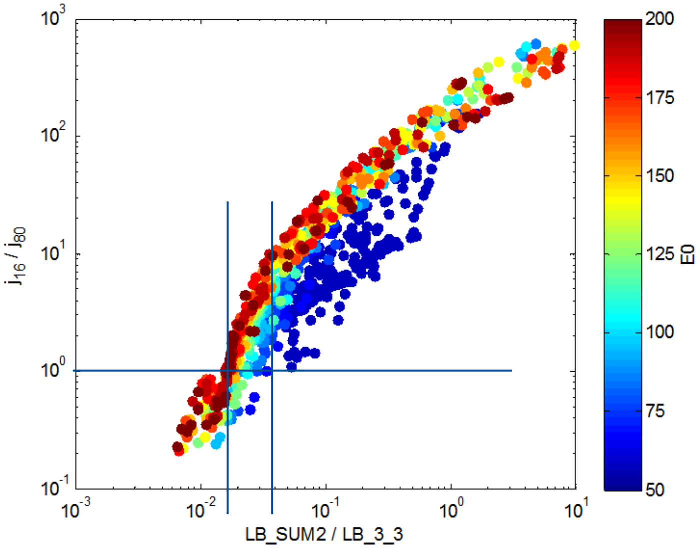
CEASE Response Functions

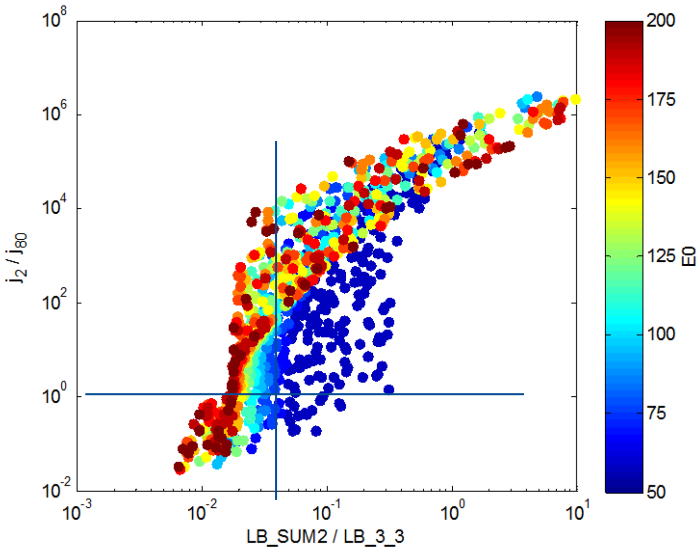




- We used isotropic response functions calculated for CEASE channels.
- Some channels have response at E < 10 MeV (lower panel).
- We will compare counts in channel LB_SUM2 (a channel with low energy response) to LB_3_3 (which responds mainly to > 80 MeV protons).
- We will investigate whether this count ratio can be used to deduce spectral shape.

Flux Ratio vs. Count Ratio



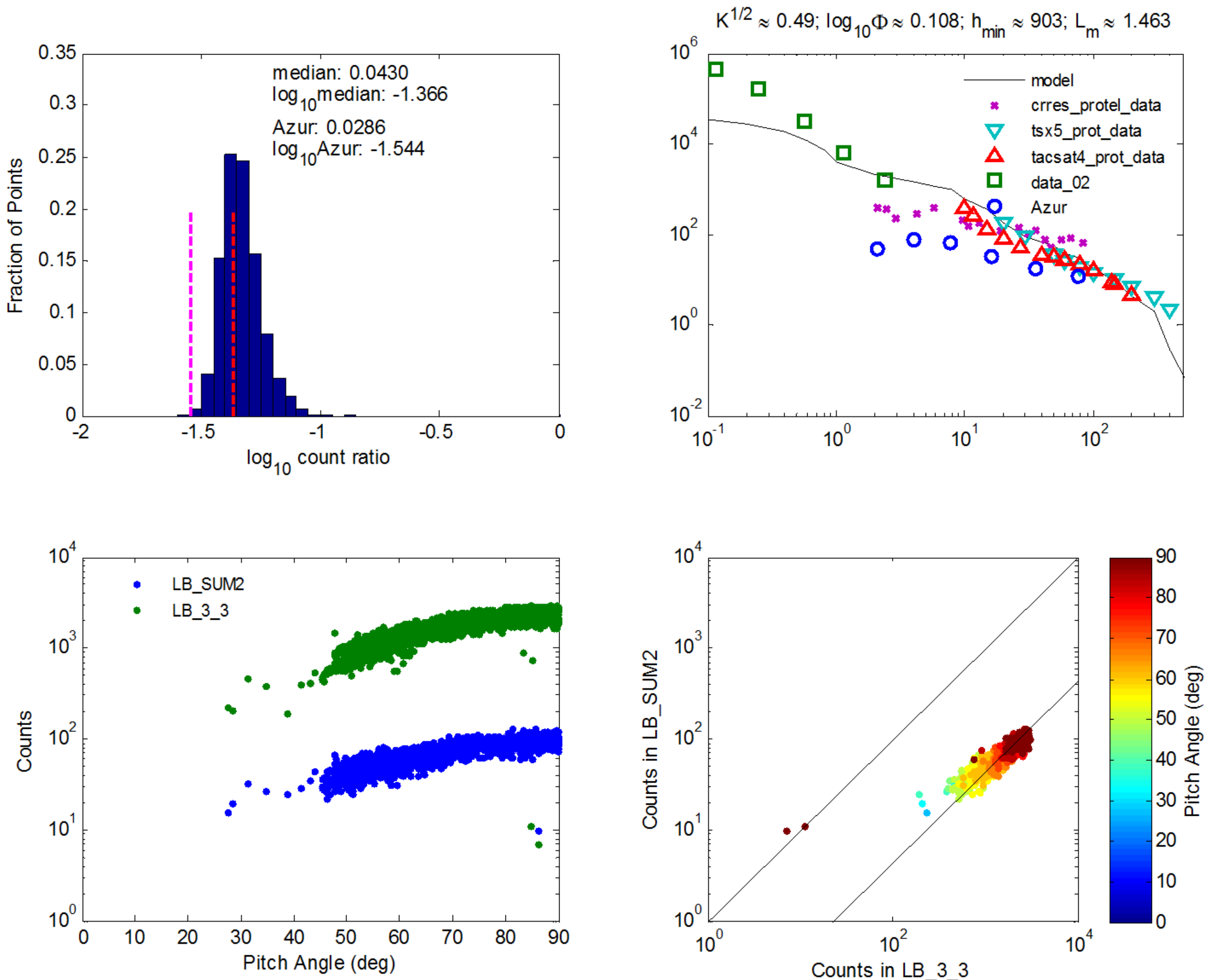


- After convolving response functions with energy spectra, we can compute expected count rates in the two channels.
- We plot the flux ratios as a function of count ratio for 16 / 80 MeV (top) and 2 / 80 MeV (bottom).
- As expected, spectral shape depends on count ratio (CR), but there is much ambiguity.
- "Flat" spectra ($j_{16} = j_{80}$) are possible for 0.015 < CR < 0.04.
- For CR = 0.04, values of j_{16}/j_{80} ranging from 1 to 10 are possible.
- For CR = 0.04, values of j_2/j_{80} ranging from 1 to 1E4 are possible.
- These plots do not necessarily indicate the likelihood of a given flux ratio for a given count ratio.

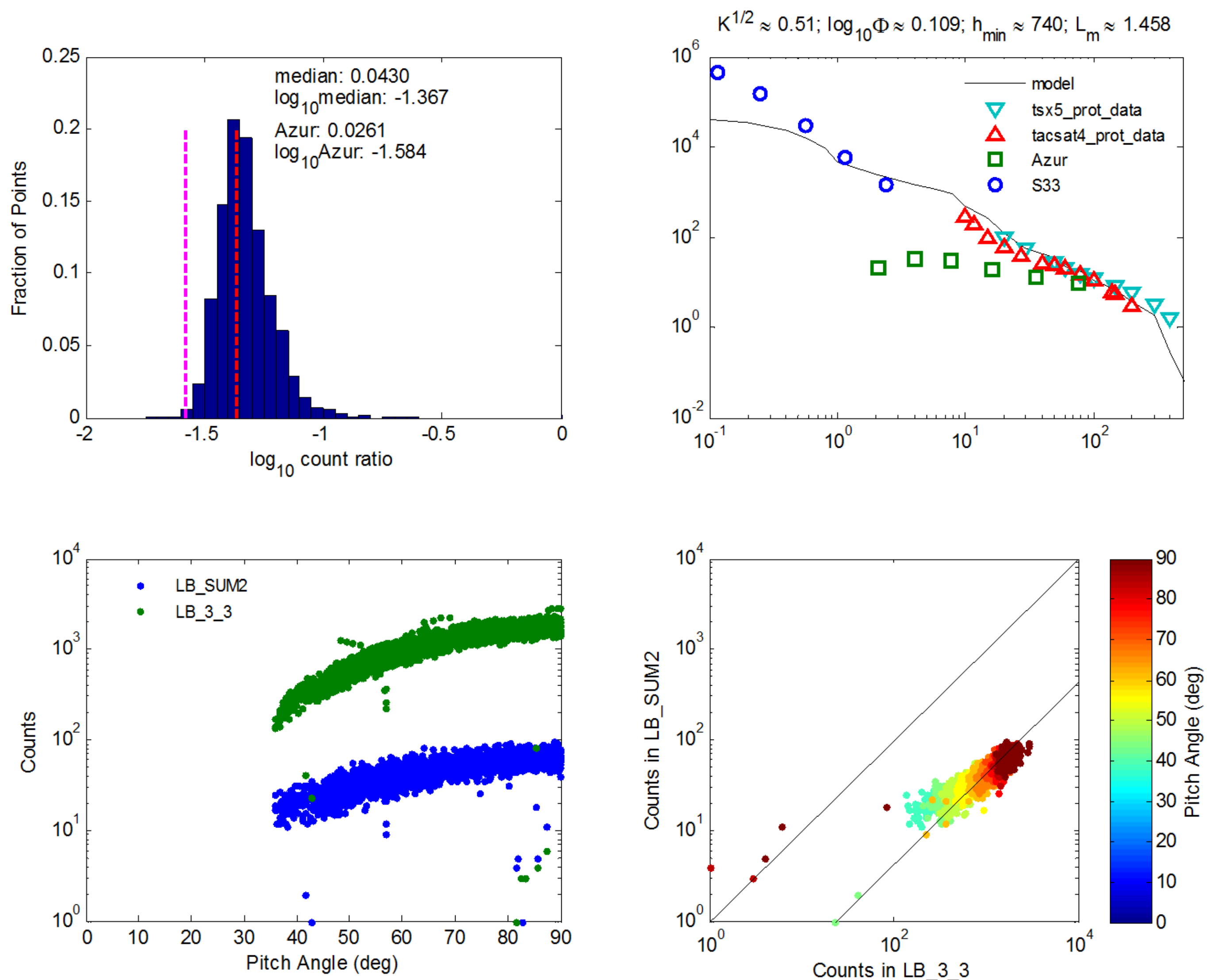
TacSat-4 Data

- The following charts show data from TacSat-4 in several K/h_{min} bins.
- In addition to the TacSat-4 data, we calculated the expected CEASE count ratio given the Azur spectrum in each bin.
- Upper left: histogram of ratio of counts in LB_SUM2 to LB_3_3, corresponding to the analysis above. The median value is shown as a dashed red line. The count ratio determined for the Azur spectrum is indicated by a dashed pink line.
- Lower left: counts in the two channels as a function of detector pitch angle, as a check on side-penetrating particles (a flat pitch angle distribution could be an indication of contamination).
- Lower right: counts in LB_SUM2 vs. LB_3_3, with a diagonal line indicating the median of the ratio.
- Upper right: “binspectra” plot from AP9 showing data and AP9 model fluxes in the bin.

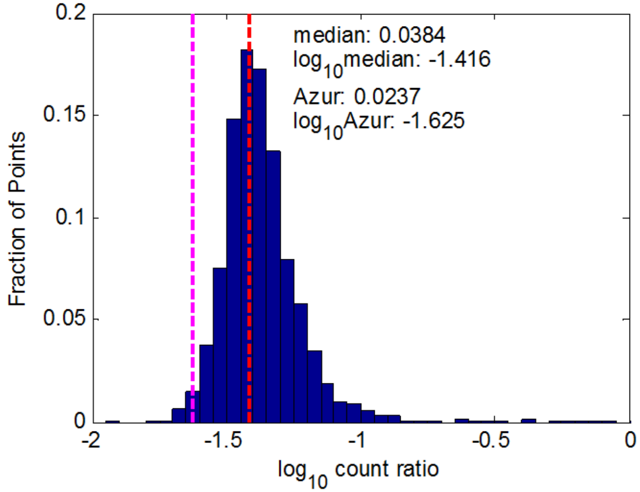
$L_m \approx 1.463$, $K^{1/2} \approx 0.49$, $h_{min} \approx 903$

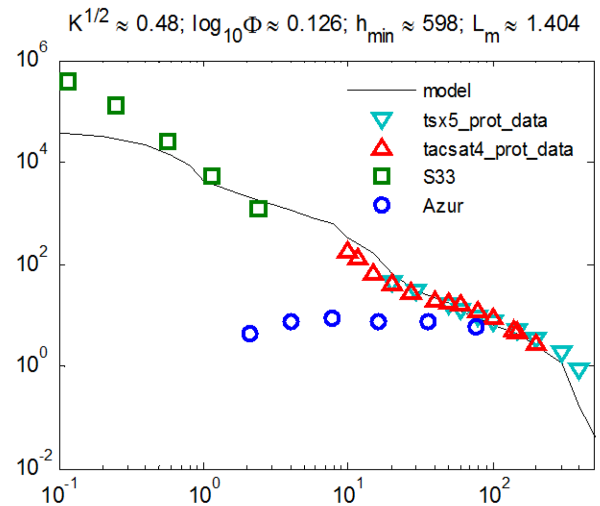


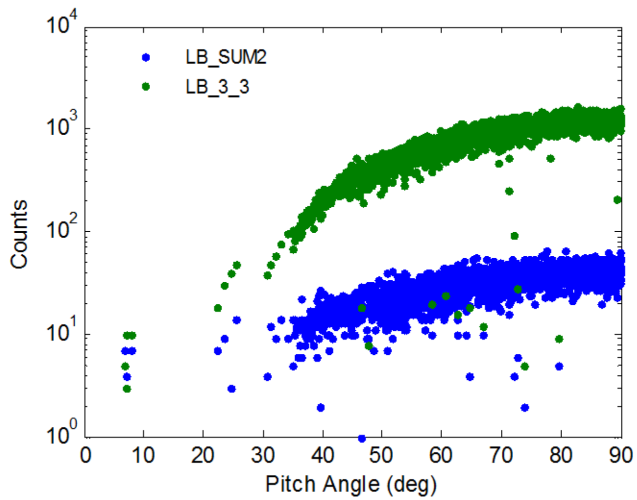
$L_m \approx 1.458$, $K^{1/2} \approx 0.51$, $h_{min} \approx 740$

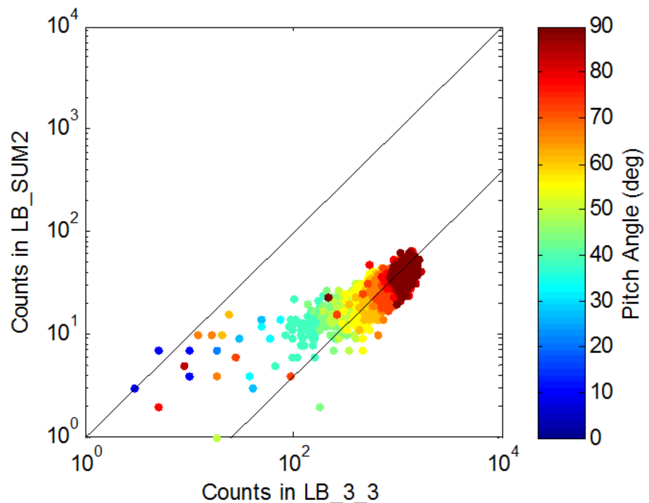


$L_m \approx 1.404, K^{1/2} \approx 0.48, h_{min} \approx 598$

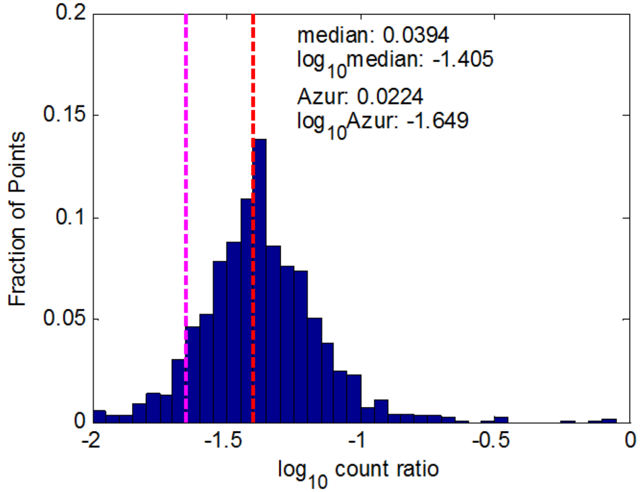


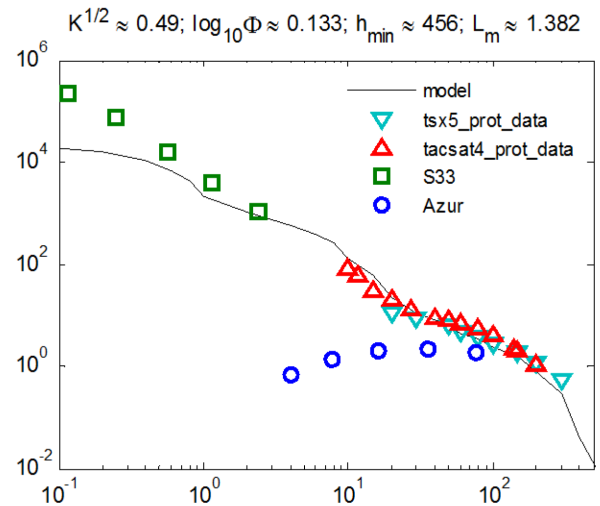


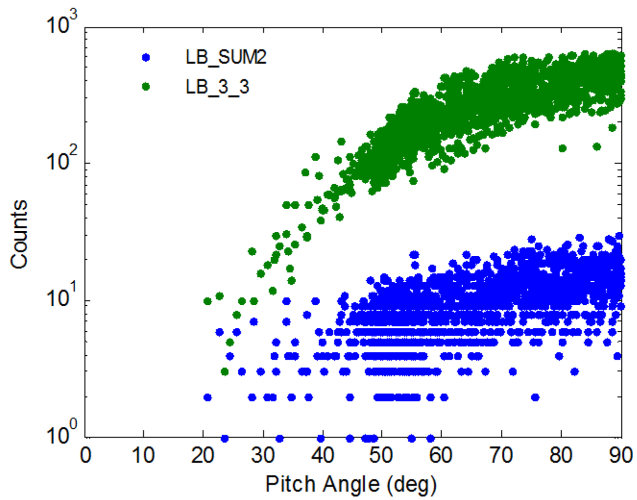


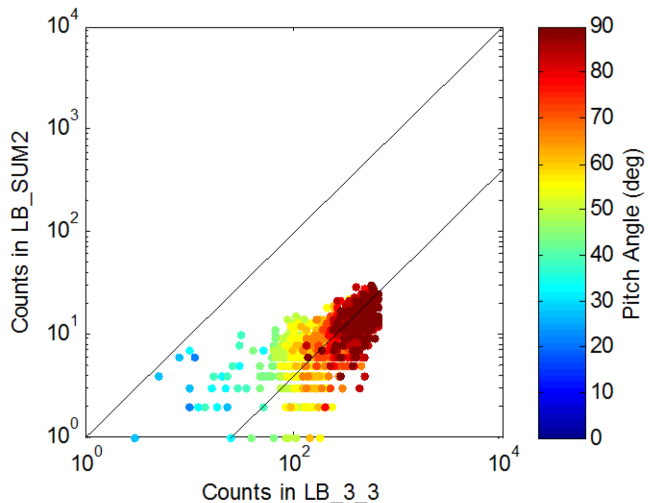


$L_m \approx 1.382$, $K^{1/2} \approx 0.49$, $h_{min} \approx 458$









Conclusions

- For these bins, the CEASE count ratios (LB_SUM2 to LB_3_3) are all about 0.04.
  - Based on spectral analysis, these count ratios are somewhat ambiguous as to spectral shape.
  - However, flat or peaked spectra are considered unlikely.
- Count ratios computed from Azur spectra are consistently smaller than those measured by CEASE.
  - Lends further evidence that these spectral shapes are unlikely based on CEASE measurements.
  - Note, however in the first bin ($L_m \approx 1.463$), CRRES/PROTEL spectrum has a shape similar to Azur.
- Other tests indicate that CEASE measurements are unlikely to be contaminated.
- These calculations used isotropic response functions and assumed an isotropic flux. If anisotropy decreased the CEASE count ratio by a factor of 2, this would bring CEASE more into line with Azur spectra. However, anisotropy would likely affect both CEASE channels more or less equally. The plots of count rate vs. pitch angle do show a small effect. For now I consider this to be a minor effect.
- TacSat-4/CEASE response appears to be inconsistent with Azur spectral shapes.