**ERPA Energy Levels and Current Calculation Methods/Results**

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Current Result Document: ERPA Energy Levels v3.xlsx

Current Script Document: ERPA\_Current.mlx

Contents

[Overall Notes 1](#_Toc159495528)

[Method (~Fall 2021) - FAST 1](#_Toc159495529)

[Method (12/23/21) - FAST 2](#_Toc159495530)

[Method (2/7/22) - FAST 3](#_Toc159495531)

[Method (5/10/22) - FAST 4](#_Toc159495532)

[Method (6/7/22) - CREX2 5](#_Toc159495533)

[Method (8/2/22) - CREX2 7](#_Toc159495534)

[Method (8/25/22) - RENU2 7](#_Toc159495535)

[Method (11/8/22) - RENU2 8](#_Toc159495536)

# Overall Notes

This document explains all the methods included in the MatLab script, ERPA\_Current.mlx. This includes methods of Fall 2021 and 12/23/21 that were found to be incorrect that were commented out. As well as method at 11/8/22 that is unfinished, as a better plan was thought of soon after.

The most useful methods are:

* 2/7/22 – integrating FAST data
* 5/10/22 – more detailed integration of FAST data
* 8/2/22 – CREX-2 EPLAS data as current
* 8/25/22 – introducing RENU2 ERPA data

# Method (~Fall 2021) - FAST

**Goal**

Use data from FAST to see if the ERPA can measure the incoming flux.

**Assumptions**

* Assume that FAST data is relevant to our instrument and flight
* Picked 10^9 1/cm^2\*s as the amount of electrons in the cusp
* Diameter of the anode = 1 in

**Method**

1st attempt:

* Unit conversion using charge of an electron:
  + Convert diameter of anode to cm
  + Multiply the number flux, 10^9 1/cm^2\*s by charge, 1.6\*10^-19
* Find minimum area for 1 nA of current
  + Get an area by dividing the minimum current, 1 nA = 10^-9 A, and divide by the current previously calculated
  + Calculate diameter from this area and convert from cm to inches
  + Compare to the size of the ERPA anode diameter

**Results**

* The ERPA diameter of 1 inch is slightly too small to collect 1 nA
* This seems incorrect, need to discuss with Marc and Laura

**Notes**

* Using the charge of an electron and flux like this to get current is incorrect. Need to come up with a new method
* Need to check our understanding of the ERPA instrument and minimum current
* This method was completely commented out as it was incorrect

**Sources**

FAST data/information:

* (Chaston et al. 1999): <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/1998GL900246>
* (Chaston et al. 2003, Laura was on this one!): <https://onlinelibrary.wiley.com/doi/abs/10.1029/2001JA007537>
* (Hatch et al. 2017): <https://onlinelibrary.wiley.com/doi/abs/10.1002/2017JA024175>

# Method (12/23/21) - FAST

**Goal**

* Calculate incoming flux using a more comprehensive understanding of number flux from FAST
* Use this data to find energy bins we should select for the ERPA

**Assumptions**

* Assume a linear relationship between the data points 10^9 # / (eV \* sr \* s \* cm^2) at 10 eV and 10^8 # / (eV \* sr \* s \* cm^2) at 100 eV
* Diameter of the anode = 1 in

**Method**

* Fit the data points (10, 10^9) and (100, 10^8) to get a linear function
* Normalize by dividing each number flux along that linear function by its corresponding energy at steps of 1 eV from 10 eV to 150 eV
* Fit the resulting plot of the energy vs the normalized data, variable “dense”
  + Found that a two term exponential function works best
* Then for every energy level:
  + Integrate from energy level to either 150 eV or 1000 eV
  + Multiply by charge of an electron and area of anode to get current
  + Multiply current by accumulation time in seconds to get charge

**Results**

Values appear very wrong, will need to consult Marc and Laura

**Notes**

* This method normalizes the data TWICE – the values Laura and I agreed upon were already normalized.
* These values were found to be wrong and are NOT included in ERPA Energy Levels v3.xlsx.
* This method was completely commented out of the script as it was incorrect.

**Sources**

FAST data/information:

* (Chaston et al. 1999): <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/1998GL900246>
* (Chaston et al. 2003, Laura was on this one!): <https://onlinelibrary.wiley.com/doi/abs/10.1029/2001JA007537>
* (Hatch et al. 2017): <https://onlinelibrary.wiley.com/doi/abs/10.1002/2017JA024175>

# Method (2/7/22) - FAST

**Goal**

Remove the extra normalization that the previous calculation included and see the results.

**Assumptions**

* Incoming flux from precipitating electrons is 10^10 eV / (eV \* sr \* s \* cm^2) based on FAST satellite data
  + Like this for approximately 3 eV – 1000 eV
* Each energy level has an accumulation time of 100 ms
* Diameter of anode is 2.54 cm

**Method**

1. Normalize flux by dividing 10^10 by eV at 10 eV and 100 eV
   1. Gives points 10^9 # / (eV \* sr \* s \* cm^2) at 10 eV and 10^8 # / (eV \* sr \* s \* cm^2) at 100 eV
2. Created a linear fit between these points
3. For every energy level we want to know about:
   1. Integrate from energy level to either 150 eV or 1000 eV
   2. Multiply by charge of an electron and area of anode to get current
   3. Multiply current by accumulation time in seconds to get charge

**Results**

Data is in the first set of columns in the excel file, ERPA Energy Levels v3.xlsx.

**Notes**

The idea of normalization was provided by Dr. Laura Peticolas, and the calculation method was discussed with her as well.

* Previously I thought I had to normalize the values of 10^9 and 10^8, not realizing that they were already normalized. This fixes that
* Energies of 3 eV – 1000 eV approximately follow the normalization used

**Sources**

Same as previously used FAST data:

* (Chaston et al. 1999): <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/1998GL900246>
* (Chaston et al. 2003, Laura was on this one!): <https://onlinelibrary.wiley.com/doi/abs/10.1029/2001JA007537>
* (Hatch et al. 2017): <https://onlinelibrary.wiley.com/doi/abs/10.1002/2017JA024175>

# Method (5/10/22) - FAST

**Goal**

* Normalize by each energy level with step dE of 1 eV and compare to previous method of two points.
* Extrapolate two points to be between 10^9 and 10^7 instead of 10^9 and 10^8.

**Assumptions**

* Incoming flux from precipitating electrons is 10^10 eV / (eV \* sr \* s \* cm^2) based on FAST satellite data
  + Like this for approximately 3 eV – 1000 eV
* Each energy level has an accumulation time of 100 ms
* Diameter of anode is 2.54 cm

**Method**

Two points:

1. Normalize flux by dividing 10^10 by eV at 10 eV and 100 eV
   1. Gives points 10^9 # / (eV \* sr \* s \* cm^2) at 10 eV and 10^8 # / (eV \* sr \* s \* cm^2) at 100 eV
2. Created a linear fit between these points
3. For every energy level we want to know about:
   1. Integrate from energy level to either 150 eV or 1000 eV
   2. Multiply by charge of an electron and area of anode to get current
   3. Multiply current by accumulation time in seconds to get charge

Steps of 1 eV:

1. Normalize by dividing 10^10 by energy b a loop for each step dE = 1 eV
   1. Divide 10^10 by energy at step dE
   2. Gives points 10^9 # / (eV \* sr \* s \* cm^2) at 10 eV and 10^8 # / (eV \* sr \* s \* cm^2) at 100 eV
2. Created a linear fit between these points
3. For every energy level we want to know about:
   1. Integrate from energy level to either 150 eV or 1000 eV
   2. Multiply by charge of an electron and area of anode to get current
   3. Multiply current by accumulation time in seconds to get charge

**Results**

* Data under the 5/10 Update section in the excel file, ERPA Energy Levels v3.xlsx.
* The two methods above, two points and steps of 1 eV, are plotted and compared in the script and put in the same excel file.

**Notes**

Suggested to use CREX-2 EPLAS data instead as it is using data closer to our altitude with instruments we know more about/closer to what we will be using.

**Sources**

Same as previously used FAST data

* (Chaston et al. 1999): <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/1998GL900246>
* (Chaston et al. 2003, Laura was on this one!): <https://onlinelibrary.wiley.com/doi/abs/10.1029/2001JA007537>
* (Hatch et al. 2017): <https://onlinelibrary.wiley.com/doi/abs/10.1002/2017JA024175>

# Method (6/7/22) - CREX2

**Goal**

Use the CREX-2 data that shows values in MHz to approximate the data.

**Assumptions**

* Marc and I approximated 5 (log) MHz as the value for these events.

**Method**

1. Converted 5 logMHz into Hz
2. Assumed constant Hz over these energies, integrated from energy level to 150 eV
3. Took this Hz and multiplied by charge to get current
4. Multiplied by 0.1 seconds (100 ms) to get charge

I did this in a loop for all energy levels in two different sets. One set integrating to 1 keV and another to 150 eV.

**Results**

Data under the “6/7 Update” section in the excel file, ERPA Energy Levels v3.xlsx.

**Notes**

I do have some concerns since the assumption that 5 logMHz is constant along these energies looks a lot like the pre-normalized data from what I was doing before. I also don't know what the altitude is for this dataset.

**Sources**

Referring to this CREX-2 Data (received through email from Marc):

A screenshot of a graph

Description automatically generated

# Method (8/2/22) - CREX2

**Goal**

Convert Hz data from CREX-2 into number density, allowing us to compare the EPLAS and ERPA instruments.

**Assumptions**

* Difference in radii between the inner and outer electrodes is 0.196 cm (Ian Cohen’s thesis)

**Method**

* Divide the data by the geometric factor of the CREX-2 EPLAS,
  + g = 1.12x10^-4 sr \* cm^2 \* (ev/ev) according to Ian Cohen’s thesis
  + Multiply g by the number of anodes to get the full geometric factor
* Multiply by the area of EPLAS to get the current

**Results**

Data is not on ERPA Energy Levels v3.xlsx. But, is printed out in the most recent MatLab script, ERPA\_Current.mlx

**Notes**

* Does this need to be normalized like I have previously done with the FAST data?
* Next step is to compare to ERPA data

**Sources**

* Ian Choen’s thesis: <https://scholars.unh.edu/dissertation/2203/>
* Same CREX-2 data as the previous method (6/7/22)

# Method (8/25/22) - RENU2

**Goal**

Use the RENU2 ERPA values in nA when looking at energies of 3 eV and above.

**Assumptions**

* Approximate peak current from electron precipitation events were seen as 0.8 nA, 1.5 nA, 1.0 nA, 0.7 nA, 1.4 nA, 0.5 nA.
* Background current was approximately 0.2 nA
* Assume that the flux distribution is approximately flat over all energies

**Method**

ERPA values and multiply by the fraction of total energy from that energy level to 150 eV

**Results**

An example calculation was done, with the result printed on the MatLab script.

**Notes**

* RENU2 ERPA has a cadence of 1 ms
* Data is from two different rockets/flights – next step would be to compare the ERPA and EPLAS from RENU2

**Sources**

RENU2 ERPA data used:

A graph of a flight

Description automatically generated

# Method (11/8/22) - RENU2

**Goal**

* Compare RENU2 ERPA and EPLAS data to see how flux distribution above 3 eV.
* Start thinking about how this can be used for the pointing requirement

**Assumptions**

* RENU2 EPLAS has energy range of 5 eV – 14.6 keV
* Event 7:44:30 appears linear in the log colorbar, so it is possibly more of an average event to inform the requirement.

**Notes**

UNFINISHED – this section was dropped, instead went on to use David Kenward’s code and the actual data from the RENU2 launch instead of approximating from the plots.

**Sources**

* David Kenward’s thesis: <https://scholars.unh.edu/dissertation/2508/>
* Specifically referencing figure 28:

A screen shot of a graph

Description automatically generated