ACCELERATION, TRANSPORT, & TRAPPING OF ULTRA-HEAVY IONS IN THE INNER ZONE

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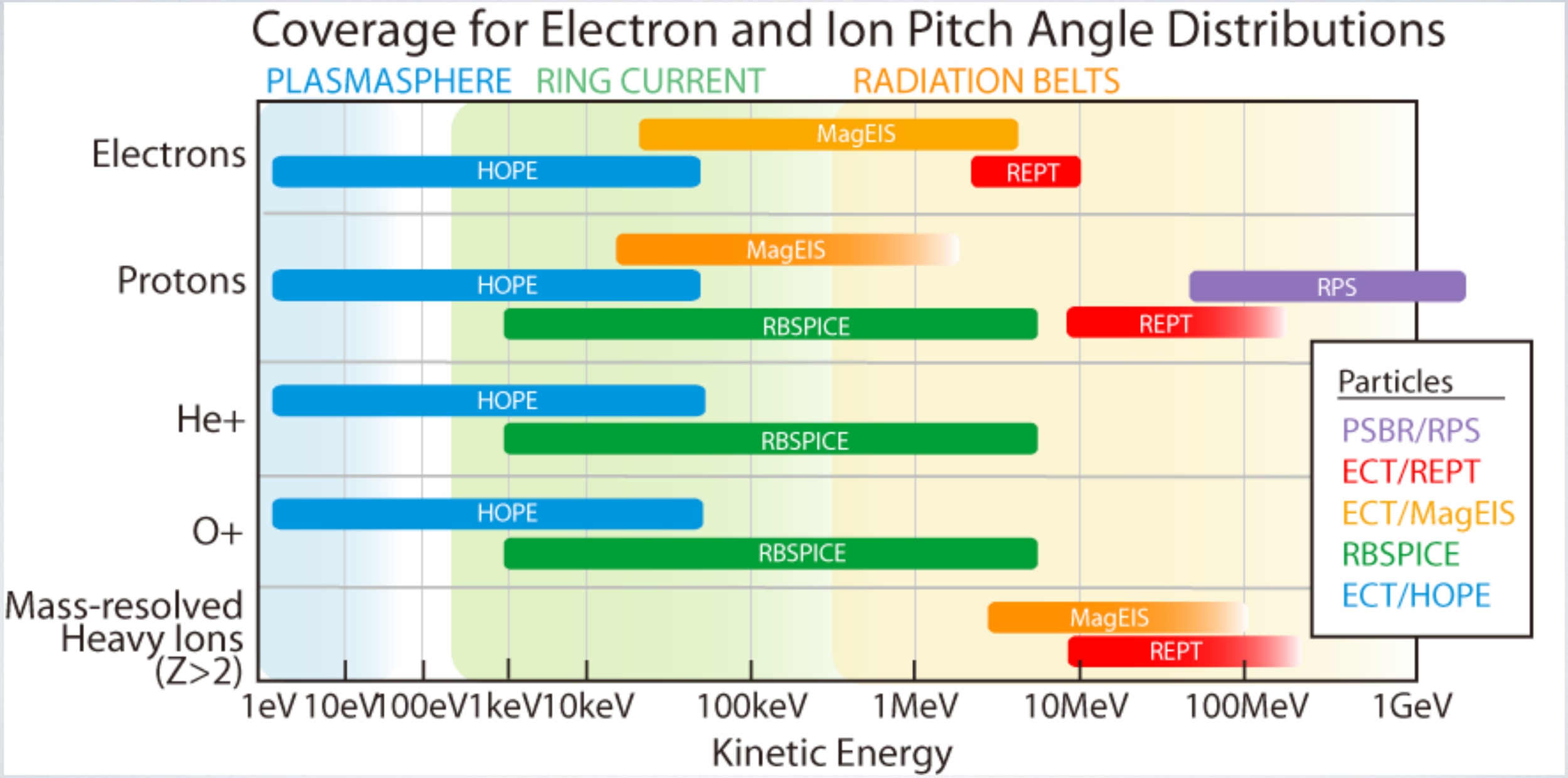
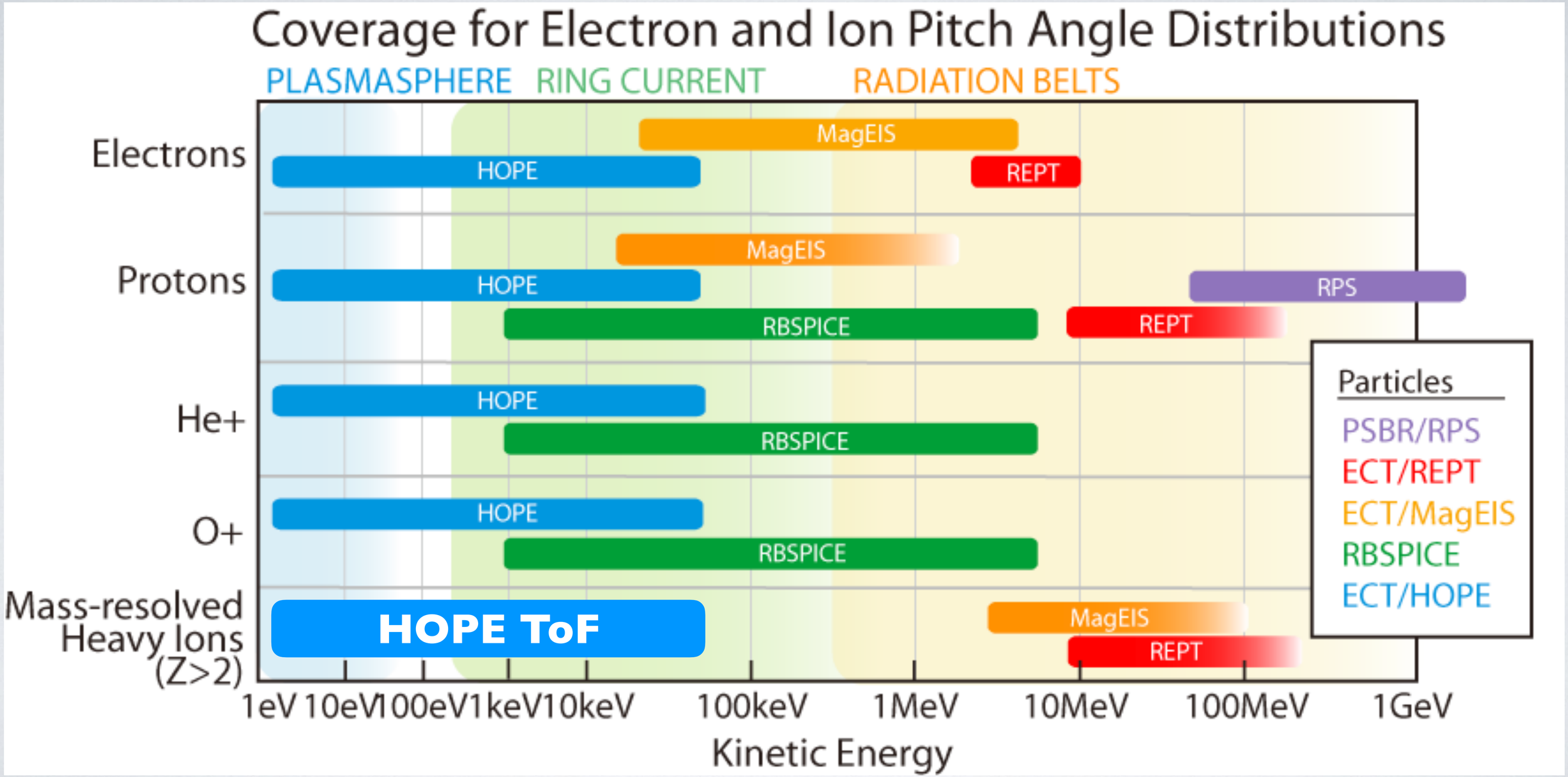
Brian Larsen, Herb Funsten, Ruth Skoug, Phil Fernandes, Mick Denton,
Alex Boyd and Harlan Spence


Coverage for Electron and Ion Pitch Angle Distributions
PLASMASPHERE
RING CURRENT
RADIATION BELTS
Electrons
Protons
He+
O+
Mass-resolved Heavy Ions (Z>2)
MagEIS
HOPE
REPT
MagEIS
HOPE
RPS
RBSPICE
REPT
HOPE
RBSPICE
HOPE
RBSPICE
MagEIS
REPT
Particles
PSBR/RPS
ECT/REPT
ECT/MagEIS
RBSPICE
ECT/HOPE
1eV
10eV
100eV
1keV
10keV
100keV
1MeV
10MeV
100MeV
1GeV
Kinetic Energy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10MeV
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Kinetic Energy

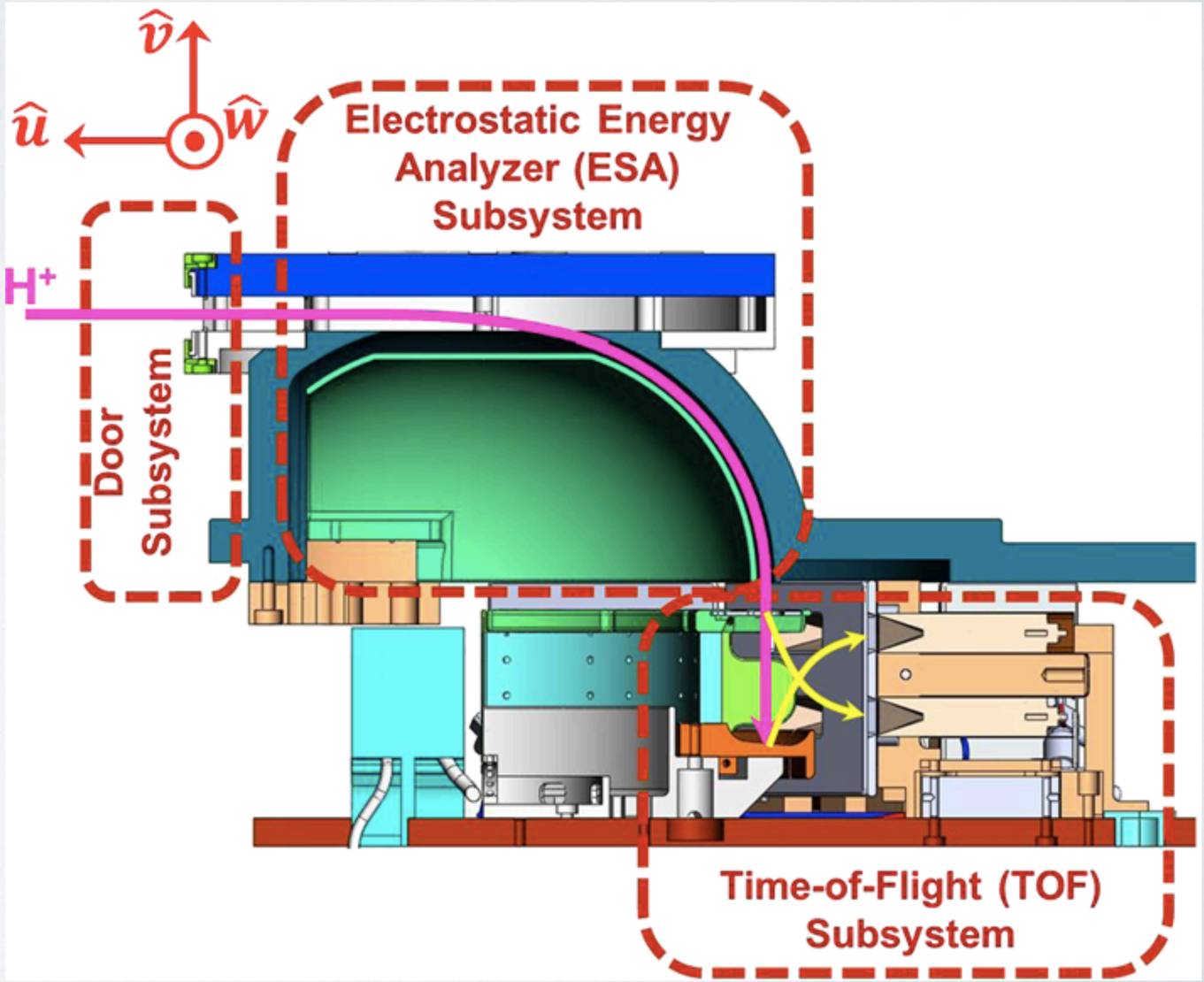
HOPE MEASUREMENT TECHNIQUE

Electrostatic Analyzer (ESA)

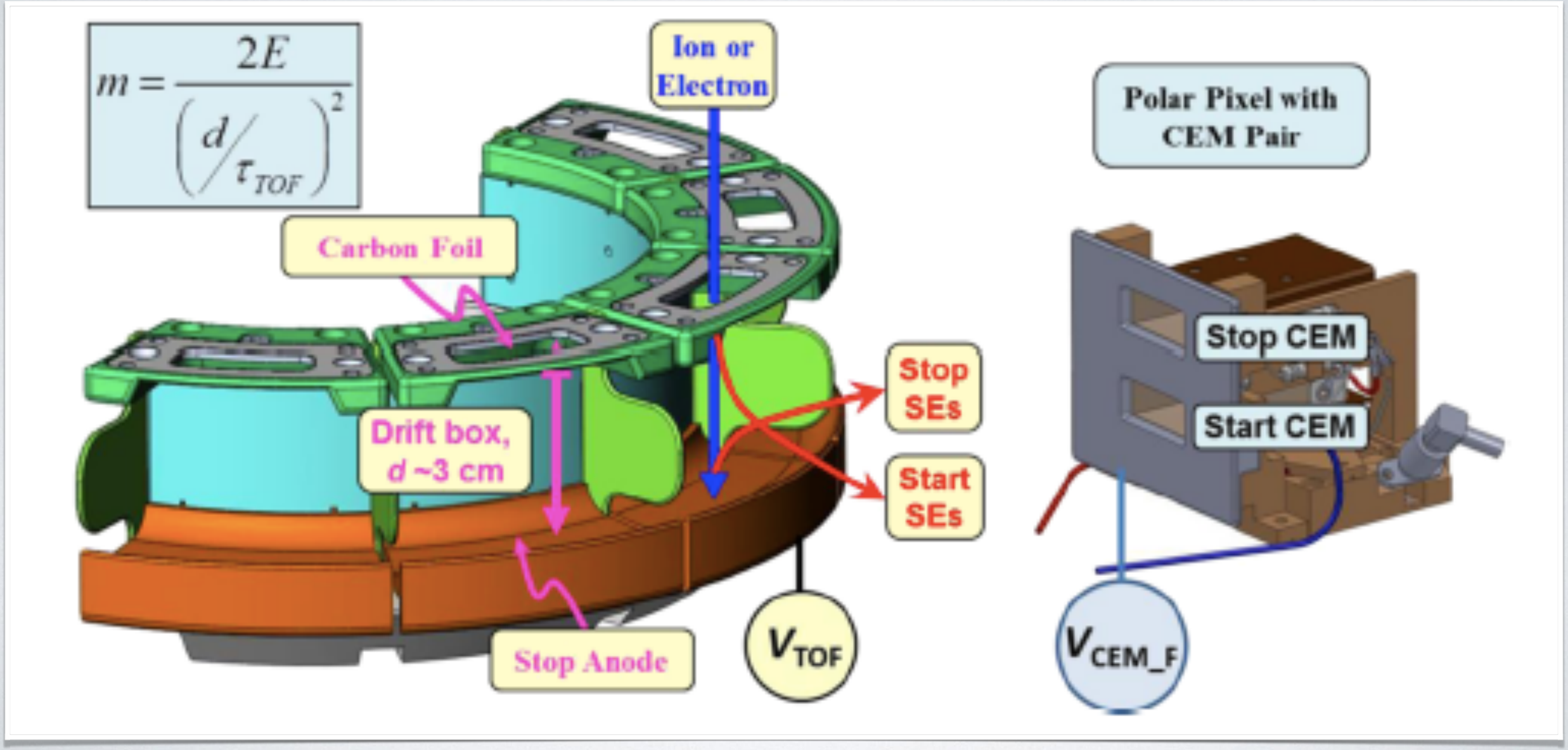
- measures E/q

Time of Flight (TOF) System

- Carbon Foil start electron
- ‘Bathtub’ stop electron
- TOF measures velocity
- Infers mass



TIME OF FLIGHT SEGMENT

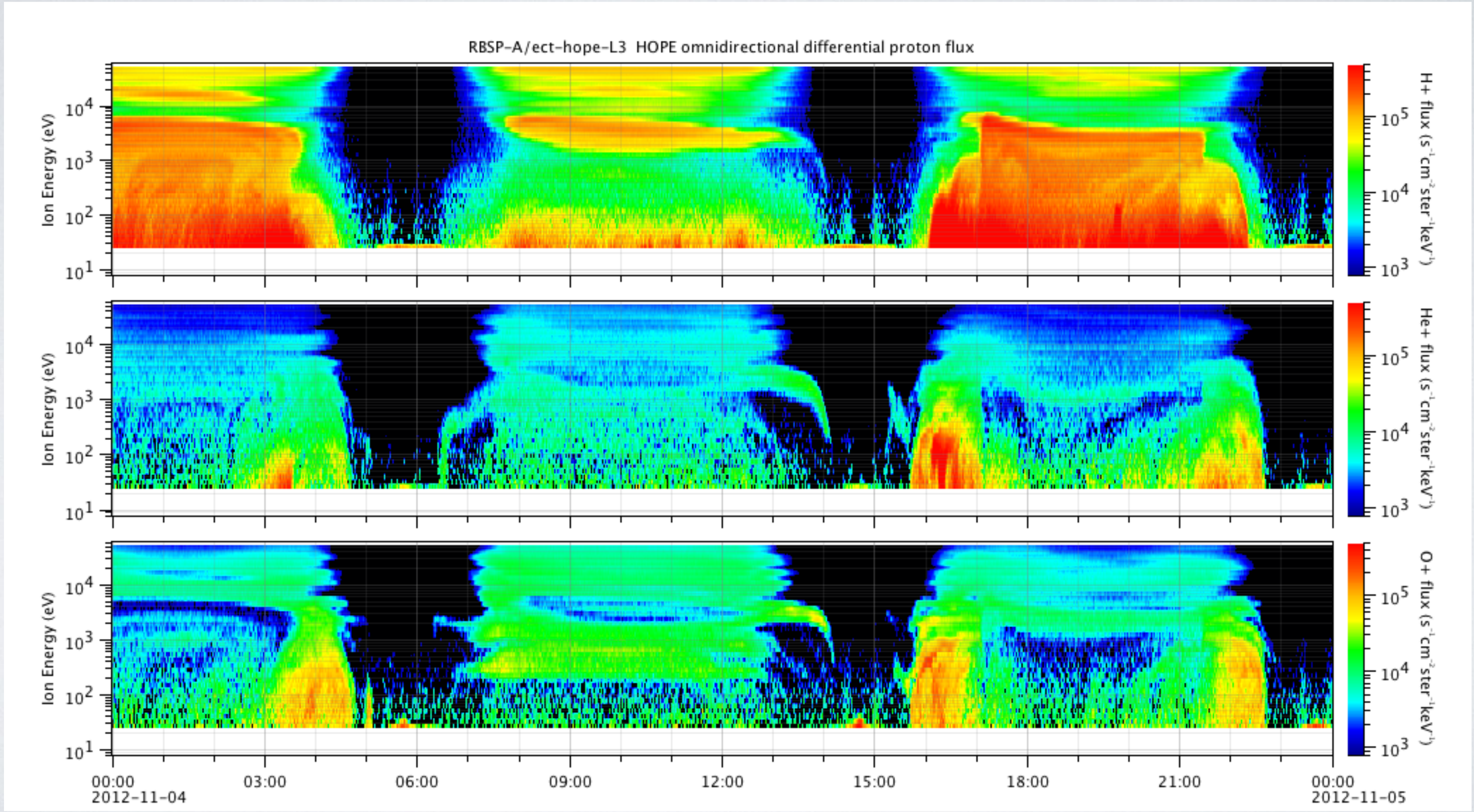


TYPICAL HOPE DATA

H+

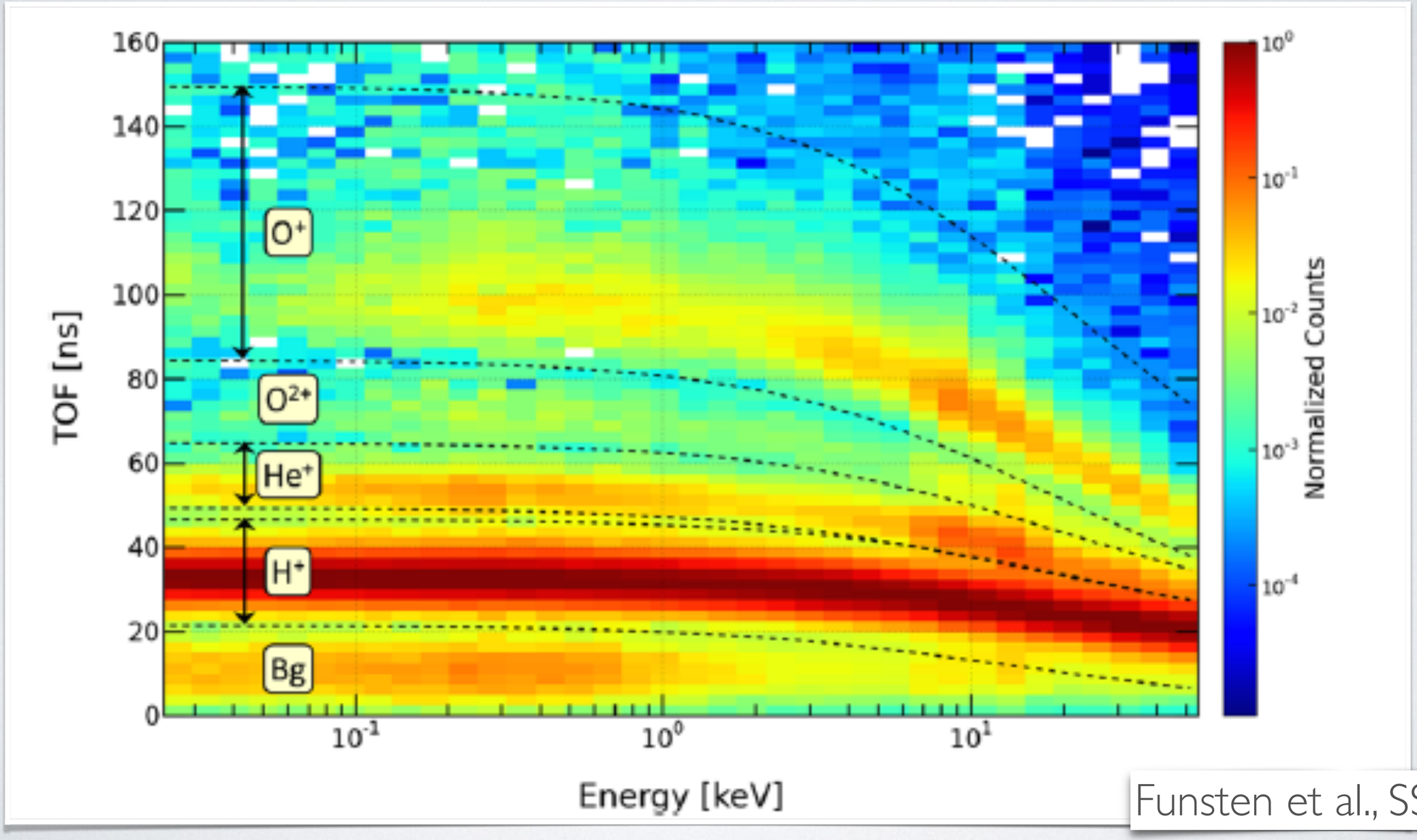
He+

O+



TIME-OF-FLIGHT MATRIX

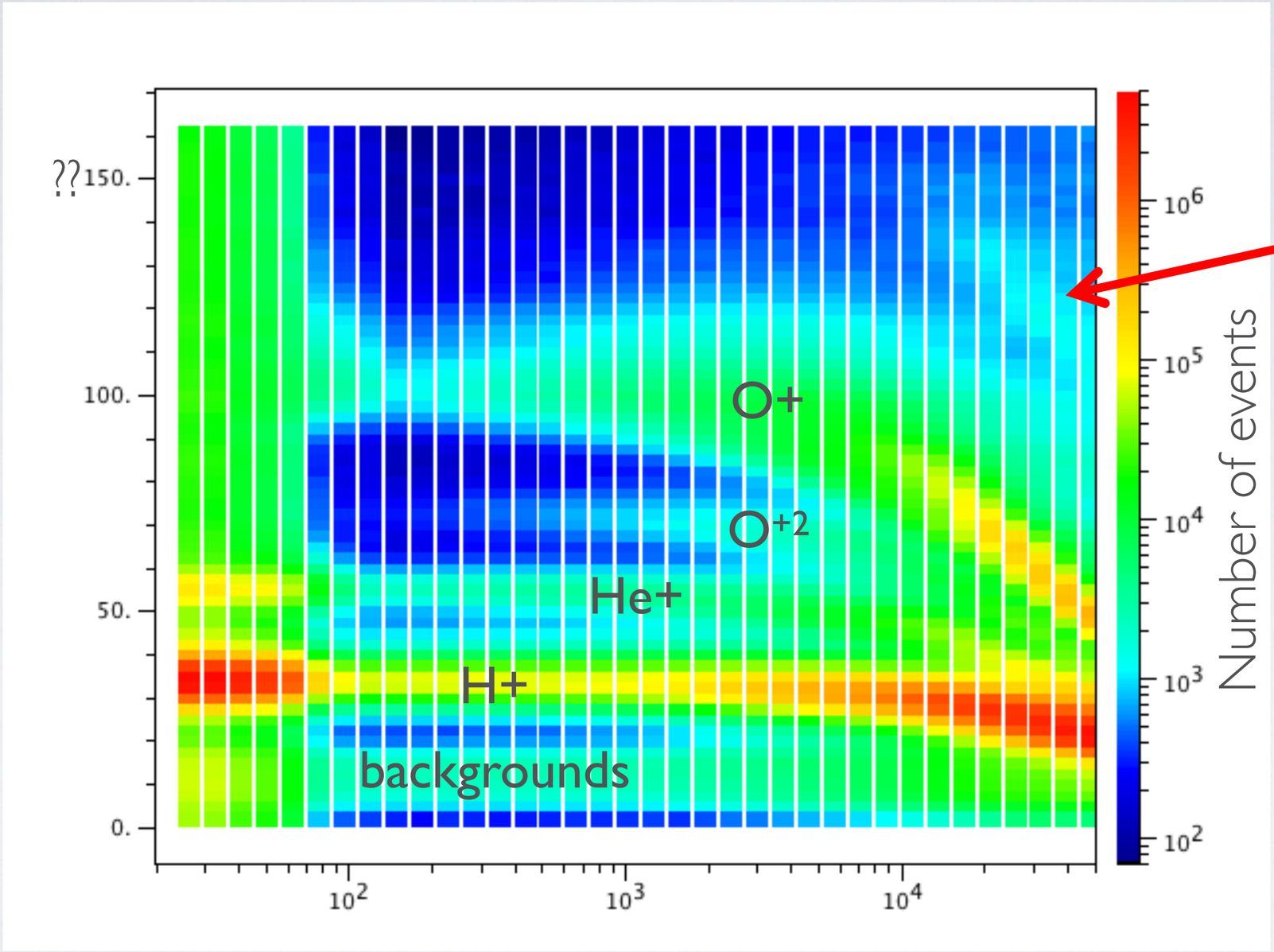
Heavier
Slower



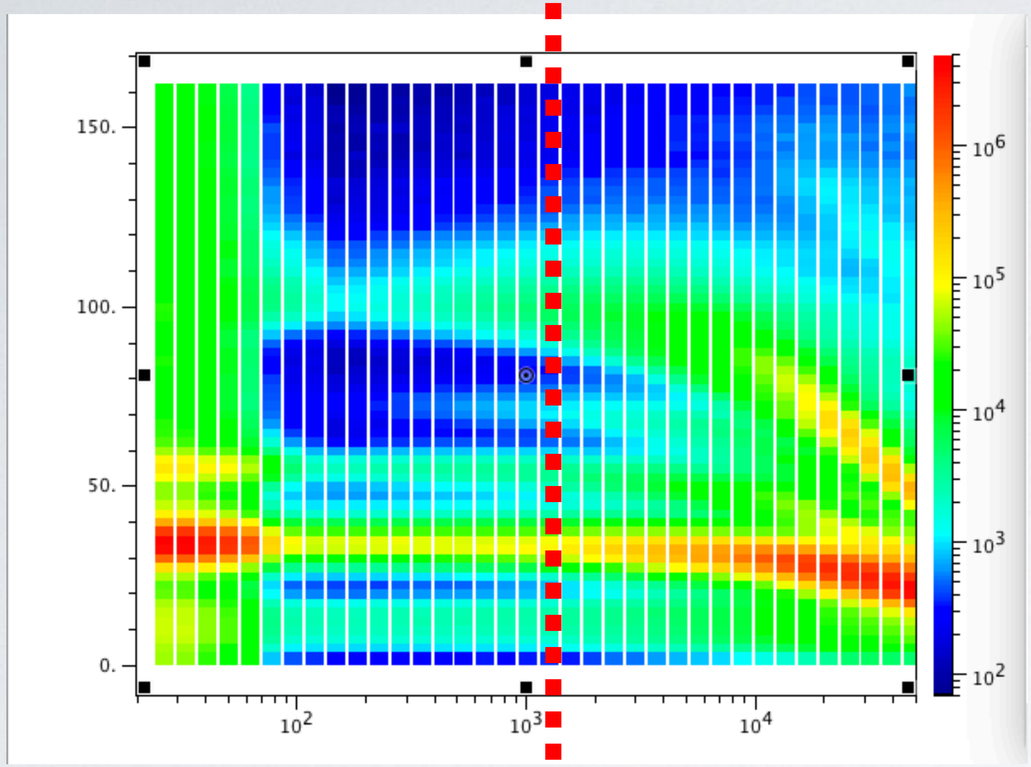
Funsten et al., SSR 2014

SEARCH FOR HEAVIER IONS

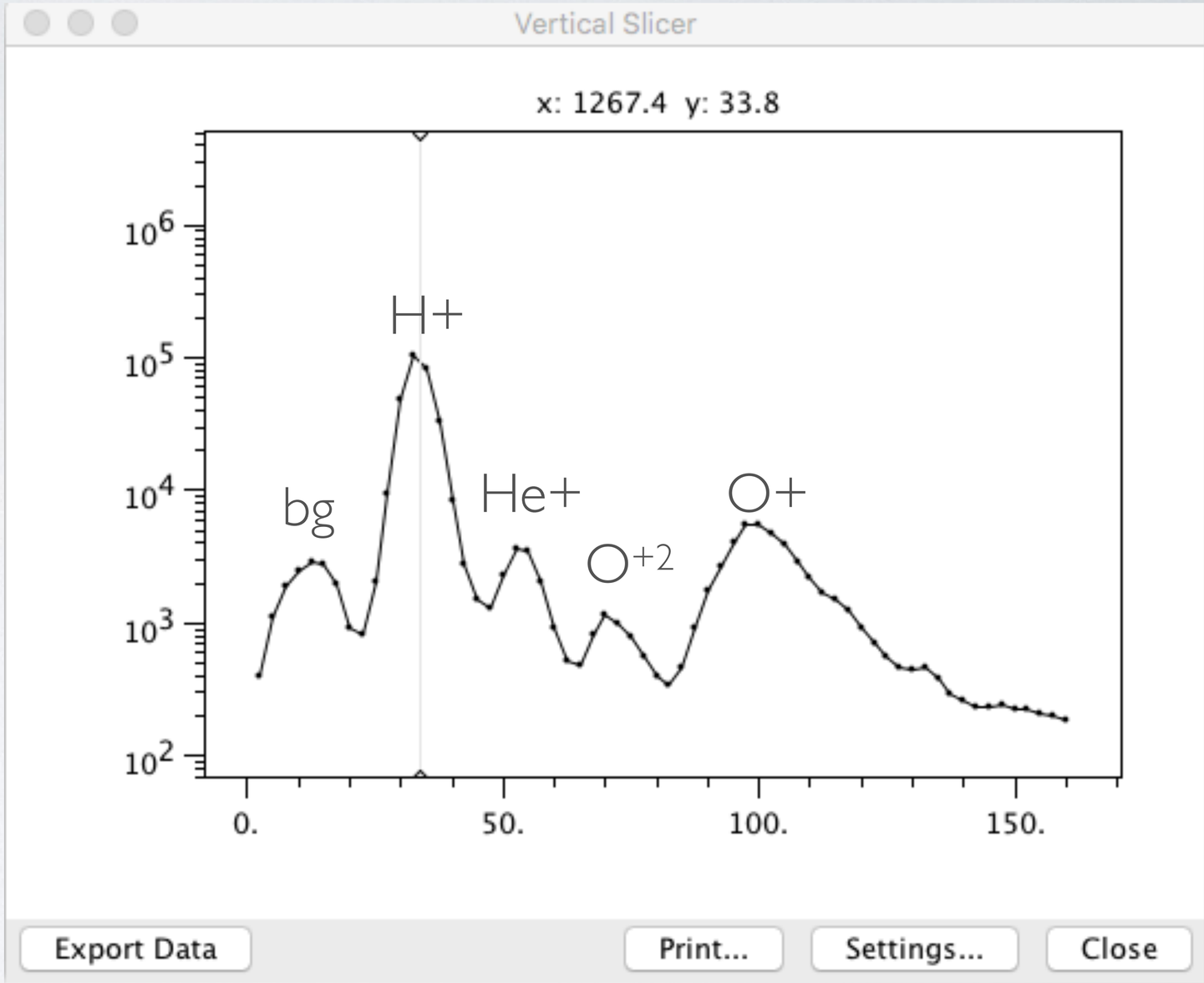
- Take all the RBSPA TOF matrices and sum them up
- Proper decoder ring applied to data
  - Data are in the level1 raw data and heavily commutated
  - A few pixels at a few energies are collected each spin
  - HOPE is not synced to S/C spin so PA is always different
  - Energies step up and down
- Ask Brian Larsen if you need to borrow the decoder ring


TOF [ns]
??
??150.
100.
50.
0.
10^2
10^3
10^4
O+
O^{+2}
He+
H+
backgrounds
10^6
10^5
10^4
10^3
10^2
Number of events
Energy [eV]

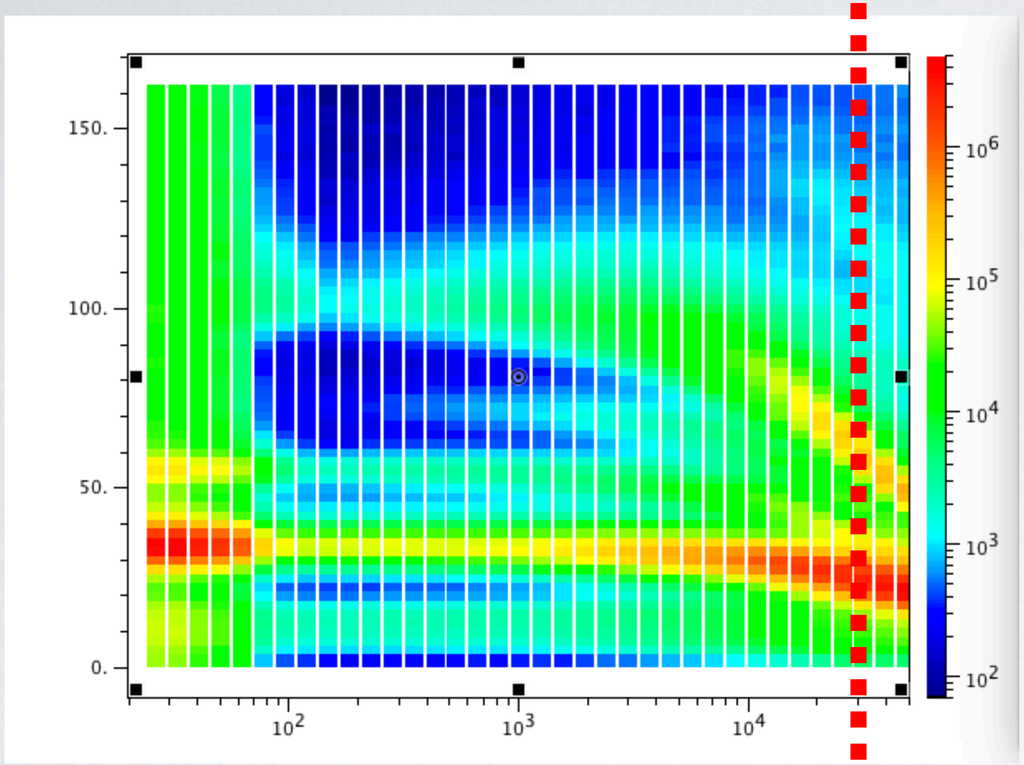
1,267eV

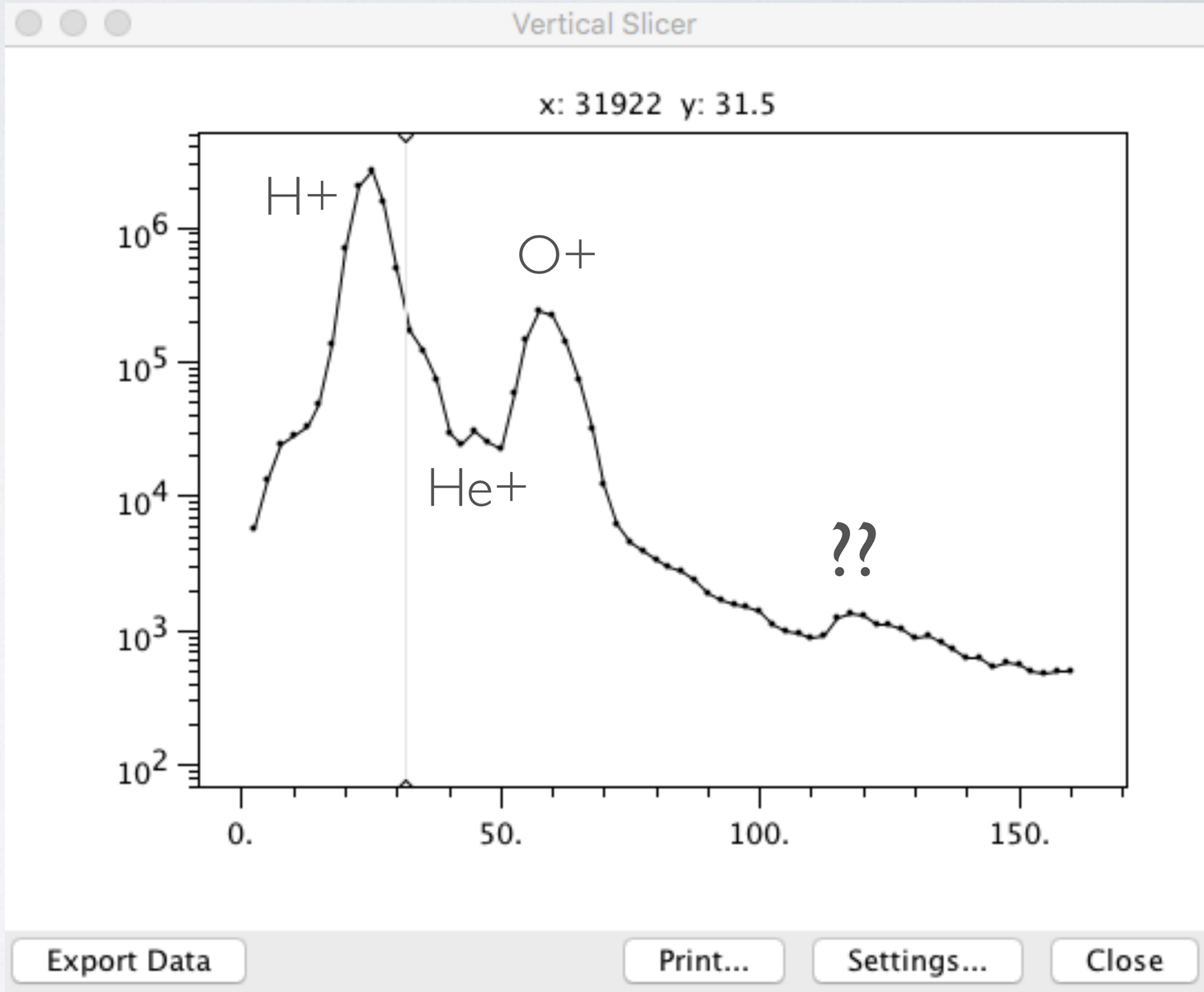


- Note that "O" means particles with mass ≈16 (i.e. C/N/O)
- Note O^{+2} is faster (shorter ToF) than O^{+}



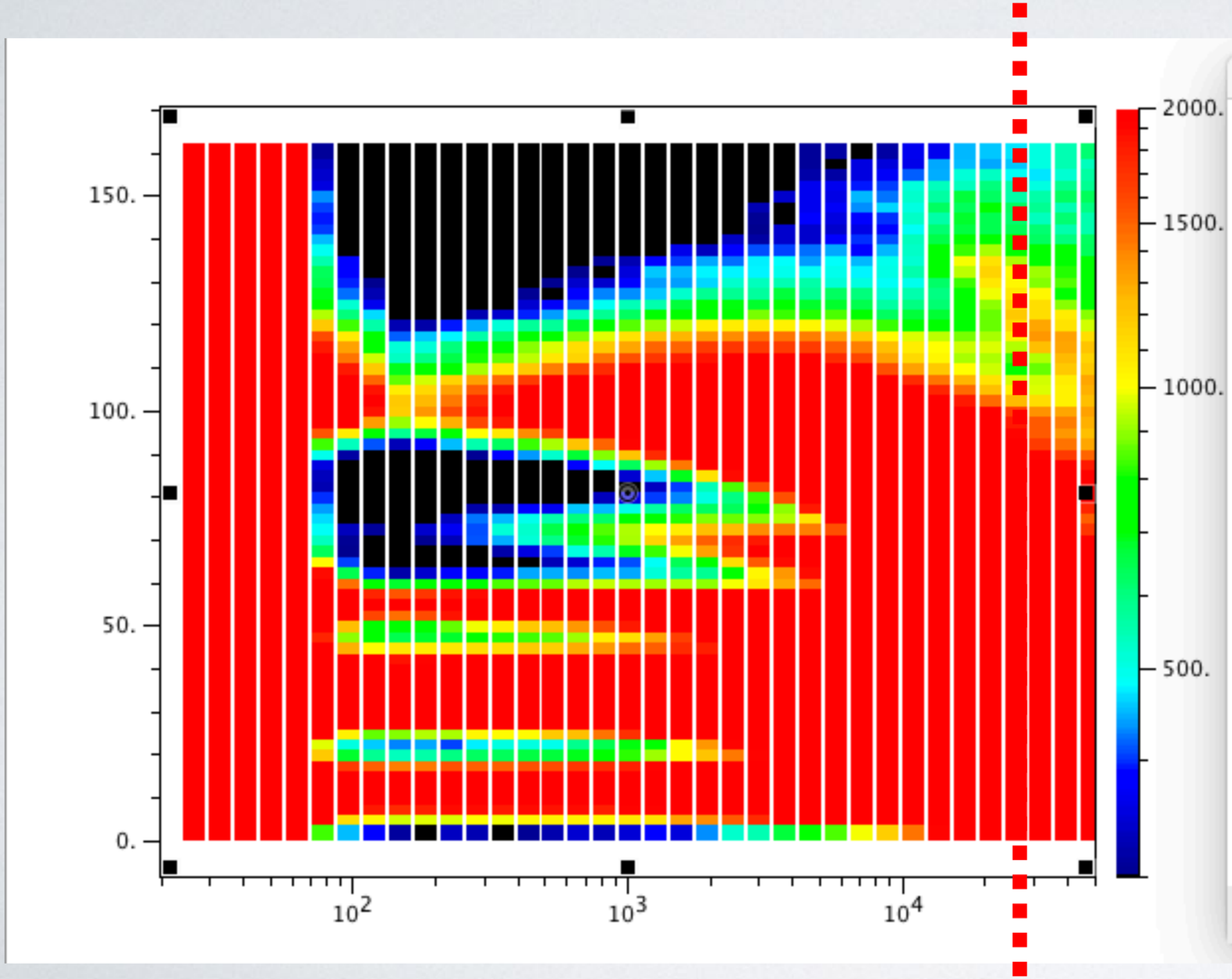
31,900 eV

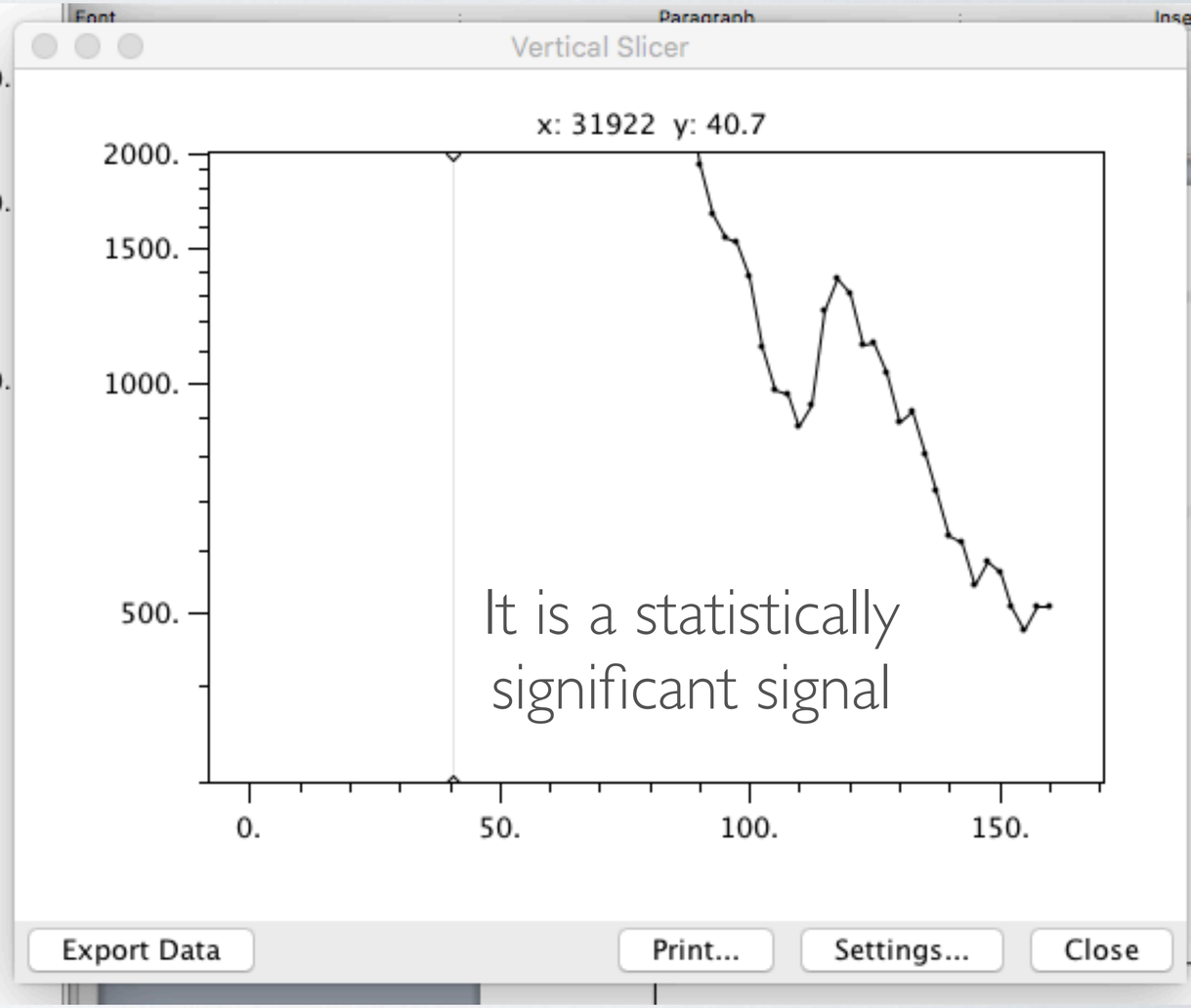




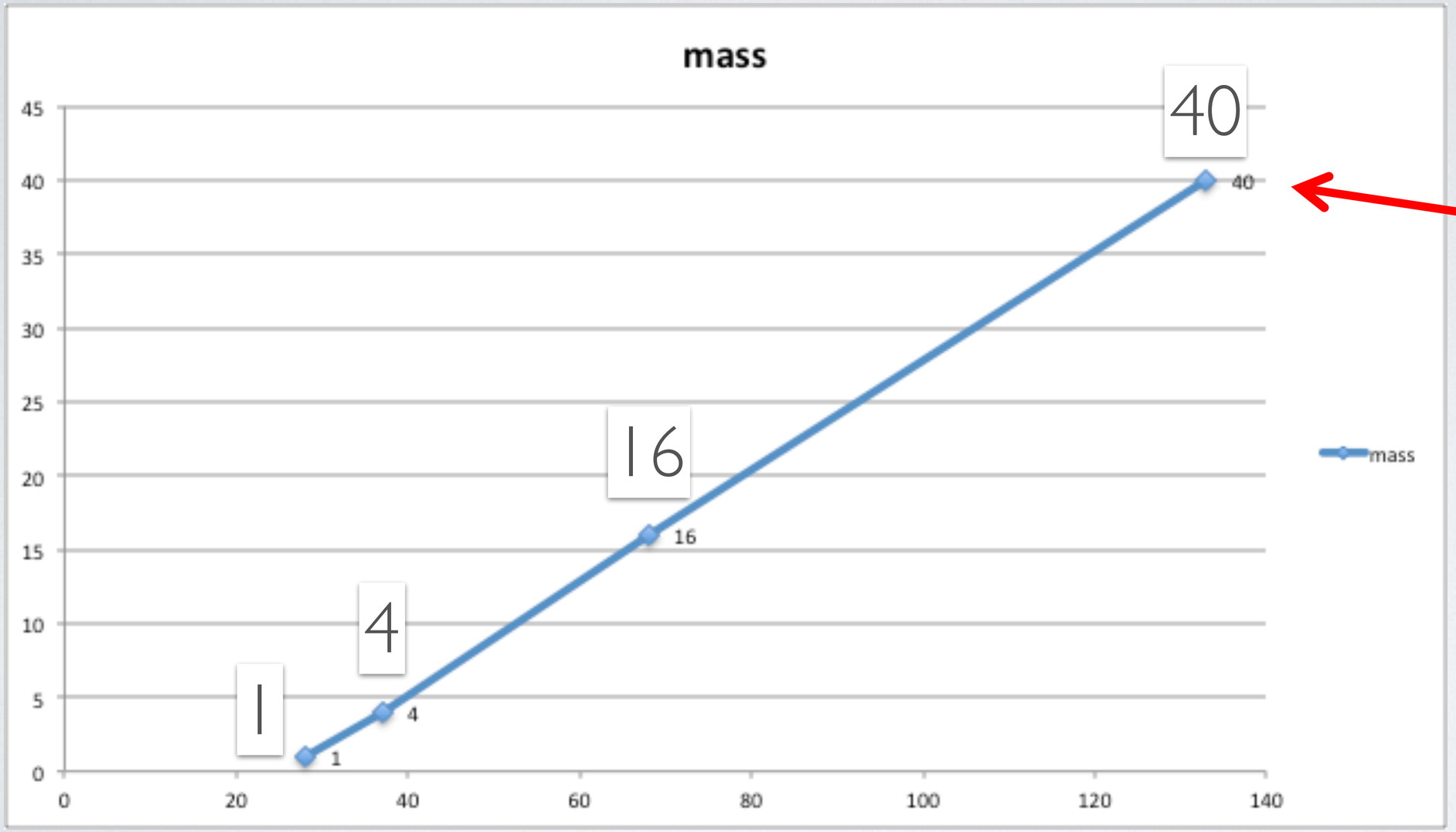
For the same species, higher energies have shorter ToF

SAME DATA DIFFERENT COLOR SCALE





WHAT MASS (SPECIES) IS THAT PEAK?!?!

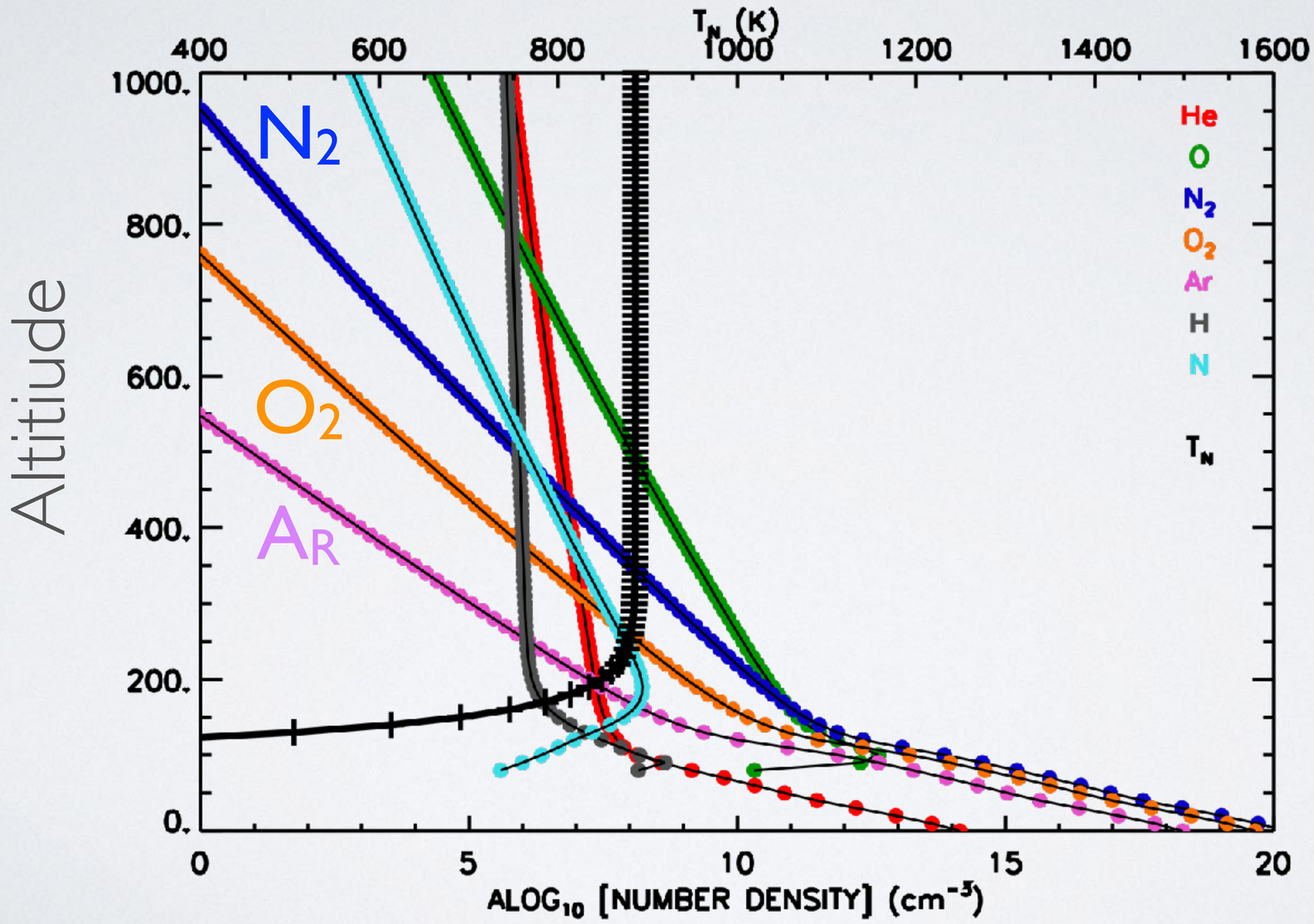


mass

TOF bin

To make this a straight line the mass must be ~40

ATMOSPHERIC CONSTITUENTS



$N_2^+ = 28$

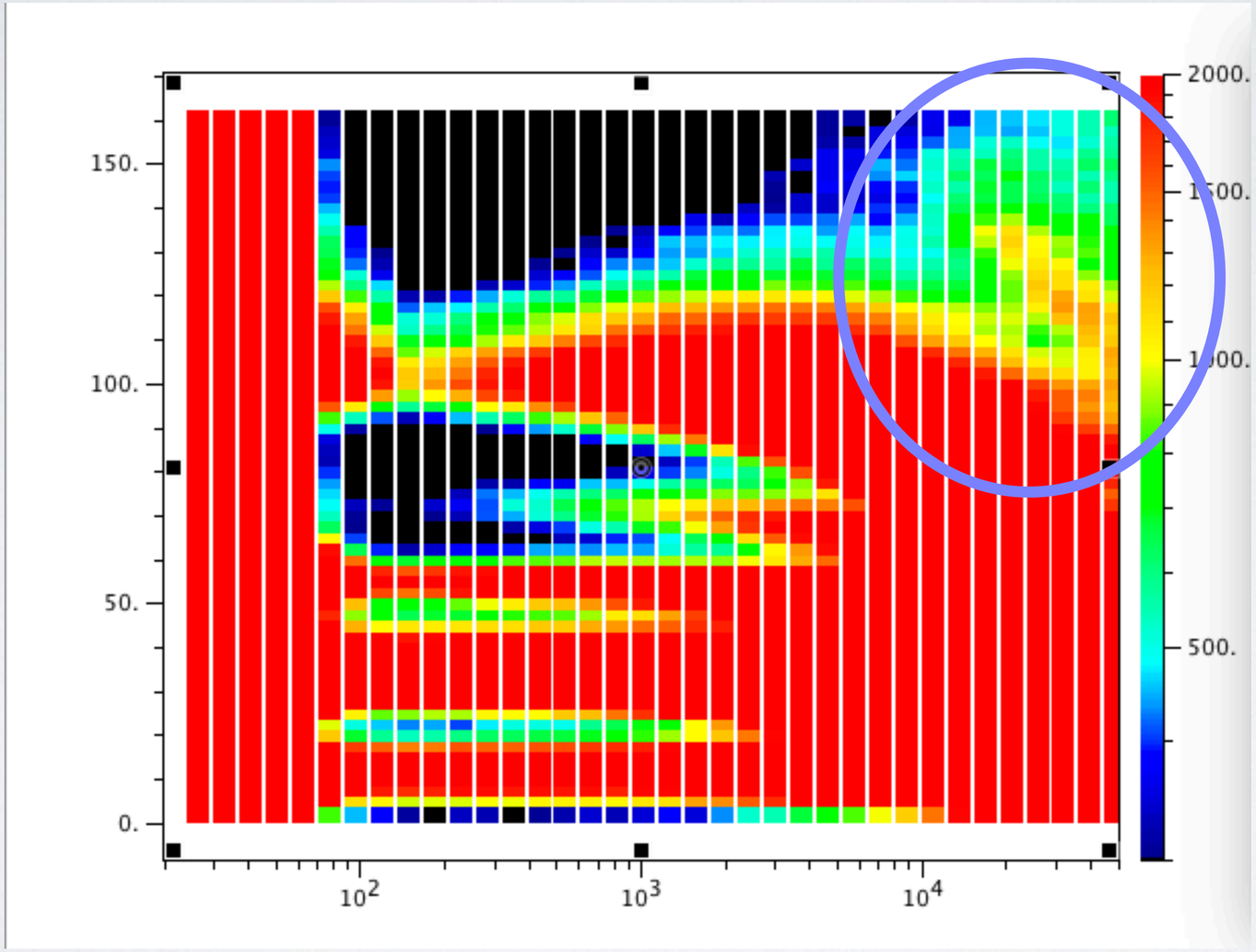
$NO^+ = 30$

$O_2^+ = 32$

$Ar^+ = 40$

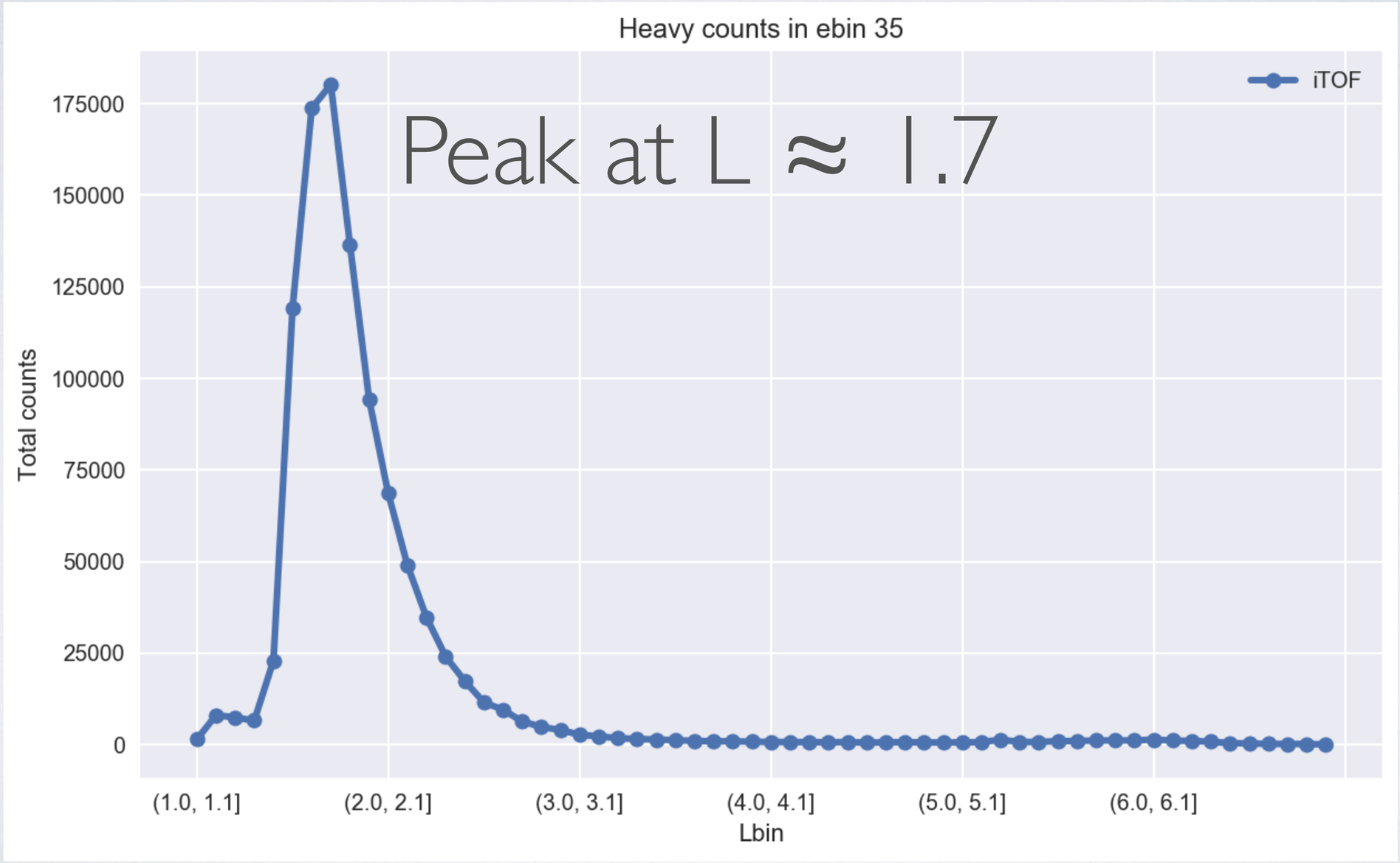
Energies ≈ 5 to 50 keV

Lower Energies likely do exist but would be off scale

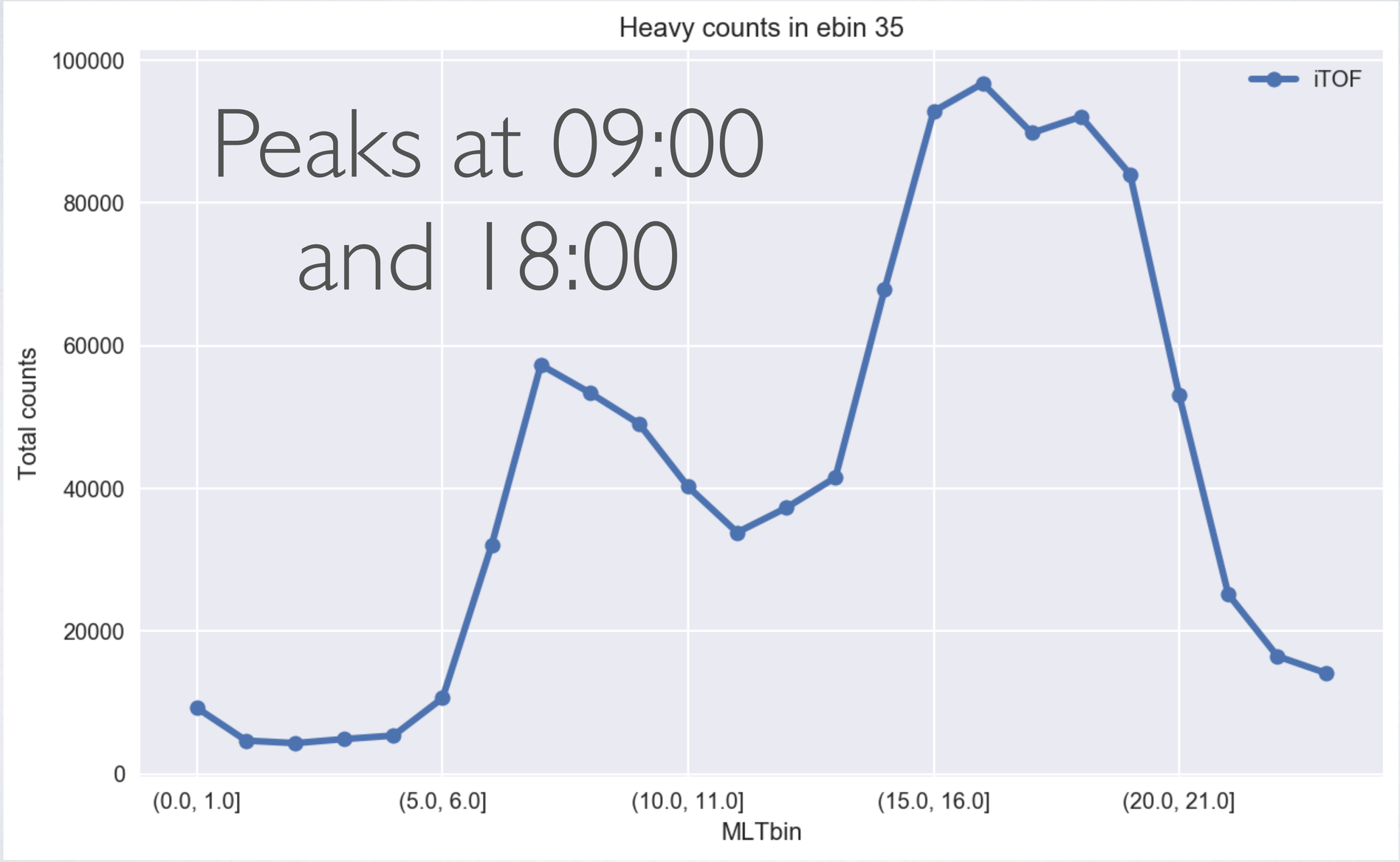


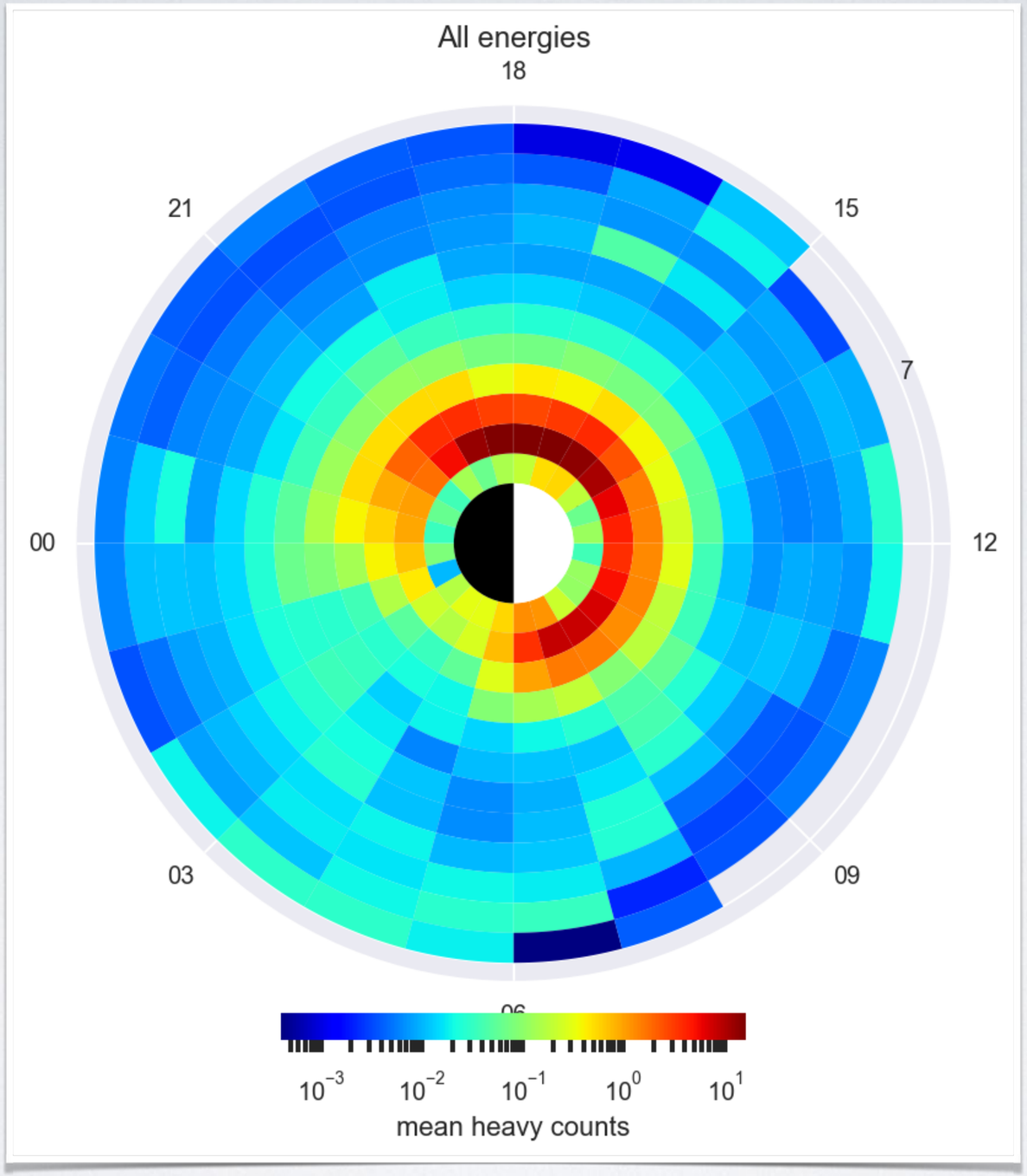
If Charge = 2
then mass = 80

HEAVY IONS ARE LOW L

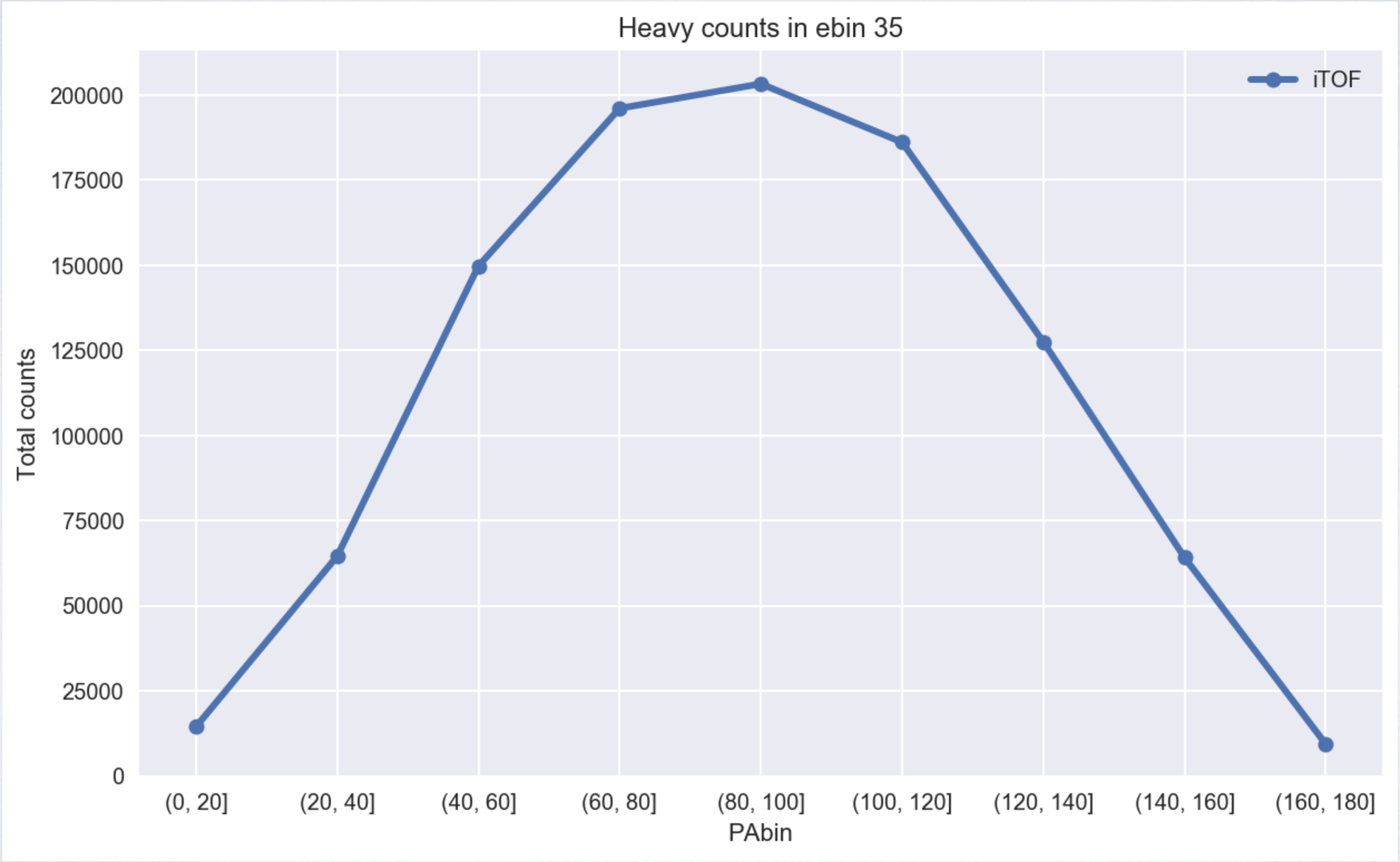


MLT DISTRIBUTION




All energies
18
21
15
7
00
12
03
09
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
mean heavy counts

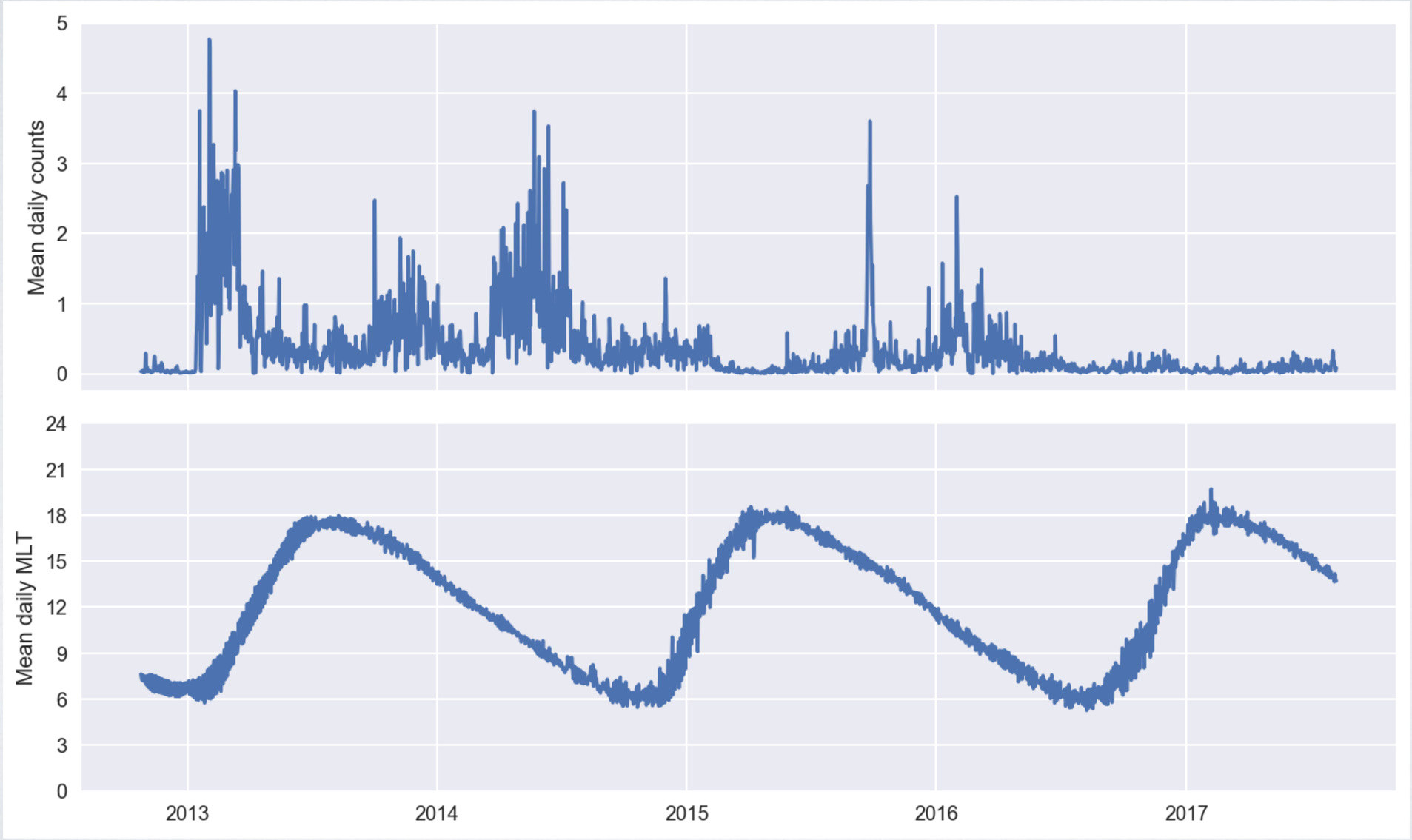
PITCH ANGLES PEAKED AT 90°



THERE IS A CLEAR TIME DEPENDENCE

Heavy Counts

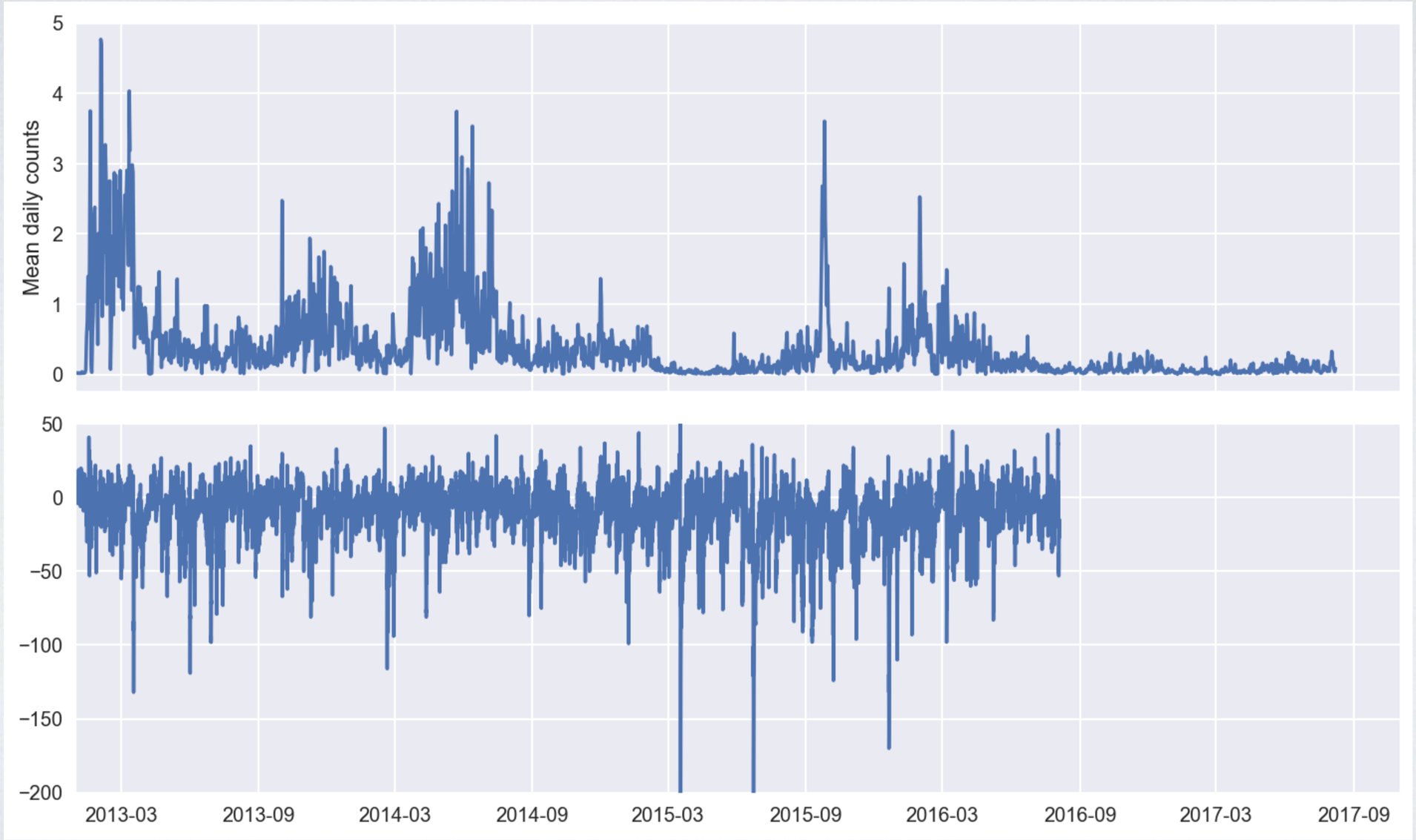
Mean Daily MLT



BUT NOT WITH DST, AE, AU, AL

Heavy Counts

Dst



WHAT WE KNOW

- Energies ≈ 5 to 50 keV
- Mass ≈ 40 implies molecular ions or argon:

  $N_2^+ = 28$

  $NO^+ = 30$

  $O_2^+ = 32$

  $Ar^+ = 40$
- Pancake pitch angle distributions (peaked at 90°)
- Peaked fluxes at L≈1.7 but not symmetric in MLT

WORKING HYPOTHESIS

- Whatever it is…
- it leaves the ionosphere at low energies and high L-shells
- gains energy through radial transport from high L to L < 2
- implies lifetimes of months (charge exchange, photo-dissociation)
- but is can this be reconciled with asymmetric MLT distribution?
- also, what explains the time dependence?