SWA PAS Calibration Tables
Conversion to Physical Values
and Moments Calculations

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1 Reference frames and bins allocation

Figure 1 shows the Elevation and angle angles and bins in the PAS frame. Figure 2 shows the same in the spacecraft frame. Note the the solar orbiter frame corresponds to the RTN Heliocentric frame most of the time.

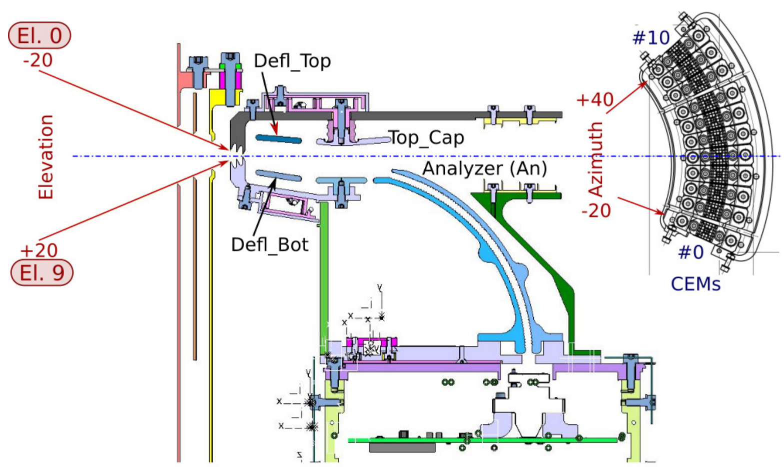

Figure 1: Elevation and azimuth bins and angles in the PAS analyzer frame. The CEMs plane is shown from the Analyzer.

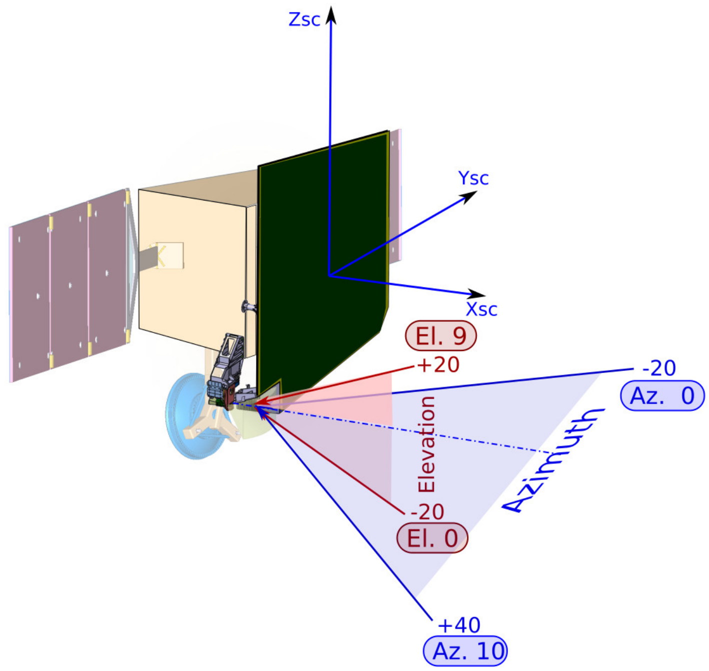

Figure 2: Elevation and azimuth bins in the Solar Orbiter frame.

2 Onboard Moments Decoding

The decode TM moments values to physical values use rules as follows:

```
Telemetry Density: NT (integer value)

    N  = float(N)/10.0   [cm-3]

Telemetry V: VT  (integer value)

    Vx = float(VTx)                            [km/s]
    Vy =  float(VTy) - 2000.0                  [km/s]
    Vz =  float(VTy) - 2000.0                  [km/s]

Telemetry Pressure tensor: PT (integer value)

    P = 2.0^(Pe-15)*(1.0+Pf/1024.0)*1.0e17/65504.0 [(cm^-1)*(s^-2)]
    here Pe = PT / 1024
    here Pf = (float)PT/1024.0 - (float)Pe
```

Note, that P is the pressure of particles of mass 1 (pressure of particles of mass 1 of number density expressed in cm^{-3} and thermal velocity expressed in $cm \cdot s^{-1}$). Thus to get a physical value (like $J \cdot cm^{-3}$) we have to multiply this value to proton mass and to N.

```
To calculate the temperature from the pressure tensor use the formula as follows:
```

$$T[eV] = (P_{XX} + P_{YY} + P_{ZZ})/N \cdot 5.251 \cdot 10^{-13} \cdot (2/3)$$

3 L1 data conversion and moments calculation

Instrument sampling is expressed as a 3-D array as follows:

$$Count_{ie,iel,iaz}$$

Here:

ie is the energy index [0 .. 95]

iel is the elevation index [0 .. 8]

iaz is the azimuth index [0 .. 10]

Open the files from the PAS CALIBRATION RECORD indicated in Table 1.

Name	Dimensions	Description
PAS_PFM_V_full_array.txt	96x9x11	Velocity array
PAS_PFM_GF_array.txt	9x11	Geometrical factor for **the real** accumulation time
PAS_PFM_El_full_array	9x11	Elevation angles
PAS_PFM_CN_array.txt	96x9x11	Conversion factor
PAS_PFM_AZ_full_array	9x11	Azimuth angles
PAS_PFM_dEE_full_array	9x11	Energy resolution

Table 1: Full Calibration record set

Then do as follows:

1. Read velocities $V_{ie,iel,iz}$ **in km/s** from the file PAS_PFM_V_full_array.txt
2. Read sin $SinElev_{iel,iaz}$ and cos $CosElev_{iel,iaz}$ of the elevation angles from the file PAS_PFM_El_full_array
3. Read sin $SinAz_{iel,iaz}$ and cos $CosAz_{iel,iaz}$ of the elevation angles from the file PAS_PFM_AZ_full_array
4. Make the arrays of Vx, Vy, and Vz in the SPACECRAFT frame for each energy, elevation, and azimuth as follows

```
VxarrSC(*,iel,iaz) = -Varr*CosElArr(iel)*CosAzArr(iaz) [km/s]
VyarrSC(*,iel,iaz) = -Varr*CosElArr(iel)*SinAzArr(iaz)
VzarrSC(*,iel,iaz) = -Varr*SinElArr(iel)
```

5. Read the geometrical factor $GV_{iel,iaz}$ array from the file PAS_PFM_GF_array.txt and calculate the proton distribution function value in each Velocity point (see item 4) as follows:

$$DF_{ie,iel,iaz} = Count_{ie,iel,iaz}/(GV_{ie,iel,iaz} \cdot (V^4_{ie,iel,iaz} \cdot 10^{20}))$$

To calculate the moments we do as follows:

1. Read conversion factor from the file PAS_PFM_CN_array.txt
2. Calculate partial density array (number density [cm^{-3}] in each velocity point) as follows:

$$\Delta n_{ie,iel,iaz} = Count_{ie,iel,iaz} \cdot CN_{ie,iel,iaz}$$

3. Calculate number density in $[cm^{-3}]$ as follows:

$$n = \sum_{ie,iel,iaz} \Delta n_{ie,iel,iaz}$$

4. Calculate bulk velocity **in km/s** as follows (X component as example):

$$V_X = (\sum_{ie,iel,iaz} VxarrSC_{ie,iel,iaz} \cdot \Delta n_{ie,iel,iaz})/n$$

5. Calculate pressure tensor in $[J/cm^3]$ as follows (XY components as an example), here “m” is the particle mass [kg]:

$$P_{XY} = \sum_{ie,iel,iaz} (VxarrSC_{ie,iel,iaz} - V_X)(VyarrSC_{ie,iel,iaz} - V_Y)\Delta n_{ie,iel,iaz} \cdot m \cdot 10^6$$