daily

August 19, 2025

Dark-Fiber Charakterisierung

für entanglement polarisierter QKD

Aufbereitung und Analyse der Messdaten nach Tageszyklen

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Datensatz: Nordhausen - Sundhausen

1 Aufbereitung der Messdaten

1.1 Ressourcen und Literatur

- Messdaten
- Messgerät
- Plotting-Tool “py_pol”

1.2 Verwendete Libraries / Softwaretools

[78]:
```
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
import matplotlib.ticker as ticker
import numpy as np
import io
import datetime
from IPython.display import Image

from scipy.stats import norm
from scipy.signal import butter, filtfilt

from py_pol.jones_vector import Jones_vector, degrees
from py_pol.stokes import Stokes
```

1.3 Eigene Hilfsfunktionen

[3]:
```
def format_time(x, pos):
    h = int(x) // 3600
    m = (int(x) % 3600) // 60
    return f"{h:02d}:{m:02d}"
```

[4]:
```
def lowpass(data, box = 100):
    box = box
    LP_filter = np.full(int(box), 1/box)
    lps = np.convolve(ydata, LP_filter)
    lps = lps[ int((box-1) / 2) :len(lps) - int((box - 1) / 2)]
    return lps

def highpass(data, box = 100):
    lps = lowpass(data, box)
    hps = data - lps[:-1]
    return hps
```

[5]:
```
def butter_filter(data, cutoff, fs=18, order=4, btype='low'):
    nyq = 0.5 * fs
    normal_cutoff = cutoff / nyq
    b, a = butter(order, normal_cutoff, btype=btype, analog=False)
    y = filtfilt(b, a, data)
    return y
```

[6]:
```
def convert_angel(az, el):
    az = np.array(az) * degrees
    el = np.array(el) * degrees

    x = np.cos(2*el) * np.cos(2*az)
    y = np.cos(2*el) * np.sin(2*az)
    z = np.sin(2*el)
    return x, y, z
```

[7]:
```
def calculate_freq(x, y, z):
    bins = 50
    coords = np.vstack((x, y, z)).T
    hist, edges = np.histogramdd(coords, bins=bins)

    # Indices for each coordinate pair (with clipping)
    bin_indices = [
        np.clip(np.digitize(x, edges[0]) - 1, 0, bins - 1),
        np.clip(np.digitize(y, edges[1]) - 1, 0, bins - 1),
        np.clip(np.digitize(z, edges[2]) - 1, 0, bins - 1)
    ]
    freq = hist[bin_indices[0], bin_indices[1], bin_indices[2]]
```

```
    return freq
```

[8]:
```
def plot_poincare(x, y, z, freq, elev=15, azim=45, title="Not given"):
    fig = plt.figure(figsize=(6, 6))
    ax = fig.add_subplot(111, projection='3d')

    # Poincaré-Sphere
    u = np.linspace(0, 2 * np.pi, 50)
    v = np.linspace(0, np.pi, 50)
    X = np.outer(np.cos(u), np.sin(v))
    Y = np.outer(np.sin(u), np.sin(v))
    Z = np.outer(np.ones(np.size(u)), np.cos(v))

    ax.plot_surface(X, Y, Z, color='lightgray', alpha=0.1, edgecolor='k',␣
 ↪linewidth=0.5)

    # Axes
    ax.plot([0, 1.6], [0, 0], [0, 0], color='red')     # +S1
    ax.plot([0, -1.6], [0, 0], [0, 0], color='red')    # -S1
    ax.plot([0, 0], [0, 1.6], [0, 0], color='green')   # +S2
    ax.plot([0, 0], [0, -1.6], [0, 0], color='green')  # -S2
    ax.plot([0, 0], [0, 0], [0, 1.4], color='blue')    # +S3
    ax.plot([0, 0], [0, 0], [0, -1.4], color='blue')   # -S3

    # Labeling Axes
    ax.text( 2.0, 0, 0,  'S1',  color='red', fontsize=10)
    ax.text(-1.8, 0, 0, '-S1',  color='red', fontsize=10)
    ax.text( 0, 1.8, 0,  'S2',  color='green', fontsize=10)
    ax.text( 0, -2.0, 0, '-S2',  color='green', fontsize=10)
    ax.text( 0, 0, 1.6, 'S3',   color='blue', fontsize=10)
    ax.text( 0, 0, -1.6, '-S3',  color='blue', fontsize=10)

    # Measurement
    sc = ax.scatter(x, y, z, c=freq, cmap='hot', s=15)
    plt.colorbar(sc, label='density')

    # Scaling
    ax.set_box_aspect([1, 1, 1])
    ax.set_xticks([]); ax.set_yticks([]); ax.set_zticks([])

    # Aligning Poincaré-Sphere
    ax.view_init(elev=elev, azim=azim)

    ax.set_title(title)

    plt.show()
```

1.4 Datenaufbereitungsschritte

[9]:
```
filename ='29.11.2024_10d.csv'
skip = 8
sep = ";"
```

[10]:
```
columns = ['Time[date hh:mm:ss] ', ' Elapsed Time [hh:mm:ss:ms]', ' Normalized␣
 ↪s 1 ', ' Normalized s 2 ', ' Normalized s 3 ', ' S 0 [mW]', ' S 1 [mW]', ' S␣
 ↪2 [mW]', ' S 3 [mW]', ' Azimuth[°] ', ' Ellipticity[°] ', ' DOP[%] ', '␣
 ↪DOCP[%] ', ' DOLP[%] ', ' Power[mW] ', ' Pol Power[mW] ', ' Unpol Power[mW]␣
 ↪', ' Power[dBm] ', ' Pol Power[dBm] ', ' Unpol Power[dBm] ', '␣
 ↪Power-Split-Ratio ', ' Phase Difference[°] ', ' Warning']
for c in range(len(columns)):
    print(c, ': ', columns[c])

colors = ["tab:blue", "tab:orange", "tab:green", "tab:red", "tab:purple"]
```

```
0 :  Time[date hh:mm:ss]
1 :   Elapsed Time [hh:mm:ss:ms]
2 :   Normalized s 1
3 :   Normalized s 2
4 :   Normalized s 3
5 :   S 0 [mW]
6 :   S 1 [mW]
7 :   S 2 [mW]
8 :   S 3 [mW]
9 :   Azimuth[°]
10 :   Ellipticity[°]
11 :   DOP[%]
12 :   DOCP[%]
13 :   DOLP[%]
14 :   Power[mW]
15 :   Pol Power[mW]
16 :   Unpol Power[mW]
17 :   Power[dBm]
18 :   Pol Power[dBm]
19 :   Unpol Power[dBm]
20 :   Power-Split-Ratio
21 :   Phase Difference[°]
22 :   Warning
```

2 Polarisationsgrad (DOP [%])

[11]:
```
degree = pd.read_csv(filename,skiprows=skip, sep=sep, usecols=[columns[0],␣
 ↪columns[11]])
```

[12]:
```
degree[columns[0]] = pd.to_datetime(degree[columns[0]])
degree.set_index(columns[0], inplace=True)
```

2.1 Tägliche Aufteilung der Messdaten

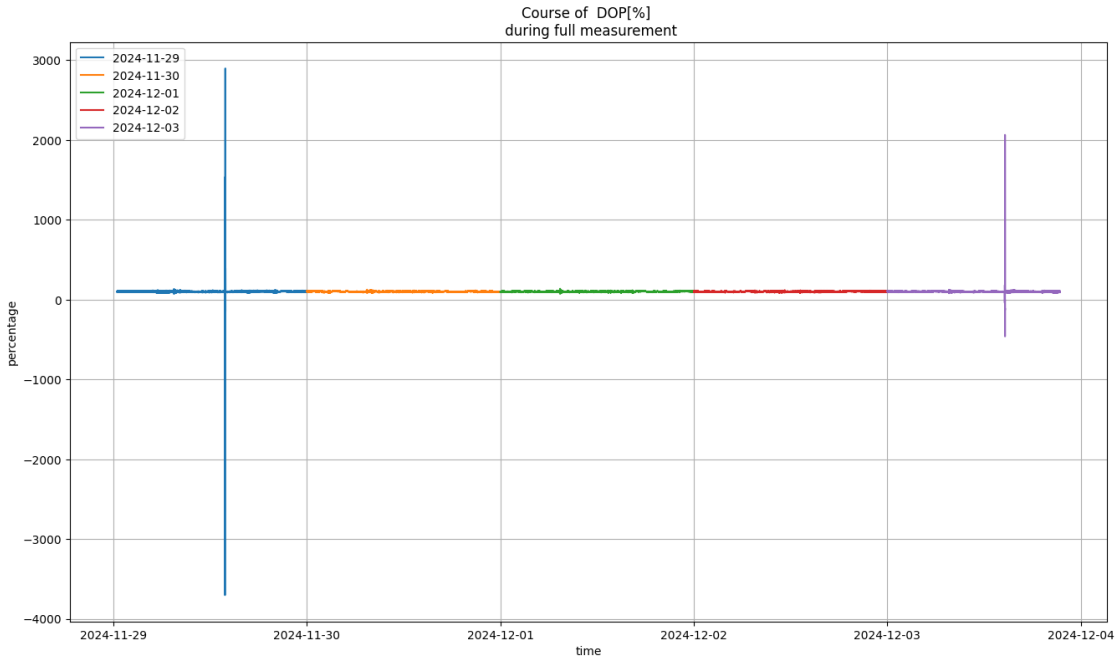
[13]:
```
degree_daily = degree.groupby(degree.index.date)
degree_daily_list = list(degree_daily)
```

[14]:
```
for date, df_day in degree_daily_list:
    print(date, '\n')
    print(df_day.describe())
    print('')
```

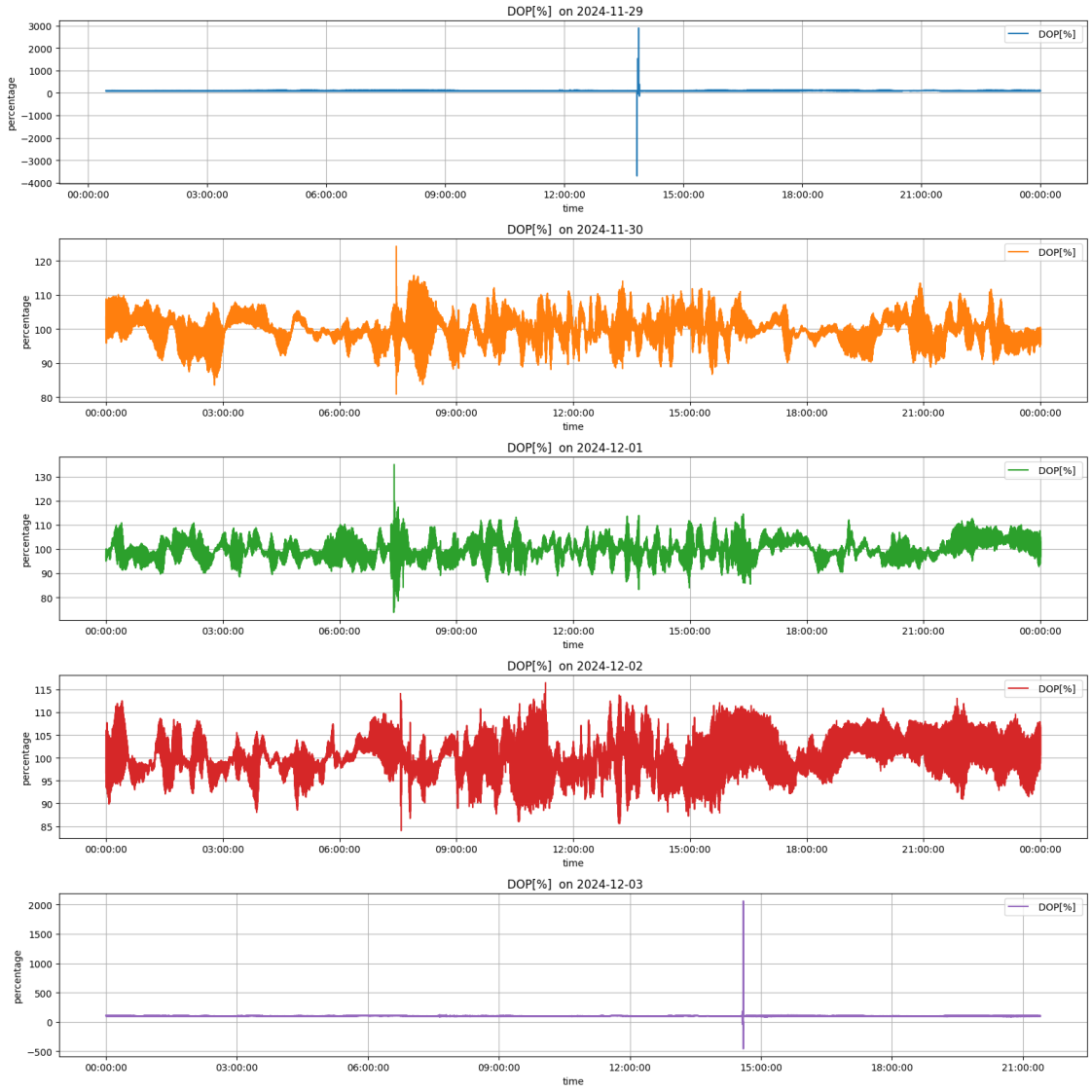
```
2024-11-29

            DOP[%]
count  1.676194e+06
mean   9.956919e+01
std    7.112112e+00
min   -3.703300e+03
25%    9.688000e+01
50%    9.967000e+01
75%    1.024400e+02
max    2.895590e+03

2024-11-30

            DOP[%]
count  1.500099e+06
mean   9.981857e+01
std    3.211169e+00
min    8.088000e+01
25%    9.752000e+01
50%    9.969000e+01
75%    1.022700e+02
max    1.242400e+02

2024-12-01

            DOP[%]
count  1.429572e+06
mean   9.977245e+01
std    3.271031e+00
min    7.374000e+01
25%    9.734000e+01
50%    9.938000e+01
75%    1.022900e+02
max    1.350300e+02
```

```
2024-12-02

            DOP[%]
count  1.368538e+06
mean   1.001463e+02
std    3.223490e+00
min    8.404000e+01
25%    9.781000e+01
50%    9.985000e+01
75%    1.025800e+02
max    1.164700e+02

2024-12-03

            DOP[%]
count  1.117895e+06
mean   9.903248e+01
std    4.732648e+00
min   -4.618900e+02
25%    9.733000e+01
50%    9.897000e+01
75%    1.007900e+02
max    2.062070e+03
```

[15]:
```python
plt.figure(figsize = (16,9))
for date, df_day in degree_daily_list:
    values = df_day
    plt.plot(values, label=str(date))
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Course of {columns[11]}\n during full measurement')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```

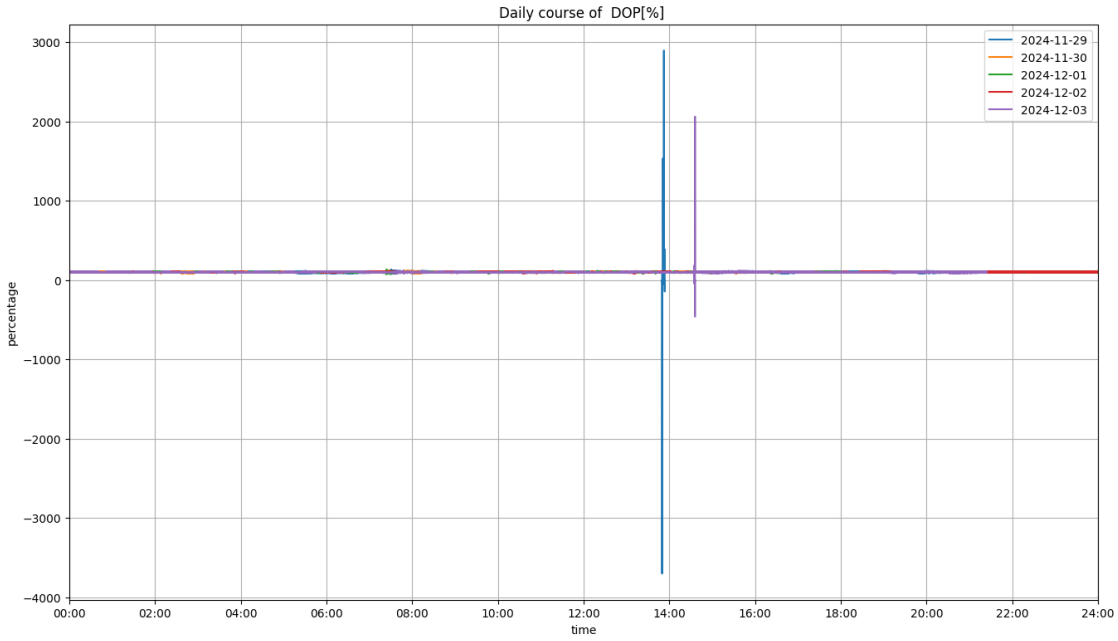


[16]:
```
fig, axs = plt.subplots(len(degree_daily_list), 1, figsize=(16, 16),␣
 ↪sharex=False)

for i in range(len(degree_daily_list)):
    ax = axs[i] if len(degree_daily_list) > 1 else axs
    df_day = degree_daily_list[i][1]

    ax.plot(df_day.index, df_day, label=columns[11], color=colors[i])
    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'{columns[11]} on {degree_daily_list[i][0]}')
    ax.set_xlabel('time')
    ax.set_ylabel('percentage')

    ax.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

plt.tight_layout()
plt.show()
```



[17]:
```
fig, ax = plt.subplots(figsize = (16,9))

for date, df_day in degree_daily_list:
    times = (df_day.index - df_day.index.normalize()).total_seconds()
    values = df_day
    plt.plot(times, values, label=str(date))


ax.xaxis.set_major_locator(ticker.MultipleLocator(3600 * 2))
ax.xaxis.set_major_formatter(ticker.FuncFormatter(format_time))
ax.set_xlim(0, 24 * 3600)

plt.grid()
```

```
plt.legend(loc = 'best')
plt.title(f'Daily course of {columns[11]}')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```



2.2 Stundenweise Aufteilung (Beispiel: erster Tag)

[18]:
```
# exemplary day
day = 0 #first day
```

[19]:
```
degree_one_day = degree_daily_list[day][1]
hourly = degree_one_day.groupby(degree_one_day.index.hour)
degree_hourly = list(hourly)
```

[20]:
```
for hour, df_hour in degree_hourly:
    print(f'{hour}:00\n')
    print(df_hour.describe())
    print('')
```

```
0:00

            DOP[%]
count  41275.000000
mean      98.782586
std        2.762127
```

```
min       92.610000
25%       96.120000
50%       99.190000
75%      101.250000
max      106.270000
```

1:00

```
            DOP[%]
count  74616.000000
mean      98.671192
std        2.760749
min       92.290000
25%       96.050000
50%       98.895000
75%      101.180000
max      106.340000
```

2:00

```
            DOP[%]
count  74706.000000
mean      99.697654
std        2.657860
min       93.690000
25%       97.170000
50%       99.890000
75%      102.180000
max      106.550000
```

3:00

```
            DOP[%]
count  74791.000000
mean     100.668886
std        2.529215
min       94.970000
25%       98.290000
50%      100.970000
75%      102.970000
max      107.430000
```

4:00

```
            DOP[%]
count  74793.000000
mean     101.770583
std        2.758068
```

```
min       89.800000
25%       99.520000
50%      101.790000
75%      103.920000
max      113.100000
```

5:00

```
            DOP[%]
count  74747.000000
mean      98.515741
std        3.715355
min       82.720000
25%       95.980000
50%       98.600000
75%      101.040000
max      117.820000
```

6:00

```
            DOP[%]
count  74828.000000
mean      98.409908
std        4.205050
min       84.190000
25%       95.090000
50%       98.430000
75%      101.590000
max      112.910000
```

7:00

```
            DOP[%]
count  74694.000000
mean     100.838734
std        3.681271
min       73.140000
25%       98.550000
50%      100.890000
75%      103.250000
max      131.350000
```

8:00

```
            DOP[%]
count  74628.000000
mean     101.480403
std        3.417497
```

```
min       87.190000
25%       99.240000
50%      101.590000
75%      103.882500
max      115.510000
```

9:00

```
            DOP[%]
count  74538.000000
mean      98.771017
std        3.083574
min       88.420000
25%       96.300000
50%       98.600000
75%      101.070000
max      110.460000
```

10:00

```
            DOP[%]
count  74219.000000
mean      96.175932
std        1.902132
min       88.210000
25%       94.670000
50%       95.980000
75%       97.630000
max      105.260000
```

11:00

```
            DOP[%]
count  74138.000000
mean      97.215173
std        2.521470
min       86.640000
25%       95.080000
50%       97.190000
75%       99.170000
max      112.180000
```

12:00

```
            DOP[%]
count  72813.000000
mean      99.000588
std        3.209165
```

```
min       88.910000
25%       96.530000
50%       98.770000
75%      101.270000
max      117.370000
```

13:00

```
            DOP[%]
count  73844.000000
mean      93.298756
std       28.597326
min    -3703.300000
25%       94.810000
50%       96.520000
75%       98.550000
max     2895.590000
```

14:00

```
            DOP[%]
count  70606.000000
mean      96.375985
std        2.143110
min       88.650000
25%       94.870000
50%       96.080000
75%       97.690000
max      105.030000
```

15:00

```
            DOP[%]
count  73448.000000
mean     100.860022
std        3.351608
min       89.790000
25%       98.330000
50%      101.020000
75%      103.250000
max      115.080000
```

16:00

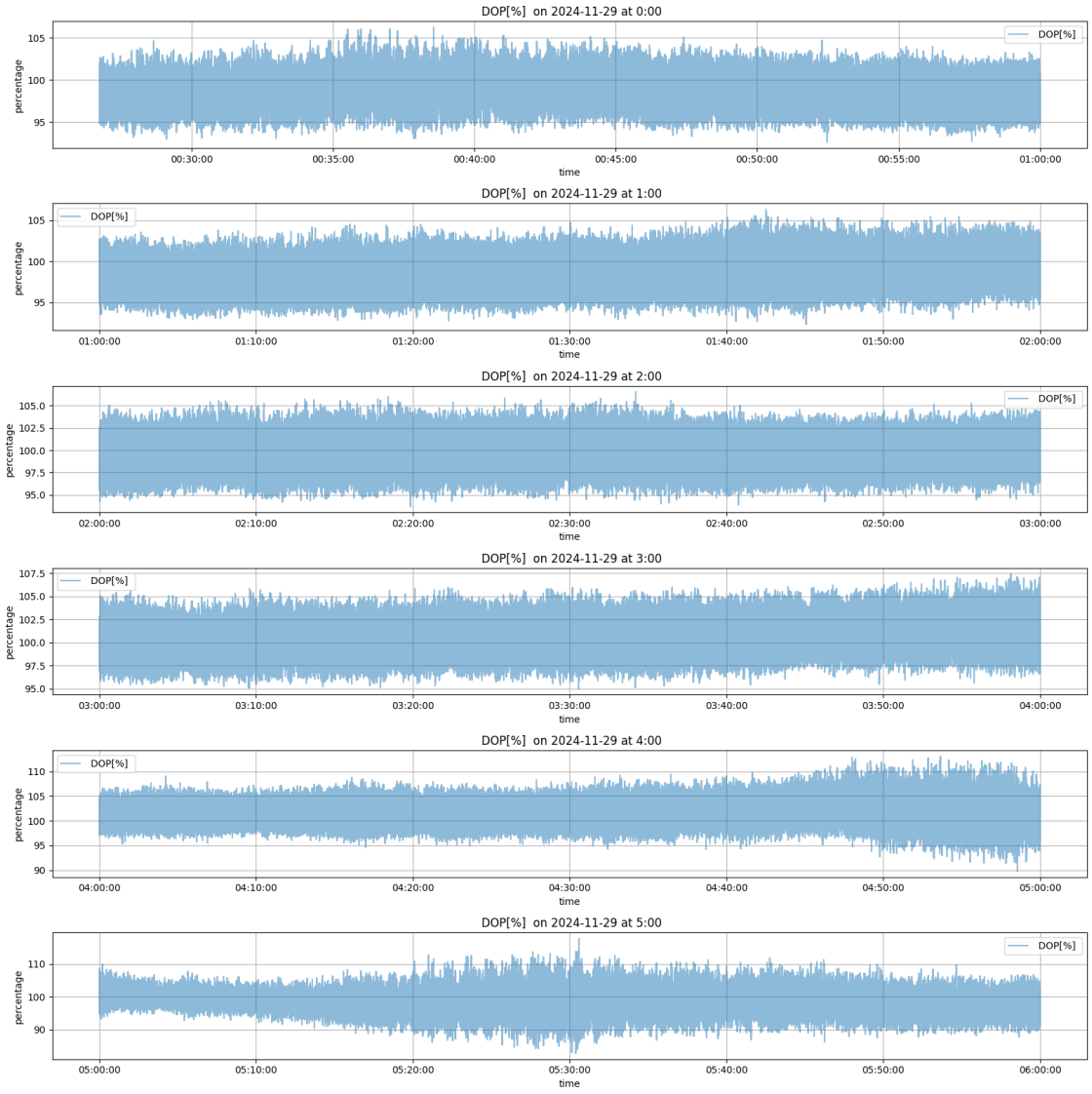
```
            DOP[%]
count  70765.000000
mean     100.038458
std        3.674802
```

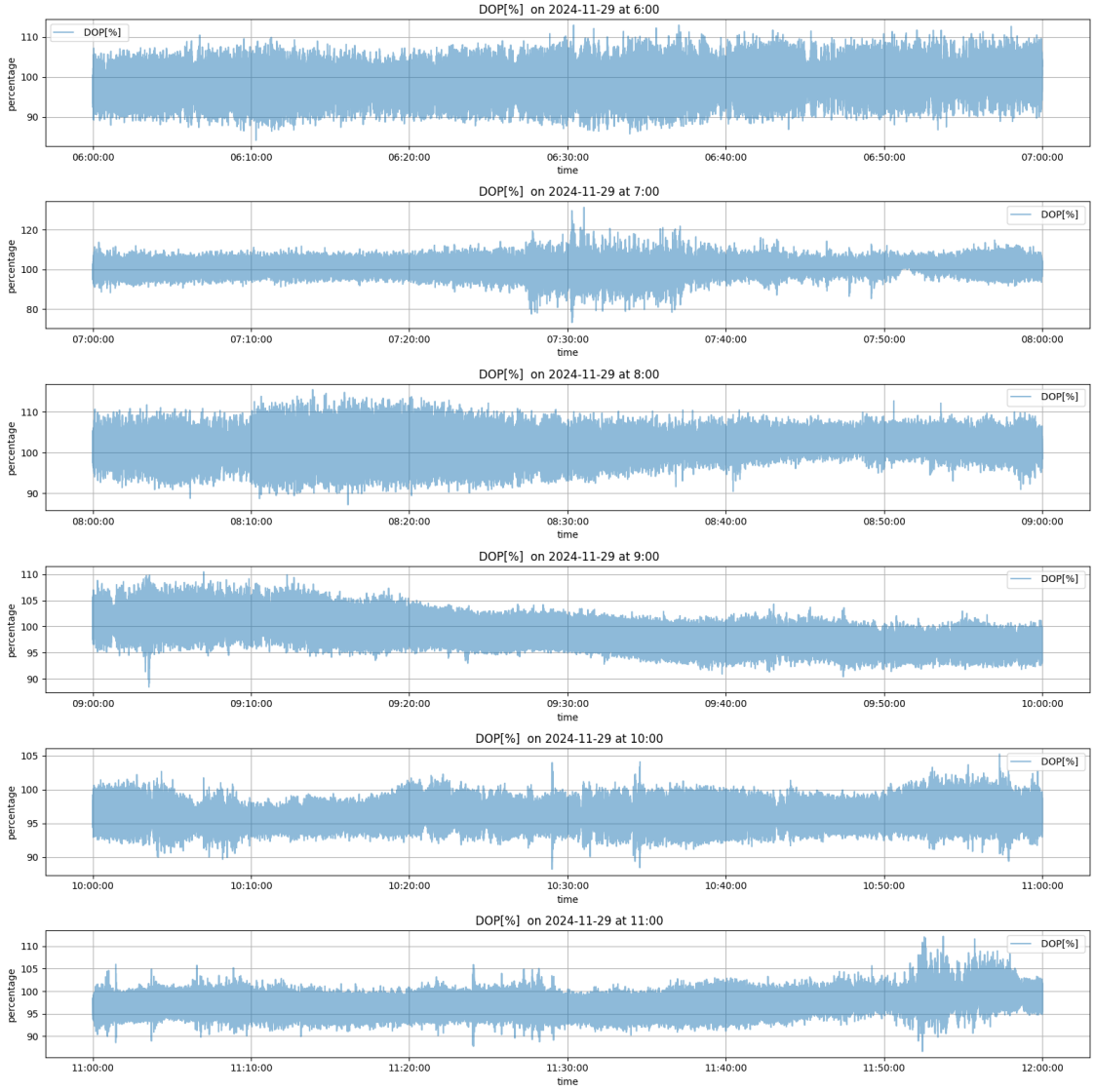
```
min       84.490000
25%       97.970000
50%      100.380000
75%      102.480000
max      113.170000

17:00

            DOP[%]
count  62936.000000
mean     102.334199
std        3.289435
min       89.740000
25%      100.020000
50%      102.380000
75%      104.670000
max      113.440000

18:00

            DOP[%]
count  67232.000000
mean     104.355162
std        2.338354
min       95.440000
25%      102.650000
50%      104.210000
75%      106.010000
max      112.740000

19:00

            DOP[%]
count  70870.000000
mean     101.068998
std        3.861459
min       84.220000
25%       98.390000
50%      101.080000
75%      103.790000
max      113.610000

20:00

            DOP[%]
count  63528.000000
mean      99.768936
std        2.936399
```

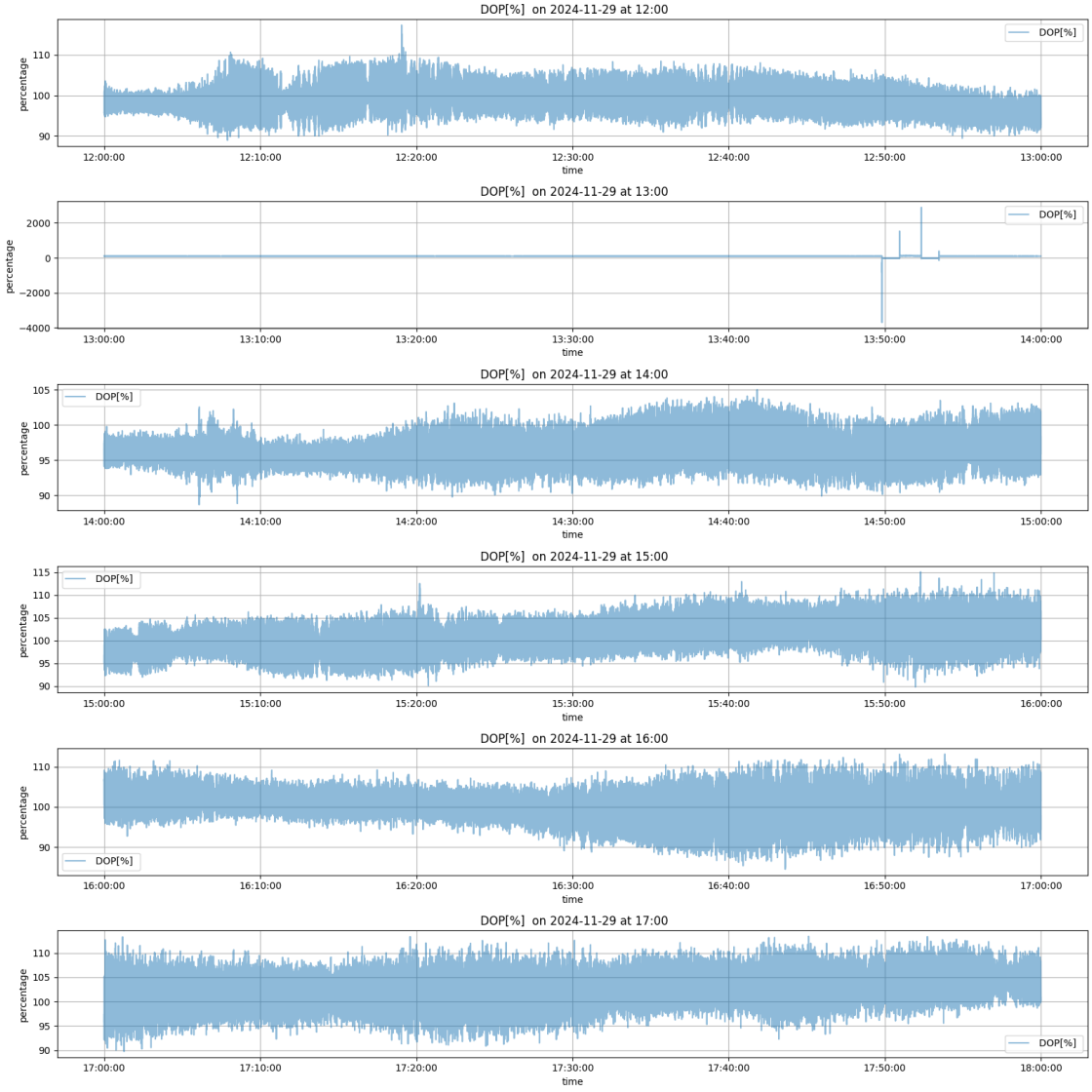
```
min       85.690000
25%       98.100000
50%       99.510000
75%      101.820000
max      115.660000

21:00

            DOP[%]
count  62861.000000
mean     101.711952
std        3.132026
min       90.220000
25%       99.770000
50%      102.450000
75%      103.930000
max      108.160000

22:00

            DOP[%]
count  62481.000000
mean      99.940909
std        3.276664
min       90.690000
25%       97.320000
50%       99.830000
75%      102.300000
max      111.310000

23:00

            DOP[%]
count  62837.000000
mean     100.938768
std        3.197490
min       90.440000
25%       98.670000
50%      100.990000
75%      103.430000
max      113.040000
```

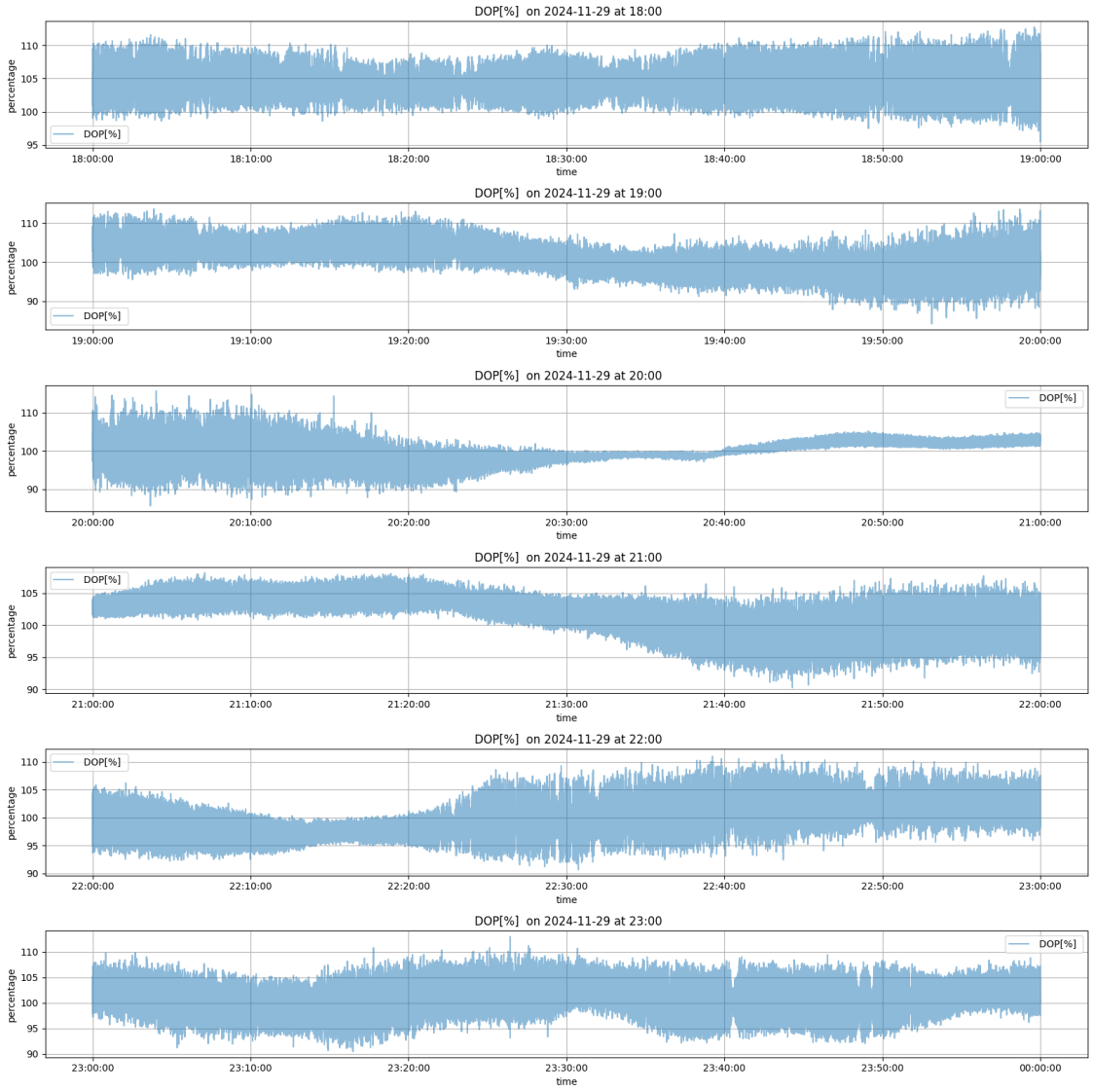
[21]:
```
daily_quaters = [degree_hourly[:6], degree_hourly[6:12], degree_hourly[12:18],␣
 ↪degree_hourly[18:]]
for quater in daily_quaters:
    fig, axs = plt.subplots(len(quater), 1, figsize=(16, 16), sharex=False)
```

```
  for i in range(len(quater)):
      ax = axs[i] if len(quater) > 1 else axs
      df_day = quater[i][1]

      ax.plot(df_day.index, df_day, label=columns[11], color=colors[day],␣
↪alpha=0.5)
      ax.grid()
      ax.legend(loc='best')
      ax.set_title(f'{columns[11]} on {degree_daily_list[day][0]} at␣
↪{quater[i][0]}:00')
      ax.set_xlabel('time')
      ax.set_ylabel('percentage')

      ax.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

  plt.tight_layout()
  plt.show()
```


DOP[%] on 2024-11-29 at 0:00
DOP[%]
percentage
time
DOP[%] on 2024-11-29 at 1:00
DOP[%]
percentage
time
DOP[%] on 2024-11-29 at 2:00
DOP[%]
percentage
time
DOP[%] on 2024-11-29 at 3:00
DOP[%]
percentage
time
DOP[%] on 2024-11-29 at 4:00
DOP[%]
percentage
time
DOP[%] on 2024-11-29 at 5:00
DOP[%]
percentage
time


DOP[%] on 2024-11-29 at 6:00
DOP[%]
percentage
time
DOP[%] on 2024-11-29 at 7:00
DOP[%] on 2024-11-29 at 8:00
DOP[%] on 2024-11-29 at 9:00
DOP[%] on 2024-11-29 at 10:00
DOP[%] on 2024-11-29 at 11:00


DOP[%] on 2024-11-29 at 12:00
DOP[%] on 2024-11-29 at 13:00
DOP[%] on 2024-11-29 at 14:00
DOP[%] on 2024-11-29 at 15:00
DOP[%] on 2024-11-29 at 16:00
DOP[%] on 2024-11-29 at 17:00
percentage
time
DOP[%]



2.3 Ausreißerbereinigung

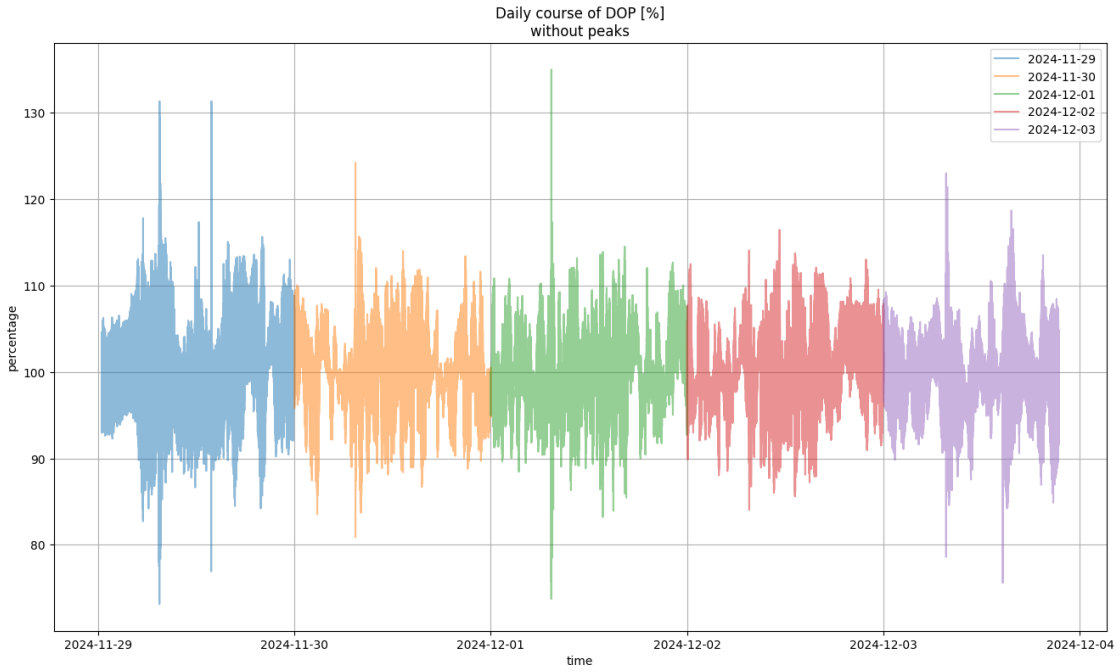
[22]:
```
new_degree = degree[columns[11]]
new_degree = new_degree.drop(new_degree[(new_degree > 140) | (new_degree < 0)].
  ↪index)
new_degree.describe()
```

[22]:
```
count    7.088521e+06
mean     9.974852e+01
std      3.296249e+00
min      7.314000e+01
25%      9.738000e+01
```

```
50%      9.950000e+01
75%      1.021600e+02
max      1.350300e+02
Name:  DOP[%] , dtype: float64
```

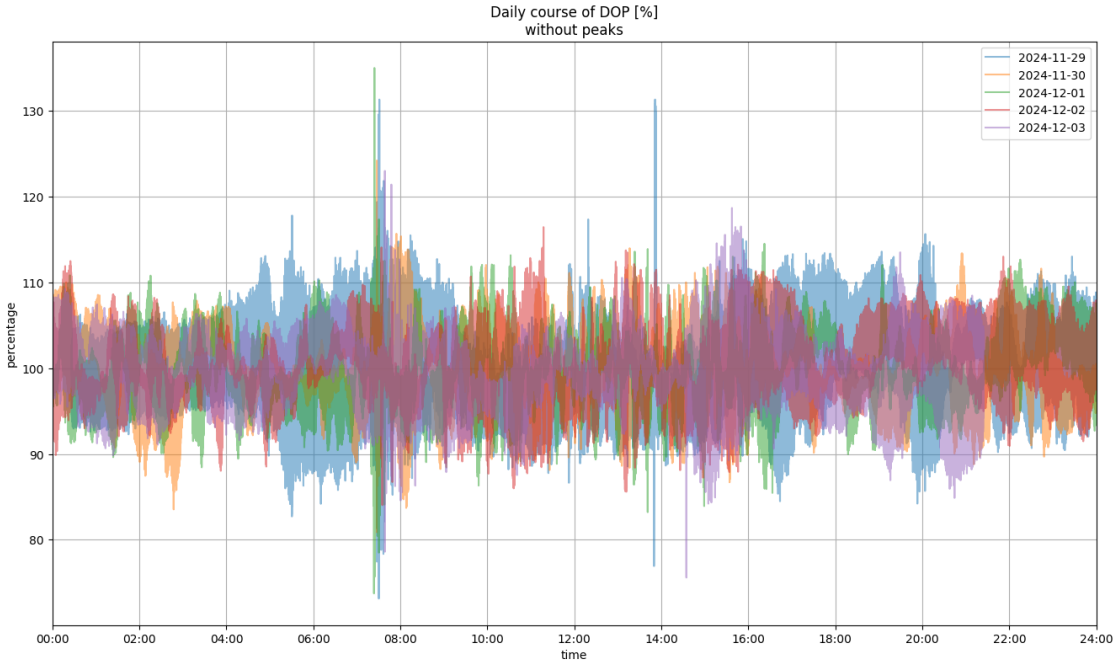
[23]:
```
new_degree_daily = new_degree.groupby(new_degree.index.date)
new_degree_daily_list = list(new_degree_daily)
```

[24]:
```
plt.figure(figsize = (16,9))
for date, df_day in new_degree_daily_list:
    values = df_day
    plt.plot(values, label=str(date), alpha = 0.5)
plt.grid()
plt.legend(loc = 'best')
plt.title('Daily course of DOP [%]\nwithout peaks')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```



[25]:
```
fig, ax = plt.subplots(figsize = (16,9))

for date, df_day in new_degree_daily_list:
    times = (df_day.index - df_day.index.normalize()).total_seconds()
    values = df_day
    plt.plot(times, values, label=str(date) , alpha=0.5)
```

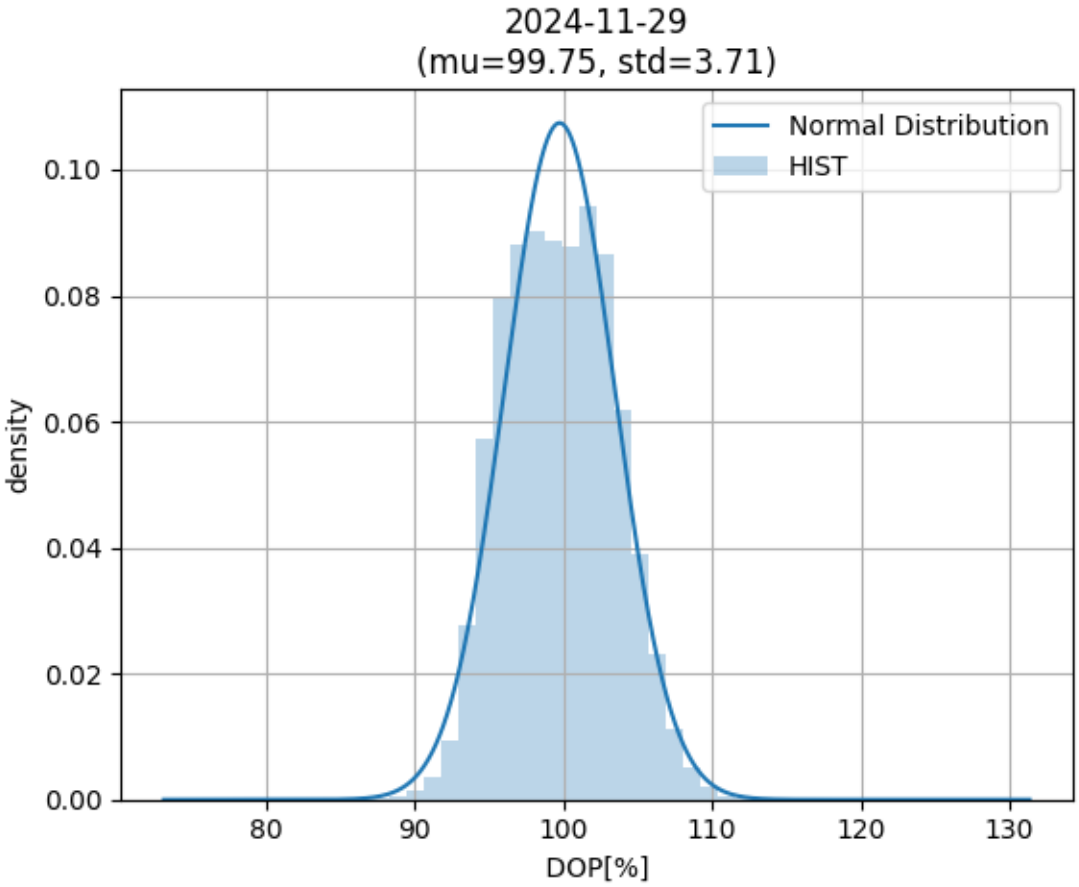
```
ax.xaxis.set_major_locator(ticker.MultipleLocator(3600 * 2))
ax.xaxis.set_major_formatter(ticker.FuncFormatter(format_time))
ax.set_xlim(0, 24 * 3600)

plt.grid()
plt.legend(loc = 'best')
plt.title('Daily course of DOP [%]\nwithout peaks')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```



2.4 Tägliche Normalverteilung mit Histogramm

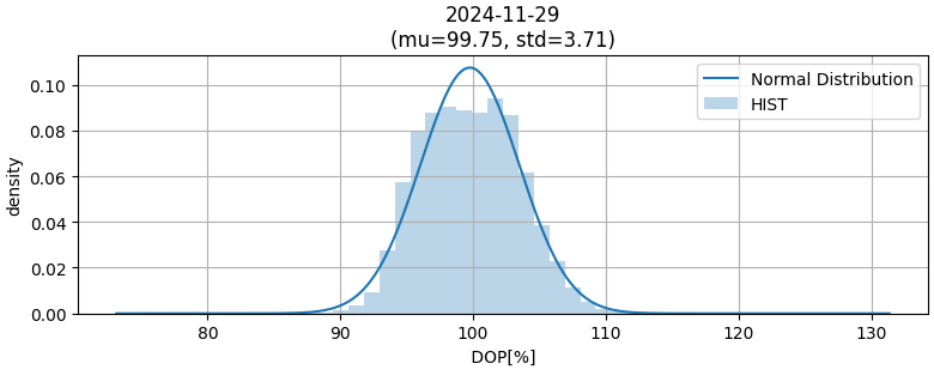
[26]:
```
ydata1 = np.array(new_degree_daily_list[day][1])
mu1 = np.mean(ydata1)
sigma1 = np.std(ydata1)
x1 = np.linspace(ydata1.min(),ydata1.max(),len(ydata1))
y1 = norm.pdf(x1, mu1, sigma1)

plt.plot(x1, y1, label = 'Normal Distribution', color=colors[day])
plt.hist(ydata1, bins = 50, density = True, color=colors[day], alpha = 0.3,␣
↪label = "HIST")
```

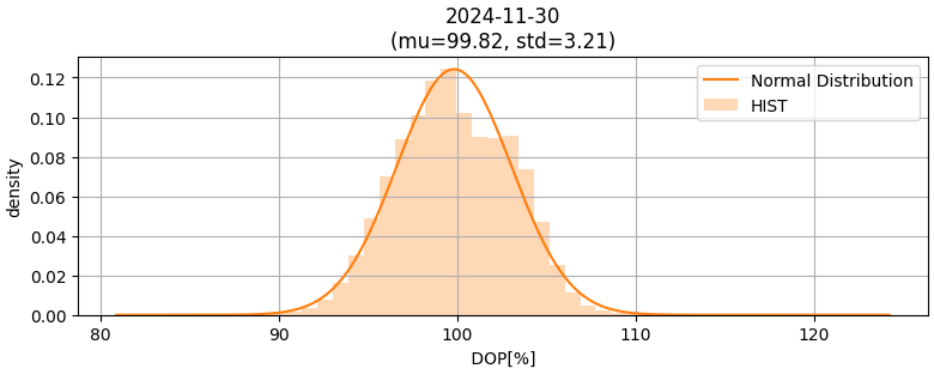
```
plt.title(f'{new_degree_daily_list[day][0]}\n(mu={mu1:.2f}, std={sigma1:.2f})')
plt.legend(loc = 'best')
plt.xlabel(columns[11])
plt.ylabel('density')
plt.grid()
plt.show()
```

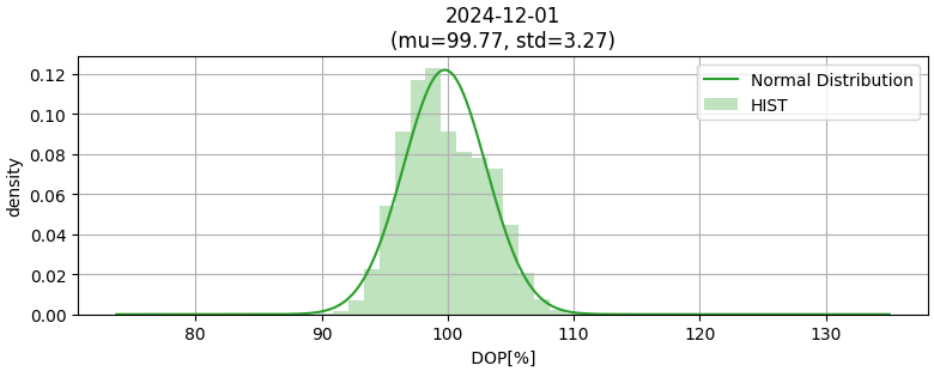


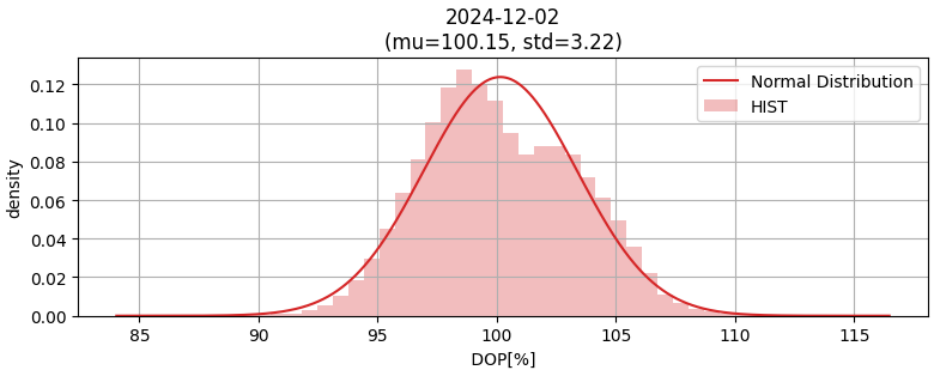
[27]:
```
fig, axs = plt.subplots(len(new_degree_daily_list), 1, figsize=(8, 16),␣
↪sharex=False)

for i in range(len(new_degree_daily_list)):
    ax = axs[i] if len(new_degree_daily_list) > 1 else axs
    ydata1 = np.array(new_degree_daily_list[i][1])
    mu1 = np.mean(ydata1)
    sigma1 = np.std(ydata1)
    x1 = np.linspace(ydata1.min(),ydata1.max(),len(ydata1))
    y1 = norm.pdf(x1, mu1, sigma1)
```

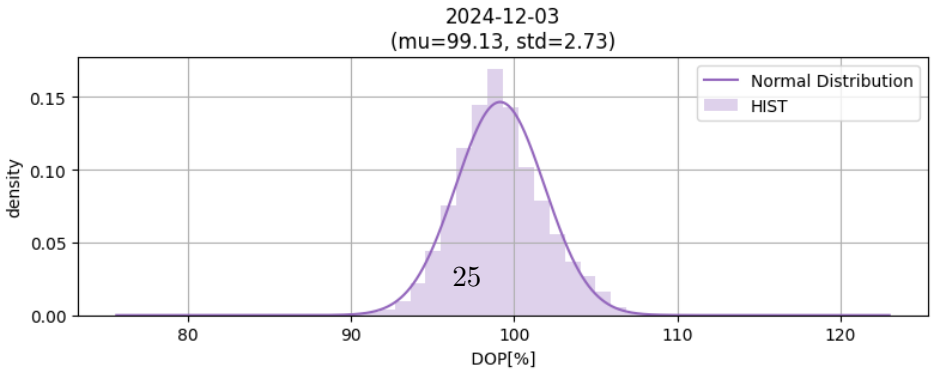
```
    ax.plot(x1, y1, label = 'Normal Distribution', color=colors[i])
    ax.hist(ydata1, bins = 50, density = True, color=colors[i], alpha = 0.3,␣
 ↪label = "HIST")

    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'{degree_daily_list[i][0]}\n(mu={mu1:.2f}, std={sigma1:.2f})')
    ax.set_xlabel(columns[11])
    ax.set_ylabel('density')

plt.tight_layout()
plt.show()
```


2024-11-29
(mu=99.75, std=3.71)
Normal Distribution
HIST
density
DOP[%]

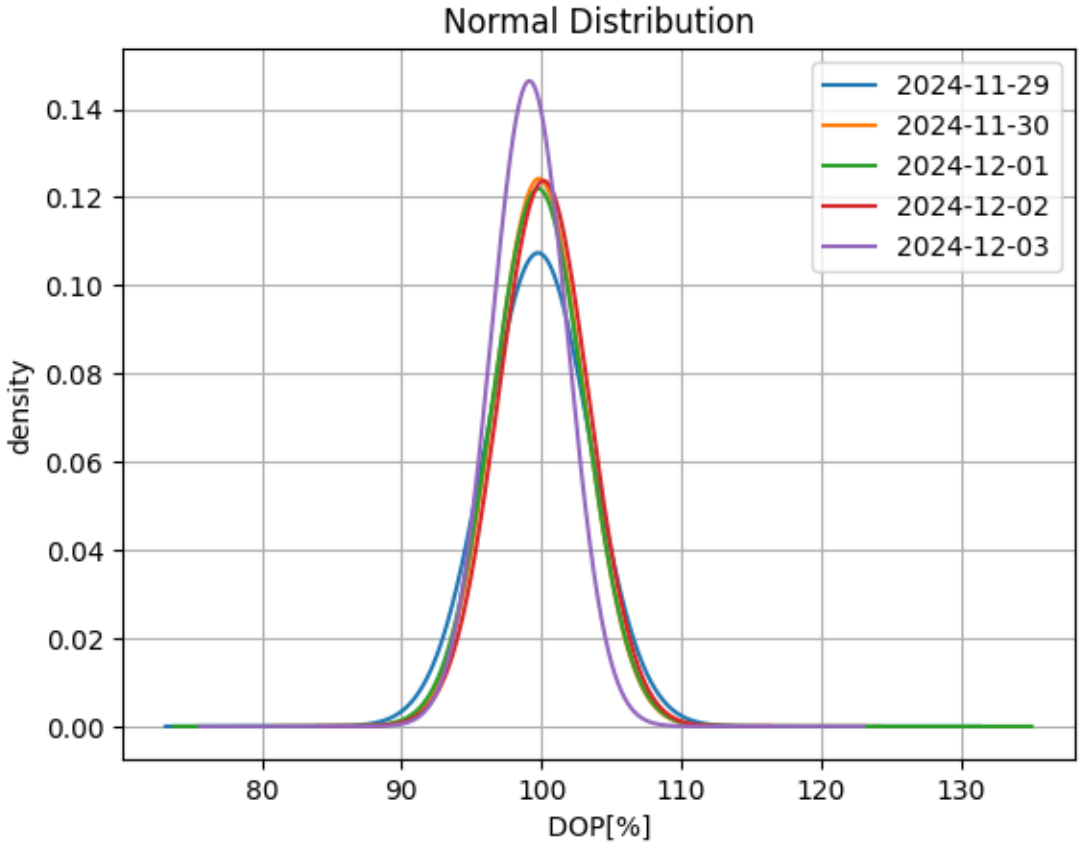

2024-11-30
(mu=99.82, std=3.21)
Normal Distribution
HIST
density
DOP[%]


2024-12-01
(mu=99.77, std=3.27)
Normal Distribution
HIST
density
DOP[%]


2024-12-02
(mu=100.15, std=3.22)
Normal Distribution
HIST
density
DOP[%]

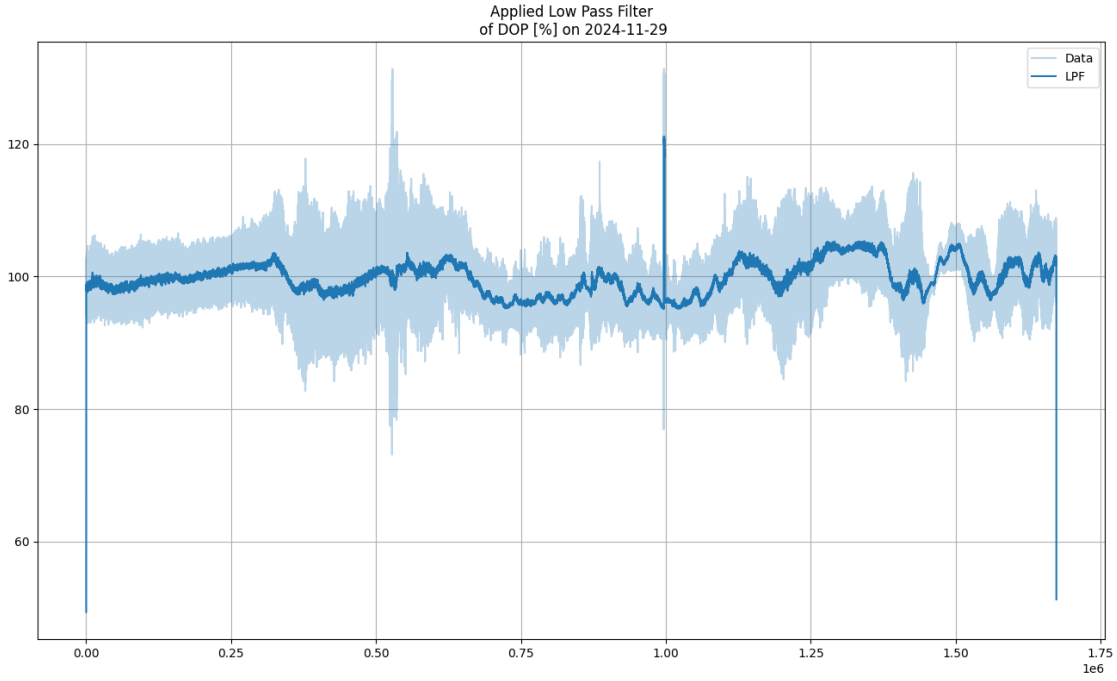

2024-12-03
(mu=99.13, std=2.73)
Normal Distribution
HIST
density
DOP[%]

[28]:
```
for i in range(len(new_degree_daily_list)):
    ydata1 = np.array(new_degree_daily_list[i][1])
    mu1 = np.mean(ydata1)
    sigma1 = np.std(ydata1)
    x1 = np.linspace(ydata1.min(),ydata1.max(),len(ydata1))
    y1 = norm.pdf(x1, mu1, sigma1)

    plt.plot(x1, y1, label = new_degree_daily_list[i][0])

plt.title(f'Normal Distribution')
plt.legend(loc = 'best')
plt.xlabel(columns[11])
plt.ylabel('density')
plt.grid()
plt.show()
```

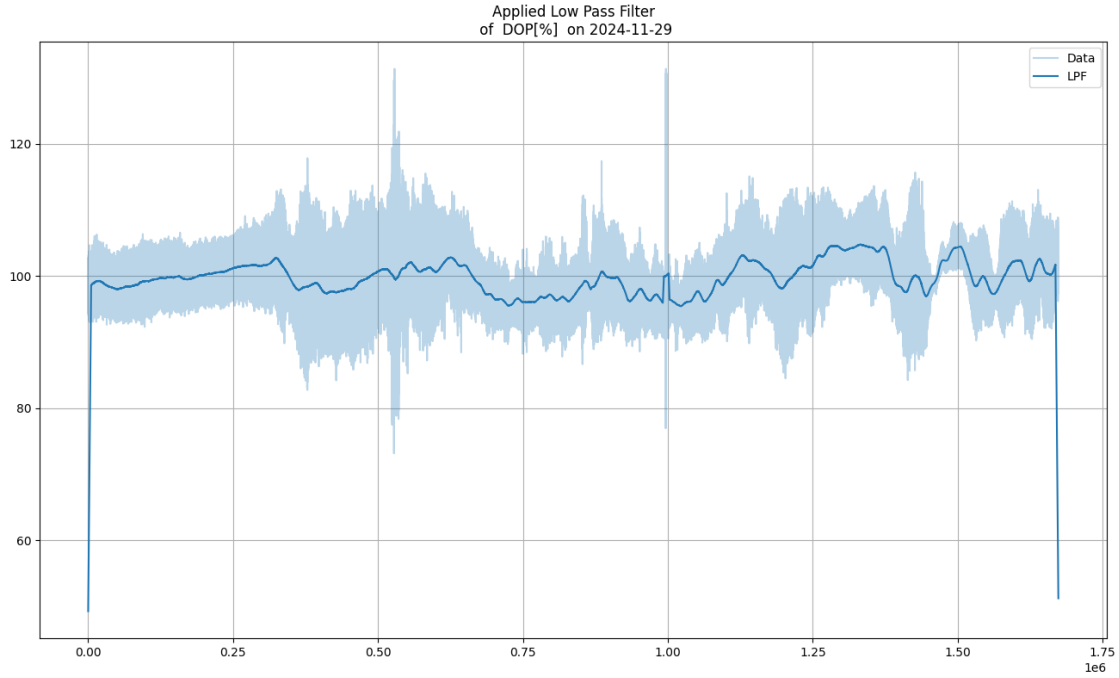


2.5 Filterung mittels Tief- und Hochpass

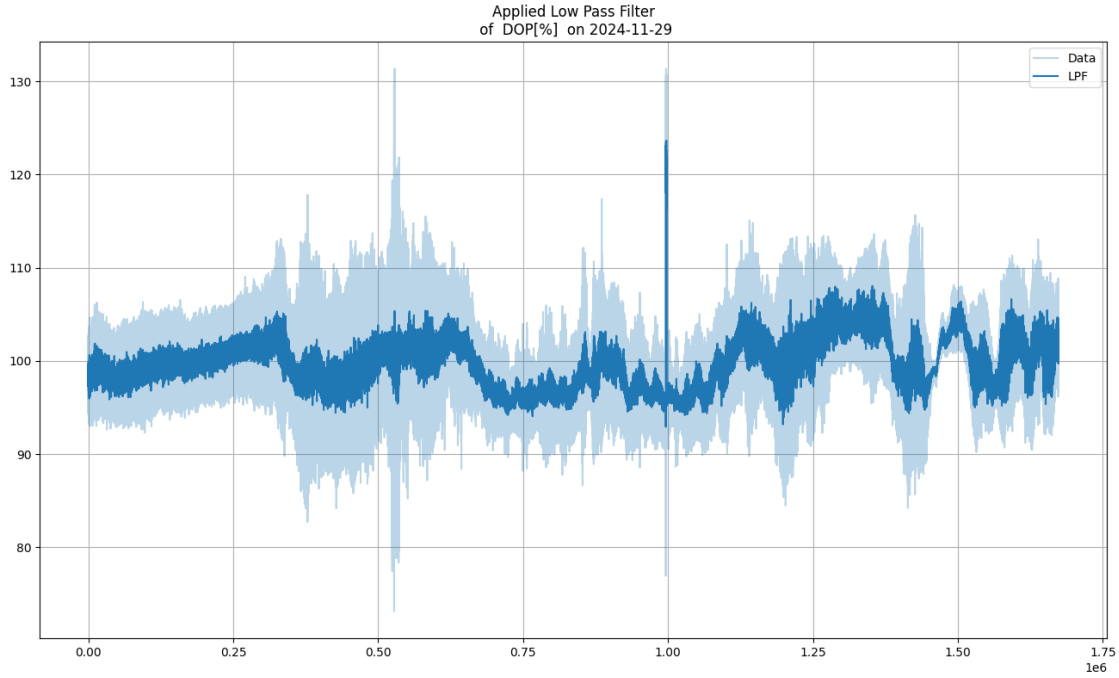
[29]:
```
ydata = np.array(new_degree_daily_list[day][1])

lps = lowpass(ydata, 100)
plt.figure(figsize = (16,9))
plt.plot(ydata, label = 'Data', color = colors[day], alpha=0.3)
plt.plot(lps, label = 'LPF', color = colors[day])
plt.title(f'Applied Low Pass Filter\n of DOP [%] on␣
 ↪{new_degree_daily_list[day][0]}')
plt.grid()
plt.legend(loc = 'best')
plt.show()
```



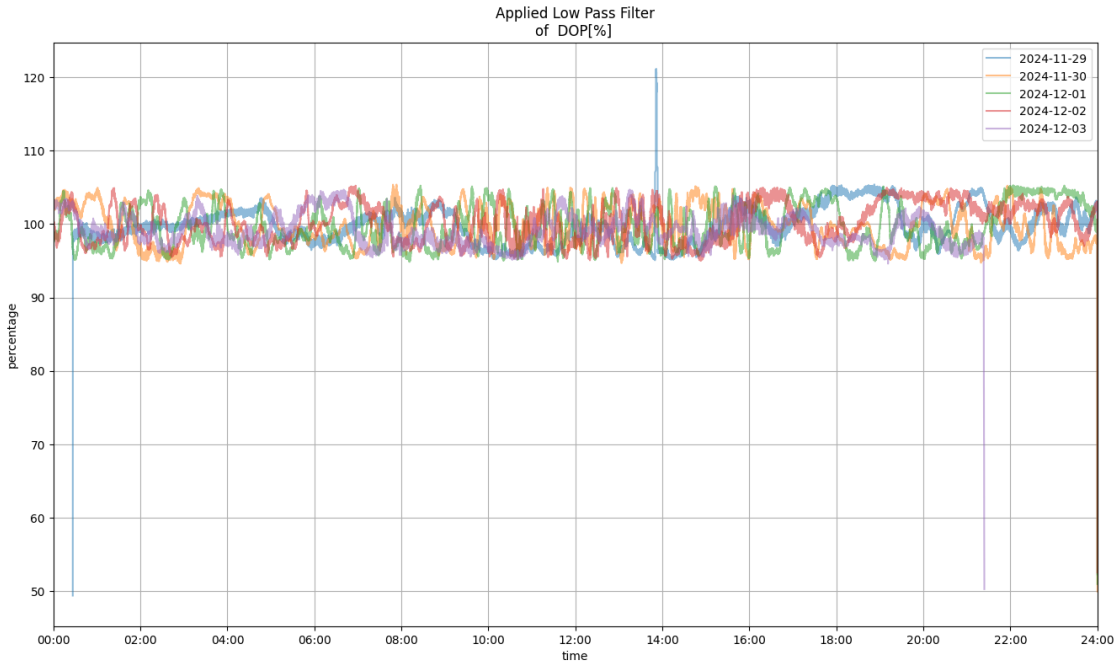
[30]:
```
ydata = np.array(new_degree_daily_list[day][1])

lps = lowpass(ydata, 10000)
plt.figure(figsize = (16,9))
plt.plot(ydata, label = 'Data', color = colors[day], alpha=0.3)
plt.plot(lps, label = 'LPF', color = colors[day])
plt.title(f'Applied Low Pass Filter\n of {columns[11]} on␣
 ↪{new_degree_daily_list[day][0]}')
plt.grid()
plt.legend(loc = 'best')
plt.show()
```



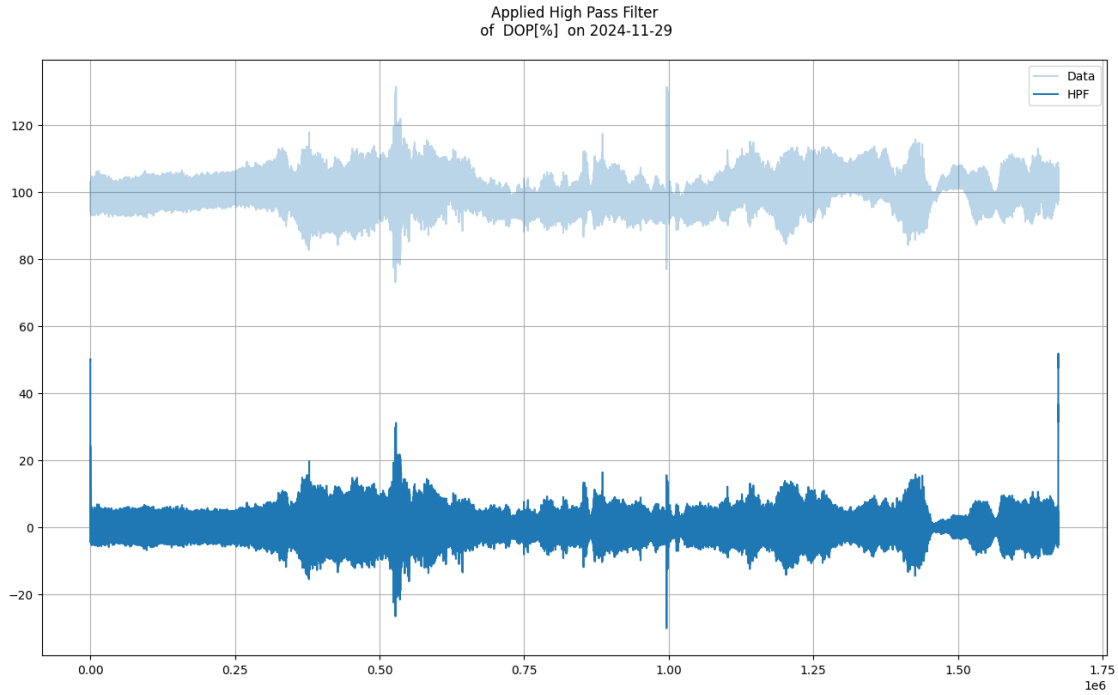
[32]:
```
cutoff = 1.0
btype='low'

ydata = np.array(new_degree_daily_list[day][1])
lps = butter_filter(ydata, cutoff = cutoff, btype=btype)
plt.figure(figsize = (16,9))
plt.plot(ydata, label = 'Data', color = colors[day], alpha=0.3)
plt.plot(lps, label = 'LPF', color = colors[day])
plt.title(f'Applied Low Pass Filter\n of {columns[11]} on␣
 ↪{new_degree_daily_list[day][0]}')
plt.grid()
plt.legend(loc = 'best')
plt.show()
```



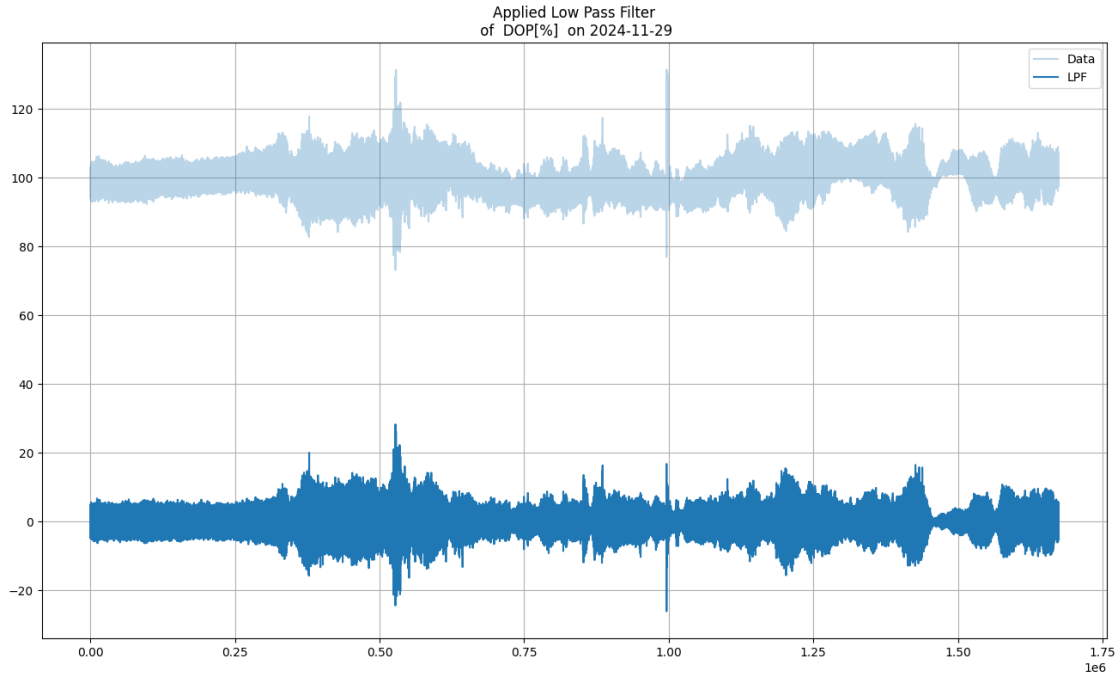
[33]:
```
fig, ax = plt.subplots(figsize = (16,9))

for date, df_day in new_degree_daily_list:
    times = (df_day.index - df_day.index.normalize()).total_seconds()
    ydata = np.array(df_day)
    lps = lowpass(ydata, 100)
    plt.plot(times, lps[:-1], label=str(date) , alpha=0.5)


ax.xaxis.set_major_locator(ticker.MultipleLocator(3600 * 2))
ax.xaxis.set_major_formatter(ticker.FuncFormatter(format_time))
ax.set_xlim(0, 24 * 3600)

plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied Low Pass Filter\nof {columns[11]}')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```



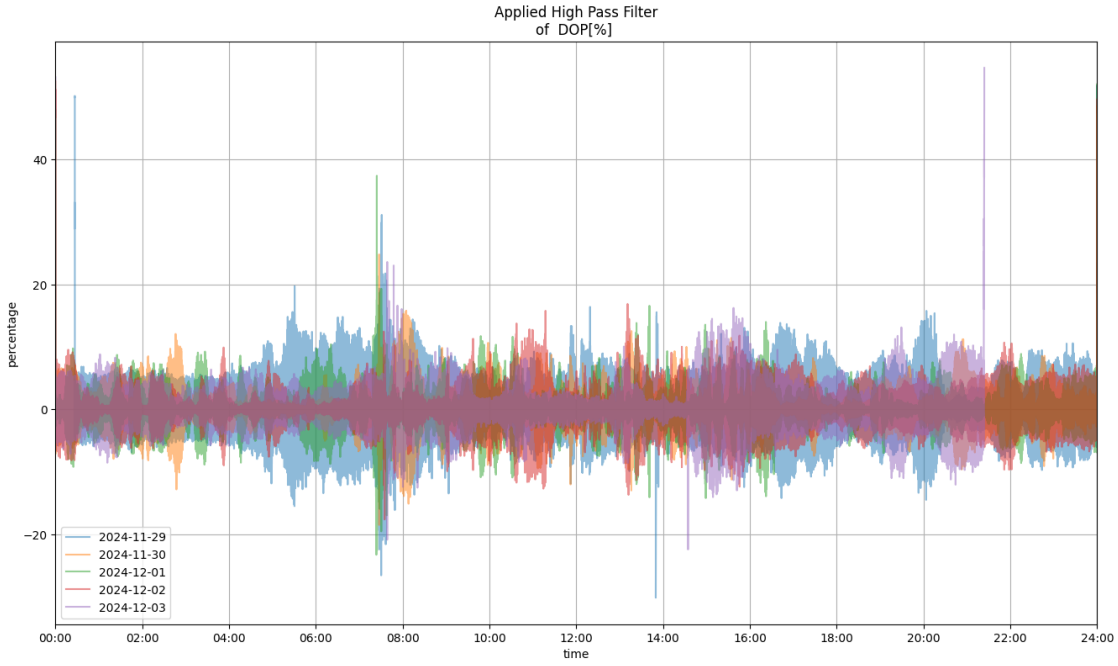
[34]:
```
ydata = np.array(new_degree_daily_list[day][1])

hps = highpass(ydata, 100)
plt.figure(figsize = (16,9))
plt.plot(ydata, label = 'Data', color=colors[day], alpha=0.3)
plt.plot(hps, label = 'HPF', color=colors[day])
plt.title(f'Applied High Pass Filter\n of {columns[11]} on␣
  ↪{new_degree_daily_list[day][0]}\n')
plt.grid()
plt.legend(loc = 'best')
plt.show()
```



[36]:
```
cutoff = 1.0
btype='high'

ydata = np.array(new_degree_daily_list[day][1])
lps = butter_filter(ydata, cutoff = cutoff, btype=btype)
plt.figure(figsize = (16,9))
plt.plot(ydata, label = 'Data', color = colors[day], alpha=0.3)
plt.plot(lps, label = 'LPF', color = colors[day])
plt.title(f'Applied Low Pass Filter\n of {columns[11]} on␣
 ↪{new_degree_daily_list[day][0]}')
plt.grid()
plt.legend(loc = 'best')
plt.show()
```



[35]:
```
fig, ax = plt.subplots(figsize = (16,9))

for date, df_day in new_degree_daily_list:
    times = (df_day.index - df_day.index.normalize()).total_seconds()
    ydata = np.array(df_day)
    hps = highpass(ydata, 100)
    plt.plot(times, hps, label=str(date) , alpha=0.5)


ax.xaxis.set_major_locator(ticker.MultipleLocator(3600 * 2))
ax.xaxis.set_major_formatter(ticker.FuncFormatter(format_time))
ax.set_xlim(0, 24 * 3600)

plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied High Pass Filter\nof {columns[11]}')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```



3 Winkelparameter (Azimut [°], Ellipticität [°])

[37]:
```
angle = pd.read_csv(filename,skiprows=skip, sep=sep, usecols=[columns[0],␣
↪columns[9], columns[10]])
```

[38]:
```
angle[columns[0]] = pd.to_datetime(angle[columns[0]])
angle.set_index(columns[0], inplace=True)
```

3.1 Tägliche Aufteilung der Messdaten

[39]:
```
angle_daily = angle.groupby(angle.index.date)
angle_daily_list = list(angle_daily)
```

[40]:
```
for date, df_day in angle_daily_list:
    print(date, '\n')
    print(df_day.describe())
    print('')
```

```
2024-11-29

        Azimuth[°]   Ellipticity[°]
count  1.676194e+06     1.676194e+06
mean   5.728160e+00    -1.144504e+00
std    2.365813e+01     1.490541e+01
min   -9.000000e+01    -4.468000e+01
```

25%	-5.880000e+00	-1.364000e+01
50%	6.930000e+00	1.240000e+00
75%	2.023000e+01	1.106000e+01
max	9.000000e+01	4.454000e+01

2024-11-30

	Azimuth[°]	Ellipticity[°]
count	1.500099e+06	1.500099e+06
mean	2.428019e+00	1.063311e+00
std	5.500757e+01	1.903680e+01
min	-9.000000e+01	-4.497000e+01
25%	-4.778000e+01	-1.415000e+01
50%	8.700000e-01	1.020000e+00
75%	5.337000e+01	1.478000e+01
max	9.000000e+01	4.498000e+01

2024-12-01

	Azimuth[°]	Ellipticity[°]
count	1.429572e+06	1.429572e+06
mean	7.651423e+00	-2.963670e+00
std	5.176796e+01	1.858525e+01
min	-9.000000e+01	-4.496000e+01
25%	-3.570000e+01	-1.659000e+01
50%	9.750000e+00	-3.400000e+00
75%	5.514000e+01	9.940000e+00
max	9.000000e+01	4.496000e+01

2024-12-02

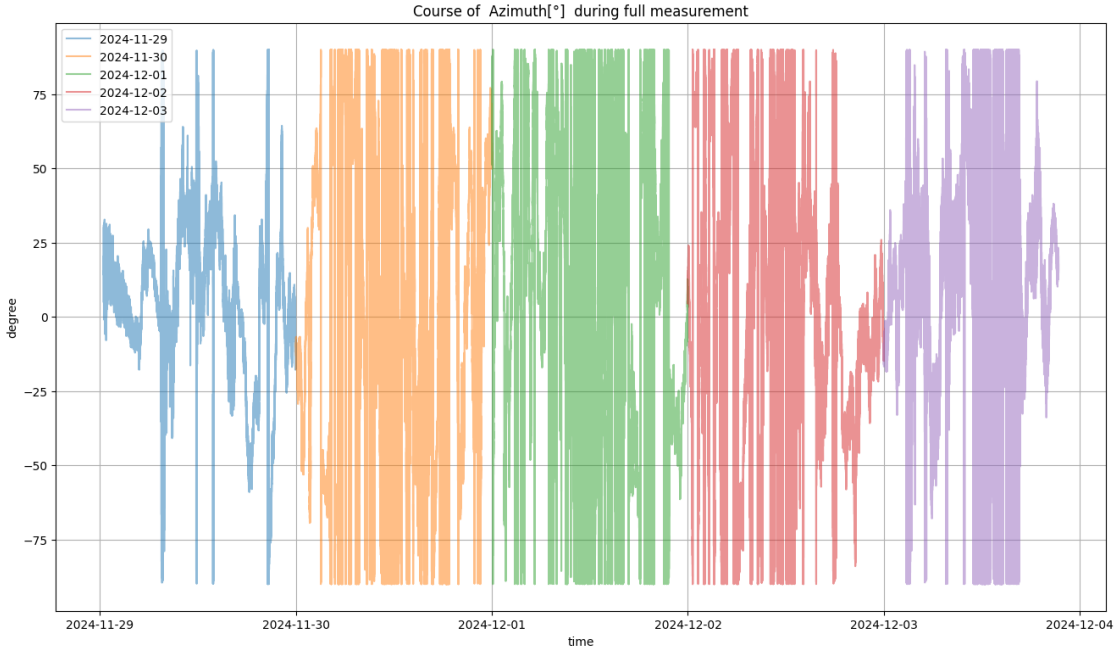
	Azimuth[°]	Ellipticity[°]
count	1.368538e+06	1.368538e+06
mean	2.967946e+00	-4.818185e+00
std	4.593922e+01	1.803721e+01
min	-9.000000e+01	-4.496000e+01
25%	-2.711000e+01	-1.765000e+01
50%	-7.500000e-01	-6.490000e+00
75%	3.369000e+01	7.630000e+00
max	9.000000e+01	4.497000e+01

2024-12-03

	Azimuth[°]	Ellipticity[°]
count	1.117895e+06	1.117895e+06
mean	8.673327e+00	-1.437671e+01
std	4.252360e+01	1.777982e+01
min	-9.000000e+01	-4.498000e+01

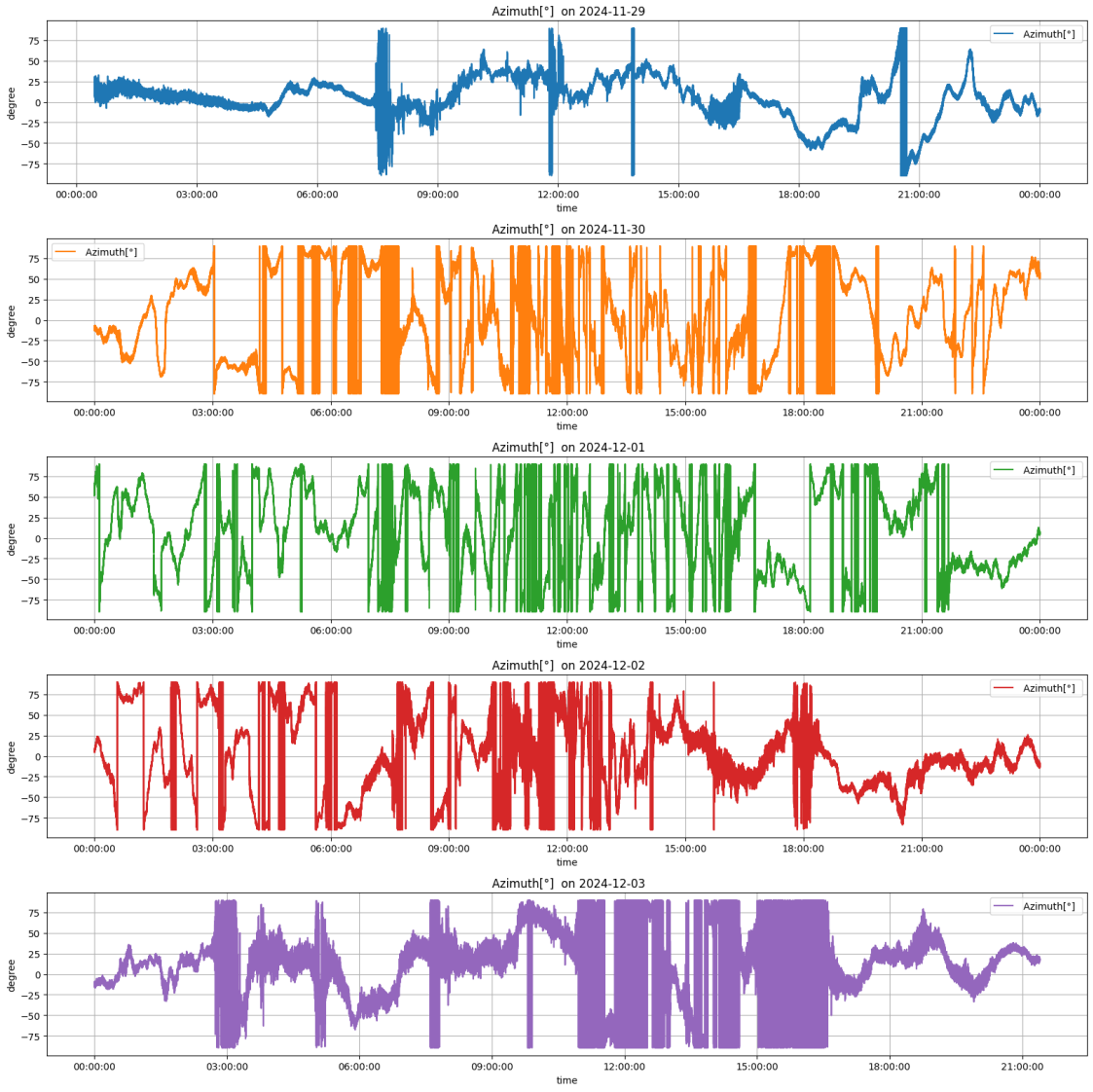
```
25%   -1.337000e+01    -2.748000e+01
50%    1.513000e+01    -1.789000e+01
75%    3.113000e+01    -4.460000e+00
max    9.000000e+01     4.408000e+01
```

[41]:
```
plt.figure(figsize = (16,9))
for date, df_day in angle_daily_list:
    values = df_day[columns[9]]
    plt.plot(values, label=str(date), alpha=0.5)
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Course of {columns[9]} during full measurement')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()
```



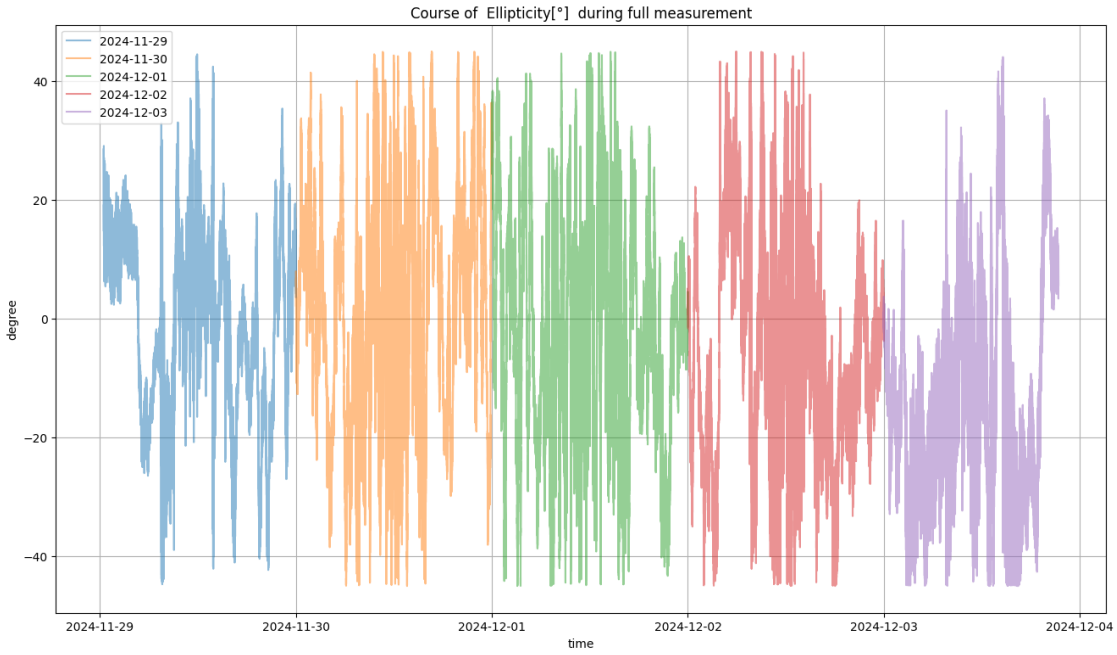
[42]:
```
fig, axs = plt.subplots(len(angle_daily_list), 1, figsize=(16, 16),␣
↪sharex=False)

for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    df_day = angle_daily_list[i][1][columns[9]]

    ax.plot(df_day.index, df_day, label=columns[9], color=colors[i])
    ax.grid()
```

```
    ax.legend(loc='best')
    ax.set_title(f'{columns[9]} on {angle_daily_list[i][0]}')
    ax.set_xlabel('time')
    ax.set_ylabel('degree')

    ax.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

plt.tight_layout()
plt.show()
```



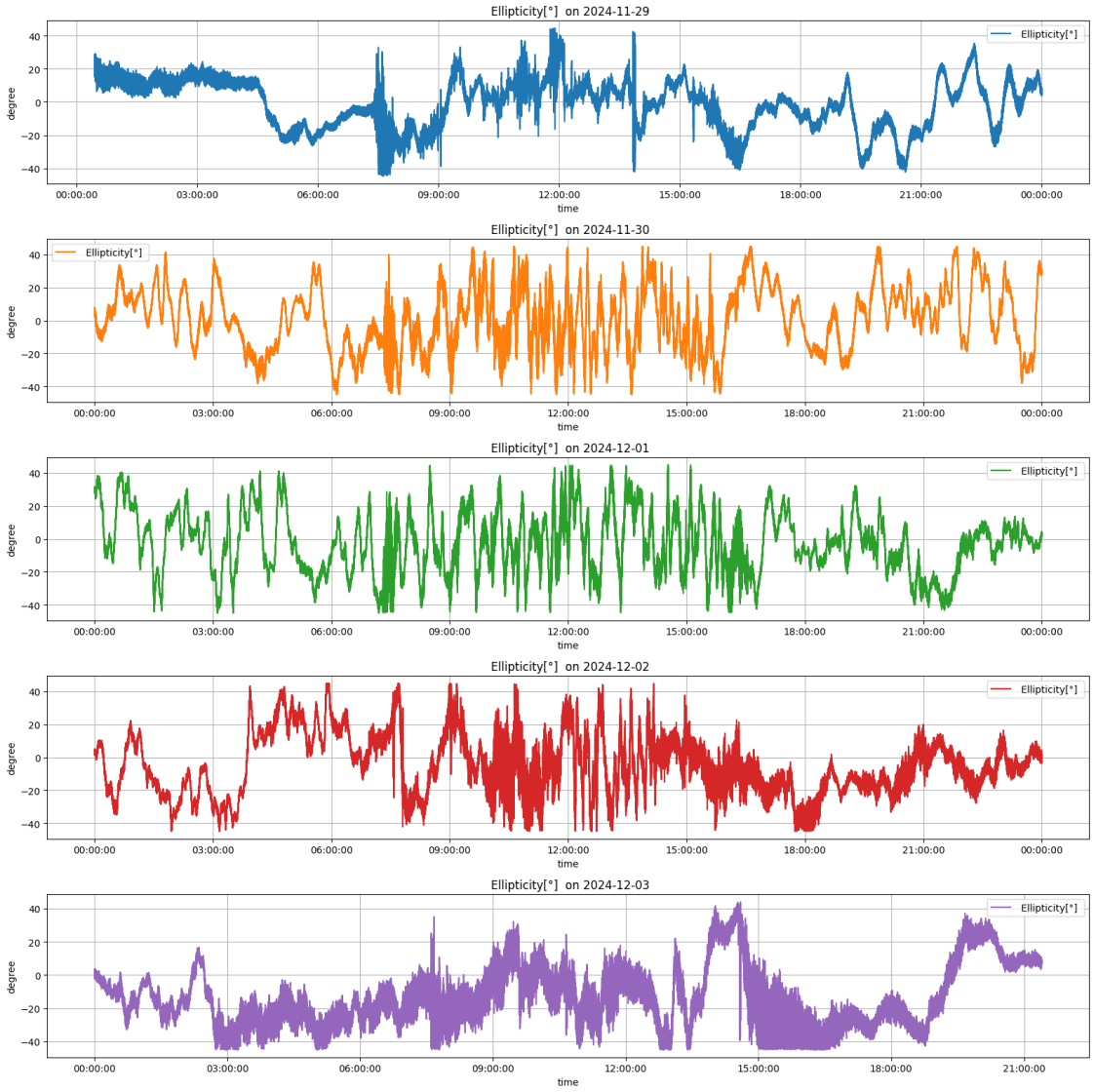
[43]:
```
plt.figure(figsize = (16,9))
for date, df_day in angle_daily_list:
    values = df_day[columns[10]]
```

```
    plt.plot(values, label=str(date), alpha=0.5)
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Course of {columns[10]} during full measurement')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()
```



[44]:
```
fig, axs = plt.subplots(len(angle_daily_list), 1, figsize=(16, 16),␣
 ↪sharex=False)

for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    df_day = angle_daily_list[i][1][columns[10]]

    ax.plot(df_day.index, df_day, label=columns[10], color=colors[i])
    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'{columns[10]} on {angle_daily_list[i][0]}')
    ax.set_xlabel('time')
    ax.set_ylabel('degree')

    ax.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

plt.tight_layout()
```

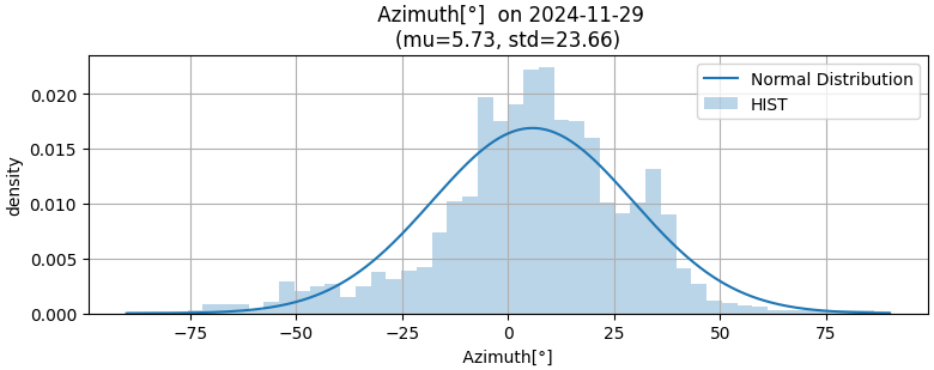
```
plt.show()
```

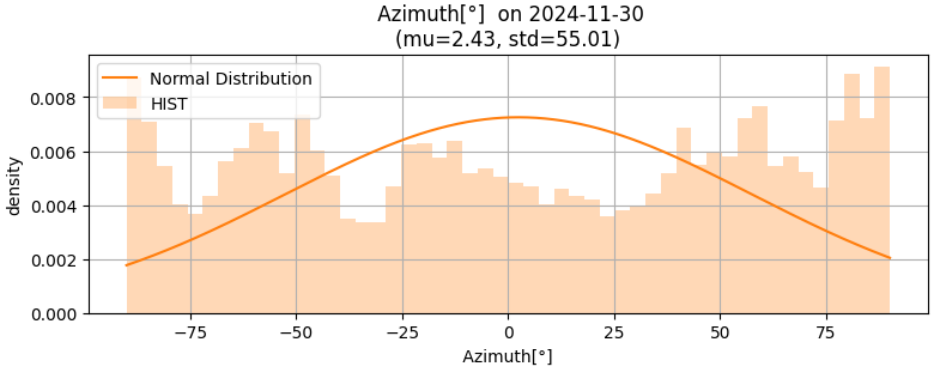


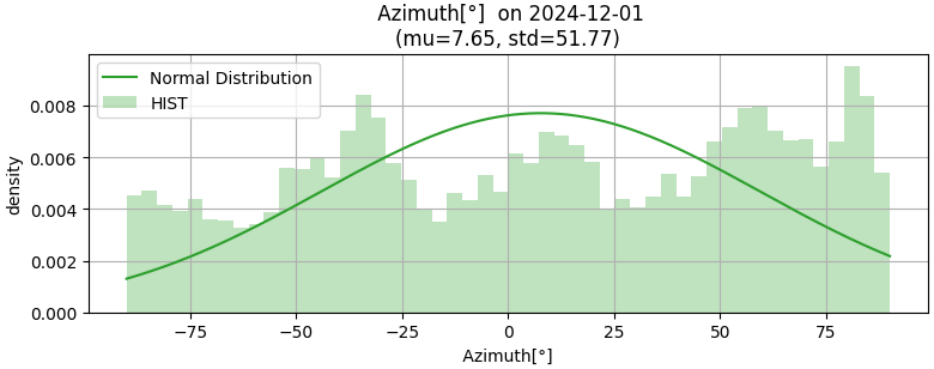
3.2 Tägliche Normalverteilung mit Histogramm

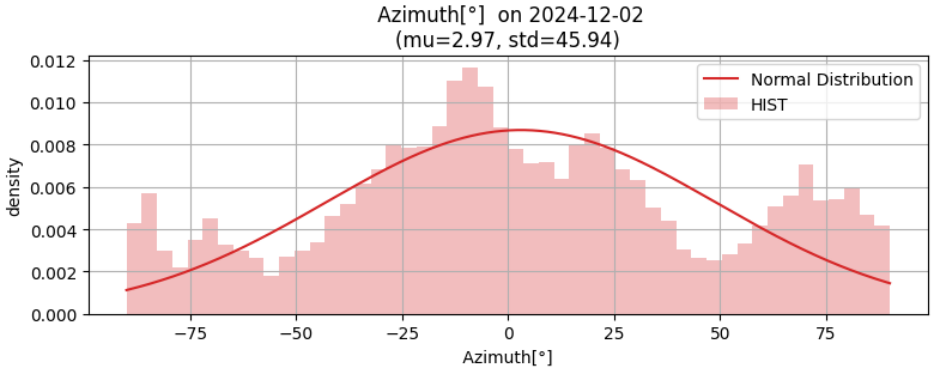
[45]:
```
fig, axs = plt.subplots(len(angle_daily_list), 1, figsize=(8, 16), sharex=False)

for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    ydata1 = np.array(angle_daily_list[i][1][columns[9]])
    mu1 = np.mean(ydata1)
    sigma1 = np.std(ydata1)
    x1 = np.linspace(ydata1.min(),ydata1.max(),len(ydata1))
```

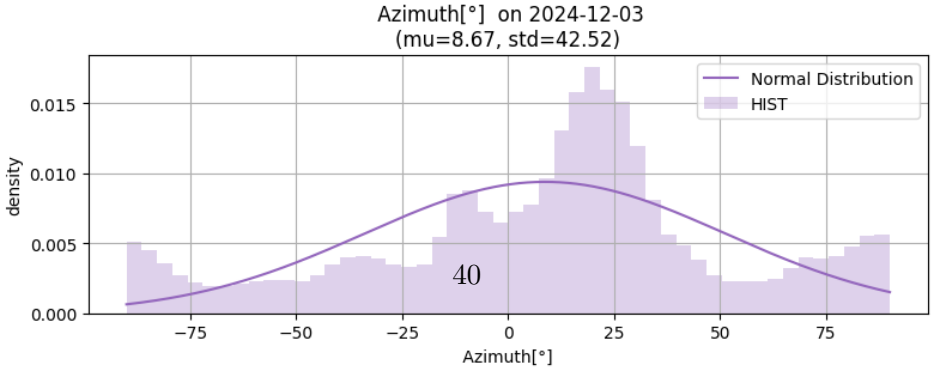
```
    y1 = norm.pdf(x1, mu1, sigma1)

    ax.plot(x1, y1, label = 'Normal Distribution', color=colors[i])
    ax.hist(ydata1, bins = 50, density = True, color=colors[i], alpha = 0.3,␣
 ↪label = "HIST")

    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'{columns[9]} on {angle_daily_list[i][0]}\n(mu={mu1:.2f},␣
 ↪std={sigma1:.2f})')
    ax.set_xlabel(columns[9])
    ax.set_ylabel('density')

plt.tight_layout()
plt.show()
```


Azimuth[°] on 2024-11-29
(mu=5.73, std=23.66)
Normal Distribution
HIST
density
Azimuth[°]

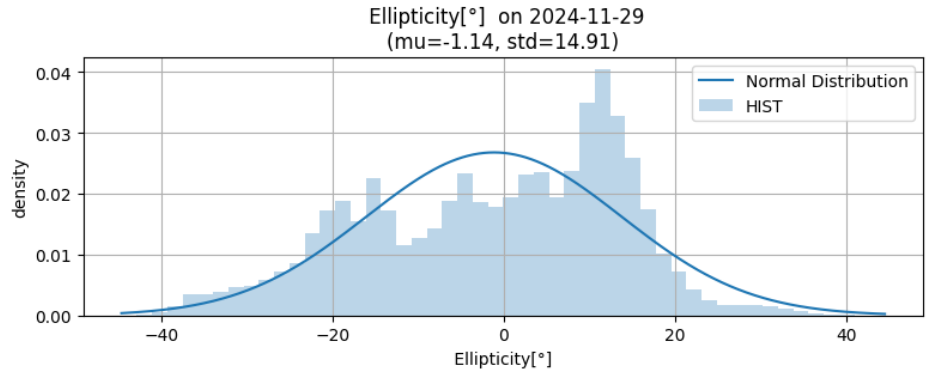

Azimuth[°] on 2024-11-30
(mu=2.43, std=55.01)
Normal Distribution
HIST
density
Azimuth[°]

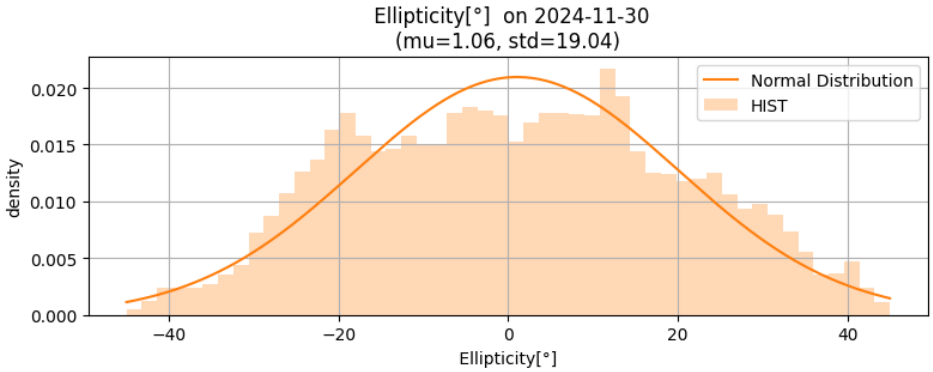

Azimuth[°] on 2024-12-01
(mu=7.65, std=51.77)
Normal Distribution
HIST
density
Azimuth[°]

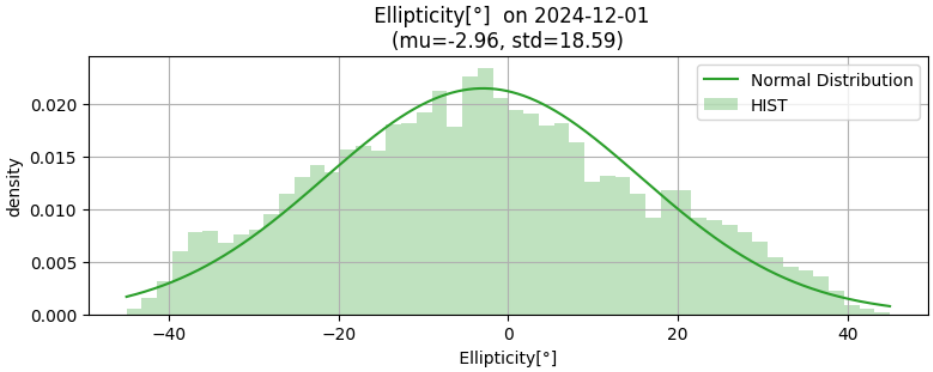

Azimuth[°] on 2024-12-02
(mu=2.97, std=45.94)
Normal Distribution
HIST
density
Azimuth[°]

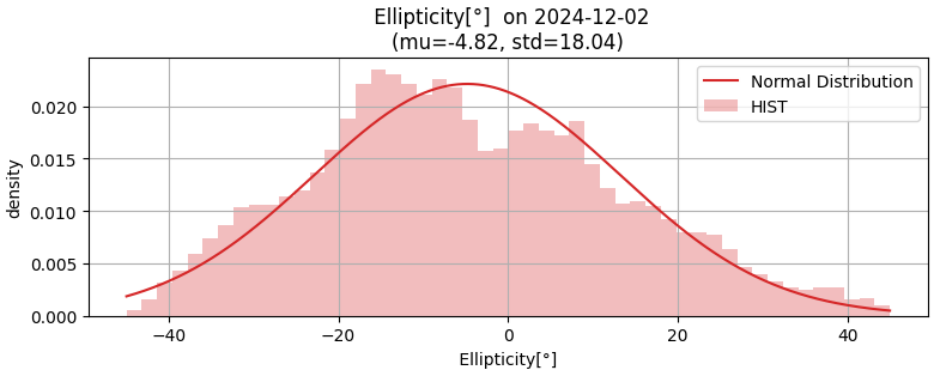

Azimuth[°] on 2024-12-03
(mu=8.67, std=42.52)
Normal Distribution
HIST
density
Azimuth[°]

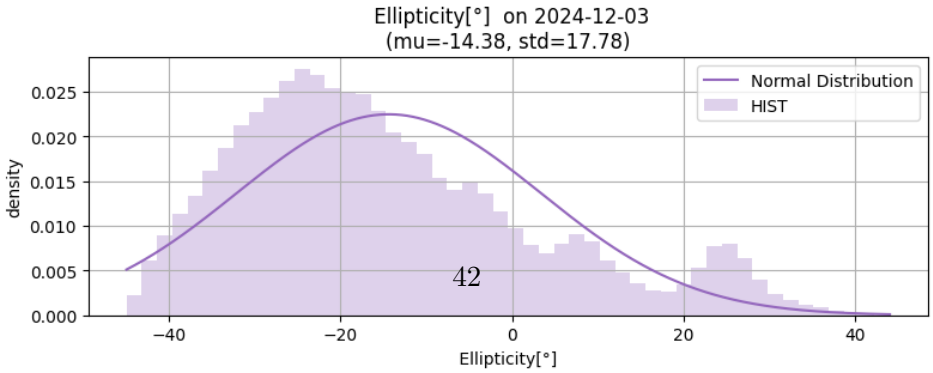
[46]:
```
fig, axs = plt.subplots(len(angle_daily_list), 1, figsize=(8, 16), sharex=False)

for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    ydata1 = np.array(angle_daily_list[i][1][columns[10]])
    mu1 = np.mean(ydata1)
    sigma1 = np.std(ydata1)
    x1 = np.linspace(ydata1.min(),ydata1.max(),len(ydata1))
    y1 = norm.pdf(x1, mu1, sigma1)

    ax.plot(x1, y1, label = 'Normal Distribution', color=colors[i])
    ax.hist(ydata1, bins = 50, density = True, color=colors[i], alpha = 0.3,␣
 ↪label = "HIST")

    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'{columns[10]} on {angle_daily_list[i][0]}\n(mu={mu1:.2f},␣
 ↪std={sigma1:.2f})')
    ax.set_xlabel(columns[10])
    ax.set_ylabel('density')

plt.tight_layout()
plt.show()
```


Ellipticity[°] on 2024-11-29
(mu=-1.14, std=14.91)
Normal Distribution
HIST
density
Ellipticity[°]


Ellipticity[°] on 2024-11-30
(mu=1.06, std=19.04)
Normal Distribution
HIST
density
Ellipticity[°]

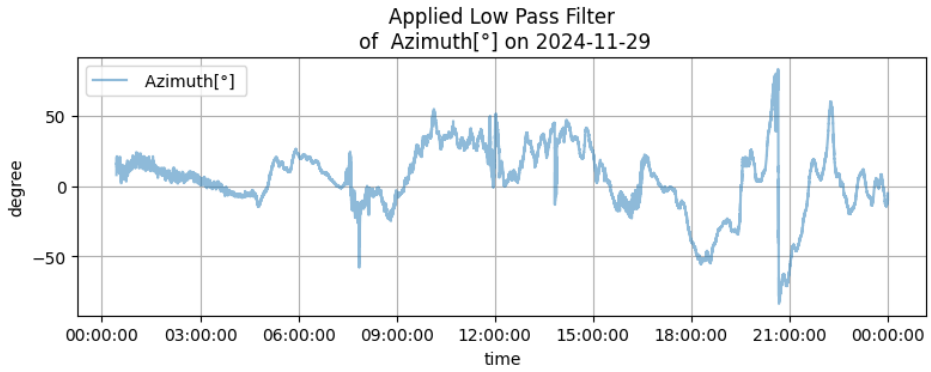

Ellipticity[°] on 2024-12-01
(mu=-2.96, std=18.59)
Normal Distribution
HIST
density
Ellipticity[°]

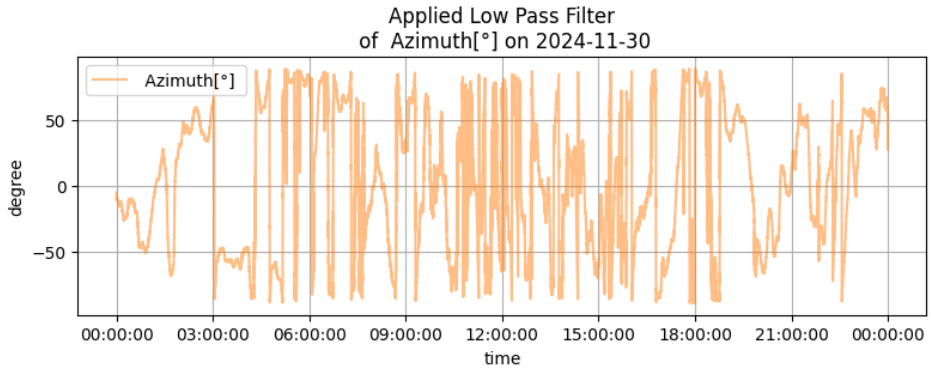

Ellipticity[°] on 2024-12-02
(mu=-4.82, std=18.04)
Normal Distribution
HIST
density
Ellipticity[°]

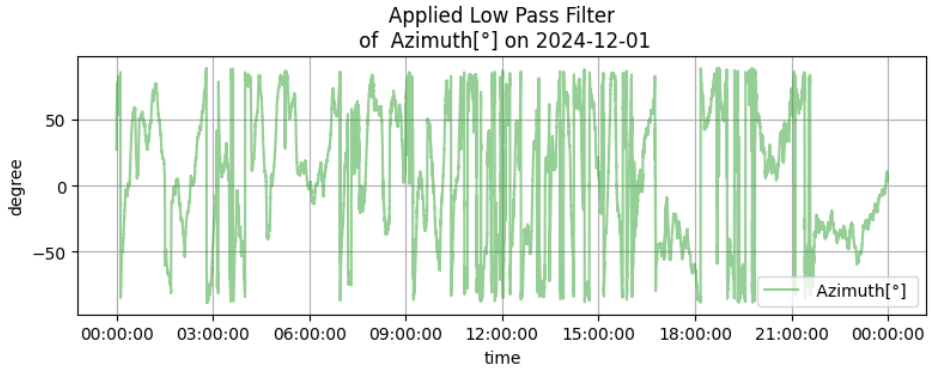

Ellipticity[°] on 2024-12-03
(mu=-14.38, std=17.78)
Normal Distribution
HIST
density
Ellipticity[°]

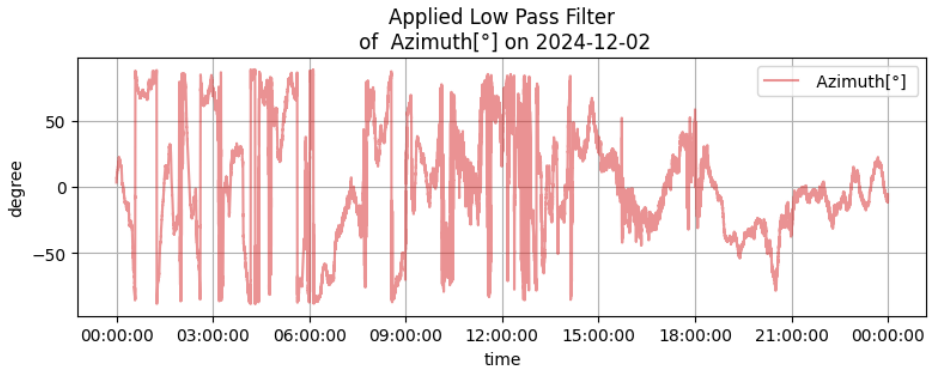
3.3 Filterung mittels Tief- und Hochpass

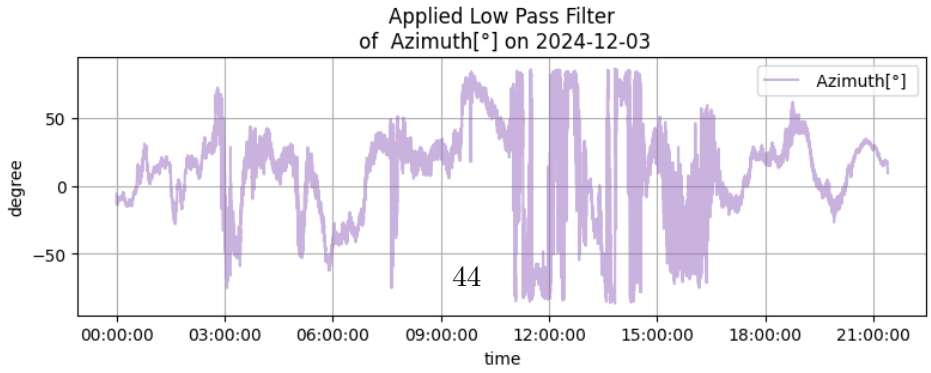
[47]:
```
fig, axs = plt.subplots(len(angle_daily_list), 1, figsize=(8, 16), sharex=False)

for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    df_day = angle_daily_list[i][1][columns[9]]
    ydata = np.array(df_day)
    lps = lowpass(ydata, 100)

    ax.plot(df_day.index, lps[:-1], label=columns[9], color=colors[i], alpha=0.
 ↪5)

    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'Applied Low Pass Filter\n of {columns[9]}on␣
 ↪{angle_daily_list[i][0]}')
    ax.set_xlabel('time')
    ax.set_ylabel('degree')

    ax.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

plt.tight_layout()
plt.show()
```


Applied Low Pass Filter
of Azimuth[°] on 2024-11-29
Azimuth[°]
degree
50
0
−50
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time

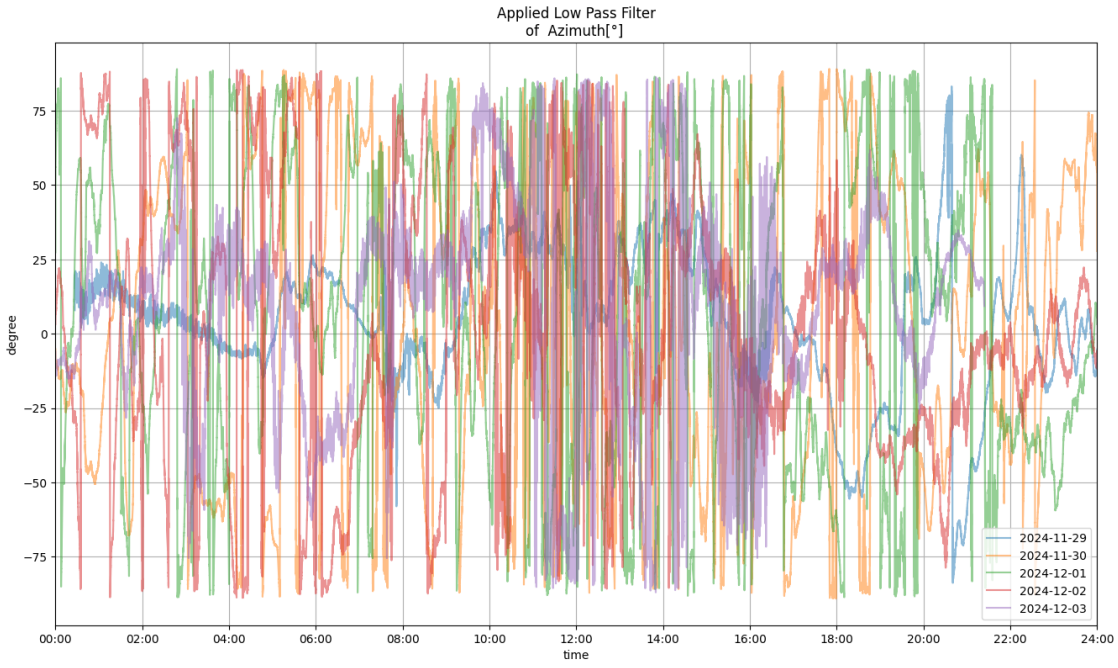

Applied Low Pass Filter
of Azimuth[°] on 2024-11-30
Azimuth[°]
degree
50
0
−50
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time


Applied Low Pass Filter
of Azimuth[°] on 2024-12-01
Azimuth[°]
degree
50
0
−50
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time


Applied Low Pass Filter
of Azimuth[°] on 2024-12-02
Azimuth[°]
degree
50
0
−50
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time

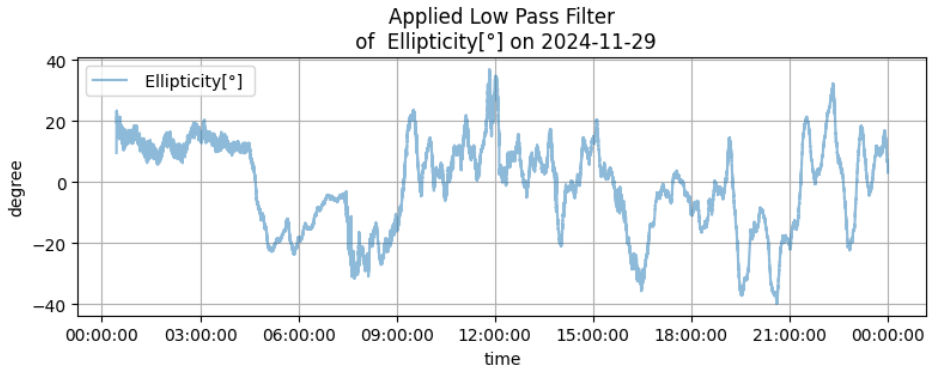

Applied Low Pass Filter
of Azimuth[°] on 2024-12-03
Azimuth[°]
degree
50
0
−50
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
time

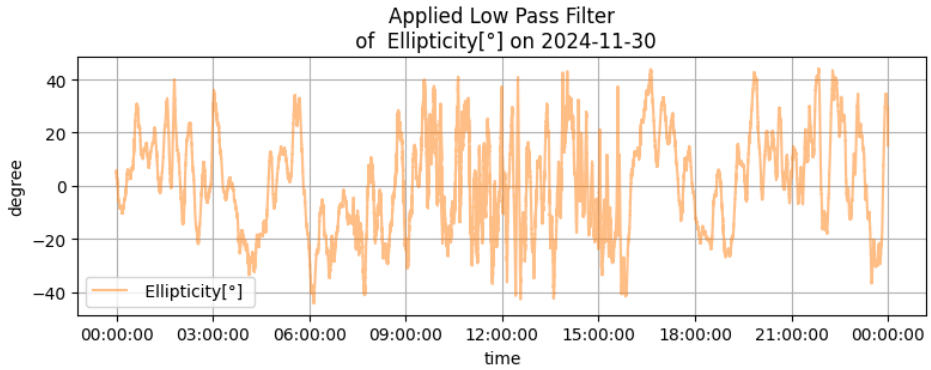
[48]:
```
fig, ax = plt.subplots(figsize = (16,9))

for date, df_day in angle_daily_list:
    times = (df_day.index - df_day.index.normalize()).total_seconds()
    ydata = np.array(df_day[columns[9]])
    lps = lowpass(ydata, 100)
    plt.plot(times, lps[:-1], label=str(date) , alpha=0.5)


ax.xaxis.set_major_locator(ticker.MultipleLocator(3600 * 2))
ax.xaxis.set_major_formatter(ticker.FuncFormatter(format_time))
ax.set_xlim(0, 24 * 3600)

plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied Low Pass Filter\nof {columns[9]}')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()
```

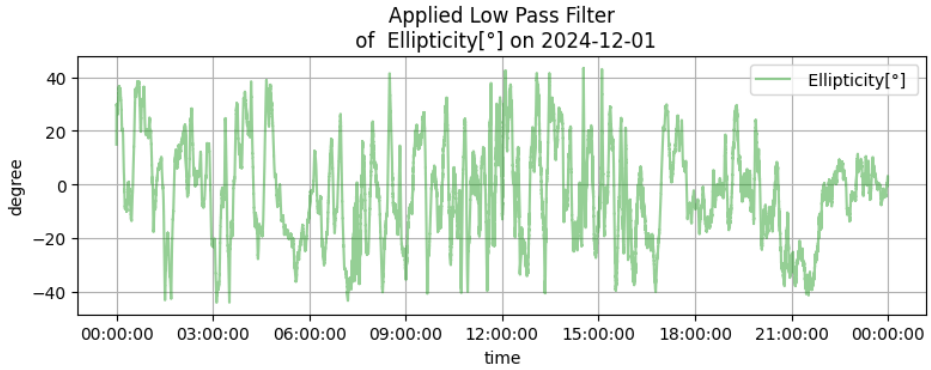


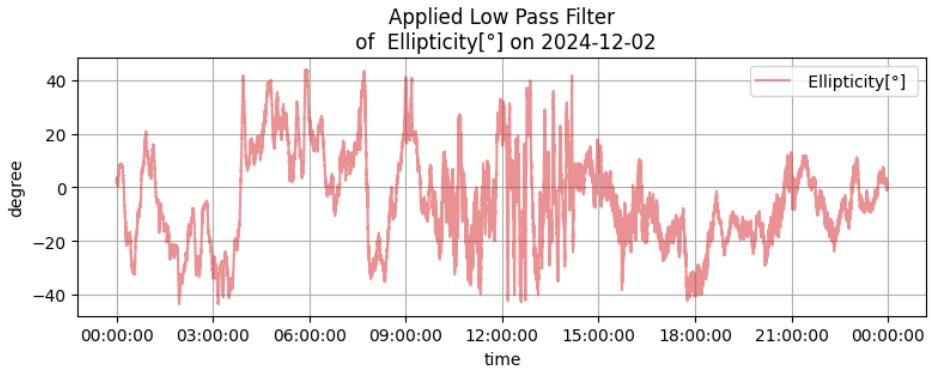
[49]:
```
fig, axs = plt.subplots(len(angle_daily_list), 1, figsize=(8, 16), sharex=False)
```

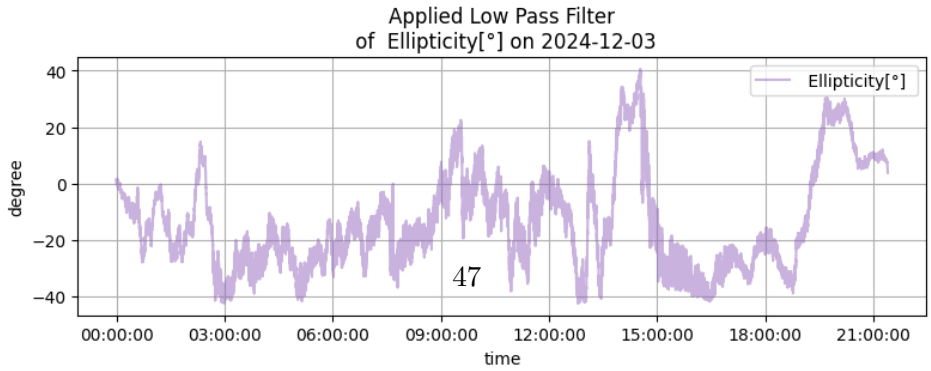
```
for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    df_day = angle_daily_list[i][1][columns[10]]
    ydata = np.array(df_day)
    lps = lowpass(ydata, 100)

    ax.plot(df_day.index, lps[:-1], label=columns[10], color=colors[i], alpha=0.
 ↪5)

    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'Applied Low Pass Filter\n of {columns[10]}on␣
 ↪{angle_daily_list[i][0]}')
    ax.set_xlabel('time')
    ax.set_ylabel('degree')

    ax.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

plt.tight_layout()
plt.show()
```


Applied Low Pass Filter
of Ellipticity[°] on 2024-11-29
Ellipticity[°]
degree
time
40
20
0
−20
−40
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00

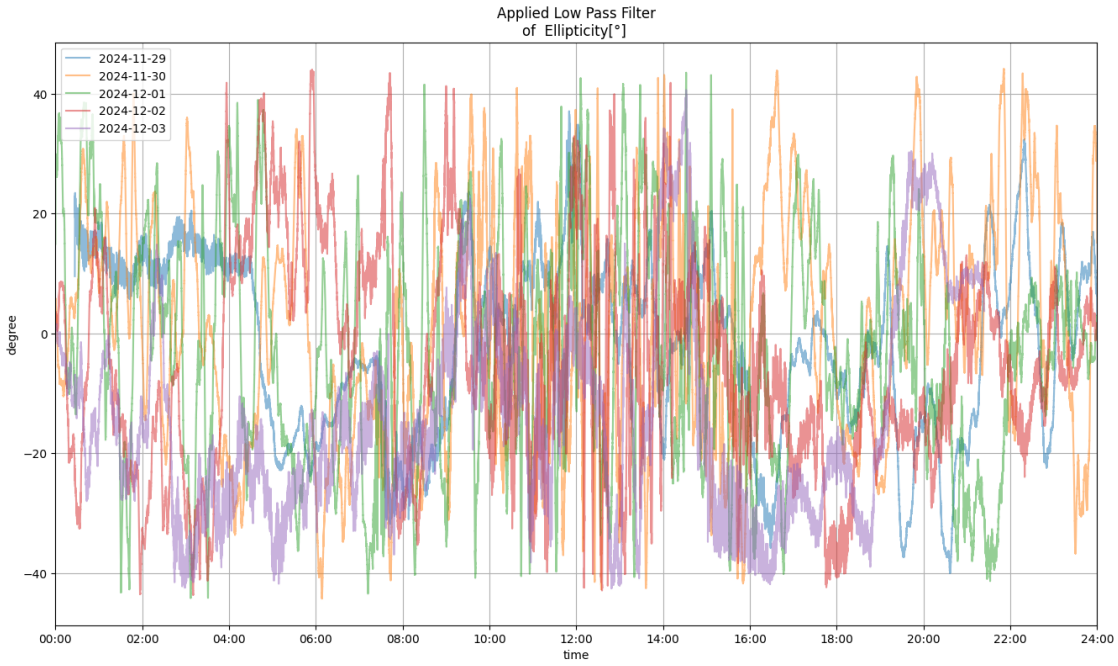

Applied Low Pass Filter
of Ellipticity[°] on 2024-11-30
Ellipticity[°]
degree
time
40
20
0
−20
−40
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00


Applied Low Pass Filter
of Ellipticity[°] on 2024-12-01
Ellipticity[°]
degree
time
40
20
0
−20
−40
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00


Applied Low Pass Filter
of Ellipticity[°] on 2024-12-02
Ellipticity[°]
degree
time
40
20
0
−20
−40
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00

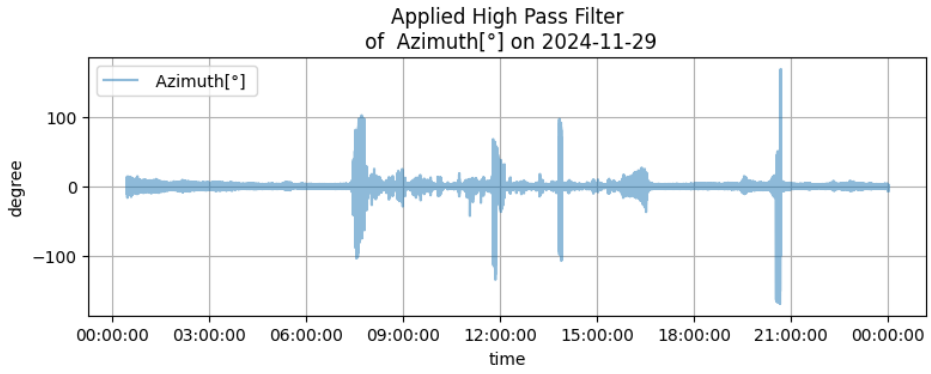

Applied Low Pass Filter
of Ellipticity[°] on 2024-12-03
Ellipticity[°]
degree
time
40
20
0
−20
−40
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00

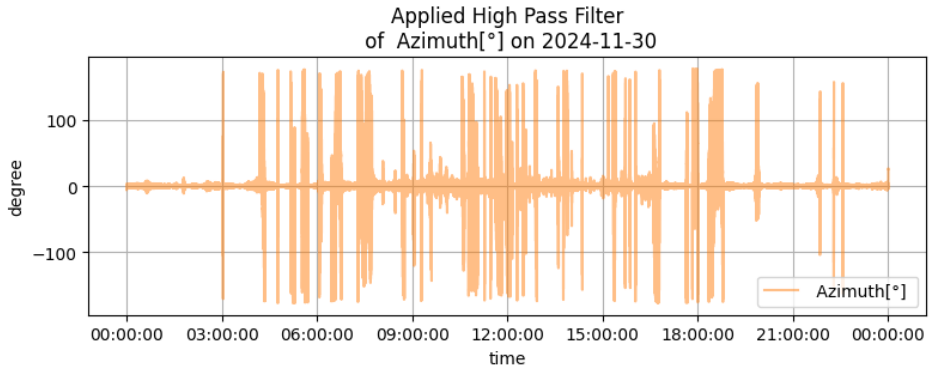
[50]:
```
fig, ax = plt.subplots(figsize = (16,9))

for date, df_day in angle_daily_list:
    times = (df_day.index - df_day.index.normalize()).total_seconds()
    ydata = np.array(df_day[columns[10]])
    lps = lowpass(ydata, 100)
    plt.plot(times, lps[:-1], label=str(date) , alpha=0.5)


ax.xaxis.set_major_locator(ticker.MultipleLocator(3600 * 2))
ax.xaxis.set_major_formatter(ticker.FuncFormatter(format_time))
ax.set_xlim(0, 24 * 3600)

plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied Low Pass Filter\nof {columns[10]}')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()
```

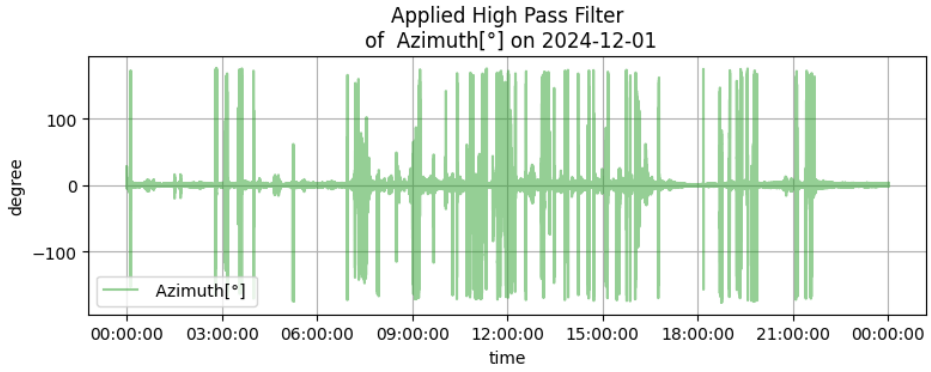


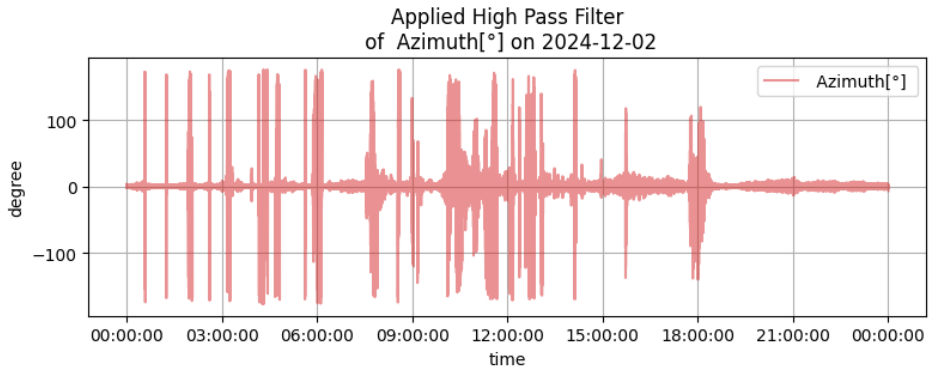
[51]:
```
fig, axs = plt.subplots(len(angle_daily_list), 1, figsize=(8, 16), sharex=False)
```

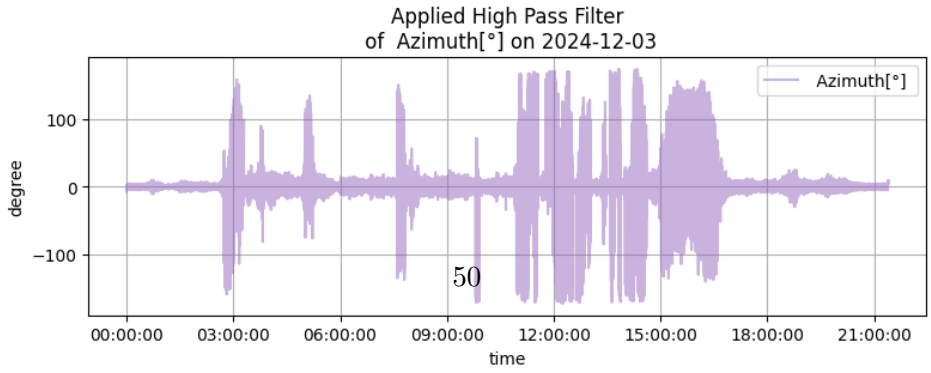
```
for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    df_day = angle_daily_list[i][1][columns[9]]
    ydata = np.array(df_day)
    hps = highpass(ydata, 100)

    ax.plot(df_day.index, hps, label=columns[9], color=colors[i], alpha=0.5)

    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'Applied High Pass Filter\n of {columns[9]}on␣
 ↪{angle_daily_list[i][0]}')
    ax.set_xlabel('time')
    ax.set_ylabel('degree')

    ax.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

plt.tight_layout()
plt.show()
```


Applied High Pass Filter
of Azimuth[°] on 2024-11-29
Azimuth[°]
100
0
−100
degree
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time

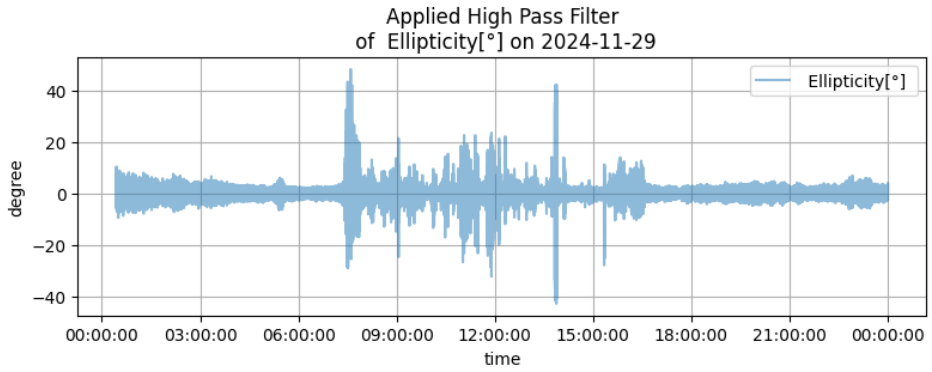

Applied High Pass Filter
of Azimuth[°] on 2024-11-30
100
0
−100
degree
Azimuth[°]
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time

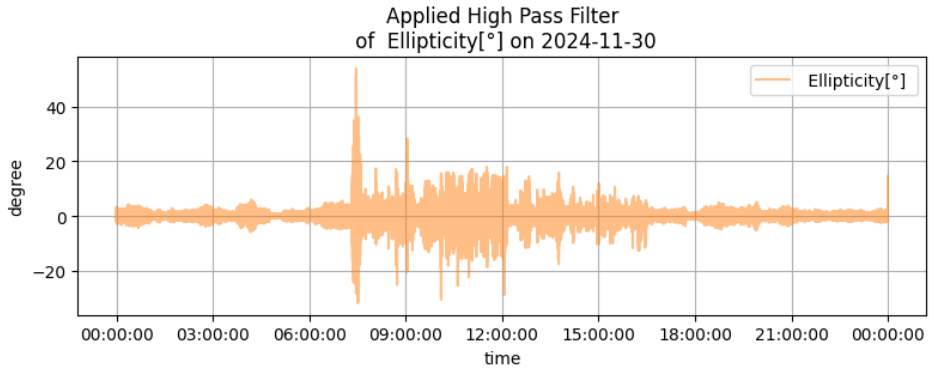

Applied High Pass Filter
of Azimuth[°] on 2024-12-01
100
0
−100
degree
Azimuth[°]
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time

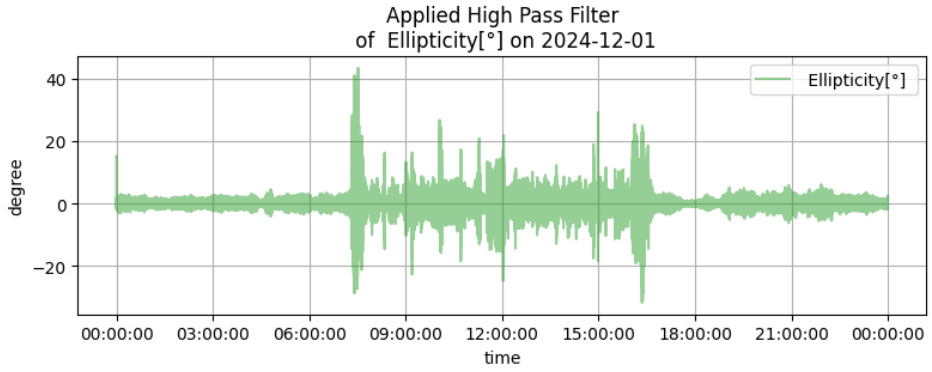

Applied High Pass Filter
of Azimuth[°] on 2024-12-02
Azimuth[°]
100
0
−100
degree
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time

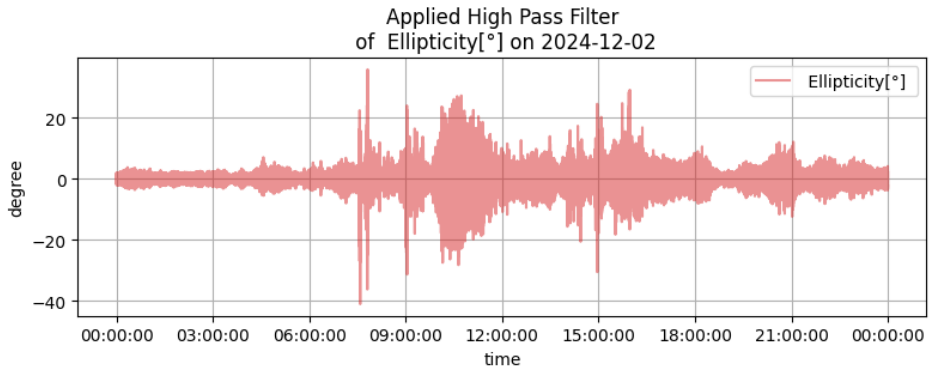

Applied High Pass Filter
of Azimuth[°] on 2024-12-03
Azimuth[°]
100
0
−100
degree
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
time

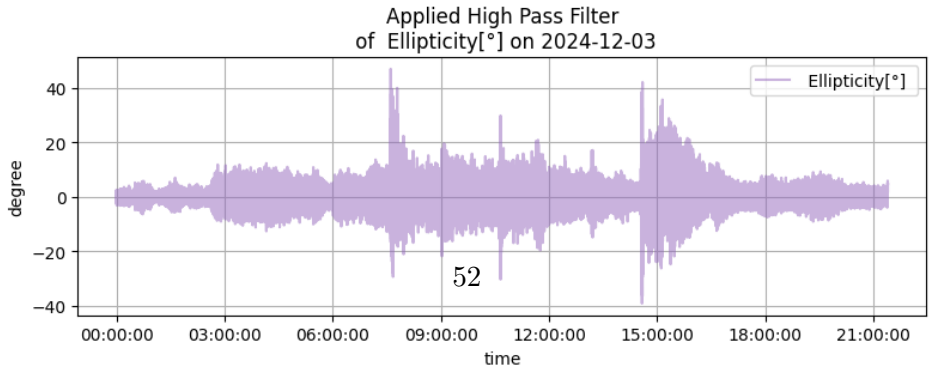
[52]:
```
fig, axs = plt.subplots(len(angle_daily_list), 1, figsize=(8, 16), sharex=False)

for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    df_day = angle_daily_list[i][1][columns[10]]
    ydata = np.array(df_day)
    hps = highpass(ydata, 100)

    ax.plot(df_day.index, hps, label=columns[10], color=colors[i], alpha=0.5)

    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'Applied High Pass Filter\n of {columns[10]}on␣
 ↪{angle_daily_list[i][0]}')
    ax.set_xlabel('time')
    ax.set_ylabel('degree')

    ax.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

plt.tight_layout()
plt.show()
```


Applied High Pass Filter
of Ellipticity[°] on 2024-11-29
Ellipticity[°]
degree
40
20
0
−20
−40
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time


Applied High Pass Filter
of Ellipticity[°] on 2024-11-30
Ellipticity[°]
degree
40
20
0
−20
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time


Applied High Pass Filter
of Ellipticity[°] on 2024-12-01
Ellipticity[°]
degree
40
20
0
−20
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time


Applied High Pass Filter
of Ellipticity[°] on 2024-12-02
Ellipticity[°]
degree
20
0
−20
−40
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
time


Applied High Pass Filter
of Ellipticity[°] on 2024-12-03
Ellipticity[°]
degree
40
20
0
−20
−40
00:00:00
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
time

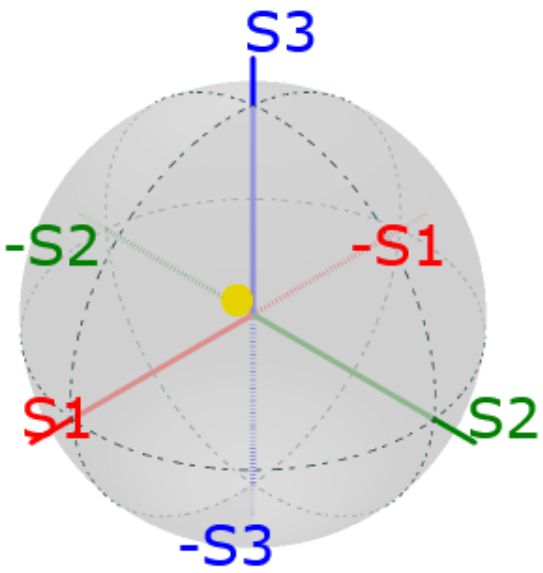
3.4 Darstellung auf der Poincaré-Kugel

3.4.1 Visualisierung mit dem Python-Tool „py_pol“

[53]:
```
one_second = datetime.timedelta(seconds=1)
one_minute = datetime.timedelta(minutes=1)
one_hour = datetime.timedelta(hours=1)
one_quater = datetime.timedelta(hours=6)
one_half = datetime.timedelta(hours=12)
one_day = datetime.timedelta(days=1)

start_time = datetime.datetime.strptime(str(angle.index[0]), '%Y-%m-%d %H:%M:%S.
 ↪%f')
end_time_second = start_time + one_second
end_time_minute = start_time + one_minute
end_time_hour = start_time + one_hour
end_time_quater = start_time + one_quater
end_time_half = start_time + one_half
end_time_day = start_time + one_day
```

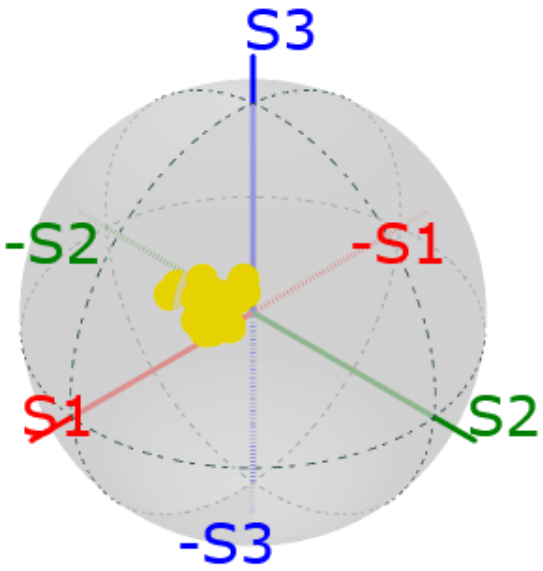
[80]:
```
first_val = angle.iloc[0]

az = np.array(first_val[columns[9]]) * degrees
el = np.array(first_val[columns[10]]) * degrees

S = Stokes("Calculated Point")
S.general_azimuth_ellipticity(az, el)

fig = S.draw_poincare(kind="scatter")
#fig.show()
Image(filename="./img/first_val.png")
```

[80]:



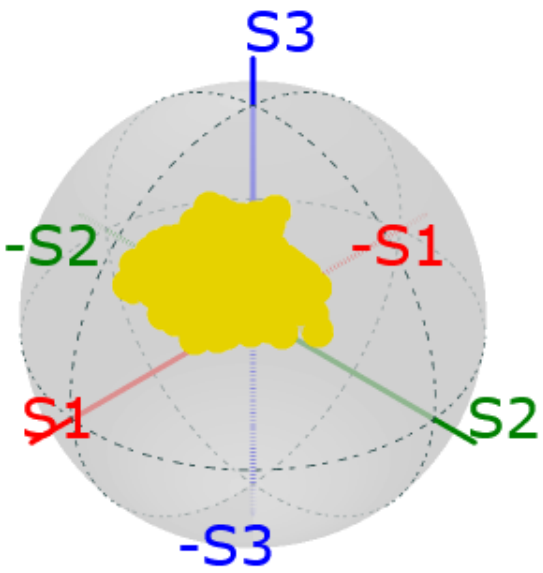
[81]:
```
first_second = angle.loc[(angle.index >= start_time) & (angle.index <␣
↪end_time_second)]

az = np.array(first_second[columns[9]].values) * degrees
el = np.array(first_second[columns[10]].values) * degrees

S = Stokes("Calculated Points")
S.general_azimuth_ellipticity(az, el)

fig = S.draw_poincare(kind="scatter")
#fig.show()
Image(filename="./img/first_second.png")
```

[81]:



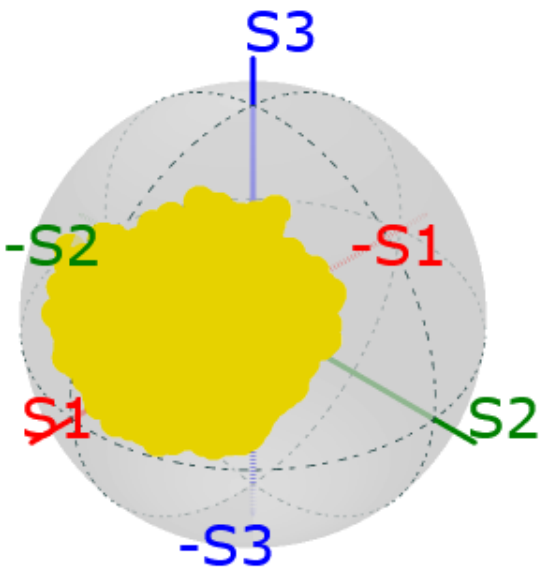
[82]:
```
first_minute = angle.loc[(angle.index >= start_time) & (angle.index <␣
↪end_time_minute)]

az = np.array(first_minute[columns[9]].values) * degrees
el = np.array(first_minute[columns[10]].values) * degrees

S = Stokes("Calculated Points")
S.general_azimuth_ellipticity(az, el)

fig = S.draw_poincare(kind="scatter")
#fig.show()
Image(filename="./img/first_minute.png")
```

[82]:



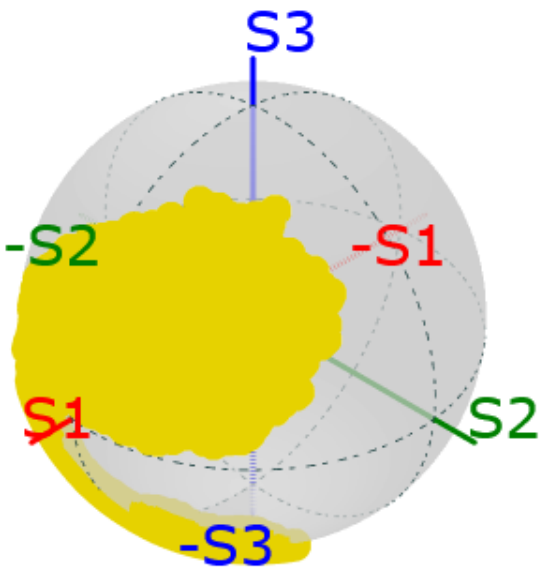
[83]:
```
first_hour = angle.loc[(angle.index >= start_time) & (angle.index <␣
↪end_time_hour)]

az = np.array(first_hour[columns[9]].values) * degrees
el = np.array(first_hour[columns[10]].values) * degrees

S = Stokes("Calculated Points")
S.general_azimuth_ellipticity(az, el)

fig = S.draw_poincare(kind="scatter")
#fig.show()
Image(filename="./img/first_hour.png")
```

[83]:



[84]:
```
first_quater = angle.loc[(angle.index >= start_time) & (angle.index <␣
↪end_time_quater)]

az = np.array(first_quater[columns[9]].values) * degrees
el = np.array(first_quater[columns[10]].values) * degrees

S = Stokes("Calculated Points")
S.general_azimuth_ellipticity(az, el)

fig = S.draw_poincare(kind="scatter")
#fig.show()
Image(filename="./img/first_quater.png")
```

[84]:



3.4.2 Eigene Berechnung und Visualisierung der Daten

[59]:
```
normalized_stokes = pd.read_csv(filename,skiprows=skip, usecols=[columns[2],␣
 ↪columns[3], columns[4]], sep=sep, nrows=19)
x,y,z = convert_angel(first_second[columns[9]].values,␣
 ↪first_second[columns[10]].values)

data = pd.DataFrame({
    "S1": x,
    "Normalized S1": normalized_stokes[columns[2]],
    "S2": y,
    "Normalized S2": normalized_stokes[columns[3]],
```

```
    "S3": z,
    "Normalized S3": normalized_stokes[columns[4]]
})
print(data)
```

```
          S1  Normalized S1        S2  Normalized S2        S3  Normalized S3
0   0.596336           0.60  0.511483           0.51  0.618683           0.62
1   0.701573           0.70  0.488696           0.49  0.518624           0.52
2   0.700520           0.70  0.482535           0.48  0.525769           0.53
3   0.655133           0.66  0.534695           0.53  0.533762           0.53
4   0.646914           0.65  0.488193           0.49  0.585807           0.59
5   0.604898           0.60  0.497930           0.50  0.621421           0.62
6   0.550527           0.55  0.498488           0.50  0.669649           0.67
7   0.569661           0.57  0.523097           0.52  0.633921           0.63
8   0.613659           0.61  0.484291           0.48  0.623607           0.62
9   0.661133           0.66  0.472976           0.47  0.582407           0.58
10  0.720448           0.72  0.431179           0.43  0.543174           0.54
11  0.717083           0.72  0.469604           0.47  0.515038           0.52
12  0.701476           0.70  0.469243           0.47  0.536416           0.54
13  0.687339           0.69  0.397475           0.40  0.607930           0.61
14  0.656328           0.66  0.424273           0.42  0.623880           0.62
15  0.645526           0.65  0.435085           0.44  0.627691           0.63
16  0.645842           0.65  0.383778           0.38  0.660002           0.66
17  0.706732           0.71  0.317914           0.32  0.632029           0.63
18  0.736016           0.74  0.307279           0.31  0.603208           0.60
```

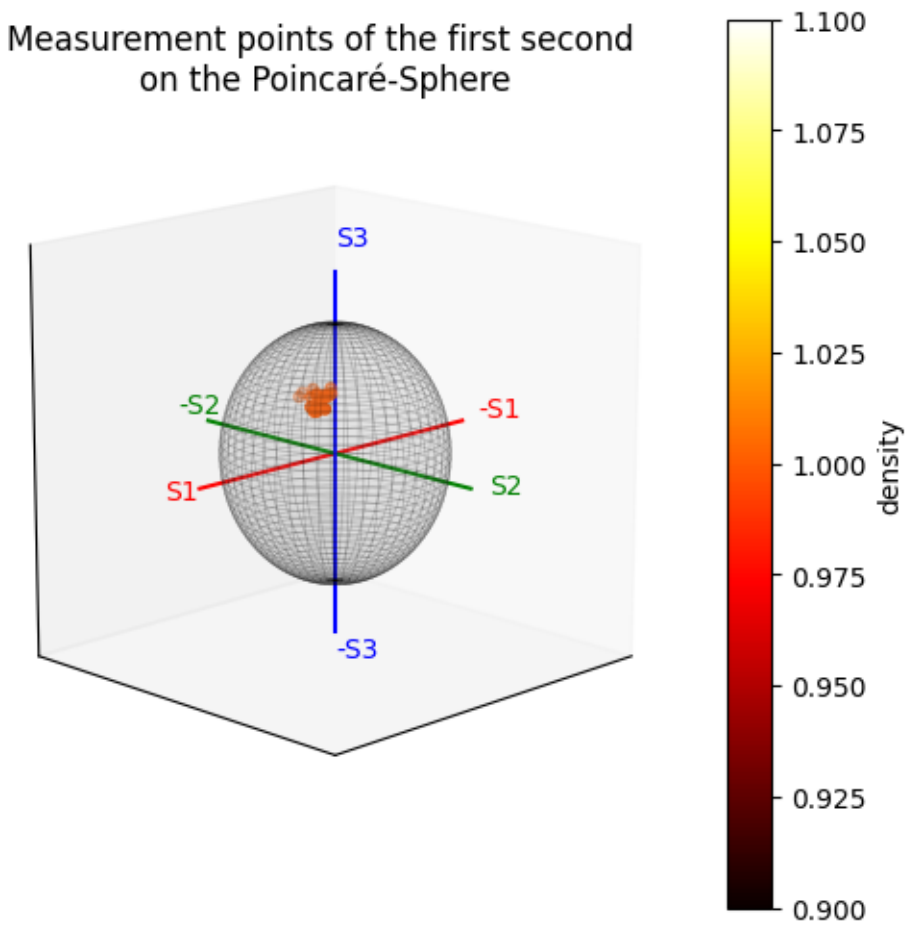
[60]:
```
print("Original normalized S1 equals calculated S1? ", data['Normalized S1'].
  ↪equals(round(data['S1'], 2)))
print("Original normalized S2 equals calculated S2? ", data['Normalized S2'].
  ↪equals(round(data['S2'], 2)))
print("Original normalized S3 equals calculated S3? ", data['Normalized S3'].
  ↪equals(round(data['S3'], 2)))
```

```
Original normalized S1 equals calculated S1?  True
Original normalized S2 equals calculated S2?  True
Original normalized S3 equals calculated S3?  True
```

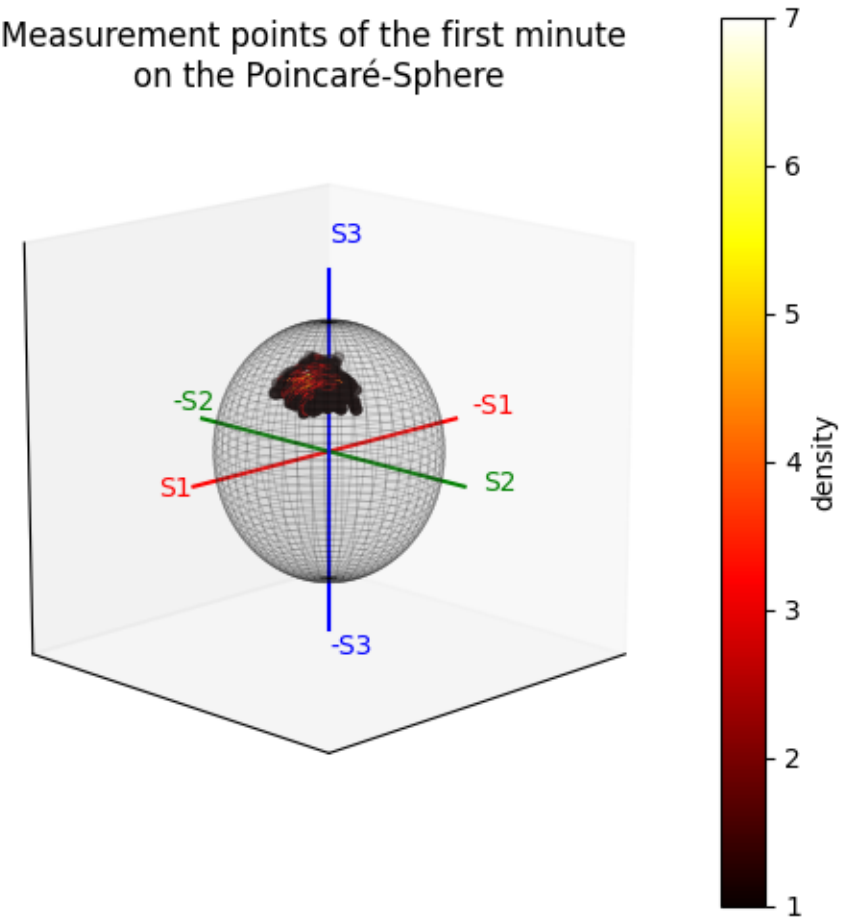
[62]:
```
#%matplotlib notebook # interaktiver Plot-Mode
%matplotlib inline # statischer Plot-Mode
```

```
UsageError: unrecognized arguments: # statischer Plot-Mode
```

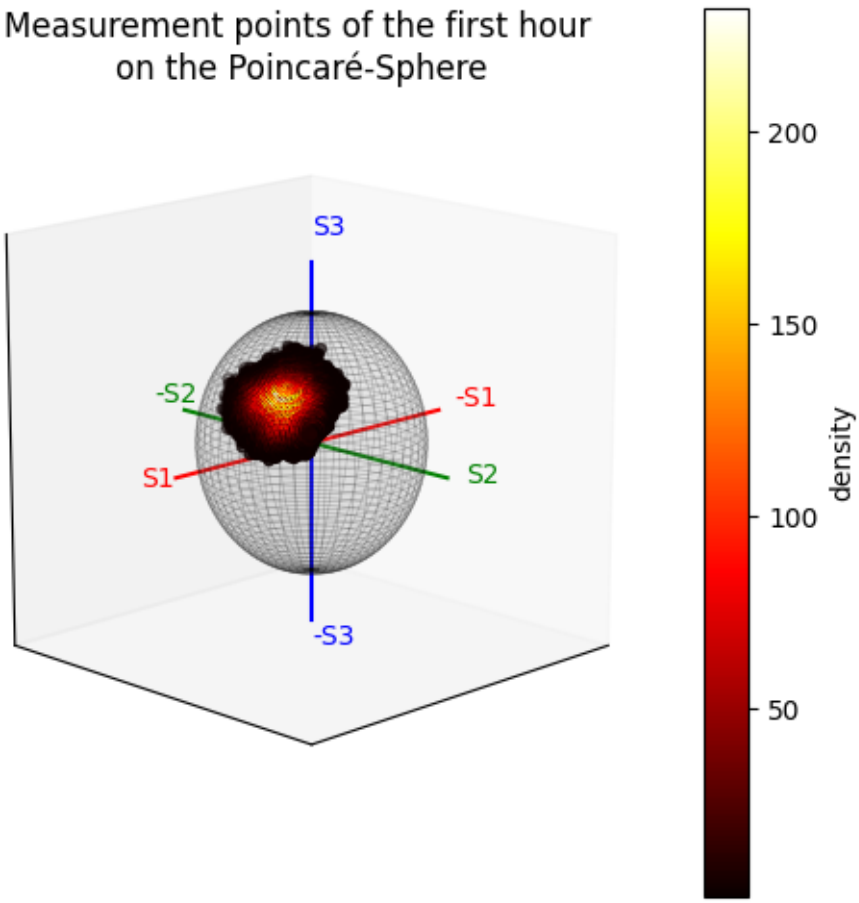
[65]:
```
title = 'Measurement points of the first second \non the Poincaré-Sphere'
x,y,z = convert_angel(first_second[columns[9]].values,␣
  ↪first_second[columns[10]].values)
freq = calculate_freq(x, y, z)
plot_poincare(x, y, z, freq, title=title)
```



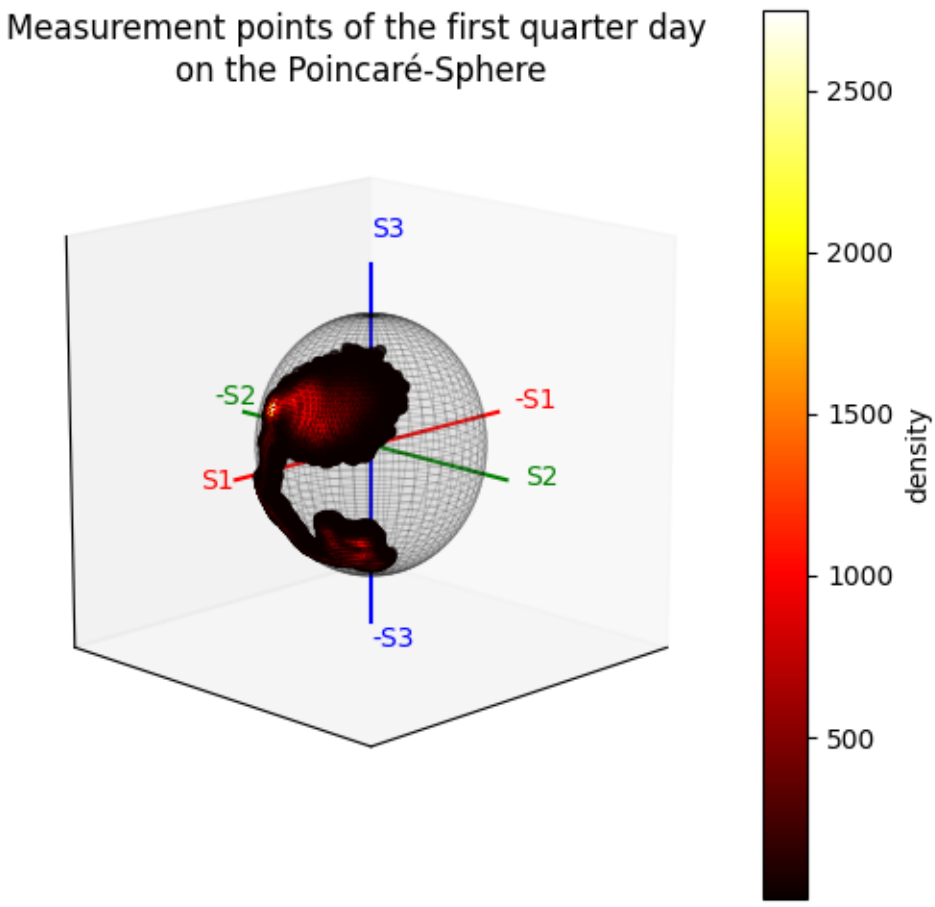
[66]:
```
title = 'Measurement points of the first minute \non the Poincaré-Sphere'
x,y,z = convert_angel(first_minute[columns[9]].values,␣
  ↪first_minute[columns[10]].values)
freq = calculate_freq(x, y, z)
plot_poincare(x, y, z, freq, title=title)
```



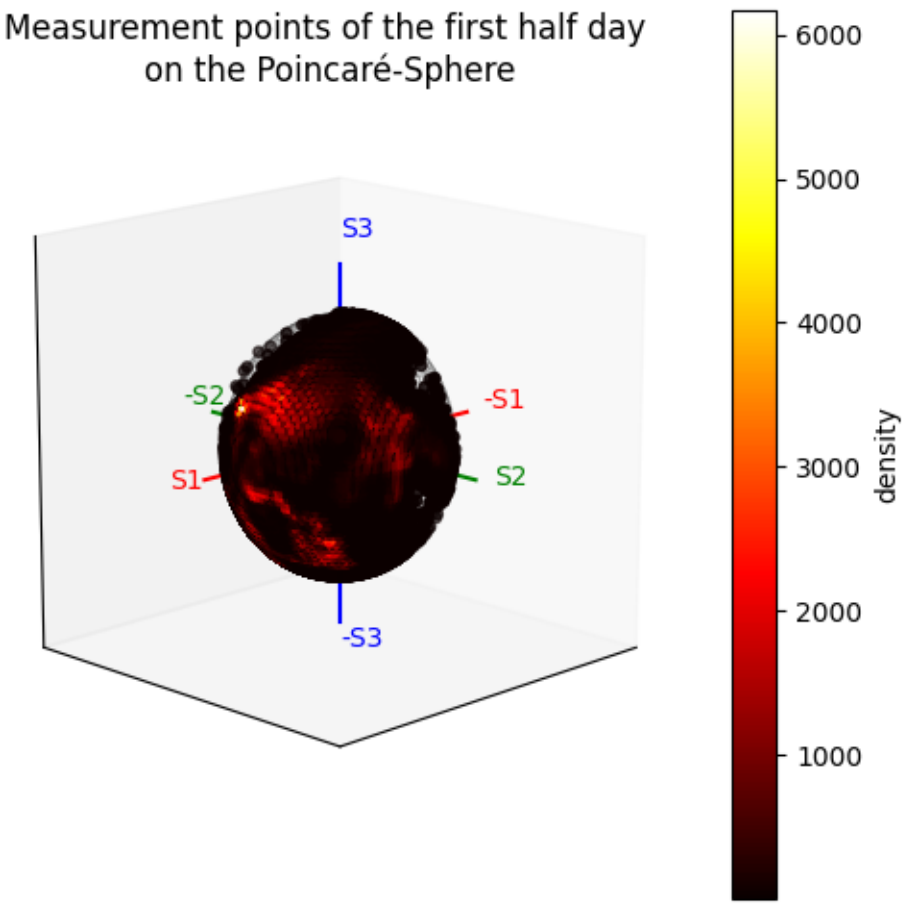
[67]:
```
title = 'Measurement points of the first hour \non the Poincaré-Sphere'
x,y,z = convert_angel(first_hour[columns[9]].values, first_hour[columns[10]].
 ↪values)
freq = calculate_freq(x, y, z)
plot_poincare(x, y, z, freq, title=title)
```



[68]:
```
title = 'Measurement points of the first quarter day \non the Poincaré-Sphere'
x,y,z = convert_angel(first_quater[columns[9]].values,␣
 ↪first_quater[columns[10]].values)
freq = calculate_freq(x, y, z)
plot_poincare(x, y, z, freq, title=title)
```



[70]:
```
first_half = angle.loc[(angle.index >= start_time) & (angle.index <␣
 ↪end_time_half)]

title = 'Measurement points of the first half day \non the Poincaré-Sphere'
x,y,z = convert_angel(first_half[columns[9]].values, first_half[columns[10]].
 ↪values)
freq = calculate_freq(x, y, z)
plot_poincare(x, y, z, freq, title=title)
```



[71]:
```
angle_seconds_resample = angle.resample('s').mean().ffill()
angle_seconds_resample.head()
```

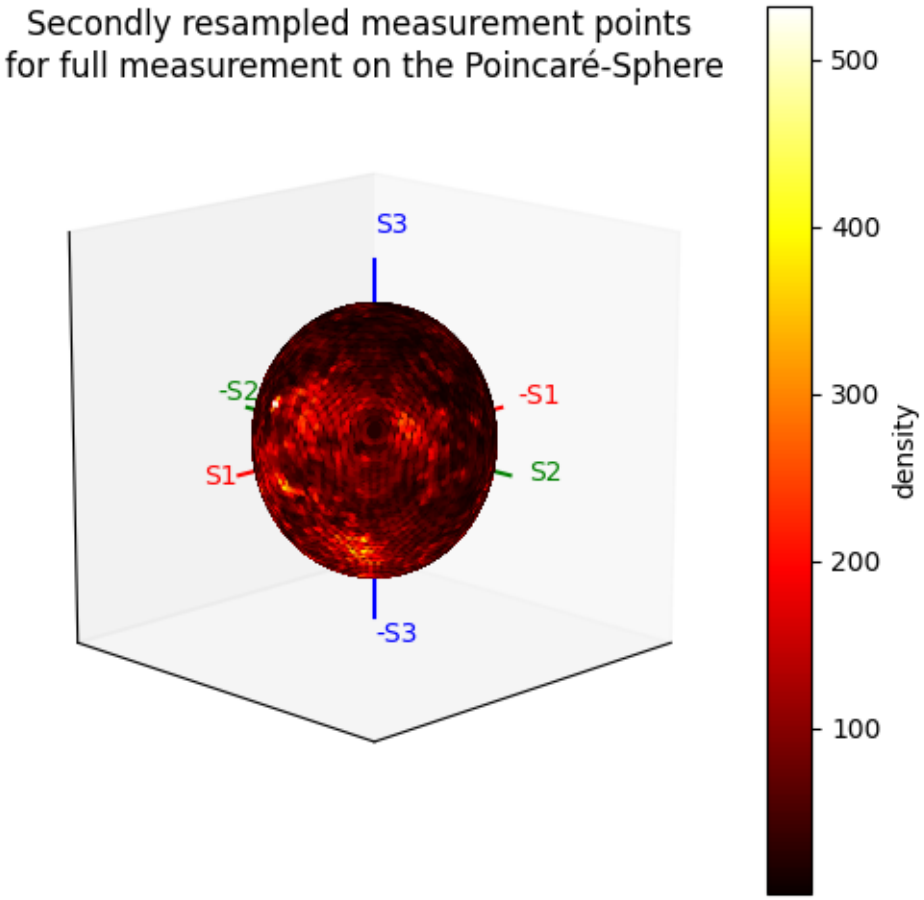
[71]:

Time[date hh:mm:ss]	Azimuth[°]	Ellipticity[°]
2024-11-29 00:26:44	19.217000	18.165000
2024-11-29 00:26:45	12.858095	18.943810
2024-11-29 00:26:46	17.388500	19.627000
2024-11-29 00:26:47	17.231053	19.551053
2024-11-29 00:26:48	15.330952	22.748571

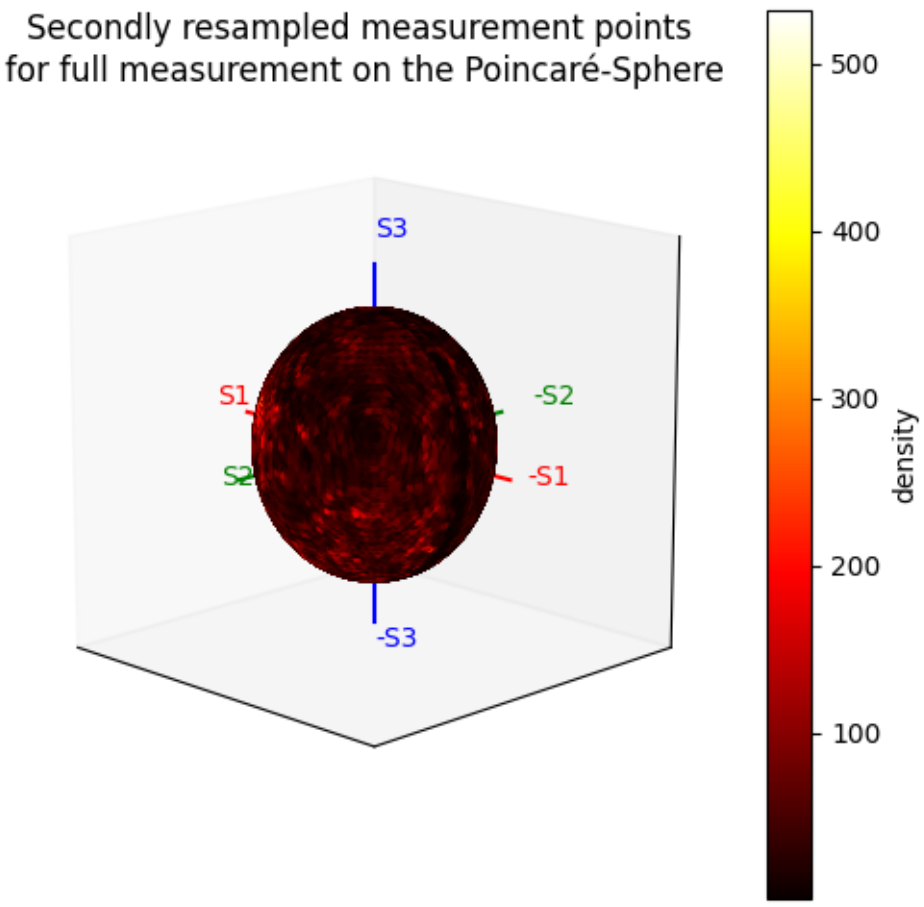
[72]:
```
print(angle_seconds_resample.isnull().sum())
print(type(angle.index))
```

```
Azimuth[°]         0
Ellipticity[°]     0
dtype: int64
<class 'pandas.core.indexes.datetimes.DatetimeIndex'>
```

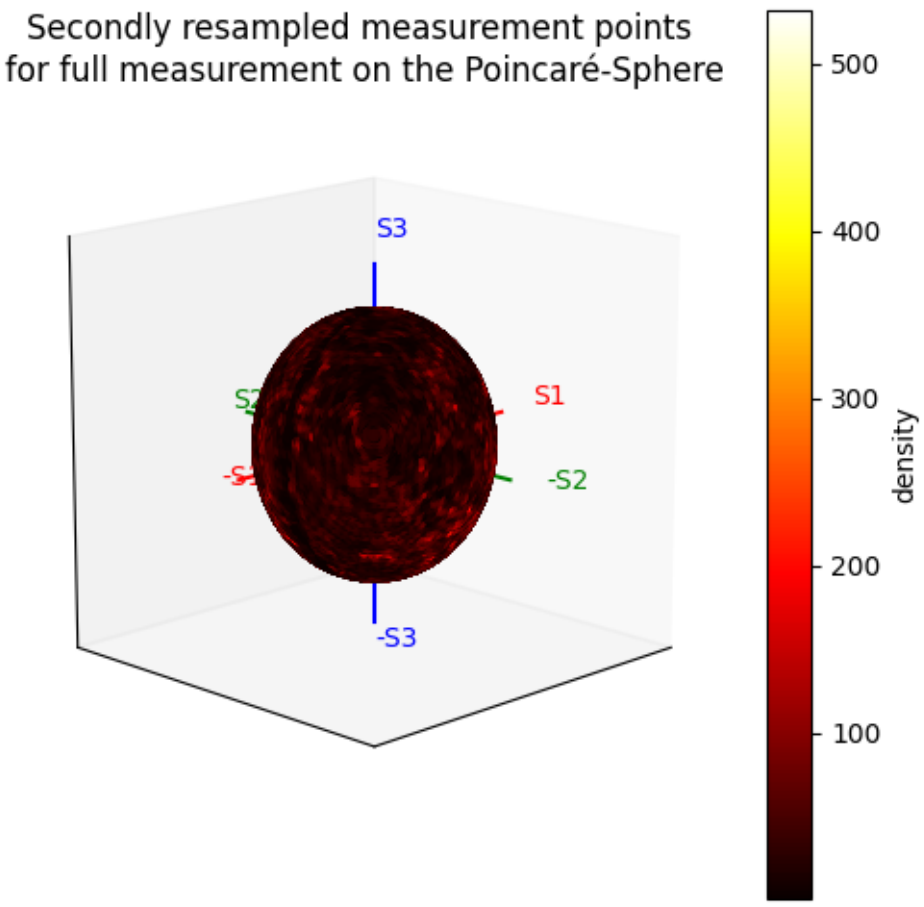
[74]:
```
title= 'Secondly resampled measurement points \nfor full measurement on the␣
 ↪Poincaré-Sphere'

x,y,z = convert_angel(angle_seconds_resample[columns[9]].values,␣
 ↪angle_seconds_resample[columns[10]].values)
freq = calculate_freq(x, y, z)
plot_poincare(x, y, z, freq, title=title)
```



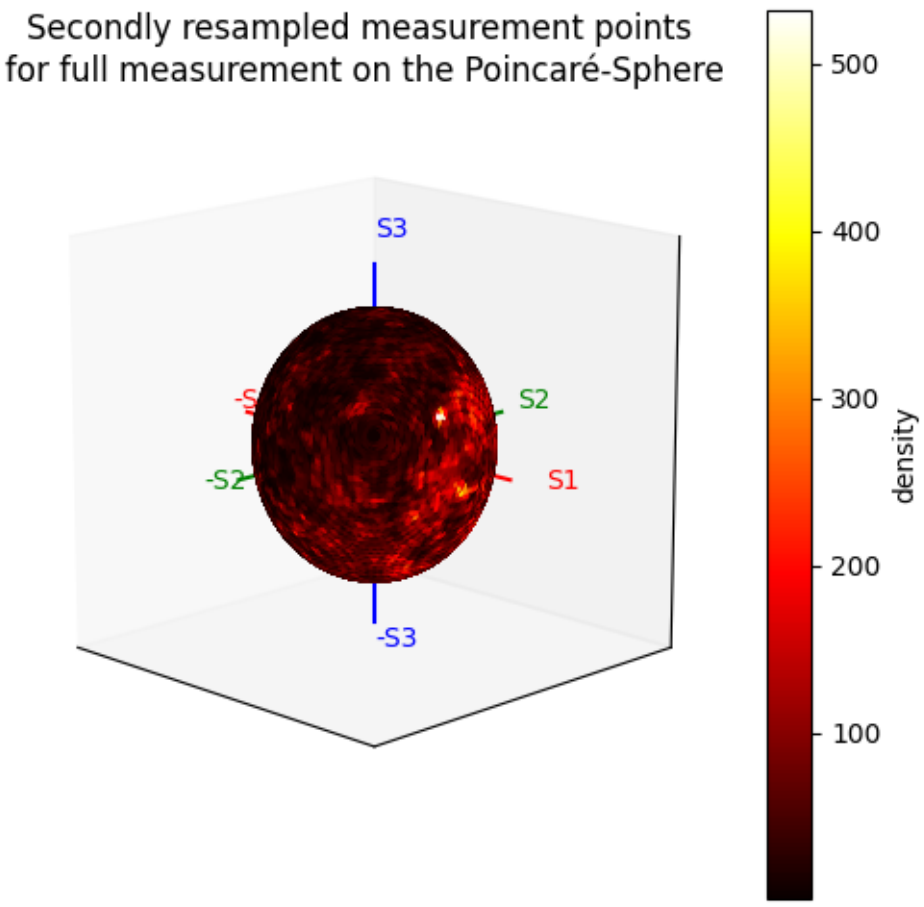
[75]:
```
#elev=15, azim=45
title= 'Secondly resampled measurement points \nfor full measurement on the␣
 ↪Poincaré-Sphere'
plot_poincare(x, y, z, freq, elev=15, azim=135, title=title)
```



[76]:
```
#elev=15, azim=45
title= 'Secondly resampled measurement points \nfor full measurement on the␣
 ↪Poincaré-Sphere'
plot_poincare(x, y, z, freq, elev=15, azim=225, title=title)
```



[77]:
```
#elev=15, azim=45
title= 'Secondly resampled measurement points \nfor full measurement on the␣
 ↪Poincaré-Sphere'
plot_poincare(x, y, z, freq, elev=15, azim=315, title=title)
```


Secondly resampled measurement points
for full measurement on the Poincaré-Sphere
S3
-S3
S2
-S2
S1
500
400
300
200
100
density

[ ]: