
[4]

DEPENDENCY OF THE PERFORMANCE ON THE COOLDOWN VELOCITY OF MID-T HEAT TREATED 1.3 GHZ CAVITIES

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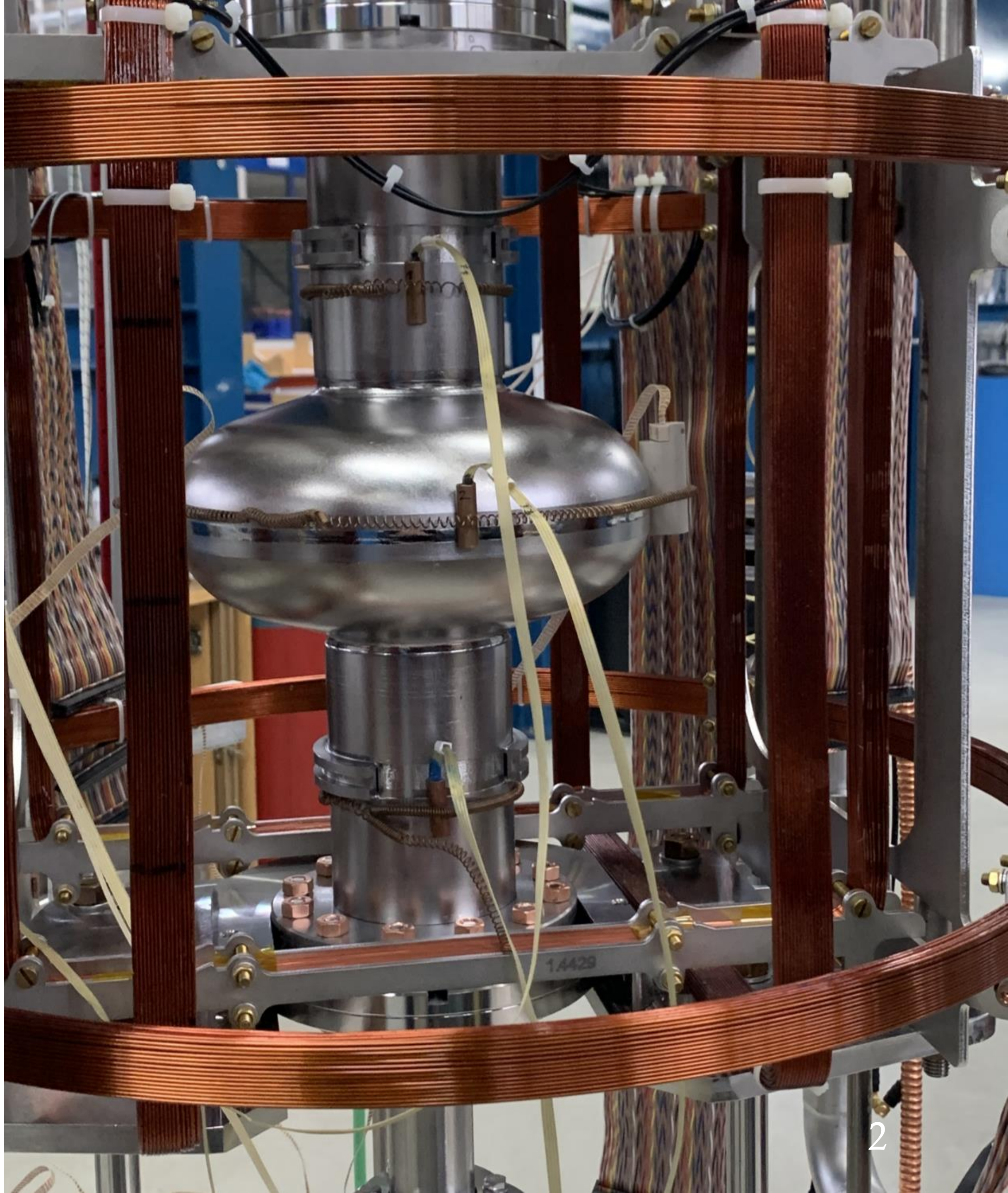
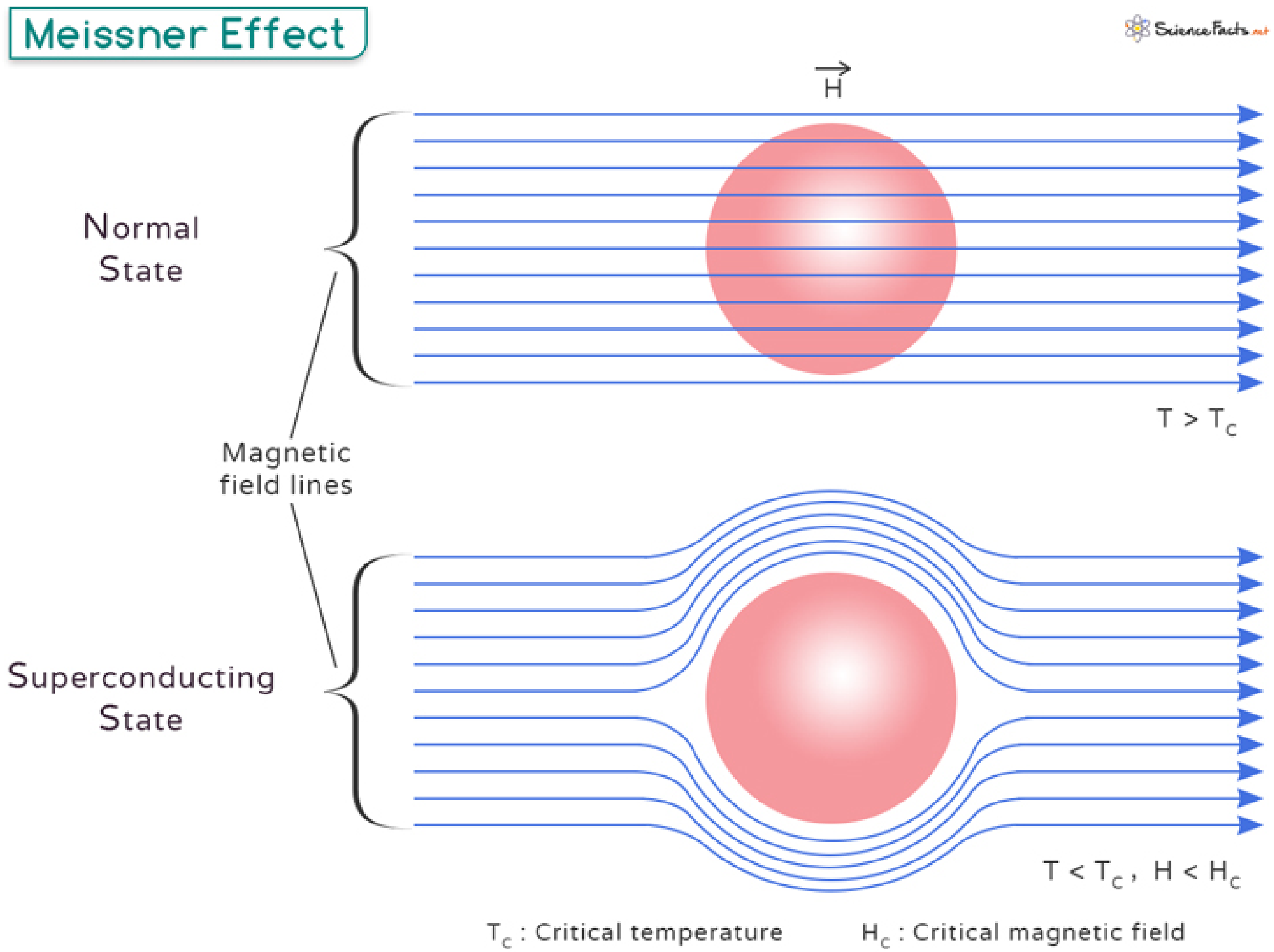
SRF CAVITY

- Operated at Cryogenic temperatures
- Niobium:
  high critical temperature (9.2K)
  critical magnetic field (0.22T)
- Higher quality factor than normal conducting cavities
- Oscillating EM-fields
  in practice used for accelerating particles



MEISSNER-EFFECT

- Magnetic field expulsion
- Occurs on cooldown below critical temperature, magneticfield
- Superconductor reaches zero electrical resistance
- Possible inclusions of magnetic field due to the cooldown velocity and material impurities



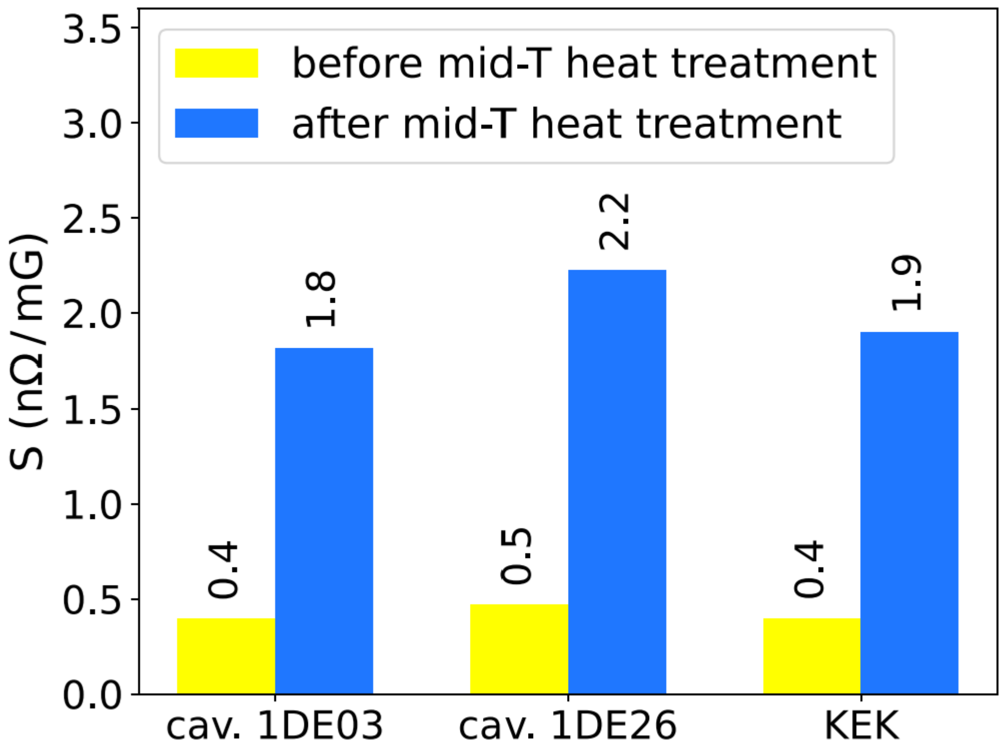
[1]

RESISTANCE AND SENSITIVITY

- BCS theory describes superconductors due to cooper pairs
- Resistance composed of:
  R_{BCS} : resistance depending on the temperature and energy gap at T
  R_{flux} : due to normal conducting material impurities
  R_{res} : due to contamination, field emission, environmental magnetic fields
- $S = \frac{\Delta R}{B}$

MID-T HEAT TREATED SRF CAVITIES

- Temperature range: 250°C bis 350°C
- Treated for 3-20 h
- Higher Q_0 than normal SRF cavities
- Earlier quench than normal SRF cavities
- Sensitivity increased concerning magnetic fields



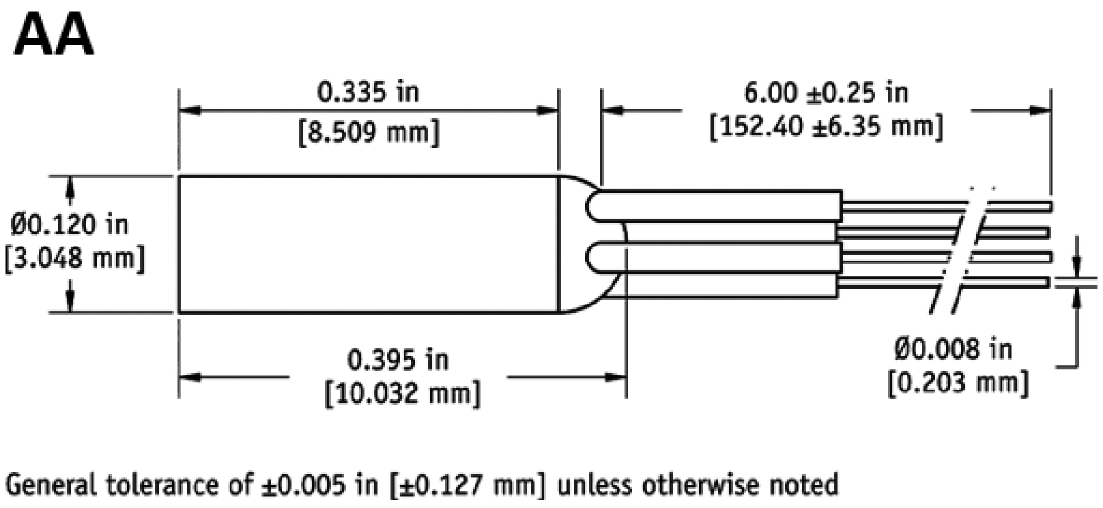
[3]

CRYOSTAT AND INSERT

- Diameter of around 1 m
- Cooldown in steps, first 100K than 4K lastly 2K or lower
- Cavities slotted into inserts
- Inside of cavity is a vacuum, outside liquid helium

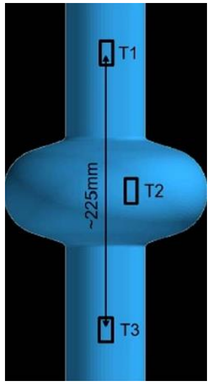
TEMPERATURE SENSORS

- Cernox Temperature sensors
- Cryogenic temperature range (100mK to 420K)
- Change of resistance is measured
- Fast response time for cryogenic temperatures
- Located at cavity's outside wall

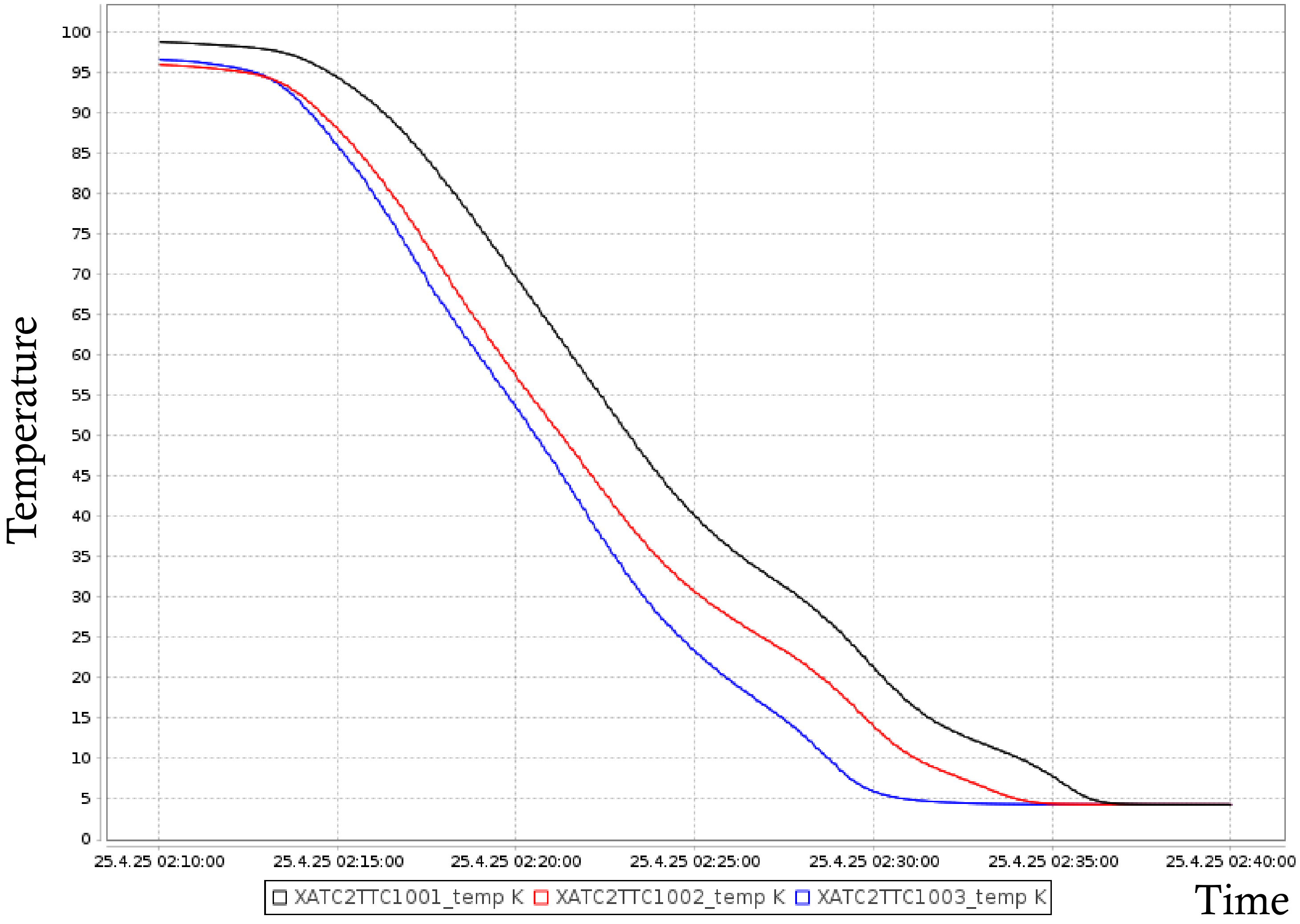


MEASUREMENTS

- Temperature measured at 3 spots, distance (Sensor 1 to 3) ~225mm
- $Q_0\,(E_{acc})$ measured after cooldown to 2K
- E_{acc} acceleration field



[3]



ANALYTIC TOOL

```
def TempmitPandas(Start,End):
    with open("Sensor1.txt") as file1, open("Sensor2.txt") as file2, open("Sensor3.txt") as file3:
        F1 = [line.split() for line in file1.readlines()[2:]]
        F2 = [line.split() for line in file2.readlines()[2:]]
        F3 = [line.split() for line in file3.readlines()[2:]]
    T1=[]
    T2=[]
    T3=[]
    Pandastime1 = []
    Pandastime2 = []
    Pandastime3 = []
    for entry in F1[:-2]:
        T1.append(float(entry[2].replace(',', '.')))
        Pandastime1.append(entry[0].replace('/', '-') + ' ' + entry[1])
    for entry in F2[:-2]:
        T2.append(float(entry[2].replace(',', '.')))
        Pandastime2.append(entry[0].replace('/', '-') + ' ' + entry[1])
    for entry in F3[:-2]:
        T3.append(float(entry[2].replace(',', '.')))
        Pandastime3.append(entry[0].replace('/', '-') + ' ' + entry[1])
    Pandastime1_dt = pd.to_datetime(Pandastime1, format='%d-%m-%Y %H:%M:%S', errors='coerce')
    Pandastime2_dt = pd.to_datetime(Pandastime2, format='%d-%m-%Y %H:%M:%S', errors='coerce')
    Pandastime3_dt = pd.to_datetime(Pandastime3, format='%d-%m-%Y %H:%M:%S', errors='coerce')
    df1 = pd.DataFrame({'timestamp': Pandastime1_dt, 'value': T1})
    df2 = pd.DataFrame({'timestamp': Pandastime2_dt, 'value': T2})
    df3 = pd.DataFrame({'timestamp': Pandastime3_dt, 'value': T3})
    ref_timeline = pd.DataFrame({
        'timestamp': pd.date_range(start=Start, end=End, freq='5S')
    })
    aligned1 = pd.merge_asof(ref_timeline, df1, on='timestamp', direction='nearest', tolerance=pd.Timedelta('3s'))
    aligned2 = pd.merge_asof(ref_timeline, df2, on='timestamp', direction='nearest', tolerance=pd.Timedelta('3s'))
    aligned3 = pd.merge_asof(ref_timeline, df3, on='timestamp', direction='nearest', tolerance=pd.Timedelta('3s'))
    aligned1['value'] = aligned1['value'].interpolate(method='linear')
    aligned2['value'] = aligned2['value'].interpolate(method='linear')
    aligned3['value'] = aligned3['value'].interpolate(method='linear')
    aligned1['diff'] = aligned1['value'].diff()
    aligned2['diff'] = aligned2['value'].diff()
    aligned3['diff'] = aligned3['value'].diff()
    aligned1 = aligned1[aligned1['diff'] < 0]
    aligned2 = aligned2[aligned2['diff'] < 0]
    aligned3 = aligned3[aligned3['diff'] < 0]
    target_value=9.2
    tolerance=0.03
    filtered_values1 = aligned1[(aligned1['value'] >= (target_value - tolerance)) &
                              (aligned1['value'] <= (target_value + tolerance))]
    filtered_values2 = aligned2[(aligned2['value'] >= (target_value - tolerance)) &
                              (aligned2['value'] <= (target_value + tolerance))]
    filtered_values3 = aligned3[(aligned3['value'] >= (target_value - tolerance)) &
                              (aligned3['value'] <= (target_value + tolerance))]
```

- Creating a python script to interact with Web-Archive and Cavityplots-server
- Using temperature data to calculate:
- Spatial temperature gradient
  Calculated at 9.2 K (Sensor 3)
- $\frac{\Delta K}{\Delta T} = \frac{(T(Sensor\ 3) - T(Sensor\ 1))}{225mm}$
- Cooldown velocity
  Gradient of the temperature curve at 9.2K
- Correlate cooldown velocity on mid-T heat treated cavities with the performance
- Host a local site to access these cooldown velocity, spatial temperature gradient and corelation with the performance

TIMELINE

- Creating the analytical tool for temperature data (~2 weeks)
- Script to interact with cavity plots server gathering Q(E) (~4 weeks)
- Matching cooldown velocity to Q(E) (~5 weeks)
- Display and operate webpage with the analysed data (~6 weeks)
- Possible dedicated measurements for different cooldown velocities (~inbetween or after if needed)

SOURCES

- [1]: https://www.sciencefacts.net/meissner-effect.html [accessed 28 Apr 2025]
- [2]: Cernox product page https://www.lakeshore.com/products/categories/specification/temperature-products/cryogenic-temperature-sensors/cernox [accessed 28 Apr 2025]
- [3]: Correlation of srf performance to oxygen diffusion length of medium temperature heat treated cavities, C. Bate, arXiv:2407.07779v1, 2024
- [4]: The International Linear Collider, Technical Design Report, Volume 3.1: Accelerator R&D - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/A-13-GHz-superconducting-niobium-ninecell-cavity_fig2_252628009 [accessed 28 Apr 2025]