TTC/ARIES topical workshop on flux trapping and magnetic shielding

Report of Contributions

https://indico.cern.ch/e/FluxTrapping

Contribution ID: **7** Type: **not specified**

Registration

Thursday 8 November 2018 08:15 (30 minutes)

Session Classification: Welcome, Registration and Introduction

Contribution ID: **8** Type: **not specified**

Measurement of magnetic shielding performance and permeability of soft magnetic alloys for SRF

Thursday 8 November 2018 09:00 (25 minutes)

Magnetic shield products are manufactured through specialized processes, including heat treatment and performance testing of DC magnetic shielding. By May 2018, all of the magnetic shields for the SRF of the FRIB were completed and passed performance tests at room temperature in our factory. Those products are made of mu-metal, a nickel-iron alloy, instead of from an alloy for cryogenic temperatures. Heat treatment was done at 1100 degrees Celsius with a hydrogen gas atmosphere, and the permeability of the mu- metal increased by about 100 times larger than that of the raw material. In the final process, the performance of each product was tested in a 40-50 uT DC magnetic field. The shielding factors were calculated from magnetic field strengths measured by a magnetometer, which is carefully calibrated. The talk will also discuss the behavior of permeability at several levels of cryogenic temperature for farther understanding of shielding performance at 4.2, 25, 50, 100, and 200K.

Presenter: Mr SAKAKIBARA (Othama CO)

Session Classification: Magnetic shielding

Contribution ID: **9** Type: **not specified**

Small magnetic field measurements and control at CERN

Thursday 8 November 2018 09:25 (25 minutes)

At CERN, magnetic measurement activities typically concern fields up to about 10 T, with uncertainties in the 10-100 ppm range. In some cases, however, measurement and control of very low fields, in the range of nano to microcrotesla, is needed. In this talk, we shall first review briefly such cases, which are mostly motivated by the mitigation of beam perturbations at very low energy or over large regions. Next we will discuss the instrumentation best suited for such low levels, including both custom-made and commercially available sensors, which are mostly designed for geomagnetic applications. Finally, we will list the specific capabilities available at CERN in this area, which include commercial teslameters of various types, manufacturing capabilities for inductive sensors, controllable scalar and vector field sources and other test and calibration facilities.

Presenter: BUZIO, Marco (CERN)

Session Classification: Magnetic shielding

Contribution ID: **10** Type: **not specified**

Magnetic field management in cryomodules and vertical cryostats at CEA-Saclay

Thursday 8 November 2018 09:50 (25 minutes)

Limitation of the flux trapping in superconducting cavities requires magnetic field management around cavities. At CEA, this activity is carried out both for cryomodules (IFMIF, ESS, SARAF) and test facilities. Appropriate magnetic shielding must be provided, and magnetic field sources must be avoided close to the cavities. This latter point requires the selection of non magnetic material for all elements located close to the cavity. When solenoids are located inside cryomodules (e.g. IFMIF, SARAF), it must be verified that the surrounding elements will not be magnetised.
The presentation will describe tests and solutions implemented at CEA for this purpose.

Presenter: PLOUIN, Juliette (CEA)

Session Classification: Magnetic shielding

Contribution ID: **11** Type: **not specified**

Magnetic field management for SRF

Thursday 8 November 2018 10:30 (35 minutes)

Magnetic field management for SRF cavities has grown in importance with recent projects desiring greater Q, implying smaller magnetic fields at the cavities. This requires cryomodules and facilities to be designed with additional measures, such as global and/or local passive magnetic shielding as well as active methods to reduce fields. I will provide a summary of these techniques as applied to the LCLS-II project.
In addition to the LCLS-II results, I shall also present techniques and results from FRIB, on behalf of Kenji Saito.

Presenter: CHANDRASEKARAN, Saravan (FNAL)

Session Classification: Magnetic shielding

Contribution ID: **12** Type: **not specified**

Characterisation of the magnetic shield efficiency for the ESS double spoke cavities

Thursday 8 November 2018 11:05 (15 minutes)

Measurements of the efficiency of the magnetic shield have been carried out for the ESS Spoke cavities. The magnetic shield is made of Cryophy, a Nickel-Iron alloy, and is mounted around the Double-Spoke cavity. It is composed of two 1mm-thick layers, actively cooled by cryogenic circuit (LHe @ 4K). The installation of a mock-up cavity in the prototype cryomodule (made of stainless steel) gave us the opportunity to characterize the efficiency of the magnetic shield. The set-up of the experiment will be presented. First results showed that, at room temperature, the residual magnetic field inside the mock-up cavity is reduced by a factor of approximately 300. Measurements at lower temperatures, between 20K and 60K, have also been carried out and showed no degradation of the magnetic shield efficiency. Results will be presented in details and discussed.

Presenter: SANSINE, Vateanui (Institut de Physique nucléaire d'orsay)

Session Classification: Magnetic shielding

Contribution ID: **13** Type: **not specified**

Q&A on Magnetic shielding

Thursday 8 November 2018 11:20 (5 minutes)

Session Classification: Magnetic shielding

Contribution ID: **14** Type: **not specified**

Review of magnetic flux expulsion

Thursday 8 November 2018 11:25 (25 minutes)

This presentation will give an overview of magnetic flux expulsion. This will include a general description of the phenomenon and how it is fits into the larger picture of Q0 degradation due to trapped flux. A historical overview will be presented, focusing particularly on recent developments in the understanding of flux expulsion. The importance of this parameter to achieve high Q0 will be highlighted. In addition, areas will be noted where understanding is lacking and additional insight is needed

Presenter: POSEN, Sam (Fermilab)

Session Classification: Flux expulsion efficiency

Contribution ID: **15** Type: **not specified**

Can the present techniques for cavity flux expulsion efficiency measurements be unified?

Thursday 8 November 2018 11:50 (15 minutes)

Presently, three different techniques are used for deducing the trapped flux of SRF cavities quantitatively based on measurements of flux expulsion at the phase transition moment during the cavity cool-down process. It is still an open question as to whether these techniques give results that are consistent to each other. In this talk, we introduce two formulae that allow direct cross checking of trapped fluxes measured with different techniques. It is shown that the measured trapped fluxes can be quite different depending on the technique adopted. It follows then that further effort is still needed in developing a universal technique for the measurement of local trapped fluxes over the entire wall of an elliptical shape cavity.

Presenters: GENG, Rongli (Jefferson Lab); HUANG, Shichun (IMP)

Session Classification: Flux expulsion efficiency

Contribution ID: **16** Type: **not specified**

Efficiency measurements with MO, AMR, and Fluxgates

Thursday 8 November 2018 12:05 (15 minutes)

This presentation will discuss techniques used for magnetic field measurement in SRF cavities as well as samples. Advances, challenges and future prospects will be given.

Presenter: KÖSZEGI, Julia-Marie (HZB)

Session Classification: Flux expulsion efficiency

Contribution ID: **17** Type: **not specified**

Microscopic investigation of flux expulsion at FNAL

Thursday 8 November 2018 14:00 (10 minutes)

The efficiency of flux expulsion during the cavity superconducting transition is affected significantly by the properties of the material used to fabricate the cavity itself. Significant variability is indeed observed when comparing cavities fabricated with material coming from different vendors. Here we present results from a recent study in which the microscopic properties of different production grade materials are analyzed, aiming to correlate such properties with the flux expelling behavior of cavities

Presenter: MARTINELLO, Martina (Fermilab - IIT)

Session Classification: Flux expulsion efficiency

Contribution ID: **18** Type: **not specified**

Study on temperature dependent EBSD measurements

Thursday 8 November 2018 14:10 (10 minutes)

We started EBSD measurements, which can be observed while changing temperature of Nb samples in a chamber. We expect measurements on grain orientation, stress and dislocation can give us important information to understand pinning center and flux expulsion

Presenter: Dr UMEMORI, Kensei (KEK)

Session Classification: Flux expulsion efficiency

Contribution ID: **19** Type: **not specified**

Update on Experimental Study of Flux Expulsion and Cold Work

Thursday 8 November 2018 14:20 (10 minutes)

In this presentation, a brief update will be presented on a study in which flux expulsion is measured in two large grain cavities, one of which was heavily deformed during the manufacturing process, and one of which went through the standard fabrication steps. The most recent measurements were performed after high temperature furnace treatment at 800 C

Presenter: POSEN, Sam (Fermilab)

Session Classification: Flux expulsion efficiency

Contribution ID: **20** Type: **not specified**

Discussion on the impact of material on expulsion efficiency

Thursday 8 November 2018 14:30 (10 minutes)

Session Classification: Flux expulsion efficiency

Contribution ID: **21** Type: **not specified**

Flux epulsion experiments with a 704 MHz elliptical cavity

Thursday 8 November 2018 14:40 (10 minutes)

Initial investigations on magnetic flux expulsion in the CERN vertical test cryostats are discussed, with measurements taken on a bulk Nb 704 MHz 5-cell elliptical cavity. Cool down procedure is assessed in terms of both magnetic field flux expulsion and thermal currents, and the implication to RF performance is discussed.
In addition, mapping of magnetic field inside the cryostat is addressed in an effort to correlate with ambient magnetic field simulations and expected flux expulsion.
Measurements show a high degree of flux trapping and clear signs of thermal currents, which is discussed in relation to the cavity preparation and cool down.

Presenter: IVANOV, Anton Evgeniev (CERN)

Session Classification: Flux expulsion efficiency

Contribution ID: **22** Type: **not specified**

Flux expulsion experiments with QWR at RIKEN

Thursday 8 November 2018 14:50 (10 minutes)

In each VT for QWR at RIKEN, we measure the vertical magnetic field at the upper part of the cavity. We report the obtained data, mainly at a moment the cavity shifts from NC to SC, and from SC to NC.

Presenter: UMEMORI, Kensei (KEK)

Session Classification: Flux expulsion efficiency

Contribution ID: **23** Type: **not specified**

Discussion on non 1.3 GHz experiments

Thursday 8 November 2018 15:00 (10 minutes)

Session Classification: Flux expulsion efficiency

Contribution ID: **25** Type: **not specified**

LCLS-II Cryomodule expulsion

Thursday 8 November 2018 15:10 (10 minutes)

In this presentation, I will give an overview of the substantial influence of magnetic flux expulsion on the performance of production cavities for LCLS-II, focusing particularly on their performance in cryomodule tests. Strong correlations are observed between Q0 and the temperature at which vacuum furnace treatment occurred.

Presenter: POSEN, Sam (Fermilab)

Session Classification: Flux expulsion efficiency

Contribution ID: **26** Type: **not specified**

LCLS-II TD material batch study on flux expulsion

Thursday 8 November 2018 15:20 (10 minutes)

The SLAC National Accelerator Laboratory is currently constructing a major upgrade to its accelerator, the Linac Coherent Light Source II (LCLS-II). Several Department of Energy national laboratories, including the Thomas Jefferson National Accelerator Facility (JLab) and Fermi National Accelerator Laboratory (FNAL), are participating in this project.The 1.3-GHz cryomodules for this project consist of eight cavities produced by two vendors, Research Instruments GmbH in Germany (RI*) and Ettore Zanon S.p.a. in Italy (EZ*), using niobium cell material from Tokyo Denkai Co., Ltd. (TD) and Ningxia Orient Tantalum Industry Co., Ltd. (OTIC/NX).

The initial production cavities showed multiple deficiencies including manufacturing flaws from one

Presenter: PALCZEWSKI, Ari (Thomas Jefferson National Accelerator Facility)

Session Classification: Flux expulsion efficiency

Contribution ID: **27** Type: **not specified**

Status of flux trapping related activities at DESY

Thursday 8 November 2018 15:30 (10 minutes)

The present status of the measurements and analysis wrt. the residual static magnetic field in the vertical test cryostats and the used test inserts at DESY are presented. First commissiong tests to determine the flux expulsion of 120C electropolished cavities have been done. The more than 1200 vertical tests done on the European XFEL series cavity production gave no indication about a cavity performance dependency on the cool down rate.

Presenters: RESCHKE, Detlef (DESY); SCHAFFRAN, Joern (Deutsches Elektronen-Synchrotron (DE)); WENSKAT, Marc (Deutsches Elektronen-Synchrotron DESY)

Session Classification: Flux expulsion efficiency

Contribution ID: **28** Type: **not specified**

Discussion on 1.3 GHz experiments

Thursday 8 November 2018 15:40 (10 minutes)

Session Classification: Flux expulsion efficiency

Contribution ID: **29** Type: **not specified**

Angular dependency of flux expulsion

Thursday 8 November 2018 16:10 (10 minutes)

The absolute calibration of the AMR sensors used in our flux expulsion experiment will be presented. Furthermore the latest results obtained with the 3D magnetic field mapping system, investigating the flux expulsion efficiency of a 1.3 GHz TESLA-type single cell cavity will be discussed.

Presenter: KRAMER, Felix (HZB)

Session Classification: Flux expulsion efficiency

Contribution ID: **30** Type: **not specified**

How is trapped flux affected by the cavity geometry

Thursday 8 November 2018 16:20 (10 minutes)

Measurements of magnetic sensitivity to trapped flux on several type of cavity geometries have been performed at IPNO showing a clear geometrical effect. Magnetic sensitivity is dependent on the cavity geometry and on the residual magnetic field orientation. A presentation of experimental data will be done. These will be as well compared to the theoretical magnetic sensitivities calculated thanks to a simple Labview routine.

Presenter: LONGUEVERGNE, David (IPNO)

Session Classification: Flux expulsion efficiency

Contribution ID: **31** Type: **not specified**

Discussion on geometrical aspects

Thursday 8 November 2018 16:30 (10 minutes)

Session Classification: Flux expulsion efficiency

Contribution ID: **32** Type: **not specified**

Pinning studies for SC magnets and insights for SRF

Thursday 8 November 2018 16:40 (25 minutes)

This talk will provide a short review of the different pinning mechanisms that operate in useful superconductors. We will consider both high kappa superconducting materials used for high field magnets and low kappa materials used for SRF. We will visualise the different pinning processes that operate and discuss the theoretical descriptions for such processes. Finally we will identify the experimental measurements best suited for characterising pinning

Presenter: Prof. HAMPSHIRE, Damian (Durham University)

Session Classification: Flux expulsion efficiency

Contribution ID: **33** Type: **not specified**

General discussion on possible future experiments

Thursday 8 November 2018 17:05 (20 minutes)

Session Classification: Flux expulsion efficiency

Contribution ID: **34** Type: **not specified**

Introduction to the session

Friday 9 November 2018 09:00 (3 minutes)

Presenter: MIYAZAKI, Akira (University of Manchester (GB))

Session Classification: Sensitivity to trapped flux

Contribution ID: **35** Type: **not specified**

Trapped flux sensitivity studies as a function of: treatment, RF field and frequency

Friday 9 November 2018 09:03 (17 minutes)

The trapped flux surface resistance dependence on surface treatment, RF field and resonance frequency has been intensively studied at FNAL. The findings of this study are here presented, with a particular focus on the level of sensitivity at high fields given by the state-of-the-art high-gradient treatments such as 120C baking, N-infusion and modified 75-120C baking . Analyzing these results altogether with the variation of the BCS surface resistance component, it is possible to understand which treatment gives the highest Q-factor at a given RF field, frequency and amount of trapped flux

Presenter: MARTINELLO, Martina (Fermilab - IIT)

Session Classification: Sensitivity to trapped flux

Contribution ID: **36** Type: **not specified**

Overview of flux trapping at Cornell

Friday 9 November 2018 09:20 (17 minutes)

We report an overview of Cornell's measurements of residual resistance due to trapped flux in Nb3Sn and impurity-doped niobium in single-cell 1.3 GHz and 2.6 GHz TESLA-shape cavities

Presenter: MANISCALCO, James (Cornell University)

Session Classification: Sensitivity to trapped flux

Contribution ID: **37** Type: **not specified**

Sensitivity to trapped flux in high-purity large-grain niobium based on cavity measurements

Friday 9 November 2018 09:37 (17 minutes)

Surface resistance arising from trapped flux is experimentally measured, by which the sensitivity to trapped flux is derived. Measurements are carried out with single-cell L-band SRF cavities made of high-purity large-grain niobium materials, immersed in a uniform externally applied magnetic field generated by a solenoid whose axis overlaps the cavity axis. The surface resistance is found by using the standard technique for Q0 measurement and the customary G/Q0 analysis.Q0 values at a fixed low surface field are used. The trapped flux is found by measuring flux densities at a selected location using a single-axis fluxgate magnetometer attached to the cavity outer surface: Ba*[1-(Bsc-Bnc)/(Bscˆ(0)-Bnc)], where Ba is the applied external field, Bnc and Bsc is the local flux density measured just above and below Tc, respectively, during a field-cooling of the cavity whose Q0 is then measured, Bscˆ(0) is measured in a separate zero-field-cooling by keeping the cavity in the same location and turning on the identical applied field Ba at a temperature well below Tc . Several magnetometers are placed at various locations. It is found that the sensitivity to trapped flux in high-purity large-grain niobium to be 1.9 nOhm/microTesla on average. This is to be compared to 3-9 nOhm/microTesla in high purity fine-grain niobium and 10-50 nOhm/microTesla in nitrogen-doped high-purity niobium reported by other groups. We will discuss the measurement results as well as the measurement techniques.

Presenter: GENG, Rongli (Jefferson Lab)

Session Classification: Sensitivity to trapped flux

Contribution ID: **38** Type: **not specified**

Flux trapping investigation in superconducting samples via the quadrupole resonator

Friday 9 November 2018 09:54 (17 minutes)

Magnetic flux trapping has been demonstrated to be very detrimental for the performances of superconducting radio frequency (SRF) cavities for accelerators. How exactly the flux, trapped in pinning centers in the form of vortices, results in dissipation of the RF power is an interesting open question. Theoretical models have been proposed to explain the experimental observations. A possible discriminant between the different models is the dependence of the trapping sensitivity as a function of the RF frequency.
The quadrupole resonator (QPR) at CERN is a tool that allows for the measurement of the surface resistance of flat samples at different temperatures, peak magnetic fields at the sample surface and RF frequencies. This makes the QPR very appealing for fundamental studies on flux trapping. Indeed, frequency dependencies can be investigated on a single superconducting sample, with no need to change the object under test.
In this work, we present results of the surface resistance measured for both a bulk niobium and superconducting films on a copper sample in the presence of external magnetic field to enhance the trapping effect. The results are presented in comparison to the proposed models, with particular focusing on the frequency dependence.

Presenter: ARZEO, Marco (CERN)

Session Classification: Sensitivity to trapped flux

Contribution ID: **39** Type: **not specified**

Reports on sensitivity measurements at KEK

Friday 9 November 2018 10:11 (7 minutes)

"Sensitivity measurements have been performed for several kinds of surface treatment in SRF cavities. Experimental setup and results will be shown"

Presenter: UMEMORI, Kensei (KEK)

Session Classification: Sensitivity to trapped flux

Contribution ID: **40** Type: **not specified**

Optimization of High Temperature N2 Doping for Minimization of Sensitivity to Trapped Flux and Maximization of Quench Fields

Friday 9 November 2018 10:18 (12 minutes)

We will describe Fermilab experiments that focus on the optimization of doping parameters to achieve low sensitivity to magnetic flux while maintaining very high Q characteristic of nitrogen doped cavities and same or higher quench fields. One of the directions pursued is using lighter doping recipes which have been shown in the past to increase the mean free path of the resonator and decrease the sensitivity to magnetic flux; moreover, a correlation has been found between lighter doping and higher quench fields, while maintaining sufficiently low surface resistance. We will describe new progress obtained via new doping recipes, explored partially in the context of the LCLS-2 high energy upgrade

Presenter: BAFIA, Daniel (Fermi National Accelerator Laboratory)

Session Classification: Sensitivity to trapped flux

Contribution ID: **41** Type: **not specified**

Dissipation caused by oscillating vortices in the SRF cavities

Friday 9 November 2018 11:00 (25 minutes)

In this talk I discuss the RF dissipation of trapped vortices which contribute to the residual surface resistance in SRF cavities. In particular, the power caused by oscillations of flexible pinned vortex segments driven by a weak RF field, and the dependencies of the RF power on frequency, spatial distribution of pinning centers and purity of the material are considered. A brief overview of the vortex viscous drag is given, starting from the conventional Bardeen-Stephen model and its generalizations including the effect of the De-Gennes energy levels in the vortex core and the nonmagnetic impurity scattering. A nonlinear vortex viscosity at strong RF current drives, terminal velocities of vortices penetrating the cavities at the RF fields close to the superheating field, and the extent to which pinning can mitigate the RF vortex dissipation are discussed.

Presenter: GUREVICH, Alexander (Old Dominion University)

Session Classification: Sensitivity to trapped flux

Contribution ID: **42** Type: **not specified**

Trapped flux sensitivity in the low amplitude radio-frequency regime

Friday 9 November 2018 11:25 (17 minutes)

In this study, the radio-frequency complex response of trapped vortices in superconductors calculated for small values of applied radio-frequency field, will be presented. In agreement with experimental data on bulk niobium radio-frequency cavities, the calculated surface resistance shows a non-monotonic trend as a function of the mean-free-path and a sigmoidal-like trend as a function of the frequency. These two trends are shown to be generated by the interplay of two different dissipation regimes - pinning and flux-flow - which can be tuned either by acting on the material parameters (mean-free-path, pinning sites configuration, pinning strength, coherence length and penetration depth) or on the resonator frequency.

Presenter: Dr CHECCHIN, Mattia (FNAL)

Session Classification: Sensitivity to trapped flux

Contribution ID: **43** Type: **not specified**

A simple model for the RF field dependence of the trapped flux sensitivity based on a non-linear pinning force

Friday 9 November 2018 11:42 (17 minutes)

The improvement of the performance of RF superconducting cavities has recently motivated a considerable research effort to elucidate the effect of trapped magnetic flux on the surface resistance . In this paper we show that by introducing a non-linear pinning force in the Gittleman-Rosenblum equations for the RF power dissipation due to a trapped magnetic flux in a superconductor, we can properly describe the linear dependence of the additional surface resistance on the RF field amplitude . In particular, we also show that the proportionality between the RF-field dependent and independent parts and , and the frequency dependence of follow naturally from this approach

Presenter: VAGLIO, Ruggero (1950)

Session Classification: Sensitivity to trapped flux

Contribution ID: **44** Type: **not specified**

Vortex dynamics and hysteretic flux losses due to pinning

Friday 9 November 2018 11:59 (17 minutes)

In this talk, I will explain the hysteretic mechanisms that are responsible for field-dependent residual losses of SRF cavities due to the motion of isolated trapped vortex lines under the action of parallel oscillating fields at the surface. By invoking collective weak pinning theory in the context of the Bardeen-Stephen model of vortex dynamics, I will present simple estimates, approximate analytical calculations, and numerical simulations that compare well with cavity tests performed in CERN and Cornell. Our simple formulas describing power losses and crossover behavior can be used to guide the tuning of material parameters to optimize cavity performance.

Presenter: LIARTE, Danilo (Cornell University)

Session Classification: Sensitivity to trapped flux

Contribution ID: **45** Type: **not specified**

Discussion

Friday 9 November 2018 12:16 (14 minutes)

Session Classification: Sensitivity to trapped flux

Contribution ID: **46** Type: **not specified**

Discussion

Thursday 8 November 2018 12:20 (10 minutes)

Session Classification: Flux expulsion efficiency

Contribution ID: **47** Type: **not specified**

Welcome & logistics

Thursday 8 November 2018 08:45 (15 minutes)

Presenter: GERIGK, Frank (CERN)

Session Classification: Welcome, Registration and Introduction

Contribution ID: **48** Type: **not specified**

Wrap-up : Magnetic shielding

Friday 9 November 2018 14:00 (20 minutes)

Presenters: MASUZAWA, Mika (KEK); CHANDRASEKARAN, Saravan (FNAL)

Session Classification: Summary & discussion

Contribution ID: **49** Type: **not specified**

Wrap-up : flux expulsion efficiency

Presenters: LONGUEVERGNE, David (IPNO); KOESZEGI, Julia (HZB); UMEMORI, Kensei (KEK)

Session Classification: Summary & discussion

Contribution ID: **50** Type: **not specified**

Wrap-up :sensitivity to trapped flux

Friday 9 November 2018 14:40 (20 minutes)

Presenters: MIYAZAKI, Akira (University of Manchester (GB)); CHECCHIN, Mattia (FNAL)

Session Classification: Summary & discussion

Contribution ID: **51** Type: **not specified**

Wrap up: expulsion efficiency

Friday 9 November 2018 14:20 (20 minutes)

Presenters: LONGUEVERGNE, David (IPNO); KOESZEGI, Julia (HZB); UMEMORI, Kensei (KEK)

Session Classification: Summary & discussion