Welcome to SRF2023 Tutorial

K. Saito, SRF2023 Chair

22 June 2023

MICHIGAN STATE UNIVERSITY

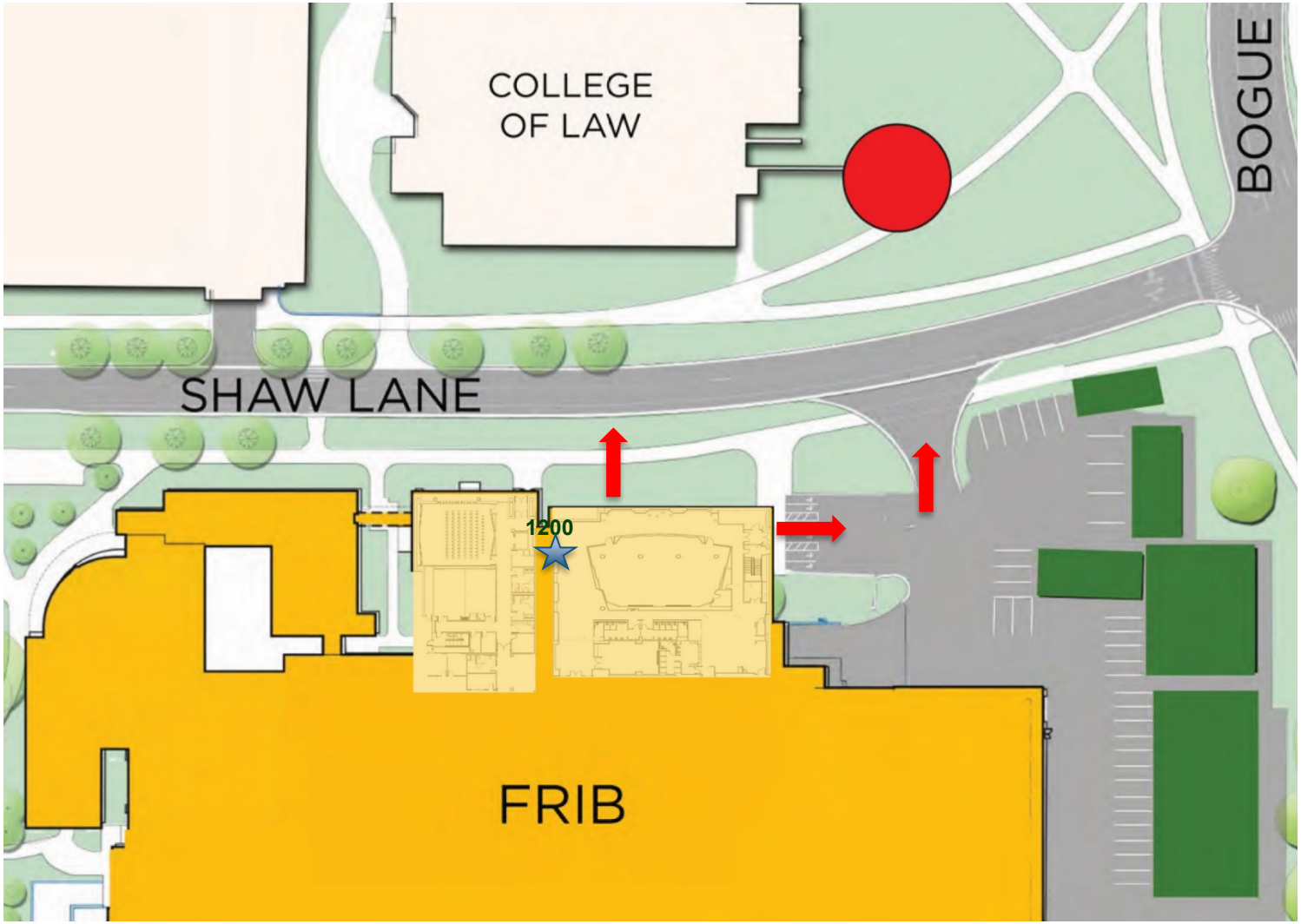
U.S. DEPARTMENT OF ENERGY | Office of Science

This material is based upon work supported by the U.S. Department of Energy Office of Science under Cooperative Agreement DE-SC0000661, the State of Michigan and Michigan State University. Michigan State University designs and establishes FRIB as a DOE Office of Science National User Facility in support of the mission of the Office of Nuclear Physics.

Outline

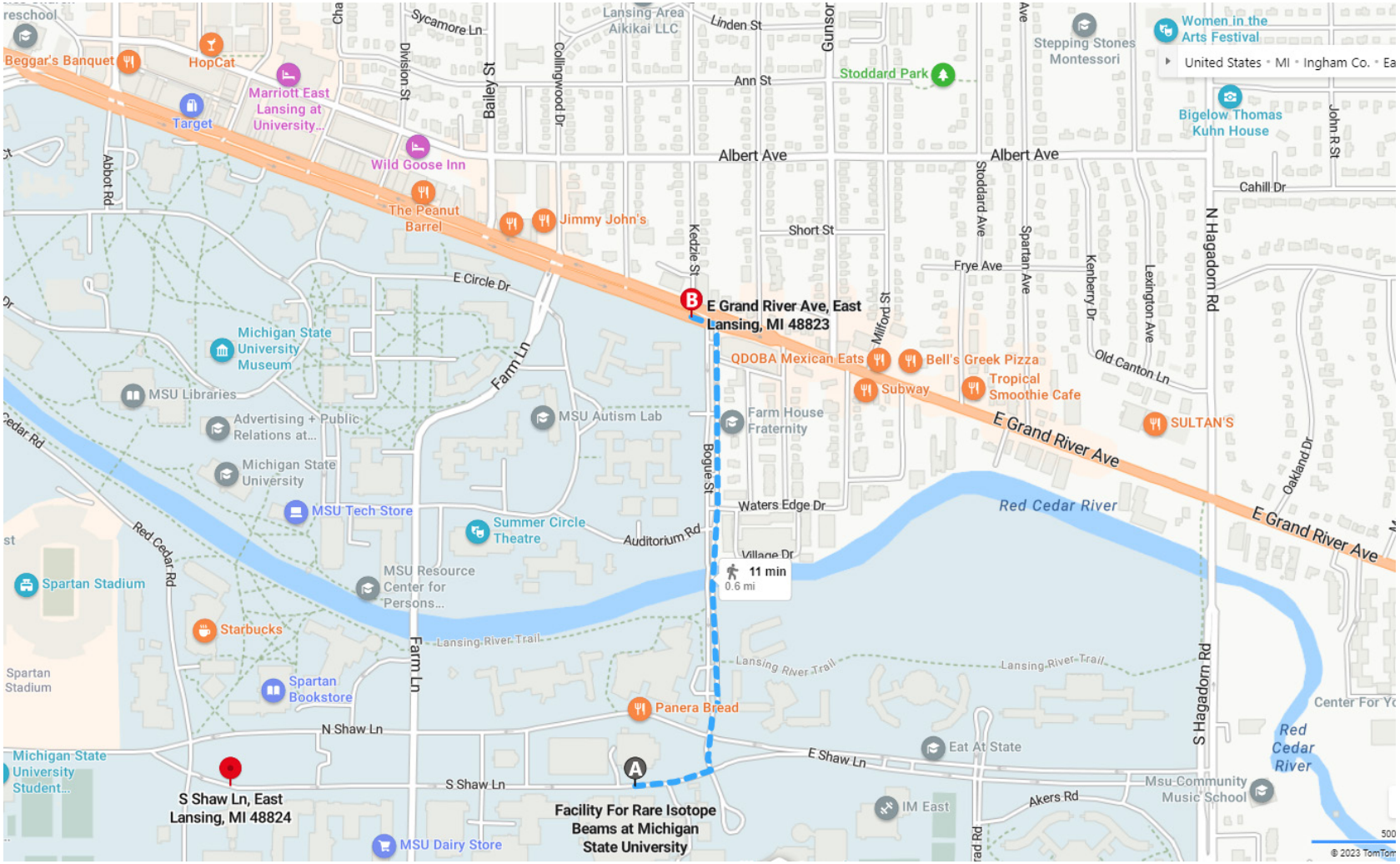
- Welcome to MSU Campus
  - Emergency evacuation
  - Lunch/ Dinner place
  - Internet connection
  - Information of bus transportation to Grand Rapids on Sunday
- Purpose of SRF23 Tutorial
- Very Brief Overview of SRF2023 Tutorial
- Theme of SRF2023 Conference

Emergency Evacuation



Nearest Lunch Place

Nearest Lunch Location Shaw Hall



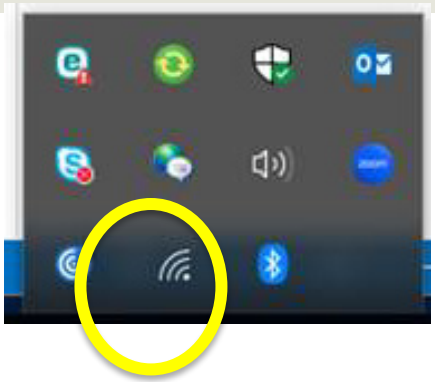
Map of good restaurants (and other local stuff)

local places to eat and campus landmarks

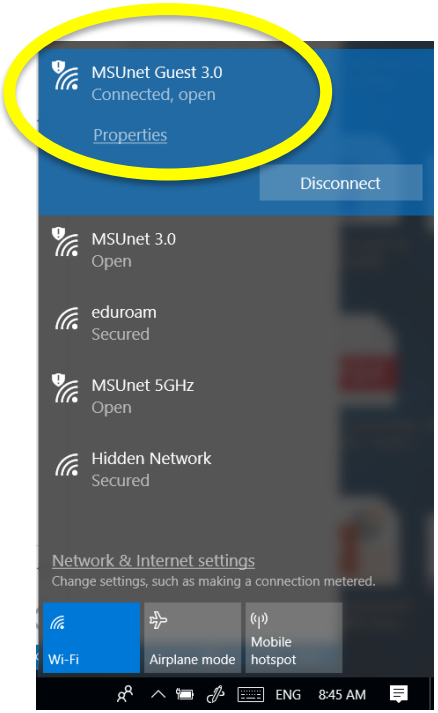
We are here

MSU Internet Connection

Open your WIFI search function on your PC

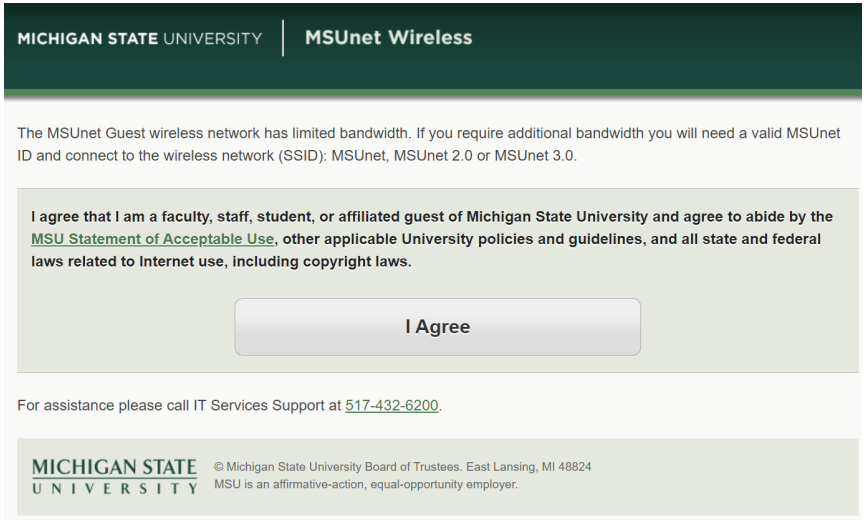


Then, you will see the
WIFI selection in MSU



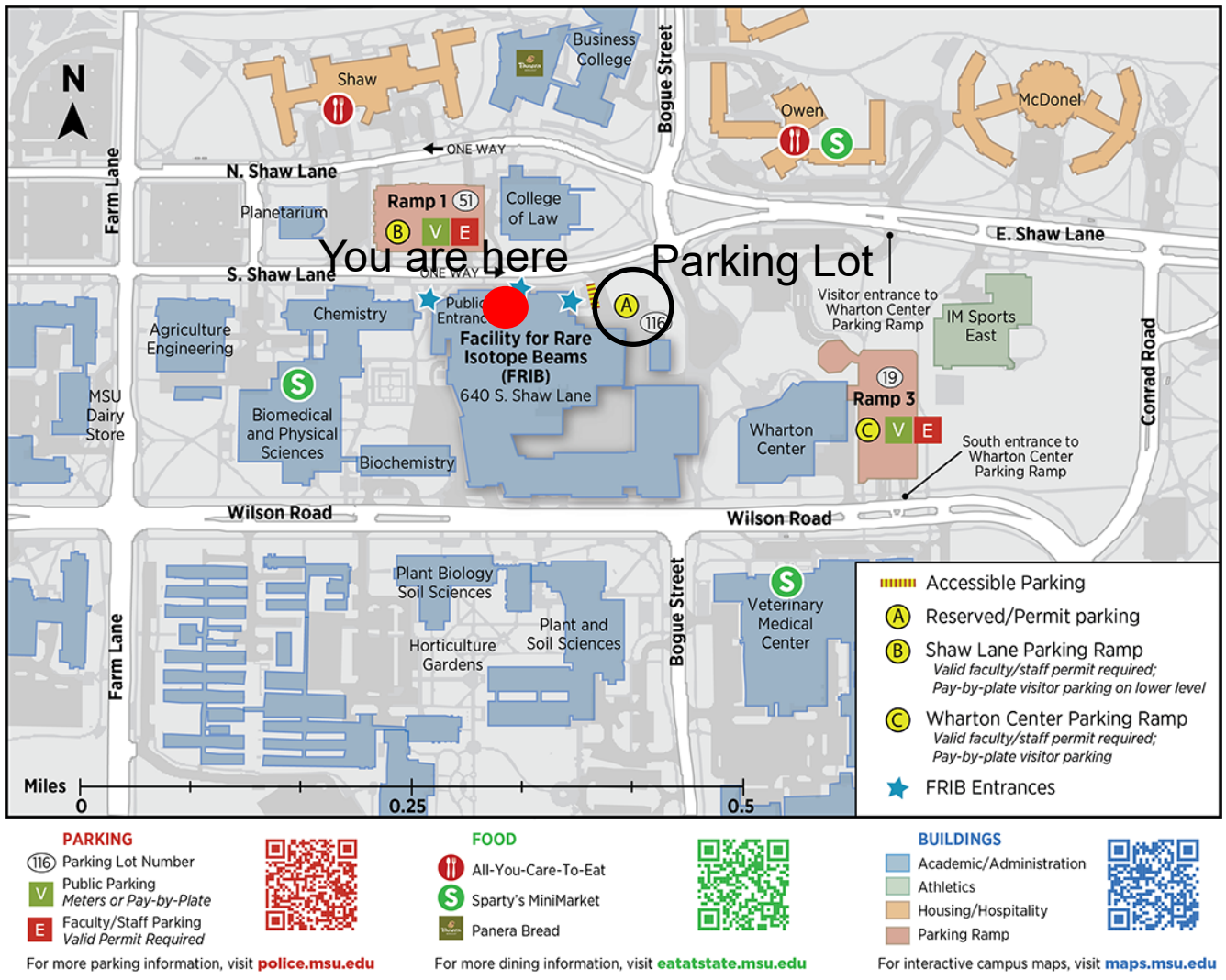
Select “MSUnet Gust 3.0

Click I Agree



Bus transportation Service to Grand Rapids on Sunday

The bus will arrive at 11:15 am on Sunday. We will meet in the parking lot at 11:30.



Purpose of the Tutorial

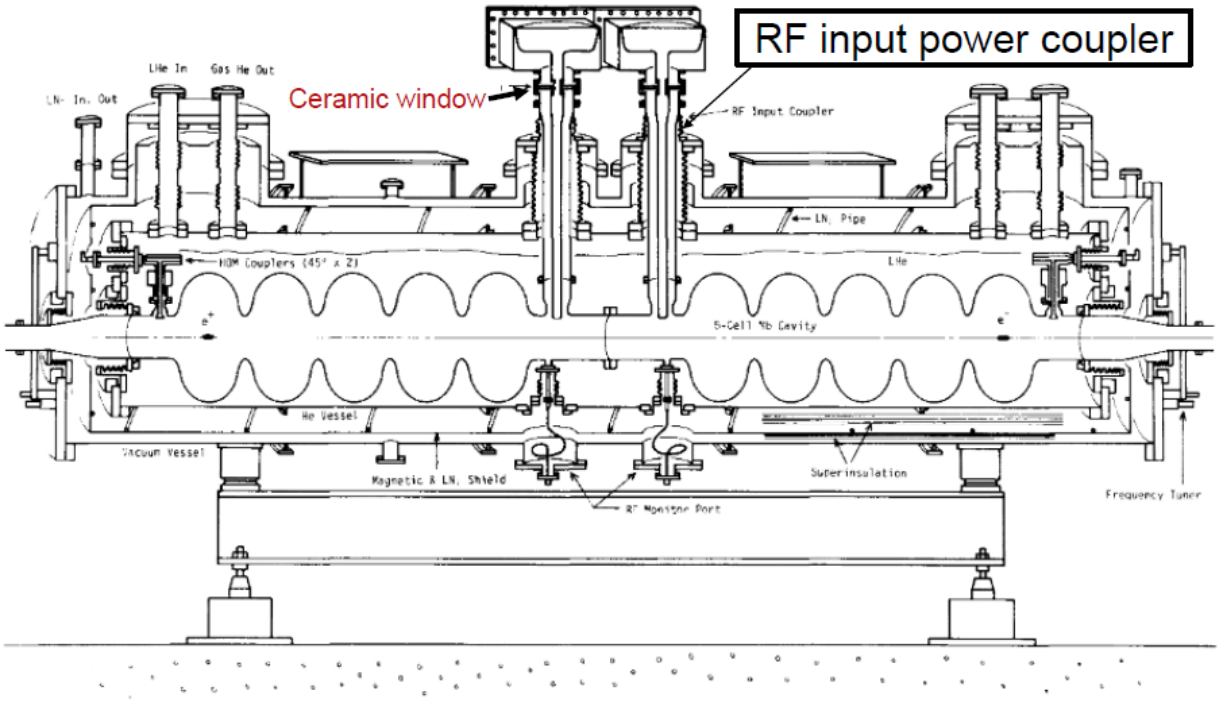
- SRF conference tutorial is traditional event.
- SRF2023 tutorial is intended to give foundational knowledge to young researchers, engineers, and students who are interested in Superconducting Radio Frequency (SRF).
- 12 topics will be lectured by excellent tutors. Each topics is 90min including question and answer.
- In future, these younger researcher will select a specific field(s) in the SRF. This tutorial will give a good opportunity for participants to see the overall topics in SRF. It will be very important for young generation to start the job.

Very Brief Overview of SRF2023 Tutorial

Composition of SRF Cryomodule

- Cavities
- RF couplers
- HOM couplers or HOM damper
- RF pickup cabled
- Tuner
- LHe tank or Jacket
- Thermal Shield
- Magnetic shield, global or local
- Vacuum changer
- Liquid Helium 4.3K or 2K
- LHe distribution system

SRF Cryomodule
KEK TRISTAN Cryomodule (4.5 K operation)



National Science Foundation
Michigan State University

NSCL Spring lecture on Mar 21, 2017
Saito - Slide 4

Very Brief Overview of Tutorial Topics
Topic 1

- SRF is an application of microwave to superconductors, which mainly intends to accelerate charged particles.
- SRF is something different from DC superconductivity application, superconducting magnets (no electric resistance): surface resistance occurs in SRF, very small but can't ignore.

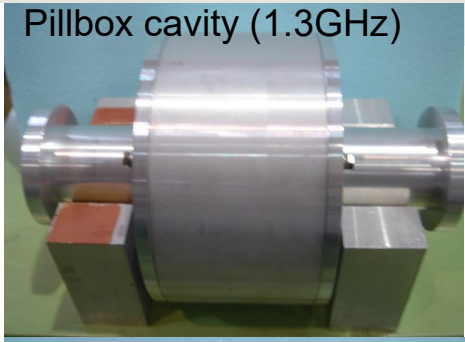
This phenomenon largely dominates SRF !

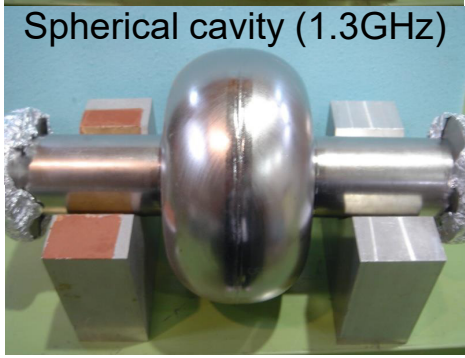
- **Topic 1**: SRF fundamental/Nb material, will explain fundamentals of superconductivity and why surface resistance in SRF.

- Current SRF cavities are mostly produced by high purity Niobium material (Nb).
  - **Topic 1** will show the superconducting properties of Nb and explain why Nb is best, so far.

Very Brief Overview of Tutorial
2nd/3rd Topics

- **Needs SRF cavity design** to fabricate SRF cavities.
  - Feature of SRF: use standing wave.
  - Most basic cavity is Pillbox cavity analytically designed by Maxwell equations, but mostly elliptical shaped cavities are commonly used. Behind of this, multipacting issue exists.
  - **Topic 2** will introduce the cavity design method using computer cords, and explain why elliptical/spherical shape is used.
  - **Topic 2** also will show the guideline od the SRF cavity design, for instance Ep/Eacc, Bp/Eacc, and etc..





Need to fabricate cavities, and make clean SRF surface to reach high performance

- **Topic 3** will show how to make cavity. Important technologies are forming, and electron beam welding.
- **Topic 3** also will introduce surface preparation to remove the surface defect layer, and make particle-free clean SRF surface. Important technologies are buffered chemical polishing (BCP), electropolishing (EP), hydrogen degassing, ultrapure water, and high pressure rinsing.
- **Topic 3** also will introduce clean cavity assembly in class 10-100 cleanroom.

Very Brief Overview of Tutorial
4th/5th Topics

- **SRF cavity needs to cooldown by liquid helium.**
  - **Topic 4** will explain how to produce liquid helium
  - MSU has a good student program for this, to cryogenics initiative.

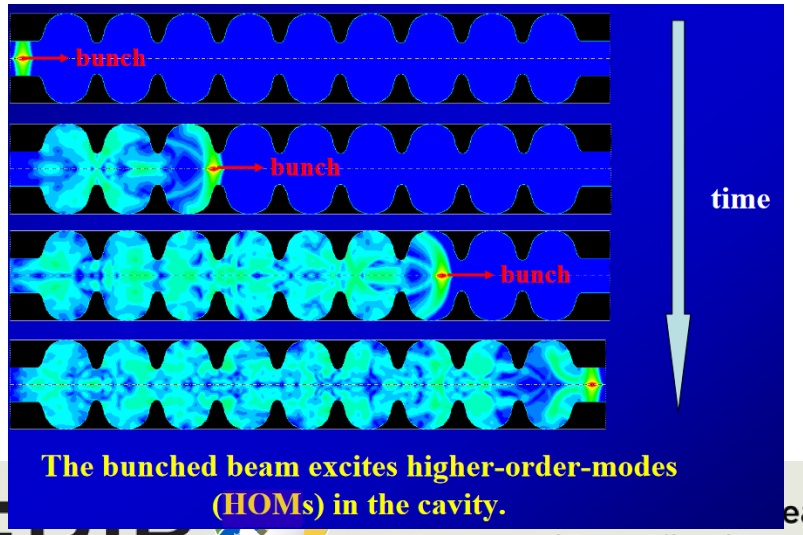
- **Need to measure the cavity performance at cryogenic temperature**
  - **Topic 5** will explain how to measure the SRF cavity performance at cryogenic temperature.
    - » Feature of SRF cavity: very high Q ~ 10^8-10^{11}

      Can't use the normal conducting method Q = $\frac{f_0}{2\Delta f_0}$, Df_0 = 0.13 Hz when f_0 = 1300 MHz, and Q0=10^{10}.
    - » Use pulse method to measure decay time of the stored energy
    - » Cavity frequency is very sensitive ambient vibration, use PLL control, RF source frequency follows to the cavity frequency.
  - **Topic 5 will** introduce the phenomena limit the SRF cavity performance, and diagnostics.

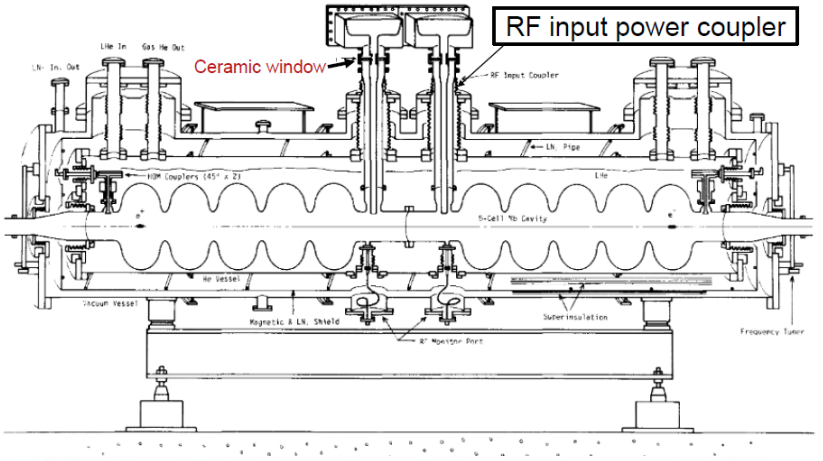
Very Brief Overview of Tutorial
6th/7th Topics

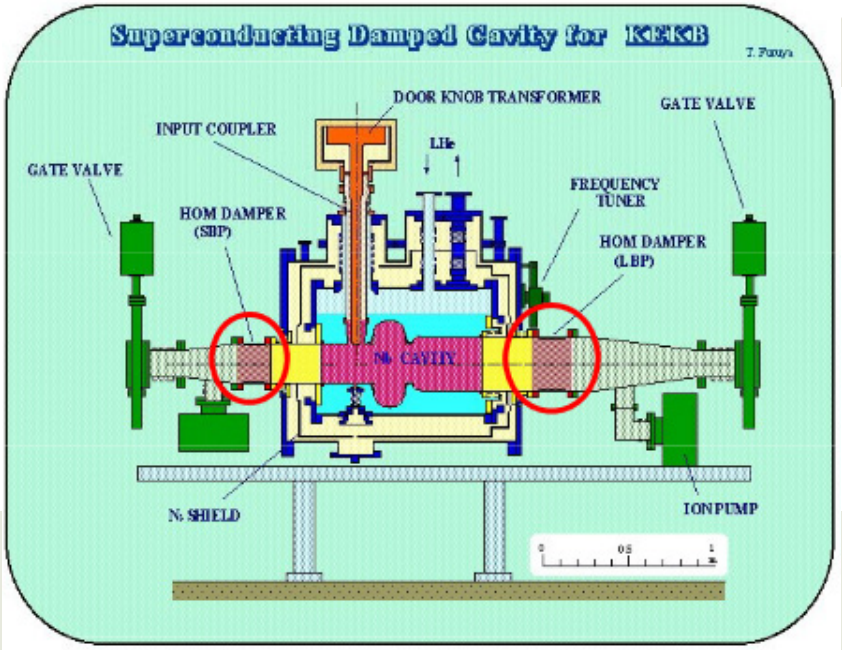
- **Needs RF power coupler to feed microwave power into SRF cavity.**
  - **Topic 6** will introduce design of RF power couplers, fabrication, and issues

- **Cavity-beam interaction produces higher modes which kick the particle came after, Need to extract or damp these HOMs.**
  - **Topic 7** will lecture how to HOMs are produced, how to extract or damp them



SRF Cryomodule
KEK TRISTAN Cryomodule (4.5 K operation)





Very Brief Overview of Tutorial
8th/9th Topics

- **In real SRF machine needs to control the cavity: RF control**
  - **Topic 8** will lecture overviews LLRF's fundamental and practical aspect for SRF cavities.
    - » The cavity frequency should be kept the accelerator frequency.
    - » Cavity frequency is controlled by mechanical tuner, which is different from vertical cavity testing (no tuner, AF source follows cavity frequency).
    - » Coupled RF control is feedback RF power level, RF phase. Much more sensitive compared with normal conducting cavity control.

- **To build cryomodule, cryomodule design, fabrication, and assembly need.**

  Topic 9 provide the basic for cryomodule design, fabrication, and assembly

Very Brief Overview of Tutorial
10th/11th and 12th Topics

- **When completed cryomodule assembly, the cryomodule need bunker test, then installed on the accelerator beam line, and beam operated.**
  - Topic 10 will review measurement of cryomodule test in the bunker prior to install the
  - Topic 10 will also introduce the beam operation in the machine.

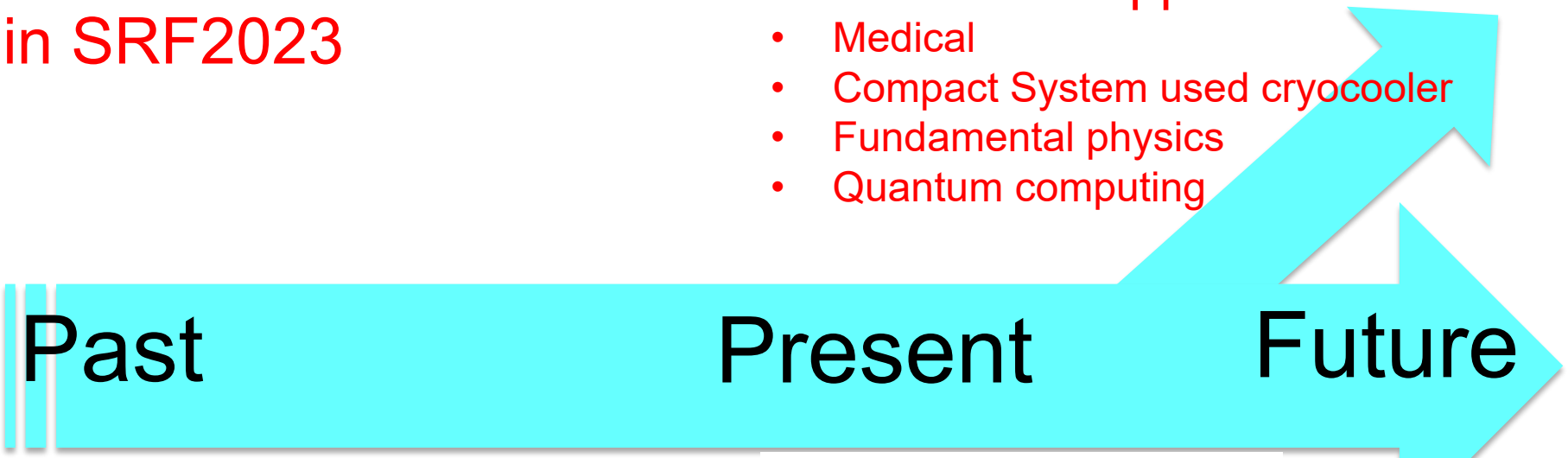
- **SRF community is developing very simple SRF system for future SRF application**
  - Topic 11 will introduce a 4.3K cryomodule system using Nb3Sn cavity, conduction cooling.
- **SRF community is looking for beyond Nb bulk cavity**
  - Nb bulk cavity high gradient performance will be limited 60MV/m.
  - Topic 12 will introduce R&D status of film, multilayer cavity R&D.

Theme of SRF2023

Past, Present, and Future of SRF Worldwide

Red: Presentation in SRF2023

SRF Future Applications
- Medical
- Compact System used cryocooler
- Fundamental physics
- Quantum computing



1963-1980
Stanford era

1980-2010
Electron/heavy ion accelerators

2010-present
XFELs,
Proton/heavy ion linacs

~ 2030
EIC

~ 2035
ILC,
CEPC,
FCC

Past: Stanford Era

Stanford Era

- Commemorative event: Tuesday evening 18:00-20:00
  - » 60-year anniversary celebration for the first SRF paper by P. B Wilson, Stanford University
  - » Drs. Schwettman (in-person), Todd (in-person), and Turneare (Zoom) will talk about the pioneering work at Stanford University
  - » Good for young generation
  - » Enjoy very exciting early developments
  - » Respect the foundational work done in the early era

Facility Session

- Commissioning of the large electron/heavy ion SRF linacs
  - FRIB, RISP, MINERVA, SRILA: heavy ions
  - LCLS-II: electrons
- Ongoing Projects: ESS, PIP-II, LCLS-II-HE, SHINE,…
- Upgrade Projects: SNS 2.8 MW power upgrade, FLASH upgrade, FRIB energy upgrade….
- Operational experience with large-scale SRF accelerators
  - CEBAF, FLASH, Euro XFEL, SuperKEKB (3A heavily loaded electron-positron ring collider) ……
- Future Projects: EIC, Shenzhen FEL, ILC ~ 2035 or later

Fundamental R&D Session

- Fundamental R&D session provides exciting reports continuing from previous conferences
  - N/O doping technologies to push up Q_0
  - Theories and experiments to understand the physics of "anti-Q_0 slope" behavior with doped cavities
  - Dynamics of flux trapping
  - Nb_3Sn cavities for high Q_0 operation at ~ 4K
  - Thin-film technologies beyond Nb bulk materials
  - Others

SRF Technology Session

- Practical realization of mid-*T* baked cavities
- Plasma in-situ cleaning
- Crab cavities
- Spoke cavities
- Harmonic cavities
- SRF photo-injectors
- Conduction cooling for future compact SRF machines
- Others

SRF Application Session

- Achievement of ILC milestone
- SRF thin-film technology
- Industrial activities: Niowave, RadiaBeam
- Application of cryocooler and development of powerful cryocooler at SHI
- SRF cavity applications: dark matter searches, gravitational wave detection, quantum computing

ILC

- Keynote: “Current status and future technological collaboration for the ILC” by Shinichiro MICHZOMO, Director of ILC promoting office at KEK
- SRF Technology: Achievement of ILC milestone, talk in the SRF applications session

Please enjoy SRF2023 Tutorial

and

the Conference

The End

Bus transportation to Grand Rapids Tomorrow

- Please sign in on the front desk for bus transportation to Grand Rapids Tomorrow
- Tow Bus will come at 11:00 am, the parking Lot nearby this building.
- Don't miss the bus.