Is there a need for a 'European Infrastructure for R&D and Test of SRF cavities and cryomodules?

Wolfgang Weingarten - CERN

first ACCNET meeting: 04.12.2008

ACCNET
Accelerator Science Networks

Coordination & Communication

coordinated by
Walter Scandale, CERN ; Alessandro Variola, LAL
Frank Zimmermann, CERN (from Nov. 2009)

EUROLUMI

accelerators & colliders performance

coordinated by
Frank Zimmermann, CERN
Ezio Todesco, CERN

RFTECH

sc & nc rf technologies

coordinated by
Jean-Marie de Conto, UJF
Mariusz Grecki, DESY (&TUL)
Wolfgang Weingarten, CERN

RFTech goals

- The goals of RFTech are to provide a network for information exchange and close collaboration between the European, and worldwide, experts on accelerator RF systems. The scientific objectives are the improvements of RF cavity design, superconducting RF (**equipment for R&D and test of cavities and cryomodules**), low-level and high-power RF systems, and costing tools.
- http://accnet.lal.in2p3.fr/Tasks/Rftech/

Objective: Define a strategy for SRF test infrastructures

i.e. the **main objective** of the "SRF sub-task" consists in intensifying a collaborative effort between European accelerator labs with the aim of planning and later providing for European accelerator users a multi-purpose state-of-the art network of equipment for R&D and test of SRF cavities and cryo-modules within 2 years, to be presented to the funding agencies

What commitment did we take?

EuCARD Deliverable

https://edms.cern.ch/nav/CERN-0000077769/CERN-0000077787

EDMS No. D4.3.2:

Strategy/result for SRF test infrastructures

Due delivery month 24 (March 2011)

What do we learn from the past?

1^{st} lesson

- The SRF community is relatively small and well known to each other. If need is, arrangements are taken between labs with focus on a specific project of mutual interest:
  - Examples:
    - CERN profited from students from University labs (e.g. Darmstadt with the S-DALINAC)
    - The first beam test of a CERN made sc cavity was done at DESY 1982/3 (going to equip the HERA e-ring with SRF cavities)
    - The SPL study is associated with European and overseas partners (e.g. CNRS, CEA, BNL, TRIUMF, TEMF Darmstadt, Rostock University, RHU London, possibly ESS Lund, …)

2nd lesson

- The SRF community is well integrated in supra-national integrative attempts (partly providing resources):

Example: Crosslinks to other institutes via …

- CERN consortia
  - SPL collaboration: CEA, CNRS, TRIUMF, BNL, German Universities, RHU London, …
- FP7 consortia
  - EuCARD (mainly Work Package 10: Superconducting RF technology for proton accelerators and electron linear accelerators);https://eucard.web.cern.ch/EuCARD/
  - SLHC-PP

    http://info-slhc-pp.web.cern.ch/info-SLHC-PP/

    ILC-HiGrade

    http://www.ilc-higrade.eu/
  - Institutes from not retained SRF Infrastructure proposal: BESSY (D), …
- National Consortia
  - Physics at the Terascale Initiative (D)

    http://www.terascale.de/
  - BMBF (D) Initiative (22 Oct 2008): TEMF Darmstadt, Uni Rostock, TUD, BUW, …

    http://www.bmbf.de/foerderungen/13099.php

Other International Activities

- TESLA Technology Collaboration Meetings

  http://tesla-new.desy.de/

Example

in statu nascendi

- An attempt was initiated to re-group European accelerator infrastructures: **TIARA**
- The main objective of **TIARA** (Test Infrastructure and Accelerator Research Area) is the integration of national and international accelerator R&D infrastructures into ***a single distributed European accelerator R&D facility***.

  http://www.eu-tiara.eu/

3rd lesson

- Universities played an important role for scientific innovations
- Large scale applications in technology and engineering mostly done in research centers
- Reproducibility mostly achieved in close interaction between industry and research centers

Important innovations in SRF 1/3

Apologies for possible personal bias

Innovation	Year	Laboratory	Type of work
Computer programs for e-m fields (LALA, SUPERFISH, MAFIA)	1966 - 1977	Los Alamos Nat. Lab./Darmstadt University	R&D for accelerator
UHV firing of Nb cavities	1968	Stanford University	R&D for sc accelerator
Electropolishing of cavities	1971	Siemens Erlangen Research Lab	R&D for sc accelerator
Field emission (Cure by Helium processing)	1974	Stanford University	R&D for sc accelerator
Numerical analysis of Mattis-Bardeen integrals	1974	Karlsruhe University /Research Centre	R&D for sc p-accelerator/separator
Nb_3Sn coating of cavities	1975	Bonn University Siemens Erlangen Research Lab	Diploma thesis R&D for sc accelerators
2nd sound diagnostics	1977	Argonne Nat. Lab.	R&D for sc heavy ion accelerator ATLAS
Operation with permanently installed sc cavity	1977 ff.	Stanford University/ Illinois University/Darmstadt University	R&D for sc accelerator /MUSL accelerator/S-Dalinac

Important innovations in SRF 2/3

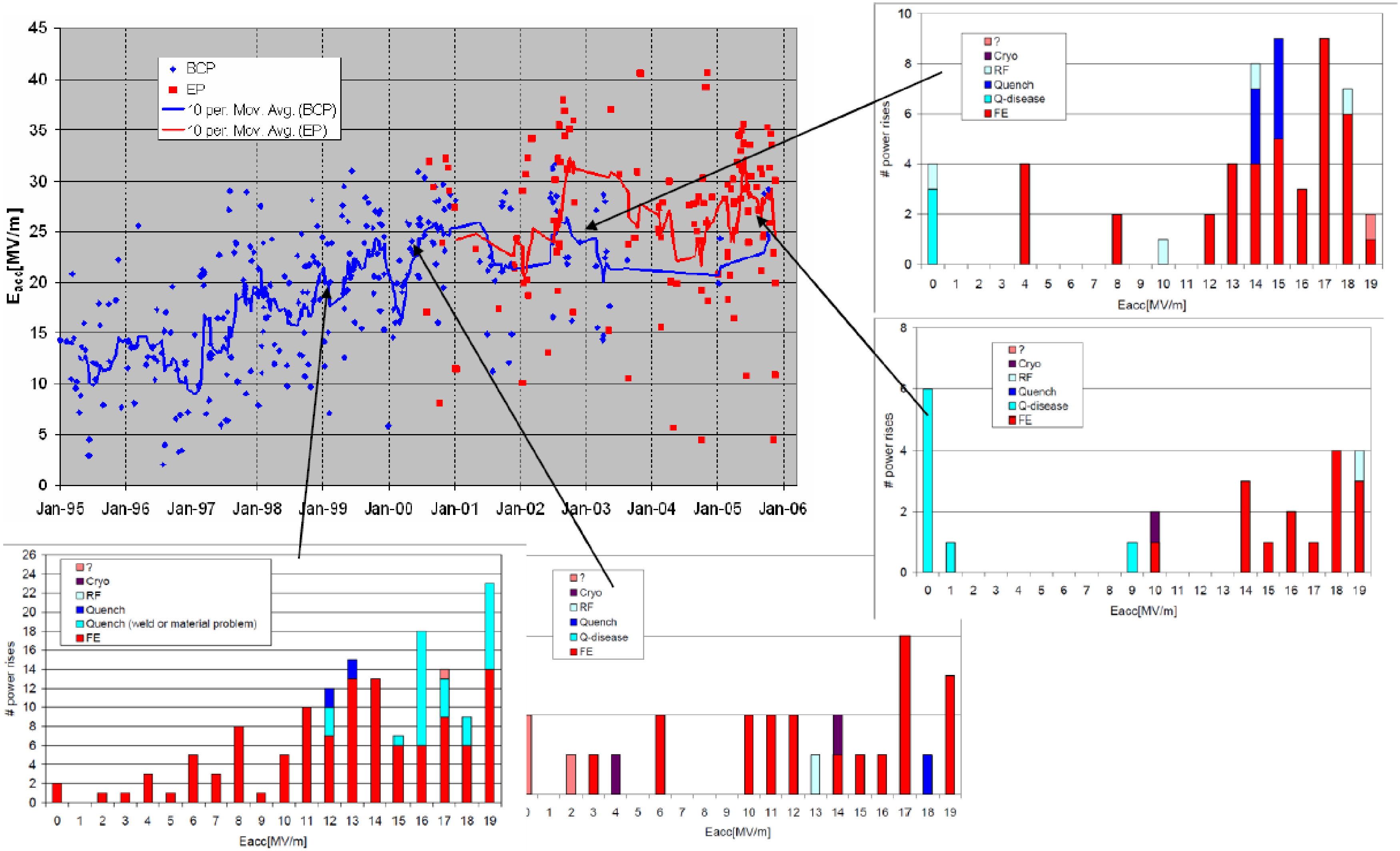
Innovation	Year	Laboratory	Type of work
Multipacting (analysis, cures)	1977/8	Stanford University/Wuppertal University	R&D for sc accelerator
Temperature mapping diagnostics	1980	CERN/ Wuppertal University	R&D for LEP200
Thermal conductivity (cure against quench)	1980	Cornell University	R&D for sc storage ring
High power RF processing	1984-94	SLAC/ Cornell University	R&D
Nb on Cu coating	1984	CERN	R&D for LEP200
Dust particles as field emitters in RF	1984	CERN	R&D for LEP200
Ultra-Clean water (cure against field emission)	~1985	KEK	R&D for TRISTAN
DC Identification of field emitters	1986	Geneva University	R&D for LEP200
Seamless multi-cell cavities (Nb)	1987 -2003	Cornell University, DESY, INFN Legnaro	R&D for TESLA/FLASH/XFEL

Important innovations in SRF 3/3

Innovation	Year	Laboratory	Type of work
TRISTAN SC system in operation	1988	KEK	Technology & Engineering
Seamless multicell cavities (Cu)	1989	CERN	R&D for LEP200
High pressure water rinsing (cure against field emission)	1991	CERN	R&D for LEP200
Demountable HOM hook type beam tube coupler	1991	CERN/CEA-Saclay	R&D for LEP200
HERA SC system in operation	1992	DESY	Technology & Engineering
CEBAF SC system in operation	1995	JLAB	Technology & Engineering
LEP200 SC system in operation	1998	CERN	Technology & Engineering
Max. RF field near theoretical limit	2007	Cornell University/ KEK	R&D for ILC
LHC SC system in operation	2008	CERN	Technology & Engineering

Performance History

DESY cavity experience



L. Lijie's summary of DESY cavity databank, DESY, 2006

4^{th} lesson

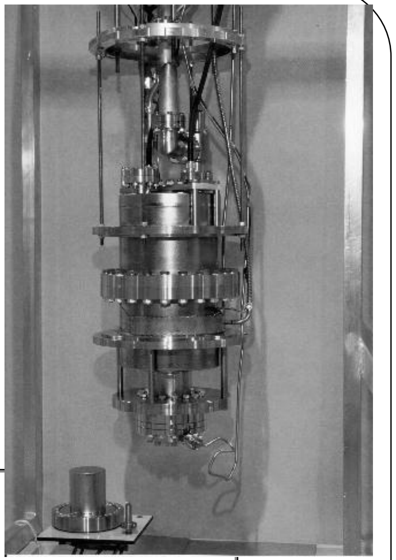
- The Nb technology touches its (predicted) theoretical limits; however issues such as reproducibility of high gradient performance and cost reduction issues are still challenging.
- About four decades R&D efforts passed up till obtaining the theoretical limit of the Nb SRF technology - more years are ahead up till obtaining reproducible results
- The innovation most promising in the future consists in (classical) high T_c supercondctors, such as Nb_3Sn
  - they would allow larger acc. gradients (thanks to their larger thermodynamic critical field B_C) and would also allow operation at 4.2 K instead of 2 K (for $f \geq 700$ MHz)

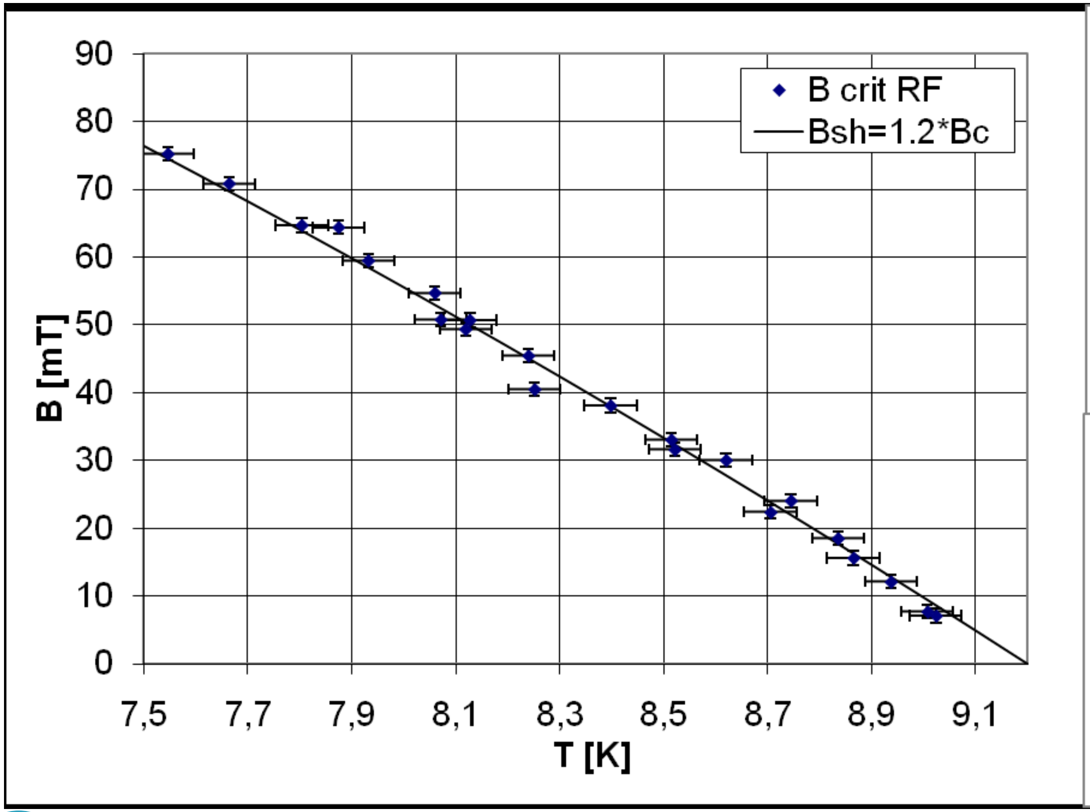
Nb is approaching the theoretical predicted limit 1/2

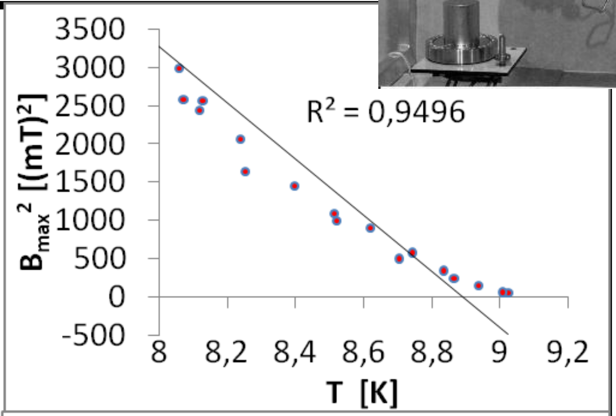
$$B_{crit}^{RF} = B_{sh} = 1.2\ B_c$$

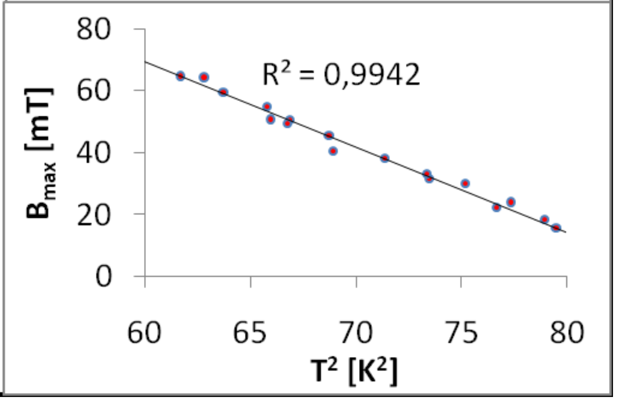
Plots Courtesy T. Junginger / CERN

Quadrupole resonator/ CERN









Nb is approaching the theoretical predicted limit 2/2

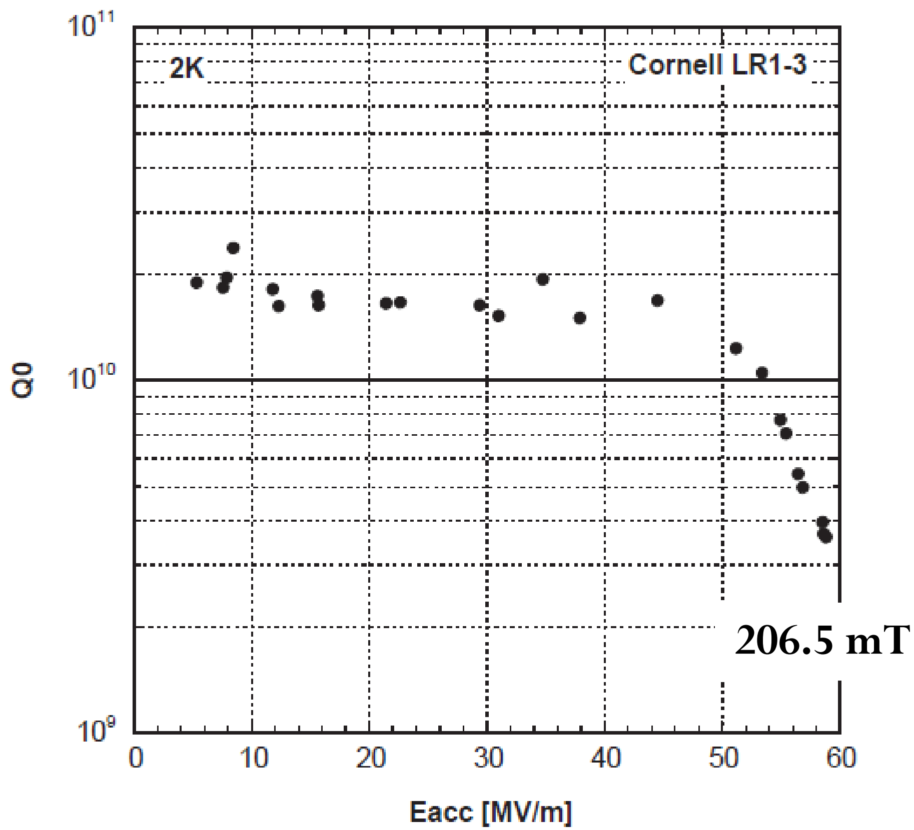


Figure 3: $Q(E_{acc})$ of the 60 mm aperture single-cell cavity LR1-3.

$B_{crit}^{RF} = B_{sh} = 1.2\ B_c = 230$ mT @ 1.8 K

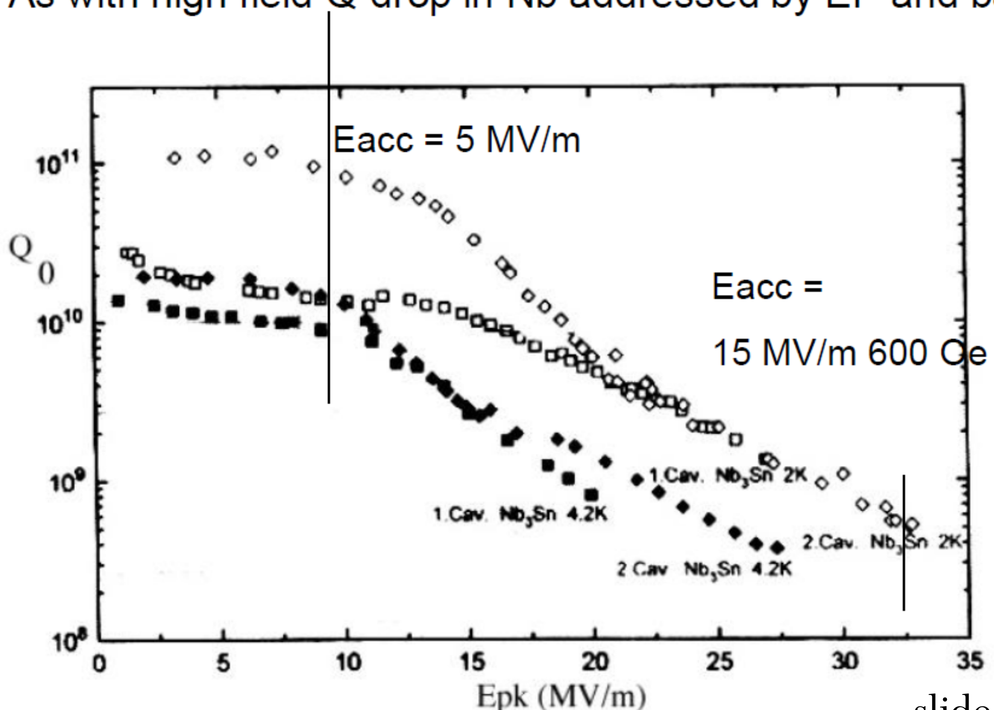
Figure 1: Left: 60 mm aperture re-entrant cavity; Right: 70 mm aperture TESLA cavity.

Cornell - KEK collaboration

Nb_3Sn thin film coating

Best CW Result for Single Cell Nb3Sn Cavity 1300 MHz (Mueller and Kneisel)

- Q-slope observed in CW measurements may be addressed by improved material preparation
- As with high field Q-drop in Nb addressed by EP and baking.



Since the BCS surface resistance is approximately

$$R_s(T_c, f, T) = a \cdot f^{1.7} \cdot e^{-1.8\frac{T_c}{T}} / T$$

Nb_3Sn thin films, with their larger T_c = 18 K, and their larger B_c = 540 mT compared to Nb, allow the perspective of operation at 4.5 K and larger gradients than for Nb for planned linear colliders, proton drivers, ERLs and crab cavities with f ≥ 600 -700 MHz.

slide taken from H. Padamsee's tutorial SRF2009, Dresden, Berlin

Conclusion on lessons learnt

- The SRF community is relatively small and well known to each other.
- The SRF community is well integrated in supra-national integrative attempts
- Mutual interaction of universities and research centers lays the ground for technological and scientific success
- Niobium technology is approaching the predicted theoretical limit: In view of the long development time, alternatives such as the classical high T_c superconductors should be picked up

  NOW

  to obtain larger gradients and more economic operation (4.5 K)

Information from EuCARD coordinator:

Next SRF relevant call from EU-FP7 program due end of 2011!

Spare slides

Procedural method

very similar as for the preparation for EuCARD during 2007/8 (European SRF Infrastructure proposal)?

1. Identify and contact labs with SRF activities; compile **existing equipment**, its availability, **cost for refurbishment**, if needed
2. Identify in **future projects** making use of SRF, their host lab, timescale and specificities (operating frequency, gradient, Q-value, temperature, beam structure and current, ancillaries such as power and HOM coupler, tuner, cryostat,…)
3. Define for each future project the **required equipment** for R&D and tests
4. By comparing 2 and 3, identify **missing equipment**, for each project, both in **host and collaborating labs**, and figure out the **costs for acquisition**
5. Prepare a **project description** including required resources to be provided to funding agency after 2 years
6. **Coordinate SRF test activities**, if needed, already during the preparation phase

What was done during the preparation for EuCARD in 2007/8 (European SRF Infrastructure proposal)?

Available equipment at different labs

Laboratory	Equipment
BESSY	HoBiCaT test facility for high and low power operation of fully equipped cavity systems at 1.8-2.2 K Cavity tests at 1300 MHz Coupler tests at 1300 MHz
BUW	Field emission scanning of samples
CERN (central infrastructure)	Vertical tests of different sizes of SRF cavities between 4.5 and 2.0 K Assembly and horizontal tests of fully equipped cryo-modules at 352/400/704 or 1300 MHz between 4.5 K and 2.0 K Annealing and heat treatment in different UHV furnaces Coating with niobium of different sizes of RF cavities made of copper RF characterization of samples (surface resistance vs. RF magnetic field)
CI	Sample tests (XPS/SEM, RF tests)
DESY	XFEL infrastructure and TESLA TEST FACILITY
INFN Roma	Coating techniques of niobium on copper alternative to sputtering
IPJ	Experimental facilities for UHV arc deposition of pure Nb and Pb layers
SUPRATECH	88, 352, 704, 1300 MHz power coupler tests Vertical tests of SRF cavities of different size Horizontal cryostat for high power RF tests at 2.0 K (CryHoLab) Electro-polishing of niobium High temperature annealing furnace (900 °C)
TUD	High temperature annealing of samples and small size cavities
UEN	Microwave imaging laser scanning of samples