Processing of SPL cavities to obtain design performance

Introduction

Sergio Calatroni

Tasks

- Main goal of the SPL Collaboration Meeting:

  « To propose how to demonstrate 25 MV/m (β = 1) and 19 MV/m (β= 0.65) before mid-2011 »

- Goals within this Working Group - Subtask:
  - (β = 0.92 or β = 1?)
  - Define strategy to reach full performance (25 MV/m for β = 1 cavities) for a fully equipped prototype cryomodule
  - Identify required equipment (e.g. electro-polishing, HPWR) and what is missing

EUCARD WP 10.2 (from Dieter Proch)

- Cavities for Proton Linacs, Electropolishing and surface investigations
  - Sub-task 1: Design and fabrication of $\beta = 0.65$; 704 MHz elliptical cavity equipped with a titanium helium reservoir. Preparation and assembly in clean room. Test of the cavity in vertical cryostat.
  - Sub-task 2: Design and fabrication of $\beta = 1$; 704 MHz elliptical cavity. Preparation of the cavity and assembly in clean room. Development of a vertical EP bench.
  - Sub-task 3: Study of interfaces between the cavity and the cryomodule.

Why EP?

- SPL goal: 25 MV/m accelerating field for β =1
- SPL goal: 19 MV/m accelerating field for β= 0.65

Cavity	Accelerating field [MV/m]	Peak surface electric field [MV/m]	Peak surface magnetic field [mT]
β=1	25	50	100
β=0.92	24.5	50	105
β=0.65	19	50	100

- These values have been chosen because they are (and we want to achieve) state-of-the art performance.
- Must be obtained reliably on fully equipped cryomodules
- Statistically, only EP processed cavities can reach these goals (FE, quenches, etc.)

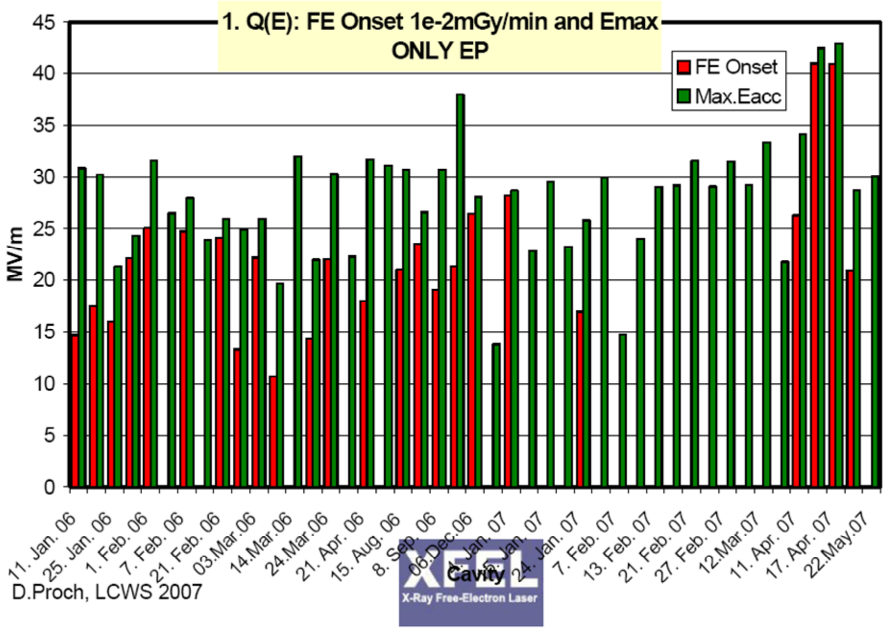
Choice of accelerating gradient
Stochastic parameters - DESY results

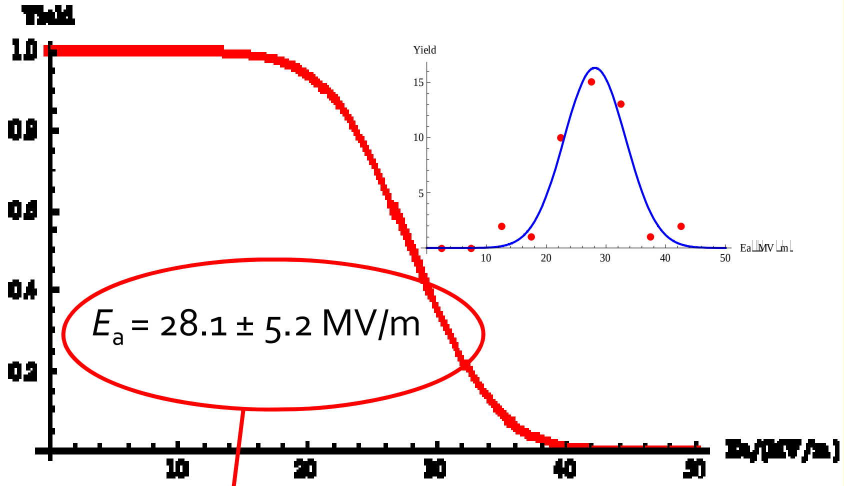
Series tests E_a

Development of Field Emission since Jan 06

compiled by D.Reschke

- Analysis of 1. Q(E)-results **only EP cavities** (all tests, not preparations):





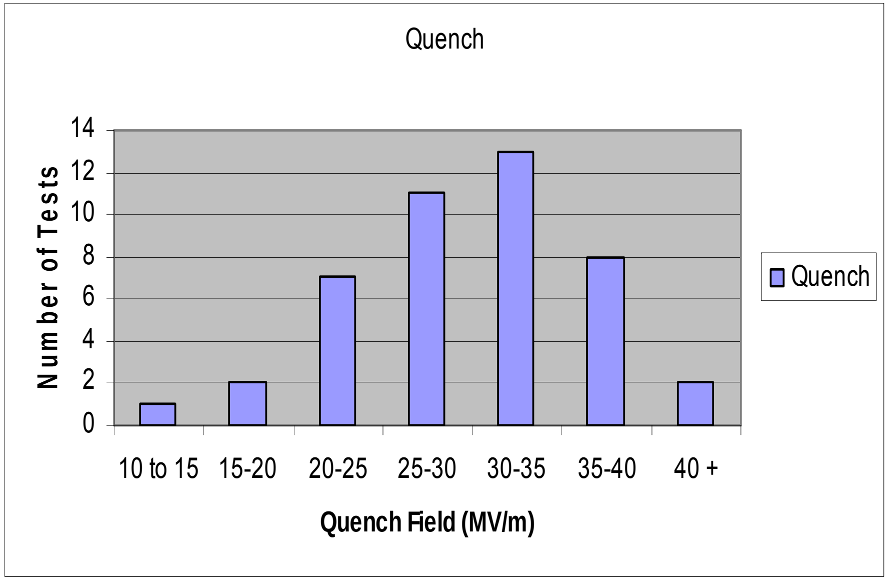
$E_a = 28.1 \pm 5.2$ MV/m

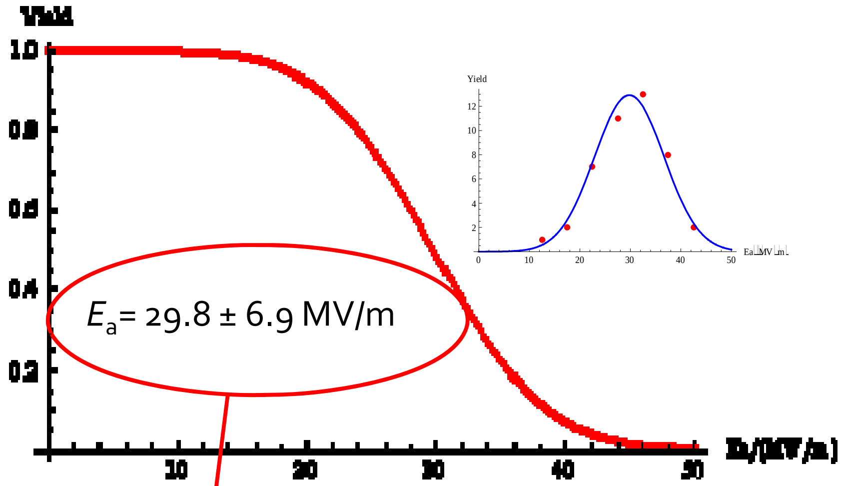
E_p=56.2 MV/m

Choice of accelerating gradient
Stochastic parameters - DESY results

Gradient spread Due to Quench

Probability of "Quench Only" DESY 9-cell Cavities (EP cavities only)





Compiled by H.Padamsee from DESY Data Base, TTC Meeting at DESY, January 14 - 17, 2008 https://indico.desy.de/conferenceOtherViews.py?view=standard&confId=401

B_p=120 mT

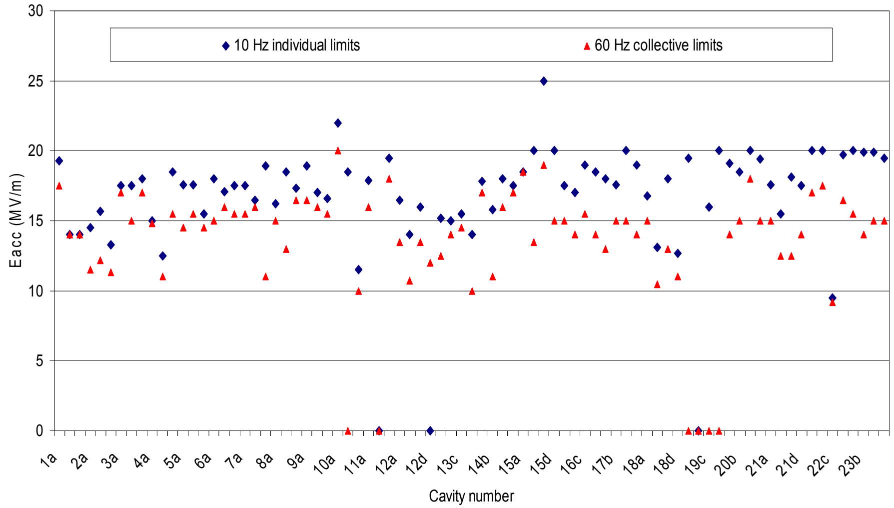
30 April 2008 SPL Review @ CERN - WW 19

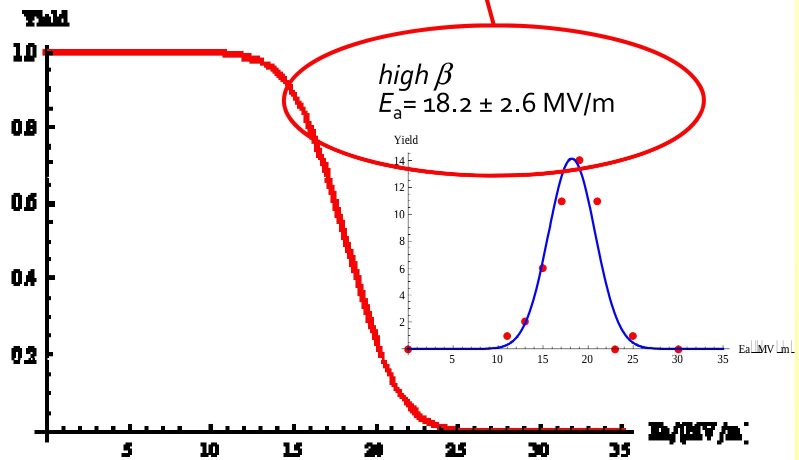
Choice of accelerating gradient

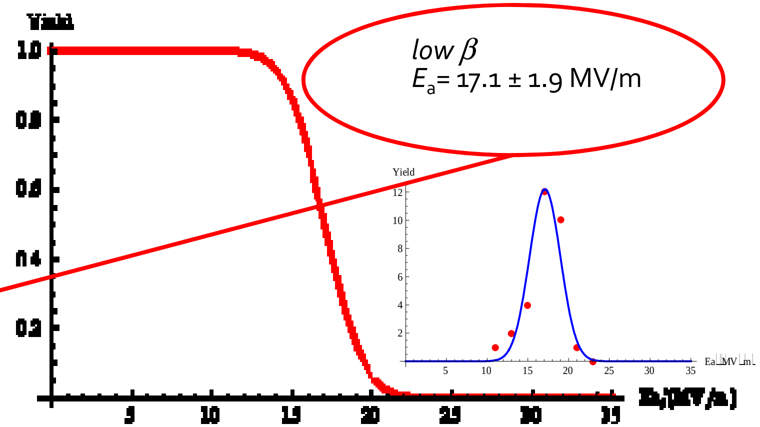
Stochastic parameters

ORNL/JLAB results (BCP only)

E_p=40.4MV/m





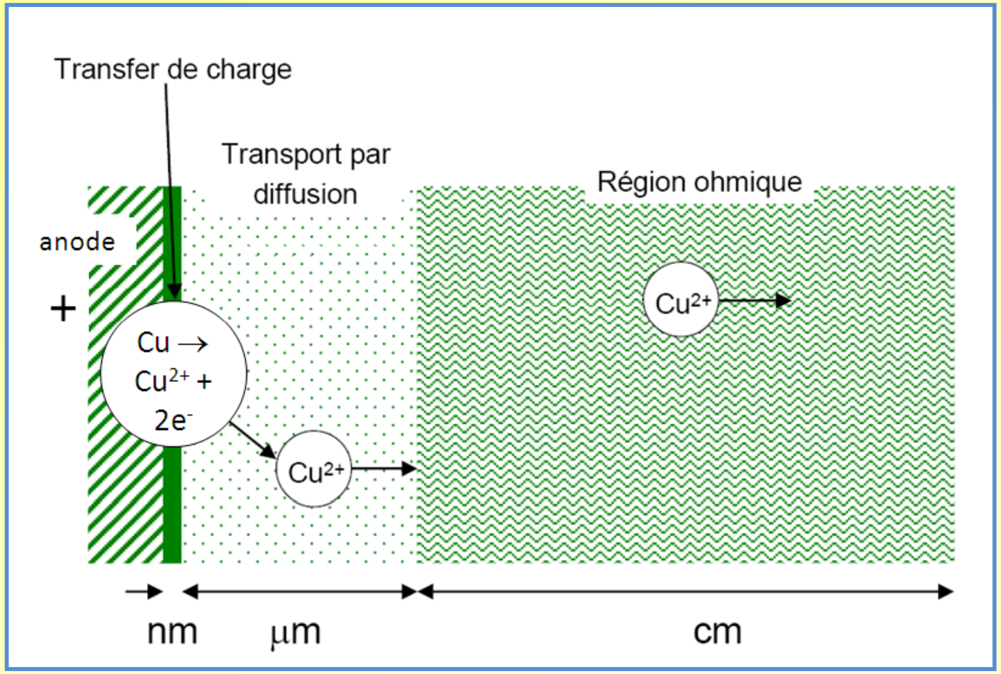


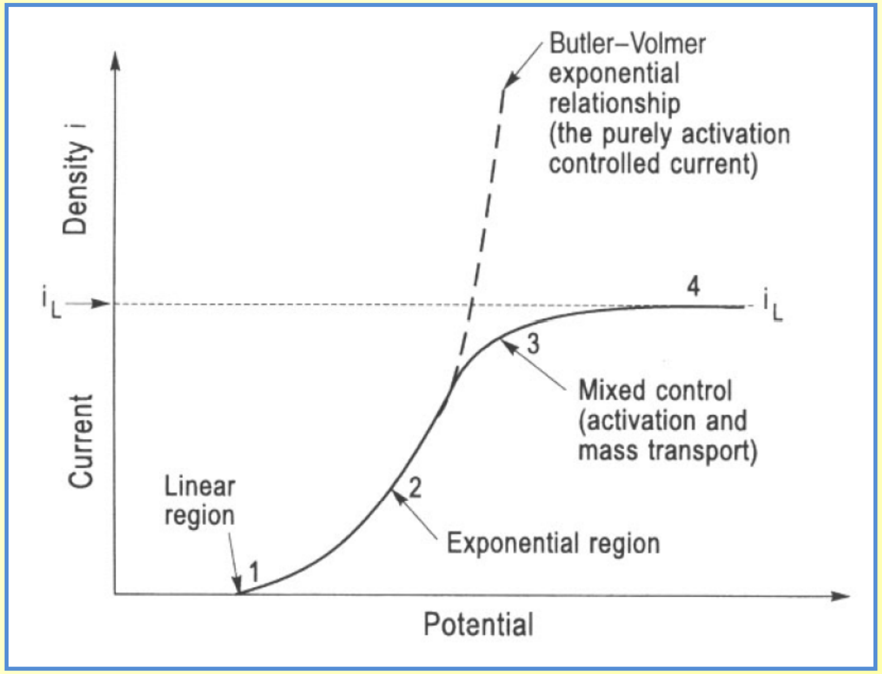
Source: I. E. Campisi and S.–H. Kim, **SNS Superconducting Linac operating experience and issues**, Accelerator Physics and Technology Workshop for Project X, November 12-13, 2007 http://projectx.fnal.gov/Workshop/Breakouts/HighEnergyLinac/agenda.html

E_p=46.7 MV/m

30 April 2008 SPL Review @ CERN - WW 21

Electropolishing: diffusion layer



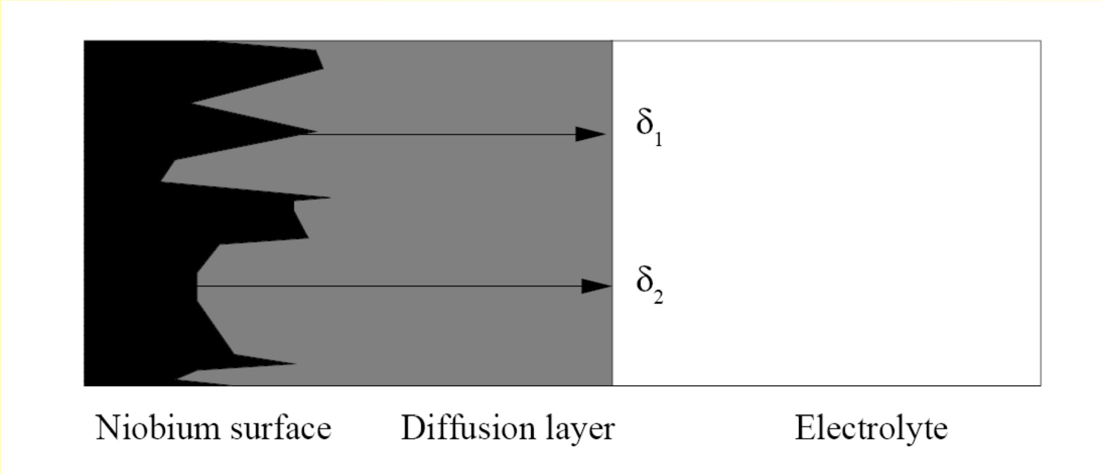


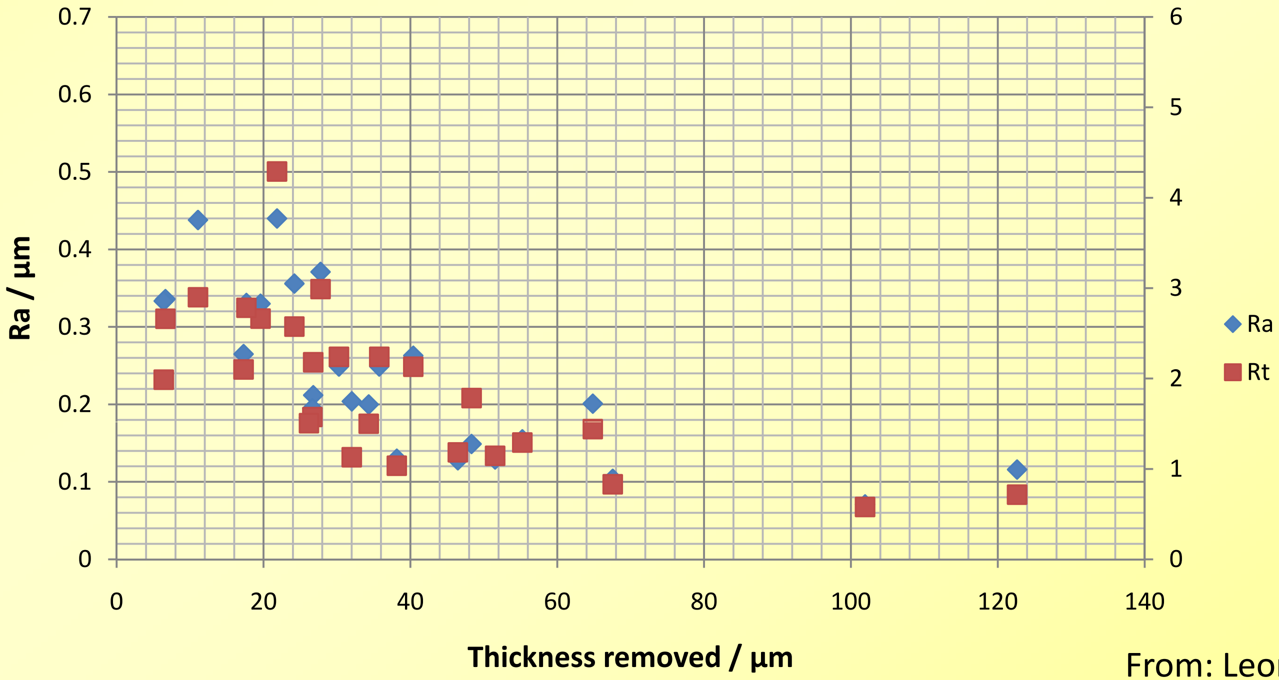
At the cathode, with no competing reaction:

$$I = I_0 \exp\left\{\frac{nF}{RT}\underbrace{(E - E_{eq})}_{}\right\} \longleftarrow \boxed{\mu = \mu_0 + RT\log(Cf)}$$

Overpotential, in practice the voltage across the cell

Polishing effect

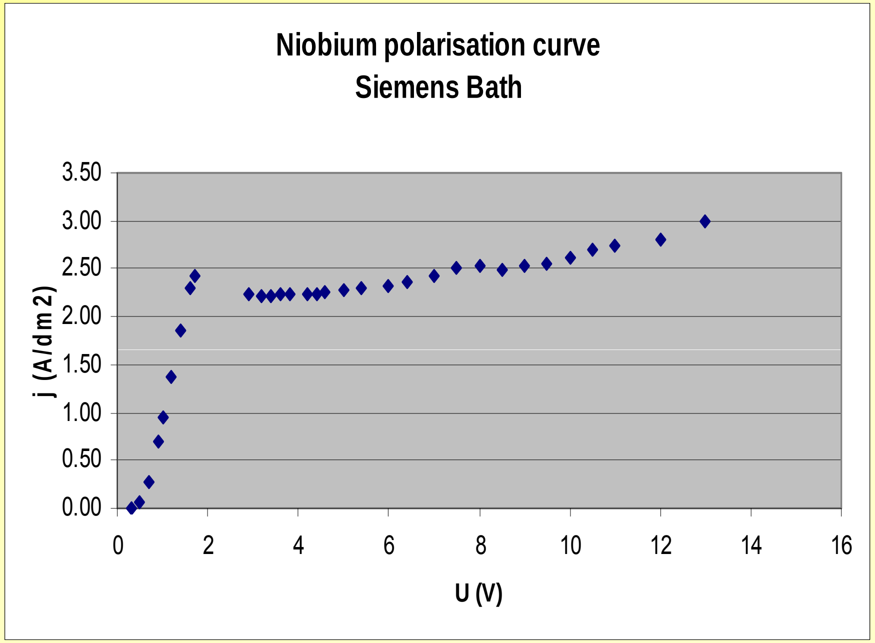




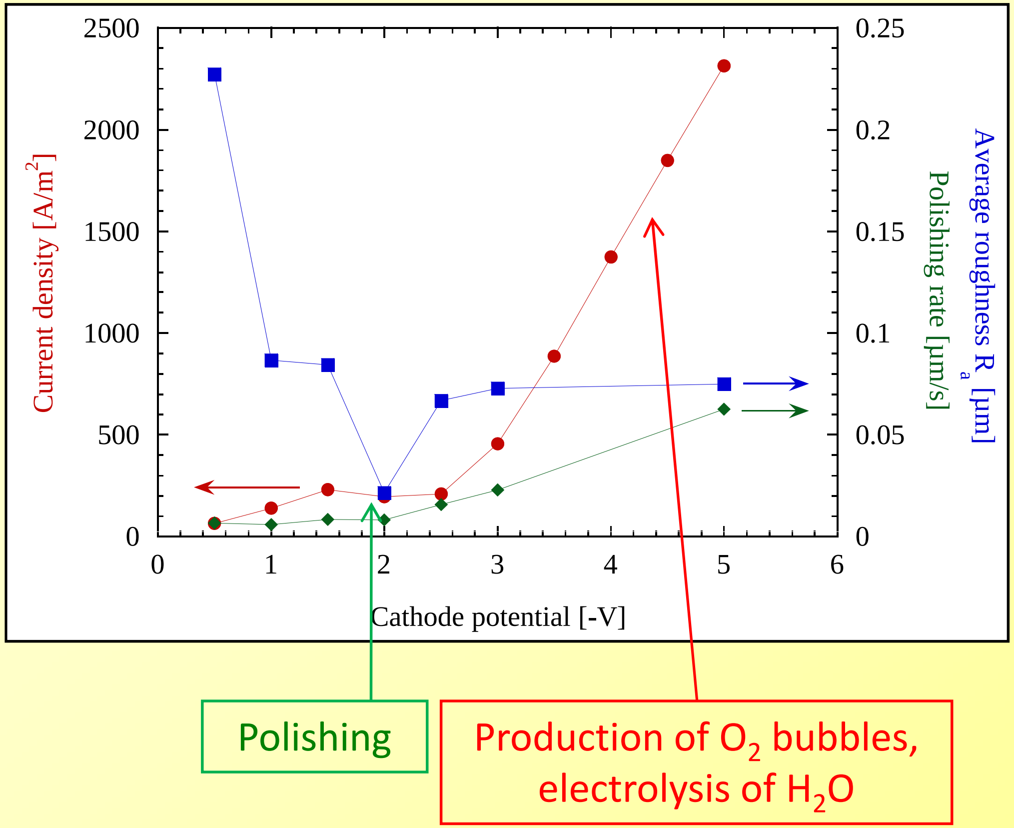
From: Leonel Ferreira

Polarisation curves

Niobium



Copper



From: Leonel Ferreira

Low-β cavities

Figure 10: (left) XADS 700 MHz, β=0.65 cavity (IPN Orsay) and β=0.5 cavity (INFN Milano).

HIPPI 704 MHz β=0.5 cavity

EP difficulties

- To uniformly distribute the potential all-over the cavity surface (in particular for β=0.65)
  - → Computer simulations of cathode shape
- To cope with the mass transfer limitations
  - → Include simulations of flow. Circulation vs. stirring.
- To cope with the heating generated by the process
  - → Cooling capacity must be adapted to keep the acid within the optimal temperature window
- To handle potentially harmful acids in a safe way
  - → Vertical electropolishing simplifies assembly
- Post-treatment not 100% understood
  - → Chemical etching vs. detergent cleaning.
- ...

Further needs for surface preparation

- EP before cavity welding (cortical layer removal)
  - → Lab or industry?
- Vacuum firing of niobium
  - → Lab or industry?
- Final HPWR
  - → opportunity for nozzle optimisation?
- "Mild" bakeout
  - → Almost certainly needed. Experience in low β cavities?
- ...

Goals and beyond

- Fabrication, surface preparation and vertical test of one (or few) β=1 cavity: under control within EUCARD (CEA)
- Fabrication, EP and vertical test of one β=0.65 cavity: under control within EUCARD (IN2P3), EP to be done either at CEA or CERN
- Fabrication, surface preparation of the full complement of β=1 cavities for a cryomodule: options?
  - Needs for resources
  - Availability of industry for manufacture
  - Needs for infrastructure in labs: surface preparation, assembly, vertical test, cryomodule assembly, horizontal test

WP10.2 Deliverables

10.2.1	Results of SC proton cavity tests (b = 1 and b = 0.65)	R	M33
10.2.2	Reproducibility of the process as a Function of the EP-Mixture	R	M36
10.2.3	Summary of test results with vertical EP	R	M42
10.2.4	Evaluation of enhanced field emission in Nb samples	R	M48

Relative comparison

TABLE X: Summary of results in other labs.

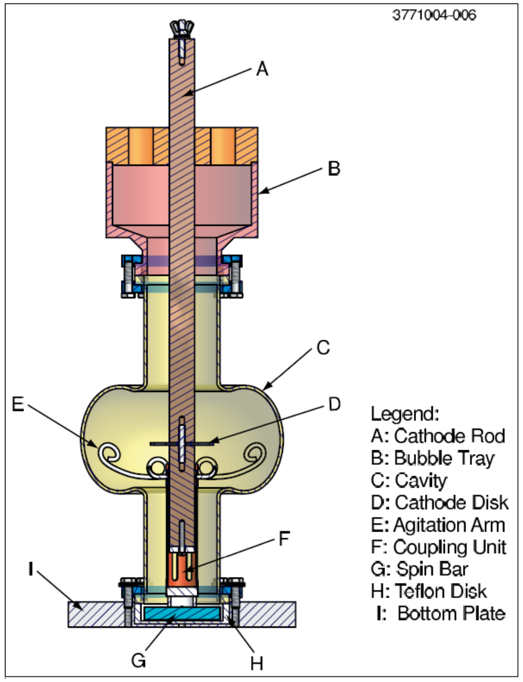
Laboratory	$< E_a >$ [MV/m]	ΔE_a [MV/m]	$\Delta E_a / < E_a >$ [%]	$< E_a >$ [MV/m] at 90 (50) [%] processing yield †
DESY 1.3 GHz (all)	28	5.2	19	22 (28)
ditto (quench) 9-cell	30	6.9	23	23 (30)
ORNL/JLAB SNS 805 MHz				
$\beta = 0.61$ 6-cell	17.1	1.9	11	15 (17)
$\beta = 1$ (extrapolated)‡	23.0	2.6	11	20 (23)
$\beta = 0.81$ 6-cell	18.2	2.6	14	15 (18)
$\beta = 1$ (extrapolated)	20	2.8	14	16 (20)

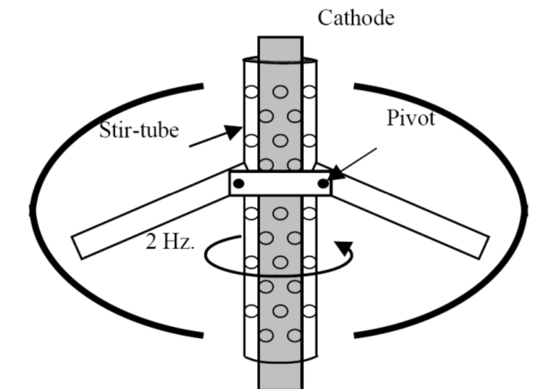
† 90 or 50% yield is equivalent to 11 or 100% of re-processing needed, respectively. The re-processing rate in percent is equal to 100(100-yield)/yield.

‡ The extrapolated valued is calculated by means of the relation as in Fig. 5, depending whether the field limitation is caused by a quench or field emission. In the first case the surface magnetic field scaling relation is used, in the second case the surface electric field relation is applied.

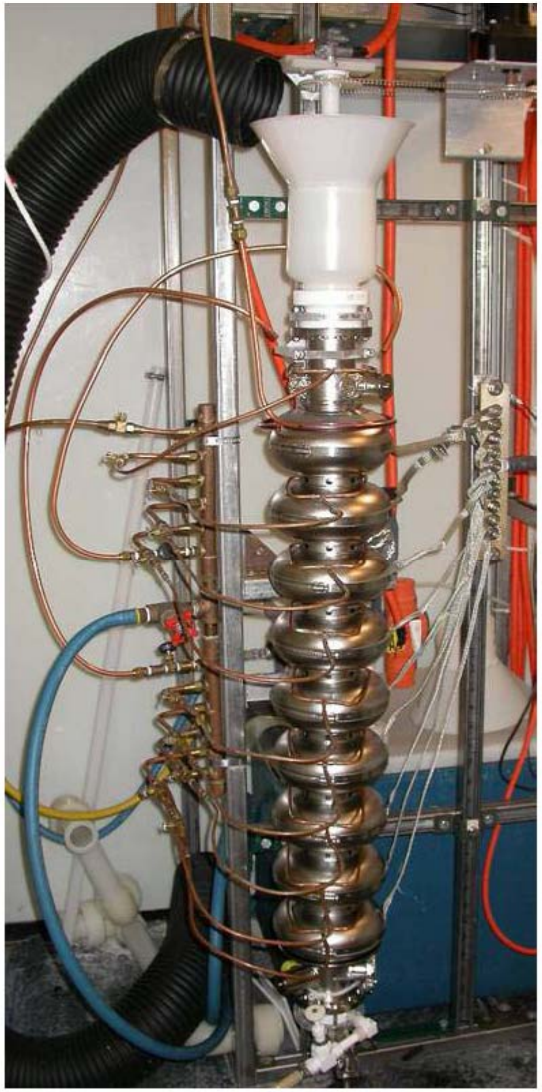
From: **Assessment of the basic Parameters of the CERN SPL** - O. Brunner, S. Calatroni, E. Ciapala, M. Eshraqi, R. Garoby, F. Gerigk, A. Lombardi, R. Losito, V. Parma, C. Rossi, J. Tuckmantel, M. Vretenar, U. Wagner, W. Weingarten - CERN-AB-2008-067 BI/RF

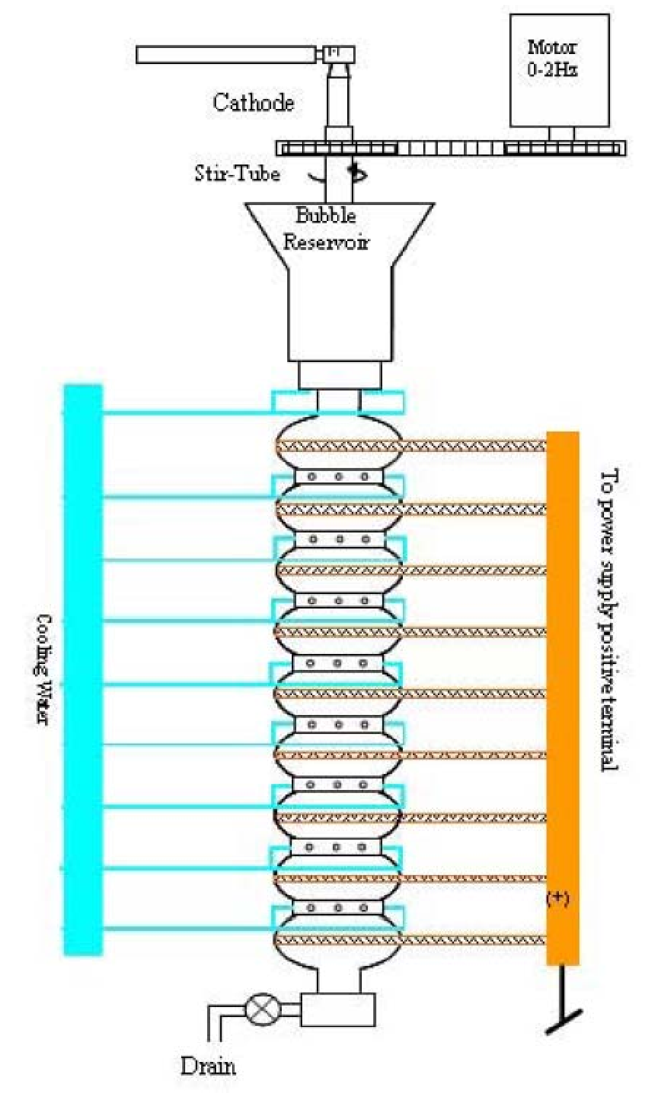
Vertical EP in Cornell





No forced circulation





Cooling by water spraying on the outside

EP system for 1.5 GHz Cu cavities at CERN