CEA EXPERTISE WITH VERTICAL ELECTROPOLISHING (VEP)

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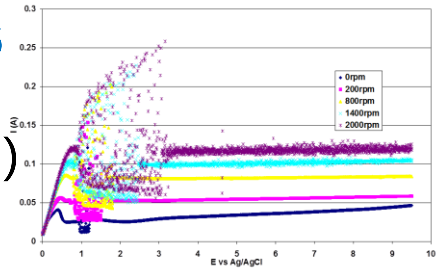
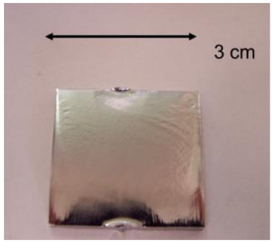
LCWS14 October 7th 2014

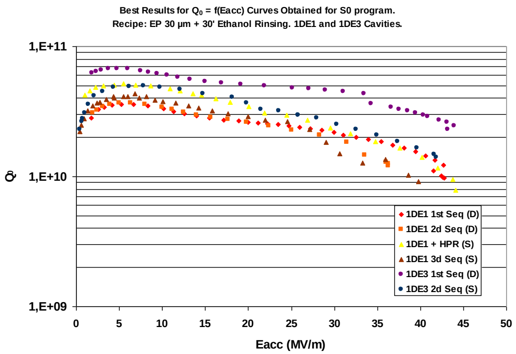
ELECTROPOLISHING AT CEA/IRFU: 2004-2014

EP on samples (CARE program): 2004-2006

- Parameters optimization
- Understanding of the process (F^- diffusion)
- Study of the aging of electrolytes
- Sulfur contamination







1Cell Horizontal EP: 2006-2009

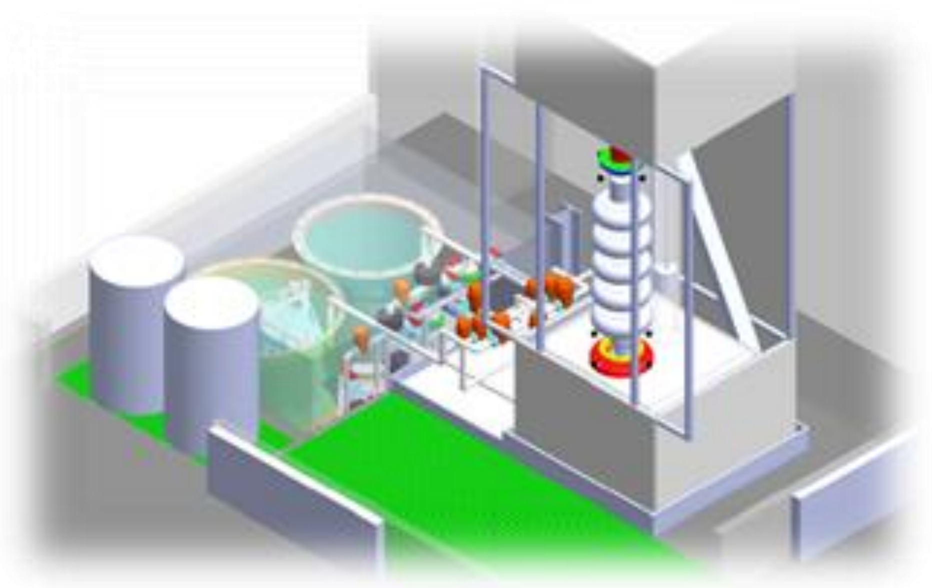
- Achievement of high gradients
- Alternative recipe tested
- Low voltage EP

Design and operation of a Vertical EP system 2009-…

- Operating since 2011
- Optimization on 1Cell cavities
- Operation with ILC and SPL cavities

VEP SET-UP AT CEA SACLAY

F. Eozenou et al., PRST-AB, 15, 083501 (2012)



- Designed for large cavities
- Circulating acid
- Injected from bottom
- 300L acid capacity
- Cooling system

(heat exchanger in acid tank)

- Emptying by gravity
- Nitrogen blowing in top of cavity/acid tank
- Cathode inserted in horizontal position

(Fixed cathode, no stirring)

SPL Cavity insertion in the cabinet

Cathode's insertion in horizontal position

HORIZONTAL VS VERTICAL EP (VEP)

Pros:
- Good evacuation of gases (cavity half filled)
- Demonstrated efficiency
- Large range of parameters

Cons:
- Complicated process, rotary seals
- Switching of the cavity

Pros:
- Simple process, adapted for big cavities
- Low floor surface
- Improved safety

Cons:
- Sensitive to fluid dynamics
- Proper parameters to be determined…

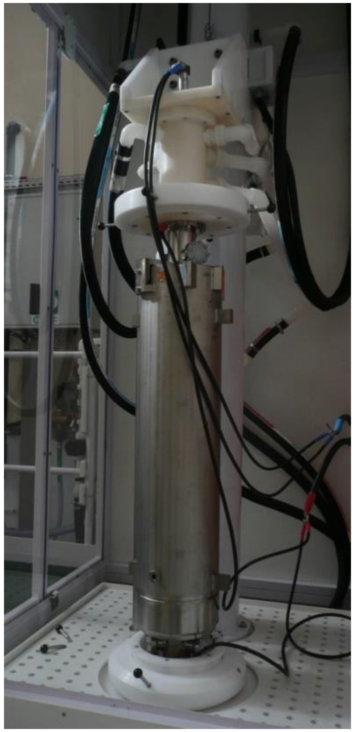
Once optimized, vertical configuration is more suitable for cavity treatment at industrial scale.

CAVITIES TREATED BY VEP AT CEA

1Cell Tesla 1.3 GHz

9Cell ILC 1.3 GHz

Fermilab



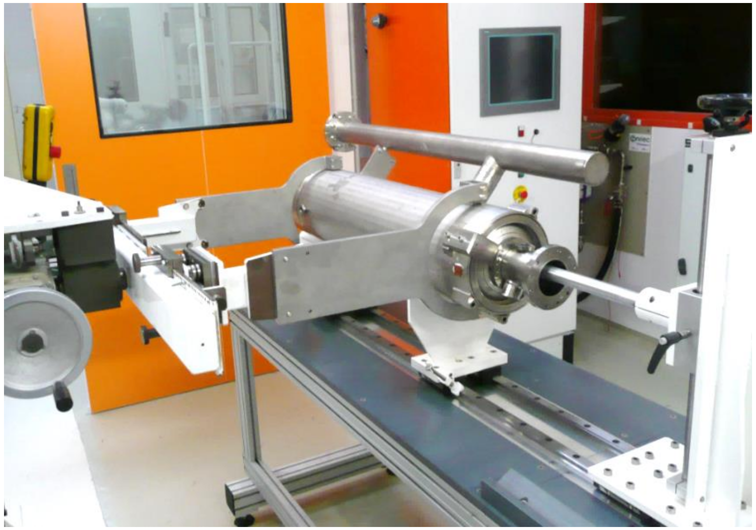
9Cell jacketted TESLA

DESY

5Cell β=1 SPL 704 MHz

DEDICATED HANDLING TOOLS

Handling tools for 704 MHz and 1300 MHz resonators



Horizontal insertion of the cathode

VEP PARAMETERS

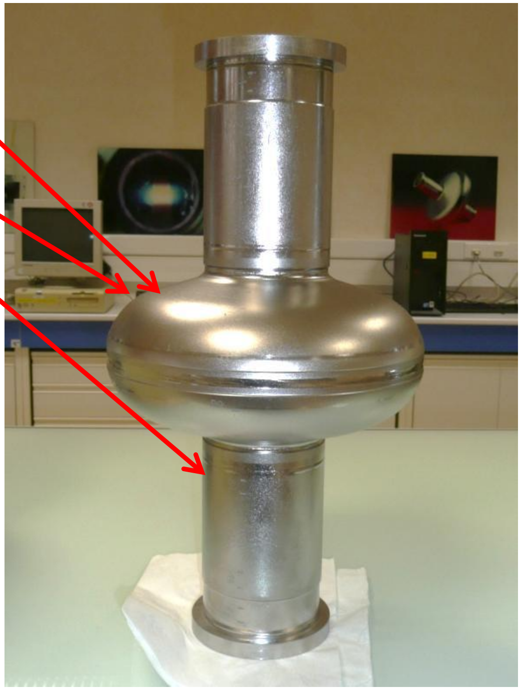
The choice for appropriate parameters is vital for efficient VEP

Set of parameters derived from Horizontal EP process is not recommended… Example: VEP at 10 V and 30 °C

Bubble traces

Pitting

Bright Surface



Strong assymetry. The local removal rate at pitting area is very high: ~ 1µm/min

MAIN CHALLENGES OF VEP PROCESS

- Efficient hydrogen outgassing

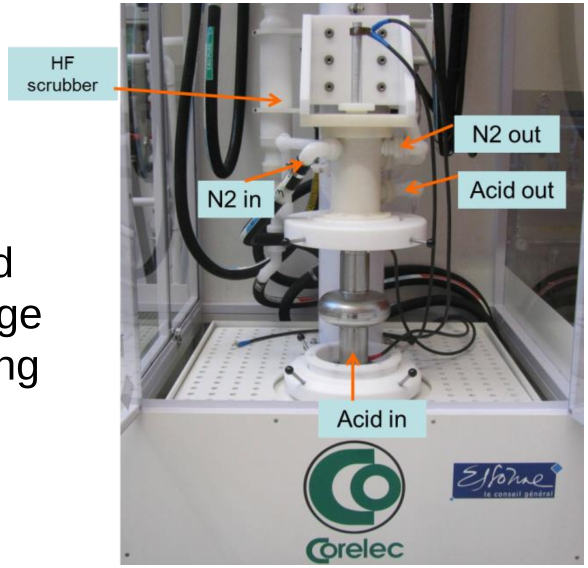
- Temperature control of the process

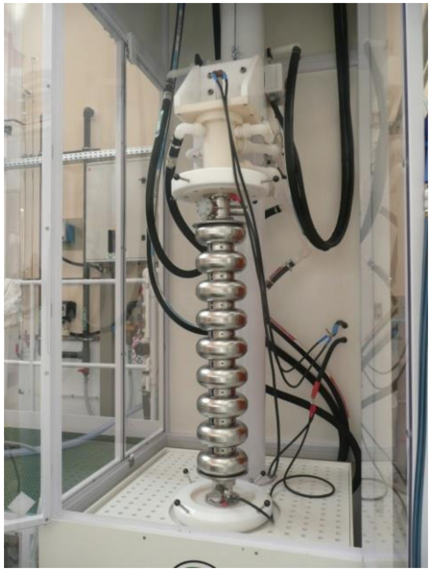
  Temperature - Voltage relation in SPL case
  U = 7.5 V $\Delta T < 1°C$ (acid temperature rise between bottom and top)
  U = 10 V $\Delta T > 4°C$

- Asymmetry of the process to overcome?

PARAMETERS CHOSEN FOR 1300MHZ VEP

- Circulating acid
- Constant voltage
- Nitrogen blowing



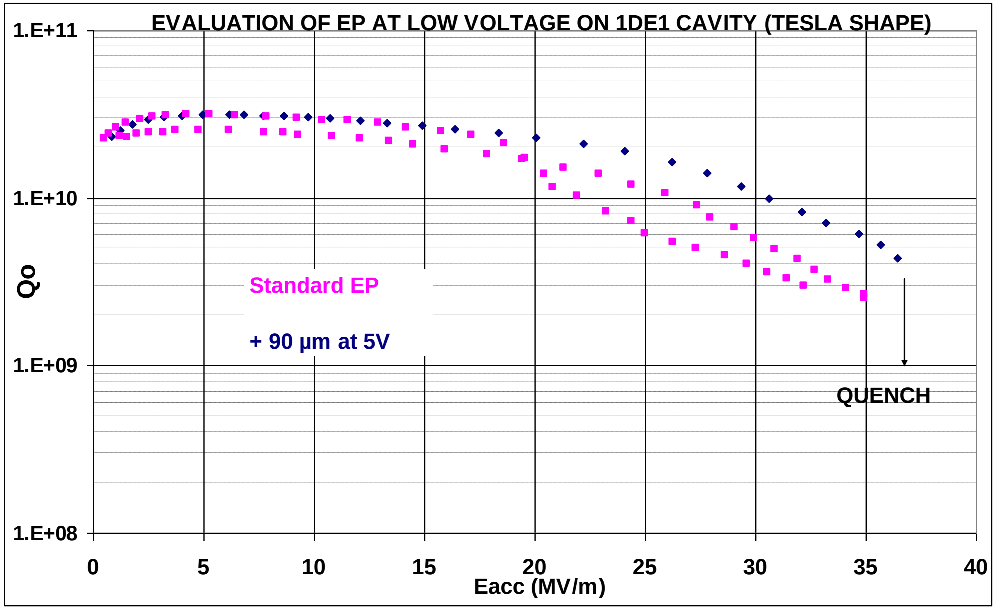


Fermilab

TB9RI025 cavity
Prior VEP

- High acid flow (25 L/min)
  - Improved outgassing (H2)
- Low voltage (~ 6 V)
  - Lower heating
- Temperature: 20°C

MOTIVATION FOR EP AT LOW-VOLTAGE



- ❖ Reduction of parasitical reactions
- ❖ Lower heating of EP bath
- ❖ Longer lifetime of the electrolyte
- ❖ No deterioration of performance

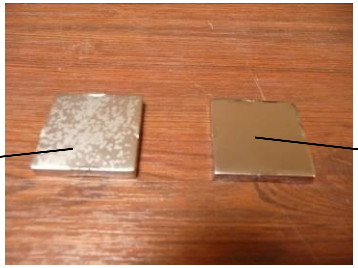
Study on 1Cell after horizontal EP: Voltage has no impact on performance

F. Eozenou et al., PRST-AB, 13, 083501 (2010)

Study on sample: Voltage Vs Contamination

For similar removal, high voltage generates visible contamination !

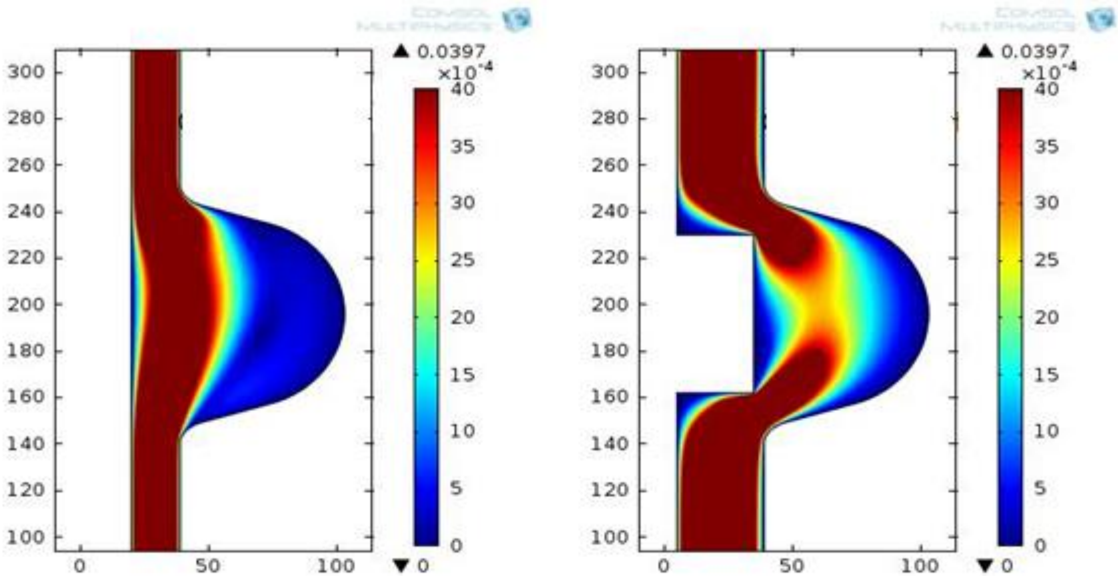
Sample electro-polished at 20 V



Sample electro-polished at 5 V

= Way to reduce Sulfur Contamination

CHOICE OF THE CATHODE: ROD Vs SHAPED

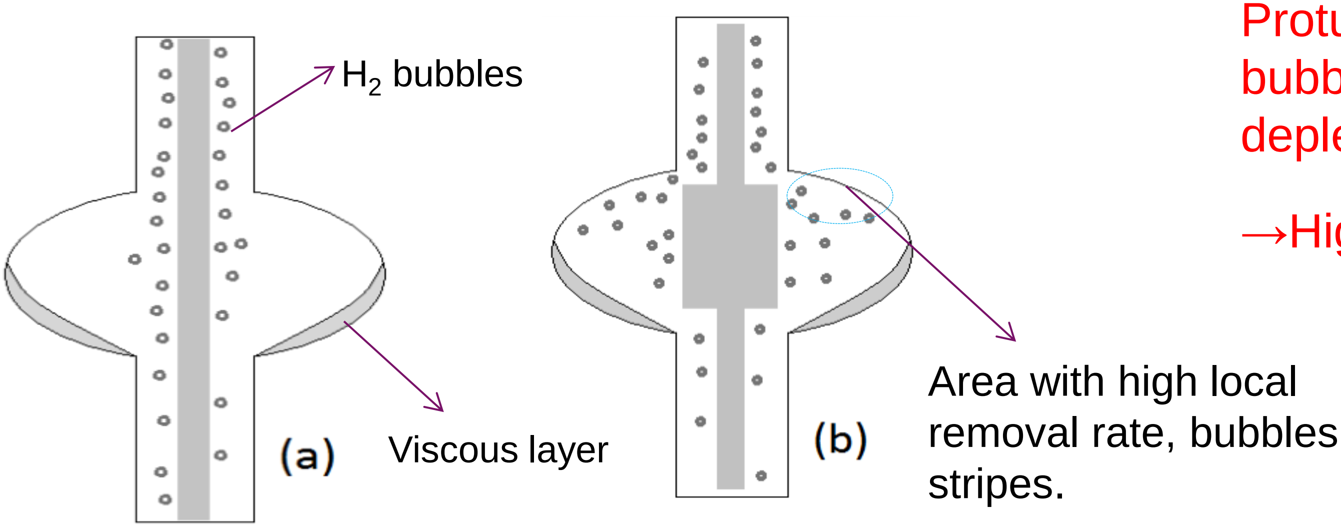


In Theory, fluid distribution and electric field are improved by the use of rod cathodes…

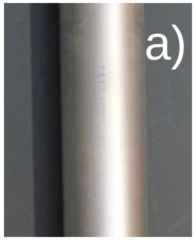
… In practice, asymmetry is increased, and more bubbles stripes are visible at the upper side of the cell.

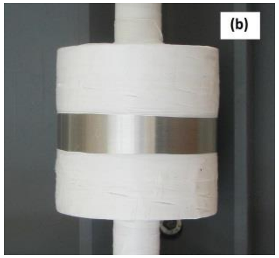
Protuberance guides the bubbles in a viscous layer depleted area.

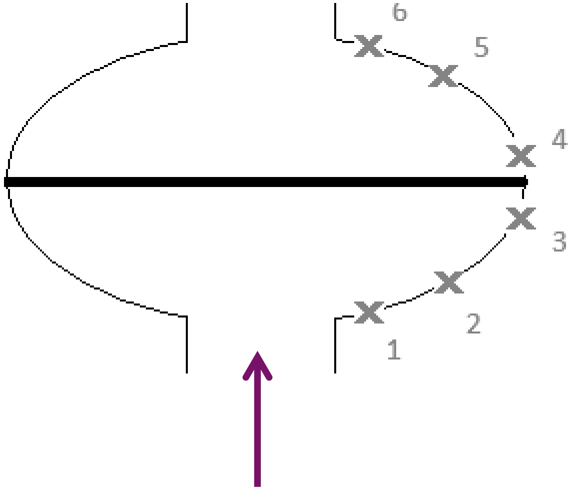
→Higher local removal rate



Assumed gas distribution in the cavity







Cathode configuration	30 mm rod (a)		Shaped (b)
Average removal (µm)	90		120
Removal at #6	160-170		290
#5	100		200
#4	80		100
#3	60-70		50
#2	30-40		40
#1	30-40		50

With shaped cathode, the removal is more uniform in the lower part of the cell (#1, #2 and #3) but vertical asymmetry is strongly increased with upper part of the cell.

FLOW IN THE CAVITY

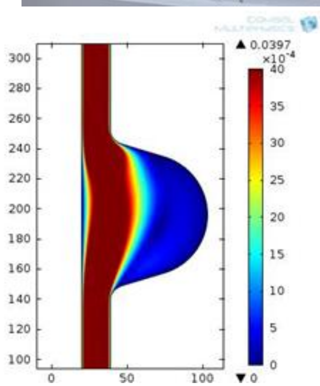
Set-up to investigate inner surface of the cavity during VEP:

1.3 GHz 1Cell cavity cut and embedded in resin box

First test with acid (Ø 30mm rod cathode):

- Hydrogen bubbles flow alongside the cathode
(In agreement with modelling)

- Air bubbles trapped at the cavity surface if filling flowrate is too high

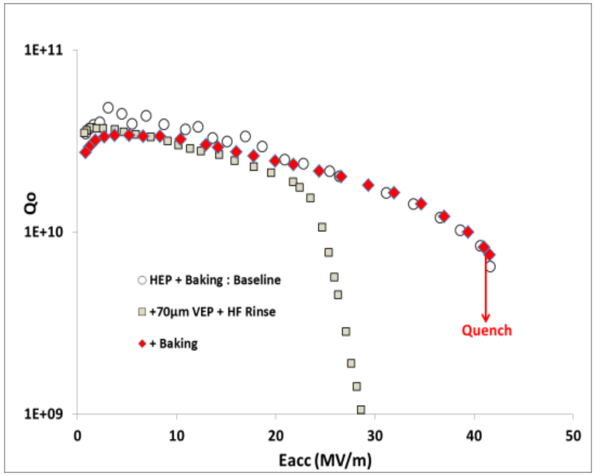


Flow in the cell: rod cathode:
Its velocity is max close to the cathode

We have chosen to use rod cathodes for multiCell cavity treatment

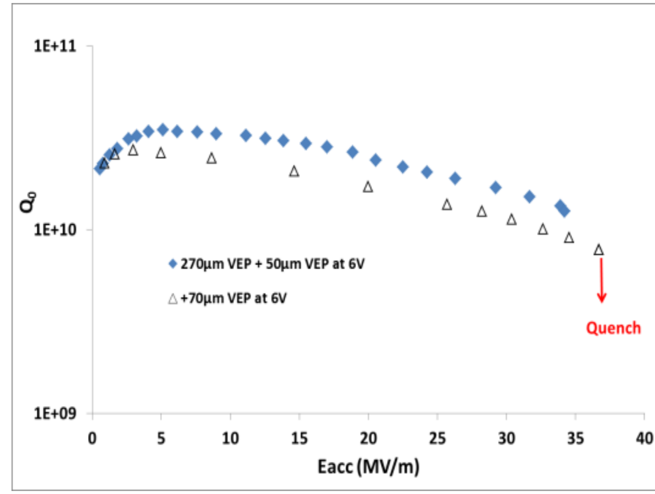
RESULTS ACHIEVED AFTER VEP ON 1300 MHZ CAVITY

F. Eozenou et al., SRF2013



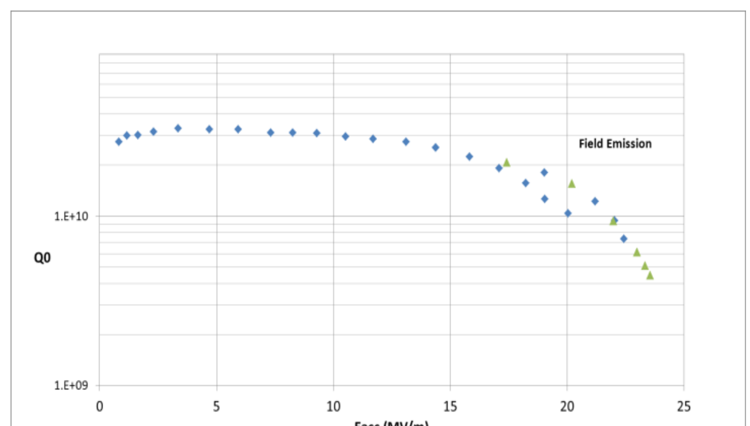
1DE1 cavity horizontally EP'ed + VEP

- ❖Similar performance Vs Horizontal EP
- ❖Benefits of baking similar



1AC3 cavity after heavy VEP
High gradients achieved

VEP makes it possible to reach performance similar to HEP

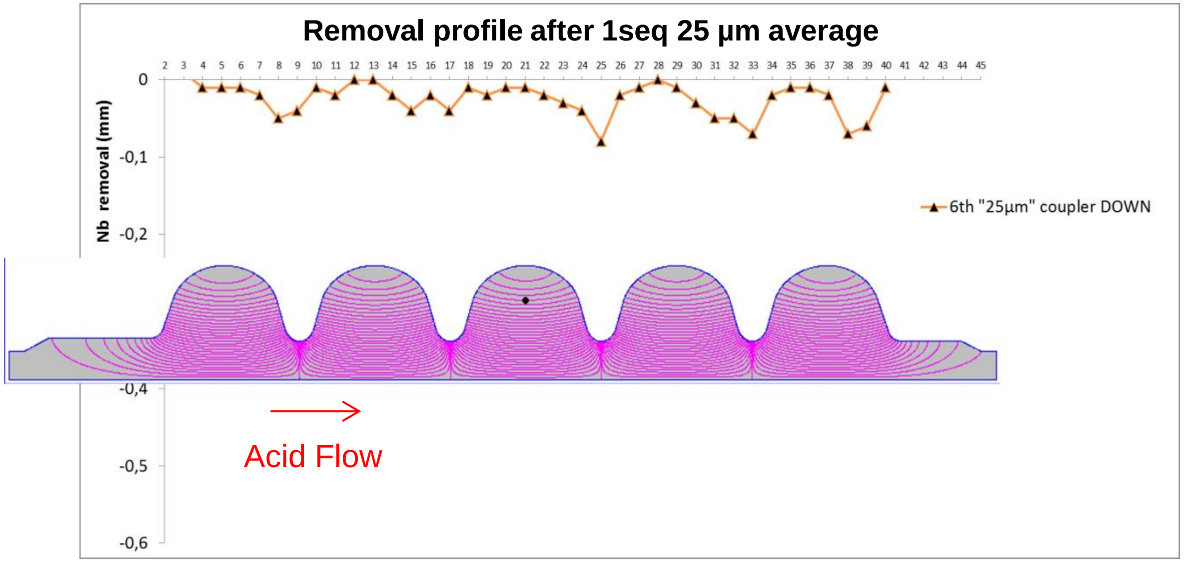


9Cell cavity Horizontally EP'ed from Fermilab
After additionnal VEP, Gradient limited by field emission

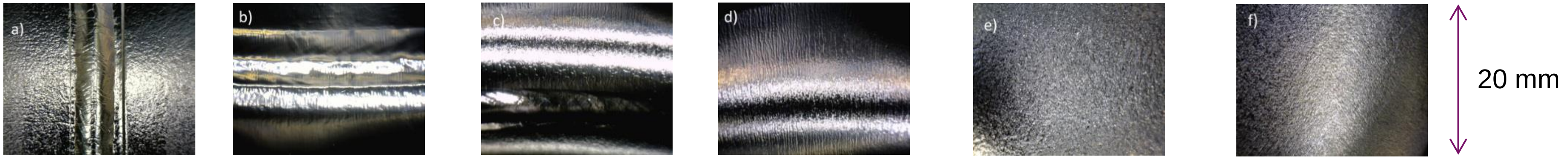
VEP OF SPL CAVITY. ASSYMETRY OF THE PROCESS

F. Eozenou et al., PRST-AB, 17, 083501 (2014)

- Voltage: 7.5-10V
- Flowrate 20 L/min
- T<15°C
- Rod cathode Ø 70mm

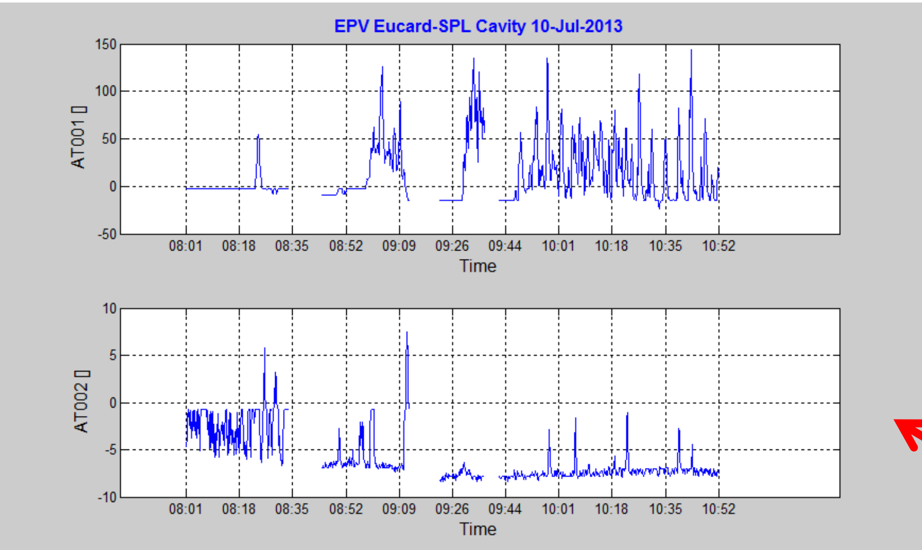


- Asymmetry in the cell: higher removal in the upper part of the cells
- Asymmetry in the cavity: the higher cell, the faster removal
- Achieved surface depends on the location in the cavity



Typical surface morphologies after >100µm VEP at different locations. The weldings at a) equators, and b) irises are smooth. Bubbles stripes are observed at the proximity of irises c) and d). In the areas between equators and irises e) and f), the surface is rougher.

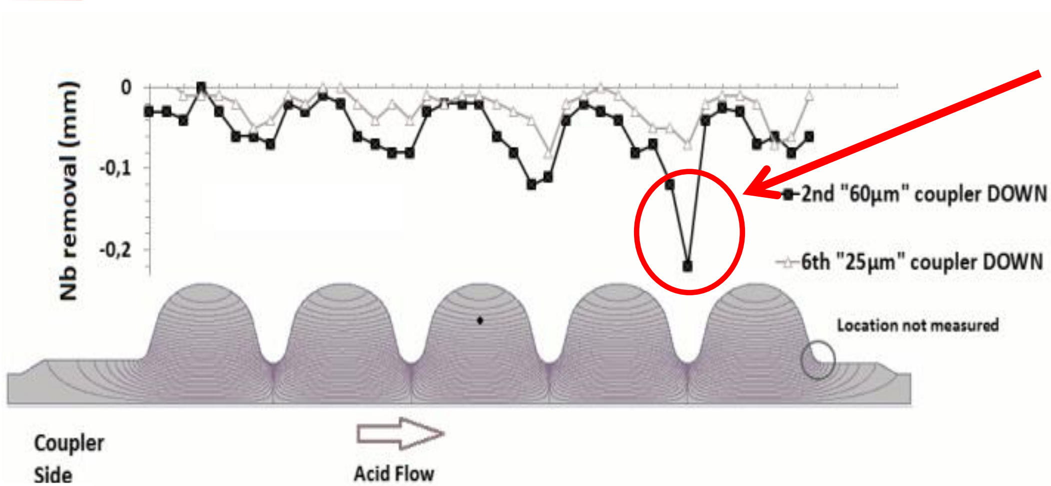
VEP AND HYDROGEN, SPL CAVITY (I)



We experienced problems with degassing due to acid condensation in the exhaust pipe

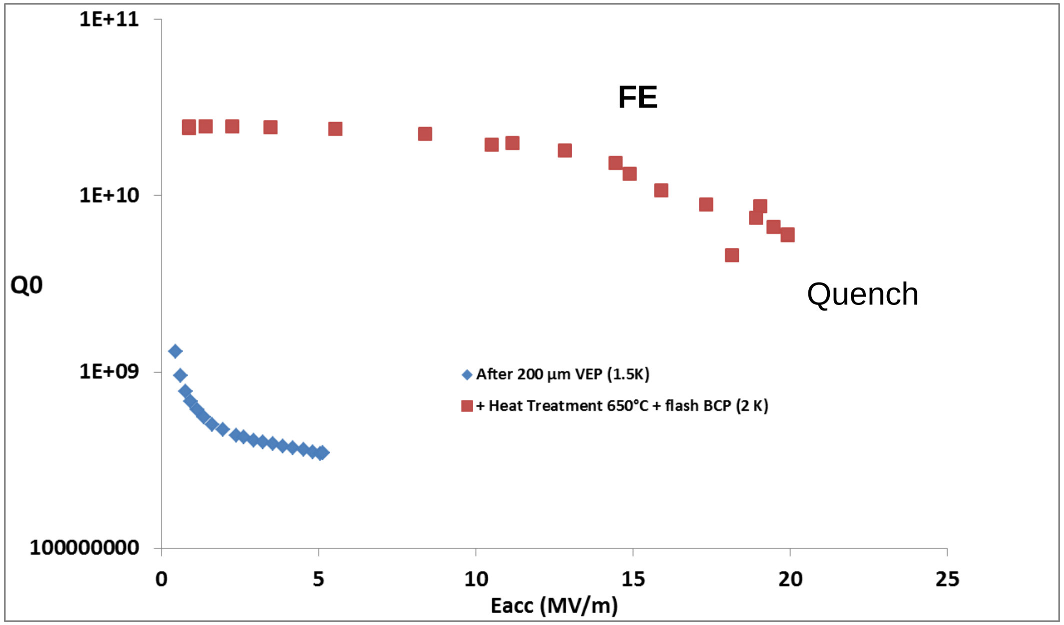
Detection of H_2 peaks in the cabinet

MAIN CONSEQUENCES



Strong local attack in upper cells

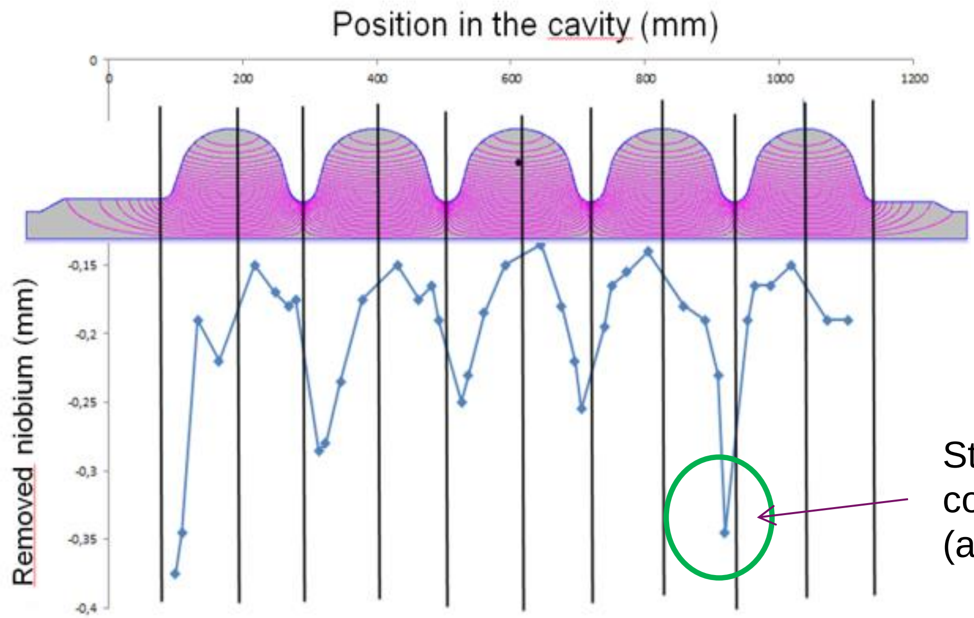
VEP AND HYDROGEN, SPL CAVITY (II)



- SPL cavity has been tested after 200 µm VEP without heat treatment
- Strong Q disease detected
- Heat treatment 650°C x 24h at CERN + flash BCP (< 5 µm)

- Q recovery is observed

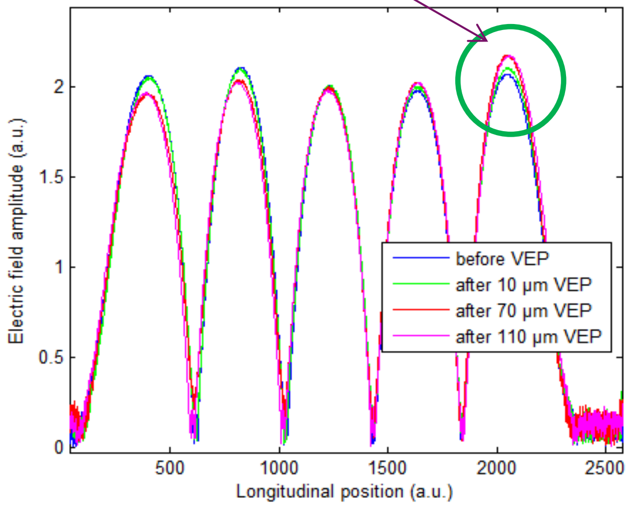
FIELD FLATNESS EVOLUTION AFTER VEP



Distribution of the removal after total 200 µm
(4 sequences with turning the cavity in between)

Strong local attack due to acid condensation in exhaust pipe (after 70 µm total VEP)

Responsible for a shift in field flatness



- Symmetric removal in the cavity
- Ratio iris/equator: 2/1 = similar compared to ILC shape
- Low field flatness shift once hydrogen properly evacuated

KEK-MARUI / CEA VEP COLLABORATION

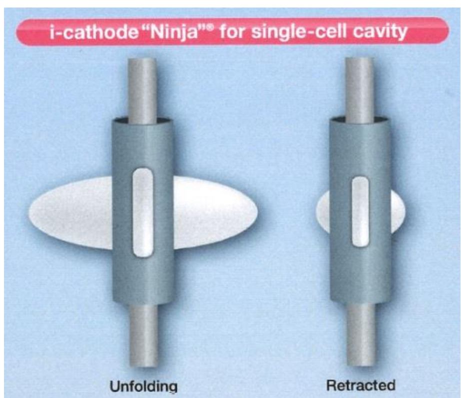
(TYL Program)

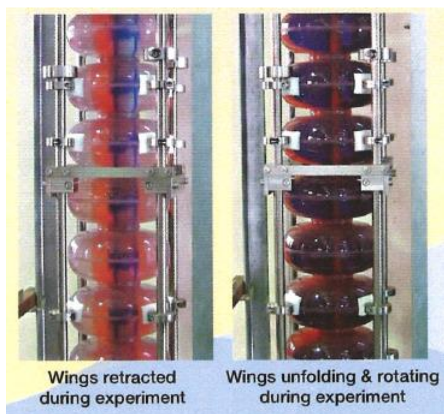
Different cathode configurations among labs/companies:

- For CEA, fixed cathode, no stirring.

- Cornell: Rotating stirrer around the cathode. F. Furuta et al., IPAC 2012, TUPPR045

- 3rd technology developped at Marui Galvanizing Company:
Rotating cathode with retractable wings: Patented Ninja Cathode





- **Improved fluid distribution with unfolded cathode.**

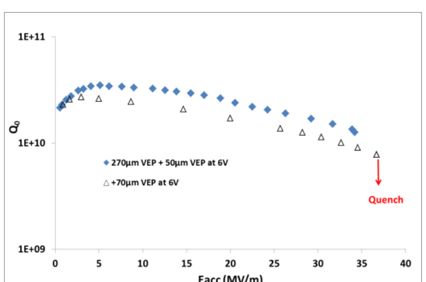
K. Nii et al., SRF 2013, TUP052

- **Better hydrogen removal.**

V. Chouhan et al. LINAC 2014, THPP098

See also presentation by T. Saeki.

CEA and Marui technologies will be compared after VEP sequences on the same 1Cell cavity



1AC3 after VEP at Saclay to be tested after VEP at

CONCLUSIONS

- VEP is a much simpler process, adapted to industrial scale
- A safer process
- Makes it possible to treat ‘big’ cavities and cavities with He tank
- CEA has developpped VEP with low voltage and high acid flow
- Results after VEP / HEP are similar on Tesla shape cavities

- However it is an asymmetric process
- Surface less homogenous compared to HEP
- Using a rod cathode, cavity must be turned over for symmetric removal

Studies are on going for further improvement

DE LA RECHERCHE À L'INDUSTRIE

THANK YOU FOR YOUR ATTENTION