Reentrant Cavity and First Test Result

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Background

August 19, 2004: ITRP recommends SC RF for ILC

> ITRP executive summary:
> The machine will be designed to begin operation at 500 GeV, with a capability for an upgrade to about 1 TeV, as the physics requires. This capability is an essential feature of the design. Therefore we urge that part of the global R&D design effort be focused on increasing the ultimate energy to the maximum extent feasible.

Higher Eacc needed to reach higher energy (same linac length)

TESLA 800 GeV: 35 MV/m (Achieved already)
TESLA 1 TeV: 44 MV/m (R&D needed)

Paths toward higher Eacc

The maximum feasible Eacc is determined by the RF critical magnetic field $H_{crit,RF}$. When the surface magnetic field exceeds $H_{crit,RF}$, superconductivity breaks down into normal conductivity.

$$Eacc^{\max} = \frac{H_{crit,RF}}{H_{pk} / Eacc}$$

Determined by material

Determined by cavity geometry

Paths to raise Eacc: Raise $H_{crit,\ RF}$ or decrease Hpk/Eacc

Approach – new geometry

Perspective of raising $H_{crit,RF}$ with new material still remote.
High gradient need is imminent (in 5 years).

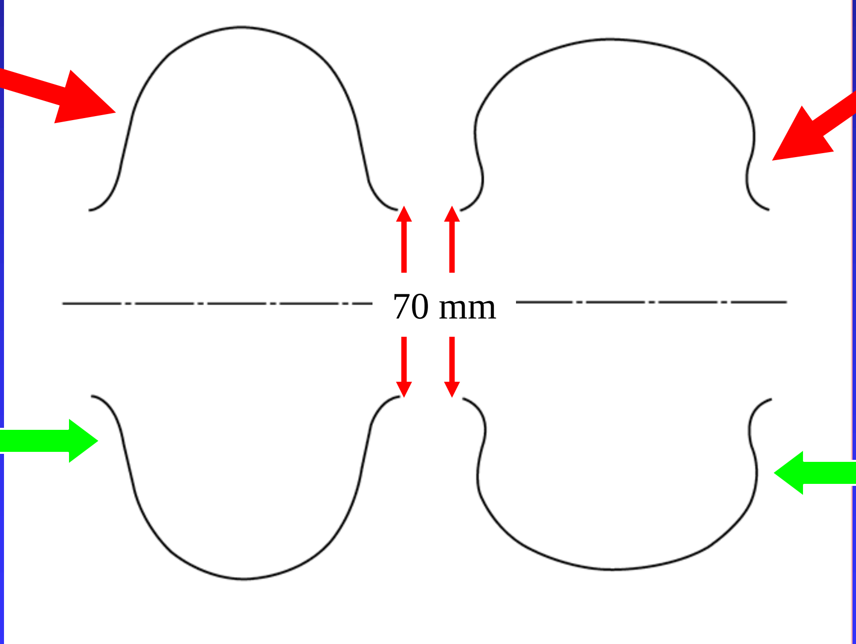
Solution: Nb cavity of New geometry with a reduced Hpk/Eacc.

Advantage: Cavity is based on well established Nb technology.
Disadvantage: Eacc improvement is inherently small (<30%).

Bottom line: As will be shown, the new geometry offers a space-efficient solution to establish the feasibility of ILC upgrade to 1 TeV .

Approach - reentrant cavity

A reentrant cavity geometry offers a reduced Hpk/Eacc, preserving at the same time the large bore diameter at the iris. Large bore diameter is the inherent advantage of SRF.



Regular TESLA shape

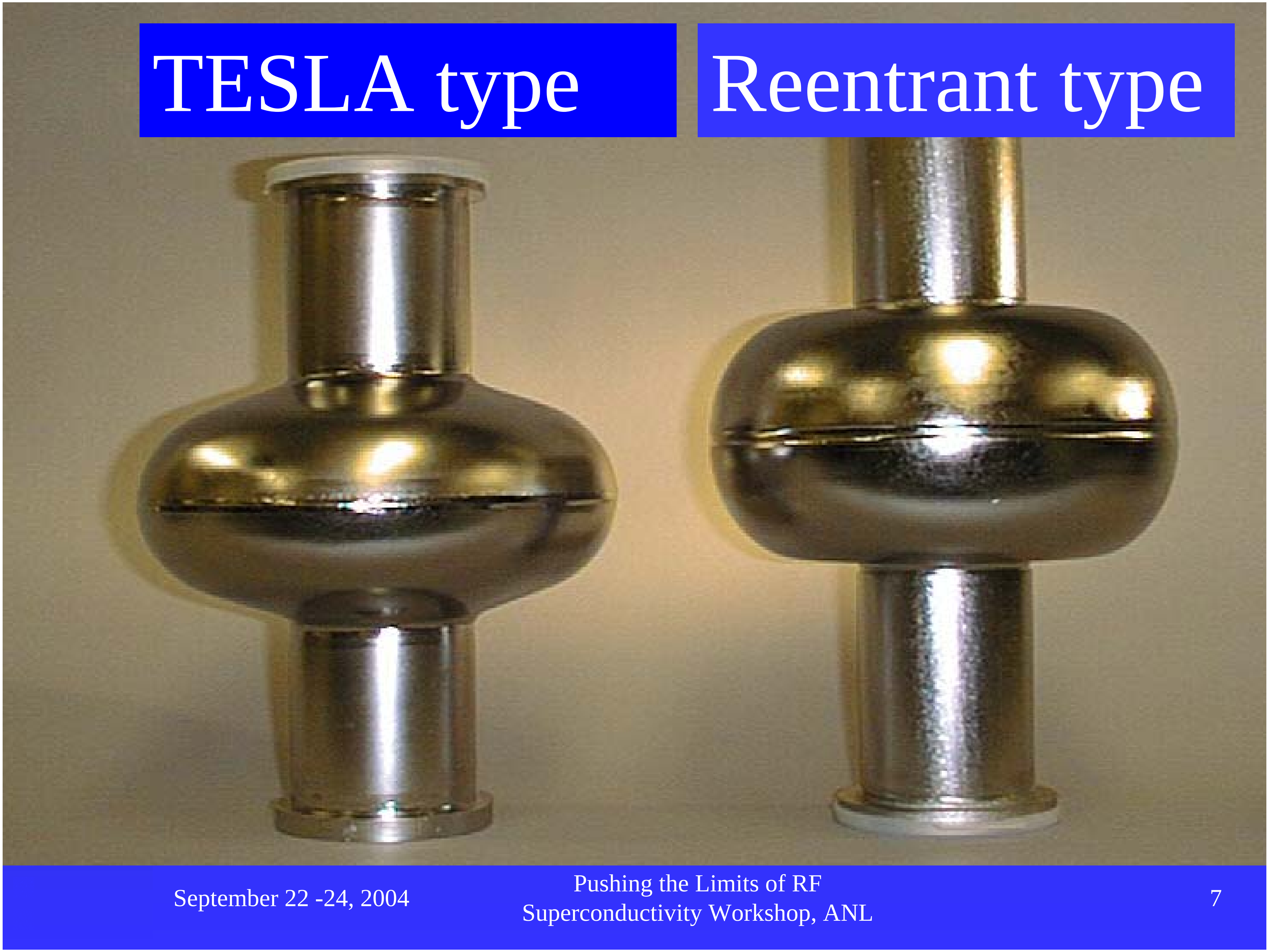
Reentrant shape

Hpk/Eacc
reduced
by 10%

$$\frac{H_{pk}}{E_{acc}} = 42$$

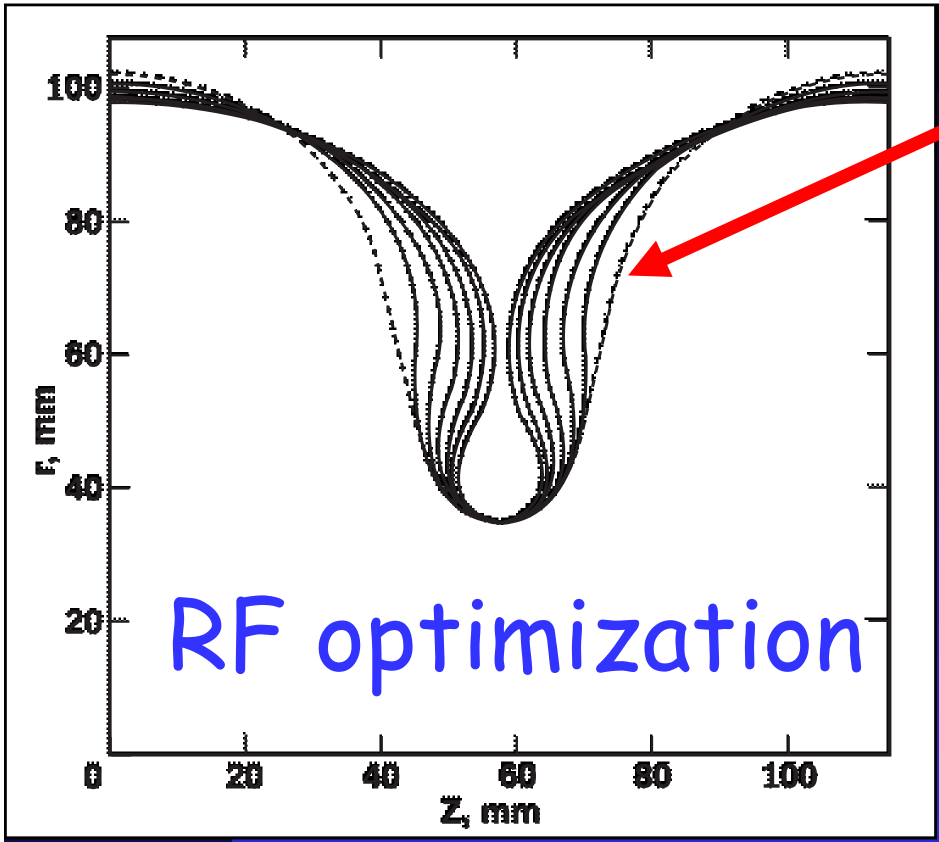
Hpk/Eacc in Oe/(MV/m)

$$\frac{H_{pk}}{E_{acc}} = 37.8$$



TESLA type

Reentrant type



RF optimization

Regular TESLA

$$e = 1$$
$$h = 1$$

$$e = \frac{E_{pk} / E_{acc}}{2}$$
$$h = \frac{H_{pk} / E_{acc}}{42}$$

reduction in surface magnetic field ratio $\delta h(\%)$	increase in surface electric field ratio $\delta e(\%)$	cell-cell coupling $k(\%)$
-7.92	+10	2.10
-10.00	+20	2.38
-11.36	+30	2.64
-12.30	+40	2.88
-12.99	+50	3.06

fabricated

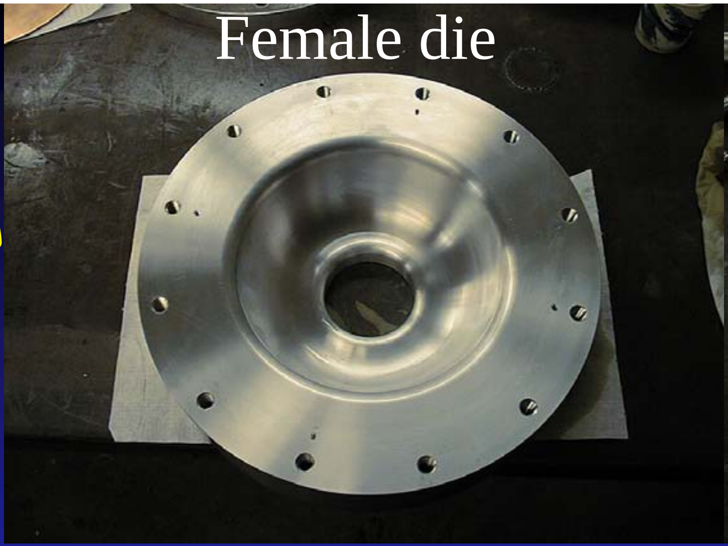
Single cell:
Hpk/Eacc=37.9
Epk/Eacc=2.19

Multi-cell:
Hpk/Eacc=37.8
Epk/Eacc=2.4

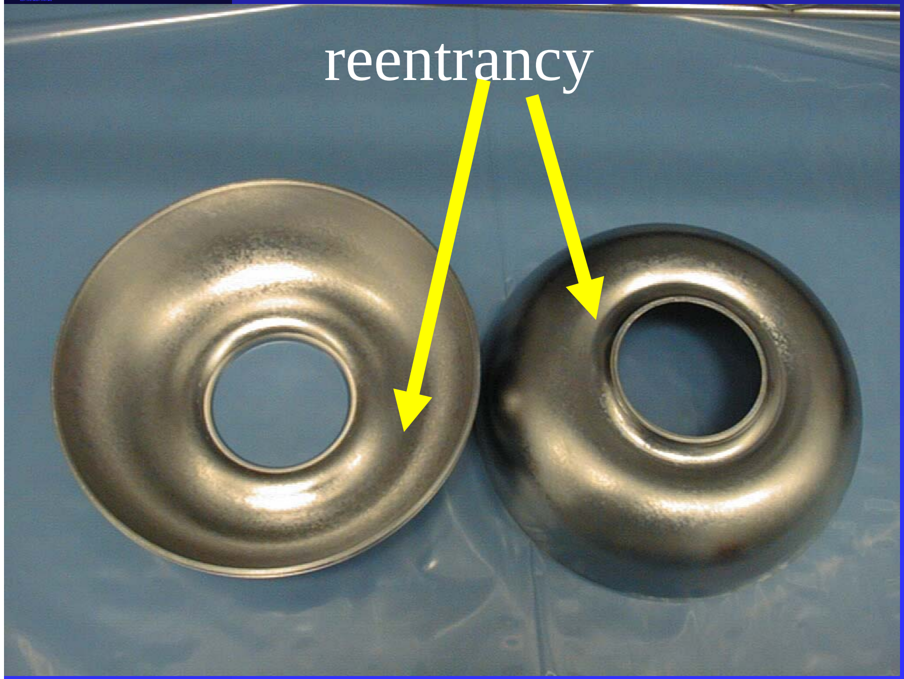
A higher Epk is the price for a lower Hpk
But no fundamental limit to surface electric field

Shemelin, Padamsee, Geng, NIM A 496 (2003) 1-7.

Fabrication



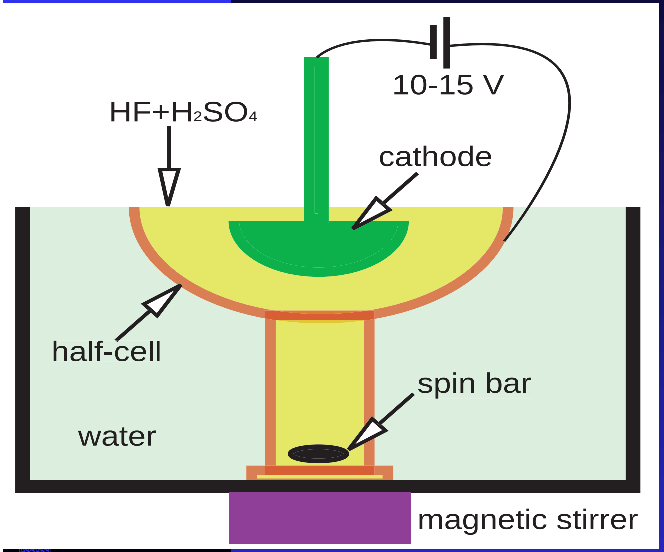
Regular deep drawing/coining sufficient to build the reentrant shape

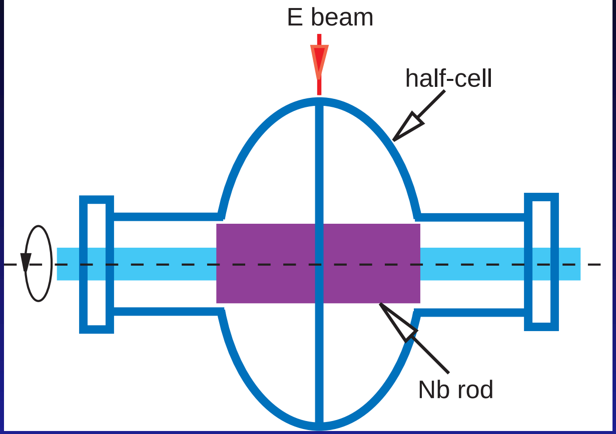


Half-cell heat treatment with Yt
1200 °C 4 hours
to improve Nb thermal conductivity

RRR increased from 250 to 400-500

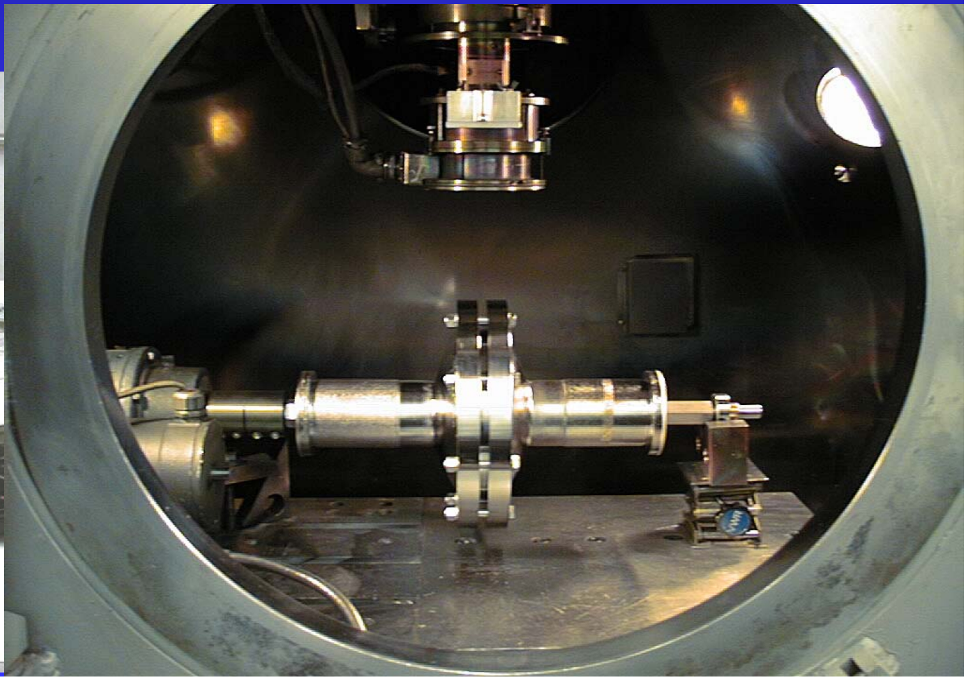
Fabrication





Equator EBW with a central rod
to shield RF surface from Nb vapor

Electropolish half-cell/beam tube



Treatment

- Standard BCP after equator weld to remove residual Nb deposit.

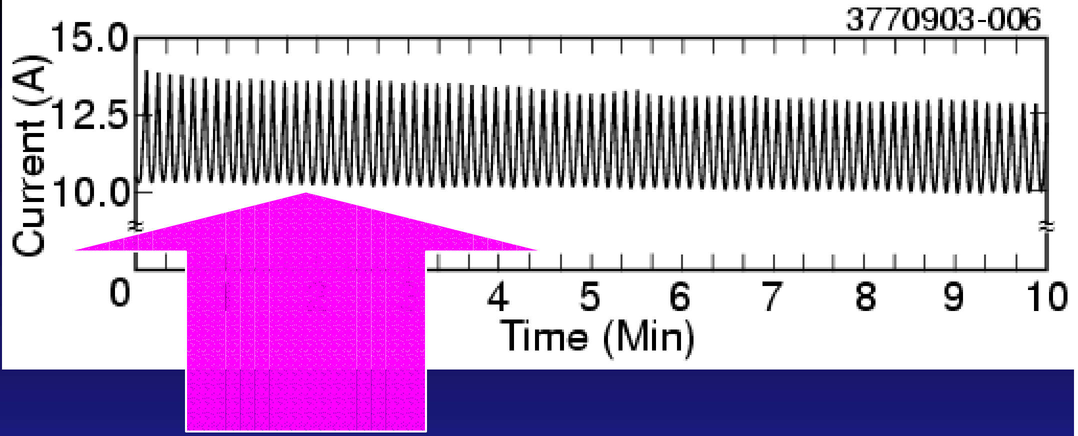
- Flip cavity between HPR cycles for thorough rising of reentrant surface.

- Dry cavity horizontally to avoid trapped water in reentrant pocket.

- Vacuum bake out at 100 – 120 °C for 48 hour.

- Vertical electropolish single cell cavity.

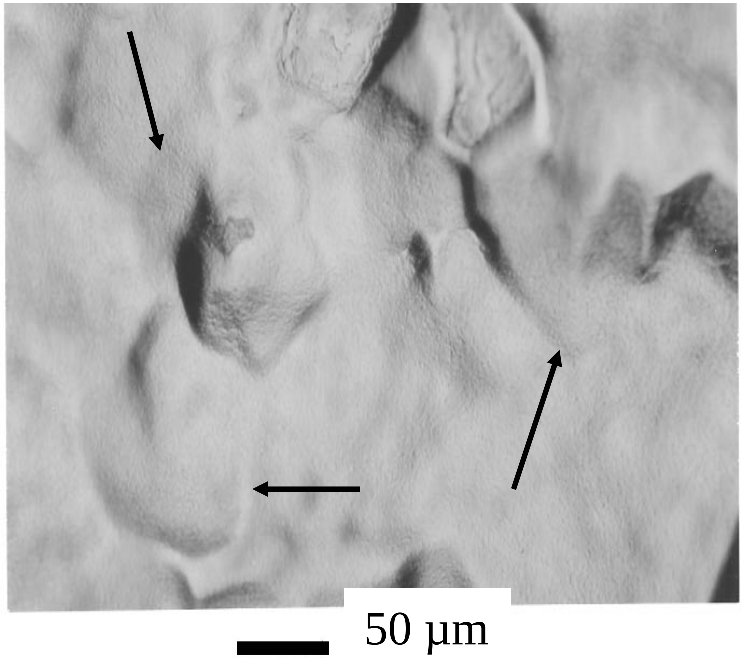
Treatment



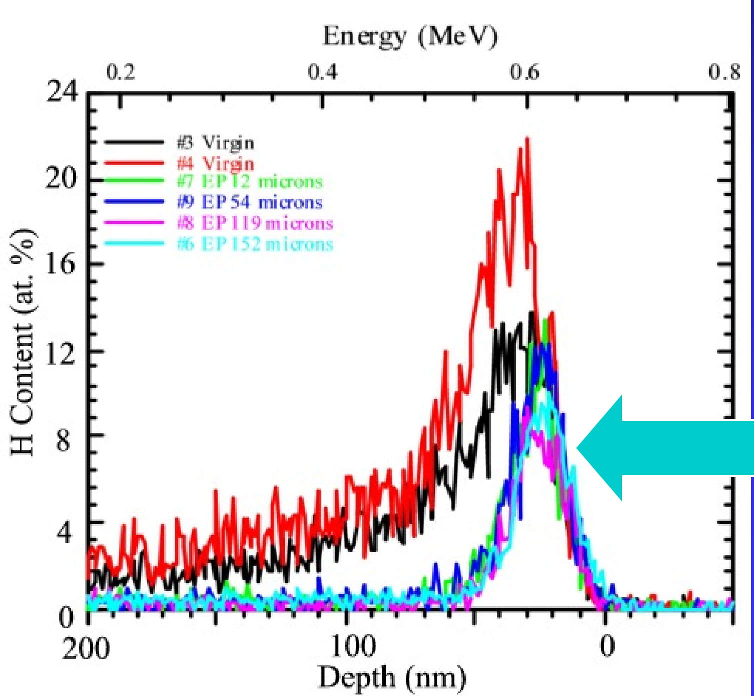
CCO-EP

Continuous current oscillation electropolish

Suppressed grain boundaries
(120μm BCP+30 μm CCO-EP)



Geng et al., the 11th SRF Workshop,
Travemunder/Lubeck, Germany,
September 8 - 12, 2003



Low surface hydrogen

Vertical RF test

Tests run at 1.8 – 2.0 K, 7 tests to date

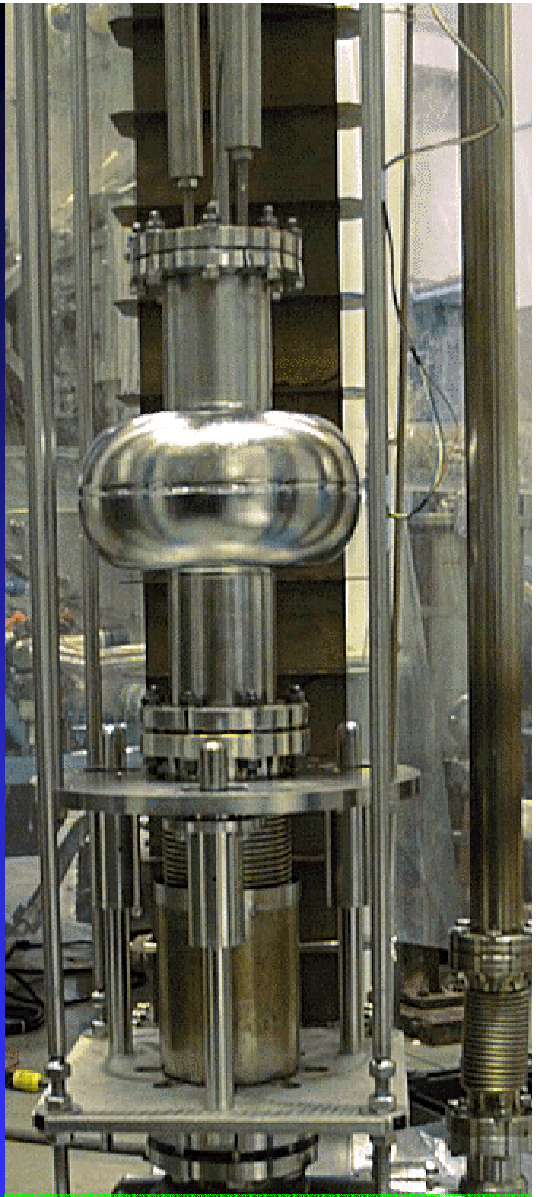
First test reached Eacc = 27 MV/m

CCO-EP applied to single cell

Soft multipacting barrier near Epk = 55 MV/m

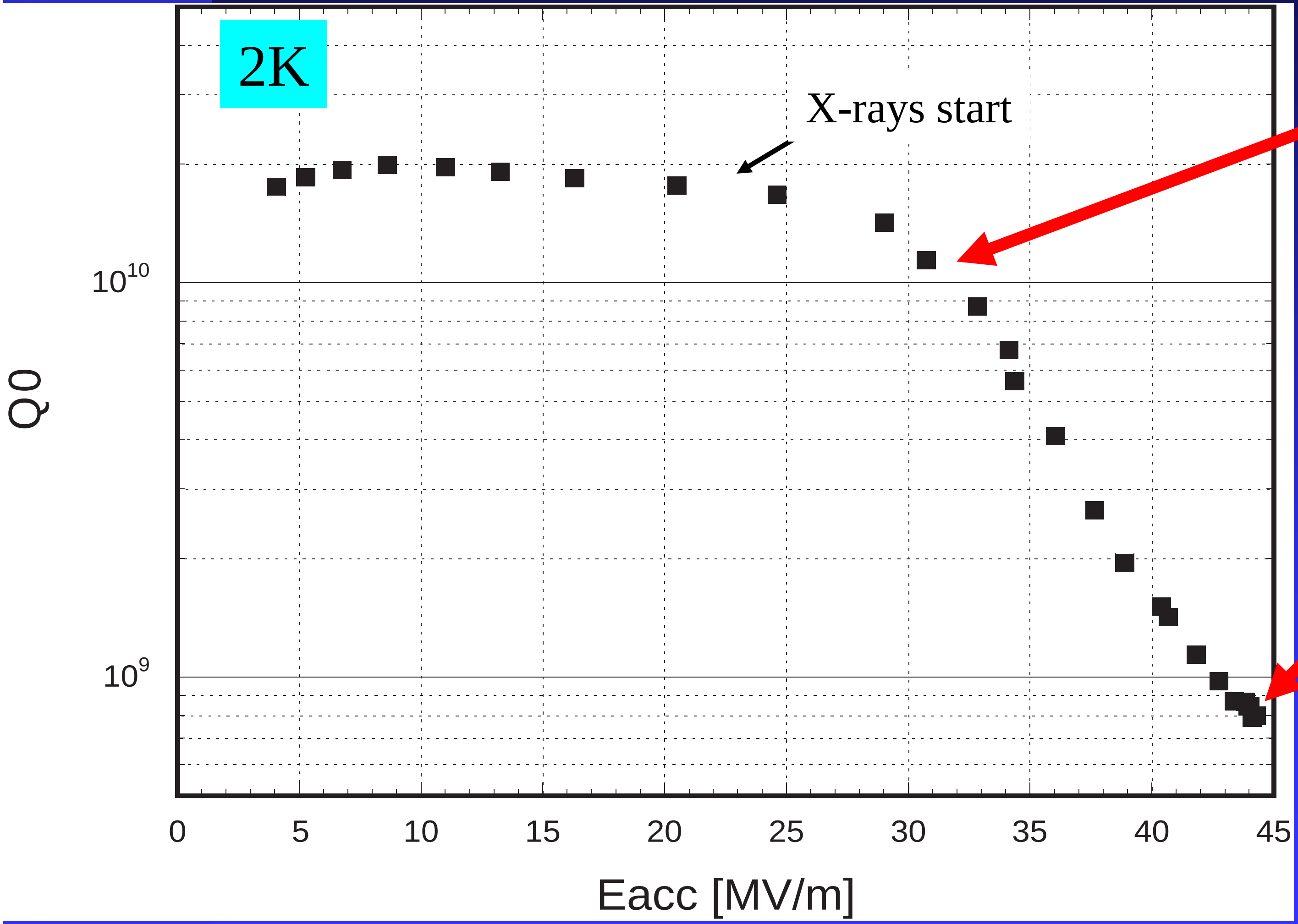
Gas helium processing at Epk > 90 MV/m

Highest Eacc = 44.4 MV/m



Test stand has MW capability for HPP with short RF pulse

Achieved performance

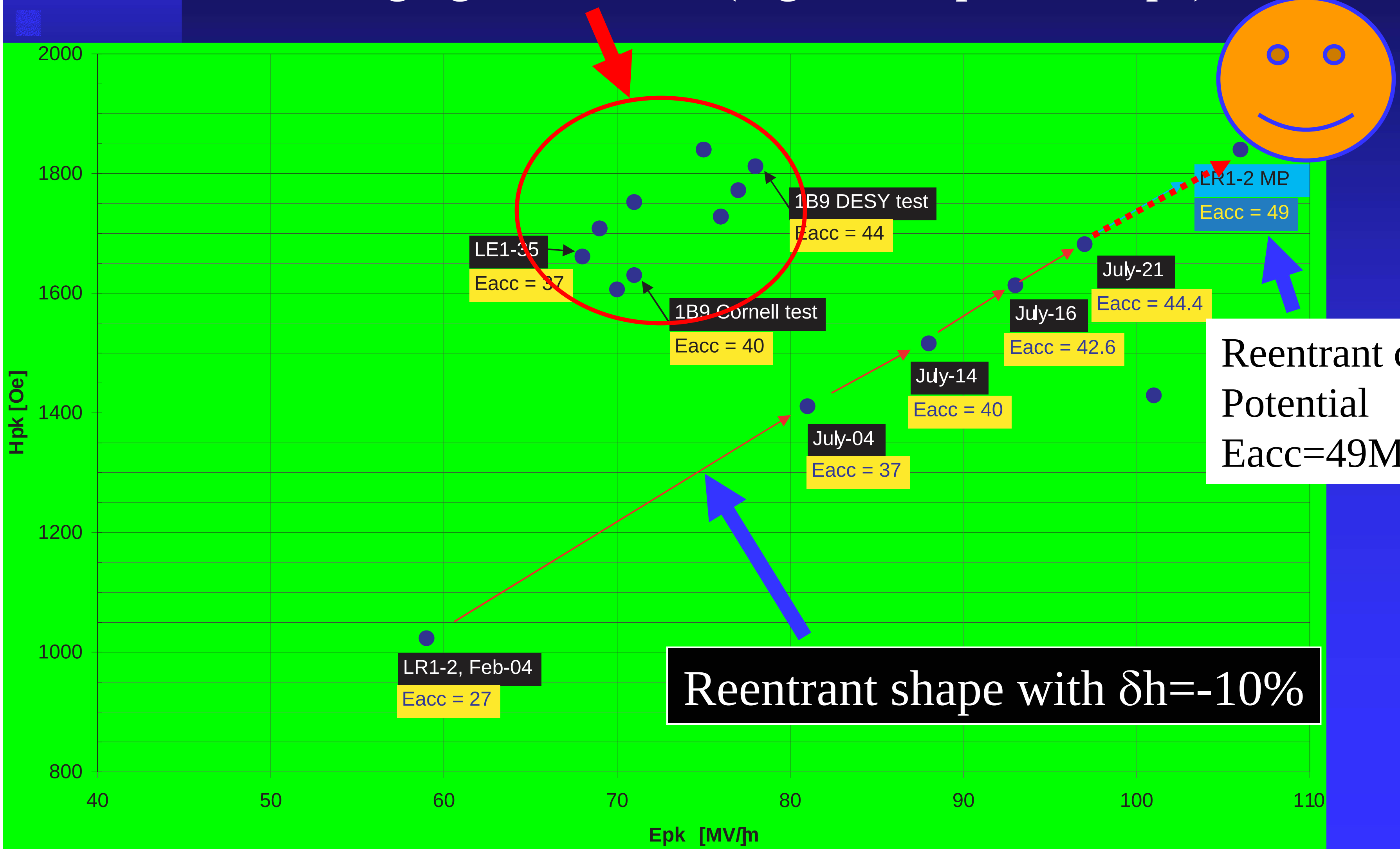


Q_0>1E10 at 30 MV/m

Eacc = 44.4 MV/m
Quench limit

High gradient cavity comparison

World high gradient data (regular elliptical shape)



Reentrant cavity
Potential
Eacc=49MV/m

Reentrant shape with δh=-10%

Summary

Nb cavity with Eacc in excess of 44 MV/m demonstrated.

Reentrant geometry has no multipacting limit.

Half-cell technology is viable for high gradient.

Epk reached ~ 100 MV/m, FE needs to be dealt with seriously.

Helium processing at Epk > 90 MV/m boosts Eacc by 17%.

Hpk reached ~ 1700 Oe so far, push beyond 1700 Oe possible.

Reentrant cavity has potential to reach Eacc ~ 50 MV/m.

Acknowledgement

RF design of reentrant cavity by
Valery Shemelin

In building/testing reentrant cavity, crucial contributions made by
Curtis Crawford
Joe Kirchgessner
Andy Seaman
James Sears

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