BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

ACCELERATOR DEPARTMENT
Informal Report

MASTER

RF ACCELERATING CAVITIES FOR ISABELLE

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November 19, 1971

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CRISP 71-42
 ISABELLE PROJECT

INTERSECTING STORAGE ACCELERATOR NOTES

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The parameters for rf acceleration in ISABELLE are outlined in CRISP 71-14. They are:

harmonic number, h	=	30
accelerating frequency, f_0	=	4.45 MHz
rf voltage, V	=	40 kV
stable phase angle during acceleration ϕ_s	=	15 degrees
beam intensity, I_b	=	6×10^{14} protons = 15 amps.

The frequency change required for full acceleration to 216 GeV is 0.05%, therefore a fixed tuned accelerating cavity with adequate bandwidth is proposed.

Commercial vacuum capacitors for this frequency range are readily available in the 10 kV to 20 kV voltage range. If a gap voltage of 10 kV is chosen, tuning capacitors can be procured with good over voltage ratings to allow fault transients. Four gaps are therefore required.

As described in CRISP 71-39 the tuning capacity must be sized compatible with the desired circulating beam and the gap voltage.

$$C = \frac{1}{2\pi f_0} \cdot \frac{I_b Q}{2rV}$$

where Q is the tank circuit Q and r is the ratio of permitted frequency shift to tank circuit bandwidth (see CRISP 71-39). Thus $C = 1600$ pf for $Q = 30$, $r = \frac{1}{2}$.

From this the following can be computed: $V = 0.08$ joules, $L = 0.8$ microhenries, circulating current in the tank circuit = 450 amps, power per gap = 74.5 kW.

Rf flux level in ferrite material can be increased until the heat generated in the material presents a cooling problem. Conventional edge water cooling of interleaved copper and ferrite layers will handle a heat generation rate of 0.25 watts/cc. The heat generation rate for the new conversion rf cavities accommodates 0.35 watts/cc. If we choose the conservative heat generation rate of 0.25 watts/cc, the rf flux level can be determined from previous measurements as 67 gauss; 4.45 MHz is a point on existing measurements. For other frequencies it can be extrapolated using the following relationship

$$\text{power/volume} = K \frac{1}{\mu Q} B^2 f ,$$

where B = flux, μ = permeability.

Using the following, the ferrite air gap and core area can be computed. (Assume all the energy is stored in the air gap.)

$$4\pi I = B\ell , \quad J = \frac{B^2 A \ell}{8\pi 10^7}$$

$$\ell = 16.9 \text{ cm} , \quad A = 267 \text{ cm}^2 .$$

These dimensions lead to a practical design as shown in Figs. 1 and 2.

Table I shows similar parameters for design based on different harmonic numbers. For the $h = 30$ and $h = 50$ case, the total accelerating voltage was chosen to contain a $\Delta p/p$ of .007. The $h = 1$ case is sized to have a 30 degree stable phase point during the 120 sec accelerating rate. $h = 15$ is the point where both the conditions are satisfied by the same gap voltage.

TABLE I, SUMMARY

		h = 50	h = 30	h = 15	h = 1
Frequency	f	7.42 MHz	4.45 MHz	2.22 MHz	.154
Total peak rf voltage		69 kV	40 kV	20 kV	20 kV
Number of gaps		6	4	2	2
Nominal of volts/gap	V	11.5 kV	10 kV	10 kV	10 kV
Tuning capacitor	C	830 pf	1600 pf	3200 pf	46,25
Stored energy	J	.055 J	.08 J	.16 J	2.3 J
Circulating current	I_b	450 A	450 A	450 A	450 A
Q		30	30	30	30
Power/gap	P	85.2 kW	74.5 kW	74.4 kW	74.4
P/cc in ferrite		.25 W	.25 W	.25 W	.30 W
Cavity inductance	L	.55 μ H	.8 μ H	1.6 μ H	23.1
Ferrite material		4C4	4C4	4C4	3B7
Max. rf flux in ferrite		56 G	67 G	100 G	900 G
Total air gap	l	9.95 cm	8.5 cm	5.6 cm	.62 cm
Core area, total	A	428 cm ²	534 cm ²	710 cm ²	1156
Volume of ferrite		34,200 cm ³	42,720 cm ³	56,800 cm ³	92,48
Power in ferrite/gap		8.5 kW	10.7 kW	14.2 kW	23.1
$\Delta P/P$		.007	.007	.007	.03
Feed through beam power/gap during acceleration		25 kW	37.5 kW	75 kW	75 kW
Total rf power/gap (peak)		110.2 kW	112 kW	149.4 kW	149.4
Total rf power (peak)		661 kW	450 kW	300 kW	300 kW

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TABLE I, SUMMARY

		h = 50	h = 30	h = 15	h = 1
Frequency	f	7.42 MHz	4.45 MHz	2.22 MHz	.154 MHz
Peak rf voltage		69 kV	40 kV	20 kV	20 kV
Number of gaps		6	4	2	2
Field of volts/gap	V	11.5 kV	10 kV	10 kV	10 kV
Capacitor	C	830 pf	1600 pf	3200 pf	46,250 pf
Energy	J	.055 J	.08 J	.16 J	2.3 J
Beam current	I_b	450 A	450 A	450 A	450 A
		30	30	30	30
Power gap	P	85.2 kW	74.5 kW	74.4 kW	74.4 kW
Power in ferrite		.25 W	.25 W	.25 W	.30 W
Inductance	L	.55 μ H	.8 μ H	1.6 μ H	23.1 μ H
Core material		4C4	4C4	4C4	3B7
Flux in ferrite		56 G	67 G	100 G	900 G
Gap length	l	9.95 cm	8.5 cm	5.6 cm	.62 cm
Area, total	A	428 cm ²	534 cm ²	710 cm ²	1156 cm ²
Volume of ferrite		34,200 cm ³	42,720 cm ³	56,800 cm ³	92,480 cm ³
Power in ferrite/gap		8.5 kW	10.7 kW	14.2 kW	23.1 kW
		.007	.007	.007	.03
Through beam power/gap during operation		25 kW	37.5 kW	75 kW	75 kW
RF power/gap (peak)		110.2 kW	112 kW	149.4 kW	149.4 kW
RF power (peak)		661 kW	450 kW	300 kW	300 kW

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Fig. 1

Fig. 2