- Title

High Gradient Air Core Cavity for Long Bunch

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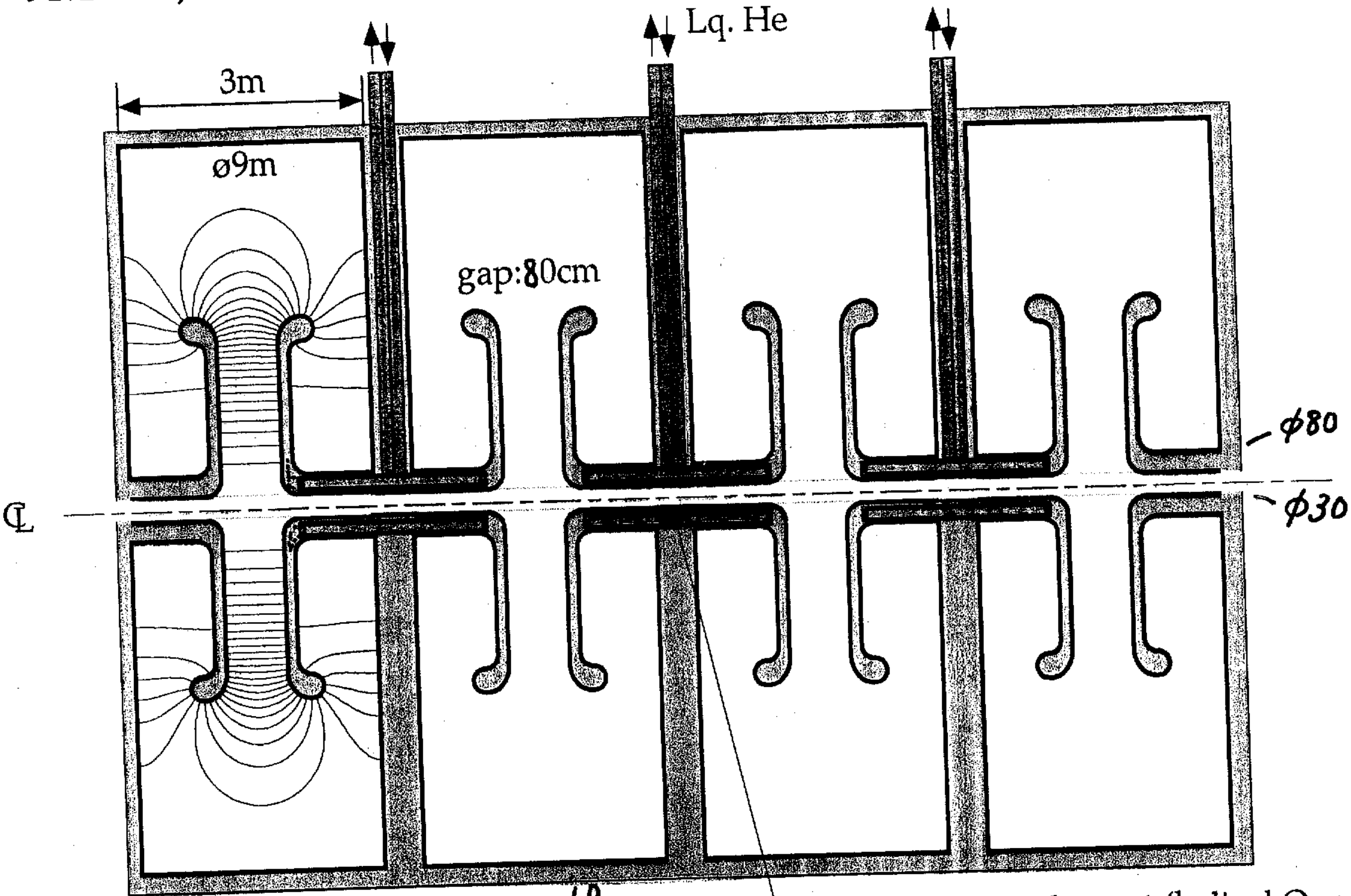
- Introduction– LFC, CPEC for Muons
- Scenario A: Very Low Frequency Air Core Cavity
- Scenario B : CPEC – Dual Frequency Cavity

• f=9MHz , 1MΩ/m, 1.5MV/m, 6MW$_{peak}$/cavity



Superconducting Solenoid Coil (ø40cmx2.6m) or other focusing element (helical Q magnet?)

(simple pillbox cavity with ø25.4m has Z=3MΩ/m and can genarate ~18MV/3m at 9MHz.)

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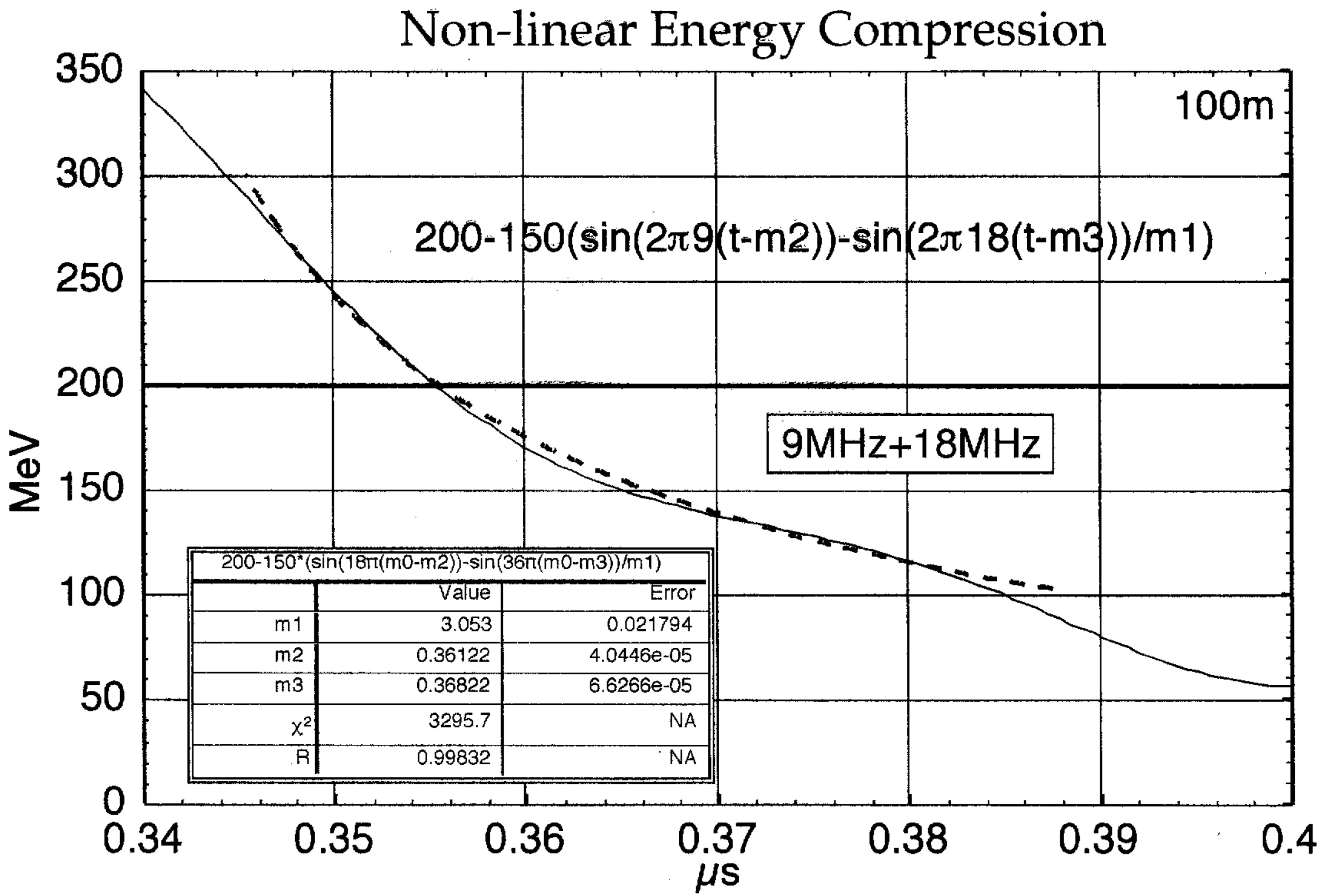
• Scenario A: Very Low Frequency Air Core Cavity



200-150*(sin(18π(m0-m2))-sin(36π(m0-m3))/m1)		
	Value	Error
m1	3.053	0.021794
m2	0.36122	4.0446e-05
m3	0.36822	6.6266e-05
χ^2	3295.7	NA
R	0.99832	NA

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• Very Rough Cost Estimation and Summary with LFC (D9L3)

narrow band, pulse

Let us suppose that

Cost = A [yen/m] x L [m] (cavity cost) + B [yen/MW] x P [MW] (amp. cost)

And use:

$(V[MV])^2 = Z[M\Omega/m] \times L[m] \times P\,[MW]$ or $P = V^2/(Z \times L)$.

We get

$Cost = A \times L + B \times V^2/(Z \times L)$ —> $Cost_{min} = 2 \times A \times L$ @ $L = (B/A \times Z)^{1/2} V$.

Assuming that A = 50 M (30~50M?) [yen/m], V = 100 [MV],

B = 50 M (50~70M?) [yen/MW], Z = 1 [MΩ/m],

we get total cost of 10G [yen] at L=100m (100億円 or ~$100M?).

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f=9MHz Z=1.4MΩ/m x 80% →1.1MΩ/m

Z=1.1MΩ/m
P=6MW/3m } E~1.5MV/m → 4.5MV@3m

Q ~3.2×10^4 x 80% → filling time: $\tau = Q/\omega$ ~ 450μs

E_{max}~7MV/m~$1.4E_{kp}$ (E_{kp}=5MV/m @ 9MHz)

L=100m → P_{cav}=6MW x 33 unit = 200MW peak

(simple pill box cavity with ø25.4m has Z=3MΩ/m and can genarate ~18MV/3m.)

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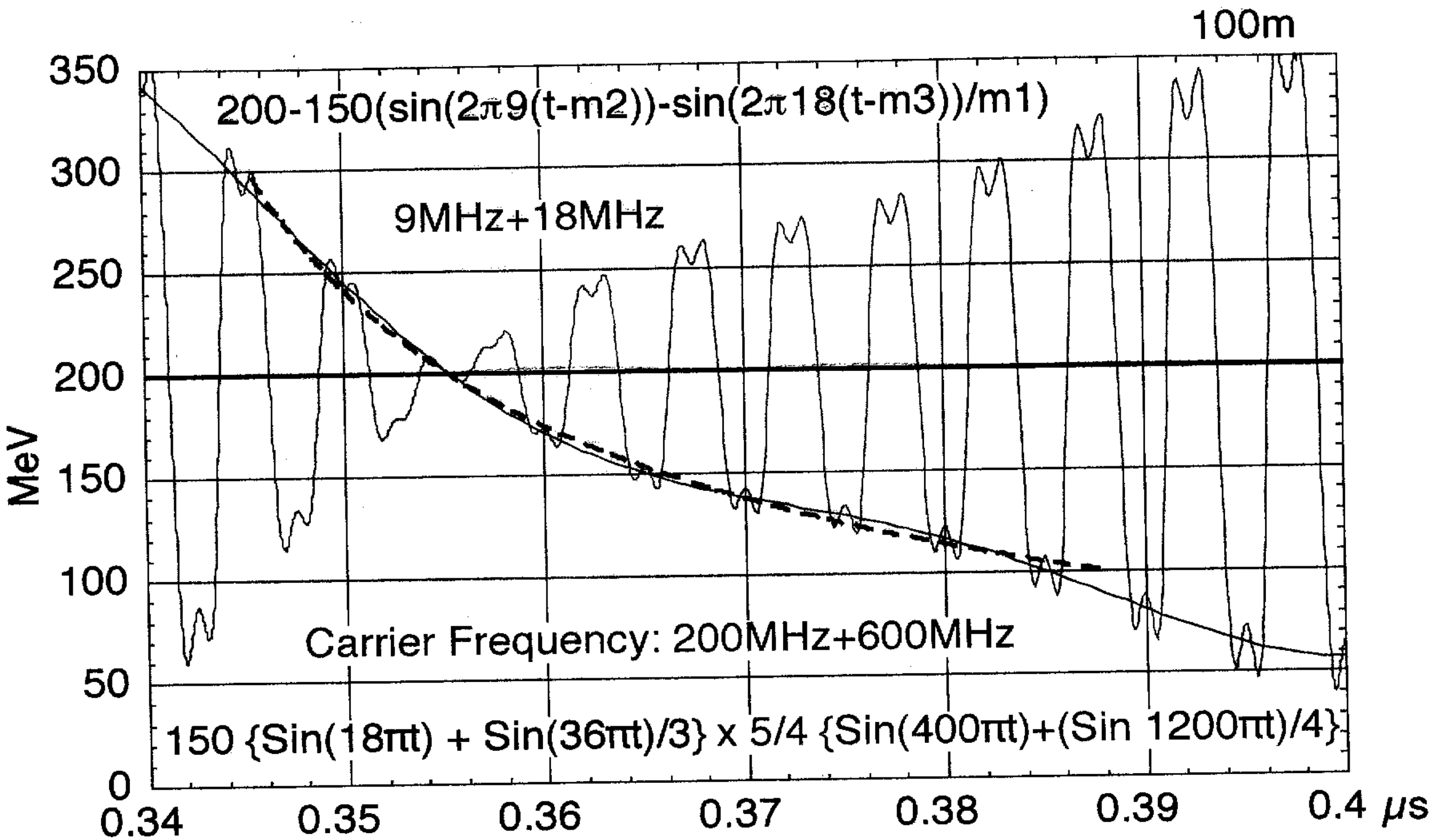
• Scenario B: Comb Pulse Energy Compression – DFC



- This waveform can be generated by eight cavities!
- Drops 2/3 but both + and – particles are included!
- Phase splips between cavities may be harmful!

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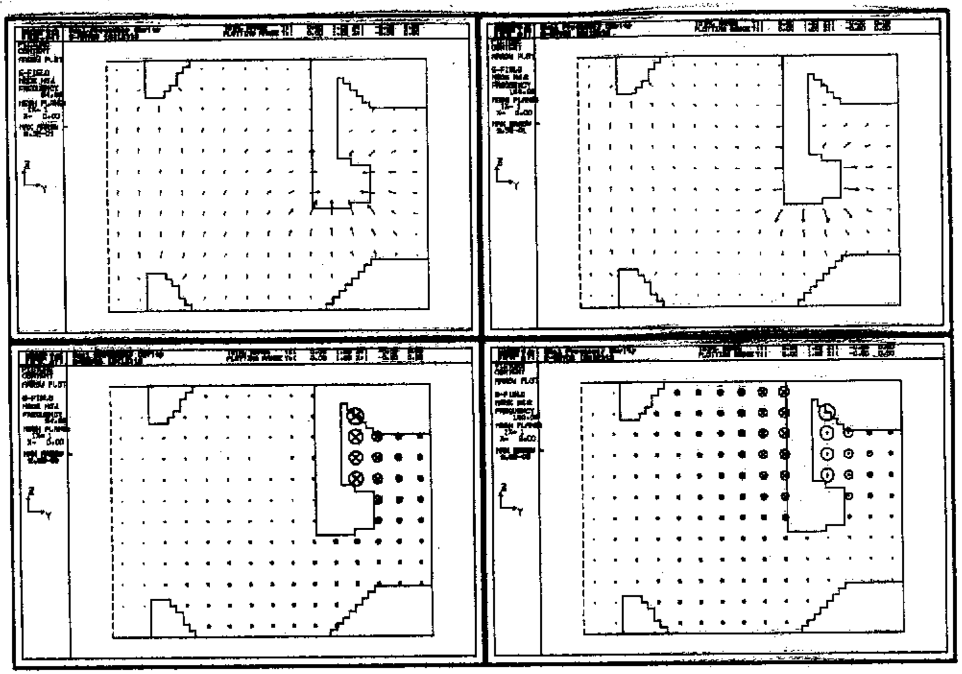
•Dual Frequency Cavity



DATE: 2-MAY00 TIME:15:57:15 JOBNAME:IWASHITA V88023

ELECTRICAL COMPONENTS OF FORCE INTEGRAL

	X-COMPONENT	Y-COMPONENT	Z-COMPONENT
INTEGRAL E*COS(WZ/V)DZ=	-1.219921E-06	-1.537037E-06	0.147603
INTEGRAL E*SIN(WZ/V)DZ=	-5.781545E-06	-6.344526E-06	-3.175485E-03

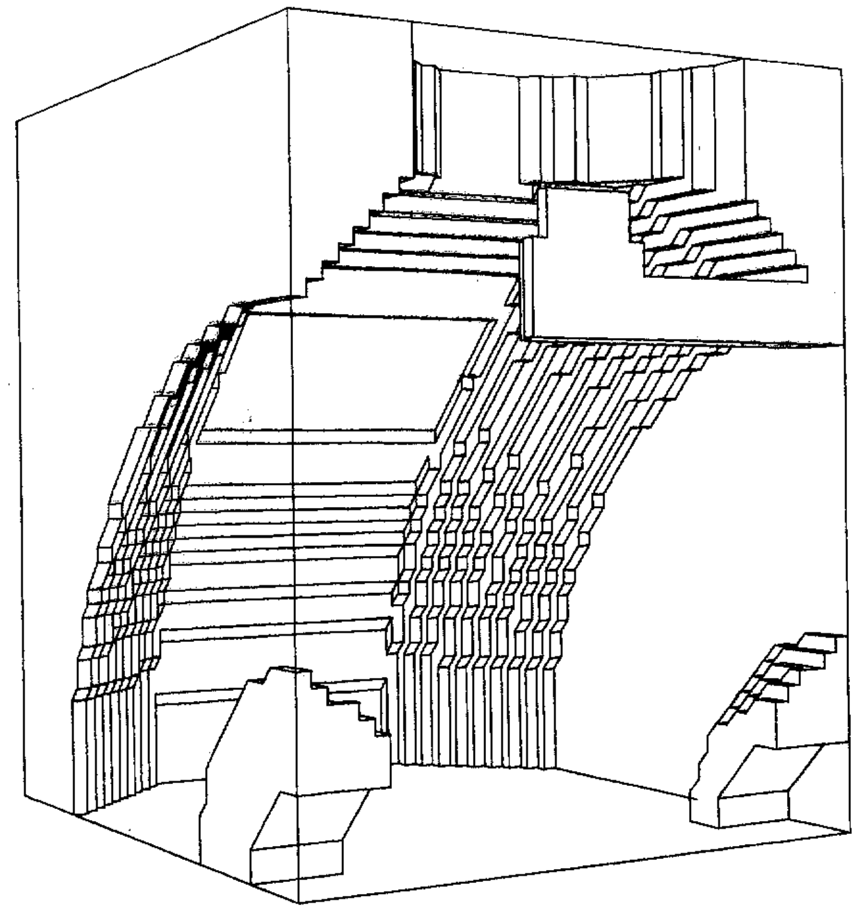
POTENTIAL = 0.164914 **7.85 MΩ**

ELECTRICAL COMPONENTS OF FORCE INTEGRAL

	X-COMPONENT	Y-COMPONENT	Z-COMPONENT
INTEGRAL E*COS(WZ/V)DZ=	1.444880E-06	1.876839E-06	0.129063
INTEGRAL E*SIN(WZ/V)DZ=	-6.309247E-06	-4.866613E-06	4.196561E-03

POTENTIAL = 0.154690 **7.2 MΩ**

MODE	FREQUENCY(MHZ)	TOTAL_ENERGY/pJ	LOSSES/μW	Q
1	94.659	6.103E-02	8.656E-04	4.194E+04
2	120.060	4.785E-02	8.311E-04	4.344E+04
3	188.344	0.247	4.260E-03	6.874E+04



Rough Example

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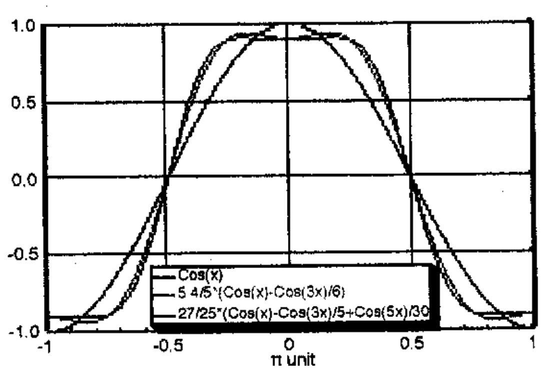
• CPEC Assemble with DFC

reduction of trigonometric function
only lowest freq. - 4 terms (+1)
reduced from 8 to 5 cavities

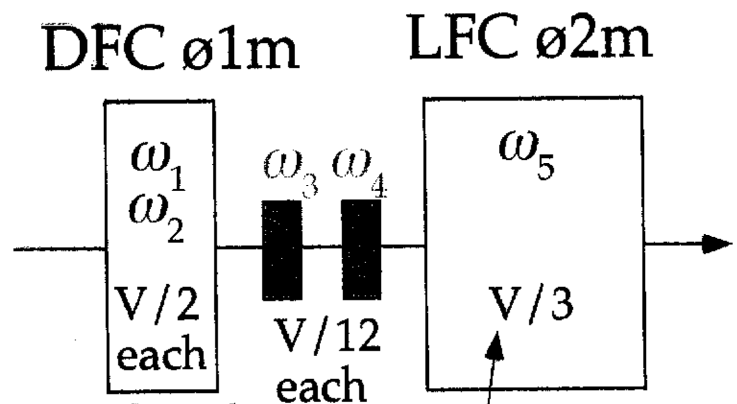
$$\sin(\omega t - \phi_1)\left(\cos\omega_c t - \frac{1}{6}\cos 3\omega_c t\right)$$

$$= \frac{1}{12}\left(-\sin(\omega t - 3\omega_c t - \phi_1) + 6\sin(\omega t - \omega_c t - \phi_1) + 6\sin(\omega t + \omega_c t - \phi_1) - \sin(\omega t + 3\omega_c t - \phi_1)\right)$$

e.g.
191MHz,209MHz,
591MHz,609MHz (if needed)
+18MHz
V=12MV / module
($E_{Kilpatrick}$~15MV / m@200MHz)



One Module



If Z=5MΩ and
P=7MWpeak for
each mode, each cavity,
E=6MV / m x2

Conventional Low
Frequency Cavity

Should be easy for these cavities

May be reduced if transit time factor is considered

• Modulated Buncher

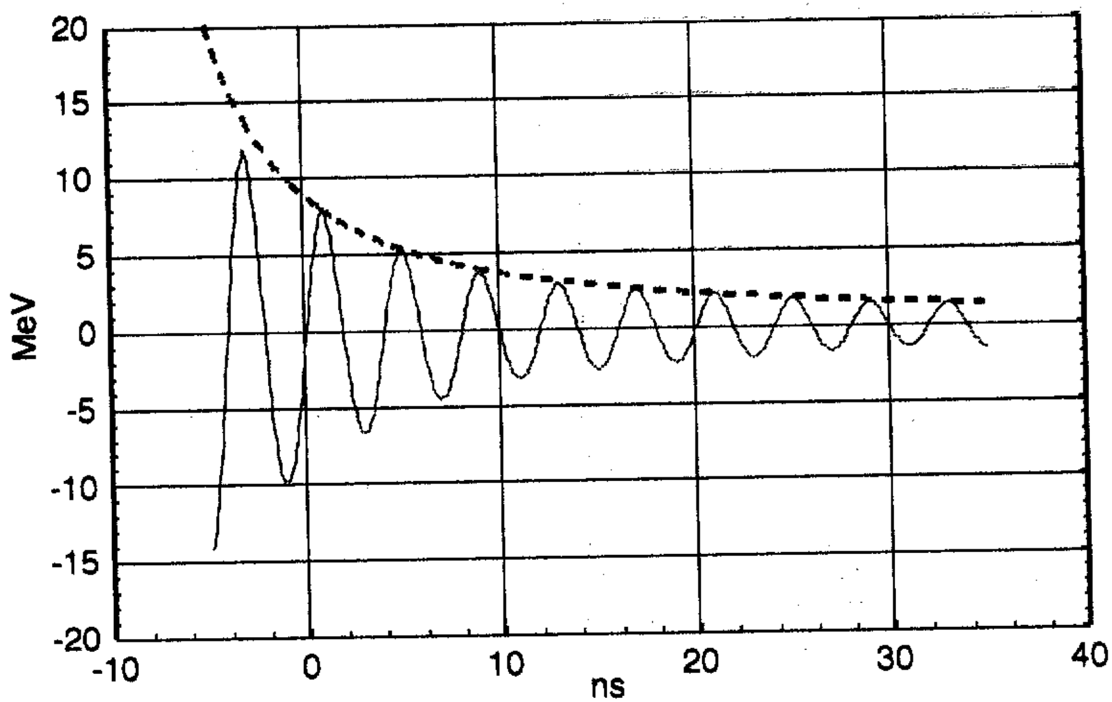
Bunching voltage changes to match the energy.

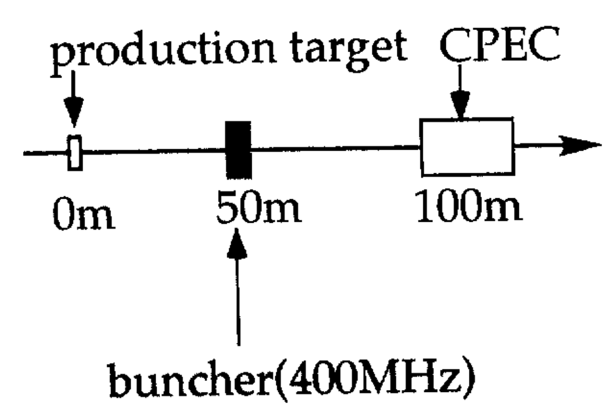
reduction of trigonometric function

(16.8 - 20 Sin[9.35 t] - 5.2 Sin[18.7 t]) Sin[400 t] =

-2.6 Cos[381.3 t]-10 Cos[390.65 t]+10 Cos[409.35 t]+2.6 Cos[418.7 t]+16.8 Sin[400 t]

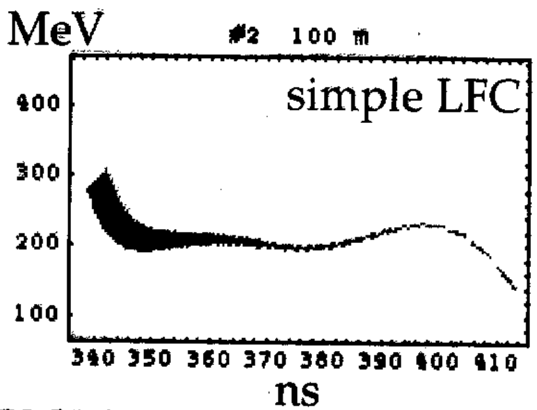
(phase constants are omitted)

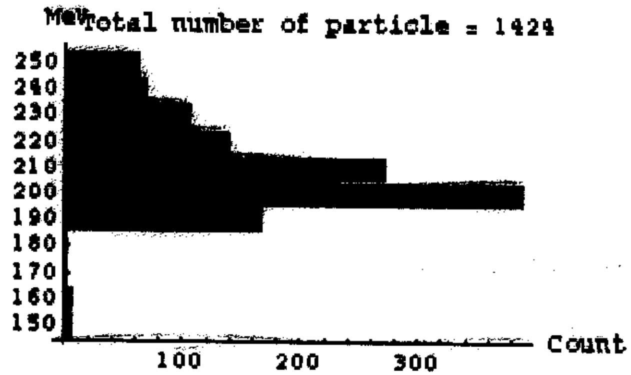




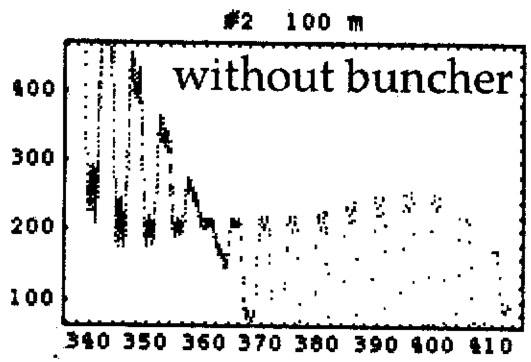
•CPEC rough simulation

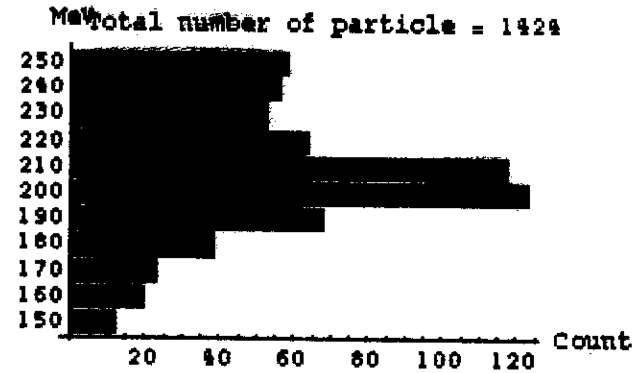
Initial Condition:
±1.5ns time spread
100m after production target
uniform energy distribution.



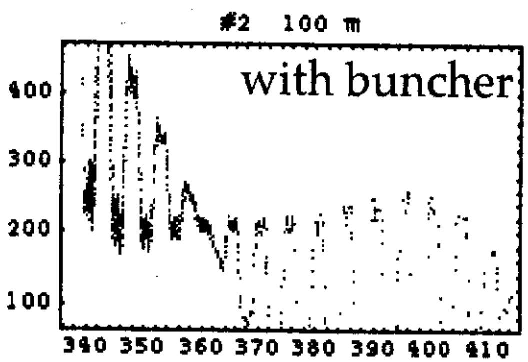


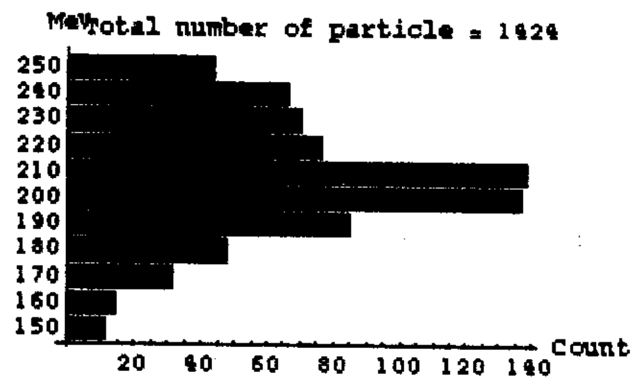
Just low frequency cavities (9MHz+18MHz)

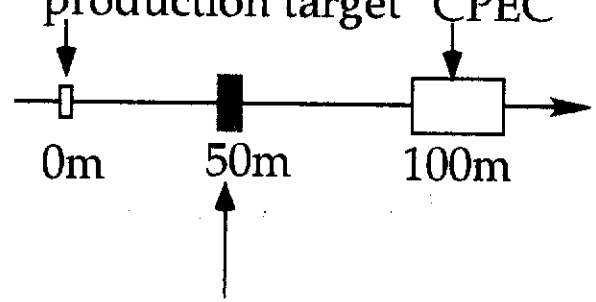




Cavities used:
191, 209 MHz 100 MV (10m)
591, 609 MHz 25 MV (2m)
18 MHz 50 MV (20m?)







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- Concluding Remaks

✌ Air Core Cavity has higher Z and High Gradient

✌ CPEC scheme reduces cavity size.
higher shunt impedance
higher field gradient
bunched (modutaled buncher)

! LFC – ø9m x 3m @ 9MHz.
Very Large Diameter
Civil Engineering?
buried in a building (tank ship?)

! CPEC –
Only 30% saved ... with prebuncher?
Both μ+ and μ- can be gathered
complicated system?
phase slip between cavities

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