1 GeV リニアックの　簡単な考察

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構成　ion source + RFQ + DTL + CCL

RFQ	50 keV ---> 2 MeV	200 MHz
DTL	2 MeV ---> 100 MeV	200 MHz
CCL	100 MeV ---> 1 GeV	600 MHz

上の区分は更に最適化されるべき値である。

Criterion for optimized design

1. almost no beam loss at the high energy part
2. low cost of construction (structure and rf)
3. low cost of operation
4. reliability of operation

Given parameters

peak 10 mA, 500 μsec, 50 Hz

rf pulse length 550～650 μsec

duty factor　2.75～3.25%

決めるもの

1. type of structure
   RFQ DTL は決まり、CCL は相当のstudyをしないと決まらない。
2. rf frequency
3. transition energy
4. accelerating field
5. synchronous phase
6. bore radius and focusing parameters

86.6.23 から約一週間の間にした結果を簡単にまとめる。計算に使用した値の不確定性が大きい事に注意するが、パラメーターの比較には充分役立つと思われる。

1) Power consumption in CCL vs. frequency and E_0　　Fig.1, Fig.2

assumption　ZT^2 in 800 MHz = 33 MΩ/m

$ZT2 \propto \omega^{1/2}$

Accelerating field = Kilpatrick limit/6

CCL　100 MeV ----> 1000 MeV

$$Pc = E_0^2 / (Pc/L) = V2 / (ZT^2 L\cos\phi\cos\phi) = VE_0T/(ZT^2\cos\phi)$$

	800 MHz	600 MHz	400 MHz
E0 (MV/m)	4.44	3.84	3.24
ZT^2 (MΩ/m)	33	28.58	23.33
L (m)	289.0	334.1	396.0
Pc (MW)	113.2	113.1	116.9

beam power　10 mA, 20 mA ----> 9 MW, 18 MW

2) DTL injection energy (0.75 -- 2.25 MeV)

frequency (200, 400 MHz)

synchronous phase (-26, -30, -35 degree)

Normalized acceptance	Fig.3
Longitudinal current limit	Fig.4
Bmax of Q-magnet	Fig.5

3) Dumping in DTL

final energy (70, 100, 150, 200 MeV)
synchronous phase (-26, -30, -35 degree)
beam current (0, 0.02, 0.2 A)

free parameter = ratio of average radius at entrance and exit
これは focusing の選び方により、自由に選択できる。

assumption

200 MHz, max. beam radius = 1.2 cm, modulation ψ =2.43
initial half phase spread = ABS (ϕ)
injection energy = 2 MeV

half bunch at exit (-26° , 0.2 A)	Fig.6
half bunch at exit (-30° , 0.2 A)	Fig.7
half bunch at exit (-35° , 0.2 A)	Fig.8
half bunch at exit (-26° , 0.02 A)	Fig.9
half bunch at exit (-30° , 0.02 A)	Fig.10
half bunch at exit (-35° , 0.02 A)	Fig.11

$\Delta\phi$ max1 / $\Delta\phi$ 1 = safety factor (-26° , 0.2 A)	Fig.12
$\Delta\phi$ max1 / $\Delta\phi$ 1 = safety factor (-30° , 0.2 A)	Fig.13
$\Delta\phi$ max1 / $\Delta\phi$ 1 = safety factor (-35° , 0.2 A)	Fig.14
$\Delta\phi$ max1 / $\Delta\phi$ 1 = safety factor (-26° , 0.02 A)	Fig.15
$\Delta\phi$ max1 / $\Delta\phi$ 1 = safety factor (-30° , 0.02 A)	Fig.16
$\Delta\phi$ max1 / $\Delta\phi$ 1 = safety factor (-35° , 0.02 A)	Fig.17

43) CCL injection

CCL frequency (400, 600, 800 MHz)
synchronous phase (-26, -30, degree)
beam current (0, 0.02, 0.2 A)

assumption

injection haif phase spread = 7.02°
injection half energy spread = 598 keV

CCL phase acceptance / input phase (-26, -30° , 0.02 A)	Fig.18
CCL phase acceptance / input phase (-26, -30° , 0.2 A)	Fig.19
CCL phase acceptance / input phase (-26, -30° , 0 A)	Fig.20
CCL half phase acceptance (-26,-30° , 0, 0.02, 0.2 A)	Fig.21
CCL half energy acceptance (-26,-30° , 0, 0.02, 0.2 A)	Fig.22
CCL energy acceptance / inj. energy spread	Fig.23

5 4) CCL focusing parameters

assumption

intertank length	0.5 m
tank length	4,5,6 m
Q mag length	0.1 m
length between antisymmetrical doublet	0.2 m
injection energy	100 MeV
synchronous phase	-30°

Normalized acceptance	(600 MHz)	Fig.24
Qmag gradient	(600 MHz)	Fig.25
Modulation factor ψ	(600 MHz)	Fig.26
Normalized acceptance	(μ =70, 50° , 5 m)	Fig.27
Modulation factor ψ	(μ =70, 50° , 5 m)	Fig.28
Qmag gradient	(μ =70, 50° , 5 m)	Fig.29

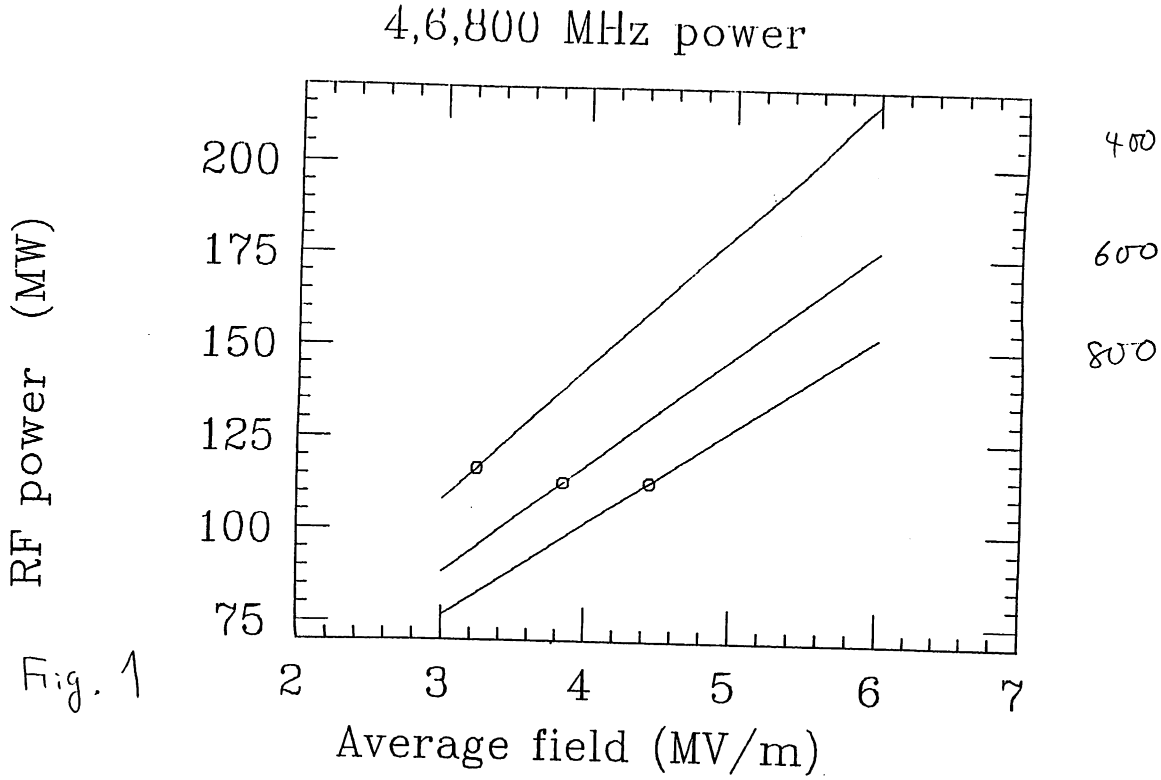

4,6,800 MHz power
RF power (MW)
200
175
150
125
100
75
2
3
4
5
6
7
Average field (MV/m)
400
600
800

Fig. 1

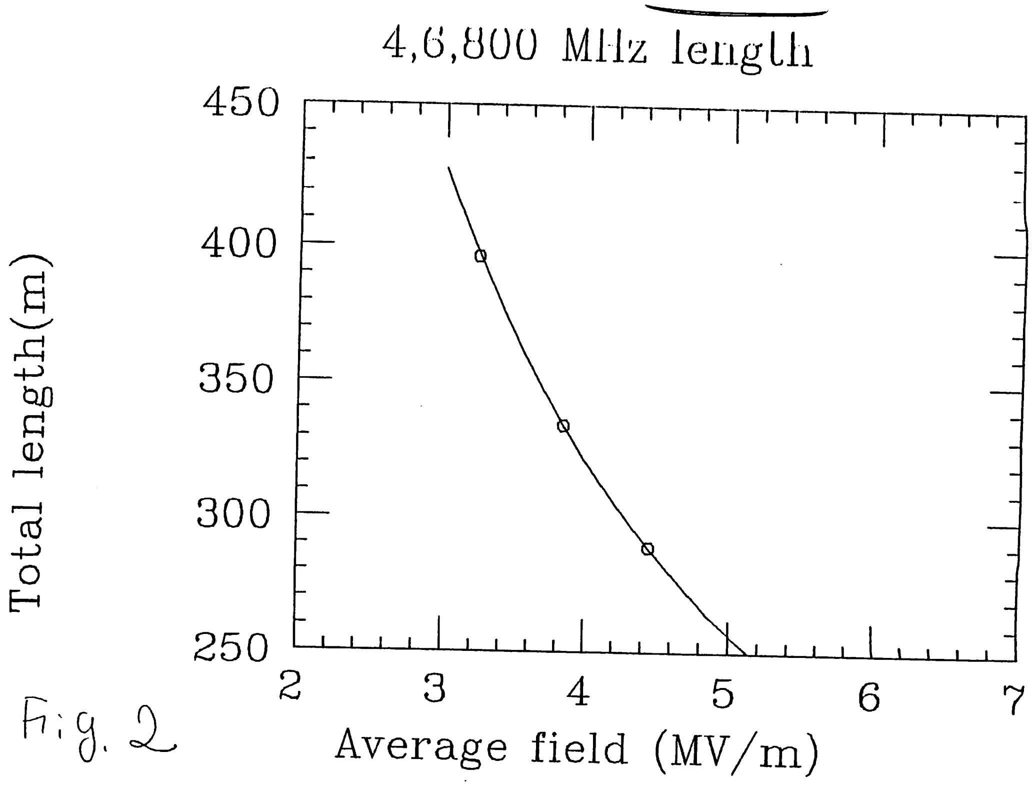

4,6,800 MHz length
Total length(m)
450
400
350
300
250
2
3
4
5
6
7
Average field (MV/m)

Fig. 2

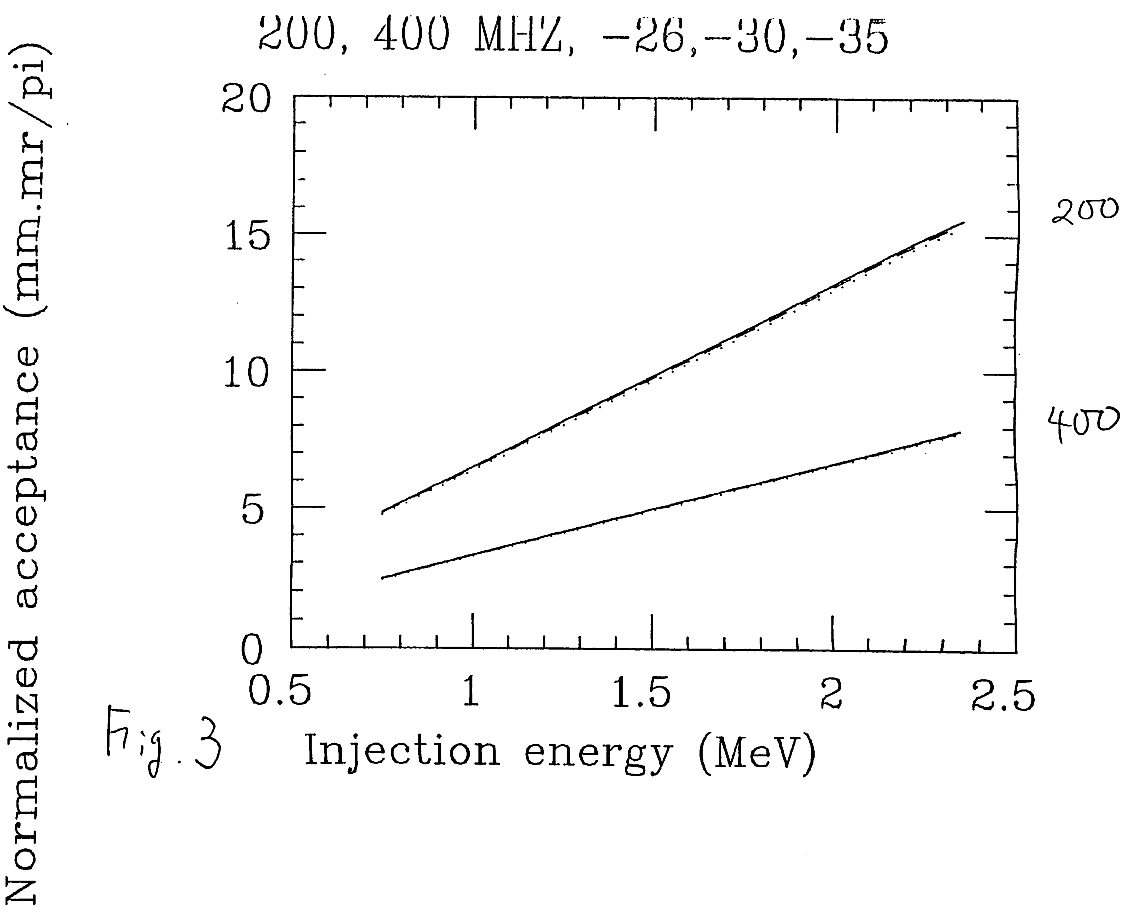

200, 400 MHZ, -26,-30,-35
Normalized acceptance (mm.mr/pi)
Injection energy (MeV)
200
400

Fig. 3

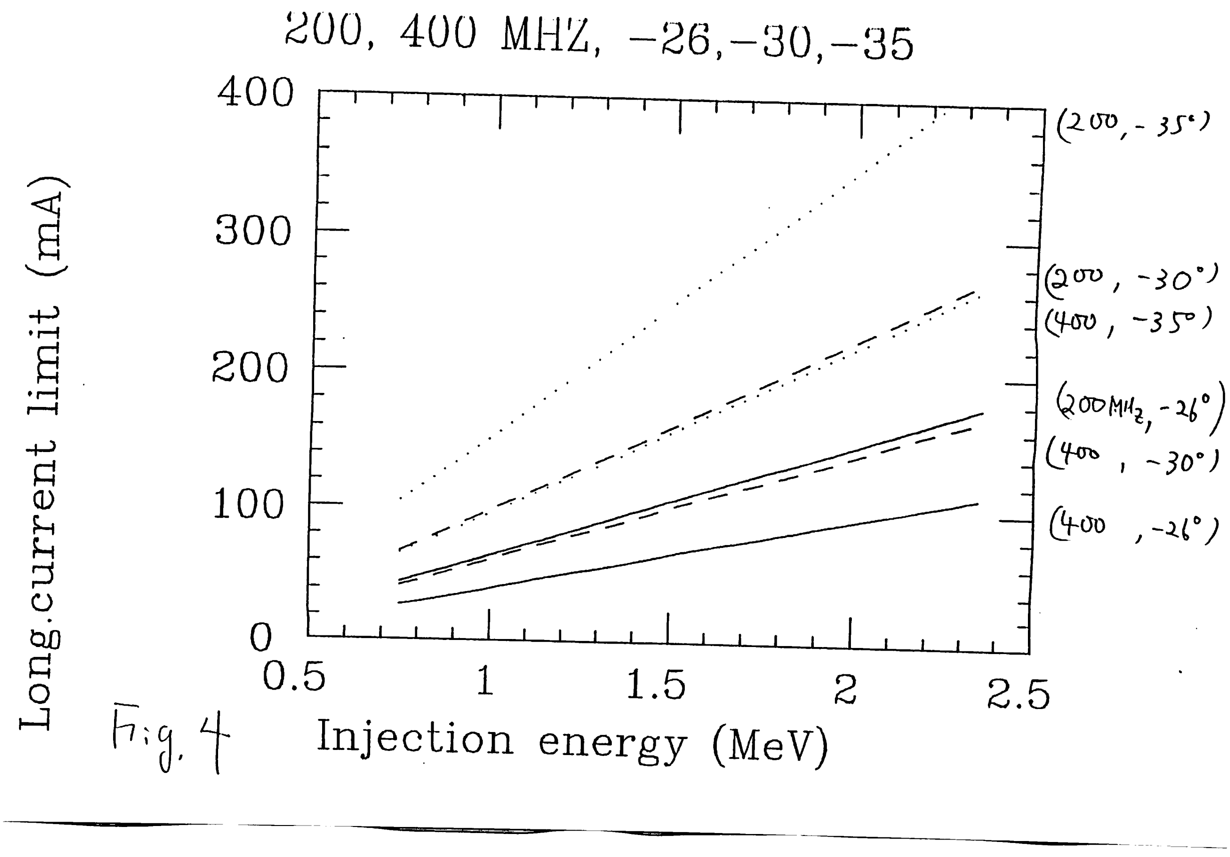
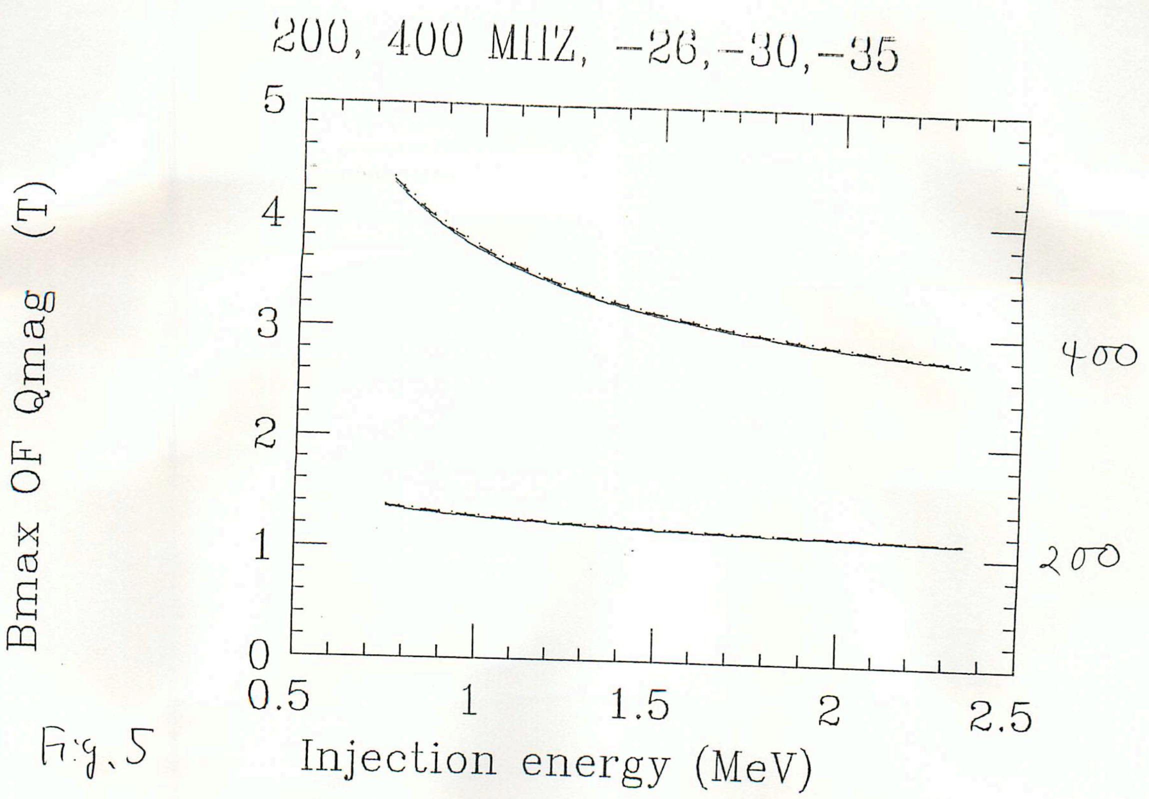
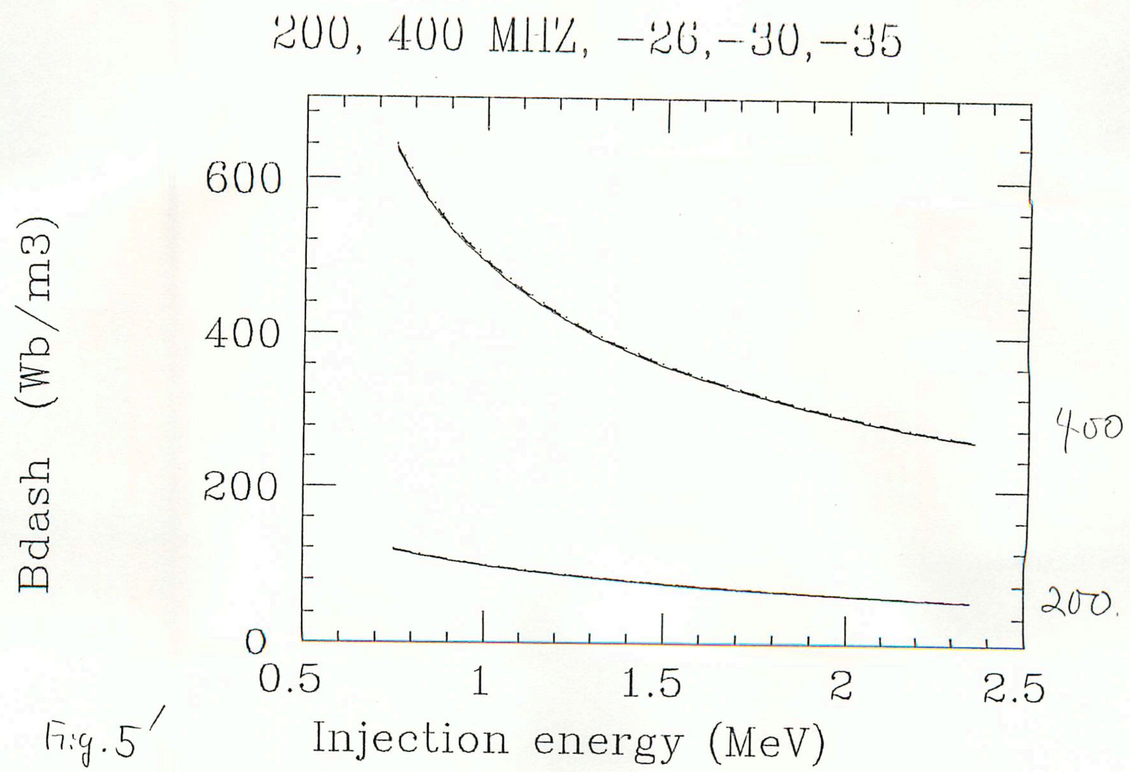

200, 400 MHZ, -26,-30,-35
Long.current limit (mA)
Injection energy (MeV)
(200, -35°)
(200, -30°)
(400, -35°)
(200MHz, -26°)
(400, -30°)
(400, -26°)

Fig. 4



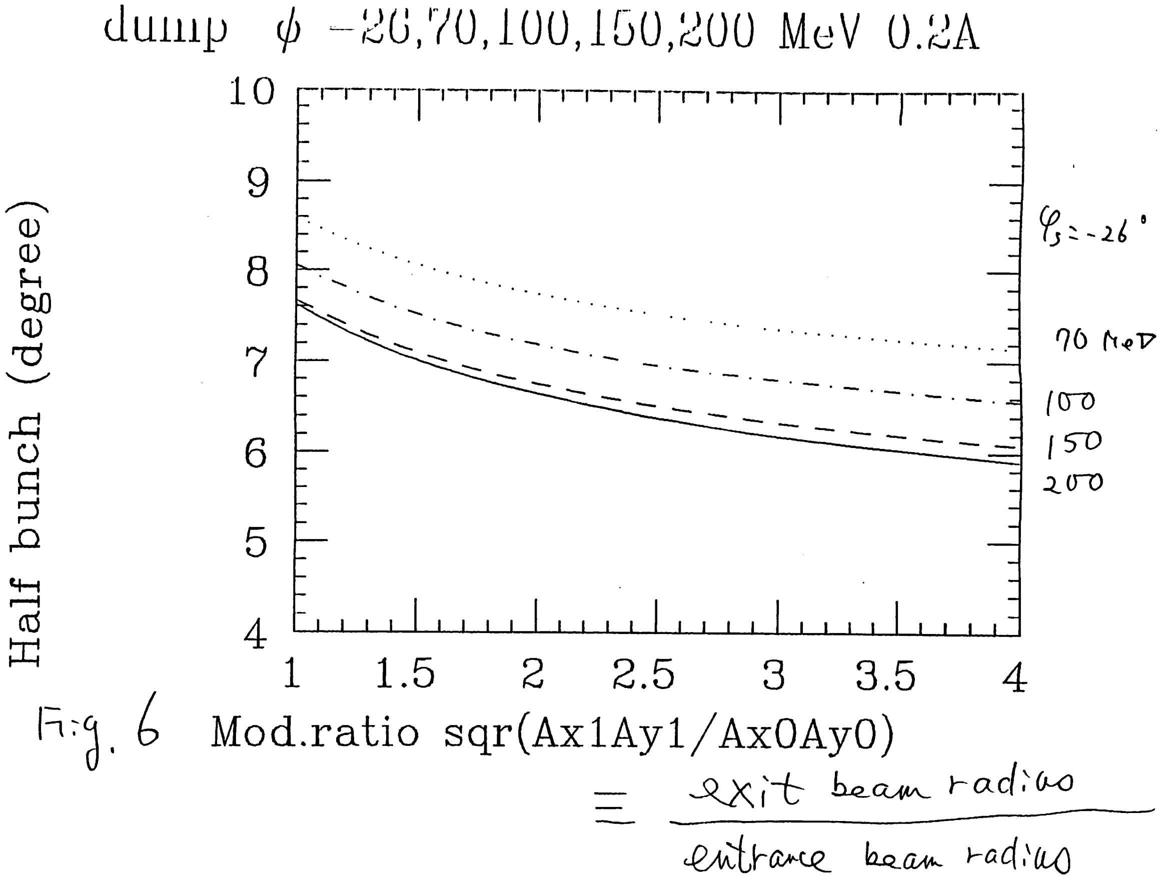
200, 400 MHZ, -26,-30,-35
Bmax OF Qmag (T)
0
1
2
3
4
5
0.5
1
1.5
2
2.5
Injection energy (MeV)
400
200

Fig. 5



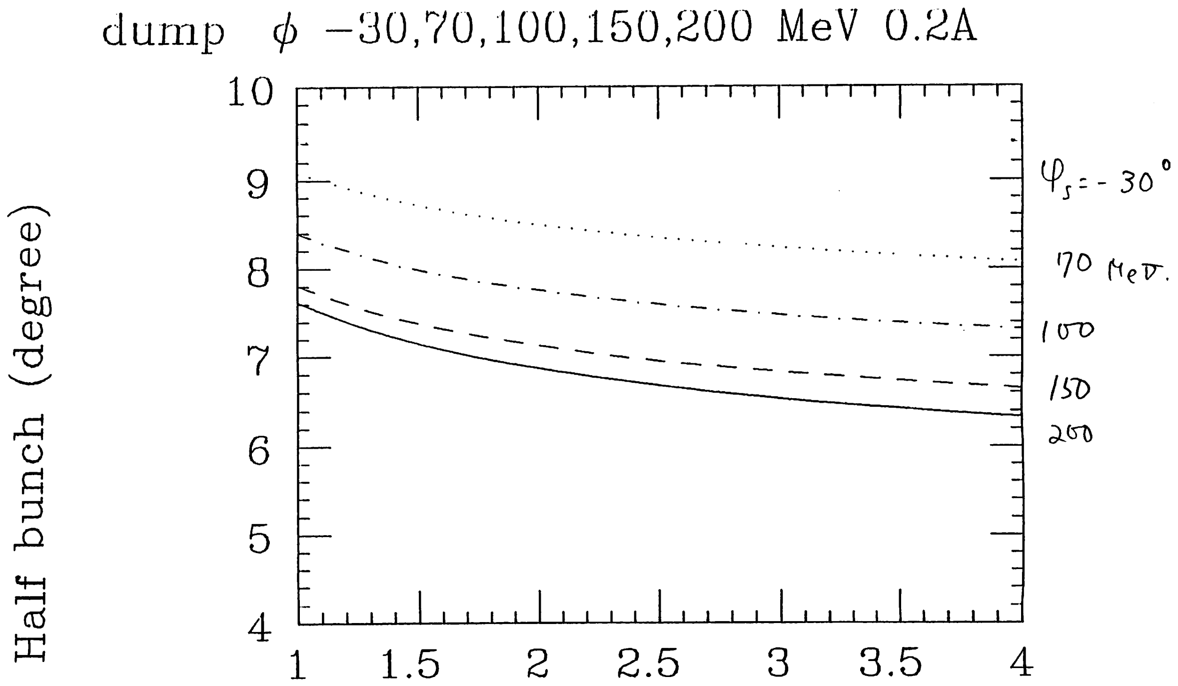
200, 400 MHZ, -26,-30,-35
Bdash (Wb/m3)
0
200
400
600
0.5
1
1.5
2
2.5
Injection energy (MeV)
400
200.

Fig. 5'



dump φ −26,70,100,150,200 MeV 0.2A
Half bunch (degree)
10
9
8
7
6
5
4
1
1.5
2
2.5
3
3.5
4
Mod.ratio sqr(Ax1Ay1/Ax0Ay0)
φs=-26°
70 MeV
100
150
200
≡ exit beam radius / entrance beam radius

Fig. 6



dump φ −30,70,100,150,200 MeV 0.2A
Half bunch (degree)
10
9
8
7
6
5
4
1
1.5
2
2.5
3
3.5
4
Mod.ratio sqr(Ax1Ay1/Ax0Ay0)
φs=-30°
70 MeV.
100
150
200

Fig. 7

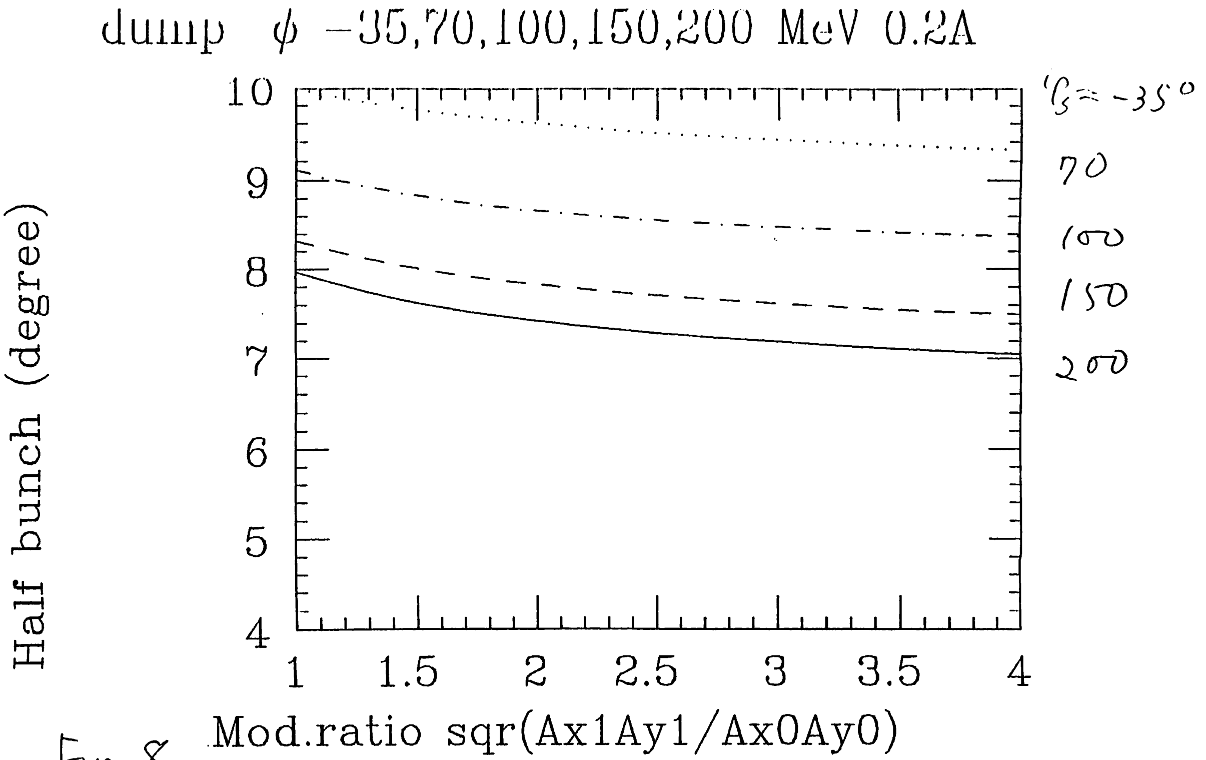

dump φ −35,70,100,150,200 MeV 0.2A
Half bunch (degree)
Mod.ratio sqr(Ax1Ay1/Ax0Ay0)
φs = −35°
70
100
150
200

Fig. 8

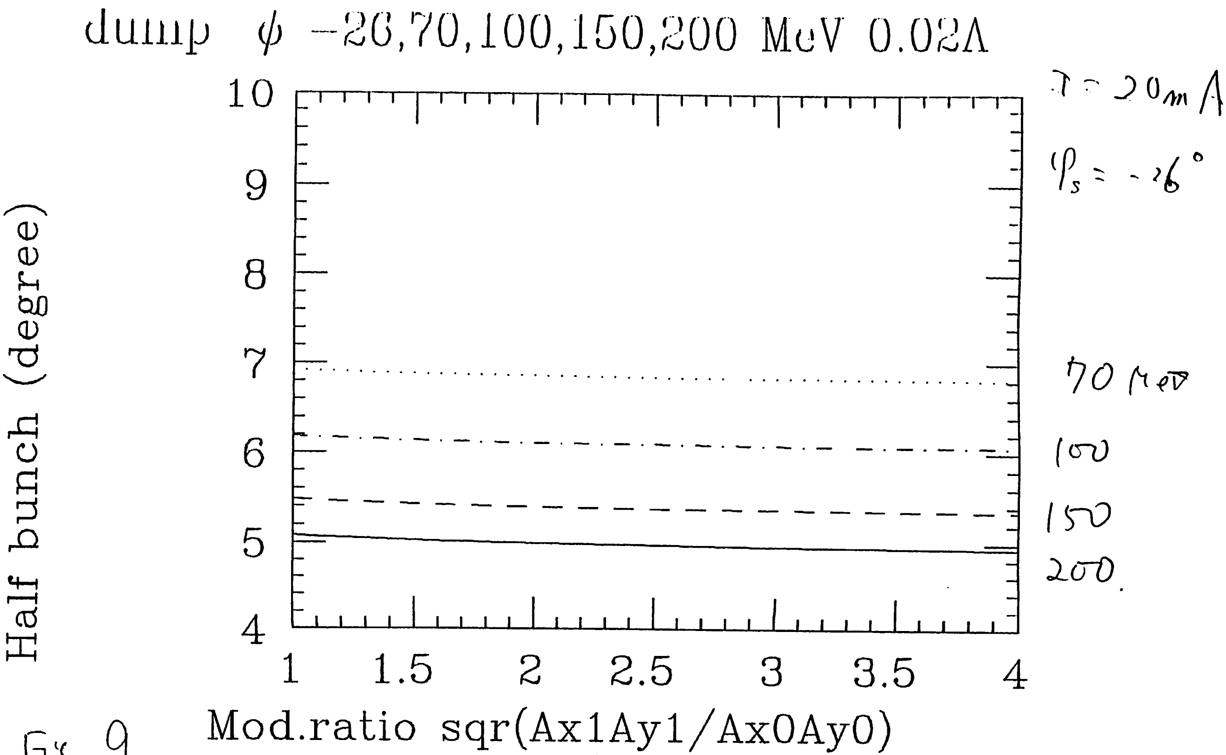

dump φ −26,70,100,150,200 MeV 0.02A
Half bunch (degree)
Mod.ratio sqr(Ax1Ay1/Ax0Ay0)
I = 20mA
φs = −26°
70 MeV
100
150
200.

Fig. 9

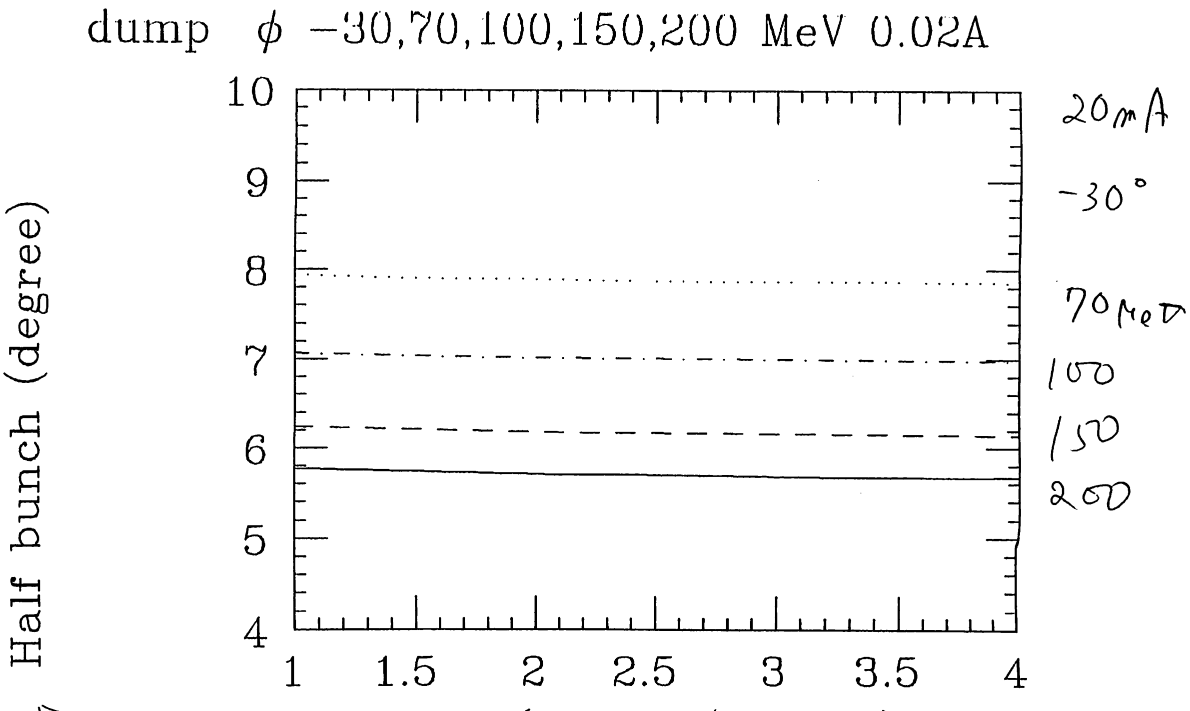


Fig.10 Mod.ratio sqr(Ax1Ay1/Ax0Ay0)

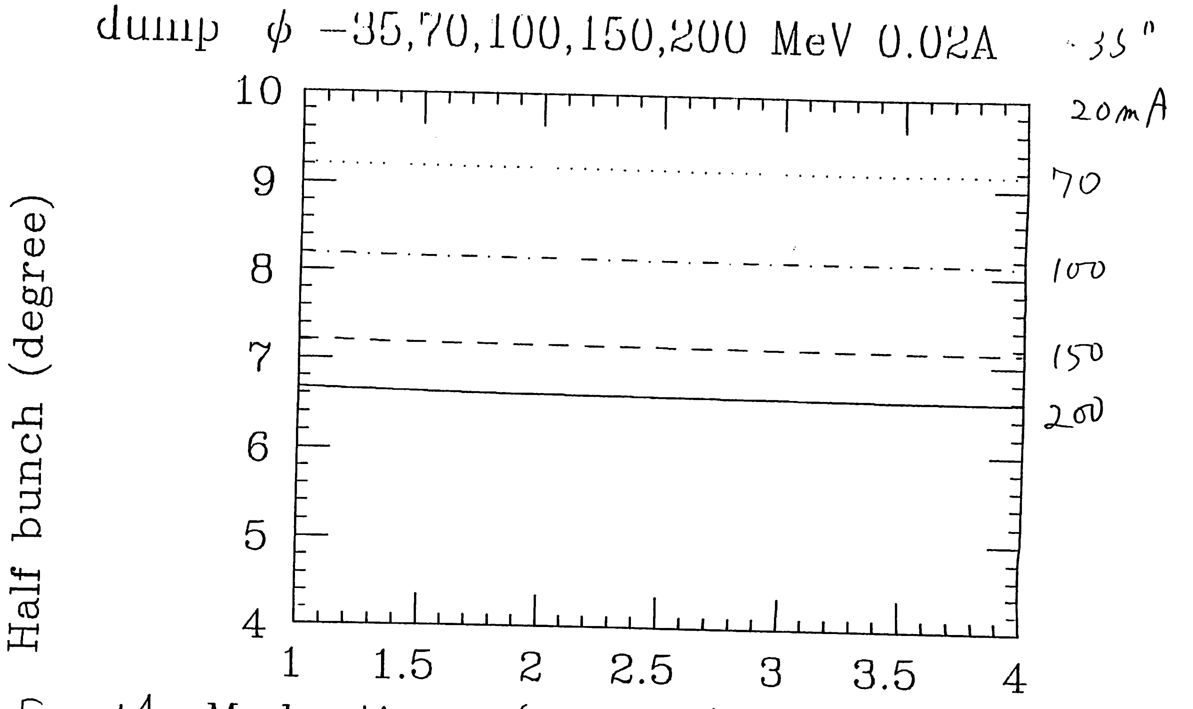


Fig. 11 Mod.ratio sqr(Ax1Ay1/Ax0Ay0)

dump TL −26,70,100,150,200 MeV 0.2A

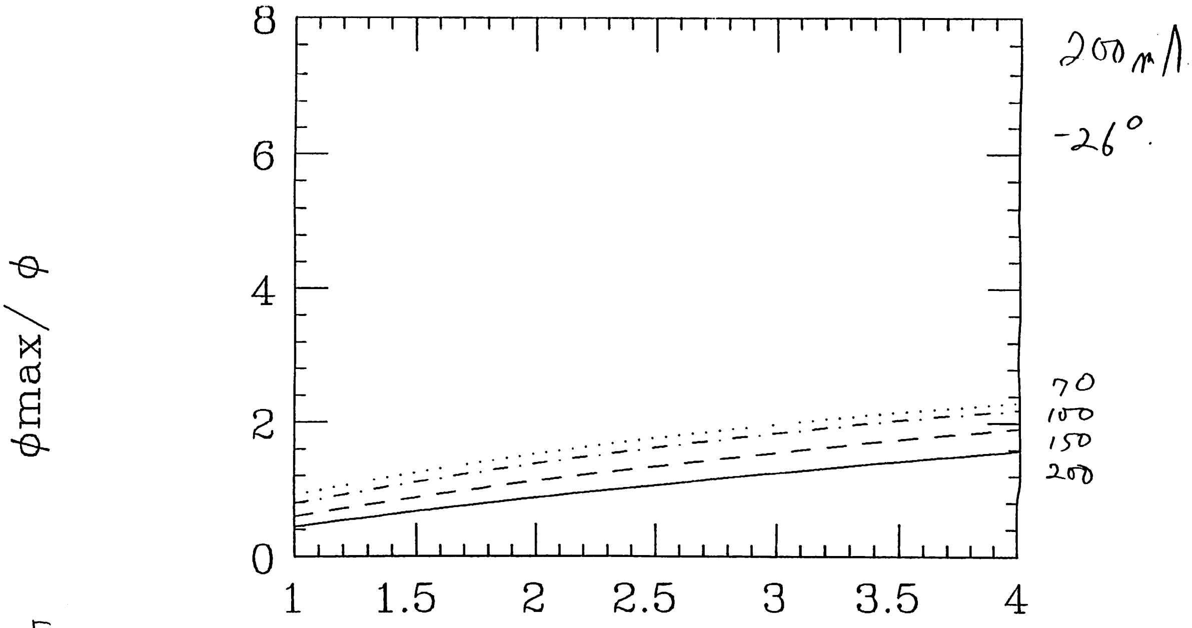


Fig.12. Mod.ratio sqr(Ax1Ay1/Ax0Ay0)

dump TL −30,70,100,150,200 MeV 0.2A

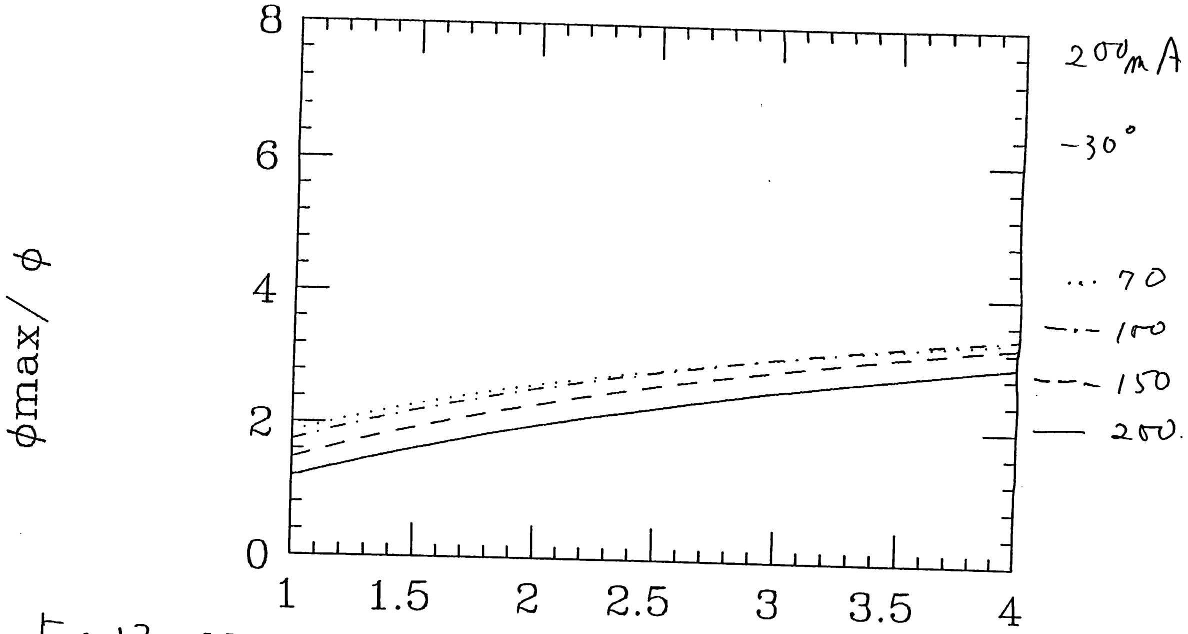


Fig.13 Mod.ratio sqr(Ax1Ay1/Ax0Ay0)

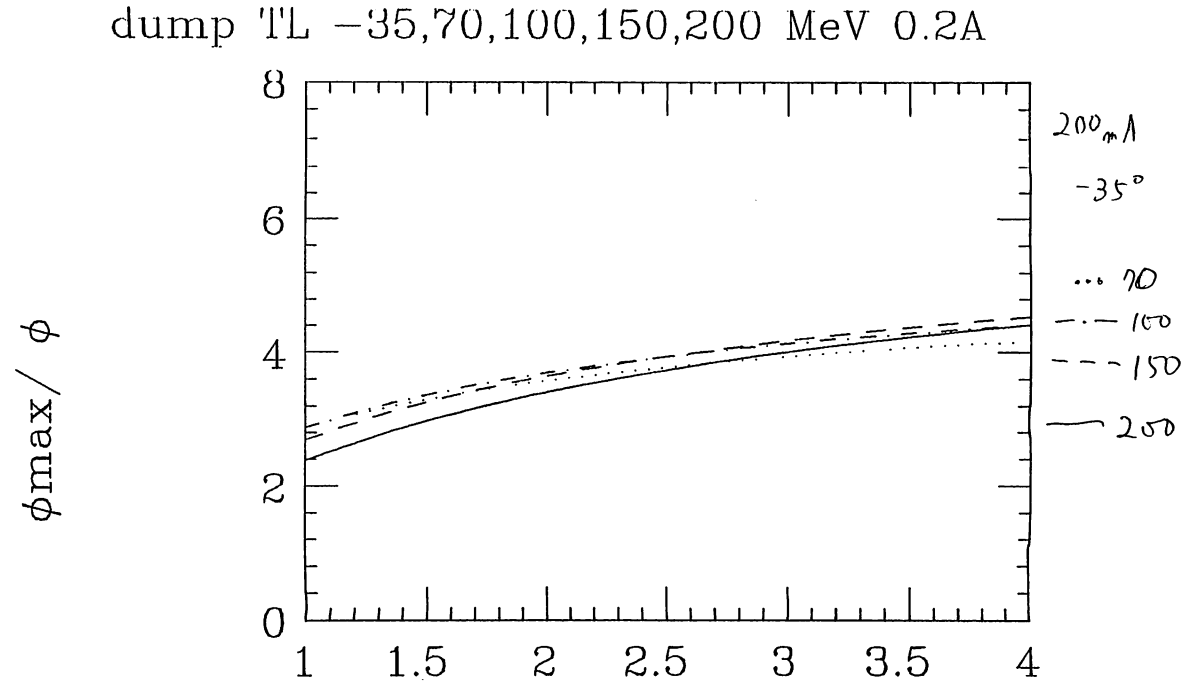


Fig. 14 Mod.ratio sqr(Ax1Ay1/Ax0Ay0)

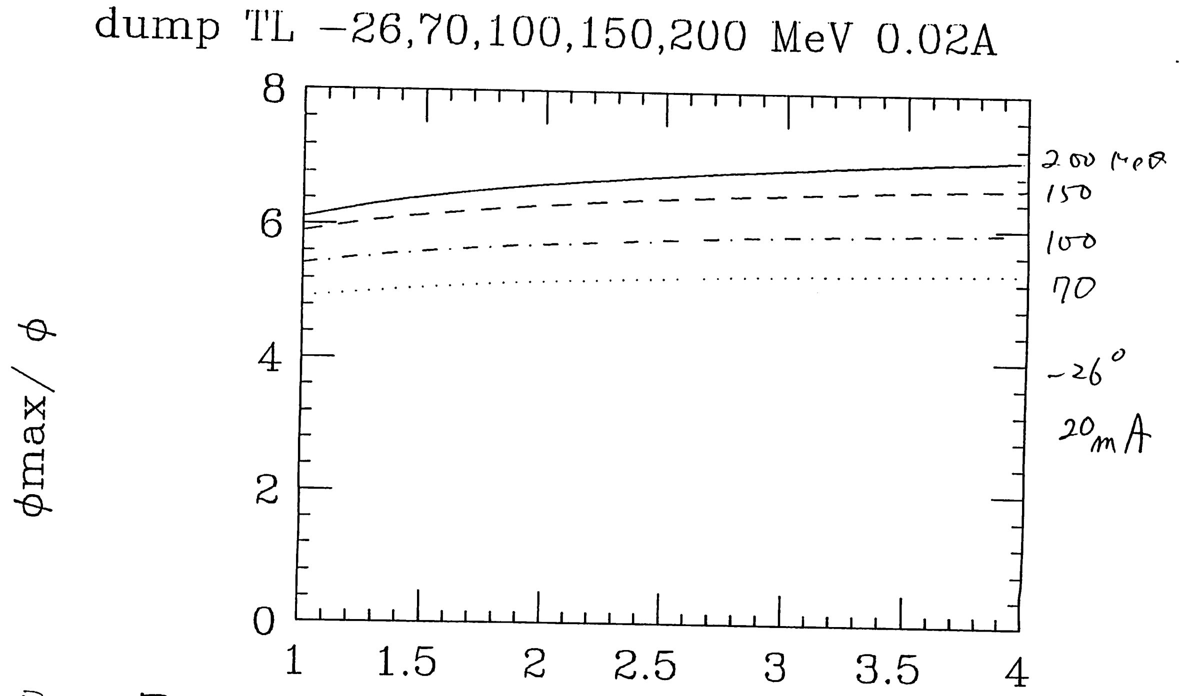


Fig. 15 Mod.ratio sqr(Ax1Ay1/Ax0Ay0)

dump TL −30,70,100,150,200 MeV 0.02A

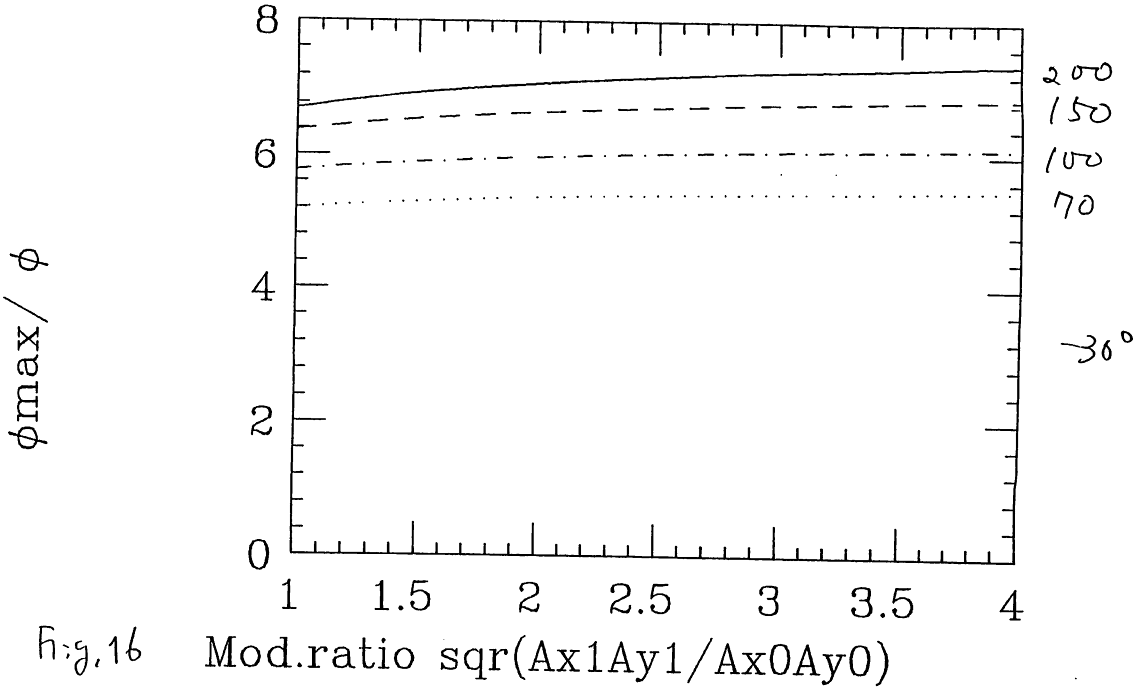


Fig.16

dump TL −35,70,100,150,200 MeV 0.02A

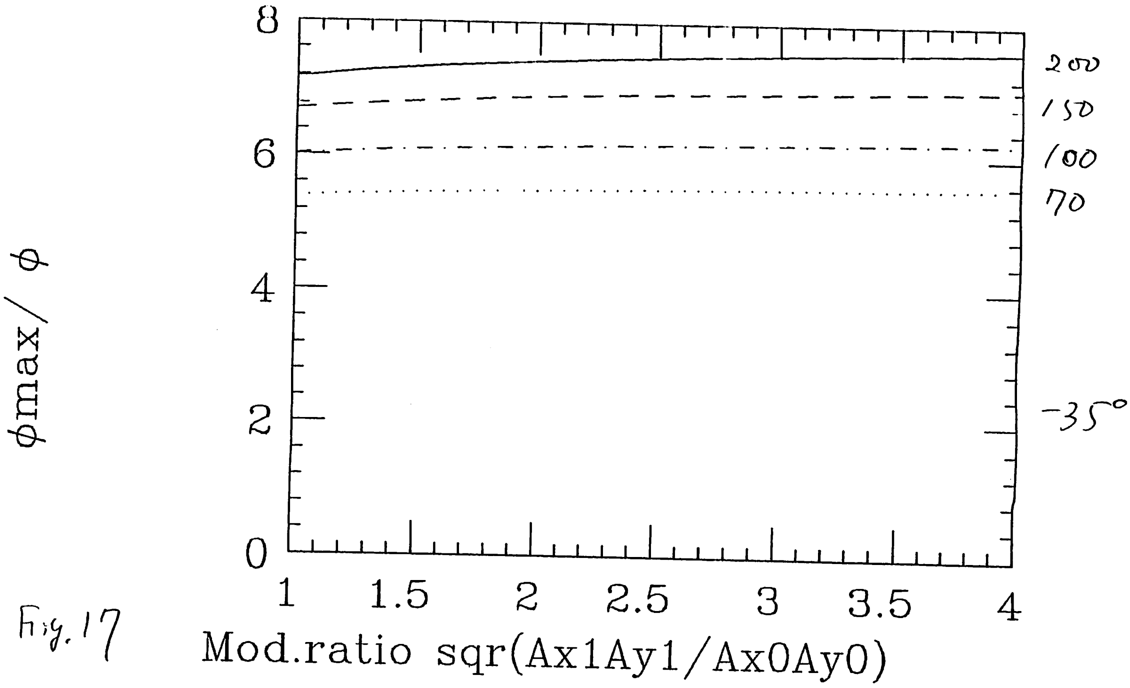


Fig.17

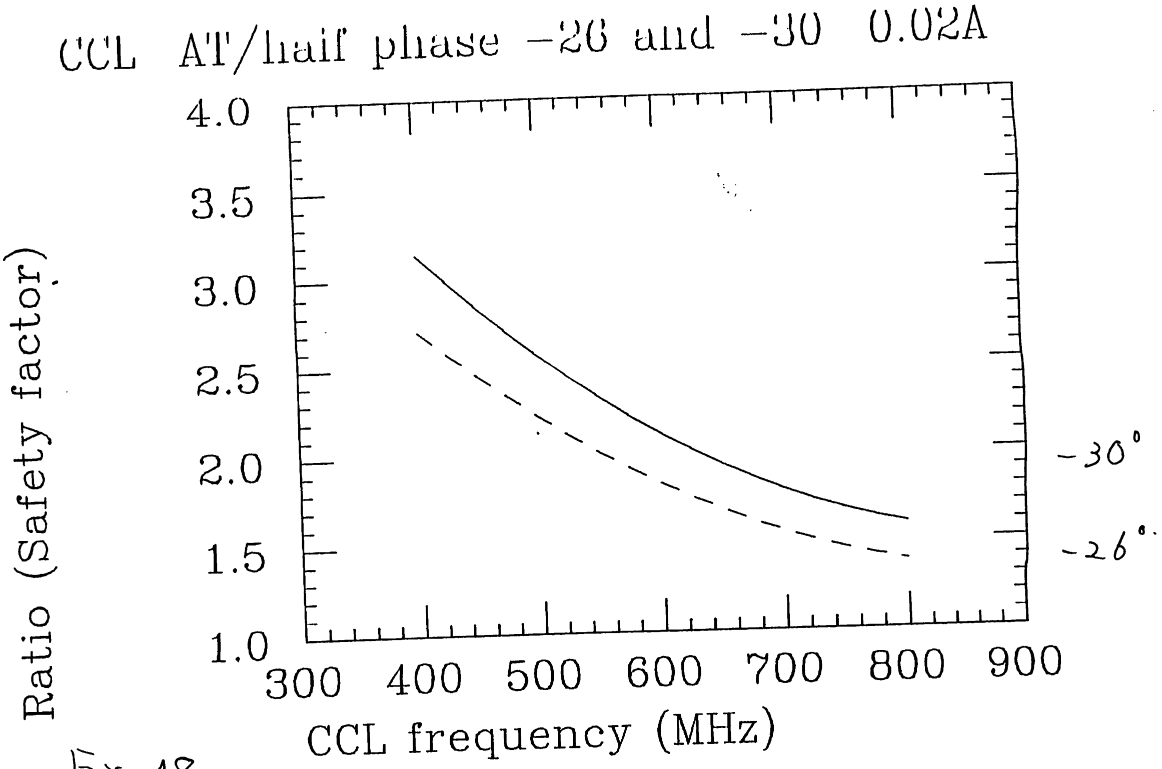

CCL AT/hair phase -26 and -30 0.02A
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Ratio (Safety factor)
300 400 500 600 700 800 900
CCL frequency (MHz)
-30°
-26°

Fig. 18

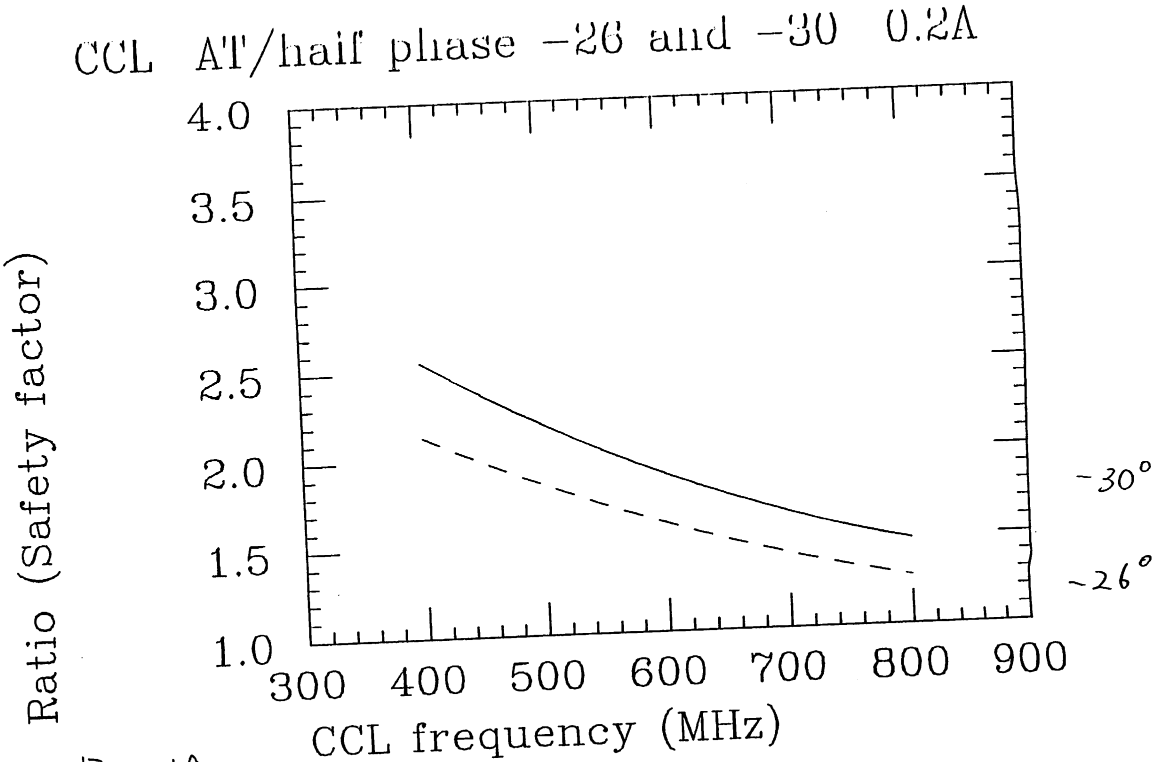

CCL AT/hair phase -26 and -30 0.2A
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Ratio (Safety factor)
300 400 500 600 700 800 900
CCL frequency (MHz)
-30°
-26°

Fig. 19

CCL ΔT/half phase −26 and −30 0A

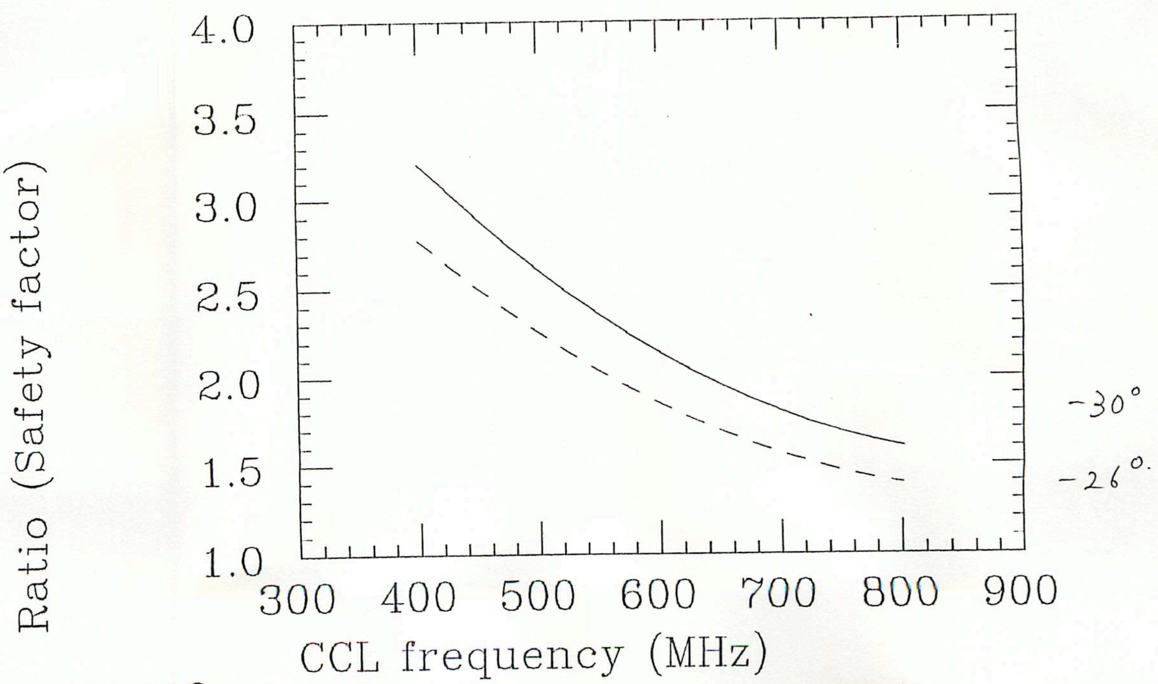


Fig. 20

CCL HALF PHASE MAX −26 −30 0,0.02,0.2A

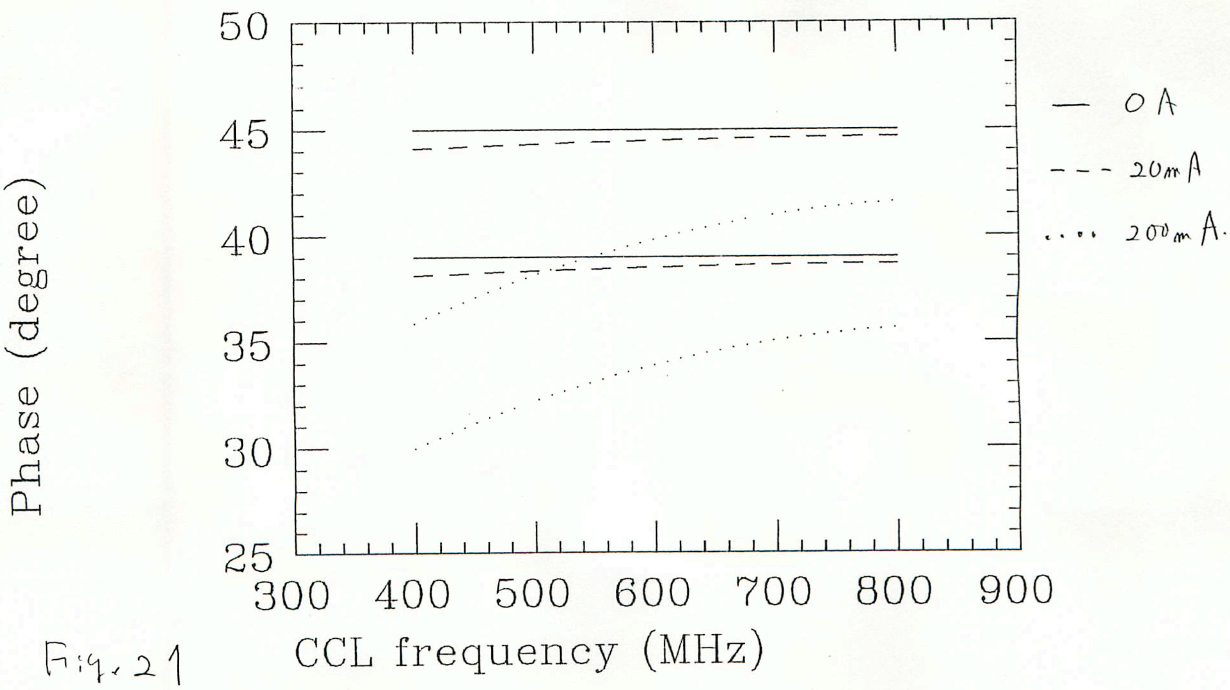
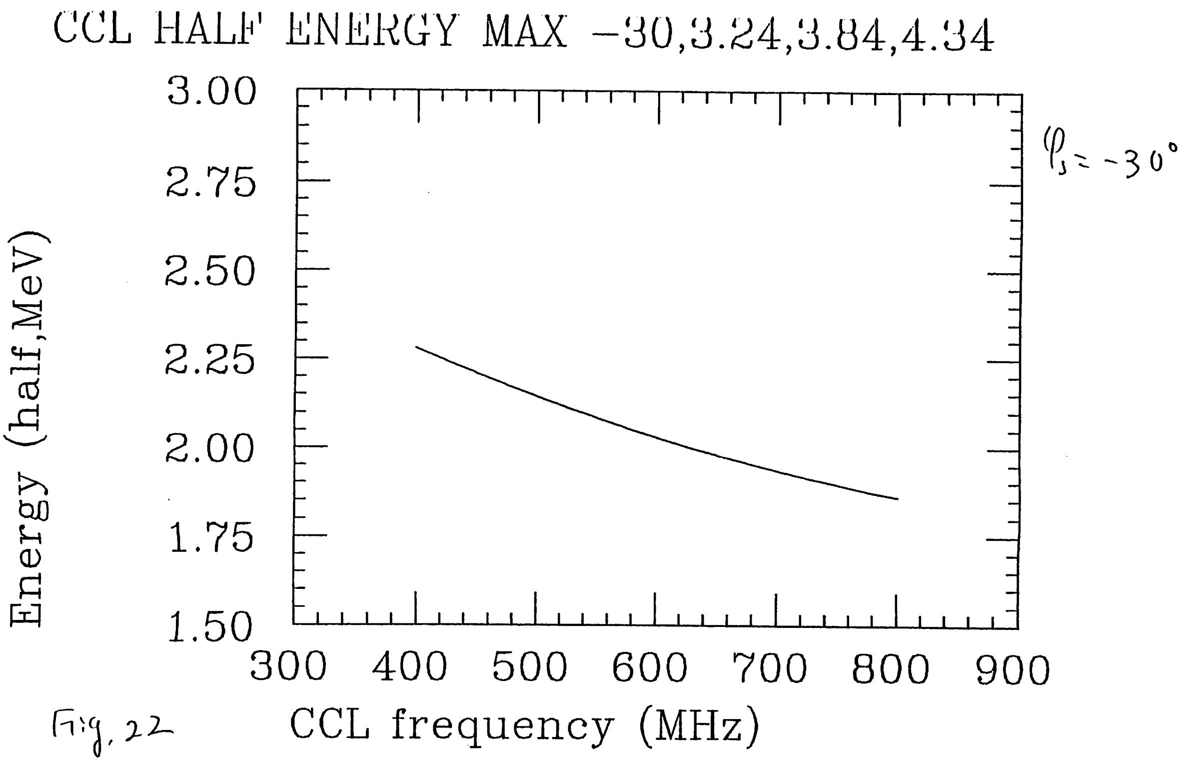
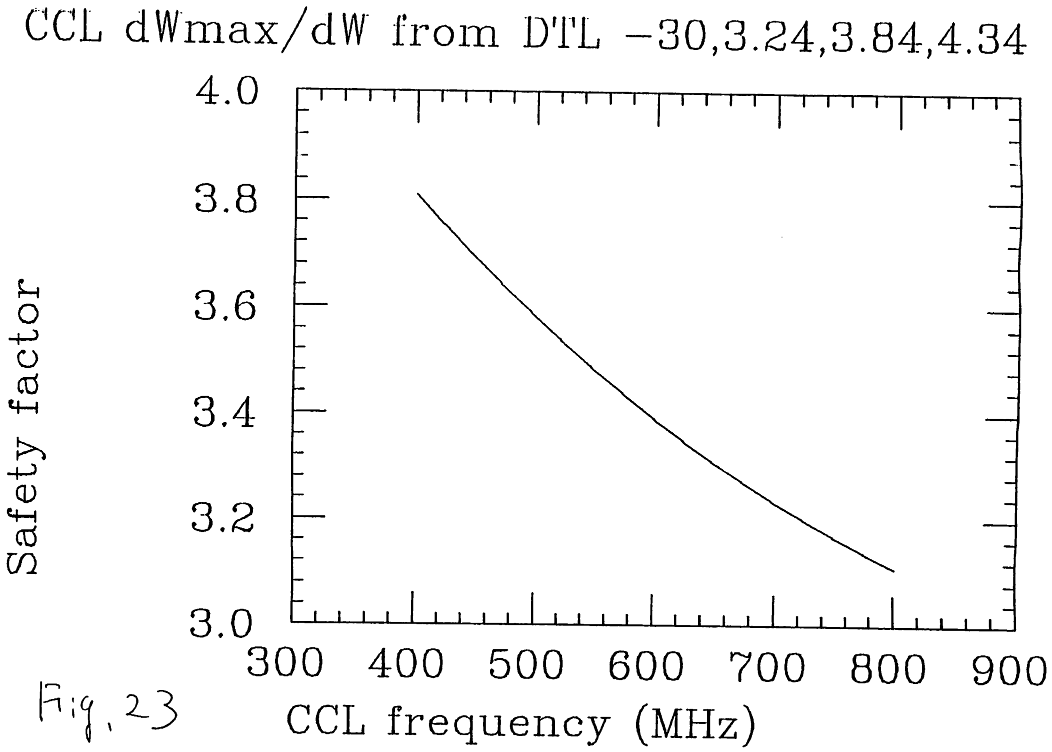


Fig. 21



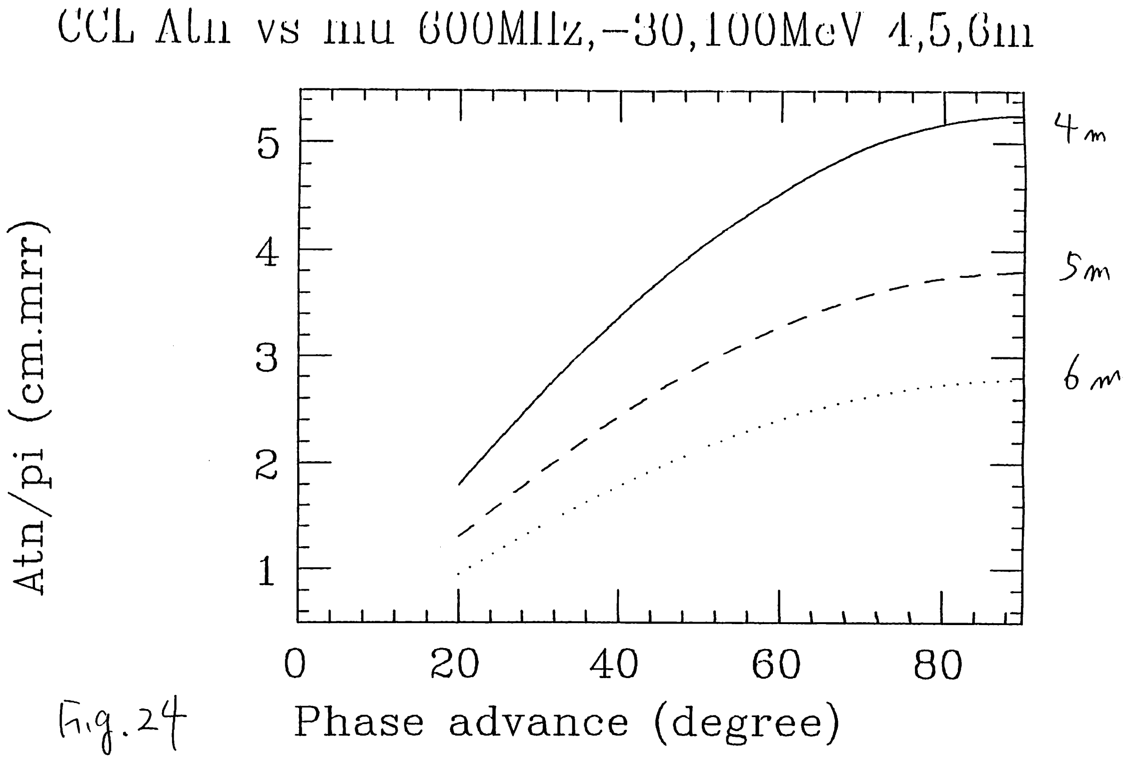
CCL HALF ENERGY MAX −30,3.24,3.84,4.34
3.00
2.75
2.50
2.25
2.00
1.75
1.50
Energy (half,MeV)
300
400
500
600
700
800
900
CCL frequency (MHz)
$\varphi_s = -30°$

Fig. 22



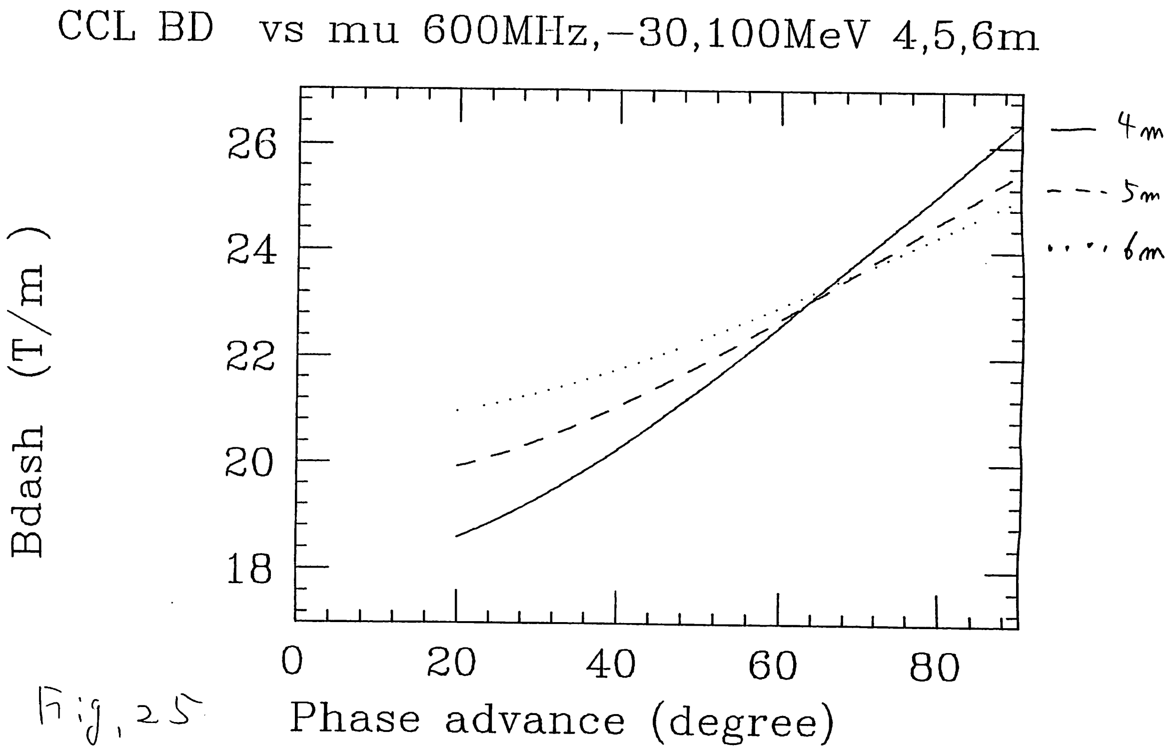
CCL dWmax/dW from DTL −30,3.24,3.84,4.34
4.0
3.8
3.6
3.4
3.2
3.0
Safety factor
300
400
500
600
700
800
900
CCL frequency (MHz)

Fig. 23



CCL Atn vs mu 600MHz,-30,100MeV 4,5,6m
Atn/pi (cm.mrr)
1
2
3
4
5
0
20
40
60
80
Phase advance (degree)
4m
5m
6m

Fig. 24



CCL BD vs mu 600MHz,-30,100MeV 4,5,6m
Bdash (T/m)
18
20
22
24
26
0
20
40
60
80
Phase advance (degree)
4m
5m
6m

Fig. 25

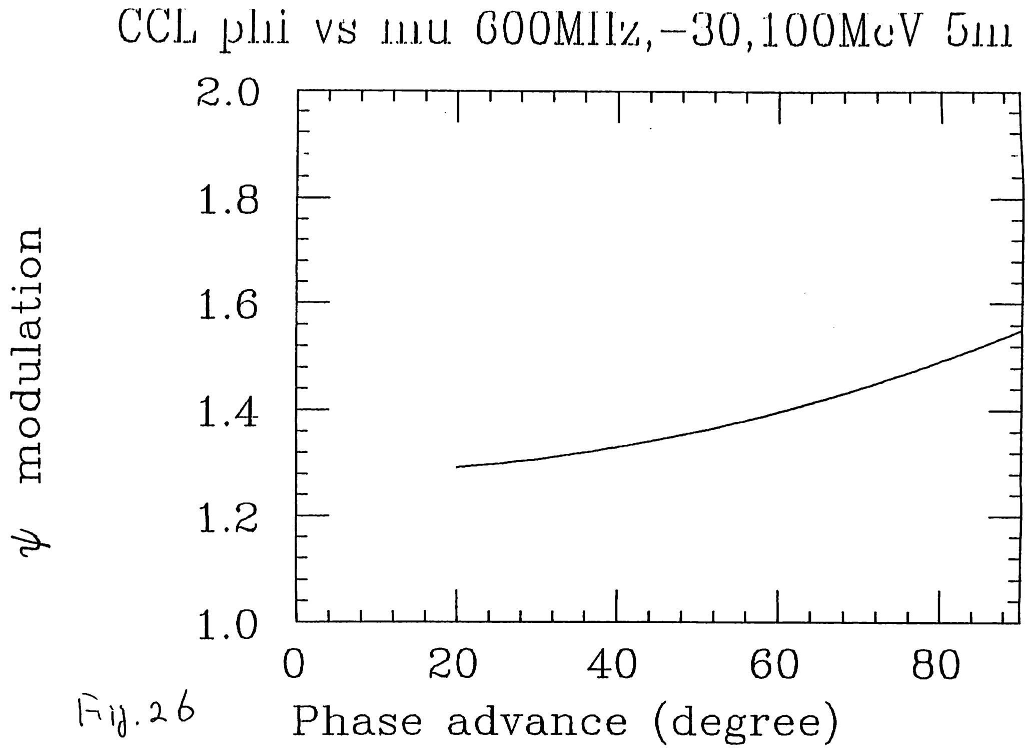

CCL phi vs mu 600MHz,-30,100MeV 5m
2.0
1.8
1.6
1.4
1.2
1.0
ψ modulation
0
20
40
60
80
Phase advance (degree)

Fig. 26

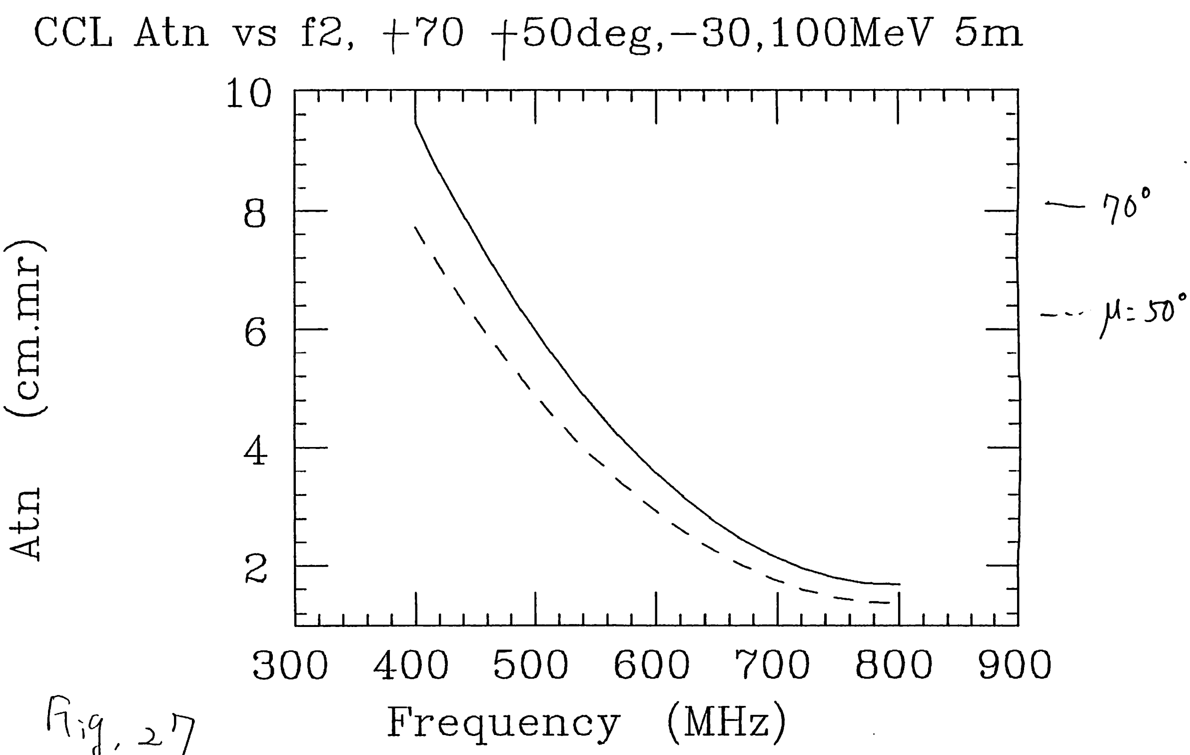

CCL Atn vs f2, +70 +50deg,-30,100MeV 5m
10
8
6
4
2
Atn (cm.mr)
300
400
500
600
700
800
900
Frequency (MHz)
— 70°
--- μ=50°

Fig. 27

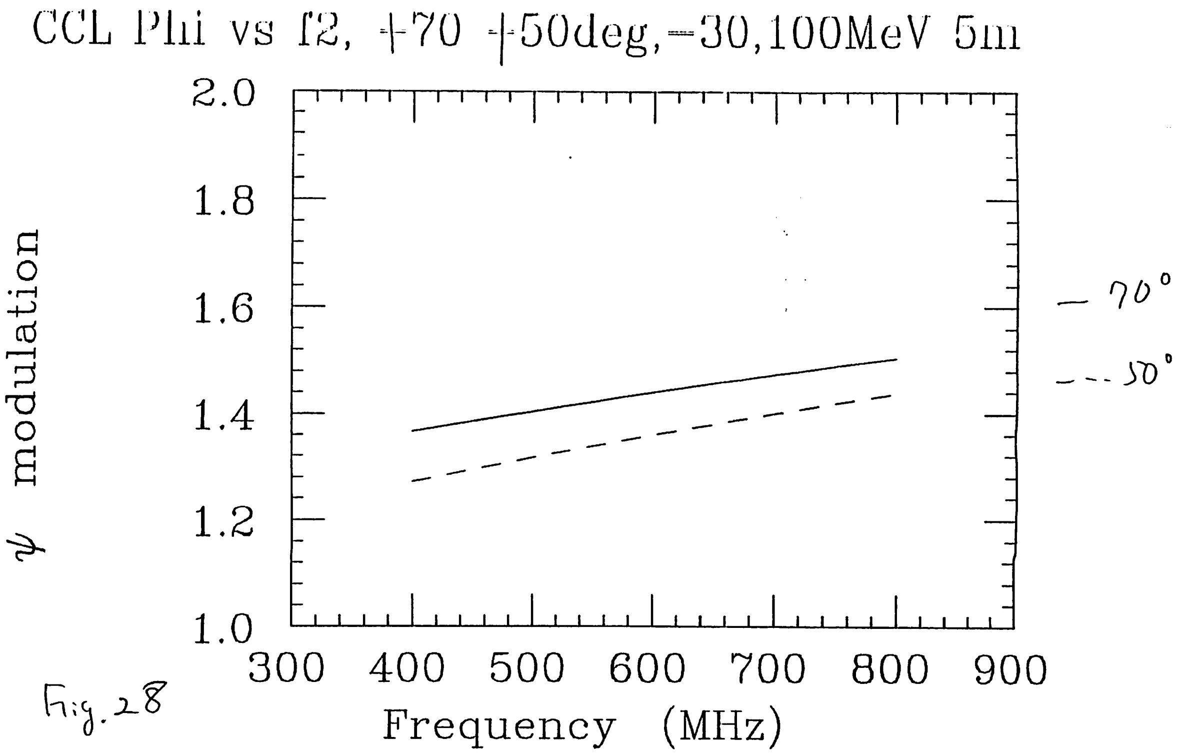

CCL Phi vs f2, +70 +50deg,-30,100MeV 5m
ψ modulation
2.0
1.8
1.6
1.4
1.2
1.0
300
400
500
600
700
800
900
Frequency (MHz)
— 70°
--- 50°

Fig. 28

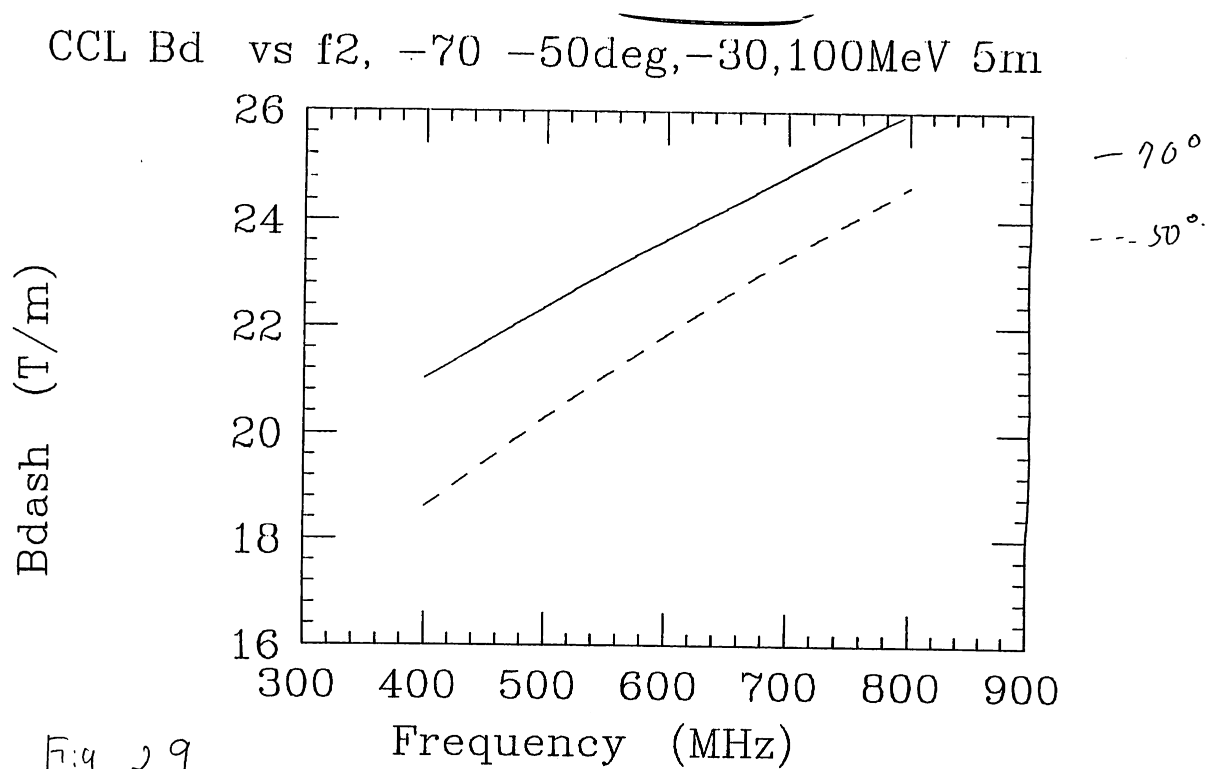

CCL Bd vs f2, -70 -50deg,-30,100MeV 5m
Bdash (T/m)
26
24
22
20
18
16
300
400
500
600
700
800
900
Frequency (MHz)
— 70°
--- 50°

Fig. 29

DTL EGROW 0.1,0.5 1.16CM ,0.1,0.5,1 PI

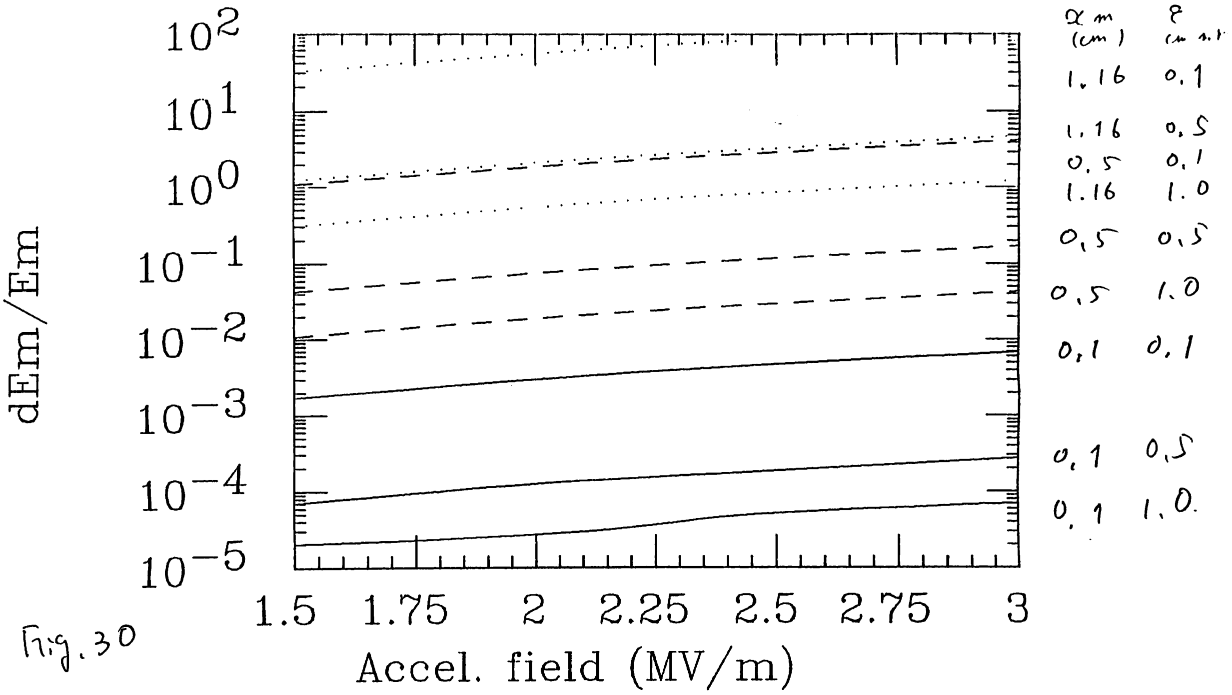


Fig. 30

DTL EGROW 0.1cm,1.5,2.12,2.46,3MV/m

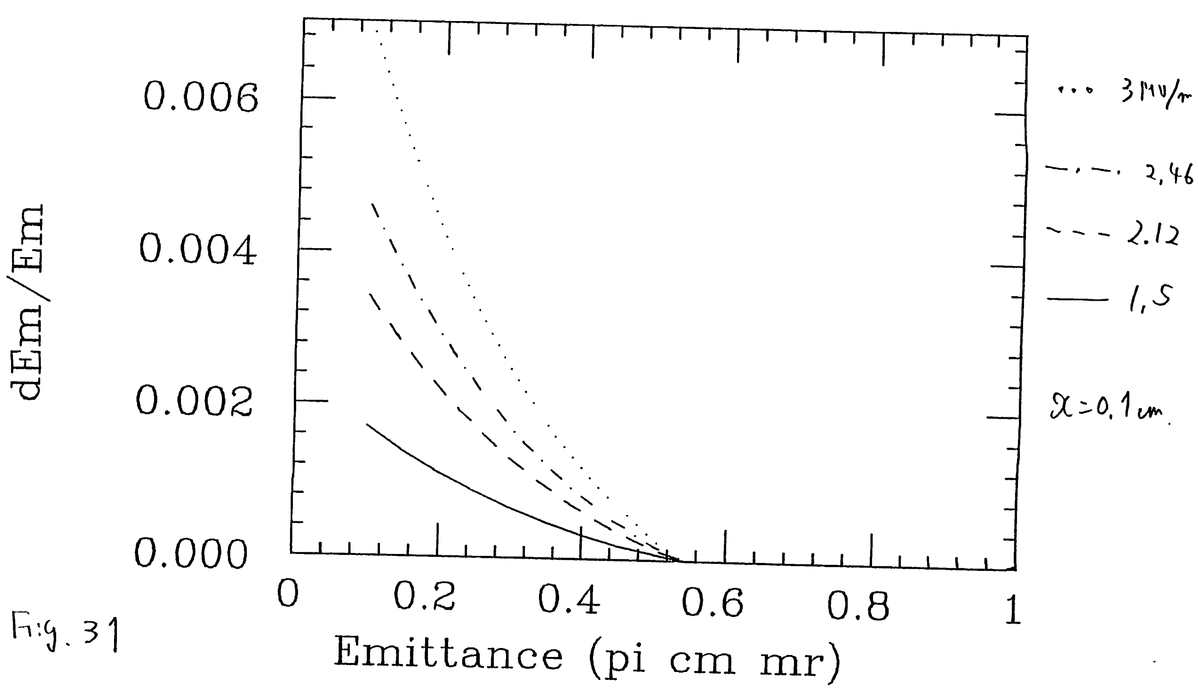


Fig. 31

DTL EGROW 0.5cm,1.5,2.12,2.46,3MV/m

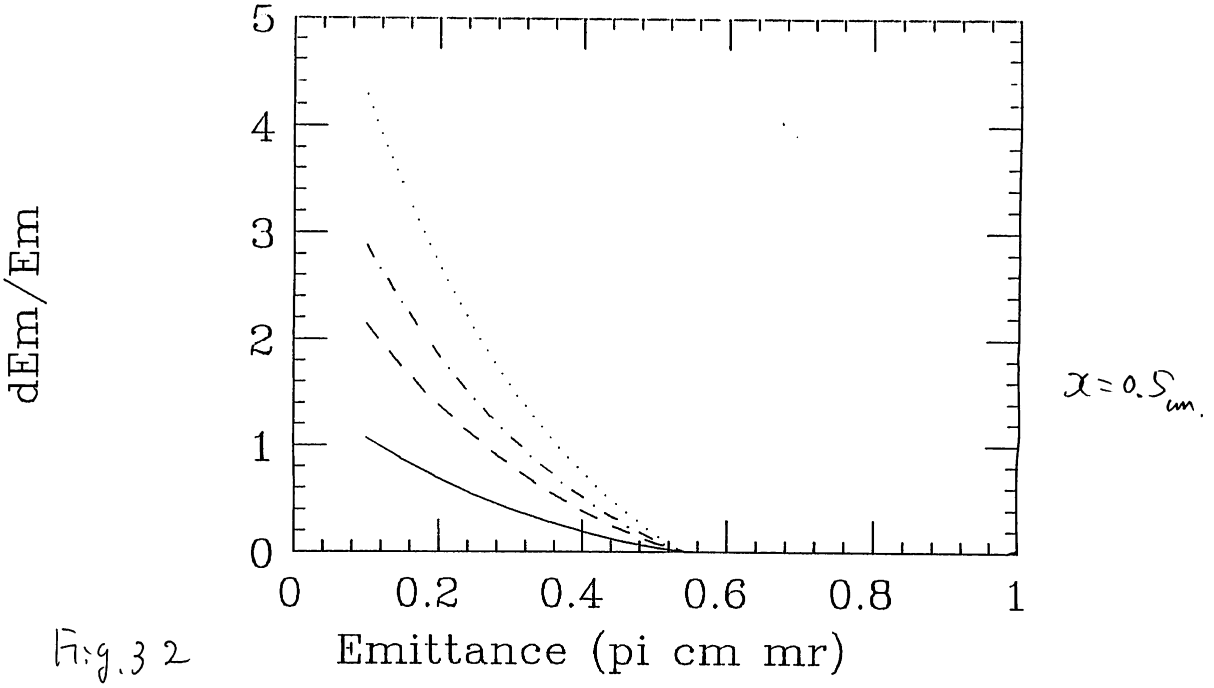


Fig. 32

DTL EGROW 1.16cm,1.5,2.12,2.46,3MV/m

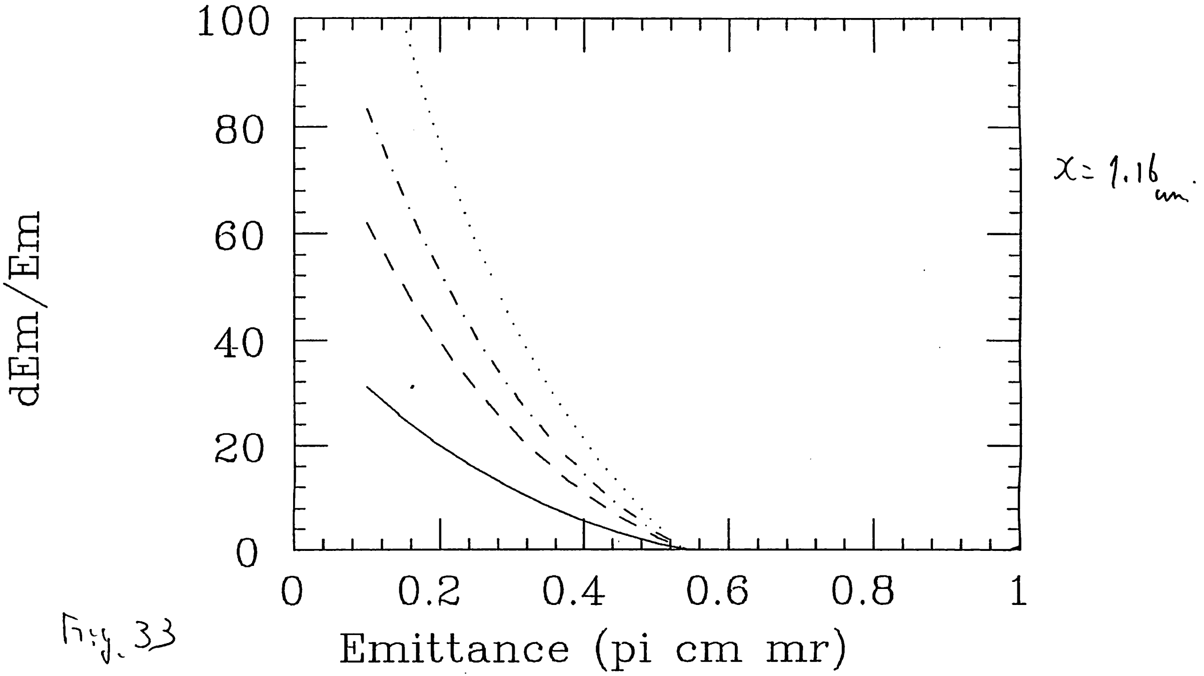


Fig. 33