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Wiggler Synchrotron Light Envelope

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Author

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ENGINEERING NOTE

CODE

SLO712

SERIAL

M5936A

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AUTHOR

EGON HONEZ

DEPARTMENT

LOCATION

DATE

6/17/82

PROGRAM - PROJECT - JOB

SLF - WIGGLER / BEAM LINE II

MASKS - GIRDEN CHAMBER

TITLE

WIGGLER SYNCHROTRON LIGHT ENVELOPE

THIS NOTE SUMMARIZES THE WIGGLER SYNCHROTRON LIGHT ENVELOPE IN THE TRANSVERSE X & Y PLANES

8/3/82 ADDED PG'S 16-19
ADDITION PG 2

BASISELZMON BEAM SIZE:

$$\Delta y = \pm 1.5 \text{ mm} \rightarrow \text{USE } 2\Delta y = \pm 3.0 \text{ mm}$$

$$\Delta x = \pm 3.2 \text{ mm} \rightarrow \text{USE } 2\Delta x = \pm 6.4 \text{ mm}$$

MAXIMUM ELZMON ORBIT DEVIATIONS: (HARRIS 3/9/82)

$$\Delta x_s = \pm 10 \text{ mm}$$

$$\Delta x_s^1 = \pm 1.34 \text{ mrad}$$

$$\Delta y_s = \pm 6 \text{ mm}$$

$$\Delta y_s^1 = \pm 0.802 \text{ mrad}$$

BEAM LIFETIME WHEN COMING CLOSE TO A CONDUCTING SURFACE:

FOR 3.0 BEV:

CURRENT (mA)	BEAM-SURFACE DISTANCE (mm)	LIFETIME (SEC)
100	2.8	< 1
100	3.0	Few
100	3.5	10's
50	3.0	10's

COMPARE TRAJECTORIES ON THE BASIS THAT THE ELZMON BEAM DISAPPEARS WHEN THE BEAM-SURFACE SPACING DISTANCE IS 2.5 mm

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ENERGY:

DEDICATED SYNCHROTRON LIGHT OPERATION:

ENERGY RANGE: 2.4 - 3.7 GeV

PARASITIC SYNCHROTRON LIGHT OPERATION

MINIMUM ENERGY: 1.5 GeV

ELECTRON CURRENT:

A

100 mA

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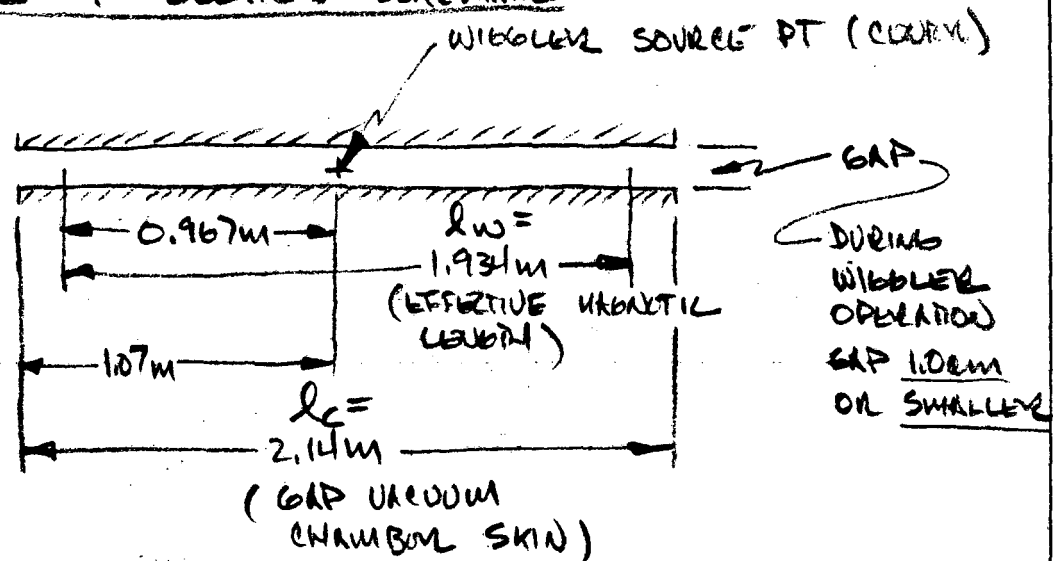
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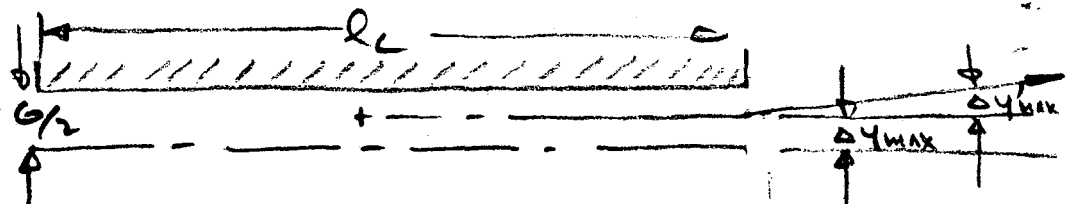
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TRANSVERSE Y PLANE:WIBBLER Y SECTION SCHEMATIC:ELECTRON BEAM ORBIT LIMITS: (LIFETIME CONSIDERATION)

- $B \leq 1.30 \text{ TES} \rightarrow 1.0 \text{ cm GAP OPERATION!}$



$$\Delta y_{\max} = \frac{G}{2} - 2.5 \text{ mm} = \frac{10 \text{ mm}}{2} - 2.5 \text{ mm} = 2.5 \text{ mm}$$

$$L_c \Delta y' \leq 2 \Delta y_{\max} \leq (2)(2.5 \text{ mm}) \leq 5.0 \text{ mm}$$

$$\Delta y' \leq \frac{5.0 \text{ mm}}{2140 \text{ mm}} \leq 2.34 \text{ mRAD}$$

THUS:

$$\Delta y'_{\max} = \Delta y'_s = 0.802 \text{ mRAD}$$

- $B = 1.75 \text{ TES} \rightarrow 0.6 \text{ cm GAP OPERATION!}$

$$\Delta y_{\max} = \frac{6 \text{ mm}}{2} - 2.5 = 0.5 \text{ mm}$$

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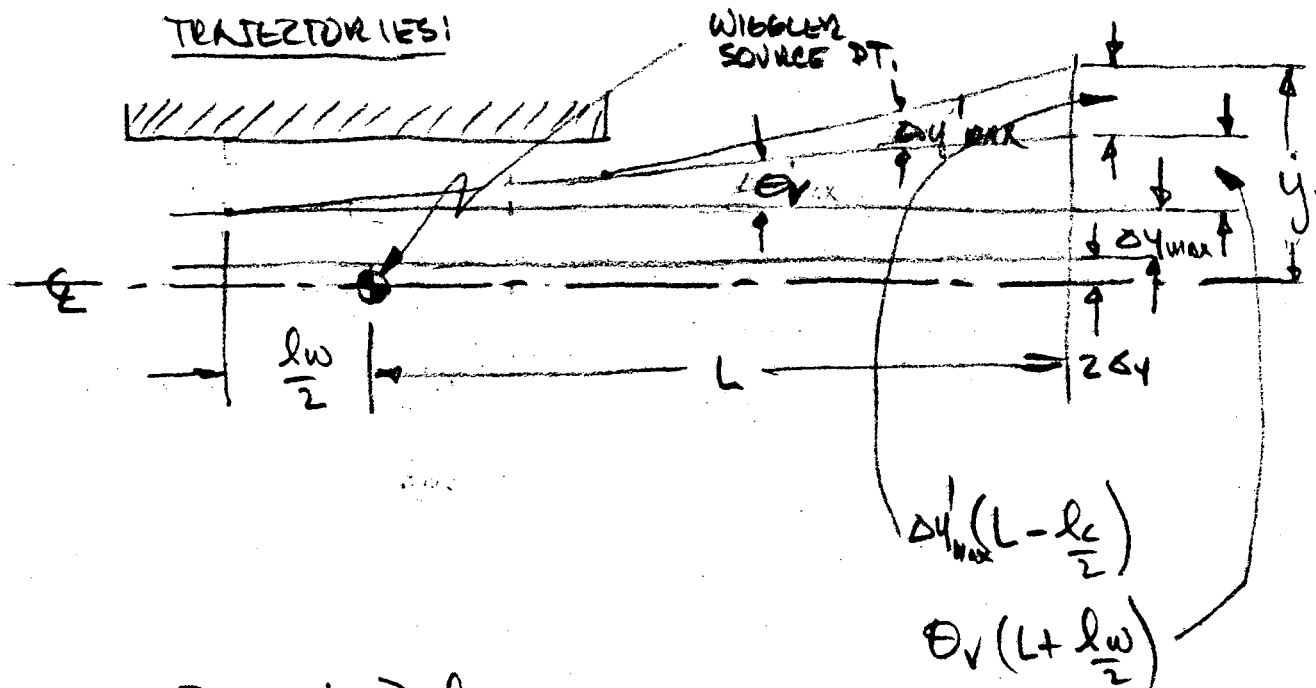
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$$\Delta y' = \frac{1 \text{ mm}}{2140 \text{ mm}} = 0.467 \text{ mrad}$$

$$\Delta y'_{\text{max}} = \Delta y' = 0.467 \text{ mrad}$$



FOR $L \geq \frac{l_w}{2}$

$$y_{\text{max}} = 2\Delta y + \Delta y_{\text{max}} + \Theta_V(L + \frac{l_w}{2}) + \Delta y'_{\text{max}}(L - \frac{l_w}{2})$$

$$\Theta_V = f(\text{VERTICAL INTENSITY PROFILES})$$

FROM M 5927, PG 12, AT 4.0M, FOR THE INTENSITY TO BE $\sim 50 \text{ W/cm}^2$, $\Theta_V = \frac{3}{\gamma}$
 FOR $B_{\text{wigg}} = 1.75 \text{ T}$, $E_{\text{beam}} = 3.7 \text{ GeV}$, $I_{\text{beam}} = 100 \text{ mA}$

USE:

$$\Theta_V = \pm \frac{3.0}{\gamma} = \pm \frac{1.53}{E(\text{GeV})} \text{ (mrad)}$$

E (GeV)	2.4	3.0	3.7	1.5
Θ_V (mrad)	± 638	$\pm .511$	$\pm .414$	± 1.020

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$$y_{\max} = \pm \left[0.30 + \Delta y_{\max} + \Theta_J (L + 967 \text{ mm}) + \Delta y' (L - 1070 \text{ mm}) \right]$$

- FOR $B \leq 1.30 \text{ TES}$ (1.0 cm GAP OPERATION)

$$y_{\max \leq 1.3 \text{ TES}} = \pm \left[0.30 + 2.50 + \Theta_J (L + 967 \text{ mm}) + 0.802^{\text{meas}} (L - 1070 \text{ mm}) \right]$$

$$y_{\max \leq 1.3 \text{ TES}} = \pm \left[1.942 + .802 L(\text{m}) + \Theta_J (\text{meas}) (L(\text{m}) + 0.967) \right]_{\text{m}}$$

EXPERIMENTAL (GAP)	Θ_J ($\pm \text{meas}$)	$y_{\max \leq 1.3 \text{ TES}}$ (cm)
2.4	.638	$2.558 + 1.440 L(\text{m})$
3.0	.571	$2.436 + 1.313 L(\text{m})$
3.7	.414	$2.342 + 1.216 L(\text{m})$
1.5	1.020	$2.928 + 1.822 L(\text{m})$

- FOR $B = 1.75 \text{ TES}$ (0.6 cm GAP OPERATION)

$$y_{\max \text{ 1.75 TES}} = \pm \left[0.30 + 0.50 + \Theta_J (L + .967 \text{ m}) + 0.467 (L - 1.07 \text{ m}) \right]$$

$$= \pm \left[0.300 + .467 L(\text{m}) + \Theta_J (\text{meas}) (L(\text{m}) + .967) \right]$$

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ENERGY (GeV)	Θ_V ($\pm$ MRAD)	y_{MAX} 1.75 σ ($\pm$ MM)
2.4	.638	0.917 + 1.105 LCM
3.0	.511	0.794 + 0.978 LCM
3.7	.414	0.700 + 0.881 LCM
1.5	1.020	1.286 + 1.487 LCM

THE TRANSVERSE VERTICAL BEAM ENVELOPES (Y)
CALCULATED ABOVE ARE SHOWN GRAPHICALLY ON
PAGE 7.

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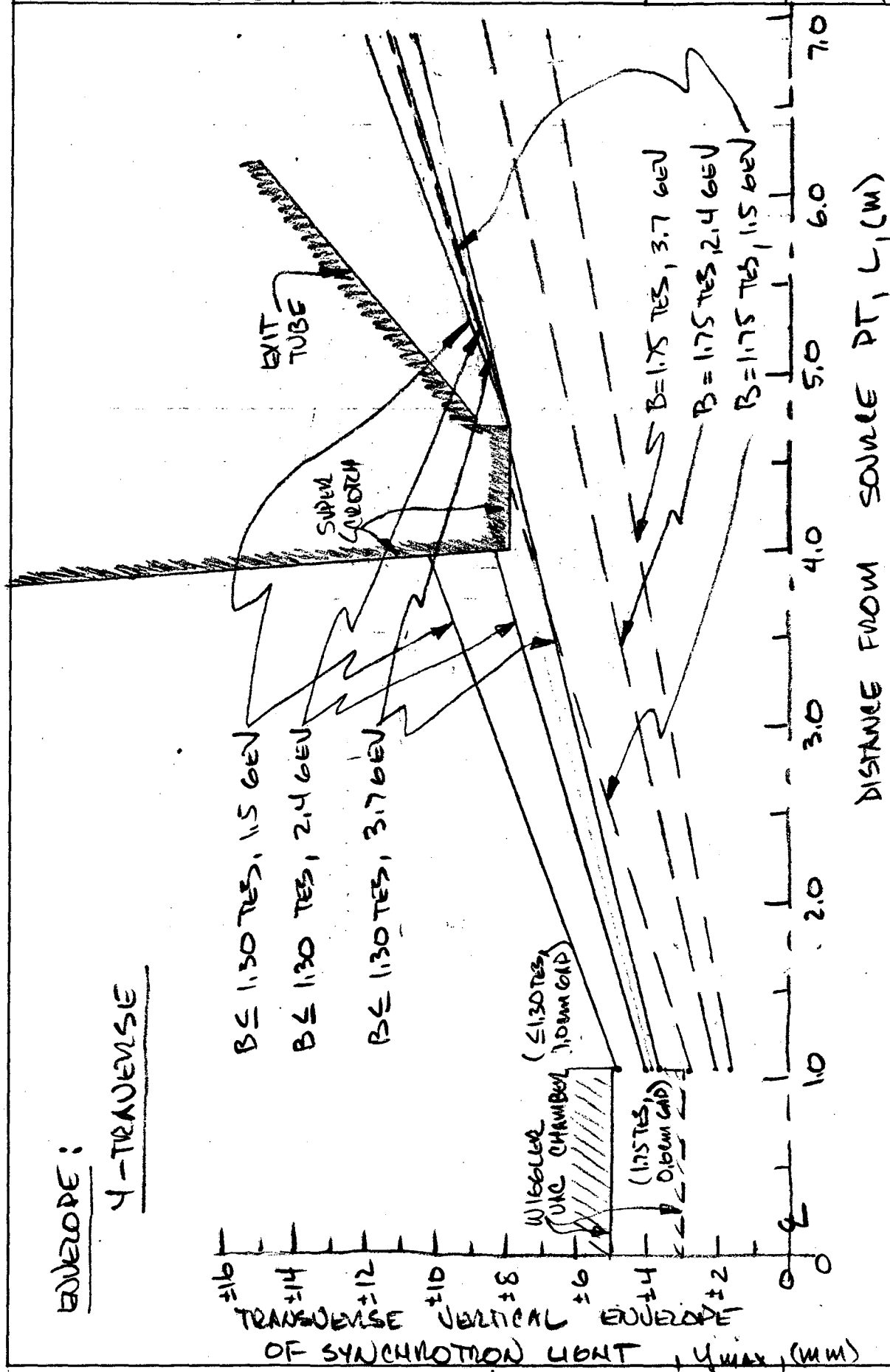
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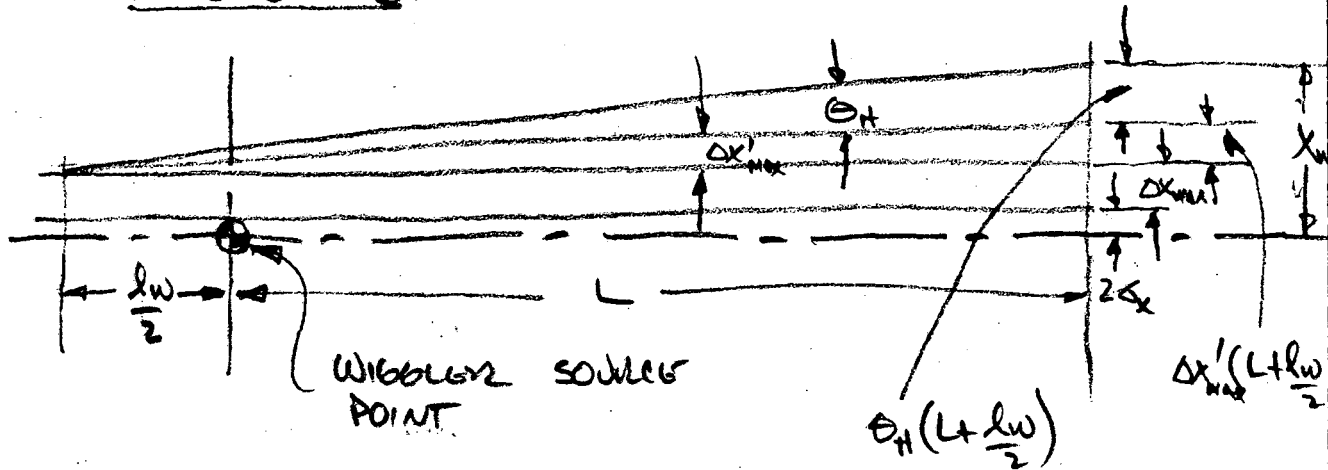
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TRANSVERSE X PLANE

THERE ARE NO LIFE TIME CONSIDERATIONS IN
THE TRANSVERSE X-PLANE

TRAJECTORIES:

$$\text{FOR } L \geq -\frac{l_w}{2}$$

$$X_{\text{max}} = 2\Delta x + \Delta x_{\text{max}} + \Theta_H + \Delta x'_{\text{max}} \left(L + \frac{l_w}{2}\right)$$

$$\Theta_H = \pm \frac{.4775 \lambda_{wib}(\text{cm}) B_{wib}(\text{tes})}{E(\text{GeV})} \quad (\text{mrad})$$

$$\text{FOR } \lambda_{wib} = 7\text{cm}$$

$$\Theta_H = \pm 3.343 \frac{B(\text{tes})}{E(\text{GeV})} \quad (\text{mrad})$$

B (tes)	E (GeV)	Θ_H (mrad)
1.30	1.5	2.897
	2.4	1.811
	3.7	1.174
1.75	1.5	3.900
	2.4	2.437
	3.7	1.581

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$$X_{\max} = \pm \left[(2)(3.20 \text{ mm}) + 10 \text{ mm} + (\Theta_H + 1.34 \text{ (mrad)}) (L + .967 \text{ m}) \right]$$

$$X_{\max} = \pm \left[16.4 + (\Theta_H + 1.34 \text{ (mrad)}) (L \text{ (m)} + .967 \text{ m}) \right] \text{ (mm)}$$

- FOR $B \leq 1.30 \text{ TES}$ (1.0 cm GAP OPERATION)

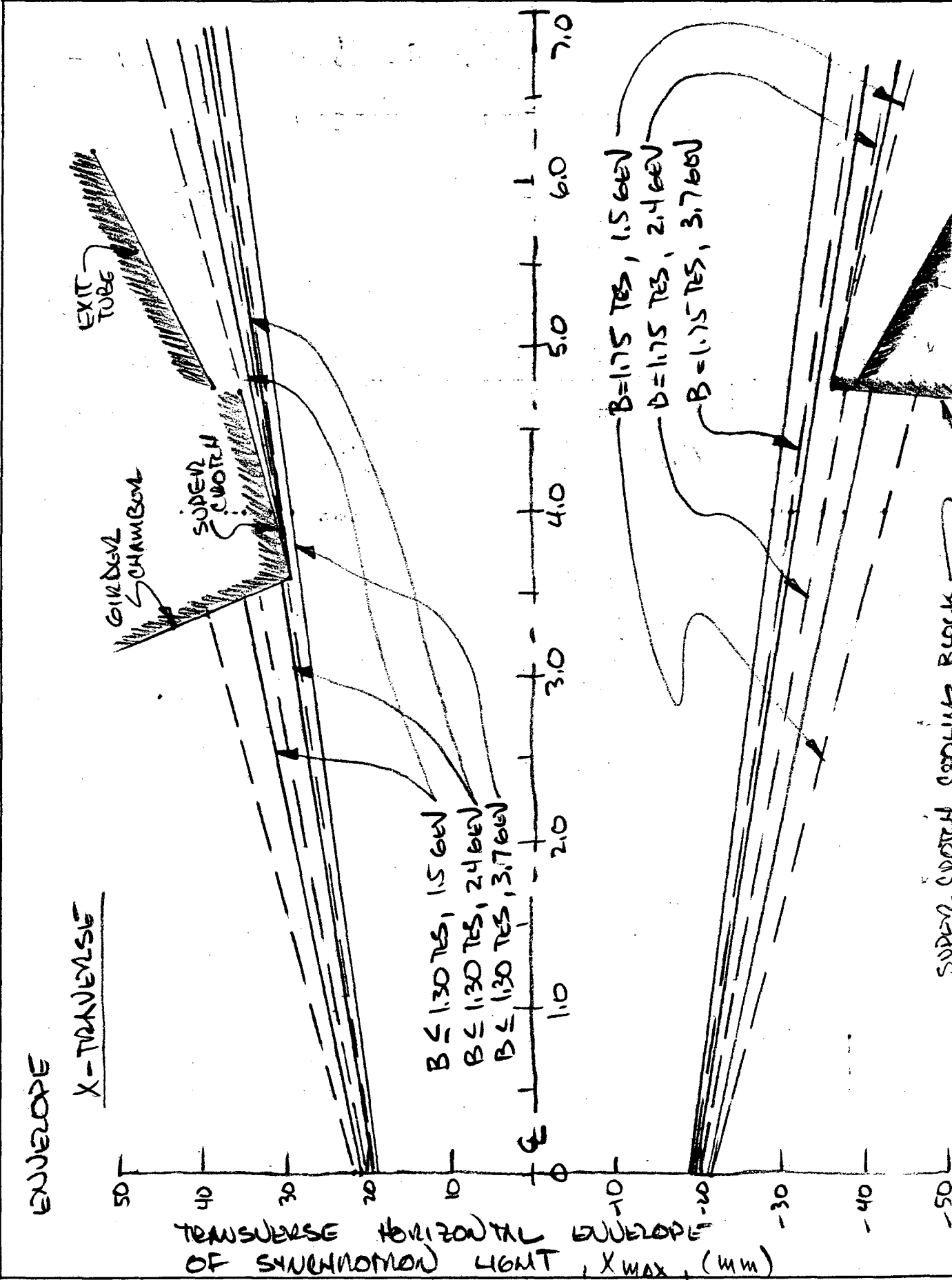
ENERGY (GeV)	Θ_H ($\pm \text{mrad}$)	$X_{\max} \leq 1.30 \text{ TES}$ (mm)
1.5	2.897	20.50 + 4.237 L(m)
2.4	1.811	19.45 + 3.151 L(m)
3.7	1.174	18.83 + 2.514 L(m)

- FOR $B = 1.175 \text{ TES}$ (0.6 cm GAP OPERATION)

ENERGY (GeV)	Θ_H ($\pm \text{mrad}$)	$X_{\max} 1.175 \text{ TES}$ (mm)
1.5	3.90	21.47 + 5.240 L(m)
2.4	2.437	20.05 + 3.777 L(m)
3.7	1.581	19.22 + 2.921 L(m)

THE TRANSVERSE HORIZONTAL ENVELOPES (X) CALCULATED ABOVE ARE SHOWN GRAPHICALLY ON PAGE 10.

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GIRDER CHAMBER ILLUMINATION:4 TRAVERSE:DEDICATED OPERATION (2.4-3.7 GeV):

@ 1.75 TES — BEAM CLEANS
GIRDER CHAMBER

@ ≤ 1.30 TES — BEAM HITS SUPER
CROUCH —
— $\frac{1}{2}$ MM IMPINGEMENT
ON 3.9° BEV @ 241
OK — BASED ON M5927
PAGE 22

— STRAIGHT SECTION
OK — BASED ON M5927
PAGE 27

PARASITIC OPERATION (1.5 GeV - 2.4 GeV)

@ 1.75 TES — BEAM HITS SUPER
CROUCH STRAIGHT SECTION
OK — SEE ABOVE

@ ≤ 1.30 TES — BEAM HITS SUPER
CROUCH
— 2.3 MM IMPINGEMENT
ON 3.9° BEV @ 1.5

POWER LEVEL @ 1.5 GeV, 100 mA, 1.3 TES

$$P_{1.5\text{GeV}} = (5206\text{ W}) \left(\frac{1.5}{3.7} \right)^2 \left(\frac{1.3}{1.75} \right)^2 = \underline{472\text{ W}}$$

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FROM PG 15, M 5927A, AVAILABLE
COOLING FOR 2.3MM OF
BEAM IMPINGEMENT > 472 W
∴ OK

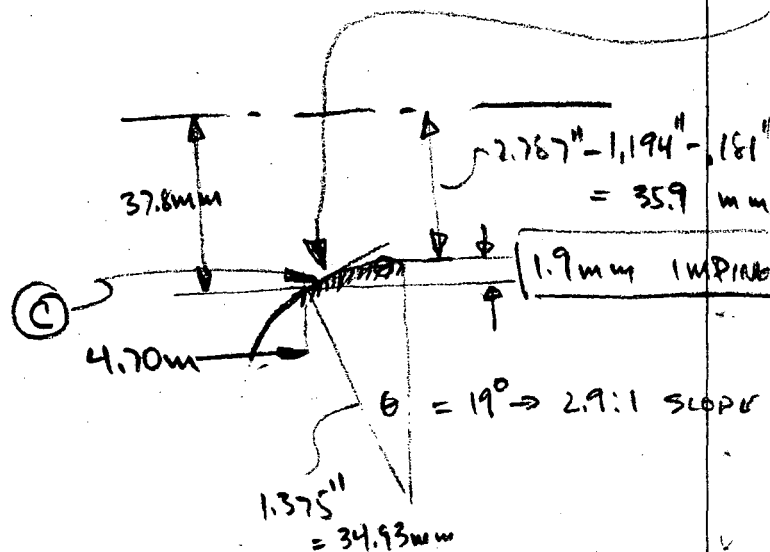
— STRAIGHT SECTION
OK — SEE ABOVE

X TRAVERSAL

DEDICATED OPERATION (2.4 - 3.7 GW) :

@ 1.75 TES

— BEAM HITS SUPERCOOLED
COOLING BLOCK @ 2.46W



MAXIMUM HEATING AT (C)

$$W_{max} = \left(\frac{44 \text{ kW}}{\text{cm}^2} \right) \left(\frac{2.4}{3.7} \right) \left(\frac{1}{4.7} \right) \left(\frac{4.75}{4.7} \right) \left(\frac{2.4}{3.7} \right) \left(\frac{7.51}{7.51 + 3.2} \right) \left(\frac{.81}{.66 + .66} \right)$$

↑ ↑ ↑ ↑ ↑ ↑
 PEAK 2.46W 4.7m 19° EX E
 @ 4.75 COOLING COOLING COOLING COOLING COOLING

= 0.532 kW/cm² — OK BASED ON PG'S 18 + 19, M 5927A

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- BEAM HITS GILDEN CHAMBER @ 3.6 mm
- 2.1 mm IMPINGEMENT @ 3.7 GW - OK M5927a PG 18 & 19
- $33.64 - 27.6 = 6.0$ mm OF IMPINGEMENT @ 2.4 GW UNIT HOT DOWN BY $\left(\frac{2.4}{3.2}\right)^2 = .42$ - OK FOR PG 19, M5927a

@ ≤ 1.30 TES

- BEAM CLEANS SUPER COOLING BLOCK
- BEAM HITS GILDEN CHAMBER 3.2 mm @ 2.4 GW OK - BASED ON ABOVE

PARASITIC OPERATION (1.5 - 2.4 GW)

@ 1.75 TES

- BEAM HITS SUPER COOLING BLOCK
- @ 1.5 GW $46.1 - 37.8 = 8.3$ mm IMPINGEMENT

WORST HEATING CONDITION OCCURS ~ 3 mm IN FROM EDGE OF IMPINGEMENT (@ 5.3 mm)

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MAX. HEATING @ 5.3mm IMPINGEMENT, 81

$$W_{\text{net}} = \left(\frac{35 \text{ kW}}{\text{cm}^2} \right) \left(\frac{1.5}{5.7} \right) \left(\frac{4.75}{4.70} \right) \left(\frac{1.5}{3.7} \right) \left(\frac{7.5}{7.5+3.2} \right) \left(\frac{1.66}{1.44+1.5} \right)$$

↑ ↑ ↑ ↑ ↑
 PEAK 1.5 SEV 4.7 W 0.4 6x
 2mm CON CON CON CON
 10 FROM
 END OF
 GRID

$$= 0.837 \text{ kW/cm}^2$$

$$\Delta T = \frac{W_c}{K_s} = \frac{(837 \text{ W/cm}^2)(2)(.066+.05) \text{ cm}}{(3.92 \text{ W/cm}^2 \cdot \text{cm})(1.0)} = 35^\circ \text{C}$$

$$\Delta = \frac{\alpha E \Delta T}{(1-\nu)} = \frac{(16.7 \times 10^{-6})(17 \times 10^9)(35)}{(1-.355)} = 15,200 \text{ PSI}$$

FOR OF HC COPPER

$$\Delta_y = 6,200 \text{ PSI} / \Delta_u = 28,600 \text{ PSI} (200^\circ \text{C})$$

$$\Delta_u = 24,500 \text{ PSI} (100^\circ \text{C})$$

$$\Delta_u = 20,600 \text{ PSI} (200^\circ \text{C})$$

SURFACE YIELDING WILL OCCUR - ON TROUBLE

— BEAM HITS GIRDER
CHAMBER - OK - BASED
ON ABOVE

@ ≤ 1.30 TES

— BEAM HITS SUPPL ENDR
COOLING BLOCK - OK - BASED
ON ABOVE

— BEAM HITS GIRDER CHAMBER
OK - BASED ON ABOVE

CONCLUSION:

BASED ON THE ABOVE, ALL AREAS
OF THE GIRDER CHAMBER ILLUMINATED
BY THE WIGGLON SYNCHROTRON LIGHT
ARE CAPABLE OF WITHSTANDING THE
INDICATED ILLUMINATION INTENSITIES.

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PEAK SYNCHROTRON LIGHT FLUX IN EXIT TUBE:

@ 5.64 μm - FIXED MASK GEOMETRY

$$\begin{aligned}
 M_{\text{PEAK}} &= \left(\frac{62 \text{ kW}}{\text{cm}^2} \right) \left(\frac{4.00}{5.64} \right)^2 \left(\frac{(6.32) \left(\frac{5.64}{4} \right)}{(6.32) \left(\frac{5.64}{4} \right) + 3.2} \right) \left(\frac{(1.54) \left(\frac{5.64}{4} \right)}{(1.54) \left(\frac{5.64}{4} \right) + 1.15} \right) \\
 &\quad \uparrow \quad \quad \quad \uparrow \quad \quad \quad \uparrow \quad \quad \quad \uparrow \\
 &\quad \text{PLAN @} \quad \quad \text{@} \quad \quad \quad \epsilon_x \quad \quad \quad \epsilon_y \\
 &\quad 4.00 \mu\text{m} \quad \quad 5.64 \mu\text{m} \quad \quad \text{CONVERSION} \quad \quad \text{CONVERSION} \\
 &\quad \quad \quad \quad \quad \quad \left(\frac{\epsilon_{HL}}{\epsilon_{HL} + \epsilon_x} \right) \quad \quad \left(\frac{\epsilon_{VL}}{\epsilon_{VL} + \epsilon_y} \right) \\
 &\quad \quad \quad \quad \quad \quad \epsilon_V = \frac{1}{2}
 \end{aligned}$$

$$= \underline{19.2 \text{ kW/cm}^2}$$

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WIGGLER VACUUM CHAMBER VERTICAL MOTION

LIMITS :

THE FOLLOWING ANALYSIS WAS CARRIED OUT ON THE BASIS THAT THE WIGGLER VACUUM CHAMBER WAS FIXED TO THE GIRDOR CHAMBER. IN REALITY, THE WIGGLER VACUUM CHAMBER CAN MOVE RELATIVE TO THE GIRDOR CHAMBER.

USING THE INFO ON PAGES 7, 11, 12 AND INFO FROM M 5927A, LIMITS AT DIFFERENT ENERGIES AND FIELDS CAN BE EXAMINED TO SET A MAXIMUM ALLOWABLE EXCURSION.

DEDICATED OPERATION (2.4 - 3.76GV)

@ 1.75 TESLAS - @ 3.76GV

$$P_g \quad 4 \Rightarrow \Delta y' = .467$$

FROM M 5927, PG 20 $\Rightarrow \Delta y' = .467$
PG 21

$$7.94 = .3 + \Delta y + (.467 + .150)(4.967)$$

$$\Delta y = 4.6 \text{ mm}$$

@ ≤ 1.30 TESLAS - @ 3.06GV - FROM M 5927, PG 20

$$\Delta y = 3.2 \text{ m}$$

- @ 3.76GV

POUNCE IS DOWN BV $\oplus$

$$\left(\frac{1.3}{1.75}\right)^2 = .552$$

$\oplus$ 1.75 TGS, 3.76GV, 100 mA

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$$\text{TOTAL POWER} = (5206 \text{ W})(.552) = 2872 \text{ W}$$

BEAM SPREAD DECREASES BY: ④

$$y = \frac{1.3}{1.75} = .74$$

FOR INCREASED RADIATION
X .552 TO EQUAL ALLOWABLE
HEAT LOAD X .74 (SEE PG 22-22)
M 5927

CLIPPING

1.0 mm

$$\frac{\Delta P}{(600)(.552)} = 331 \text{ W}$$

$$\frac{9}{(545)(.74)} = 403 \text{ W}$$

← OR

1.1 mm

$$(850)(.552) = 469 \text{ W}$$

$$(515)(.74) = 425 \text{ W}$$

← TOO HIGH

$$\theta_V = \frac{1.5 - 1.0}{4000} = .125 \text{ mrad}$$

$$\Delta y = 7.94 - (.3 + (.804)(.125))(4.907)$$

$$= 3.0 \text{ mm}$$

- @ 30 66V, 200 mA

POWER DOWN BY: ④

$$\eta = (.363)(2) = .726$$

TOTAL POWER IS

$$P = (5206)(.726) = 3780 \text{ W}$$

BEAM SPREAD DECREASES BY: ④

.74

FOR INCREASED RADIATION X .726
TO EQUAL ALLOWABLE HEAT LOAD
X .74

$$\textcircled{4} 1.75 \text{ TS, } 3.760 \text{ V, } 100 \text{ mA}$$

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BWMM CLIPPING

0.9 mm

1.0

$$\begin{array}{ccc} \Delta P & & q \\ (410)(.726) & \xleftrightarrow{\text{OK}} & (515)(.74) \\ = 298 \text{ W} & & = 381 \text{ W} \\ (600)(.726) & & (540)(.74) \\ = 436 \text{ W} & \xrightarrow{\text{100 HIGH}} & = 400 \text{ W} \end{array}$$

$$E_V = \frac{(1.5 - .9)(3.7)}{4000 \cdot 3.0} = .185$$

$$7.94 = .37 \Delta y + (.802 + .185)(4.967)$$

$$\Delta y = 2.7 \text{ mm}$$

CONCLUSION IS THAT AT 1.3 TESLAS, 3.7 GEV/100 MA CASE IS VERY CLOSE TO THE 3.0 GEV/200 MA CASE IN TERMS OF VERTICAL EXCURSION (0.3 mm DIFFERENCE)

PARASITIC OPERATION (1.5 GEV - 2.4 GEV)

@ 1.75 TESLAS - @ 2.4 GEV
POWER DOWN BY: $\odot$

$$\eta = \left(\frac{2.4}{3.7}\right)^2 = .421$$

BWMM SPREAD INCREASES BY: $\odot$

$$f = \frac{3.7}{2.4} = 1.542$$

FOR INCREMENTAL RADIATION X .421
TO EQUAL ALLOWABLE HEAT
LOADS X 1.233

CLIPPING

1.2 mm

1.5 mm

$$\begin{array}{ccc} \Delta P & & q \\ (1250)(.421) & & (605)(1.542) \\ 526 \text{ WATTS} & \text{OK} & 932 \text{ WATTS} \\ (2403)(.421) & & (700)(1.542) \\ 1095 \text{ WATTS} & \xleftrightarrow{\text{CLOSE LOADS}} & 1080 \text{ WATTS} \end{array}$$

$\odot$ 1.75 TES, 3.7 GEV, 100 MA

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THUS $\theta_v = 0$

$$\Delta y = 7.94 - 1.3 - (.467)(4.967) \\ = \underline{5.3 \text{ mm}}$$

@ $\leq 1.30 \text{ TEXAS}$ - @ 2.4 GeV

POWER IS DOWN BY: ④

$$\eta = \left(\frac{1.3}{1.75} \right)^2 - \left(\frac{2.4}{3.7} \right)^2 = .232$$

TOTAL POWER IS: ④

$$= (1.232)(5206) = 1207 \text{ WATTS}$$

BEAM SPREAD INCREASES BY: ④

$$y = \left(\frac{3.7}{2.4} \right) \left(\frac{1.3}{1.75} \right) \left(\frac{3.2 + 6.32}{6.32} \right) \\ = 1.73$$

④ $P_{ex} \text{ coll.}$

FOR RADIATION X 1.232 TO
EQUAL ALLOWABLE HEAT
LOAD X 1.73

CLIPPING

$$1.5 + 0.5 \\ = 2.0 \text{ cm}$$

DP

$$(2603 + 2110)(.232) \quad \frac{9}{(860)(1.73)} \\ 1093 \text{ WATTS} \quad \longleftrightarrow \quad 1488 \text{ WATTS} \\ \text{OK}$$

CHAMBER CAN TAKE
FULL WIGGLOW POWER
AT THIS ENERGY & FIELD
LEVEL

— BASED ON THE ABOVE, THE MAXIMUM
WIGGLOW VERTICAL EXCURSION IS $\pm 2.7 \text{ mm}$.
WITH ALIGNMENT CONSIDERATIONS, LIMIT THE
EXCURSION TO $\pm 2 \text{ mm}$.

④ 1.75 TES, 3.7 GeV, 100 mA

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