**Title**
WIGGLER SYNCHROTRON LIGHT ENVELOPE



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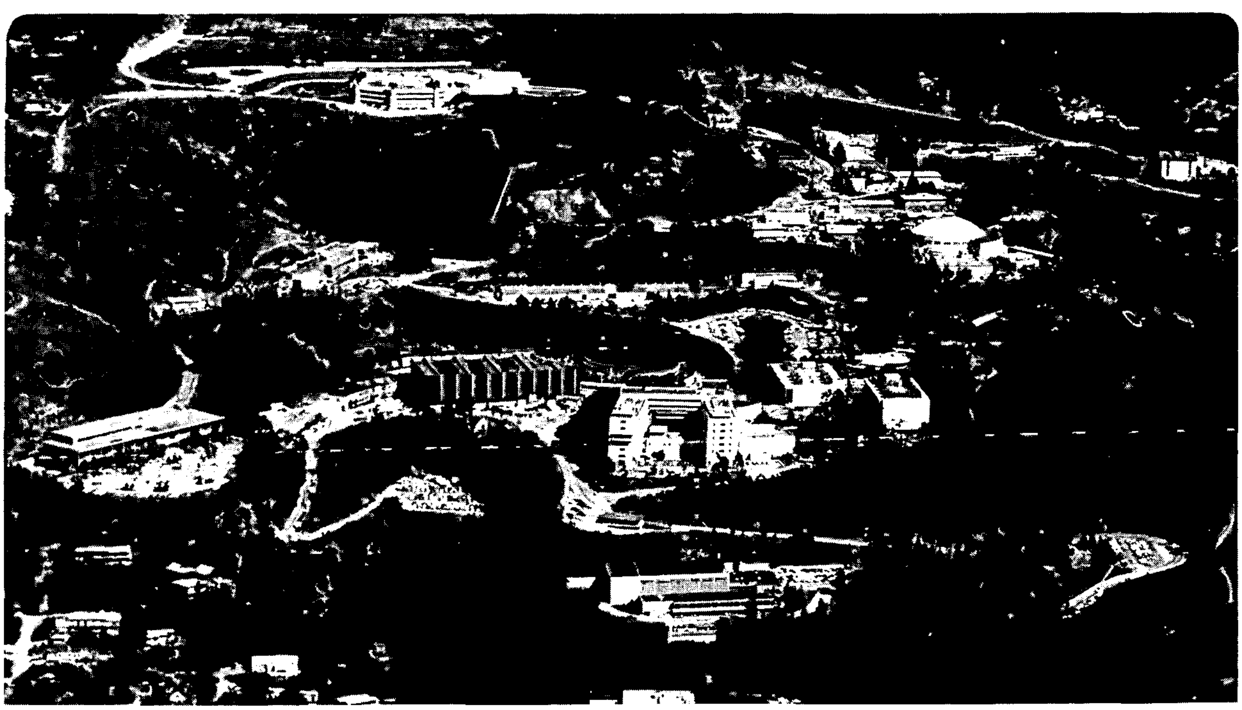
# Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

## Engineering & Technical Services Division







## DISCLAIMER

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|---|---|---|---|
| AUTHOR EGON HOYER | DEPARTMENT | LOCATION | DATE 6/17/82 |

PROGRAM — PROJECT — JOB
SLF - WIGGLER / BEAM LINE VI
MASKS - GIRDER CHAMBER

TITLE
WIGGLER SYNCHROTRON LIGHT ENVELOPE

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

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

BASIS

ELECTRON BEAM SIZE:

$\sigma_y = \pm .15$ MM → USE $2\sigma_y = \pm .30$ MM

$\sigma_x = \pm 3.2$ MM → USE $2\sigma_x = \pm 6.40$ MM

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

$\Delta x_s = \pm 10$ MM

$\Delta x'_s = \pm 1.34$ MRAD

$\Delta y_s = \pm 6$ MM

$\Delta y'_s = \pm 0.802$ MRAD

BEAM LIFETIME WHEN COMING CLOSE TO A CONDUCTING SURFACE:

FOR 3.0 GEV:

| 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 |

COMPUTE TRAJECTORIES ON THE BASIS THAT THE ELECTRON BEAM DISAPPEARS WHEN THE BEAM-SURFACE SPACING DISTANCE IS 2.5 MM

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|---|---|---|---|---|
| AUTHOR EGON HOYER | DEPARTMENT | LOCATION | DATE 6/17/82 | |

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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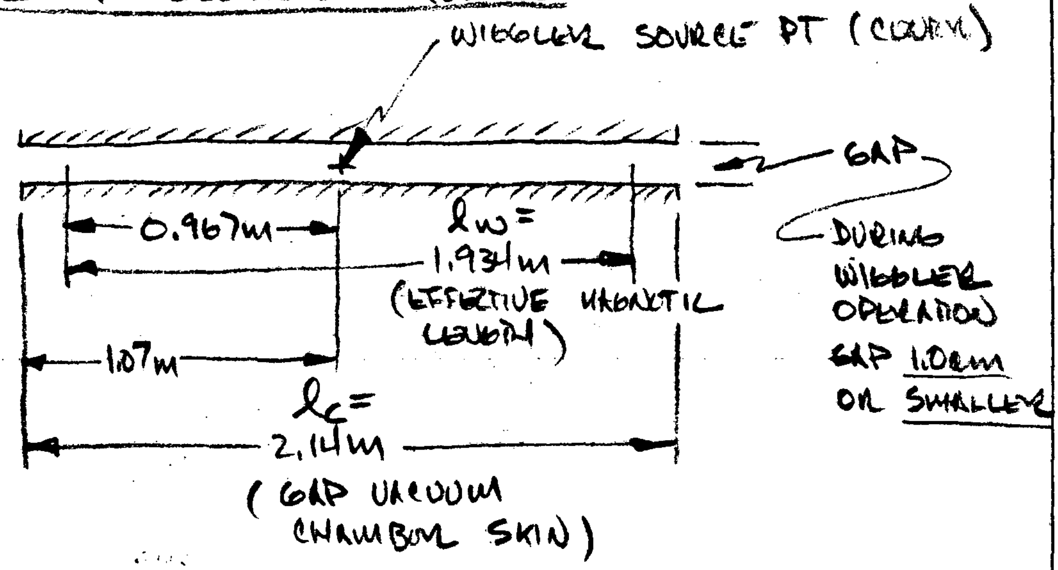
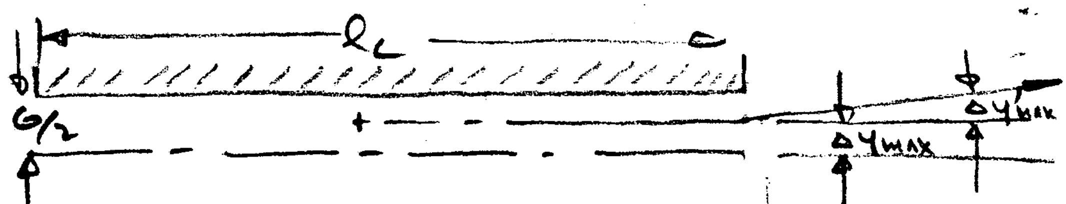
## TRANSVERSE Y PLANE:

WIGGLER Y SECTION SCHEMATIC:




ELECTRON BEAM ORBIT LIMITS: (LIFETIME CONSIDERATION)

– B ≤ 1.30TES → 1.0cm GAP OPERATION:




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

$$l_c \Delta y' \le 2\Delta y_{max} \le (2)(2.5\,mm) \le 5.0\,mm$$

$$\Delta y' \le \frac{5.0\,mm}{2140\,mm} \le 2.34\,mRAD$$

THUS: $\Delta y'_{max} = \Delta y'_s = \underline{0.802\,mRAD}$

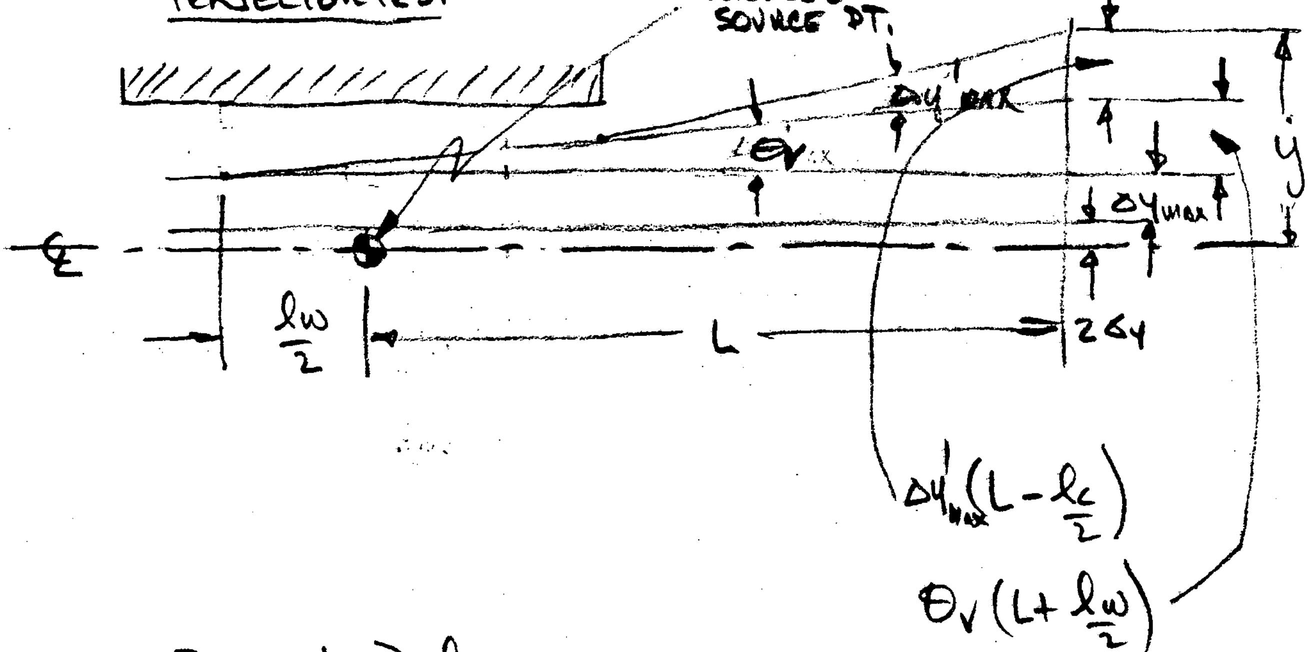
– B = 1.75 TES → 0.6cm GAP OPERATION:

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

$$\Delta y' = \frac{1\,mm}{2140\,mm} = 0{,}467 \text{ mRAD}$$

$$\Delta y'_{max} = \Delta y' = \underline{0{,}467 \text{ mRAD}}$$

TRAJECTORIES:




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

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

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

FROM M 5927, P6'2, AT 4.0m, FOR THE INTENSITY TO BE ~50 W/cm², $\Theta_V = 3/\gamma$ FOR $B_{WIG} = 1.75$ TES, $E_{SPEAR} = 3.7$ GeV, $I_{SPEAR} = 100$ mA

USE:

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

| E (GeV) | 2.4 | 3.0 | 3.7 | 1.5 |
|---|---|---|---|---|
| $\Theta_V$ (mRAD) | ± .638 | ± .511 | ± .414 | ± 1.020 |

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

- FOR B ≤ 1.30 TES (1.0cm GAP OPERATION)

$$y_{max \; \le 1.5TES} = \pm\left[0.30 + 2.50 + \Theta_V (L + 967mm) + 0.802^{mrad} (L - 1070 mm\right.$$

$$y_{max \; \le 1.5TES} = \pm\left[1.942 + .802\,L(m) + \Theta_V(mrad)\left(L(m) + 0.967\right)\right] mm$$

| ENERGY (GEV) | $\Theta_V$ (±MRAD) | $y_{max \; \le 1.3TES}$ (±MM) |
|---|---|---|
| 2.4 | .638 | 2.558 + 1.440 L(m) |
| 3.0 | .511 | 2.436 + 1.313 L(m) |
| 3.7 | .414 | 2.342 + 1.216 L(m) |
| 1.5 | 1.020 | 2.928 + 1.822 L(m) |

- FOR B = 1.75 TES (0.6cm GAP OPERATION)

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

$$= \pm\left[0.300 + .467\,L(m) + \Theta_V(mrad)\left(L(m) + .967\right)\right]$$

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| ENERGY (GEV) | $\theta_V$ ($\pm$MRAD) | $y_{max}$ 1.75 TES (±MM) |
|---|---|---|
| 2.4 | .638 | 0.917 + 1.105 L(m) |
| 3.0 | .511 | 0.794 + 0.978 L(m) |
| 3.7 | .414 | 0.700 + 0.881 L(m) |
| 1.5 | 1.020 | 1.286 + 1.487 L(m) |

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

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| CODE | SERIAL | PAGE |
|---|---|---|
| SL0712 | M 5936 | 7 OF 19 |

| AUTHOR | DEPARTMENT | LOCATION | DATE |
|---|---|---|---|
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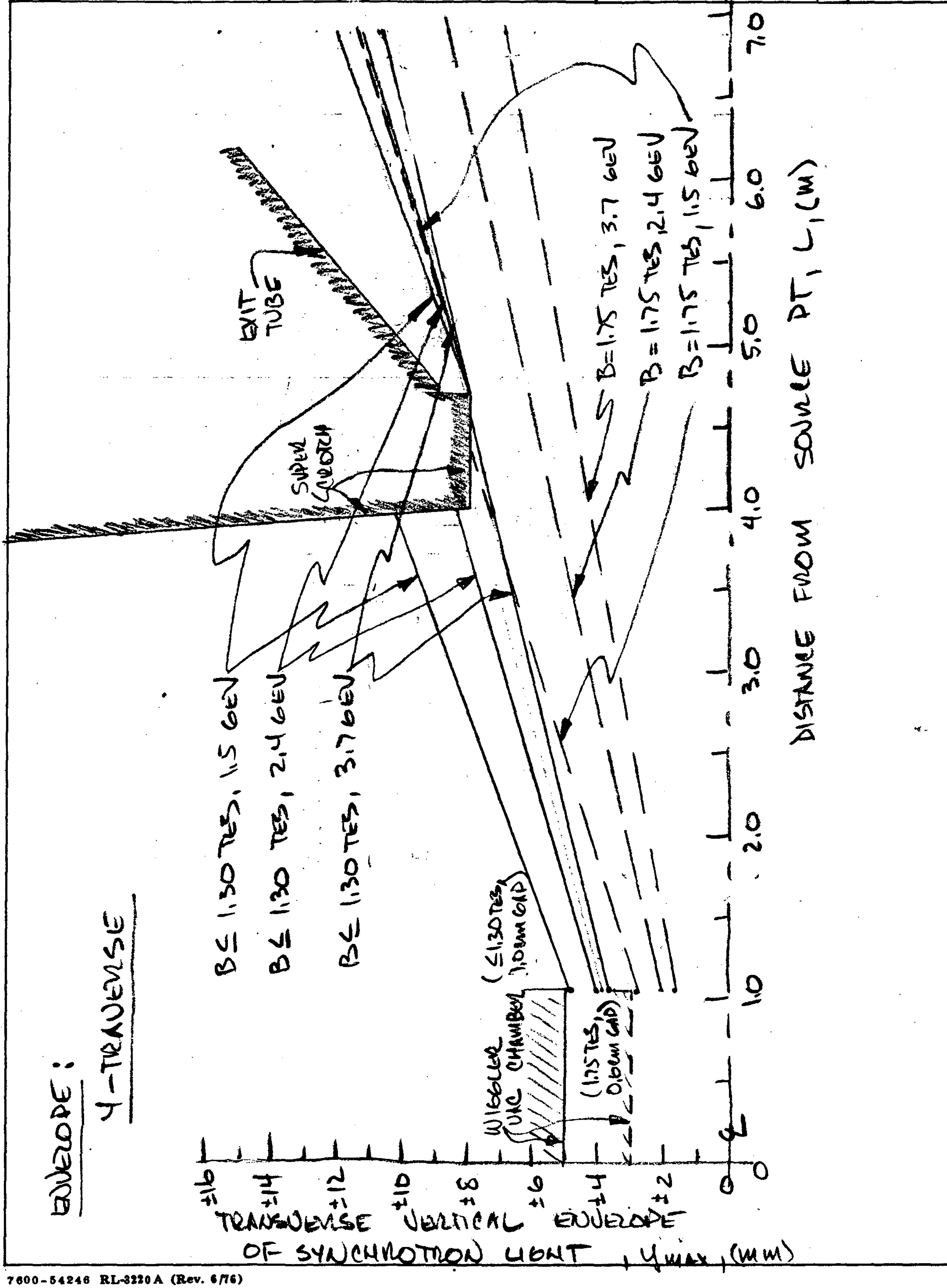
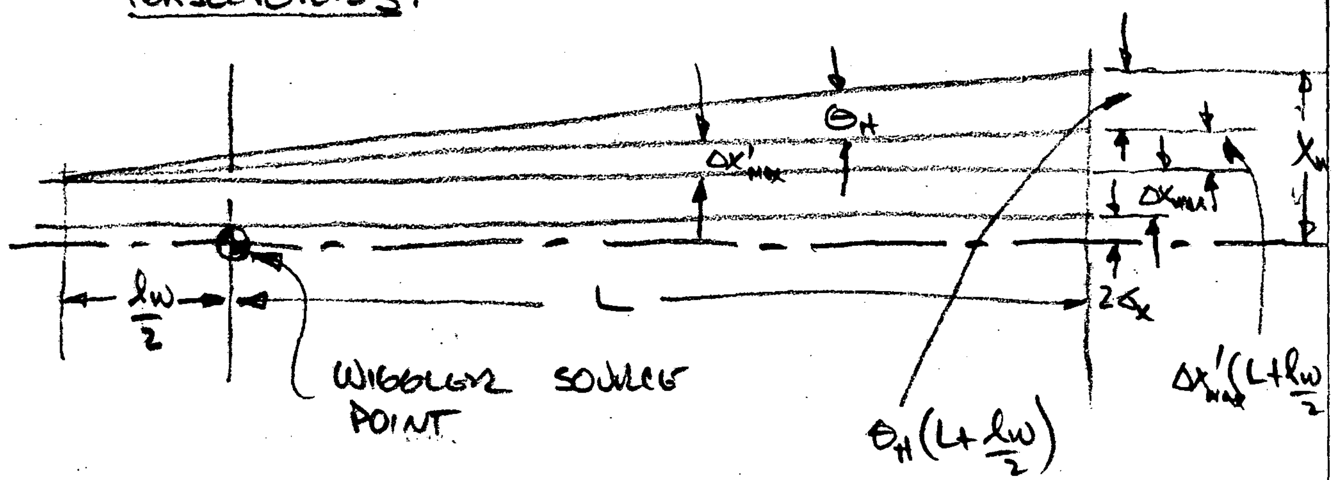


## TRANSVERSE X PLANE

THERE ARE NO LIFETIME CONSIDERATIONS IN THE TRANSVERSE X-PLANE

TRAJECTORIES:




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

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

$$\Theta_H = \pm \frac{.4775\ \lambda_{WIG}(cm)\ B_{WIG}(TES)}{E(GeV)} \quad (mRAD)$$

FOR $\lambda_{WIG} = 7cm$

$$\Theta_H = \pm\ 3.343\ \frac{B(TES)}{E(GeV)} \quad (mRAD)$$

| B (TES) | E (GeV) | $\Theta_H$ (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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$$X_{MAX} = \pm\left[(2)(3.20\,mm) + 10\,mm + (\Theta_H + 1.34\,(mRAD))(L + .967\,m)\right]$$

$$X_{MAX} = \pm\left[16.4 + (\Theta_H + 1.34\,(mRAD))(L(m) + .967\,m)\right]\,(mm)$$

- FOR B ≤ 1.30 TES (1.0 cm GAP OPERATION)

| ENERGY (GEV) | $\Theta_H$ (± mRAD) | $X_{MAX}$ ≤ 1.30 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 = 1.75 TES (0.6 cm GAP OPERATION)

| ENERGY (GEV) | $\Theta_H$ (± mRAD) | $X_{MAX}$ 1.75 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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| CODE | SERIAL | PAGE |
| --- | --- | --- |
| SL0712 | M5936 | 10 OF 19 |

| AUTHOR | DEPARTMENT | LOCATION | DATE |
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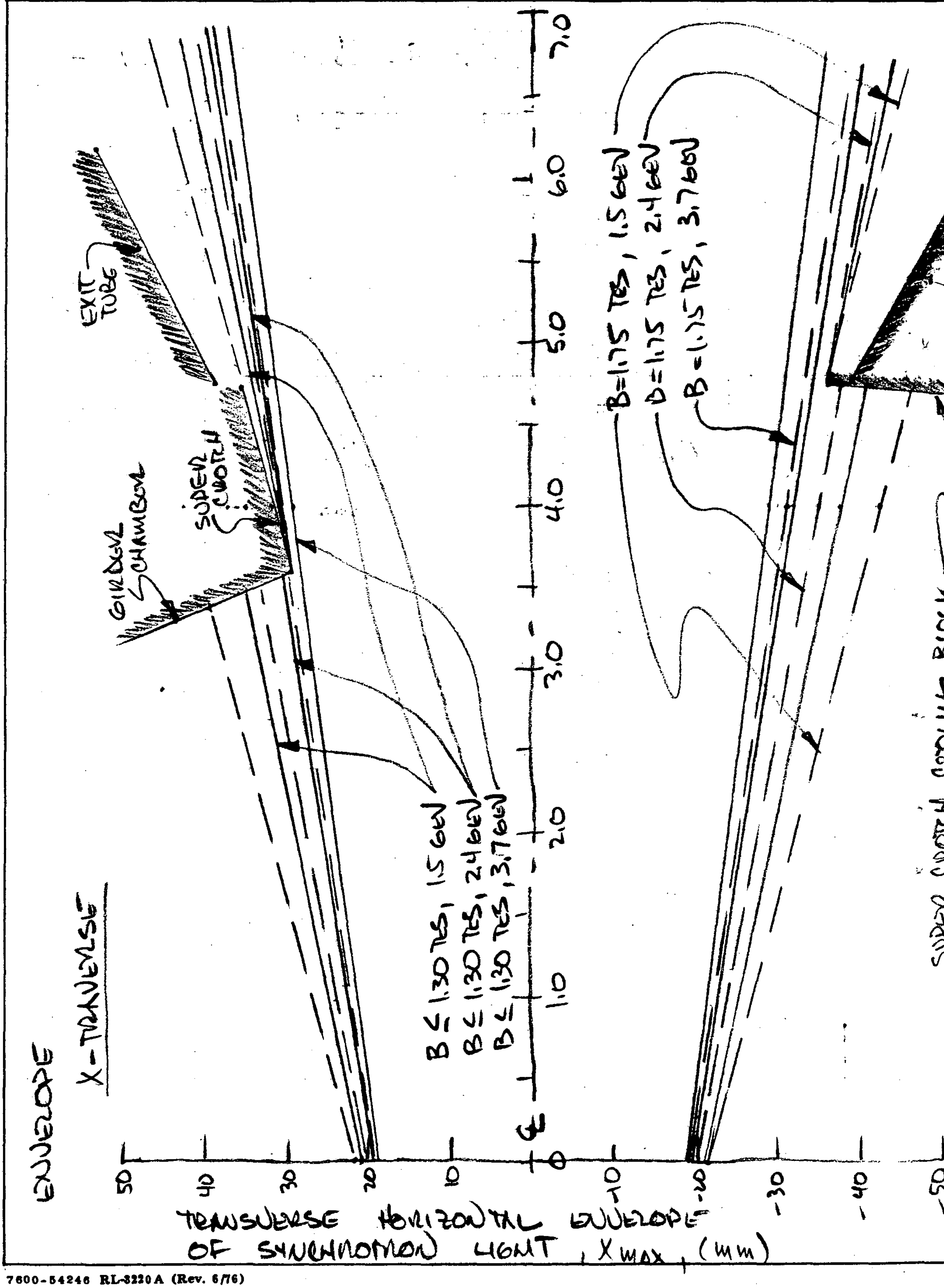


GIRDER CHAMBER ILLUMINATION:

Y TRAVERSE:

DEDICATED OPERATION (2.4 – 3.7 GEV):

@ 1.75 TES — BEAM CLEARS GIRDER CHAMBER

@ ≤1.30 TES — BEAM HITS SUPER CROTCH –

- 1/2 MM IMPINGEMENT ON 3.9° BEVEL @ 2.4
  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 CROTCH STRAIGHT SECTION
OK – SEE ABOVE

@ ≤ 1.30 TES — BEAM HITS SUPER CROTCH

- 2.3 MM IMPINGEMENT ON 3.9° BEVEL @ 1.5

POWER LEVEL @ 1.5 GEV, 100 MA, 1.3 TES

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

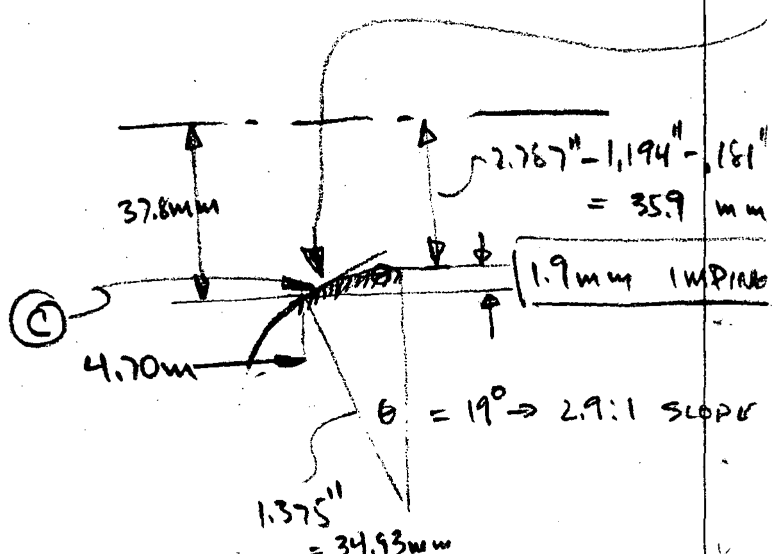
FROM PG 15, M 5927A, AVAILABLE COOLING FOR 2.3mm OF BEAM IMPINGEMENT >472 W
∴ OK

– STRAIGHT SECTION OK – SEE ABOVE

## X TRAVERSE

DEDICATED OPERATION (2.4 – 3.7 GeV):

@1.75 TES – BEAM HITS SUPER[illegible] COOLING BLOCK @ 2.4GeV




MAXIMUM HEATING AT (C)

$$H_{max} = \left(\frac{44\,kW}{cm^2}\right)\left(\frac{2.4}{3.7}\right)^2\left(\frac{1}{2.9}\right)\left(\frac{4.75}{4.7}\right)^2\left(\frac{20}{44}\right)\left(\frac{2.4}{3.7}\right)\left(\frac{7.51}{7.51+3.2}\right)^{.70}\left(\frac{.66}{.66+ \ldots}\right)^{.81}$$

(PEAK @ 4.75; 2.4 GeV CORRECTION; SLOPE; 4.7m CORRECTION; FAILING CORR.; θH CORRECTION; εx CORRECTION; ε COR…)

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

- BEAM HITS GIRDER CHAMBER @ 3.6M
- 2.1 MM IMPINGEMENT @ 3.7 GEV - OK M5927a PG'S 18 & 19
- 33.64 - 27.6 = 6.0 MM OF IMPINGEMENT @ 2.4 GEV
  UNIT HEAT DOWN BY $\left(\frac{2.4}{3.7}\right)^2 = .42$ - OK PER PG 19, M5927a

@ ≤ 1.30 TES

- BEAM CLEARS SUPER CROTCH COOLING BLOCK
- BEAM HITS GIRDER CHAMBER
  3.2 MM @ 2.4 GEV
  OK - BASED ON ABOVE

## PARASITIC OPERATION (1.5 - 2.4 GEV)

@ 1.75 TES

- BEAM HITS SUPER CROTCH COOLING BLOCK
- @ 1.5 GEV
  46.1 - 37.8 = 8.3 MM IMPINGEMENT
  WORST HEATING CONDITION OCCURS ~3 MM IN FROM EDGE OF ILLUM. (@ 5.3 MM)

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MAX. HEATING @ 5.3 mm IMPINGEMENT

$$W_{NET} = \left(\frac{35\,kW}{cm^2}\right)\left(\frac{1.5}{3.7}\right)^2\left(\frac{4.75}{4.70}\right)^2\left(\frac{1.5}{3.7}\right)\left(\frac{7.5}{7.5+3.2}\right)\left(\frac{.166}{.166+.15}\right)$$

(.70, .81, .6 — tons)

- PEAK 2 mm IN FROM ENVELOPE EDGE
- 1.5 GeV CORR
- 4.7 w. CORR
- $\theta_H$ CORR
- $\sigma_X$ CORR
- $\sigma_Y$ CORR

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

$$\Delta T = \frac{W_L}{KS} = \frac{(837\,W/cm^2)(2)(.066+.015)cm}{(3.92\frac{W}{cm\,°K})(1.0)} = 35\,°C$$

$$\sigma = \frac{\alpha E \Delta T}{(1-\nu)} = \frac{(16.7\times10^{-6})(17\times10^{6})(35)}{(1-.355)} = 15'200\ PSI$$

FOR OFHC COPPER

$\sigma_y = 6200$ PSI / $\sigma_u = 28600$ PSI (20°C)

$\sigma_u = 24'500$ PSI (100°C)

$\sigma_u = 20'600$ PSI (200°C)

SURFACE YIELDING WILL OCCUR — OK THOUGH

— BEAM HITS GIRDER CHAMBER — OK BASED ON ABOVE

@ ≤ 1.30 TES — BEAM HITS SUPER CROTCH 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 WIGGLER SYNCHROTRON LIGHT ARE CAPABLE OF WITHSTANDING THE INDICATED ILLUMINATION INTENSITIES.

## PEAK SYNCHROTRON LIGHT FLUX IN EXIT TUBE:

@ 5.64M – FIXED MASK ENTRANCE

$$W_{PEAK} = \left(\frac{62\,kW}{cm^2}\right)\left(\frac{4.00}{5.64}\right)^2 \overset{(.736)}{\left(\frac{(6.32)(\frac{5.64}{4})}{(6.32)(\frac{5.64}{4})+3.2}\right)} \overset{(.835)}{\left(\frac{(.54)(\frac{5.64}{4})}{(.54)(\frac{5.64}{4})+.15}\right)}$$

- ↑ PEAK @ 4.00M
- ↑ @ 5.64M
- ↑ $\sigma_x$ CORRECTION $\left(\frac{\theta_H l}{\theta_H l + \sigma_x}\right)$
- ↑ $\sigma_y$ CORRECTION $\left(\frac{\theta_V l}{\theta_V l + \sigma_y}\right)$, $\theta_V = \frac{1}{\gamma}$

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

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LOCATION:
DATE: 7/29/82

WIGGLER VACUUM CHAMBER VERTICAL MOTION LIMITS:

THE FORGOING ANALYSIS WAS CARRIED OUT ON THE BASIS THAT THE WIGGLER VACUUM CHAMBER WAS FIXED TO THE GIRDER CHAMBER IN REALITY, THE WIGGLER VACUUM CHAMBER CAN MOVE RELATIVE TO THE GIRDER 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 – 3.7GeV)

@ 1.75 TESLAS — @ 3.7 GeV

Pg 4 ⇒ $\Delta y' = .467$

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

PG 21

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

$\Delta y = 4.6\,mm$

@ ≤ 1.30 TESLAS — @ 3.0GeV — FROM M 5927, PG

$\Delta y = 3.2\,m$

— @ 3.7 GeV

POWER IS DOWN BY ⊛

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

⊛ 1.75 Tes, 3.7GeV, 100 ma

TOTAL POWER = (5206 W)(.552) = 2872 W

BEAM SPREAD DECREASES BY: ⊛

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

FOR INCREMENTAL RADIATION X .552 TO EQUAL ALLOWABLE HEAT LOAD X .74 (SEE PG 22-22 M5927)

| CLIPPING | ΔP | q |
|---|---|---|
| 1.0 MM | (600)(.552) = 331 W | ←OK→ (545)(.74) = 403 W |
| 1.1 MM | (850)(.552) = 469 W | ← TOO HIGH — (575)(.74) 425 W |

$$\Theta_V = \frac{1.5 - 1.0}{4000} = .125 \text{ MRAD}$$

$$\Delta y = 7.94 - (.3 + (.8024 \cdot .125)(4.907))$$

$$= \underline{3.0} \text{ MM}$$

— @ 3.0 GEV, 200 MA

POWER DOWN BY: ⊛

$$\eta = (.363)(2) = \underline{.726}$$

TOTAL POWER IS

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

BEAM SPREAD DECREASES BY ⊛ .74

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

⊛ 1.75 T/S, 3.76 GEV, 100 MA

| BEAM CLIPPING | ΔP | | q |
|---|---|---|---|
| 0.9 mm | (410)(.726) = 298 W | OR ⟷ | (515)(.74) = 381 W |
| 1.0 | (600)(.726) = 436 W ← TOO HIGH | | (540)(.74) = 400 W |

$$\theta_V = \frac{(1.5-.9)\left(\frac{3.7}{3.0}\right)}{4000} = .185$$

$$7.94 = .3 + \Delta y + (.802 + .185)(4.967)$$

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

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: ⊛

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

BEAM SPREAD INCREASES BY: ⊛

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

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

| CLIPPING | ΔP | | q |
|---|---|---|---|
| 1.2 mm | (1250)(.421) = 526 WATTS | OK | (605)(1.542) 932 WATTS |
| 1.5 mm | (2603)(.421) = 1095 WATTS | ⟷ CLOSE ENOUGH | (700)(1.542) = 1080 WATTS |

⊛ 1.75 TES, 3.7 GEV, 100 MA

THUS $\theta_V = 0$

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

$= \underline{5.3 \text{ mm}}$

@ ≤ 1.30 TESLAS — @ 2.4 GeV

POWER IS DOWN BY: ⊕

$\eta = \left(\frac{1.3}{1.75}\right)^2 \left(\frac{2.4}{3.7}\right)^2 = .232$ (.742) (.421)

TOTAL POWER IS: ⊕

$(.232)(5206) = \underline{1207 \text{ WATTS}}$

BEAM SPREAD INCREASES BY: ⊕

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

$P_{Gx}$ CORR.

$= 1.73$

FOR RADIATION × .232 TO EQUAL ALLOWABLE HEAT LOAD × 1.73

| CLIPPING | DP | q |
|---|---|---|
| 1.5 + 0.5 = 2.0 cm | (2603 + 2110)(.232) 1093 WATTS | (860)(1.73) 1488 WATTS |

1093 WATTS ←OK→ 1488 WATTS

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

— BASED ON THE ABOVE, THE MAXIMUM WIGGLER VERTICAL EXCURSION IS ± 2.7 MM. WITH ALIGNMENT CONSIDERATIONS, LIMIT VERT EXCURSION TO $\underline{\pm 2 \text{ MM}}$.

⊕ 1.75 TES, 3.7 GeV, 100 mA

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