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### Accelerator Physics Project Review On The November 23, 1983 Meeting

A. G. Ruggiero

November 1983

Collider Accelerator Department

Brookhaven National Laboratory

#### **U.S. Department of Energy**

USDOE Office of Science (SC)

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RHIC-PG-8

### ACCELERATOR PHYSICS PROJECT REVIEW ON THE NOVEMBER 23, 1983 MEETING

A. G. RUGGIERO

(BNL, November 23, 1983)

#### ACCELERATOR PHYSICS MILESTONES

| 1. | Work out Linear Lattice<br>Curved sectors + insertions  |                              |         |
|----|---|------------------------------|---------|
|    | Two cases:  |                              |         |
|    | (I) LARGE ANGLE CROSSING, LONG BUNCHES (II) HEAD-ON COLLISION, SHORT BUNCHES  | DEC.                         | 1       |
| 2• | SEXTUPOLES AND CHROMATIC EFFECT<br>ANALYSIS, PATRICIA TRACKING FOR BOTH CASES   | JAN.                         | 1       |
| 3. | INTRA-BEAM SCATTERING CALCULATION   | DEC.                         | 1       |
| 4. | Collider Performance Resolve physics implications of 2-in-1 Reference case (Gold on Gold) Scaling with different A (some species) Different species (A <sub>1</sub> on A <sub>2</sub> ) | Nov.<br>Dec.<br>Dec.<br>Jan. | 1<br>20 |
| 5• | AGREE ON INJECTOR PERFORMANCE   | JAN-                         | 5       |

Complete analysis of beam size and aperture requirements | Jan. 30

### ACCELERATOR PHYSICS SCHEDULE

|                          | . NOVEMBER | DECEMBER | JANUARY |
|--------------------------|------------|----------|---------|
| COLLIDER PERFORMANCE     |            |          |         |
| LATTICE DESIGN           |            |          |         |
| Instabilities            |            |          |         |
| VACUUM RELATED PROBLEMS  |            |          |         |
| Intra Beam Scattering    |            |          |         |
| INJECTOR PERFORMANCE     |            |          |         |
| RF-Beam Manipulation     |            |          |         |
| MAGNET BEAM MANIPULATION |            |          |         |

### The Sequence

The Heavy Ion Source

The Tandem Van de Graaff

A Pre-Booster

The Booster

The AGS

The Collider (RHIC)

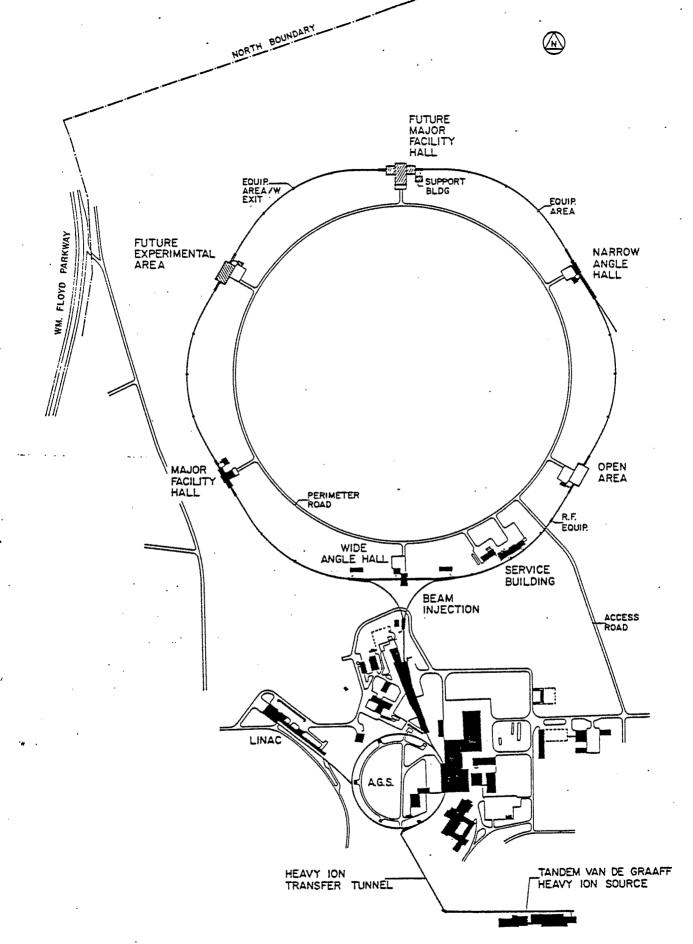
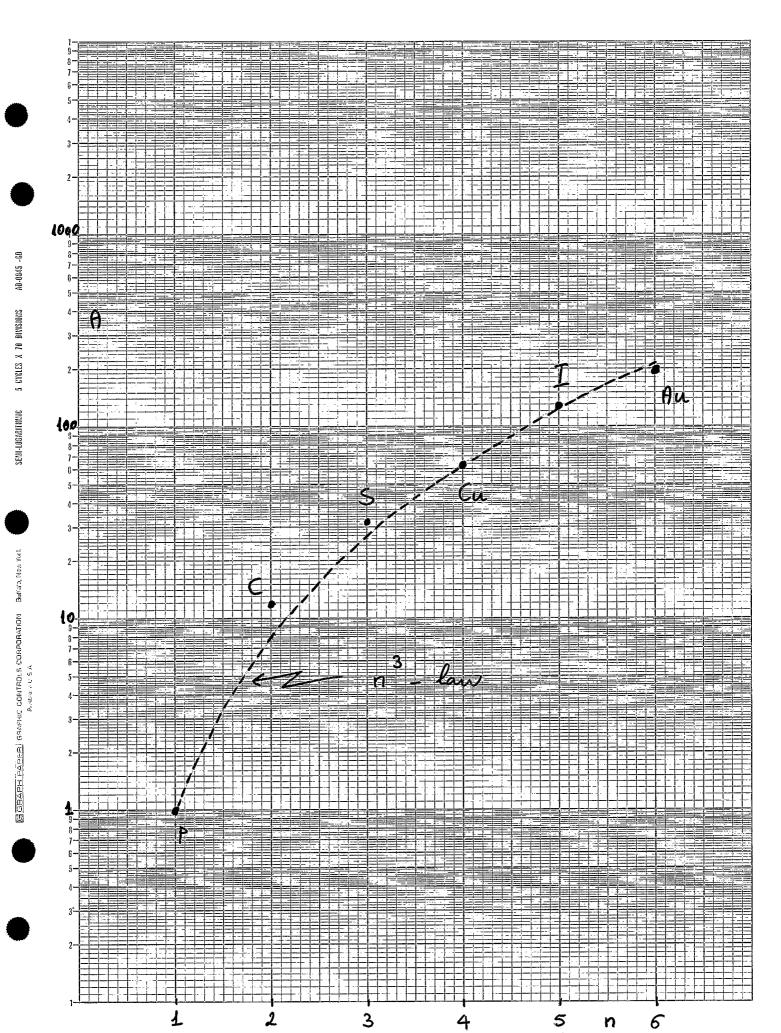


Fig. II.1 Existing CBA tunnel, experimental halls and proposed Tandem/AGS transfer tunnel.

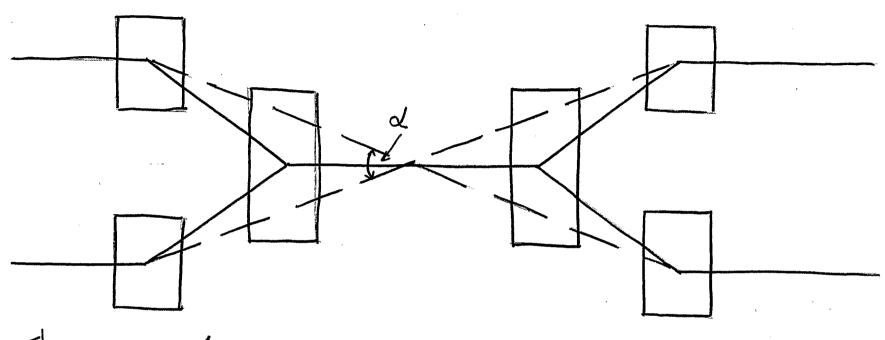
## The Chosen Species

| Specie      | <u>Z</u> | <u>A</u> | A/Z |  |
|-------------|----------|----------|-----|--|
| proton      | 1        | 1        | 1.0 |  |
| Carbon (C)  | 6        | 12       | 2,0 |  |
| Sulphur (S) | 16       | 32       | 2.0 |  |
| Copper (Cu) | 29       | 63       | 2.2 |  |
| Iodine (I)  | 53       | 127      | 2.4 |  |
| Gold (Au)   | 79       | 197      | 15  |  |



| T          | ß                    | 8  |  | Ng/EN            |  | $\mathcal{E}_{N}$   |           | NB  |                   |
|------------|----------------------|--|--|------------------|--|---|-----------|---|-------------------|
| HeV.       | 22240                | The state of the s |  | T-1 m-1          |  | T mm·mra  | d         |   |                   |
|            | 0.4.610              | / 22/200   | NYMETOTE AND COMMENT OF THE PROPERTY OF THE PR | 14               | The second secon | of a state of the |           | 8   | Back and a second |
| 1.5        |                      | 1.00 1066  |  | 4 × 10<br>5 × 10 |  | 1.85  |           | 7.4 ×10<br>9<br>1.13×10                           |                   |
| 2.         |                      | 1.002132   |  | 5.7×10           |  | 2.61  |           | 1.15×10<br>1.5×10                                 |                   |
| 3.         |                      | 1.003197   |  | 7 × 10 14        |  | 3.20  |           | 2.24×10   |                   |
| 4.         | .09204               | 1.004263   |  | 8.1×10 14        |  | 3.70  |           | 3 × 10  |                   |
| 5,         | .10283               | 1,005329   |  | 9.1×10           |  | 4.115   |           | 3.74×10   | <b>3</b>          |
| <i>N</i> = | = N <sub>B</sub> /(3 | 3×2)   | Tav  | dem 6            | nrrent   | ~ 4.4   | PMA       |   |                   |
|            | ~                    |  | N  |                  | N/turn   |   | no. turns |   | Pulse             |
| HeV        | usec                 |  | 8<br>×10   |                  | 8<br>× [0  |   |           |   | me                |
| 1.         | 14.6                 |  | 1. 23  |                  | 4.   |   | 1.85      | Secretary Co. | 27                |
| 1.5        | 11,9                 |  | 1.88   |                  | 3.3  |   | 3-4       |   | 40                |
| 2.         | 10.3                 |  | 2.48   |                  | 2.83   |   | 5.3       |   | 54.               |
| 3.         | 8.43                 |  | 3.73   |                  | 2.32   |   | 9-7       |   | 81.               |
| 4.         | 7.3                  |  | 5.0  |                  | 2.0  |   | 15        |   | 109.              |
| 5.         | 6,54                 | D. Maria Control   | 6.24   |                  | 1.8  |   | 21        |   | 137               |
| Lunina     | asity a              | 2  | (.   | N 1/2            | 3/ <sub>2</sub>  | "\2<br>B  | (B)       | ' <b>-</b> B                                      | 7/2               |
|            |                      | VEN  |  | EN               |  |   | 1/5 /     |   |                   |
| Also       | Simin                | -: 4   | N 2  |                  |  |   |           |   |                   |
| 1,536      | Sevvy, ,             | 03119  | - <del>-</del>   |                  |  |   |           |   |                   |

Head-on Collision vs. Collision at Large Angle



There are 4 cases:

- 1. (A) colliding with (A) (same species), bundled, head-on
- 2. (A1) colliding with (A2) (different species), bunded, head-on or lit length adjusted
- 3. A colliding with protons, bundled vs. unbunched, angle ±0
- 4. Protons) colliding with (protons), bunched, head-on

# With the Same Field and Gradients in both Rings

| Au | <del>( )</del>  | I  | 100 GeV/A vs. | 104 GeV/A |
|----|-----------------|----|---------------|-----------|
| Au | <del></del>     | Cu | 100           | 113       |
| Au | <b>←</b> ⇒      | S  | 100           | 125       |
| Au | <b>~</b> >      | C  | 100           | 125       |
| Au | <del>&gt;</del> | P  | 100           | 250       |

Very likely the experimentalist like to have the same energy/molion in both beams.

If this is true, then if An has 100 GeV/A also anything else (I,..., p) must have 100 GeV/A and no more (and no less). As a consequence

or and B are He same

the bunded beams can collide metaled in velocity.

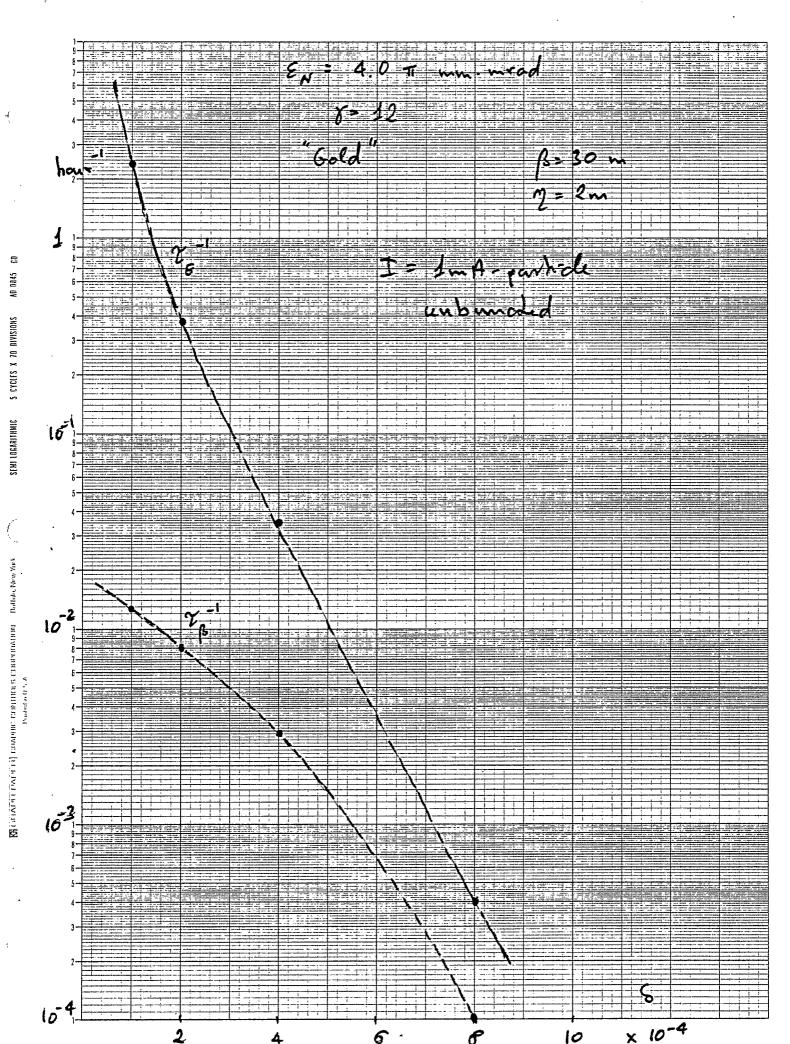
The argument of different velocities applies only to the case the two beams have different energies so, for instance, the sings magnetic field is the same.

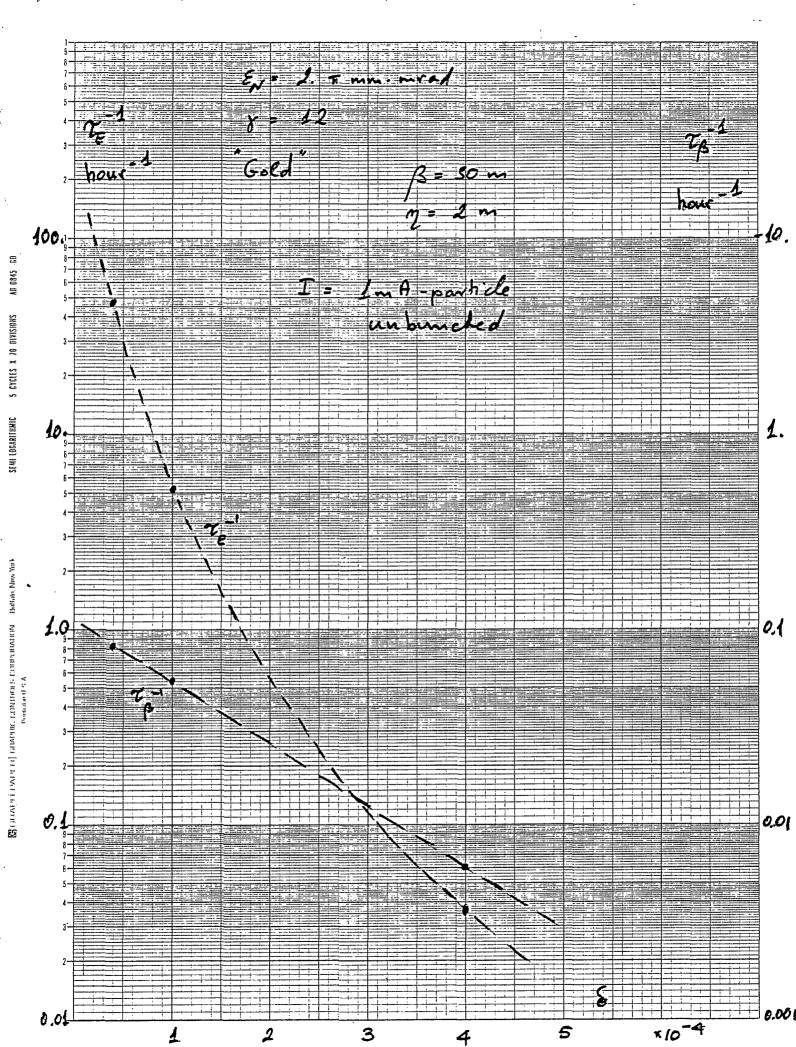
## PERFORMANCE COMPARISON BETWEEN SHORT AND LONG BUNCHES A. Ruggiero

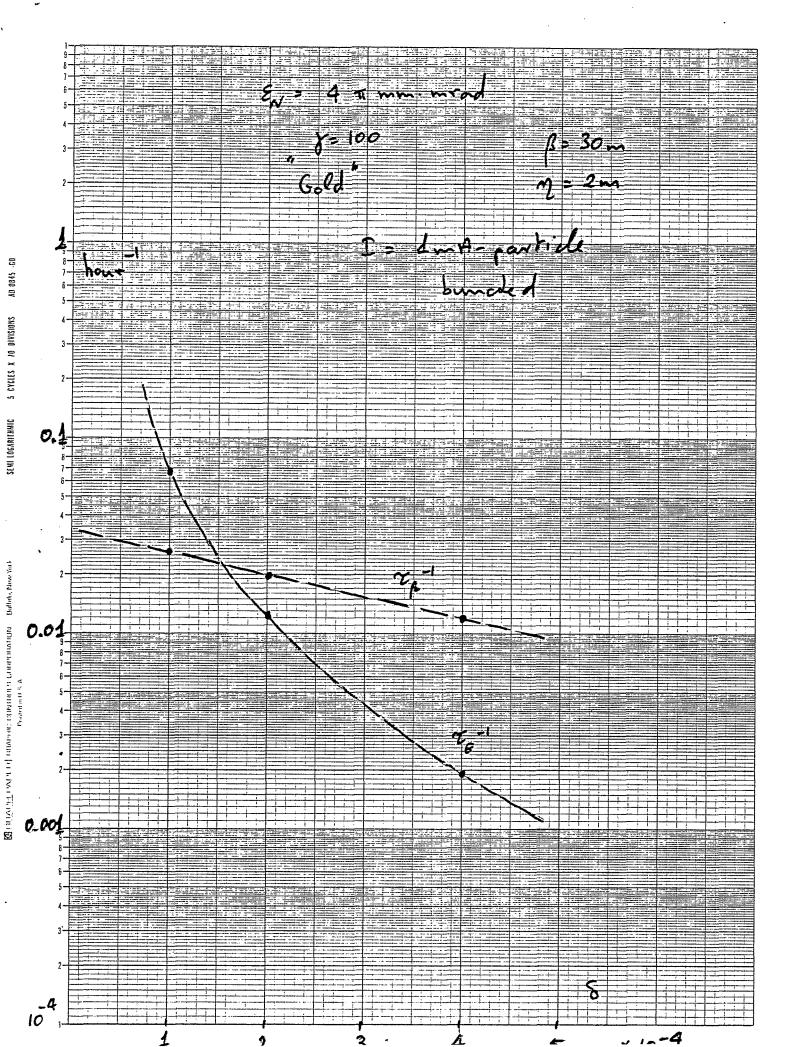
| Case                             | "S" -   | "L"  |  |  |  |
|----------------------------------|---|--|--|--|--|
| Bunches                          | Short   | Long   |  |  |  |
| Luminosity Formula               | N <sup>2</sup> B f <sub>rev</sub> /2πασ <sub>e</sub> σν | . same   |  |  |  |
| Cricumference, 2πR               | 3833.8 m  | same   |  |  |  |
| Revolution Frequency, f          | 78.1973 KHz   | same   |  |  |  |
| Crossing Angle, α                | 2 mrad  | same   |  |  |  |
| AGS Cycle Time                   | 2 sec   | same   |  |  |  |
| rms Bunch Length, o <sub>e</sub> | 10 cm   | 50 m   |  |  |  |
| No. of Bunches, B                | 57  | 3  |  |  |  |
| No. of Ions/Bunch, N             | $6.24 \times 10^8$                                      | 6 × 10 <sup>10</sup>                               |  |  |  |
| Total No. of Ions/Ring           | $3.56 \times 10^{10}$                                   | 1.8 × 10 <sup>11</sup>                             |  |  |  |
| No. of Ions/AGS Pulse            | $1.87 \times 10^9$                                      | same   |  |  |  |
| No. of Bunches/AGS Pulse         | 3   | same   |  |  |  |
| No. of AGS Pulses/Ring           | 19 box car  | (19 box car)×(6RF stacking)                        |  |  |  |
| Normalized Emittance             | 4.0 π mm-mrad   | same   |  |  |  |
| Emittance @ 100 GeV/A            | 0.04 π mm-mrad  | . same   |  |  |  |
| β <b>*</b><br><b>V</b>           | 2m  | same   |  |  |  |
| σ*<br>V                          | 0.01155 cm  | same   |  |  |  |
| Luminosity, L                    | $1.2 \times 10^{27} \text{ cm}^{-2} \text{s}^{-1}$      | $1.2 \times 10^{27} \text{ cm}^{-2} \text{s}^{-1}$ |  |  |  |
| Filling Time                     | 2 × 1 minute  | 2 × 12 minutes                                     |  |  |  |

## PERFORMANCE COMPARISON BETWEEN SHORT AND LONG BUNCHES A. Ruggiero

| ·                   |  |   |
|---------------------|--|---|
| Case                | "S"  | "L"   |
| Bunches             | Short  | · Long  |
| Initial Luminosity  | $1.2 \times 10^{27} \text{ cm}^{-2} \text{s}^{-1}$ | 1.2 × 10 <sup>27</sup> cm <sup>-2</sup> s <sup>-1</sup> |
| Additional Stacking | 2 × 2 betatron stacking<br>100% emittance dilution | (A) 24 RF stacking/ring                                 |
| Improved Luminosity | $1.0 \times 10^{28} \text{ cm}^{-2} \text{s}^{-1}$ | $1.8 \times 10^{28} \text{ cm}^{-2} \text{s}^{-1}$      |
| New Filling Time    | 2 × 4 minutes                                      | 2 × 48 minutes  |
| Additional Stacking |  | (B) 2×2 betatron stacking 100% emittance dilution       |
| Improved Luminosity |  | $1.0 \times 10^{28} \text{ cm}^{-2} \text{s}^{-1}$      |
| Filling Time        | • • • • • • • • • • • • • • • • • • •              | 2 × 30 minutes  |
| Additional Stacking |  | (C) combination of (A) and (B)                          |
| Improved Luminosity | # <b>= =</b>                                       | $1.6 \times 10^{29} \text{ cm}^{-2} \text{s}^{-1}$      |
| Filling Time        |  | 2 × 2 hours   |







Te/E = 4x10-4

Er = 4T mm. mrad

| y=100 |       |                |              |                   | -N - All mm.mvad |             |             |                |      |   |
|-------|-------|----------------|--------------|-------------------|------------------|-------------|-------------|----------------|------|---|
|       | L     | B              | $\bar{\eta}$ | η <sub>ε</sub> -1 |                  | -1          | $t_L$       | $\delta_{	au}$ | Z/n  |   |
|       | M     | m              | ~            | -1<br>h           |                  | -1          | hours       |                | ohm  |   |
|       | 2.16  | 5              | 0.05         | _                 | ·                |             | _           | 110            | 0.3  |   |
|       | 4.33  | 10             | 0.2          | _                 | -                | <u> </u>    |             | 55             | 3.9  |   |
|       | 6.49  | 15             | 0.44         | .0044             | .00              | 34          | 1.1         | 37             | 10.6 |   |
|       | 8.66  | 20             | 0.786        | ,0033             | .002             | .0073       | 1.6/0.8     | 28             | 19.8 |   |
| 1.    | 10.82 | 25             | 1.23         | .0025             | .0051            | 10.         | 1.1/0.7     | 22             | 33   | * |
|       | 12.99 | 30             | 1.77         | .002              | .0076            | 1.0119      | 0.9/0.6     | 18.6           | 47   |   |
| -     | 15.15 | 35             | 2.41         | .0016             | .01              | (33         | 0.56        | 16.            | 64   |   |
|       | [7.32 | 40             | 3.146        | .0013             | .02              | 143         | 0.53        | 14             | 84   |   |
|       | 19.48 | 45             | 3.98         | .0011             | .01              | L81         | 0.43        | 12.4           | 108  |   |
|       | 21.64 | 50             | 4.92         | .0009.            | .02              | 211         | 0.38        | 11             | 137  |   |
|       |       |                |              |                   | -                |             |             |                |      |   |
|       |       | T <sub>P</sub> | = 1          | 20 m              | - port           | ide         | 6           | = 10 cn        | )    |   |
|       |       |                |              |                   |                  |             |             |                |      |   |
|       |       | <u> </u>       | = 0.         | 25 €              | V/A - se         | <b>c</b>    |             |                |      |   |
|       |       |                |              |                   |                  |             |             |                |      |   |
|       |       |                |              |                   |                  |             |             |                |      |   |
| -     |       |                |              |                   |                  | <del></del> | <del></del> |                | ·    |   |
| 1 !!  |       |                |              |                   |                  |             |             |                |      |   |
|       |       |                |              |                   |                  |             |             |                |      |   |
|       |       |                |              |                   |                  |             |             |                |      |   |
|       |       |                |              |                   |                  |             |             |                |      |   |
|       |       |                |              |                   |                  |             |             |                |      |   |
|       |       |                |              |                   |                  |             |             |                |      |   |
|       |       |                |              |                   |                  |             |             |                |      |   |
|       |       |                |              |                   |                  |             |             |                |      |   |

90° phase advance.

6 = /E = . 4 × 10 -4 S=0.25 eV/A-se=5

8=100

EN = 471 mm. mrad

| L      | B                                     | $\overline{\eta}$ | 2-1      | 2/5           | $t_L$        | 87                                    | 2/n.  |              |
|--------|---------------------------------------|-------------------|----------|---------------|--------------|---------------------------------------|-------|--------------|
|        | 1                                     |                   |          | ]             |              |                                       |       | i            |
| m      | m                                     | m                 | h-1      | h             | hours        |                                       | ohm   | i            |
|        | "                                     | 1                 |          | :             | 1,000.5      |                                       | DAIAN |              |
|        |                                       |                   |          |               |              |                                       |       | [            |
|        | !<br>                                 | 0.022             |          | -             |              | 10.6                                  | 0 77  | t<br>:       |
| 2.5    | 5                                     | 0.033             | _        |               | : <b>-</b>   | 136                                   | 0.77  | ·            |
| 5.     | 10                                    | 0.131             |          |               | -            | 68                                    | 2.    |              |
| 7.5    | 15                                    | 0.295             | -        | -             |              | 45                                    | 6.6   |              |
| 10.    | 20                                    | 0.525             | .0036    | .0020         | 1.5          | 34                                    | 13    |              |
| 12.5   | 25                                    | 0.82              | .0028    | .0013 / .0051 | 2./1.0       | E7.3                                  | 21    |              |
| 45.    | 30                                    | 1.18              | .0024    | .0037         | 1.37         | 22.7                                  | 31    | *            |
| 17.5   | 35                                    | 1.61              | .0020    | .0060         | 1.0          | 19.5                                  | 42    |              |
| 20.    | 40                                    | 2.10              | 0017     | .0078         | 0.9          | 17.                                   | 56    |              |
| . 22.5 | 45                                    | 2.66              | .0014    | .0092         | 0.8          | 15.                                   | 73    |              |
| ` 25.  | 50                                    | 3.28              | .0011    | .0120         | 0.64         | 13.6                                  | 89    |              |
| 1      |                                       |                   |          |               |              |                                       |       |              |
|        |                                       | $T_n = I$         | 20 mf    | I-particli    |              |                                       |       |              |
|        |                                       | P                 |          | <u> </u>      | <del> </del> | <del> </del>                          |       | ļ            |
|        |                                       |                   |          | 1             |              |                                       |       |              |
|        |                                       |                   |          |               |              |                                       |       | <del> </del> |
|        |                                       | ·                 |          |               |              |                                       |       |              |
|        |                                       |                   |          |               |              |                                       |       |              |
|        | <u> </u>                              |                   |          | i             |              | <del>.</del>                          |       | 1            |
|        |                                       |                   |          |               |              |                                       |       | <u> </u>     |
|        |                                       | ļ                 |          |               |              |                                       |       |              |
|        |                                       |                   |          |               |              |                                       |       |              |
| •      |                                       |                   |          |               |              |                                       |       |              |
|        |                                       |                   |          |               |              | · · · · · · · · · · · · · · · · · · · |       | 1            |
|        |                                       | -                 |          |               |              |                                       |       |              |
|        |                                       |                   |          |               |              |                                       |       | <del> </del> |
| !      |                                       |                   |          |               |              |                                       |       |              |
|        |                                       |                   |          |               |              |                                       |       |              |
| 1      |                                       |                   |          |               |              |                                       |       |              |
| 1      |                                       | :                 | <u> </u> | i             |              |                                       |       |              |
|        | · · · · · · · · · · · · · · · · · · · |                   | ;        |               |              |                                       |       |              |
|        |                                       | 1 .               |          |               |              |                                       |       |              |
|        |                                       |                   |          |               |              |                                       |       |              |
| . :    |                                       | 1                 |          |               | i !          |                                       |       | <u> </u>     |
|        |                                       | 1 !               | 1        | 1             |              |                                       |       | 7            |

90° phase advance

OE/E = 2×10-4

S = 0.125 1V/A-sec

y=100

Er= 411 mm. mrad

| •                                     |        |             | · · · · · · · · · · · · · · · · · · · |             |          |                |                   |             |              |
|---------------------------------------|--------|-------------|---------------------------------------|-------------|----------|----------------|-------------------|-------------|--------------|
| L                                     | B      | $\bar{z}$   | $\tau_{\varepsilon}^{-1}$             |             | Z-1      | t <sub>L</sub> | $\mathcal{S}_{T}$ | Z/n         |              |
|                                       |        |             |                                       |             | 1        |                |                   |             |              |
| m                                     | m      | m           | h 1                                   |             | h-1      | hours          |                   | ohns        |              |
|                                       |        |             |                                       |             |          | 10-1-1         |                   | :           |              |
|                                       | 1      |             |                                       |             | :        |                |                   | <u> </u>    |              |
| 2.5                                   | 5      | .033        | _                                     |             |          | _              | 136               | 0-19        |              |
|                                       |        |             |                                       |             |          |                |                   | 1           |              |
| 5                                     | 10     | 0.131       | _                                     | -           | -        | -              | 68                | 0.5         | <del> </del> |
| 7.5                                   | 15     | 0-295       | -                                     |             | <u> </u> | _              | 45                | 1.7         |              |
|                                       |        |             |                                       |             | ļ        |                |                   |             |              |
| 10                                    | 20     | 0.525       | 0.0195                                | 0.00        | 27       | 0.4            | 34                | 3.2         |              |
| 12.5                                  | 25     | 0.82        | 0.0162                                | 0.0018      | .0074    | 0.5/0.35       | 27. 3             | 5.2         |              |
| it .                                  | •      | !<br>!      |                                       | •           |          |                |                   | 1           |              |
| 15                                    | 30     | 1.18        | 0.0144                                | 0.00        | 55       | 0.4            | 22.7              | 7.7         | *            |
| 17.5                                  | 35     | 1.61        | 0.0123                                | 0.00        | 92       | 0,4            | 19,5              | 10.5        |              |
| li                                    |        |             |                                       |             |          | ļ              | ·                 |             |              |
| 20                                    | 40     | 2.10        | 0.0107                                | 0.0         | 126      | 0.36           | 17                | 14          |              |
| 22.5                                  | 45     | 2.66        | 0.0094                                | 00          | 154      | 0.34           | 15                | 18.2        |              |
| İ                                     | i      |             |                                       |             | 1        |                |                   |             |              |
| 25                                    | 50     | 3.28        | 0.0081.                               | 0.0178/     | 0.0229   | 0.32/0.27      | 13.6              | 22.2        |              |
|                                       |        |             |                                       |             |          |                |                   |             |              |
|                                       |        | $T_p = 120$ | o mA-                                 | Partic      | l,       |                |                   |             |              |
|                                       |        | P           | T                                     | 1 -0        | <u> </u> |                | 1.06m             | 1           |              |
|                                       | ,      | 1.06        | m                                     | 0 -         | 3.0T     |                | 1                 |             |              |
| B = 3KG                               | cm     |             |                                       | ರ=.         | 3.01     |                |                   |             |              |
| !!                                    |        | 1 4         |                                       |             |          |                |                   | <b>5</b>    |              |
| bore radius                           | = 4cm  |             |                                       |             |          |                |                   |             |              |
| B = 12 K                              | G      |             |                                       | 10.47       | 2m       |                |                   |             |              |
|                                       | 2.5    | m           | Sa                                    | gitta ~     | 5 cm     |                | 2.9               | 5 m         |              |
|                                       |        |             | !<br>[                                | <u> </u>    |          |                |                   | 1           | ļ            |
| R                                     | = 51 m |             | m                                     | - 11        | 5 m      |                |                   |             |              |
| 3max                                  | = 21 W |             | 2max                                  |             | 4 (11    |                |                   | 1           | <u> </u>     |
| · · · · · · · · · · · · · · · · · · · |        |             |                                       | <u> </u>    | -        |                |                   | 1           |              |
| 01 6                                  | -CN/D  | ina         | 04 1                                  | 10          | lam      | height         |                   | 12 n        | in           |
| HT 3                                  | 6eV/H  | - 111       | ax Ju                                 | - D         | com      |                |                   |             |              |
|                                       |        | <b>.</b>    | , 1                                   | 10          |          | width          |                   | 13-15       |              |
|                                       |        | mo          | <u>~</u>                              | <u>v</u> b. | Ram      | WIDVIN         |                   | 13-23       | mm           |
|                                       |        |             |                                       |             |          |                | ~ 5               | A )         |              |
|                                       |        |             | !                                     |             | !        | (              |                   | <u> </u>    | 1            |
| i                                     |        |             |                                       |             |          |                |                   | <del></del> | <del> </del> |
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