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Accelerator Physics Project Review On The November 23, 1983 Meeting

A. G. Ruggiero

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Collider Accelerator Department
Brookhaven National Laboratory

U.S. Department of Energy

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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
CURVED SECTORS + INSERTIONS

TWO CASES:
 - (I) LARGE ANGLE CROSSING, LONG BUNCHES
 - (II) HEAD-ON COLLISION, SHORT BUNCHESDEC. 1

2. SEXTUPOLES AND CHROMATIC EFFECT
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) Nov. 23
SCALING WITH DIFFERENT A (SOME SPECIES) DEC. 1
DIFFERENT SPECIES (A_1 ON A_2) DEC. 20
JAN. 15

5. AGREE ON INJECTOR PERFORMANCE JAN. 5

6. 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)

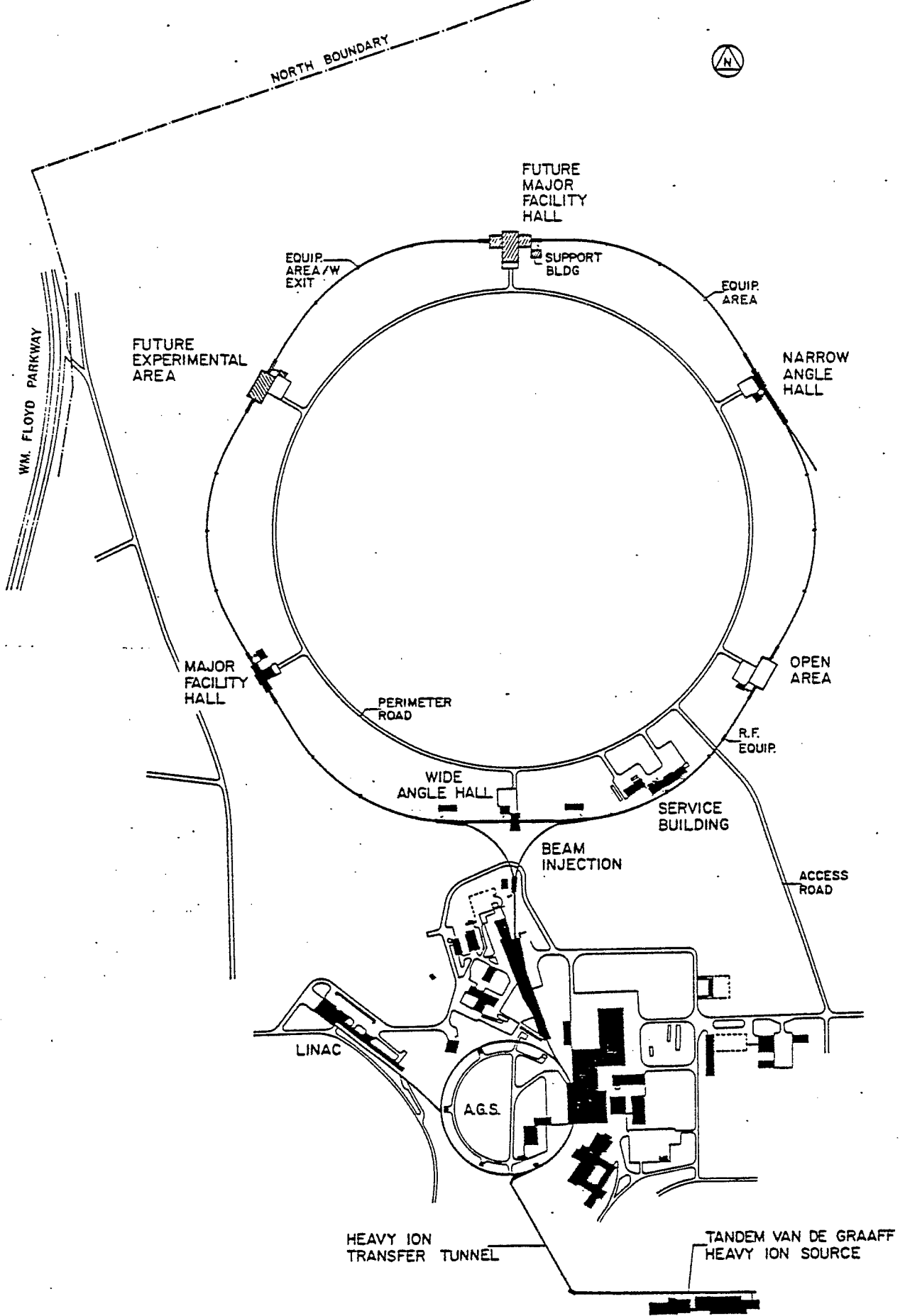
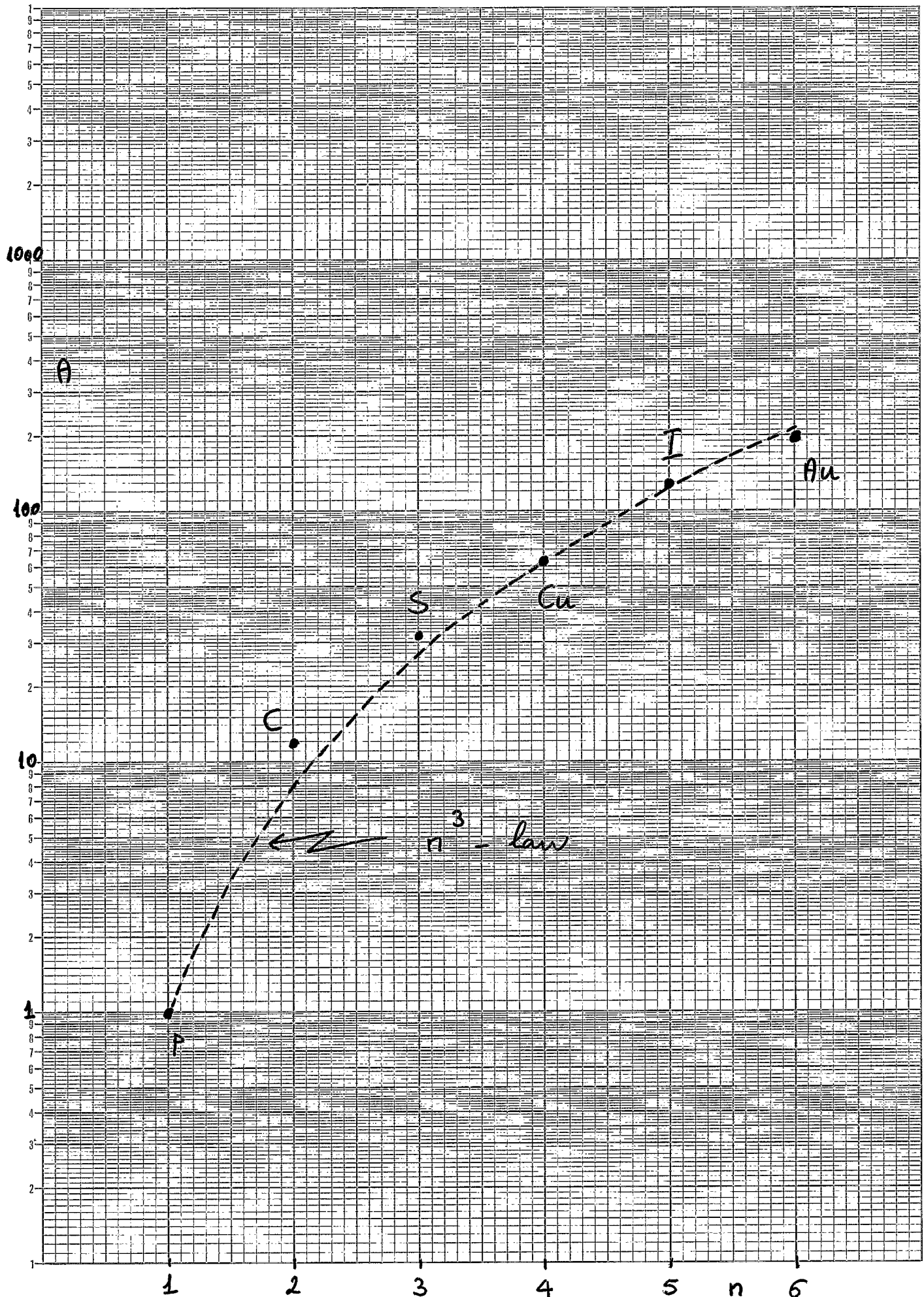


Fig. II.1 Existing CBA tunnel, experimental halls and proposed Tandem/AGS transfer tunnel.

The Chosen Species

<u>Species</u>	<u>Z</u>	<u>A</u>	<u>A/Z</u>
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	2.5



$$\frac{N_B}{E_N} = (\beta\gamma^2) \frac{\pi B_f \Delta\nu}{2\epsilon_0 F} \frac{A}{Q^2}$$

$$E_N = (\beta\gamma) 40\pi \text{ mm} \cdot \text{mrad} \quad (5)$$

T	β	γ	N_B/E_N	E_N	N_B
MeV			$\pi^{-1} \text{ m}^{-1}$	$\pi \text{ mm} \cdot \text{mrad}$	
1	.04613	1.001066	4×10^{14}	1.85	7.4×10^8
1.5	.05648	1.001599	5×10^{14}	2.26	1.13×10^9
2	.06519	1.002132	5.7×10^{14}	2.61	1.5×10^9
3	.07978	1.003197	7×10^{14}	3.20	2.24×10^9
4	.09204	1.004263	8.1×10^{14}	3.70	3×10^9
5	.10283	1.005329	9.1×10^{14}	4.15	3.74×10^9

$$N = N_B / (3 \times 2)$$

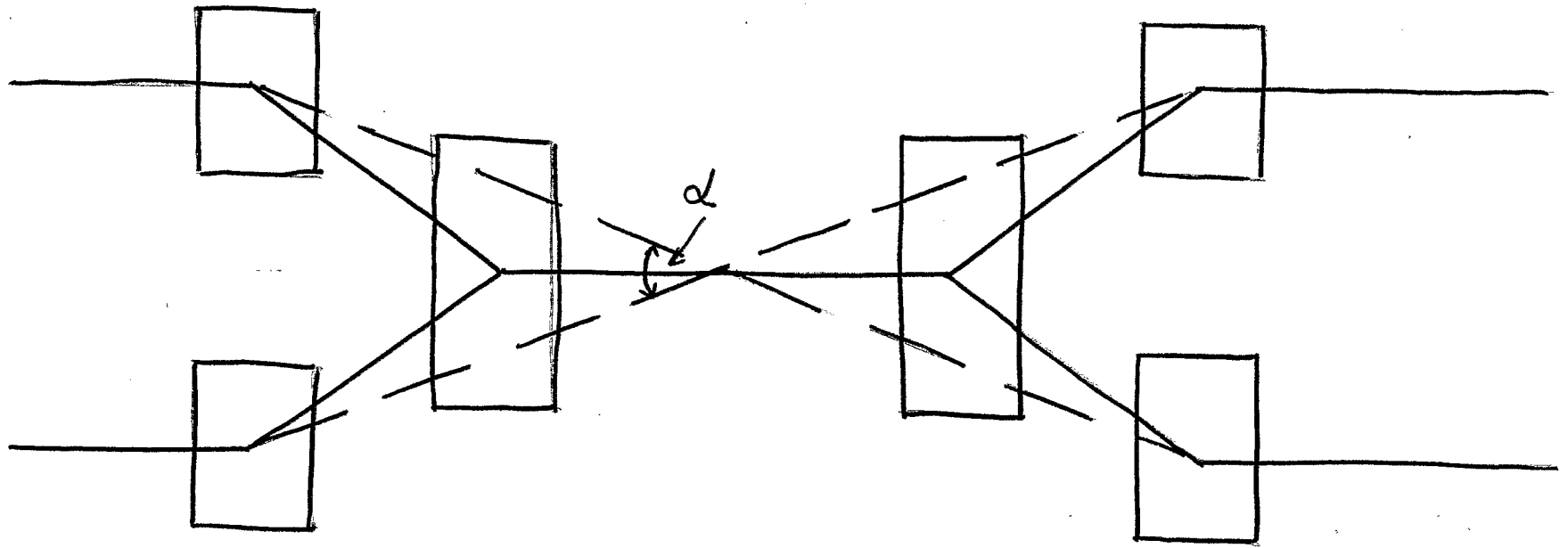
Tandem Current $\sim 4.4 \mu\text{A}$

T	τ	N	N_B/turn	no. turns	Pulse length
MeV	μsec	$\times 10^8$	$\times 10^8$		μs
1	14.6	1.23	4	1.85	27
1.5	11.9	1.88	3.3	3.4	40.5
2	10.3	2.48	2.83	5.3	54.6
3	8.43	3.73	2.32	9.7	81.8
4	7.3	5.0	2.0	15	109.5
5	6.54	6.24	1.8	21	137

$$\text{Luminosity} \sim \frac{N^2}{\sqrt{E_N}} = \left(\frac{N}{E_N}\right)^{1/2} N^{3/2} \sim \beta^{1/2} (\beta^2)^{3/2} = \beta^{7/2}$$

$$\text{Also luminosity} \sim \frac{N^2}{\sigma_e}$$

Head-on Collision vs. Collision at Large Angle



There are 4 cases :

1. (A) colliding with (A) (same species), bunched, head-on
2. (A_1) colliding with (A_2) (different species), bunched, head-on
orbit length adjusted
3. (A) colliding with (protons) , bunched vs. unbunched, angle $\neq 0$
4. (Protons) colliding with (protons) , bunched, head-on

With the Same Field and Gradients in both Rings

Au	↔	I	100 GeV/A	vs.	104 GeV/A
Au	↔	Cu	100		113
Au	↔	S	100		125
Au	↔	C	100		125
Au	↔	P	100		250

Very likely the experimentalist like to have the same energy/nucleon in both beams -

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

γ and β are the same

the bunched beams can collide matched in velocity -

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

PERFORMANCE COMPARISON BETWEEN SHORT AND LONG BUNCHES

A. Ruggiero

Case Bunches	"S" - Short	"L" Long
Luminosity Formula	$N^2 B f_{\text{rev}} / 2\pi\alpha\sigma_e\sigma_v$	same
Circumference, $2\pi R$	3833.8 m	same
Revolution Frequency, f_{rev}	78.1973 KHz	same
Crossing Angle, α	2 mrad	same
AGS Cycle Time	2 sec	same
rms Bunch Length, σ_e	10 cm	50 m
No. of Bunches, B	57	3
No. of Ions/Bunch, N	6.24×10^8	6×10^{10}
Total No. of Ions/Ring	3.56×10^{10}	1.8×10^{11}
No. of Ions/AGS Pulse	1.87×10^9	same
No. of Bunches/AGS Pulse	3	same
No. of AGS Pulses/Ring	19 box car	(19 box car) × (6RF stacking)
Normalized Emittance	4.0π mm-mrad	same
Emittance @ 100 GeV/A	0.04π mm-mrad	same
β^*_v	2m	same
σ^*_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 Bunches	"S" Short	"L" Long
Initial Luminosity	$1.2 \times 10^{27} \text{ cm}^{-2}\text{s}^{-1}$	$1.2 \times 10^{27} \text{ cm}^{-2}\text{s}^{-1}$
Additional Stacking Improved Luminosity New Filling Time	2 × 2 betatron stacking 100% emittance dilution $1.0 \times 10^{28} \text{ cm}^{-2}\text{s}^{-1}$ 2 × 4 minutes	(A) 24 RF stacking/ring $1.8 \times 10^{28} \text{ cm}^{-2}\text{s}^{-1}$ 2 × 48 minutes
Additional Stacking Improved Luminosity Filling Time	--- --- ---	(B) 2×2 betatron stacking 100% emittance dilution $1.0 \times 10^{28} \text{ cm}^{-2}\text{s}^{-1}$ 2 × 30 minutes
Additional Stacking Improved Luminosity Filling Time	--- --- ---	(C) combination of (A) and (B) $1.6 \times 10^{29} \text{ cm}^{-2}\text{s}^{-1}$ 2 × 2 hours

$E_N = 4.0 \pi$ mm-meas

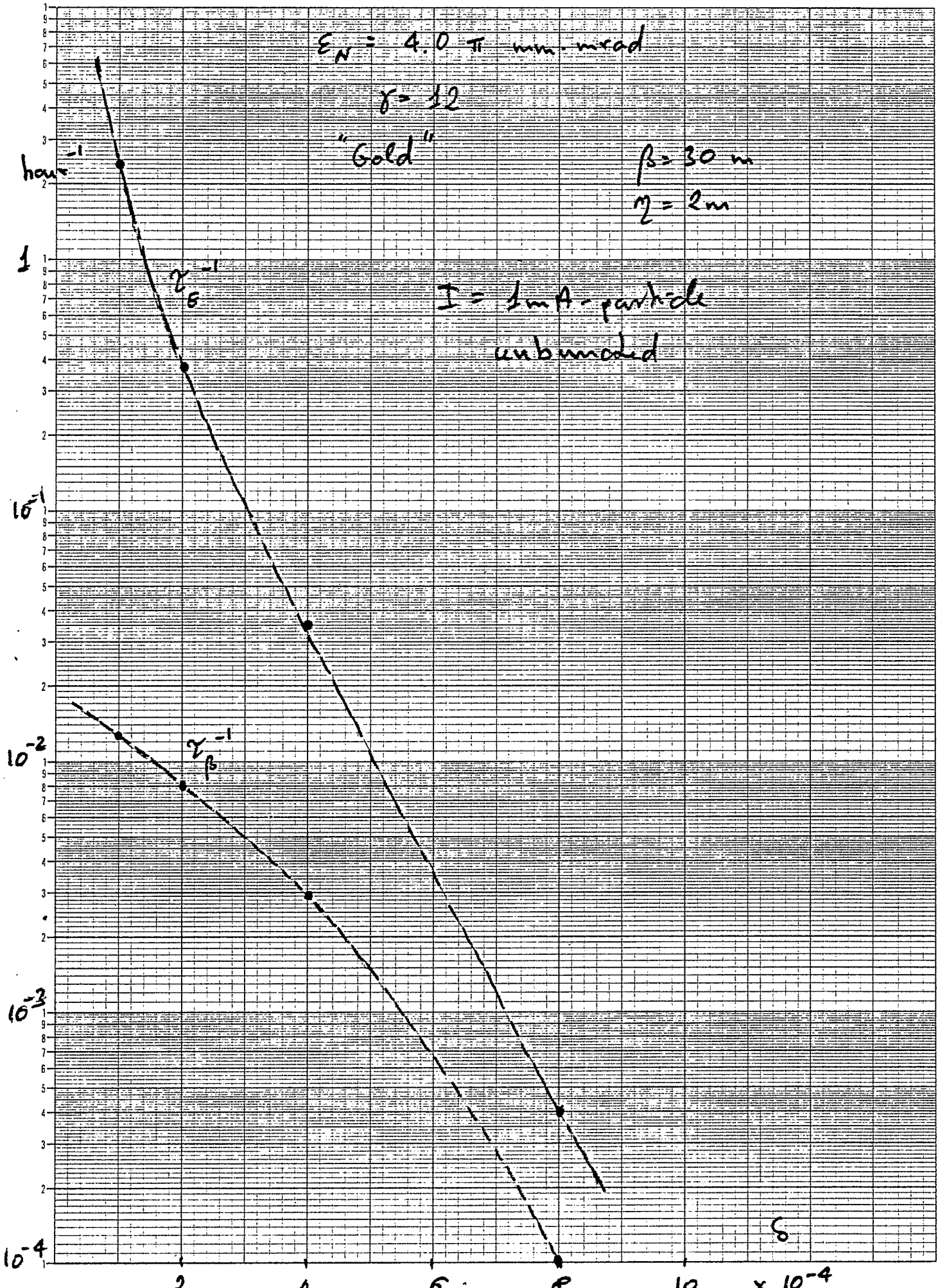
$\delta = 12$

"Gold"

$\beta = 30$ m

$\eta = 2$ m

$I = 1$ mA - particle
unbunched



$E_N = 2. \pi \text{ mm. mrad}$

$\gamma = 12$

"Gold"

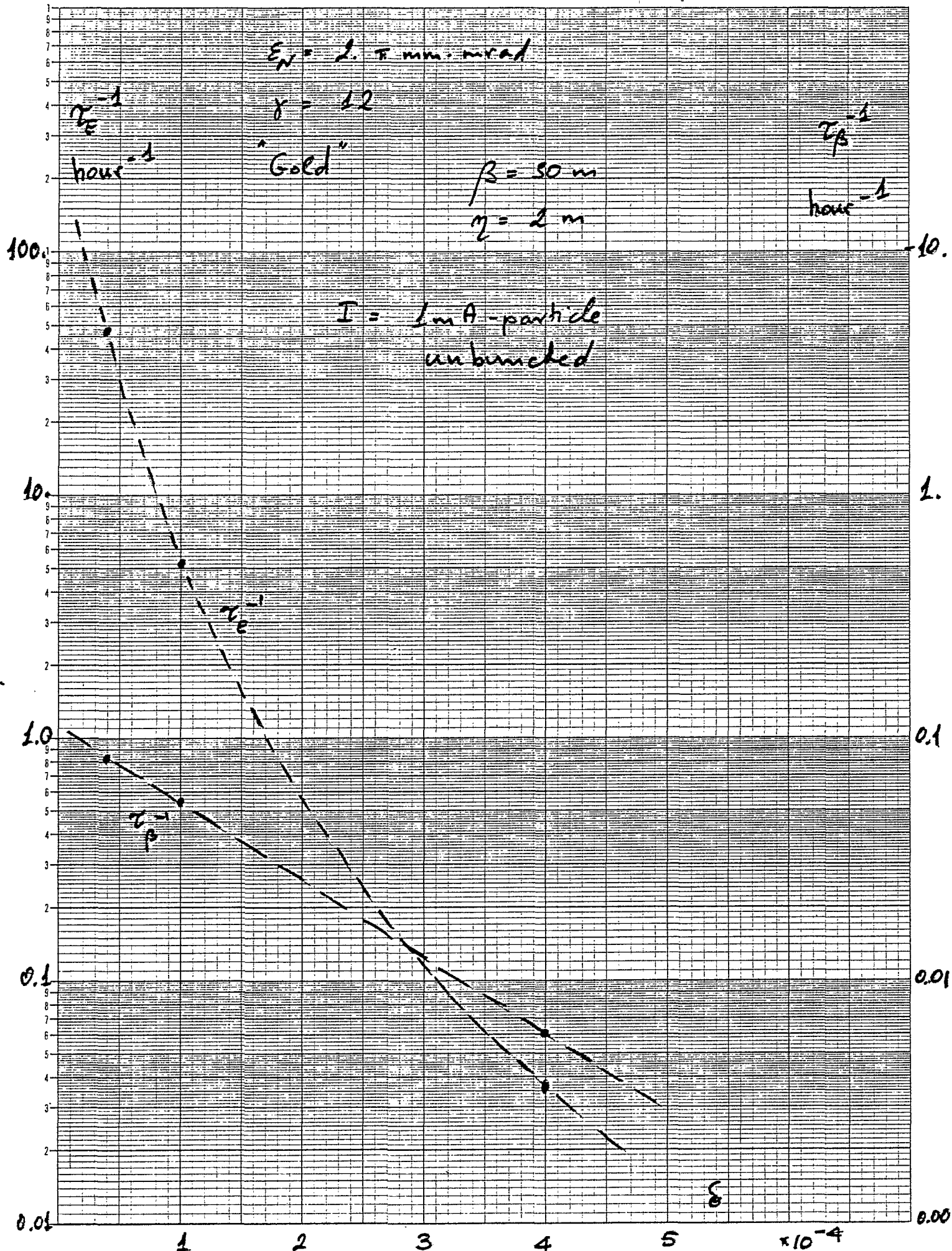
$\beta = 50 \text{ m}$

$\eta = 2 \text{ m}$

τ_E^{-1}
 hour^{-1}

τ_B^{-1}
 hour^{-1}

$I = 1 \text{ mA - particle}$
 unbunched



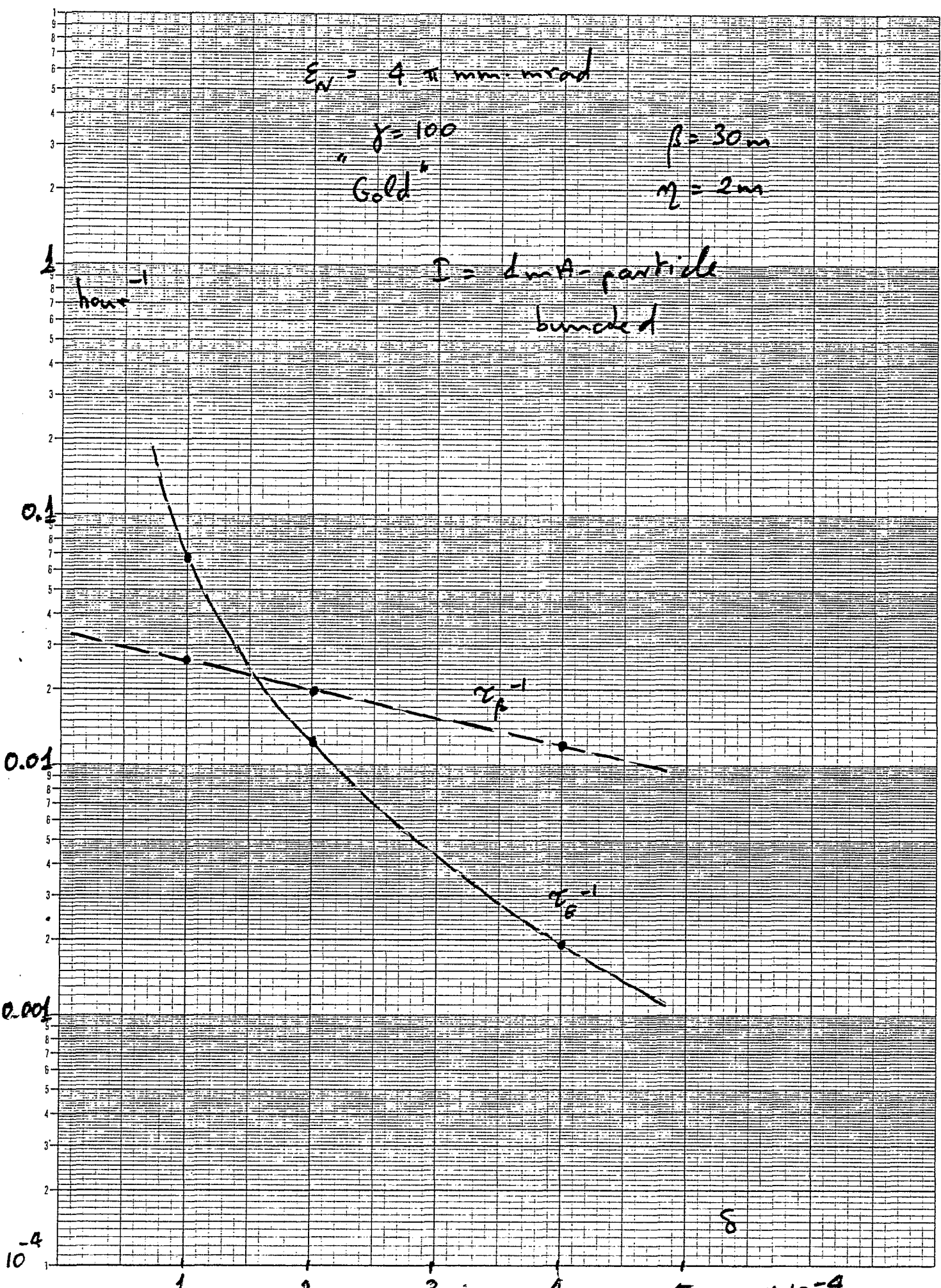
$E_N = 4 \pi \text{ mm mrad}$

" $\gamma = 100$
Gold"

$\beta = 30 \text{ m}$
 $\eta = 2 \text{ m}$

$\frac{1}{\text{hour}}^{-1}$

$I = \text{d mA - particle}$
bunched



60° phase advance cell

$$\delta = 100$$

$$\sigma_E/E = 4 \times 10^{-4} \quad - 8 -$$

$$E_N = 4\pi \text{ mm} \cdot \text{mrad}$$

L	$\bar{\beta}$	$\bar{\sigma}$	τ_E^{-1}	τ_p^{-1}	t_L	δ_T	Z/n
m	m	m	h^{-1}	h^{-1}	hours		ohm
2.16	5	0.05	-	-	-	110	0.3
4.33	10	0.2	-	-	-	55	3.9
6.49	15	0.44	.0044	.0034	1.1	37	10.6
8.66	20	0.786	.0033	.002 / .0073	1.6 / 0.8	28	19.8
10.82	25	1.23	.0025	.0051 / .01	1.1 / 0.7	22	33 *
12.99	30	1.77	.002	.0076 / .0119	0.9 / 0.6	18.6	47
15.15	35	2.41	.0016	.0133	0.56	16	64
17.32	40	3.146	.0013	.0143	0.53	14	84
19.48	45	3.98	.0011	.0181	0.43	12.4	108
21.64	50	4.92	.0009	.0211	0.38	11	137

$$I_p = 120 \text{ mA} - \text{particle} \quad (r_c = 10 \text{ cm})$$

$$S = 0.25 \text{ eV/A-sec}$$

90° phase advance

$$\sigma_E/E = 4 \times 10^{-4}$$

$$S = 0.25 \text{ eV/A-sec} \text{ (5)}$$

$$\delta = 100$$

$$E_N = 4\pi \text{ mm.mrad}$$

L	$\bar{\beta}$	$\bar{\eta}$	α_E^{-1}	α_β^{-1}	t_L	δ_T	Z/n
m	m	m	h^{-1}	h^{-1}	hours		ohm
2.5	5	0.033	-	-	-	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	27.3	21
15.	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

$$I_p = 120 \text{ mA - particle}$$

90° phase advance

$\sigma = 100$

$$\sigma_E/E = 2 \times 10^{-4}$$

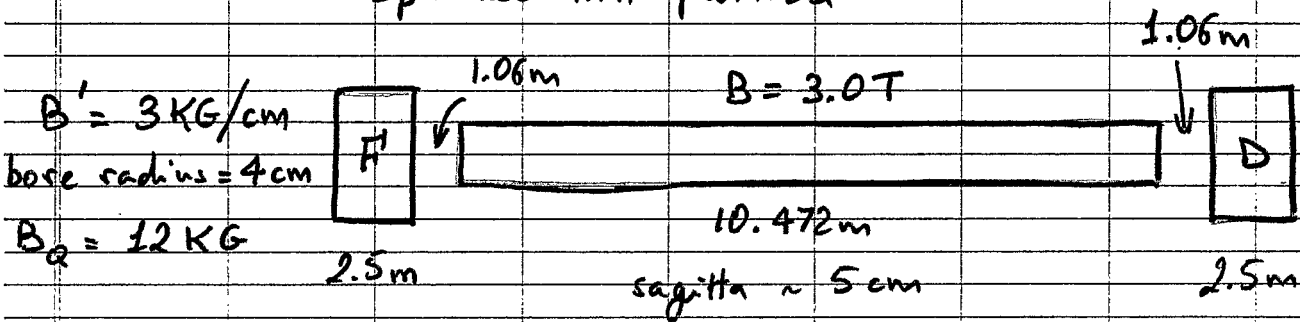
$$E_{\text{ex}} = 4\pi \text{ mm} \cdot \text{mrad}$$

$$S = 0.125 \text{ eV/A-sec}$$

(6)

L	$\bar{\beta}$	$\bar{\eta}$	τ_E^{-1}	τ_p^{-1}	z_L	γ_T	Z/n
m	m	m	h^{-1}	h^{-1}	hours		ohms
2.5	5	0.83	-	-	-	136	0.19
5	10	0.181	-	-	-	68	0.5
7.5	15	0.295	-	-	-	45	1.7
10	20	0.525	0.0195	0.0027	0.4	34	3.2
12.5	25	0.82	0.0162	0.0018 / 0.0074	0.5 / 0.35	27.3	5.2
15	30	1.18	0.0144	0.0055	0.4	22.7	7.7 *
17.5	35	1.61	0.0123	0.0092	0.4	19.5	10.5
20	40	2.10	0.0107	0.0126	0.36	17	14
22.5	45	2.66	0.0094	0.0154	0.34	15	18.2
25	50	3.28	0.0081	0.0178 / 0.0229	0.32 / 0.27	13.6	22.2

$I_p = 120 \text{ mA} - \text{particle}$



$$\beta_{\text{max}} = 51 \text{ m}$$

$$\eta_{\text{max}} = 1.6 \text{ m}$$

At 5 GeV/A max full beam height = 12 mm

max full beam width = 13-15 mm

(~ 5σ)