RHIC-PG-8

ACCELERATOR PHYSICS PROJECT REVIEW ON THE NOVEMBER 23, 1983 MEETING

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(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 bunches	Dec. 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	Nov. 23
	Reference case (Gold on Gold)	Dec. 1
	Scaling with different A (some species)	Dec. 20
	Different species (A_1 on A_2)	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)

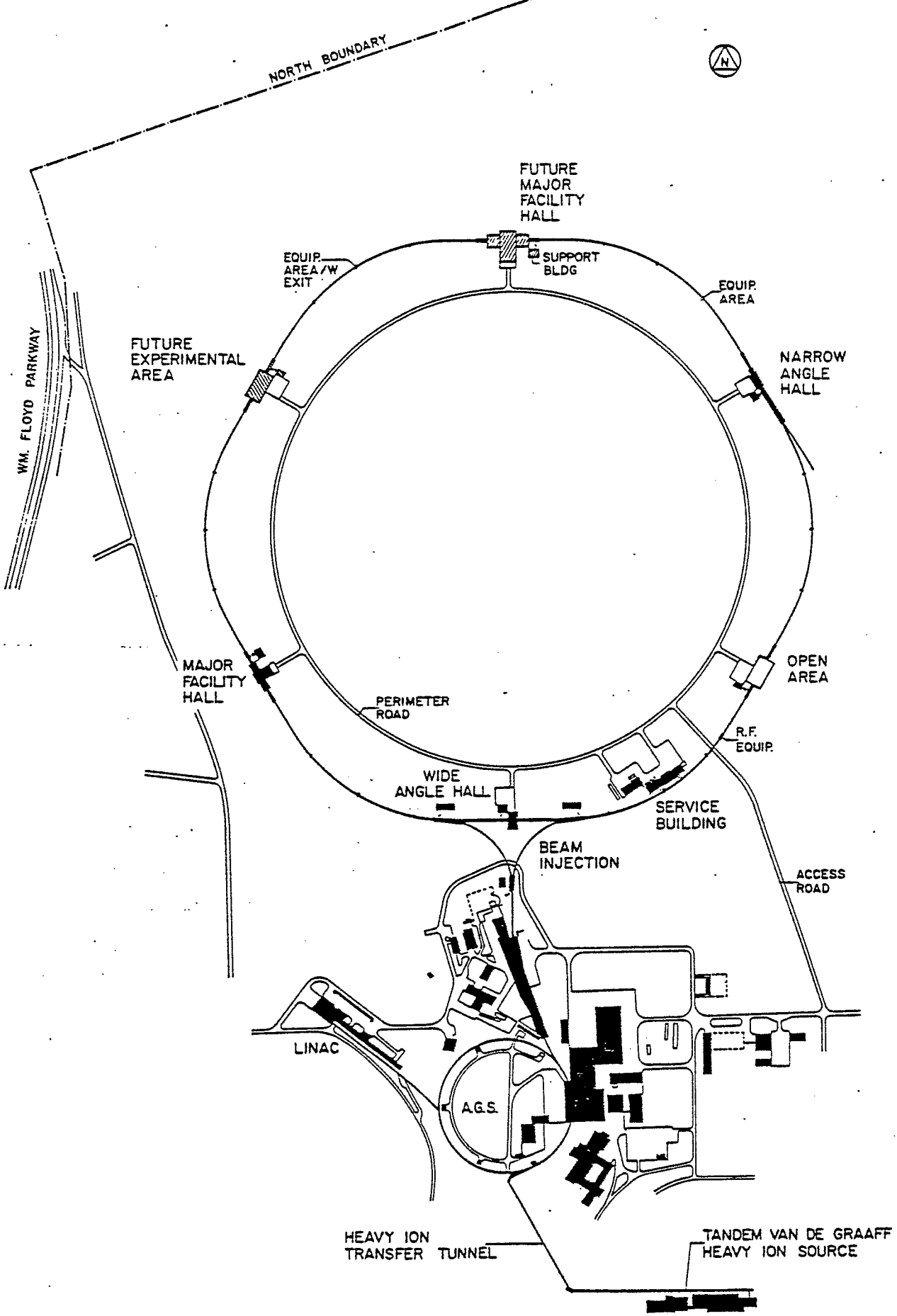
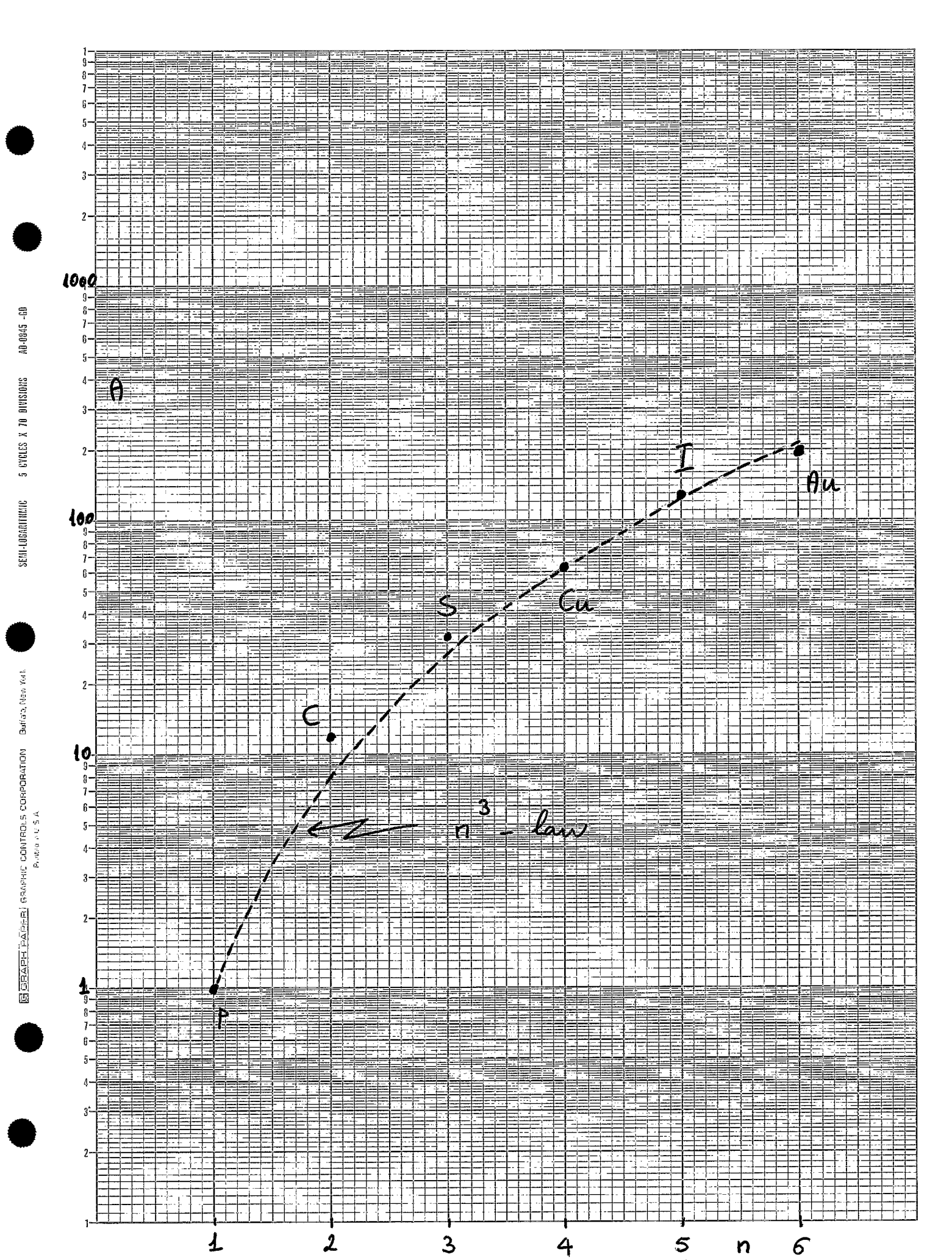


Fig. II.1 Existing CBA tunnel, experimental halls and proposed Tandem/AGS transfer tunnel.

The Chosen Species

Specie	Z	A	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	2.5


1000
100
10
1
A
n
1
2
3
4
5
6
P
C
S
Cu
I
Au
n^3 - law

$$\frac{N_B}{\varepsilon_N} = (\beta\gamma^2)\,\frac{\pi B_f \Delta\nu}{2c_0 F'}\,\frac{A}{Q^2} \qquad \varepsilon_N = (\beta\gamma)\,40\pi \text{ mm·mrad}$$

T	β	γ		N_B/ε_N		ε_N		N_B	
MeV				$\pi^{-1}\,m^{-1}$		π mm·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}		4.115		3.74×10^{9}	

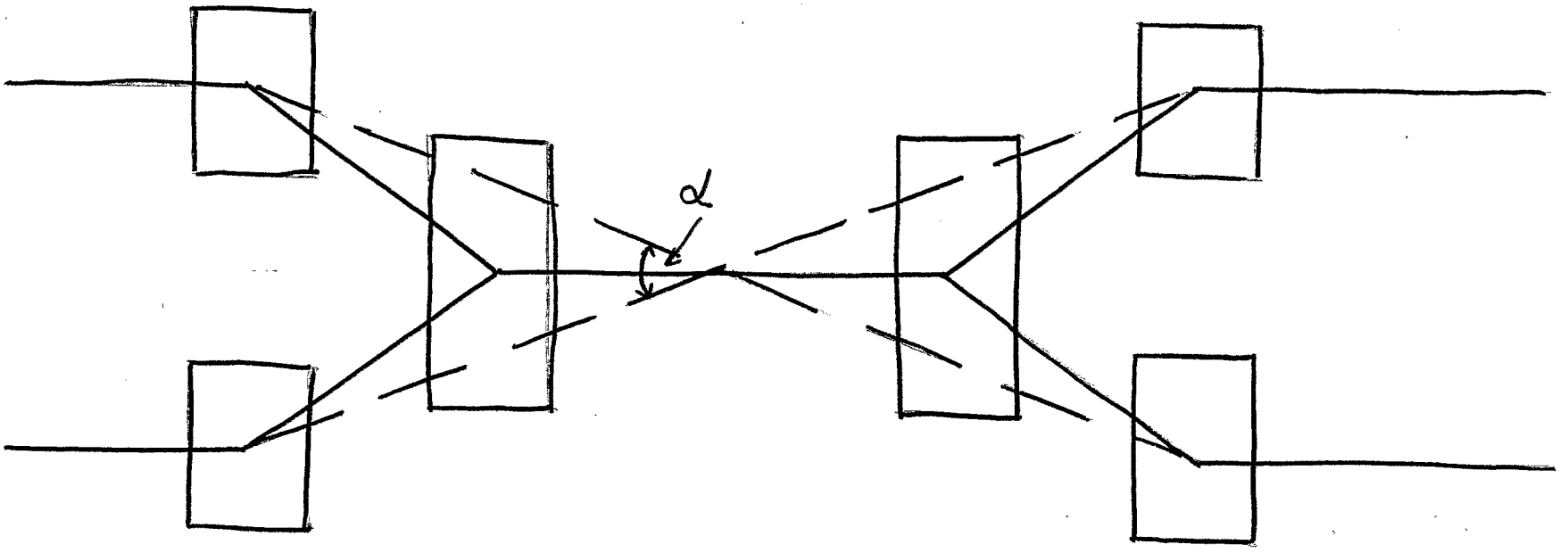
$N = N_B/(3\times2)$ Tandem Current ~ 4.4 pμA

T	τ		N		N_B/turn		no. turns		Pulse length
MeV	μsec		$\times10^{8}$		$\times10^{8}$				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.

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

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

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 ≠ 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

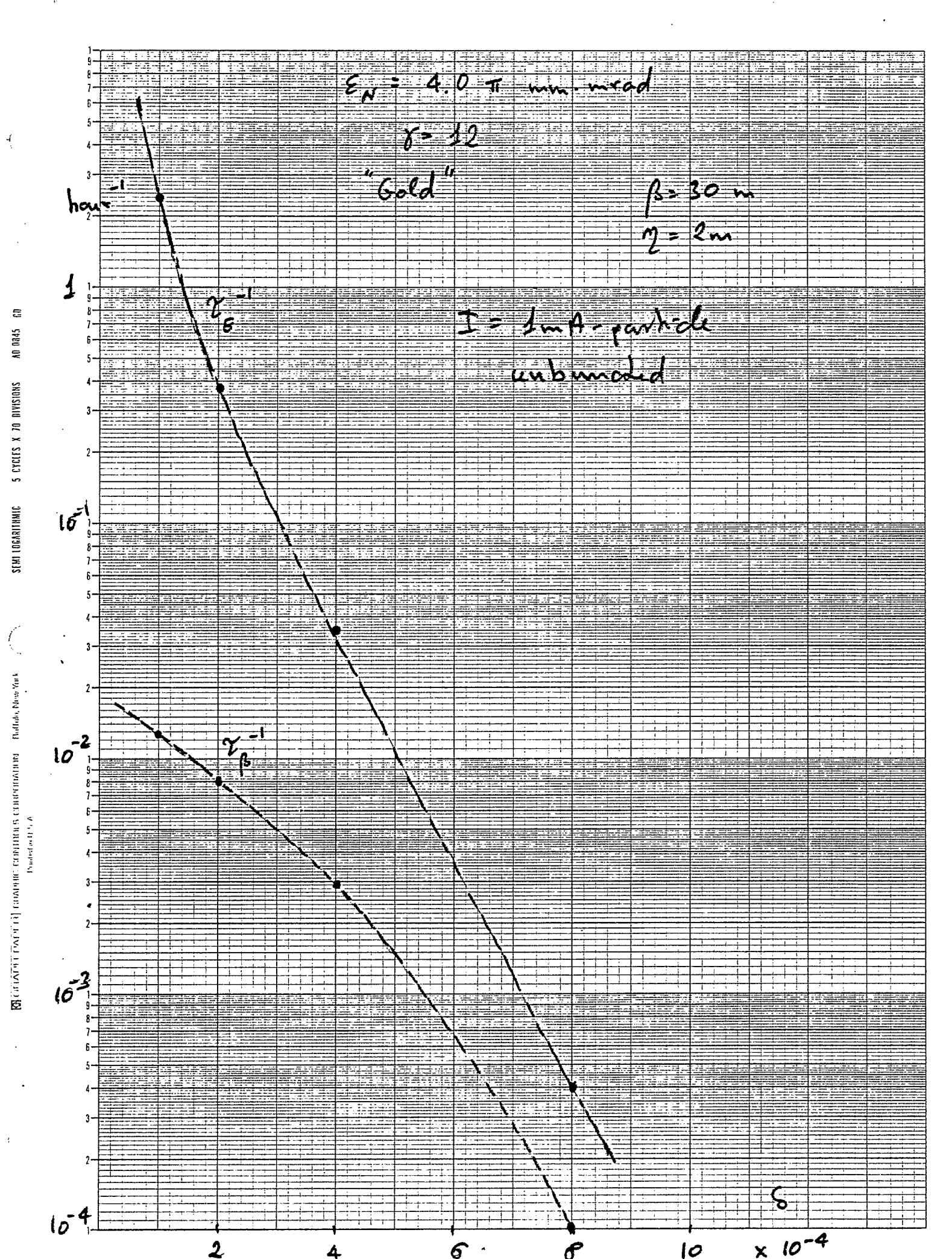
A. Ruggiero

Case Bunches	"S"- Short	"L" Long
Luminosity Formula	$N^2 B f_{rev}/2\pi\alpha\sigma_e\sigma_v$	same
Cricumference, $2\pi R$	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	4.0 π mm-mrad	same
Emittance @ 100 GeV/A	0.04 π mm-mrad	same
β^*_v	2m	same
σ^*_v	0.01155 cm	same
Luminosity, L	1.2×10^{27} $cm^{-2}s^{-1}$	1.2×10^{27} $cm^{-2}s^{-1}$
Filling Time	2 × 1 minute	2 × 12 minutes

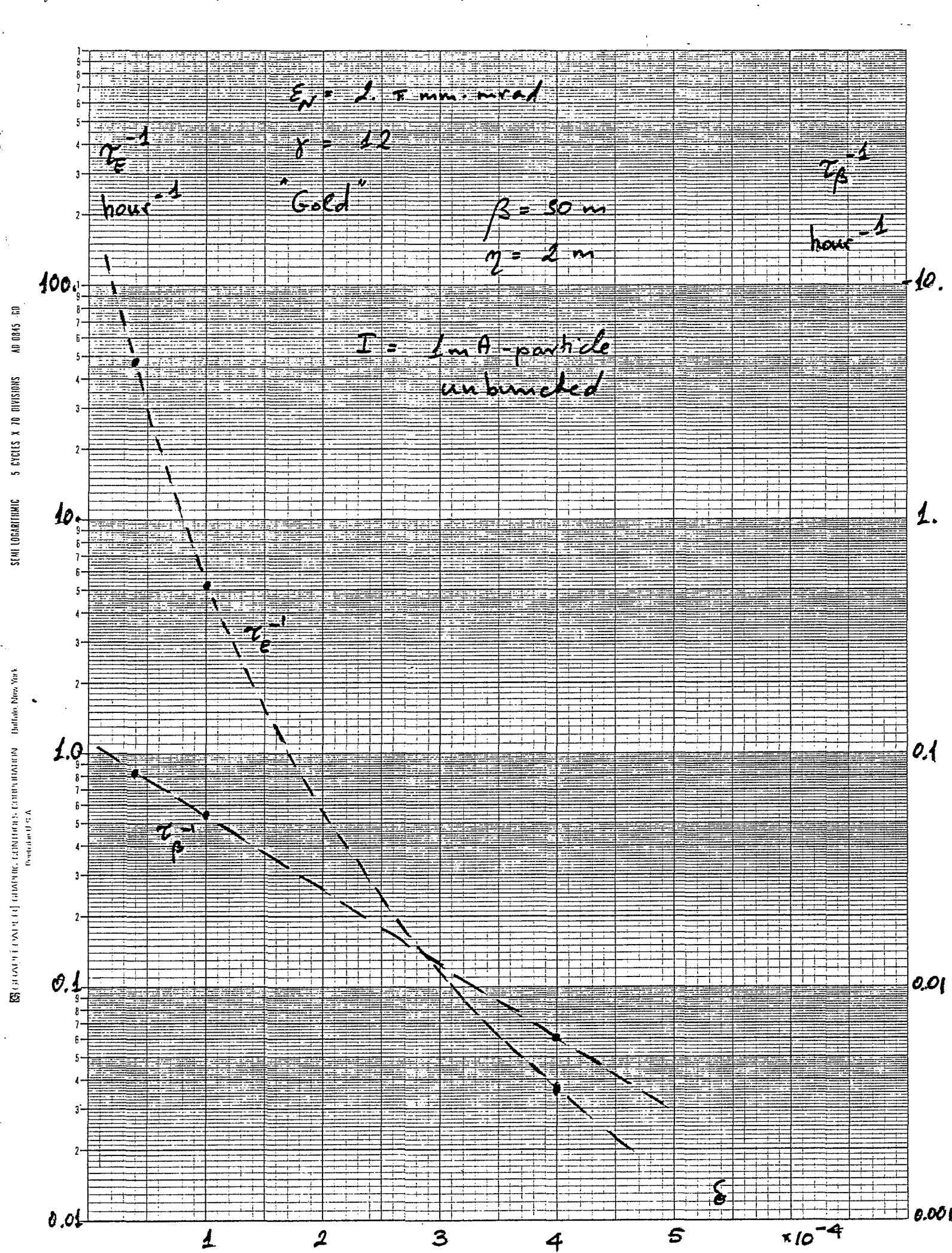
PERFORMANCE COMPARISON BETWEEN SHORT AND LONG BUNCHES

A. Ruggiero

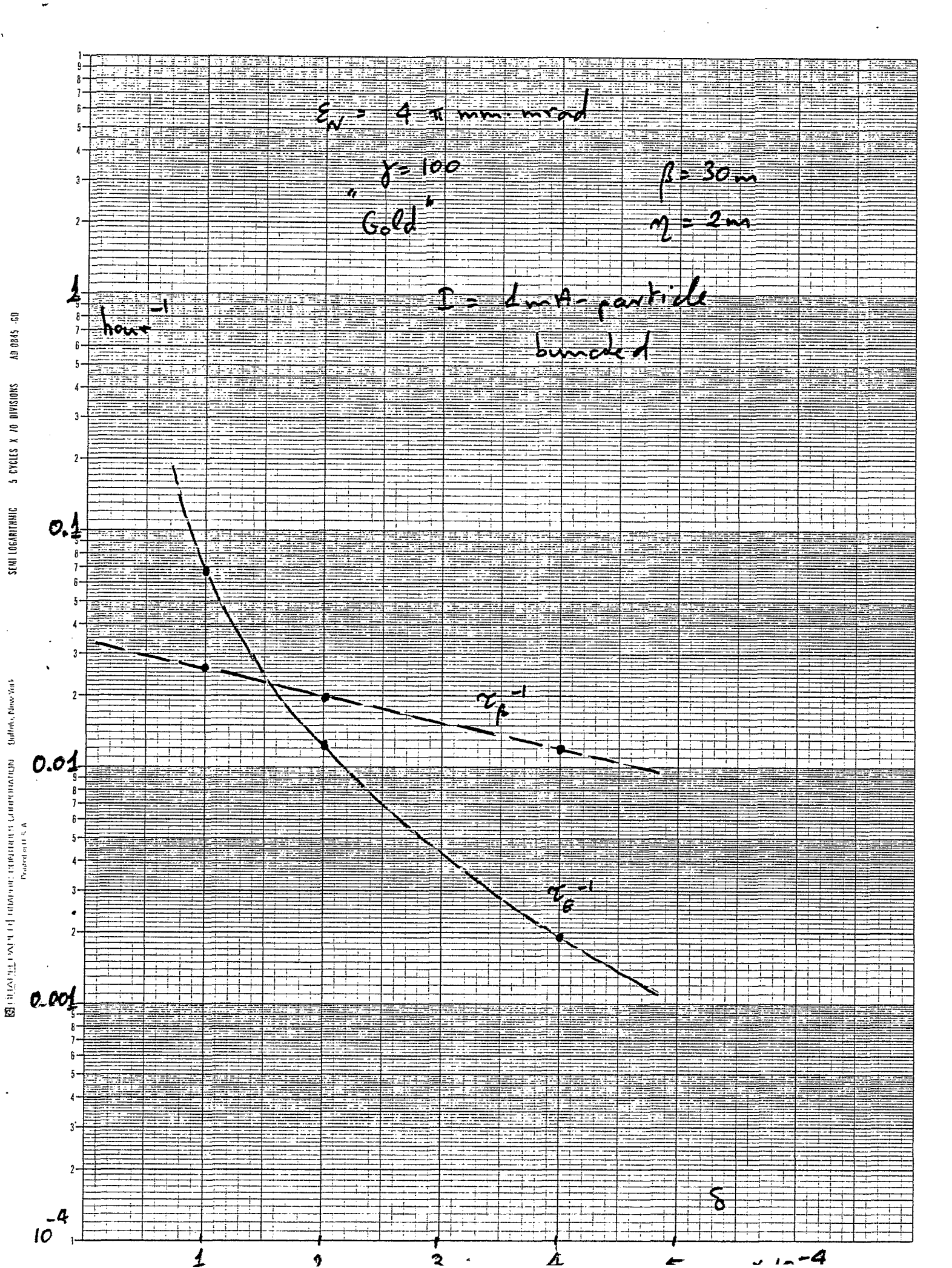
Case Bunches	"S" Short	"L" Long
Initial Luminosity	1.2×10^{27} $cm^{-2}s^{-1}$	1.2×10^{27} $cm^{-2}s^{-1}$
Additional Stacking	2 × 2 betatron stacking 100% emittance dilution	(A) 24 RF stacking/ring
Improved Luminosity	1.0×10^{28} $cm^{-2}s^{-1}$	1.8×10^{28} $cm^{-2}s^{-1}$
New Filling Time	2 × 4 minutes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



$\varepsilon_N = 4.0\ \pi$ mm-mrad
$\gamma = 12$
"Gold"
$\beta = 30$ m
$\eta = 2$ m
I = 1mA-particle
unbunched
hour^{-1}
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
τ_ε^{-1}
τ_β^{-1}
δ
2
4
6
8
10
$\times 10^{-4}$
SEMI LOGARITHMIC 5 CYCLES X 70 DIVISIONS AD 0845 GD
GRAPHIC CONTROLS CORPORATION Buffalo, New York



SEMI LOGARITHMIC 5 CYCLES X 70 DIVISIONS AD 0845 GD
GRAPH PAPER GRAPHIC CONTROLS CORPORATION Buffalo, New York
Produced in U.S.A.


$\varepsilon_N = 4\pi$ mm·mrad
$\gamma = 100$
" Gold"
$\beta = 30$ m
$\eta = 2$ m
$I = 4$ mA - particle bunched
hour^{-1}
τ_p^{-1}
τ_G^{-1}
0.1
0.01
0.001
10^{-4}
δ

60° phase advance cell

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

$\gamma = 100$

$\varepsilon_N = 4\pi$ mm·mrad

L	$\bar{\beta}$	$\bar{\eta}$	τ_E^{-1}	τ_β^{-1}	t_L	γ_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 mA - particle (σ_ℓ = 10 cm)

S = 0.25 eV/A - sec

90° phase advance $\sigma_E/E = 4 \times 10^{-4}$ $S = 0.25$ eV/A-sec (5)

$\gamma = 100$ $\varepsilon_N = 4\pi$ mm.mrad

L	$\bar{\beta}$	$\bar{\eta}$	τ_E^{-1}	τ_β^{-1}	t_L	γ_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	

$I_p = 120$ mA - particles

90° phase advance

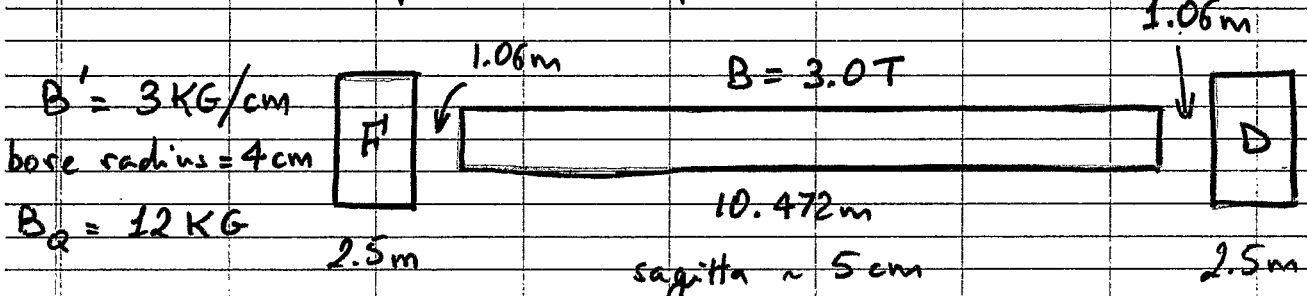
$\sigma = 100$

$\sigma_E/E = 2 \times 10^{-4}$ $\quad S = 0.125$ eV/A-sec

$\varepsilon_N = 4\pi$ mm·mrad

L	$\bar{\beta}$	$\bar{\eta}$	τ_E^{-1}	τ_β^{-1}	t_L	γ_T	Z/n	
m	m	m	h^{-1}	h^{-1}	hours		ohm	
2.5	5	.033	-	-	-	136	0.19	
5	10	0.131	-	-	-	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 / .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	

$I_p = 120$ mA - particle



$\beta_{max} = 51$ m $\qquad \eta_{max} = 1.6$ m

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

max full beam width = 13-15 mm

(~50)