Accelerator Physics Project Review On The November 23, 1983 Meeting

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U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

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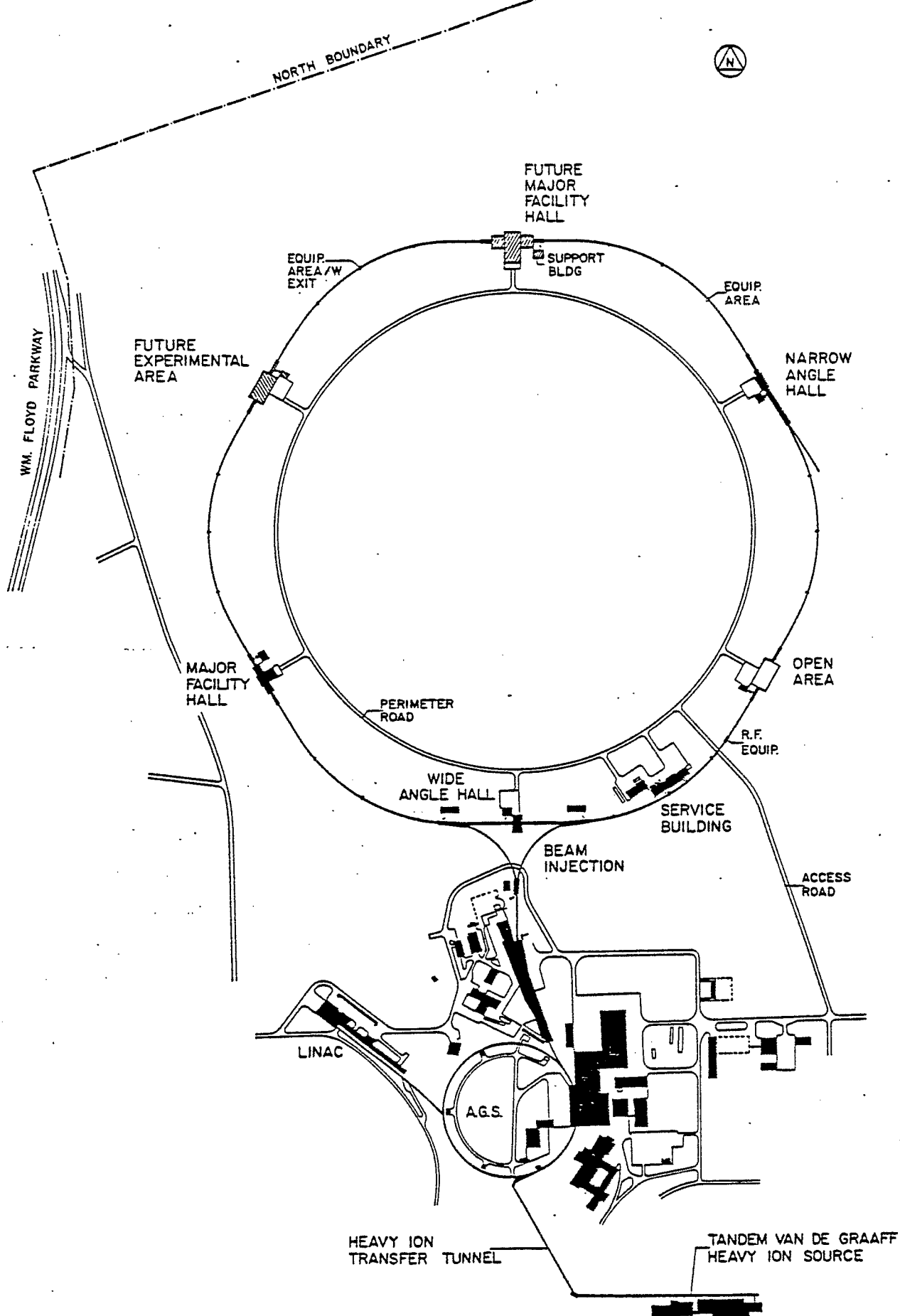
Fig. II.1 Existing CBA tunnel, experimental halls and proposed Tandem/AGS transfer tunnel.

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

A

1000

100

10

1

P

C

S

Cu

I

Au

n^3 - law

1   2   3   4   5   n   6

$$\frac{N_B}{\varepsilon_N} = (\beta\gamma^2)\,\frac{\pi B_f \,\Delta\nu}{2 c_0\, F^1}\,\frac{A}{Q^2} \qquad\qquad \varepsilon_N = (\beta\gamma)\,40\pi\,\text{mm}\cdot\text{mrad}$$
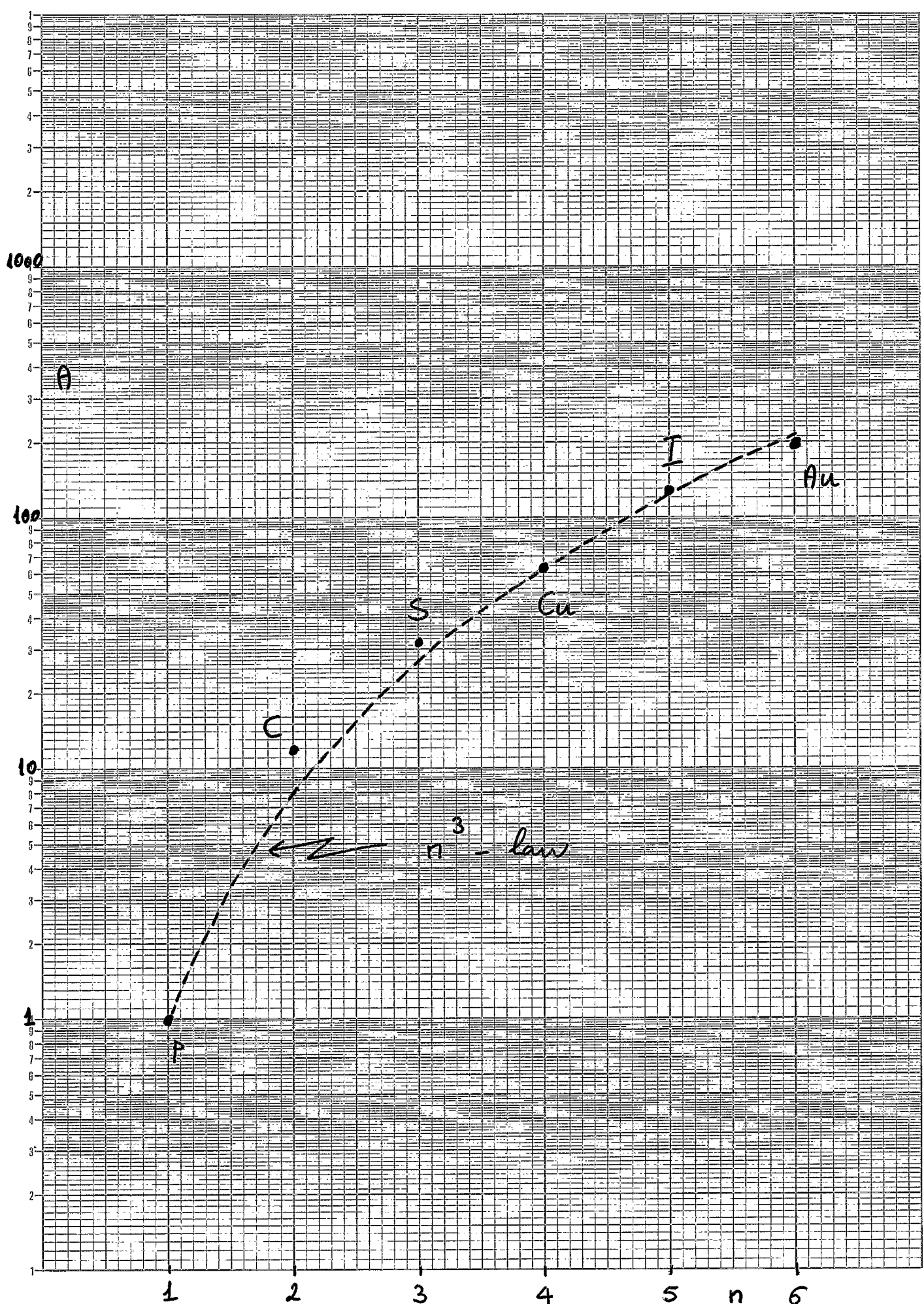
T	β	γ		N_B/ε_N		ε_N		N_B
MeV				$\pi^{-1} m^{-1}$		π mm·mrad		
1.	.04613	1.001066		4×10^{14}		1.85		7.4×10^{8}
1.5	.05648	1.001599		5×10^{14}		2.26		1.13×10^{9}
2.	.06519	1.002132		5.7×10^{14}		2.61		1.5×10^{9}
3.	.07978	1.003197		7×10^{14}		3.20		2.24×10^{9}
4.	.09204	1.004263		8.1×10^{14}		3.70		3×10^{9}
5.	.10283	1.005329		9.1×10^{14}		4.115		3.74×10^{9}

$$N = N_B/(3\times2) \qquad\qquad \text{Tandem Current} \sim 4.4\ p\mu A$$

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
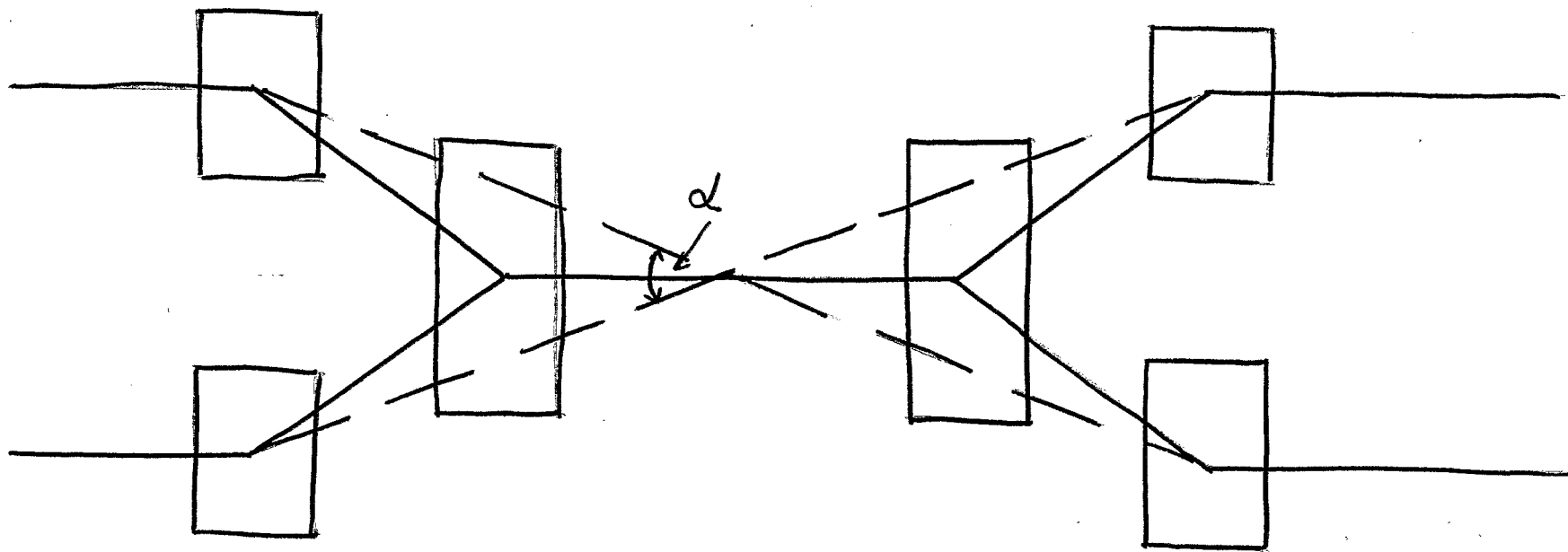
There are 4 cases:

1. $\textcircled{A}$ colliding with $\textcircled{A}$ (same species), bunched, head-on

2. $\textcircled{A_1}$ colliding with $\textcircled{A_2}$ (different species), bunched, head-on
   orbit length adjusted

3. $\textcircled{A}$ colliding with $\boxed{protons}$, bunched vs. $\underline{unbunched}$, angle $\neq 0$

4. $\boxed{Protons}$ colliding with $\boxed{protons}$, 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

$$\gamma \text{ and } \beta \text{ are the same}$$

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	$4.0\ \pi$ mm-mrad	same
Emittance @ 100 GeV/A	$0.04\ \pi$ 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 Improved Luminosity New Filling Time	2×2 betatron stacking 100% emittance dilution 1.0×10^{28} cm^{-2}s^{-1} 2 × 4 minutes	(A) 24 RF stacking/ring 1.8×10^{28} cm^{-2}s^{-1} 2 × 48 minutes
Additional Stacking Improved Luminosity Filling Time	--- --- ---	(B) 2×2 betatron stacking 100% emittance dilution 1.0×10^{28} cm^{-2}s^{-1} 2 × 30 minutes
Additional Stacking Improved Luminosity Filling Time	--- --- ---	(C) combination of (A) and (B) 1.6×10^{29} cm^{-2}s^{-1} 2 × 2 hours

$\varepsilon_N = 4.0\,\pi$ mm·mrad

$\gamma = 12$

"Gold"

$\beta = 30$ m

$\eta = 2$ m

$I = 1$ mA-particle

unbunched

τ_ε^{-1}

τ_β^{-1}

hour^{-1}

$\varepsilon_N = 2. \pi \text{ mm} \cdot \text{mrad}$

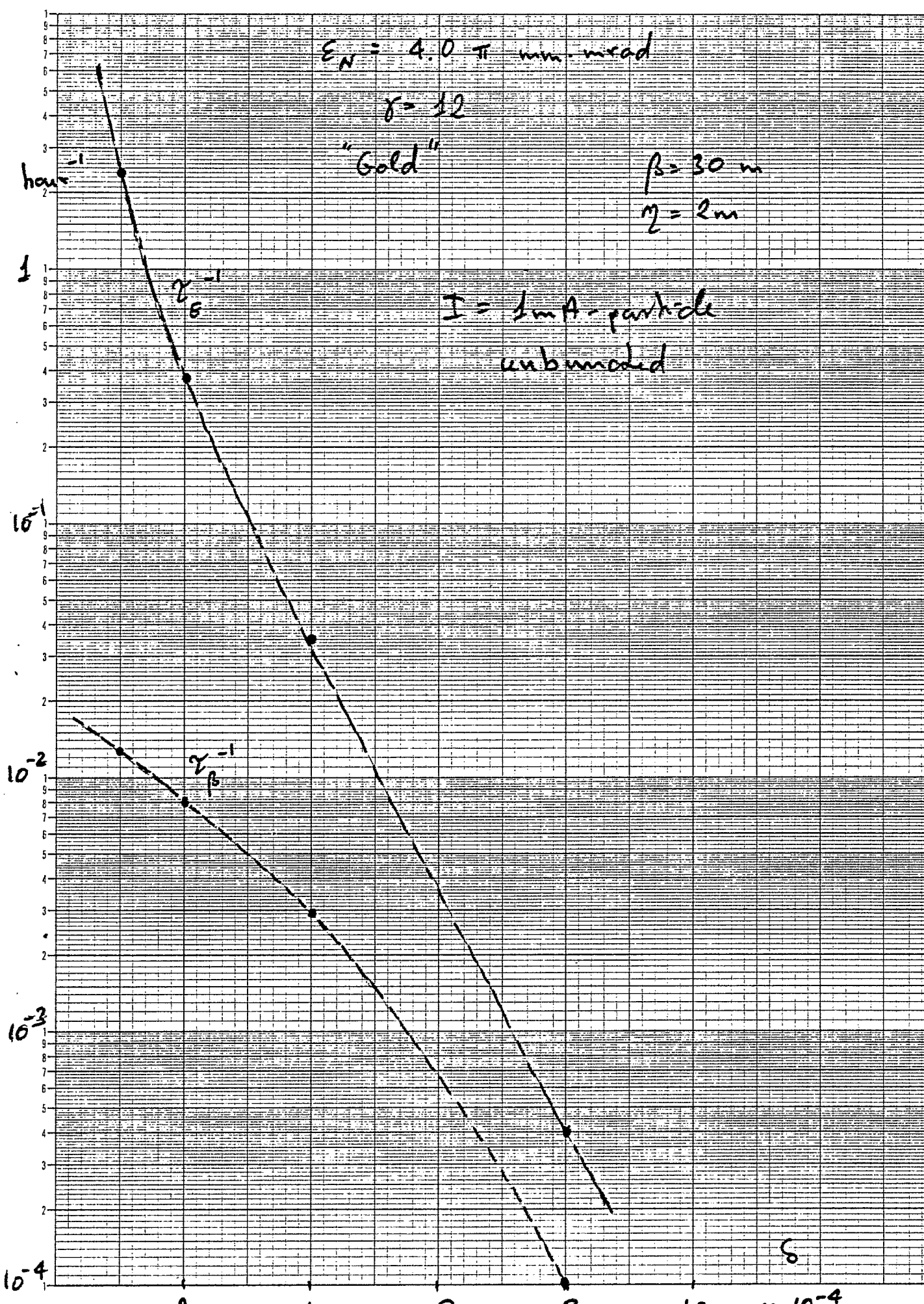$\gamma = 12$

"Gold"

$\beta = 50 \text{ m}$

$\eta = 2 \text{ m}$

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

τ_E^{-1} hour^{-1}

τ_β^{-1} hour^{-1}

τ_e^{-1}

τ_β^{-1}

δ
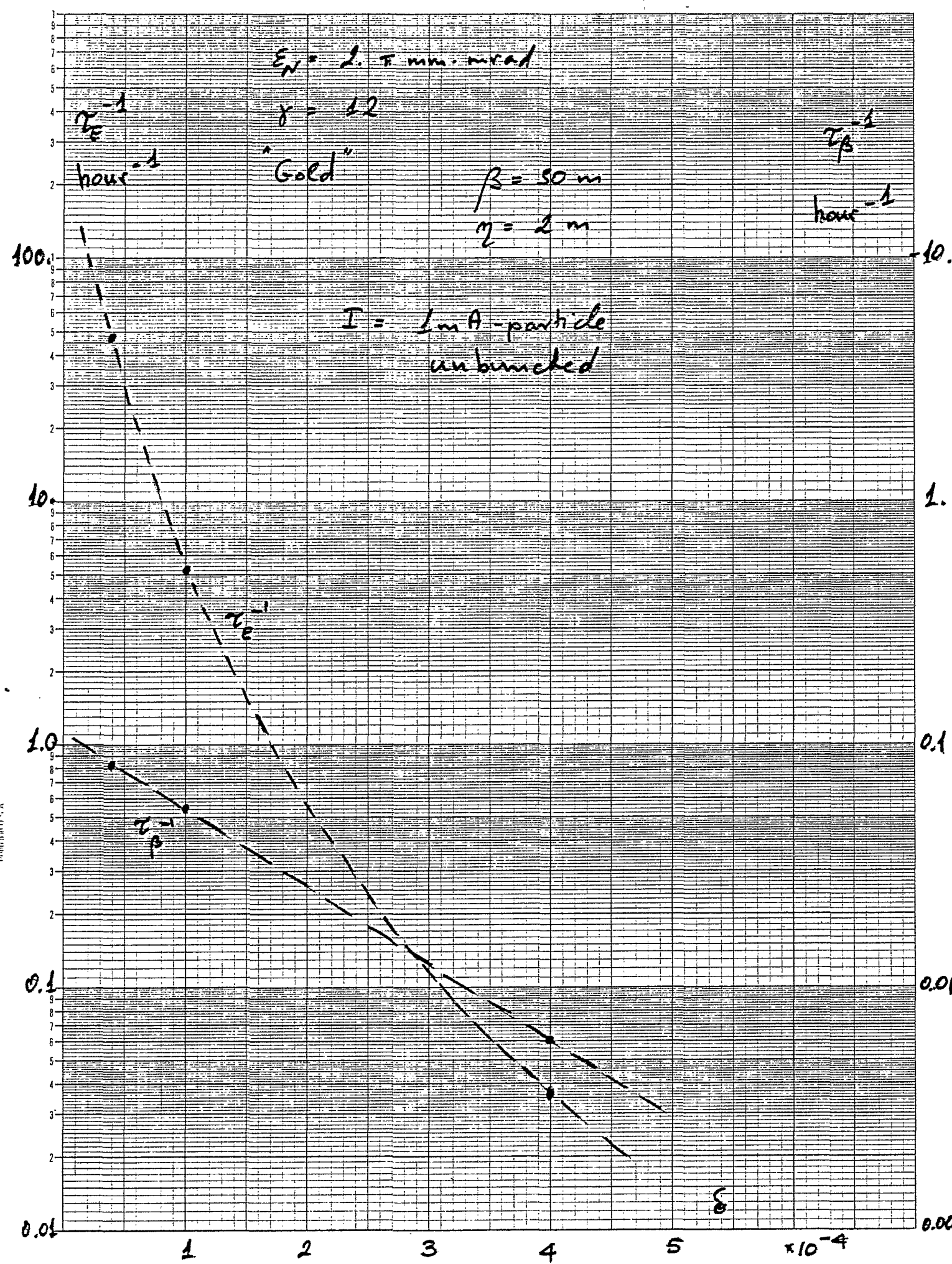
$\varepsilon_N = 4 \pi$ mm·mrad

$\gamma = 100$

"Gold"

$\beta = 30m$

$\eta = 2m$

$I = 4mA$ - particle bunched

hour^{-1}

τ_p^{-1}

τ_6^{-1}

δ
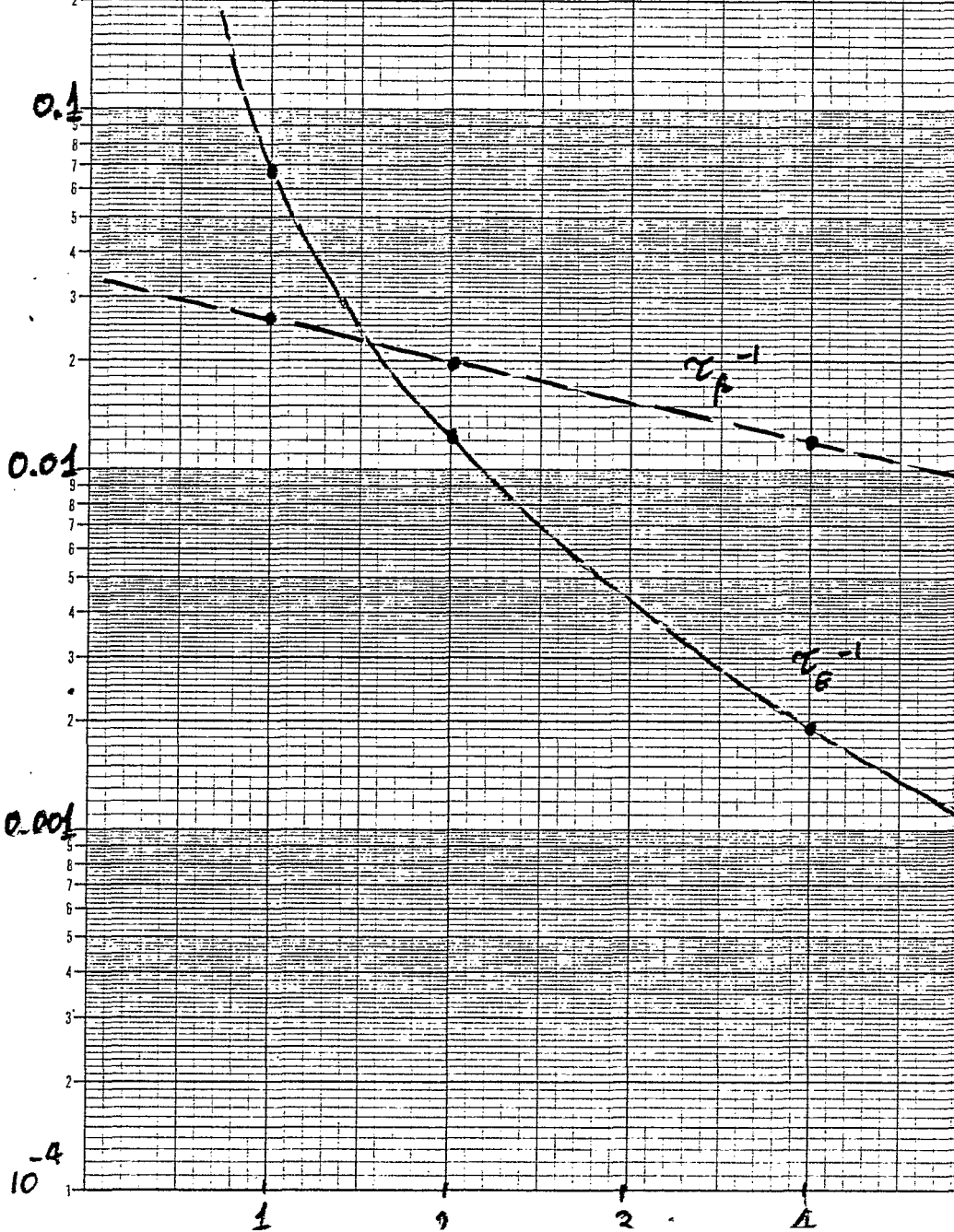
$60°$ phase advance cell

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

$\gamma = 100$

$\varepsilon_N = 4\pi \text{ mm·mrad}$

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

$$I_P = 120 \text{ mA - particle} \qquad (\sigma_\ell = 10 \text{ cm})$$

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

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

$\gamma = 100$ $\qquad$ $E_N = 4\pi$ 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 -particle

90° phase advance

$\gamma = 100$

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

$\varepsilon_N = 4\pi \, \text{mm·mrad}$

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		ohms	
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	

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

$B' = 3 \, \text{KG/cm}$

bore radius $= 4 \, \text{cm}$

$B_Q = 12 \, \text{KG}$

1.06m $B = 3.0 \, T$ 1.06m

F'   D

2.5m   10.472m   2.5m

sagitta ~ 5 cm
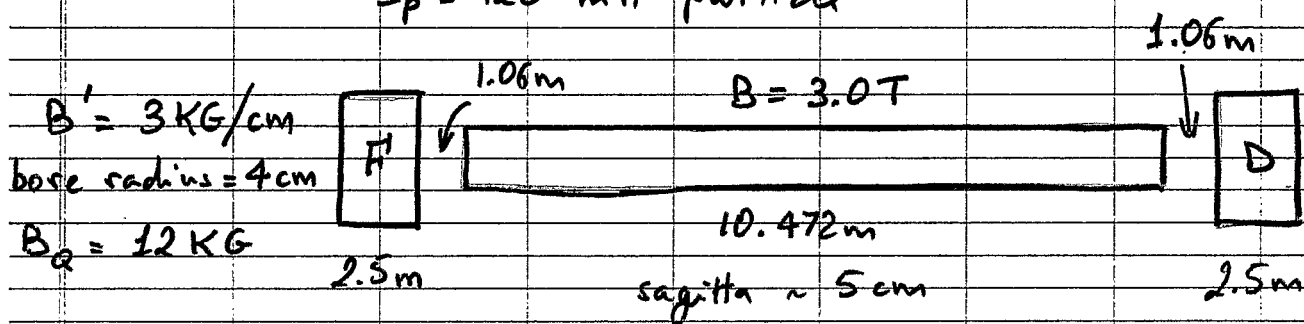
$\beta_{max} = 51 \, m$ $\eta_{max} = 1.6 \, m$

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

max full beam width $= 13-15 \, mm$

$(\sim 5\sigma)$