BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

ACCELERATOR DEPARTMENT
Informal Report

AGS SECONDARY BEAMS AND PARAMETERS - FY75

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June 25, 1974

ABSTRACT

A compilation is presented of the AGS secondary beam parameters and fluxes.

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AGS SECONDARY BEAMS AND PARAMETERS - FY75

A compilation is presented of the AGS secondary beam parameters and particle fluxes. Fig. 1 shows the layout of the secondary beams at the AGS as of June 1974. Some details of the beams from the G10, A, B, B', C, C', and D target stations for 1974 and 1975 are given in Fig. 2 and 3 respectively.

Table I gives a summary of the secondary beams. Fig. 4, 5, and 6 indicate the π^- , K^- , and $\bar{p}$ fluxes obtained in various beams in typical running conditions of experiments.

References on beam properties are those available on hand, and no effort is made for completeness. The compilation will be revised when new beams and more information become available. We welcome comments and contributions from experimenters, especially with respect to measured beam fluxes.

Beam 4 - High Energy Separated Beam for 80-in. Bubble Chamber

Particles $K^\pm$, $p^\pm$, $\pi^\pm$, d

Momentum range	K, 3.5 to 15 GeV/c (flux limited below 3.5 GeV/c) $\bar{p}$, 3 to 15 GeV/c (flux limited above 15 GeV/c) $\pi^\pm$, to 24 GeV/c (focal strength limited above 24 GeV/c) π^- , to 25 GeV/c (unseparated) P, to 29 GeV/c (unseparated) d, 20 to 29 GeV/c (momentum separated)
Momentum bite	1%
Target location	External target near I 13
Target material	Be
Target size	0.2-in. wide, 0.15-in. wide, 10-in. long
Production angle	0°
Solid angle	0.0066 msr
Separator	Three deflectors
Length	129m
Purity	$\geq 90\%$

Beam 4 (continued)

Flux/burst (A)	Momentum particles/ 10^{11}		incident protons (at 25 GeV/c)			
	(GeV/c)	π^+	π^-	K^+	K^-	$\bar{p}$
	8	5000	2300	70	17	18
	10	4700	2000	85	16	10
	12	4000	1500	80	11	5
	15			60	4	2
(B)		particles/ 10^{12}		incident protons (at 27 GeV/c)		
	4			30	20	200
	6			250	100	250

References: H.W.J. Foelsche, V.D. VanderBurg, T. Ferbel, and P. Yamin, in Summer Study on AGS Utilization (Ed. T.E. Toohig), BNL 16000 (1970).

H.W.J. Foelsche, private communication.

Beam 5A - Medium Energy Partially Separated Beam

Particles	$K^\pm, \bar{p}$
Momentum range	1.3 to 3.1 GeV/c
Momentum bite	$\pm 2\%$ (to $\pm 3\%$)
Target location	G10
Target material	Boron Carbide
Target size	.02-in. high, .04-in. wide, .64-in. long at 10^0 to the circulating beam.
Production angle	10^0
Solid angle	0.47 msr
Length	1788-in.
Beam size	~ 0.8 -in. diameter at experimenter's target
Separators	2 electrostatic separators
Purity	$K^+/\text{other} \approx 0.5$

Beam 5A (continued)

Flux/burst	Momentum (GeV/c)	Particles/ 10^{12} circulating protons		
		K^+	K^-	$\bar{p}$
	1.3	3500		
	1.6	15000		8200
	1.8	28000	13000	17000
	2.0	50000	22000	29000
	2.2	68000	33000	42000
	2.4	85000		58000
	2.6	103000		70000

References: B. Barish and T.F. Kycia (preprint).

S. Mori, D. Lazarus, Y.Y. Lee, private communication.

Beam 5B - Medium Energy Partially Separated Beam

Particles	$K^\pm, \bar{p}$		
Momentum range	1 to 2.5 GeV/c		
Momentum bite	± 1 to $\pm 3\%$		
Target location	G10		
Target material	Boron Carbide		
Target size	.02-in. high, .04-in. wide, .64-in. long at 10° to the circulating beam.		
Production angle	10°		
Solid angle	0.47 msr		
Length	1522-in.		
Separators	2 electrostatic separators		
Purity	π^+/K^+	1-4	
	π^-/K^-	1-4	
	$\pi^-/\bar{p}$	1-15	
Flux/burst	Momentum (GeV/c)	Particles/ 10^{12} circulating protons	
		K^+	$\bar{p}$
	0.8		500
	1.0	950	1700
	1.5	11000	7500
	2.0	30000	20000
	2.4	5000	27000
			40000

References: B. Barish and T.F. Kycia (preprint).
 J.K. Yoh, et al., Phys. Rev. Letters 23, 506 (1969).
 Y. Nagashima, private communication.

Beam 6A - G10 4.7° Neutral Beam

Particles	K_L^0		
Momentum range	3 to 10 GeV/c		
Target location	G10		
Target material	Boron Carbide		
Target size	.02-in. high, .04-in. wide, .64-in. long at 10° to the circulating beam.		
Production angle	4.7°		
Solid angle	3.09 μ sr		
Length	190-ft.		
Flux/burst	Momentum (GeV/c)	K_L /sr/GeV/c/circulating proton at G10 target	$K_L/10^{12}$ circulating protons at detector
	3	0.025	39000
	4	0.026	48000
	5	0.023	46000
	6	0.020	42000
	7	0.013	28000
	8	0.008	18000
	9	0.005	11000
	10	0.003	7000
Total $2.4 \times 10^6 K_L$			

References: J.W. Cronin, in Possible Beams and Experiments for a High
 Intensity AGS (Ed. L.C.L. Yuan), RNL 7957 (1964), p. 44,
 also private communication.
 E. Engels, private communication.

Beam 6B - Medium Energy Test Beam

Particles	$\pi^\pm$, p (unseparated)
Momentum range	2 to 17 GeV/c
Momentum bite	$\pm 2\%^*$

Beam 6B (continued)

Target location	G10												
Target material	Boron Carbide												
Target size	0.02-in. high, 0.04-in. wide, .64-in. long at 10^0 to the circulating beam.												
Production angle	4.7^0												
Solid angle	$9 \mu\text{sr}^{**}$												
Beam size	3-4 in. horizontal, 2-3 in. vertical												
Flux/burst	<table><tr><td>Momentum (GeV/c)</td><td>Particles/10^{12} $\pi^\pm$</td><td>circulating protons p</td></tr><tr><td>6</td><td>10^6</td><td>9×10^6</td></tr><tr><td>12</td><td>2.5×10^6</td><td>7×10^6</td></tr><tr><td>17</td><td>2×10^4</td><td>2×10^6</td></tr></table>	Momentum (GeV/c)	Particles/ 10^{12} $\pi^\pm$	circulating protons p	6	10^6	9×10^6	12	2.5×10^6	7×10^6	17	2×10^4	2×10^6
Momentum (GeV/c)	Particles/ 10^{12} $\pi^\pm$	circulating protons p											
6	10^6	9×10^6											
12	2.5×10^6	7×10^6											
17	2×10^4	2×10^6											

Remarks: * This is the maximum momentum band transmitted. Under normal conditions the momentum defining aperture C_2 will be reduced so that the beam flux corresponds to the requirements of the Radiation Safety Committee.

** This is dependent upon the collimator C_1 at the input to quadrupole Q_1 . The figure given here is for the collimator installed for Exp. 556 in the neutral beam. An acceptance of $150 \mu\text{sr}$ is attainable with no collimator.

References: T. Blair and D. Lazarus, EP&S Tech. Note 48 (1972).
D. Lazarus, private communication.

Beam 7A - G10 20^0 Neutral Beam

Particles	K_L^0
Momentum range	1 to 4 GeV/c
Target location	G10
Target material	Boron Carbide
Target size	0.02-in. high, 0.04-in. wide, .64-in. long at 10^0 to the circulating beam.
Production angle	20^0
Solid angle	$\sim 0.0784 \text{ msr}$

Beam 7A (continued)

Flux	Momentum (GeV/c)	K_L^0 /sr/100 MeV/c per 10^4 circulating protons
	1.0	0.63
	1.2	1.55
	1.4	2.12
	1.6	2.07
	2.0	1.55
	2.4	1.01
	2.8	0.63
	3.3	0.27
	3.8	0.14

Reference: D. Nygren, private communication.

Beam 7B - G10 18° Test Beam

Particles	$\pi^\pm$, $K^\pm$, $p^\pm$, D, T, H_e^+ , H_e^-
Momentum range	0.8 to 3.3 GeV/c
Momentum bite	$\pm 1\%$
Target location	G10
Target material	Boron Carbide
Target size	0.02-in. high, 0.04-in. wide, .64-in. long at 10° to the circulating beam
Production angle	18°
Solid angle	9.1×10^{-8} sr

Flux/burst	Momentum (GeV/c)	Particles/1.5 x 10 ¹² circulating protons					
		p	π ⁺	π ⁻	K ⁺	K ⁻	
	1.5	57000	54000	50000	8300	1700	
	2.5	22000	18000	14000	3600	1100	
	3.3	9000	6500	5000	1700	370	
	(GeV/c)	p/π ⁺	π ⁻ /π ⁺	D/π ⁺	T/π ⁺	H _c ⁺ /π ⁺	H _c ⁺ /D
	1.5	1.0	0.003	0.02	0.001	0.0002	0.02
	2.5	1.2	0.005	0.03	0.001		0.003
	3.3	1.5		0.04	0.0005		

References: A.S. Carroll, et al., Phys. Rev. Letters 20, 607 (1968).

C.L. Wang, Phys. Rev. Letters 22, 1011 (1969).

Beam B1 - High Energy Charged Beam

Particles $\pi^\pm, K^\pm, p^\pm$
 Momentum range 6 to 24 GeV/c
 Momentum bite Variable (at the first focus, $\Delta p/p \approx \pm 1.2\%$
 with $\pm 3/4"$ momentum slit)
 Target location B station
 Target material Be .2" x .2" x 6" .1" x .04" x 2" .05 diam x 6"
 and size

	<u>Height</u>	<u>Width</u>	<u>Length</u>	<u>Angle</u>
Cu (trapizoidal)	.04"	.1"	2"	6°
Heavymet (trapizoidal)	.04	.1	2	6
	.04	.1	4	6
	.04	.1	4	6 (w/heat sink)
	.04	.1	6	6

Production angle 0°
 Solid angle ~ 0.3 msr
 Length 3000-in.

Flux/burst (1) Based on preliminary data from Pennsylvania Group
 (Exp. 555, 635) $\sim 2 \times 10^6$ particles at any momentum
 by varying the momentum slit

Approximate composition

Momentum	π^+	K^+	p	π^-	K^-	$\bar{p}$
10 GeV/c	.49	.01	.50	.98	.013	.005
20	.028	.003	.97	.99	.006	.0002

(2) Based on Sanford-Wang curves (BNL 11299 and BNL 11479)

Momentum	π^-	K^-	$\bar{p}/10^{12}$ incident protons
6 GeV/c	1.3×10^7	2×10^7	1.9×10^5
12	1.1×10^7	2×10^7	8.7×10^4
18	3.1×10^6	1.8×10^6	5.0×10^3
24	2.8×10^6	2.7×10^6	70

Beam B2, B4 - Medium Energy Separated Beam

Particles	$K^{\pm}, \bar{p}, \pi^{\pm}$						
Momentum range	K, 1.6 to 6.7 GeV/c						
	$\bar{p}$, 0.5 to 9.6 GeV/c						
	π , 0.8 to 10 GeV/c						
Momentum bite	± 2.2 to $\pm 3\%$						
Target location	B station						
Target material		Height	Width	Length			
and size	Be	.04"	.1"	4"			
		.04	.1	2			
	Cu	.04	.1	2			
	W	.04	.1	2			
Production angle	6° (phase 1)						
	3° (phase 2 - for this later phase, particle fluxes at higher momentum will be increased).						
Solid angle	92 - 294 μ sr						
Separator	2 electrostatic separators						
Beam size	~ 0.6 -in. diameter at experimenter's target						
Length	3182-in.						
Flux/burst	Mode	$\overset{3}{\pi^+ \quad \pi^-}$		$\overset{\text{combined}}{K^+ \quad K^-}$	$\bar{p}$	$\overset{1}{\pi^-/10^{12} \text{ interacting protons}}$	
	Momentum (GeV/c)						
	2	6.7×10^6	5.2×10^6	1.7×10^4	5×10^3	2.5×10^6	3.4×10^7
	3	9.2×10^6	7.0×10^6	1.4×10^6	4.8×10^4	4.3×10^6	4.6×10^7
	4	9.2×10^6	6.8×10^6	3.7×10^6	1.3×10^5	4.8×10^6	4.1×10^7
	5	7.6×10^6	5.5×10^6	2.3×10^6	8.6×10^4	4.2×10^6	3.3×10^7
	6	5.6×10^6	4.0×10^6	1.4×10^6	4.3×10^5	3.1×10^6	2.5×10^7
	8	2.7×10^6	1.7×10^6			4.5×10^4	9.1×10^6
	10	1.0×10^6	7.0×10^5				

- References: A.S. Carroll, in Summer Study on AGS Utilization (Ed. T.E. Toohig), BNL16000.
 J.D. Fox, EP&S Division Tech. Note No. 38 (1970).
 J.D. Fox and C.T. Murphy, BNL 16916 (1972), BNL 18627 (1974).
 C.T. Murphy, EP&S Division Tech. Note No. 59 (1973), No. 62 (1973).

Beam B5 - B Station Neutral Beam

Particles	K_L^0, K_S^0
Momentum range	3 to 10 GeV/c
Target location	B' station
Target material and size	Ir 0.1" diam. x 3"
Production angle	4°
Solid angle	$360 \mu\text{sr} (K_L^0), 98 \mu\text{sr} (K_S^0)$
Length	16-ft. (K_L^0) and 12.5 -ft. (K_S^0) from B' target to the beginning of decay volume. Length of decay volume 10-ft.

Flux/burst	Momentum (GeV/c)	K_L /sr/GeV/c/ incident proton	$K_L/(1-3) \times 10^{11}$ incident proton at detector
	3	.017	5.7×10^{12}
	4	.017	6.0×10^{12}
	5	.015	5.3×10^{12}
	6	.013	4.7×10^{12}
	7	.009	3.1×10^{12}
	8	.005	1.7×10^{12}
	9	.003	1.4×10^{12}
	10	.002	0.7×10^{12}
		Total	$2.9 \times 10^{13} K_L$

Reference: Preliminary data from Princeton/U. of Mass. Group (Exp. 572), private communication.

Beam C1 Muon Beam

Particles	$\mu^\pm$
Mean momentum	5.8 and 7.3 GeV/c (momentum range 5-9.5 GeV/c) The beam is modified to extend the momentum up to 12 GeV/c.
Momentum bite	$\pm 10\%$
Target location	C station
Target material	Cu
Target size	0.1-in. high, 0.2-in. wide, 1.5-in. long

Beam C1 Muon Beam (continued)

Horizontal spread (at target)	± 2.5 cm
Vertical spread (at target)	± 1.8 cm
Tagging efficiency	$\sim 60\%$
$\Delta p/p$ for tagged muons	1.5%
$(\text{r.m.s.})\Delta\theta_x = (\text{r.m.s.})\Delta\theta_y$ for tagged muons	10^{-3} radians
$(\text{r.m.s.})\Delta x = (\text{r.m.s.})\Delta y$ for tagged muons	2.1 mm
Pion contamination	$< 5 \times 10^{-7}$
Beam/halo	2/1
Flux	$\sim 10^6/10^{12}$ protons on target

Reference: A. Entenberg et al., Univ. of Rochester Report, UR-469,
C00-3065-68(1973).

Beam C2, C4 - Low Energy Separated Beam

Particles	$K^\pm, \bar{p}, n^\pm$
Maximum momentum	1.1 GeV/c
Momentum bite	$\pm (1-2)\%$
Target location	Target station 'C'
Target material and size	Cu (0.1-in. high, 0.2-in. wide, 4.1-in. long) Ir (.2-in. diam. x 3-in.)
Production angle	10.5°
Solid angle	2.64 msr
Separator	1 electrostatic separator
Length	580-in.
Beam size	2-in. wide, 1-in. high (FWHM) at 66-in. downstream of the last quadrupole

Beam C2, C4 (continued)

Flux and purity	Target	$\frac{\Delta P}{P}$	Flux						Purity	
			Momentum (GeV/c)	Particles/ 10^{12} incident protons						
				K^+	K^-	$\bar{p}$	π^+/K^+	π^-/K^-	π^-/p^-	
	Cu	$\pm 1\%$	.5		5.0×10^4	18		360	470	
			.6	8.8×10^3	2.7×10^3	280	26	56	68	
			.8	4.0×10^4	9.8×10^3	1300	7	13	17	
			1.0	1.0×10^5	3.7×10^4	3400			16	
			1.1			5000				
	Ir	$\pm 2\%$	.7		4.2×10^4					
			.75	2.5×10^5	8.0×10^4	15000	2.8	10		

References: J.D. Fox, EP&S Div. Tech. Note No. 7 (1967) and No. 20 (1968).

M. Zeller, L. Rosenson, and R.E. Lanou, Jr., in Summer Study on AGS Utilization (Ed. T.E. Toohig), BNL 16000 (1970).

A.S. Carroll et al., EP&S Div. Tech. Note No. 54 (1972), No. 64 (1973).

S. Smith, D. Cheng, private communication.

Beam C3 - Hyperon Beam

Particles	Σ^-, Ξ^-
Momentum range	17 to 26 GeV/c
Momentum bite	$\pm 0.5\%$
Target location	C' station
Target material	Be
Target size	0.1-in. high, 0.2-in. wide, 10-in. long
Production angle	0°
Solid angle	$22 \mu\text{sr}$
Length	172-in.

Beam C3 (continued)

Flux detected/burst	Momentum (GeV/c)	Σ -trigger/ 10^{11} incident protons	(Σ/π) trigger	(π/Σ) detected
	19	12	7.4×10^{-4}	
	20	28	2.5×10^{-4}	
	20.5			2.85×10^{-2}
	21	56	6.9×10^{-4}	
	22	88	1.4×10^{-3}	
	23	121	3.1×10^{-3}	
	24	180	9.4×10^{-3}	
	25	160	1.4×10^{-2}	
	26	105	1.6×10^{-2}	

Yield

Σ^-/π^- production ratios and forward Σ^- production
laboratory cross sections for protons on beryllium.

Secondary Momentum GeV/c	Σ^-/π^-	$d^0 \sigma/dp d\Omega$ mb (sr GeV/c) ⁻¹
25.8 GeV/c Incident Protons		
17.75	0.329 ± 0.042	14.41 ± 1.8
18.75	0.465 ± 0.048	13.3 ± 1.4
19.75	0.669 ± 0.067	12.0 ± 1.2
20.75	1.08 ± 0.077	11.7 ± 0.8
21.75	2.41 ± 0.14	14.9 ± 0.9
22.75	2.85 ± 0.14	9.4 ± 0.5
23.75	21.91 ± 1.4	4.0 ± 0.2
29.4 GeV/c Incident Protons		
17.0	0.185 ± 0.011	25.3 ± 1.5
19.0	0.263 ± 0.016	19.0 ± 1.2
20.0	0.374 ± 0.022	19.0 ± 1.1
20.5	0.380 ± 0.021	16.3 ± 1.0
21.0	0.463 ± 0.028	16.3 ± 1.0
22.0	0.648 ± 0.037	15.3 ± 0.9
23.45	1.19 ± 0.07	15.0 ± 0.9
25.0	1.72 ± 0.16	10.1 ± 0.9
26.0	2.62 ± 0.16	6.0 ± 0.4

Reference: V. Hungerbuehler et al, Phys. Rev. Lett. 24 1234 (1973),
Nuclear Instr. and Methods 115 221 (1974).

Beam U Wide Bend Neutrino Beam

Particles	$\nu, \bar{\nu}$	
Energy	Peaked at ~ 1.5 GeV	
Target location	U station	
Target material	Sapphire	
Target size	Diameter 0.5 cm, length 45 cm	
Length	π, K decay region - 208-ft.	
	ν filter - 96-ft. iron	
	from target to bubble chamber - 336-ft.	
Optics	3 magnetic fingers focusing pions and kaons toward the bubble chamber	
Flux/burst	Energy (GeV)	Neutrinos/(interacting proton-meter ² ·GeV) (averaged over 70 cm radius area)
	.5	3.5×10^{-4}
	1	9.5×10^{-4}
	1.5	1.4×10^{-3}
	2	1.1×10^{-3}
	4	2.2×10^{-4}
	6	3.7×10^{-5}
	8	1.3×10^{-5}
	10	6.8×10^{-6}
	12	3.6×10^{-6}
Remark	Recent estimate shows that approximately 1.5 times more flux than given above can be expected.	
Reference:	N.P. Samios, R.B. Palmer, W.B. Fowler, and R.I. Louttit; AGS Proposal #A-427 (1967). BNL neutrino beam group, private communication.	

Distribution: B2

TABLE I
SUMMARY OF AGS SECONDARY BEAMS

<u>Separated Beams</u>	<u>Production Angle (degree)</u>	<u>Solid Angle (mrad)</u>	<u>Momentum Bite (%)</u>	<u>Momentum Range (GeV/c)</u>	<u>Flux</u>
C2, C4	10.5	2.64	2 - 4	0 - 1.2	5.6×10^8 K^- at 750 MeV/c
5	10	.47	2 - 6	1.3 - 3.2	2.2×10^8 K^- at 2 GeV/c
B2, B4	6	.092-.294	4.4 - 6	1.5 - 9	4×10^8 K^- at 5 GeV/c
<u>Neutral Beams</u>					
6A	4.7	.003	wide band	3 - 10	2.4×10^{15} K_L^0 between 3-10 GeV/c
B5	4	.36	wide band	3 - 10	2.9×10^{15} K_L^0 between 3-10 GeV/c
U			wide band	0.5 - 12	4×10^{11} ν at 1.5 GeV
<u>Unseparated Beams</u>					
B1	0	.3	2.4	6 - 24	$\sim 10^7$ π^- at 12 GeV/c
A1					HEUB - mid 1975
<u>Special Beams</u>					
C1			20	5 - 9.5	10^{15} μ^+
C3	0	.022	1	19 - 26	$300 \Sigma^-$ at 25 GeV/c

FIGURE 4

FIGURE 5

FIGURE 6