32. NEUTRINO BEAM LINES AT HIGH-ENERGY PROTON SYNCHROTRONS

Revised January 2016 with numbers verified by representatives of the synchrotrons (contact C.-J. Lin, LBNL). For existing (future) neutrino beam lines the latest achieved (design) values are given.

The main source of neutrinos at proton synchrotrons is from the decay of pions and kaons produced by protons striking a nuclear target. There are different schemes to focus the secondary particles to enhance neutrino flux and/or tune the neutrino energy profile. In wide-band beams (WBB), the neutrino parent mesons are focused over a wide momentum range to obtain maximum neutrino intensity. In narrow-band beams (NBB), the secondary particles are first momentum-selected to produce a monochromatic parent beam. Another approach to generate a narrow-band neutrino spectrum is to select neutrinos that are emitted off-axis relative to the momentum of the parent mesons. For a comprehensive review of the topic, including other historical neutrino beam lines, see the article by S. E. Kopp, "Accelerator-based neutrino beams," Phys. Rept. **439**, 101 (2007).

	PS (CERN)				SPS (CERN)				PS (KEK)	Main Ring (JPARC)
Date	1963	1969	1972	1983	1977	1977	1995	2006	1999	2009
Proton Kinetic Energy (GeV)	20.6	20.6	26	19	350	350	450	400	12	30 (50)
Protons per Cycle (10^{12})	0.7	0.6	5	5	10	10	36	48	6	200 (330)
Cycle Time (s)	3	2.3	-	-	-	-	14.4	6	2.2	2.48 (3.5)
Beam Power (kW)	0.8	0.9	-	-	-	-	180	510	5	390 (750)
Target	-	-	-	-	-	-	Be	Graphite	Al	Graphite
Target Length (cm)	-	-	-	-	-	-	290	1000	66	91
Secondary Focussing	1-horn WBB	3-horn WBB	2-horn WBB	bare target	dichromatic NBB	2-horn WBB	2-horn WBB	2-horn WBB	2-horn WBB	3-horn off-axis
Decay Pipe Length (m)	-	-	-	-	-	-	110	130	200	96
$\langle E_\nu \rangle$ (GeV)	1.5	1.5	1.5	1	50,150[†]	20	24.3	17	1.3	0.6
Experiments	HLBC, Spark Ch.	HLBC, Spark Ch.	GGM, Aachen-Padova	CDHS, CHARM	CDHS, CHARM, BEBC	GGM,CDHS, CHARM, BEBC	NOMAD, CHORUS	OPERA, ICARUS	K2K	T2K

	Main Ring (Fermilab)							Booster (Fermilab)	Main Injector (Fermilab)	
Date	1975	1975	1974	1979	1976	1991	1998	2002	2005	2016
Proton Kinetic Energy (GeV)	300,400	300,400	300	400	350	800	800	8	120	120
Protons per Cycle (10^{12})	10	10	10	10	13	10	12	4.5	37	43 (49)
Cycle Time (s)	-	-	-	-	-	60	60	0.2	2	1.333
Beam Power (kW)	-	-	-	-	-	20	25	29	350	580 (700)
Target	-	-	-	-	-	-	BeO	Be	Graphite	Graphite
Target Length (cm)	-	-	-	-	-	-	31	71	95	120
Secondary Focussing	bare target	quad trip., SSBT	dichromatic NBB	2-horn WBB	1-horn WBB	quad trip.	SSQT WBB	1-horn WBB	2-horn WBB	2-horn off-axis
Decay Pipe Length (m)	350	350	400	400	400	400	400	50	675	675
$\langle E_\nu \rangle$ (GeV)	40	50,180[†]	50,180[†]	25	100	90,260	70,180	1	3-20[‡]	2
Experiments	HPWF	CITF, HPWF	CITF, HPWF, 15' BC	15' BC	HPWF 15' BC	15' BC, CCFRR	NuTeV	MiniBooNE, SciBooNE, MicroBooNE	MINOS, MINERνA	NOνA, MINERνA, MINOS+

[†]Pion and kaon peaks in the momentum-selected channel.

[‡]Tunable WBB energy spectrum.