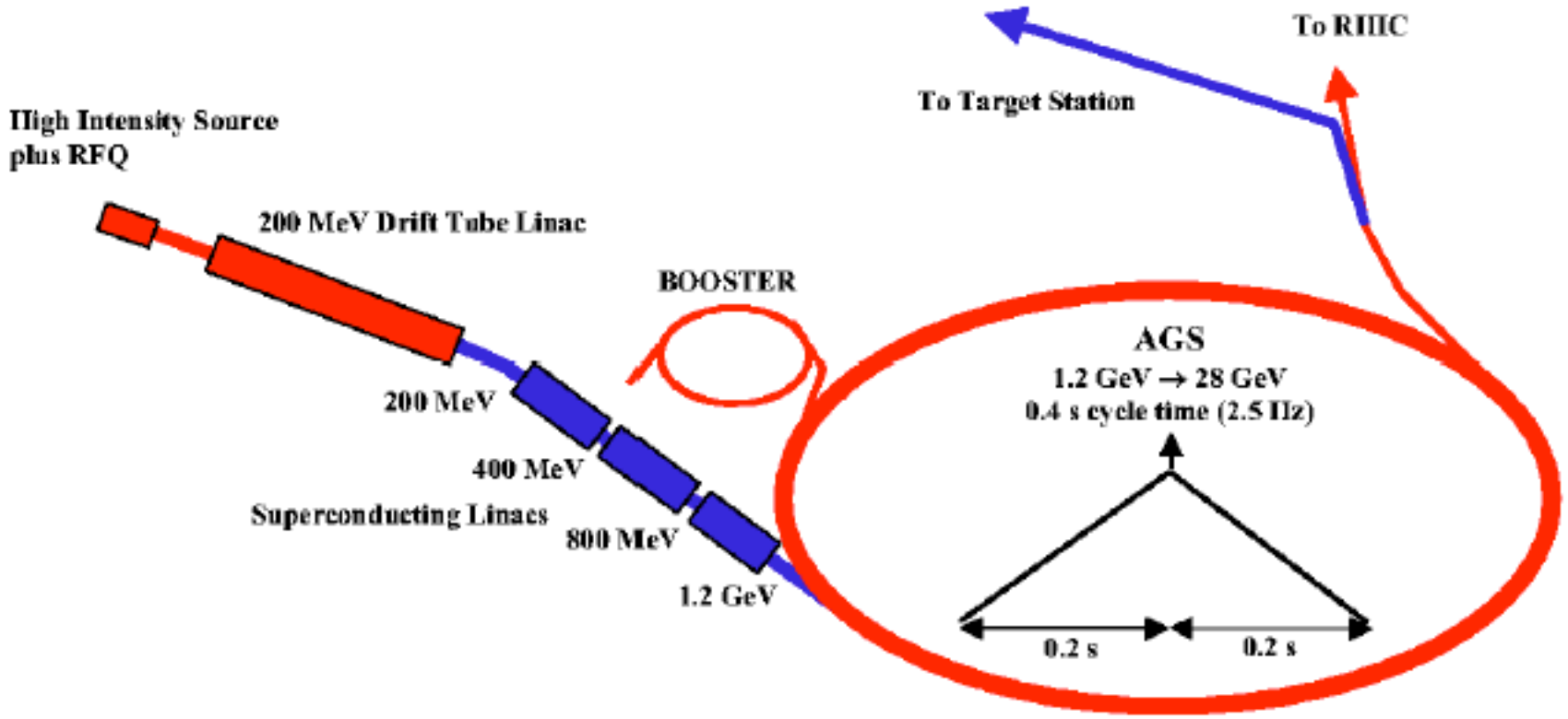
Superbeam vs betabeam ?

Milind Diwan

BNL-AGS Target Power Upgrade to 1 MW



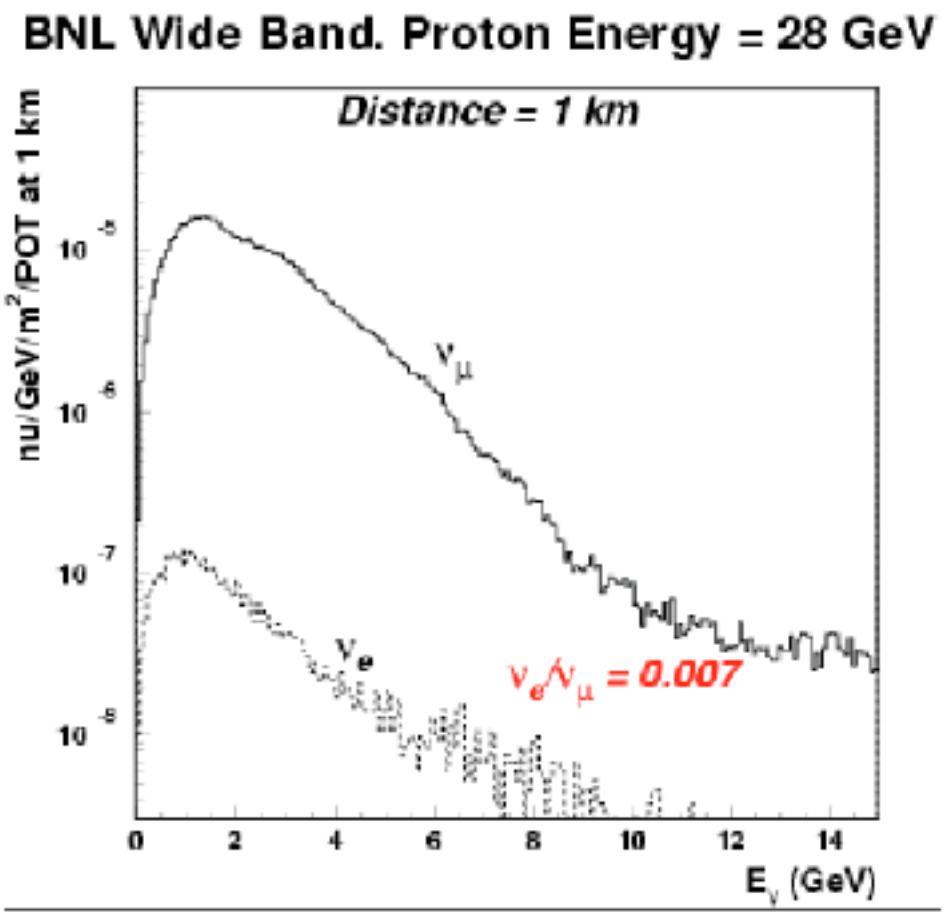
AGS is currently the highest intensity machine.
Simple plan. Run the AGS faster. 2.5 Hz
Need new LINAC @ 1.2 GeV to provide protons.
Cost $265M FY03 (TEC) dollars.
Energy is 28 GeV. 2.5 Hz operation is 1 MW

$7 \times 10^{13} protons/2sec$

$9 \times 10^{13} protons/0.4sec$

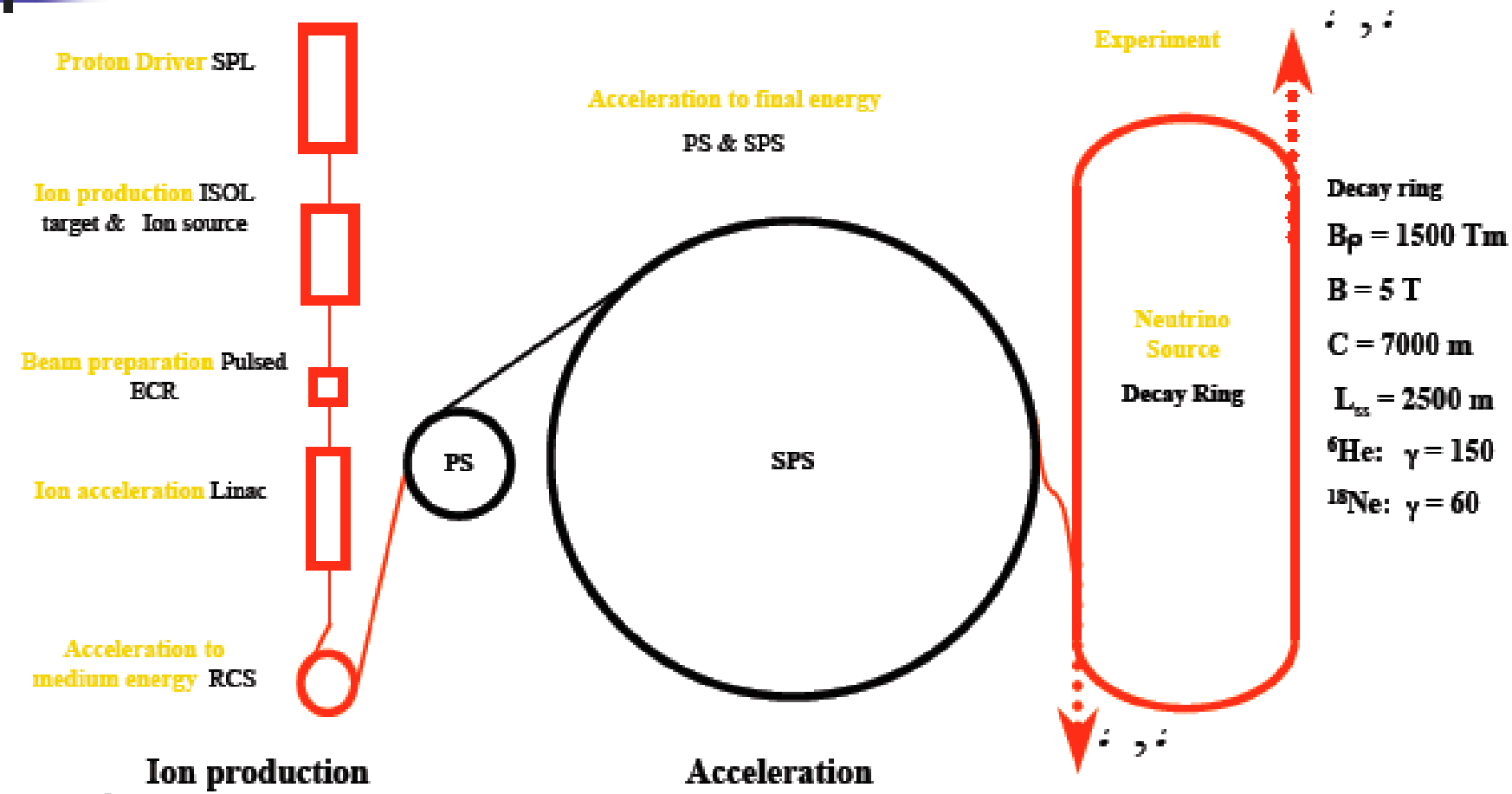
BROOKHAVEN NATIONAL LABORATORY

Neutrino spectrum from AGS



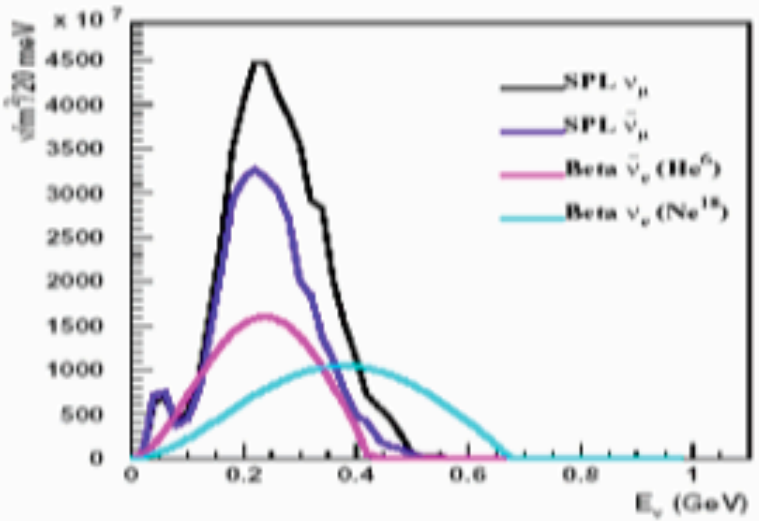
- Proton energy 28 GeV
- 1 MW total power
- ~10^{14} proton per pulse
- Cycle 2.5 Hz
- Pulse width 2.5 mu-s
- Horn focused beam with graphite target
- 5×10^{-5} ν/m^2/POT @ 1km
- 52000 CC events.
- 17000 NC events.

Beta-beam baseline design

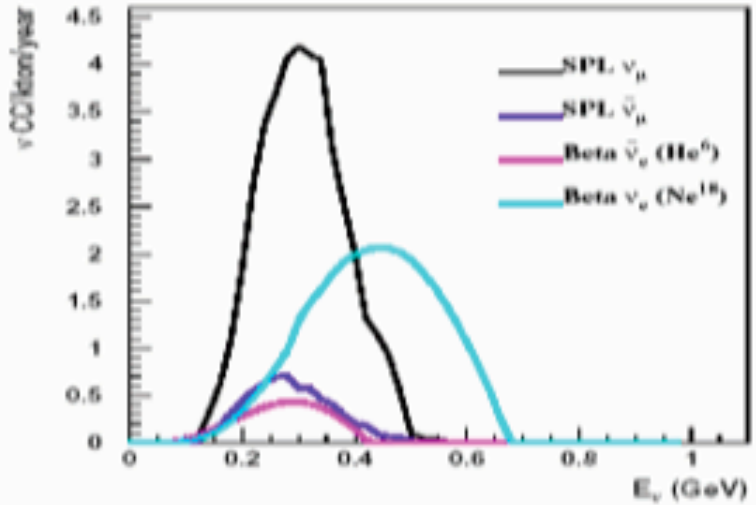


beta beam is pure nu_e or anti-nue, not pulsed like superbeam, is low energy ~200 -1000 MeV, upper range very hard.

Fluxes



CC Rates



	Fluxes @ 130 km $\nu/m^2/yr$	$< E_\nu >$ (GeV)	CC rate (no osc) events/kton/yr	$< E_\nu >$ (GeV)	Years	Integrated events (440 kton × 10 years)
SPL Super Beam						
ν_μ	$4.78 \cdot 10^{11}$	0.27	41.7	0.32	2	36698
$\overline{\nu}_\mu$	$3.33 \cdot 10^{11}$	0.25	6.6	0.30	8	23320
Beta Beam						
$\overline{\nu}_e$ ($\gamma = 60$)	$1.97 \cdot 10^{11}$	0.24	4.5	0.28	10	19709
ν_e ($\gamma = 100$)	$1.88 \cdot 10^{11}$	0.36	32.9	0.43	10	144783

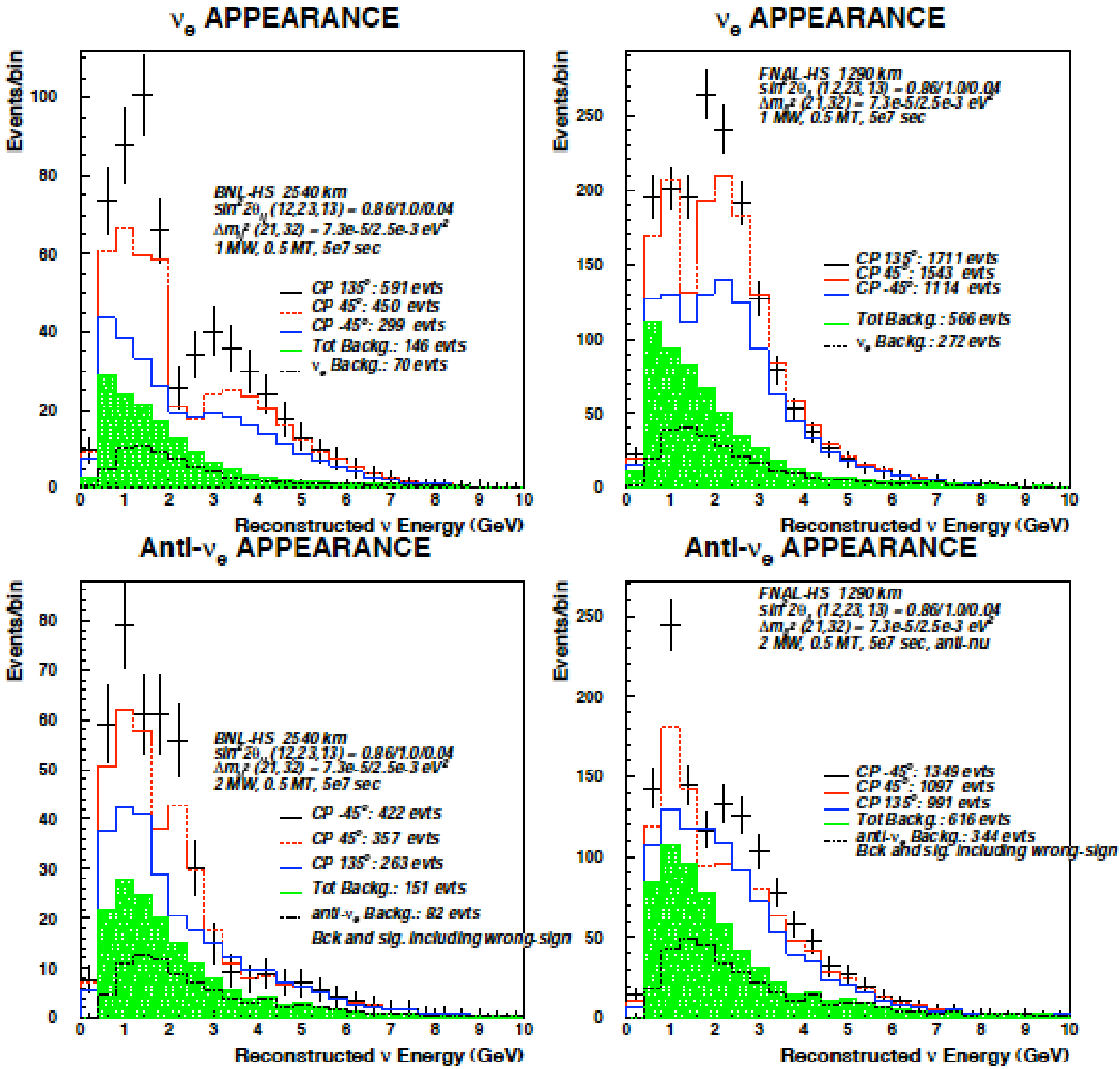
$\delta m^2_{12} = 7 \cdot 10^{-5}\ eV^2$, $\theta_{13} = 1°$, $\delta_{CP} = \pi/2$, $\text{sign}(\Delta m^2) = +1$

	Beta Beam ^6He ($\gamma = 60$)	Beta Beam ^{18}Ne ($\gamma = 100$)	SPL-SB ν_μ (2 yrs)	SPL-SB $\overline{\nu}_\mu$ (8 yrs)
CC events (no osc, no cut)	19710	144784	36698	23320
Oscillated at the Chooz limit	681	5304	1491	1182
Oscillated	1	118	2	34
δ oscillated	-12	54	-27	16
Beam background	0	0	140	101
Detector backgrounds	1	397	37	50

δ-oscillated events indicates the difference between the oscillated events computed with $\delta = 90°$ and with $\delta = 0$.

Problems of low energy:

- Fermi motion makes difficult the use of energy bins, only counting
- Uncertainties for the cross sections
- Atmospheric backgrounds


ν_e APPEARANCE
Events/bin
BNL-HS 2540 km
$\sin^2 2\theta_{ij}$ (12,23,13) = 0.86/1.0/0.04
Δm^2 (21,32) = 7.3e-5/2.5e-3 eV^2
1 MW, 0.5 MT, 5e7 sec
CP 135°: 591 evts
CP 45°: 450 evts
CP -45°: 299 evts
Tot Backg.: 146 evts
ν_e Backg.: 70 evts
Reconstructed ν Energy (GeV)
ν_e APPEARANCE
Events/bin
FNAL-HS 1290 km
$\sin^2 2\theta_{ij}$ (12,23,13) = 0.86/1.0/0.04
Δm^2 (21,32) = 7.3e-5/2.5e-3 eV^2
1 MW, 0.5 MT, 5e7 sec
CP 135°: 1711 evts
CP 45°: 1543 evts
CP -45°: 1114 evts
Tot Backg.: 566 evts
ν_e Backg.: 272 evts
Reconstructed ν Energy (GeV)
Anti-ν_e APPEARANCE
Events/bin
BNL-HS 2540 km
$\sin^2 2\theta_{ij}$ (12,23,13) = 0.86/1.0/0.04
Δm^2 (21,32) = 7.3e-5/2.5e-3 eV^2
2 MW, 0.5 MT, 5e7 sec
CP -45°: 422 evts
CP 45°: 357 evts
CP 135°: 263 evts
Tot Backg.: 151 evts
anti-ν_e Backg.: 82 evts
Bck and sig. including wrong-sign
Reconstructed ν Energy (GeV)
Anti-ν_e APPEARANCE
Events/bin
FNAL-HS 1290 km
$\sin^2 2\theta_{ij}$ (12,23,13) = 0.86/1.0/0.04
Δm^2 (21,32) = 7.3e-5/2.5e-3 eV^2
2 MW, 0.5 MT, 5e7 sec, anti-nu
CP -45°: 1349 evts
CP 45°: 1097 evts
CP 135°: 991 evts
Tot Backg.: 616 evts
anti-ν_e Backg.: 344 evts
Bck and sig. including wrong-sign
Reconstructed ν Energy (GeV)

$\Delta m^2_{31} = 7 \cdot 10^{-3}\ eV^2$, $\theta_{13} = 1°$, $\delta_{CP} = \pi/2$, $\mathrm{sign}(\Delta m^2) = +1$

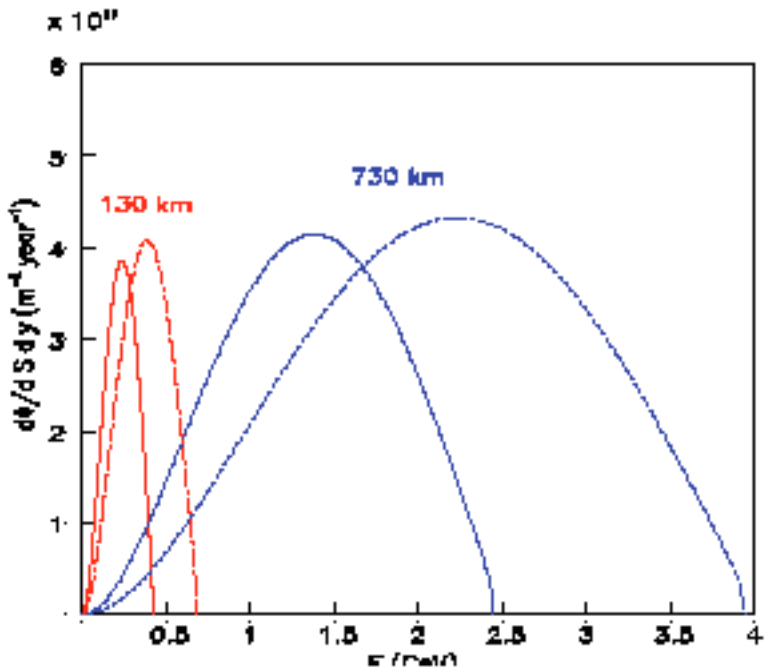
	Beta Beam		SPL-SB	
	${}^6He^+$ ($\gamma = 60$)	${}^{18}Ne^+$ ($\gamma = 100$)	ν_μ (2 yrs)	$\overline{\nu}_\mu$ (8 yrs)
CC events (no osc, no cut)	19710	144781	36698	23320
Oscillated at the Chooz limit	681	5301	1401	1182
Oscillated	1	118	2	34
δ oscillated	-12	54	-27	16
Beam background	0	0	140	101
Detector backgrounds	1	397	37	50

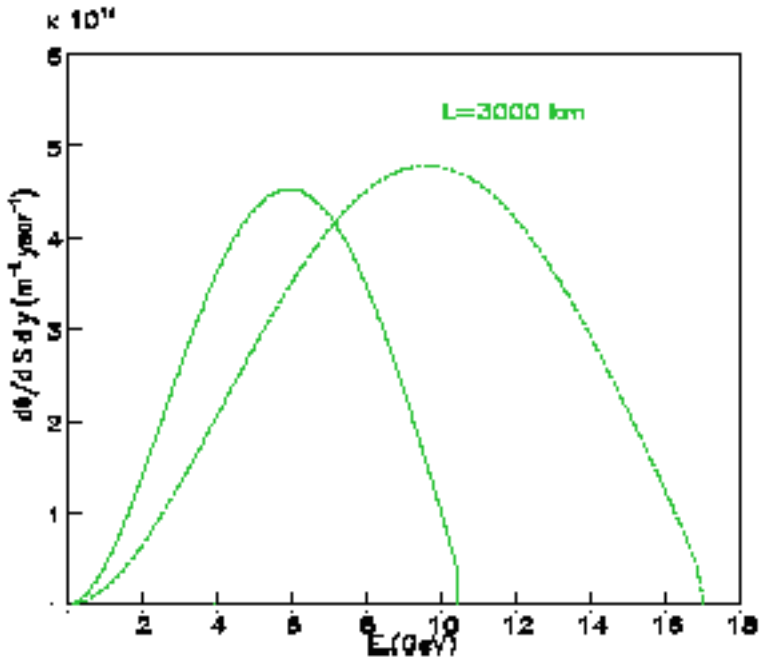
δ-oscillated events indicates the difference between the oscilated events computed with $\delta = 90°$ and with $\delta = 0$.

- chooz limit: ~10 deg. ?
- For BNL superbeam plots I have used 5.7 deg.

Higher-gamma Beta Beam example

γ	$L(km)$	$\bar{\nu}_e$ CC (KTon y)	ν_e CC (KTon y)	$\langle E_\nu \rangle (GeV)$
60/100	130	4.7	32.8	0.23/0.37
350/580	730	57.5	224.7	1.35/2.18
1500/2500	3000	282.7	993.1	5.80/9.39

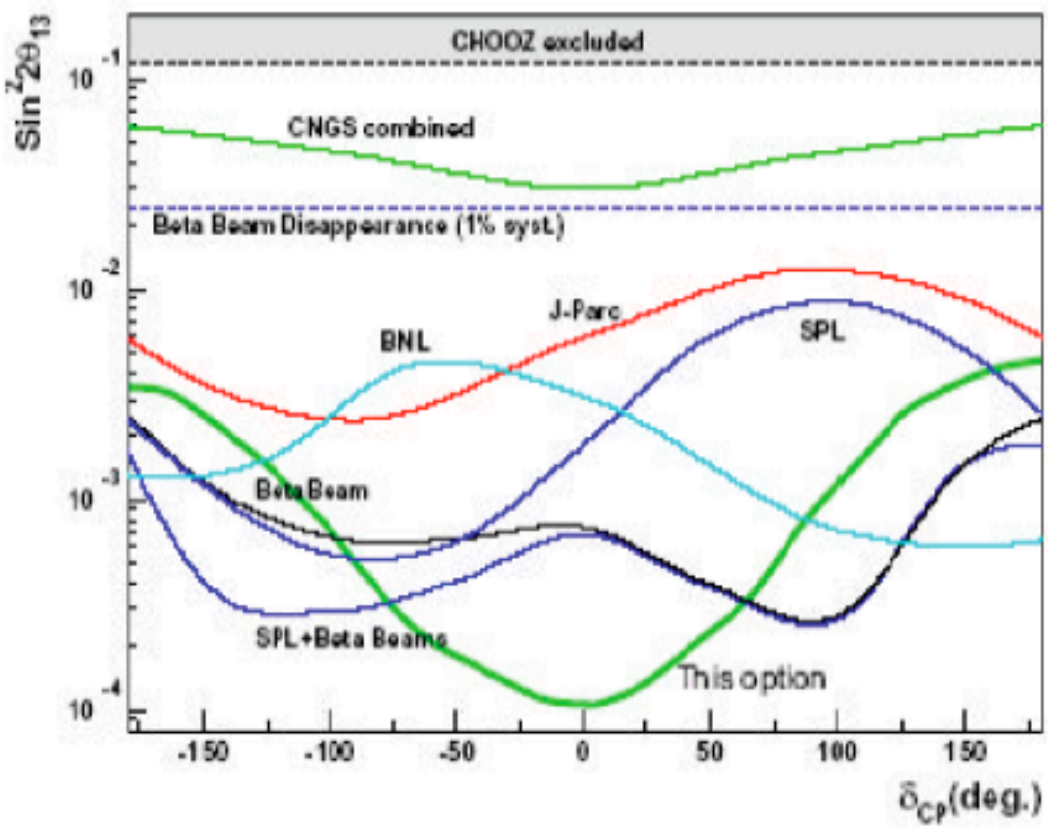




P. Hernández

HIGH ENERGY BETA BEAMS (II) (P. Migliozzi)

P. Migliozzi, F. Terranova et al., hep-ph/0405081



γ = 2500 (LHC)

cheap detector (muon counting) installed at Gran Sasso

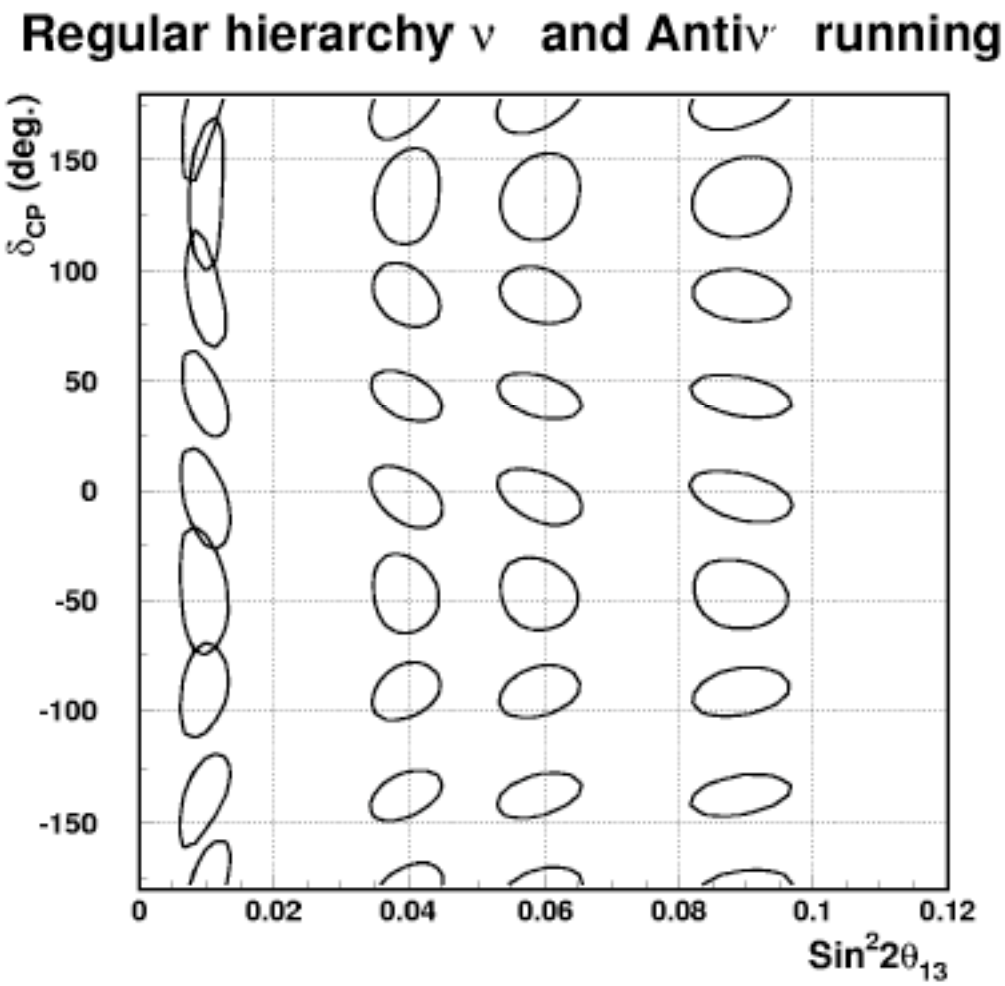
Question:

Flux ????

High to LNGS

Phase convention must be reversed for BNL. The BNL curve is only for neutrino running with 1 MW. With anti-nu running you cover all delta range.

Important Considerations

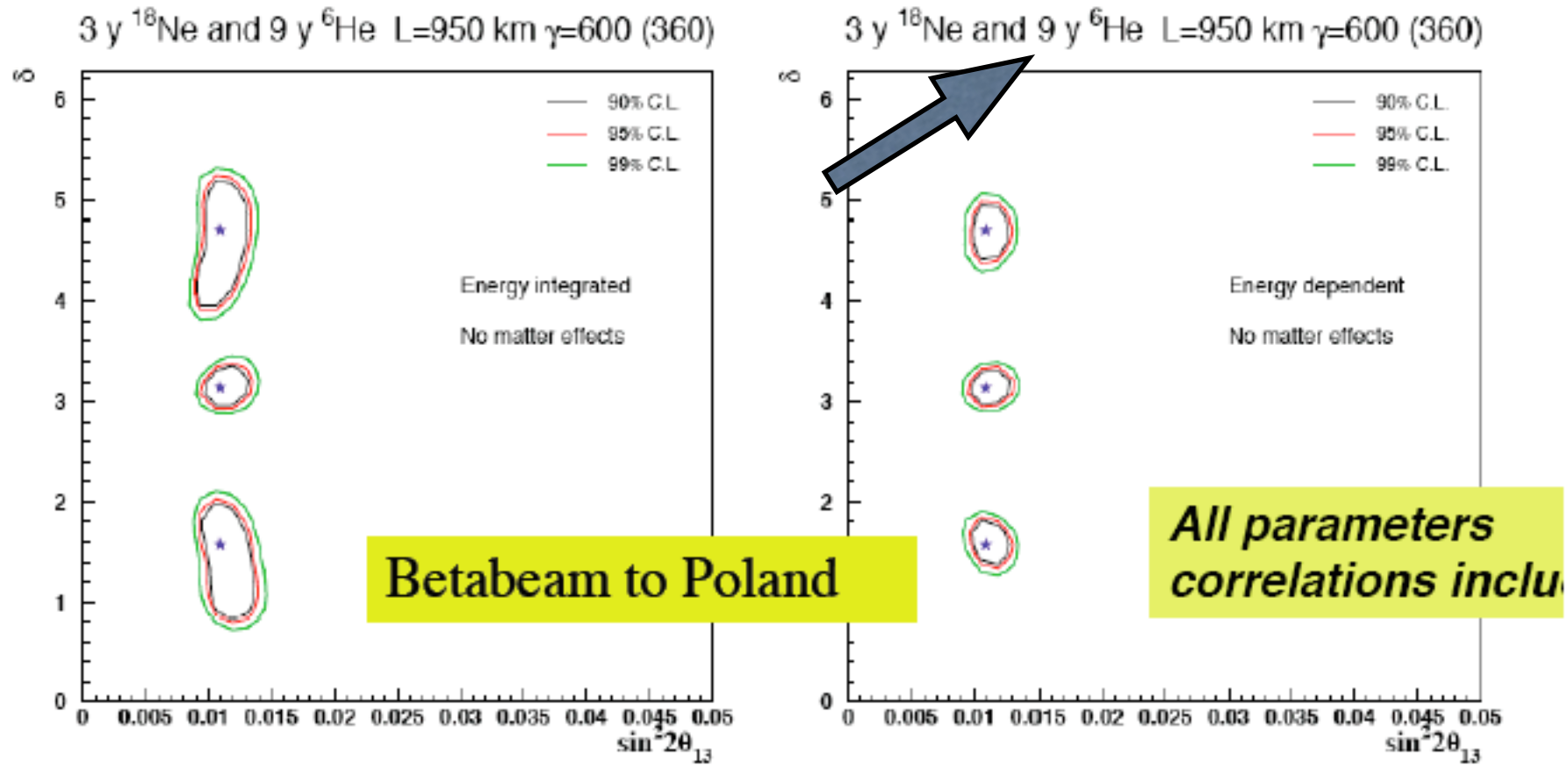


If signal is well above background CP resolution is indep. of $\sin^2 2\theta_{13}$

Wide band beam and 2540 km eliminate many parameter correlations.

For 3-generation mixing only neutrino running is needed. Anti-neutrino running gives better precision or New physics.

CP-violation parameters measurement



Betabeam to Poland

All parameters correlations inclu

Figure 13: 90%, 95% and 99% C.L. allowed regions on the θ_{13} and δ plane with 3 years of running using a ν_e beam and 9 years with a $\overline{\nu}_e$ beam at L=950 km with a 100 ktor detector. Stars indicate the best values of the parameters for every fit. We compare the results non including (left) and including (right) the ν_μ energy dependence in the fit. The expected constraints on the other oscillation parameters from future experiments are considered.

Conclusions

- A low energy (gamma=60, 90) beta-beam is good for th_13 determination, but not competitive with a 1 MW superbeam.
- To be competitive need to think about a higher energy beta beam (gamma=2000).