JHF-SK ν WS
@Epochal, Tsukuba
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Details of Neutrino Beam Properties

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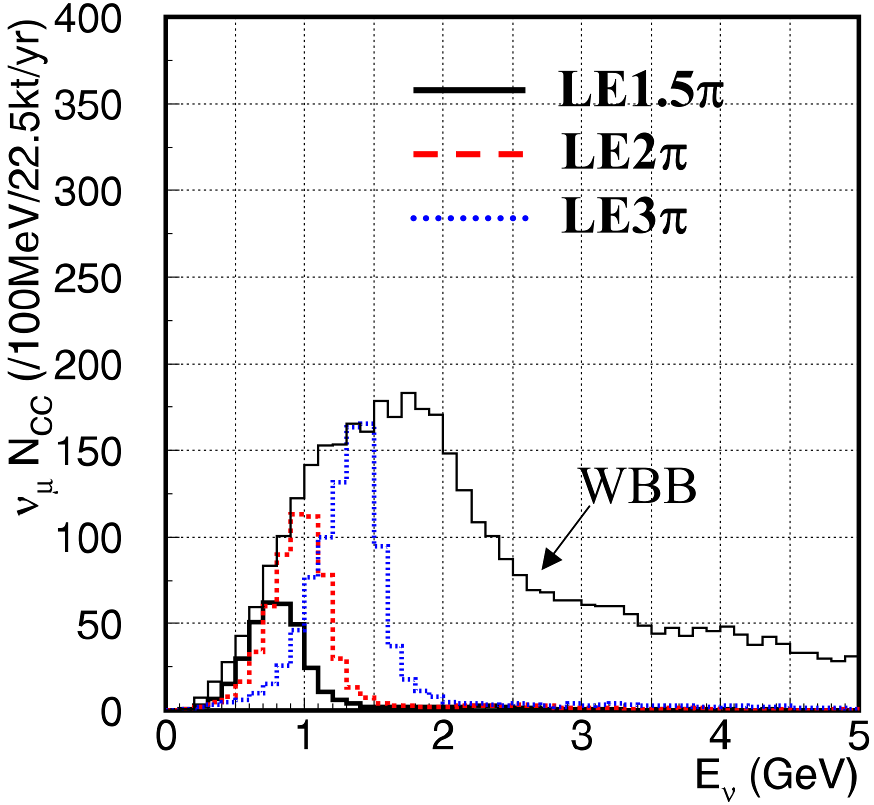
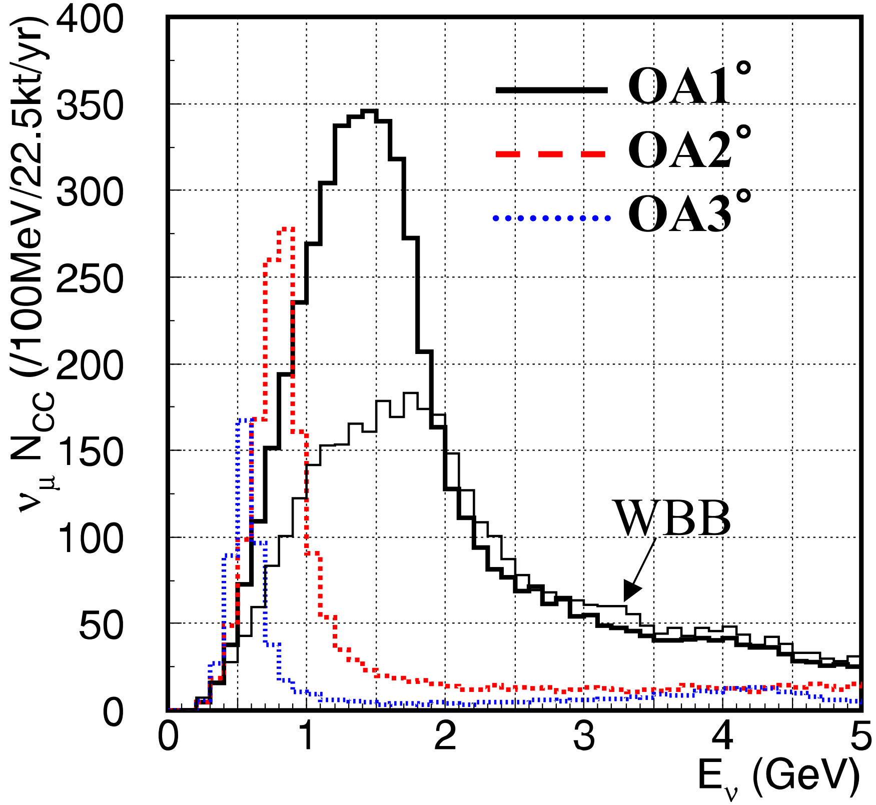
Contents

of CC events of various beams





WBB:**5200** CC int./22.5kt/yr

NBB: **620** CC int./22.5kt/yr (2GeV/c π tune)

OAB: **2200** CC int./22.5kt/yr (2degree)

Beam at FD @ 280m from target

	ν_μ			ν_e	
	Flux	Ntot	Ncc	Flux	Ntot
LE2π	9.8	1.8	1.3	7.8	0.015
OA2°	25.6	5.6	4.1	24.5	0.11
WIDE	32.8	12.2	9.0	29.1	0.17

FD size: ±3m

Unit:

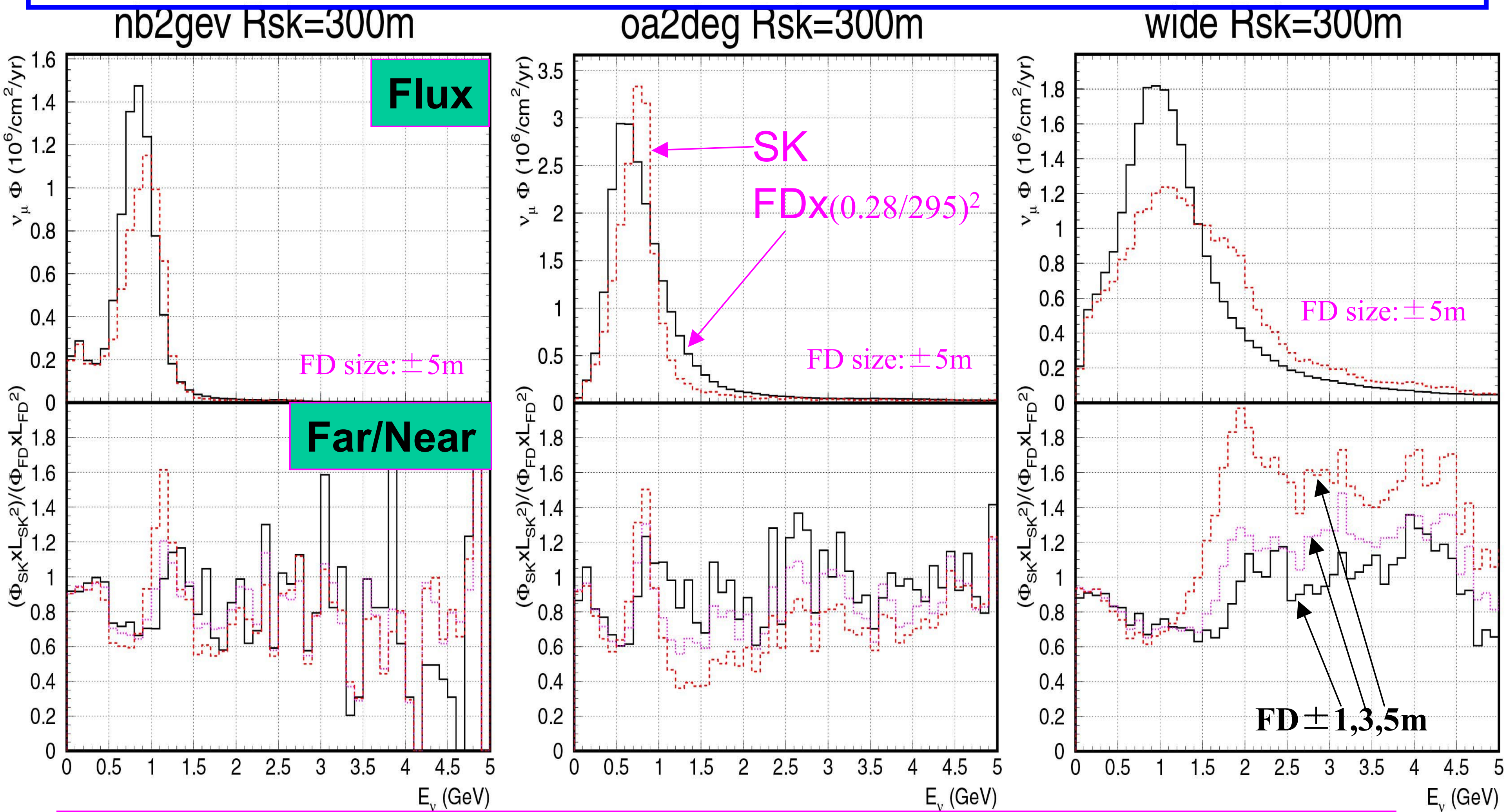
flux for ν_μ : $10^{12}/cm^2/10^{21}$POT

flux for ν_μ : $10^{10}/cm^2/10^{21}$POT

# of int : /100ton.spill ($3.3x10^{14}$ppp)

~1kt Water Cherenkov @ 280m hard to work for OAB/WBB

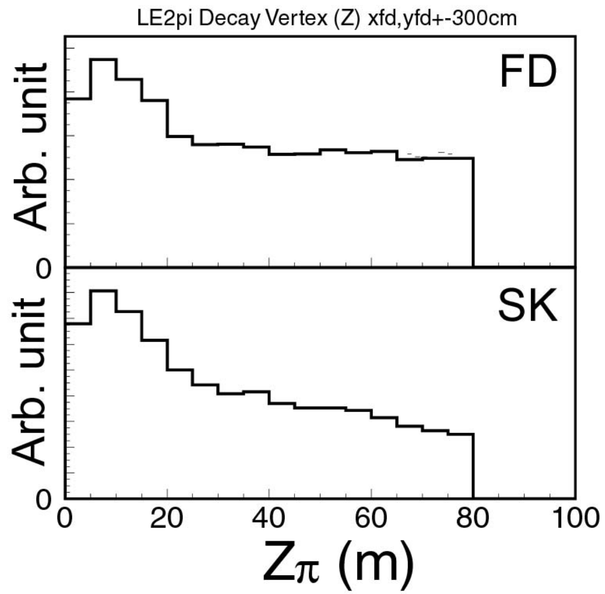
Spectrum difference btw. near and far



- Peak energy shift → serious syst.
- dependence of high energy side on FD size → Handle to estimate correction
- Low energy side does not depend on FD size

Far/near ratio(finite decay pipe length)

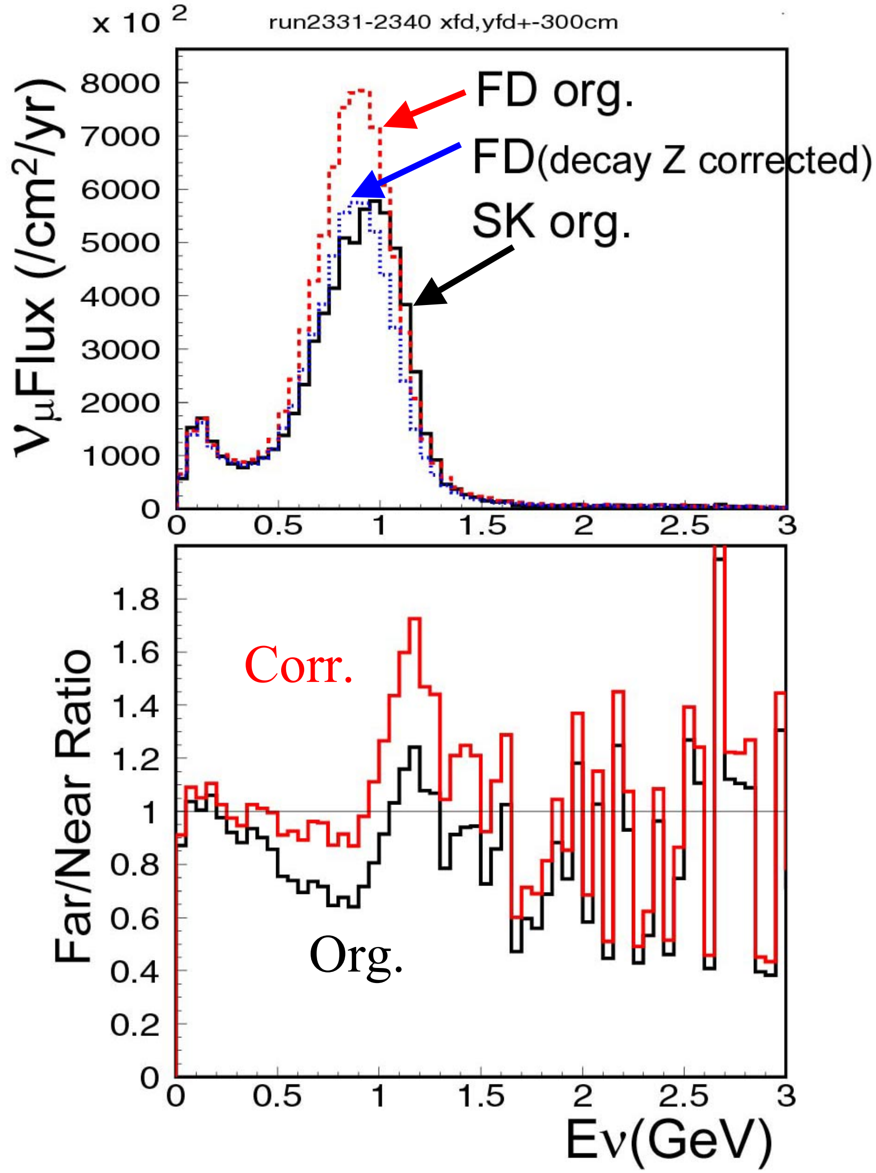
Decay vertex (z) dist. of parent pions



More downstream pion contribute to FD (solid ang)

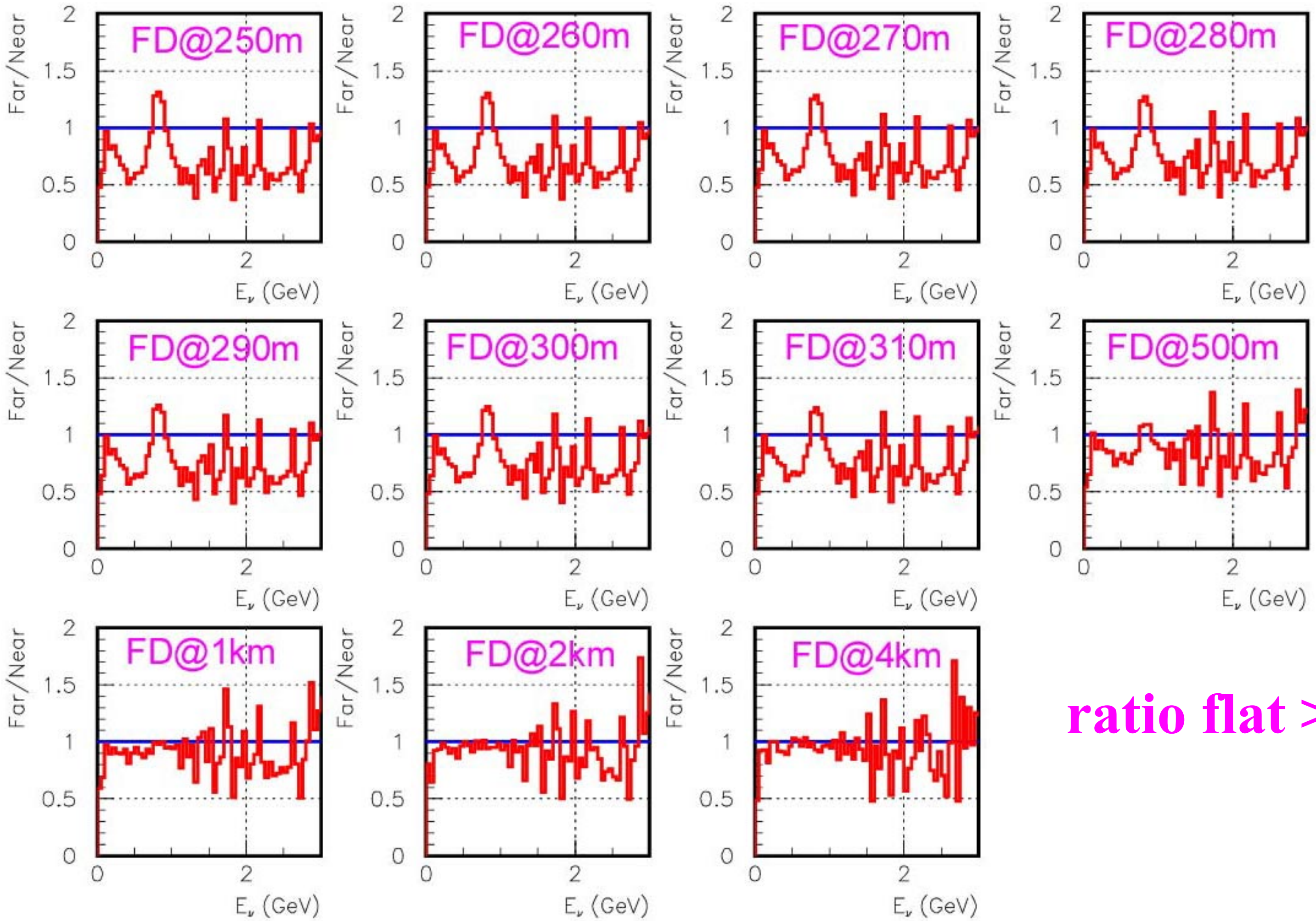
The effect of finite decay pipe length observed in wide *E_ν* range >300MeV

Change decay pipe length???
Observe ν at large angle???



Far/near ratio @ various Z

oa2deg FD+-3m

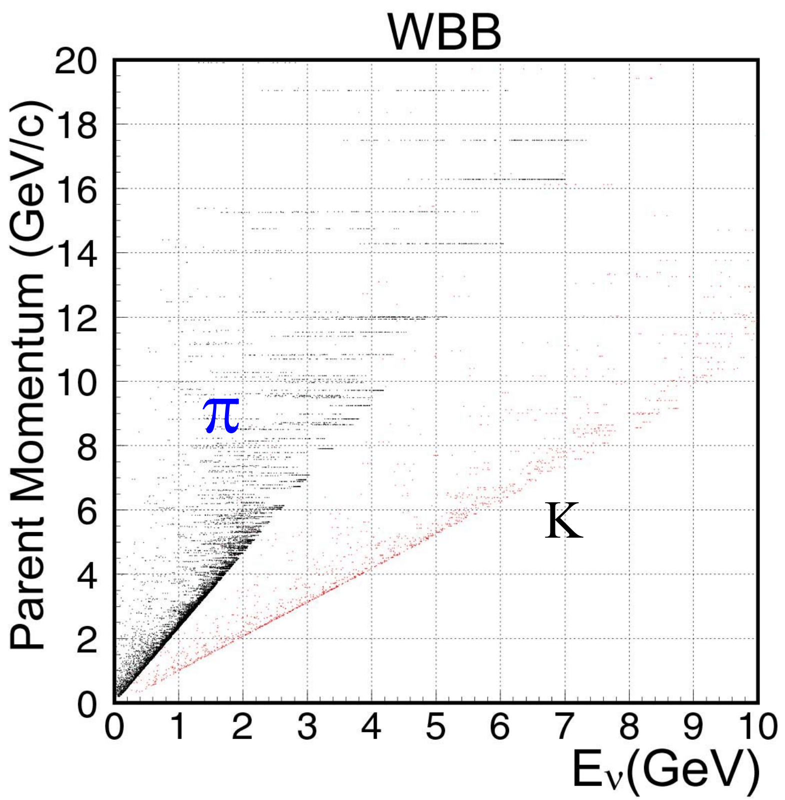


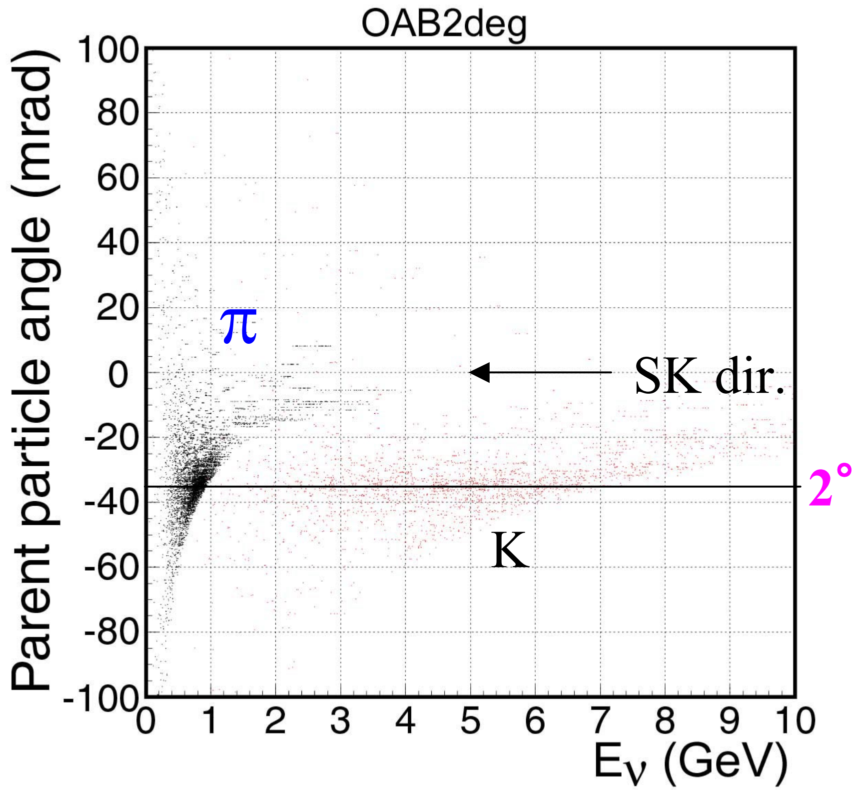
ratio flat >~1km

Det@~km "Ultimate" Solution!

Kajita-san's talk for more detail

High Energy Tail

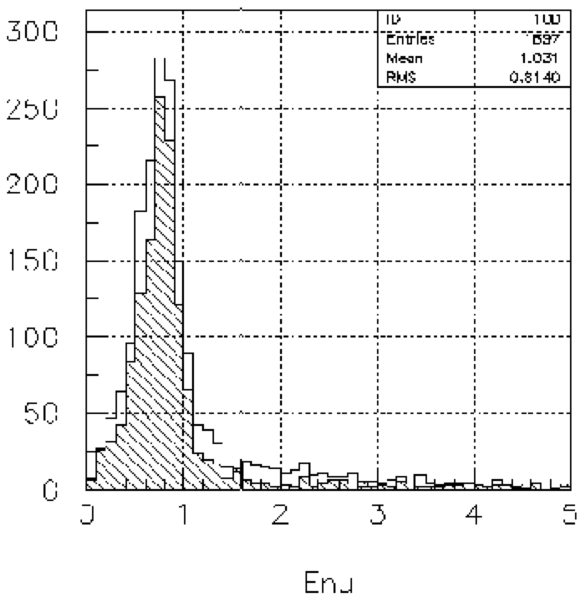


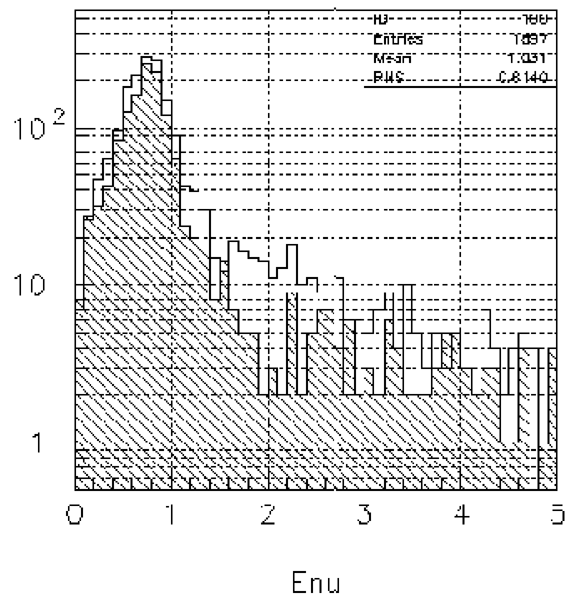


High energy π for WBB
Small angle π for OAB
contribute HE tail.

Beam plug/decay pipe shape optimization might further reduce HE tail.

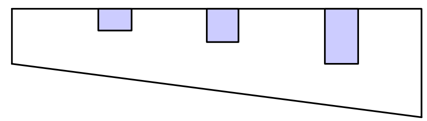
OAB2 w/ narrow decay volume





as one trial how to reduce HE tail

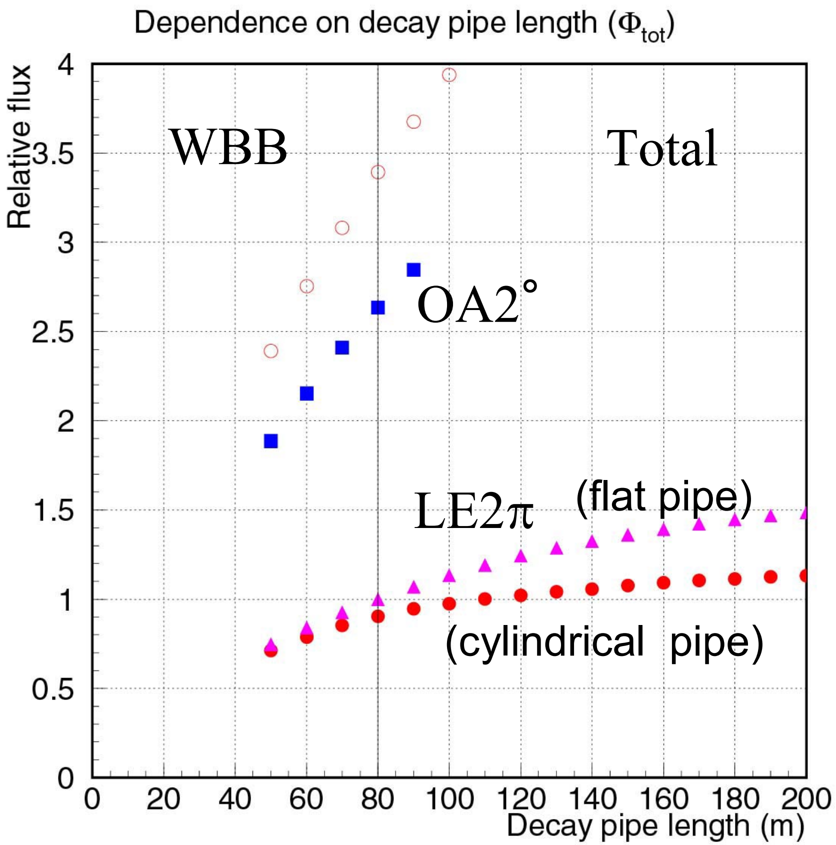
(Ichikawa-san's study)

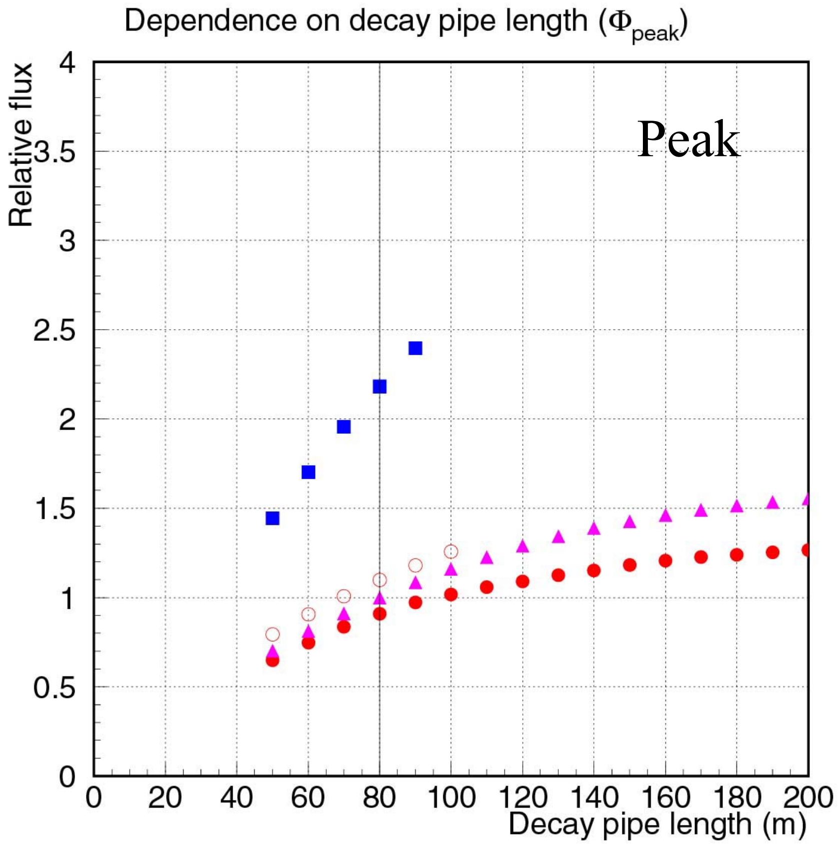


	0.4<En<1.1	En>1.2	N/S
Wide decay volume	1284	427 (K:48%)	33%
Narrow dv	1049 (82%)	218	21% (-36%)

We need optimization taking cost, tunability into account

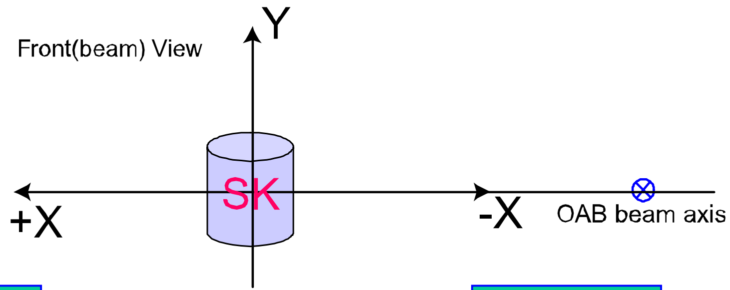
Flux dependence on decay pipe length

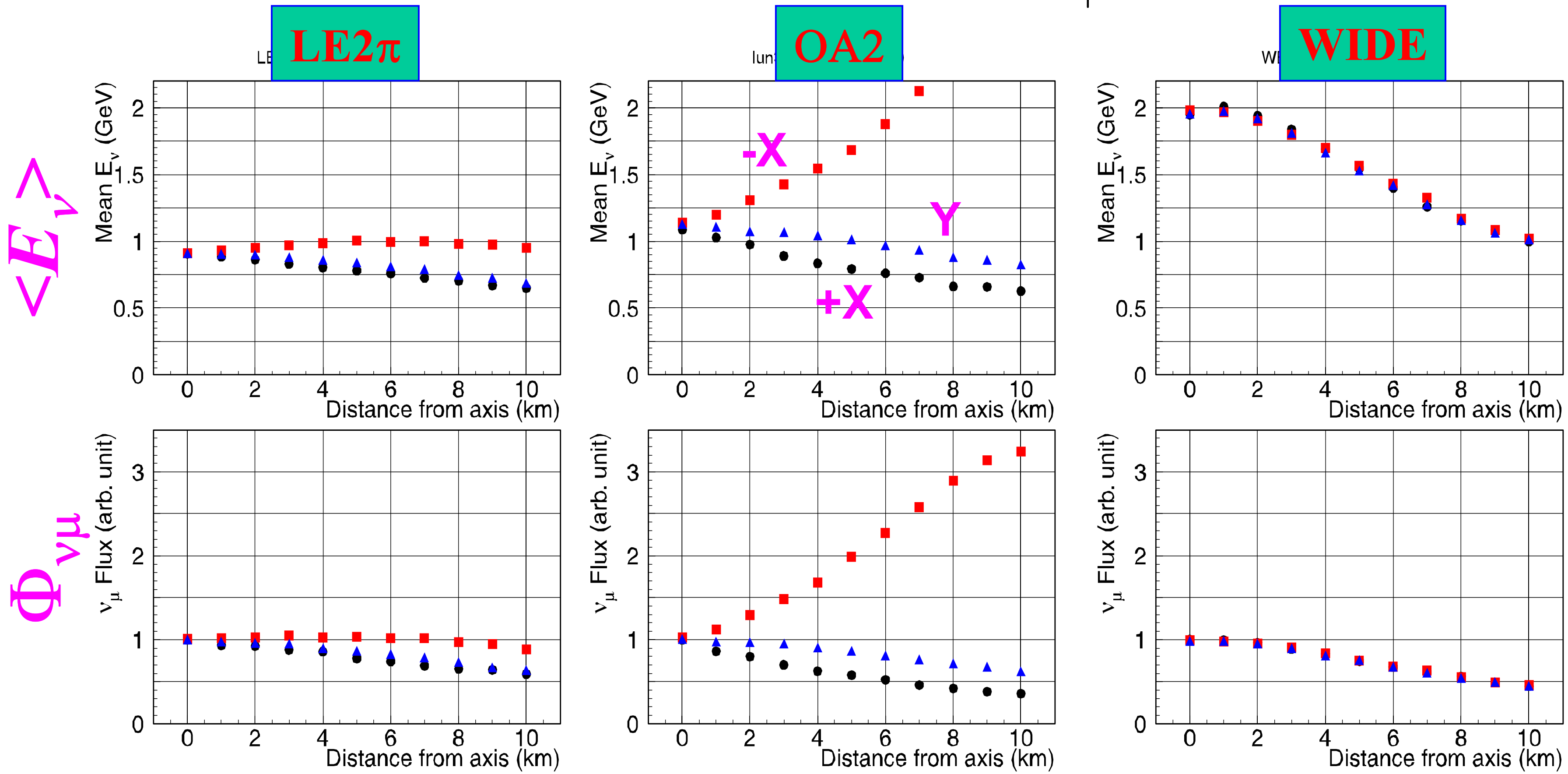




For LE NBB, WBB, flux is almost saturating at 80m
OAB is still rapidly increasing.

Beam Profile at SK





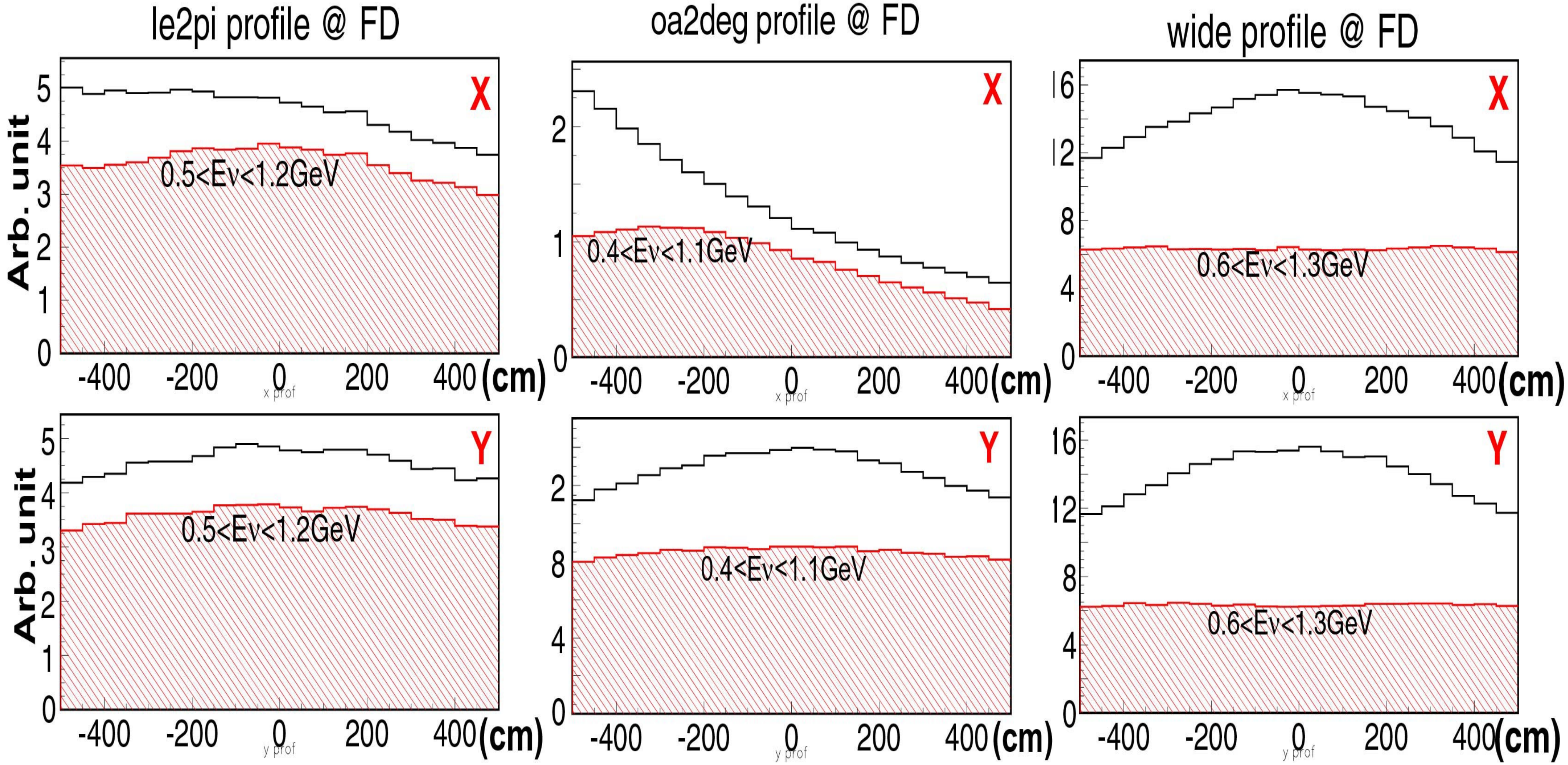
NBB/WBB mild behavior

OAB: $\langle E_\nu \rangle$ ~25MeV/mrad→δ(Δm^2)**~1x10^{-4}eV^2**

$\Phi_{\nu\mu}$ ~4%/mrad

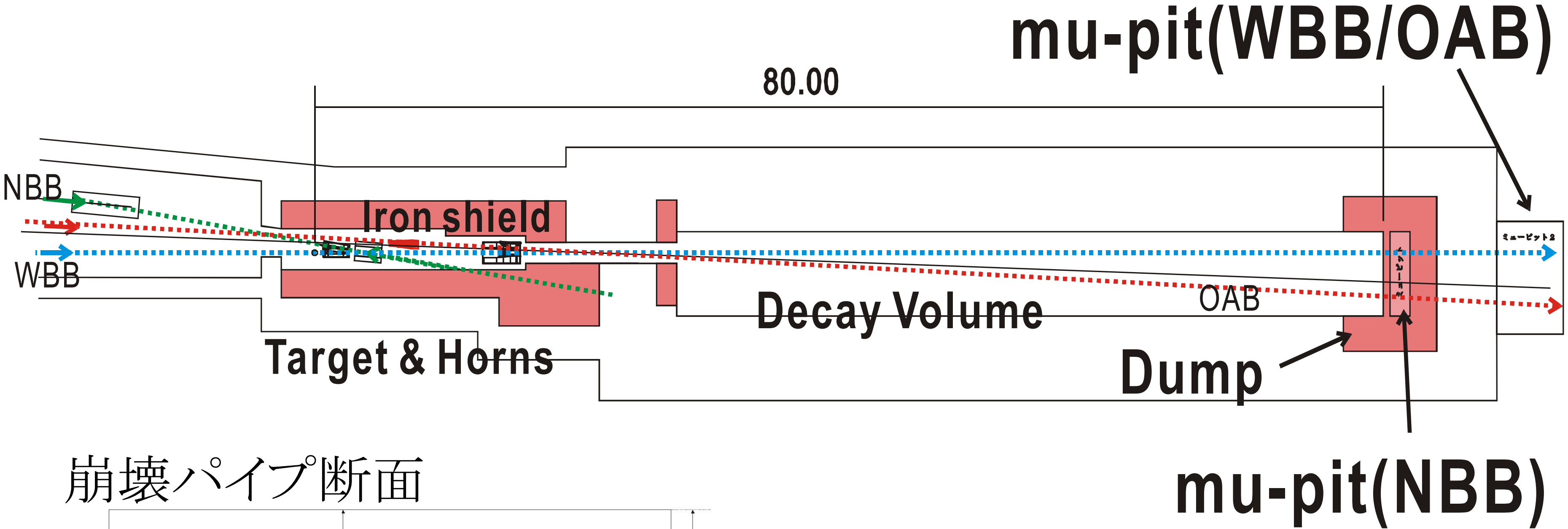
Possible syst. error!

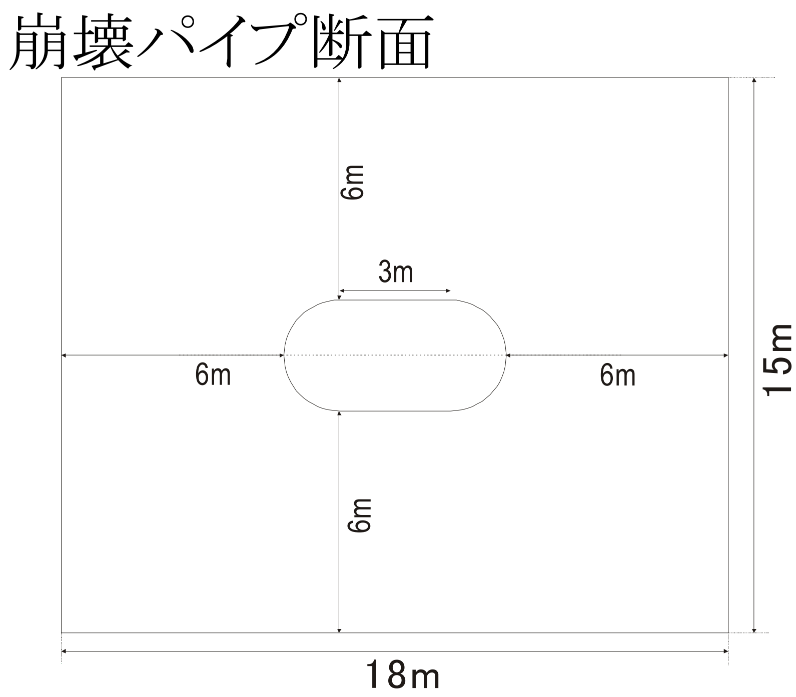
Neutrino profile @ FD



WBB/OAB direction can be monitored w/ same manner as K2K on beam axis
NBB asymmetric broad peak. Stab. OK. But abs. direction <-> beam cent?

Decay volume





Flat shape decay pipe accommodate

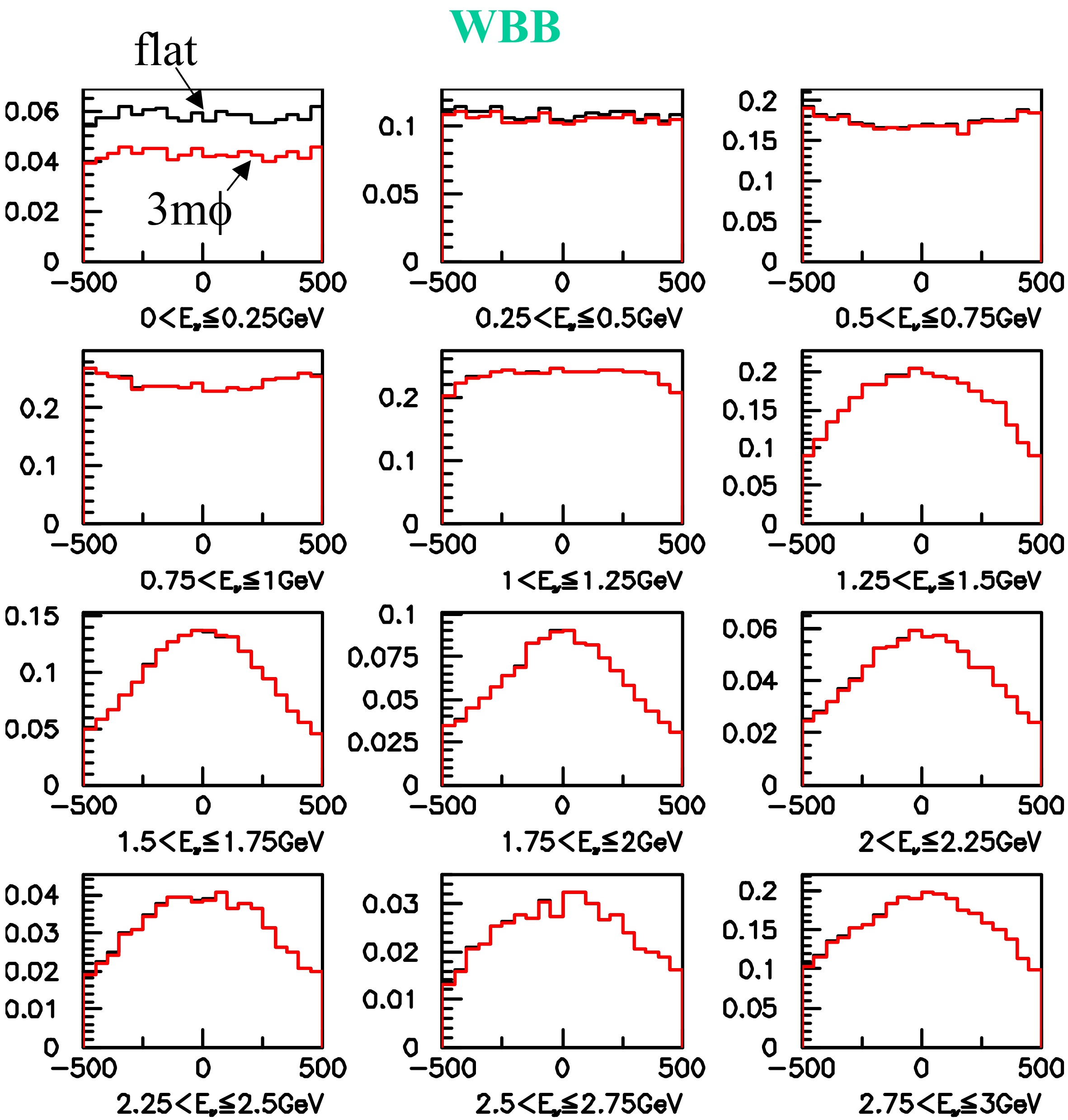
WBB

NBB

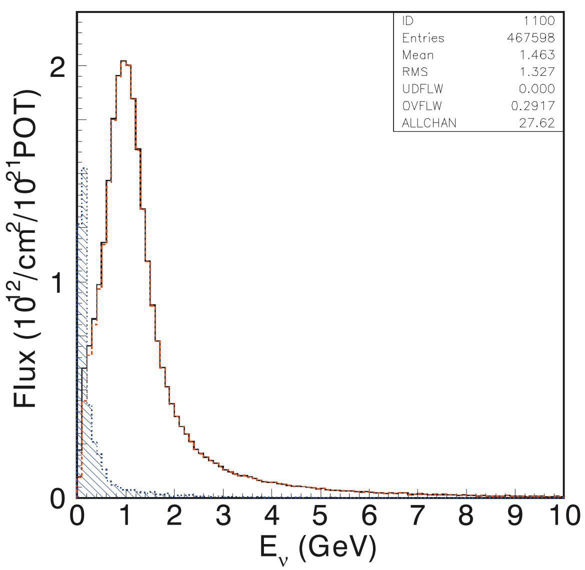
OAB upto 3°

Concrete shield of 6m thickness

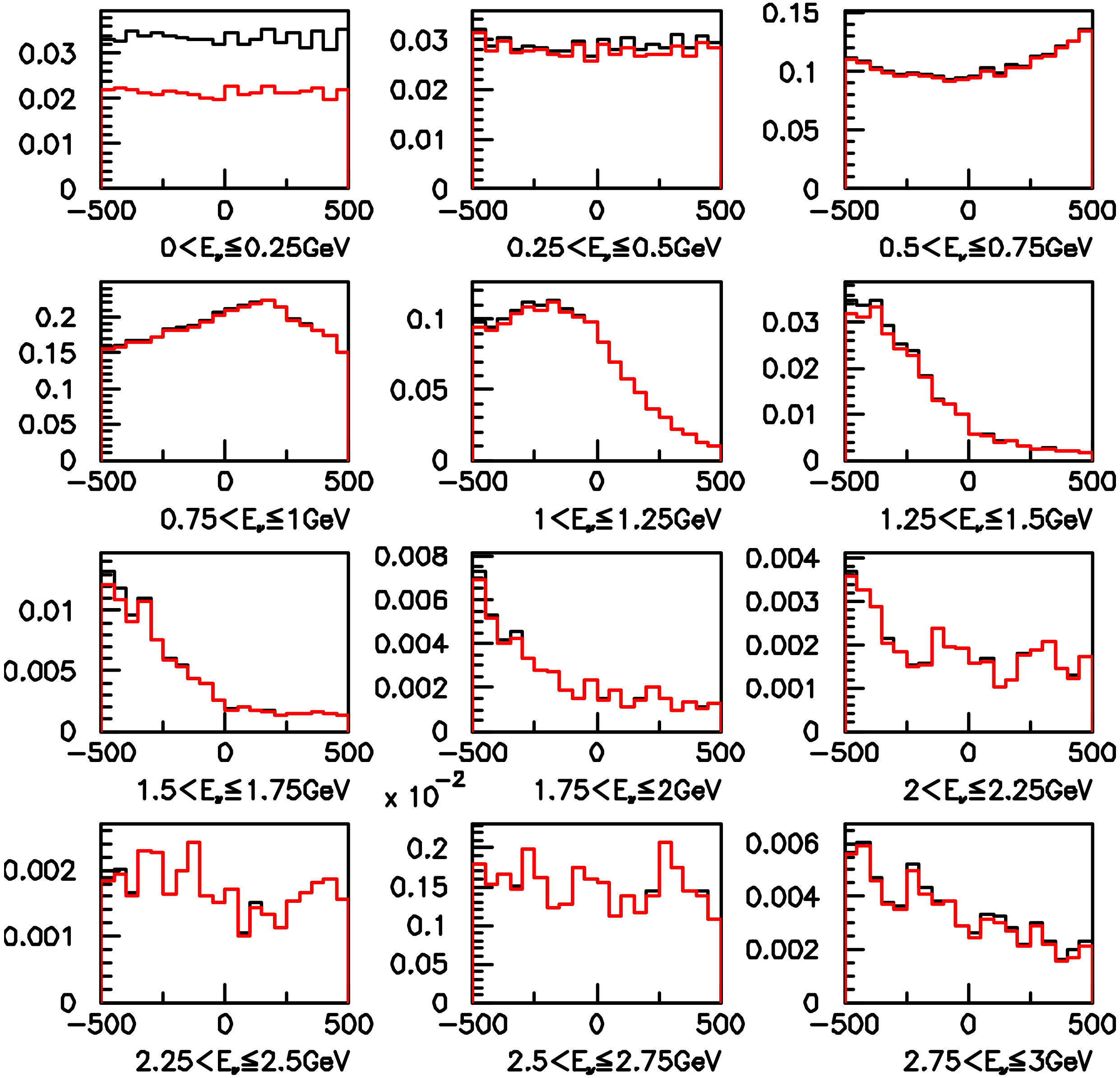
Effect of flat decay pipe (WBB/OAB)



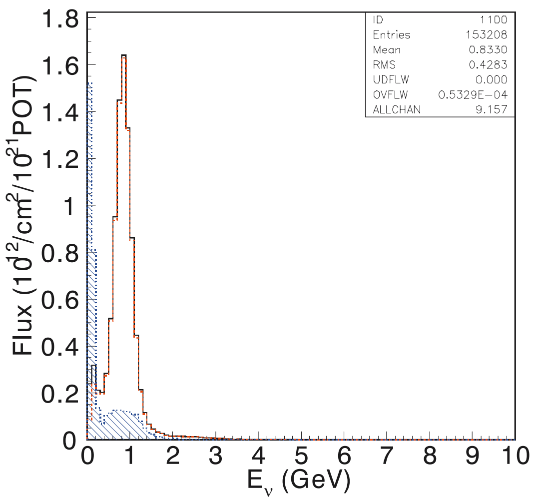
Negligible



Effect of flat decay pipe (NBB)

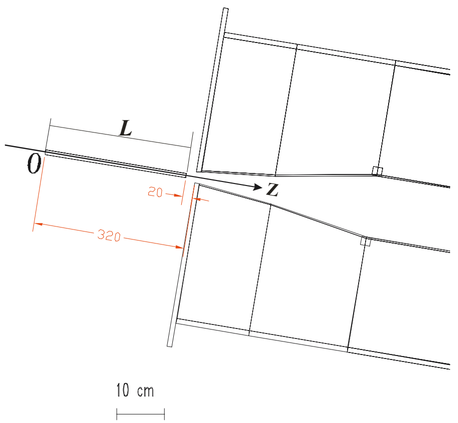


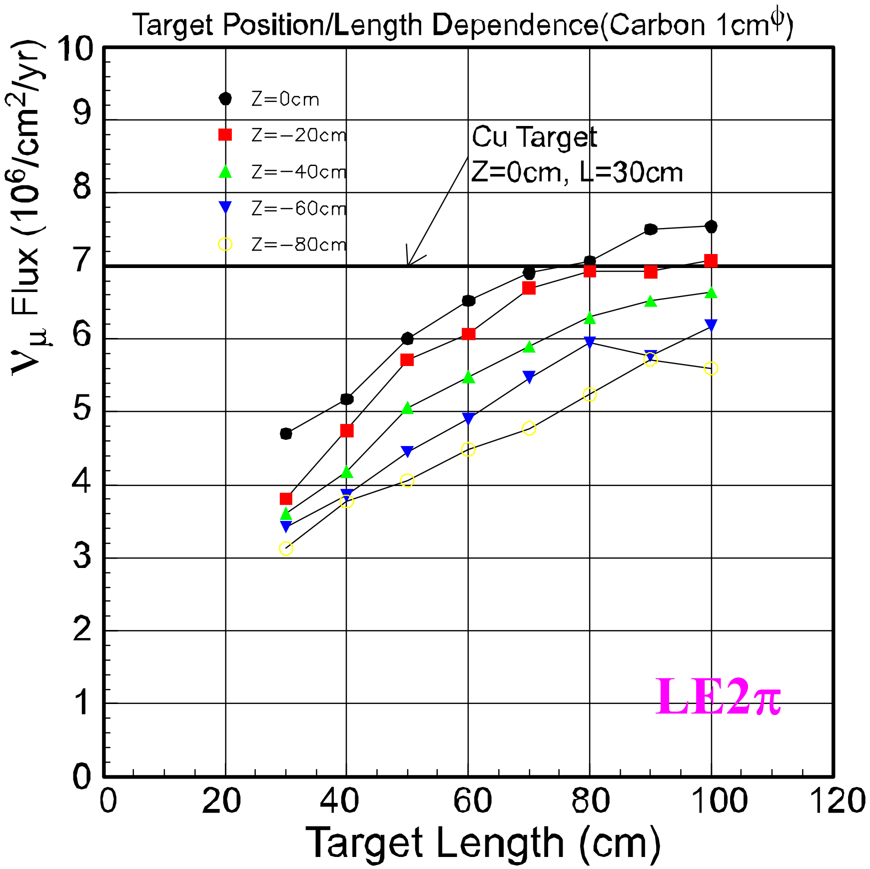
Negligible



ν_μ flux from Carbon target

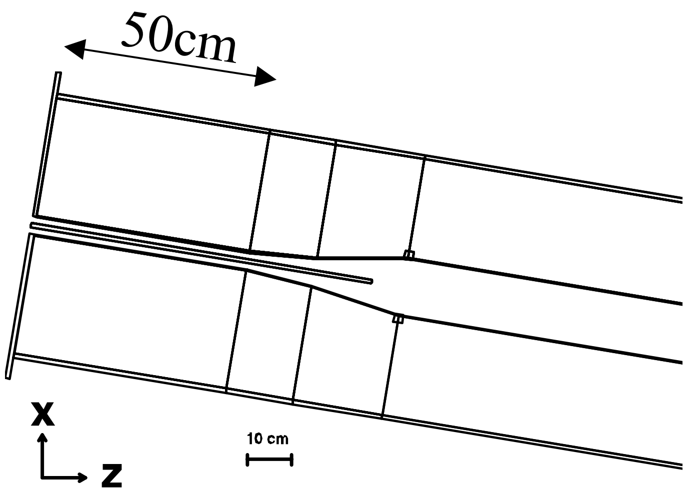
1. Energy deposit in target ~ few **100kJ/pulse** (~100GW instantaneously)
2. Cu (L_I=15cm) target may not sustain
3. Possible solution : Carbon (L_I=38cm)
4. → lower density → longer target → worse focusing effect → less flux??

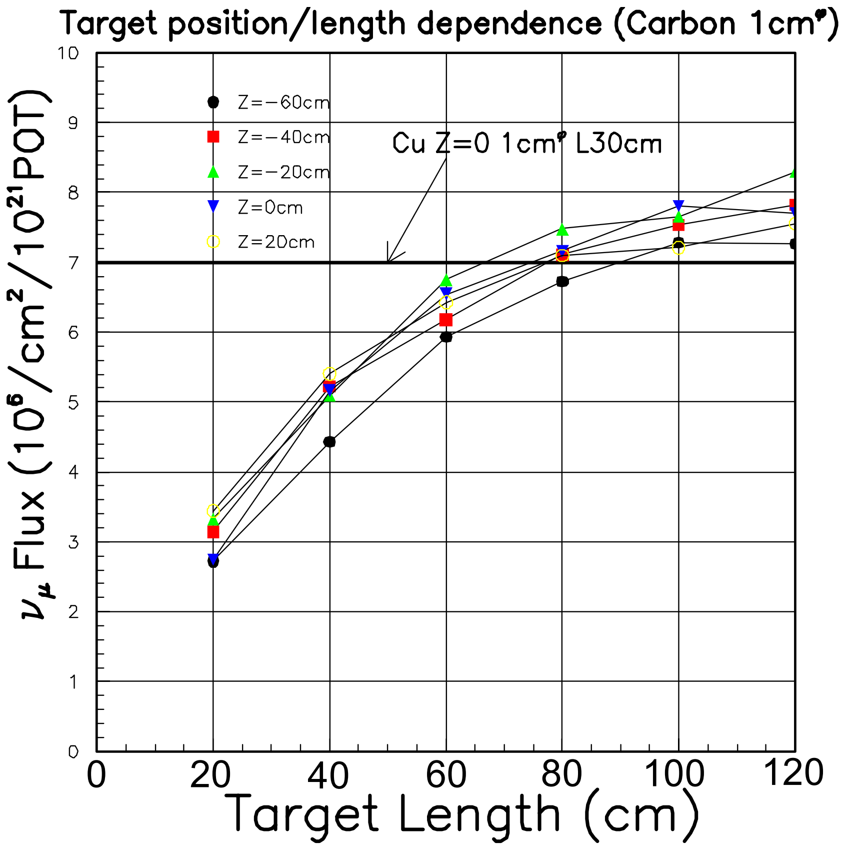




With same length in unit of L_I, Cu and C target produce almost same ν_μ flux.

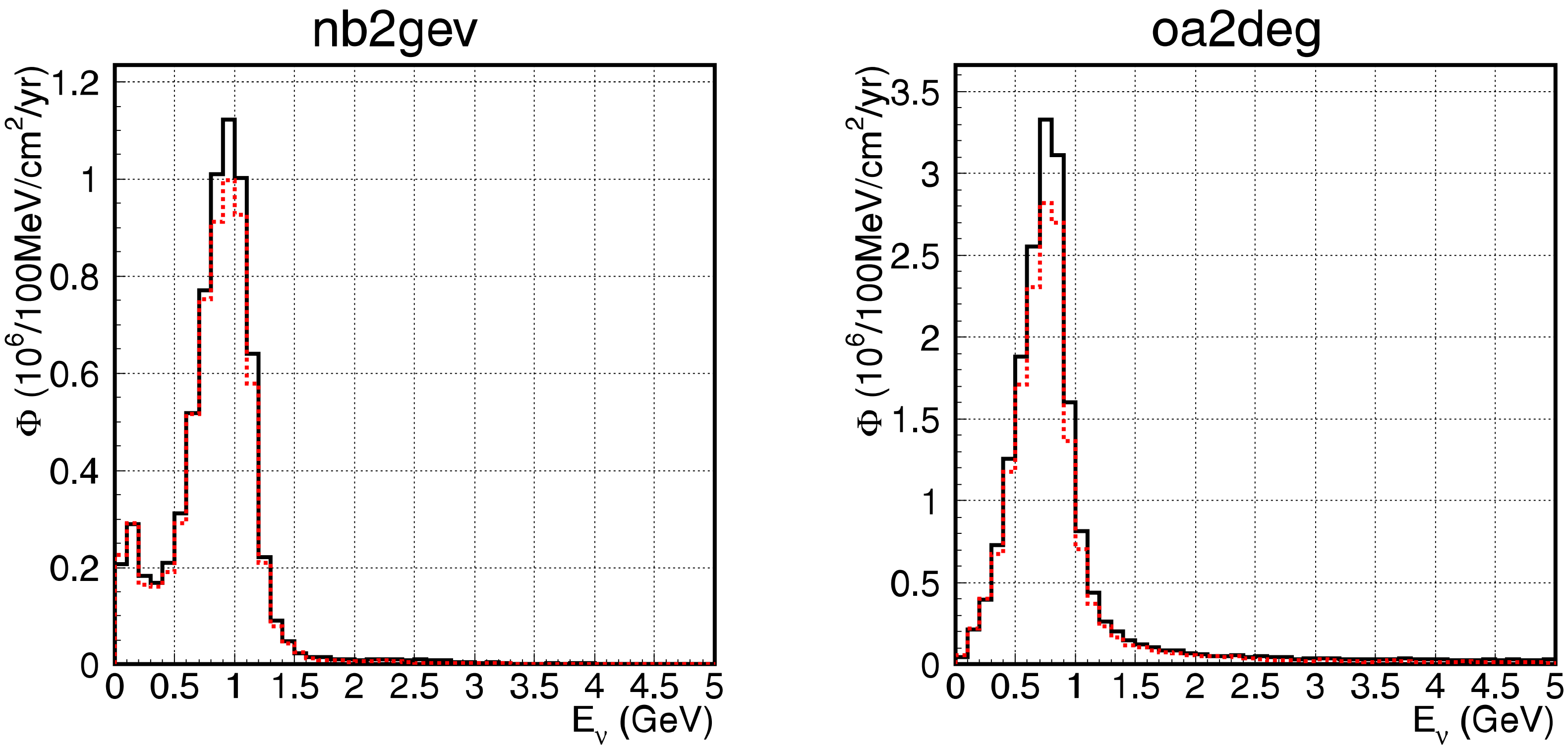
Effect of B field around target





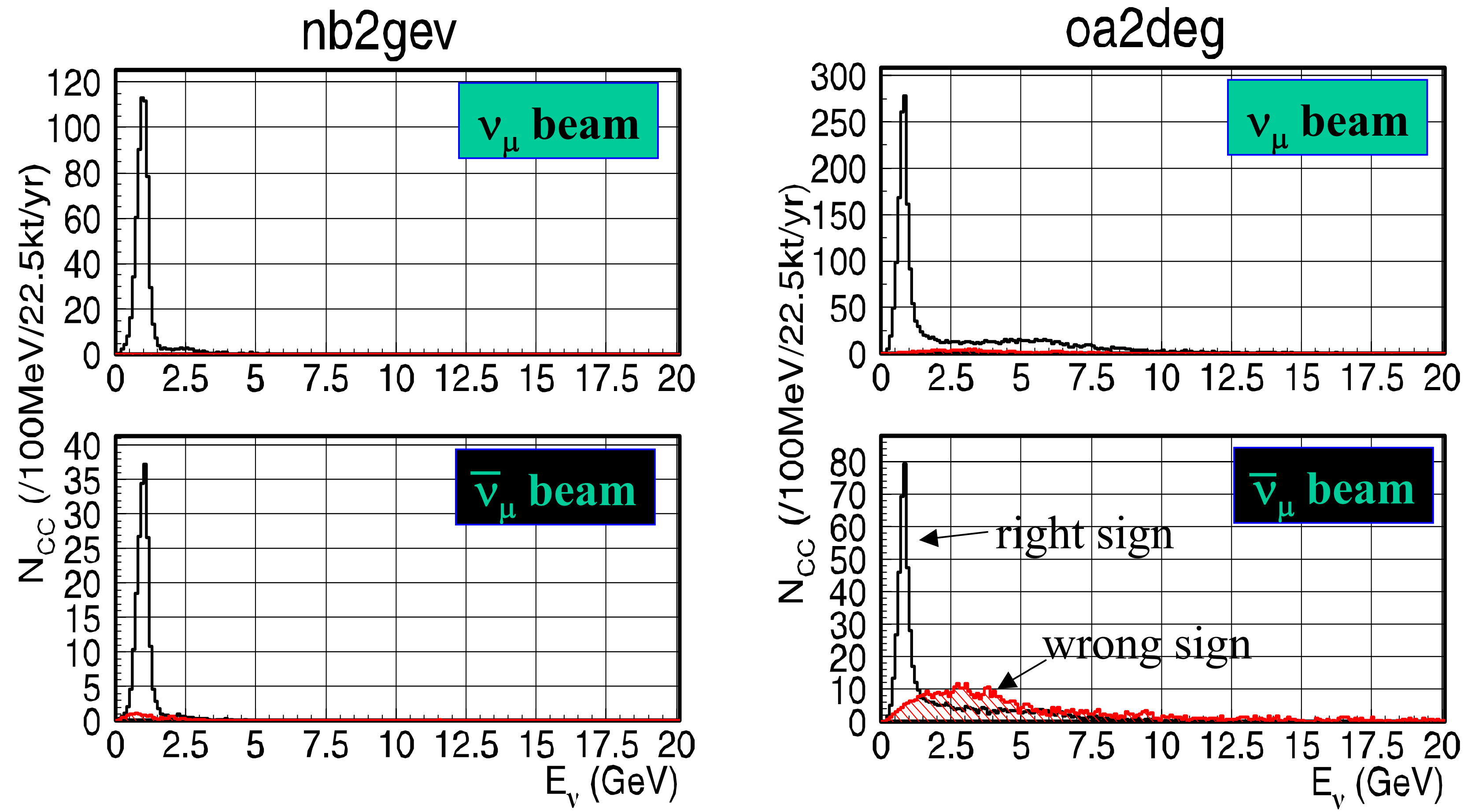
Increase in flux is not so large.

$\nu_\mu / \overline{\nu_\mu}$ flux for CPV meas.



$\overline{\nu_\mu}$ flux is almost same as ν_μ flux within ~10%

$\nu_\mu / \bar{\nu}_\mu$ # of CC int.



- # of int. for $\bar{\nu}_\mu$ is factor ~3 smaller than ν_μ due to cross section.
- Wrong sign contamination is worse for OAB.

Summary of beam @ SK

ν_μ Beam

Beam	$\langle E_\nu \rangle$	Flux (/cm^2/yr) (10^6) ν_μ	(10^4) ν_e	ν_e/ν_μ(%)	# of interactions (/22.5kt/yr) ν_μ	ν_e	$\bar{\nu}_\mu$	$\bar{\nu}_e$
WIDE	1.95	25.5	18.8	0.74(0.34)	7000(5200)	78(59)	420(300)	13((9.6)
LE1.5π	0.69	5.3	5.3	1.00(0.39)	510(360)	5.7(4.2)	5.9(4.1)	0.41(0.29)
LE1.8π	0.79	6.5	4.6	0.71(0.19)	740(530)	5.7(4.2)	6.3(4.4)	0.33(0.23)
LE2π	0.86	7.0	5.1	0.73(0.15)	870(620)	6.8(5.0)	6.1(4.3)	0.41(0.29)
LE3π	1.19	8.0	5.2	0.65(0.16)	1400(1000)	9.3(6.9)	6.4(4.5)	0.48(0.34)
OA1°	1.75	37.7	27.5	0.73(0.20)	9400(6900)	120(88)	370(270)	16(12)
OA2°	1.13	19.2	19.2	1.00(0.21)	3100(2200)	60(45)	250(180)	11(7.6)
OA3°	0.77	10.6	12.8	1.21(0.20)	1100(800)	29(22)	96(69)	5.2(3.7)

(@peak) total(CC)

$\bar{\nu}_\mu$ Beam

Beam	$\langle E_{\bar{\nu}} \rangle$	Flux $\bar{\nu}_\mu$	$\bar{\nu}_e$	$\bar{\nu}_e/\bar{\nu}_\mu$	# of interactions ν_μ	ν_e	$\bar{\nu}_\mu$	$\bar{\nu}_e$
WIDE	1.63	21.6	14.3	0.66(0.21)	1700(1300)	42(32)	2300(1600)	22((16)
LE1.5π	0.66	5.0	3.7	0.74(0.27)	24(17)	1.4(1.0)	160(110)	1.4(0.98)
LE2π	0.83	6.5	4.4	0.68(0.24)	24(17)	1.4(1.0)	280(200)	1.9(1.4)
OA2°	0.96	16.4	14.5	0.88(0.19)	780(590)	28(21)	870(610)	19(14)
OA3°	0.67	9.3	8.8	0.94(0.14)	340(250)	15(11)	310(220)	9.2(6.6)

R&D/Optimization Items

- Primary optics
- Super conduction magnets
- Production target
- Horn & decay pipe design
- Beam monitors
  - intensity/profile of primary proton beam
  - intensity/profile of secondary pion/muon
- Beam dump (& beam window)
- Shielding design
- Method of maintenance/changing focusing optics

More and more and more ………..

Summary

- Far/near ratio
  - One of most important systematics
  - R dep. gives handle to estimate part of it
  - Need idea to estimate finite pipe length effect→~km det best
- Profile @ SK:

  controllability of beam direction <1mrad required for OAB to reach 10-4eV2 precision
- Flat decay pipe has no significant defect
- Reasonable flux can be obtained w/ long Carbon target of $\sim 2L_I$
- Many (challenging) R&D items