JHF-SK ν WS
@Epochal, Tsukuba
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Neutrino Beam @ JHF

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Contents

Requirements on Neutrino Beam

1. As intense as possible

No need to explain

2. Low Energy

Tune peak energy at oscillation maximum

Super-Kamiokande Atm. ν obs. → Δm_{23}^2=1.6~4x10^{-3}eV^2

→ **E_ν=0.4~1GeV**

3. Narrow Spectrum

Neutrino Energy Reconstruction using Quasi elastic interaction

Non oscillating HE tail makes background

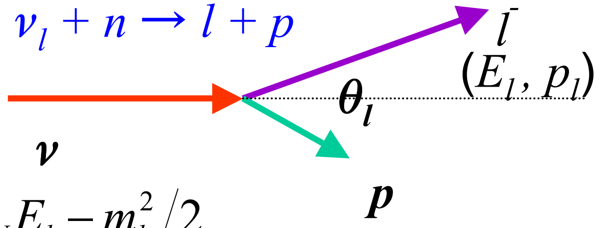
4. Small ν_e contamination

5. Controllability (systematics)

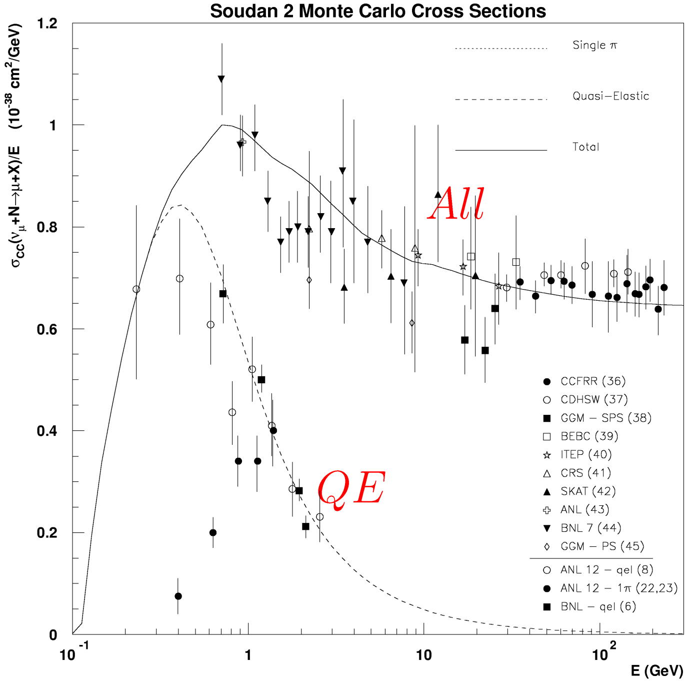
Neutrino Energy Reconstruction

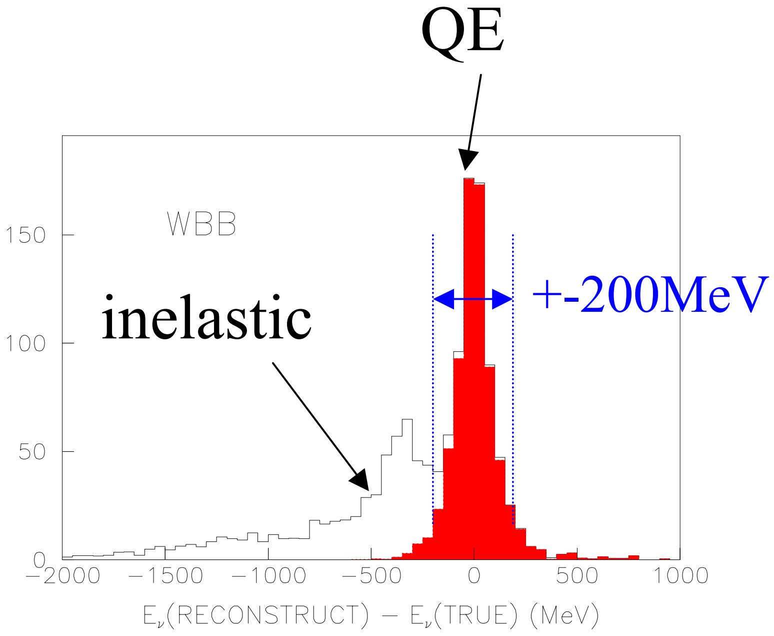
Assume CC quasi elastic (CCQE) reaction

$\nu_l + n \rightarrow l + p$



$$E_\nu = \frac{m_N E_l - m_l^2/2}{m_N - E_l + p_l \cos\theta_l}$$

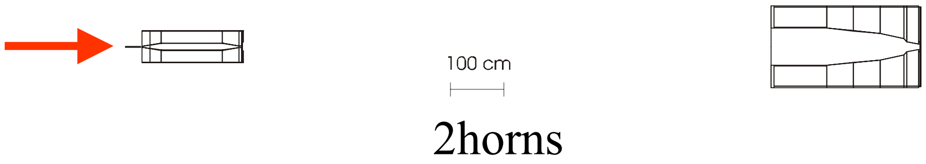




QE dominate at ～

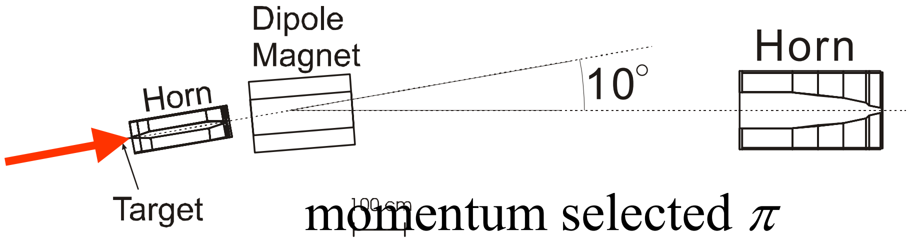
Three Beams

Wide Band Beam



- Intense
- Wide sensitivity in Δm^2
- BG from HE tail
- Syst. err from spectrum extrapolation

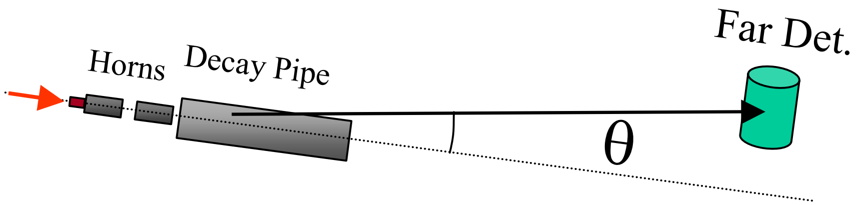
Narrow Band Beam



momentum selected π

- Less HE tail
- Less sys err from spectrum
  "counting experiment"
- Easy to tune E_ν

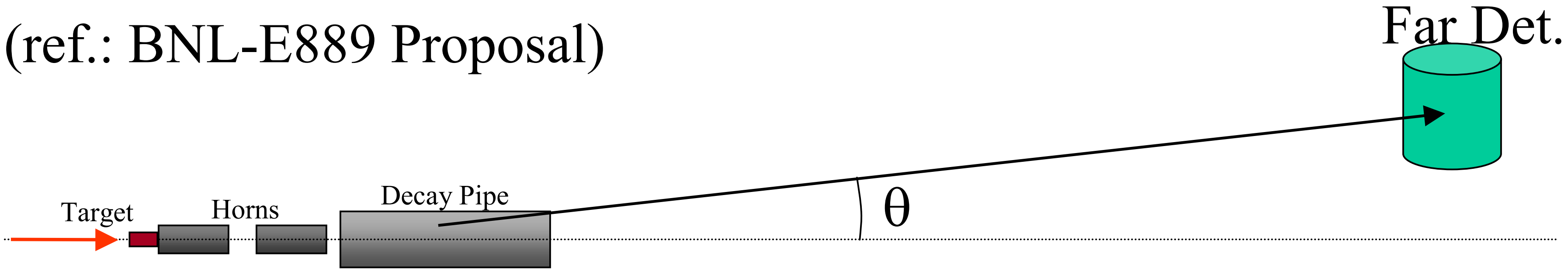
Off Axis Beam



- High int. narrow band beam
- More HE tail than NBB
- Hard to tune E_ν

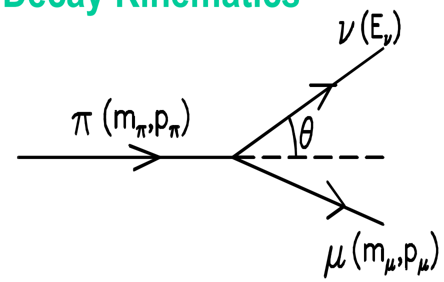
Off Axis Beam (another NBB option)

(ref.: BNL-E889 Proposal)

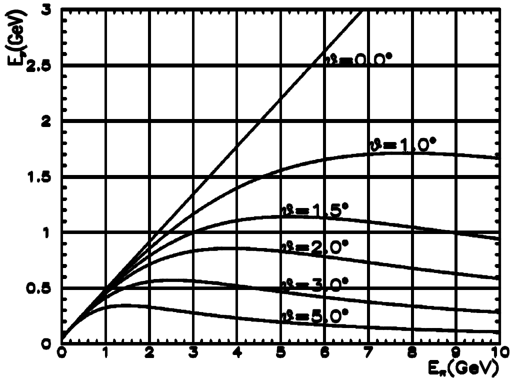


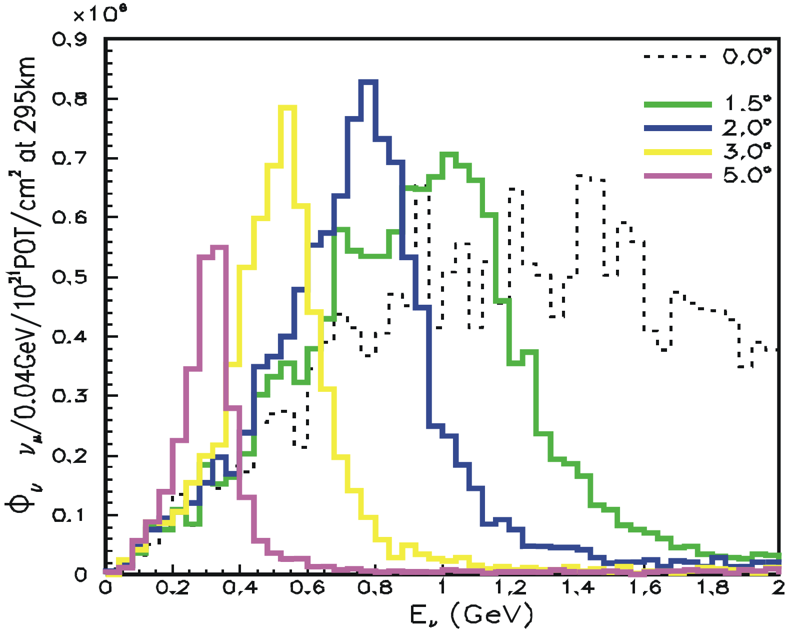
WBB w/ intentionally misaligned beam line from det. axis

Decay Kinematics



$$E_\nu = \frac{m_\pi^2 - m_\mu^2}{2(E_\pi - p_\pi \cos\theta)}$$

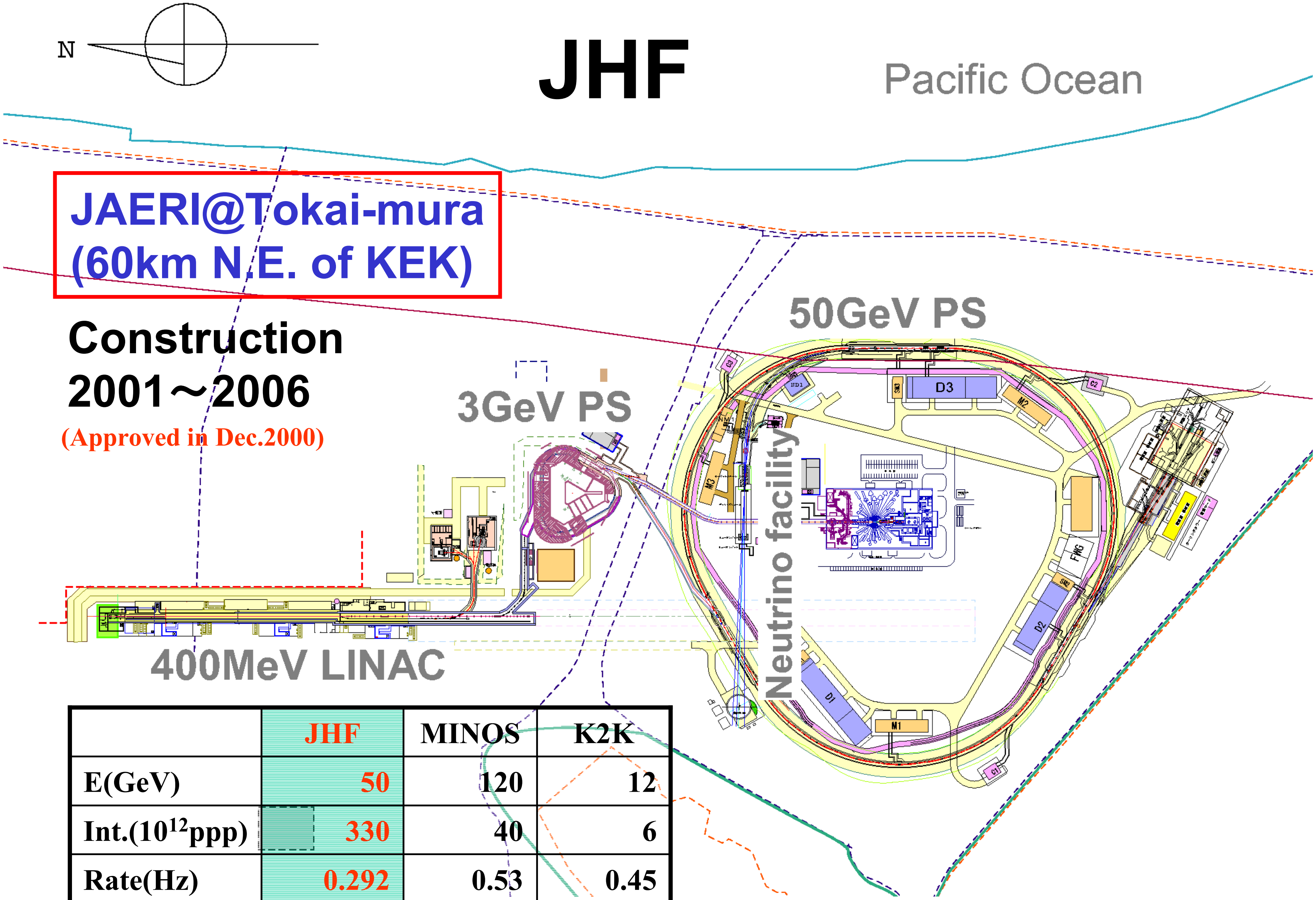




Quasi Monochromatic Beam

Neutrino Facility

JHF



JAERI@Tokai-mura
(60km N.E. of KEK)

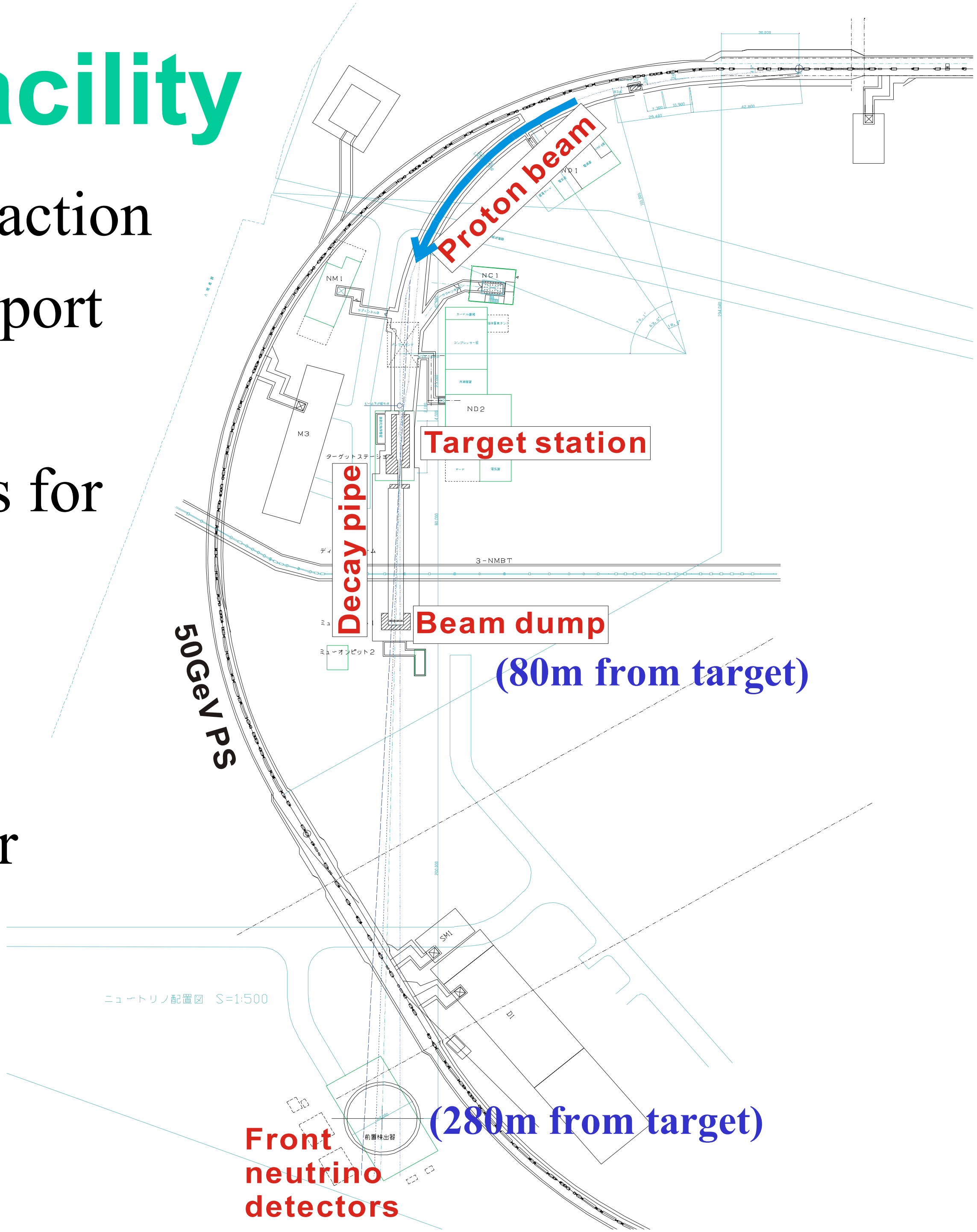
Construction
2001～2006

(Approved in Dec.2000)

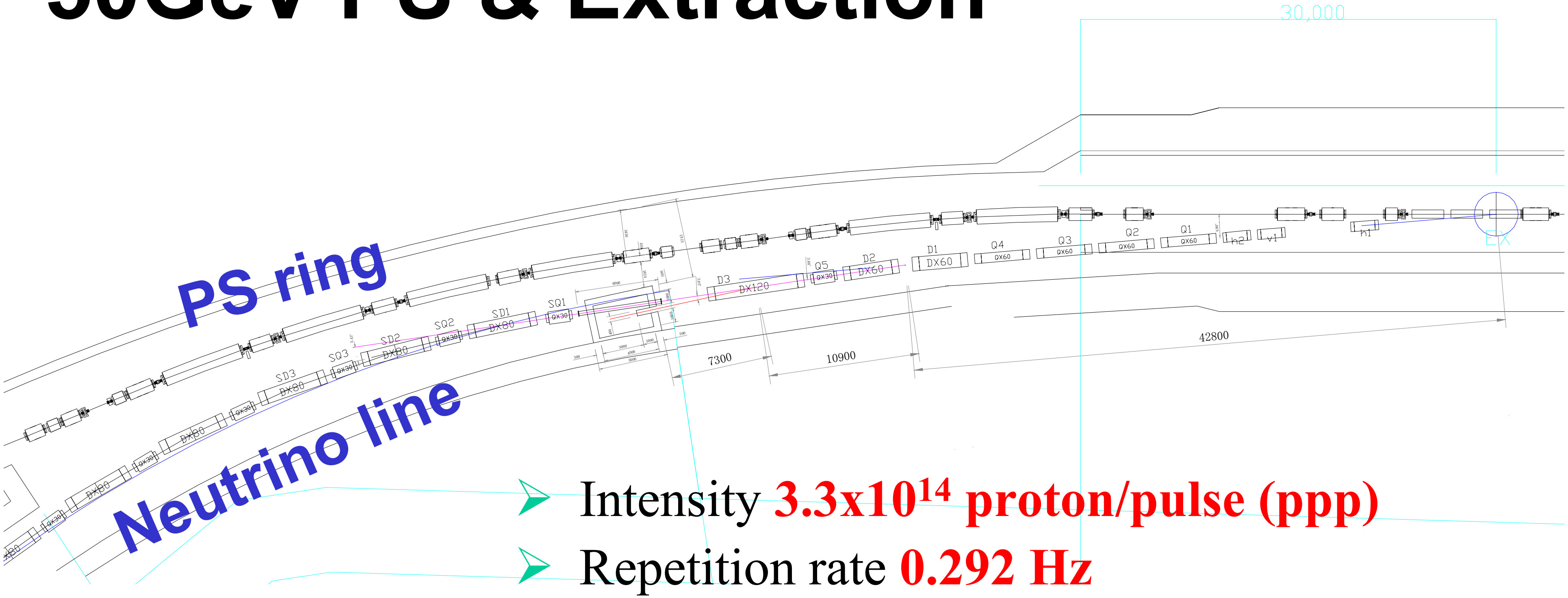
	JHF	MINOS	K2K
E(GeV)	50	120	12
Int.(10^{12}ppp)	330	40	6
Rate(Hz)	0.292	0.53	0.45
Power(MW)	0.77	0.41	0.0052

Neutrino Facility

- Protron beam extraction
- Proton beam transport
- Production target
- Focusing elements for pions
- Decay pipe
- Beam dump
- Beam monitors for $p/\pi/\mu/\nu$



50GeV PS & Extraction



- Intensity **3.3x10^{14} proton/pulse (ppp)**
- Repetition rate **0.292 Hz**
- Power **0.77 MW** (2.64 MJ/pulse)
- Single turn fast extraction (~**5.23μsec** spill)
- 8 bunches/spill (2 out of 10buckets empty)
- Kicked **4.9°** inside PS ring

Typical 1 year operation ＝10^{21} protons on target (POT)

Arc & Final focus

Bend ~85° to SK direction

50GeV, 110 m curvature

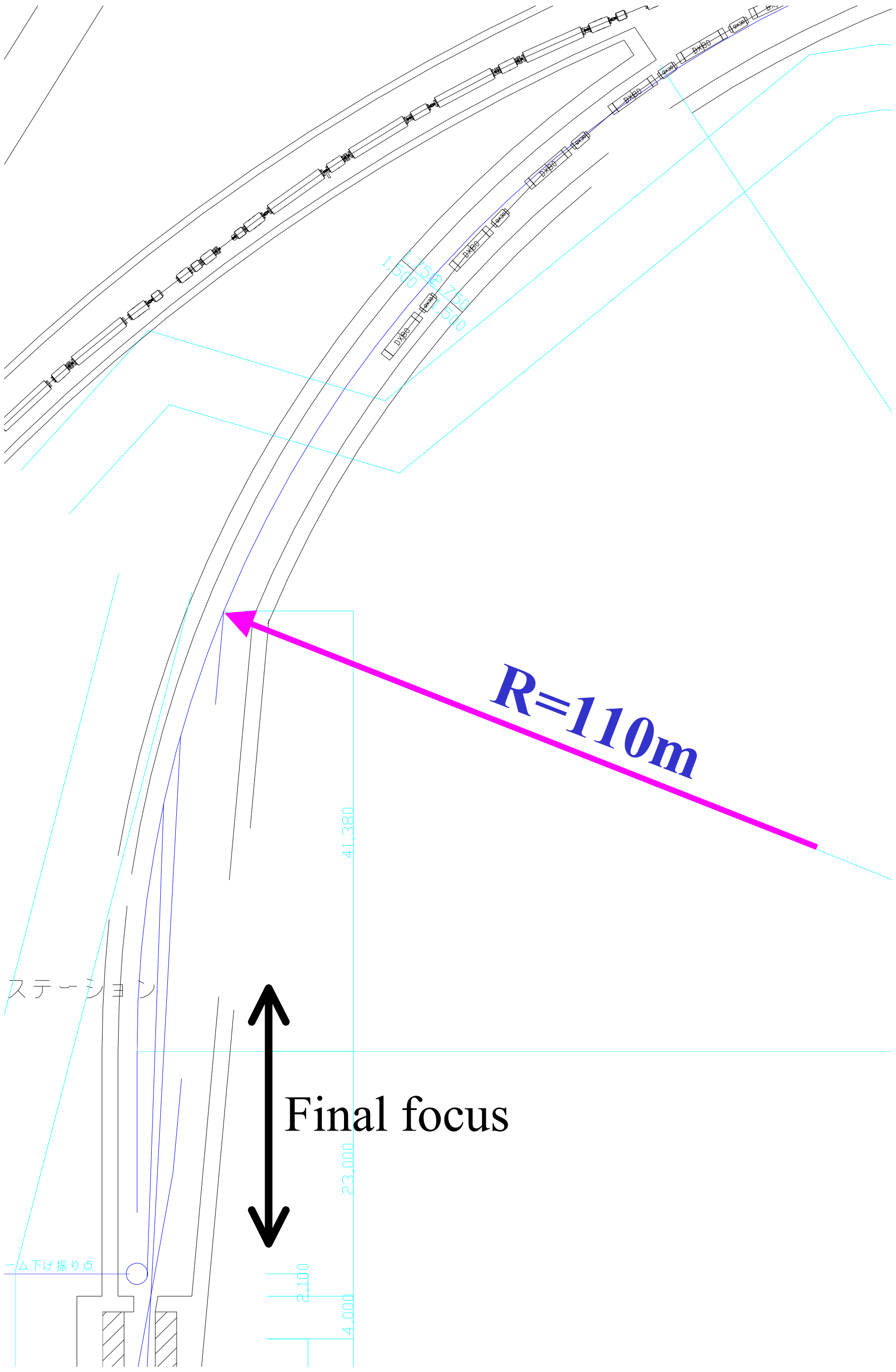
→Need super con. mag.

Typical magnet parameters

~4T, ~4m long(to be decided)

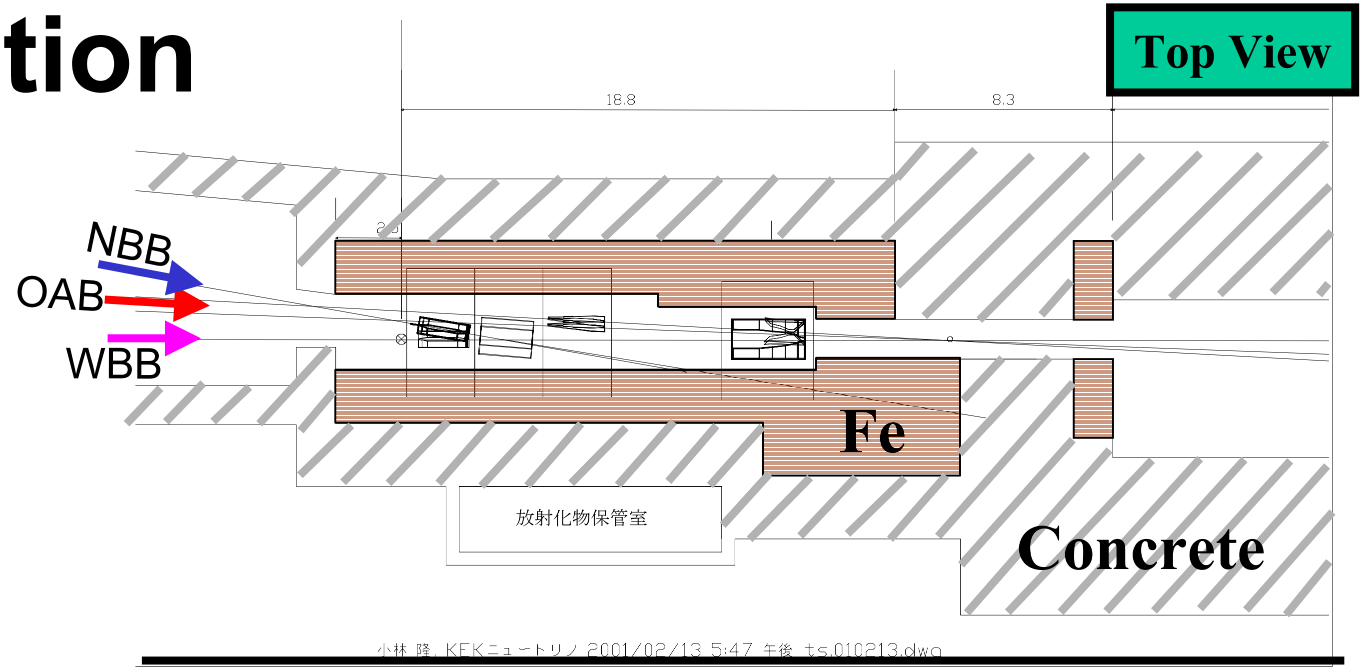
→need 15~20 dipole magnets

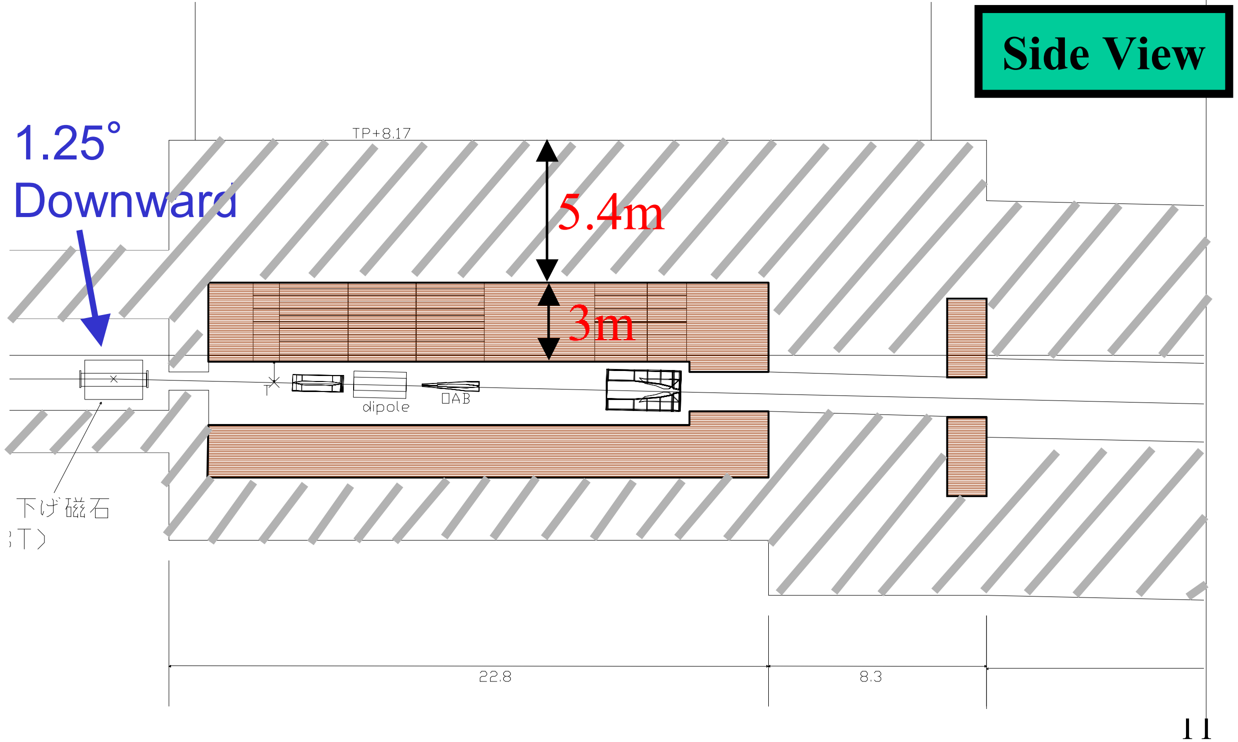
Proton directed 1.25° downward



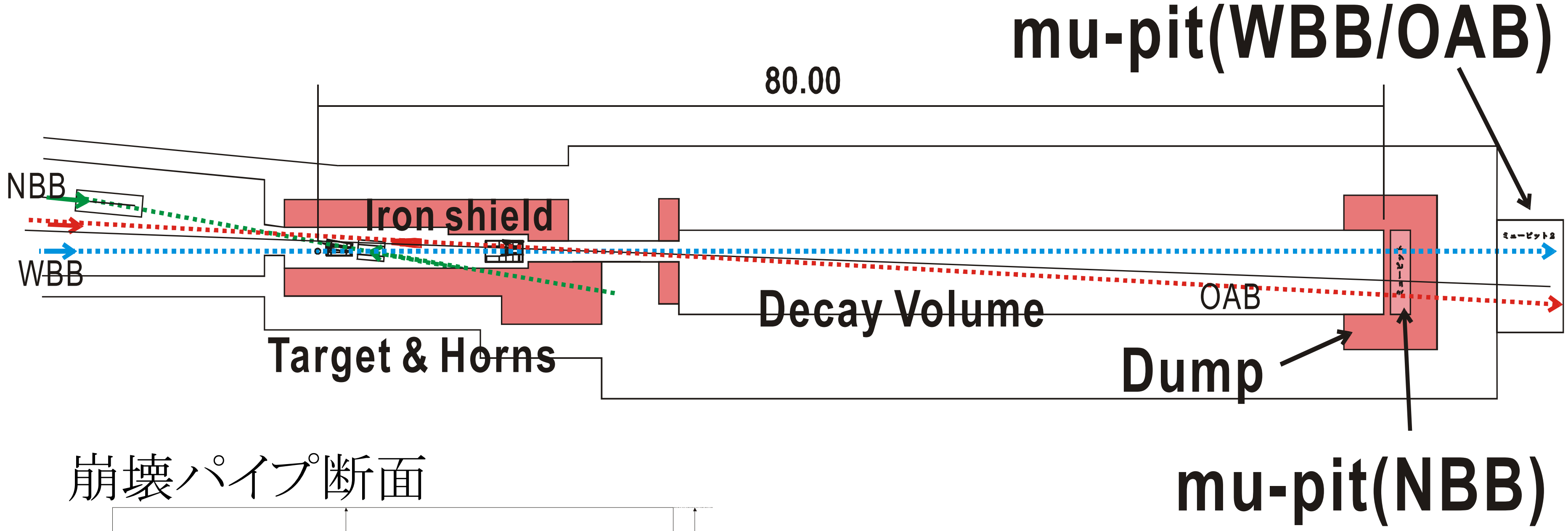
Target Station

- Accommodate 3 beam options
- No free space for maintenance
  (to reduce shield)
- Horn replacement from ceiling

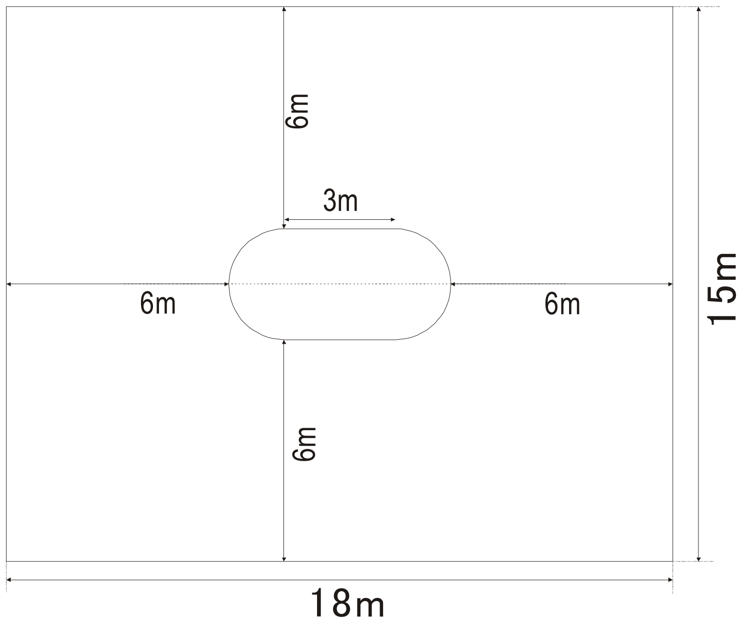




Decay volume



崩壊パイプ断面



Flat shape decay pipe accommodate

WBB

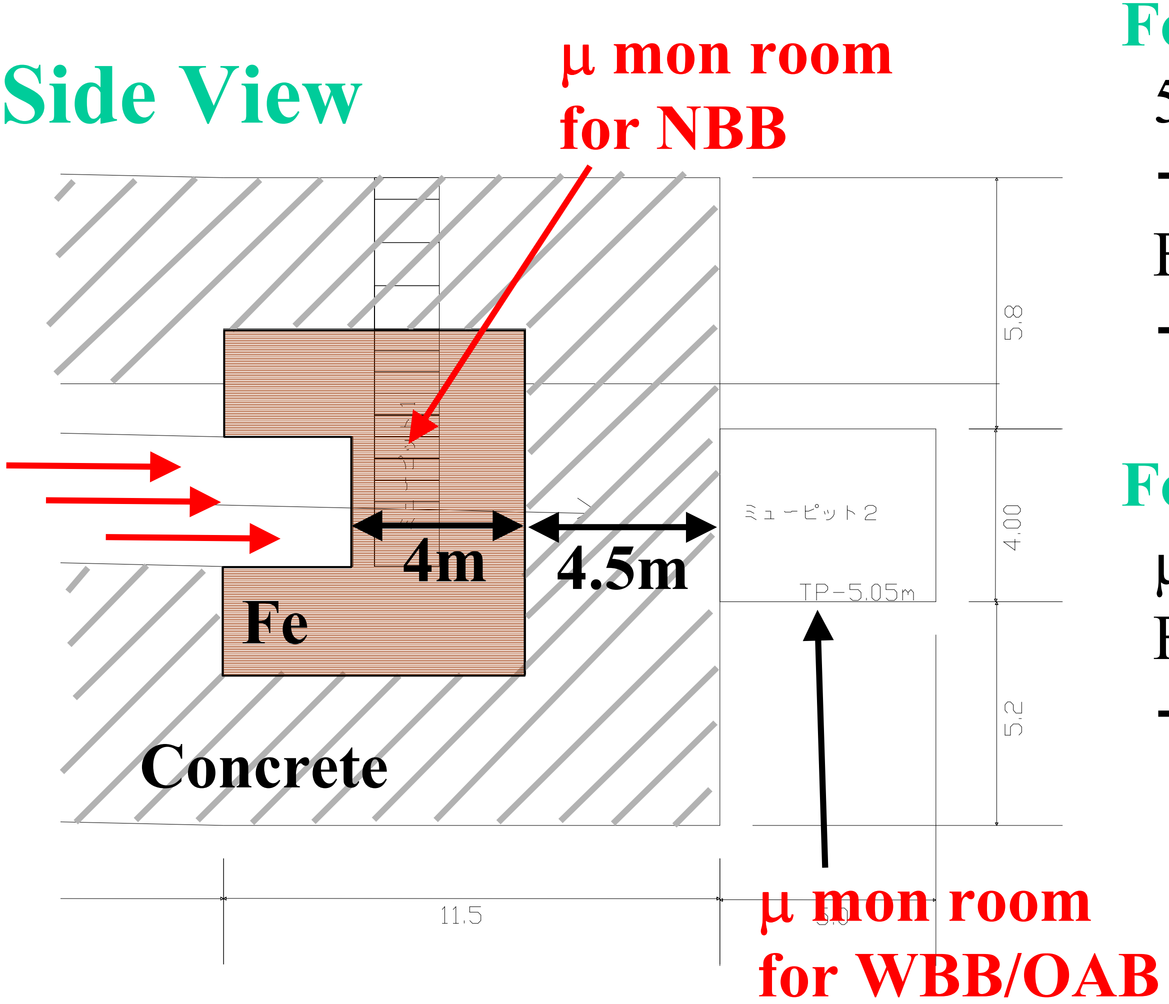
NBB

OAB upto 3°

Concrete shield of 6m thickness

Beam Dump & μ monitor room

Side View



For WBB/OAB

50GeV *p* comes

→ thick shield

Fe:4m, Conc:4.5m

→Only **μ >8.4GeV**

reach μ mon. room

For NBB

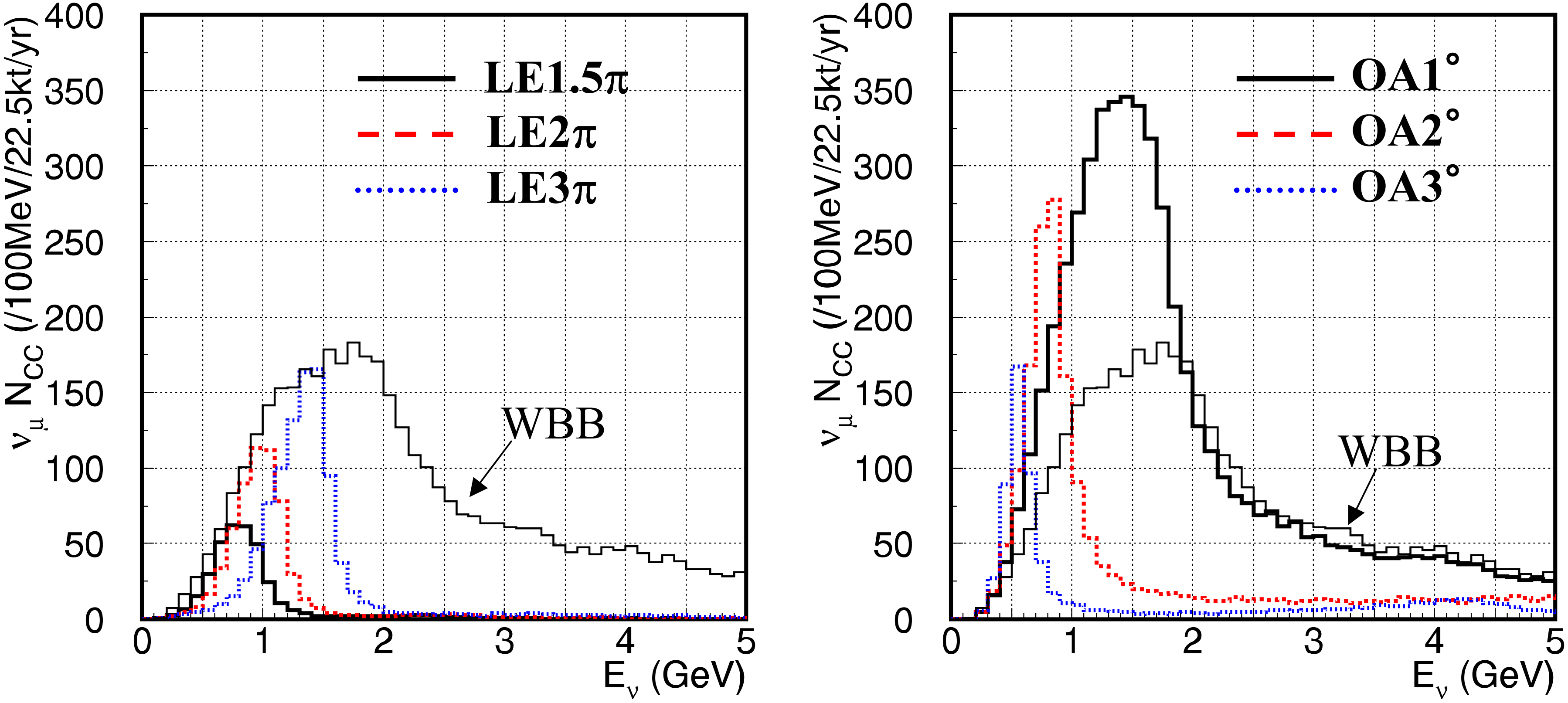
μ mon room behind 50cm

Fe shield

→ **μ >800MeV** can reach

Neutrino Beam

of CC events of various beams



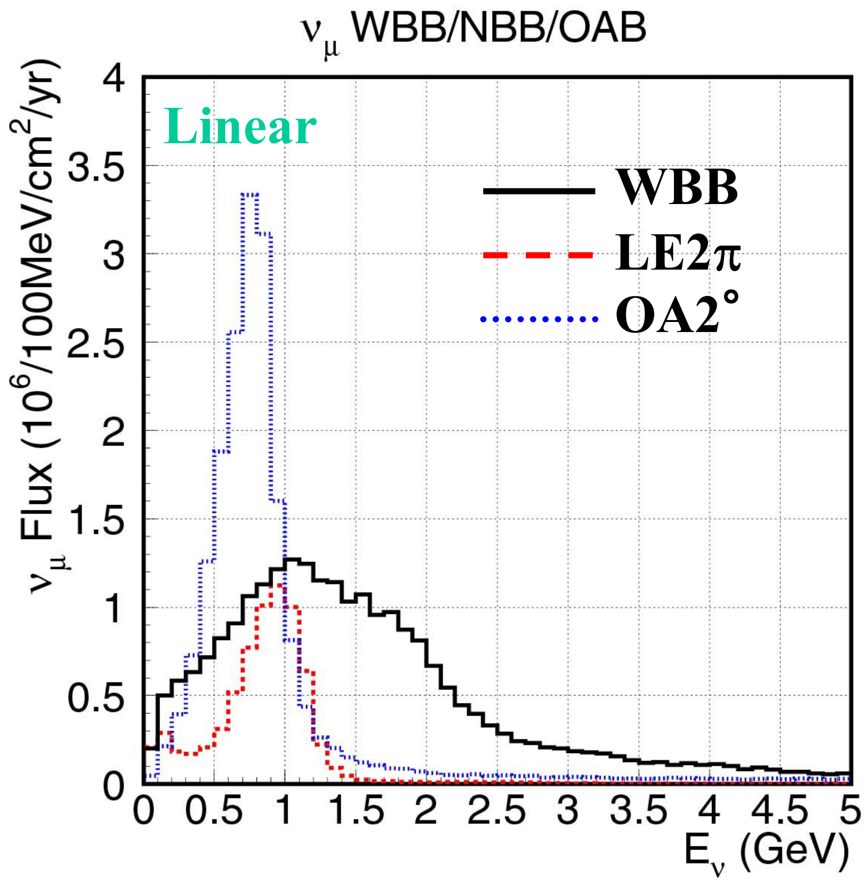
WBB:**5200** CC int./22.5kt/yr

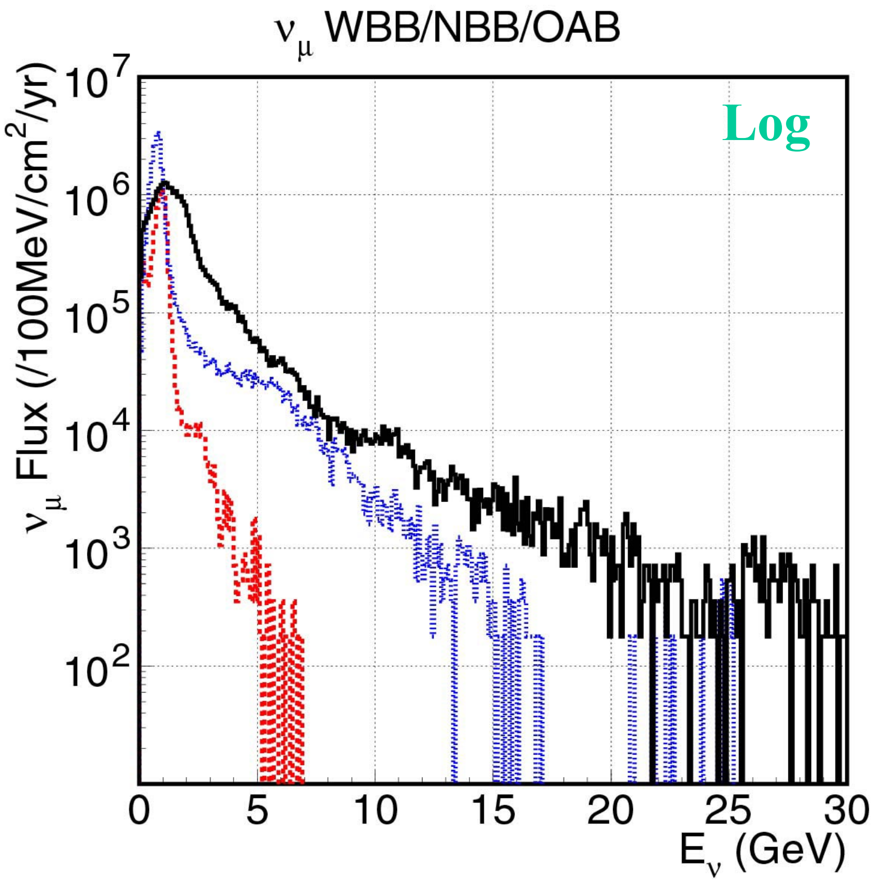
NBB: **620** CC int./22.5kt/yr (2GeV/c π tune)

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

Comparison of spectra

Target: Cu. 1cm$^{\phi}$, 30cm rod
SK size: ±500m



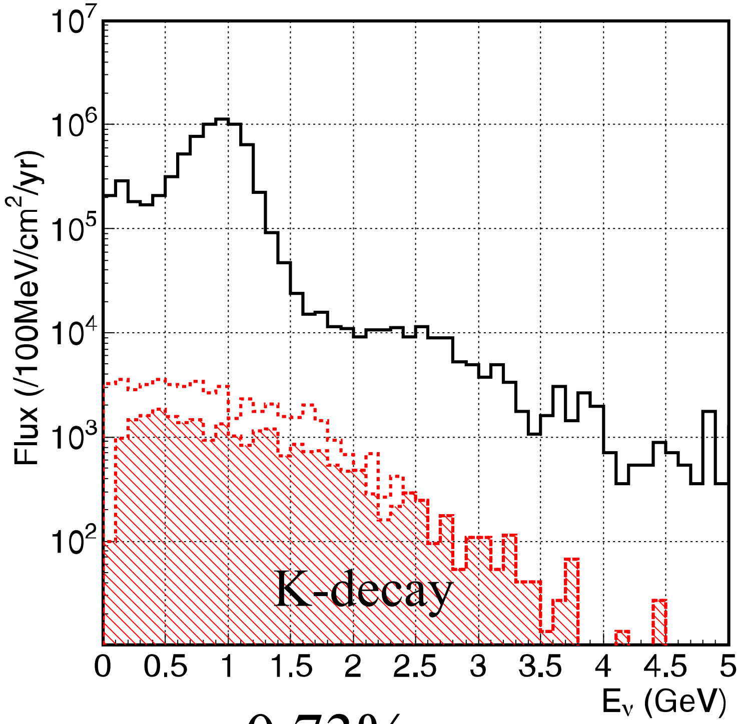


Peak @ 800MeV~1GeV
Sharp peak for NBB/OAB
OAB produce very intense “NBB”

OAB/WBB long HE tail

ν_e components

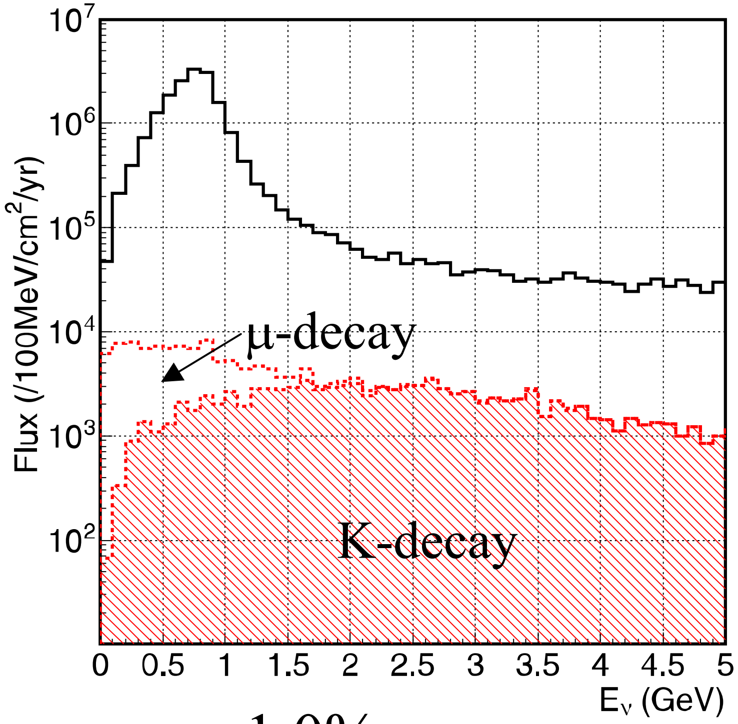
NBB (LE2π)



0.73%

(**0.15%**@peak)

OAB (2degree)



1.0%

(**0.21%**@peak)

Very small ν_e/ν_μ ratio at ν_μ spectrum peak.

$1\sim2\times10^{-3}$

Summary of beam simulations

	(GeV)	Flux		$\nu_e/\nu_\mu(\%)$		# of interactions (/22.5kt/yr)	
Beam	E_{peak}	ν_μ	ν_e	total	E_{peak}	ν_μ	ν_e
WIDE	1.1	25.5	0.19	0.74	0.34	7000(5200)	78(59)
LE1.5π	0.7	5.3	0.05	1.00	0.39	510(360)	5.7(4.2)
LE2π	0.95	7.0	0.05	0.73	0.15	870(620)	6.8(5.0)
LE3π	1.4	8.0	0.05	0.65	0.16	1400(1000)	9.3(6.9)
OA2°	0.7	19.2	0.19	1.00	0.21	3100(2200)	60(45)
OA3°	0.55	10.6	0.13	1.21	0.20	1100(800)	29(22)

(10^6/cm^2/10^{21}POT)

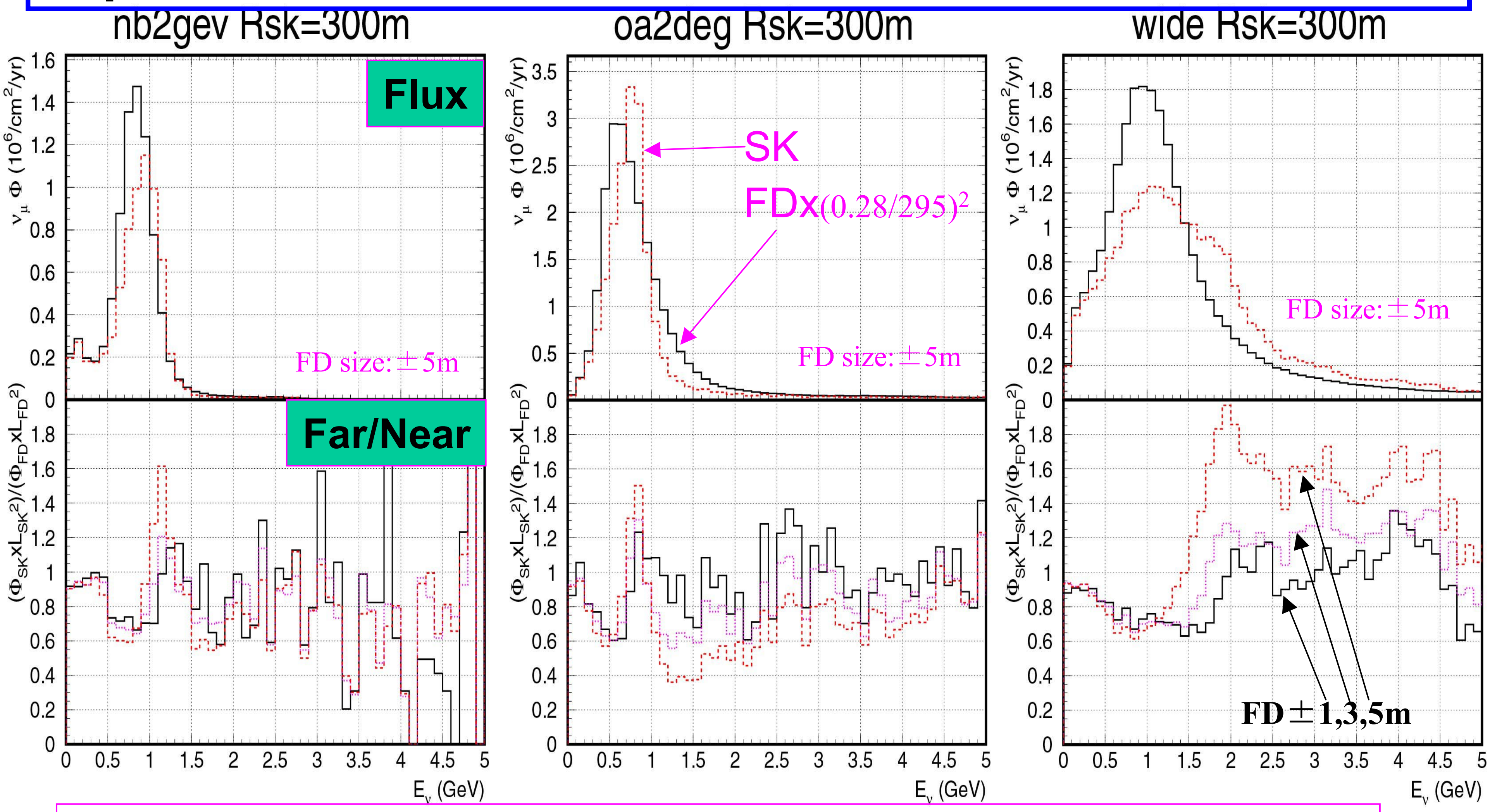
Tot. (CC)

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

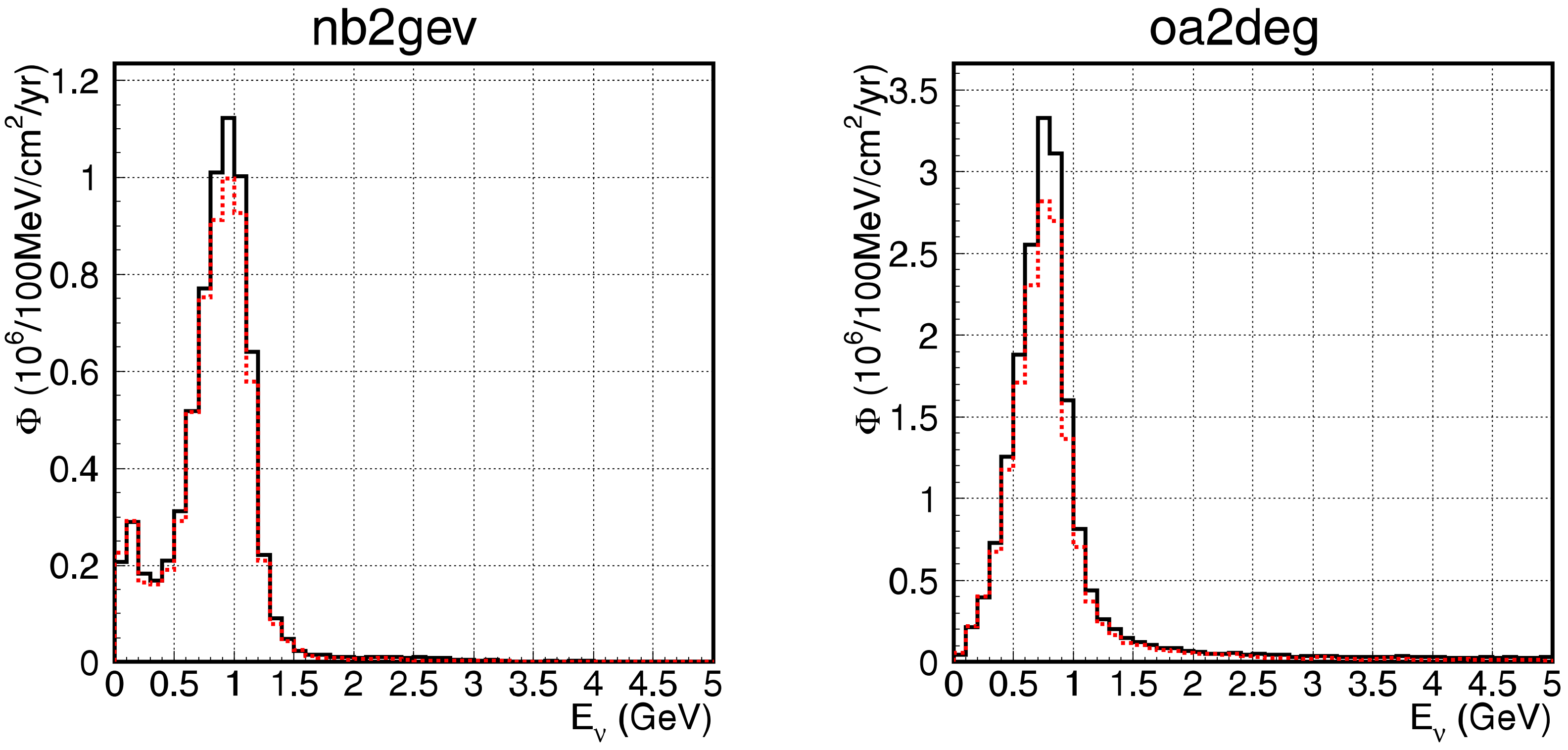
FD size: ±3m
Unit:
flux for ν_μ : 10^{12}/cm^2/10^{21}POT
flux for ν_μ : 10^{10}/cm^2/10^{21}POT
# of int : /100ton.spill (3.3×10^{14}ppp)

Spectrum difference btw. near and far



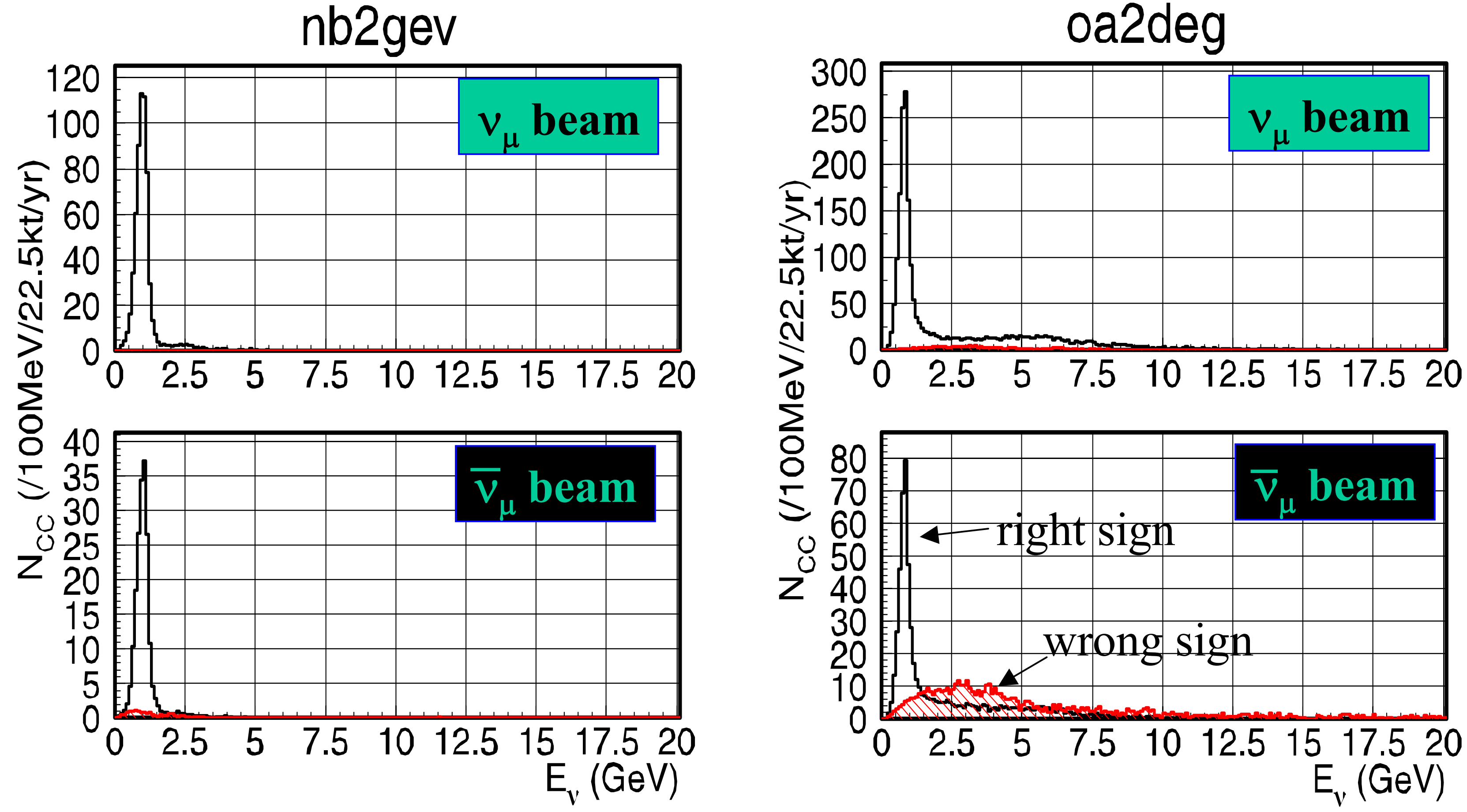
- Peak energy shift → serious syst.
- dependence of high energy side on FD size → Handle to estimate correction
- Low energy side does not depend on FD size

$\nu_\mu / \overline{\nu}_\mu$ 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

- Tunable low energy beam tuned at osc. max.
- Primary proton 3.3×10^{14}ppp, 0.77MW
- Technical design of facility going on
- Use super conducting magnets
- 3 beam configurations
  - WBB **5200** ν_μCC int/22.5kt/yr
  - NBB **620** ν_μCC int/22.5kt/yr
  - OAB **2200** ν_μCC int/22.5kt/yr
- beam ν_e comtamination **$1\sim2 \times 10^{-3}$**@ peak
- Start construction 2002 Completion Mar.2007