2KM water Cherenkov detector: reconstruction & preliminary analysis

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- Reconstruction status
- "simple" scaling analysis à la march 05
- Combined fitter : preliminary studies

2KM MC production

Ran into several problems :

- random shooting of vertices for numu
- Polfit behaviour @ 2KM --> see next slides

The problems are now fixed, and things are running smoothly

- Nue ready (92,548 events in FV)
- Numu : ~777,000 events generated so far (282,126 in FV) [~1 year]

1 beam year = 8 CPU days (110 CPUS at Kashiwa)

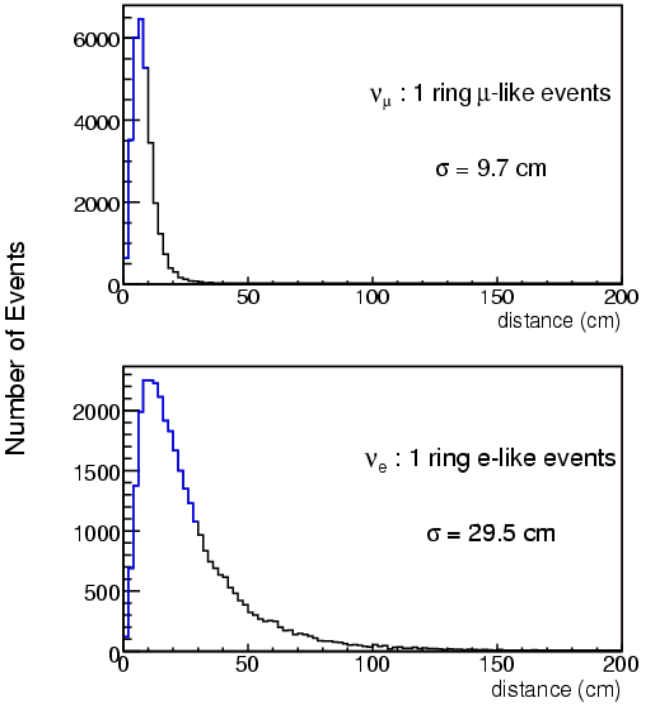
You can get those ntuples from http://www.phy.duke.edu/~mfguest/
(usual username & passwd for T2K 2KM talks web page)

SK ntuples : J. Raaf finished processing them
suketto : /net/sukatmd1/work21/t2k/sk/ntuples

Position & direction reconstruction

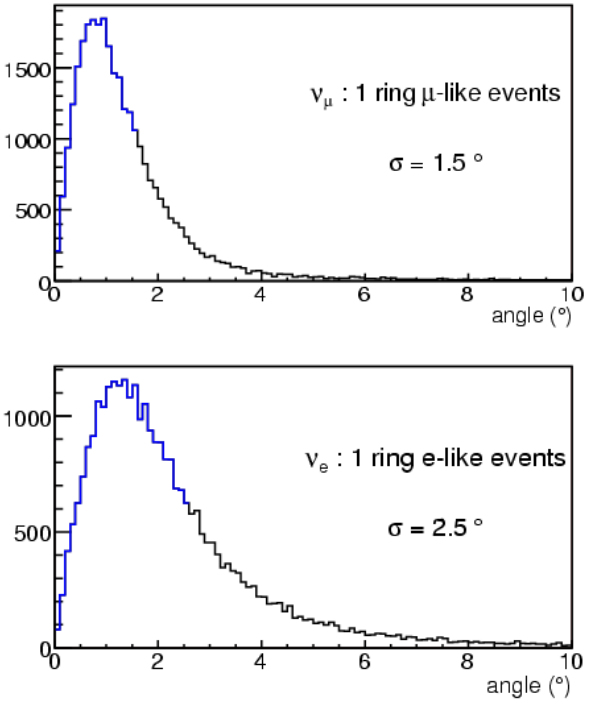
- Determine quality of vertex & direction reconstruction for single ring events
- Define resolution as 68% quantile of distributions
- Results slightly improved compared to SK because of double MS-fit iteration

MS-fit : distance



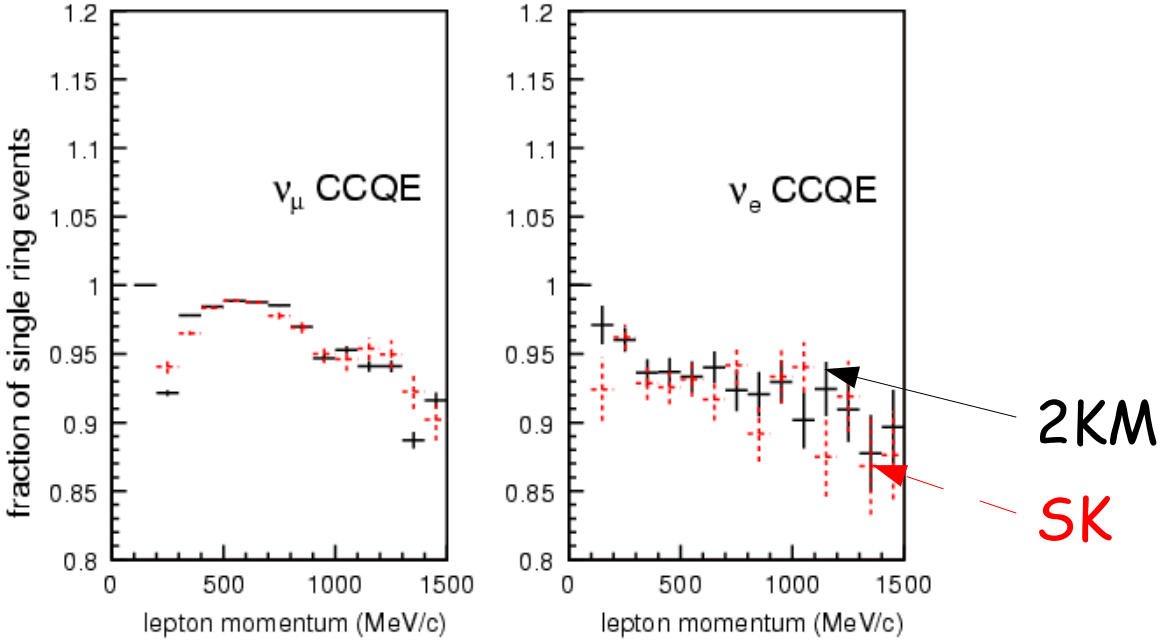
Better than SK for $\nu\mu$ (23.9cm) similar for νe

MS-fit direction

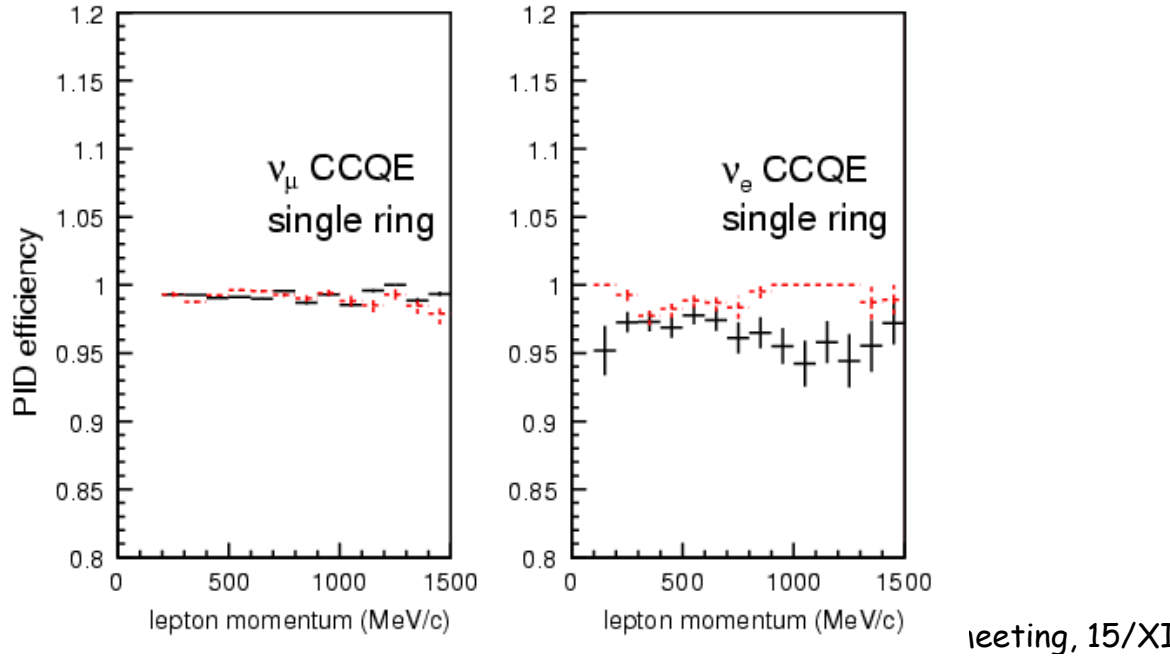


Better than SK (resp. 2.0° & 3.3°)

Ring counting & PID efficiencies for CCQE events



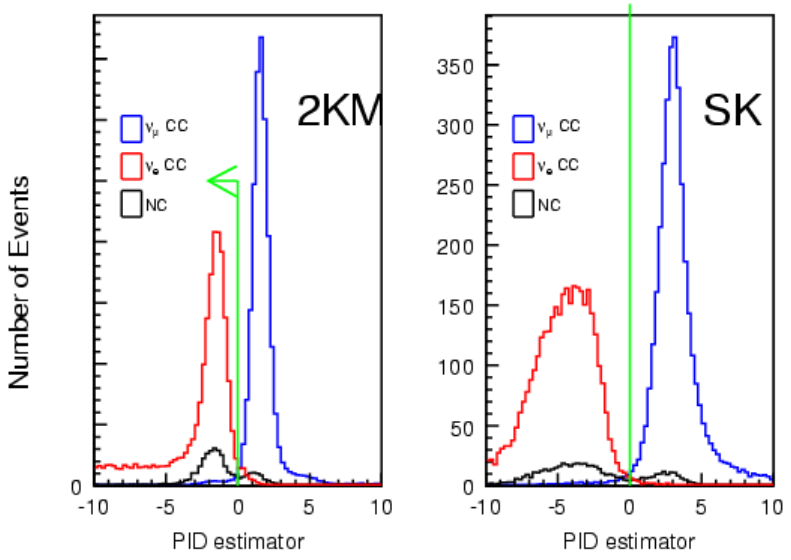
Efficiency drops off because 2nd ring is found
Similar @ SK & 2KM



muon PID is very good !

PID cut less efficient for nues @ 2KM
-> small "signal" efficiency loss at 2KM

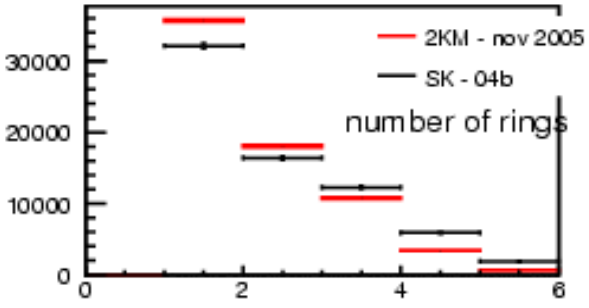
RC & PID estimators

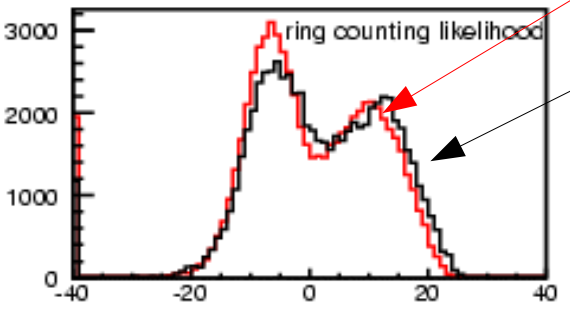


ν_e rescaled to same number as ν_μ

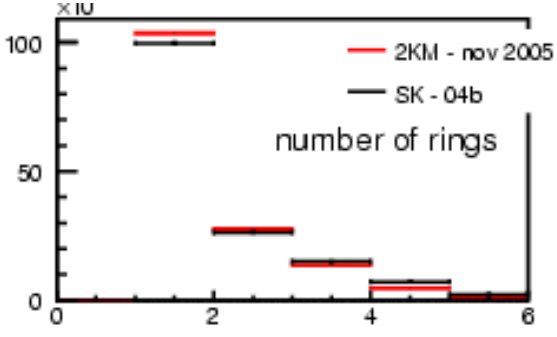
2KM

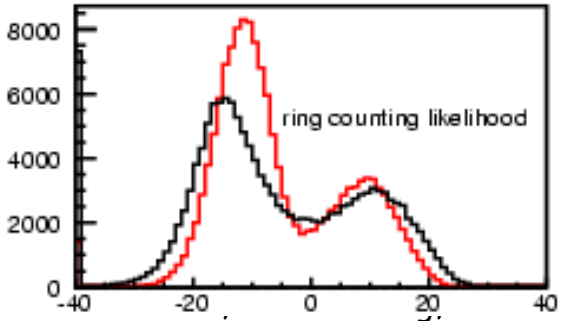
SK





ν_e (FC,FV,E_{vis}>100 MeV)





ν_μ (FC,FV,E_{vis}>100 MeV)

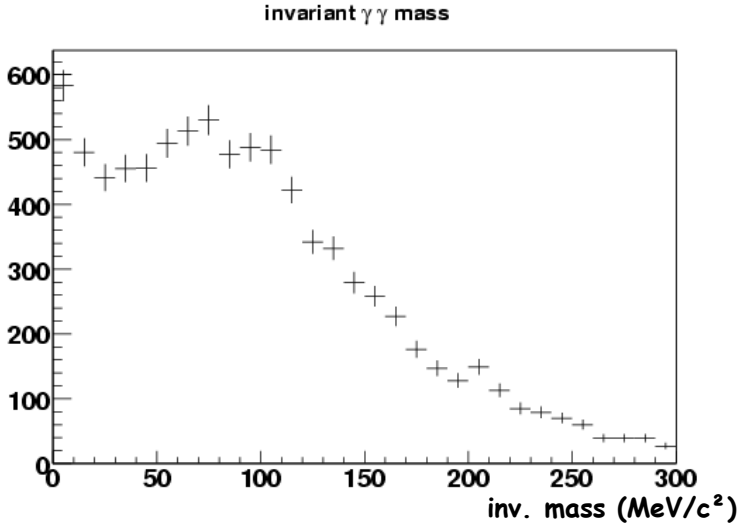
Polfit problems

- Presented last time during the video meeting : peak @ 60 MeV

in the polfit $\gamma\gamma$ invariant mass for CCQE νe events [incorrect, destroys e/pi0 separation]

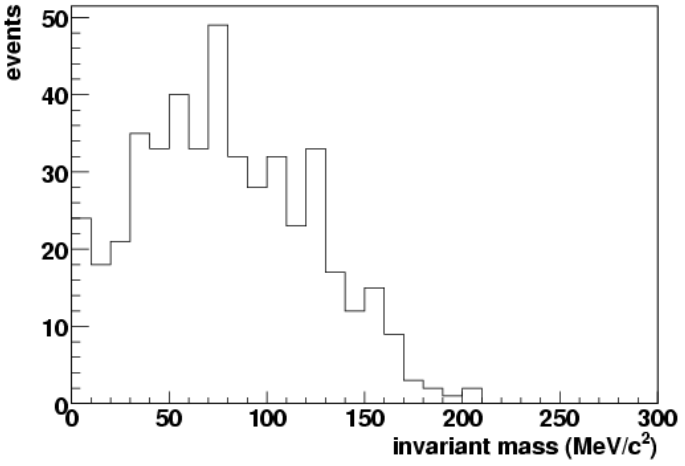
- Checked event displays : the 2nd ring was found inside the scattered light
- Tried both versions of the expected light library (expq,expq++), with wide range of scattering parameters --> no improvement
- We observe "too much" scattered light in true e- events for polfit

-->the timing cut which is applied before polfit does not remove enough light@2KM



With 2KM ν_e events

(shown last time)

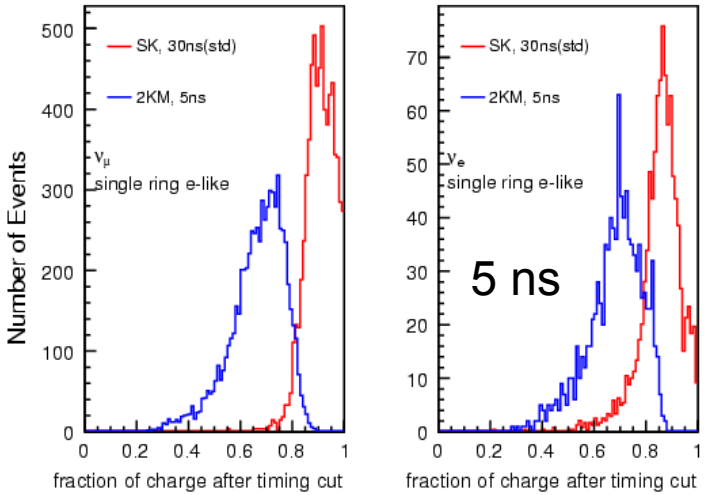


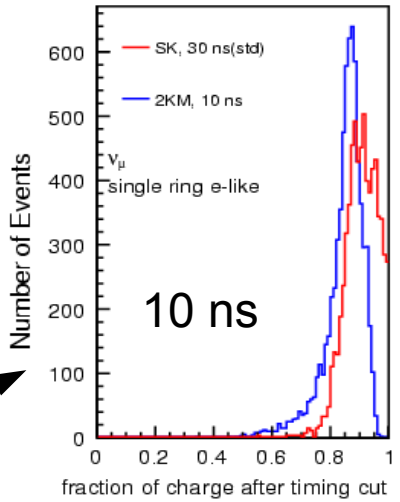
Problem reproduced with monochromatic e- events (400 MeV/c)

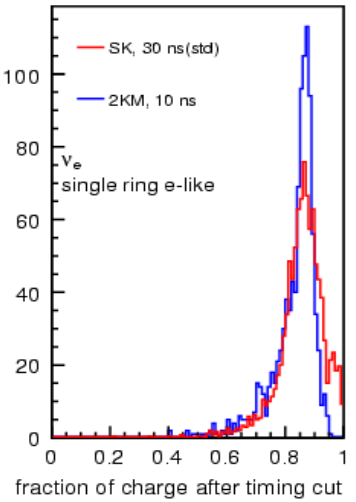
Ritofcut

FC, FV (2m from wall), single ring, e-like events from numu & nue @ SK & 2KM

Get **fraction of the total charge remaining after the cut** as a function of the width

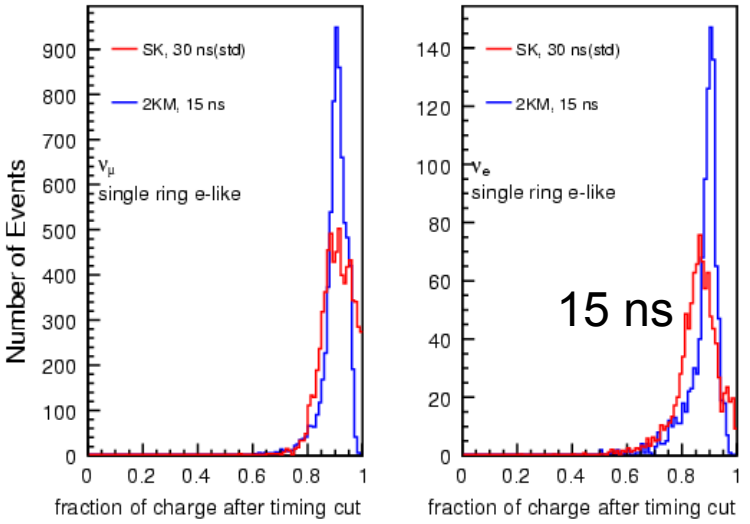


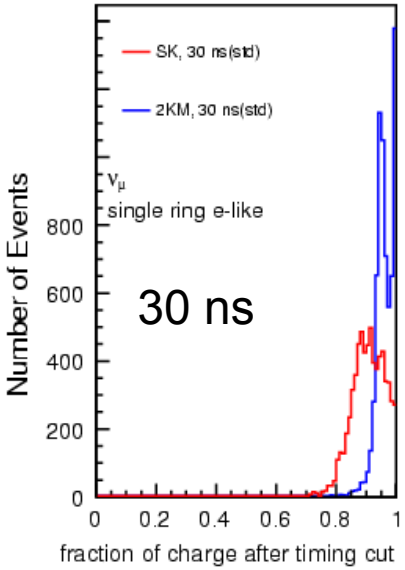


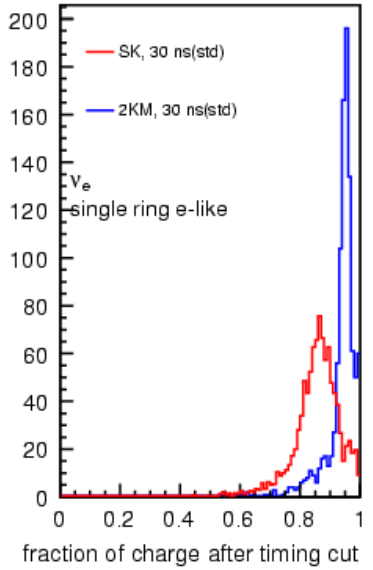


10 ns is best

The 2KM tank is smaller !



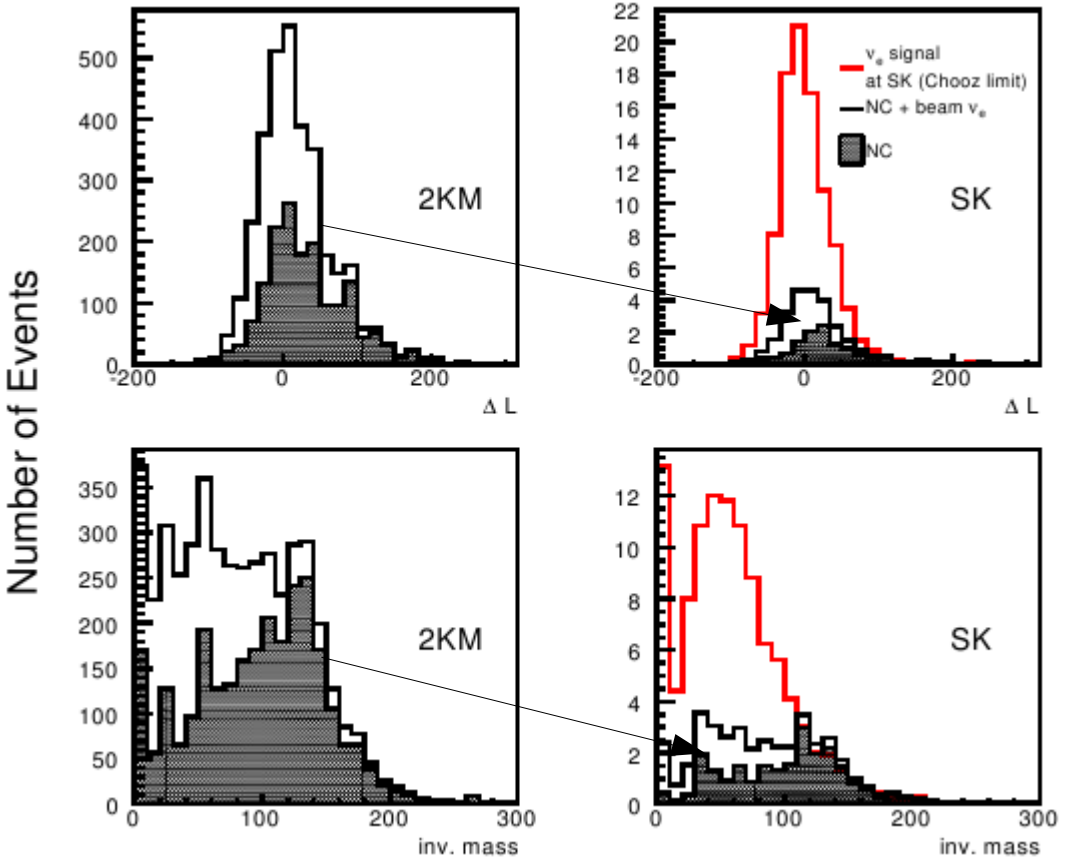




Solution

- Use 10 ns for this timing cut at 2KM
- This timing cut width does not work with the vertex fits in polfit5 (large vertex biases, detroys e/pi0 separation) --> to be investigated later
- For the next meeting : use polfit2 with 10 ns @ 2KM

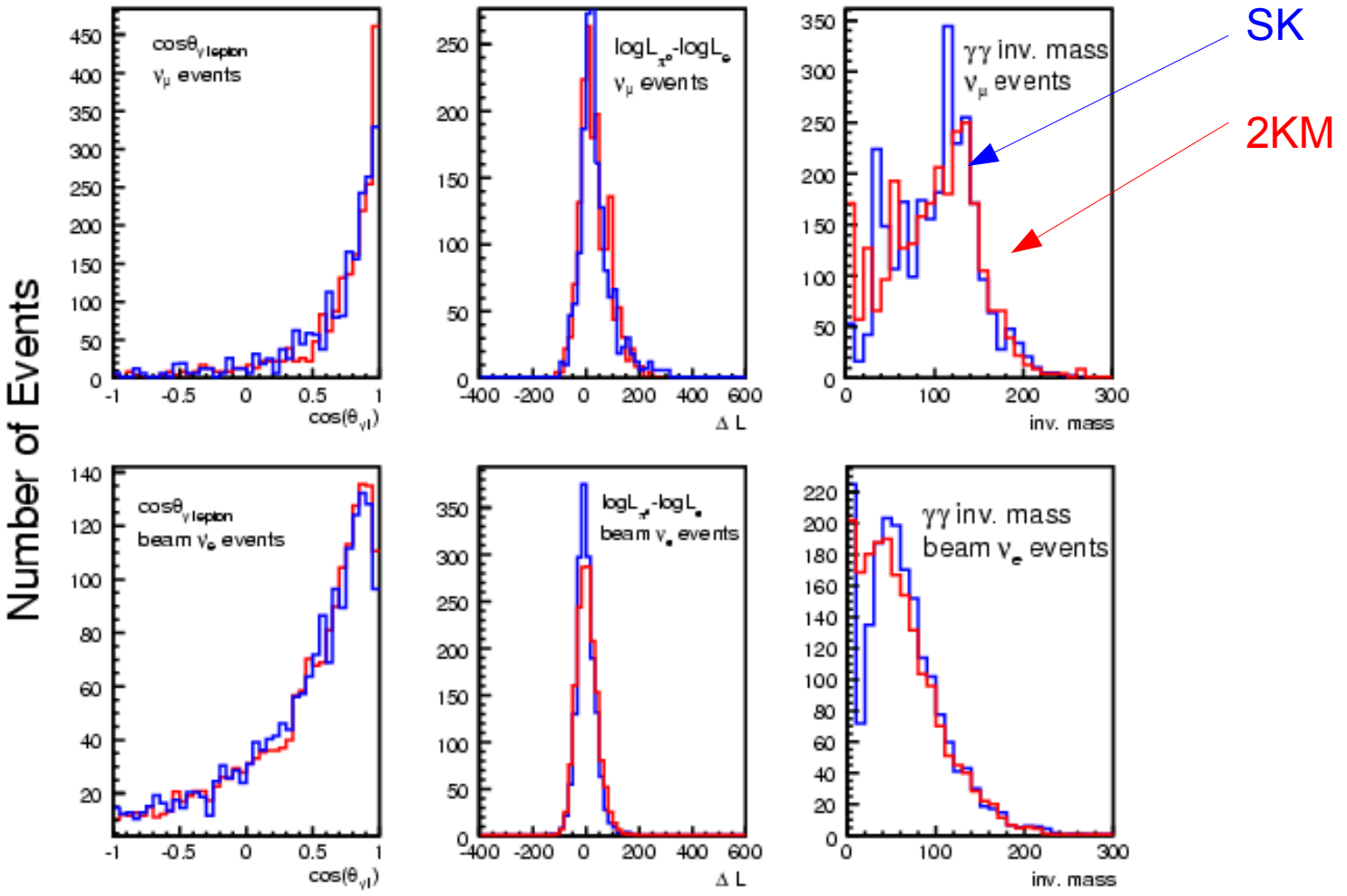
Using events after passing all criteria except the one under study
FCFV, 1ring, e-like, no decay e-,
cos $\theta_{\nu l}$ < 0.9 , 0.35 GeV < Eν < 0.85 GeV



NC events have a peak @ the π^0 mass like they should and ν_e events do not

Effect of the π^0 cuts

Using events after passing all criteria except the one under study
FCFV, 1ring, e-like, no decay e-, cos $\theta_{\nu l}$ < 0.9 , 0.35 GeV < Eν < 0.85 GeV



SK & 2KM have very similar responses
Confirmed with higher statistics !

ν_e appearance analysis

- Use the "usual" ν_e appearance cuts
- Compare selection efficiencies at SK & 2KM like in march 2005
- Numbers are quoted for 5 years (5.10^{21} pot)

Two types of analysis :

- Determine a conservative estimate of the systematics on background "prediction" from 2KM
- Use this in a combined SK+2KM fit with all reconstruction systematics (not fully operational yet).

2KM ν_e appearance cuts SK

- **FV 100t** (-415cm<Z<215cm && sqrt(x^2+y^2)<225cm)
- **FC** (max charge on a PMT < 100 p.e.)
- **Evis** > 100 MeV
- **1 ring, e-like**
- **No decay electron** : use MC info to compute decay e- detection probability and use random numbers...
- **cos $\theta_{\nu e}$ < 0.9** (coherent pi0 suppression)
- **Polfit M$\gamma\gamma$ < 100 MeV/c²**
- **Δlog-likelihood < 80**

- **FV 22.5 kt** (distance to wall > 200 cm)
- **FC** (# of OD clusters < 10)
- **Evis** > 100 MeV
- **1 ring, e-like**
- **No decay electron** : use reconstructed decay e- info
- **cos $\theta_{\nu e}$ < 0.9** (coherent pi0 suppression)
- **Polfit M$\gamma\gamma$ < 100 MeV/c²**
- **Δlog-likelihood < 80**

Selection efficiencies at SK

At Super-K , 22.5 kt, 5 years, Δm^2_{23} = 2.5e-3 eV²:

	$\nu\mu$ CC mis-ID	NC	Beam νe	Signal (chooz)
FC,FV,Evis>100 (MeV)	2086.7	803.2	182.9	217.9
Single ring	983 (47.1%)	218 (27.1%)	89 (48.7%)	184 (84.6%)
E-like	38.8 (1.9%)	170 (21.1%)	86.7 (47.4%)	182 (83.6%)
No decay e-	11.0 (0.53%)	150 (18.7%)	71.6 (39.1%)	166 (76.2%)
0.35<Eν<0.85 (Gev)	1.17 (0.06%)	50.6 (6.3%)	20.7 (11.3%)	127 (58.3%)
Cos$\theta_{\nu lepton}$<0.9	0.82 (0.04%)	35.7 (4.4%)	17.5 (9.6%)	111 (51.1%)
Polfit M$\gamma\gamma$ < 100 MeV/c²	0.32 (0.02%)	12.1 (1.5%)	13.9 (7.6%)	94 (43.2%)
ΔlogLikelihood < 80	0.27 (0.013%)	10.0 (1.2%)	13.5 (7.4%)	91.8 (42.1%)

- Efficiencies very similar to the previous analysis (0.03%, 1.06%, 7%, 42% respectively)
- Differences in the event rates come from the use of a different version of the cross-section MC from the "official event rate"

I may have to reweight them. Hayato-san will clarify this shortly.

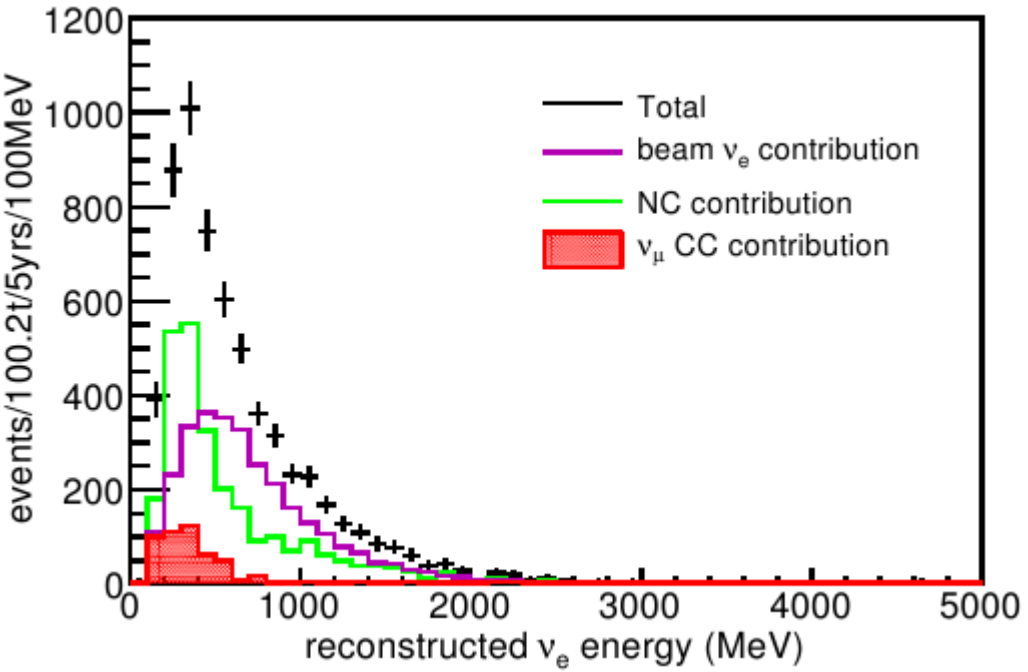
The important point is to use the same x-section models @ SK AND @ 2KM

[true at the moment as far as I can tell]

Background measurement at 2KM

	νμ CC mis-ID	NC	Beam νe
FC,FV,Evis>100 (MeV)	565857	94395.1	20104
Single ring	427593 (75.6%)	26659 (28.2%)	10459 (52%)
E-like	12326.5 (2.2%)	21537 (22.8%)	10040 (49.9%)
No decay e-	1316.5 (0.23%)	17847 (18.9%)	8038.3 (40%)
0.35<Eν<0.85 (Gev)	395 (0.07%)	7175 (7.6%)	2425 (12%)
$\cos\theta_{\nu\text{lepton}}$ <0.9	316 (0.06%)	4879.7 (5.2%)	2078.5 (10.3%)
Polfit $M_{\gamma\gamma}$ < 100 MeV/c²	211 (0.04%)	1430.6 (1.5%)	1641.5 (8.2%)
ΔlogLikelihood < 80	201.9 (0.04%)	1097.1 (1.2%)	1580.2 (7.9%)
SK, ALL CUTS	0.27 (0.013%)	10.0 (1.2%)	13.5 (7.4%)

Almost identical !



Extrapolation from 2KM to SK

First : Simple scaling (same as march meeting) :

$$N_{sk} = N_{2km} \; (M_{sk}/M_{2km})(L_{sk}/L_{2km})^2(\epsilon_{sk}/\epsilon_{2km})$$

Assumed to be 1 here

Get estimation of BG at SK from 2KM measurement assuming identical efficiencies & spectra -> simple scaling with distances^2 and fiducial masses.

Systematics :

- Analysis cuts --> next slide
- Escale ~ 3 % --> shift all energy-related cuts and measure changes in the number of events
  --> add in quadrature SK + 2KM
- FV ~ 4 % = (error @ SK + error @ 2KM in quadrature) -> overestimated if correlated
- NEW : Beam differences :
  use upper bound of F/N ratio difference from 1 as conservative estimate -> 5 %

Extrapolation systematics : differences between SK & 2KM

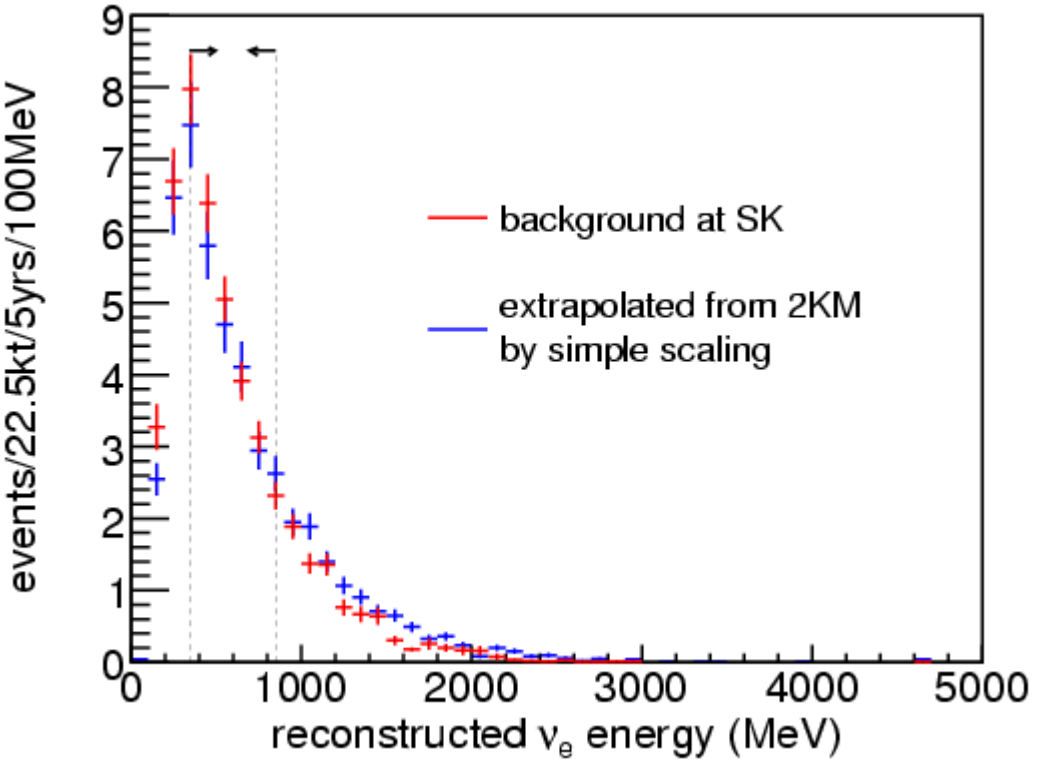
- March 2005 analysis : use difference between SK & 2KM efficiencies at each step as an estimate of the systematic on each cut, & add in quadrature
- This measures the error on the difference between SK & 2KM
- Used to be ~ 7% for NC, 6 % for beam νe, 3 % for $\nu\mu$ CC, with greatest contribution from ring counting & PID

	NC	beam νe	$\nu\mu$ mis-ID
FV,100<Evis<1000, FC			
1R	-0.63%	1.25%	-1.10%
e-like	1.10%	0.61%	0.20%
no decay e-	0.15%	0.03%	-0.20%
cos θ	-0.53%	0.24%	-0.20%
M$\gamma\gamma$	-0.15%	0.55%	-0.10%
ΔL	-0.04%	0.34%	-0.09%
TOTAL	1.40%	1.60%	1.20%
OLD TOTAL (march 05)	~7%	~6%	~3%

SK & 2KM performances for νe appearance are now similar to within ~ 1.5 – 2 % !

- Energy scale systematics ~ 2.5-3% for all categories of events ->dominate the analysis error

Extrapolation : results



Excellent agreement !

	NC	Beam νe	νμ
SK simulation	10	13.5	0.27
Prediction from 2km (±stat±syst)	9.2±0.28±0.24	13.2±0.33±0.57	0.23±0.02±0.02

(systematics on Escale & analysis only)

Extrapolation : results

Background for ν_e appearance :

Super-Kamiokande : 23.80 ± 20% (stat)
scaled from 2KM : 22.61 ± 0.44 (stat) ± 1.56 (syst)
= 22.6 ± 7.2 % (this analysis)

removing beam systematics (same as march) : 22.61 ± 0.44 (stat) ± 1.18 (syst) = 22.6 ± 5.2%
results from the meeting in march 05 23.4 ± 8 %

The systematic error is now dominated by the error on the FV (4%) & by the error caused by the energy scale (2.5%-4% depending on the channel).
(+ Beam error ~ 5% : conservative)

Those results are still preliminary : I will update the numbers as MC stats increases

Combined fitter : status

- build a full chi² including pull terms for each systematic term, including all the relevant SK systematic errors including reconstruction errors
- Compare minimizer & linear matrix inversion method à la SK combined paper
- Continuing work by N. Tanimoto – the code can use both methods

- Method : reweight each MC events according to oscillation probabilities ;

each systematic parameter ε enters as $(1.0+\sigma\times\varepsilon)$ where σ is the estimated uncertainty on ε

- Parameters can be correlated / anti-correlated between samples :

PID is anti-correlated between e-like & mu-like ; RC is anti-correlated between 1R & multi – R etc...

Need several samples to constrain parameters completely : if only e-like events are used, then PID term is just an overall normalization term.

-> adding mu-like events (varying in the opposite direction) constrains it.

- At the moment 2 terms :

NC cross-section error & ring counting

Use 4 samples : 1 R e like @ SK & 2KM and 2 ring e-like @ SK & 2KM

Still doing preliminary tests and checks.

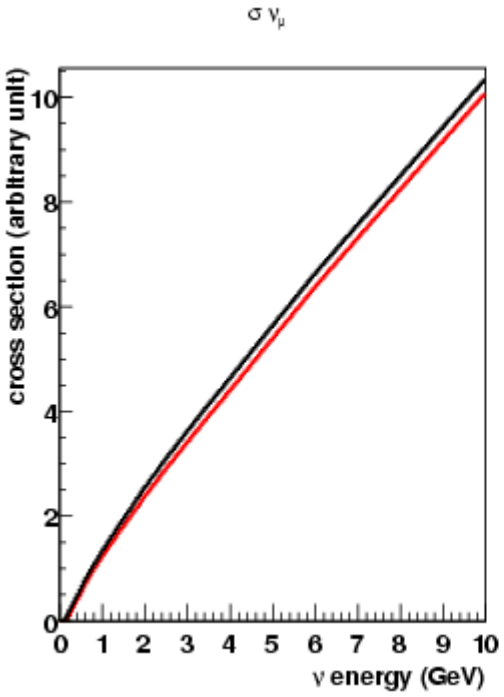
Conclusion

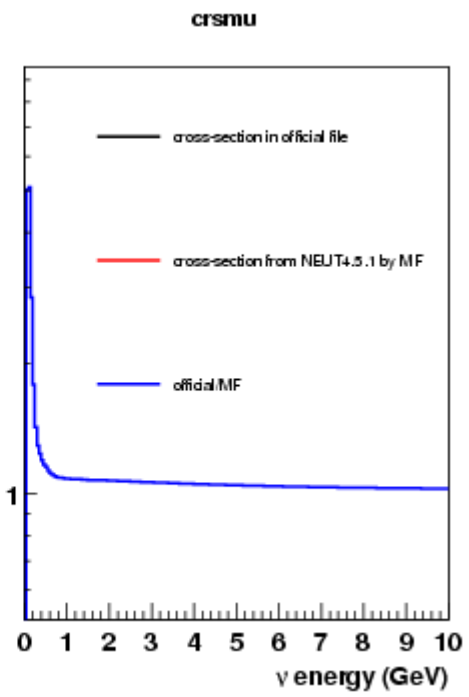
- Problems in the $\nu\mu$ MC production are finally solved, and processes now run smoothly
- Already 1 year available, expect ~ 4-5 years by plenary T2K meeting (~ 10^6 $\nu\mu$ in FV)
- Need to study effect of timing cut width on polfit (any version), also at SK
- With ~ 1 year available, comparison between SK & 2KM gives excellent results
- No need to remove NC elastic events @ 2KM any more : GEANT4 "binary cascade" hadronic model working fine !
- "simple scaling" extrapolation method :

    - 2KM & SK are similar to within 2% for νe appearance
    - Very conservative estimate of systematics -> total error is 7.2 % on predicted BG falls to 5.2% when using march 05 analysis (compared to 8%)

- Combined fitter under study -> checking preliminary results , will be ready in 1 month for the meeting...

Backup slide : cross-section differences with official analysis





- "Official" event rates built with black curve
- Vectors (2KM & SK) generated with red curve
- Waiting for explanation of differences
- I can reweight the events if necessary
- OF COURSE must use same weights at both positions !