Introduction of beam analysis toward Dec. face-to-face oscillation analysis meeting

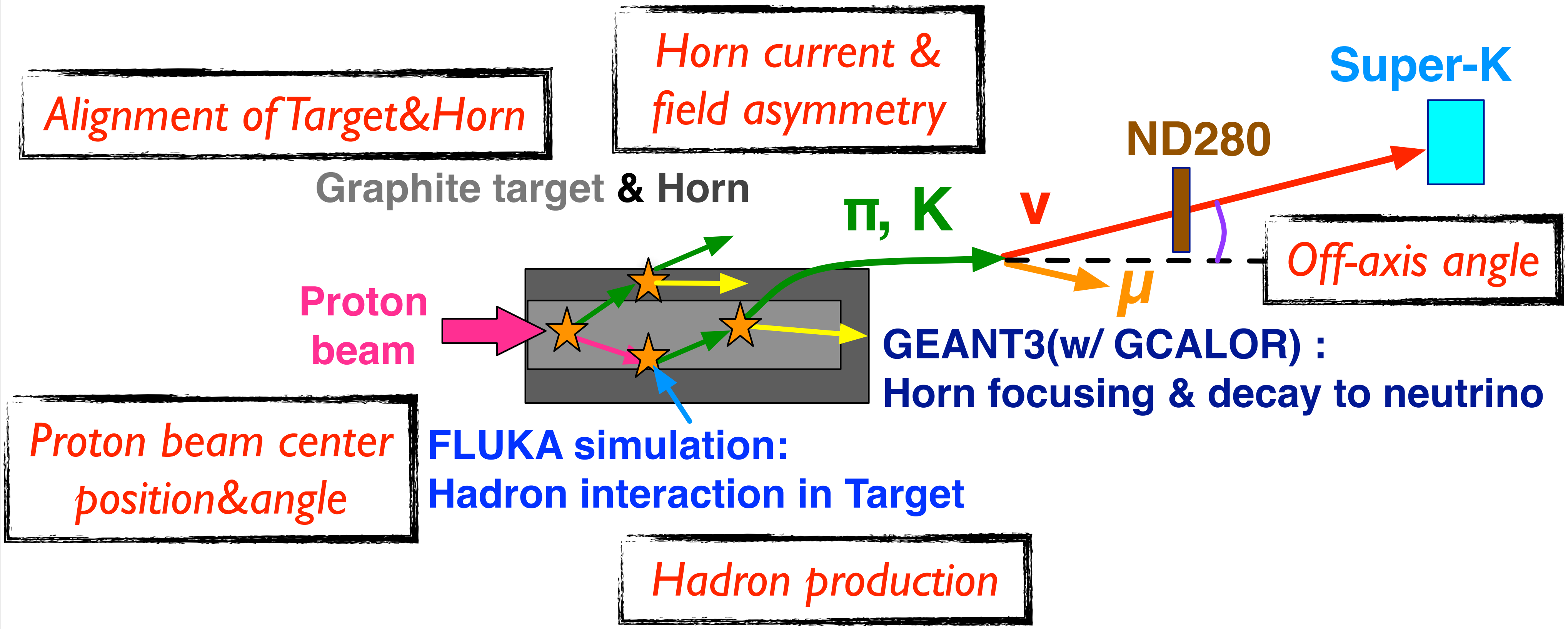
Beam group

Contents

- Review of current flux uncertainty
- Update of flux uncertainty in Dec. analysis meeting at Tokai
- Current study status

Flux uncertainty components

Overview of flux simulation and components of flux uncertainty



Flux uncertainty comes from each components uncertainty.

Current flux uncertainty in 2010a nue analysis

$\sin^2 2\theta_{23} = 1$, $\Delta m^2_{23} = 2.4 \times 10^{-3}$ eV^2 and $\sin^2 2\theta_{13} = 0.1(0.0)$ for ν_e (ν_μ)

Hadron production

Source	Percent Errors of expected number of events				
	N_{ND}	N_{SK}(1 Ring μ)	N_{SK}(ν_e Sig.)	N_{SK}(ν_e Bgnd.)	N_{SK}(ν_e Tot.)
Pion Multiplicity	5.53	5.47	6.86	6.04	6.06
Tertiary Pion scaling	1.39	1.76	1.32	1.12	1.27
Kaon Multiplicity	10.01	10.63	1.76	11.71	4.21
Prod. Cross Sections	7.65	7.12	11.61	6.66	10.39
Sec. Nucleon Multiplicity	5.87	6.35	6.76	6.55	6.69
Proton Beam	2.22	1.78	1.05	0.04	0.80
Off-axis Angle	2.65	3.19	2.07	2.09	2.08
Target Alignment	0.26	0.34	0.08	0.05	0.05
Horn Alignment	0.57	0.52	0.41	0.47	0.42
Horn Abs. Current	0.47	0.08	1.23	0.71	1.11
Total	15.43	15.83	15.48	16.35	14.92

Already update : 11av2.x (as reported Collabo. or ASG meeting)

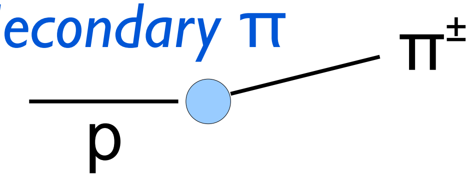
Investigate to update for the Dec. analysis meeting or near future.

Make the flux covariance matrix for the next analysis

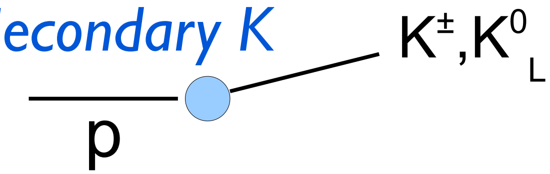
Hadron production

Production Type	ν_μ Fraction for SK	ν_e Fraction for SK
Secondary π	70%	40%
Secondary K	8%	39%
Secondary nucleon → Tertiary π,K (p)	16%	14%
Secondary nucleon → Tertiary π,K (n)	5%	5%

Secondary π

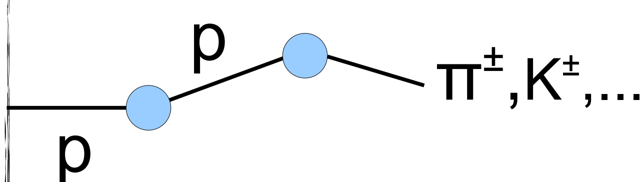


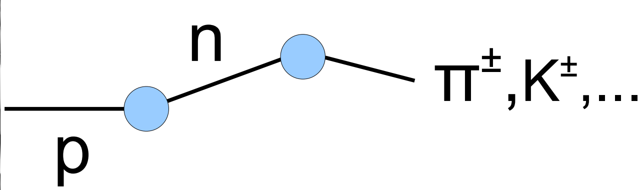
Secondary K



- FLUKA is compared with NA61 Pion/Kaon data.
- About not covered by NA61, use interpolated data of other experiment (Eichten, Allaby).

Secondary nucleon → Tertiary π,K





- For secondary nucleon production, FLUKA is compared with the experiment data.
- For tertiary pion/kaon production, the same error as secondary pion/kaon by scaling method (w/ scaling uncertainty)

Proton beam parameters

- Only RunI proton beam position/angle uncertainty was considered for 2010a flux uncertainty.
- Uncertainties of beam center position/angle (especially in Y) during RunII period are larger than RunI period → Better to be update

RunI beam parameters

	center position (cm)	center angle (mrad)	profile width (RMS)(cm)	emittance (π mm.mrad)	Twiss parameter α
X	-0.037	0.044	0.4273	2.13	0.60
Y	0.084	0.004	0.4167	2.29	-0.09

RunII beam parameters

	center position (cm)	center angle (mrad)	profile width (RMS)(cm)	emittance (π mm.mrad)	Twiss parameter α
X	-0.0149	0.080	0.4037	5.27	0.16
Y	-0.0052	-0.007	0.4083	5.17	0.14

Proton beam uncertainty

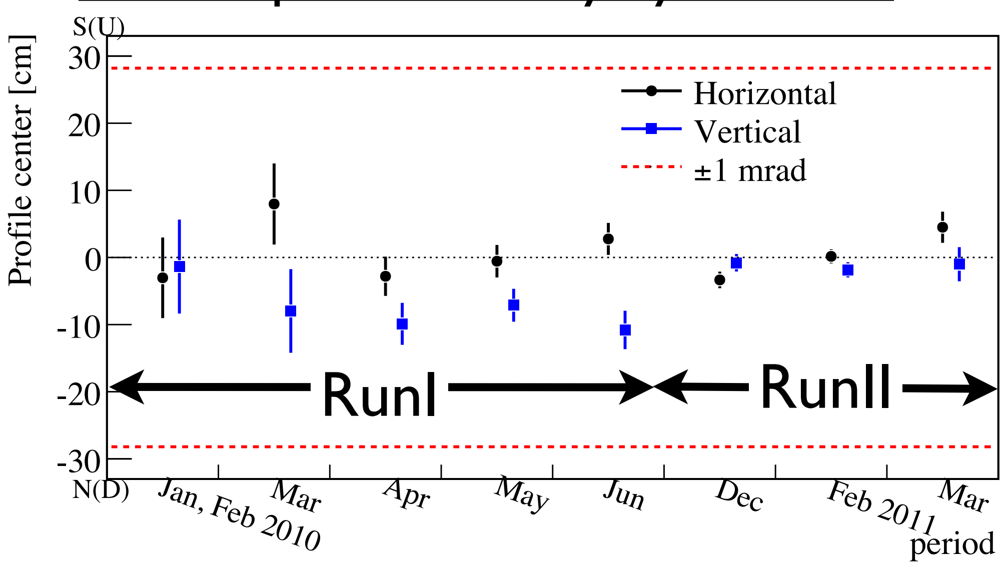
	Run I	Run II
width in X (mm)	0.11	0.26
width in Y (mm)	0.97	0.82
Twiss α in X	0.32	0.26
Twiss α in Y	1.68	0.49
position in X(mm) (x)	0.38	0.27
position in Y(mm) (y)	0.58	0.62
angle in X (mrad) (x')	0.056	0.064
angle in Y (mrad) (y')	0.286	0.320
$\mathrm{cov}(x, x')$	0.011	0.013
$\mathrm{cov}(y, y')$	0.065	0.079

TN054(v2.3)

Off-axis angle

- The following factors cause flux uncertainty
  - The deviation of the beam direction from the beam-axis.
  - Stat. error of the beam direction measurement.
  - Beam direction uncertainty from INGRID detector systematic error
- Current error estimated by only RunI data.
  - We controlled neutrino beam better in RunII than RunI → Flux uncertainty will be reduced for RunII data.

ν beam profile history by INGRID



Summary of INGRID beam profile measurements

Beam center from the INGRID center	X center[cm]	Y center[cm]
RUN1 + RUN2	-0.4 ± 0.7 ± 9.2	-3.0± 0.7 ± 10.4
RUN1 only	0.4 ± 1.4 ± 9.2	-8.6± 1.5
RUN2 only	-0.7± 0.8 ± 10.4	-1.4± 0.8

Toward face-to-face Dec. analysis meeting

- Already release 11av2.1 flux uncertainty
- Will release flux uncertainty 11av2.2 around Dec. analysis meeting.
  - (At least) Establish the format of flux covariance matrix for 2011a analysis.
- Will discuss about the problem for the overflow bin (>10GeV) in the 11av2 tuning histograms.
- Followings studies for 2011a (or near future) analysis are ongoing
  - Proton beam & off-axis angle uncertainty by using RunII data and same method as for 2010a analysis
  - Compare FLUKA2011/2008
  - Horn field & angular alignment uncertainty
  - Consider MUMON measurement for off-axis uncertainty
  - And so on...

Note of 11av2.1, v2.2 uncertainty

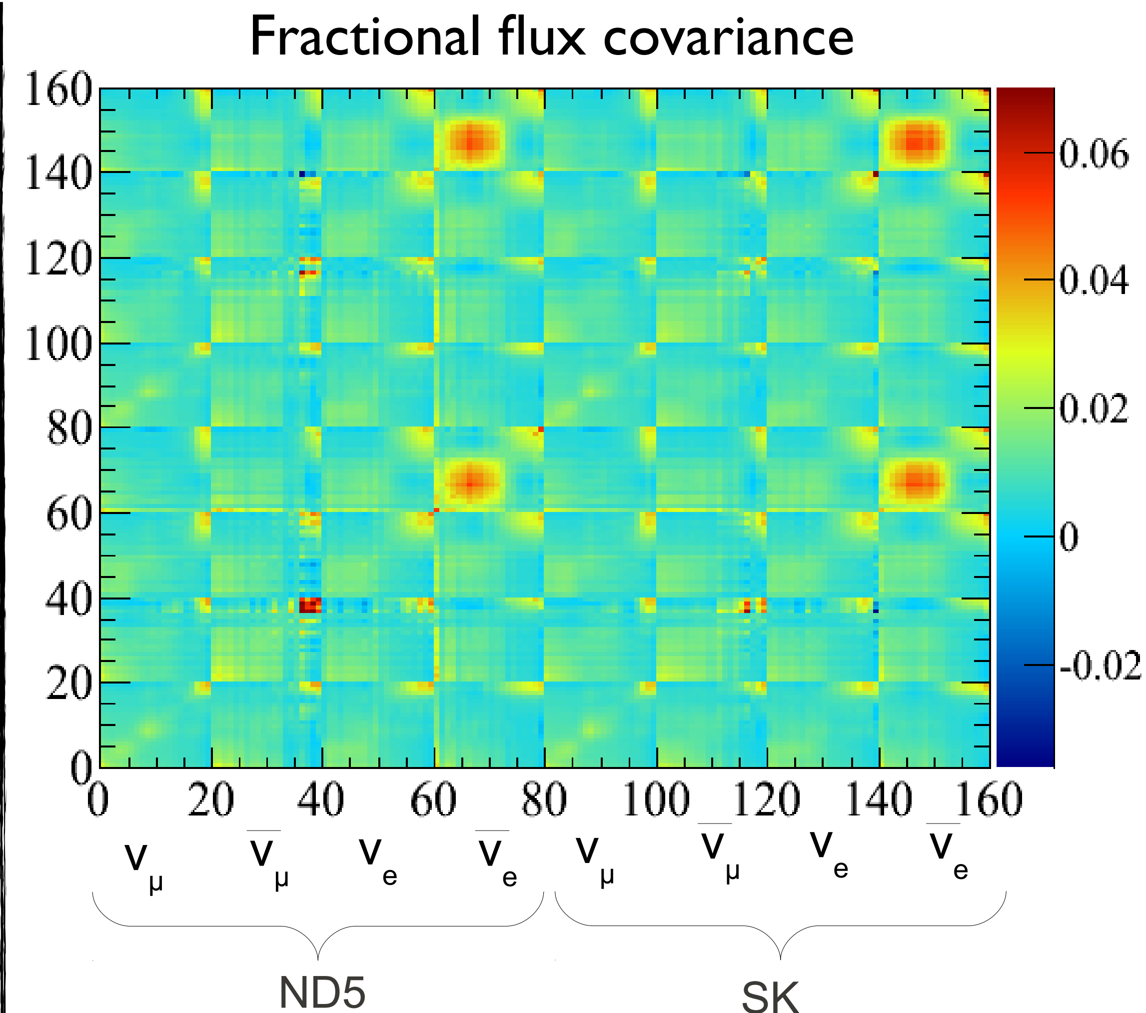
- 11av2.1 uncertainty: already released (http://www.t2k.org/beam/NuFlux/FluxRelease/11arelease/11av2p1covariance)
  - Include Kaon flux uncertainty by using NA61 Kaon data.
    - The NA61/SHINE kaon results are now publicly available as e-Print: arXiv:1112.0150 [hep-ex], CERN-PH-EP-2011-199, and submitted to Phys. Rev. C
  - Release with only coarse binning for flux covariance matrix
  - Include nu_e-bar uncertainty for sources where it has been evaluated
  - Update the proton beam error with Run 2 y-y' variations (tentatively use the different method (JReWeight) from evaluation for 2010a).
  - Include horn/target alignment and horn absolute current using variations evaluated for 2010a
- 11av2.2 uncertainty:
  - Include finely binned covariance that can be used for binning studies
  - Include missing nu_e-bar uncertainties at 11av2.1
  - Include results of some studies about flux uncertainties if ready

Flux covariance matrix (11av2.1)

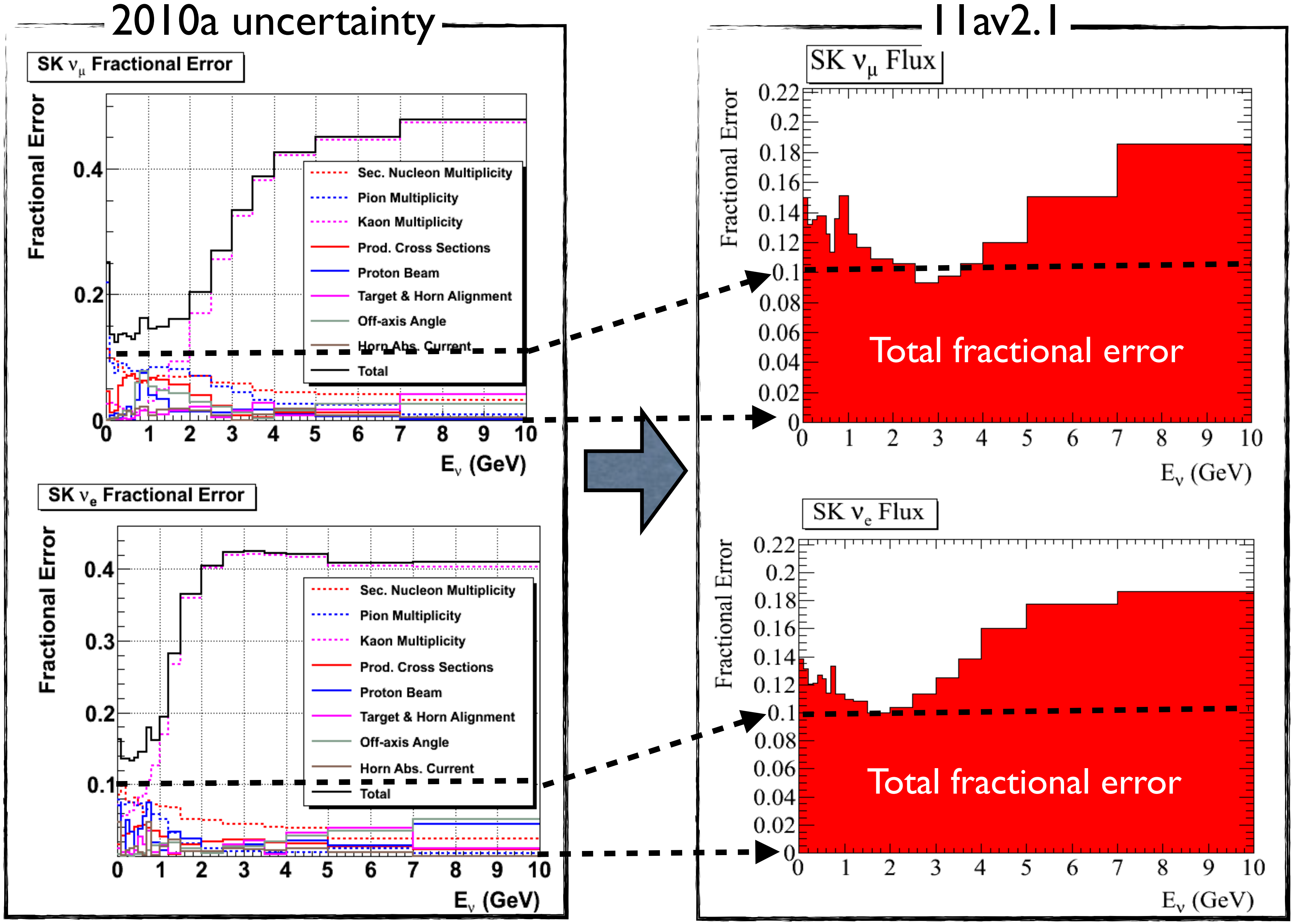
Flux covariance for ν_μ, anti-ν_μ, ν_e and anti-ν_e at ND5 and SK detector planes

Error Sources:

- Pion production : updated for 11av2 tuning
- Kaon production : updated for 11av2 tuning
- Secondary nucleon production : same as 10dv3
- Production cross sections : same as 10dv3
- Off-axis angle : no nu_e-bar errors at this time (10dv3 errors)
- Proton beam errors : y-y' errors calculated with JReWeight
- Horn&Target alignment : no nu_e-bar errors at this time (10dv3 errors)
- Horn absolute current : same as 10dv3



Update flux uncertainty (11av2.1)



→ Flux uncertainty at the high energy region reduced drastically

Overflow bin in tuning histogram

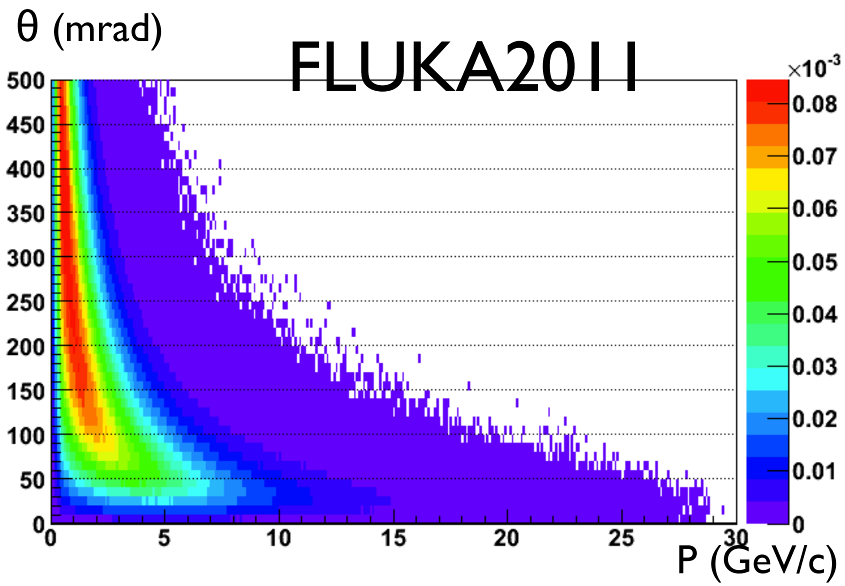
k.suzuki

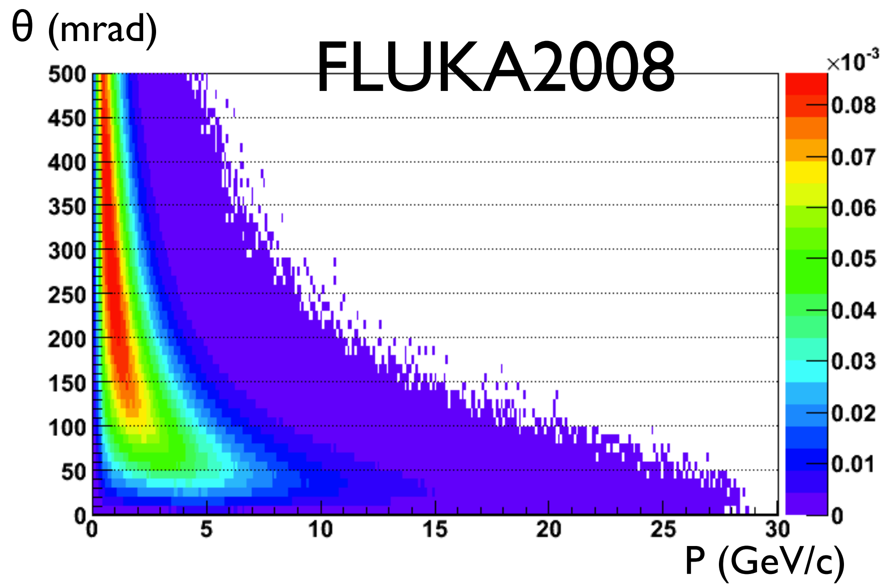
- 11av2 tuning histograms have no entry above 10GeV (overflow region).
- The tuning factors for flux are the ratio of tuned/nominal flux. So the factor above 10GeV is 0.
  - All events with neutrino energy > 10GeV are weighted to 0.
- Now Suzuki-san is updating the 11av2 tuned histograms which include the overflow bin.
  - At Dec. meeting, will report the studies of the overflow bin.
  - Expect to release fixed 11av2 tuning histograms after Dec. analysis meeting.

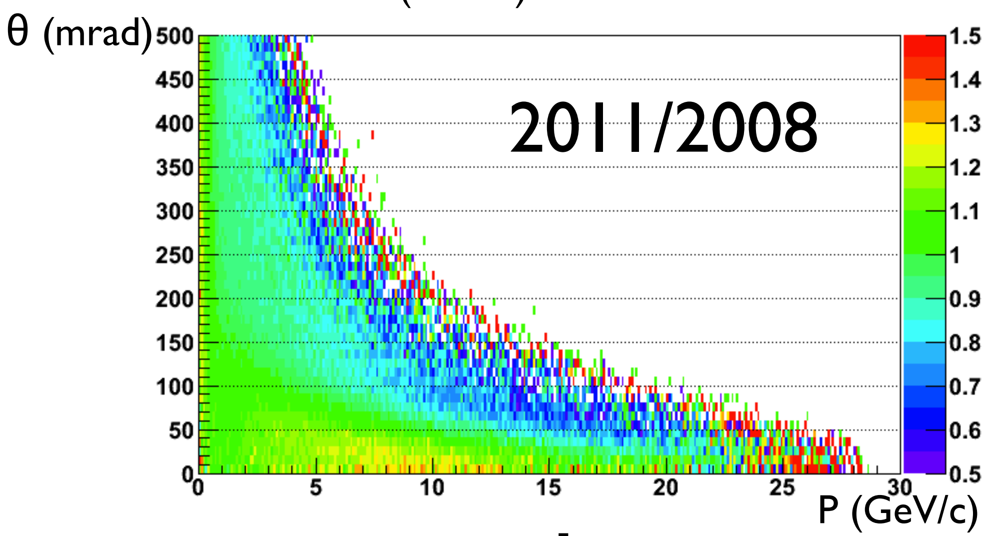
Comparison FLUKA2011/2008

Multiplicity (p-θ) distribution (π+)

K.suzuki





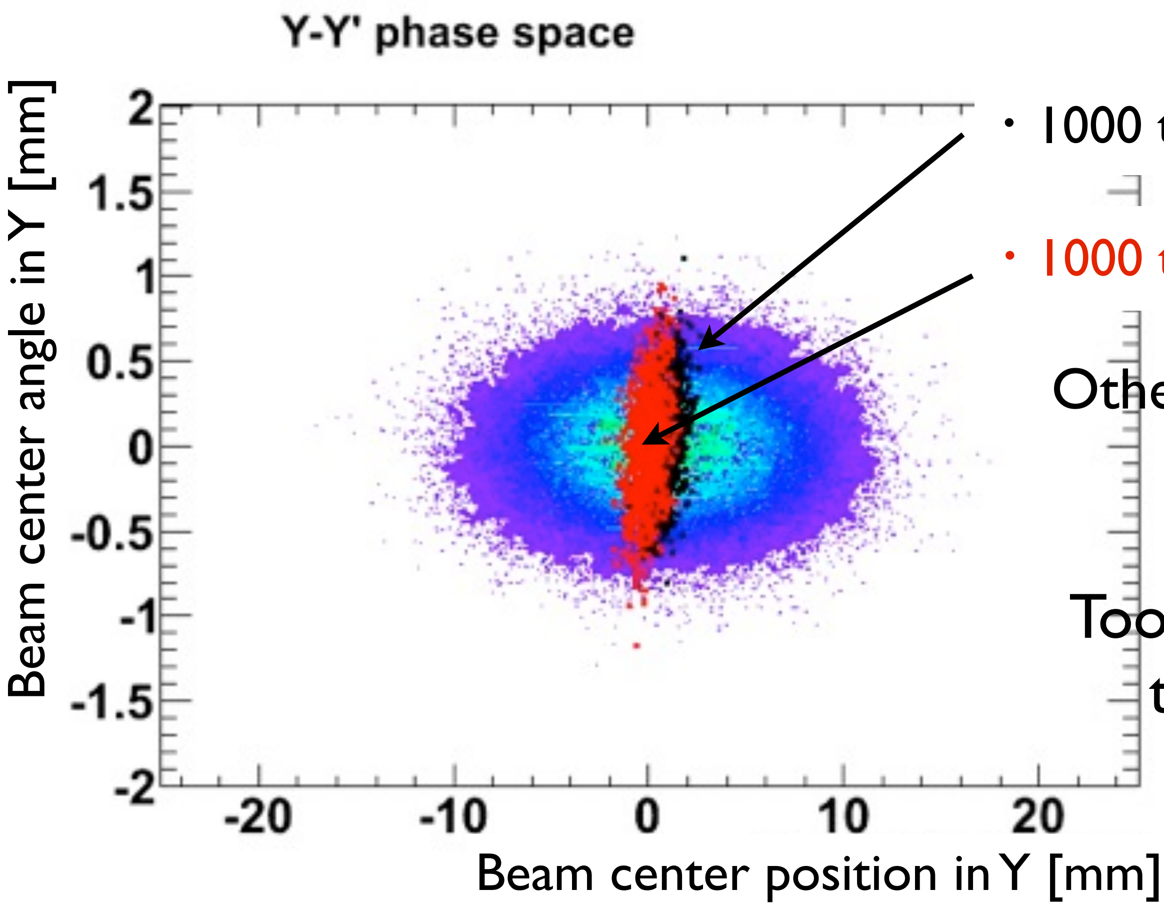


- Now checking the effect on the neutrino flux

Back up

Update of proton beam uncertainty

- Estimate flux uncertainty from proton beam by using RunII data and the same method as 2010a



・1000 throwing by RunI p-beam parameters.

・1000 throwing by RunII p-beam parameters

Other dots : using flux made with wide p-beam parameter

Tool large Y-angle variation compared to generated wide p-beam flux.

Discard throw samples with too large Y-angle to estimate uncertainty or more wider p-beam flux samples