Update of flux uncertainty

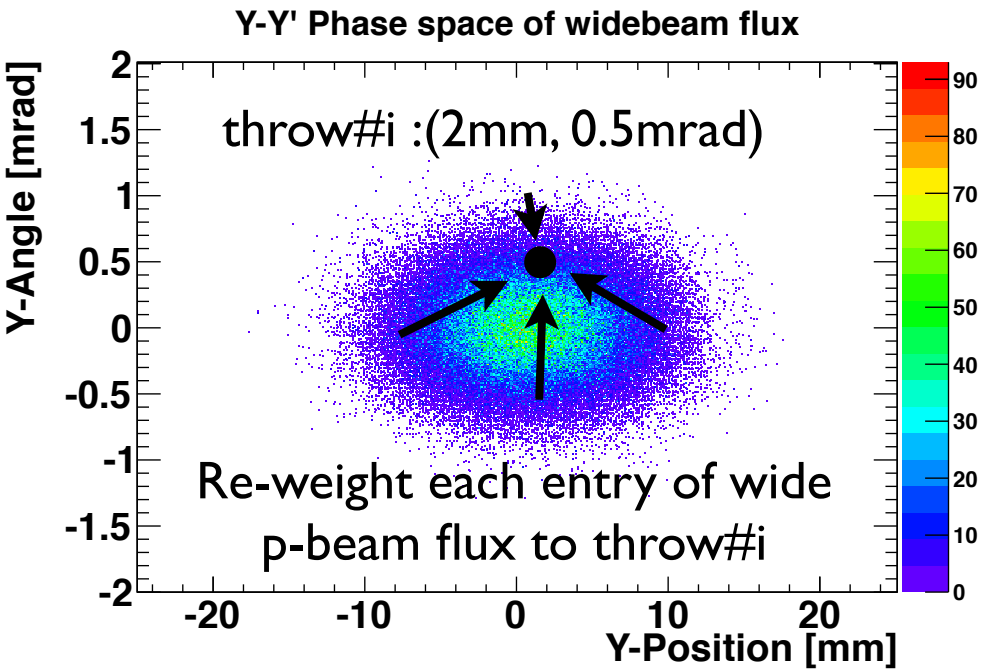
A.Murakami

Plan of next flux uncertainty

- Hope to release next version (11av2.2) of flux uncertainty by next collabo. meeting.
  - Establish the flux covariance matrix for 2011a analysis.
    - At least fix the format. Want to update each flux uncertainties when ready
    - Include finely binned covariance that can be used for binning studies
    - Include missing νe-bar uncertainties at 11av2.1
- Show the status of some ongoing works for update of flux uncertainty
  - Proton beam flux uncertainty by using RunII data and same method as for 2010a analysis
  - Off-axis angle uncertainty by using RunII data & the same method as for 2010a analysis
  - Horn field flux uncertainty
  - Other studies also going on (Horn angular alignment, Off-axis angle from MUMON)

Proton beam flux uncertainty

- 2010a analysis flux uncertainty estimated by 100 proton beam throws



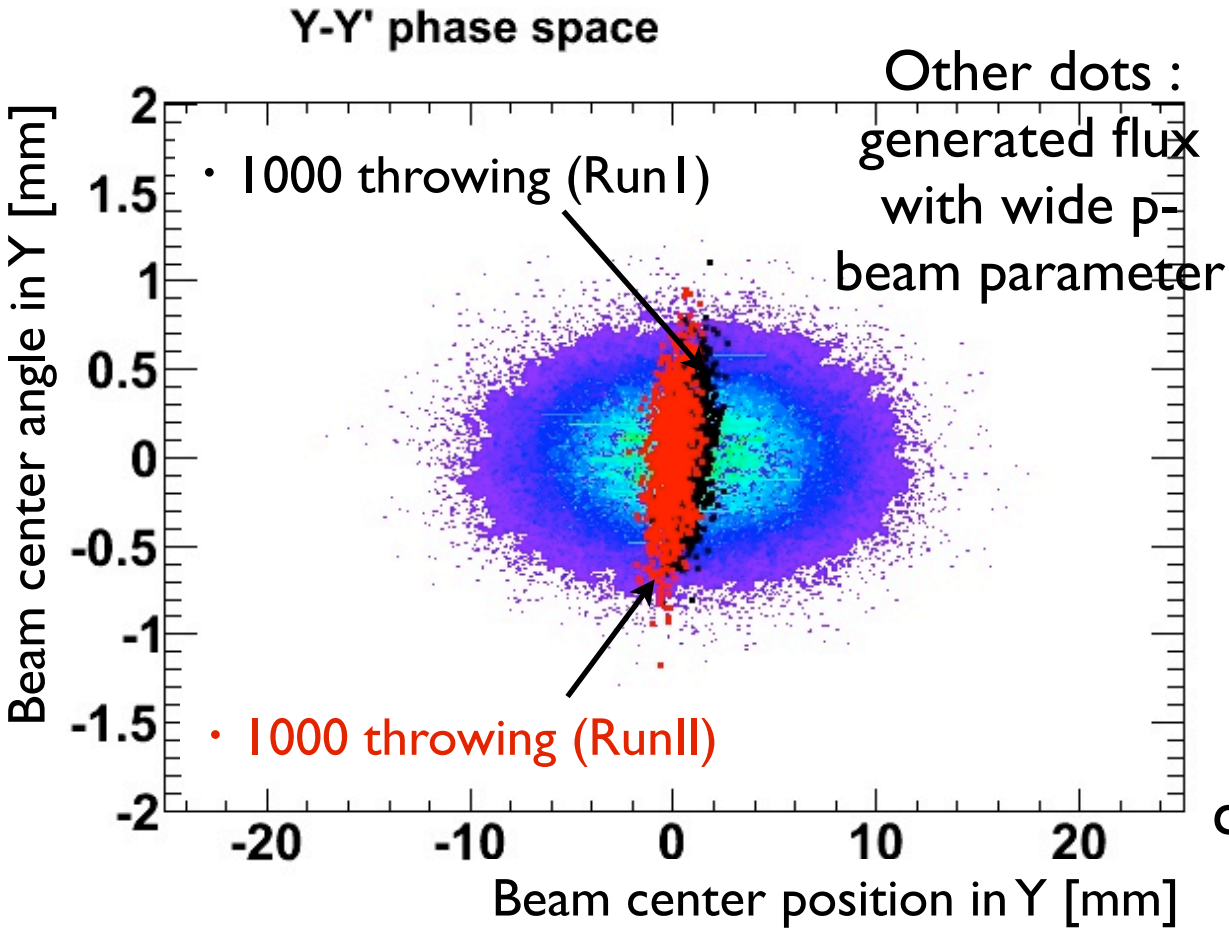
- Make 100 proton beam throws which change beam center/angle in Y by RunI proton beam average/uncertainty
- Re-weight flux generated w/ wide proton beam by 100 throws and calc. covariance/error

- Found 100 throws are not enough, increase # of throws (100 → 1000)
- Also flux uncertainty by using RunII proton beam uncertainty
- Check consistency b/w 10a method and JReWeight method (11av2.1)

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

Throw y-y' phase-space of RunI,II

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

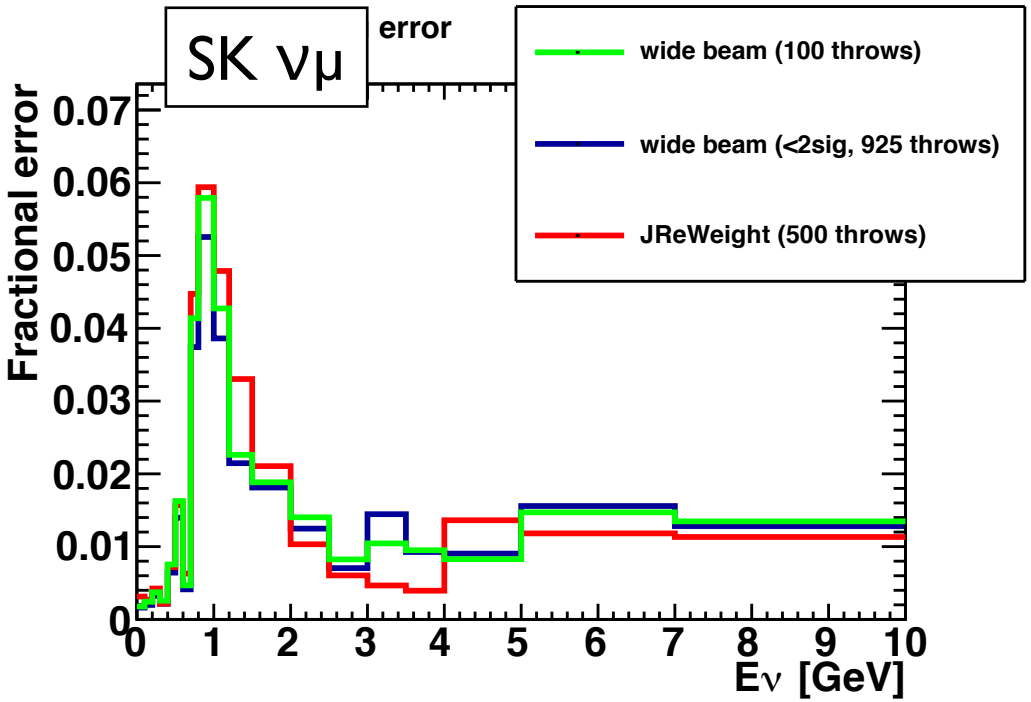


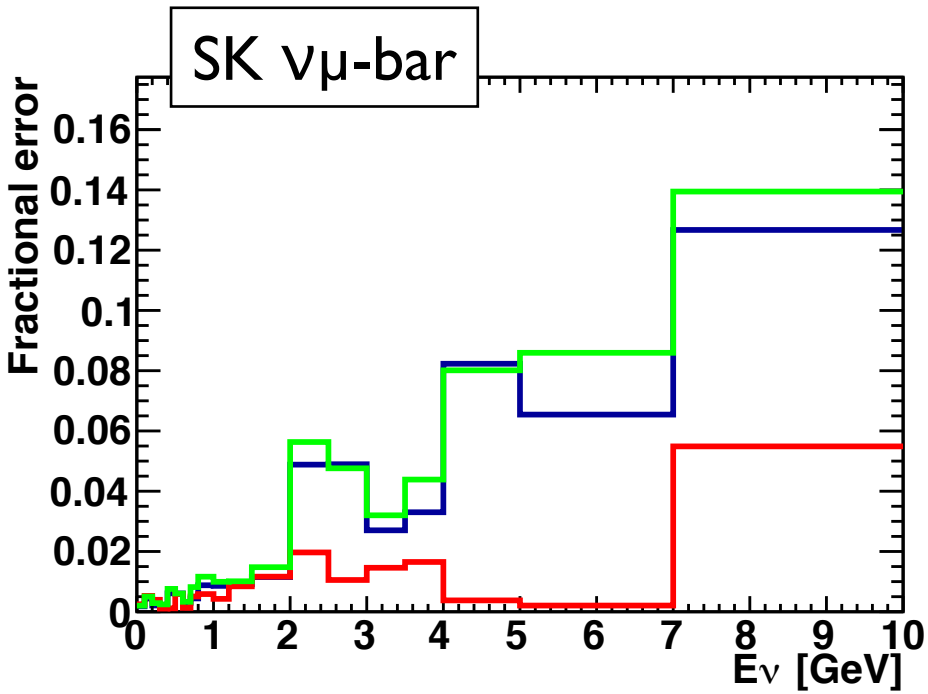
	r.m.s. of Y-Position [mm]	r.m.s. of Y-Angle [mrad]
RunI	**0.589**	**0.292**
Run2	**0.613**	**0.321**
wide beam flux	**4.146**	**0.299**

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

- Discard throwing samples with too far Y-angle (>2sigma) to estimate uncertainty
  - or more wider p-beam flux samples

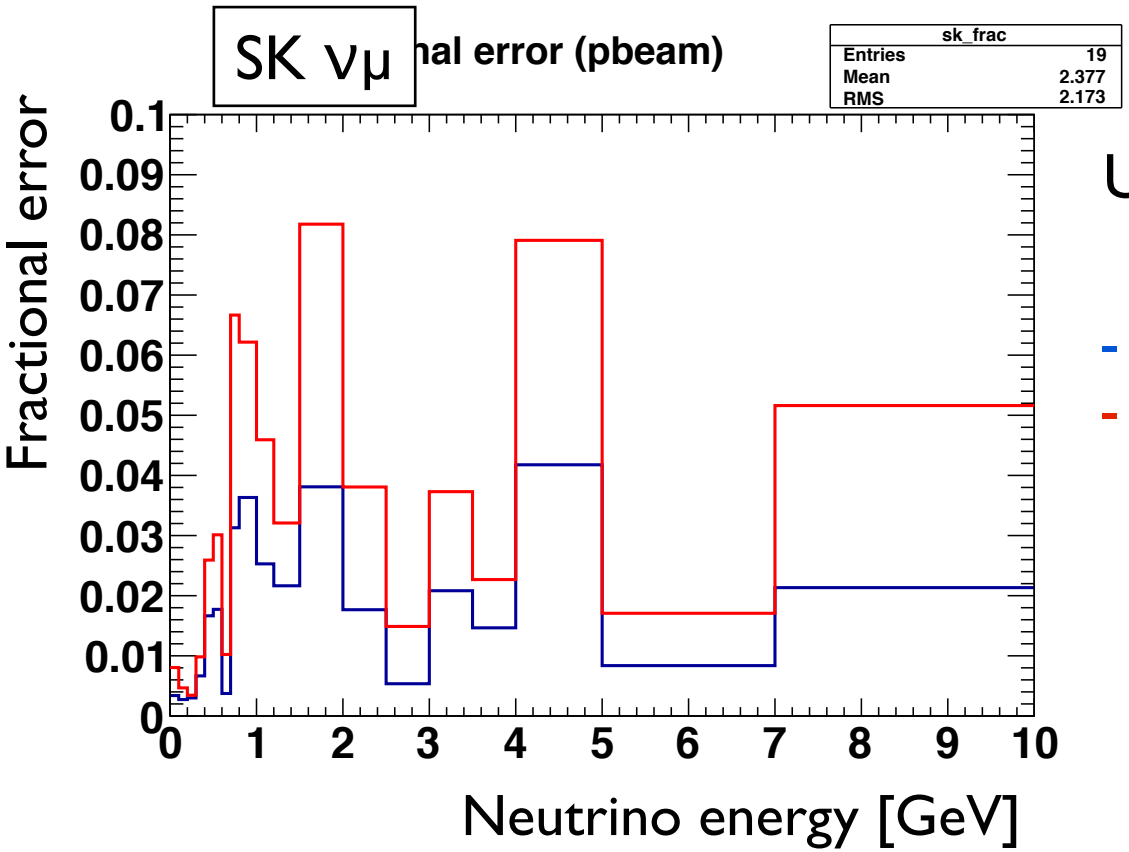
Flux uncertainty (w/ RunI)





- For SK νμ, three results seem to be consistent.
- For SK νμ, not consistent between the wide beam results and JReWeight → need more study.

Flux uncertainty (w/ RunII)



Use 1000 throws generated by RunII p-beam uncertainty

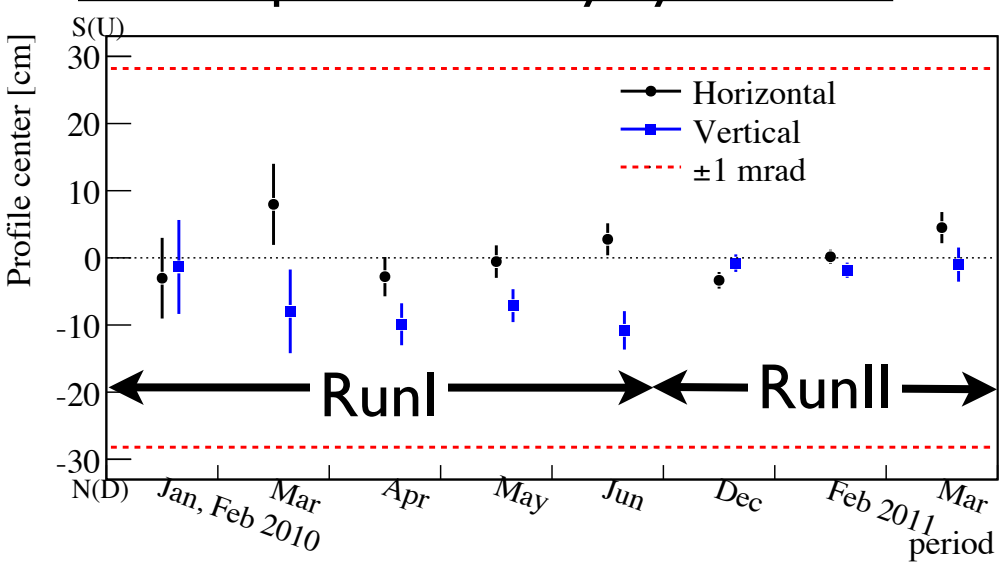
- Select p-beam < 1sigma(RunII)
- Select p-beam < 2sigma

- Need flux generated with more wider proton beam angle in Y
- Study still going on.

Off-axis angle uncertainty

- 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

Update of off-axis angle

Beam profile center in RunI for 2010a flux uncertainty

	x	y
Profile center (cm)	$0.2 \pm 1.4(\text{sta.}) \pm 9.2(\text{sys.})$	$-6.6 \pm 1.5(\text{sta.}) \pm 10.4(\text{sys.})$
Beam direction (mrad)	$0.01 \pm 0.05(\text{sta.}) \pm 0.33(\text{sys.})$	$-0.24 \pm 0.05(\text{sta.}) \pm 0.37(\text{sys.})$

Beam profile center in INGRID technote (#41, v7.2)

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

- Difference of RunI beam profile center between two tables. → Values in INGRID latest technote are correct.
- Correct values written in technote#54 (“Beam update for 2010a”), but used values for 2010a flux uncertainty are still old (incorrect).
  - Transfer of information might not work well.

Estimate flux uncertainty by using corrected off-axis angle uncertainties

Conformation of beam center

- Re-calculate the beam profile center by myself by the same # of INGRID observation as Otani-san's → Consistent w/ Otani-san's.
- Re-estimate the syst. error of beam center by myself by the same method as Otani-san's → same as Otani-san's.

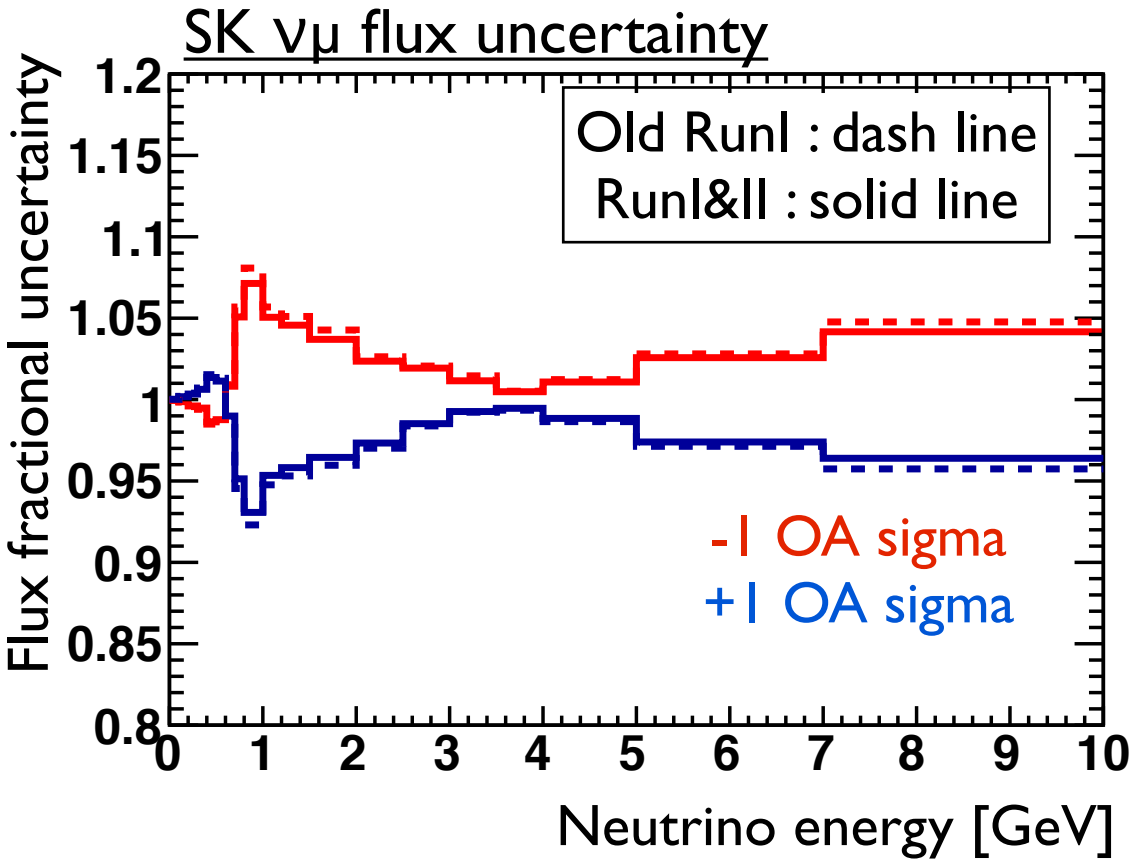
Beam center measurement of INGRID

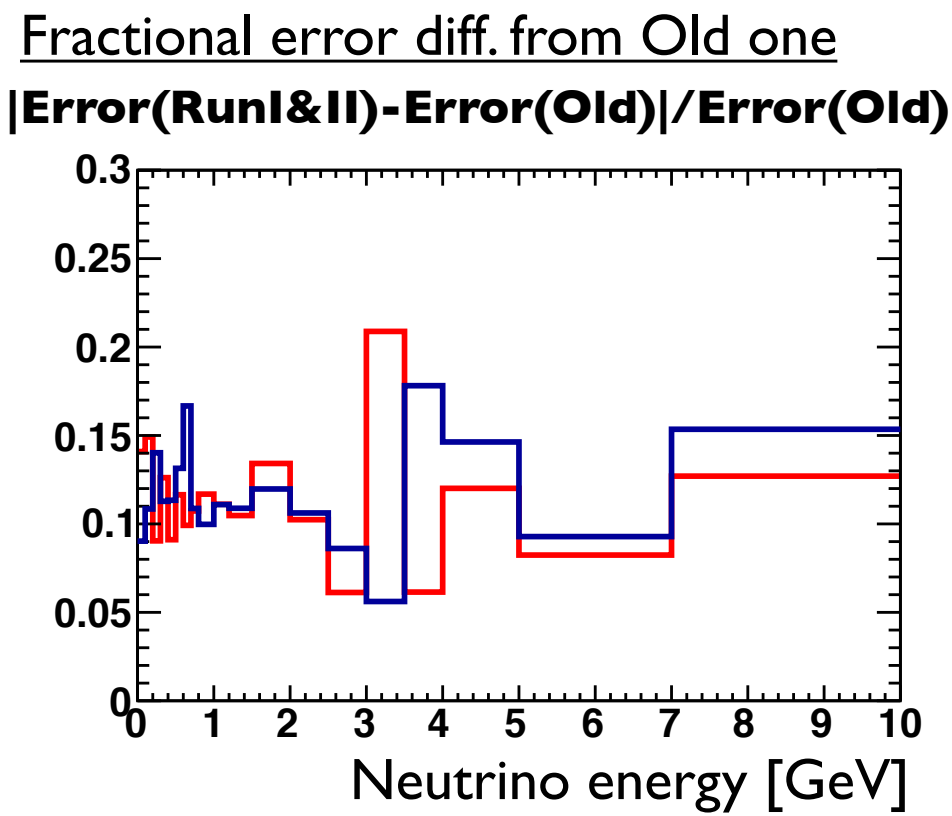
	X center [cm]	Y center [cm]
2010a	0.2 ± 1.4 ± 9.2	-6.6 ± 1.5 ± 10.4
RunI only	0.40 ± 1.39 ± 9.32	-8.59 ± 1.51 ± 10.14
RunII only	-0.71 ± 0.76 ± 9.25	-1.36 ± 0.82 ± 10.17
RunI&II	-0.45 ± 0.67 ± 9.26	-3.00 ± 0.72 ± 10.17

Off-axis angle uncertainty from INGRID measurement

	OA angle uncertainty [mrad]	Diff. from 2010a
2010a	0.44	
RunI only	0.47	0.07
RunII only	0.37	-0.16
RunI&II	0.38	-0.14

Updated flux uncertainty (RunI&II)



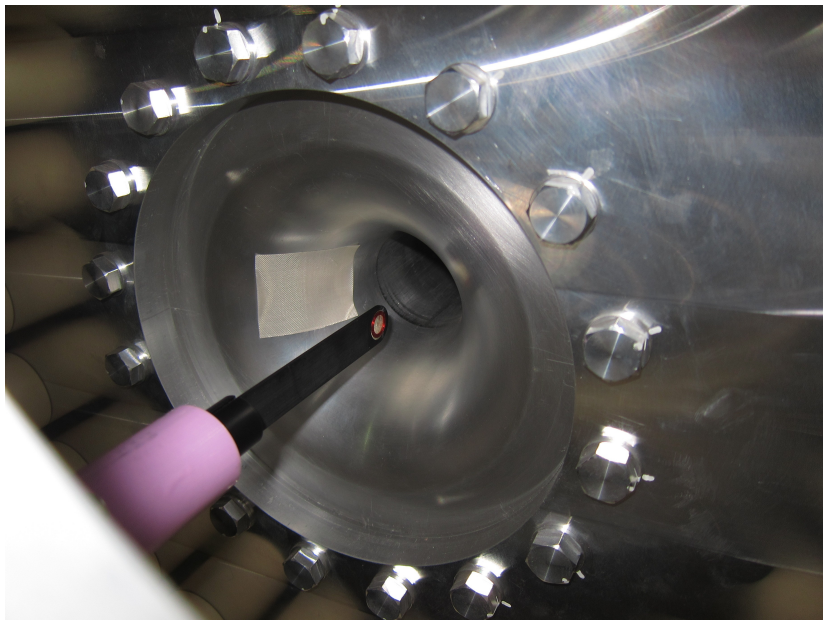


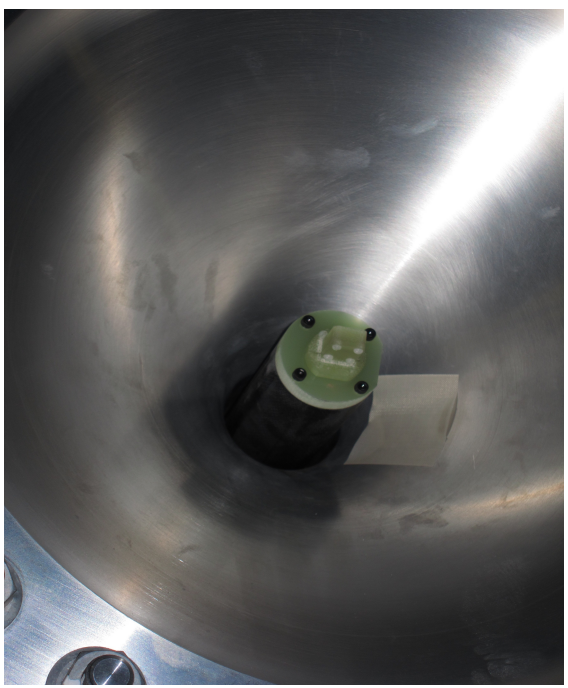
- Off-axis uncertainty decreases from Old to RunI&II : -14% → Flux uncertainty decrease in similar to off-axis uncertainty change
  - For ND νμ, flux uncertainty also decrease by this level

Spare Horn 1 Field measurements

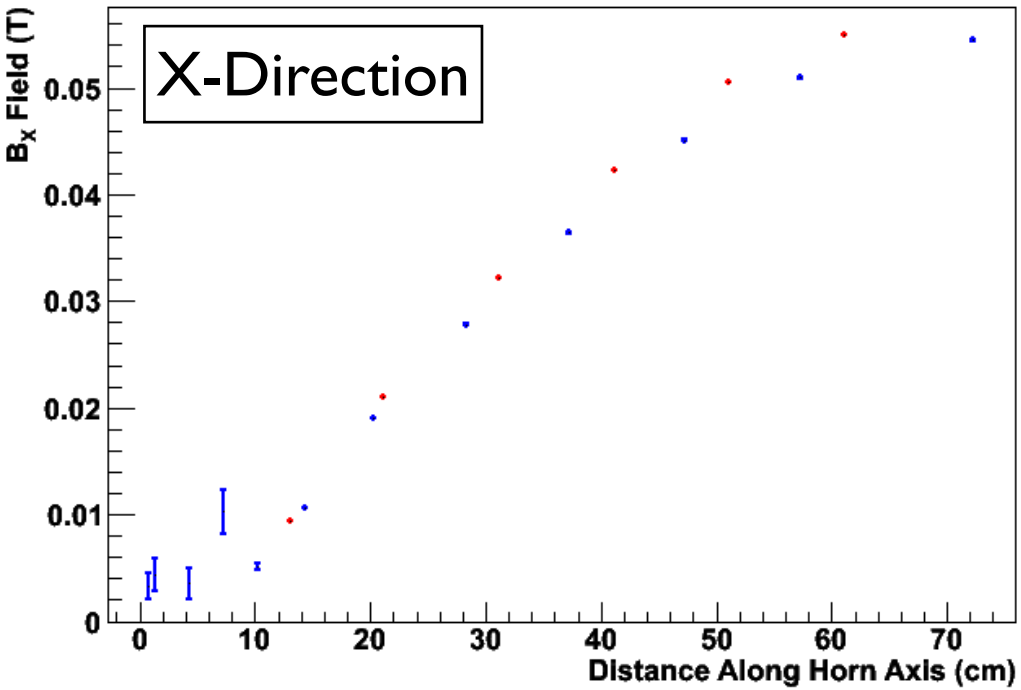
Andrew Missert

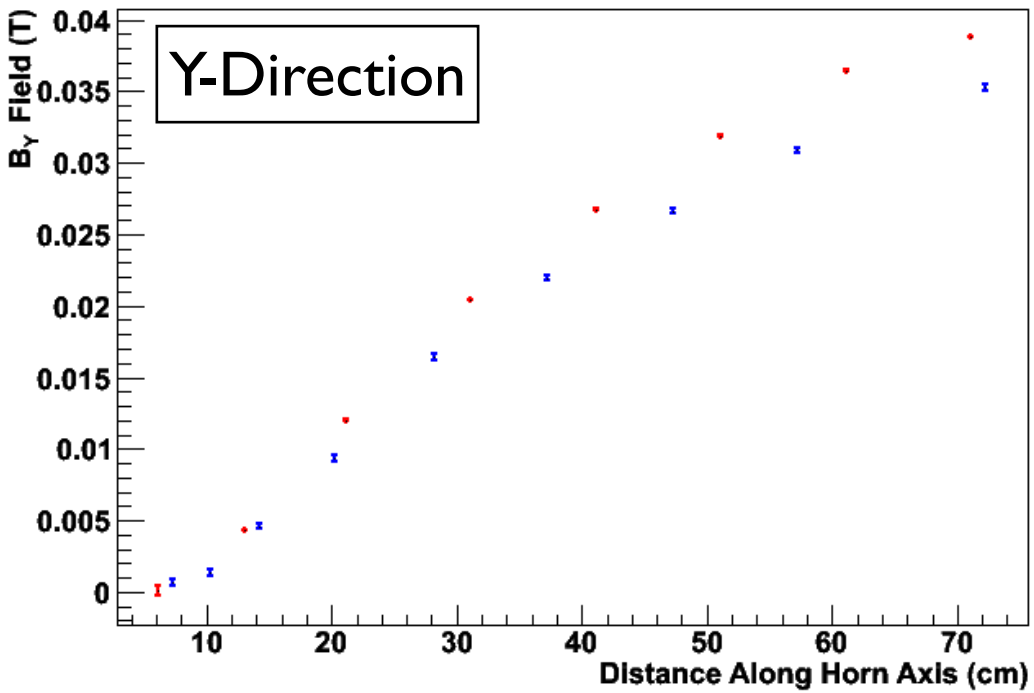
- Three times measurements of spare horn 1 field in this year (8/9-10, 9/30, 10/27-28)
- New measurements : October 2011 Measurements
  - New equipment:
    - Pickup Coil
    - Longer probe mount (2m) for on-axis measurements
  - Field measurements taken:
    - On-axis w/ pickup coil on 1m probe mount)
    - On-axis w/ Hall probe on 2m probe mount
    - Off-center on-axis w/Pickup coil on 1m probe mount





On-Axis Pickup Coil Measurements

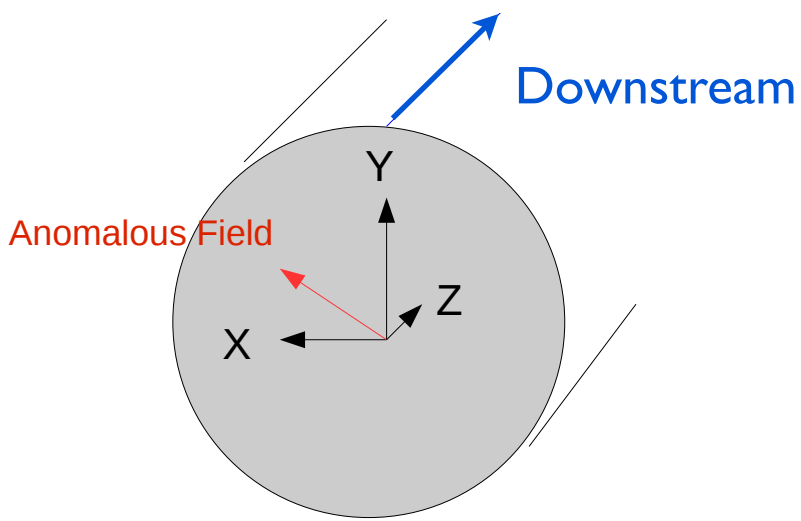




3-Axis Hall Measurements (September)

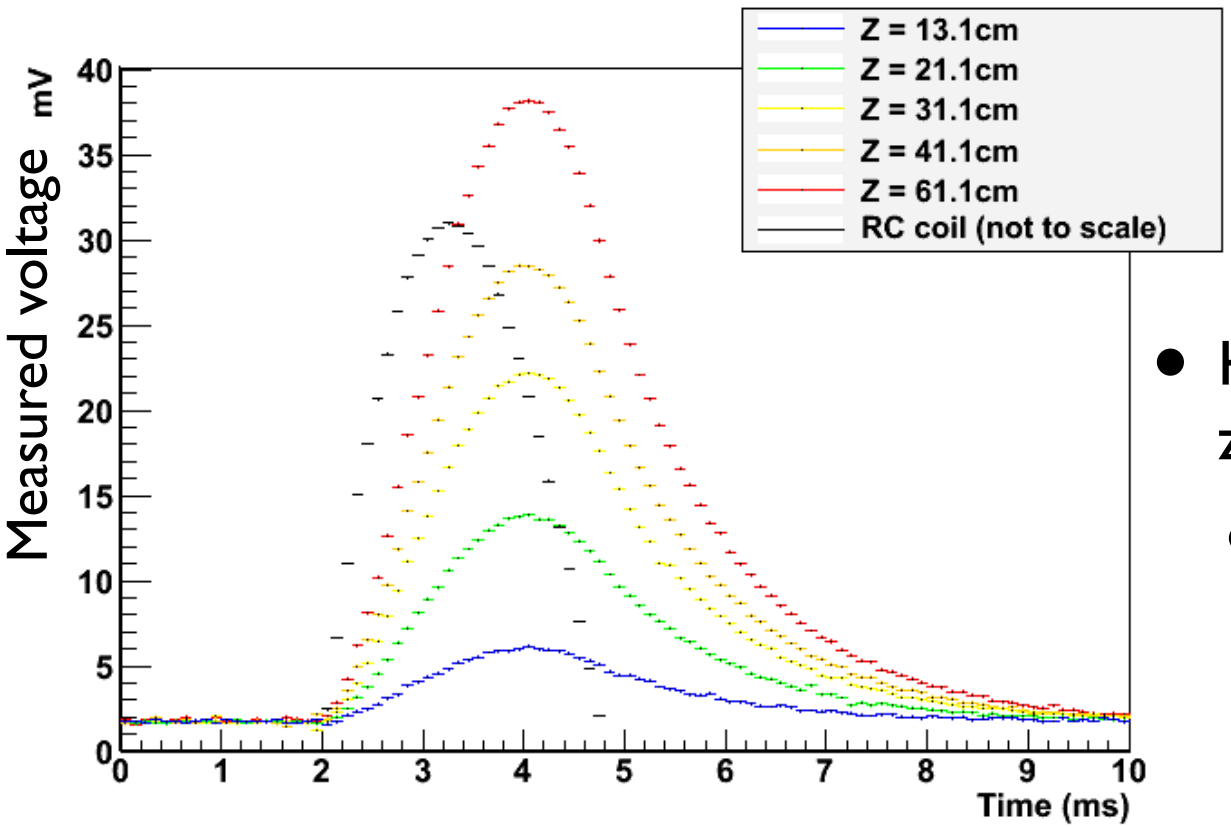
Pickup Coil Measurements (October)

- Dependence with the distance from center of B field observed



On-axis Coordinate Definitions

On-Axis Pickup Coil Measurements



- Horn current measured at each z-position with pickup coil
  - Compare to hall probe measurement (RC coil)

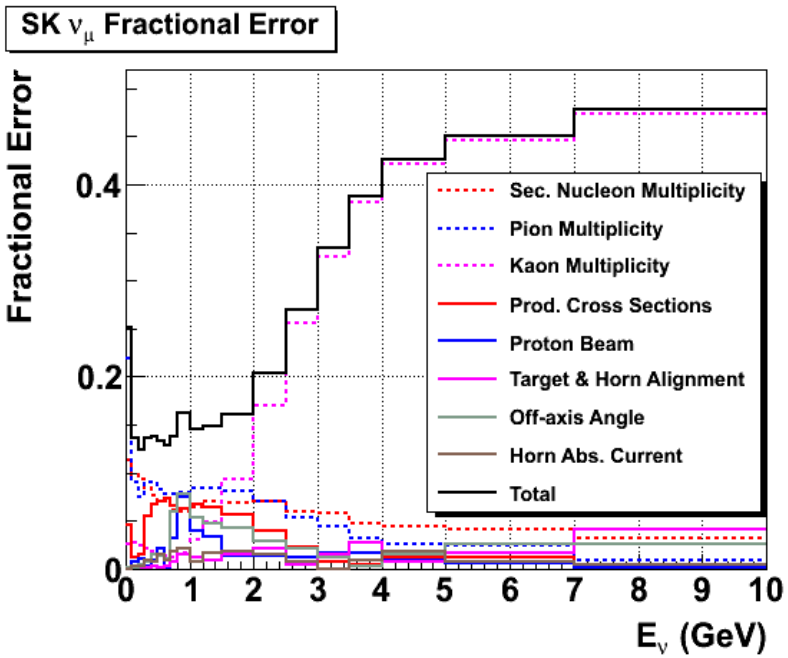
- As with Hall probe measurements, peak offset of 0.76ms is observed.
  - Now investigate the reason of this dependence

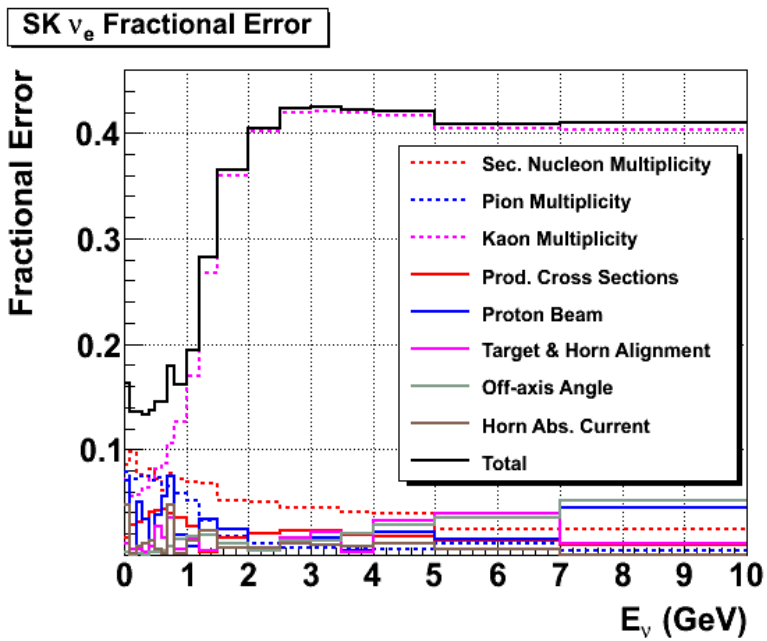
Summary

- Again, hope to release the next flux uncertainty based on 11av2 tuned flux (11av2.2) by the next collaboration meeting
- Now some studies are going on to update flux uncertainties
  - More study for proton beam flux uncertainty
  - Update of off-axis angle flux uncertainty almost done
    - Apply the result from RunI&II.
  - Hope to reflect horn field study on the 11av2.2

back up

2010a flux uncertainty





SK and ND inputs.

	Percent Errors in Far Near Ratio			
Source	(1 Ring μ)/ND	(ν_e Sig.)/ND	(ν_e Bgnd.)/ND	(ν_e Tot.)/ND
Pion Multiplicity	1.88 (4.41)	3.41 (10.70)	2.29 (5.55)	3.04 (9.10)
Tertiary Pion scaling	0.37 (–)	0.08 (–)	0.28 (–)	0.13 (–)
Kaon Multiplicity	4.29 (4.90)	8.65 (9.64)	7.68 (7.17)	7.30 (7.88)
Prod. Cross Sections	0.50 (0.16)	3.68 (4.03)	0.92 (0.67)	2.54 (2.84)
Sec. Nucleon Multiplicity	0.55 (–)	0.85 (–)	1.36 (–)	0.87 (–)
Proton Beam	0.43 (0.39)	1.15 (1.11)	2.13 (2.06)	1.39 (1.35)
Off-axis Angle	0.52 (0.53)	0.56 (0.61)	0.54 (0.58)	0.56 (0.60)
Target Alignment	0.08 (0.07)	0.34 (0.34)	0.21 (0.21)	0.31 (0.31)
Horn Alignment	0.05 (0.05)	0.16 (0.17)	0.10 (0.10)	0.15 (0.15)
Horn Abs. Current	0.39 (0.38)	0.76 (0.77)	0.24 (0.24)	0.63 (0.64)
Total	4.82 (6.64)	10.15 (15.03)	8.48 (9.35)	8.52 (12.48)

How proton beam reweighting

- Evaluate the effect of y-y' uncertainty by the following PDF:

$$PDF(\bar{Y},\bar{Y}') = \frac{1}{2\pi\sigma_{\bar{Y}}\sigma_{\bar{Y}'}\sqrt{1-\rho^2}} \times \exp\left(-\frac{1}{2(1-\rho^2)}\left[\frac{\Delta^2_{\bar{Y}}}{\sigma^2_{\bar{Y}}} + \frac{\Delta^2_{\bar{Y}'}}{\sigma^2_{\bar{Y}'}} - \frac{2\rho\Delta_{\bar{Y}}\Delta_{\bar{Y}'}}{\sigma_{\bar{Y}}\sigma_{\bar{Y}'}}\right]\right)$$

  - Δ_Y = diff. from the mean of proton beam position
  - $\Delta_{Y'}$ = diff. from the mean of proton beam angle.

- Each entry of wide beam flux is weighted the following factor :

PDF(Run1 average + varied Y-Y') / PDF(wide proton beam)

  - Y and Y' are varied within the measured uncertainty of the proton beam in Run1 (or Run2) (according to Gaussian)

Schematic view of the beamline axis and the Super-K direction