Flux syst. error due to off-axis angle uncertainty

A.Murakami

Motivation

- Current flux syst. error due to off-axis angle uncertainty is calculated based on RunI data.
  - Matsuoka-san estimated this value.
  - We use this error for oscillation analysis because beam direction is conformed to be stable in RunI and RunII by INGRID measurement.
- Calculate the syst. error in only RunI, only RunII, RunI&II to estimate more precise flux uncertainty.

Used current Off-axis error

Beam center summary of RunI in Matsuoka-san's doctor thesis
(Current error is estimated by him)

Table D.2: Mean neutrino beam direction measured by INGRID during the physics run (in the INGRID coordinate system).

	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)	$0.01 \pm 0.05(\text{sta.}) \pm 0.33(\text{sys.})$	$-0.24 \pm 0.05(\text{sta.}) \pm 0.37(\text{sys.})$

These values are estimated based RunI data
→ Need update by using RunII data.

Current INGRID measurement error

INGRID technical note (v7.2)

Table 5.1: Summary of the beam center measurements by INGRID

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

The definition of table value:

{Deviation of beam center from beam-axis}
± {Fit error of beam profile (w/ stat. error)} ± {Syst. error by ToyMC}

- I have some questions
  1. Beam deviation in RunI (={0.4, -8.6}) are different from one used for estimation of flux syst. (={0.2, -6.6})
  2. Syst. error of Y center in RunI only and in RunII only are not shown.
- I asked Otani-san about these questions.

Reply from Otani-san

1. "Beam deviation in RunI (={0.4, -8.6}) are different from one used for estimation of flux syst. (={0.2, -6.6})"
   - For Y-center, not included miss alignment (-1.9cm). Fix it.
   - Some parts are typo.
   - Old value may be used for Matsuoka-san's analysis.

Beam center summary (Run 29~34)in Matsuoka-san's doctor thesis

Table D.2: Mean neutrino beam direction measured by INGRID during the physics run (in the INGRID coordinate system).

	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 center summary (Run 29~34) in tech note (v5, 2011.1.19)

Table 5.1: Summary of the beam center measurements by INGRID

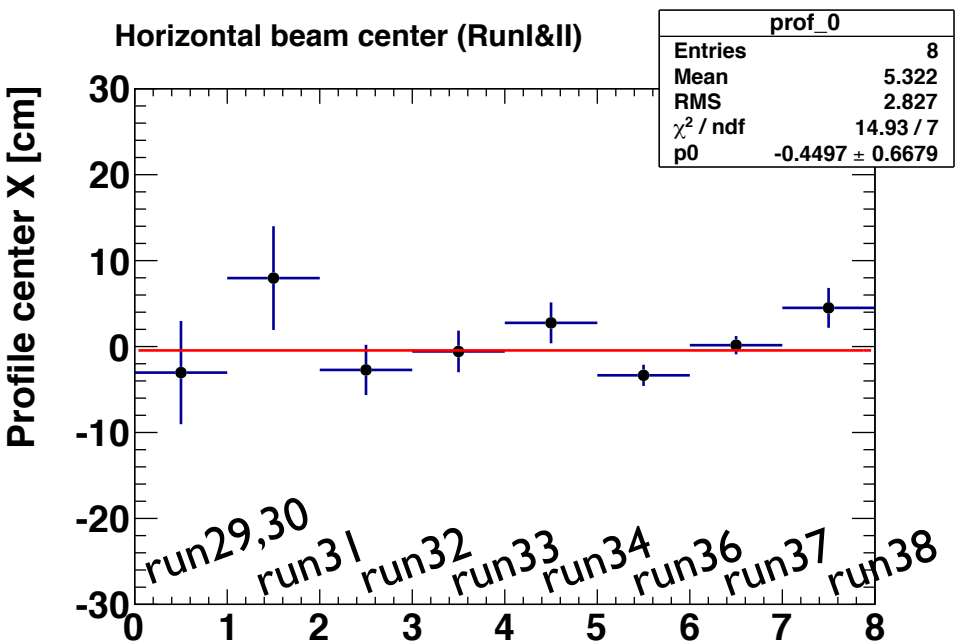
Beam center from the INGRID center	X center[cm]	Y center[cm]
Measurement	$+0.2 \pm 1.4 \pm 9.3$	$-6.6 \pm 1.5 \pm 10.5$

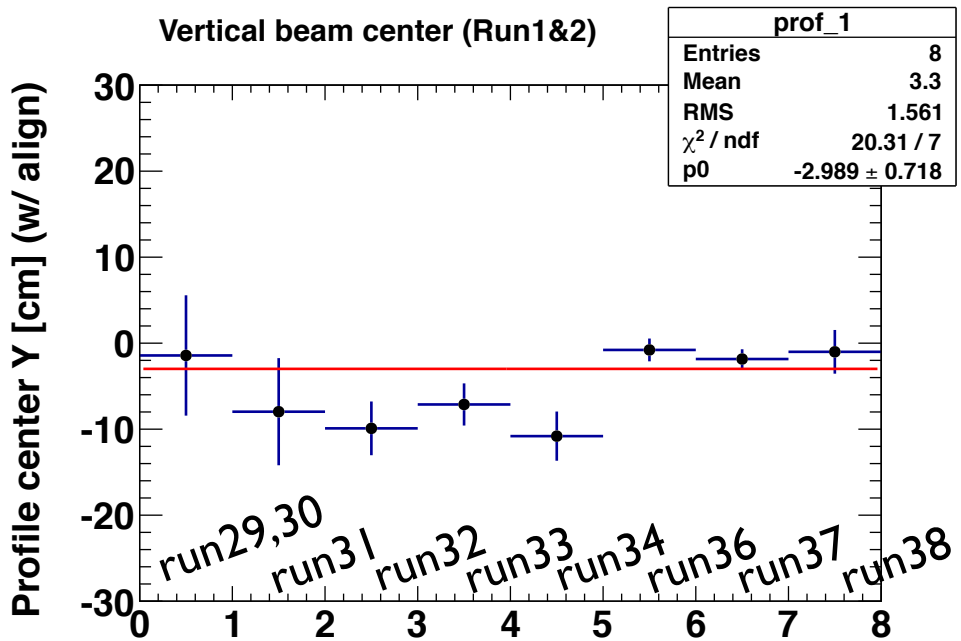
2. "Syst. error of Y center in RunI only and in RunII only are not shown."

→ Not yet estimated

Confirmation of beam center

I calc the beam center by INGRID beam data same as Otani-san's analysis for confirmation.





	X center [cm]	X error [cm]	Y center [cm]	Y error [cm]
RunI&II	-0.4	0.7	-3.0	0.7
RunI only	0.4	1.4	-8.6	1.5
RunII only	-0.7	0.8	-1.4	0.8

→ same as latest tech note value. OK

Estimate syst. error of beam center

- I estimate syst. error of beam center for only RunI measurement and only RunII.
- The basic method is same as Otani-san's analysis (thanks for Otani-san). → The detail is in next page.
  - # of observed events in INGRID are also same as Otani-san's.

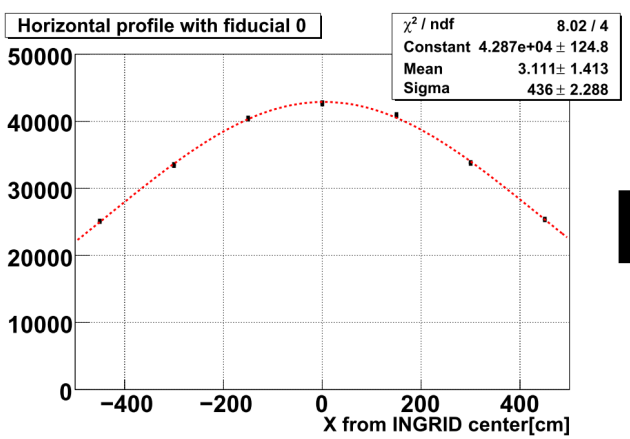
The method of estimation for systematic error of beam center

Otani-san' method

- $N_{obs.}$ systematic error of each module is already estimated. (now we neglect the errors of hadron production and x-section because it should be canceled at each module in 1st order)
- Make toy profile in which $N_{obs.}$ of each module is varied with the syst. error and fit the profile and get the center.

→ Make 10^5 toy profiles and the r.m.s. of reconstructed beam center distribution of 10^5 toy profiles.

Original(Run29 ~ 34)

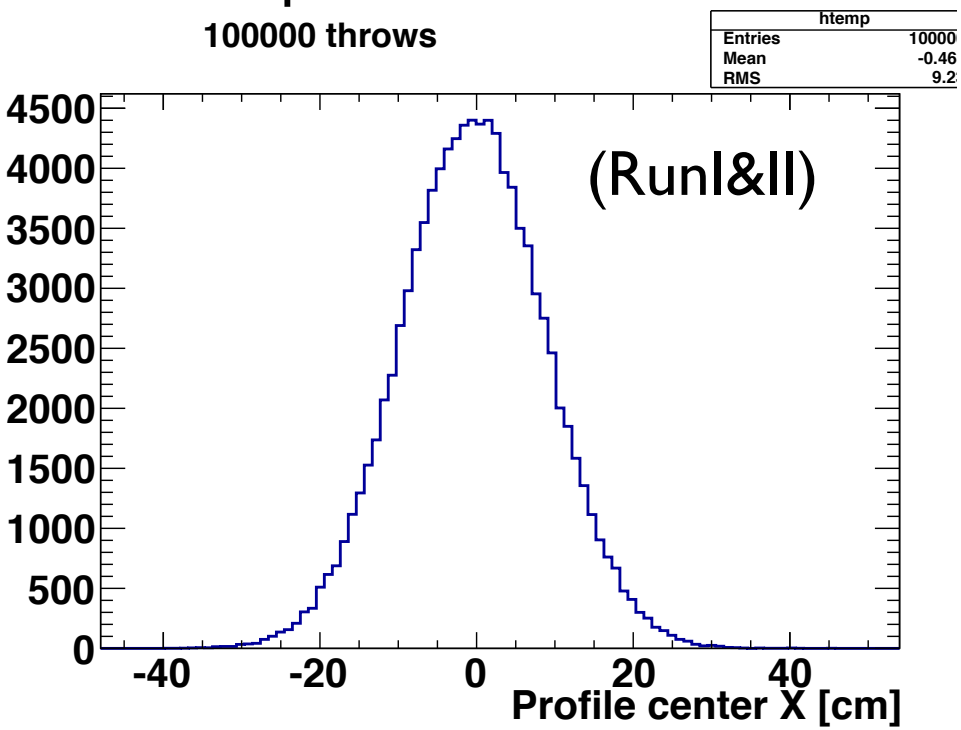


cont'd

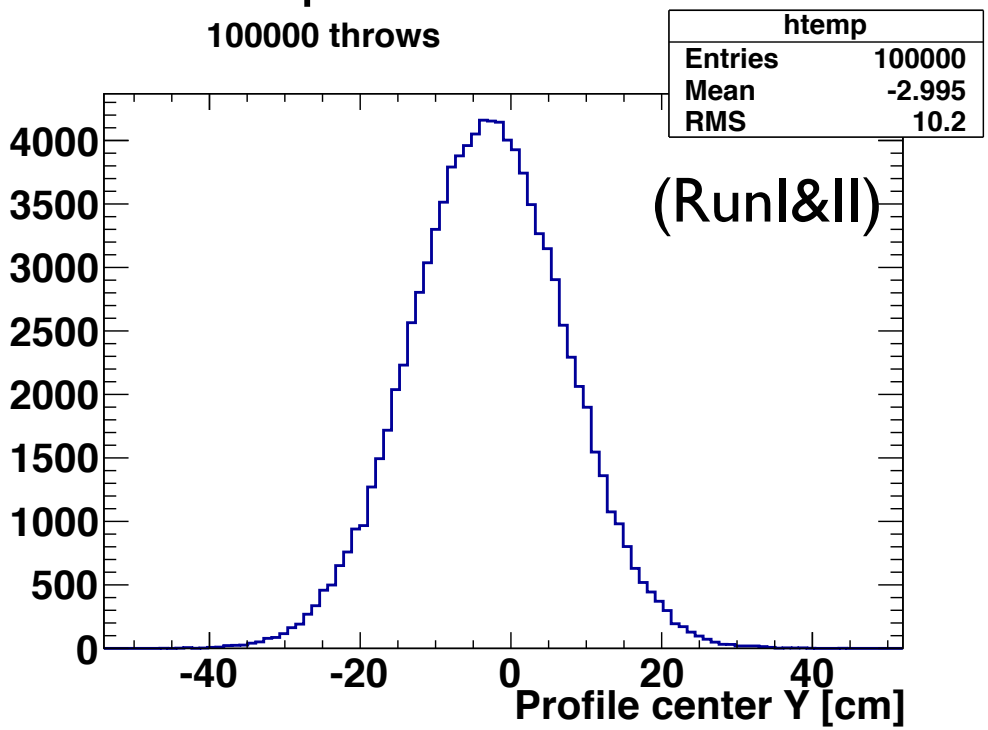
- Make toy profiles by using each Run period data.
- Use same method as Otani-san's analysis.
  - When fit toy MC profile w/ Gaussian, consider only MC stat. error for # of events of each module.

Results of fitting toy profile

Horizontal profile



Vertical profile



	X RMS [cm]	X RMS [cm]
RunI&II	9.3	10.2
RunI only	9.3	10.1
RunII only	9.2	10.2

~0.1cm difference from tech note value

Summary

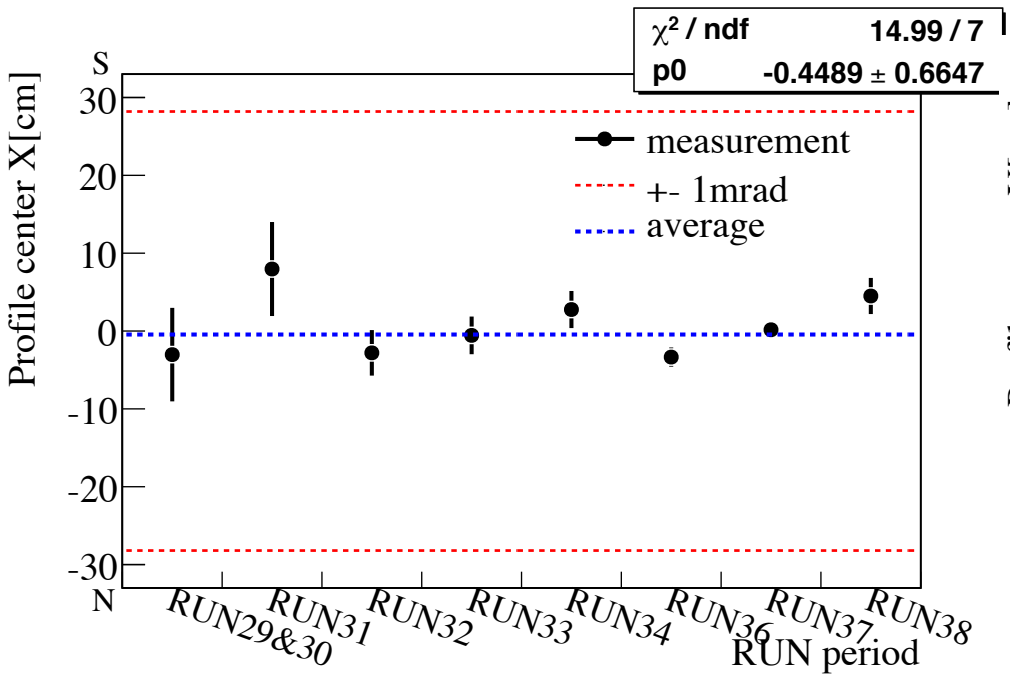
- I investigate update of flux syst. due to off-axis uncertainty
- Need to update the off-axis uncertainty estimated by INGRID measurement.
  - Calculate the syst. error in each Run period with same method as current INGRID analysis (Otani-san' method).
- Checking for confirmation is going on.
- After checking, I try to estimate flux syst. error in other Run periods with current same method and new off-axis uncertainties.

Supplyment

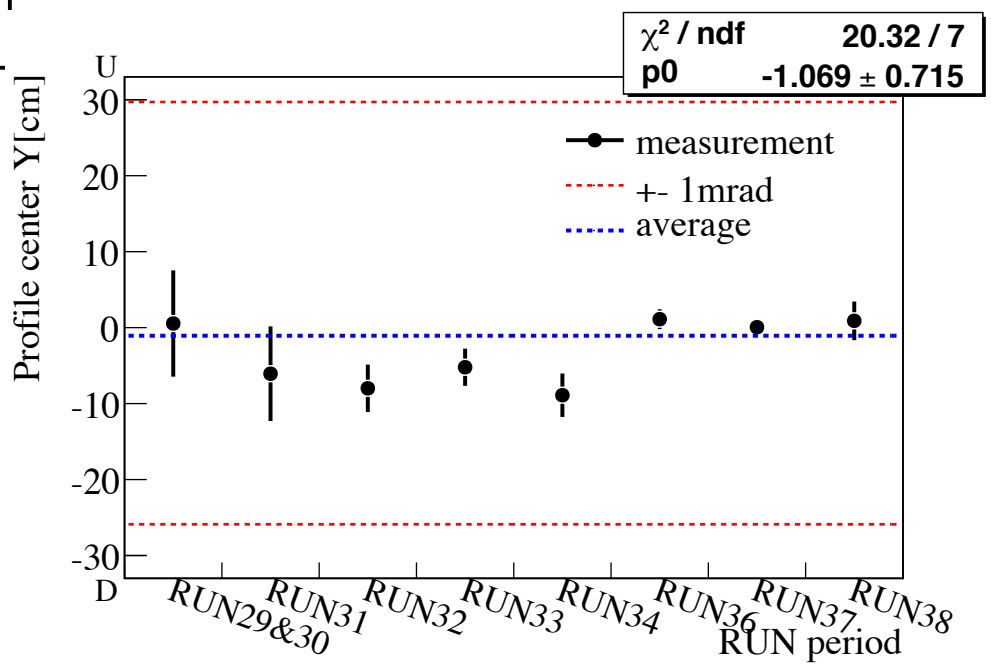
INGRID beam profile measurement

INGRID technical note (v7.2)

w/ only stat. error

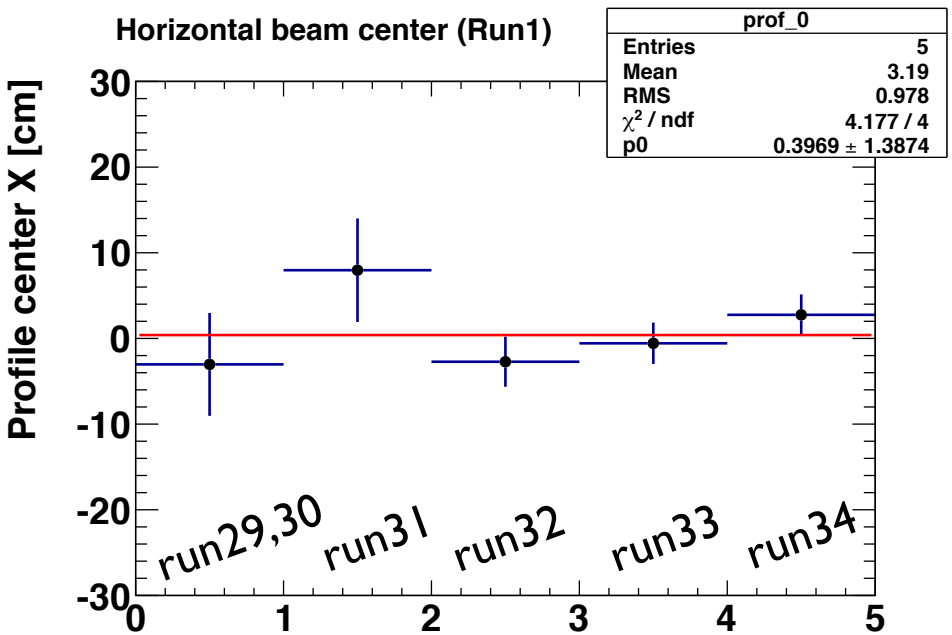


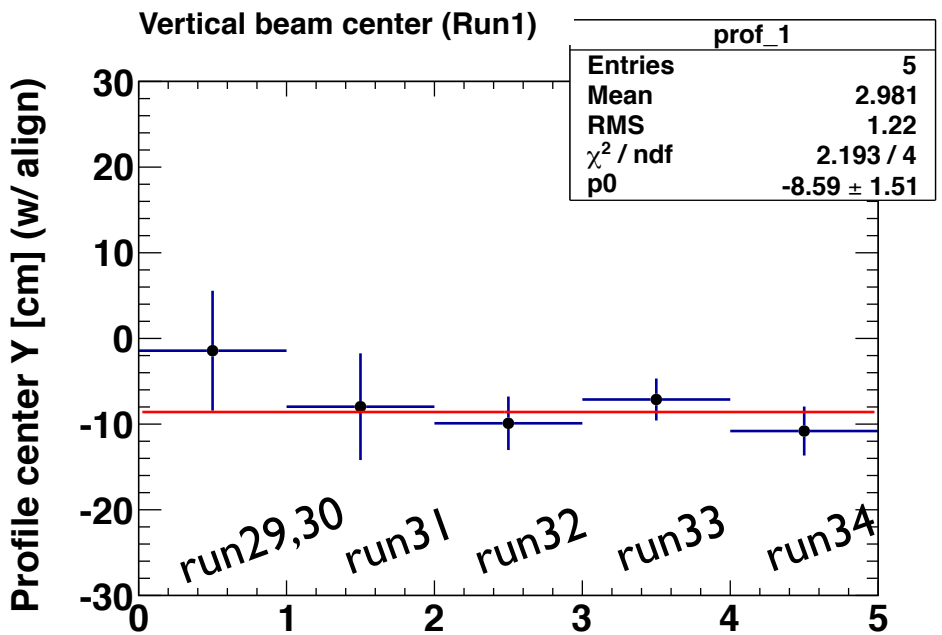
Horizontal profile center

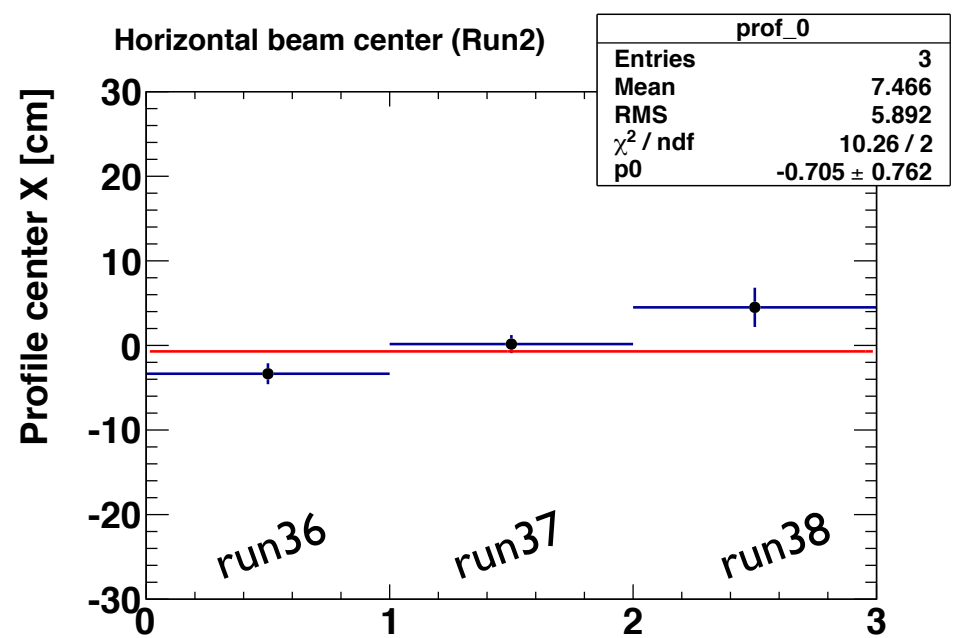


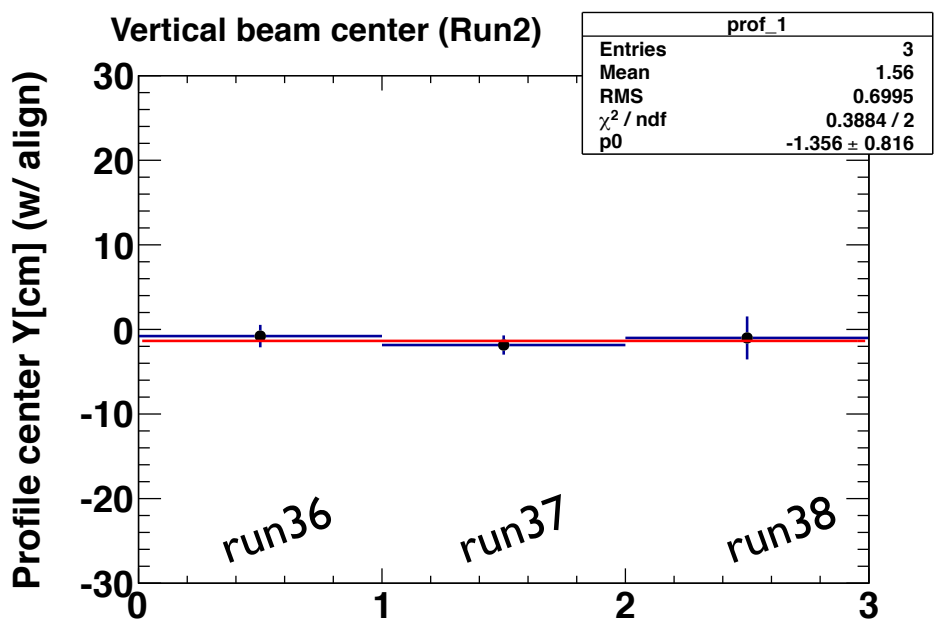
Vertical profile center

Beam center measurement







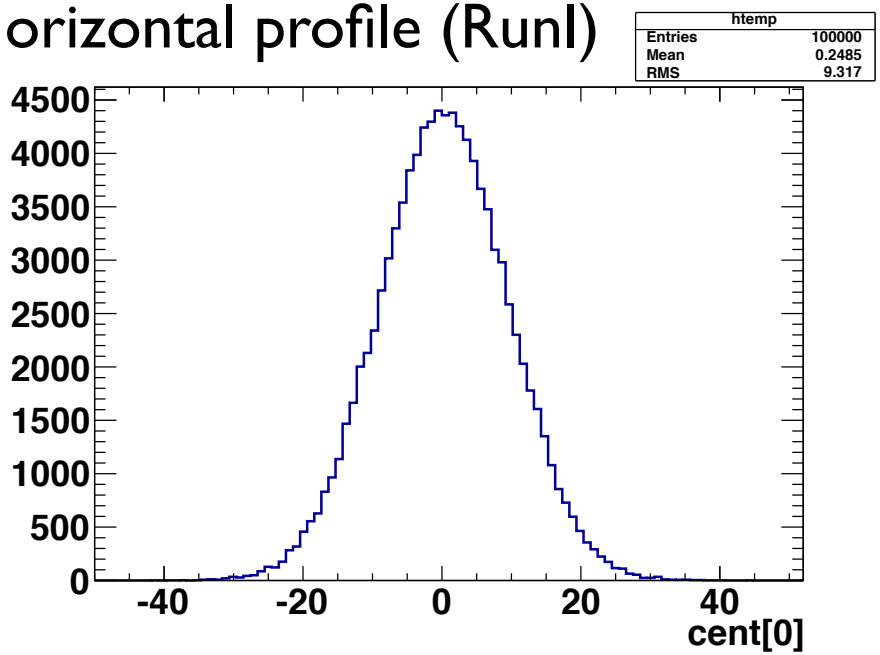


Beam center measurement

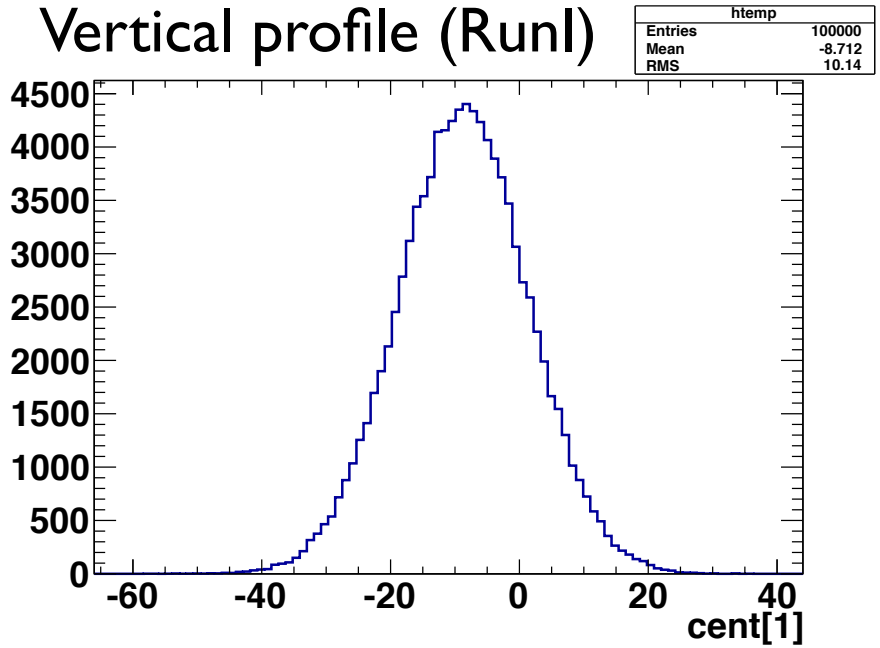
beam center	X center [cm]	X error [cm]	Y center [cm]	Y error [cm]
run29&30	-3.03	6.01	-1.43	7
run31	7.97	6.04	-7.98	6.22
run32	-2.72	2.92	-9.9	3.12
run33	-0.57	2.42	-7.13	2.45
run34	2.76	2.38	-10.8	2.86
run36	-3.35	1.24	-0.78	1.32
run37	0.16	1.06	0.16	1.13
run38	4.5	2.32	-1.01	2.54

Results of fitting toy profile

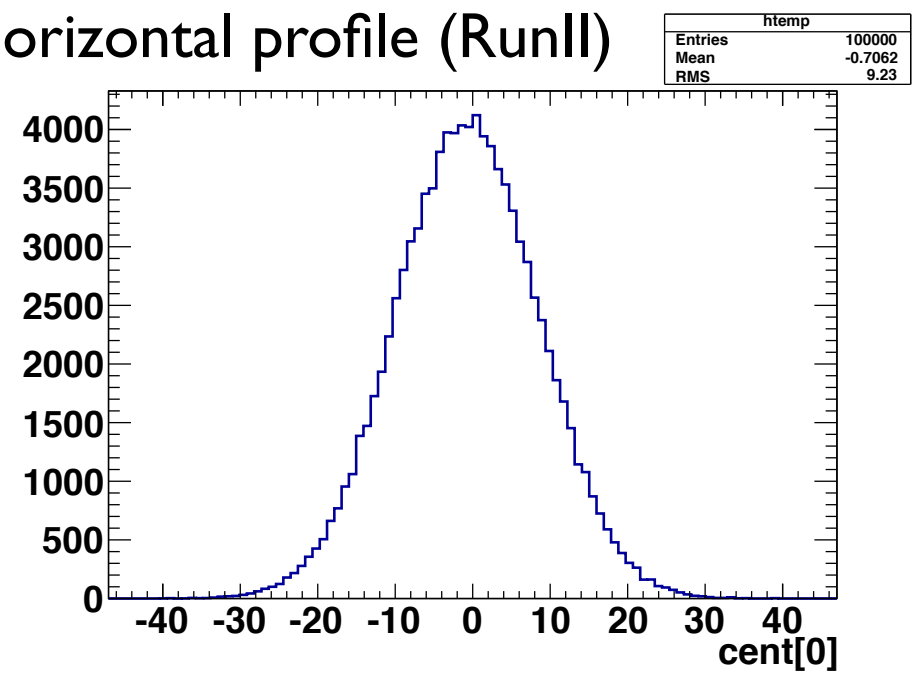
Horizontal profile (RunI)



Vertical profile (RunI)



Horizontal profile (RunII)



Vertical profile (RunII)