Beam monitor studies

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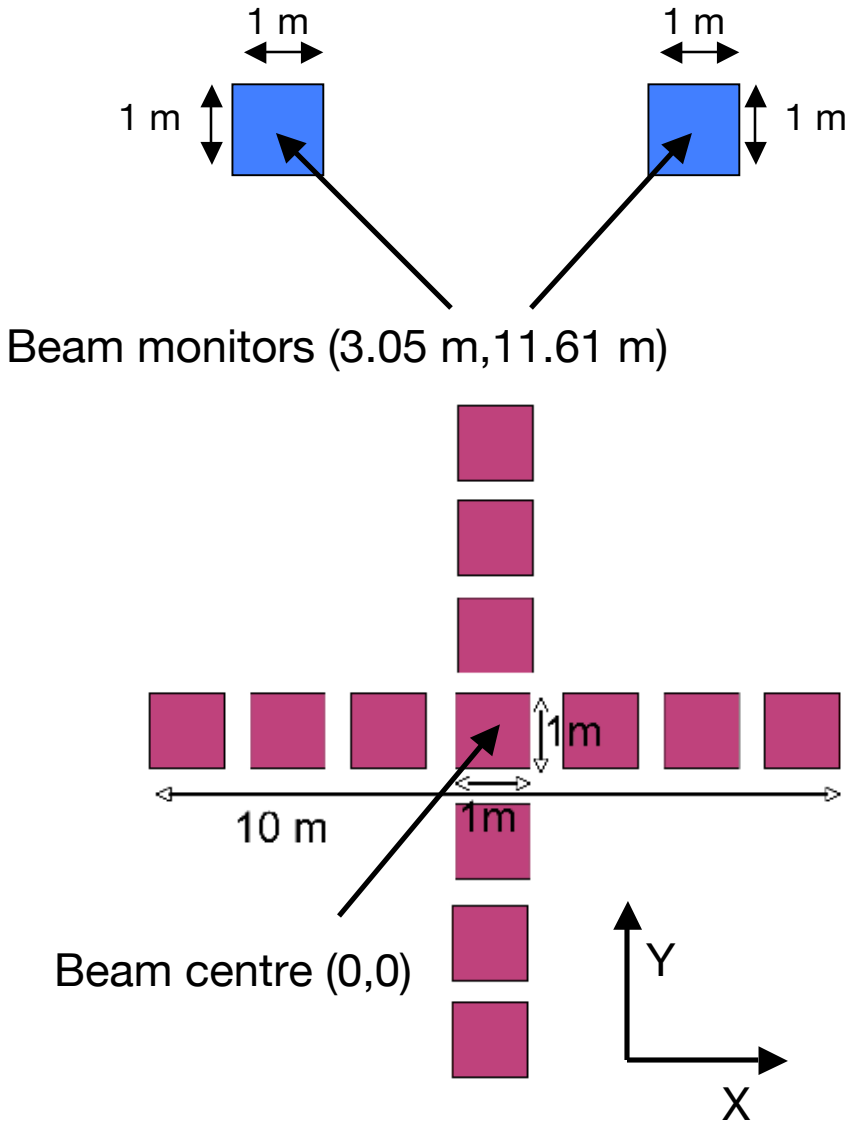
Detectors

- ✓ The 280m on axis detector is a cross 10 m large and 10 m high; each module (7 in a row) has a 1m x 1m area and a mass of 5 ton.
- ✓ The beam monitors are located at 11.61 m in Y direction (level of SK) and 3.05 m (- 3.05 m) in X direction (position of ND5). The mass is 5 ton.
- ✓ The number of p.o.t. used is 1E+20 (about 1 month).
- ✓ Only events with energy less than 5 GeV have been considered.



Expected events

CROSS	module 1 (1m x 1m, 5 ton)	module 2 (1m x 1m, 5 ton)	module 3 (1m x 1m, 5 ton)	module 4 (1m x 1m, 5 ton)
X direction (from centre outward)	411000	380000	302000	212000
Y direction (from centre outward)	411000	386000	317000	233000

BEAM MONITOR (1m x 1m, 5 ton)	41000

1E+20 proton on target.

Considered only events with energy less than 5 GeV.

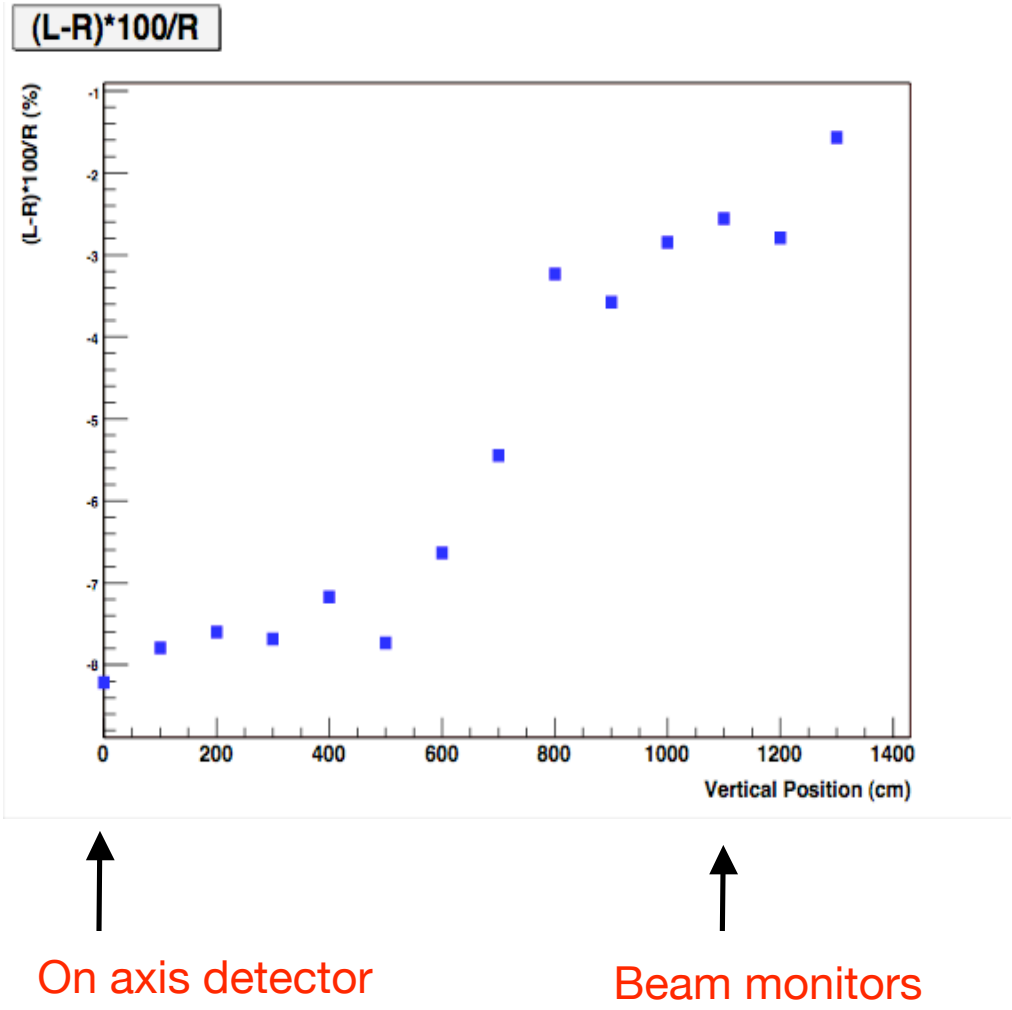
About 8 times less with respect to the 280m on axis detectors.

Asymmetry as a function of position

- ✓ The Left/Right asymmetry has been studied for a shift of the protons on target and for a shift of the horn number 2, as a function of the position of the beam monitor detectors.
- ✓ The X position was fixed (i.e. ±3.05 m which is the same value of ND5).
- ✓ The Y position spanned from 0 m (beam centre level) to 13 m.
- ✓ NOTE: Only for this study the mass of the detectors was set to 1 ton and the p.o.t. used was 1E+21.

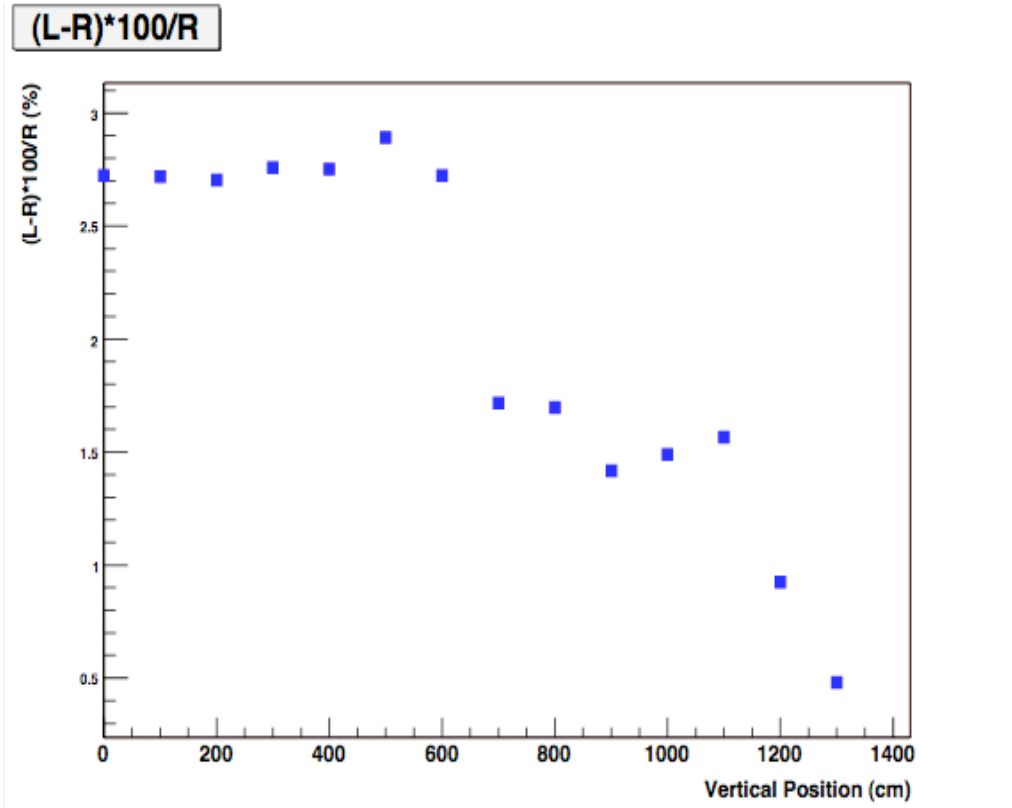
Test beam monitor at different heights
Shift protons 3mm left

HEIGHT	ANGLE (deg)	LEFT	RIGHT	L-R/R(%)
0 cm	3.637	577312	628997	-8.2
100 cm	3.432	561269	608693	-7.8
200 cm	3.228	516417	558876	-7.6
300 cm	3.023	451046	488588	-7.7
400 cm	2.819	378654	407893	-7.2
500 cm	2.614	307295	333043	-7.7
600 cm	2.409	248373	266026	-6.6
700 cm	2.205	198908	210370	-5.4
800 cm	2.000	160777	166148	-3.2
900 cm	1.796	130273	135107	-3.6
1000 cm	1.592	106043	109149	-2.8
1100 cm	1.387	89041	91377	-2.5
1200 cm	1.183	74278	76412	-2.8
1300 cm	0.979	63444	64455	-1.6



Test beam monitor at different heights
Shift horn2 3mm left

HEIGHT	ANGLE (deg)	LEFT	RIGHT	L-R/R(%)
0 cm	3.637	603047	587743	2.7
100 cm	3.432	585755	570246	2.7
200 cm	3.228	538785	524597	2.7
300 cm	3.023	472141	459467	2.8
400 cm	2.819	397316	386675	2.8
500 cm	2.614	322595	313539	2.9
600 cm	2.409	258130	251286	2.7
700 cm	2.205	205475	202006	1.7
800 cm	2.000	165173	162417	1.7
900 cm	1.796	133728	131858	1.4
1000 cm	1.592	109643	108034	1.5
1100 cm	1.387	91281	89873	1.6
1200 cm	1.183	76539	75837	0.9
1300 cm	0.979	64468	64160	0.5



On axis detector

Beam monitors

Remarks

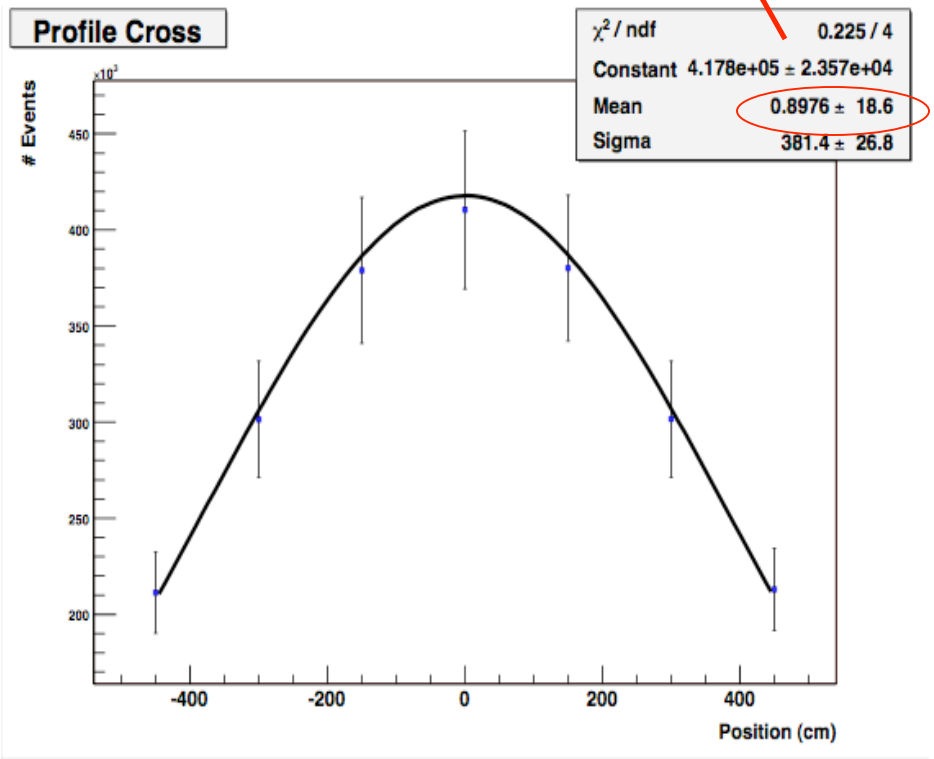
- ✓ Both in case of shift of the protons on target and shift of the horn, there is a “definite” trend of the L/R asymmetry as a function of the height.
- ✓ At the height of the beam monitor the asymmetry is less visible and there is about a factor 3 on the effect both for shifting of the protons and of the horns.
- ✓ The effect is smaller at larger values of Y since it depends on the difference on the radial distance from the beam centre between L and R position. This difference gets smaller the bigger the vertical Y coordinate is.

Detection of beam asymmetries

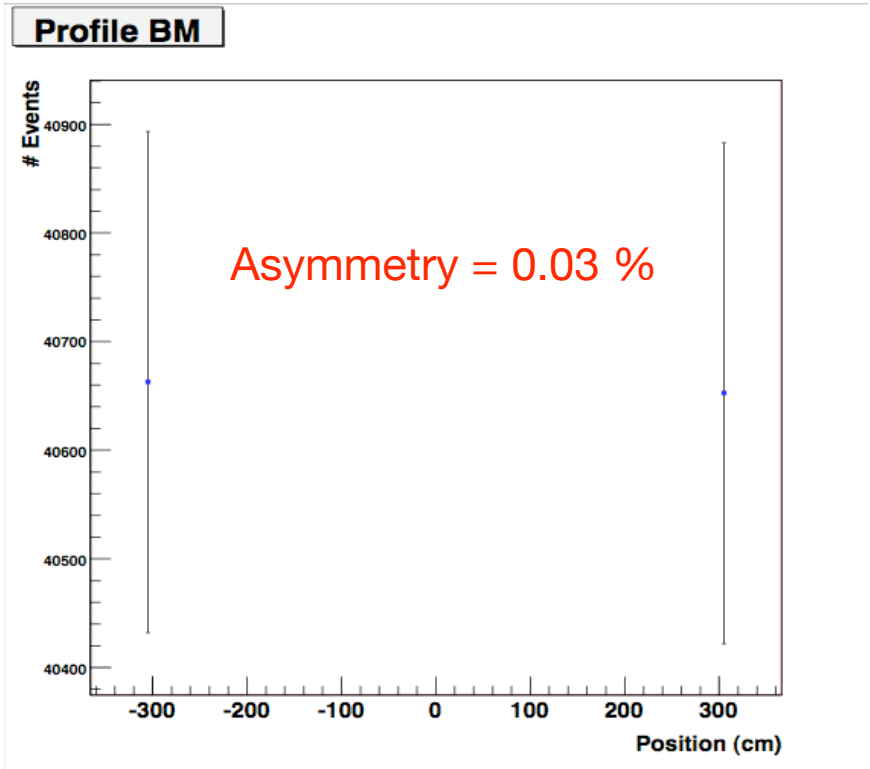
- ✓ The possibility to detect beam asymmetries using the on axis detector (cross) and the beam monitors has been investigated.
- ✓ In the measurement using the on axis detector, the beam profile on the X axis is measured with 7 detectors. The number of events in each one is measured and the 7 points are fitted with a Gaussian function.
- ✓ The error on the number of events measured in each detector is a sum of the real statistical one, the MC statistical one and 10% systematics due to intercalibration of the modules.
- ✓ In the measurement using the beam monitors, the Left/Right asymmetry between the two detector is measured.
- ✓ The error on the number of events measured in each detector is a sum of the real statistical one and the MC statistical one. **No systematics has been included** (Possibility to use one detector and slide it from left to right position?).

Beam Centred

Systematics = 10% ⇒ error = 18.6 cm
Systematics = 5% ⇒ error = 9.7 cm
Systematics = 2% ⇒ error = 3.9 cm



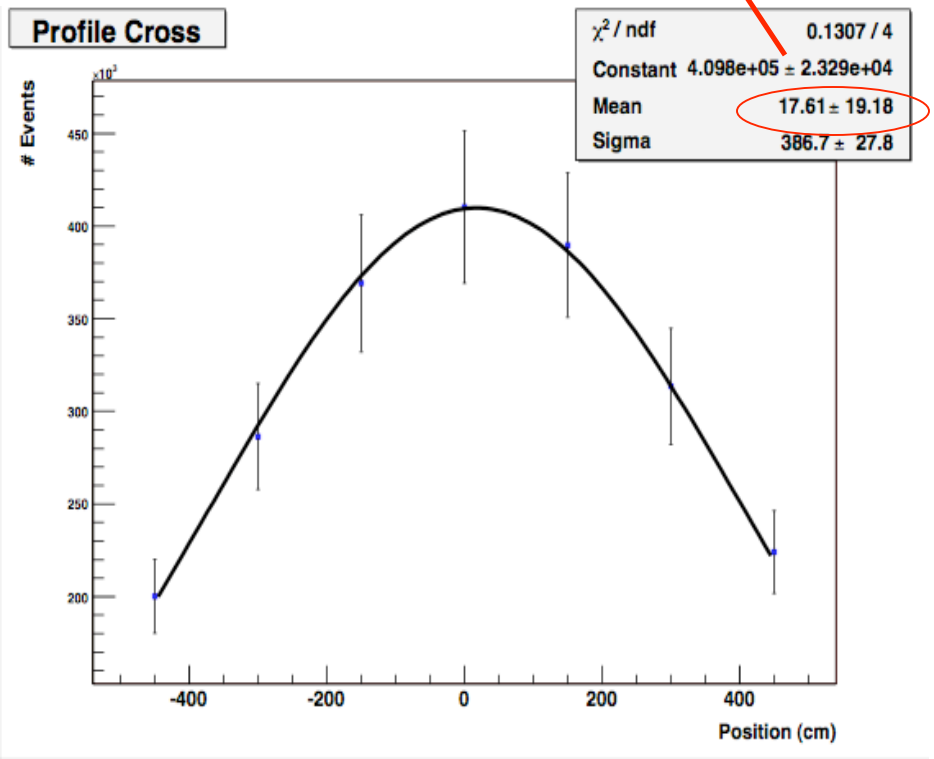
On axis detector



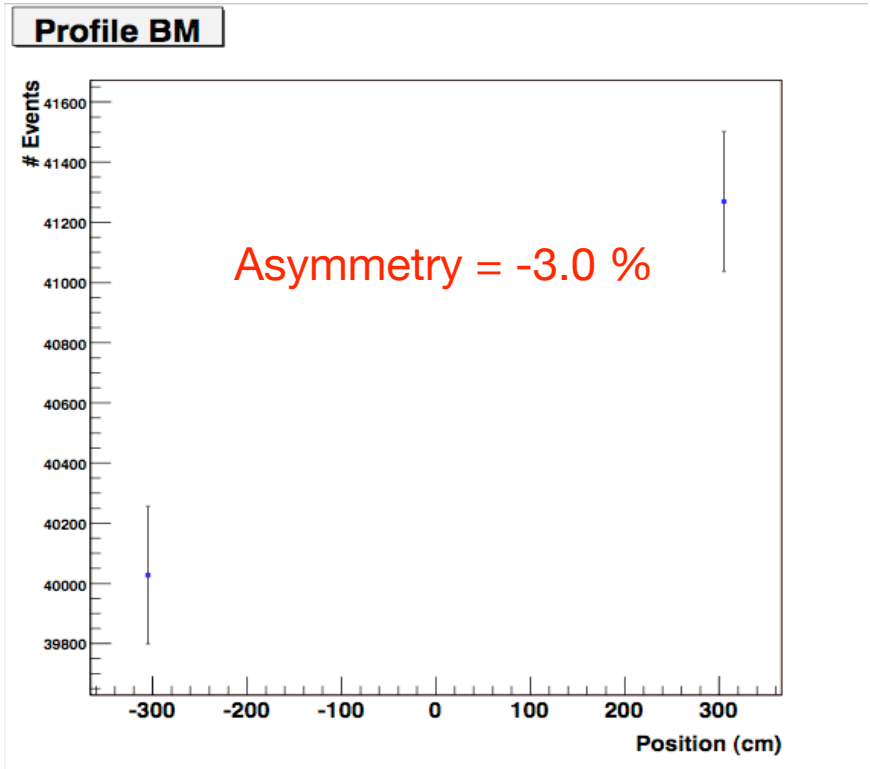
Beam monitor

Beam Shifted 3mm left

Given the error on the mean as a function of the systematics and a mean of about 18 cm for a shift of the beam of 3mm, the error on the intercalibration must be smaller than 10%.



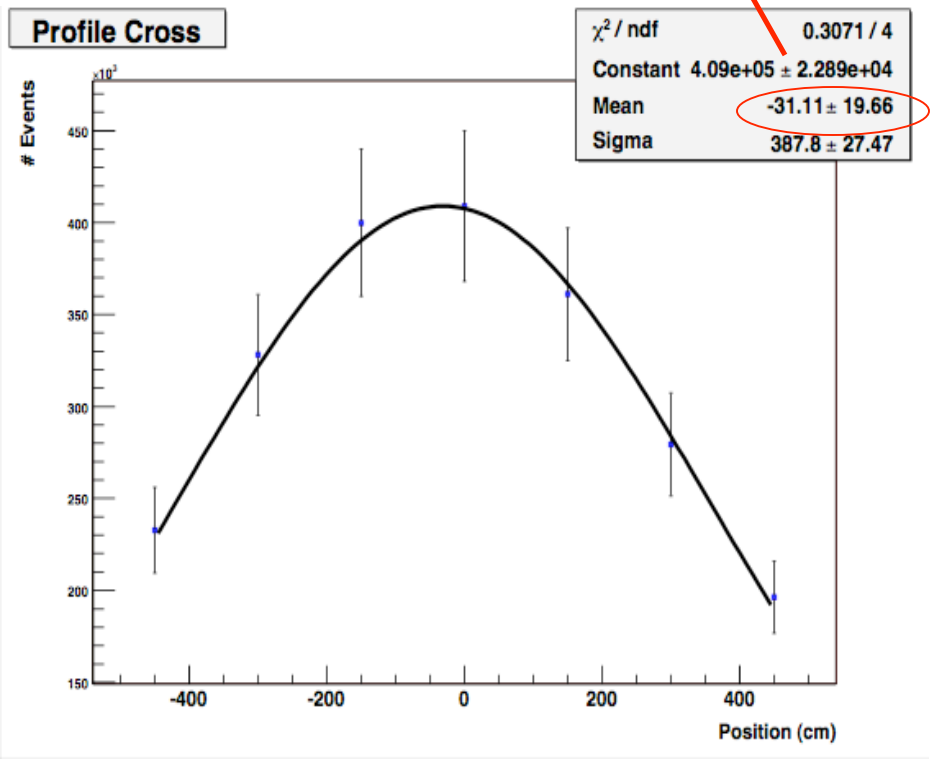
On axis detector



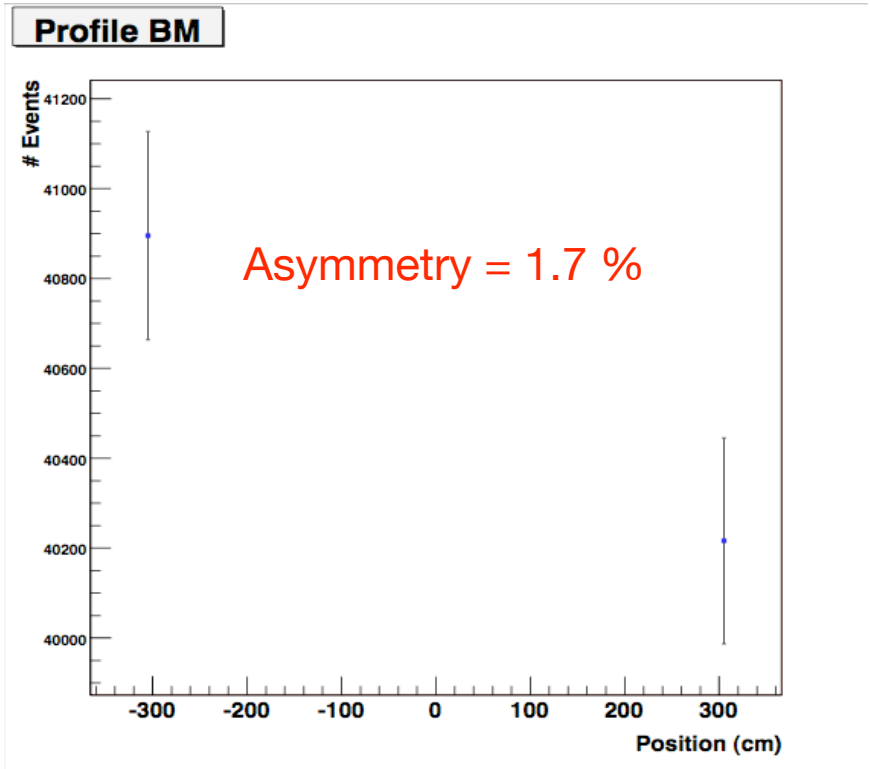
Beam monitor

Horn1 shifted 3mm left

Given the error on the mean as a function of the systematics and a mean of about 30 cm for a shift of the horn1 of 3mm, there is not a strict constraint on the error on the intercalibration. However, it should be smaller than 15%.



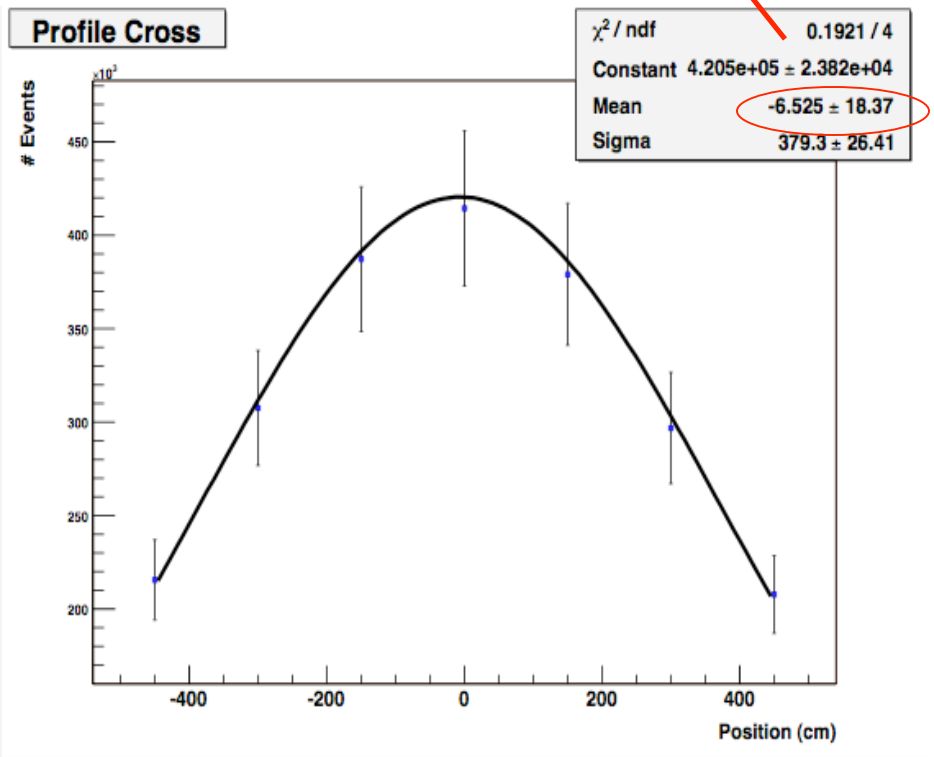
On axis detector



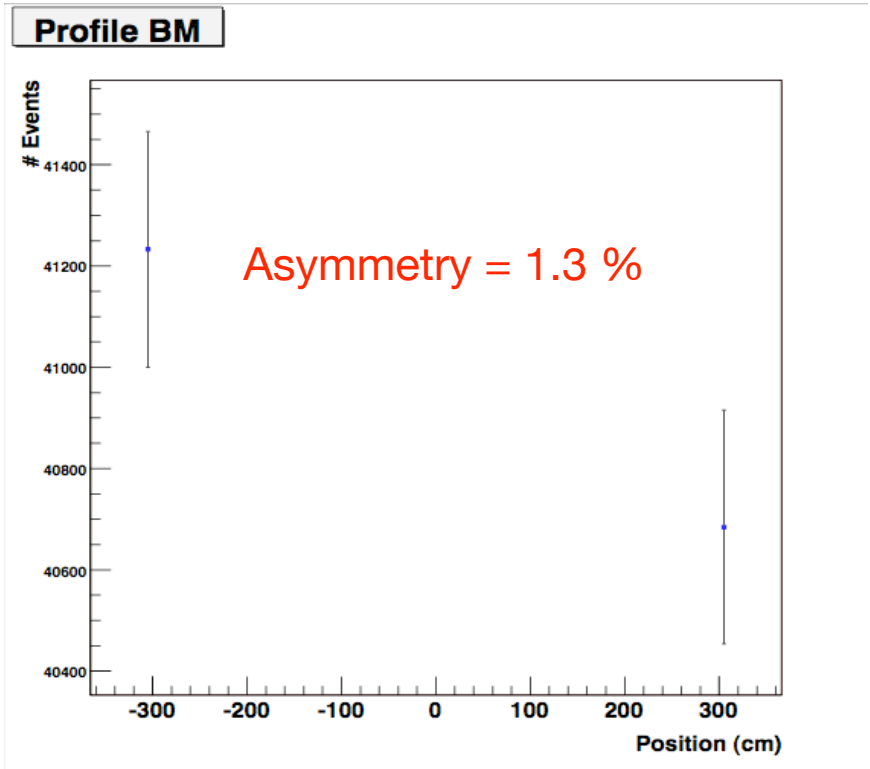
Beam monitor

Horn2 shifted 3mm left

Given the error on the mean as a function of the systematics and a mean of about 6 cm for a shift of the horn2 of 3mm, the error on the intercalibration must be smaller than 5%.



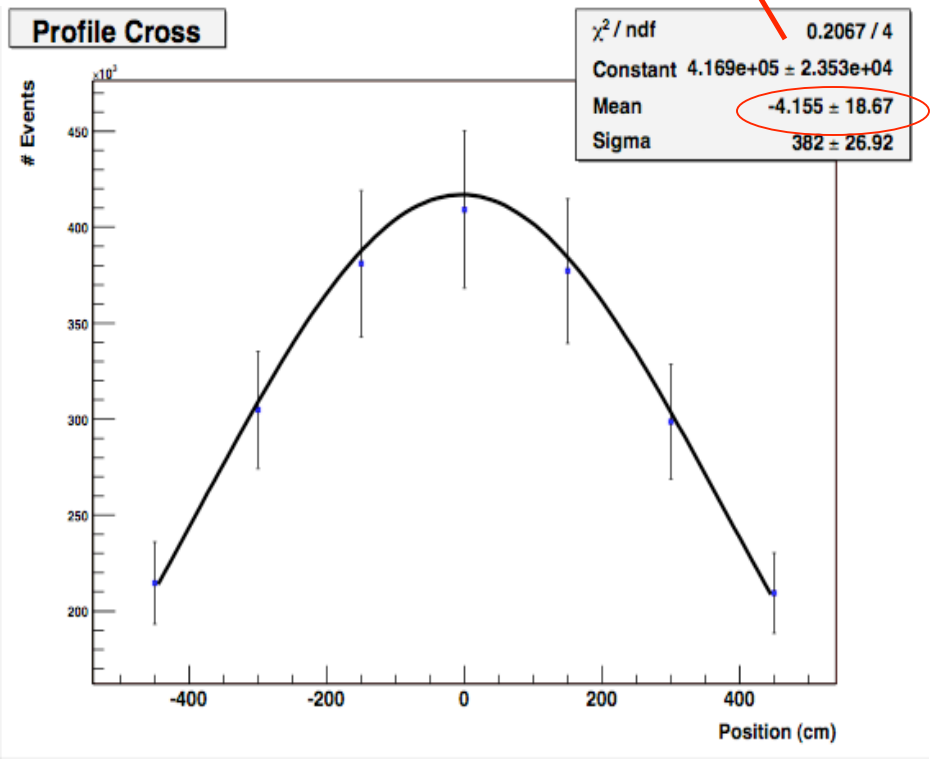
On axis detector



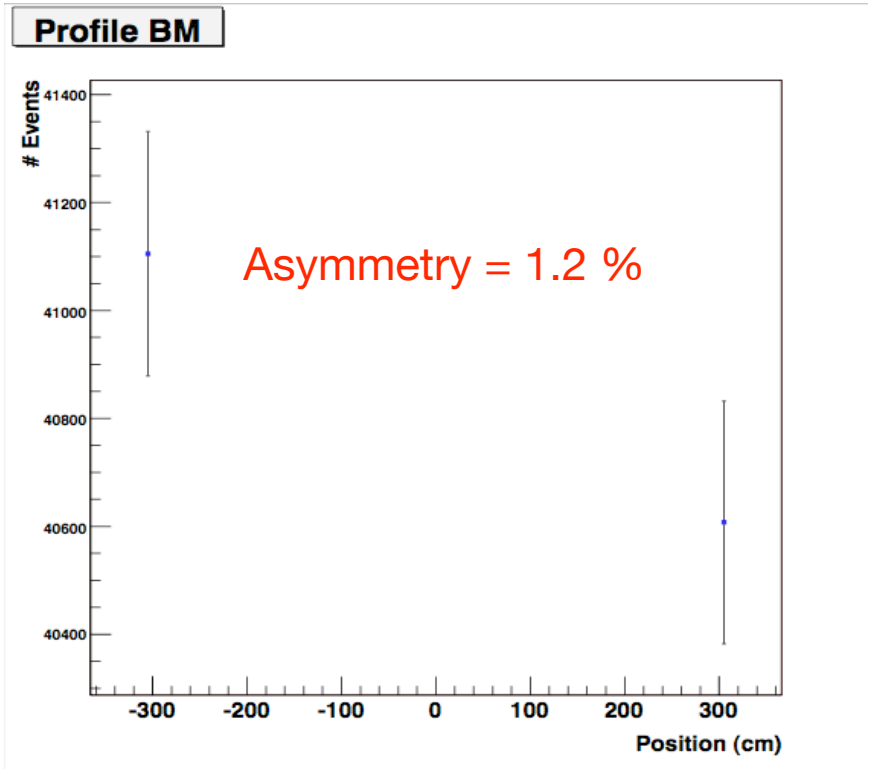
Beam monitor

Horn3 shifted 3mm left

Given the error on the mean as a function of the systematics and a mean of about 4 cm for a shift of the horn3 of 3mm, the error on the intercalibration must be smaller than 5%.



On axis detector



Beam monitor

Remarks

- ✓ The intercalibration of the different modules of the 280 m on axis detector plays an important role on the beam shifts sensitivity.

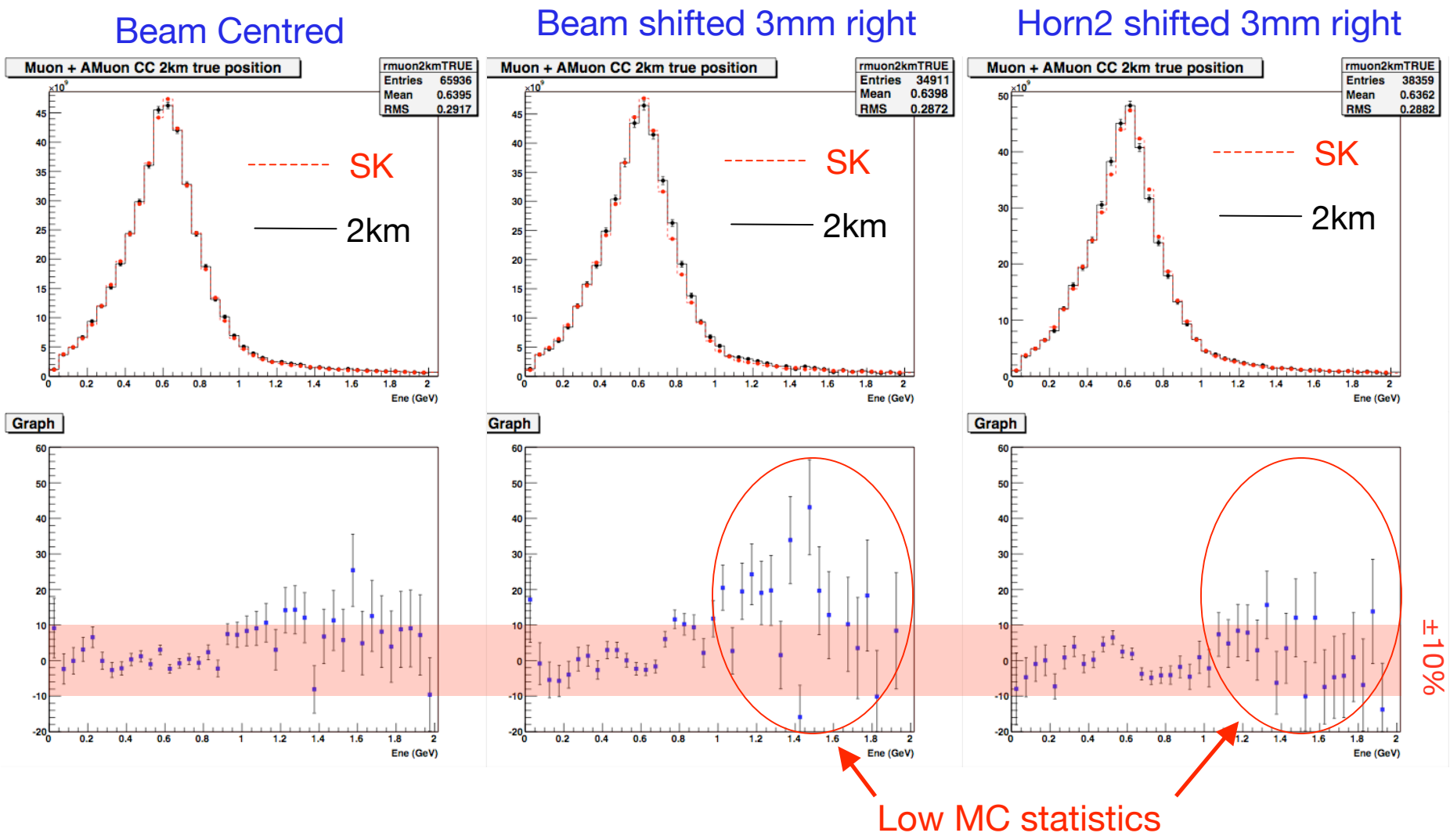
- ✓ In order to appreciate the difference given by a shift of the beam of 3mm the systematic on the intercalibration must be less than 10%, for a shift of the horn2 and 3 by 3mm it must be less than 5%.

- ✓ As far as the beam monitor are concerned, no systematic on intercalibration has been included (possibility to use the same detector and slide it into different positions), but it must be below 2% to appreciate a shift of the beam of 3mm and below 1% to detect a shift of the horns by 3mm.

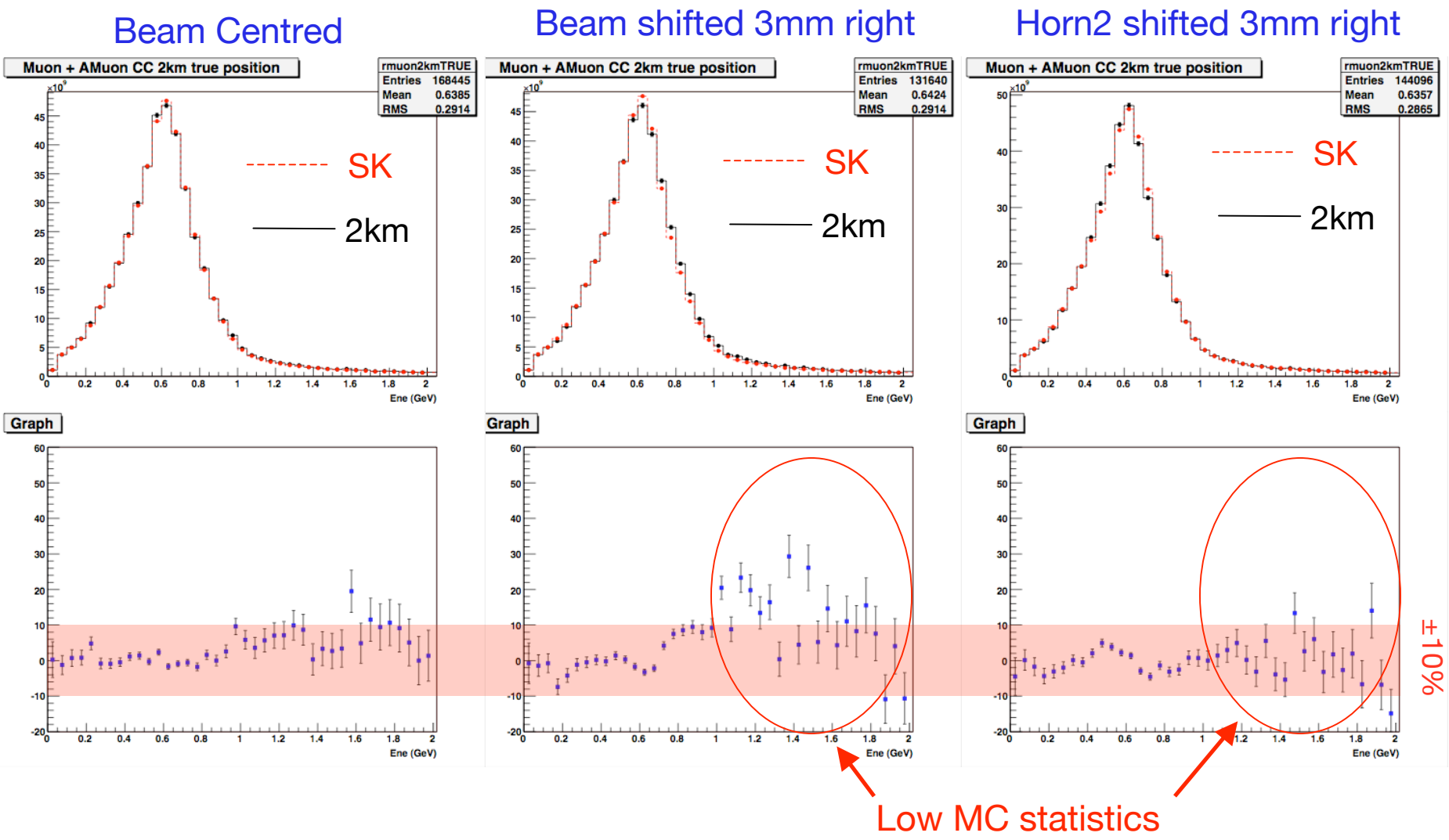
- ✓ Since at the height of the BM the changes due to proton shifts on target are about 3%, the change of the ratio between fluxes at 2km and SK detector should not be too large (see next slide).

- ✓ Since at the height of the BM the changes due to horns shifts are about 1.5%, the change of the ratio between fluxes at 2km and SK detector should be negligible (see next slide).

Flux ratio comparisons



Flux ratio comparisons (increased statistics)



Conclusions

- ✓ The number of expected events in the beam monitor detectors would be about a factor 8 smaller than the events measured in each component of the 280 m on axis detector.

- ✓ At the height of the beam monitor beam asymmetries are less visible respect to the beam plane (i.e. asymmetries measured by the on axis detector): there is about a factor 3 on the effect both for shifting of the protons and of the horns.

- ✓ The possible advantage of the beam monitors comes from the possibility to get rid of the systematics due to intecalibration.

- ✓ Although monitoring beam asymmetries represents a delicate and important aspect, shifts of the proton and of the horns of 3 mm do not affect too much the flux ratio between 2km detector and SK.