

# Updates on test beam 2018

(4° analysis meeting 13/7/2018)

A. Principe

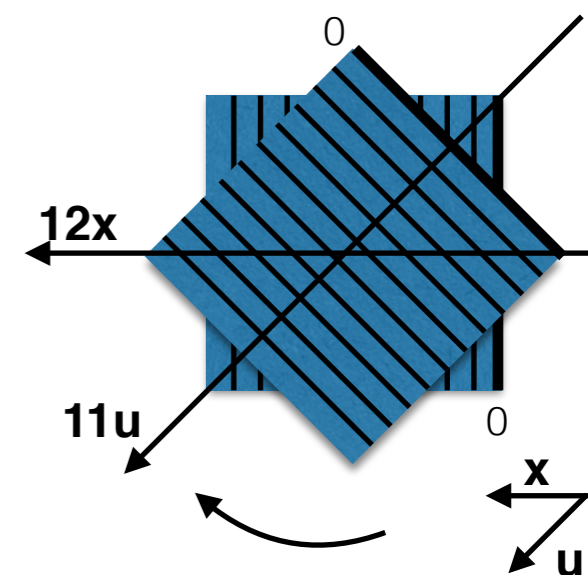
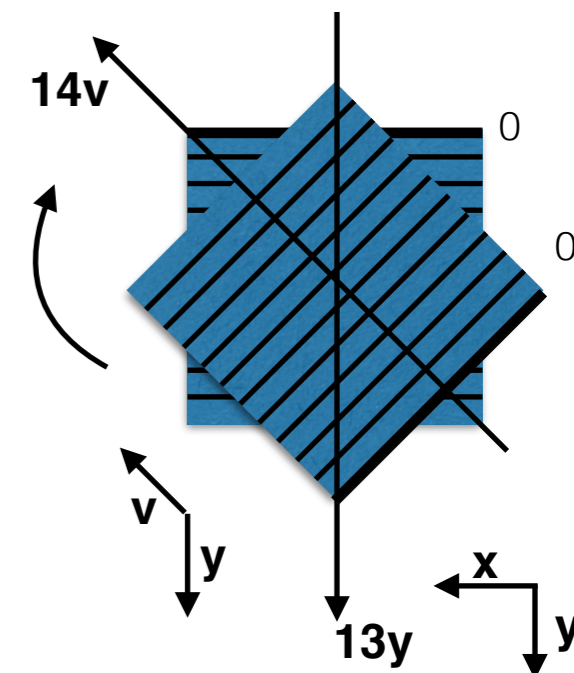
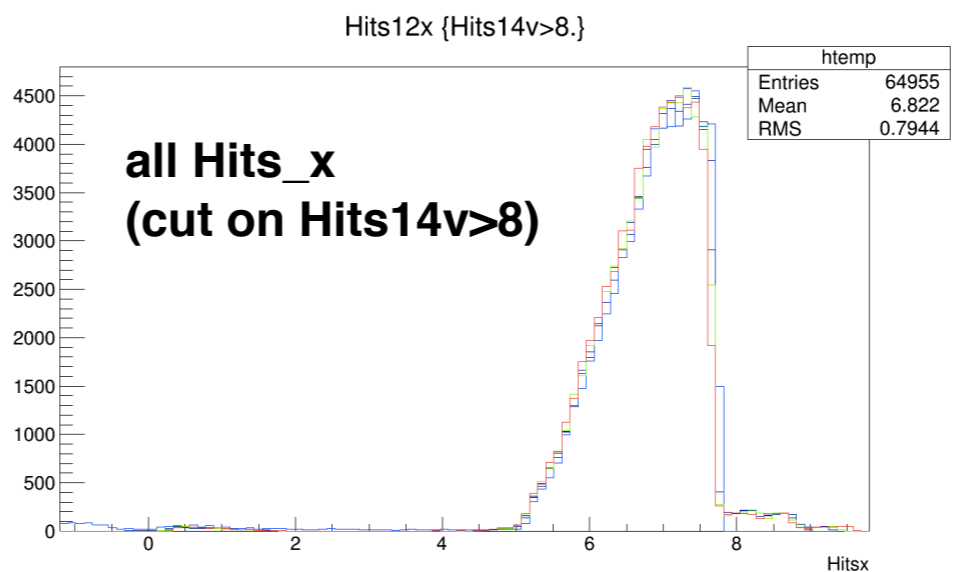
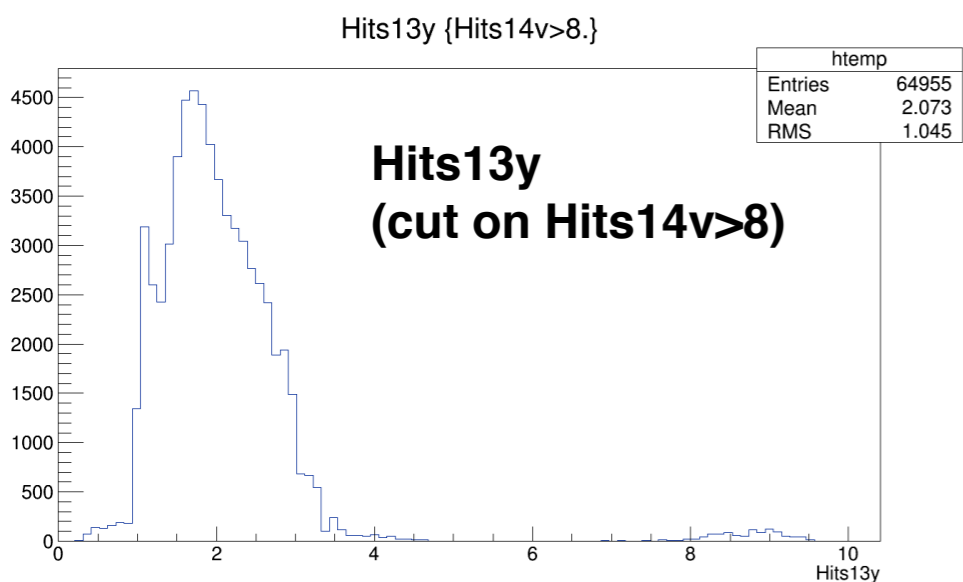
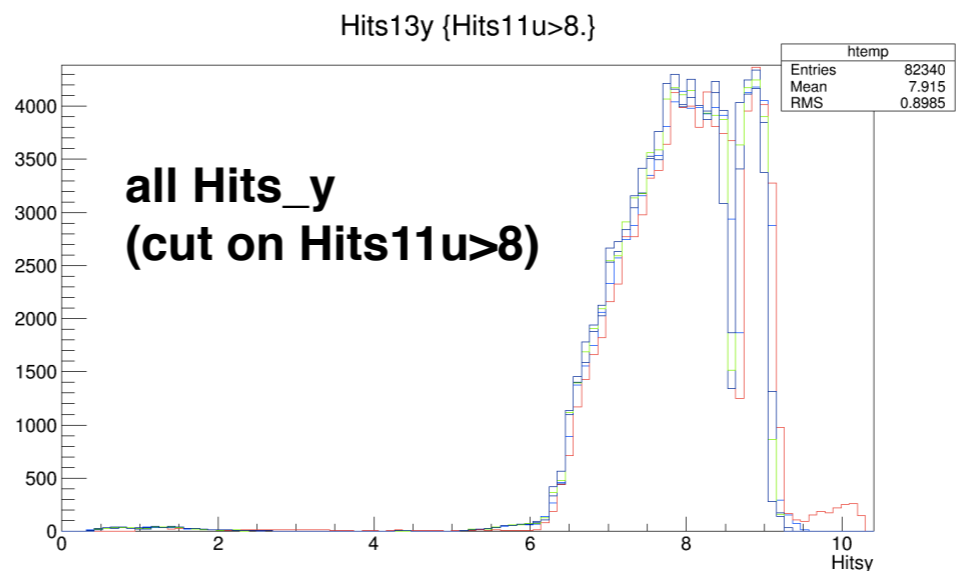
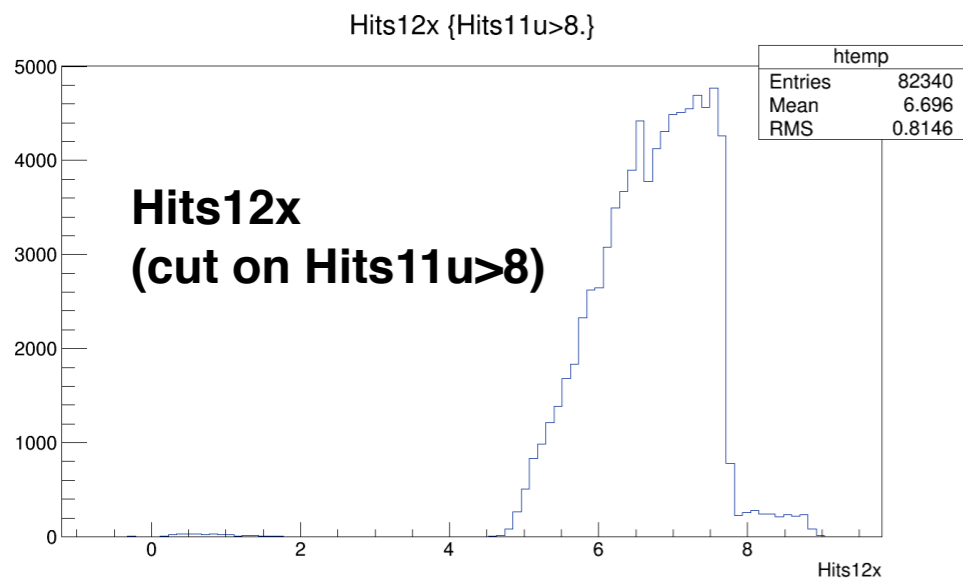
See also previous discussions (on Indico page):

**1° meeting - 15/06**

**2° meeting - 28/06**

**3° meeting - 04/07**

# Checks stereo planes



- Tutte le analisi sono state fatte prendendo come **ref 7y-8x / 15y-16x**: risultati analoghi con 5y-6x / 15y-16x oppure 4x-5y / 15y-16x. Prendendo come ref 3y qualche problema con l'allineamento dei layer stereo.
- **Si sono inseriti nella procedura iterativa anche alcuni tilt per i layer y.**

# Stereo layers alignment

- residuals:**

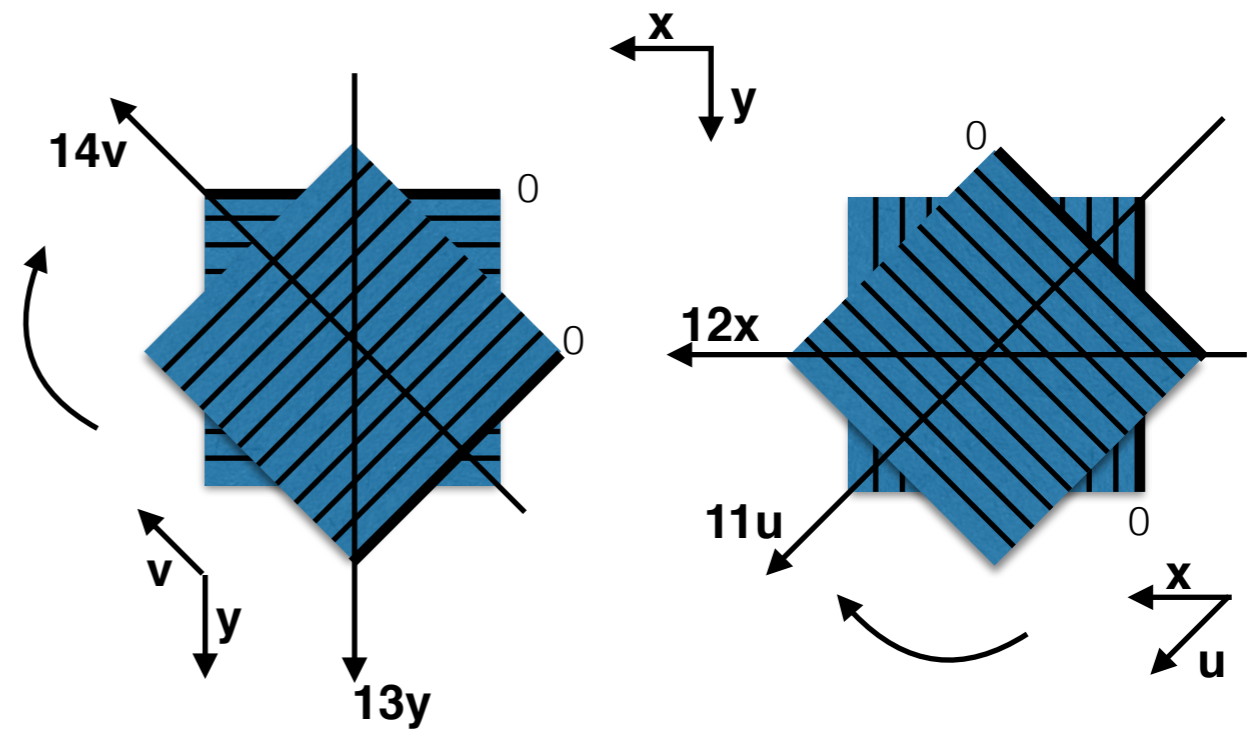
$$res_i = hits_i - [\cos \beta(a_x z_i + b_x) - \sin \beta(a_y z_i + b_y)] + c_i$$

$$\beta = -\frac{\pi}{4} \quad \text{for } i = 11u$$

$$\beta = +\frac{\pi}{4} \quad \text{for } i = 14v$$

$$c_{11u} = 1.8036 \text{ cm}$$

$$c_{14v} = -5.1100 \text{ cm}$$



- alignment (in uv direction):**

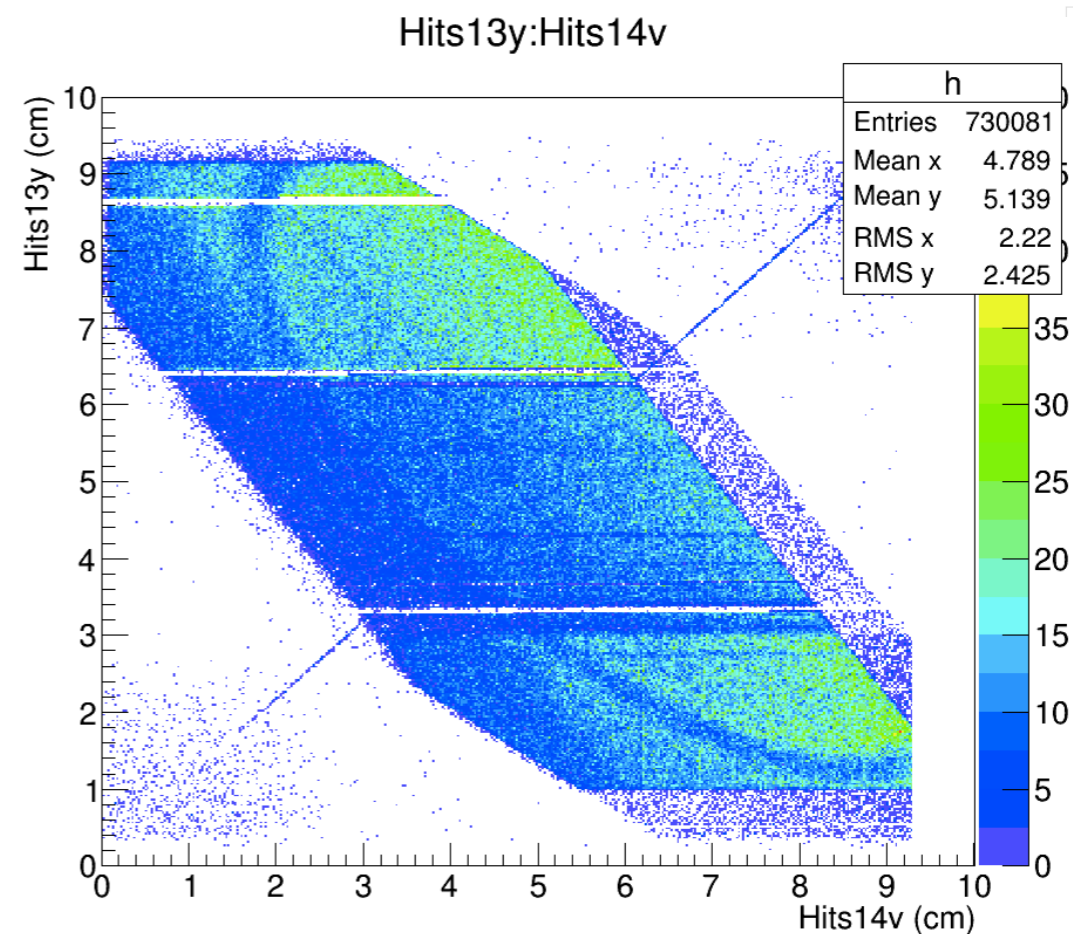
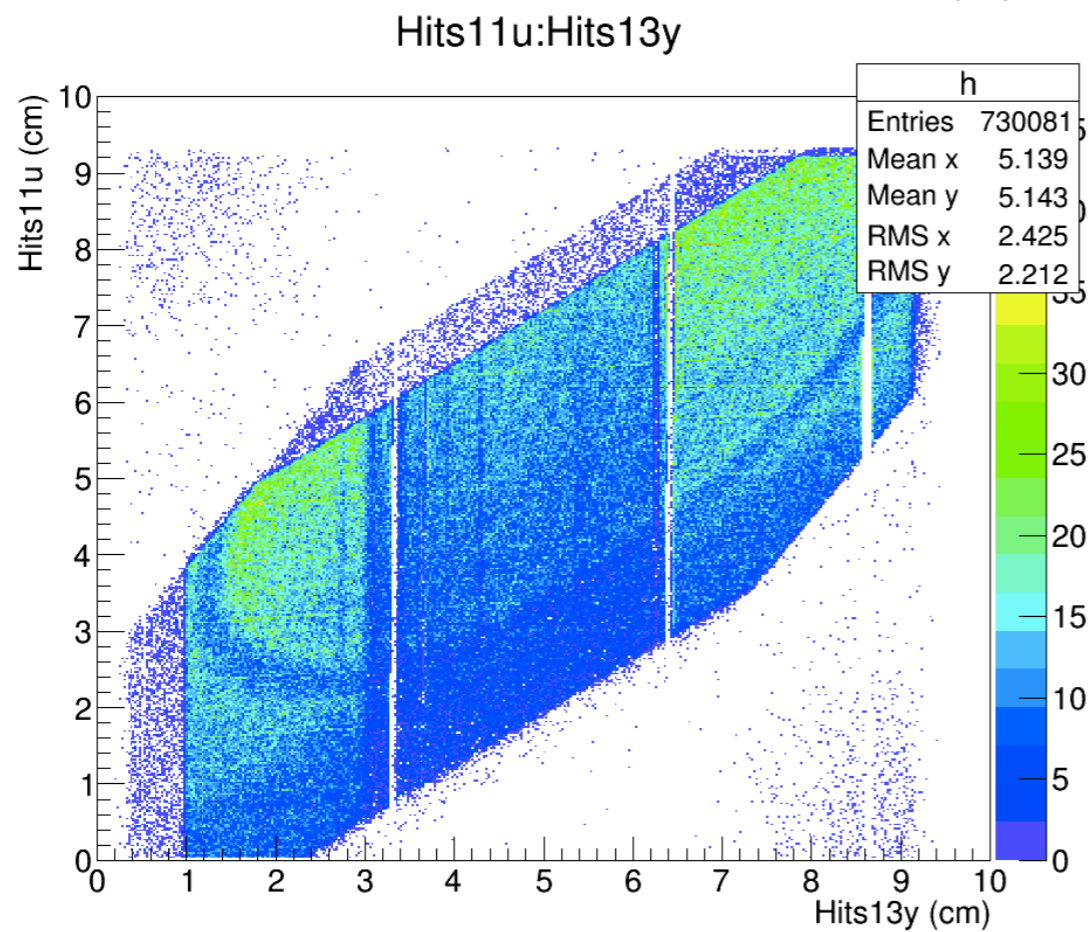
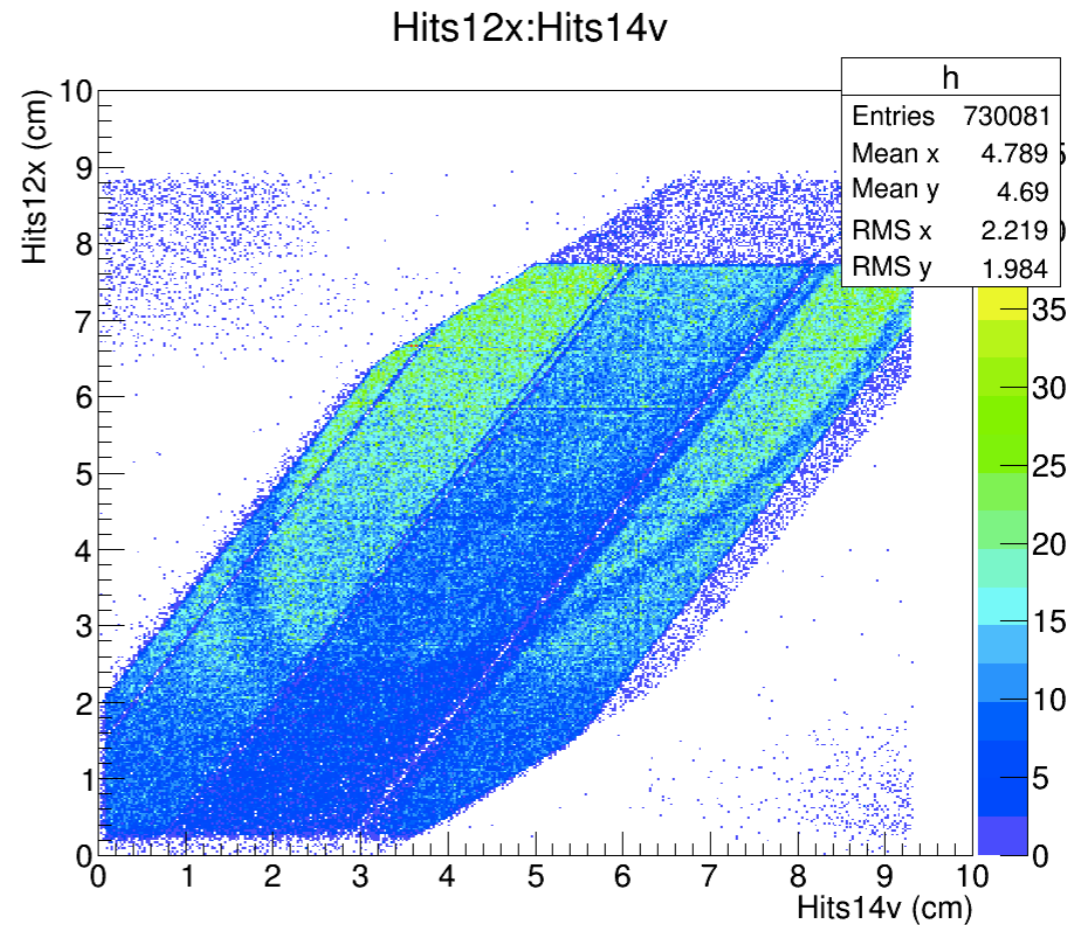
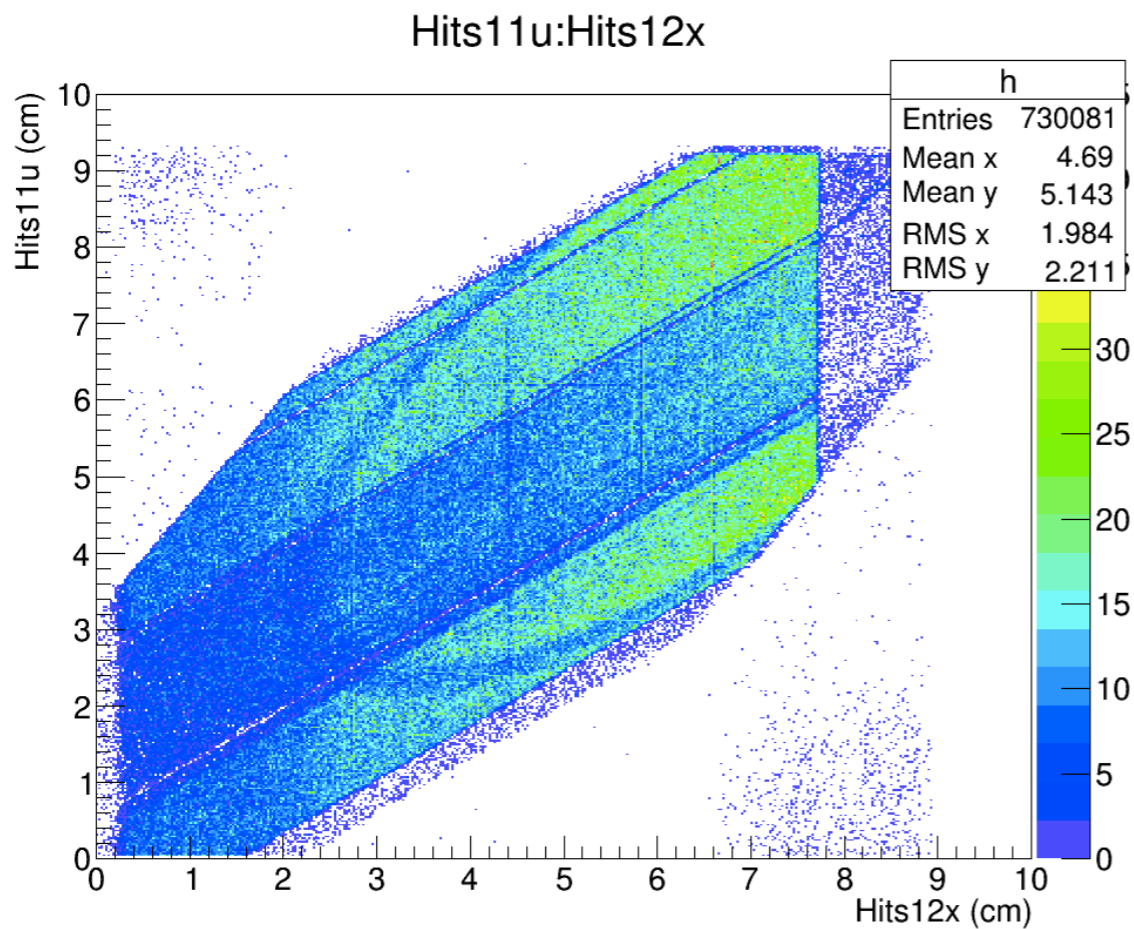
$$hits'_i = hits_i - r_i - a_i \cdot hits_j$$

$$\implies r_i \text{ from } res_i$$

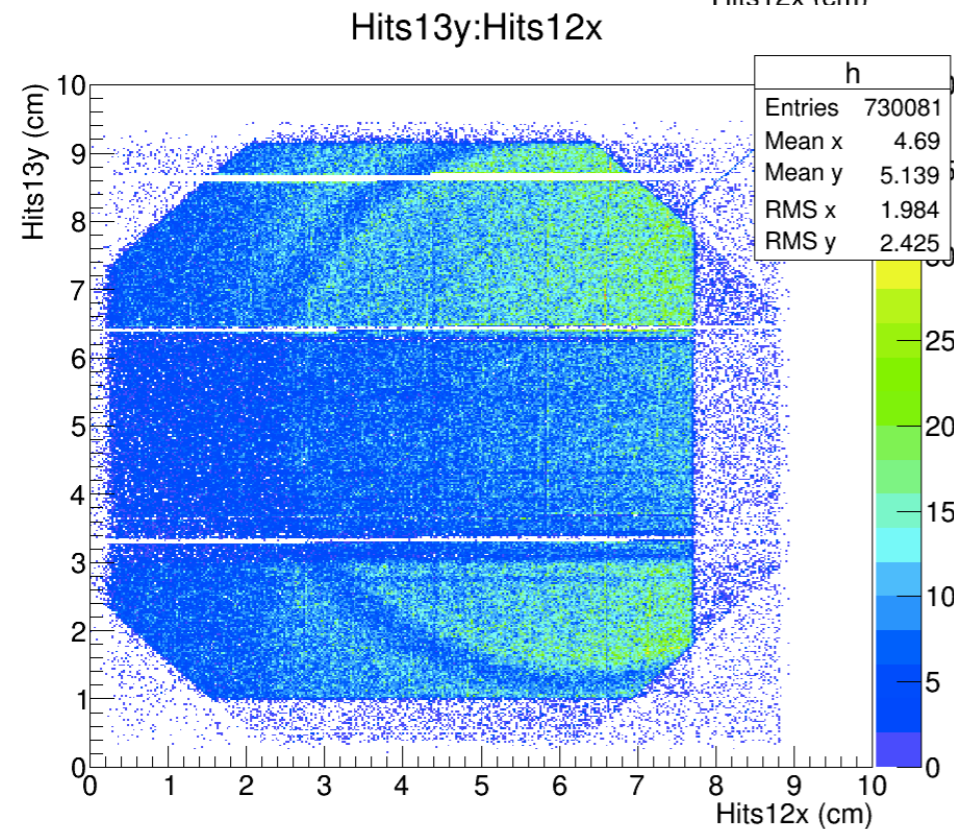
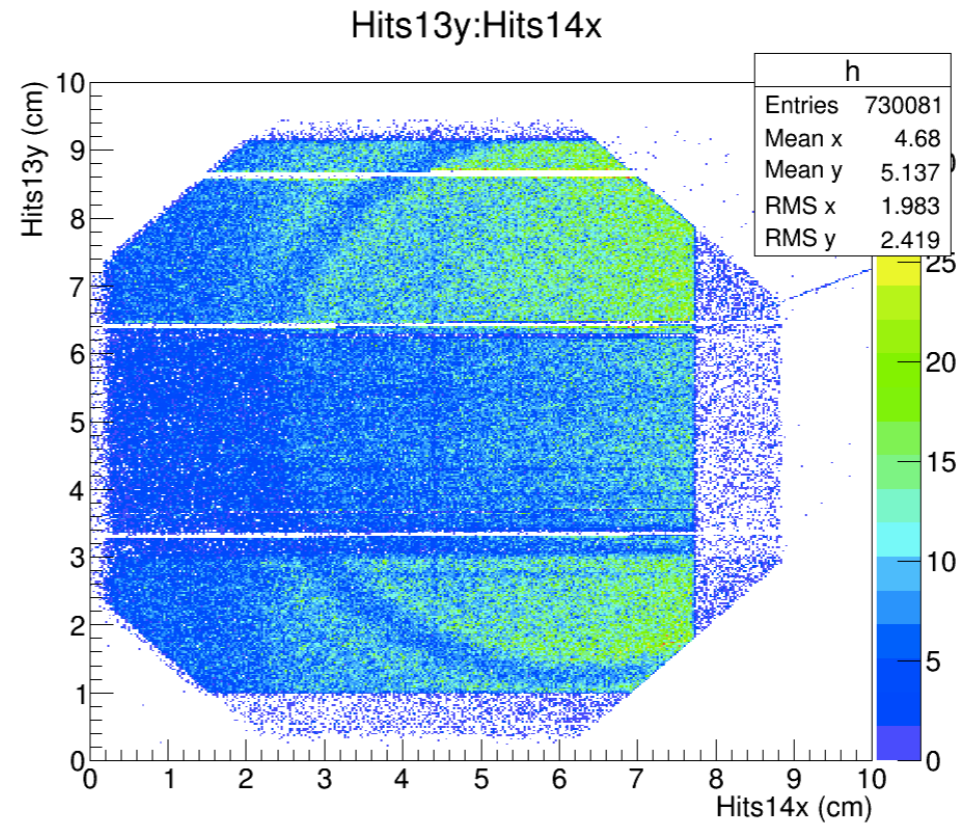
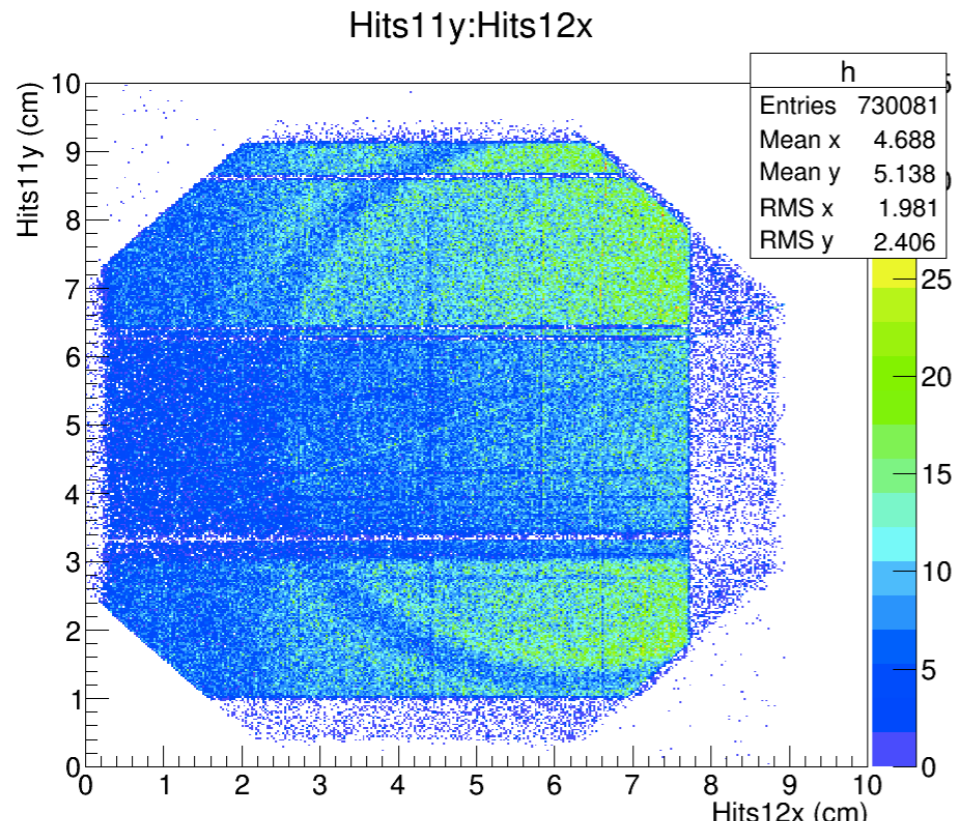
$$\implies a_i \text{ from } res_i \text{ vs } hits_j$$

$j = 13y$  for both !

# Stereo planes rotations



# 11y 14x views



- Ruotato (iterativamente) i piani 11u e 14v

$$[11y] = \sqrt{2} [11u] - [12x] + (2 - \sqrt{2})c$$

$$[11y]' = [11y] - r_{11y} - a_{11y} \cdot [12x]$$

$$[14x] = \sqrt{2} [14v] + [13y] - \sqrt{2}c$$

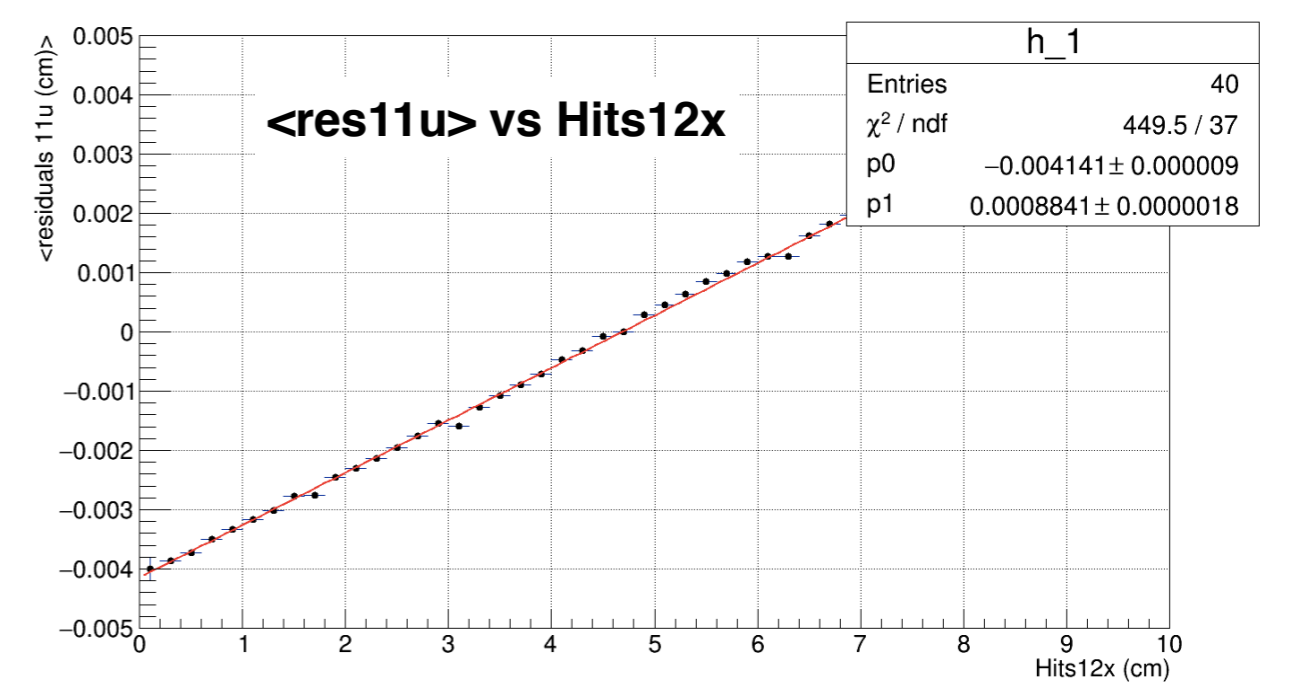
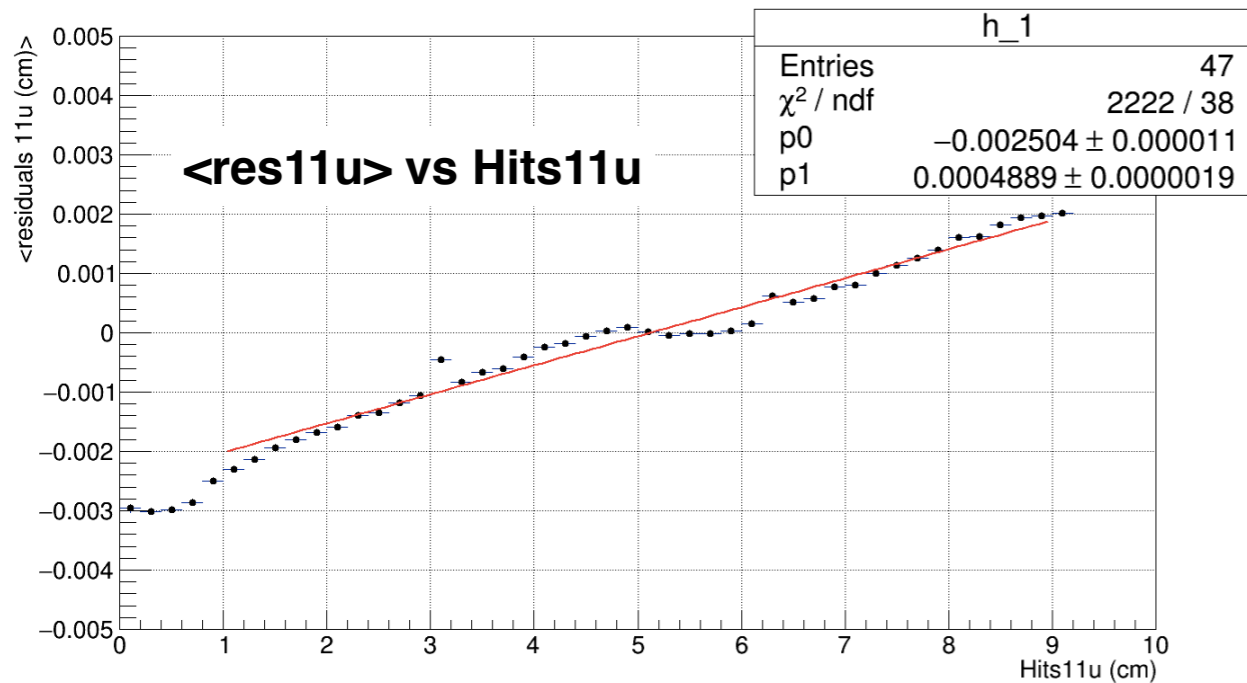
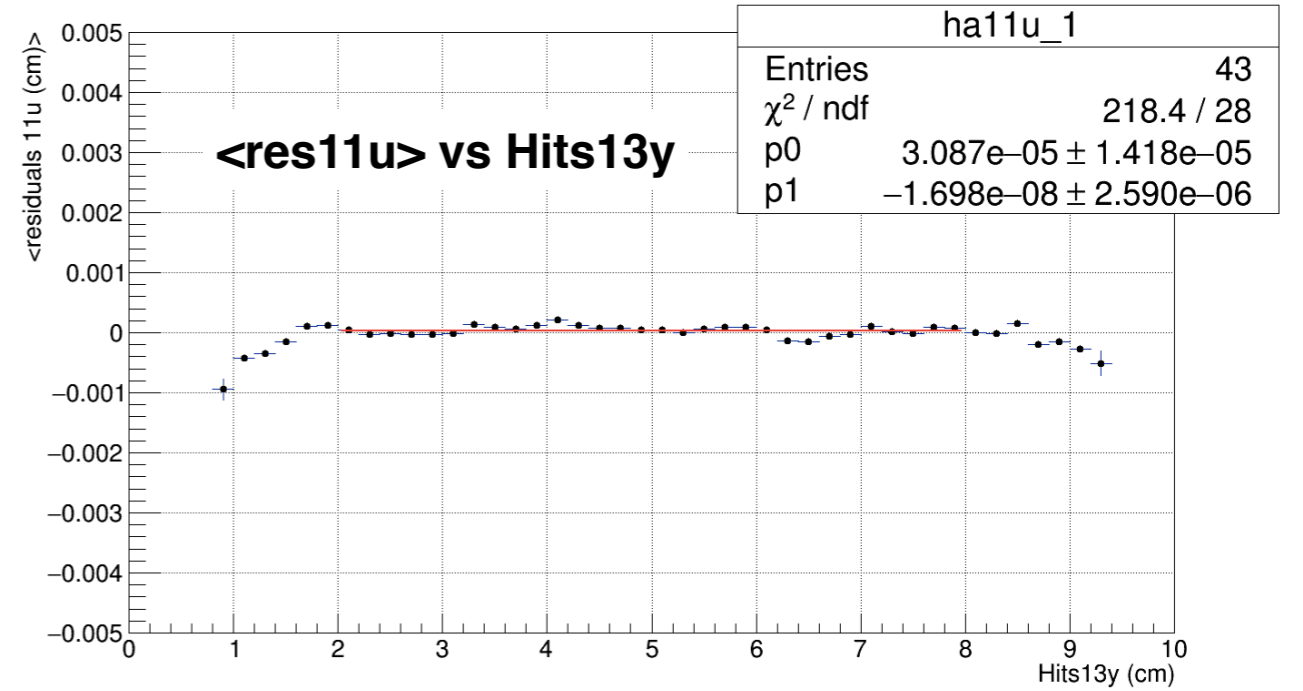
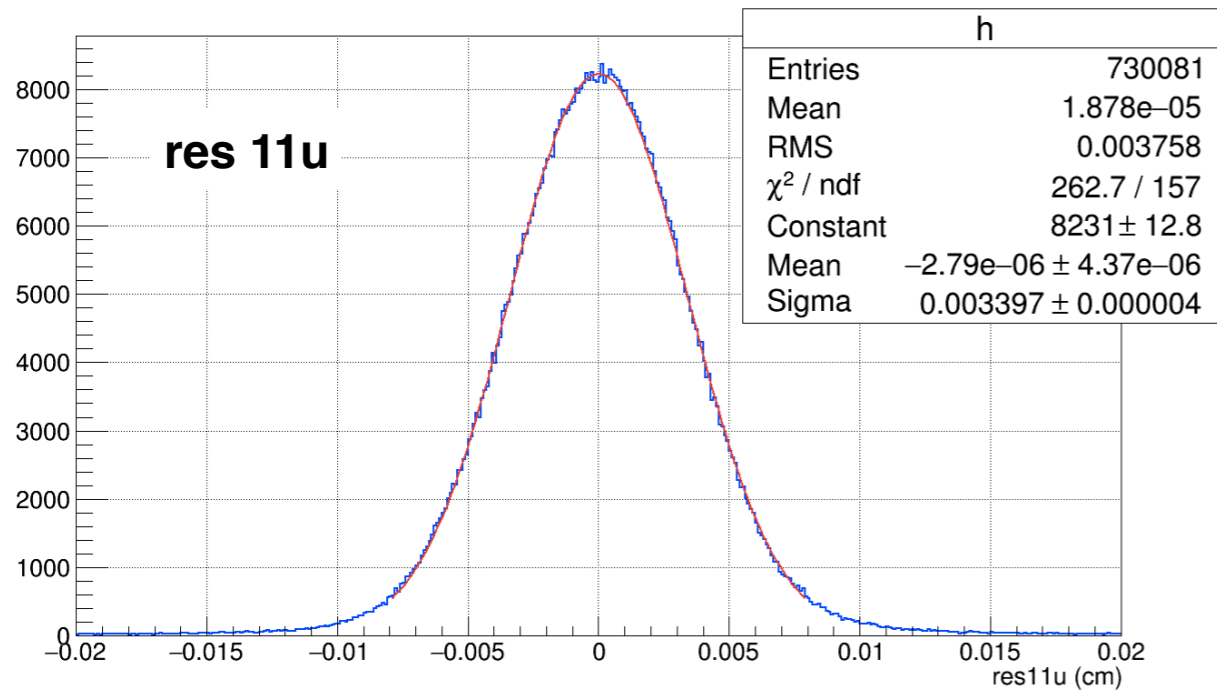
$$[14x]' = [14x] - r_{14x} - a_{14x} \cdot [13y]$$

$$c = 4.75 \text{ cm}$$

$$r_{11y} = 0.2328 \text{ cm} \quad a_{11y} = -0.00024 \text{ rad}$$

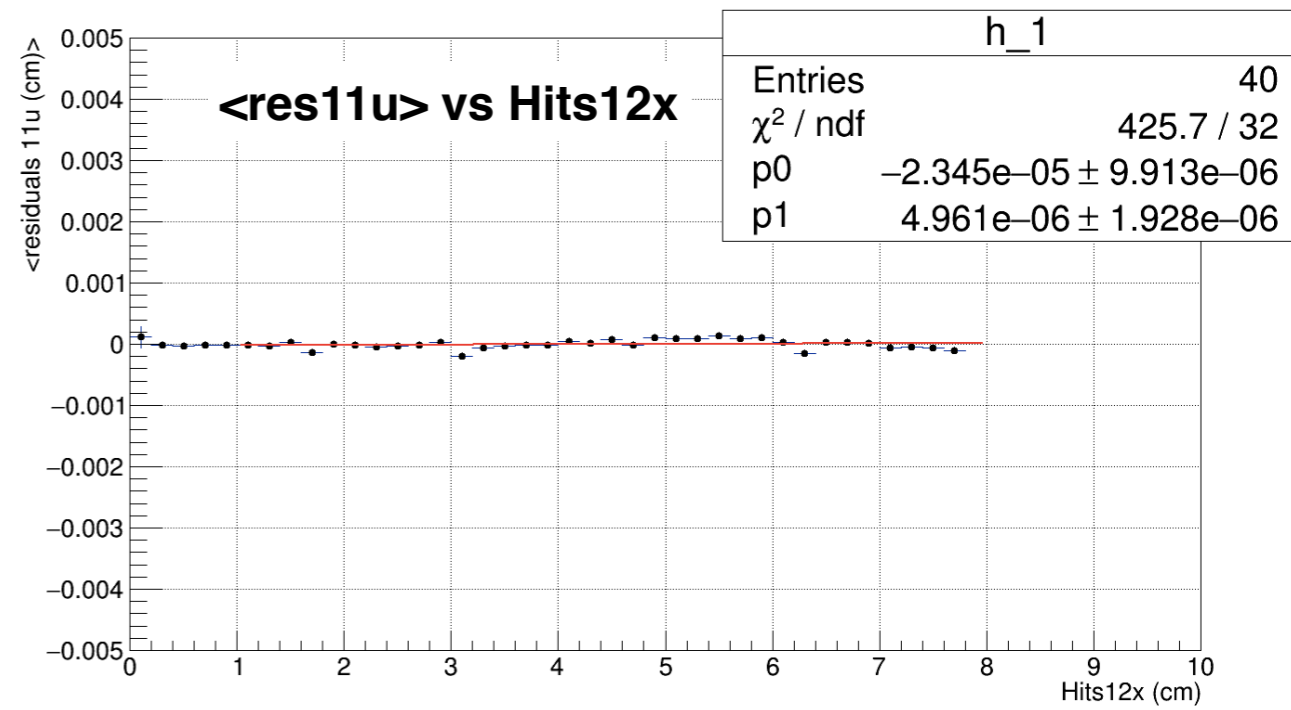
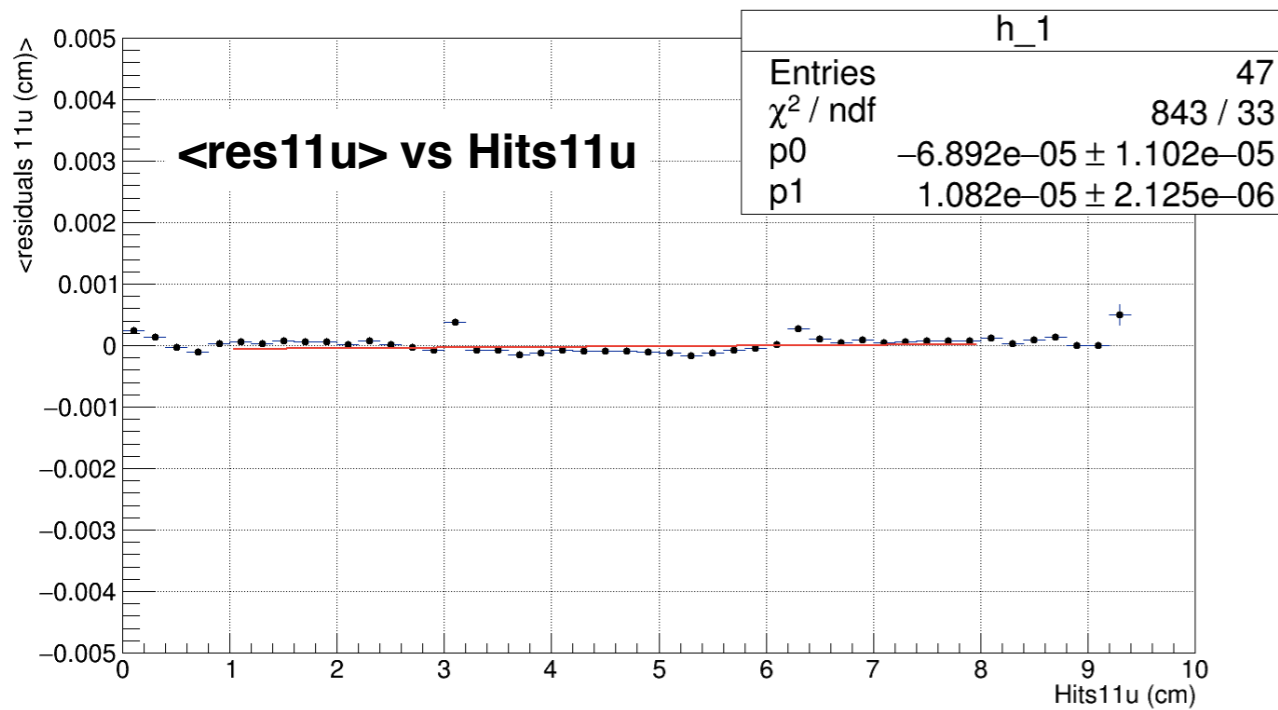
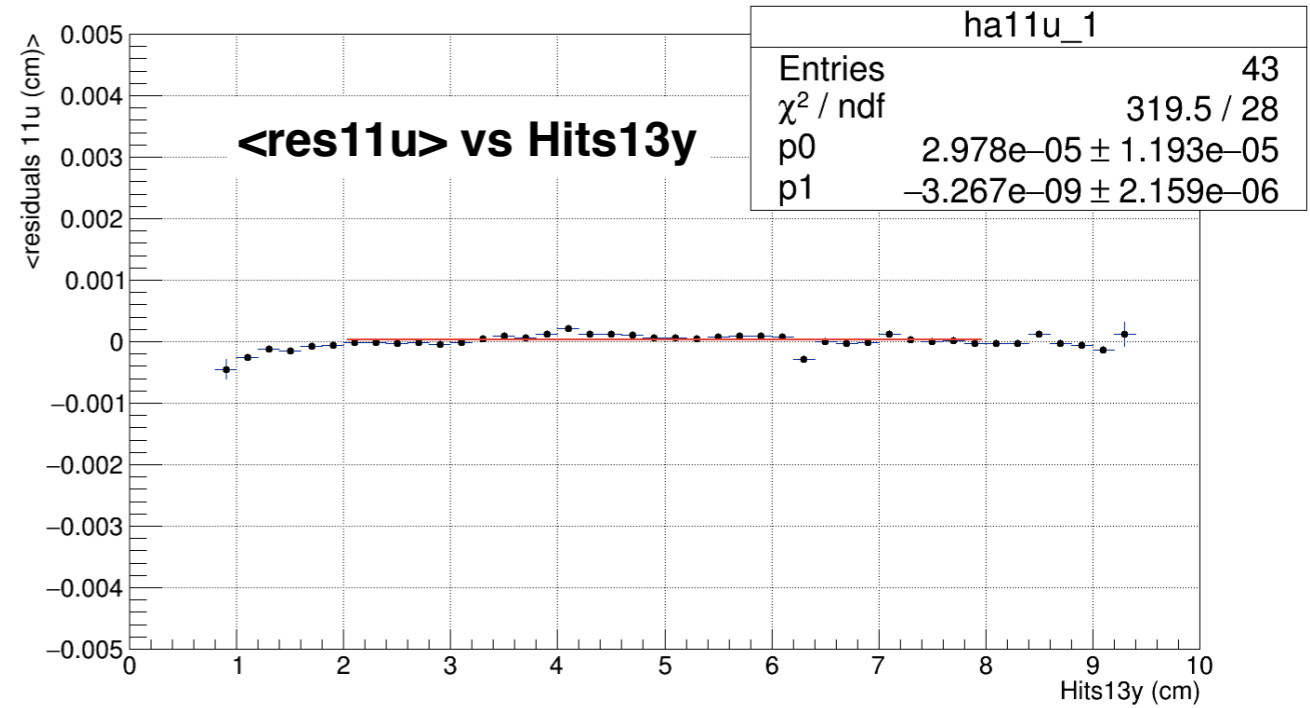
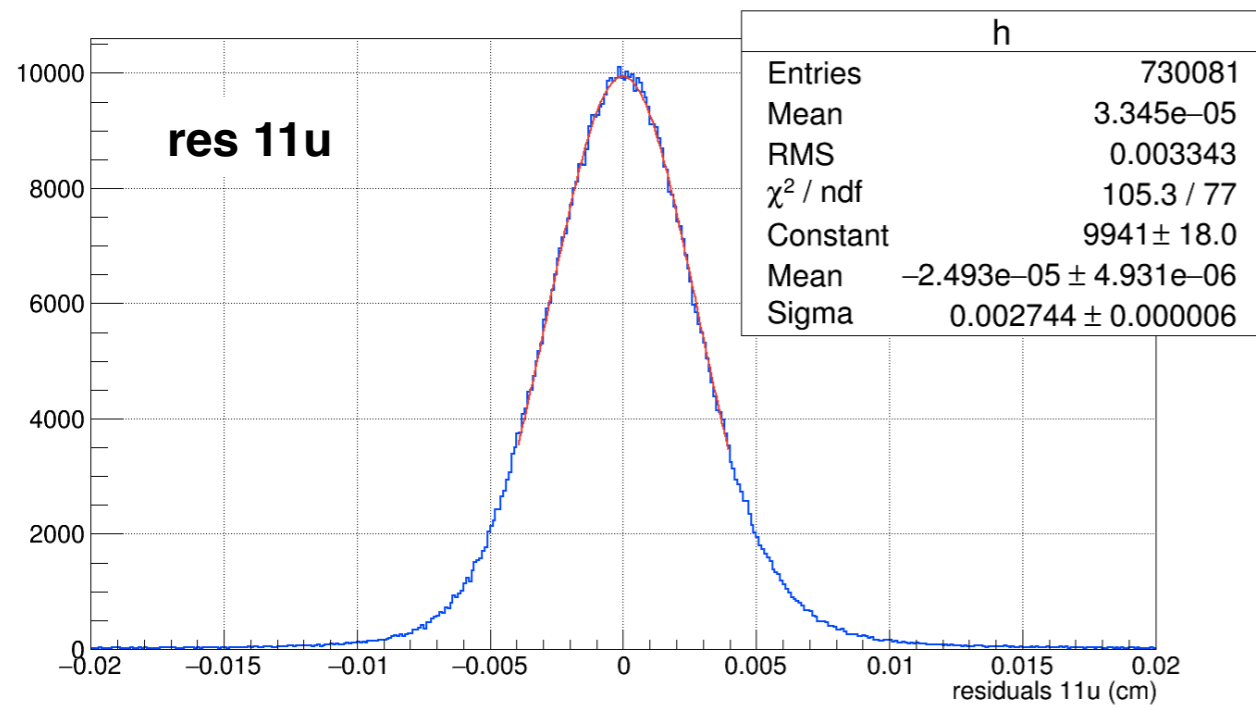
$$r_{14x} = 0.5081 \text{ cm} \quad a_{14x} = 0.00020 \text{ rad}$$

# Alignment 11u pre tilt correction



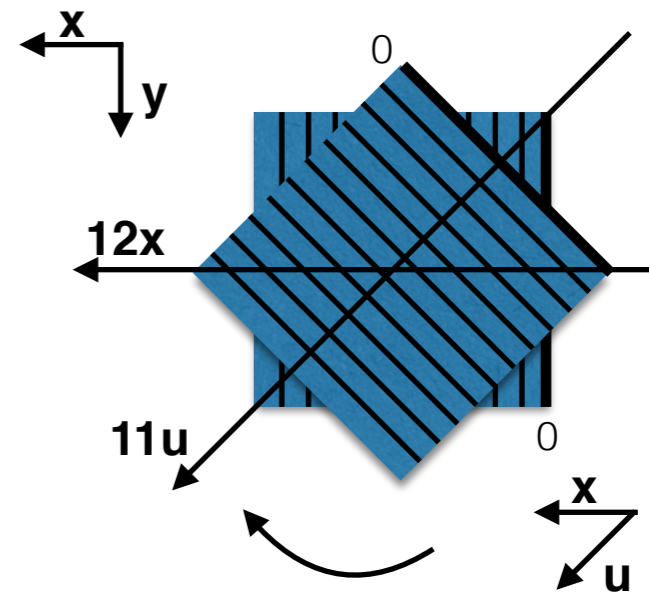
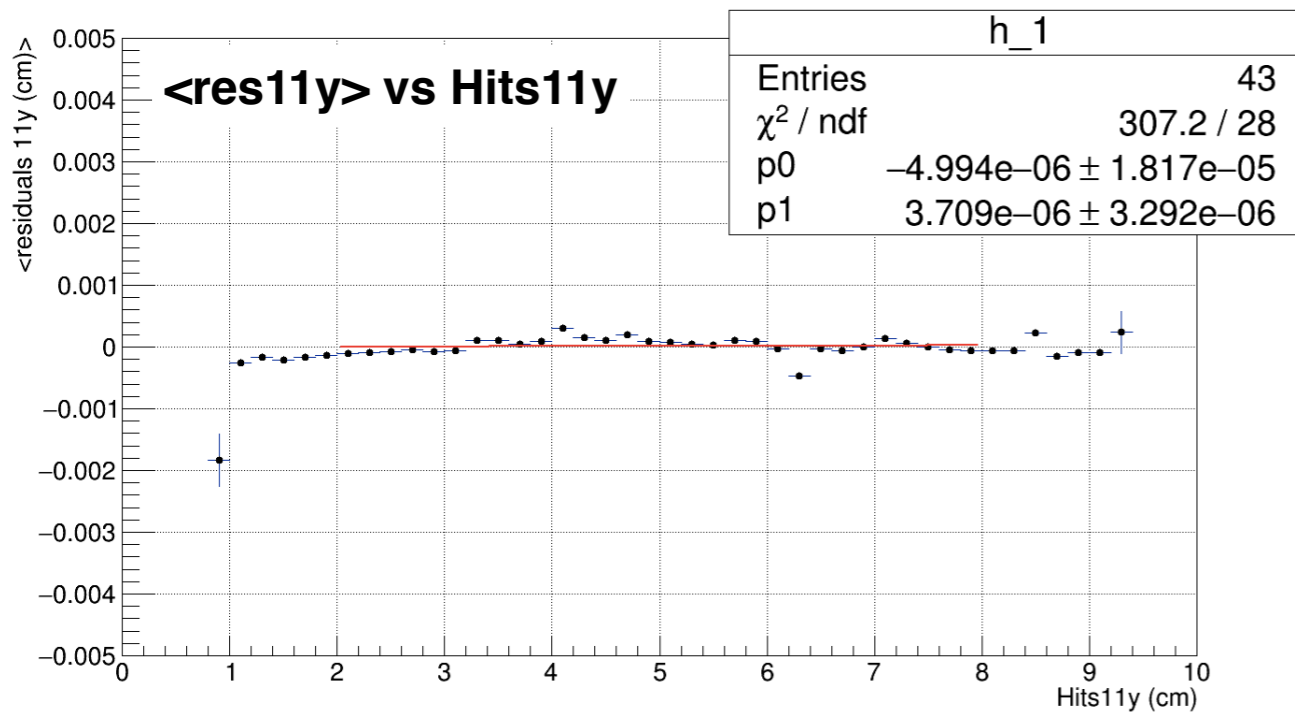
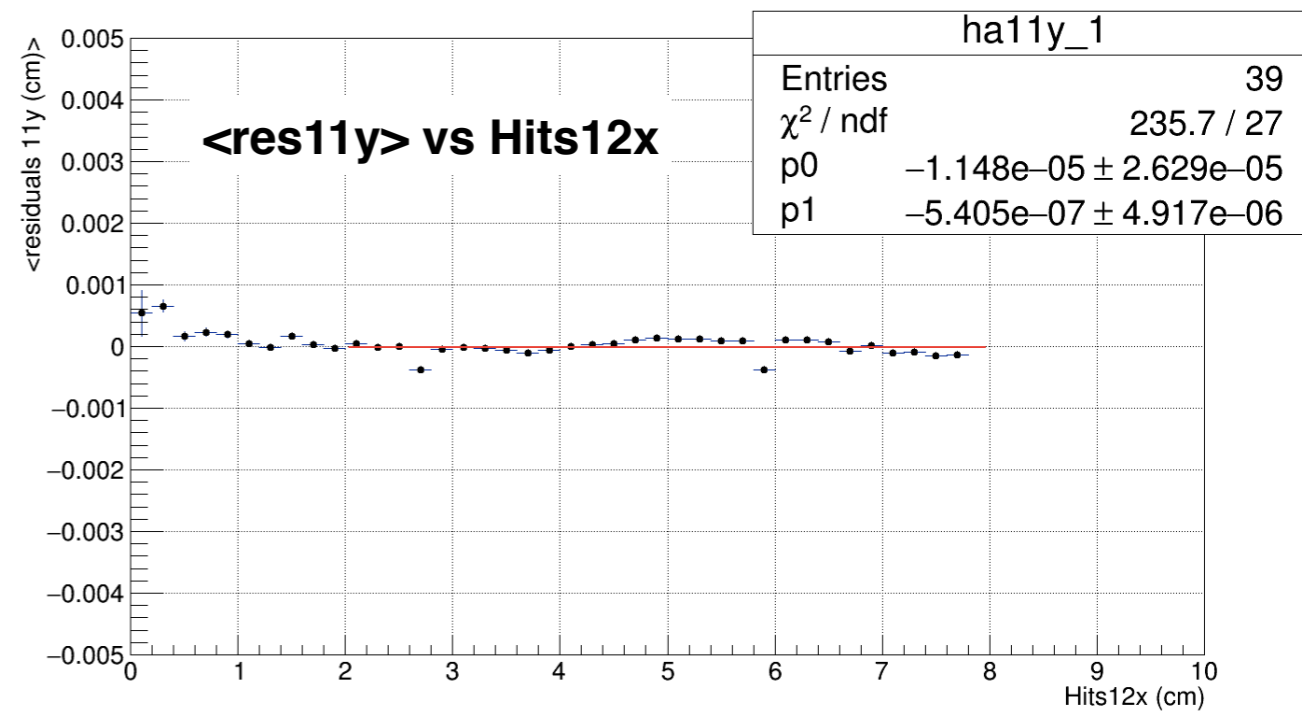
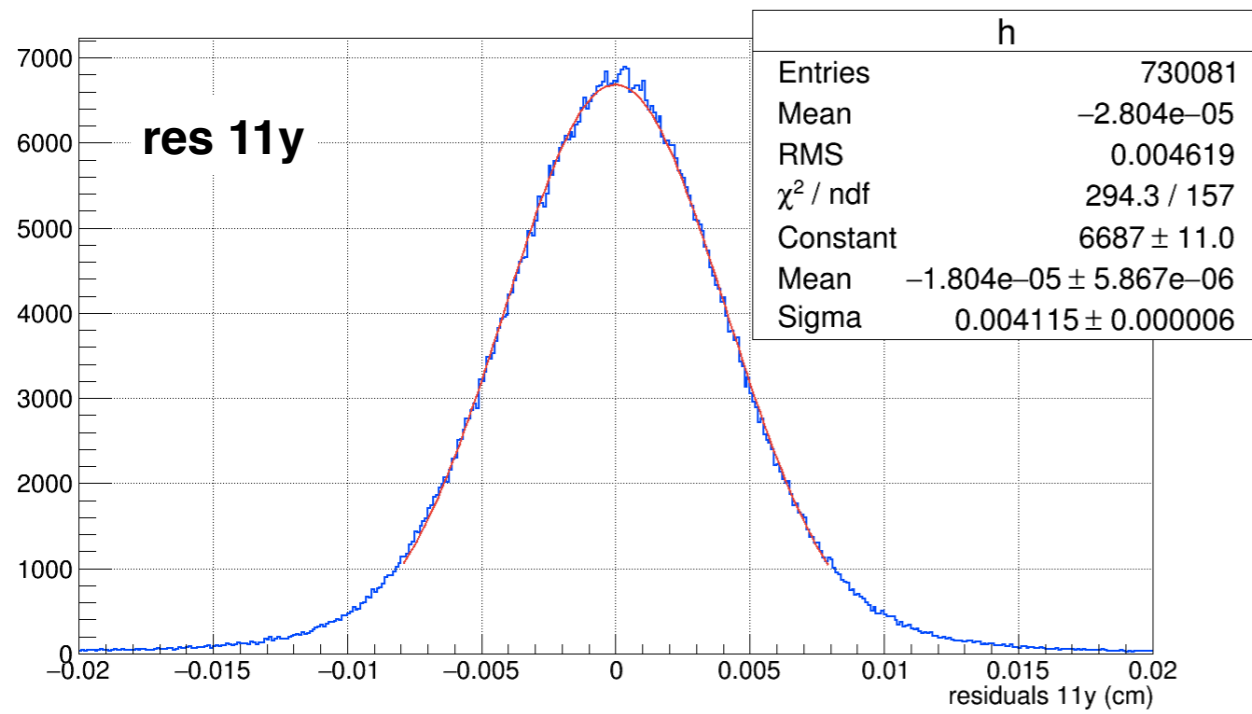
- Il tilt (?) del layer 11u, se non corretto, induce una correlazione con il 12x che appare come una rotazione residua non corretta. Correzione: **Hits11u' = (1-0.001244)\*Hits11u**. Non è possibile applicarla iterativamente, data l'entità.

# Alignment 11u post correction



- **Hits11u' = (1-0.001244)\*Hits11u**. Questa correzione elimina automaticamente anche quella con il 12x.
- La sigma del residuo migliora significativamente.

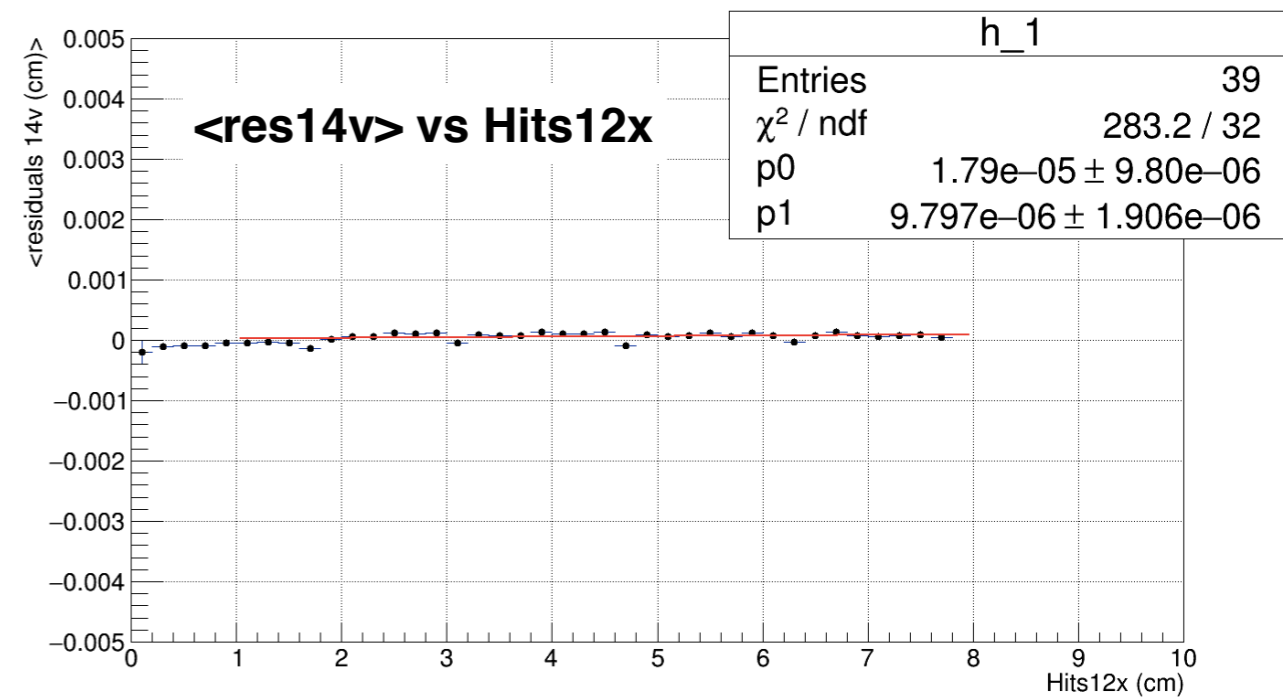
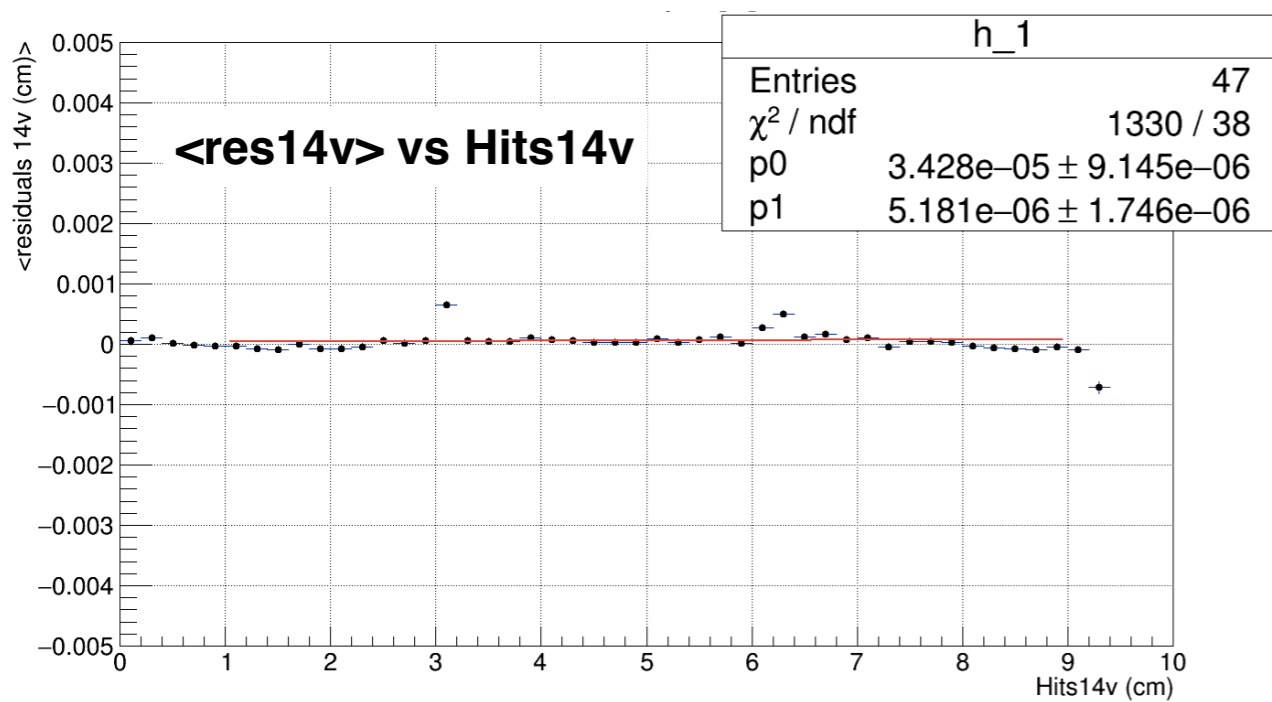
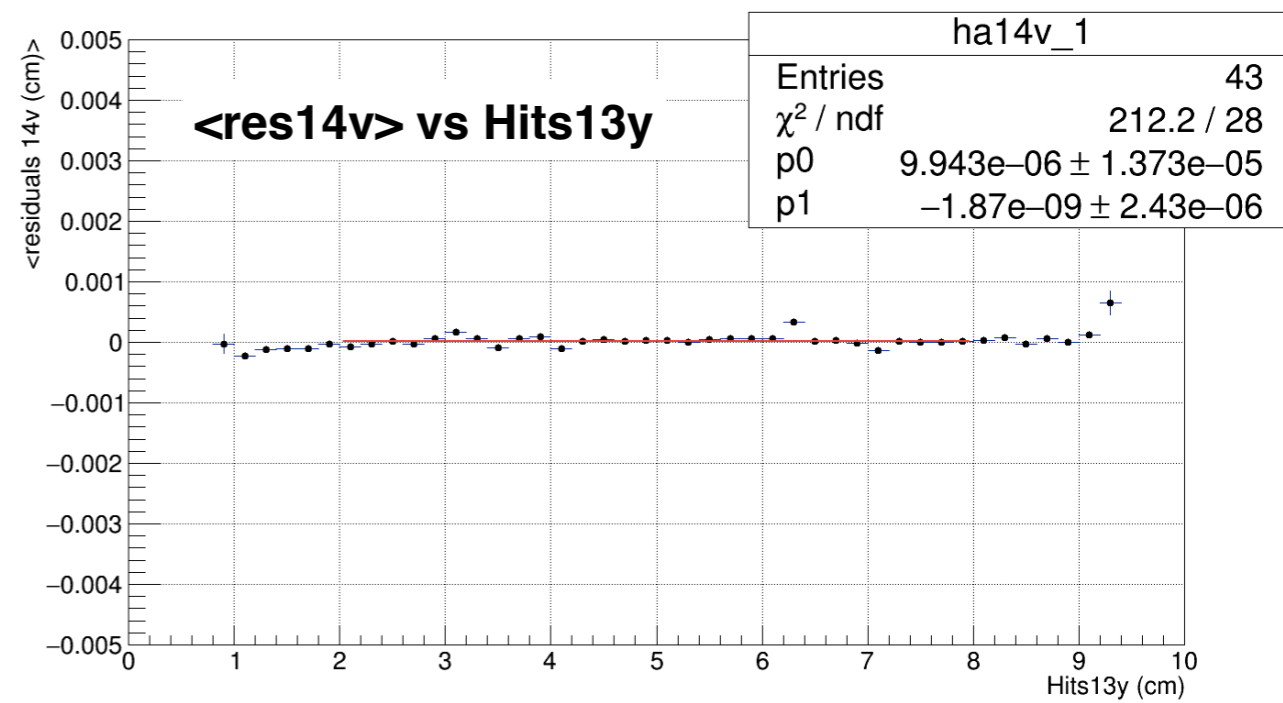
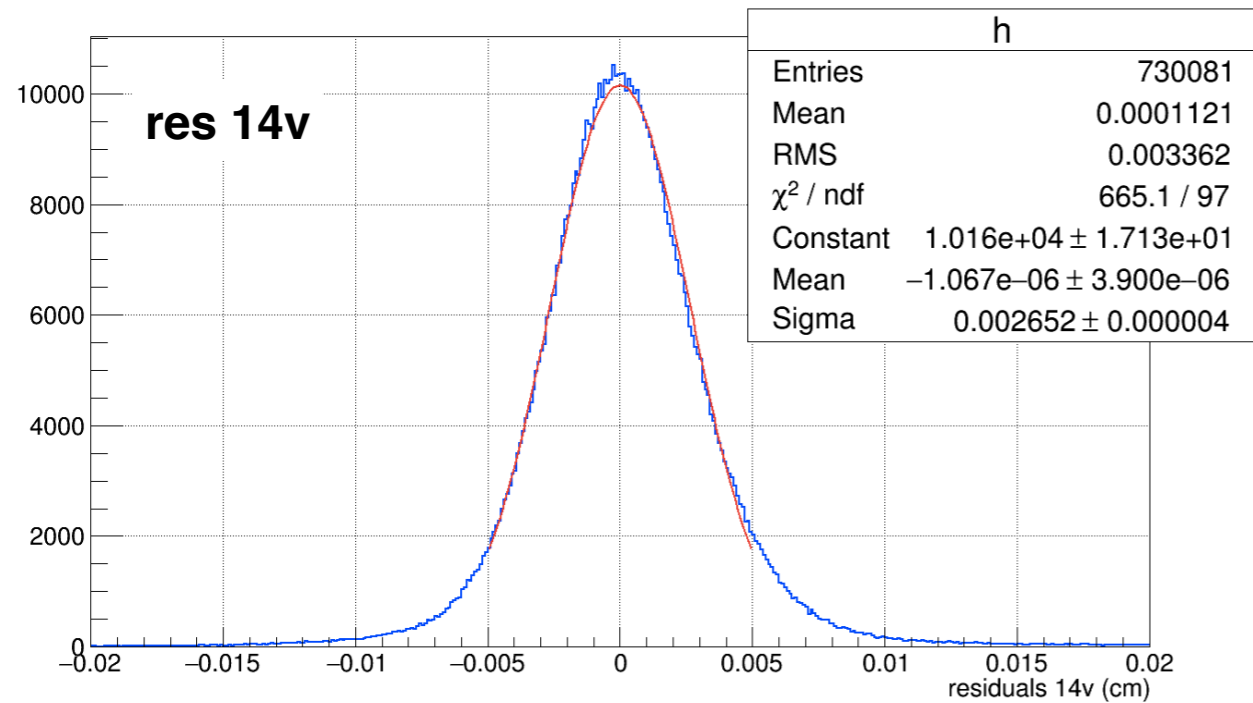
# Alignment 11y



- Le hits 11u ruotate di  $+45^\circ$  “diventano” 11y: sono allineate (iterativamente).
- Il residuo 11y ha sigma più elevata.

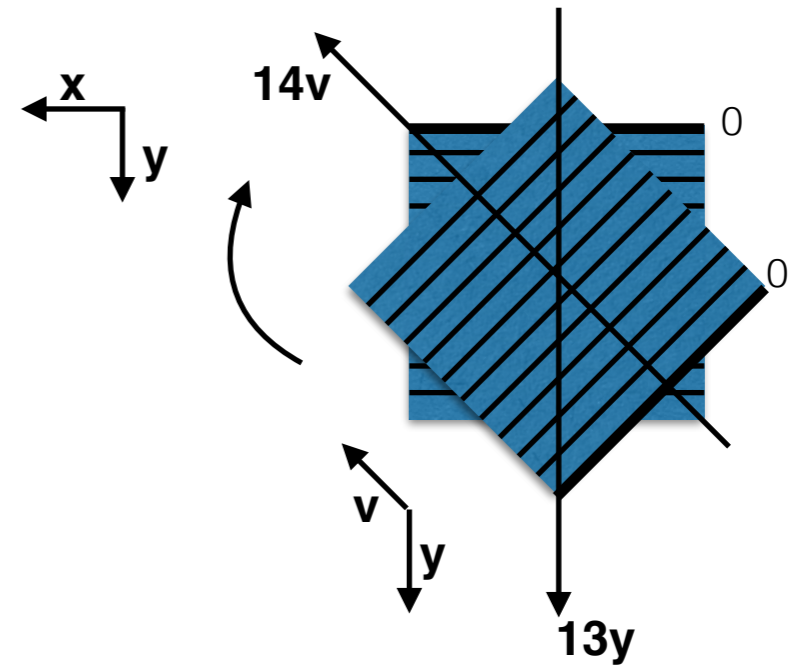
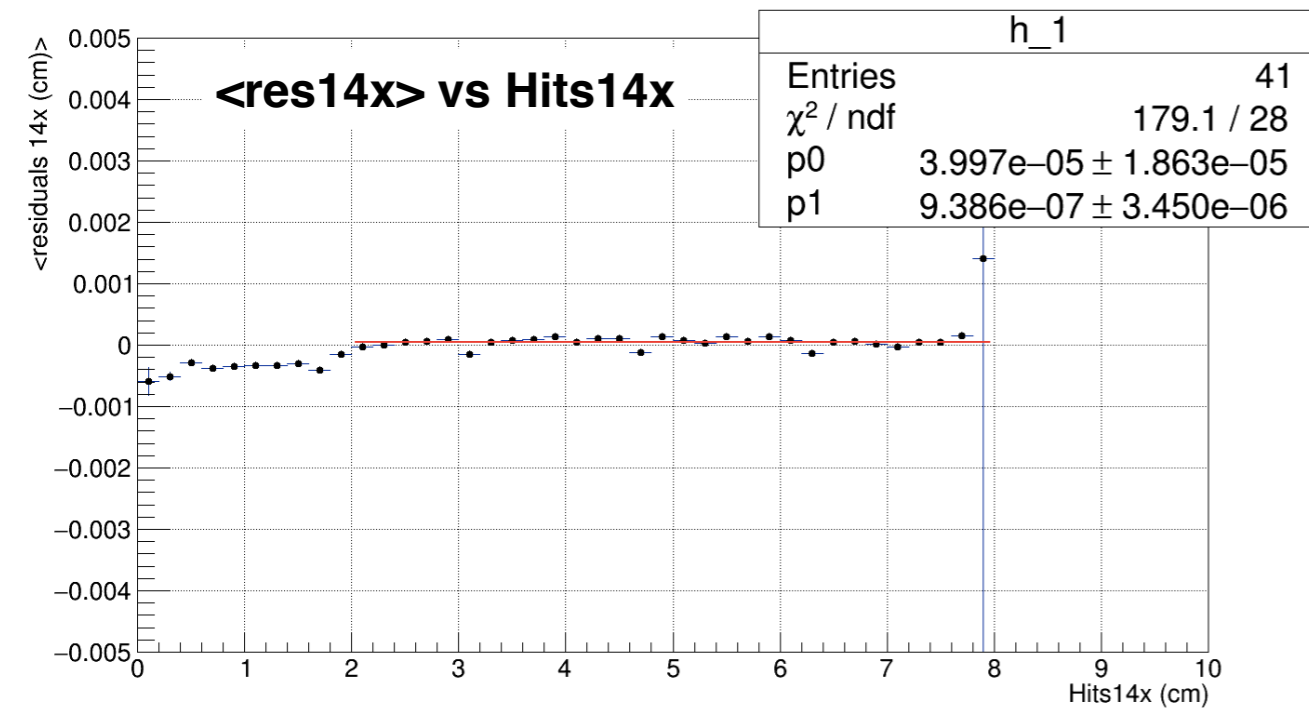
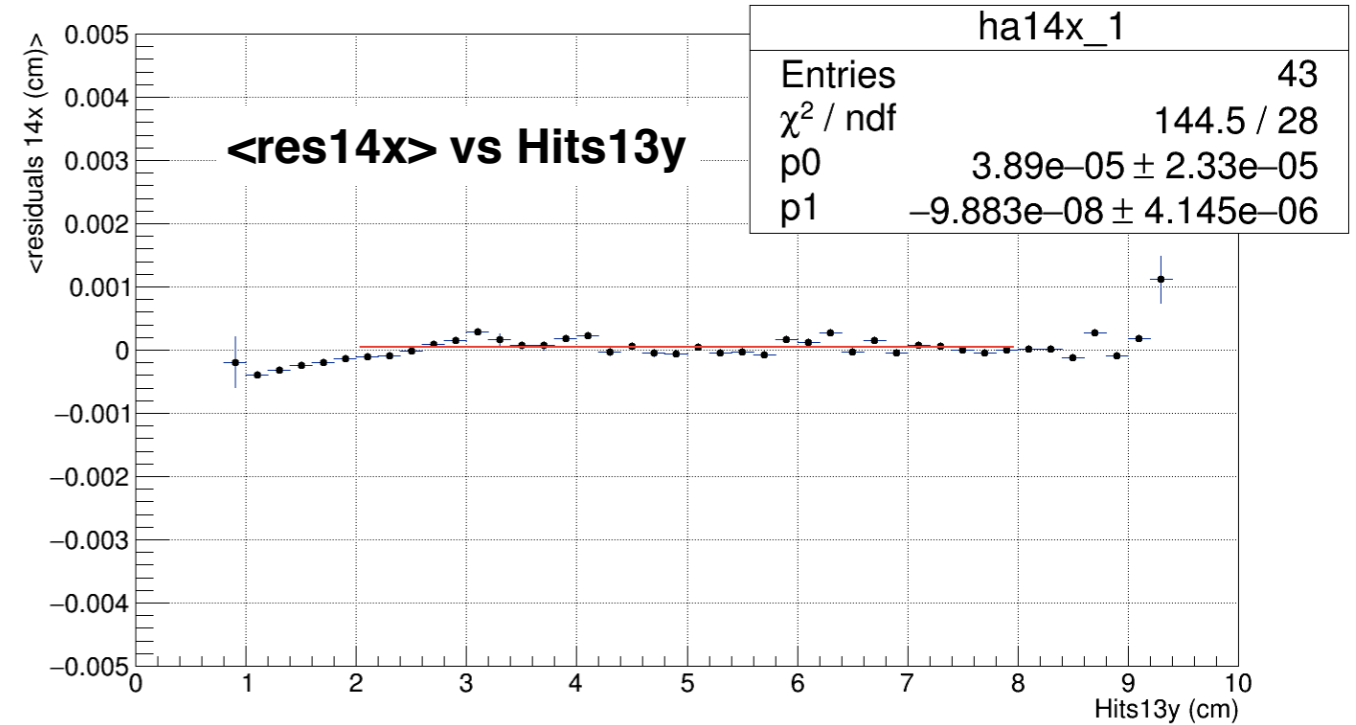
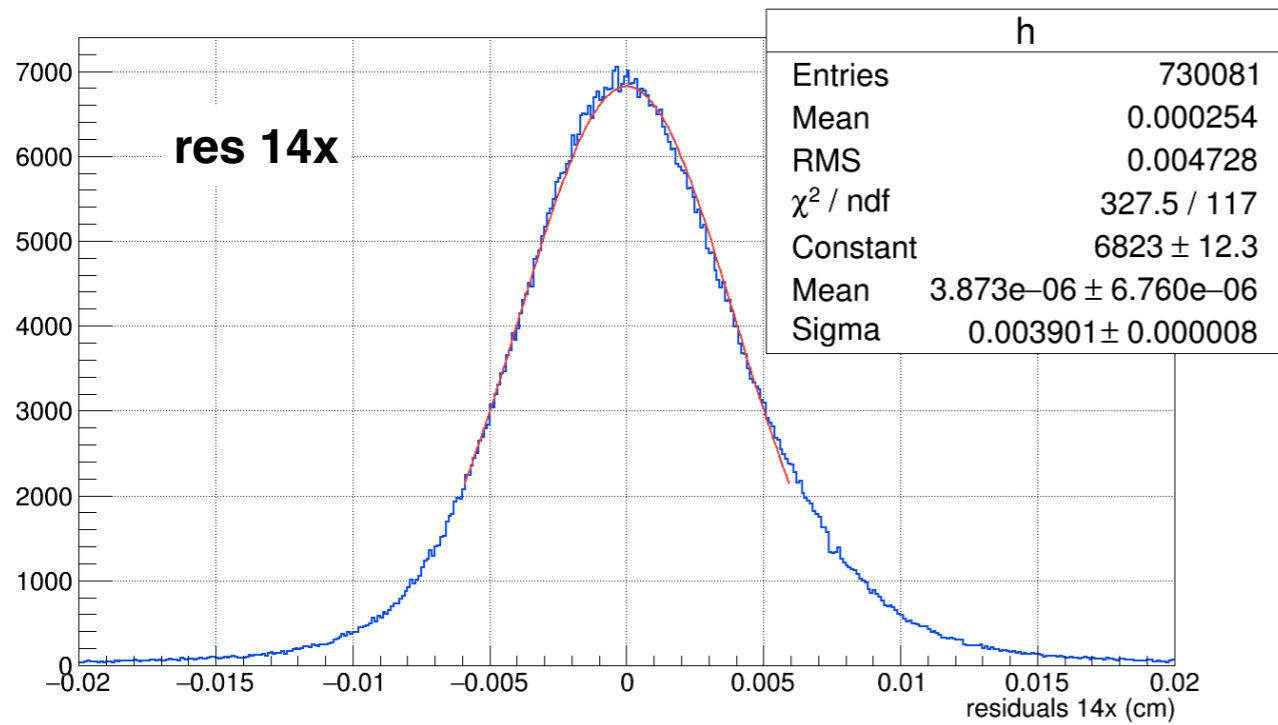


# Alignment 14v



- Correzione tilt 14v: **Hits14v' = (1-0.000133)\*Hits14v**. Questa correzione elimina automaticamente anche quella con il 12x.
- Il residuo, nonostante l'ottima risoluzione, mostra delle asimmetrie.

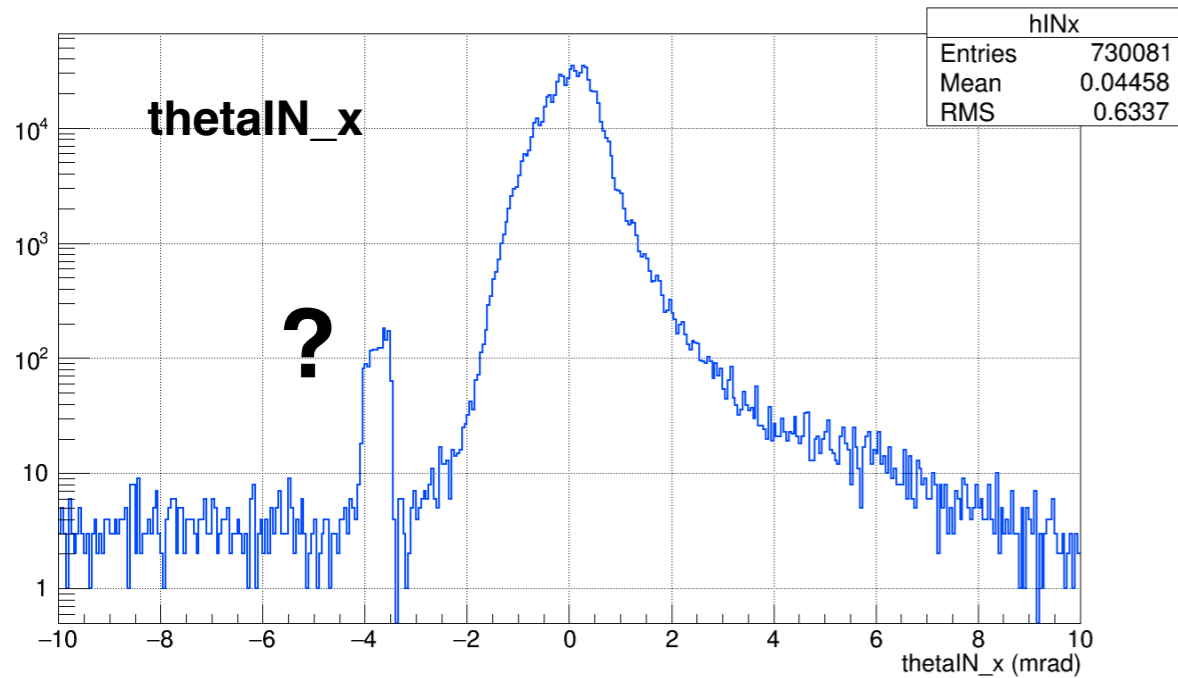
# Alignment 14x



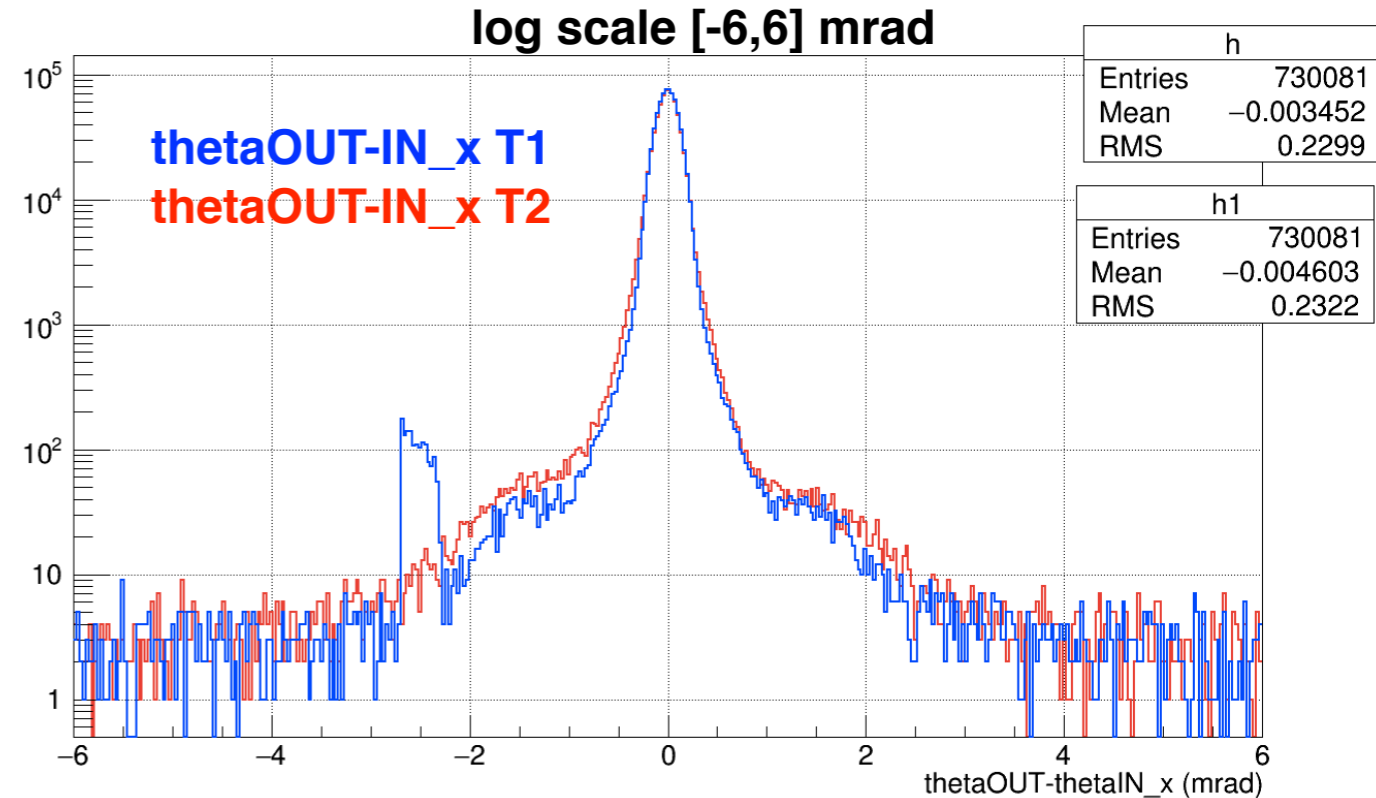
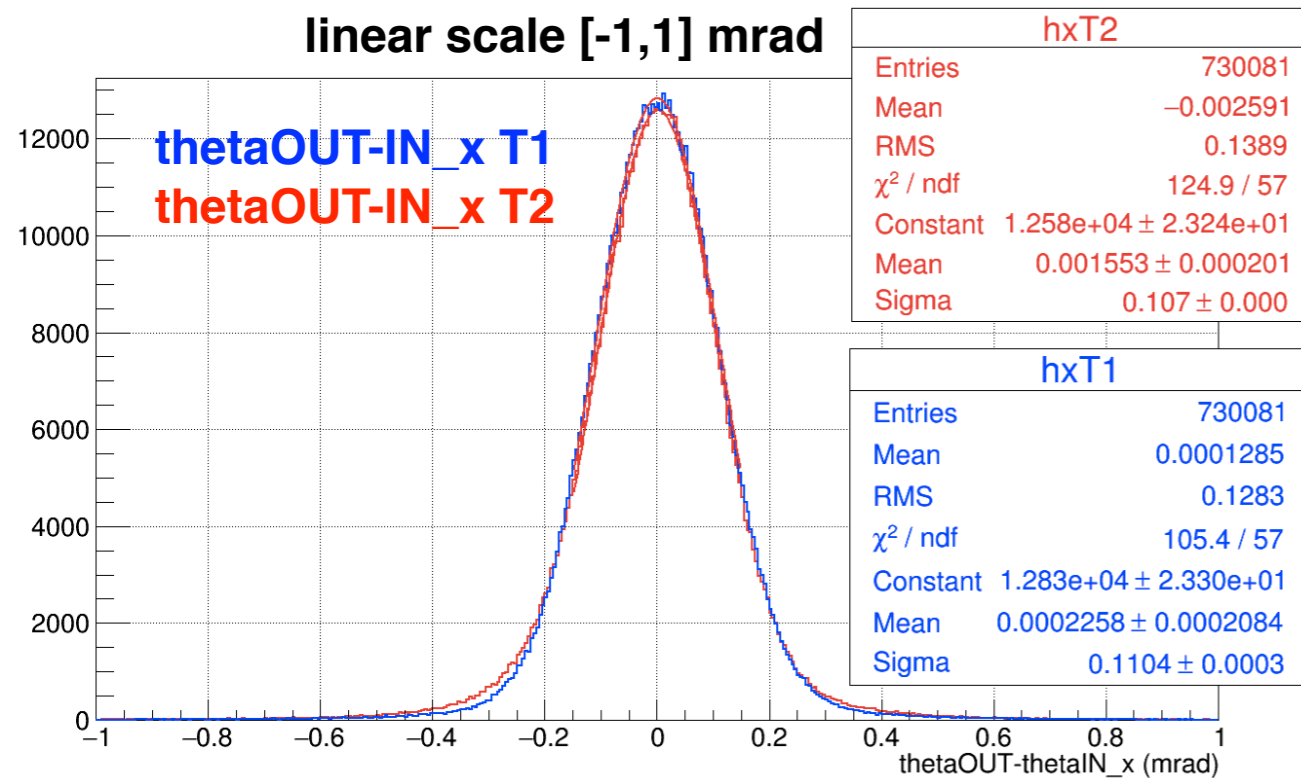
- Le hits 14v ruotate di  $+45^\circ$  “diventano” 14x: sono allineate (iterativamente).
- Anche in questo caso, il residuo 14x ha sigma più elevata.

## **Some physics preliminary results**

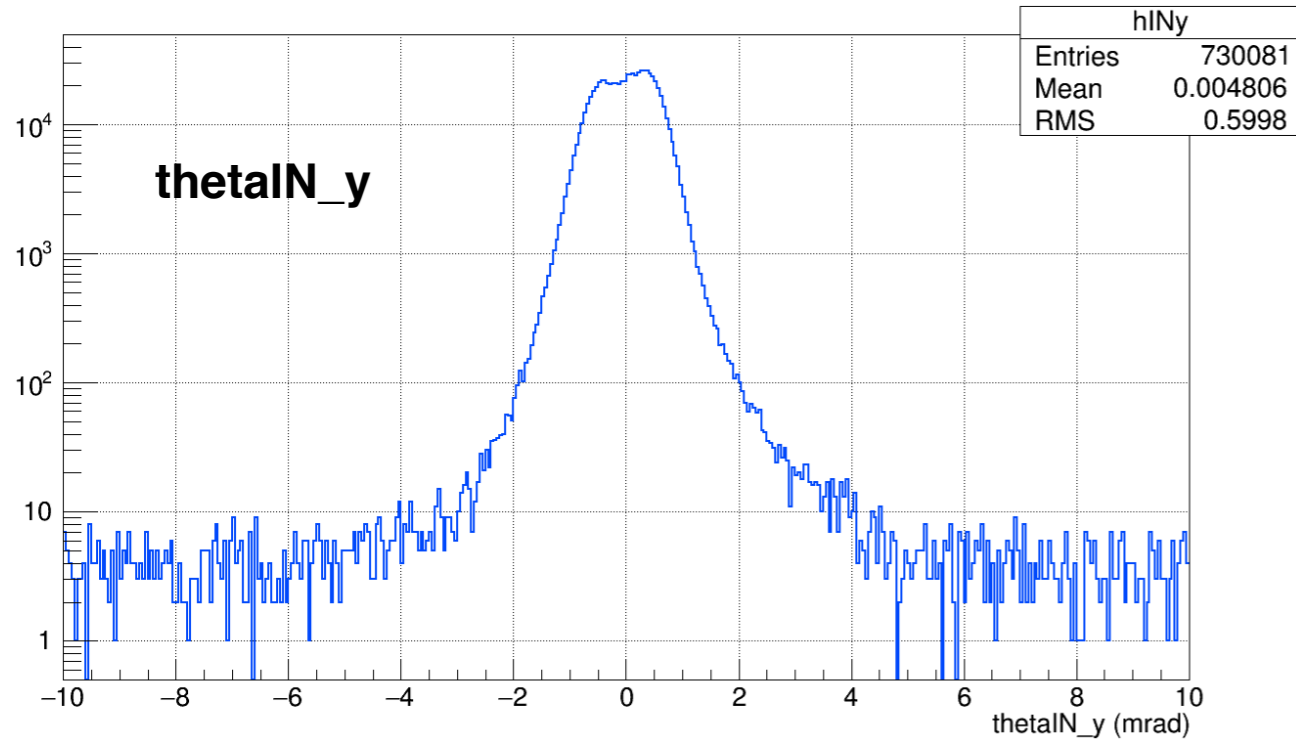
# Angular deflection on X view



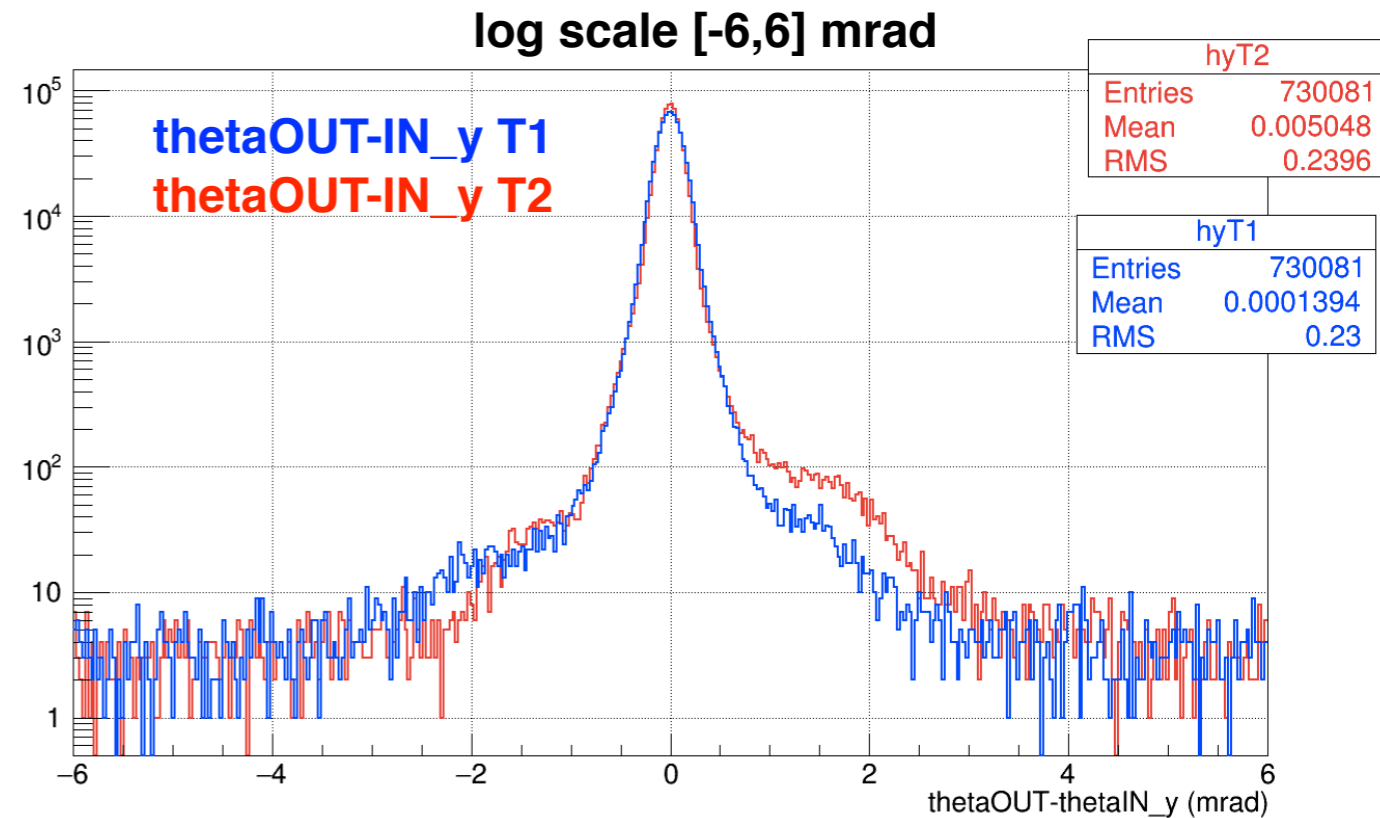
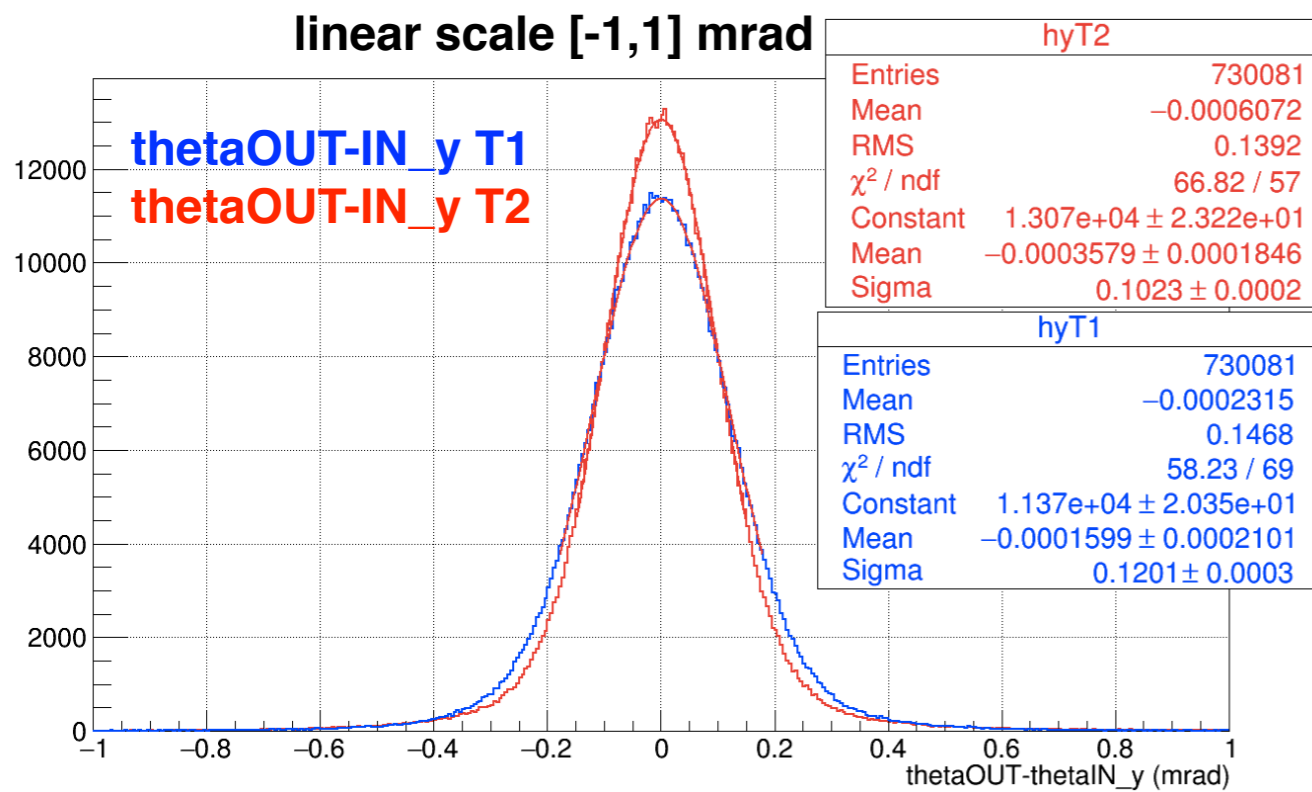
- Le distribuzioni appaiono ben allineate: si sono usati i piani **4x-6x / 8x-12x / 14x-16x**.
- Le sigma delle deflessioni angolari (vista X), per T1 e T2, sono compatibili tra loro e con quelle previste, basate su msc e risoluzione intrinseca.
- Bump nelle distribuzioni 3 ordini di grandezza sotto il picco (slide successive).



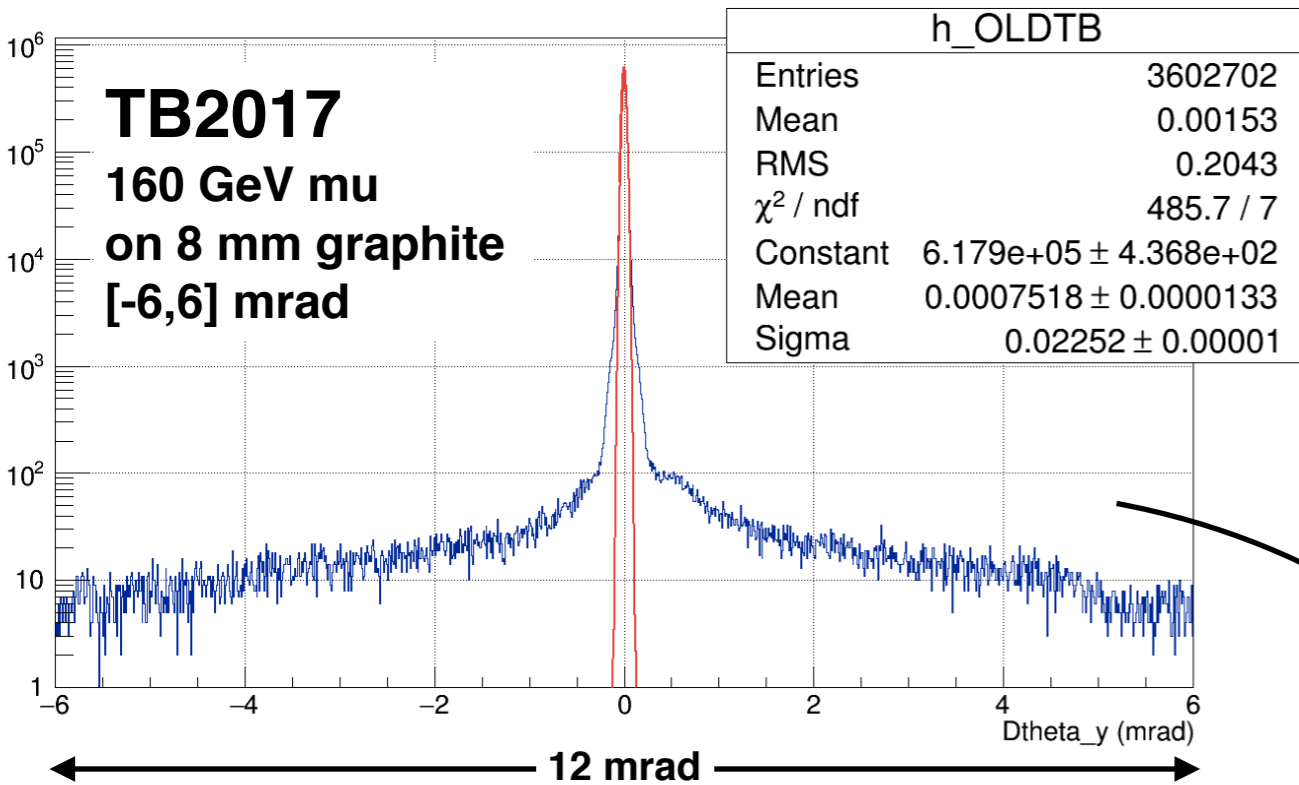
# Angular deflection on Y view



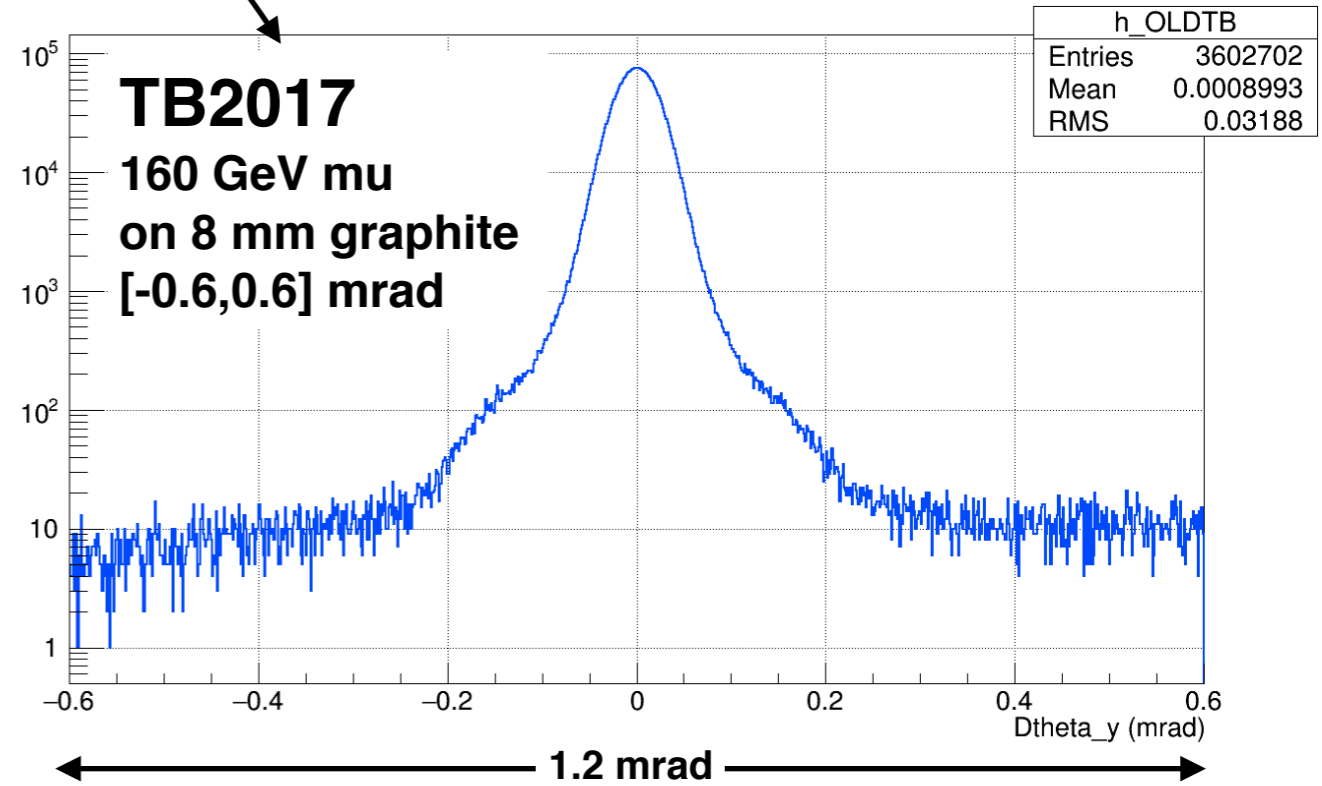
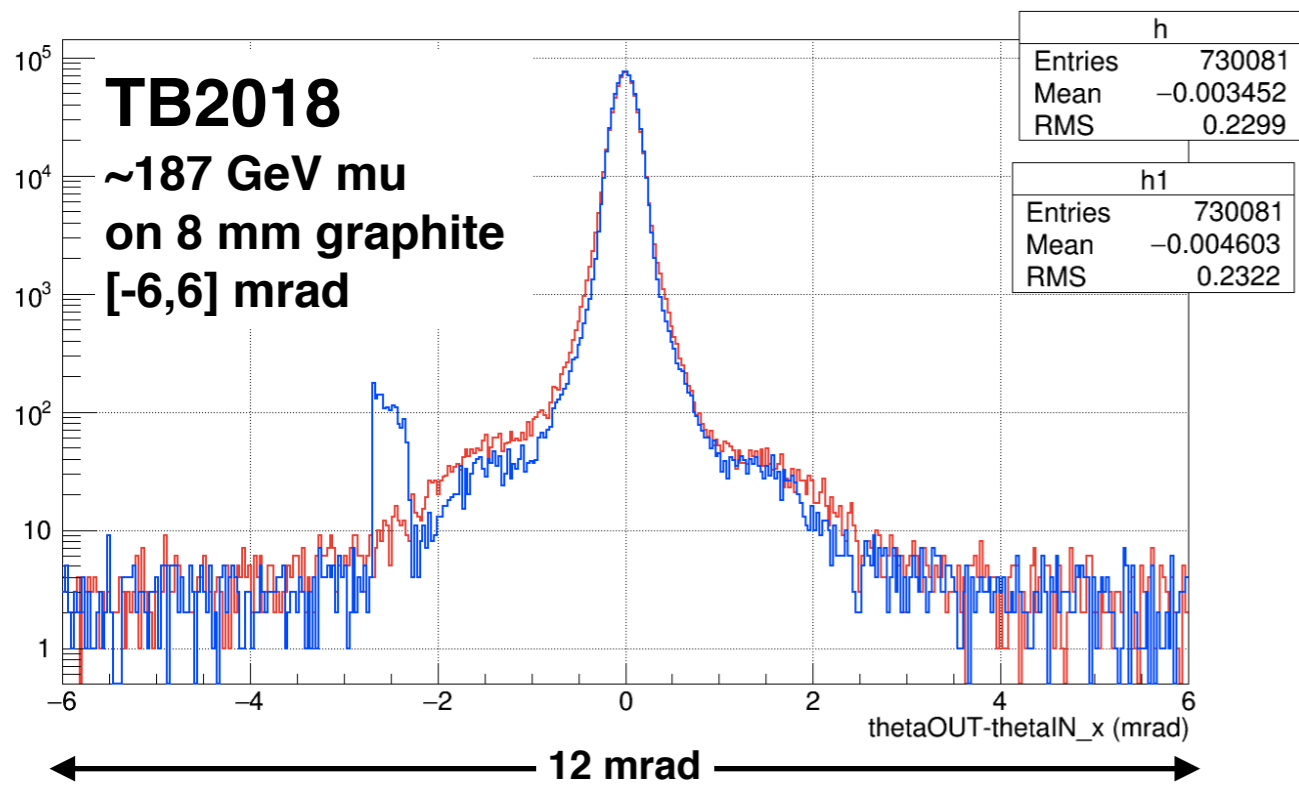
- Le distribuzioni appaiono ben allineate: si sono usati i piani **3y-5y / 7y-11y / 13y-15y**.
- La sigma relativa al primo target T1 appare significativamente più larga.
- Anche in questo caso, bump nelle distribuzioni, 3 ordini di grandezza sotto il picco: per T2 appare non in asse.



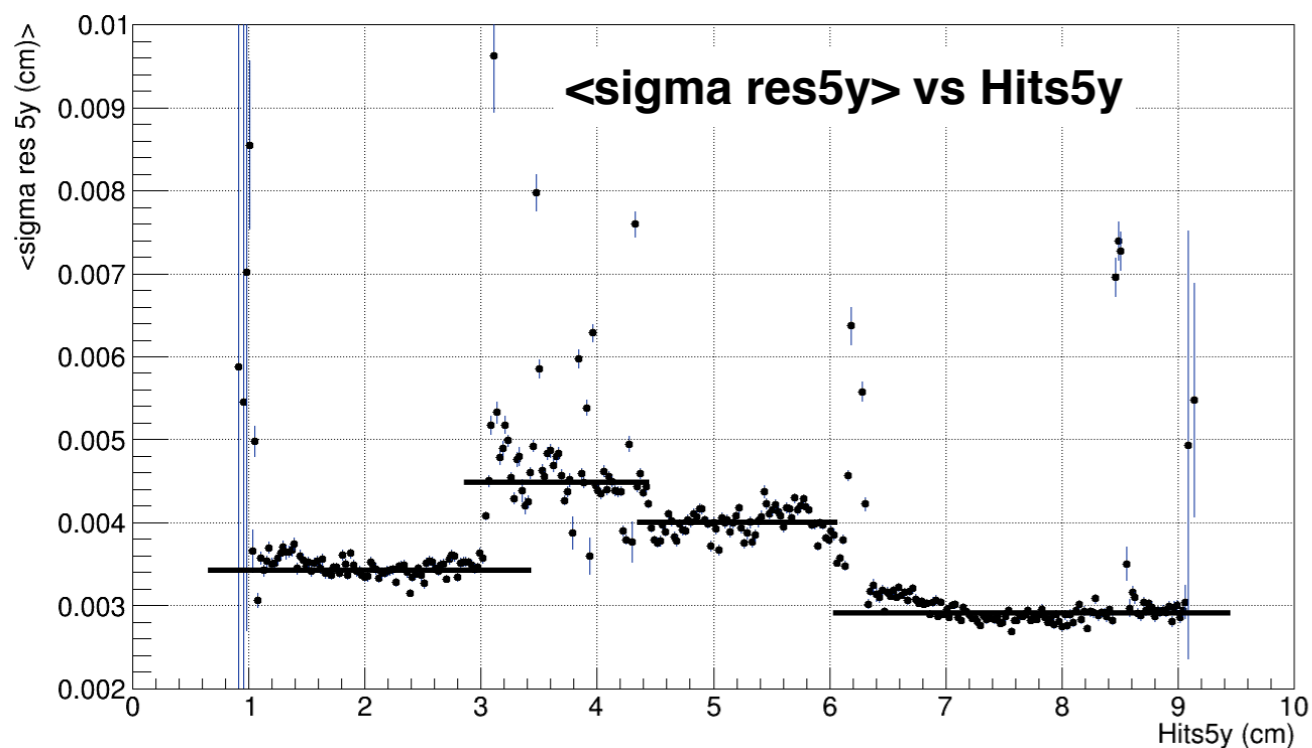
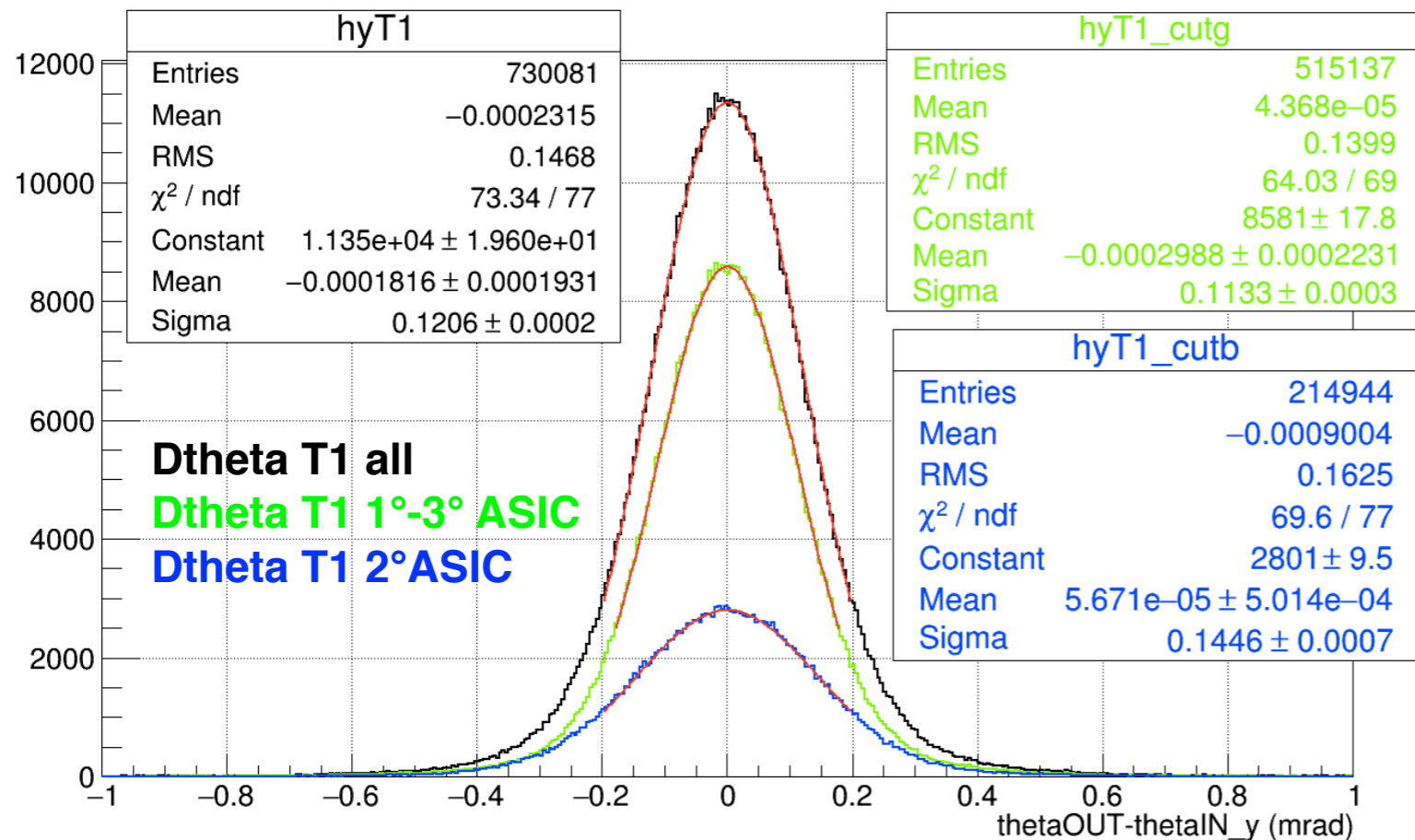
# Bumps comparison: TB2018 vs TB2017



- Al di là delle differenze tra i fasci (notare le scale differenti!), questo andamento caratteristico appare molto simile: nel tb2017 lo avevamo interpretato, grazie all'analisi del chi2, come una probabile contaminazione di carichi di più bassa energia (elettroni?).
- Non si notato nel tb2018 correlazioni con sensori, asic, dunque non sembra essere un problema relativo ai trackers.



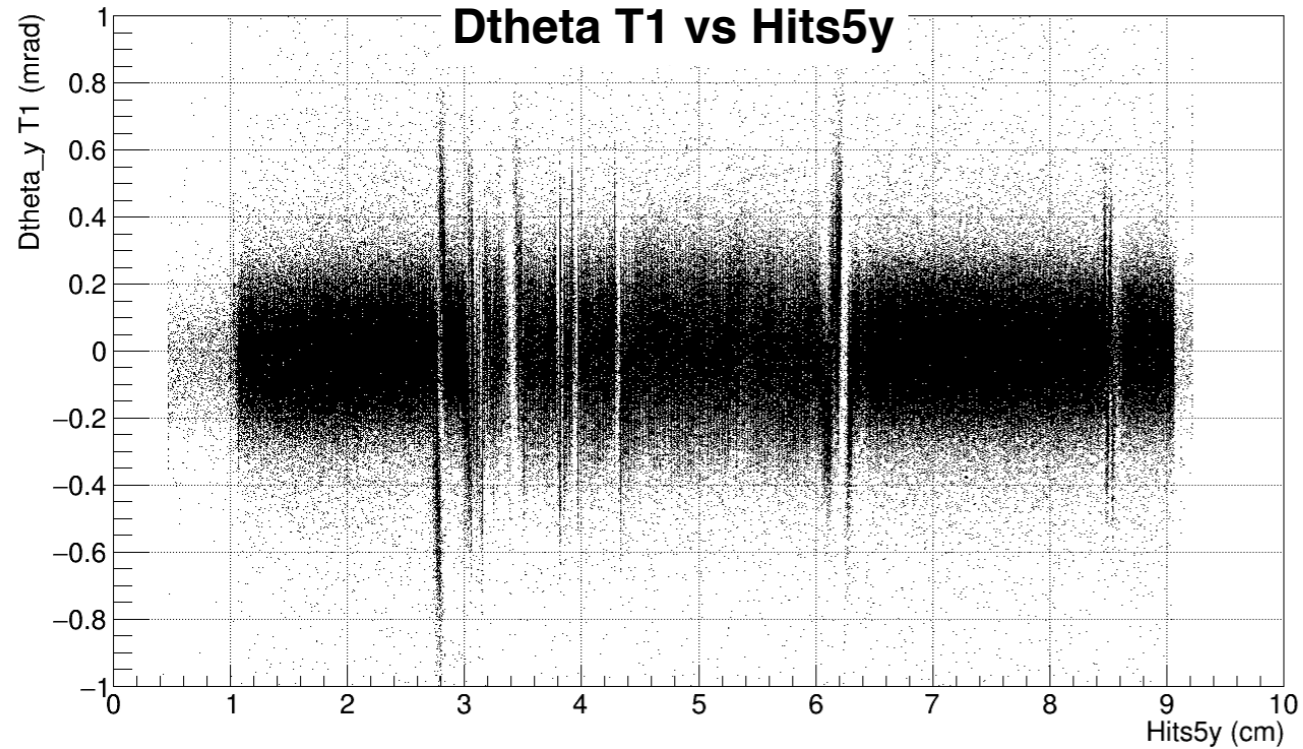
# Resolution effect on T1 angular deflection (1): cut on 5y



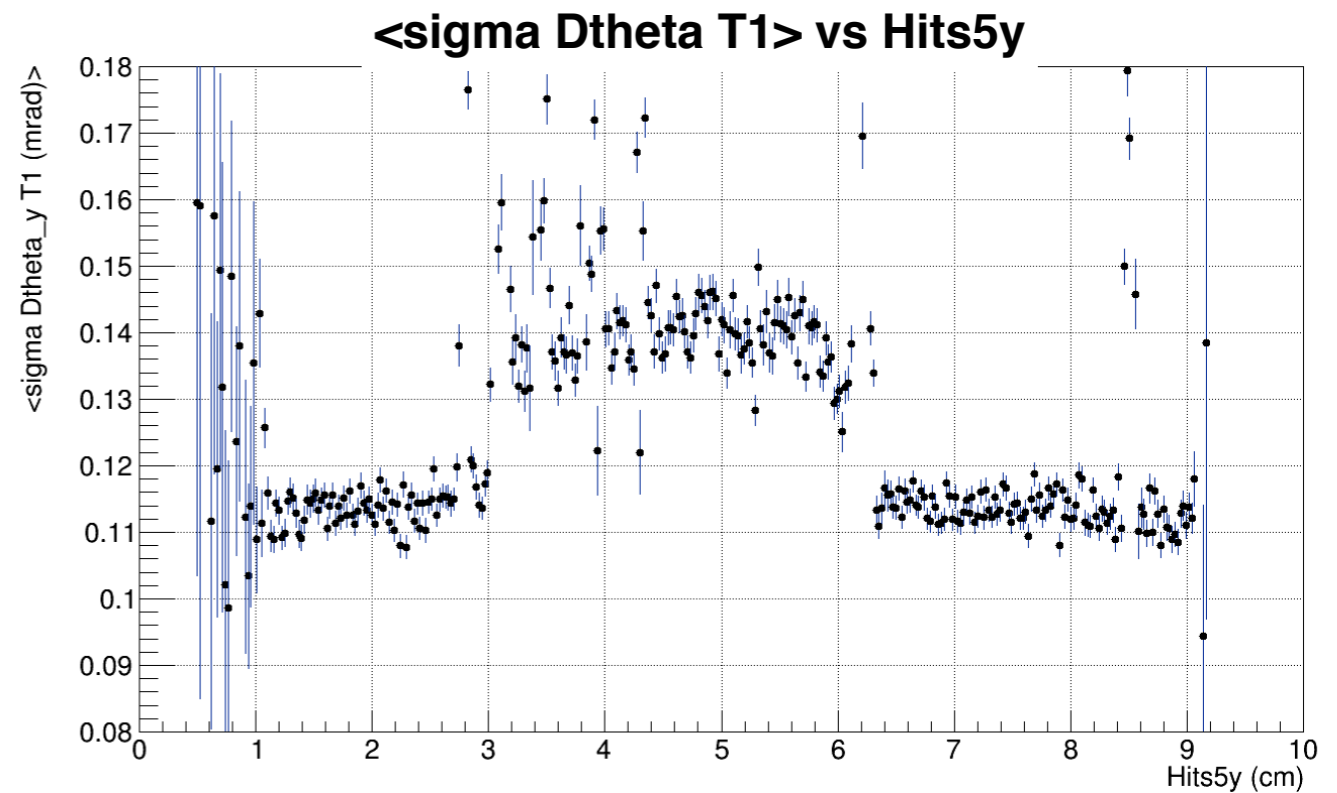
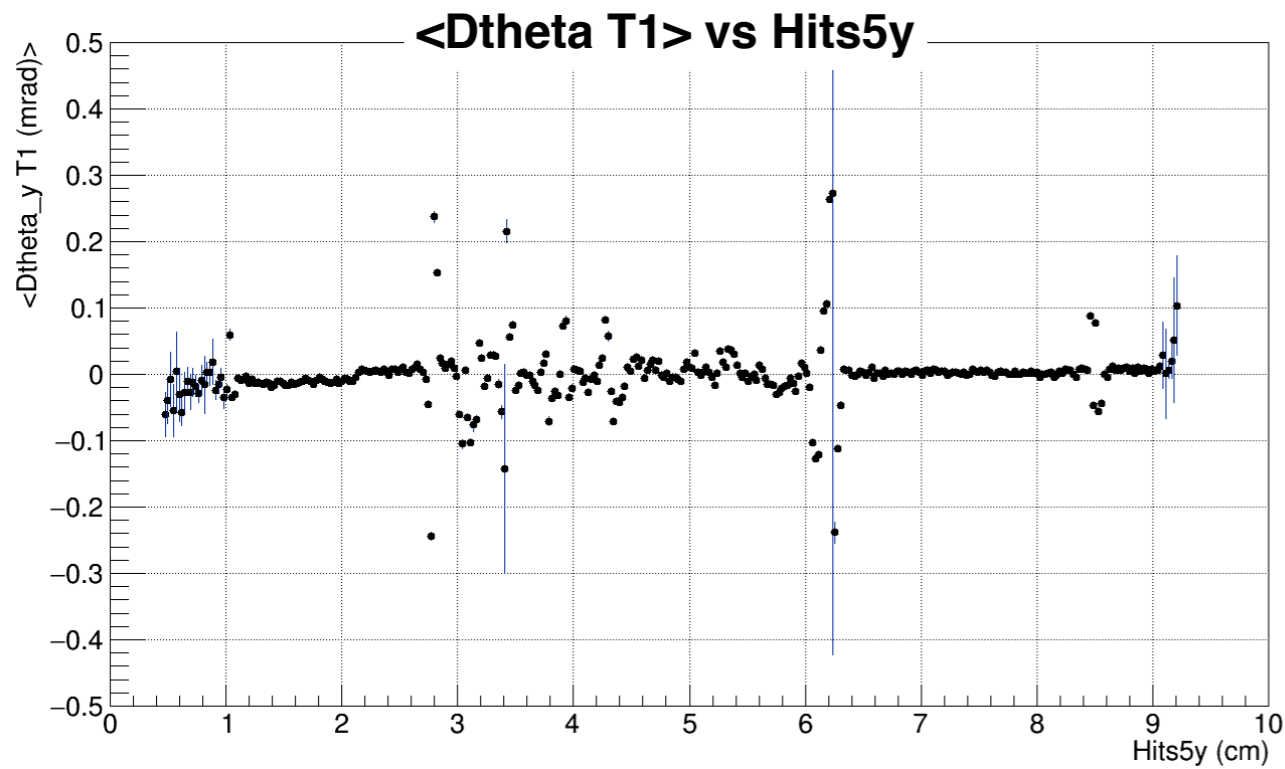
- Differenza tra le sigma misurate da ASIC centrale e gli altri del 5y: **circa 22% (0.1133 vs 0.1446 mrad)**. La figura totale (nera) media tra i due gruppi.
- Tale differenza si ritrova in quella tra le risoluzioni: per ASIC 1-3 circa 33 um, per ASIC 2 circa 43 um, **23%** di differenza.
- Questo è l'impatto diretto sulla misura angolare (Dx -> Dtheta): probabilmente sarà ridotto dalla procedura di fit.

# Resolution effect on T1 angular deflection (2): layer 5y

$$((\text{Hits11y}-\text{Hits7y})/55.17-(\text{Hits5y}-\text{Hits3y})/50.)*1.e3:\text{Hits5y}$$



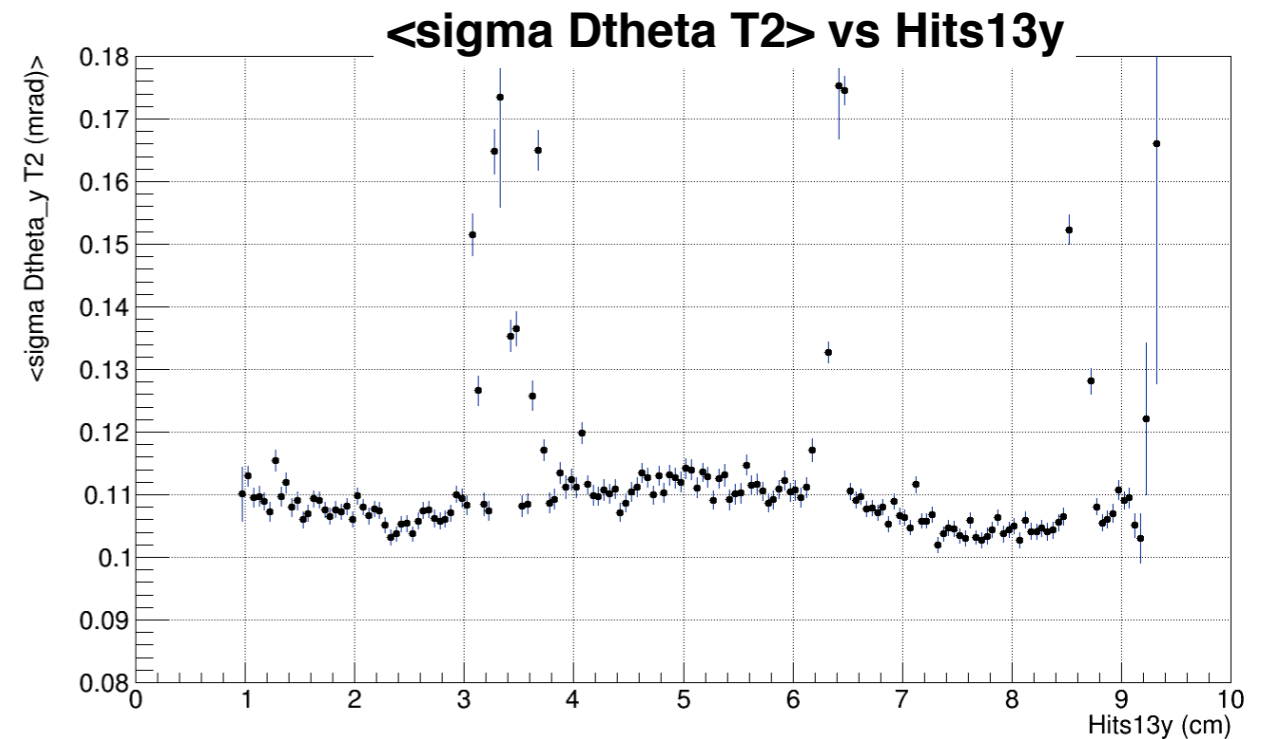
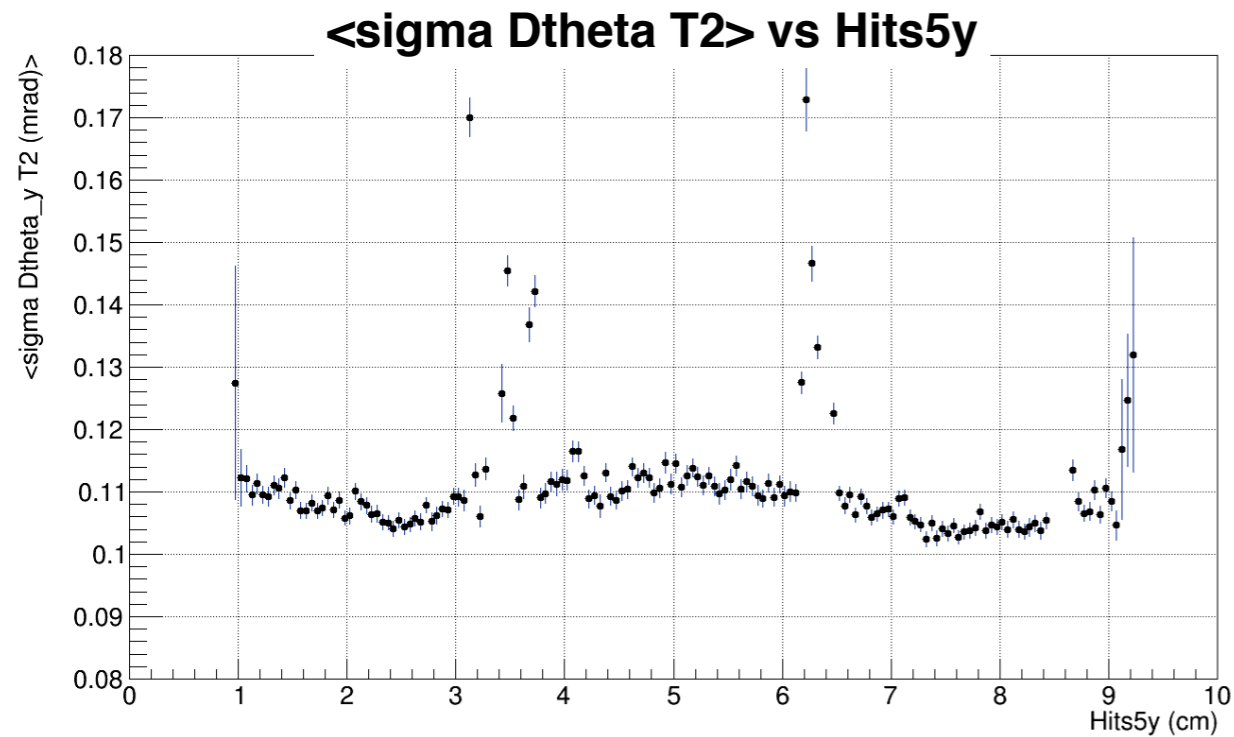
- Plot simili a quelli res5y vs hits5y: mostrano da un altro punto di vista il problema che induce questo layer. Altri non lo presentano.
- Si nota inoltre lo shift sistematico nella ricostruzione dell'angolo dato dalle strip vicine a quelle che non leggono.





# Resolution effect on T2 angular deflection: hits\_y

IN from 7y-11y / OUT from 13y-15y



- Ovviamente il layer 5y non propaga i suoi problemi (differente risoluzione) alla misura a valle.
- Gli altri layer non presentano questo problema, ma certamente quello del **sistematico ai bordi delle dead strips (da trattare)**.

**Some numbers and conclusions (on alignment)**

# Multiplicity and some numbers (1)

ev TOT: 2684341

—>  $I(\mu/s) * 4s(\text{durata spill SPS}) * 2000(\text{n spill nel run}) \sim 2.6e6 (?)$

—>  $I(\mu/s) \sim 325 \mu/s$

—> intensità “**vista**” dall’apparato, **al netto delle inefficienze e del rate (6-7kHz)?**

Intensità reale in arrivo:

M2:  $\sim 20e7/\text{spill}$  ( $\sim 5e7 \mu/s$ ) a 150 GeV ->  $\sim$ un fattore 10 in meno(?) a 190 GeV  $\sim$  **5e6  $\mu/s$**

(intensità dichiarata nel paper MUonE: **1.3e7  $\mu/s$** )

**—> fattore 4e3 in meno di intensità**, contando il fascio meno intenso a 190GeV)

\*\*\*\*\*

(1u2x) 3y4x 5y6x **T** 7y8x 9y10x 11u12x **T** 14v13y 16x15y

11 11 **T** = 2287465

11 11 **T** 22 = 173424

11 11 **T** 22 22 = 8276

11 11 **T** 22 22 22 = 2646

11 11 **T** 22 22 22 **T** 22 22 = 222

11 11 **T** 12 22 22 = 451

11 11 **T** 21 22 22 = 834

11 11 **T** 22 12 22 = 786

11 11 **T** 22 21 22 = 4080 -> inefficienza 10x

11 11 **T** 22 22 12 = 1486 ->11u

11 11 **T** 22 22 21 = 682

11 11 **T** 22 2n 22 = **8704**  $\sim 9 \cdot 10^3$  ->  $\sim 0.4\%$  (su m=1 upstream)

n1 11 **T** 22 2n 22 = **10462**

11 11 **T** 22 2n 22 **T** 22 22 = 1072

n1 11 **T** 22 2n 22 **T** 22 22 = 1308

# Multiplicity and some numbers (1)

Geant4 LO cross section

$5.0e5 / 5e8$  (mu in tot)  **$\sim 0.1\%$  di cui 70% segnale e 30% fondo** (quasi il 100% coppie)

(150 GeV mu on 20 mm Be, accettazione 50 mrad, eff=100%)

\*\*\*\*\*

Richieste MUonE

**$\sim 10e12$  eventi di segnale** nel piano mu-e

Proiezione, supponendo 60 moduli come quelli del TB2018:

**$\sim 9e3$  eventi** interessanti in un run per day (diminuiti di un fattore 3 se si richiedono le hits anche sul 10x)

$\sim 9e3 * 0.7 = 6.3e3$  di segnale (basandomi sul ratio signal/background Geant)

$6.3e3$  di segnale \* 100  **$\sim 6.3e5$  di segnale (100 giorni)**

$6.3e5 * 3 = 2e6$  in un anno utile di presa dati

$2e6 * 2 * 60 = 2.4e8$  **eventi di segnale** in due anni, intero apparato.

Manca un fattore  $10e12 / 2.4e8 \sim 4e3$ , proprio pari al rapporto tra le intensità [  $M2(150\text{GeV}) / M2(190\text{GeV}) \sim 10$  ]:

**$I$  (richiesta MUonE) /  $I$  (vista dal TB2018) =  $(1.3e7 \text{ mu/s}) / (325 \text{ mu/s}) = 4.e4 / 10 = 4.e3$**

I conti tornano?

# Blobel on alignment(1)

<http://www.desy.de/~blobel/finzuali.pdf>

**Histogramming.** The basic idea of the histogram method, already mentioned in the previous section, is to extract parameter corrections from the peak (or mean or median) of residual histograms. The advantage of this method is that almost no extra code is necessary and the histograms can be generated from  $n$ -tuples of the residuals. However, the residuals are taken from biased fits and no precision alignment can be expected. In order to obtain convergence, many iterations would be necessary and therefore the method is extremely slow. The method is limited to those parameters which are directly accessible from residuals histograms. Furthermore it is not obvious how to fix undefined or badly defined degrees of freedom.

**Simultaneous alignment and track fit.** The so-called *global*  $\chi^2$ -function is the least squares sum over a large number of tracks from different data sets

$$\chi^2 = \sum_{\text{data sets}} \left( \sum_{\text{events}} \left( \sum_{\text{tracks}} \left( \sum_{\text{hits}} w_i r_i^2 \right) \right) \right), \quad (3)$$

which is minimized either with respect to the alignment corrections  $\Delta p$  only (solution I), or with respect to the corrections  $\Delta p$  and *all* track parameters  $q_j$  (solution II).

[http://www.desy.de/~blobel/blobel\\_align.pdf](http://www.desy.de/~blobel/blobel_align.pdf)

The reason for non-convergence is simple:

Two degrees of freedom are undefined: a simultaneous shift and a rotation of all planes!

(This simple fact is not always mentioned in reports on the method!)

Improvement for second residual attempt:

- 1 Fix the displacement (i.e. displacement = 0) of two planes, which are assumed to be carefully aligned externally (e.g. planes 3 and 9).

Other possibilities are:

- 2 • Use only fixed planes (planes 3 and 9) in the fit, and determine the residuals of other planes;
- 3 • for the determination of the displacement of a certain plane use all other planes in the fit.

These possibilities are in fact used by several collaborations!

Large changes in first iteration, then many smaller and smaller changes: convergence is **linear** and slow, because the determination of displacements is based on biased fits.

Residual-based methods work with biased results. **Can the bias be avoided by an improved fit?**

**Yes:** include the alignment parameters in the parameters fitted in track fits – requires a simultaneous fits of many tracks, with determination of (global) alignment parameters and (local) track parameters.

model:  $y_i \cong a_1^{\text{local}} + a_2^{\text{local}} \cdot x_i + a_j^{\text{global}}$   $a_j^{\text{global}}$  = shift for plane, where  $y_i$  is measured

# Blobel on alignment(1)

<http://www.desy.de/~blobel/alirepcern.pdf>

Because the track fit parameters are determined *before* the alignment step, the residuals are biased and the resulting alignment parameter corrections, determined either directly from the means of residuals or by the least squares fit are biased. In order to reduce or remove the bias in the result, iterations of the procedure are necessary, where the track fits are repeated with the improved alignment hoping, that the procedure converges. It is difficult to relate the procedure to any iterative method found in mathematical textbooks. If the convergence is linear, then the convergence rate depends on the eigenvalue spectrum of the complete system, and one could expect a good progress for the initial iterations and a slower and slower progress with increasing iteration number. Reported are iteration numbers until convergence in the range from 20 to 100.

## Domande finali (conclusioni?):

- Come trattiamo, allora, i problemi legati alle dead strips?
- Come procediamo alla finalizzazione della procedura di allineamento?
- Ovvero come controlliamo, ammesso sia possibile (data la procedura che abbiamo adottato), eventuali bias residui introdotti dalla scelta di piani con misallineamenti?
- Come usiamo i piani uv per disambiguare?
- Come tracciamo: nelle due viste separate e/o direttamente nello spazio? In questo secondo caso, bisogna costruire a mano un codice, definire una distanza (che comprenda gli uv) da minimizzare. ROOT, ad esempio, non presenta un metodo standard: l'argomento non è banale.