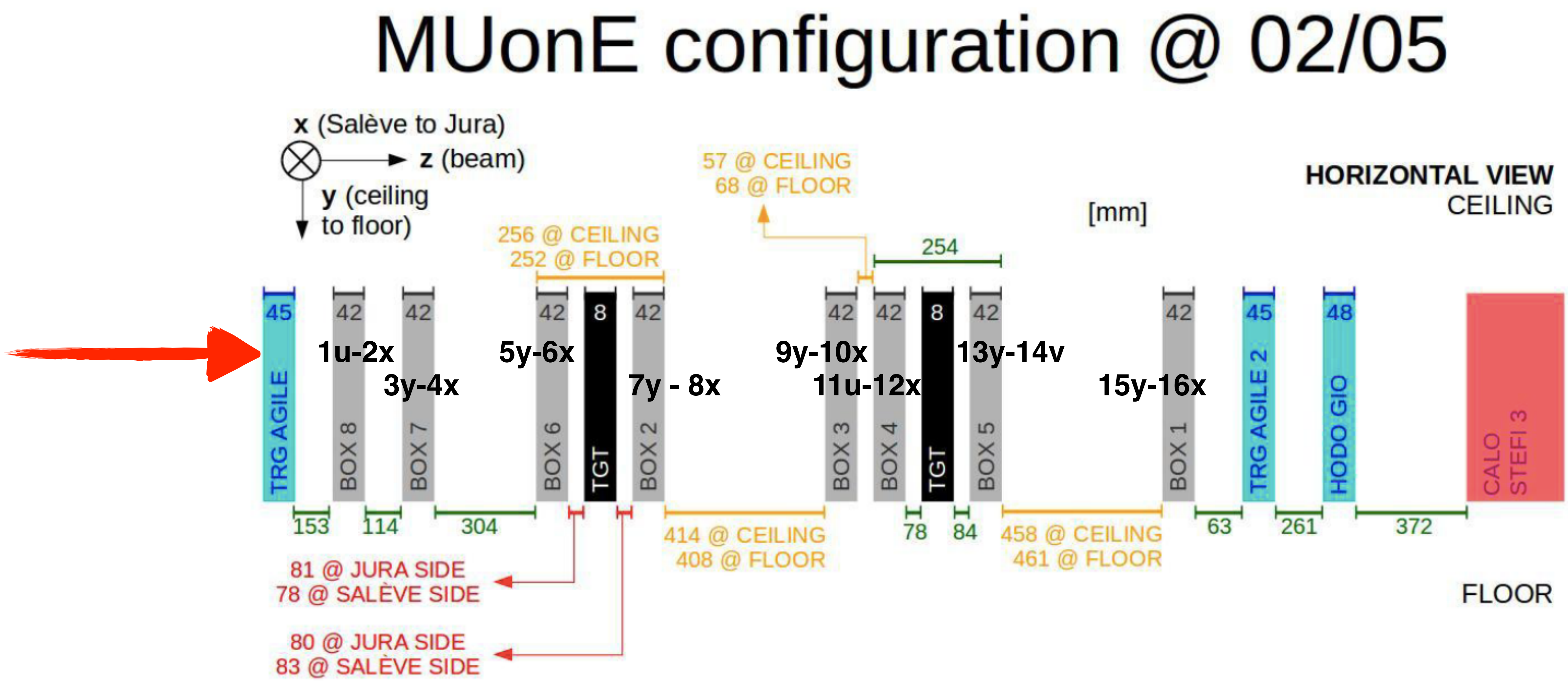
Summary on alignment test beam 2018

MUonE meeting
04/12/2018

A. Principe

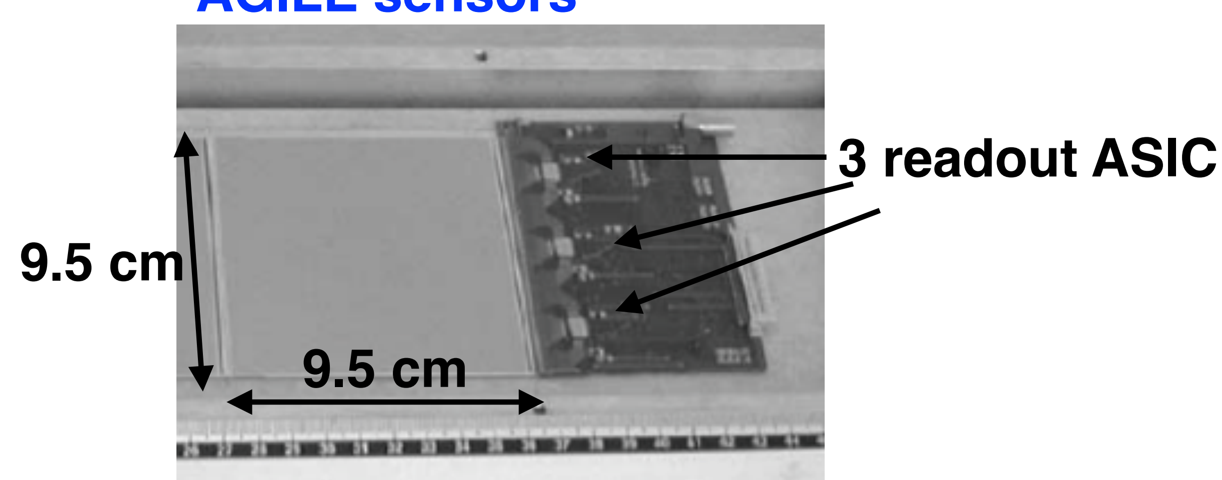
Test beam apparatus



- Strip pitch: 242 um
- Nominal point resolution ~ 35-40 um

- **from 4/05: 3 upstream boxes**
- **from 27/06: no target 2**
- **from 20/08: new box 8 and 3**

AGILE sensors



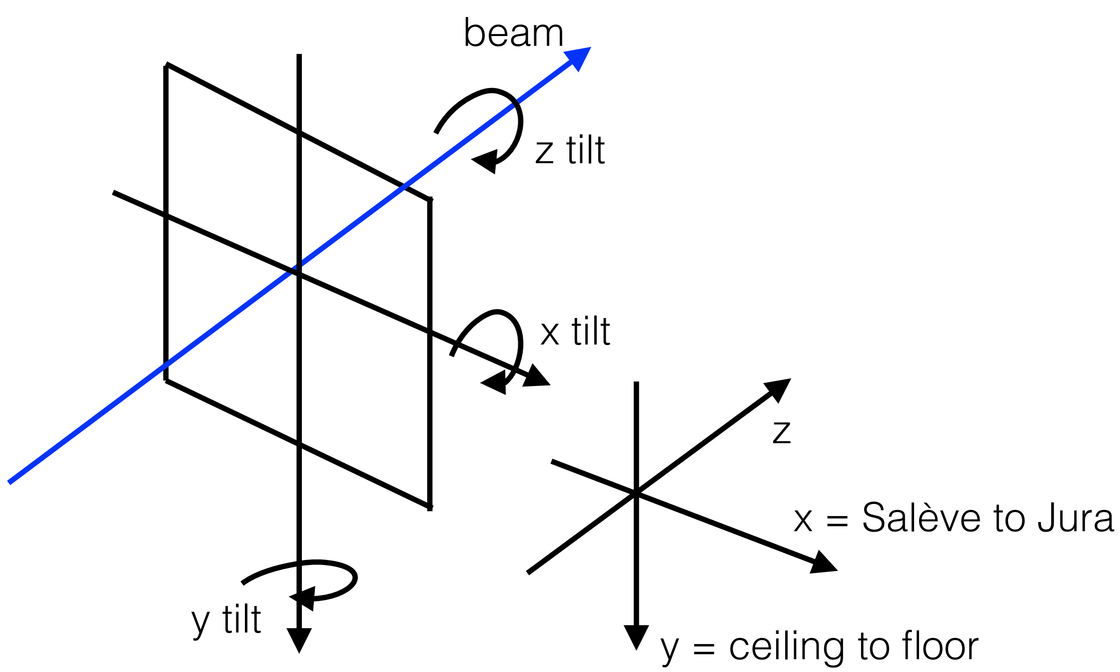
Alignment procedure

- We have chosen an histogram-based procedure suitable for small apparatus, like test beams: with some changes, we have adapted the algorith used for the test beam 2017.

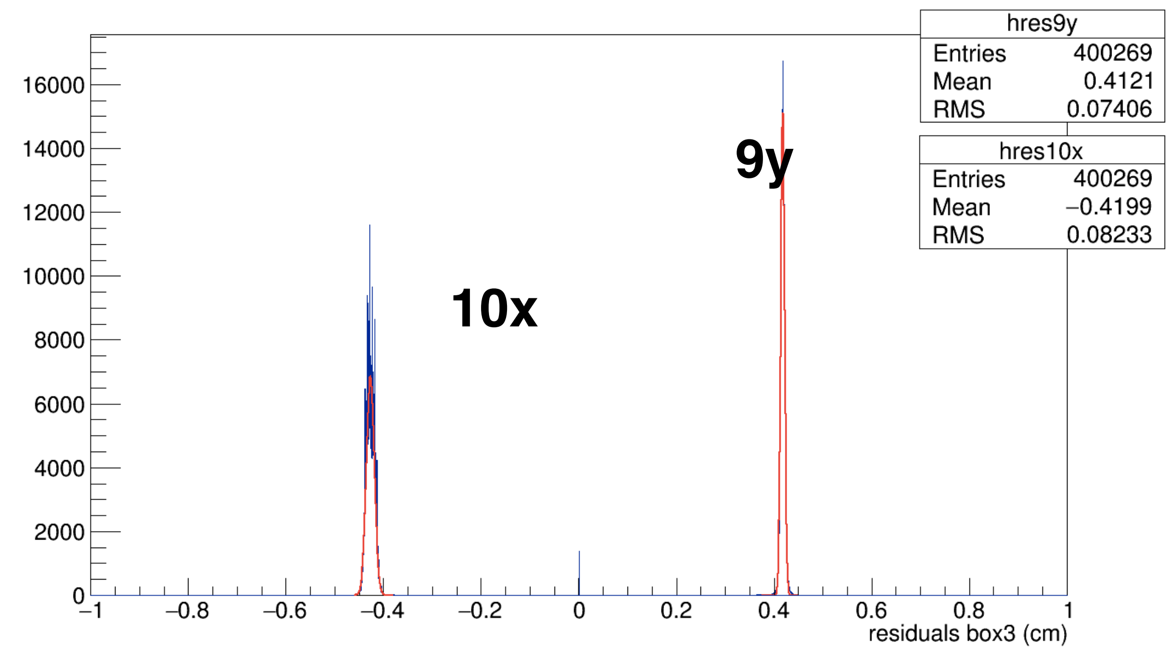
$$hits'_i = hits_i - r_i - a_i \cdot hits_j$$

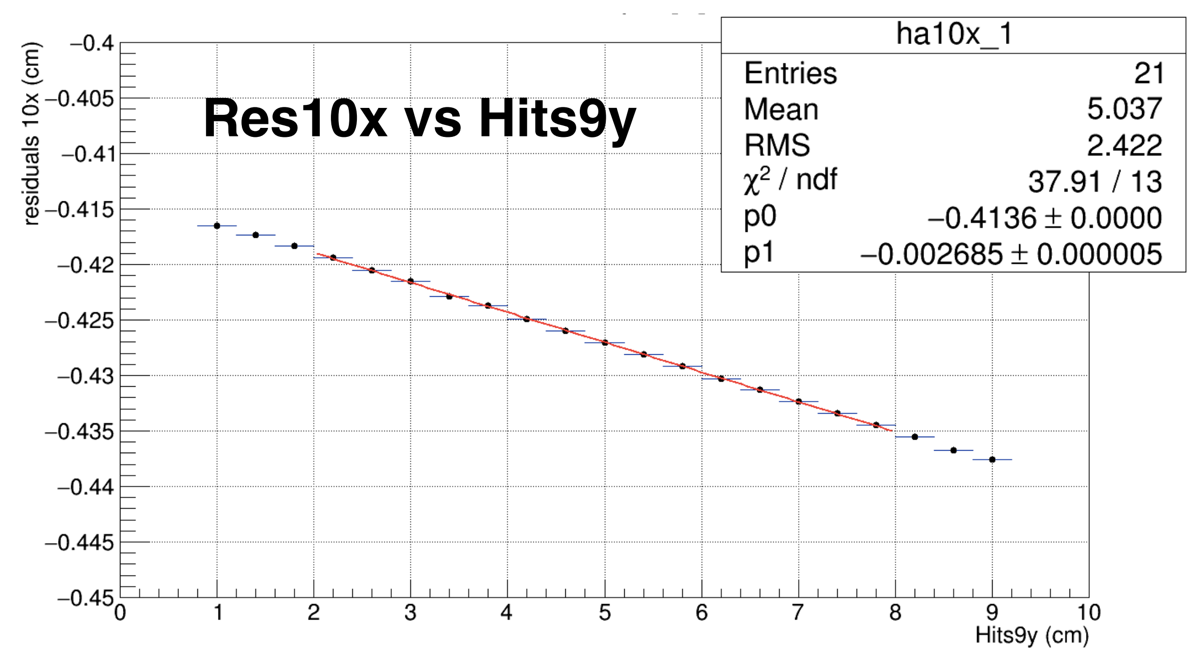
$$\Longrightarrow \quad r_i \quad \text{from} \quad res_i$$

$$\Longrightarrow \quad a_i \quad \text{from} \quad res_i \text{ vs } hits_j$$



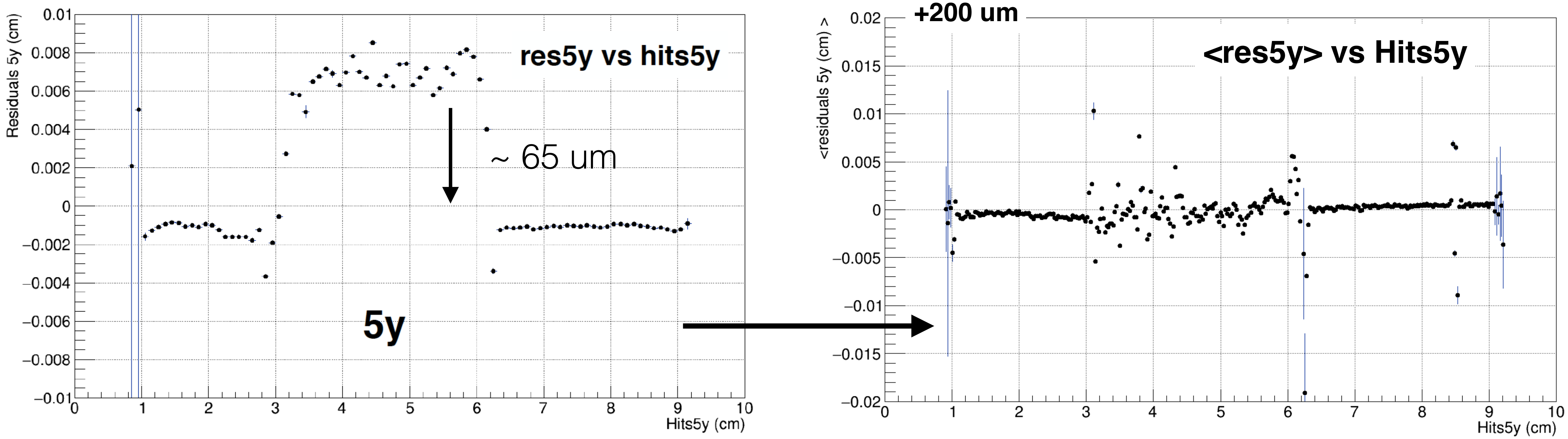
- With single muons along all apparatus:

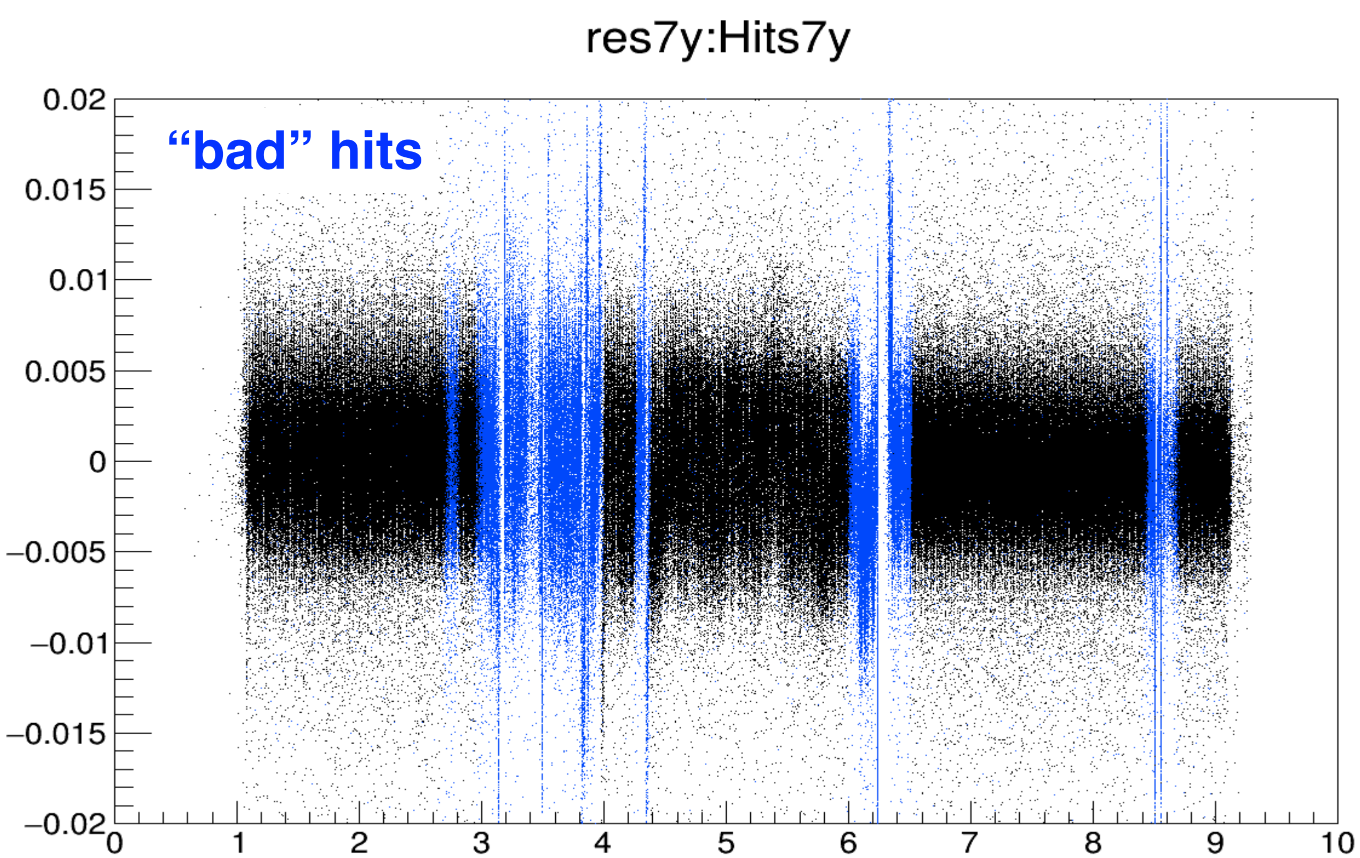




- This procedure is **iterative** and can only converge if two layers per view are chosen as references.
- This is a drawback, as we have seen that all layers have more or less some misalignments.
- Only a posteriori it's possible to check the bias introduced by these reference planes (next slides).

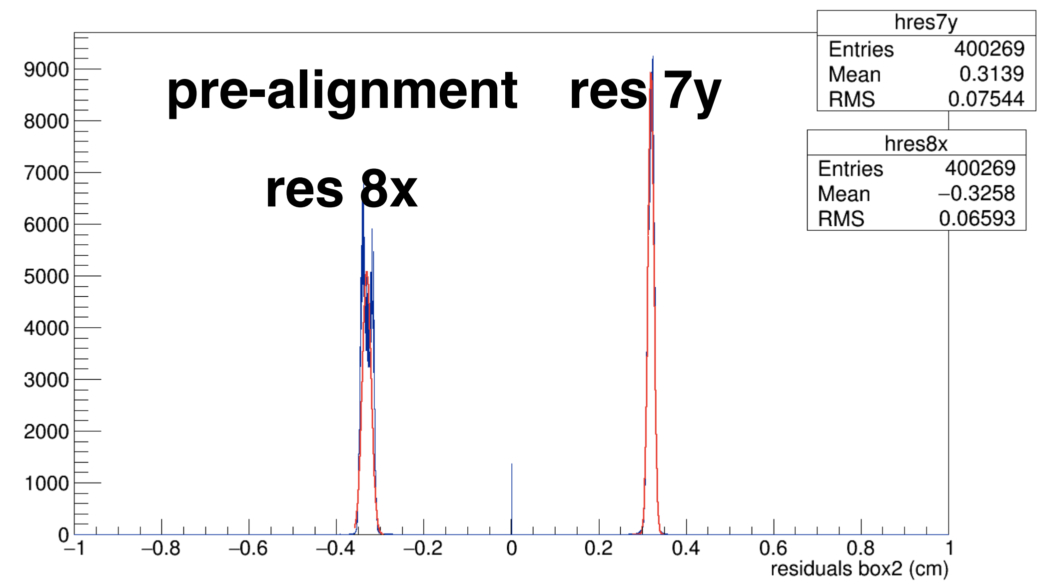
Before alignment: example of layer problems





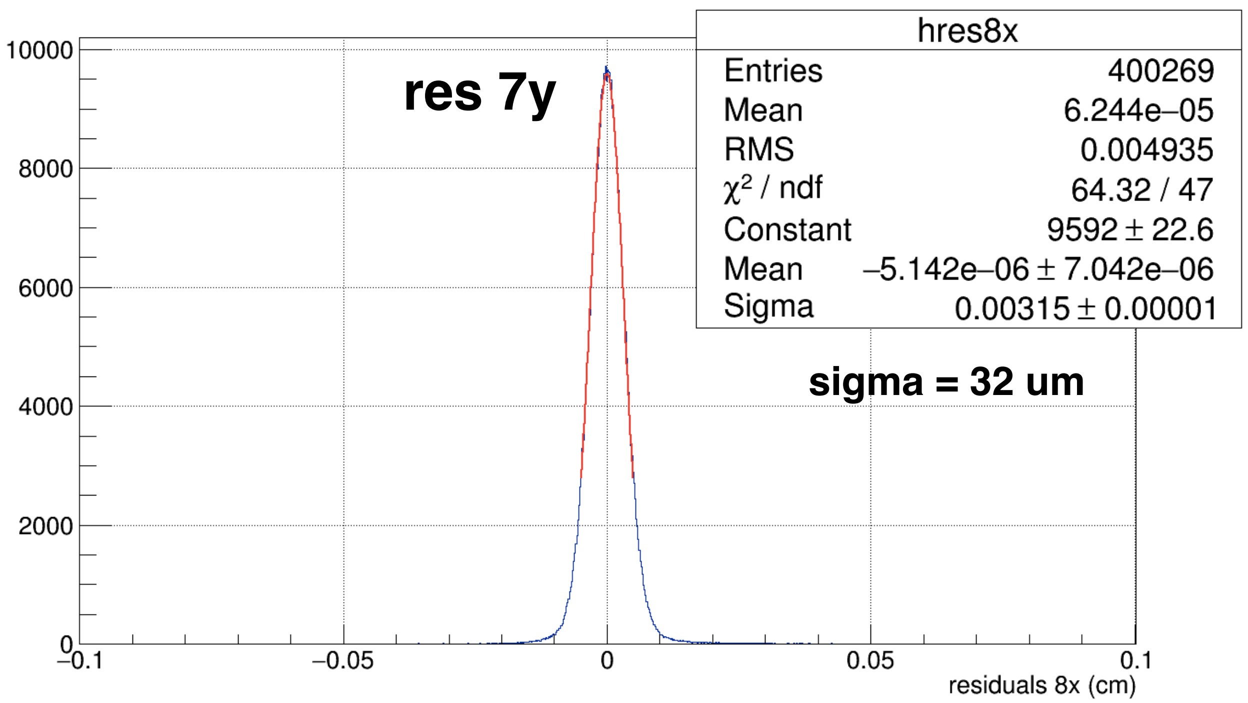
- Systematic readout shifts of layer 5y (~ 65 um) and 3y (~ 21 um) were corrected in analysis.
- Dead strips and nearest strips were masked, layer per layer.

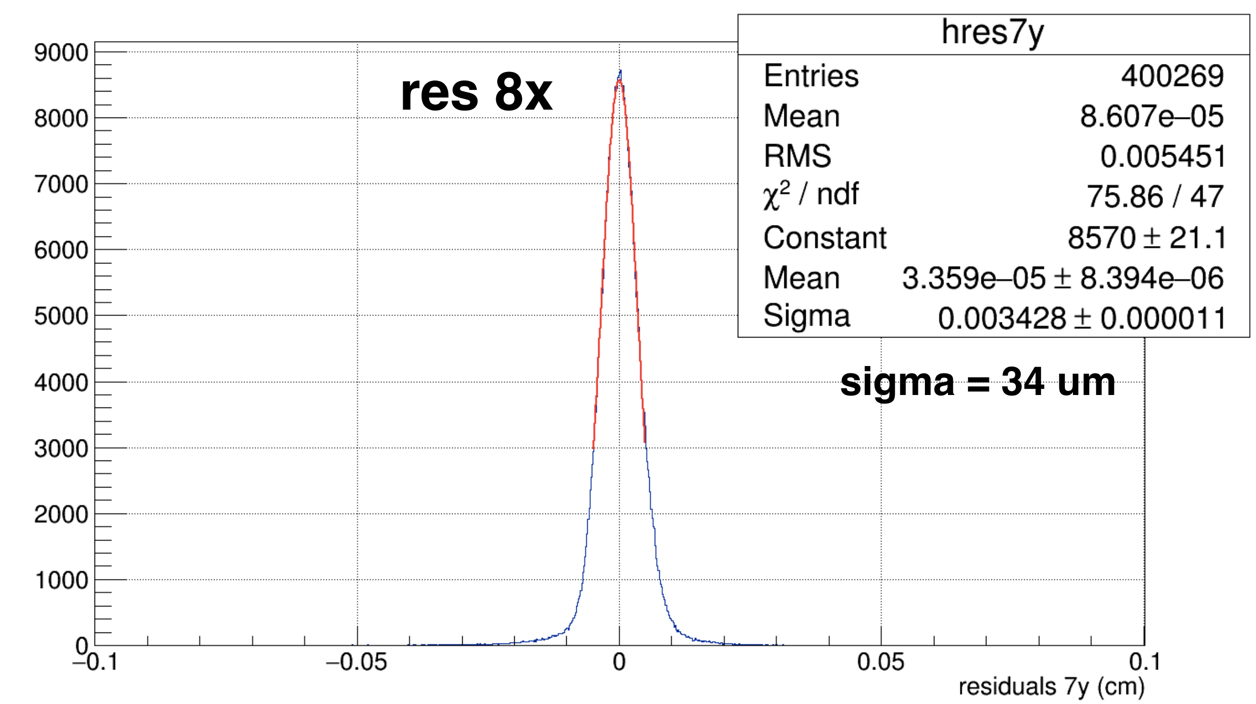
x / y shifts and intrinsic resolution



- From residual distributions can be disentangled multiple scattering effect and point silicon resolution: in this case, as a first approximation (->180-190 GeV muons), residuals sigma can be considered the intrinsic resolution of silicon trackers.

post-alignment



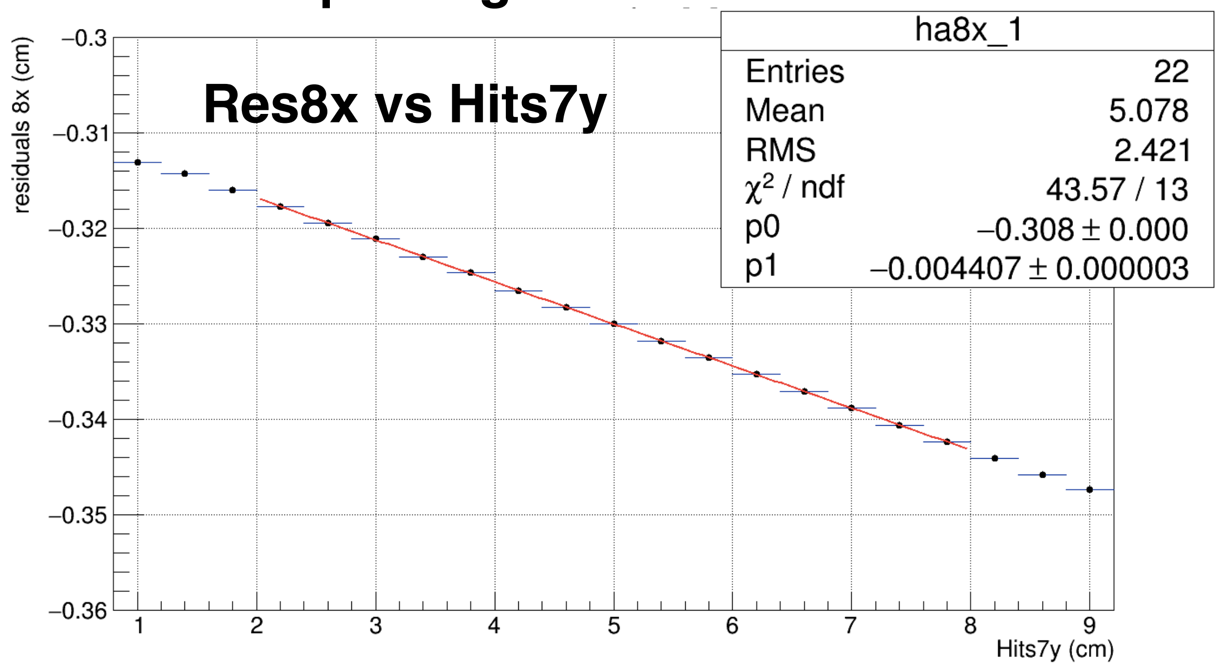


- A position resolution of roughly 37-47 micron is indicated as a reference in (1).
- AGILE readout strip pitch: **242 um** with “floating strip” (2).
- So geometrical tracker resolution is: 242/2 / sqrt(12) = **34.9 micron**. →
- After refinements, some sigma < 30 um: **26 / 25 um** for 7y / 8x (next slides).

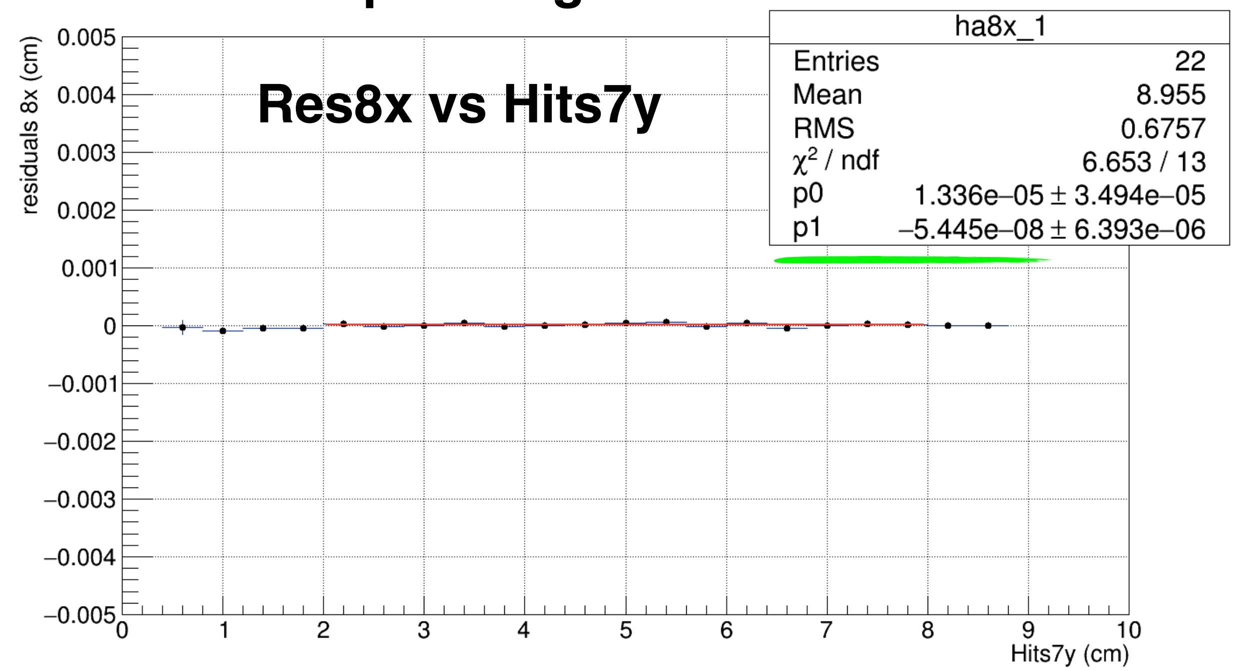
! (1) https://www.lnf.infn.it/acceleratori/public/BTF_user/AGILE/nima490agile.pdf
(2) https://www.lnf.infn.it/acceleratori/public/BTF_user/AGILE/nima501agile.pdf !

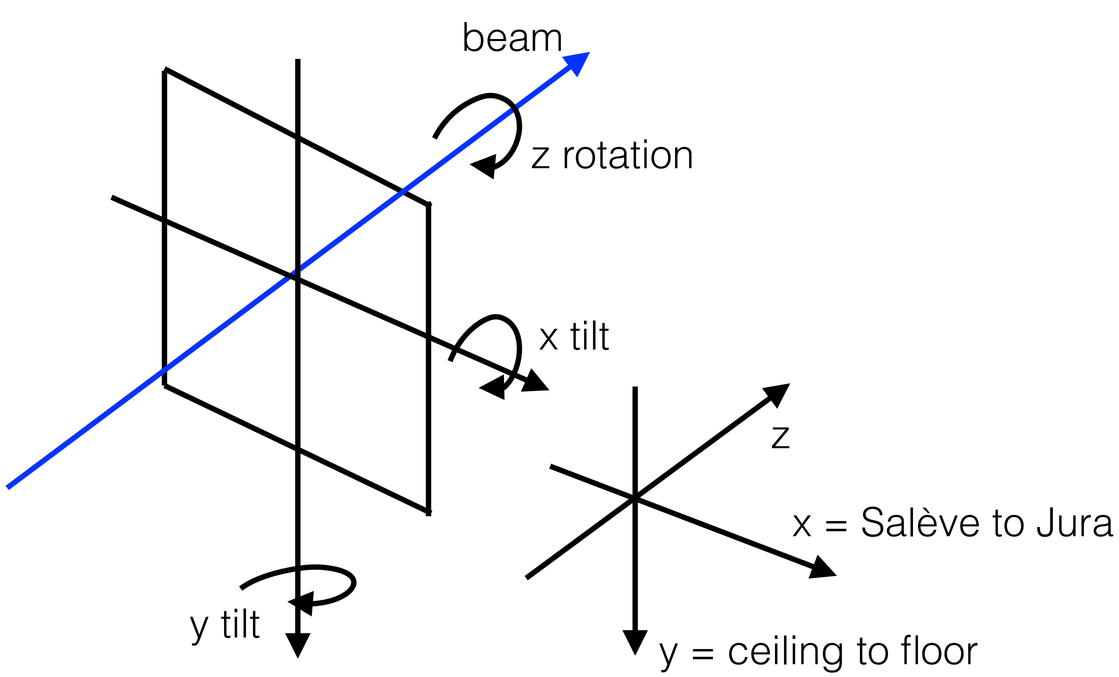
z rotations

pre-alignment



post-alignment



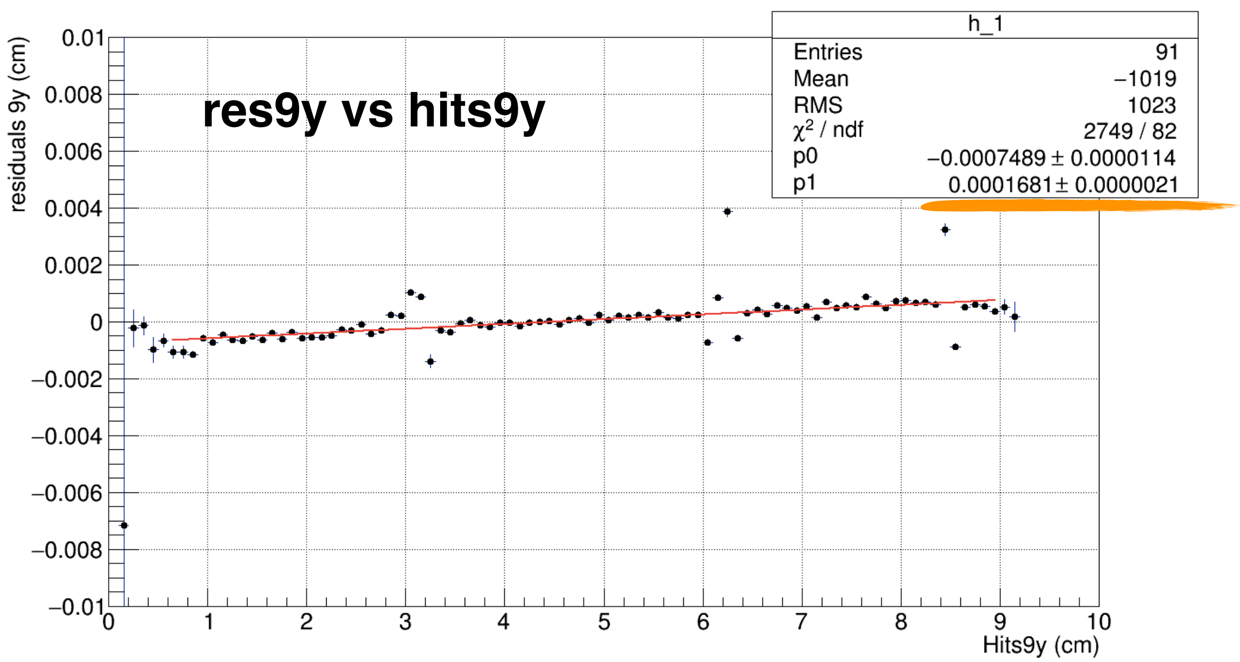


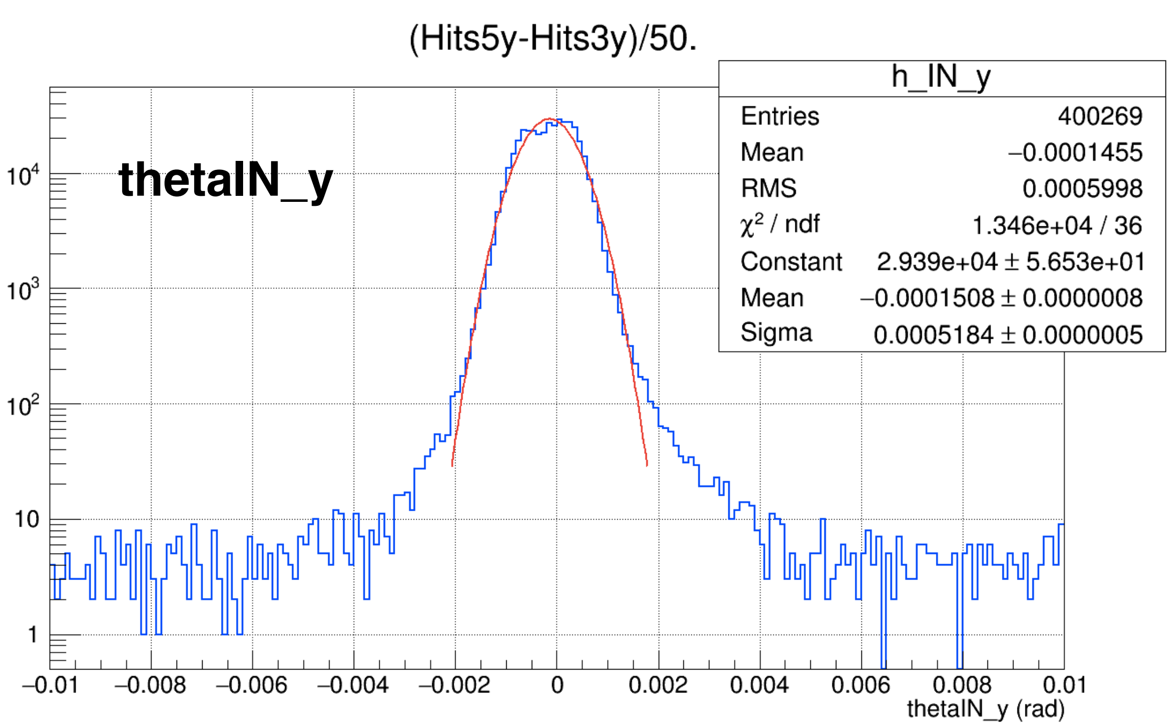
Alignment summary

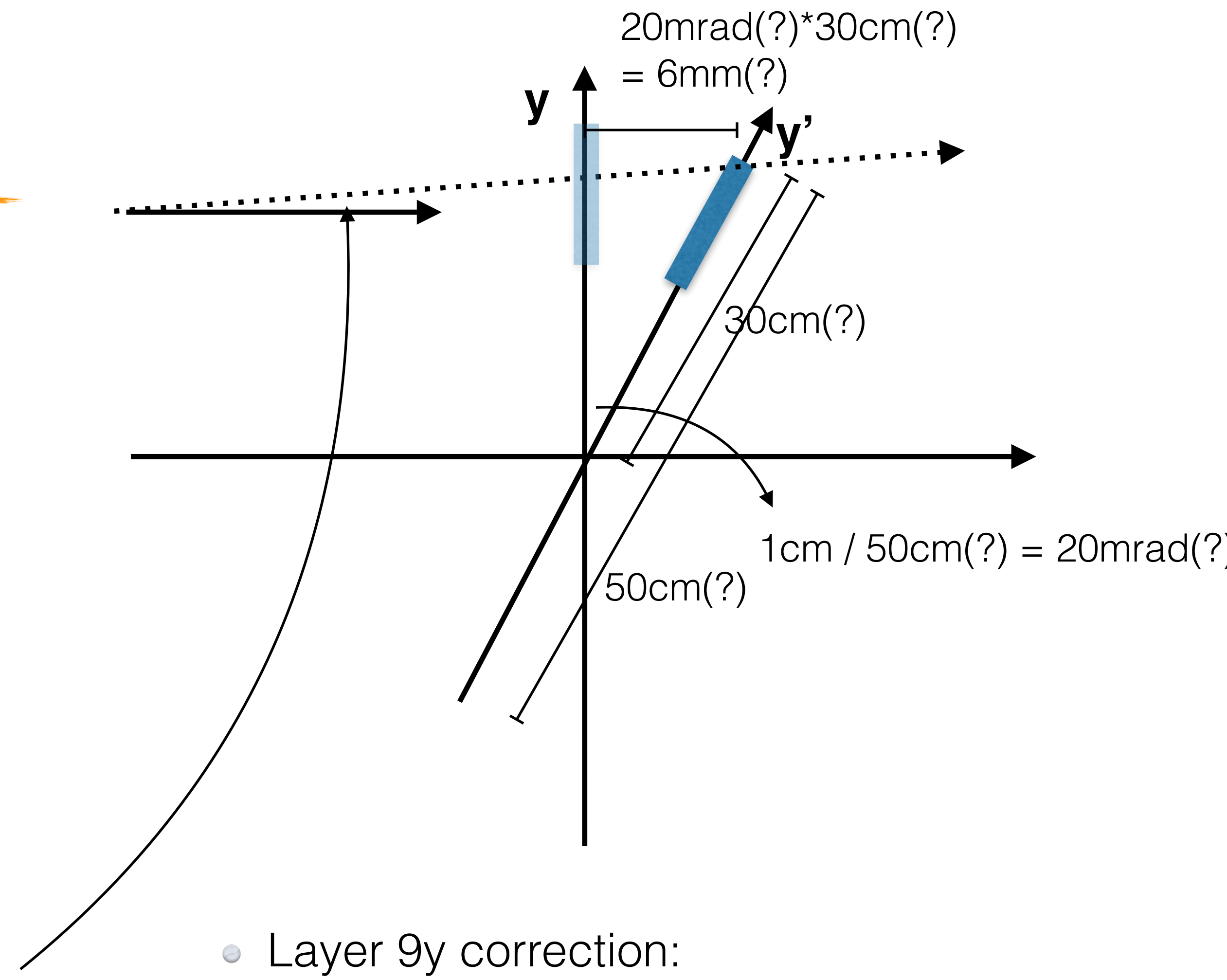
- shifts in x / y **< 5 mm** corrected within 1 um.
- rotations along z axis **< 5-6 mrad**, corrected within 0.1 mrad.

Tilt correction

- We have some sensibility also on tilts (rotations along y / x axis): second-order corrections.







- Layer 9y correction:

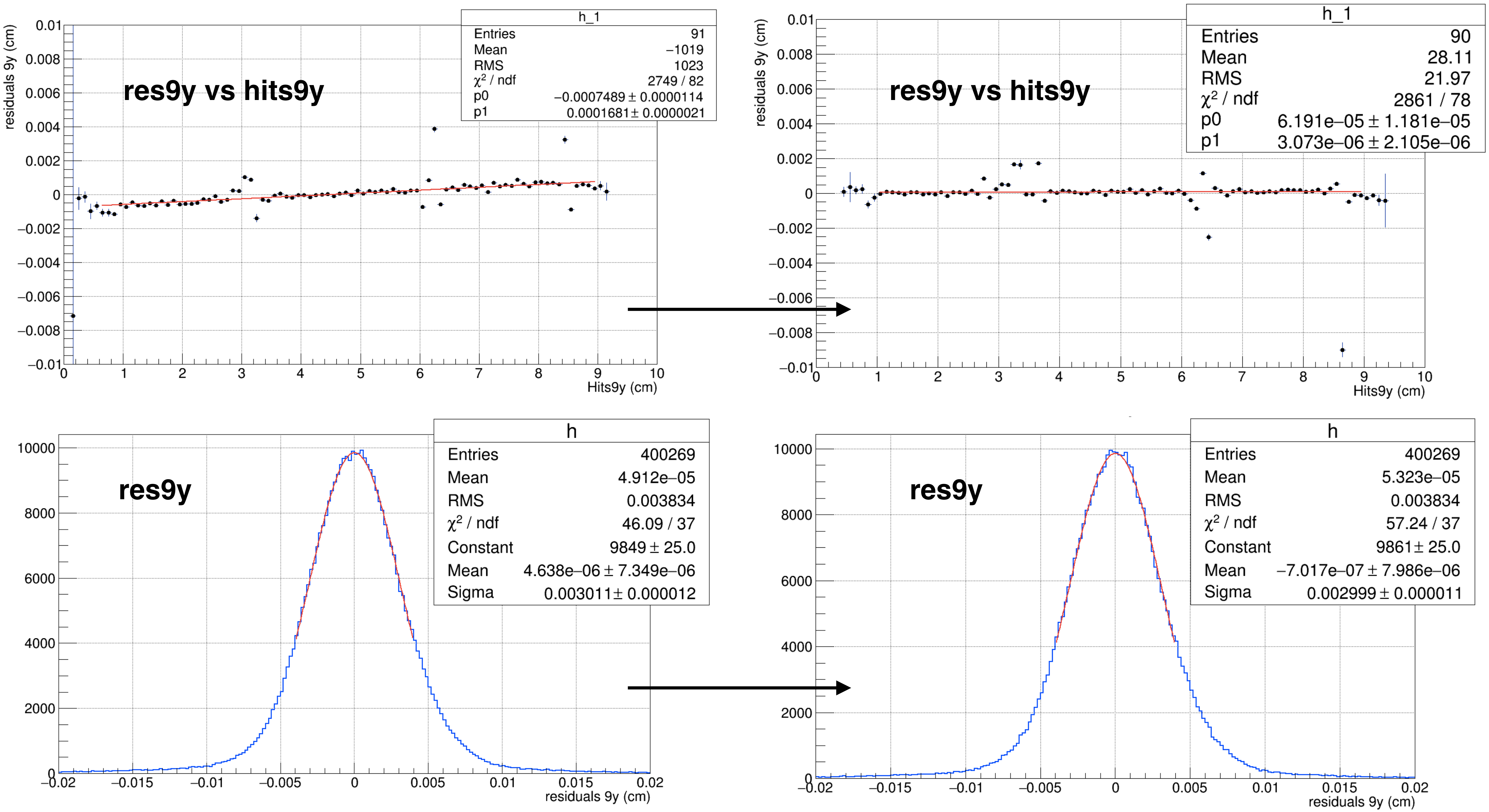
hits9y' = cosα * hits9y

hits9y' ~ (1 - $\alpha^2/2$) * hits9y

$\alpha^2/2 = 0.00017$ -> $\alpha = 0.018$ rad

(This tilt angle deduced from correlation looks like compatible with layers distances).

Tilt correction of 9y



- The positive correlation disappears and small improvements on residual.
- Given the large amount of these rotations, it is not possible to correct them iteratively. We are outside the linearity of the corrections.

Stereo layers alignment

- **residuals:**

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

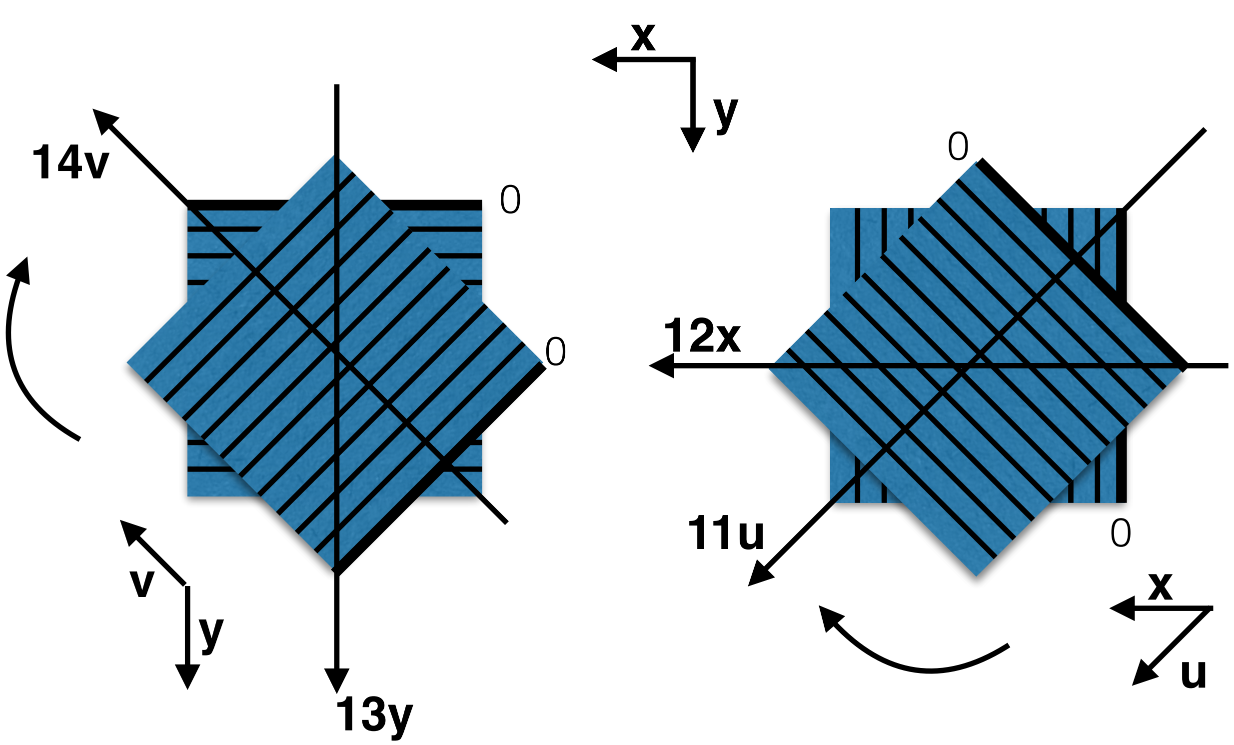
$$\beta = -\frac{\pi}{4} \quad \text{for} \quad i = 11u$$

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

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

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

iteratively!



- **alignment (in uv direction):**

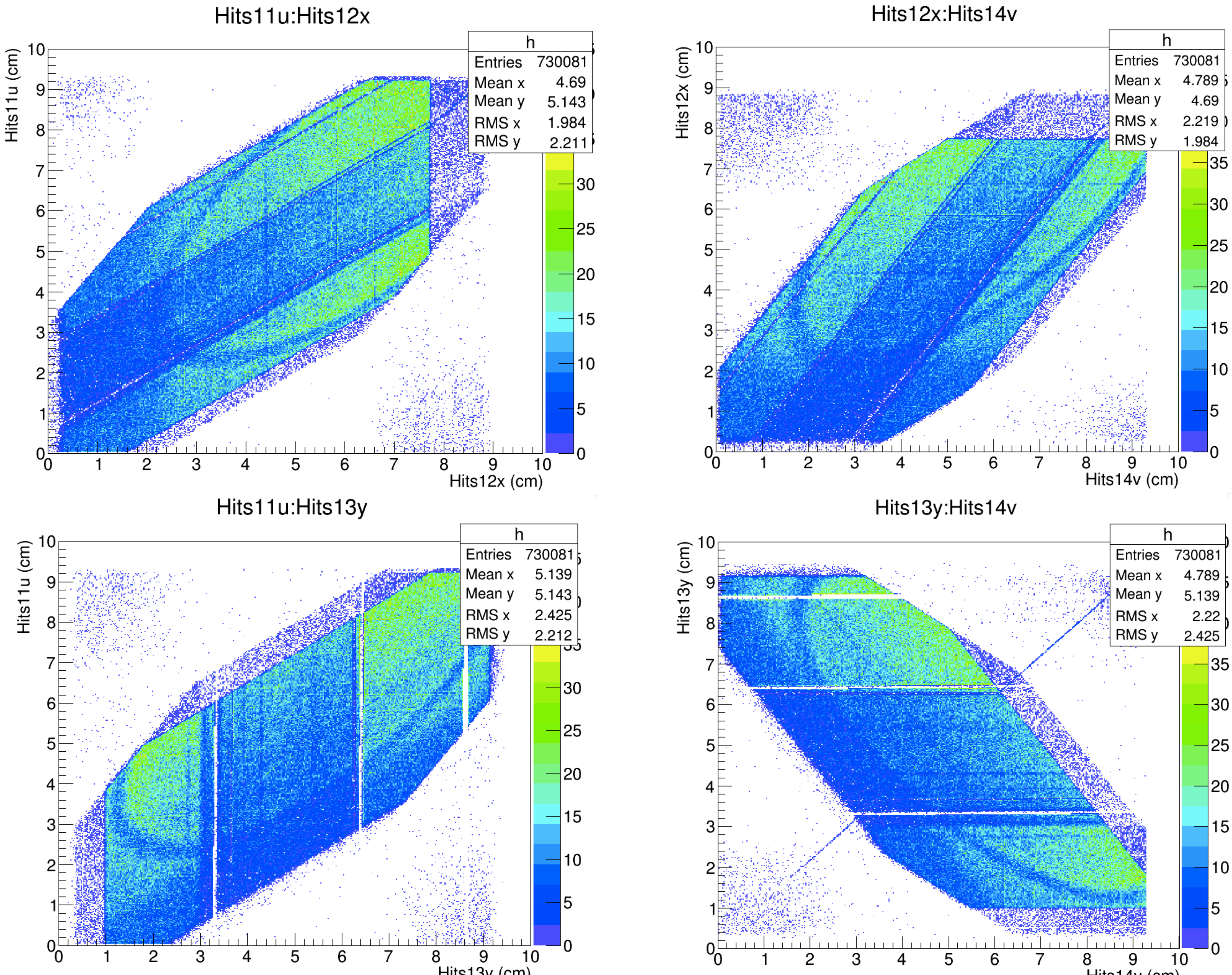
$$hits'_i = hits_i - r_i - a_i \cdot hits_j$$

$$\Longrightarrow \quad r_i \quad \text{from} \quad res_i$$

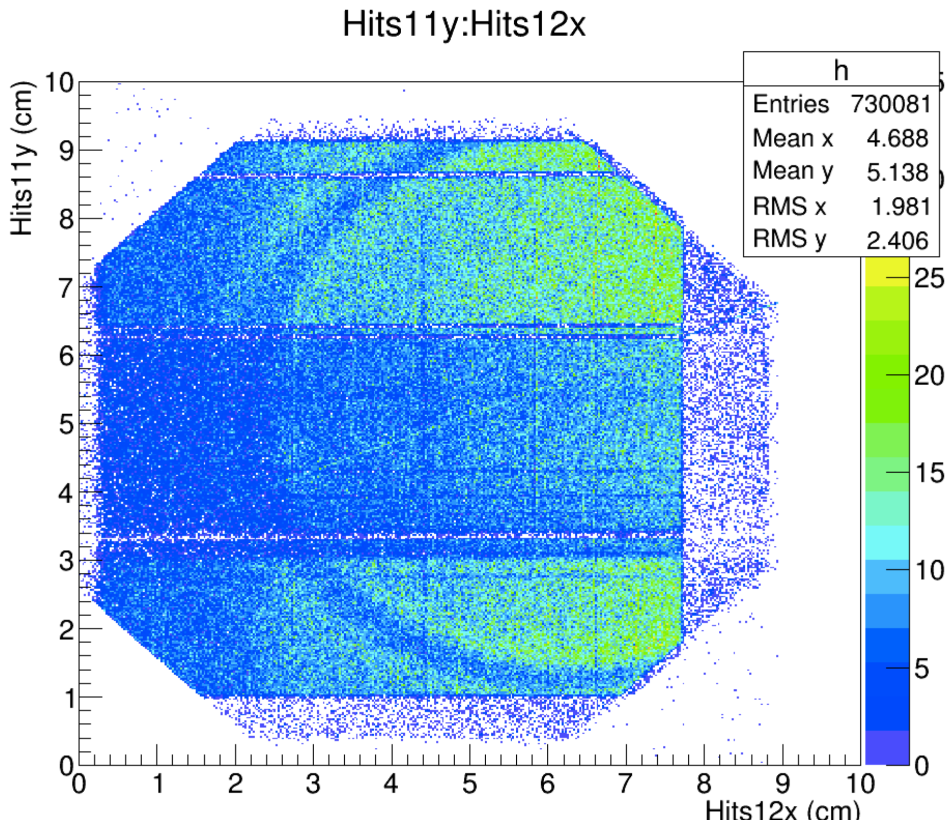
$$\Longrightarrow \quad a_i \quad \text{from} \quad res_i \text{ vs } hits_j$$

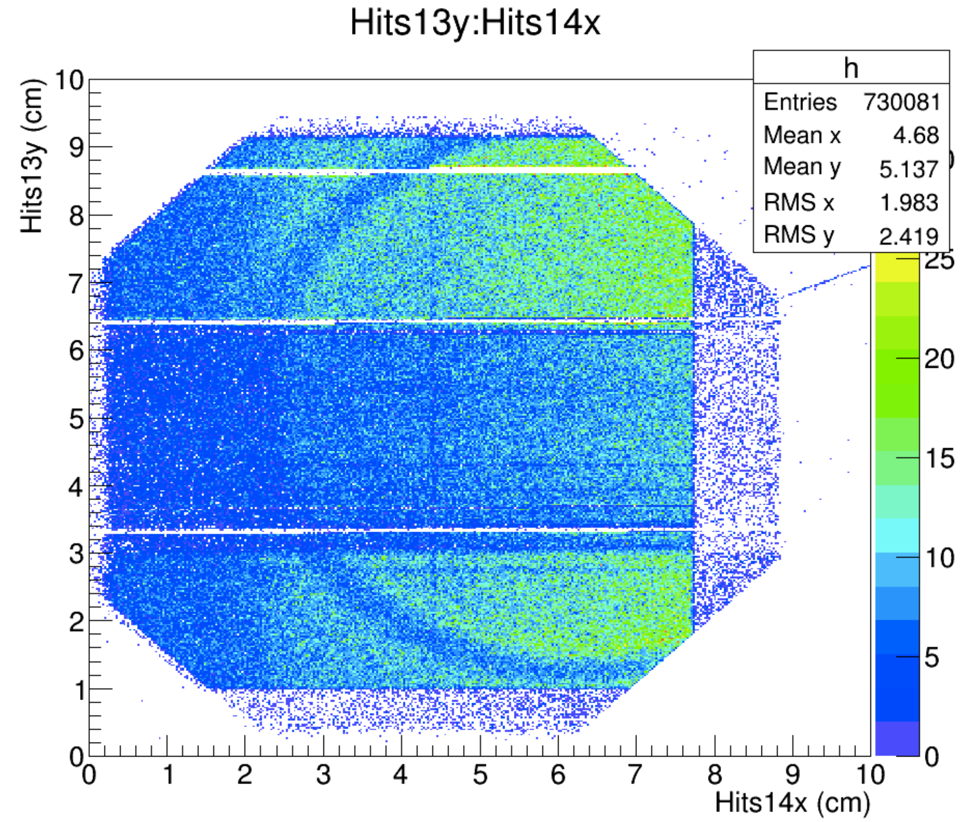
$j = 13y$ for both !

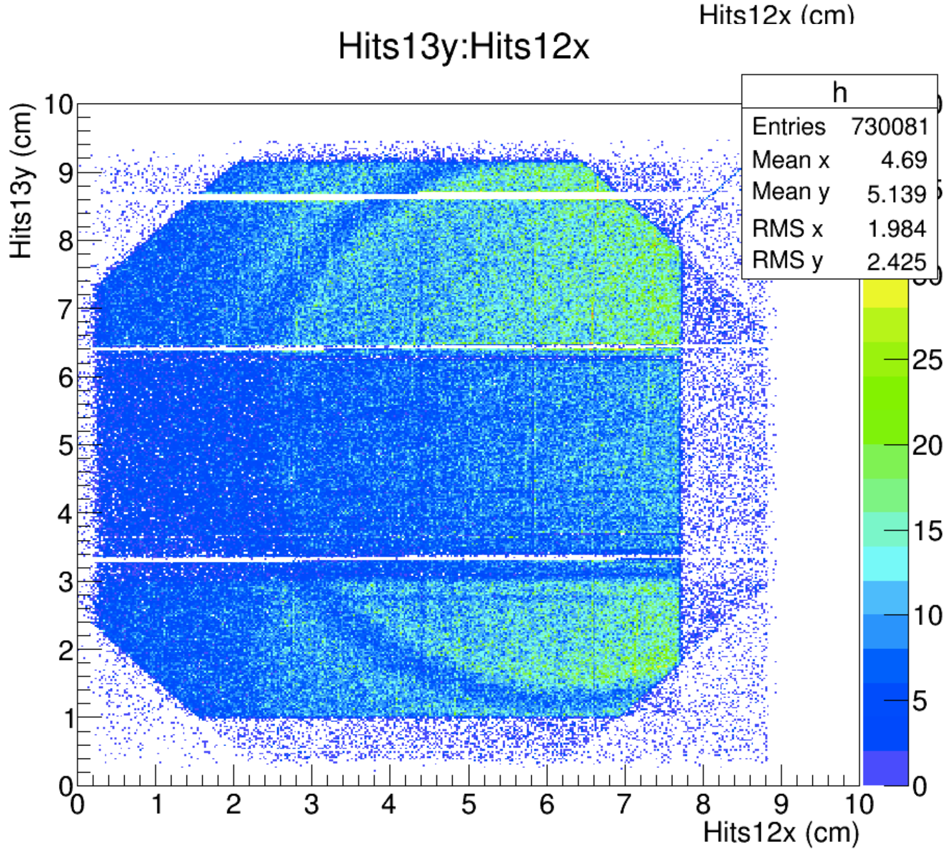
Stereo planes rotations



11y 14x views







- Iteratively rotations of planes 11u / 14v

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

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

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

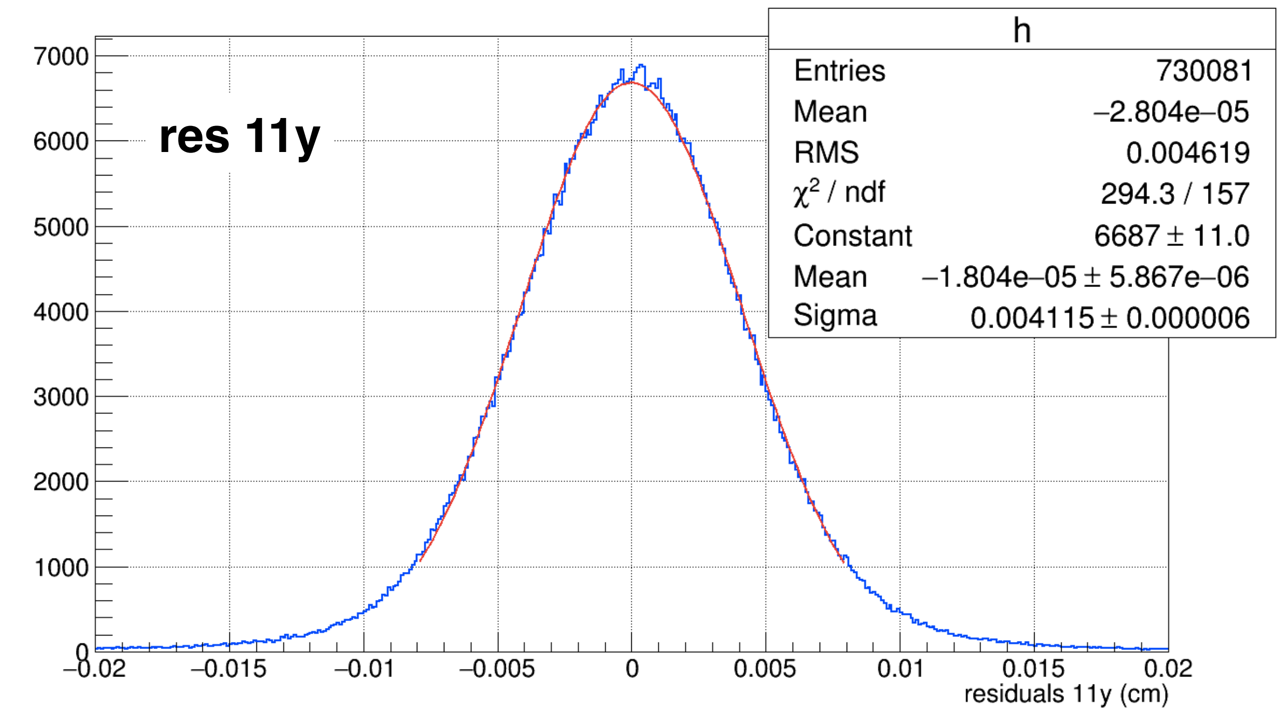
$$[14x]' = [14x] - r_{14x} - a_{14x}\cdot[13y]$$

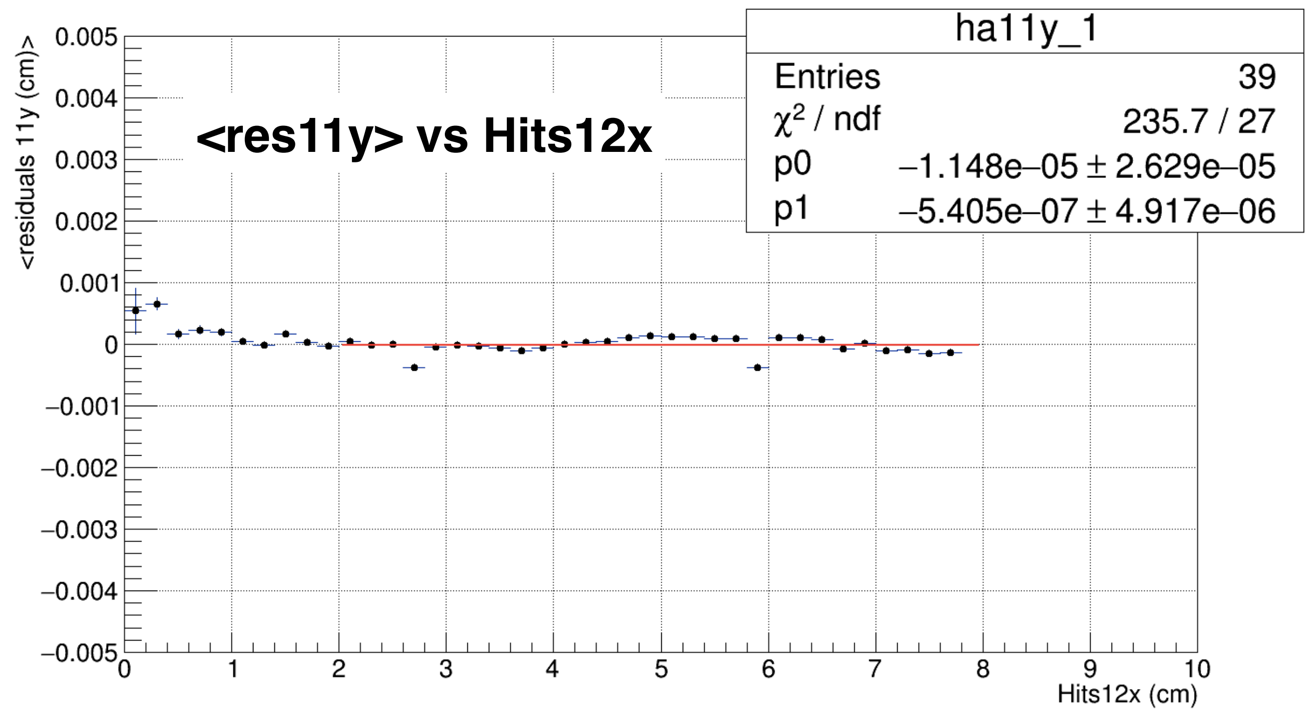
$$c = 4.75\,cm$$

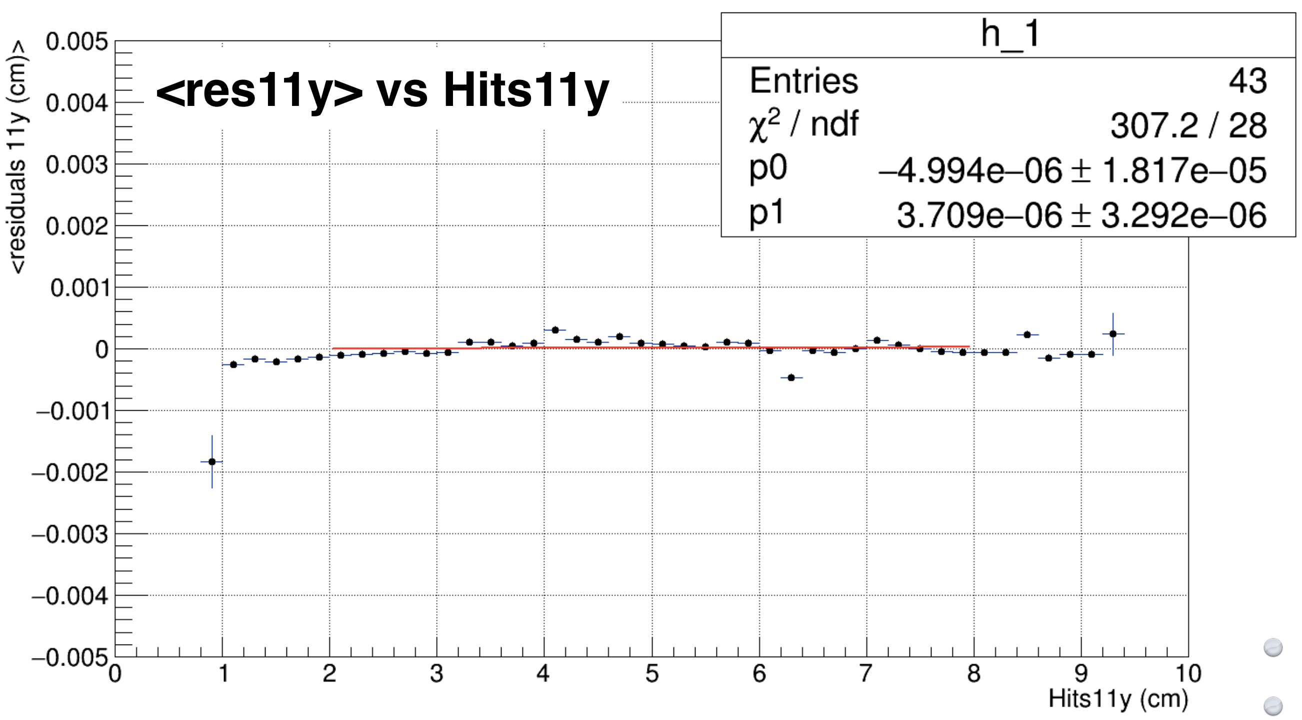
$$r_{11y} = 0.2328\,cm \quad a_{11y} = -0.00024\,rad$$

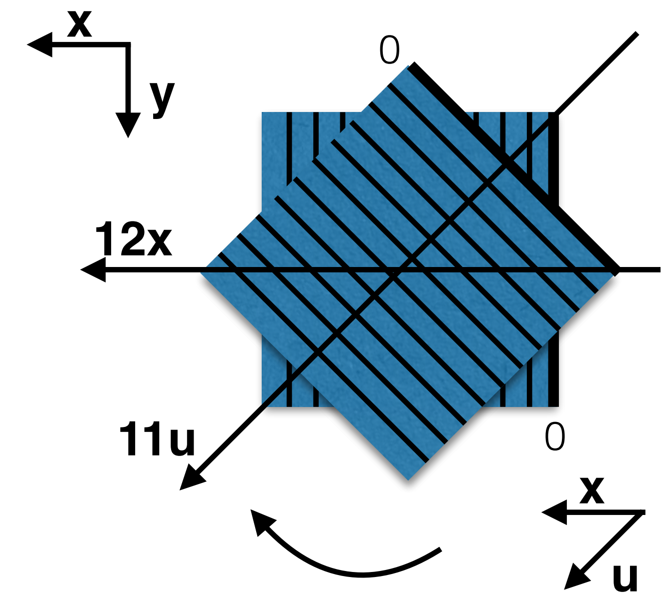
$$r_{14x} = 0.5081\,cm \quad a_{14x} = 0.00020\,rad$$

Alignment 11y









- Rotated hits (of 45°) becomes11y.
- Obviously 11y residual has higher sigma than 11u: 27 um -> 41 um.

Final checks

Layer resolution | **% bad hits**

$\sigma_{residual}$		Cutted hits % (with mask)	
1y	49 μm	1y	~34%
2x	38 μm	2x	~13%
3y	43 μm	3y	~6%
4x	40 μm	4x	~3%
5y	31 μm	5y	~19%
6x	32 μm	6x	~10%
7y	26 μm	7y	~7%
8x	25 μm	8x	~5%
9y	28 μm	9y	~4%
10x	40 μm	10x	~65%
11y	39 μm	11y	~1%
12x	25 μm	12x	~1%
13y	31 μm	13y	~8%
14x	41 μm	14x	~1%
15y	45 μm	15y	~5%
16x	48 μm	16x	~16%

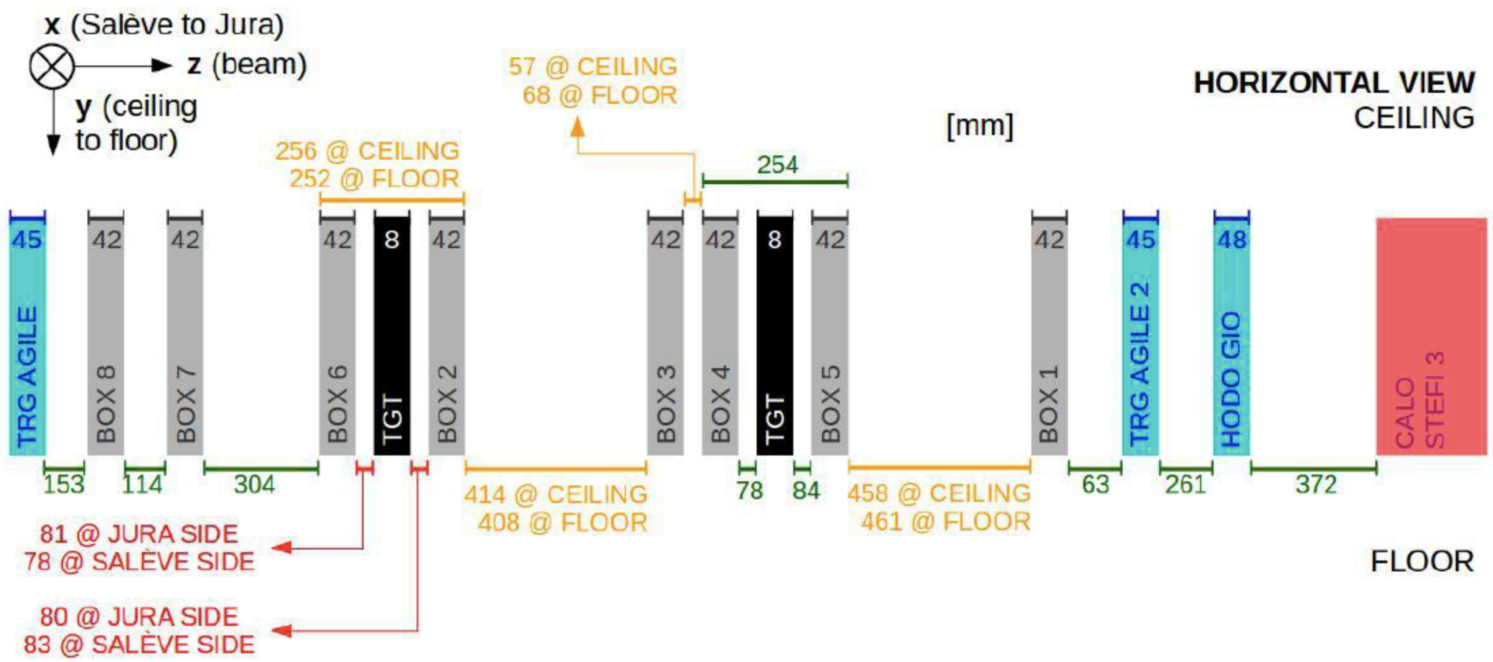
- With a fit for all planes, we checked layer efficiencies, resolutions and also residual misalignments of planes chosen as a reference (5-6 and 15-16).

- Reference shifts in x / y: **within 1 um**.
- Reference rotations along z axis within 0.1 mrad: more accurate checks would have been necessary.

- Anyway the choice of reference planes can introduce bias which can difficult to correct, especially if the misalignments are large, as in this case.

Conclusions

MUonE configuration @ 02/05



- **from 4/05: 3 upstream boxes**
- **from 27/06: no target 2**
- **from 20/08: new box 8 and 3**
    - Provided distances up to 20/08 contain an error: **-2 mm** for layers 1 - 2 - 3 - 4.
    - I only checked the effect on tracking a posteriori, without re-aligning all samples uploaded on eos.

- `z distances` <u>`in cm`</u>`.`
- `reference zero: bottom edge BOX8`
- **<u>before 20/08 (in cm):</u>**

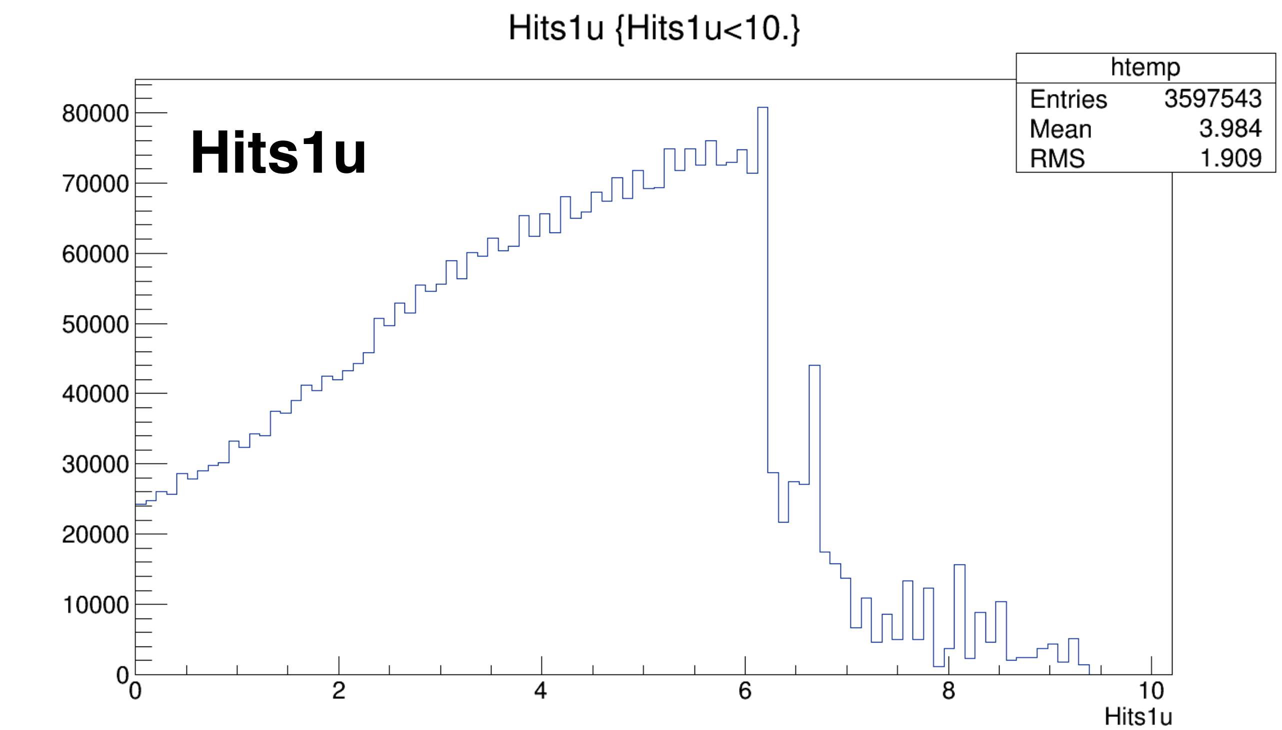
z(01) -2.40 → stereo (u)
z(02) -0.30
z(03)= 15.60 -2.50
z(04)= 15.60 -0.50

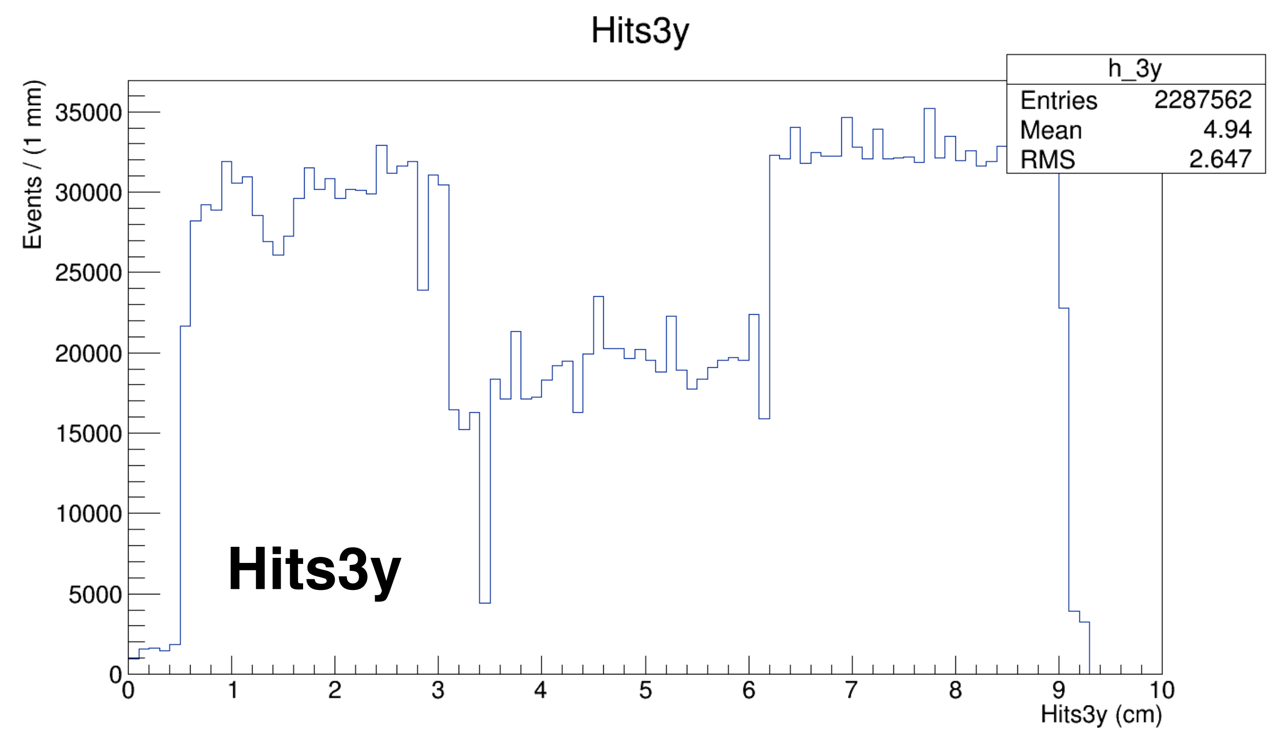
-2 mm!

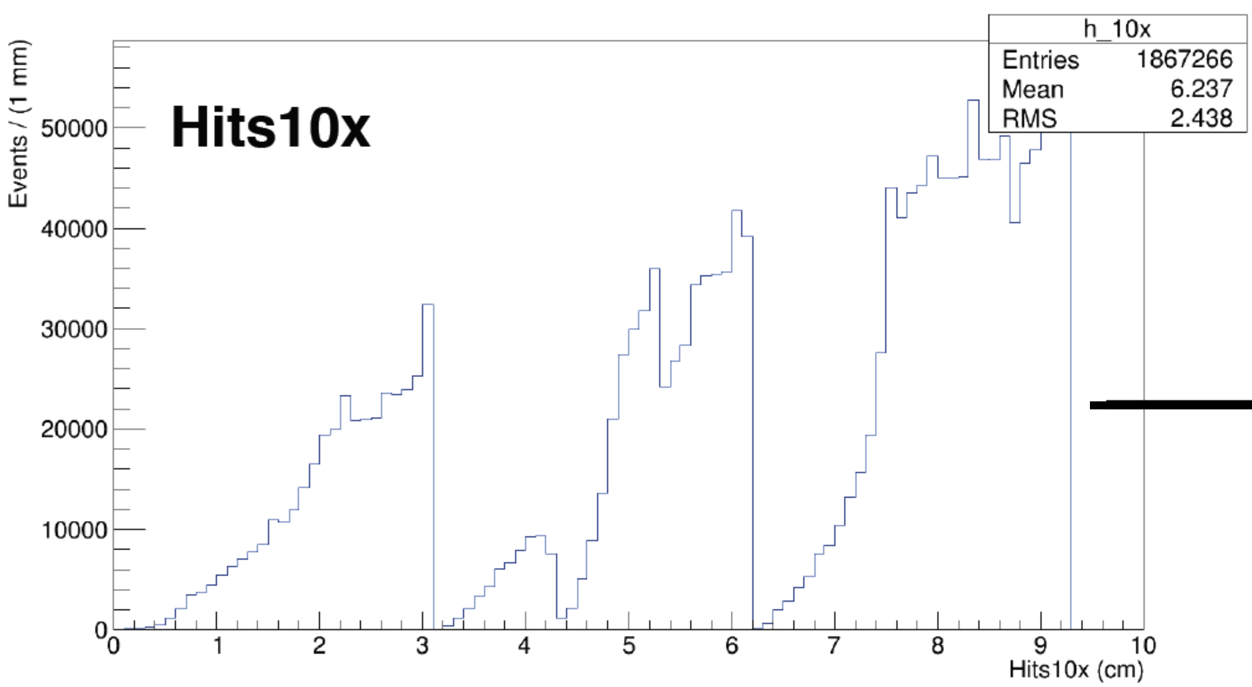
z(05)= 50.00 -2.50
z(06)= 50.00 -0.50
z(07)= 71.40 -1.50
z(08)= 71.40 -0.33
z(09)=117.00 -2.50
z(10)=117.00 -0.50
z(11)=126.90 -1.83 → stereo (u)
z(12)=126.90 -0.50
z(13)=148.10 -0.34
z(14)=148.10 -1.56 → stereo (v)
z(15)=198.10 -1.00
z(16)=198.10 -2.30

Backup

Layer problems: some examples

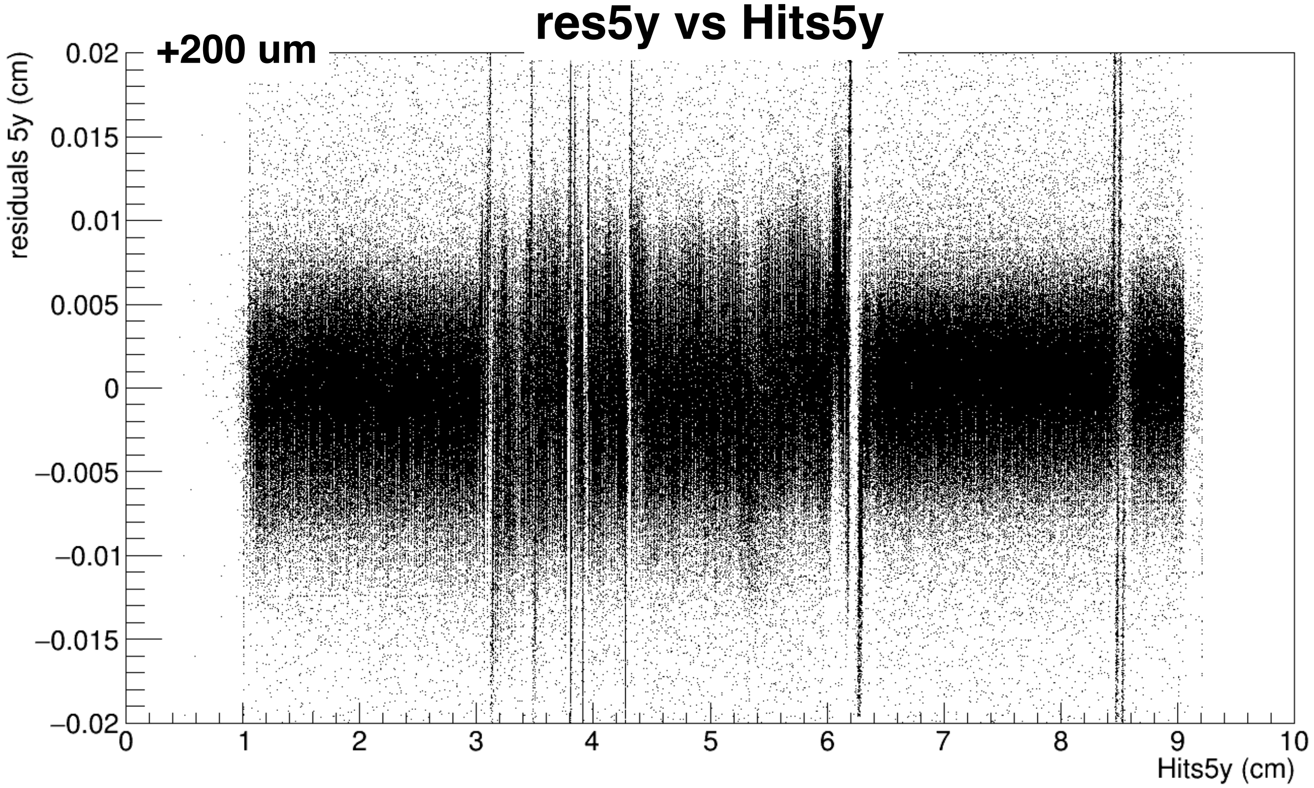


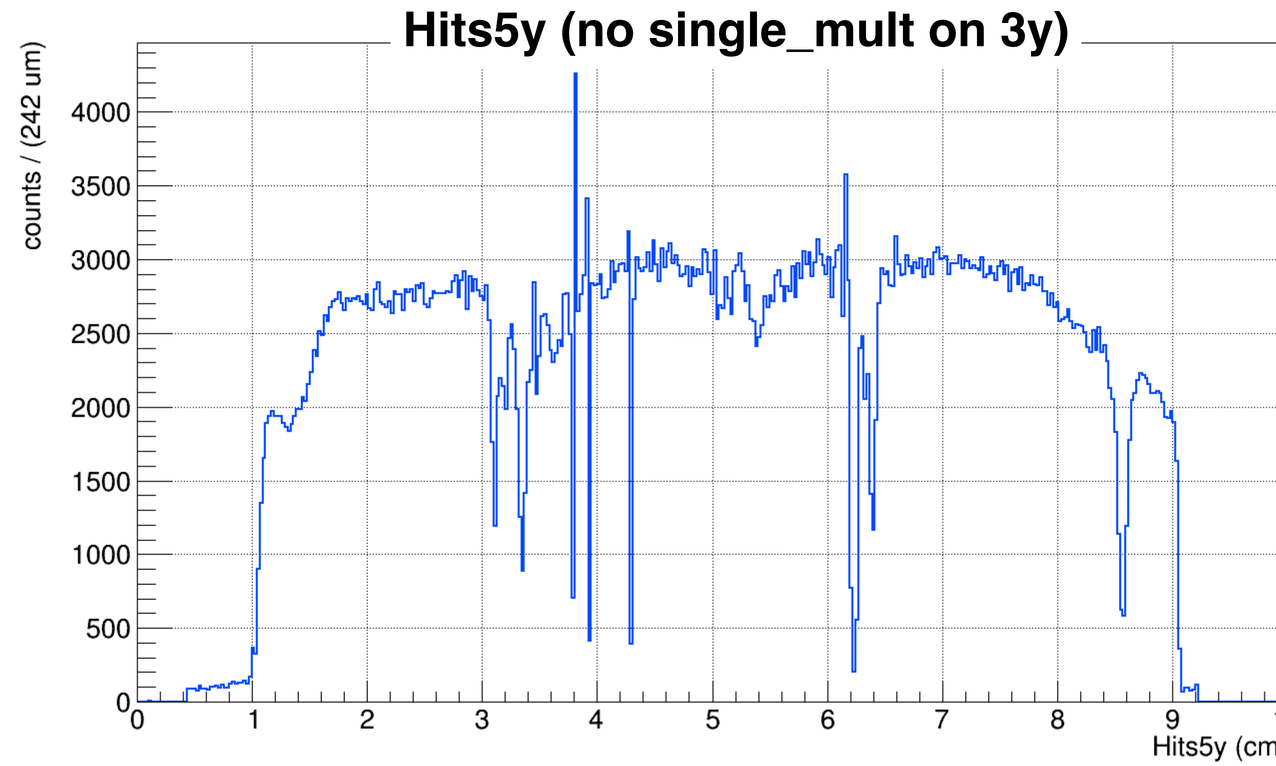


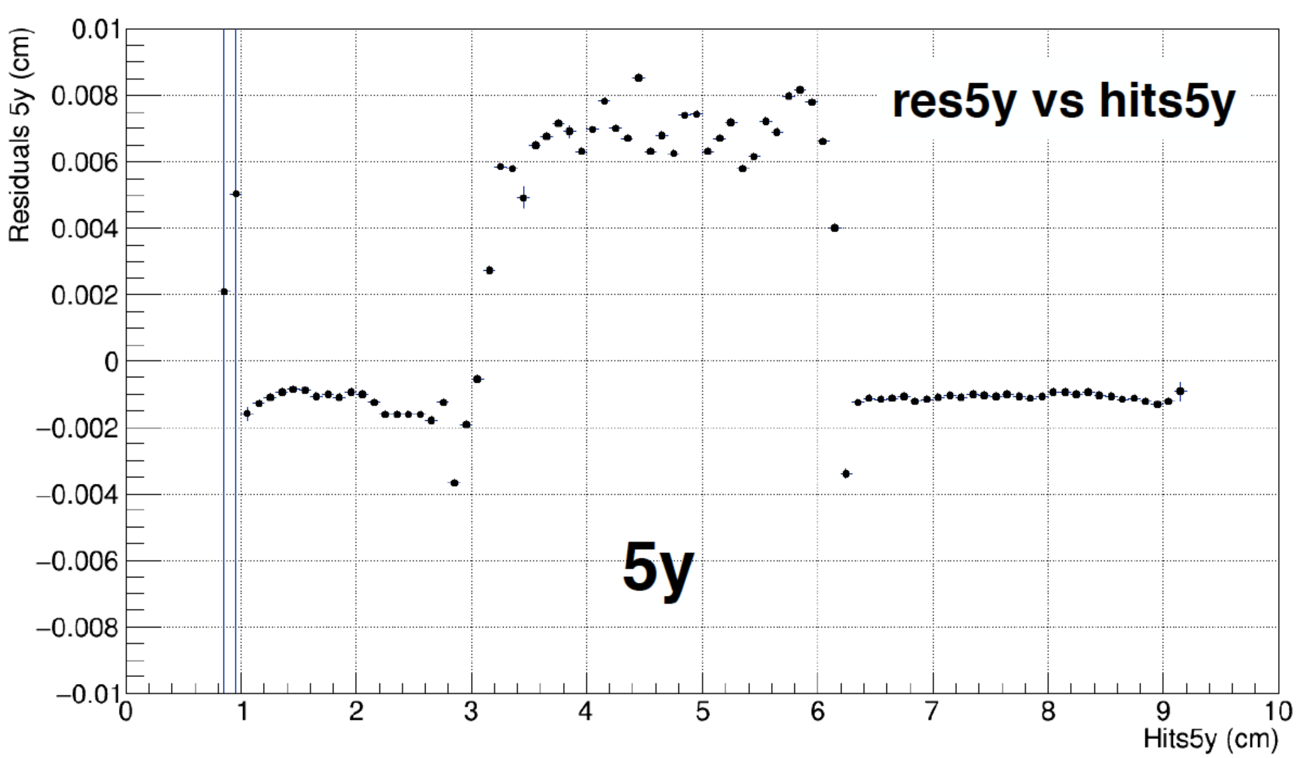


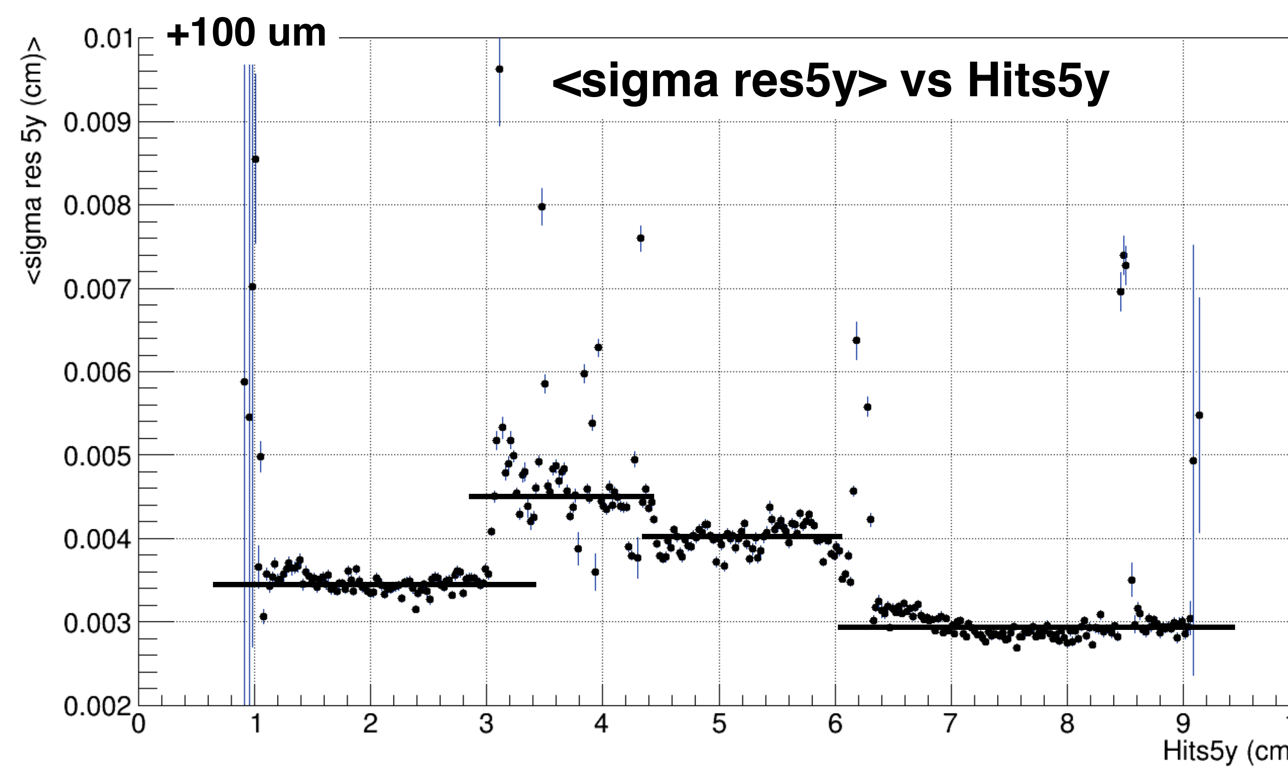
- Almost all layers show inefficiency problems: it's very clear the ASIC structure.
- In the next slides a quantitative efficiency analysis.
- We've correlated some of these problems with the high beam intensity relatively to the apparatus readout.
- Layers 1u and 10x have been changed at the end of August (test beam is running from May).
- In these slides new setup (new boxes) are not shown.

Layer problems: plane 5y



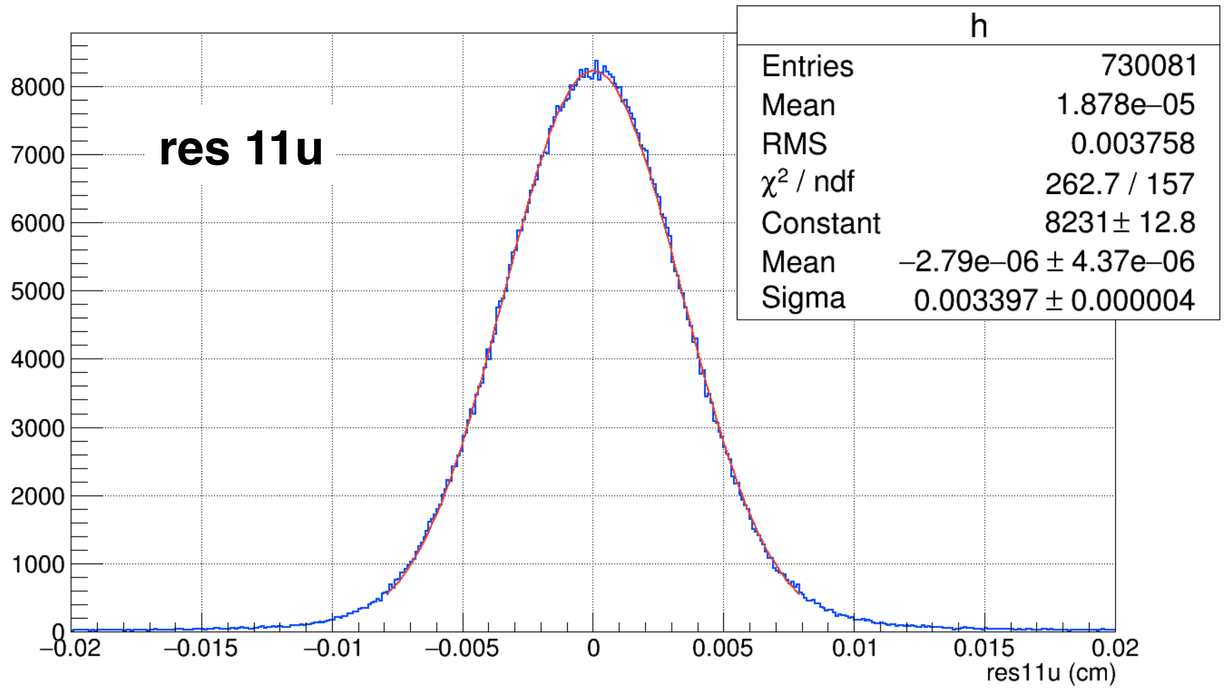


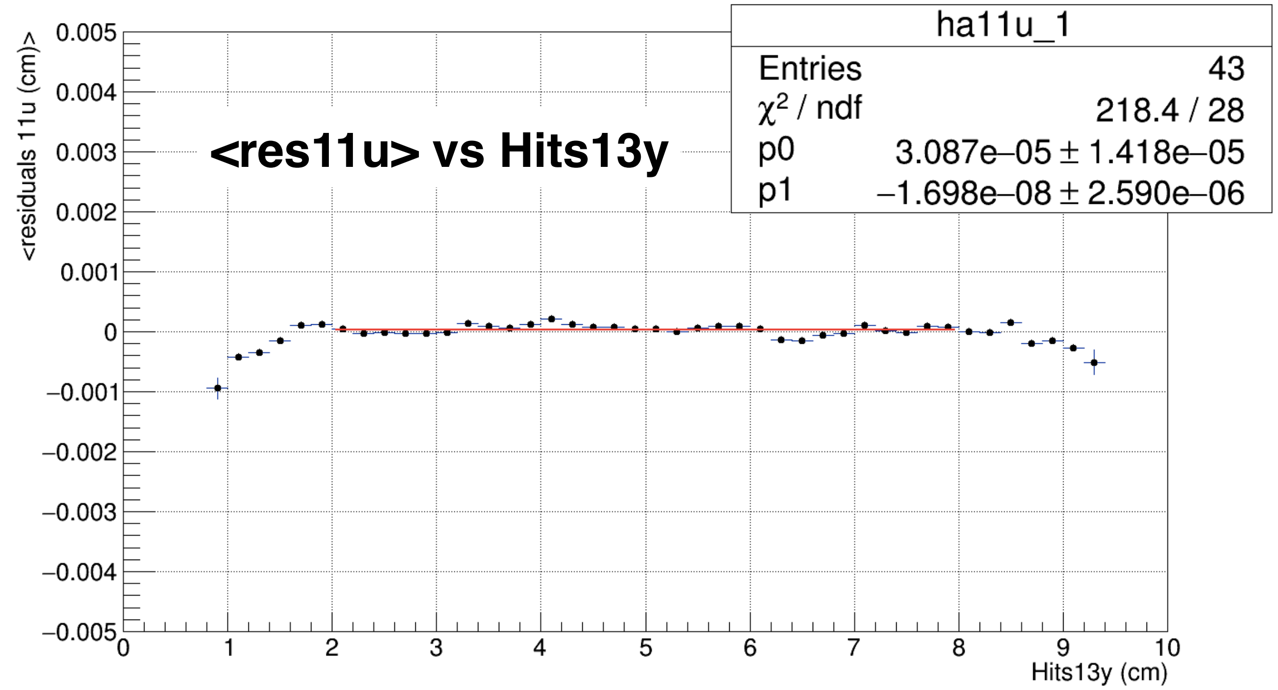


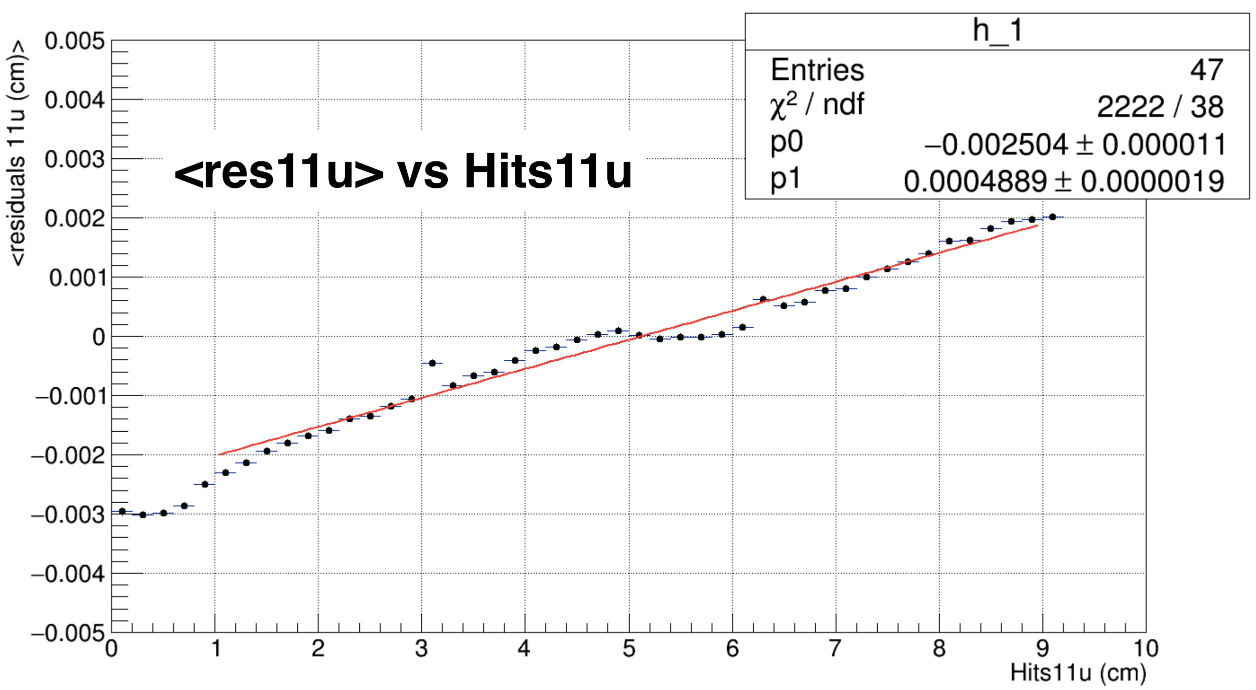


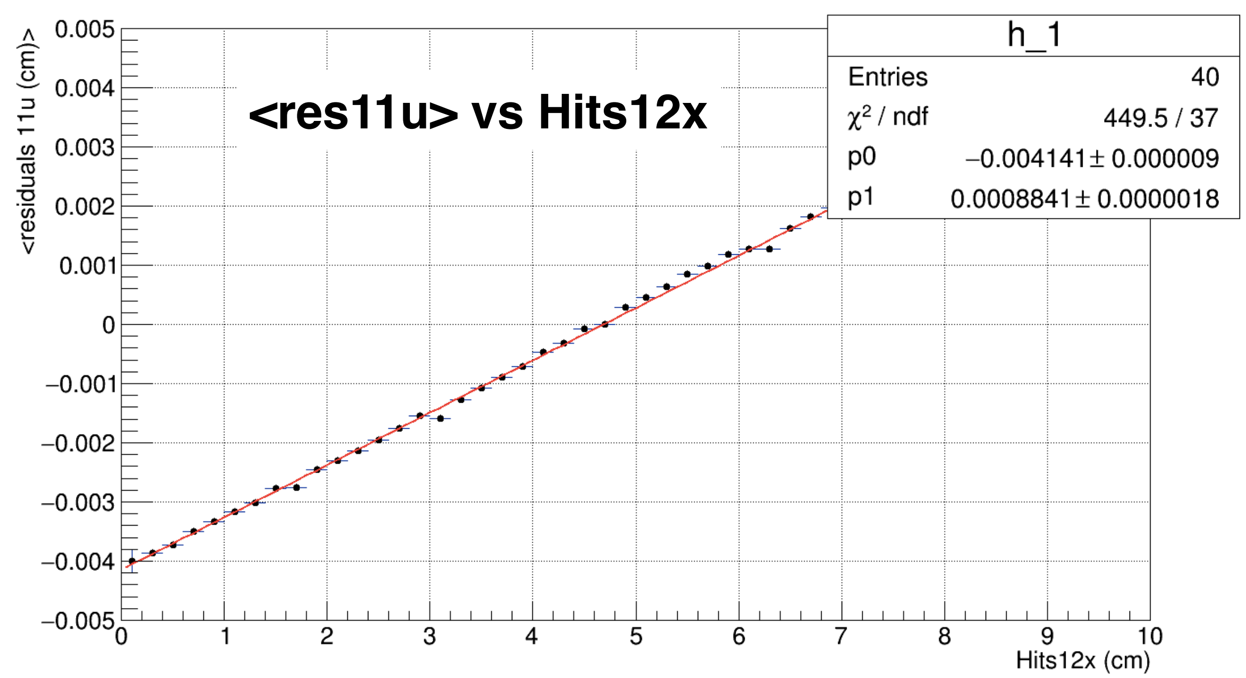
- Situation of 5y trackers (upstream) **pre-correction**: noisy behavior and shift of central ASIC. Also the resolution at the center is significantly different (sigmas plot).
- As other planes, many dead strips which induce a bad reco of nearest strips.

Alignment 11u pre tilt correction



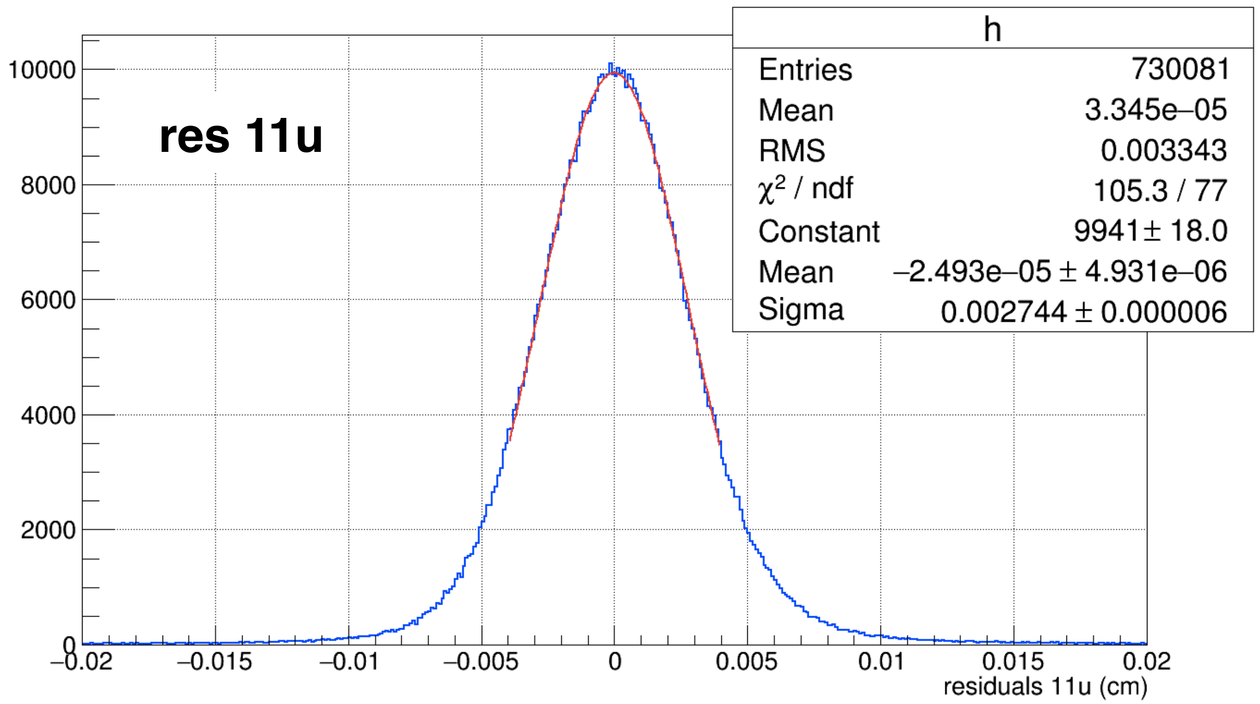


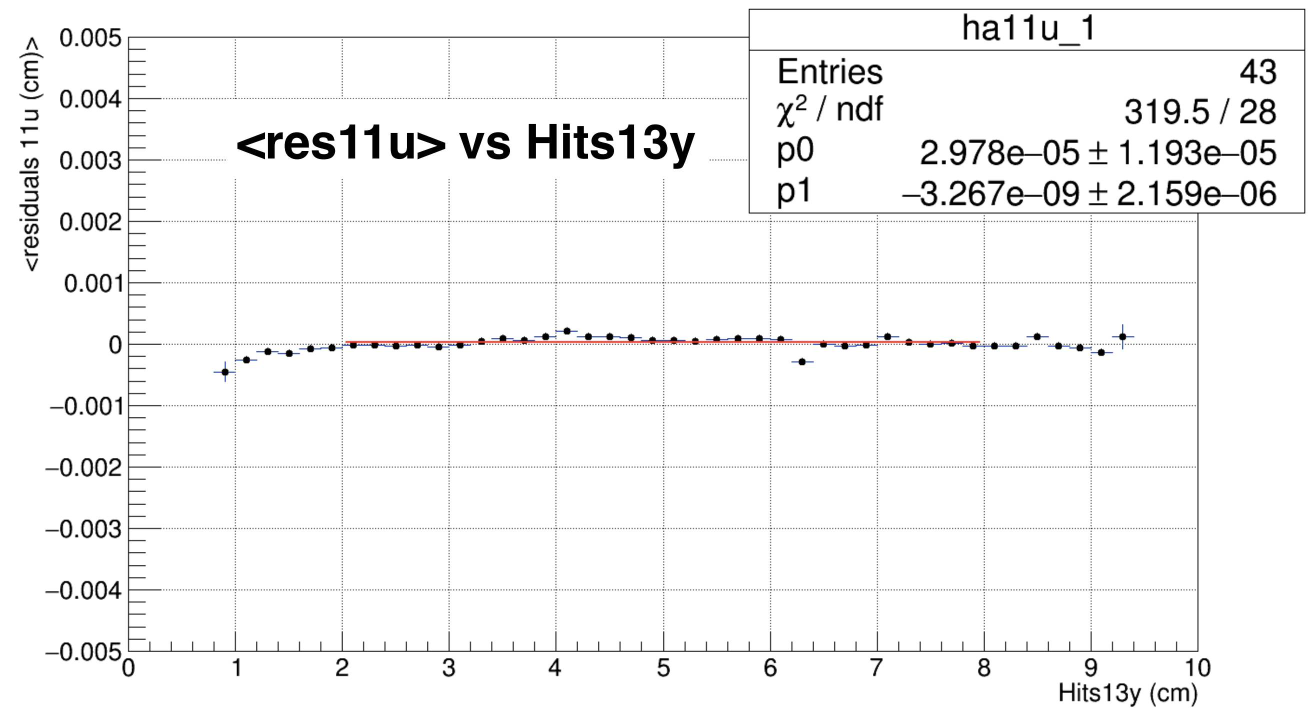


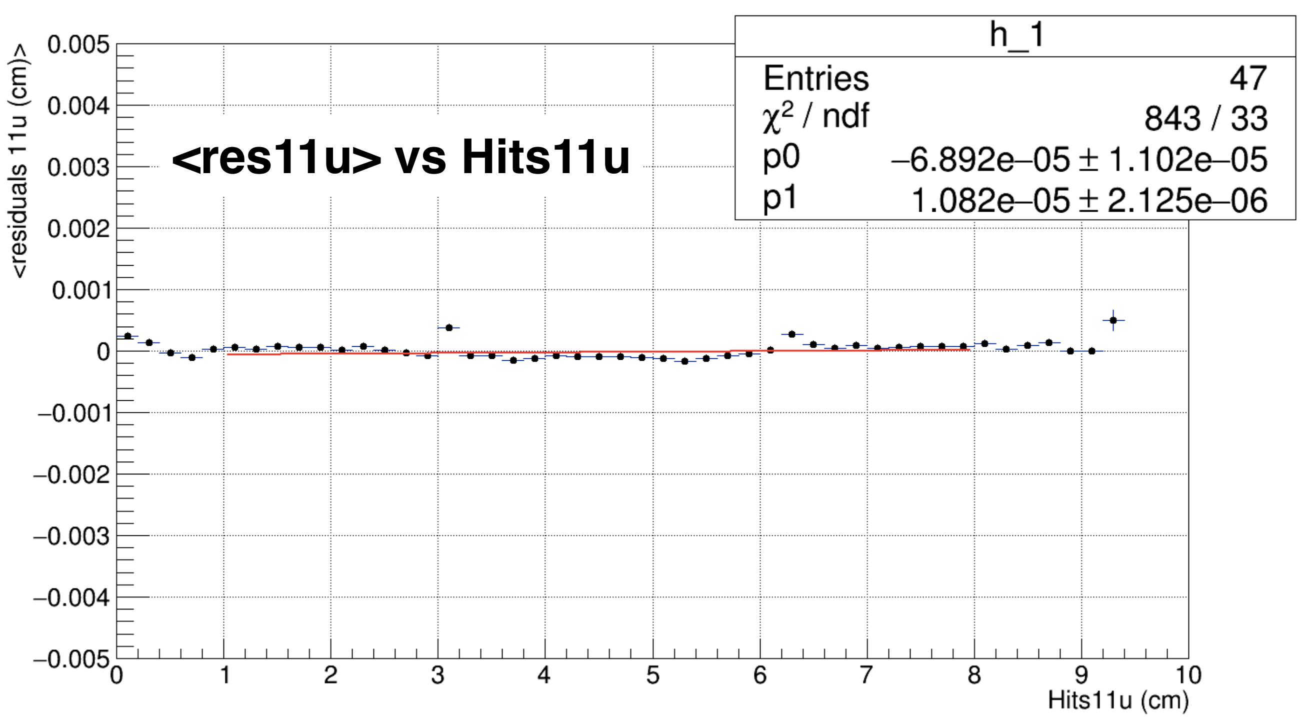


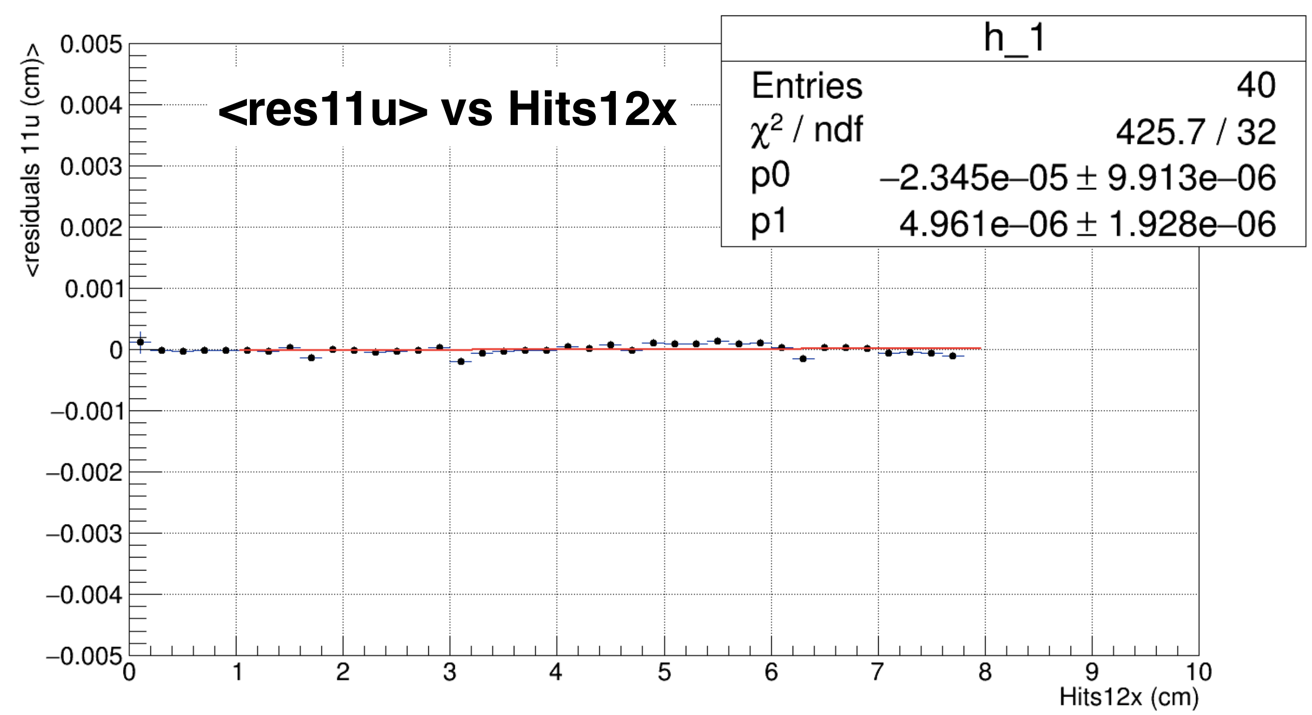
- Correlation (tilt-like) between res11u and hits11u, induces a correlations res11u vs hits12x, which appears like a relative rotation. Correction: **Hits11u' = (1-0.001244)*Hits11u**. It's not possible to apply it iteratively.

Alignment 11u post correction









- **Hits11u’ = (1-0.001244)*Hits11u**. The residual and other correlations improve significantly: 34 um -> 27 um.

Efficiencies analysis: hit / event

Layer resolution		% bad hits		Hit eff	
$\sigma_{residual}$		Cutted hits % (with mask)		$\epsilon_{3.28\sigma}$ $\chi^2_x + \chi^2_y < 26$ (only chi2, no mask)	
1y	*49 µm*	*1y*	*~34%*	**1y**	**94.6%**
2x	*38 µm*	*2x*	*~13%*	**2x**	**95.1%**
3y	*43 µm*	*3y*	*~6%*	**3y**	**73.9%**
4x	*40 µm*	*4x*	*~3%*	**4x**	**76.8%**
5y	*31 µm*	*5y*	*~19%*	**5y**	**98.6%**
6x	*32 µm*	*6x*	*~10%*	**6x**	**98.8%**
7y	*26 µm*	*7y*	*~7%*	**7y**	**96.1%**
8x	*25 µm*	*8x*	*~5%*	**8x**	**96.7%**
9y	*28 µm*	*9y*	*~4%*	**9y**	**59.9%**
10x	*40 µm*	*10x*	*~65%*	**10x**	**59.2%**
11y	*39 µm*	*11y*	*~1%*	**11y**	**98.2%**
12x	*25 µm*	*12x*	*~1%*	**12x**	**98.4%**
13y	*31 µm*	*13y*	*~8%*	**13y**	**94.8%**
14x	*41 µm*	*14x*	*~1%*	**14x**	**94.3%**
15y	*45 µm*	*15y*	*~5%*	**15y**	**82.1%**
16x	*48 µm*	*16x*	*~16%*	**16x**	**83.4%**

Event efficiencies downstream planes

7y	**67.5%**
8x	**54.4%**
9y	**78.2%**
10x	**25.0%**
11u	**81.3%**
12x	**88.6%**
13y	**83.8%**
14v	**79.5%**
15y	**80.6%**
16x	**85.2%**

4 runs only T1
2x-3y-4x-5y-6x (m==1)
11111 T: 18.4e+06 incoming muons

- Taking in coincidence 3 best layers per view: (11u-12x-13y-14v-15y-16x)

0.81*0.89*0.84*0.80*0.81*0.85 ~ 33%
(best event eff)

- With the worst: (7y-8x-9y-10x-15y-16x)

0.68*0.54*0.78*0.25*0.81*0.85 ~ 5%
(worst event eff)