

# Muon alignment with Cosmics: Real and Monte Carlo data

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# Outline

- Reminder on the Alignment of real Cosmic data
- Analysis of Montecarlo Cosmics data
- Conclusions

# Real data sample

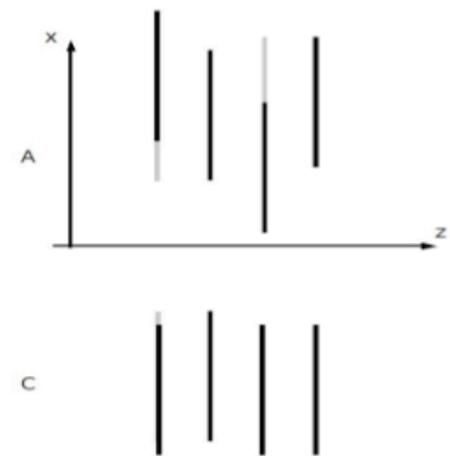
- **Local alignment of Muon Half stations** (Sep-Oct 2008 data)
  - Trigger ECAL U Muon
  - Multiple BX acquisition  $\pm 7$  TAE
  - Noisy channels masked on & off-line
  - Nnet-track finding (Xtalk hits) with at least 3 station hit
  - **130k tracks useful for alignment**

# Alignment results (translations x,y,Rz)

- Kalman-fit based alignment (iterative)
  - fixed 2 stations (M3&M5) as reference

- **Translations in X and Y:**

- A side compatible with a shearing in the X-Z plane AND a displacement of M5 of 7 mm
- C side compatible with the survey measurements in X
- Y compatible with survey measurements



- **Rotations around Z:** O(0.1 mrad), compatible with survey

	Survey x (mm)	Tx (mm)	Survey y (mm)	Ty (mm)	Survey Rz (mrad)	Rz (mrad)
<b>M2 A</b>	+9.0 ± 1.0	+11.97 ± 0.17	0.0 ± 1.0	-0.38 ± 0.50	0.0 ± 0.5	-0.16 ± 0.11
<b>M2 C</b>	+9.0 ± 1.0	+ 9.68 ± 0.15	0.0 ± 1.0	+1.12 ± 0.45	0.0 ± 0.5	-0.04 ± 0.10
<b>M4 A</b>	+10.0 ± 1.0	+ 5.56 ± 0.20	0.0 ± 1.0	+0.28 ± 0.32	0.0 ± 0.5	-0.21 ± 0.09
<b>M4 C</b>	+10.0 ± 1.0	+ 9.93 ± 0.20	0.0 ± 1.0	+0.44 ± 0.32	0.0 ± 0.5	+0.04 ± 0.09

From S.Pozzi's talk at the 3rd Detector Alignment Workshop 15/06/09 ([link](#))

Compatible results if we fix two ≠ stations

# Alignment (translations & rotations)

- Kalman-fit based alignment (iterative)
  - Cosmics data have some sensitivity to the "z" position due to the larger track slopes
  - Significant up to 10mm misalignments found in z BUT inconsistent picture found if different set of stations are fixed
  - Rotations of the whole half-station around x/y have been tested
    - Significant up to 6mrad misalignments found in  $R_y$  BUT inconsistent picture found if different set of stations are fixed

see S.Pozzi's talk at the 52th LHCb week 26/05/09 ([link](#))

... need a Monte Carlo to validate these results and better understand possible systematic effects (Cosmics highly non projective, geometric acceptance)

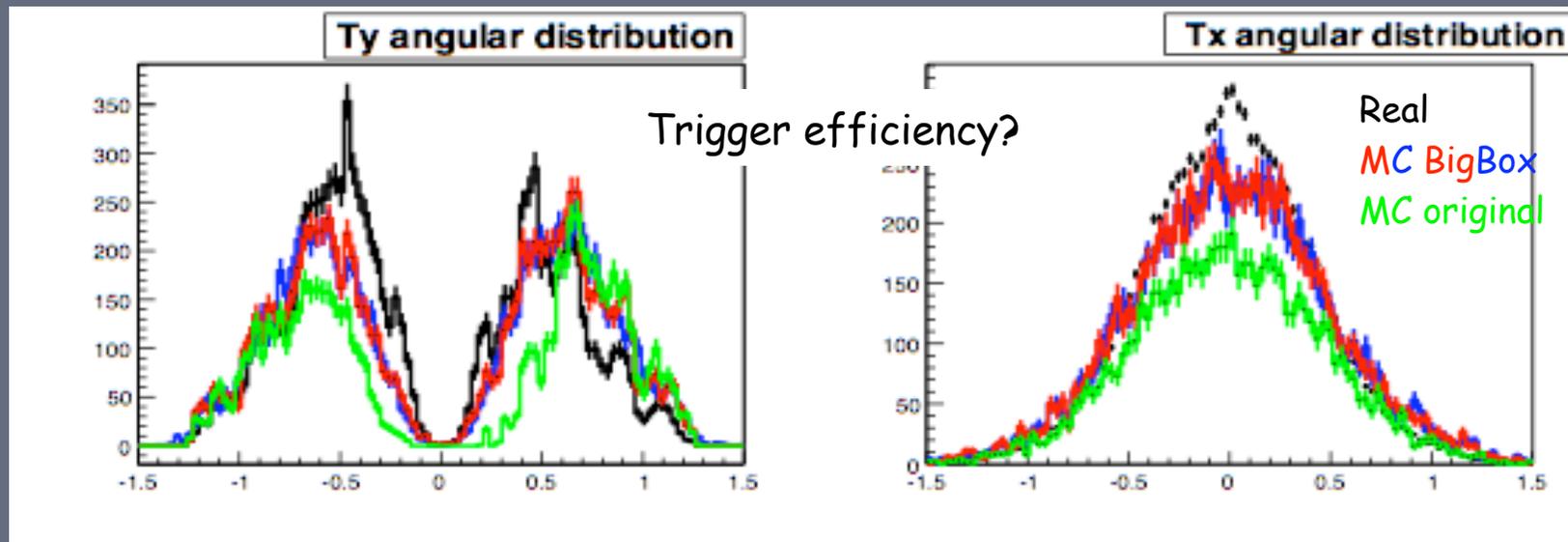
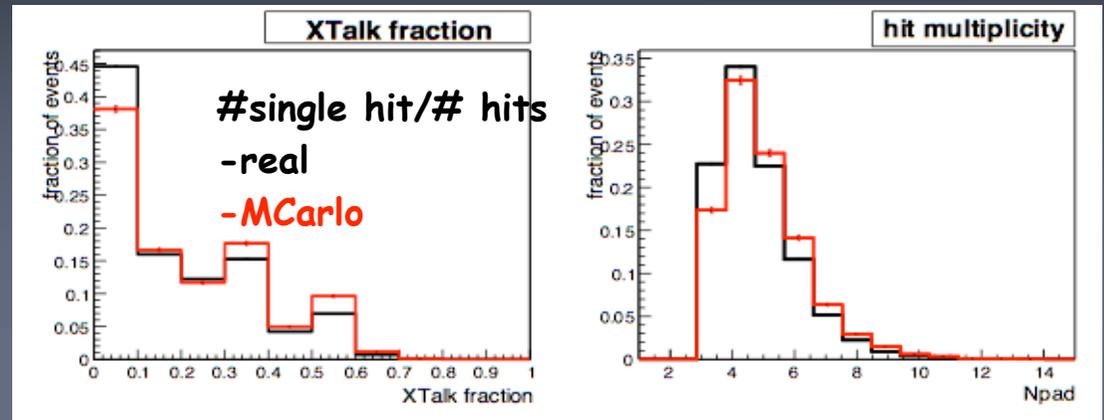
# Monte Carlo for Cosmics

- Simulation: based on [Gen/ParticleGuns/Cosmics.cpp\(h\)](#)
  - Generates from a xz plane 6m on top of LHCb  $\mu\pm$  in order to have a uniform coverage on a vertical xy plane.
  - Some minor changes applied to have the right proportions of “horizontal” cosmics (enlarge the sizeOfWorldVolume)
- **Generated** 3M events with  $\delta$ Rays on in MuonFilters
  - 1M evts on M2 / M3/ M4 surfaces ( $t_0 \sim 45-50$  ns)
- **Digitized** with TAE  $\pm 4$ , Xtalk, Electronic Noise
- NNet-based track **reconstruction** (like real data) **No M1**

**Crucial point for the alignment: provide the same spatial & angular distributions of the Real data**

# Some comparison

- Track requirements:
  - hit at least 3 stations / 4 (Nnet)
  - match the CALO acceptance

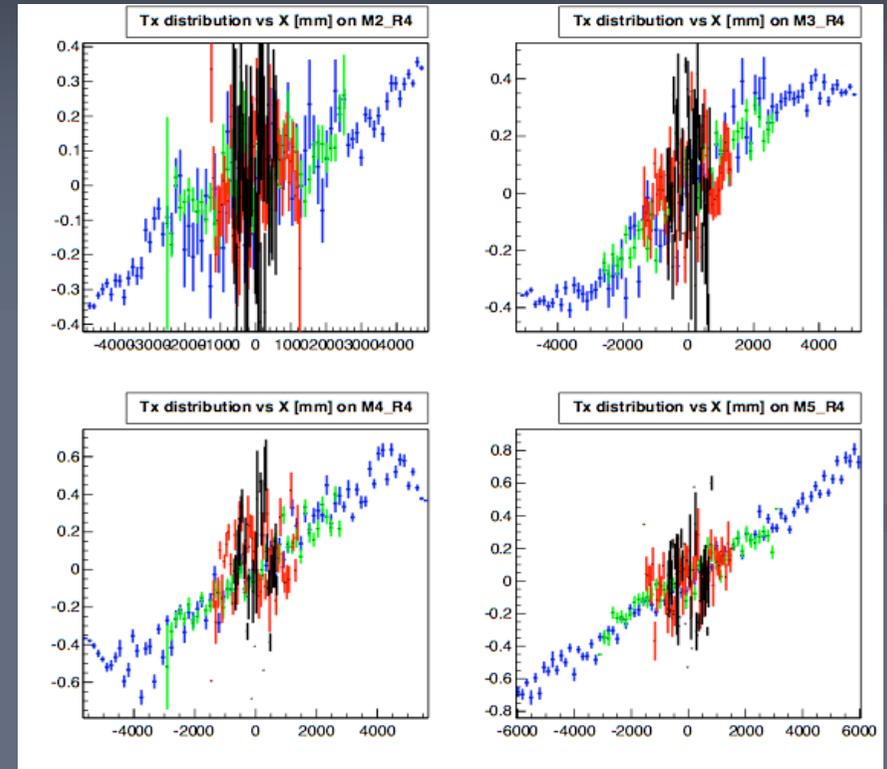
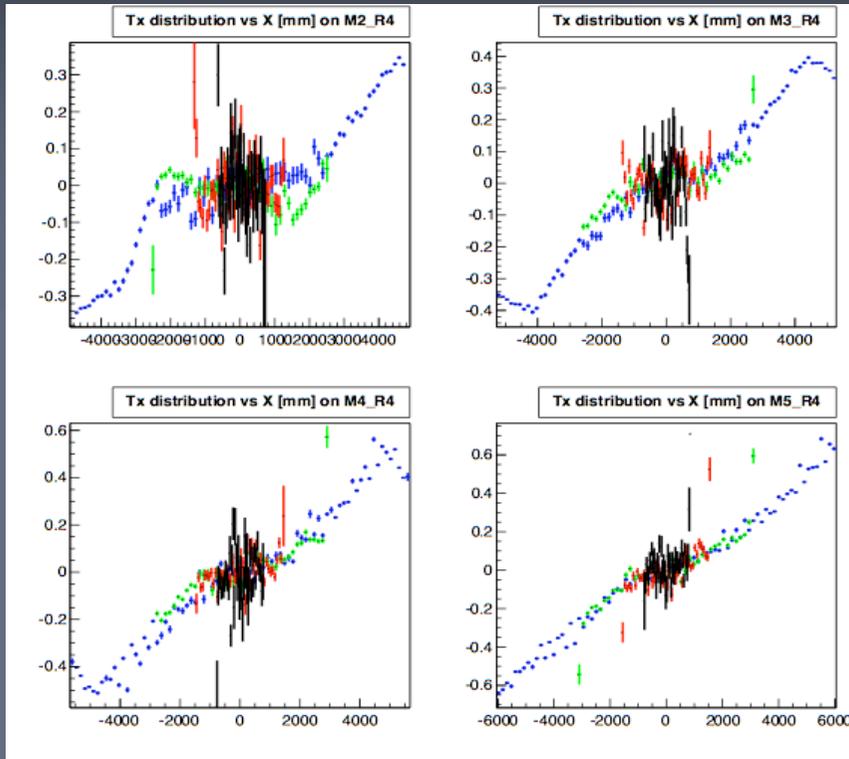


# Some comparison: $\langle Tx \rangle$ vs $x$

R1 R2 R3 R4

Real

MonteCarlo



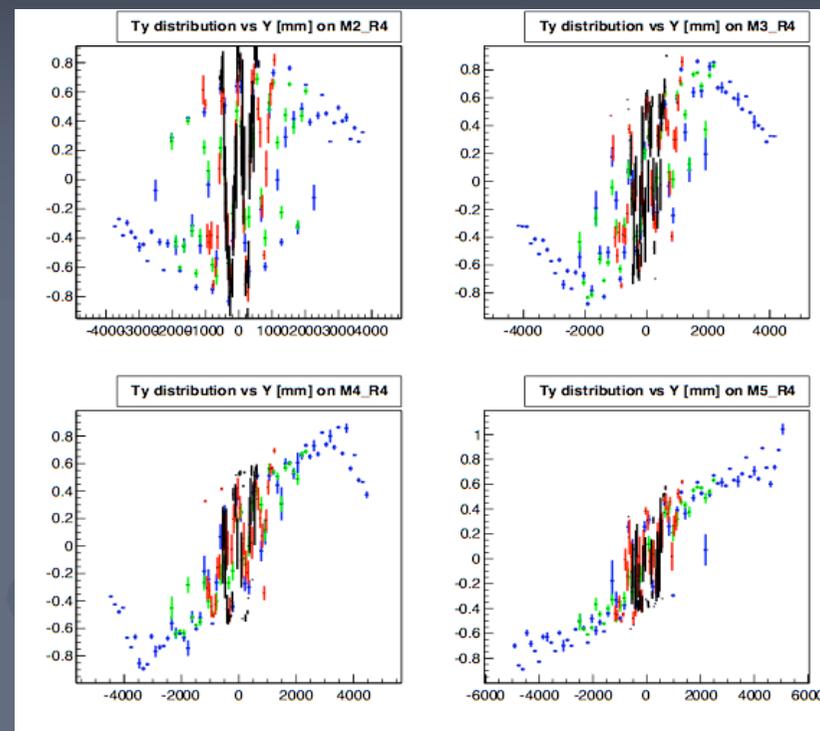
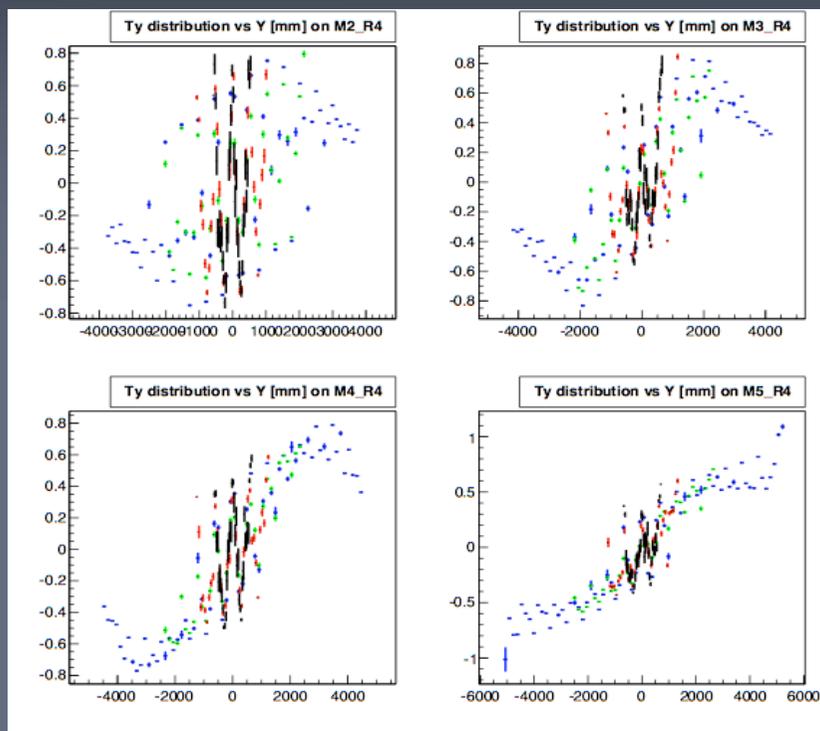
- $\langle Tx \rangle$  vs  $x$  similar distribution
  - depends on the initial distributions & on correlations

# Some comparison: $\langle Ty \rangle$ vs $y$

R1 R2 R3 R4

Real

MonteCarlo

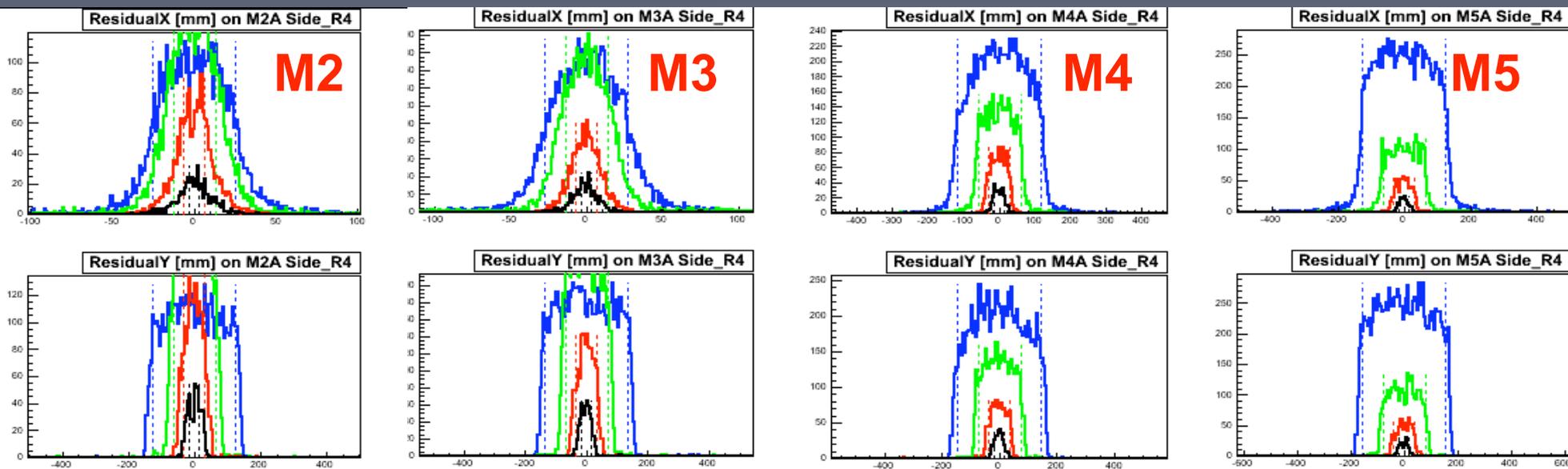


- $\langle Ty \rangle$  vs  $y$  similar distribution
  - Strong modulation due to chamber to chamber gaps & non projectivity
  - depends on the initial distributions & on correlations

# Residual distributions: hit - MChit

- Requirement: track passing through M3&M5&Calo
  - No major deviation from box distribution (Xtalk x)

R1 R2 R3 R4



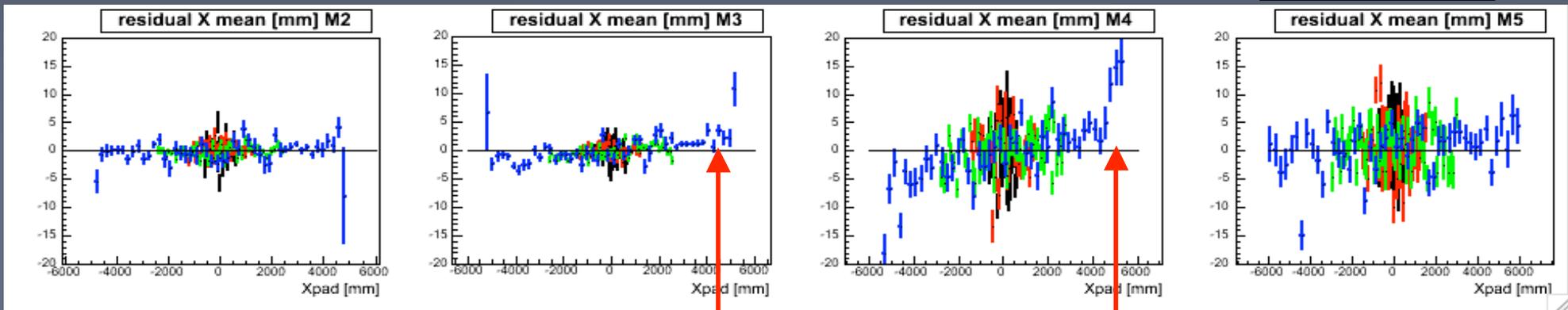
....but.....

# <X\_hit - X\_MChit> vs X dependence

- Requirement: track passing through M3&M5&Calo

$$\text{Error bar} = \sigma^{\text{res}}/\text{sqrt}(N)$$

R1 R2 R3 R4

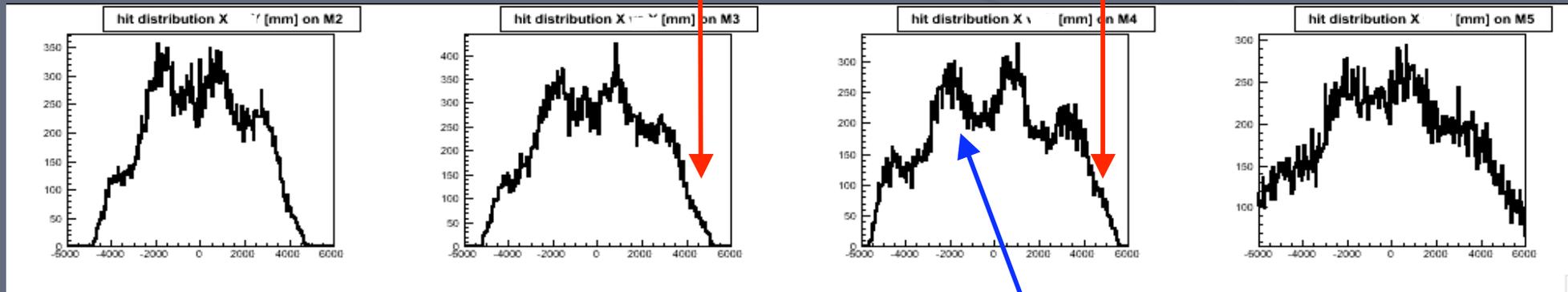


pad size 1/4

+ 1/4 pad size

+ large pad size

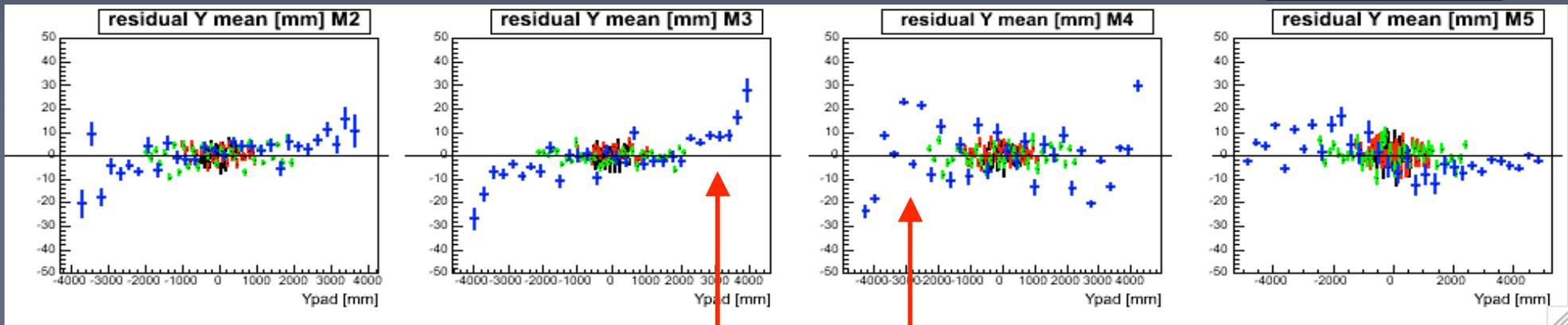
Non uniform distribution of the MChit of the selected tracks



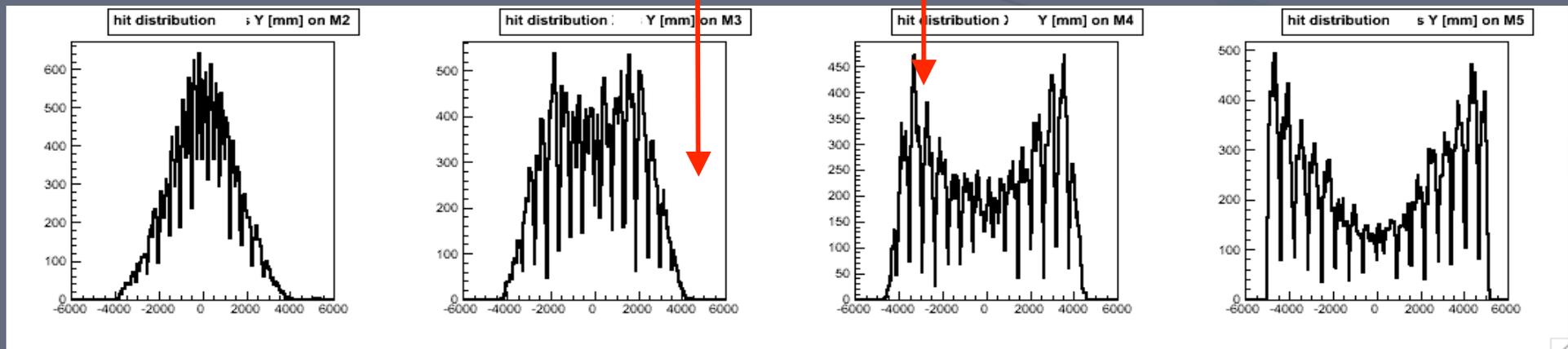
# $\langle Y_{hit} - Y_{MChit} \rangle$ vs $Y$ dependence

- Requirement: track passing through M3&M5&Calo

R1 R2 R3 R4

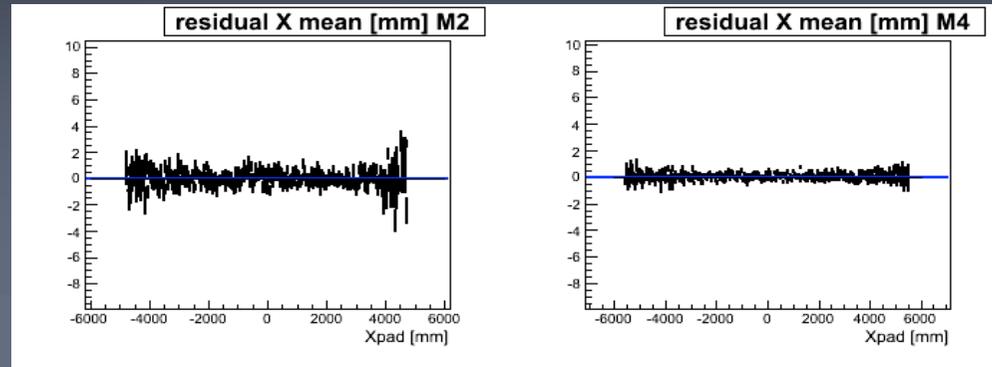


Non uniform distribution of the Mchit  
Due to the selection & GAPS between chambers



# Mean Residual distributions: M3&M5 fixed(X)

$\langle MChit-fit^{MChit} \rangle$



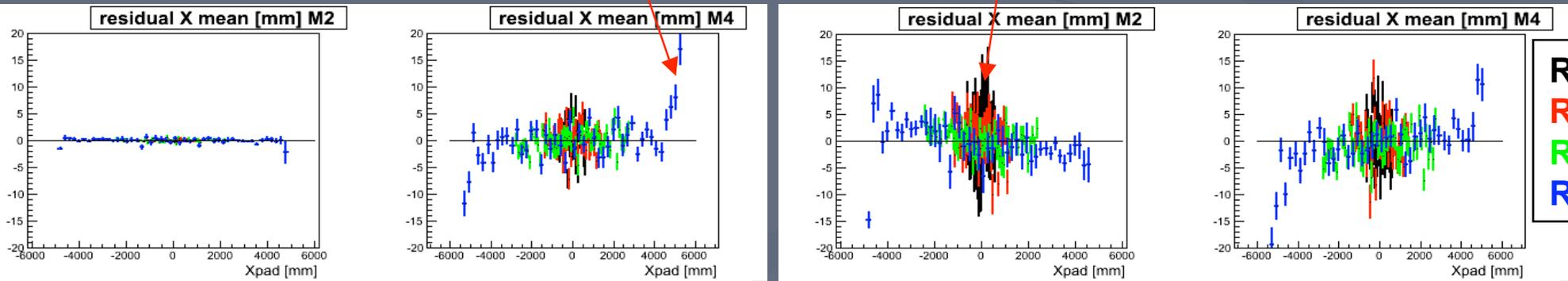
Would be like this if we had a very high spatial resolution detector

Sampling of the measurement + non uniformity of the MChit distribution within a pad

Sampling of the measurement & of the track parameters

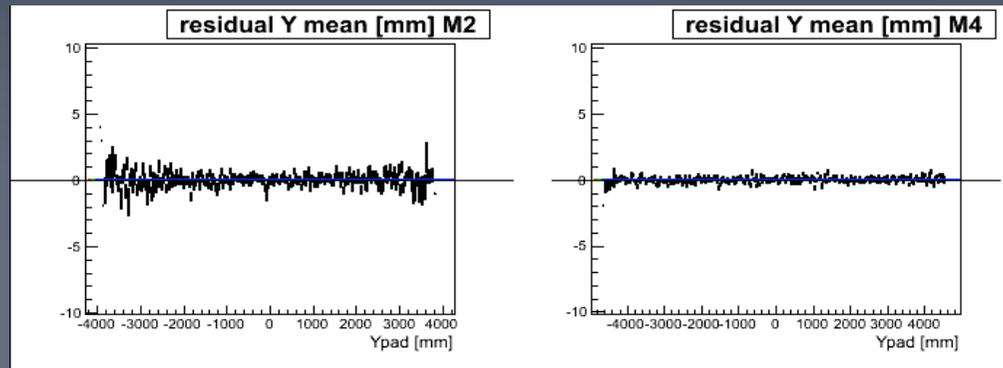
$\langle hit-fit^{MChit} \rangle$

$\langle hit-fit^{hit} \rangle$



# Mean Residual distributions: M3&M5 fixed (Y)

$\langle \text{MChit-fit}^{\text{MChit}} \rangle$

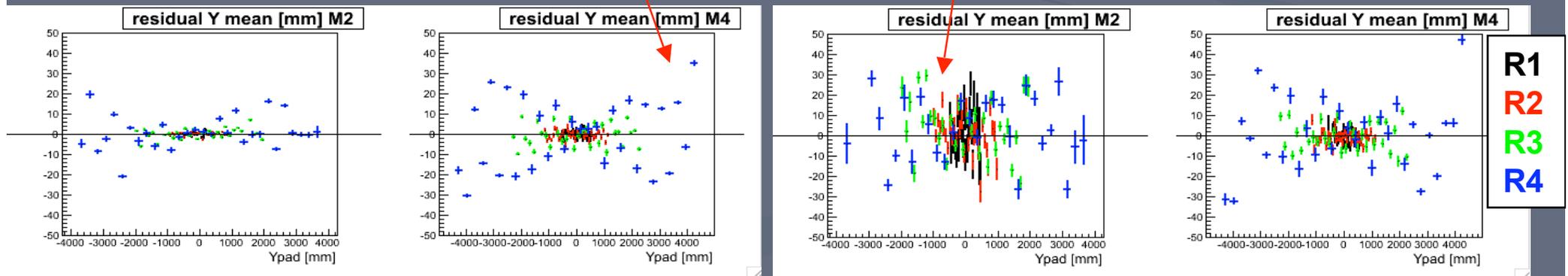


Sampling of the measurement + non uniformity of the MChit within a pad (GAPs)

Sampling of the measurement & of the track parameters

$\langle \text{hit-fit}^{\text{MChit}} \rangle$

$\langle \text{hit-fit}^{\text{hit}} \rangle$

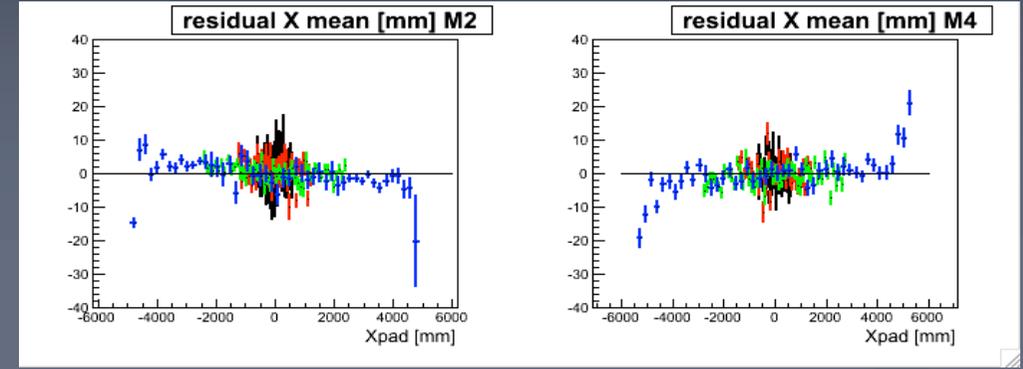
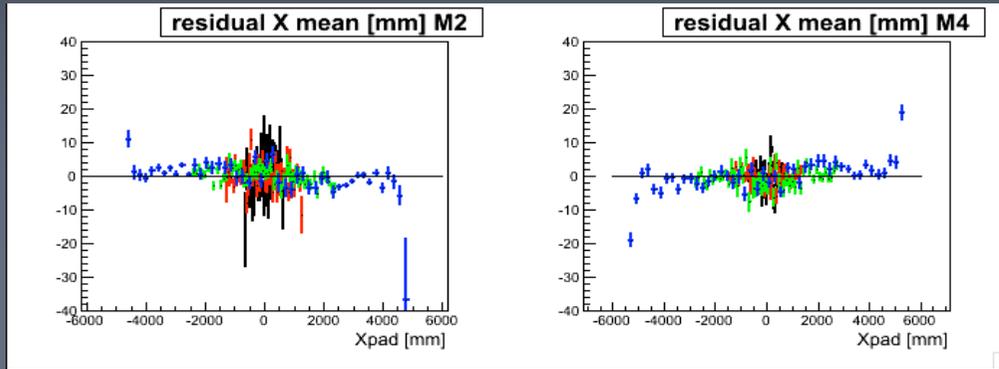


# Comparison with real cosmics (after Alignment) **M3&M5 fixed**

R1 R2  
R3 R4

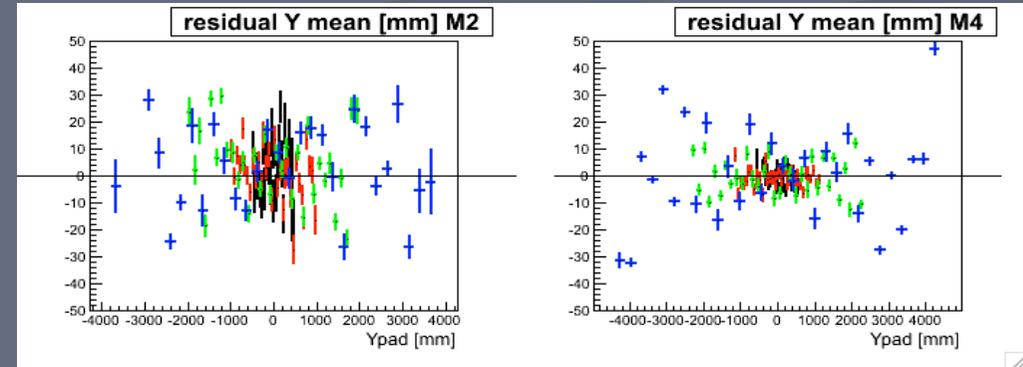
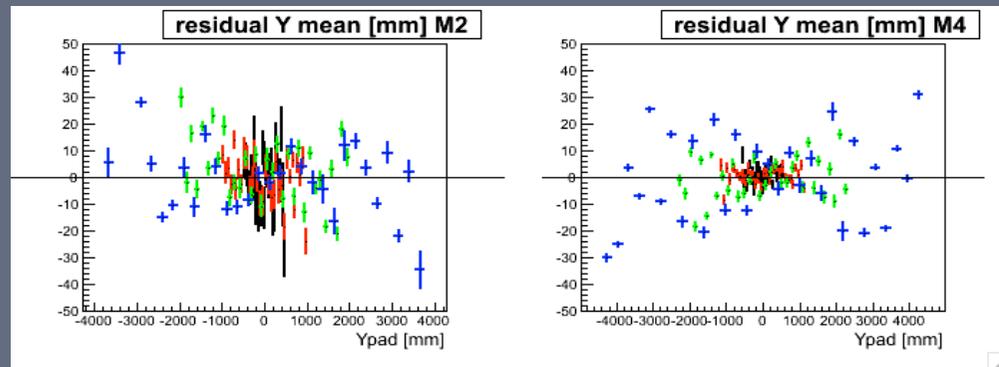
Real X  $\langle \text{hit-fit}^{\text{hit}} \rangle$  130k tracks

Mcarlo X  $\langle \text{hit-fit}^{\text{hit}} \rangle$  75k tracks



Real Y  $\langle \text{hit-fit}^{\text{hit}} \rangle$

Mcarlo Y  $\langle \text{hit-fit}^{\text{hit}} \rangle$



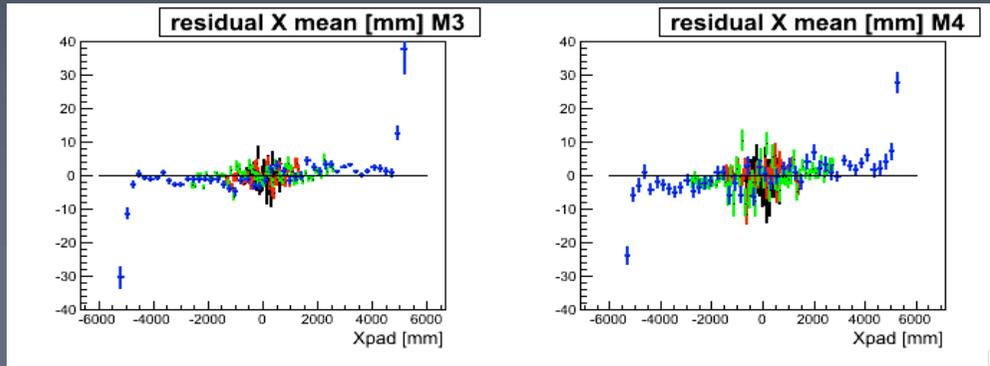
**Very similar distributions**

NB: Mcarlo statistics  $\sim 0.56$  Real  
Error bar =  $\sigma^{\text{res}}/\text{sqrt}(N)$

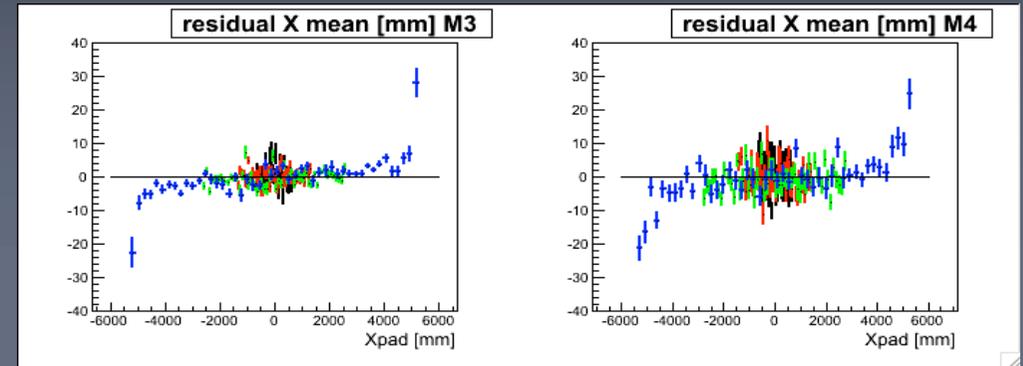
# Comparison with real cosmics (after Alignment) **M2&M5 fixed**

R1 R2  
R3 R4

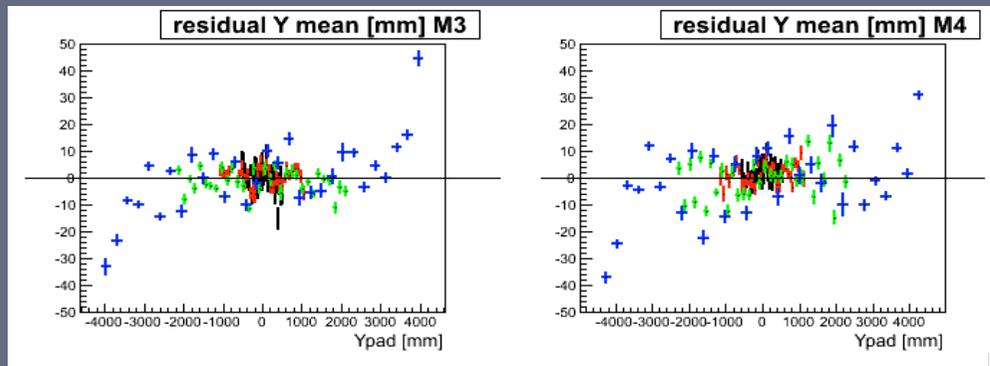
Real X  $\langle \text{hit-fit}^{\text{hit}} \rangle$  96k tracks



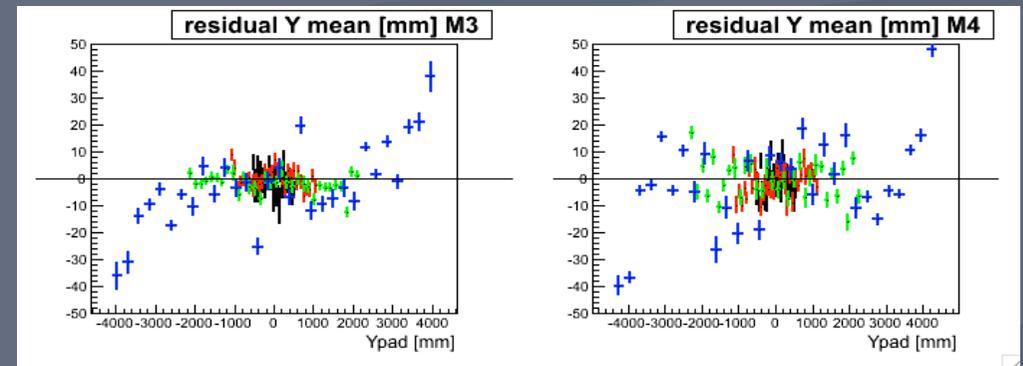
Mcarlo X  $\langle \text{hit-fit}^{\text{hit}} \rangle$  60k tracks



Real Y  $\langle \text{hit-fit}^{\text{hit}} \rangle$



Mcarlo Y  $\langle \text{hit-fit}^{\text{hit}} \rangle$



**Very similar distributions**

# Alignment results (translations x,y)

- Kalman-fit based alignment (iterative) fixed 2 stations (M3&M5)

- → 40 k tracks used in the alignment

	Input x (mm)	Tx (mm)	Input y (mm)	Ty (mm)	Input Rz (mrad)	Rz (mrad)
M2 A	0.0	-0.09 ± 0.28	0.0	-1.98 ± 0.83	0.0	0.28 ± 0.20
M2 C	0.0	+0.51 ± 0.28	0.0	-1.40 ± 0.82	0.0	0.02 ± 0.21
M4 A	0.0	+0.16 ± 0.38	0.0	+0.88 ± 0.63	0.0	-0.22 ± 0.16
M4 C	0.0	+0.04 ± 0.38	0.0	+1.14 ± 0.63	0.0	-0.19 ± 0.17

- **Translations in X and Y:** compatible with the null input misalignment
- **Rotations around Z:** compatible with the null input misalignment
- On simulated data the algorithm works as expected

40k tracks

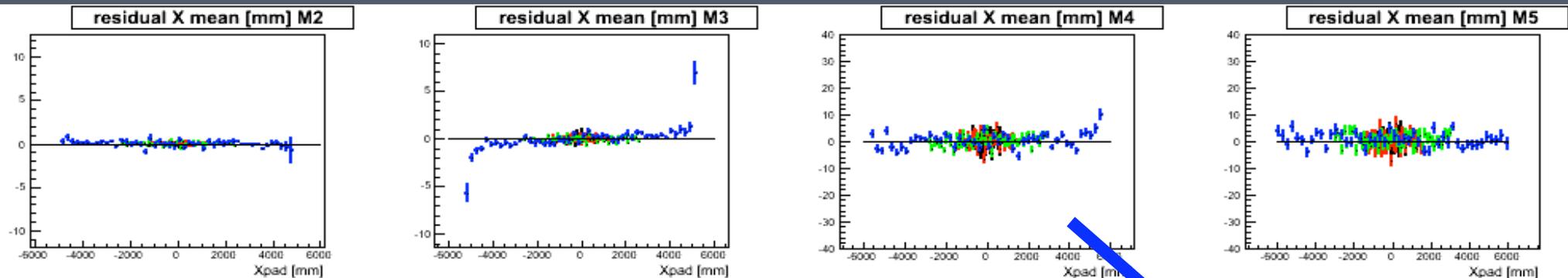
- **Compatible results if we fix two ≠ stations**
- Adding translations in z or rotation x,y we still get controversial results by fixing different pairs of stations (sampling?)
  - Tz: some significant up to 8mm misalignments found in z
  - Rx, Ry: some significant up to 1mrad misalignments found in Ry

# Further steps: align single chambers?

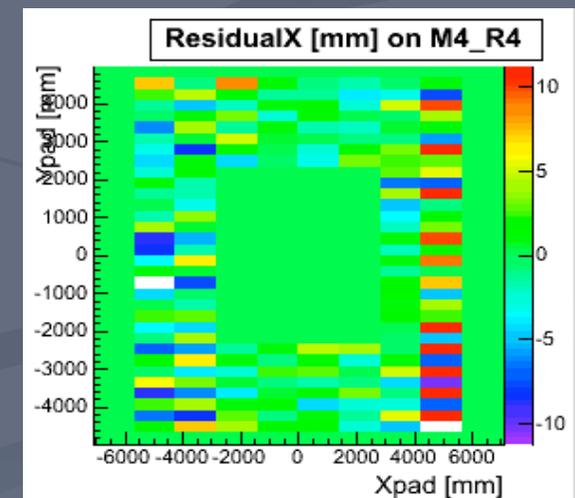
Mean residuals X (fit of all the measurement)

Requirements: at least 3 stations hit (any)

R1 R2 R3 R4



Non uniformity & large pad size effects shouldn't be mis-interpreted as misalignments of the chambers.....  
Inner regions should be OK.

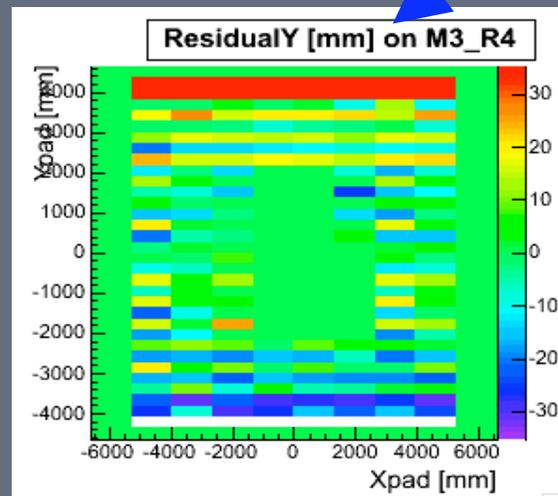
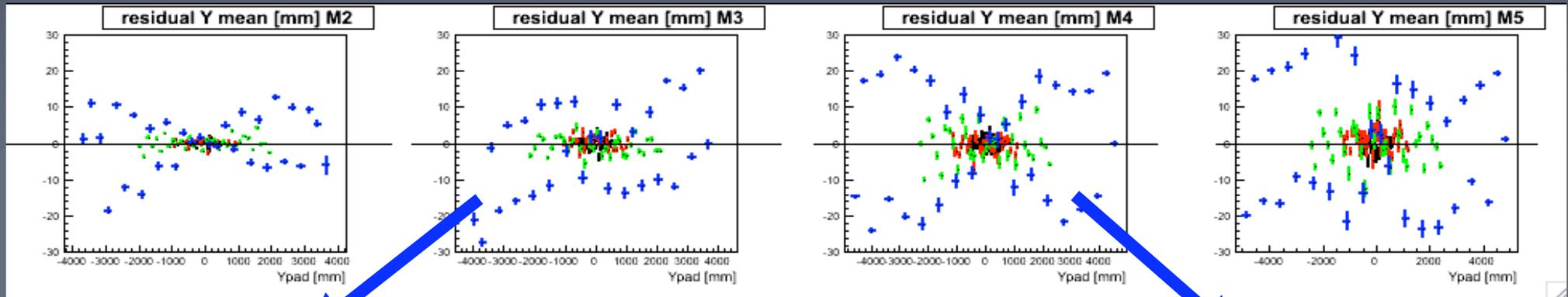


# Further steps: align single chambers?

Mean residuals Y (fit of all the measurement)

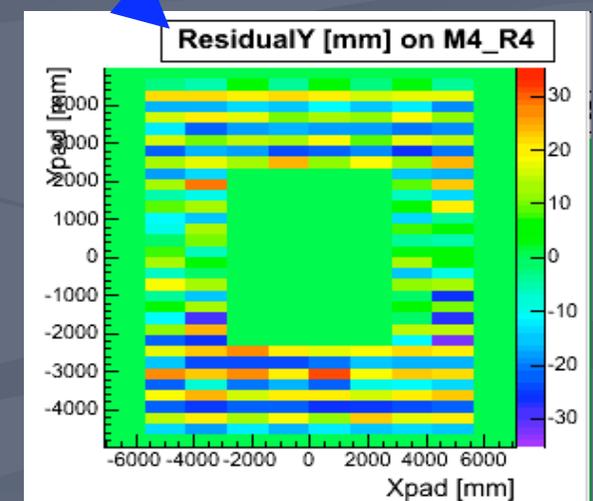
Requirements: at least 3 stations hit (any)

R1 R2 R3 R4



geometric acceptance due to chambers @ different z (4 columns) ==> different gaps size (non projective muons)

**A NIGHTMARE ..!!!!**



# Conclusion

- From the analysis of Real Cosmics (2008) **130k tracks**
  - **Misalignments along X A-side** (shearing + M5 out 7mm) incompatible with the survey measurements; **Y and Rz compatible with 0**
  - If more d.o.f. are used (Rx, Ry, Tz) we get controversial results if we fix different pairs of stations as reference ==> Systematics? Sampling? ←
- Generated Montecarlo Cosmics **90k tracks**
  - Same track selection ==> Similar angular & space distributions
  - The track selection makes the hit distribution non uniform (geometrical acceptance + gaps between chambers)
    - Border effects on ResX vs X M4 (large pad size)
    - Jumps in the ResY vs Y distribution due to sampling
  - Comparison with Real (aligned) Cosmics **show a reasonable agreement**
  - **Alignment of half stations is compatible with the input null displacements (Tx, Ty, Rz)**
  - If more d.o.f. are used (Rx, Ry, Tz) analogies & differences (\*)
  - **The alignment of single chambers seems very difficult with cosmics (Y)**