Optics 2018, minimum x_0 measurement

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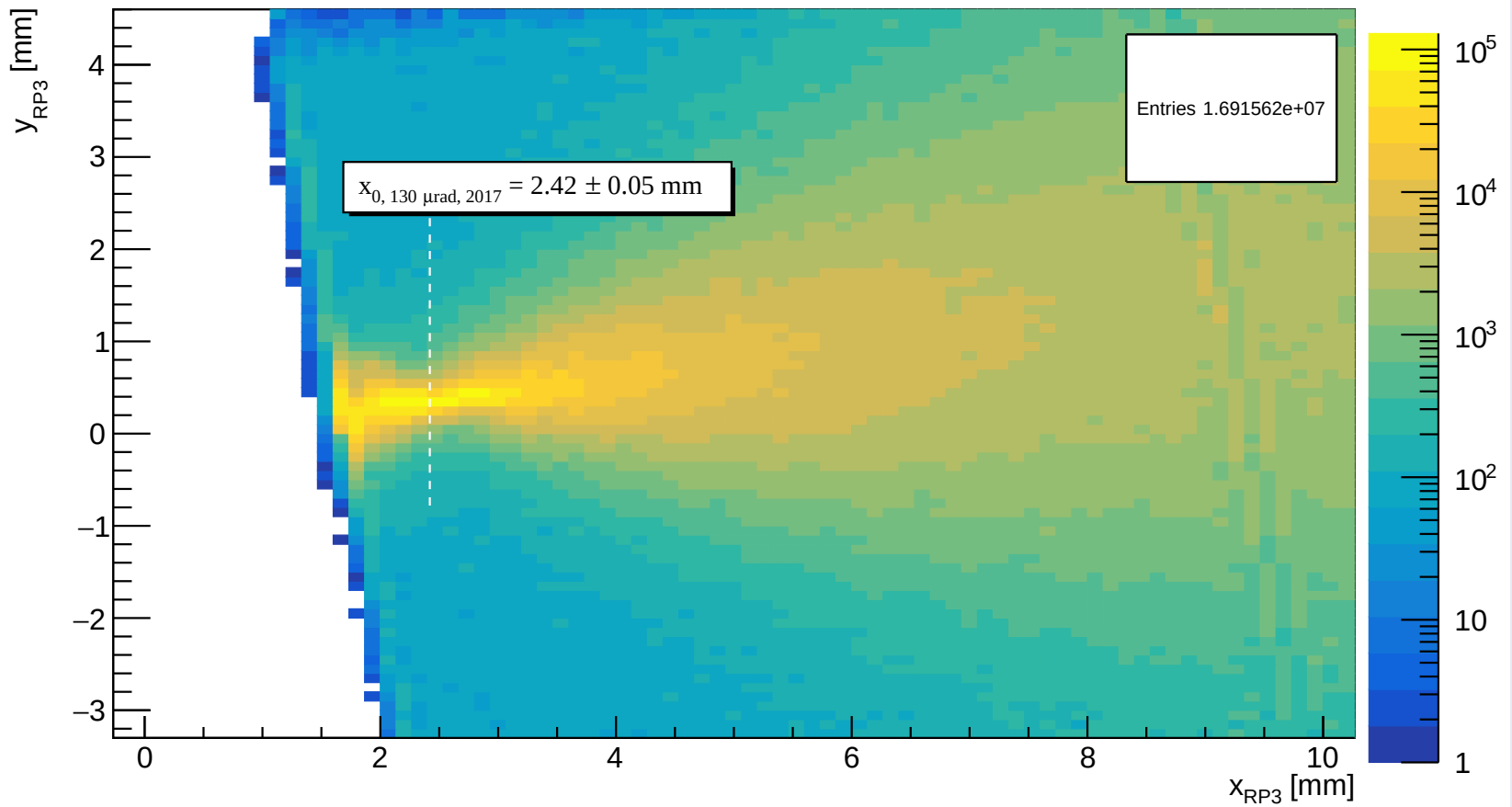
March 12, 2019

x-angle 130 μrad, $\beta^* = 0.25$ m

(Run 314276, 2018, April)

The "neck"

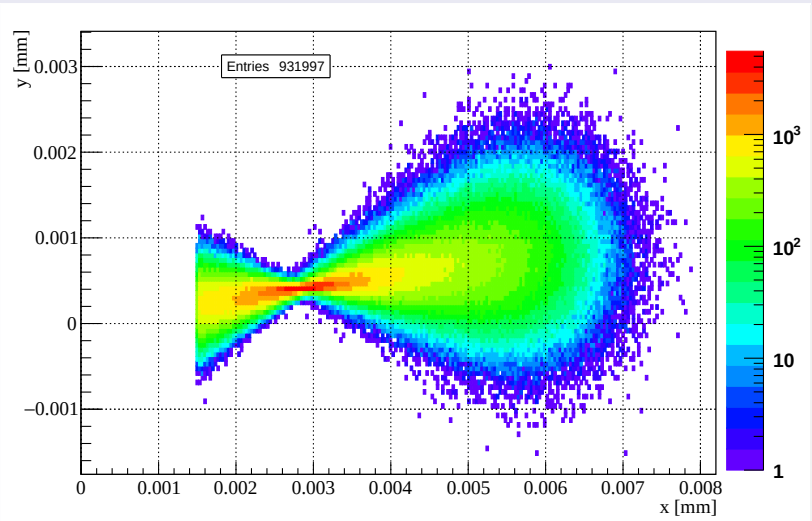
RP3, left arm, s =213 m

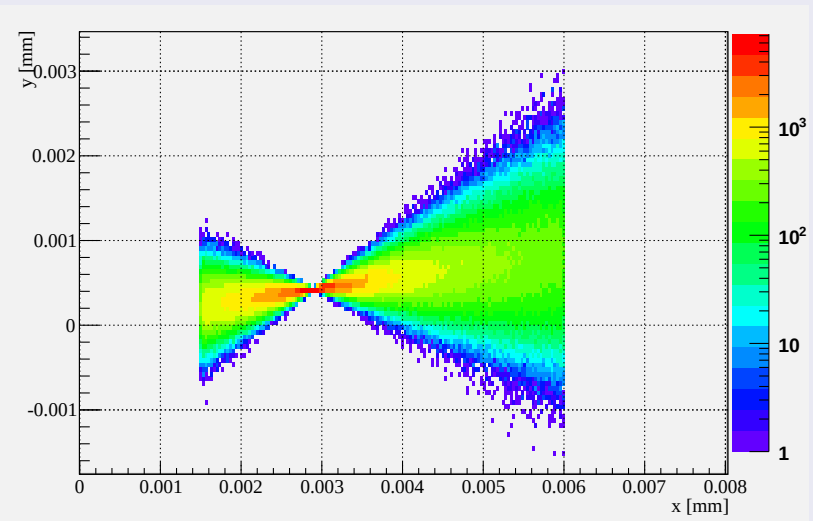


Monte Carlo plots: hitmap with and without θ_x^*

- The smearing due to scattering angle
- In the data we cannot switch of L_x or so
- However, one can make a cut on θ_x

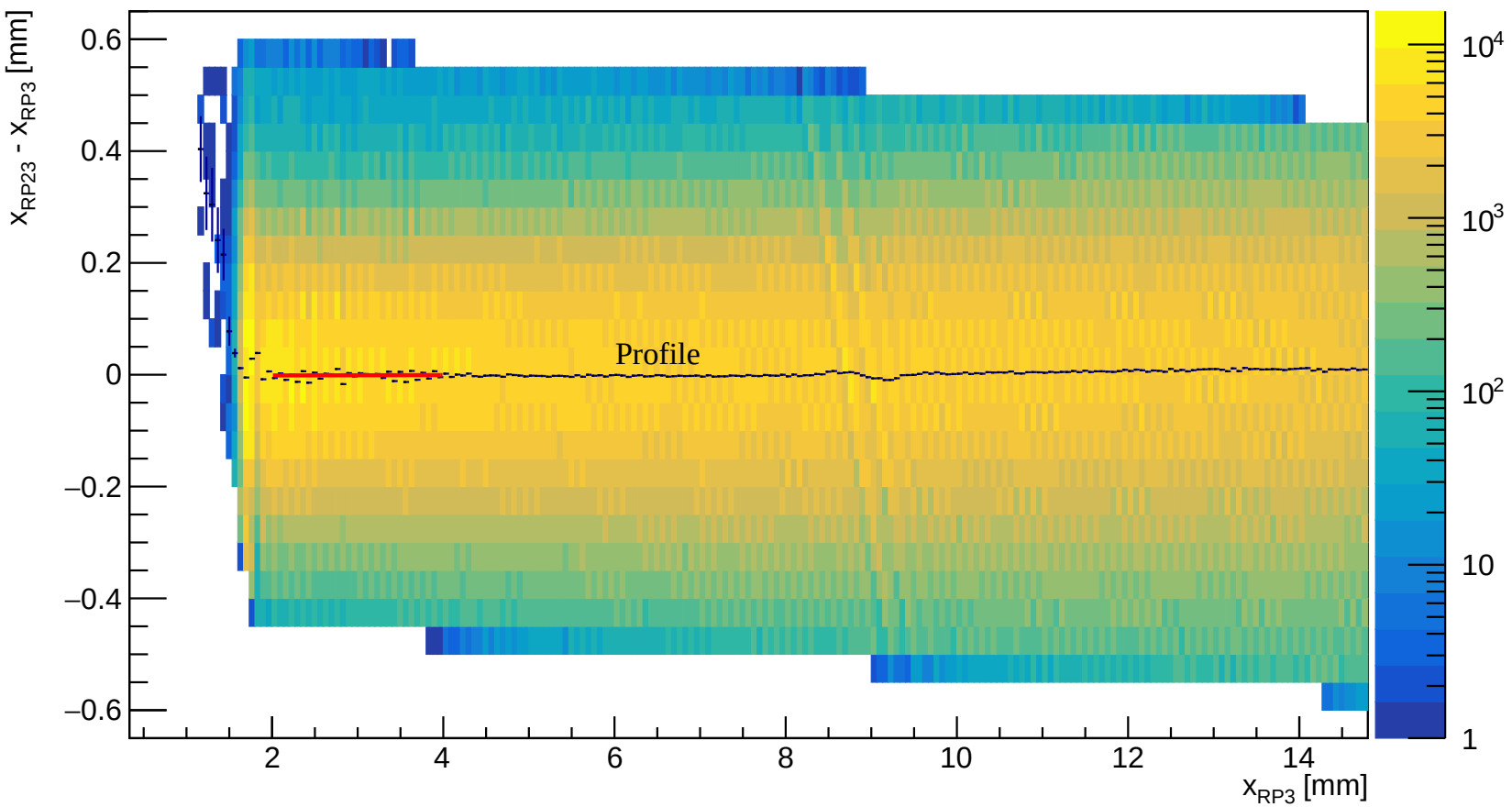
$$x = v_x \cdot x^* + L_x \cdot \theta_x^* + D_x \cdot \xi \tag{1}$$





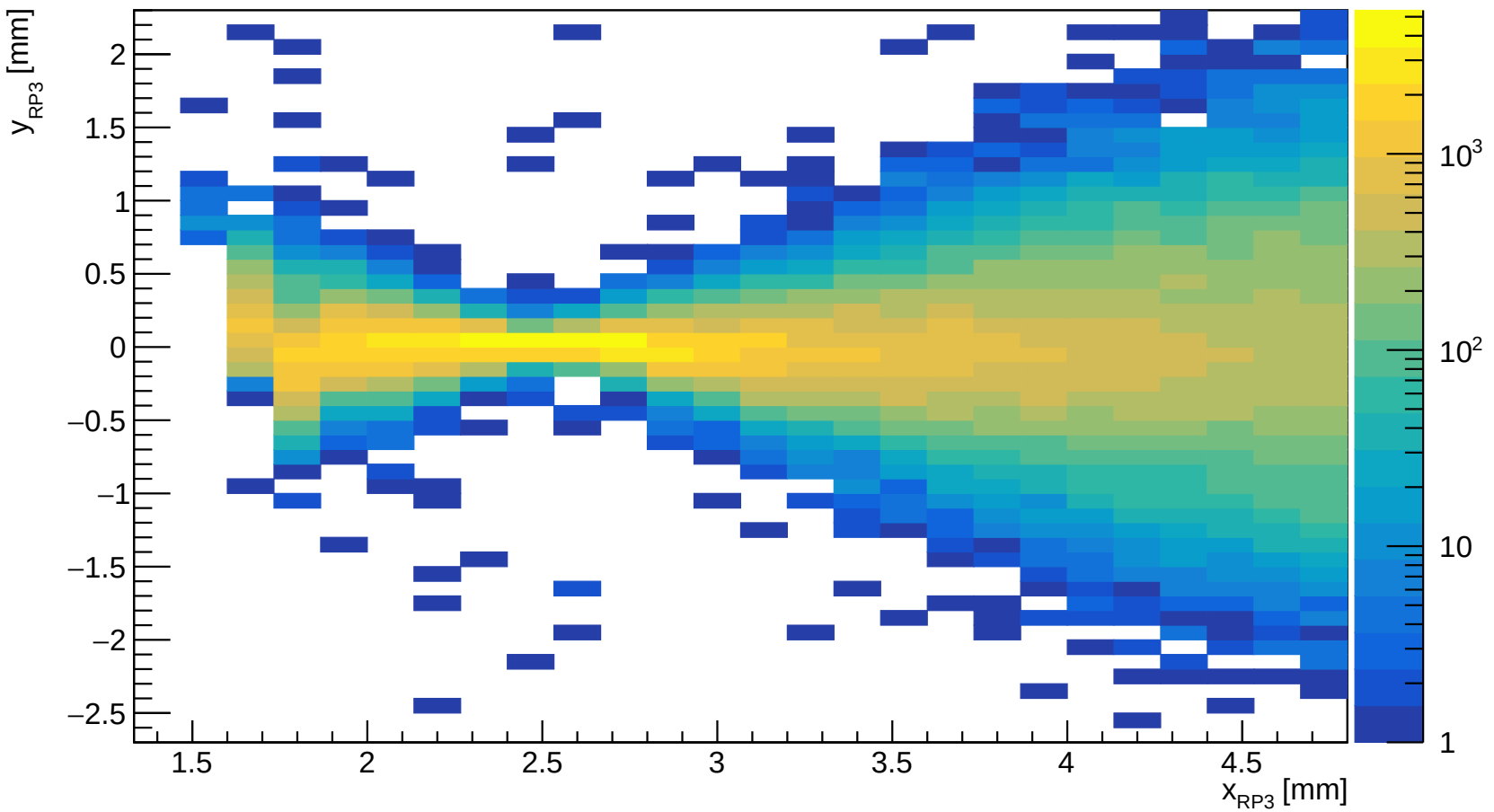
The x-coordinate difference between RP23 and RP3

- Red line shows the cut line (mean)
- The σ of the cut is 0.0125 mm



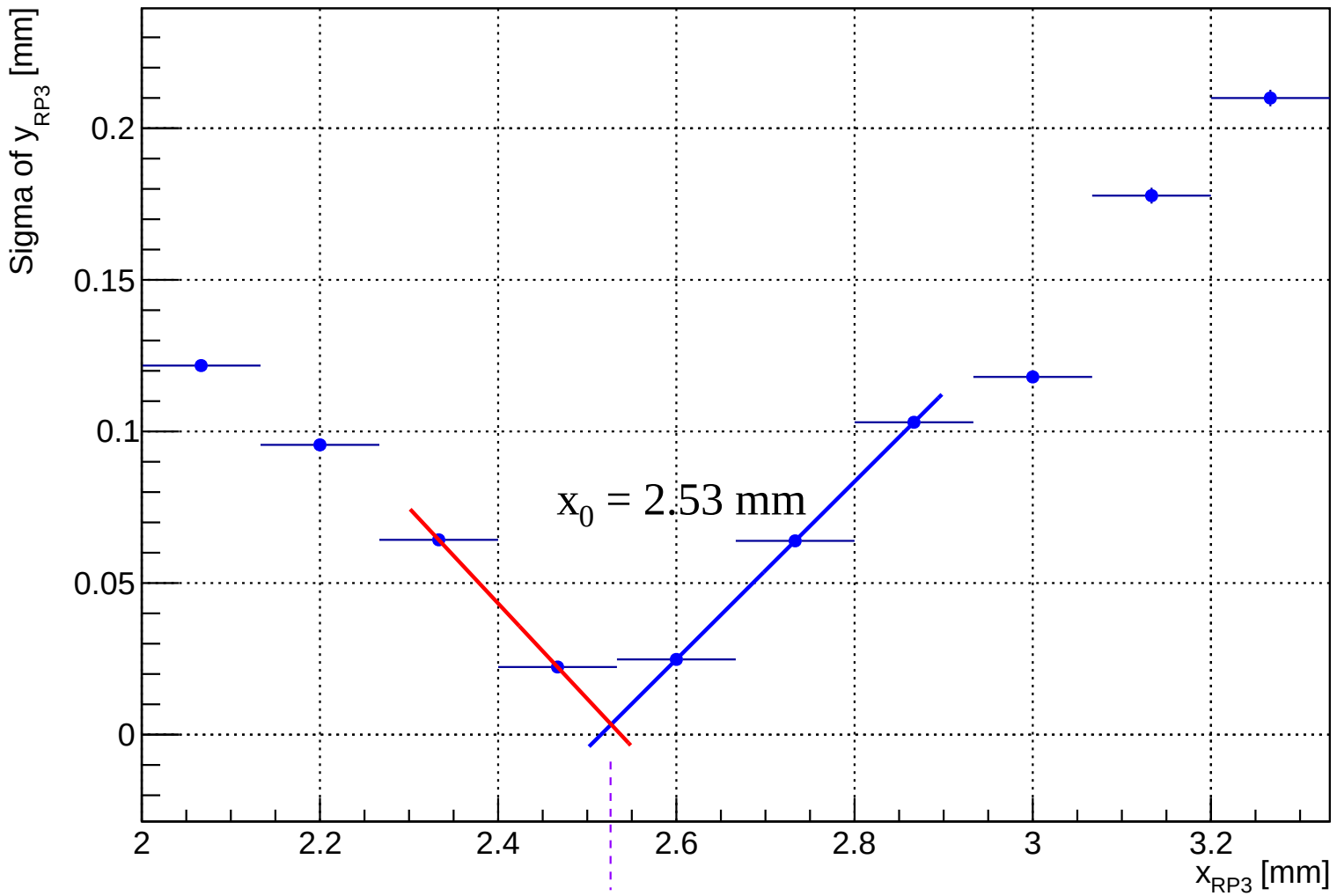
The x-y hitmap after the dx cut

- The angular smearing is close to 0
- Note: for these events $\xi_{\mathrm{singleRP}} = \xi_{\mathrm{multiRP}}$



The RMS of the y-coordinate

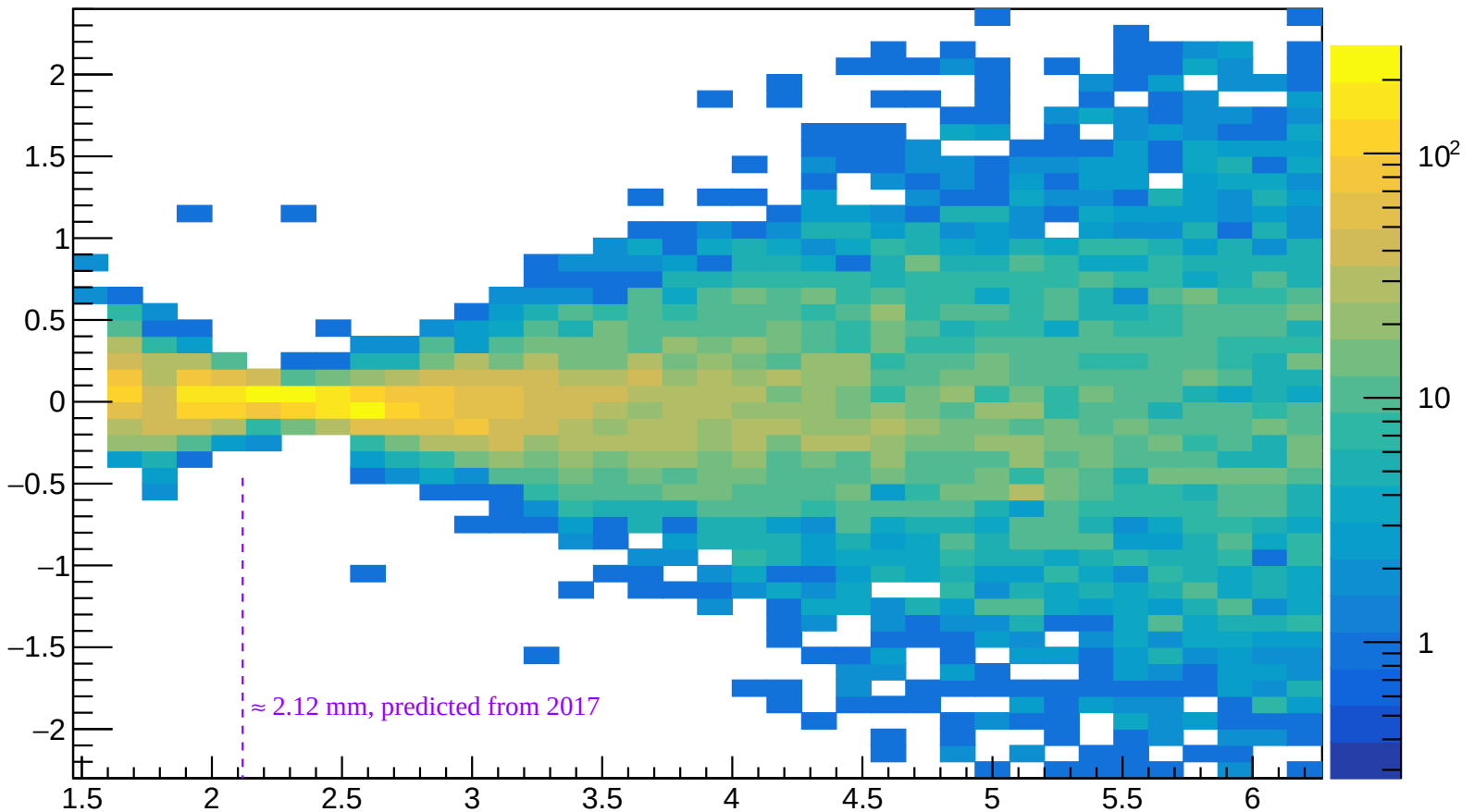
- The minimum shows the quick L_y cross-over 0



x-angle 160 μrad

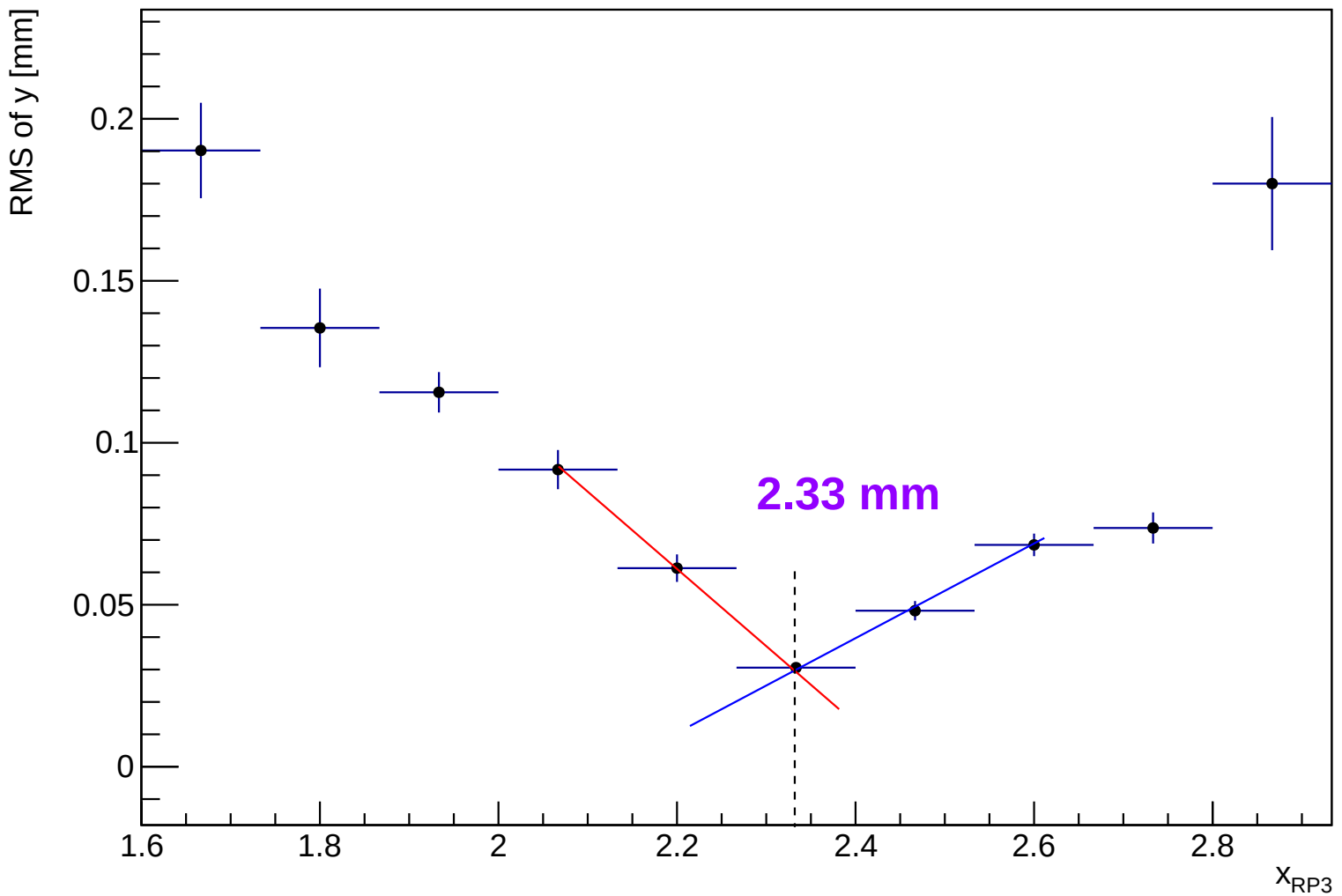
(Run 314247, 2018, April)

The RP3 x-y hitmap after the dx cut

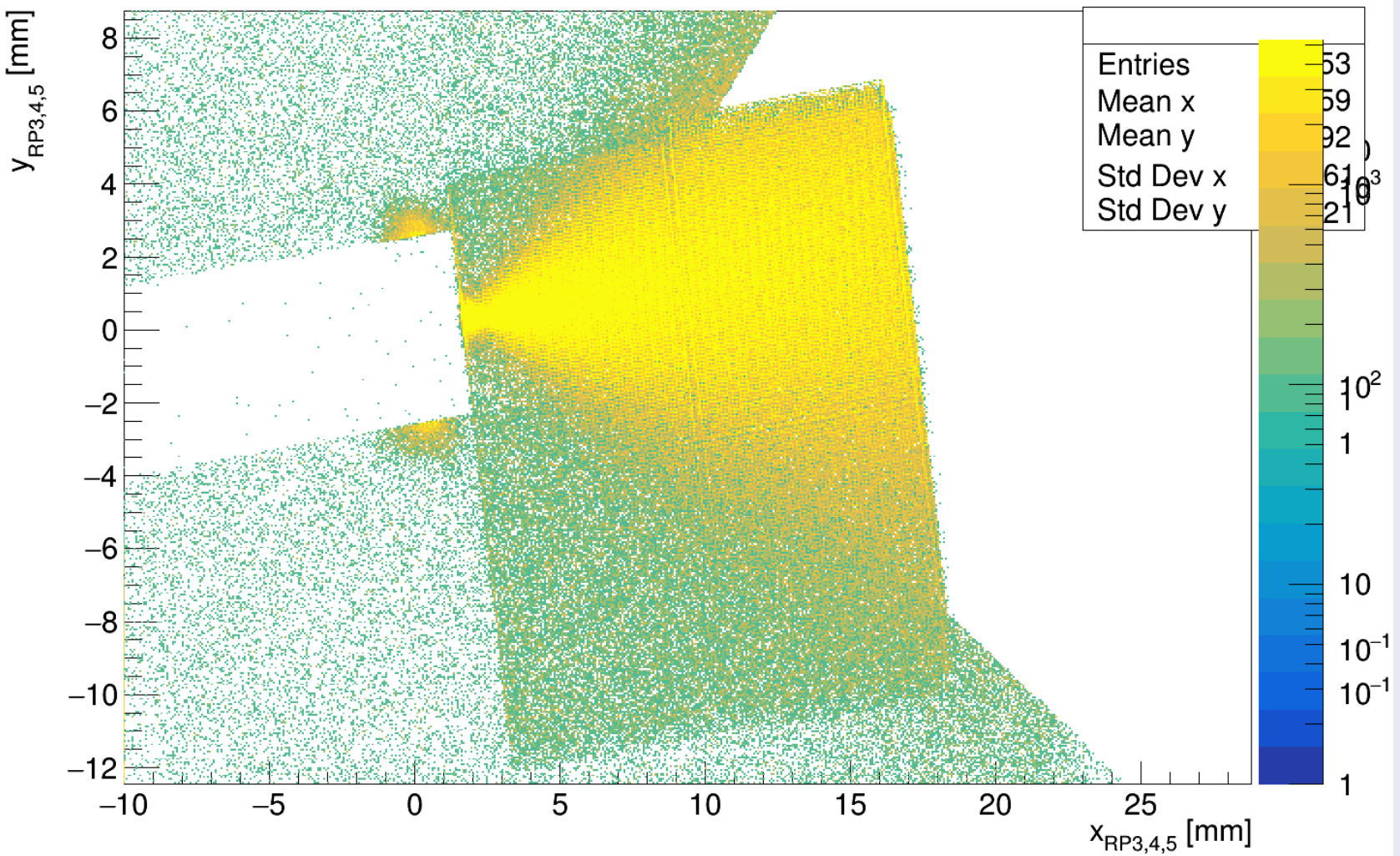


The RMS of the y-coordinate and x_0

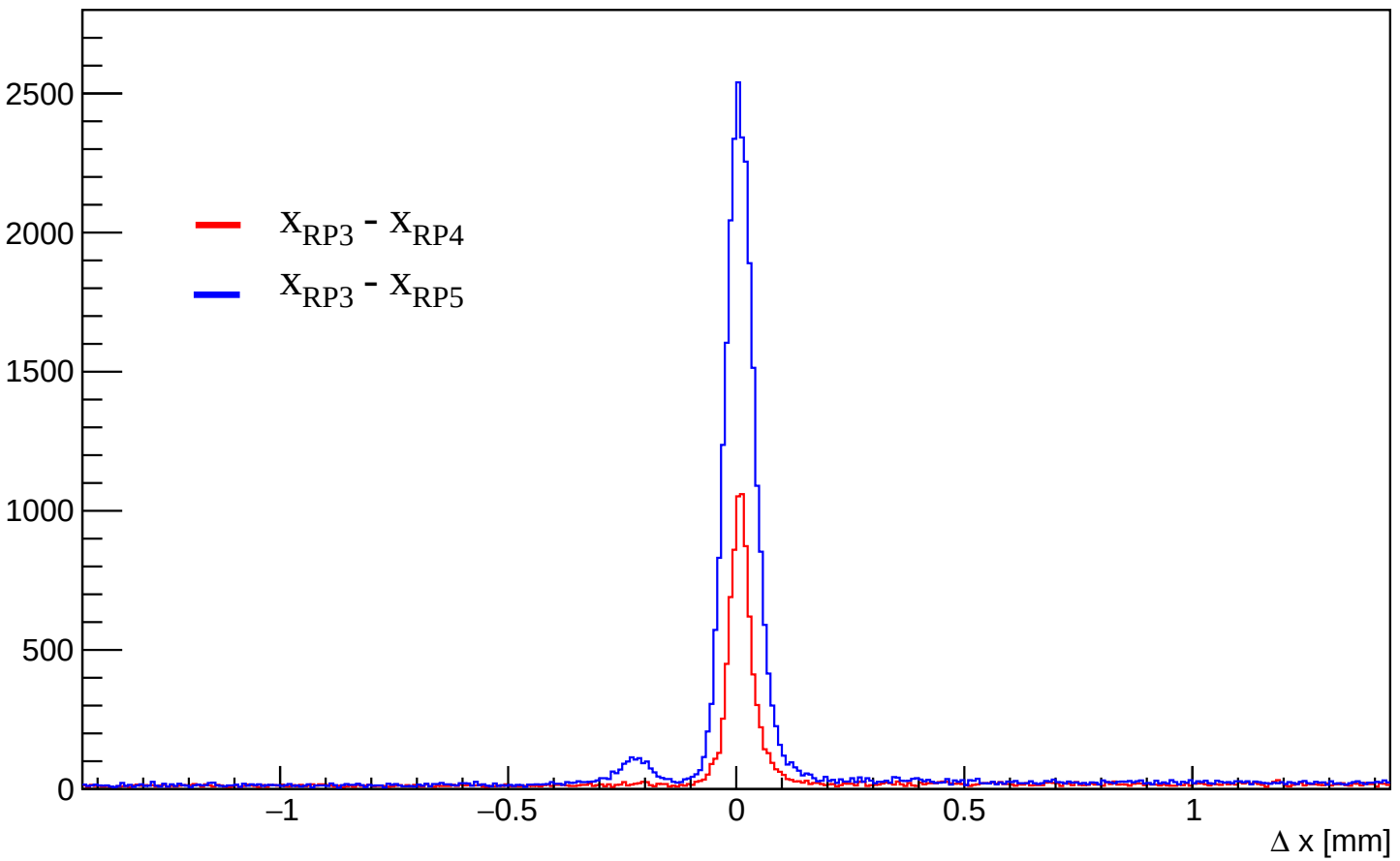
- A bit unexpected (see later with September 130 μrad data)
- Would break dispersion as function of x-angle from 2017



Overlap between RP3, 4 and 5

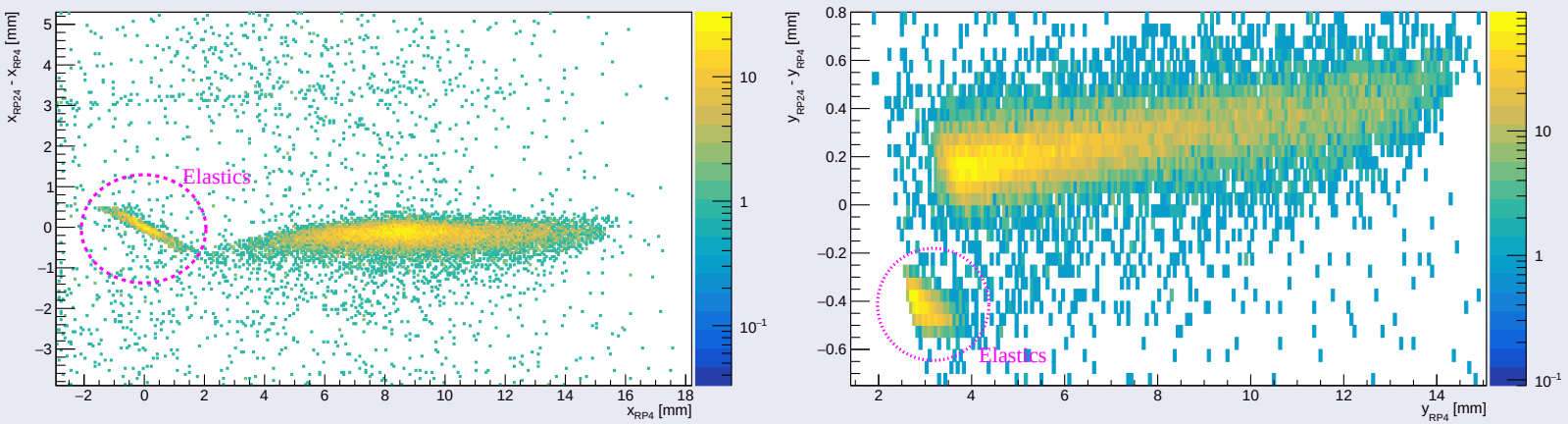


Horizontal alignment test between RP3, 4 and 5



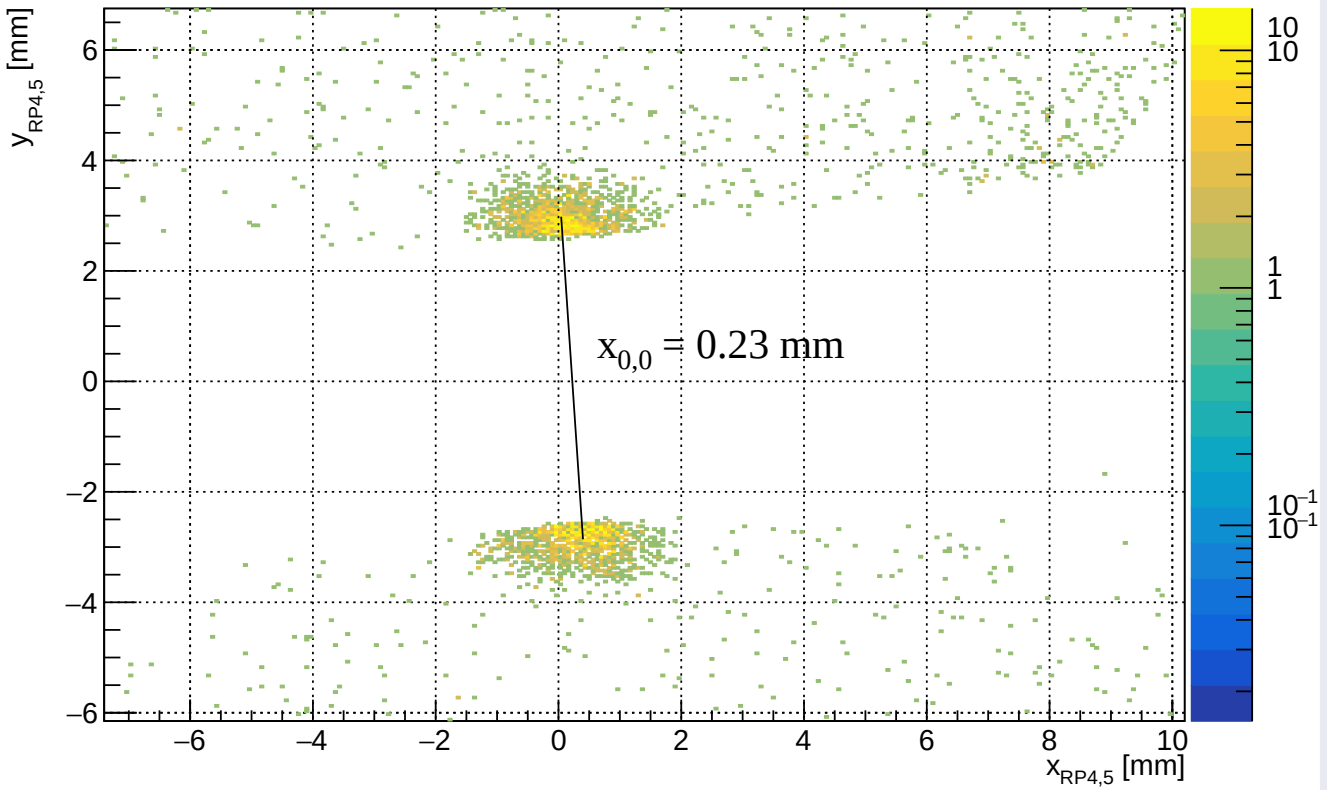
Elastics at 160 μrad: single arm correlations

- RP4 and 24: top verticals
- TOTEM methods to identify elastics
- Note: focusing



Elastics at 160 μrad: test of absolute horizontal alignment

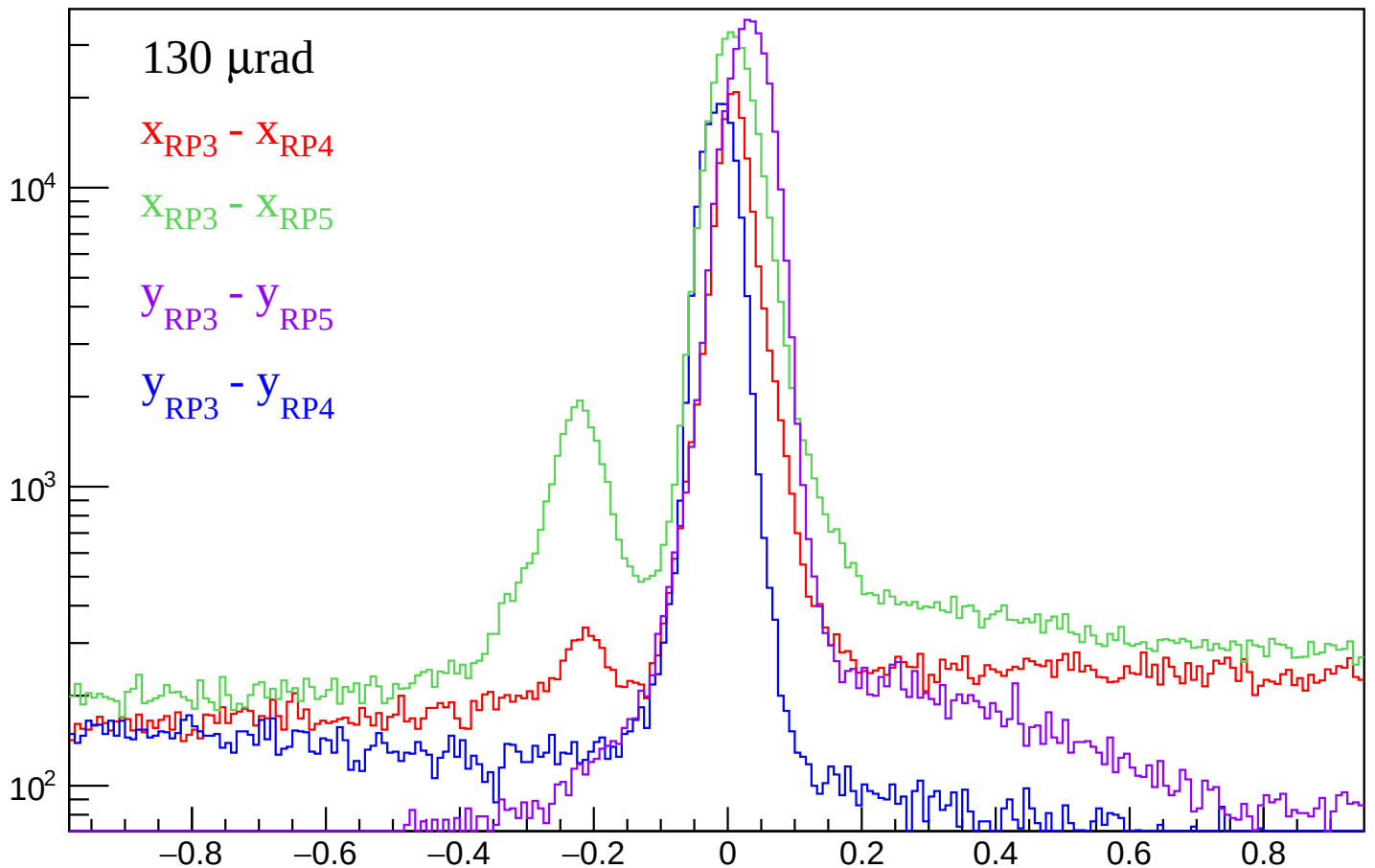
- $x_0 \approx 2.33$ - $0.23 = 2.1$ mm



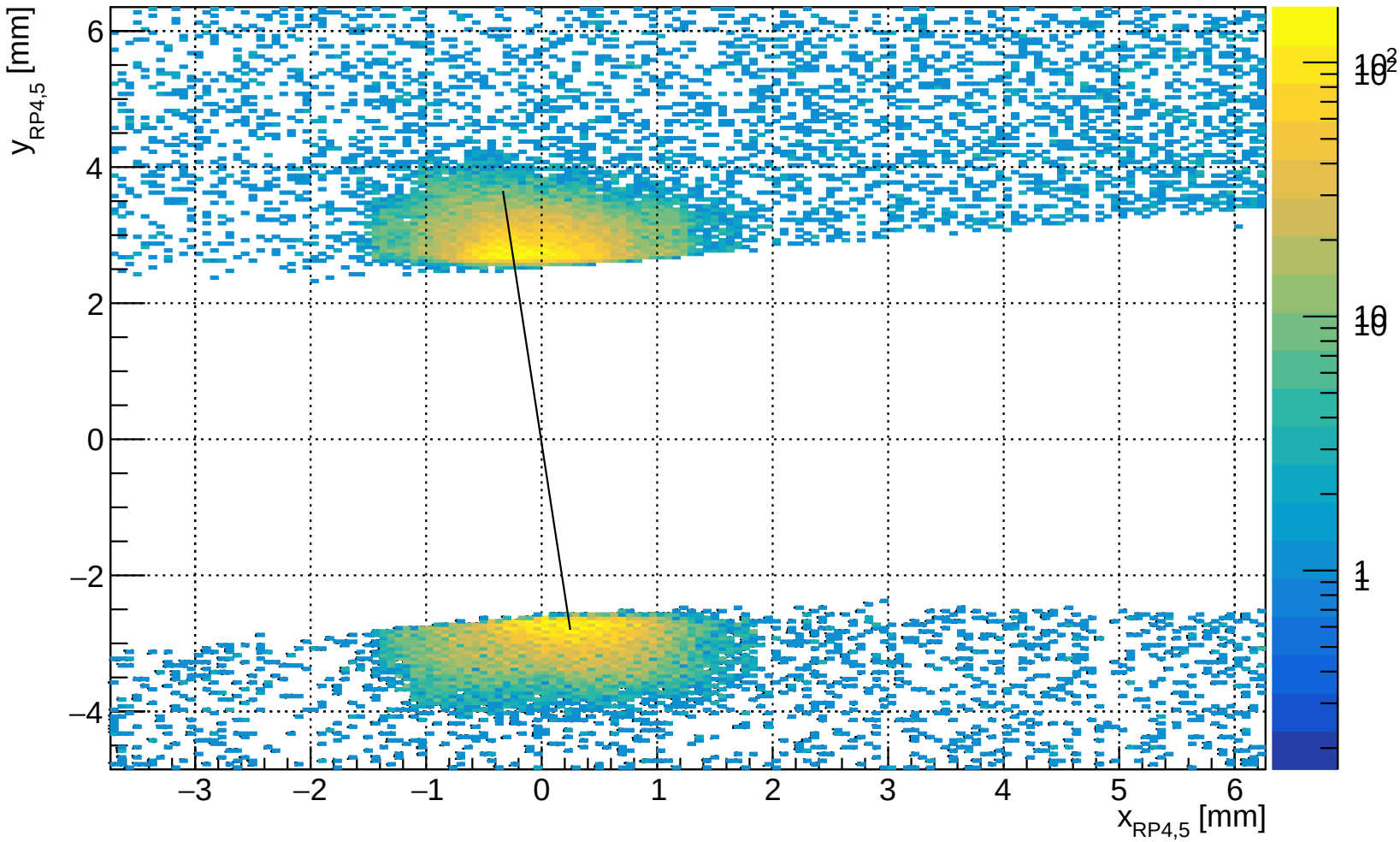
Remaining alignment tests for x-angle 130 μrad

(2018, April)

Overlap between RP3, 4 and 5



Test of "absolute" alignment with elastics

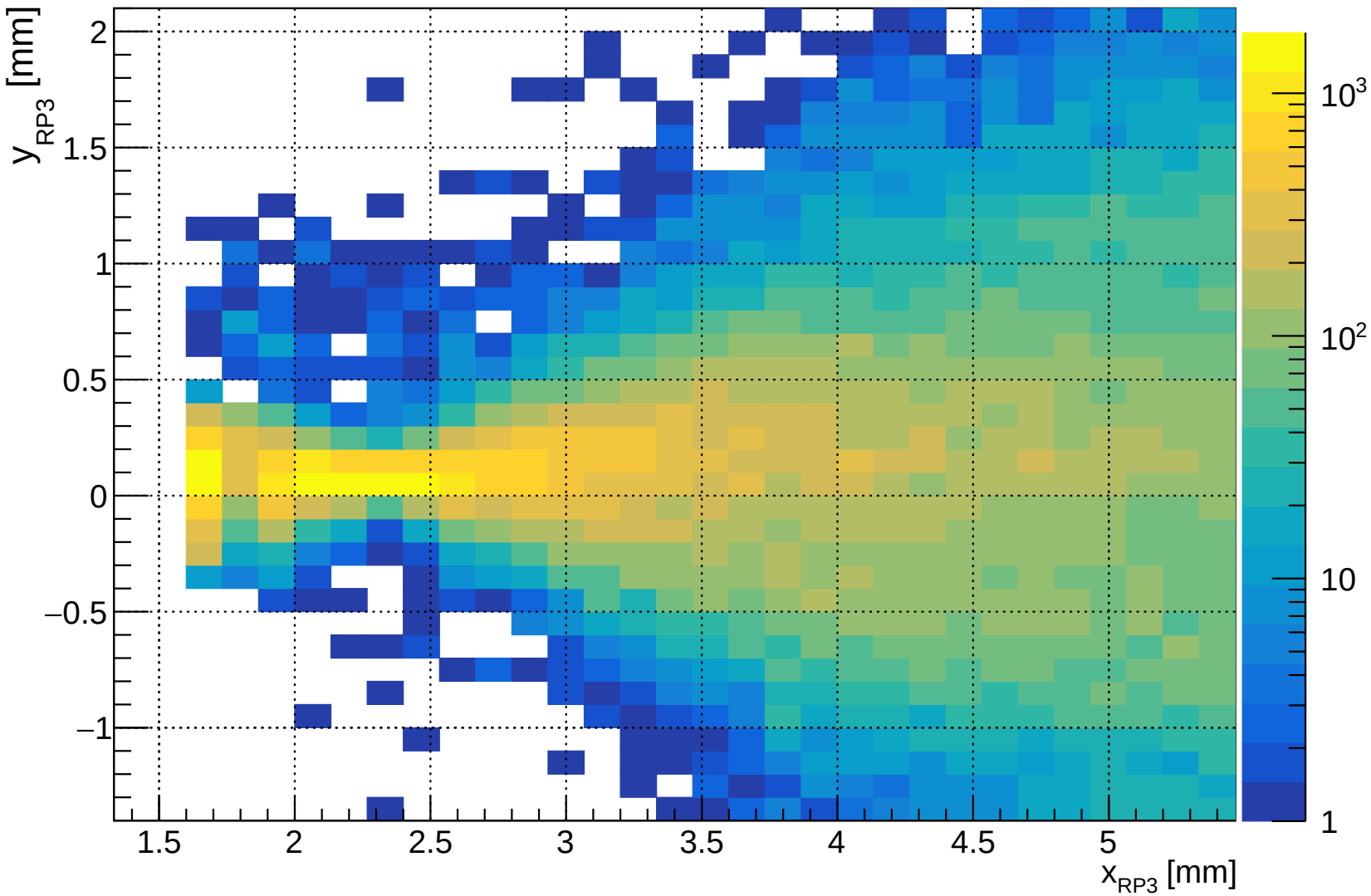


x-angle 130 μrad, $\beta^* = 0.25$ m

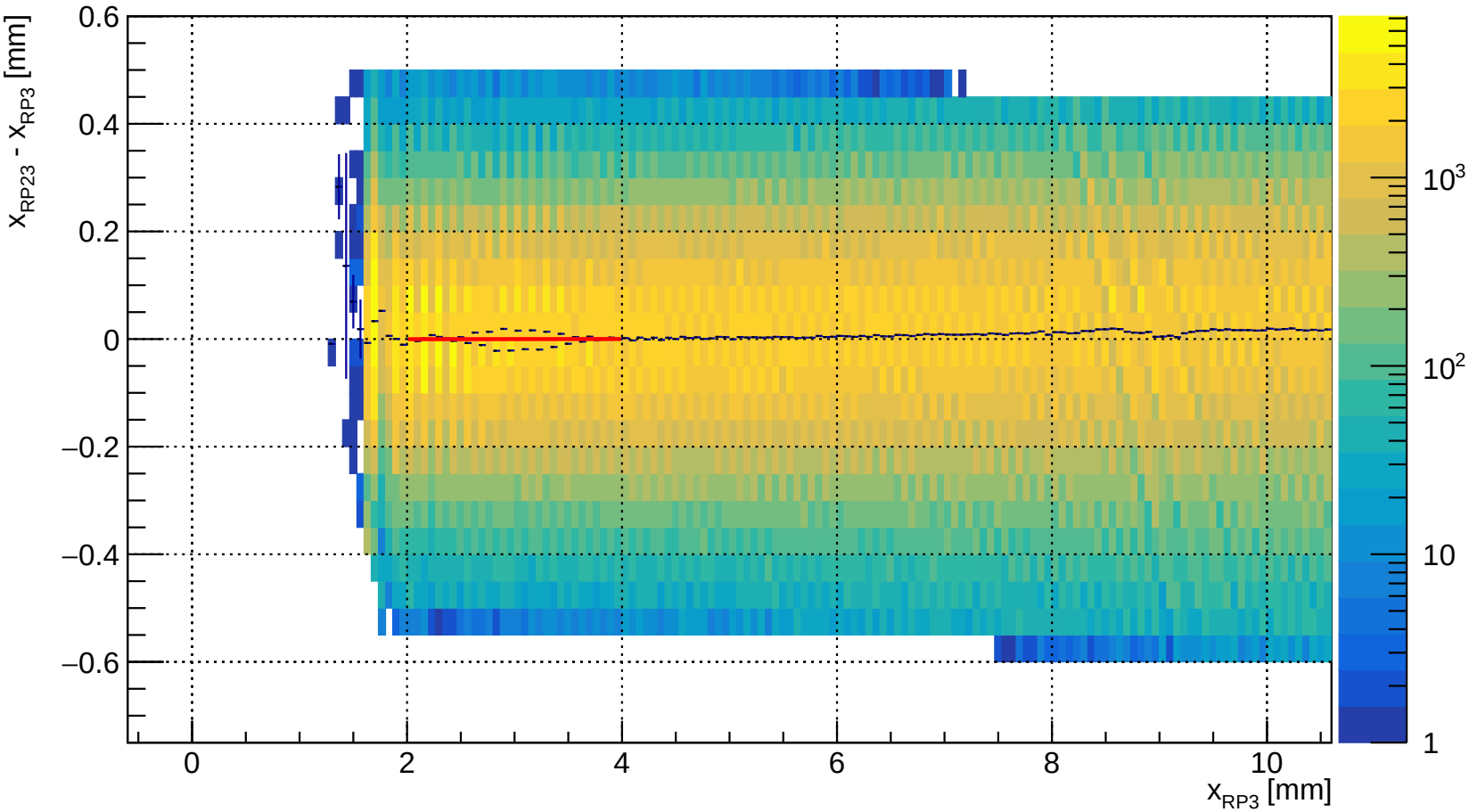
(Run 323316, 2018, September)

The "neck" after cut

- Remains a bit noisy even after cut in the important range
- x_0 clearly below 2.5 mm

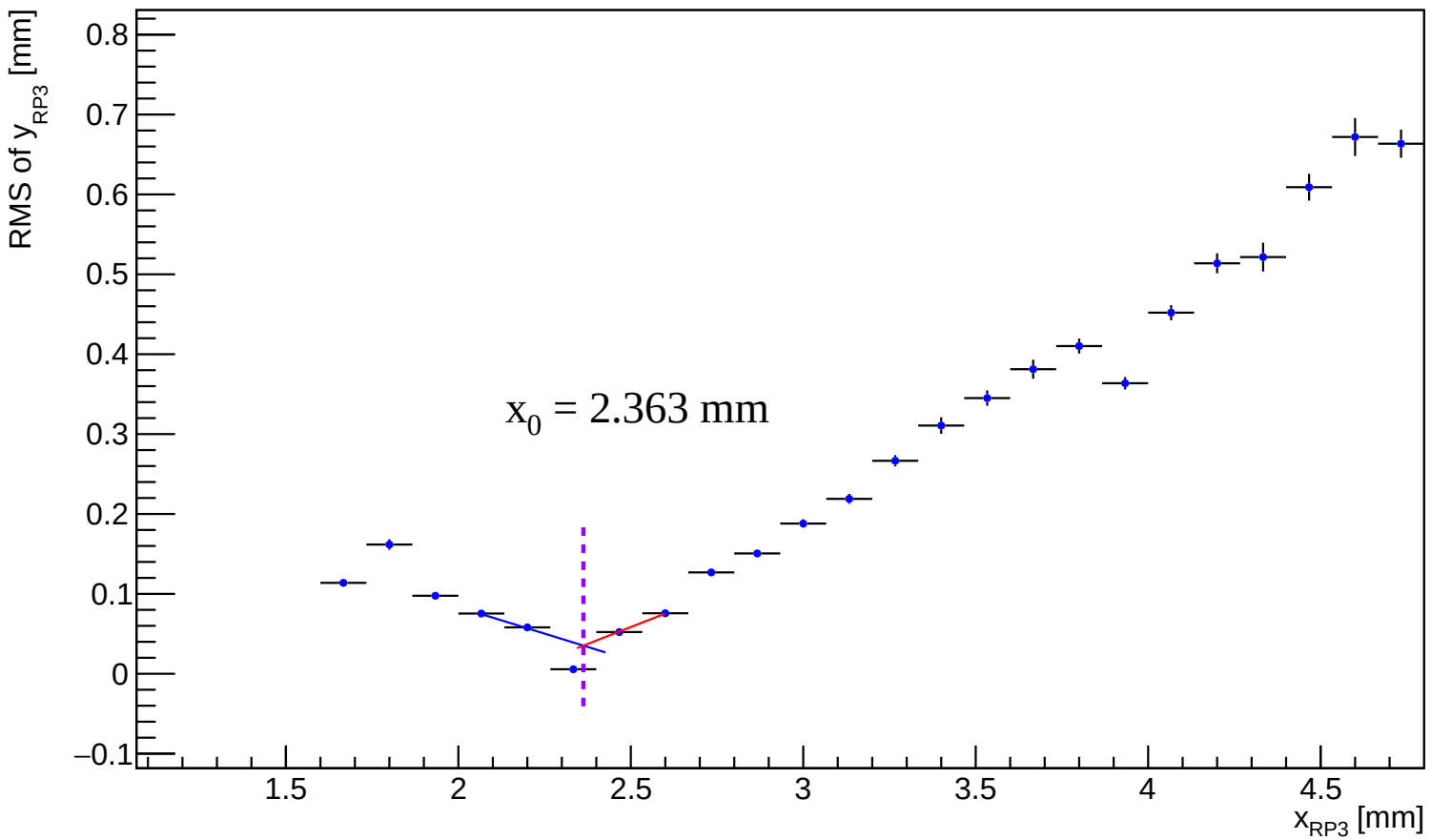


The dx cut



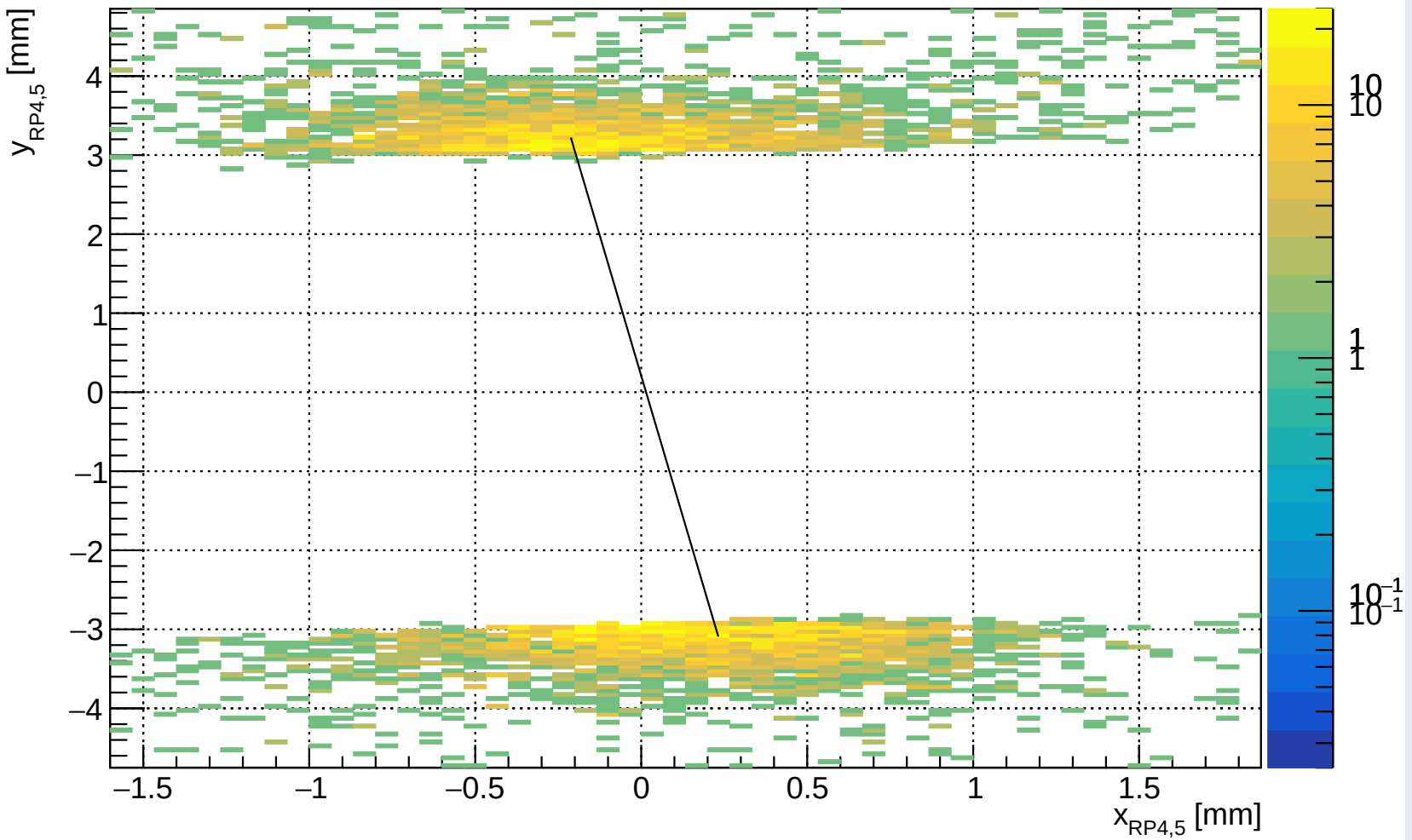
The x_0 point

- x_0 seems to be 7 % lower than in April
- Alignment, optics, resolution, x-angle ?



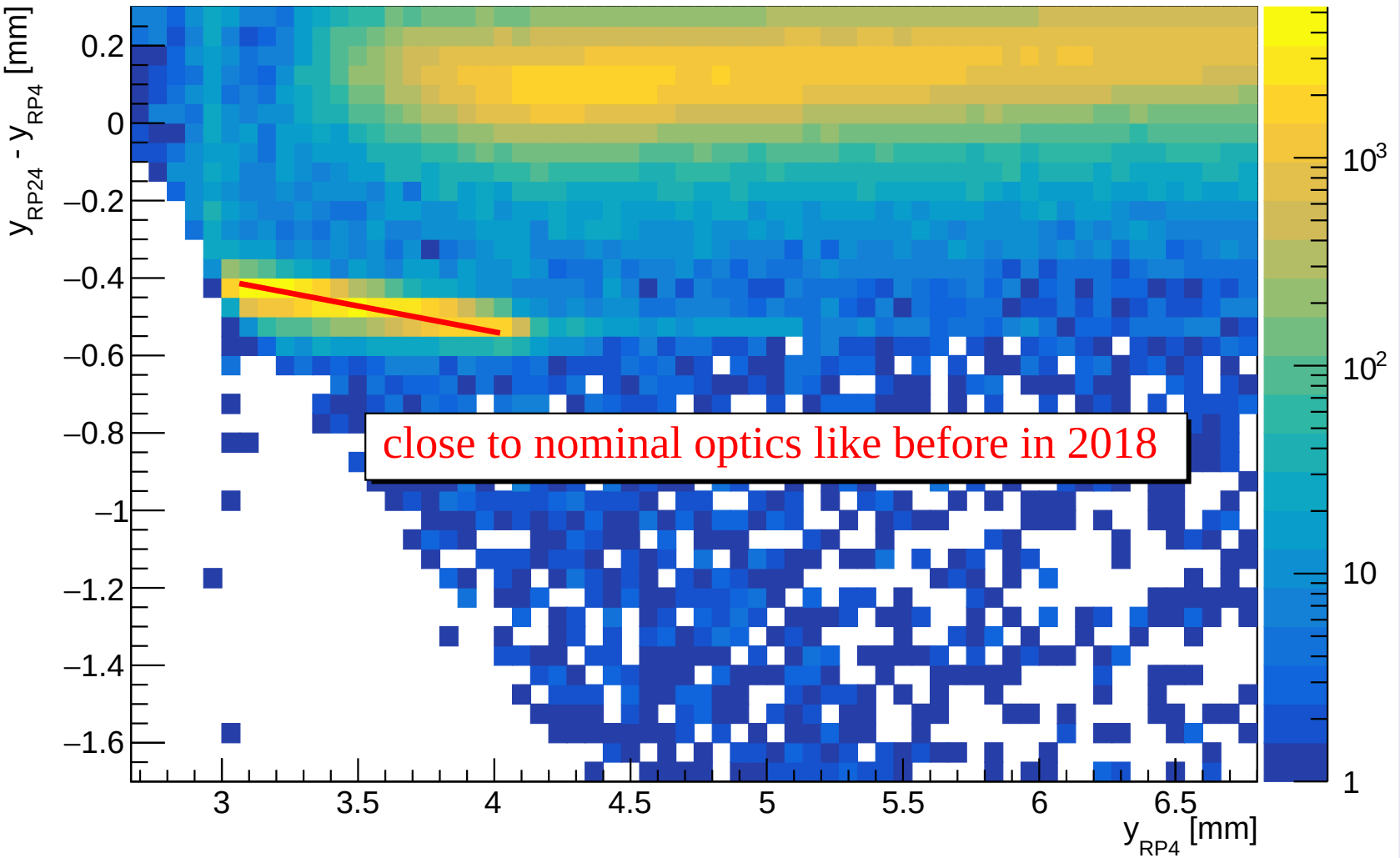
The absolute alignment

- Ok, even with TProfiles
- Common in events in RP 3, 4, 5 are also Ok



The vertical effective length L_y

- Ok

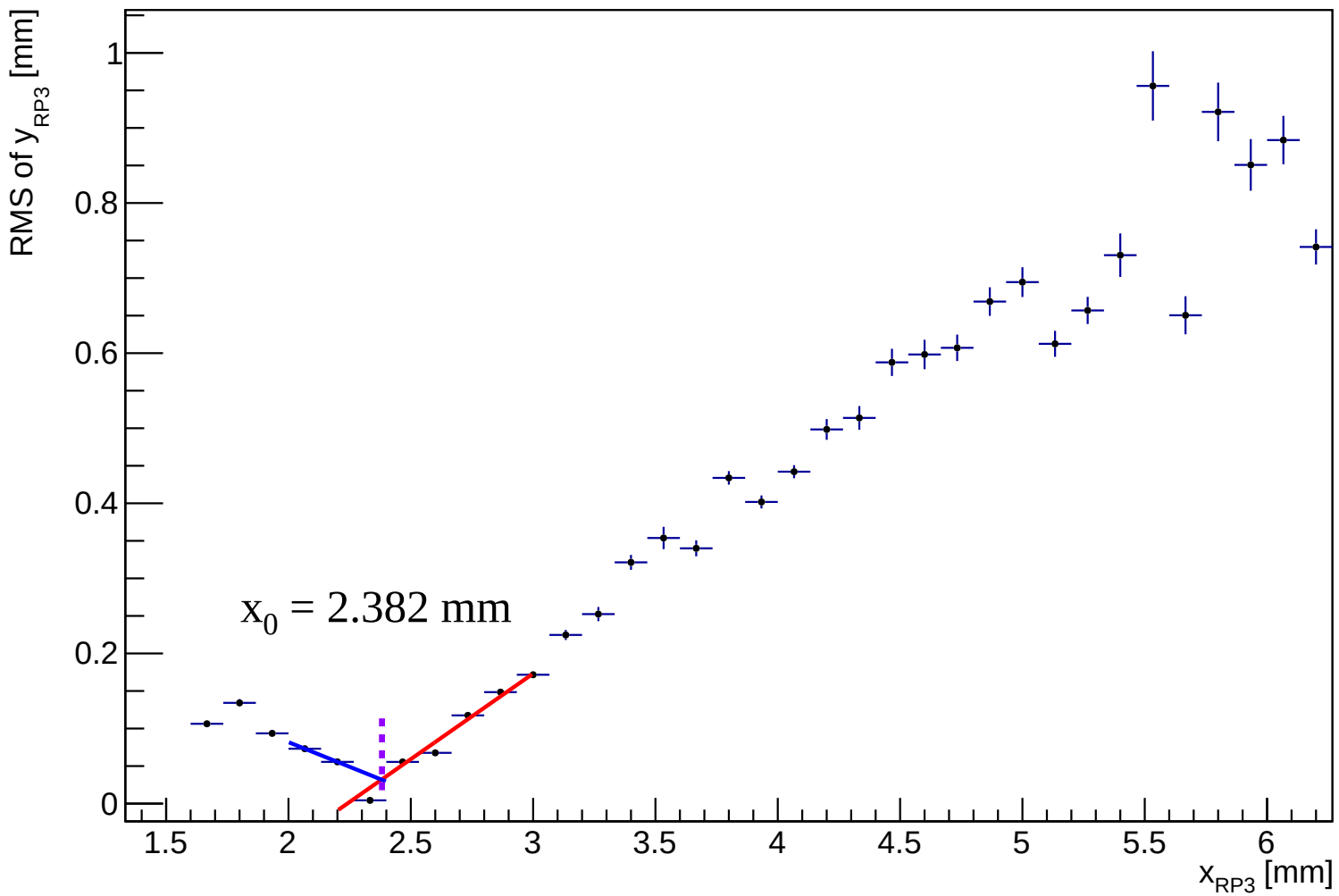


x-angle 130 μrad, $\beta^* = 0.27$ m

(Run 323311, 2018, September)

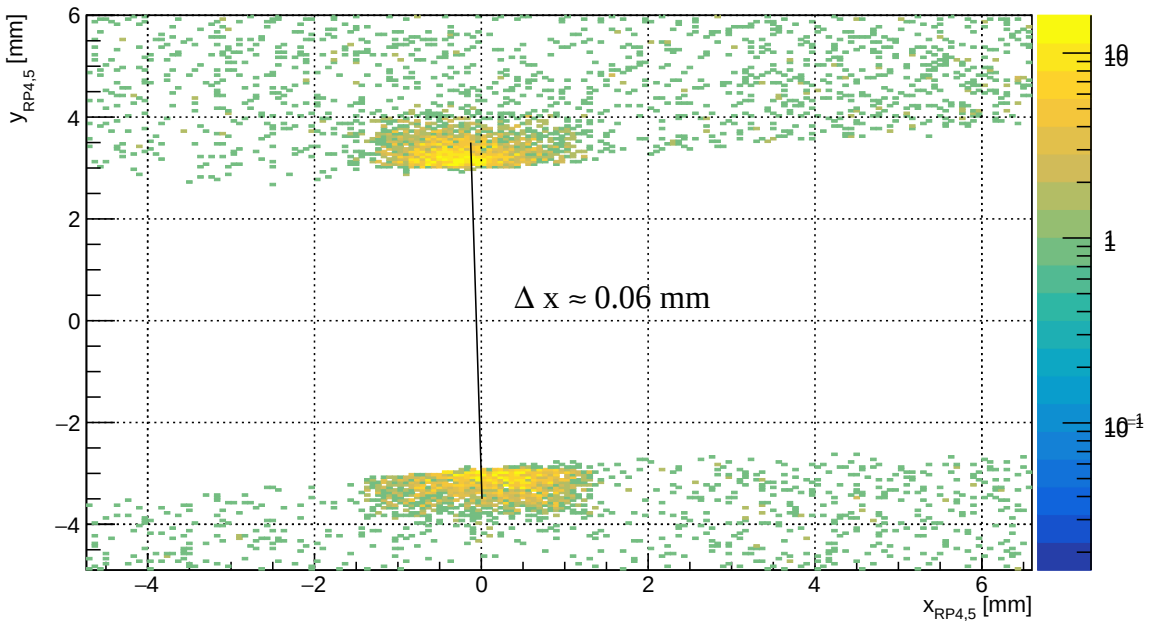
The x_0 point

- Ok



Absolute alignment and the x_0 point

- $x_0 \approx 2.382$ mm + 0.06 mm$= 2.442$ mm



Summary of April and September

- 130 μrad: $x_0 \approx 2.445$ mm $\pm$ 0.08
- 160 μrad: $x_0 \approx 2.10$ mm

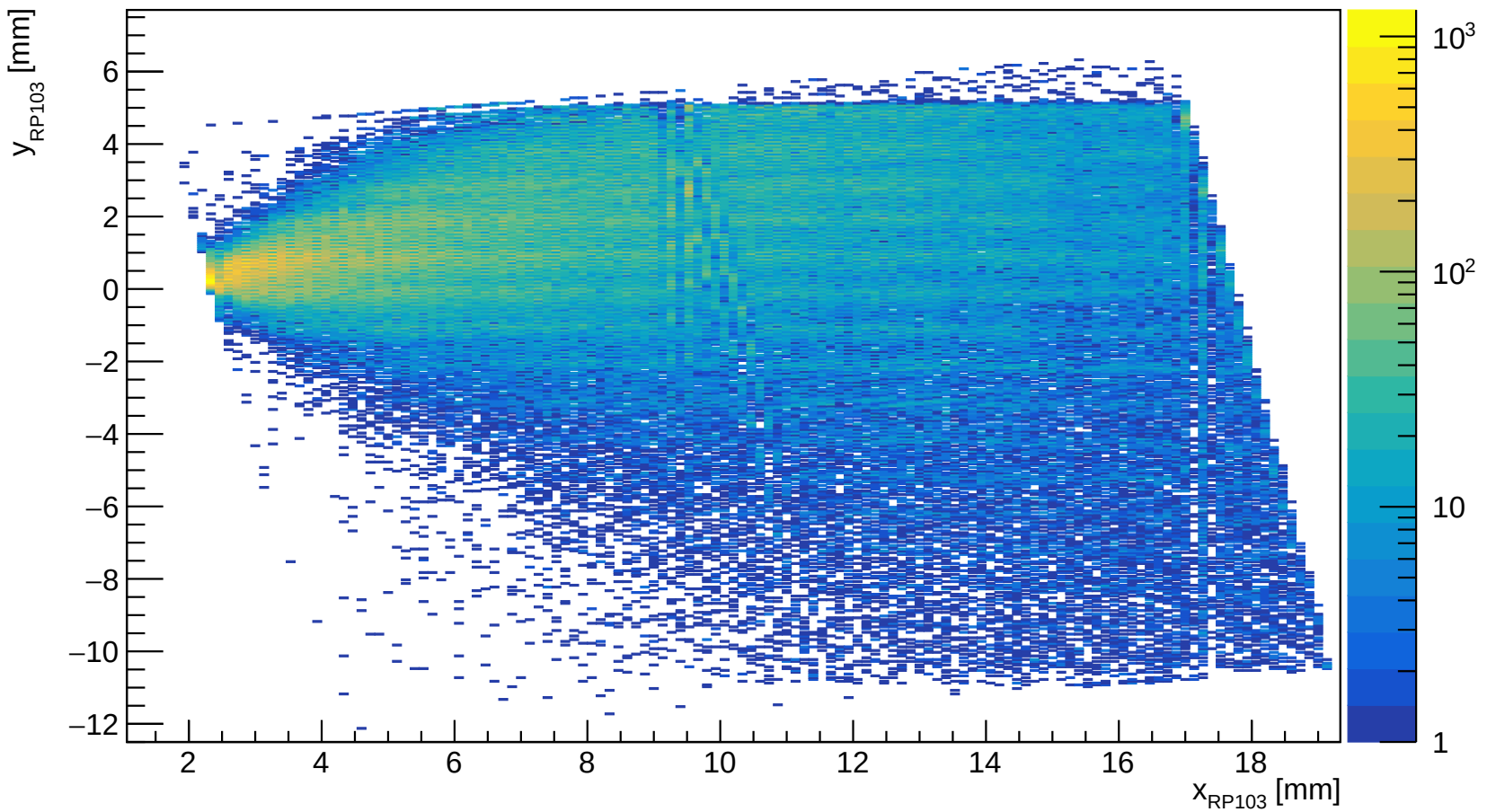
Right arm

x-angle 130 μrad, $\beta^* = 0.25$ m

(Run 314276, 2018, April)

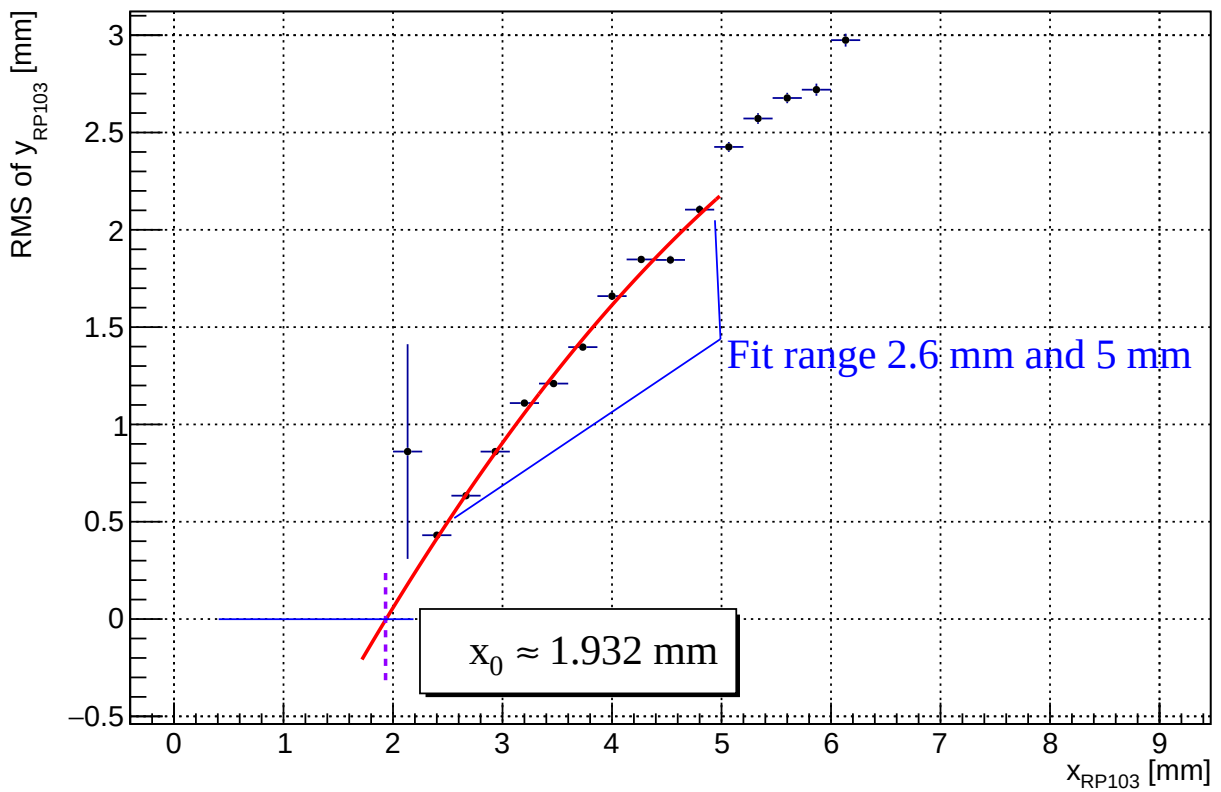
The x_0 point in RP103

- Calibration point is not visible
- 2017 data suggest a factor 1.298 between left and right arm
- x_0 "should" be around 1.883 ± 0.08



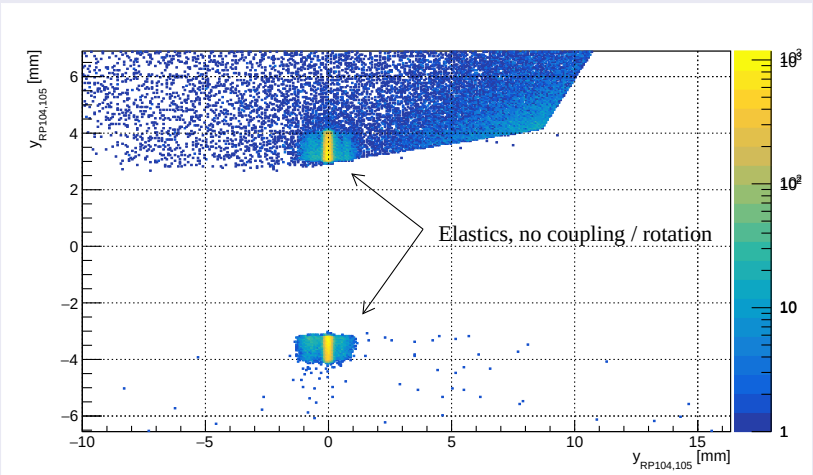
The x_0 point in RP103

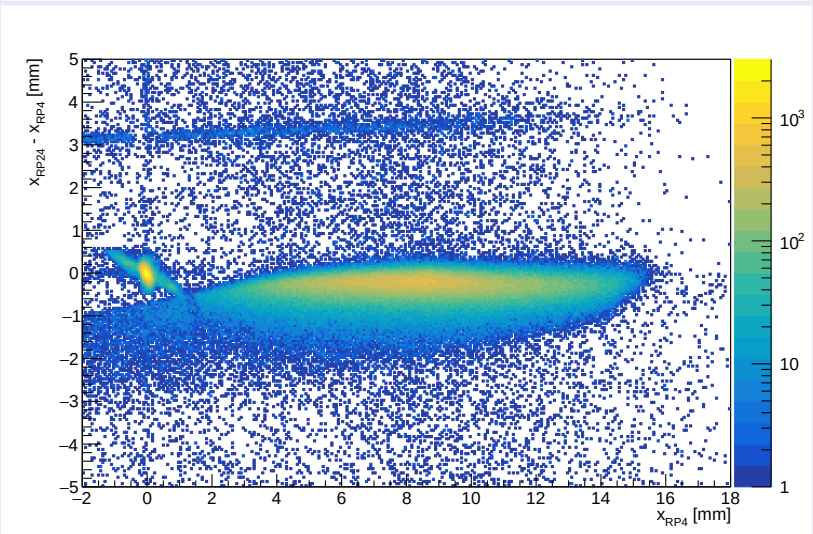
- Parabolic fit
- First points not used, fit quality very low
- Extrapolation point is OK
- Dimuon data will help (also for left arm!)



A curiosity in the right arm from September

- Reason: $L_x = 0$ close to RP
- No coupling (MQSX off)
- Good for optics checks!



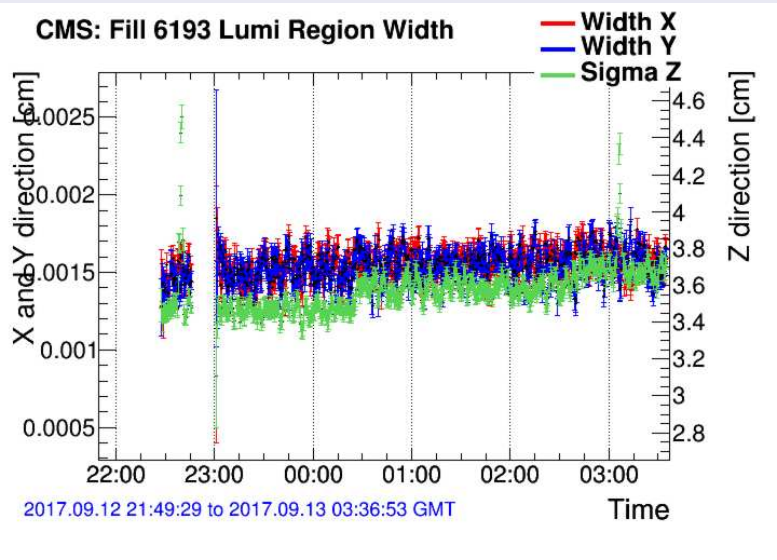


Notes on beam divergence

Based on emittance and beam spot

Beam divergence study from CT-PPS Physics meeting

- Lorentz $\gamma_{\text{proton}} = \frac{E_{\text{beam}}}{M_{\text{proton}}} = \frac{6500\ \text{GeV}}{0.93827\ \text{GeV}}$
- $\sigma^*_{x,y} = \sqrt{\frac{\beta^*_{x,y} \cdot \epsilon}{\gamma_{\text{proton}}}} = \sqrt{\frac{0.4 \cdot 3.5 \cdot 10^{-6}}{\gamma_{\text{proton}}}} = 14\ \mu\text{m}$ (ϵ stands for the emittance)
- The figure shows the physics run closest to the alignment run (from Jonathan)
- Excellent agreement between data and model
- Page 6: beam divergence $\sigma(x')^* = \sigma(x)^*/\beta^* = 14\ \mu m/0.4m = 35\ \mu rad$

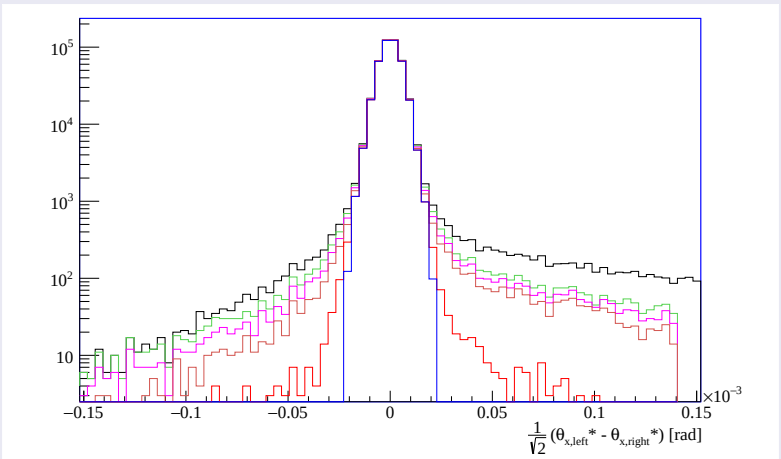


Why $\sigma(x')^* = \sigma(x)^*/\beta^*$?

$$x'' - k(s)x = 0\,, \quad k = \frac{1}{B\cdot\rho}\frac{\mathrm{d}B_y}{\mathrm{d}x}\,. \tag{2}$$

- Beam equation, harmonic oscillator with magnetic strength $k(s)$
- Ansatz: $x(s) = \sqrt{\beta_x(s)\varepsilon}\cos\left[\phi_x(s) + \phi_0\right]$ and $\phi' = \frac{1}{\beta}$
- Its derivative $x(s)'$ is the beam divergence and $x(s)' \propto \sqrt{\frac{\varepsilon}{\beta(s)}}\sin(...)$
- At points $\beta' = 0$, see Wilson's book, the thesis of Hubert or mine
- Phase space ellipse and area: $\pi\sigma(x)\sigma(x') = \pi\epsilon = \textit{constant}$ (Liouville theorem)

The Gaussian shape of $\sigma(x')$ by TOTEM at 13 TeV from CERN preprint:



Summary

- New and reliable method for "neck" position measurement
- Applied for available x-angles: remains close to 2017
- Rigorous test of alignment / optics assumptions
- Beam divergence notes

Note: alignment data with more x-angle combination would be useful. Now we have almost only 130 μrad!