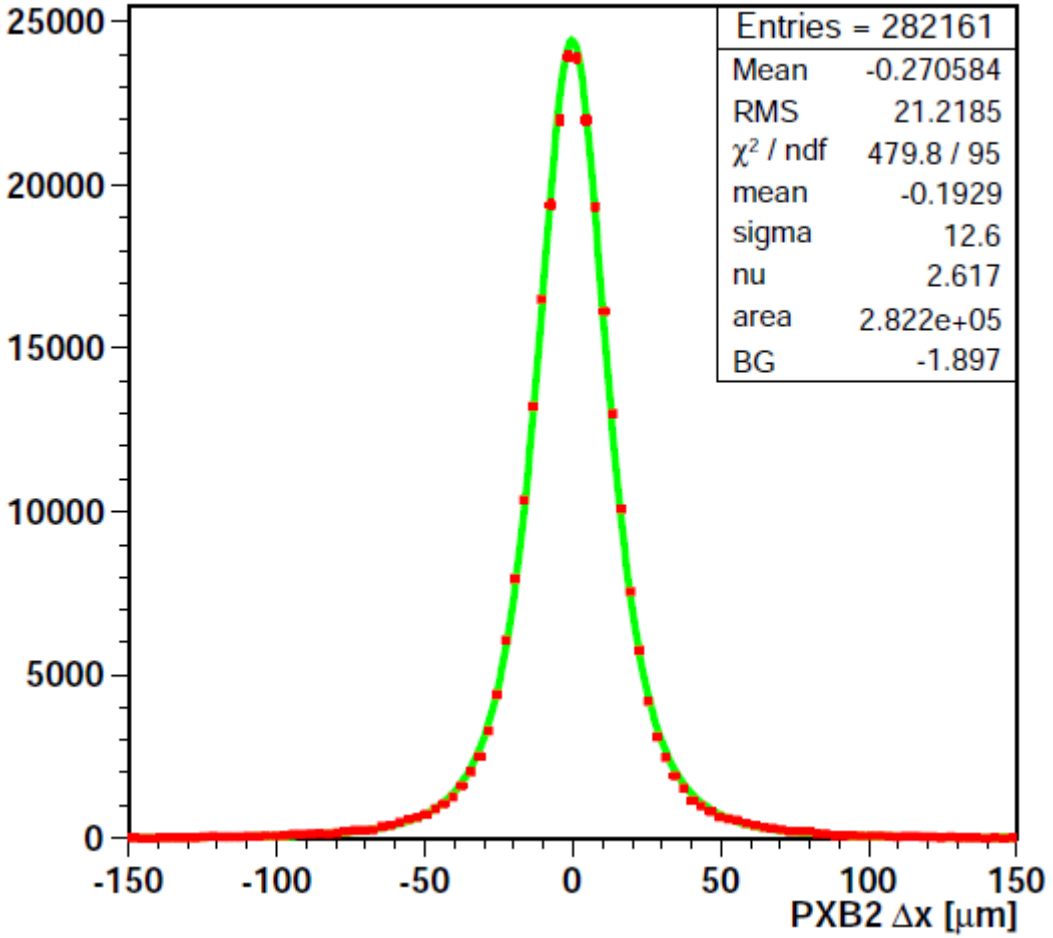
Barrel pixel resolution in 2012

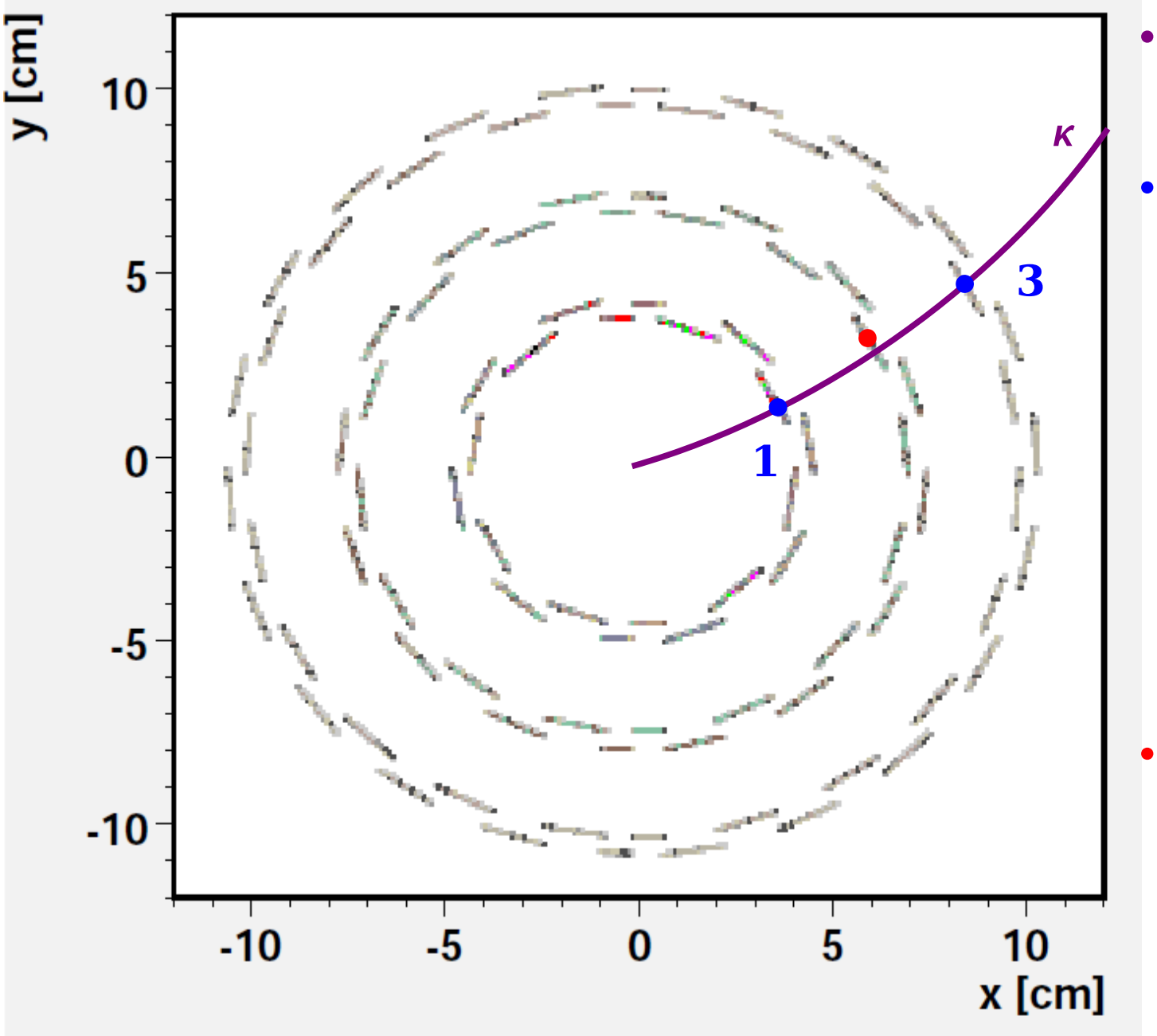
Armin Burgmeier, Daniel Pitzl, DESY

CMS Pixel DPG, 19.4.2012



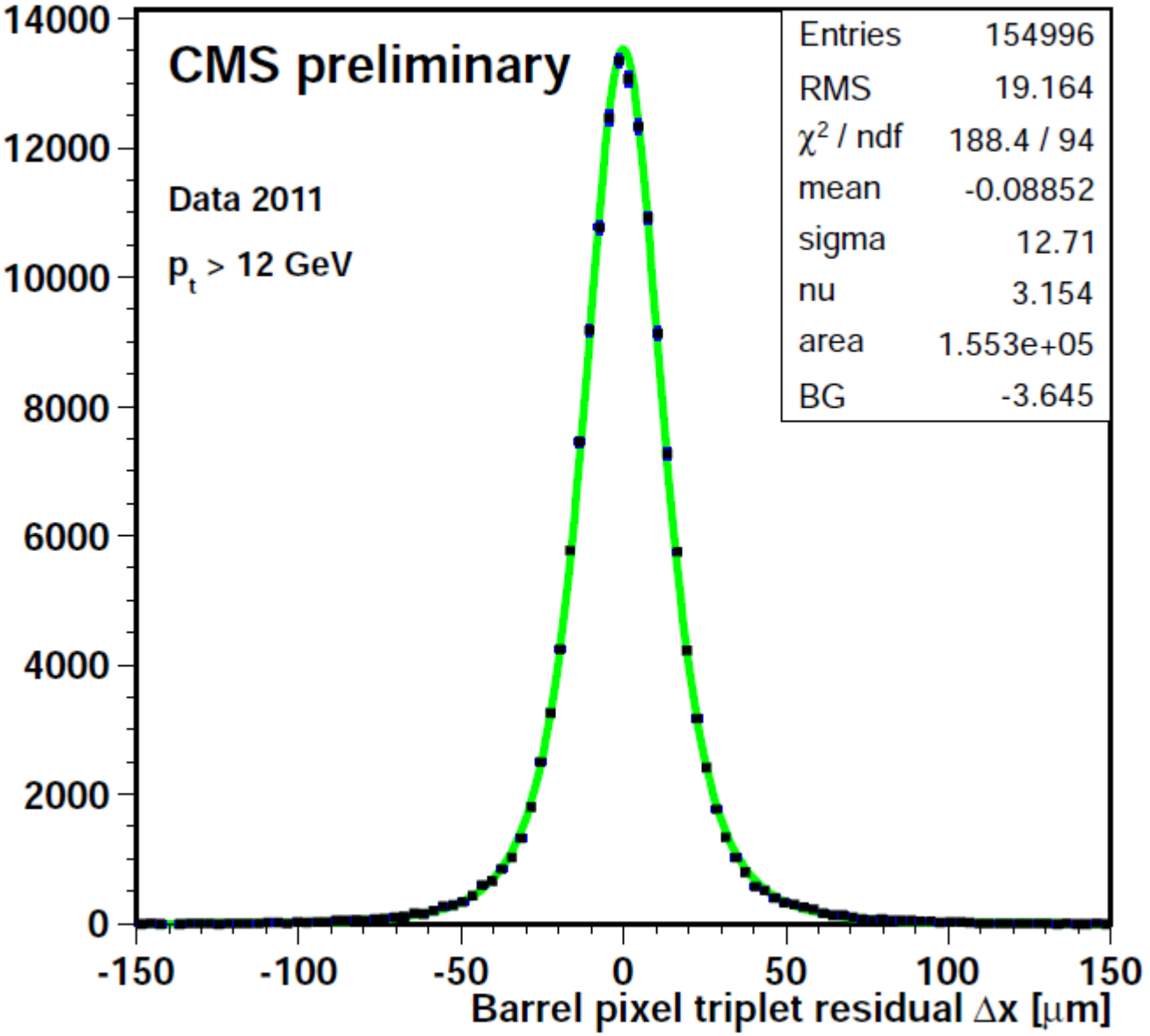
- Triplet method
- Data Apr '12 vs Oct '11
  - residuals
  - resolution profiles

Pixel triplets



- Select tracks with hits in 3 pixel layers.
- Redefine track:
  - curvature κ from full tracker,
  - position and angles from hits 1 and 3.
  - analytic code from J. Gassner 1996 (ETH Zürich, H1).
- Interpolate to middle layer:
  - residual between track and hit.

Barrel pixel triplet *rφ* residuals at high p_t



- Data Mar 2011
- Width of the residual distribution at high p_t:

$$\sigma_r^2 = \sigma_2^2 + (\sigma_1/2)^2 + (\sigma_3/2)^2$$

- All σ equal:

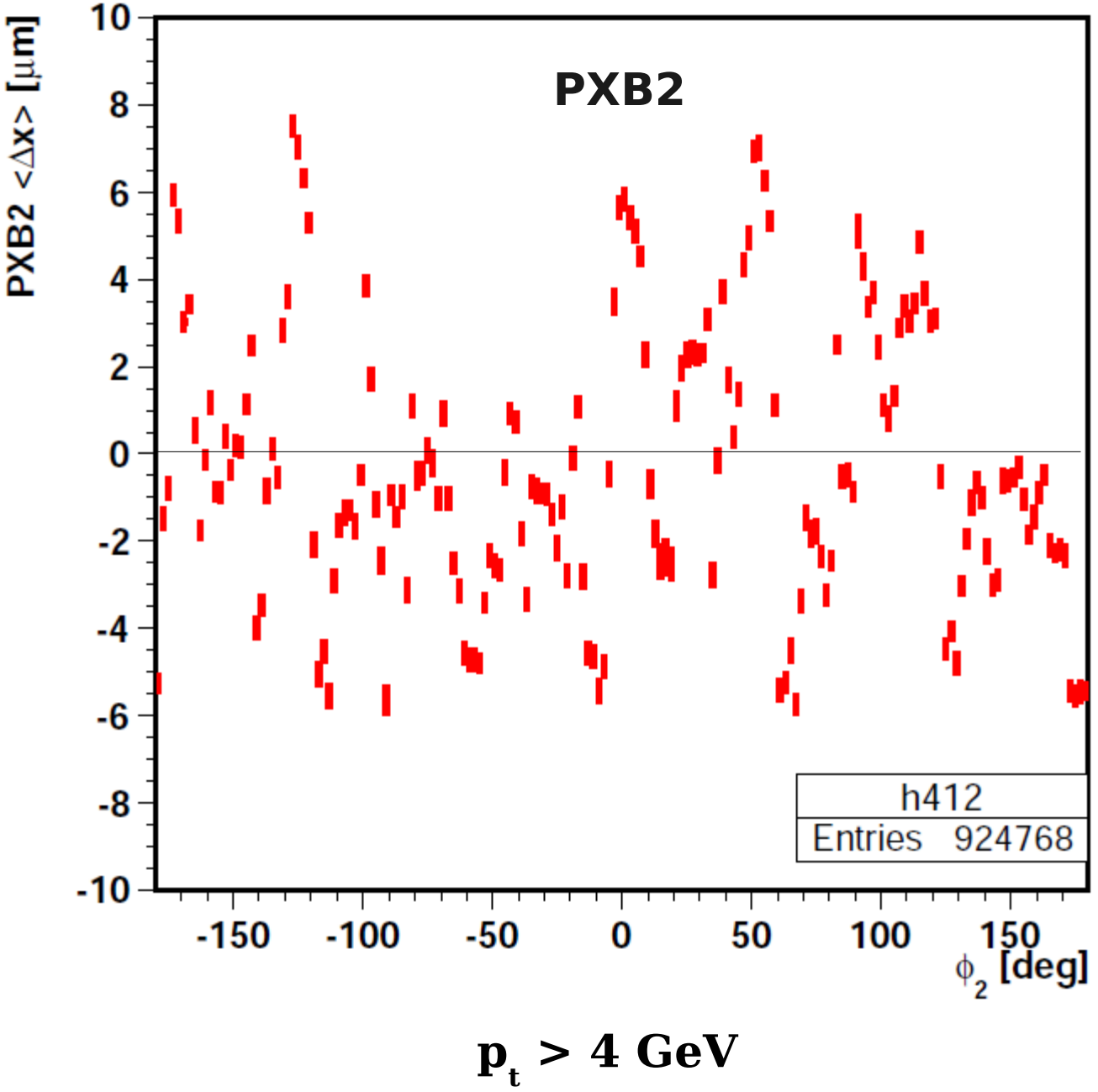
$$\sigma_r = \sqrt{3/2}\,\sigma_i$$

- Result:
  - σ_r = 12.7 μm,
  - σ_i = 10.4 μm.
  - with 100 μm pixel size!

Data

- Apr 2012, run 190678
  - promptReco_v1
  - CMSSW_5_2_3
  - Global tag GR_P_V35::All,
  - Jet sample.
- Oct 22, 2011, run 179452 (fill 2240)
  - Nov19 reReco
  - CMSSW_4_4_2
  - Fixed global tag FT_R_44_V11::ALL
  - singleMu sample.
- Using
  - GeneralTracks, TransientTracks and TransientRecHits
  - tracks are re-fit

Alignment check vs φ in PXB2



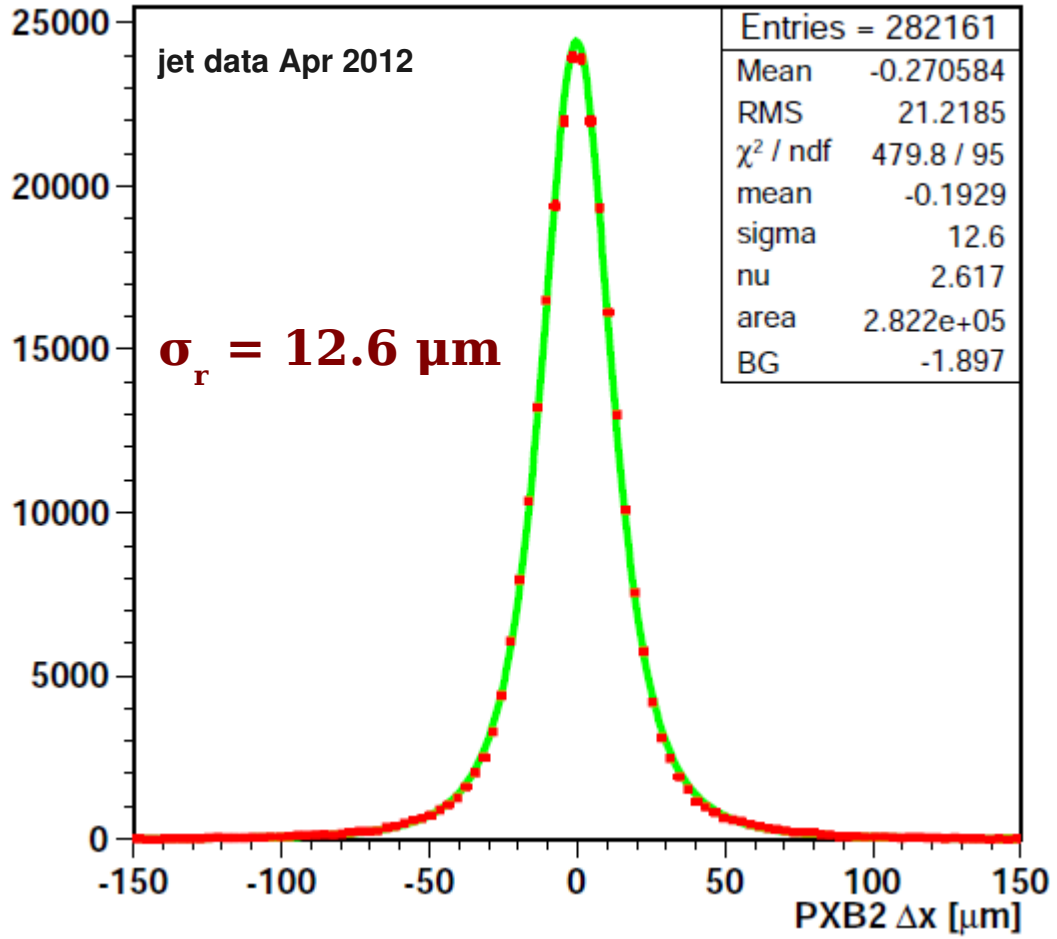
$p_t > 4$ GeV

- Barrel pixel mean triplet residuals: should be zero.
- Apr 2012 data
- Shifts of up to ±6 μm, indication of 30-fold ladder pattern?
- Can the alignment be improved?

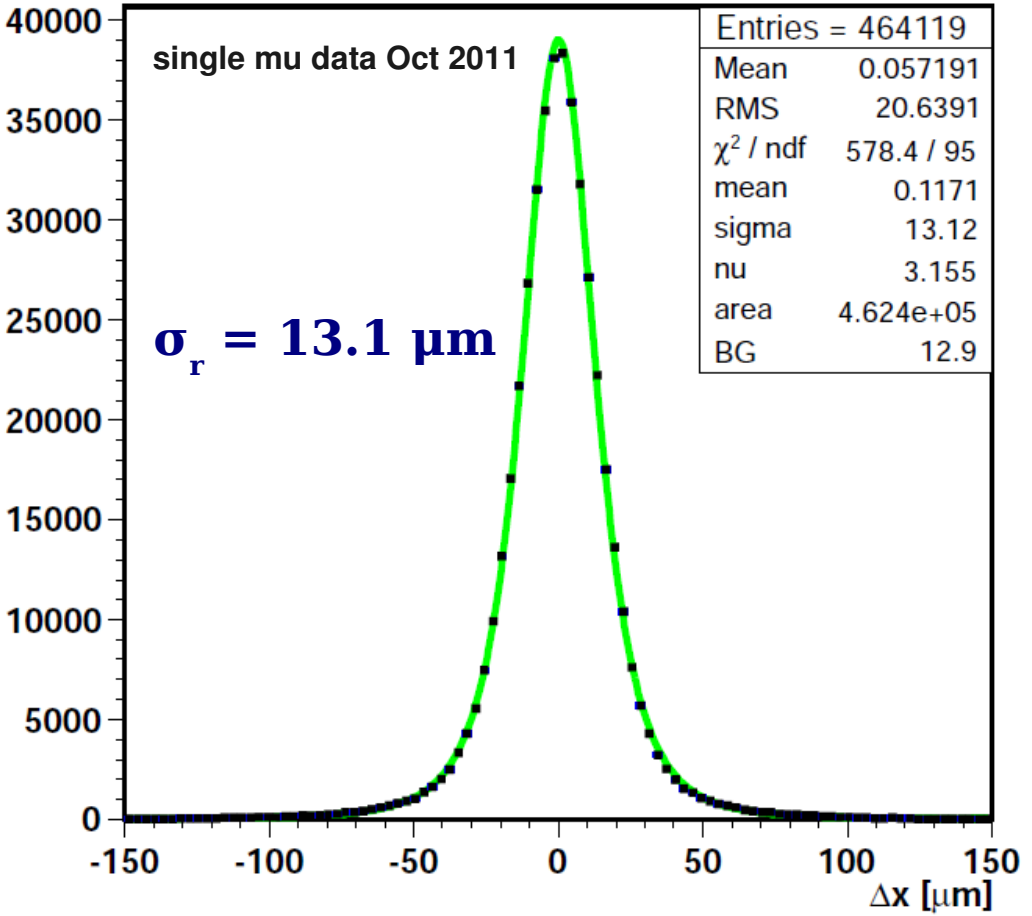
Barrel pixel layer 2 $r\varphi$ resolution

track p_t > 12 GeV

Apr 2012 Jet data

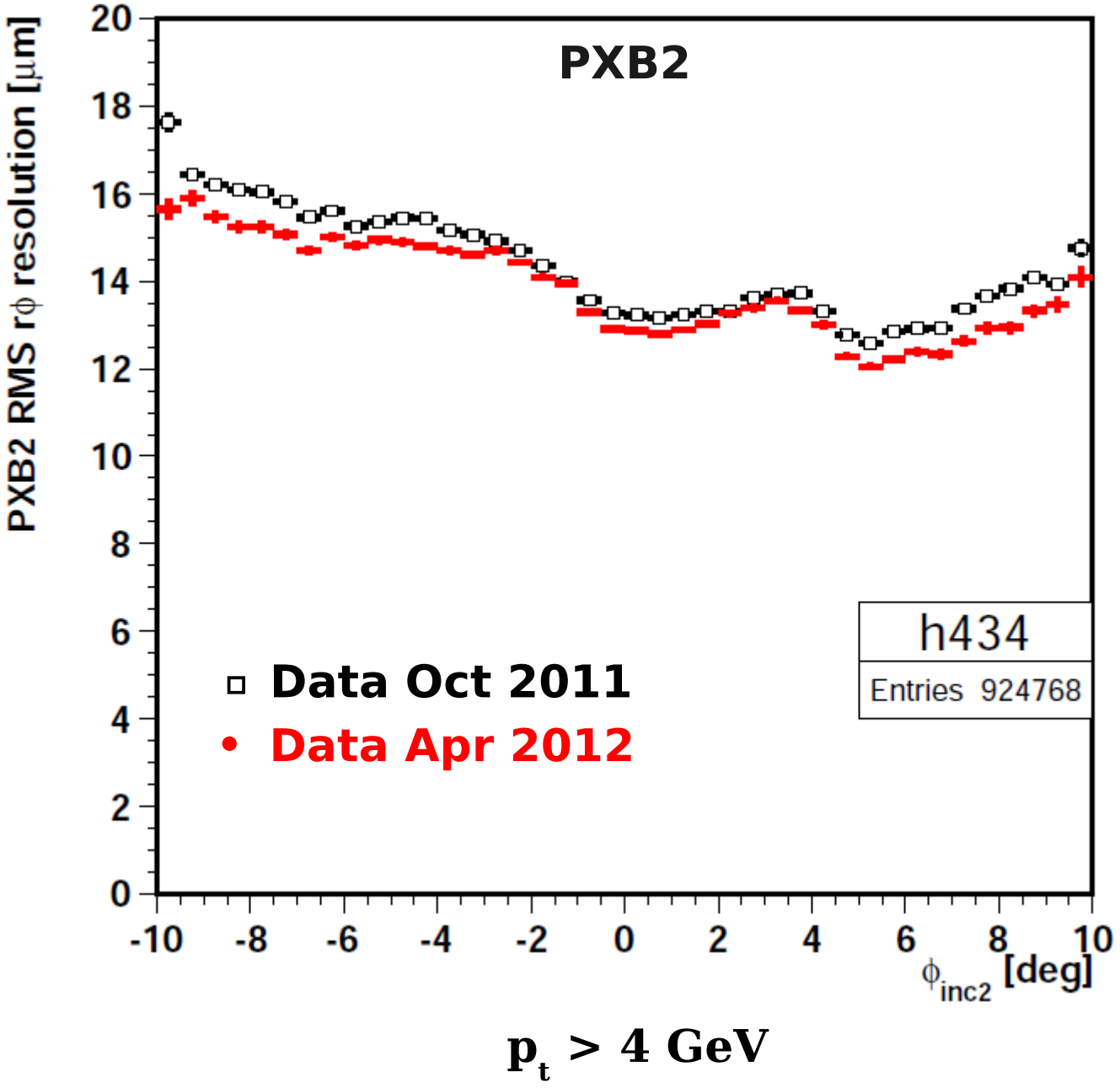


Oct 2011 singleMu data



intrinsic resolution $\sigma_i = \sigma_r / \sqrt{(3/2)} = 10.3$ µm

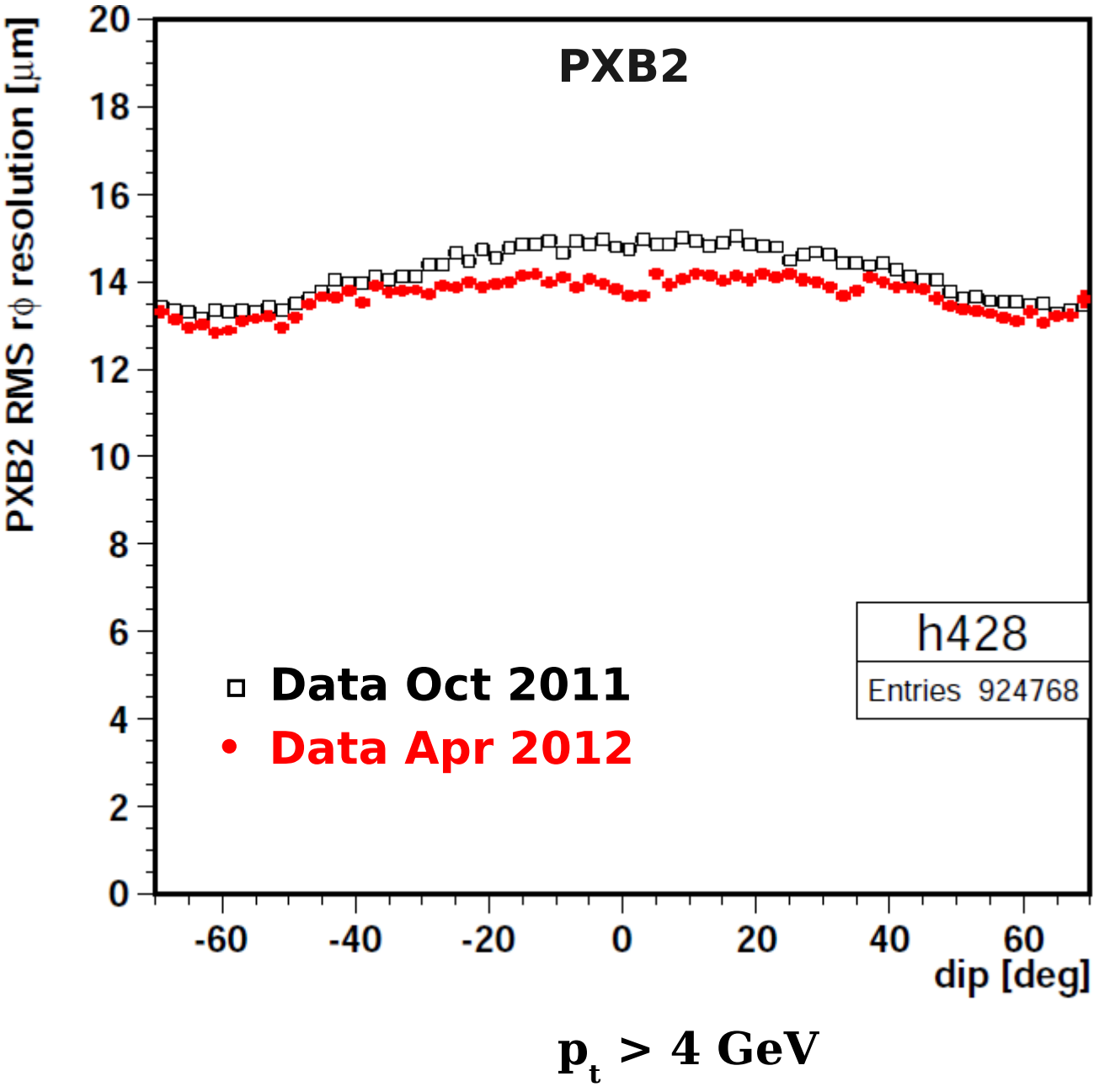
PXB2 *rφ* resolution vs incident angle



p_t > 4 GeV

- Track angle of incidence with module normal vector in *rφ*.
- Pixel barrel layer 2 has 30 (full) modules:
  - each covers ±6° in azimuth,
  - larger angles due pixel offset to beam.
- Optimal *rφ* resolution reached for incidence between -1° and +7°.
- Apr 2012 resolution is slightly better.

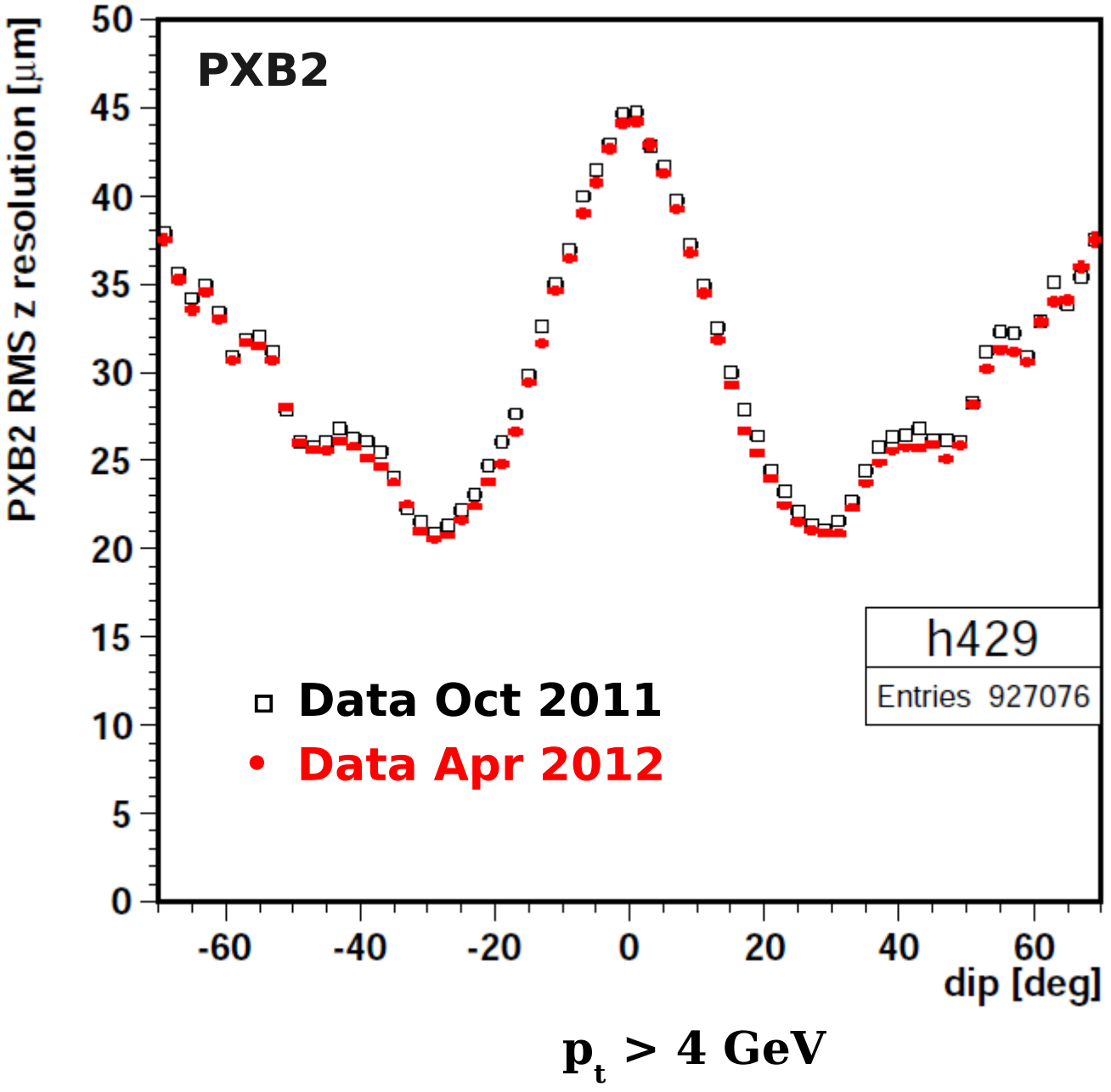
PXB2 $r\varphi$ resolution vs dip angle



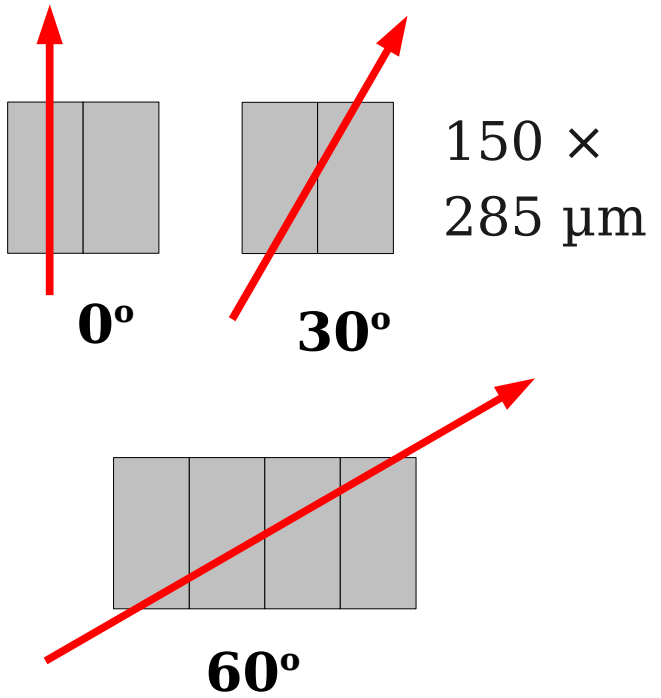
p_t > 4 GeV

- truncated RMS of the residuals
- dip angle $\lambda = \pi/2 - \theta$
- Apr 2012 data slightly better.

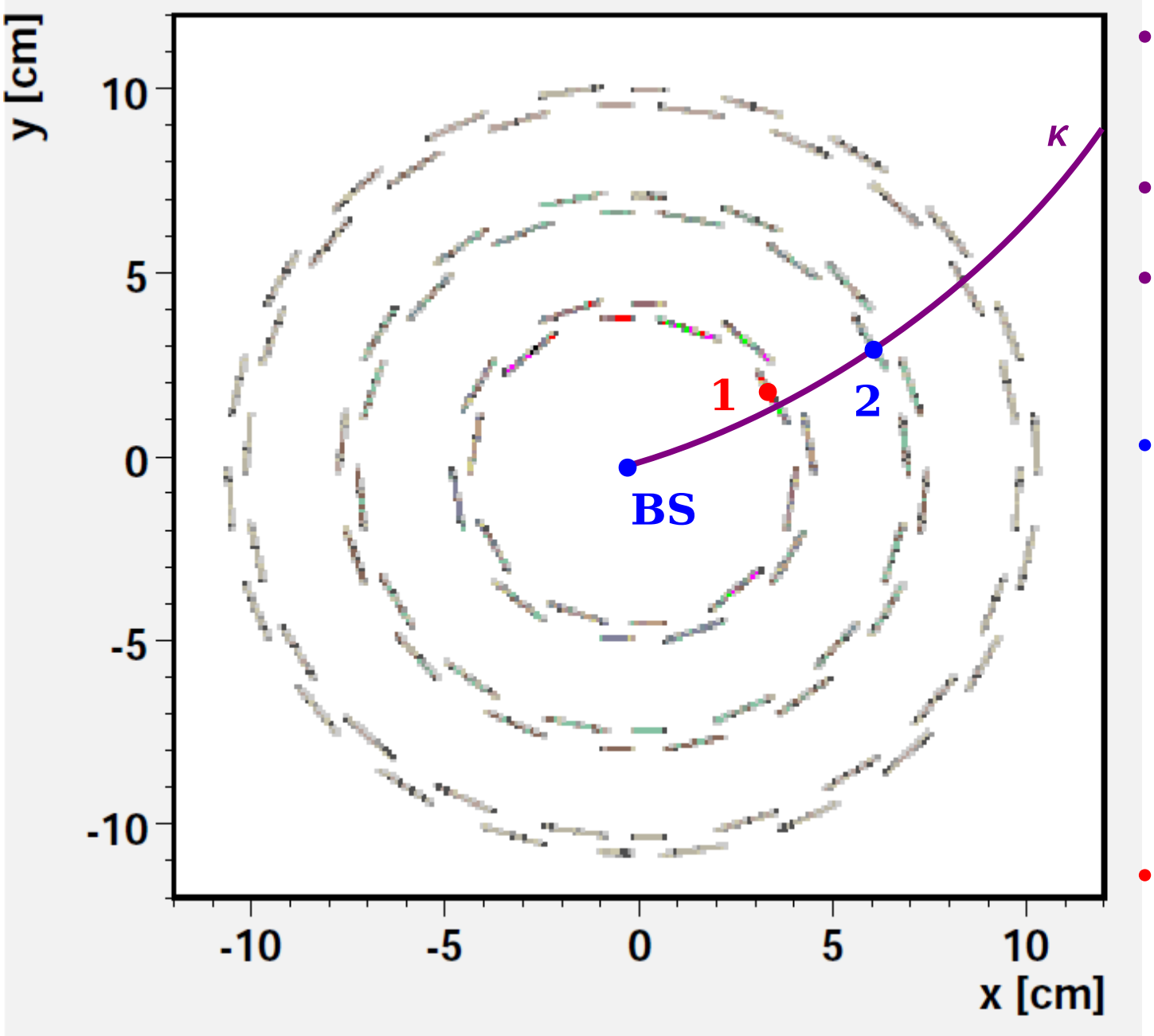
PXB2 z resolution vs dip angle



- optimal resolution at $\lambda = \pm 30^o$:
  - sharing between neighboring pixels
- Apr 2012 resolution is slightly better.

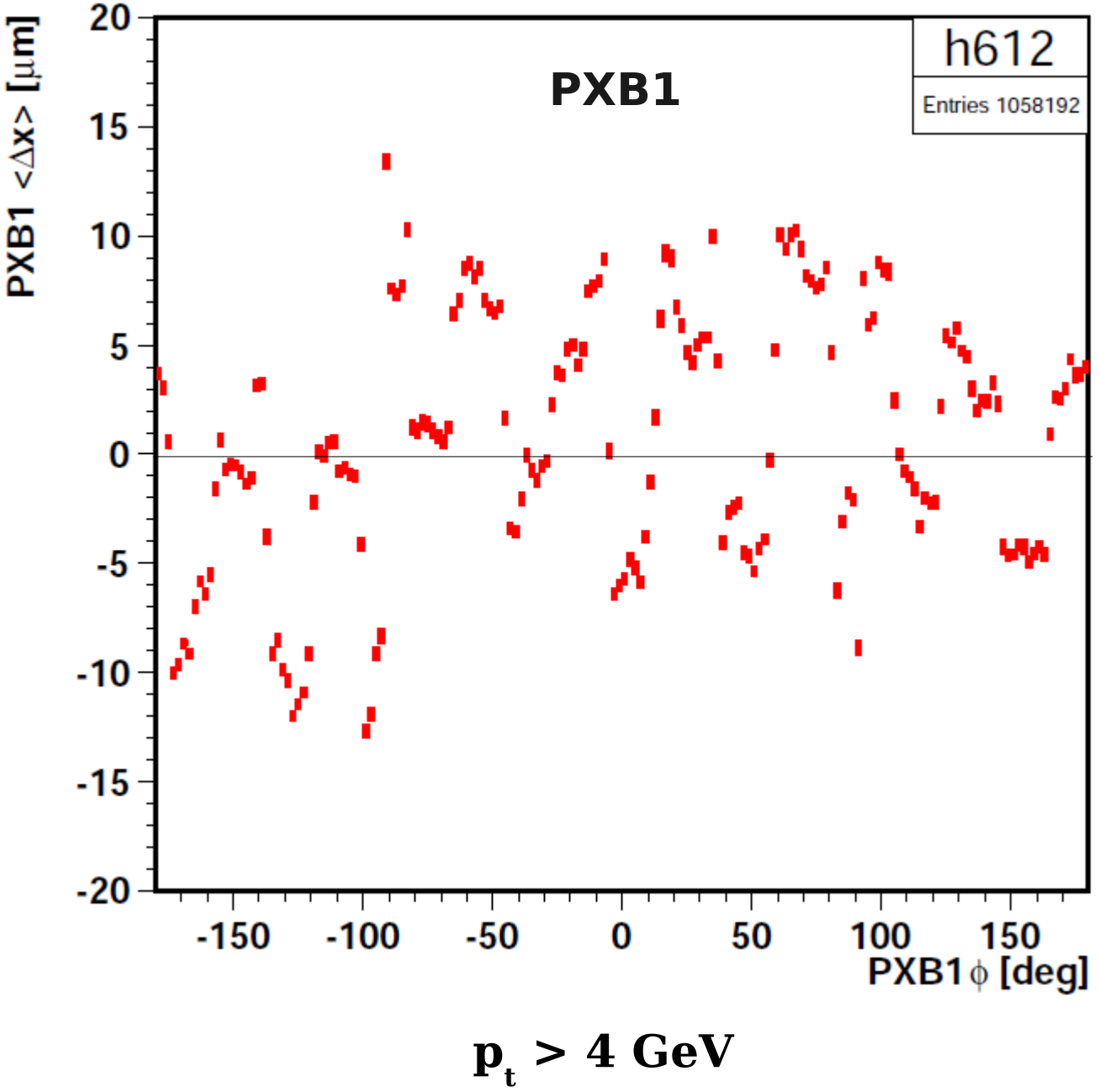


layer 1 residual using the beam spot



- Select tracks with hits in 2 pixel layers.
- Use offline beam spot.
- Impact parameter: $|d'_{CA}| < 5\ \sigma$.
- Redefine track:
  - curvature κ from full tracker,
  - position and angle from beam spot and 2nd layer, in $r\varphi$.
- Interpolate to 1st layer.

Alignment check vs φ in PXB1



p_t > 4 GeV

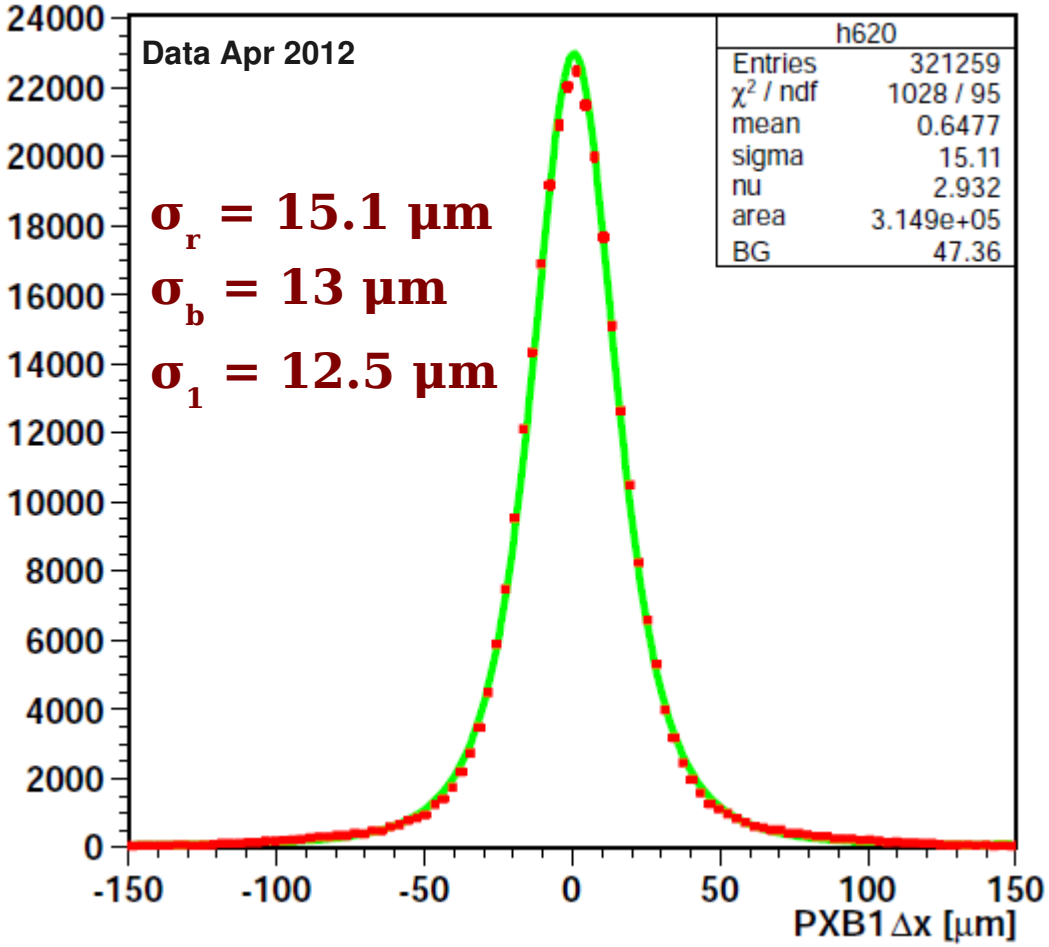
- Barrel pixel mean triplet residuals: should be zero.
- Apr 2012 data
- Shifts of up to ±10 μm, 18-fold ladder pattern.
- Can the alignment be improved?

Barrel pixel layer 1 $r\varphi$ resolution 2011

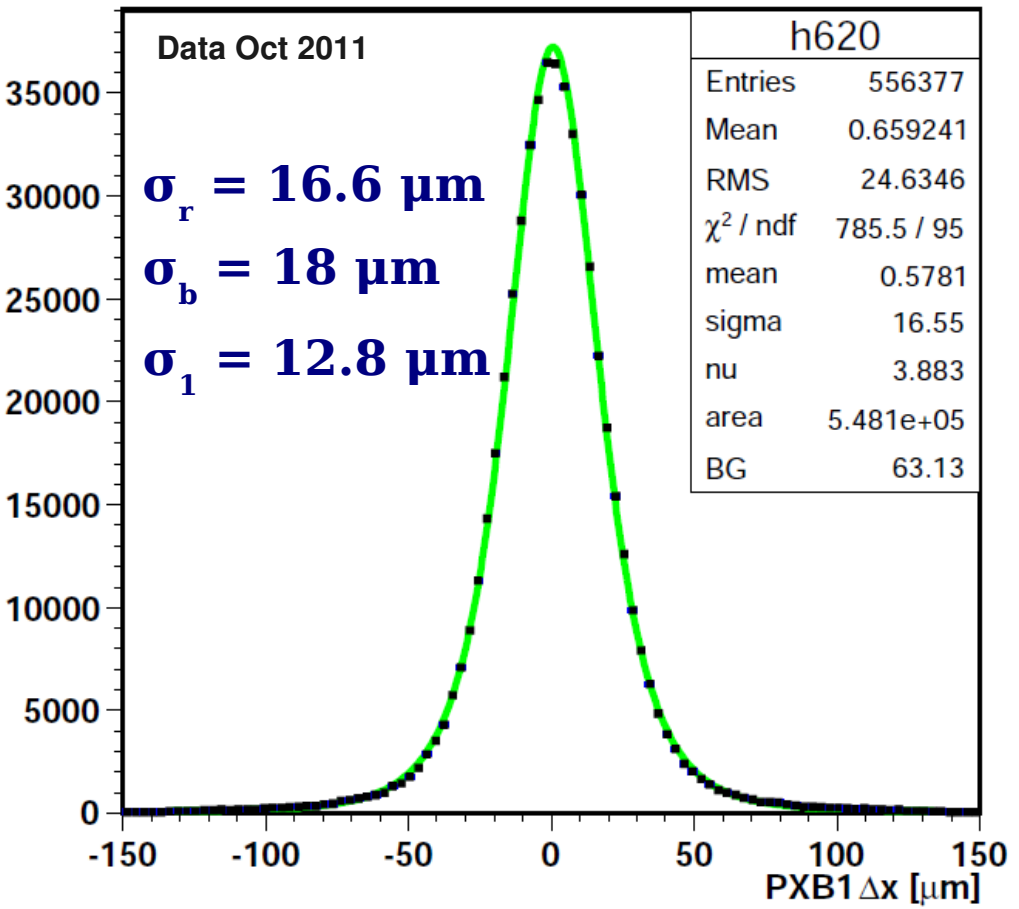
track p_t > 12 GeV, $|d'_{CA}| < 5\ \sigma$

need to subtract beam spot size contribution

Mar 2011 Jet data

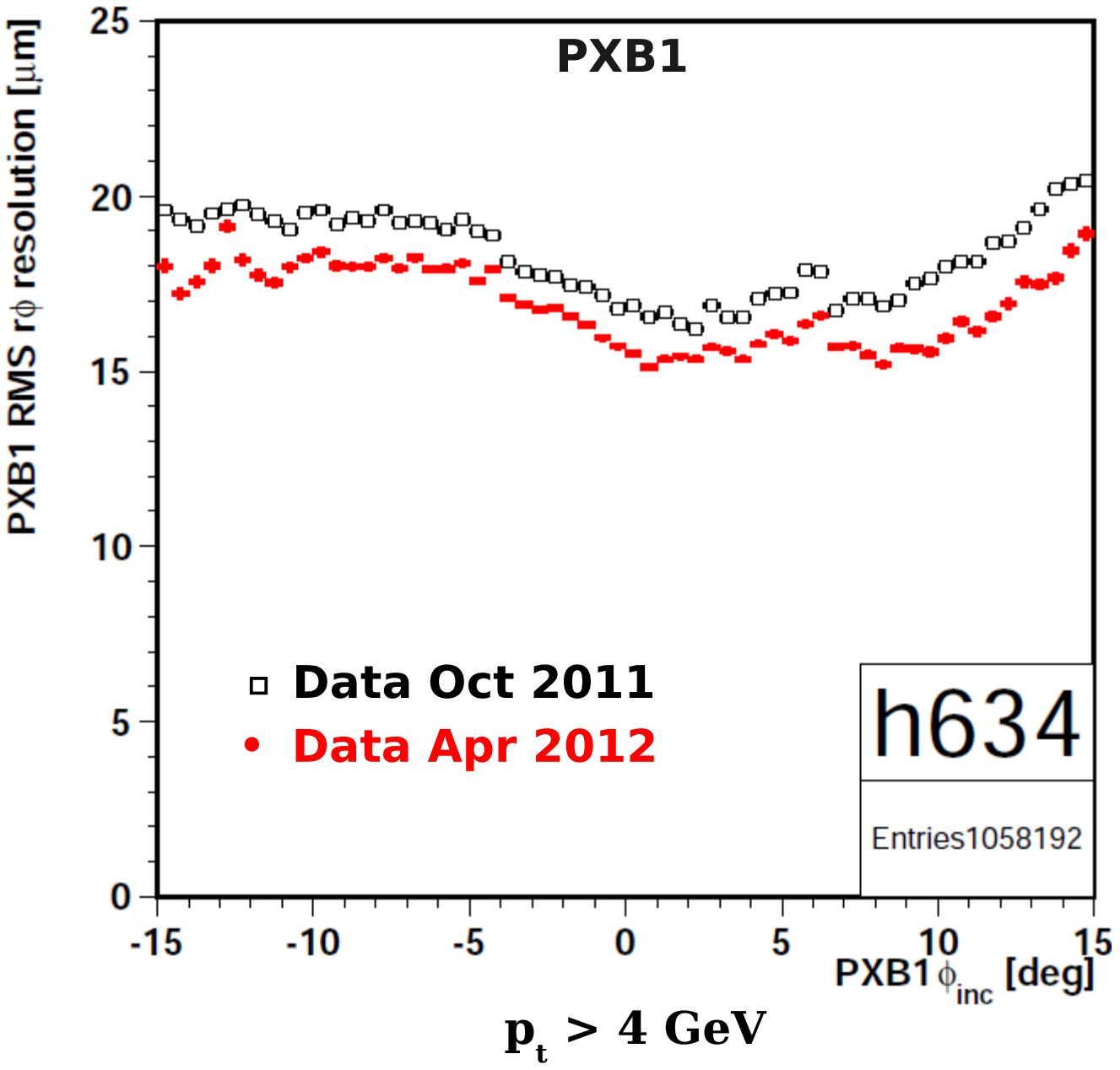


Oct 2011 singleMu data



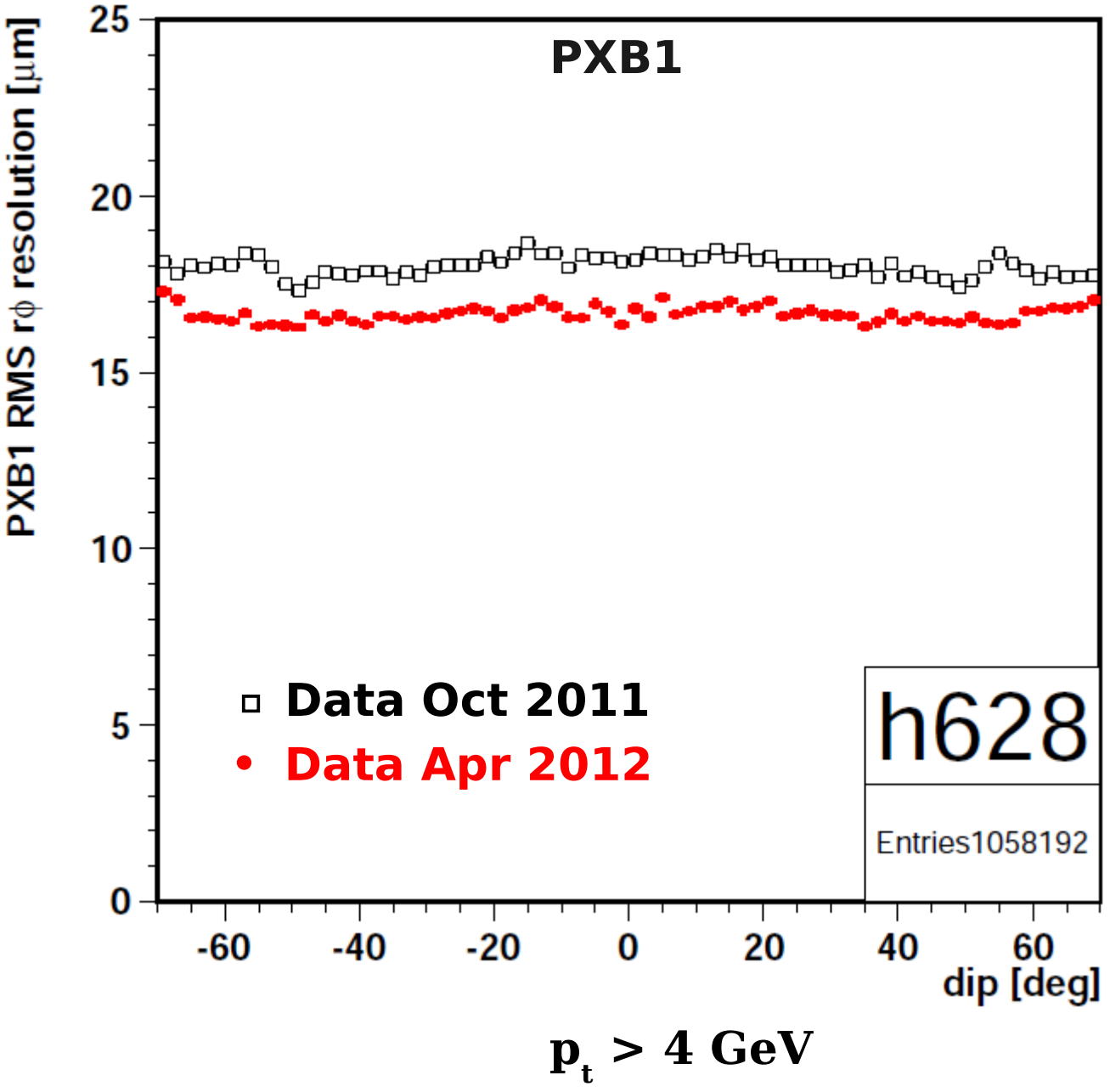
PXB1 worse than PXB2?

PXB1 *rφ* resolution vs incident angle



- Track angle of incidence with module normal vector in *rφ*.
- Pixel barrel layer 1 has 18 (full) modules:
  - each covers ±10° in azimuth,
  - larger angles due pixel offset to beam.
- Optimal *rφ* resolution reached for incidence between -3° and +11°.
- Oct 2011 resolution is slightly worse.

PXB1 $r\varphi$ resolution vs dip angle

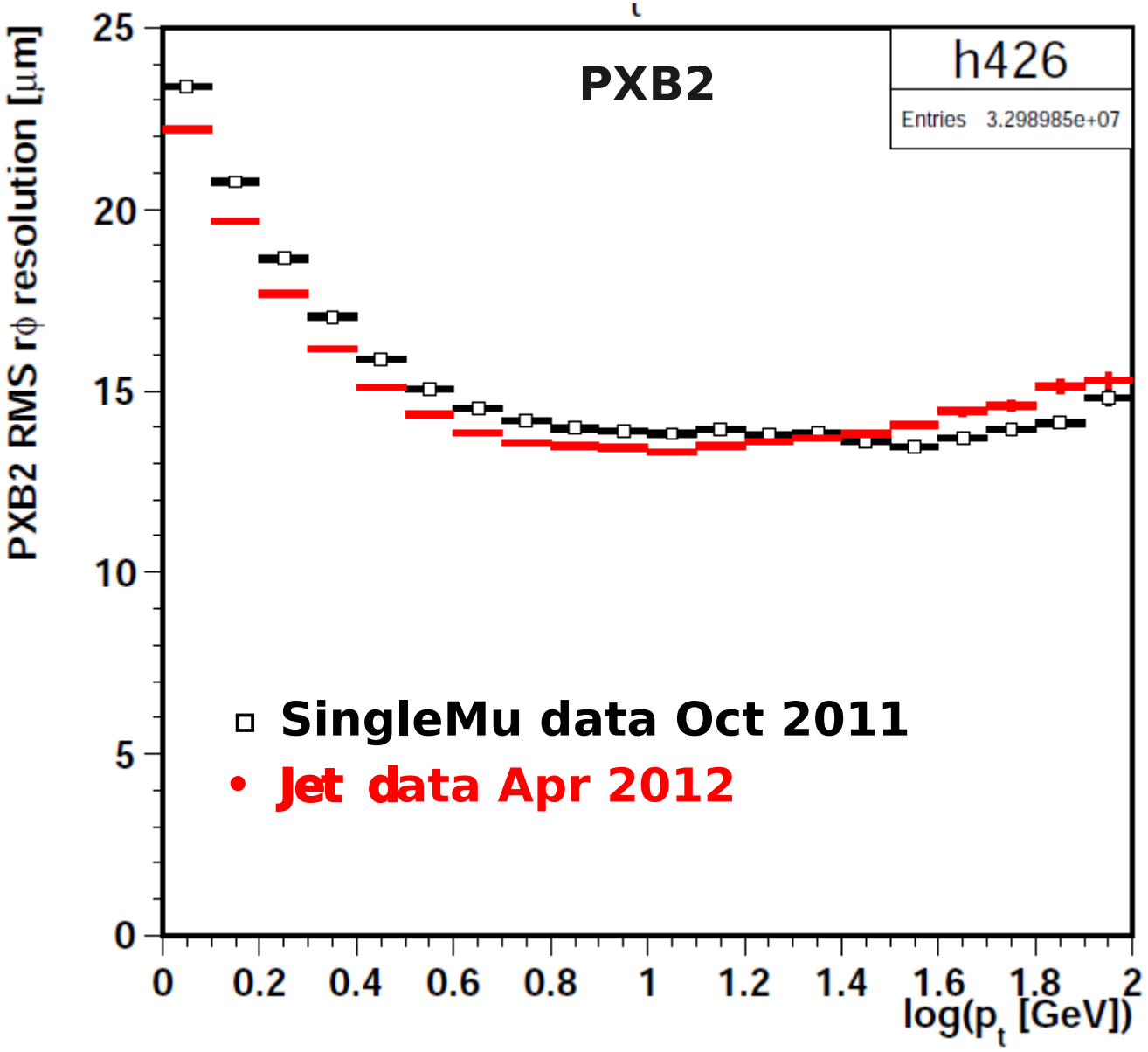


- truncated RMS of the residuals
- (different) beam spot contribution not subtracted!
- Apr 2012 data slightly better.

Summary

- Barrel pixel resolution measured in April 2012 data using triplet residuals.
- Small improvement compared to Oct 2011:
  - due to lower thresholds?
- Alignment shifts in rφ of up to ±6 µm (PXB2) and ±10 µm (PXB1) varying from ladder to ladder.
- To be followed through 2012...

p_t dependence of $r\varphi$ resolution



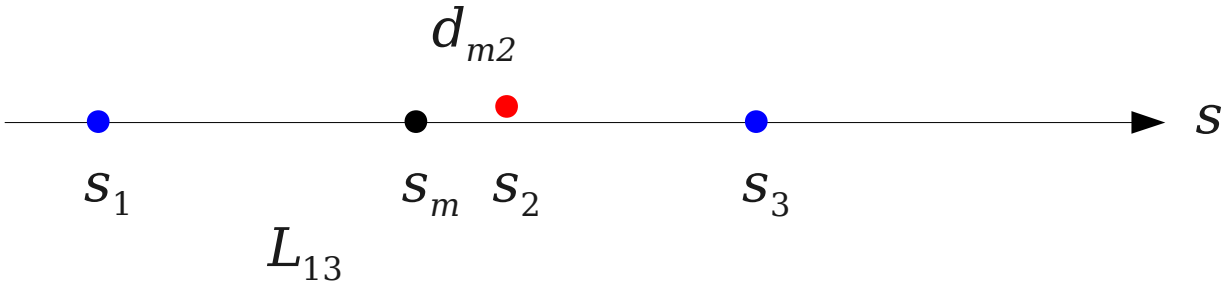
- Multiple scattering:
  - Need $p_t > 4$ GeV to observe intrinsic pixel resolution.
- Apr 2011 jet data:
  - slightly better at medium p_t.
  - slightly worse than singleMu at highest p_t: core of jets.

triplet resolution function

Propagation of the intrinsic resolution at high p_t:

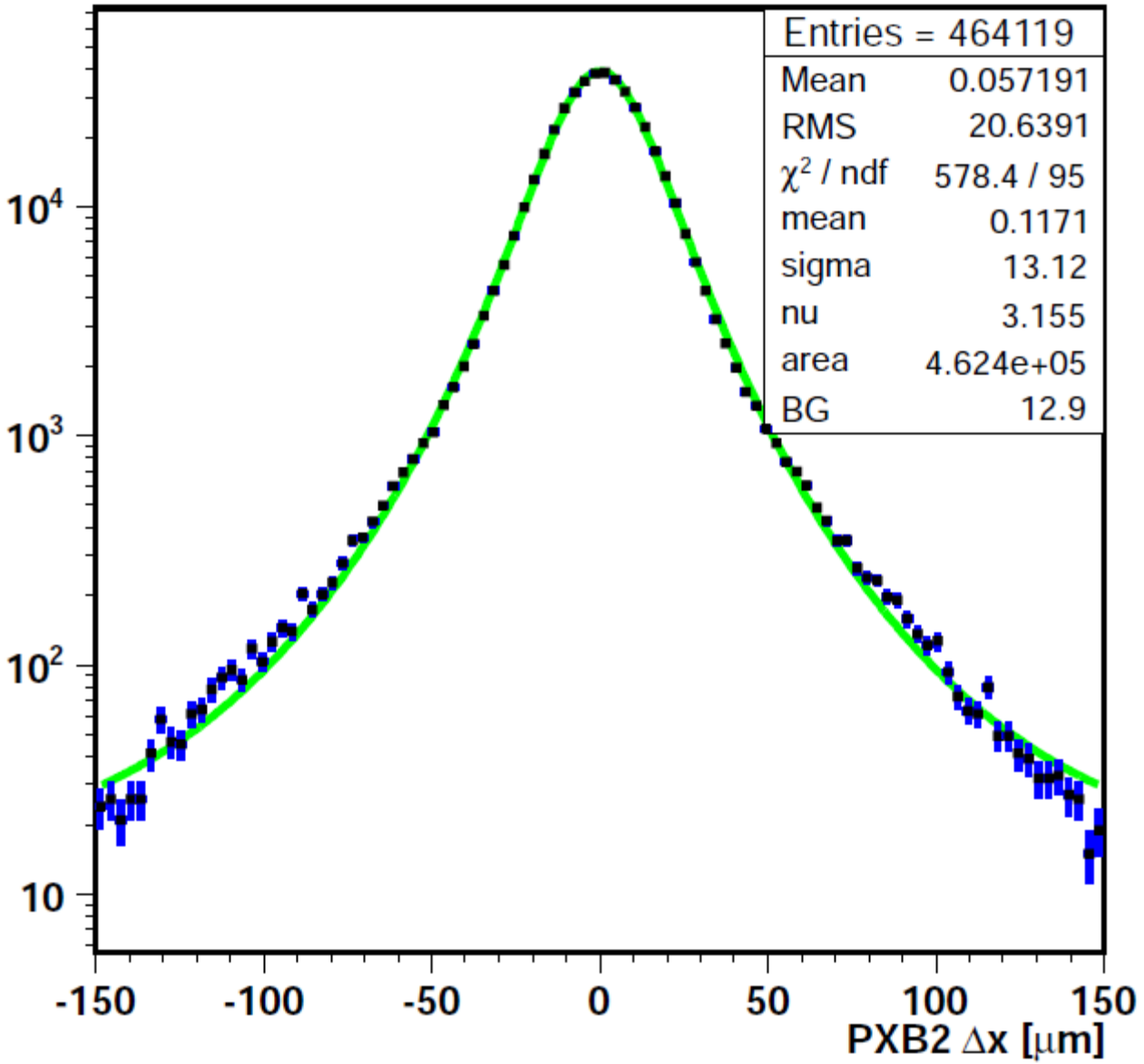
$$\sigma_r^2 = \sigma_2^2 + \frac{\sigma_1^2}{4} + \frac{\sigma_3^2}{4} + \frac{d_{m2}^2}{L_{13}^2}\left(\sigma_1^2 + \sigma_3^2\right)$$

$L_{13} = s_3 - s_1$	length of base line
$d_{m2} = s_2 - s_m$	distance of point 2 from mid point
$s_m = (s_1 + s_3)/2$	mid point
s	radial coordinate (arc length)



like for a straight line developed around its center, where offset and slope are uncorrelated.

Barrel pixel triplet rφ residuals at high p_t



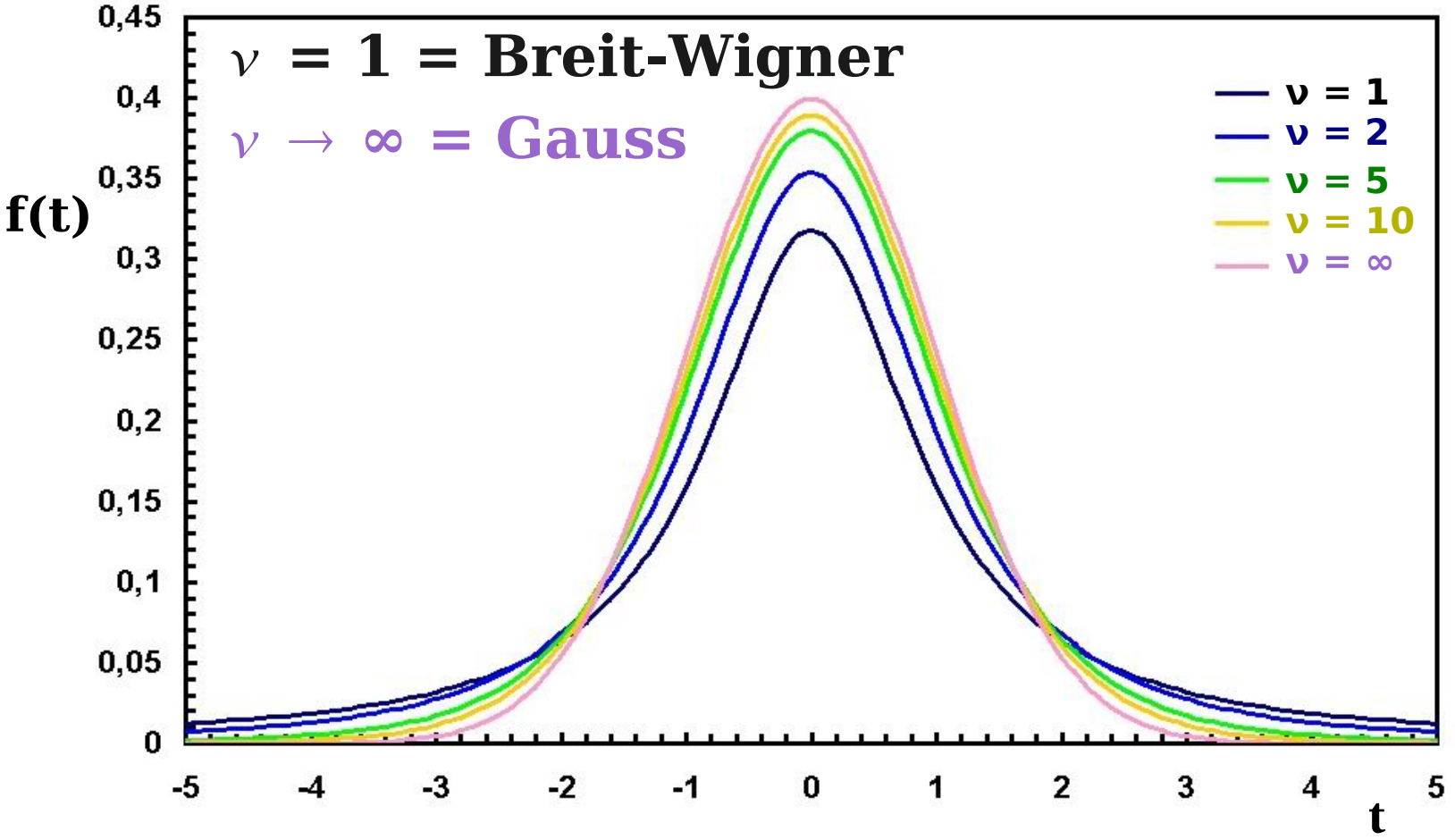
- SingleMu data Oct 2011
- Fit by Student's *t* function:
  - non-Gaussian tails better described,
  - RMS is 50% larger than fitted σ.

Fitting peaks with Student's *t*

$t = (x\text{-}x_0)/\sigma$ = normalized residual.

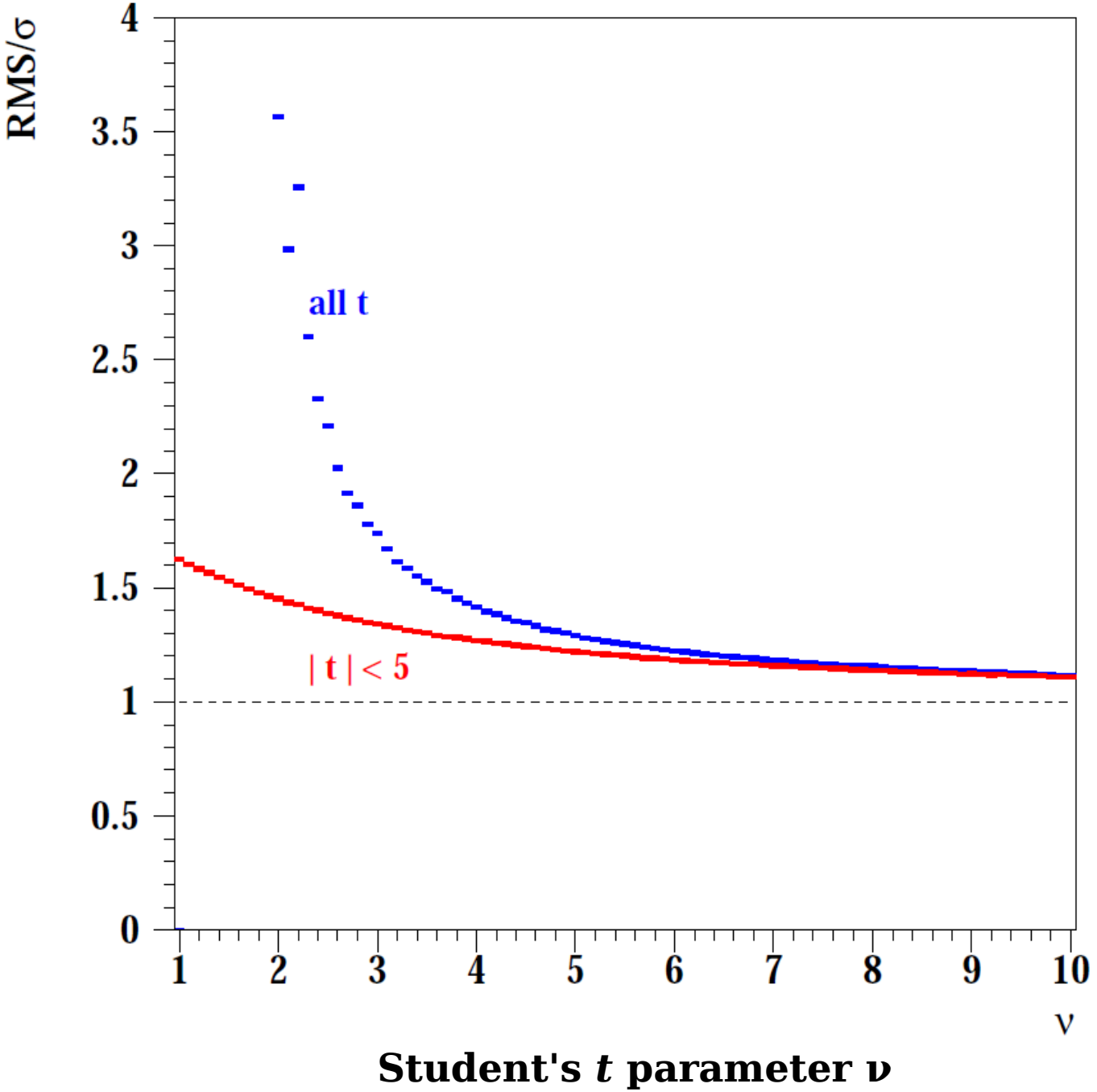
$$f(t) = \frac{\Gamma((\nu+1)/2)}{\sqrt{\nu\pi}\,\Gamma(\nu/2)}(1+t^2/\nu)^{-(\nu+1)/2}$$

f(t) is a normalized probability density.
Γ function is in PAW, ROOT.



Parameter ν interpolates between Gaussian and Breit-Wigner.

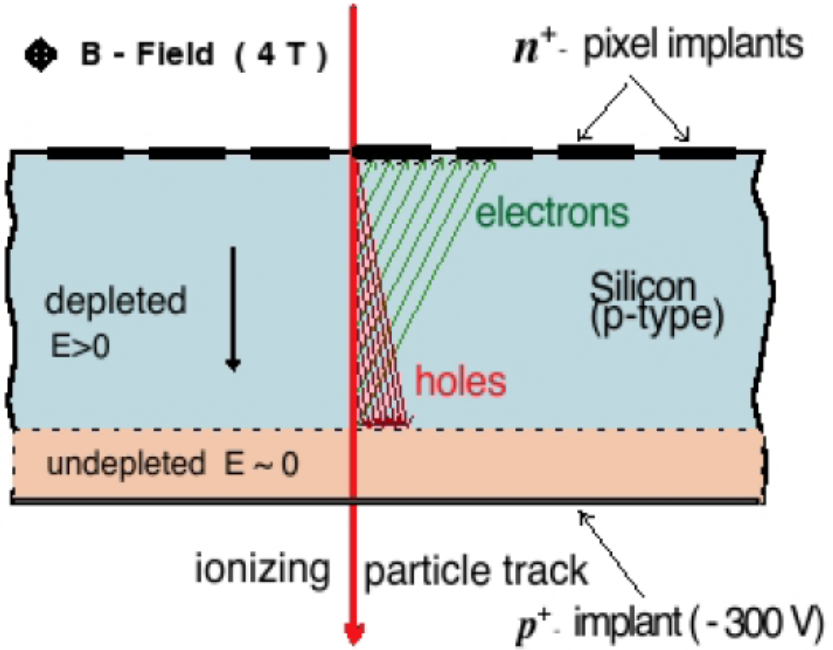
RMS/σ for Student's *t*

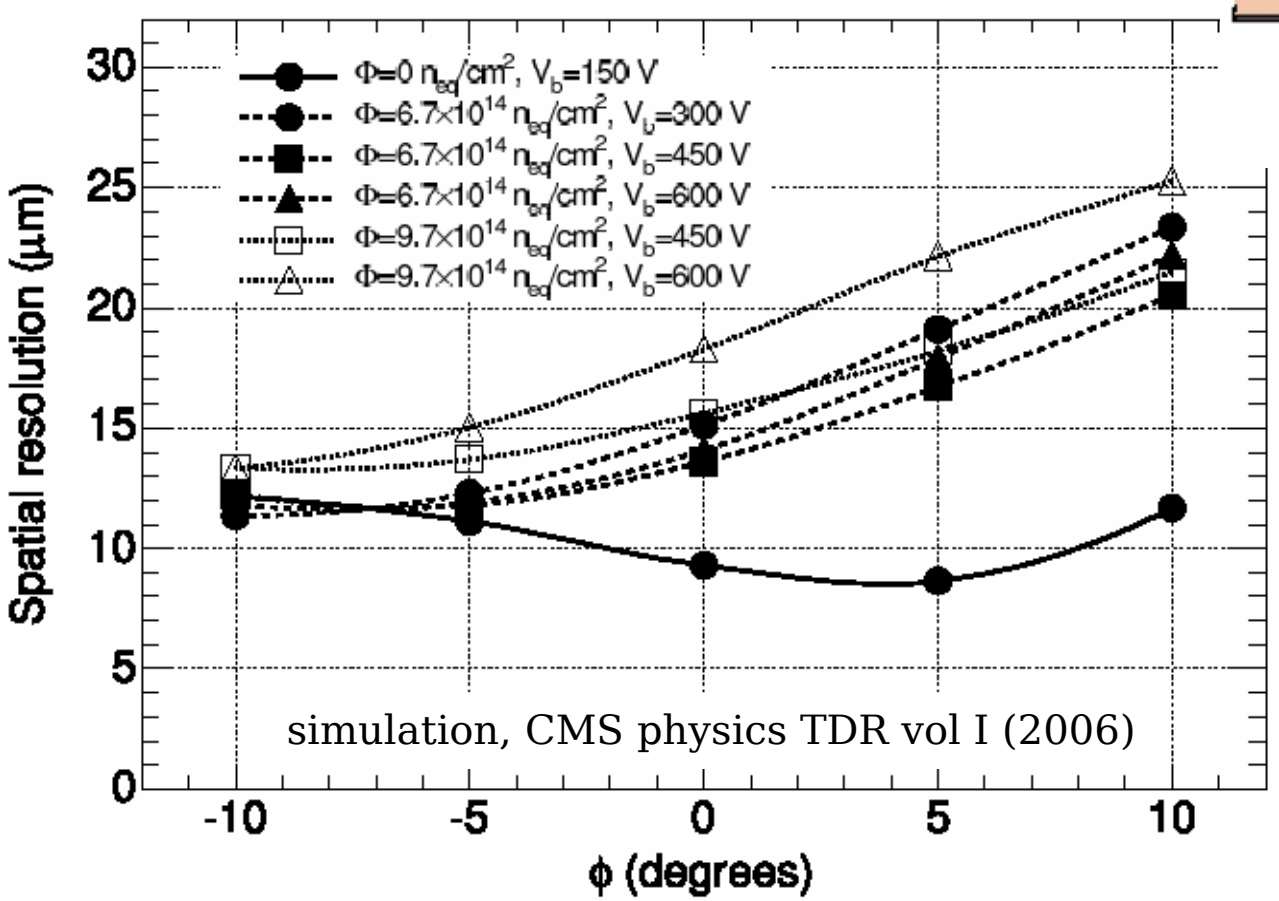


- Generate random numbers according to Student's t for different ν (see W. Hoermann, Computing 81 (2007) 317).
- calculate RMS:
  - for all t (RMS diverges for $\nu = 1$).
  - for $|t| < 5$ (RMS stays below 1.62 for all $\nu \geq 1$).
- Asymptotic value (RMS/σ = 1) slowly approached.

CMS Pixel hit resolution

The pixel position resolution profits from charge sharing due to Lorentz drift, and low readout thresholds. Expect degradation of position resolution after radiation damage:





Fluence 2011:

~$1.8 \cdot 10^{13}$ n_{eq}/cm^2 PXB1

~$7.5 \cdot 10^{12}$ n_{eq}/cm^2 PXB2

(T. Rohe at RD50)