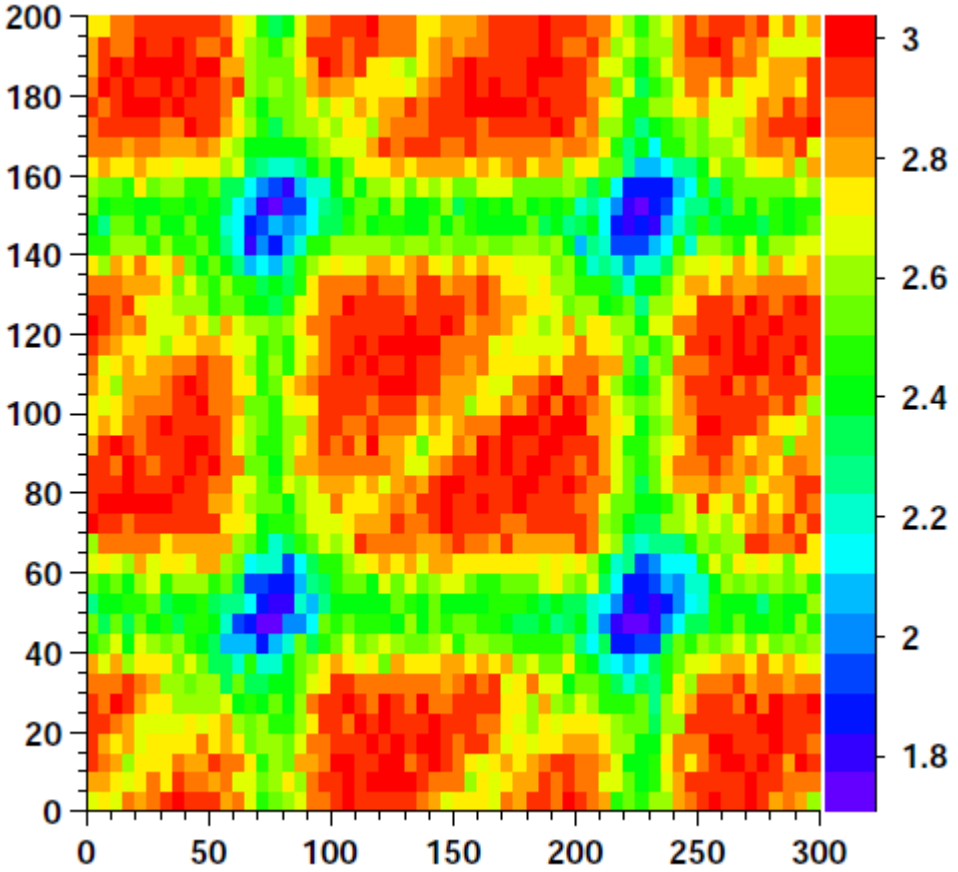
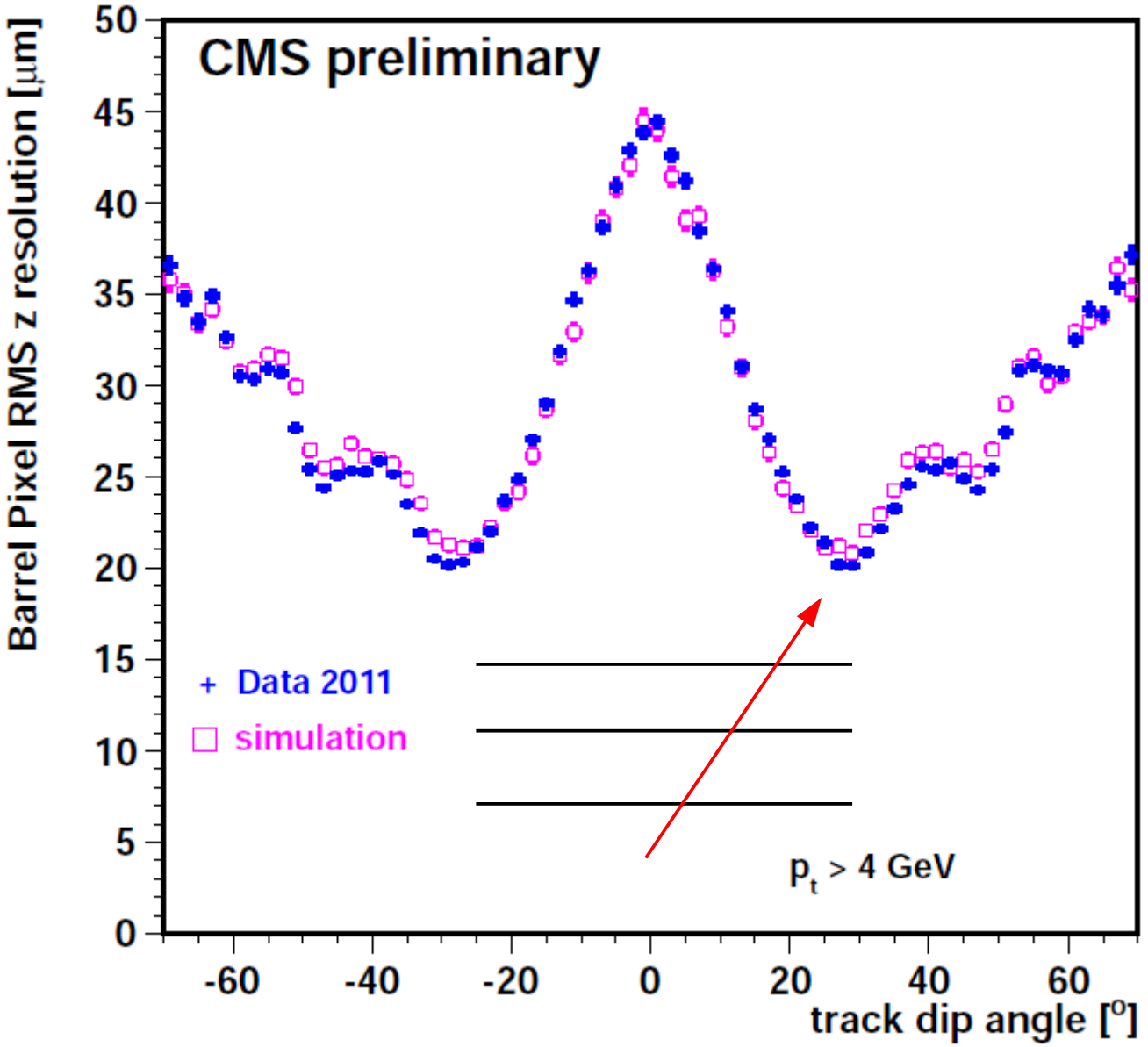
Beam test with turn and tilt

Ganna Dolinska, Ievgen Korol, Hanno Perrey,
Daniel Pitzl, Simon Spannagel
Hamburg CMS Pixel Upgrade meeting, 22.2.2013

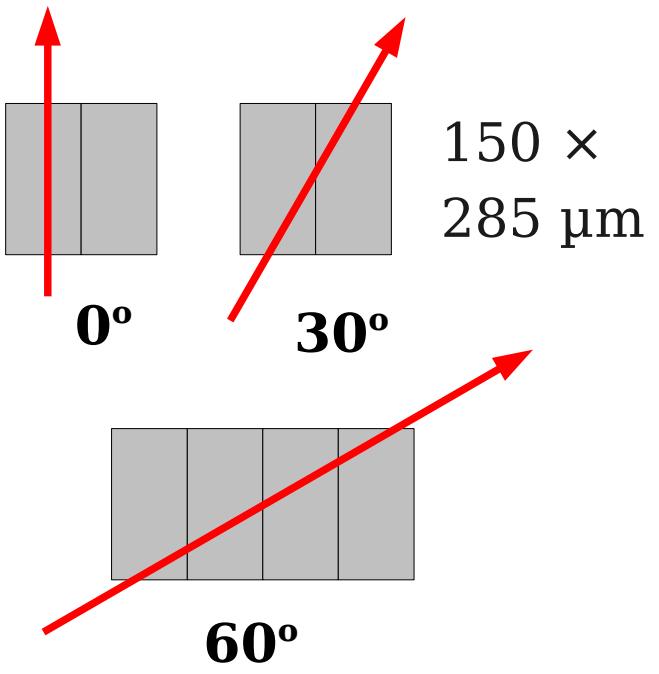


- turn sensor to study charge sharing between columns
  - incident angle similar to dip angle in CMS
- beam test Feb 4-9, 2013
- results

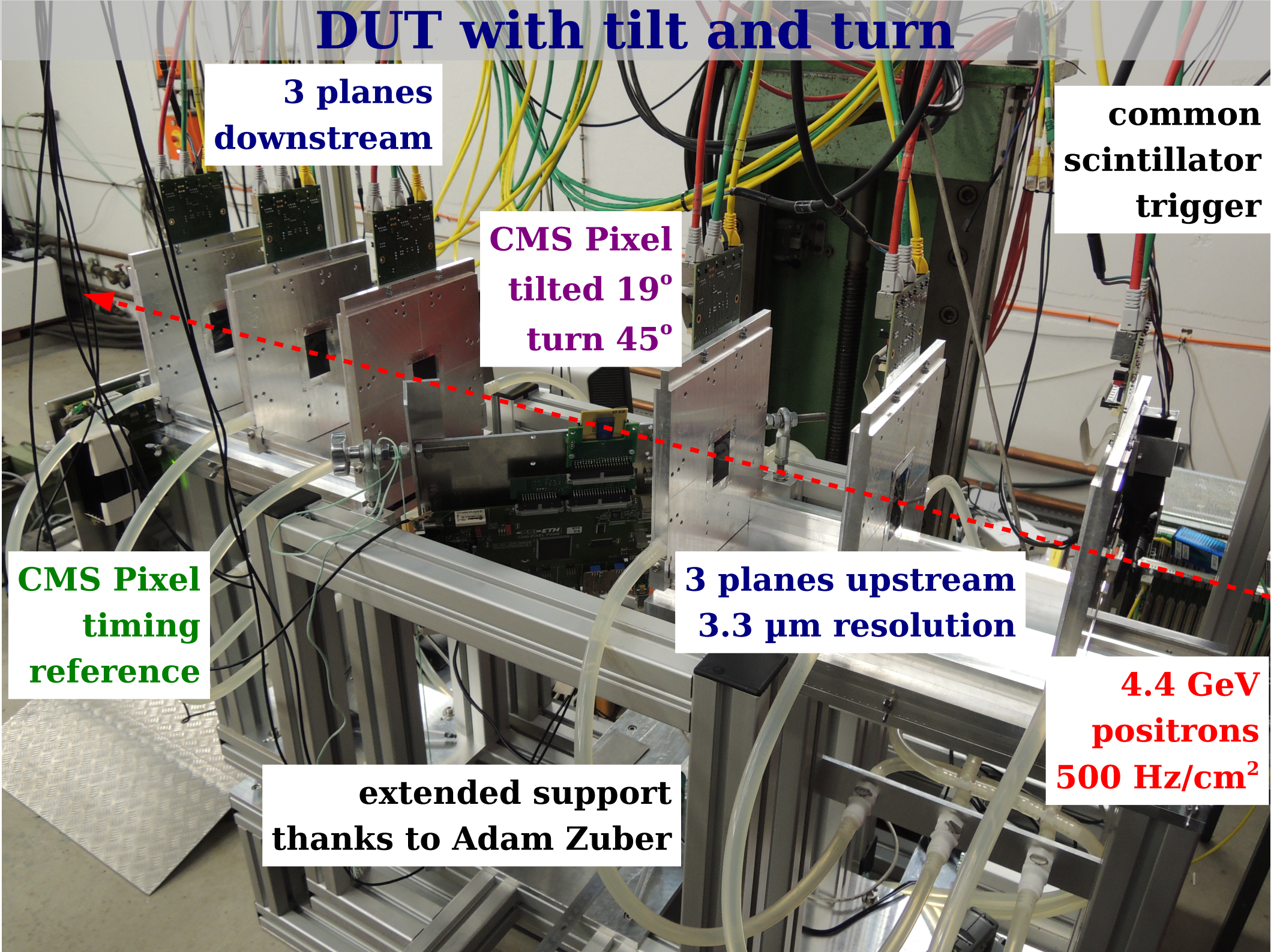
CMS: dip angle dependence of z resolution



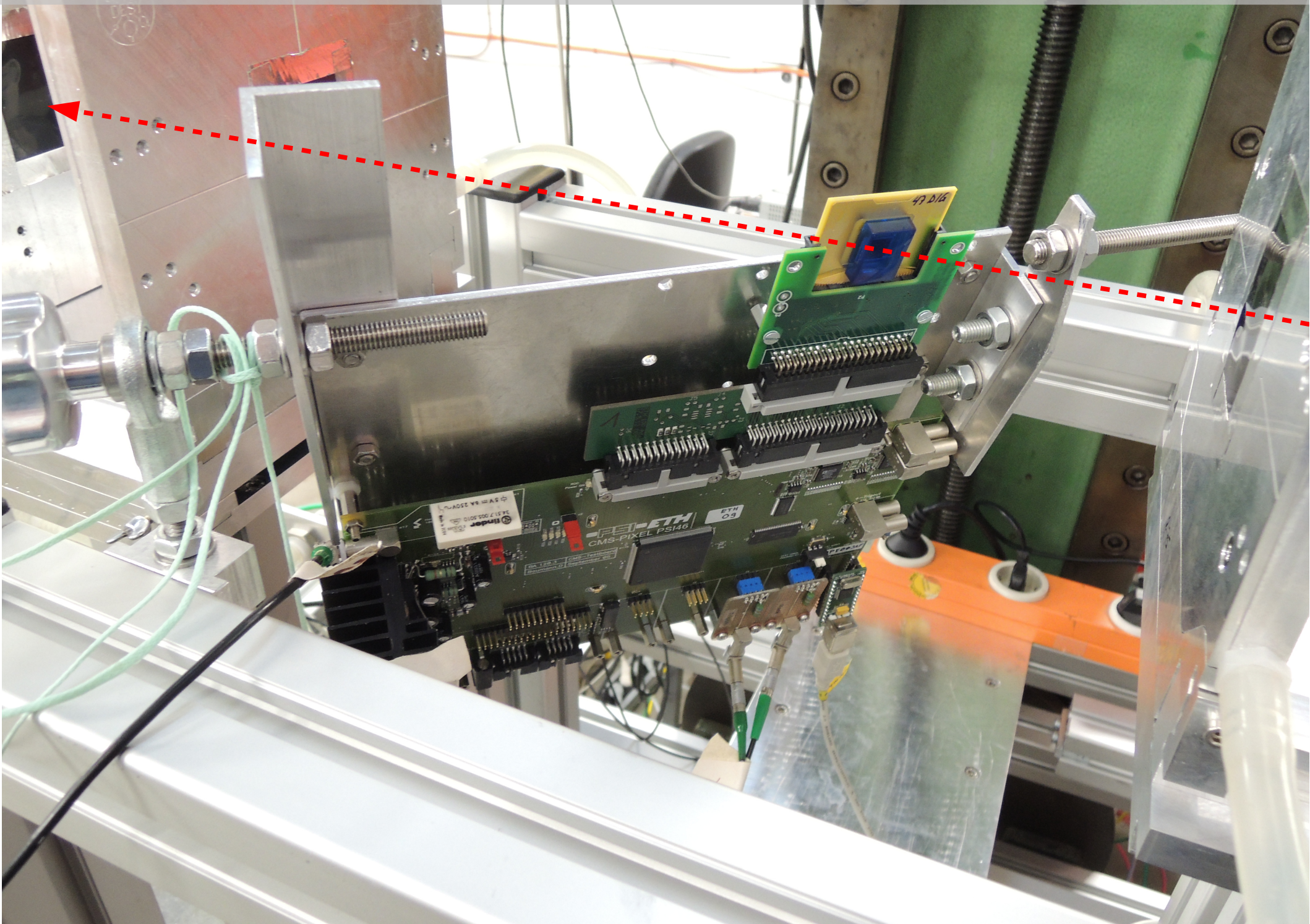
- dip angle:
  - $\lambda = \pi/2 - \theta$.
- z = column direction
- optimal resolution at 28° = atan(150/285)
  - sharing between neighboring pixels



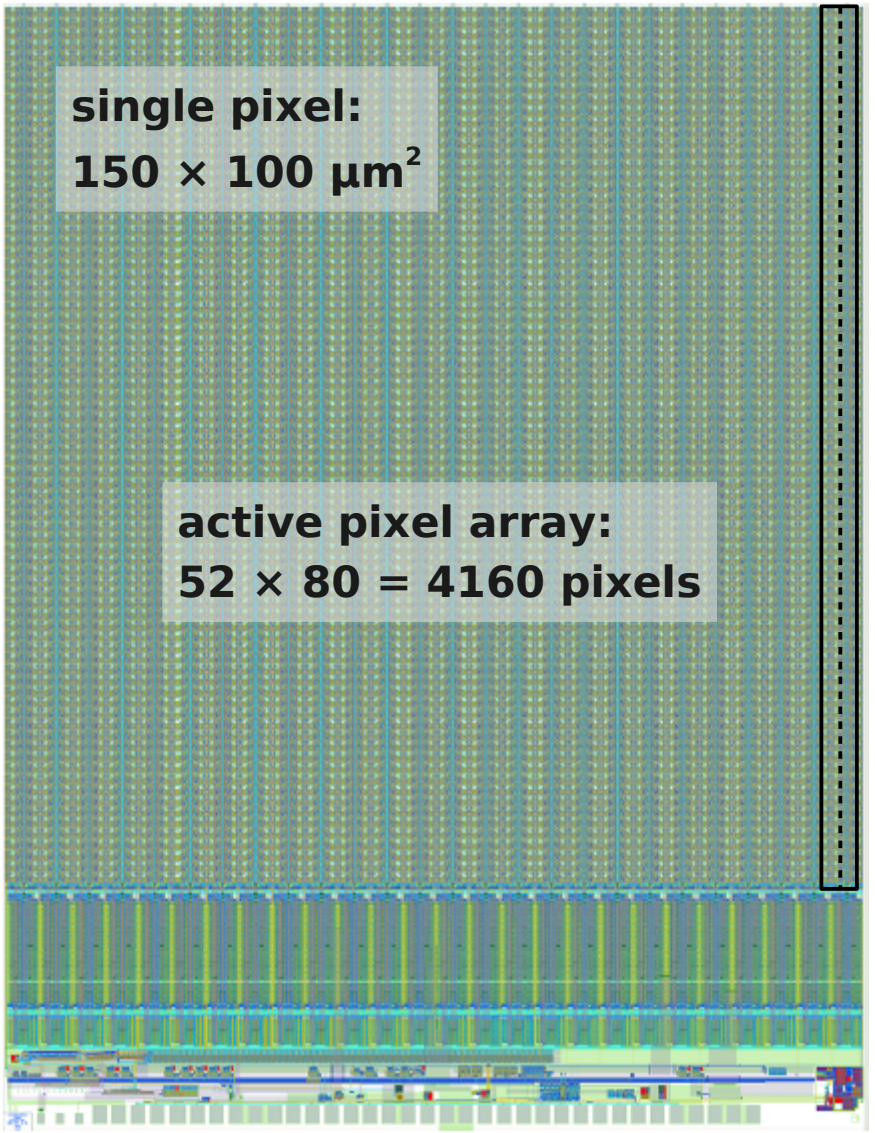
DUT with tilt and turn



DUT with tilt and turn



psi46dig pixel readout chip



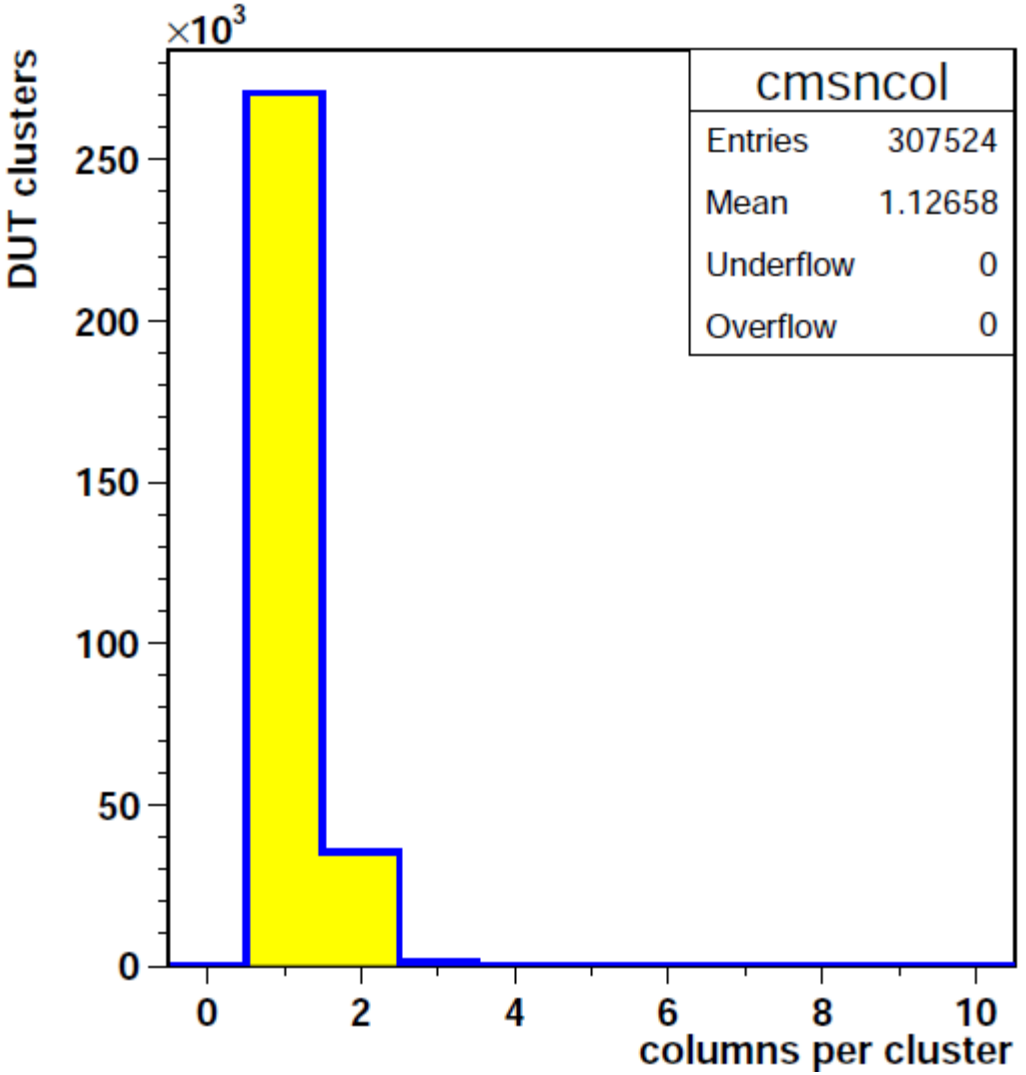
Beam test program

- single chip module with psi46dig chip 47
  - bump and wire bonded at PSI
  - thresholds trimmed to 25, 30, 35, 40, 50, 60, 80 DACs (50 e)
  - bias -150 V
  - fixed tilt angle 19^{o} (like Lorentz angle in CMS)
  - 4.4 GeV, typically 500 Hz telescope trigger rate with 9E9 e^{-} in DESY
- Vary turn angle:
  - 27^{o}, 18^{o}, 45^{o}, 36^{o}, 9^{o}, 0^{o}.
  - take threshold scan at each angle
  - at least two good 5 min runs (150 k events) per point
- Achieved in 11 shifts of 4 hours

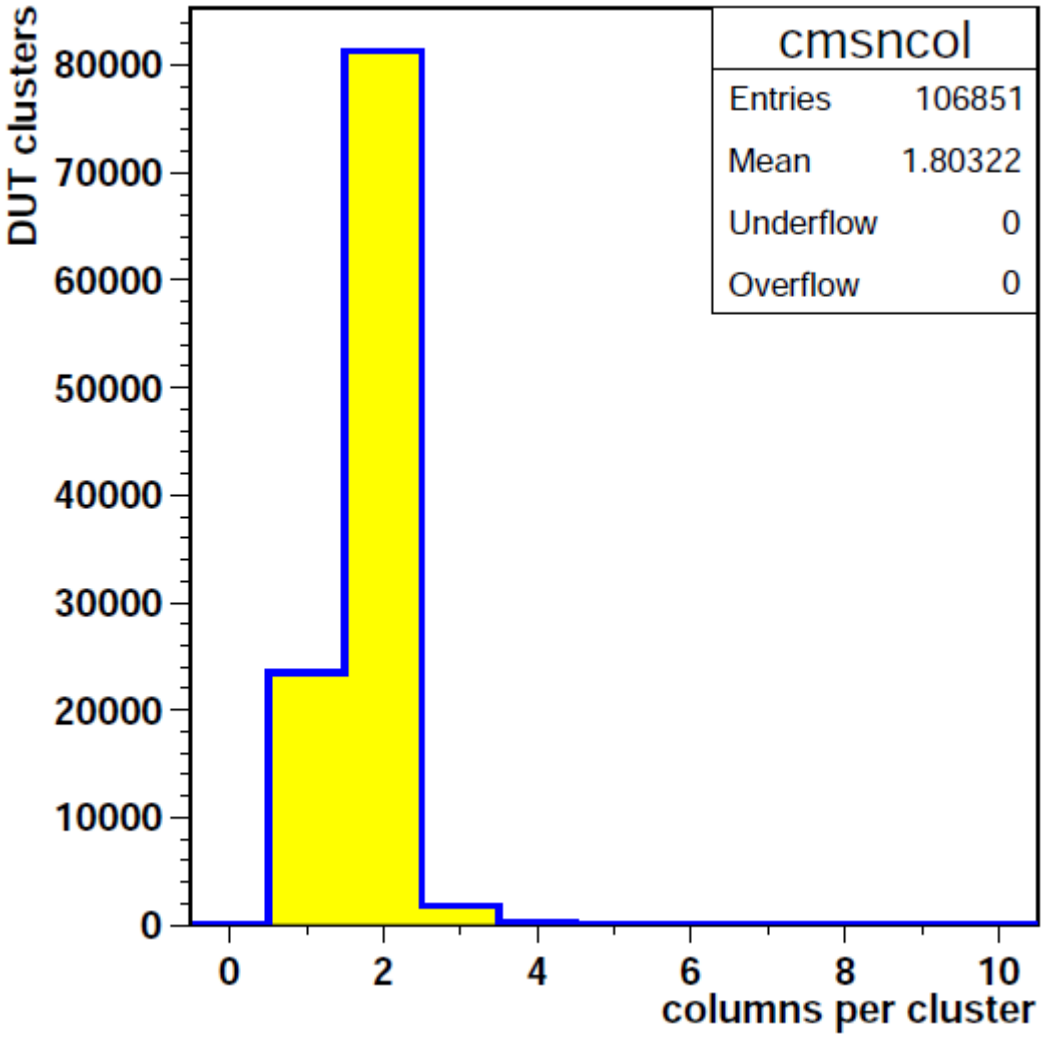
columns per cluster

trim 30 (1.5 ke)

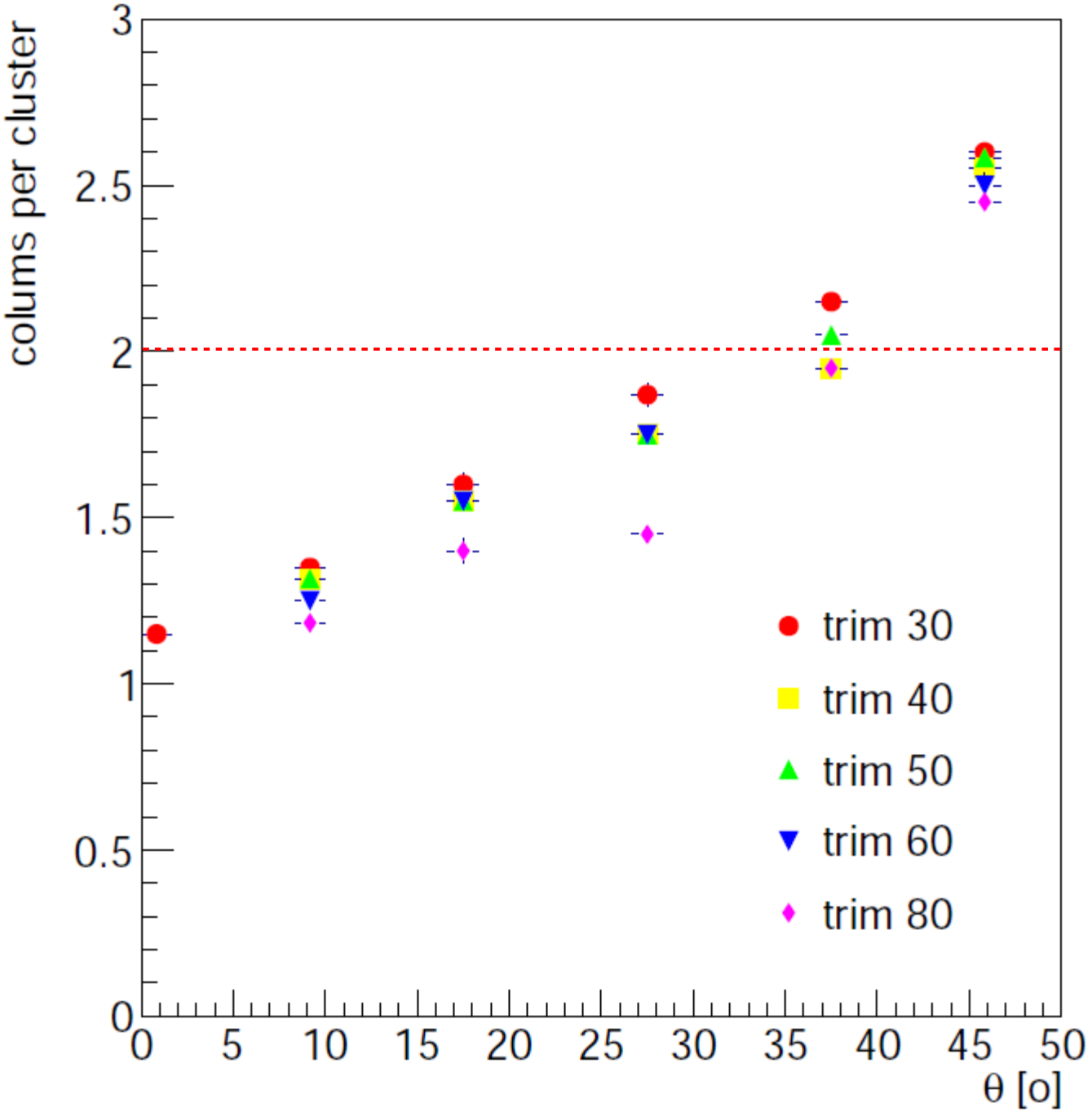
no turn



26° turn



columns per cluster vs turn angle



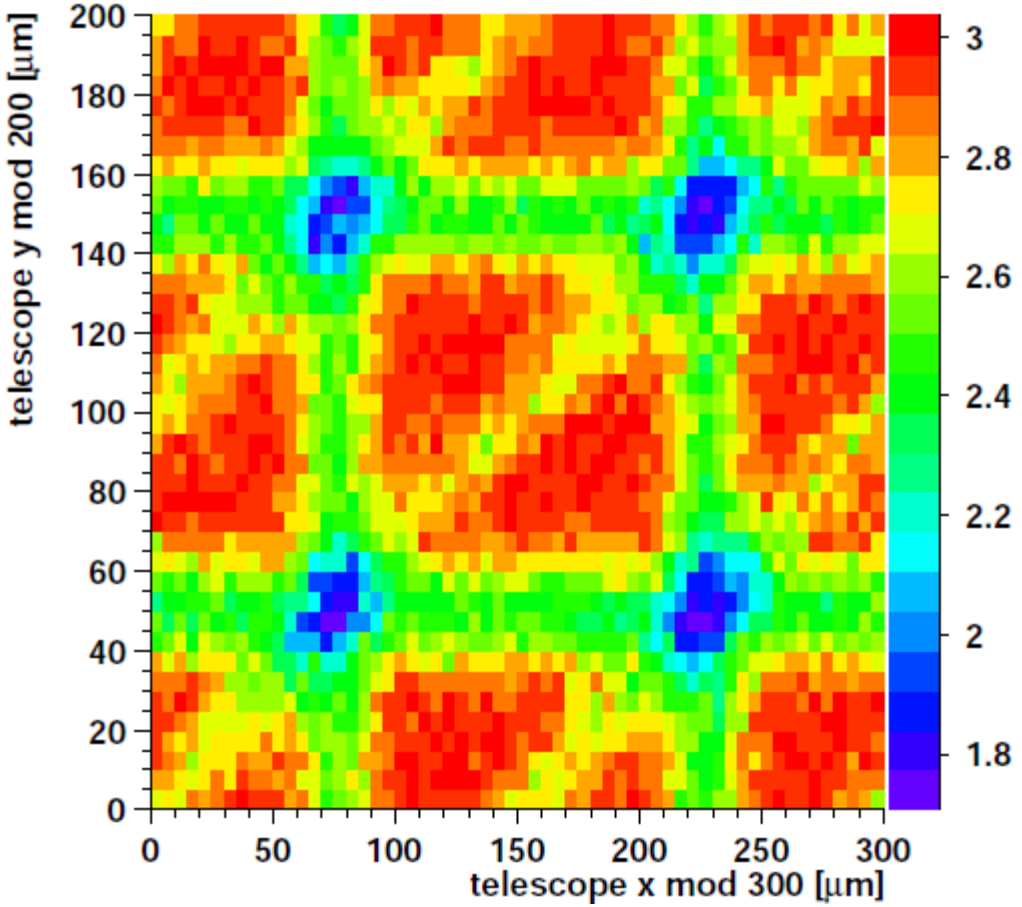
- psi46dig chip 47
  - Ia 25 mA
  - trim: ~50 e/DAC
- Optimum:
  - 2 columns/cluster
  - reached at 27 deg, as expected from geometry

pixels per cluster

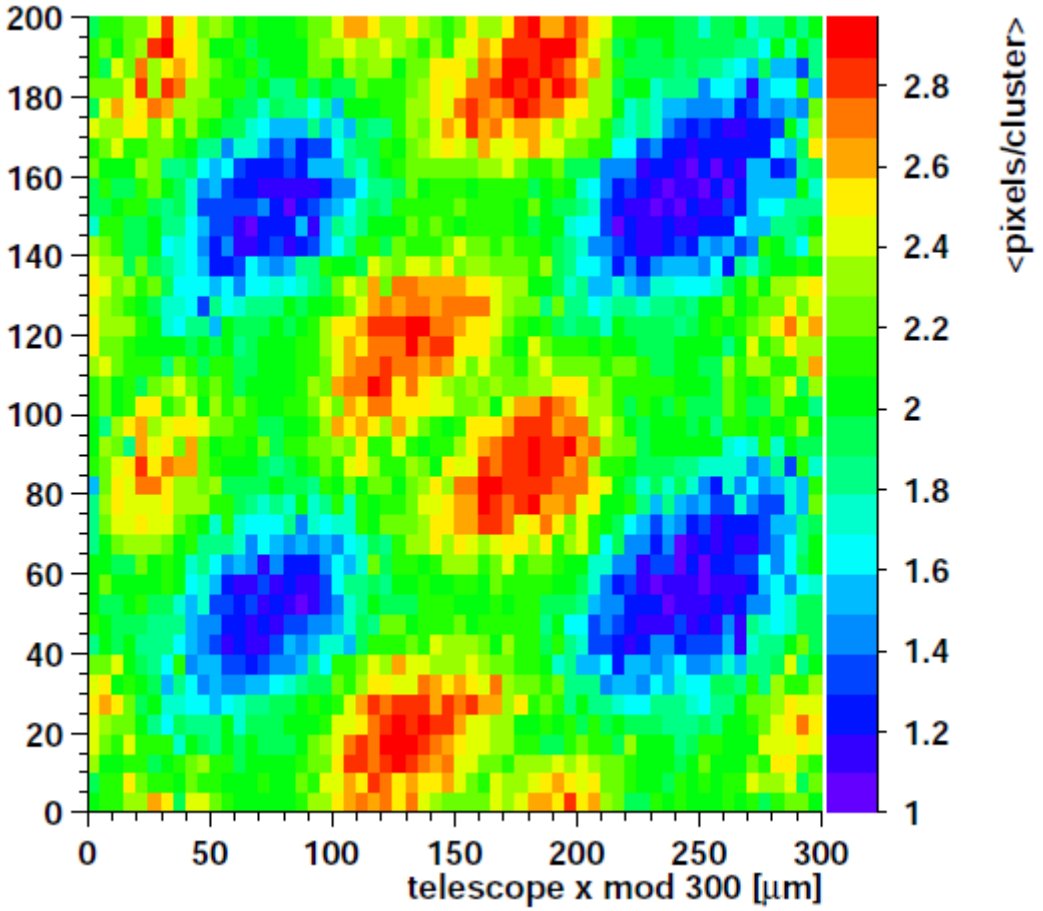
turn 27°, tilt 19°

2 × 2 pixels

trim 30

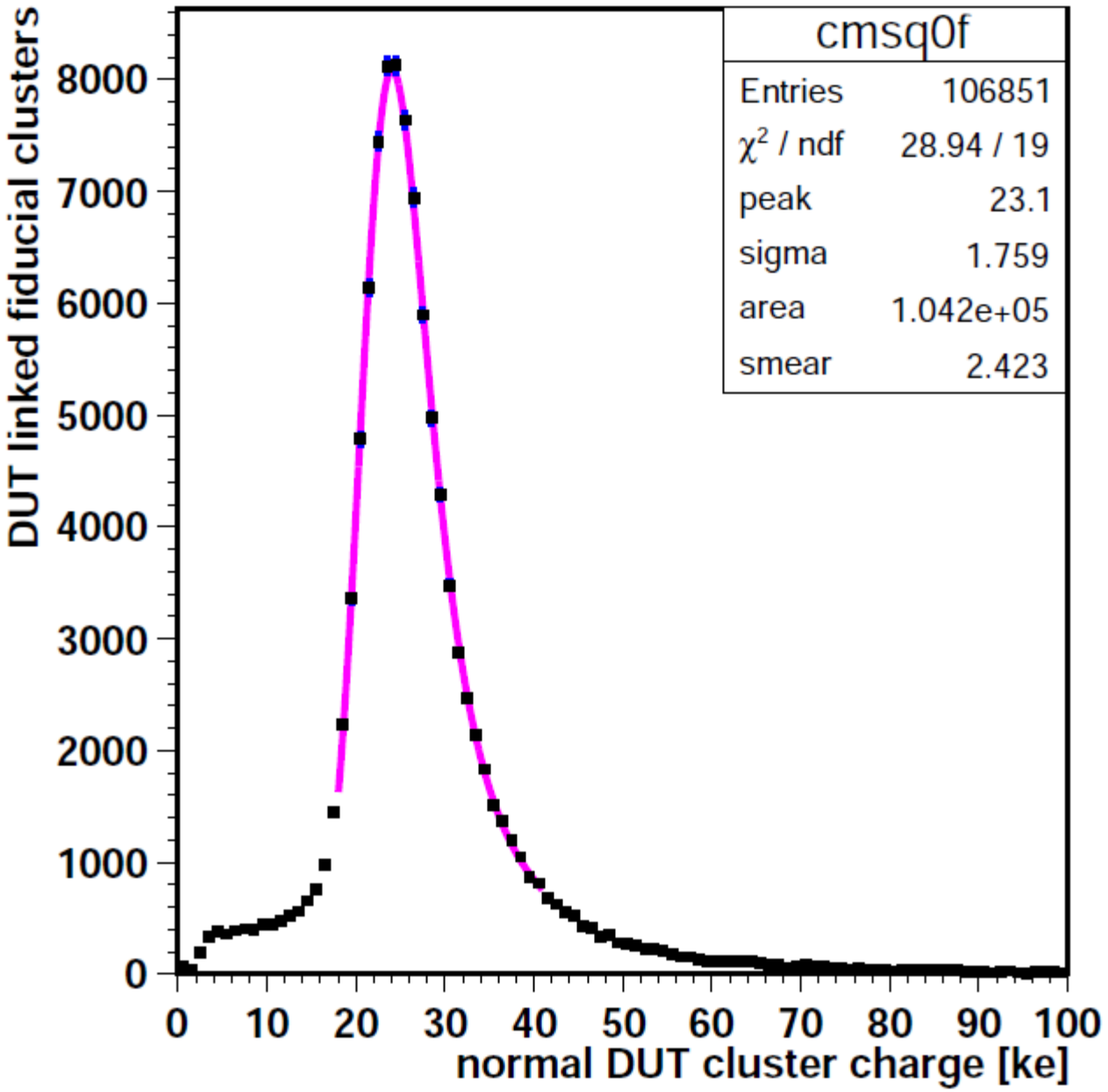


trim 80



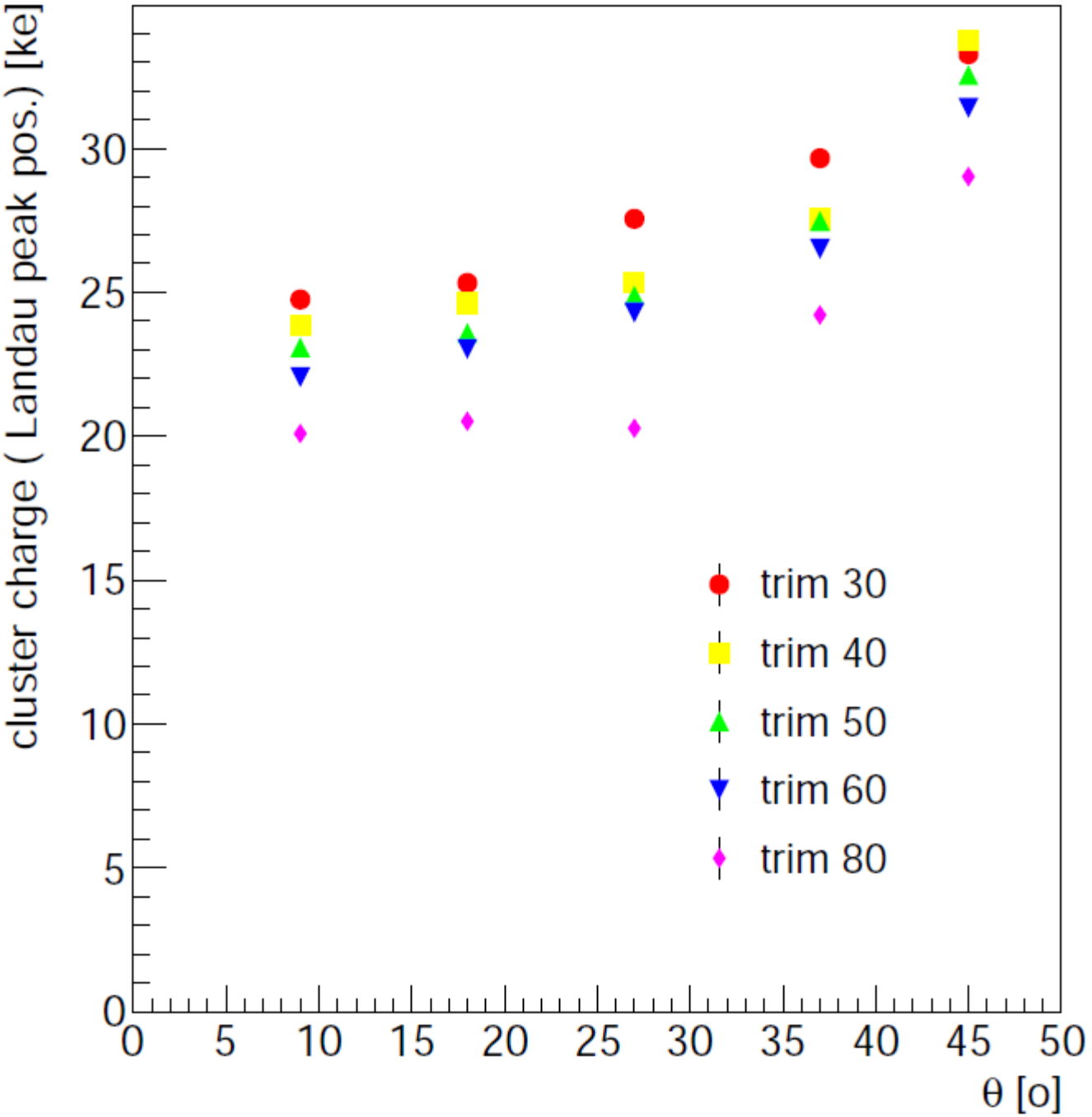
fodder for a simulation?

Landau distribution chip 47



- digital chip 47
- Telescope run 5559:
  - bias -150V
  - turn 26°, tilt 19°
  - normalized to vertical incidence
- Gain calibration: Weibull fit, nominal gain 50e/DAC used.
- Cluster charge distribution fit by Landau ⊗ Gauss
  - peak at 23.1 ke a little low.

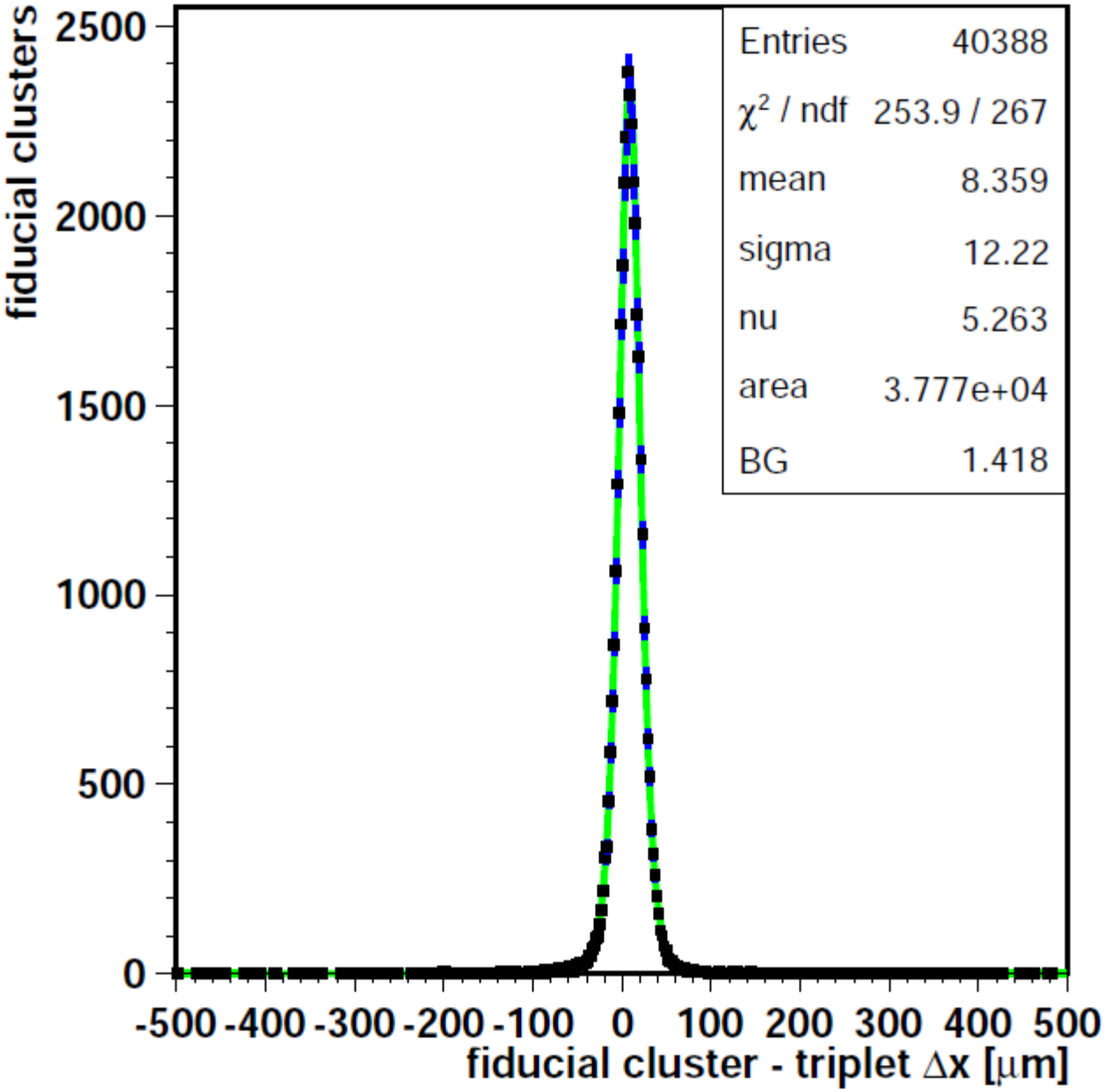
Landau peak position vs turn angle



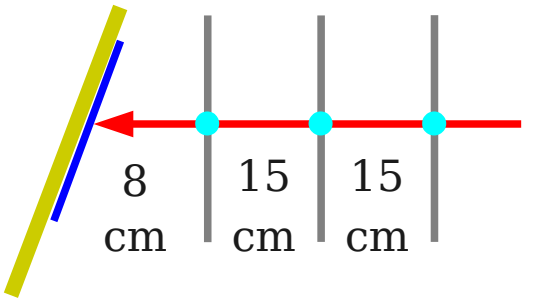
- psi46dig chip 47
  - Ia 25 mA
  - nominal gain calibration: 50 e / DAC
- Geometry:
  - Q ~ 1 / cosθ
  - confirmed
- 20% loss at threshold 80 (4 ke)

column resolution with turn angle

dig chip47, trim 30, run 6208, 4.4 GeV, 27° turn



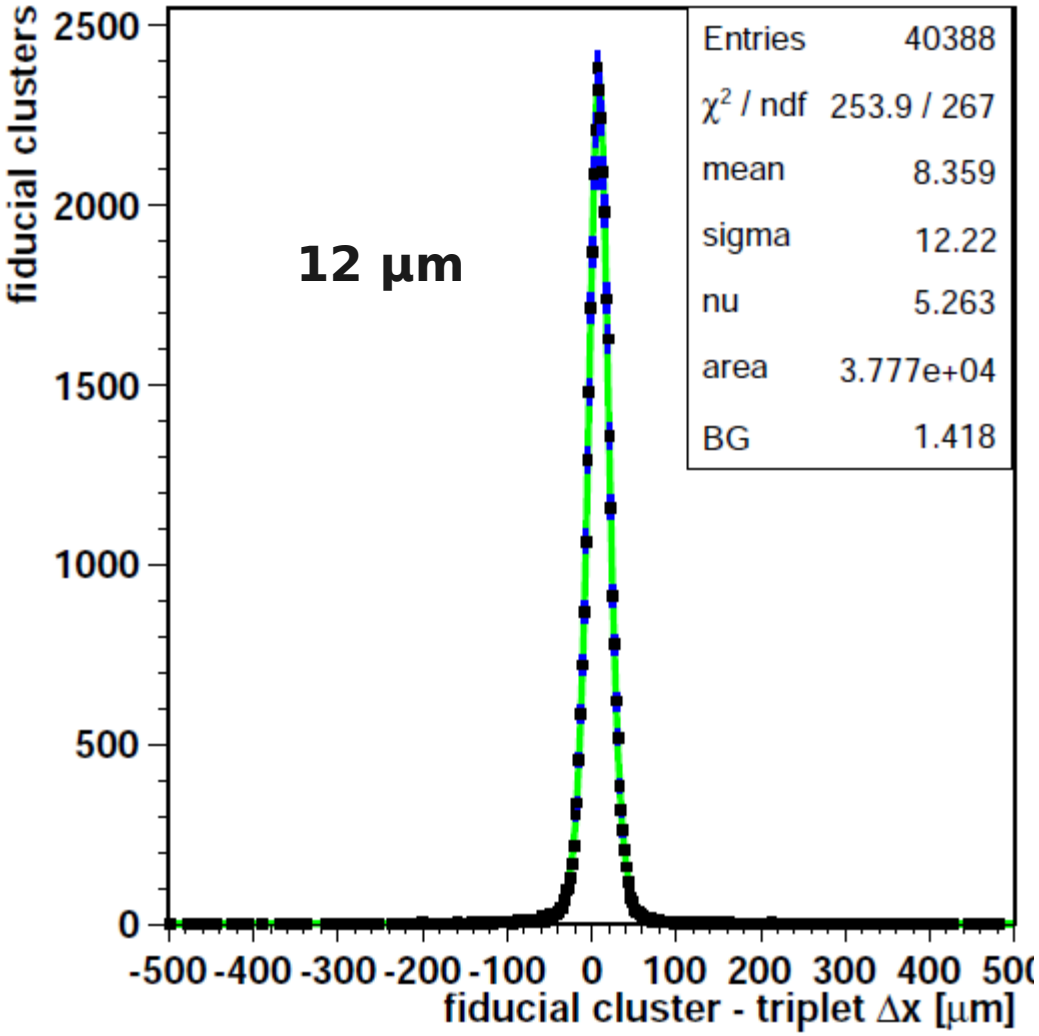
top view:



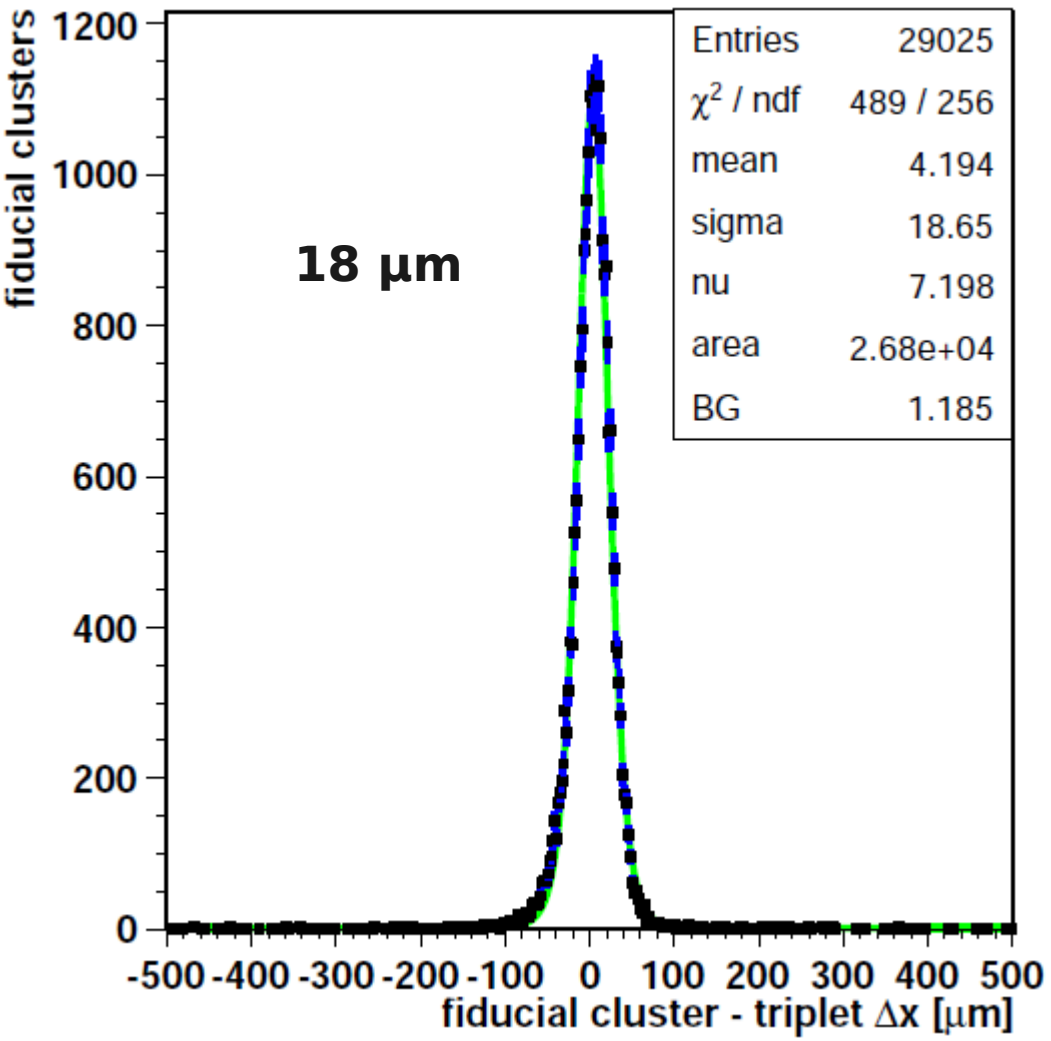
- Horizontal = columns
  - pixel width 150 µm
- turn angle:
  - charge sharing
  - residuals have Gaussian distribution
  - sigma = 12.2 µm
  - subtract telescope 7 µm
  - σ_{column} = 10 µm

column resolution at 27°

trim 30 (1.5 ke), run 6208

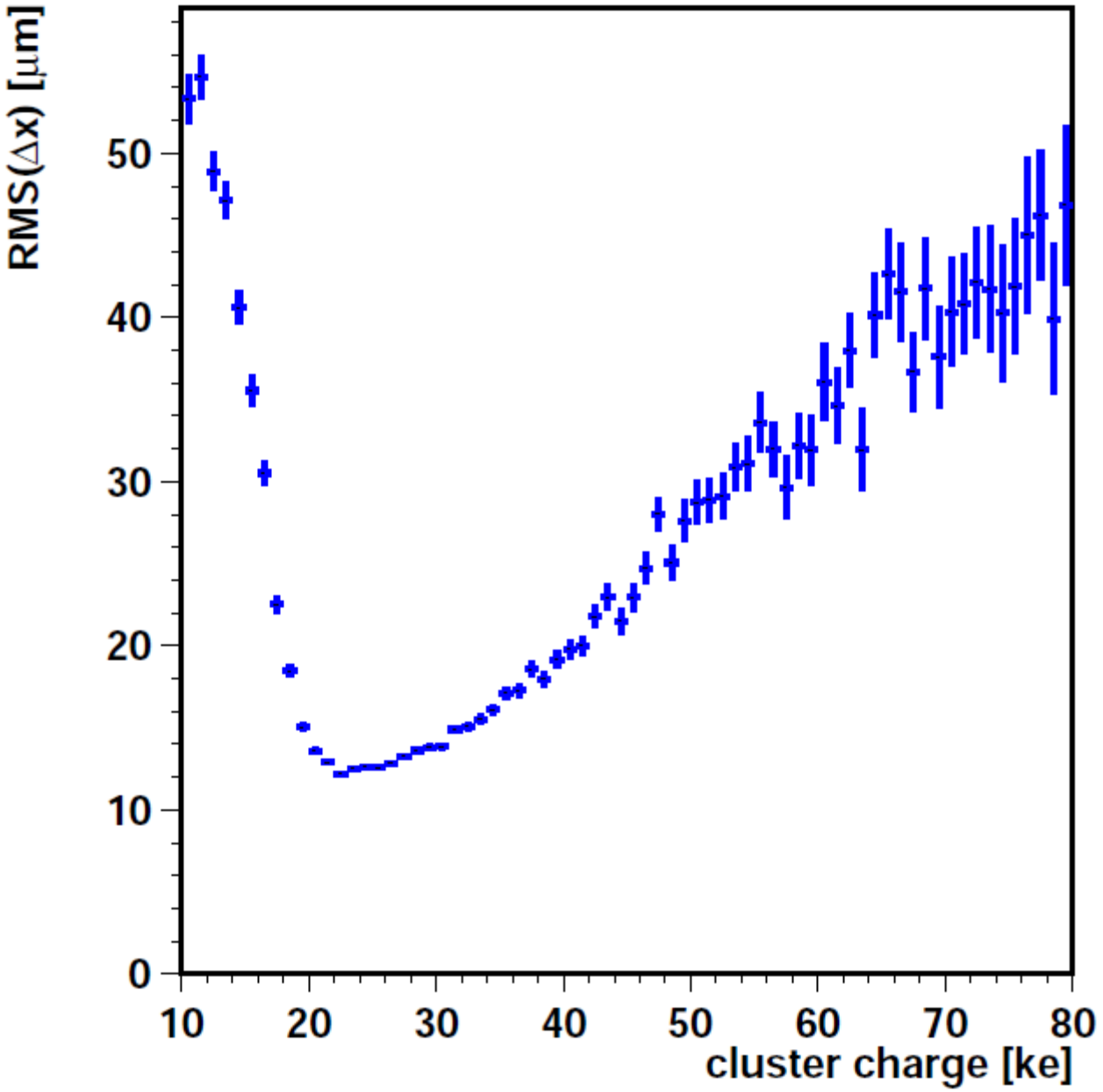


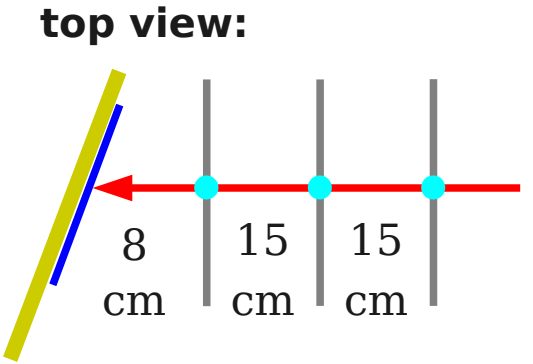
trim 80 (4 ke), run 6200



column resolution vs cluster charge

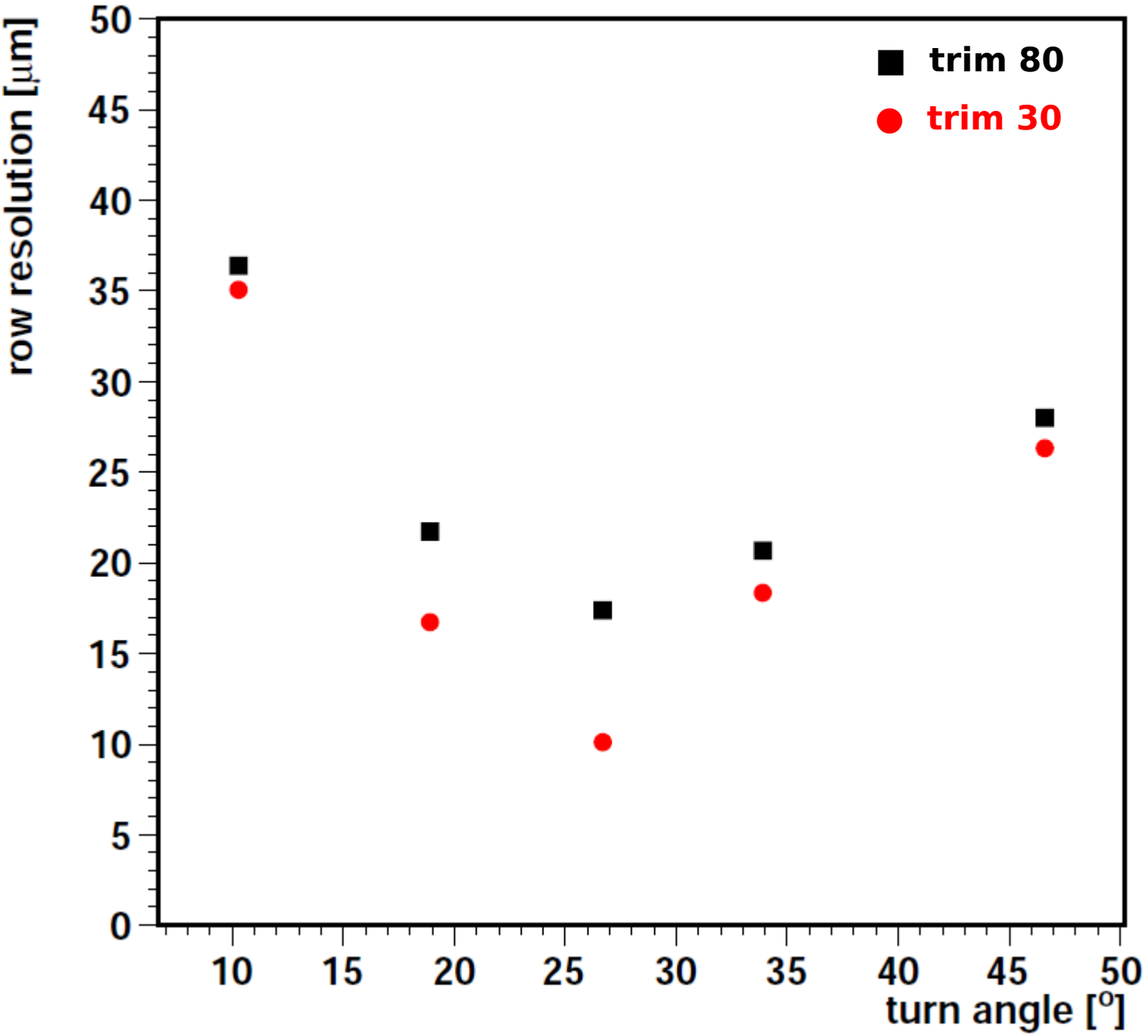
dig chip39, trim 24, run 5559, 4.4 GeV, 26° turn





- Best resolution for mips at the Landau peak around 24 ke
- Poor resolution below 18 ke:
  - broken clusters
- Poor resolution in Landau tail above 40 ke:
  - delta rays
- Select 18 < Q < 30 ke

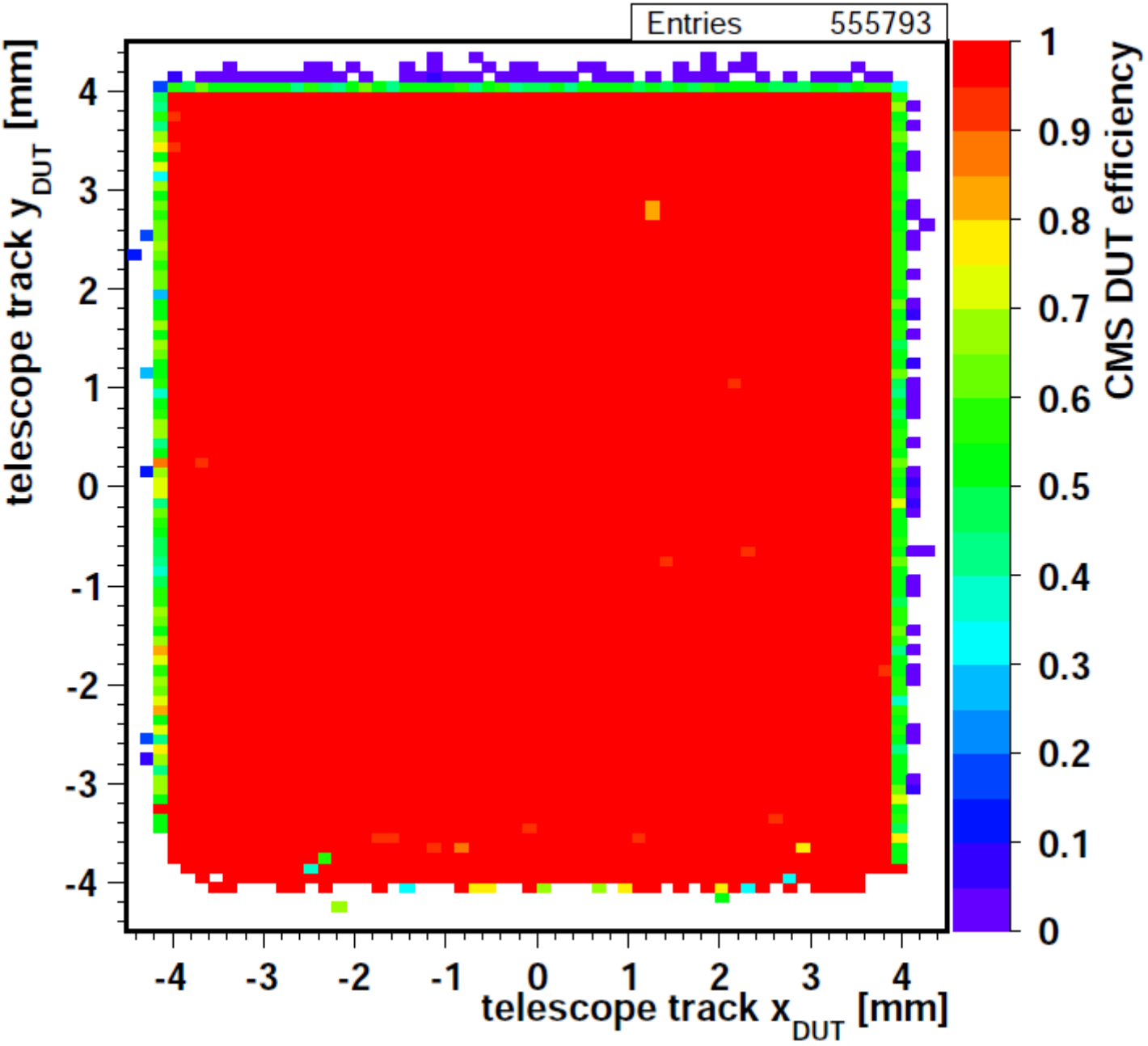
column resolution vs turn angle



- psi46dig chip 47:
  - Ia 25 mA
- optimal:
  - 10 µm at 27° with lowest threshold
- Less threshold dependence at other angles

efficiency psi46dig chip47

eff = (dig linked clusters) / (telescope tracks with REF cluster)



- chip 47
  - I_A 25 mA
  - trim 30
  - tilt 0°
  - turn 0°
- runs 6352-6371, selected
- **99.4% in fiducial volume**

Summary

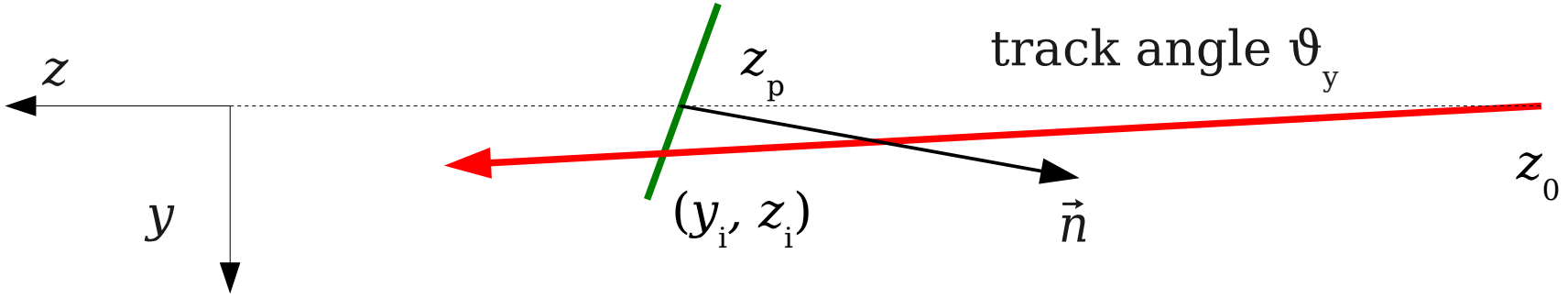
- Our test beam setup allows turning in addition to tilting
  - study charge sharing in column direction
  - extended up to 45° turn angle
- Optimal resolution at 27°:
  - 30% improvement by reducing threshold from 4 to 1.5 ke.
- Less improvement at other angles
- More studies possible:
  - efficiency
  - charge sharing vs track impact point
  - different cluster algorithmns

Back up

DESY Testbeam Schedule 2013 - version of December 14 2012

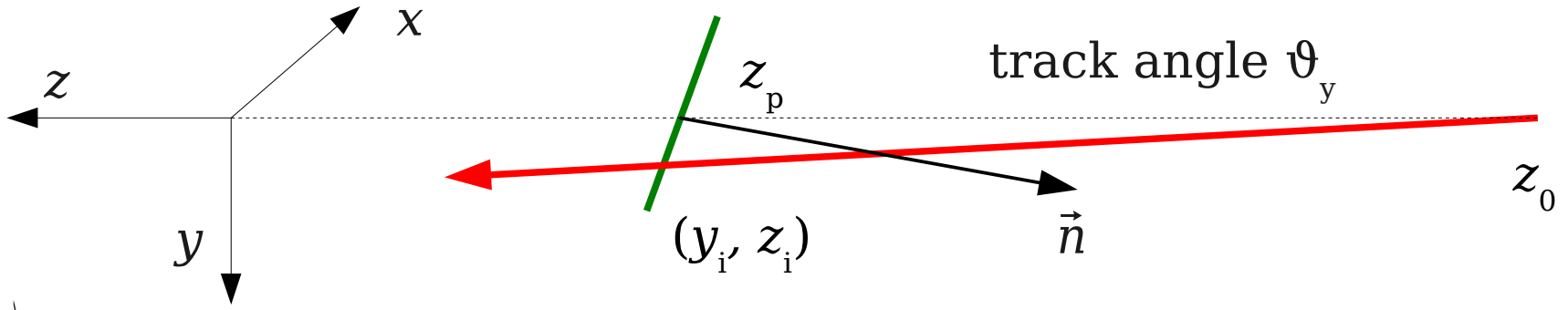
	Week		TB21		TB22		TB24/1		TB24
swapped			DATURA (telescope)	none	Telescope	CAL	Telescope PCMAG	PCMAG	none
	2		---	---	---	---	---	---	---
14-Jan	3		---	ITER	Tele setup				
	4		X0		---	CALICE AHCAL			
	5	swapped	CMS Pix-irrad	---	---	CALICE AHCAL	---	TPC MMG	ECAL
2-Feb	6	order	CMS Pix-fwd	---	ATLASPix	---	---	TPC MMG	---
	7		CLICpix	---	---	SiPM	LorAngle	---	---
	8		---	SiW ECAL	---	SiPM	LorAngle	---	---
	9		---	Sc ECAL	EUTelescope	---	---	DESY TPC	---
4-Mar	10								
	11		ALICE ITS	---	MuPix 2	---	---	DESY TPC	---
	12		CMS Pix-irrad	---	APIX PPS	---	---	DESY TPC	---
	13		CMS Pix-KA	---	APIX PPS	---	---	LCTPC Time	---
1-Apr	14		---	GRPC-SDHCAL	APIX IBL	---	---	LCTPC Time	---
	15		---	GRPC-SDHCAL	APIX DBM	---			
	16		X0		ILCPOL				
	17		---	SiW ECAL	ILCPOL		SBS GEM		
	18		---	SC ECAL	---	RD50	SBS GEM		
6-May	19		DEPFET	---	---	RD50	LorAngle		
	20		FE-I4		---	CAL MMG	---	GridPix	---
	21		CMS Pix-ro		---	CAL MMG	---	---	Belle 2 PID
	22		X0			CALICE AHCAL			
3-Jun	23		CLICpix	---	---	CALICE AHCAL			
	24		CLICpix	---	MuPix 3	CALICE AHCAL			
	25		ALICE ITS	---	APIX 3D		---	---	PICSEL
	26		CMS Trk II	---	DIA-SiGe	---	---	---	PICSEL

changes to EUTelescope code



- inclined track:
  - $x = x_0 + (z - z_0) \tan\vartheta_x$
  - $y = y_0 + (z - z_0) \tan\vartheta_y$
- sensor plane at z_p defined by normal vector $\vec{n} = (n_x, n_y, n_z)$
- plane equation: $\{ \vec{r} \mid \vec{n}(\vec{r} - \vec{r}_p) = 0 \}$
- insert track equation into plane equation to get intersect:
  - $z_i - z_0 = \left(n_z(z_p - z_0) - n_y y_0 - n_x x_0\right) / \left(n_x t_x + n_y t_y + n_z\right)$
  - get x_i and y_i by inserting z_i into track equations

Rotations and transformations



$$\begin{pmatrix} n_x \\ n_y \\ n_z \end{pmatrix} = R_y(\omega)\ R_x(\alpha) \begin{pmatrix} 0 \\ 0 \\ -1 \end{pmatrix}$$

$$R_y(\omega) = \begin{pmatrix} \cos\omega & 0 & \sin\omega \\ 0 & 1 & 0 \\ -\sin\omega & 0 & \cos\omega \end{pmatrix} \qquad R_x(\alpha) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{pmatrix}$$

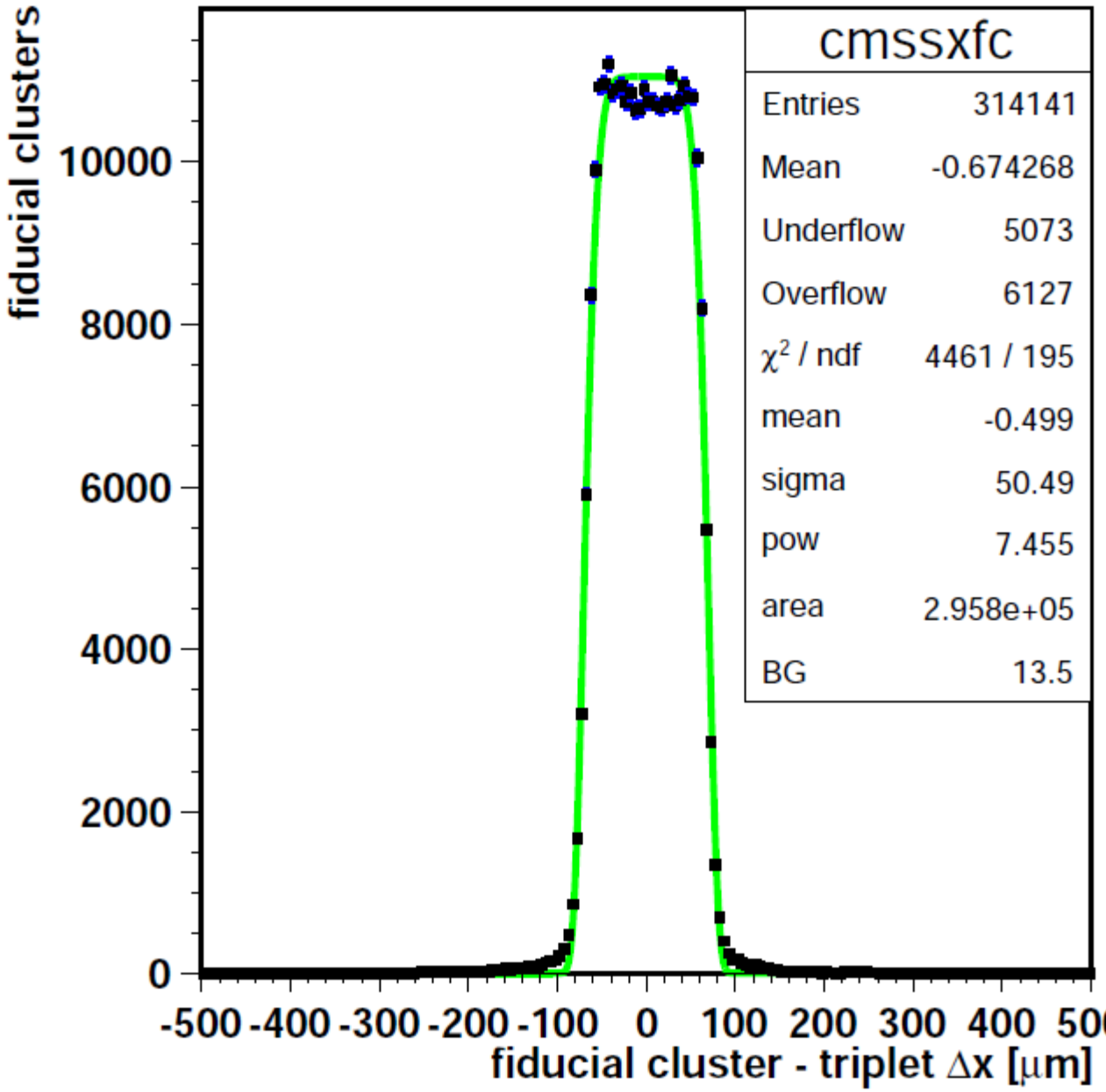
Transform intersect point into sensor coordinates:

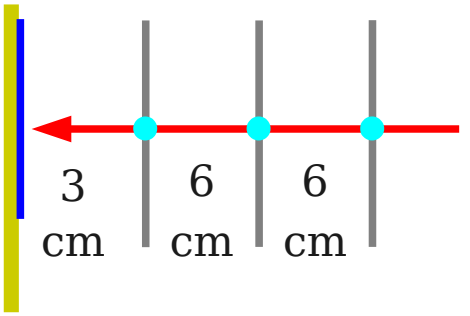
$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = R_z(\phi)\ R_x(-\alpha)\ R_x(-\omega) \begin{pmatrix} x_i \\ y_i \\ z_i \end{pmatrix} + \begin{pmatrix} a_x \\ a_y \\ 0 \end{pmatrix} \qquad \text{where} \quad z' = 0$$

with alignment parameters ϕ, α, ω, a_x, a_y.

column resolution at vertical incidence

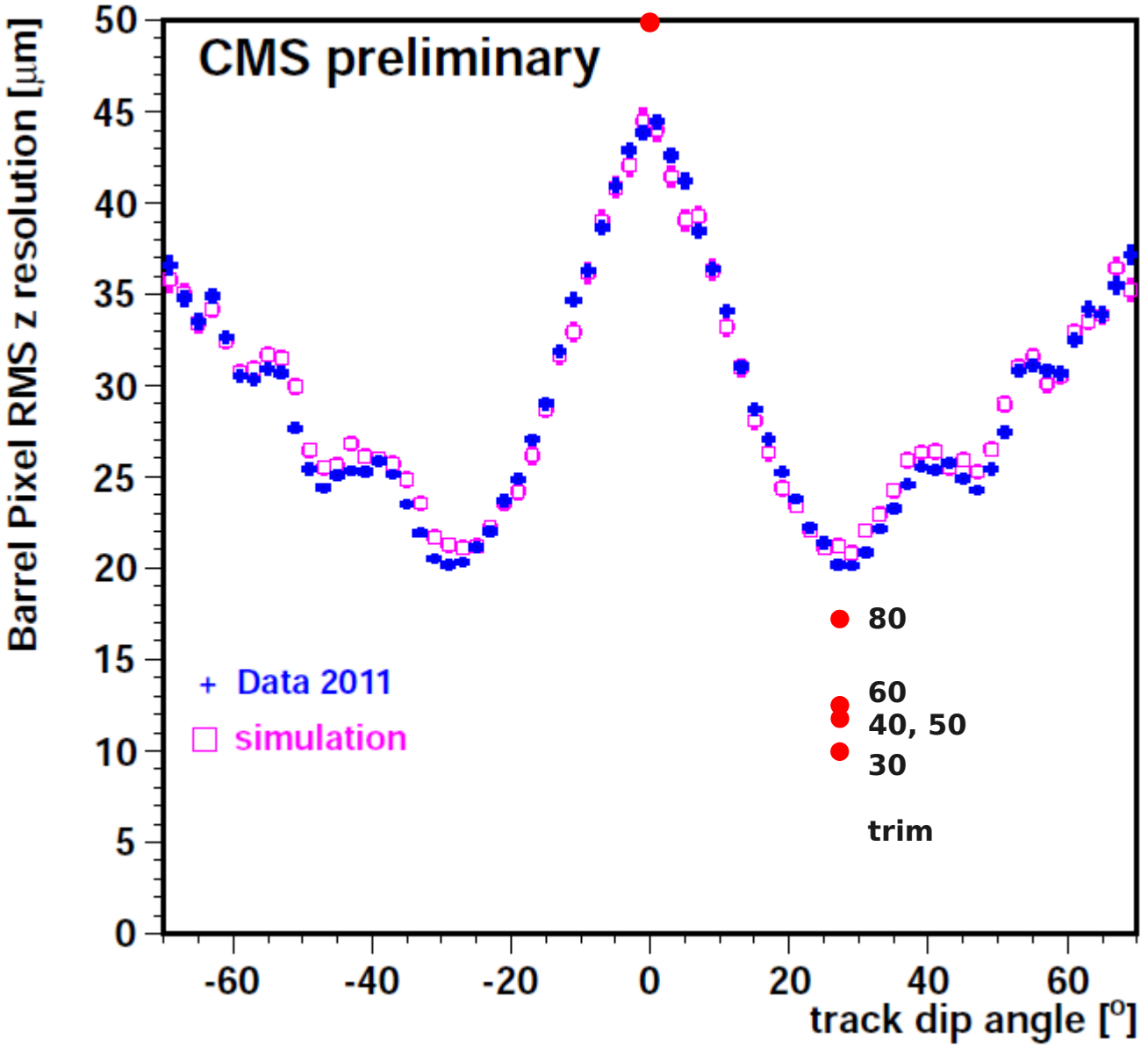
dig chip47, trim 24, run 5474, 4 GeV, 0° turn





- Horizontal = columns
  - pixel width 150 µm
- Vertical incidence:
  - no charge sharing
  - residuals have box distribution
- Fit with generalized error function
  - Residual: 50 µm,

beam test vs CMS



- caveat: truncated RMS vs Student's t fit
- data at 9°, 18°, 36°, 45° to be analyzed...