Thin sensor test beams: status and future plans

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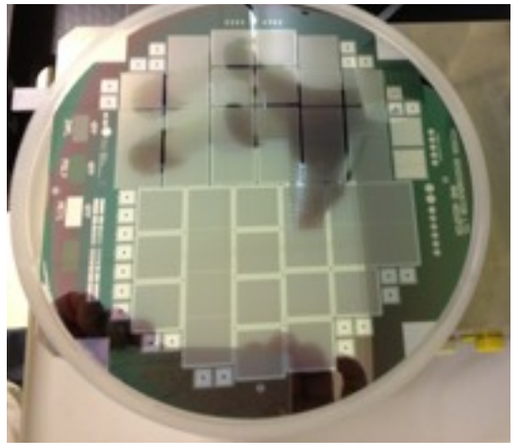
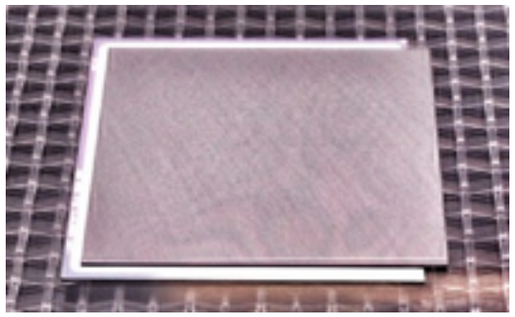
on behalf of the LCD vertex group

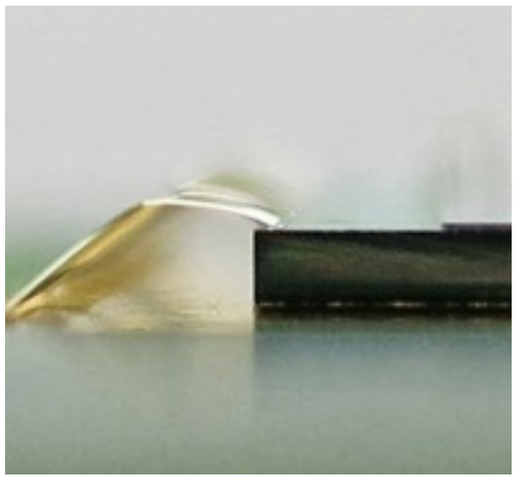
CLICdp collaboration meeting 11.06.14

Thin sensor test beams: status and future plans

- 2013 DESY test beams
- Test beam data analysis
- Comparison of data with simulation
- 2014 LNLS test beam
- Sensor calibration
- Upcoming 2014 CERN test beams
- Sensor procurement







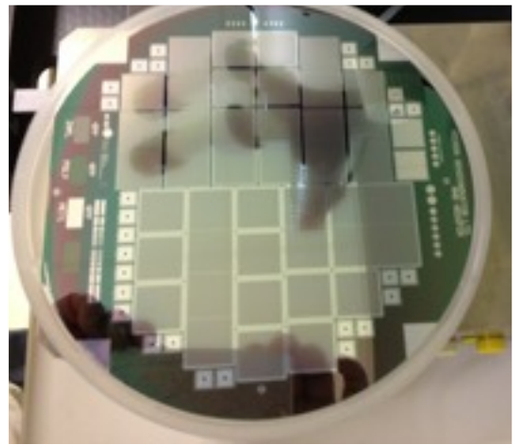
2013 DESY test beams

- 7 weeks of test beam at DESY between Feb 2013 and Feb 2014
- Data recorded with 17 different sensors:

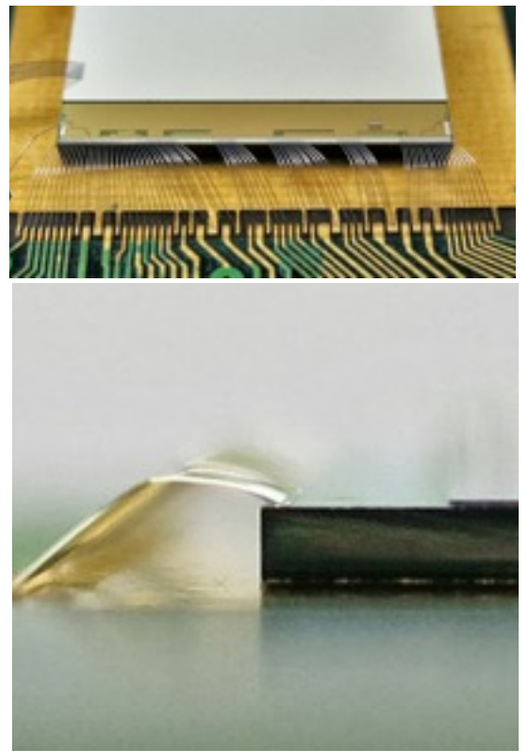
Assembly	Sensor producer	Sensor thickness [um]	Sensor type	Sensor edge design	ASIC thickness [um]
B04-W0110	Advacam	50	p-in-n	50 um active	750
A06-W0110	Advacam	50	p-in-n	20 um active	750
C04-W0110	Advacam	50	p-in-n	50 um active	750
C06-W0110	Advacam	50	p-in-n	20 um active	750
J09-W0110	Advacam	50	p-in-n	50 um active	750
C06-W0126	Micron	100	p-in-n		100
D05-W0126	Micron	100	p-in-n		100
D09-W0126	Micron	100	p-in-n		100
L04-W0125	Micron	100	p-in-n		750
L05-W0125	Micron	100	p-in-n		750
D04-W0125	Micron	150	n-in-p		750
D05-W0125	Micron	150	n-in-p		750
D08-W0125	Micron	150	n-in-p		750
B06-W0125	Micron	200	n-in-p		750
B07-W0125	*Micron*	*300*	*p-in-n*		*750*
I10-W0015	Canberra	300	p-in-n		750
D03-W0170	Canberra	500	p-in-n		750

~175M events recorded

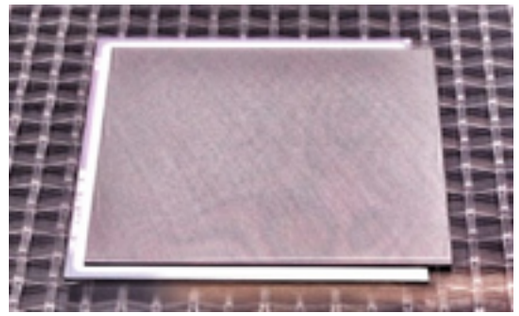
- Characterise thin sensor assemblies with 55 um pixels
- Validate simulation and extrapolate to 25 um pixels



200 um thick Sensor wafer



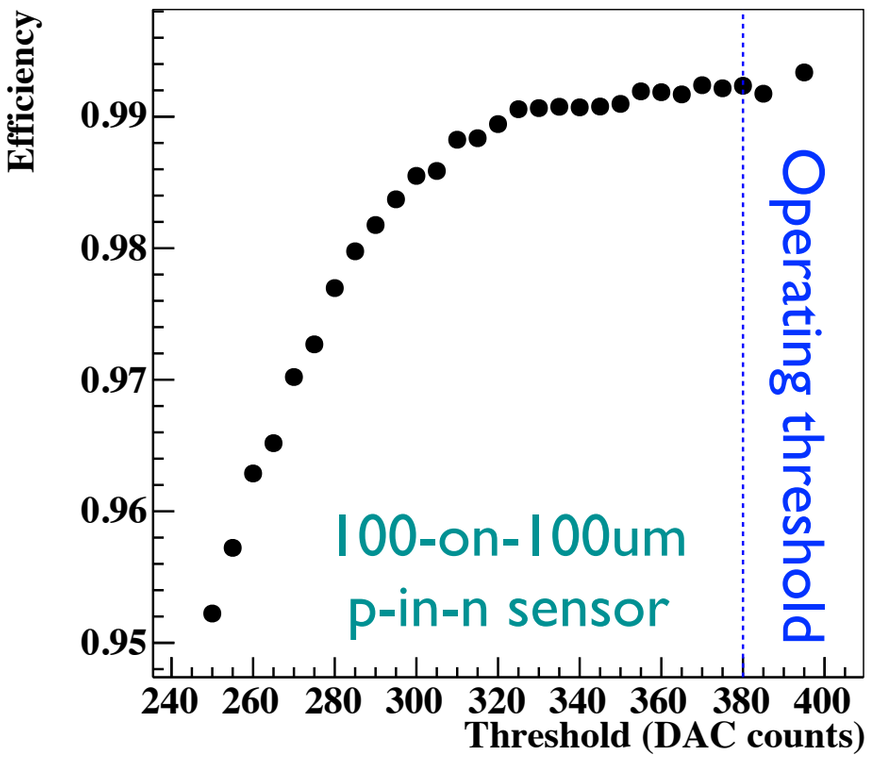
50um Sensor on 750um ASIC functional Timepix assembly

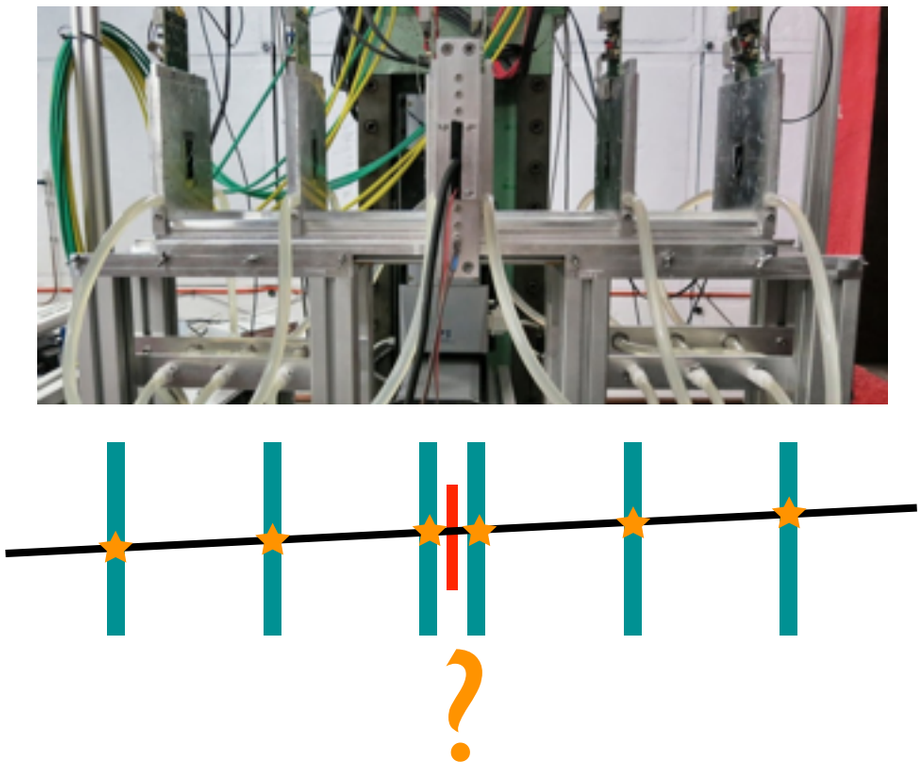


100um ASIC -on-100um Sensor functional Timepix assembly

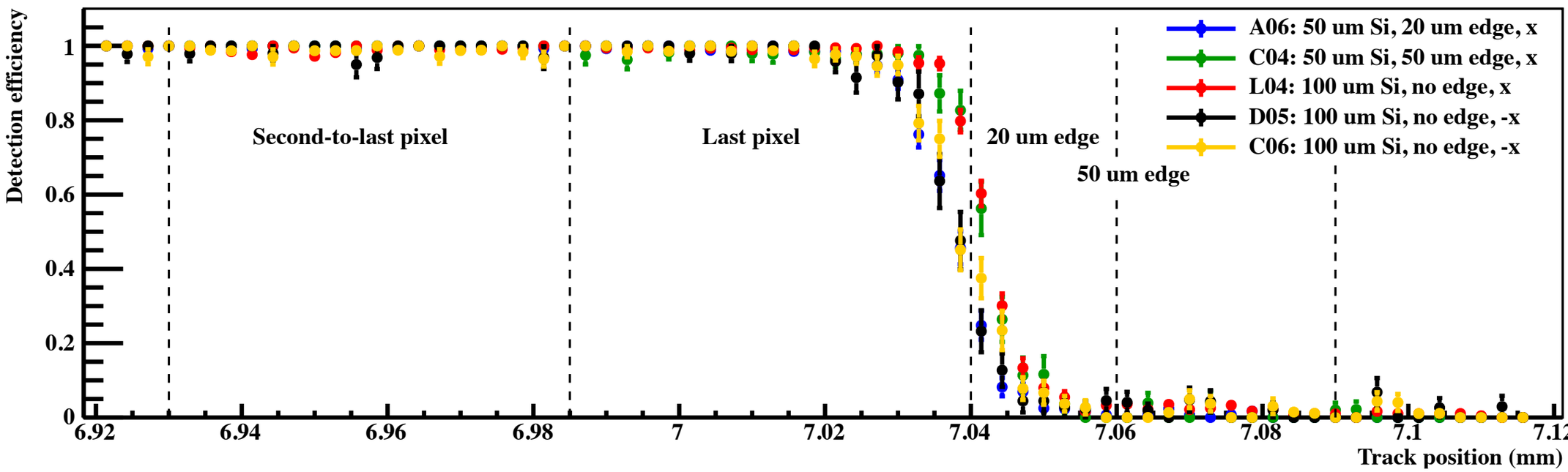
Test beam data analysis: detection efficiency

- Is a hit detected where we expect from using the telescope to extrapolate track to DUT?

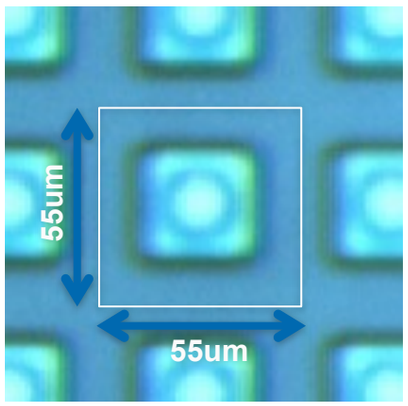




- Edge efficiency: how does the detection efficiency vary at the edge of the sensor?

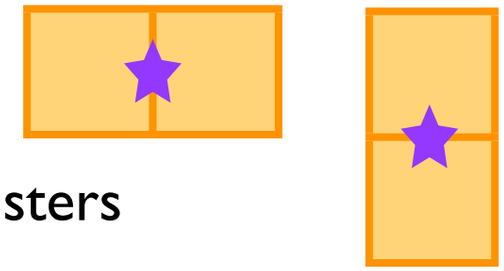


Implant size vs pixel size

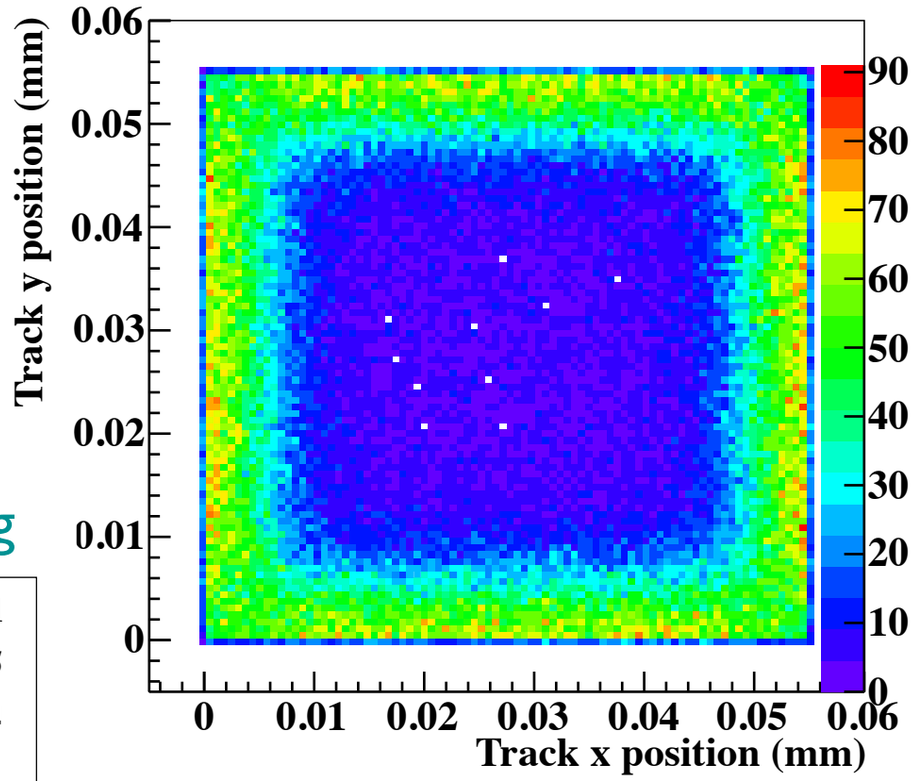


Charge sharing and resolution

- Two hit cluster topologies:

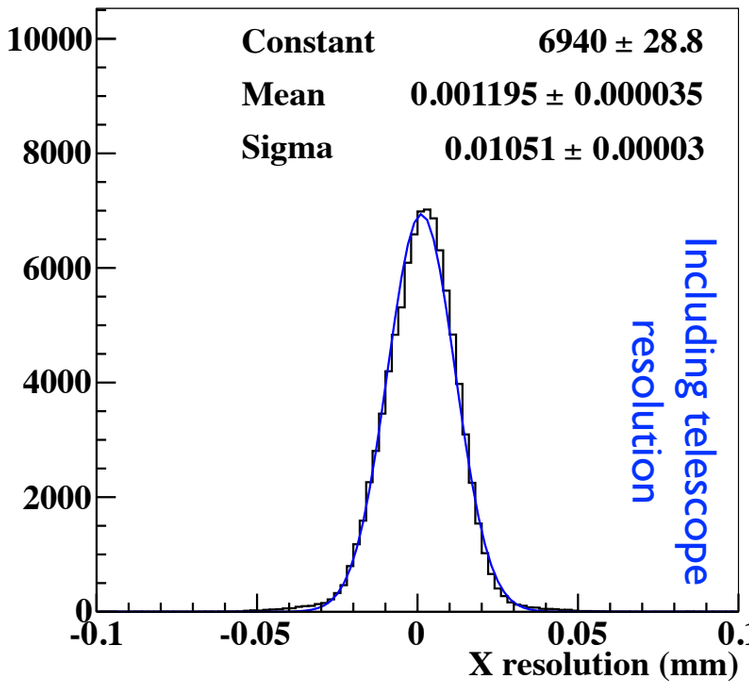


- Track position for two hit clusters

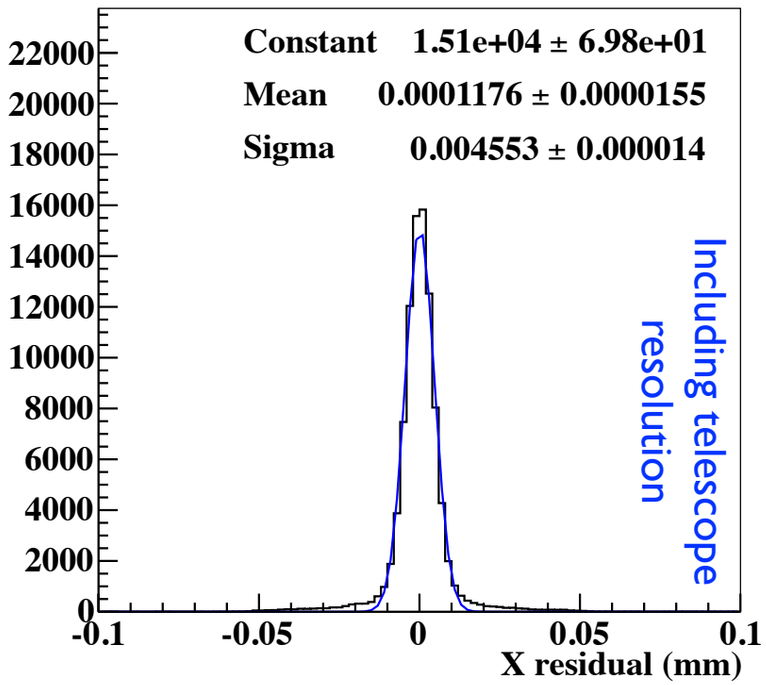


- Effect of eta correcting charge weighted method

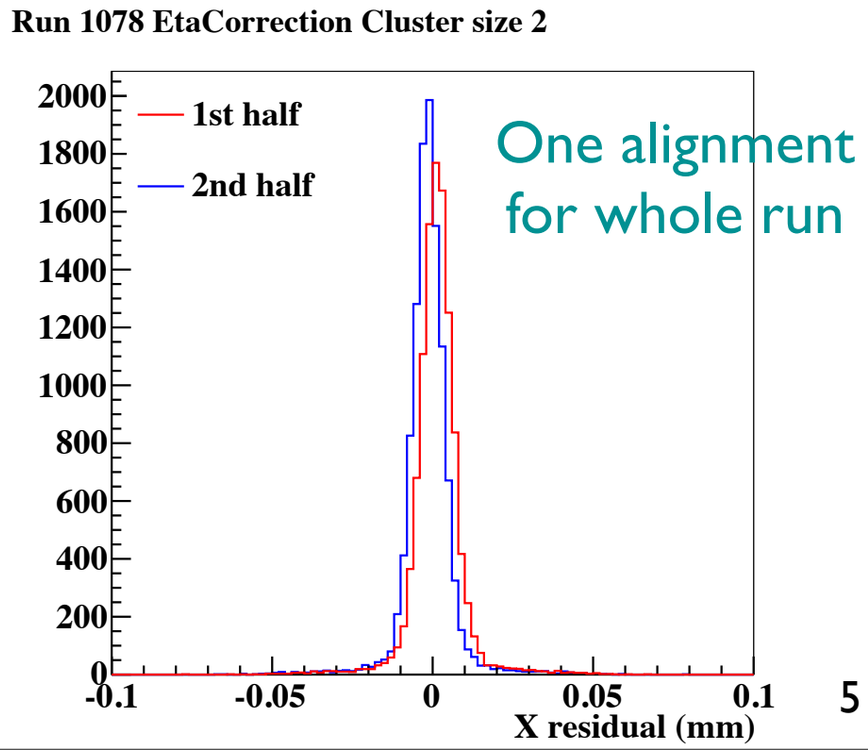
Linear charge weighting



Corrected charge weighting

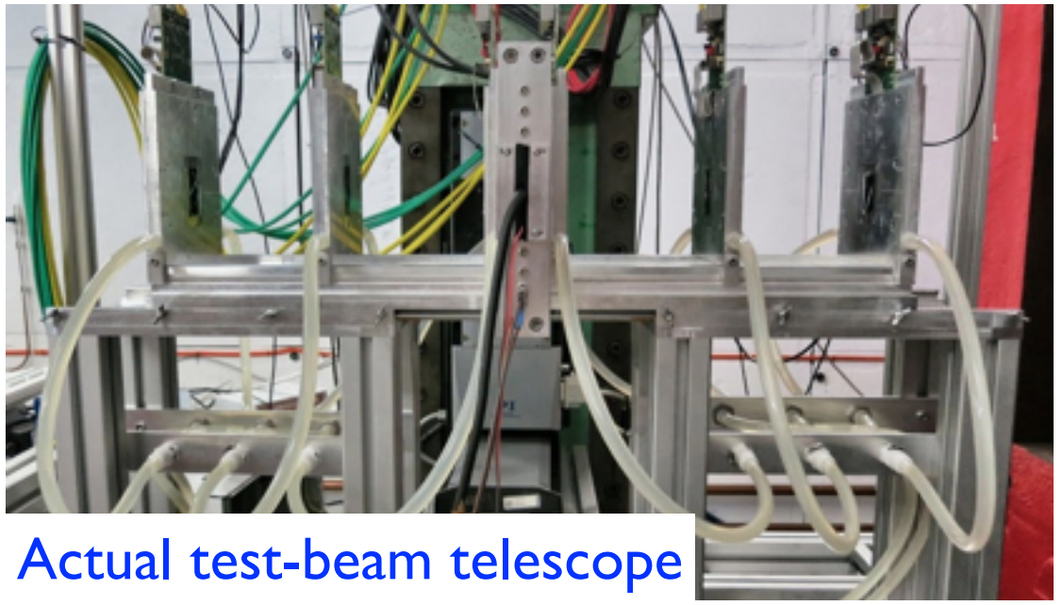


- But, alignment has a large effect on measured resolutions
- Can we align / correct within a run?

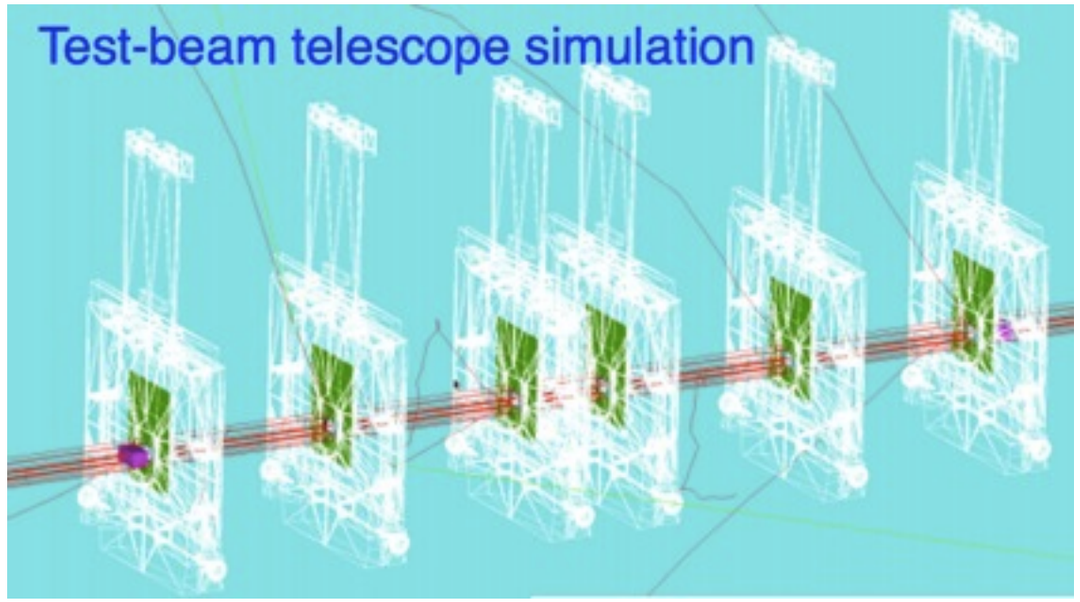


Test beam simulation: AllPix

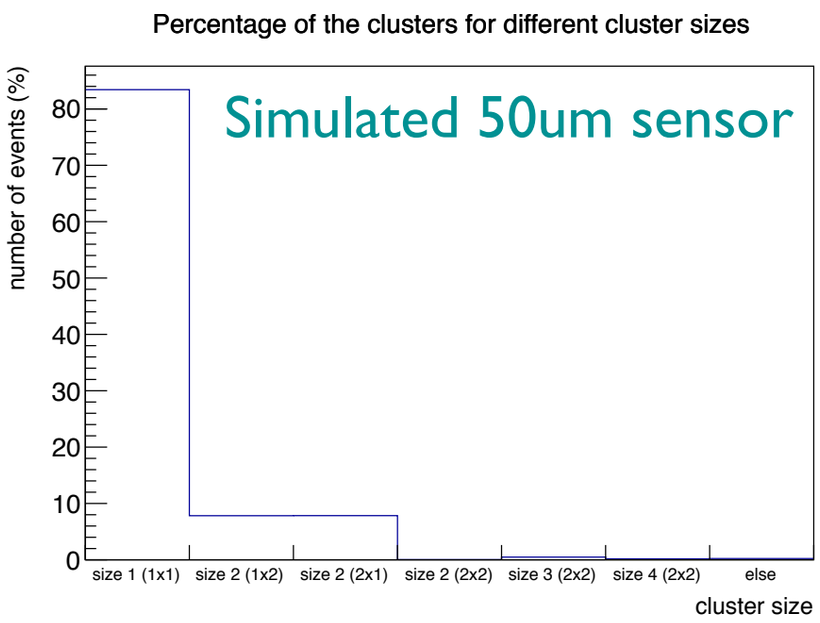
- AllPix: a general purpose pixel detector simulation and digitisation framework
  - based on Geant4 and TCAD
  - fully customisable geometry
  - used for simulation of test beam and lab measurements
  - used in ATLAS and CLICdp
- Will allow extrapolation of test beam results to small-pitch pixels

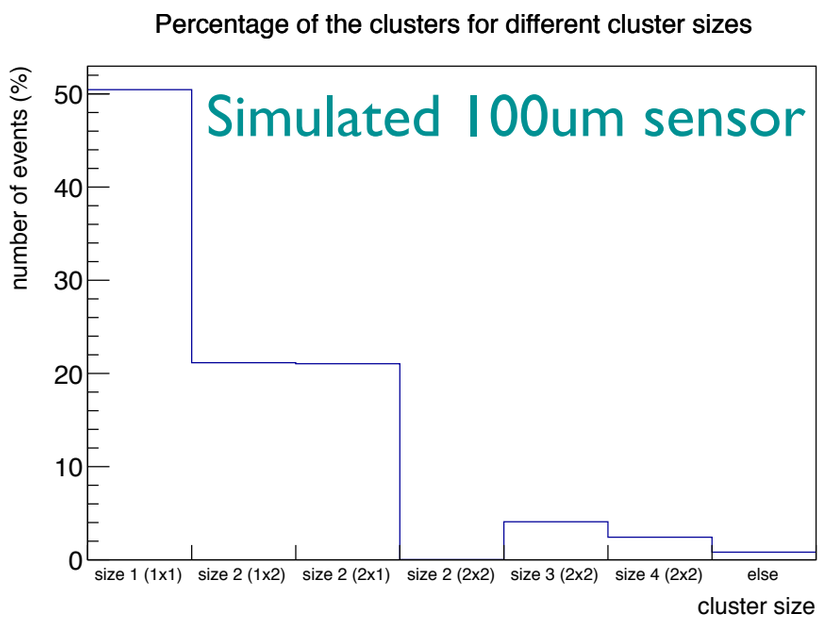


Actual test-beam telescope

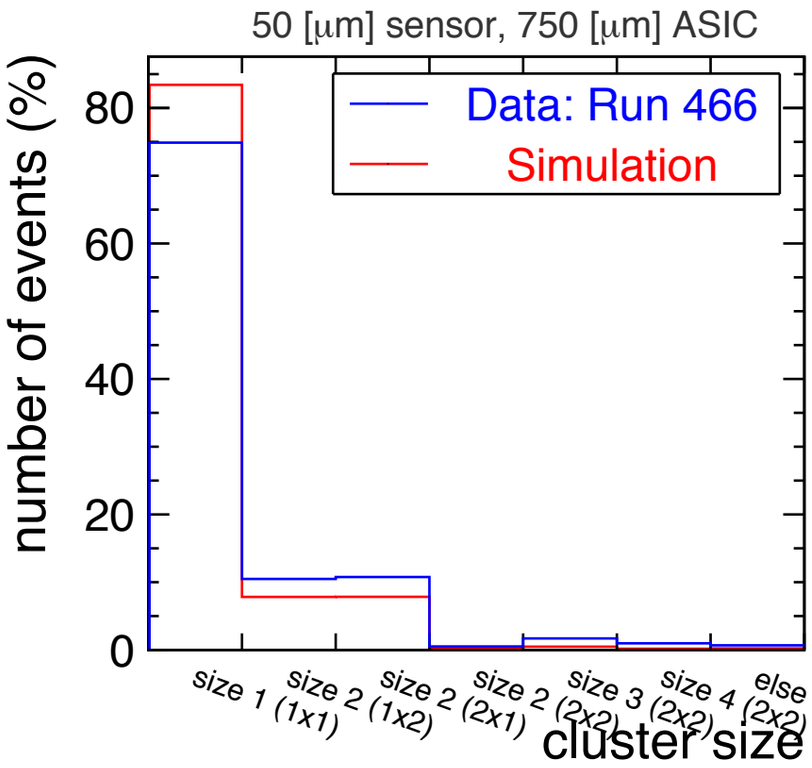


Comparison of data with simulation



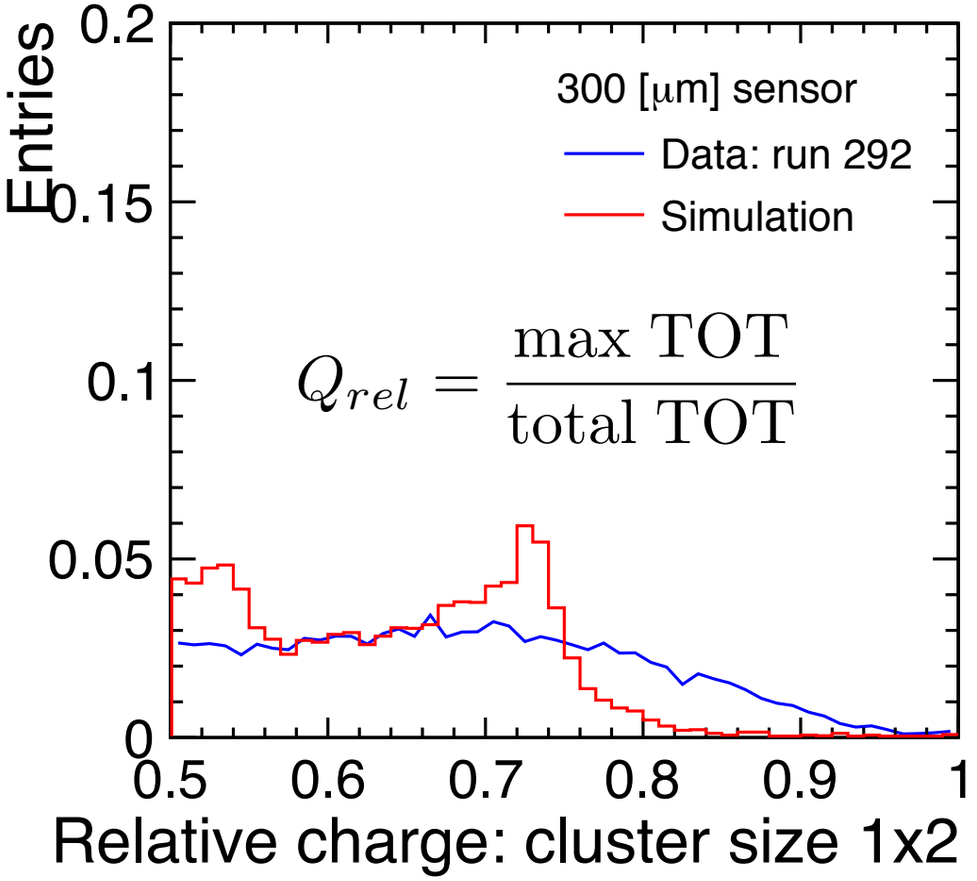


Charge sharing increases with sensor thickness

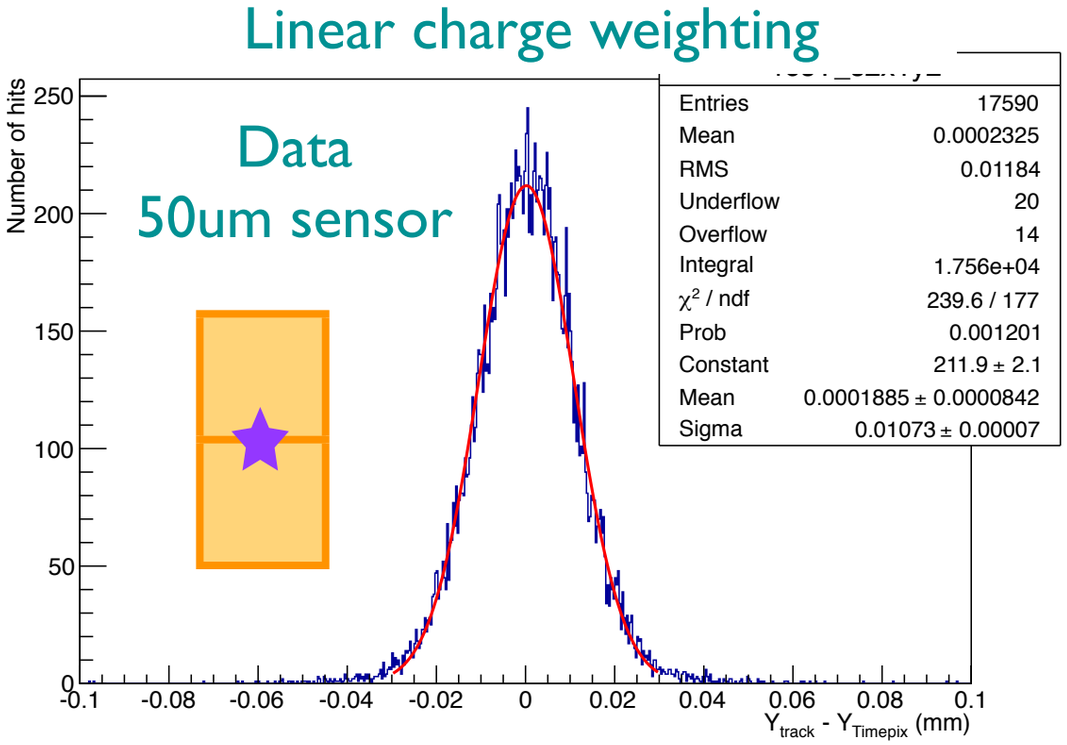


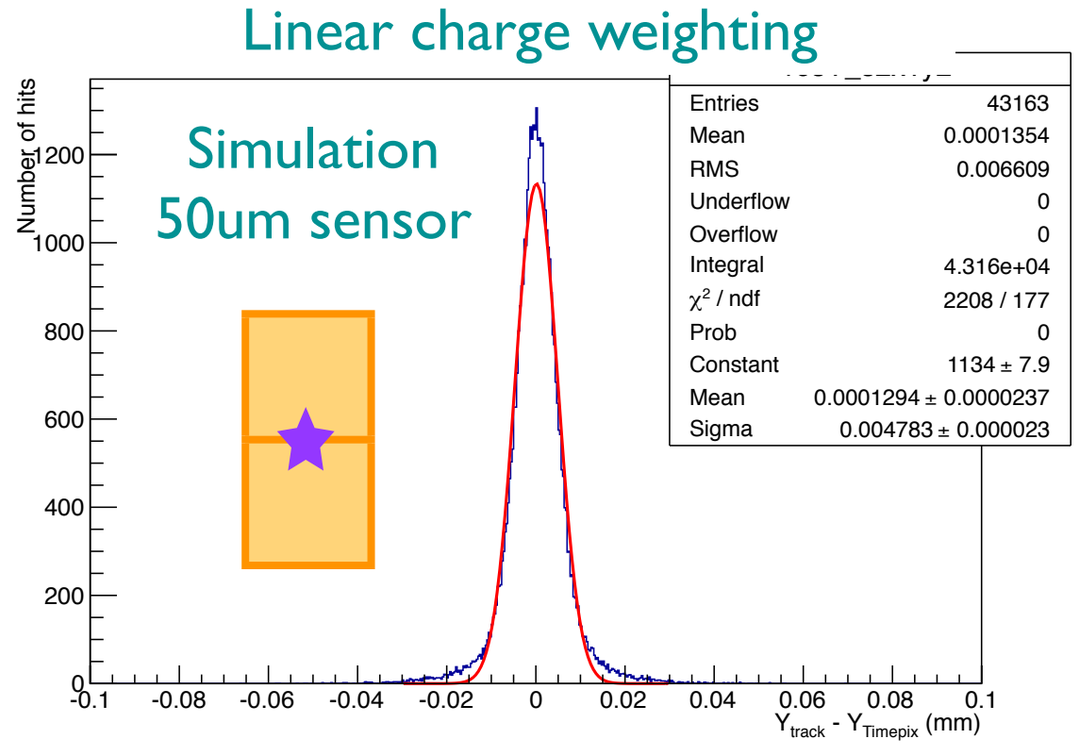
But not enough charge sharing in simulation compared to data

Relative charge (how the charge is shared between two pixels) looks suspect



Resolution comparison

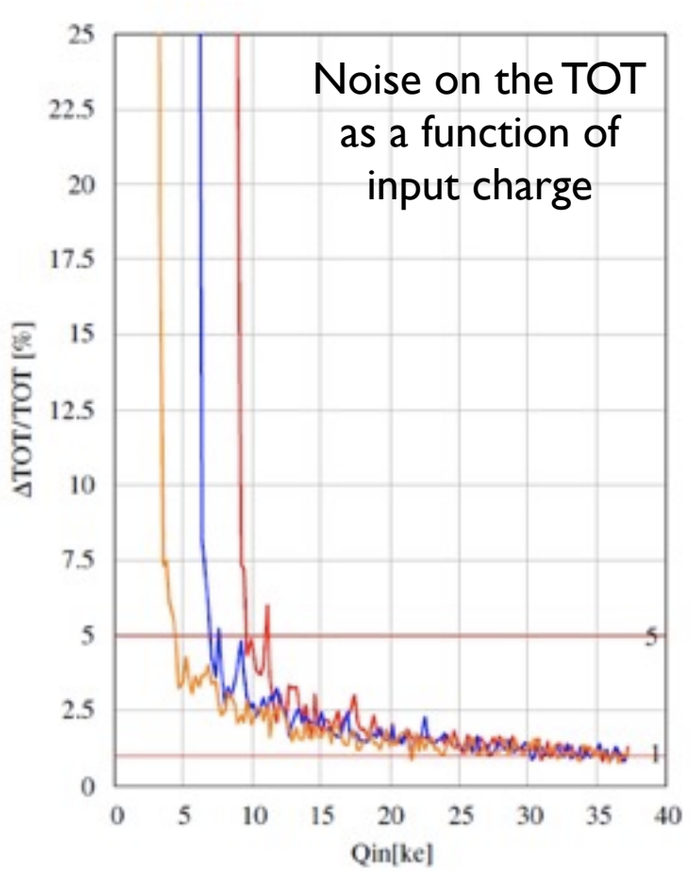




- Resolution too good in simulation (charge weighted method, also true of eta correction method)

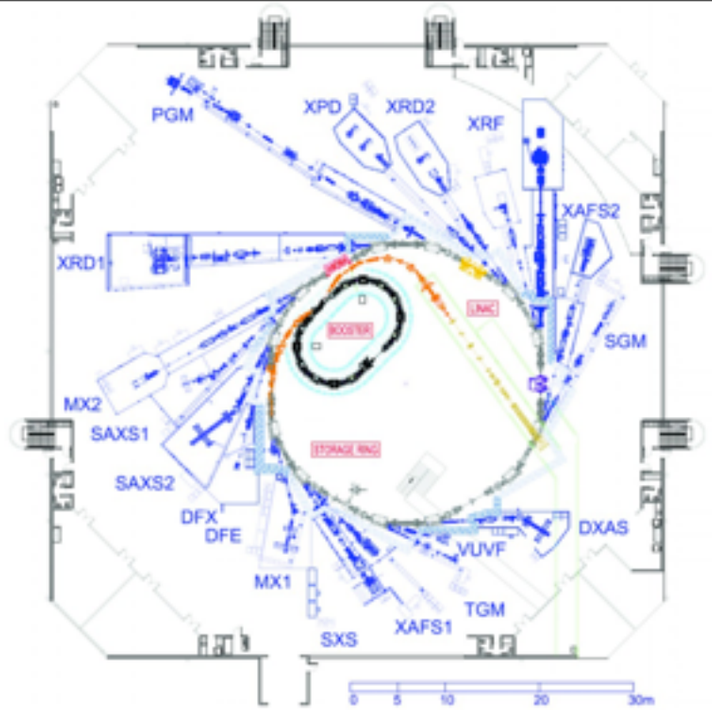
Future plans for AllPix:

- Understand charge sharing difference with data
- Introduce noise due to electronics
- Better electric field simulation in sensor
- Simulate active edges on sensors



2014 LNLS test beam

- Fluorescence measurements with 10^{12} photons per second
- Additional calibration points for sensor A06:

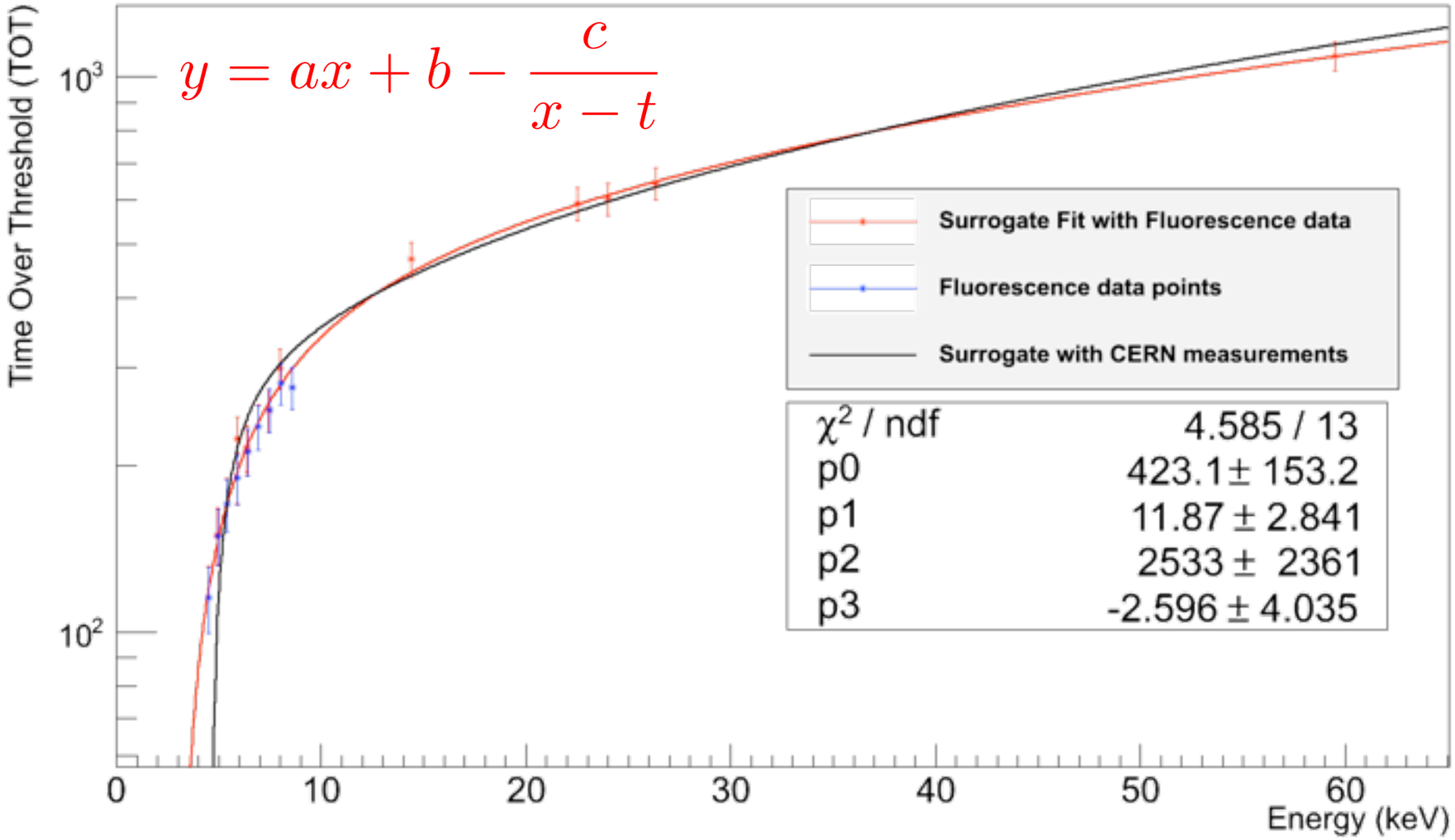


CERN

Target/Source	^{55}Fe	Brass	^{09}Cd	Indium	^{241}Am	^{241}Am
E (kα) in keV	5.8	8.1	22.9	24	26.2	60

LNLS

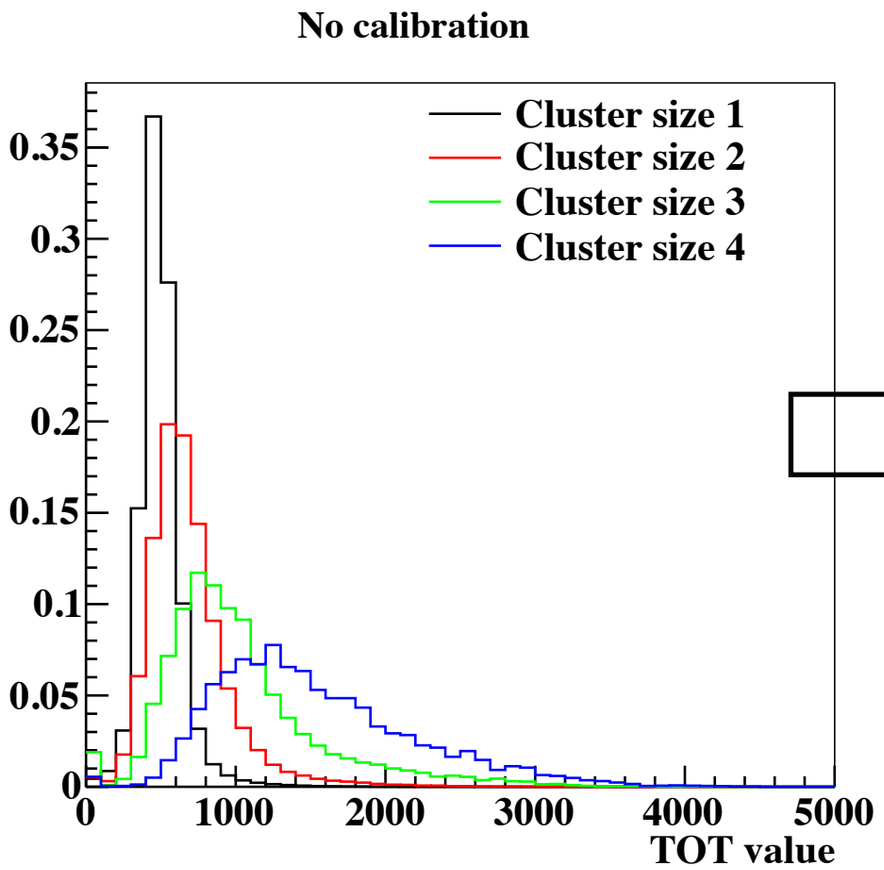
Target	Co	Cr	Cu	Fe	Mn	Ni	Ti	V	Zn
E (kα) in keV	4.51	4.95	5.414	5.89	6.4	6.93	7.47	8.04	8.63

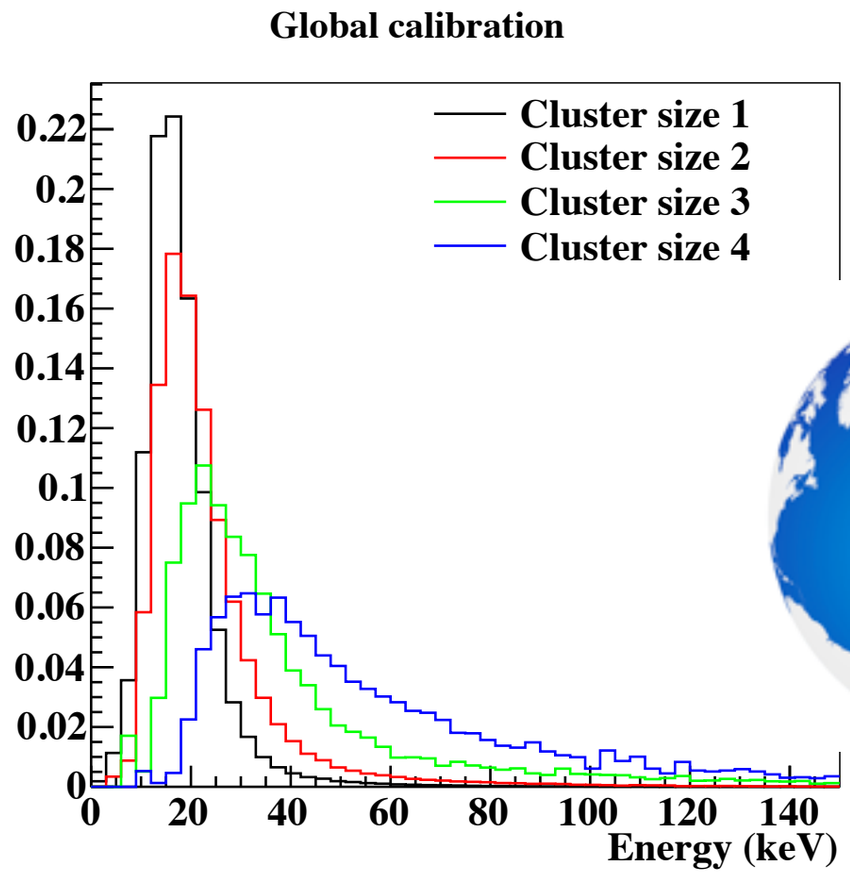


Additional data from LNLS better constrains the 'knee'

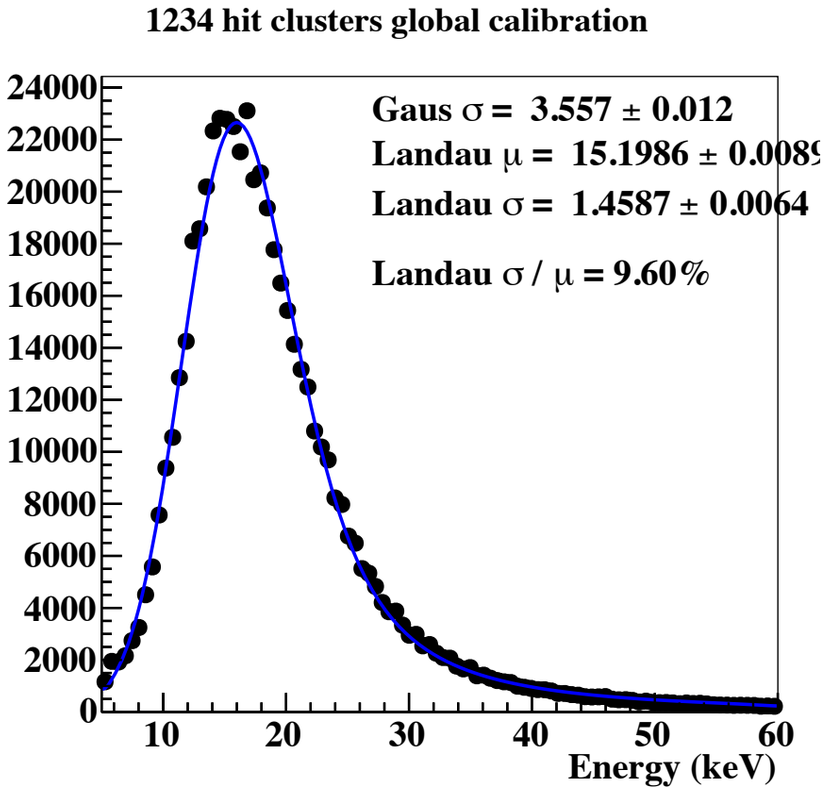
Analysis of systematic uncertainties ongoing

Application of calibration to DESY test beam data





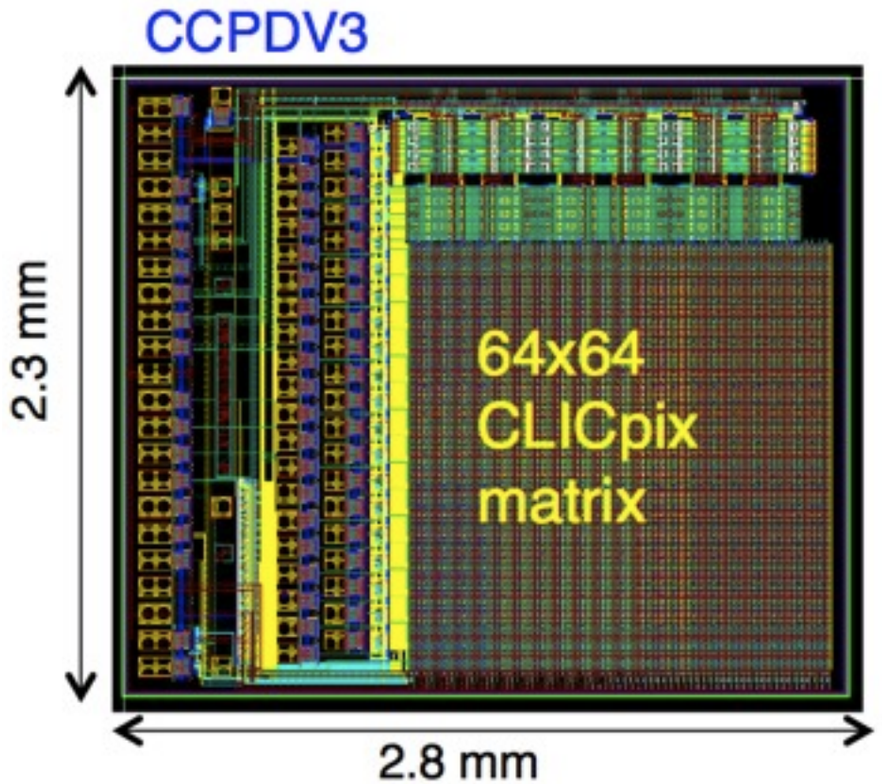
- Global calibration of DESY test beam data of sensor A06 using CERN, LNLS data
- Energy distributions of cluster sizes close up but don't align - high energy deposits tend to have larger cluster sizes
- Landau MPV as expected for 50um sensor



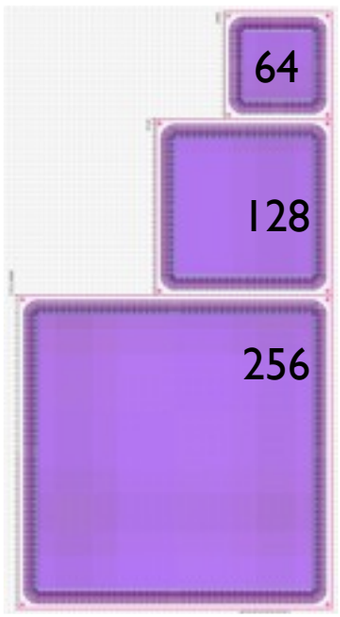
See following talks for technology details

Sensor procurement 1

- Summer: Timepix3 + Canberra sensors to test ASIC
- Summer: CLICpix + CCPDV3 sensors (HV-CMOS active sensor with capacitive coupling)
  - Test feasibility of low mass interconnect with layer of glue
- Autumn: Micron production of sensors matching CLICpix footprint (25 x 25 um pixels)



- First trial for die bonding and bump bonding using indium bumps to take place at SLAC using CLICpix



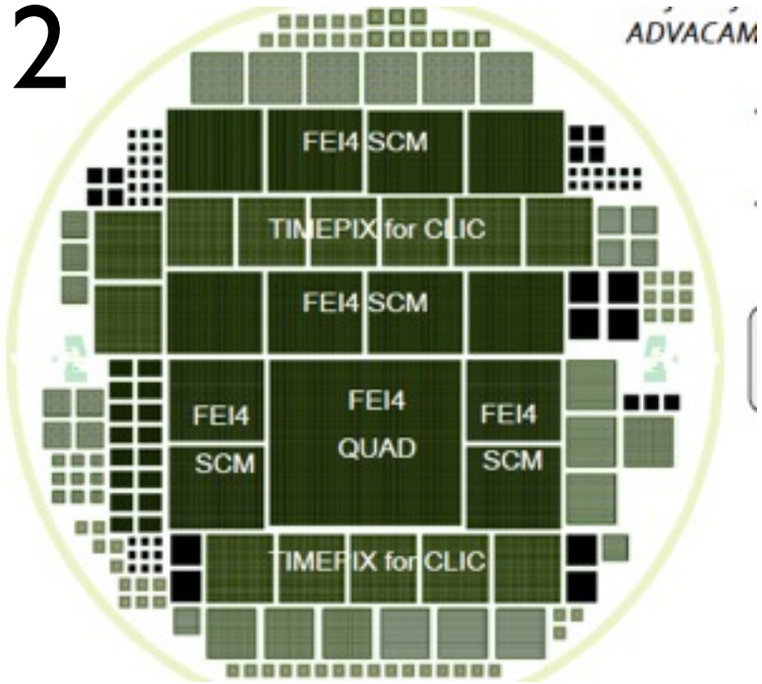
CLICpix design for Micron production

Micron production wafer layout

Sensor procurement 2

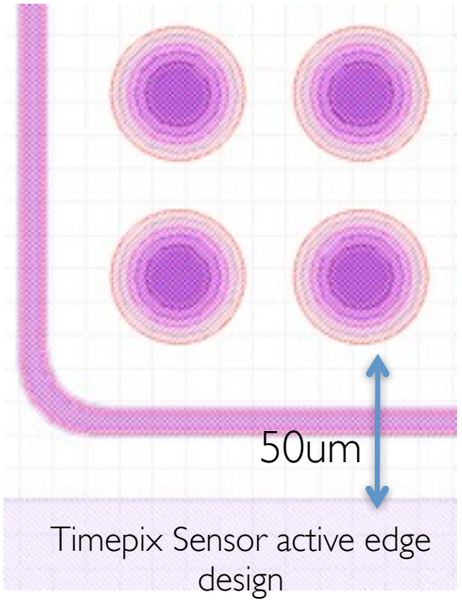
Long term: Advacam multi-project wafer:

- ATLAS, UNIGe, CLICdp
- 15 thin wafers: 5 x 50um, 5 x 100um, 5 x 200um
- Timepix1, Timepix3 and CLICpix compatible sensors
- 20um and 50um active edges

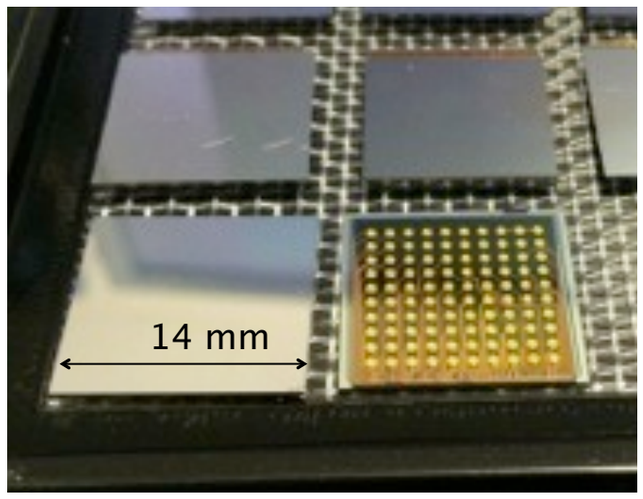


ADVACAM multi-project wafer layout

- Possibility to flip-chip to Timepix3 with TSV (parallel project with CEA-Leti) (end of the year)
  - TSV already demonstrated with Medipix3
  - next phase: TSV with 50um thick Timepix3



Timepix Sensor active edge design




Medipix Collaboration + CEA-Leti

First Medipix3 Image taken with TSV assembly (fish head):

2014 CERN test beams

Igor Rubinskiy - TIPP'14

		Particle type	Energy, GeV	N particles per pulse	length, seconds	next pulse/bunch/spill
DESY II	LINAC primary	e (prim.)	6.3	$< 10^{10}$	eff~0.040	0.080 (12.5 Hz)
	secondaries	e+/e−	1 – 6	$< 10^{3}$	instant	> 1 μs
CERN	PS East (T9)	e/hadrons/μ	1 – 15	$< 10^{6}$	0.400	33.6
	SPS North (H6)	e/hadrons/μ	5 – 205	$< 10^{8}$	4.9 – 9.6	14 – 48

- Timepix1: time structure is much less favourable for the shutter-based slow readout, leading to a much lower data-taking efficiency at CERN than at DESY
- Timepix3 the readout is much faster, resulting probably in a better data-taking efficiency
- PS: August 14 - 21, October 1 - 8
  - additional 100-on-100 assemblies, repeat 300um silicon sensor, new Timepix3 and CLICpix+CCPDV3 tests, rate limited so focus on basic runs, nominal parameters, telescope integration
- SPS: November 10 - 17
  - CLICpix+CCPDV3 at higher rate, CLICpix hybrid assemblies, Timepix3 at higher rate, angle runs, bias and threshold scans

Thin sensor test beams

Summary

- Successful test beam campaign at DESY - still in the process of analysing and extracting results
- Data analysis including efficiencies, resolutions and calibrations
- Simulation will be validated against data, then used to study further properties of thin assemblies and extrapolate to smaller pitch
- LNLS test beam improved sensor calibration
- CERN test beams later this year: testing new readout ASICS and assembly technology

Thanks for material: N. Alipour Tehrani, M. Benoit, D. Dannheim,