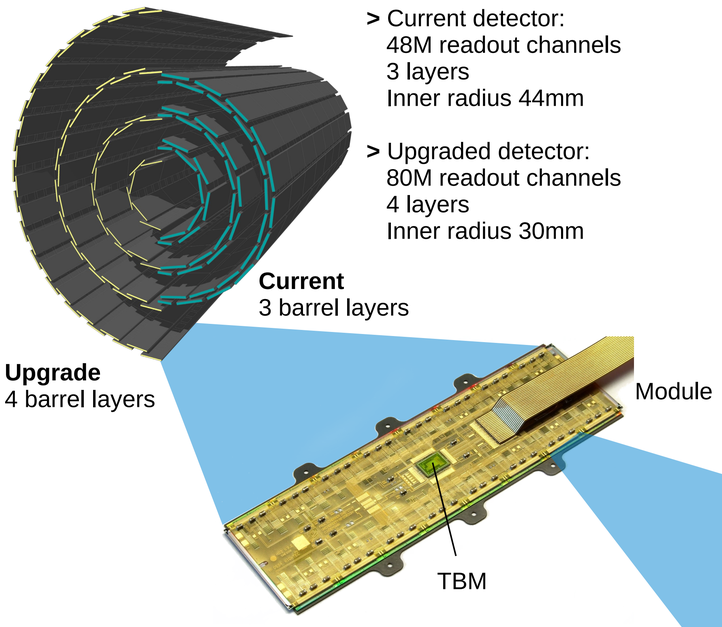
Test Beam Campaigns for the CMS Phase I Upgrade Pixel Readout-Chip.

Simon Spannagel for the DESY CMS Pixel Detector Group
10th International Conference on Position Sensitive Detectors, 7-12/9/2014

CMS Barrel Pixel Detector

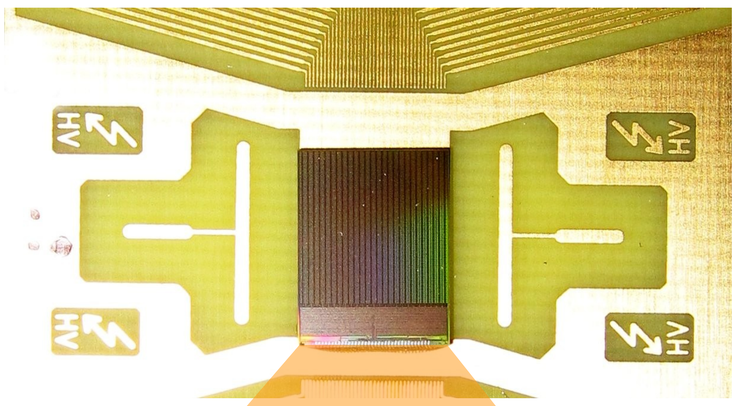


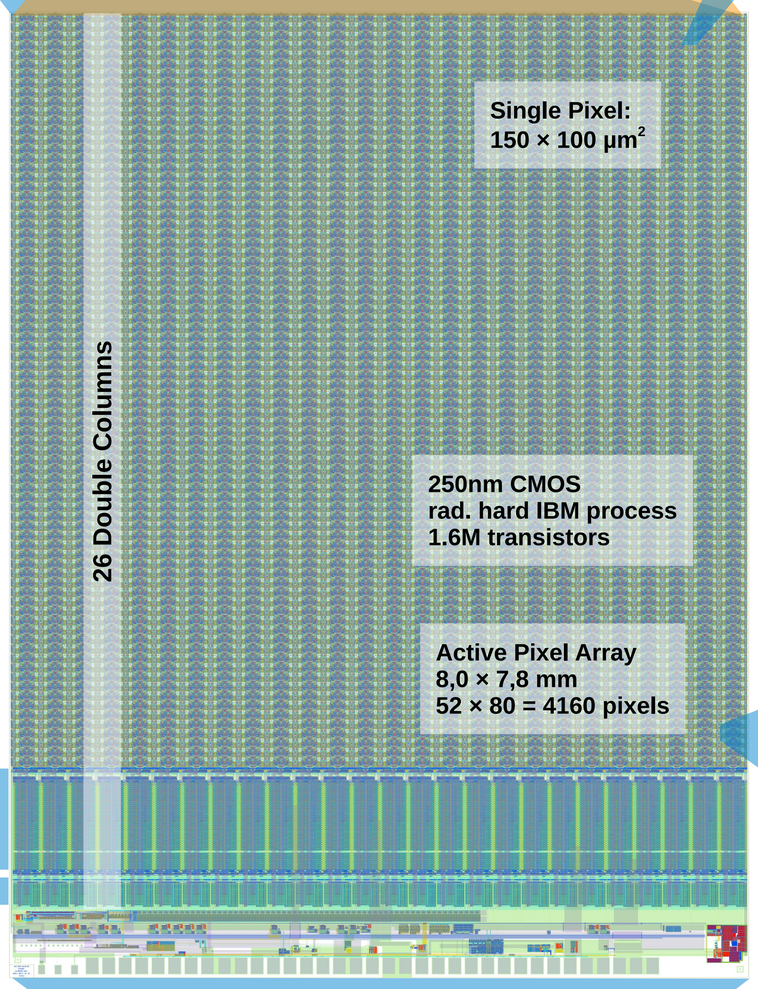
> Current detector:
  48M readout channels
  3 layers
  Inner radius 44mm

> Upgraded detector:
  80M readout channels
  4 layers
  Inner radius 30mm

> Pixel detector built of modules
> Each module comprises 16 Read-out chips (ROCs) on one Si sensor
> Programming and data transfer managed by the Token-Bit Manager (TBM) chip

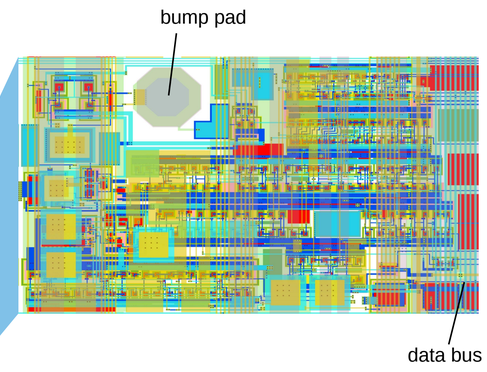
The CMS Pixel Readout-Chip





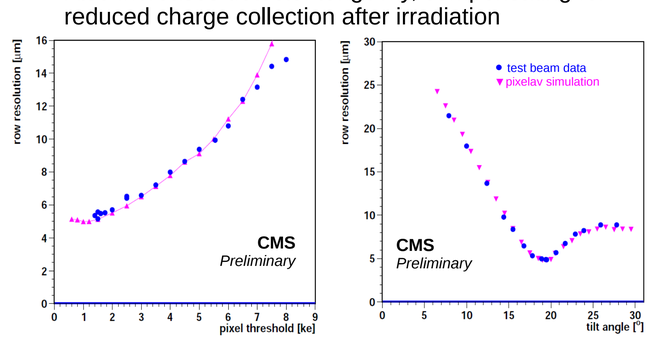
Pixel Unit Cell

> Smallest logic unit of the Readout-Chip, 256 transistors
> Contains preamplifier, shaper and comparator for zero-suppressed pulse readout
> Organized in Double Columns for data readout



Low Threshold, High Position Resolution

> In-time threshold (assigned to correct trigger window)
  Current ROC: **~ 3,500 e**
  New ROC: **< 1,800 e**
> Reduced internal cross-talk from power rails
> Increased comparator speed
> Reduced threshold allows better position resolution
> Also increases detector longevity, compensating for reduced charge collection after irradiation



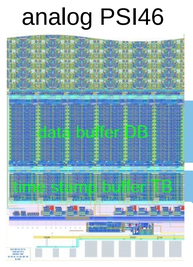
Data Loss Predictions

	Data loss for different luminosities		
Detector & Layer	$1x10^{34}$ $cm^{-2}s^{-1}$ 25ns BX	$2x10^{34}$ $cm^{-2}s^{-1}$ 25ns BX	$2x10^{34}$ $cm^{-2}s^{-1}$ 50ns BX
Current L1	4.0%	16.0%	50.0%
Current L2	1.5%	5.8%	18.2%
Upgraded L1	1.19%	2.38%	4.76%
Upgraded L2	0.23%	0.46%	0.93%

Digital 160MHz Readout & additional on-Chip Buffers

> Fully-digital 160 MHz readout for higher bandwidth
> Replaces analog level-based 40 MHz approach
> fast on-chip 8-bit ADC for pulse-height sampling

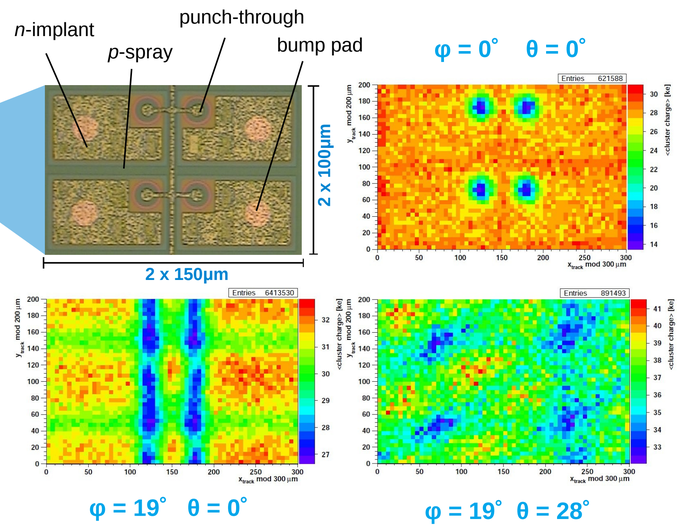
analog PSI46



Additional buffer cells

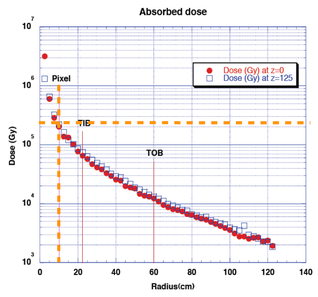
> Data buffers:
  32 cells to 80 cells
> Time stamp buffers:
  12 cells to 24 cells
> Reduced buffer cell size to stay compatible with old design
> Reduced dead time during readout by additional global readout buffer

Detailed ROC/Sensor Studies



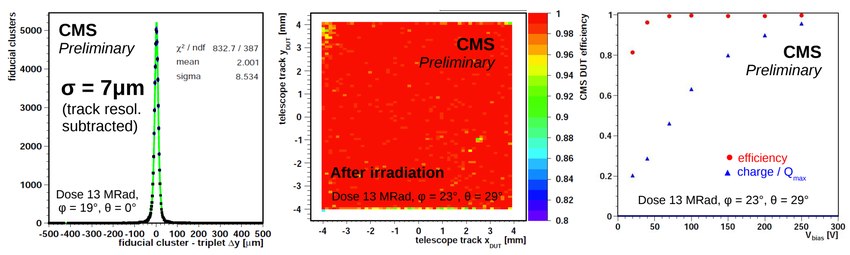
Performance of Irradiated Devices

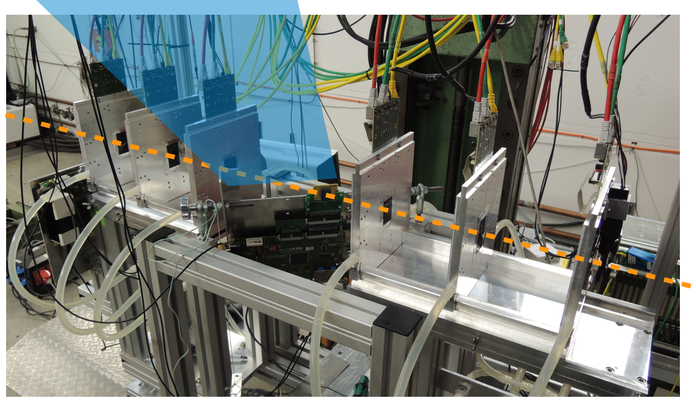
> Irradiation: 24 GeV protons
> Two devices, doses up to D = 13 Mrad
  $\Phi \approx 2.3 \times 10^{14}$ n_{eq} / cm^2
> Expected lifetime dose 500fb^{-1} of Layers 4
> Tracking and charge collection studied in the DESY test beam



After irradiation:

> Only partially depleted sensor (limits on power dissipation)
> *n*-in-*n* implant concept as the sensor undergoes type inversion
> Depletion and charge collected at implant side
> High resolution, tracking efficiency and charge collection maintained



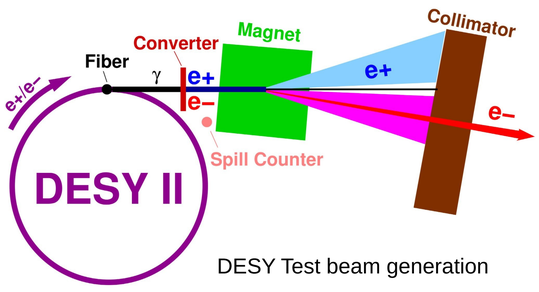


DESY Testbeam & DATURA Telescope

> Beam generation via brems-strahlung and pair production
> Energies selectable from 1-6 GeV
> (Instantaneous) particle rates in the Hz – few kHz range
> Energy spread of 5%
> Beam Divergence ~1mrad

> **Test beam** equipped with beam telescopes
> Developed at DESY for test beams worldwide
> High-precision tracking, low material budget

> Six MIMOSA26 MAPS, 18.4µm pitch, 50µm thickness, 120µs integration window
> Mechanical Support, cooling, Trigger Logic Unit (TLU), four-fold coincidence trigger
> Full-featured Data Acquisition (DAQ) and analysis system (EUDAQ, EUTelescope)



DESY Test beam generation

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efficiency map of the DUT

HELMHOLTZ ASSOCIATION