LHeC Tracker Design viewed from CMS

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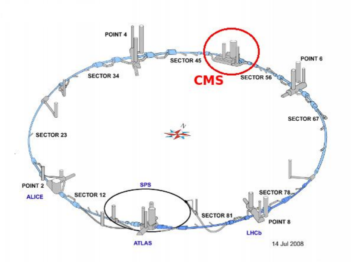
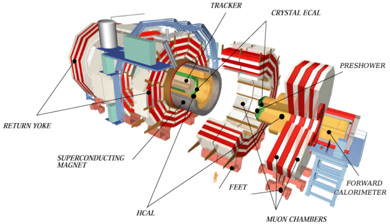
CMS at LHC



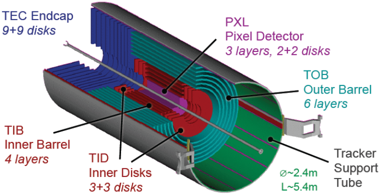
LHC:

- 27 km ring, 1232 superconducting (1.9 K) dipoles
- $p-p$ collider, 7 TeV each beam
- nominal luminosity $10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$, rate 40 MHz



CMS:

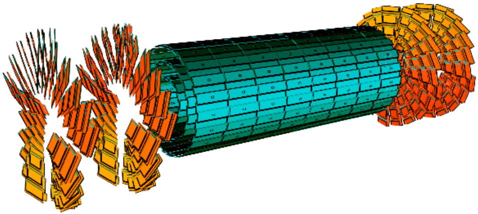
- Length 22 m , diameter 15 m, weight 12.5 kton
- Magnetic field 3.8 Tesla

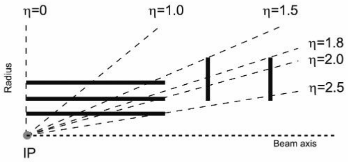


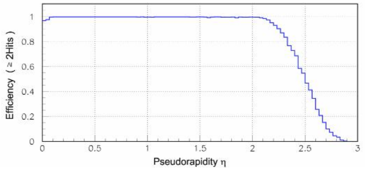
Tracking Detector:

- Pixel volume: $L = 93(53)\,\mathrm{cm}$, $R = 4.2 \div 15\,\mathrm{cm}$
- Strip volume: $L = 540(225)\,\mathrm{cm}$, $R = 21 \div 120\,\mathrm{cm}$
- Pixel: 65.9M ch.(1.1 m^2), Strips: 9.7M ch.(210 m^2)

CMS Pixel Detector







CMS Pixel Detector built of:

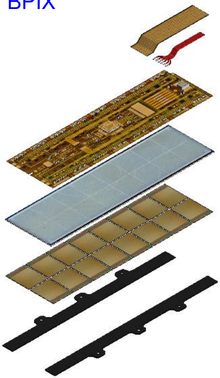
- BPix: 768 modules, 11520 ROCs, 48 Mpixels
- FPix: 192 panels, 4320 ROCs, 18Mpixels

Rapidity coverage:

- with 3 pixel hits up to $|\eta|$=2.1
- with 2 pixel hits within 2.1<$|\eta|$<2.5

Pixel: different module designs

BPIX



Cables: signal&power

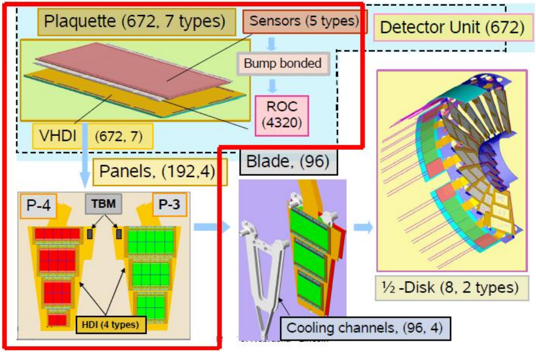
HDI print with TBM

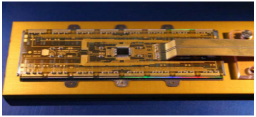
Si sensor

16 ROCs

Base strips: Si_3N_4

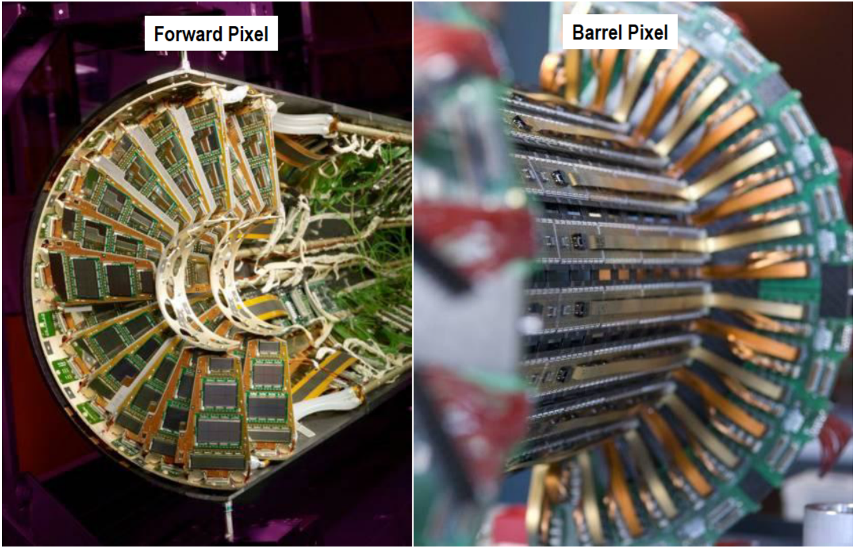
FPIX





- BPix has 2 module designs: 16ROCs and 8 ROCs
- FPix has 7 plaquette designs: 2-10 ROCs

Pixel barrel and endcup

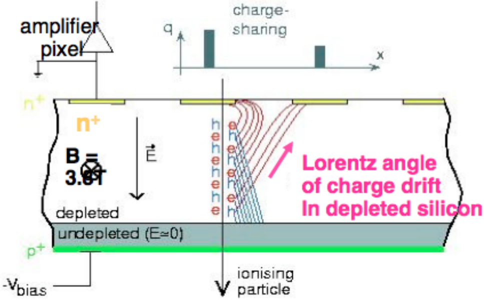


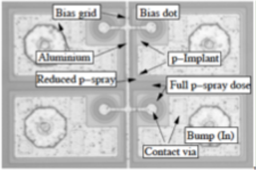
Sensor concept (n-in-n)

Signal charge sharing by Lorentz angle

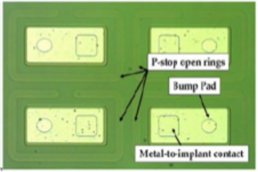
→**precise coordinates in rφ → z**

- n^+-on-n silicon sensors
  - 100 μm x 150 μm pixels
  - Collecting electrons
    - Strong Lorentz effect
    - Profit from charge sharing for improved resolution
    - rad. degradation → loose rφ resolution but keep robust hits
- Two sensor variants, developed for endcap FPIX and barrel BPIX separately with two vendors
  - P-spray (**BPIX**)
  - Open p-stops (**FPIX**)





BPix sensor



FPix sensor

Readout Chip

- **4160 pixel / chip**
- pixel size **100μm x 150μm**
- **251 transistors /pixel** → 60μ²/FET
- **35μW/pixel**, pixel ampl. 20nsec peaking
- on chip regulators 2.6-2.1V → 1.9V
- analog coded readout of addr. & p'height
- operating **pixel threshold = 2500 e**
- radiation hard design (~4 x10^{15} p/cm^2)
- designed for pixel hit rates <100MHz/cm^2

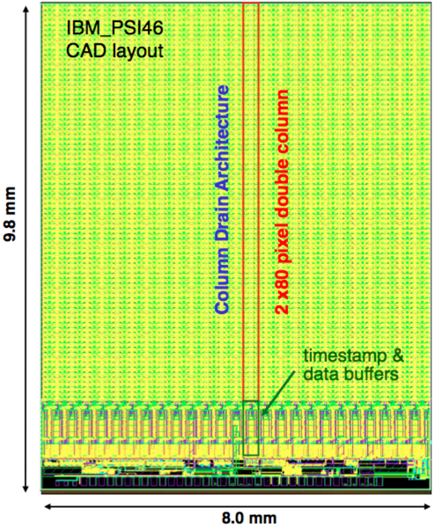
Time Stamp & Data Buffers in DCOL

TS buffers 12 deep

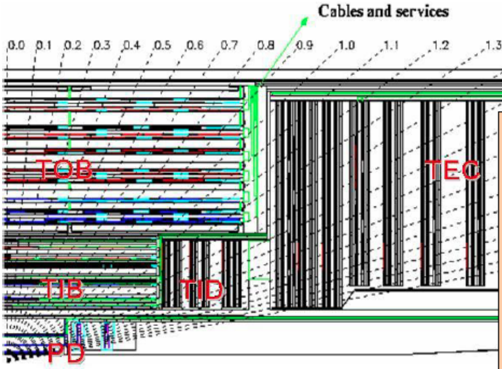
DB buffers 32 deep

Buffer depth in DCOL are leading order limitation of ROC eff. at high rate LHC.

Data throughput in Column Drain not our problem yet → later yes



CMS Strip Detector



Modules:

- 3112 + 3024 Thin modules (ss +ds)
- 5496 + 3600 Thick modules (ss +ds)

Silicon:

- 6,136 Thin sensors = $48 m^2$
- 18,192 Thick sensors = $162 m^2$

210 m^2 of silicon microstrip sensors

FE Electronics:

75,376 APV chips

9,648,128 strips ≡ electr. Channels

Tracker Inner Barrel (TIB): **4 layers:** 2 Rϕ (2D), 2 Rϕ-Stereo (3D)

Tracker Outer Barrel (TOB): **6 layers**, **:** 4 Rϕ (2D), 2 Rϕ-Stereo (3D)

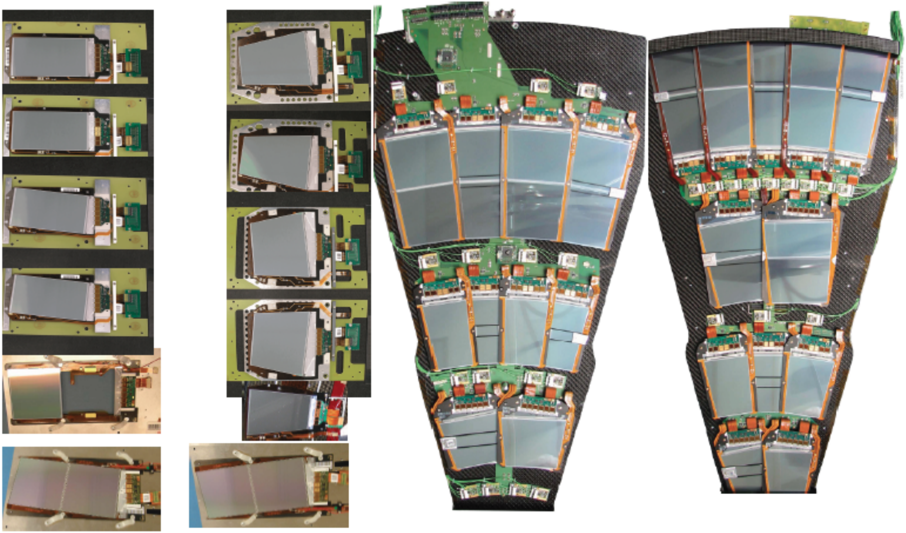
Tracker Inner Disks (TID): **3*2 disks**, **:** 1 Rz (2D), 2 Rz-Stereo(3D)

Tracker EndCap (TEC): **9*2 disks**, **:** 4 Rz (2D), 3 Rz-Stereo(3D)

Each Track has at least 10 high precision measurements for Pt and 4 in Θ

Coverage: | η | < 2.5

Strips: different module geometries



Strip sensors and modules

Silicon Microstrip Detector
5

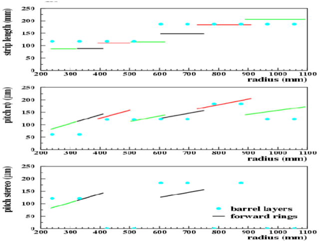
- •p+ n detectors,
- •6″ technology, <100> orientation
- •AC coupled, R-poly biased,
- •w/p=0.25, 4-8 μm metal overhang,
- •Vbreak >500V

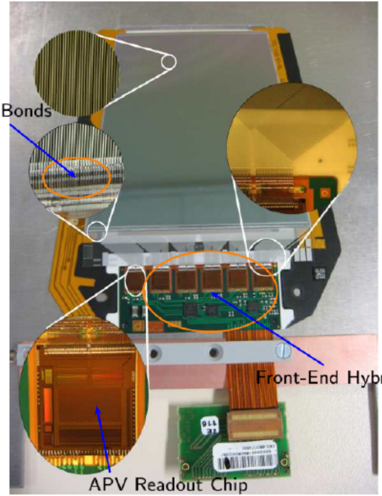
Thin sensors:300 μm, ρ = 1.5-3 kΩcm

Thick sensors:500 μm, ρ = 3.5-7 kΩcm

Different geometries and strip length.

Capacitance at preamplifier ~ 1.2 pf/cm





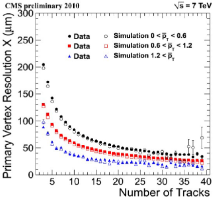
Module summary

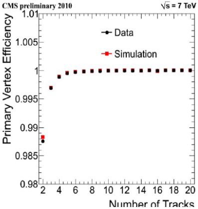
Table 3.3: Pitch, strip length, signal-to-noise ratio and equivalent noise charge after common mode subtraction for different module types. The TEC and TOB measurements are for hybrid temperatures of below 0°C, the TIB measurements were performed at room temperature. Sensors of type IB1 and IB2 are used in TIB, layers 1 and 2 and layers 3 and 4, respectively. In the TOB, layers 1–4 are equipped with OB2 sensors, layers 5 and 6 with OB1 sensors. The sensor geometries abbreviated with W are wedge-shaped sensors used in TEC and TID, with the number corresponding to the ring. W1 sensors have a slightly different geometry in TID and TEC.

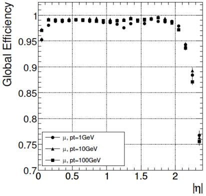
Module type	Pitch [μm]	Strip length [mm]	S/N Peak mode	S/N Dec. mode	ENC [e^-] Peak mode	ENC [e^-] Dec. mode
IB1	80	116.9	25.8 ± 1.3	18.3 ± 0.5	931 ± 48	1315 ± 37
IB2	120	116.9	29.5 ± 1.4	20.3 ± 0.6	815 ± 37	1182 ± 31
OB1	122	183.2	36	25	1110 ± 47	1581 ± 75
OB2	183	183.2	38	27	1057 ± 17	1488 ± 22
W1TEC	81–112	85.2	33.1 ± 0.7	21.9 ± 0.6	714 ± 23	1019 ± 37
W2	113–143	88.2	31.7 ± 0.5	20.7 ± 0.4	741 ± 25	1068 ± 51
W3	123–158	110.7	29.2 ± 0.6	20.0 ± 0.4	802 ± 16	1153 ± 48
W4	113–139	115.2	28.6 ± 0.5	19.2 ± 0.3	819 ± 21	1140 ± 26
W5	126–156	144.4	42.2 ± 1.1	24.1 ± 1.1	971 ± 29	1354 ± 57
W6	163–205	181.0	37.8 ± 0.6	23.0 ± 0.4	1081 ± 26	1517 ± 47
W7	140–172	201.8	35.5 ± 1.0	20.3 ± 1.1	1155 ± 40	1681 ± 107

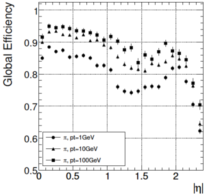
Tracker performance

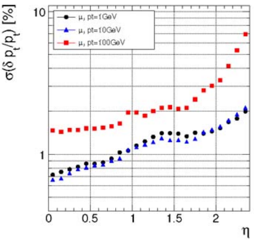
- Silicon Strip Detector
  - 10÷14 points per track
  - hit resolution: 15-45 $\mu\mathrm{m}$
- Pixel Detector
  - 3 points per track
  - hit resolution: 10-35 $\mu\mathrm{m}$
- Tracker
  - $\sigma_{p_T}/p_T \simeq 1 \div 2\%$ ($p_T \simeq$100GeV/c)
  - $\sigma_{IP} \simeq 10 \div 20\mu m$ ($p_T \simeq$100÷10GeV/c)

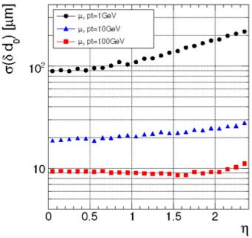


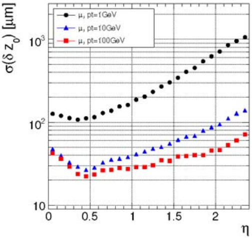












Pixels: operational status

- >99% single hit efficiency
- 13 µm resolution in rφ (measured)
- 25 µm resolution in rz (measured)

- Thresholds of 2450 electrons

Working very well to date

- 97% operational < BPIX+FPIX>
- 99% uptime

Main issues

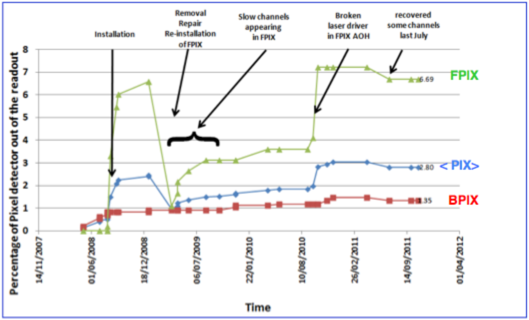
- Beam-background events (PKAM)
- Radiation effects ($I_{leak} \sim r^{-1.25}$)
- Parts failures, though progress made to recover lost parts.

Next removal and service in 2013/14 long shutdown (LS1)

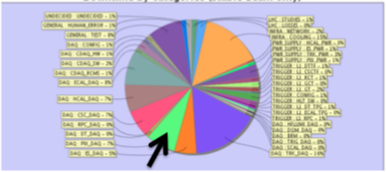
→ remove old beam pipe & install new OD=45mm beam pipe (end 2013)

Very shallow beam induced tracks in BPIX , so called PKAM events → timeouts in Pixel DAQ

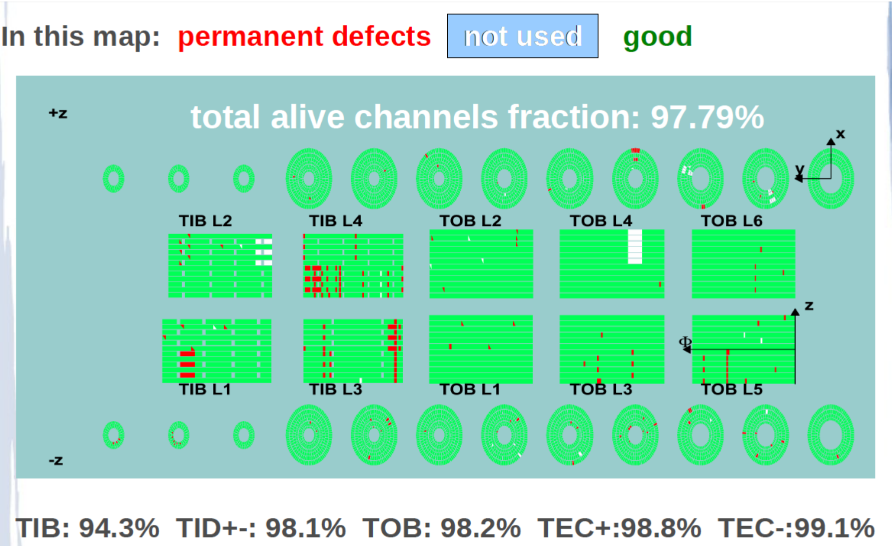
Xmas 2011/12 vacuum problem fixed at -18m



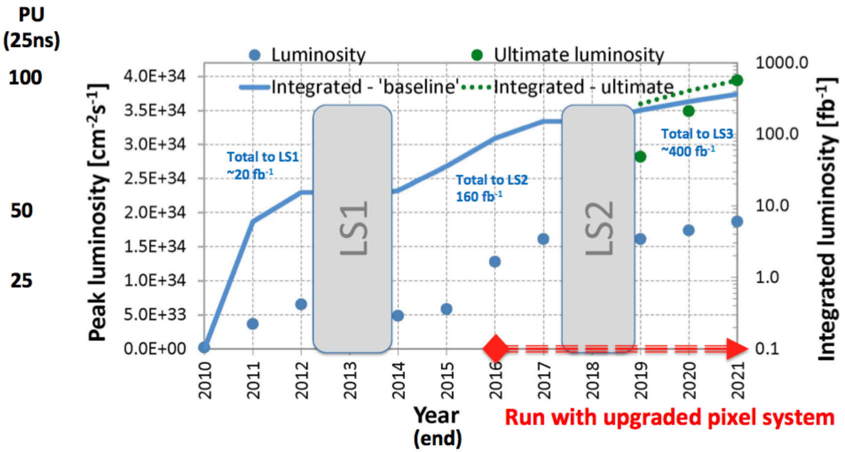
Downtime by categories (Stable Beam only)



Strips: operational status



Outlook: 10 years of LHC luminosity



Run with upgraded pixel system

- **Goal: detector ready mid-2016**
- **5 months to install and commission**

Present Pixel Detector

- Designed for radiation fluences of $6x10^{14} n_{eq}/cm^2$
  - ROC with sensor irrad.tests show at least 3-4 more → rad. damage not main issue

- More passive material in support structures than needed
  - e.g. cooling designed for larger power DMILL readout chip pre-dating 250nm CMOS

- 3 Layer system designed for 20-25 PU events of nominal LHC operation
  - future LHC operation with 50 PU or even 100 PU events will require more robust track seeding by pixel system.
  - defects (thermal contacts & lost modules) in silicon strip TIB need more pixel hits

- Readout designed for nominal LHC conditions of 10^{34} Hz/cm^2 and 25ns bunch spacing → operations beyond this and 50ns bc timing impose serious limits
  - ROC data losses at 2x 10^{34} Hz/cm^2 and 25ns ~16% data loss for BPIX layer-1
  - Optical links from pixel modules to FED & DAQ impose limits at 50nsec operations beyond $1.3x10^{34}$ Hz/cm^2 (same for 25ns at $2.6x10^{34}$ Hz/cm^2 and 100KHz L1)

- Tracking and vertexing, important to almost all physics analyses, will be compromised for operations significantly above 10^{34} Hz/cm^2 and/or 50ns

Proposed Pixel upgrade

- BPIX 3 Layer → 4 Layers
- FPIX 2x2 Disk → 3x2 Disk

Increase number pixel tracking points 3 → 4

- CO_2 cooling based Ultra Light Mechanics
- Shift material budget out of tracking η–region

Significant X/X_0 reduction

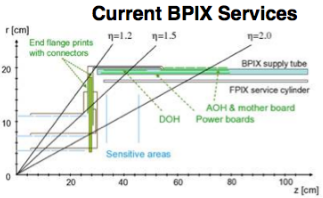
- Minimize 1 Layer radius

reduced impact δ_{xy} & δ_z error

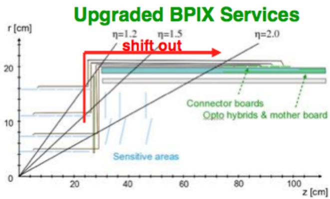
- ROC modifications for operation up to L ~ 2×10^{34}
- Use same cabling → DC/DC converters for power
  → 320MHz digital readout on fibres

→ pixel tracking & vertexing significant improved and robustified

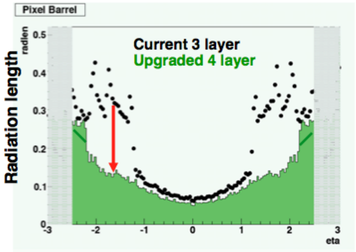
Shift material budget out of tracking region

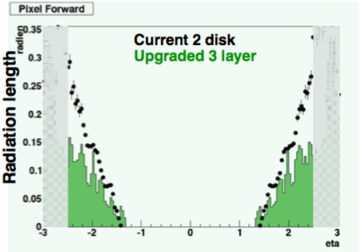


η<2.2 : weight = 16.9 Kg (3 layer)



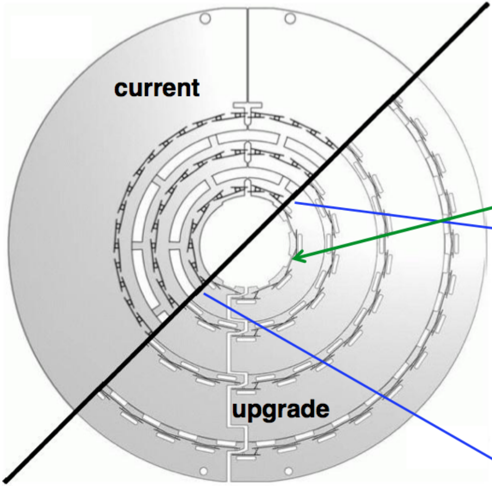
η<2.2 : weight = 6.5 Kg (4 layer)





η ~1.5 : γ-conversion for H→ γγ from 22% to 11% for new 4 Layer Pixel System

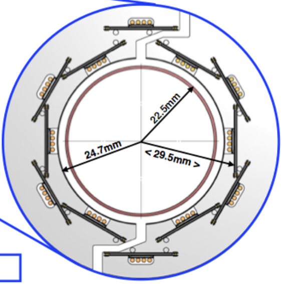
BPix upgrade mechanics



- **Full module type only**

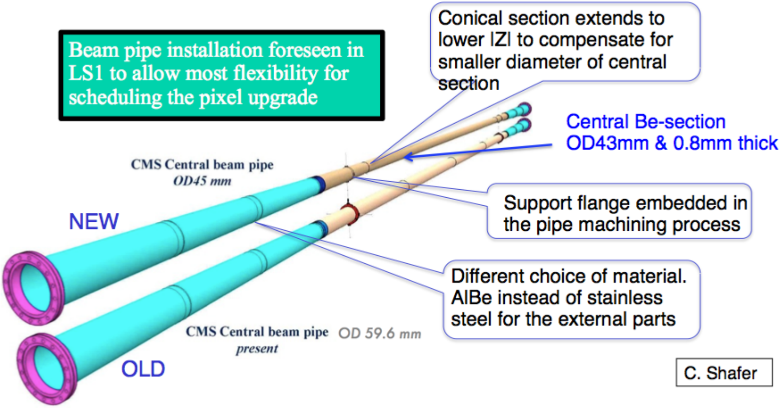
Layer 1: r = 30mm; 12 faces
Layer 2: r = 68mm; 28 faces
Layer 3: r = 109mm; 44 faces
Layer 4: r =160mm; 64 faces

fall back with old beam pipe
Layer 1: r = 39mm ; 16 faces



beam pipe OD = 43 mm → 1st Layer: 12 faces <R>=29.5mm

New central beam pipe

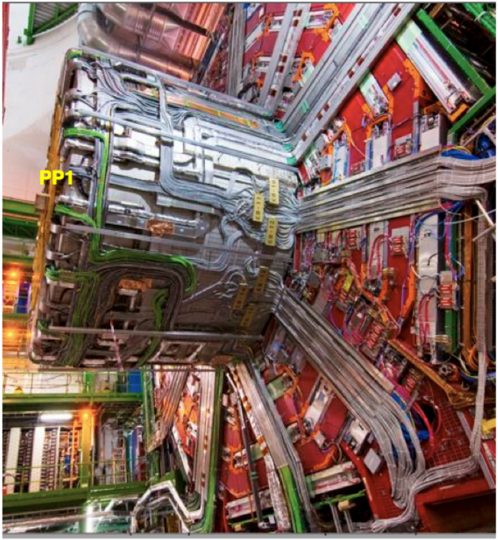


New central beam pipe EDR passed in 5. March 2012 → order ongoing

Constraint of present CMS services

- To bear in mind also, an important boundary condition for the upgrade
  - Must re-use services from balconies to detector “PP1” patch panel
  - Cooling pipes
  - Power cabling
  - Optical cabling

- Pixels and Tracker cables and pipes buried under ECAL/HCAL services

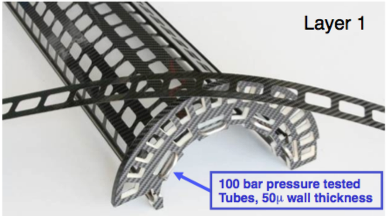


Pixel Phase I Upgrade installation planned 2016/17 Xmas shutdown

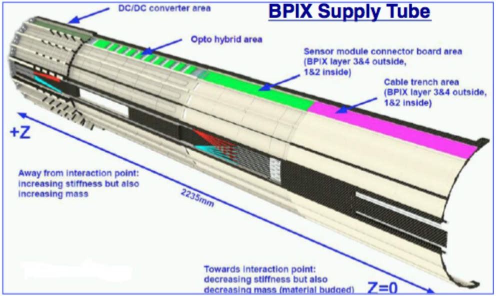
→ use same fibers
→ re-use Cu-pipes for CO_2 cooling

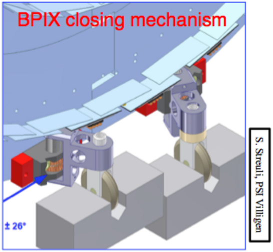
Ultra light mechanics for BPix

- UL mechanics with integrated CO_2 cooling. Supply Tube heat sources as preheaters for CO_2 loops.
- Large effort on insertion procedure and tooling, including fine-adjustment of BPIX positioning around the new beam-pipe



Weight Layer1 42g + 7g CO_2 → 30% of old first layer X/X_0





New supply tube

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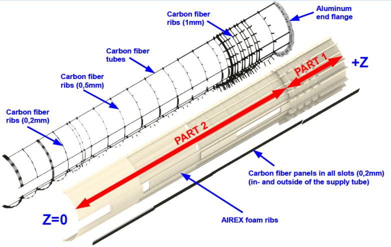
Primary elements of the supply tube



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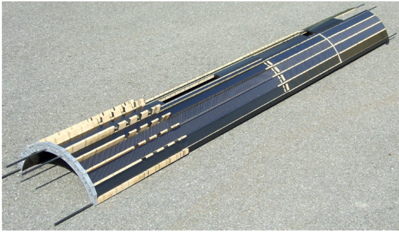
The new supply tube



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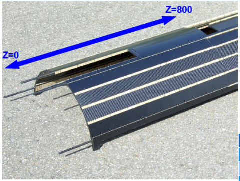
Material breakdown for sector C



Material	Weight
Airex C70/55	83gr.
Carbon fiber ribs	11gr.
Carbon fiber tubes	27gr.
Carbon fiber wheel support	7gr.
Carbon fiber facets	180gr.
Epoxy glue	100gr.
Total weight	408gr.

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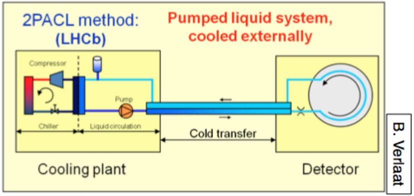
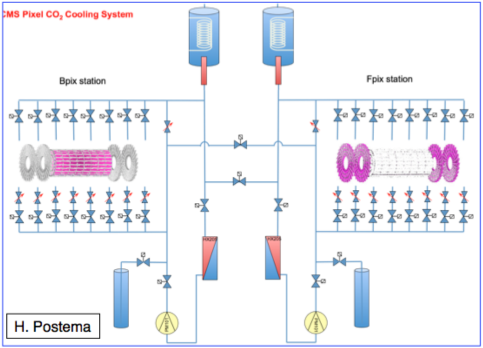
Material breakdown of new supply tube

Material	Weight
Airex foam C70/50	368gr.
Carbon fiber 0,2mm	972gr.
Carbon fiber 0,5mm	29gr.
Carbon fiber 1mm	132gr.
Carbon fiber 6mm	7gr.
Carbon fiber tube Ø 7mm x 2000mm	31gr.
Carbon fiber tube Ø 6mm x 7092mm	92gr.
Aluminium end flange	421gr.
Epoxy glue	848gr.
Total weight of supply tube incl. missing carbon fiber parts	2900gr.

CO2 cooling for lighter detector

- Use 2PACL method
  (2PACL = 2-Phase Accumulator Controlled Loop)



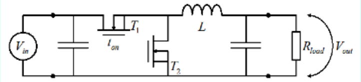


- Two systems will be installed
  1 for FPIX, 1 for BPIX
- Different temperatures possible for FPIX and BPIX
- ***Redundancy***: BPIX and FPIX can both be run on either one of the two cooling plants

DC-DC LV Power Converters

- LV power conversion 12V → 2.5V by DC-DC Buck converters
- Efficiency ~ 75-80%
- Use for beginning old CAEN 4603 power supplies
- Total 1183 converters

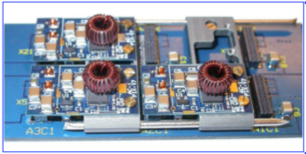
"Buck" converter

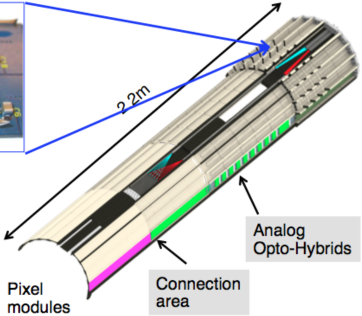


Idea: P = U·I = (rU)·(I/r) with conversion ratio r > 1

Duty cycle $D = t_{on}/T$; $1/D = I_{out}/I_{in} = V_{in}/V_{out} = r$

K. Klein et al. TU Aachen





CO_2 cooling of DC-DC converters as pre-heat of the incoming CO_2 to reach proper 2-phase state

Construction and operation experience

- Avoid too many module designes
- Readout chip DACs should be optimized in a lab for different operational T (to be used later during detector operation)
- Foresee enough time for detector commissioning after installation (several months: 5-6)
- Foresee T and current measurements of the installed detector with highest possible granularity
- In case of presence detector volumes operated at different T, pay attention on sealing
- Foresee spare cabling (for future possible upgrades)

Construction and operation experience (cont.)

- Carefully design insertion procedure of the detector (and exercise before installation!)
- DAQ SW
  - start to write it as early as possible
  - be ready for SEU handling and unexpected (like PKAM in CMS)
  - foresee to use the same calibration algorithms as used during testing/QA in the lab
  - start to collaborate with central DAQ as early as possible (even better to have a 'spy' there)

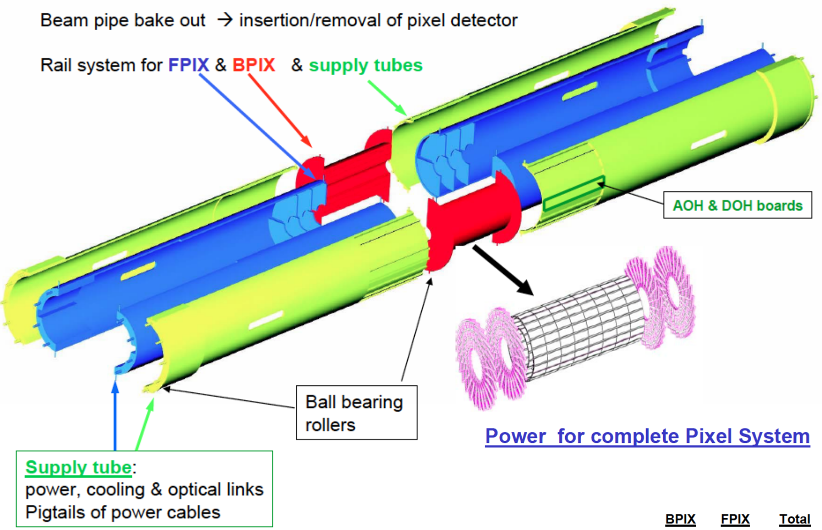
Thanks to my colleagues who helped me with this talk and/or whose material I've used here: R.Wallney, R.Horisberger, D.Kotlinski, W.Erdmann, T.Rohe, H.-Ch.Kaestli, W.Bertl, S.Streuli, K.Gill, L. De Maria, F.Hartmann, G.Sguazzoni, F.Palmonari, P.Kostka, A.Polini

Back up slides

a bit of history

- Main steps:
  - 1994: Pixel detector proposed for CMS, Technical Proposal
  - 1998: Tracker Design Report
  - 1994-2005: R&D on readout chip (ROC) and sensor
  - 2005-2006: final version of ROC and sensors production
- FPix:
  - 6/2006-10/2007: plaquette and panel construction and testing
  - 2/2007-11/2007: disk assembly
  - 4/2007-12/2007: delivery from FNAL to CERN
  - 1/2008-7/2008: system tests at TIF
- BPix:
  - 6/2006-3/2008: module production and testing
  - 11/2007-3/2008: mounting modules on ladders
  - 2/2008-4/2008: integration with supply/service tubes
  - 3/2008-6/2008: system tests at PSI
- 2008: insertion of BPix on July 23-24 and FPix on July 29-31

Pixel Detector System



Power for complete Pixel System

	BPIX	FPIX	Total
Unirradiated & High Lumi	1.88 KW	0.62 KW	2.5 KW
Irradiated & High Lumi	2.67 KW	0.88 KW	3.6 KW

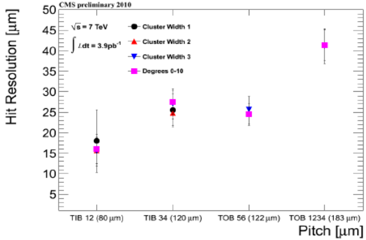
Hit resolution

Hit resolution

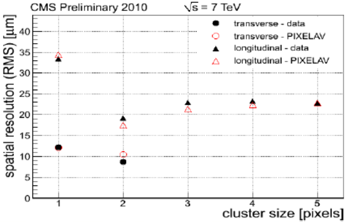
Hit resolution depends on sensor thickness and strip pitch:
the minimum value is reached for an angle corresponding to optimal charge sharing

Obtained hit resolutions:
Strips: 15 µm to 45 µm

Layers	pitch µm	degrees 0-10
TIB 12	80	16.0±3.5
TIB 34	120	27.9±2.9
TOB 1234	183	41.3±3.8
TOB 56	122	24.5±2.7

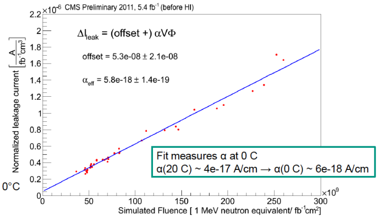


Pixels: 9 µm to 35 µm
with 2 independent method:
- Overlaps
- Hit triplets
(overlap shown in the plot)

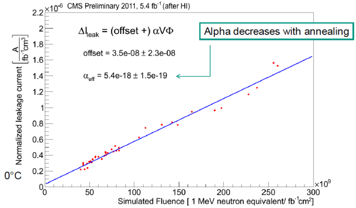


Leakage current

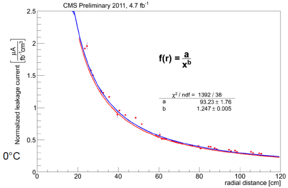
Measured Leakage Current within the Barrel Region of the Strips Tracker vs. Fluence



Measured Leakage Current within the Barrel Region of the Strips Tracker vs. Fluence

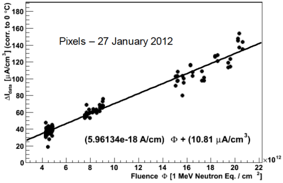


Measured Leakage Current within the Barrel Region of the Strips Tracker vs. Radius

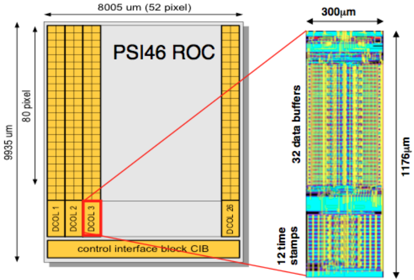


- Blue curve fit of measurement
- Red curve FLUKA simulations (with alpha value from fit see slide 4)

Pixel Leakage Current vs. Fluence



ROC data losses



Present ROC for 1st Layer:

Luminosity	bx-spacing	Data Loss
$1\times10^{34}cm^{-2}s^{-1}$	25nsec	4%
	50nsec	16%
$2\times10^{34}cm^{-2}s^{-1}$	25nsec	15%
	50nsec	~50%

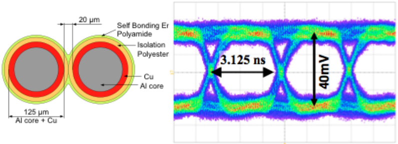
50nsec operation of LHC was not planned in original ROC architecture in 1998.

Data losses removed by ROC changes:

	Status
1) increase depth of	
- data buffer 32 → 80	done
- timestamps 12 → 24	done
2) add readout buffer	done
3) 160Mbit/sec serial binary data out	now
4) deal with PKAM events → DAQ resync	

µ-twisted CCA pair (**C**opper-**C**ladded **A**luminum)

- 1m long low mass link at 320MHz , chips done !



Material budget (BPix example)

768 modules (3 layer)	1744g	23%
mechanics (no pipes)	1607g	21%
cooling (pipes, C_6F_{10}, manifolds)	2245g	30%
cables, prints, connectors	1990g	26%
Present BPIX (detector only)	7586g	100%
Service tube (up to z=820mm)	9308g	

1216 modules (4 layer)	1738g	48%
mechanics (no pipes)	728g	20%
cooling (pipes 1.4mm, CO_2)	705g	20%
cables, prints, connectors	429g	12%
2014 BPIX (detector only)	3599g	100%
Service tube (up to z=820mm)	1632g	

Total mass within $\eta = 2.17$: 16894g (3.3 * more)

Scaling detector to 4 layers: ~13000g (w/o ST)

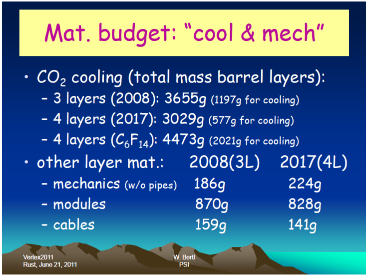
(with ST: ~ 4.4 * BPIX 2014 !!!)

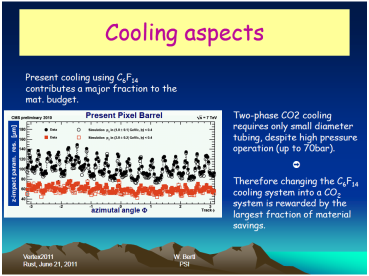
Total mass within $\eta = 2.17$: 5231g

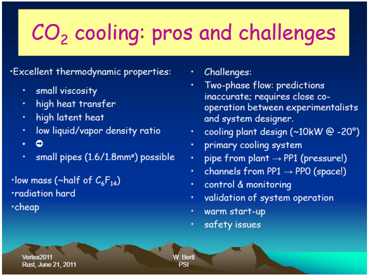
2014 BPIX w C_6F_{10} cooling: ~6800g (w/o ST)

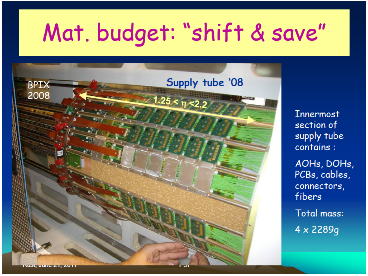
(53% of weight devoted to cooling !)

Lighter detector

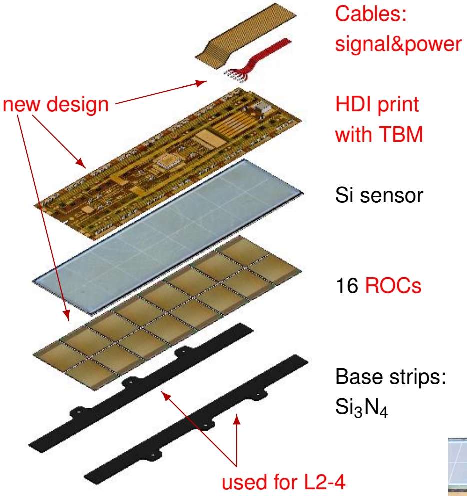






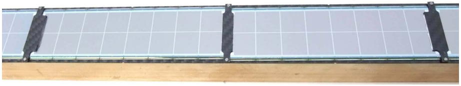


Upgrade pixel module



- Increased number of modules
  - BPix: 1184 (instead of 768)
  - FPix: 672 (same number but with more ROCs per module on average)
  - in total about 125M pixels (instead of 64M)
- One module design: 2x8 ROCs
  - new type of signal/power cables
  - 3 types of HDI: 2 in BPix and 1 in FPix
  - new digital readout chips
  - no base strips for L1 modules

Layer 1 mounted modules



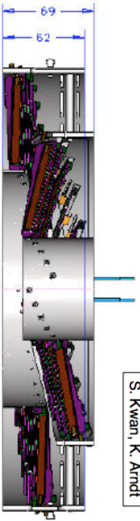
FPix upgrade

- **Forward** (FPIX): Half disks with inner and outer rings
  - All blades using same 2x8 ROC module type on thermal pyrolytic graphite (TPG)
  - Blades on inner ring tilted outward by 12° in to optimize hit coverage
  - All blades are rotated by 20° around radial axis to enhance charge sharing and position resolution.

- Substantially lighter structure than present generation parts, also profiting from CO_2 cooling

- 6 disk of 112 sensors each
  - 672 modules
  - 10752 ROCs
  - **~44M pixel (= 2.5 x *present* FPIX)**

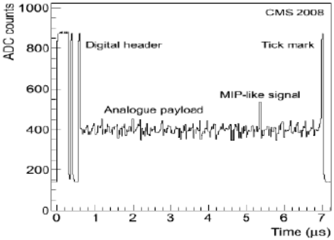
FPIX end cap half disks made by 2x8 sized modules (blades)



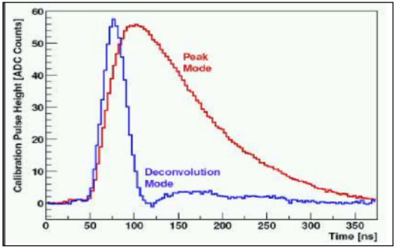
S. Kwan, K. Arndt

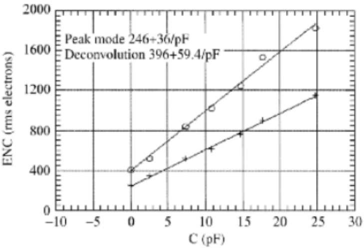
APV25 chip

Front end chip preamplifier:
- 0.25 μm technology , rad-hard tested
- 128 channels, mux at 20 MHz
- 50 ns shaping time, 192 analog cell pipe line

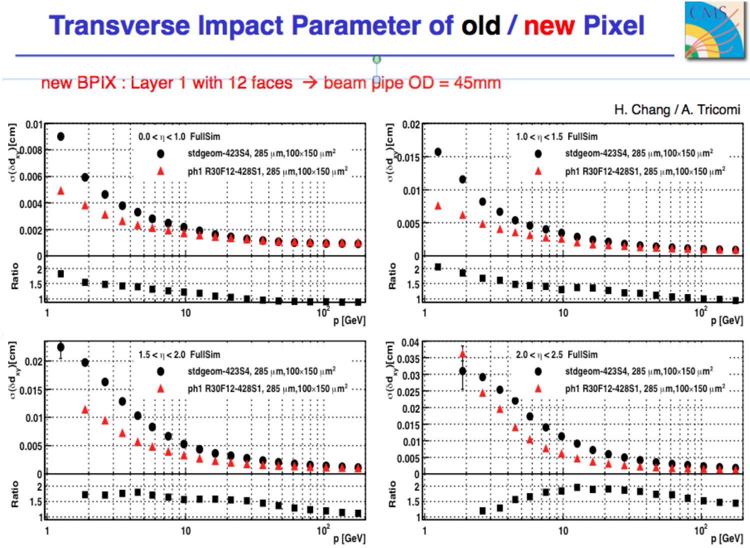


Can run in two modes:
- PEAK mode: normal CR-RC (50ns)
  - slow, lower noise
- **DECONVOLUTION**: takes 3 consecutive sampling and applying deconvolution algorithm
  - faster signal, higher noise





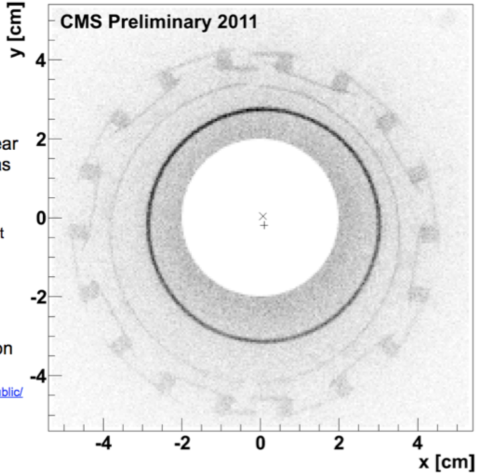
Performance comparison



Tolerances of new Pixel and Beam Pipe crucial

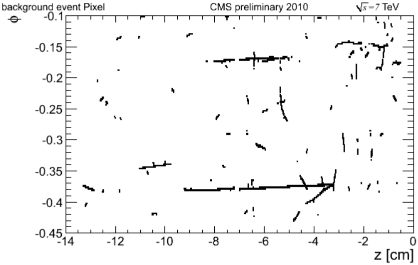
From event with nuclear interactions get actual position of beam pipe, pixel and beam !

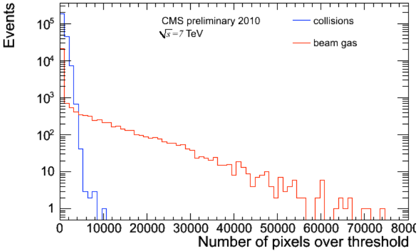
- Information
  - Contacts:
    maxime.gouzevitch@cern.ch
    giacomo.sguazzoni@cern.ch
  - Ref: TRK-10-003
- xy view of reconstructed Nuclear Interactions vertices in Min Bias events at B=3.8T
  - -20cm<z<20cm
  - '×' represents average beam spot position; '+' the fitted beam pipe center
  - First pixel layer is visible
  - Central blank spot is a selection artifact
- More details and high resolution plots:
  - https://twiki.cern.ch/twiki/bin/view/CMSPublic/DPGResultsTRK



Beam-gas background (PKAM) I

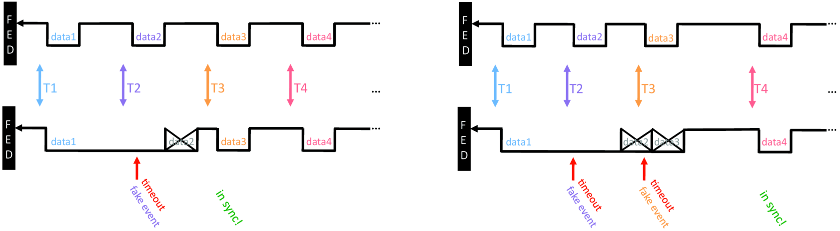
- What is beam-background events:
  - showers of particles that graze the detector along the beam axis (z)
  - occur coincident with bunch crossings
  - consistent with beam-gas interactions in the beam pipe
  - lead to a huge occupancy in BPix (but concentrated in 1 out of 36 FED channels)
  - impose challenges to maintaining event synchronization, especially at high trigger rates





Beam-gas background II

- **Where is a problem:**
  - beam-gas event is large and can block FED(s) for long time
  - next event comes at NOT expected time (later)
  - FED(s) stays out of synchronization (timeout sent to CMS DAQ)
- **Solution:**
  1. drop the event(s) that not arrive when expected (event 'data2')
  2. if N (tunable) consecutive timeouts, stop CMS trigger, so FED can resynchronize itself

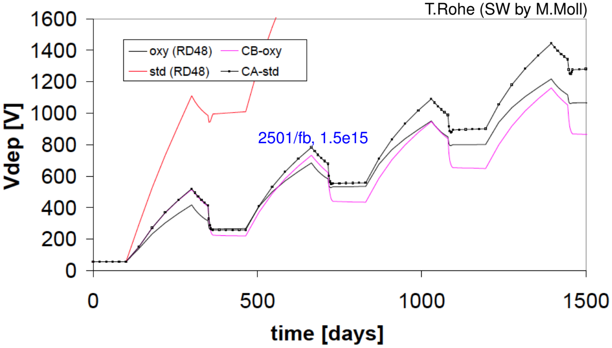


Longevity of pixel module

- Present ROC and Si sensor:
  - tested at $\geq 1.2 \times 10^{15}$neq/cm^2 and stay operational with V_{BIAS}=450V
  - and designed to work under-depleted
- Below L1 is discussed since the rate at L2 4 times lower
- Inputs for rate calculations
  - from present detector: rate at L1 (4.2cm) per 1fb^{-1} is 3×10^{12}neq/cm^2
  - E factor (7TeV to 14TeV): 1.13
  - R factor (1/R$^{1.3}$): 1.7
- Hence 250fb^{-1} corresponds to 1.5×10^{15}neq/cm^2
- Sensor limiting factors at high radiation dose:
  - higher bias voltage required
  - high leakage current
  - lower charge collected
  - detection efficiency and spacial resolution degrade

Depletion voltage

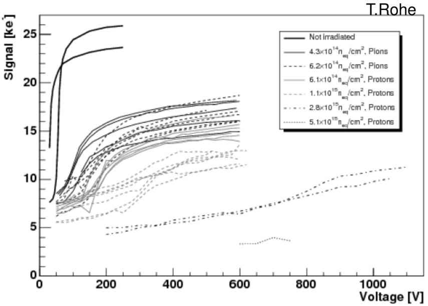
- Depletion voltage calculated using different models
- To take into account annealing a year splited as follows
  - 50 days cold at T=0°C with no beam (winter shutdown)
  - 200 days cold at T=0°C with beam (data taking)
  - 100 days cold at T=0°C with no beam (pauses in data taking)
  - 15 days warm at T=+20°C with no beam
- 4 years with 125 fb^{-1} per year for L1 at R=3cm

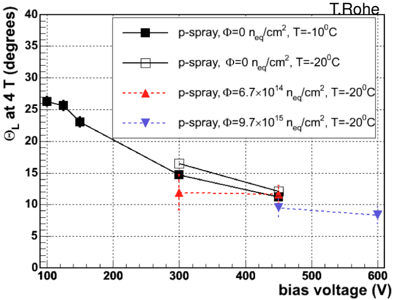


Sensor performance summary

L1 (2.9cm), Thr = 3200 e^-, resolution from M.Swartz

Φ [n_{eq}/cm^2]	0	1.2×10^{15}	2.4×10^{15}
L [fb^{-1}]	0	200	400
V_{BIAS} [V]	150	600	1000
$\sigma_{r-\phi}$ at η=0 [μm]	10	20	28 (binary)
σ_z at η=0.5 [μm]	14	20	43 (binary)
Signal [e^-]	24k	12k	$\sim$ 12k
Detection efficiency [%]	$\sim$100	$\geq$95/98(0/3 Tesla)	$\geq$92(600V)



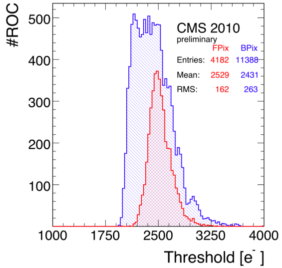


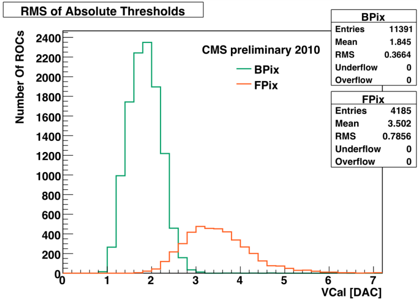
Detector status: known problems

Detector component	# ROCs	Problem
FPix_BmO_D1_BLD9_PNL2	24	low signal amp. (bad TBM)
FPix_BmI_D1_BLD11_PNL2	24	one ROC without analog output, whole panel lost
FPix_BmO_D2_BLD8_PNL2	24	bad Address Levels (slow rise-time)
FPix_BmO_D2_BLD8_PNL1	21	bad Address Levels (slow rise-time)
FPix_BmO_D2_BLD7_PNL1	21	bad Address Levels (slow rise-time)
FPix_BmO_D2_BLD9_PNL1	21	bad Address Levels (slow rise-time)
FPix_BmI_D2_BLD10_PNL1	21	bad Address Levels (slow rise-time)
FPix_BmI_D1_BLD6_PNL1	21	no signal
FPix_BpI_D2_BLD4_PNL1	21	no I2C to AOH, need to open CMS
FPix_BpI_D2_BLD4_PNL2	24	no I2C to AOH, need to open CMS
FPix_BpI_D2_BLD5_PNL1	21	no I2C to AOH, need to open CMS
FPix_BpI_D2_BLD5_PNL2	24	no I2C to AOH, need to open CMS
FPix_BpI_D2_BLD6_PNL1	21	no I2C to AOH, need to open CMS
FPix_BpI_D2_BLD6_PNL2	24	no I2C to AOH, need to open CMS
BPix_BpI_SEC5_LYR3_LDR12F_MOD2	16	no HV
BPix_BpI_SEC8_LYR3_LDR22H_MOD4	8	no HV
BPix_BpO_SEC1_LYR2_LDR1H_MOD4	8	no HV
BPix_BpO_SEC8_LYR2_LDR16H_MOD4	8	no HV
BPix_BpO_SEC7_LYR2_LDR13F_MOD3 TBM-B	8	token lost
BPix_BmI_SEC2_LYR3_LDR4F_MOD3	16	token lost
BPix_BpO_SEC4_LYR2_LDR8F_MOD1 TBM-A	8	bad ROC
BPix_BmI_SEC3_LYR2_LDR5F_MOD3 TBM-A	8	bad ROC header
BPix_BmI_SEC3_LYR2_LDR5F_MOD3 TBM-B	8	ROC cannot be programmed
BPix_BmO_SEC7_LYR2_LDR14F_MOD4	16	dead module
BPix_BpI_SEC8_LYR1_LDR9F_MOD2	16	no trigger
BPix_BmO_SEC4_LYR2_LDR8F_MOD4 TBM-A	8	bad ROC
BPix_BmI_SEC3_LYR1_LDR4F_MOD4 TBM-B	8	no signal (wire bond?)
BPix_BpO_SEC7_LYR3_LDR19F_MOD2	16	token lost
BPix_BpI_SEC1_LYR3_LDR3F_MOD2	16	can't be programmed
BPix_BmI_SEC5_LYR3_LDR13F_MOD2	16	remote sensing wire

Thresholds

- Procedure :
  - The mean absolute threshold on each ROC is computed from a subset of pixels on the ROC (2%)
  - The absolute threshold of each pixel is obtained from an SCurve calibration covering two bunch crossings
  - An SCurve is the hit efficiency as a function of injected charge (VCal).
  - The threshold is taken as the VCal corresponding to 50% efficiency
- Conversion: #electrons=65.5$\times$VCal - 414 (X-ray calib.)





DACs optimization

- Few operational parameters are T dependent
  - some DACs tuned dynamically, so no need for a special procedure
  - others should be re-adjusted
- BPix
  - 2 sets of DACs for +17 °C and -10 °C taken at PSI
  - T dependence approximately linear
  - new DACs obtained by linear interpolation from 2 sets
- FPix
  - DACs tuned in P5 using special calibration procedures
- Thresholds are minimized in BPix/FPix: 2740/2480 e^-