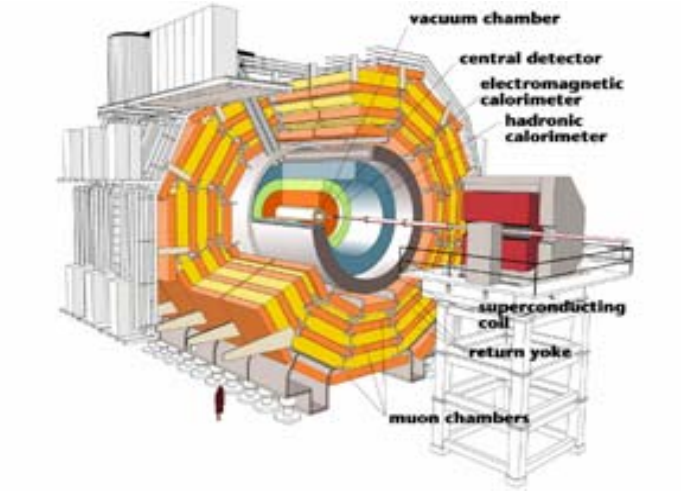
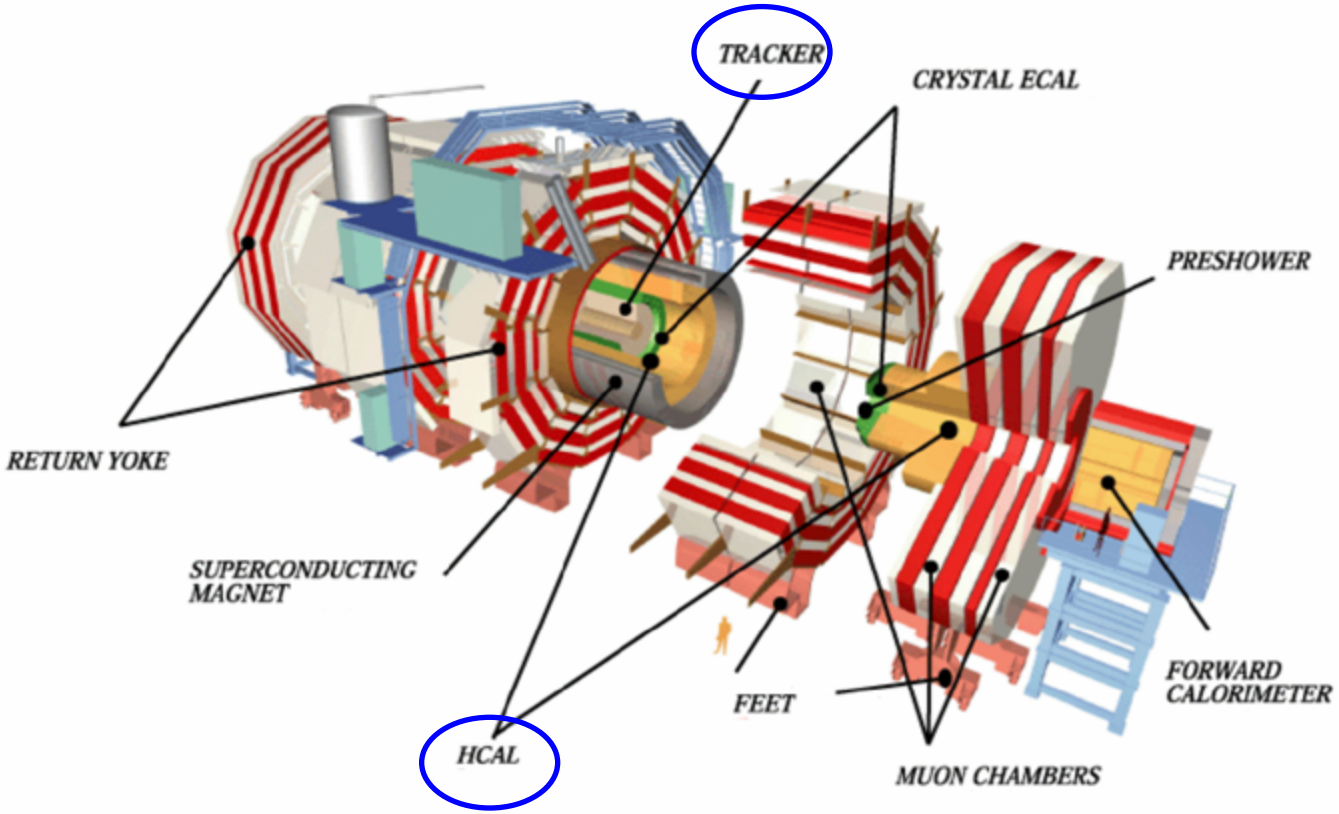
CMS Upgrade Activities

G. Eckerlin
DESY – WA, 1. Feb. 2011

CMS @ LHC
CMS Upgrade Phase I
CMS Upgrade Phase II
Infrastructure
Conclusion

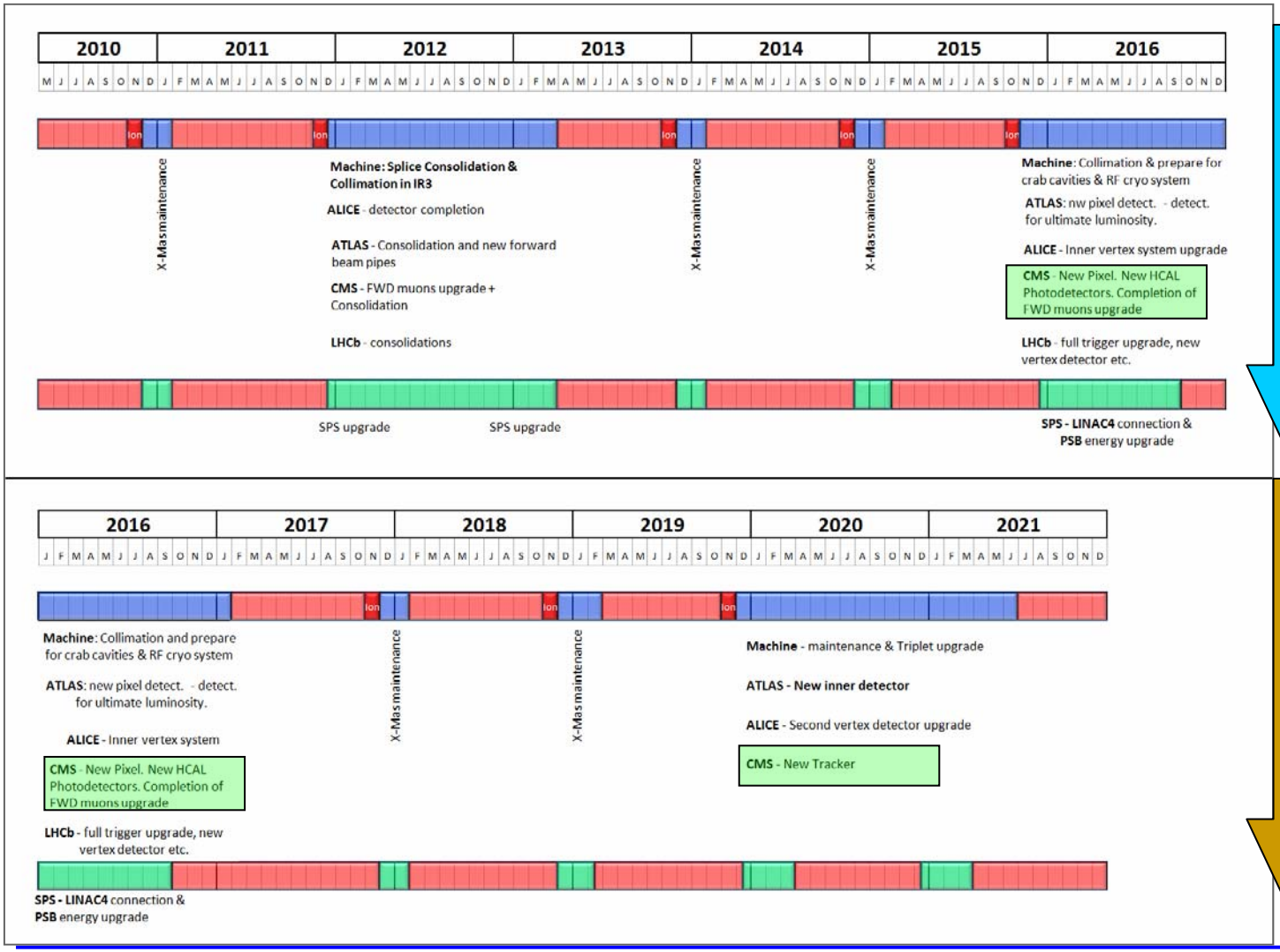


The CMS Experiments at the LHC



CMS upgrade activities with DESY involvement

LHC - 10 Year Plan (S. Meyers LHCC, Sep 22nd 2010)



Improve detector performance

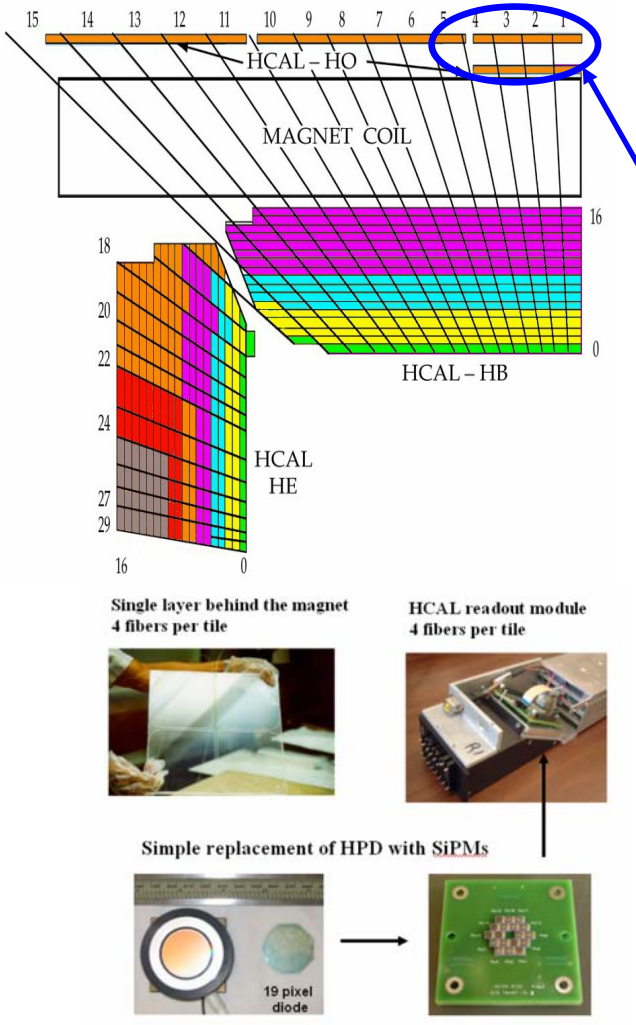
Higher lumi, rates & radiation

2012/13
HCAL HO

2016
New pixel
HCAL HB/HE

2020
New tracker

Phase I : SiPM for CMS HCAL



Performance upgrade for CMS HCAL :

- Replacing HPDs with SiPM

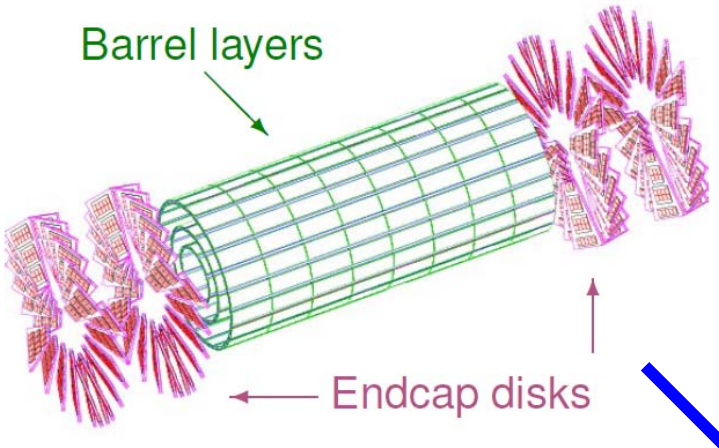
  Higher gain, more robust in b-field
  will allow for longitudinal segmentation
  and improved energy reconstruction

- Start in 2012/13 with outer rings HO :

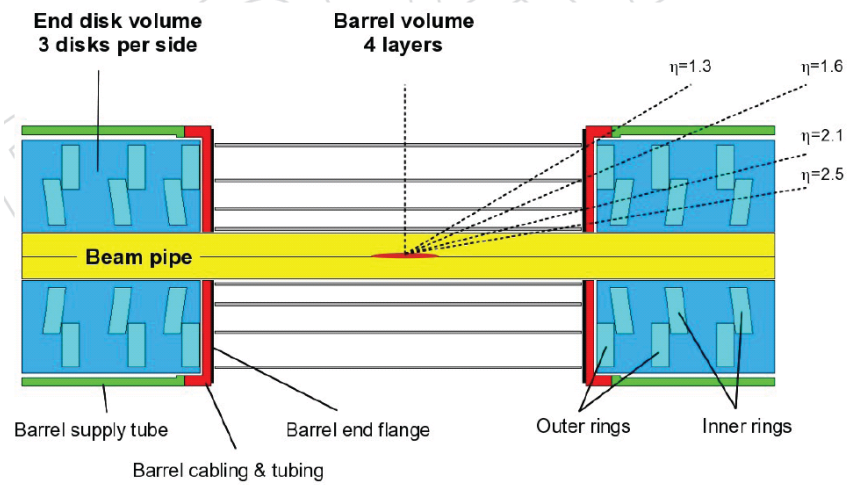
  Ring 1 & 2 by US(FNAL) and India
  Ring 0 by DESY, ITEP and Aachen

- DESY Activities :
  SiPM for Ring 0 funded by LEXI
  Lightmixer studies
  SiPM tests
  System integration (contact person)
  Simulation

Phase I : New Pixels for CMS

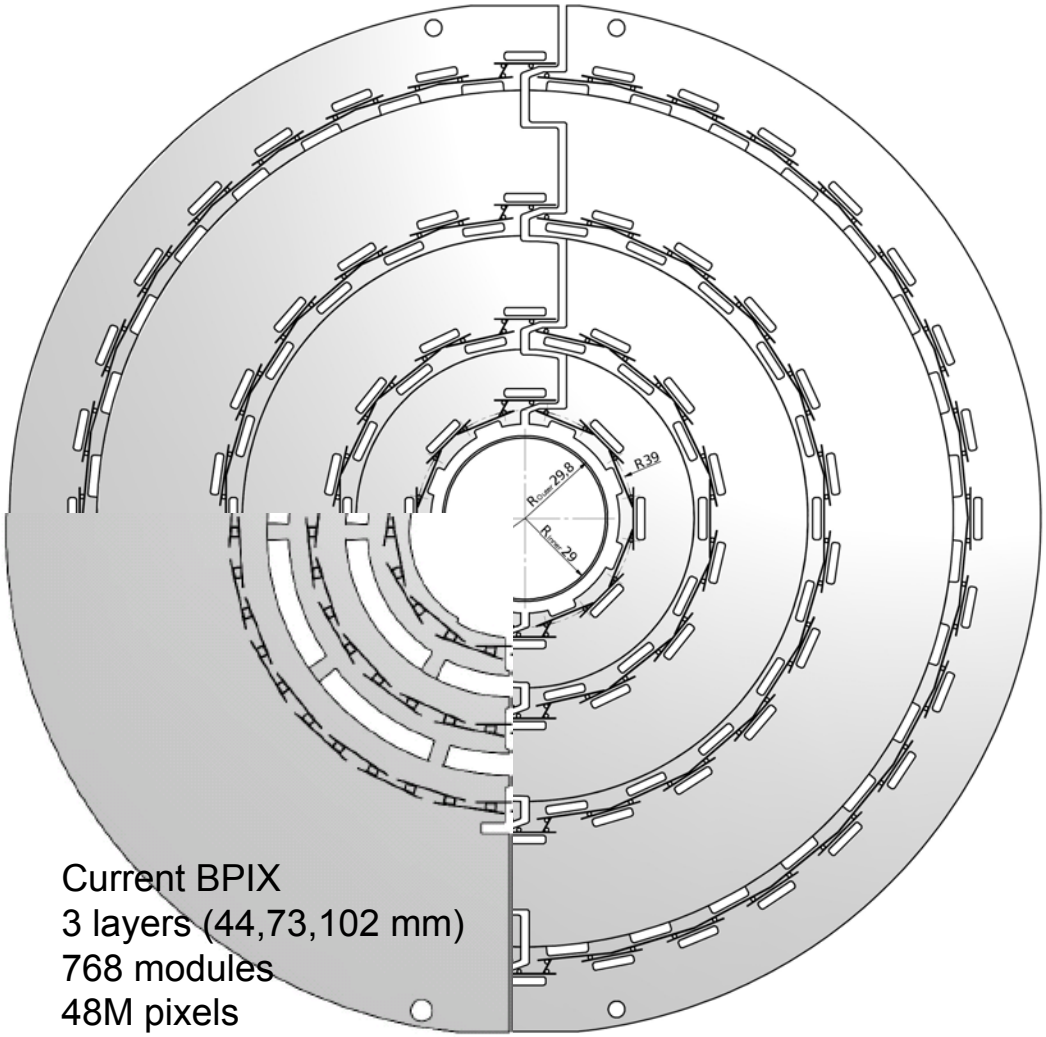


current CMS pixel detector
Barrel with 3 cylindrical layers
2 end caps with 2 disks



new CMS pixel detector
Barrel with 4 layers
2 end caps with 3 disks

New Barrel Pixel (BPIX) for CMS



Current BPIX
3 layers (44,73,102 mm)
768 modules
48M pixels

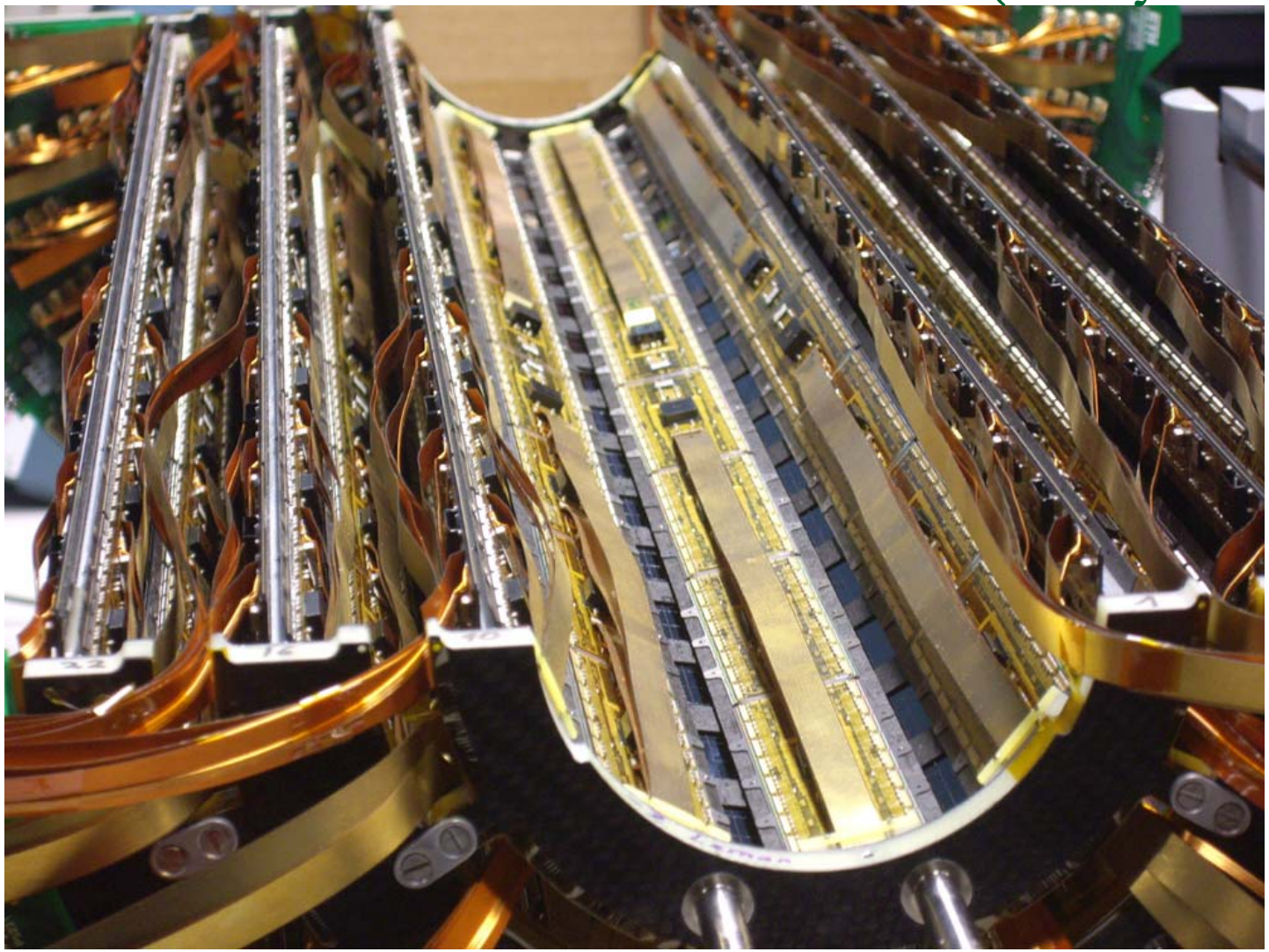
New BPIX design:
(as proposed by PSI)

2 identical half-shells
4 layers @ 39, 68,109,160mm
1216 modules (79M pixels)

to increase performance :

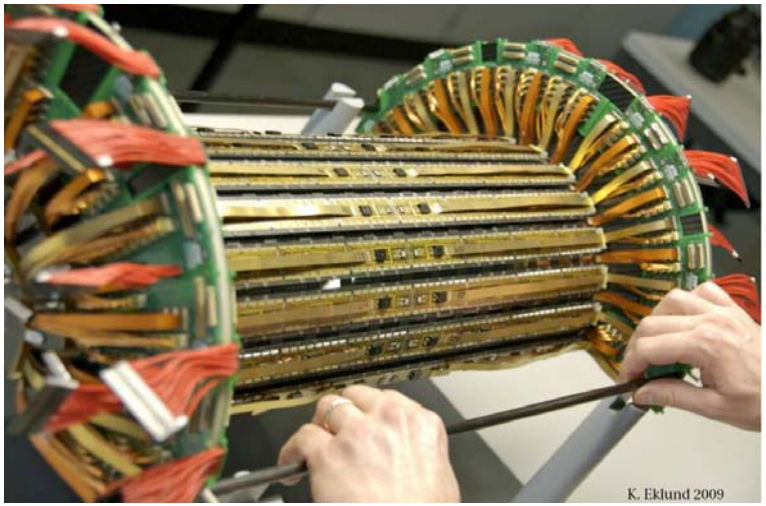
- Less material (ultra light weight)
- Smaller inner radius (b-tagging)
- Larger lever arm (improved tracking)
- Improved r/o (DT beyond $2 \cdot 10^{34}/cm^2$)
- More redundancy 4 layers
- Higher efficiency (3 of 4 seeds)

One Half of Current BPIX (3 layers)

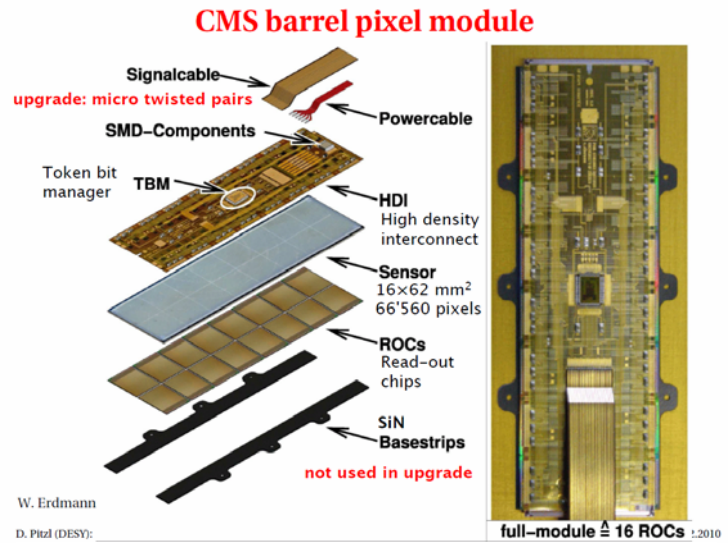


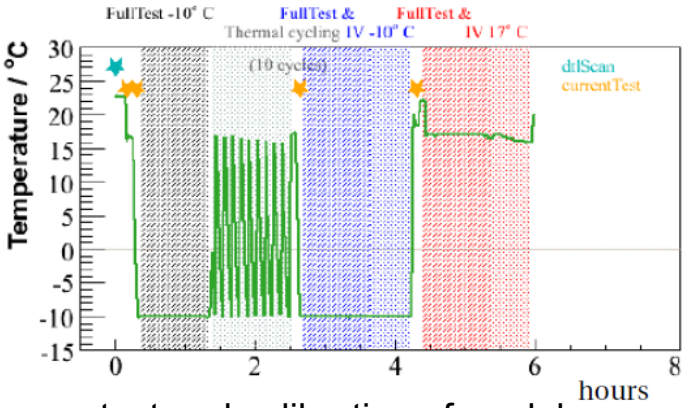
Building Layer 4 of BPIX

current BPIX with 3 layers



carbon fiber frame for new BPIX





test and calibration of modules

Pixel Upgrade Schedule

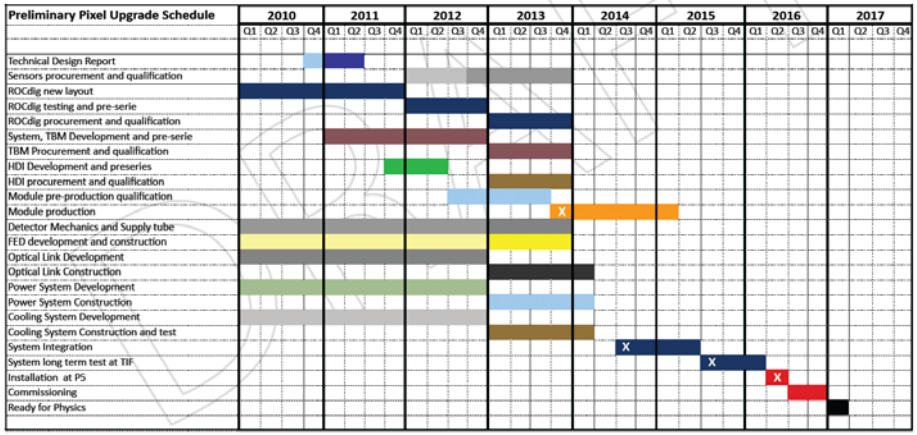


Figure 6.27: Tentative schedule for the Phase 1 upgrade pixel detector.

Schedule taken from TP :

Pre-series (ROC, TBM, HDI)	2011 - 12
Material procurement	2012 - 13
Module production	2013 - 14
System integration	2014
System test at TIF	2015
Installation	2015/16

Work packages by country :
expressed interests (preliminary)

Germany marked in blue
DESY : all blue except power system

V1

Preliminary Areas of Interests for the Pixel Upgrade

	Deliverables	A	D	I	CERN	CH	GB	TW	USA	F	B	FI
1	Silicon Pixel Sensors qualification		x	x	x	x			x			
2	Read Out Chip (ROC)					x						
3	ROC qualification		x	x		x		x	x			
4	Token Bit Manager (TBM) chip								x			
5	High Density Interconnection (HDI) circuit					x			x			
6	Module production and test		x	x		x		x	x			
7	Test Beams and System Qualification		x	x	x	x	x	x	x			x
8	Detector Mechanics and Supply tubes					x			x			
9	DAQ and Control Systems	x				x	x		x	x		
10	Optical Link System				x				x			x
11	Control, Safety and environmental Systems				x				x			
12	Power System		x		x				x			
13	CO2 Cooling System				x				x	x		
14	Module Integration and Tests		x	x	x	x			x			
15	Services, Mechanical Integration and tests				x					x		
16	System long term test at TIF	x	x	x	x	x	x	x	x	x		
17	Installation and Engineering				x	x			x			
18	Commissioning in CMS	x	x	x	x	x	x	x	x			

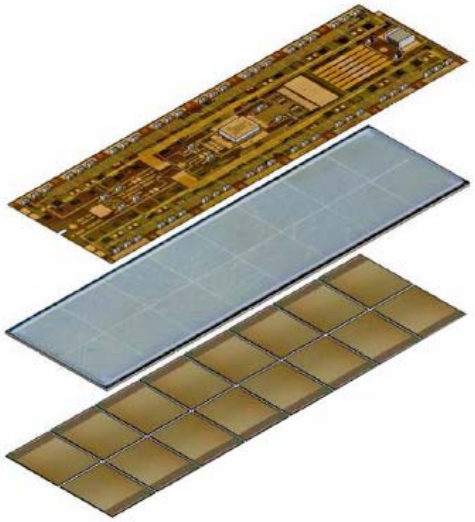
In red countries that has commented

Taiwan and CERN effort will be join their effort based at CERN

BPIX – DESYs Steps Towards Layer 4

- Getting ready / training
  - use old modules & chips to setup infrastructure
  - participate in pre-series testing of components
- Setting up production line
  - gluing tools (production started at University of Hamburg) (✓)
  - bump bonding at DESY or external (IZM?)
  - micro placer/reflow infrastructure
  - wire bonding
- Setup of test and calibration
  - Probe station (PA300) for raw module tests ✓
  - PSI test board setup for full module tests (✓)
  - Cold box for full module tests
  - X-ray test setup
- Setup of layer assembly & test
  - Needs tooling to fix and rotate layer
  - HV, cooling, readout for final layer tests

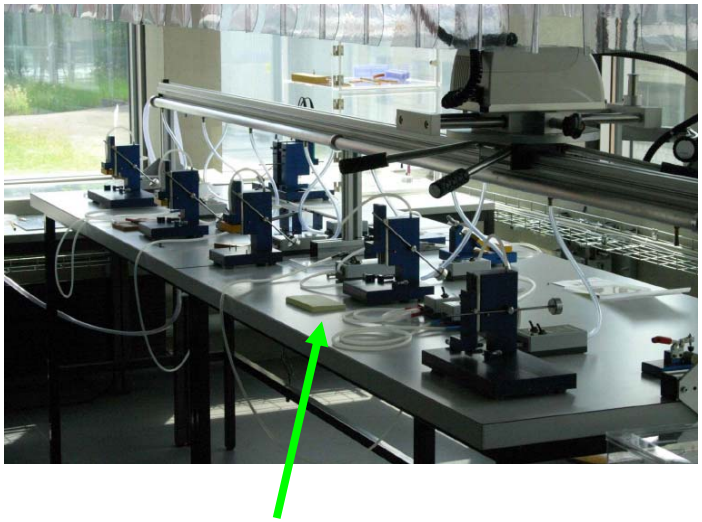
Barrel Pixel Module Production



High density interconnect
3-layer flexprint
Glued to back of sensor

Silicon sensor
16x64 mm^2
66'650 pixels

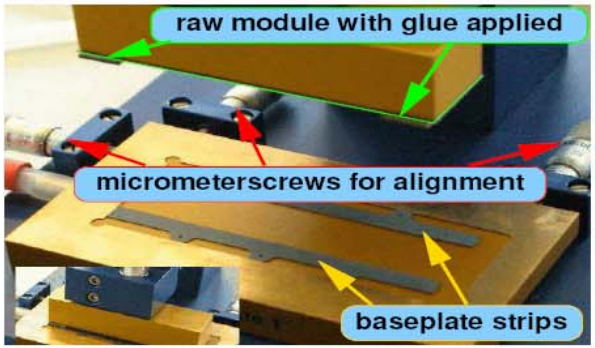
16 read-out chips
Bump bonded to sensor pixels
Wire bonded to flex print

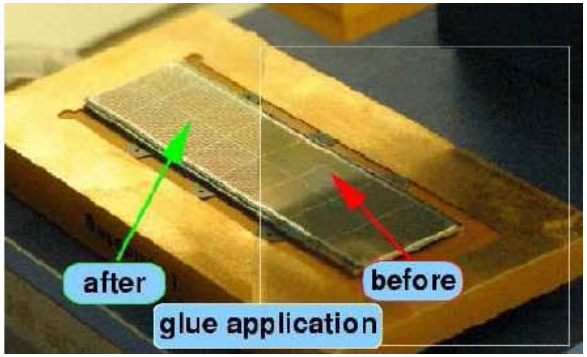


Gluing : Production line at PSI

Work packages distributed among :
DESY, Hamburg, Karlsruhe, Aachen

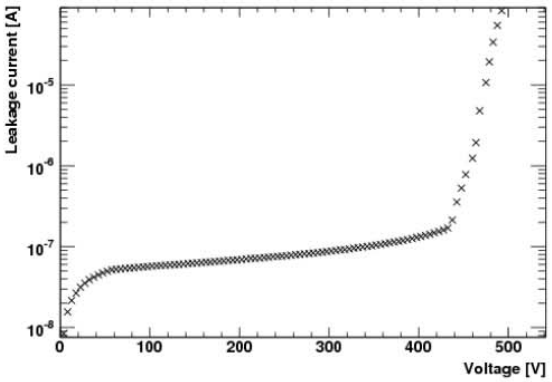
Tools for gluing from PSI - two stations as prototypes have been rebuilt at Uni-HH now

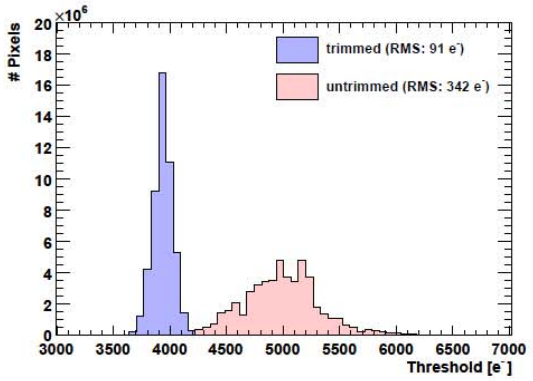




Module test classifications

- Start-up adjustments
  - Analog current setting
  - Threshold and delay settings
  - Analog levels setting
- Functionality tests
  - Verification of pixel readout
  - Check bump bonding quality
  - Functionality of 4 trim bits
- Performance tests
  - Pixel noise measurements
  - Si sensor IV curves
- Calibrations
  - Find separation between address levels
  - Threshold unification (trimming)
  - Puls height calibration
  - Internal signal (VCal) calibration with X-rays

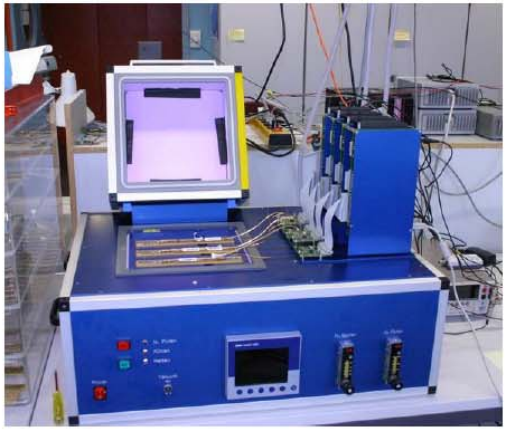


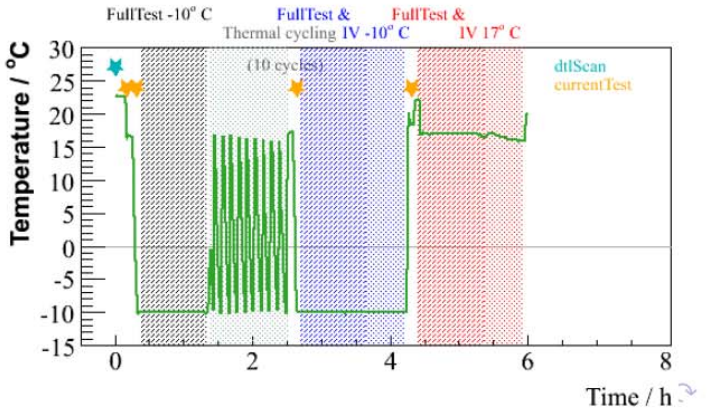


(experience from previous production)

Testing set up and procedure

- Challenges
  - Huge number of channels: 5 ÷ 6x10^7
  - Multy-dimensional parameter space: 29 DACs/ROC
  - Temperature dependence: tests done at -10°C and +17°C
- Test set up
  - Programmable cooling box
  - 4 modules at a time
  - Custom built test-boards with FPGA
- Procedure
  - Start-up adjustments
  - Full test at -10°C
  - 10 thermal cycles
  - Full test and IV at -10°C and +17°C





(experience from previous production)

BPIX - Current Status

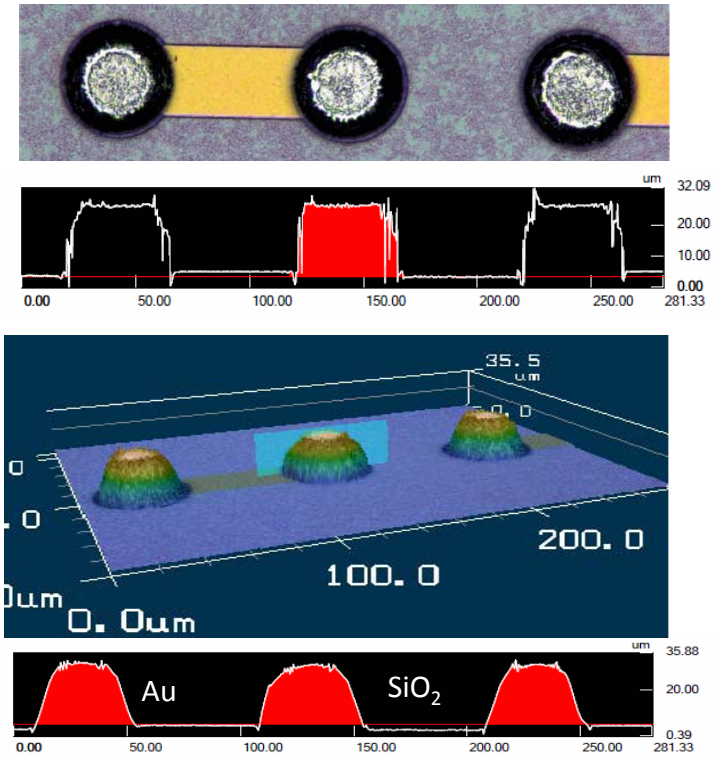
- Within CMS
  - CMS technical proposal submitted to LHCC end 2010
  - Approval by LHCC and RRB meetings this year
  - Followed by technical design report
  - Tracker upgrade organization being setup
  - MoA ~ Autumn 2011

- At DESY

  Infrastructure being setup
  - probe station (PA300) operational
  - buy micro placer system for bump bonding in 2011 (if bump bonding test results positive)
  - production of gluing tools started in 2010 (close collaboration with Uni HH Workshop)
  - PSI full module test board tests with old spare modules

  Bump bonding tests (close collaboration with FE)
  - first test structures done with different companies
  - comparing technologies

  Supporting MC studies for TP & TDR
  - 3 vs 4 layers, triplets vs quadruplet (bJet Trigger in HLT, b-tagging performance, …)



Comparing micro bumps from S.E.T. and Pac Tech (K. Hansen, DESY – FE)

Infrastructure – Example

Süss Microtech Probe Station

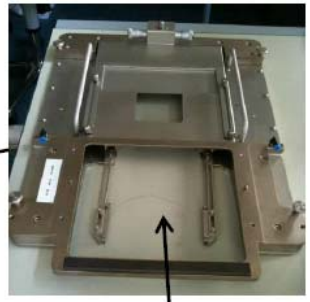
19" Rack

AWG5000

TLA6000

MSO5000

Probe-Card Holder



Probe Card

- ✓ Standard
- ✓ High Speed

Type PA 300

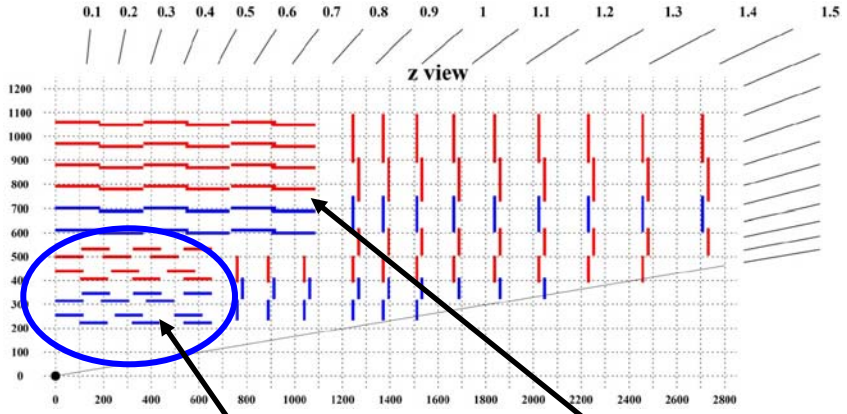
- ✓ Semi-Automatic
- ✓ Shielded

Thermo Chuck

- ✓ 12"-inch Wafer
- ✓ -40 ... 125°C

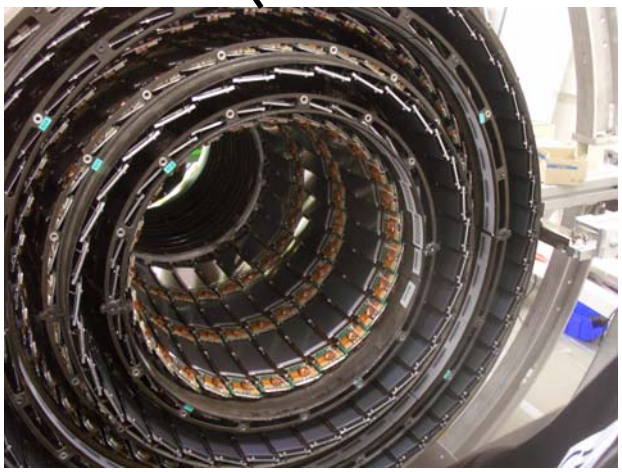
Setup and installation in close collaboration with DESY-FE

Phase II : New Si Tracker for CMS



Current CMS Si Tracker
barrel and end caps
10^7 channels, 200 m^2

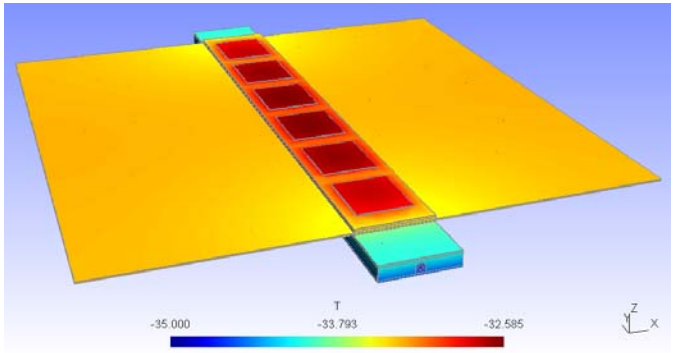
Goal :
improved radiation hardness
less material
better performance
pt trigger capability



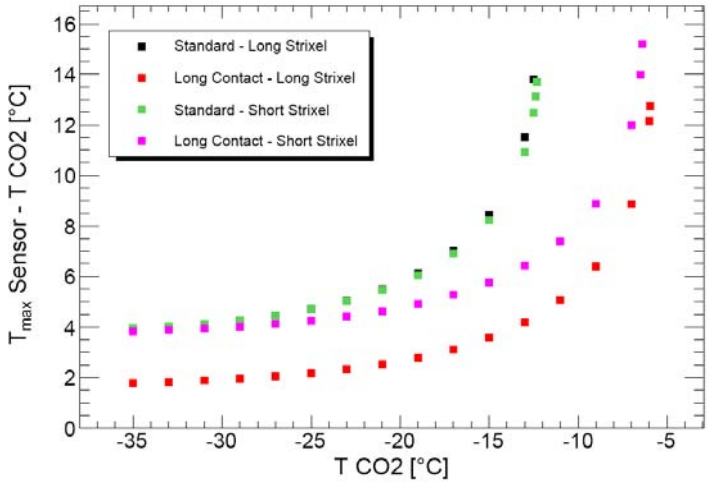
Inner barrel

Outer barrel

CMS Outer Tracker for HL-LHC



FE simulation of temperature distribution on a tracker module

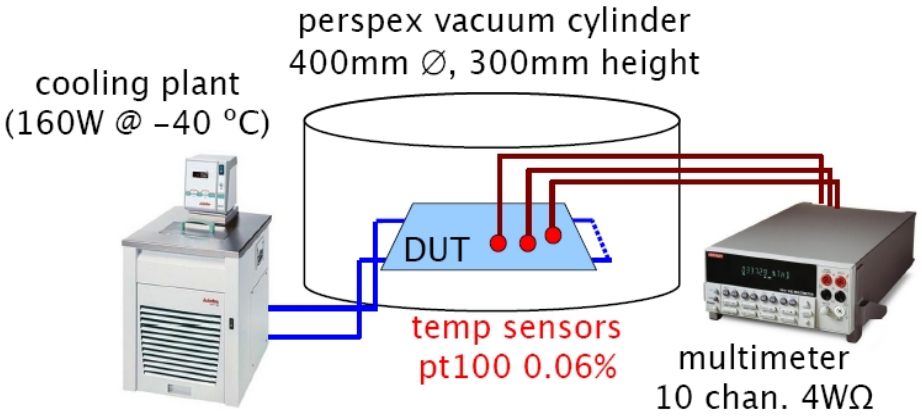


The FE simulation results on the temperature difference (sensor – cooling) is shown vs T of cooling for different module configurations.

At DESY we started with module design studies
- material budget optimization
- FE calculations (thermal & mechanical)
- verification of modeling with test setup

Goal
- Module assembly, test & integration

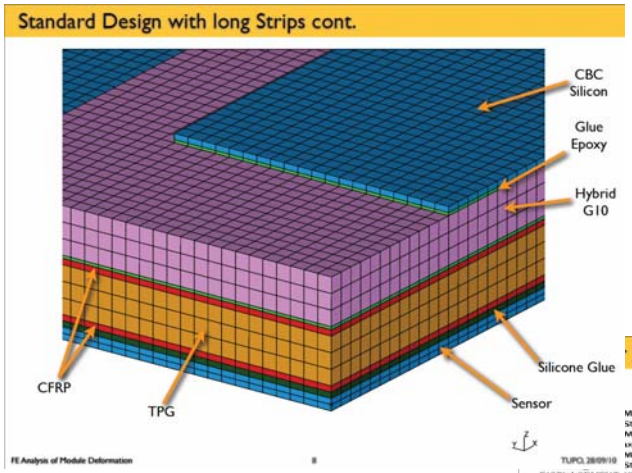
- Timeline : Tracker ready for HL-LHC ~ 2020
  10 year for R&D, Construction and Tests
  Sensors, ASCIS, Electronics, Mechanics,...



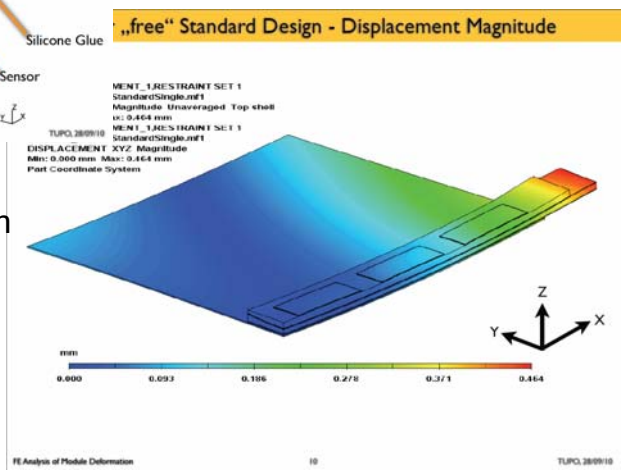
Laboratory setup for thermal tests

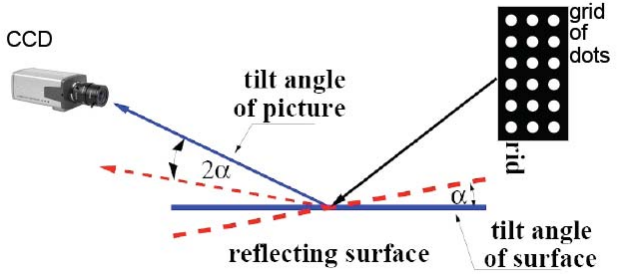
Tracking Module Mechanics

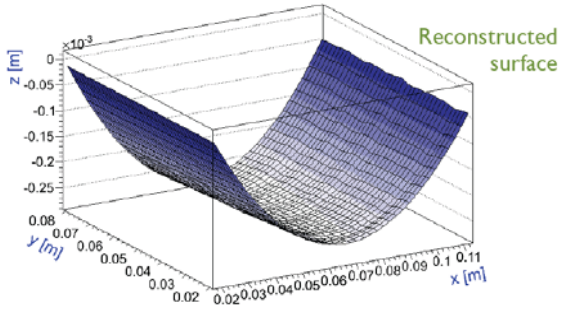
- started with finite element calculation for different materials/compositions
- will be followed by thermal and mechanical tests
- goal : material tests and module prototyping



FE calculation of sensor deformation







- develop reconstruction algorithms using simulated images to find optimum geometry

Optical measurement of surface deformation

Silicon Sensors for HL-LHC

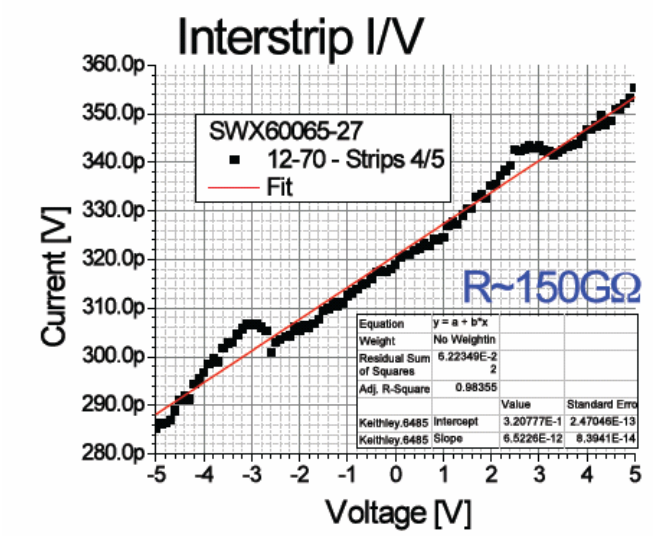
Goal: Explore different sensor materials and layout technologies to obtain a basis for the technology choice

Participating in CMS upgrade project (CEC)

DESY (Zeuthen) responsibilities:

- field simulations
- data base
- sensor qualifying (non-irradiated and irradiated)

PA200



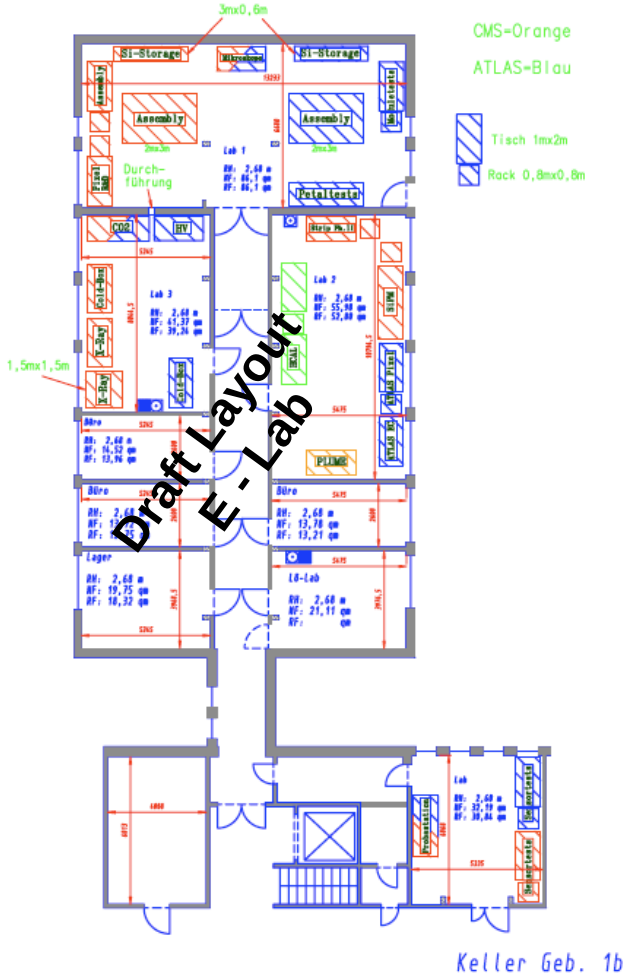
Clearn room ISO4 (10k) at DESY Zeuthen with probe station (PA200), equipped with:

- Cold chuck (min. temperature – 30⁰ C)
- Dark box
- two independent needle sets
- Nitrogen flux

Measurments :

- I/V
- C/V
- interstrip R, C

Common Infrastructure in FH



Use available resources in FH efficiently (ATLAS, CMS, FLC/ILC Activities)

Share investments for upgrade activities

Share technical personal in FH

Use renovation of Bldg 1 to concentrate facilities

1b : E-Lab

1c : M-Lab

Reuse of existing infrastructure from FH

Add equipment where needed

Conclusion

Building, commissioning and maintaining complex detectors is a strength of DESY- FH.

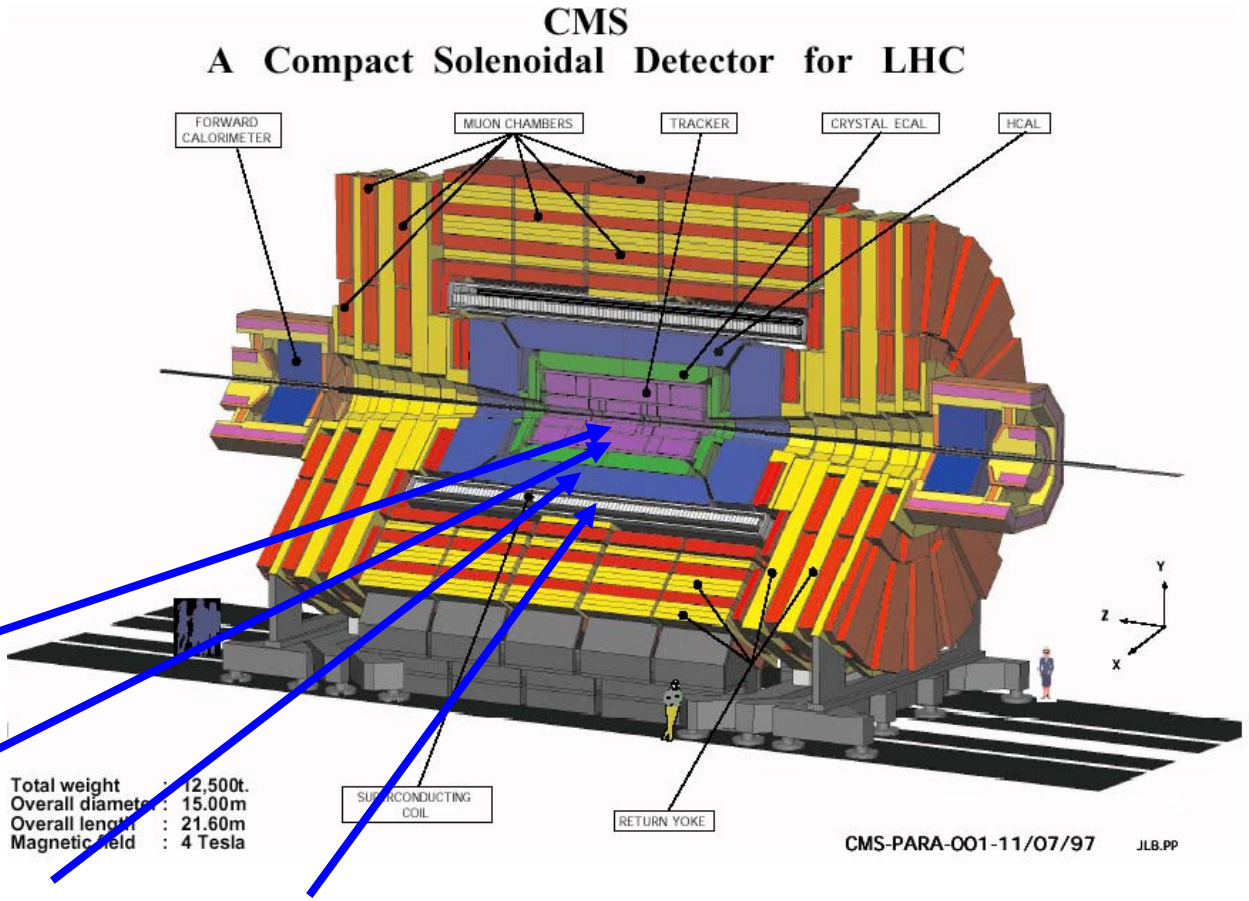
- **participating in ATLAS & CMS upgrades**
  - helps keeping this expertise on detector at DESY
  - enables us to keep track with new developments in detector R&D
  - is highly welcomed by the collaborations
  - and strengthens the networking with the other (German) HEP institutes

- **joining infrastructure within FH**
  - maximizes usage of DESY infrastructure (mechanics & electronics)
  - new FH laboratory infrastructure in Building 1
  - HGF detector initiative may give additional synergy

- **strong participation in ATLAS & CMS increases visibility of DESY**
  - we should profit from synergy participating in hardware, on/offline and analysis
  - example from CMS : tracking, alignment & calibration, heavy flavor tagging, etc
  - this will increase attractiveness of DESY for young scientists

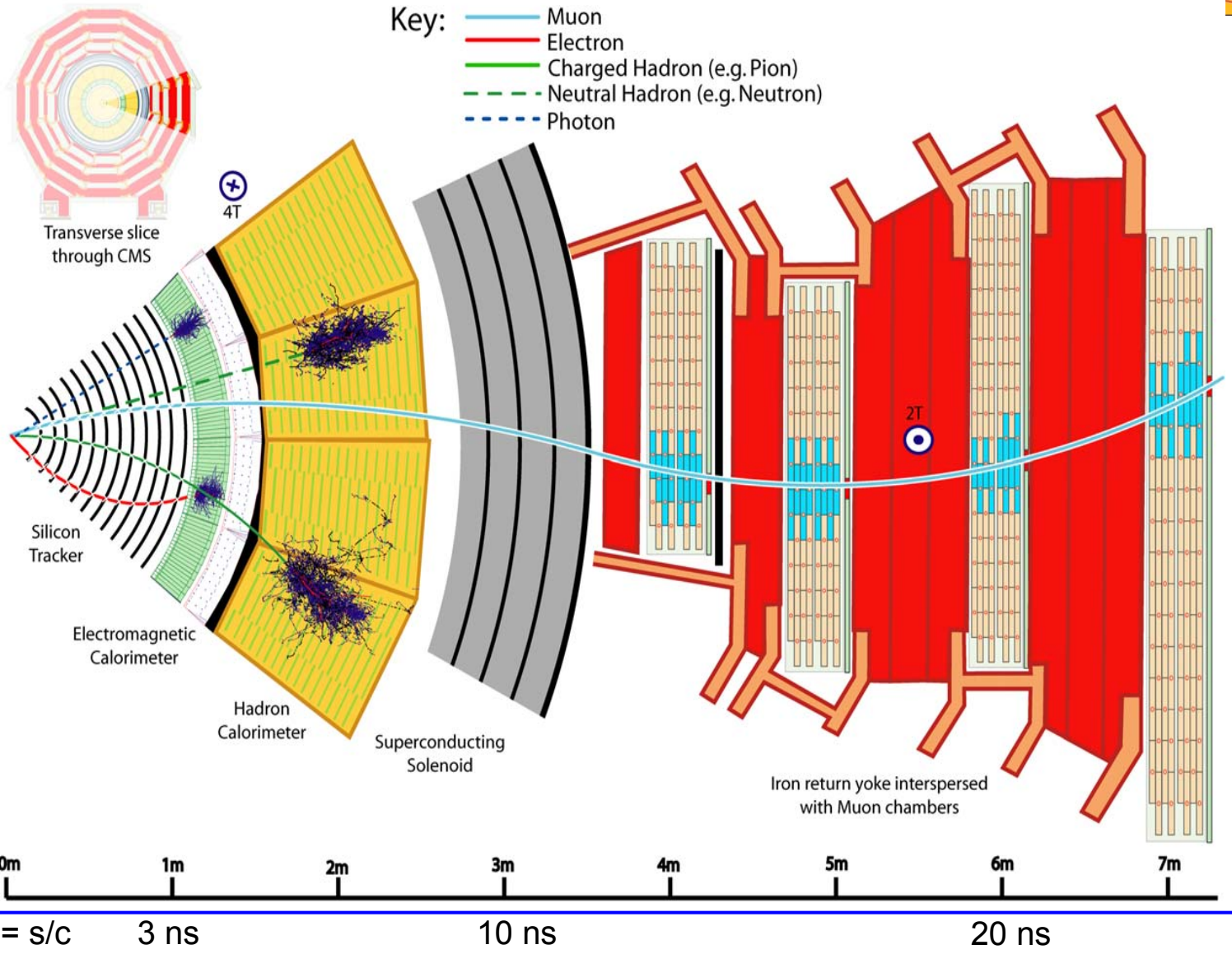
The LHC upgrades will strengthen our role in the future (collider) detector era

DESY Activities on CMS Upgrades



- Pixel
- Tracker
- SiPM for HCAL & MTT

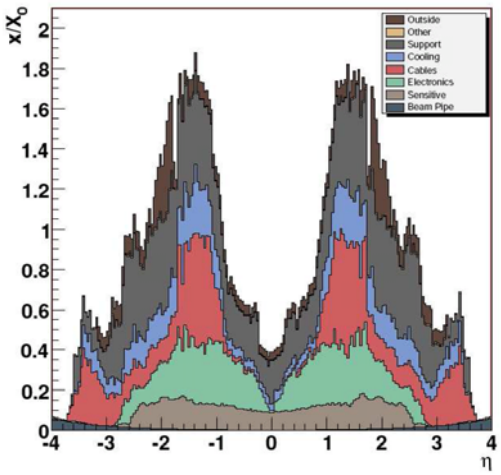
A slice of CMS



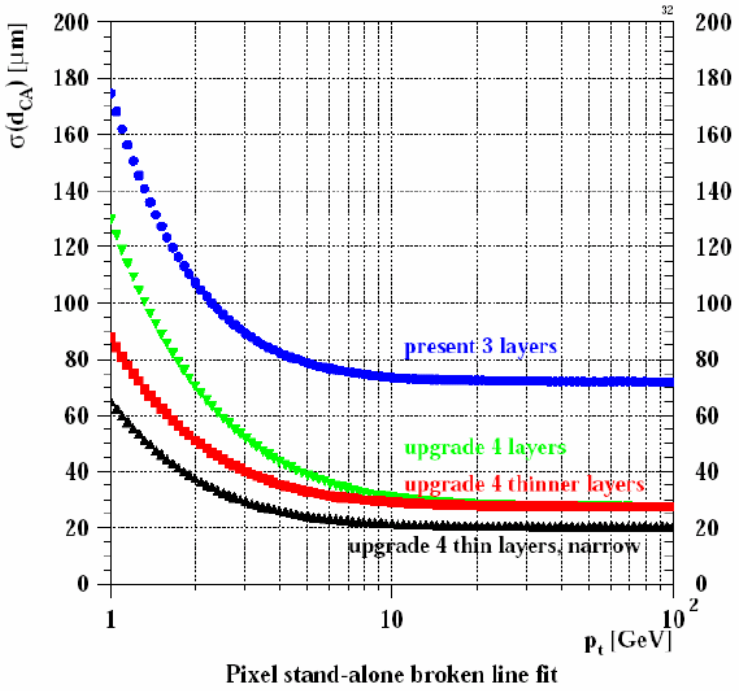
DESY Contribution to the CMS Tracker Upgrades

CMS-DESY Upgrade Proposal (PRC-2010-69-3)

- Low mass, 4 layer barrel pixel for 2015/16
  (towards a CMS technical proposal this year)
- Low mass, rad. hard outer tracker for sLHC
  (approved CMS Upgrade Project)
- Goal :
  - Improve performance
  - Reduce material
  - Improve radiation tolerance (for sLHC)



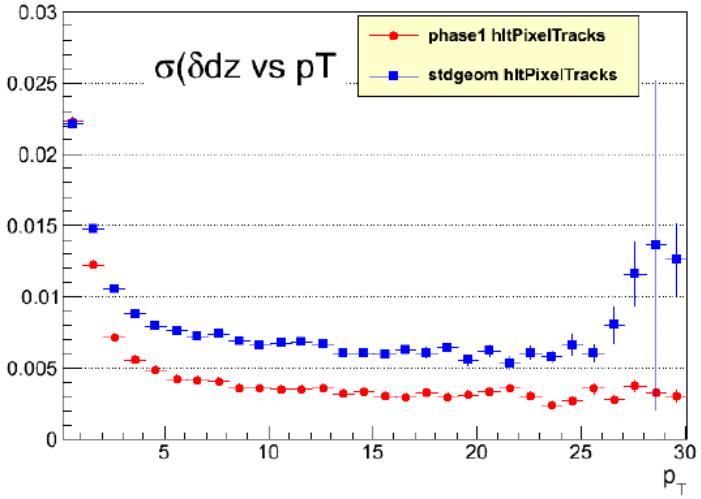
Tracker material vs η
(Current tracking configuration)

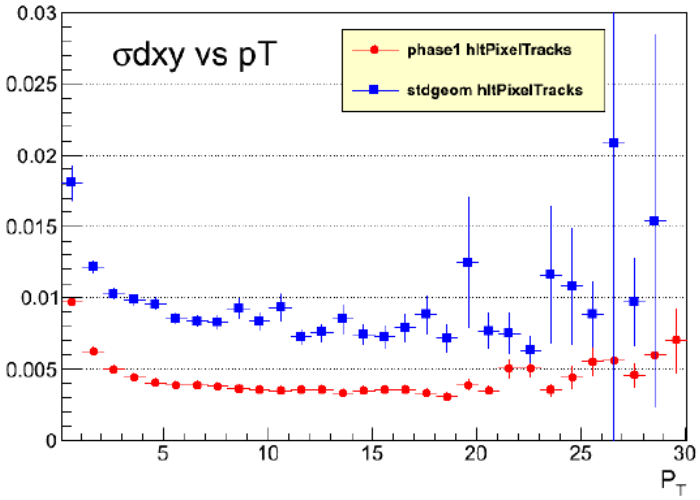


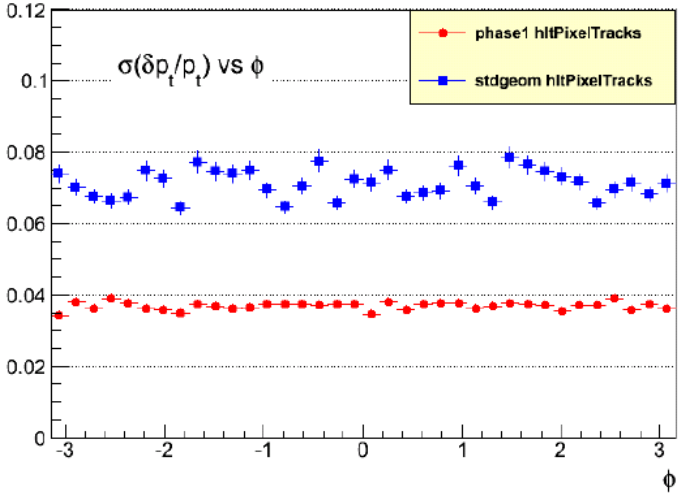
Impact parameter resolution in HLT
Comparison of present 3 vs 4 layer pixel
Different beam pipe radii simulated

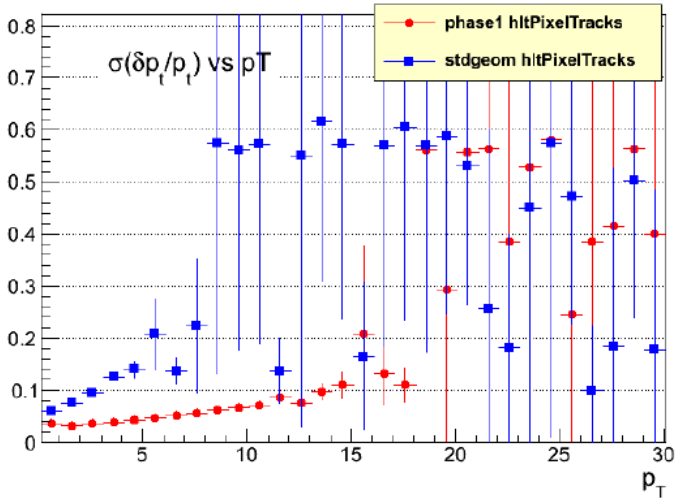
L2.5 (pixel-only) track properties

stdgeom (triplets) phase1 (quadruplets)

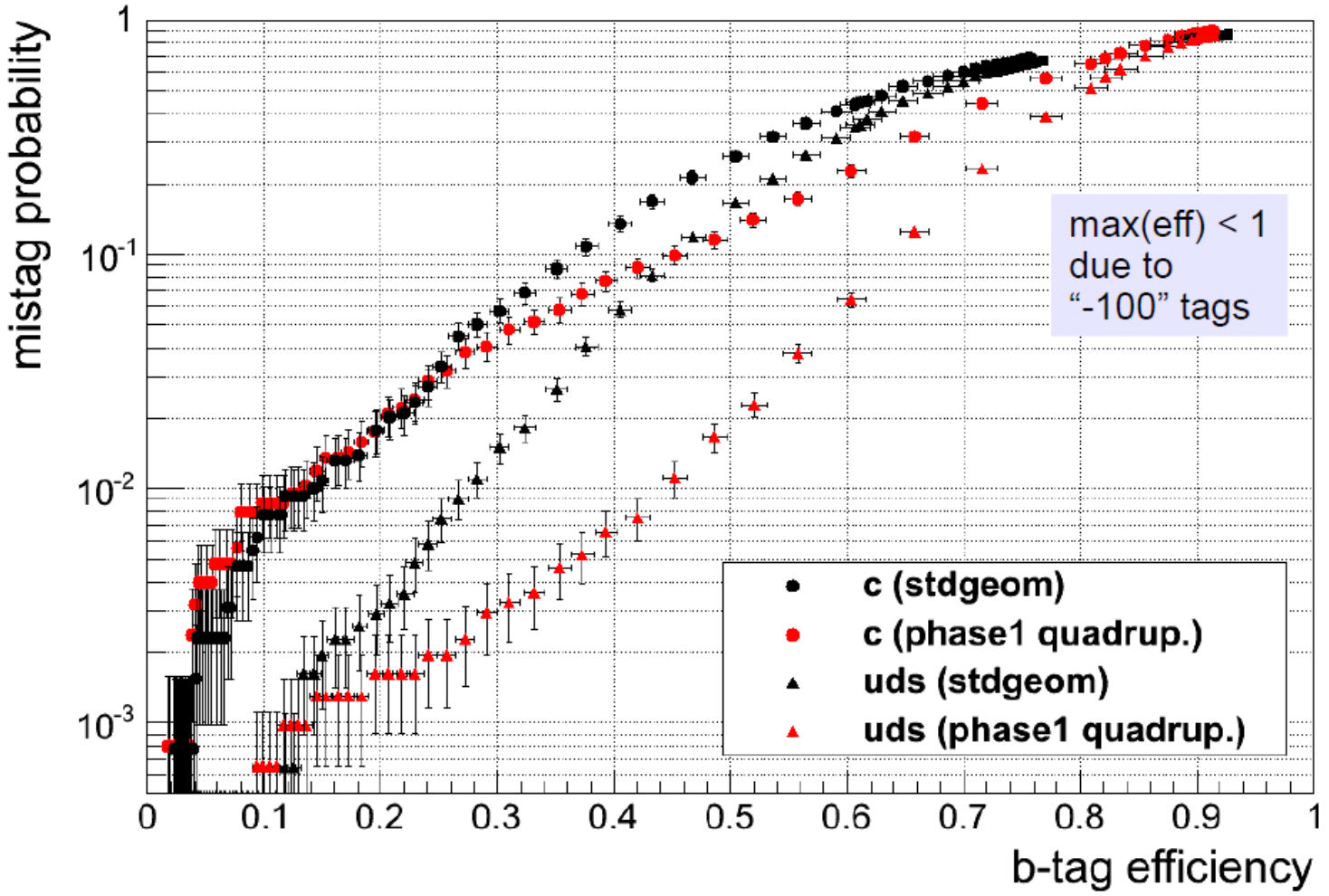




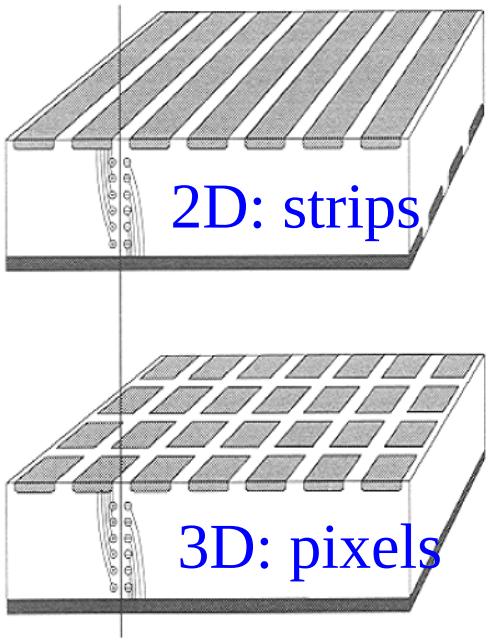




BPIX - Simulation B-tag (pixel only)



Silicon Pixels



Requires readout chip
bump-bonded
to the sensor: