

# Status of CMS at DESY

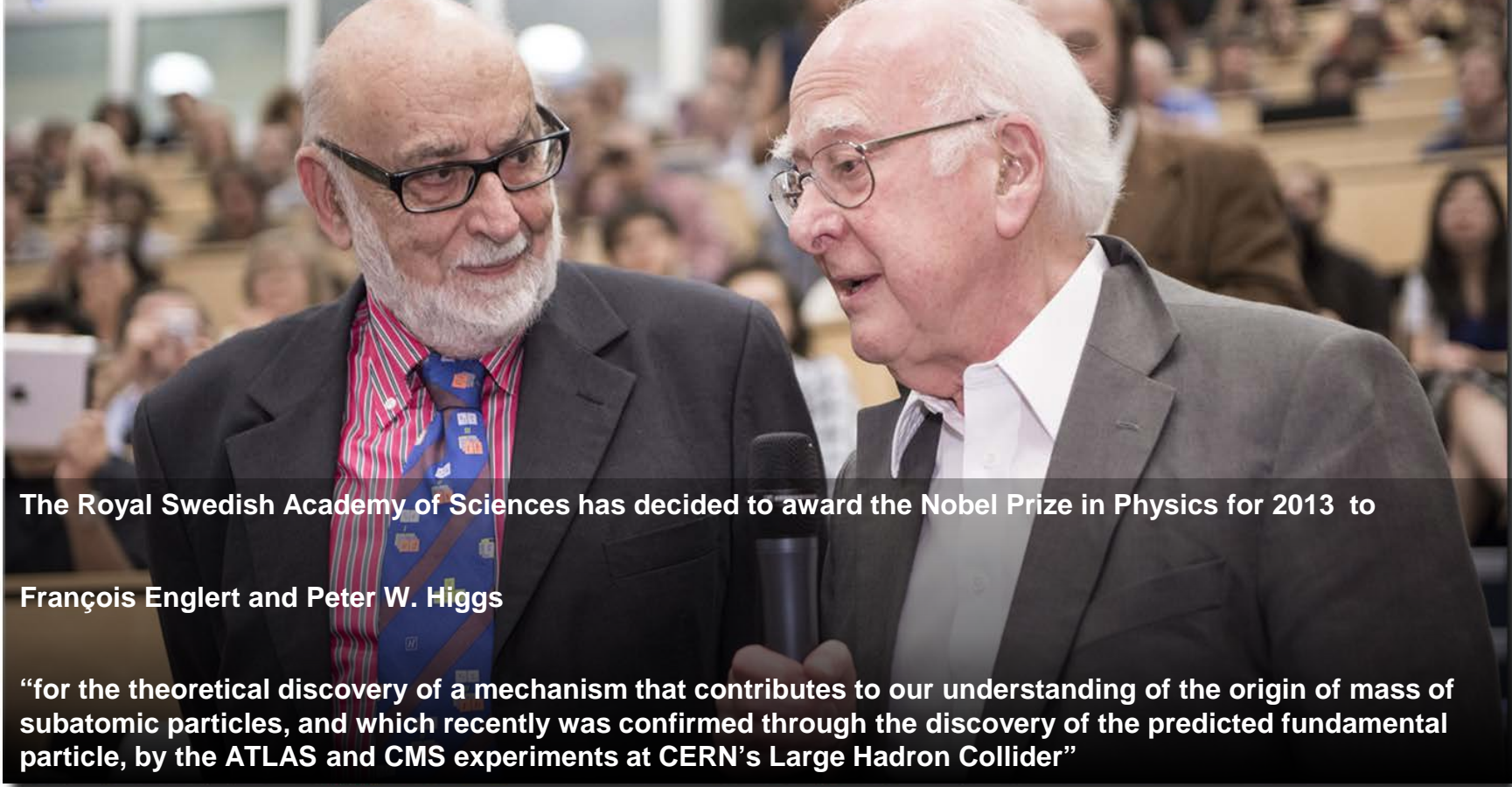
Report to the 76th Physics Research Committee

Open session, Oct 24th, 2013

Benjamin Lutz

Status of CMS at DESY

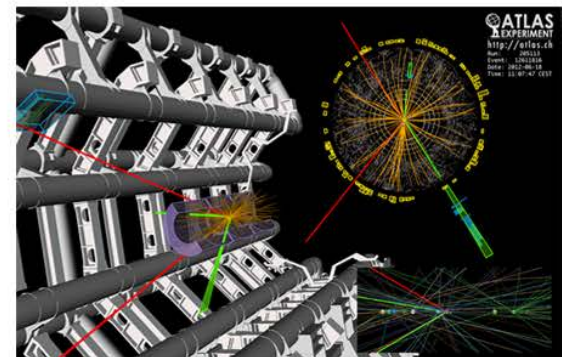
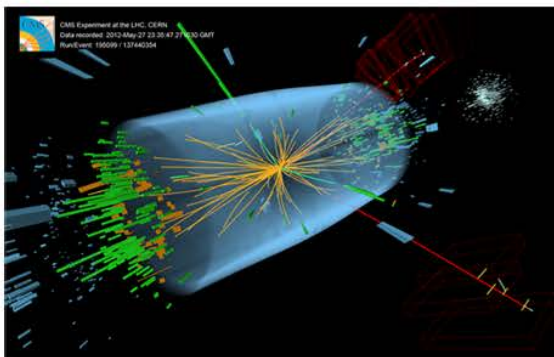
Hamburg, 24th October 2013



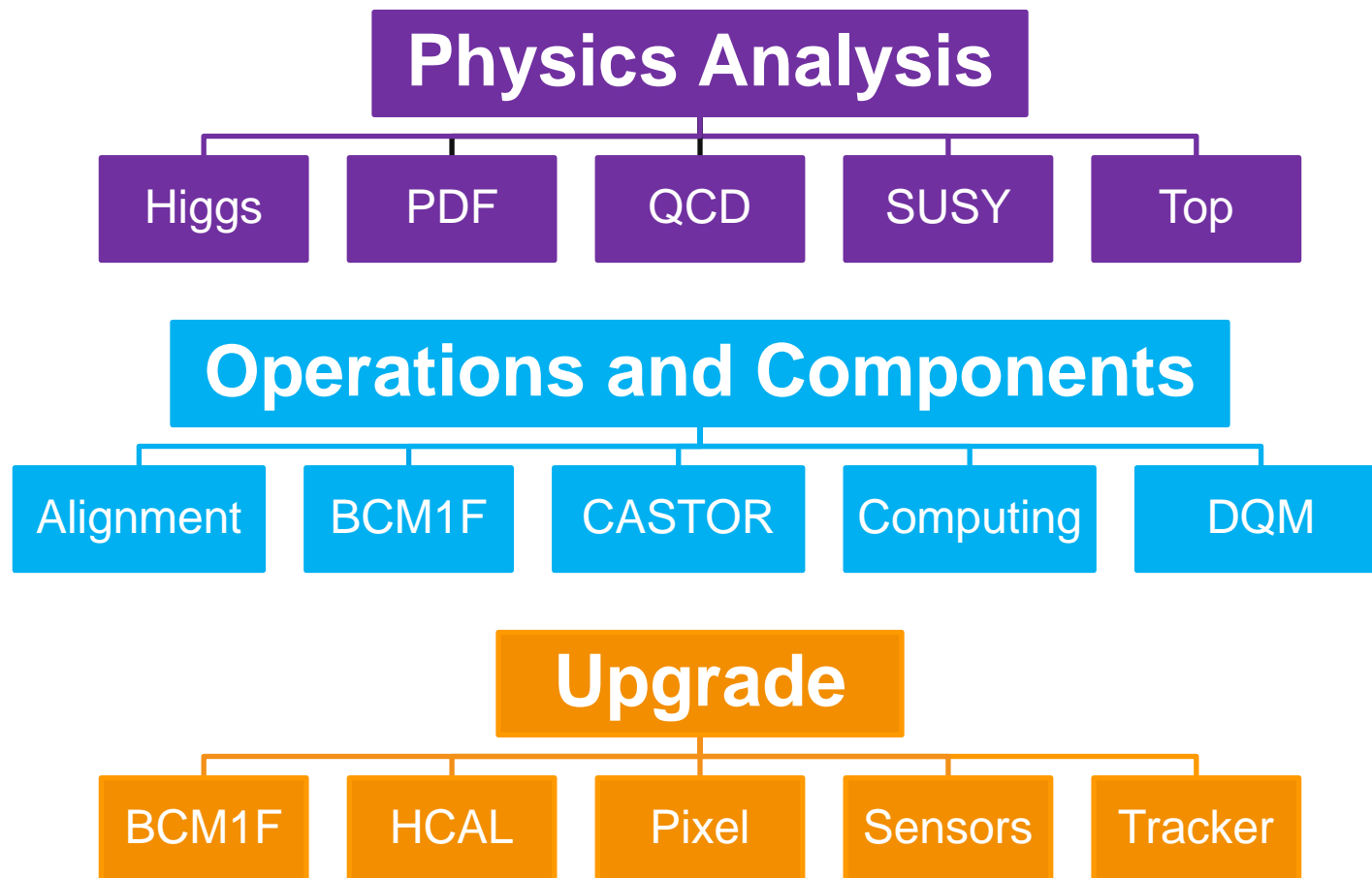
The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics for 2013 to

François Englert and Peter W. Higgs

“for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN’s Large Hadron Collider”



21 staff, 17 post-docs, 26 PhD students; engineers & technicians



## Past and Present

### > Advanced & finished analyses

- $H \rightarrow \tau\tau \rightarrow (\mu\mu, ee)$  SM + MSSM



- $H \rightarrow bb$  MSSM



### > Since last PRC

- NMSSM  $H_1 \rightarrow bb$  in SUSY cascades



- $ttH(bb)$ , in top di-lepton channel  
(joint effort with top group)

### > Technical contributions

- Production & validation of  $Z \rightarrow \tau\tau$   
embedded samples for  $H \rightarrow \tau\tau$  analysis

Cooperation:

Karlsruher Institut für Technologie  
Universität Hamburg  
Universität Zurich (UZH)  
UC Riverside  
IC London  
DESY Theory Group (joint SFB project)

## Started and Targeted

### > Started topics

- NMSSM  $H_2 \rightarrow H_1 H_1 \rightarrow (\tau\tau)(\tau\tau)$



- Properties of  $H(126)$  in the  $H \rightarrow \tau\tau$  channel  
(13TeV)



### > Targeted topics (all 13 TeV)

- MSSM  $H \rightarrow \tau\tau$  search



- MSSM  $H \rightarrow bb$  search

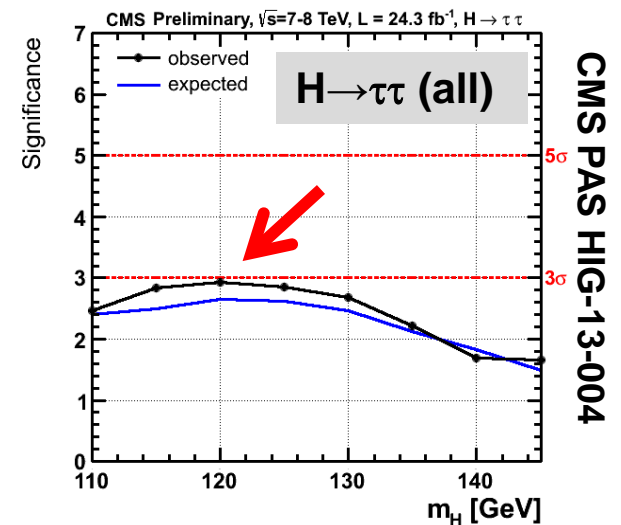
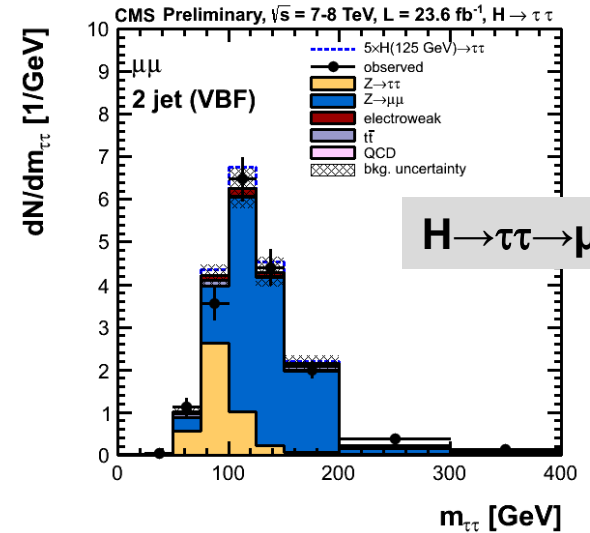
- NMSSM  $H_1 \rightarrow bb$  searches in SUSY  
cascades

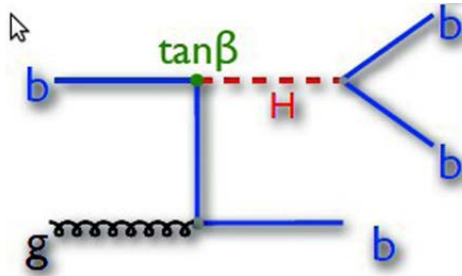
- $ttH$  (joint effort with top group)

### > Young Investigator Group

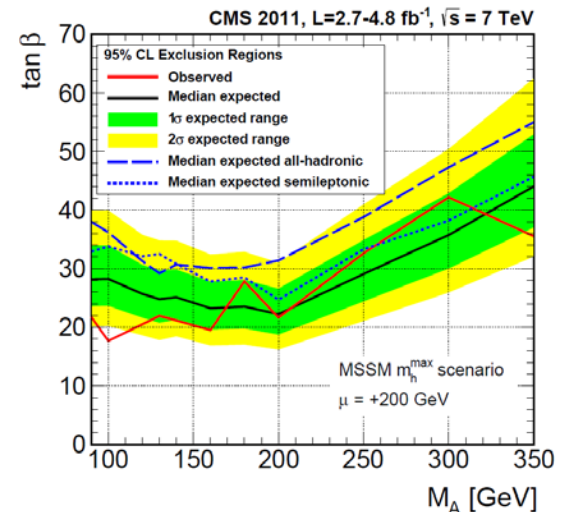
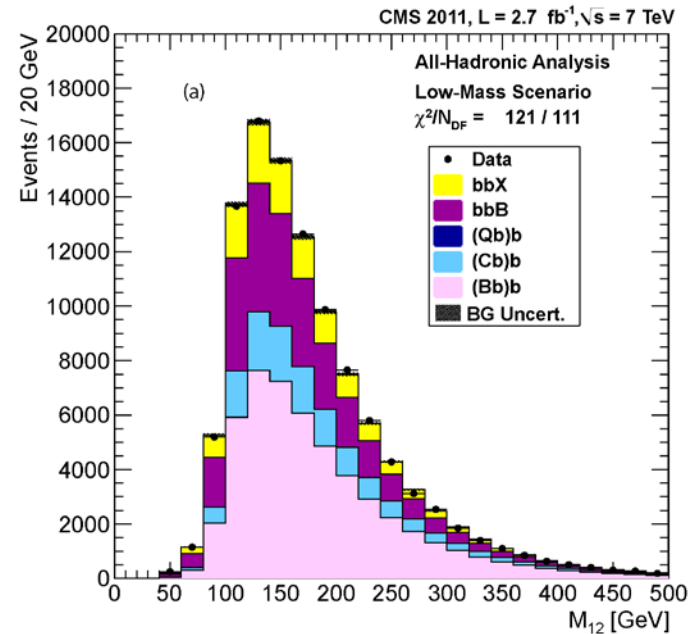
- **Alexei Raspereza until 2014**

- > Key question: does H couple to leptons (or fermions in general)?
  - Preliminary 7+8 TeV result for Moriond was tantalizing:  $2.9 \sigma$  observed significance!
- > Huge effort ongoing to achieve optimal result for final publication with improved methodology
  - Addition of ee channel (DESY)
  - Refined definition of event categories
  - Enhancement of sensitivity
  - DESY responsibility: ee,  $\mu\mu$ ,  $VH \rightarrow \tau_{\text{had}}\tau_{\text{had}} + l$  channels
- > MSSM search in the  $\tau\tau$  channel is being updated in parallel
  - Extend to full 7 TeV + 8 TeV data sample
  - Addition of ee and  $\tau_{\text{had}}\tau_{\text{had}}$  channels
  - Improved sensitivity
  - DESY responsibility: ee,  $\mu\mu$ ,  $\mu e$  channels
- > Timeline: SM paper fall of this year, MSSM spring 2014





- > Structure of Higgs Sector?
  - search for additional Higgs
    - Is it one SM Higgs, are there more?
    - Couplings study shows:  $BR_{BSM} < 52\%$
    - Still much room for BSM Higgs
- > MSSM 7 TeV  $H \rightarrow bb$  analysis: published
  - Phys.Lett. B 722 (2013) 207
  - World-best sensitivity in this channel
- > Analysis of 8 TeV data is in progress
  - Benefit from larger integrated luminosity
  - Extend sensitivity to higher masses
    - dedicated high-mass triggers
  - collaboration with Univ. Zurich and ITEP Moscow
  - Aiming for spring conferences



Phys.Lett. B 722 (2013) 207



## Past and Present

### > Analyses

- Correlations between forward and central jets
- $dn/d\eta$  measurement including Totem
- Leading tracks and mini-jet measurement
- 4-jet measurement

### > Interpretation

- Jet production and the inelastic pp cross section at the LHC<sup>1</sup>
- Longitudinal momentum shifts, showering and non-perturbative corrections in matched NLO-shower event generators-jet measurement<sup>2</sup>
- Higgs as a gluon trigger<sup>3</sup>

<sup>1</sup>Phys.Rev. D 86(2012)117501

<sup>2</sup>Phys.Rev.D 87(2013) 094009

<sup>3</sup>arXiv:1308.1655

## Started and Targeted

### > High mass Drell Yan production

- Started: DY & multi-jets (7 TeV data)
- Preapproval 2013

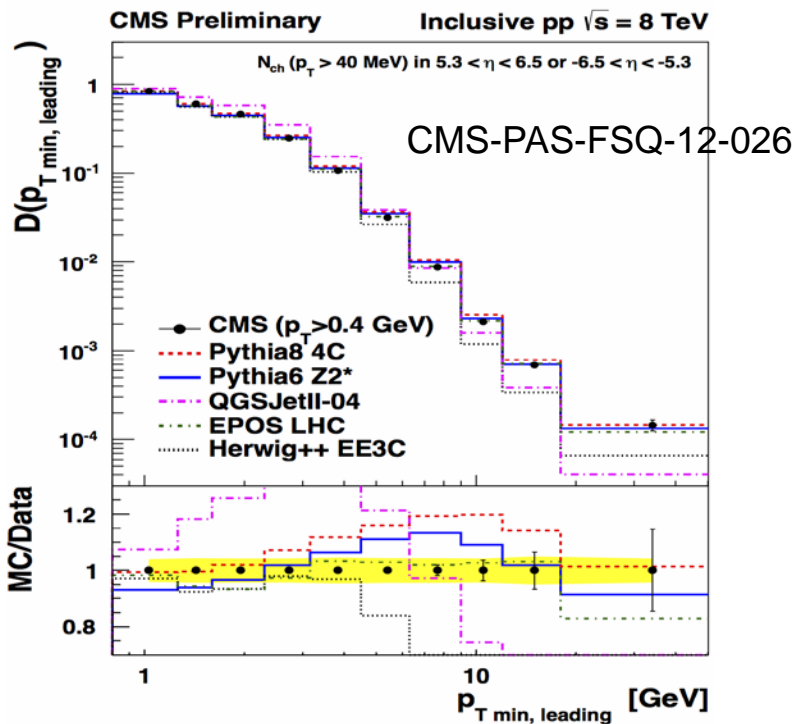
### > 2b+2jet production

- 2010 data (low pileup)
- Preapproval 2013

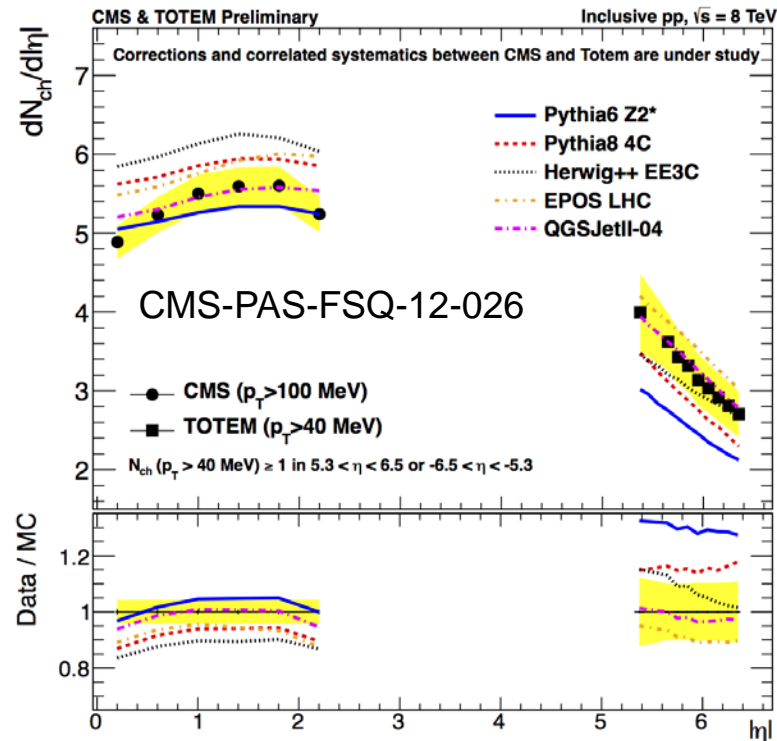
### > Targeted topics for 13 TeV

- Higgs vs. DY
- Higgs + jets (UE & QCD analysis)

Cooperation: Karlsruhe Institut für Technologie  
Antwerp



- > Significant deviations in medium  $p_T$  range
- > Information on transition from perturbative to saturated region
- > Testing different MC models




- >  $dn/d\eta$  over full acceptance range of CMS-Totem
- > Measurement in an unexplored region of phase space
- > Test of model predictions from central to forward rapidities



## Past and Present

### > Analyses

- Direct stop production in the single-lepton final state<sup>1</sup> 
- Opposite-sign di-leptons<sup>2</sup>
- Non-simplified SUSY: pMSSM stau-coannihilation at LHC and ILC<sup>3</sup>

### > Technical contributions

- SUSY DQM contact (until 06/2013)
- SUSY Future analysis studies

Cooperation: Universität Hamburg  
DESY ILC group  
FNAL  
Strassbourg  
USCD  
USCB

<sup>1</sup> Submitted to EPJC, [arXiv:1308.1586](https://arxiv.org/abs/1308.1586)

<sup>3</sup> Snowmass white paper


<sup>2</sup> Thesis finished

## Started and Targeted

### > Started topics

- Common 0/1/2 lepton stop paper on 8 TeV (contact for common pre-selection team)
- Follow-up paper on 14 TeV LHC-ILC study

### > Targeted topics for 13 TeV

- 1-lepton stop analysis 
- VBF SUSY production at 13 TeV
- Stop sensitivity study with fullsim for SUSY Phase II Upgrade TDR

### > Young Investigator Group

- **Isabell Melzer-Pellmann** until 2014

# SUSY top-squark Pair Production Search



## > DESY contribution

- Use of kinematic variable  $M_{T2}^W$  to suppress main background (di-leptonic  $t\bar{t}$ )
- Study of jet energy corrections
- Common pre-selection contact

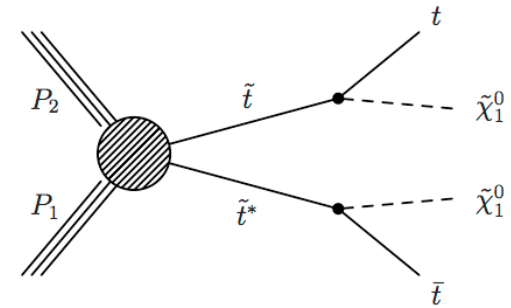
## > Paper

- Submitted to EPJC
- [arXiv:1308.1586](https://arxiv.org/abs/1308.1586)

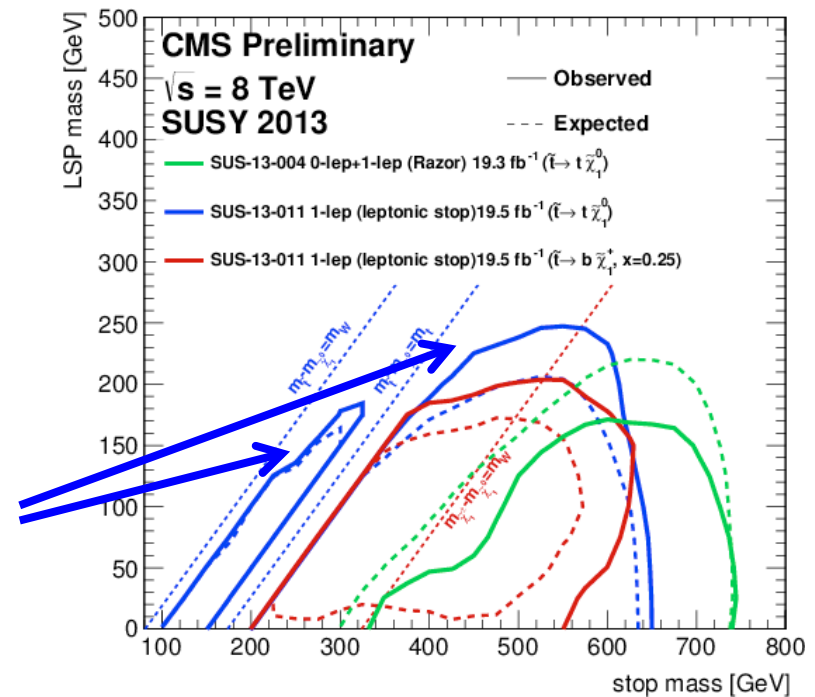
## > Plan

- Combined (0,1,2)-lepton analysis



Best measurement for low stop masses







$\tilde{t}\tilde{t}^*$  production



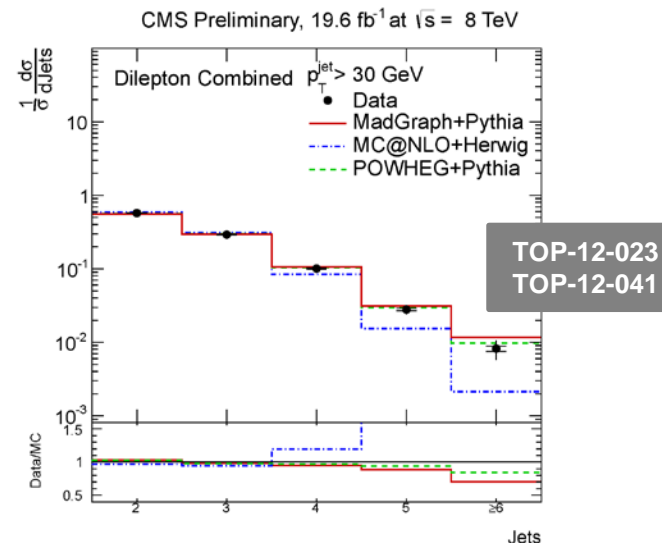
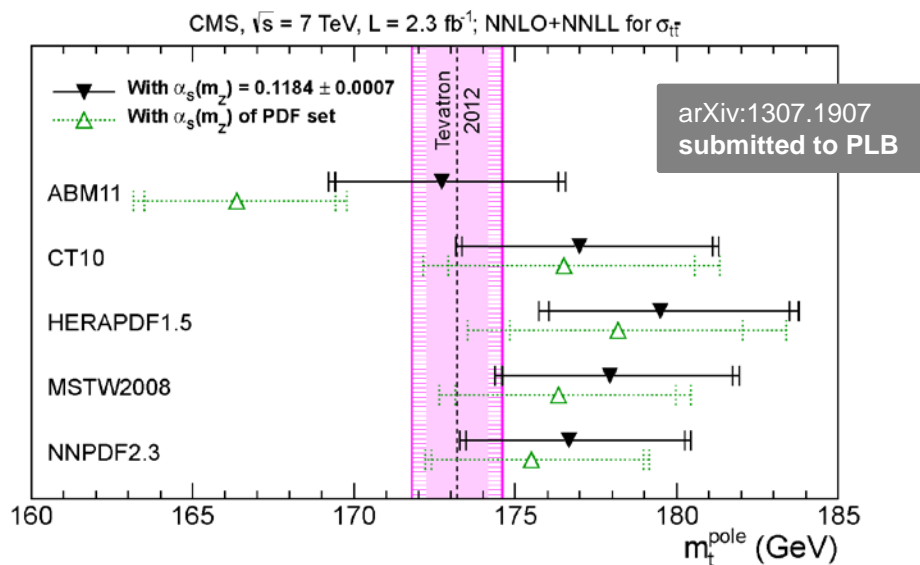
## Past and Present

- > **Analyses (di-lepton channel)**
  - Differential cross sections 
  - Measurement of tt+jets 
  - Incl. cross section, 8/7 and tt/Z ratios
- > **Interpretation**
  - Top mass,  $\alpha_s$  and PDF from x-sections
- > **Projections**
  - Prospects for the top-mass accuracy
- > **Technical contributions**
  - Trigger analysis
  - Generator contact
  - Top DQM

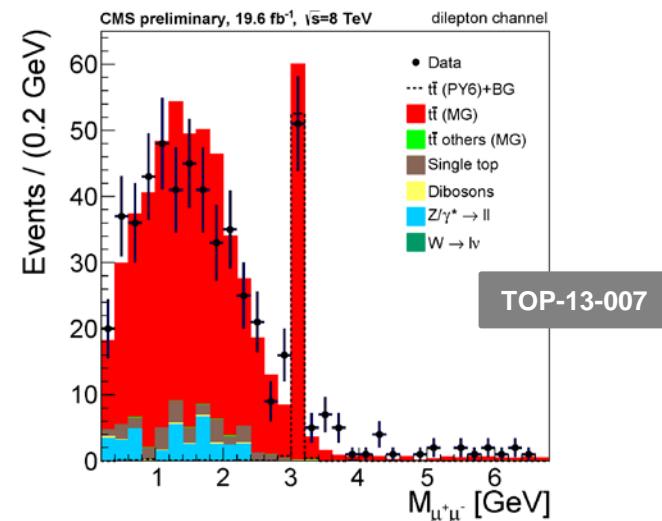
## Started and Targeted

- > **Higgs (with and in Higgs group)**
  - Started: tt+(H $\rightarrow$ bb) 
  - Planned: tt+(H $\rightarrow$ TT)
- > **Started topics for 8 TeV**
  - Top mass from tt+1jet distributions
  - ttZ (4 leptons)
  - J/ $\psi$  and fragmentation studies
- > **Targeted topics for 13 TeV**
  - Preparation of TOP trigger menu
  - ttbb, ttH, ttZ
  - tt incl. and diff. cross sections
- > **Young Investigator Group** 
  - **Maria Aldaya starting 2014**
  - Cooperation with  + 

Cooperation: Universität Hamburg  
Karlsruher Institut für Technologie



- > Compared measured cross section to QCD prediction, preserving correlations between top-mass,  $\alpha_s$  and PDF
  - First top-pole mass at NNLO
  - First  $\alpha_s$  at NNLO from a hadron collider
- > Jet multiplicity (new for LHCP May 2013)
  - Good description by default Madgraph
  - Sensitivity to different QCD parameters/models, potential to tune simulation
- >  $J/\psi \rightarrow \mu\mu$  from b from t
  - Avoiding use of b-jet energy scale for top-mass measurement



## Physics Analysis

Higgs

PDF

QCD

SUSY

Top

## Operations and Components

Alignment

BCM1F

CASTOR

Computing

DQM

## Upgrade

BCM1F

HCAL

Pixel

Sensors

Tracker

> New: Millipede-II based alignment procedure is also used to simultaneously calibrate Lorentz angle

- Lorentz angle: deflection of drift charges in magnetic field
- Key ingredient: data without magnetic field
- Detailed time dependence

> Clear offset between  $Z < 0$  (rings 1-4) and  $Z > 0$  (rings 5-8)

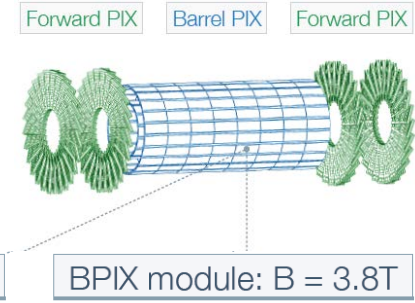
- Related to bias voltage?

> Variation equivalent to shift of the modules of  $\sim 4 \mu\text{m}$

> Clear improvement in resolution

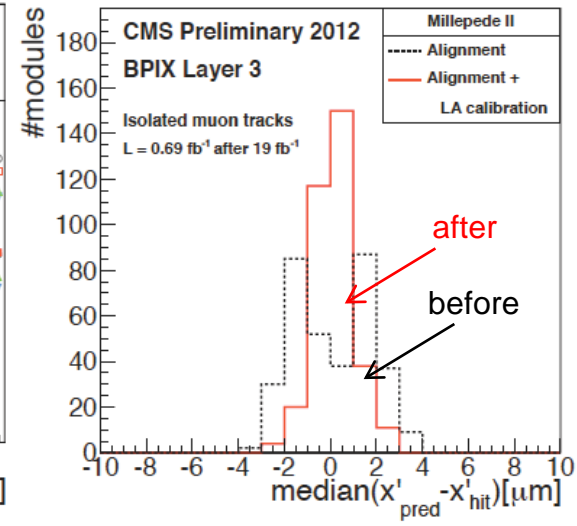
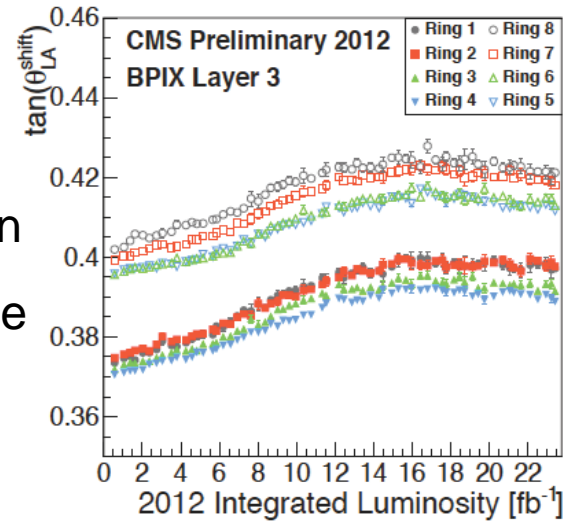
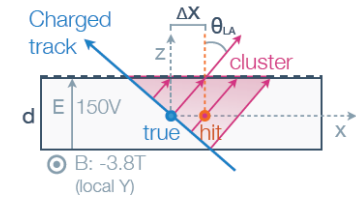
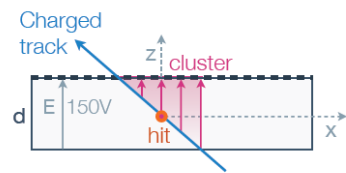
> Even stronger time-dependence expected in run II of LHC

- Higher radiation dose



BPIX module:  $B = 0\text{T}$

BPIX module:  $B = 3.8\text{T}$





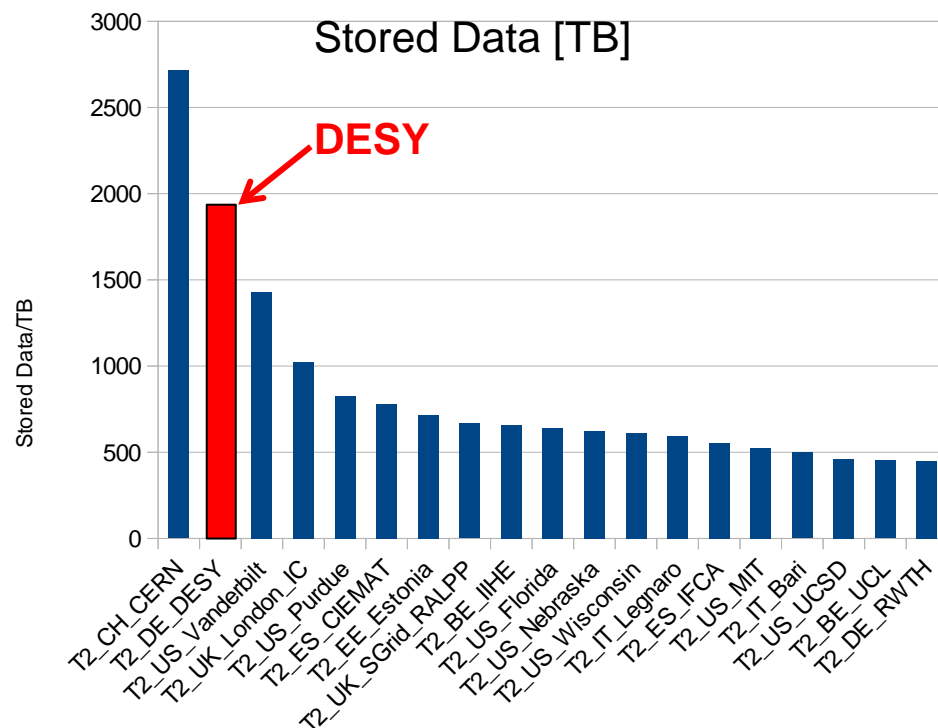


## > CMS Tier2 T2\_DE\_DESY:

- Largest CMS T2 (after CERN-EOS) w.r.t. datasets hosted on disk
- Very reliable and therefore actively used for Analysis and MC production

## > Migration to NAF2.0 has started

- Majority of users to be moved by the end of 2013
- Finish migration by April 2014



## > Regular (4 times per year) strategy meeting ATLAS-CMS-IT(+NUC chair)

- Very productive meetings
- Common strategy for the coming months concerning
  - > Investments
  - > NAF migration plans



## Physics Analysis



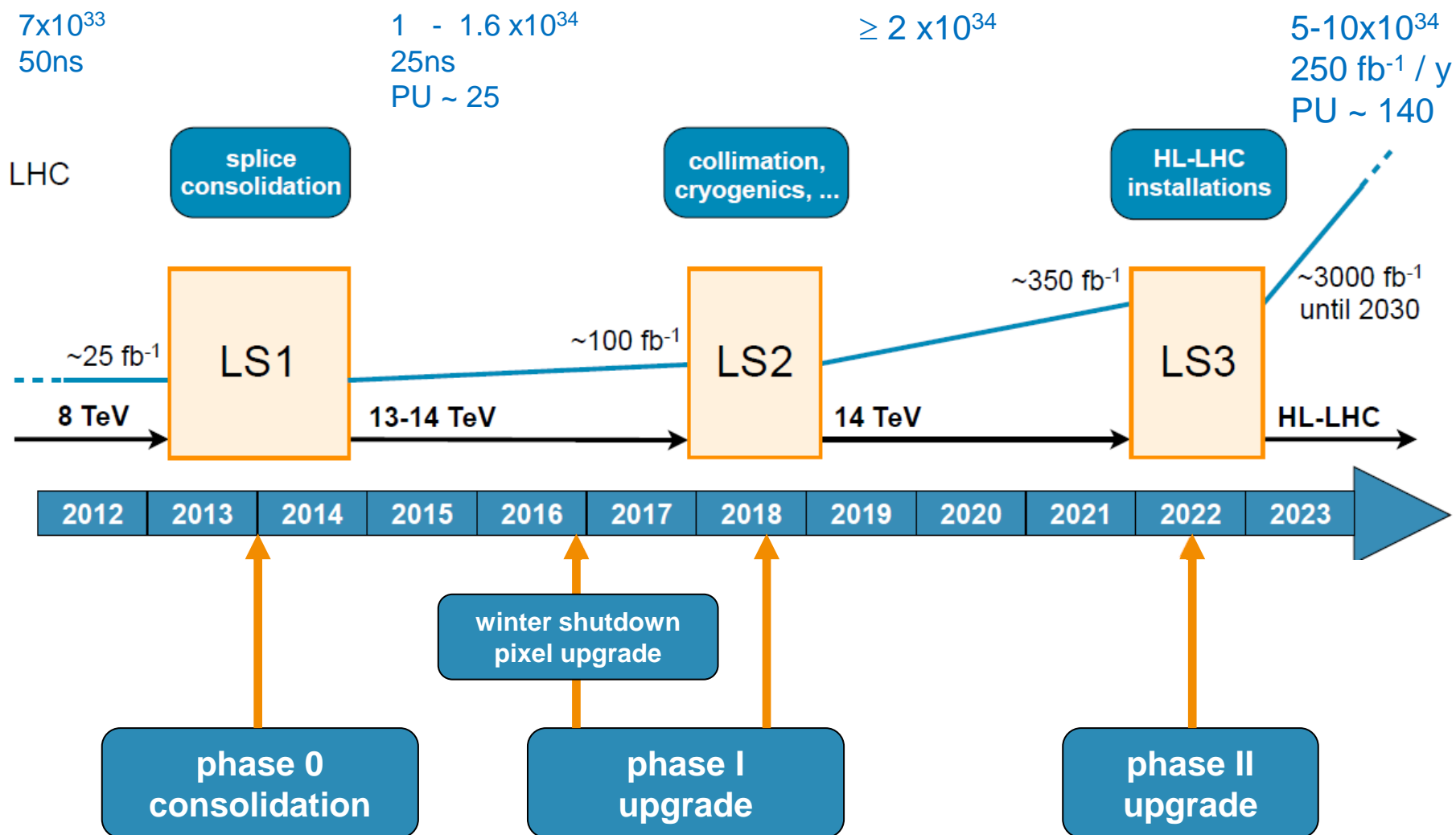
## Operations and Components



## Upgrade



# LHC and CMS Upgrade Schedule

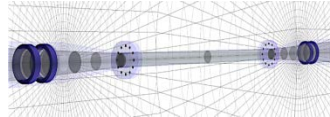


## BCM1F

Enhanced Functionality: on-line Luminosity  
(part of the BRIL project)

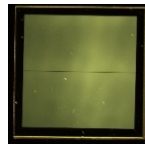
### > New geometry design

- Particular MC studies done



### > Sensors and FE ASICs

- 24 sensors, two pads/sensor, first sensor under test
- Fast FE ASICs, CMOS 130nm ready matching needs for 25 ns bunch spacing

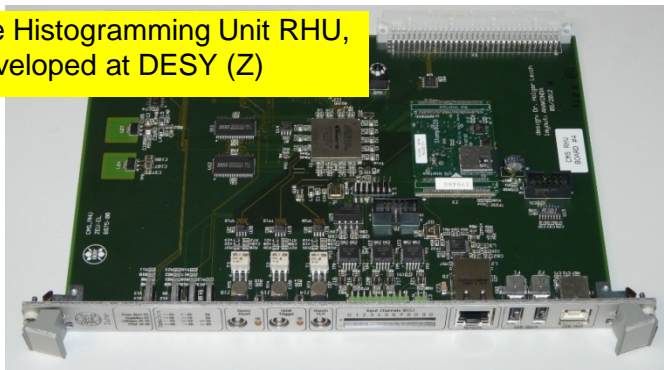


### > Back-end and DAQ

- 12 RHU in production, tests start in November
- Development of logic units almost completed, tests of prototype ongoing

### > Installation starts in May 2014

Real Time Histogramming Unit RHU,  
Developed at DESY (Z)



## Hadron Outer

Replace photo-sensors

### > First use of SiPM in CMS

### > DESY is a key contributor

- Leading QC, installation, and commissioning
- 1/3 of installation man-power

### > Installation progressing well

- 58% completed
- Slightly ahead of schedule

### > Commissioning running in parallel

- Well ready for beam by end 2014

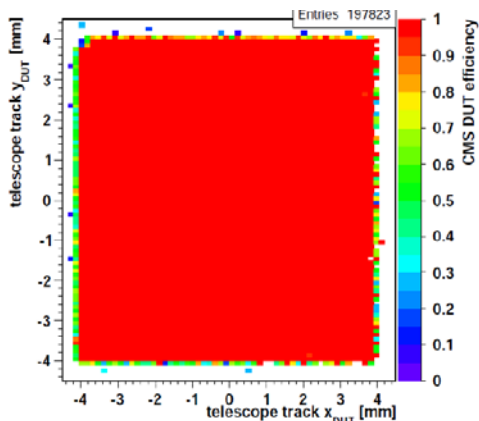


## In house bump bonding established

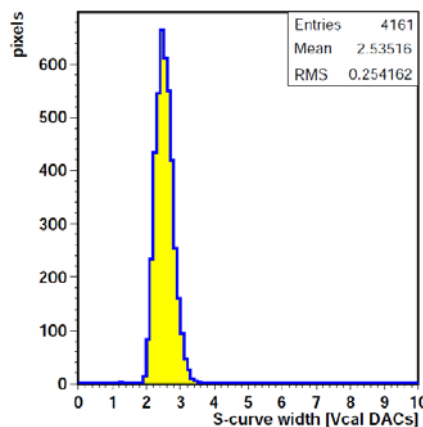
- SnAg ball placing at 4.5Hz with SB2 laser jetter
- Tacking and reflow with femto flip chip bonder
- Bump yield > 99.95%

## single chip modules tested

DESY test beam :  
efficiency 99.96%

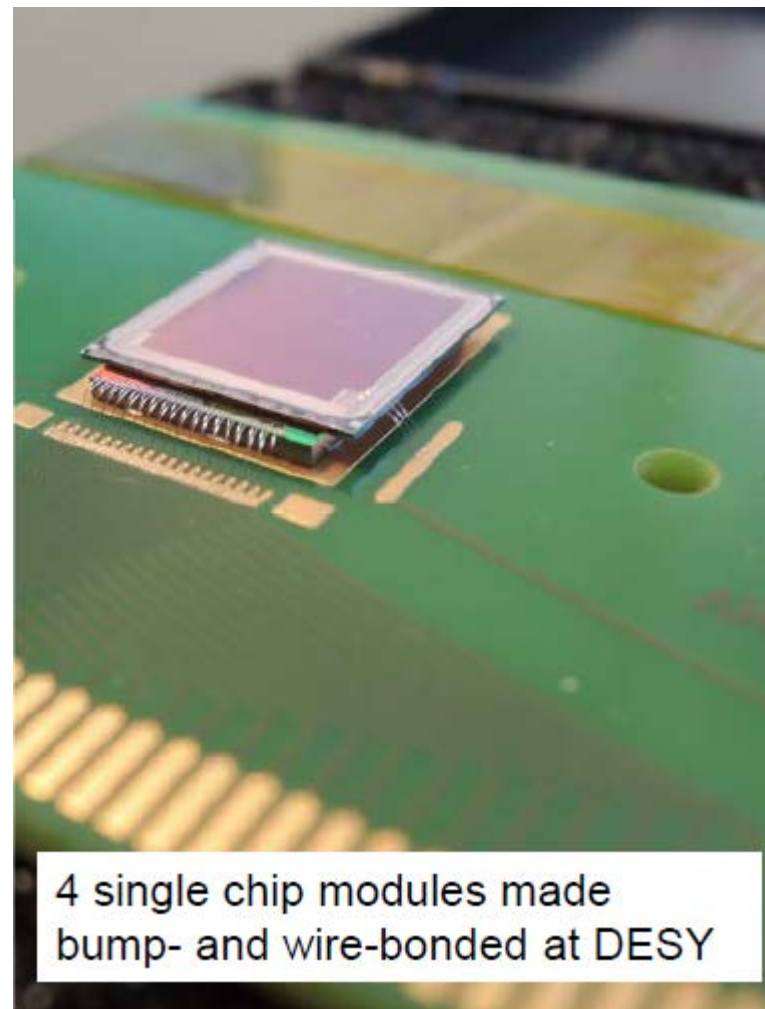


noise similar to smaller  
Indium bumps



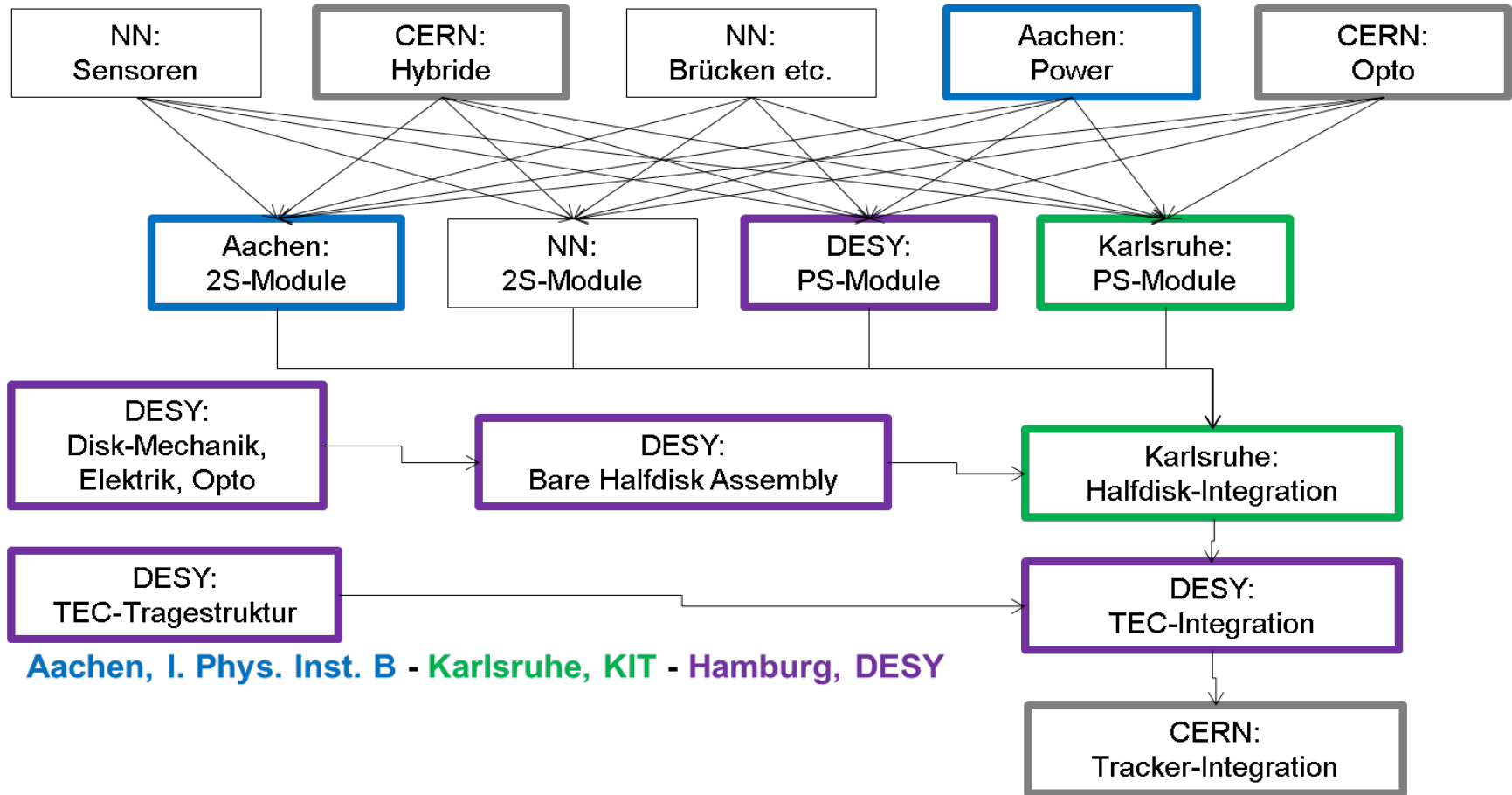
## Next steps:

- Optimize tacking parameters
- Produce full (2x8) module



4 single chip modules made  
bump- and wire-bonded at DESY

# Phase II – Possible Logistics for Tracker-Endcap



- > Coordinated effort within Germany to build one tracker end-cap for CMS
- > DESY assembly facility planned as shared infrastructure for ATLAS & CMS
- > Funding for end-cap via BMBF and Helmholtz (application in preparation)



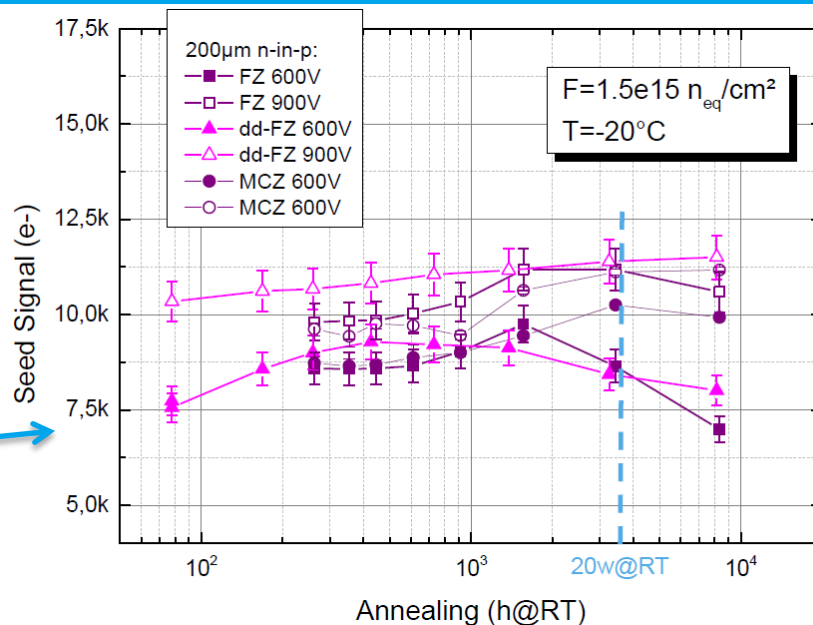




## > Results from HPK Campaign:

### ➔ CMS decided to concentrate on n-in-p sensors

- Signals from p-in-n and n-in-p sensors similar
- above  $7 \times 10^{14} n_{eq}/cm^2$  random ghost hits appear in p-in-n sensors, not in n-in-p
- **the 200 $\mu$ m n-in-p sensors would work for the entire Tracker under HL-LHC conditions:**
  - ➔ flat annealing behavior
  - ➔ seed signal above 8ke- at 600V bias until ~20 weeks at room temperature



## > Radiation Tolerance of MPix Sensors

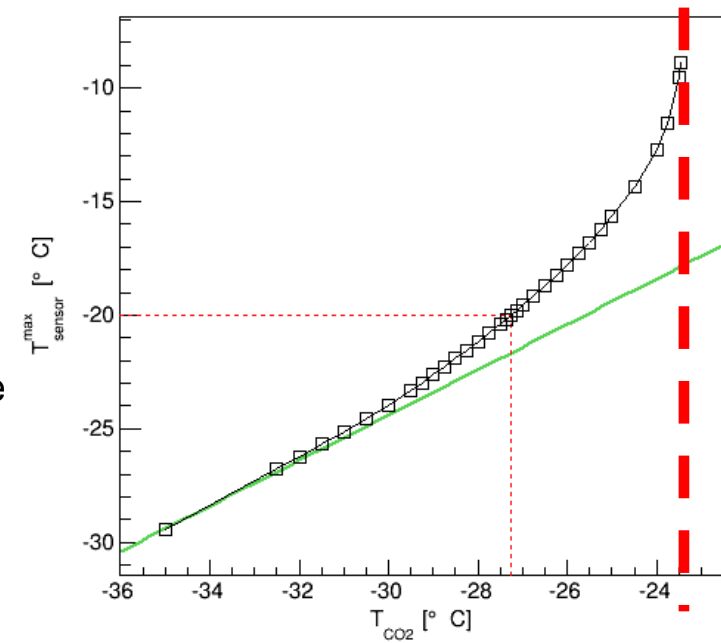
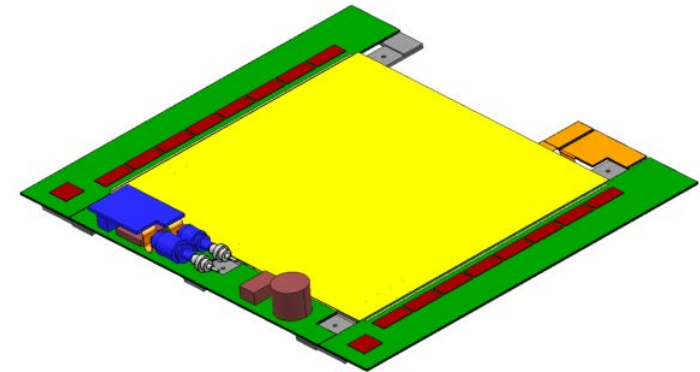
- Leakage current increases less in magnetic Czochralski than in floatzone sensors (~10x)
- Polysilicon biasing scheme is stable (within 20% up to  $13.9 \times 10^{14} n_{eq}/cm^2$ )
- Punch-through biasing scheme under study

## > Future Plan:

- Evaluate additional vendor through 8" run with Infineon
- Cost saving (8" vs. 6")



- > Design of 2S module is in very advanced state
  - Thermal performance is well within design goals
  - 50% safety and margin to thermal runaway
  - mass estimate is 30 g per module
- > Will start prototyping this year
  - Many parts already available
  - First prototype hybrid expected soon
- > Optimization of details has started
  - Module to cooling block thermal interface
  - Will be studied with lab equipment available at DESY
- > Trigger capable prototype modules
  - 2S module prototypes with two front-end chips will be evaluated in DESY test-beam in November
  - First beam test to investigate trigger capability of new front-end chips





- > Strong impact on physics analyses
  - Precision measurements based on the full 7 and 8 TeV datasets
  - After Higgs discovery, emphasis moving to measurements of its properties
  - Use of extended LHC potential for new particle searches
  - Studies for upgrade scenarios
  
- > Significant contributions to CMS operations
  - Consolidation, methodological improvements, preparation for run II
  
- > Substantial involvement in detector upgrades
  - HCAL: Key contributor to HO SiPM upgrade in LS1
  - BCM1F: Enhancement to on-line luminosity during LS1
  - Pixel: Module production for barrel layer-4 on track for phase I
  - Tracker: Plan to build one CMS end-cap in Germany for phase II, Significant R&D establishing the technology

→ DESY has a strong position in CMS



# BACKUP



## > Level-1 Management

- M. Kasemann: Chair of the Authorship Board
- K. Borrás: Conference Committee Chair; designated Deputy Spokesperson (2014/15); Chair of the HINDAWI committee, MB, CB, FB

## > Physics

- H. Jung: Convener of Physics Comparison and Generator Tunes subgroup (L3, 2013), FSQ-PRF Pub. Committee, Chair of Theorists in CMS committee
- I. Melzer-Pellmann: Convener of SUSY Future subgroup (L3), Member of SUSY Pub. Committee
- A. Meyer: Convener of top cross sections subgroup (L3, 2012/13), Convener of top working group (L2, 2014/15)
- S. Naumann-Emme: Convener of top quark mass subgroup (L3, 2013/14)
- K. Lipka, R. Placakyte: Coordinators of PDF@CMS Forum
- I. Marfin: b-tag HLT subgroup convener

## > Computing

- C. Wissing: Operation (L2)
- M. Kasemann: Chair of Computing Resource Board

## > Data Quality Monitoring

- D. Krücker: Organizer of remote DQM shifts (L3)
- E. Ron: DQM for MC simulation (L3)
- R. Placakyte: Data Certification (L3)

## > Tracker

- G. Eckerlin: Tracker Upgrade Steering Committee, Tracker Finance Board
- D. Eckstein, W. Lange: CEC Sensor & Qualifying
- A. Mussgiller: Convenor of Strip-Tracker Module-Design group

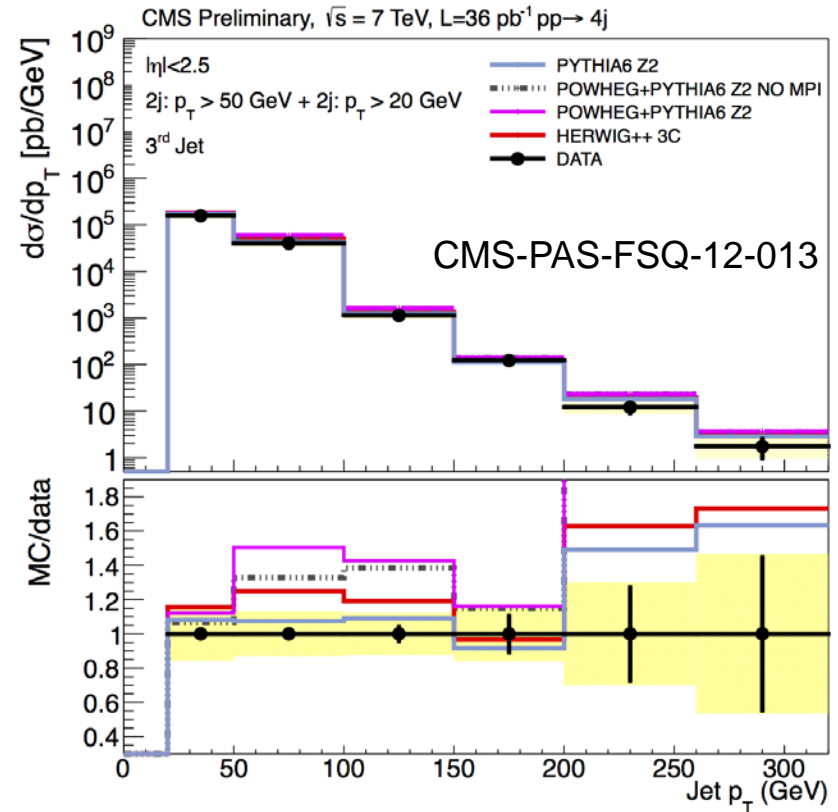
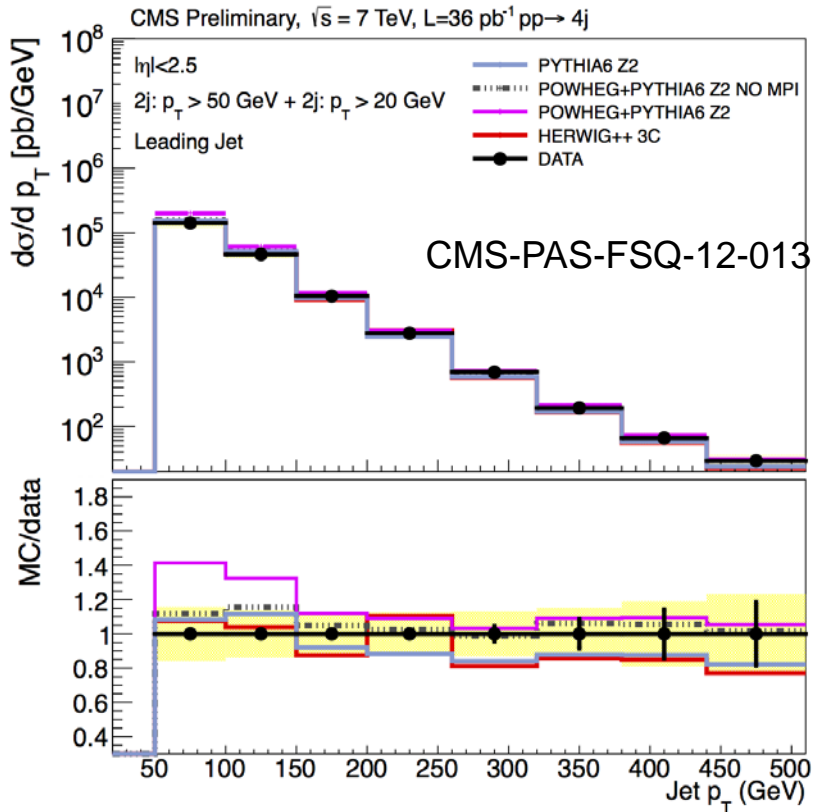
## > BRIL

- W. Lohmann: Chair of Institutional Board
- R. Walsh: DPG convener

## > Hadron Outer Calorimeter

- B. Lutz: Coordinator for HO Upgrade at Point 5

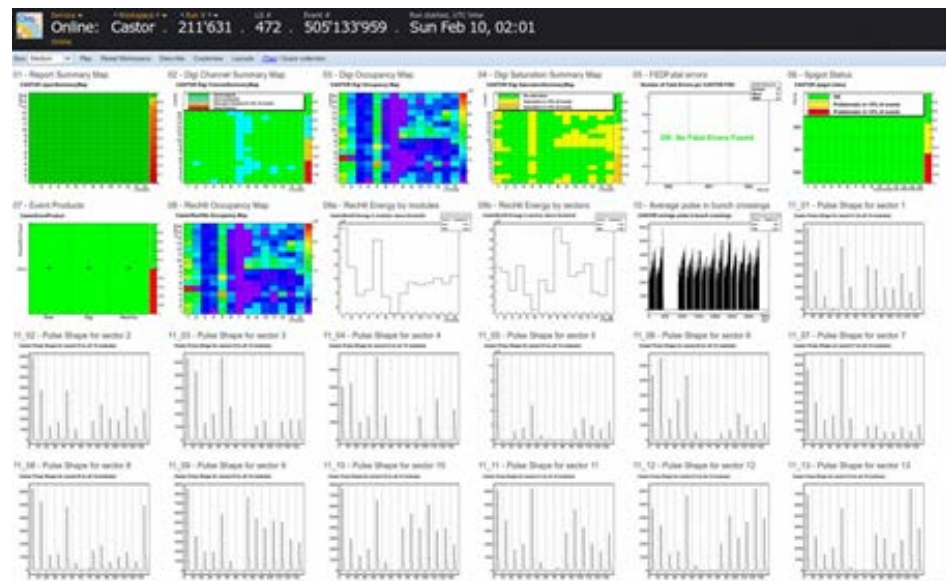




- > First cross section measurement of 4 jets in CMS
- > Important test for higher order QCD calculation
- > Also used to estimate contribution from double parton interactions



- > CASTOR was installed for
  - P-p at 2.76 TeV: 5.41 pb<sup>-1</sup> collected with 100% efficiency
  - P-Pb runs: 31.13 nb<sup>-1</sup> collected with >99.8% efficiency
- > DQM code was updated
  - CASTOR was included in the official DQM certification chain

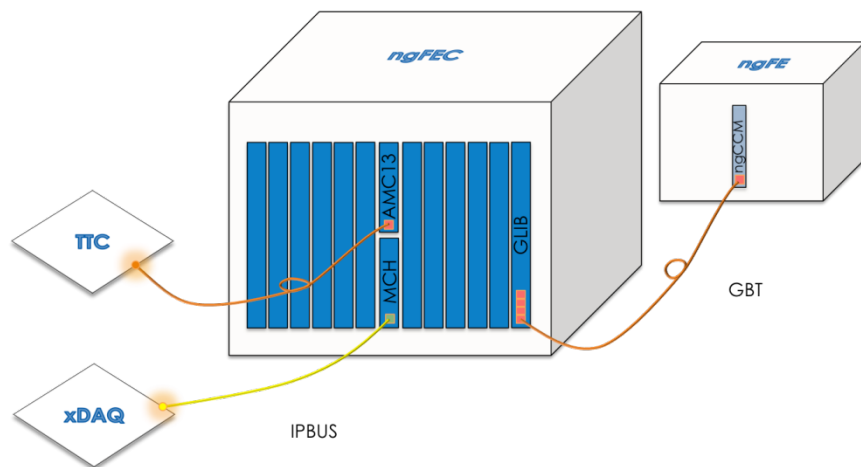
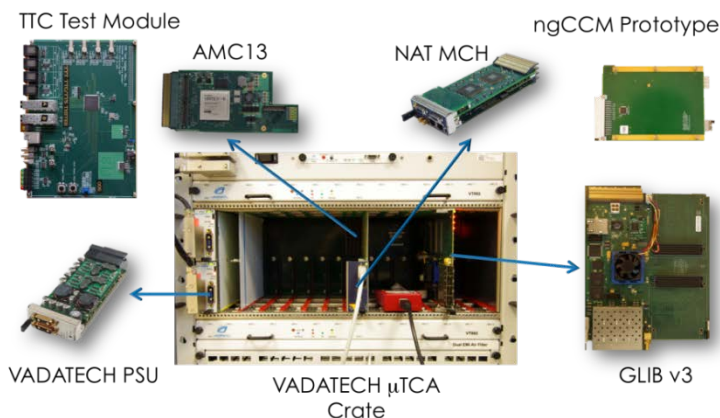


- > n-tuples with Totem and CASTOR data have been produced

## Future plans:

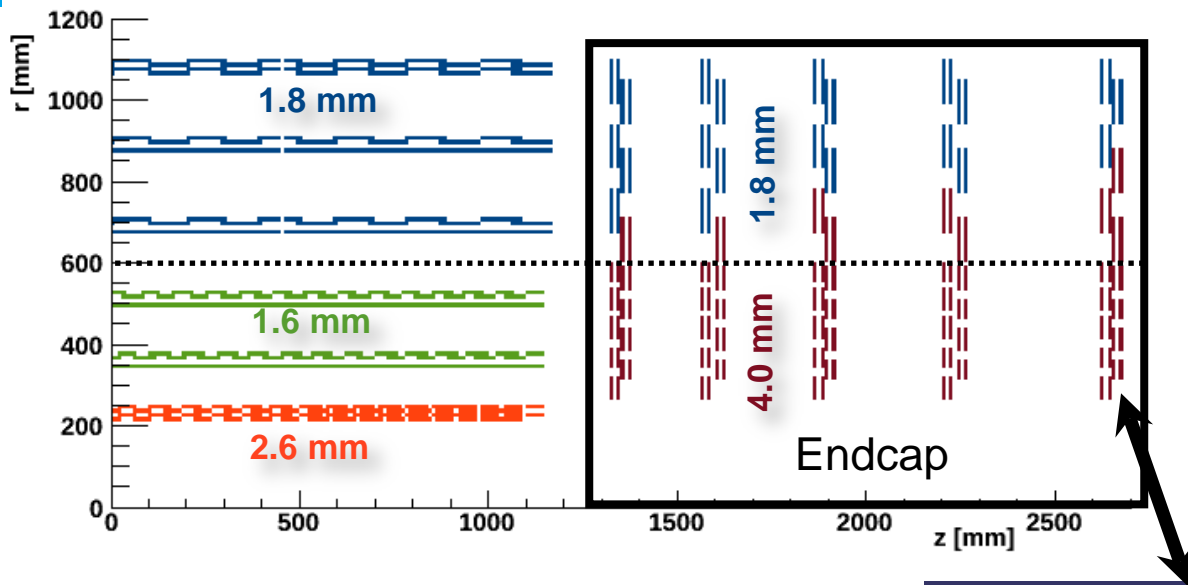
- > Install CASTOR for 2015 heavy ion run
- > Preparing the DQM code for the new CMSSW framework requirements (multi-thread, LS-based certification, etc)

- > Micro Telecommunications Computing Architecture (mTCA) is a new communication standard aimed for telecommunications and computer network systems.
- > mTCA will replace the VME standard in the HCAL electronics infrastructure.
- > Better power and cooling management
- > Small form factor
- > Hot swapping
- > Significantly faster



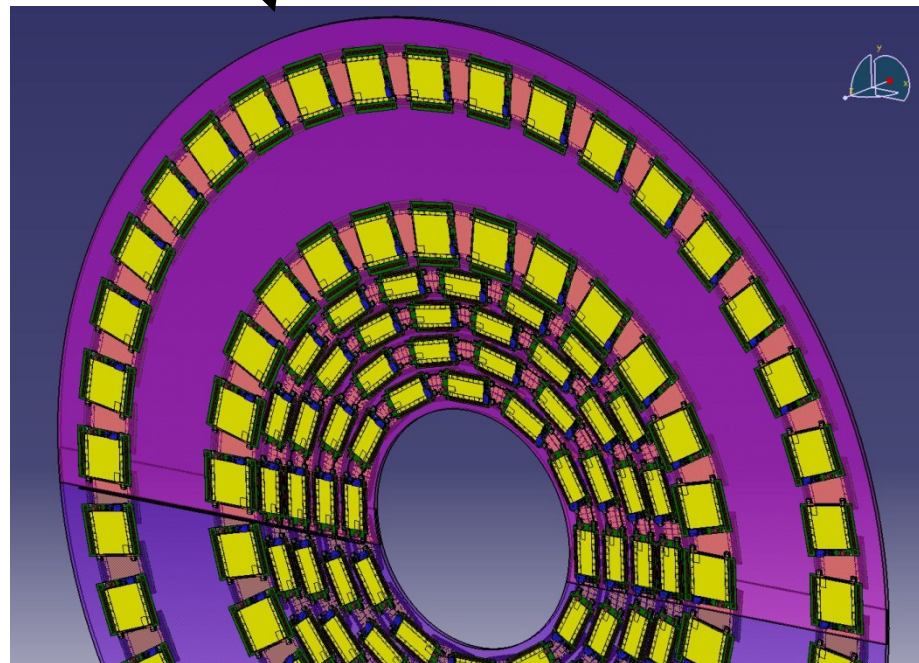
- > At DESY we are developing ngFEC (Front End Controller) and we would like to have a complete readout test bench by the end of next year.
- > The ngFEC controller developed by DESY will be tested with the other components in December at Fermilab.

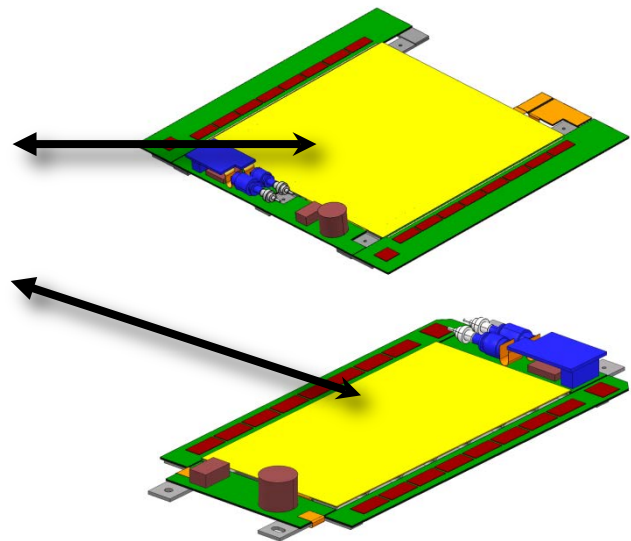
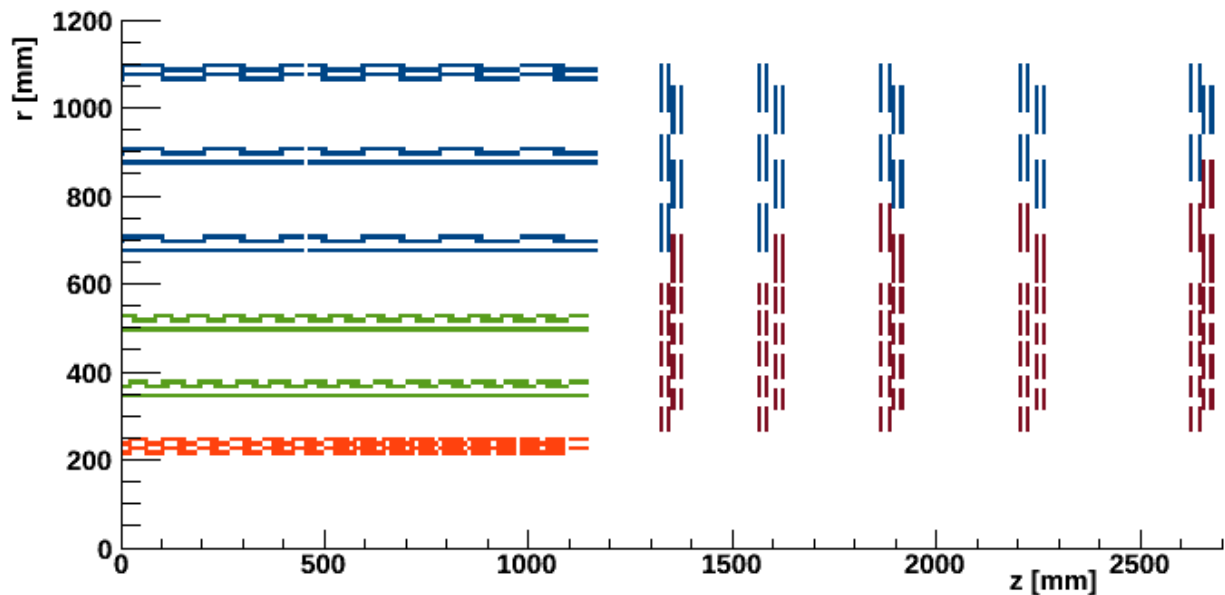
# CMS Phase II Endcap



Number of modules

	full Tracker	per Endcap
1.8 mm 2S Module	7400	1468
4.0 mm 2S Module	944	472
1.6 mm PS Module	3156	
2.6 mm PS Module	1008	
4.0 mm PS Module	2752	1376
	15260	3316





## > main objectives

- higher granularity
- radiation hard sensors operated at  $-20^{\circ}\text{C}$
- reduced material budget
- provide information to Level 1 trigger

## > $p_{\text{T}}$ discrimination at module level

- two-strip (2S) and pixel-strip (PS)
- two sensor stacks with 1.6-4mm separation
- correlation of both planes in front-end electronics
- trigger information (track-stubs) each bunch-crossing