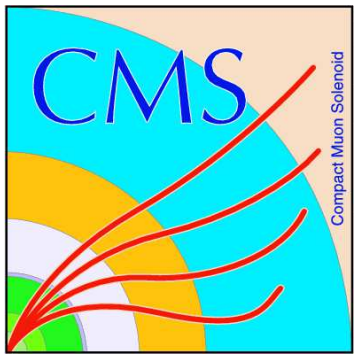
Status of CMS at DESY

Report to the 78th Physics Research Committee

Open Session



Johannes Hauk
On behalf of the DESY CMS group

DESY Zeuthen, 16.10.2014

HELMHOLTZ ASSOCIATION

DESY

Overview

- LHC Schedule and Implications for Experiments
- News from CMS
- CMS at DESY

21 staff
21 postdocs, visitors
22 PhD students
plus technical staff

Operations + Components

- Alignment
- BCM1F
- Computing
- DQM
- HLT, DAQ

Upgrades

- BCM1F
- HCAL
- Pixel
- Sensors
- Tracker

Physics Analysis

- Higgs
- PDF
- QCD
- SUSY
- TOP

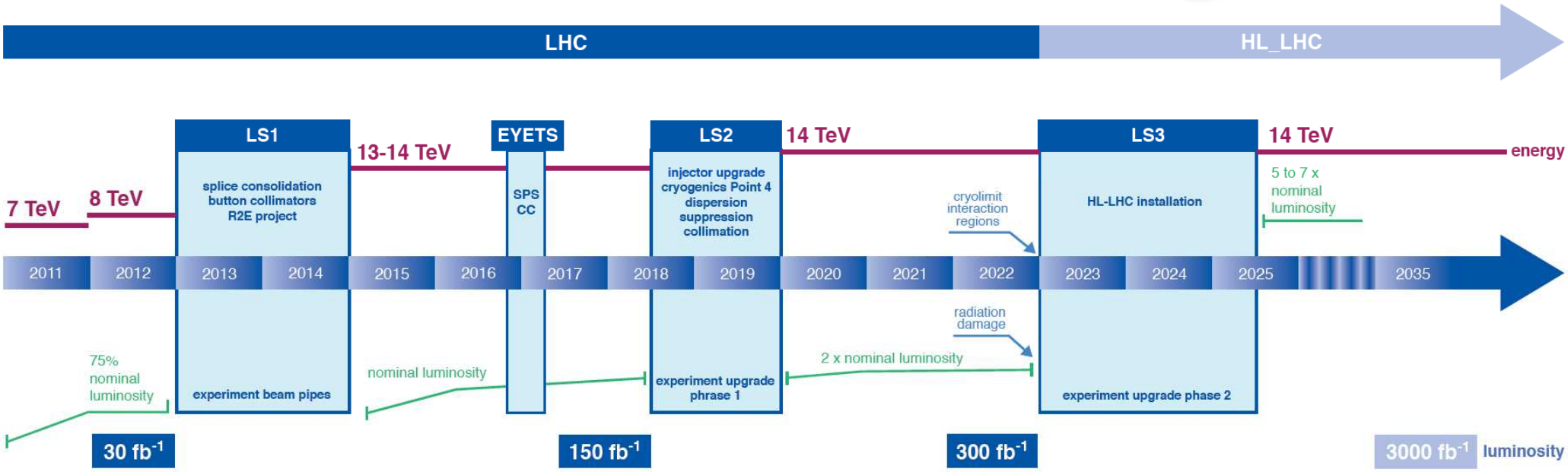
LHC Status

- Consolidations for 13 TeV successful, cool-down ongoing
- Updated schedule (September) for 2015
  - About 1 month delay compared to previous one
- LHC on track for collisions in 2015

LHC / HL-LHC Plan

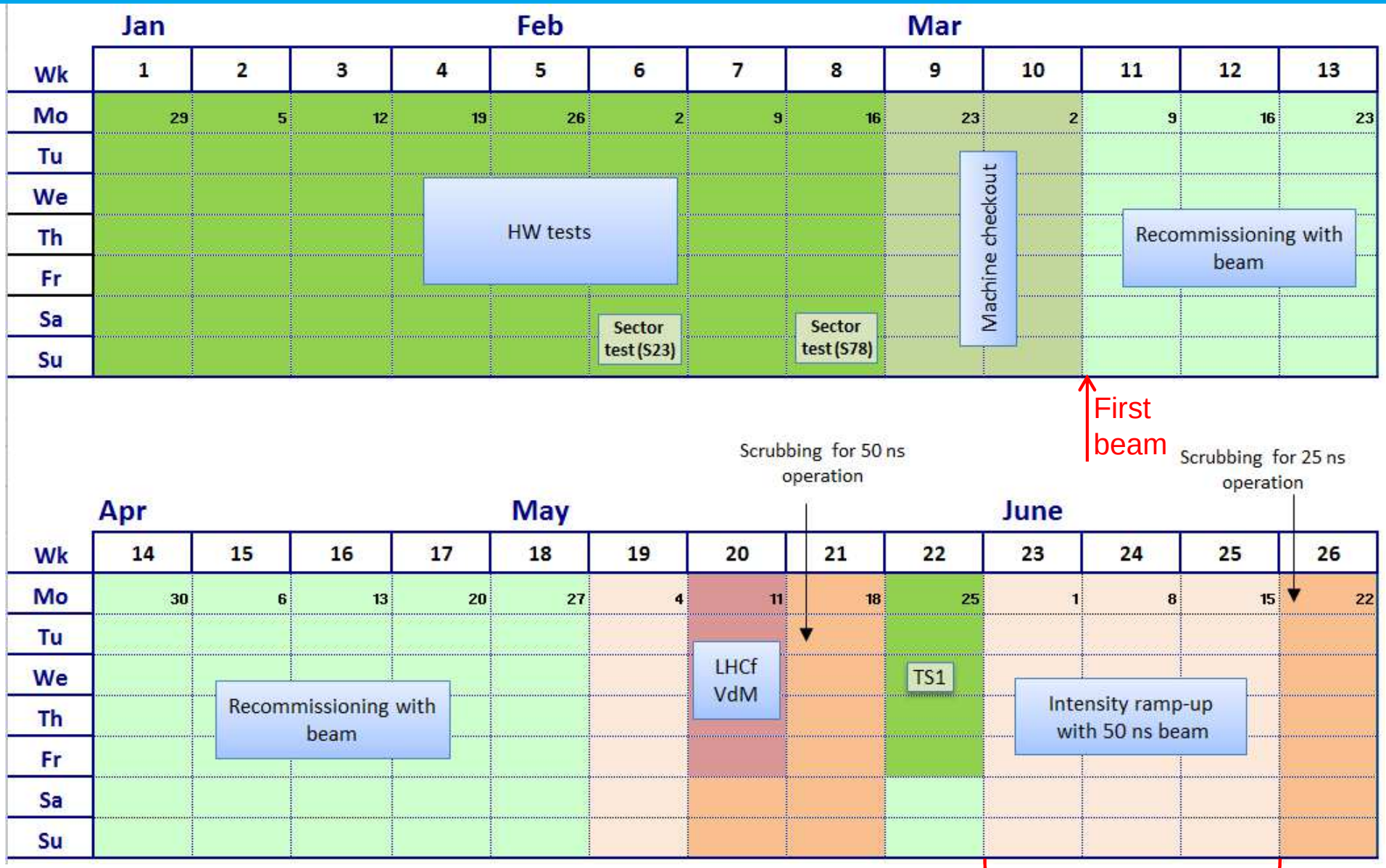
High Luminosity LHC

24.09.2014

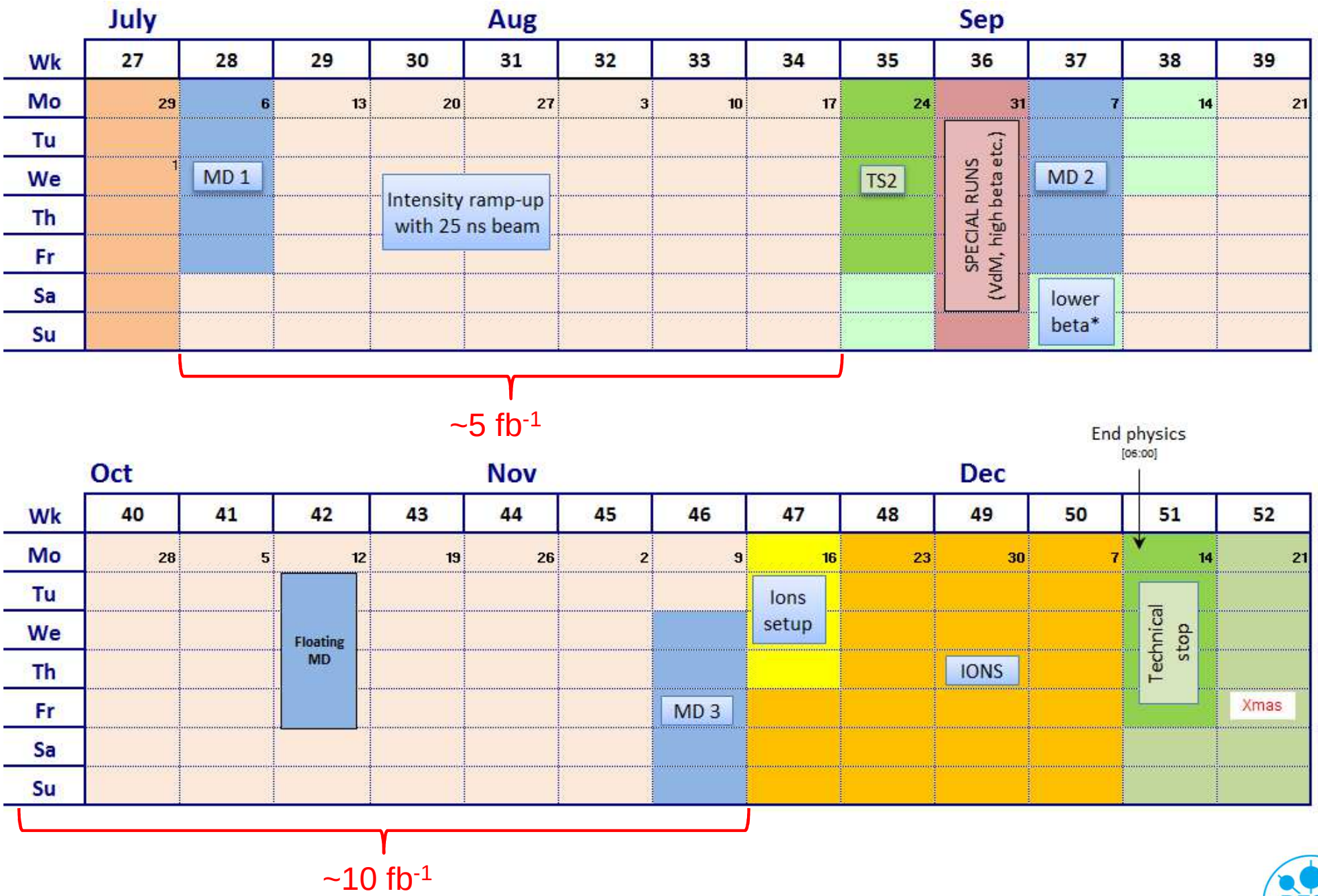


DESY

LHC Beam Schedule (1st half of 2015)

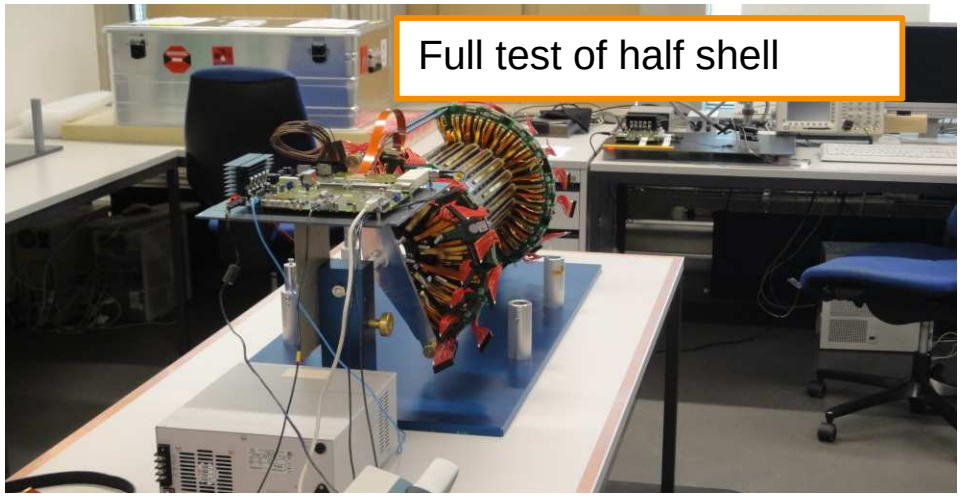


LHC Beam Schedule (2nd half of 2015)



News from CMS

- LS1 upgrades and repairs done
- Strip tracker commissioned at -15°C for required longevity (500 fb^{-1})
- Some pixel modules were not responding in re-assembly tests
  - Modules repaired or replaced by new ones
  - Re-installation shifted to December or January, consistent with LHC plan



- New beam pipe installed
- CMS in full re-commissioning mode
- Extended cosmic run planned in/around November
  - New tracker alignment, but without pixel
- Technical Proposal (TP) for Upgrade Phase II is being prepared
  - Main focus on physics cases now

CMS Publications with Substantial Contributions from DESY

- CMS. “Alignment of the CMS tracker with LHC and cosmic ray data”, J. Inst. 9 P06009 (2014) — Technical

- CMS. “Differential tt cross section as function of jet multiplicity and gap fraction”, Eur. Phys. J. C 74 (2014) 3014
- CMS. “Measurement of the muon charge asymmetry in inclusive pp → W+ X production at sqrt(s) = 7 TeV and an improved determination of light parton distribution functions”, Phys. Rew. D 90 (2014) 032004

Publications 7 TeV

- CMS. “Direct evidence for the Higgs boson decay to fermions”, Nature Phys. 10 (2014)
- CMS. “Evidence for the 125 GeV Higgs boson decaying to a pair of tau leptons”, JHEP 05 (2014) 104
- CMS. “Observation of the Associated Production of a Single Top Quark and a *W* Boson in *pp* Collisions at $\sqrt{s}$ =8 TeV”, Phys. Rev. Lett. 112 (2014) 231802
- CMS. “Measurement of the *tt* production cross section in the dilepton channel in pp collisions at $\sqrt{s}$ = 8 TeV”, JHEP 02 (2014) 024
- CMS. “Search for Neutral MSSM Higgs Bosons Decaying to Tau Pairs in pp Collisions”, arXiv:1408.3316
- CMS. “Search for new physics in multijets and missing momentum final state at 8 TeV”, arXiv:1402.4770

Publications 8 TeV

- CMS. “Determination of the top quark mass from the mlb distribution in dileptonic ttbar events at sqrt(s) = 8 TeV”, PAS-TOP-14-014
- CMS. “Correlations between forward and central jets”, PAS-FSQ-12-008

PAS for Publications

- CMS. “Combination of ATLAS and CMS top quark pair cross section measurements in the emu final state using proton-proton collisions at sqrt(s) = 8 TeV”, PAS-TOP-14-016

PAS only

Phenomenology Publications

- Highlighting DESY CMS group members participating in author list

- H. Jung et al. “Transverse momentum dependent gluon density from DIS precision data”, Nucl. Phys. B883 (2014) 1
- K. Lipka, R. Placakyte et al. “Determination of Strange Sea Quark Distributions from Fixed-target and Collider Data”, arXiv:1404.6469
- M. Guzzi, K. Lipka et al. “Top-quark pair production at hadron colliders: differential cross section and phenomenological applications with DiffTop”, arXiv:1406.0386
- S. Dooling, H. Jung et al. “Hadroproduction of electroweak gauge boson plus jets and TMD parton density functions”, Phys. Lett. B736 (2014) 293
- H. Jung et al. “The CCFM uPDF evolution uPDFevolv”, Eur. Phys. J. C74 (2014) 3082
- H. Jung et al. “TMDlib and TMDplotter: library and plotting tools for transverse-momentum-dependent parton distributions”, arXiv:1408.3015

Operations + Components

- Alignment
- BCM1F
- Computing
- DQM
- HLT, DAQ

Short Overview

- Alignment
  - Legacy paper published **J. Inst. 9 P06009 (2014)**
  - Critical task during cosmics data taking and restart of collisions – preparations ongoing
- BCM1F
  - Still in Upgrade, next time in Operations+Components
- Computing
  - Next Slide
- DQM
  - Mid-week global runs re-started for re-commissioning
- HLT, DAQ
  - In Upgrade

CMS Computing @DESY

> CMS Tier-2 T2_DE_DESY

- WLCG pledges for 2015

  - Increased according to CMS request
  - 24.2 kHS06 CPU (+25%)
  - 1,510 TB Disk (+8%)

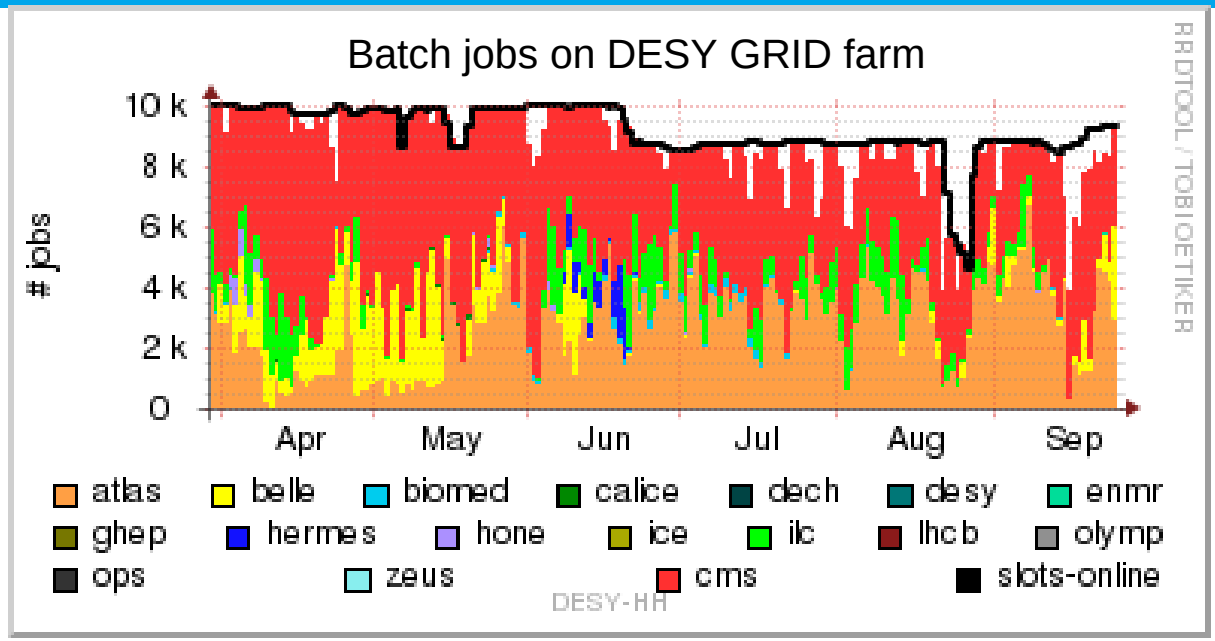
- Resources well utilized (by CMS)
- Data management will become much more dynamic

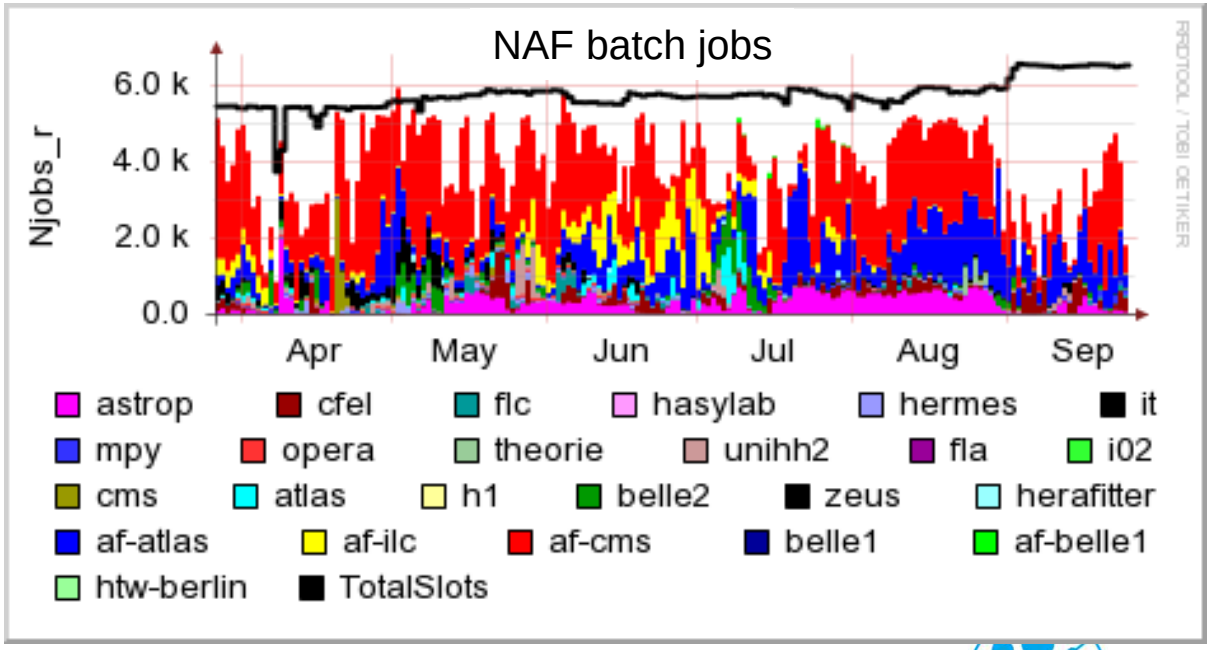
  Effort required to efficiently manage data for convenient local access

> NAF2.0

- Actively used by CMS
- Migration Feedback meeting with IT in May 16th

  - Discussed open issues
  - Priorities for e.g. documentation

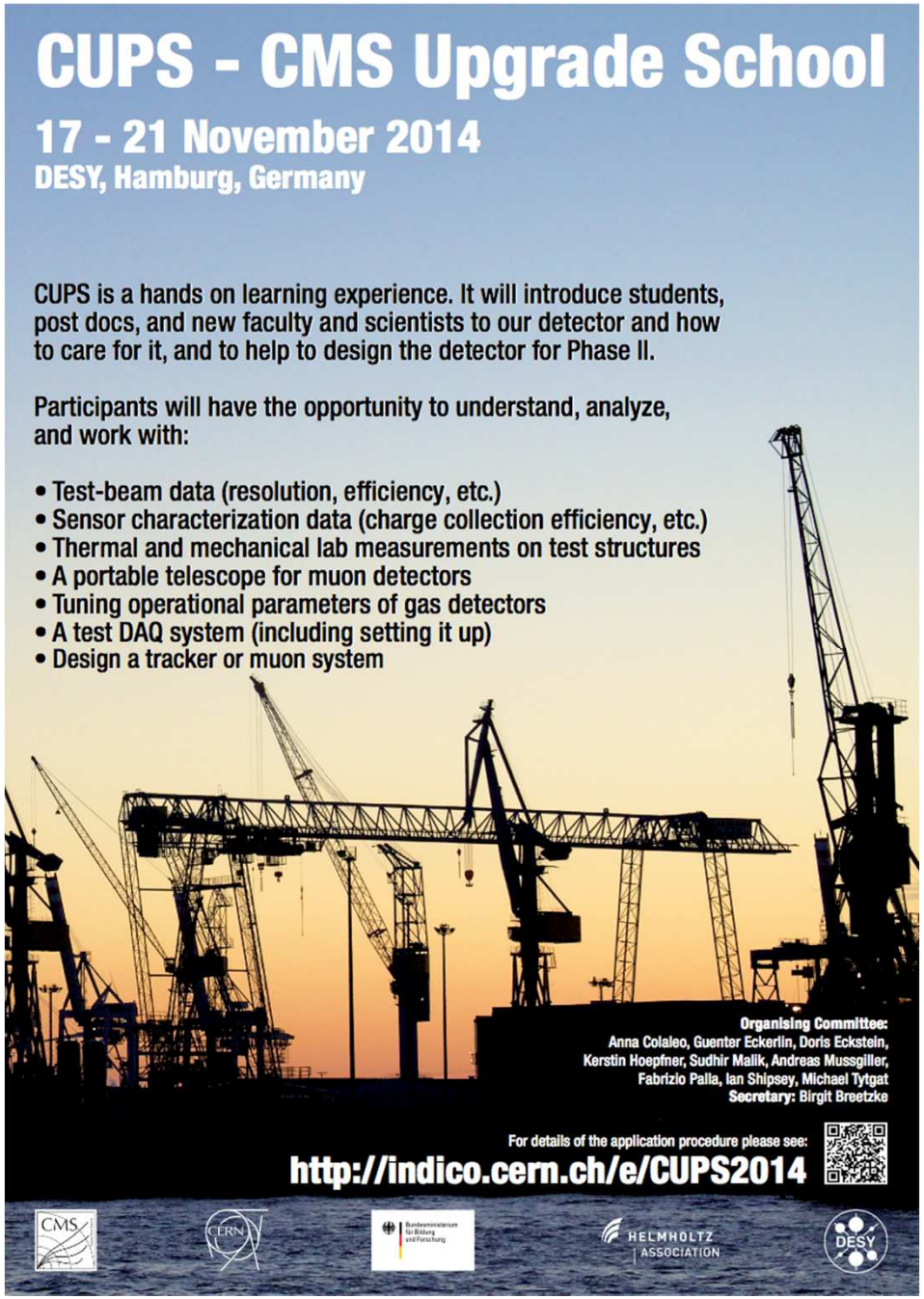




Upgrades

- BCM1F
- HCAL
- Pixel
- Sensors
- Tracker

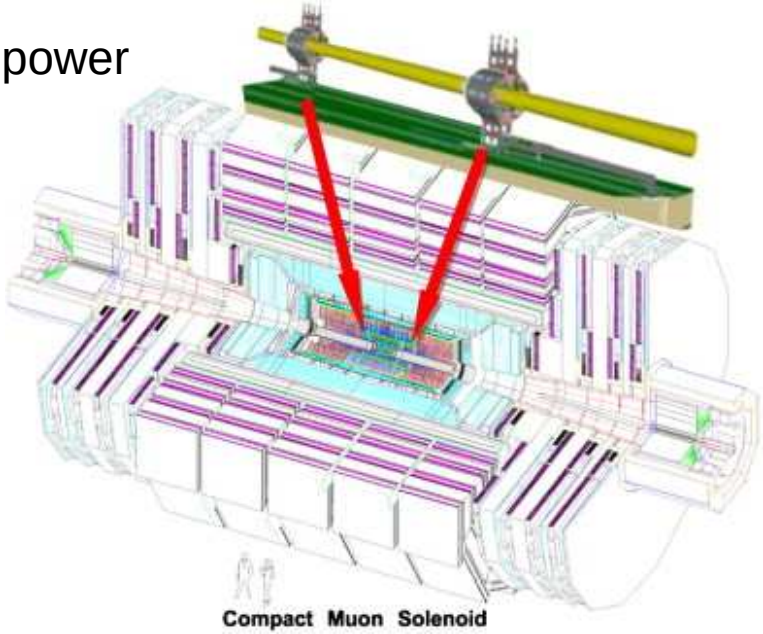
CMS Upgrade School – CUPS 2014

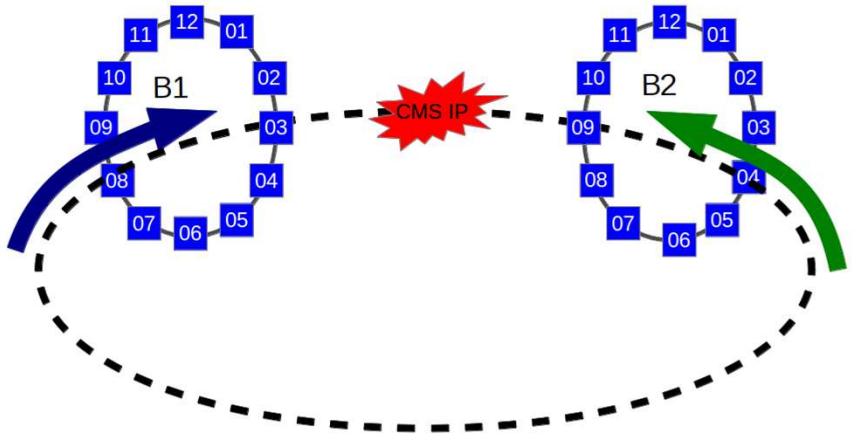


- Great success of CMS Data Analysis School triggered CMS Upgrade School
- First upgrade school ever

BCM1F – Beam Conditions Monitor & Luminometer

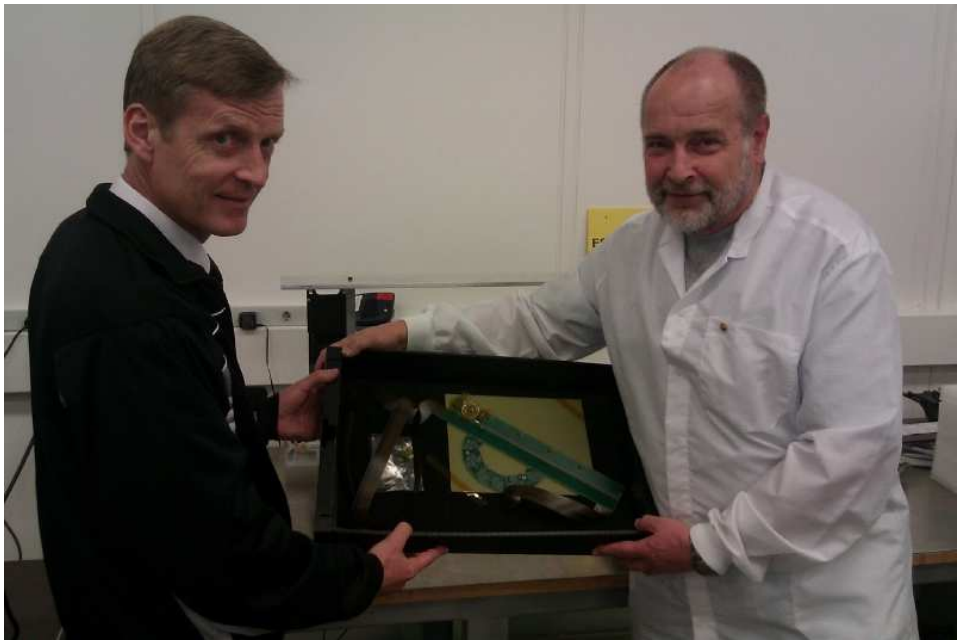
- Multi-purpose device under responsibility of DESY (Zeuthen)
  - Machine induced background → impact on tracker and trigger performance
  - Online luminometer → independent of CMS status and power
- Developed at Zeuthen, partially supported by YIG (VH-NH-503)
  - 50+ single-crystal diamond sensors characterised, 24 needed matching requirements
  - Assembly of detector modules ongoing, 12 diamonds mounted

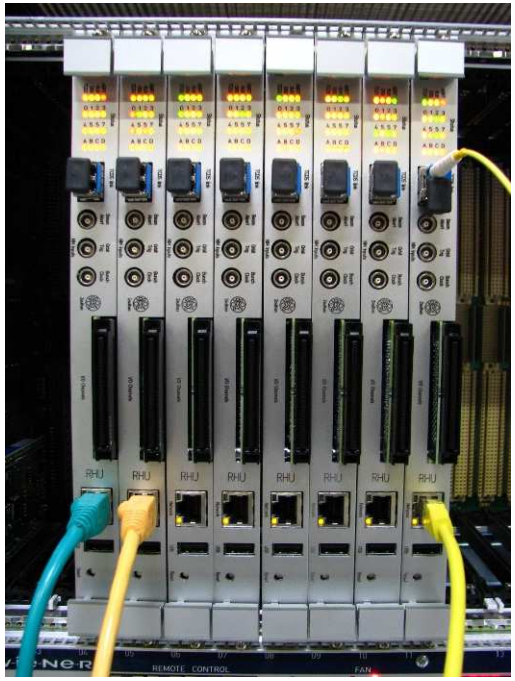




BCM1F – Back-End Electronics & Full System Integration

- First fully assembled detector module arrived at CERN September 29th
- Realtime Histogram Unit (RHU) back-end electronics
  - Dead-time free
  - Bunch-by-bunch luminosity measurement
  - Electrical and functionality tests successful



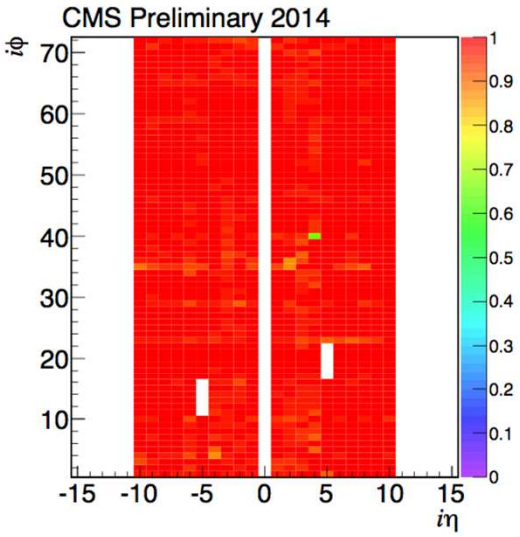


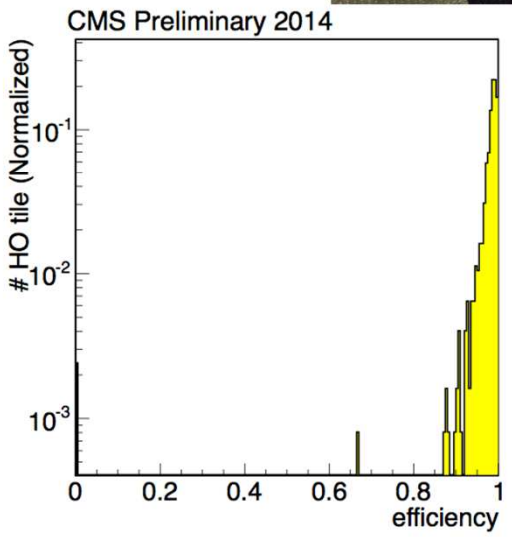
- Back-end electronics modules delivered
  - Integration started
- Prepared for installation in December
- Commissioning in 2015
- Exploitation for CMS and LHC in full Run 2

HCAL – HCAL Outer (HO)

- HO photo-detector upgrade
  - Installation completed in July
  - Fully commissioned and operational
  - Calibration with cosmic muons

High signal over noise
Muon detection efficiency >98%

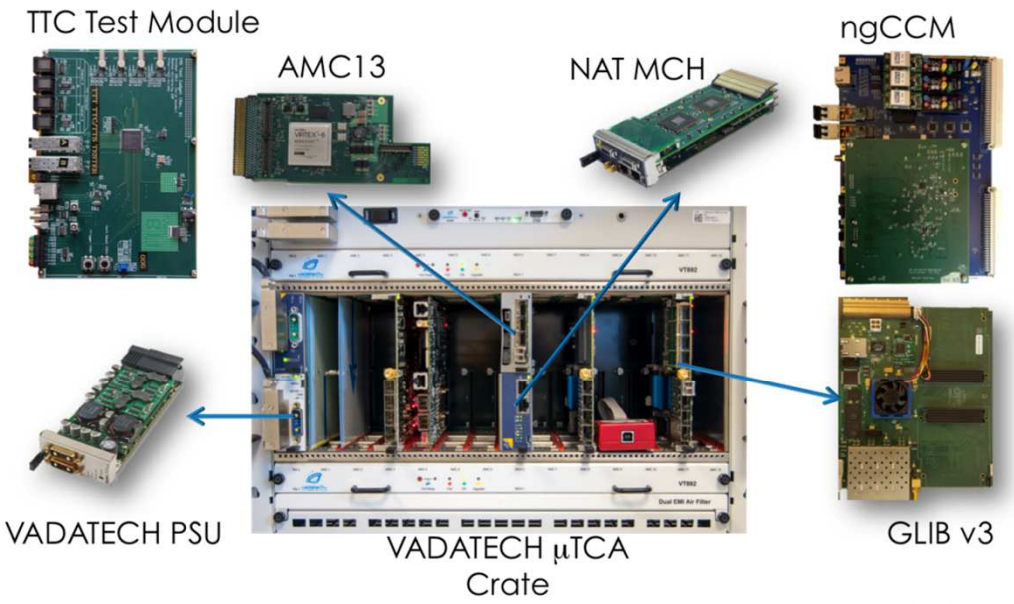




- New DESY project: HO inclusion in upgraded muon L1 trigger
  - Significant progress at hardware level
  - Physics performance studies ongoing, first results look promising

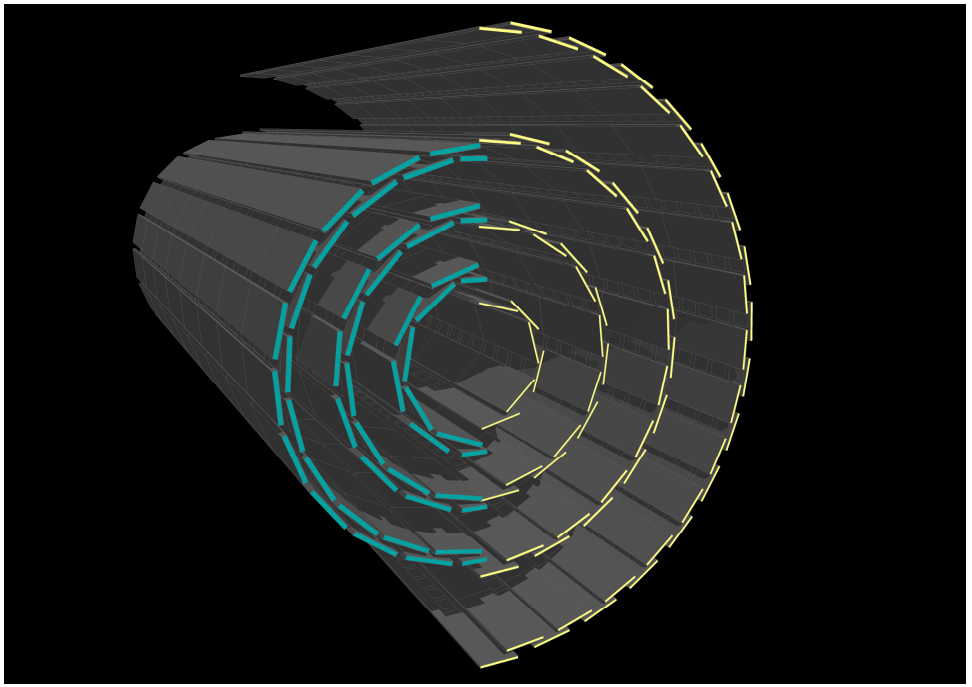
HCAL – µTCA Upgrade

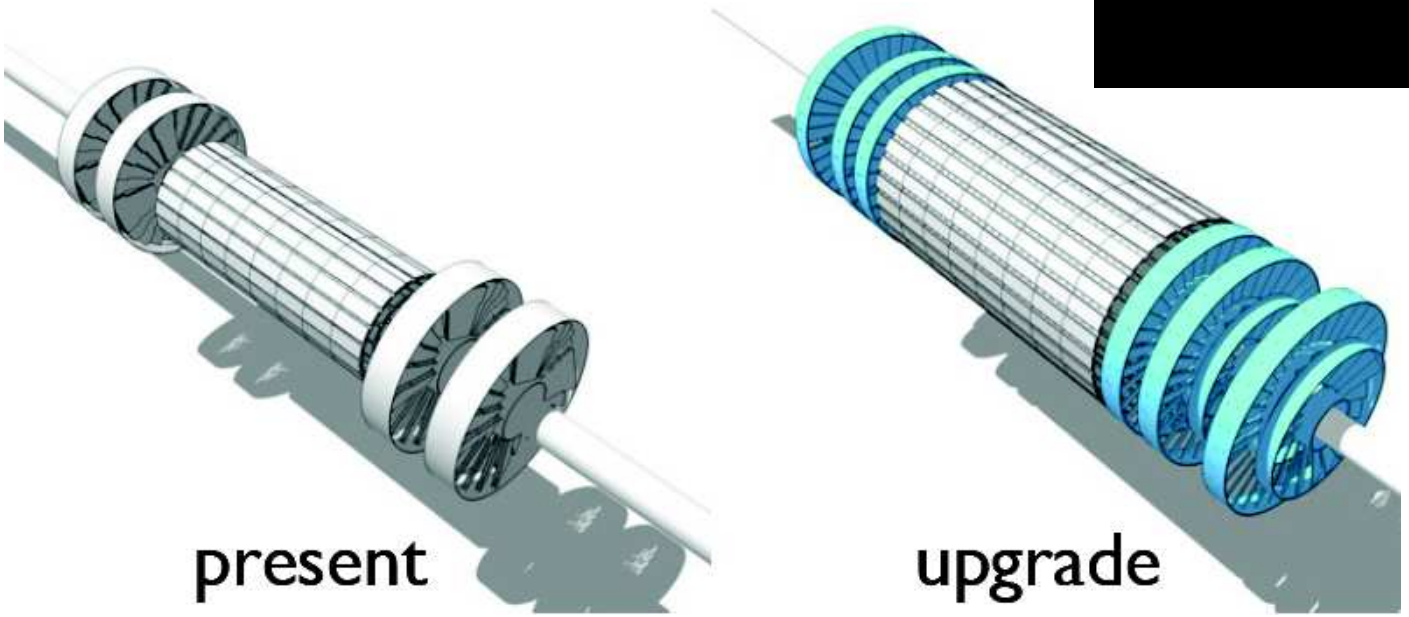
- CMS plan: upgrade of HCAL electronics
  - First detector to switch to µTCA based technology
- next generation Front-End Control card (ngFEC): distributing fast timing signals and slow control data to front-end system (through optical links)
  - Requires software and firmware for ngFEC
- DESY responsible for developing, testing and maintenance of ngFEC
  - Operating ngFEC test stand at DESY



Pixel Phase I – Project Overview

- Need to maintain tracking efficiency at increased occupancy
  - New readout chip, 4th barrel layer, 3rd endcap disk
- Installation end-of-year shutdown 2016
- German institutes build 4th barrel layer
  - One half by DESY+UHH





Pixel Phase I – Module Assembly

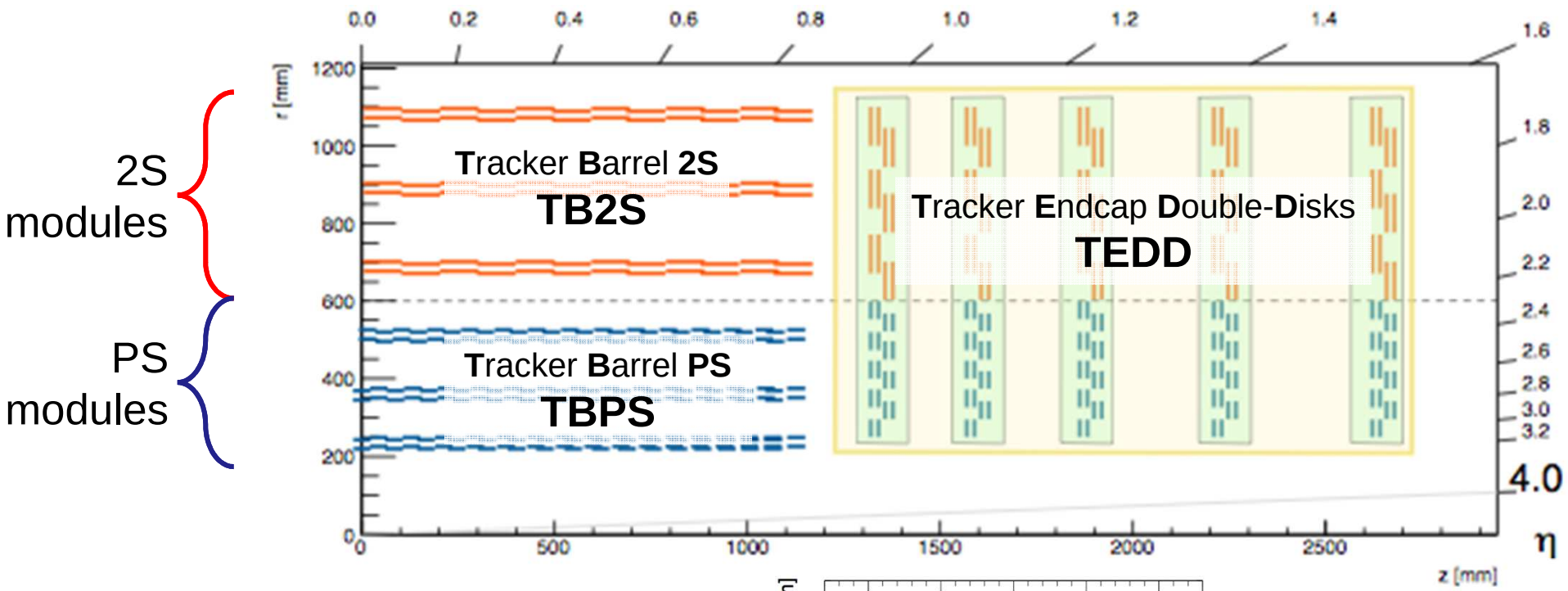
- First module assembled
  - Flip-chip bump bonded
  - Flex-print and TBM chip glued (at UHH)
  - Wire bonded

To be tested

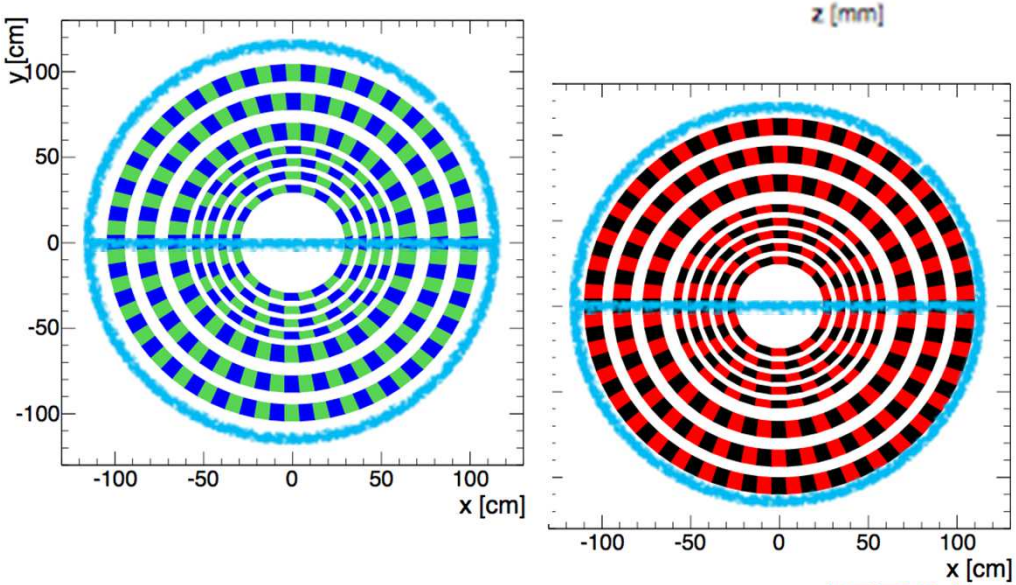
- In-house flip-chip bump bonding
  - 12 full-size modules (66592 bonds each), 2 with thinned readout chips (175/700 µm)
  - Quality variations under study: leveling, alignment, force
- Wire bonding
  - 635 Al wire bonds per module without failure, process parameters being optimised
- Module production
  - Test software ready, cold calibration to be commissioned
  - Final readout chip delivered (from IBM to PSI), tested good next: metallisation, thinning, dicing

Series production to ramp up from December, produce and calibrate 256+X modules in 2015

Tracker Phase II – Outer Tracker Mechanics



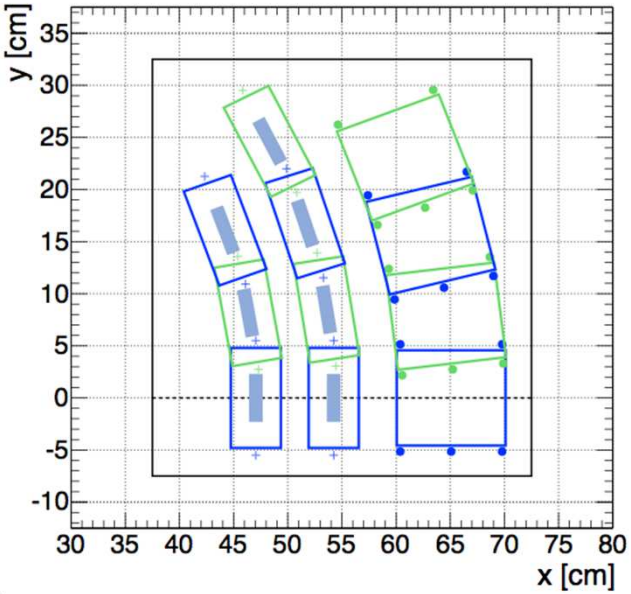
- 5 double-disks per end cap
  - Each consists of 4 dees
  - Diameter 2.4 m
- Modules mounted on dee
  - Overlap in ϕ within dee (front/back)
  - Overlap in r within double-disk



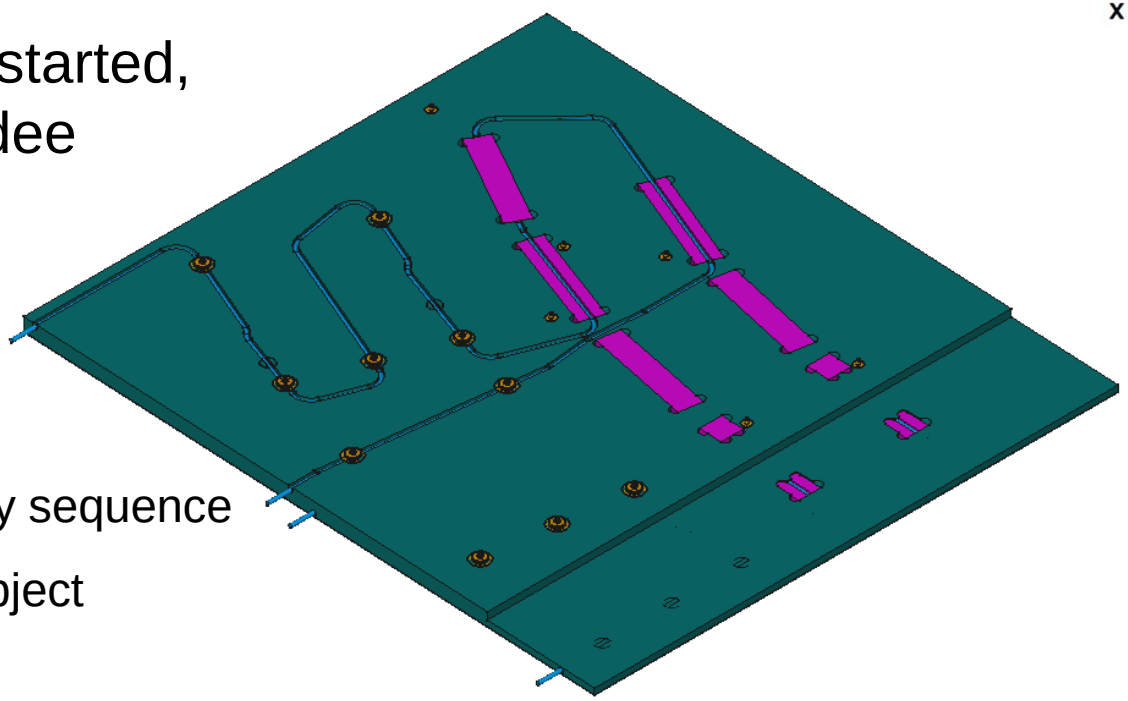
Tracker Phase II – Prototype Dee

- Several functionalities combined in large object with minimum mass
  - Mechanical stability
  - Embedded cooling pipes, blocks and inserts
  - Positioning of modules

    - PS modules directly on dee, positioning via pins
    - 2S modules on cooling inserts embedded in dee



- Work on prototype at DESY started, covering all features of real dee
  - Transition PS to 2S modules
  - Dee overlap
- Goals
  - Develop and establish assembly sequence
  - Understand scalability to real object
  - Feedback to design



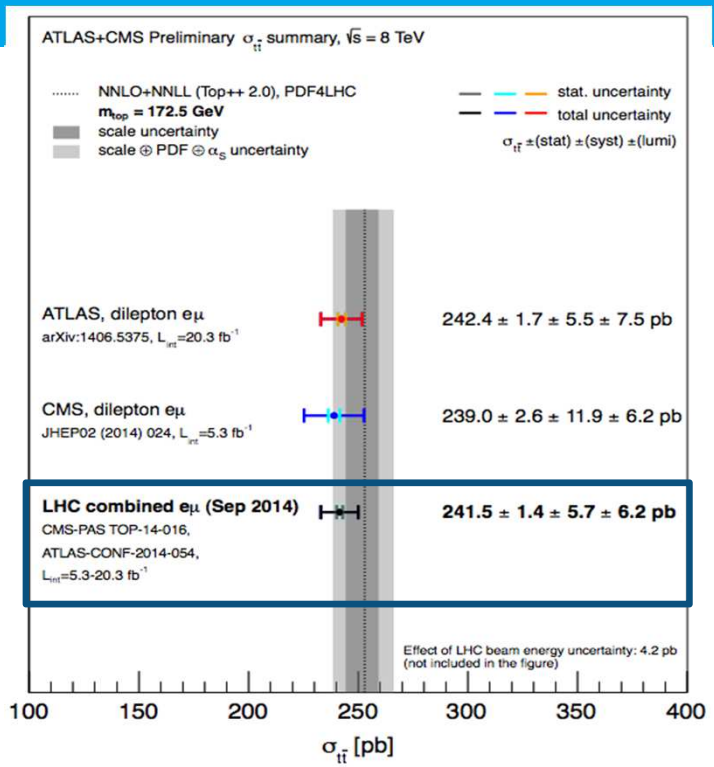
Physics Analysis

- TOP
- PDF
- QCD
- SUSY
- Higgs

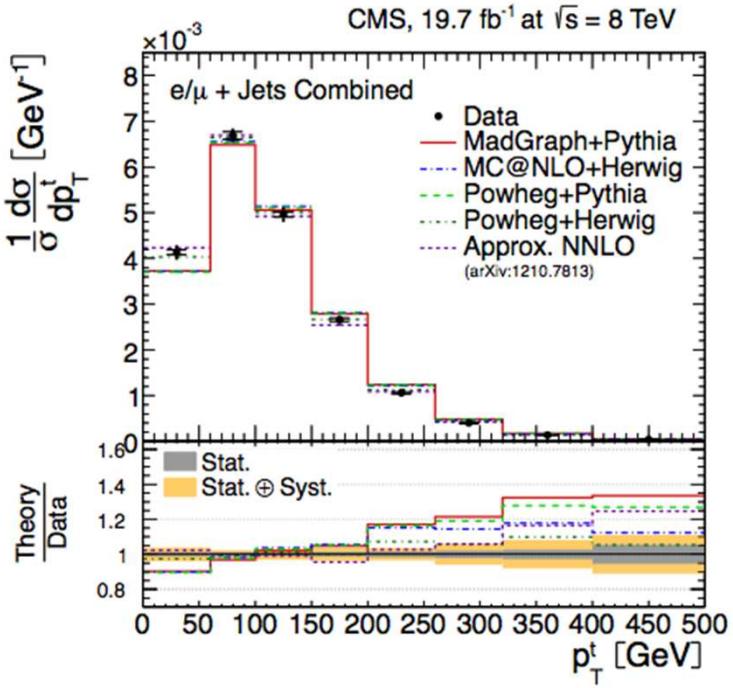
Top – Inclusive and Differential Cross Sections

- All analyses on top-pair dilepton final states

- Inclusive top-pair cross sections
  - First ATLAS+CMS combination at 8 TeV
  - Working on Run 1 Legacy paper (7 and 8 TeV)
    - Full phase space and fiducial cross sections
    - tt/Z and 8/7 TeV ratios



CMS-PAS TOP-14-016

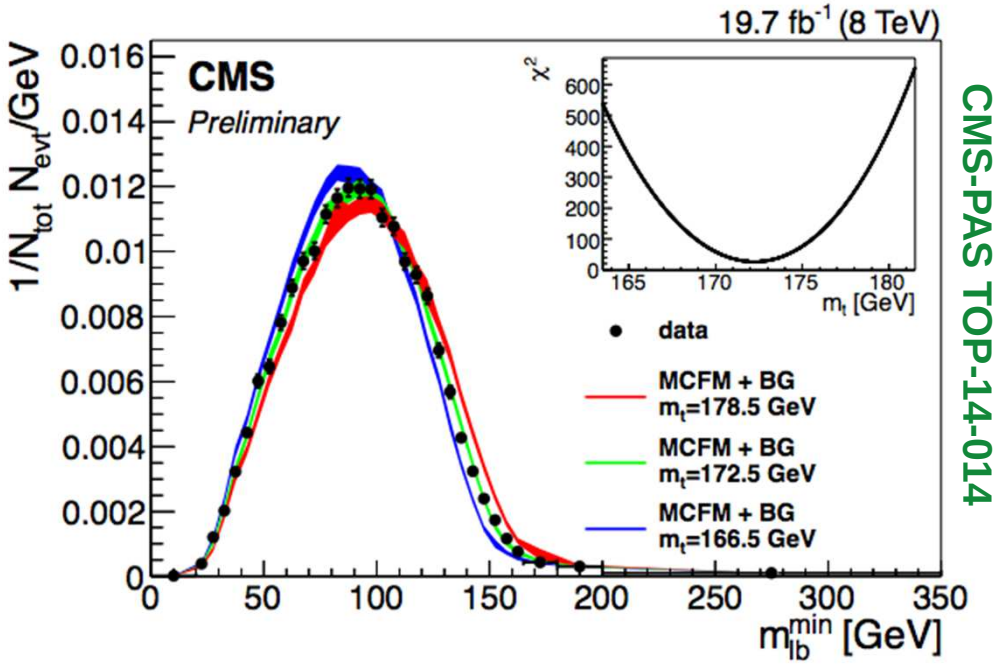


CMS-PAS TOP-12-027/028

- Differential top-pair cross sections
  - As function of top-pair, top, lepton and b jet kinematic variables at 8 TeV (1D measurements), paper close to publication
  - tt+jets at 7 TeV published **EPJC 74 (2014) 3014**
  - tt+jets, tt+bb at 8 TeV working on paper
- Working on 2D measurements at 8 TeV

Top – Mass and Higgs-Associated Production

- First top pole mass determination from m_{lb} at CMS
  - Fold any predicted m_{lb} distribution to reconstruction level (detector response), extract mass
  - Results from LO & NLO predictions within ~1 GeV
- Working on top mass from tt+1jet cross section



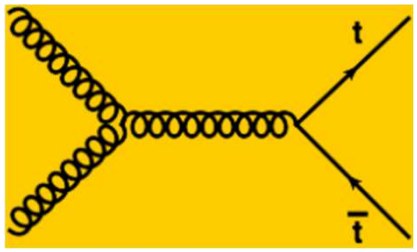
CMS-PAS TOP-14-014

MadGraph+Pythia (m_{lb}):
M(top) = 172.3 +1.2 -1.1 GeV

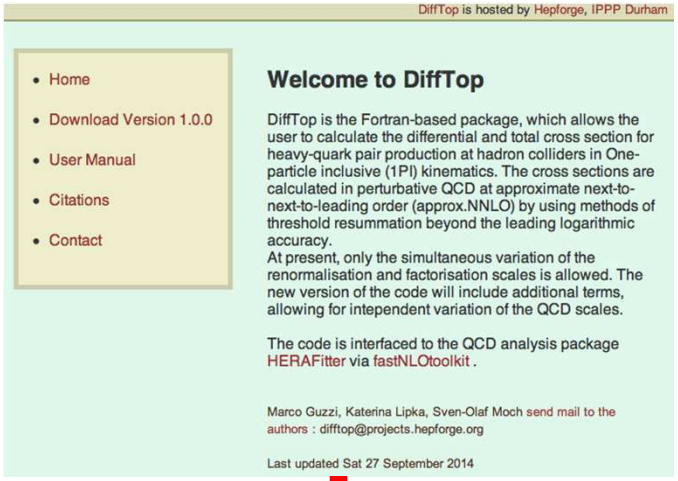
- tt+H(→bb)
  - Focus on reconstruction of Higgs boson mass from jets
- Targeted for 13 TeV
  - Total and differential top-pair cross sections (first few fb^{-1})
  - Discovery/exclusion limits of tt+H

PDF – gPDF Constraints from Top-Pair Production

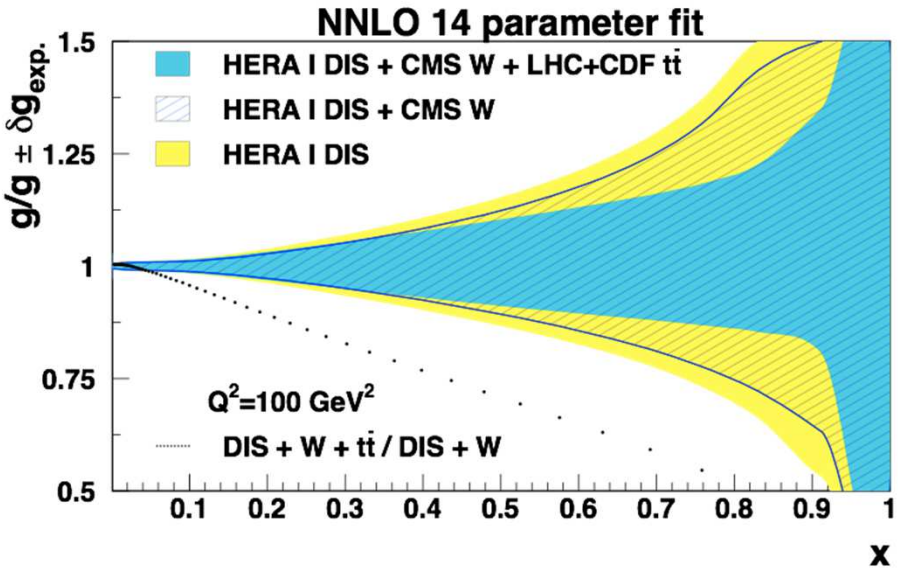
- Top-pair production probes gluon PDF, top mass and α_s
  - High sensitivity of $\sigma_{tt}(p^t_T)$ to gluon PDF expected at high x (kinematics of new physics)

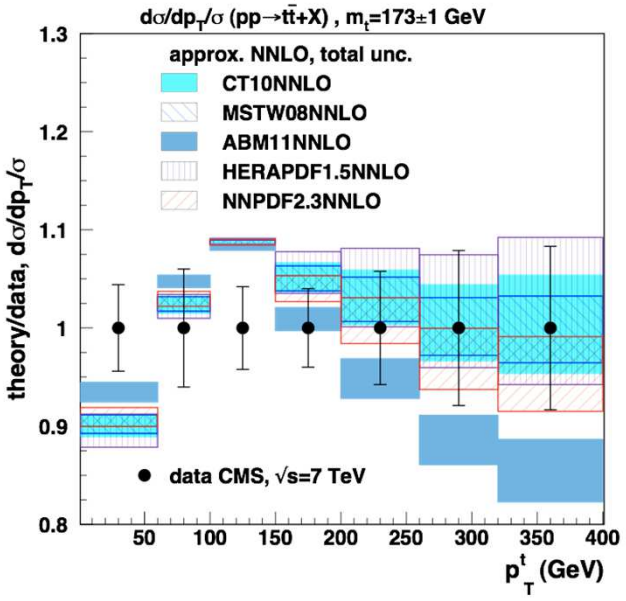


arXiv: 1406.0386
http://difftop.hepforge.org



- DiffTop
  - Phenomenological analysis of $\sigma_{tt}(p^t_T)$ at approx. NNLO
- Full PDF fit at NNLO using HERAFitter
  - Including top-pair total and differential cross sections



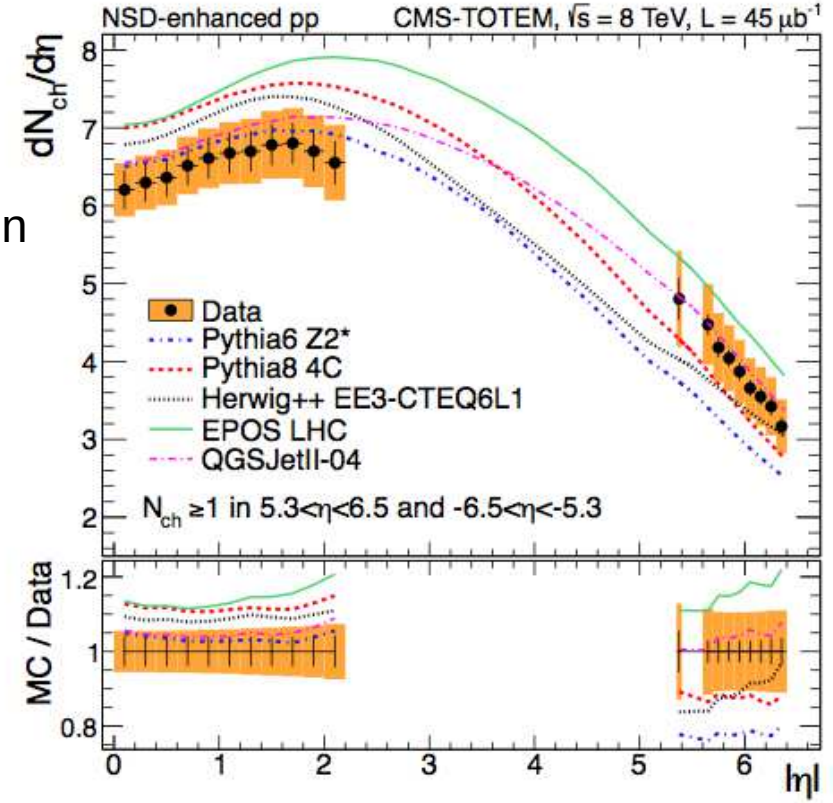


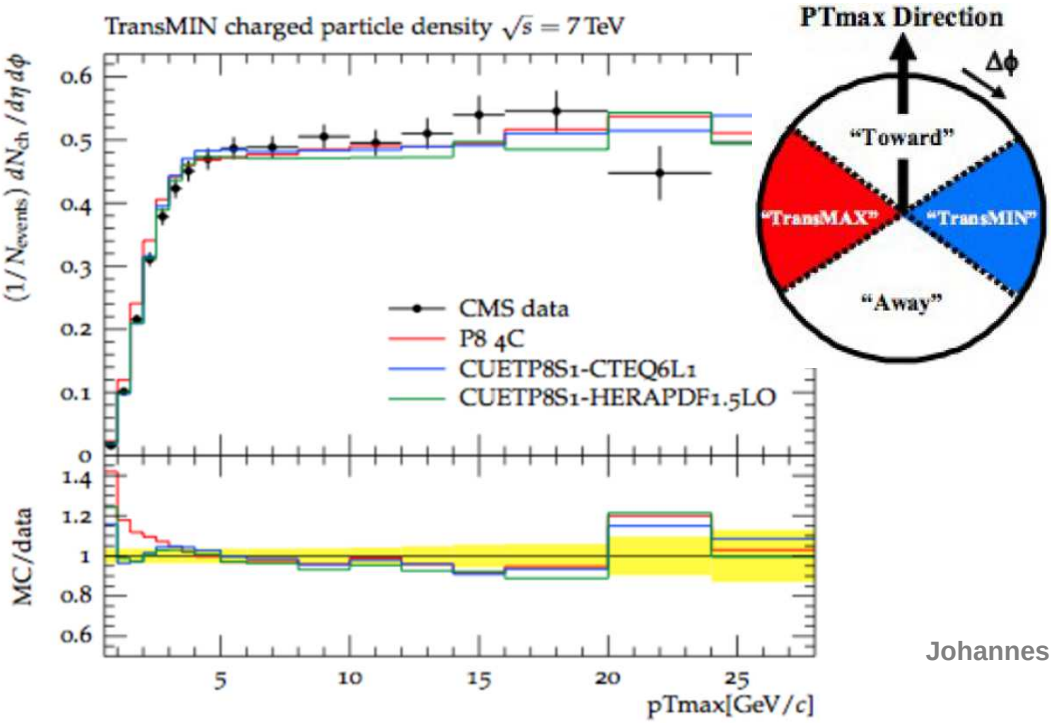
First time ever top-pair differential cross sections used in NNLO fit

Moderate improvement on uncertainty, significant change of shape

QCD – Run 1 and Run 2 Measurements

- QCD at the extremes measurements
  - Low *x* region – dN/dη, multijets done
  - High x region – high mass Drell-Yan in preparation
- Preparations for run 2 – early day measurements
  - Relevant for testing/determining MC tunes
  - dN/dη along the line of CMS-TOTEM publication



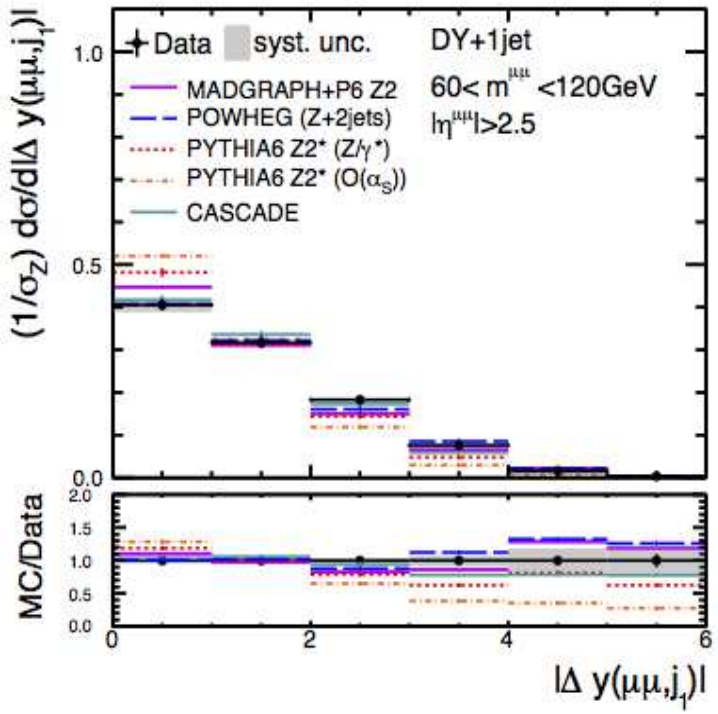


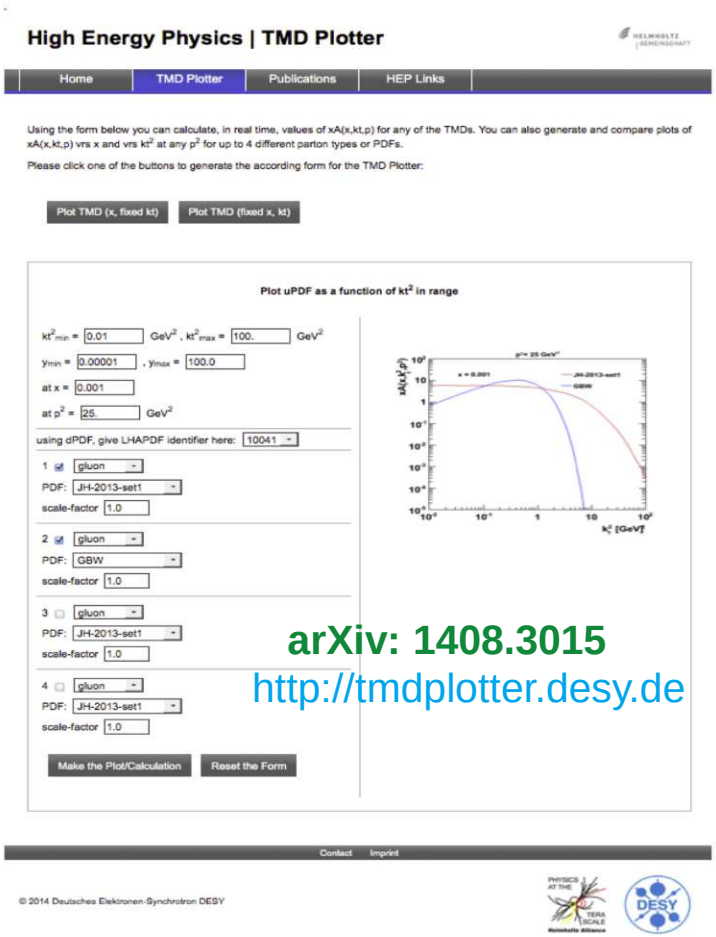
CMS-PAS GEN-14-001

- Underlying event (UE) measurement
- UE tunes at 8 TeV extrapolated to 13 TeV, include different energies for extrapolation

QCD – Phenomenological Work with Data

- Transverse momentum dependent PDFs (TMD)
  - Needed for p_T spectrum of Z, but also high p_T jets from parton shower
  - Gluon determined from HERA, **Eur. Phys. B 883 (2014) 1** evolution **Eur. Phys. J. C (2014) 74:3082**
- TMDlib & TMDplotter
  - Library of all TMDs (similar to LHApdf)
  - Plotter: web-based tool for plotting TMDs



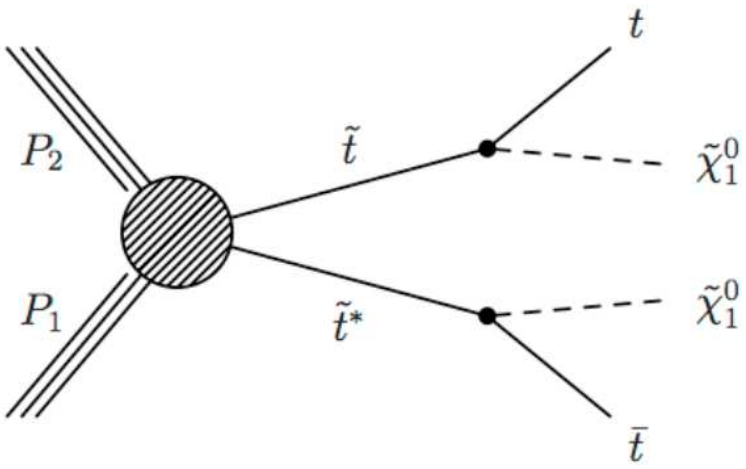


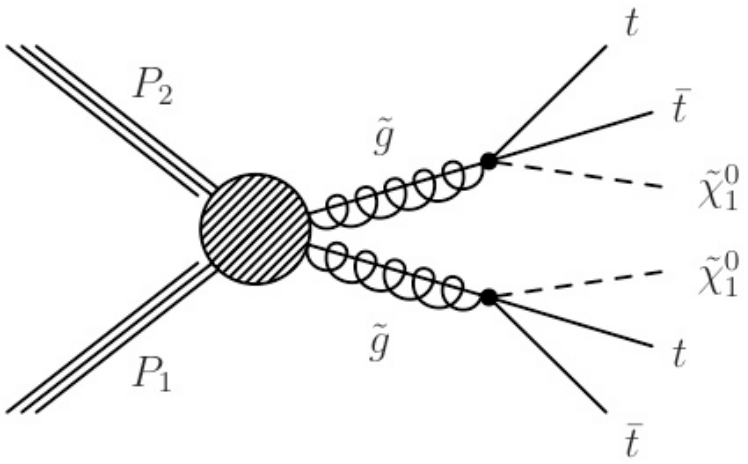
arXiv: 1408.3015
http://tmdplotter.desy.de

- Application of TMDs (CMS data)
  - W+jets **Phys. Lett. B736 (2014) 293**
  - Drell-Yan DY+1jet production

SUSY – Run 1 and Run 2 Analyses

- Ongoing work
  - Direct stop production in 1-lepton final state (going to preapproval)
  - Future analysis studies (next slide)
- Started
  - Common 0/1/2-lepton stop paper 8 TeV (contact for common preselection)
  - Follow-up paper on 14 TeV LHC-ILC study
- Targeted for 13 TeV
  - 1-lepton search (1-5 fb^{-1}), gluino-gluino and gluino-squark production
  - 1-lepton stop analysis (whole 2015 dataset)

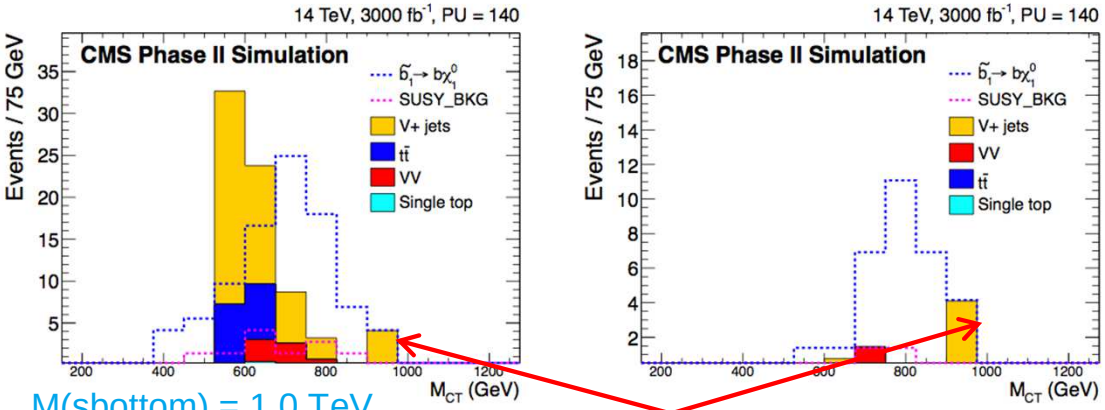




SUSY – Studies for Phase II Technical Proposal

- Examples for possible discovery with full SUSY models
  - Full model analyses, signal generation
  - Will be shown on ECFA workshop

- Search for sbottom
  - Typical search requiring 2 sbottom quarks + MET can lead to clean signal with endpoint (depending on sbottom and LSP mass)

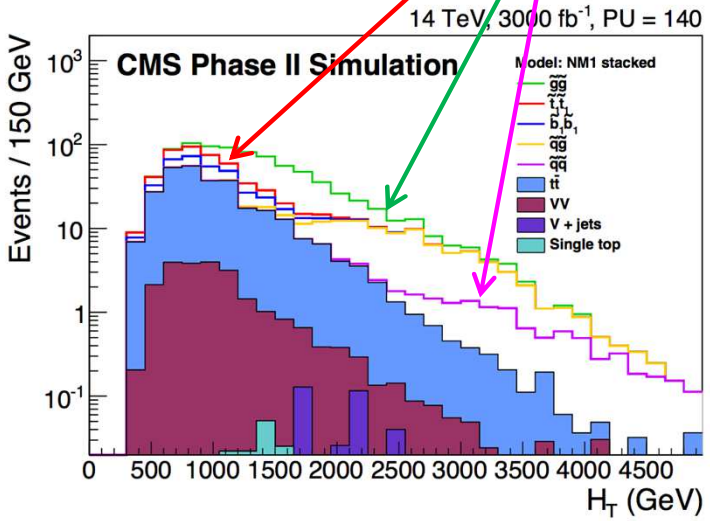


M(sbottom) = 1.0 TeV
M(gluino) = 2.1 TeV
M(squark) = 3.4 TeV

Endpoint stable in different signal regions

- Search for stop (1-lepton)
  - Typical search also sensitive to 3rd generation squarks from gluino/squark
  - Direct production difficult to observe if gluino is relatively light

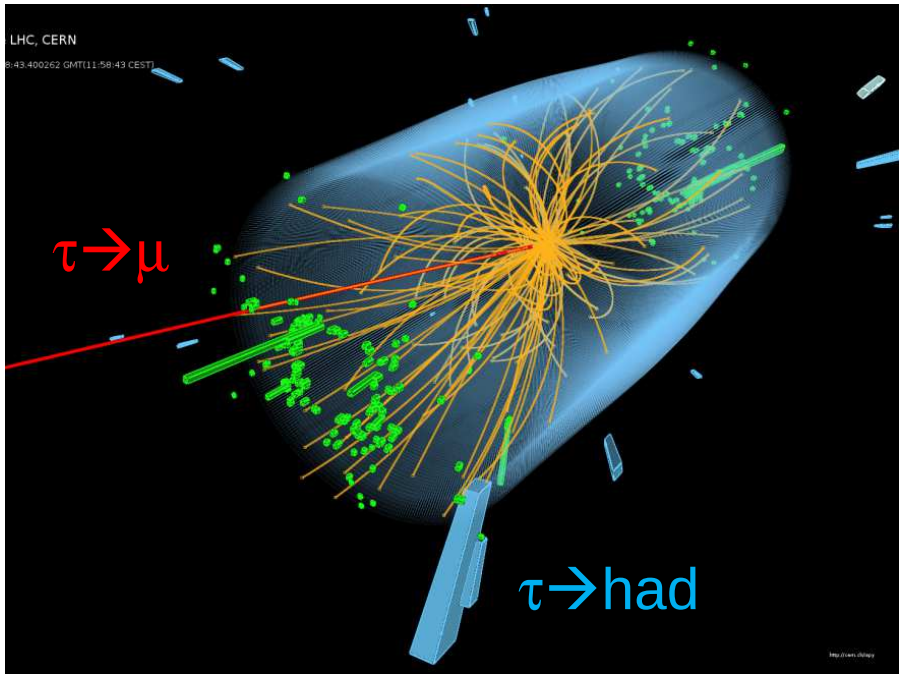
M(stop) = 1.1 TeV
M(gluino) = 1.7 TeV
M(squark) = 3.0 TeV



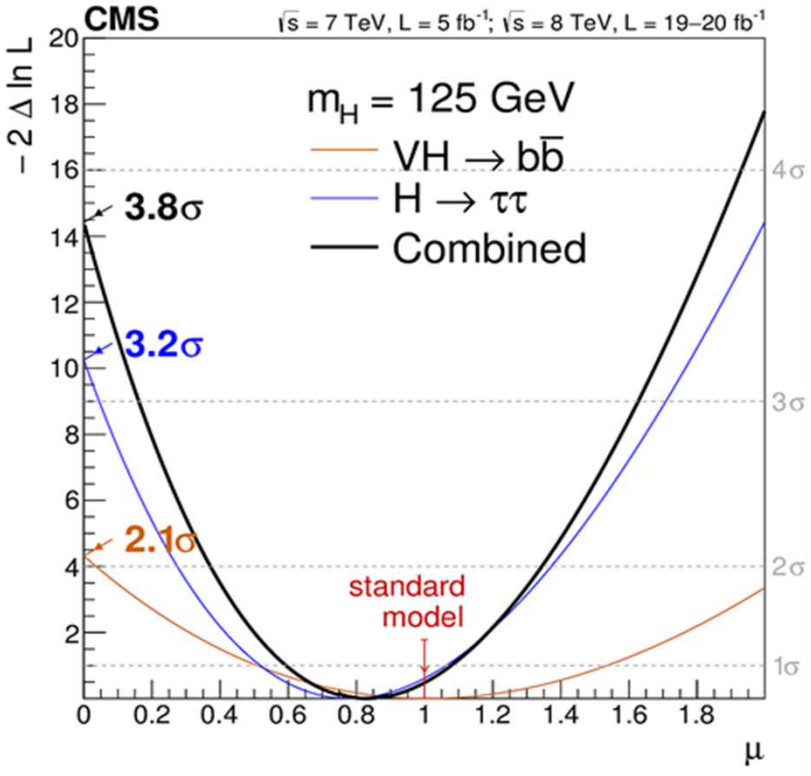
CMS SUS-14-012

Higgs – Direct Evidence for Fermionic Decays

- Evidence for H→ττ at 3.2σ observed (3.8σ expected)
  - Indicates coupling to leptons (SM expected)
  - Couplings κ(ττ) >> κ(μμ) (SM expected)



JHEP 05 (2014) 104



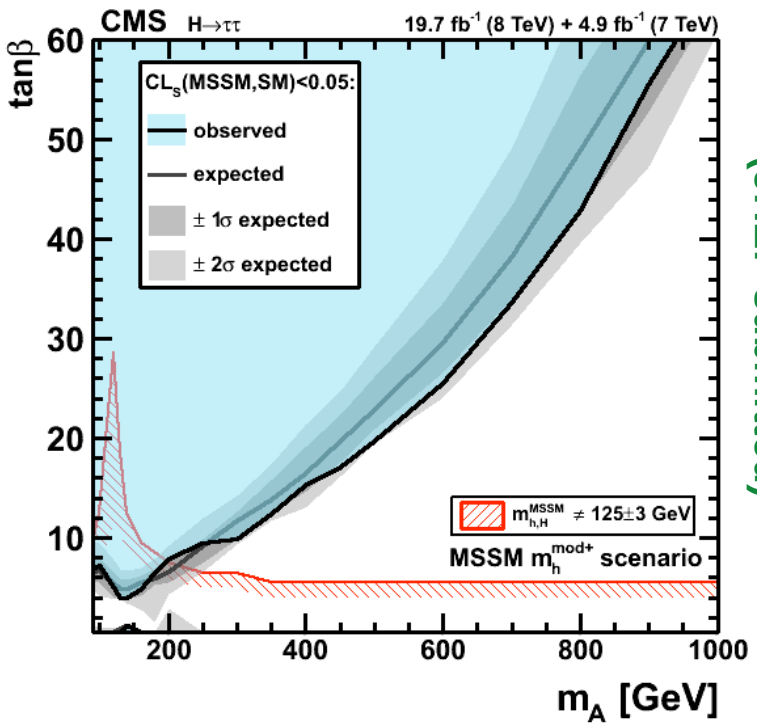
Nature Phys. 10 (2014)

- Combination with VH→bb, total observed significance 3.8σ for fermionic couplings

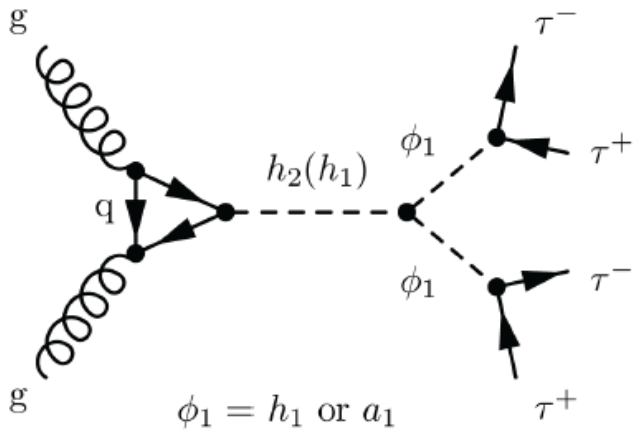
DESY

Higgs – Searches for Non-SM Bosons

- MSSM H→ττ legacy paper
  - Interpretation accounting for full Higgs spectrum, proper accounting for H(125) state
  - MSSM vs. SM (in background only hypothesis)
  - Recently updated benchmark scenarios, more realistic in view of H(125)
- Further 8 TeV analyses expected to be finalised by end of year
  - MSSM H→bb search
  - Light NMSSM Higgs search in SUSY cascades
  - $h_{1,2}(125) \rightarrow \phi_1\phi_1 \rightarrow (\tau\tau)(\tau\tau)$
- Preparations for 13 TeV ongoing
  - SM Higgs properties in H→ττ
  - Continuing BSM Higgs searches/interpretations



arXiv: 1408.3316 (JHEP submitted)



Summary

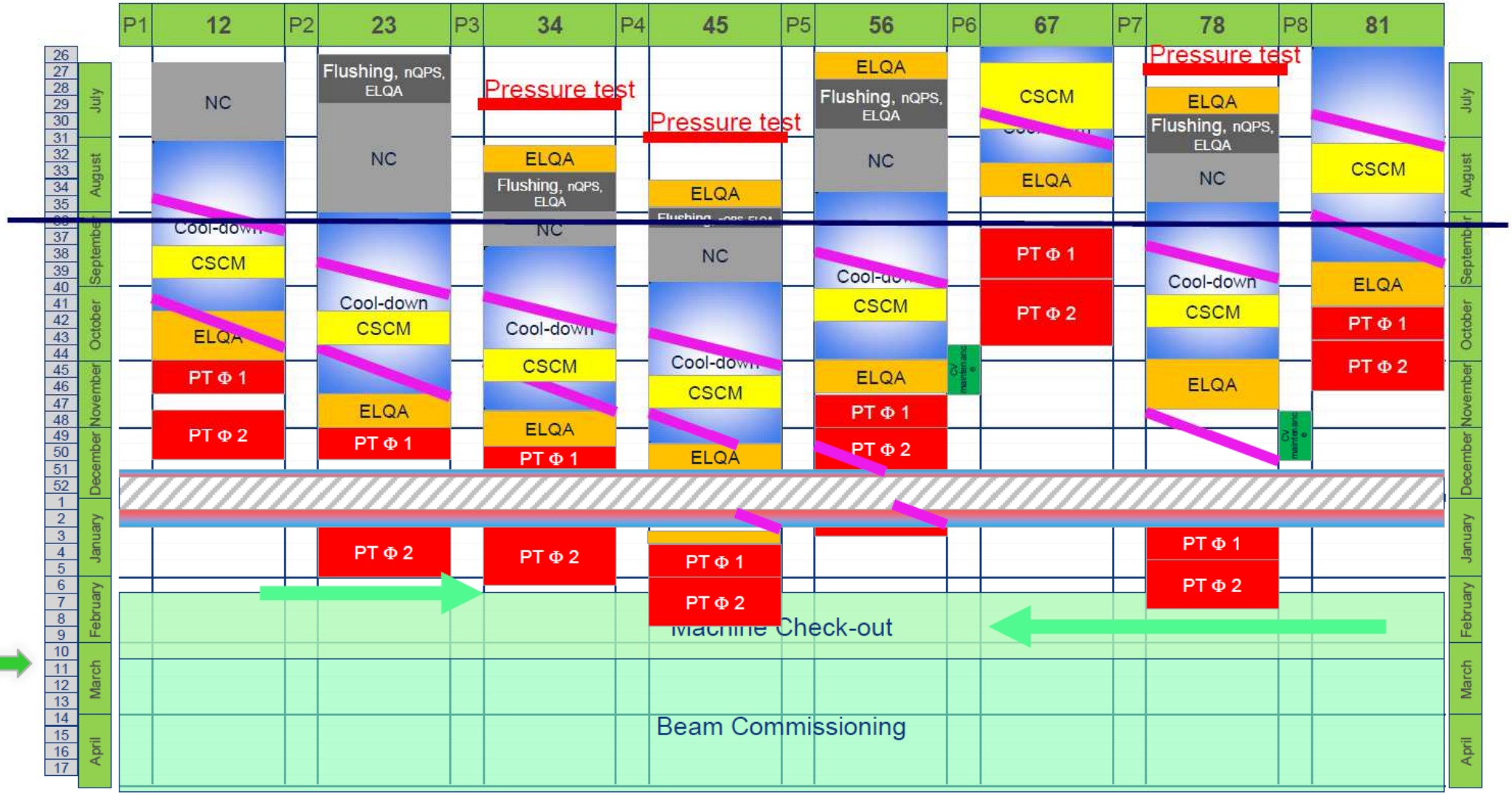
- Responsibilities and contributions in detector operations + components
  - Methodological improvements, preparations in view of run 2 in good shape
- Responsibilities and contributions to upgrades
  - LS1 contributions mainly accomplished, on schedule
  - Phase I pixel: Building 4th layer, preparing for module production
  - Phase II tracker: Significant R&D contributions, work on prototype dee started
- Major results in physics analyses
  - Run 1: Last 7/8 TeV analyses close to finalisation
  - Run 2: Many analyses in preparation, covering hot topics
  - HL-LHC: Involvement in future studies with 3000 fb^{-1} for upgrade TP

DESY CMS prepared and looking forward to interesting physics with 13 TeV

Backup

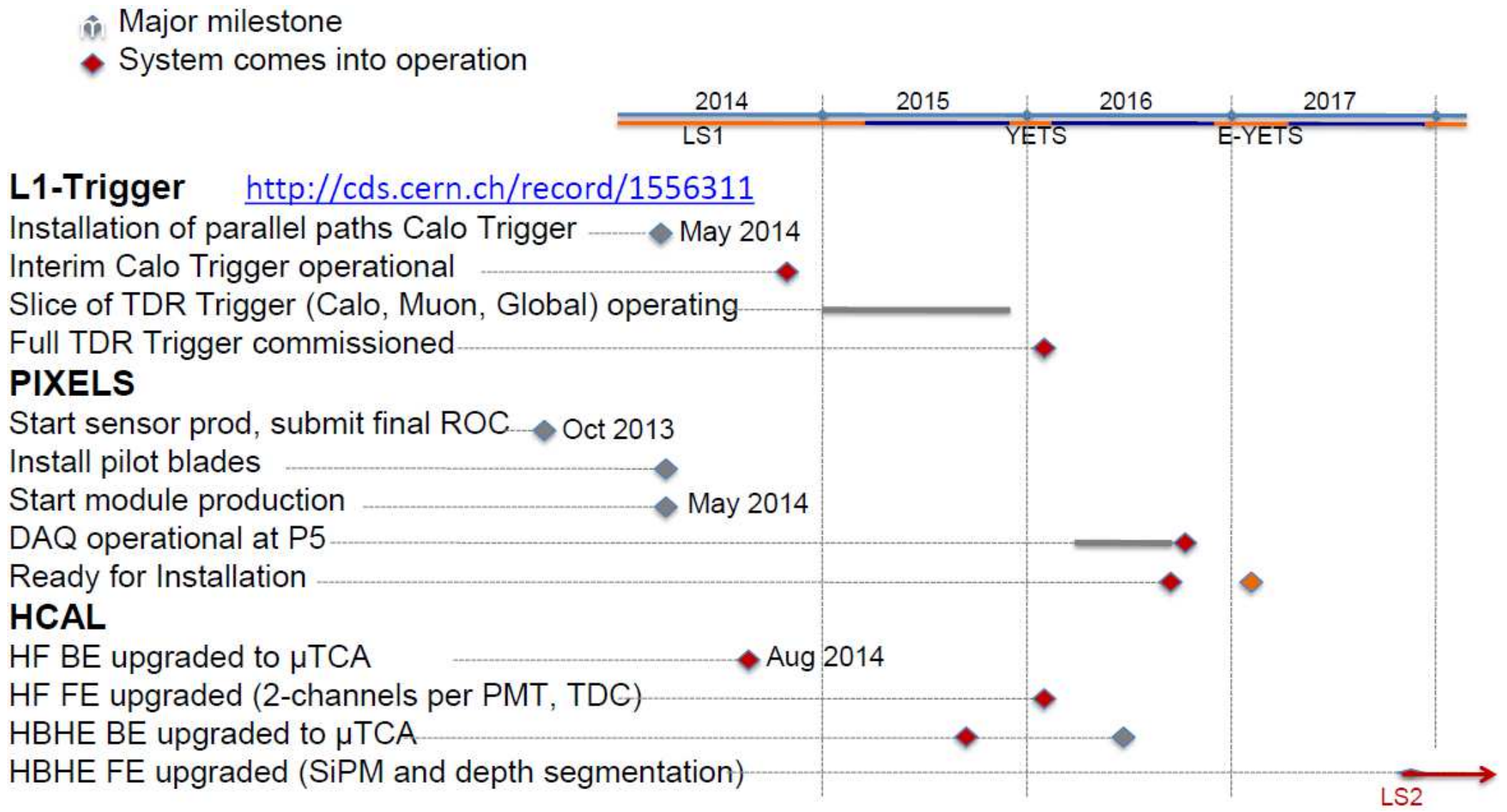
LHC Sector Schedule

> Consolidations successful, cool-down ongoing

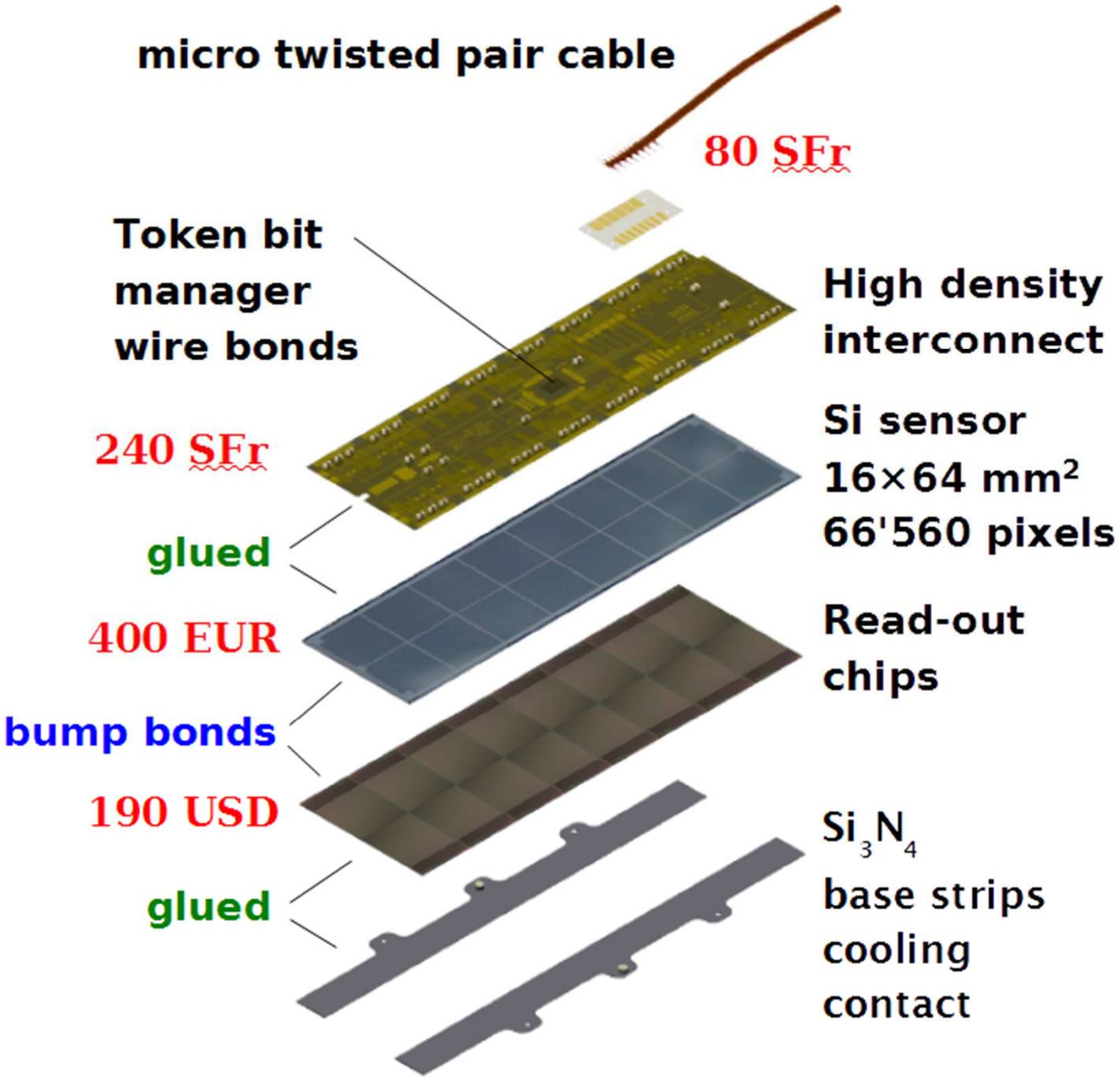


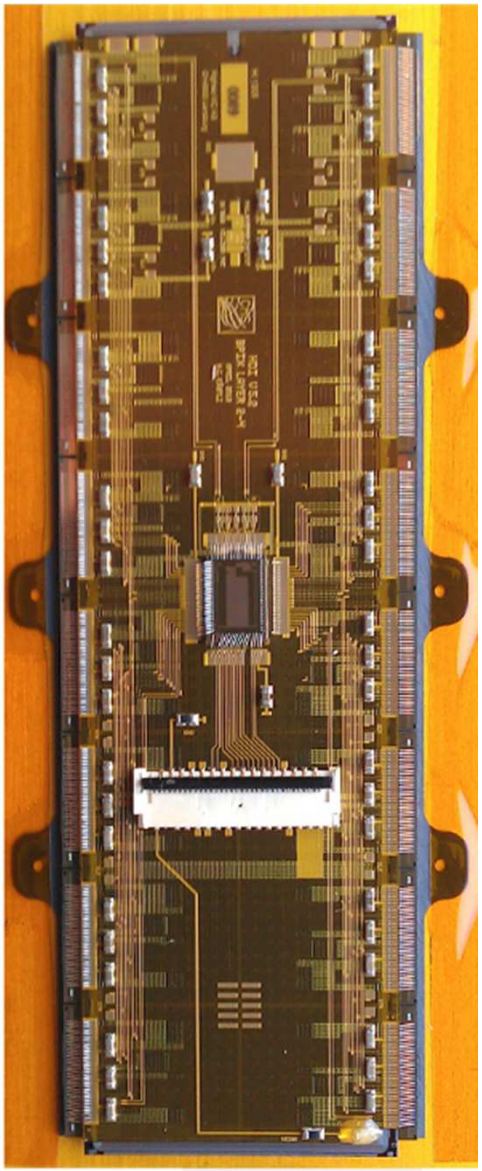
1st beam on week 11 (starting 9th March 2015)

Phase I Upgrade Planning (LS1→LS2 Period)



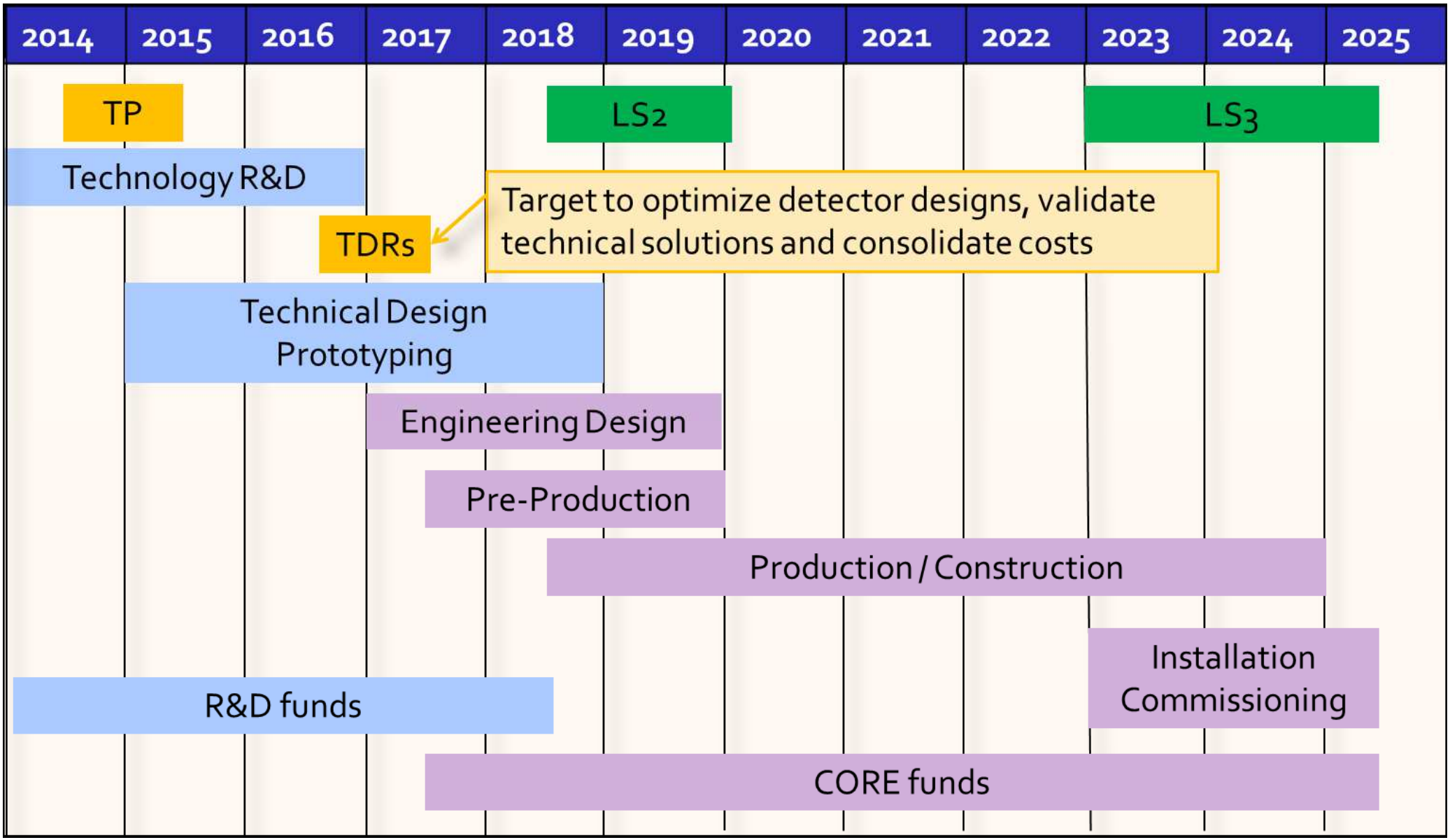
Phase I Upgrade – Barrel Pixel Module





PSI 2013

Phase II Upgrade Planning



CMS Upgrade School – CUPS 2014

- Great success of CMS Data Analysis School triggered CMS Upgrade School
- First upgrade school ever
- 28 participants from 11 countries
  - Belgium, Finland, France, Germany, India, Iran, Italy, South Korea, Switzerland, UK, US
- First 3 days
  - Lectures:
    Upgrade activities and detector technologies
  - Hands-on exercises:
    Test beam analysis
    Detector design, commissioning, tuning
    DAQ
- Last 2 days
  - Detector design studies for specific physics processes

Phase II Upgrade – Sensors R&D

- CMS HPK campaign has led to choice of sensor polarity
  - p-type sensors with 200 µm thickness baseline for Outer Tracker
  - Investigations now concentrate on

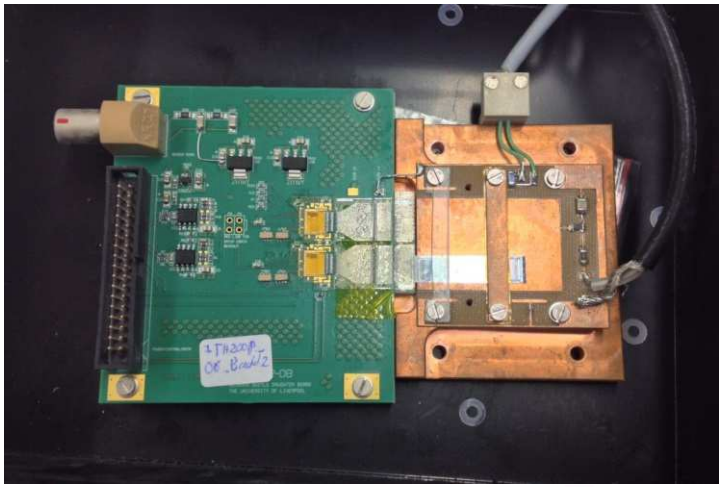
    - Sensor layout optimizations
    - Radiation-hard sensors for layers closer to interaction point
    - Vendor qualification

  - TCAD device simulations entered the CMS Detector note CMS-DN-2014/06

- DESY contributes with
  - Ongoing analysis of testbeam studies of e.g. epitaxial sensors of 100 µm thickness
  - Transient Current Technique (TCT) setup currently being brought into operation

    → Will enable us to study in detail sensor properties, i.e. electric field, charge collection and their change with irradiation and sensor layout

Strip sensor mounted on AliBaVa daughter board as used for testbeam



DESY CMS – Coordinating Roles in CMS

- **Level-1 Management**
  - K. Borras: Deputy Spokesperson (Jan. 2014 – Aug 2016); FB member
  - M. Kasemann: Chair of the Authorship Board; FB member, CB advisory
- **Physics**
  - H. Jung: FSQ-PRF Pub. Committee, Chair of Theorists in CMS committee, Convener of Physics Comparison and Generator Tunes group (MC group)
  - I. Melzer-Pellmann: Convener of SUSY Future subgroup (L3), Member of SUSY Pub. Committee
  - A. Kalogeropoulos: Dataset Definition Team (DDT) coordinator (L3 within PPD mandate)
  - A. B. Meyer: Convener of Top group (L2)
  - A. Nayak: Convener of tau identification group (L3)
- **Computing**
  - C. Wissing: Operation (L2)
  - M. Kasemann: Chair of Computing Resource Board
- **Data Quality Monitoring (DQM)**
  - M.Schröder: Organizer of remote DQM shifts (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: Convener of Strip-Tracker Module-Design group
- **Beam Radiation Instrumentation & Luminosity (BRIL)**
  - W. Lohmann: Chair of Institutional Board
  - R. Walsh: DPG convener

Collaborations with Other Groups – Upgrade

- **BCM1F**
  - CERN
- **HCAL**
  - HO SiPM: Aachen, TIFR
  - HO trigger: INFN, Warsaw, Boston
  - µTCA: CERN
- **Pixel Phase I**
  - 4th barrel layer: German Institutes (esp. UHH)
- **Sensors Phase II**
  - UHH, KIT
- **Tracker Phase II**
  - Dee prototype: Lyon, CERN

Collaborations with Other Groups – Physics Analysis

- **TOP**
  - Inclusive cross sections: ICFA, Oviedo, Strasbourg
  - Differential cross sections (1D): UHH
  - Differential cross sections (tt+jets): KIT
  - tt+H: KIT, Ohio, Notre Dame, Virginia
- **PDF**
  - Exchange program: DESY – Southern Methodist U
  - Close collaboration with CTEQ, ABM PDF groups
  - Member of physics project of Alliance (UHH, Mainz, Freiburg, Wuppertal, KIT)
  - DiffTop: UHH
- **QCD**
  - Double-parton scattering, forward jets: Antwerp
  - Phenomenology: Oxford, Moscow
- **SUSY**
  - 1-lepton stop: UHH
  - 13 TeV 1-lepton search: Athens, CERN
  - LHC-ILC study: DESY ILC
- **Higgs**
  - $H \rightarrow \tau\tau$: KIT, CERN, Ecole Polytechnique
  - MSSM $H \rightarrow bb$: Zurich, Moscow, Bejing
  - NMSSM $H \rightarrow bb$: UHH
  - $h_{1,2} \rightarrow \phi_1\ \phi_1 \rightarrow (\tau\tau)(\tau\tau)$: IC, Rutherford Appleton Lab, Riverside