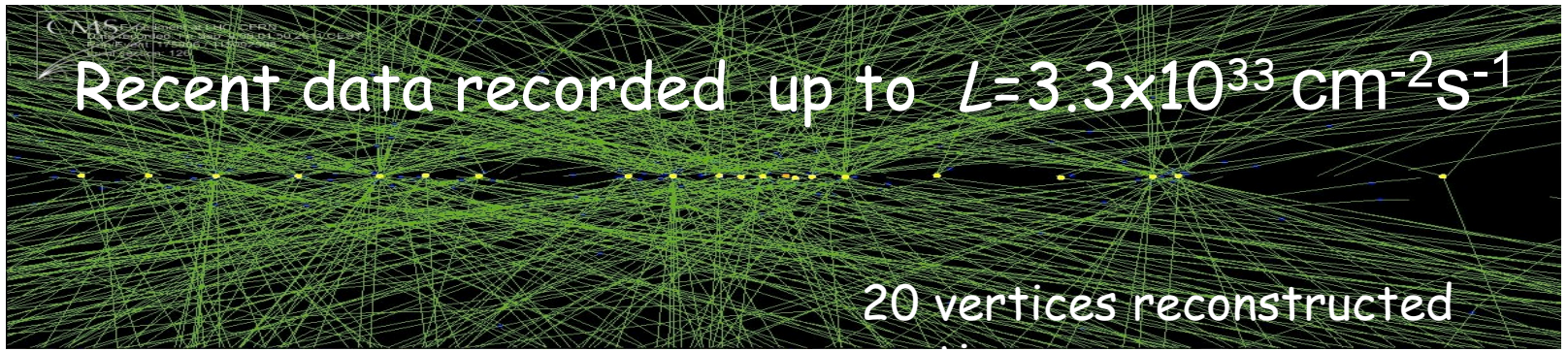
LHC Status & Status of DESY-CMS



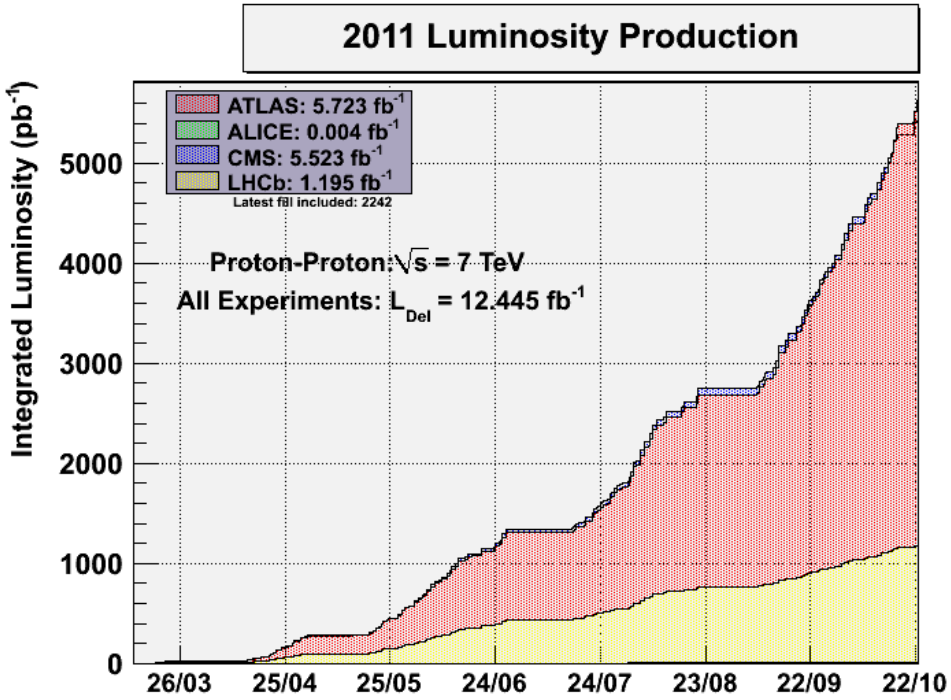
- LHC Status and Outlook
- Global CMS Status
- DESY CMS Activities
  - Physics Analysis
  - CMS Operations
  - CMS Computing
  - Detector Upgrades

On behalf of the DESY CMS Group

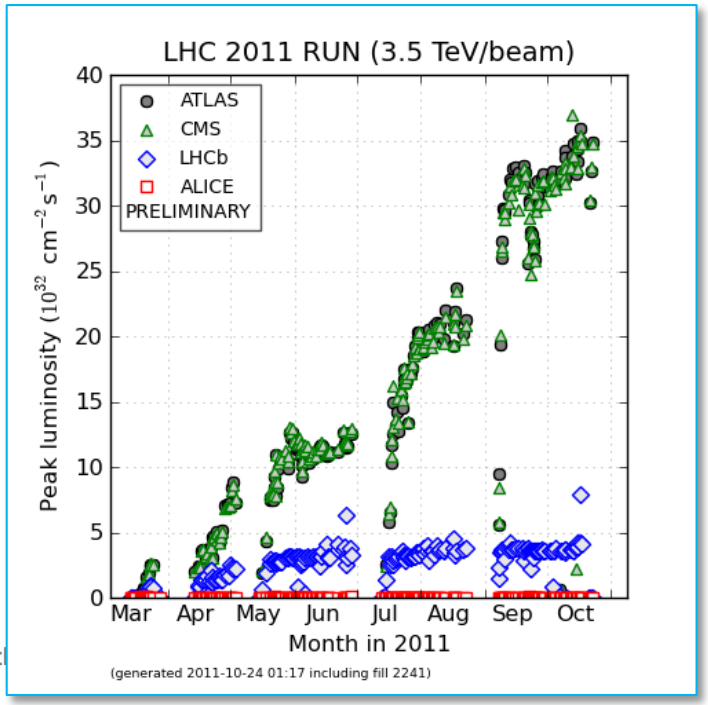
Matthias Kasemann

72. Physics Research Committee
Open Session, 25.10.2011

LHC performance in 2011

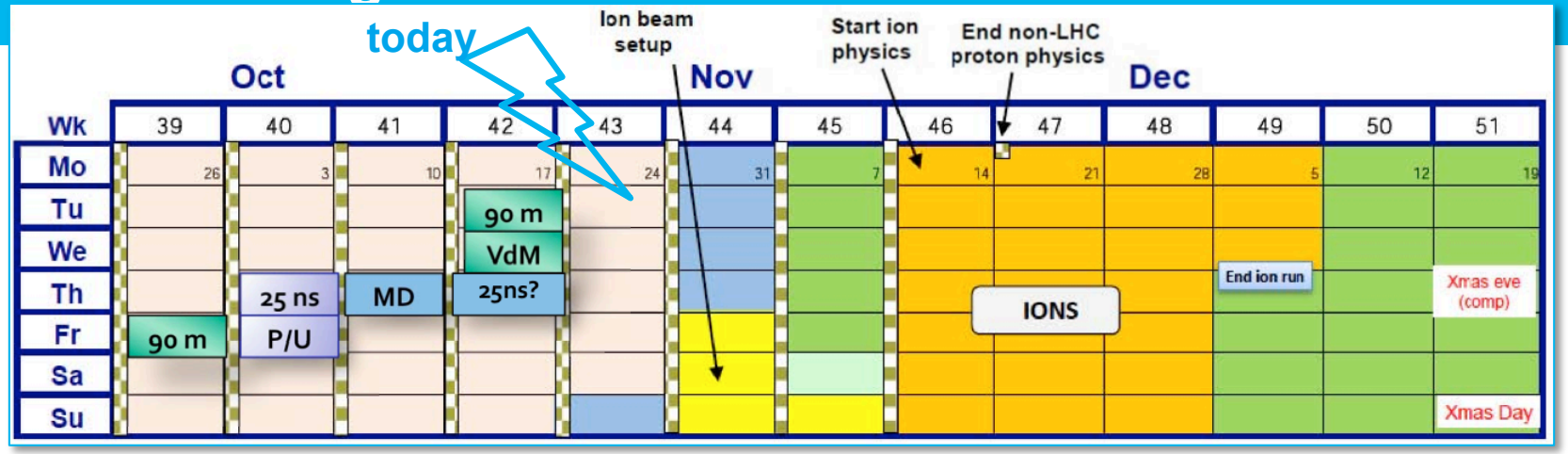


- LHC delivered ~5.5 fb^{-1} to ATLAS & CMS
  - Record weekly Luminosity > 400 pb^{-1}
  - Delivered during last 4 weeks: ~2 fb^{-1}
- Current issues during operation at high intensities:
  - Single-Event-Upsets (SEU): intensity and luminosity related
  - UFOs are not intensity related
  - Higher-Order-Mode-Heating: intensity and bunch length dependent
  - Vacuum instabilities at very high p-intensities



- Peak luminosity increased from 1.2×10^{33} to 3.69×10^{33} $cm^{-2}s^{-1}$
- Successfully implemented luminosity leveling for LHCb + luminosity calibration (vdM scans)
- Improvements during 2011:
  - 50 nsec bunch spacing (started with 75 nsec)
  - Increase of bunch charges to 1.68×10^{14} p-per-beam
  - Increase focusing to β^*=1m
  - Reduce emmittance to ~2 μm

LHC Running in 2011 and 2012:



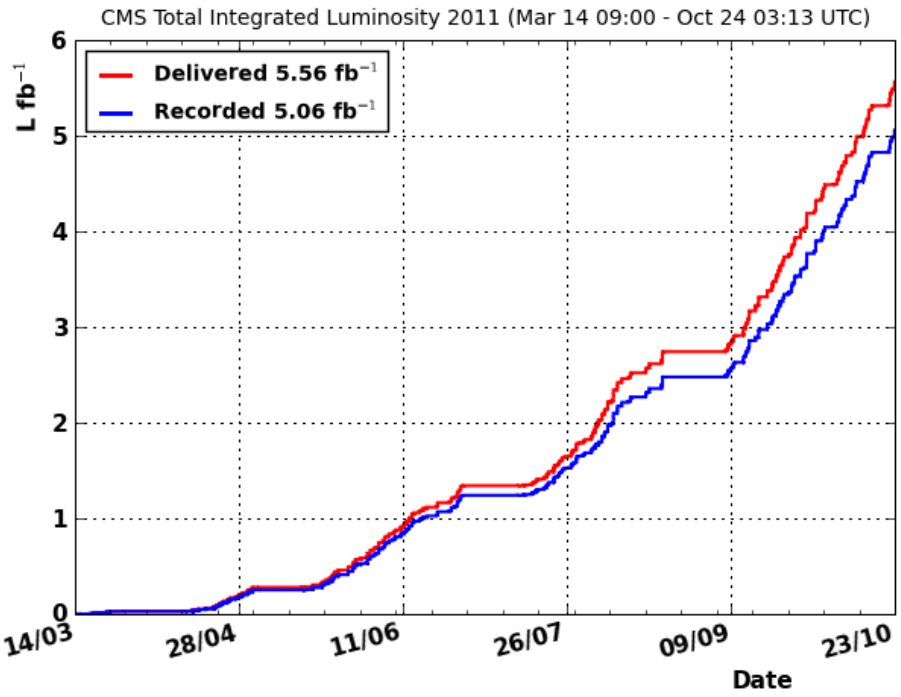
- 2011 schedule:
  - p-p running until end of this week,
  - then 4 weeks of Heavy Ion running,
  - then Year-end-Technical-Stop of ~ 19? weeks

- 2012: Current planning foresees running at 50ns bunch-spacing.
  - Possible luminosity increases by reducing further the focusing (β*).
  - The official luminosity goal is set to 10 fb^{-1} per experiment.
  - Issues for 25ns are under study.

- It seems possible to increase the energy to 8TeV.
  The benefit is important: 10-15% in low mass Higgs searches;
  factors of ×3 to ×5 when looking for high mass resonances.

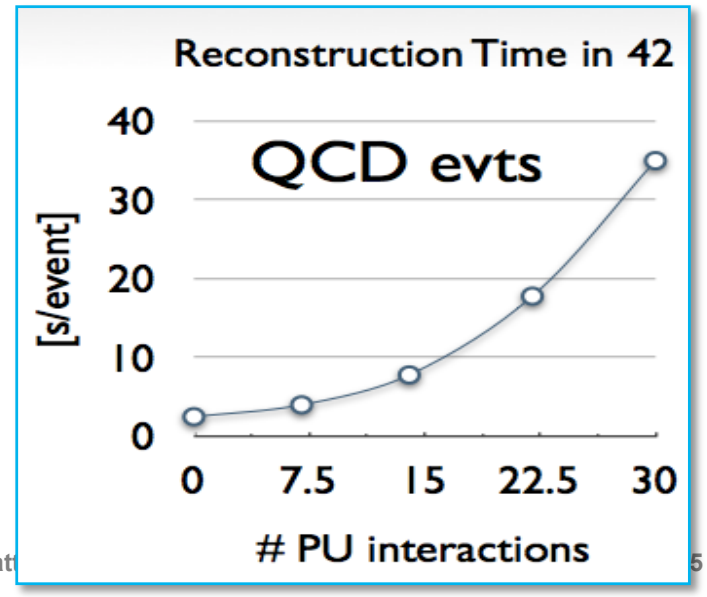
There will be a meeting of the experiments with CERN Directorate at the end of November in preparation for the discussion at Chamonix 2012.

More than 5 inverse femtobarn delivered to CMS!

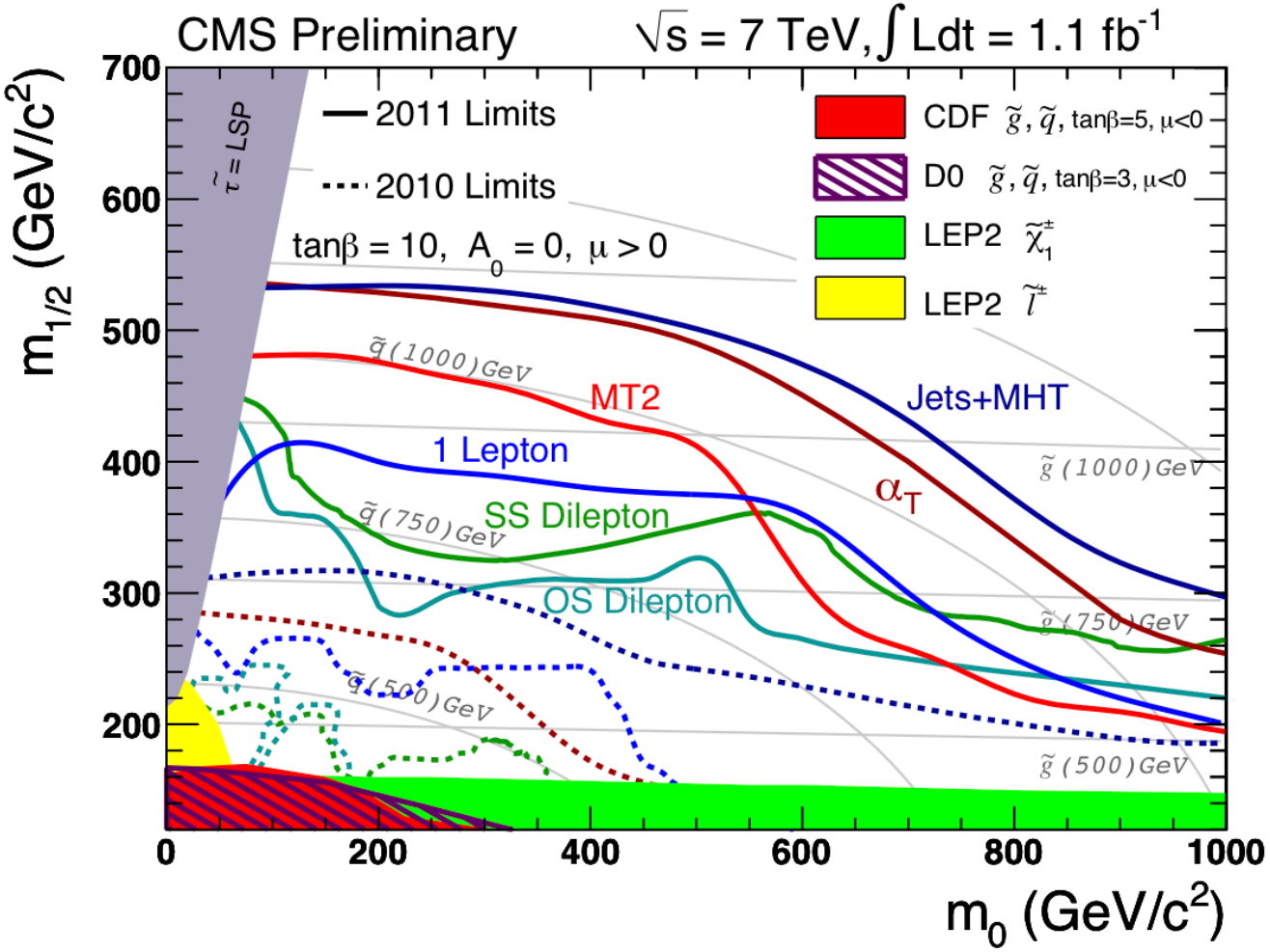


- Recorded 5.0 fb^{-1} of 5.5 fb^{-1} delivered
  - Data-taking efficiency is about 90%
- Certification for physics analyses (up to August Stop)
  - 84% for all systems perfect
  - 91% for muon analyses (without calorimeters)
- 2011 physics analyses reported at conferences used: 0.23 – 1.7 fb^{-1}
  - most at 1.1 fb^{-1}
- Luminosity uncertainty is 4.5%

- LHC fills starts with ~15 <av.> pile-up interactions (tested during MD run: PU of 30)
- Improving trigger setup kept rate and dead-time under control while preserving physics!
  - Event recording rate up to 400 Hz with 2-3% deadtime
  - Just about enough computing resources available for reconstruction and analysis.



SUSY: new limits on CMSSM



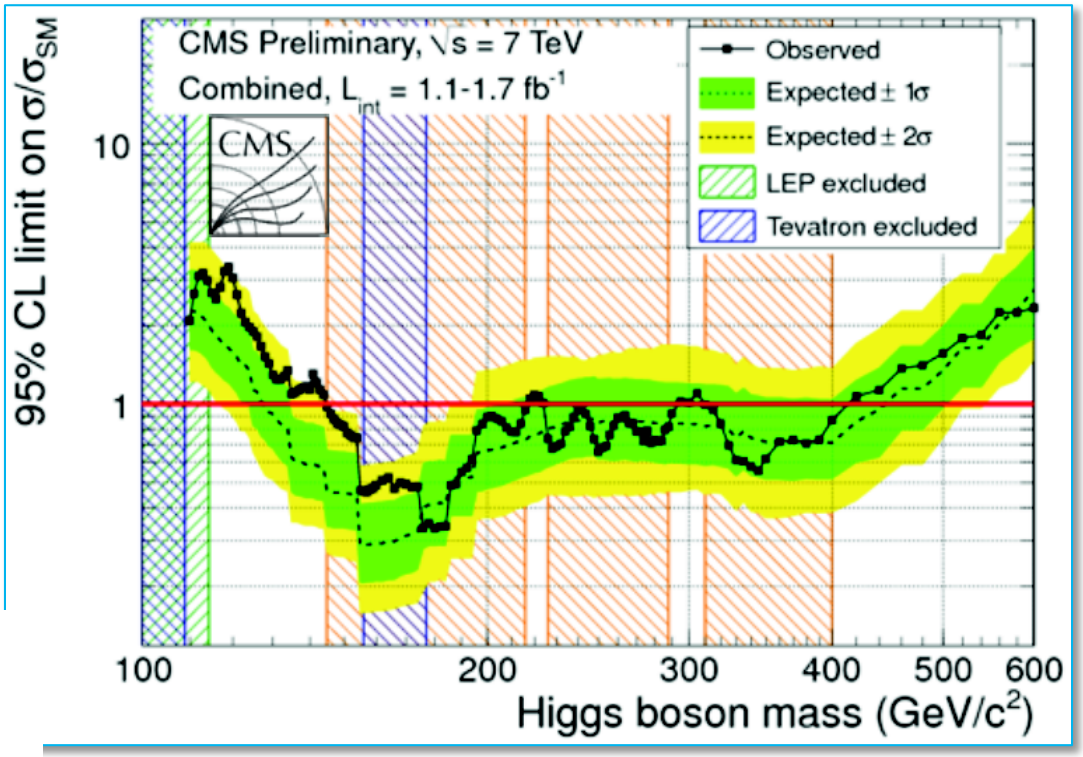
Within the constrained MSSM models we have crossed the border of excluding gluinos and squarks up to 1TeV and beyond.
Significantly improved limits, parameter space is getting small.

More conclusive results are expected for the winter conferences.

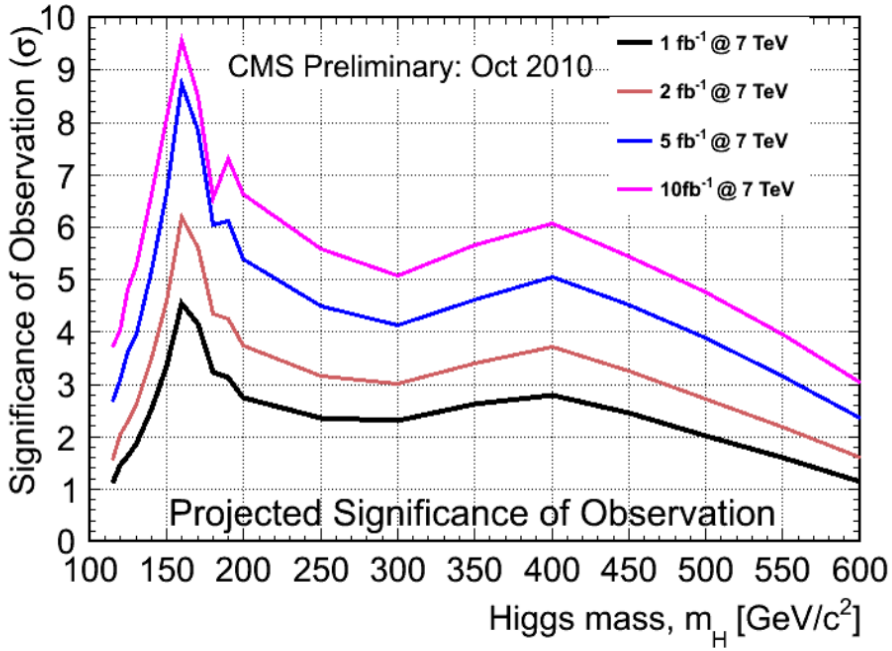
The Search for the SM Higgs Boson

With 5fb^{-1} and the combination of the two major LHC experiments the discovery reach is almost everywhere in the range from 114 to 600 GeV.

Alternatively, we could start ruling out the SM Higgs.



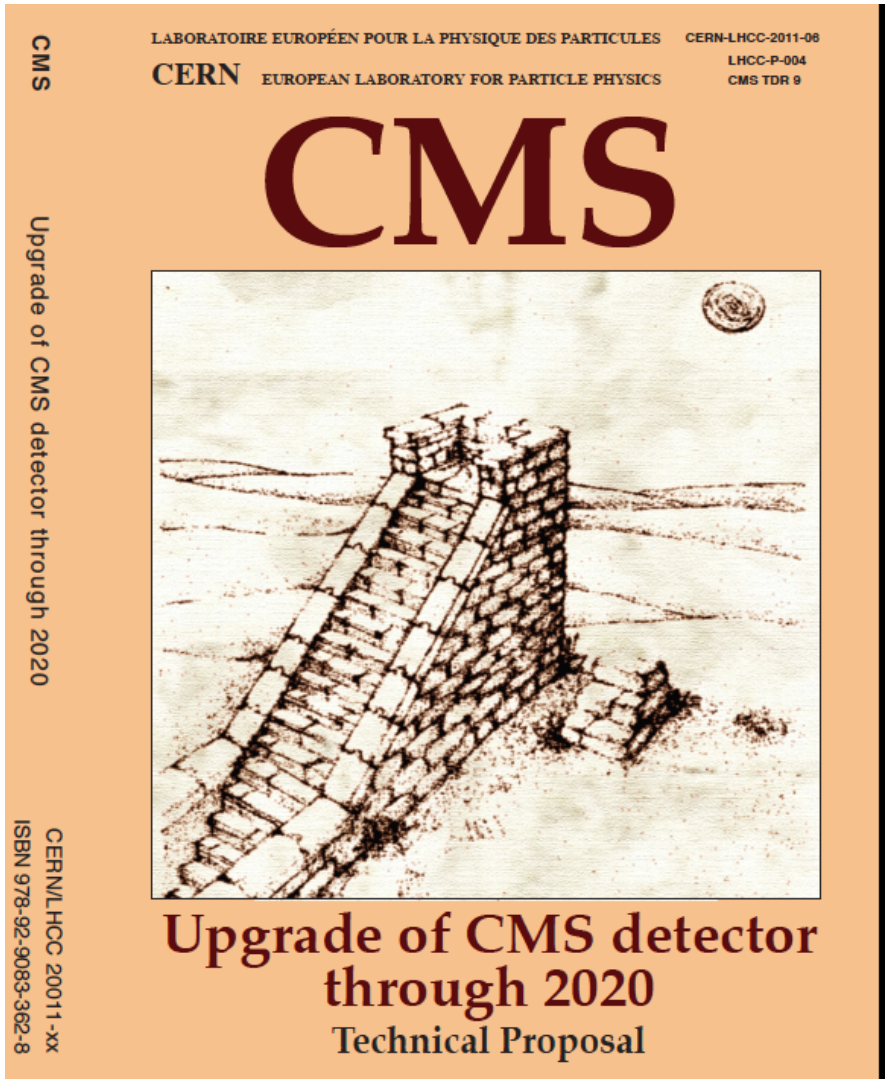
Good chance for a Higgs discovery in 2012:



CMS, V. Sharma, Lepton-Photon 2011

CMS Upgrades summary

- **Technical Proposal for Phase 1 Upgrade accepted by LHCC and document is now public.**
- Technical Design reports being prepared for Pixels, HCAL, Trigger.
- Detailed scheduling of installation and commissioning depends on the timing of the long shutdowns
  - Plans for the first shutdown are clear
  - Overall schedule aiming to complete the upgraded detector components relatively early (2016)
  - Maintain possible flexibility in installation



DESY CMS Physics Overview

- QCD / Forward Physics
  - Multiparton Interactions / UE
  - MC Tuning
  - Forward Energy Flow
  - Hard forward / central jets
- Higgs
  - SM and MSSM Higgs Searches
    - $H(A) \rightarrow \tau\tau \rightarrow \mu\mu$
    - $H(A)$ VBF $\rightarrow \tau\tau \rightarrow \mu\mu$
    - $bH(A) \rightarrow bbb$
  - Drell/Yan cross sections (with EWK)
  - B-tagging studies using ttbar events
- SUSY
  - Di-lepton analysis with μ and e
    - same sign
    - opposite sign
  - Leptons with b-tag
- Top Quarks
  - Differential cross section measurement in the di-lepton channels
  - Top quark mass determination
  - bbZ production (with EWK)
- Predictions based on HERAPDF
- PDF fits using CMS data NEW!

Many synergies used between physics analysis

CMS Papers with major DESY contributions:

- EWK-10-013 JHEP 1108:117,2011 - Measurement of the inclusive Z cross section via decays to tau pairs in pp collisions
- TOP-11-002 JHEP 1107:049,2011 - Measurement of the ttbar production cross section and the top quark mass in the dilepton channel
- FWD-10-011 submitted to JHEP - Forward Energy Flow in the CMS detector

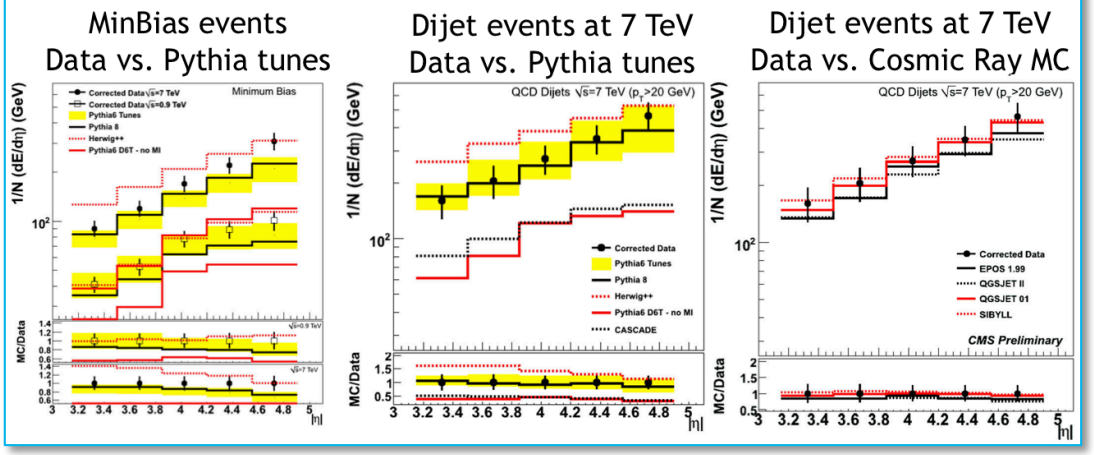
DESY Forward Physics result published

- Forward Physics topics at LHC:
  - Small-x parton radiation, parton dynamics
  - Multi-parton interaction
  - Diffraction
  - Exotic QCD phenomena

  Sensitive input to MC tuning
  Sensitive to new physics

- *Measurement of fwd energy flow in minimum bias and hard dijet events at $\sqrt{s}$=0.9 / 7 TeV*
  - Sensitivity to MPI modeling
  - No model describes all data
  - Used for MC tuning
    also comparing to Cosmic Ray MC

Forward Energy Flow in Minimum Bias and Dijet Events @ 0.9 and 7 TeV
Official CMS PAS: CMS-FWD-10-011
Analysis performed exclusively at DESY



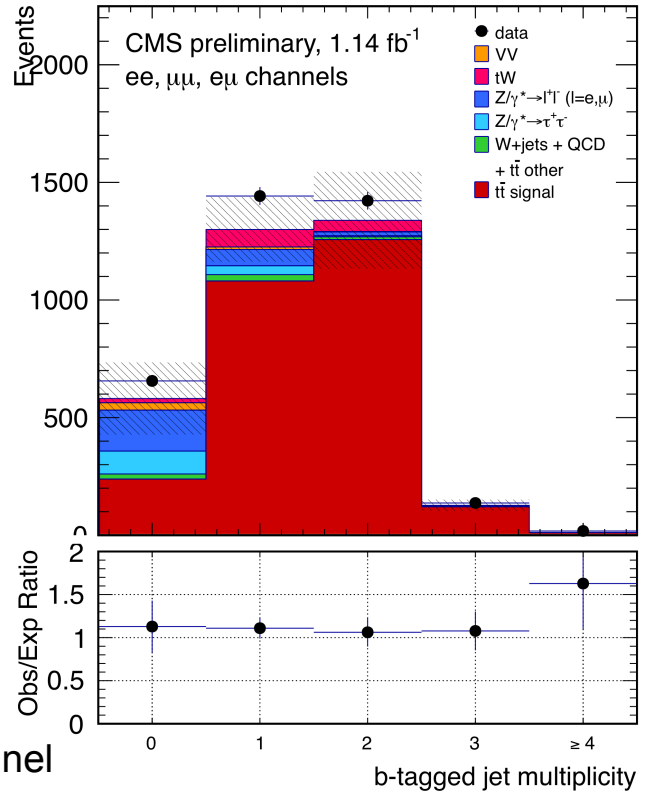
Preprint	
Report number	arXiv:1110.0211 ; CMS-FWD-10-011 ; CERN-PH-EP-2011-086
Title	**Measurement of energy flow at large pseudorapidities in pp collisions at $\sqrt{s}$ = 0.9 and 7 TeV**
Author(s)	CMS Collaboration *Show all 2208 authors*
Imprint	04 Oct 2011. - 35 p.
To be published in:	*J. High Energy Phys.*
Subject category	Particle Physics - Experiment
Accelerator/Facility, Experiment	CERN LHC ; CMS
Keywords	QCD ; forward physics ; experimental results
Abstract	The energy flow, dE/d(eta), is studied at large pseudorapidities in proton-proton collisions at the LHC, for centre-of-mass energies of 0.9

- Result shown at summer conferences and submitted to JHEP.
- 1 PhD thesis finished yesterday:
  N.Sen: *Measurement of the Energy Flow at Large Pseudorapidities using CMS at the LHC*

Top Quark analysis in 2011

- Main analysis (pre-approved, in CMS approval process):
  Differential Top quark pair production cross section measurement in the di-leptonic final state at 7 TeV
  - Normalized differential cross sections in μμ, μe, ee channels: $1/\sigma \times d\sigma_{ttbar} / dX$
  - Combined PAS in preparation with results from UHH (e+jets, μ+jets) and Korean groups (m_{tt} in dileptons)
  - Inclusive cross section measurement, (cross check for CMS-PAS TOP-11-005, shown at "LP'11")

  DESY plans publication of full 2011 result!



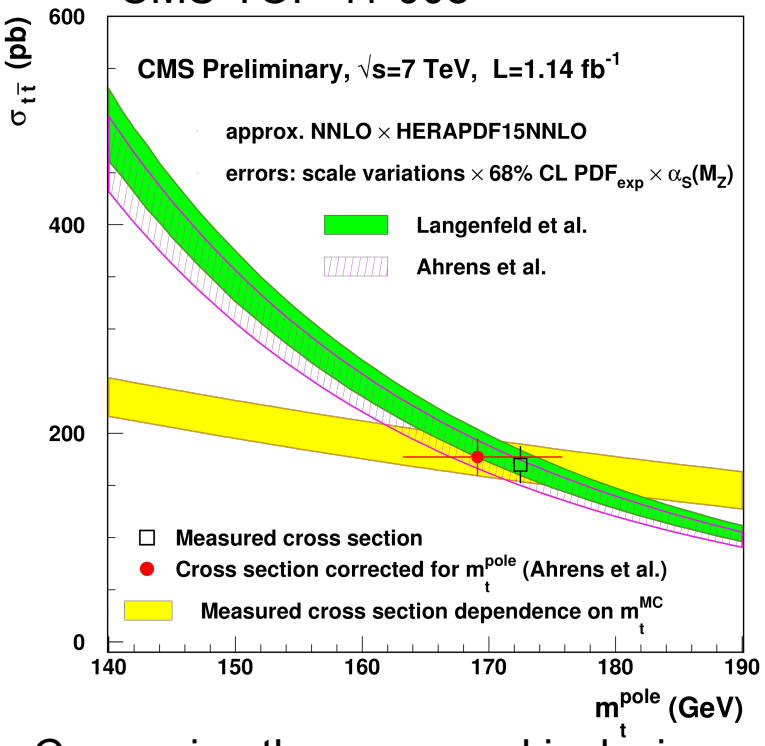
- Publication:
  TOP-11-002 JHEP 1107:049,2011 - Measurement of the ttbar production cross section and the top quark mass in the dilepton channel

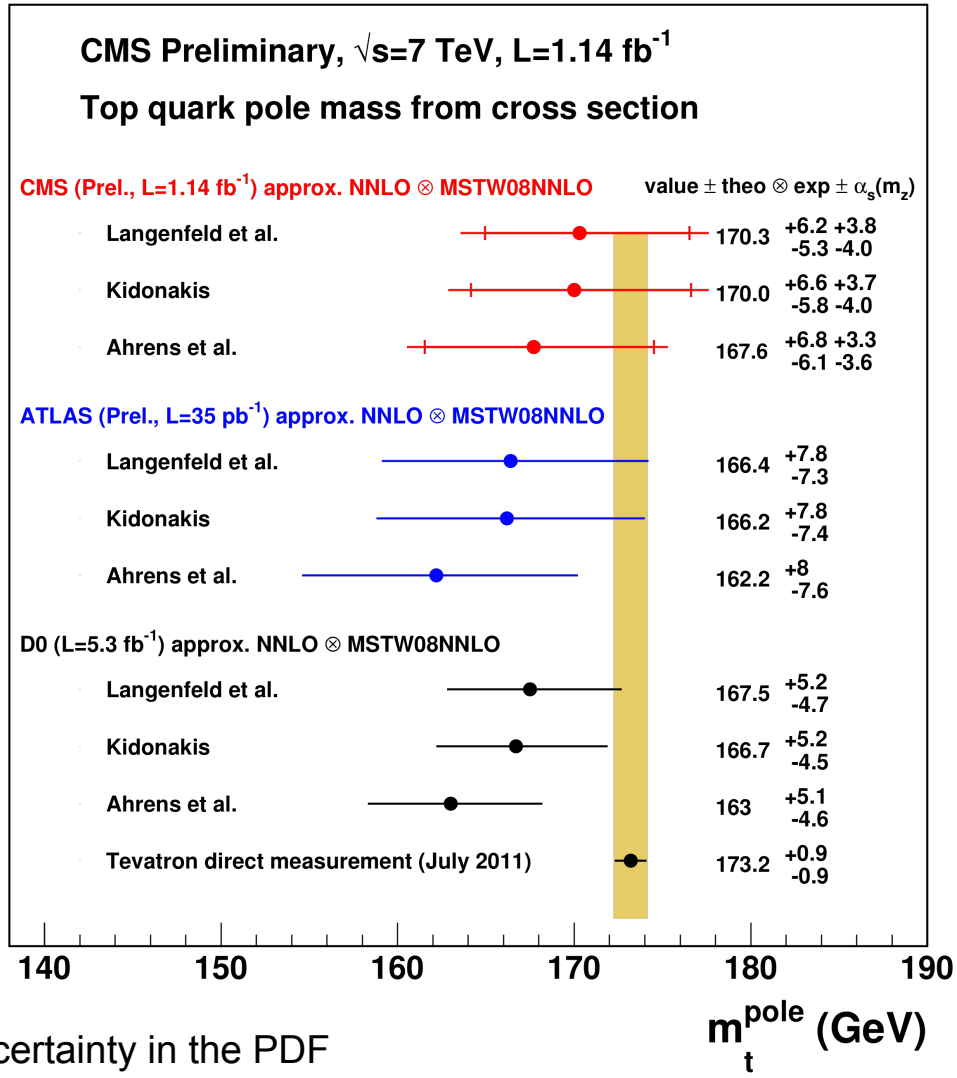
- 2 PhD thesis finished:
  D.Dammann: *Production Cross Section Measurement of Top-Antitop Pairs in the Dimuon Decay Channel at √s = 7 TeV with the CMS Experiment*

  M.Marienfeld: *Measurement of the Top Quark Pair Production Cross Section in the Muon-Electron Decay Channel in pp Collisions at √s = 7 TeV with the CMS Experiment*

DESY: Determination of m_t^{pole} and $m_t(m_t)$ from σ_{ttbar}

CMS-TOP-11-008 Presented at "TOP 2011". top pole mass





Comparing the measured inclusive production cross section to fully inclusive calculations at high-order QCD involves an unambiguous definition of m_t.

Precision limitations:

- Cross section uncertainty, PDF uncertainty + α_S uncertainty in the PDF

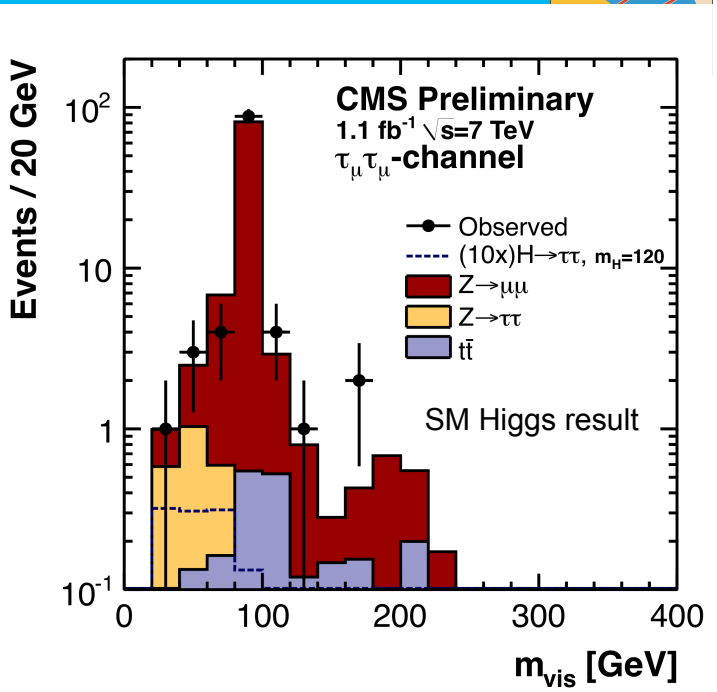
The result is in good agreement with previous measurements by ATLAS and D0!

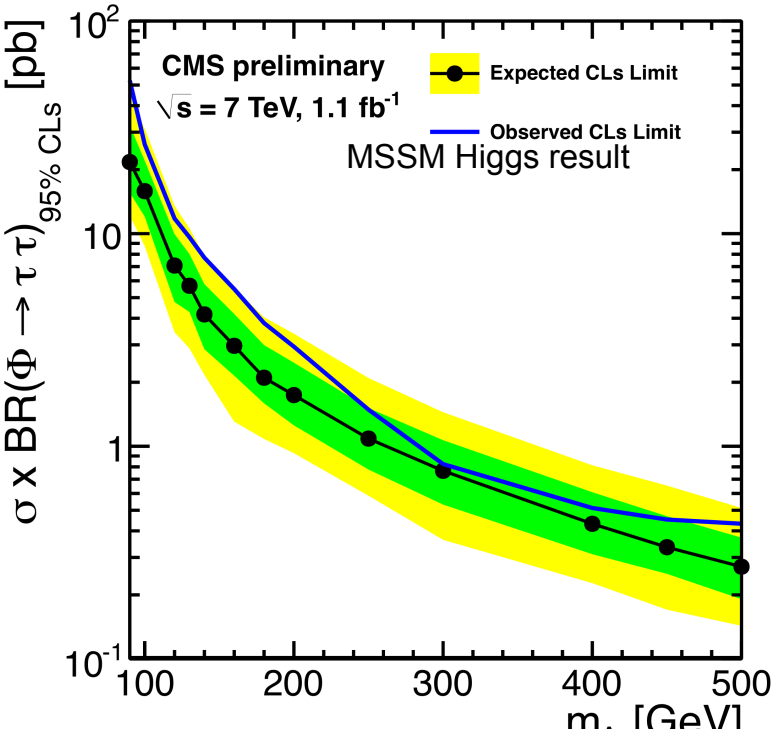
DESY Higgs analysis: $H \to \tau\tau \to \mu\mu$

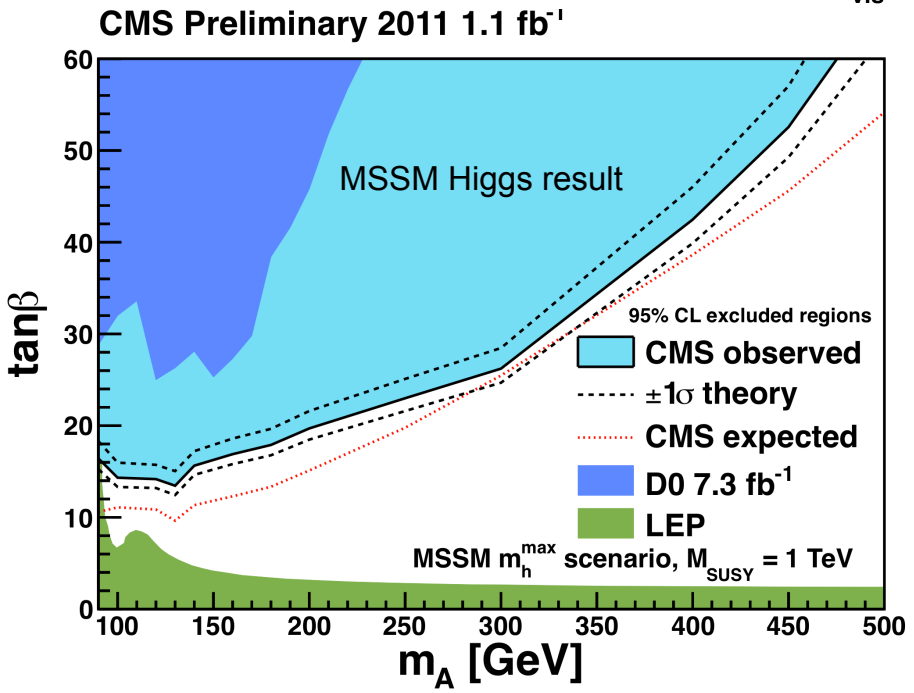
CMS public result: No excess observed!

Search for Neutral Higgs Bosons Decaying to Tau Pairs in pp Collisions at $\sqrt{s}$ = 7 TeV:
Result presented at EPS'11,
included in LP'11 Higgs combination

DESY: $H \to \tau\tau \to \mu\mu$ channel
- in collaboration with KIT



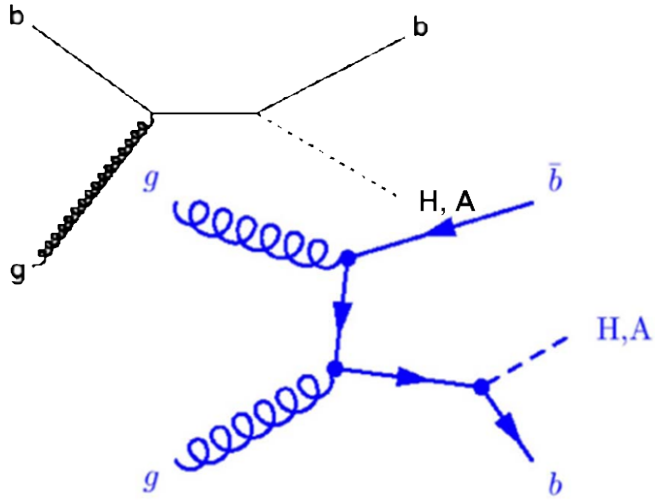


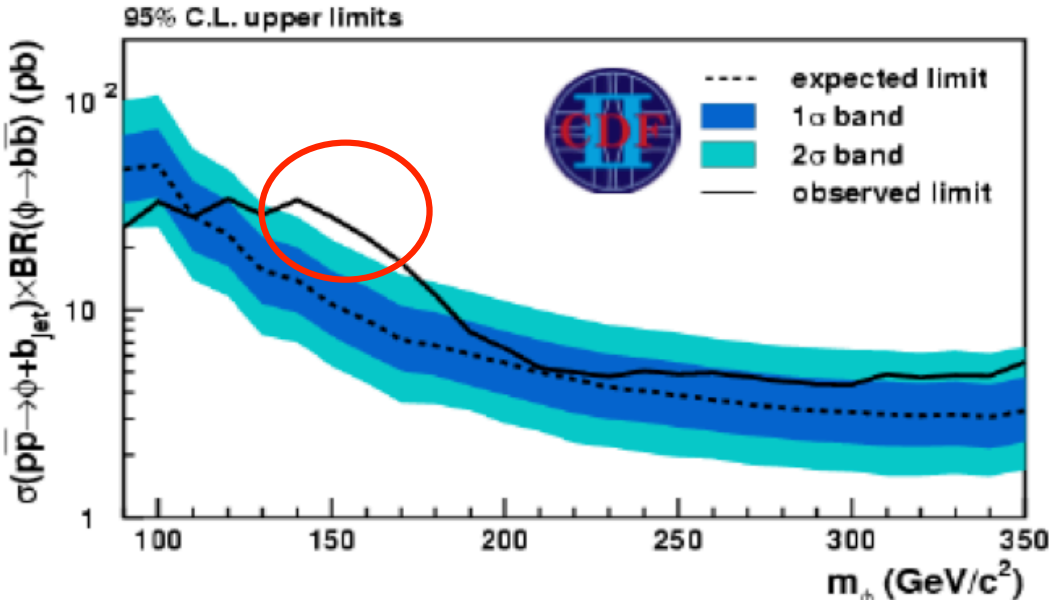


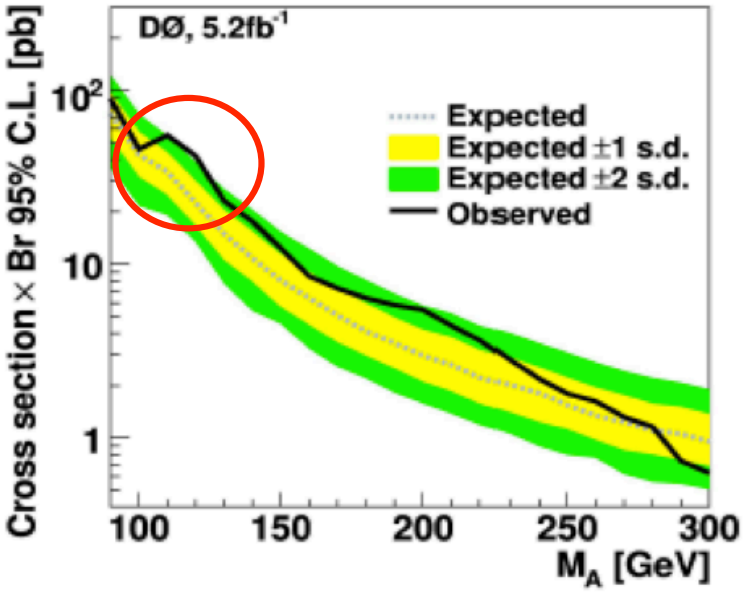
SUSY low mass Higgs search: bH(A) → bbb signal

Experimental signature: 3 b-tagged jets (huge QCD background)
DESY group developed dedicated trigger, running since end of May

- Status:
  - Challenging determination of trigger efficiencies
  - Production of more MC samples
  - Background being assessed by fitting templates to the data (obtained using double b-tagged real data)
- Target: result on full 2011 statistics!



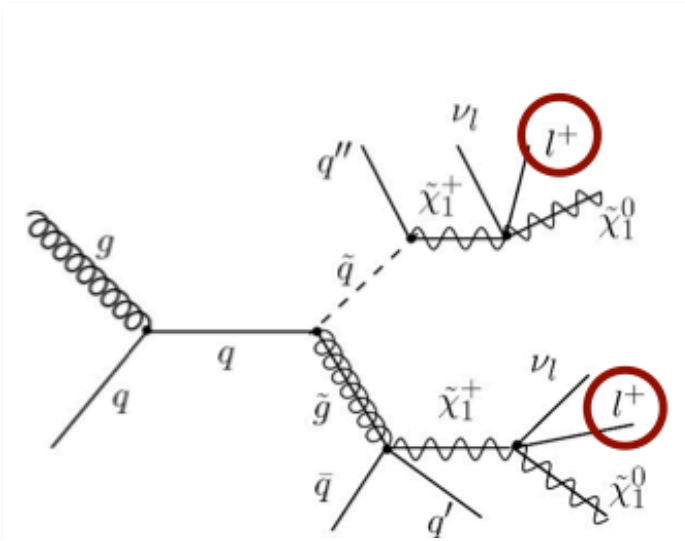




DESY SUSY analysis activities

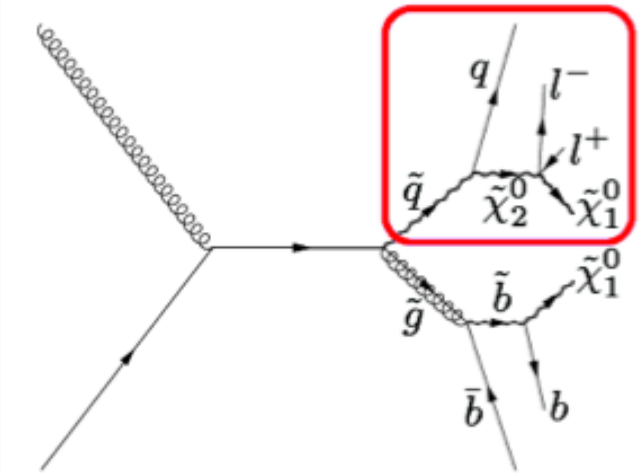
- SUSY signal: - single lepton + b-tag(s)
  (pre-approved for LP'11, now in CMS approval process)
  - Working on b-tagging scale factors,
  - Signal contamination in background estimations
  - Finalizing limit setting procedure
  - Including all 2011 statistics

Status: on-track for publication on full 2011 result



- SUSY signal: – same-sign di-leptons
  - background estimation method implemented

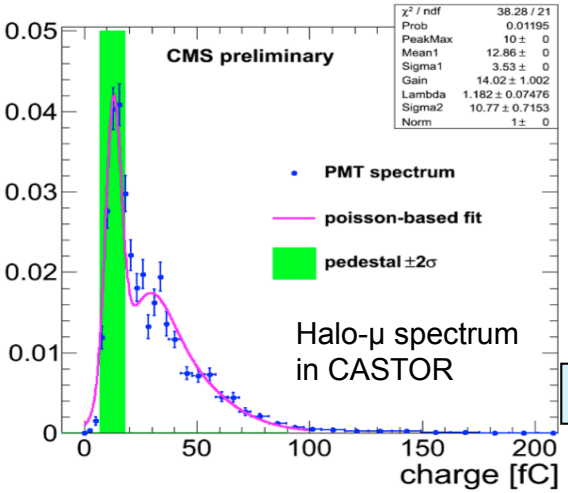
Status: one thesis finishing soon

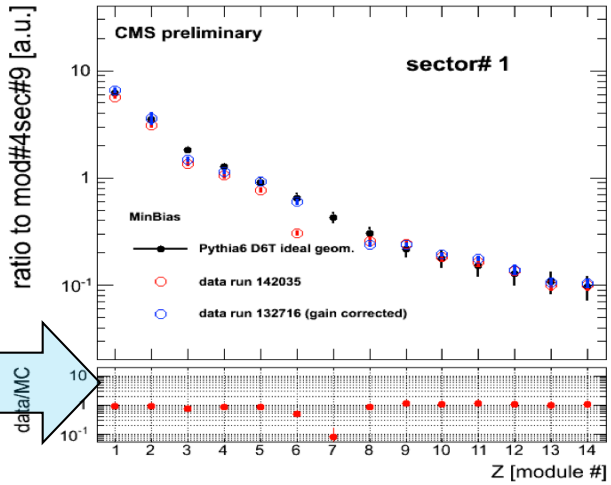


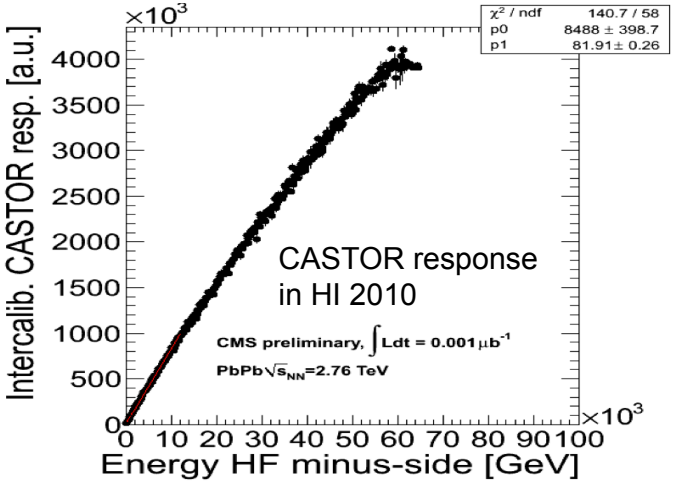
- SUSY signal: – opposite-sign di-leptons
  - Work in progress
- Supporting work performed:
  - Study of b-tagging at high b-jet p_T

CMS Operations: Castor Calibration @ TIPP 2011

- CASTOR is taking data continuously during CMS running: p-p + Heavy Ion
- Relative calibration of CASTOR is done using beam-halo muons with 20% precision (cross-checked with splash-run)
- An absolute CASTOR calibration has been achieved based on HF energy extrapolation with 30% precision: *581 GeV / (20960 fC / fcastor) = 0.015 GeV/fC*
  - Will improve with results from J/Ψ, Υ, Z → ee, Jet-p_T balance, UPC: AA →μμ, ττ, ee, jets
  - data certification and gain corrections for 2011 are pending







Physics results in preparation at DESY:

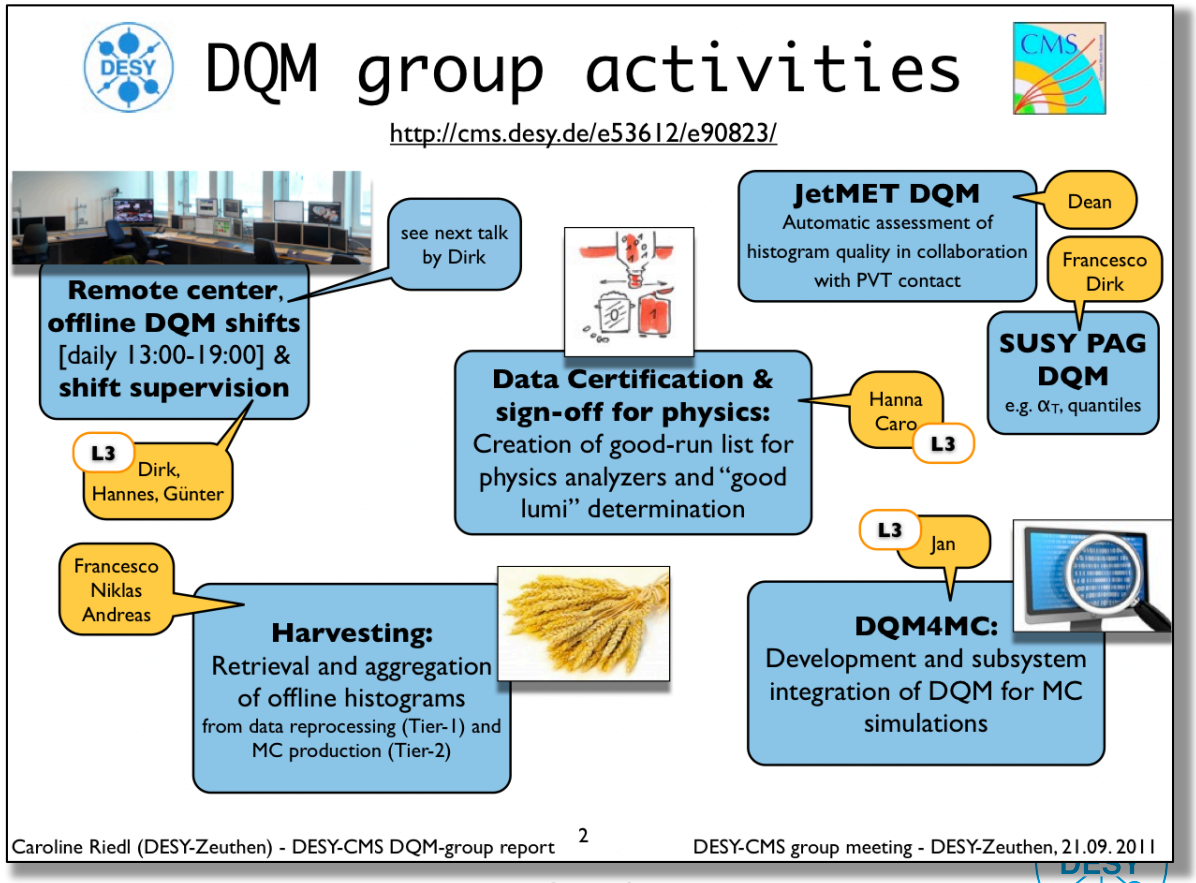
- Extend Forward energy flow measurement to η ≥ -6.2
- Jet energy measurements at high η

Strategy for operation in 2012 Heavy Ion running and at 14 TeV is prepared and reviewed

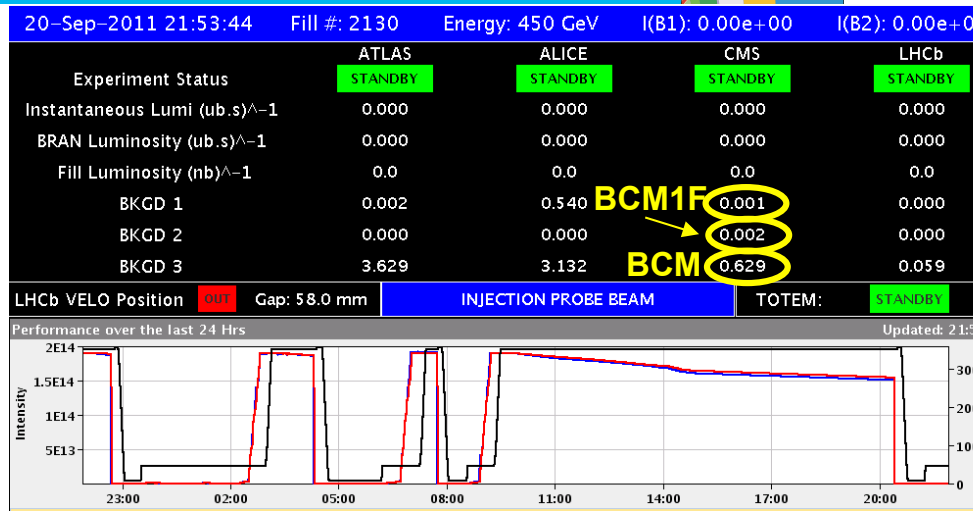
- Including plan to replace aging and radiation damaged PMTs

CMS Operations: Data Quality

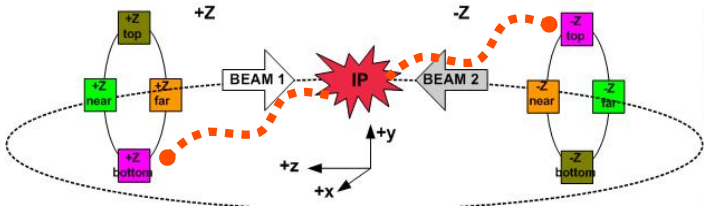
- DESY group continues to run 1×6h DQM shift per day at DESY remote center.
- DESY is co-leading the CMS data certification for physics analysis: substantial work under high pressure and scrutiny
  - Major communication and coordination effort for weekly release of certified integrated luminosity
  - Creation of weekly official **JSON files** for physics analyzers.
  - Collected vs. certified integrated luminosity.
  - "Lumi-Loss" reports. *How much collected lumi got NOT certified? Why?*
  - Extensive documentation



Diamond sensors: BCM feedback to LHC

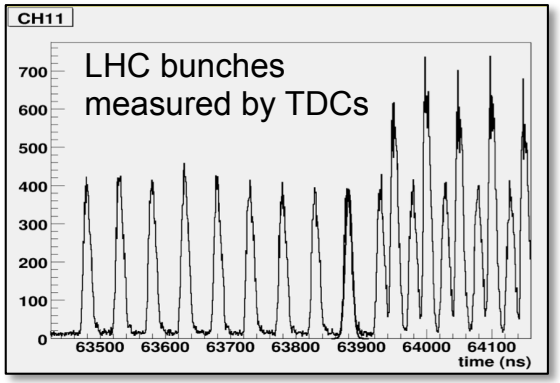


- Tasks: Support beam tuning, monitor rates and protect CMS
  - Background monitor for LHC (beam-gas)
  - Additional luminosity monitor: coincidence method, rate method



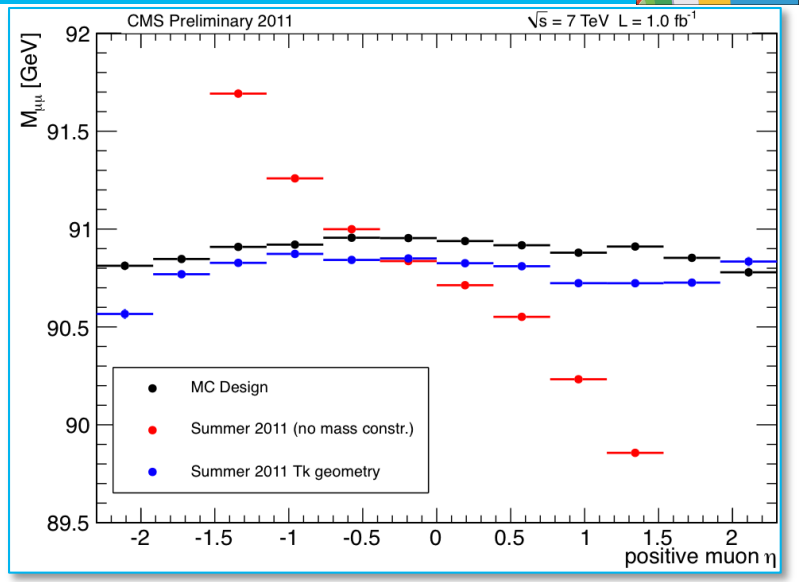
- Running conditions well understood
  - No radiation damage observed, upgrade for higher luminosity in preparation
  - Test with 25 nsec bunch spacing successful

- BCM1F4LHC: one module installed at p8, DAQ operational @ Prevessin
  - 7 more will be installed 2011/12 for next run.



Diamond sensors are successfully and reliably used in LHC running.

DESY group is a key player in tracker alignment.



- Track based alignment with ~200k parameters: successfully fitted with Millipede algorithm
  - determining sensor bows and kinks
  - following time dependent movements of large pixel structures
  - controlling momentum changing weak modes using the Z mass in alignment fit.
- Signed-off at CMS (PVT meeting), depending alignments and beam spot ready:
  - <u>available for reprocessing to serve physics analysis</u>
- Alignment paper in preparation: most material available.

Expected Content

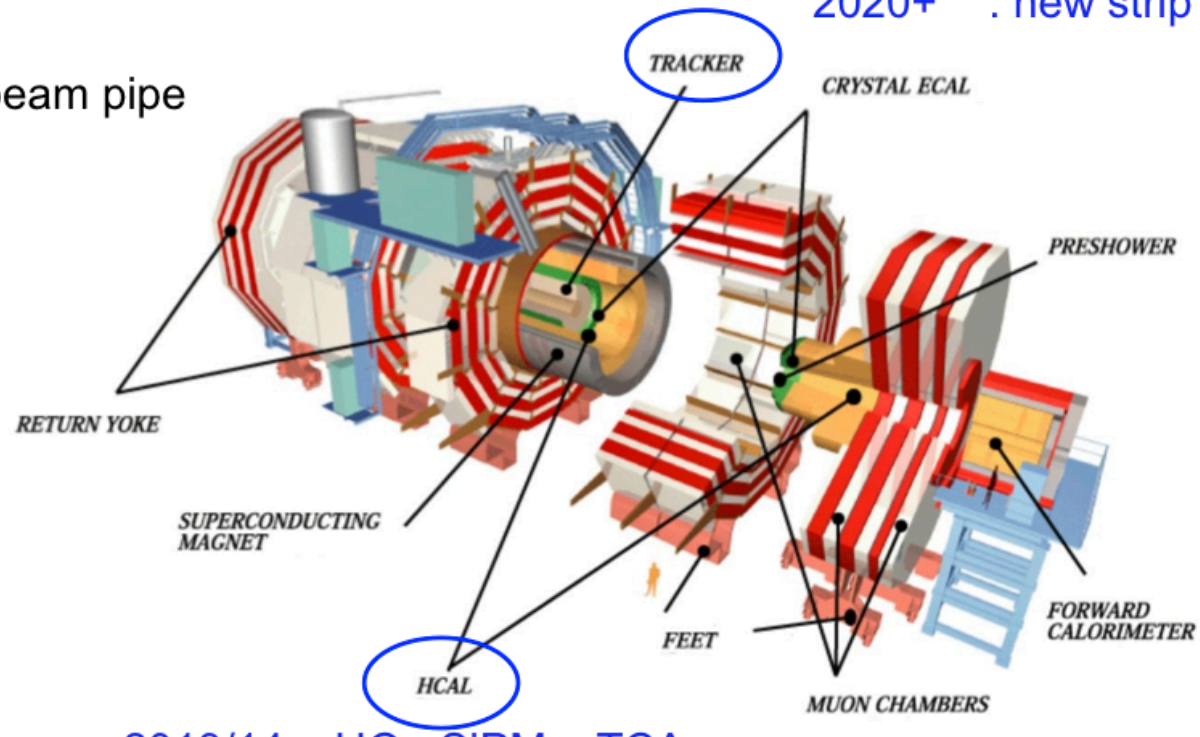
- CMS geometry and alignment challenge
- Alignment monitoring
- Track-based alignment methodology
- Statistical alignment accuracy
- Sensor shape parameters
- Tracker tilt relative to *B*-field
- Control of weak modes (better understanding of ϕ mode desirable)
- Alignment error estimation

CMS Upgrades & DESY involvement

CMS Upgrade Activities Phase I & Phase II

2016/17 : new pixel
2020+ : new strip tracker & pixel

2013/14 : new beam pipe

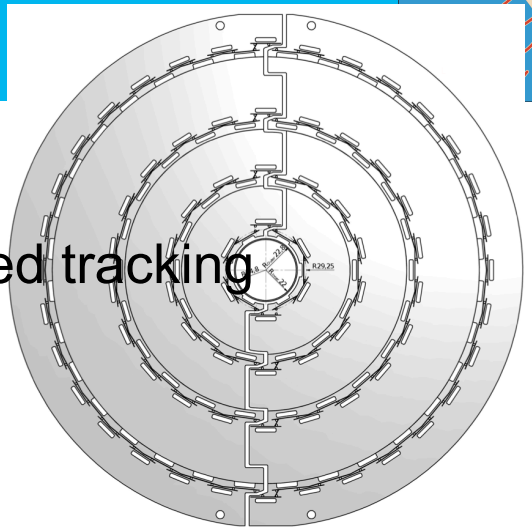


2013/14 : HO : SiPM, uTCA
2017/18 : HB/HE : SiPM, uTCA

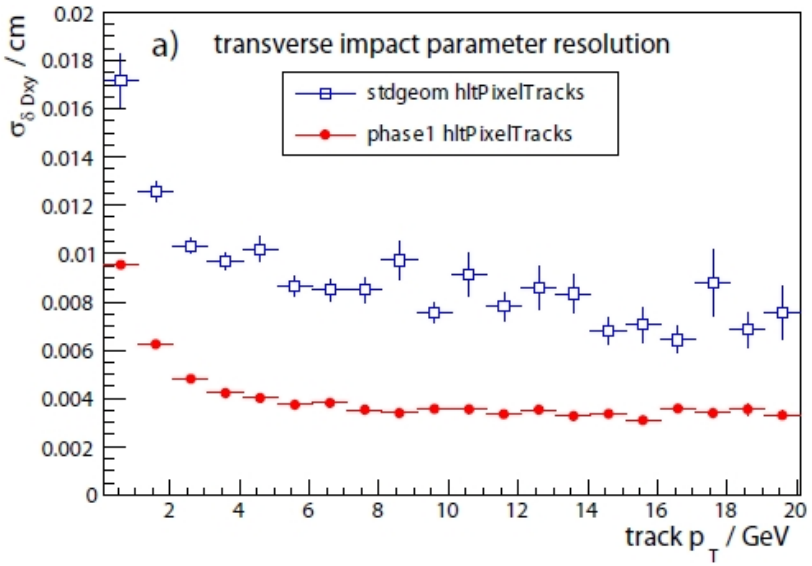
2013/14 ME 1/1 FE
2016/17 End caps (YE4)

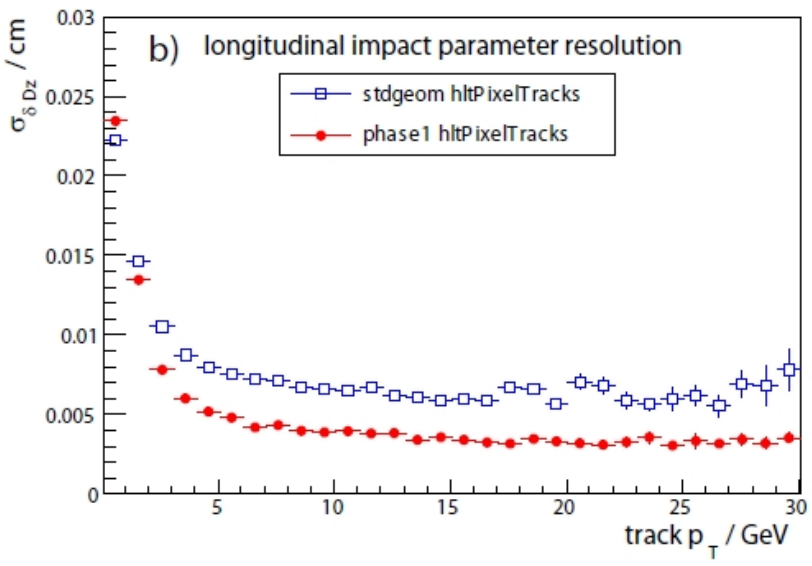
DESY involvements

CMS Barrel Pixel Detector Upgrade



- 4-layer detector designed (now 3)
  - better resolution, efficiency, and purity for pixel based tracking
  - reduced material in the tracker volume
    - CO2 cooling,
    - low mass design,
    - services moved to higher η
- Readout chip modification: prepare for high occupancy
  - increased buffering & faster readout

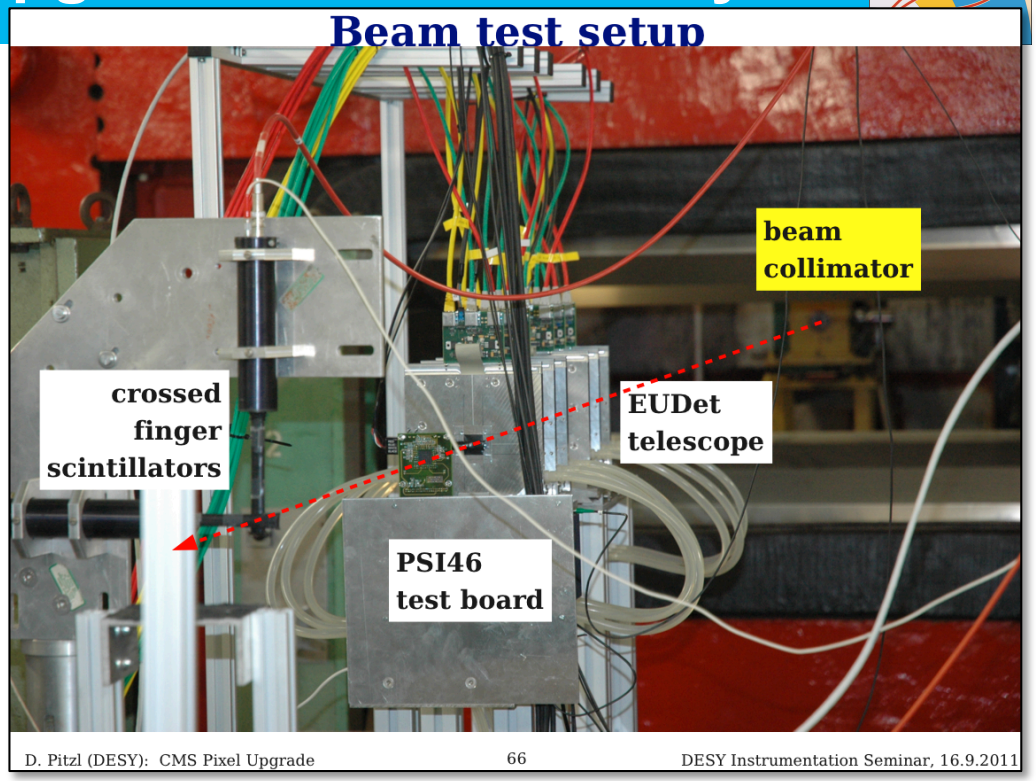




- Current schedule: new Pixel required for Run 3 with luminosity up to 2.2×10^{34} by 2017/18

CMS Barrel Pixel Detector Upgrade: current activity

- Pixel readout module operated with Ru source and in test beam
- Cold calibration will be set up @ DESY (up to -20°C)
  - probe station exists at FEC



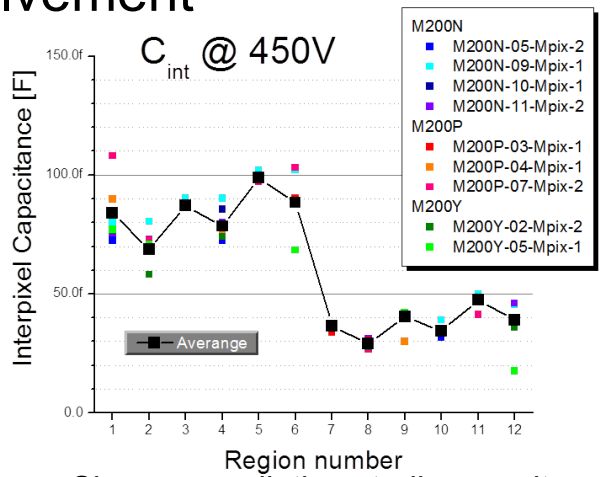
- The German CMS institutes are preparing contributions:
  - work packages are being defined in D-CMS (DESY, HH, KIT, RWTH)
    - Design optimization and physics evaluation,
    - module assembly and testing of outer (largest) layer: (512 modules + 100 spares + 88 rejects = 700)
    - DC-DC converter development and production.

<u>Timeline: Mid 2016: ready for installation in CMS</u>

CMS Upgrades

- SiPM for HCAL: replace HPDs with SiPM: HO first, then HB
  - HPDs have low gain, problematic to operate in magnetic stray field, aging
  - DESY designed light-mixer for HO upgrade, currently in test-beam at CERN
  - DESY involvement in HB upgrade depending on supplemental funding, planning testing of SiPMs before installation

- Tracker Phase 2 upgrade: DESY plans major involvement
  Current activities:
  - Module design: thermal FE simulations performed,
  - Thermal test stand being completed in new detector lab rooms (1b/SS)
  - Tracker sensor radiation studies as part of CEC sensor campaign
    - preparation of sensors for testbeam at FNAL and CERN
    - Irradiation at Ljubljana and KIT
    - data analysis ongoing
    - Measurement of ~ 30 multi-pixel sensors within the HPK campaign



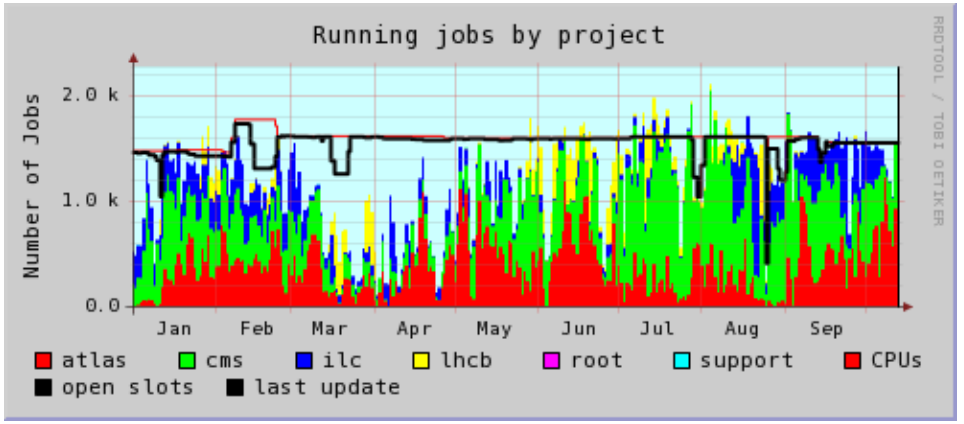
Si sensor radiation studies results

- DESY Detector lab planned to be ready for Si-strip tracker construction by 2016/17

CMS Computing: CMS T2 performance, NAF usage

- The DESY Tier-2 continues to be used very successfully used for CMS analysis:
  - Analysis at CMS T2: DESY Top#4 in CPU and Top#1 in analysis data provided

- NAF is completely overloaded:
  - 2011 analysis speed is resource constrained.



  - NAF Availability ~ 95% is good, but…
    … to be competitive we need the NAF reliably when the experiment milestone is due!

Conclusions: LHC and global CMS

- LHC continued to improve luminosity substantially over 2011:
  Big success: More than 5 fb^{-1} delivered to ATLAS and CMS each.
  - Managed to overcome problems in time
  - 2012 running is being planned now, final decision in Chamonix (Feb. 2012)

- CMS presented a large number of competitive physics results in summer based on 1-2 fb^{-1}
  - SM: Reaching precision era, confronting predictions
  - Higgs:
    - No evidence yet, although wide mass regions for minimal SM Higgs are becoming dis-favoured at 95% CL (also heavy 4^{th} generation fermion coupling)
  - SUSY and Exotica
    - Sensitivity to squark and gluino masses in range 0.5 – 1 TeV
    - Many resonant/non-resonant signals sought

- High pile-up conditions are a challenge for operations and analysis, CMS is prepared.

- We expect exciting results from full 2011 dataset.

Conclusions: CMS at DESY

The DESY CMS group has mature and major involvements in CMS

- Physics analysis
  - Top physics: Differential cross section with di-leptons with full 2011 data, mass determination
  - SUSY: Search with single leptons + b-tags with full 2011 data
  - HIGGS: $H \to \tau\tau \to \mu\mu$ and $bH \to bbb$ searches
  - EWK and QCD: Forward energy flow, include CASTOR
  - PDF fits using CMS data
- Operations:
  - Data Quality monitoring and certification for physics
  - CASTOR operations and calibration
  - Tracker alignment
  - Fast beam condition monitoring and luminosity measurement
  - Computing for analysis
- Preparations in CMS upgrade projects
  - HCAL readout with SiPMs: first HO, then HB
  - New Barrel Pixel: 4th layer will be build by D-CMS, DESY has major involvement
  - Tracker phase 2: major involvement planned, new detector lab planned.
    For now: thermal module design and tests, testing radiation hardness of sensor material

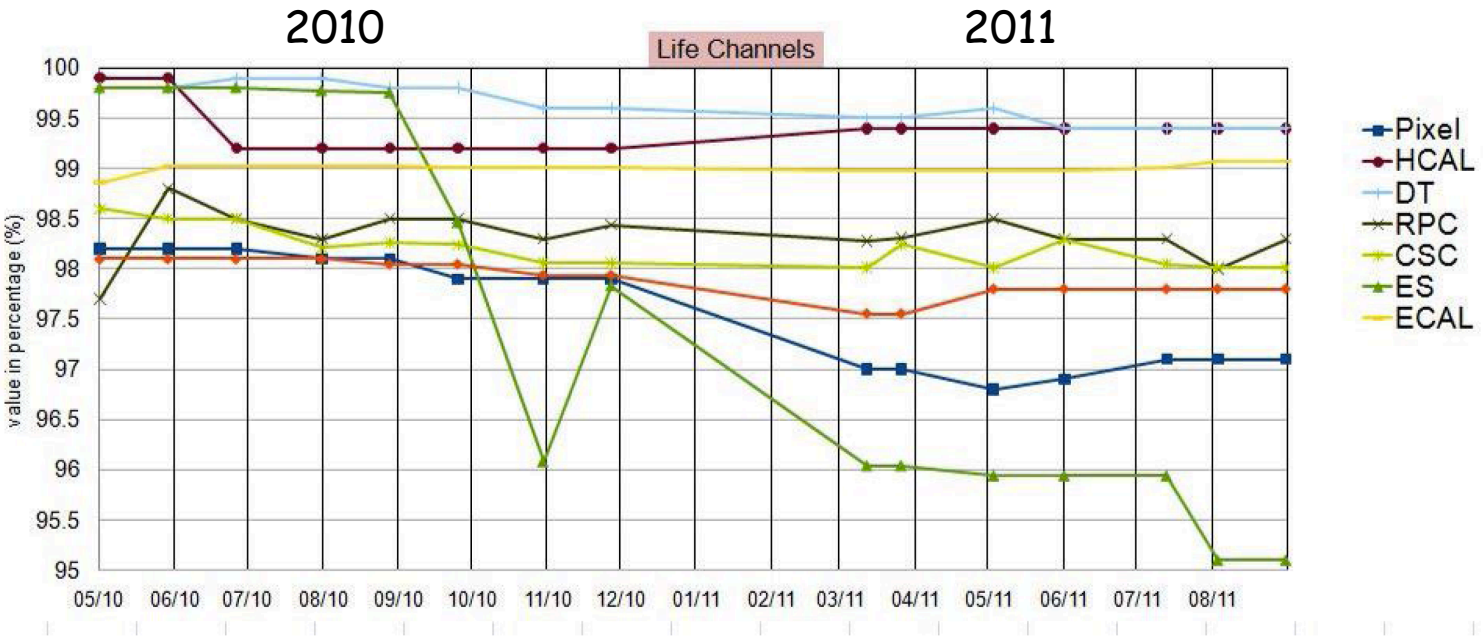
We expect exciting new results in near future.

It is attractive to work in CMS these days!
(at DESY confirmed by 14 Summer students, 5(+4) new PhD students, 5 new Postdocs)

> … if you want to learn more…

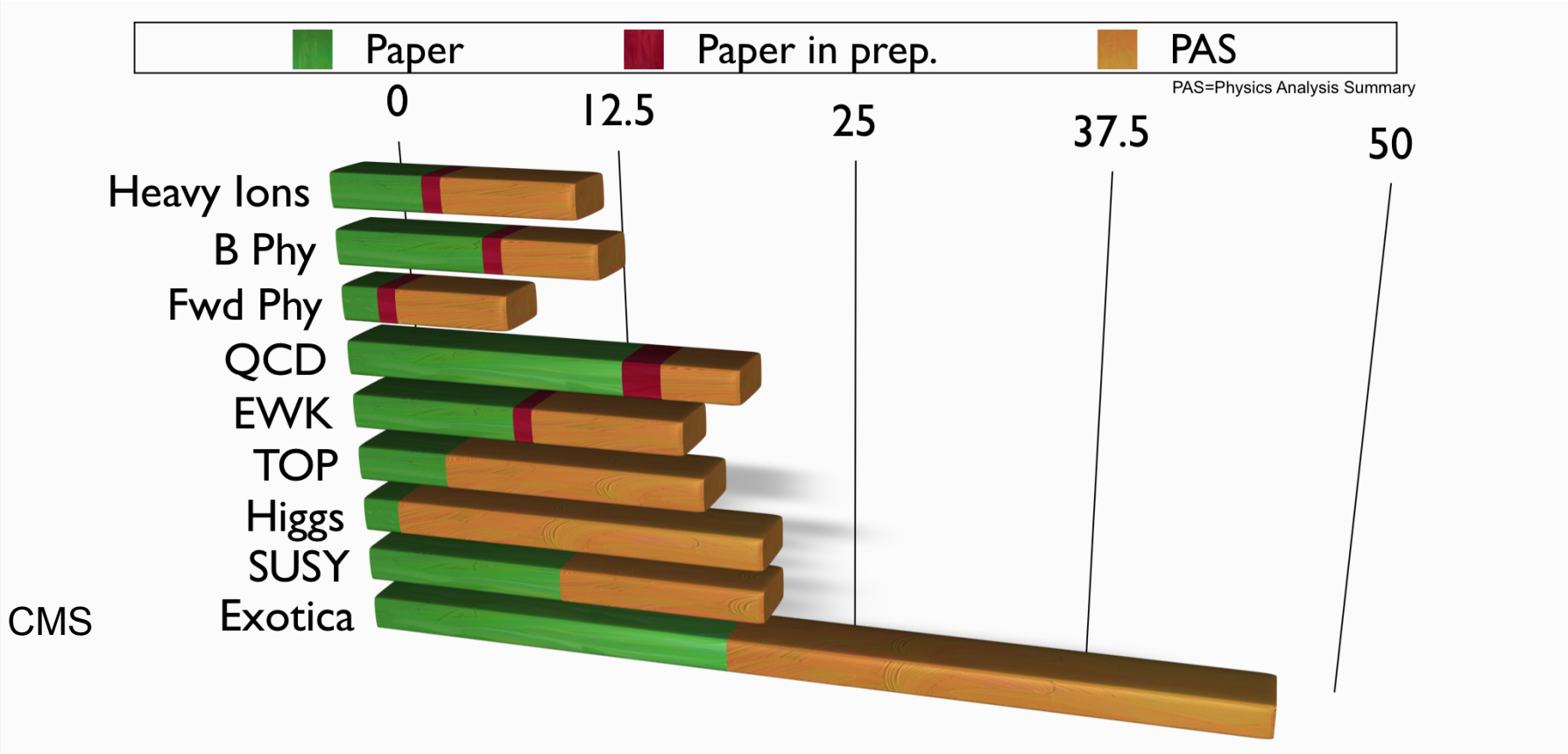
CMS Operational Status

95% →



- Live detector channels
  - Very stable over 2010-11
  - Forward pixels recovered some channels
    Preshower has slight drop due to leakage current in one sensor type
- Computing
  - Data rates and storage have been as expected
    (LHC live time and trigger rate)

CMS reached 100 papers on August 3rd



Last week: 109 papers + 6 close to be submitted.

86 papers on physics analyses

24 performance papers on cosmic data

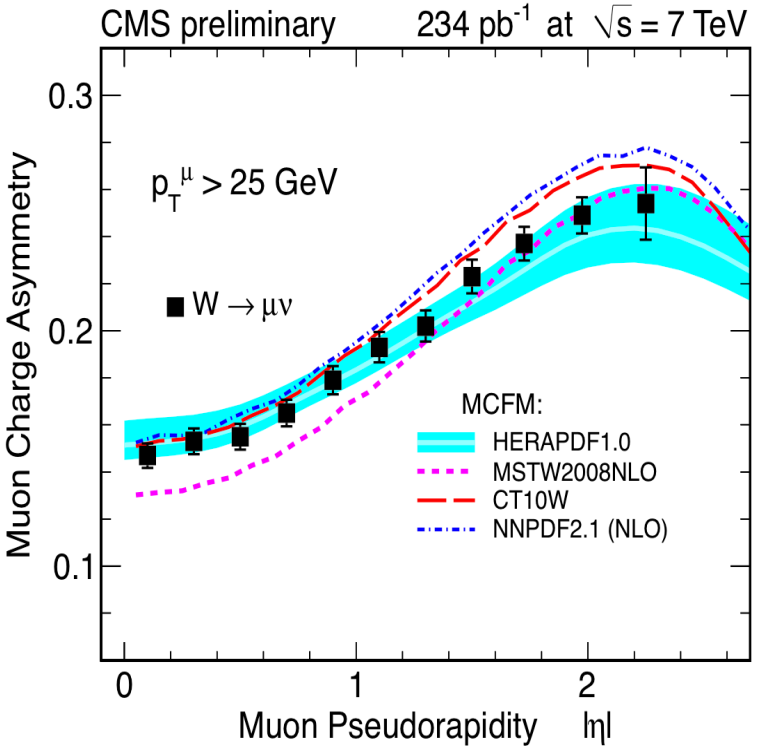
5 performance papers on collision data

+ 106 Physics Analyses Summaries

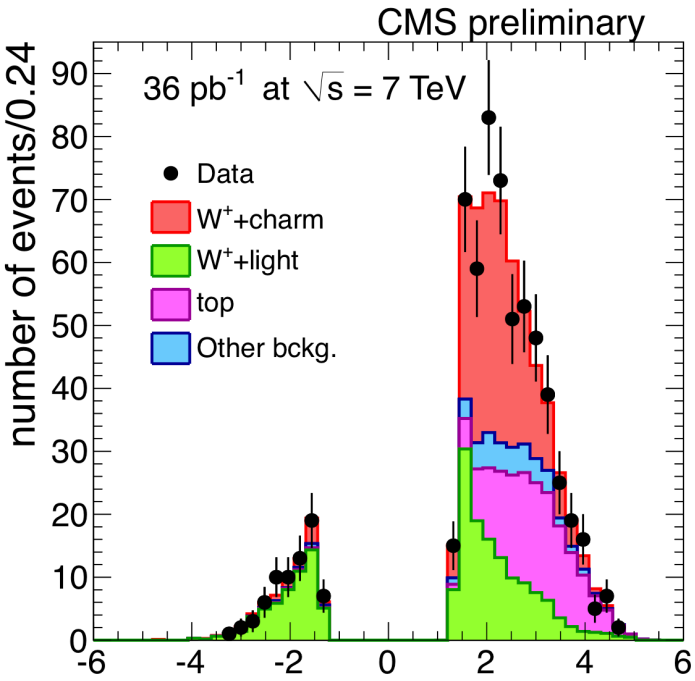
+ ~700 Conference Notes on physics results

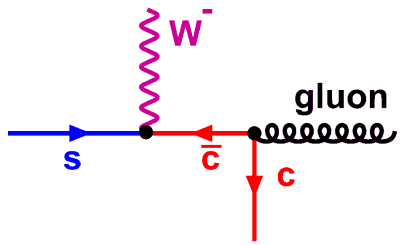
Electroweak: access to proton PDFs

W→μν charge asymmetry vs. η_μ



W+charm (strange content)





D_{SSVHE}: Secondary vertex decay length discriminator

$R^{\pm}_c = \sigma(W^+c)/\sigma(W^-c)=0.92 \pm 0.19(stat.)\pm 0.04(syst.)$

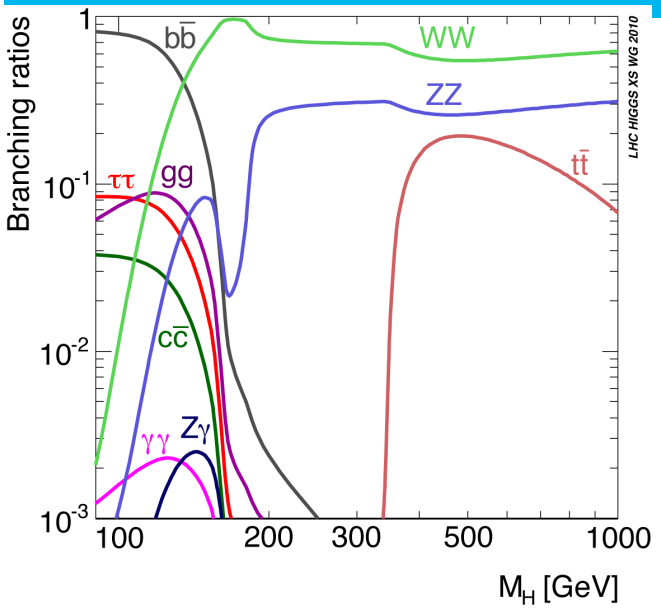
$R_c = \sigma(Wc)/\sigma(W+jets)=0.143 \pm 0.015(stat.)\pm 0.024(syst.)$

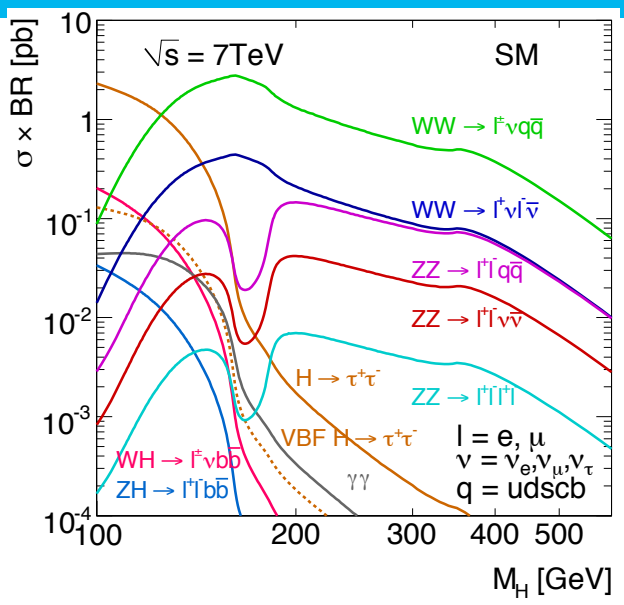
NLO predictions:

$R^{\pm}_c = 0.91\pm 0.04 \quad R_c = 0.13\pm 0.02$

PAS EWK-11-005, 013

SM Higgs Decay Modes Vs Mass





Events expected to be produced with L=1 fb^{-1}

m_H, GeV	WW→lvlv	ZZ→4l	γγ
120	127	1.5	43
150	390	4.6	16
300	89	3.8	0.04

Mode	Mass Range	Data Used (fb^{-1})	CMS Document
H → γγ	110-150	1.7	HIG-11-021
H → bb	110-135	1.1	HIG-11-012
H → ττ	110-140	1.1	HIG-11-009
H →WW →2l 2v	110-600	1.5	HIG-11-014
H → ZZ →4l	110-600	1.7	HIG-11-015
H → ZZ →2l2τ	180-600	1.1	HIG-11-013
H → ZZ →2l2j	226-600	1.6	HIG-11-017
H → ZZ →2l2v	250-600	1.5	HIG-11-016

CMS Upgrade plan

Shutdown	System	Action	Result	Physics
LS 1 2013-2014	Muon (ME4_2,ME1_1)	RPC and CSC (Complex YE4 installation) New electronics	Improved μ trigger and reconstruction (1.1<|η|<1.8, 2.1<|η|<2.4)	W acceptance WH, $H^{\pm} \rightarrow \tau\nu$
LS 1 2013-2014	Hadron Outer	Replace HPDs with SiPMs to reduce noise	Single μ trigger Tails of very high p_T jets	Muons from τ $Z/H \rightarrow \tau\tau \rightarrow \mu X$
LS 1 2013-2014	Hadron Forward	Install new PMT to reduce window hits	Forward jet tagging Improves MET	Vector-boson fusion H
LS 1 2013-2014	Beam Pipe	Install new beam pipe	Easier pixel installation	b-tagging
LS 2 2017 or 18	New Pixel system	Low mass 4 Layers, 3 Disks with new ROC	Reduces dead time Improves b-tag.	$H \rightarrow bb$, SUSY decay chains
LS 2 2017 or 18	HCAL Barrel and Endcap μTCA trigger	Replace HPDs with SiPMs for longitudinal segmentation New electronics	Reduces pileup effects Improves MET Improves τ, e, γ clustering and isolation	SUSY $H \rightarrow \tau\tau$ $H \rightarrow ZZ \rightarrow ll\tau\tau$
LS 3 >2020	TRACKER New Trigger Endcap Calo.	Replace tracker Replace trigger	Maintain performance at high SLHC Lumi	Guided by early discoveries