



# Status report from DESY CMS group

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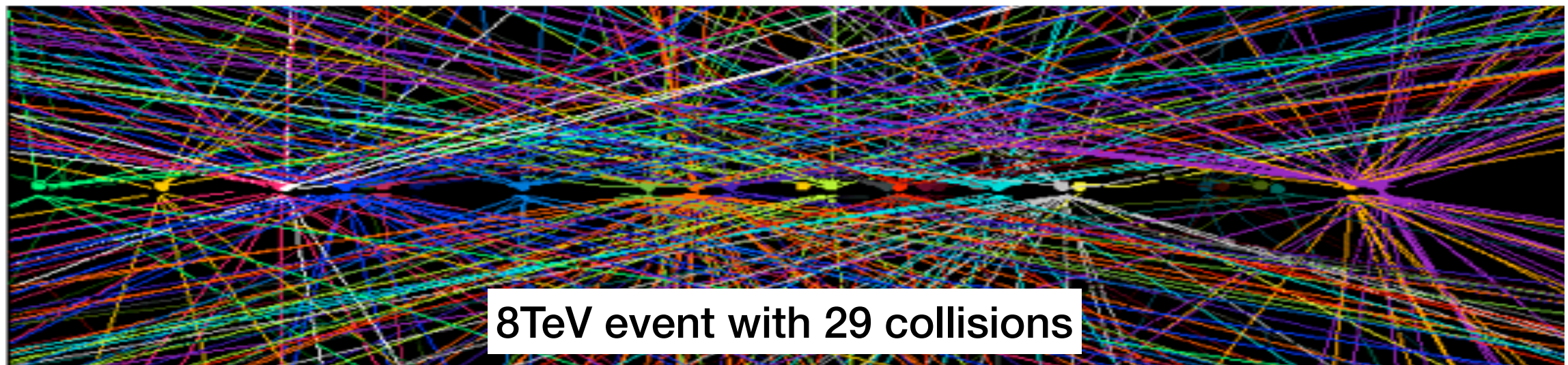
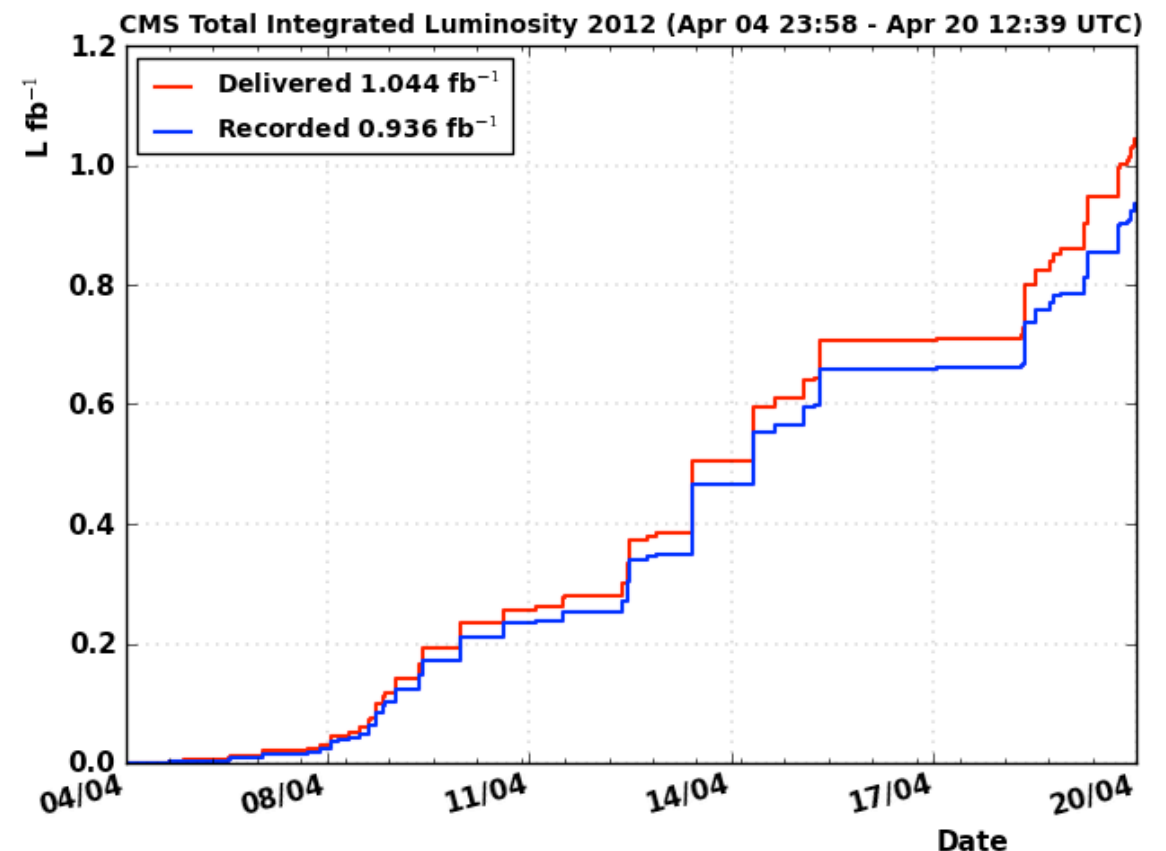
Roberval Walsh  
*on behalf of the DESY CMS Group*

73. Physics Research Committee  
Open session, 26 April 2012



# CMS Performance

- LHC restart in 2012 with  $\sqrt{s} = 8$  TeV
- About 20% of all 2011 data delivered by the machine in less than 20 days!
- CMS with excellent performance >90% efficiency in data taking.
- Detector and analyses coping well with high pile-up and high rates.



8TeV event with 29 collisions



# DESY Group in CMS

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- Group strength
  - 23 staff
  - 25 post-docs
  - 20 PhD students
  - + engineers and technicians
- Involvement in CMS
  - Physics analysis
  - Operation
  - Computing
  - Detector upgrade



# DESY CMS Physics Panorama

## Higgs searches

- Standard Model (SM) and beyond
  - $H \rightarrow \tau\tau \rightarrow \mu\mu$  (CMS PAS HIG-12-007)
  - $H \rightarrow \tau\tau \rightarrow ee, e\mu, \tau_h\tau_h$
  - $H \rightarrow bb$  (MSSM and NMSSM)

## QCD-Forward Physics

- Forward energy flow with CASTOR (CMS PAS-FWD-11-003)
- Forward jets and forward/central (CMS-FWD-11-002, arxiv:1202.0704)
- Determination of PDFs at the LHC

## SUSY searches

- Single lepton with b jets and missing  $E_T$  (CMS PAS SUS-11-028)
- Di-leptons with same and opposite sign and missing  $E_T$

## Top physics

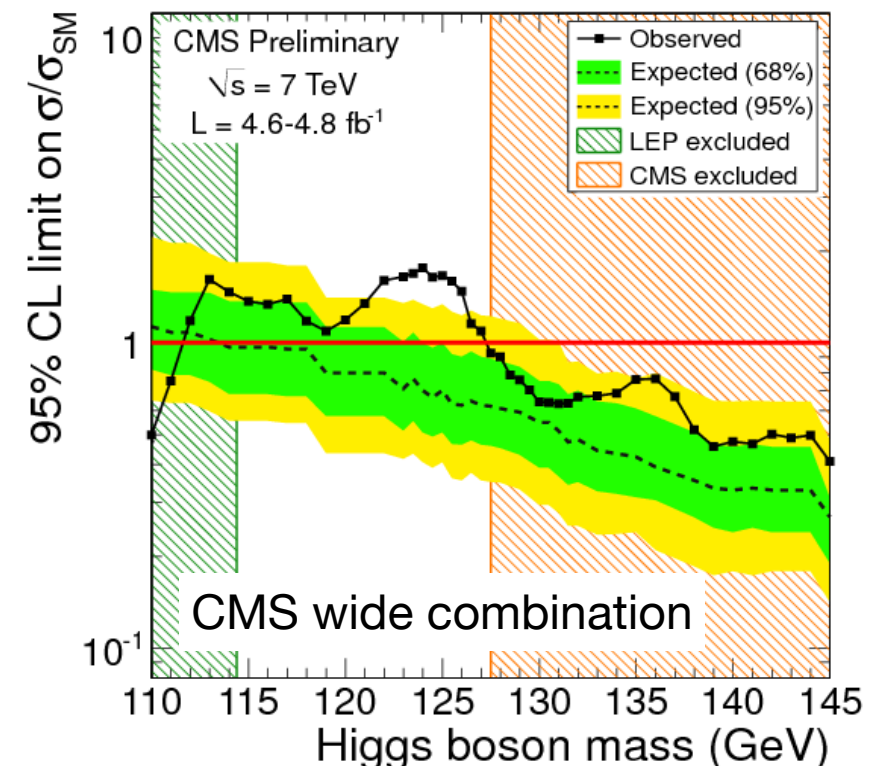
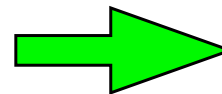
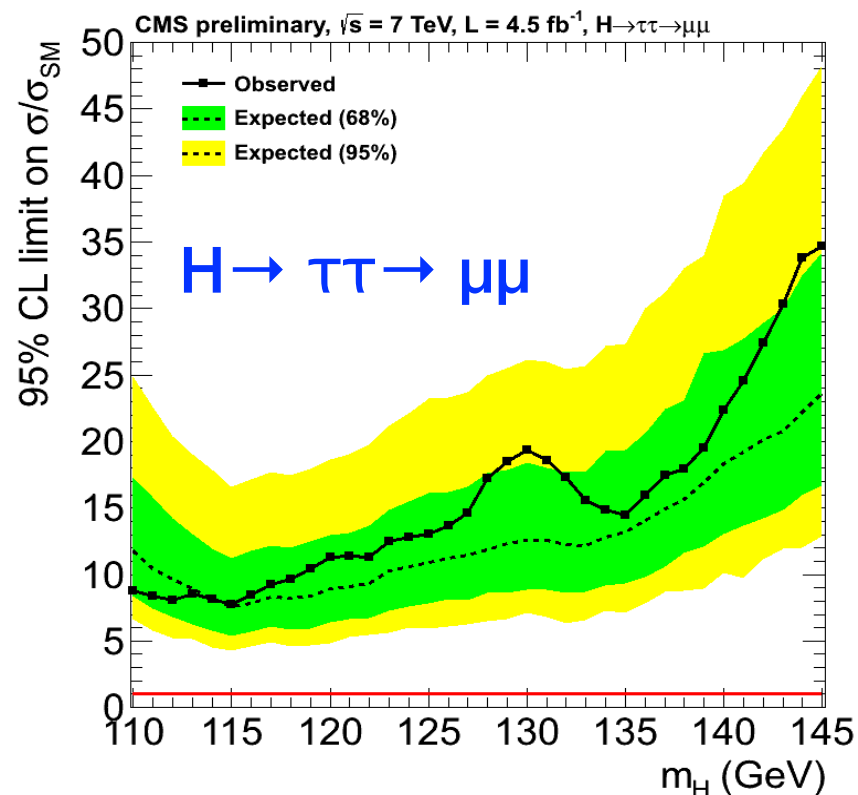
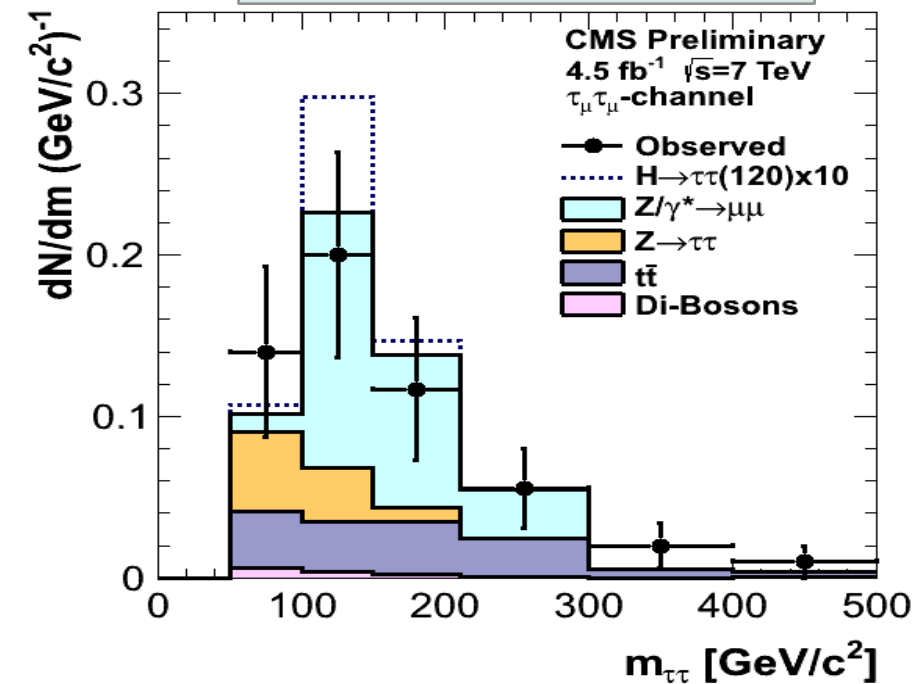
- $t\bar{t}$  differential cross section (CMS PAS TOP-11-013)
- Top quark mass from cross section (CMS PAS TOP-11-008)
- Inclusive  $t\bar{t}$  cross section,  $t\bar{t} + X$ , PDFs



# Higgs Analyses

- Search for  $H \rightarrow \tau\tau \rightarrow \mu\mu$  (SM & MSSM)
  - Large DY  $Z/\gamma^* \rightarrow \mu\mu$  background
  - Small topological branching fraction  $\text{Br}(\tau\tau \rightarrow \mu\mu) \sim 3\%$
  - Public results for 2012 winter conferences – CMS PAS HIG-12-007
  - Results included in the CMS wide combination – CMS PAS HIG-12-008

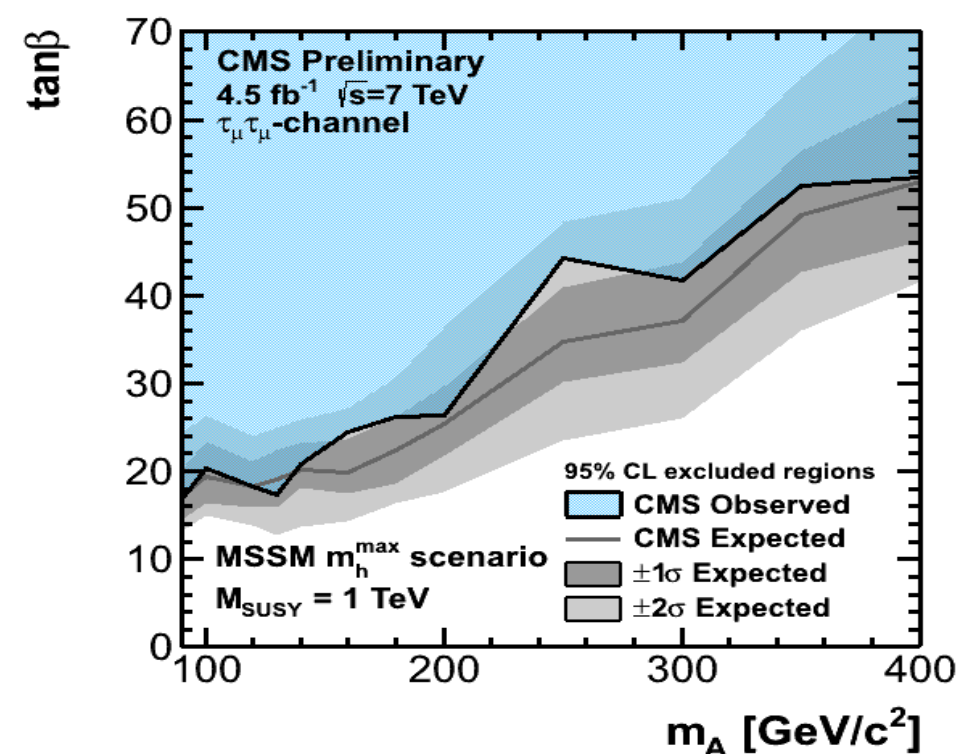
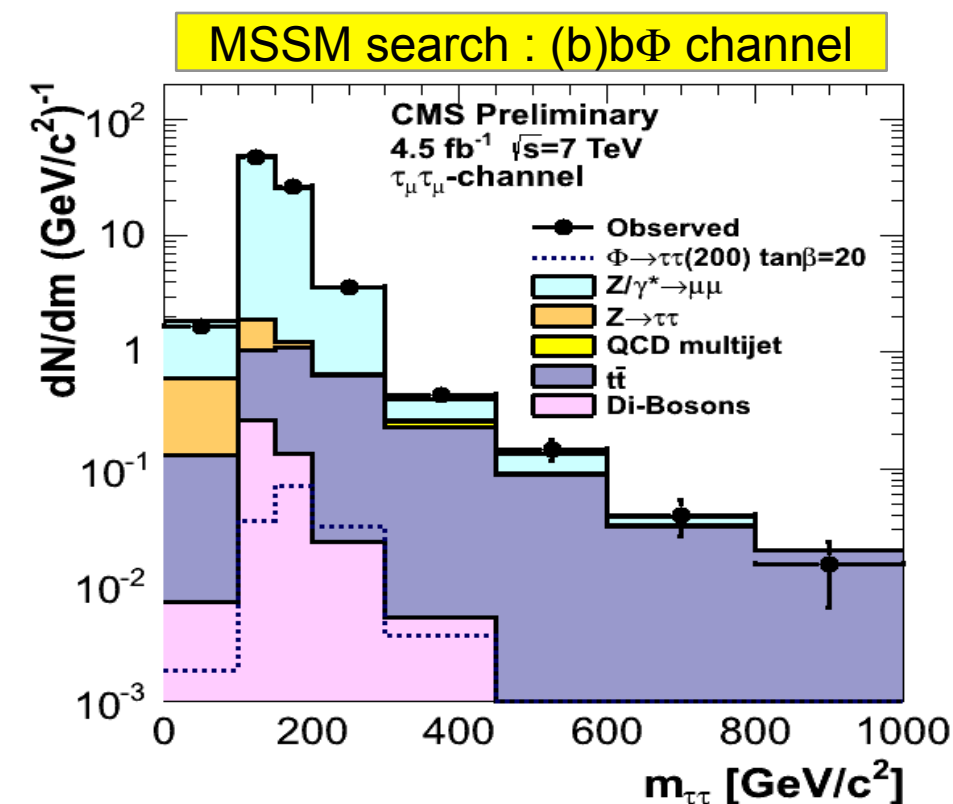
SM search : VBF channel





# Higgs Analyses (II)

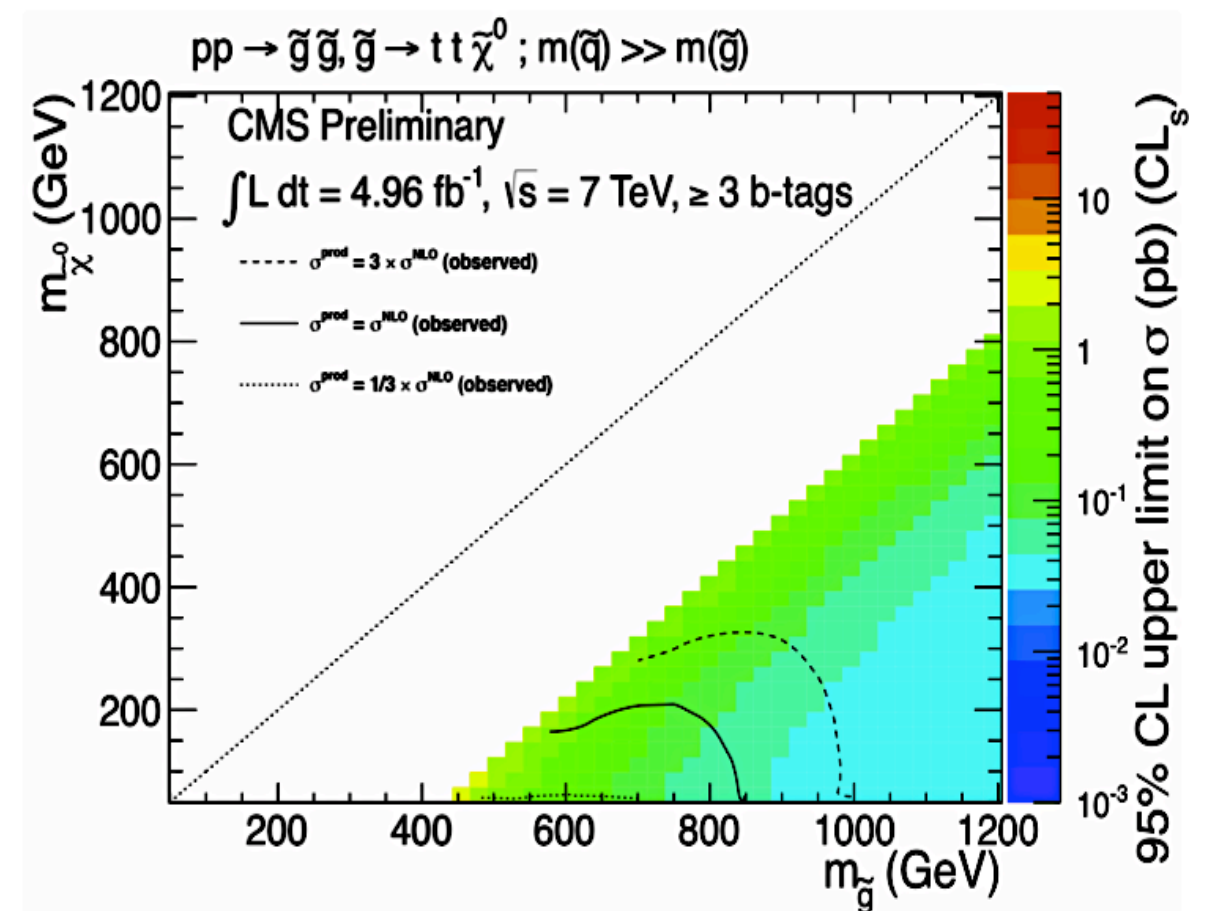
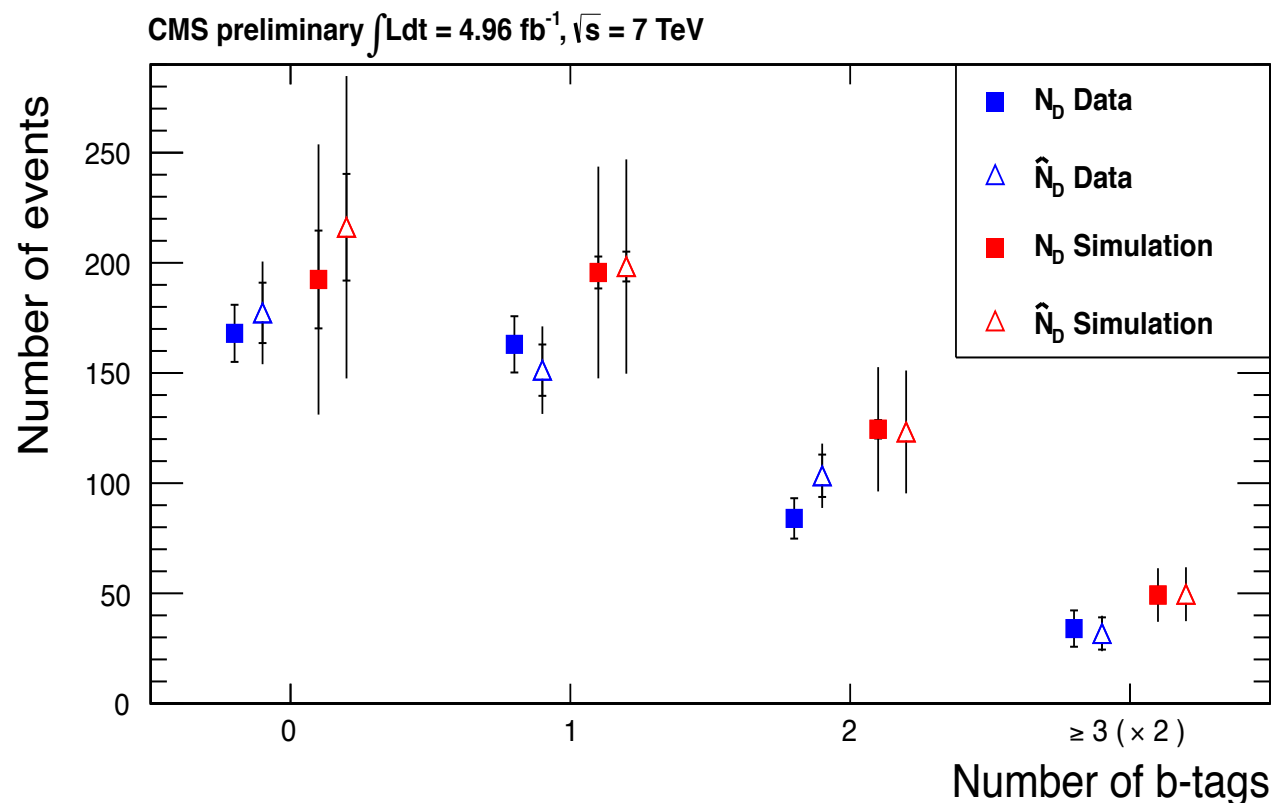
- Search for  $H \rightarrow \tau\tau \rightarrow 2\mu$  (cont'd)
  - In the MSSM search this channel alone is competitive with Tevatron.
  - CMS high priority analysis for ICHEP.
- Search for  $H \rightarrow \tau\tau \rightarrow ee, e\mu, \tau_h\tau_h$
- Synergy with KIT, Aachen
- Search for MSSM  $\phi \rightarrow bb$  produced in association with b quarks (aiming approval for this summer)
- Search for NMSSM  $H \rightarrow bb$  produced in SUSY cascades (just started)





# Supersymmetry Analyses

- Searches with 1 lepton + b jets + missing ET
  - Background estimation from data in agreement with expected number of events in the signal region. No excess observed.
  - Interpretation in the context of constrained MSSM (cMSSM) and simplified models.
  - Results approved for 2012 summer conferences – CMS PAS SUS-11-028
  - Plan to analyse the 2012 data at 8 TeV.





# Supersymmetry Analyses (II)

- PhD theses with focus on di-leptonic final states (muons, electrons)
  - Same-sign di-leptons + missing  $E_T$ 
    - Status: thesis almost finished and being written up.
  - Opposite-sign di-leptons + missing  $E_T$ 
    - Status: new method to distinguish between background and signal in the invariant mass plot developed.
    - Work on thesis ongoing.
    - Plans to analyse 2012 data.

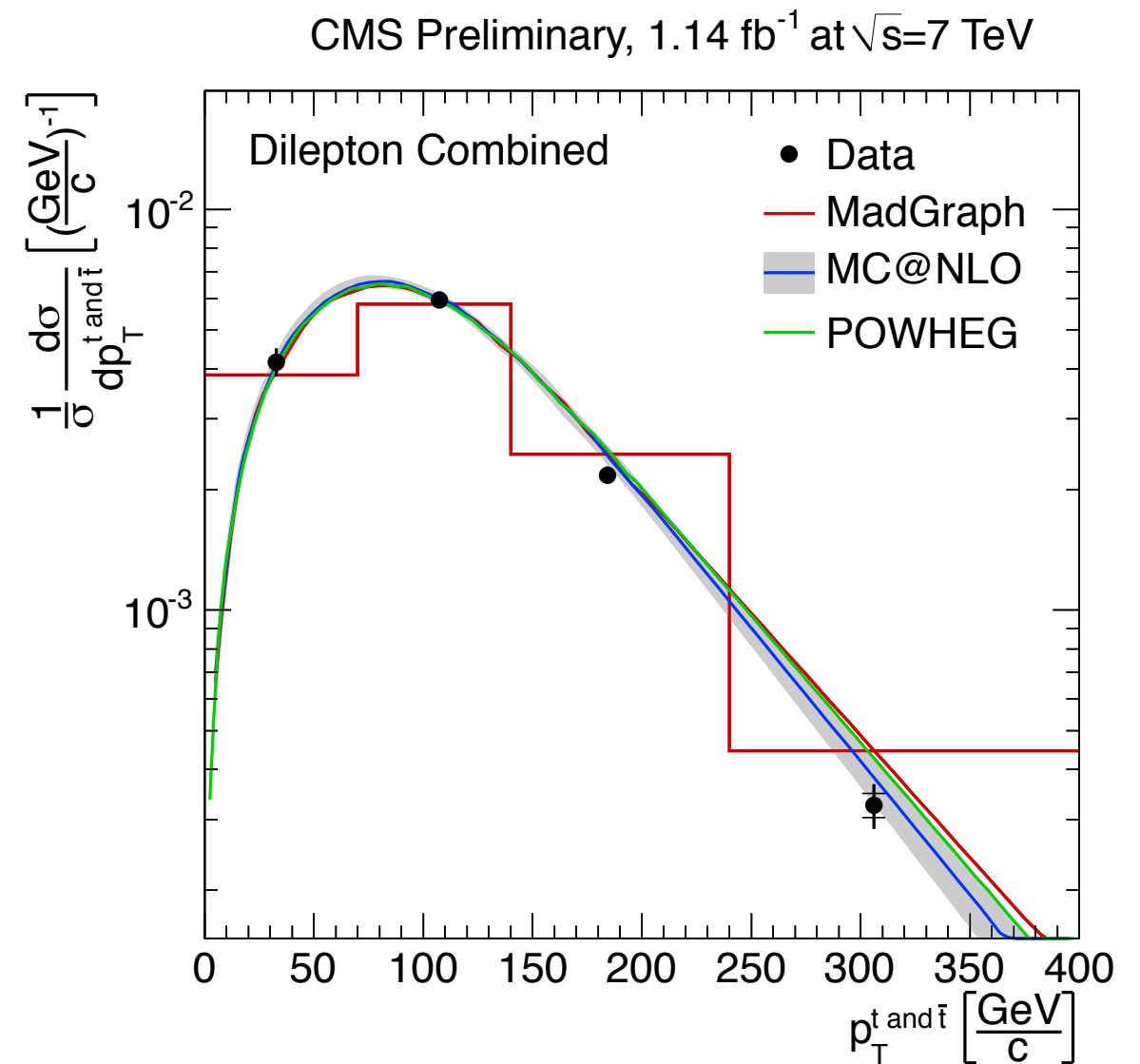




# Top Analyses

- $t\bar{t}$  differential cross sections

- Novel analysis at the LHC!
- Measured the normalised differential cross sections of various observables.
- DESY: di-lepton channels ( $\mu\mu$ ,  $\mu e$ ,  $ee$ ).
- Good agreement with predictions for all variables
- Public results for 2012 winter conferences CMS PAS TOP-11-013
- Working on the paper using  $5 \text{ fb}^{-1}$  (full 2011 data)
- Plan to continue analysis with 2012 data at 8 TeV





# Top Analyses (II)

- Extraction of the top quark mass from  $t\bar{t}$  cross section
  - Results public in September 2011 – CMS PAS TOP-11-008
  - Continuation of the analysis with full 2011 data based on the measured  $t\bar{t}$  cross section.
  - Extraction of  $m_{\text{top}}$ , (pole and  $\overline{\text{MS}}$ ) from CMS combined cross section with full 2011 data.
  - Continue the analysis with 2012 data at 8 TeV.
- Cross section ratio  $t\bar{t}/Z$  in the  $ee$  and  $\mu\mu$  final states (diploma thesis March 2012)

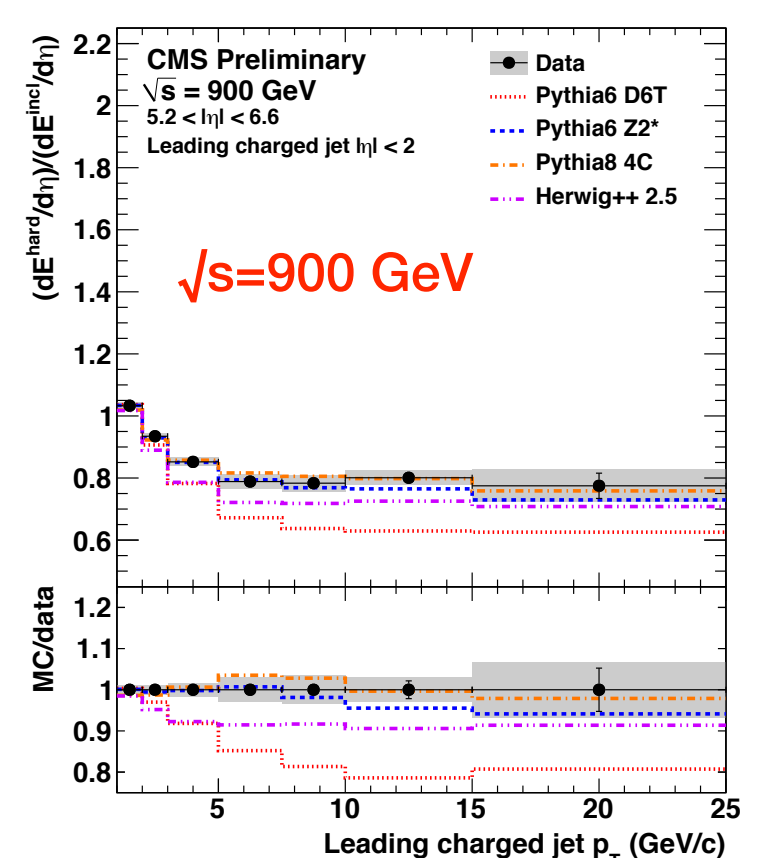
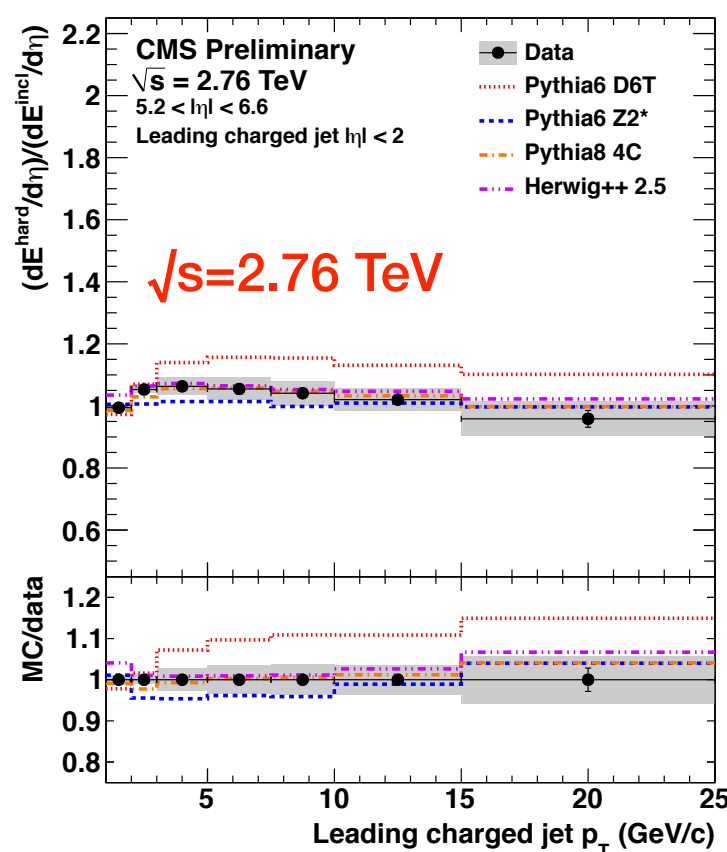
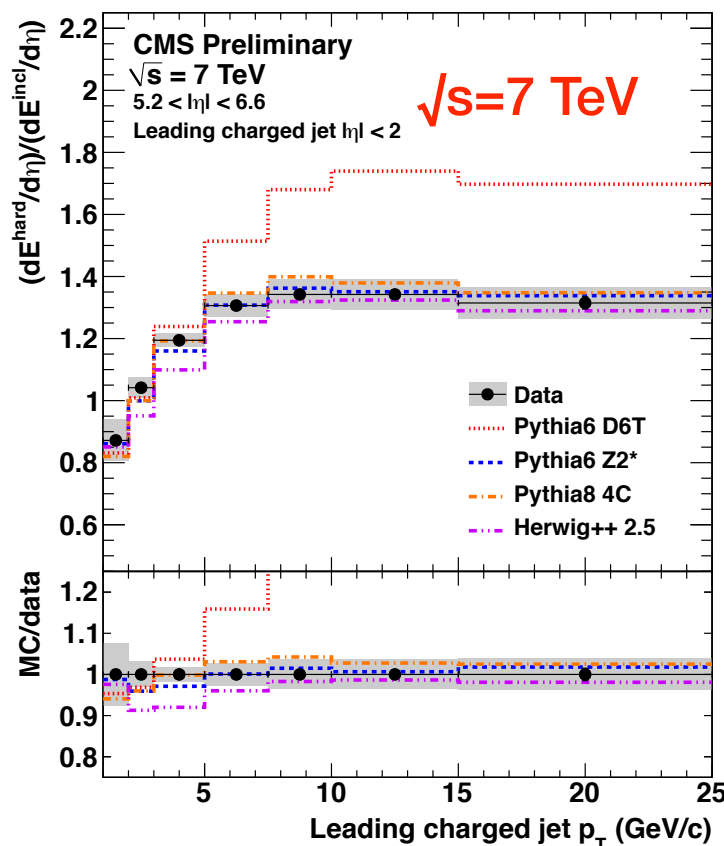
New and planned analyses for 2012 data:

- Inclusive  $t\bar{t}$  cross section (CMS high priority analysis for ICHEP)
- $t\bar{t}+X$ , particularly  $t\bar{t}+bb$
- Constrain PDFs using  $t\bar{t}$  and single top; contribution to HERAFitter development



# QCD Analyses

- Very forward energy flow with CASTOR
  - First public physics results from CASTOR – CMS PAS-FWD-11-003
  - Measurement of the hard-to-inclusive ratio of the energy density as a function of the hard scale and as function of the centre-of-mass energy.
  - Probe the underlying event/multi-parton interactions.
  - Collaboration with KIT group



# QCD Analyses (II)

- Inclusive forward jets and forward central di-jets

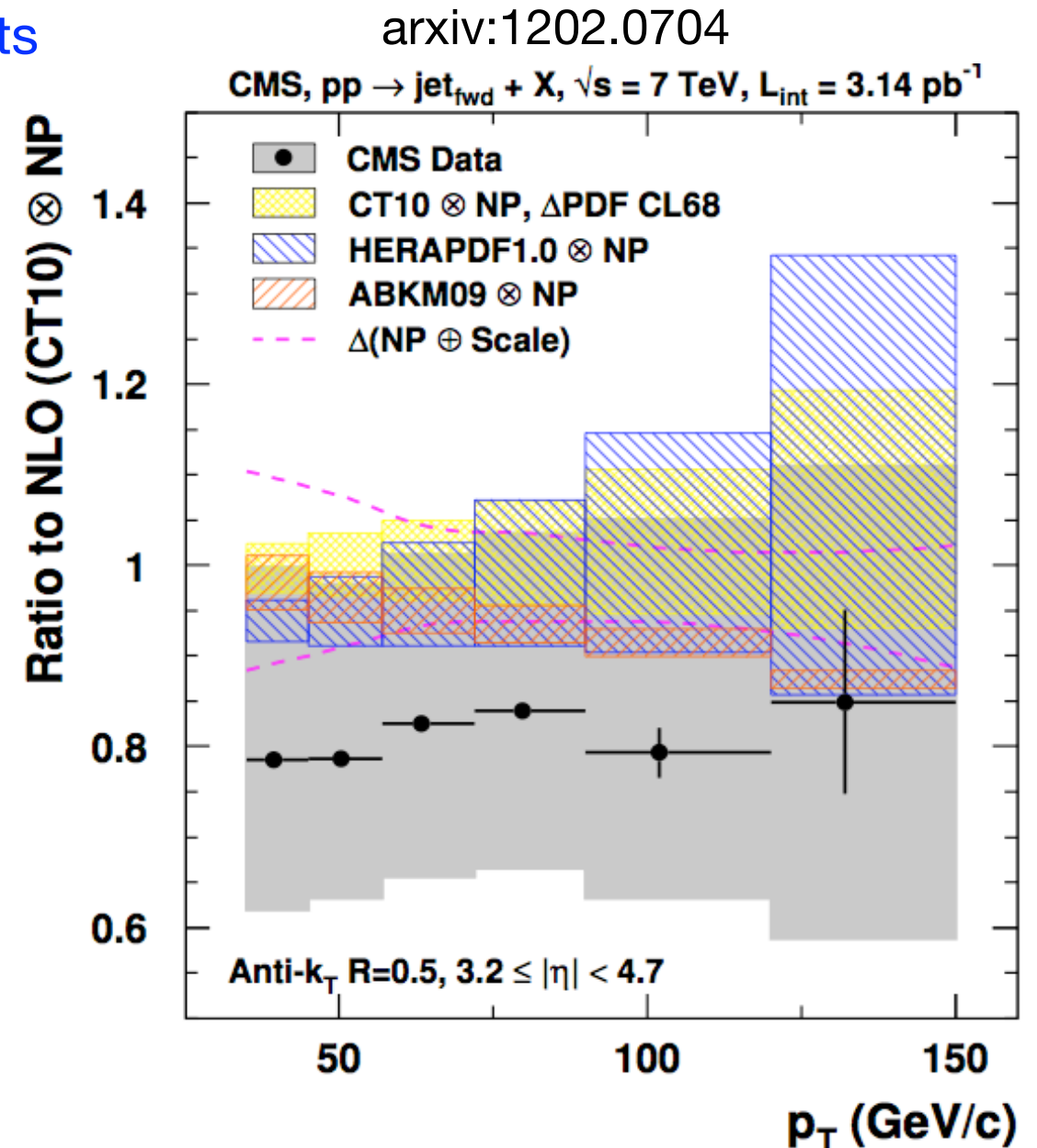
- Constrain high- and low-x parton distributions from forward jet measurement.
- Comparison with HERAPDF, ABKM09.
- Important input for new PDF fits.
- Published result CMS-FWD-11-002, [arxiv:1202.0704](https://arxiv.org/abs/1202.0704)

- Forward-central jet correlations and spectra

- Additional information for understanding di-jet ratio at large  $|\Delta y|$  discrepancy with theories.

- Determination of PDFs at the LHC

- Perform PDF fits using CMS data.
- Contribution to HERAFitter development.

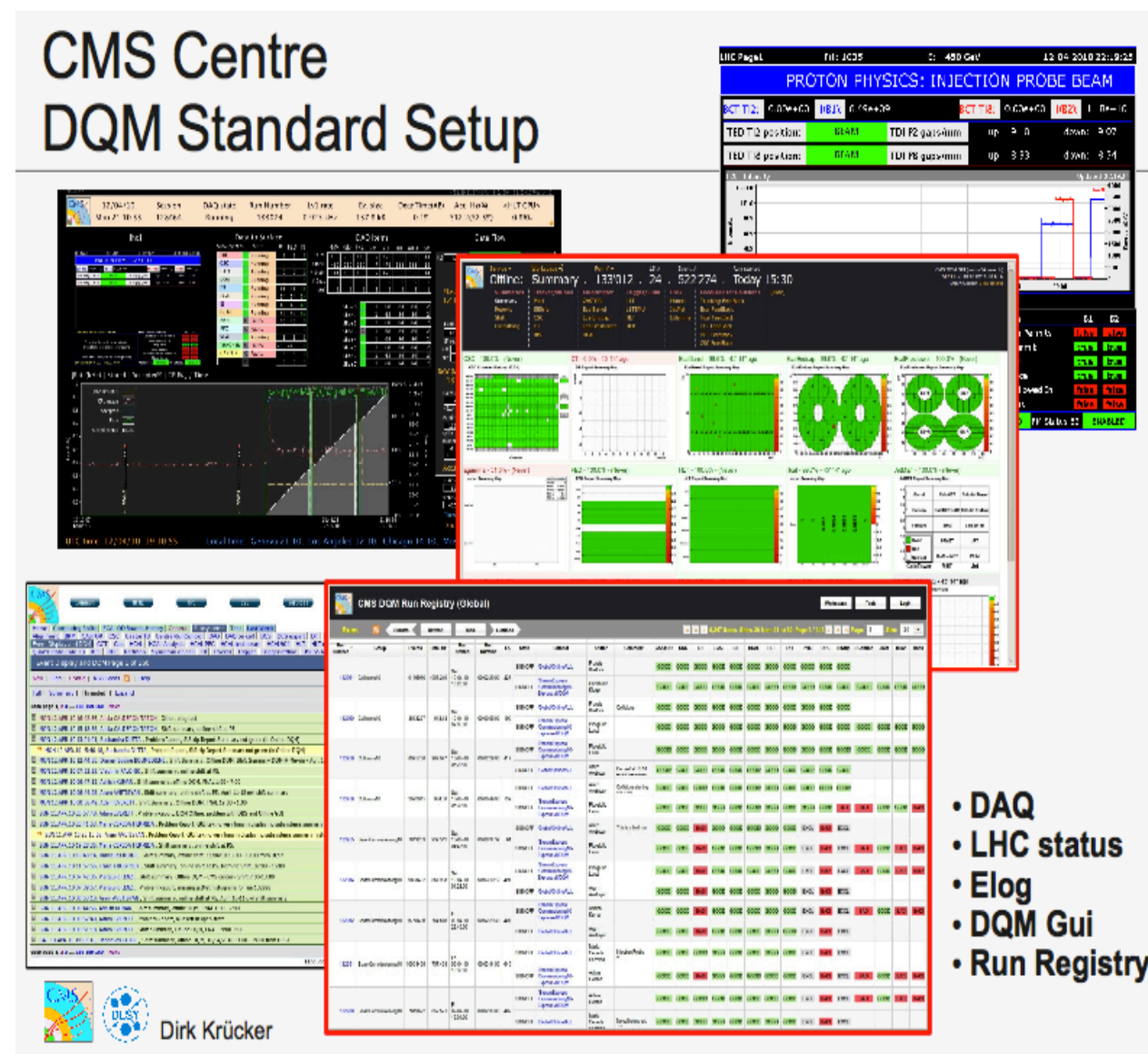






# CMS Operations: Data Quality

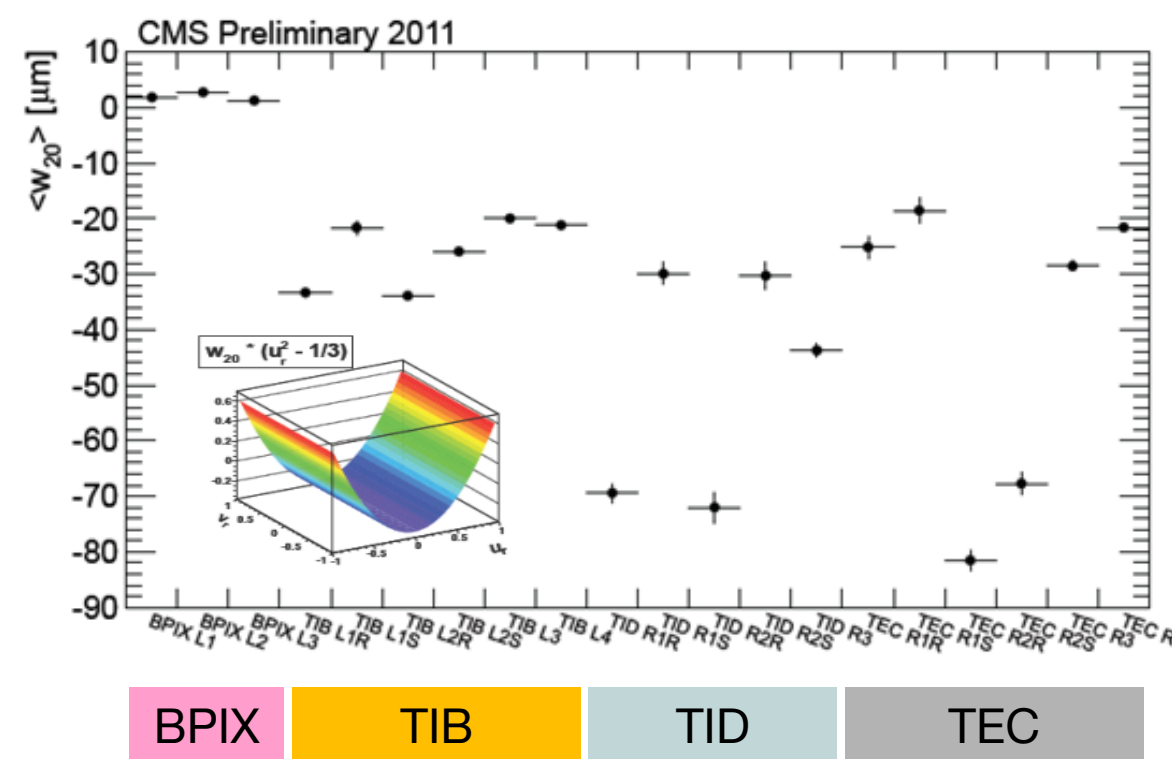
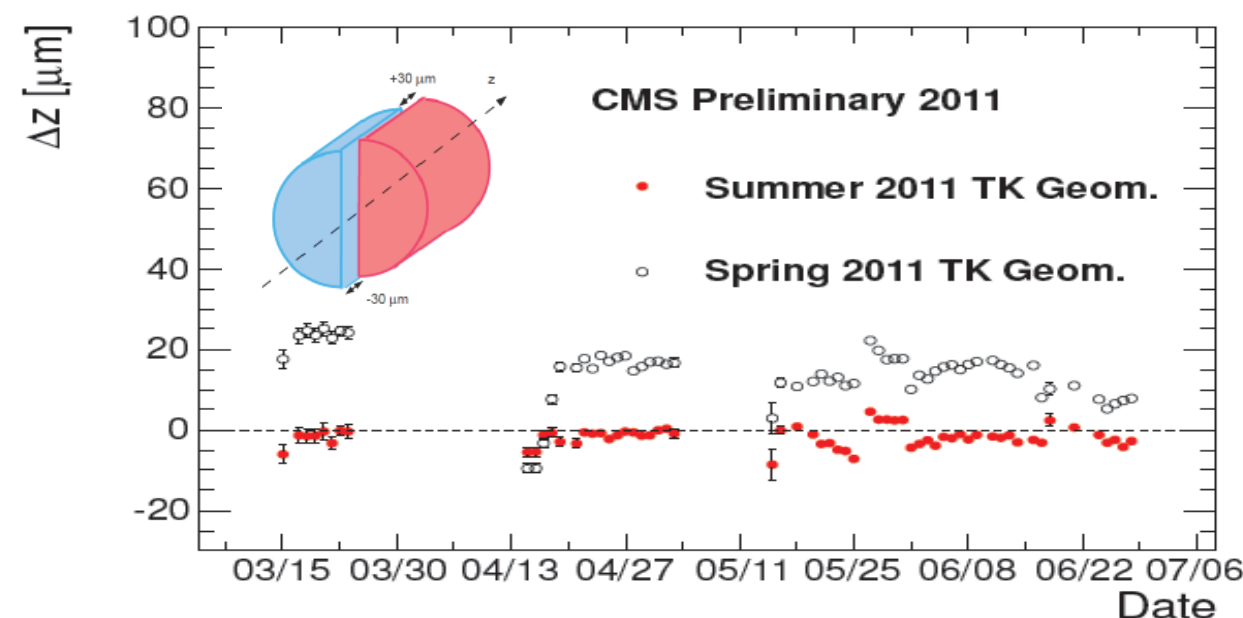
- Daily 6-hour offline shifts at DESY Remote Centre
- Software Integration (MC validation)
- Harvesting operations (aggregation of DQM histograms from all T1/T2 processes – Monte Carlo and reprocessed data)
- Data Certification: official JSON files for physics analyses (good-run lists)
- In 2012 DESY will have similar contributions as in 2011



Data certification

# Tracker Alignment

- Best CMS alignment to-date achieved with 2011 data
  - Time-dependent alignment of pixel tracker.
  - Curvature parameters determined sensor-by-sensor (up to 80  $\mu\text{m}$  sagitta).
  - Determine  $O(200000)$  free parameters.
  - Control of systematic errors (with cosmics and  $Z \rightarrow \mu\mu$  decays).
- Millepede-II program currently supported by Terascale Alliance.
- Paper close to completion.

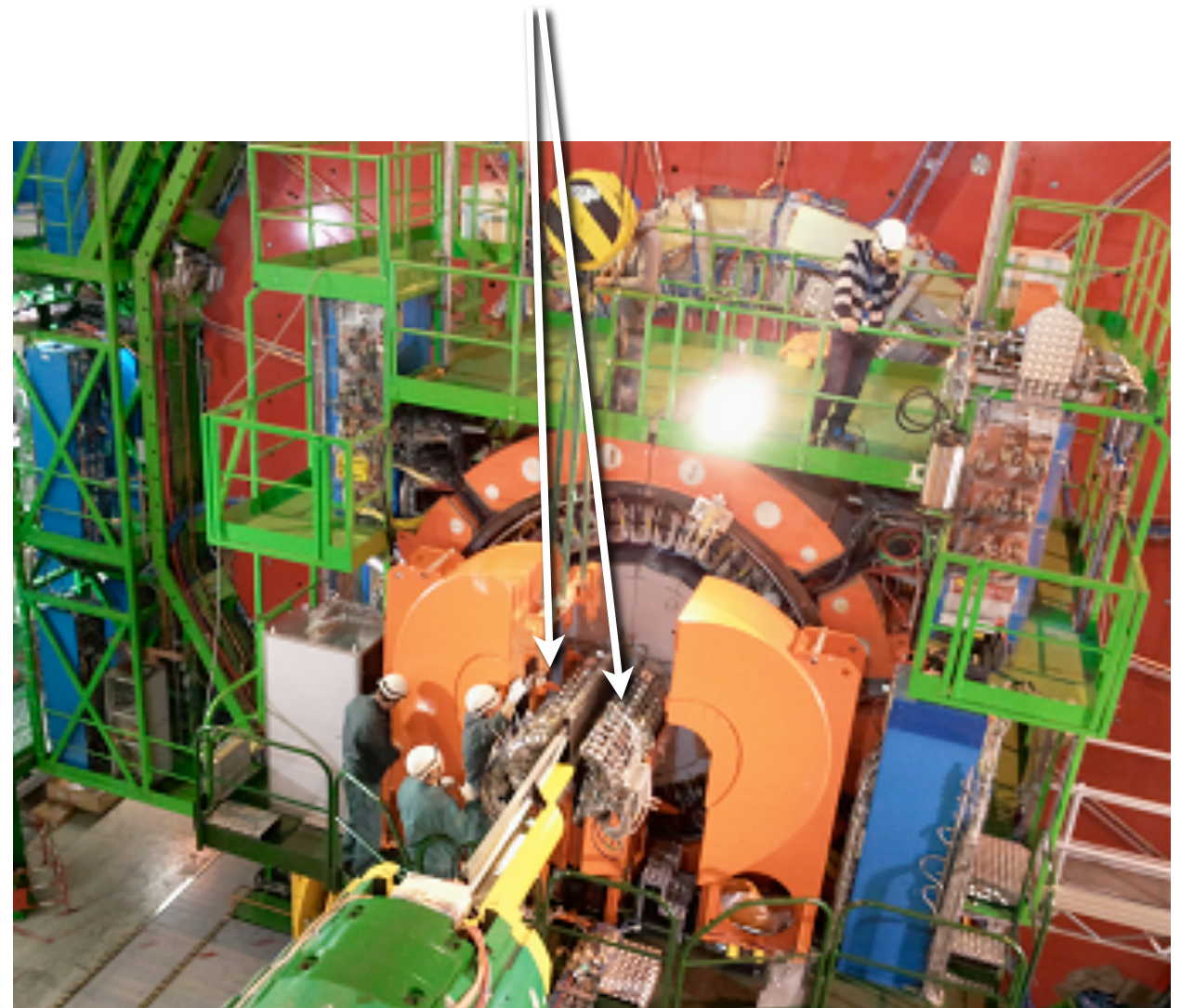




# Forward CASTOR Calorimeter

- Status at the end of 2011 heavy ion run
  - Successful data taking
  - Common data taking with TOTEM
  - **CASTOR removed for PMT upgrade with demonstration of re-insertion with beam-pipe at vacuum**
- Plans for 2012 heavy ion run:
  - Replacement of PMTs.
  - Upgrade of monitoring system.
  - Commissioning in September 2012.
  - CASTOR re-installation for heavy ions.
- Plans of a setup for long-term cosmic muon data-taking during long shutdown if investment application by KIT is successful.

CASTOR removal and re-insertion Dec 2011

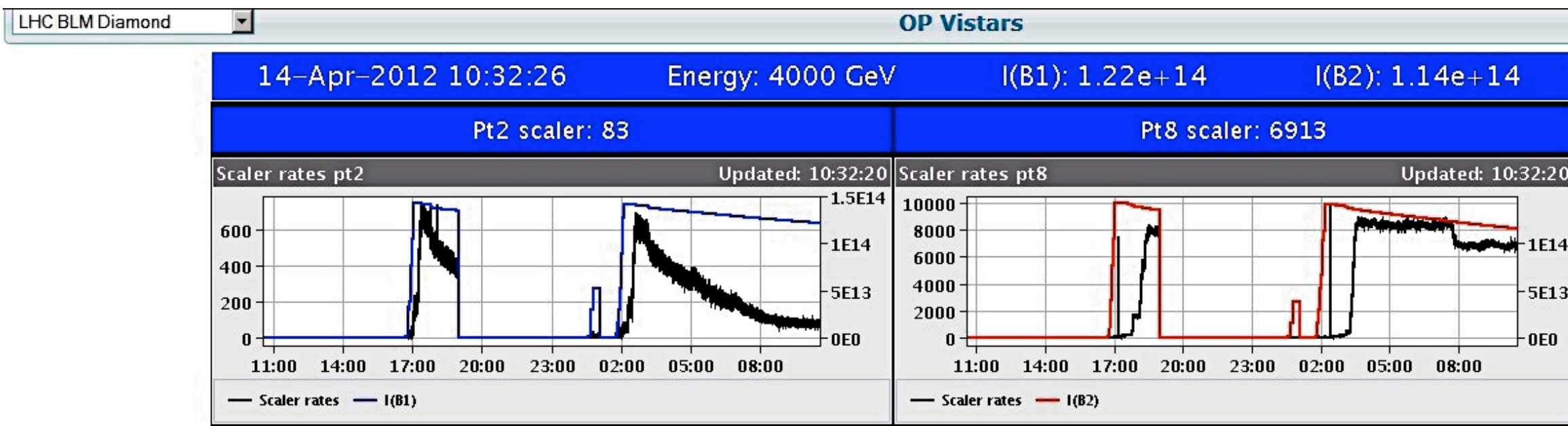
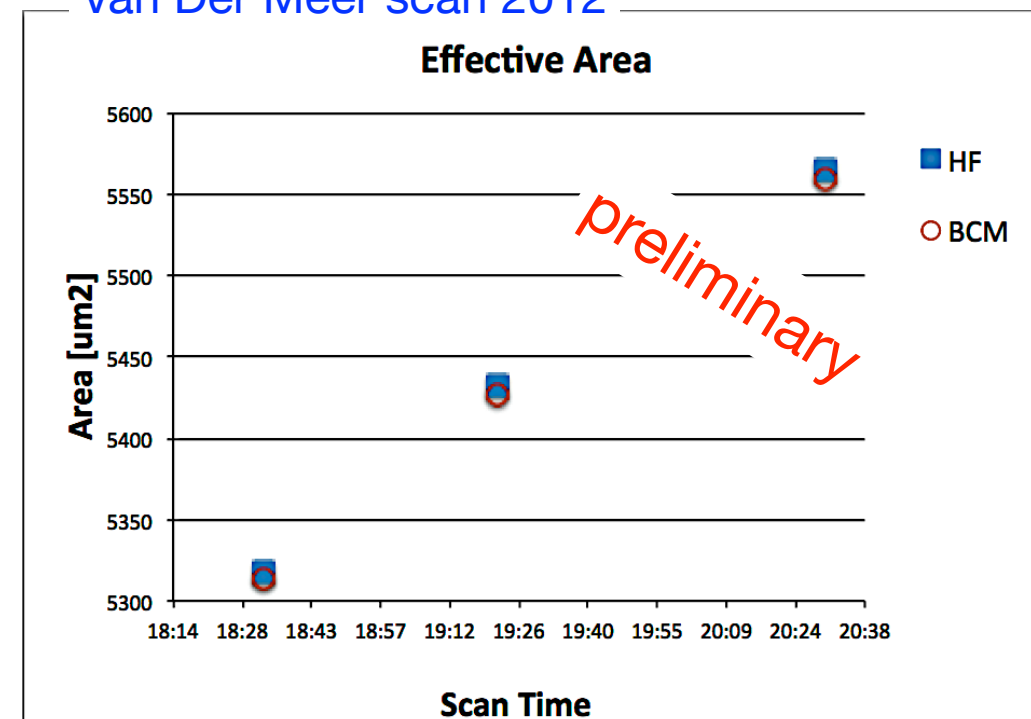




# Fast Beam Conditions Monitor (BCM1F)

- Current status
  - Providing backgrounds 1 and 3 for CMS and LHC
  - Halo veto for L1 trigger
  - Upgraded for luminosity monitoring
- Upgrade (2015)
  - New front-end ASIC with less than 10 ns peaking time
  - Global design, integration, commissioning
- BCM1F for LHC (8 modules foreseen to be installed):
  - Two modules running (LHCb and ALICE)
  - Two additional modules just installed (near P5)
  - Data transferred to LHC

Van Der Meer scan 2012

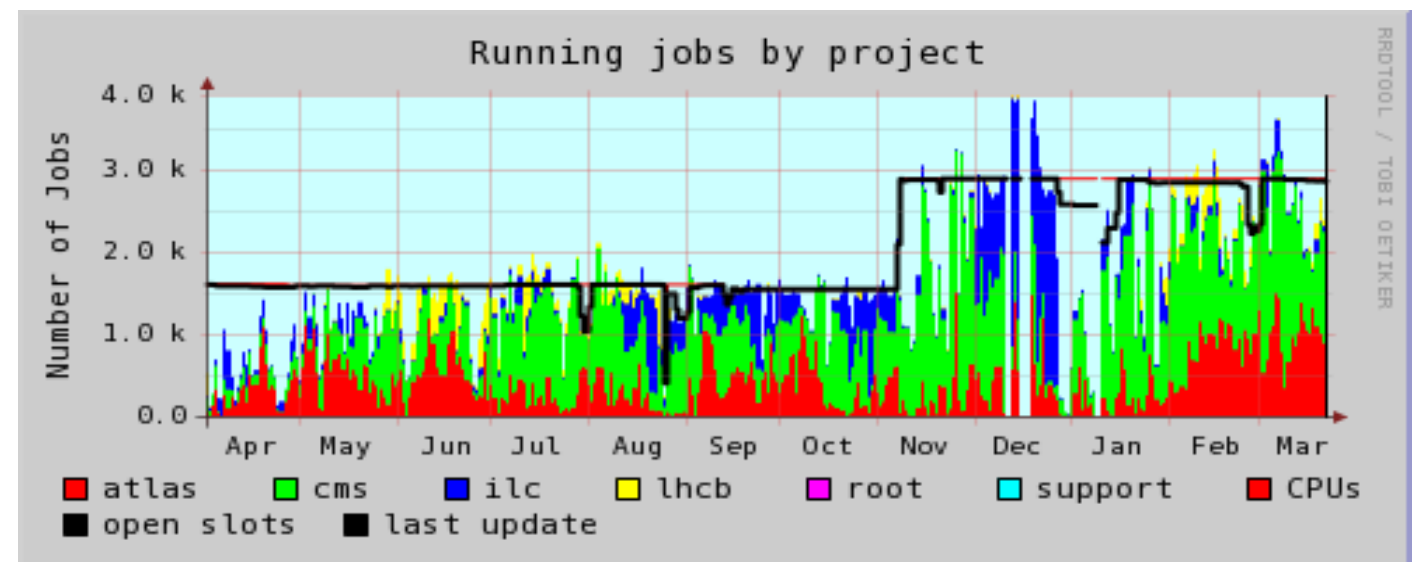






# Computing

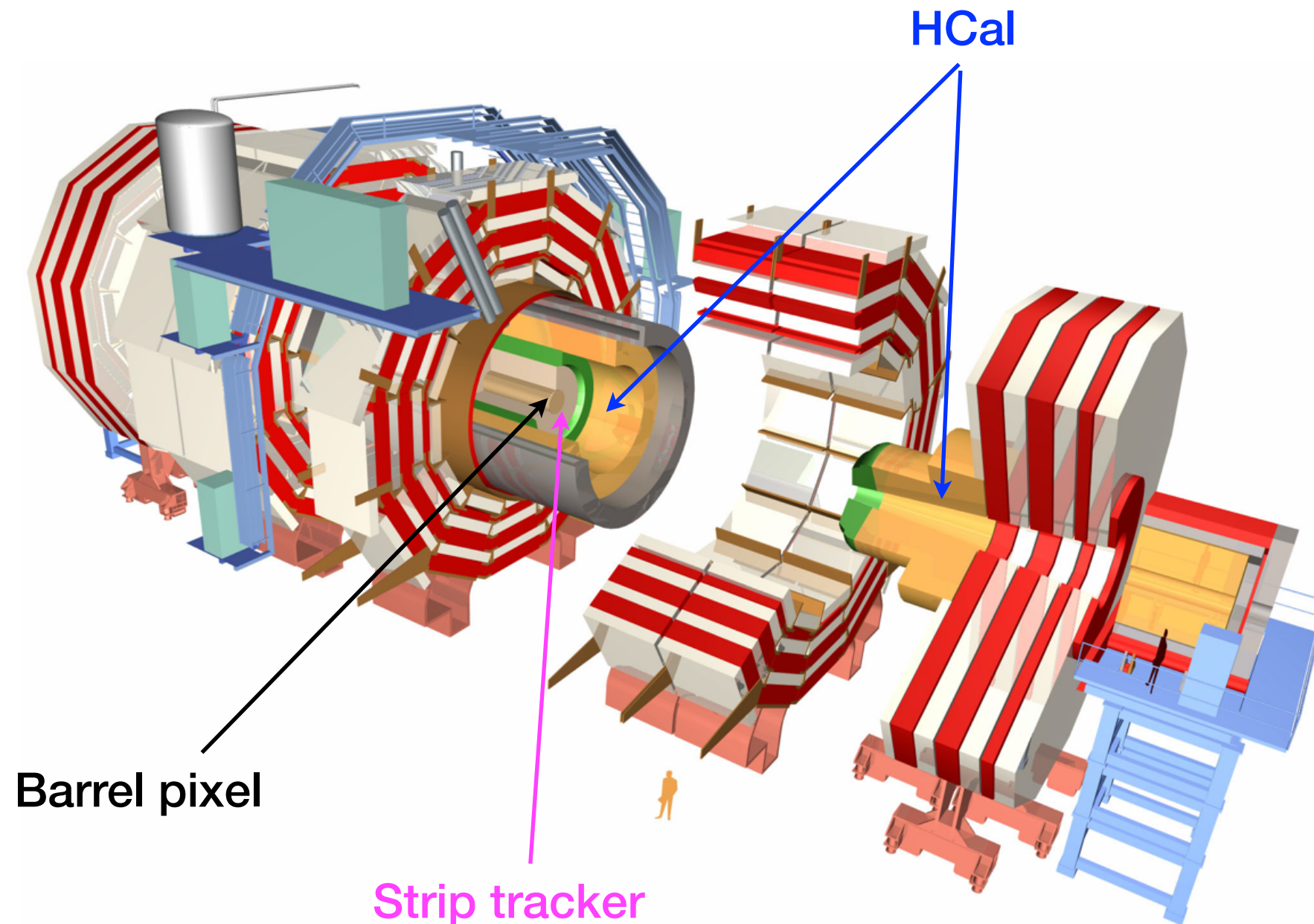
- Tier2:
  - **T2\_DE\_DESY belongs to the largest and best performing Tier2 sites in CMS.**
  - WLCG Pledges 2012 in accordance with the German fraction of CMS (7.5%).
- NAF:
  - **Crucial analysis resource for German CMS groups.**
  - Local groups looking forward to use high I/O SONAS system.
- Prepare for analysis of 2012 data: More luminosity, more complex events.
  - Intensive effort in local analysis activities to shrink and slim data formats.
  - Need to satisfy strong data demands with only doubling the resources.
  - Establish regular strategic meetings towards most efficient usage of the resources.





# CMS Detector Upgrade

DESY involved in Phase 1 and Phase 2

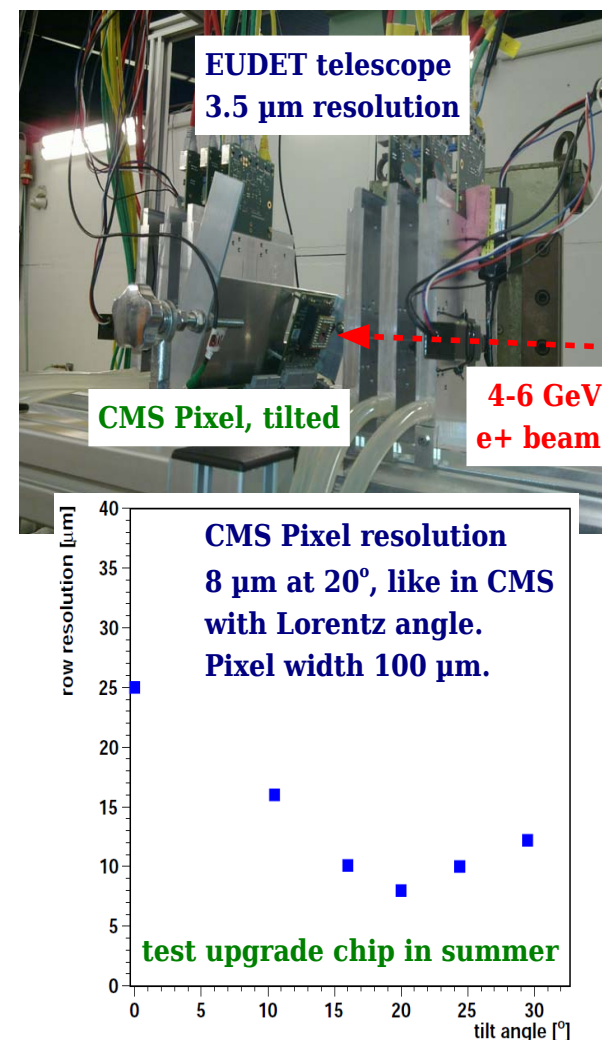




# Barrel Pixel Upgrade : Phase 1

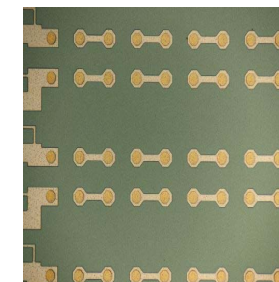
- CMS aims to install the new pixel detector during technical stop in 2016/2017
- The 4th layer of the new barrel pixel detector will be produced and calibrated by German institutes.
- Half of the 512 modules of 4th layer will be built, tested and calibrated by DESY and UHH.
- Preparatory work at DESY progressing well
  - Pixel software prepared and tested with pixel sensors in test beam.
  - DESY and UHH preparing infrastructure for gluing and wire bonding.
  - Test and calibration procedures (x-ray, cold-box, test beam) in preparation.
  - Bump bonding in evaluation with industry.
- Module production to start in 2013.

## Pixel in test beam



## Bump bonding

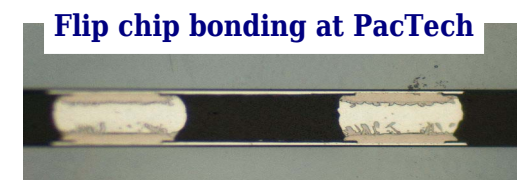
with industry: PacTech



Our contact chain test structures made at CIS Erfurt with Ni-Au under-bump metal from PacTch



30  $\mu\text{m}$  SnAg solder balls placed at PacTech.

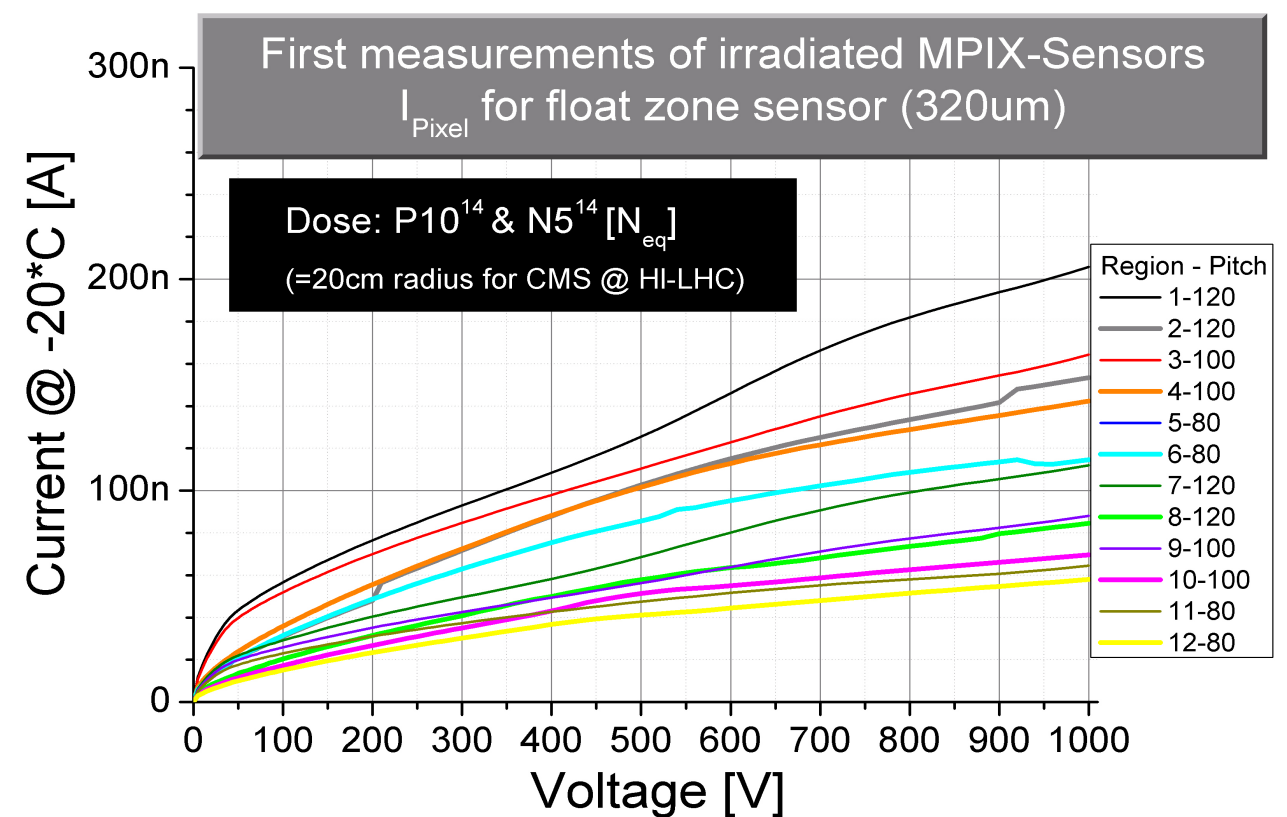
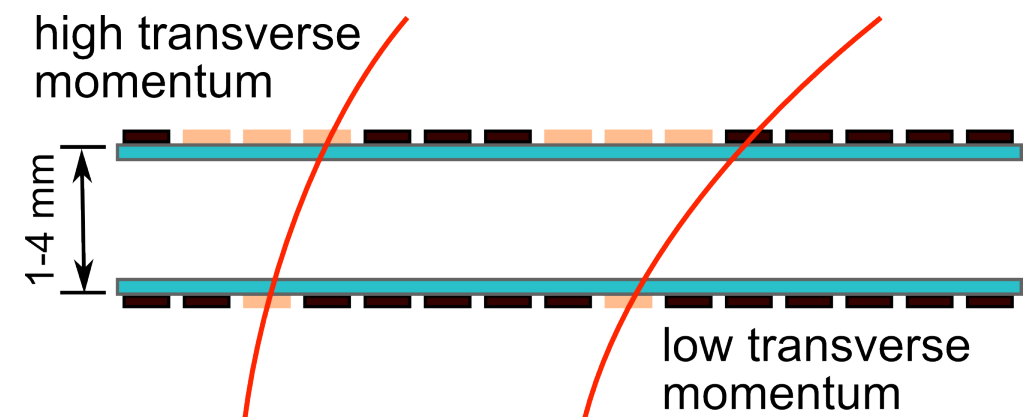


our picture after cut, grind, polish

Full sensor processed (66k bumps), under evaluation.  
Machine order imminent.

# Tracker Upgrade : Phase 2

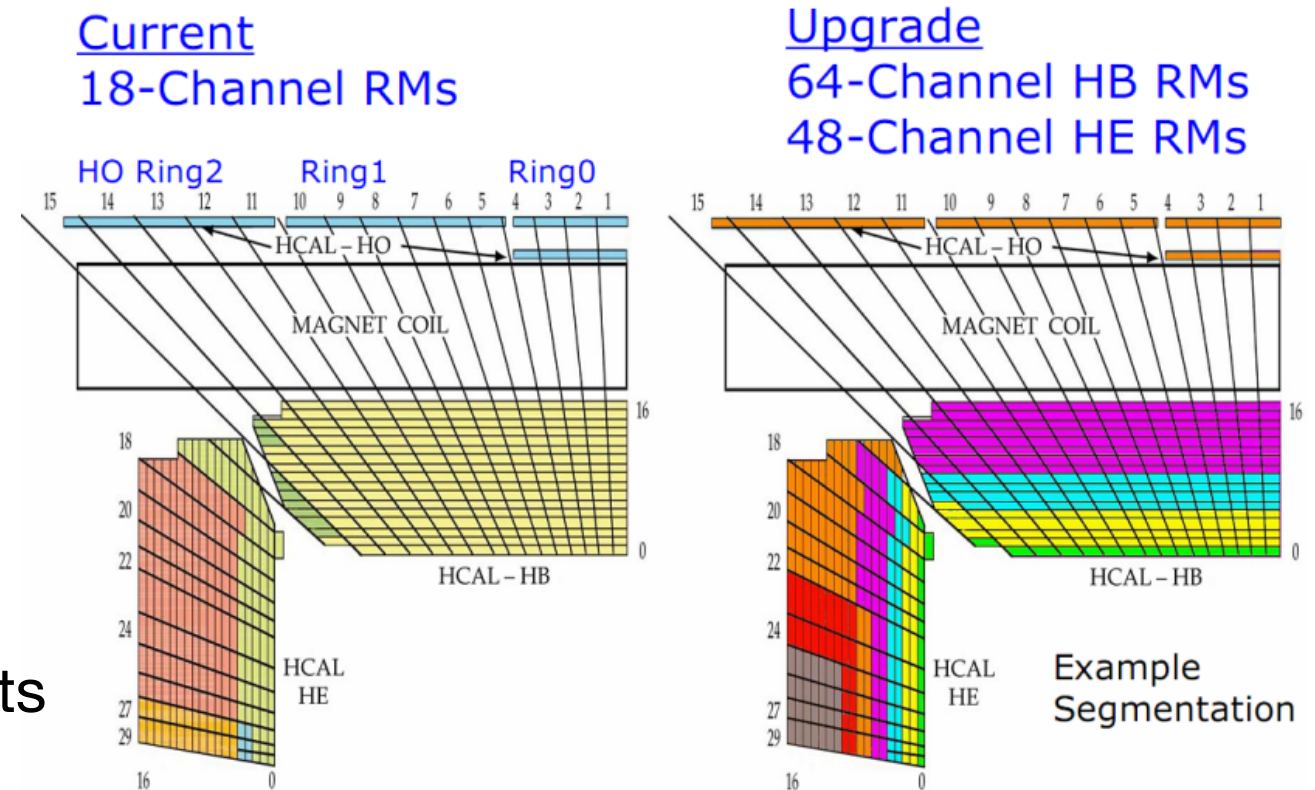
- The future tracker will provide a trigger information for the Level-1 trigger of CMS.
- Mechanical prototype for one possible module design will be built this year.
- DESY contributing to
  - Module design
  - Thermal and deformation tests
  - Finite elements analysis
  - Characterisation of sensors of different technologies: radiated and non-radiated
- Construction and commissioning of laboratory equipment.
- Dedicated workshop on materials is planned for the end of this year.





# HCAL Upgrade

- Replacement of HPDs with SiPM for the HCAL Outer (HO) (2013/2014)
  - SiPM improves gain and operation in magnetic field.
  - Development of light mixers.
  - New test stand for optical examination.
  - Coordination of test beam measurements at CERN
  - Analysis of presently running SiPMs and studies for HCAL Outer in physics events.
  - Collaboration with RWTH Aachen group.
- Upgrade HCAL Barrel (HB) with SiPM (2016/2017) and new readout technology  $\mu$ -TCA (2012-2017)





# Summary

- DESY makes significant contributions to CMS in many areas.
- **Physics analysis**
  - Frontier physics.
  - Accomplished public results in all physics areas (Higgs, Susy, Top and QCD).
- **Operation**
  - Providing crucial contributions to CMS.
- **Computing**
  - Outstanding infrastructure for production and analyses.
- **Detector upgrade**
  - Well established projects in CMS.
  - Excellent progress of upgrade activities.
- **Close cooperations with German institutes, as well as international ones.**

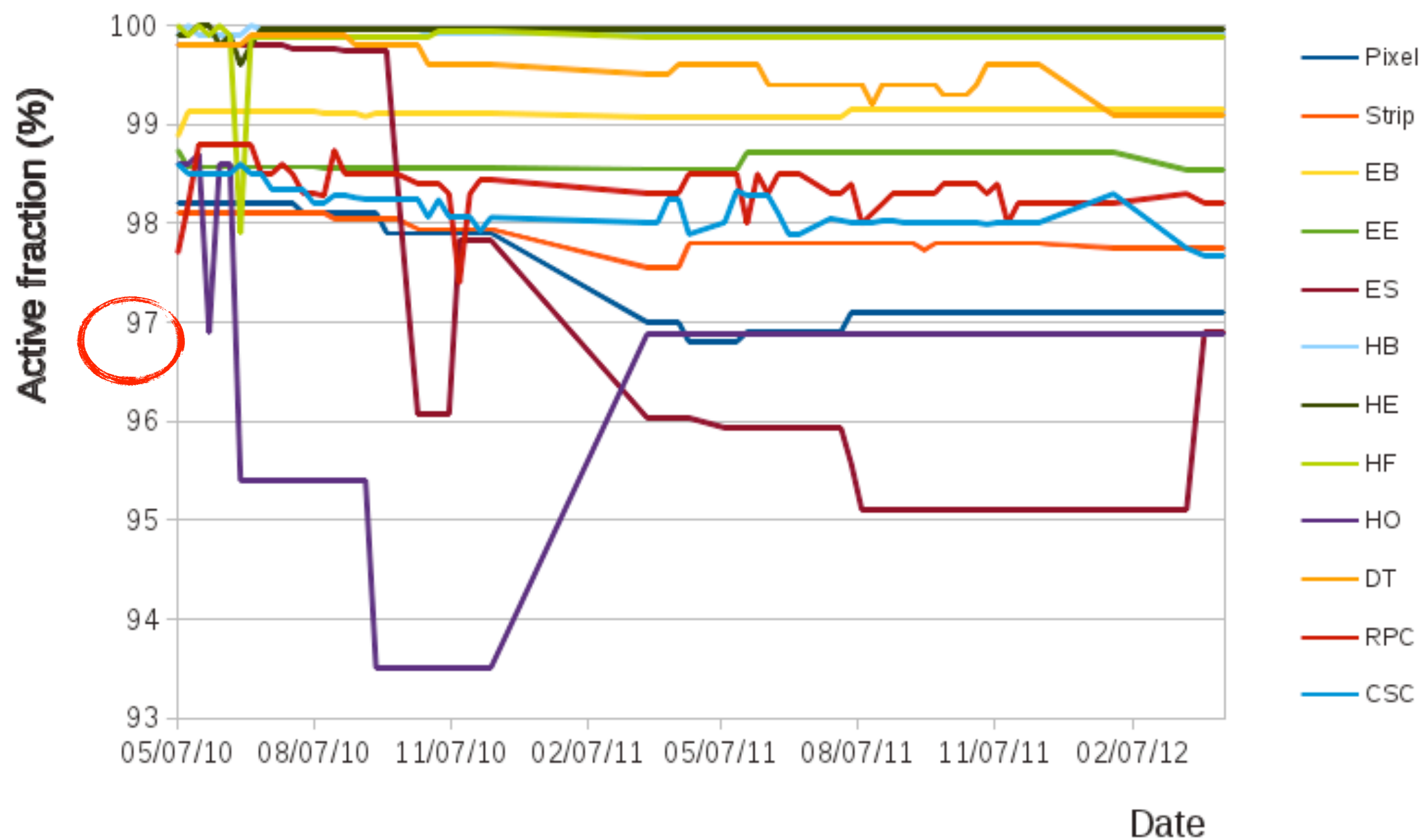


# Backup slides



# CMS performance

Evolution of CMS subsystems active fractions

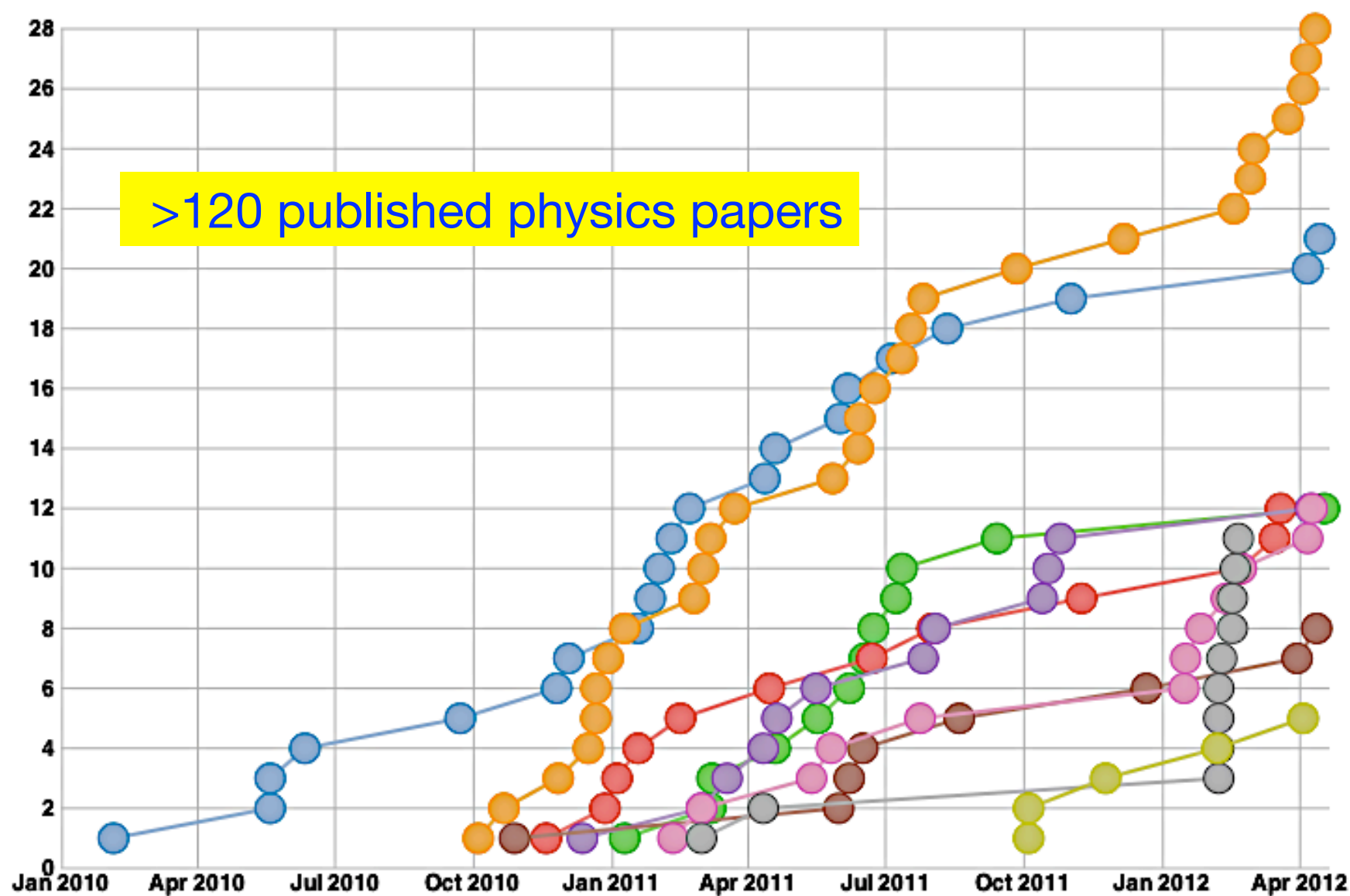


- All subsystems with 97% or more channels active



# CMS Physics Papers

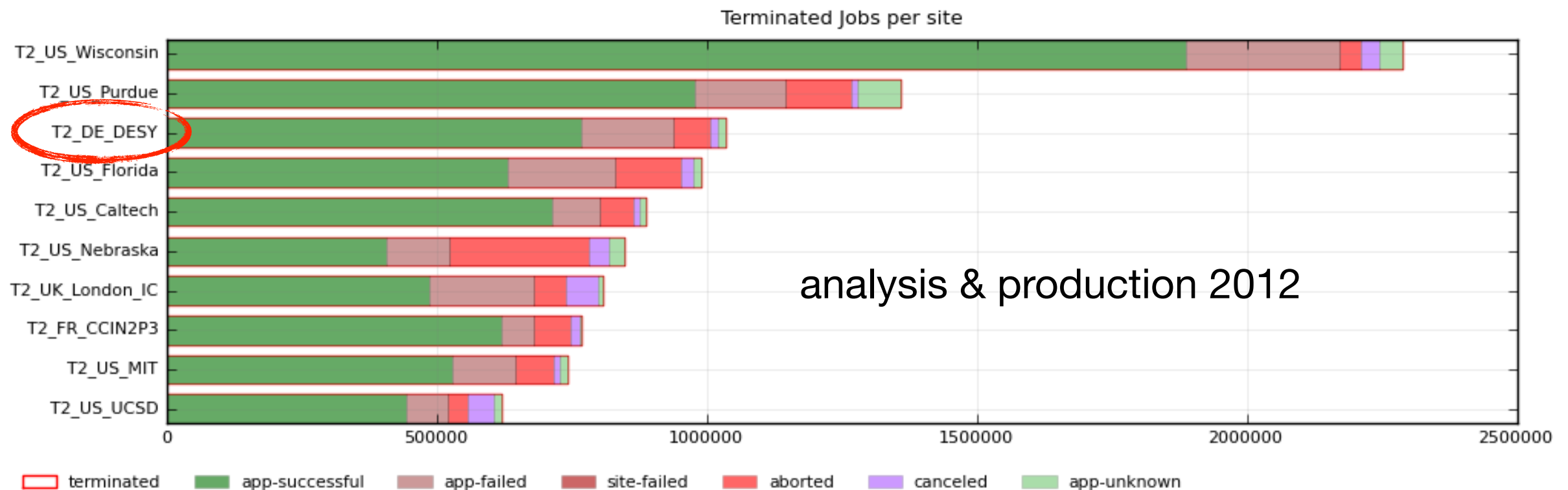
Show all QCD Physics Exotica Searches Supersymmetry B Physics Electroweak  
Top Physics Heavy Ion Physics Higgs Physics Forward Physics Standard Model







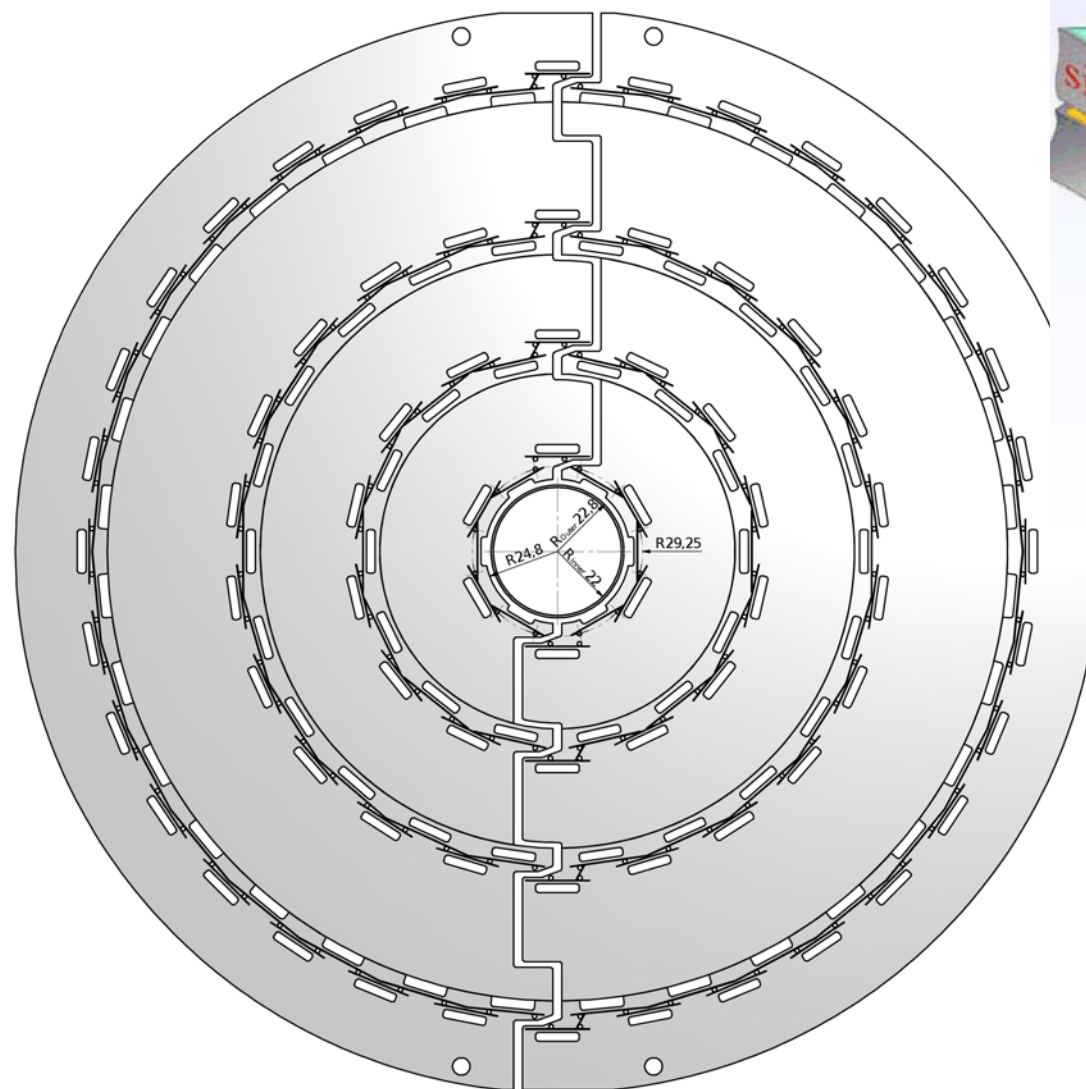
# Grid Computing at DESY



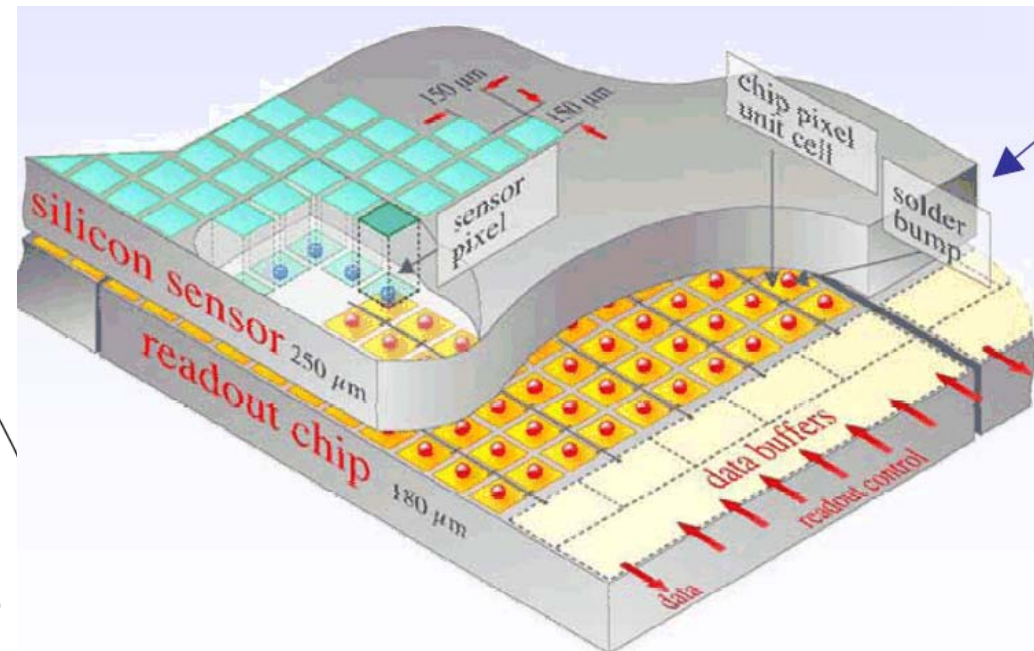
- WLCG Pledges 2012
  - 7.5% of Tier-2 resources delivered by Germany
  - 5% by DESY, 2.5% by RWTH Aachen
  - 2012 resources commissioned

# Pixel upgrade activities

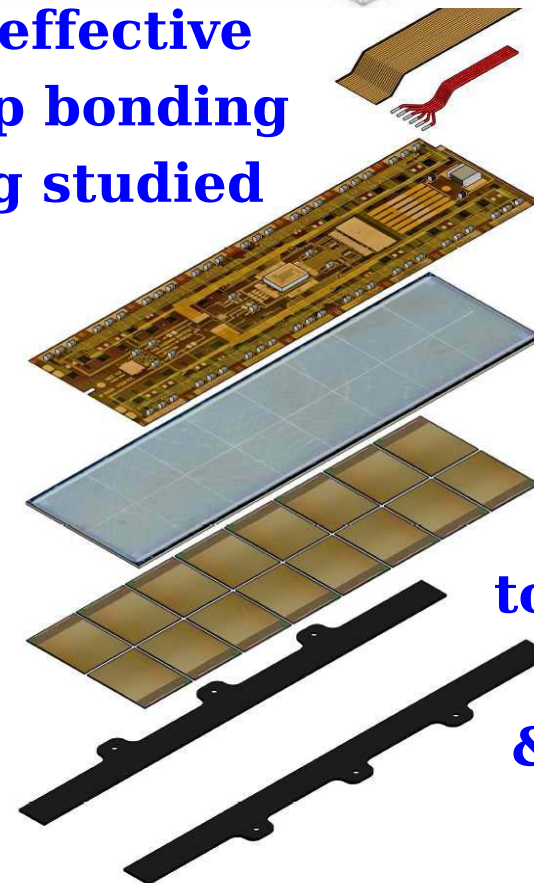
## Barrel pixel upgrade



**4 layers (now 3)**  
**inner layer at 30 mm (now 44)**  
**less material in tracking volume**  
**new readout chip for  $2 \cdot 10^{34}/\text{cm}^2/\text{s}$**



**cost effective  
bump bonding  
being studied**



**350  
modules  
to be built  
at DESY  
& Uni HH  
by 2016**



# Pixel upgrade timeline

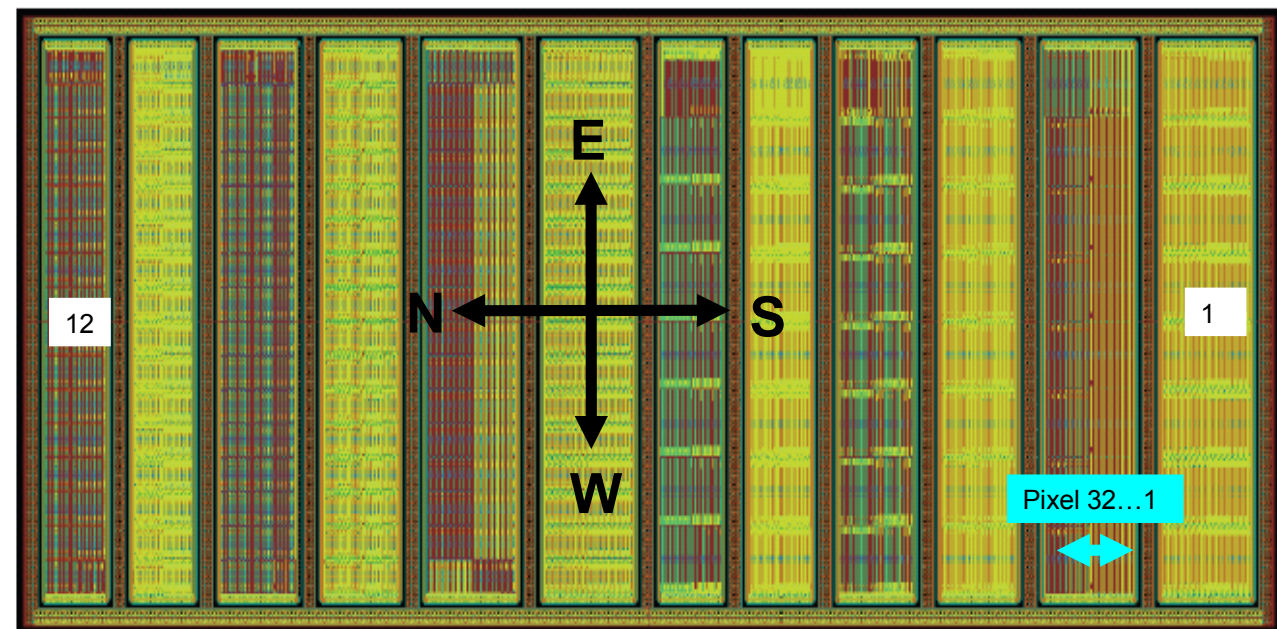
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- This years activities :
  - Establish production procedures (gluing, wire bonding)
  - test and calibration procedures (x-ray, cold-box, testbeam)
  - Purchase wire bonder (in collaboration with DESY-ATLAS)
  - Bump bonding technique to be decided until mid 2012, to be purchased and installed by end 2012
  - Participating in ROC pre-series tests starting May 2012
- Next steps :
  - Module pre-series production by mid 2013
  - production site qualification
  - Full module production and calibration mid 2013 – mid 2015
  - Outer layer assembly and test mid 2015
  - Full system test at CERN 2016
  - Installation in CMS in extended technical stop 2016/17



# Tracker Upgrade

- **Construction and commissioning of laboratory equipment is well under way**
  - study specific aspects of the mechanical prototype design (e.g. thermal interfaces),
  - characterise the mechanical prototype,
  - give feedback to the finite element analyses
- **Workshop on materials**
  - funded by the PIER Ideenfonds in collaboration with the DESY ATLAS group and UHH
  - synergy with industry on possible material solutions for future detection systems
  - strong interest in the workshop from the community
- **HPK Campaign**
  - Find the best material and geometry for the CMS tracker upgrade
  - Tests with one wafer layout designed and produced with different substrates, thicknesses and different production technologies but with same production process from Hamamatsu.



region	12	11	10	9	8	7	6	5	4	3	2	1
p+/n+	18	18	23	23	28	28	18	18	23	23	28	28
alu	31	31	36	36	41	41	31	31	36	36	41	41
length alu	1171	1171	1171	1171	1171	1171	2421	2421	2421	2421	2421	2421
pitch	80	80	100	100	120	120	80	80	100	100	120	120