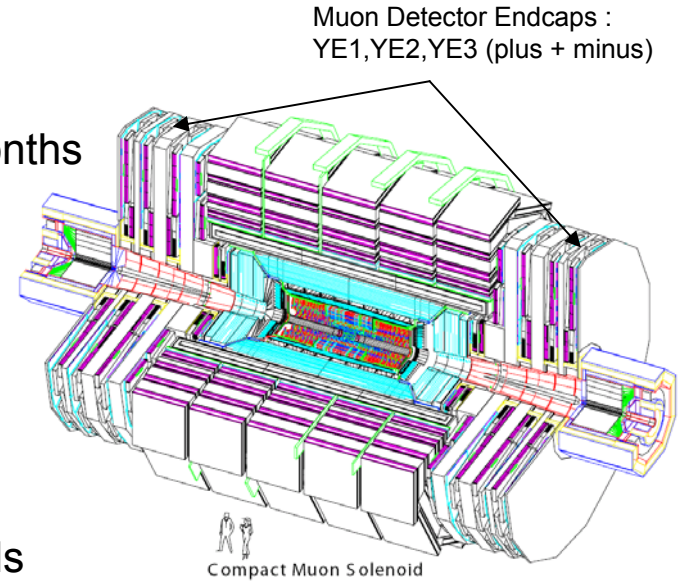
CMS at DESY

CMS Status
CMS DESY Activities
CMS Upgrade
LHC Computing
Summary

CMS Status

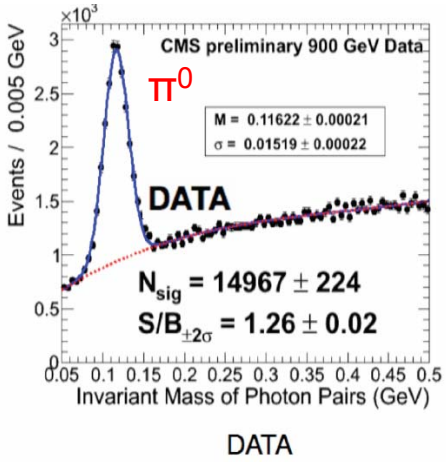
- 0.9 & 2.36 TeV collisions Dec. 2009
  - CMS was ready & performing well

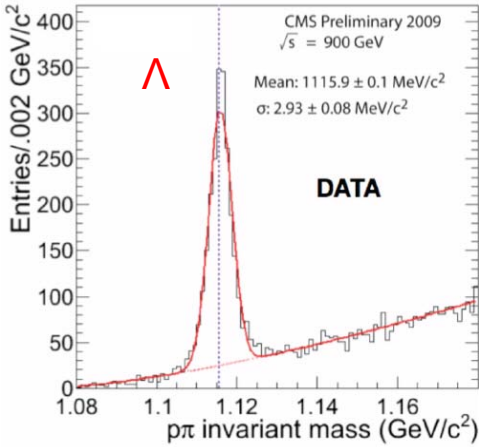
- Winter shutdown 2009/2010
  - CMS opened, maintained and closed within 2 months
  - YE cooling repaired (replaced all (>400) fittings)
  - CMS ready for beam (Feb 15th)

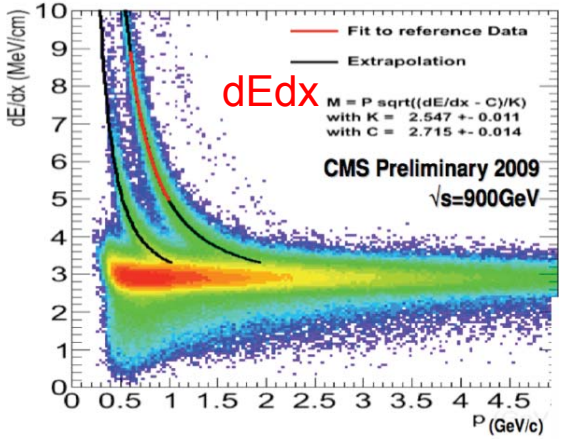


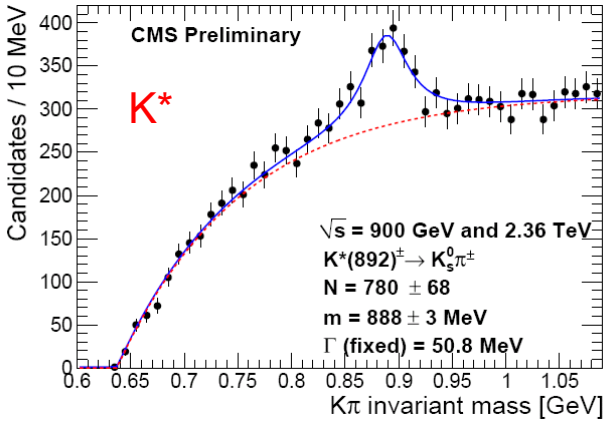
- Collisions @ 7TeV since March 30th 2010
  - First events and performance plots within seconds
  - CMS efficiently taking data since
  - Commissioning with data progressing well

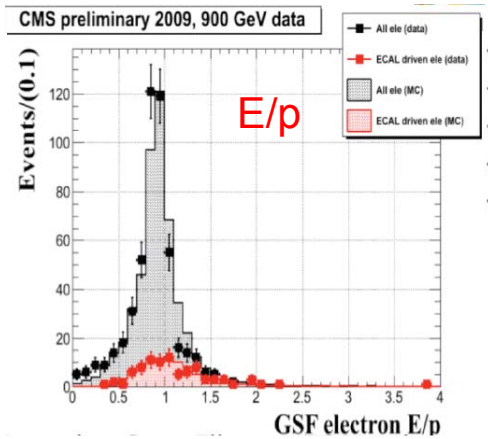
2009 - Performance @ 900GeV

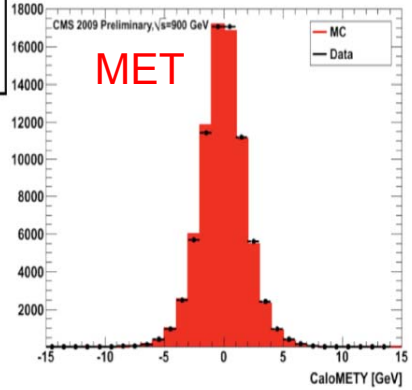










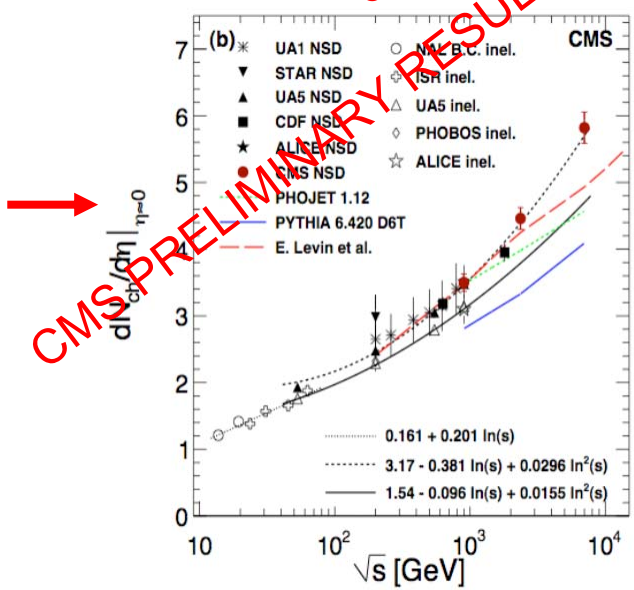


In many cases performance already close to TDR (some examples shown above)
Excellent agreement with the simulation

First CMS Paper from Collisions

- Transverse momentum and pseudorapidity distribution of charged hadrons at $\sqrt{s}$ = 900 and 2360GeV (submitted to JHEP on Feb 3rd, accepted for publication on Feb 7th)
- First detailed look at minimum bias and underlying event to prepare for high luminosity and HI running
- First measurement at 2.36 TeV
- First evidence that charged hadron multiplicity is slightly higher then expected from current Monte Carlo tunes
- The new measurements at 7TeV definitely show a steeper then expected increase of the charged hadron multiplicity with collision energy

Including 7TeV

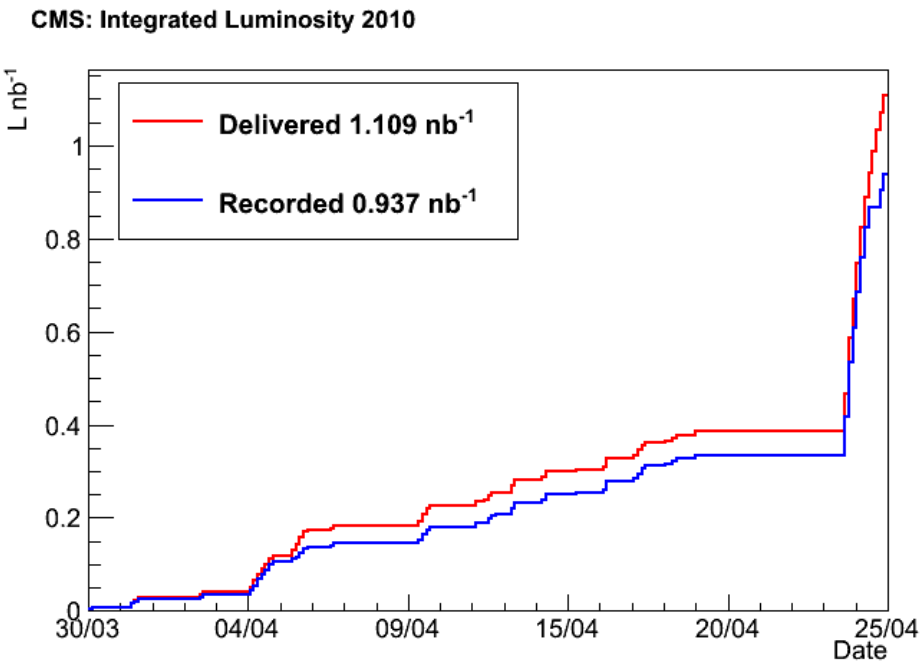


2010 - Accumulating Data @ 7TeV

Recorded 0.937 nb^{-1} of 1.109 nb^{-1} delivered

Efficiency ~ 84 %
(includes timing and calibration scan)

Goal > 90% (by end of April)



Forward muon at √s=7TeV

DESY CMS Group

- News from the Group
- Responsibilities
- Physics Activities
- Upgrade Activities

Picture from CMS Center in local TV (SAT1) during 7TeV Media Event

DESY CMS Group - News

- 20 staff (physicists), 18 post-docs (~ 26 FTE in total)
- 11 PhD students, 3 undergrad. students
- Engineers (mech.), technicians (mech. + elec.)

- W. Zeuner on leave from DESY since Feb. 2010
- K. Borras (group leader), G. Eckerlin (deputy group leader)

CMS Responsibilities of the DESY Group

- **Physics:**
  - H. Jung, Forward Physics Group Convener (L2) new
  - K. Borras, Conference Committee new
- **Computing:**
  - M. Kasemann, Coordinator (until 12/2009) (L1), CMS Management Board, Chair of Computing Resource Board and chair of Computing Security Board new
  - C. Wissing, Grid SW Deployment Coordinator (L3)
  - R. Mankel, ECOM (Evolution of Computing Model) Chair
- **Technical Coordination:**
  - W. Zeuner, Deputy TC (L1), Upgrade TC and CMS Management Board (since Feb. 2010 on leave from DESY) new
- **Data Quality Monitoring and Data Certification:**
  - A. Meyer, Convener (L2)
  - J. Olzem, DQM for Monte Carlo simulation (L3)
- **Alignment and Calibration:**
  - R. Mankel, Convener (L2)
  - G. Flucke, Alignment Software Coordinator (L3) (until 12/2009) ⇒ now A. Mussgiller new
- **CASTOR Calorimeter:** K. Borras, Project Leader, HCAL Steering Committee and CMS Financial Board
- **High Level Trigger & Data Acquisition**
- **Beam Condition Monitor**
- **The DESY CMS group is well represented → high visibility**

☞ Will concentrate on physics & upgrade activities in the following (see backup slides for others)

Physics Activities at DESY

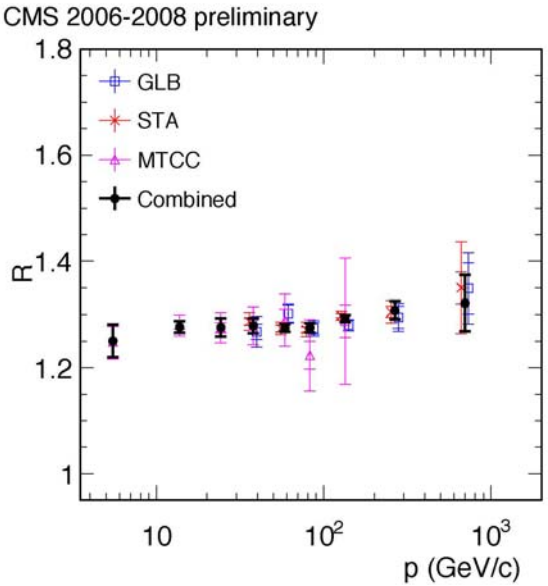
- Physics Analysis with Cosmic Data
- QCD
- TOP (incl. YIG K. Lipka)
- Higgs (mainly YIG A. Raspereza)
- SUSY (mainly YIG I. Melzer-Pellmann)
- Collaboration with Analysis Center

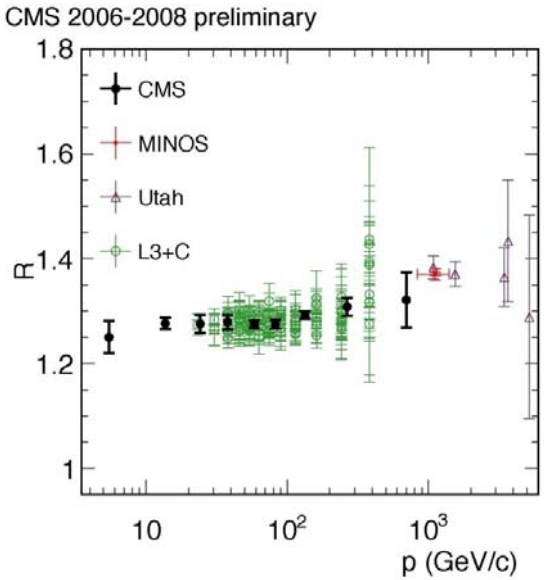
Some examples of DESY group contributions in the following

Physics Paper from Cosmic Data

Measurement of the charge asymmetry of atmospheric muons with the CMS detector
(**CMS PAS MUO-10-001**, approved on 07.04.10)

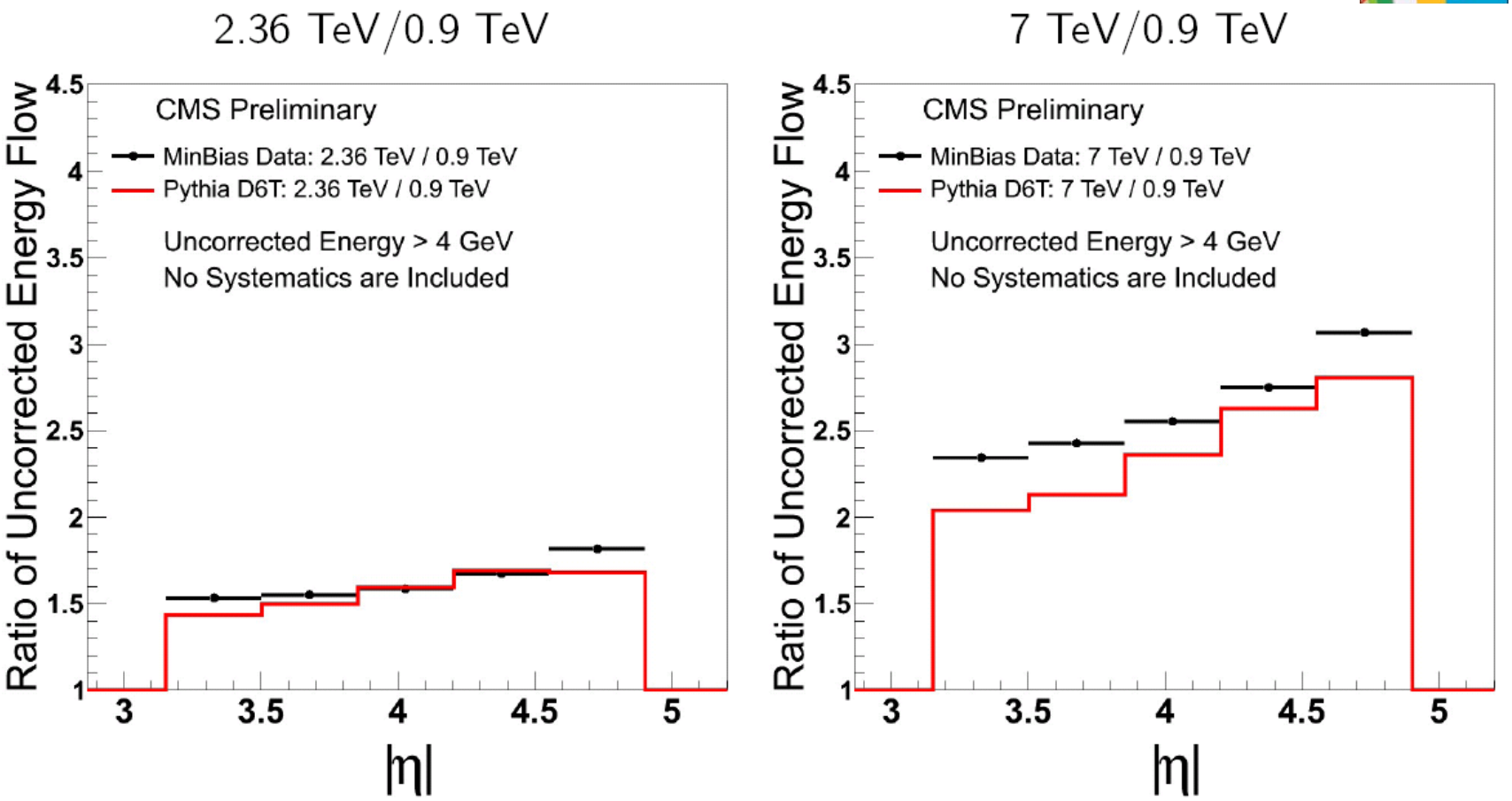
- The cosmic muon charge ratio has been measured, as a function of the muon momentum, using CRAFT08 and MTCC (2006) data
- Combination of three analyses:
  standalone- (MTCC), global-, standalone- muon analyses (CRAFT08)
- R = 1.2766 ± 0.0032 (stat) ± 0.0032 (syst) (for p <100GeV/c)
- Good agreement with previous measurements, significant improvement in precision





First physics measurement using cosmic muons in the complete CMS detector !

QCD – Energy Flow Ratio in Forward Region



Important input for multi parton interactions
Valuable input for model tuning in underlying event structure
Next step with data up to η=6.2 (with CASTOR data)
(PAS-FWD-10-002 – pre-approval)

Top Quark Physics at DESY

Activities in 2009 / 2010: preparation for physics analysis

- Total ttbar cross section measurement in dimuon decay channel (robust event selection for 50pb^{-1} @ 7TeV)
- ttbar cross section measurement in mu+jets channel (event selection for 100pb-1)
- Online/offline Data Quality Monitoring for top-like dilepton events (operational since Oct. 2009)

Ongoing activities and plans for 2010:

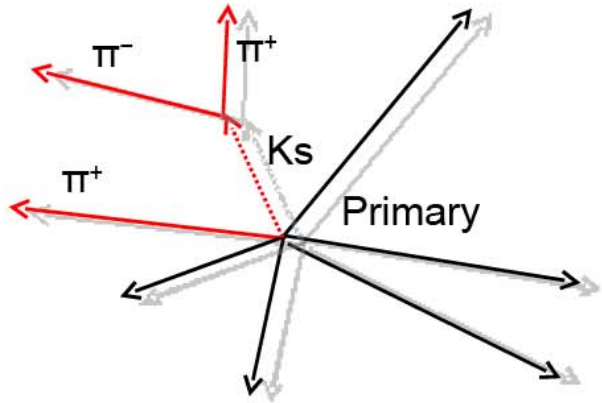
- Development of calibration tools for b-tagging using ttbar events
- Simulation studies of the b-tagging performance for the pixel detector upgrade
- Feasibility studies for measuring the top mass in the dilepton channel using the “Lxy method”

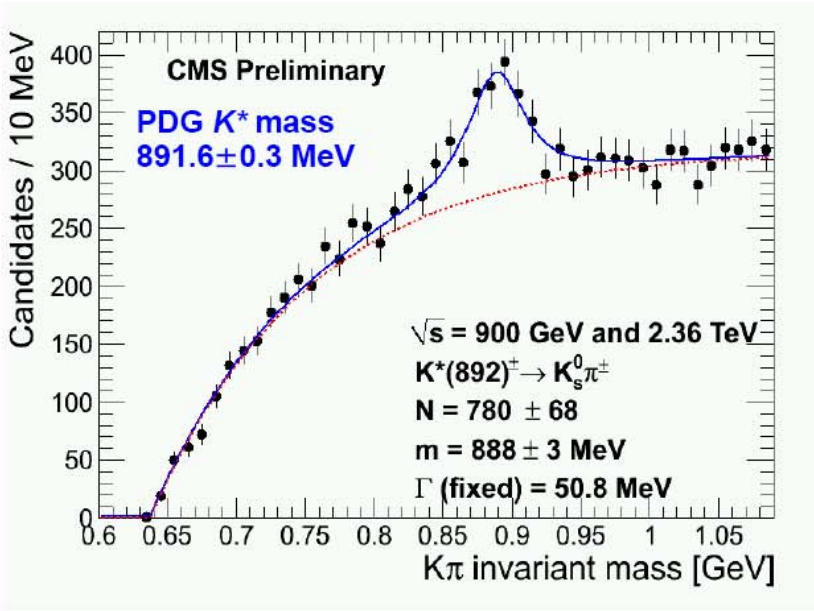
- Analysis of first LHC data (900 GeV, 2.36 TeV, 7 TeV):
  - Participation in SV validation within joint tracking and b-tagging POG effort
  - First look into muon distributions
  - First performance plots of the top analysis framework

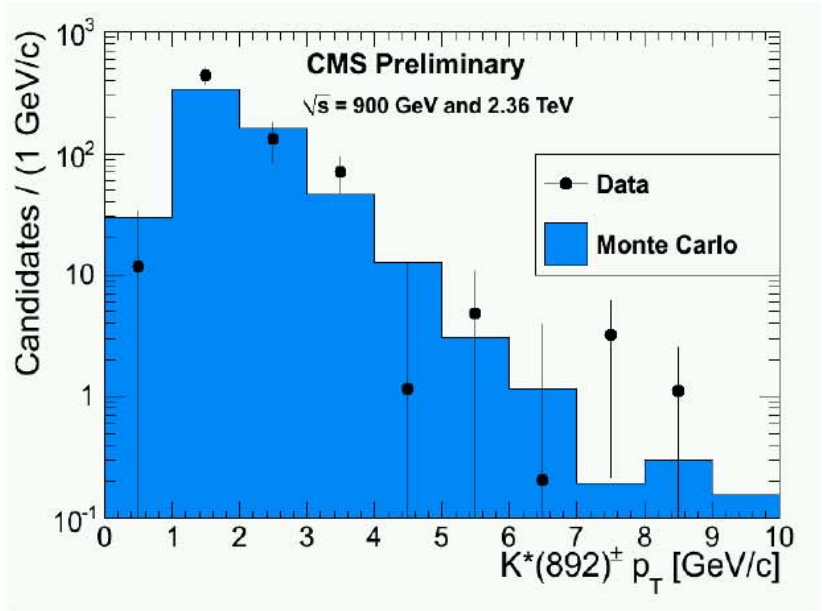
Goals for 2010:
top re-discovery and cross section measurement in dilepton and mu+jets channels

Tracking Studies with first Collisions

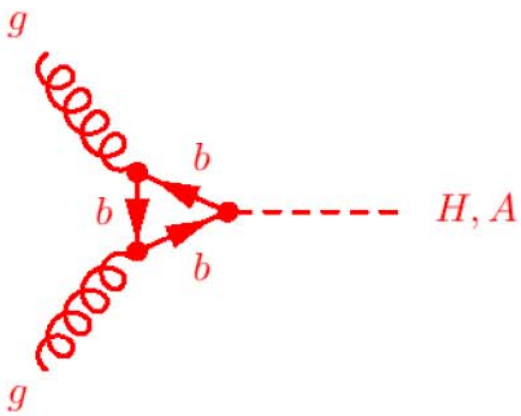
- Reconstruction of $K^*(892)^{\pm} \rightarrow K^0 s + \pi^{\pm}$ in first collisions at 900 GeV and 2.36 TeV
  - Analysis is a part of the CMS wide tracking validation effort
  - Contribution to the CMS Physics Analysis Summary (PAS-TRK-10-001)

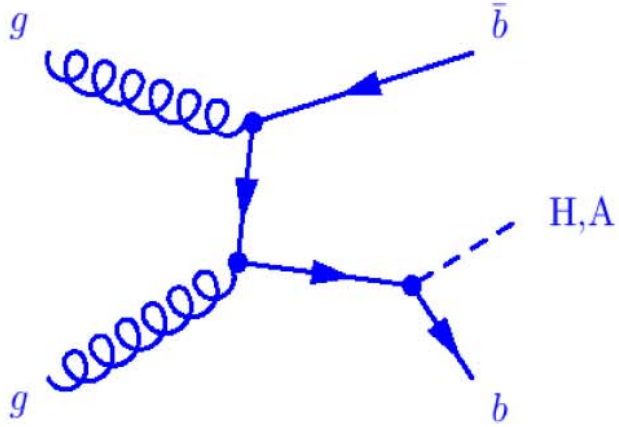




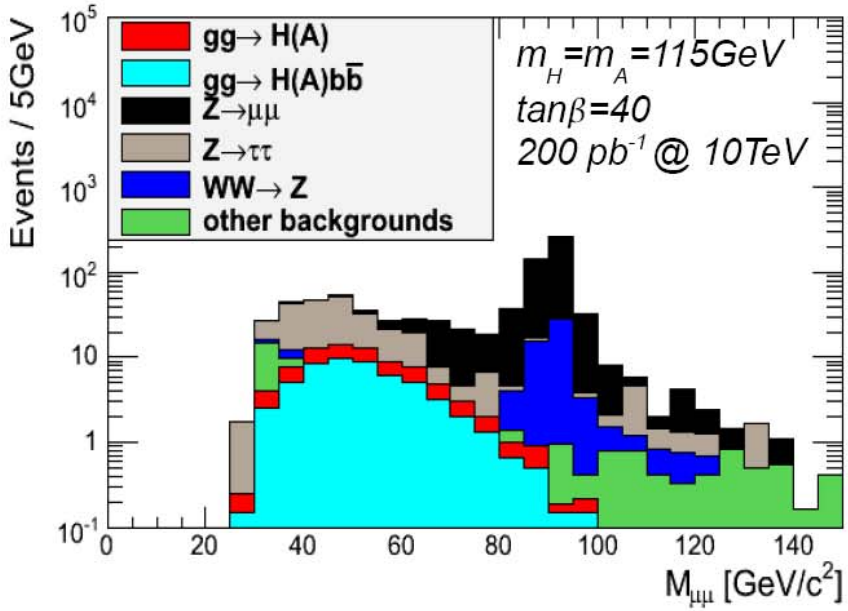


Supersymmetric Higgs Analysis



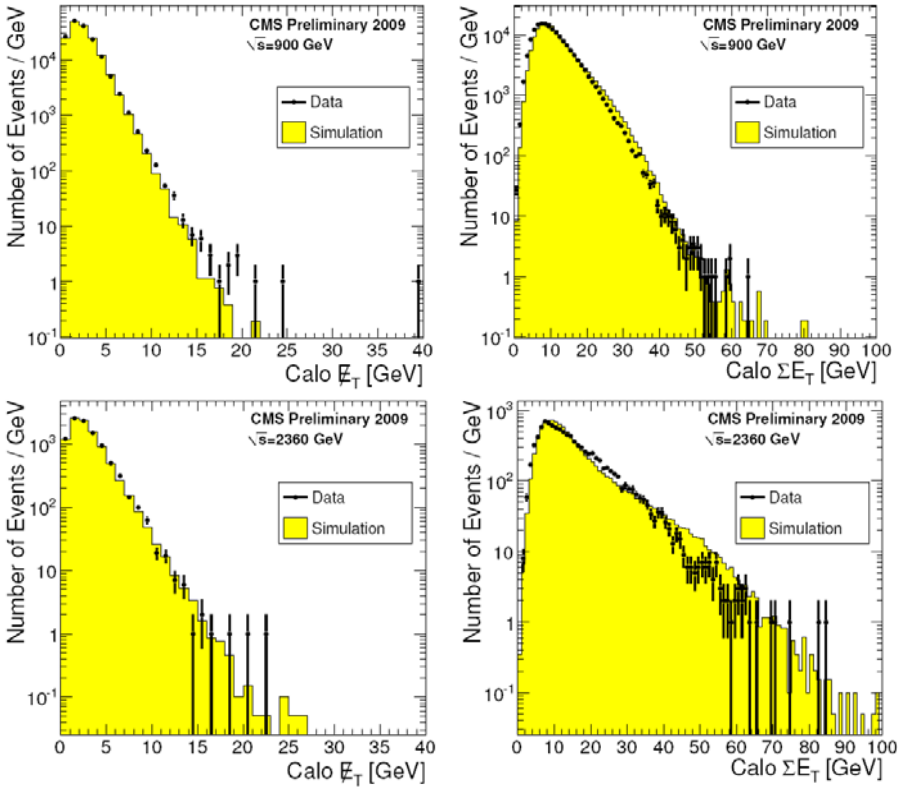


- Novel analysis searching for MSSM Higgs bosons via decay
  $H(A) \rightarrow \tau^+\tau^- \rightarrow \mu^+\mu^- + E_T^{miss}$
  - essential contribution to the signal significance
  - analysis included in combination of the MSSM Higgs searches at CMS



Data Quality Monitoring for SUSY

- Data is **monitored on short timescale** to make sure that everything is fine for the different analyses
- → Especially **important for SUSY analyses**, as signals are expected in the tails of distributions and therefore especially susceptible for detector problems (noise etc.)
- → Tested on 900 GeV and 2.36 TeV data and now applied to 7 TeV data



1 PhD student with support of 1 Postdoc working on this topic within the "SUSY CAF team"
(about 10 people working only on this subject)

Results published in Physics Analysis Summary PAS JME-10-002:
Performance of Missing Transverse Energy in 900 and 2360 GeV pp Collision Data

CMS and the Analysis Centre

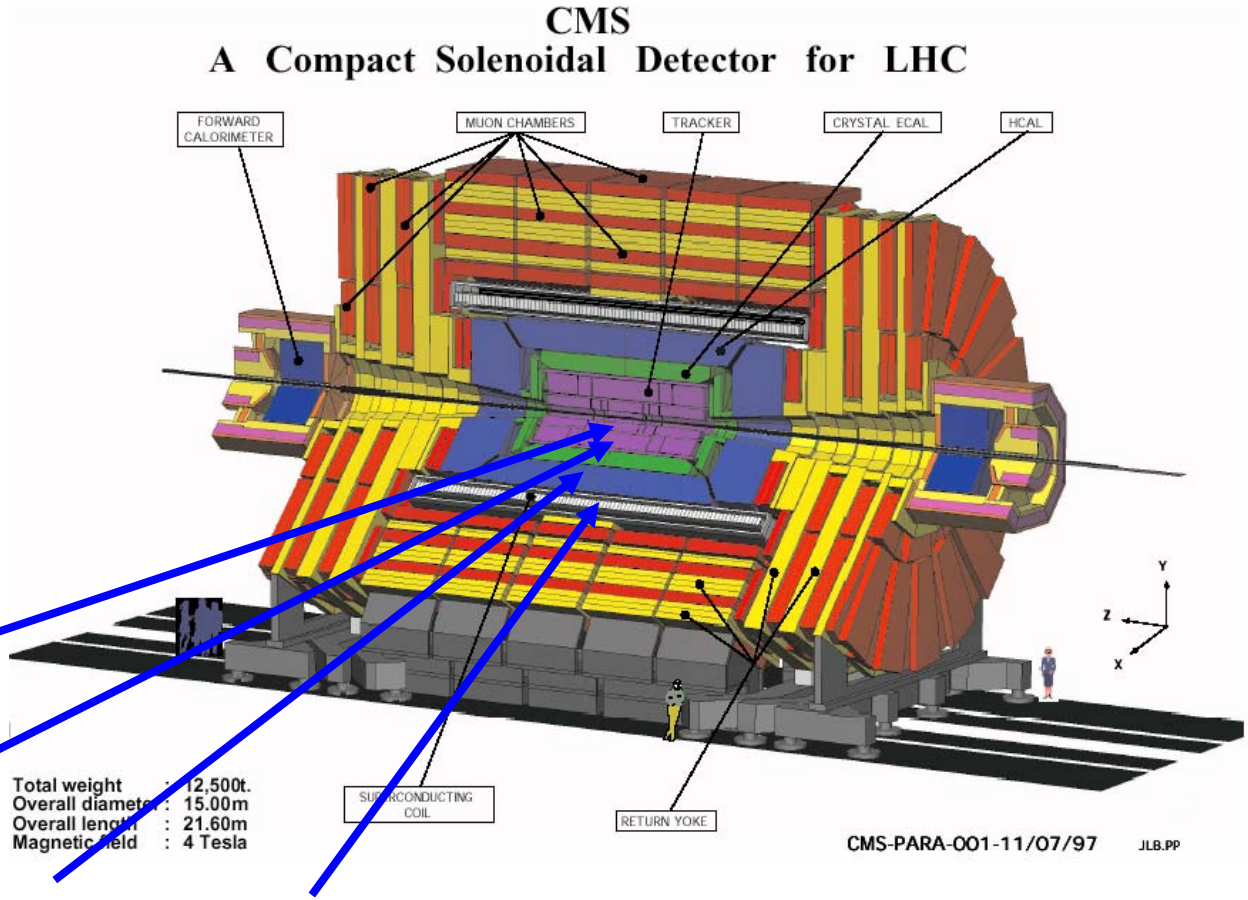
The Analysis centre of the Helmholtz Alliance “Physics at the Terascale” :

- Supports LHC (and ILC) physics analyses by
  - Schools and workshops (joint by many students and postdocs from CMS)
  - Develop MC, PDFs and Statistics tools

- Application of Analysis Centre projects in the field of statistics and MC (PDF) in CMS work:
  - Millipede → tracker alignment
  - Fitting tools developed in the Alliance Institutes (ROOSTATs, Blobelware, TMVA, etc)
  - Tuning tools for MC generators (PROFFIT)

- Analysis Centre initiating / coordinating common ATLAS-CMS-Theory discussion meetings
  - Starting in May 2010

DESY Activities on CMS Upgrades

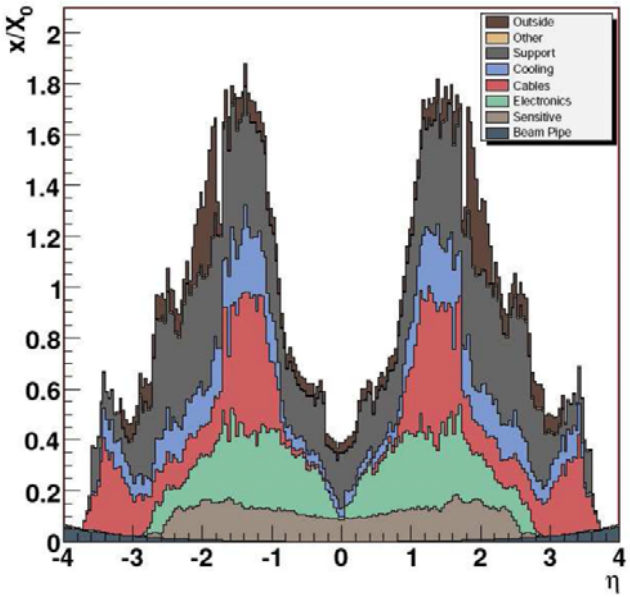


- Pixel
- Tracker
- SiPM for HCAL & MTT

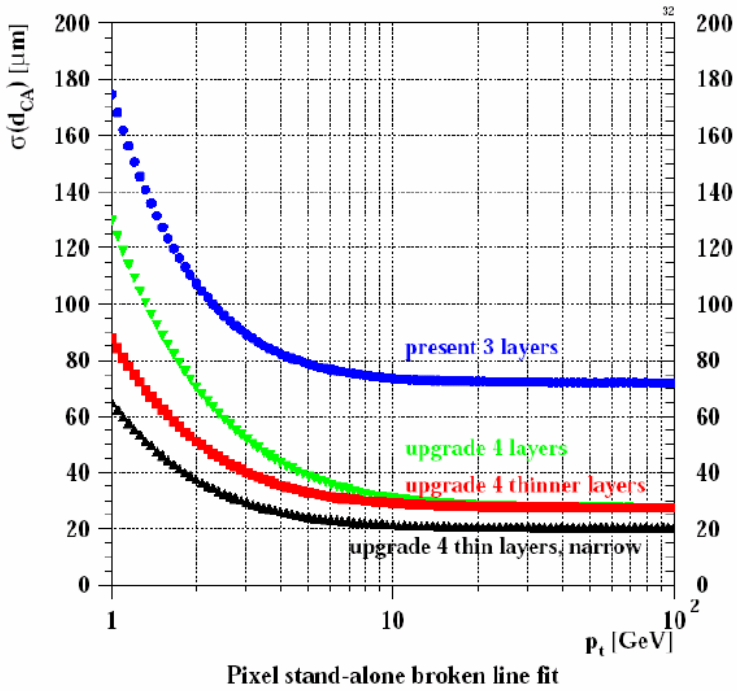
DESY Contribution to the CMS Tracker Upgrades

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

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

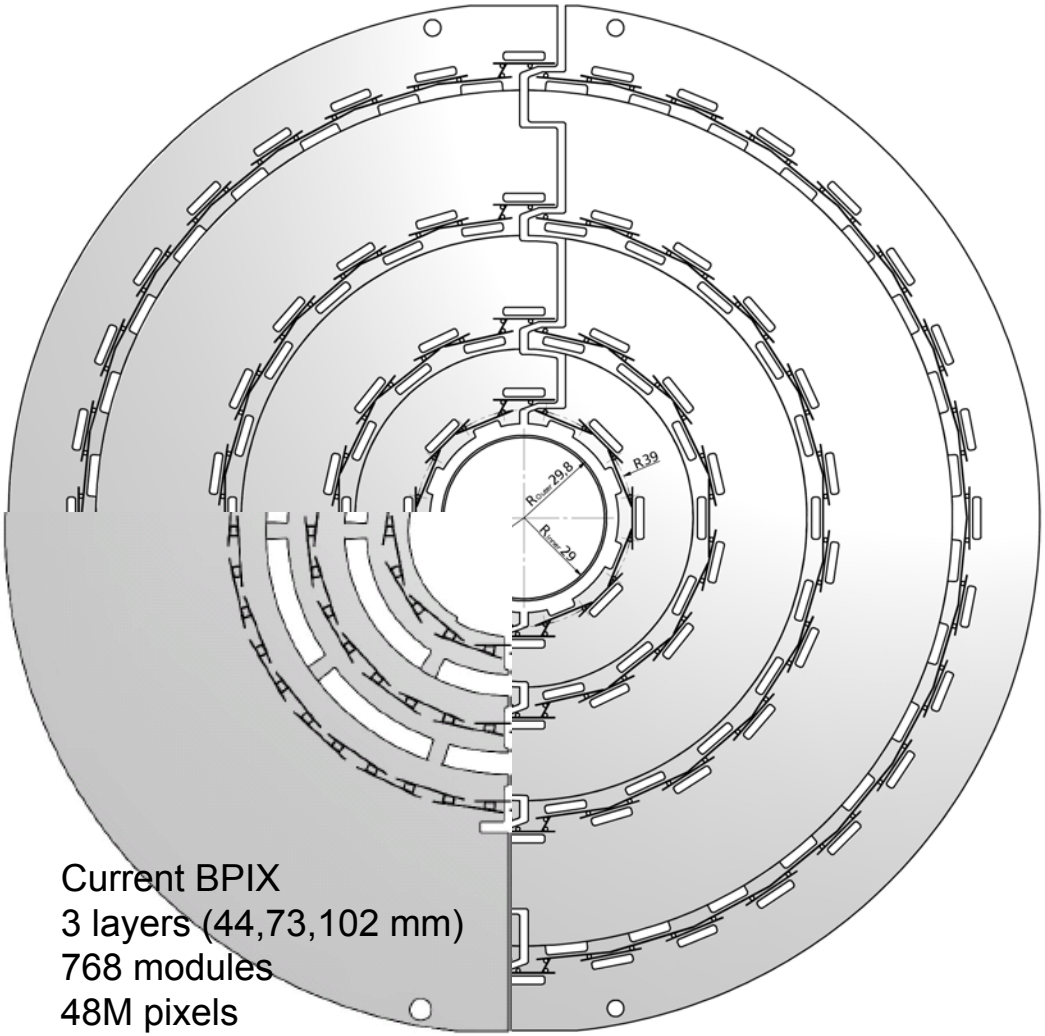


Tracker material vs η
(Current tracking configuration)



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

New Barrel Pixel for CMS



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

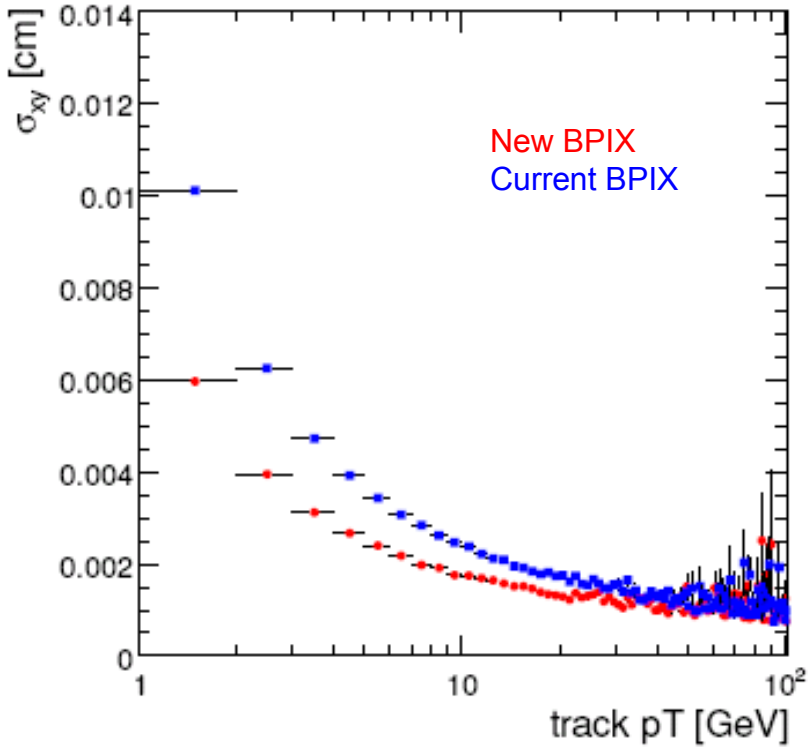
Possible new BPIX :
(Based on design proposed by PSI)

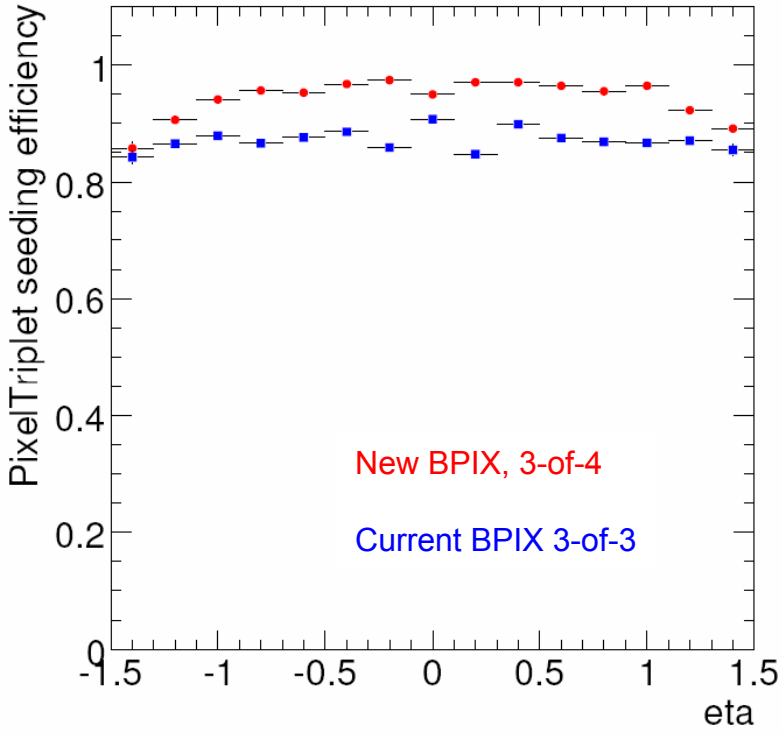
2 identical half-shells
4 layers @ 39, 68,109,160mm
1216 modules (79M pixels)

to increase performance :

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

Supporting Physics Studies (ttbar MC)



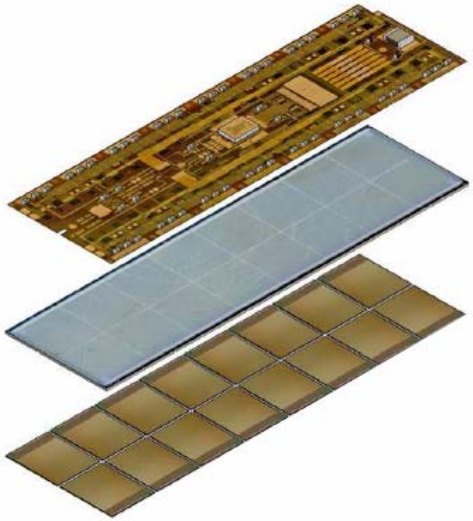


Improved impact parameter resolution due to lower material budget and inner radius of 39mm
(could be reduced to 29mm with beampipe radius ~ 23mm)

Impact on b-tagging under study

Improved triplet track seeding due to 4-th layer
(3 of 4 instead of 3 of 3)

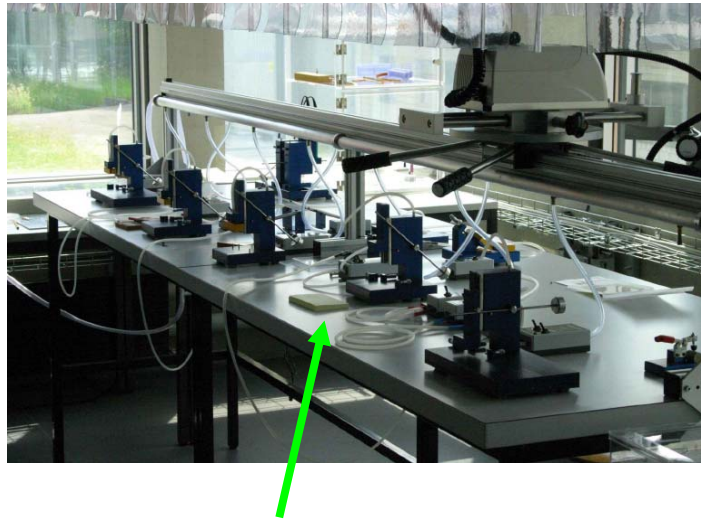
Barrel Pixel Module Production



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

Silicon sensor
16x64 mm^2
66'650 pixels

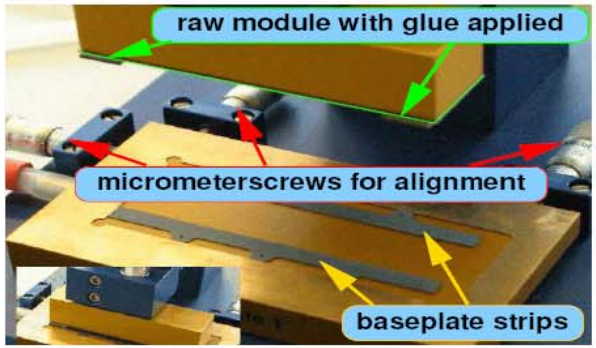
16 read-out chips
Bump bonded to sensor pixels
Wire bonded to flex print

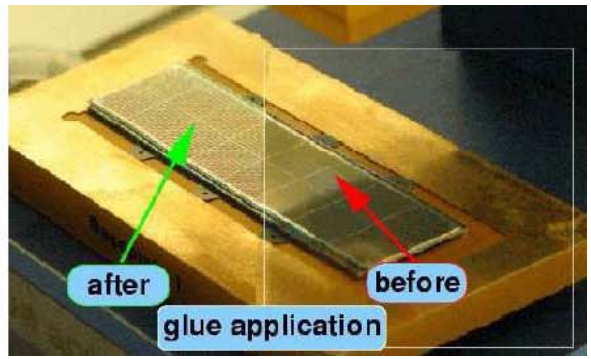


Production line at PSI

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

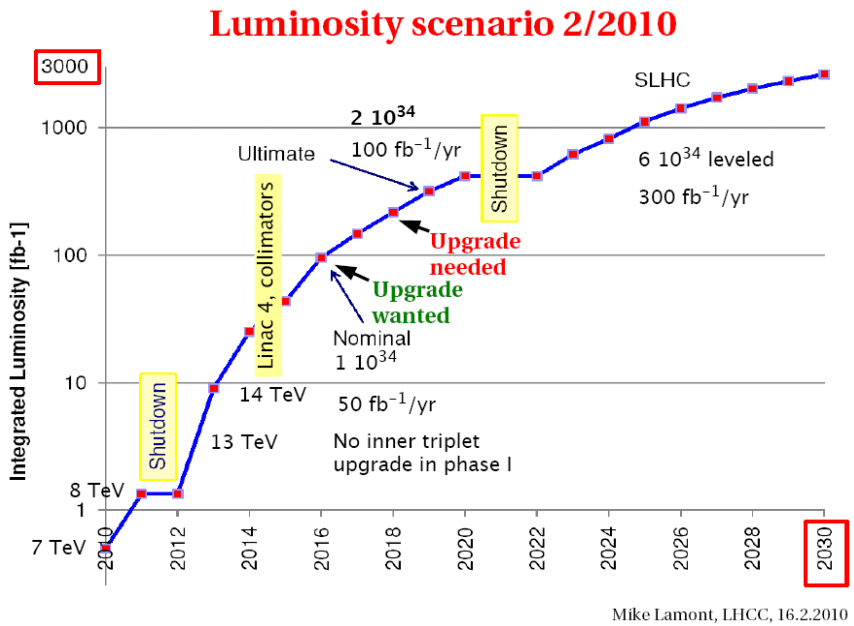
Tools for gluing from PSI - need to be rebuild





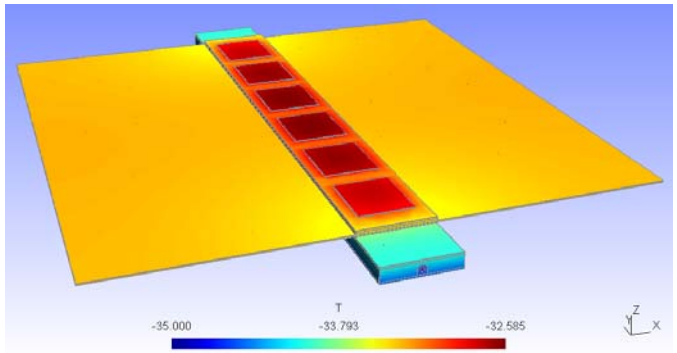
Barrel Pixel – Timeline & Resources

2010	Produce assembly tools Develop testing and calibration procedures
2010-11	Bump bonding tests
2011	Develop assembly procedures
end 2011	Decide on bump bonding techniques
2012	Establish assembly and test procedures Receive components for series production
2013-14	Module assembly and calibration
mid 2014	Layer system test at DESY
2014-15	Full system test at CERN
mid 2015	Ready for installation



Cost :
Assuming to build 4th layer = 700 modules (incl. spares and rejects)
Bump bonding : 1100 k€, material : 435 k€, tools : 345 k€, wire bonder : 300k€
To be shared by DESY, Hamburg, Karlsruhe and Aachen

CMS Outer Tracker for sLHC

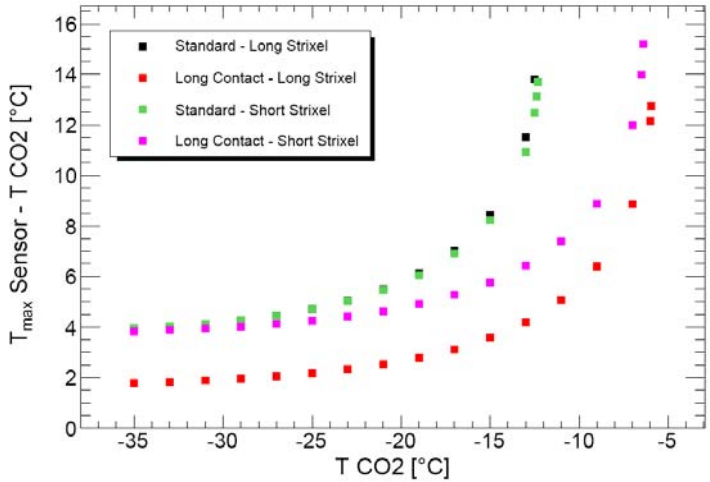


FE simulation of temperature distribution on a tracker module

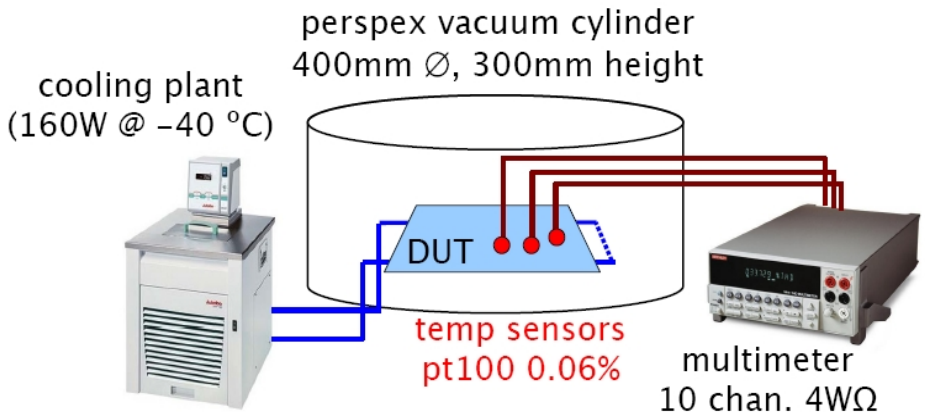
Starting with module design studies
- material budget optimization
- FE calculations (thermal & mechanical)
- verification of modeling with test setup

Goal
- Module assembly, test & integration

- Timeline modified after Chamonix
  TP ~2012/13, be ready for sLHC ~ 2020
  more time for R&D (ACIS, Electronics, Mechanics,...)



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



Laboratory setup for thermal tests

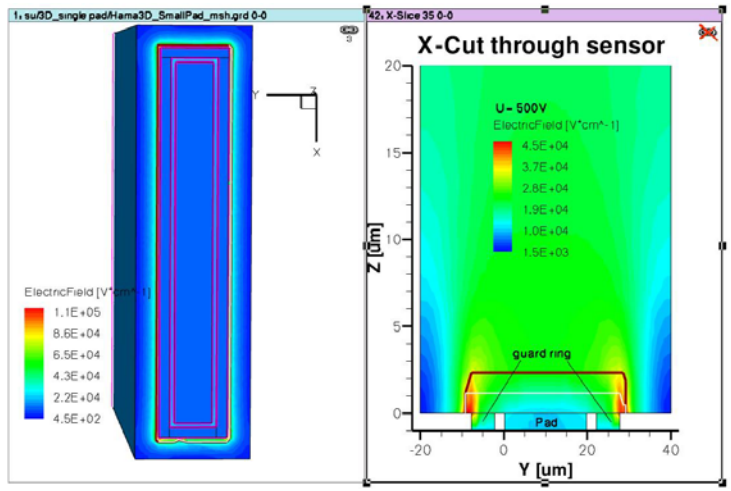
Silicon Sensors for sLHC

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

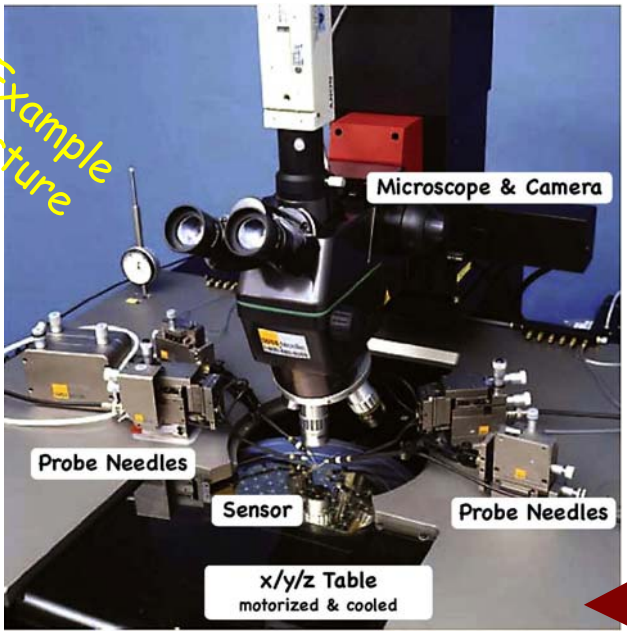
Participating in CMS upgrade project (CEC)

DESY (Zeuthen) responsibilities:

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



Field simulation of a sensor



Infrastructure :

Clean room ISO4 (10k)

Probe station ordered (PA200), equipped with:

- Cold chuck (min. temperature – 30º C)
- Dark box
- two independent needle sets
- Nitrogen flux

Silicon Photomultipliers for LHC

CMS-DESY Upgrade Proposal (PRC-2010-69-4)

Silicon PhotoMultipliers (SiPM):

Novel technology gaining strong interest → widely used in physics & medical applications as alternative to PMTs and APDs

HCAL for future LC:

prominent application in particle physics already long time of R&D
→ vast experiences from studying and operating SiPMs also on large scale
~8000 SiPMs in various test beam campaigns at CERN and at FNAL.

CMS Experiment : two applications for detector upgrades

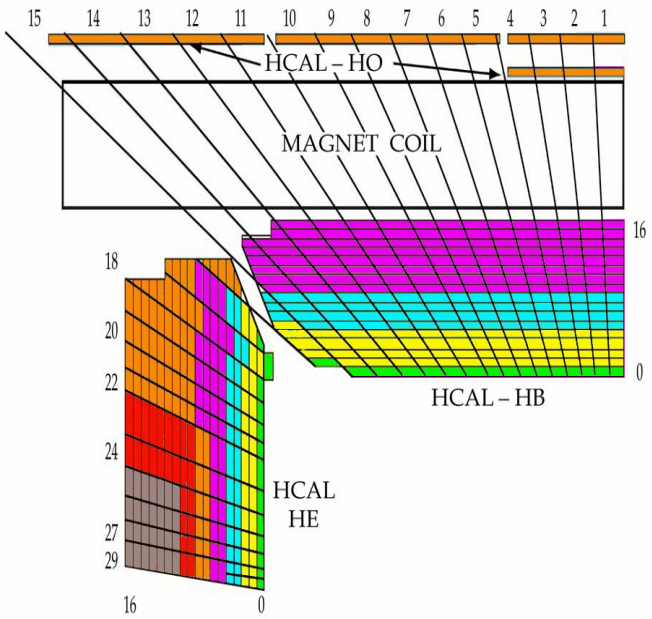
CMS HCAL group:

replace HPDs with SiPMs, performance upgrade, independent of LHC upgrade, schedule first step is replacement of HPDs in HO

CMS MTT (Muon Track Tag) group:

studies to enhance muon trigger ability by a layer of scintillators read out with SiPMs → HO replacement as a test-bed for MTT performance studies.

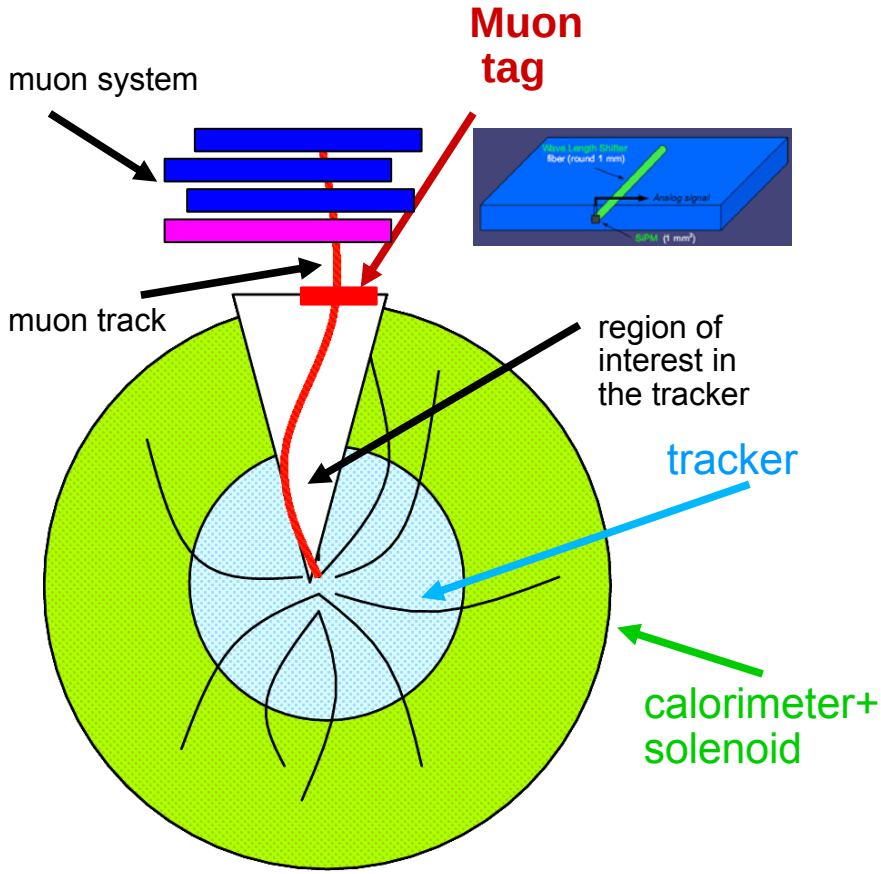
SiPM for HCAL & MTT Upgrades



Performance Upgrade for HCAL with SiPM, improved FE and new BE (µTCA)
→ longitudinal segmentation
→ weighting algorithms for energy reconstruction

DESY Interest :

- Contributions to SiPM sensor optimization → strong synergy effect with CALICE HCAL effort
- µTCA deployment for readout system synergy with CALICE and XFEL



To keep LHC L1-trigger rate (100kHz) at sLHC : Improve Muon trigger efficiency by better pT measurement with intermediate Muon Track Tag to identify track match within a region of interest inside tracker

LHC Computing

- Grid
- NAF
- ATLAS Computing
- CMS Computing

Grid and Grid-related Computing

- DESY operates a Grid Center spread over 2 locations Hamburg & Zeuthen
  - Support for various communities on a generic gLite based infrastructure
    - LHC: Tier-2 for ATLAS, CMS and LHCb
    - HERA: H1, HERMES, ZEUS
    - Linear collider: ILC, CALICE
    - Astro particle physics: IceCube, CTA
    - Lattice QCD: ILDG
    - Photon science: XFEL.EU
  - Participation in several Grid projects
    - WLCG/EGEE and NGI-DE
    - D-Grid

Central Service (mainly for HERA, ILC & Astro)

Service	Purpose
VOMS/VOMRS	VO registration
LFC	Global file catalog
WMS	Work load management

Resources

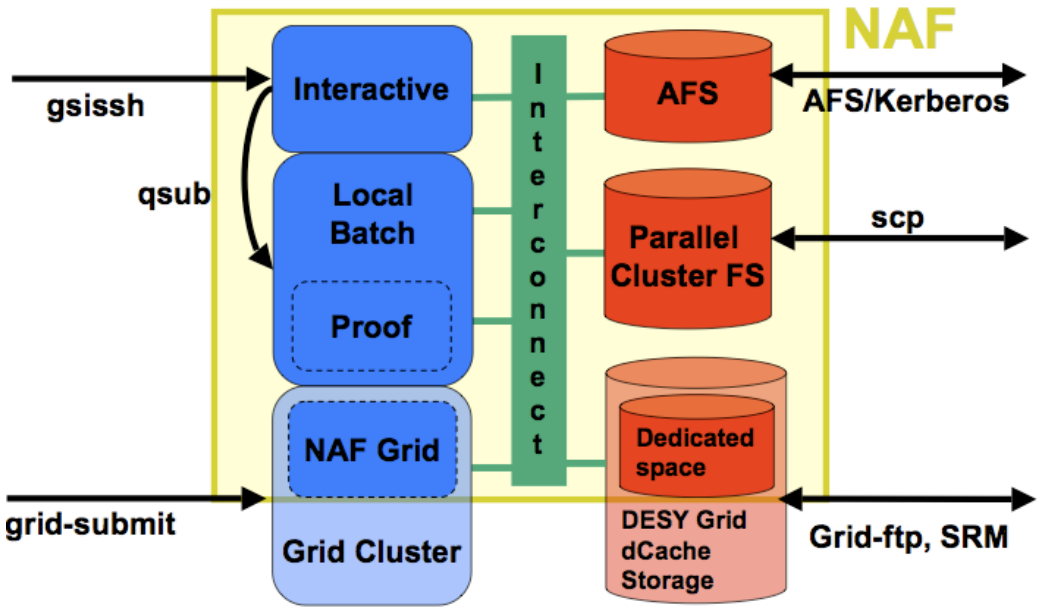
* without HERA

Site	Job Slots	Storage
DESY-HH	4300	1PB dCache*
DESY-ZN	670	1PB dCache

2010 WLCG Pledges fulfilled ✓

National Analysis Facility (NAF)

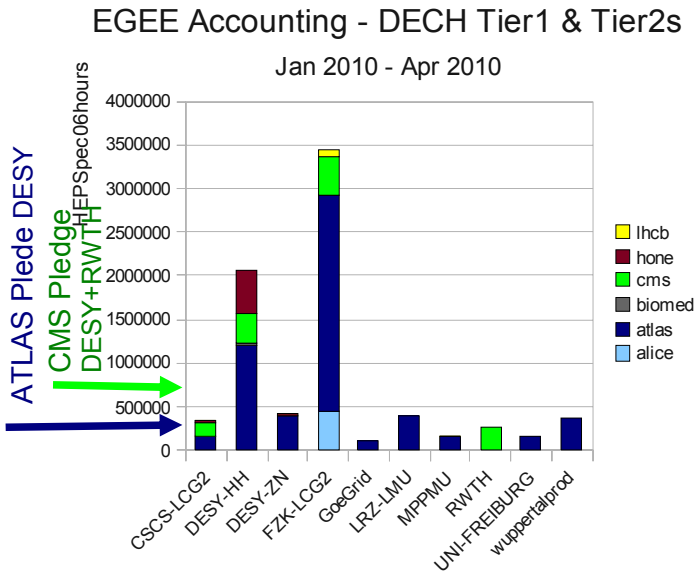
- Complements the Grid infrastructure
  - Interactive login
  - More flexible local batch system e.g. for PROOF
  - High performance storage space (Lustre)
- Part of the Helmholtz Alliance Physics at the Terascale
  - Supported experiments: ATLAS, CMS, LHCb and ILC
  - Open for members of all German institutes

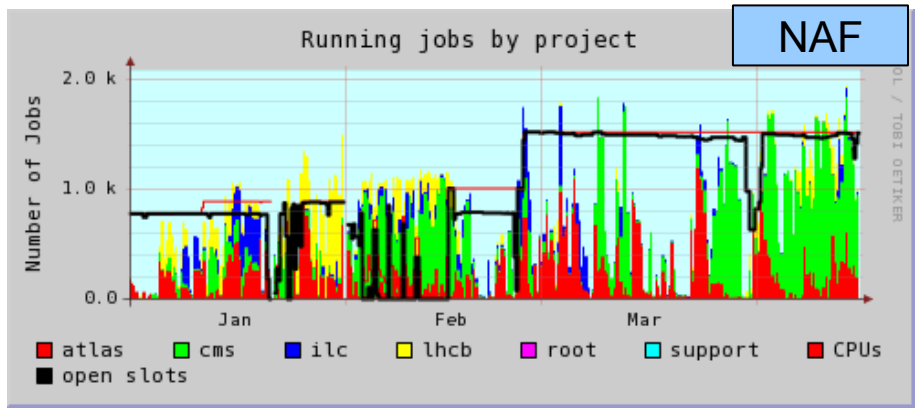


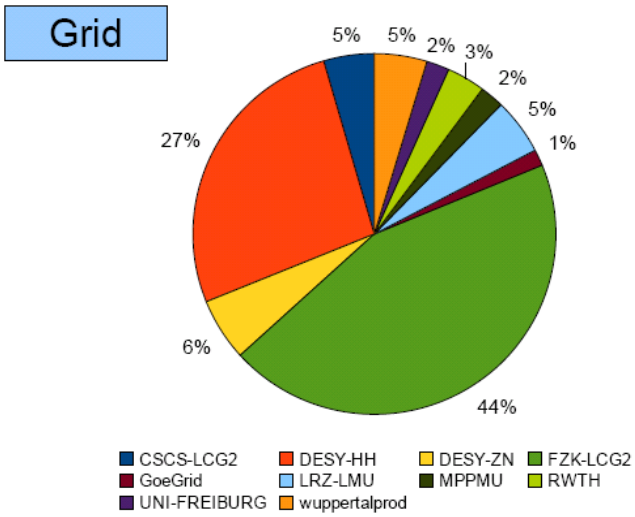
Resources (HH and Zeuthen)

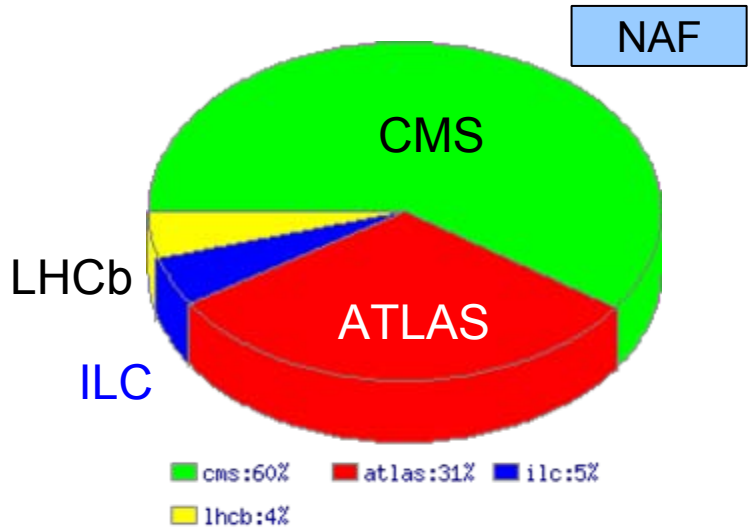
Site	Cores	Storage
NAF	1500	100TB Lustre

Resource Usage: Grid and NAF



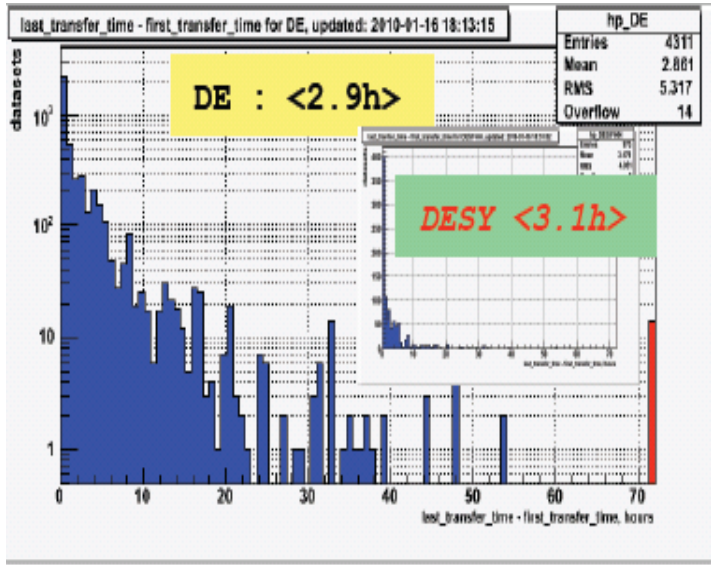






ATLAS Analysis @ DESY

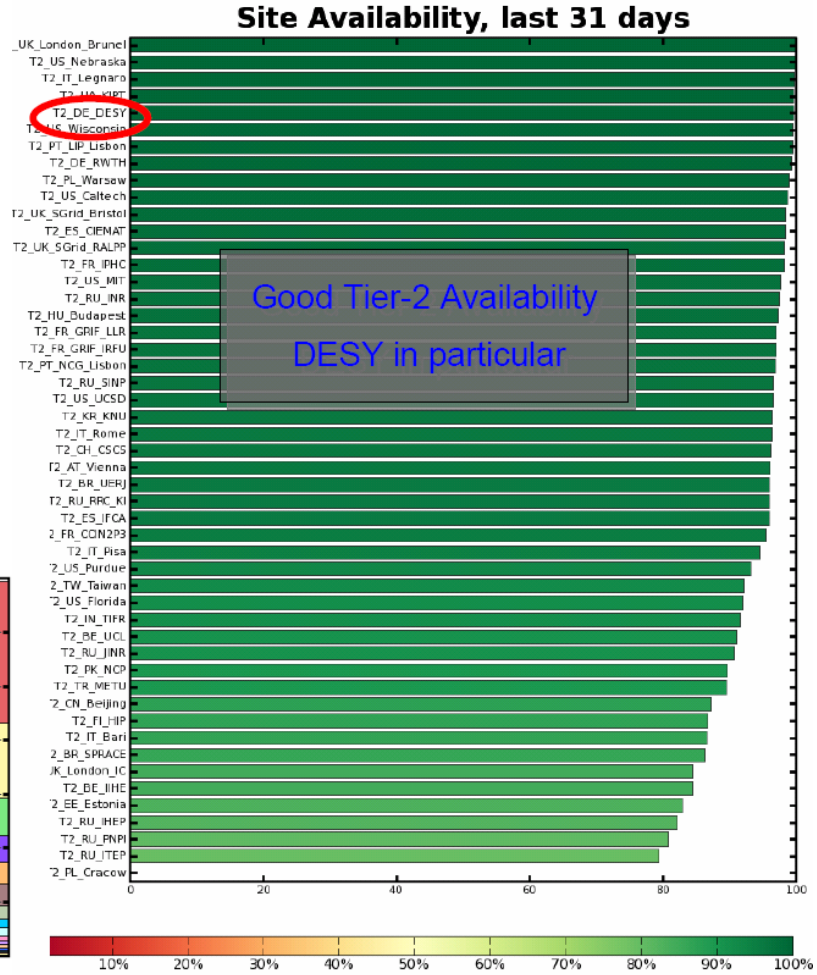
- Data import and storage is the key ingredient for fast data analysis
  - Prompt data distribution by ATLAS
    ~20min from T0->T1
    ~4h from T1->T2
  - Aim to keep all interesting data at DESY T2s
    -> Terascale contribution is essential besides WLCG contribution

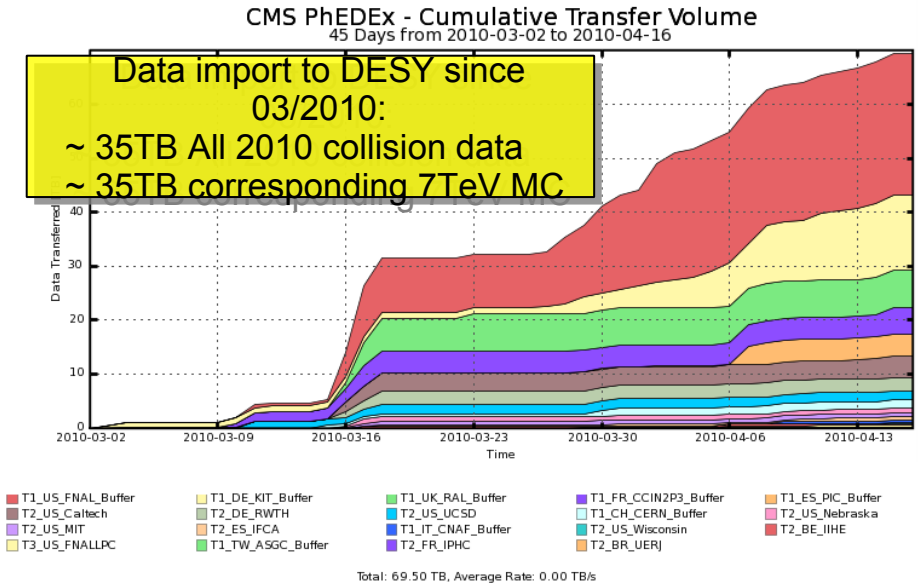


- Analysis experiences at the NAF
  - DESY ATLAS funded some CPU resources
  - With LHC data taking ATLAS probes the NAF design as an efficient analysis facility
  - First good experiences with 900 GeV analysis (~1 Mevents)
  - Tuning of analysis infrastructure (dCache, Lustre, software) for 7 TeV analyses (~10 Mevents) started
  - So far, NAF works!

CMS Tier-2 at DESY

- Reliable compute resource
- Actively used
  - MC production
  - User analysis





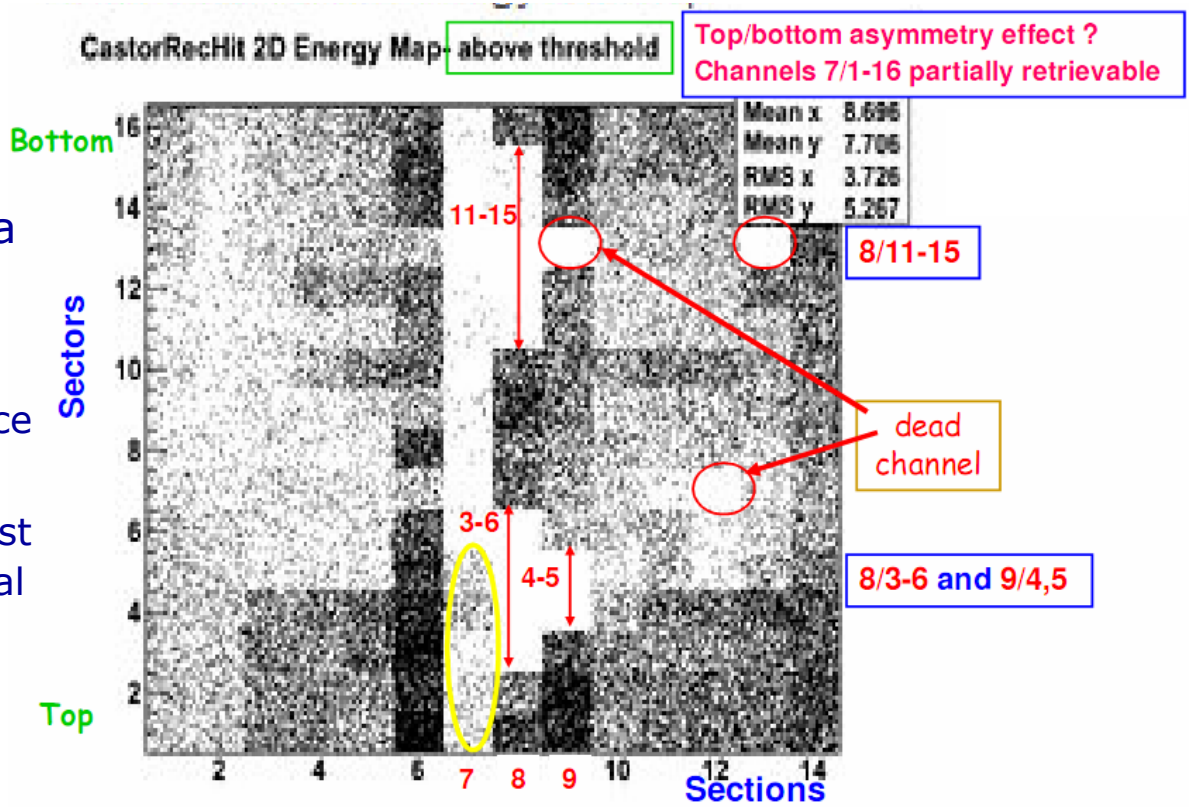
Summary

- CMS detector, software and analysis chain are in excellent shape
- CMS DESY is actively participating in key areas of management, operation & analysis
  (including DQM, Alignment, CASTOR, BCM1F)
- First CMS Physics results published, more papers in internal review
  (many noticeably contributions to papers & analysis from CMS DESY)
- CMS and the DESY group are well setup for the pb^{-1} of data to come in 2010
  (QCD, top rediscovery & high statistics measurements, signs of SUSY)
- CMS is reviewing its detector upgrade program this year (in view of Chamonix)
  (Strong participation of CMS DESY to the detector upgrade : pixel, tracker, SiPM for HCAL & MTT)
- Tier-2 and NAF at DESY are reliable, well suited and heavily used resources
  for the LHC physics analysis of ATLAS and CMS

Backup

Castor Operation

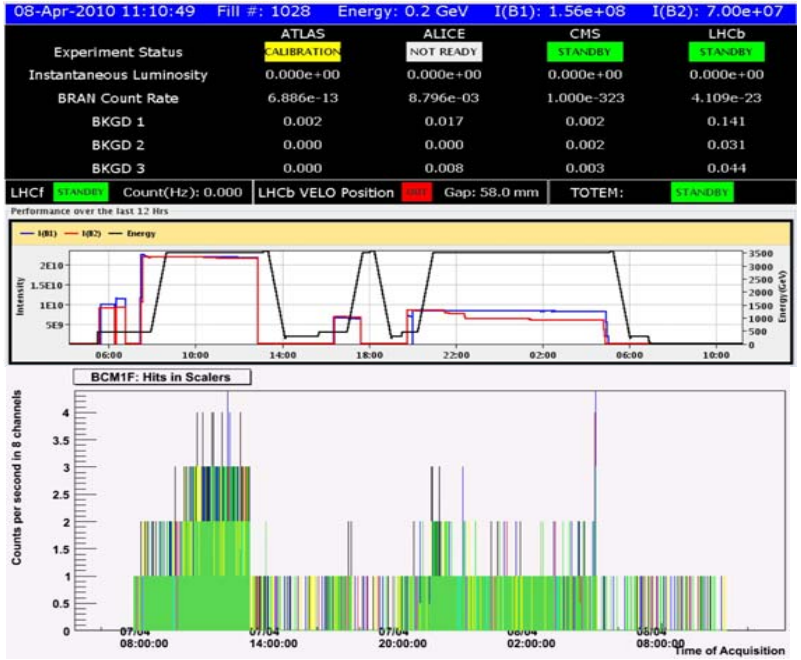
- CASTOR is in continuous operation and taking data
- Dedicated halo-muon:
  - →some channels with magnetic field disturbance might be retrievable
  - →Work is going on to adjust HV to have uniform signal
- CASTOR now fully integrated into HCAL → supervised by HCAL shifts and one dedicated CASTOR expert on call



- First physics analysis with energy flow ratio achieved pre-approval status,
- Plan for approval: finalize calibration, fine-tuning of CASTOR & CMS simulation, include also 7TeV data → hope for ICHEP

Beam Condition Monitoring (BCM1F)

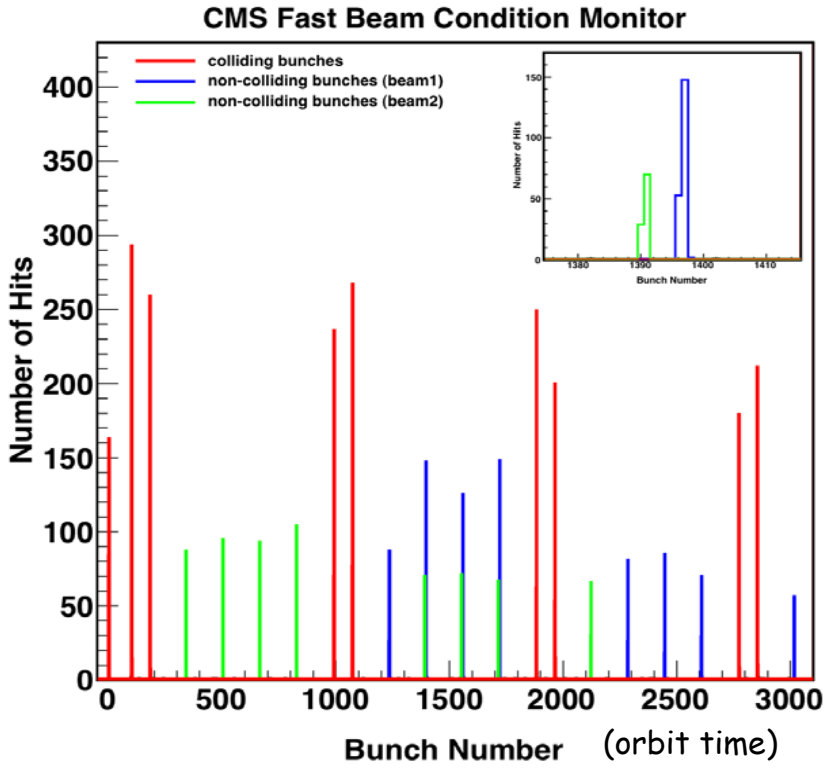
BKGD 1 (CMS) in LHC Control



http://op-webtools.web.cern.ch/op-webtools/vistar/vistars.php?usr=LHC3

Count rate of BCM1F sensors as a function of time → ensures safe data taking conditions

Bunch tagging (count rate vs. orbit)



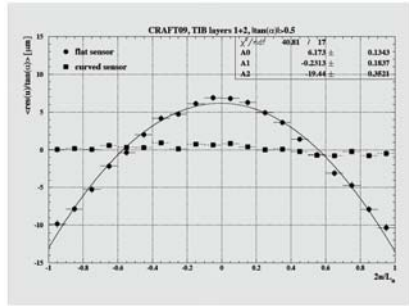
Signal arrival time vs. orbit time → tag of filled bunches (here 16x16)

Nucl. Instrum. Meth. A614:433-438,2010

Calibration & Alignment

- Alignment was well prepared for 7TeV data taking
  - Starting with tracker alignment from 2010 cosmics
  - AlCaReco skims production proceeds without problems
  - >> 10M alignment events from collision data already

- DESY group highly active in tracker alignment
  - Using beam halo muons for tracker alignment (A.Parenti)
  - Using Millipede for alignment (C. Kleinwort)

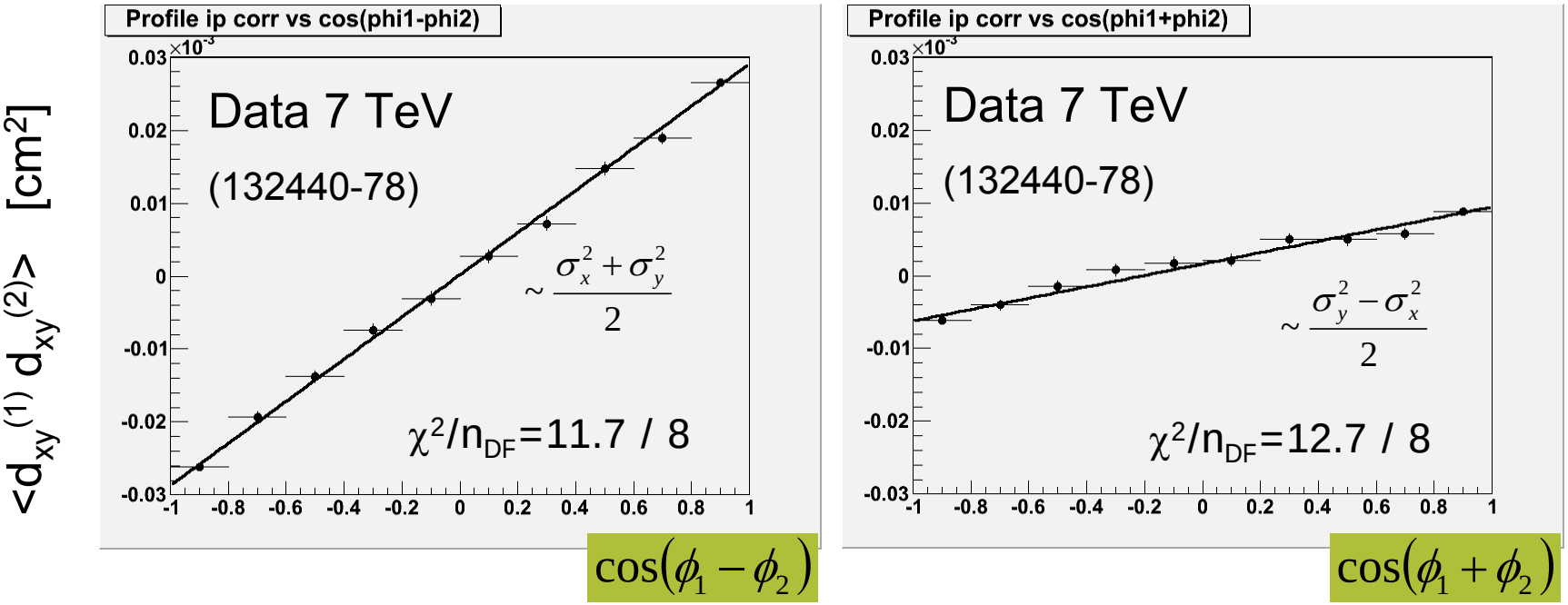


Sensor curvature from millipede fit

- Independent determination of beam spot
  - Determine σ_X and σ_Y from impact parameter correlations

    (method developed by ZEUS May 2006)

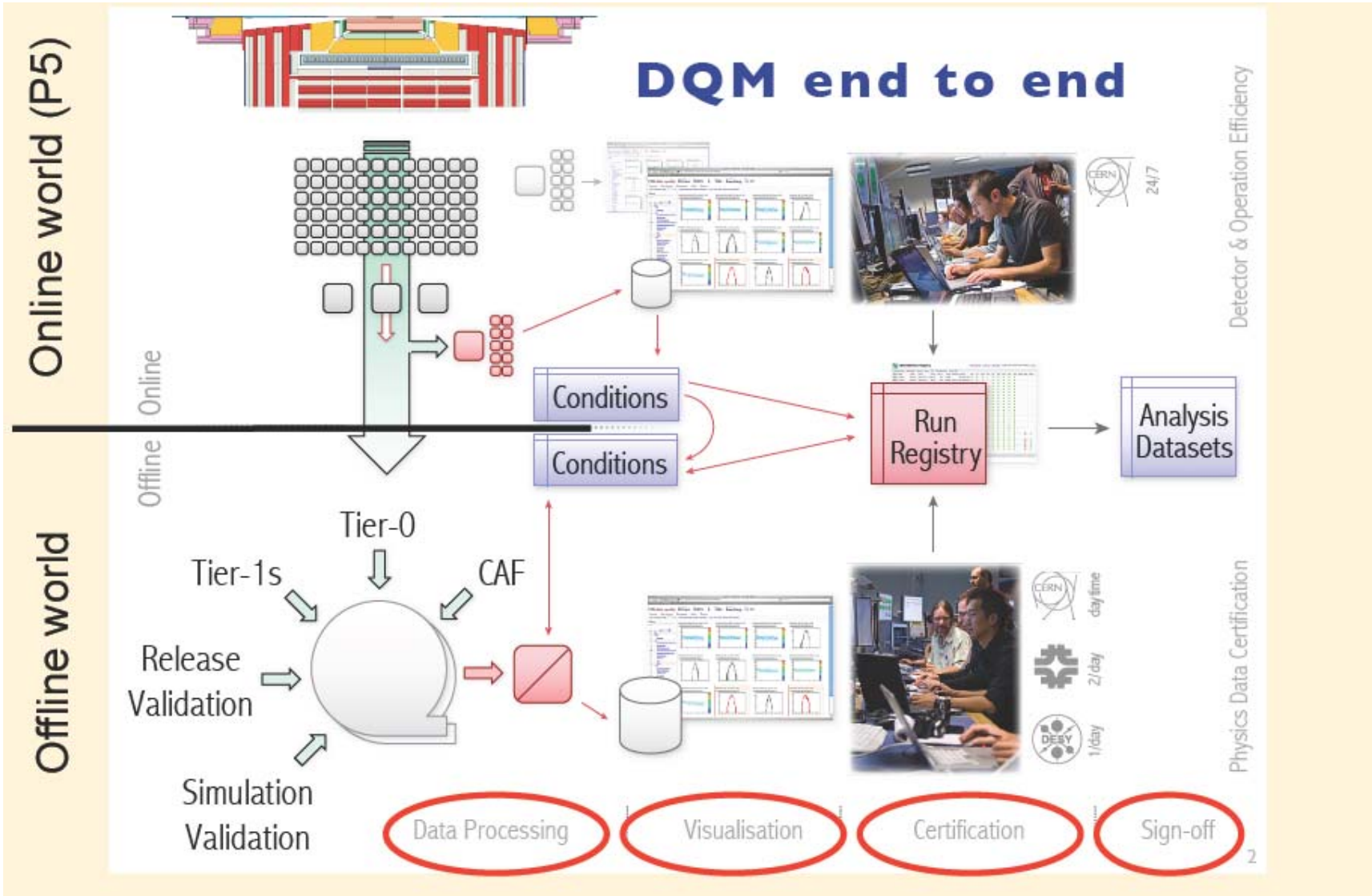
Separate Determination of σ_X and σ_Y from Impact Parameter Correlations



- Fit results:
  - σ_x = 45.9 ±0.5 μm (stat.)
  - σ_y = 60.6 ±0.4 μm (stat.)

→ in same ball park as measurements by S. Chauhan and W. Adam

DQM- Overview



DQM Status

DQM group is in charge of the complete end-to-end chain DQM system:

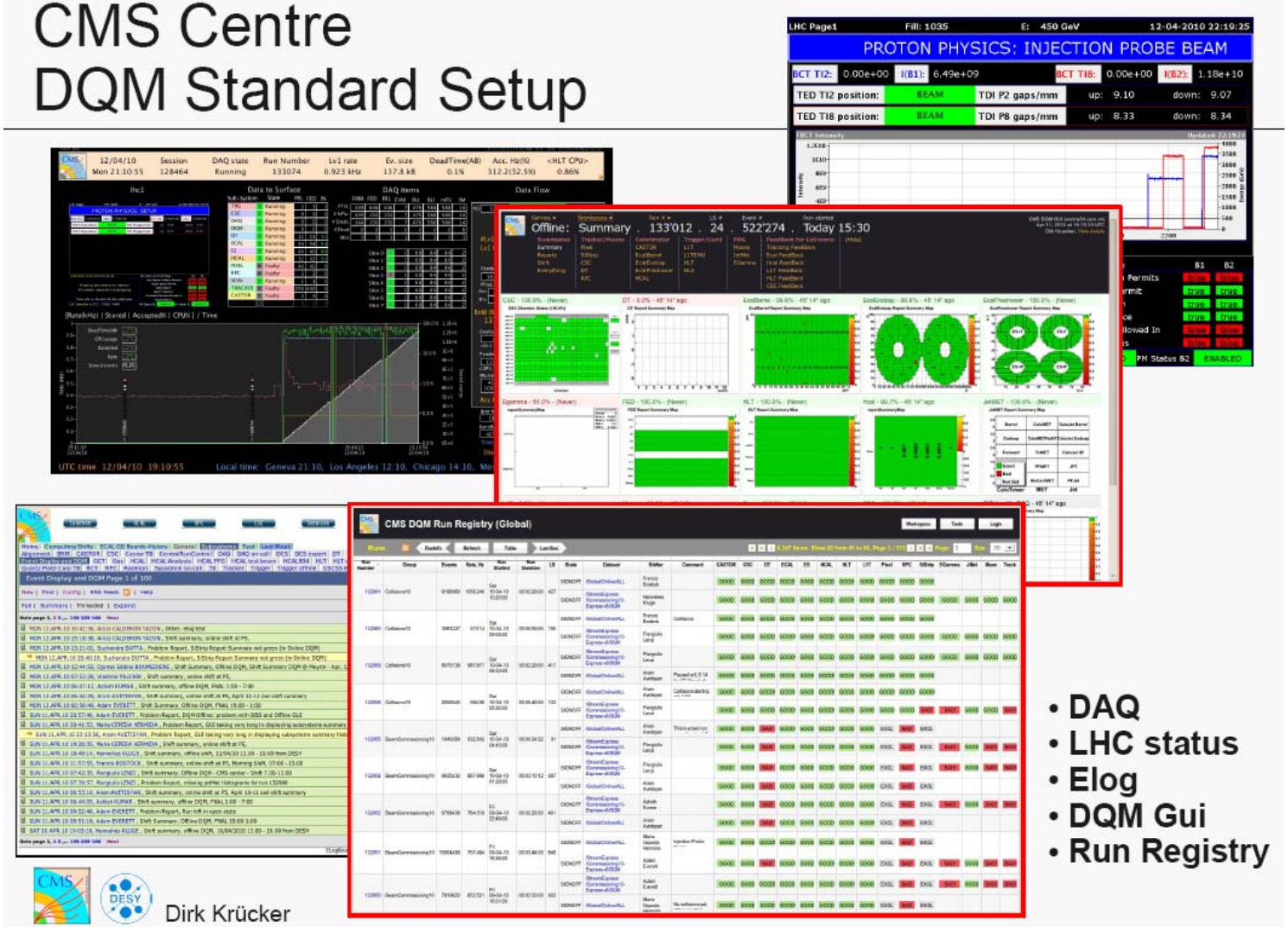
- CMS-wide development / implementation / standardization of the DQM-code
- Operation of DQM systems at the various places in order to make quality information publically available at a short timescale
- Evaluation of the data quality, the certification of 'good runs' and the subsequent data certification procedures
- Organise shift activities, maintain shift documentation, train shifters

System is vast and robust and running smoothly, but many developments still needed….

For DESY

- excellent opportunity to make contribution (outside of hardware development);
- provides visibility -> ensures DESY remains in the landscape of remote centers

CMS Centre
DQM Standard Setup



CMS offline DQM shift from remote Centers since start of 2010 running
4 shifts(6h) per day : 1xMeyrin, 1xDESY, 2xFNAL

7 TeV Media Event in the CMS Center

Online Media (incomplete list) about LHC
with reference to DESY

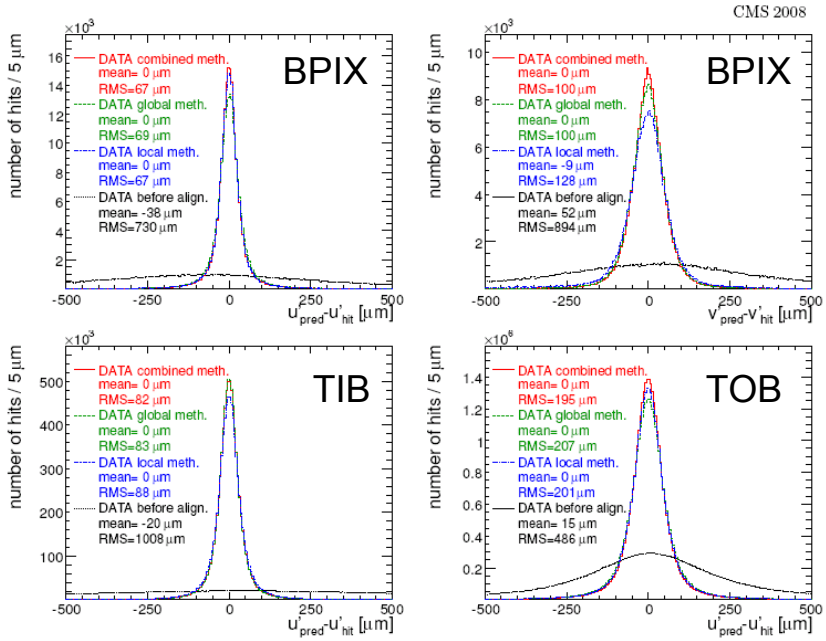
- **Hamburger Abendblatt**
- Stuttgarter Zeitung
- **Bild.de**
- Südwest Presse Online
- **Spiegel Online**
- tz online
- Maerkische Oderzeitung
- **n-tv.de**
- Lausitzer Rundschau
- BZ-Berlin
- Mitteldeutsche Zeitung
- Salzburger Nachrichten
- **Handelsblatt**
- Grenz Echo
- Märkische Allgemeine
- Lausitzer Rundschau
- Elbe-Jeetzel-Zeitung
- Passauer Neue Presse
- Stadtzeitung Augsburg
- Augsburger Allgemeine
- Oberpfalznetz
- Berliner Zeitung
- **FOCUS Online**
- Schwaebische Zeitung Online
- **Stern**
- **Welt Online**
- Mittelbayerische Zeitung
- ...

Dirk Krücker

→ **CMS Centre creates Visibility**

CMS Technical Papers

- 23 technical papers from cosmic tests (J.INST 5, March 2010)
- Two of them with active participation from DESY :
  - CMS Data Processing Workflows during an Extended Cosmic Ray Run, JINST 5, T03006
  - Alignment of the CMS Silicon Tracker during Commissioning with Cosmic Rays , JINST 5, T03009



Comparing track residuals before and after alignment (three different methods)

global method with Millipede II (V. Blobel)
with active participation of Uni-HH and DESY cooperating with the statistics tools group of the Analysis Center of the HGF Terascale Alliance

- Institutional review of 2 papers

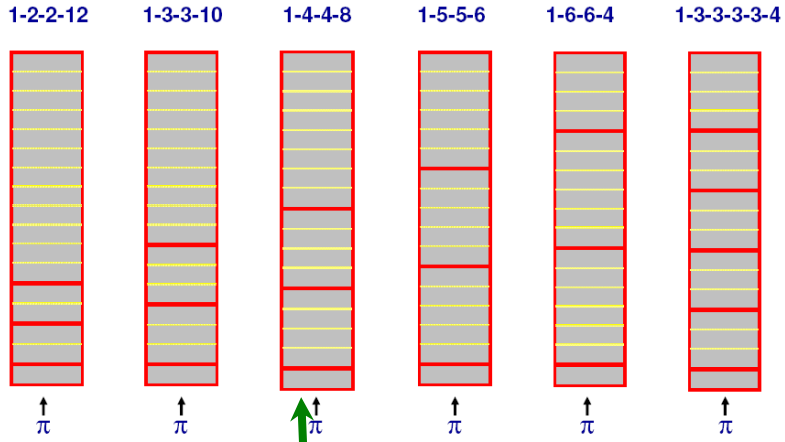
Supersymmetry (mainly YIG)

- Group established in May 2009
  - 1st postdoc started in June, 2nd position in process of being filled
  - 1st PhD student started in August, 2nd started in February
  - 3rd PhD student (started in December 2008) also joined the group
- Data analysis for this data taking period (2010/2011):
  - Participation in leptonic „Reference Analyses“
  - Main focus on measurement of missing transverse energy (MET) and on electron measurements
  - Participation in Lepton Commissioning Team of the SUSY group
- CMS contribution:
  - Development of offline data quality monitoring (DQM) tools within the SUSY Prompt Validation and Physics Commissioning team
  - Studies for the upgrade of the HCAL
  - Central shifts (DQM) at DESY (CMS Center) and CERN

HCAL Upgrade – Weighting Method

Recent work:
Study of different readout designs with 4 or 6 instead of 1 channel (4 channels currently planned for upgrade Phase I)

$$\left(\frac{\sigma(E)}{E}\right)^2 = \frac{92.2\%^2}{E} + 6.5\%^2$$



Best design

Design	after weighting sampling term	after weighting constant term	improv. Sampl. Term [%]
1-2-2-12	86.0	5.3	6.7
1-3-3-10	87.4	4.8	5.2
1-4-4-8	85.4	4.4	7.4
1-5-5-6	86.9	4.6	5.8
1-6-6-4	88.4	4.4	4.0
1-3-3-3-3-4	84.3	4.5	8.5

Results described in conference report (CMS CR-2010/028) and in an internal note (work in progress)

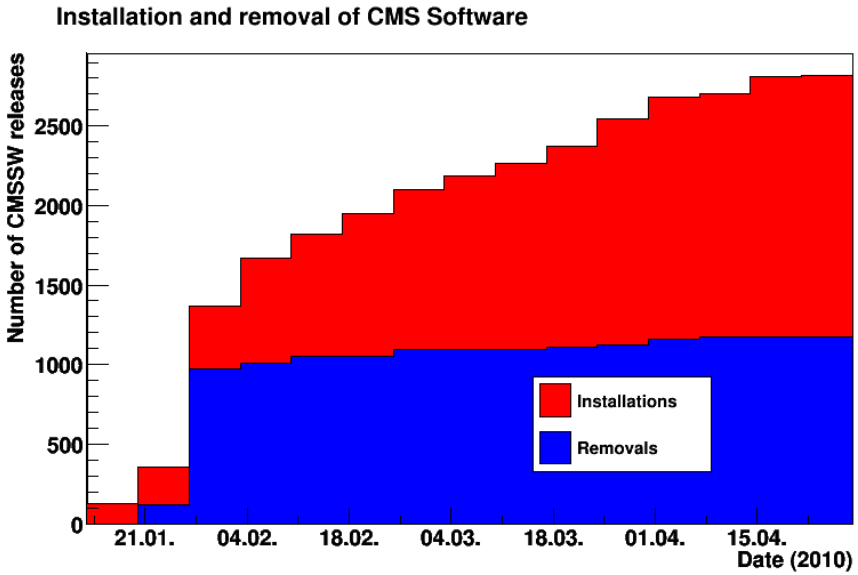
Longitudinal segmentation allows weighting procedure for compensation of $e/\pi \approx 1.2$
➔ improve linearity and energy resolution

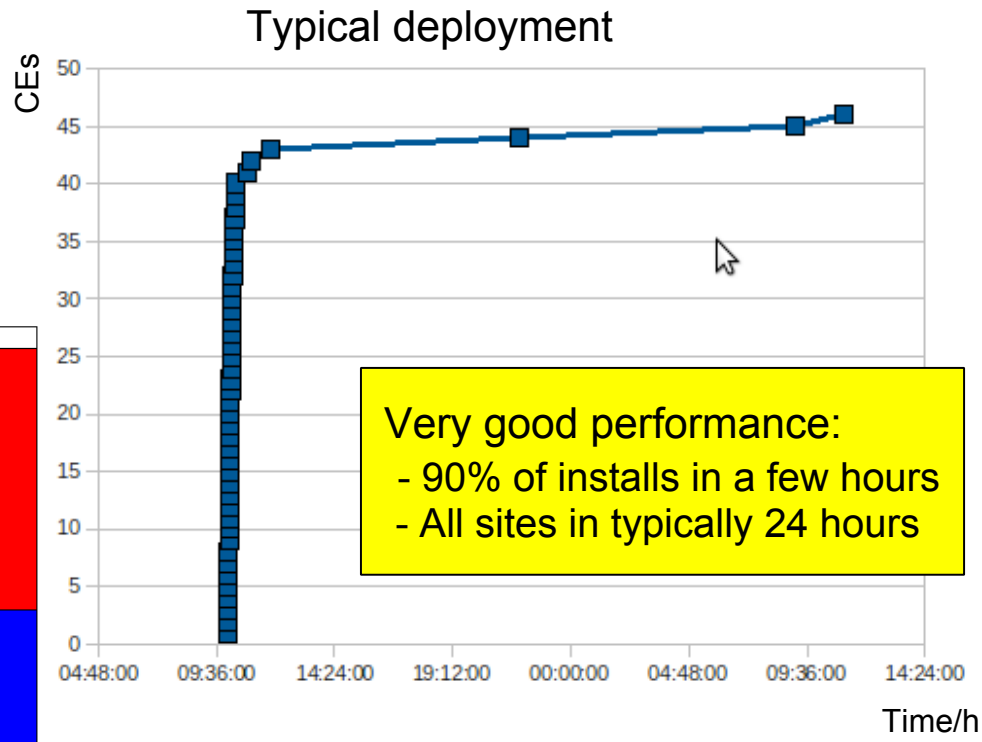
µTCA

- New Standard to replace VME to overcome deficiencies in backplane data throughput and flexibility
- high speed serial connections instead of low speed parallel bus
- In common with VME: standards for crates, backplanes, power supplies, connectors, board form factors
- Key technology for upcoming or upgraded detectors and accelerators :
  - Data acquisition systems: throughput of serial links is high enough to transport all the data of a detector, an XFEL detector for example
  - Control systems: wide range of commercial boards is available and can be combined with custom boards. High data rates allow for digital steering and control: XFEL accelerator
  - Trigger systems: CMS for example. While the existing main vertical data paths are fast enough to transport all the detector data there is a lack of fast and standardized horizontal interconnects to combine the data of readout units for monitoring and triggering for HCAL, ECAL and their regional triggers for example
- Need for standard definition (PICMIC @ DESY) and need for widely spread expertise and experts in many areas easily predictable
- Possible entry scenario: readout stand for test beam:
  - crate,
  - controller = mch (microTCA carrier hub),
  - readout card(s) = amc (Advanced Mezzanine Card)
- For CMS: many open questions, many unassigned tasks, join now
  - Even w/o test beam or test beam detector valuable participation in common efforts possible
    - for example work on protocol to be used on serial links: udp, tcp/ip

CMSSW Deployment

- Present DESY responsibilities
  - Coordination of installations at European and Asian CMS sites
    - 6 Tier-1 and ~40 Tier-2 and Tier-3 sites
  - Improvement of tools
    - More automation
    - Increased reliability





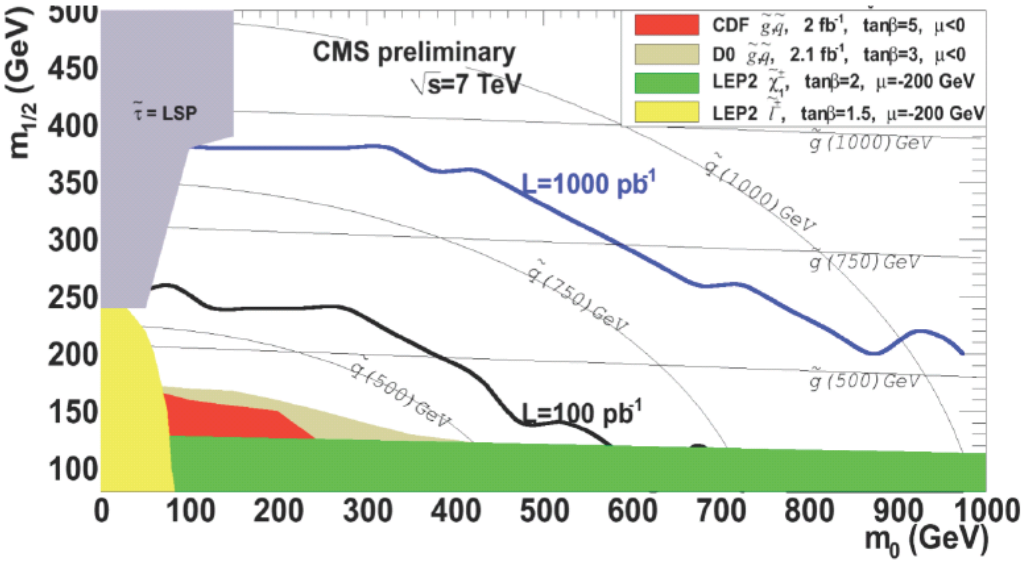
Physics Prospects for 2010

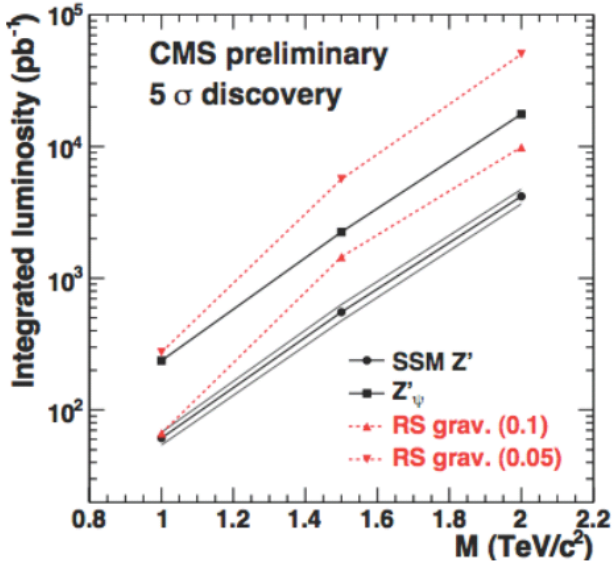
Major goals for 1-10pb^{-1}(summer 2010)

CMS has understood the Standard Model at 7 TeV and is ready for the search for new physics: careful understanding of the detector performance, of the basic tools and of the major sources of background from QCD and EWK.

Major goals for 10-100pb^{-1} (winter 2010)

Precise measurements of the SM at 7 TeV. High statistics measurements of the top. Search for early signals of SUSY and Exotica (extradimensions?).





G. Tonelli, CERN/Pisa *RRB_30* *April 19, 2010* *34*