HELMHOLTZ GEMEINSCHAFT

Status of CMS at DESY

María Aldaya

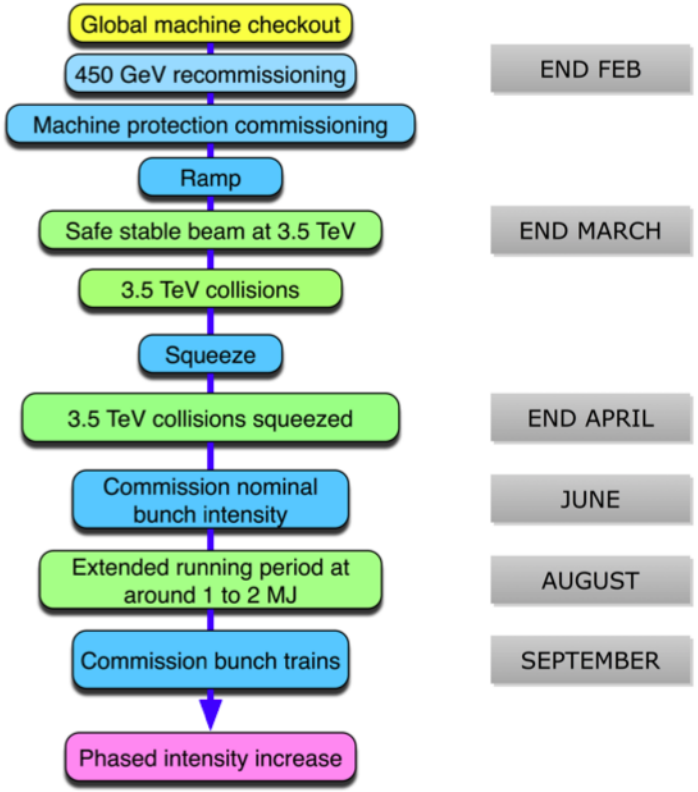
for the DESY CMS group

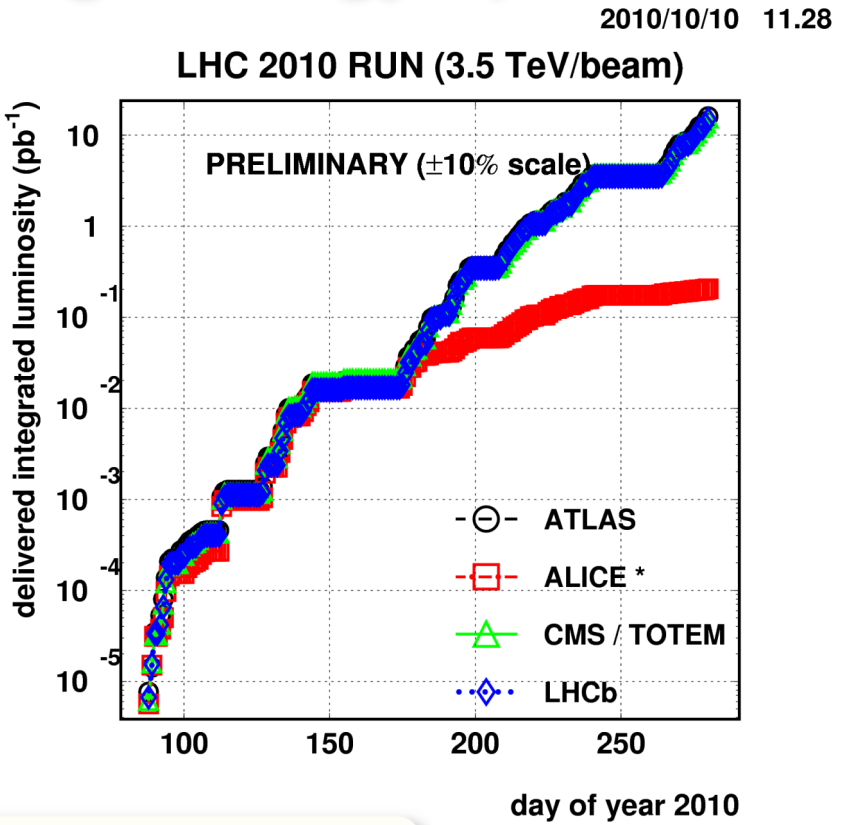
DESY-PRC-70 Open Session, Zeuthen, 14-10-2010

Outline:

- LHC Status
- CMS Status
- CMS DESY Activities

LHC 2010: First year of high energy operation





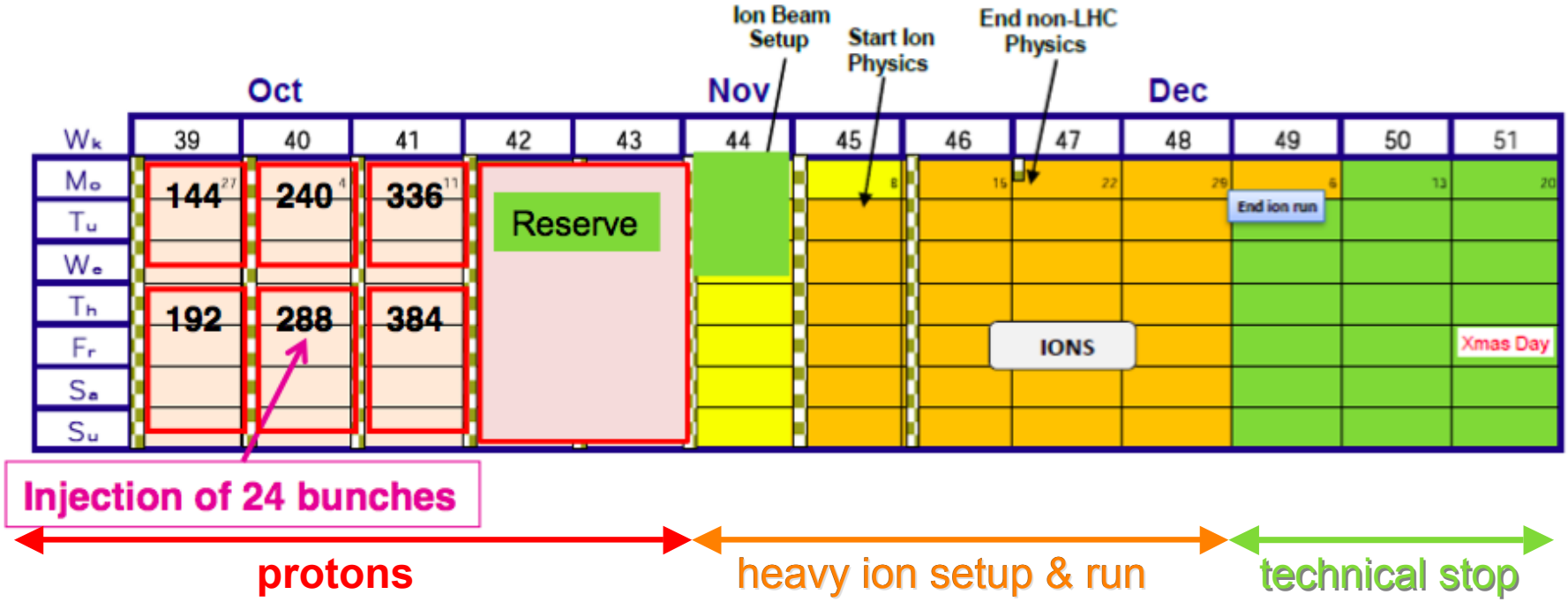
As of 30th September…	LHC design	now
Momentum at collision, TeV/c	7	3.5
Luminosity, $cm^{-2}s^{-1}$	1.0E+34	3.5E+31
Dipole field at top energy, T	8.33	4.17
Number of bunches, each beam	2808	50 --> 500
Particles / bunch	1.15E+11	1E+11 (up to 1.3E+11)
Typical beam size in ring, µm	200 – 300	300-500
Beam size at IP, µm	17	59

6th October:
200 bunches/beam
(**11.2MJ/beam**)
Record luminosity:
6.8×10^{31} $cm^{-2}s^{-1}$

Schedule 2010 / 2011

Ambitious schedule for 2010:

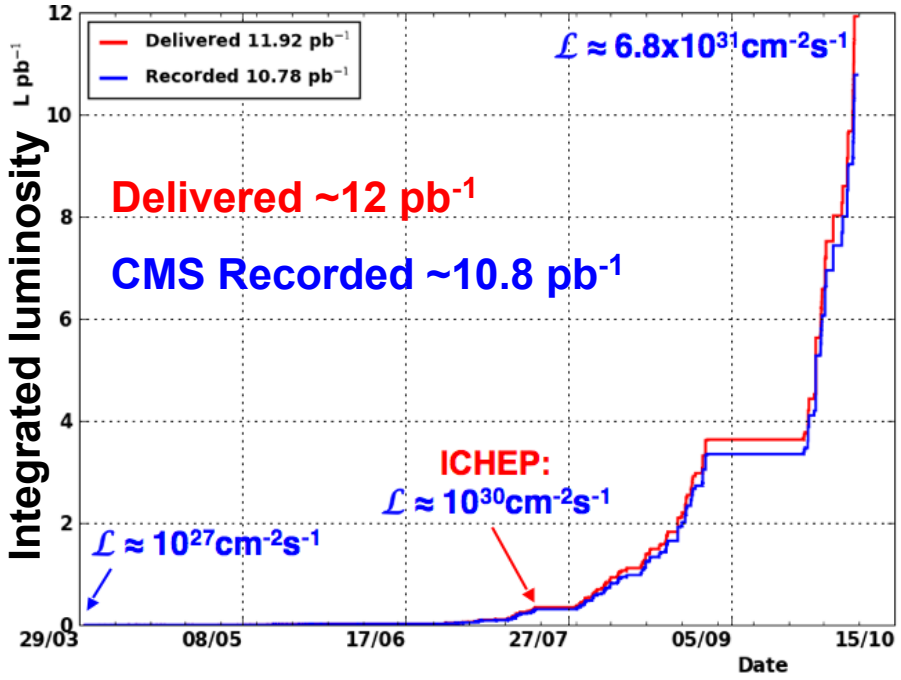
increase #bunches, 2 steps every week, to get to L = **10^{32} $cm^{-2}s^{-1}$** by end 2010



Plans for 2011:

- Restart 4th February, 3.5 TeV
- 9 months protons, 4 weeks ions
- Integrated luminosity target driven – **1 fb-1**

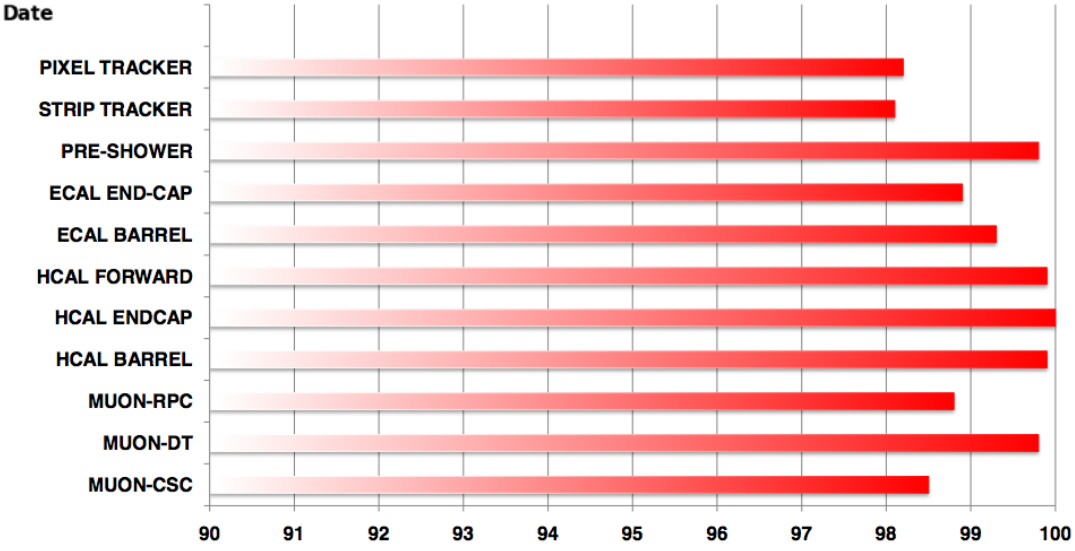
CMS 7 TeV operations since March 30th



CMS data taking efficiency **> 90%**

Good performance in coping with 4 orders of magnitude increase in instantaneous luminosity $\mathcal{L}$!

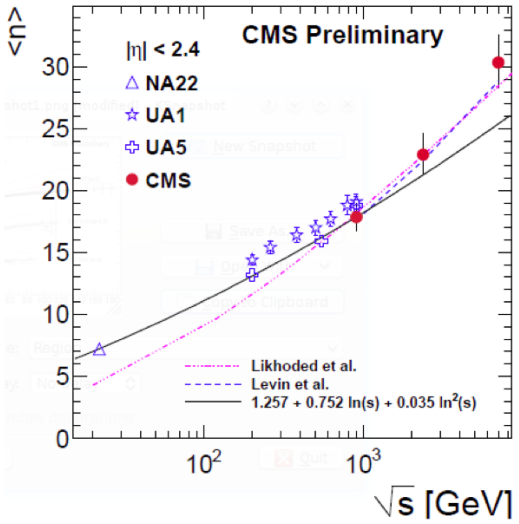
Subdetector operational status



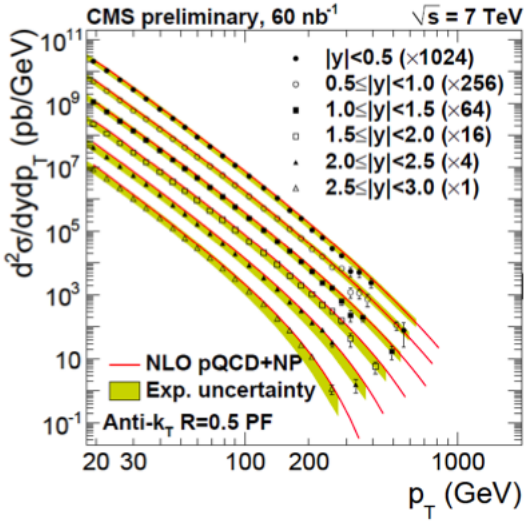
All subdetector components operation at the level > 98%

Some recent CMS results

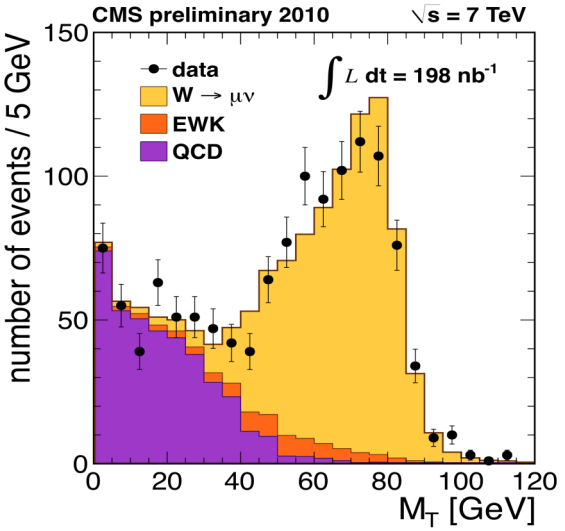
Charged particle multiplicity



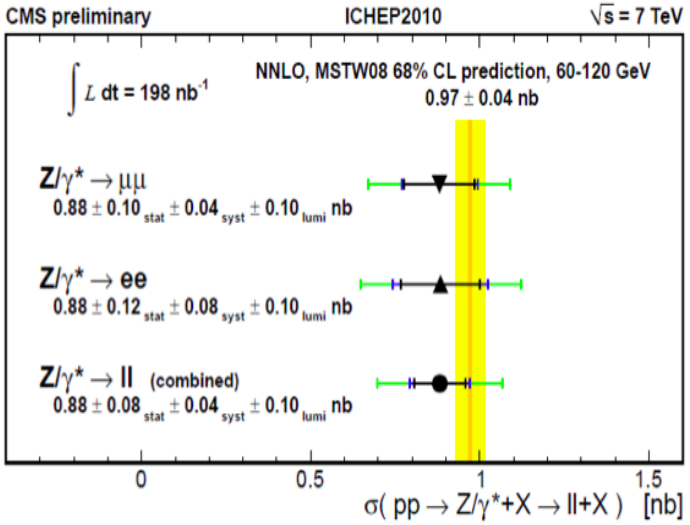
Inclusive Jet production



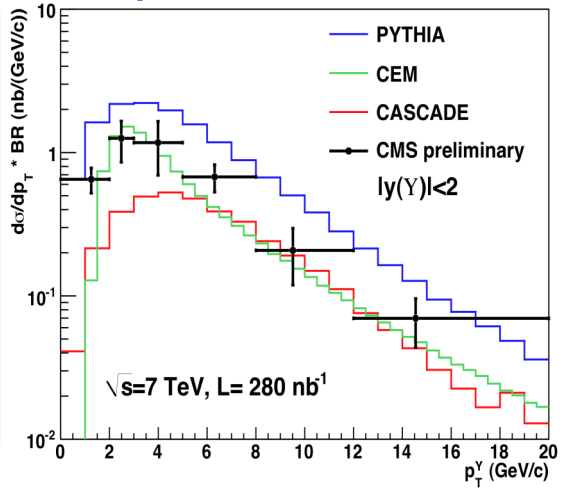
W in mu channel



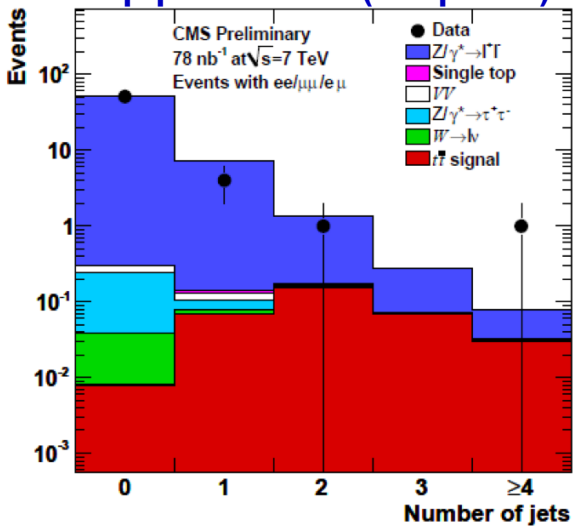
Z cross section



J/psi diff. cross section



top production (dileptons)



First physics: CMS publications

CMS published papers and preprints on physics results (since last PRC) :

- ***Search for Dijet Resonances in 7 TeV pp Collisions at CMS***
  Submitted to Phys. Rev. Lett ; arXiv:1010.0203
- ***Observation of Long-Range, Near-Side Angular Correlations in Proton-Proton Collisions at the LHC*** *J. High Energy Phys.* 09 (2010) 091 ; arXiv:1009.4122
- ***CMS Tracking Performance Results from Early LHC Operation***
  Submitted to European Physical Journal C ; arXiv:1007.1988
- ***First Measurement of the Underlying Event Activity at the LHC with $\sqrt{s}$ = 0.9 TeV*** Submitted to European Physical Journal C ; arXiv:1006.2083
- ***Measurement of the charge ratio of atmospheric muons with the CMS detector*** *Phys. Lett. B* 692 (2010) 83-104 ; arXiv:1005.5332
- ***Transverse-momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt{s}$ = 7 TeV*** *Phys. Rev. Lett.* 105 (2010) 022002 ; arXiv:1005.3299
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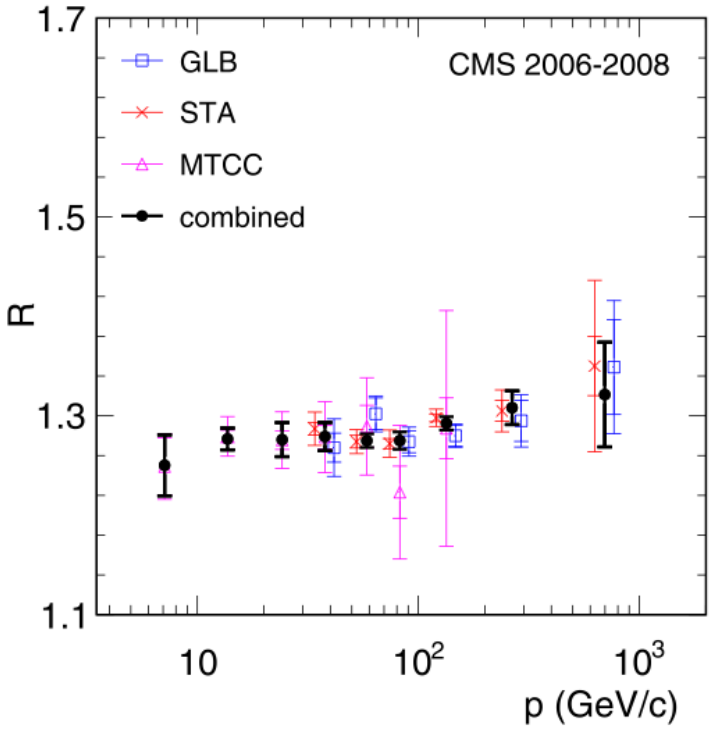
(*) Contributions from DESY

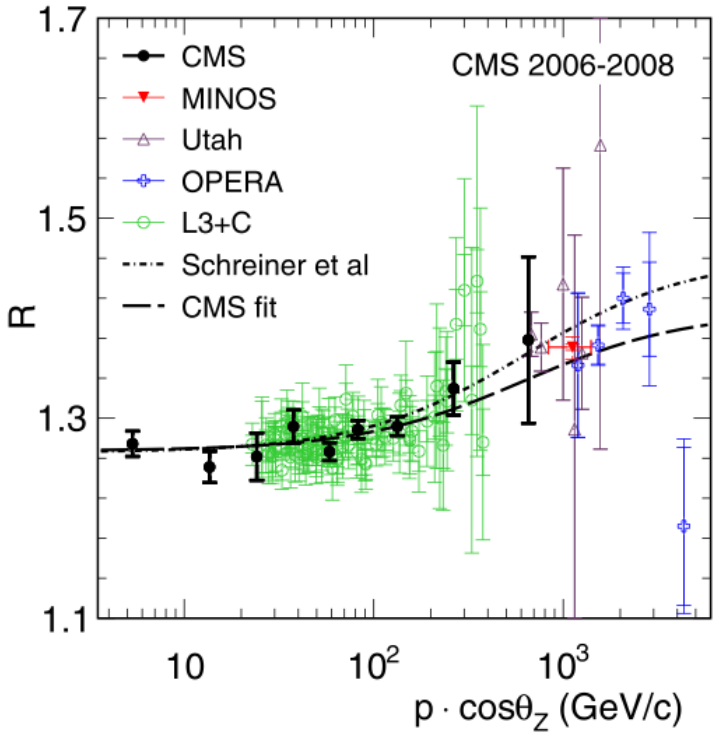
Measurement of the charge ratio of atmospheric muons with the CMS detector

- Measurement of the ratio of positive- to negative-charge muons important for
  - constraining models of cosmic showers
  - understanding atmospheric neutrinos

***Phys.Lett.B* 692 (2010) 83-104**

- **Most precise measurement for p(μ) < 500 GeV so far !**

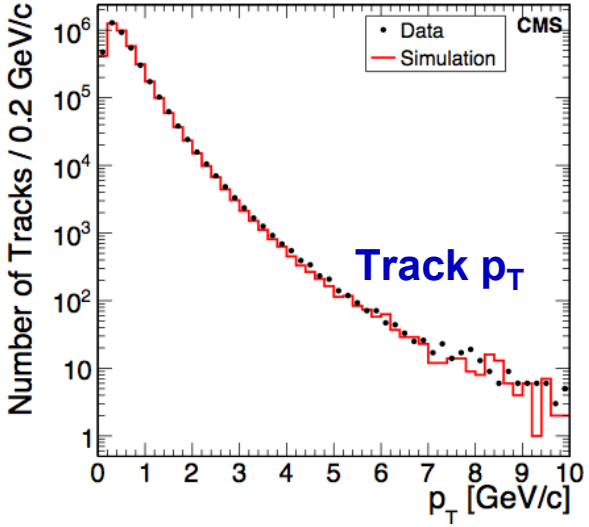


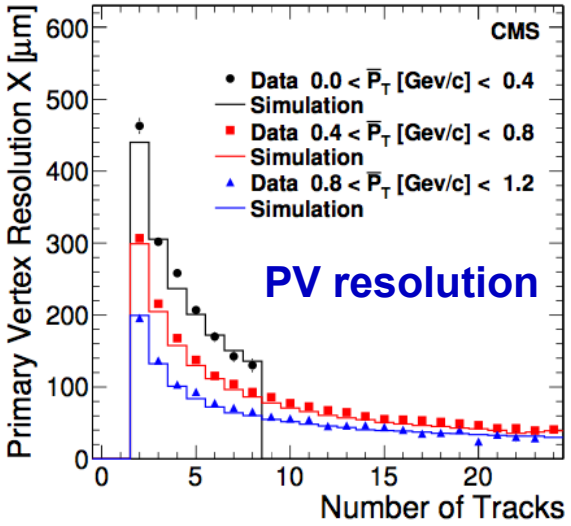


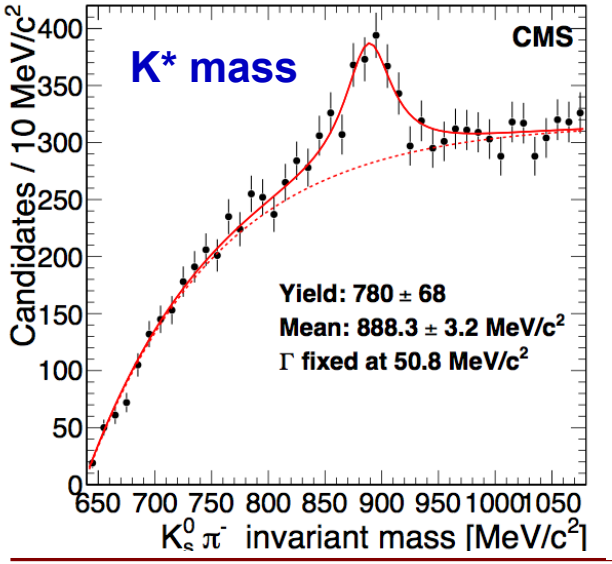
Good understanding of the muon reconstruction in the full momentum range, the (L1) trigger efficiencies and muon-tracking alignment

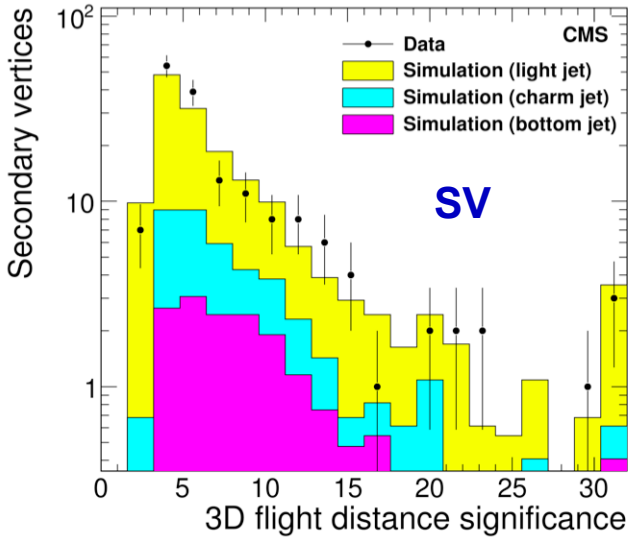
CMS Tracking Performance Results from Early LHC Collisions

Reconstructed tracks from the data taken at $\sqrt{s}$ = 900 GeV and 2.36 TeV in Dec 2009









Submitted to EPJ C
arXiv:1007.1988

- Shape of kinematics well described by simulation
- Primary vertex resolution agrees well with expected
- K^0_s, Λ, ϕ, $\Xi^{\pm}$, $K^*(892)^{\pm}$ masses agree with PDG
- Lifetime of K^0_s, Λ, in agreement withPDG
- b-tagging observables well understood

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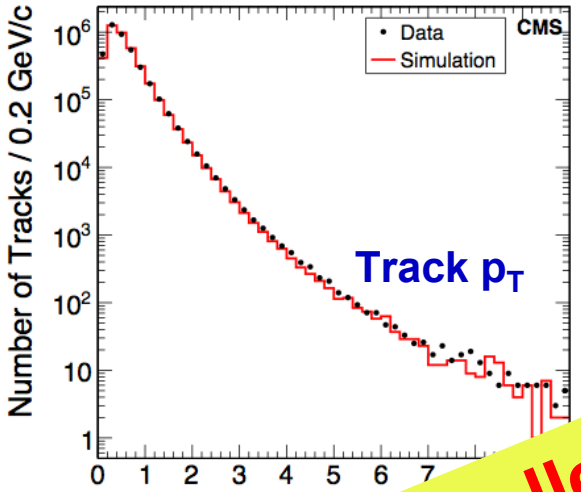
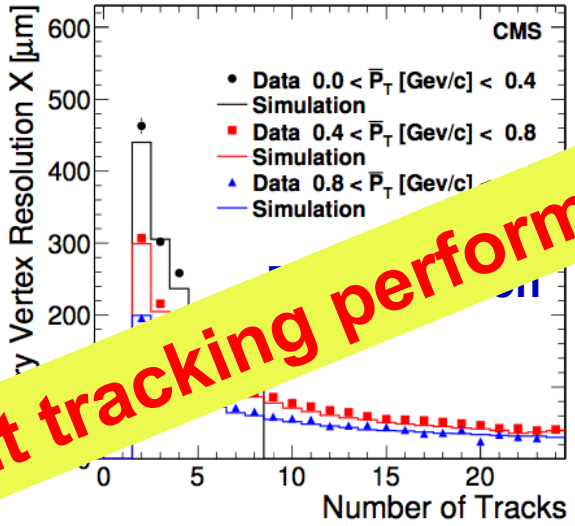
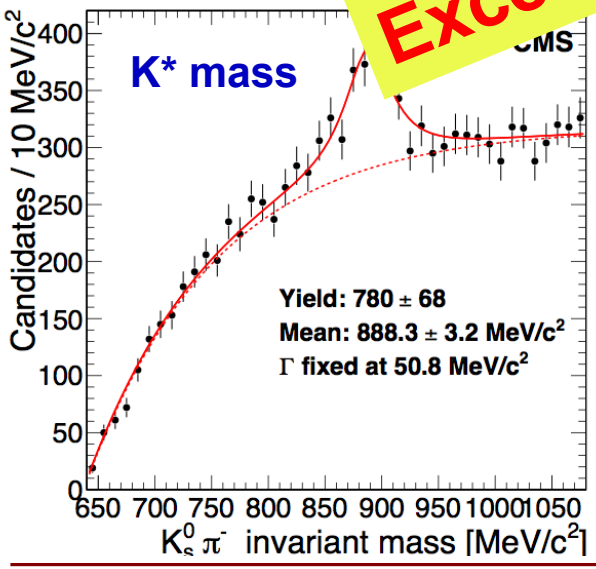
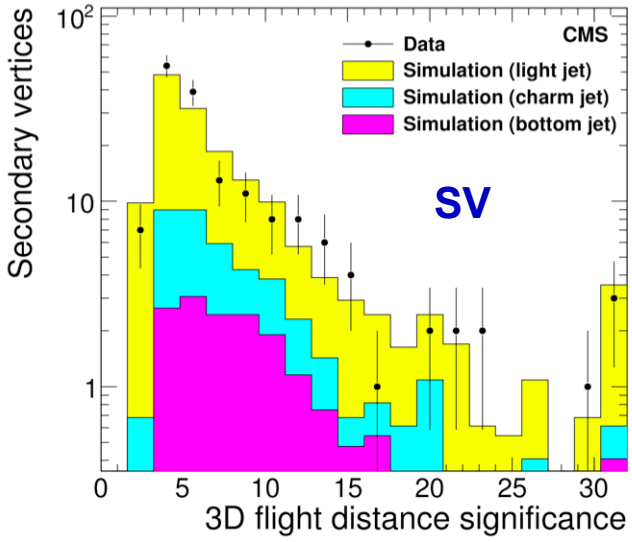




Excellent tracking performance !





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DESY CMS Physics Landscape

2010 / 2011: Preparation for physics analysis with first collision data

QCD - Forward Physics:

- Multiparton interactions/UE
- QCD at very low x

Top Quark Physics:

- top quark total cross-section in ttbar $\rightarrow$ 2W2b $\rightarrow$ 2l (l = μ,e)
- top quark mass

Higgs Physics:

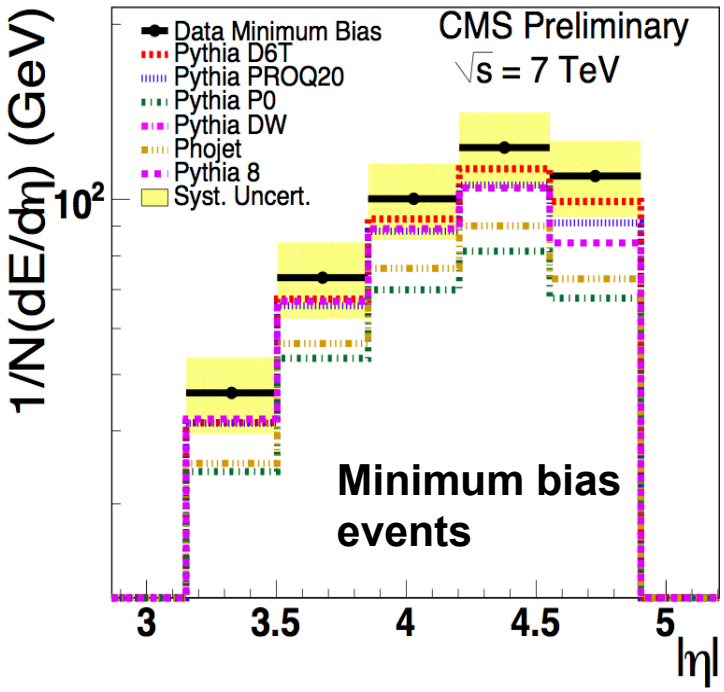
Analysis of MSSM Higgs:
$H \rightarrow \tau\tau \rightarrow \mu\mu$

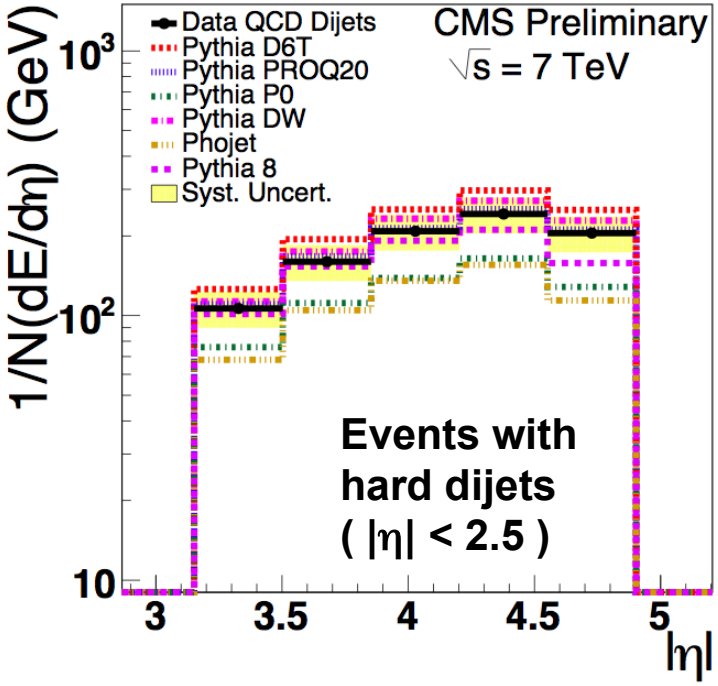
SUSY Physics:

searches in channels containing leptons (electrons and muons)

QCD - Forward physics: PAS FWD-10-002

First measurement of energy flow within $3 < |\eta| < 5$ at a pp collider



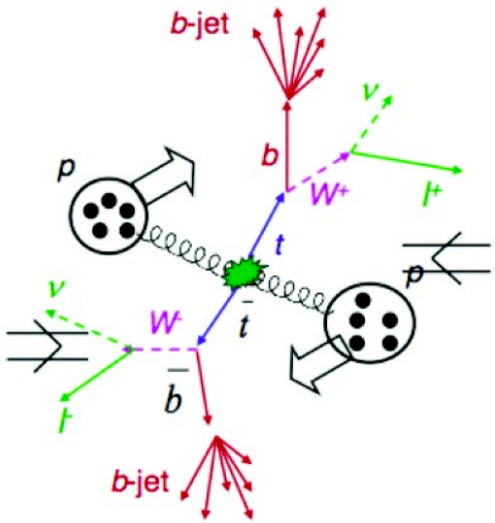


- Measured forward energy flow significantly different for both event classes
- In minimum bias events, increase in energy flow with increasing center of mass energy not reproduced by MC simulations
- Current MC simulations cannot describe both energy flow and particle spectra

➜ **important input for tuning of MC generators**

Top quark physics at DESY

Achievements in 2nd half 2010: First analyses with 7 TeV data



Total ttbar cross section measurement in dimuon decay channel:

- Muon trigger efficiencies haven been determined using data-driven "tag & probe" methods at the Z peak
- Developed a robust cut-based event selection
  → CMS "reference selection" has been reproduced

➜ Good agreement of results from data and simulation

Data quality and trigger monitoring for top-like dileptonic events:

- First results for data-driven muon trigger efficiency measurements ("tag & probe") in the J/psi-, Y- and Z-mass regions
- First estimation of background events from μ/e events

Top quark physics at DESY

Ongoing developments:

Dileptonic channel

- Data-driven methods to determine & subtract background from QCD and fake muons
- Study the feasibility of measuring the top quark mass using the “Lxy method”

Muon + jets channel

- Data-driven calibration tools for b-tagging

Further related studies

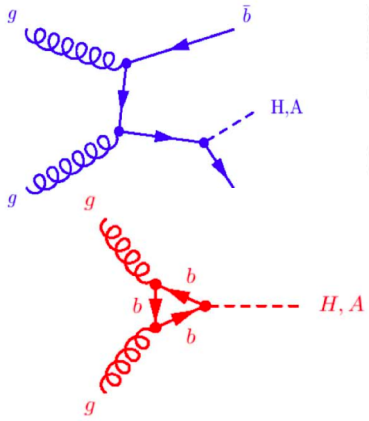
- Simulation of b-tagging performance with the Phase1 upgraded pixel detector (see later slides)
- Measurement of Zbb production cross section important background for many physics processes

Goal for 2011:
Measurement of the ttbar cross section in the dileptonic decay channels

Towards MSSM Higgs boson searches

- Novel analysis approach in CMS:

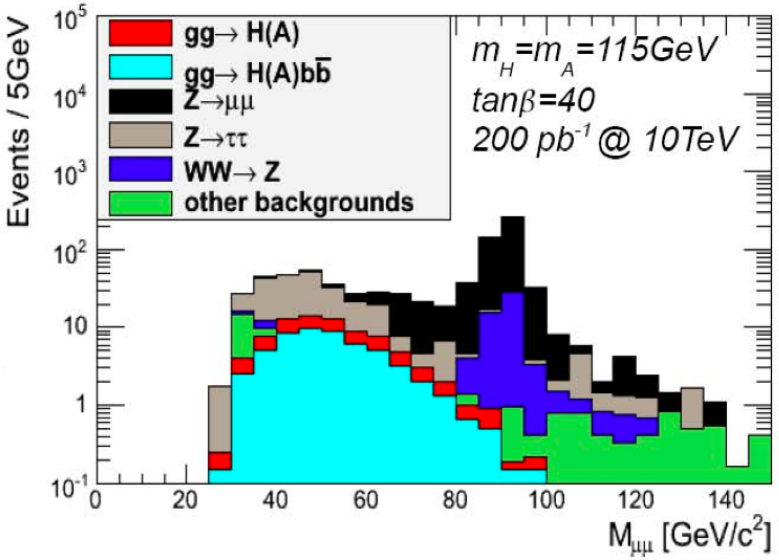
$$H(A) \rightarrow \tau\tau \rightarrow \mu\mu + \not{E}_T$$



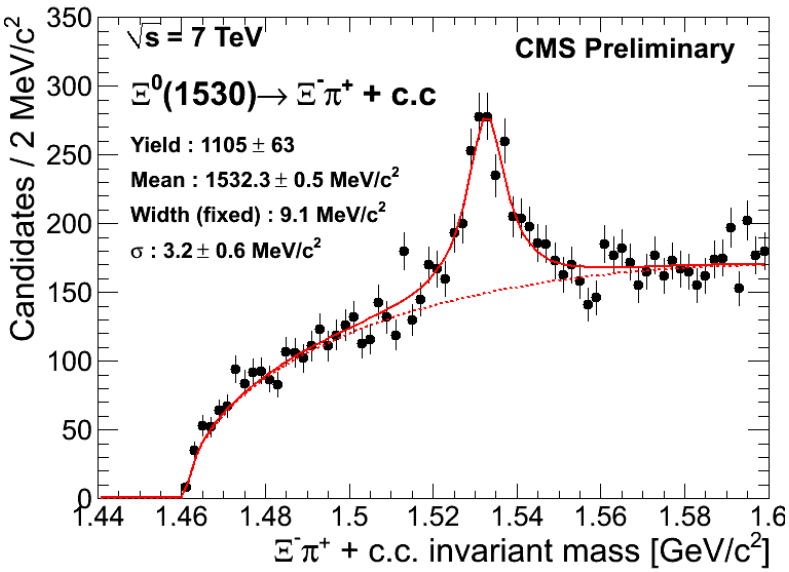
Work in progress:

$Z \rightarrow \tau\tau \rightarrow \mu\mu$ - template process for commissioning of MSSM Higgs analysis

Observation possible with 20 pb^{-1}

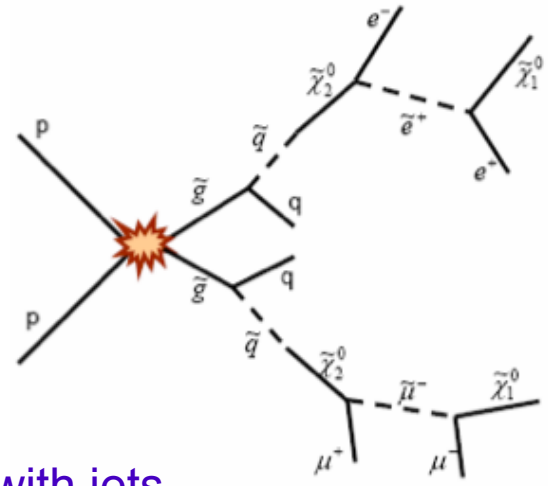


- The analysis requires good understanding of:
  - Characteristics of the relevant subdetectors
  - Performance of tracking (b-tagging)
- Application: strange resonance production
  - $K^{\pm}(892) \rightarrow K^0_s + \pi^{\pm}$
  - $\Sigma^{\pm}(1385) \rightarrow \Lambda^0 + \pi^{\pm}$
  - $\Xi^0(1530) \rightarrow \Xi^- + \pi^+$



Towards SUSY searches at DESY

Ongoing activities and plans for 2011:



- Participation in leptonic "Reference Analyses":
  - Jets + MET + 2 (same-sign) muons (or electrons)
    small QCD background
  - Jets + MET + 1 muon (or 1 electron)
    relative clean signature
    background: top quark production, QCD events with jets, electroweak boson production
  - Jets + MET + 2 (odd-sign) muons (or electrons)
    characteristic invariant mass distribution of the two muons

- Participation in Lepton Commissioning Team of the SUSY group

- Development of offline data quality monitoring (DQM) tools within the SUSY Prompt Validation and Physics Commissioning team

- Development of data-driven estimation of Standard Model backgrounds

CMS operation & development by DESY

Alignment:

- Tracker alignment
- Relative global alignment of tracker and muon system
- Alignment software coordination

Data Quality Monitoring:

- Online data taking & offline reconstruction
- MC production & Release Validation
- Data certification

Detectors:

- CASTOR calorimeter
- Fast Beam Conditions Monitor
- High Level Trigger & Data Acquisition

CMS Detector Upgrade:

- Barrel pixel module production
- Pixel upgrade simulation studies
- Tracker outer barrel module R&D
- Silicon sensors R&D
- SiPM for HCAL & MTT upgrade

Computing:

- DESY Tier-2 operations and support
- CRAB Server operations
- CMSSW deployment
- Computing integration

Alignment & Calibration

Data Quality Monitoring

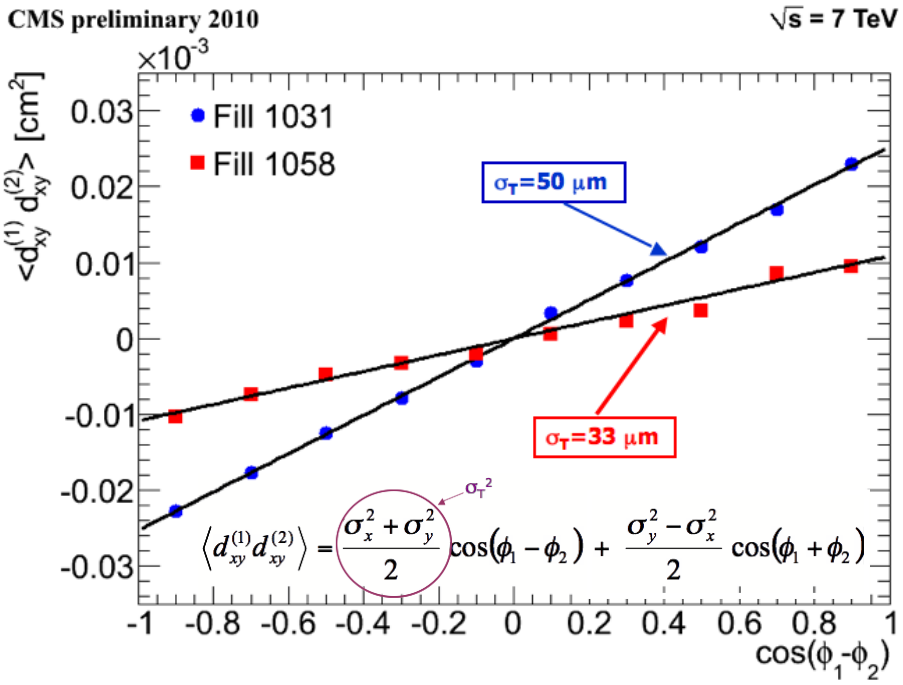
Detectors

Tracker alignment at DESY: PAS TRK-10-005

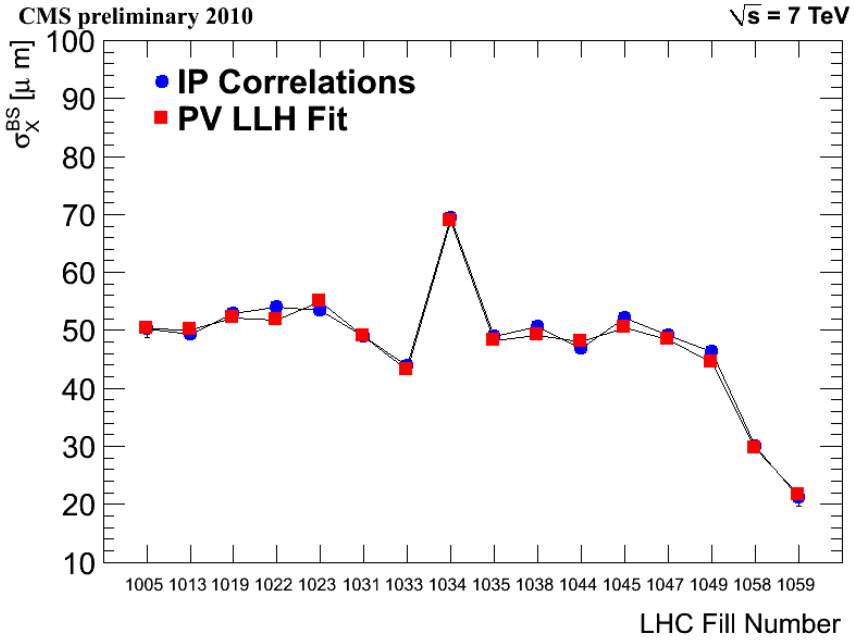
Measuring beam line width using impact parameter (IP) correlations method

Exploits the correlation between the transverse IP of tracks from the same interaction:

- Orthogonal to conventional method (fit to 3D distribution of primary vertices)
- Does not depend on the PV or IP resolutions → no need for unfolding
- Uses different information → different systematics: important for cross-check



Slope vs $\cos(\phi_1 - \phi_2)$ shows different beam line widths for different fills



CMS tracking resolutions well understood

Data Quality Monitoring (DQM)

- The CMS-wide DQM system comprises
  - Online DQM: identify detector performance problems during data taking (P5 shifts)
  - Offline DQM: verify reconstruction & calibration (shifts at CERN, DESY, FNAL)
  - Data certification: creation of CMS-wide certified list of good runs
- All detector and physics objects groups are integrated in the same system
- Same infrastructure regularly operated on

  data (online, express, prompt, re-reco), MC production, software release validation

Full end-to-end chain in place since LHC startup and working exceedingly well

All CMS analyses rely on the good-run-list from DQM as starting point for data selection

Data Quality Monitoring (DQM)

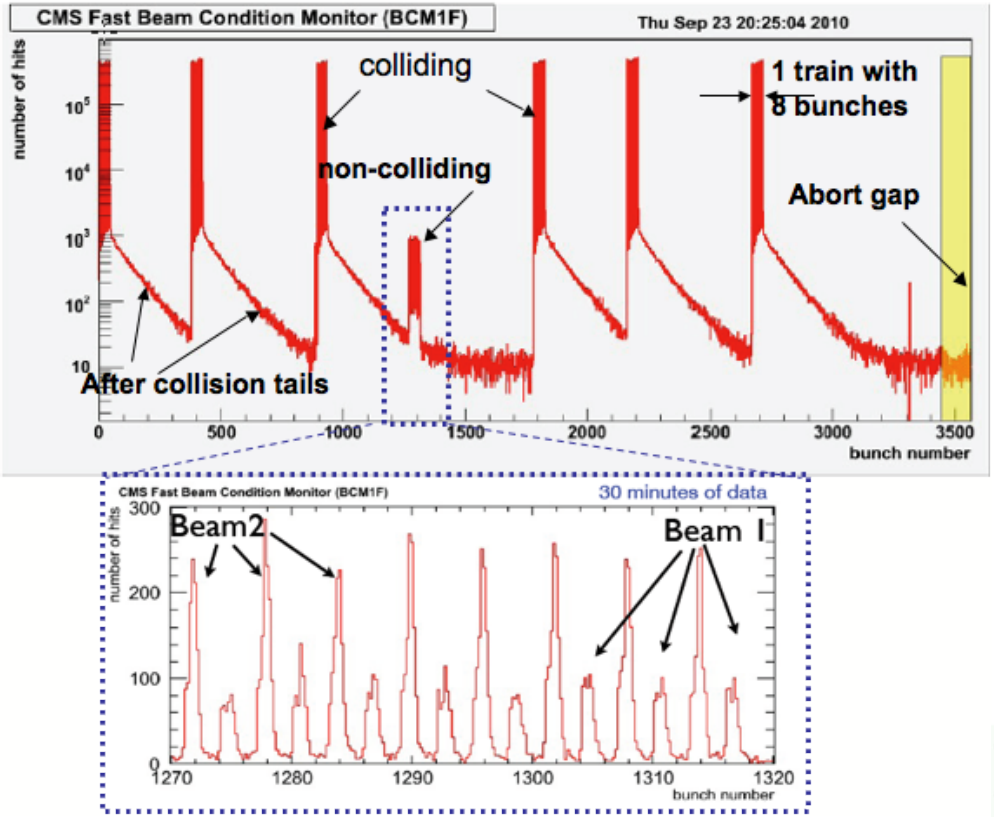
Contribution from DESY (2010):

- Project Coordination: Andreas Meyer (L2) until 31/8/10, now Amita Raval (L2, deputy)
- Offline DQM shifts (daily 13:00-19:00 at DESY CMS Center)
- Current developments:
  - Refinement of online DQM system
  - Retrieval & aggregation of offline histograms (harvesting)
  - Development & subsystem integration of DQM for Monte Carlo simulations
- Operations:

  Harvesting of DQM histograms from data reprocessing (Tier-1) and MC production (Tier-2)

Fast Beam Conditions Monitor (BCM1F)

BCM1F: two arrays of 4 diamond sensors at 1.8 m from interaction point

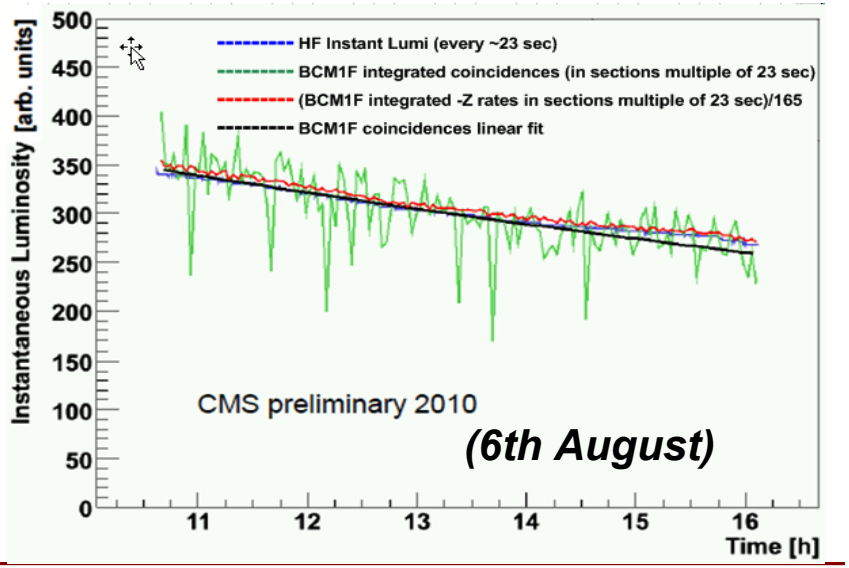


Indispensable tool for beam monitoring, providing count rates of beam-halo & collision products

Recent developments:

- Simulations for particle ID in tails
- LUT card added to DAQ to identify hit coincidences in sensors

➔ Studying the use of BCM1F for luminosity estimation



Future plans:

- Upgrades plans for 2015
- LHC demands the use of BCM1F modules to be used for beam diagnostics

CASTOR forward calorimeter

Major milestones:

Upgrade of the slow control and DAQ

- "unattended" operation by central CMS shift

Calibration efforts in different directions:

→ esp. for magnetic field effects

- MinBias analysis for √ s = 0.9, 2.36, 7 TeV
- Physics based (jet pT-balance, Z→ee, …)

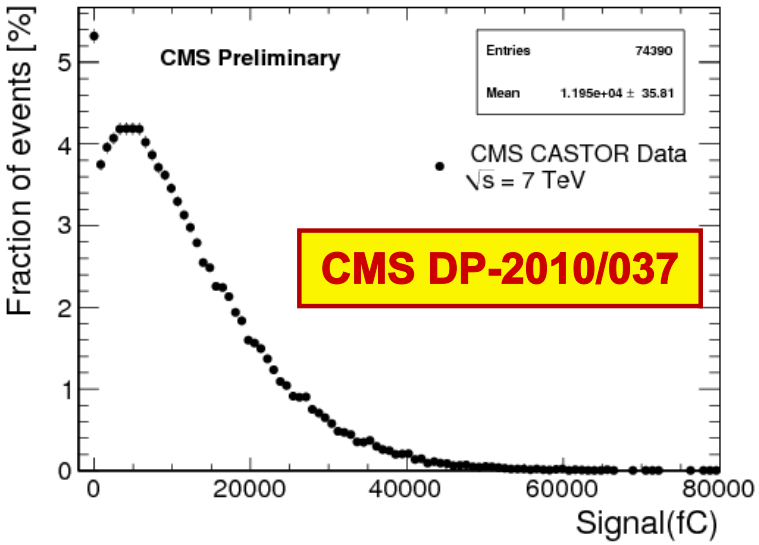
Ratio of av. signals with 3.8T and 0T

CMS preliminary

φ \ Z	1	2	3	4	5	6	7	8	9	10	11	12	13	14
16	0.96	1.03	1.06	1.10	1.44	0.71	0.03		0.79	0.92	1.00	1.09	1.12	1.06
15	1.06	1.00	1.0	1.11	1.32	1.44	0.02		0.89	1.01	0.98	1.03	1.09	1.10
14	0.93	1.02	1.07	1.06	1.35	0.60	0.04		0.82	0.94	1.13	1.12	1.21	1.3
13	1.01	1.05	1.05	1.15	1.48	0.21	0.03			0.87	1.03	1.13		1.21
12	0.99	1.10	1.12	1.10	1.10	0.17	0.00	0.00	0.67	0.86	1.07	1.05	1.16	1.21
11	0.99	1.00	1.10	1.14	1.31	0.28	0.01	0.02	0.81	0.99	1.06	1.01	1.08	1.10
10	1.10	1.06	0.99	1.06	1.08	0.34	0.01	0.69	0.98	0.98	1.01	0.95	0.99	1.19
9	0.99	1.00	1.03	1.09	1.01	0.33	0.02	0.76	0.83	0.95	0.95	0.98	1.03	0.96
8	1.03	0.85	0.94	1.00	0.91	1.14	0.02	0.77	0.78	0.88	0.95	0.93	1.03	0.95
7	1.01	0.90	1.00	1.01	1.03	0.20	0.01	0.60	0.84	0.78	0.88		0.90	0.95
6		1.14	0.95	0.90	1.23	0.32	0.02	0.02	0.75	0.76	0.89	0.76	0.80	0.94
5		1.00	0.95	0.95	1.2	0.49	0.07	0.01	0.04		0.82	0.68	1.06	1.03
4	0.93	1.01	0.94	1.01	0.90	0.58	0.03	0.00	0.02	0.78	0.85	0.94	0.96	1.06
3	0.98	1.00	0.97	0.94	1.08	0.60	0.03	0.03	0.42	0.78	0.93	0.96	1.08	0.89
2	0.94	0.88	0.98	0.96	1.02	1.48	0.07	0.25	0.79	0.85	0.83	0.96	0.99	1.00
1	1.11	0.95	1.01	1.11	1.06	1.91	0.04	0.72	0.83	0.96	0.92	0.98	0.99	1.06

Minimum bias data: Run 133874 (Nominal B-field) / Run 133239 (No B-field)

Total collected charge spectra



Special CASTOR technical trigger

- ~5 x higher statistics wrt. BCS2
- used in CASTOR calibration runs
- now being improved for physics runs

Heavy ion runs in November

- CASTOR will play a central role
- Monitoring & gain currently being adapted

CMS Upgrade Projects at DESY:

Pixel

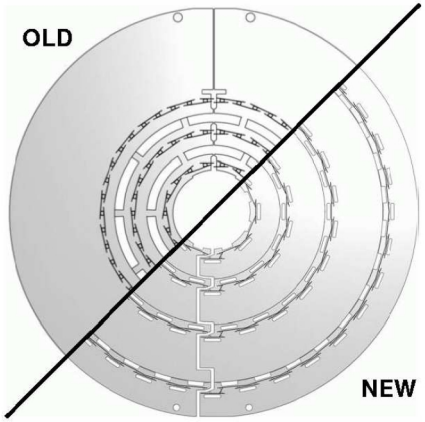
Tracker

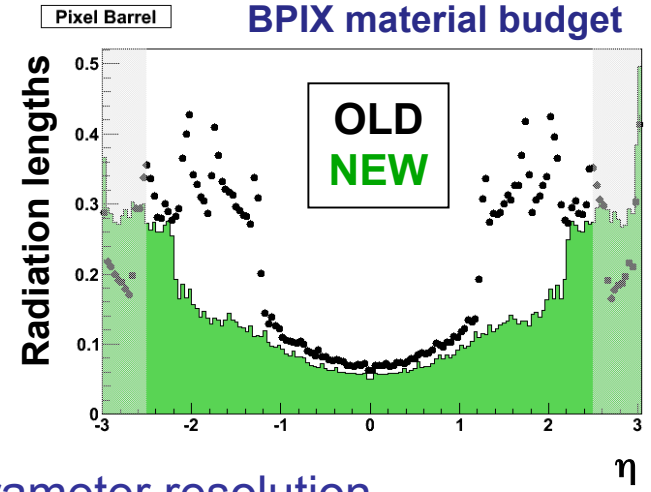
SiPM for HCAL & MTT

Phase1 pixel upgrade simulation

Phase1 pixel upgrade:

- Upgrade to 4 barrel layers / 3 end-cap disks
- Reduced material budget





➜ Expect improved vertex & impact parameter resolution

Investigating tracking & b-tagging performance:

- in the High-Level Trigger (pixel-only tracks)
- in the full CMS tracker

Contributions from DESY:

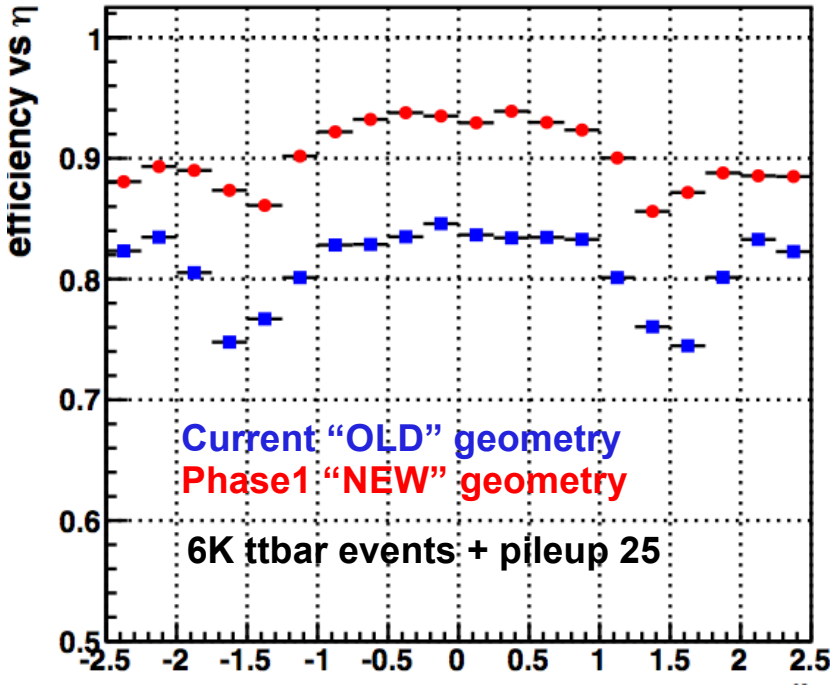
- **Provide the tools and tracking algorithms** to fully exploit the capabilities of the enhanced geometry (included in "official" CMS software upgrade releases)
- **Proving improvements in b-tagging performance** in HLT
- Participation in the CMS Upgrade Technical Proposal and Design Report

Phase1 pixel upgrade simulation

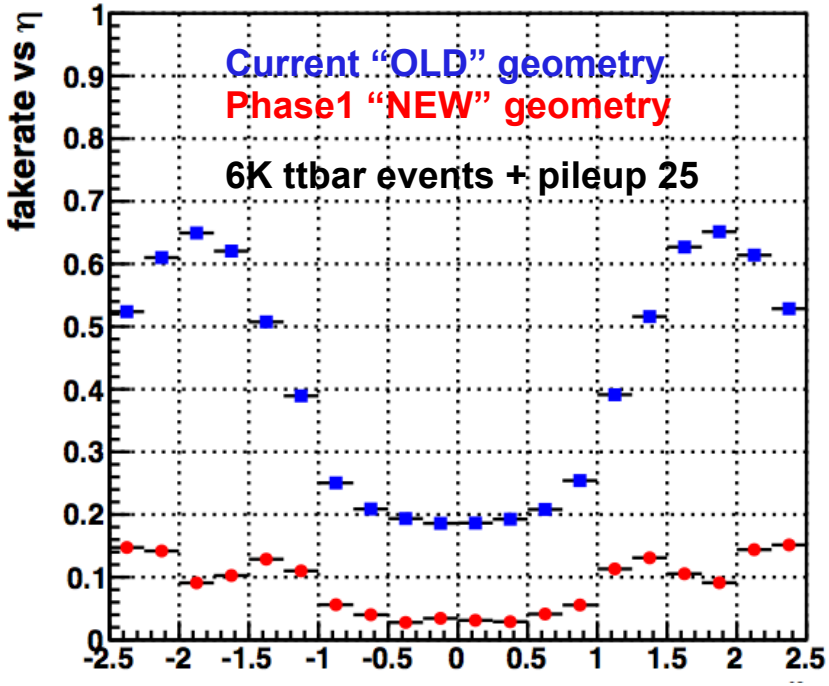
Example of improvement in tracking by new algorithms:

Efficiency and fake rate for the track seeding (first input to track reconstruction)

Seeding efficiency vs. η



Seeding fake rate vs. η



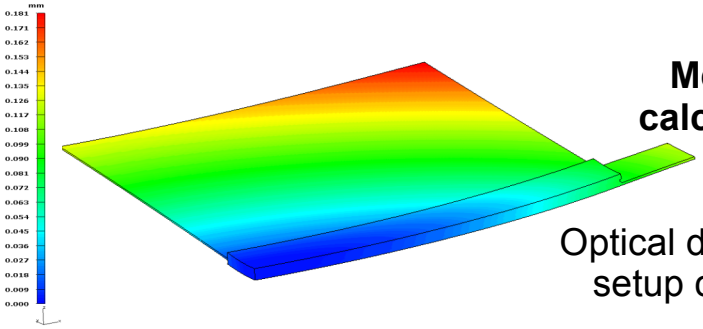
Significantly improved efficiency and decreased fake rate

New b-tagging developed, first very encouraging results for HLT

Si-Strip module R&D for Phase2 tracker upgrade

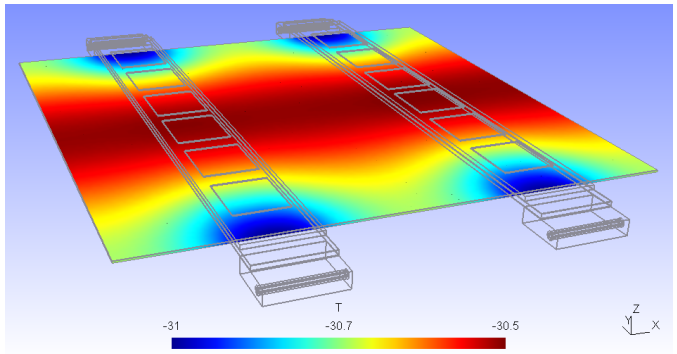
Phase2 CMS tracker upgrade: low temperature operation of sensors and restrictions in material budget will require extremely **efficient cooling:**

- Optimization of thermal interfaces & junctions
- Study cooling performance of module design options
- Sustain FE simulations with measurements

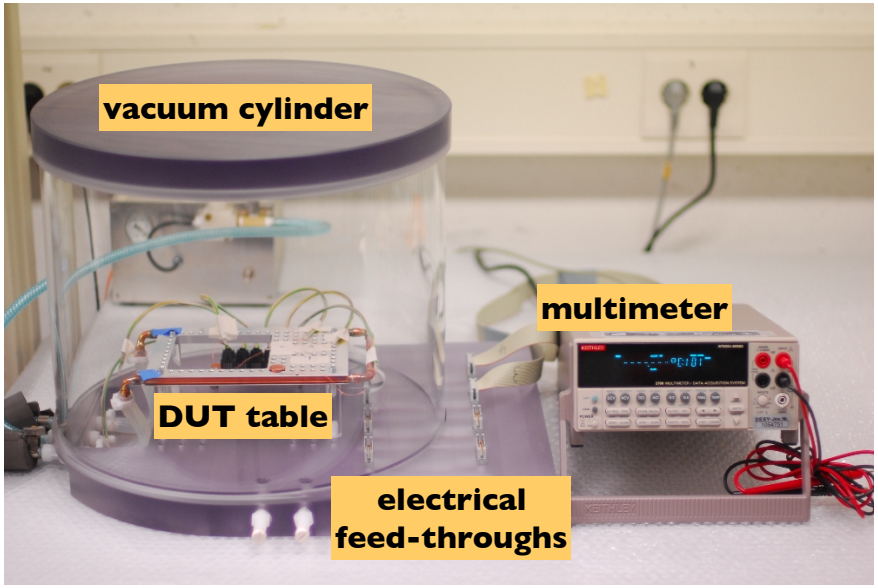


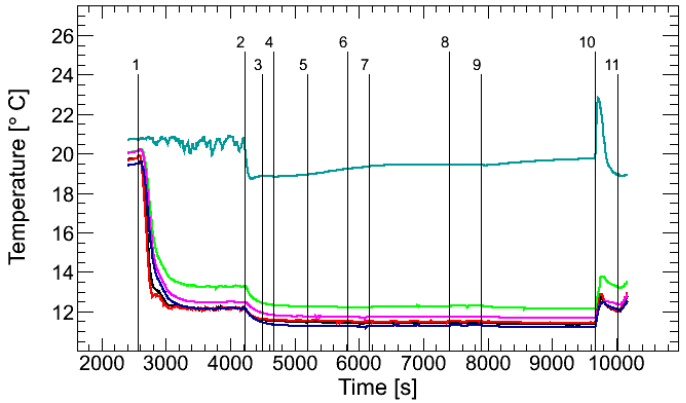
Mechanical finite element calculations of deformations due to thermal stress

Optical deformation measurement setup currently being developed



Thermal finite element calculations for various design options

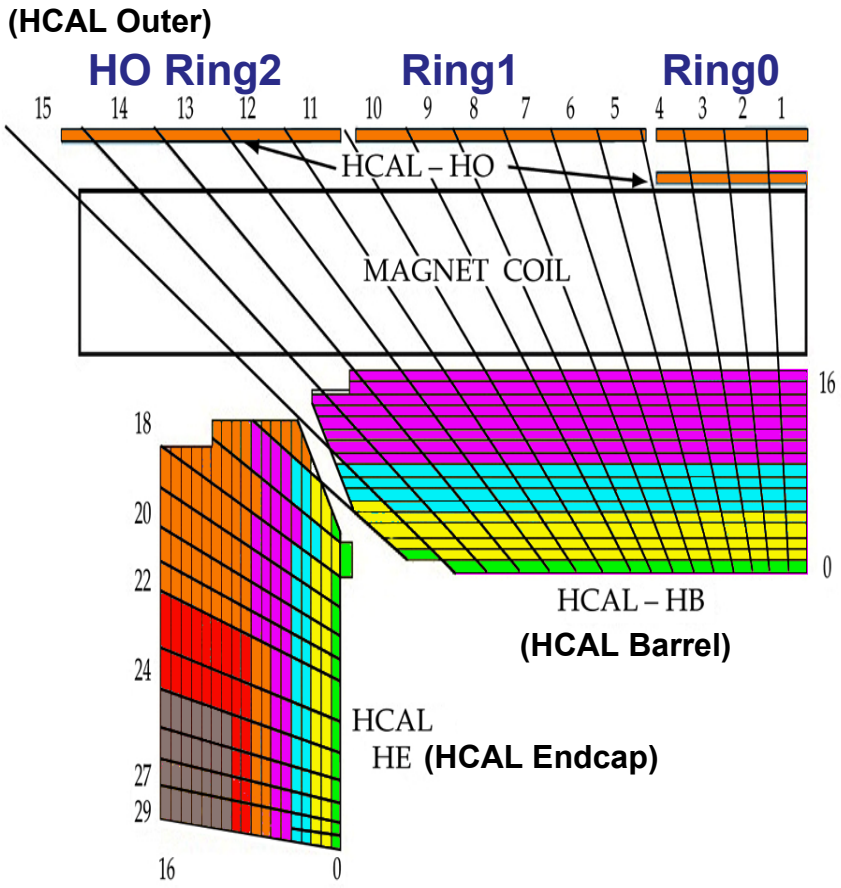




All sensors operational setup being commissioned & calibrated

High precision temperature measurement setup
Developed for cooling performance studies of test structures & module prototypes

HCAL upgrade project



Replace HPD with SiPM:

- Less sensitive to magnetic stray field
- Higher gain allows for longitudinal segmentation

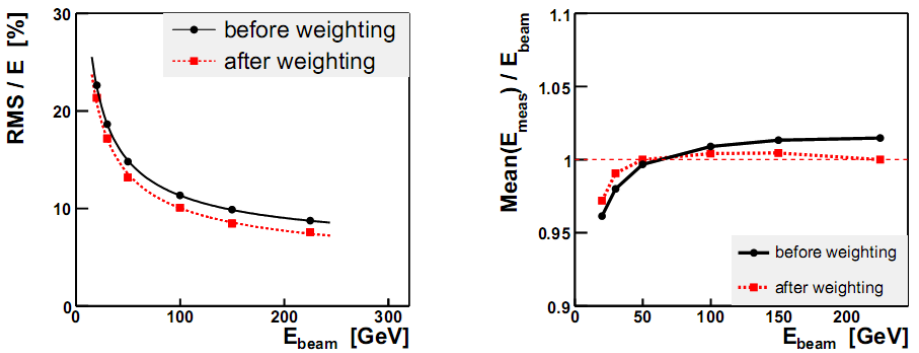
Goals for ~ 2012:

- SiPM for HO Ring0 (in approval procedure)
- HO Ring1,2 already approved & underway

Next goal: 2015/16 (in planning):

- SiPM for HB and HE
- Improvements in readout elec. & trigger

- Synergy with CALICE & XFEL
- Application for a new Helmholtz-Russia-Joint-Research Group



Weighting algorithms for energy reconstruction

CMS Computing at DESY

CMS Computing at DESY

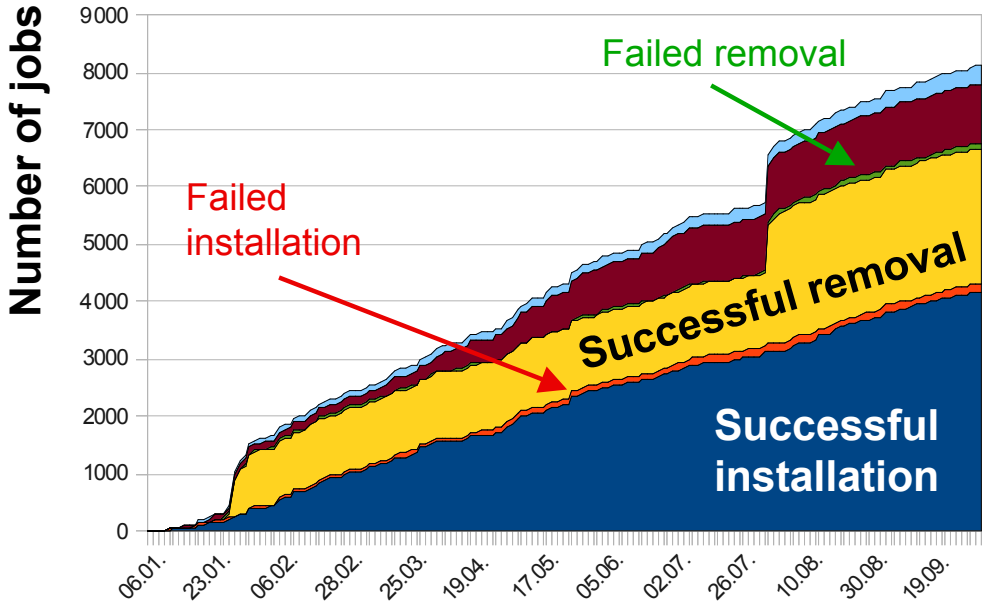
- CMS Tier-2 at DESY
  - Reliable computing and storage resource for analysis and MC production
  - Hosts 4 Physics Groups: QCD, Top, Forward, JetMET
  - CMS specific site services in close collaboration with Uni Hamburg
    - > Phedex
    - > Squid cache
  - See presentation by Y. Kemp

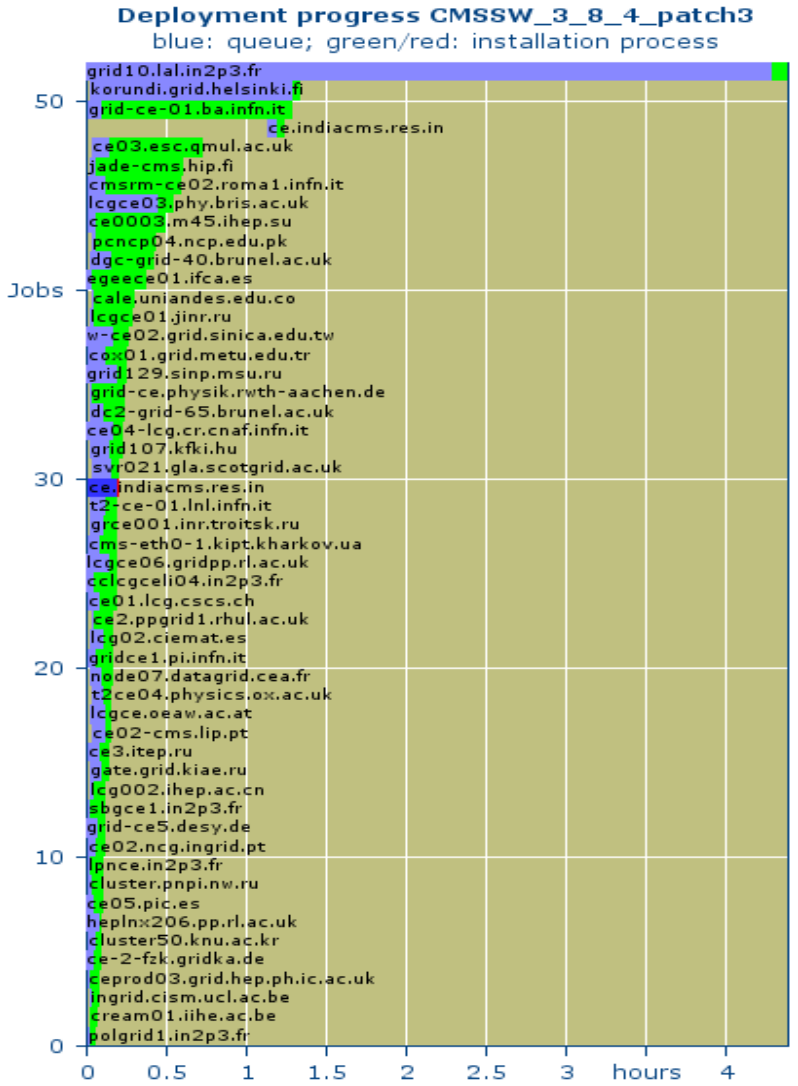
- National computing infrastructure for CMS
  - National Analysis Facility (NAF)
  - National Grid resources (beyond WLCG pledges)
    - > Available at all German CMS sites RWTH Aachen, DESY/UniHH, KIT
    - > Planning and management effort shared among all German CMS groups

CMS Software deployment

DESY: Coordination of installations at European and Asian CMS sites

- ~ 50 sites, including 6 Tier-1 sites
- Over 50 releases deployed since Jan 2010
  - Several removal campaigns
- Typical deployment cycle
  - A few hours per patch release
  - Less than 24 hour for a full release





Summary

- The LHC is running at $\sqrt{s}$ = 7 TeV and delivers data at rapidly increasing rate !

- The CMS detector is fully operational and its components show excellent performance

- DESY plays an active role in many key areas of CMS:
  → management, operations, physics analysis, detector development & upgrade

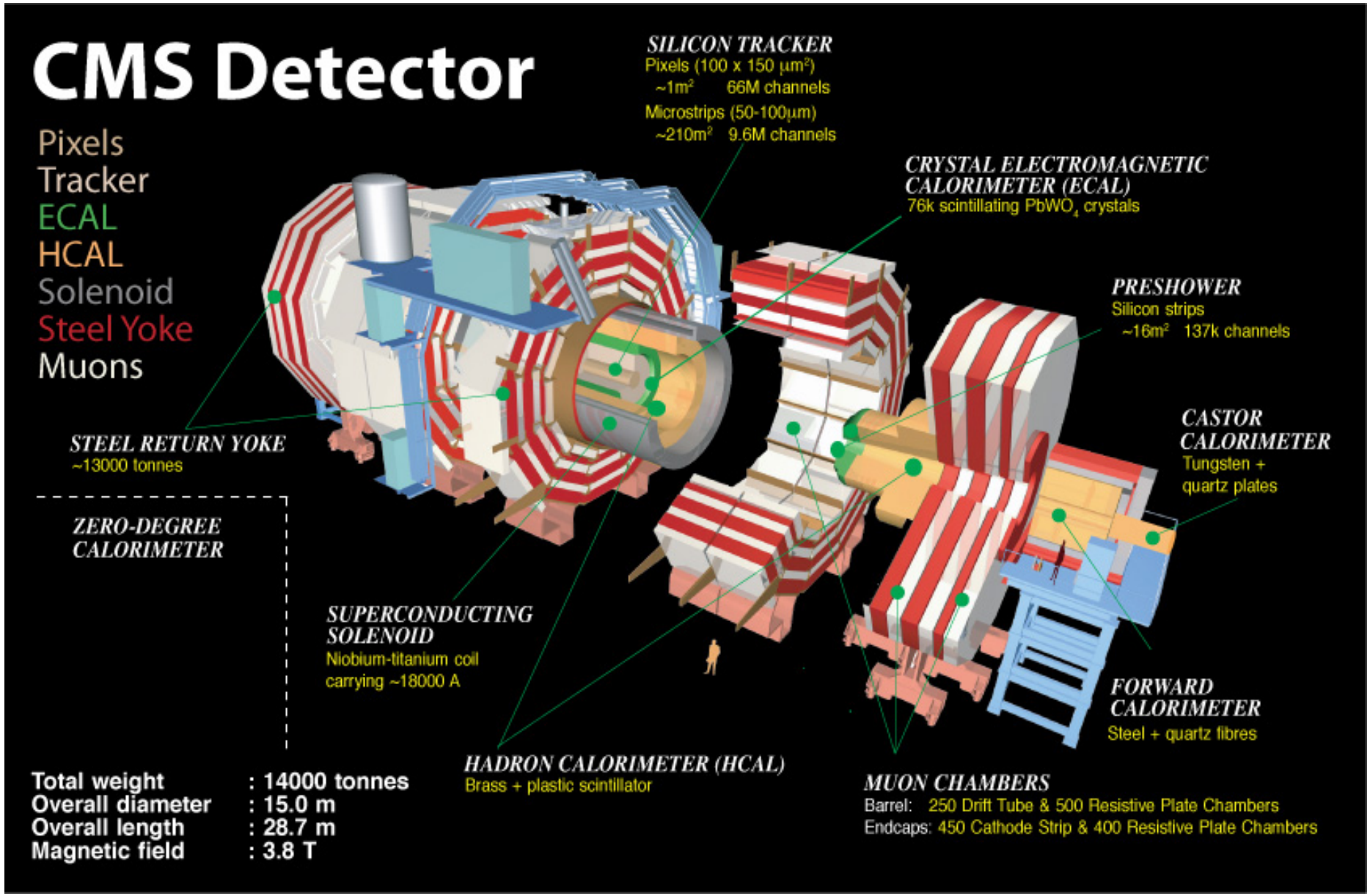
- DESY hosts & coordinates several computing resources which are crucial for CMS and particularly for the German CMS community

- CMS is producing and publishing physics results
  → with substantial contributions from DESY

- The DESY CMS group is well prepared for the 2011 high-luminosity data
  … and the exciting physics and possible surprises they will reveal in QCD, investigation of the top quark and searches for Higgs bosons and SUSY !

Additional Information

The CMS detector in a nutshell

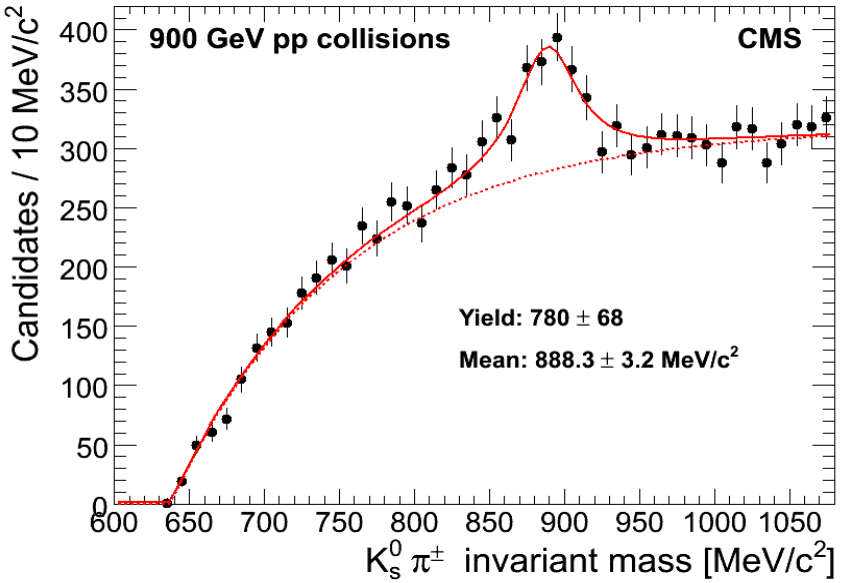


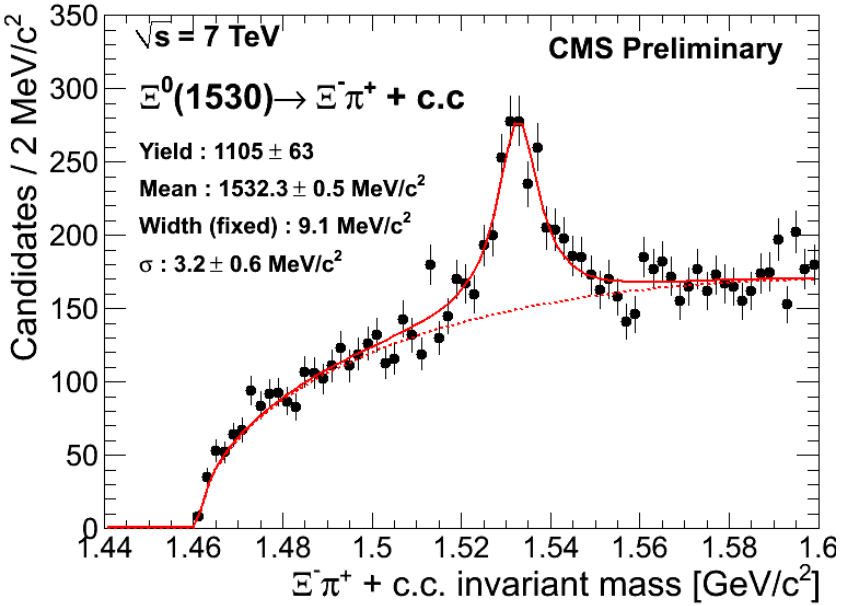
Strange resonance production at 0.9 & 7 TeV

- Studied channels:
  - $K^{\pm}(892) \rightarrow K^0_s + \pi^{\pm}$
  - $\Sigma^{\pm}(1385) \rightarrow \Lambda^0 + \pi^{\pm}$
  - $\Xi^0(1530) \rightarrow \Xi^- + \pi^+$

Objectives :

- verification of tracking performance
- provide information on production of strange particles needed for further tuning of various models
- CMS paper on strange resonance production

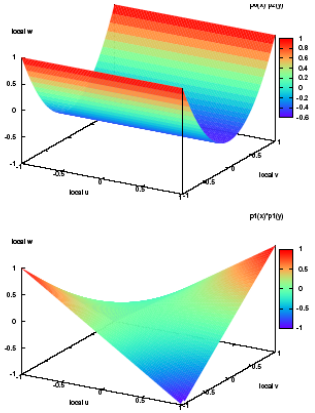


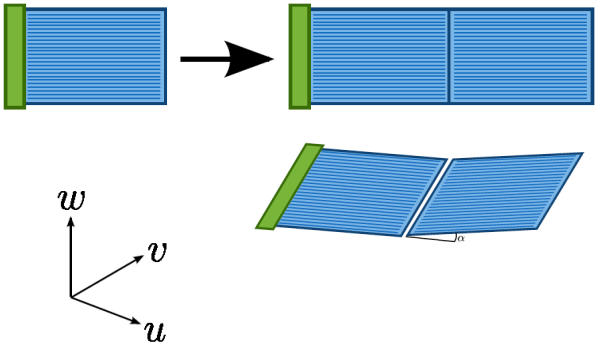


Tracker alignment at DESY

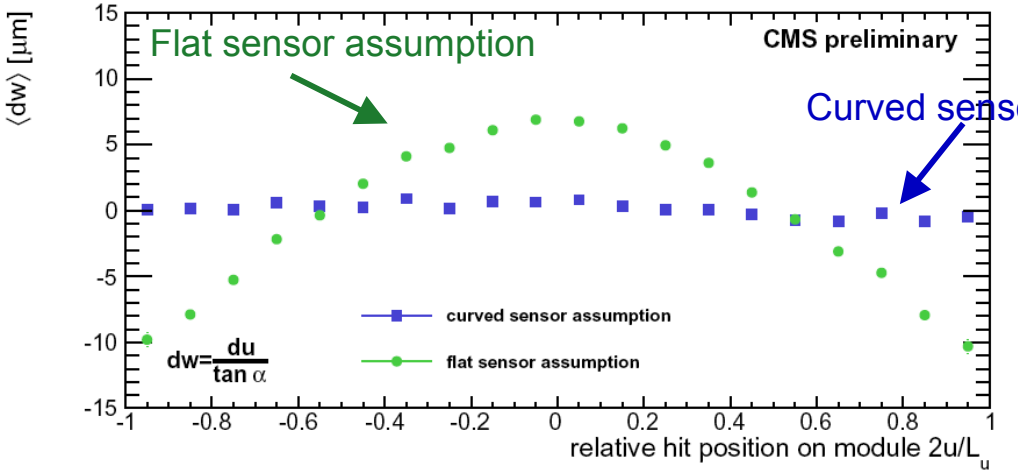
Alignment of kinks & bows from composite and curved tracker silicon sensors

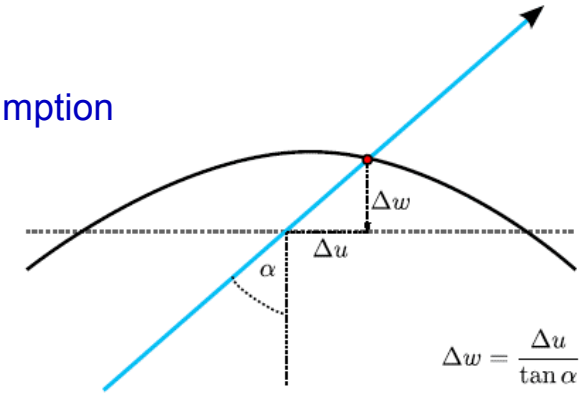
- Curvature of “flat” sensors & kink angle between the 2 parts of composite modules can now be determined using the CMS tracker
- Extended version of Millepede-II (courtesy of Helmholtz Alliance Analysis Centre) applied to data





- Correct for these effects to avoid hit bias depending on slope and position of the track

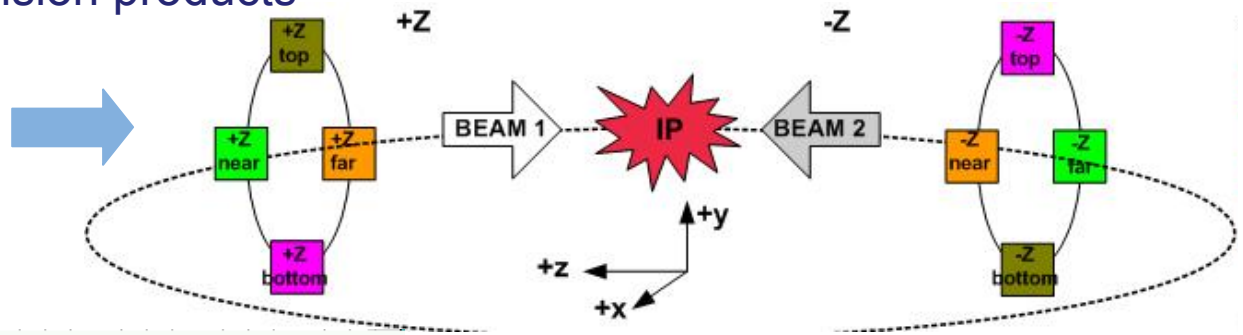


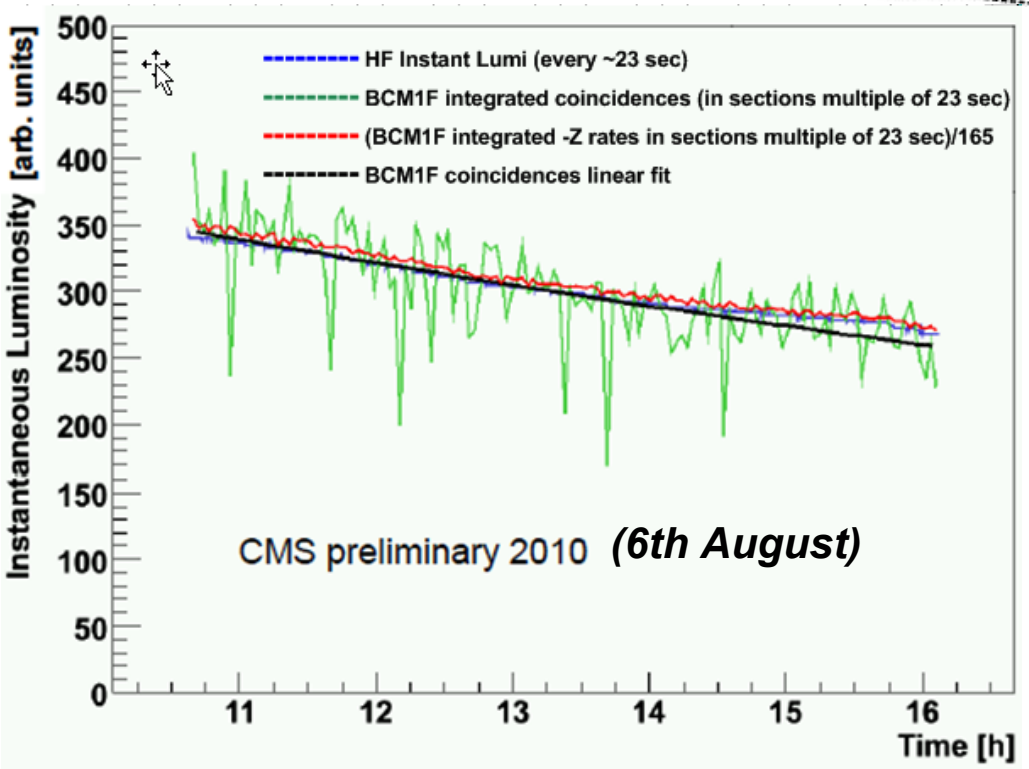


BCM1F: Luminosity estimation

LUT detects coincidences (logic AND) in pairs of back-to-back sensors

→ delivers signals from collision products

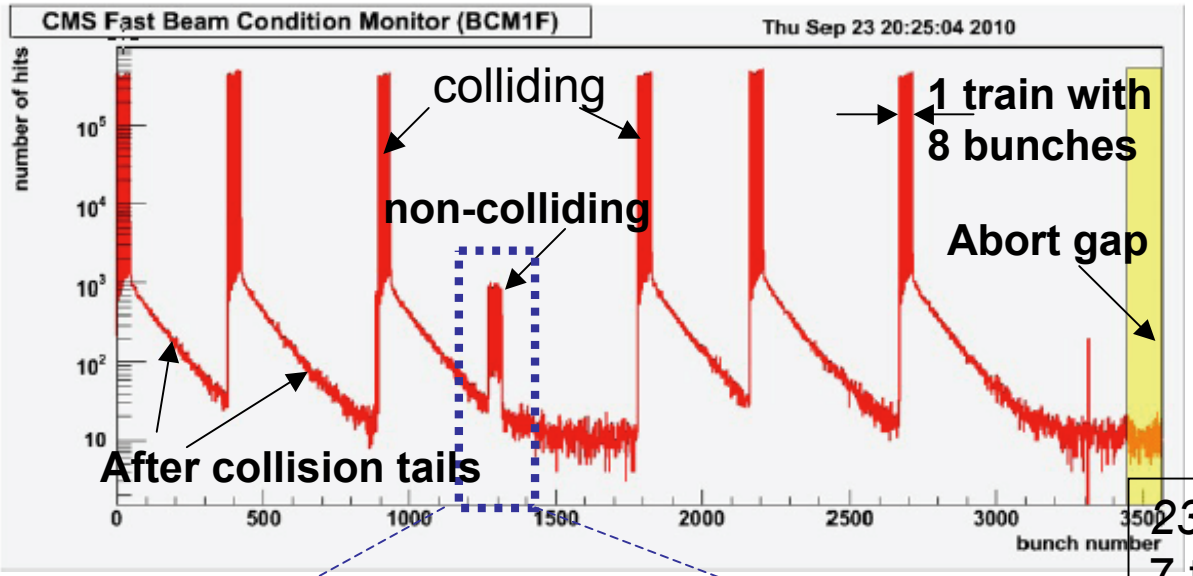


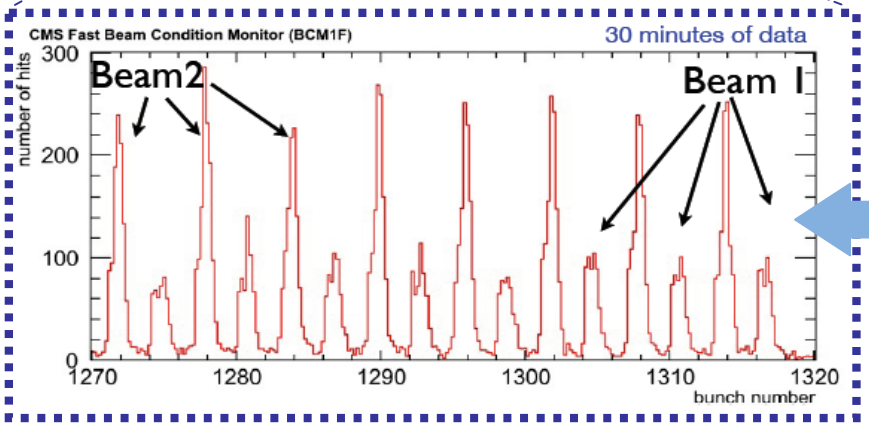


Comparison of coincidences rates with instant luminosity from HF:

- Good correlation on coincidences and raw rates
- Further studies still ongoing

BCM1F: Examples of beam monitoring





BUNCH ID PLOT

- **Pattern of bunches in LHC**
- **Higher rates in colliding bunches**
- **Delayed hits well described by simulations, long tails mainly due to neutrons**

23rd September 2010
7 trains/beam spaced by 150ns
8 bunches/train
47 collisions at CMS

BUNCH STRUCTURE ZOOMING
Useful to find buch features