Premières collisions dans CMS

an SPP oriented view of the latest CMS activities

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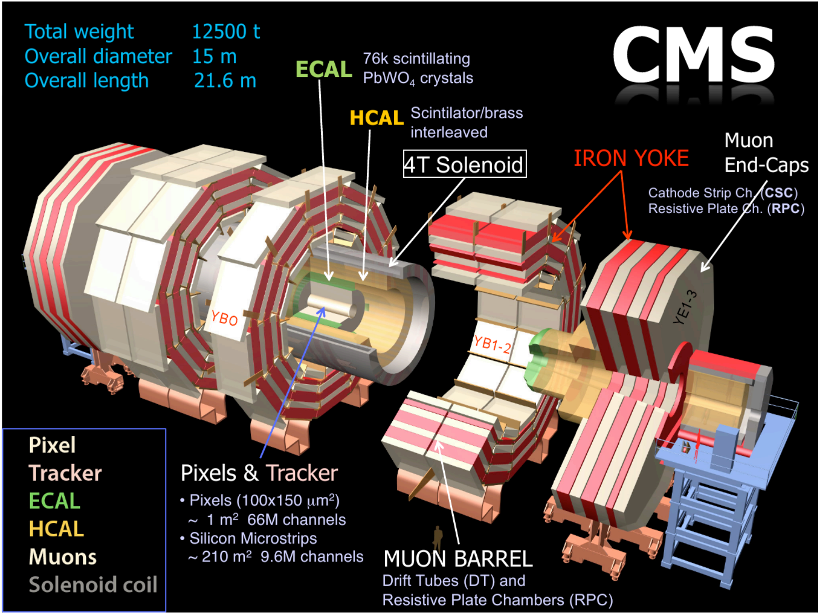
DSM/IRFU CEA/Saclay

SPP – May 31, 2010

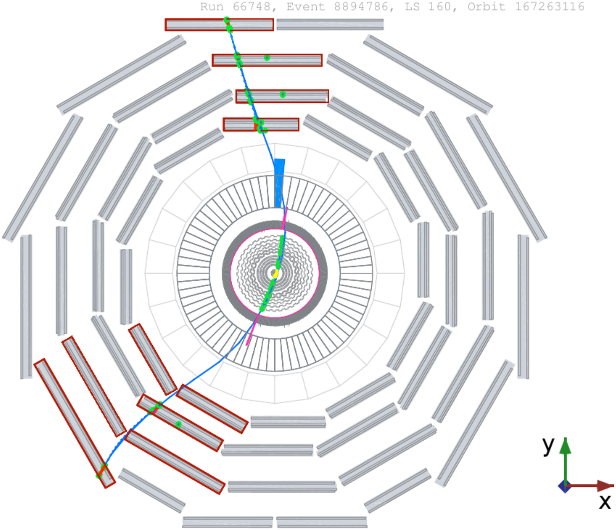
- Before the collisions
- Overview of performance at 7 TeV
- Some results at 900 GeV and 2.36 TeV
- SPP activities within CMS

Introduction



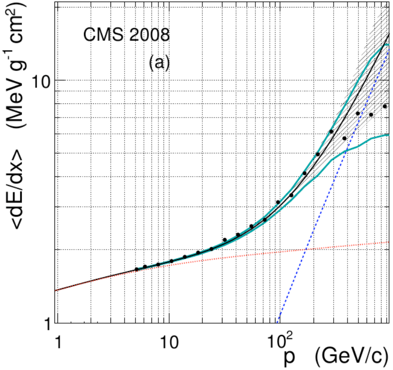
Cosmic Muon Solenoid...

- Roughly 300 millions of cosmic rays events collected
- 23 papers published on JINST
- detector performance
- calibrations
- alignments
- and more!



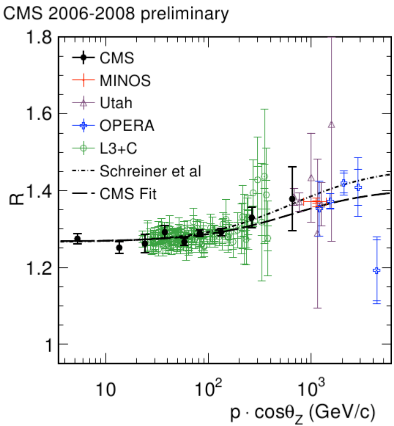
Cosmic Muon Solenoid...

Measurement of the muon **stopping power** in lead tungstate crystals



First measure ever!

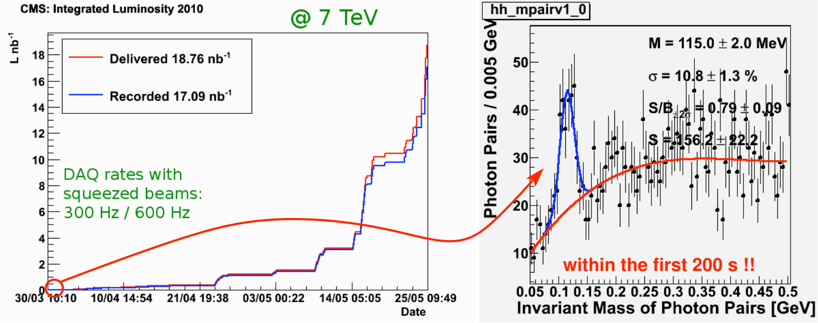
Measurement of the **charge asymmetry** of atmospheric muons



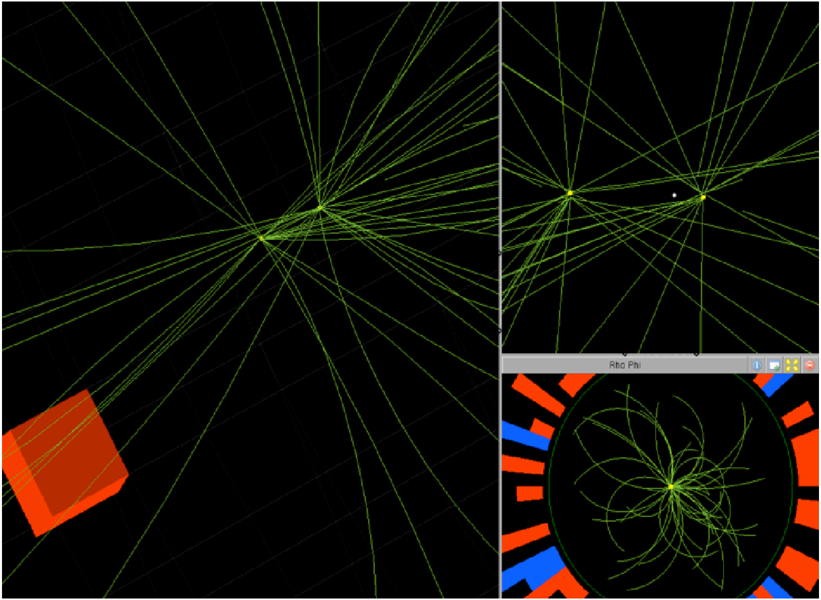
A good alignment is essential

First collisions

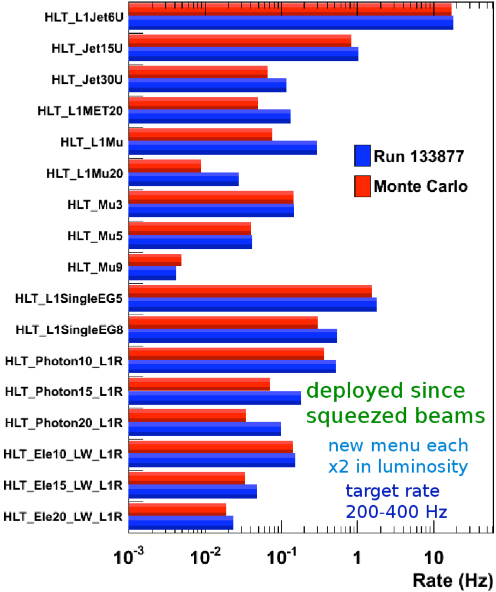
- First LHC collisions at $\sqrt{s} = 900$ GeV: 23 Nov 2009
  - $\sim 15\ \mu\text{b}^{-1}$ collected at 900 GeV
  - $\sim 1\ \mu\text{b}^{-1}$ collected at 2.36 TeV
- First LHC collisions at $\sqrt{s} = 7$ TeV: 30 March 2010
  - So far $\sim 17\ \text{nb}^{-1}$ collected



Low luminosity but. . .



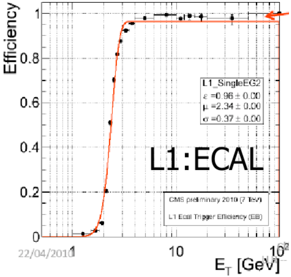
First collisions: a word on triggers

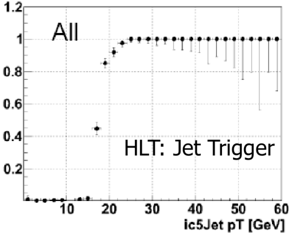


deployed since squeezed beams

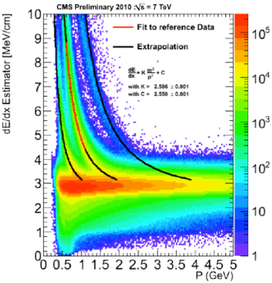
new menu each x2 in luminosity

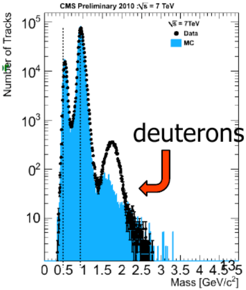
target rate 200-400 Hz

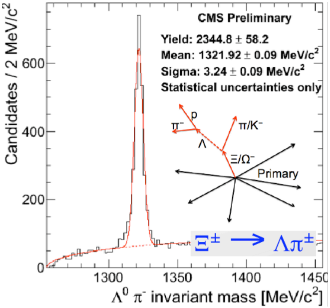


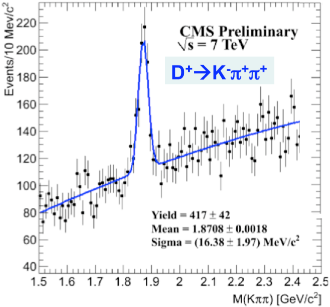


First collisions: tracker

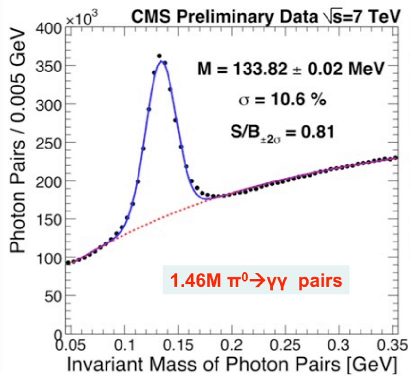


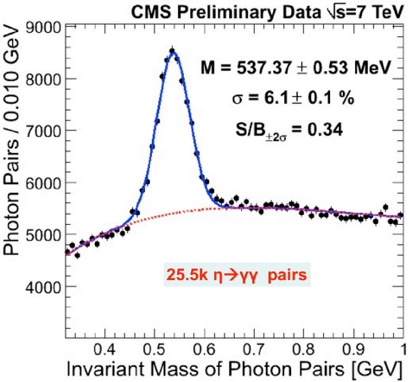






First collisions: ECAL

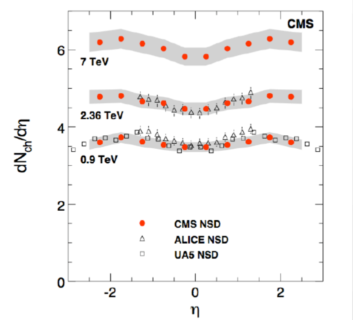


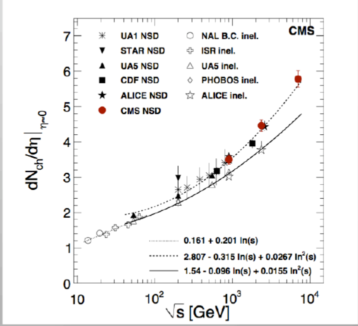


First collisions: highlighted results

p_T and η distributions of charged hadrons at $\sqrt{s}$ = 7 TeV

- Similar analysis as in the CMS paper JHEP 02 (2010) 041
- Minimum bias selection using BSC trigger.
- Three methods used: tracks, tracklets and pixel clusters
- Results corrected to Non–Single Diffractive cross section.
- Diffraction controlled via forward activity measurements in CMS





Strong rise of the particle density at 7 TeV

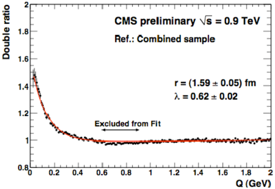
First collisions: highlighted results

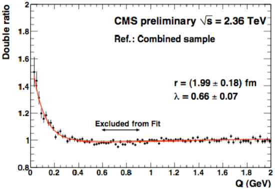
Correlations between identical bosons (pions) $\sqrt{s}$ = 0.9 and 2.36 TeV

$Q^2=-(p1-p2)^2$

$$R(Q) = C\left[1+\lambda\Omega(Qr)\right]\cdot(1+\delta Q) \qquad \Omega(Qr) = e^{-Qr},$$

- MinBias events
- Use 7 reference samples
- Combination of all ref. samples



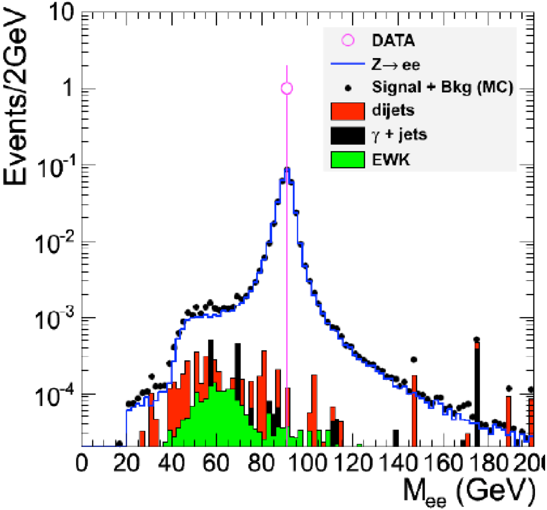


$\sqrt{s}$ = 0.9 TeV $r = 1.59 \pm 0.05$ (stat.) ± 0.19 (syst.) fm and $\lambda = 0.625 \pm 0.021$ (stat.) ± 0.046 (syst.)

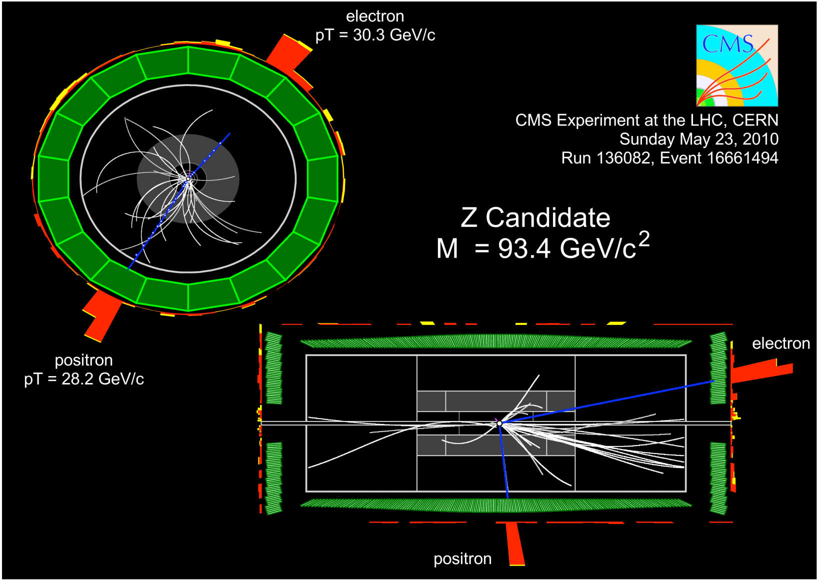
$\sqrt{s}$ = 2.36 TeV $r = 1.99 \pm 0.18$ (stat.) ± 0.24 (syst.) fm and $\lambda = 0.663 \pm 0.073$ (stat.) ± 0.048 (syst.)

First $Z \to ee$ pick

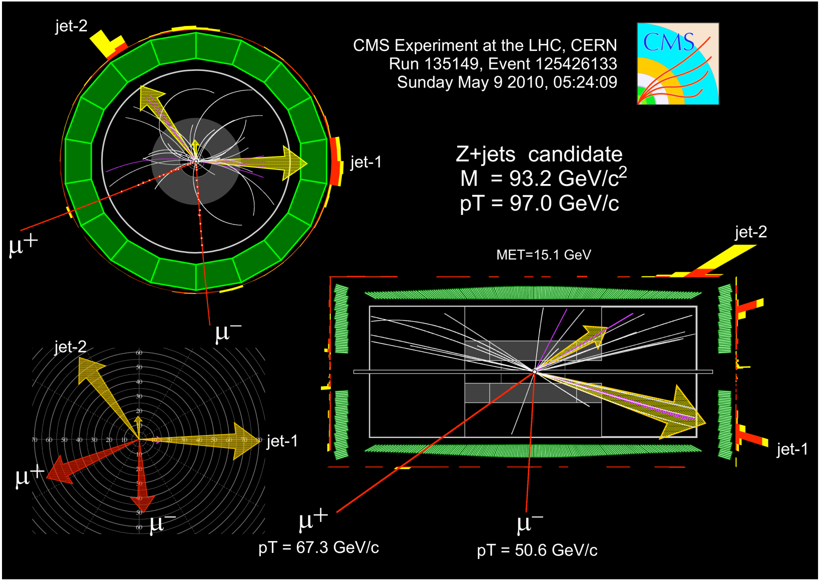
$m_Z = 91.2$ GeV$/c^2$: just luck or ECAL scale at 10^{-4}?



Another $Z \rightarrow ee$



$Z \to \mu\mu + \text{jets}$



SPP activities

Detector activities: ECAL oriented, from low level to high level

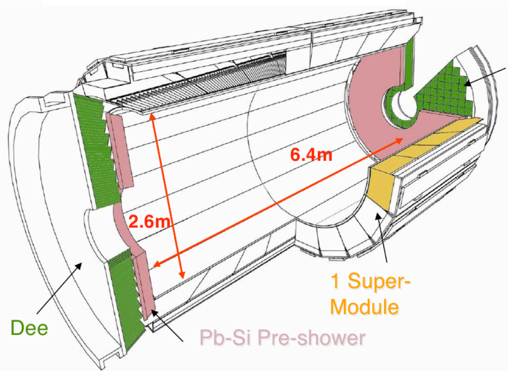
- Current responsibilities:
  - Selective Readout Process
  - Laser monitoring system (shared with Caltech for the hardware part)
  - ECAL reconstruction framework
- Long outstanding activities on ECAL performance: energy and position resolution, effect of crystal irradiation, correction of geometrical effects, noise analysis, data quality monitoring etc.

Physics analysis

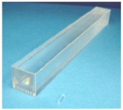
- Current involvements:
  - EWK convener
  - QCD photons convener
- long term efforts:
  - SM $H \to \gamma\gamma$, MSSM $H \to \tau\tau$
- medium/short term:
  - SM $ZZ \to \ell\ell\nu\nu$
  - inclusive photon cross-section, di-photon cross-section
  - Z studies (τ reconstruction, MET commissioning, etc.)

ECAL design

Homogenous Lead Tungstate ($PbWO_4$) Crystal Calorimeter + Pb-Si Preshower



Crystals are projective and positioned pointing slightly off the IP to avoid cracks.



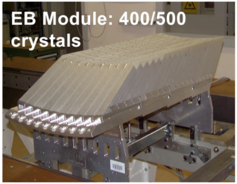
Barrel (EB):
- 61200 crystals
- 36 Supermodules (SM), each 1700 crystals
- $|\eta| < 1.48$

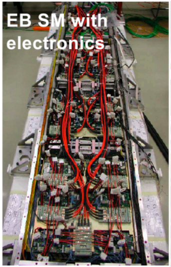
Endcap (EE):
- 14648 crystals
- 4 Dees, SuperCrystals of 5x5 xtals
- $1.48 < |\eta| < 3.0$

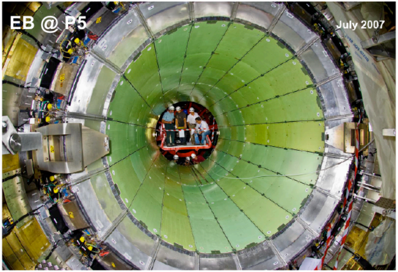
Preshower (ES):
- Pb-Si
- 4 Dees
- 4300 Si strips
- $1.65 < |\eta| < 2.6$

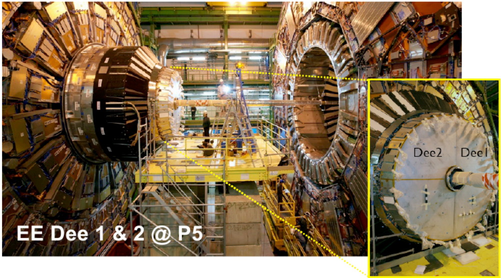
- 316 members, 27 institutes ($\sim$ 15% of CMS)

ECAL construction



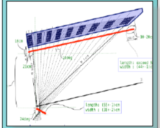






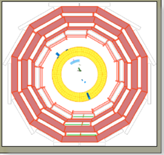
Time line

2006-2007: Commissioning & calibration of each SM with cosmics on surface

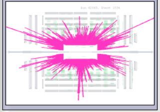


2006: H4 Test Beam: 9 SM calibrated; H2 Combined Test Beam: ECAL+HCAL

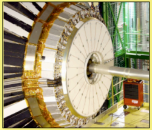
2006: 2 SM tested with B-field on surface (MTCC)



2008: Endcap Installation. Commissioning with cosmics and first beam in-situ



2009: Installation of preshower and commissioning of Endcap trigger

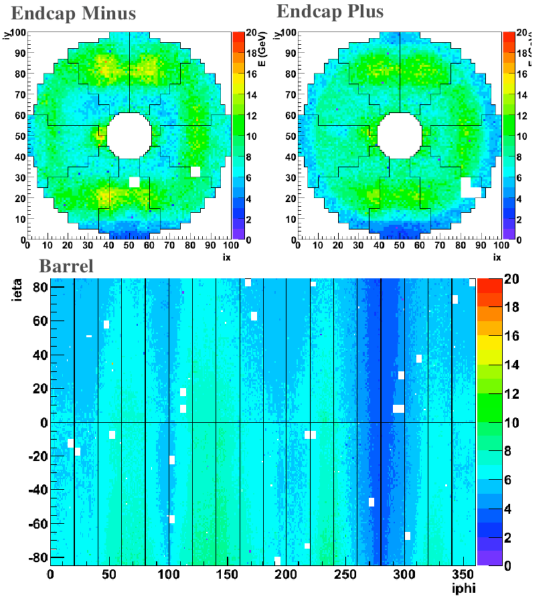


2007: H4 EE Test Beam; Individual signoff of each SM during installation

2006 2007 2008 2009

Startup conditions: status

- **More than 99% active channels for both trigger and data**
  - white regions masked at readout 0.95%
  - separate read-out paths for trigger and data
  - can recover information for most using trigger
  - only 0.15% are truly dead, with neither data nor trigger information
- Dedicated channel status map in database for handling such problematic regions in reconstruction
- **No new problematic channels since cosmic runs!**

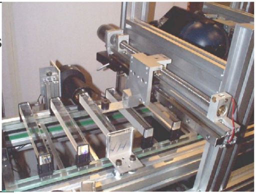


Startup conditions: calibration

- **barrel**: $\sim 1/3$ at $\sim 0.3\%$ (Test-beam), all at $\sim 1.4 - 2.2\%$ (cosmic rays)
- **endcaps**: $\sim 3\%$ at $< 1\%$ (Test-beam), all at $\sim 5\%$ (lab + beam splash)

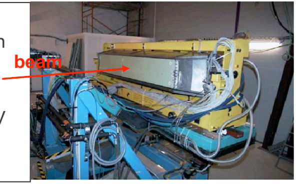
A very intense 10 years long pre-calibration campaign. Several orders of magnitude in energy: from 1 MeV of Co^{60} source to 120 GeV electron beam.

Laboratory measurements during crystal qualification phase.
(2000-2006)



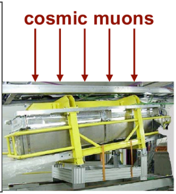
Test Beam: Cern electron beams.

From 15 GeV to 250 GeV.
(2004-2007)

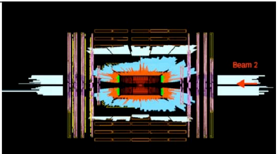


Channel intercalibration with cosmic muons (only Barrel SMs)

(2006-2007)



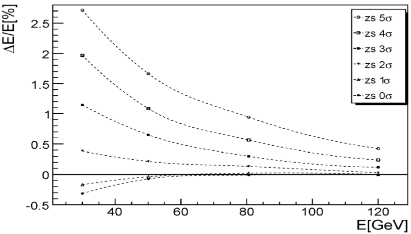
Beam Splash:
In September 2008 and November 2009, beam was circulated in LHC, stopped in collimators 150m away from CMS



red = ECAL, green=ES, blue=HCAL

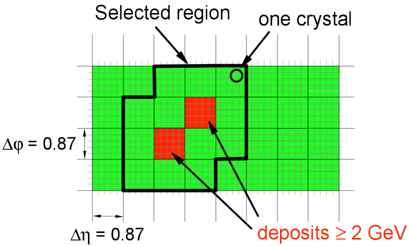
Selective Readout

- Reduces ECAL data volume by a factor 20 to fit within DAQ bandwidth (1MB/event @100kHz)
- Does not apply reduction in regions of electron and photon candidates
- Zero suppression on rest of data ($\sim 2\,\sigma_{noise}$ cut).



A static zero suppression would introduce a bias on the energy reconstruction.
Electron test beam.

- Decides type of readout (full or with zero suppression) for each readout unit (5×5 crystal matrix)
- Input: trigger primitives
- Window algorithm

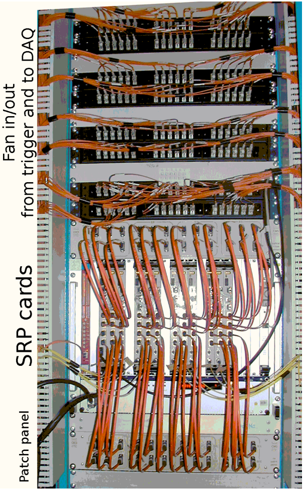


Selective Readout hardware

Innovating technologies

- Highly integrated system
  - Only 12 VME 6U boards to cover the full ECAL
  - Board logic and communication channels concentrared on a single large FPGA
- Parallel optical links: 240 links.

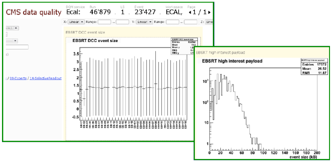
SRP card



SRP system

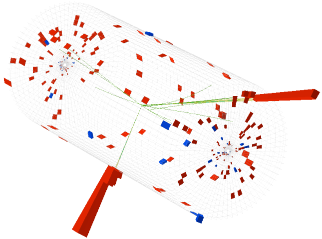
Selective Readout in action

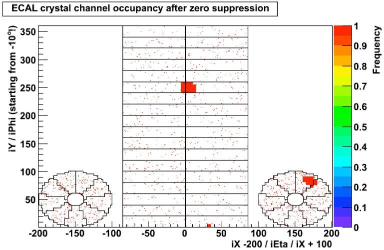
- In operation from the first collisions
- SRP system is extremly reliable, very smooth operation
- SRP decision validated offline on more than 8 Million events: not a single error



Online validation on data (*data quality monitoring*)

Run 133877 Event 28405693, $Z \to e^+e^-$ candidate

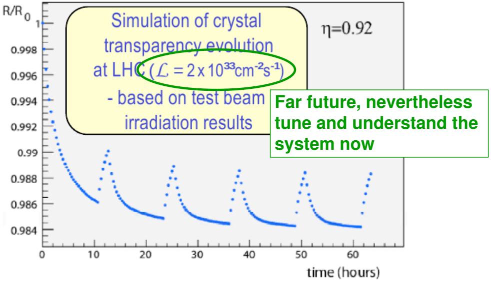


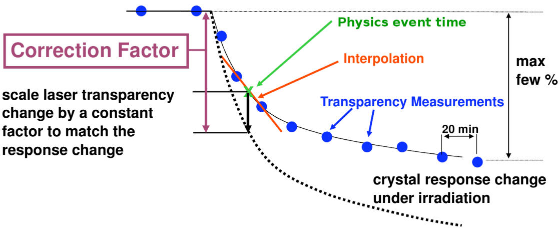


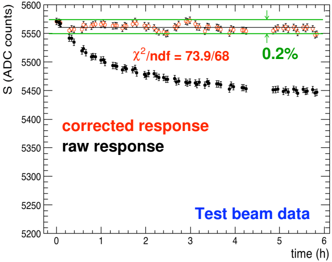
Region of the two electrons candidates were fully read out.

Transparency variations

- rapid loss and recovery of the optical transmission under irradiation (few hours)
- due to the creation of colour centres which absorb the transmitted light



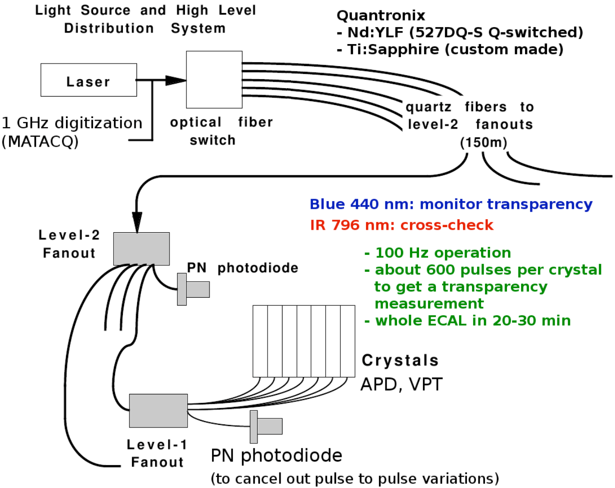




0.2% is the required precision for the target resolution of 0.5% at high energies

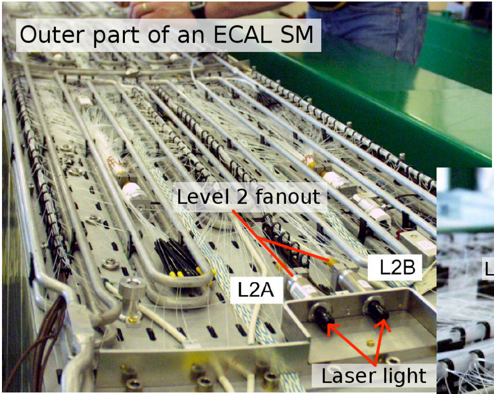
N.B. temperature variations are already controlled much better than required

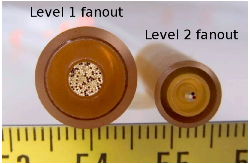
Laser monitoring system

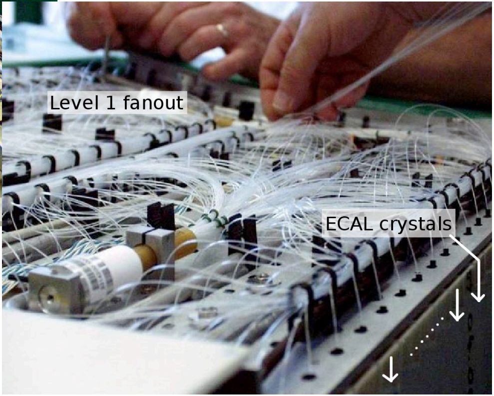


- Spectral contamination: $< 10^{-3}$
- Pulse energy: 1 mJ at the source, dynamic range up to 1.3 TeV equivalent
- Pulse width: $<$ 40 ns FWHM to match the ECAL readout
- Pulse jitter: $<$ 4 ns (24 hours), $<$ 2 ns (30 min).
- Pulse to pulse instability: $<$ 10%

Laser monitoring system

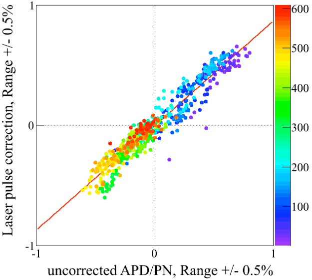




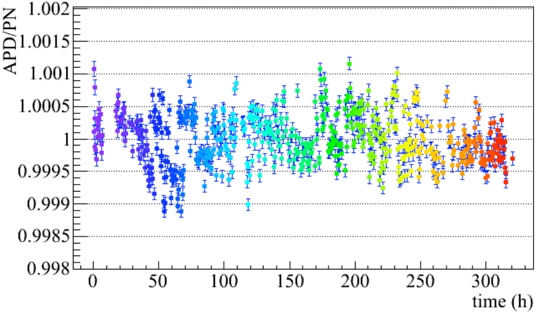


Laser transparency measurement

- PN linearity correction
- correction for the different shaping time of APD (VPT) and PN using the Single Pulse Response of each individual channel of APD (VPT) and PN convoluted with the laser shape from the 1 GHz digitization



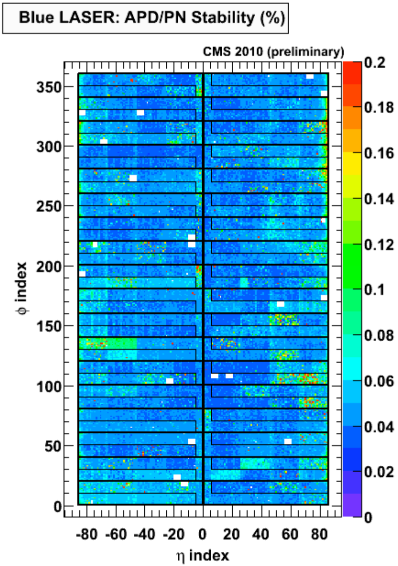
Stability for a typical channel over about 350 h



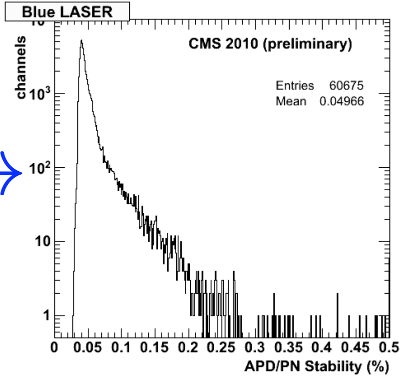
- stability defined as the r.m.s. of the considered quantity

- standard loose quality selections applied
- excellent stability: $< 4 \cdot 10^{-4}$

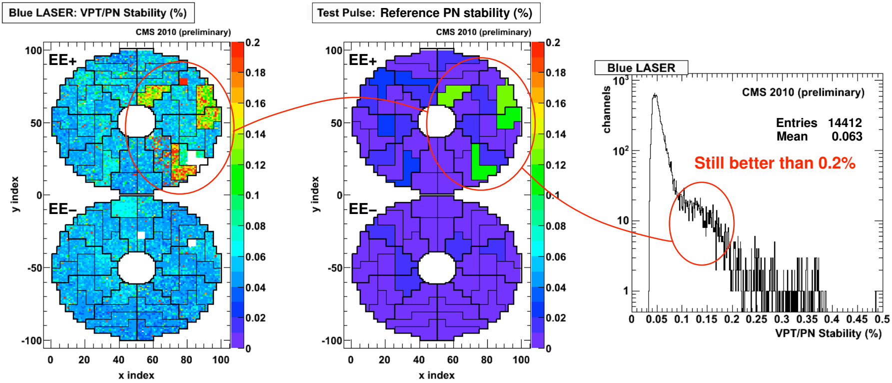
Blue laser stability: barrel



- 350 h during 2010 LHC collision data taking
- white spots are dead readout regions

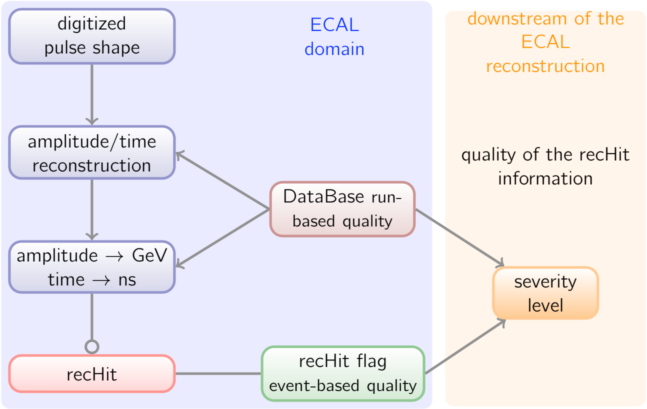


Blue laser stability: endcap



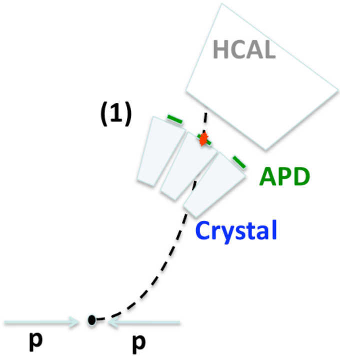
- 350 h during 2010 LHC collision data taking
- white spots are dead readout regions
- VPT/PN for the right half of EE+ is slightly less stable because it had only one active PN instead of the nominal 2 during the period considered here

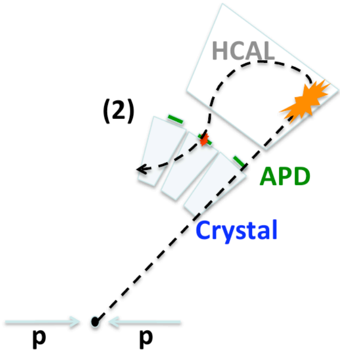
ECAL reconstruction



ECAL reconstruction

- Anomalous signals due to a deposit of energy in the ADP volume (barrel), which fakes a much larger energy deposition in the corresponding crystal
- Particles inducing the signal comes from either:
  1. directly from the Interaction Point ⇒ early signals (no scintillation time)
  2. in secondary interactions ⇒ broader timing signature

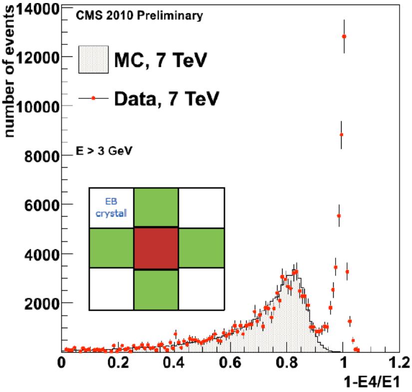




ECAL reconstruction

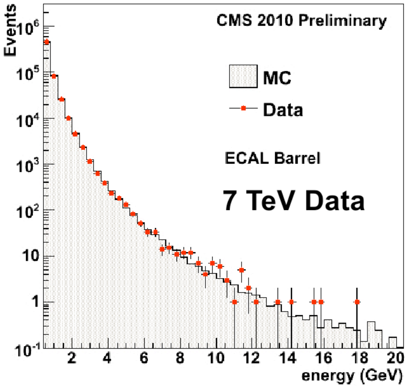
- Anomalous events observed in a small fraction of collision events (roughly 1 per 10^3 minimum bias)

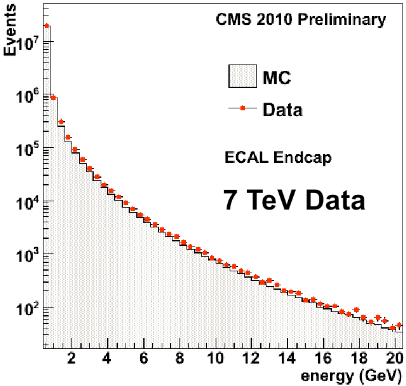
- Distinct pulse shape
- Early or broad timing distribution
- Isolated signal
- Uniform distribution in the barrel
- Not seen in EE (VPTs readout)



- **easily identified and removed** with a quality selection (e.g. $E4/E1$)
- timing and pulse shape discriminants are also deployed to tag these signals

ECAL reconstruction

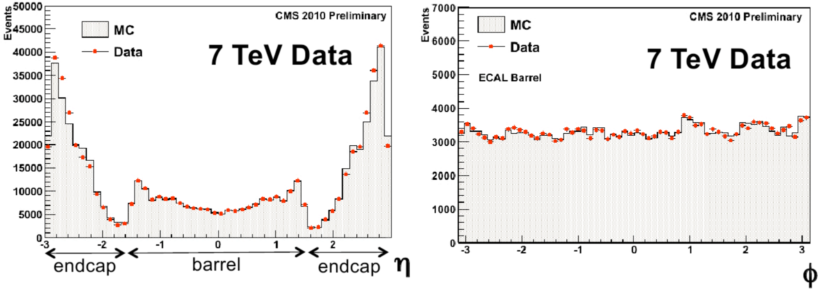




Spectra of energy deposits in ECAL crystals

- MC normalized to data luminosity
- same selections applied to both data and MC
- good agreement between data and MC

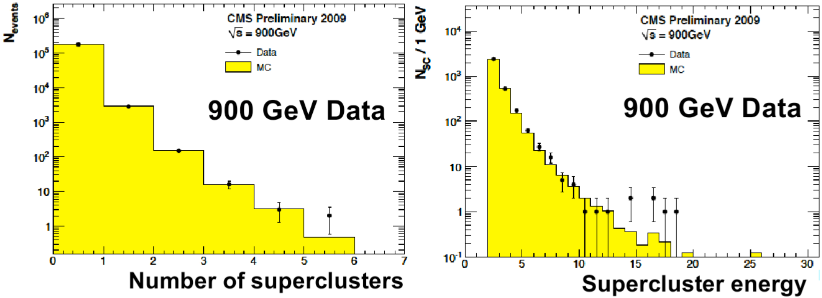
ECAL reconstruction



Rapidity and azimuth distributions of the highest E_T ECAL channel

- variations in η are due to detector geometry
- variations in phi, accurately reproduced by MC, reflect modularity and the inhomogeneity of the energy-equivalent noise in ECAL

ECAL reconstruction



Electron and photon showers deposit their energy in several crystals

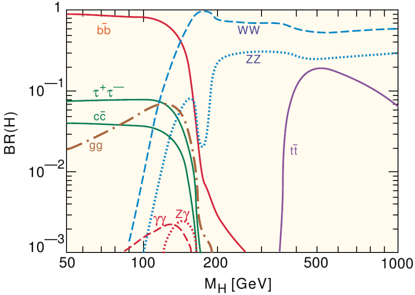
- presence of material in front of ECAL results in bremsstrahlung and photon conversions; strong B field results in energy spread azimuthally
- energy is "clustered" into super-clusters to collect energy spread in ϕ

Physics analyses

- Not an extensive presentation of all the analysis here at SPP
  - it can fill one (or more!) whole seminar(s) $\rightarrow$ next time
- Focus on strategy and early commissioning of physics observables

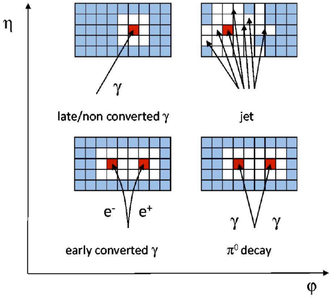
Aim: standard Model $H \to \gamma\gamma$

- the benchmark channel that has driven the design of ECAL
- discovery channel between 114.4 (LEP limit) and 150 GeV/c^2
- clean signature
- narrow peak $\mathcal{O}(10^{-3}\ \mathrm{GeV}/c^2)$ over continuous background



Recent improvements:

- unbinned maximum-likelihood approach
  - designed to facilitate analyses at low statistics
  - exploits best kinematical discriminators
- more accurate MC production and at $\sqrt{s} = 10$ TeV



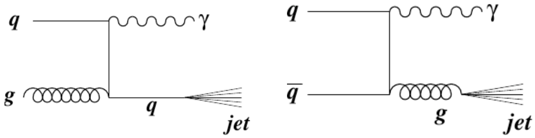
Aim: standard Model $H \to \gamma\gamma$

- Event selection: $p_T^{\gamma 1,2} = (20, 20)$ GeV
- Correct for primary vertex (studied with control sample $Z \to ee$)
- Photon isolation optimized using tracker, ECAL and HCAL information
- Best model found using toy experiments: only 3 discriminating variables for the kinematics + 4 γ categories

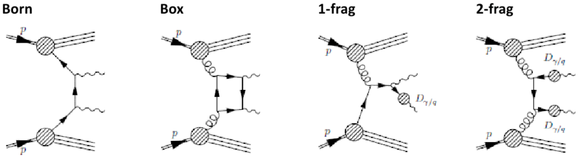
Unapproved results and plots. For details ask the CMS Saclay group over a coffee ;-)

Now: photon analyses

- Measurement of the photon spectrum as a function of the photon transverse energy, for $|\eta^{\gamma}| < 2.5|$ and $p_T^{\gamma} > 10$ GeV
- expected about 220 γ per nb^{-1} within the acceptance at 7 TeV



- Measurement of the inclusive di-photon production cross-section



Now: photon commissioning

Unapproved plots. For details ask the CMS Saclay group over a coffee ;-)

Now: diphoton commissioning

Unapproved plots. For details ask the CMS Saclay group over a coffee ;-)

Now: diphoton commissioning

Unapproved plots. For details ask the CMS Saclay group over a coffee ;-)

Aim: MSSM $H \to \tau\tau$, channel $\mu + \tau_{\text{jet}}$

- Sensitivity with 1 fb^{-1} of data already
- Preparatory steps:
  - Z boson cross-section measurements (starting with 50 pb^{-1} of data)
  - τ reconstruction studies (PFlow approach): efficiency, identification
  - commissioning of MET reconstruction
  - optimization of selections
  - data drive QCD background estimation and evaluation of systematic uncertainties

Unapproved plots. For details ask the CMS Saclay group over a coffee ;-)

Aim: diboson, $ZZ \to \ell\ell\nu\nu$

- Observation of ZZ final states to study anomalous Triple Gauge couplings
- Considered channel: $ZZ \to 2\ell 2\nu$
  - $\mathrm{BR}(ZZ \to 4\ell) = 0.36\%$
  - $\mathrm{BR}(ZZ \to 2\ell 2\nu) = 1.2\%$
- A good understanding of the missing transverse energy is mandatory!

Now: MET commissioning

Unapproved and plots. For details ask the CMS Saclay group over a coffee ;-)

Now: MET commissioning

Unapproved and plots. For details ask the CMS Saclay group over a coffee ;-)

Conclusions

CMS has performed extremely well during the first collisions period, with an impressively fast response to provide the first physics results

The ECAL SRP works perfectly since the very beginning, without a single issue over several hundred millions of events

The ECAL laser monitoring system performs very well and has proven to be amazingly stable during the first period of data taking

The ECAL reconstruction has profited from the continuous contributions of the Saclay group and is performing very well, promptly handling any new feature of the detector

The coherent strategy in place for the physics analyses allows to profit from the coming data to fully commission all the key ingredients that will be needed for the mid and long term discovery searches