CMS: Status and Physics prospects

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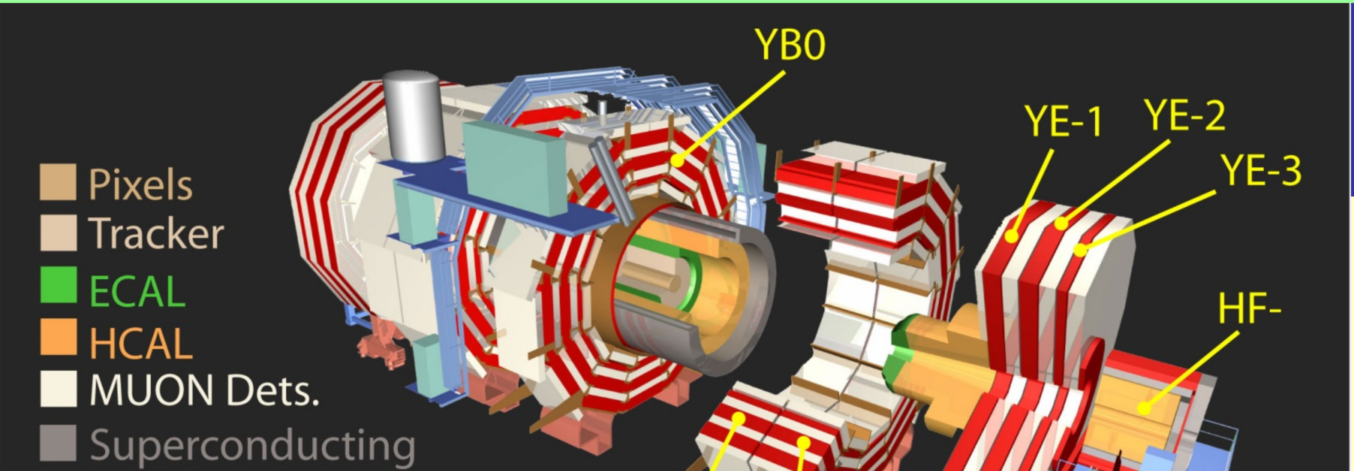
Moscow, 19-25 August, 2009

- CMS Detector completion and commissioning
- Performances with real data: cosmics and first LHC Beam
- Early Physics potential

*On behalf of the CMS Collaboration

CMS detector: compact and modular design

- **Compact solenoid (4T) containing the calorimeters and the Si tracker**
- **Muon chambers embedded in the iron return yoke**
- **Excellent and compact crystal electromagnetic calorimeter**
- **Tile calorimeter for hadronic activity**



CMS

Weight	14000t
Diameter	15m
Length	21.6m
Magnetic field	3.8T

>2500 scientists and engineers from 38 countries

Tracker: Si pixels, strips
$\sigma/p_T \approx 1.5\text{x}10^{-4} p_T + 0.005$

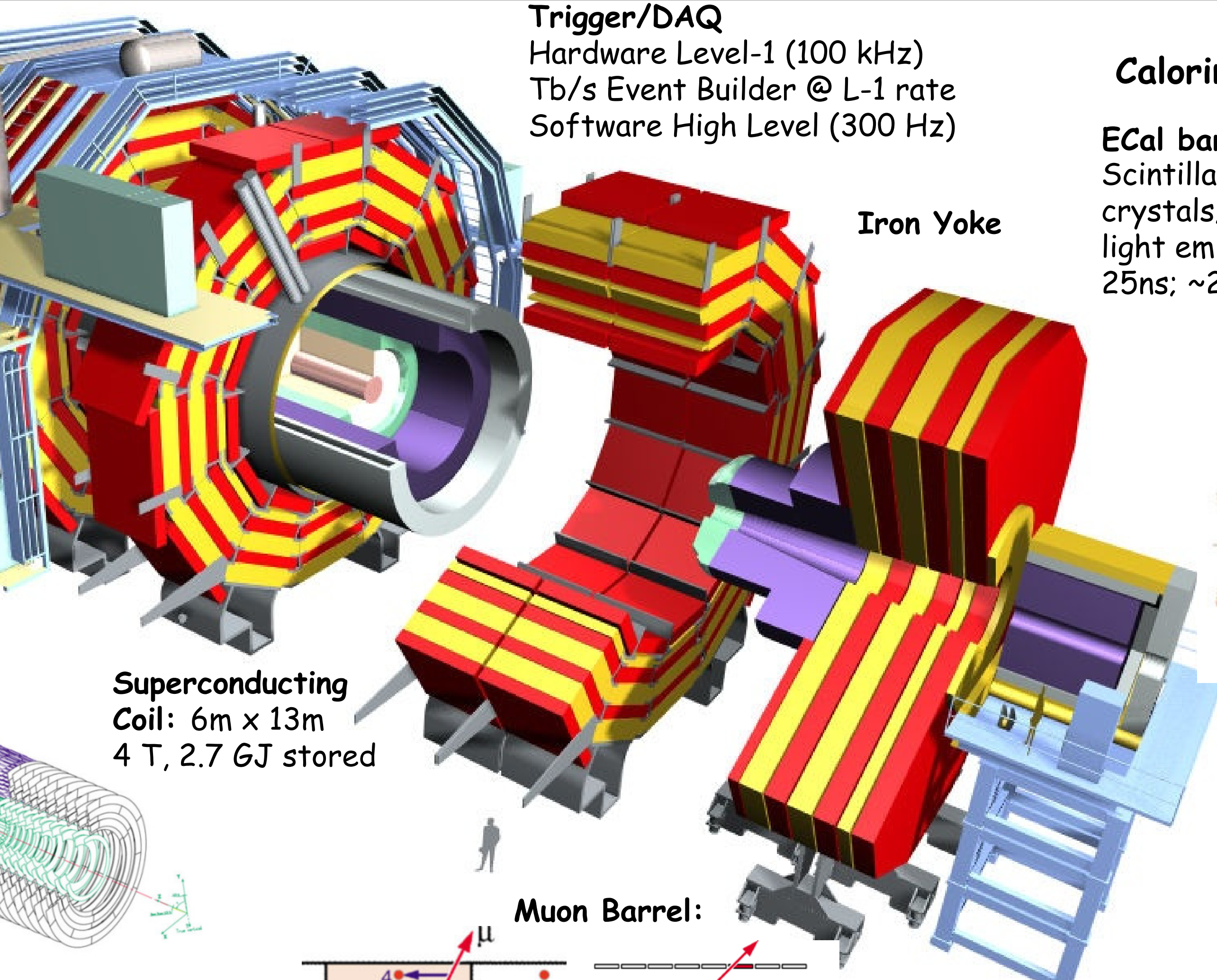
Ecal: PbWO4 crystals
$\sigma/E \approx 2\text{-}5\%/\sqrt{E} + 0.005$

Hcal: Cu+scintillator (5.8λ + catcher)
$\sigma/E \approx 100\%/\sqrt{E} + 0.05$ GeV

Muon: $\sigma/p_T \approx 1\%$ @ 50GeV to 5% @ 1TeV(ID+MS)

CMS comprises 66M pixel channels, ~10M Si microstrip ch, ~75k crystals, 150k Si preshower ch, ~15k HCAL ch, 250 DT chambers (170k wires), 450 CSC chambers (~200k wires), ~ 500 Barrel RPCs and ~ 400 endcap RPCs, muon and calorimeter trigger system, 50 kHz DAQ system (~ 10k CPU cores), Grid Computing (~ 50 k cores), offline (> 2M lines of source code).

The CMS Detector



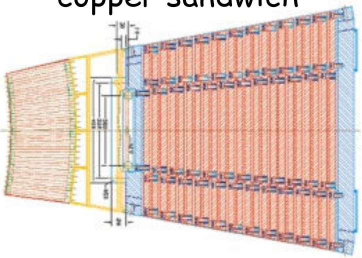
Trigger/DAQ
Hardware Level-1 (100 kHz)
Tb/s Event Builder @ L-1 rate
Software High Level (300 Hz)

Iron Yoke

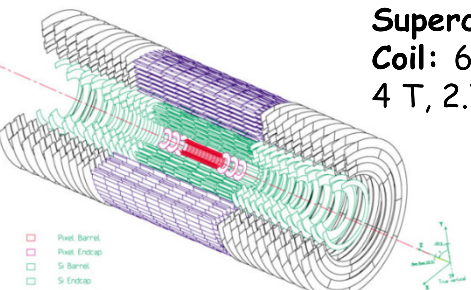
Calorimeters:

ECal barrel & endcap
Scintillating $PbWO_4$ crystals; ~80% of light emitted in 25ns; ~25 X0

HCal
Plastic scintillator copper sandwich



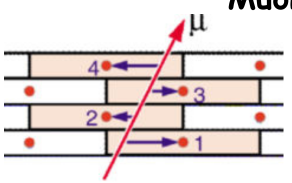
Superconducting Coil: 6m x 13m
4 T, 2.7 GJ stored



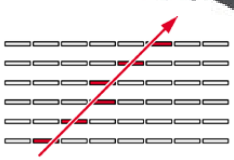
Tracker:
Silicon Microstrips: 10 barrel layers, 3+9 fw disks, tot 200m^2

Pixels: 3 barrel layers, 2 fw disks

Muon Barrel:

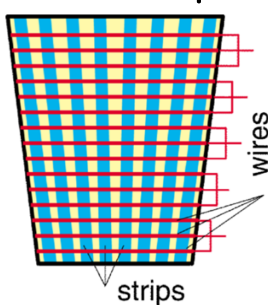


Drift tubes (DT)



Resistive Plate Chambers (RPC)

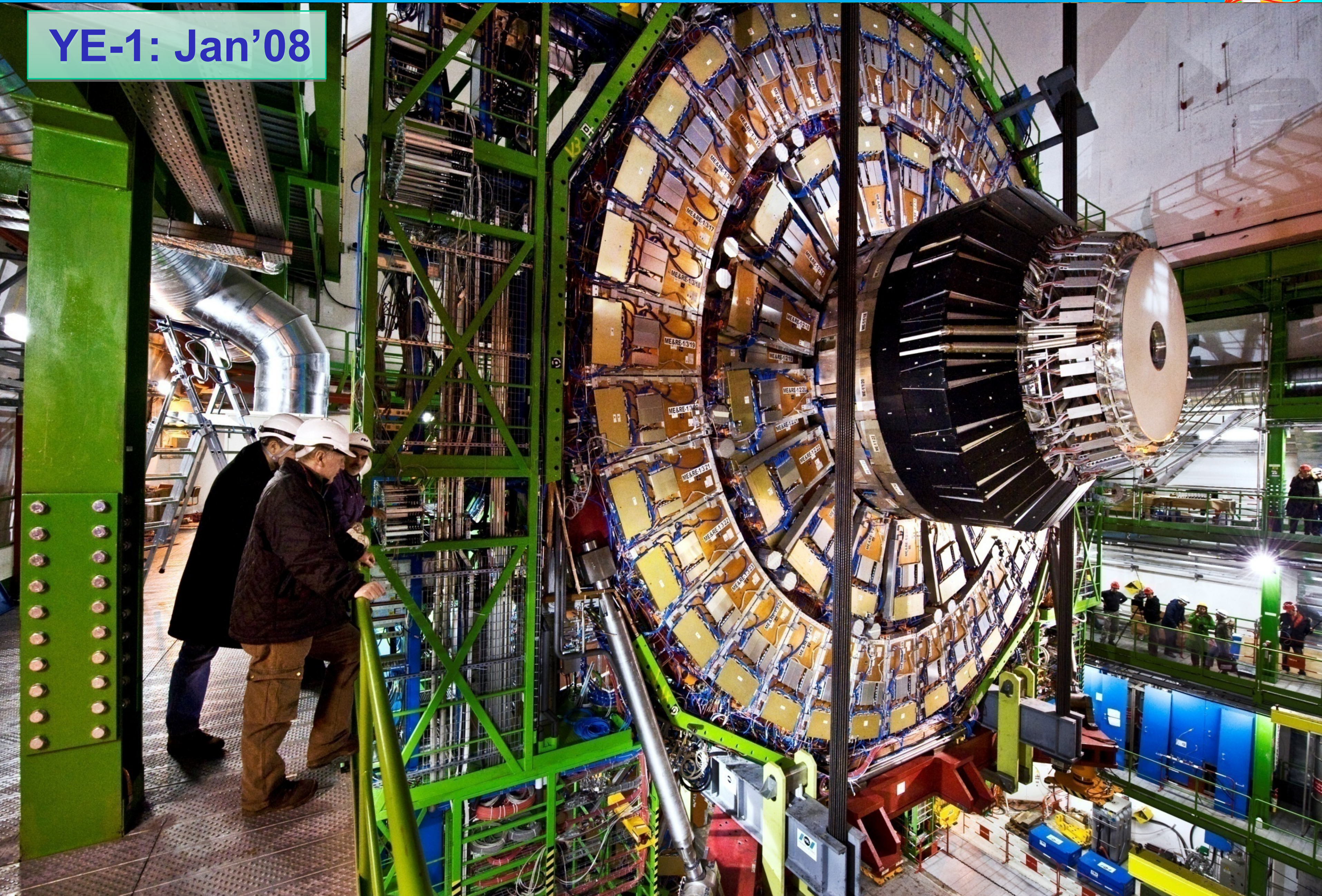
Muon EndCap:



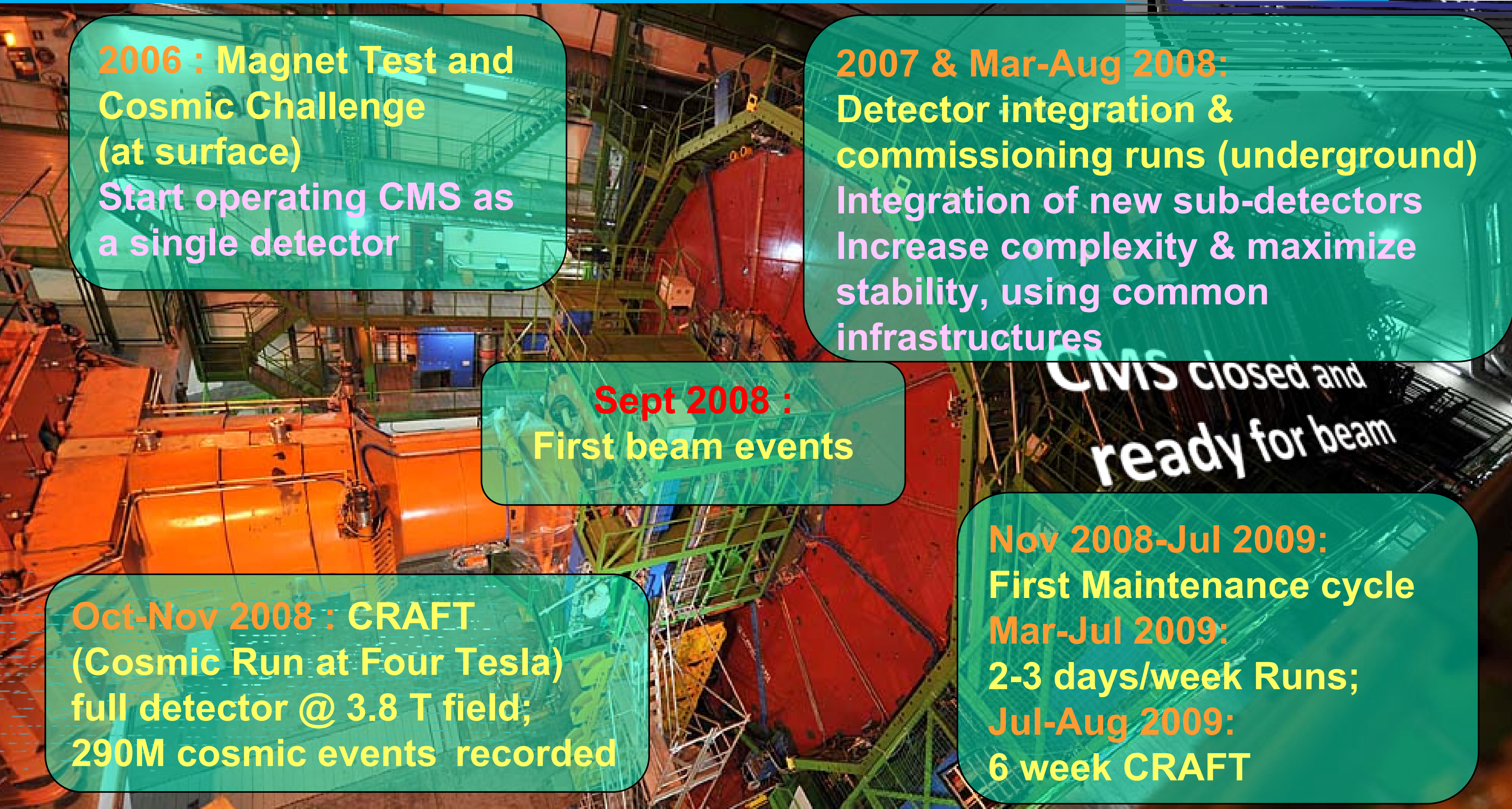
Cathode Strip Chambers (CSC)

Resistive Plate Chambers (RPC)

Going underground



September 3, 2008



2006 : Magnet Test and Cosmic Challenge (at surface)
Start operating CMS as a single detector

2007 & Mar-Aug 2008:
Detector integration & commissioning runs (underground)
Integration of new sub-detectors
Increase complexity & maximize stability, using common infrastructures

Sept 2008 :
First beam events

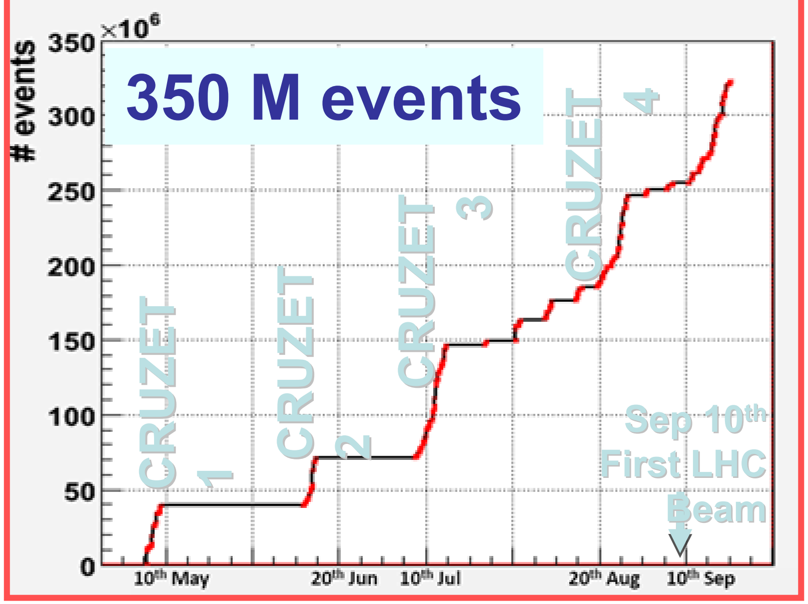
Oct-Nov 2008 : CRAFT (Cosmic Run at Four Tesla)
full detector @ 3.8 T field;
290M cosmic events recorded

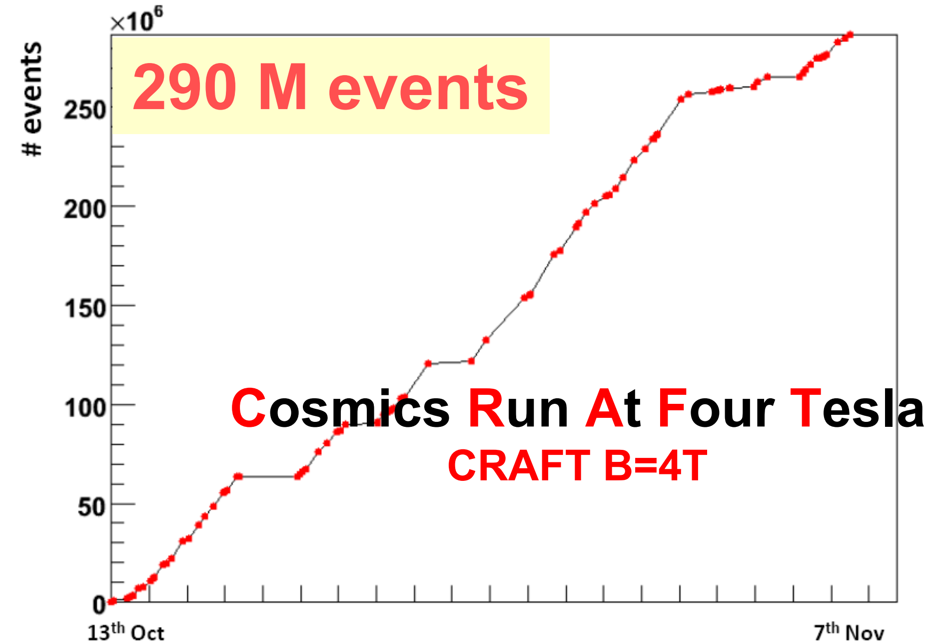
Nov 2008-Jul 2009:
First Maintenance cycle
Mar-Jul 2009:
2-3 days/week Runs;
Jul-Aug 2009:
6 week CRAFT

After almost 20 years, from conception, design, construction and commissioning CMS is closed and ready for beam

Cosmics runs

4 global cosmics runs with B=0T at 300 Hz rate, 350 M events





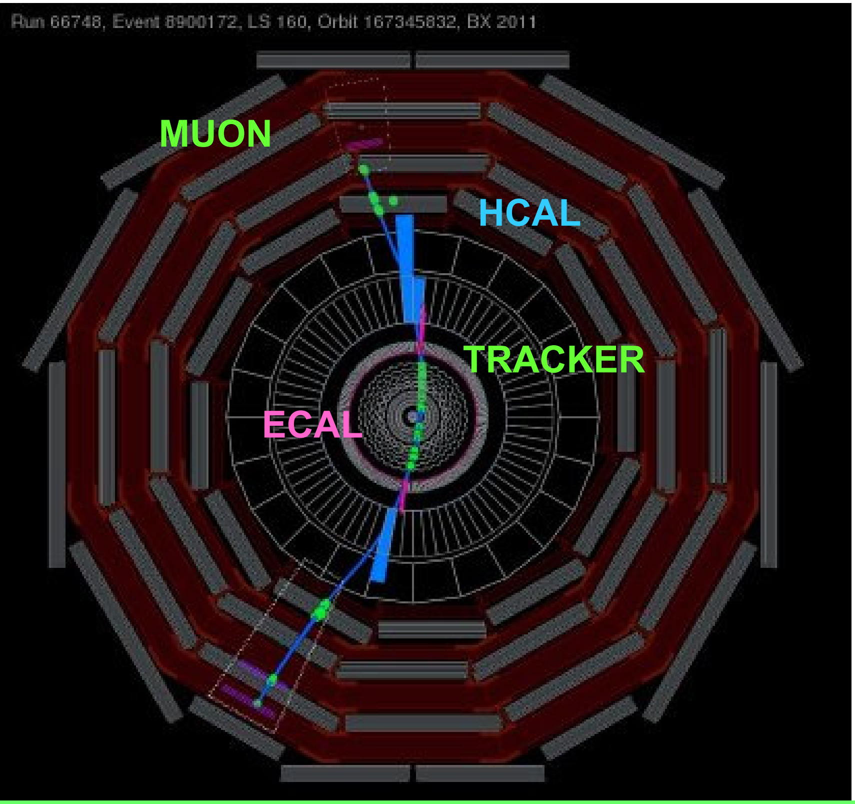
First analyses of data using s/w release destined for 2008 data-taking & LHC grid infrastructure.

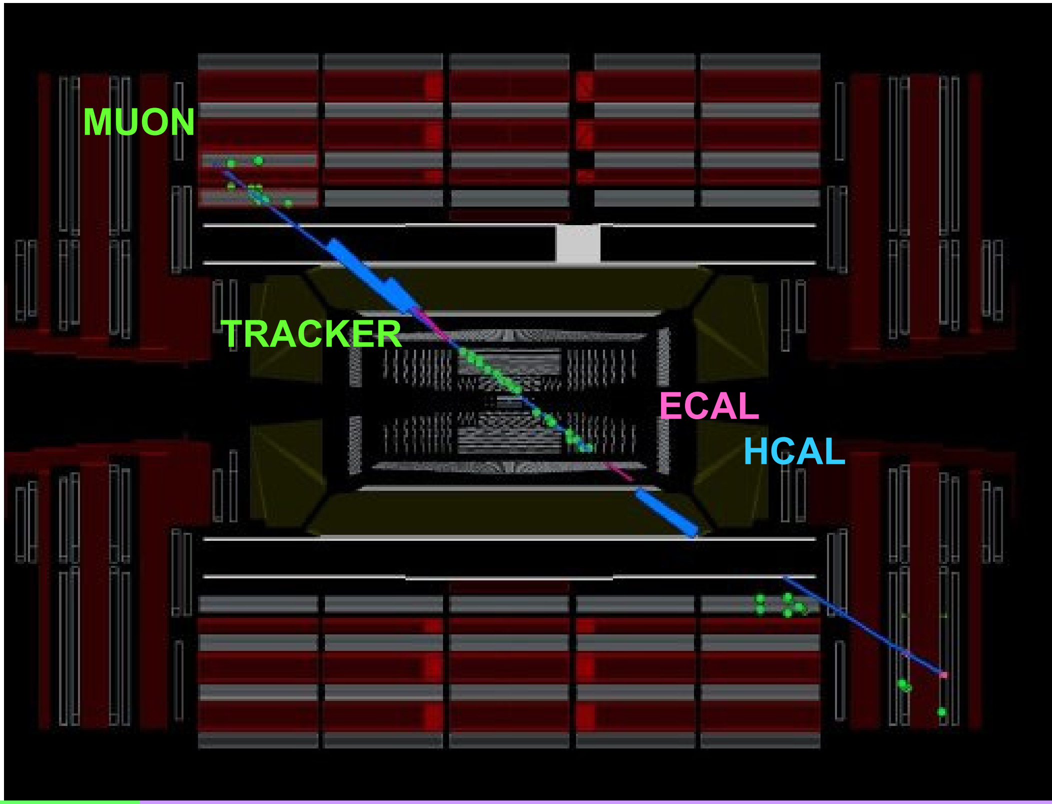
Repeat reconstruction and analyses with more advanced release versions.

- **4 weeks with B=3.8T (290M events, 400 TB of data distributed widely)**
- $\varepsilon \sim 70\%$ (24/7)
- 87% have a muon track in the chambers
- 3% have a muon track with tracker hits
- 30,000 events have a track with pixel hits

Cosmics Run at Operating Field (CRAFT)

Di-muon trigger: top-bottom coincidence, ≥ 2 stations/segment





Since cosmic muons arrive from random direction muon local reconstruction (timing) and muon finding algorithm modified (seeding, navigation). Standard "LHC" algorithms tested on "pointing" sub-sample.

Good data for ascertaining health and performance of detector (e.g. for alignment - equivalent to >10 pb^{-1}!)

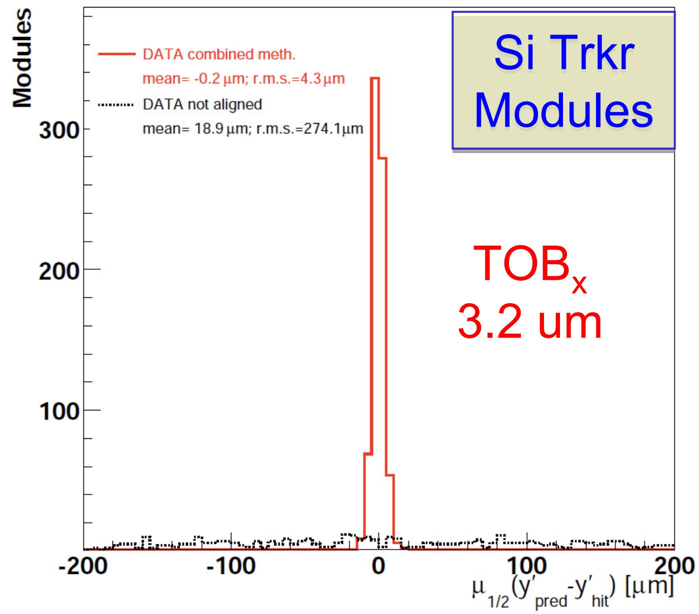
~ 25 papers in preparation

(to be sent for publication by end Sept)

Performance with Cosmics
Some Results

Tracker Performance: Alignment

13 layers in the Barrel
14 layers in the Endcaps
9.6M strips
66M pixels
More than 200 m^2 Si

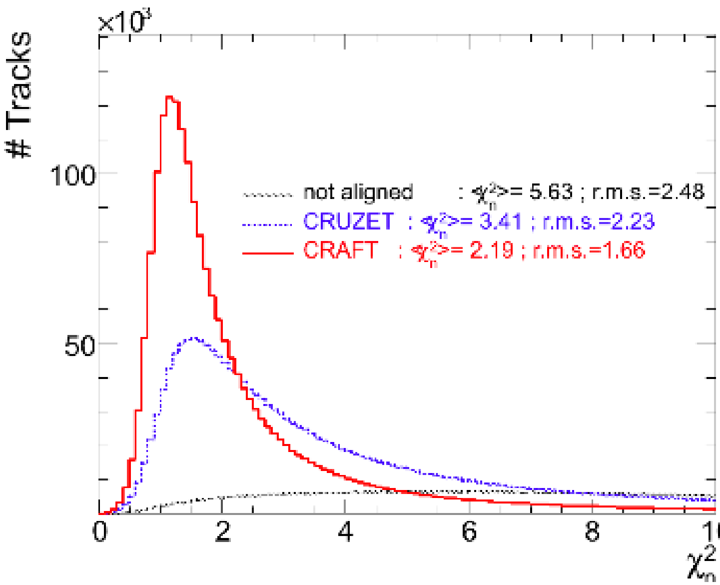


Si Trkr Modules

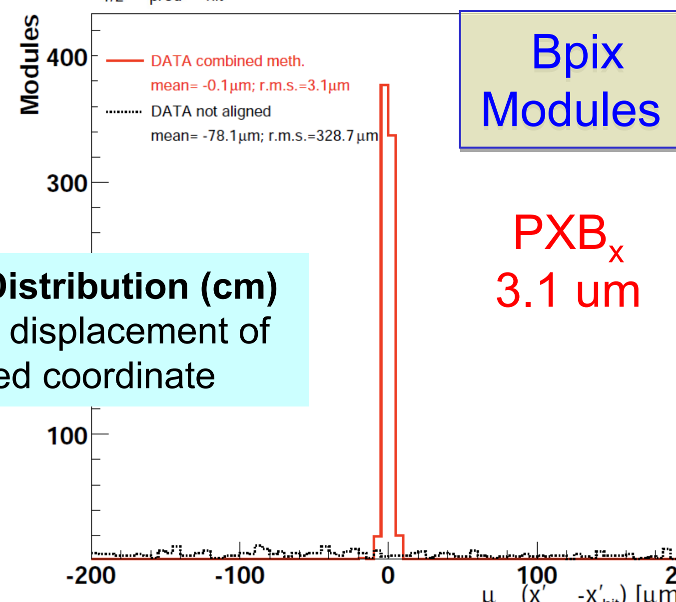
CRAFT

TOB_x
3.2 um

Large improvements as seen from chi2 distribution (no alignment errors included)



Mean of Residuals Distribution (cm)
Sensitive to remaining displacement of module in the measured coordinate



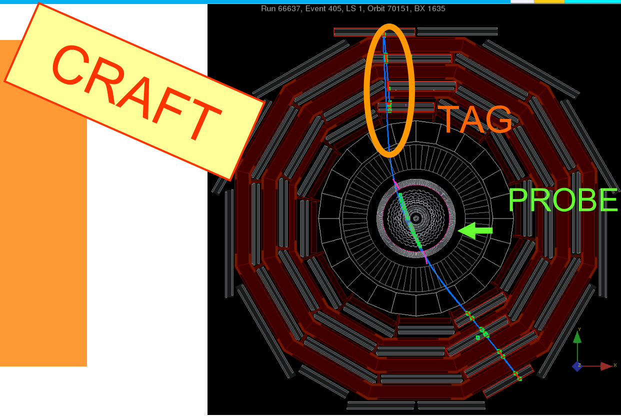
Bpix Modules

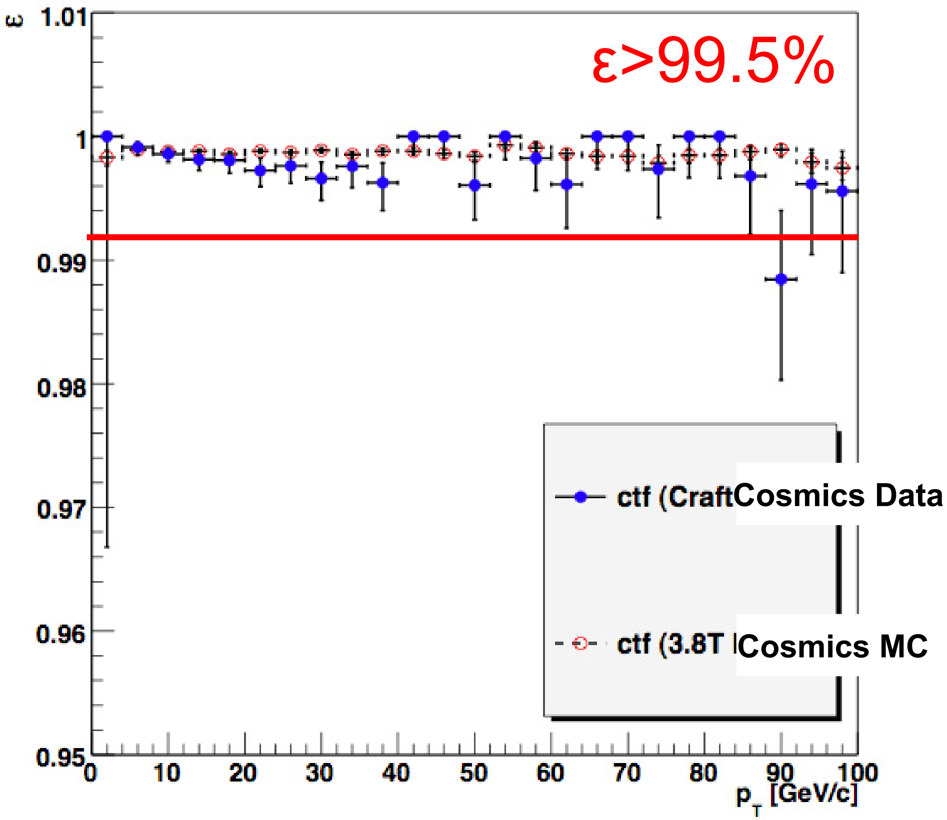
PXB_x
3.1 um

Tracker Performance: cosmic tracks finding efficiency

Tag and Probe method

- Tag : Standalone upper muons pointing to the Tracker near the origin (LHC-like tracks)
- Probe : Tracker muons





Achieved **high tracking reconstruction efficiency** demonstrated using cosmic muons:

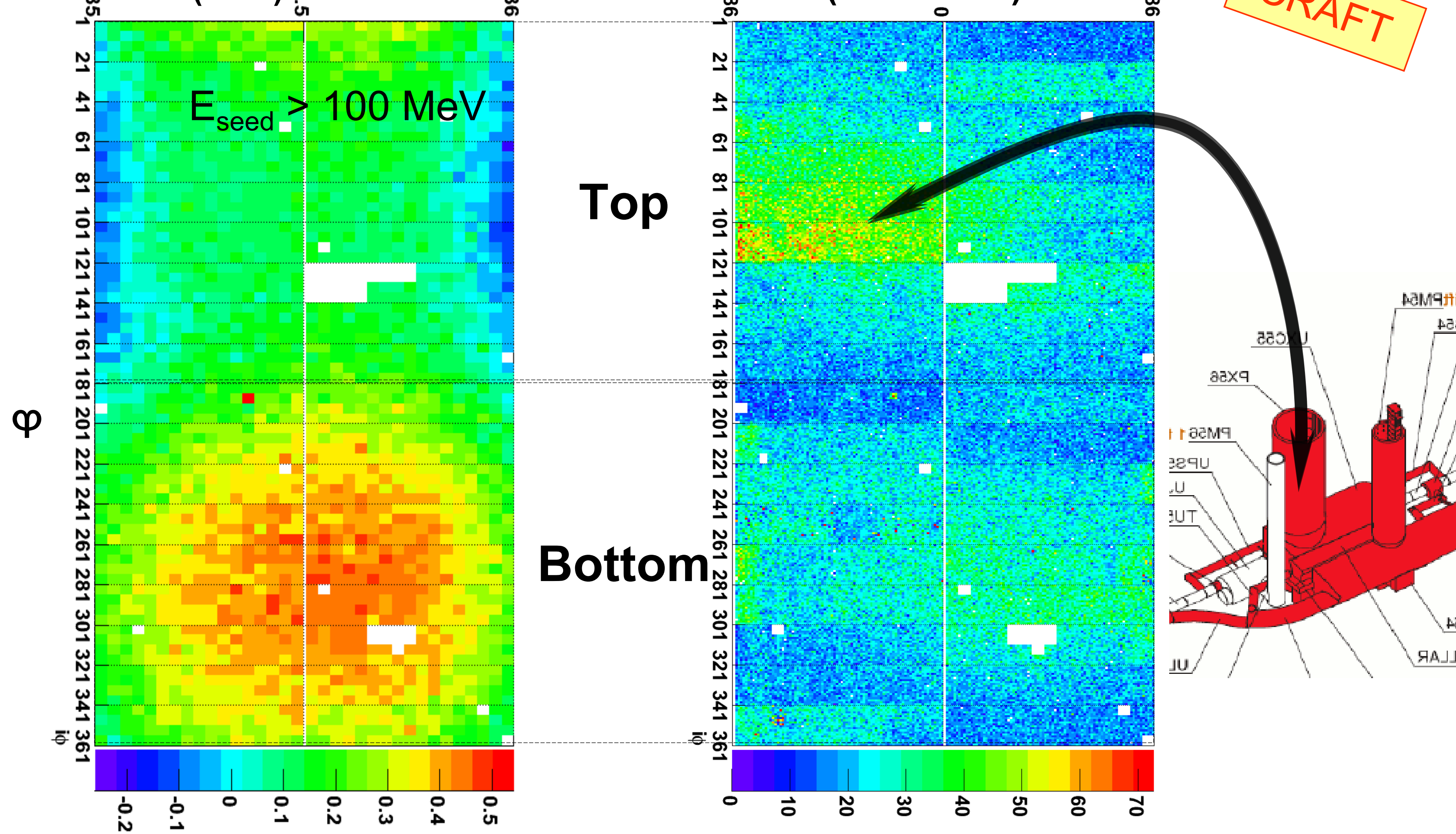
- **Strip Tracker**
    - TOB: 98%
    - TIB/TID: 96.6%
    - TEC+ : 99.2%
    - TEC-: 97.8 %
- **Pixels**
    - Barrel: 99.1%
    - Forward: 94.0%

ECAL: timing and occupancy

Timing – bottom is late (t.o.f.)

Occupancy – top is busier (shaft side)

CRAFT



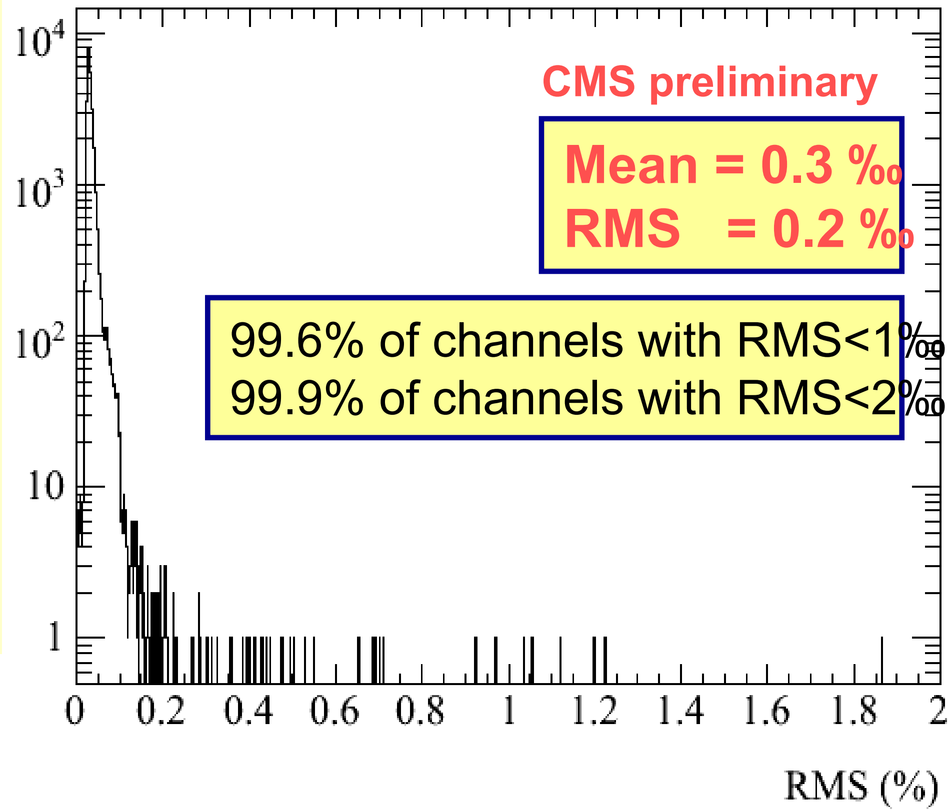
ECAL stability

ECAL design resolution requires Temperature, HV, LV stability

Under stable laser conditions, the ECAL LASER monitoring system is able to monitor the crystal response with a precision < 1‰
This precision is consistent with specifications (2‰) needed to achieve the ECAL design resolution

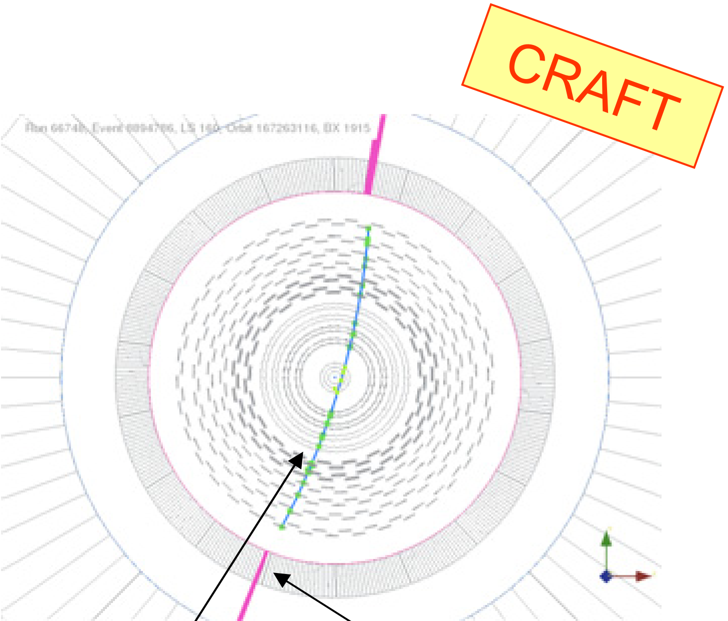
CRAFT

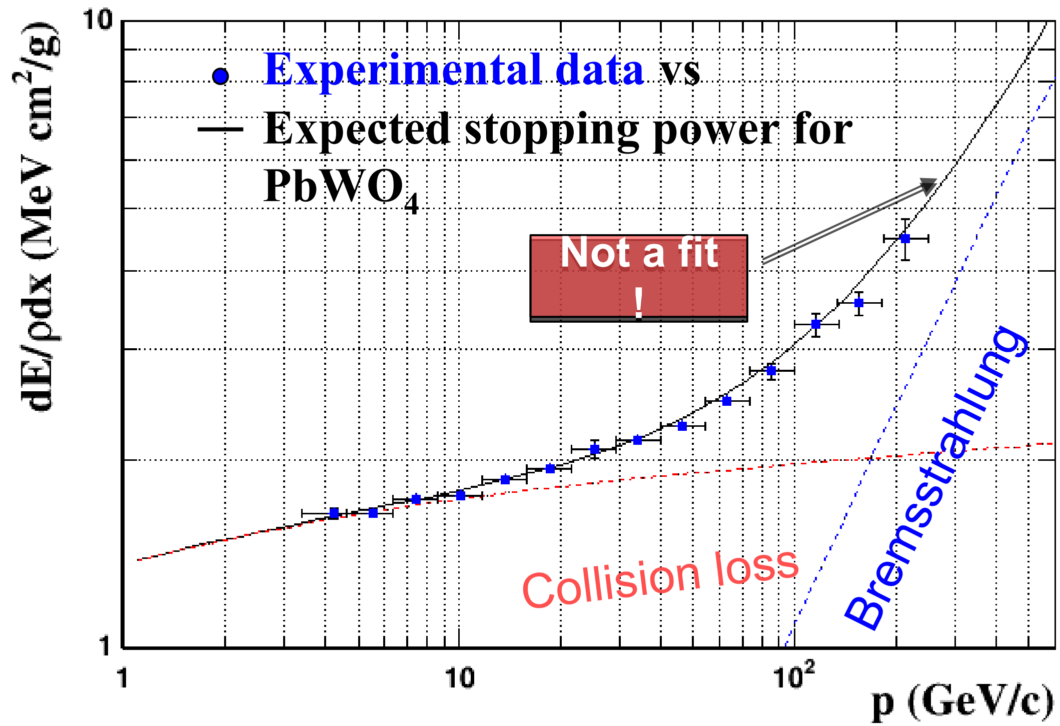
Stability of the crystal response to the Laser Calibration Signal



ECAL stopping power

Validate ECAL calibration with muons: measure energy deposition vs muon momentum





momentum **p** measured in the tracker

dE: energy from ECAL cluster, measured in the ECAL lower half

dx: is the length traversed in ECAL crystals

dE/ρdx energy deposit matched to the track corrected for muon path length

Tracker momentum matches well with ECAL energy loss, energy scale is correct

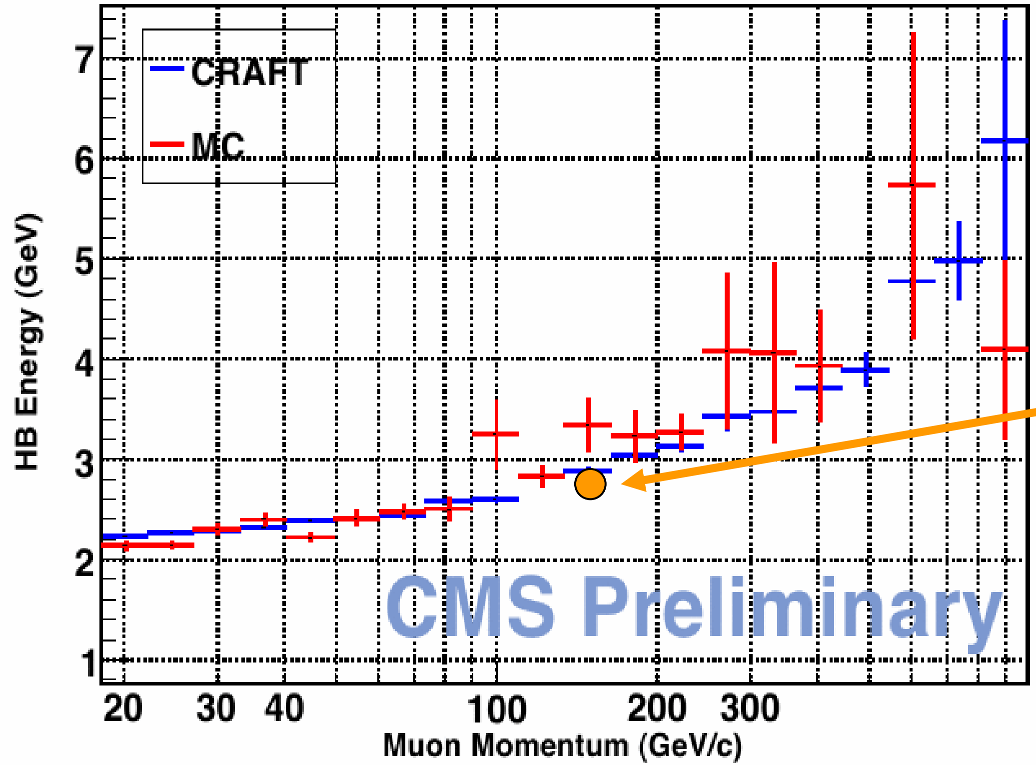
HCAL response to muons

CRAFT

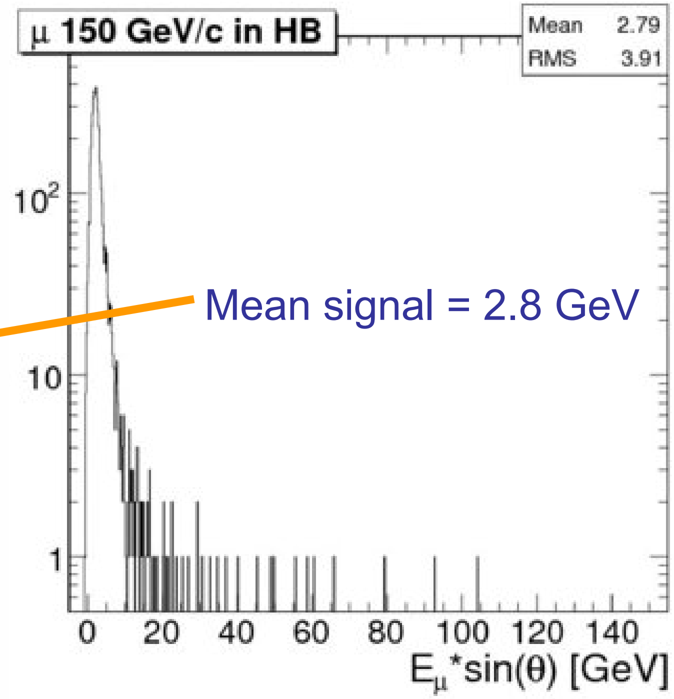
Event selection:
Muon track matching in DT and Tracker
20 GeV/c < P_μ < 1000 GeV/c

Cosmic muons data: 200 K events
MC: 15 K events

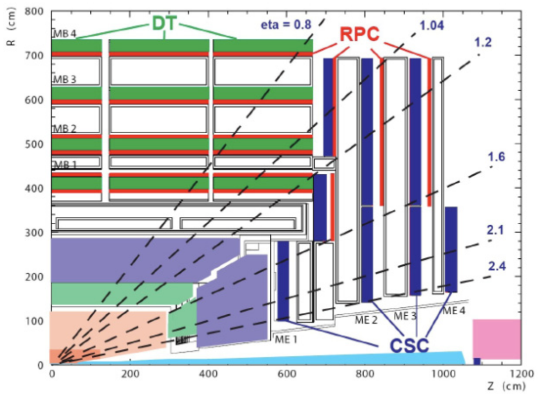
HCAL barrel energy:
signal corrected for muon path length in HCAL

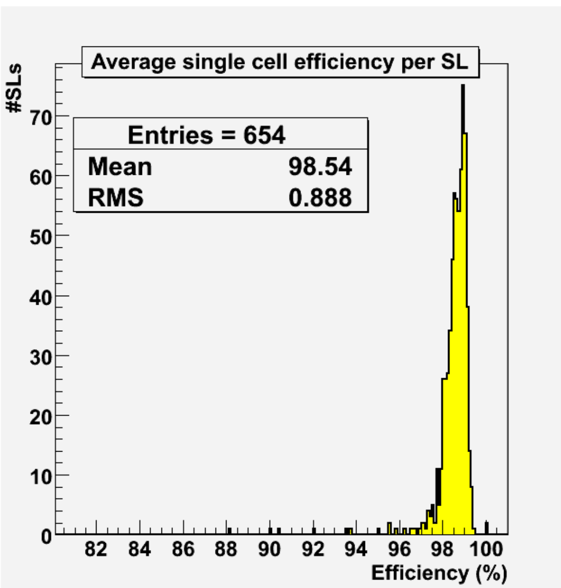


HCAL Test Beam 2006
P_μ = 150 GeV/c

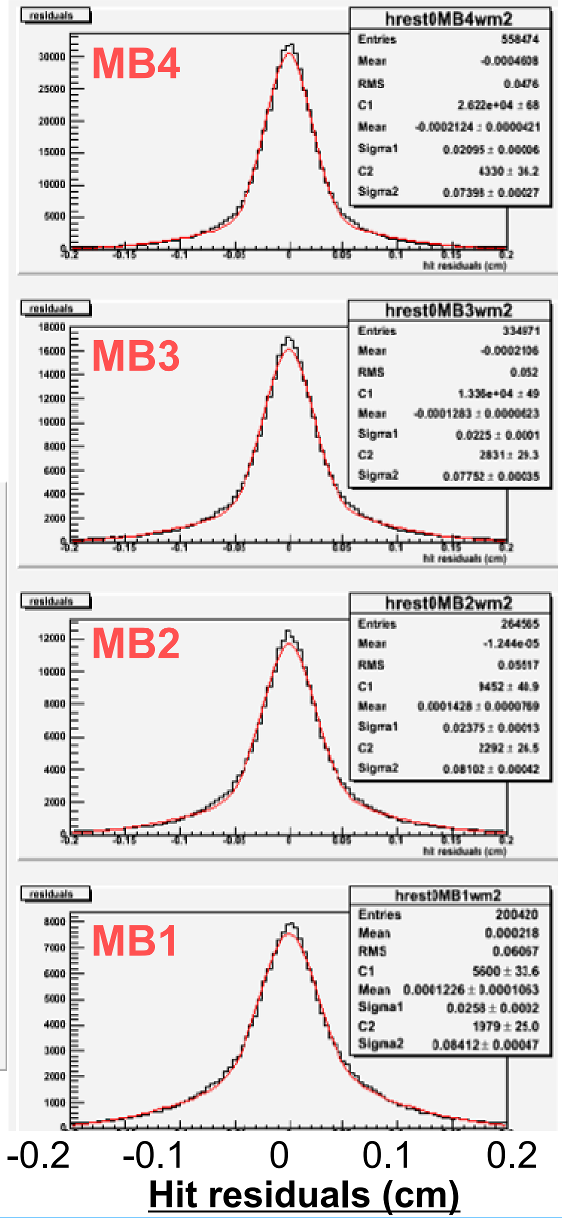


Muon DT resolution





Drift Tubes layer efficiency



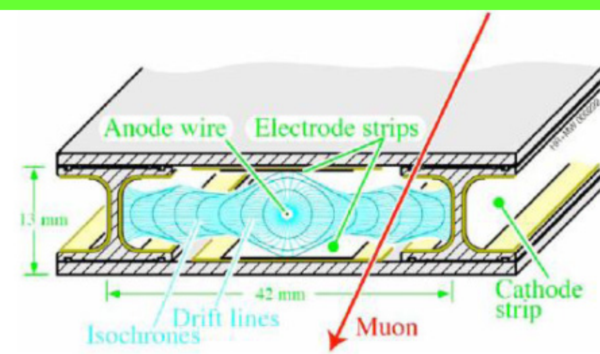
The hit resolution is computed from the residuals between the DT hits and the track segments in the muon spectrometer.

CRAFT

Typical values
σ ~ 200 – 260 μm

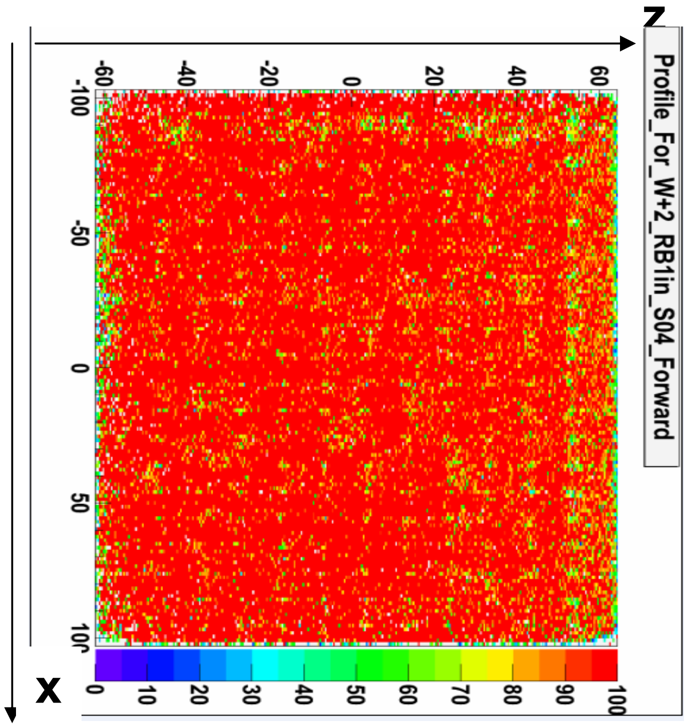
Good agreement with MC

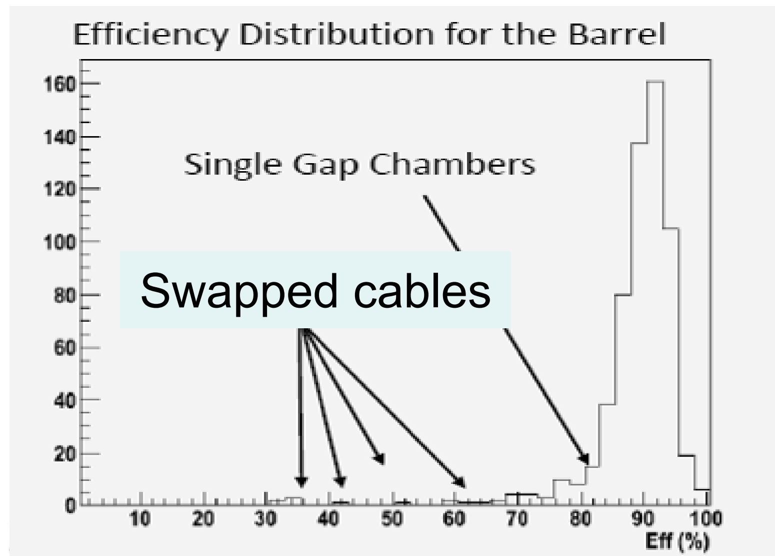
Magnetic field degrades the resolution in the inner chamber in the external wheels.

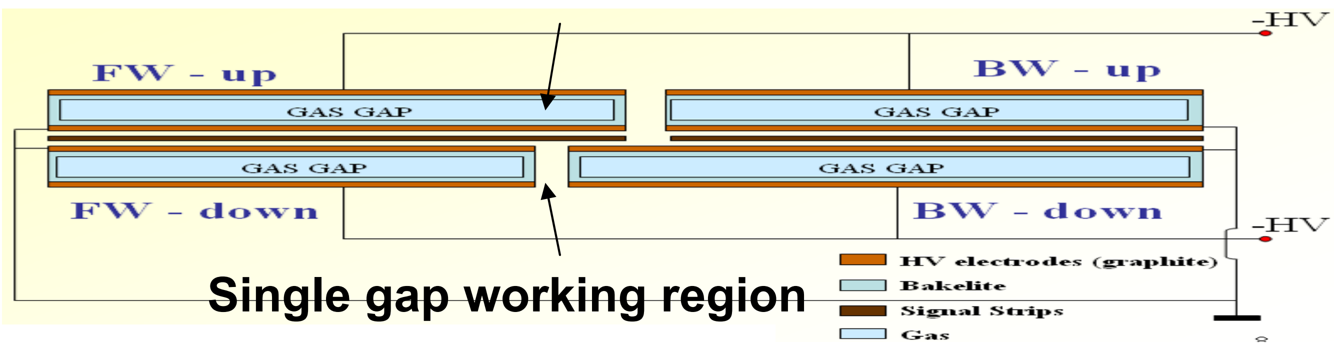


Muon Barrel: RPC efficiency

CRAFT







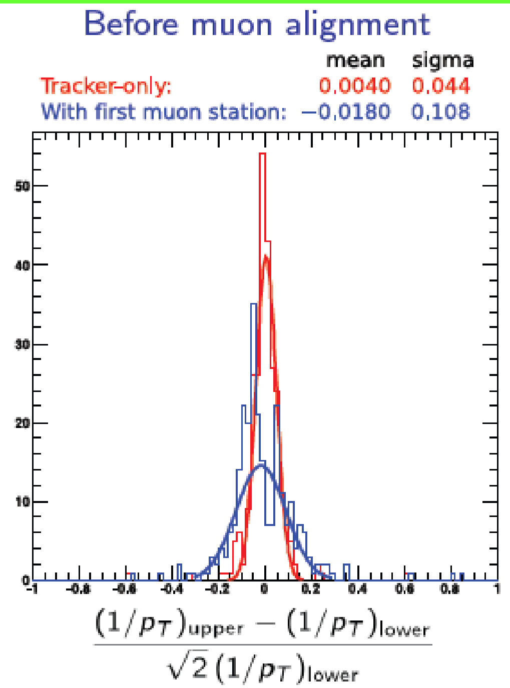
RPC efficiency vs impact point measured extrapolating the DT segment on the RPC .
The low efficiency points (in step of 10 x 10 cm^2) are due to the spacers.
A slight degradation in efficiency is observed in the single gap zone.

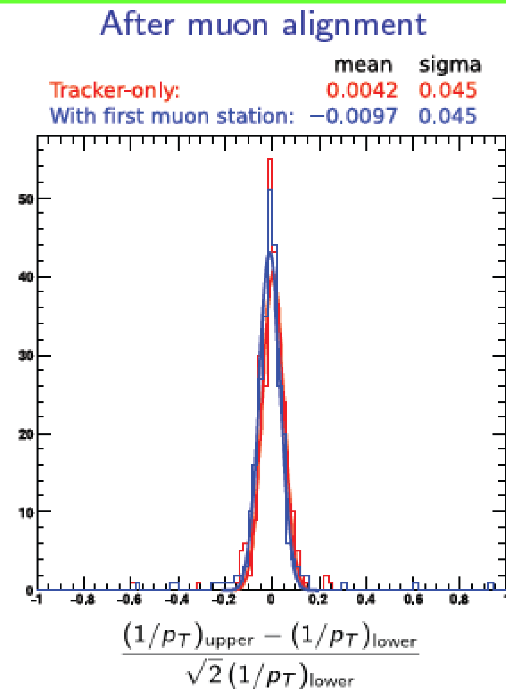
Muon Alignment

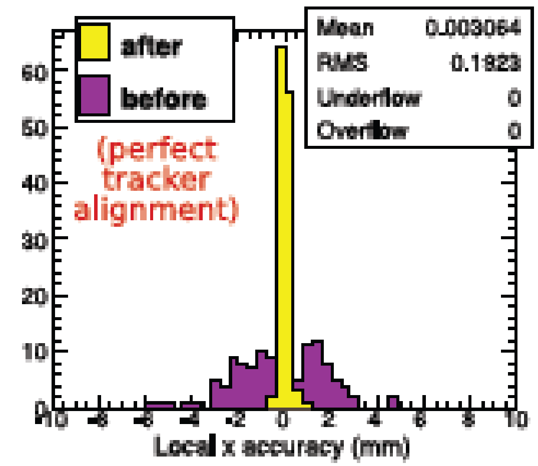
Extrapolate tracker tracks into muon barrel (endcaps not well covered)

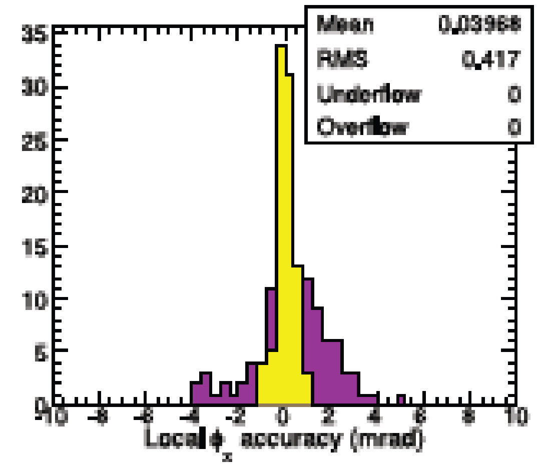
- Challenges: uneven illumination, large multiple scattering – slower convergence
- Don't really expect improvement for accessible muon momenta, but muon system should not make things worse
- 500 microrad accuracy now, syst. dominated

CRAFT









Trigger: Examples of Performance

Synchronization of trigger systems (internal and with each other) checked as part of validating firmware upgrades.

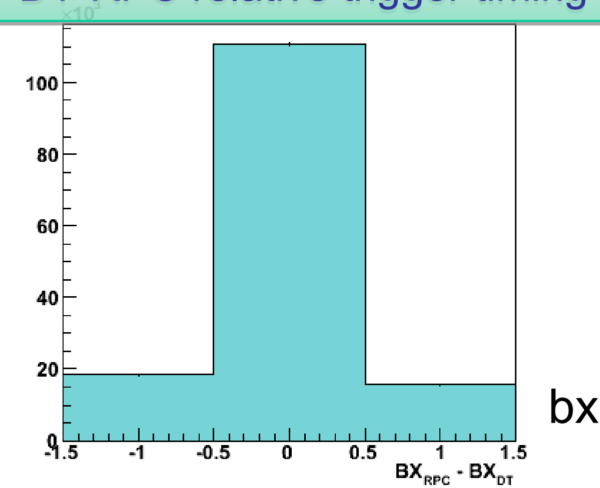
L1 & HLT triggers for startup will be very open and inclusive. Tables prepared.

Global Runs

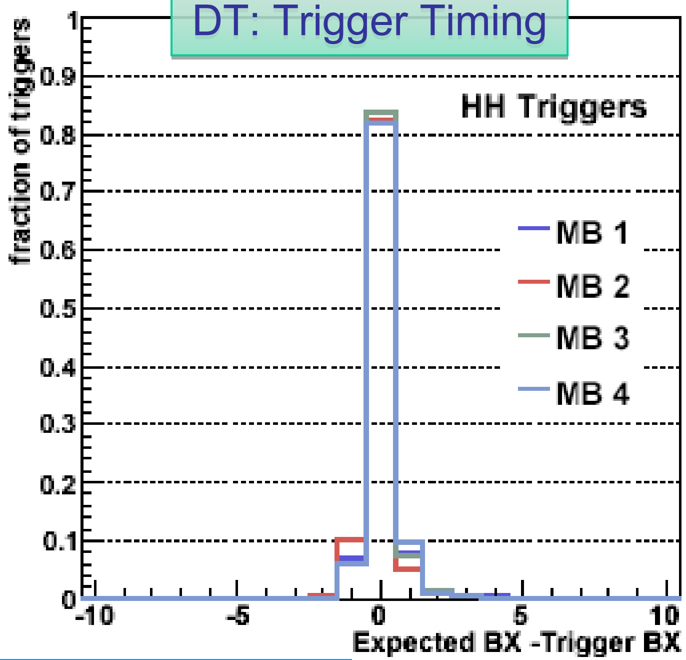
Since April deployed L1 and HLT trigger menus planned for early LHC running.

Systems throttled to >100 kHz (Full DAQ system except Filter Farm at 50 kHz)

DT-RPC relative trigger timing



DT: Trigger Timing



LHC Beam (Sept. 2008)
Some Results

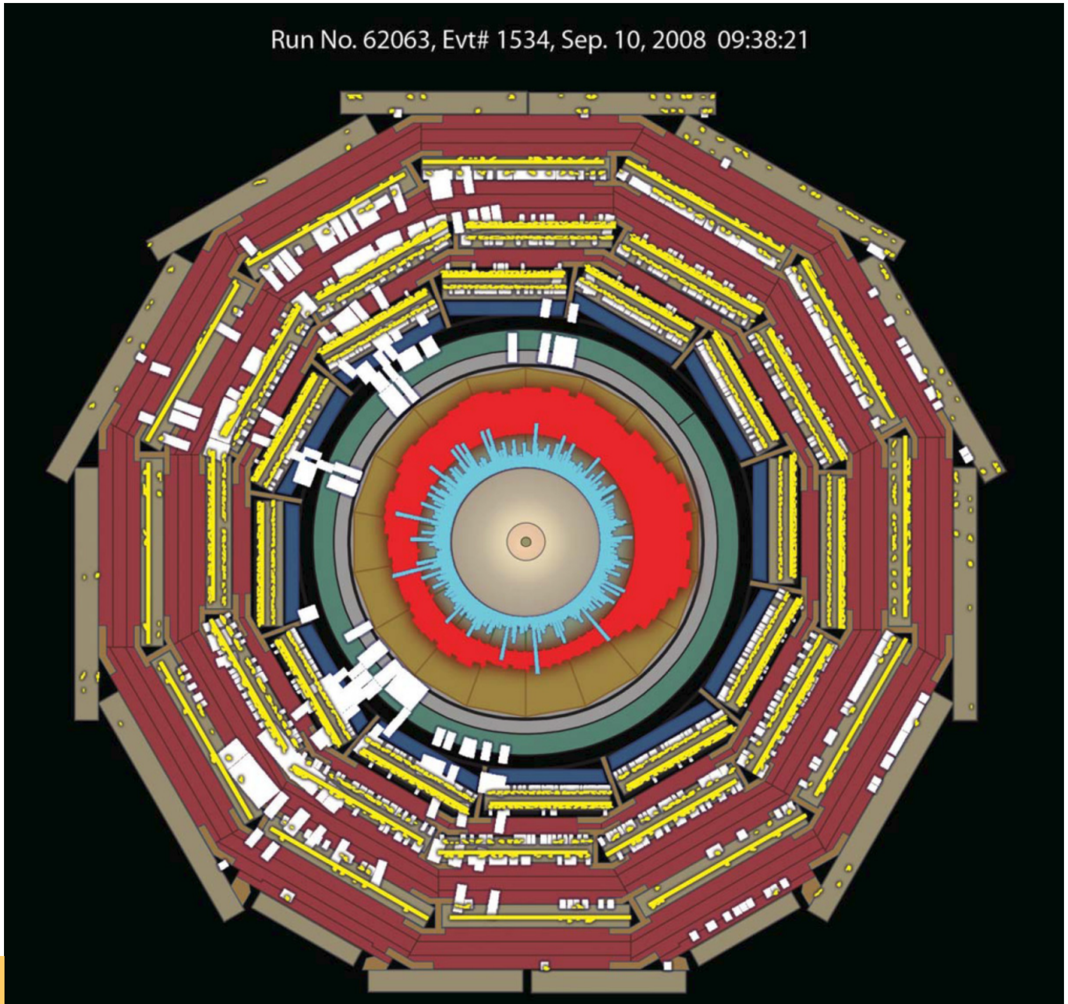
First LHC Beam in 2008

Data-taking with LHC beam.

- **Wed, 10 Sept. 2008**
  - **“Splash” events observed when beam (450 GeV, 4.10^9 p) struck closed collimators 150m upstream of CMS**
  - **Halo muons observed once beam (uncaptured and captured) started passing through CMS**

High energy deposit in the calorimeters, **particles travelling horizontally**

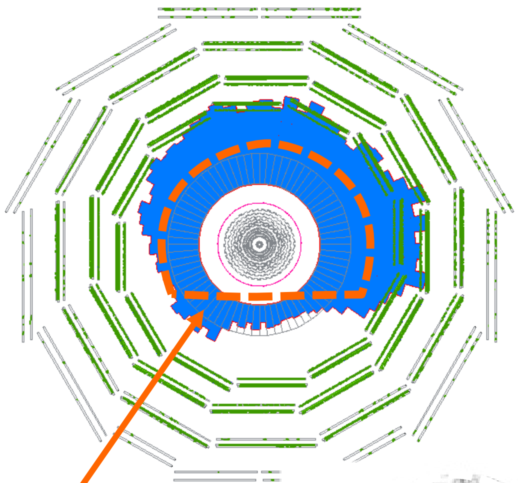
⇒ **useful to commission forward detectors**



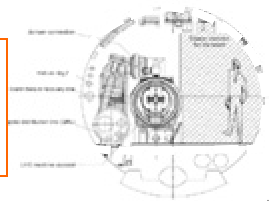
“Splash” Event

All systems ON except Tracker and Solenoid

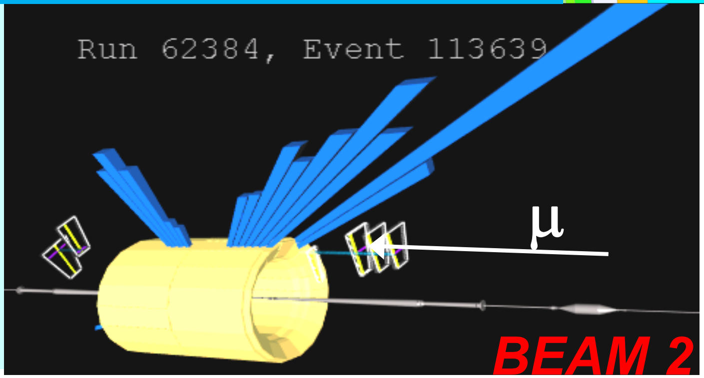
Beam Halo Muons



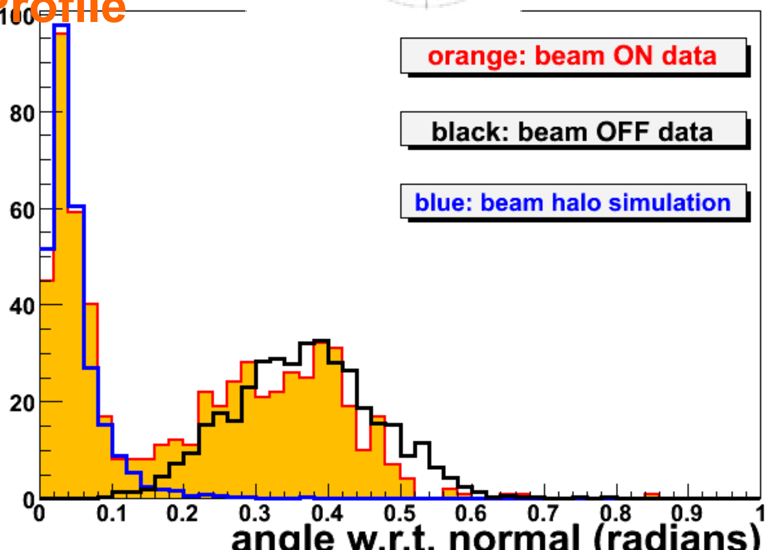
LHC Tunnel Profile



Beam Halo: muons outside of beam-pipe, arising from decays of pions created when off axis protons scrape collimators or other beamline elements



Muons go almost parallel to the beam.
A perfect X-ray of the muon Endcap

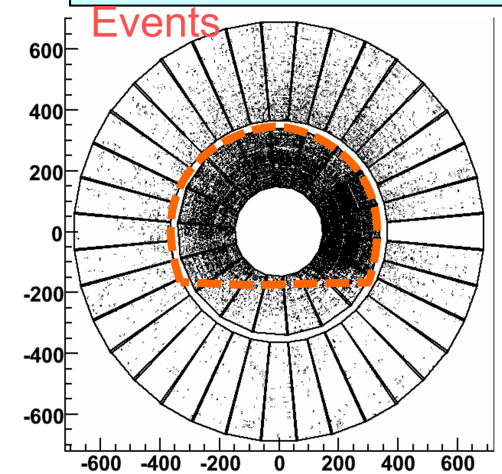


Reconstructed track angle w.r.t. the transverse plane

beam ON data combination of

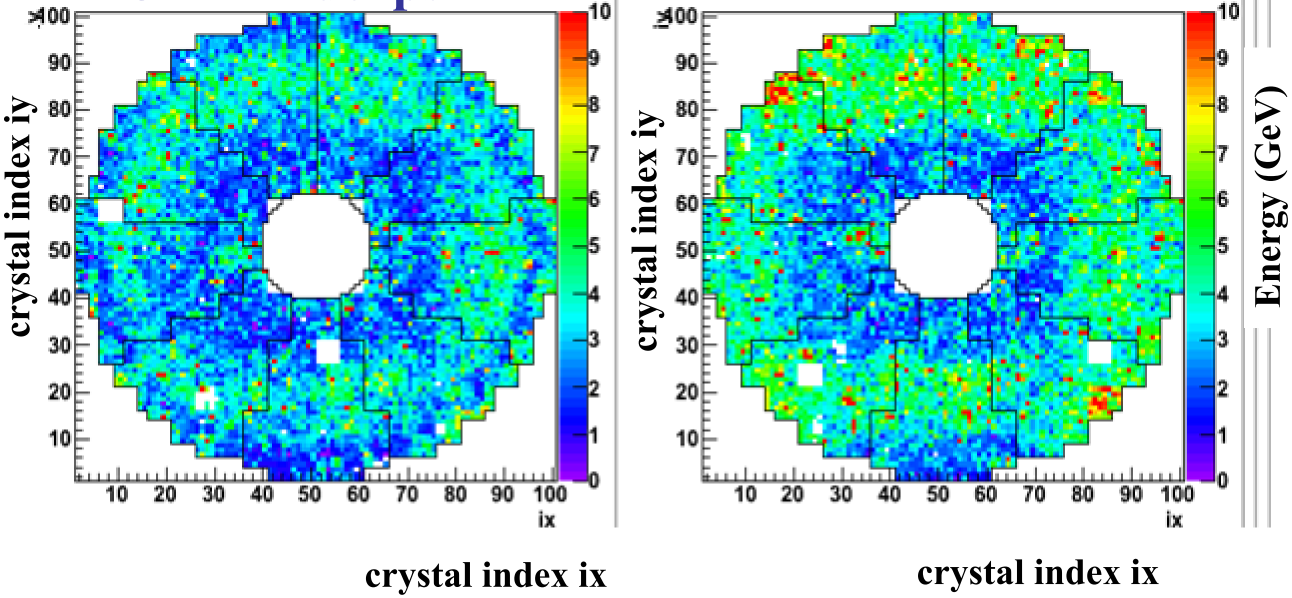
- **beam halo**
- **cosmic rays**

CSC Hit Distribution from Beam Halo Events

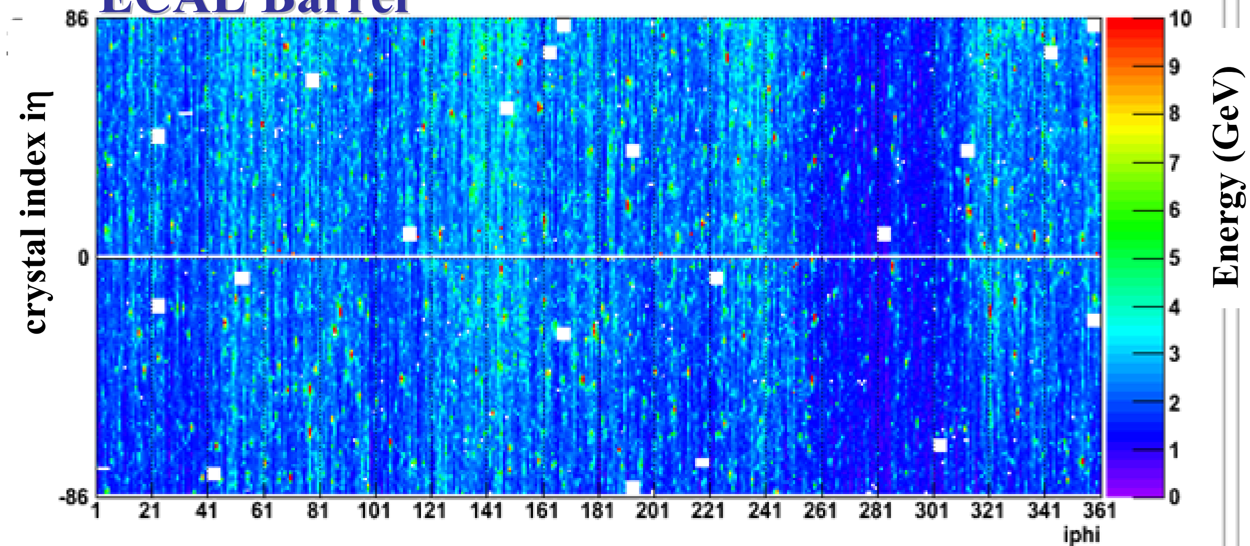


Beam Splash: ECAL Energy

ECAL Endcaps

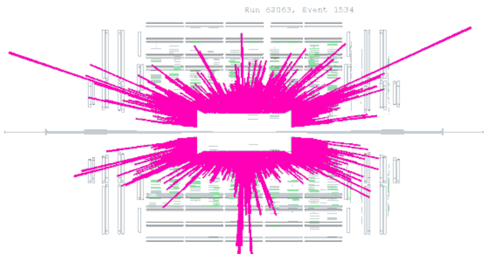


ECAL Barrel



- More than 99% of ECAL channels fired
- Estimated hundreds of thousands of muons passing through CMS per event
- ~200 TeV energy deposited in EB+EE
- Inter-crystals timing established (< 1ns), inter-crystal calibration: EB (1.5-2.5% - test beam + cosmics), EE (~7% from splash events)
- White areas: channels masked from readout

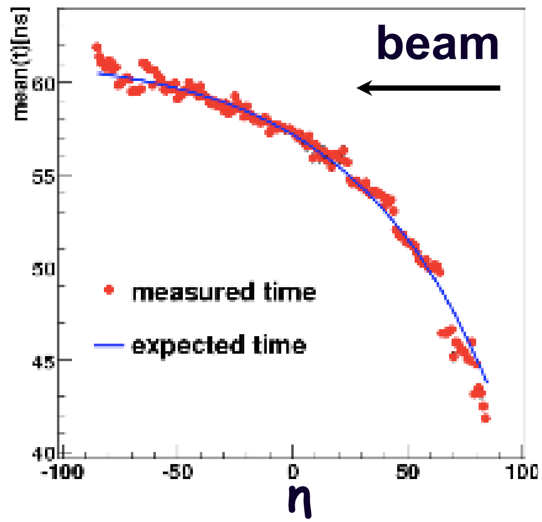
Splash synchronization of calorimeters



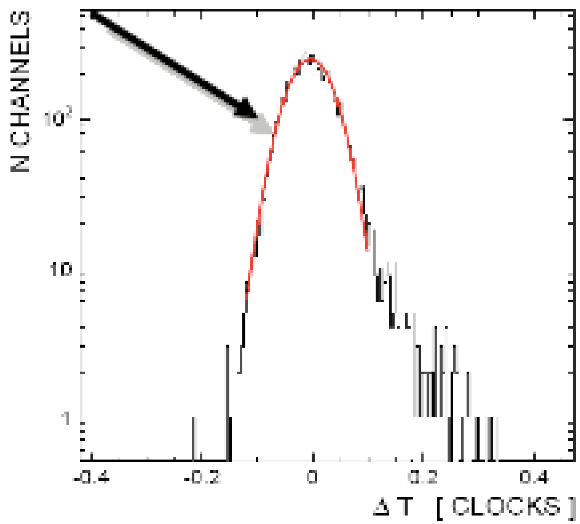
- In splash events all channels fire
- synchronize in one go all the

- time of arrival follows detector geometry

ECAL

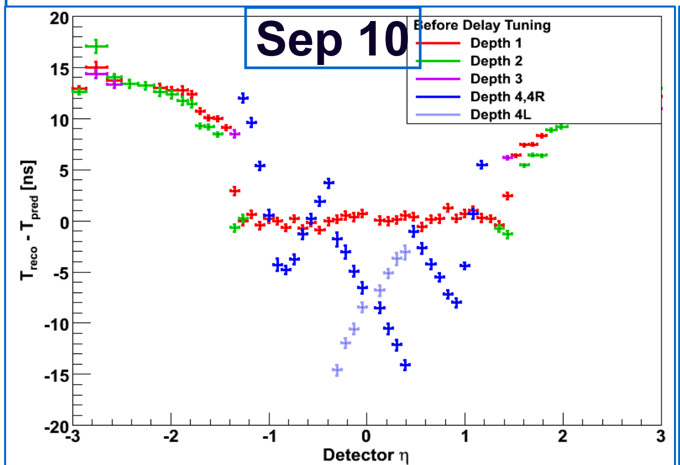


1 ns

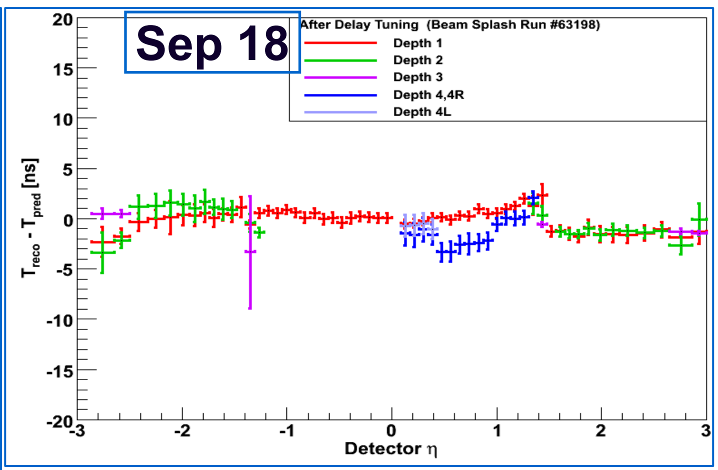


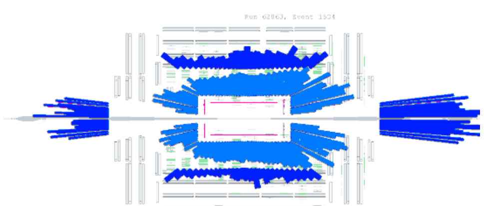
HCAL

Sep 10

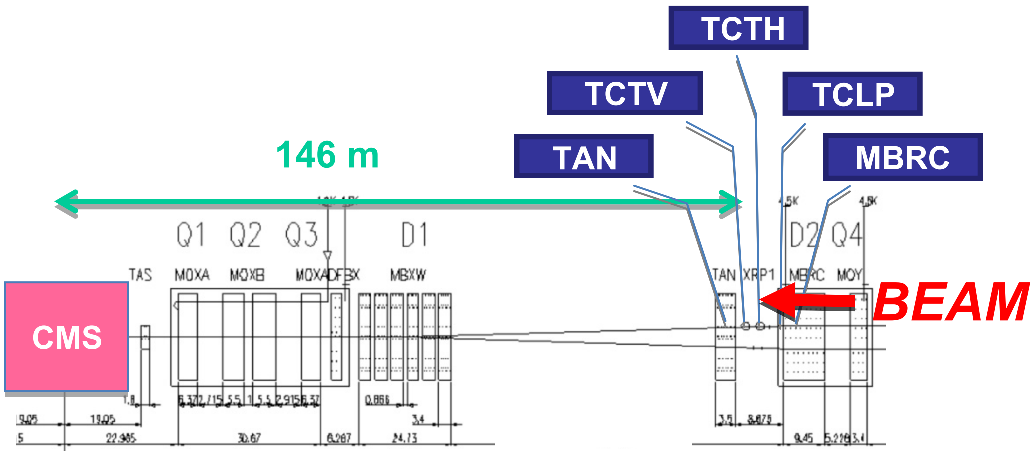


Sep 18

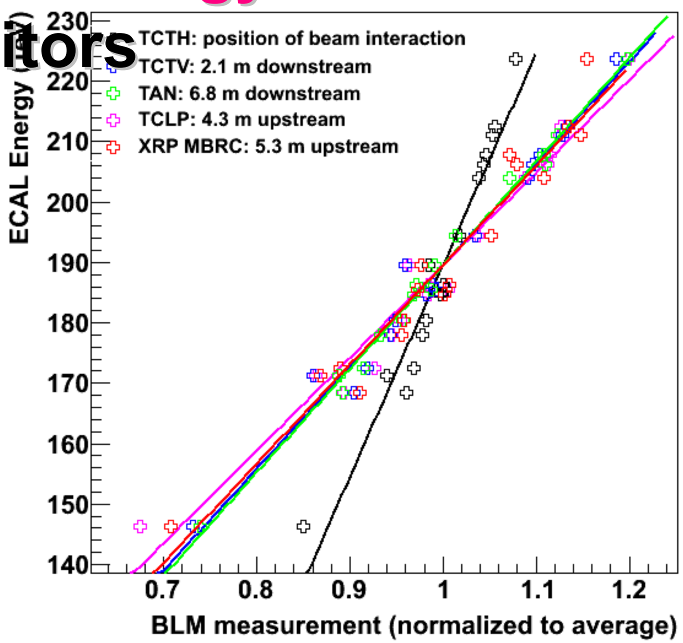


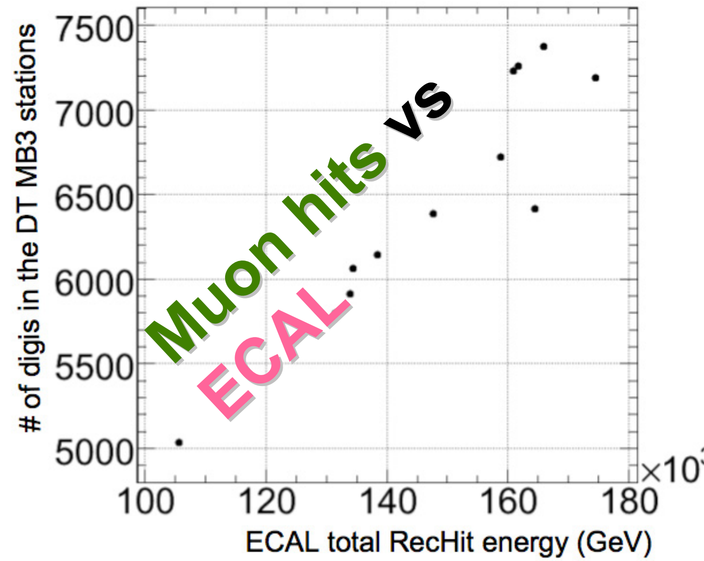


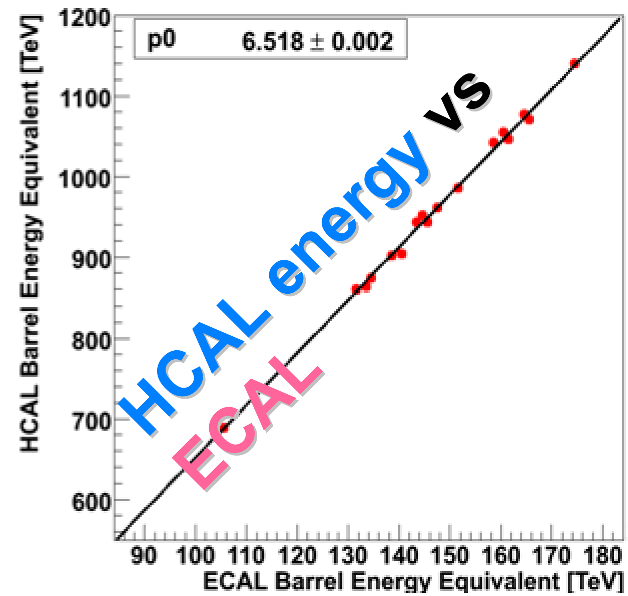
Beam Splashes



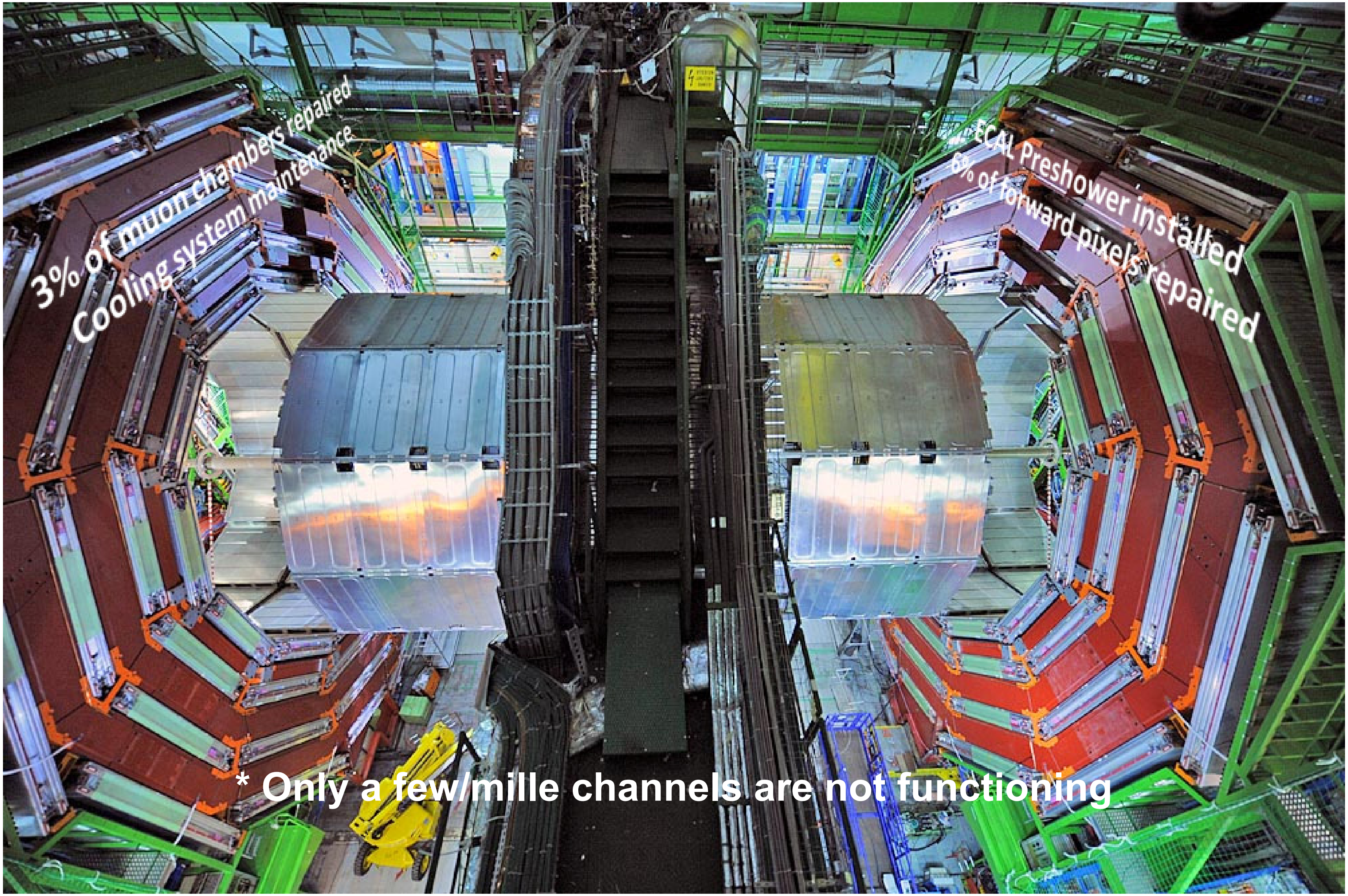
ECAL energy vs Beam Loss Monitors



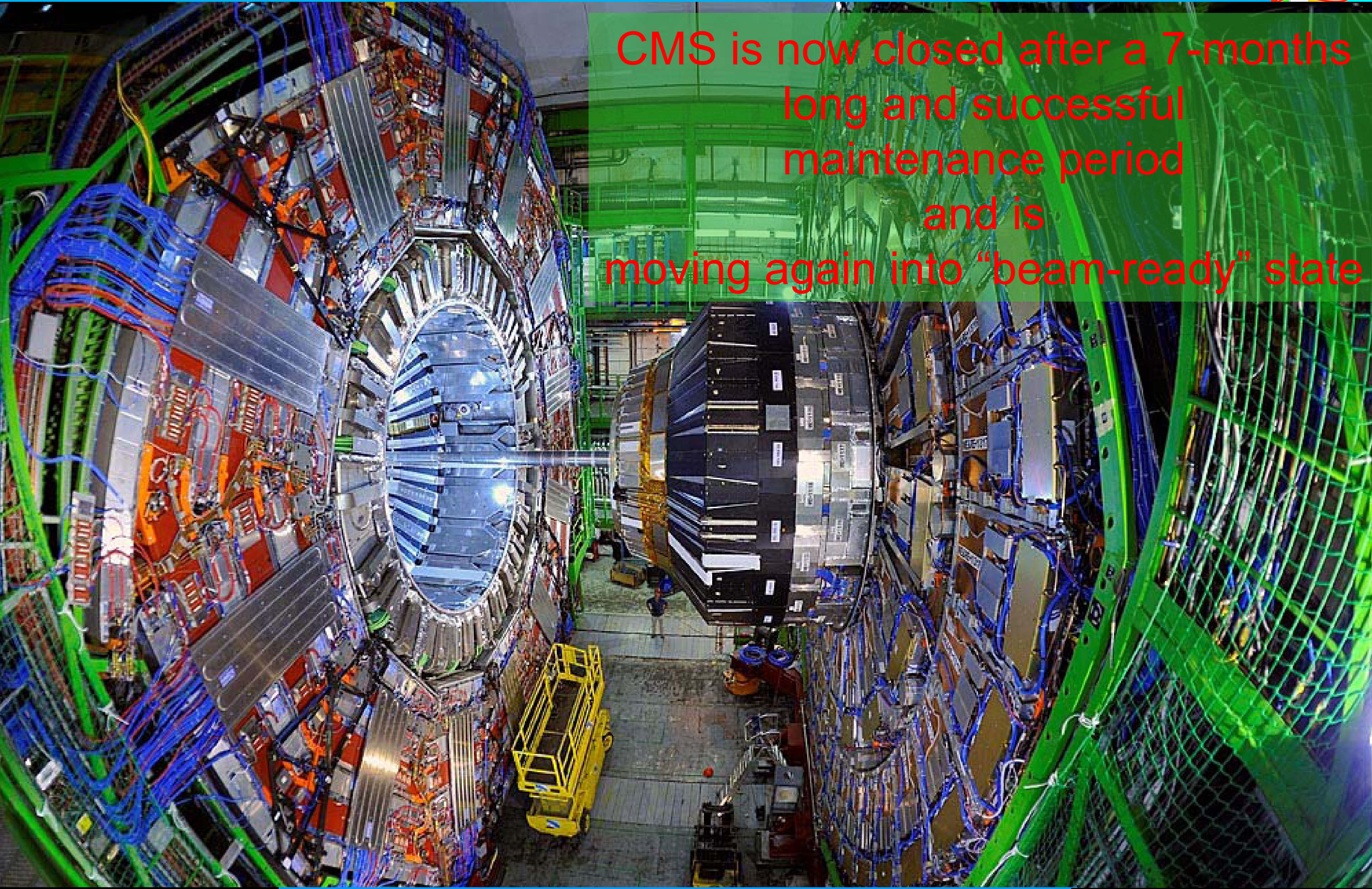




Shutdown activities: 1st maintenance cycle



Closing of CMS: 2009



CMS is now closed after a 7-months
long and successful
maintenance period
and is
moving again into "beam-ready" state

Prospects for 2009-2010 Run

- Following a meeting with the LHC people, experiments and CERN management the plan to restart has been agreed.
- Once collisions at injection energy are established will move to collision at 7 TeV center-of-mass energy.
- In consultation with experiments and LHC operation will move to higher energy once some luminosity will be accumulated by the experiments and experience gained by the machine operations.

“Physics Commissioning” Selected MC Results, mostly at 10 TeV

Early Physics Programme

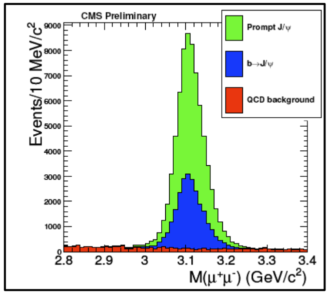
- Detector commissioning – much already done using cosmics/testbeam,..
- Early beam: splash events, first collisions at injection energy, then at 7 TeV
  - Detector synchronization, alignment with beam-halo events, minimum-bias events. Earliest in-situ alignment and calibration
- Early beam - collisions, up to 10-20 pb^{-1} @ 7 TeV
  - Commission trigger, start "physics commissioning" – "rediscover SM":
    - Physics objects; measure jet and lepton rates; observe W, Z, top
    - And, of course, first look at possible extraordinary signatures…
- 7 TeV, up to 100 pb^{-1} measure Standard Model, start searches
  - Per pb^{-1}: 3000 $W \rightarrow l\,\nu$ ($l = e,\mu$); 300 $Z \rightarrow ll$ ($l = e, \mu$); 5 ttbar $\rightarrow \mu$+X
    - Improved understanding of physics objects; jet energy scale from $W \rightarrow j\,j'$; extensive use (and understanding) of b-tagging
    - Measure/understand backgrounds to SUSY and Higgs searches
  - Early look for excesses from SUSY & Z' resonances.
- Collisions at higher energy: extend searches;
  - Explore large part of SUSY and resonances at ~ few TeV
  - ~ 1000 pb^{-1} entering Higgs discovery era

Roadmap towards discoveries with leptons at LHC

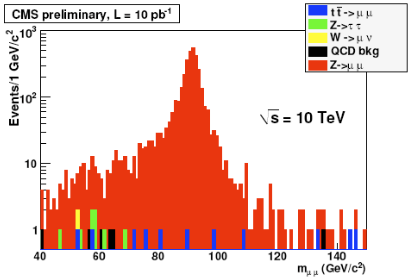
0 10 20 30 40 50 60 70 80 90 100 110 120 130

$\int \mathcal{L} dt \; (\mathrm{pb}^{-1})$

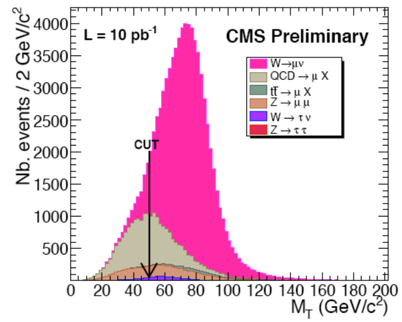
J/Ψ & Υ resonances (few pb^{-1})



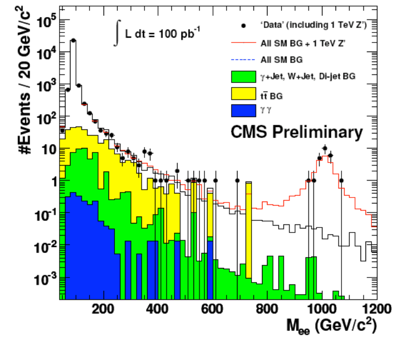
Z peak (10pb^{-1})



W cross-section measurement



Look @ DY spectrum beyond M_{ll}> 700 GeV/c^2

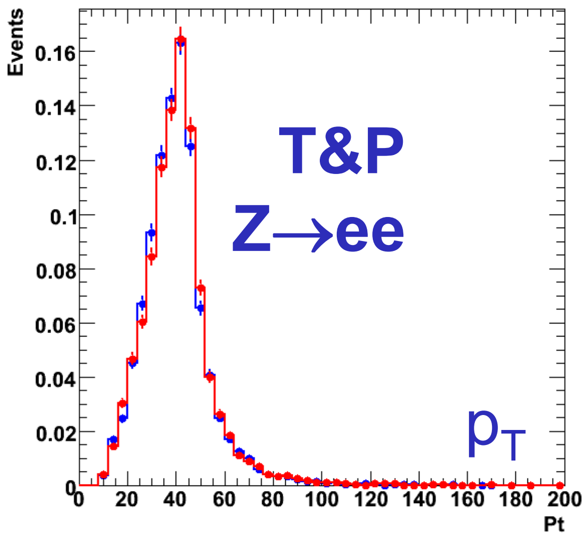


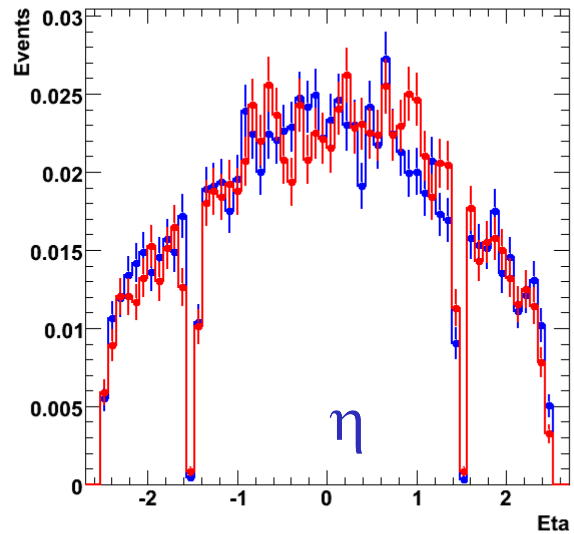
Preparation for Physics Analysis

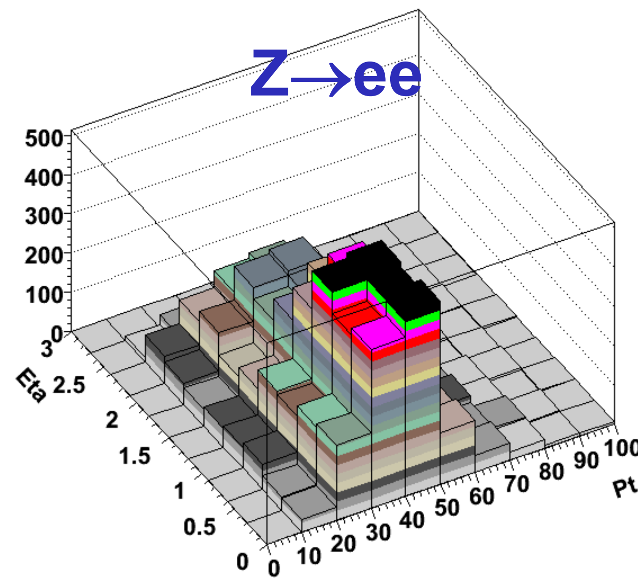
Data-driven Methods: physics objects id

Tag and Probe (T&P): identify a physics object in an unbiased way in order to study efficiencies.

e.g. Z→ee events: one tight electron (tag); the other can be a probe, provided the invariant mass of the pair is $\approx M_Z$





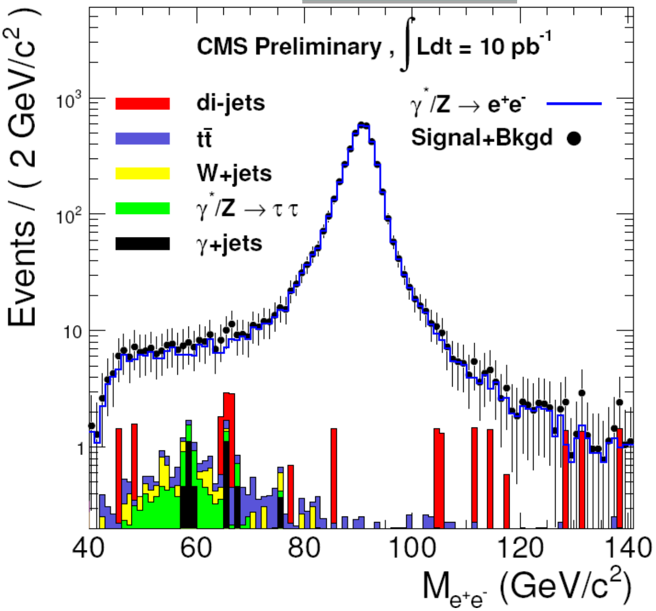


Efficiency from T&P: 94.36±0.24
Efficiency from MC truth: 94.63±0.24
} **(for 10 pb^{-1}) @ 14 TeV**

Example: W, Z (σ, BR)

(10 pb^{-1} at 10 TeV)

$Z \rightarrow ee$

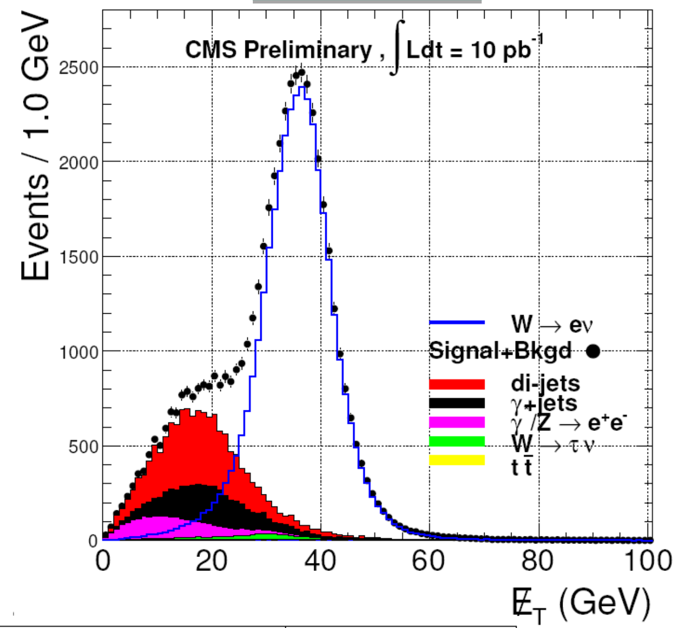


$N_{selected}$	4273 ± 65
N_{bkgd}	assumed 0.0
Tag&Probe $\varepsilon_{offline}$	90.37 ± 0.32 %
Tag&Probe $\varepsilon_{trigger}$	99.88 ± 0.016 %
Tag&Probe ε_{total}	81.57 ± 0.58 %
Acceptance Int. Luminosity	40.42 ± 0.18 % $10\ pb^{-1}$
$\sigma_{Z/\gamma^*} \times BR(Z/\gamma^* \rightarrow e^+e^-)$	1296 ± 23 pb
cross section used	1296 pb

Systematic uncertainty 2.4% + 10% for ∫Ldt

- **Z Selection**
  $E_T > 20.0$ GeV
  both e isolated
  $70 < M_{e,e} < 110$ GeV
- **W Selection**
  $E_T > 30.0$ GeV
  Isolated e
- Use data driven methods e.g. "*tag and probe*" method to work out efficiencies from "data"

$W \rightarrow e\nu$



$N_{selected} - N_{bkgd}$	37500 ± 453
Tag&Probe $\varepsilon_{offline}$	74.44 ± 0.59 %
Tag&Probe $\varepsilon_{trigger}$	97.17 ± 0.32 %
Tag&Probe $\varepsilon_{offline \times trigger}$	72.33 ± 0.62 %
Acceptance Int. Luminosity	36.6 ± 0.074 % $10\ pb^{-1}$
$\sigma_W \times BR(W \rightarrow e\nu)$	14166 ± 212 nb
cross section used	13865 pb

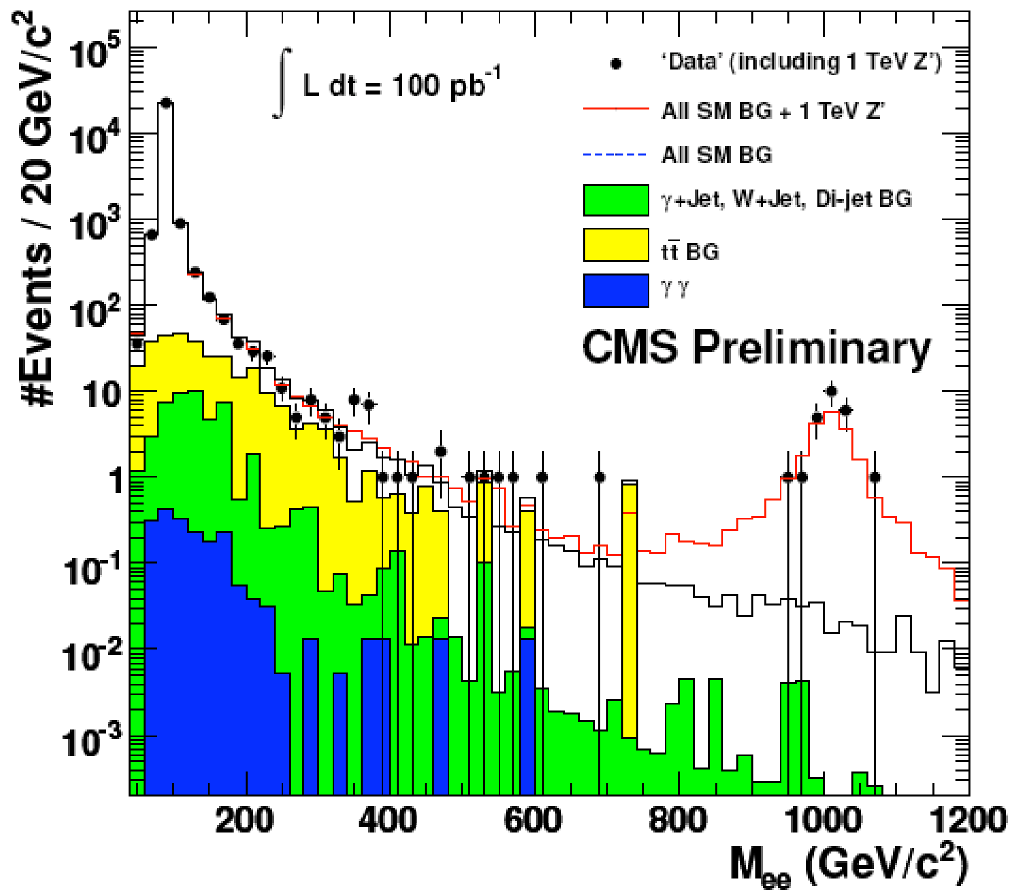
Systematic uncertainty 4.0% + 10% for ∫Ldt;

Towards discoveries: DY spectrum

Extending the knowledge of lepton beyond Z candle typically relies on MC extrapolation (requires good MC tuning)

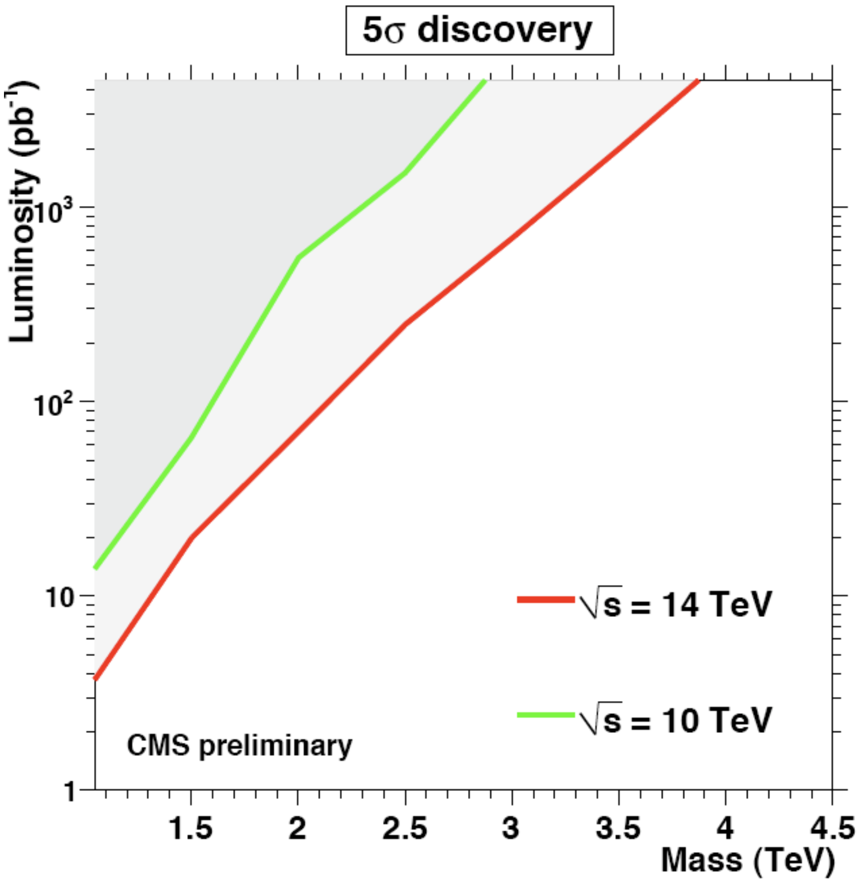
Good understanding of the DY spectrum from data will be a key check-point on the roadmap to discoveries

It will also be possible to cross-check using electrons from DY with tighter selection cuts in the control region
$200 < M_{ll} < 800$ GeV/c^2



"Easy" discoveries: W' and Z'

- Higher C.M. compared to Tevatron
- Heavy resonances can be in reach with early data



Analysis characteristics

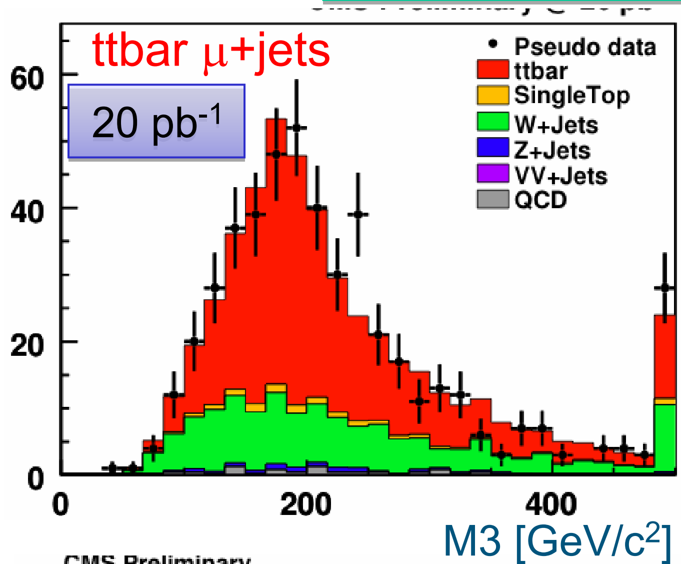
- typical muon in Z' of 1 TeV/c^2 has $p_T \approx 500$ GeV/c
- selection straight forward
- main backgrounds:
  - Drell-Yang
  - inclusive jets
  - W+jets, Z+jets

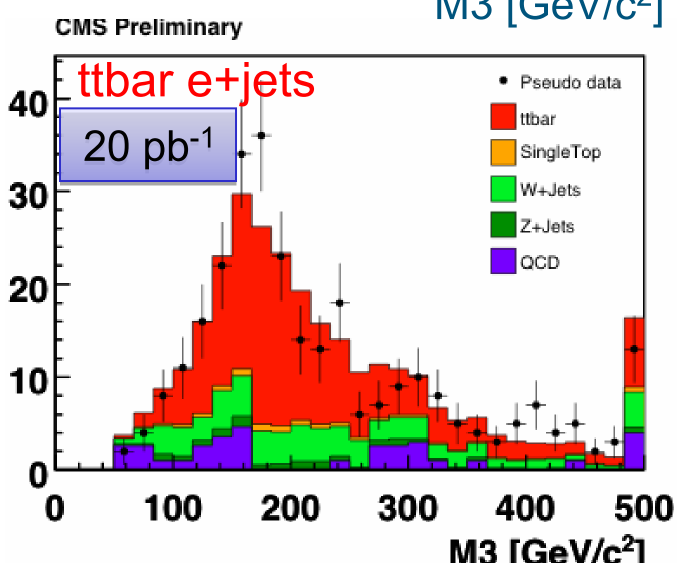
Results

- 5σ observation of $m_{Z'} = 1$ TeV/c^2: with 20-40 pb^{-1}

Top Studies

Observation and early ttbar cross sections

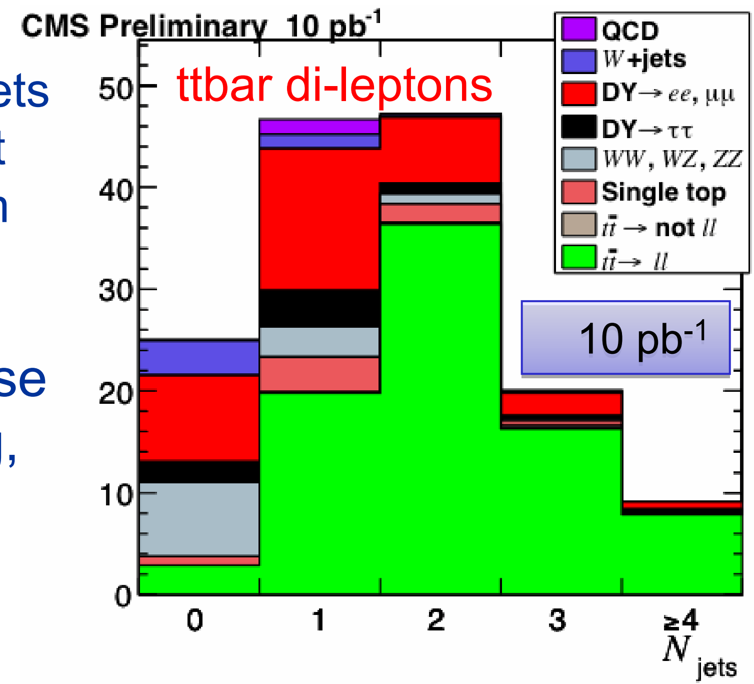




Top production is excellent testbed for the understanding of:
lepton id. (incl. taus), jet corrections, jet energy scale, b tagging, ….

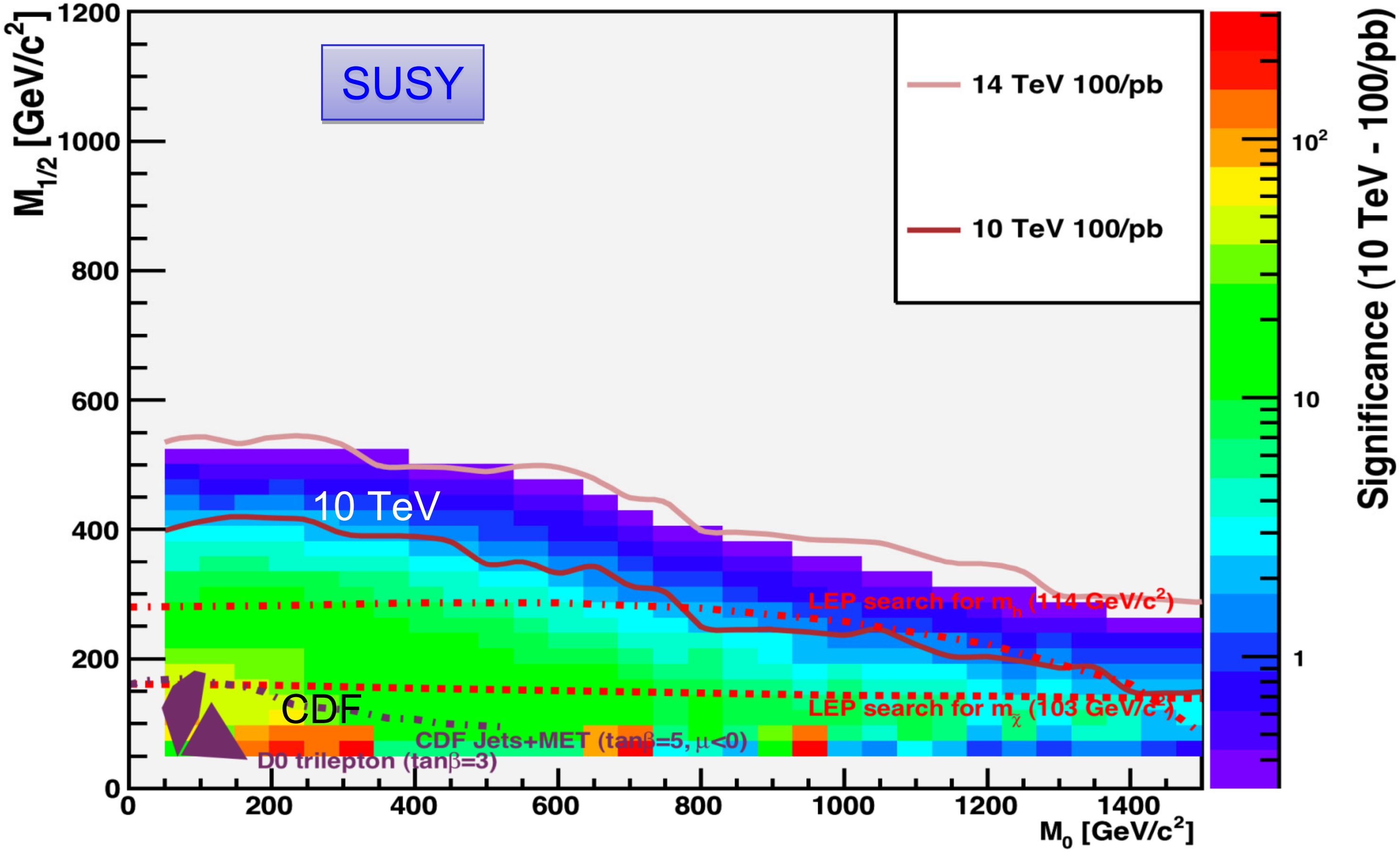
M3 = M of 3 jets with highest vector suum

Mostly w/o use of b-tagging, robust selections



Susy with early data

Expect to see Susy on first day …
First will have to overcome MET challenges



Jets and MET analysis reach with 100 pb-1

Higgs

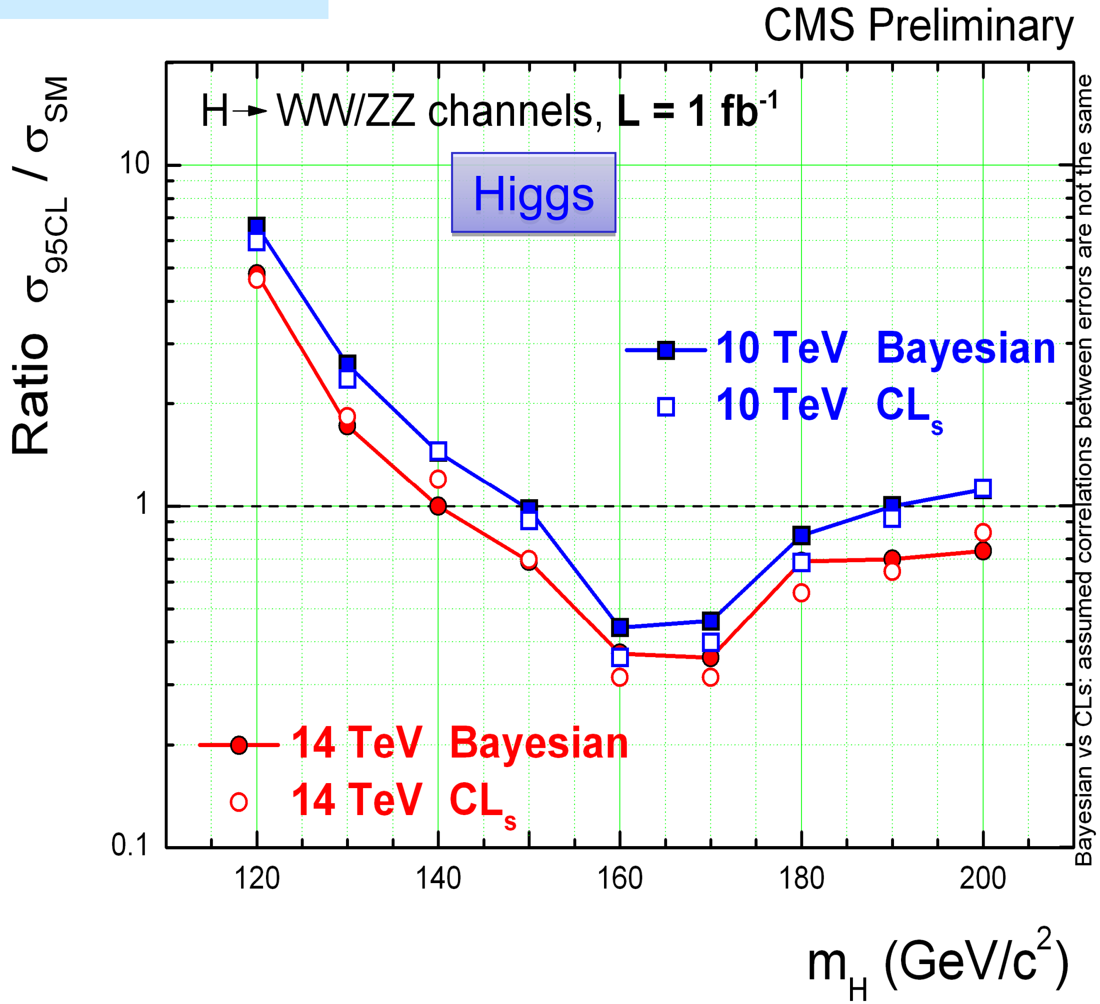
With 200 pb^{-1} reach 150-160 GeV
Sensitivity as at Tevatron

Benchmark Luminosities:

~ 0.1 fb^{-1}: exclusion limits start carving into SM Higgs cross section

> 0.5 fb^{-1}: discoveries start to become possible in the region excluded by Tevatron (MH~160□170 GeV)

~ 5-10 fb^{-1}: SM Higgs could be discovered (or excluded) in full mass range (MH~110□500 GeV)



Conclusions

- During the autumn 2008 LHC beam & cosmics run, the sub-detectors, online, offline, computing and analysis systems all performed well. Efficiencies and noise are within specifications and >99% of the channels are working for most of the detectors. Due to LHC delay we have extensively used cosmic runs to align the detector. A lot has been learnt on the detectors.

- The ensuing shutdown included broad maintenance activities, consolidation work and a program of carefully selected repairs interleaved with installation of the preshower detector.

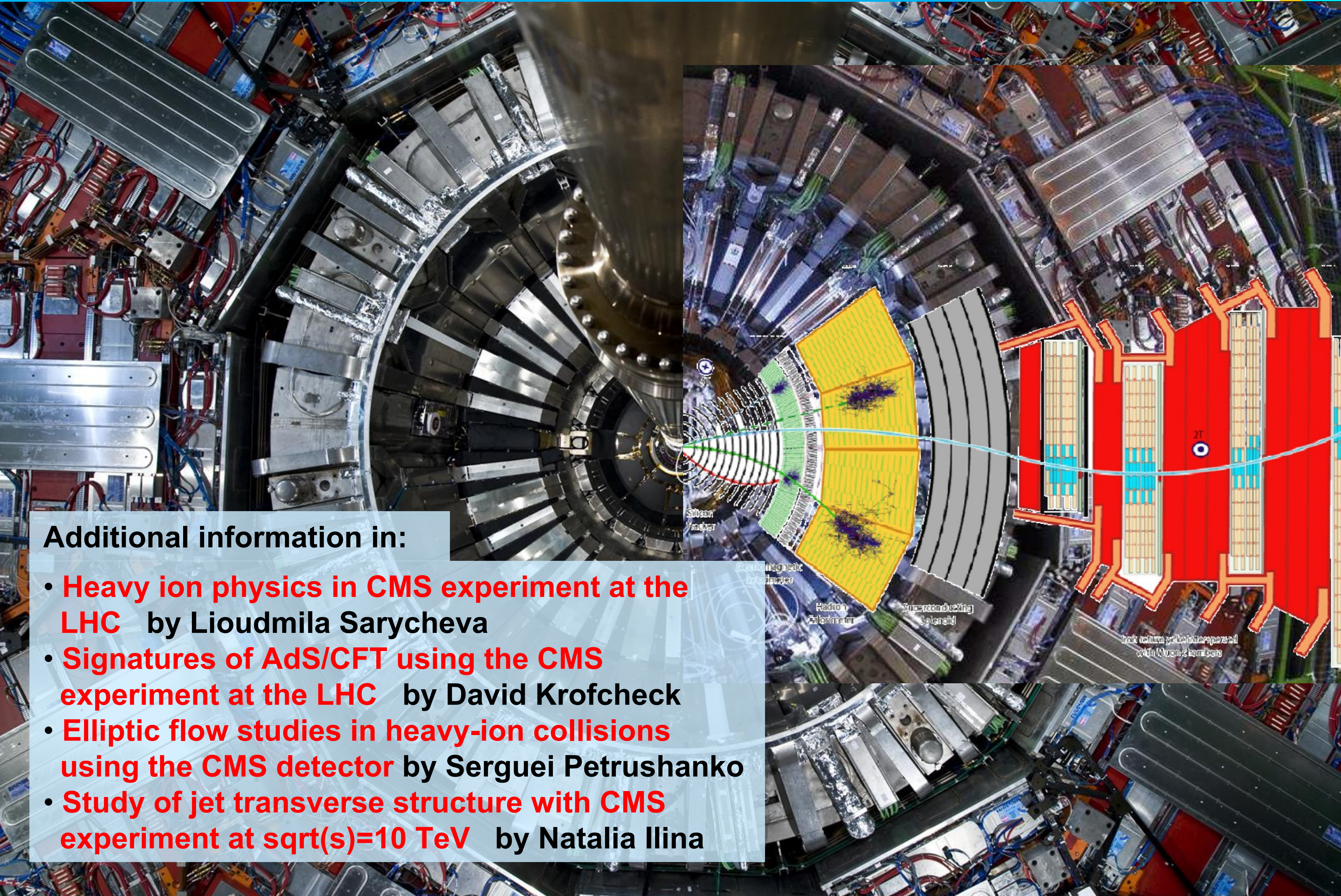
- Much VERY useful information has been extracted from the CRAFT08 data. Plan to publish ~25 papers by end-Sept.

- The software, computing systems and analysis systems is being exercised in CRAFT09 and by generating, distributing and analysing 200M events to update 10 TeV "physics analyses" (and soon 7TeV) using s/w release intended for data taking.

- The experiment is now closed and is taking a long cosmics run.

- **CMS will (again) be ready, and eager, for LHC beam.**

CMS talks



Additional information in:

- Heavy ion physics in CMS experiment at the LHC   by Lioudmila Sarycheva
- Signatures of AdS/CFT using the CMS experiment at the LHC   by David Krofcheck
- Elliptic flow studies in heavy-ion collisions using the CMS detector by Serguei Petrushanko
- Study of jet transverse structure with CMS experiment at sqrt(s)=10 TeV   by Natalia Ilina

Spares

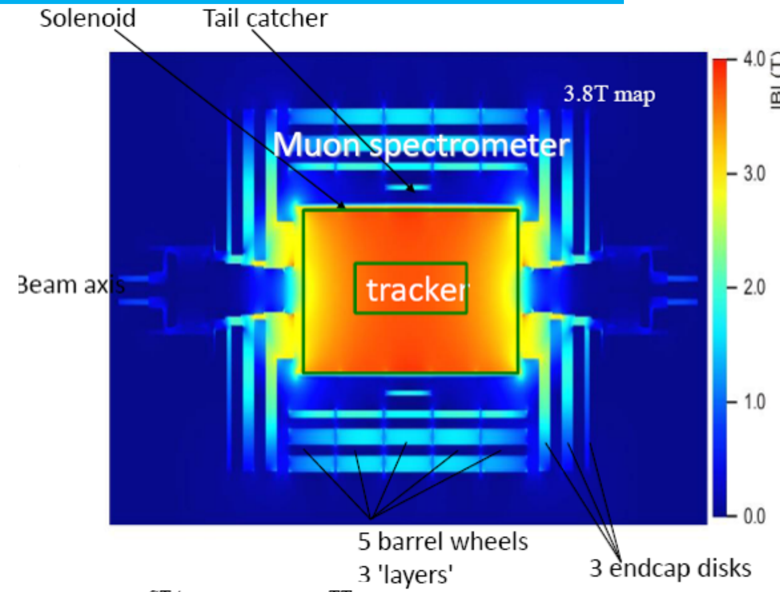
CRAFT Results: CMS Magnetic Field Map

In the Tracker Region

Measured by Field Mapper (at 2, 3, 3.5, 3.8, 4 T) in 2006 MTCC

TOSCA field map agrees < 0.1%

NMR probes inside solenoid confirm agreement scale < 0.1% between 2006 and 2008

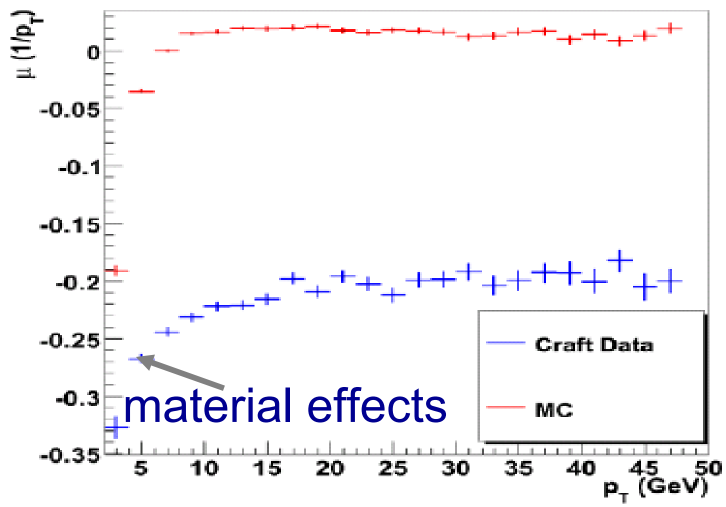


$$R = \frac{1/p_T^{STA} - 1/p_T^{TT}}{1/p_T^{TT}}$$

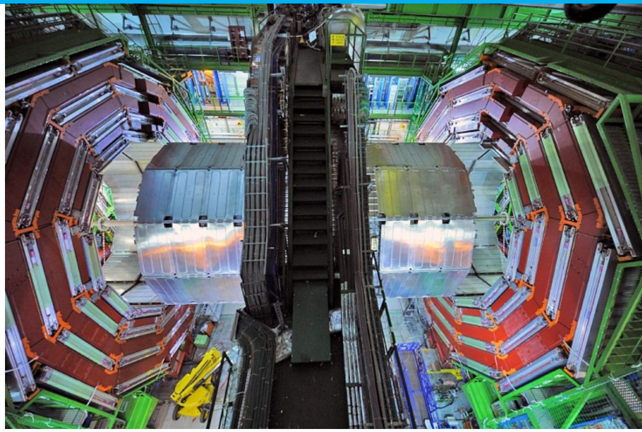
In the Return Yoke

Compare tracker vs stand-alone muon momentum scale:

- stand-alone muons, momentum is over-estimated by 20%
- Field model overestimated the field in the iron yoke.

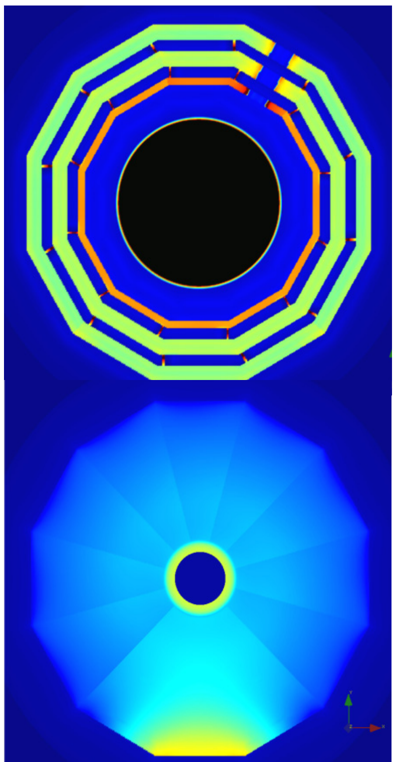


New TOSCA Field Map



New B Field Map for simulation, trigger and track reconstruction includes:
- special treatment of chimneys and feet
- additional scaling factors (1.0, 0.95, 0.91 for L1,L2, L3 resp)

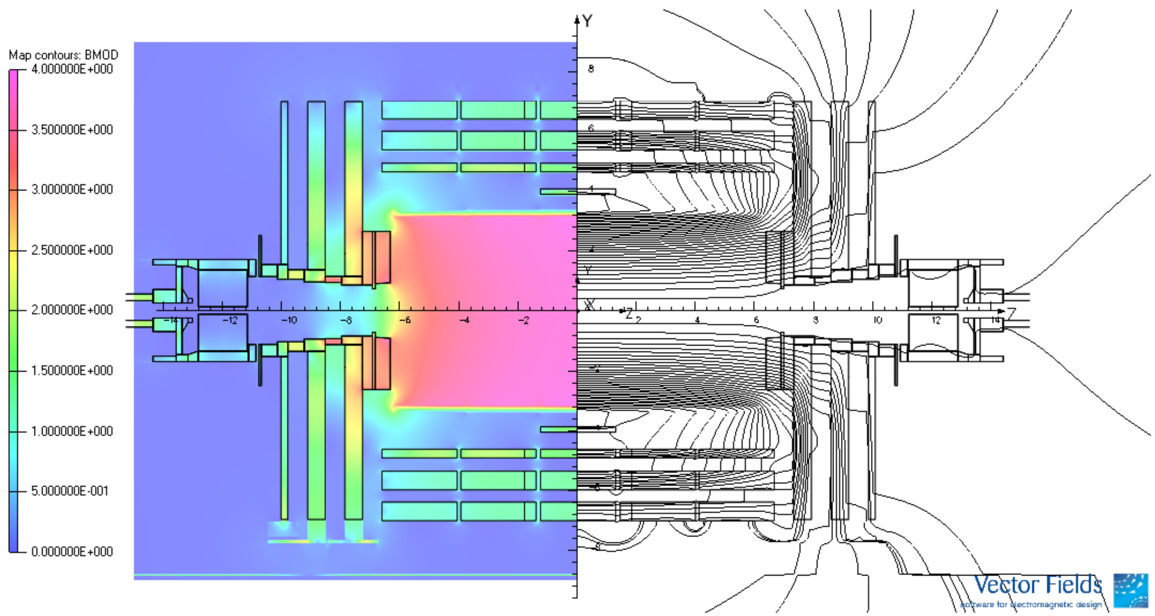
Agreement between data and MC now to better than 2%



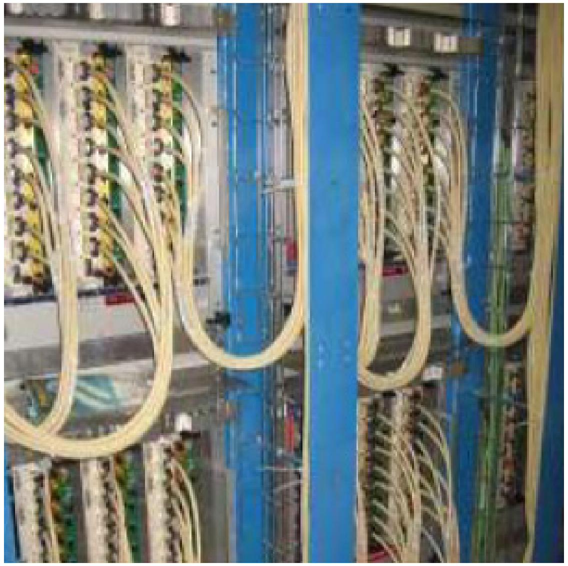
Chimneys

Feet

4Wb / line
YZ plane



DAQ and Trigger system



DAQ

•All the detectors participated in cosmic global run. Cosmics data taking at 300 Hz.

•Detector calibration triggers mixed with data

•Stress tests are regularly done at 60 kHz

Trigger

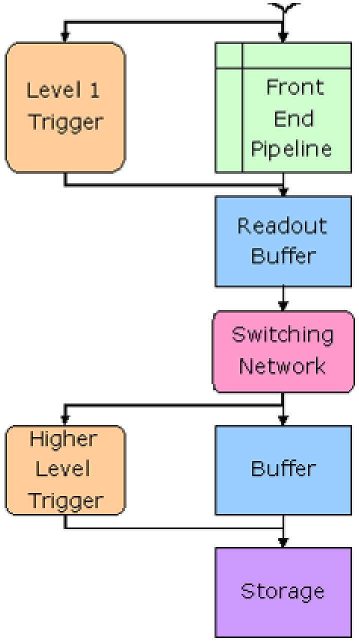
CMS Trigger system is organized in two levels: Level1 and High Level Trigger

- •During CRAFT data were read based on Level1 from Muons (DT, CSC, RPC) and Calorimeters.

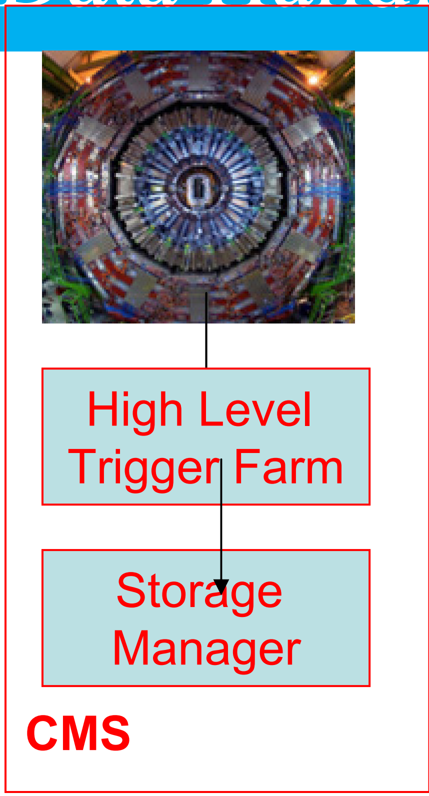
•High Level Trigger

•Online startup filter farm successfully operated during CRAFT: 720 PCs, 7 instances of HLT process on each, 5000 processes in parallel

•Regular high frequency stress test



Data Handling



Data processing

•Most jobs and data made available for analysis after 6-8 hours.

Alignment & Calibrations

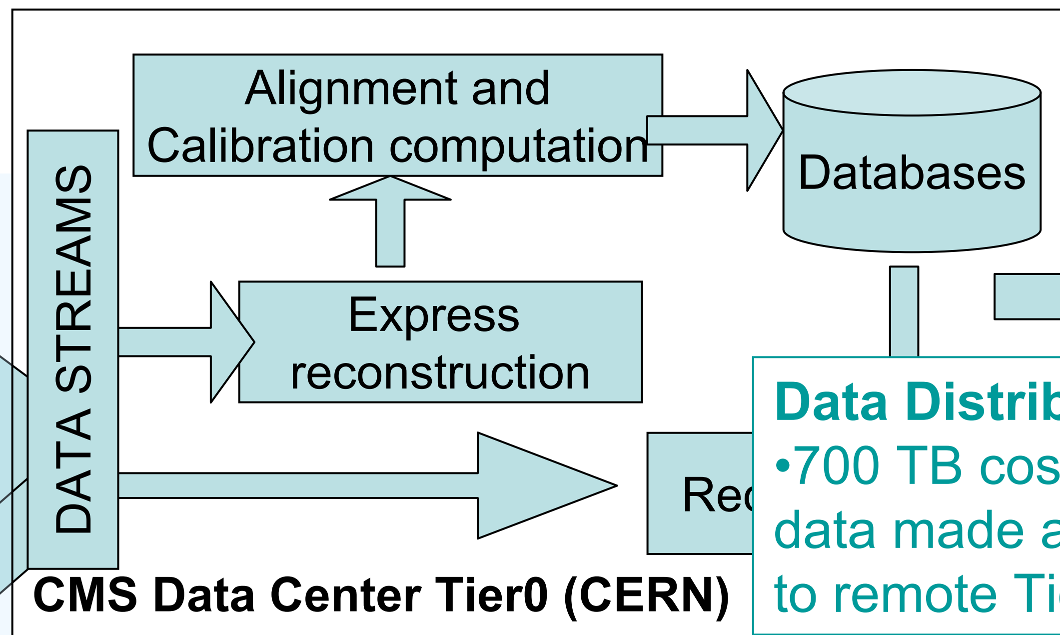
•Calibrations and alignment promptly produced and verified were inserted in the next data reconstruction.

•2 re-reconstructions done

Data flow

Bandwidth to disk > 600 MB/sec.

Well established data workflow between CMS experimental site and CMS Tier0



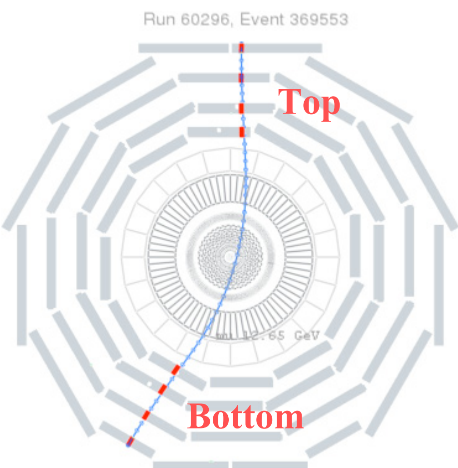
Data Distribution

•700 TB cosmics data made available to remote Tier1

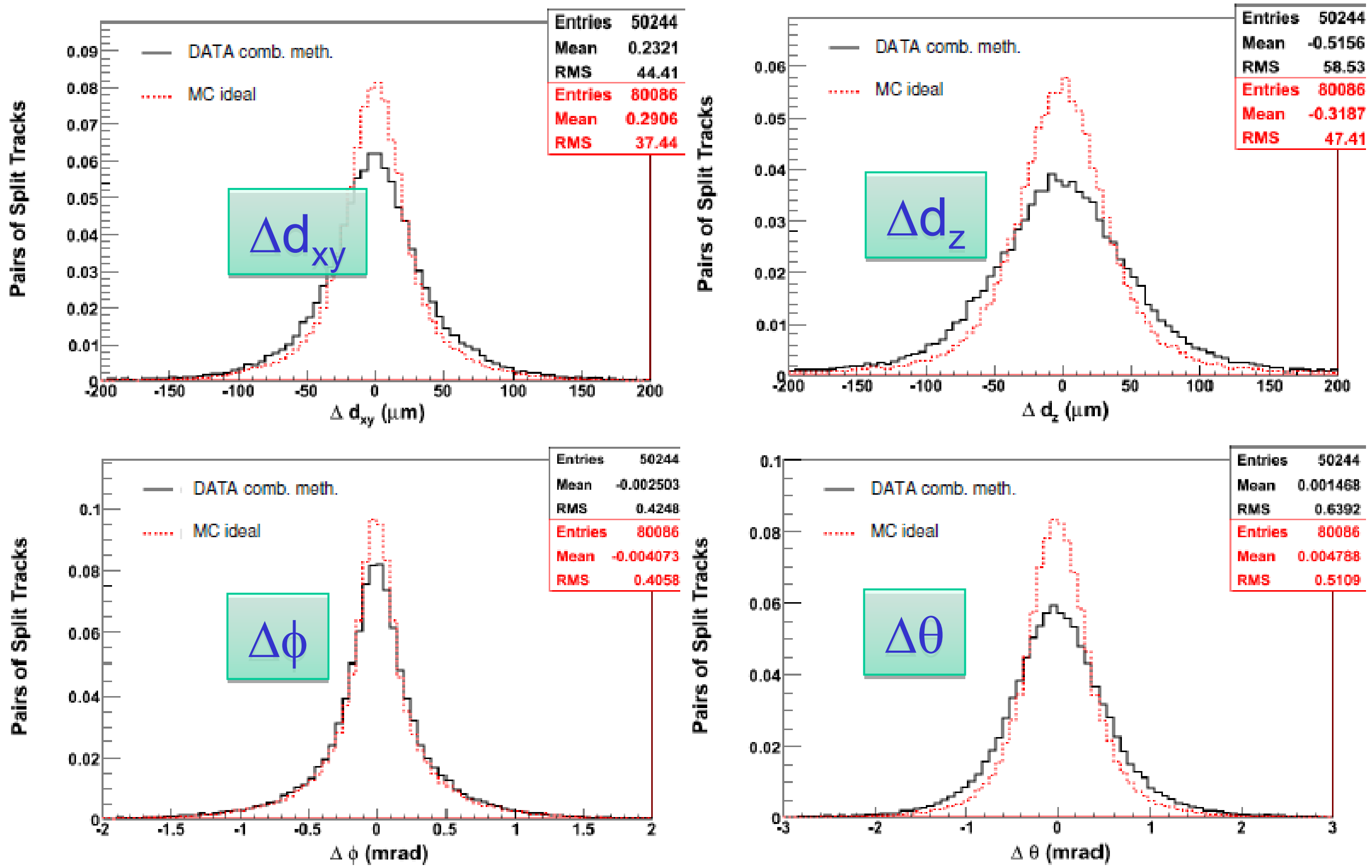
CRAFT: Tracker Performance Plots

Comparison of track parameters (impact parameters, angles) at point of closest approach to center of CMS for the top and bottom part of a cosmic reconstructed separately. For cosmics which go through the pixels detector.

CRAFT



Cosmic Track Splitting: absolute residuals (ALIGN vers.)



CAL Calibration & Monitoring

Calibration of ECAL crucial to maintain high energy resolution.

- Without inter-calibration, same signal would produce different outputs in different crystals.
- Also need overall energy scale

$$E_{e,\gamma} = G \times \mathcal{F} \times \sum_{i}^{\text{Cluster}} c_i \times A_i,$$

- G: absolute energy scale
- $\mathcal{F}$: algorithmic corrections
- c_i: inter-calibration constants
- A_i: amplitudes

Uncalibrated Supermodule:
6%-10% spread in resolution among channels

→

TestBeam Pre-Calibration:
<1% (1/4 of EB & 400 EE xtals)
Cosmic Pre-Calibration:
1.5-2.5% (all EB)
Lab Pre-Calibration:
4% EB, 9% EE (all crystals)

→

In-Situ Physics Calibration:
0.5% resolution

ECAL Monitoring (Monitor Stability and Measure Radiation Effects):

ECAL Stability (<< 0.5%):
Monitored with Laser System

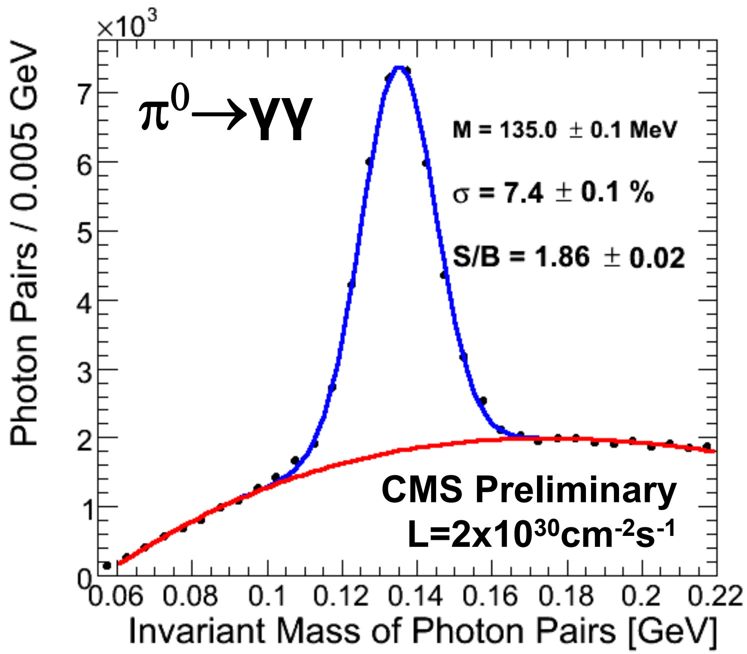
→

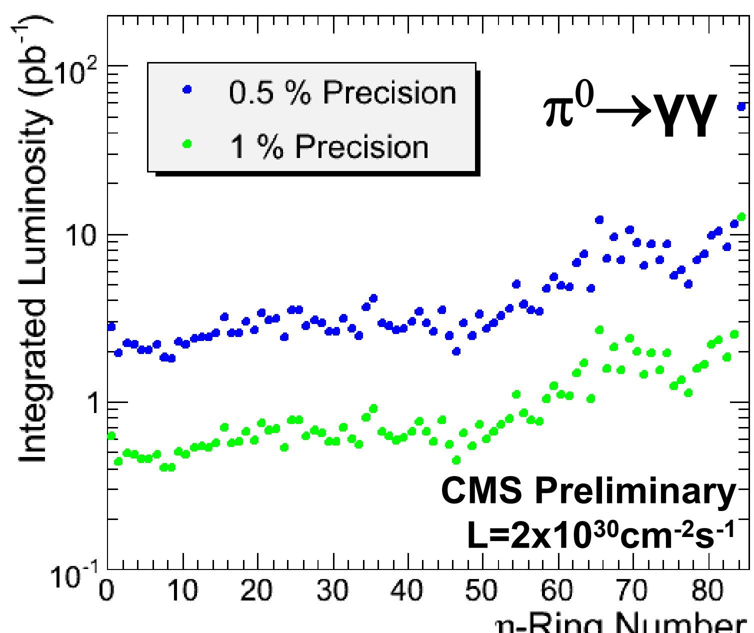
Transparency Change Correction:
Signal Change under Irradiation,
Measured with Laser Monitoring System

ECAL In-Situ Calibration

Goal: improve startup calibration as quickly as possible in-situ

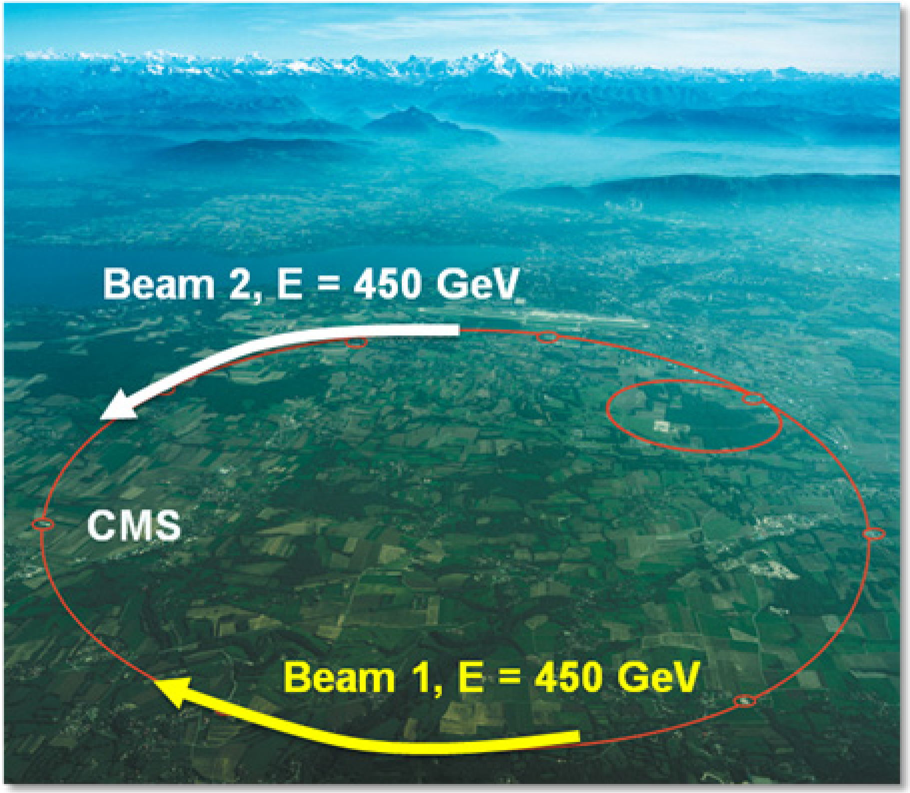
Strategy	Time	Precision
φ symmetry: use invariance of mean energy deposited by jets at fixed η	Few hours	~ 2-3%
$\pi^0 \to \gamma\gamma$ mass peak @ low luminosity	Few days	<= 1%
Z→ee: absolute energy calibration	100 pb^{-1}	< 1%
W→eν: E/p measurement	5-10 fb^{-1}	0.5%





Last year beams in the LHC

- September 7
  - Beam 1 on collimators (upstream of CMS)
- September 10
  - Beam 1, then Beam 2 circulating (hundreds of turns)
- September 11
  - RF capture (millions of orbits)
  - Beam halo through CMS
  - Beam-gas events

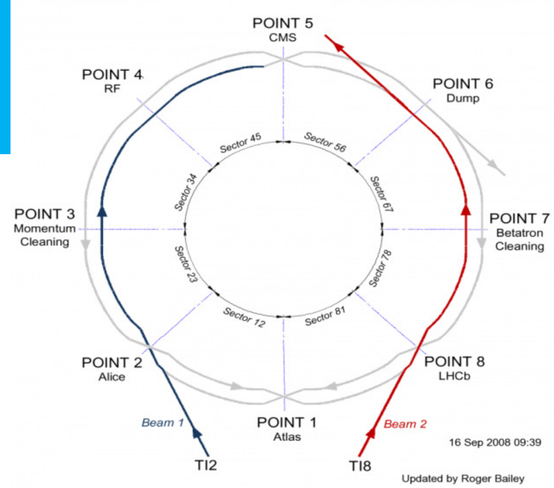


- About 40 hours of beam at or through CMS
  - All systems ON except Tracker and Solenoid

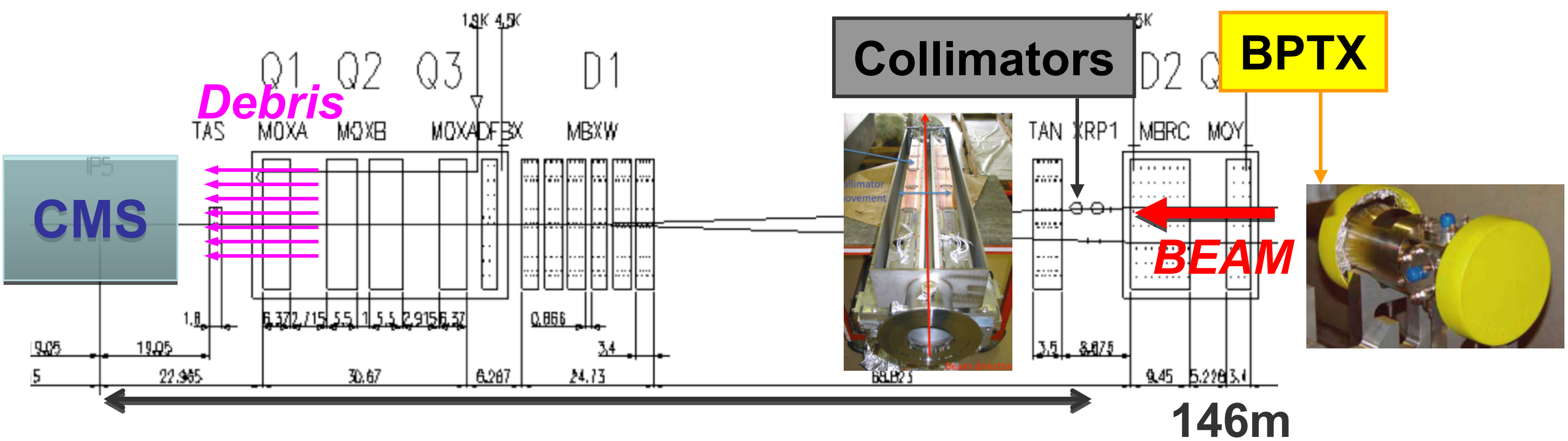
❑ CMS Trigger and DAQ fully functional: millions of beam events recorded

Beam Splash Events

- ✓ **collimators placed at 146 m away from the IP on each side of CMS to stop the beam**
- ✓ **Beam 1 at injection energy (450 GeV) shot towards CMS from z+**
- ✓ **Beam 2 tried the first time on Sept 10**



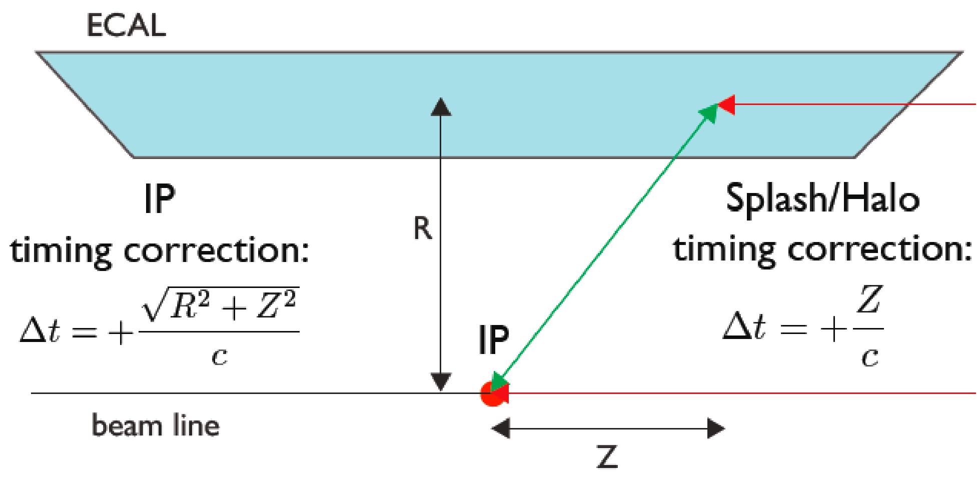
- Single beam shots of 2×10^9 protons onto closed collimators ~150m upstream of CMS
  - Hundreds of thousands of muons pass through CMS per event
  - Enormous amount of energy deposited in calorimeters
- Allowed synchronization of triggers (previously with cosmic muons)
  - Muon end caps, BPTX beam pick up, etc
- Internal synchronization of sub-detectors

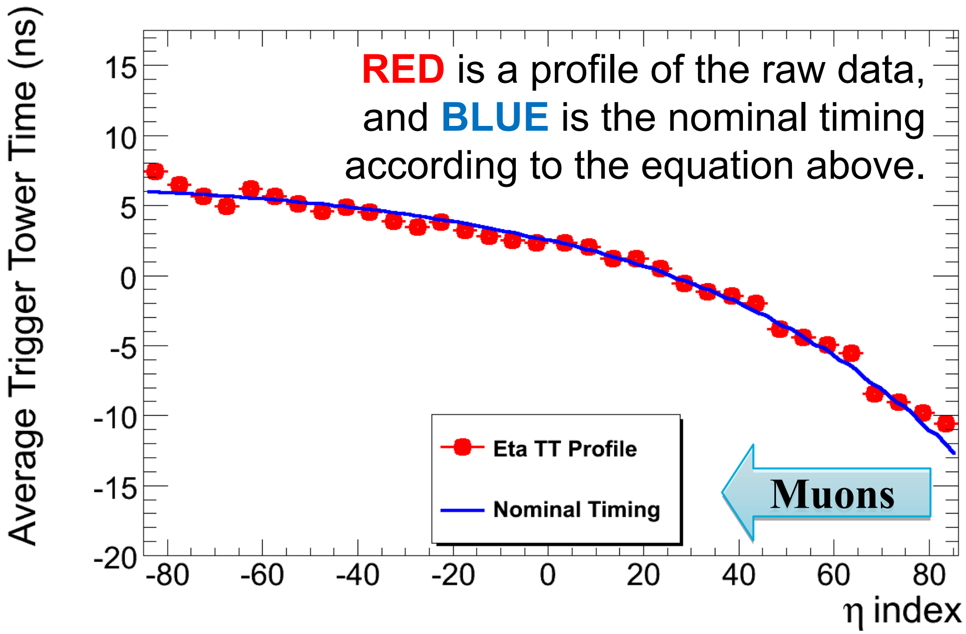


Beam Splash: ECAL Timing

Beam splash events provide a source of synchronous hits throughout detector, allowing to internally synchronize ECAL

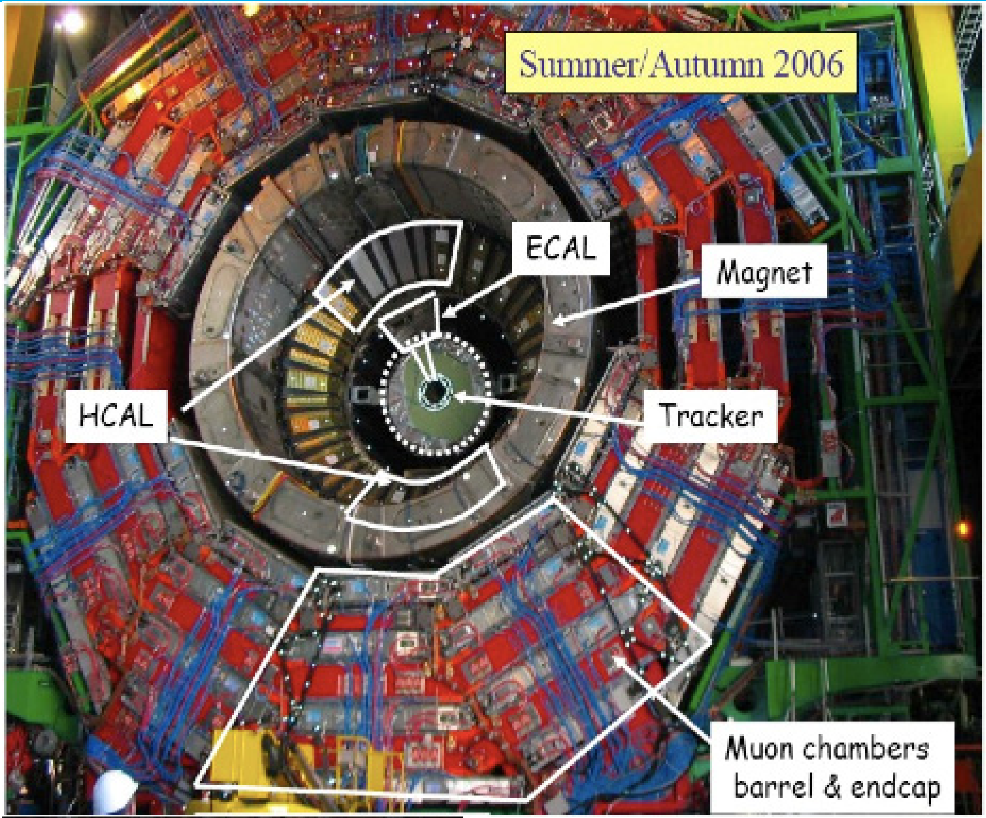
$$\Delta t = \Delta t_{Readout} + \Delta t_{PlaneWave}$$
$$= (\sqrt{x^2 + y^2 + z^2} - R \pm z)/c$$





- Synchronization prior was done with laser light
- Latency then adjusted w/ splashes: **hardware** allows steps of **1ns** steps
- Further synchronization applied in **offline** reconstruction, **better than 1 ns**
- Synchronization from splashes will be start-up condition; better precision w/ LHC data

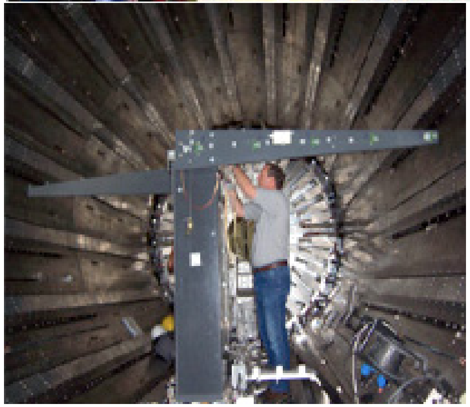
2006 - First system-wide test

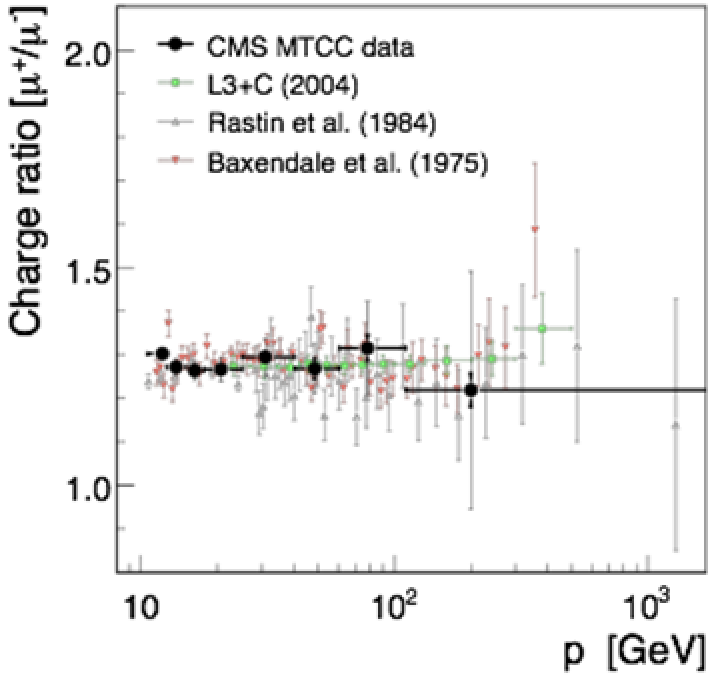


Pieces still in the surface

Scaled-down infrastructure

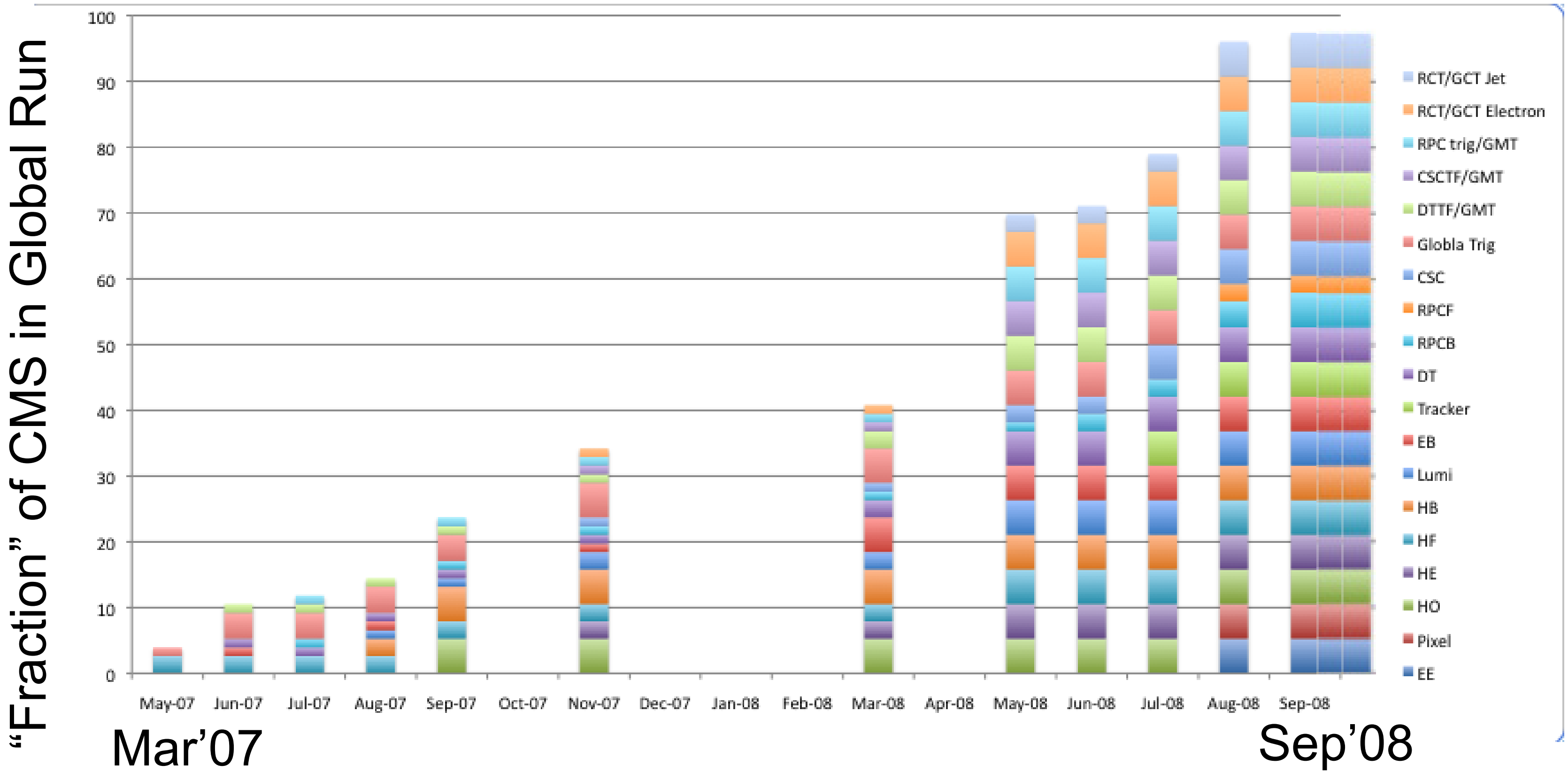
Slice of nearly all final components and DAQ





Parasitic to **B** field mapping at 5 values for physics

Commissioning of CMS (2007-2008)



CRUZET4 (Cosmics Run at Zero Tesla, Aug. 2008)

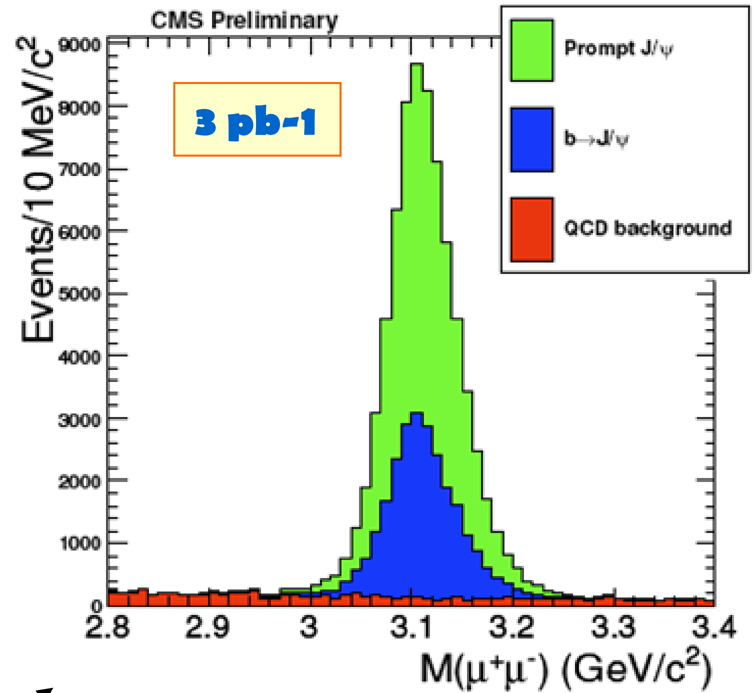
First Global run with final CMS configuration

CRAFT (Oct - Nov 2008 @3.8T)

Global run with final CMS configuration at operating field (3.8T)

Lepton commissioning: early data

Priorities for lepton commissioning:
- Understand lepton trigger
- Understand building blocks of lepton reconstruction
- Detector calibration & alignment
- Electromagnetic & momentum scale
- Comparison with MC: ID variables for signal and backgrounds, efficiencies, fakes
- Inner detector material measurement



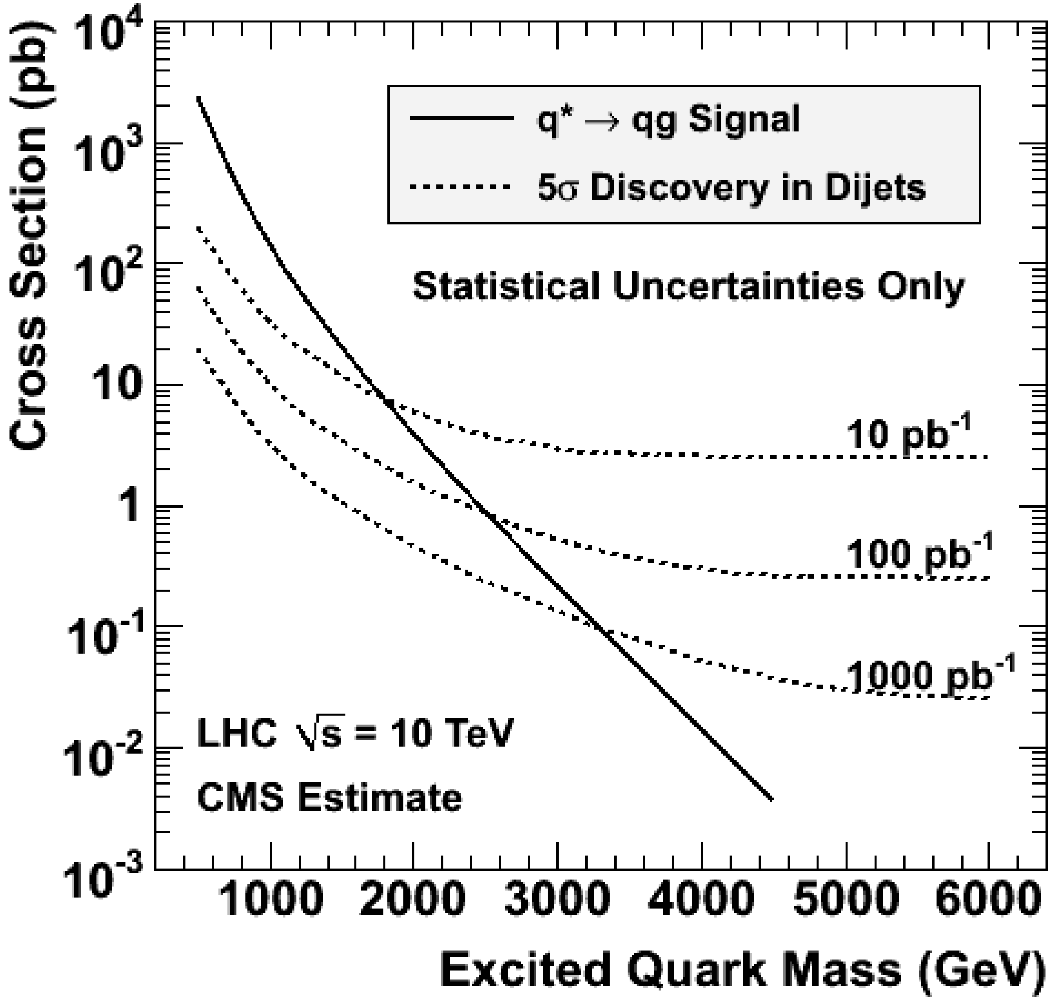
Also inclusive samples of identified leptons can be used for various purposes from the very beginning. $E_T > 35$ GeV dominated by W/Z leptons

Low mass resonances (J/Ψ &Υ): Provide abundant sources of leptons even with few pb^{-1}, but lower p_T wrt Z and less purity. On going studies to use also e^+e^- decays (larger background, lower efficiencies)

Bumps in Dijet spectrum

Also a relatively easy signal:
- Fit of bumps on top of continuous spectrum
- Excited quarks, Z' etc…. Surpass Tevatron sensitivity with early data

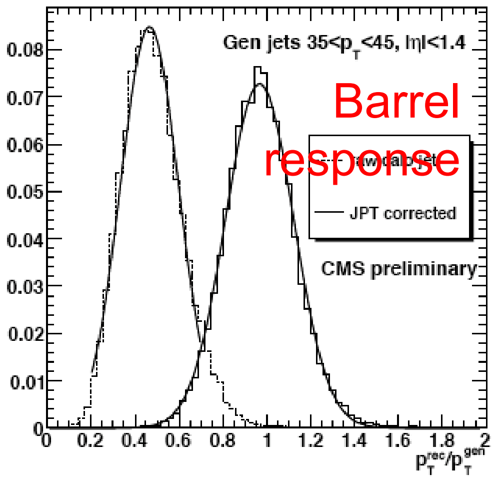
Understand instrumental effects, detector performance and tune detector simulation:
Resolution, MET, underlying events



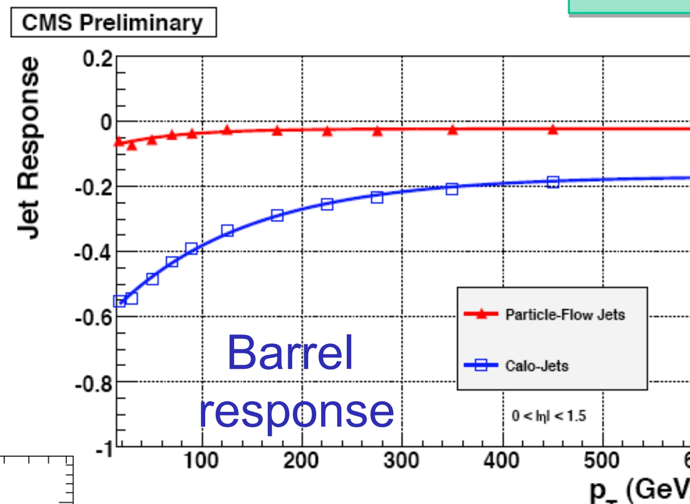
Preparation for Physics Analysis

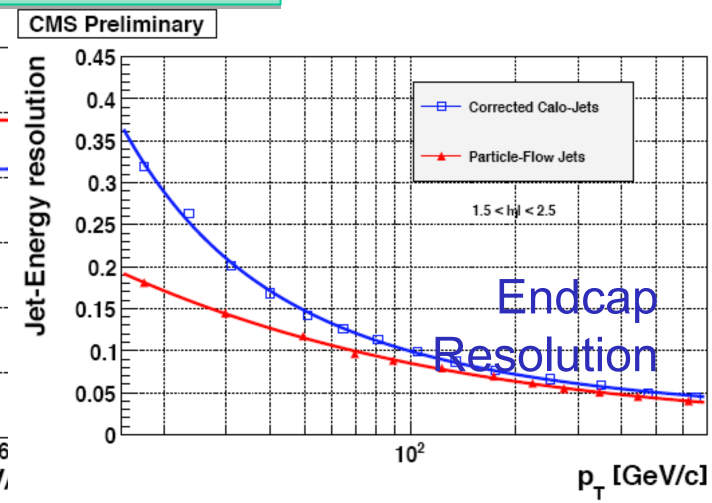
Example: Use of Tracks in Reconstructing Jets

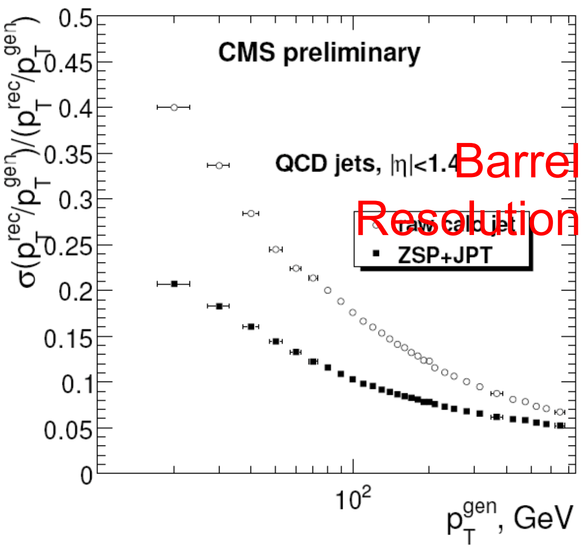
Jets+Tracks

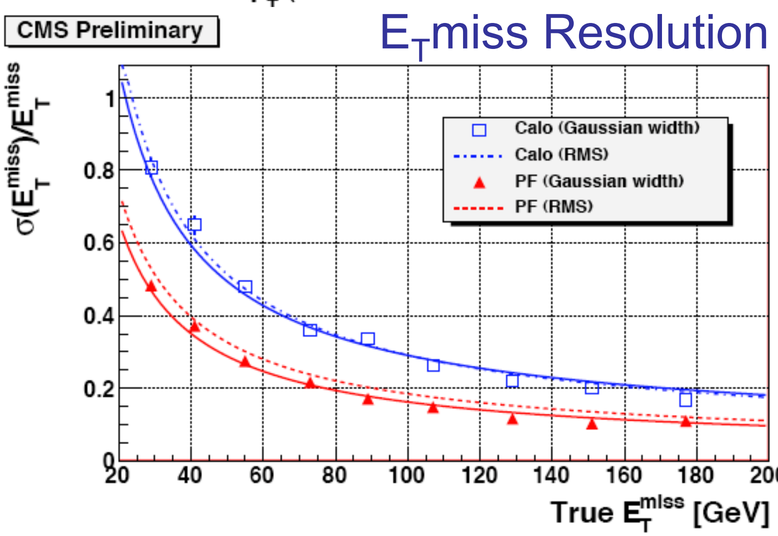


"Particle Flow"









Particle Multiplicities and B physics

Charged Hadron Multiplicity in Minimum Bias pp Collisions at 900 GeV and 10 TeV
(5k events)

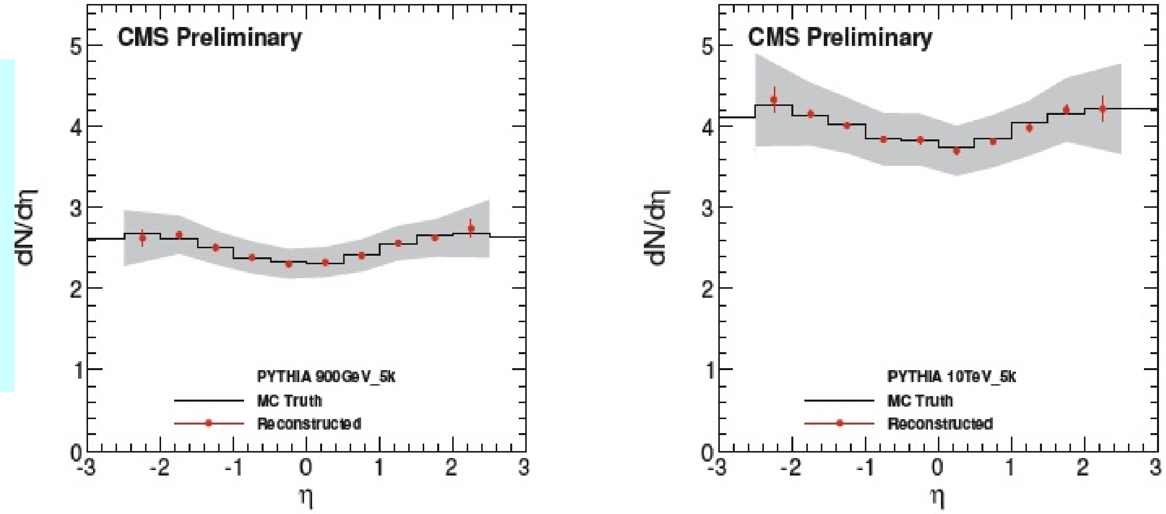
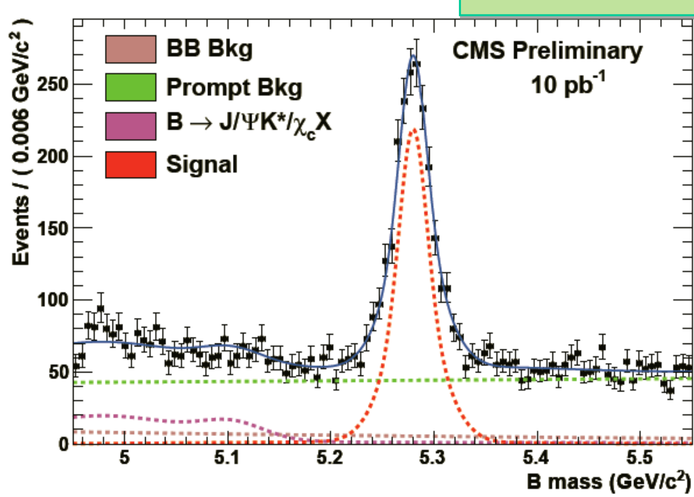


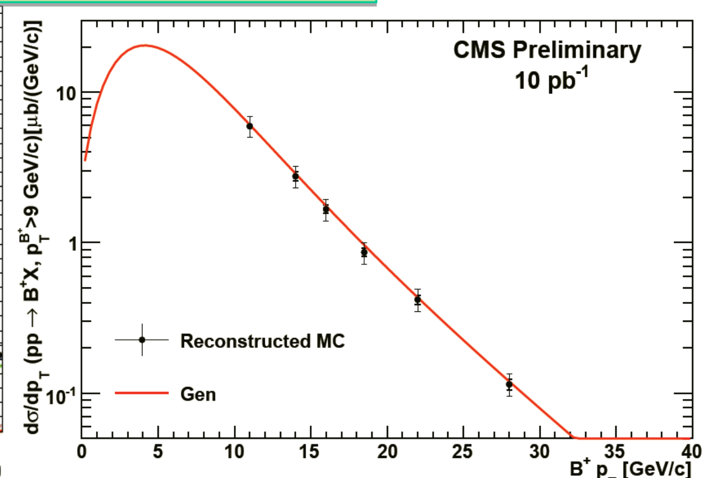
Figure 7: The measurement of $dN/d\eta$ in p+p at 900 GeV(left panel) and 10 TeV(right panel). Error bars show statistical errors using 5k events. The shaded area corresponds to 7.5 - 13.5% systematic error band.

$B^+ \rightarrow J/\psi K^+$ with $10 pb^{-1}$

E.g. **Exclusive B production** with early data:

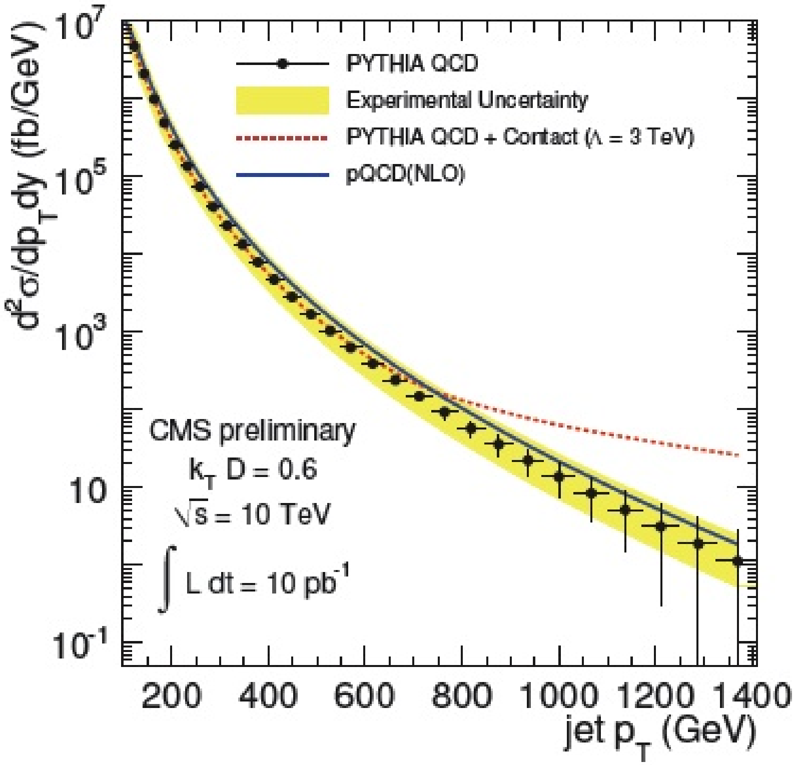
- $B^{+(0)} \rightarrow J/\psi K^{+(*0)}$ cross section and lifetime ratio

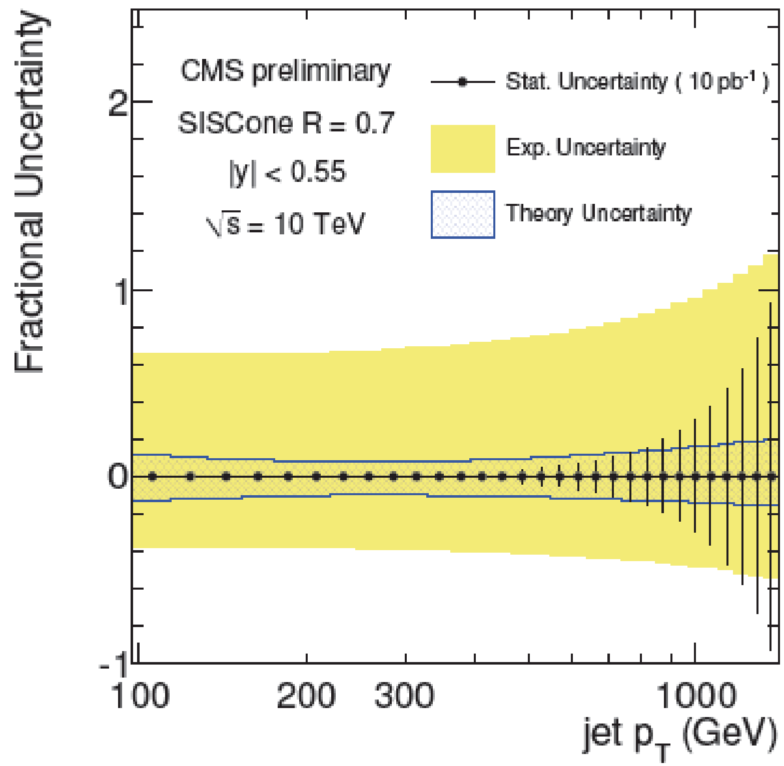




QCD: Jet Measurements

Startup inclusive jet measurement using k_T and SISCone



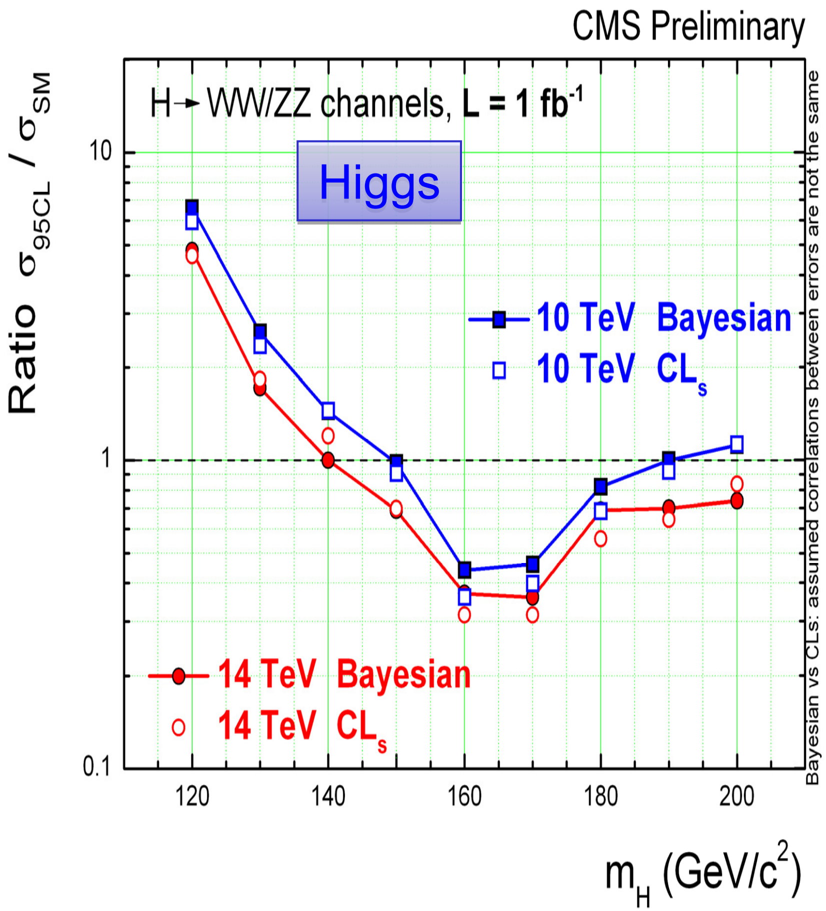


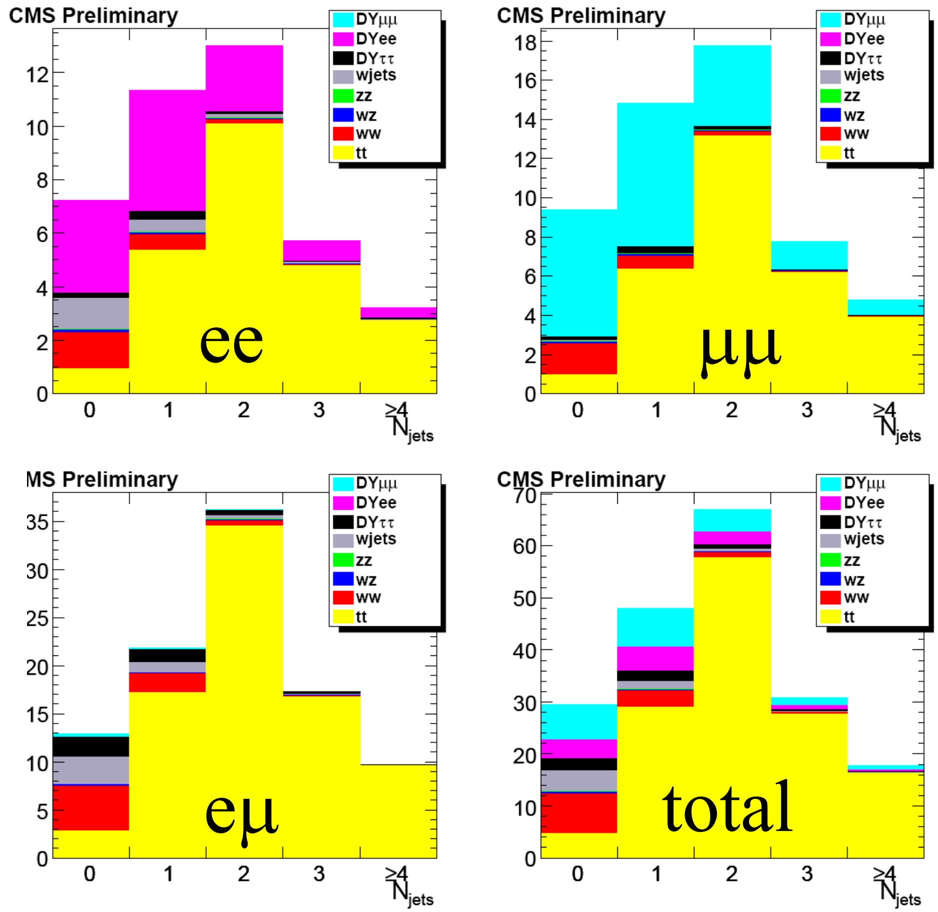
Inclusive jet cross-section measurement (k_T) for 10 pb^{-1} data

Inclusive jet cross-section uncertainties (SISCone) for 10 pb^{-1} data

Higgs and Top

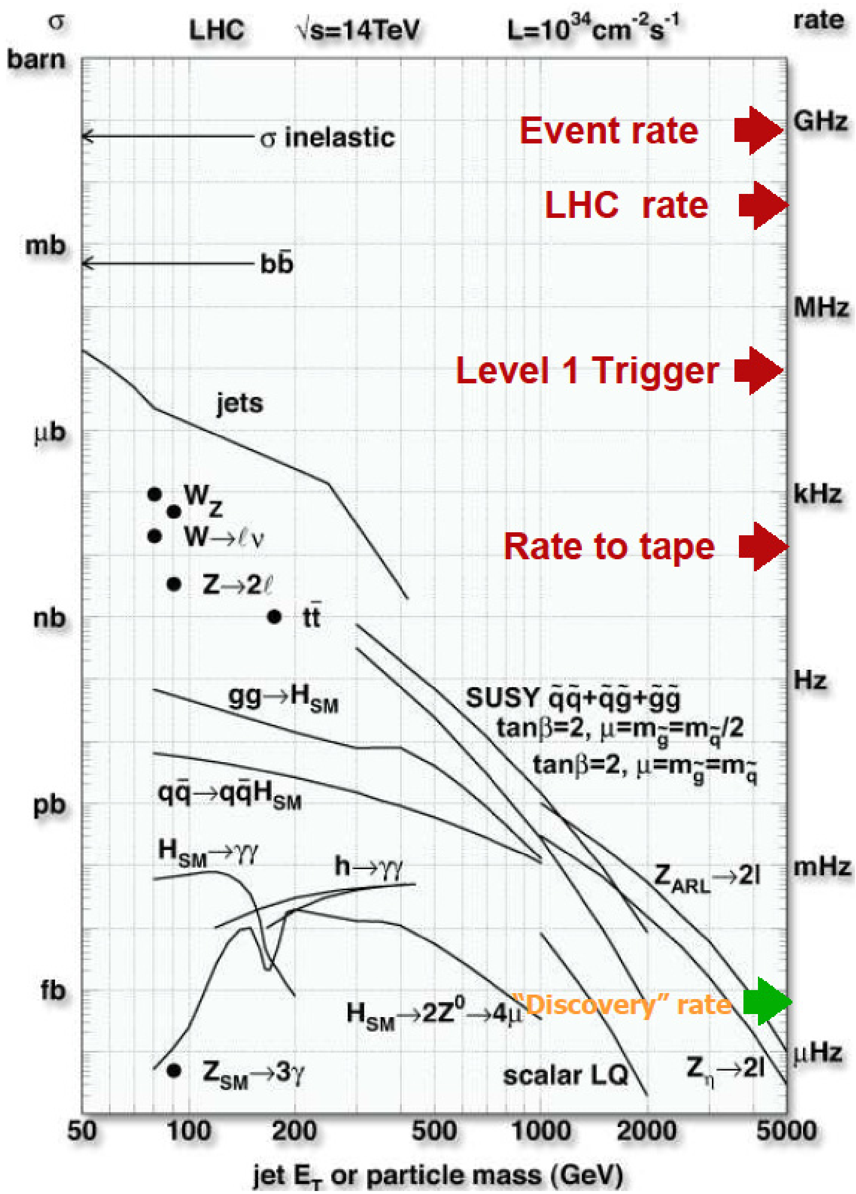
With 200 pb^{-1} reach 150-160 GeV
Sensitivity as at Tevatron





Top: about 250 e-mu events, about 700 semileptonic mu-jets in 100 pb^{-1}

Challenge: physics at LHC



- LHC designed to investigate the Electroweak Symmetry Breaking scenarios
- High energy, 40MHz collision rate, high multiplicity
- Interesting events may be hidden in a enormous QCD background
- Triggering with leptons is of key importance

‘08-’09 Shutdown - CMS Activities

After the cosmics run ended (Nov ‘08), the detector was opened for **carefully selected maintenance, consolidation and repair activities**, as well as the **installation** of the preshower subdetector.
Work progressed according to the schedule laid down in Nov. 2008.

Some highlights:

- the installation and commissioning of the preshower (ES)
- the removal, repair, and re-insertion of the forward pixel system
- the maintenance and (small) repairs involving many sub-systems
- the revision of the tracker cooling plant
- Re-commissioning of CMS – Mid-Week Global Runs and CRUZET interspersed with final maintenance and consolidation activities.

- Preparation of s/w for 2009 data taking, improving stability & reliability of computing infrastructure, large MC production and analysis at 10 TeV.

Ongoing:

Cosmics run at operating field (6 weeks started end-July)
Move to stable data-taking prior to LHC beam.