

# First Physics with CMS

Martijn Mulders (CERN)  
for the CMS collaboration

Physics at LHC –2008, Split, Croatia

# First Physics with CMS

No pp collisions yet...

Plans for first physics covered extensively in other talks

- Focus on data recorded by CMS so far (MTCC, cosmics, and first beam)
- Briefly discuss plans for first physics with pp-collisions ( $<10, 10, 100 \text{ pb}^{-1}$ )


# First Physics with CMS

Jan 2008

No pp collisions yet...

Plans for first physics covered extensively in other talks

- Focus on **data** recorded by CMS so far (MTCC, cosmics, and first beam)
- Briefly discuss **plans for first physics** with pp-collisions ( $<10, 10, 100 \text{ pb}^{-1}$ )

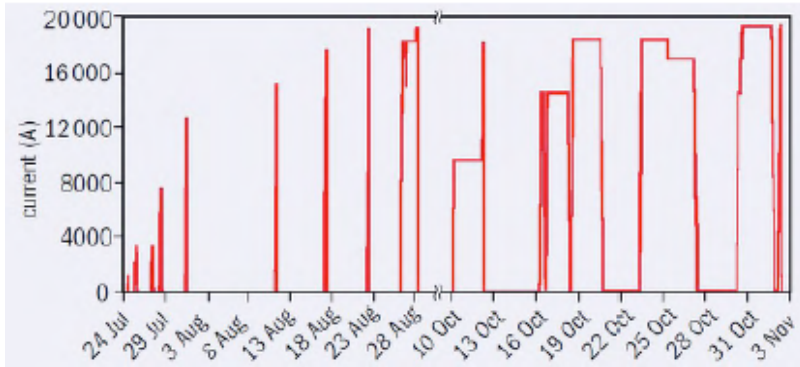
Starting with established physics: **Gravity** →  ...  
(In experiment with compact extra-large dimensions no violation of string theory found!)



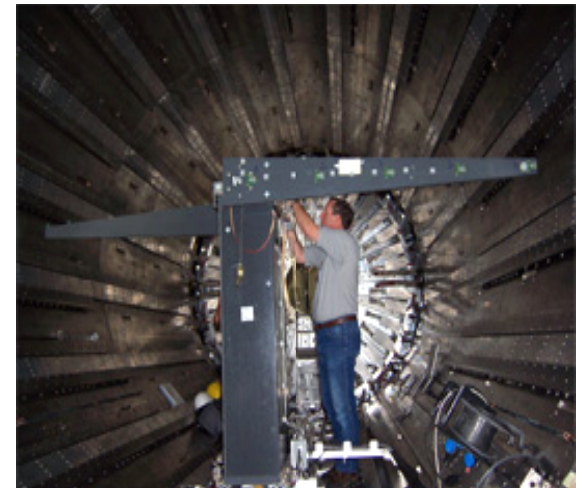
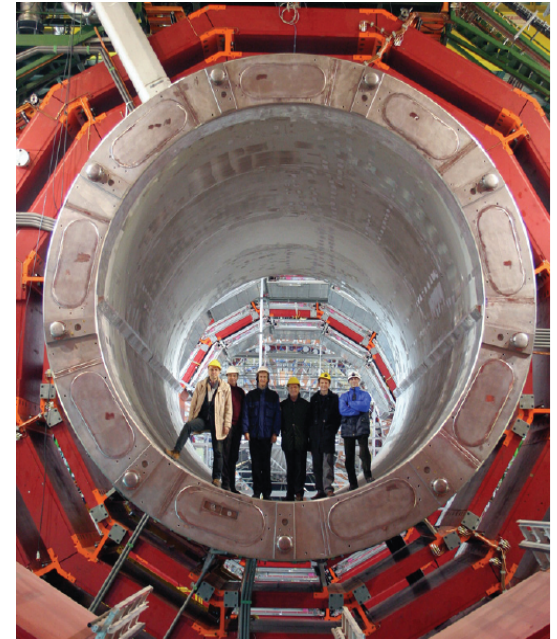


# Magnet Test

Jul-Oct 2006



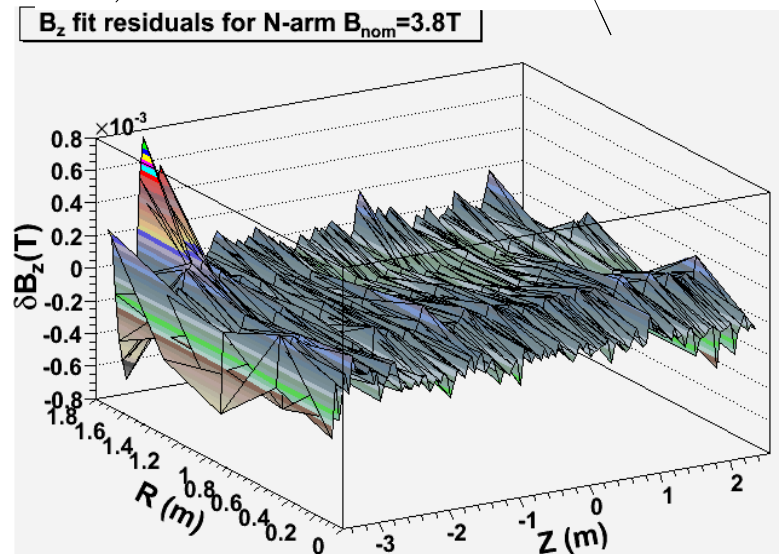
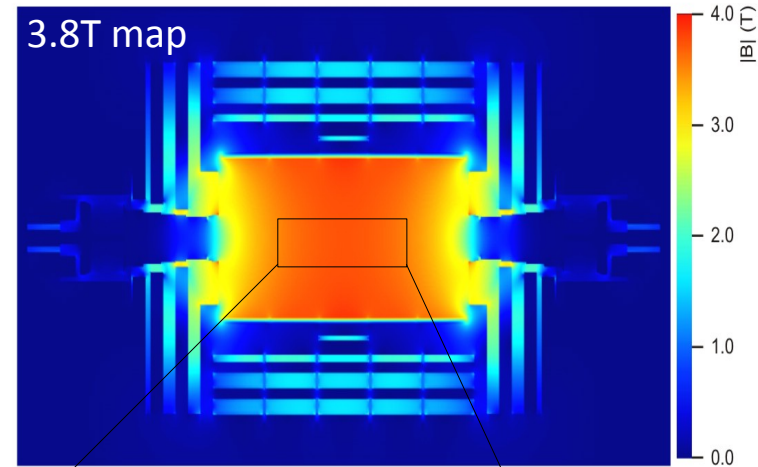
- At field values of 2, 3, 3.5, 3.8 and 4T:
  - 58'080 measurements with 3D Hall probes in cylinder of  $r=1.73$ ,  $l=7$  m (covering most of the volume inside barrel hadronic calorimeter)
  - Several scans with NMR probes
  - Flux loop measurements in iron return yoke during magnet discharges



# Field map

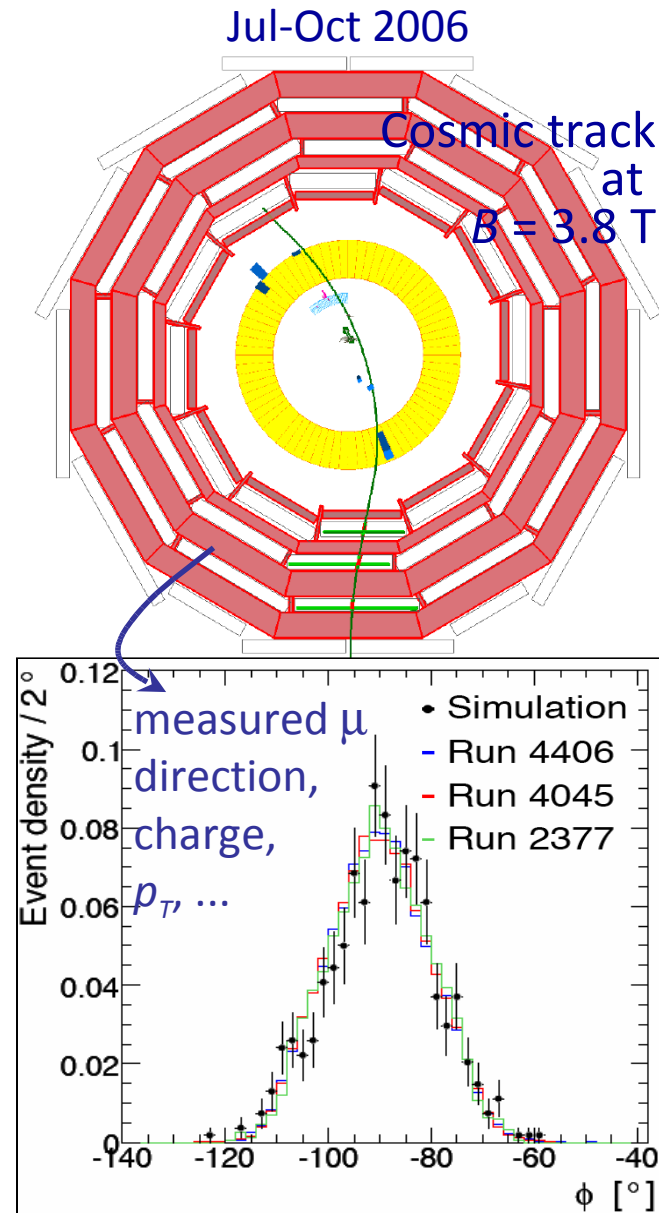
- Finite element calculation of field in entire detector volume performed (at 2, 3, 3.5, 3.8, 4 T)
- Field map with 12-fold phi-symmetry provided for physics
- Analysis of field mapper data:
  - Calibration corrections of order  $10^{-4}$  in gain and offset derived, to produce field model that agrees better than  $5 \cdot 10^{-5}$  with measurements and with Gauss' law in tracker volume (note: original calibration  $\sim 5 \cdot 10^{-4}$  !) [PhD thesis V.Maroussov, Purdue University, May 2008.]

✓ ...  $\nabla B = 0$



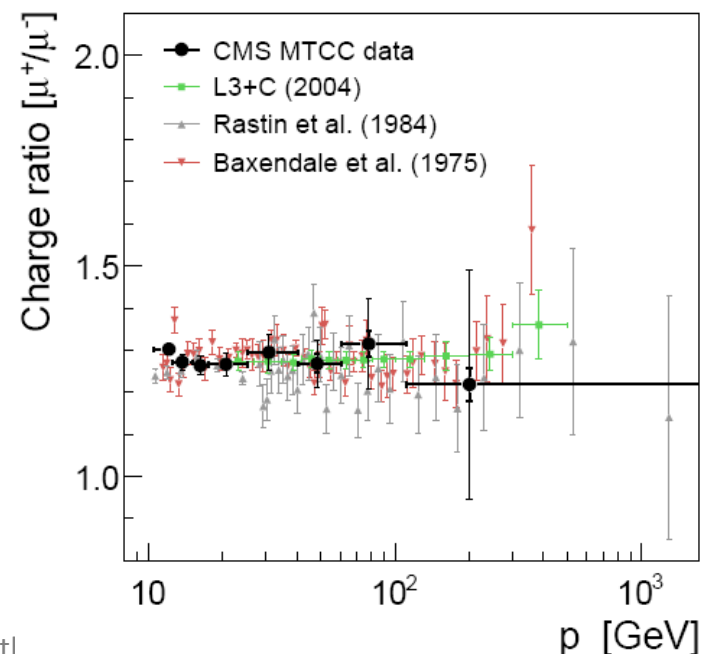
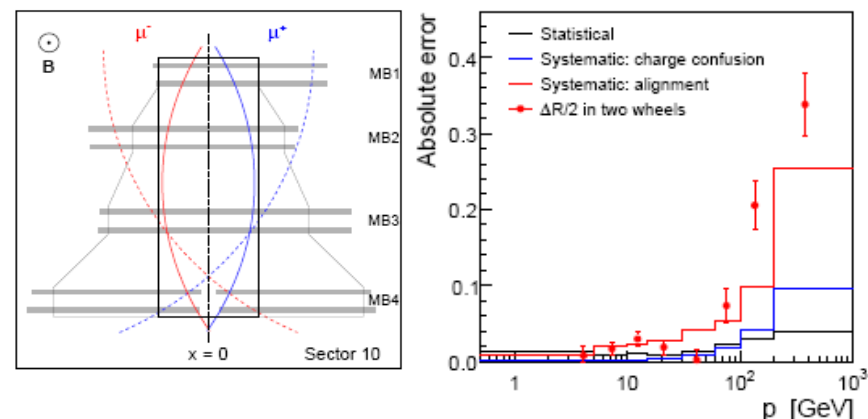
# MTCC data

- During **Magnet Test and Cosmics Challenge** >200 million cosmic events of good quality recorded, including >15 million with B field of at least 3.8T
- Tested (a slice of) nearly all final CMS components and DAQ, controls and software framework.
- Used for detailed studies of detector performance in B field, tuning of MC, and **first CMS physics measurement**



# Charge ratio of cosmic muons

- Using muons reconstructed in Drift Tube muon chambers
- Define **charge-symmetric** detector **acceptance**, apply survey **alignment**, unfold effect of **charge confusion**
- Systematics from uncertainty on charge confusion and residual mis-alignment

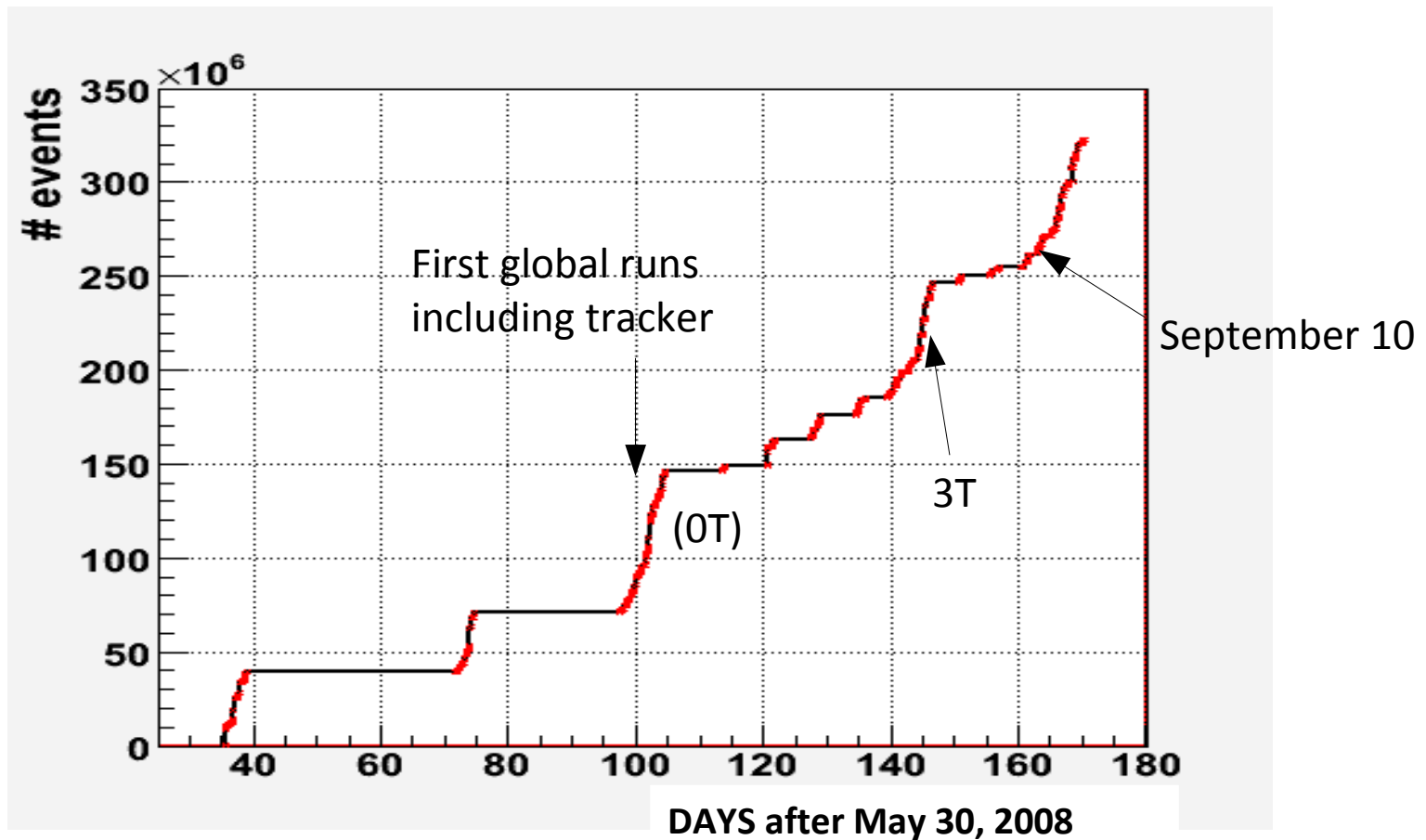


✓ ...  $\langle R \rangle = 1.282 \pm 0.004(\text{stat}) \pm 0.007(\text{syst})$

CMS Note -2008/016

# “Integrated luminosity”

Cosmic events collected by CMS in global runs during 2008



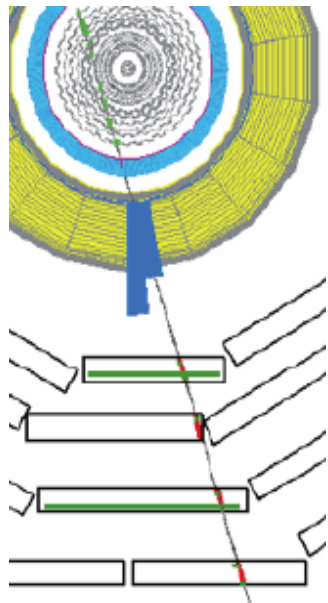
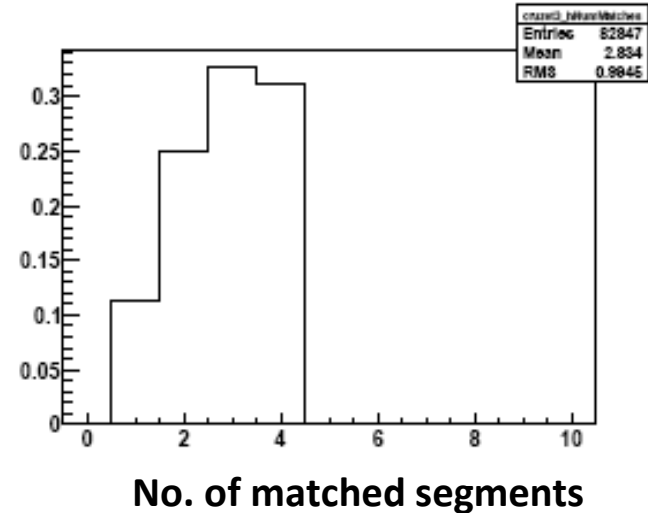


# Commissioning Muon Reconstruction

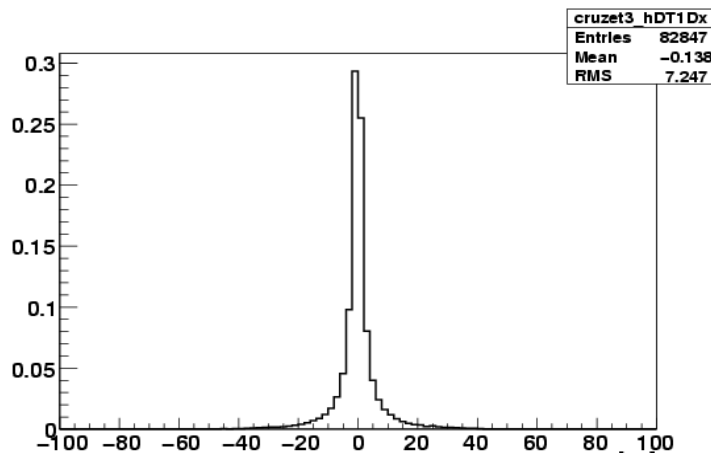
- **Global runs** essential to
  - Commission detector, learn how to operate it
  - Exercise work flows for Alignment, Calibration, prompt offline Reconstruction (and re-Reconstructions) at Tier0
  - see 'CMS commissioning' talk by Ivan Mikulec
- What can we learn about **muon reconstruction and ID**?
  - Detector response to muons (tracking, calorimetry)
  - Standard High-Level Trigger and Offline **algorithms**
  - But remember **special** Cosmics/Beam halo **conditions**: timing, magnetic field, and IP is not the origin
  - Exercise also **dedicated** cosmic muon reconstruction

# Standard MuonID sequence

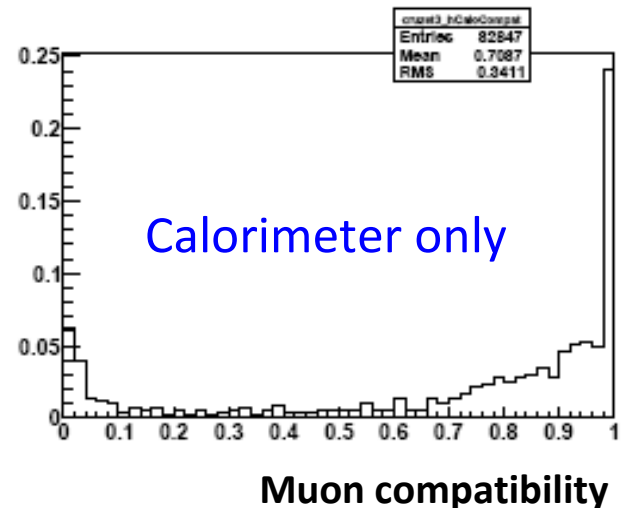
- 90k events with tracker track (B off)
- Part of standard MuonID: tracker tracks are extrapolated outwards and matched to
  - Muon segments
  - Calorimeter deposits
- Good results, even for non-pointing muons!



OT

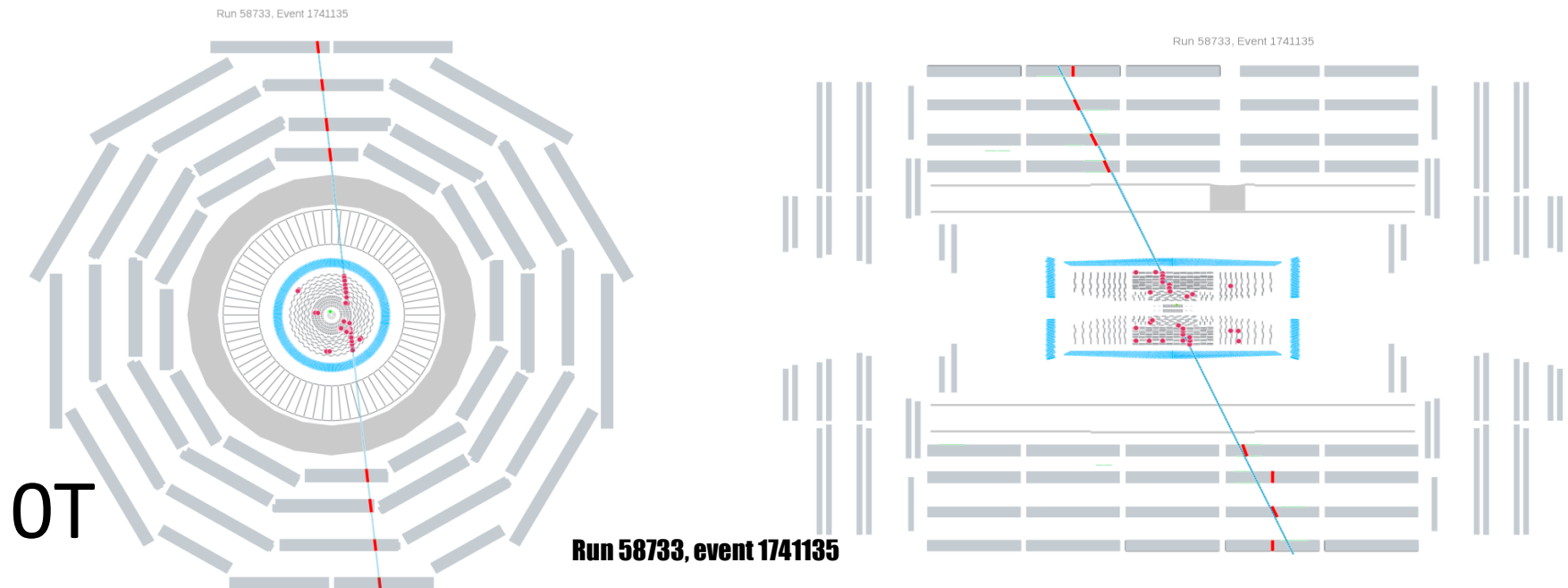


$\Delta x$  between track extrapolation and muon segment in station 1 (cm)



# Muon High Level Trigger

- High-Level-Trigger startup menu successfully deployed during global runs (+ dedicated cosmic muon trigger path)
- Standard muon HLT= global fit with “L3” tracker track, seeded from “L2” muon track, seeded from level 1 trigger candidate:

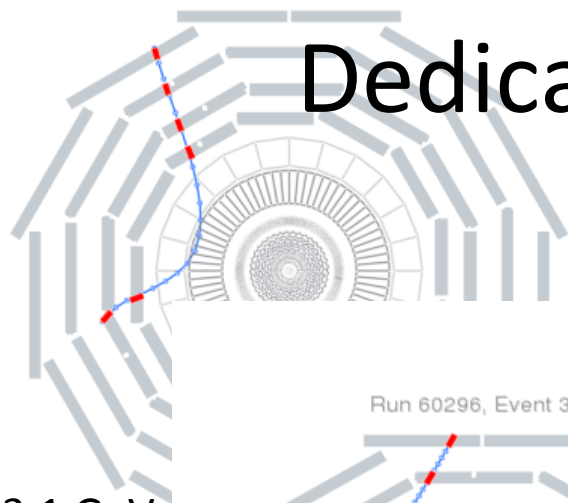


# Dedicated cosmic reconstruction

Navigation + seeding optimized for cosmic and beam halo muons [CMS Note -2008/001](#)

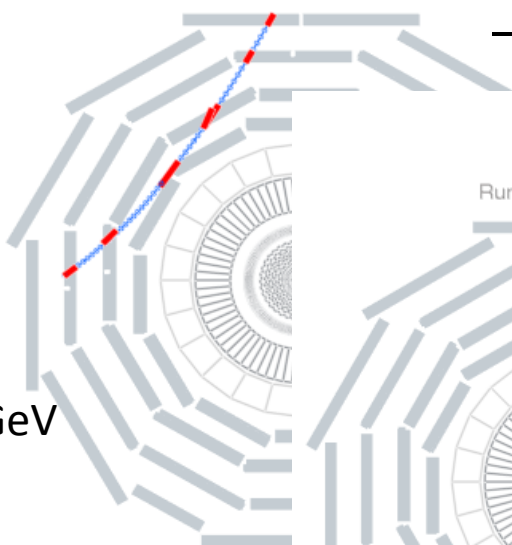
- not pointing at IP, traversing whole CMS
- using default propagator + Kalman filter fit, updated to work both with B on and off

Run 60296, Event 369736



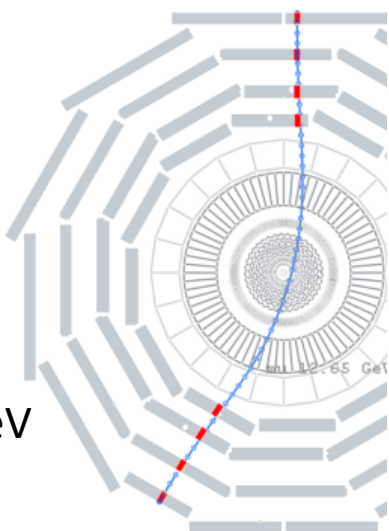
3.1 GeV

Run 60296, Event 345234



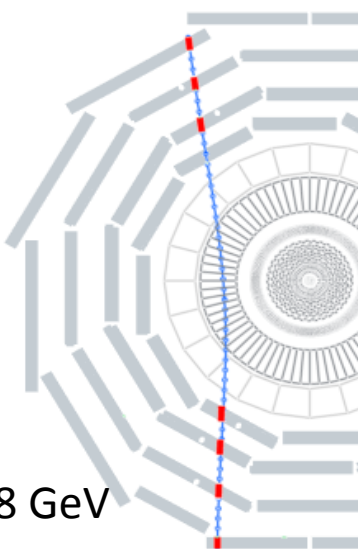
6.2 GeV

Run 60296, Event 369736



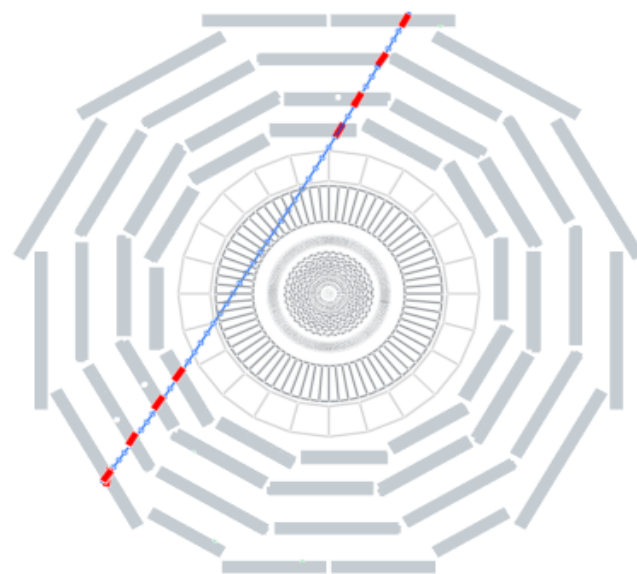
13 GeV

Run 60296, Event 369736



38 GeV

Run 60296, Event 369465

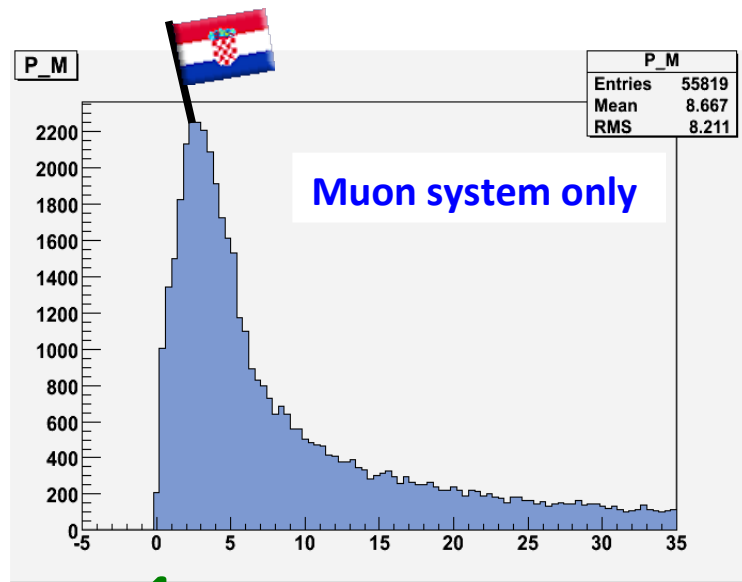


86 GeV

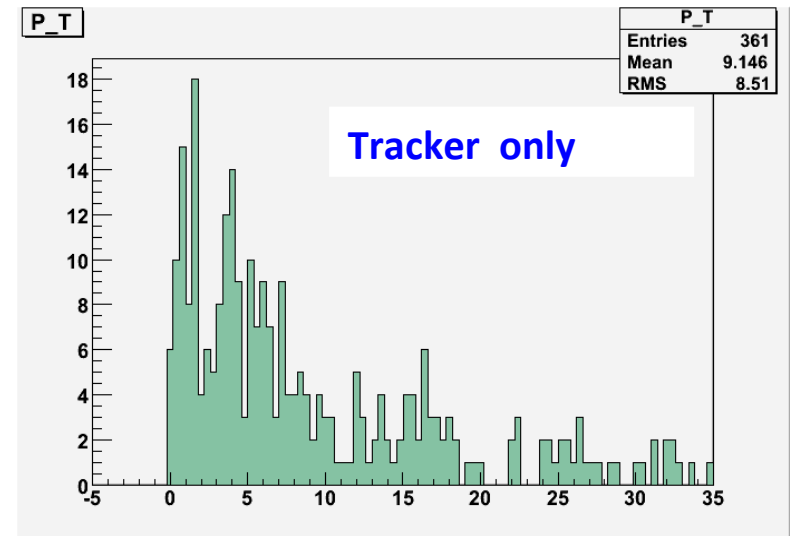
3T

# Muon momentum spectrum

Short run at 3T



... Muon momentum (GeV)



Muon momentum (GeV)

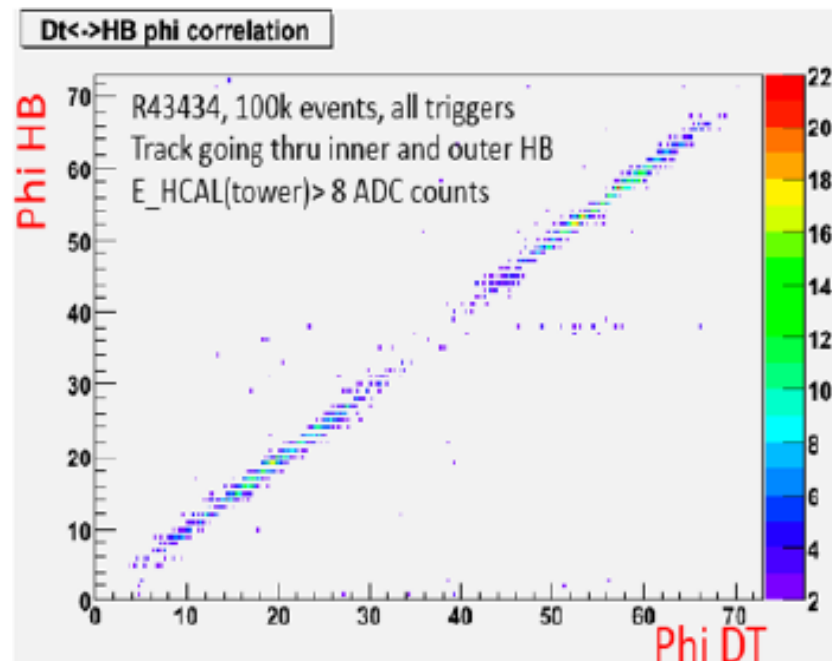
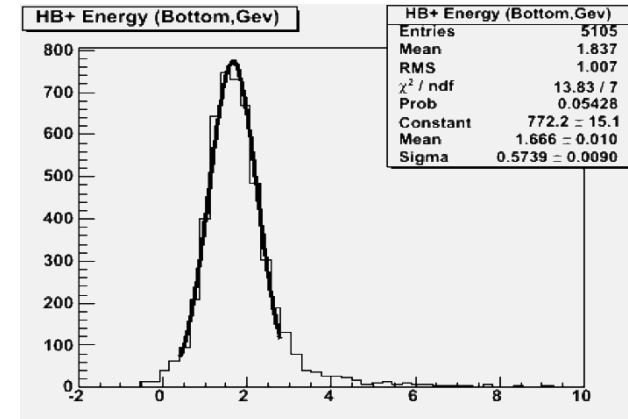
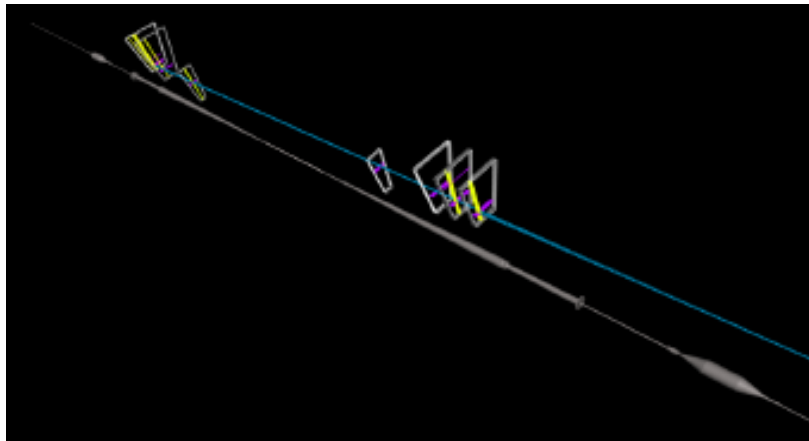
CERN SummerStudents:  
Goran Simatovic  
Marko Sostaric



# Muons used for

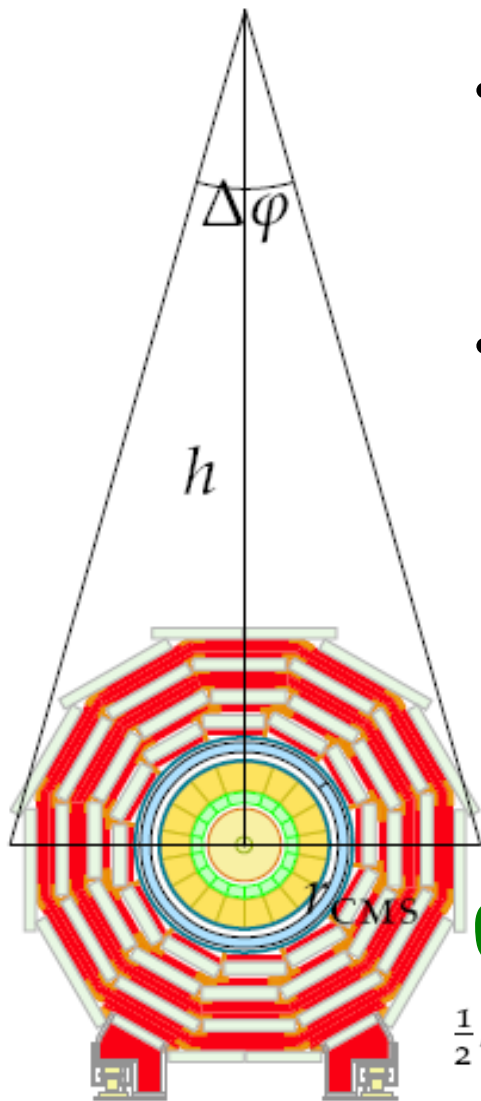
- **Alignment** with cosmics and beam halo
- Studying response of **calorimeters**
- Studying efficiency, **resolution and timing** of muon chambers

(see talk by Ivan Mikulec)



# Cosmic Shower Events:

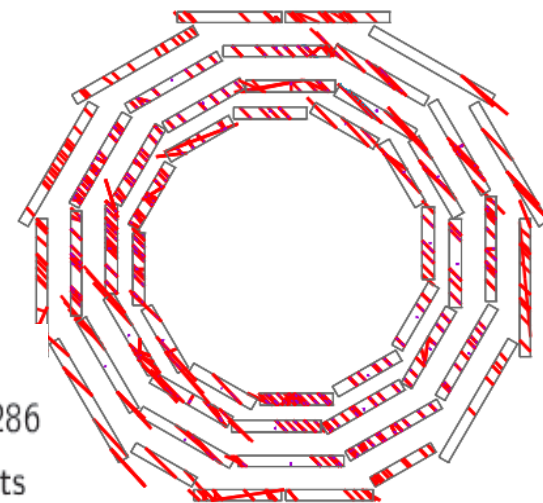
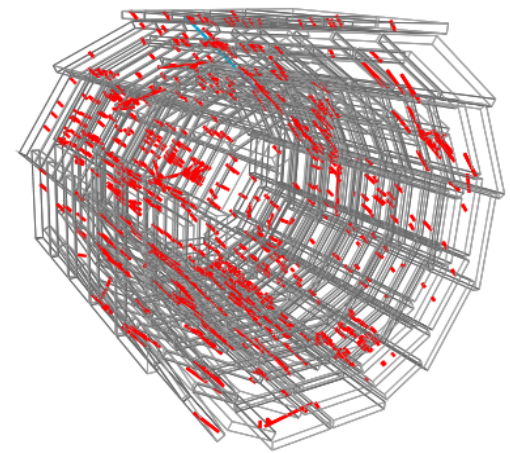
- 0.02% rate of events with >100 segments observed in  $\approx 10\text{M}$  cosmic events at 0T
- Event-by-event spread in  $\phi$  compatible with multiple scattering  $\rightarrow$  all events compatible with  $\approx$ parallel muon shower



$$\Delta\phi \approx 0.01\pi$$

$$\Rightarrow h \gtrsim 500\text{ m}$$

$$\frac{1}{2}\Delta\phi \approx \tan \frac{1}{2}\Delta\phi = \frac{r_{\text{CMS}}}{h}$$

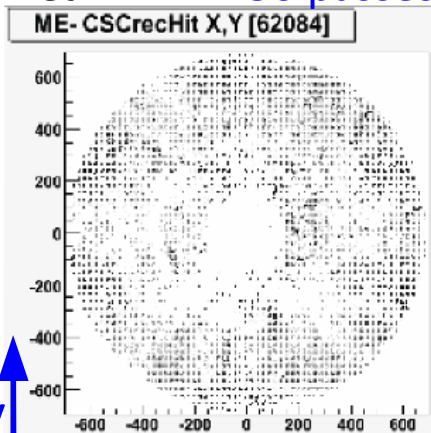


- Run 50908
- event 1057286
- 541 segments

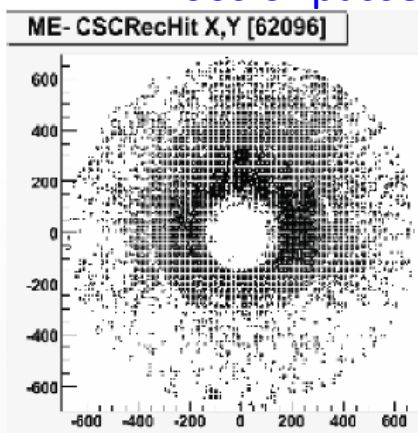
# Beam Halo

Beam quality improving from run to run:

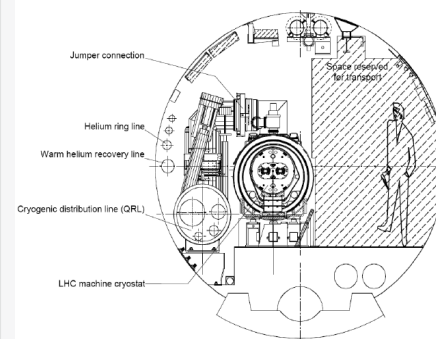
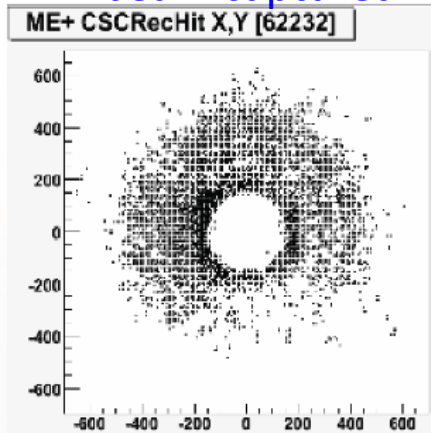
Beam 2: 50 passes



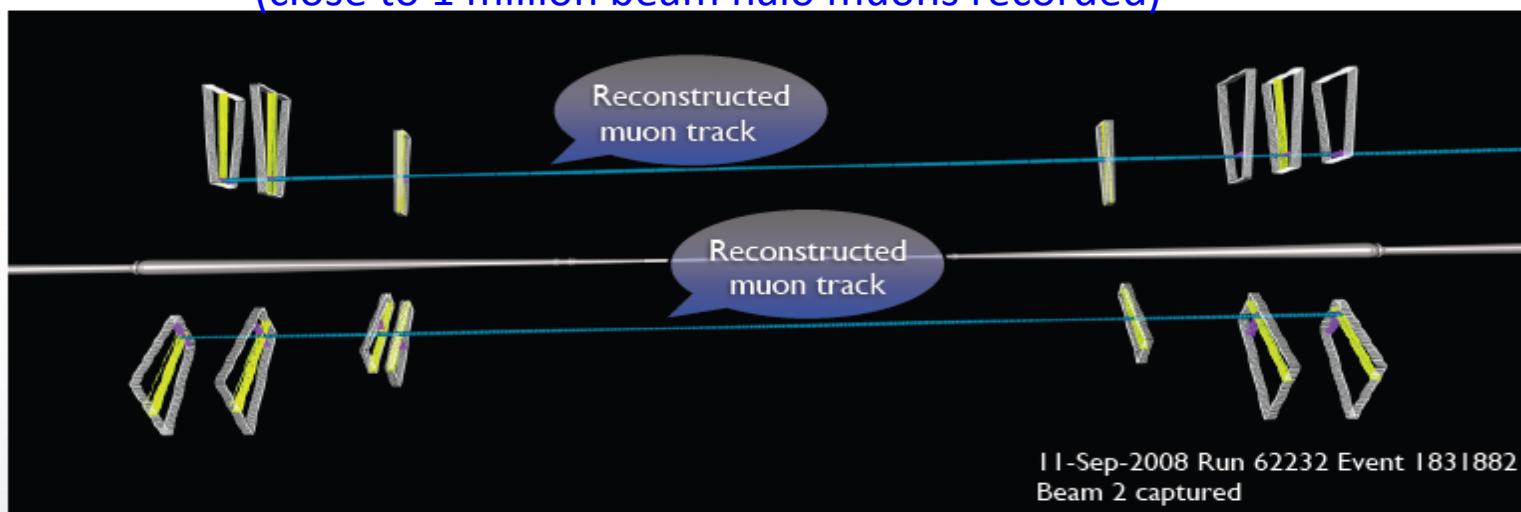
100s of passes



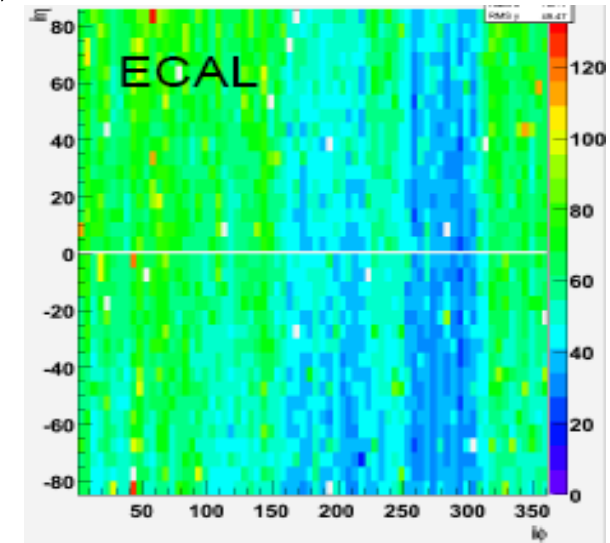
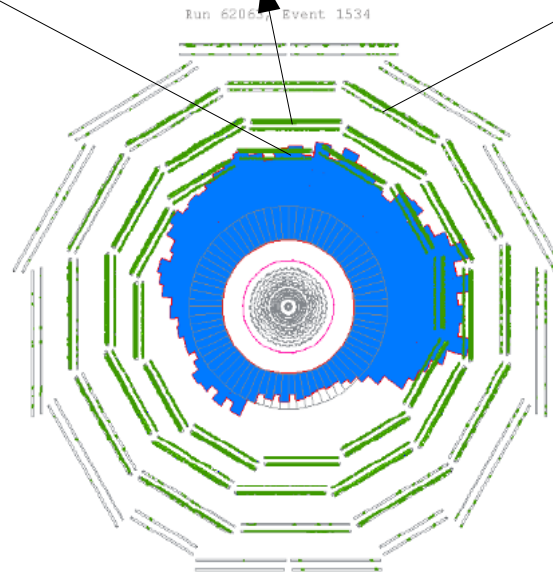
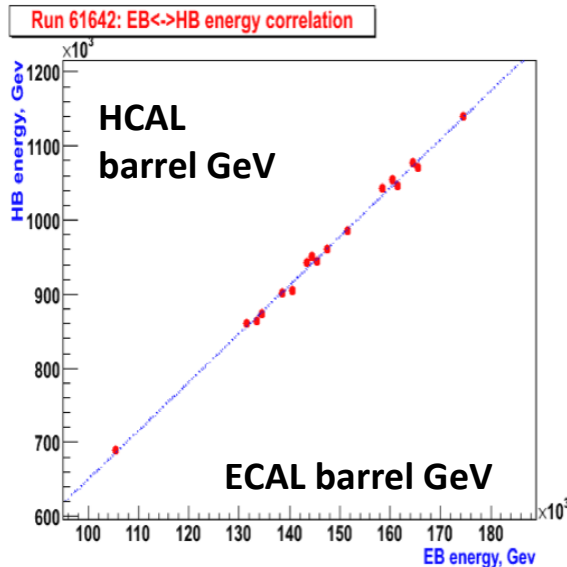
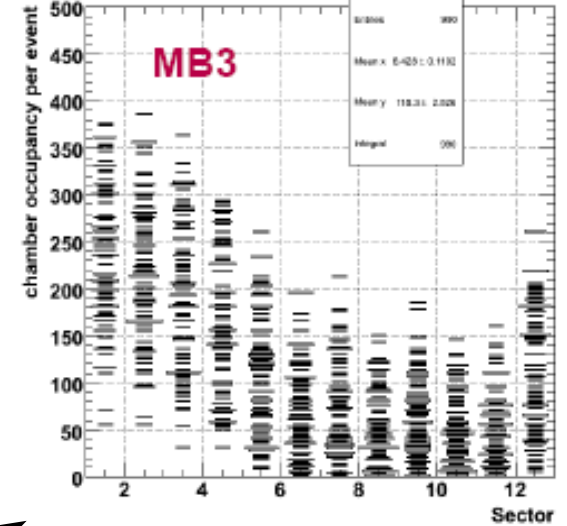
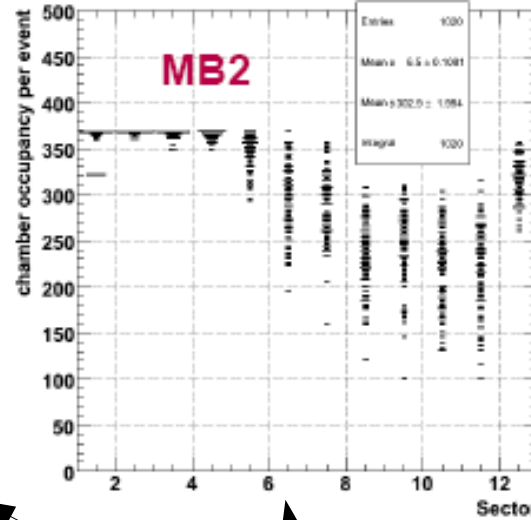
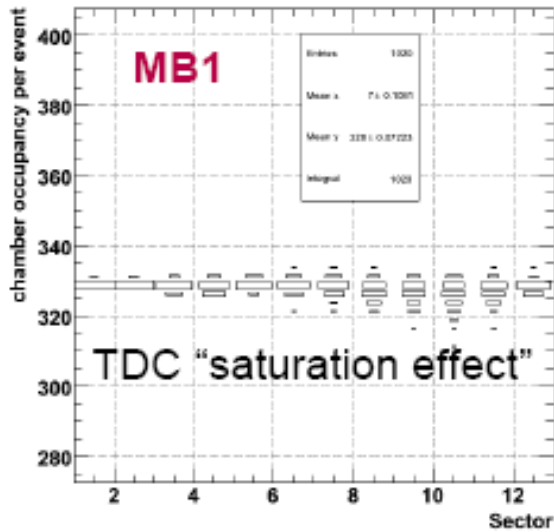
beam captured



(close to 1 million beam halo muons recorded)

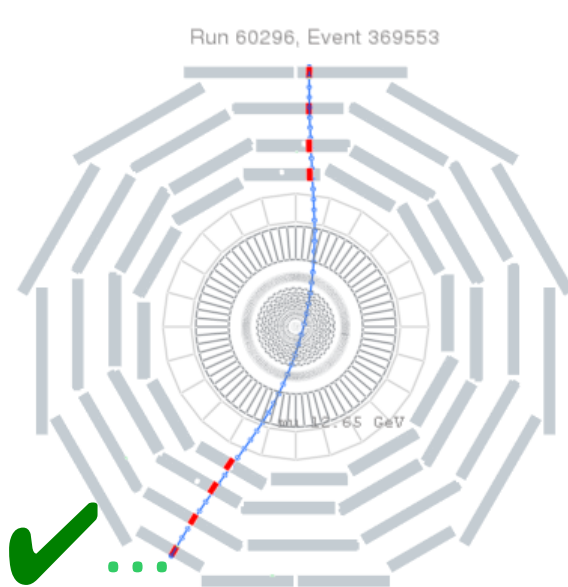


# 17 Beam “Splash” Events (Sept 7)



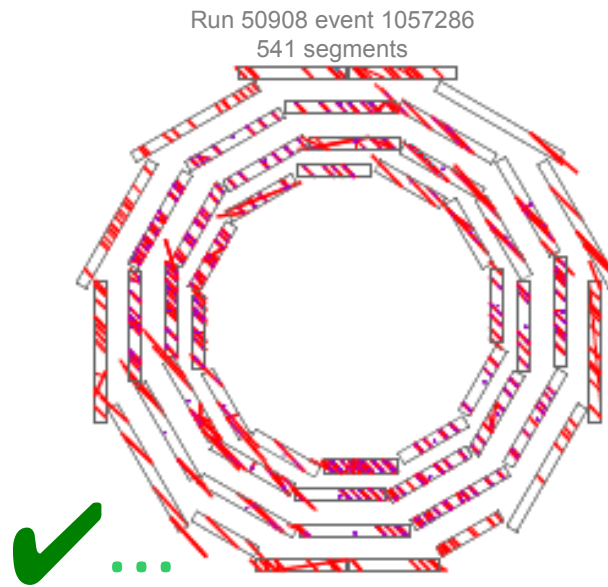
# Muon multiplicity

Analyzed events spanning 5 orders of magnitude in muon multiplicity !  
illustrates versatility and robustness of detector and software



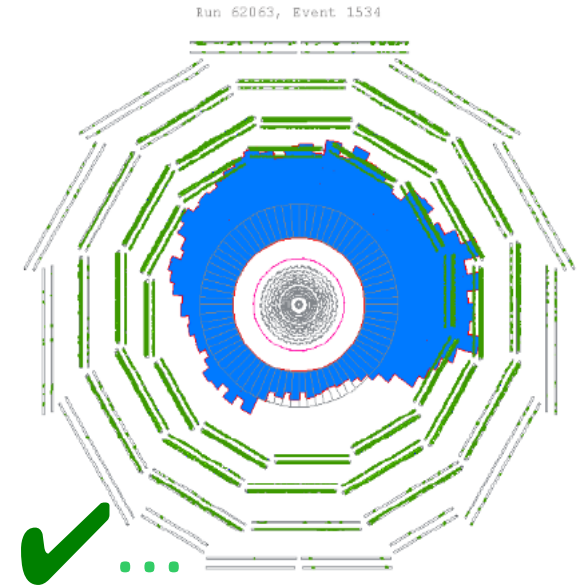
Cosmic / Beam Halo  
 $O(1)$  muon

Analysis using: **tracks**  
**cosmic charge ratio**



Cosmic Shower  
 $O(10-100)$  muons

... **segments**  
**shower origin**



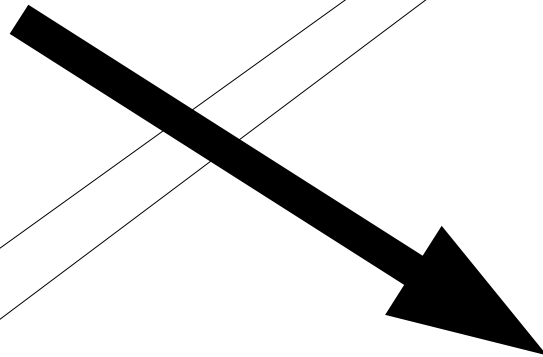
Beam "splash" event  
 $O(10^5)$  muons

... **hits**  
**shower energy and shape**



# Plans for First collisions

REAL DATA

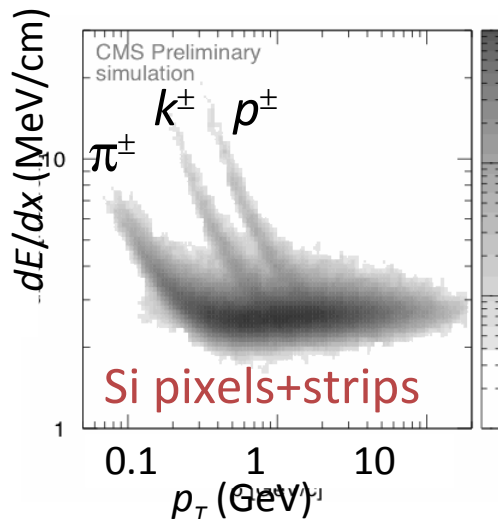


MC SIMULATION

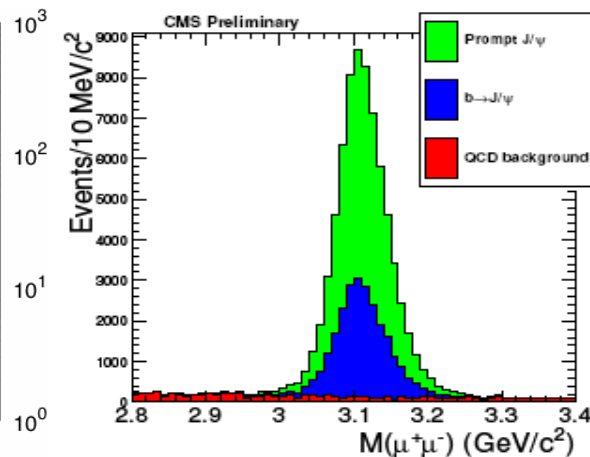
# First Physics with pp collisions

- Highest priority with the very first pp data:
  - In addition to muons, understand reconstruction performance of other **physics objects**: electrons, photons, jets ... b-tagging, taus, missing transverse energy (MET)
- First physics measurements possible with a few  $\text{pb}^{-1}$  and start-up alignment and calibration:

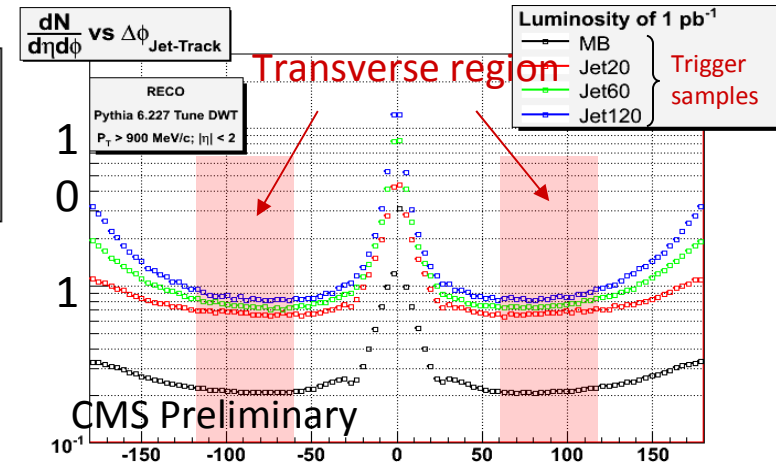
## Hadron spectra



## low mass resonances



## underlying event (MC tuning)



$$< 10 \text{ pb}^{-1}$$

Very first CMS physics analyses to be performed. See talks by:

- Ferenc Sikler, Pedrame Bargassa, Nhan Viet Tran, Olga Kodolova, and others...

CMS Public Analysis Summaries are linked from here:

<https://twiki.cern.ch/twiki/bin/view/CMS/PhysicsResults>

Measurement of charged hadron spectra  
Measurement of the Underlying Event  
Zero bias and HF-based minimum bias triggering  
Charmonium production cross section  
...

# 10 pb<sup>-1</sup>

Re-discover standard model candles [W, Z, and Top](#), and measure their cross-section at 10-14 TeV. Use them to pin down lepton, jet , MET performance. See talks by:

- Didar Dobur, Georgios Daskalakis, Frank-Peter Schilling, Brigitte Epp, and others...

<https://twiki.cern.ch/twiki/bin/view/CMS/PhysicsResults>

Plans for Jet energy corrections

b-tagging efficiency using system8 & P<sub>T</sub>rel method

measuring uds mis-tag rate of b-tag with negative tags

measuring electron efficiencies with early data

W/Z cross-section with electrons

W/Z cross-section with muons

Hadronic Event Shapes at CMS

Di-lepton ttbar with 10/pb

Semi-leptonic (muon) ttbar

Search for New Physics using high ET di-jet events

# 100 pb<sup>-1</sup> and beyond

Understand Standard Model in detail. Refine data-driven techniques to estimate backgrounds. Tune MC simulation...

Search for **new physics**! See talks by:

- Carsten Hof, Krzysztof Nawrocki, Monica Vazquez Acosta, Stephanie Baffioni, Vuko Brigljevic, Lucia di Ciaccio, Monika Grothe, Alexandre Nikitenko, and others...

<https://twiki.cern.ch/twiki/bin/view/CMS/PhysicsResults>

Observation of WZ production	Search for $Z' \rightarrow ee$
Measurement of Zbb production	Search for $Z' \rightarrow \mu\mu$
Di-lepton ttbar with 100/pb	Search for $W' \rightarrow e\nu$
Di-lepton ttbar tau channel	Search for heavy stable charge particles
Jet Energy Scale from Top events	Susy: di-lepton+jets+MET: $x_2 \rightarrow x_1 l l$
Exclusive di-lepton production	Susy: data-driven estimate of invisible Z bckgr.
Single diffractive W production	Higgs to WW
Analysis of photon-jet evts in pb-pb	qqH with $H \rightarrow \tau\tau$



# Conclusion

- After many years of hard work the CMS detector, software and computing are **ready for data taking**
- Wide range of **different types of events** thrown at CMS by Nature and by the LHC beam so far have been recorded and reconstructed elegantly and efficiently!
- **Physics analyses** have been prepared for early data
- Eagerly anticipating pp collisions

**Don't miss this talk next year at “Physics at the LHC – 2009” !**