

# Status of the CMS Experiment

Lea Caminada  
ETH | PSI

CHIPP Annual Meeting  
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ETH Institute for  
Particle Physics



# Outline

- Swiss Institutes in CMS
- Detector status
- Results from Cosmic Running 2008  
(focusing on Pixel and ECAL)
- Status of Cosmic Running 09
- Analysis activities
- Preparation for LHC Upgrade
- Conclusions

# Swiss Institutes in CMS

## ETH Zürich

G. Dissertori, C. Grab, F. Pauss,  
B. Betev, Ch. Casella,  
S. Cittolin, M. Dittmar,  
A. Herve, D. Luckey,  
W. Lustermann, F. Moortgat,  
F. Nessi-Tedaldi, L. Pape,  
A. Rizzi, F. Ronga, A. Sala (from Sept), M.-C. Sawley,  
V. Sordini, A. Thea,  
K. Theofilatos, D. Treille,  
J. Weng  
L. Caminada (PSI, ETH),  
Z. Chen, J. Eugster, W. Hintz,  
C. Marchica (PSI, ETH),  
P. Milenovic, P. Nef, T. Punz,  
A.-K. Sanchez, B. Stieger,  
M. Weber, L. Wehrli,  
D. Da Silva Calafiori,  
L. Djambazov, M. Dröge,  
G. Faber, H. P. von Gunten,  
U. Horisberger, C. Haller,  
W. Kästli, G. Leshev, U. Röser,  
S. Zelepoukine

## PSI

R. Horisberger, Q. Ingram,  
W. Bertl, K. Deiters,  
W. Erdmann,  
D. Feichtinger,  
H.-C. Kästli, D. Kotlinski,  
U. Langenegger,  
D. Renker, T. Rohe,  
A. Starodumov,  
F. Meier, J. Sibille (PSI, KU),  
B. Meier, S. Streuli

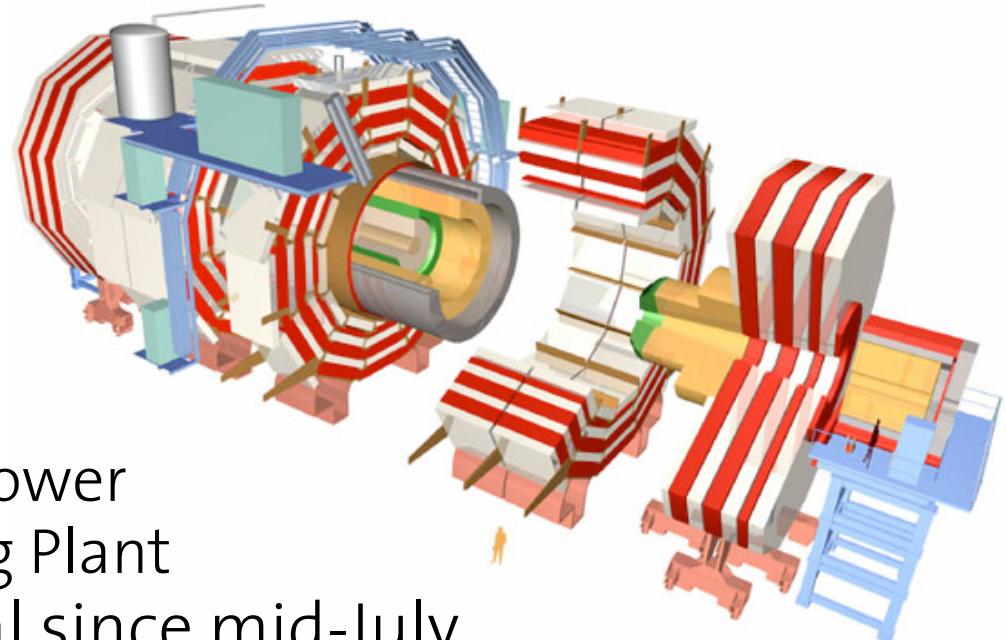
## University of Zürich

C. Amsler, V. Chiochia,  
E. Aguilo, C. Regenfus,  
P. Robmann, A. Schmidt,  
H. Snoek,  
E. Alagöz (PSI, UZH),  
M. Ivoa Rikova,  
A. Jaeger,  
B. Millan Mejias,  
T. Rommerskirchen,  
D. Tsirigkas,  
L. Wilke (PSI, UZH),  
J. Rochet, S. Steiner

77 total  
41 Physicists  
21 PhD students  
15 Techn./Eng.

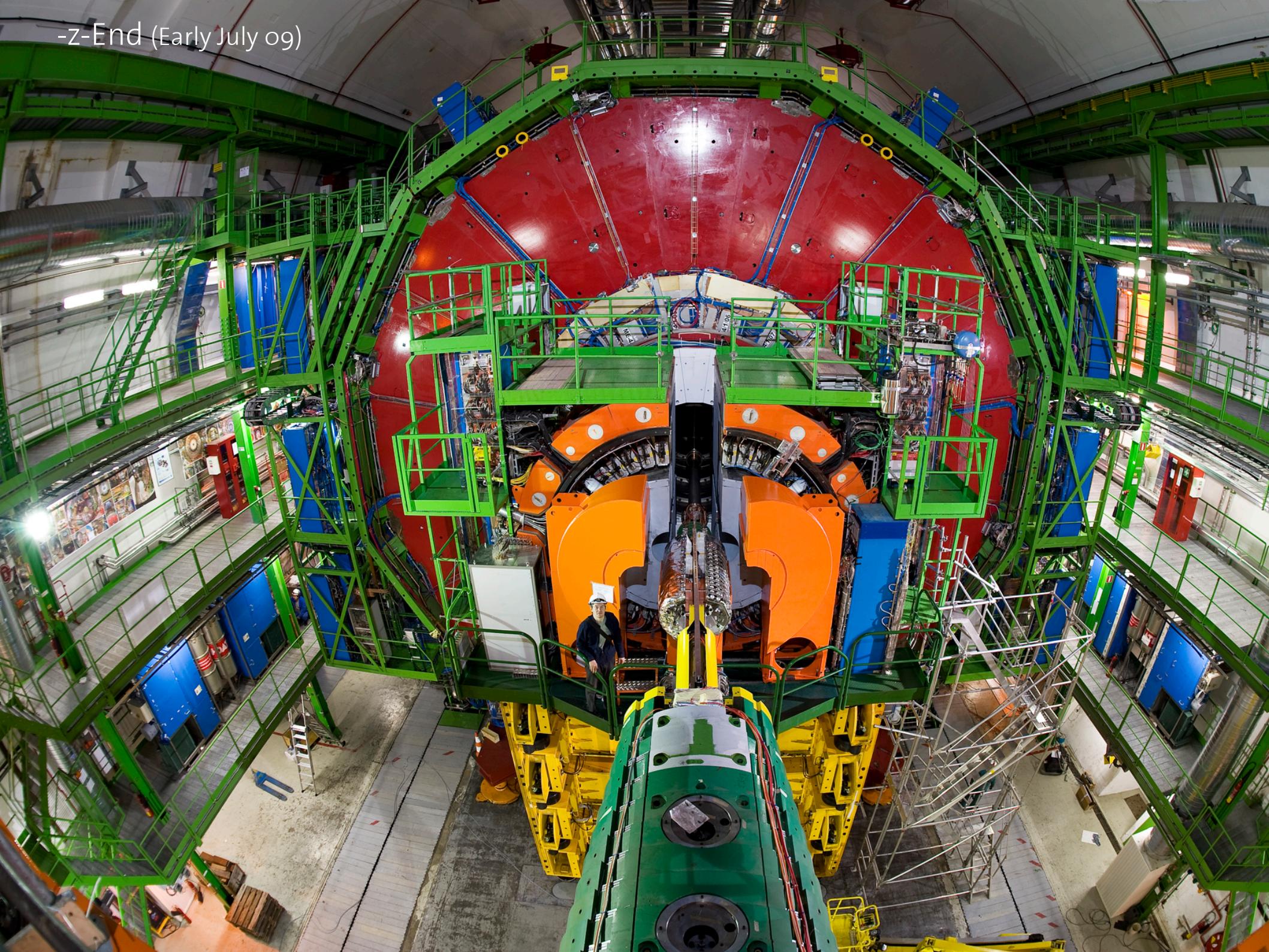
# Detector Status

- First closure in 2008
- Maintenances in 2009
  - Repair of FPIX
  - Installation of ECAL Preshower
  - Revision of Tracker Cooling Plant
- CMS closed and operational since mid-July



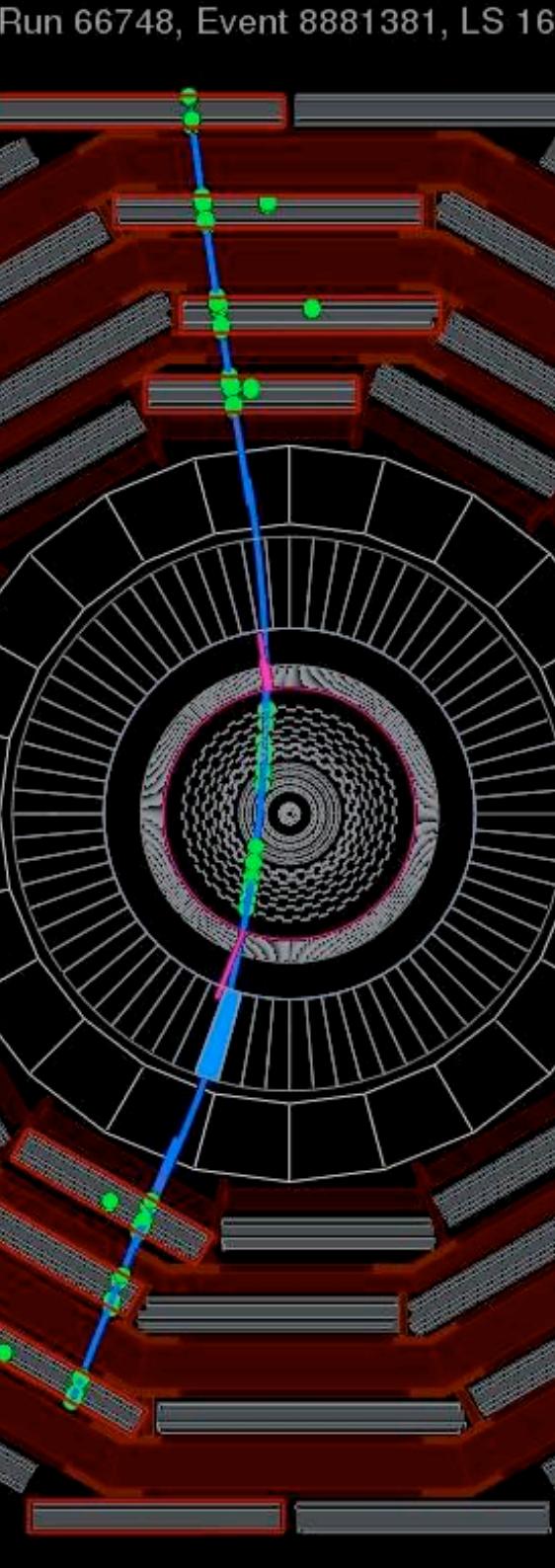
| Sub-detector                       | No. of channels        | Working (%) |
|------------------------------------|------------------------|-------------|
| Pixels                             | $66 \times 10^6$       | 98.6        |
| Silicon strip detector             | $9.3 \times 10^6$      | 98.3        |
| ECAL PbWO <sub>4</sub> calorimeter | $7.58 \times 10^5$     | 99.5        |
| ECAL ES                            | $1.37 \times 10^5$     | 99.95       |
| HCAL HB (HO) calorimeter           | 2592 (2160)            | 100 (99.1)  |
| HCAL HE (HF) calorimeter           | 2592 (1728)            | 100 (100)   |
| Muon DTs                           | $1.55 \times 10^5$     | 99.6        |
| Muon CSC (CFEB)                    | $2.18 \times 10^5$     | 99.3        |
| Muon RPC RB (RE)                   | $8.3(4.1) \times 10^4$ | 99.7 (99.5) |

-z-End (Early July 09)



# Cosmic Data in 2008

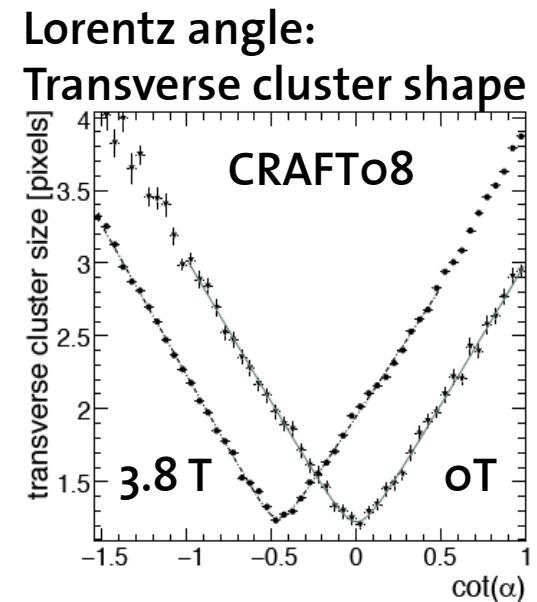
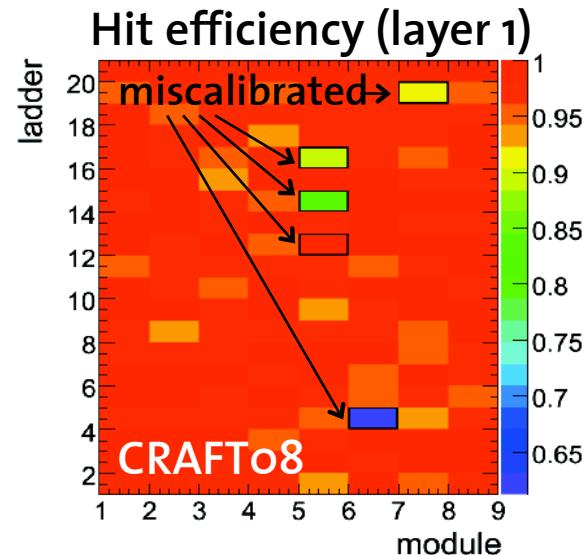
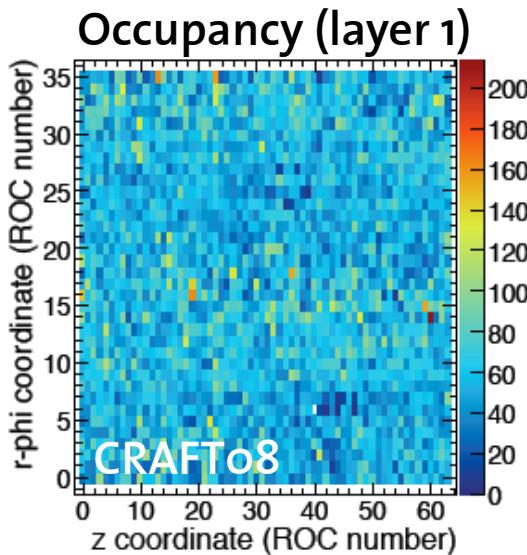
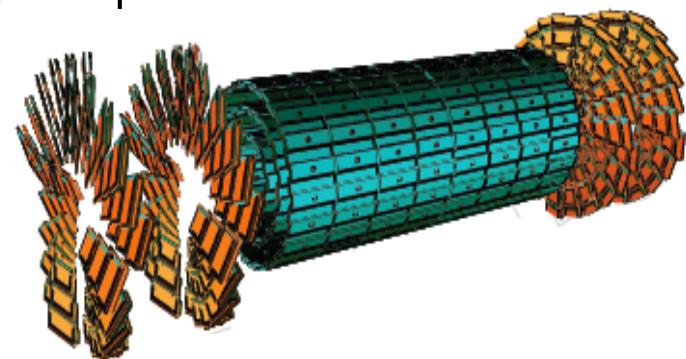
- CRUZET (0 T) and CRAFT (3.8 T)
- September-November 2008
- 300 M events at 3.8 T
  - Triggered by muon detector and calorimeter
  - 4 M tracks
  - 85 000 tracks in pixel detector
- Goals:
  - Commissioning
  - Calibration
  - Alignment
  - Testing of DAQ
  - Demonstrate readiness for data taking



# Performance of the Pixel Detector

ETH, PSI, UNIZH

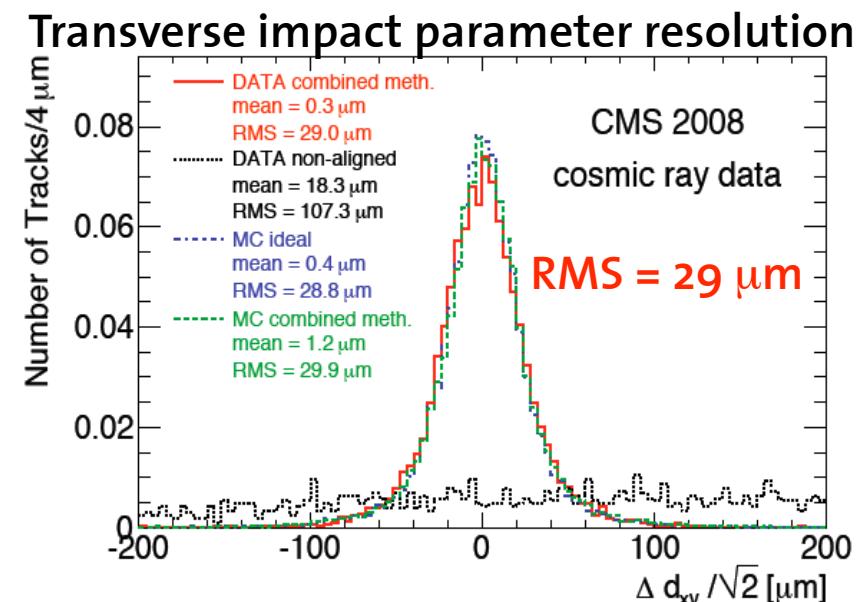
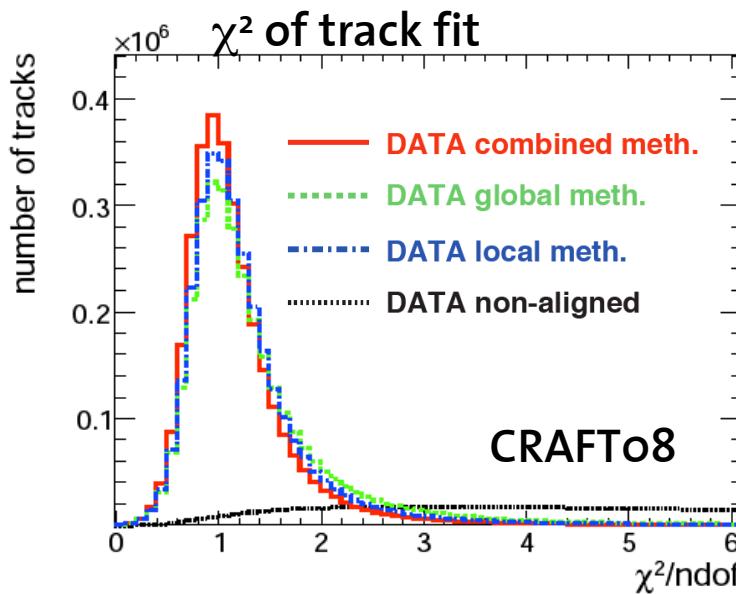
- Barrel Pixel Detector installed in July 2008
- Large effort in commissioning and calibration
  - ~700 modules, 48 M channels , > 99% operational
  - Analog readout
    - 3690 e<sup>-</sup> threshold/ 141 e<sup>-</sup> noise
    - Gain calibration
  - Hit efficiency 96-97%
  - Lorentz angle calibration



# Tracker Alignment

PSI, UNIZH

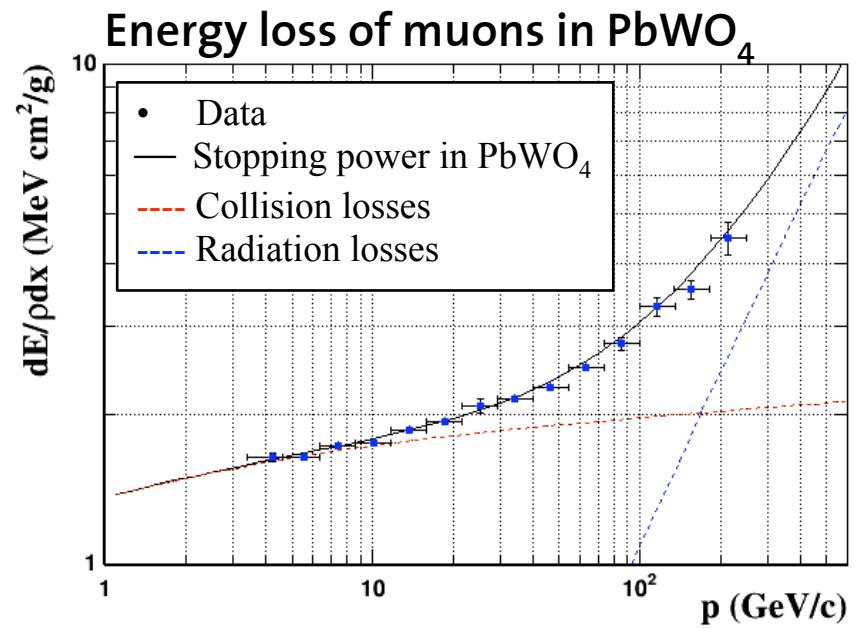
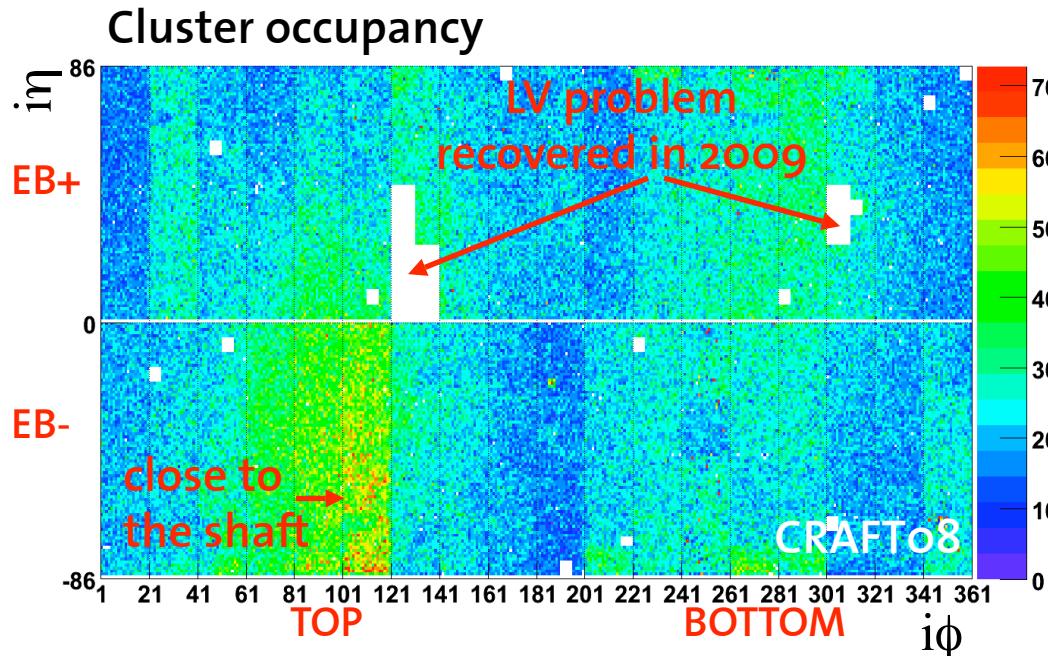
- 1440 pixel modules, 15 140 strip modules
  - Module mounting precision  $\sim 100 \mu\text{m}$
  - Optimum resolution  $15 \mu\text{m}$
- 2 complementary alignment algorithms ( $\chi^2$  fits)
  - Strategy: align large structures, then modules
  - Millepede II: global approach, uses correlation
  - HIP: local iterative approach
- Significant improvement of track parameter resolution



# Performance of the ECAL in CRAFTo8

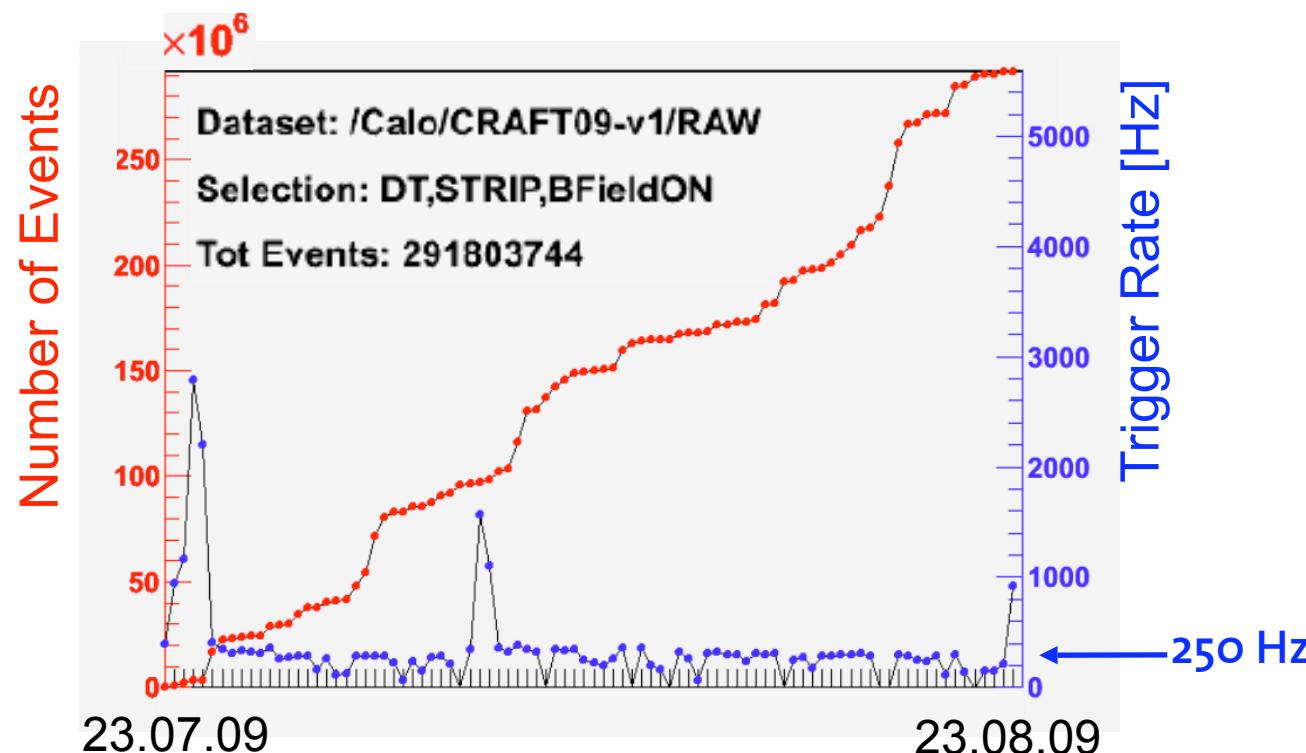
ETH, PSI

- 75 800  $\text{PbWO}_4$  crystals
- 98.3% (EB) and 99.66% (EC) operational
- ECAL shows good performance and ability to maintain stable conditions (temperature, HV, electronic noise)
- Measurement of stopping power
  - Muon momentum (tracker), energy loss (deposition in cluster) and track length in ECAL



# CRAFT 09

- July - September 2009
- Test again capability for sustained operation at an efficiency higher than in CRAFT 08
- Substantial number of Cosmic tracks already taken
- Analysis ongoing, first results expected soon



# Analysis Activities

## Physics Channels

- B Physics (ETH, PSI, UNIZH)
  - $b$  production
  - $bb$  correlations
  - B decays ( $B_s \rightarrow \mu\mu$ ,  $B_s \rightarrow J/\psi\phi$ ,  $\Lambda_b^0 \rightarrow J/\psi\Lambda^0$ ,  $B_c \rightarrow J/\psi\pi\pi\pi$ )
- QCD (ETH)
  - Hadronic event shapes
- Electroweak (ETH)
  - $Z \rightarrow \mu\mu/ee$ ,  $W \rightarrow \mu\nu_\mu/e\nu_e$
- Higgs Physics (ETH, PSI, UNIZH)
  - $H \rightarrow WW$
  - $H \rightarrow \tau\tau$

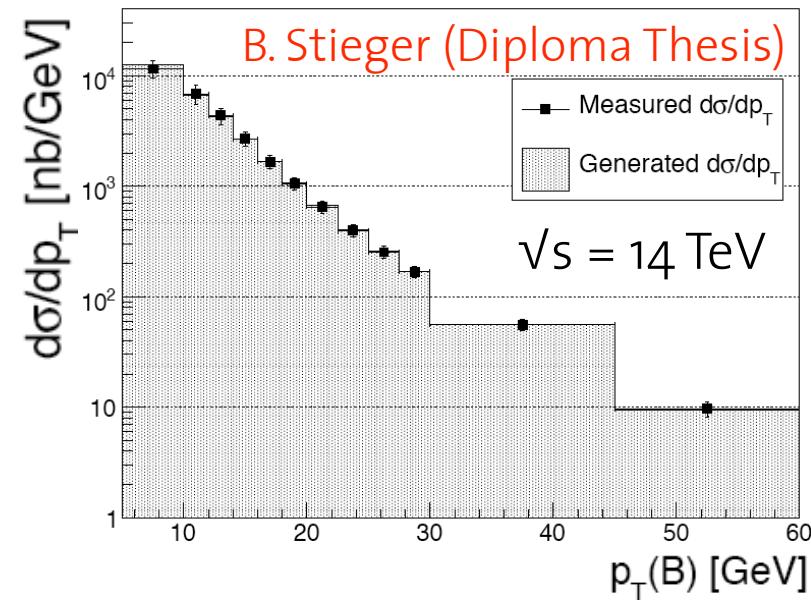
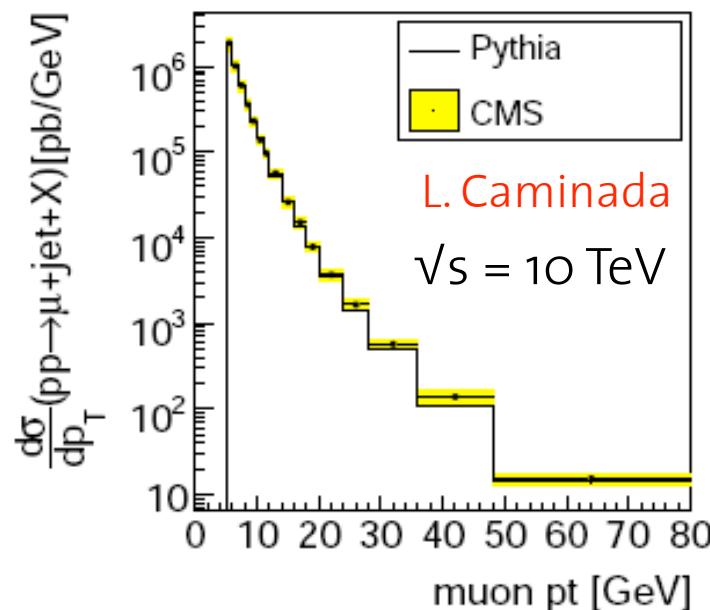
- SUSY (ETH, UNIZH)
  - Di-lepton, di-jet events
- Exotica (ETH)
  - Heavy stable charged particles

## Physics Objects

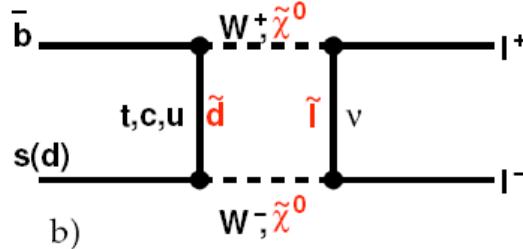
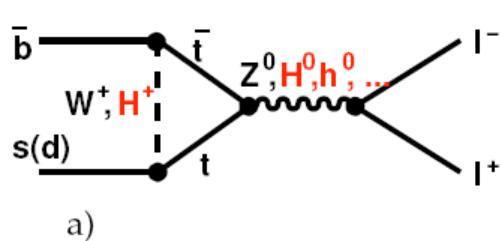
- Egamma (ETH)
- JetMET (ETH)
- Tracking (ETH, PSI, UNIZH)
- Vertex Reconstruction (PSI)
- b tagging (ETH, UNIZH)

# b Quark Production

- Large b quark production cross section at LHC
- Measurement ideally suited for start-up
- Events with muons in the decay (trigger)
- 2 analyses proposed ( $\mathcal{L} < 1 \text{ pb}^{-1}$ )
  - Inclusive b production using muon and jets ( $p_{\text{T,rel}}$ )
  - $b \rightarrow \mu D^0 X$  (reconstruction of  $D^0$  mass)
- Systematic uncertainty: 10-20%

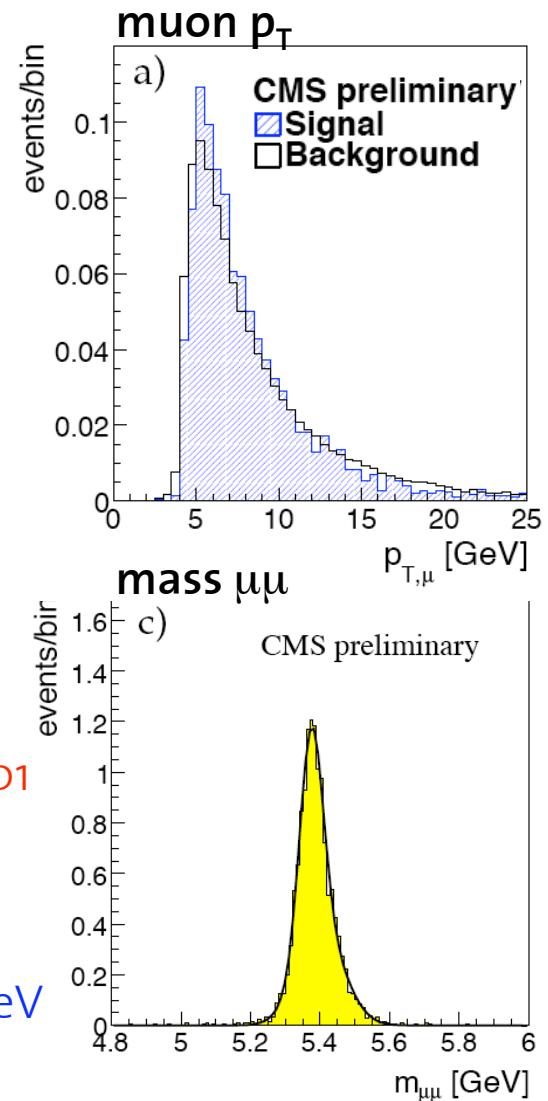


$$B_s^0 \rightarrow \mu^+ \mu^-$$



- Highly suppressed in SM
  - $\mathcal{B}_{SM} = (3.86 \pm 0.15) \cdot 10^{-9}$
- Sensitive to New Physics
- Current limit from CDF  $\mathcal{B}^{95\%} < 5.8 \cdot 10^{-8}$
- Event Selection:
  - 2 isolated muons
  - secondary vertex
  - $m_B \pm 100$  MeV
- Result:
  - $n_B = 6.53$  with  $\mathcal{L} = 1 \text{ fb}^{-1}$  at  $\sqrt{s}=14 \text{ TeV}$
  - $\mathcal{B}^{90\%} < 1.6 \cdot 10^{-8}$  or (estimate):  $\mathcal{L} = 1.5 \text{ fb}^{-1}$  at  $\sqrt{s}=7 \text{ TeV}$

C. Eggel,  
U. Langenegger,  
A. Starodumov  
CMS PAS BPH-07-001



# Hadronic Event Shapes

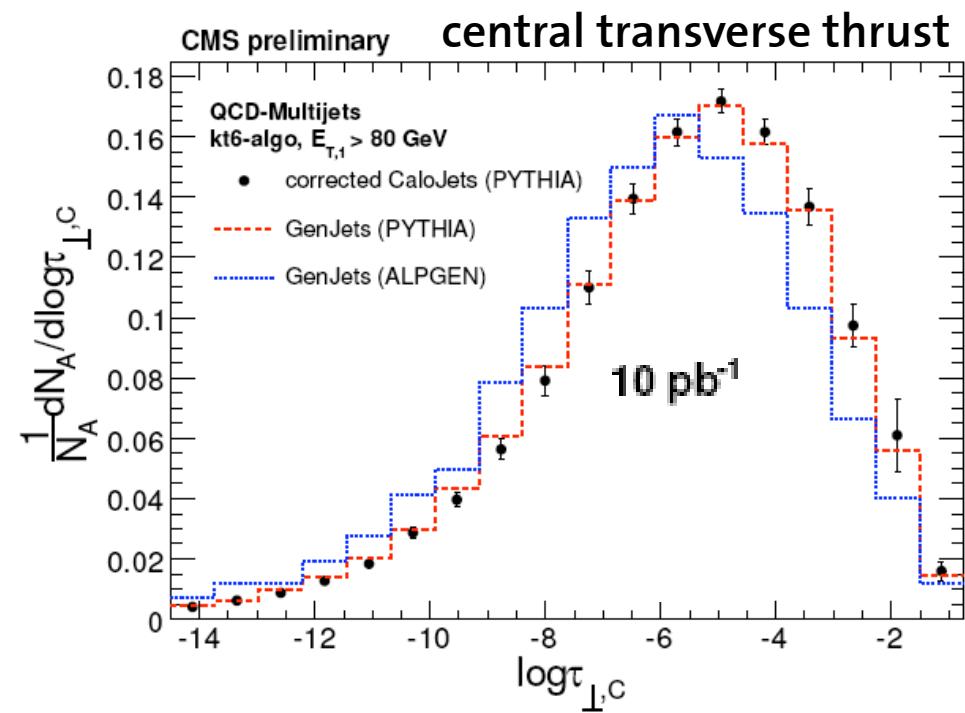
- Event shapes used to study QCD dynamics
- Robust under variations of jet clustering algorithm, jet energy scale and jet resolution
- Allow to distinguish between different MC predictions

Transverse Thrust  $T_{\perp}$

$$T_{\perp,g} \equiv \max_{\vec{n}_T} \frac{\sum_i |\vec{p}_{\perp,i} \cdot \vec{n}_T|}{\sum_i p_{\perp,i}}$$

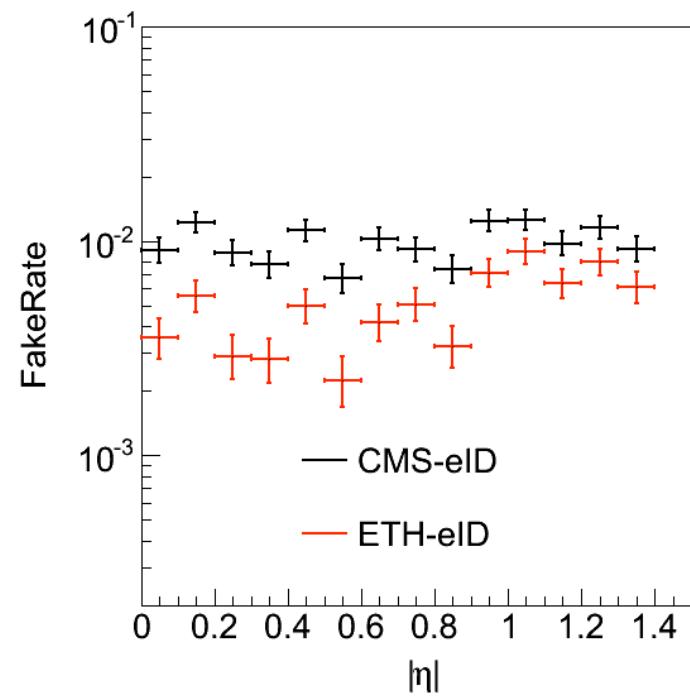
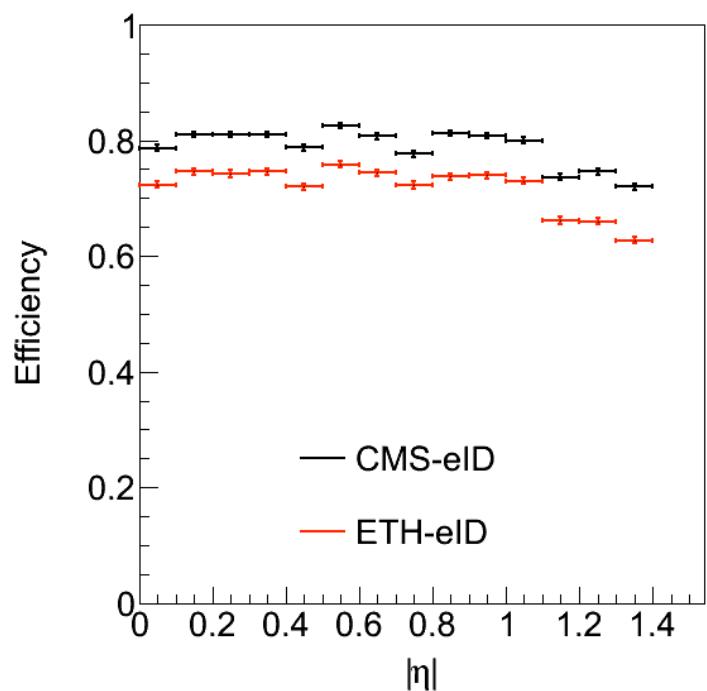
$$\tau_{\perp,g} \equiv 1 - T_{\perp,g}$$

G. Dissertori,  
F. Moortgat, M. Weber  
CMS PAS QCD-08-003



# Electron Identification

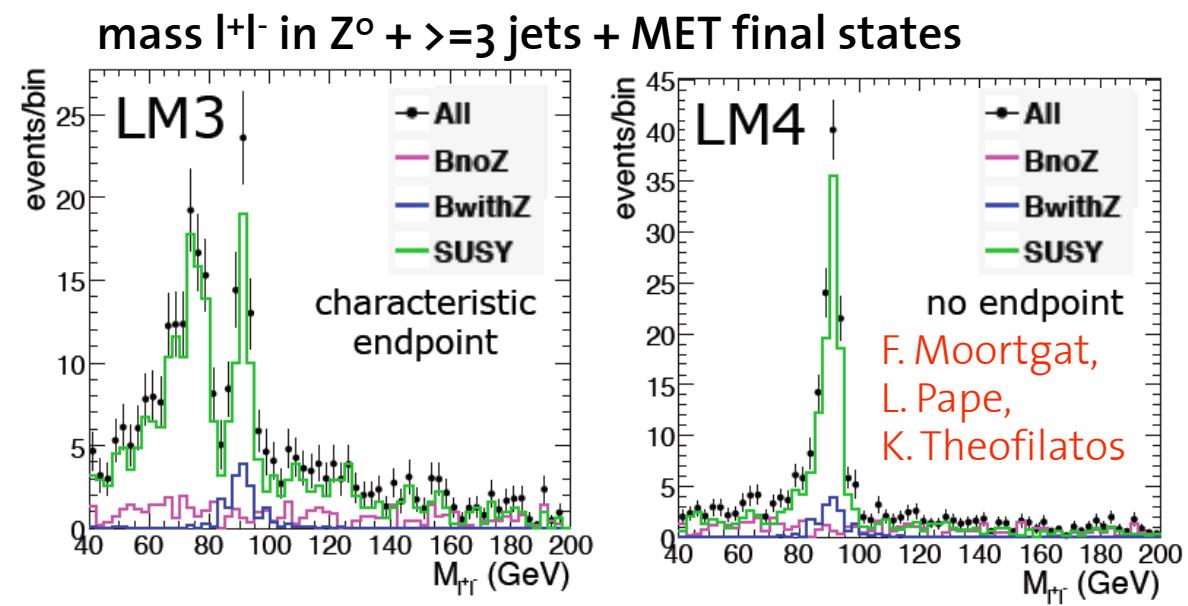
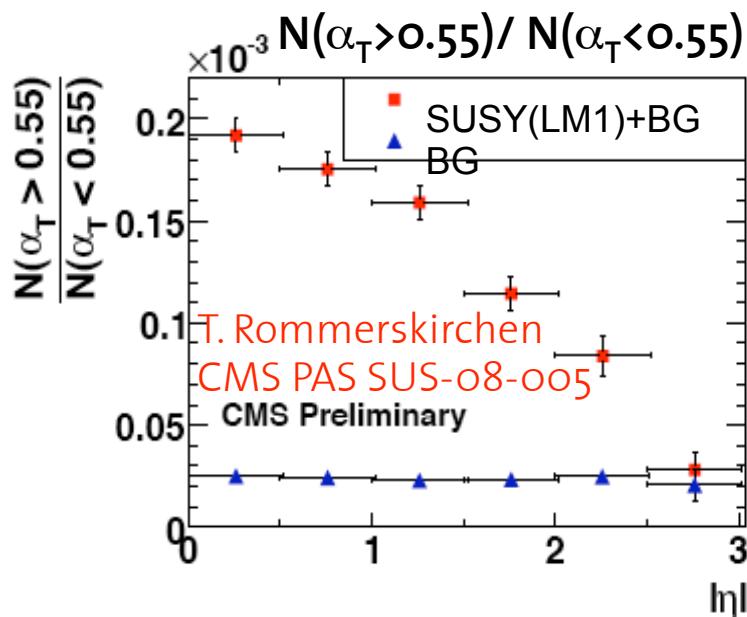
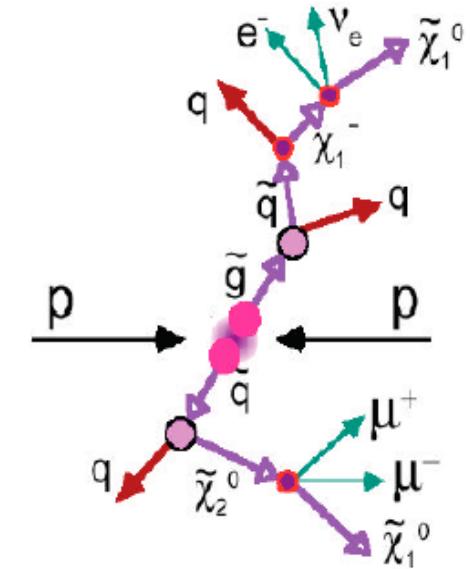
- Developed electron identification optimized for  $W \rightarrow e\nu$  to achieve minimum fake rate
- $Z \rightarrow ee$  events to determine efficiency from data
- Measurement of the  $W/Z$  ratio
- Determination of the integrated luminosity and its uncertainty



C. Marchica,  
W. Hintz,  
M. Dittmar

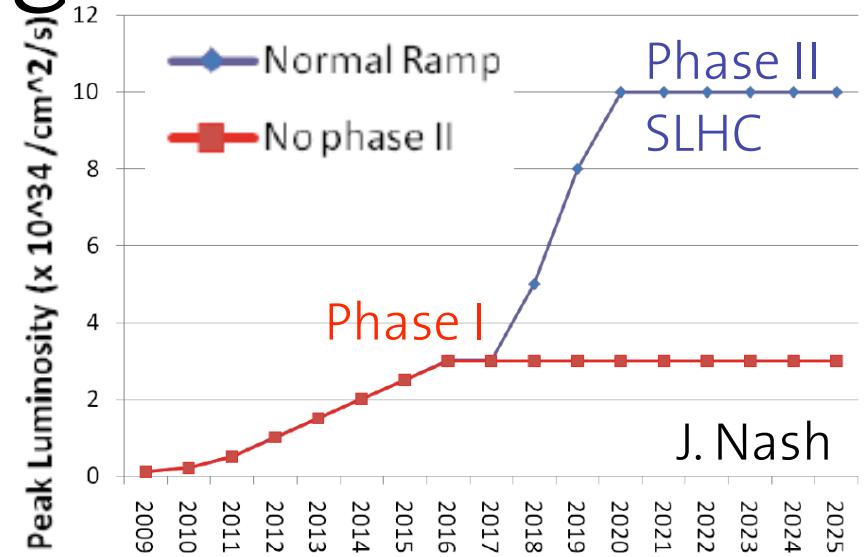
# SUSY searches

- R-parity conserving SUSY  $\Rightarrow$  existence of LSP
- Signature: jets + MET (+ leptons)
- Inclusive final states:
  - di-jet events (without cut on MET)
  - new discriminating variables  $\alpha_T = E_T^{j2} / M_{\text{inv}}^{j1,j2}$
- Exclusive final states:
  - SS/OS di-lepton signatures
  - Development of data-driven methods to control background

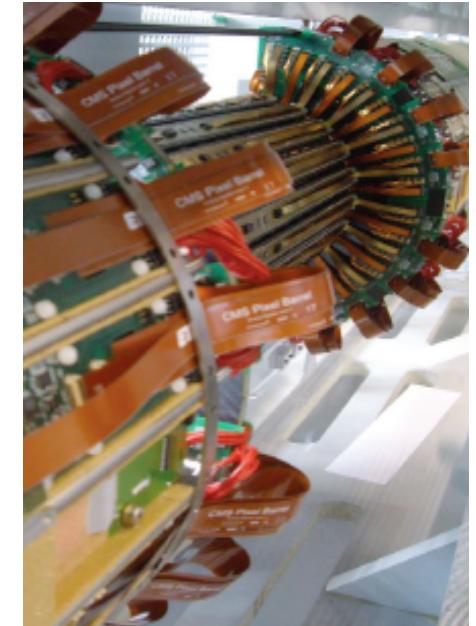


# Pixel Detector Upgrade (Phase I)

- Upgrade for increased LHC luminosity
- Proposed Pixel Upgrade:
  - Increase number of tracking points  
→ 4 layers + 3 discs
  - Reduce material significantly  
→ CO<sub>2</sub> cooled mechanics
  - move material out of tracking region
  - 320 MHz digital readout
- Constraints
  - Use existing power cables and optical fibers
  - No change to core of pixel readout chip

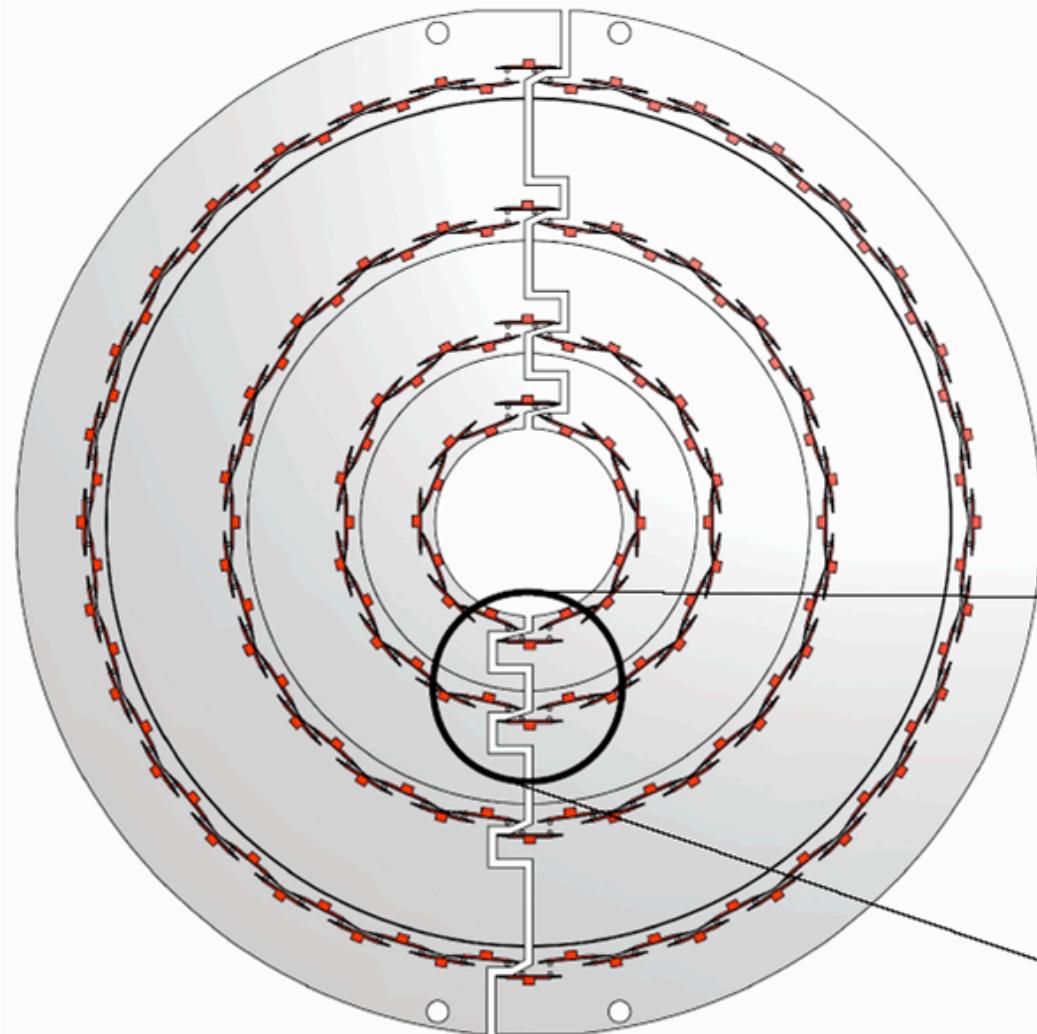


J. Nash

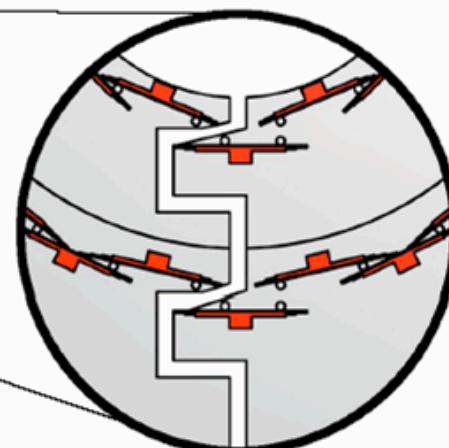


# Pixel Detector Upgrade (Phase I)

- 1216 modules ( $\times 1.6$  of present BPIX)
- $X/X_0$  reduced by 30% for layer 1



- Two identical half shells
- 1 type of fullmodule only
- Layer 1: R 39mm; 16 faces
- Layer 2: R 68mm; 28 faces
- Layer 3: R 109mm: 44 faces
- Layer 4: R 160mm: 64 faces
- Clearance to beampipe 4mm



Prototype  
of layer 1



# Conclusions

- CMS detector is ready for data taking
- Successful commissioning, calibration, alignment and cosmic running in 2008
- CRAFT09 ongoing
- Strong contribution of Swiss groups to detector commissioning and to many different analysis topics
- Preparation for LHC luminosity increase started with the upgrade project of the pixel detector

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