Recent Results from CMS

A. Gresele
On behalf of the CMS Collaboration

University of Trento - INFN Padova and Trento

ISVHECRI: The XVI International Symposium on Very High Energy Cosmic Ray Interactions
28th June 2010

Outline

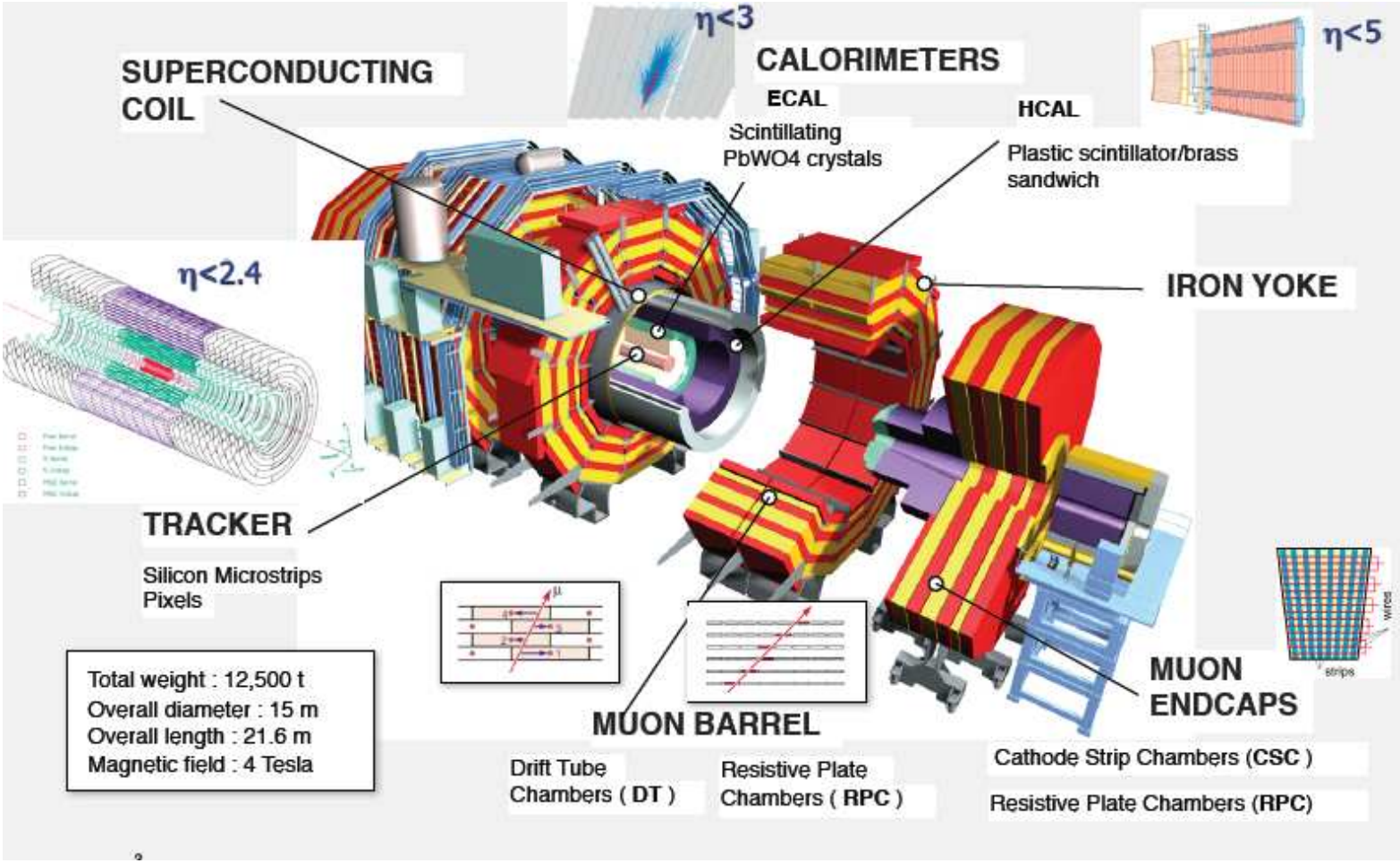
1 The CMS Detector

2 Performance Results

3 Physics Results

4 Conclusions

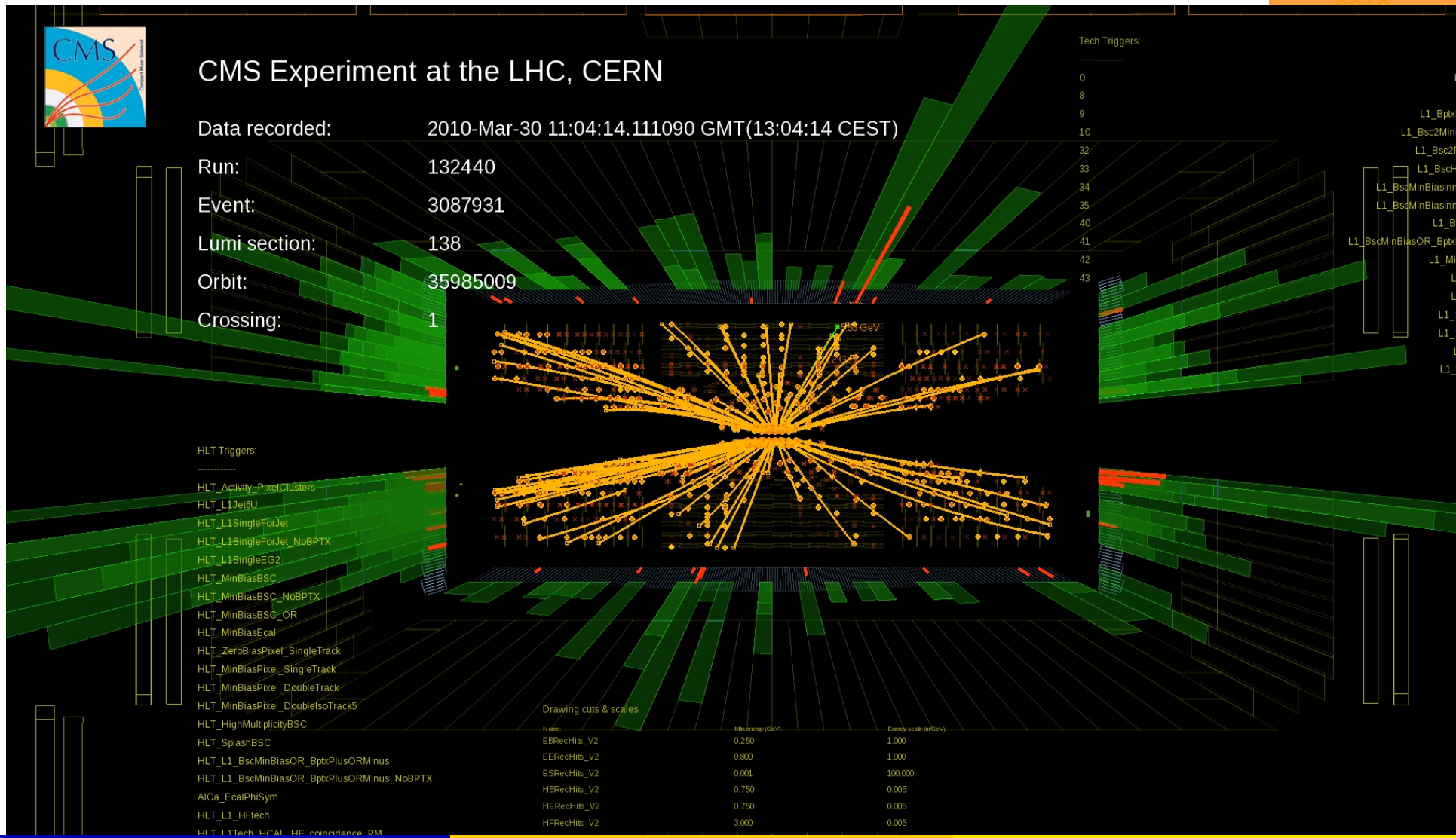
CompactMuonSolenoid



CMS timeline and energies

- 0.9 TeV
  - 23rd of November 2009, FIRST COLLISIONS!
  - 6th of December, First physics fills
- 2.36 TeV
  - 14th of December 2009, FIRST COLLISIONS!
  - About 20000 events collected
- 7 TeV
  - 30th of March 2010, FIRST COLLISIONS!

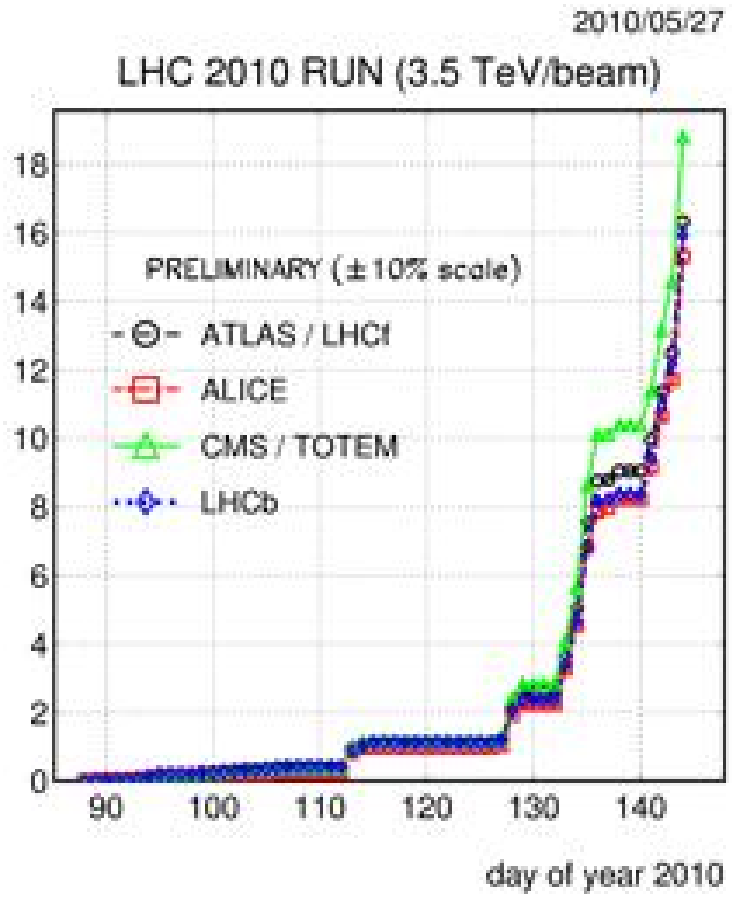
Multi-jet event @7TeV!

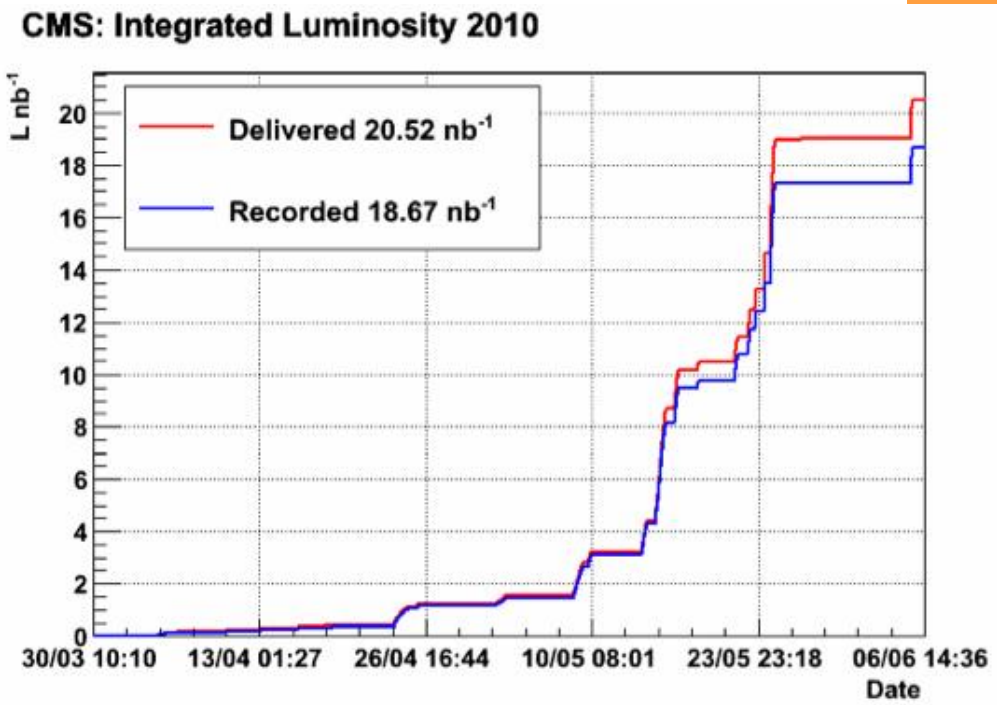


Integrated Luminosity

$\sim 21 nb^{-1}$ delivered by LHC and $\sim 19 nb^{-1}$ collected by CMS

- **91%** overall data taking efficiency
- **90%** after quality flags and data certification for physics

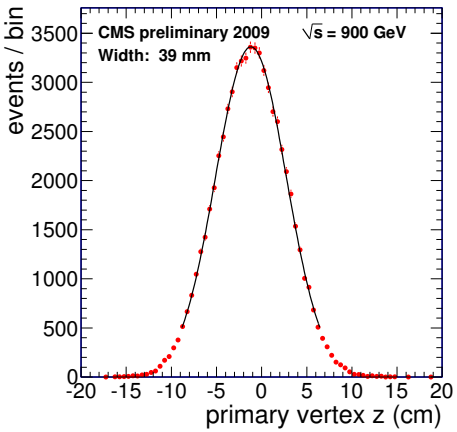


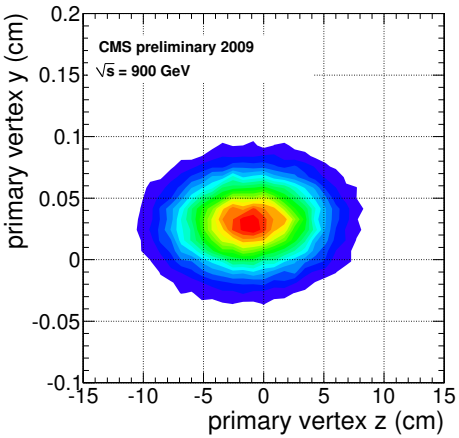


Performances

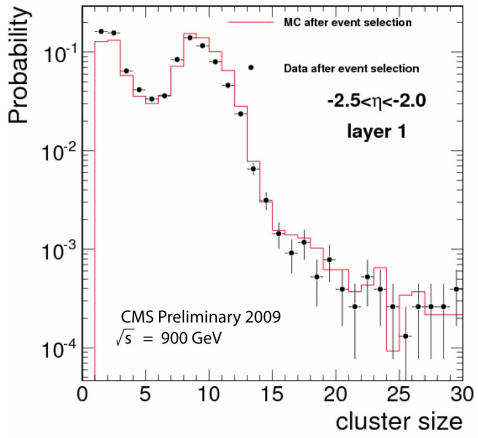
Primary Vertex, Pixel Clusters and Strip Trackers identification

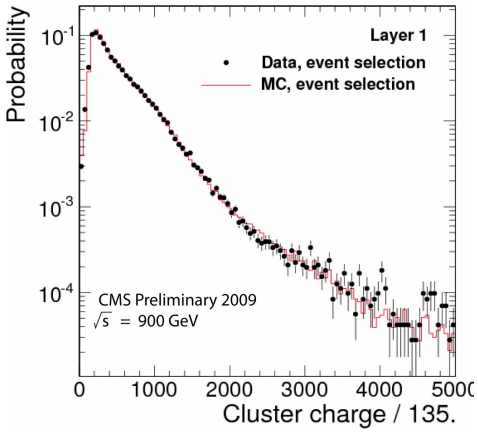
Primary Vertex



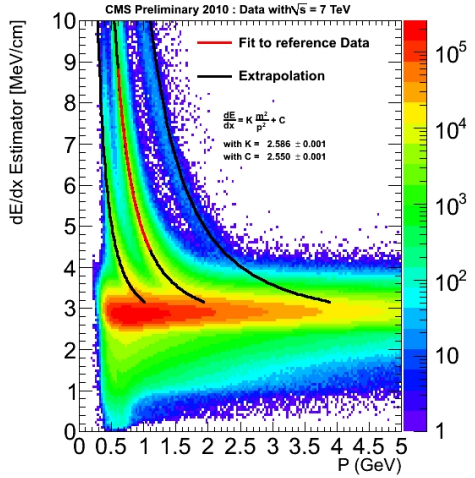


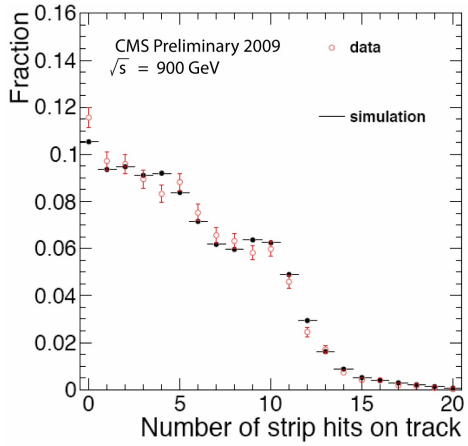
Pixel Clusters



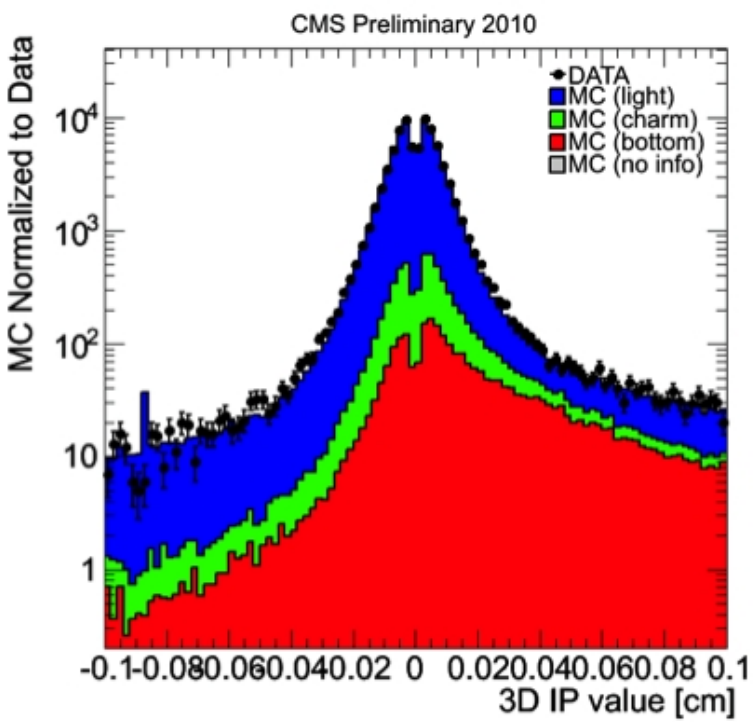


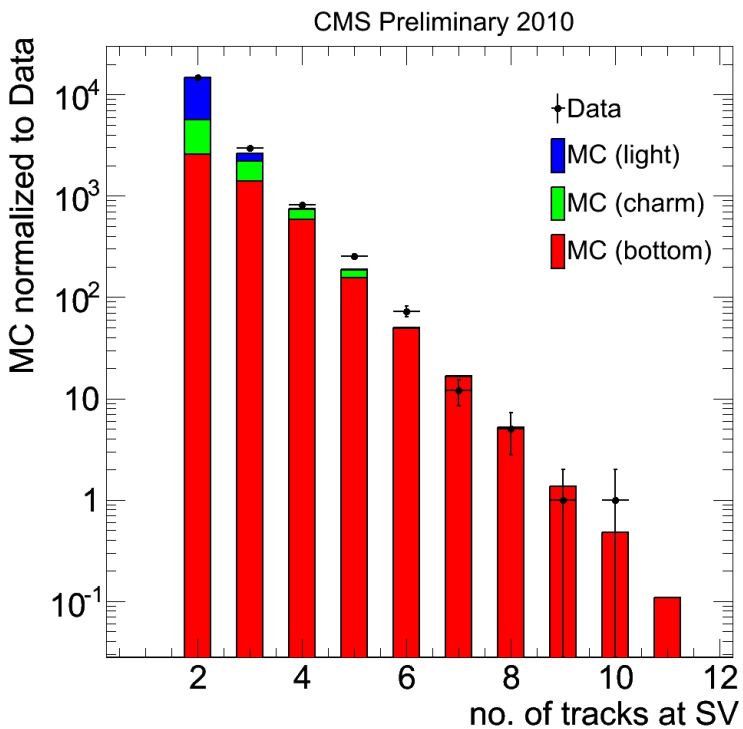
Strip Tracker





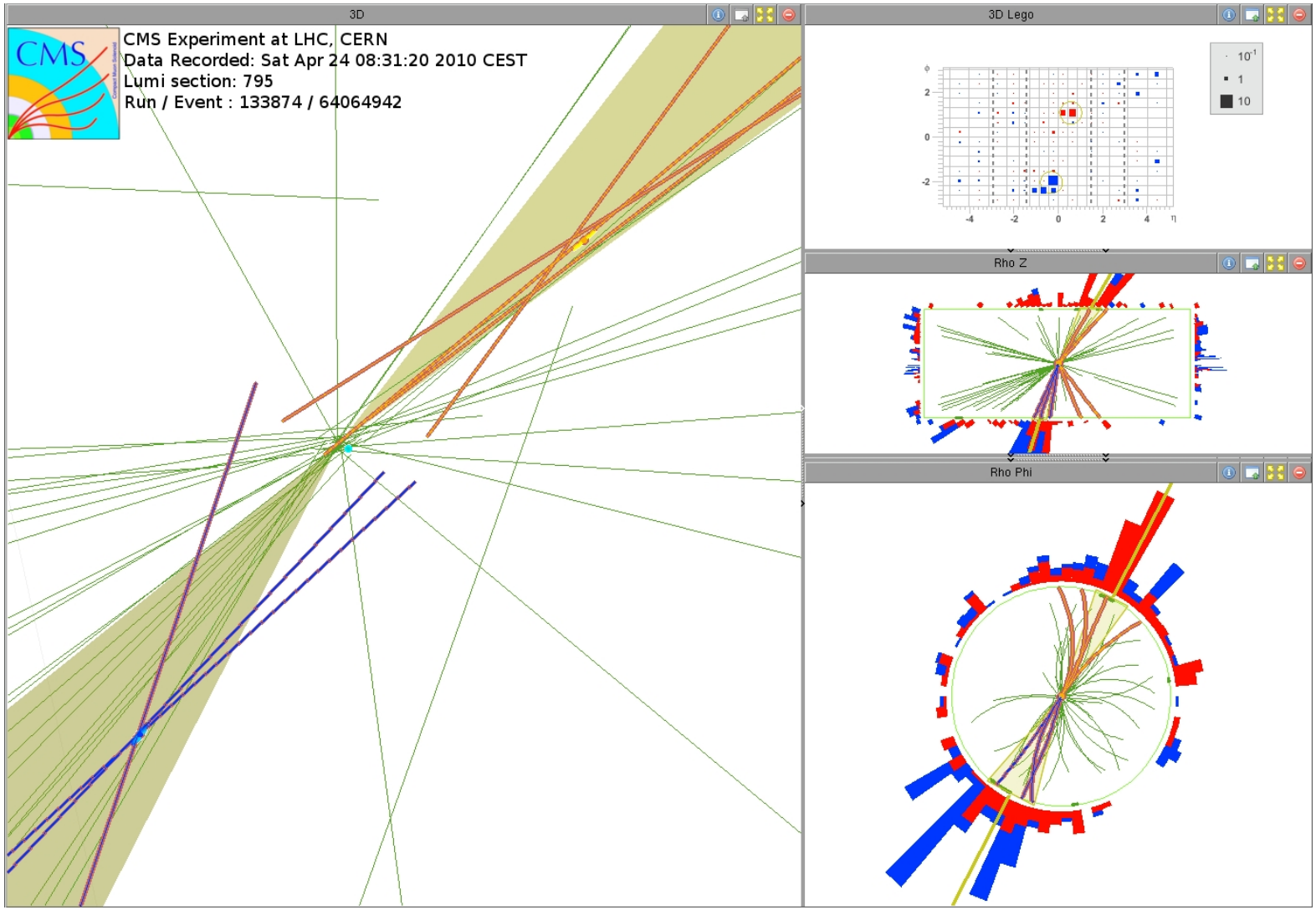
Secondary Vertices, b-tagging





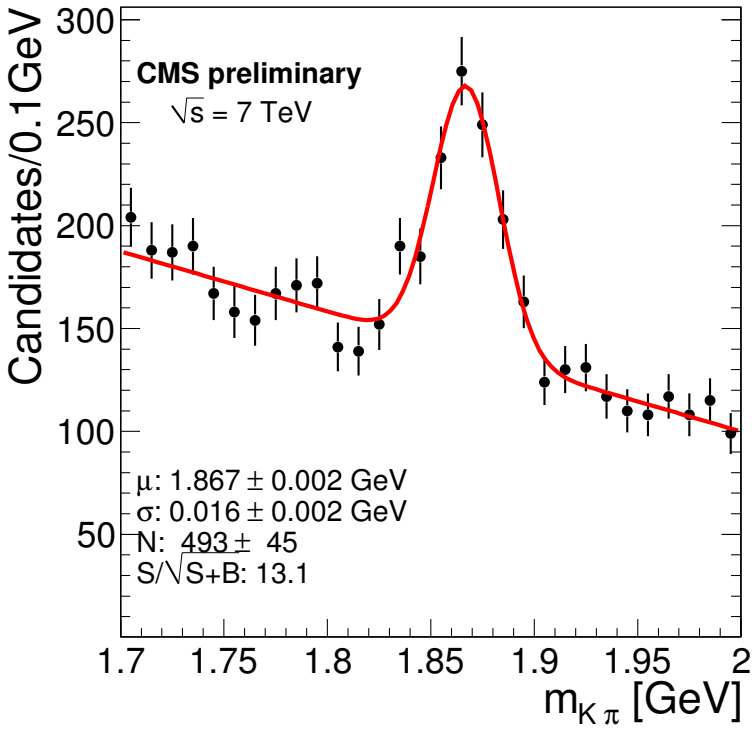
- Signed 3D impact parameter wrt primary vertex for all tracks selected for b-tagging in jets with $p_T > 40$ GeV and $|\eta| < 1.5$
- Pretty good agreement with MC expectation for key tagging ingredients

Double b-Tag in Data



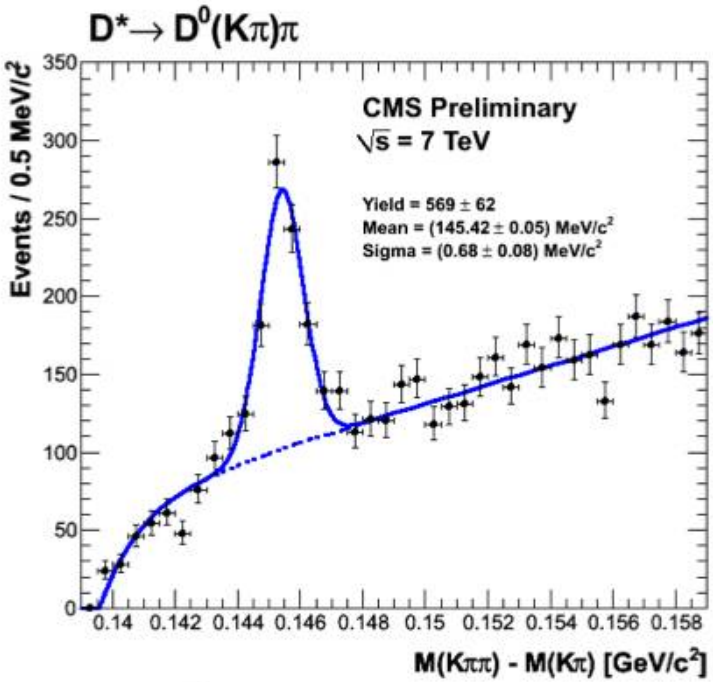
Tracking - Inclusive D^0 production

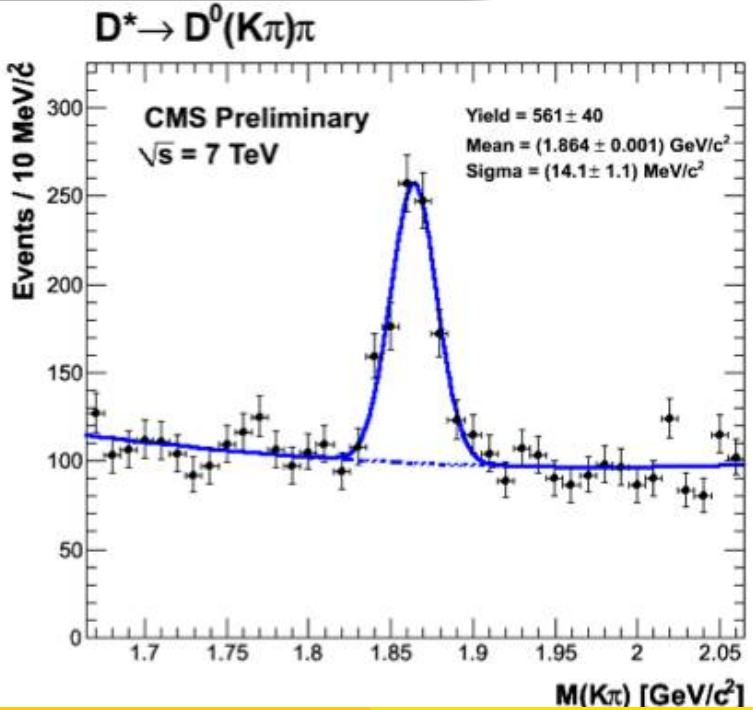
- Selection criteria
  - *good* runs: 132440 - 133038
  - transverse momentum cuts ($P_T(K) > 1.25$ GeV, $P_T(\pi) > 1.0$ GeV, $P_T(D^0) > 3.0$ GeV)
  - Vertexing cuts
- MC expectations:
  - Peak: 1.863 ± 0.002 GeV
  - Width: 0.014 ± 0.002 GeV



Tracking - D^* production

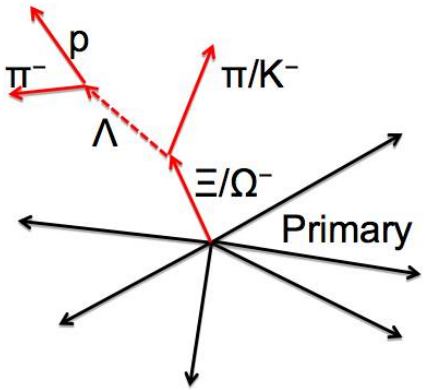
- Data: 37M events in good runs
- Reconstruct $D^* \rightarrow D^0 \pi_S$, $D^0 \rightarrow K\pi$
  - kinematical selection
  - Track quality
  - Mass windows
- Unbinned extended ML fit (RooFit)





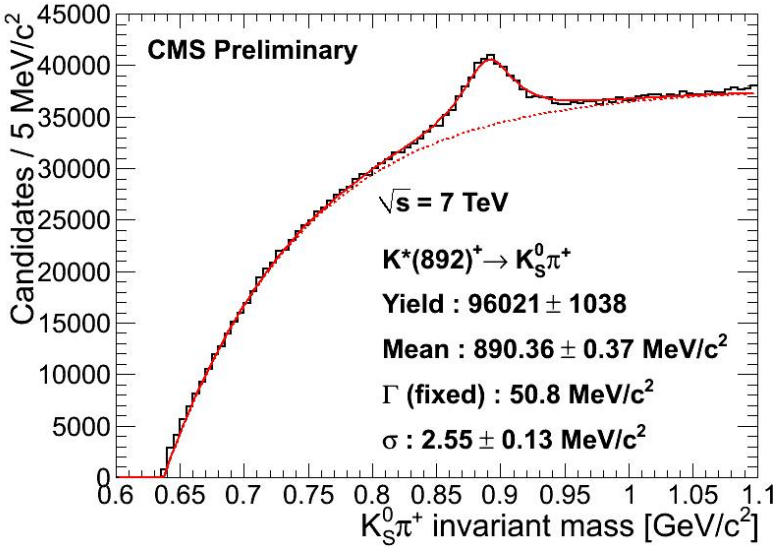
Tracking - Strange Resonances

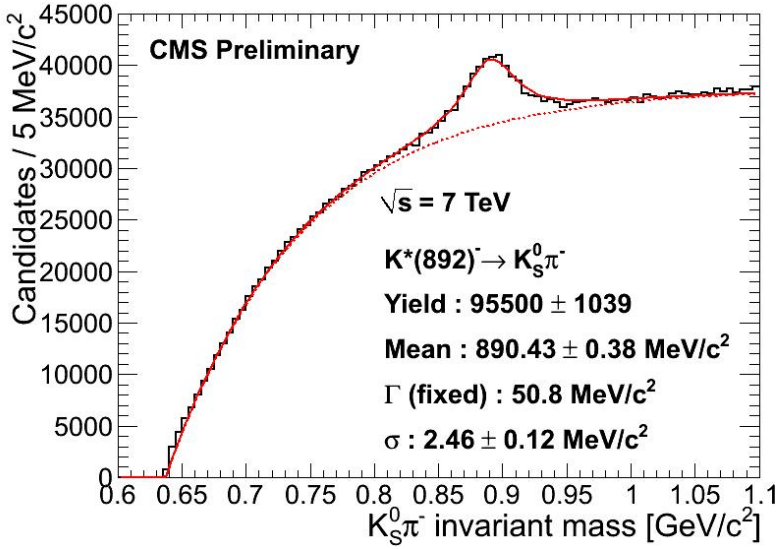
- Reconstructed channels
  - $K^*(892)^+ \rightarrow K^0_S + \pi^+$
  - $\Sigma(1385)^+ \rightarrow \Lambda + \pi^+$
  - $\Sigma(1385)^- \rightarrow \Lambda + \pi^-$
  - $\Xi(1530)^0 \rightarrow \Xi + \pi^+$

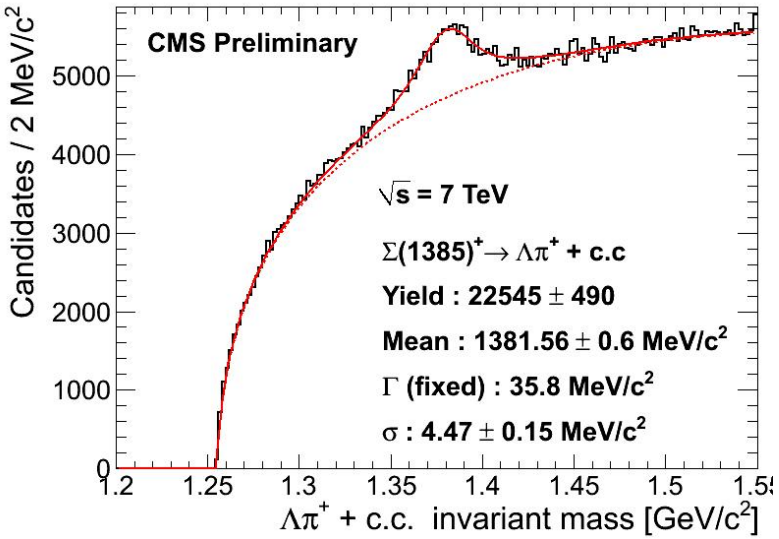


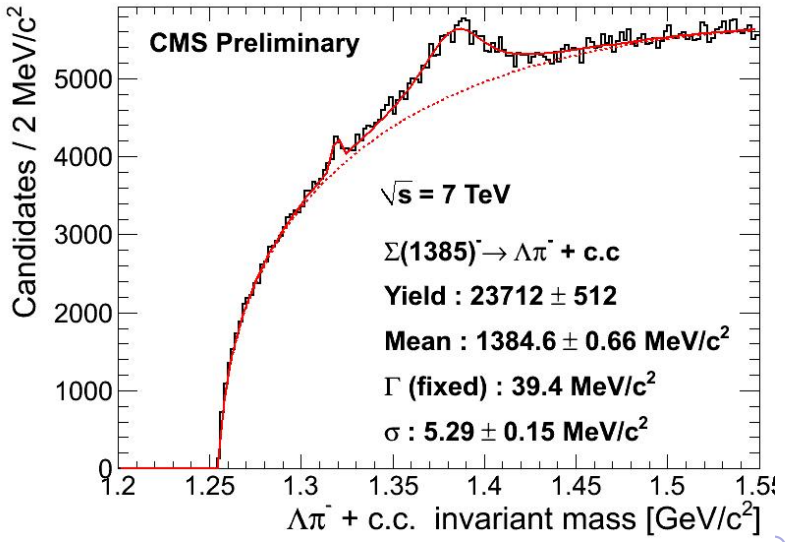
- Signatures:
  - studied states are strong resonances with very short lifetime decay instantly at the production point $\rightarrow$ decay products originate from primary vertex
  - decay chains contain neutral hadrons (K^0_S, Λ) $\rightarrow$ neutral vertices

K^* and $\Sigma(1385)$ Mass Distributions

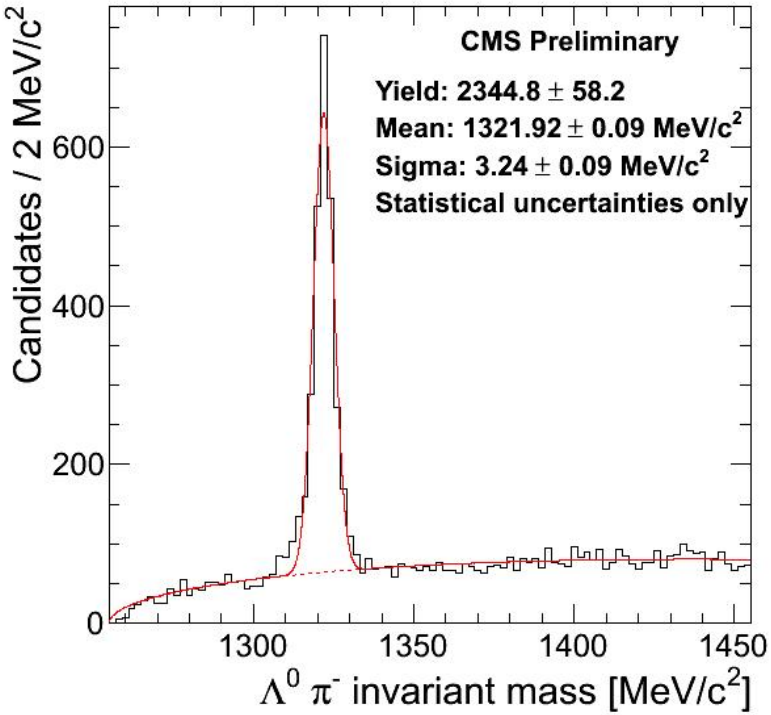


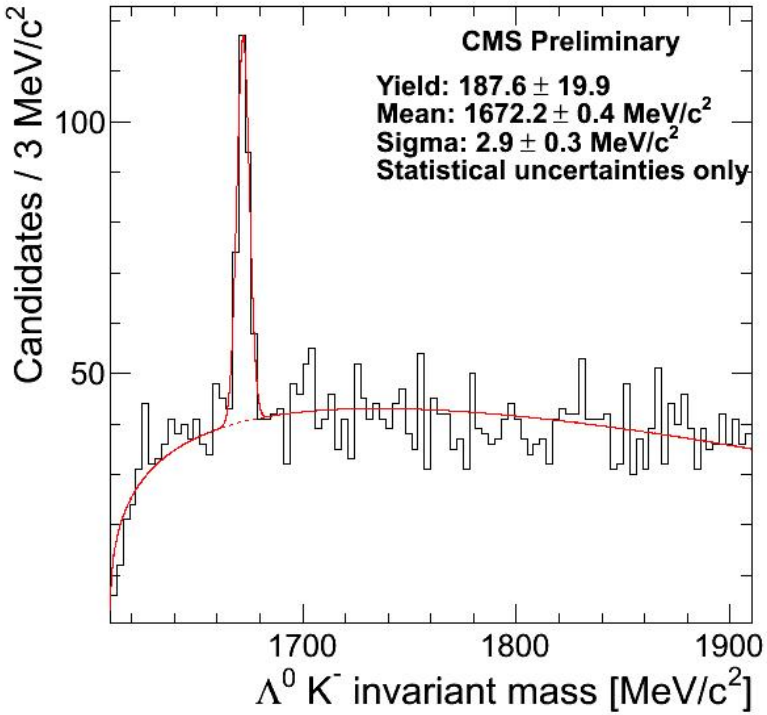






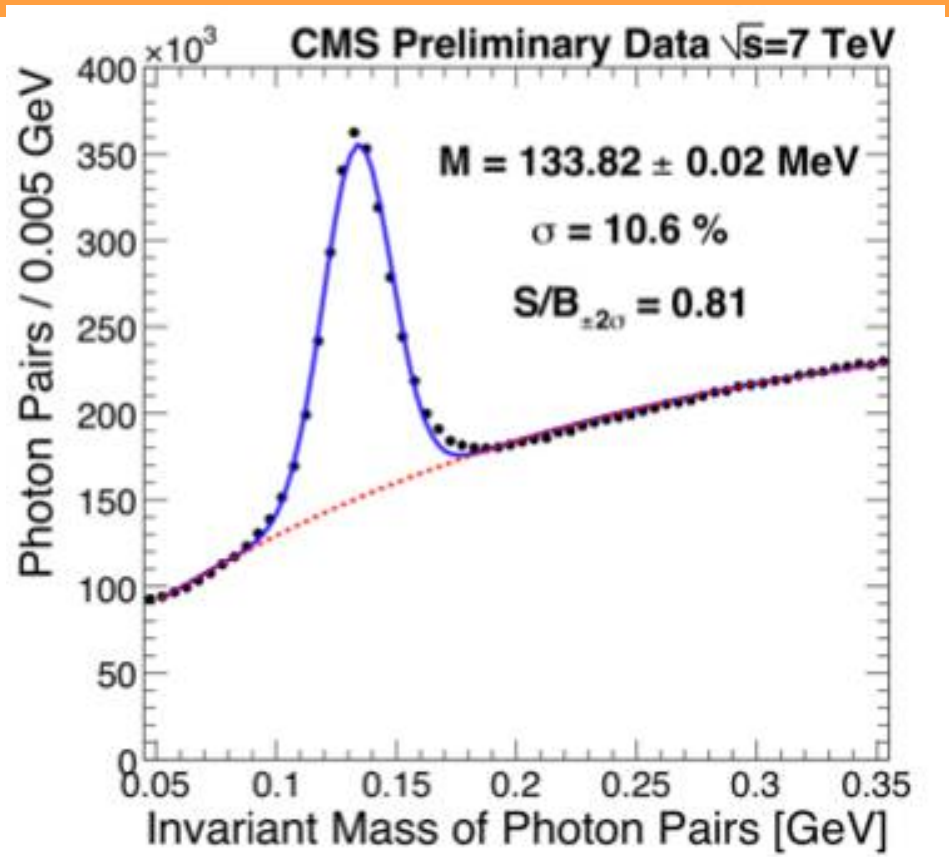
Ξ^- and Ω^- Mass Distributions





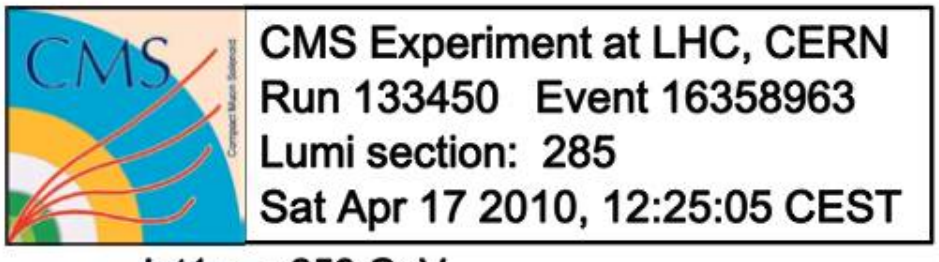
- **All mass distributions show a perfect agreement with the PDG values!**

Neutral pions decaying to $\gamma\gamma$

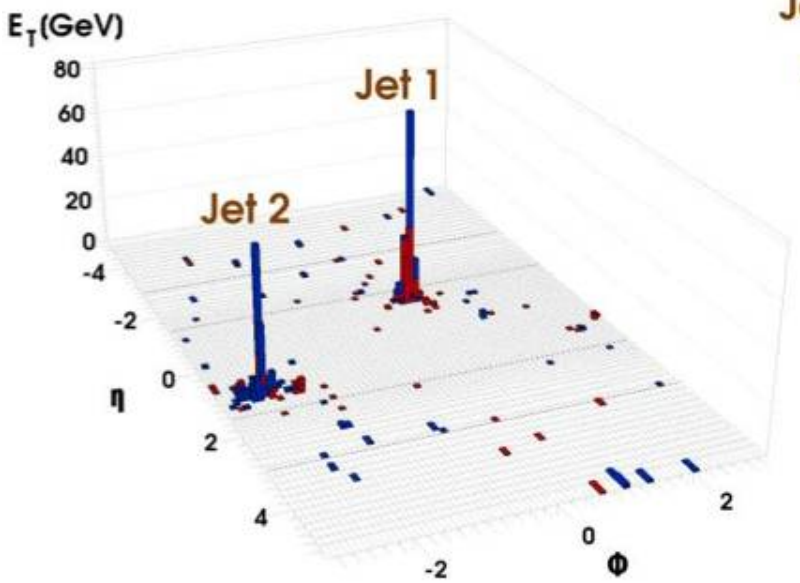


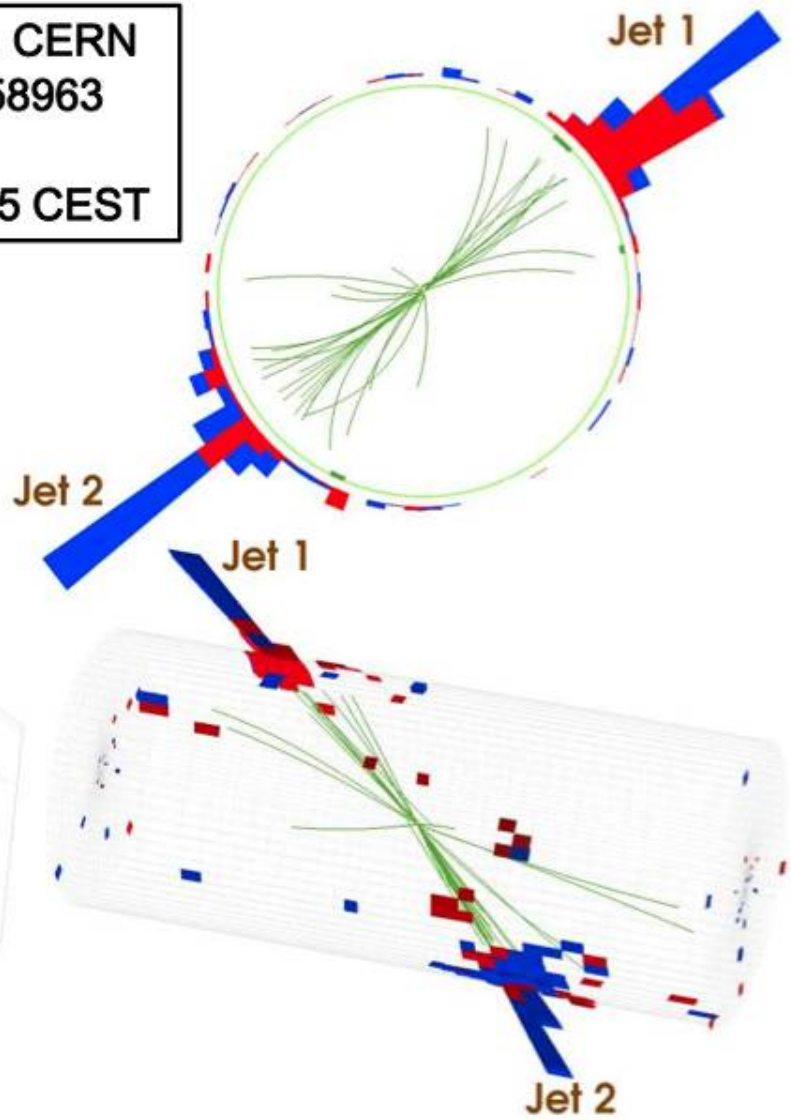
- first π^0 peak shown already the 27th November
- good agreement with MC for peak position and S/B
- uncorrected energies are shown here

Dijets candidate event at $\sqrt{s}$ = 7 TeV

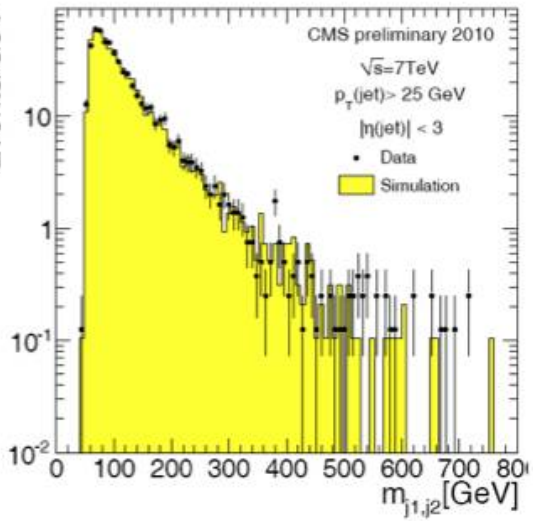


Jet1 p_T : 253 GeV
Jet2 p_T : 244 GeV
Dijet Mass : 764 GeV

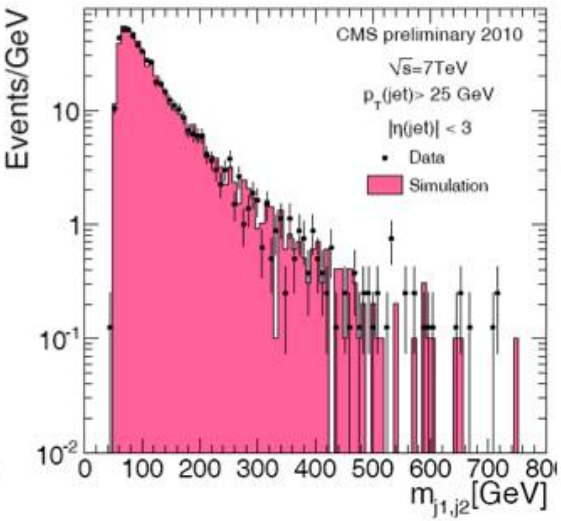




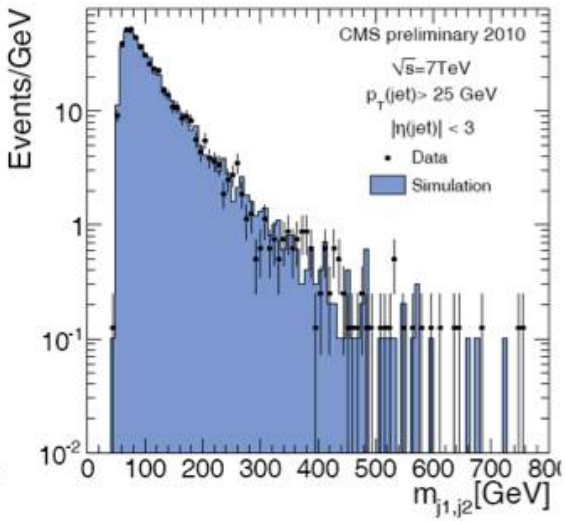
Di-jets Mass



Calorimeter



Calorimeter+Tracks



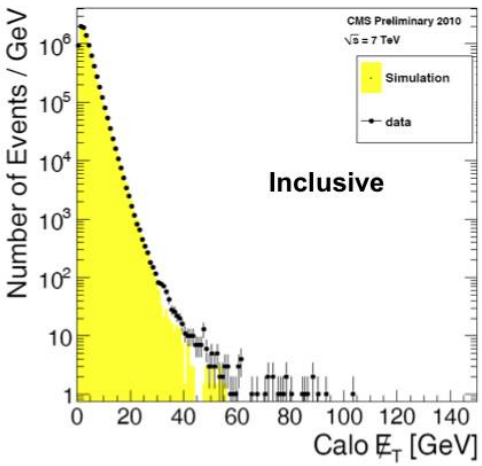
Particle Flow

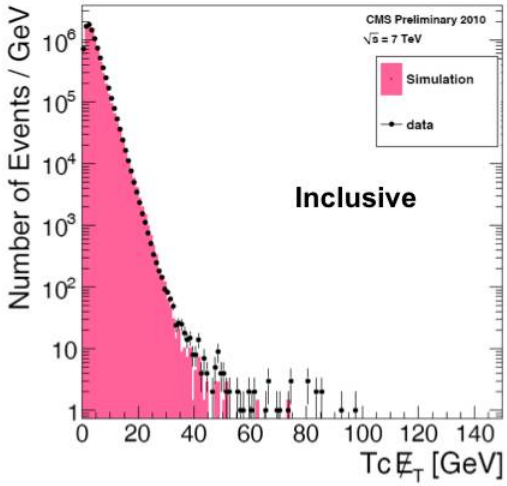
Di-jet selection: Jets $P_T > 25$ GeV, $|\eta| < 3$ and $\Delta\phi > 2.1$

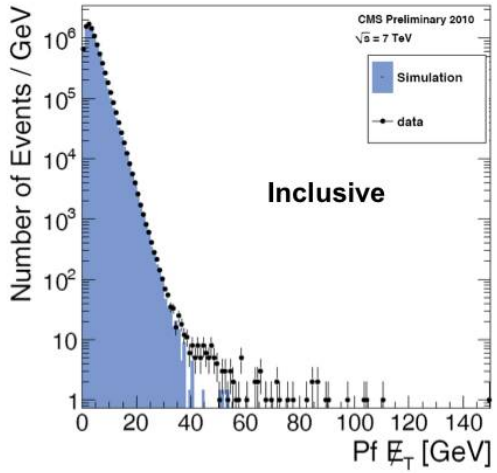
Missing Transverse Energy

Three methods for the calculation of the missing E_T:

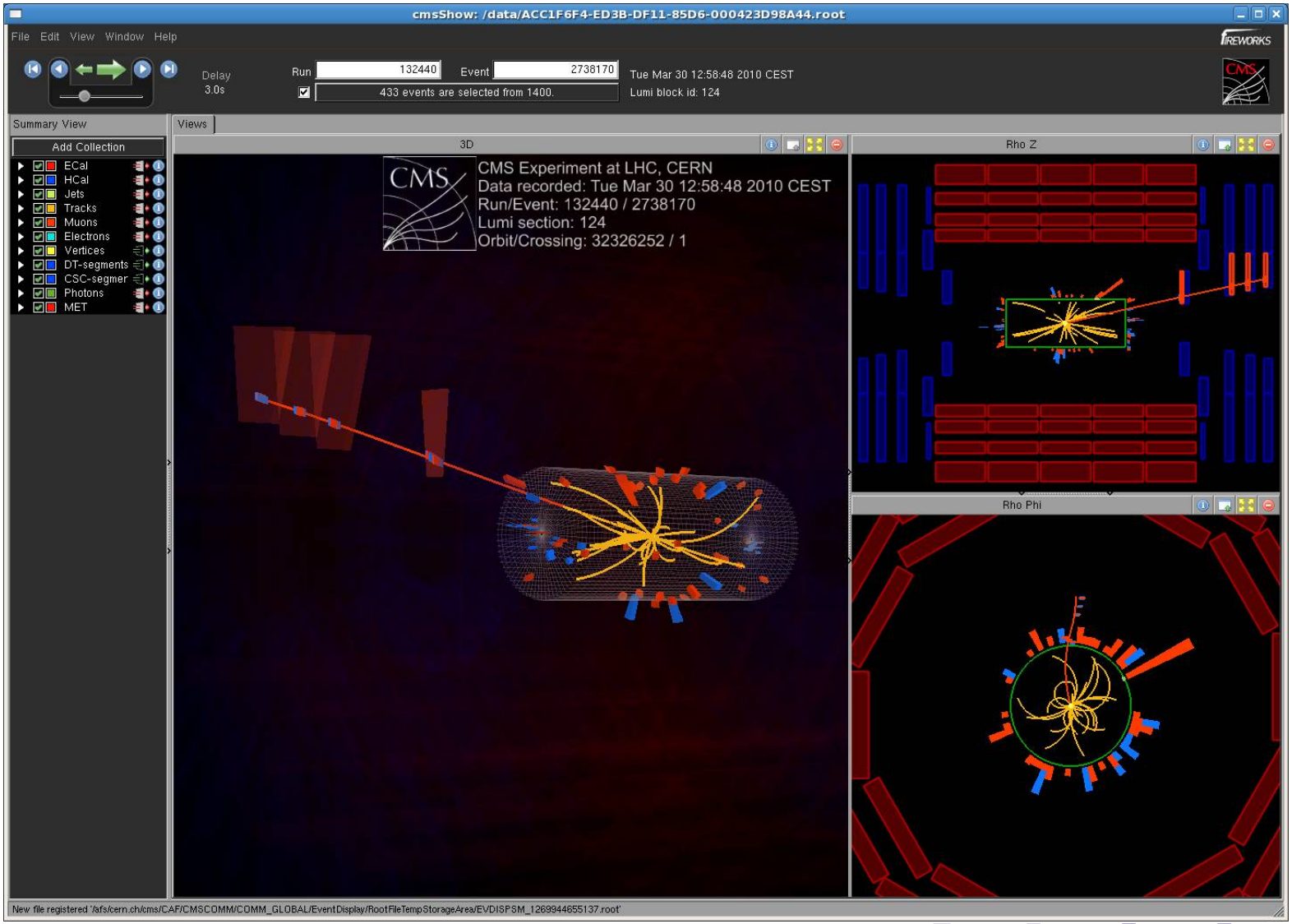
- Calorimeter
- Calorimeter+Tracks
- Particle Flow





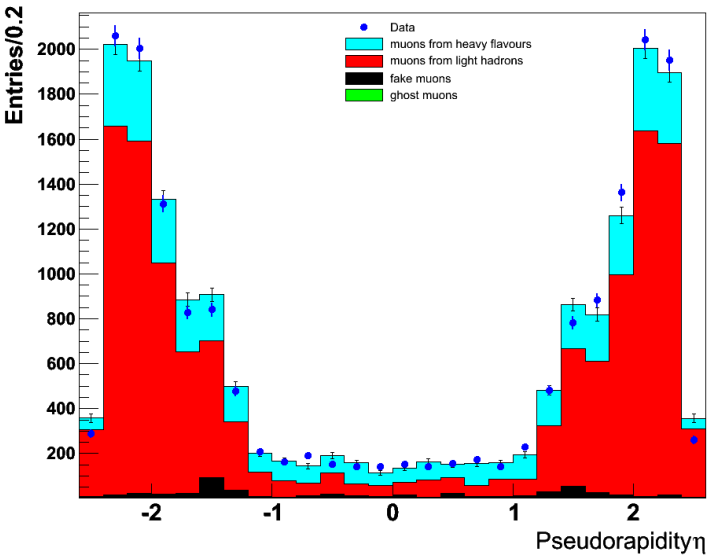


Muons At Last!

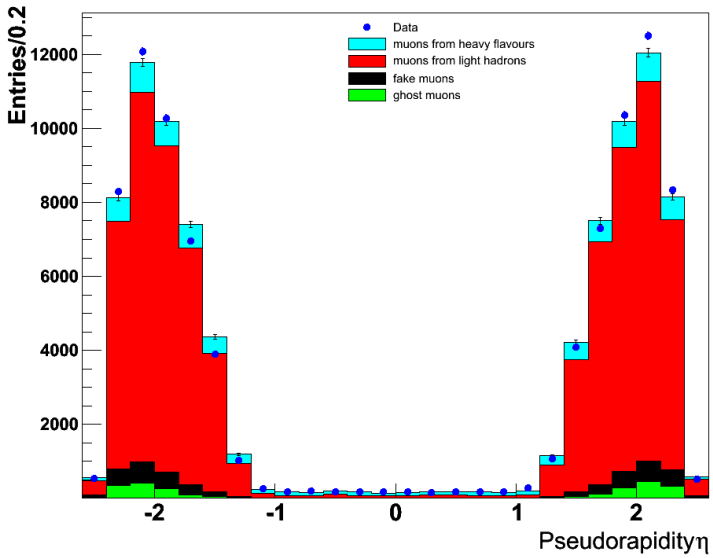


Muons, data-MC comparisons for a few kinematical distributions

- Consider two types of muon candidates:
  - Tracker muons(tracker tracks matched to least one segment in the muon system)
  - Global muons(combined fit of all tracker and muon hits)
- On all plots, MC is normalized to the number of muons in data

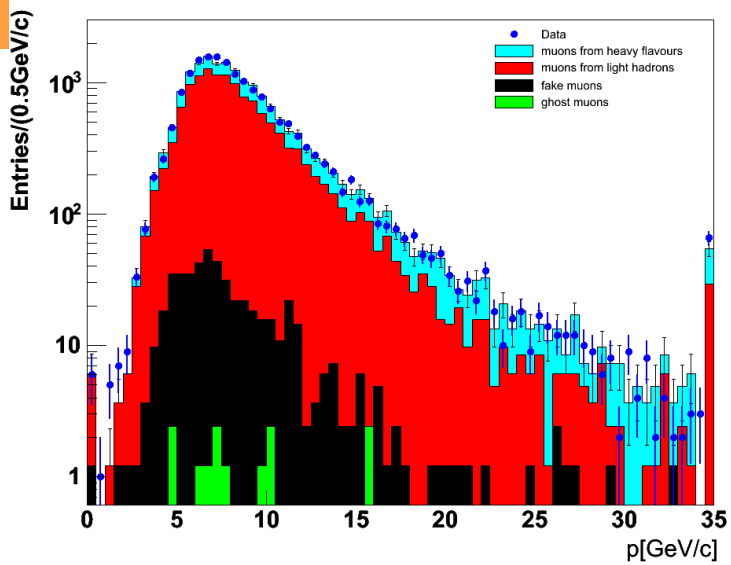


Global Muons

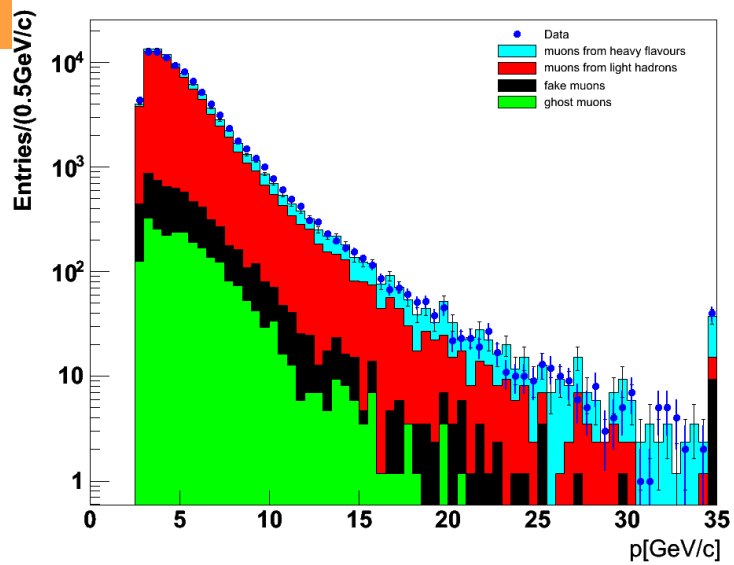


Tracker Muons

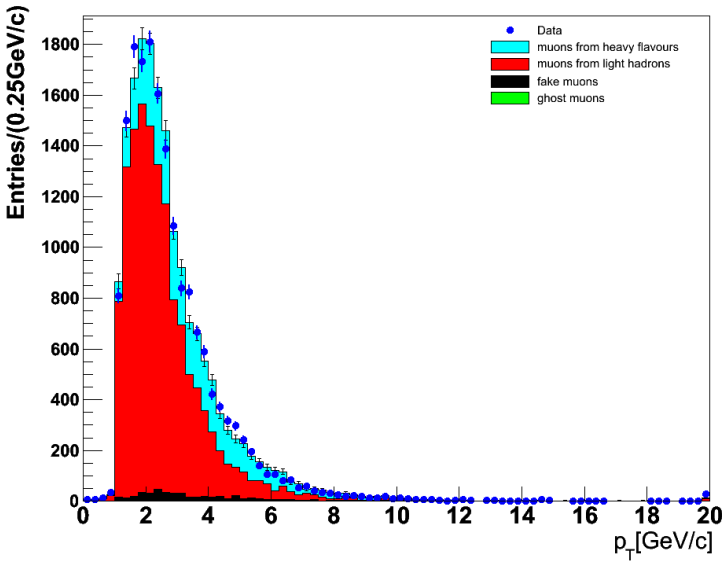
P and P_T spectra

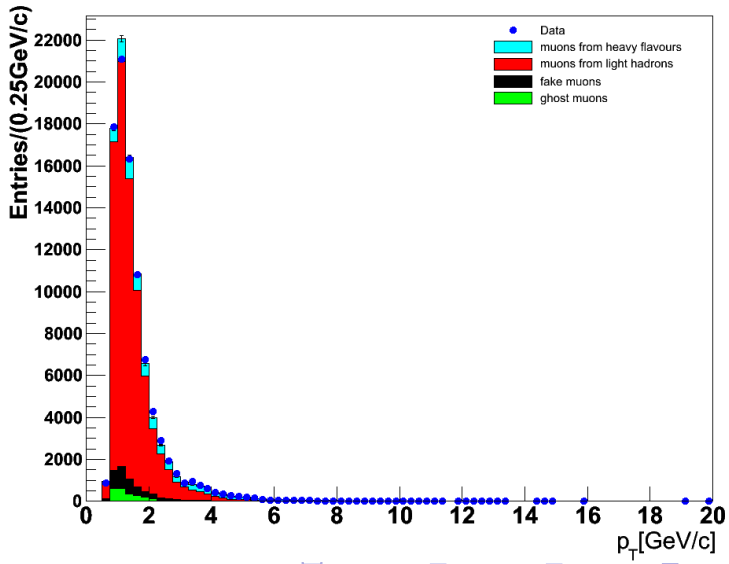


Global Muons

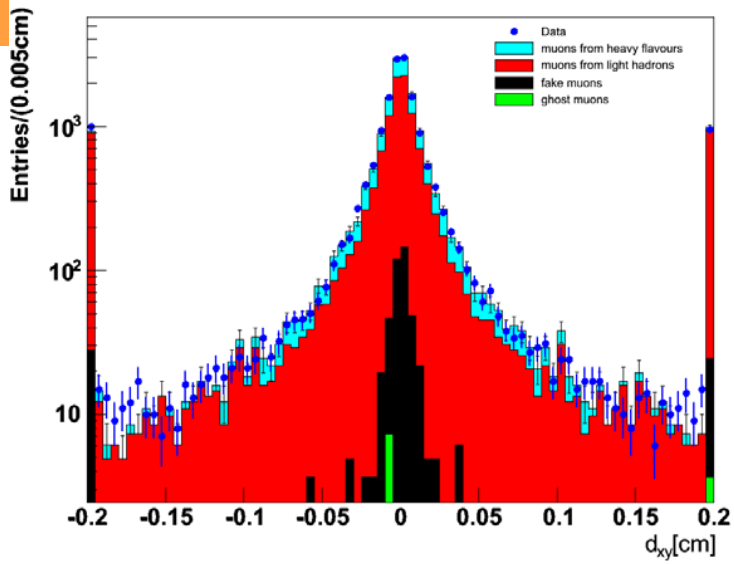


Tracker Muons

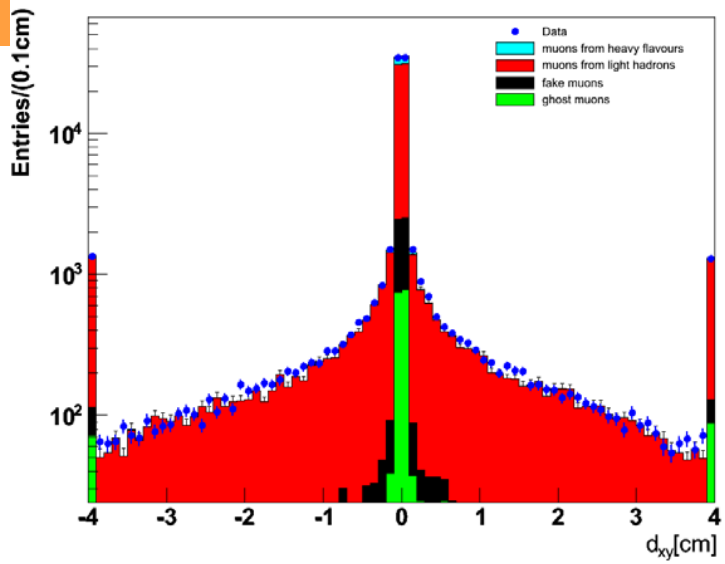




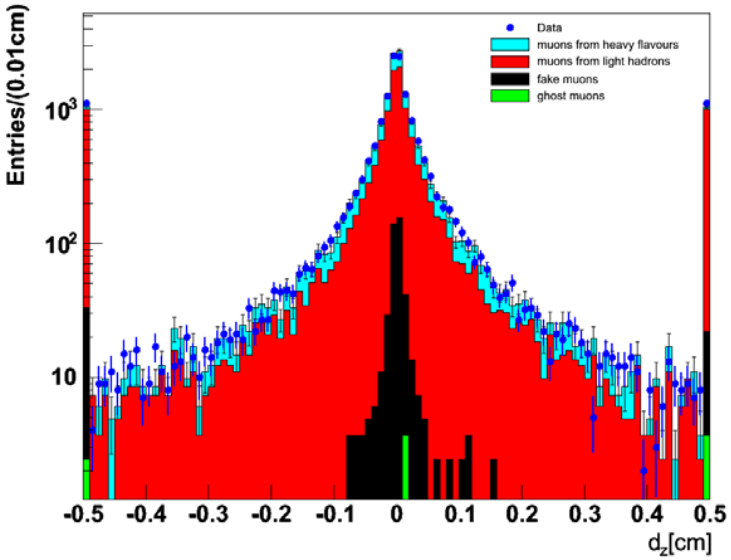
Impact Parameter w.r.t. primary vertex

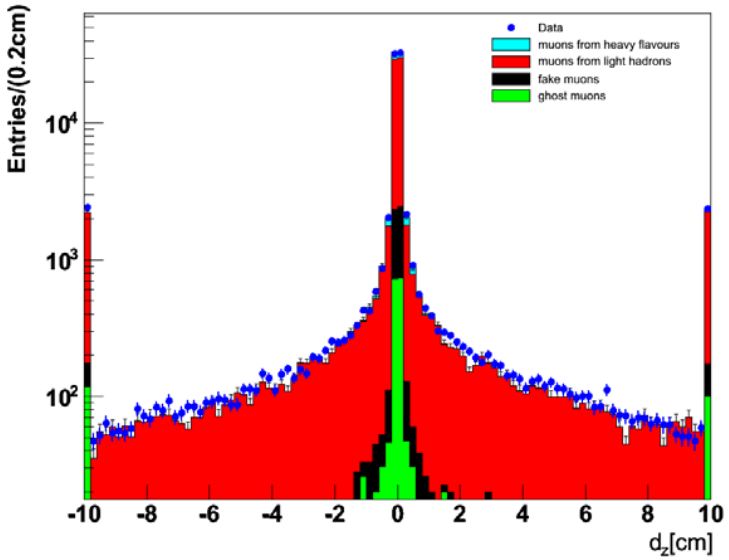


Global Muons



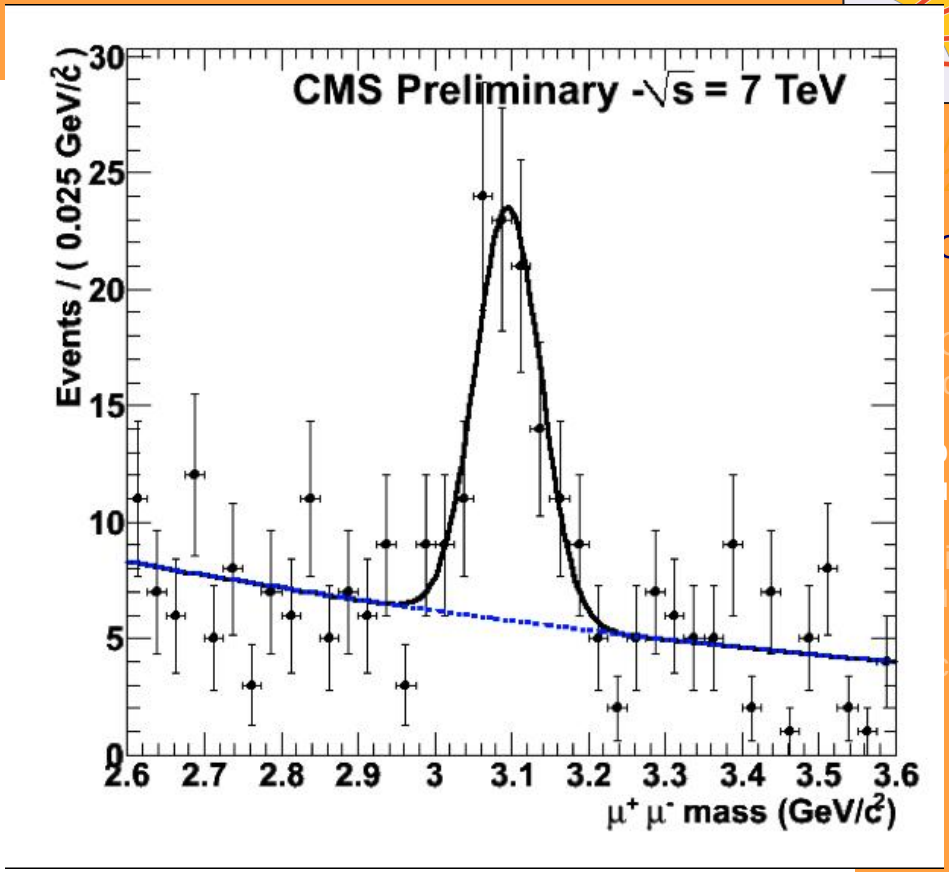
Tracker Muons





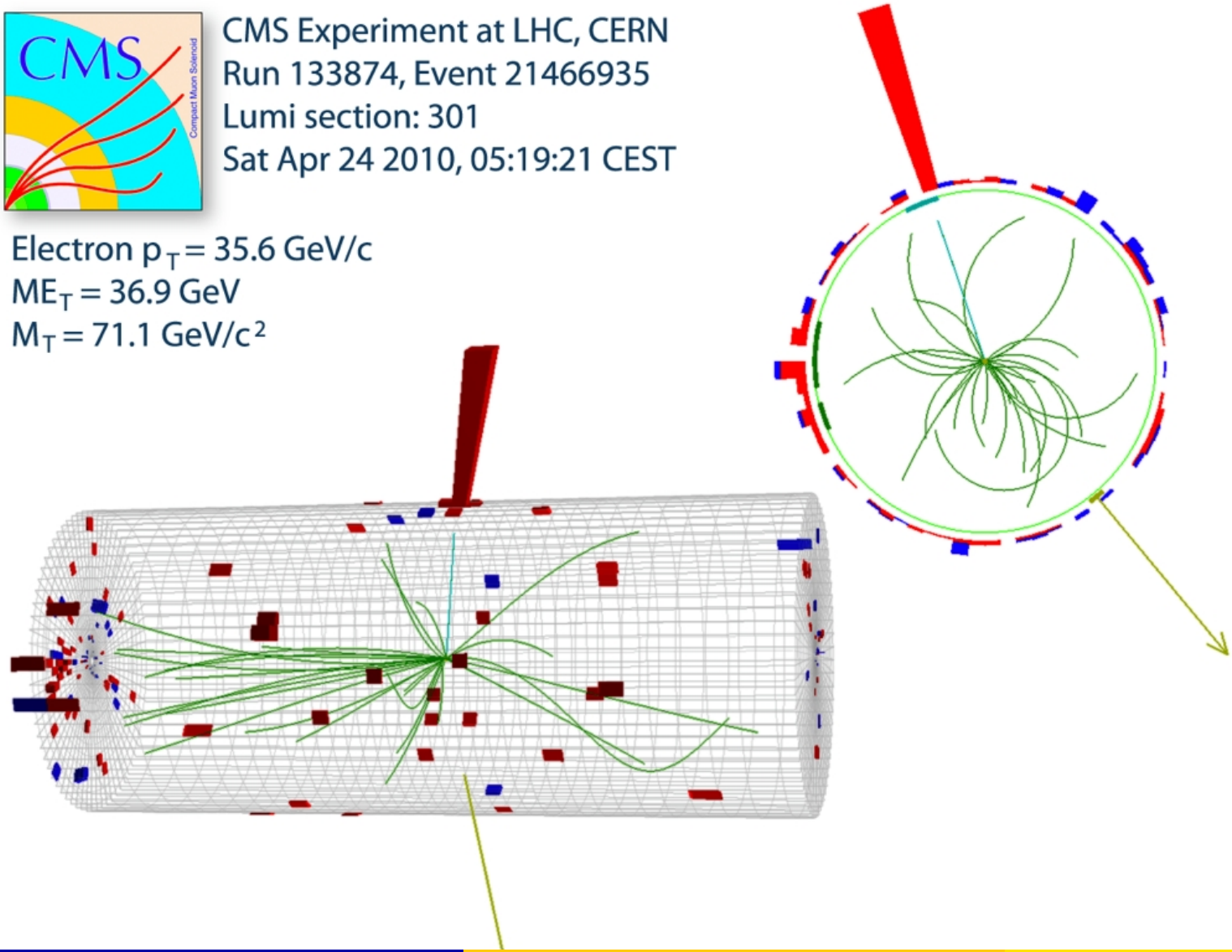
J/Ψ $\rightarrow \mu^+\mu^-$

- pixel layers with hit > 1
- pixel+strip hits > 11
- $|d_0| < 5$ cm, $|z_0| < 20$ cm
- Tracker only
- Tracker+Muon system
- vertex probability $> 0.1\%$



Crucial for the tracker and muon-system calibration and alignment!

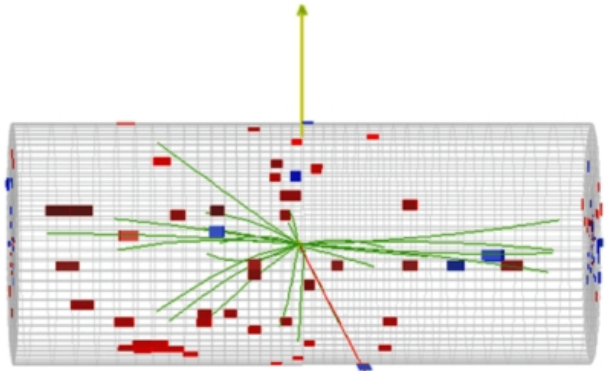
$W \rightarrow e\nu$ Candidates

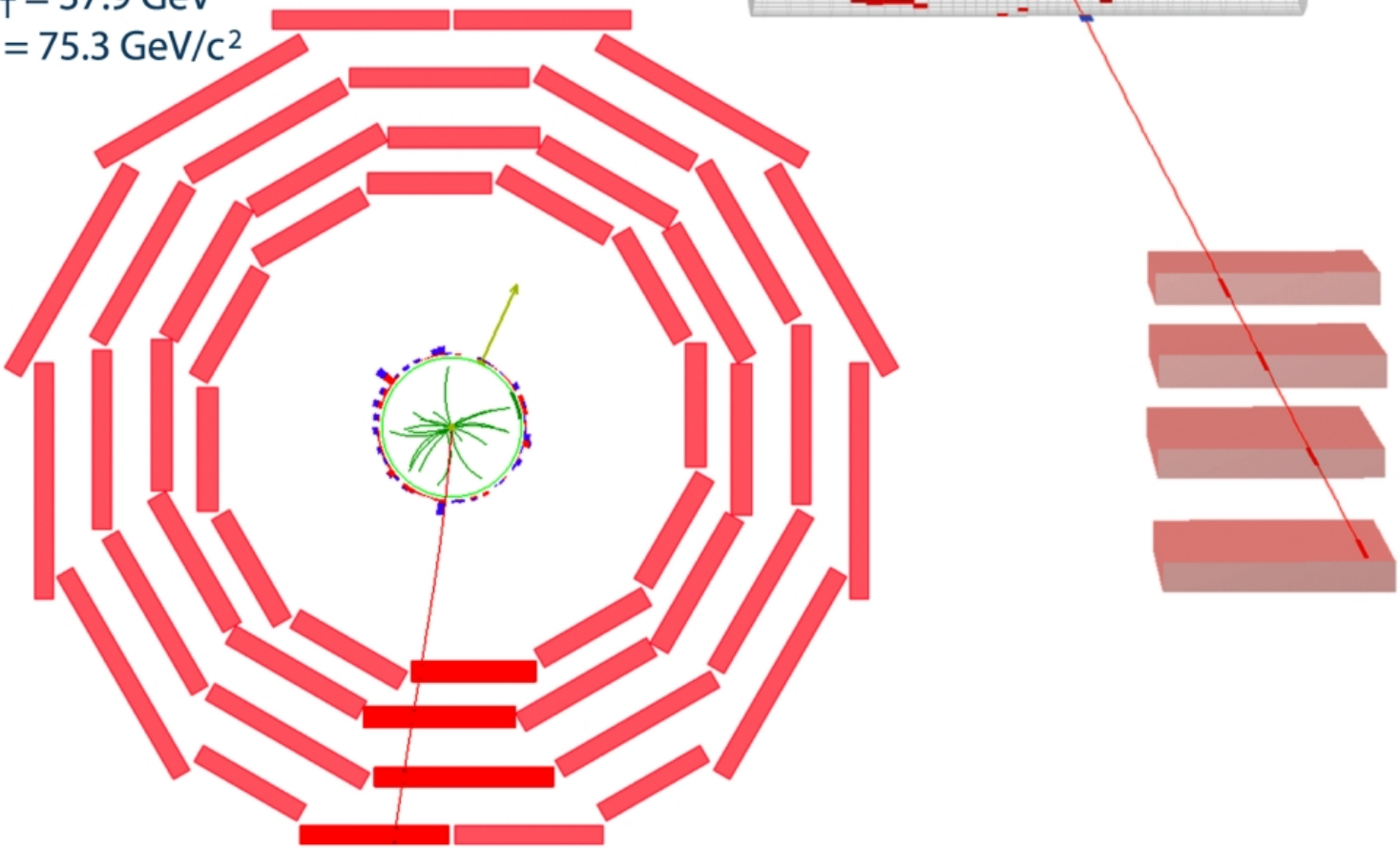


$W \rightarrow \mu\nu$ Candidates

CMS Experiment at LHC, CERN
Run 133875, Event 1228182
Lumi section: 16
Sat Apr 24 2010, 09:08:46 CEST

Muon $p_T = 38.7$ GeV/c
$ME_T = 37.9$ GeV
$M_T = 75.3$ GeV/c^2

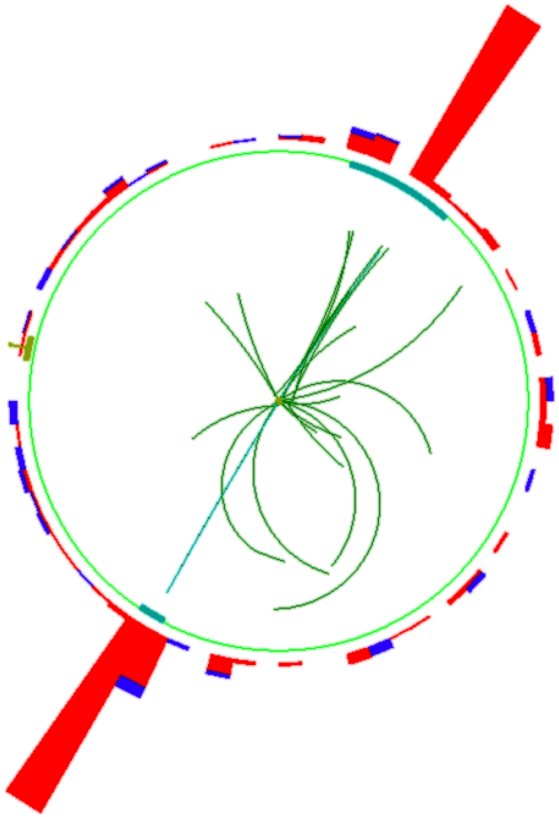


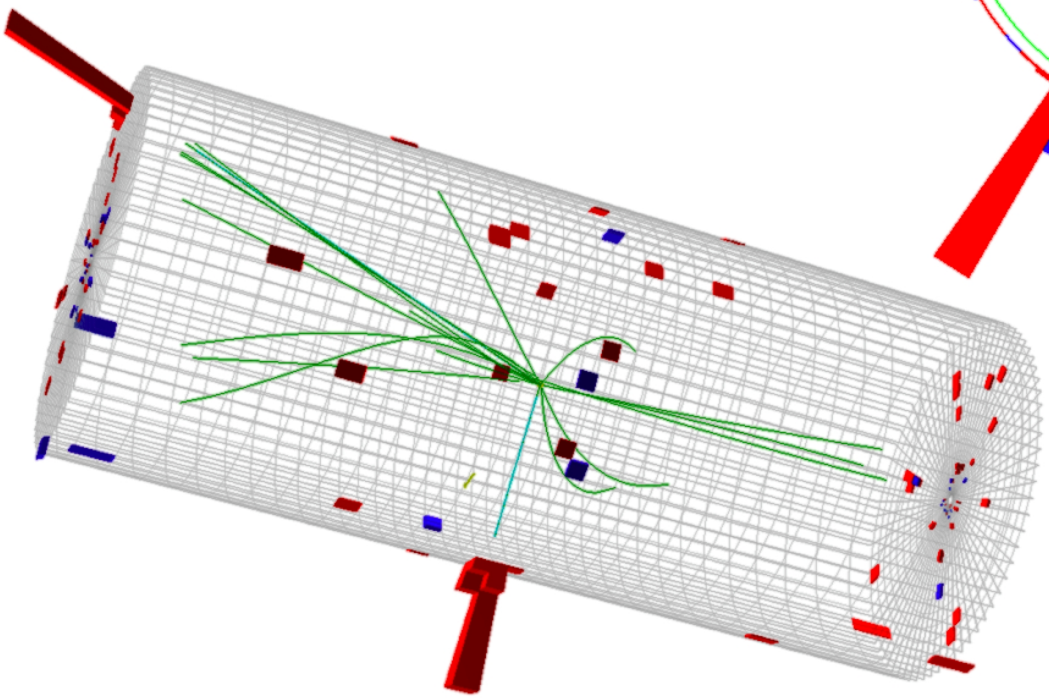


$Z \rightarrow e^+e^-$ Candidates

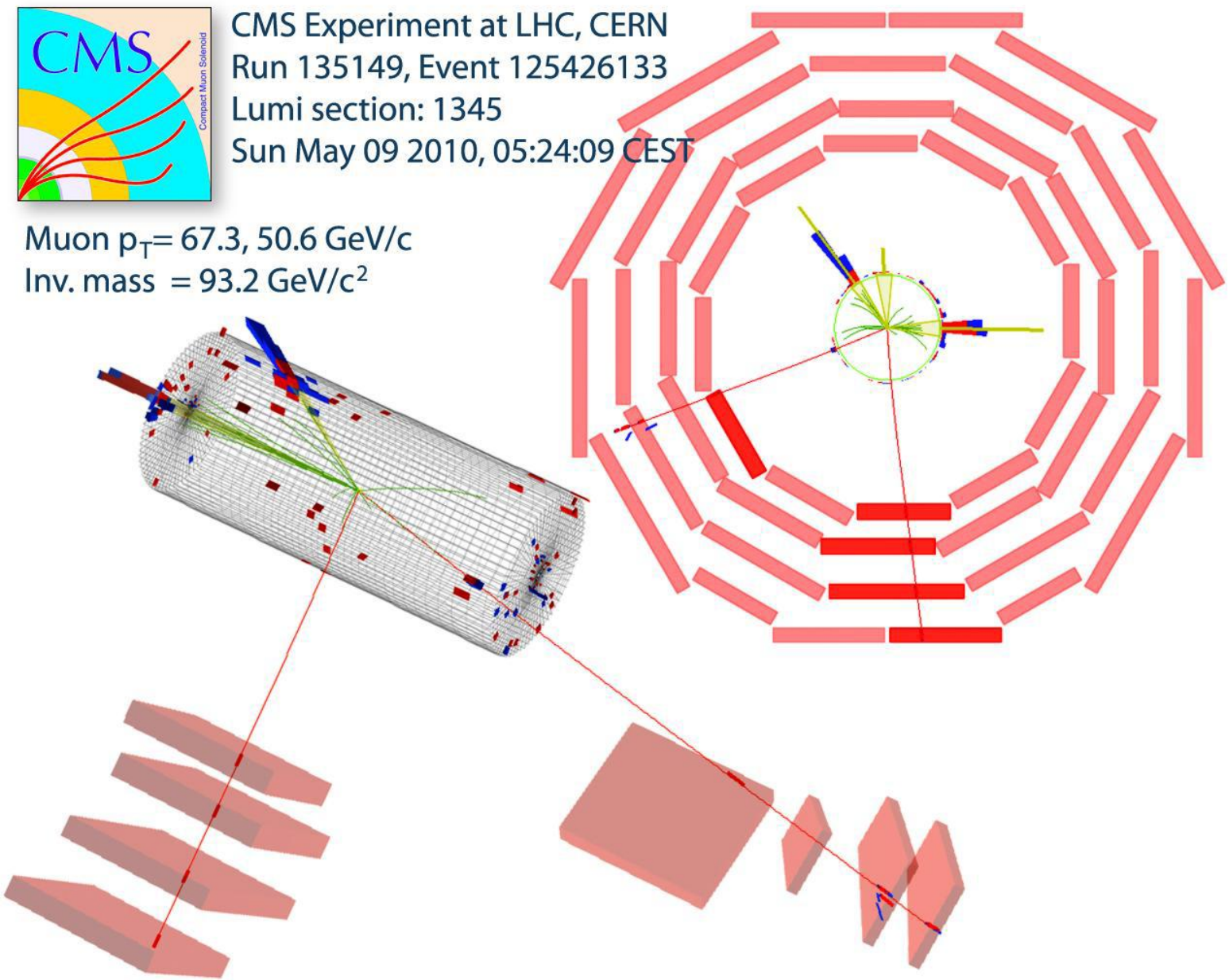
CMS Experiment at LHC, CERN
Run 133877, Event 28405693
Lumi section: 387
Sat Apr 24 2010, 14:00:54 CEST

Electrons $p_T = 34.0, 31.9$ GeV/c
Inv. mass $= 91.2$ GeV/c^2





$Z \rightarrow \mu^+\mu^-$ Candidates



Physics Results

THE FIRST CMS PAPER ON COLLISIONS DATA!

JHEP

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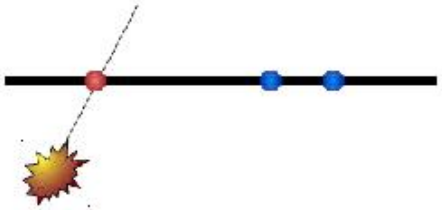
Transverse-momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt{s} = 0.9$ and 2.36 TeV

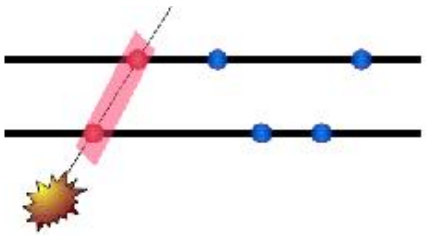
CMS Collaboration

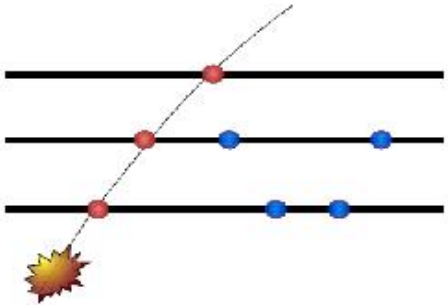
Abstract: Measurements of inclusive charged-hadron transverse-momentum and pseudorapidity distributions are presented for proton-proton collisions at $\sqrt{s} = 0.9$ and 2.36 TeV. The data were collected with the CMS detector during the LHC commissioning in December 2009. For non-single-diffractive interactions, the average charged-hadron transverse momentum is measured to be 0.46 ± 0.01 (stat.) $\pm$ 0.01 (syst.) GeV/c at 0.9 TeV and 0.50 ± 0.01 (stat.) $\pm$ 0.01 (syst.) GeV/c at 2.36 TeV, for pseudorapidities between -2.4 and $+2.4$. At these energies, the measured pseudorapidity densities in the central region, $dN_{\rm ch}/d\eta|_{|\eta|<0.5}$, are 3.48 ± 0.02 (stat.) $\pm$ 0.13 (syst.) and 4.47 ± 0.04 (stat.) $\pm$ 0.16 (syst.), respectively. The results at 0.9 TeV are in agreement with previous measurements and confirm the expectation of near equal hadron production in $p\bar{p}$ and pp collisions. The results at 2.36 TeV represent the highest-energy measurements at a particle collider to date.

JHEP02(2010)041

Charged Hadron: 3 methods

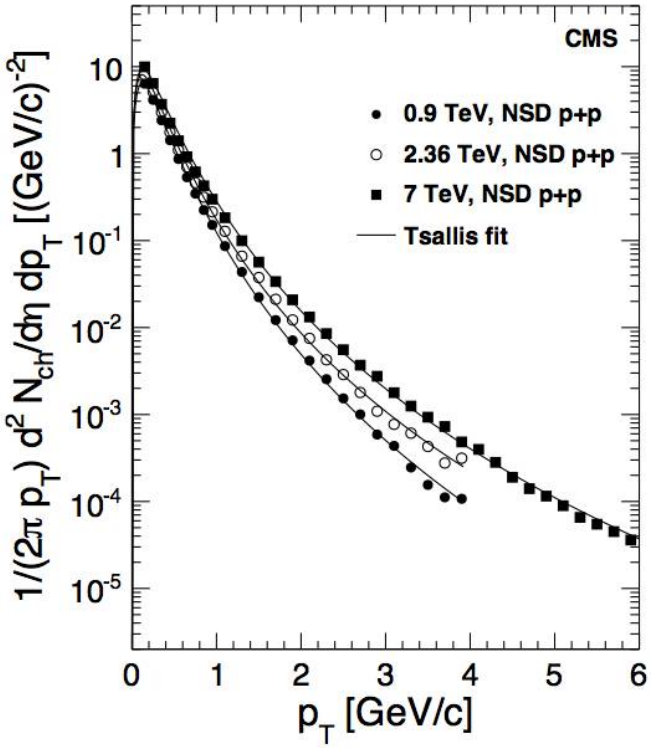


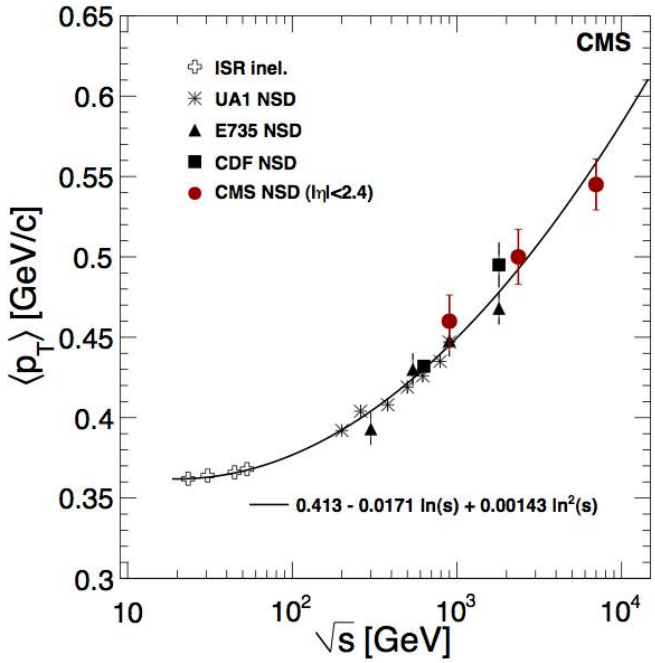




- Pixel hit counting (1 hit)
  - Using the primary vertex;
  - Immune to detector mis-alignment;
  - $p_T > 30$ MeV/c, $|\eta| < 2$;
- Tracklets (2 hits)
  - From hit pairs;
  - Data-driven background subtraction;
  - $p_T > 50$ MeV/c, $|\eta| < 2$;
- Tracks (pixel+strips)
  - Use all pixel and strip hits;
  - Sensitive, most complex;
  - $p_T > 100$ MeV/c, $|\eta| < 2.4$;

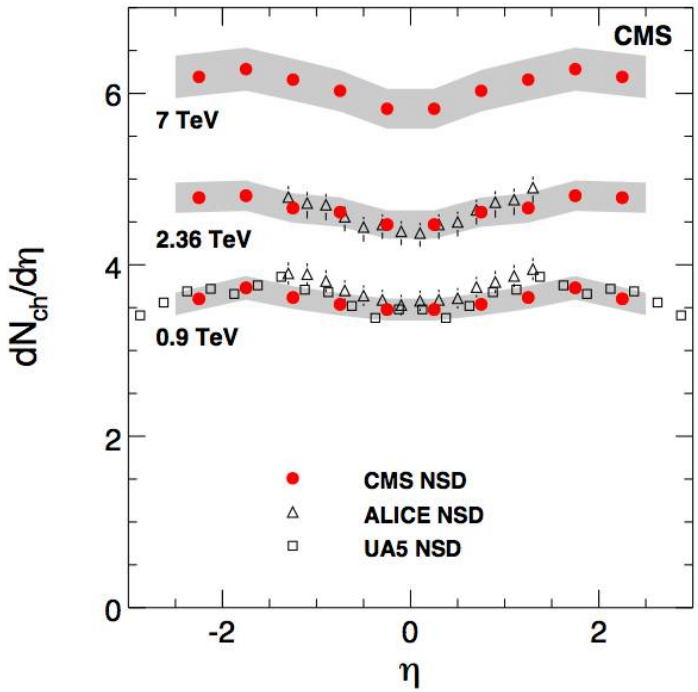
Charged Hadron P_T spectrum

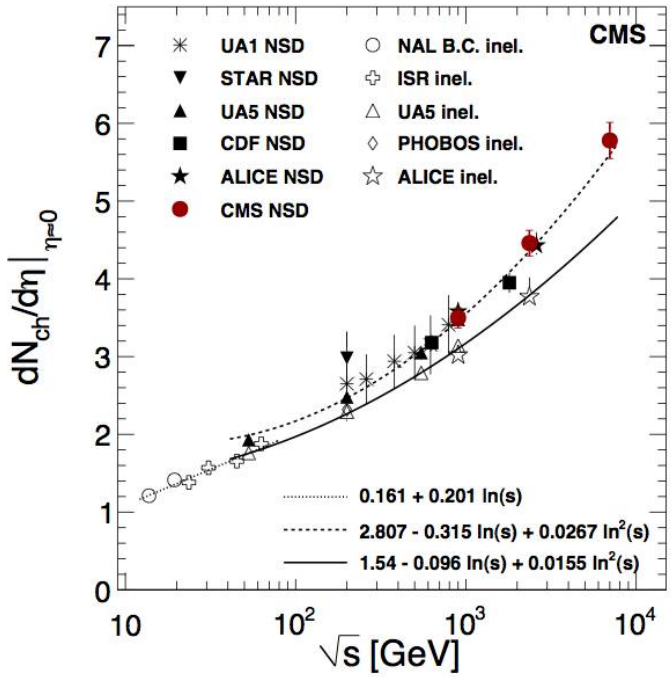




- Three different methods yielding consistent results down to $P_T > 100$ MeV
- Measurement provide valuable feedback to theoretical predictions

Charged Hadron Multiplicity

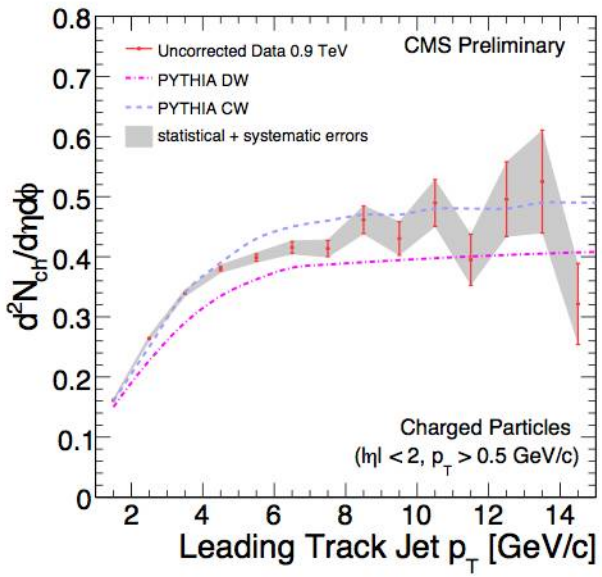


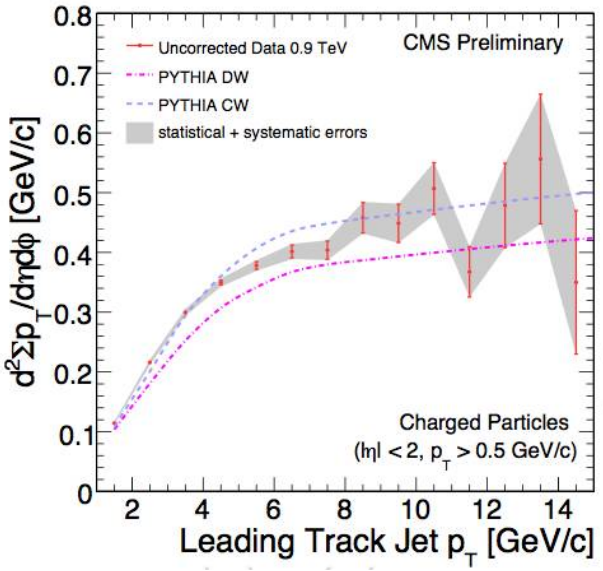


- Steeper increase of multiplicity density with collision energy compared to current predictions
  - MC tuning after few days of data taking before LHC enters high luminosity era (tuning effort is still ongoing)

Underlying Event @ 900 GeV

- Hard scattering track jets with $P_T > 3$ GeV to study underlyng event activity in transverse region
- Significant discrepancy in both shape and normalization wrt many existing Pythia tunes

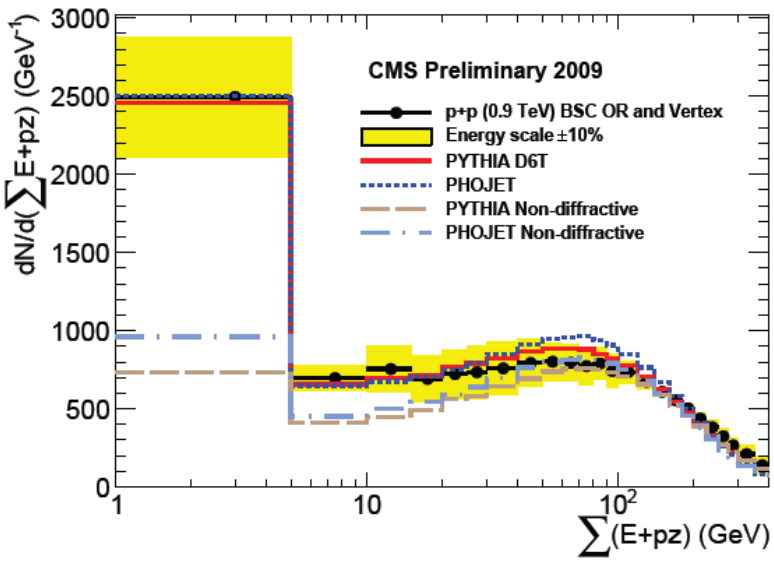


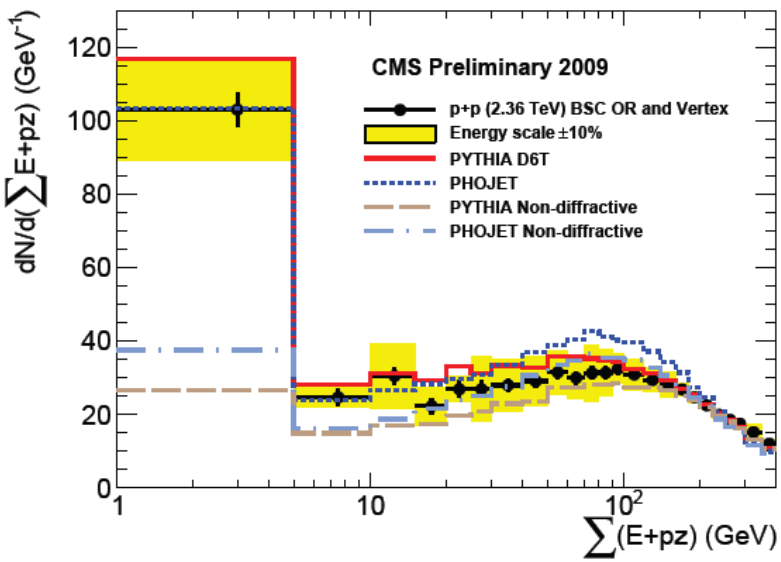


arXiv:1006.2083v1[hep-ex] 10Jun2010

Observation of Single Diffractive events

- Variable used: $\Sigma(E+p_z) = \Sigma E(1+\cos\theta)$
- The sum runs over the full calorimeter acceptance
- Events below 5 GeV are mainly SD type!





Uncorrected distributions (CMS PAS FWD-10-001)

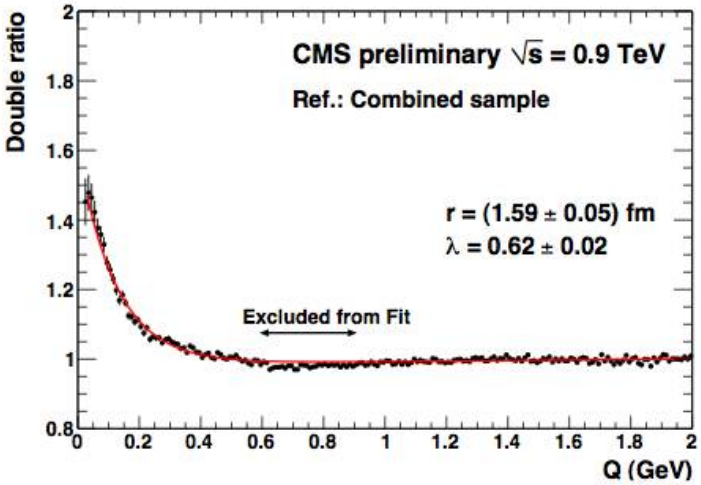
Bose-Einstein Correlations

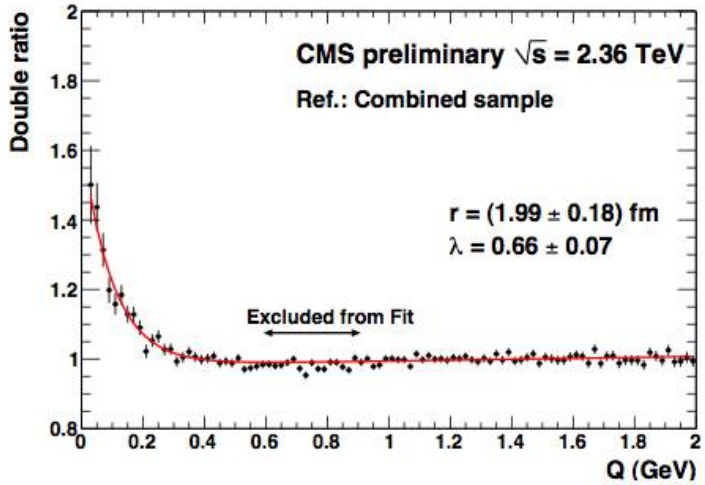
- Measure correlation between identical bosons with momenta p_1 and p_2

$$R=\frac{P(p_1,p_2)}{P(p_1)P(p_2)}=\frac{(dN/dQ)}{(dN/dQ_{ref})} \qquad Q=\sqrt{-(p_1-p_2)^2}=\sqrt{m_{inv}^2-4m_\pi^2}$$

$$R(\Omega)=C[1+\lambda\Omega(Qr)]\cdot(1+\delta Q)$$

- Several references samples for normalization
  - opposite charge pairs, rotated particles, opposite hemishpere, mixed events





Conclusions

- CMS is well advanced with the detector commissioning and calibration
- The understanding of the detector performance with the data continues to make progress
- CMS has publised three papers on Minimum Bias data so far:
  - dN/dη and dN/dp$_T$ at 0.9 and 2.36 TeV
  - dN/dη and dN/dp$_T$ at 7 TeV
  - Bose-Einstein Correlations
- CMS has used its calorimeters to observe single-diffractive events
- Many other upcoming results/publications !