



CMS Status and first data

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Rice University

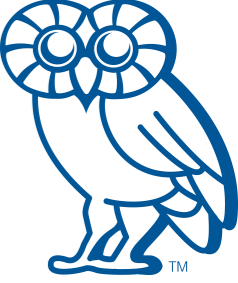
on behalf of the CMS Collaboration

TOP2010

Brugge, Belgium



Outline



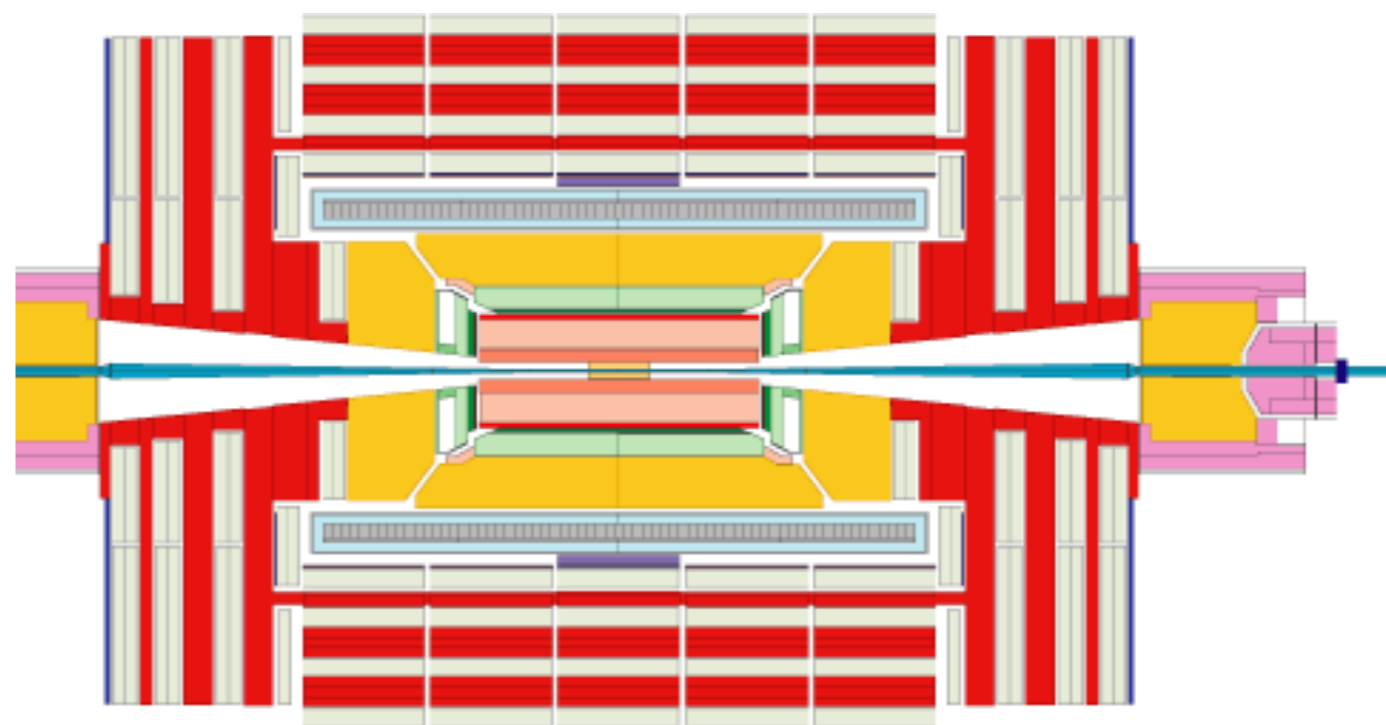
- CMS detector
- Luminosity
- Detector Performance
 - Tracking detectors
 - Calorimeters
 - Muon detectors
- Physics Performance
 - low p_T physics objects: tracks, resonances
 - Electroweak-like events: W and Z candidate events
 - looking towards the top
- Outlook

Compact Muon Solenoid

- General Purpose Detector
- Precision Silicon Tracking
 - EM Calorimeter
 - Hadron Calorimeter
 - 3.8 T Magnetic Field
 - Muon Detectors

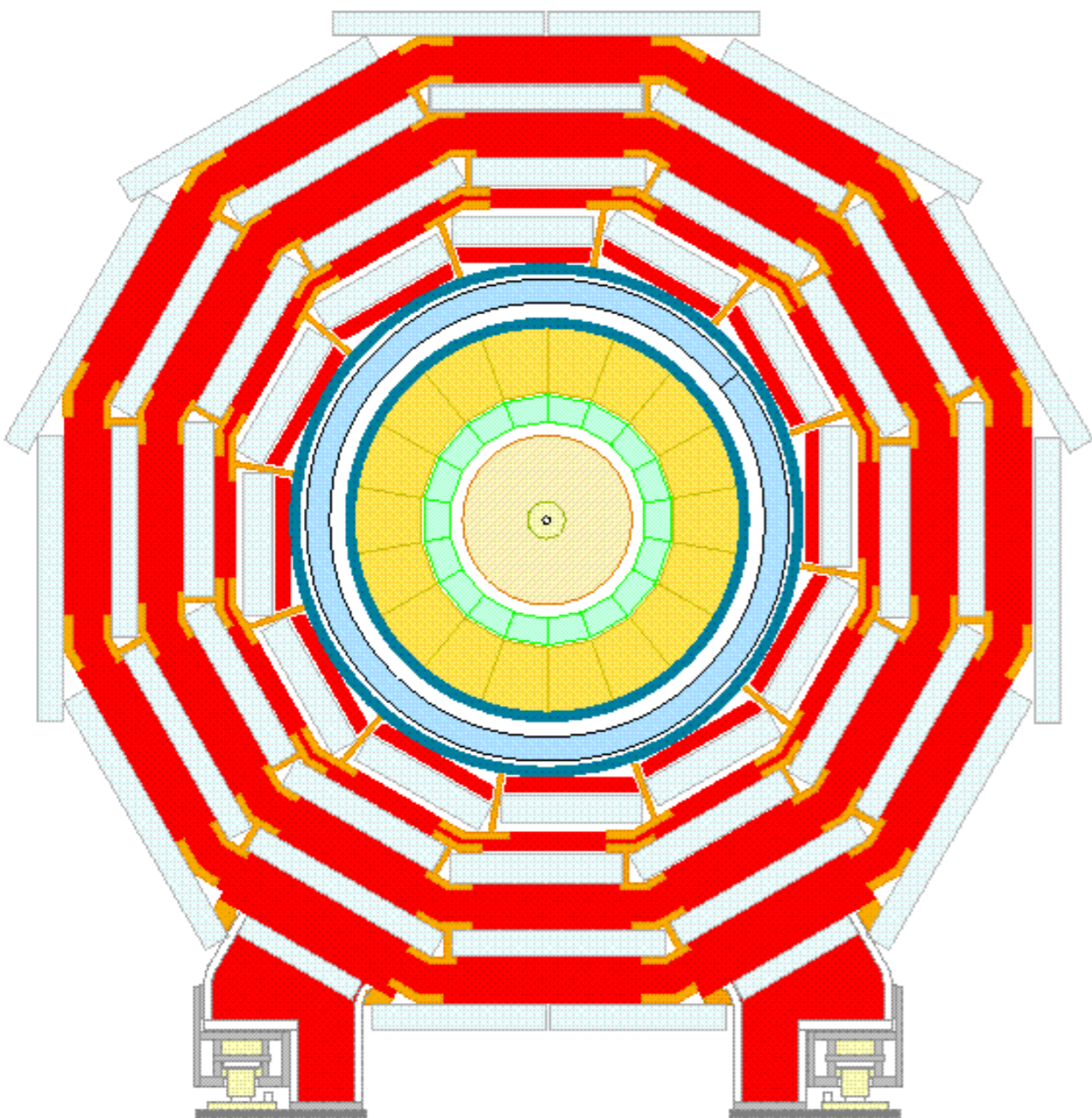
JINST 3 08004 (2008)

Longitudinal Slice



21 m

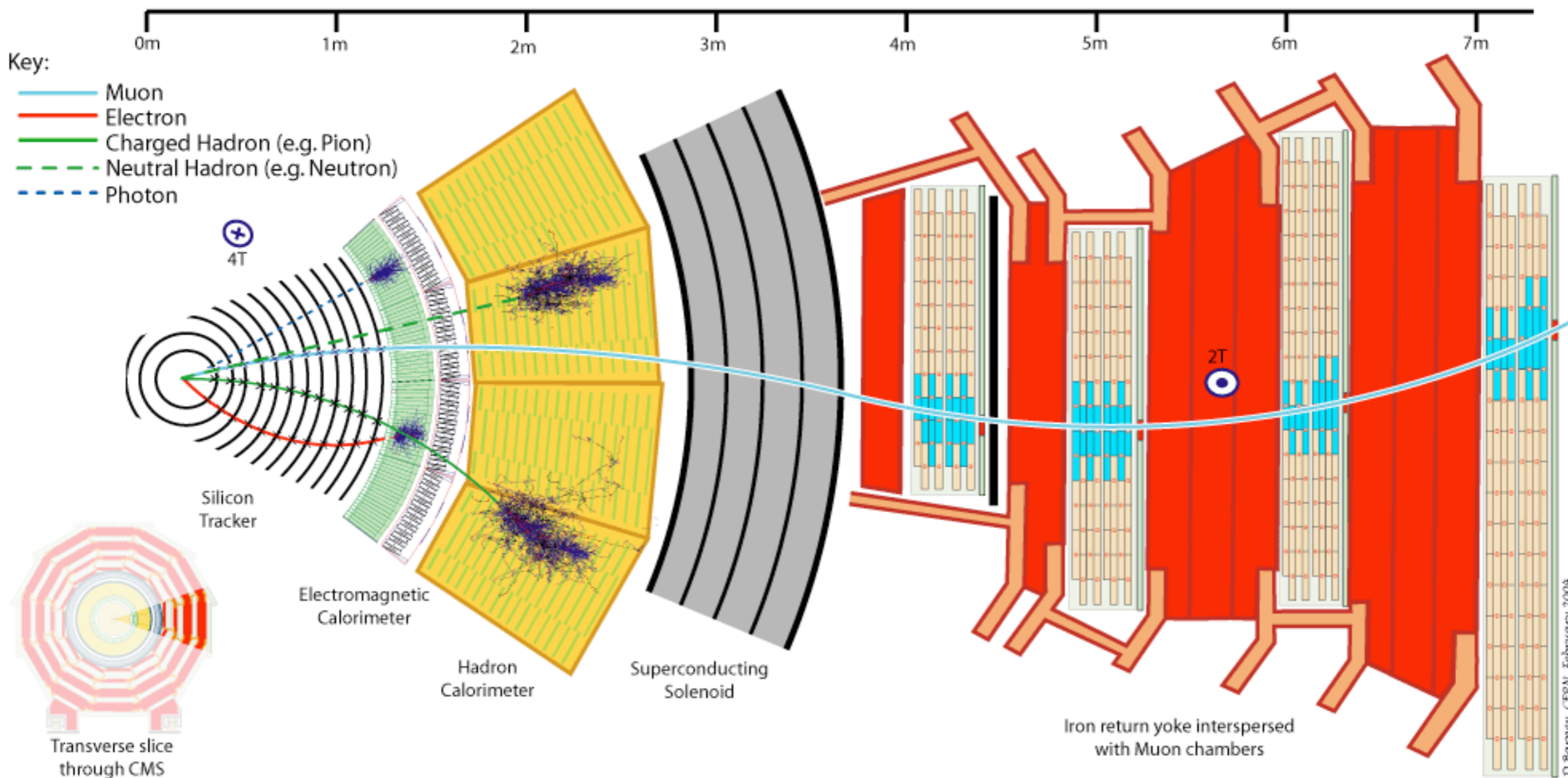
Transverse Slice



15 m

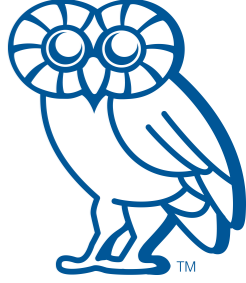


Transverse slice through CMS





CMS data-taking periods



- Cosmic Ray Run
 - months-long commissioning runs in Fall 2008, 2009
 - many detector commissioning papers:
 - Special issue of JINST 05
- Beam collisions
 - $\sqrt{s}=900$ GeV @ LHC injection energy
 - first LHC collisions December 2009
 - $\sqrt{s}=2.36$ TeV
 - December 2009
 - $\sqrt{s}=7$ TeV
 - since 30 March 2010

The New York Times

LATEST NEWS

TUESDAY, MARCH 30, 2010

Large Hadron Collider Finally Smashing Properly

BY DENNIS OVERBYE
MARCH 30, 2010

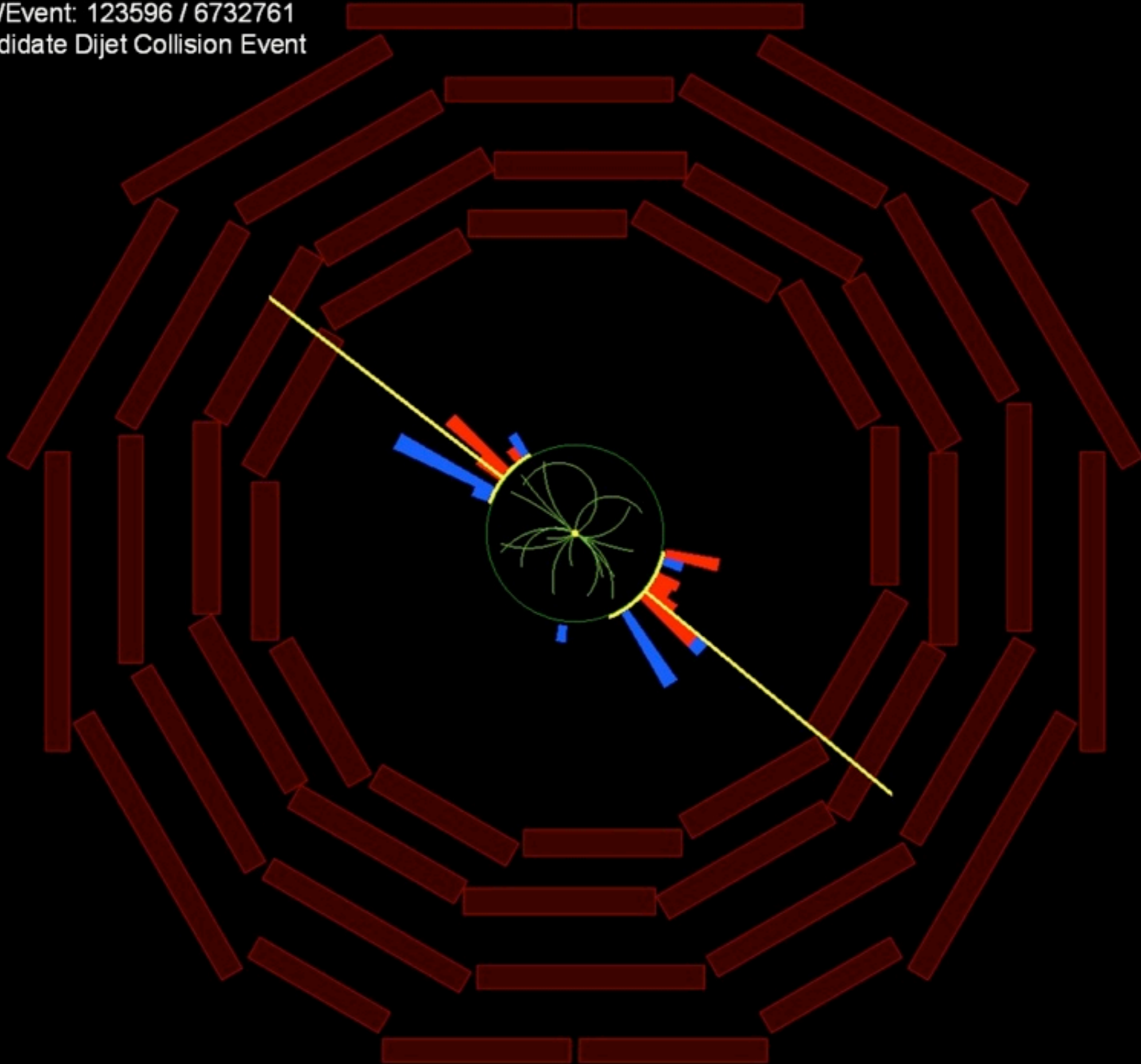
PASADENA, Calif. — After 16 years and \$10 billion — and a long morning of electrical groaning and sweating — there was joy in the meadows and tunnels of the Swiss-French countryside Tuesday: the world's biggest physics machine, the Large Hadron Collider, finally began to collide





CMS Experiment at the LHC, CERN
Date Recorded: 2009-12-06 07:18 GMT
Run/Event: 123596 / 6732761
Candidate Dijet Collision Event

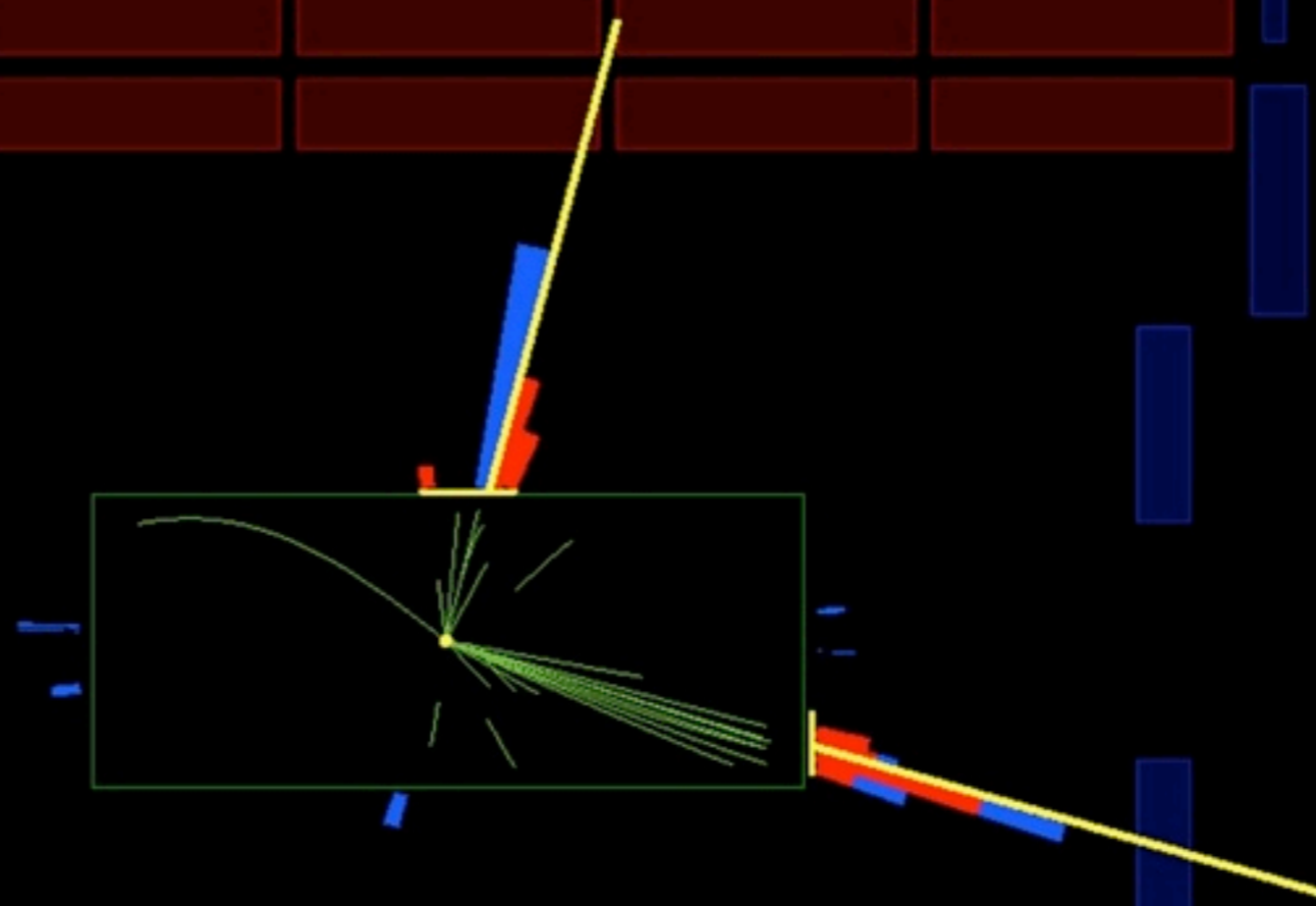
$\sqrt{s}=900$ GeV

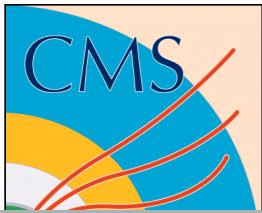




CMS Experiment at the LHC, CERN
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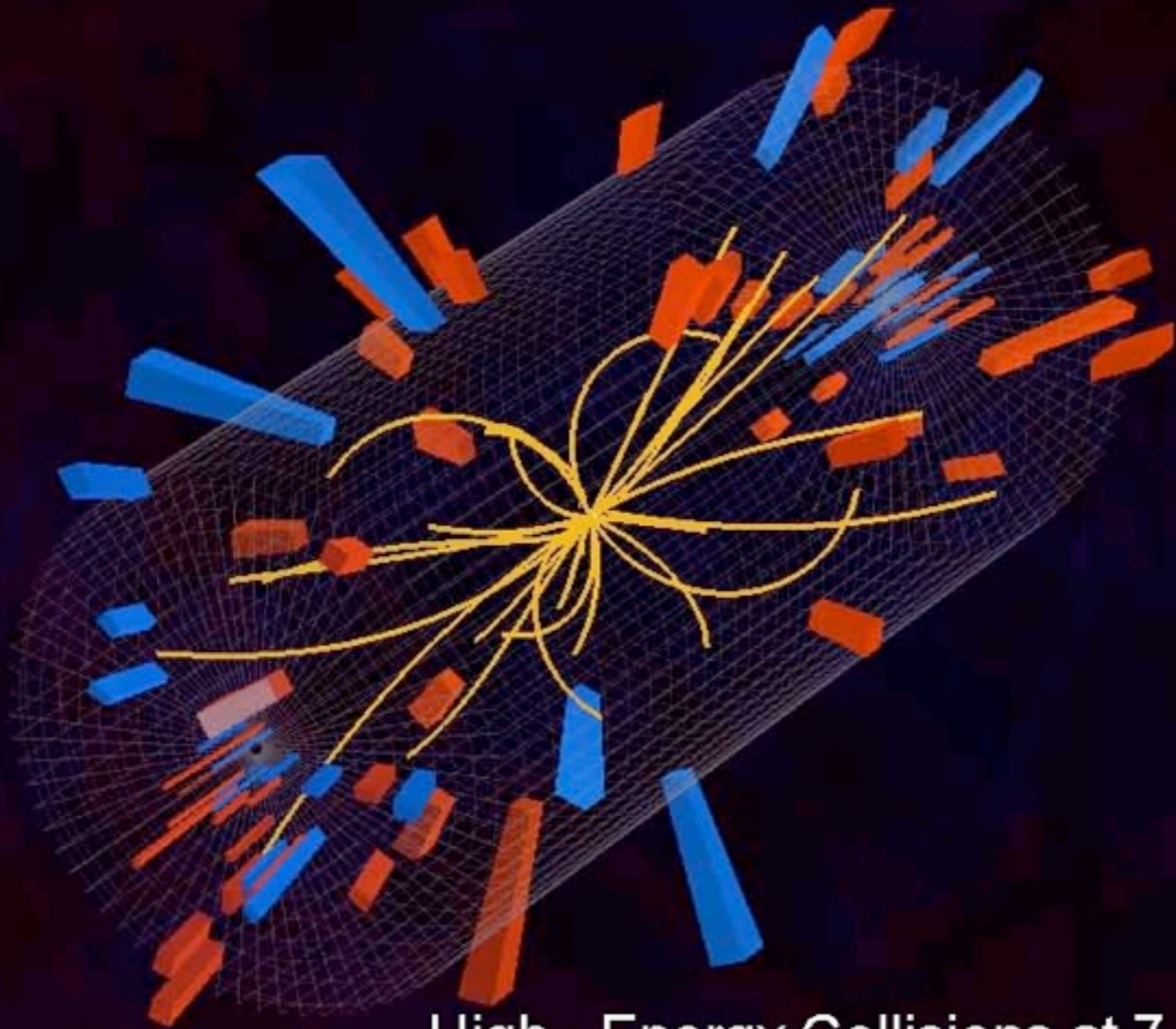




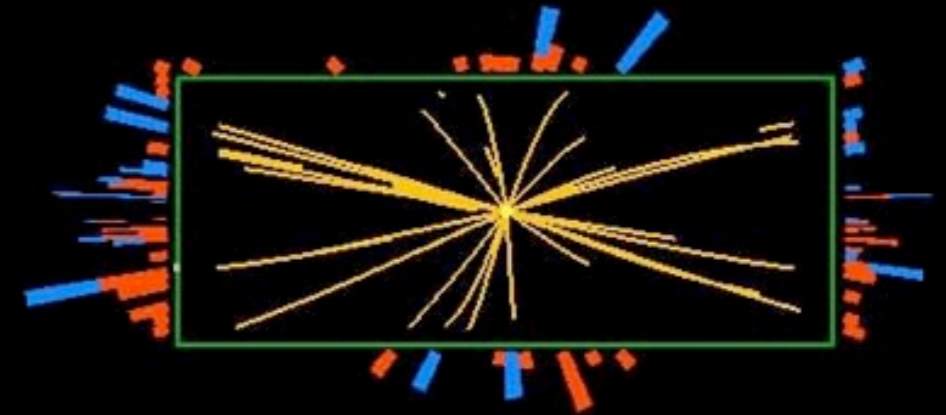
7 TeV



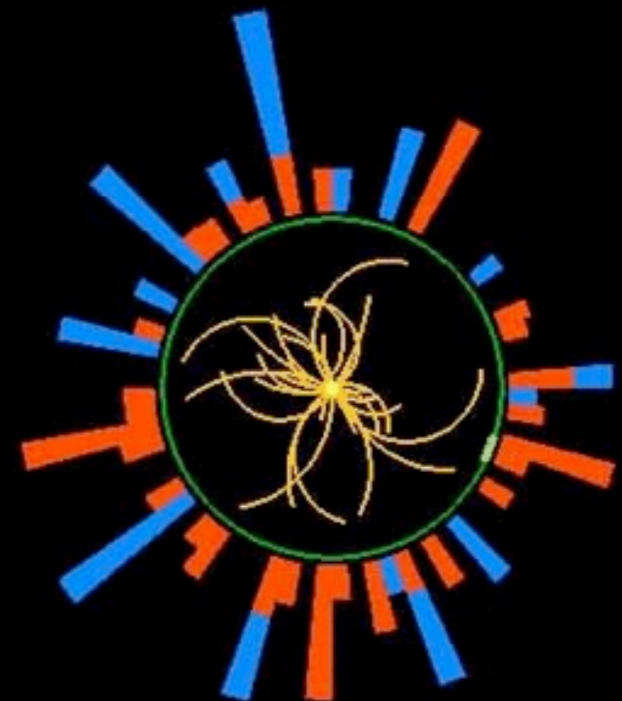
CMS Experiment at LHC, CERN
Data recorded: Tue Mar 30 12:58:48 2010 CEST
Run/Event: 132440 / 2737921
Lumi section: 124
Orbit/Crossing: 32323764 / 1



High - Energy Collisions at 7 TeV
LHC @ CERN
30.03.2010

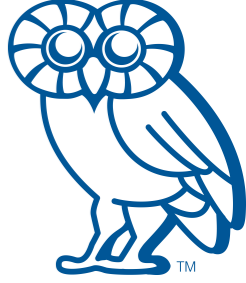


Rho Phi



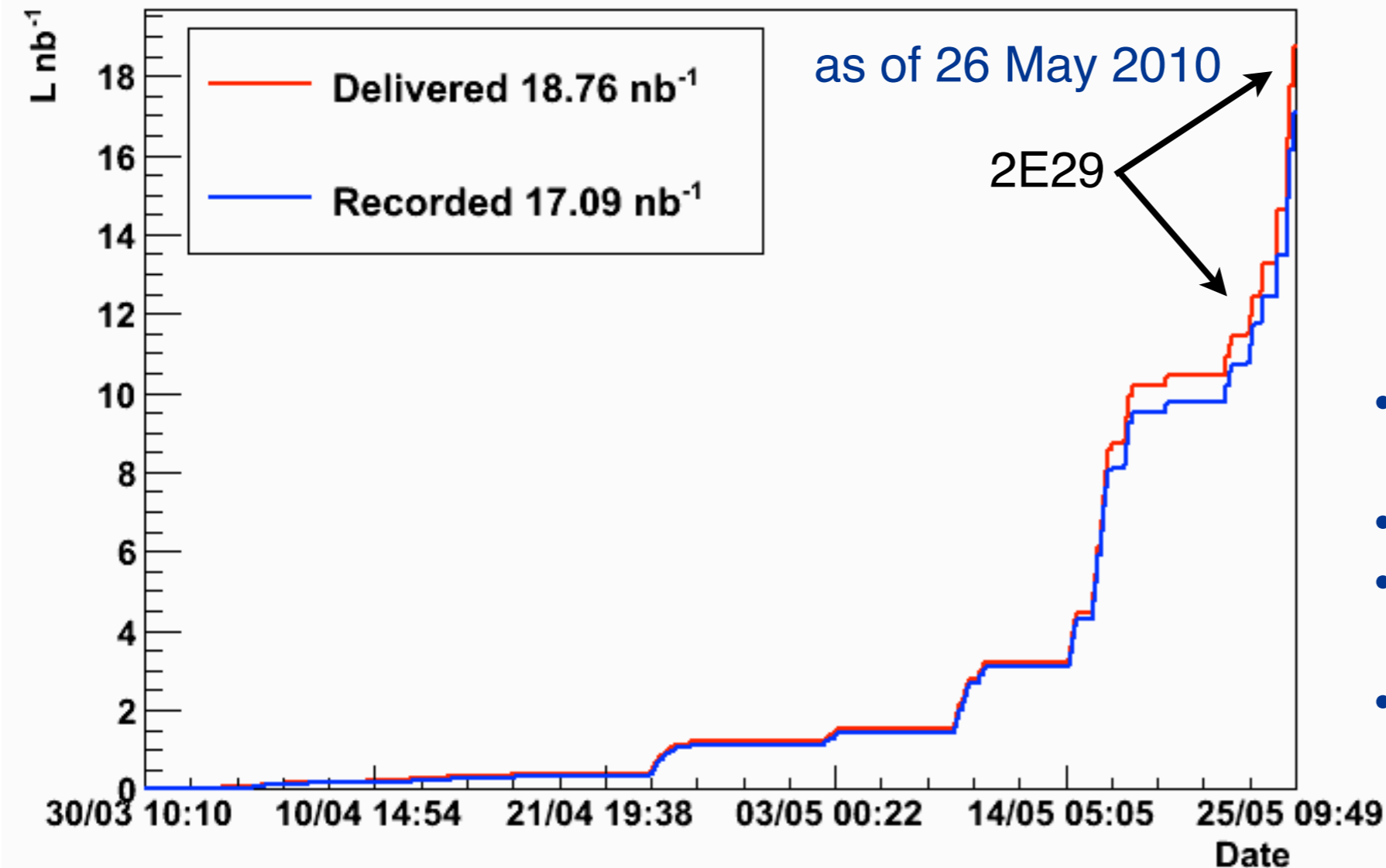


Luminosity



- 2010 7 TeV running since 30 March
 - LHC achieved $\mathcal{L}_{\text{peak}}=2\times 10^{29} \text{ cm}^{-2}\text{s}^{-1}$ with 8 colliding bunches
 - CMS data taking efficiency $> 90\%$

CMS: Integrated Luminosity 2010



2010-2011 Run
ICHEP goal: 1-10 pb^{-1}
2010 goal: 100 pb^{-1}
2011 goal: 1000 pb^{-1}

- *Very* much still in LHC commissioning phase
- CMS is commissioning too
- Improvements come in steps on a geometric growth curve
- Most lumi will come at the end of any period (e.g. ICHEP)

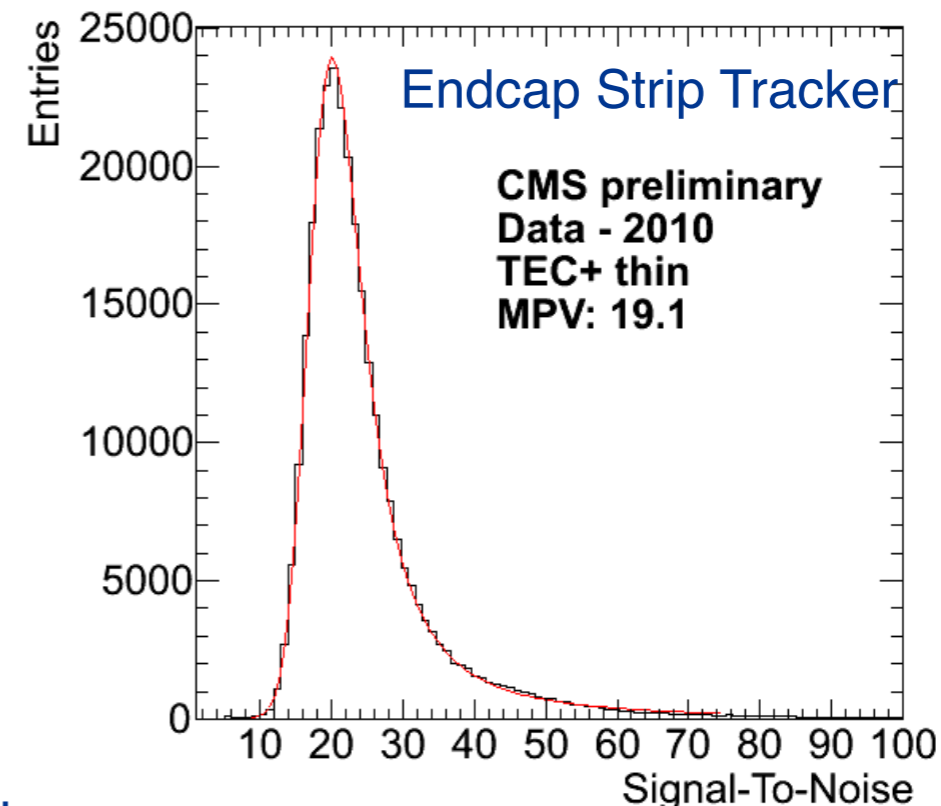
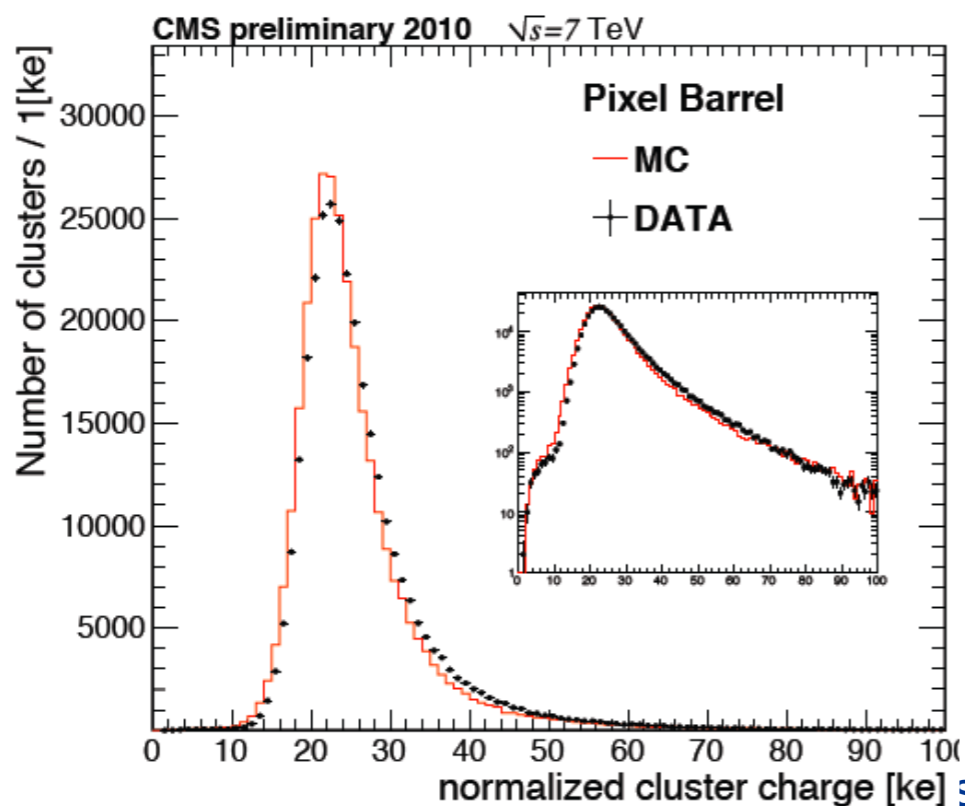
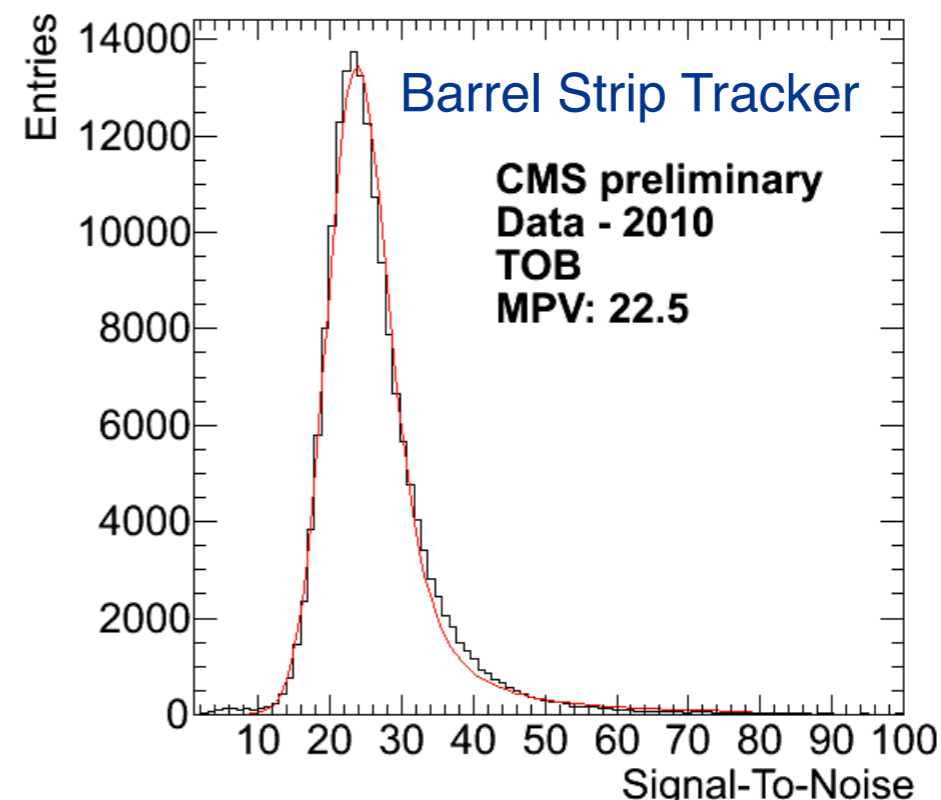
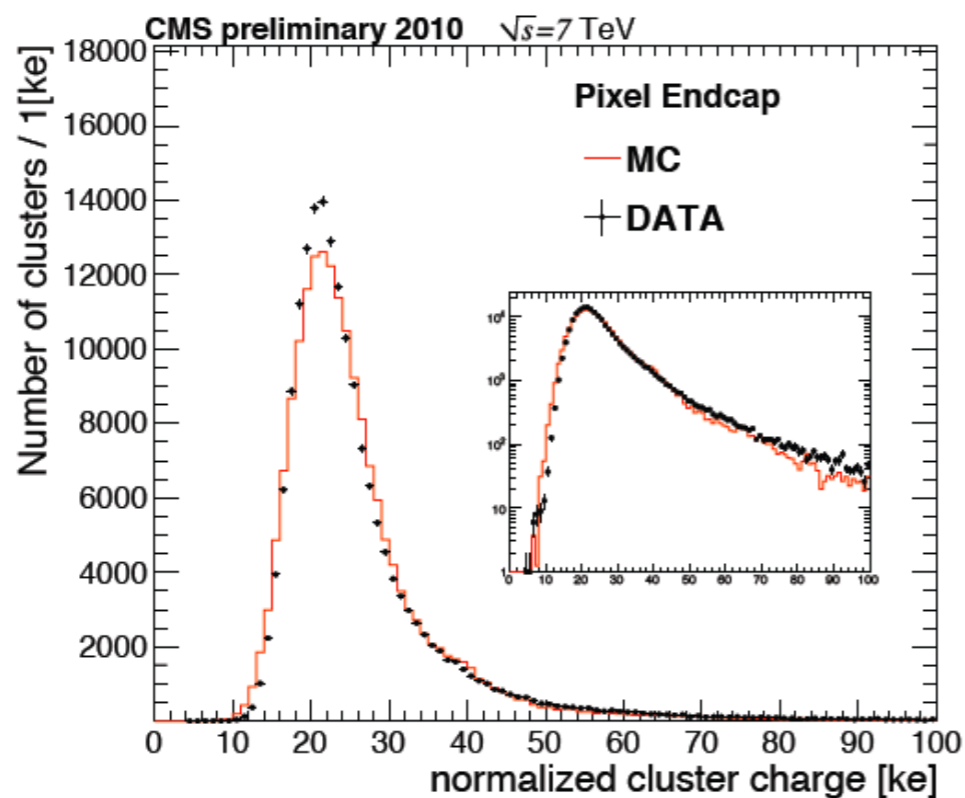


Detector Performance: Tracker



New! technique from JINST 5 T03007 (2010) and JINST 5 T03008 (2010)

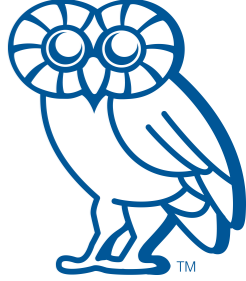
- Basic responses of detectors described well in beam data



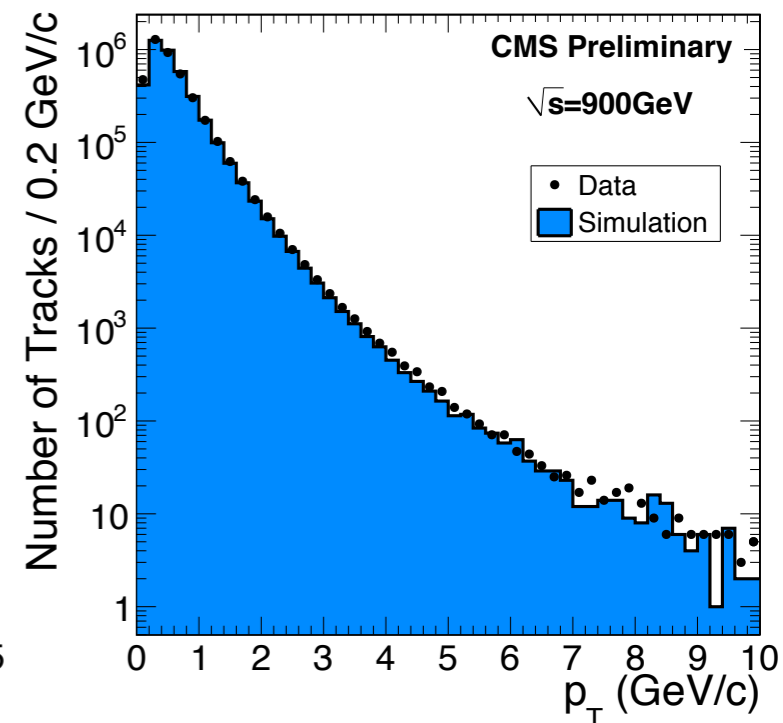
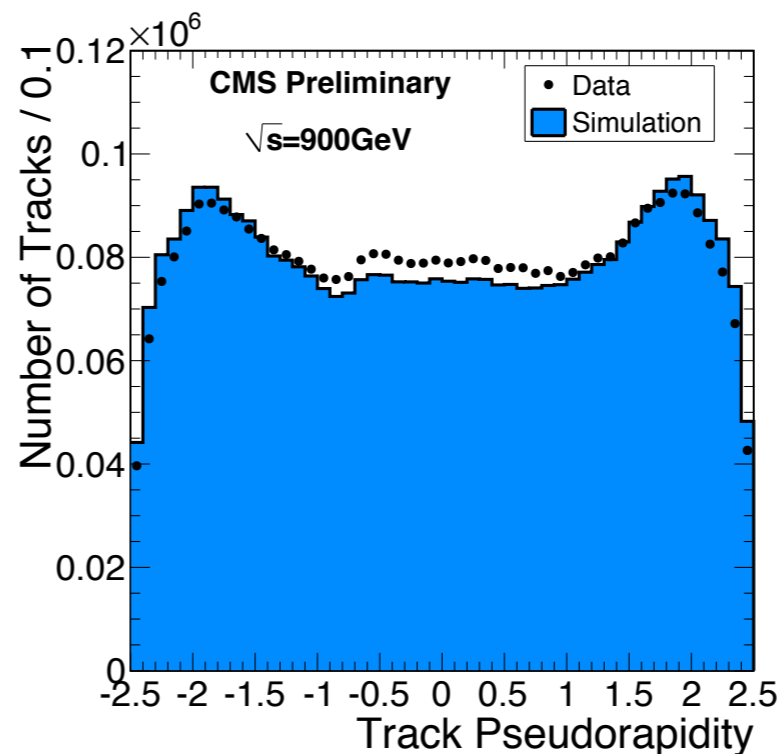
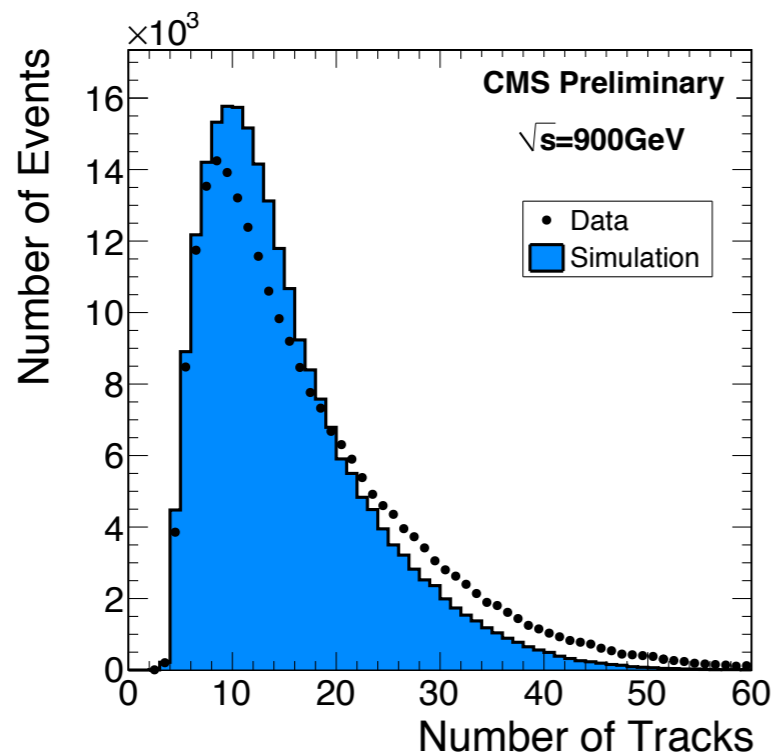
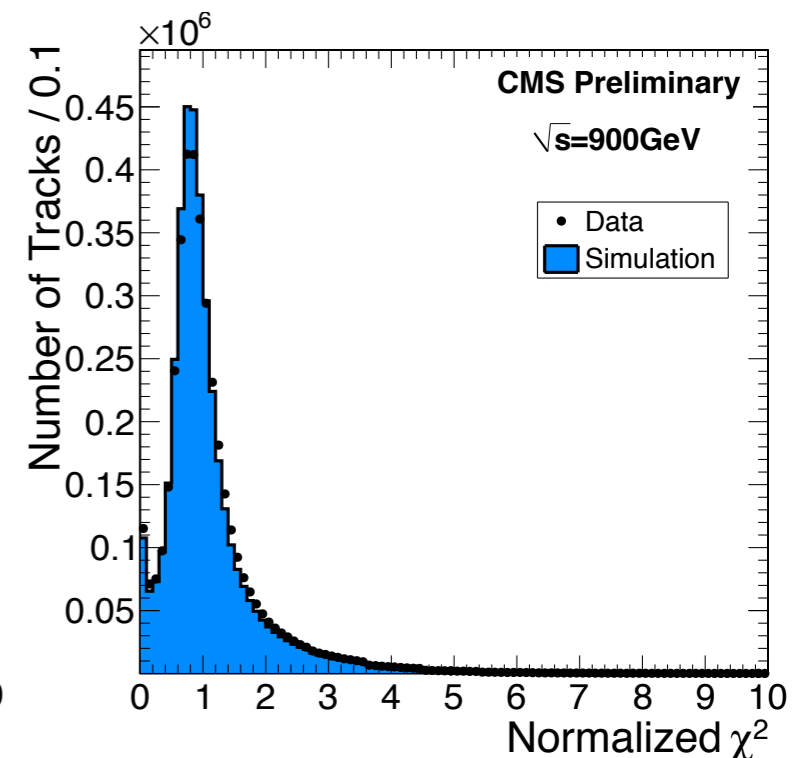
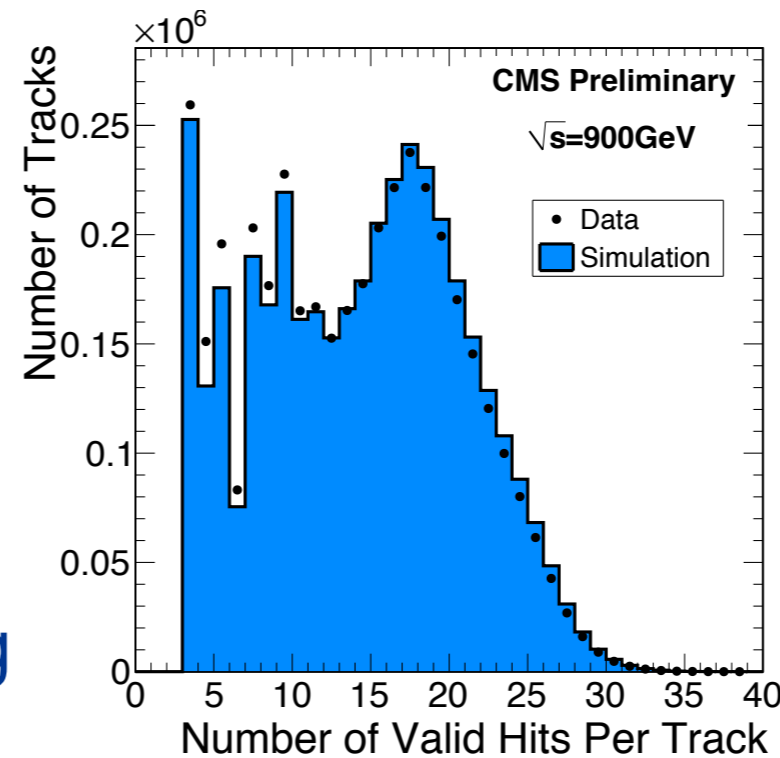


Charged Track Reconstruction

CMS PAS TRK 10-001



- Data/MC comparison 900 GeV in minimum Bias events
 - High purity track selection
 - χ^2/ndof and N_{hit}
 - $|d_{xy}/\sigma|$
 - $\sigma_{p_T}/p_T < 0.1$
 - $|d_z/\sigma| < 10$
- Need for some physics tuning
 - Pythia simulation



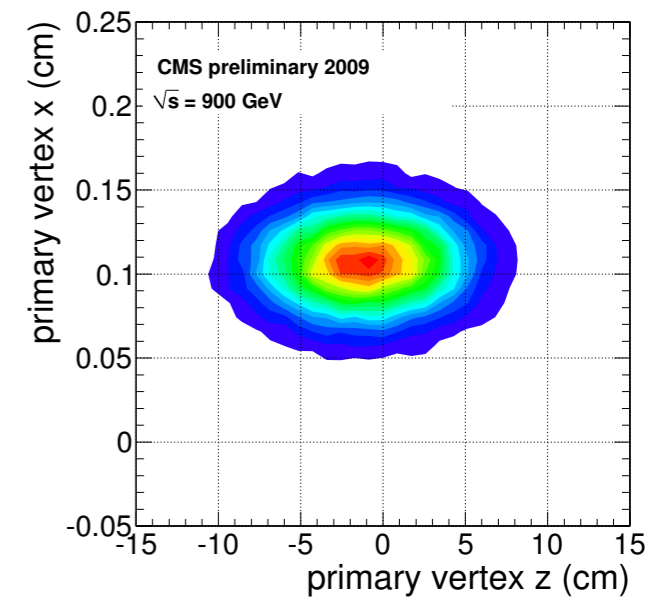
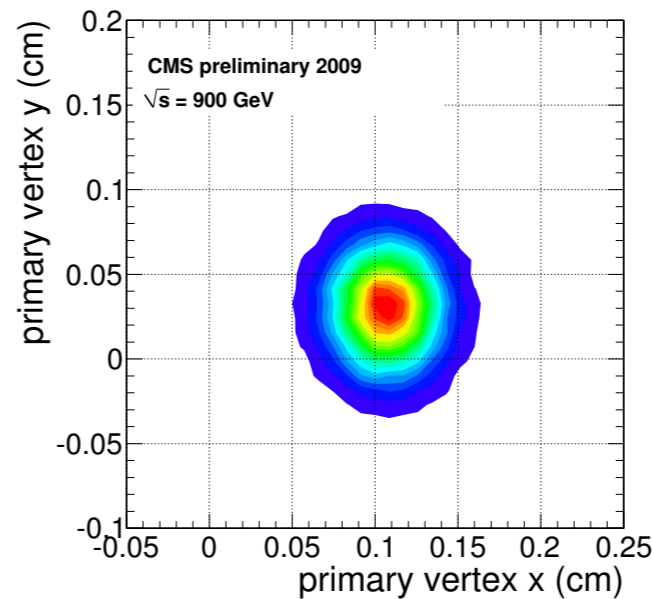
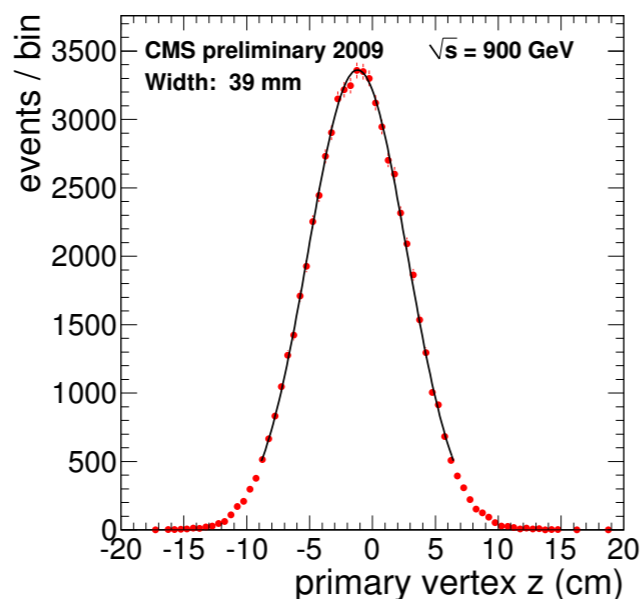
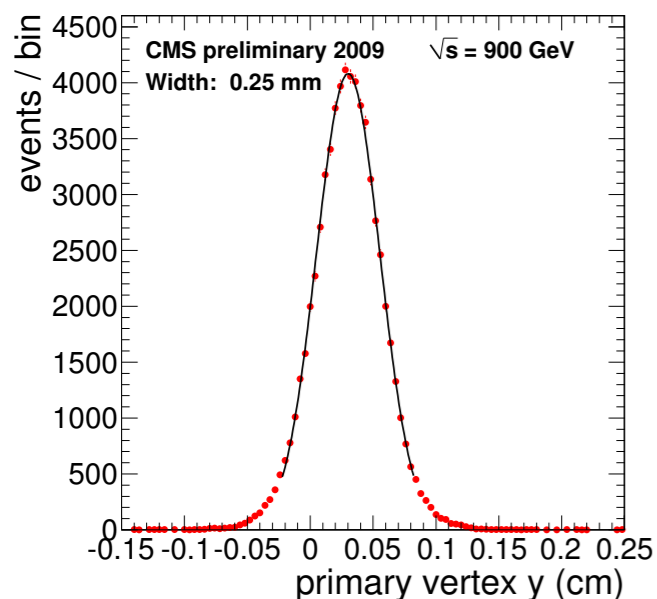


Primary Vertex Reconstruction

CMS PAS TRK 10-001

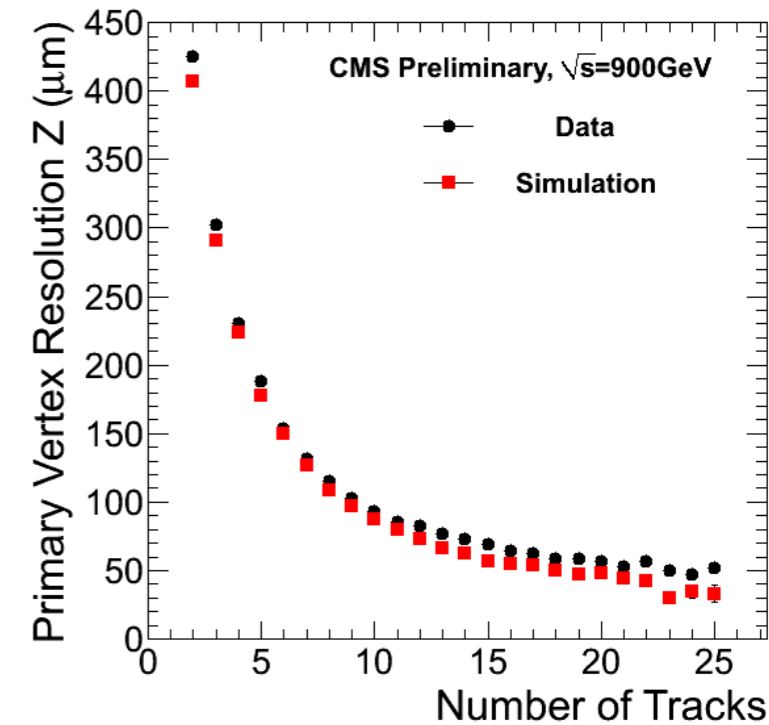
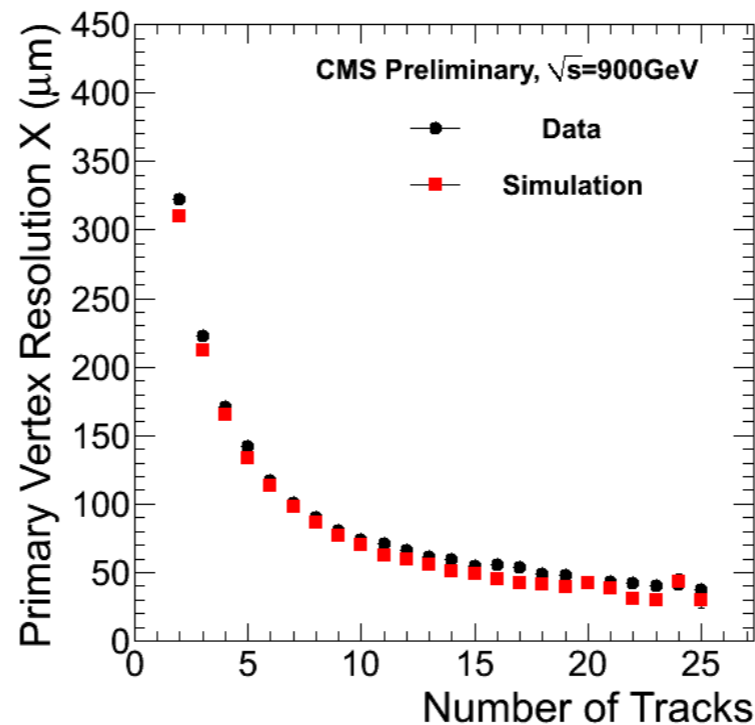


- Adaptive vertex fit to prompt tracks
 - using impact parameters & errors as described in CMS Note 2007/008



PV Position during single fill

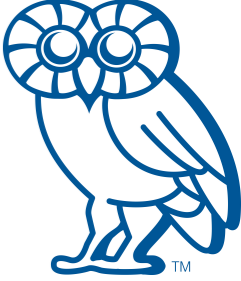
- Dominated by beam size
 - x,y : 0.25 mm
 - z: 39 mm
- PV Position tracked online
 - fed to LHC
- PV Resolution well modeled in simulation



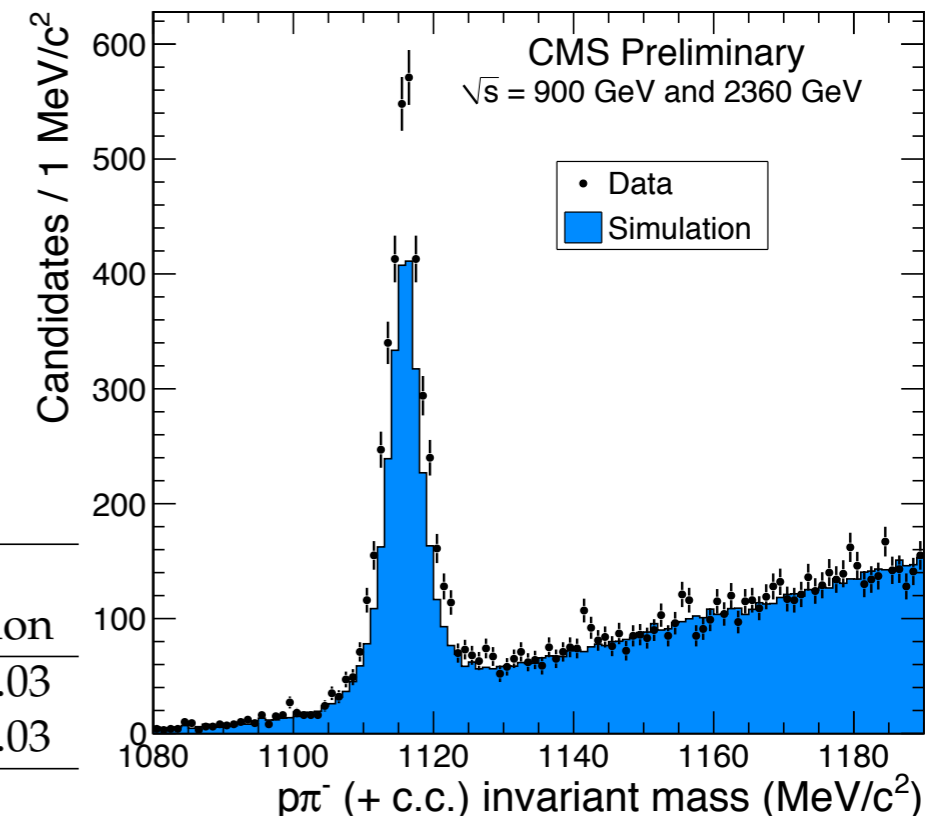
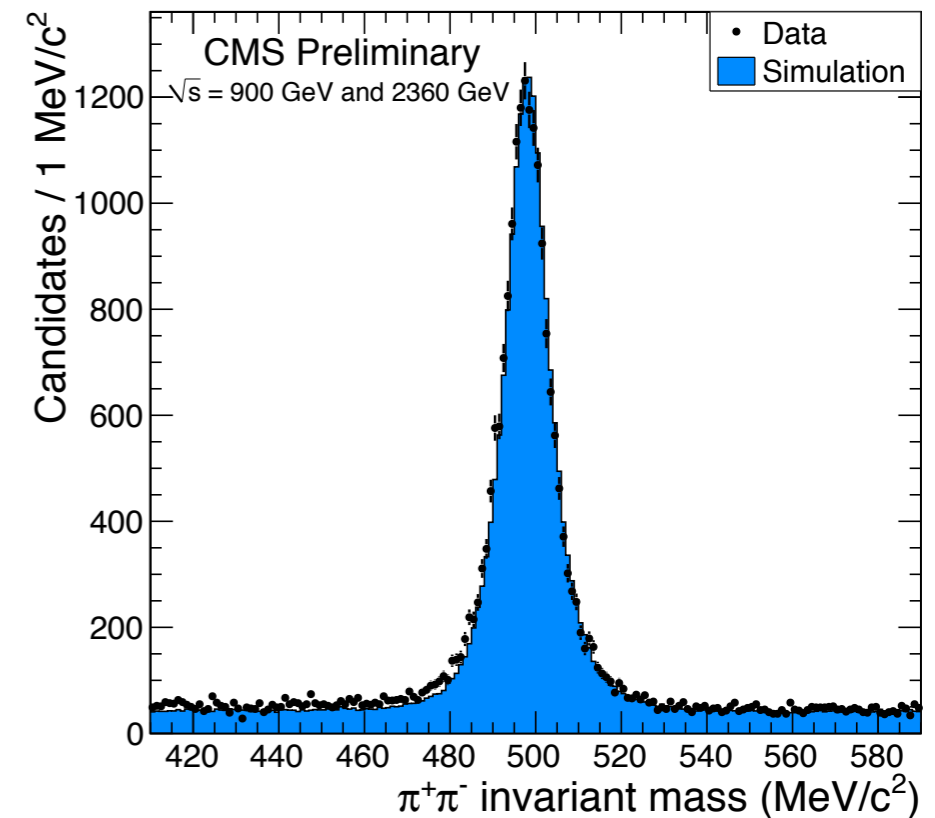


V⁰ Reconstruction

CMS PAS TRK 10-001



- Look for detached vertexes
 $K_S \rightarrow \pi^+ \pi^-$ & $\Lambda \rightarrow p \pi^-$ ($c\tau > 1 \text{ cm}$)
 - Track & Vertex selection
 - $N_{\text{hit}} > 5$ & track $\chi^2/\text{ndof} < 5$
 - impact parameter $d_{xy} > 0.5\sigma$
 - vertex $\chi^2/\text{ndof} < 7$
 - $> 15\sigma$ separation in x-y from beam spot
- Clear signals seen
 - masses, resolutions & lifetimes in agreement with expectations
 - More Λ in data \rightarrow pythia tune
 - Normalized to K_S yield



V^0	Mass (MeV/c^2)			σ (MeV/c^2)	
	Data	Simulation	PDG	Data	Simulation
K_S^0	497.68 ± 0.06	498.11 ± 0.01	497.61 ± 0.02	7.99 ± 0.14	7.63 ± 0.03
Λ^0	1115.97 ± 0.06	1115.93 ± 0.02	1115.683 ± 0.006	3.01 ± 0.08	2.99 ± 0.03



More long-lived particles

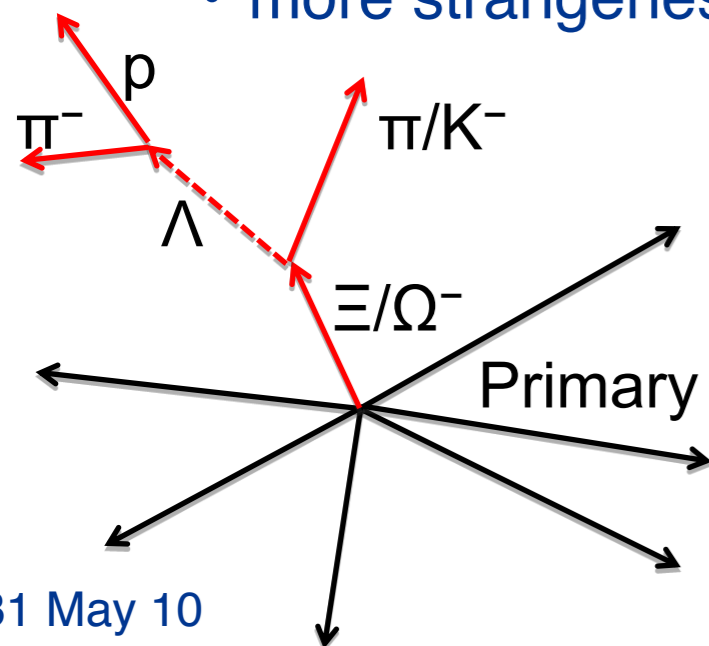
CMS DPS 2010/013



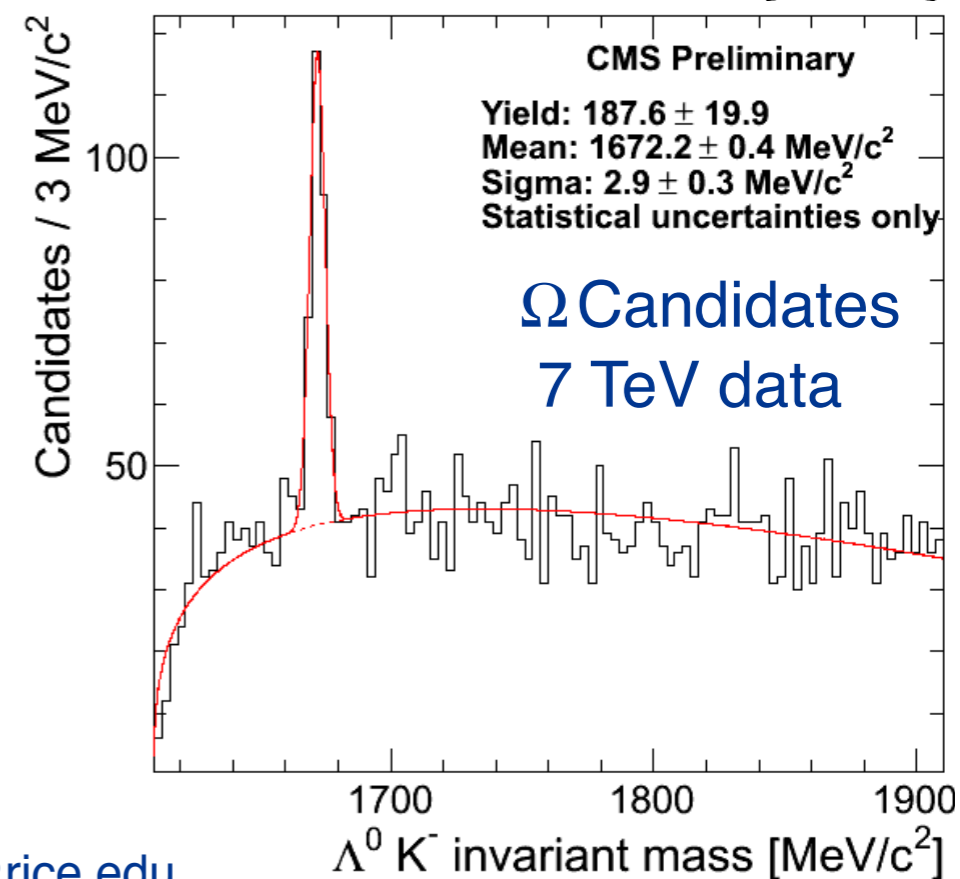
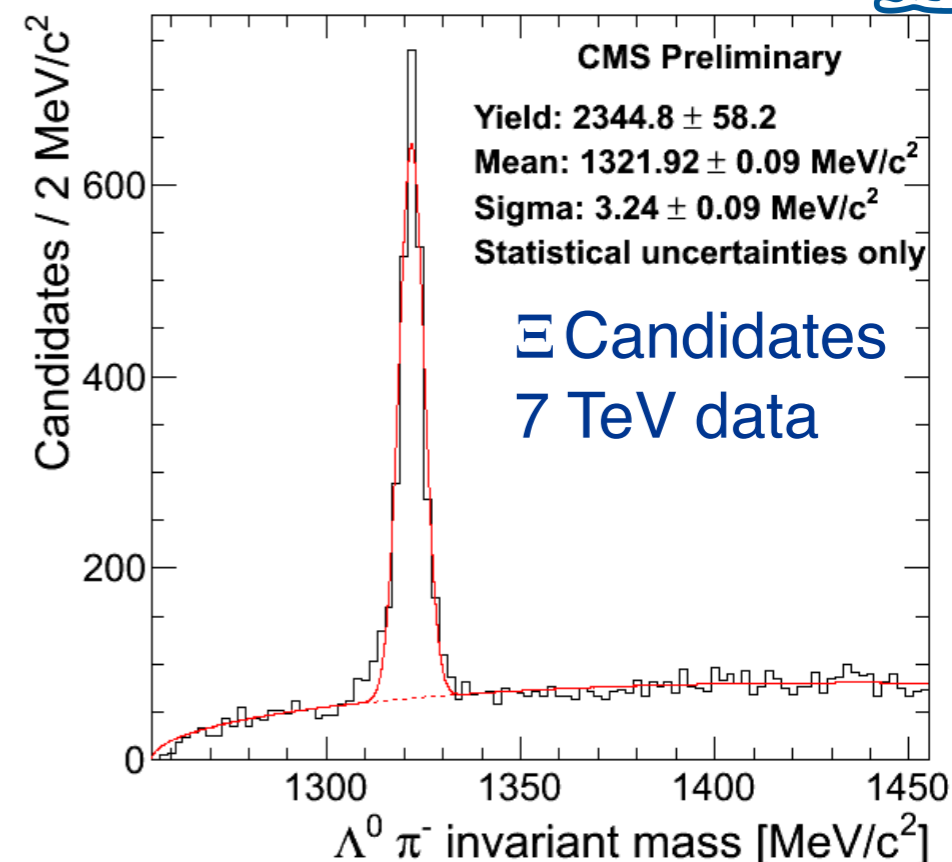
- Combine Λ^0 with displaced track: $d_0 > 0.5\sigma$
 - $m(p\pi^-)$ within 8 MeV of Λ
 - kinematic fit to Λ improves \mathbf{p}_Λ determination
 - π^- hypothesis: $\Xi^- \rightarrow \Lambda^0 \pi^-$
 - K^- hypothesis: $\Omega^- \rightarrow \Lambda^0 K^-$
 - All tracks $d^{3D} > 3\sigma$ from refit primary vertex
 - common vertex for Λ and π/K : $P(\chi^2) > 1\%$ & $v_{tx} > 4\sigma$

• Clear signals seen

- Mass and width in agreement with MC & PDG
- Yields higher than MC \rightarrow improving pythia tune
 - more strangeness, worse agreement




Demonstration of tracking & vertexing in CMS

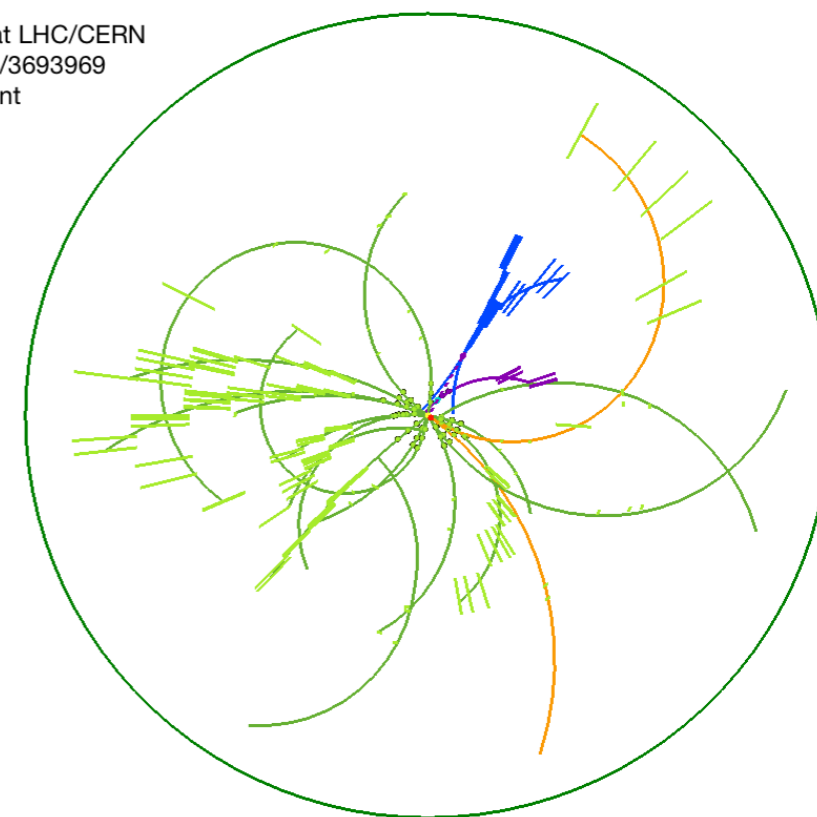





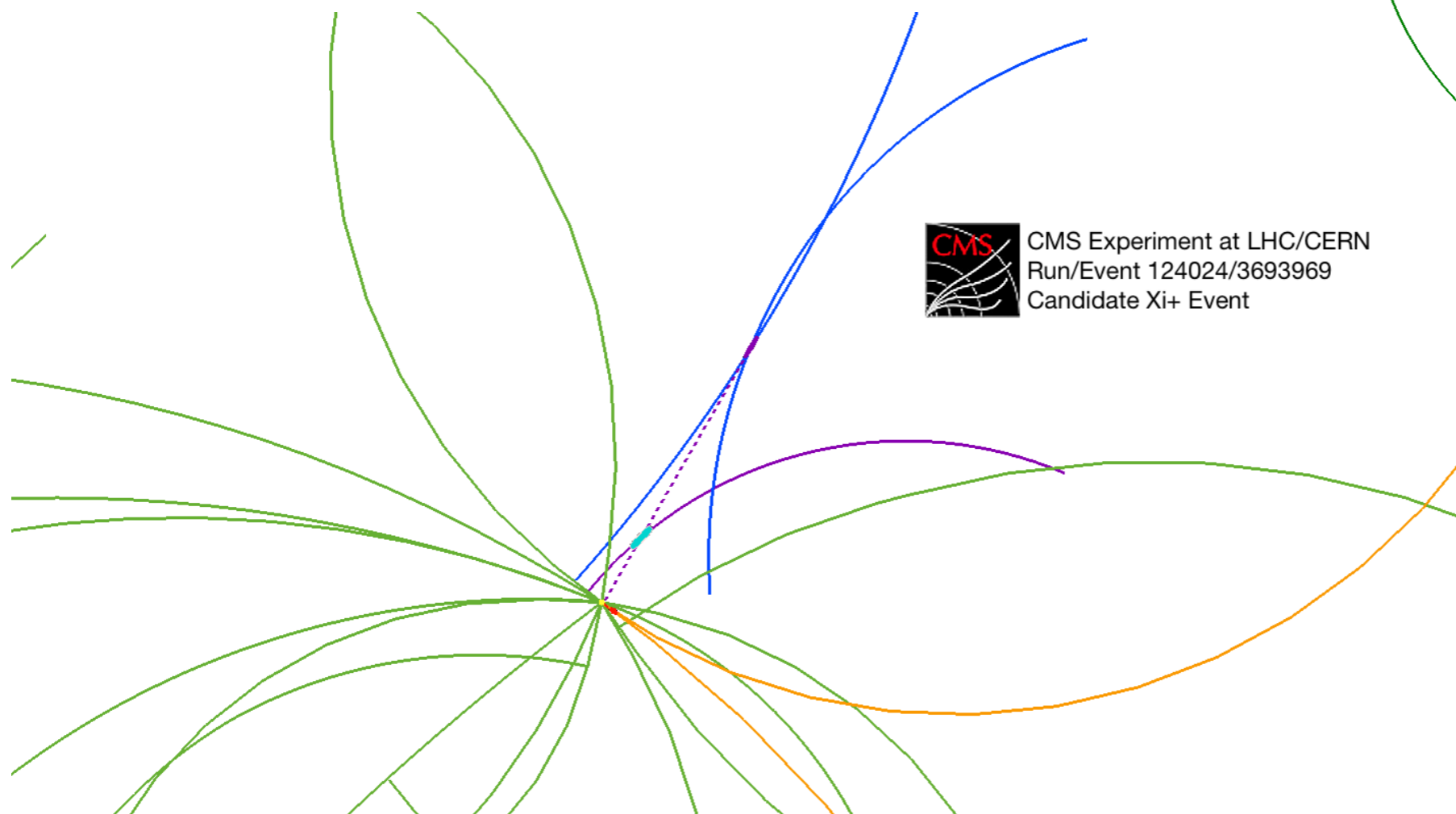
Candidate $\Xi^+ \rightarrow \bar{\Lambda}^0 \pi^+$

- $\Xi^+ \rightarrow \bar{\Lambda}^0 \pi^+$
- $\bar{\Lambda}^0 \rightarrow \bar{p} \pi^+$
- Additional $K_S \rightarrow \pi^+ \pi^-$

 CMS Experiment at LHC/CERN
Run/Event 124024/3693969
Candidate Xi+ Event



 CMS Experiment at LHC/CERN
Run/Event 124024/3693969
Candidate Xi+ Event





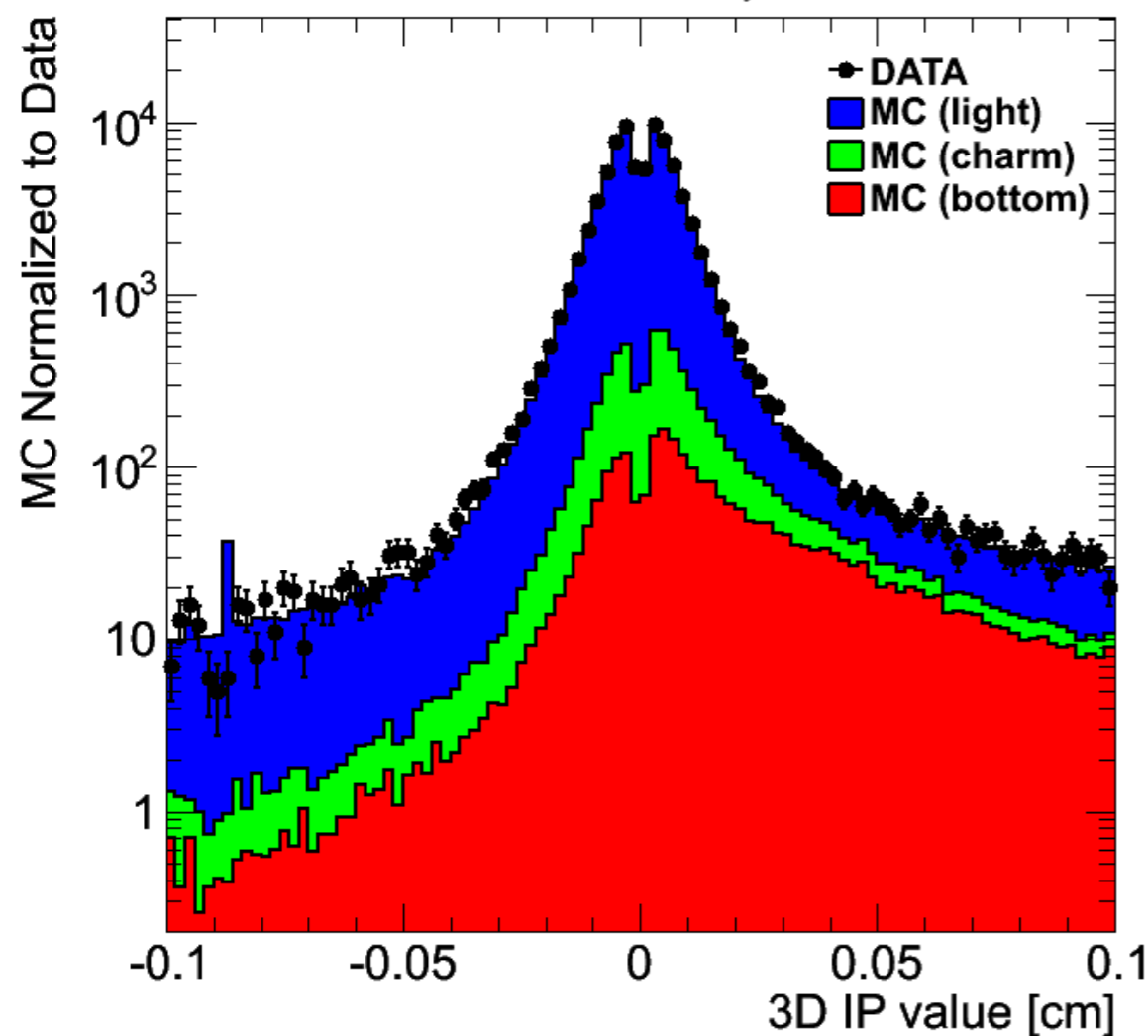
Detector Performance: B tagging



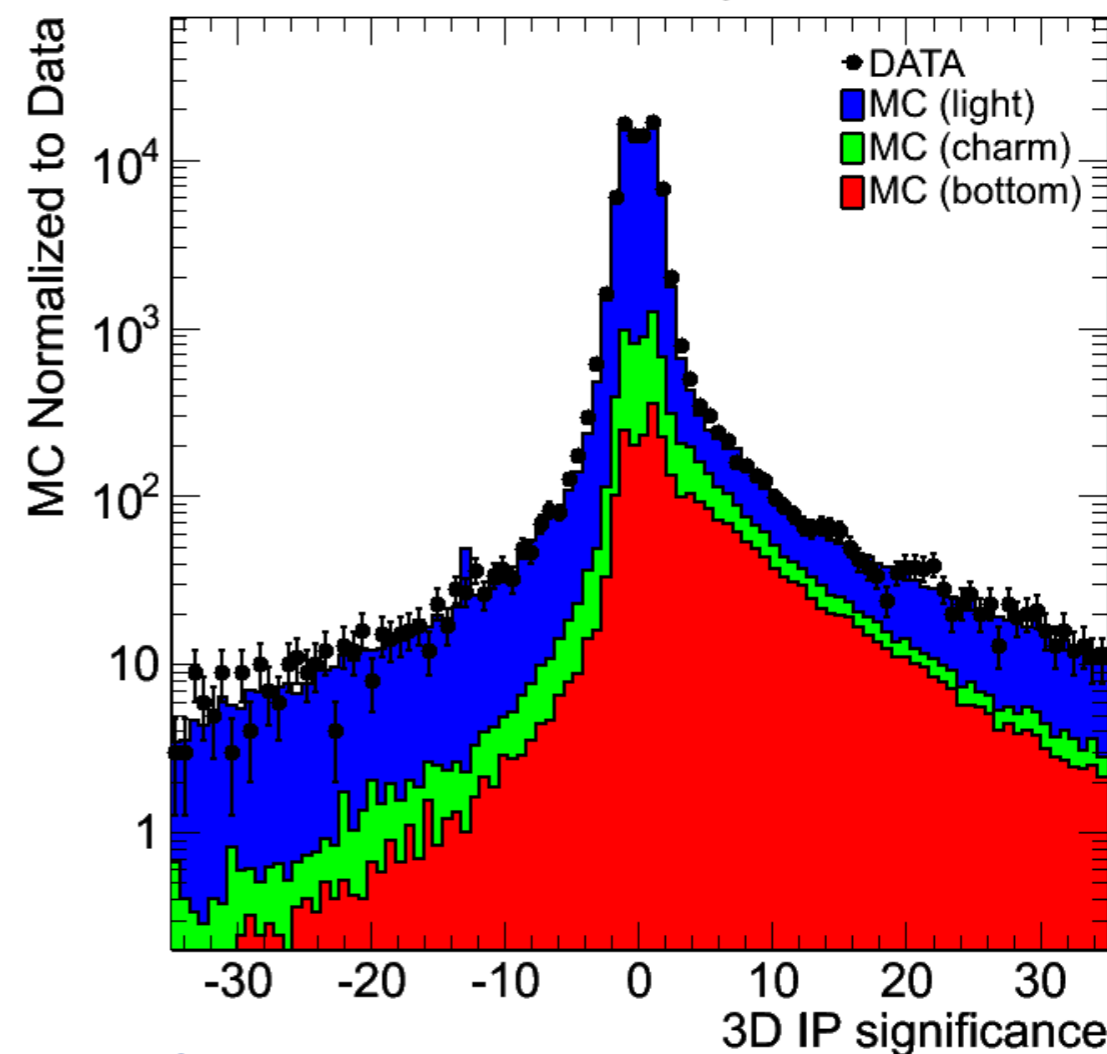
- Using 0.919 nb⁻¹ of 7 TeV data
- anti-kT jets R=0.5 (particle flow)
 - $p_T > 40$ GeV and $|\eta| < 1.5$
- MC sample: QCD and minbias mix
- 3D impact parameter (signed)

CMS DPS 2010/015

CMS Preliminary 2010



CMS Preliminary 2010





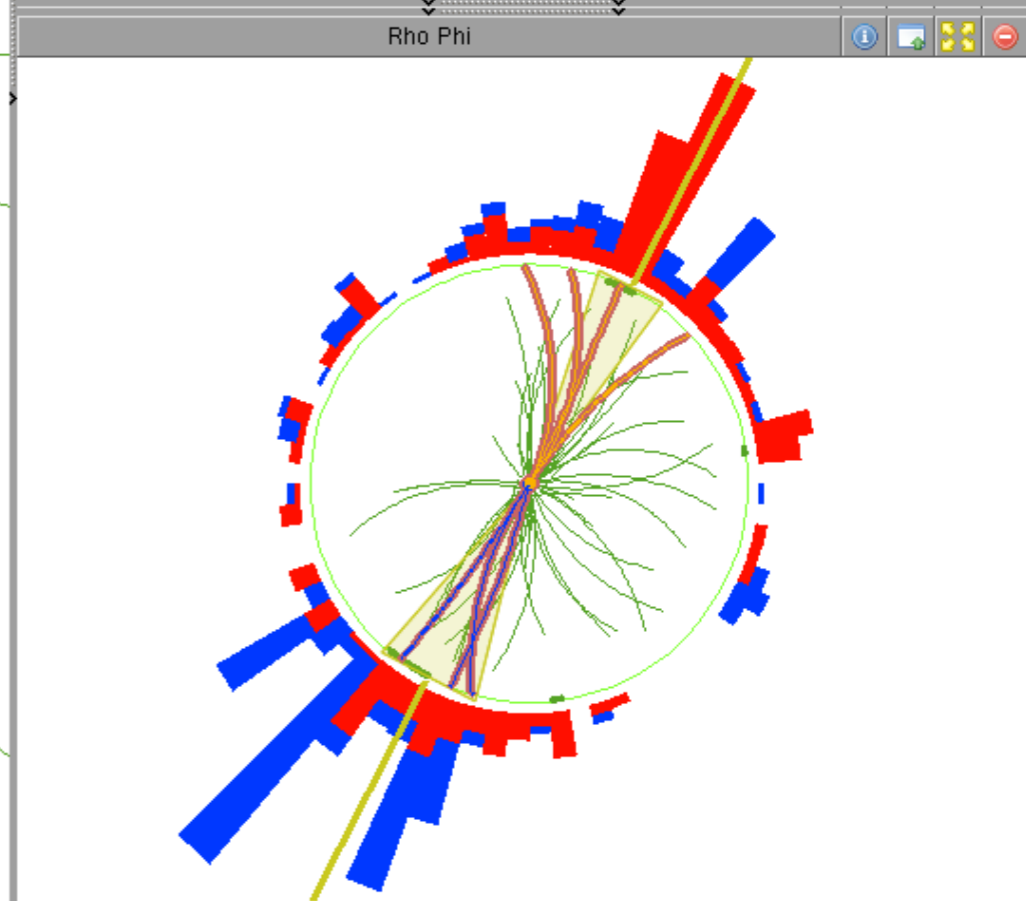
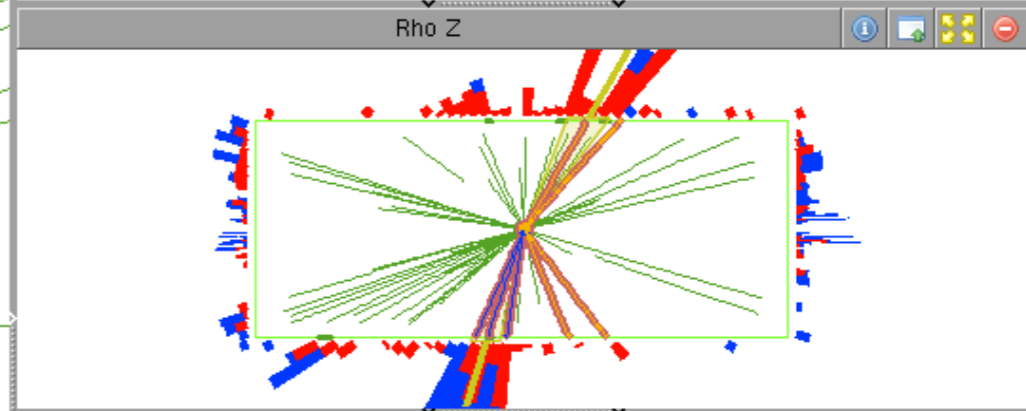
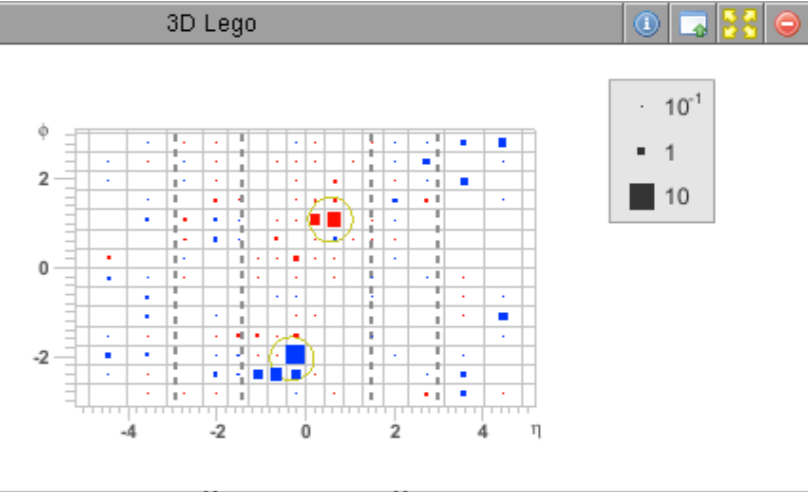
Event with 2 b-tagged jets



CMS Experiment at LHC, CERN
 Data Recorded: Sat Apr 24 08:31:20 2010 CEST
 Lumi section: 795
 Run / Event : 133874 / 64064942

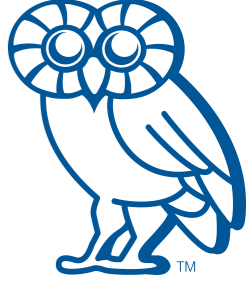
jet $p_T=43.7$ GeV
 $L_{3D}=6.3$ mm (43σ)
 $m_{SV}=2.9$ GeV
 $\chi^2/dof=6.3/5$

jet $p_T=40.3$ GeV
 $L_{3D}=8.6$ mm (55σ)
 $m_{SV}=3.1$ GeV
 $\chi^2/dof=15.9/3$



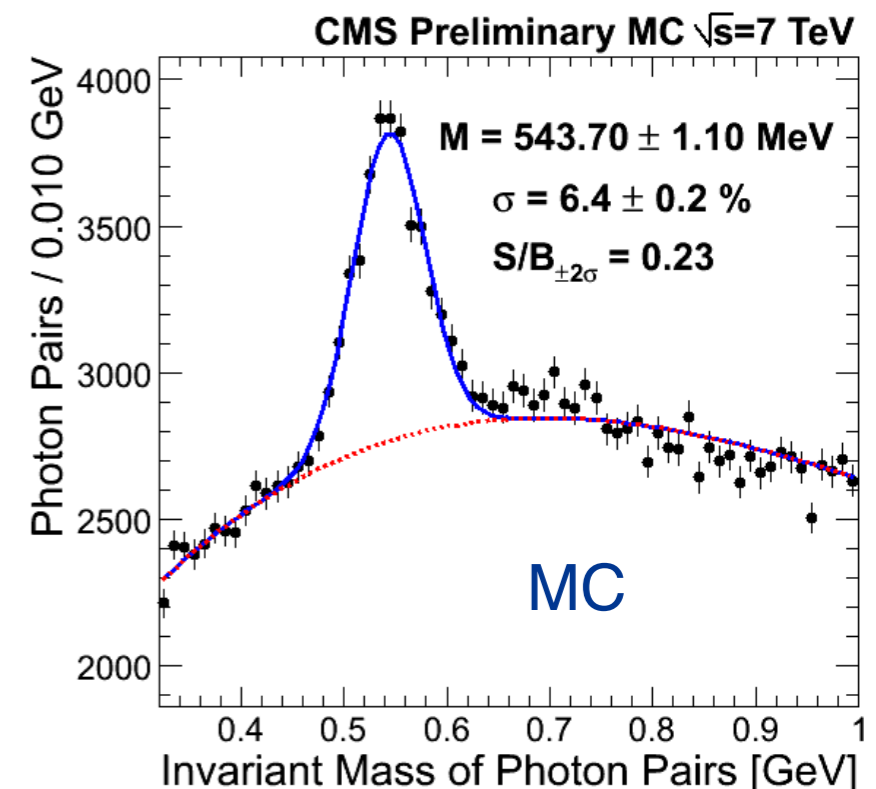
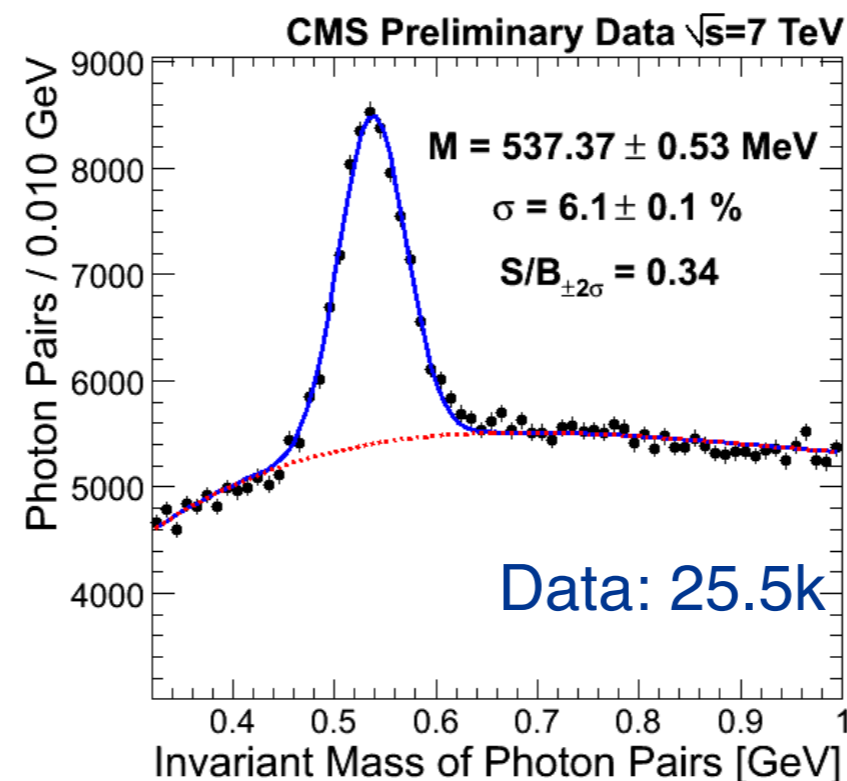
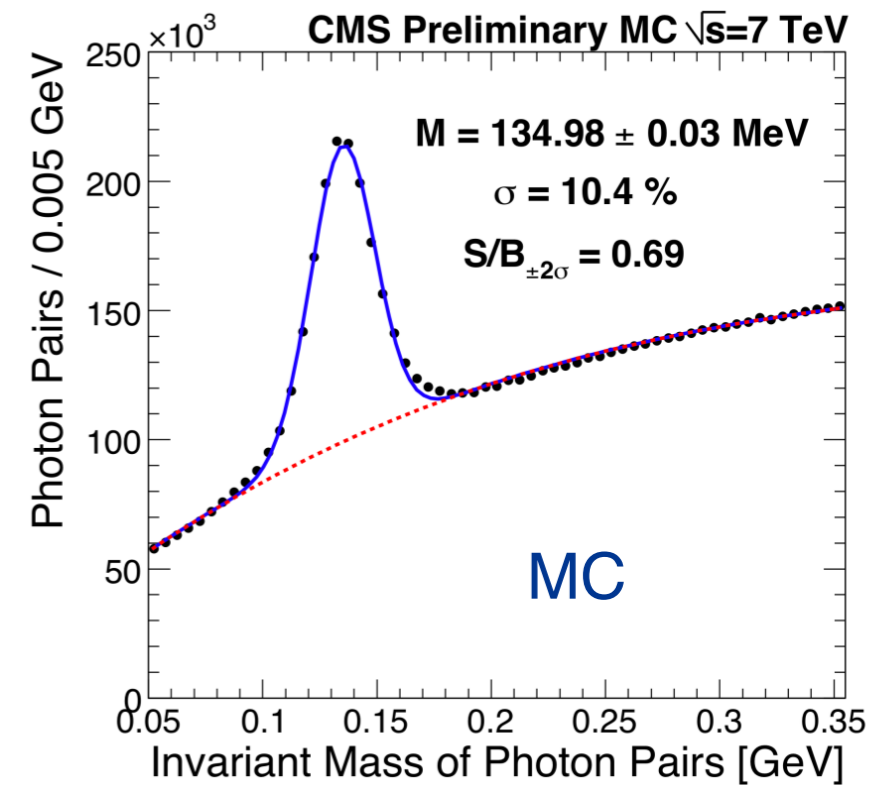
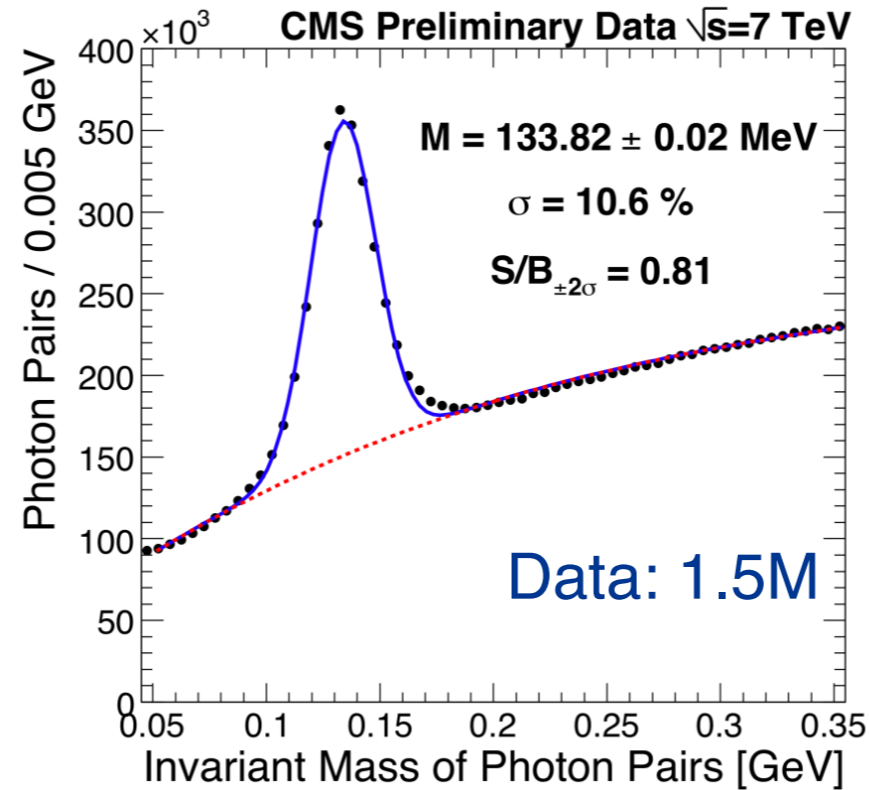


Electromagnetic Calorimeter: π^0 & η peaks



- Light diphoton resonances in 0.43 nb^{-1} of minimum bias data
- $\pi^0 \rightarrow \gamma\gamma$ selection
 - barrel γ only
 - γ shower shape
 - $p_T(\gamma) > 0.4 \text{ GeV}$
 - $p_T(\gamma\gamma) > 1 \text{ GeV}$
- $\eta \rightarrow \gamma\gamma$ selection
 - $p_T(\gamma) > 0.5 \text{ GeV}$
 - $p_T(\gamma\gamma) > 2.5 \text{ GeV}$
- Agreement on energy scale at $\sim 1\%$ level
 - width well modeled
- Now used in dedicated stream for ECAL calibration & monitoring

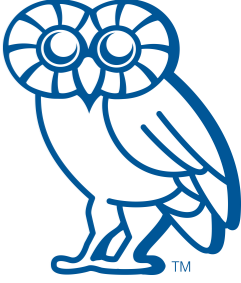
0.43 nb^{-1}





Detector Performance: Jets

CMS DPS 2010/014

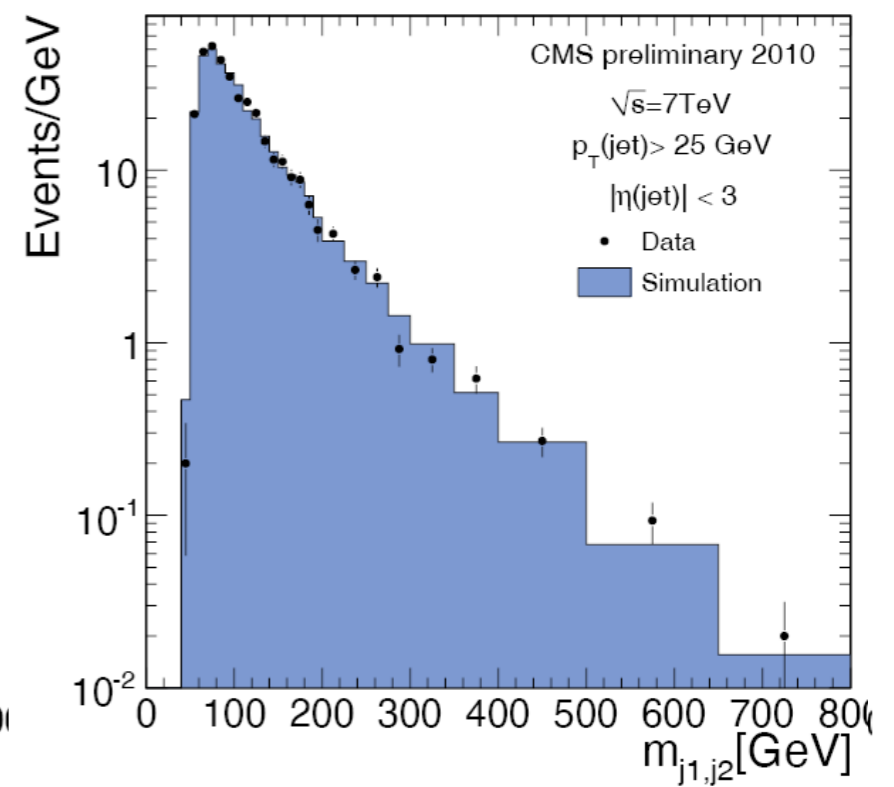
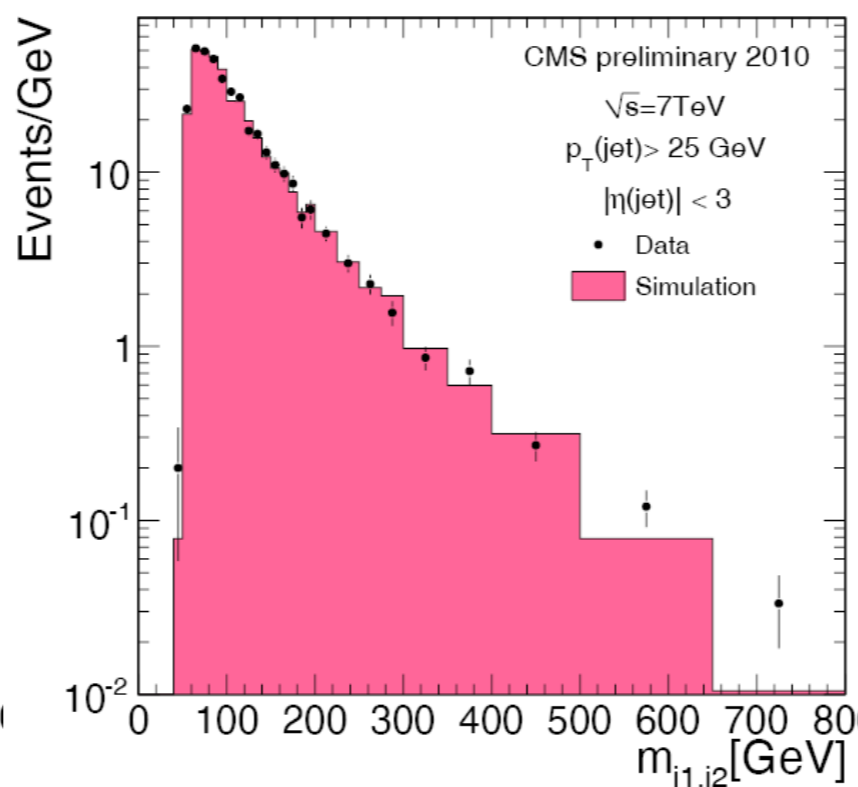
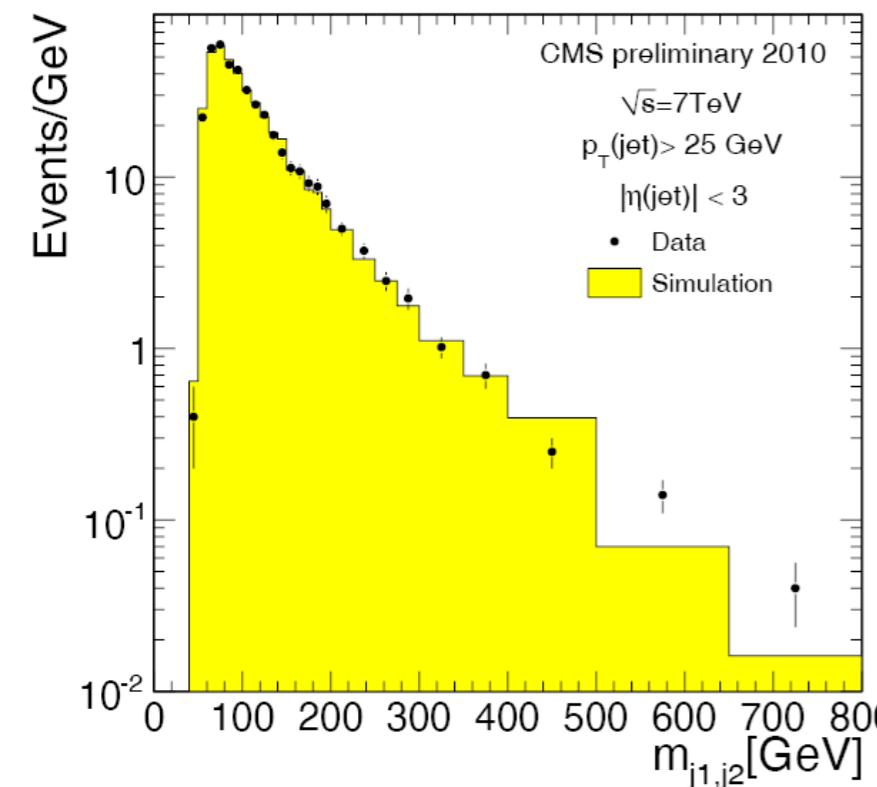


- Dijet Mass distributions at 7 TeV
 - Event selection: good primary vertex $|z| < 15$ cm, minBias
 - Jet selection: $|\eta| < 3$, $p_T > 25$ GeV, $N_{jet} = 2$, $\Delta\phi > 2.1$
 - anti-kT jet algorithm with cone size $\Delta R = 0.5$
 - initial jet calibrations (eta uniformity and absolute scale) applied
 - Three types of jet reconstruction applied

Calorimeters only

Calorimeters+Tracks

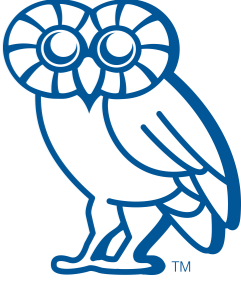
Particle Flow





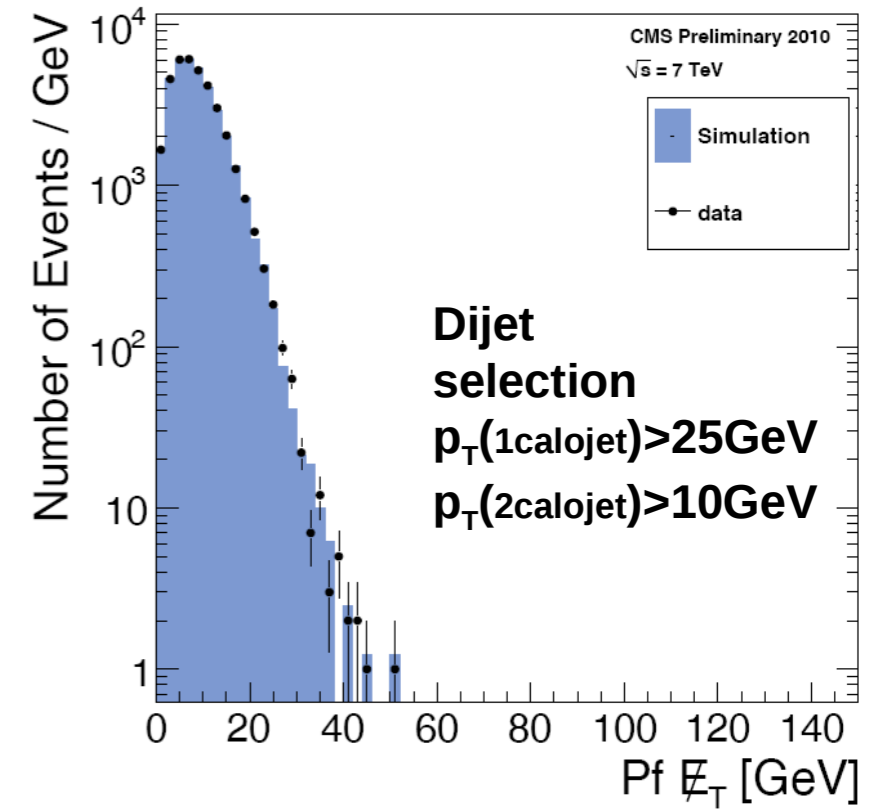
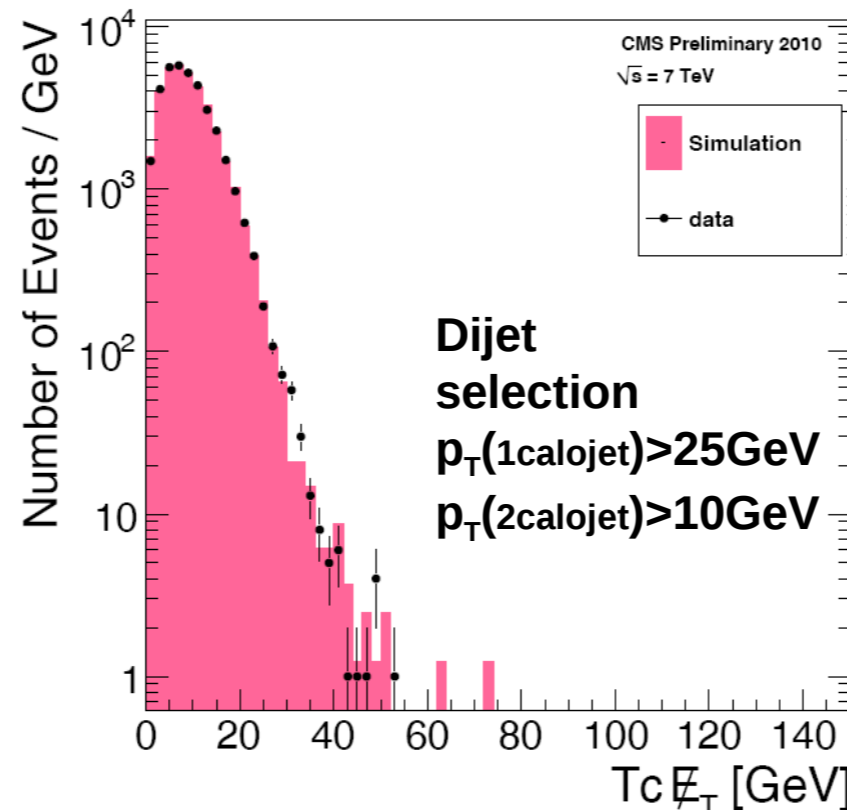
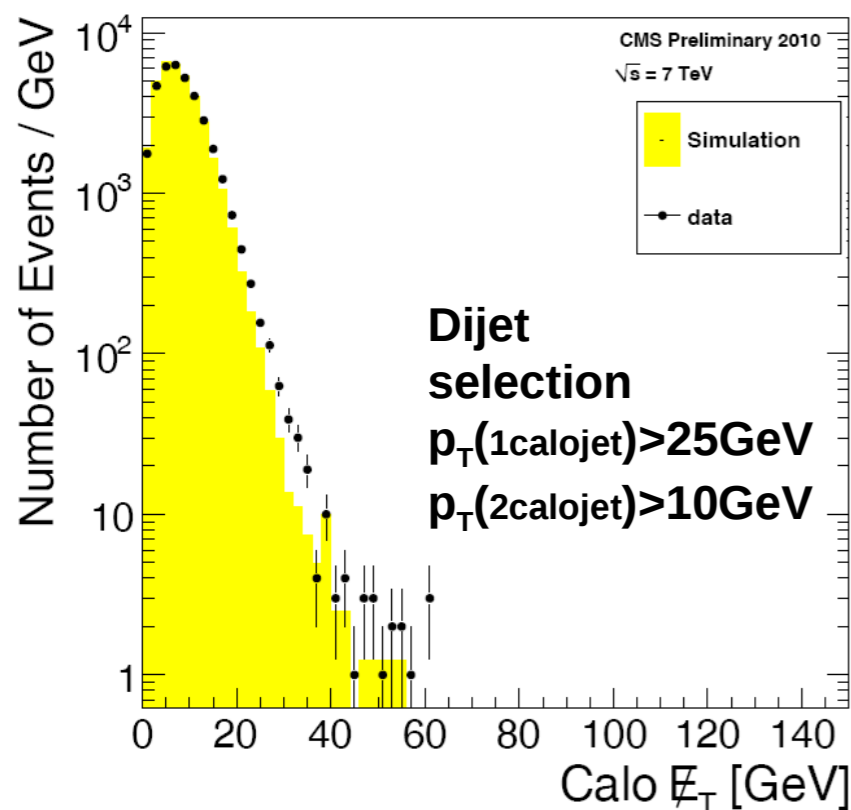
Detector Performance: Missing E_T

CMS DPS 2010/014



- Missing E_T in dijet sample
- Noise cleaning applied to correct detector effects
- Status:
 - Core described well
 - Tails reduced by cleaning, but still more tails in data
 - Ongoing work on noise removal

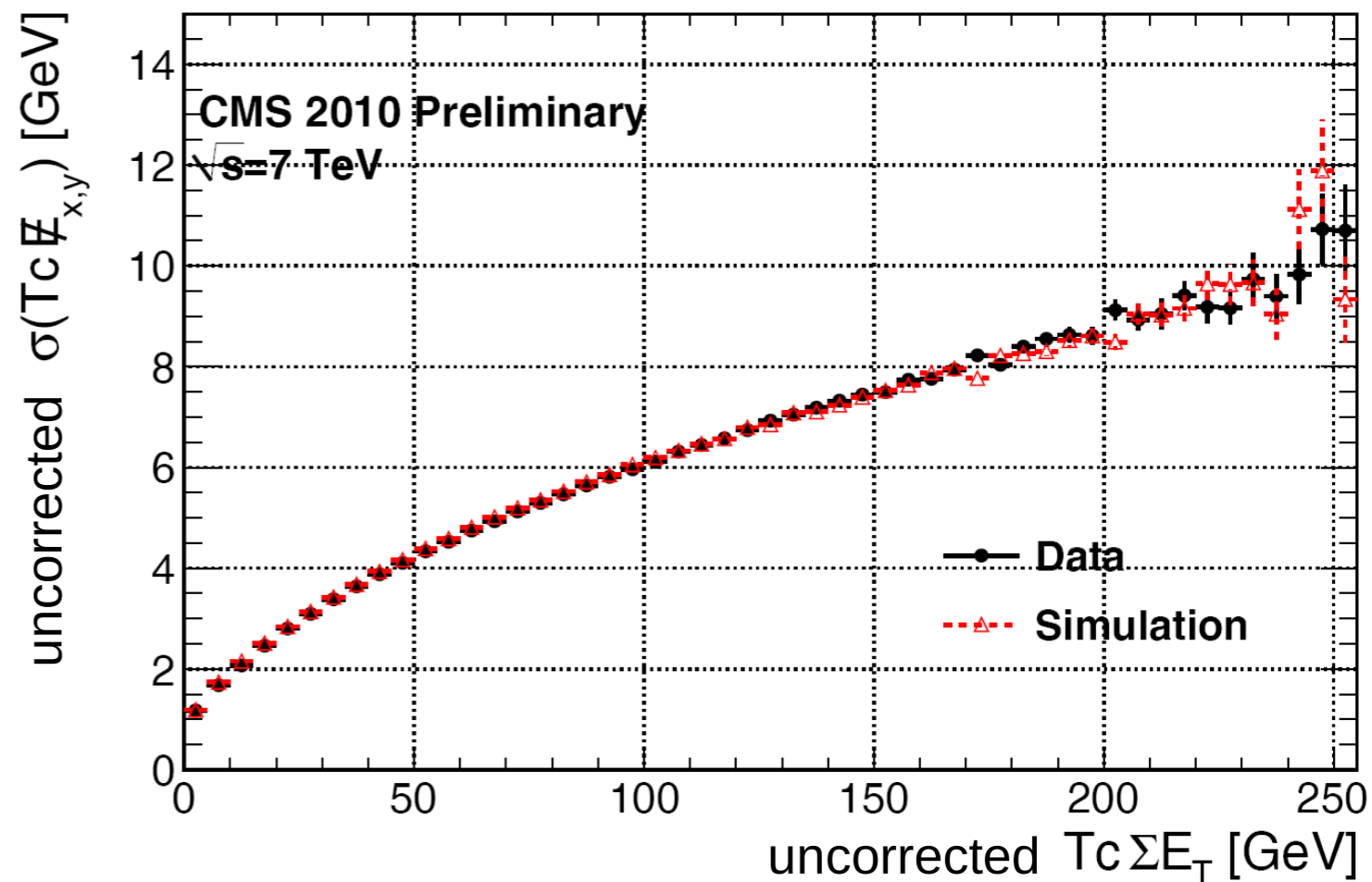
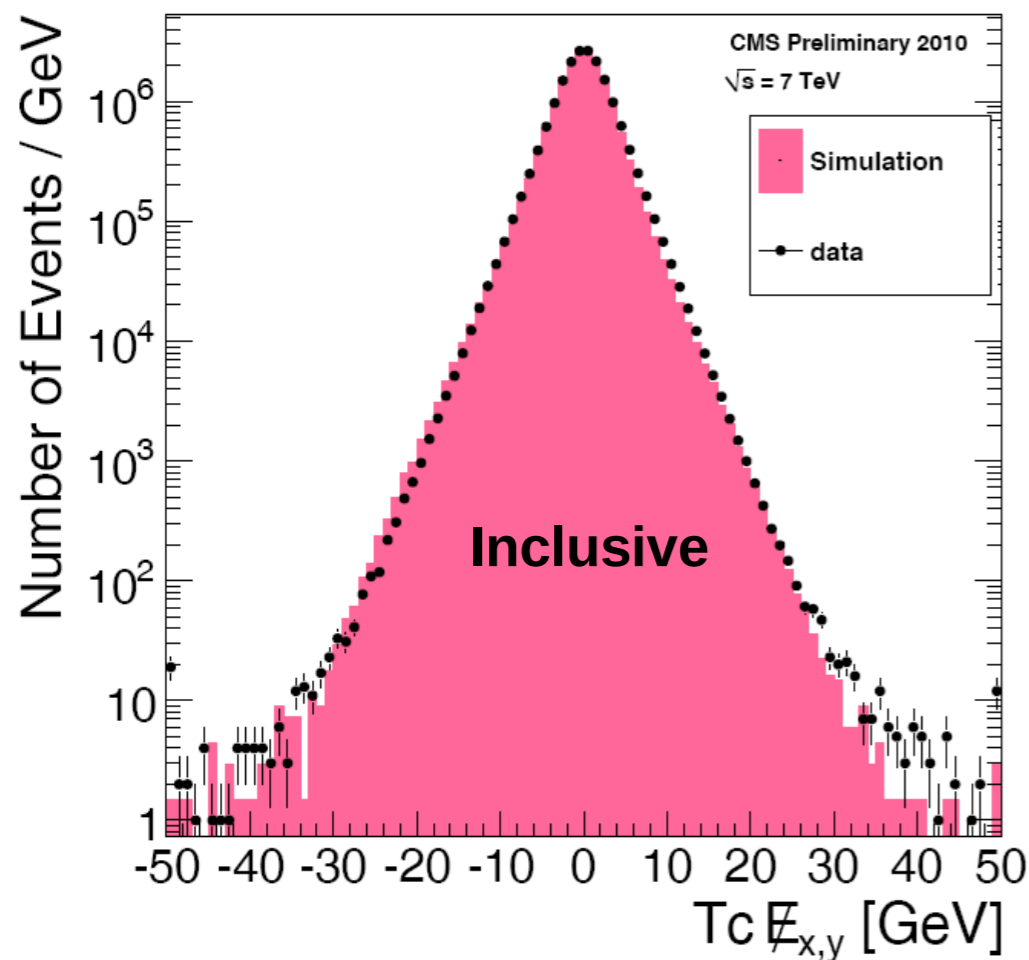
See presentation from J. Maes on Wed





Missing ET resolution: Data vs MC

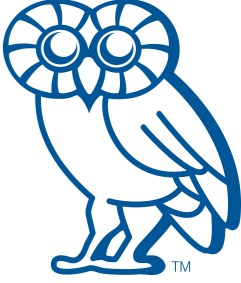
CMS DPS 2010/014



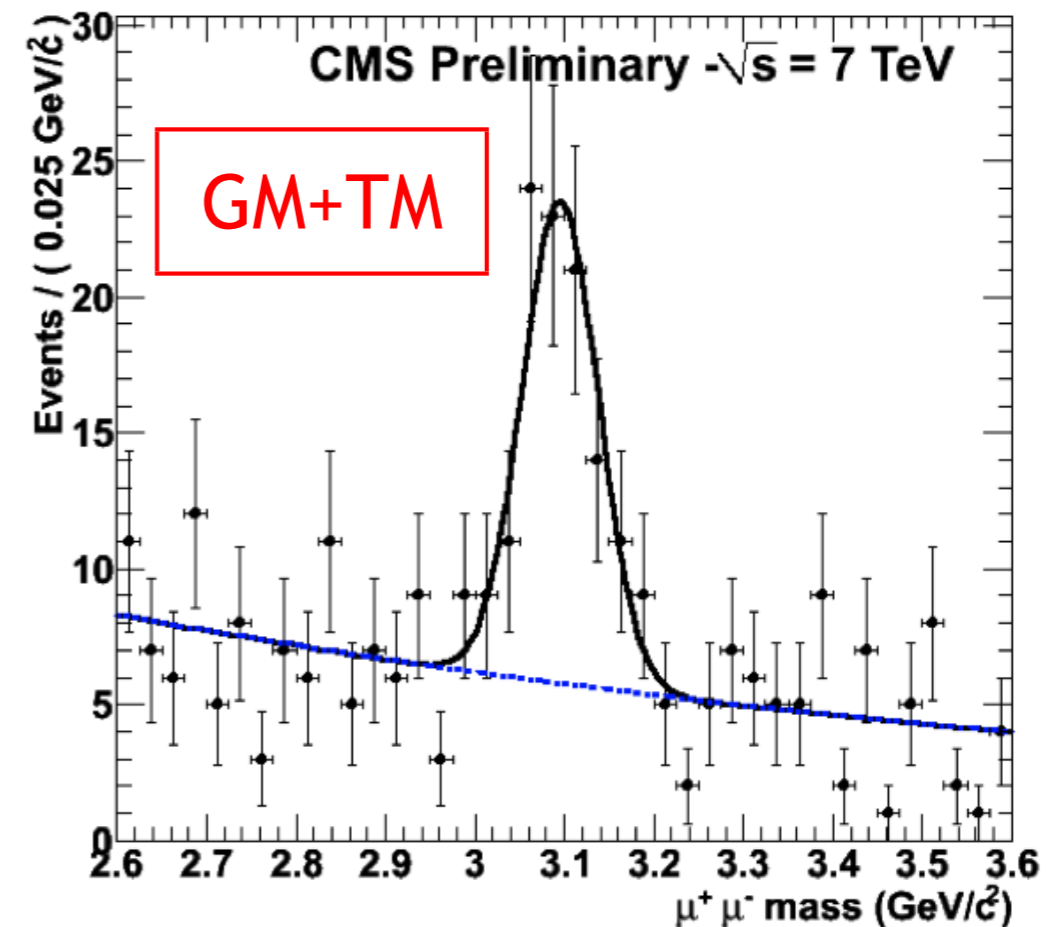
- Good agreement in $\sigma(ME_T)$ in data/MC comparisons
 - example shown for track corrected missing $E_{x,y}$ vs ΣE_T
 - Jet, Missing ET performance: CMS DPS 2010/014 (available on CDS)



Muons $J/\psi \rightarrow \mu\mu$

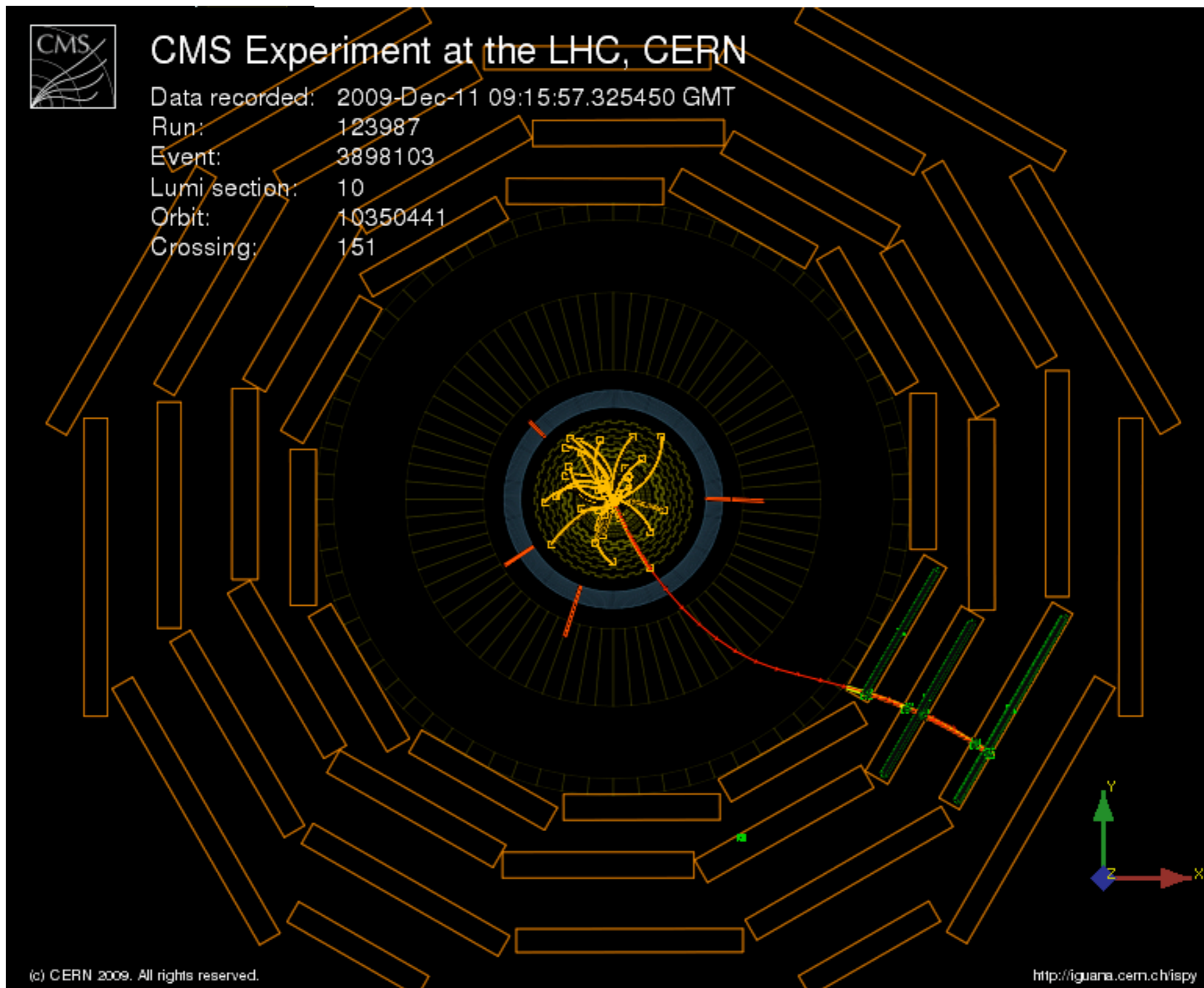


- 1 nb⁻¹ data sample
- $J/\psi \rightarrow \mu\mu$ candidates
- Single μ $p_T > 3$ GeV trigger
- Track selection
 - $d_0 < 5$ cm $d_z < 20$ cm
 - $N_{hit} > 10$
- Vertex $P(\chi^2) > 1\%$
- Global Muon (GM)
 - tracker and muon system jointly fit (outside \rightarrow in)
- Tracker Muon (TM)
 - track matched to hits in muon system (inside \rightarrow out)
- Sample for early muon studies ; Upsilon to follow soon & Z's





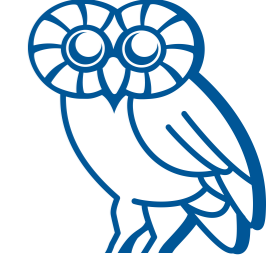
Muon Candidate



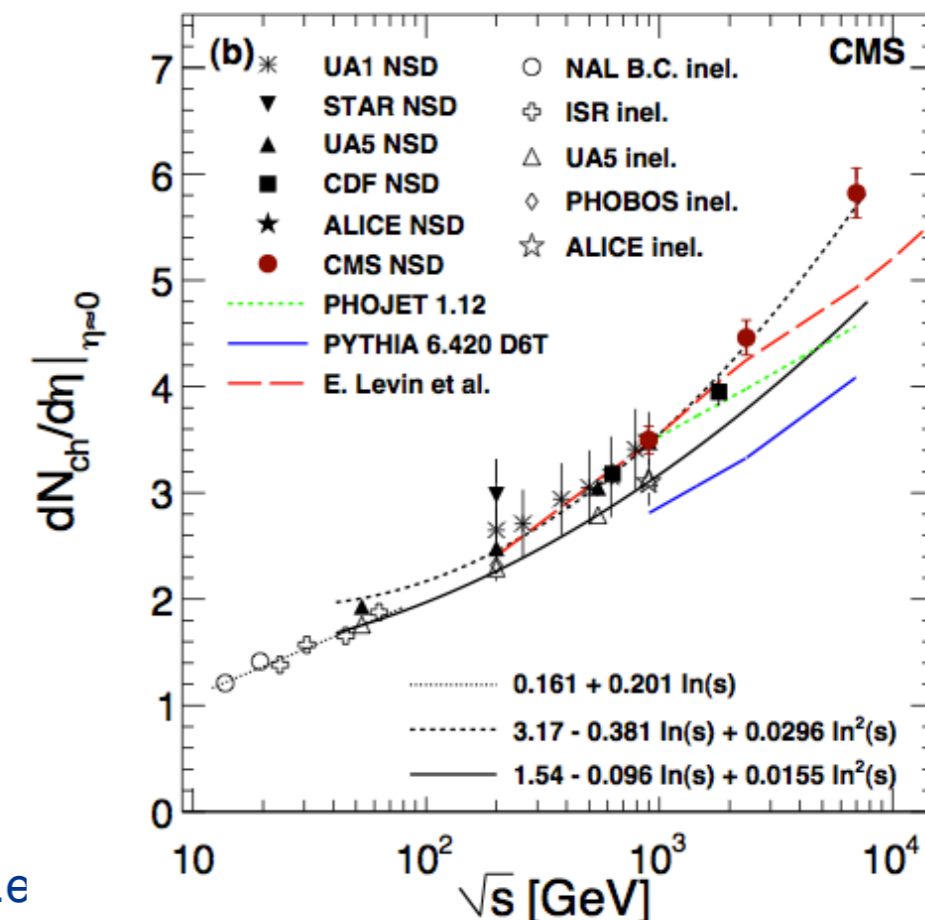
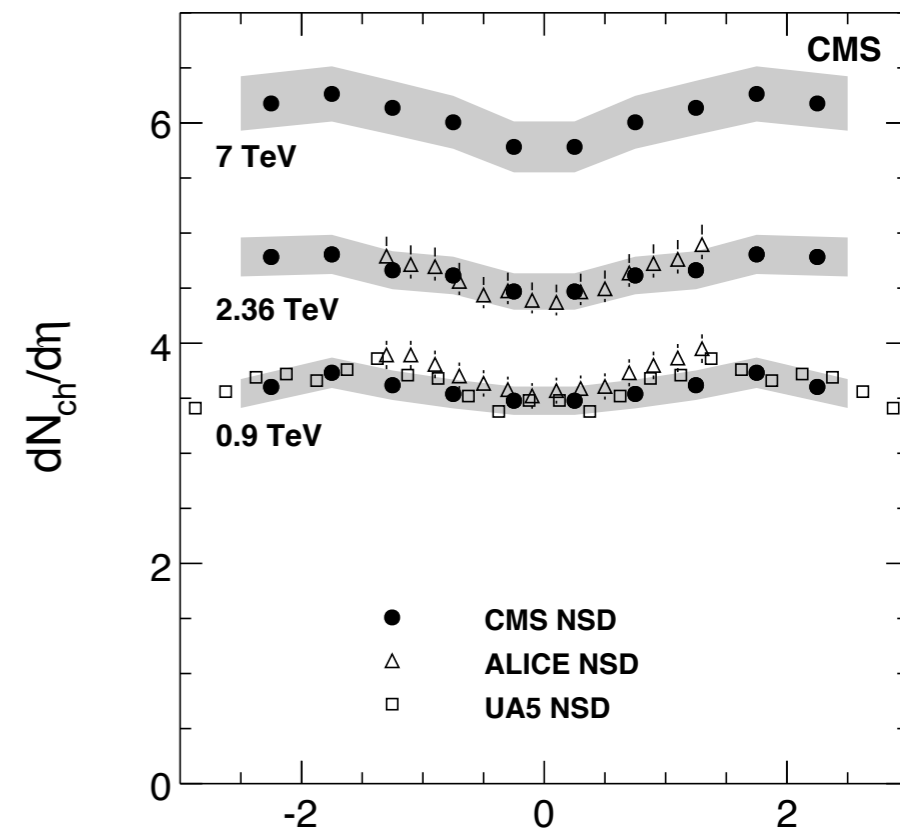


First Physics Papers:

$$\frac{dN_{ch}}{d\eta}$$



- Understanding of hadron production at 7 TeV
 - backgrounds to physics of interest at LHC
- First hour of collisions: $1.1 \mu\text{b}^{-1}$
- Minimum bias trigger from beam scintillation counters
 - require PV & forward HCAL $> 3 \text{ GeV}$
- Count charged tracks with 3 methods
 - pixel clusters, pixel tracklets & tracks
- Corrected to non-single diffractive cross section (NSD)
- Rise in particle density at 7 TeV
 - above frequently used models
 - new tune for PYTHIA

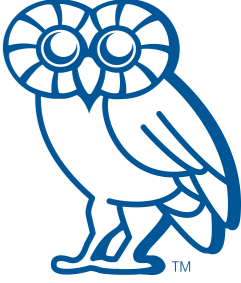


CMS-QCD-10-006 arXiv:1005.3299 (7 TeV)

JHEP 02 (2010) 041 (0.9, 2.36 TeV)



Status of High p_T Physics



With 20 nb^{-1} we can expect some W & Z candidate events. Here's what's publicly released by CMS:

First look taken with only 1 nb^{-1}

$W \rightarrow \mu\nu$ & $W \rightarrow e\nu$ selection

- muon
 - $p_T > 20 \text{ GeV}$ track pointing at mu hits
 - $|\eta| > 2.1$
- electron
 - high p_T track matched to ECAL
- track+calorimeter isolation for lepton
- Large Missing E_T
 - acoplanarity of ME_T and lepton
- Expect 8-9 W candidates in 1 nb^{-1}
- Found 3 $W \rightarrow \mu\nu$ and 3 $W \rightarrow e\nu$ candidates

$Z \rightarrow ee$ & $Z \rightarrow \mu\mu$ selection

- same lepton ID as for W
 - lepton ID predetermined with MC
- $p_T > 10 \text{ GeV}$ (two leptons!)
- invariant mass near the Z
- Expect ~ 1 event in 1 nb^{-1}
- Found 1 candidate

After this “hunting” phase, work has moved to statistical analysis of distributions, i.e. the familiar physics analysis methods.

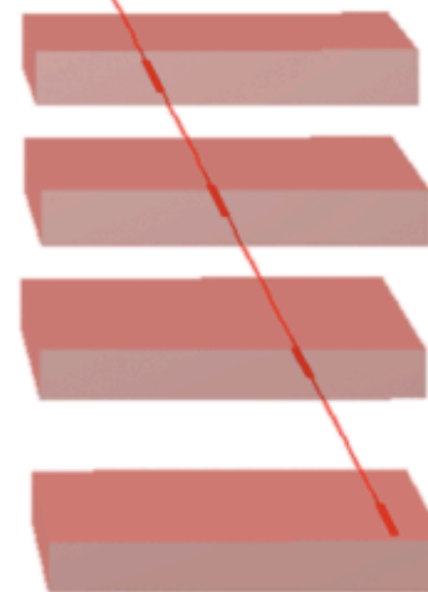
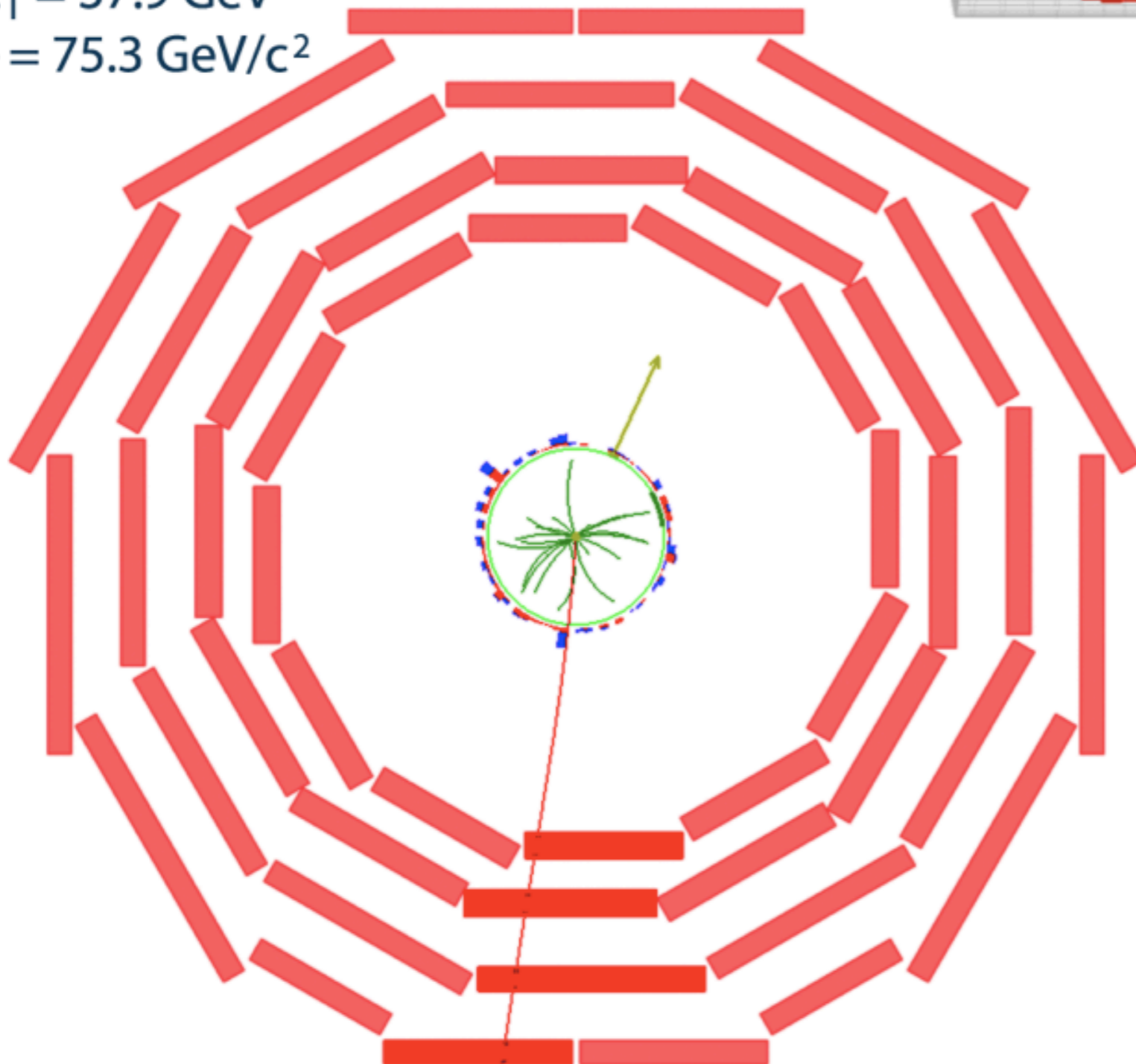
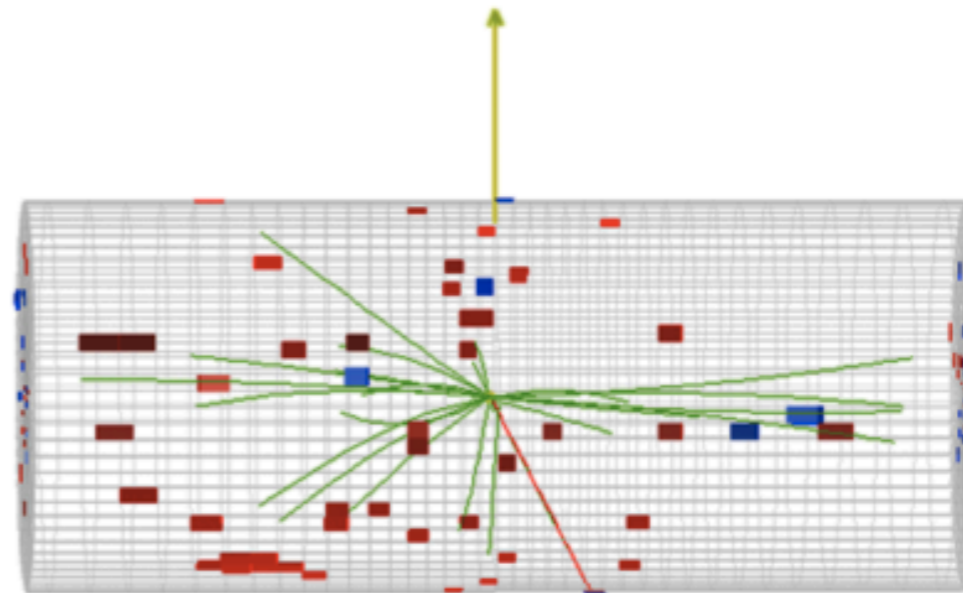
That said, here are event displays of some vector boson **candidates**.



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



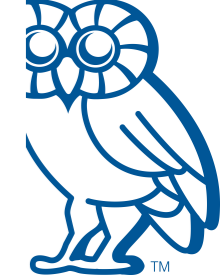
Muon $p_T = 38.7 \text{ GeV}/c$
 $ME_T = 37.9 \text{ GeV}$
 $M_T = 75.3 \text{ GeV}/c^2$



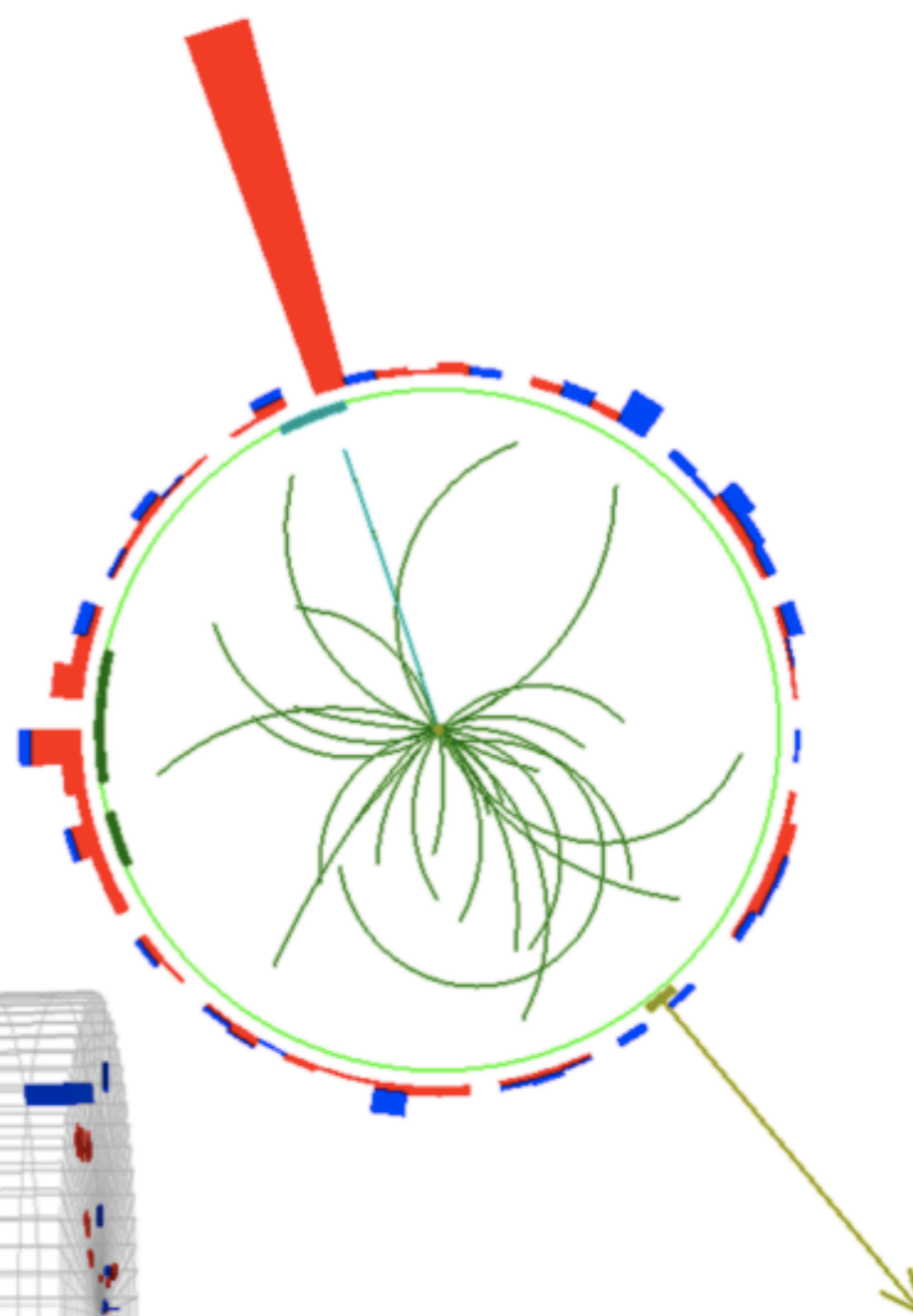
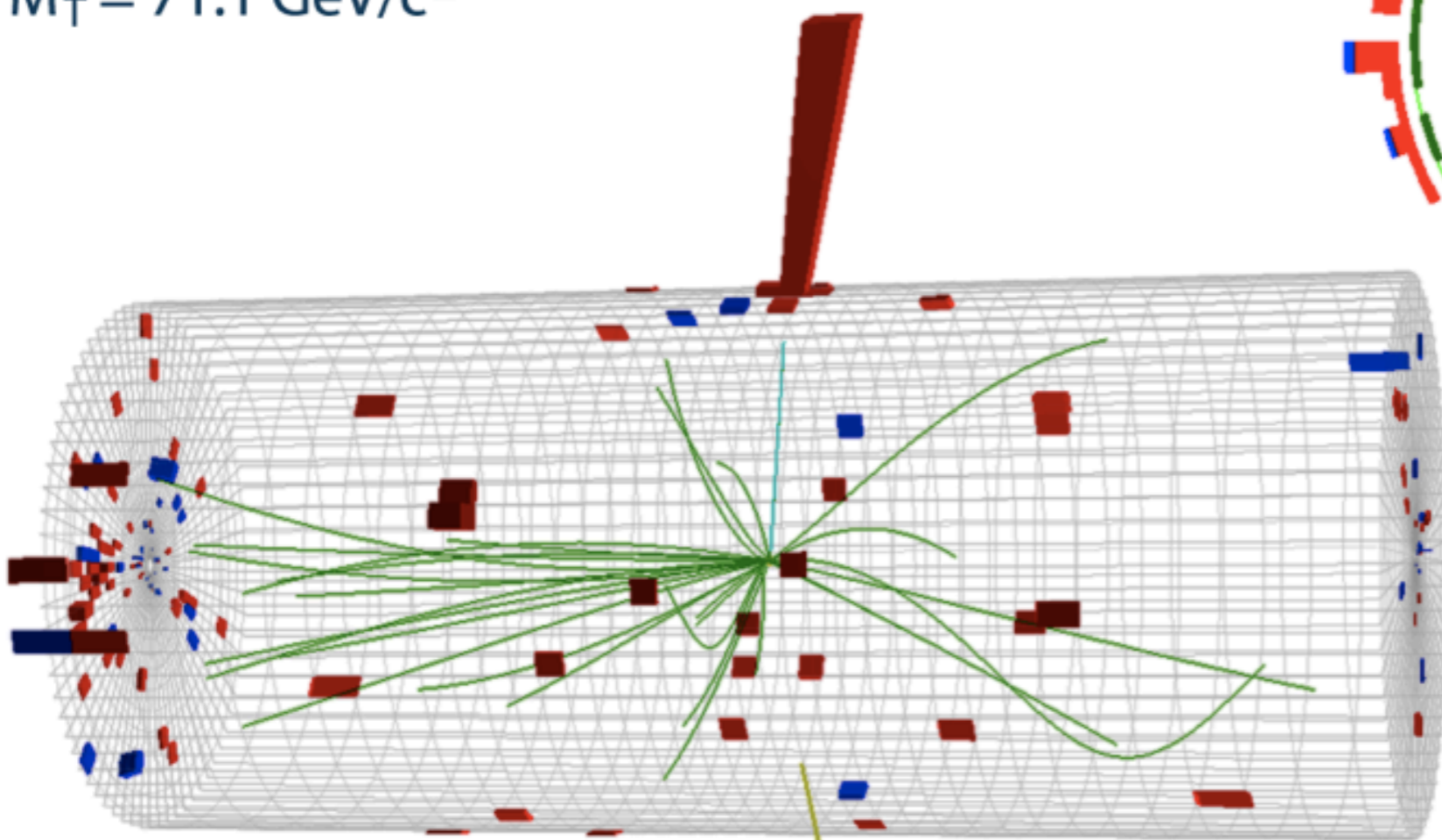
$W \rightarrow \mu \nu$ Candidate



CMS Experiment at LHC, CERN
Run 133874, Event 21466935
Lumi section: 301
Sat Apr 24 2010, 05:19:21 CEST



Electron $p_T = 35.6$ GeV/c
 $ME_T = 36.9$ GeV
 $M_T = 71.1$ GeV/c²



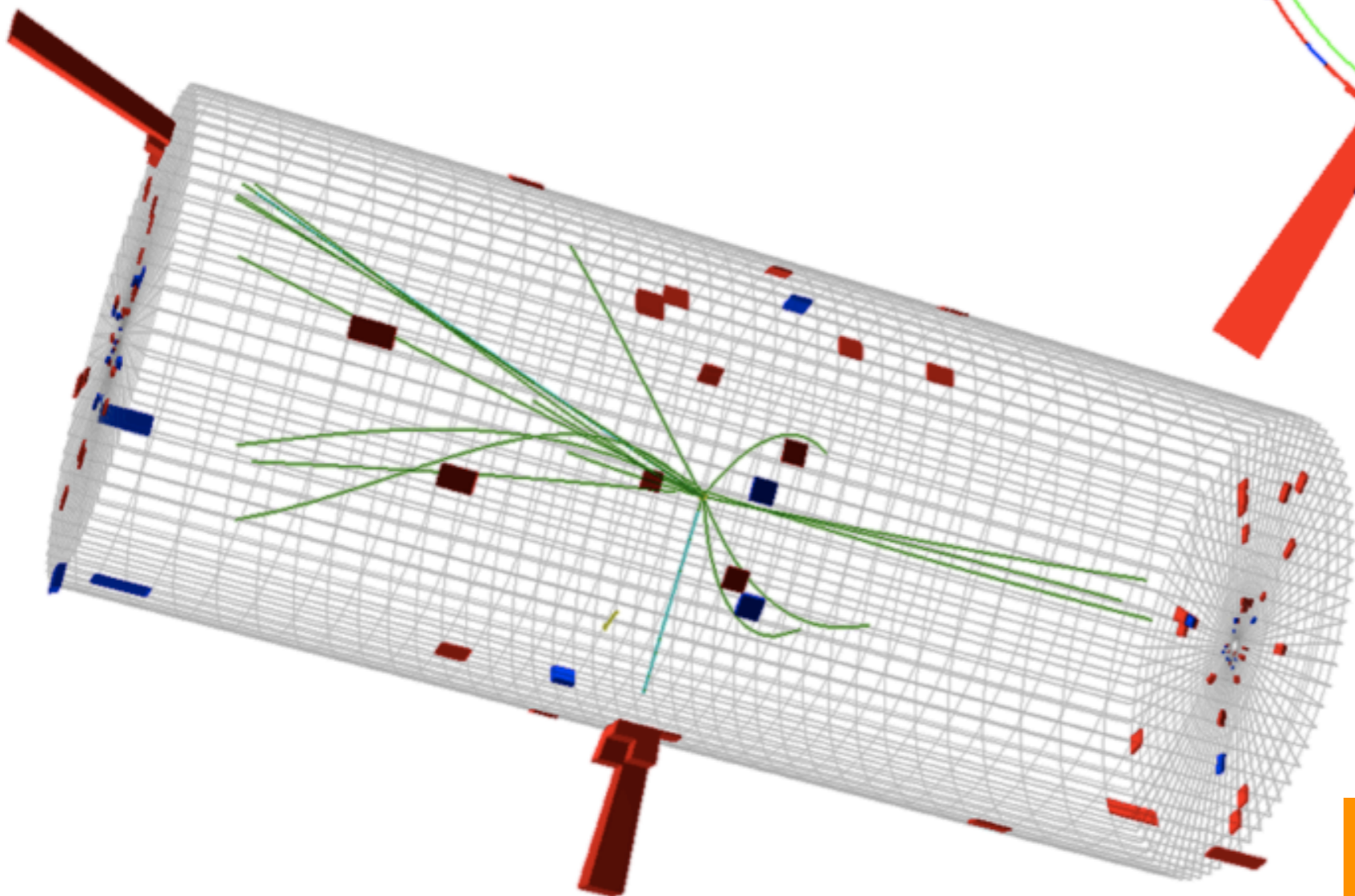
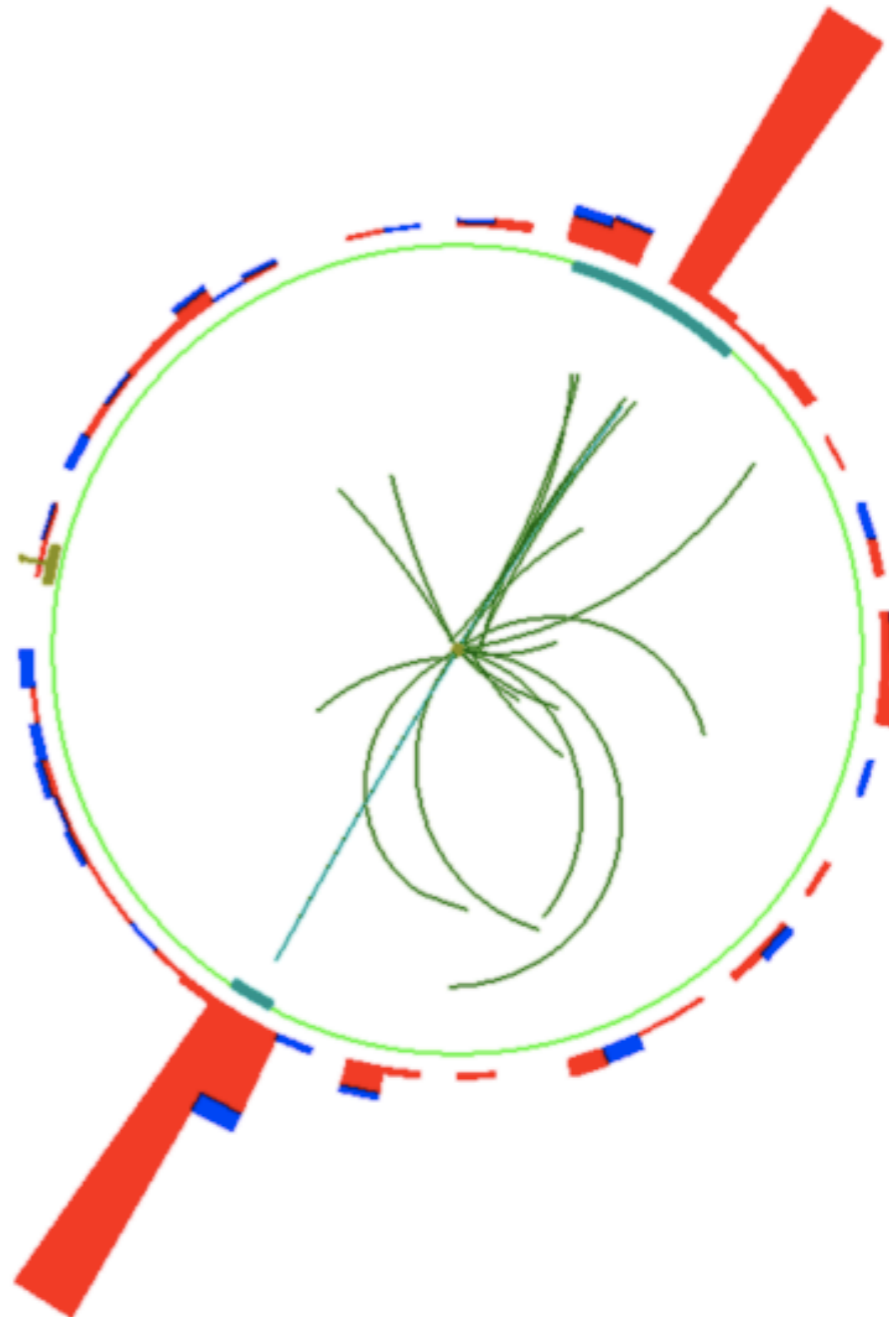
W → eν Candidate



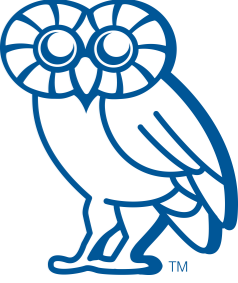
CMS Experiment at LHC, CERN
Run 133877, Event 28405693
Lumi section: 387
Sat Apr 24 2010, 14:00:54 CEST



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



Z → ee Candidate



Top Expectations

- Data samples are approaching soon where $t\bar{t}$ signals will be seen in CMS at the LHC
 - 20 nb^{-1} now, but expecting 1000 nb^{-1} by ICHEP
- I have shown you many ingredients needed for top:
 - Missing E_T , b tagging, leptons, jets
 - Additional details on CMS performance in first data to be presented by J. Maes on Wednesday
- CMS Top analysis presentations at TOP 2010 :
 - “Background Strategies” M. Barrett, on Wednesday
 - “Jets in top events” R. Wolf, on Thursday



Conclusion & Outlook



- LHC commissioning is in progress at 7 TeV, with geometric growth to the luminosity
 - Expect $\mathcal{L} \sim 1 \text{ pb}^{-1}$ by ICHEP, 100 pb^{-1} by end of 2010
 - First run at 7 TeV (2010-11): 1 fb^{-1} goal
- The CMS experiment is off and running!
 - cosmic ray and beam collision data shows expected performance
 - tracking, calorimetry, lepton ID & physics performance studies with data are well underway
- High p_T physics commissioning
 - W and Z candidates recorded, detailed studies underway
 - First top candidate events are likely on “tape”
 - Early measurements expected for ICHEP