First Physics Results from CMS experiment at LHC

B. de la Cruz (CIEMAT)

From CMS Collaboration

Dpto. Física Teórica (UCM)

16th March, 2011

Outline

- LHC collider
- CMS experiment and subdetectors performance
- First Physics results with 2010 data
- Perspectives 2011-2012

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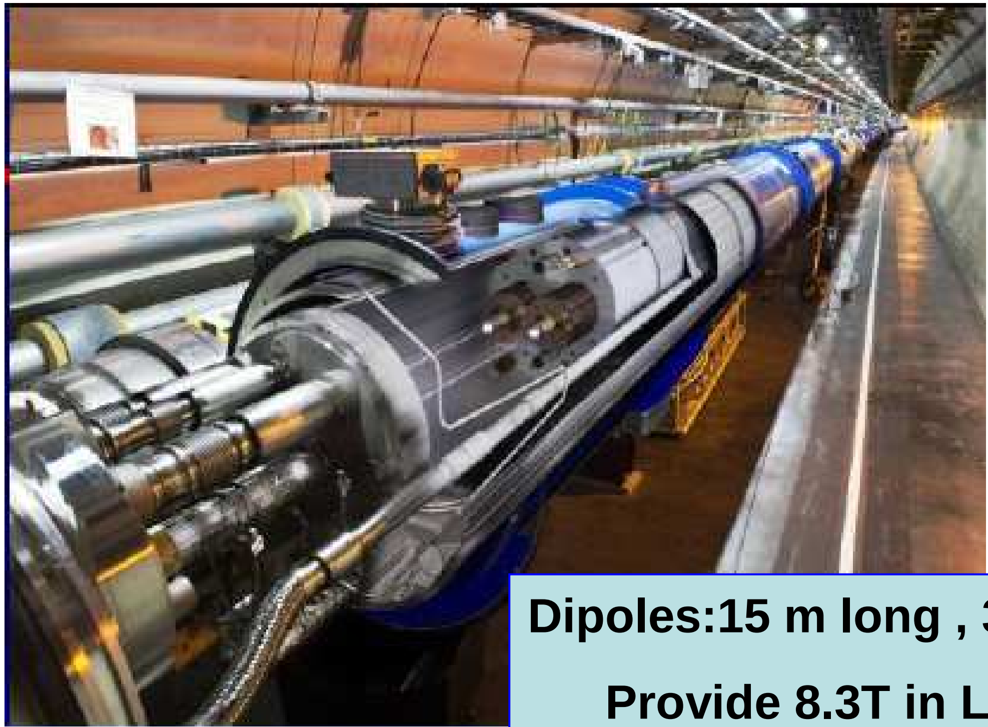
LHC Collider

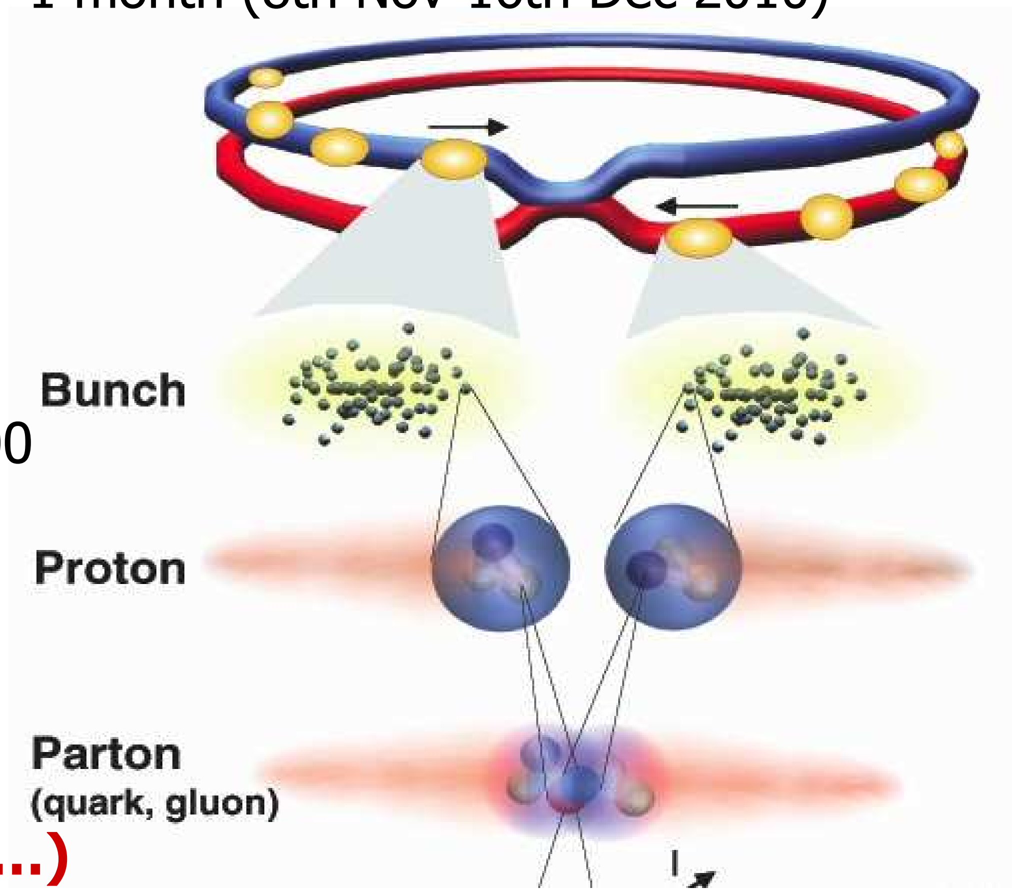


Dipoles:15 m long , 35 Ton

Provide 8.3T in LHC

Proton-proton collisions at √s = 7 TeV
From March 30th until 6th November
(initial tests & physics at √s = 0.9, 2.36 TeV
by end 2009)

Pb-Pb collisions at 2.76 TeV/nucleon during
1 month (8th Nov-16th Dec 2010)



Largest superconducting magnet system: ~8000 magnets (1232 dipoles, 400 quadrupoles,….) refrigerated with liquid He at 1.9 K

Great technological challenge in many aspects (magnets, cryogenics, vaccuum, …)

LHC Collider

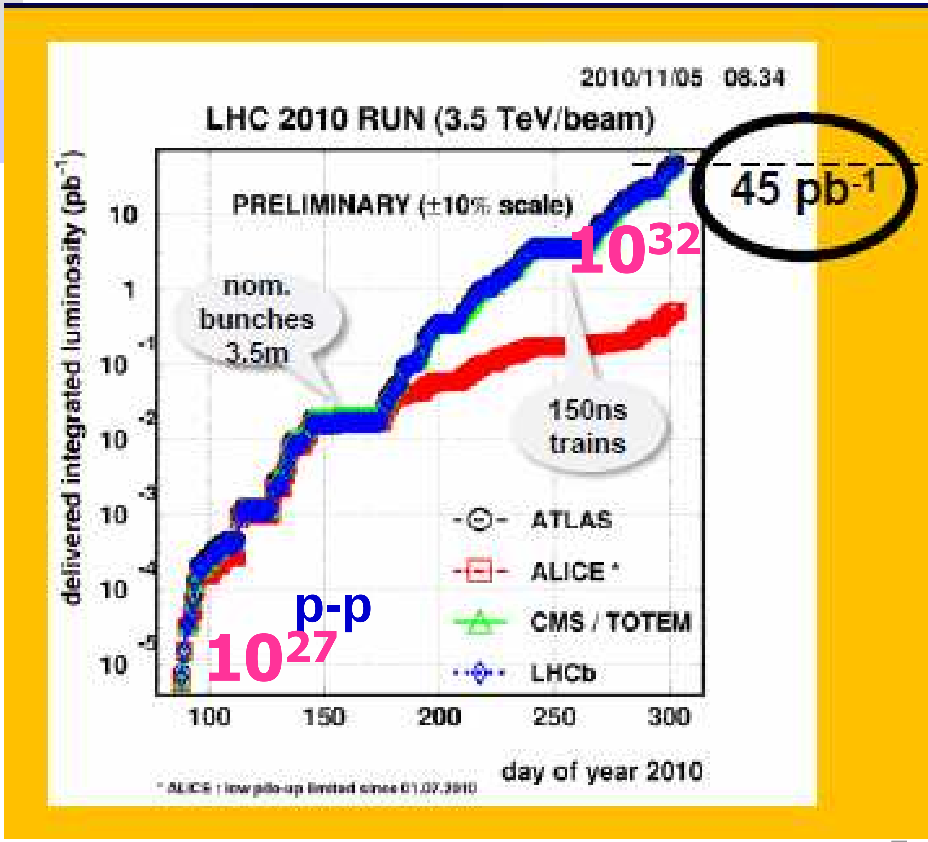
Parameter (pp Run)	2010	Nominal
Beam Energy	3.5 TeV	7 TeV
Inst. Luminosity	2. 10^{32} cm^{-2} s^{-1}	10^{34} cm^{-2} s^{-1}
Squeeze	3.5 m	0.55 m
Transverse emittance	2-3 μm rad	3.75 μm rad
Protons / bunch	Up to 1.2 10^{11}	1.15 10^{11}
Bunch separation	150 ns [a]	25 ns
Nb of bunches	368	2808

(a) Fills at 75 ns and 50 ns have also been achieved but mostly not for physics

Excellent understanding of the machine achieved!!

Five orders of magnitude in peak lumi in 200 days!!!

LHC Delivered Lumi:
- 47 pb^{-1} pp
- 9.5 μb^{-1} Pb-Pb



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LHC @ CERN (Geneva)
CMS
LHCb
ALICE
ATLAS

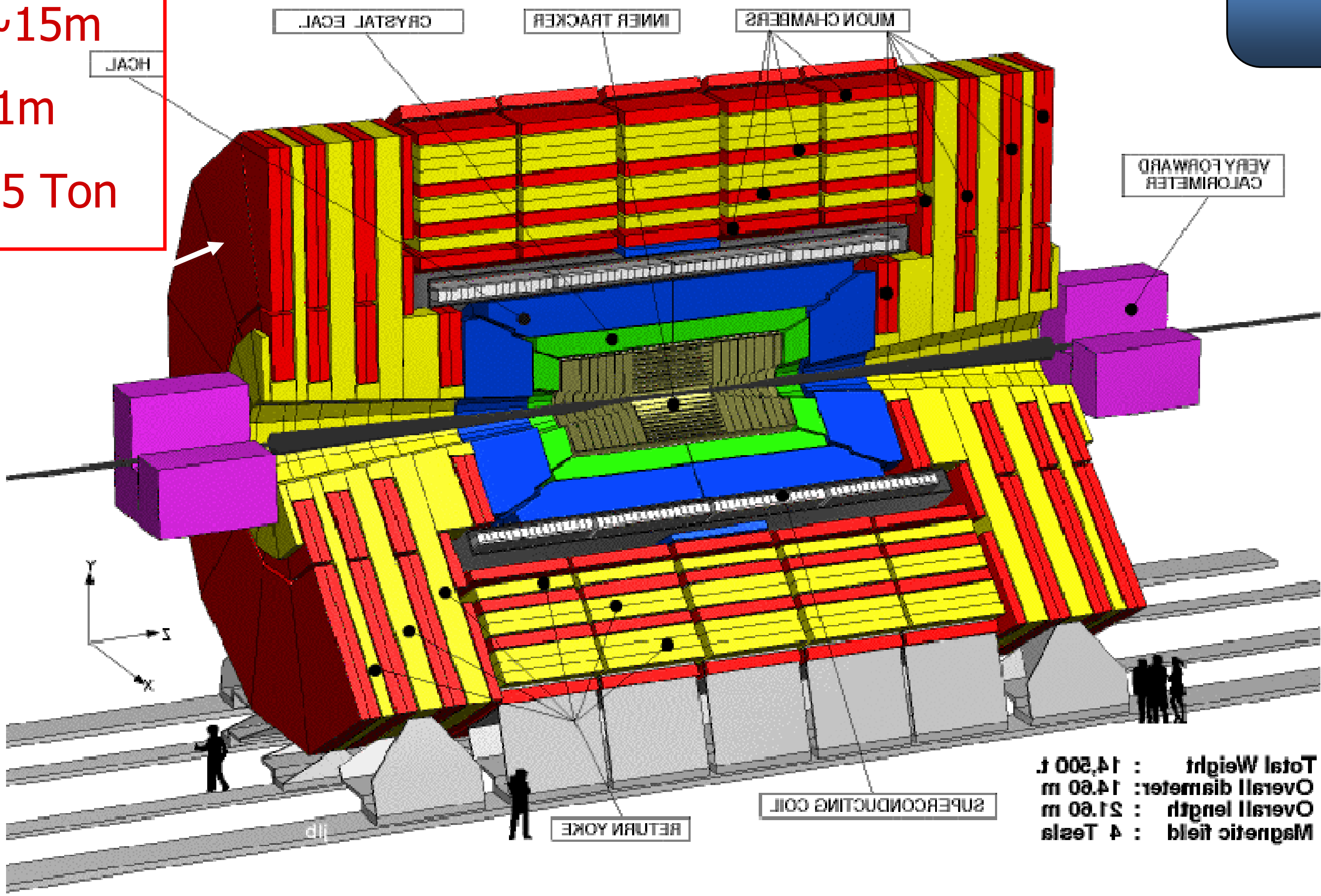
Compact Muon Solenoid

Diameter: ~15m

Length: ~21m

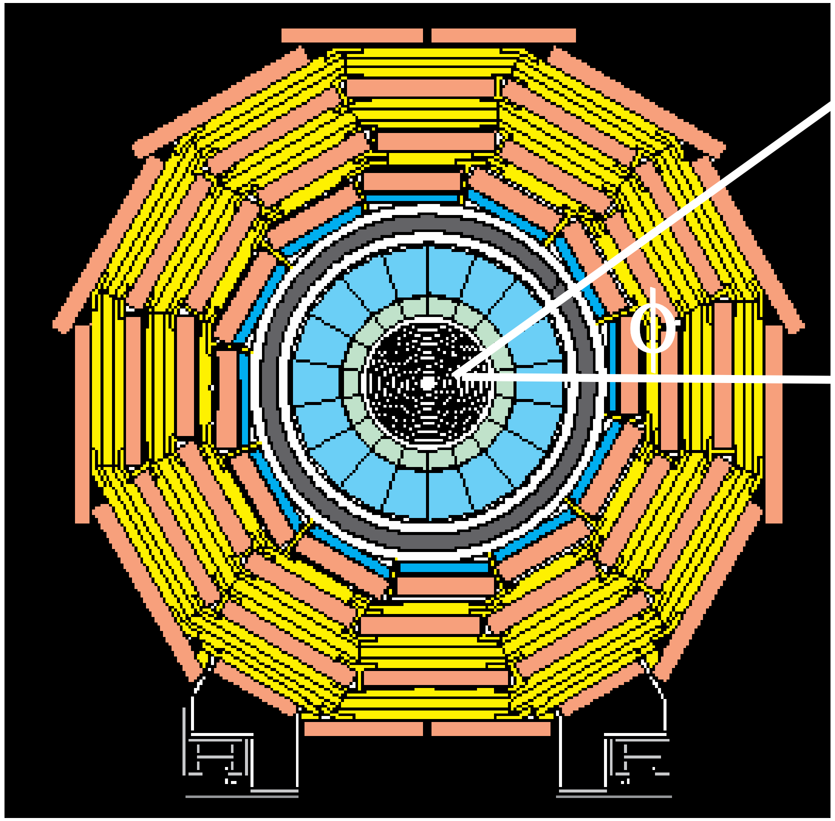
Weight: 14.5 Ton

CMS

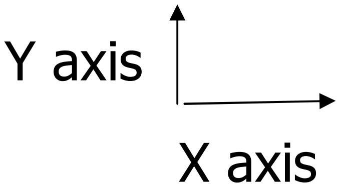


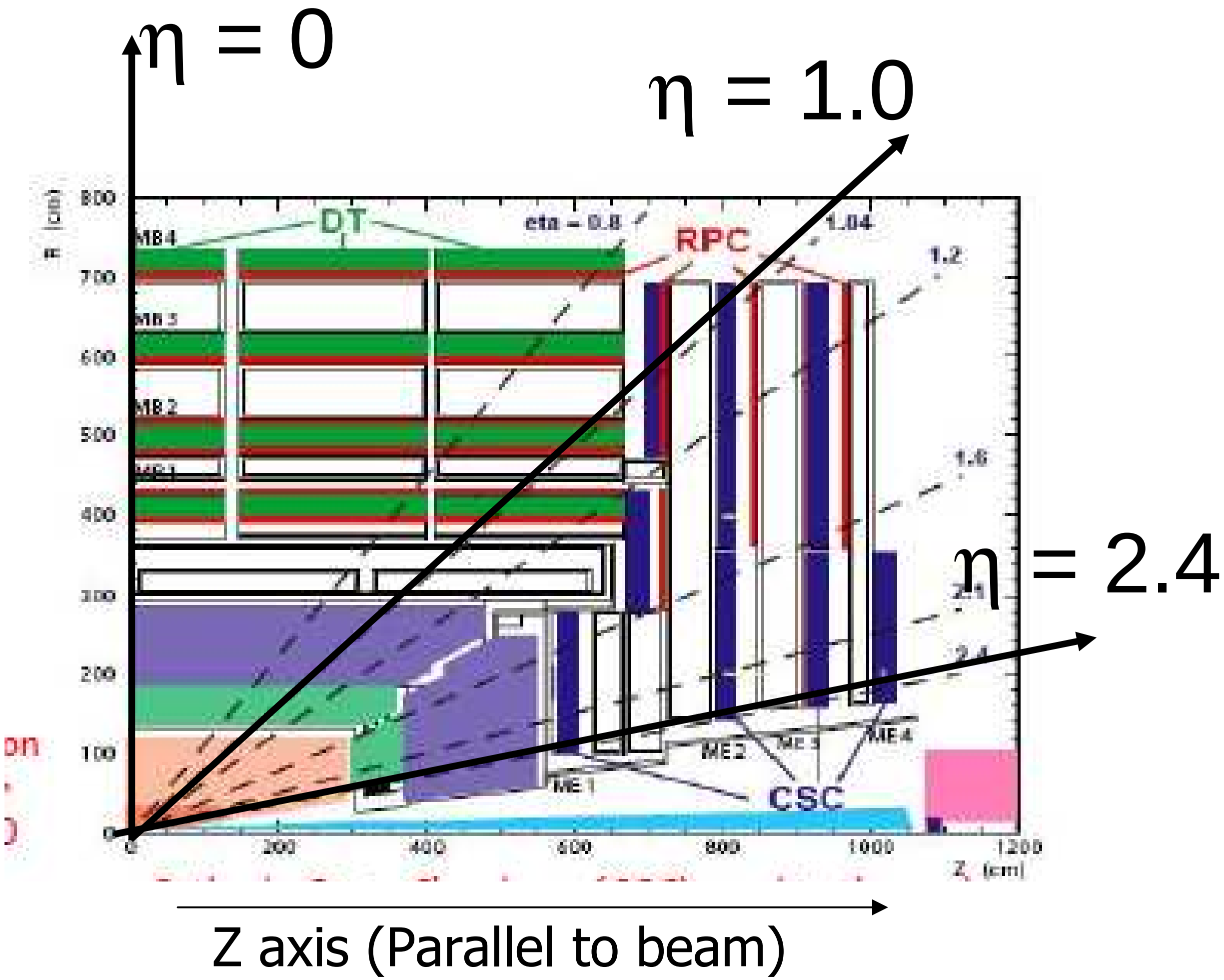
Compact Muon Solenoid

Azimuthal angle = ϕ



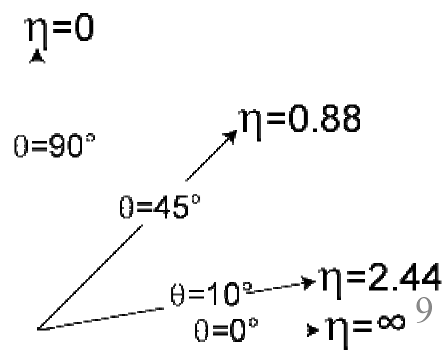
Transversal view



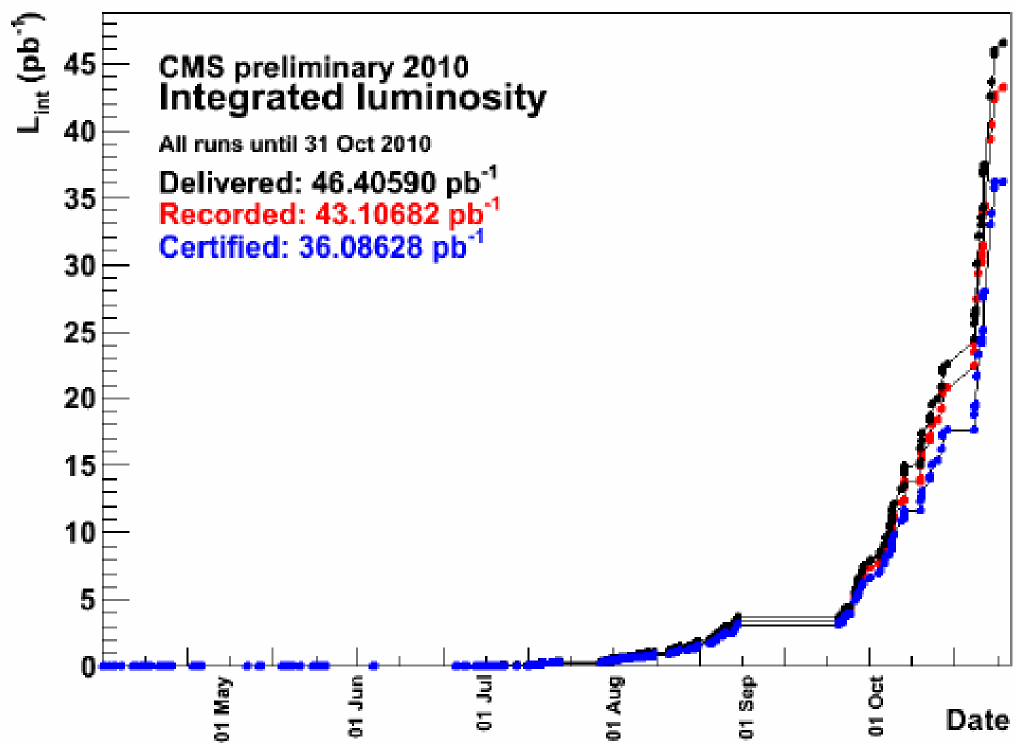


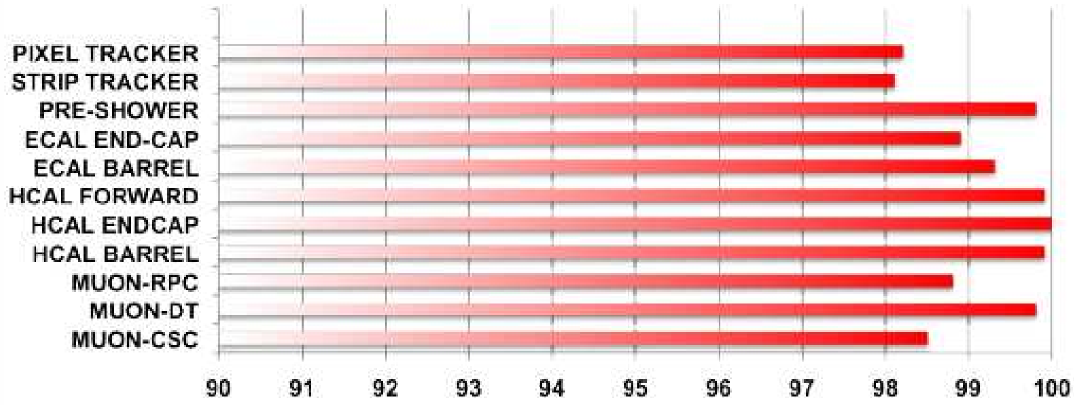
Longitudinal view

Pseudorapidity = - ln(tg(θ/2))



CMS Run 2010





	MUON-CSC	MUON-DT	MUON-RPC	HCAL BARREL	HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER
Series1	98.5	99.8	98.8	99.9	100	99.9	99.3	98.9	99.8	98.1	98.2

mmissioning10-Sep17ReReco_v2: 132440-135735
n2010A-Dec22ReReco_v1: 136033-144114
n2010B-Dec22ReReco_v1: 146428-149442

Efficiency of good LS selection:
83.71%
Rejected luminosity:
7.02054 /pb

Average fraction of operational channels per CMS sub-system **>98%.**

Collected data: **43 pb^{-1}** (DAQ Efficiency **~92%**)

Quality of the data for physics (any analysis)**~85%** of recorded data.

The CMS design: goals

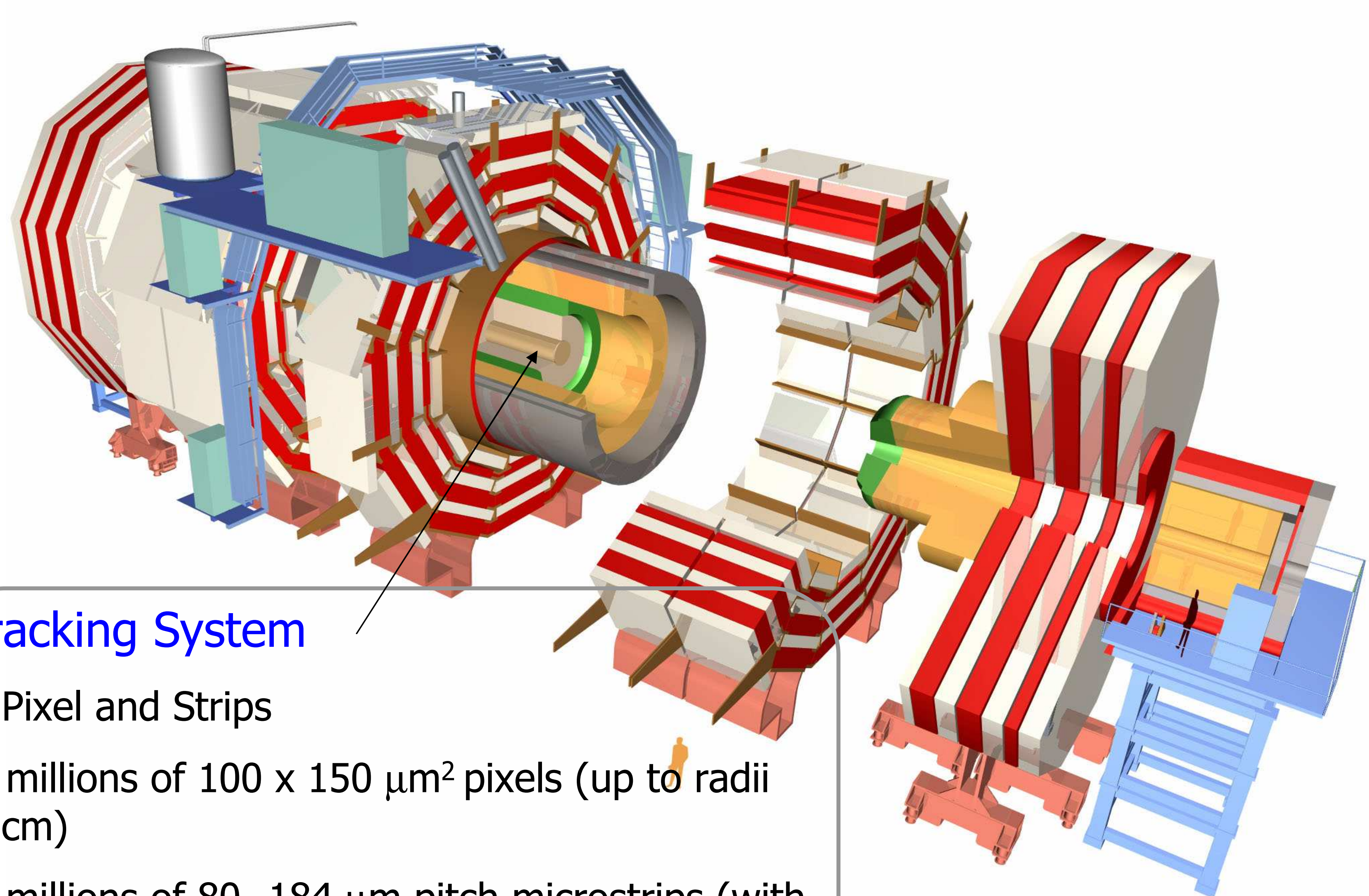
- Precise and efficient inner tracking, including vertex capabilities:
  - Strong solenoidal magnetic field (3.8T)
  - Efficient triggering and offline tagging of taus and b-jets
  - Pixel detectors close to the interaction region

- Good muon identification and momentum resolution:
  - Redundant measurement and trigger systems.
  - $\Delta M_{\mu\mu} / M_{\mu\mu} \approx 1\%$ at $p_T = 100$ GeV
  - Unambiguous determination of the charge for $p_T < 1$ TeV

- Good electromagnetic identification and photon/electron energy resolution:
  - $\Delta M_{ee} / M_{ee}$ & $\Delta M_{\gamma\gamma} / M_{\gamma\mu} \approx 1\%$ at $E_T = 100$ GeV
  - Large coverage and good granularity, π^0 rejection

- Good jet and missing transverse energy resolution (neutrino,...)
  - Hermetic coverage, fine lateral segmentation

Tracking system

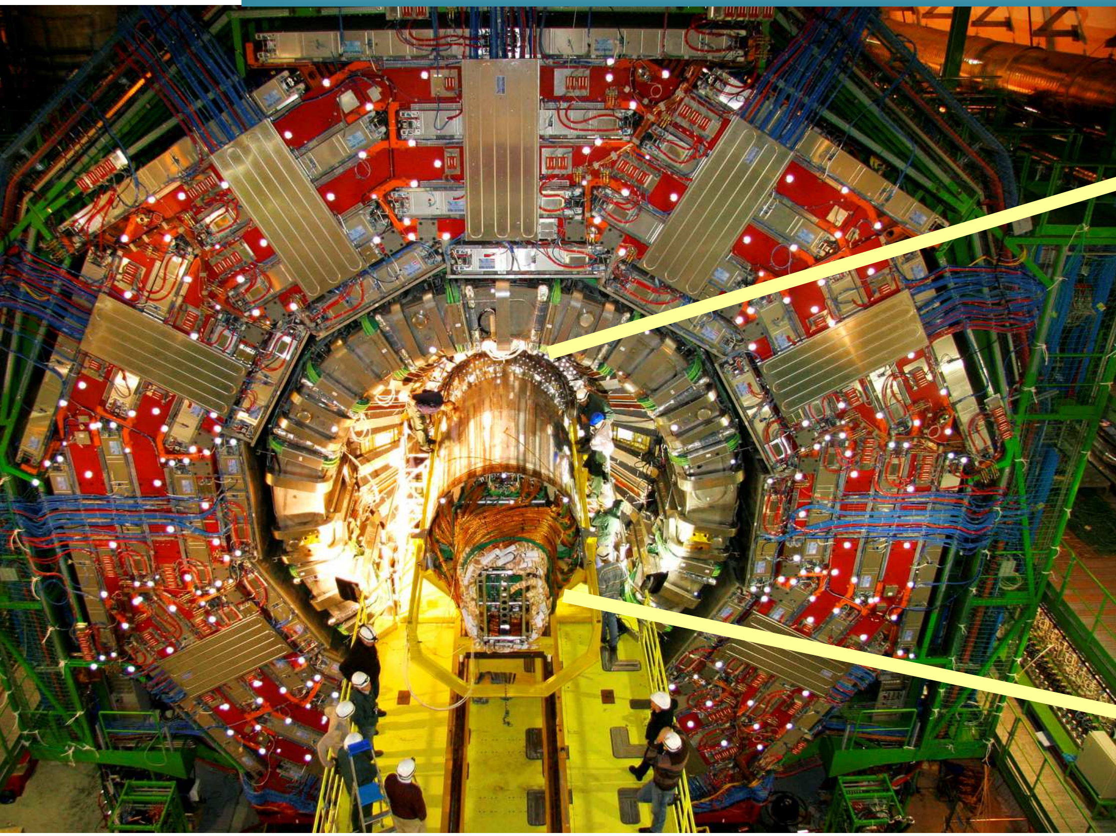


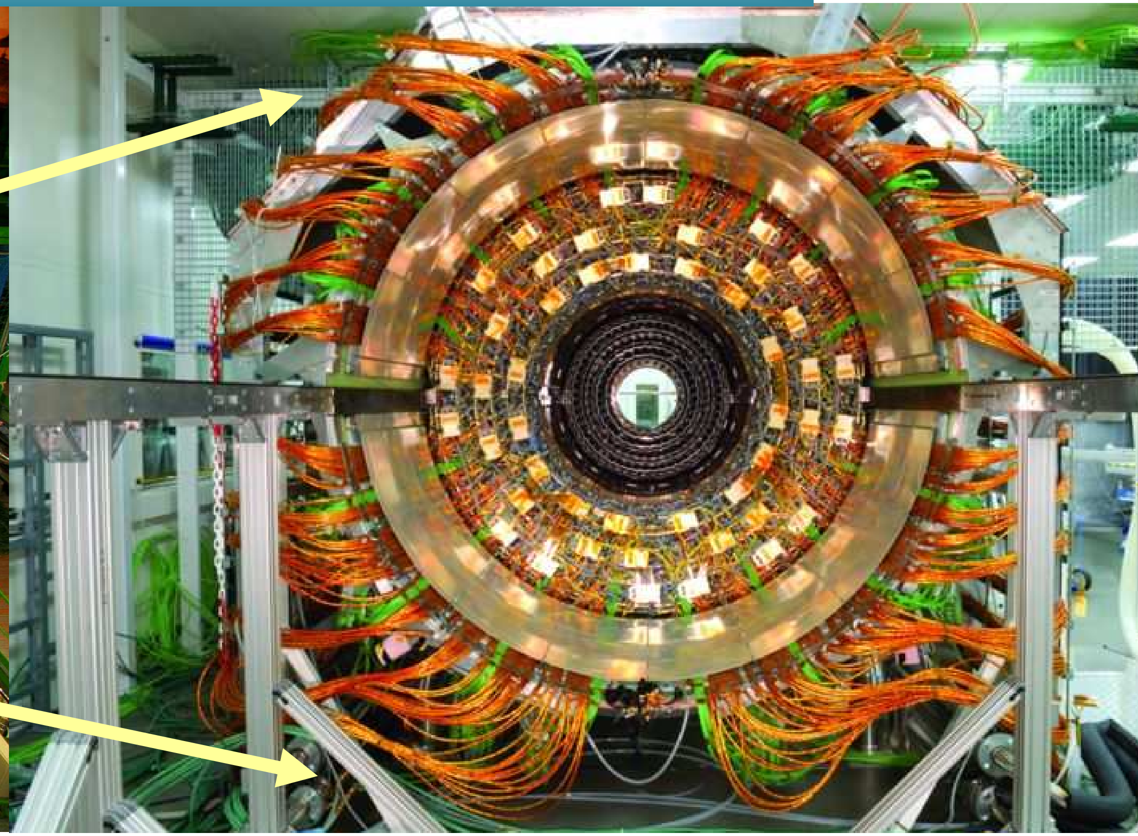
Tracking System

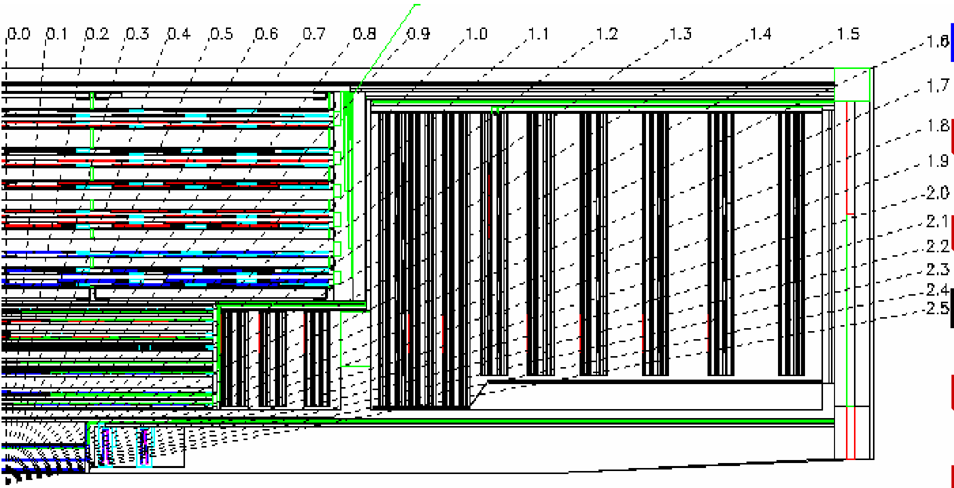
Si Pixel and Strips

- millions of 100 x 150 μm^2 pixels (up to radii 15cm)
- millions of 80 -184 μm pitch microstrips (with radii from 25 to 110 cm)

Tracking system





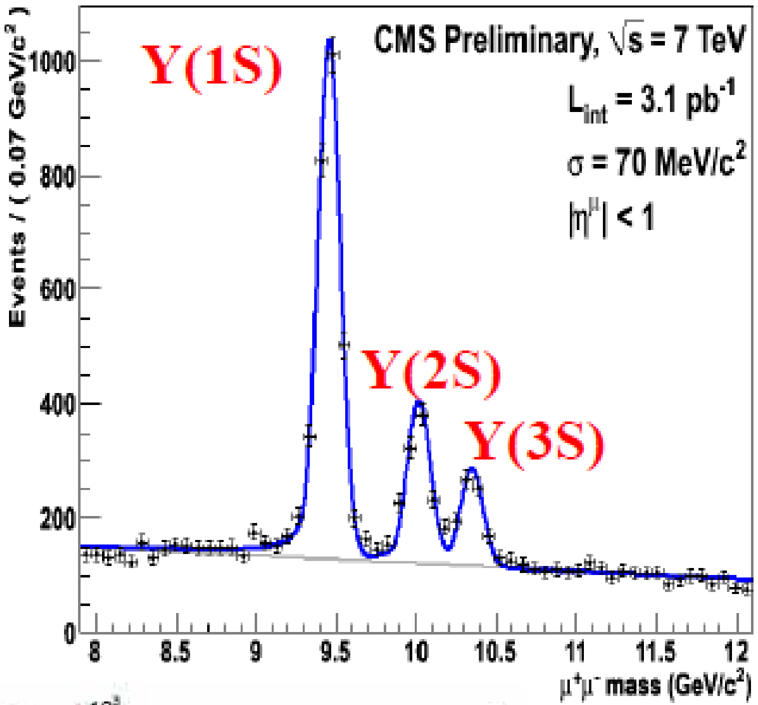


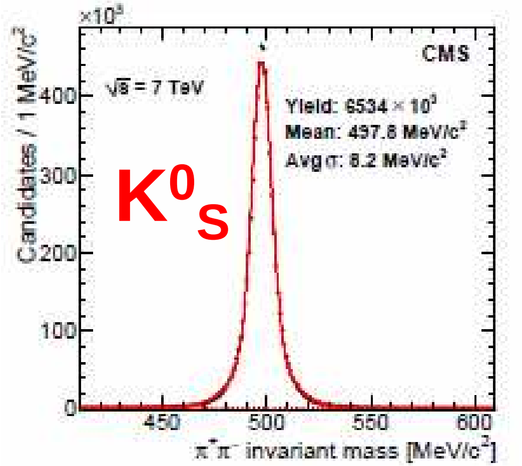
Huge, ultra-precise Silicon tracker system ($|\eta| < 2.5$):

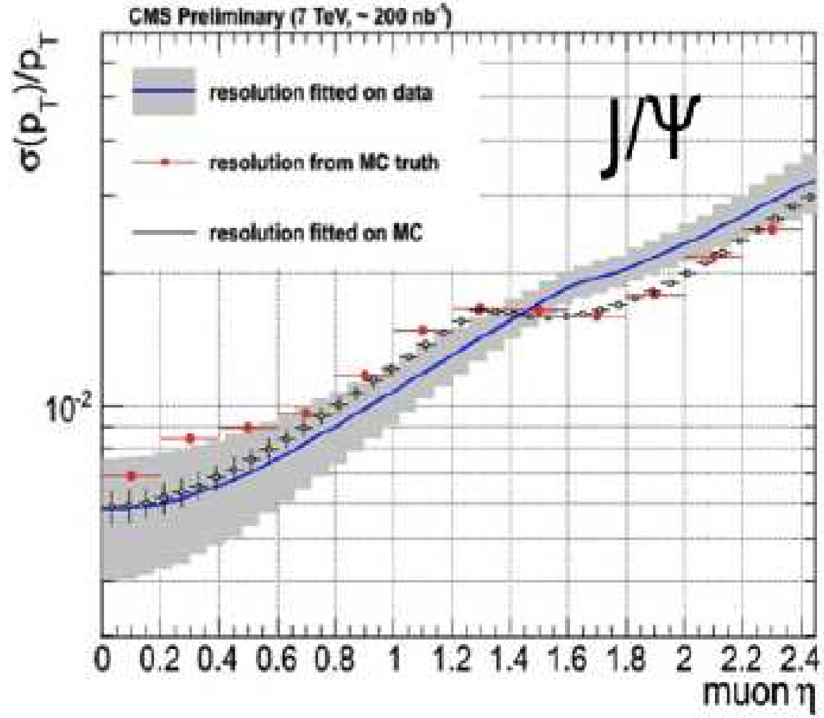
- For $p_T \leq 100$ GeV, $\Delta p_T/p_T \approx 0.7\text{-}2\%$ ($|\eta| < 1.6$)
- Muon resol. dominated by inner tracking resol for $p_T < \approx 100$ GeV
- $\Delta dxy \approx 10$ µm resolution at high p_T
- $\Delta z \approx 20\text{-}40$ µm resolution at high p_T ($|\eta| < 2$)

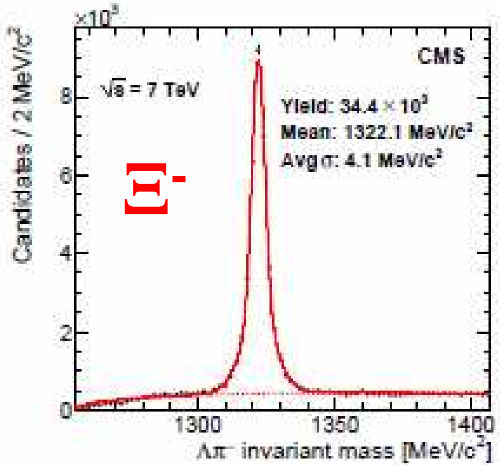
b-tagging

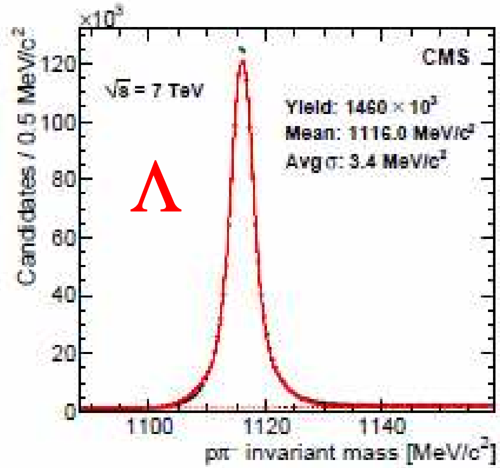
Tracking performance





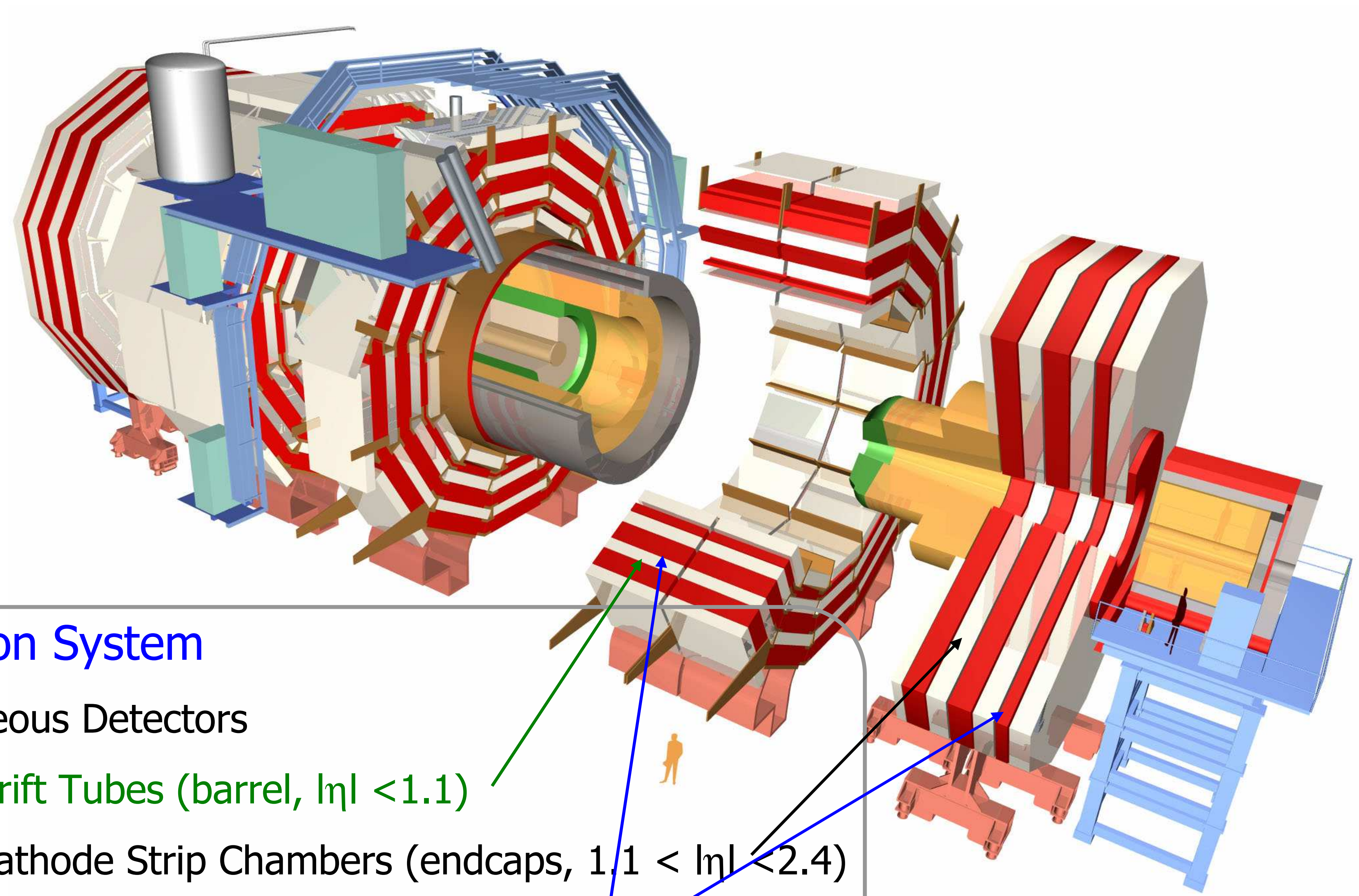






- Tracker resolution working almost as in simulation
- Resolutions extracted directly from data (narrow resonance widths)

Muon system

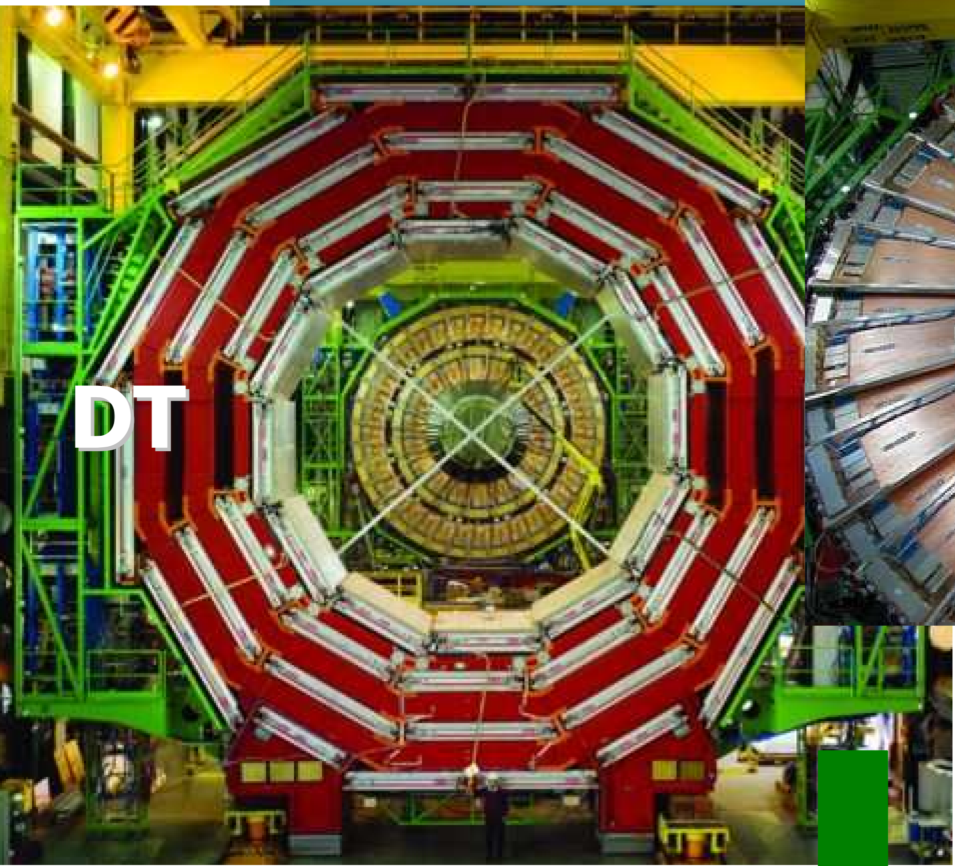


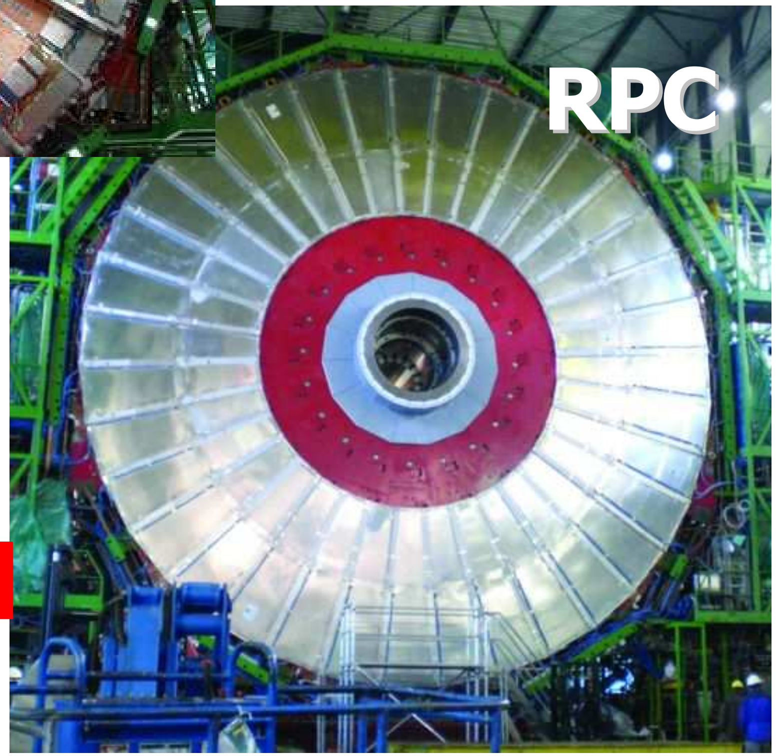
Muon System

Gaseous Detectors

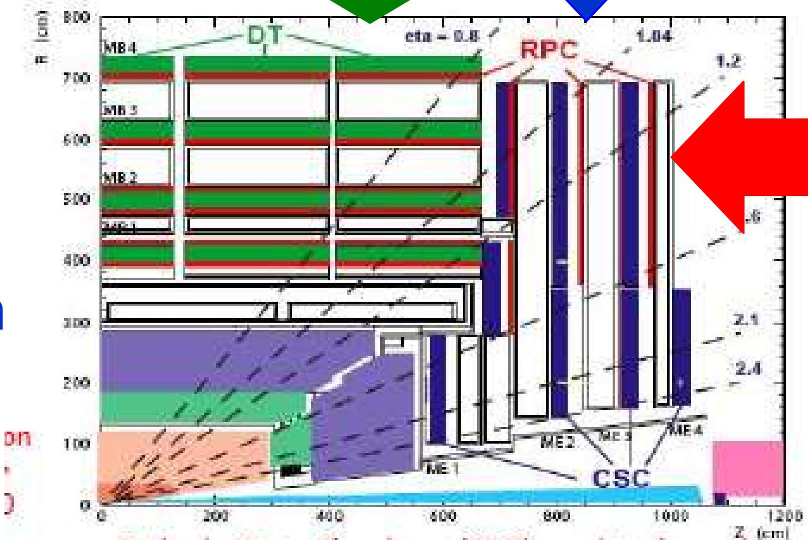
- ❑ Drift Tubes (barrel, $|\eta| < 1.1$)
- ❑ Cathode Strip Chambers (endcaps, $1.1 < |\eta| < 2.4$)
- ❑ Resistive Plate Chambers ($|\eta| < 2.4$)

Muon system

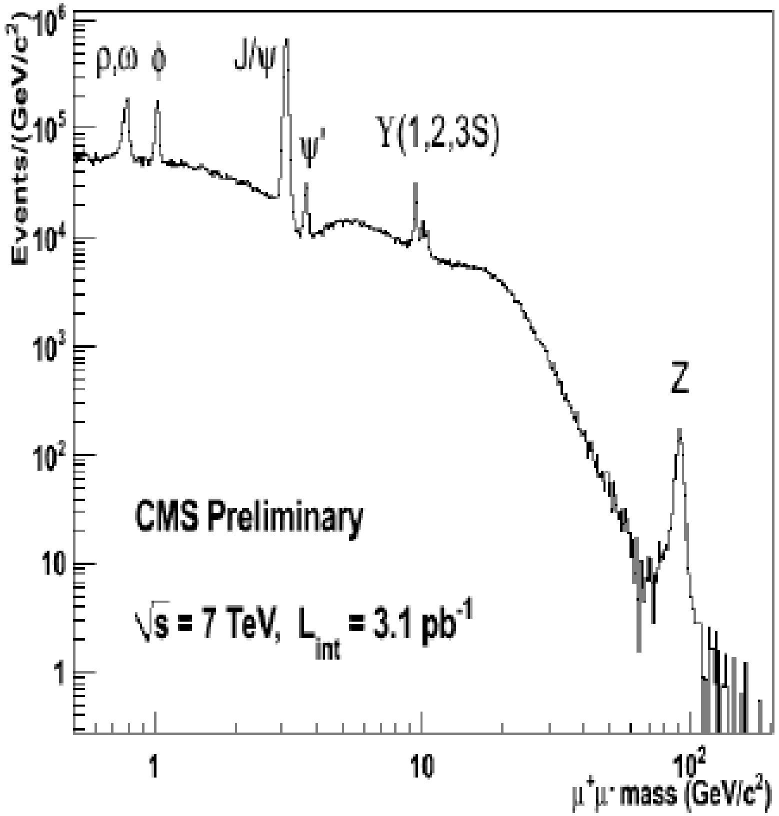


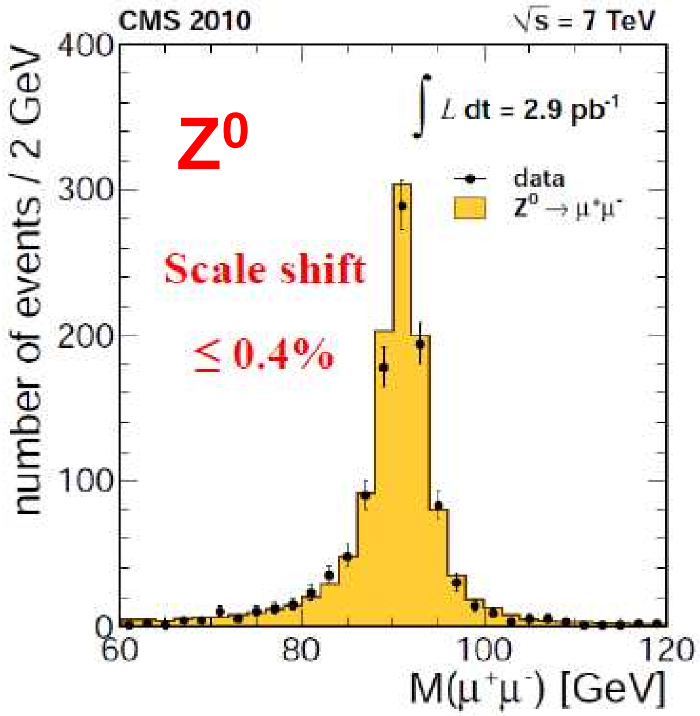


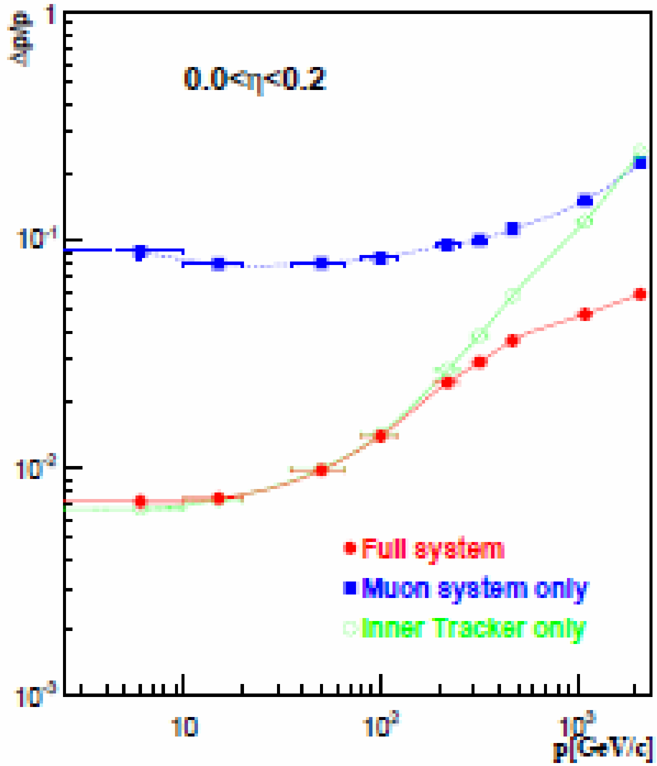
Intrinsic position resolution per chamber ~100 μm



Muon performance

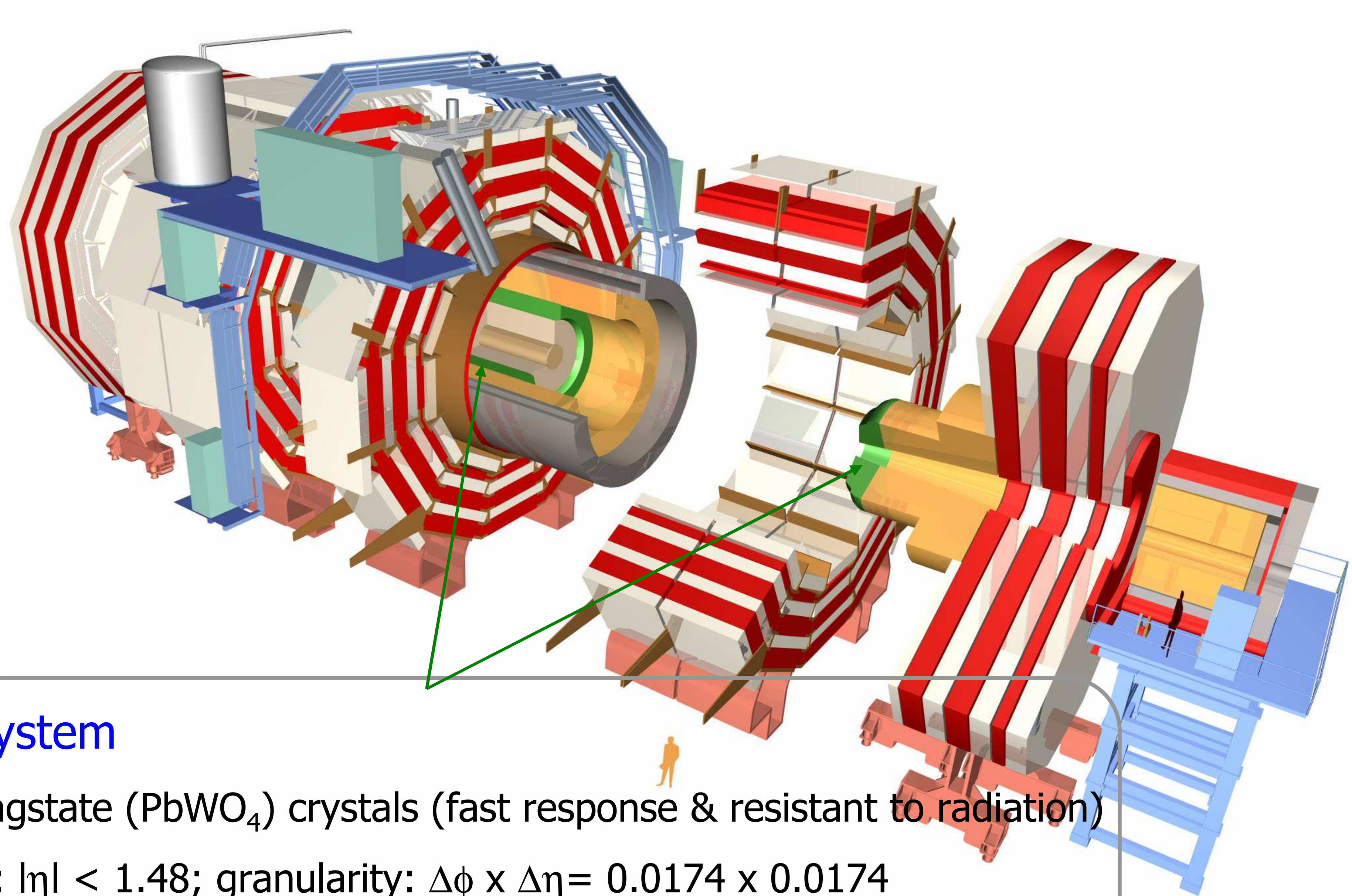






- Robust, efficient and redundant muon triggering system (DT, CSC, + fast RPC)
- Muon Tracking combines Tracker & Muon Chambers info: p_T resolution (< ~ 1%) dominated by Tracker for p_T<~100-200 GeV. For higher p_T, muon system is needed (< ~ 10 %) .
- Efficient muon identification and reconstruction (<10%) for TeV momenta (good alignment + lever arm)

Electromagnetic calorimetry

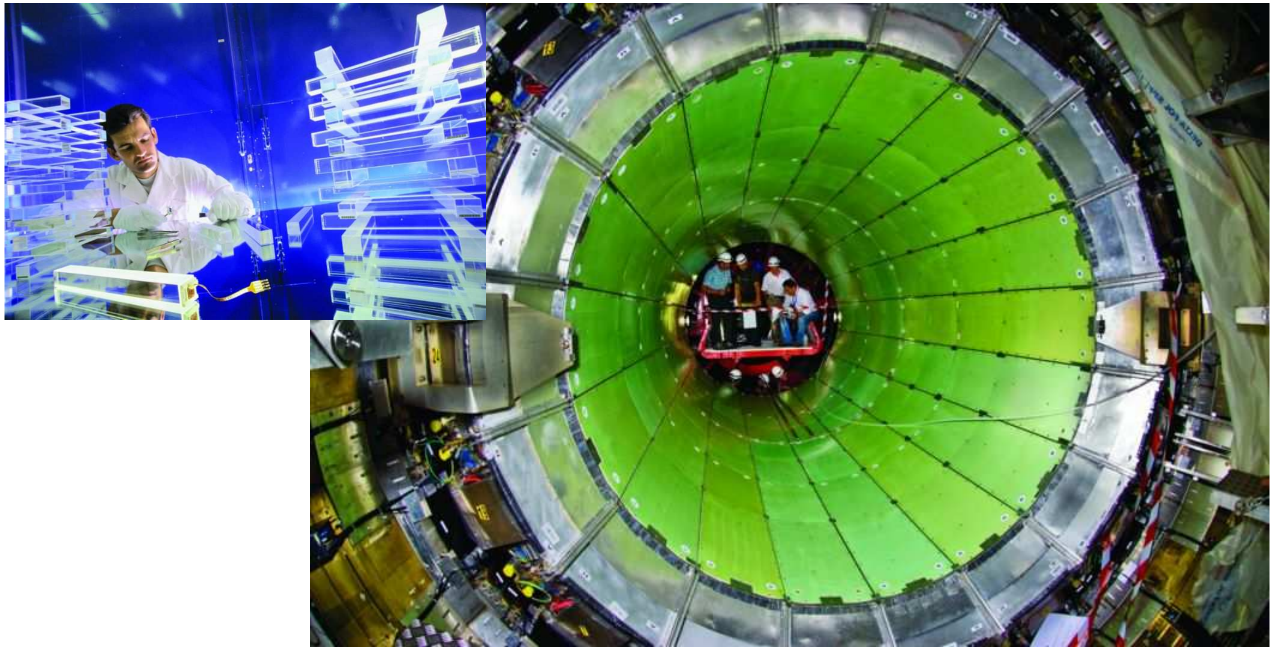


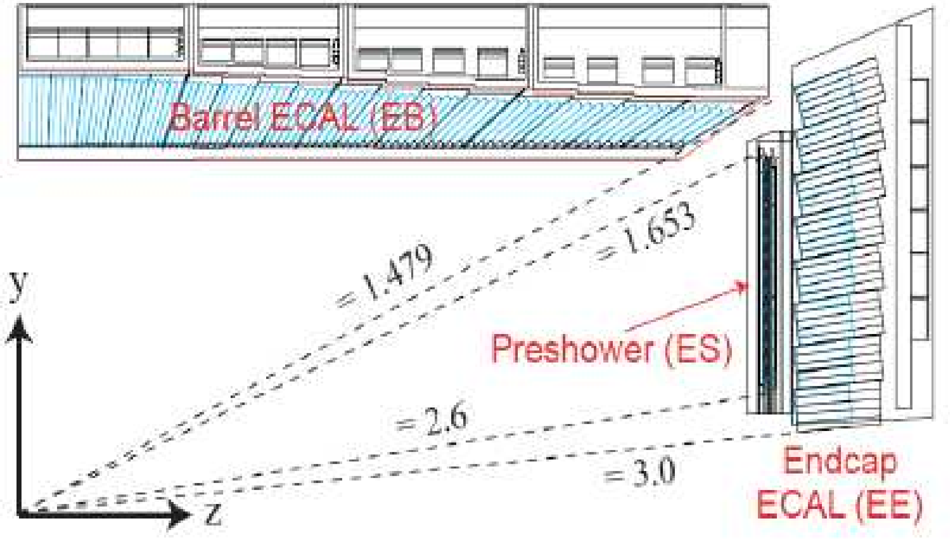
ECAL System

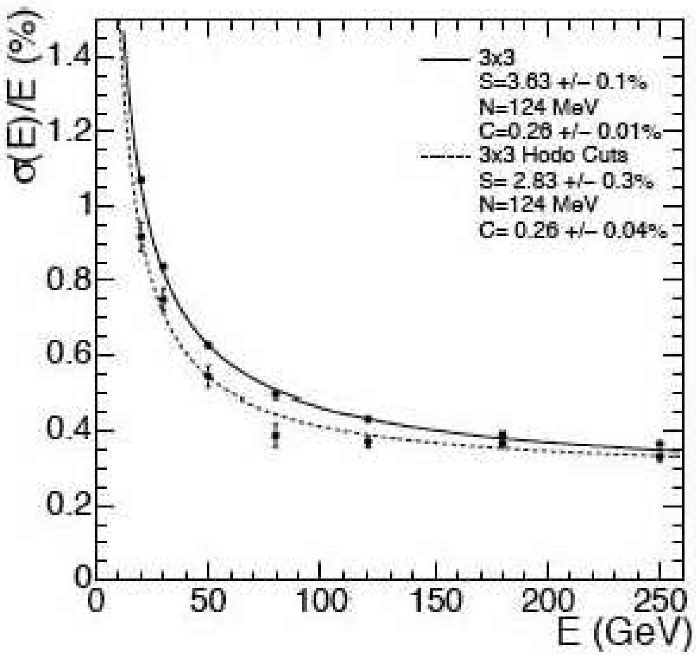
Lead Tungstate ($PbWO_4$) crystals (fast response & resistant to radiation)

- barrel: $|\eta| < 1.48$; granularity: $\Delta\phi \times \Delta\eta = 0.0174 \times 0.0174$
- endcap: $1.65\ |\eta| < 3.0$; granularity: $\Delta\phi \times \Delta\eta = 0.02 \times 0.02$

Electromagnetic calorimetry





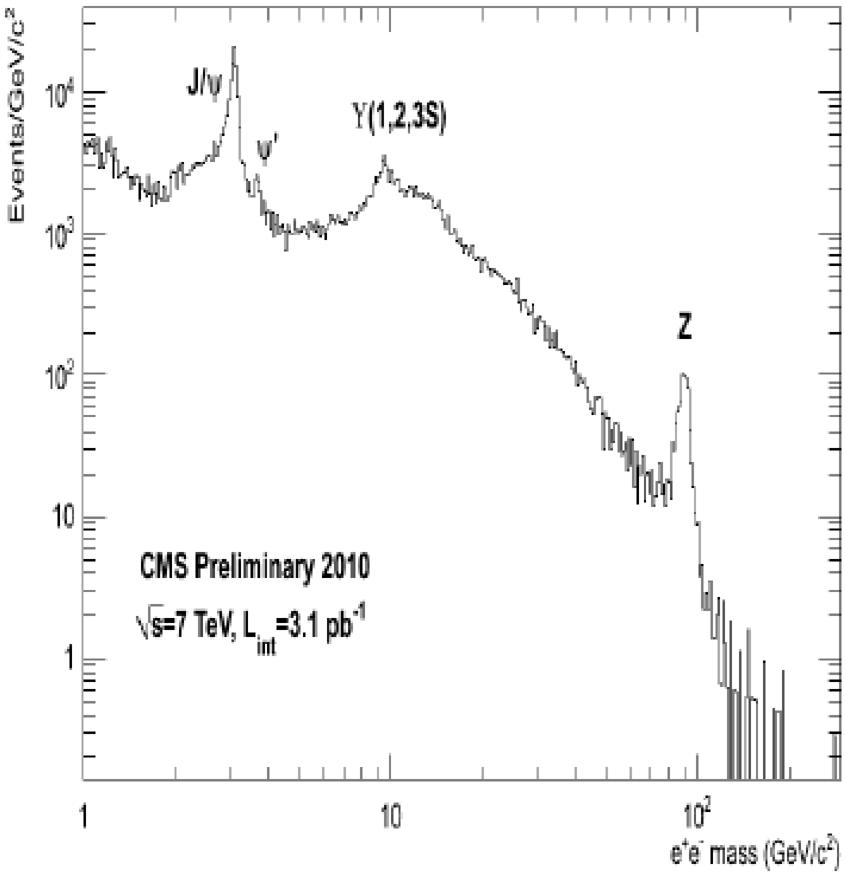


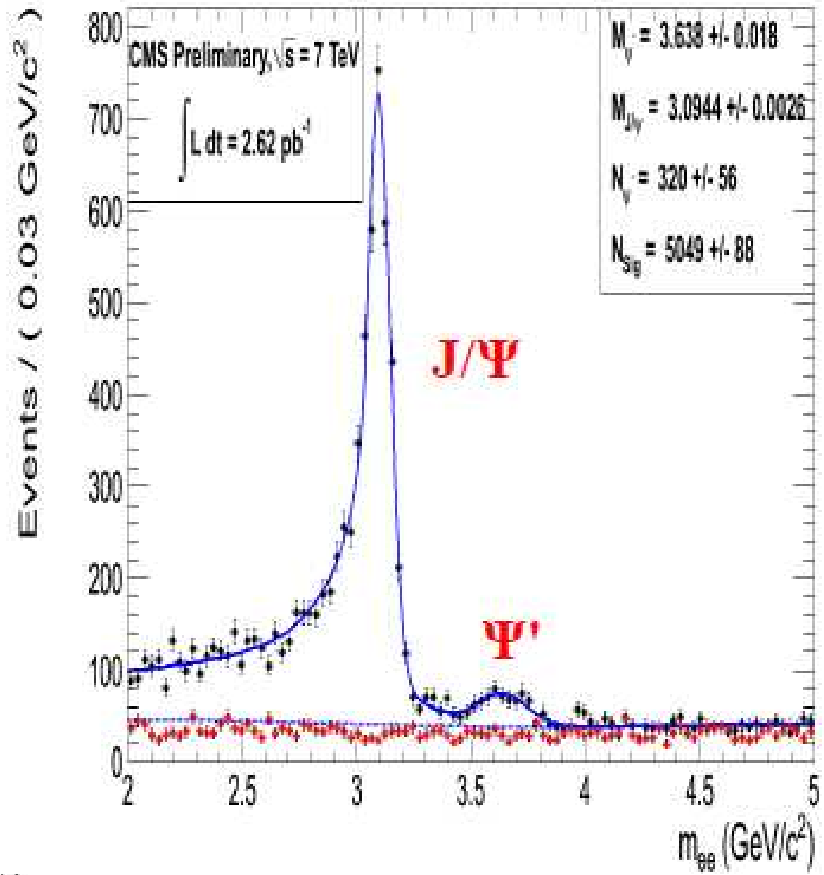
Good granularity and Excellent energy resolution
(low noise, good intercalibration)

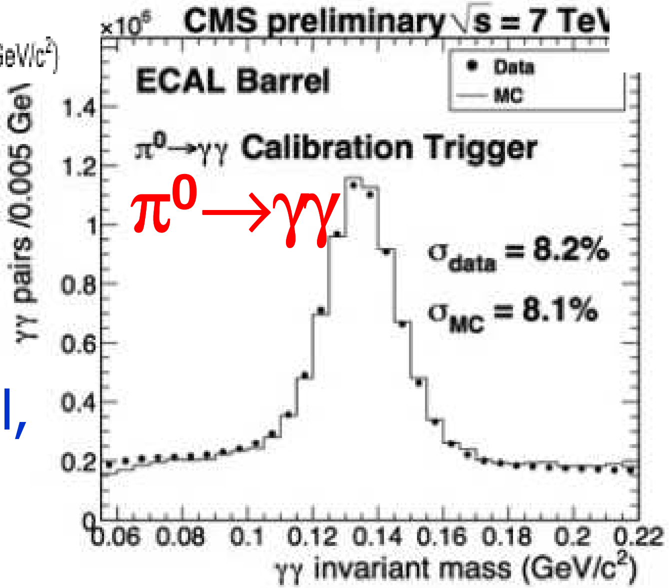
~0.5% in barrel region for E_T> 50 GeV

$$\left(\frac{\sigma}{E}\right)^2 = \left(\frac{2.8\%}{\sqrt{E}}\right)^2 + \left(\frac{0.12}{E}\right)^2 + (0.3\%)^2 \quad \text{(E in GeV)}$$

Electrons/photons

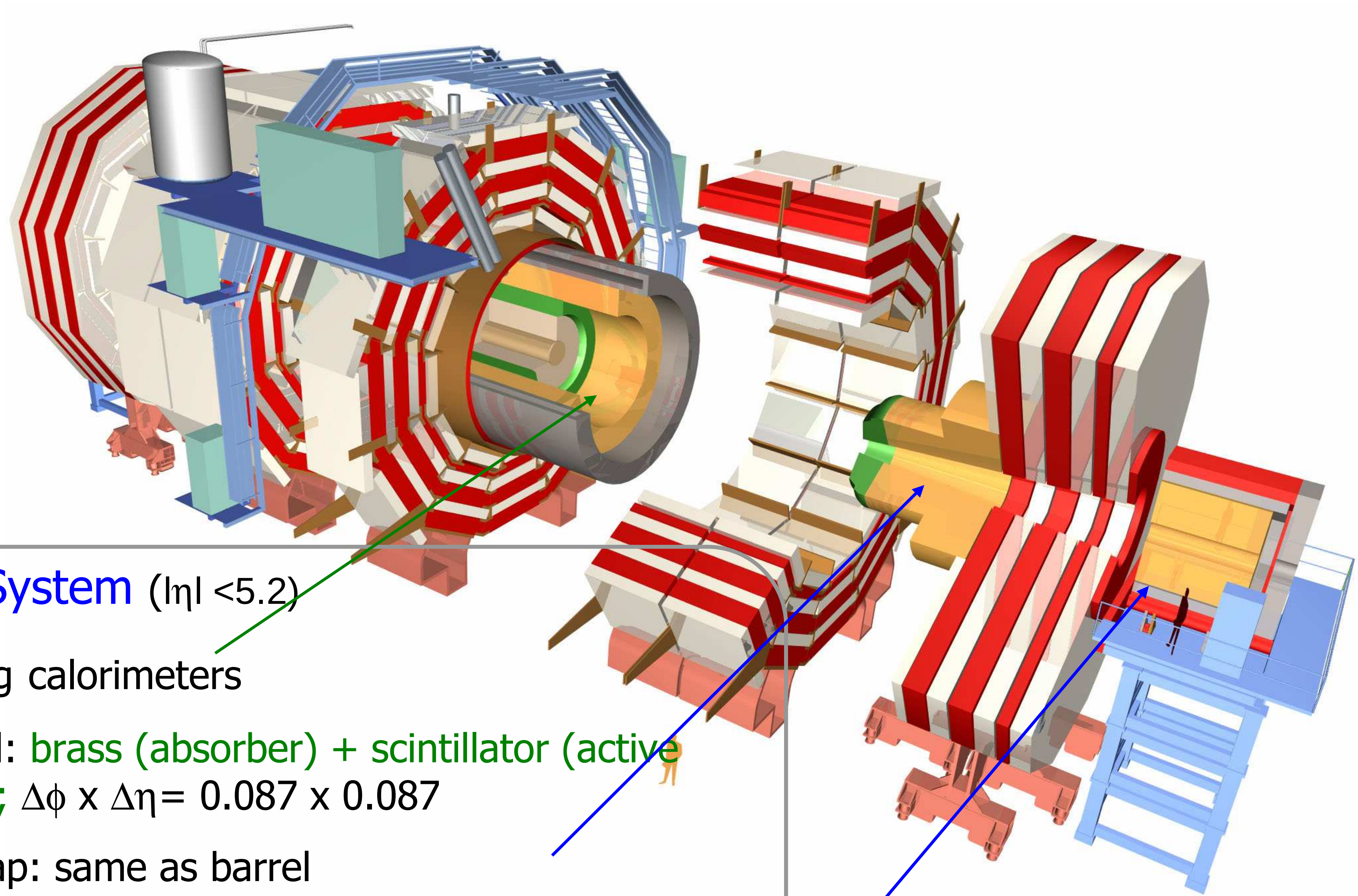






π^0 mass calibration used to set E_T scale correction (1% in barrel, 3% endcap for high E_T).

Hadronic calorimetry

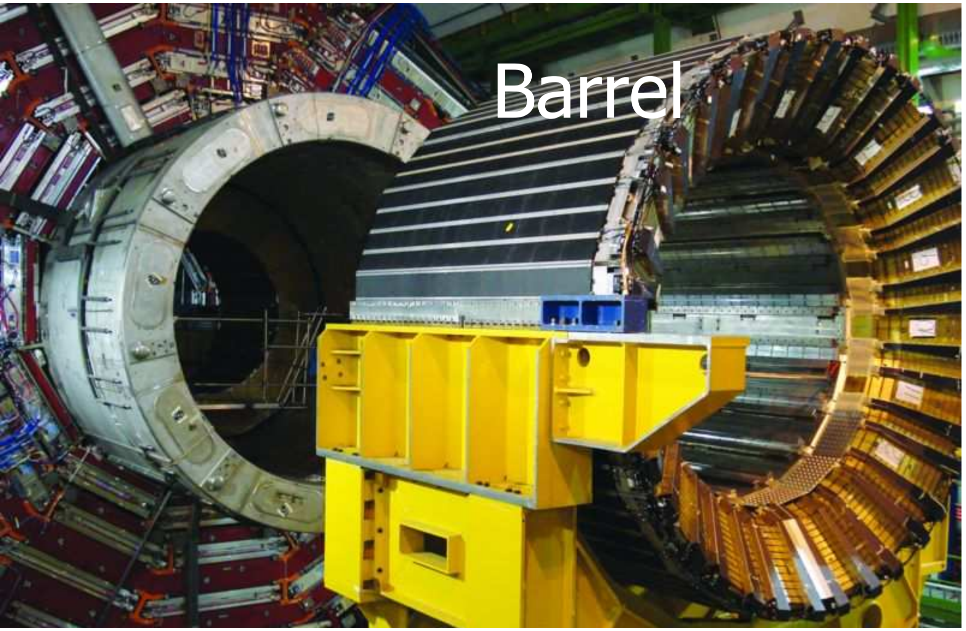


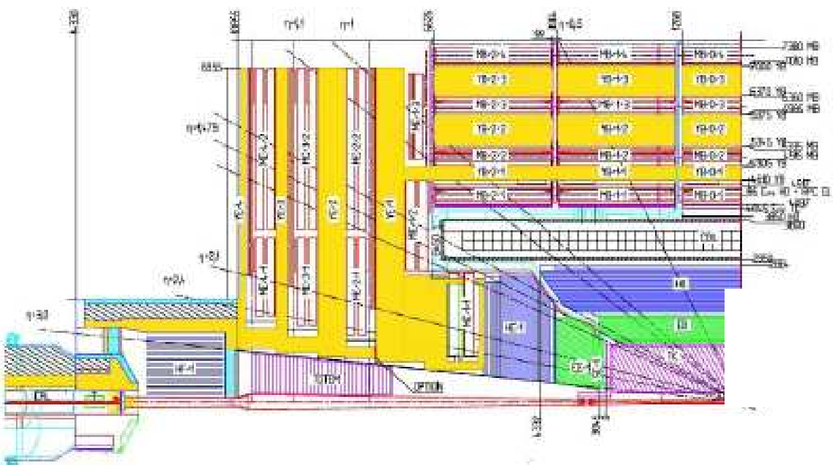
HCAL System (|η| <5.2)

Sampling calorimeters

- Barrel: brass (absorber) + scintillator (active material; $\Delta\phi \times \Delta\eta = 0.087 \times 0.087$
- Endcap: same as barrel
- Very forward calorimetry: Quartz fiber & steel; $\Delta\phi \times \Delta\eta = 0.175 \times 0.175$

Hadronic Calorimeter



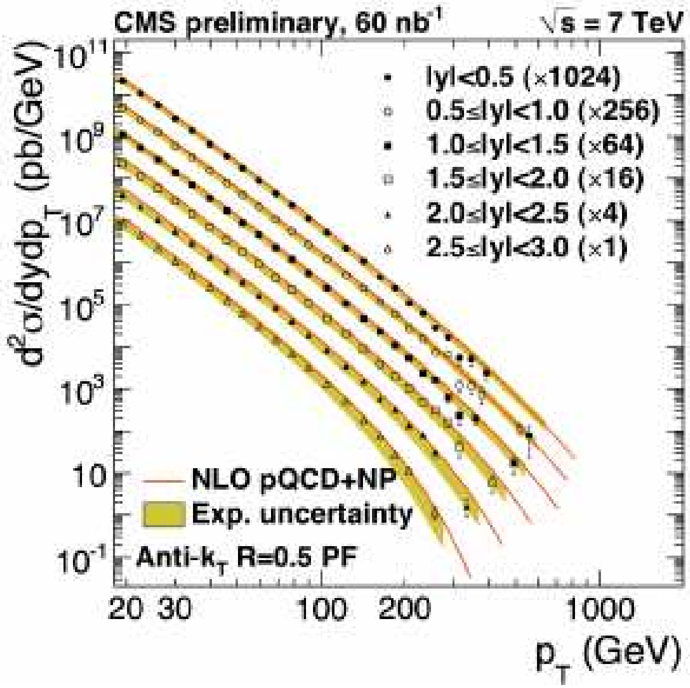


- Compact, hermetic, good segmentation and coverage (|η| <5.2).
- Jet angular resolution ~ 20 (30) mrad in φ(θ) at $E_T \geq$ 100 GeV
- Jet transverse energy resolution (using ECAL + HCAL, barrel only)

$$\left(\frac{\sigma}{E_T}\right)^2 = \left(\frac{1.25}{\sqrt{E_T}}\right)^2 + \left(\frac{5.6}{E_T}\right)^2 + (3.3\%)^2$$

- Fraction of energy deposited varies non-linearly with energy → corrections needed on raw data.

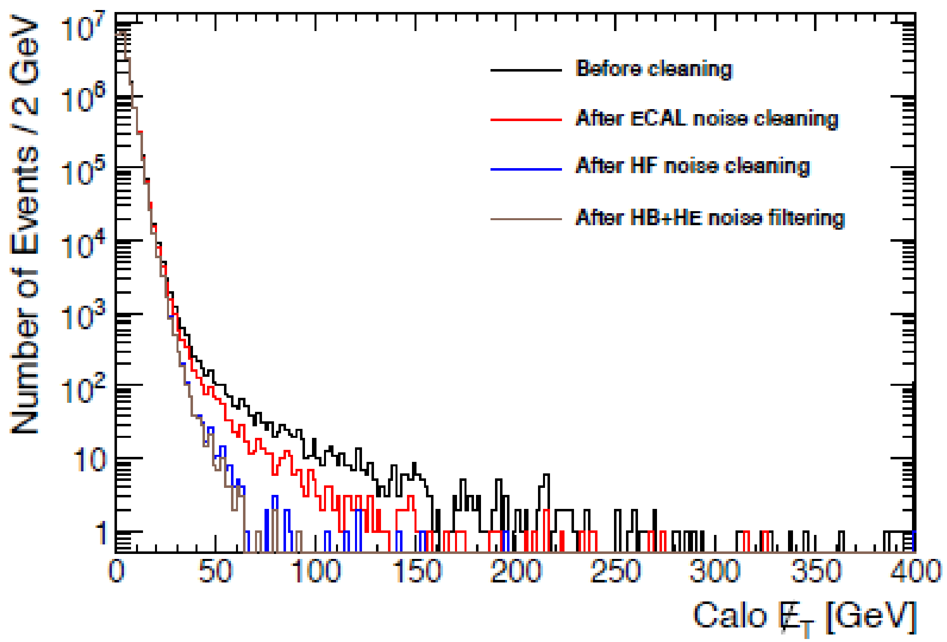
Jets & Missing ET



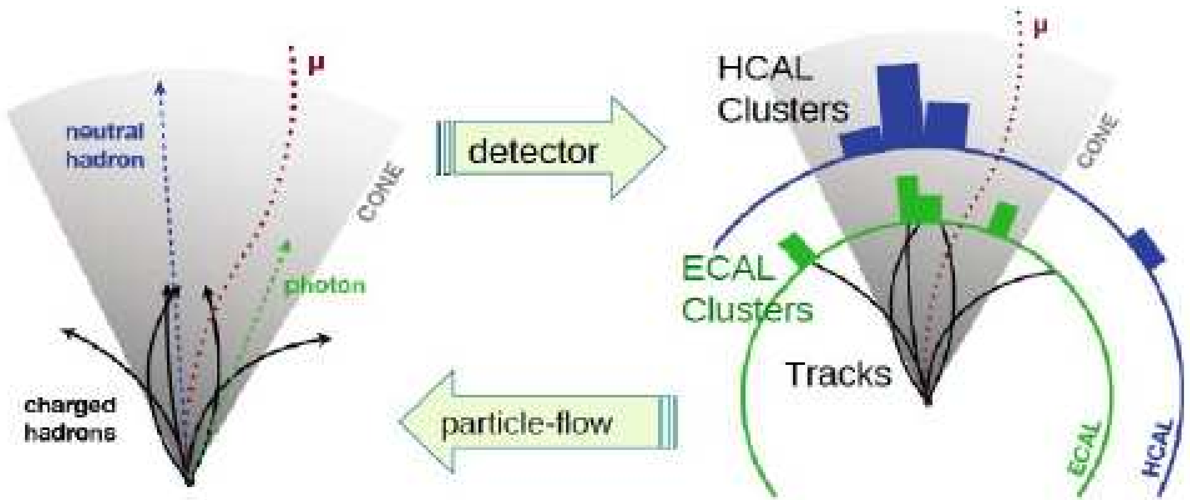
- ❑ Jets are experimental signature of quarks & gluons
- ❑ Jets reconstructed using iterative algorithms, clustering together calo-towers (with tracking info), in a certain cone with radius R.
- ❑ Jets are corrected for non-linearity and inhomogeneity of calorimeter response (from simul., test-beam & data).

Missing E_T (MET) (in transverse plane)

- ❑ from real undetected particles (neutrino, LSP)
- ❑ from mis-measured jets or from jet energy resolution



Tools: Particle Flow



In CMS, charged particles get well separated due to the huge tracker volume and the high magnetic field (3.8 T)

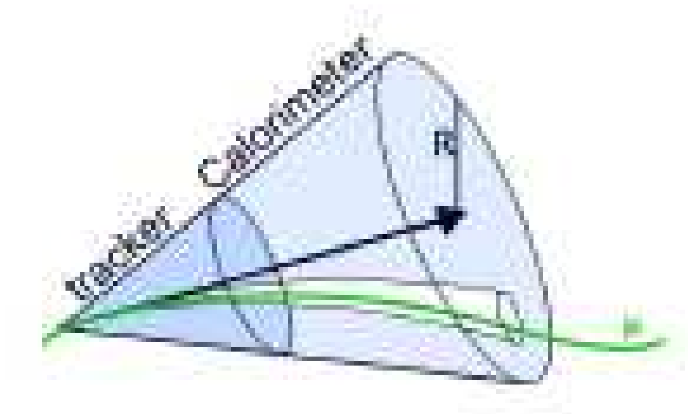
CMS has an excellent tracking resolution, able to go to down to very low momenta (~few hundred MeVs)

CMS has also an excellent electromagnetic calorimeter with good granularity

In multijet events, only 10% of the energy corresponds to neutral (stable) hadrons

- Clustering starts from a list of "identified particles"
- Big improvement in energy resolution and identification using Particle-Flow techniques.
- Especially Jets (PFJets), Missing E_T (PFMET), Taus (PFTaus)

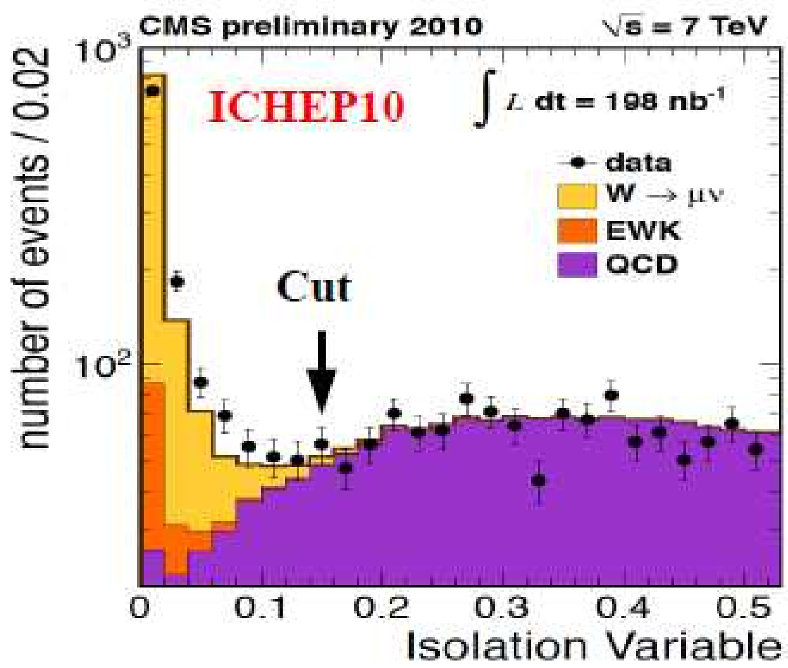
Tools: lepton isolation



- Leptons from hard processes are produced isolated.
- Isolation measured as the amount of energy (calorimeters) or the pt (tracker) in a cone around de “isolated” particle.

Isolated muons from W, Z decays

Muons from QCD



Very powerful tool to distinguish QCD from EWK events

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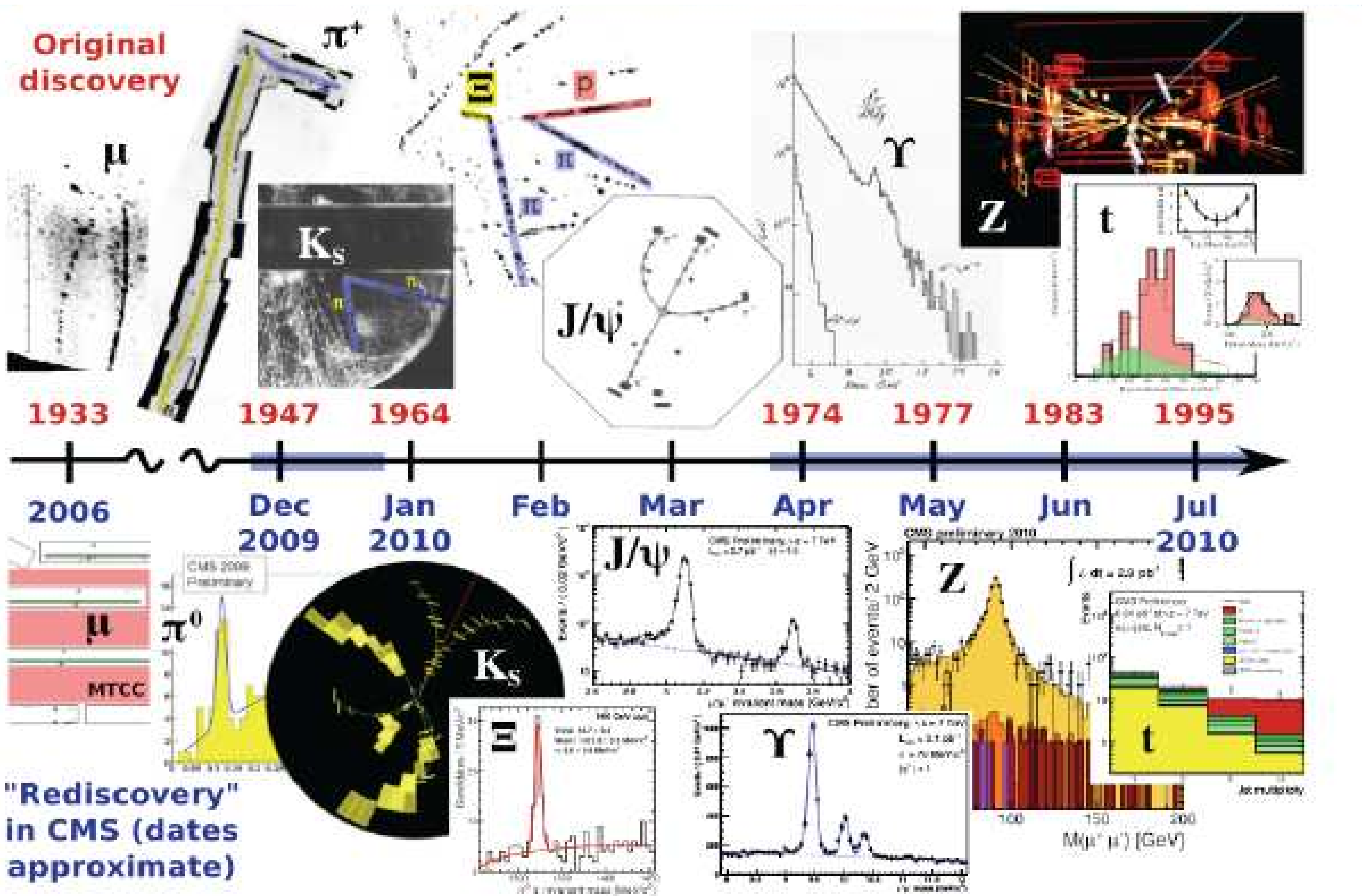
Re-discovering Standard Model at 7 TeV



LHC Processes

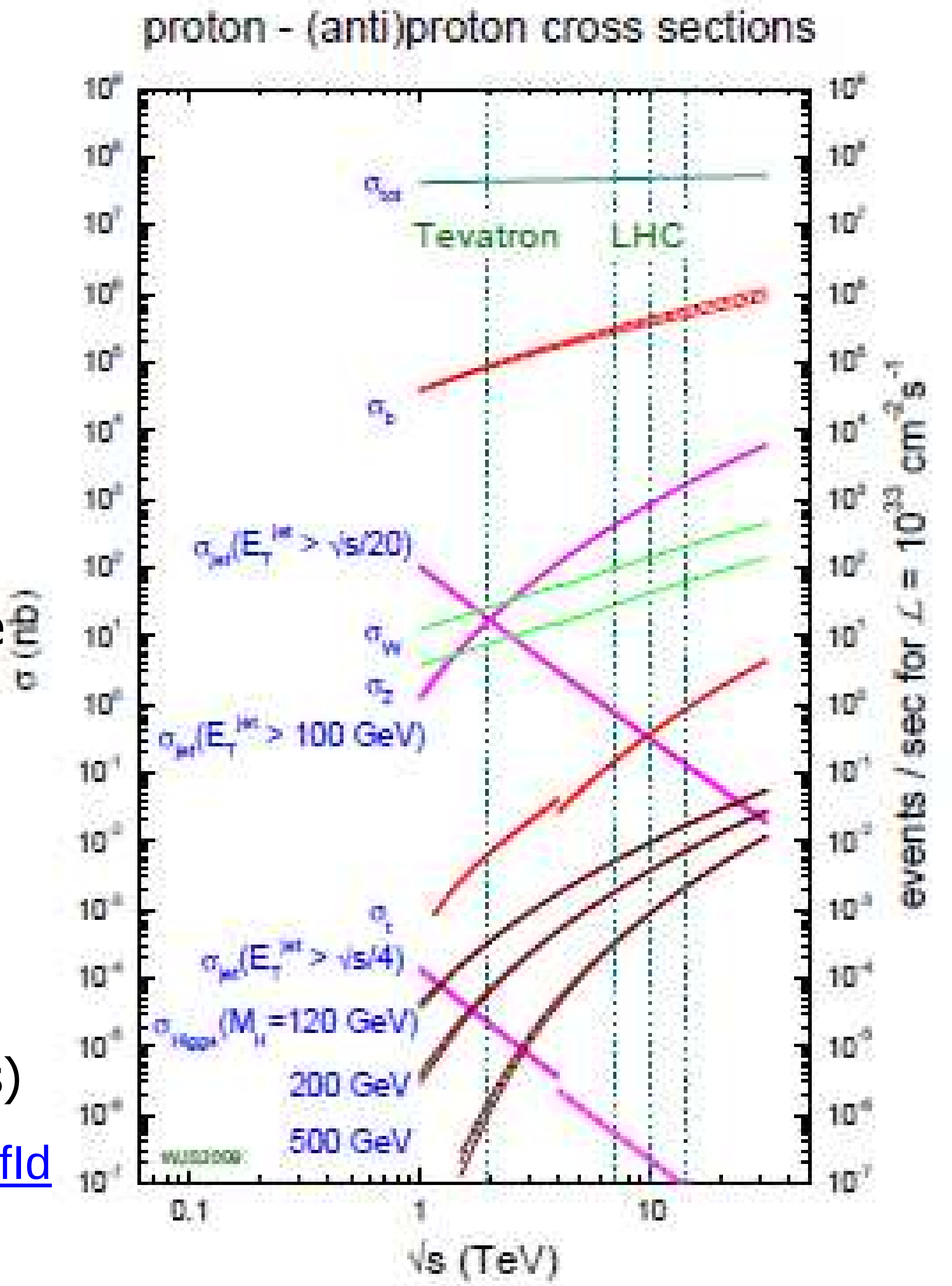
At CMS we have addressed analysis as data have been collected and statistics increased, starting by processes

- with largest cross-sections (QCD, b production, Electroweak bosons, top…)
- small pt regions involved.

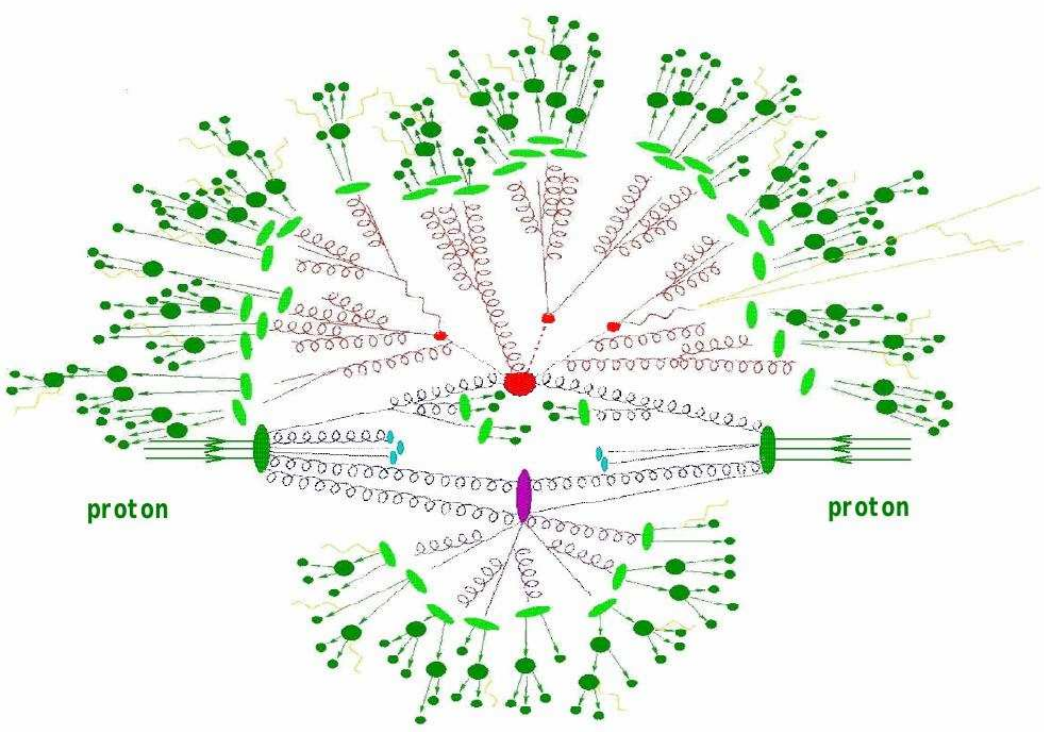
- Establishing SM at √s = 7 TeV, with also some new observations
- Searches for exotic particle production
- And later… SUSY and Higgs

To-date 35 papers published by CMS with 2010 data, and many more in the internal approval procedure (for publication or Winter Conferences)

http://indico.in2p3.fr/conferenceOtherViews.py?confId=4403&view=nicecompact Moriond Conferences

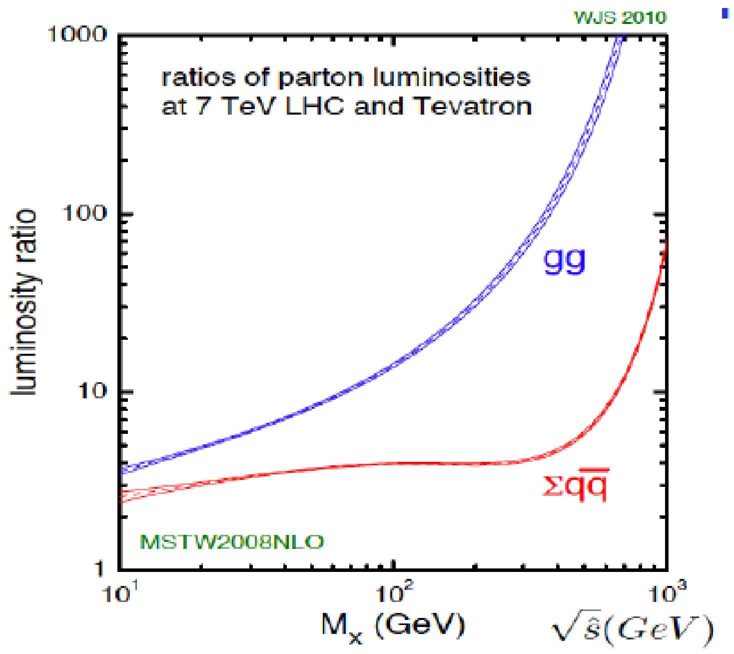


QCD



- Gluon-gluon dominant in LHC versus Tevatron
- Characterize better gluon and heavy flavour
- Measure α_s, constraint PDFs
- Study non-perturbative effects: underlying event, multi-parton interactions, hadronization

First results already at LHC start, with low luminosity collected at $\sqrt{s}$ = 0.9, 2.36, 7 TeV

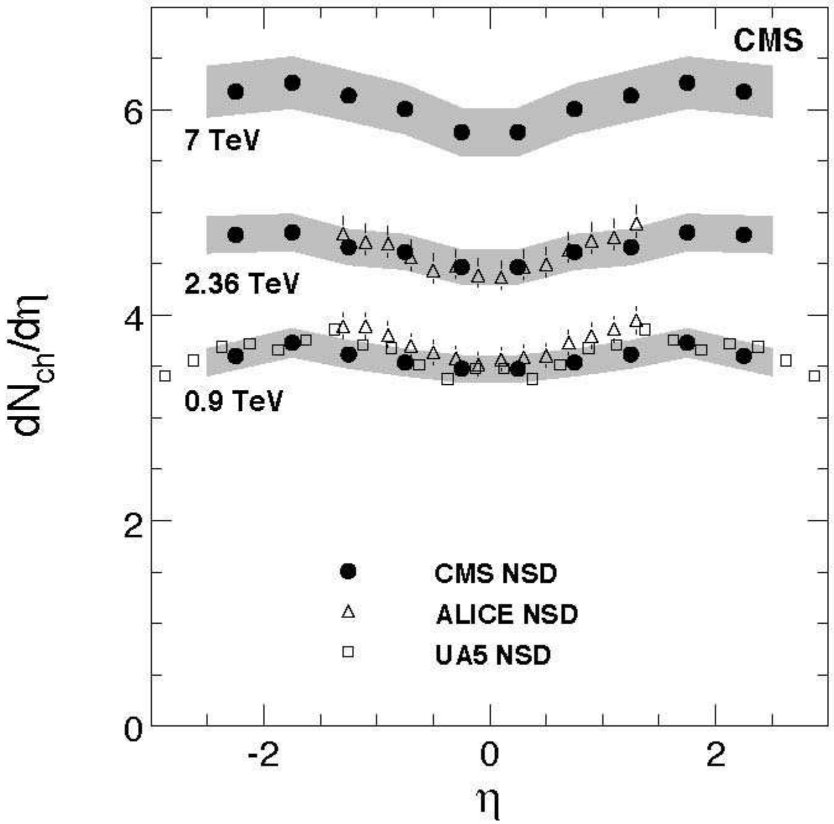


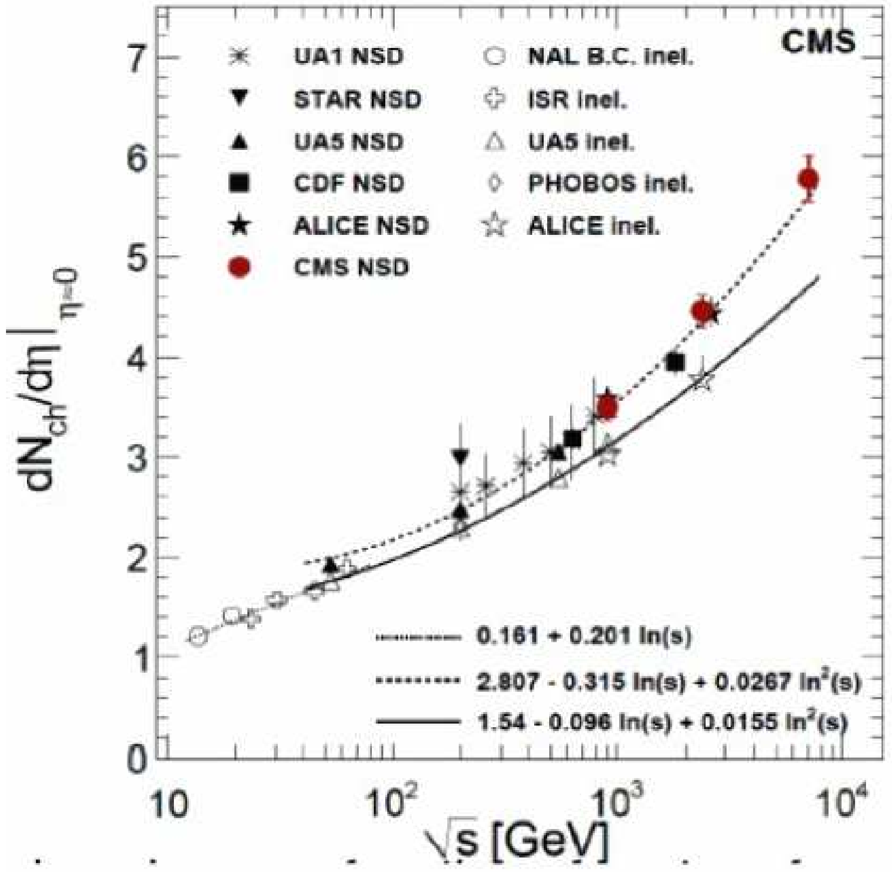
QCD : charged particle spectra

Charged hadron transverse momentum and pseudorapidity distributions at sqrt(s) = 0.9, 2.36, 7 TeV

Phys. Rev. Lett. 105 (2010) 022002

J. High Energy Phys. 02 (2010) 041

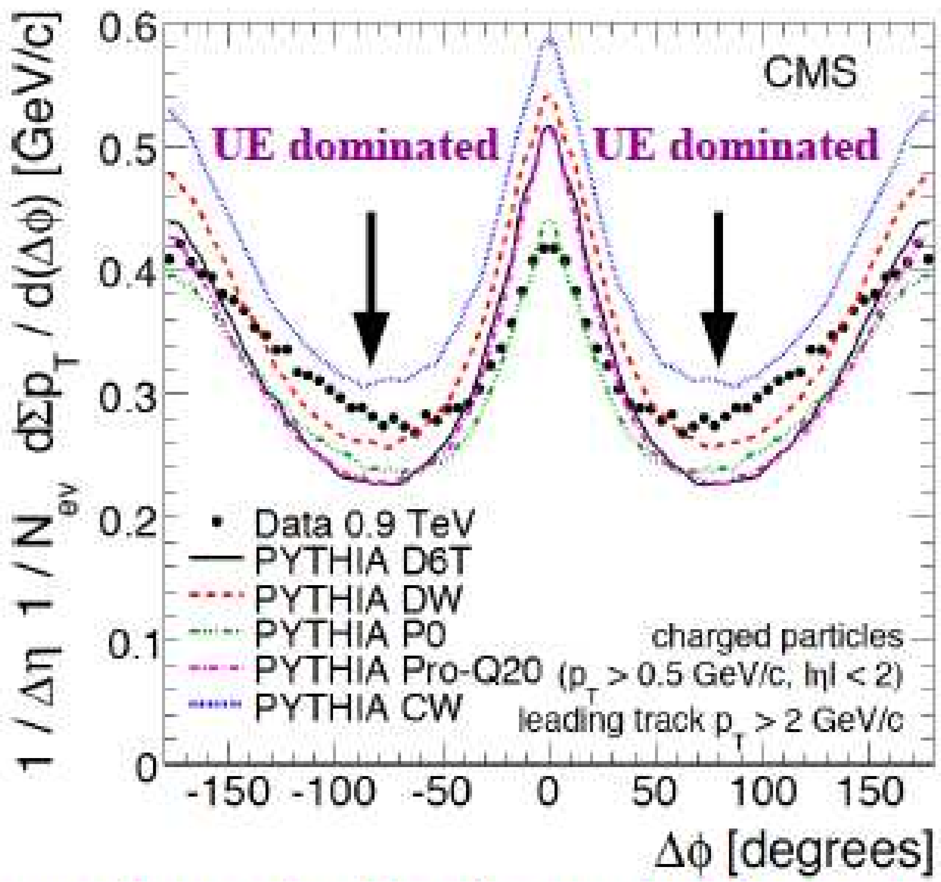




Steeper rise in particle density with $\sqrt{s}$ than what most models predict (Phojet and various tunings of Pythia). ➔ New MC tunings based on LHC data are ongoing

QCD: Underlying event

Eur. Phys. Journal C 70 (2010) 555



Azimuthal separation Δφ between leading track and any other track:

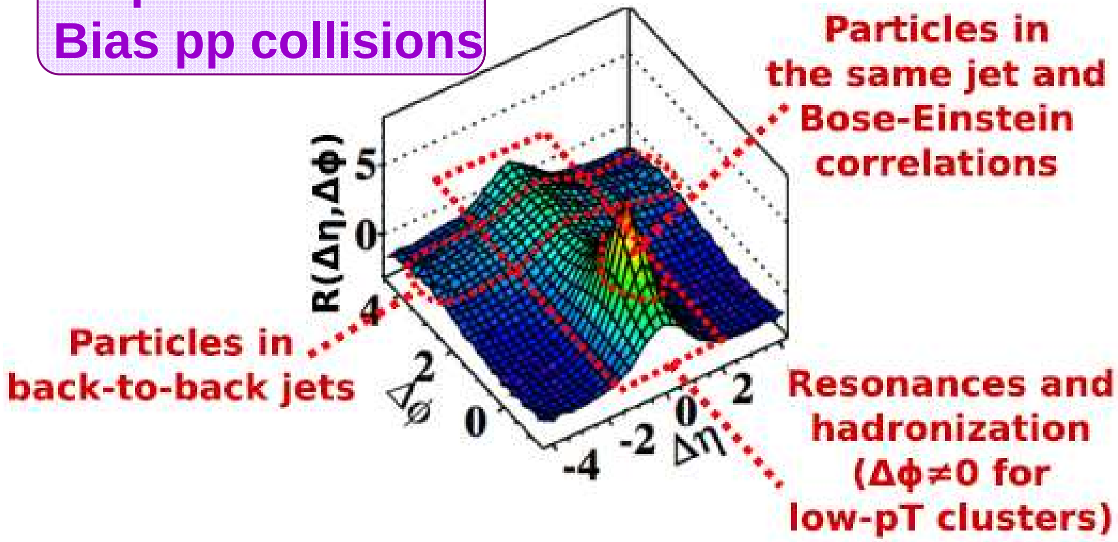
- Δφ < 60 degrees due to parton fragmentation and radiation
- |Δφ| > 120 degrees, two back-to-back jet characteristic distribution
- 60 < |Δφ| <120 degrees, hadron production is depleted but it is nonzero, a feature attributed mainly to MultiParticle Interactions (MPI)
- Not well reproduced by various Pythia settings

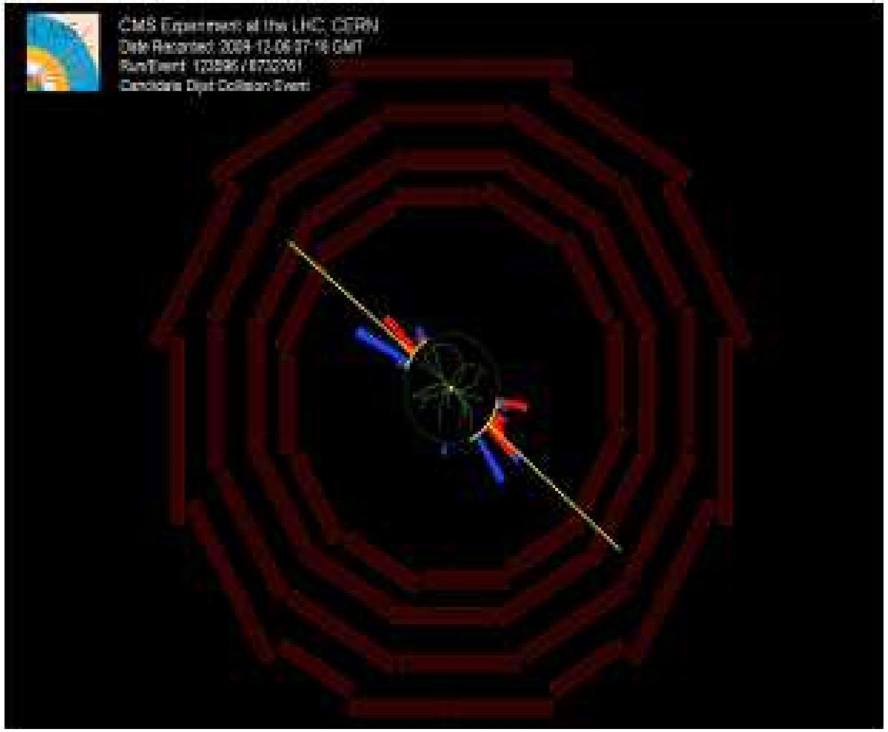
MPI not correctly treated in generators at these higher energies

QCD: Two-particle angular correlations: The Ridge

J. High Energy Phys. 09 (2010) 091

Expected in Min Bias pp collisions



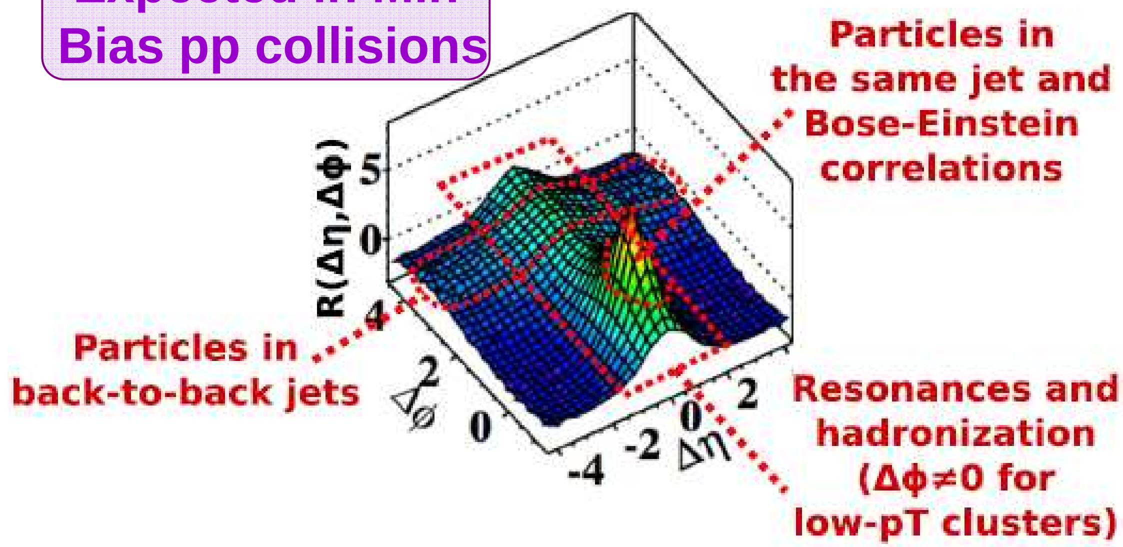


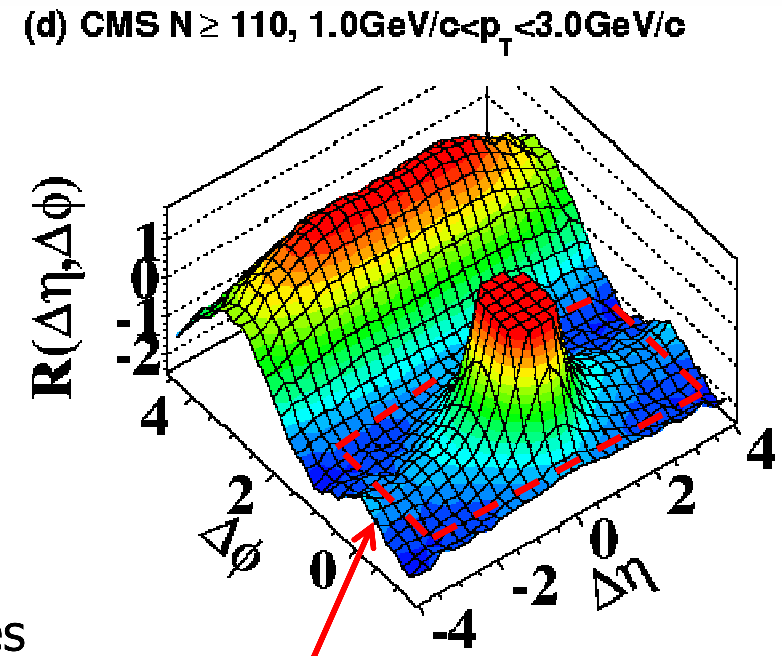
QCD: Two-particle angular correlations: The Ridge

J. High Energy Phys. 09 (2010) 091

$$R(\Delta\eta,\Delta\varphi) = \left\langle (N-1)\left(\frac{S_N(\Delta\eta,\Delta\varphi)}{B_N(\Delta\eta,\Delta\varphi)} - 1\right)\right\rangle_N$$

Expected in Min Bias pp collisions





Unexpected correlations seen for high multiplicity events

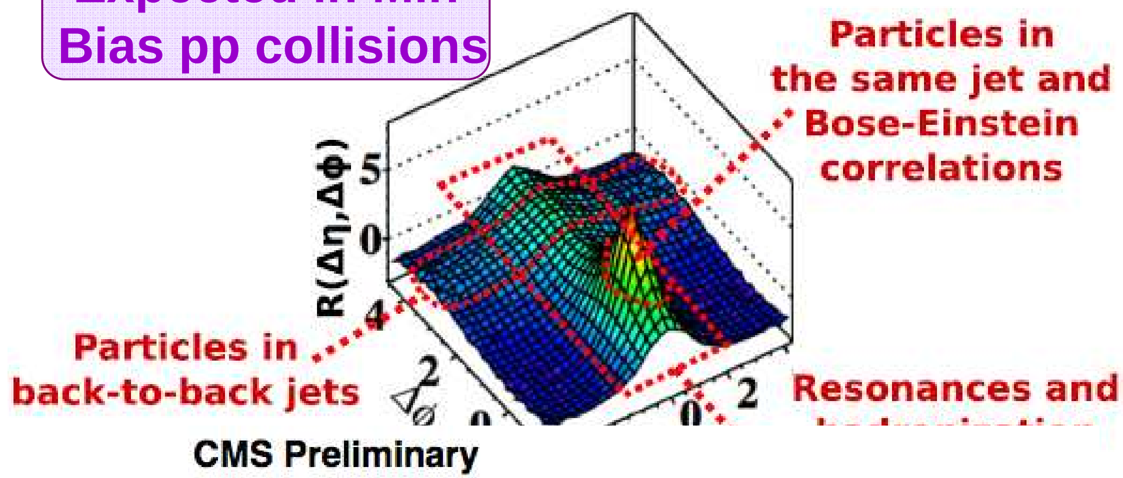
- Unexpected angular correlations between pairs of particles with Δϕ≈0 and any Δη
- Not reproduced by our reference MonteCarlos (Pythia..)
- Similar effects have been observed in Heavy Ion experiments
- Physics origin not understood yet (possibly related to MPI effect not accounted for in MC). Studies going on.

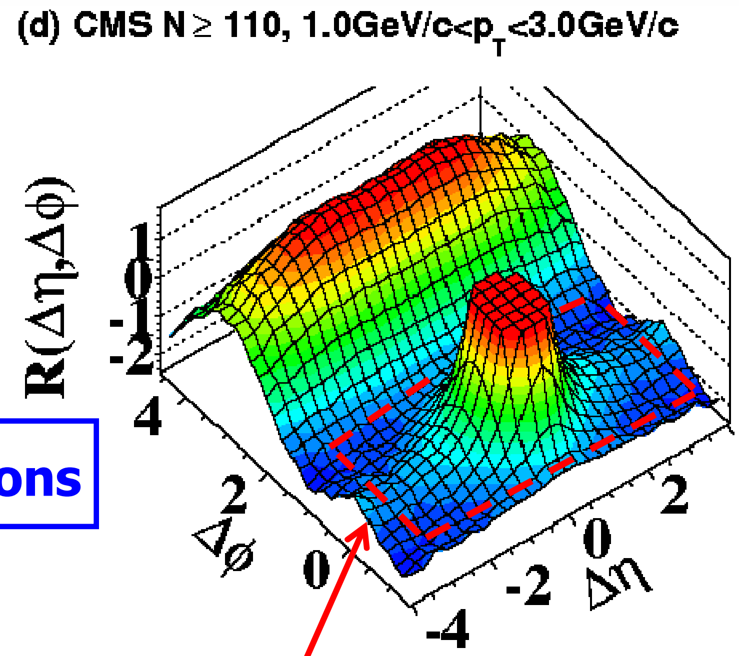
QCD: Two-particle angular correlations: The Ridge

J. High Energy Phys. 09 (2010) 091

$$R(\Delta\eta,\Delta\varphi) = \left\langle (N-1)\left(\frac{S_N(\Delta\eta,\Delta\varphi)}{B_N(\Delta\eta,\Delta\varphi)} - 1\right)\right\rangle_N$$

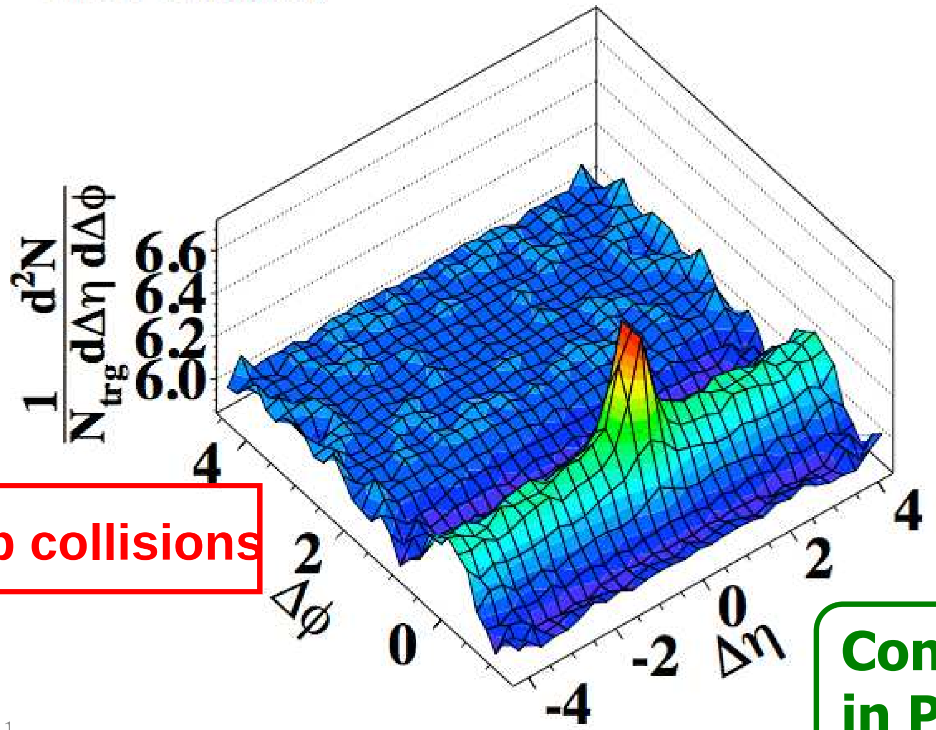
Expected in Min Bias pp collisions





pp collisions

Unexpected correlations seen for high multiplicity events



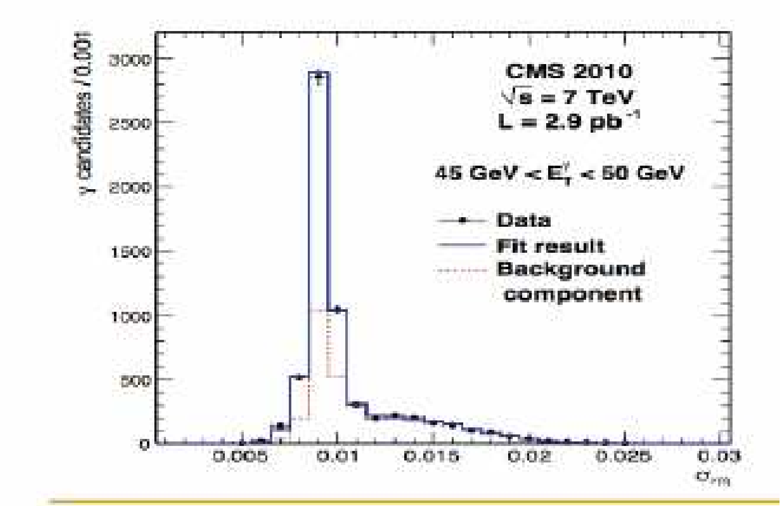
PbPb collisions

Confirmed long-range, near-side correlations in PbPb collisions at 2.76 TeV/nucleon

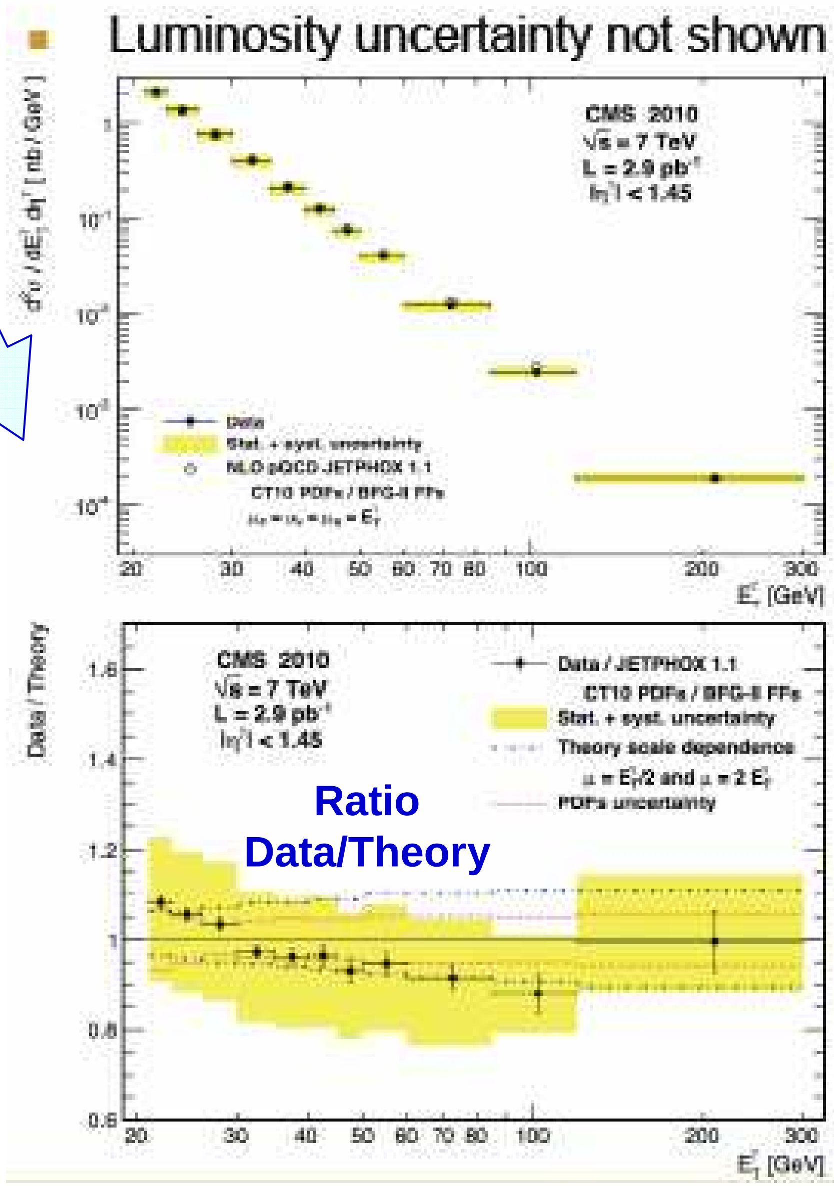
QCD : Isolated prompt photon

Phys. Rev. Lett. 106 (2011) 082001

- Cross-section measurement in a kinematic unexplored region of low $x_T=2\ E_T/\sqrt{s}$: $0.006 < x_T < 0.086$
- Test of pQCD => good agreement with NLO predictions
- Constraint on proton PDFs
- Benchmark for photon identification and backgd estimation for New Physics searches (Higgs$\rightarrow\gamma\gamma$)
- Signal: qg Compton scattering, qqbar annihilation
- Bkgd: π^0 and η decays



Cluster η extent, narrow for signal, with tails for meson decays



QCD : Dijets

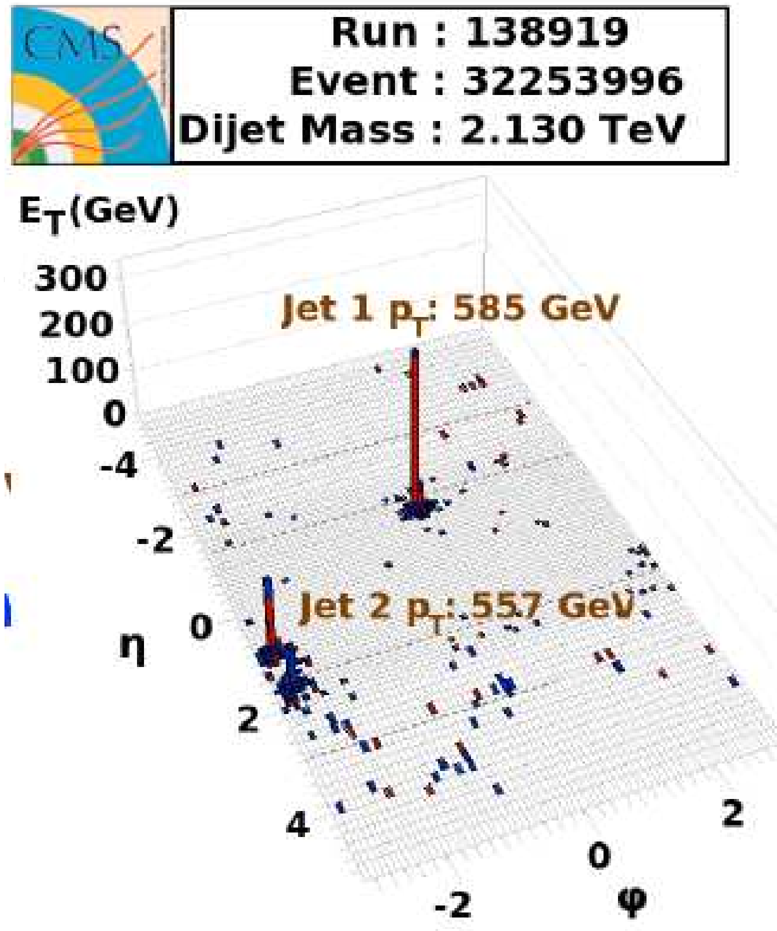
Di-jet production is good scenario

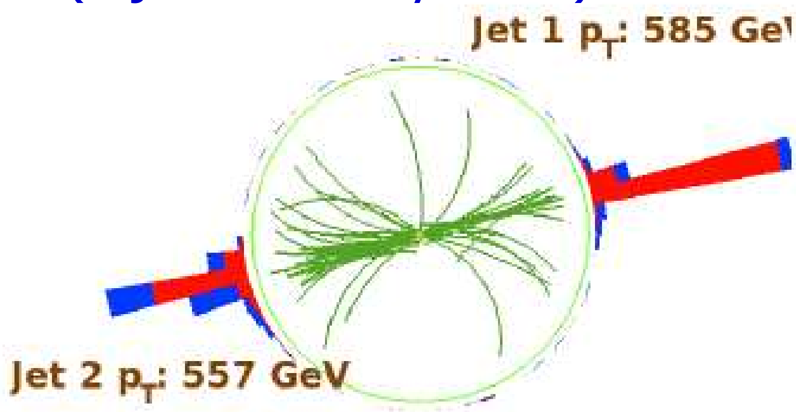
- large cross-sections,
- clean experimental signature: balanced back-to-back jets

to compare with predictions and search for New Physics different models

Look for

- Dijet Resonances
- Quark Compositeness (Dijet Centrality Ratio)





Highest energy dijet event observed in 2010 data

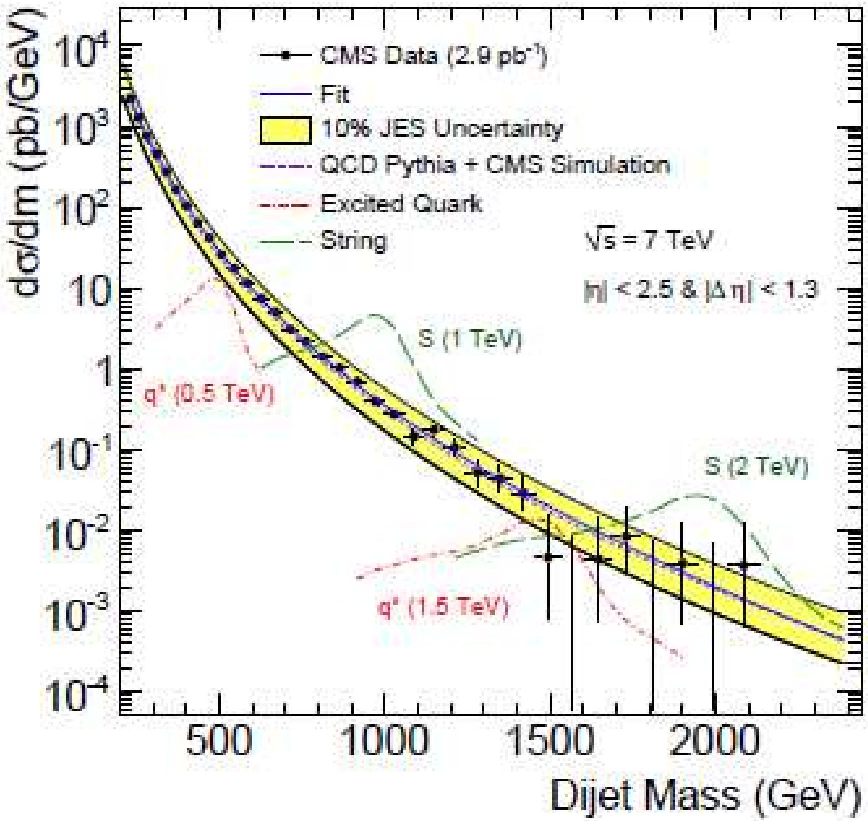
QCD : Dijets Mass Resonances

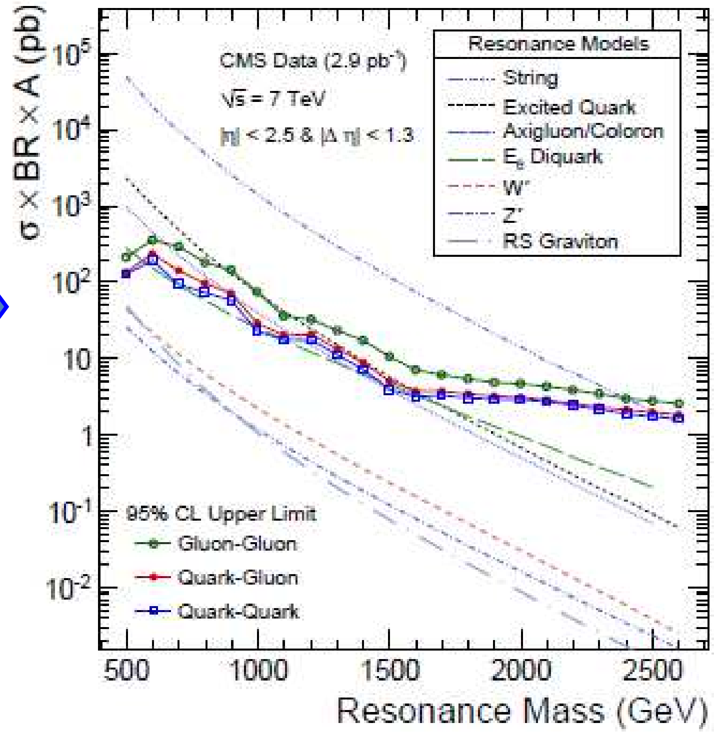
Phys. Rev. Lett. 105 (2010) 211801

- The invariant mass spectrum of the two jets with largest pT (dijets) in event falls steeply and smoothly, as predicted by QCD
- Dijet mass distribution fitted to 4 parameter function

$$\frac{d\sigma}{dm} = \frac{P_0(1 - m/\sqrt{s})^{P_1}}{(m/\sqrt{s})^{P_2 + P_3 \ln(m/\sqrt{s})}}$$

- Look for bumps in Dijet mass spectrum
- None observed in L_{int} = 2.9 pb^{-1} ➔ set upper limits at the 95% confidence level (CL) on the resonance cross section x BFractions into dijets (several models)





Excited quarks excluded up to M_{q^*} < 1.58 TeV

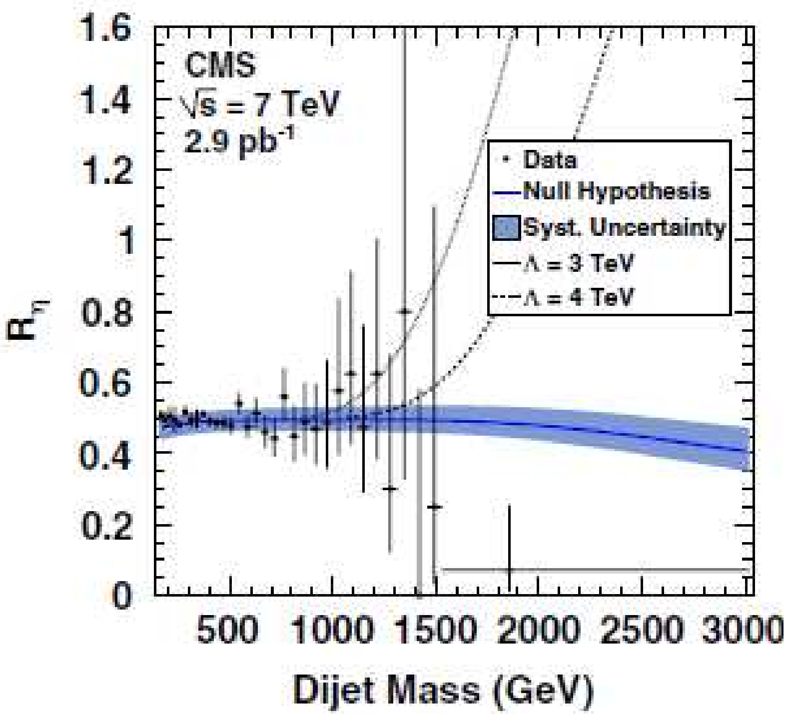
String Resonances excluded up to M_S < 2.5 TeV

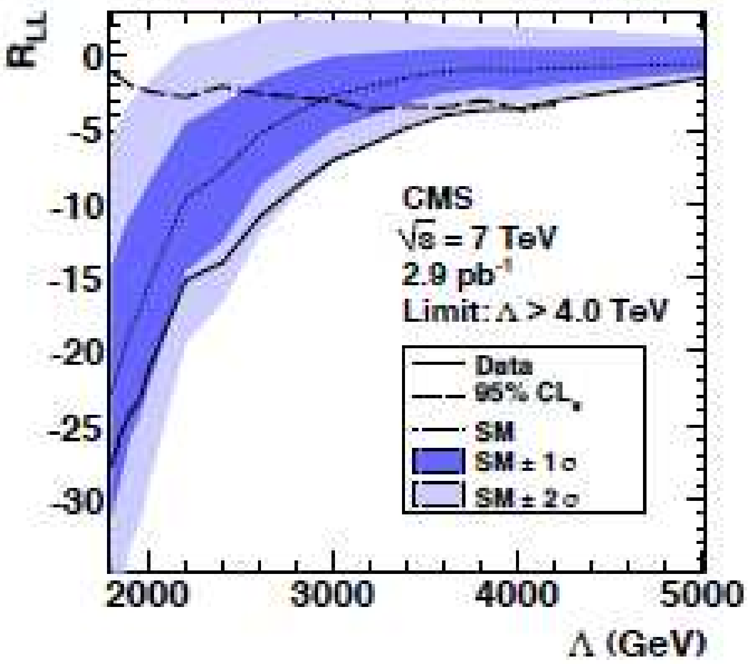
QCD : Dijet Centrality Ratio

Phys. Rev. Lett. 105 (2010) 262001

- Look for excess of central dijet events compared to forward dijet events
- New Physics predicted to decay isotropically
- QCD tends to be forward
  - Deviation from flat is sign of NP (eg. Contact Interaction, Λ)
  - Lint = 2.9 pb-1 data consistent with flat $\rightarrow$ set limits

$$R_\eta \equiv \frac{N_{2j}(|\eta| < 0.7)}{N_{2j}(0.7 < |\eta| < 1.3)}$$





Λ> 4 TeV (expected limit Λ>2.9 TeV)

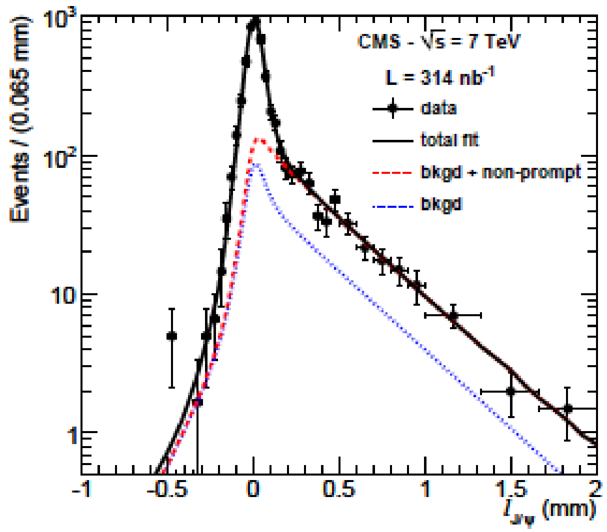
Quarkonia($c\bar{c}$ & $b\bar{b}$) & B Physics

- Provide important tests of QCD in new kinematical regions
- Profit from high production cross-section (~μb) and of low pt region for objects (muons) to obtain results in the first phase of experiment

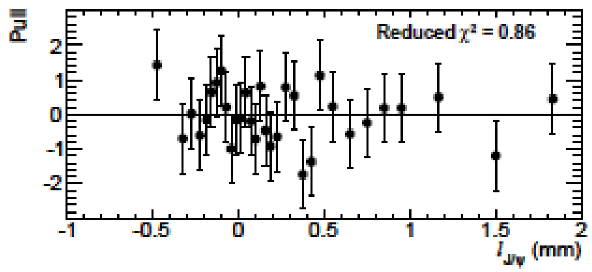
J/Ψ prompt vs non-prompt

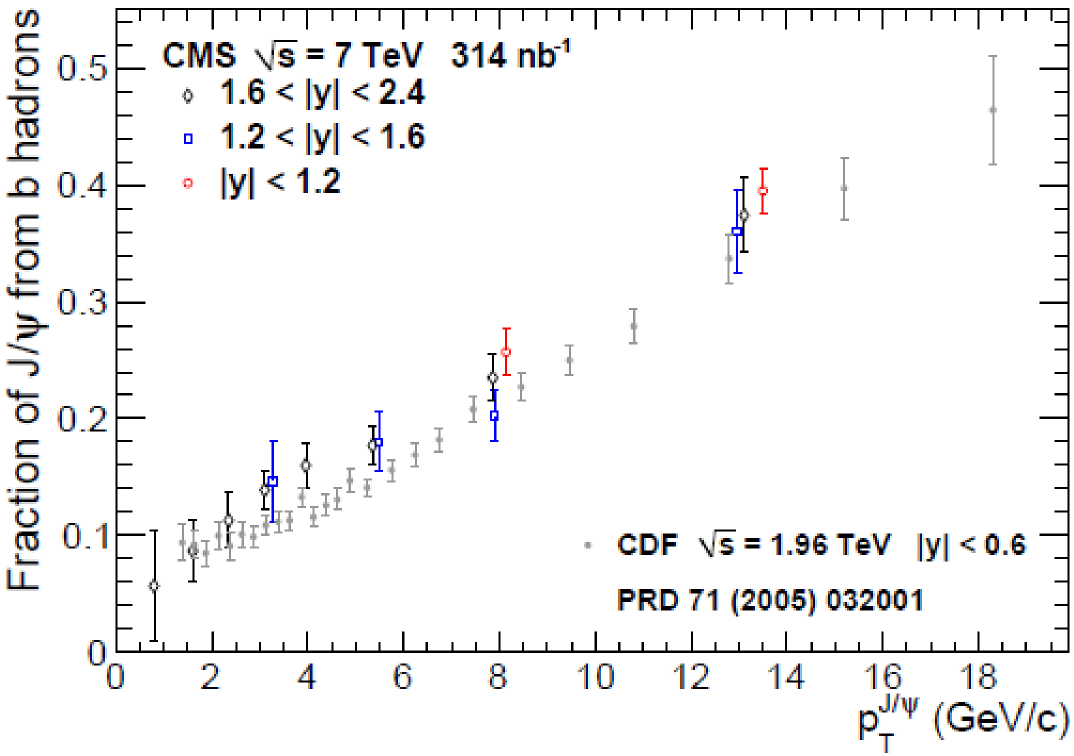
arXiv:1011.4193v1 [hep-ex]

A fit to decay length distribution used to separate prompt (direct or through charmonium) from non-prompt (b hadron decay) component of J/Ψ production



6.5 < pT < 10 GeV/c; 1.6 < lyl < 2.4

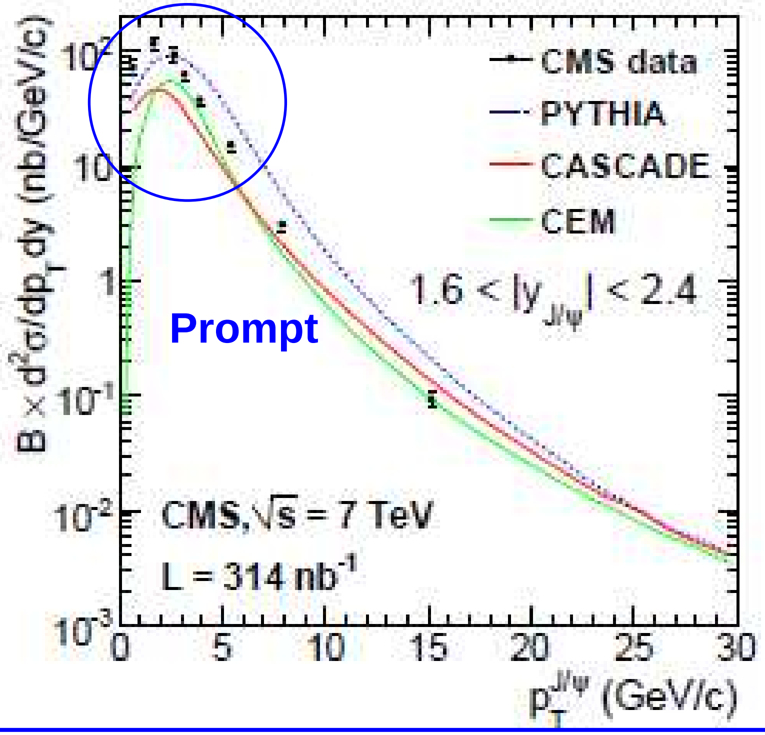


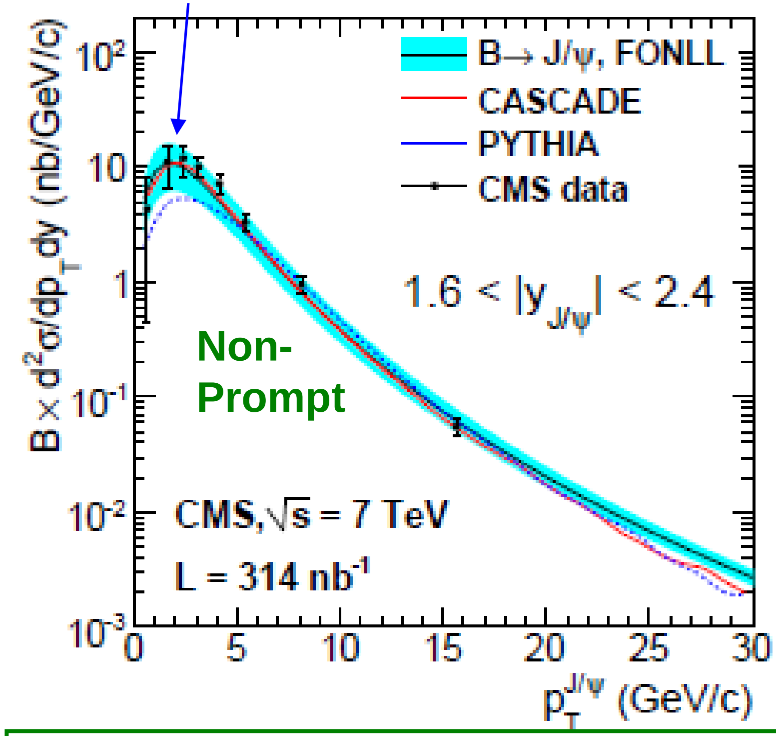


J/Ψ prompt vs non-prompt

arXiv:1011.4193v1 [hep-ex]

Ability to trigger
on low pt





Prompt contribution : excess at low pt and high lyl not accounted for in models

Non-prompt contribution (b decays): good theoretical description

$$\sigma(pp \to bX \to J/\psi X) \cdot BR(J/\psi \to \mu^+\mu^-) = 26.0 \pm 1.4\,(\text{stat}) \pm 1.6\,(\text{syst}) \pm 2.9\,(\text{luminosity})\text{ nb}$$

$$\sigma(pp \to J/\psi + X) \cdot BR(J/\psi \to \mu^+\mu^-) = 70.9 \pm 2.1(\text{stat}) \pm 3.0(\text{syst}) \pm 7.8(\text{luminosity})\text{ nb}$$

For 6.5 < pT < 30 GeV/c and lyl < 2.4

$B_S \to J/\Psi\,\phi$ and $B^+ \to J/\Psi K^+$

- First fully reconstructed B decays
- After very small momentum corrections applied $O(10^{-4})$ derived from J/ψ, reconstructed mass just on top of PDG value

Fit results:

$\mu_{gauss} = 5.3670 \pm 0.0012$ GeV/c²

$\sigma_{gauss} = 16.4 \pm 1.2$ MeV/c²

$N_{signal} = 377 \pm 26$

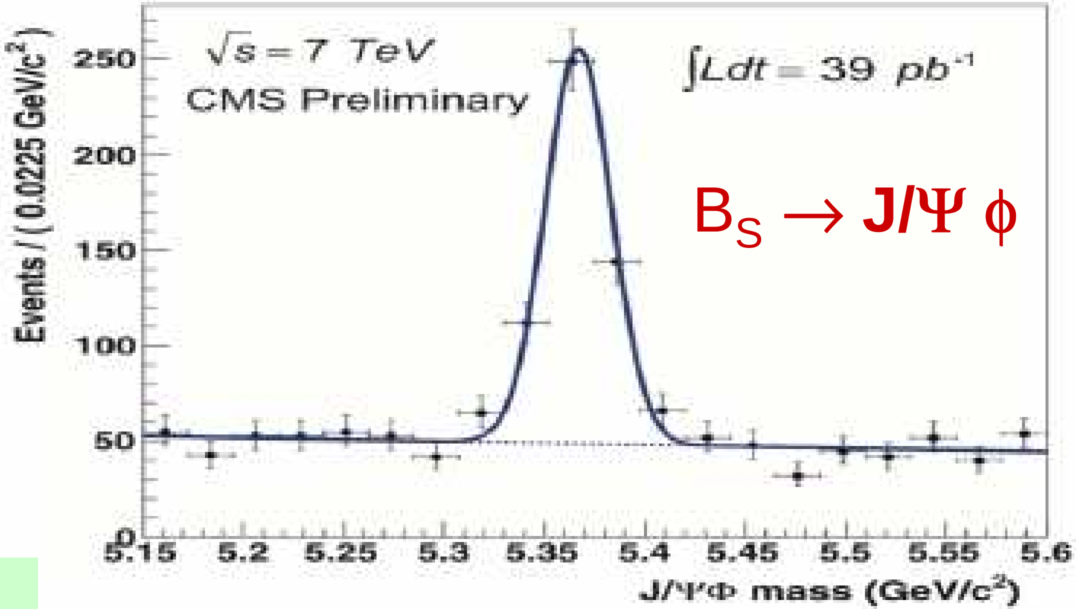
$N_{BG} = 978 \pm 36$

$\chi^2/ndof = 0.91$

$S/\sqrt{(S+B)} \approx 10$

$S/B \approx 0.4$

arXiv:1101.0131



- Exclusive decay B+ -> J/ψK+, with J/ψ-> μμ is used to measure differential and total production cross section:

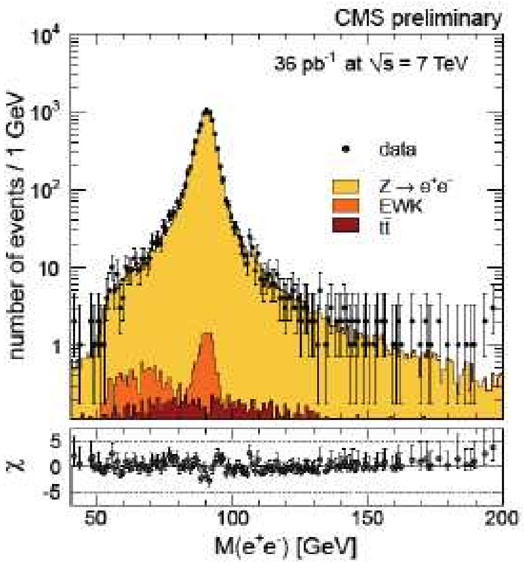
$$28.1 \pm 2.4 \pm 2.0 \pm 3.1\ \mu b \text{ for } p_T^B > 5\,\text{GeV and } |y^B| < 2.4$$ **with L_{int} = 5.9 pb⁻¹**

Data agree with Model predictions for p_T^B and y^B shapes, but normalization is 1.5 times larger than MC@NLO calculations

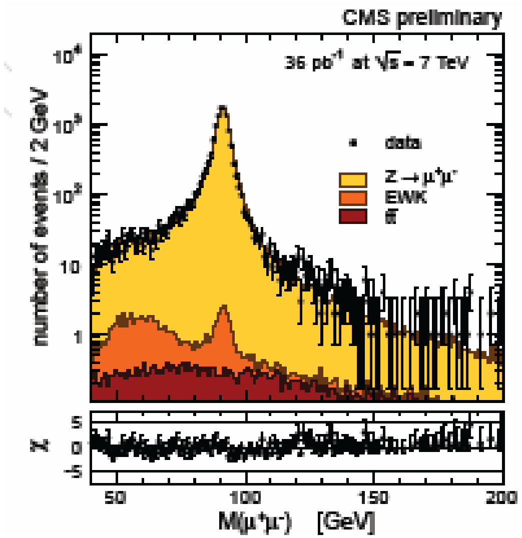
Electroweak Vector Bosons W & Z

- Benchmark for SM
  - object (e,μ,τ) reconstruction
  - backgd evts for new physics searches.
- Very "clean" and unbiased selection based on high p_T (p_T>20 GeV/c) isolated lepton(s), fitting invariant mass reconstructed (Z) or missing Et (Transverse mass) (W) distributions.
- Experimental effects (efficiencies, resolutions), and signal/background shapes extracted from data.

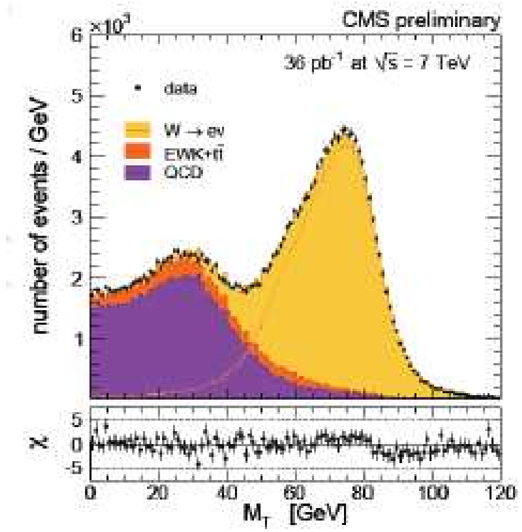
Distributions with L_{int} = 36.1 pb^{-1}



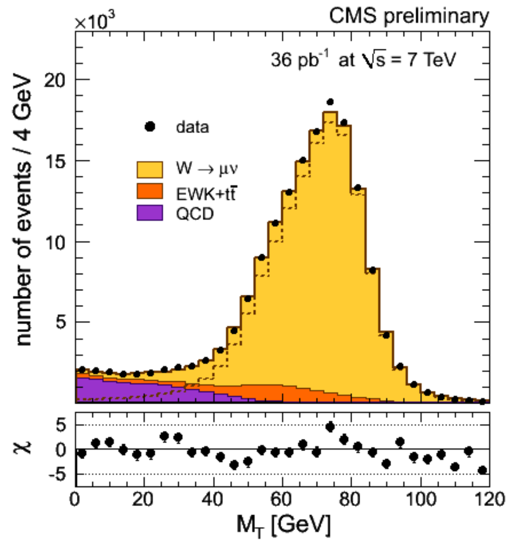
$Z^0 \rightarrow e^+ e^-$



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



$W^\pm \rightarrow e^\pm \nu$

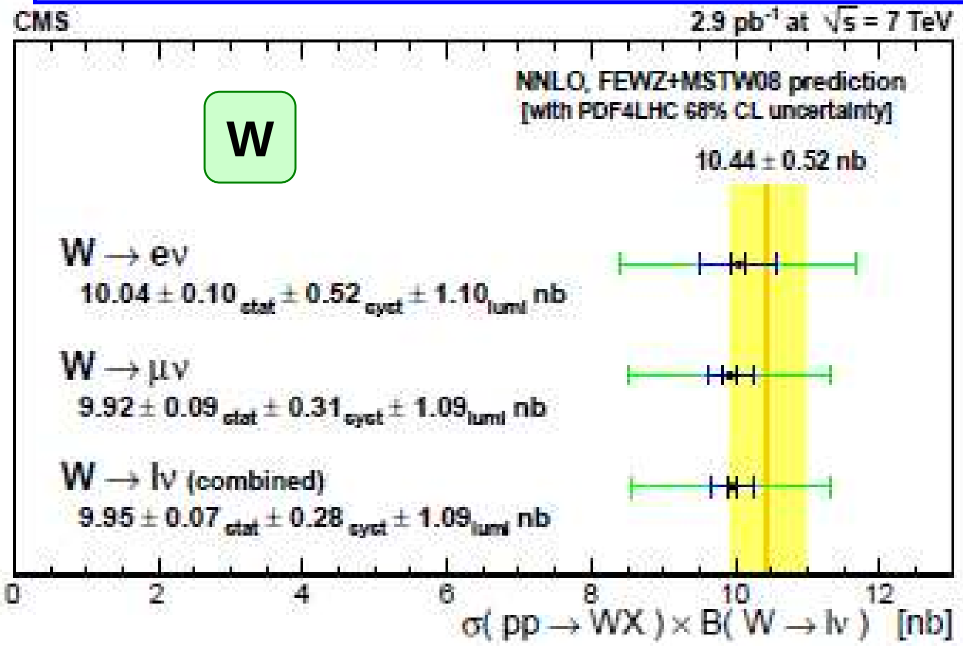


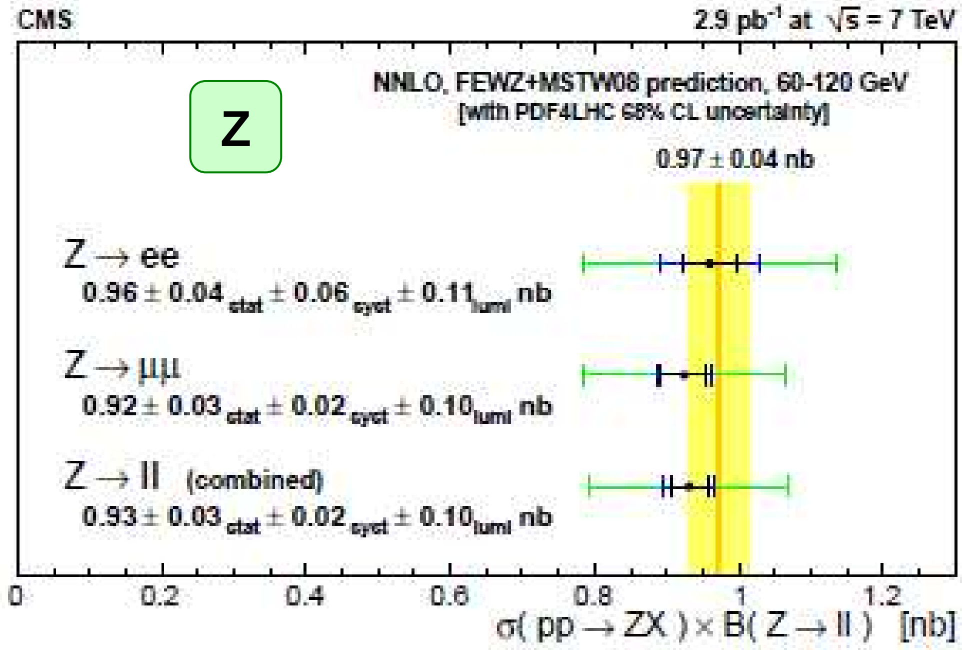
$W^\pm \rightarrow \mu^\pm \nu$

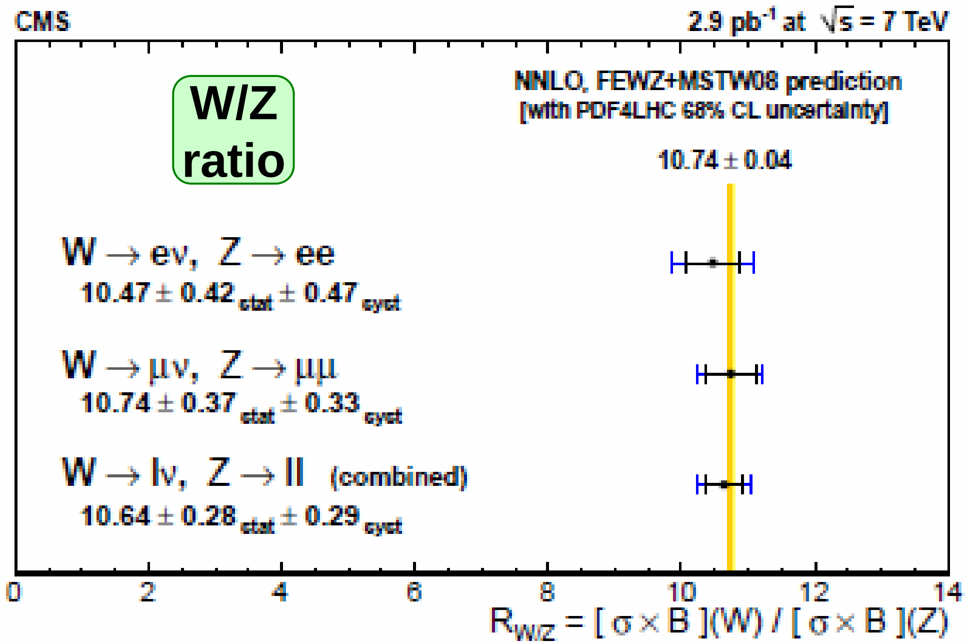
Electroweak Vector Bosons W & Z

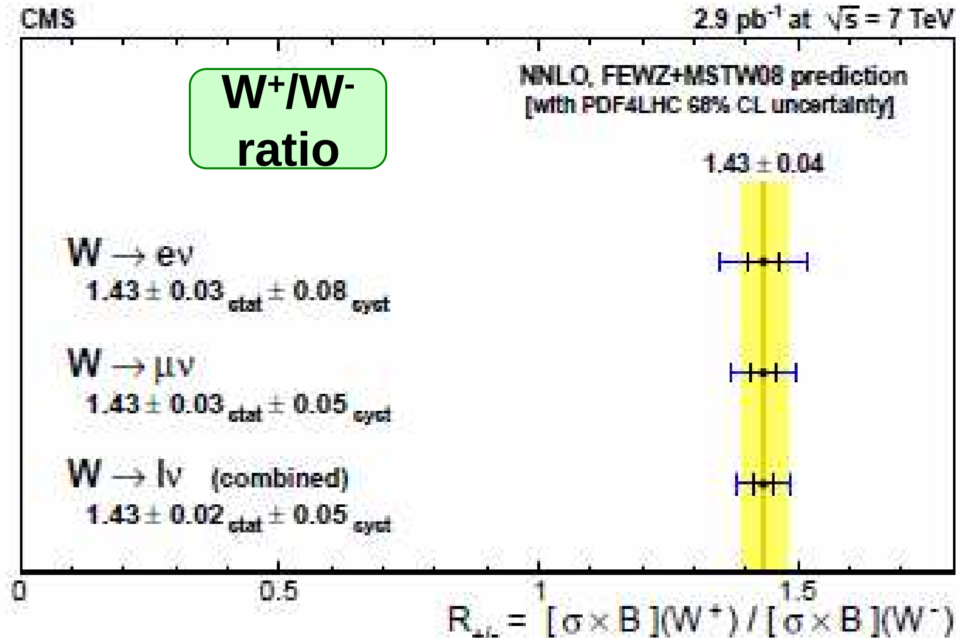
Cross section measurements published with L_{int} = 2.9 pb^{-1}

J. High Energy Phys. 01 (2011) 080





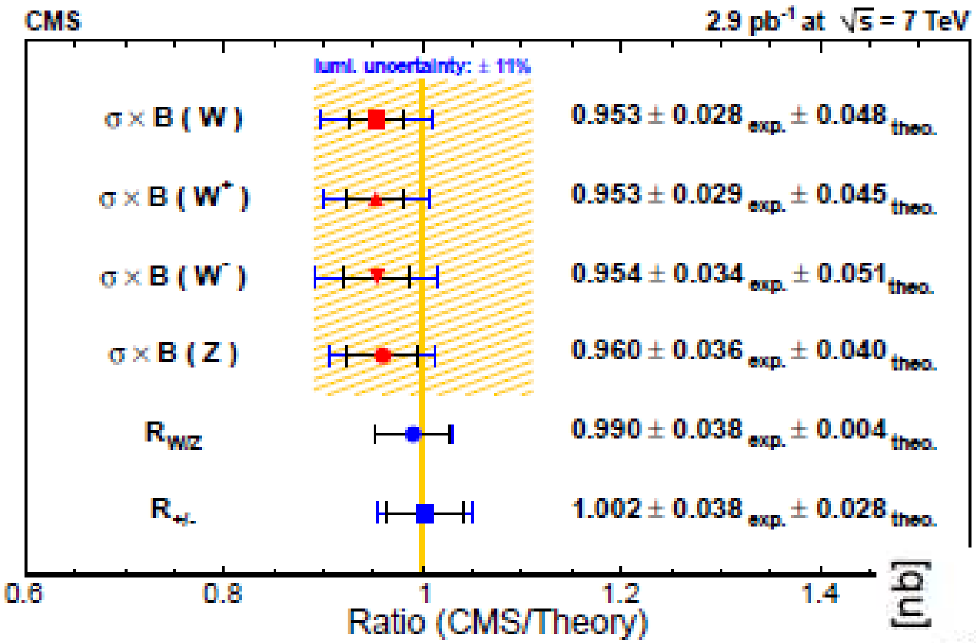




Electroweak Vector Bosons W & Z

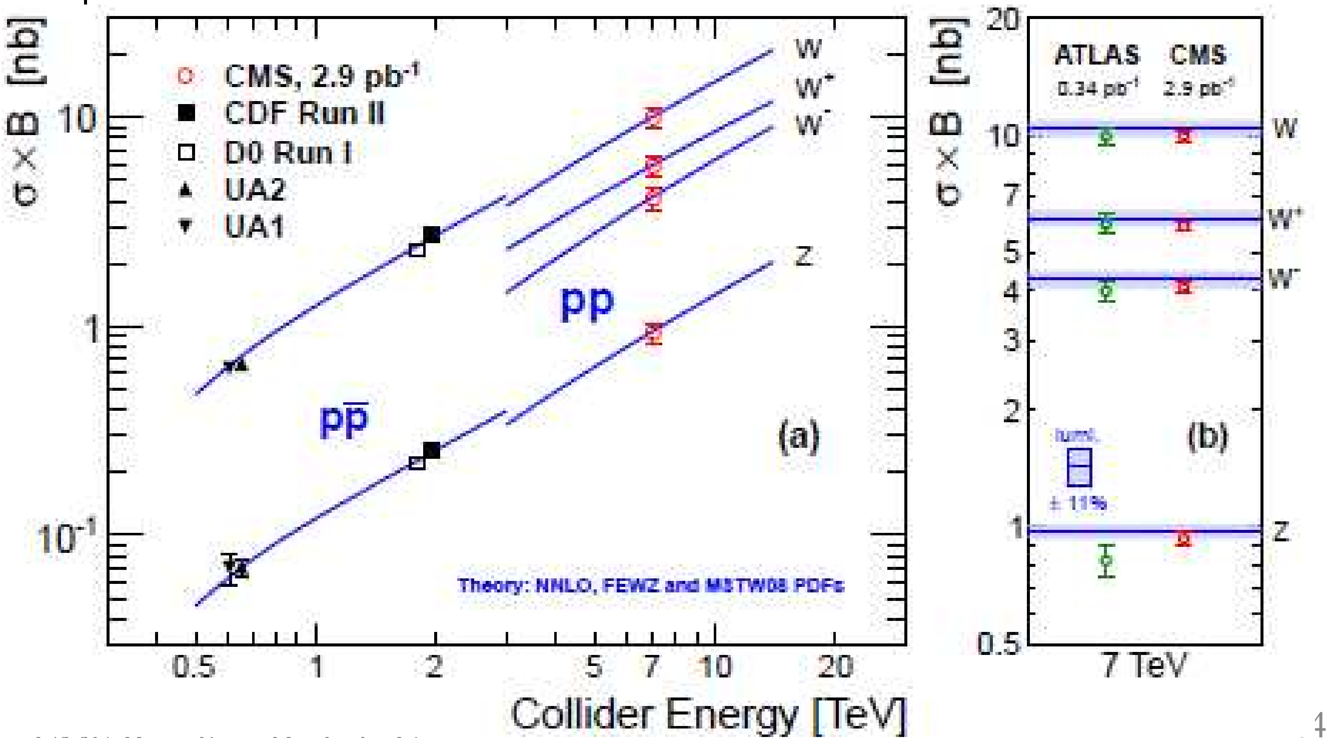
J. High Energy Phys. 01 (2011) 080

Cross section measurements published with L_{int} = 2.9 pb^{-1}



Comparison
CMS Data/ Theory (NNLO)

Comparison with other experimental results

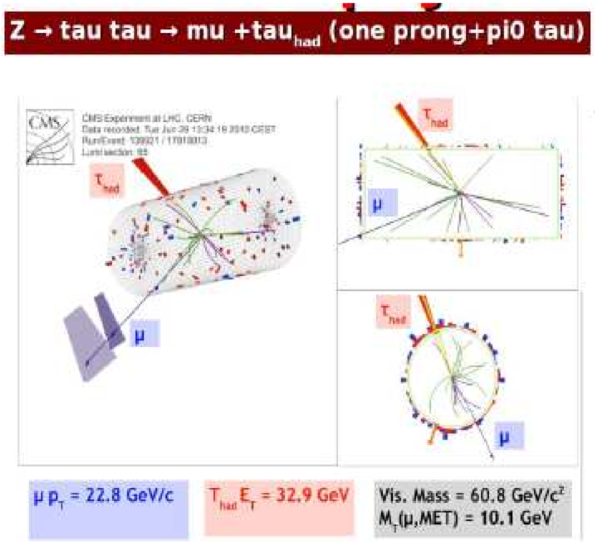


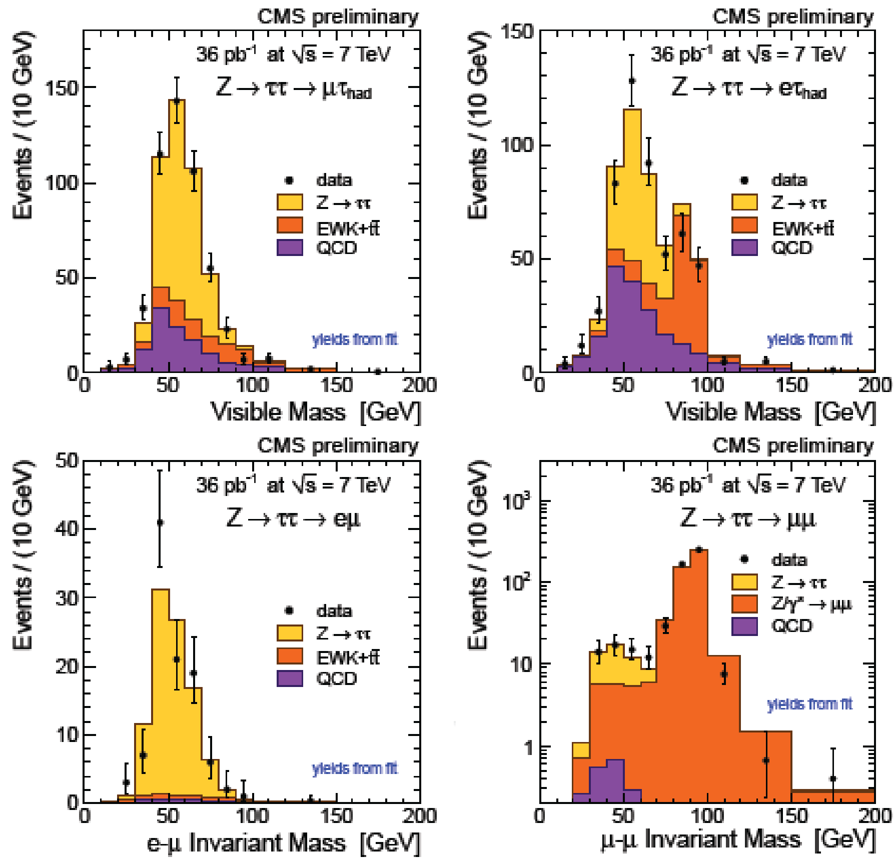
EW Vector Bosons: $Z \rightarrow \tau^+ \tau^-$

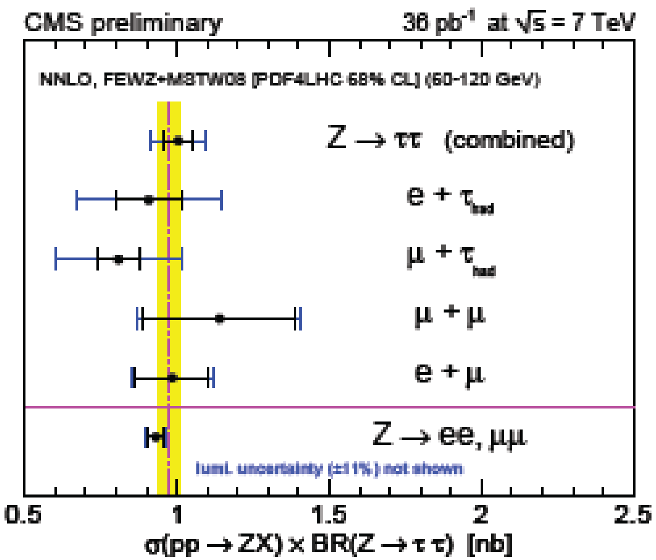
CMS-PAS-EWK-10-013 (2011)

Tau decays considered: Leptonic: $\tau \rightarrow \mu \nu_\mu \nu_\tau$, $\tau \rightarrow e \nu_e \nu_\tau$; Semihadronic: 1-3 pions+ ν_τ

- Lepton isolation and Particle Flow techniques relevant in τ identification
- Hadronic tau decays appear as low particle multiplicity & highly collimated jet

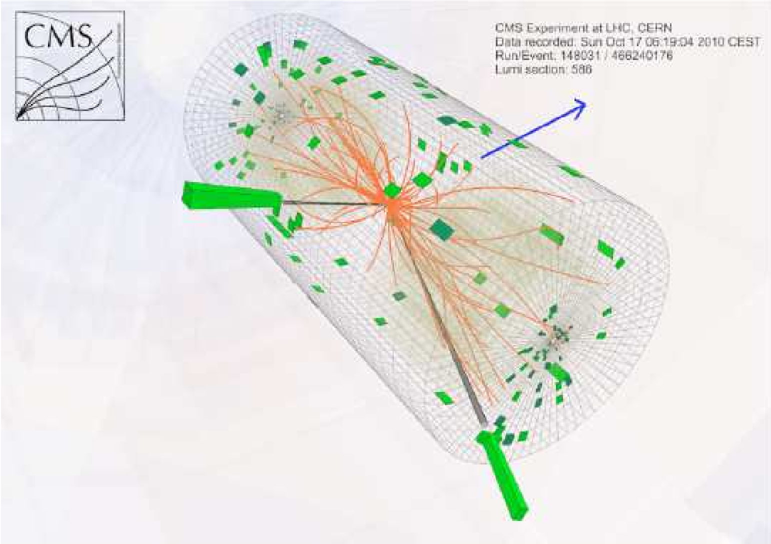


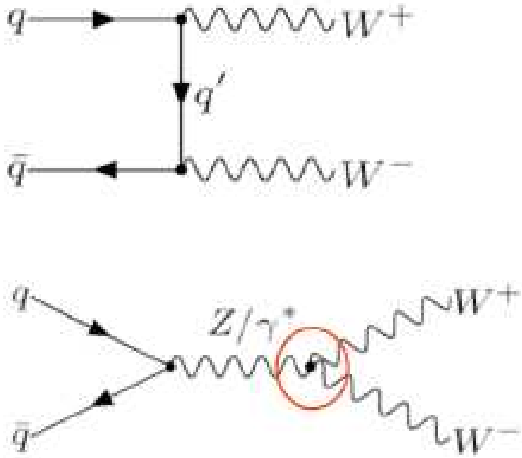




Di-boson production:WW

arXiv:1102.5429



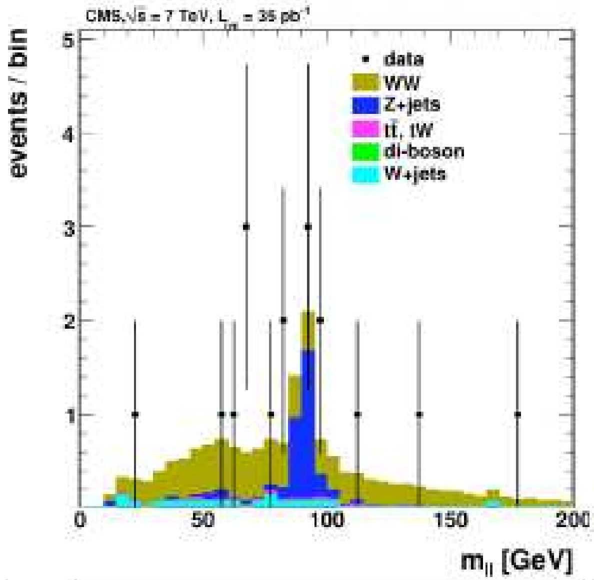


Lint = 36 pb-1

Leptonic decay channels (ee,eμ, μμ + MET)

Standard Model measurement, but also important to New Physics as

- Dominant background Higgs: H → WW
- Anomalous Couplings WWγ, WWZ enhance WW production in New Physics scenarios



Di-lepton mass distribution after all cuts except di-lepton mass cut

Channel	Event Yield
ee	1
μμ	2
eμ	10
Total	13

Di-boson production

arXiv:1102.5429

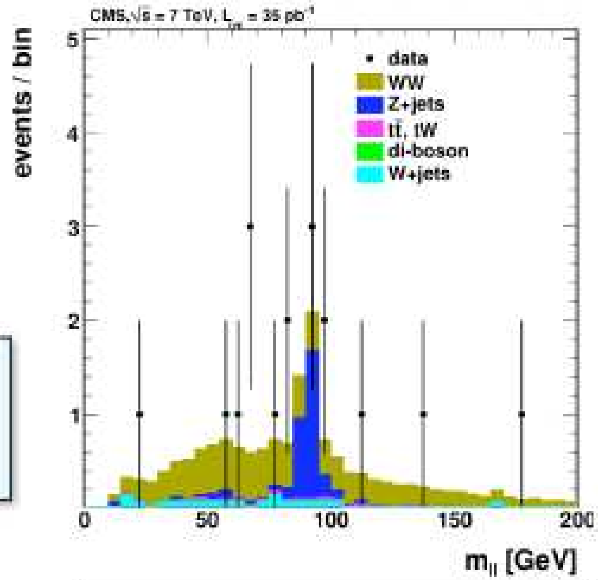
- W+jets and QCD (jet faking a lepton)
  - Jet veto: reject events containing jets with p_T>25 GeV/c and $|\eta|$<5.0
- Drell-Yan Z→ll
  - reject events with M_{ll} within 15GeV of Z mass or M_{ll}<12 GeV
- tW, ttbar
  - Top vetos based on soft-muon and *b*-jet tagging
- Diboson: Wγ, WZ, ZZ
  - Reject events with a 3rd lepton with p_T>10 GeV/c

$$\sigma_{WW} = 41.1 \pm 15.3(stat.) \pm 5.8(syst.) \pm 4.5(lumi.)\,pb$$

NLO prediction: 43.0 ± 2.0 pb

$$\frac{\sigma_{WW}}{\sigma_W} = (4.46 \pm 1.66 \pm 0.64) \cdot 10^{-4}$$

NLO prediction: $(4.45 \pm 0.30).10^{-4}$



Di-lepton mass distribution after all cuts except di-lepton mass cut

Channel	Event Yield
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Total	**13**

ElectroWeak measurements @ 7 TeV

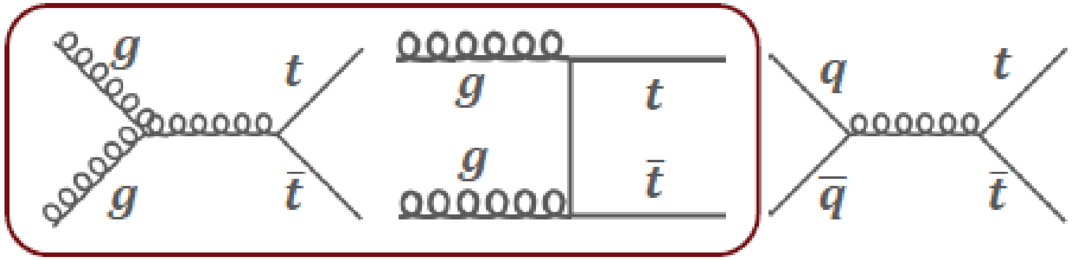
Other analyses and ElectroWeak measurements going on presently and many of them being presented at the Winter Conferences

W and Z cross-sections	Drell-Yan ($d\sigma/dM$)
W charge asymmetry	Z Differential cross-sections ($d\sigma/dq_T$, $d\sigma/dY$)
W polarization	Di-lepton A_{FB} and $\sin^2\theta_W$
W,Z + γ	W,Z + jets
$\sigma(Z\rightarrow\tau\tau)$	Z+bb

Top physics

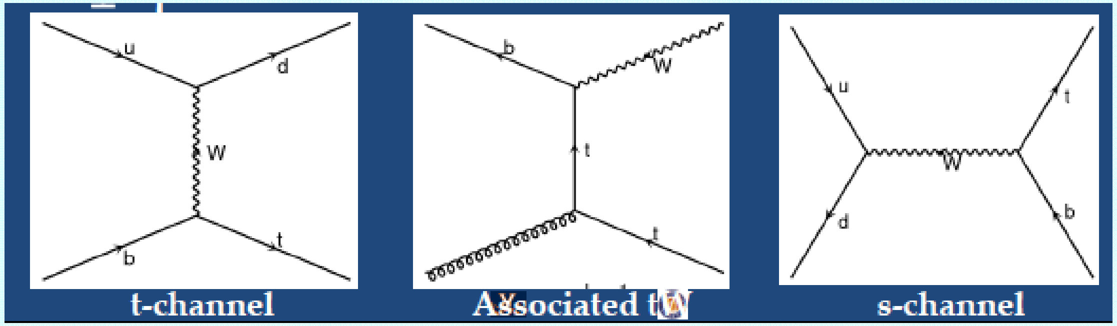
- m_t ~173 GeV huge, indication of special role in EWSB? (large couplings to Higgs)
- New Physics may appear in this third generation (if any), or decay through top quarks.
- "Almost free" quark → top decays almost 100% in Wb before hadronizing
- At LHC main production is ttbar, but also single top is possible

Top pair production:
70% gluon induced in 7 TeV pp collisions



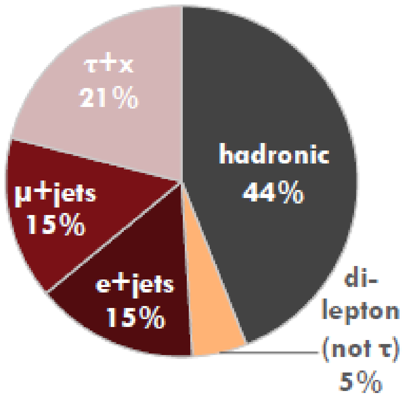
σ = 158 ± 23 pb @ NLO (MCFM)

Single top production



σ = 79 ± 3 pb @ NLO (MCFM)

Top pair decay channels
$t \to Wb, W \to jj \text{ or } l\nu$



Decay modes are defined by W-decays:

- Dilepton $(2b + 2l + 2\nu)$
- Lepton+jets $(2b + 2q + l\nu)$
- Alljets $(2b + 4q)$

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- m_t ~173 GeV huge, indication of special role in EWSB? (large couplings to Higgs)
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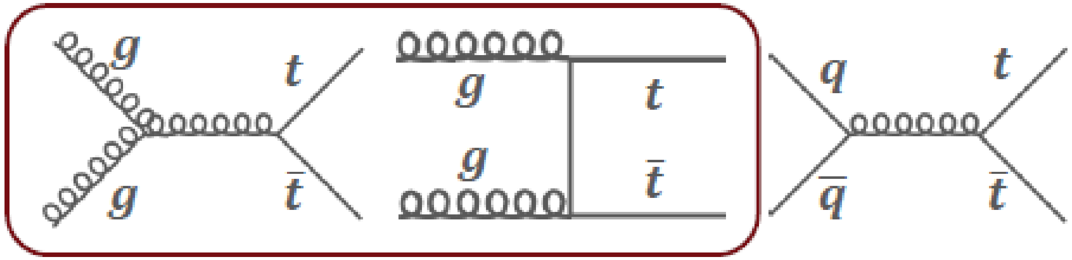

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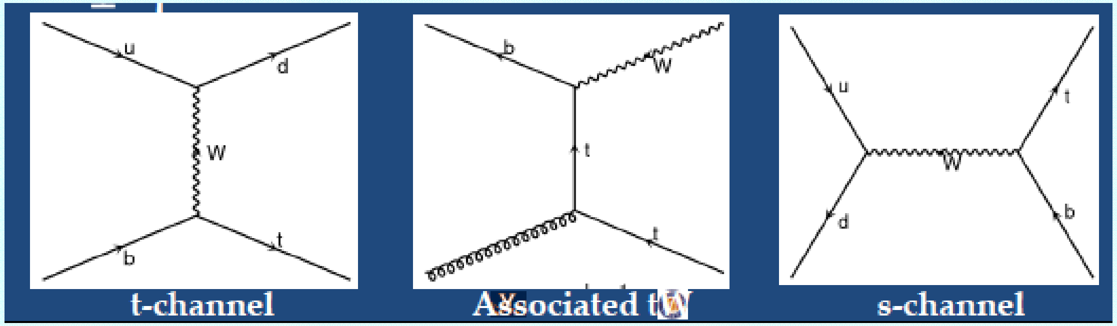

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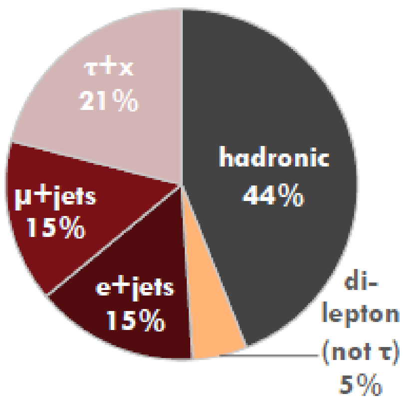

Decay modes are defined by W-decays:

- Dilepton $(2b + 2l + 2\nu)$
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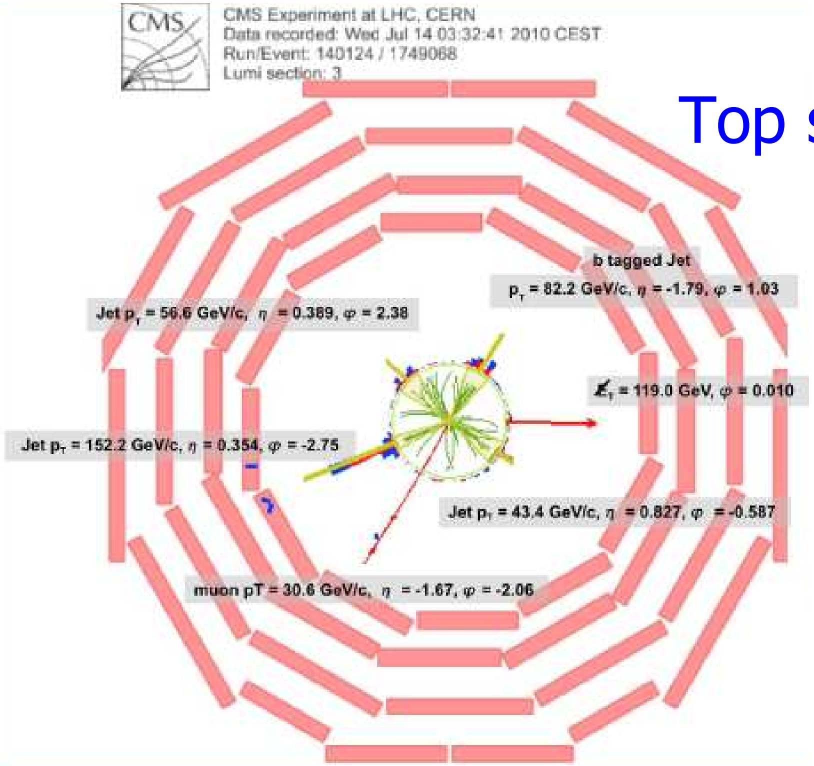
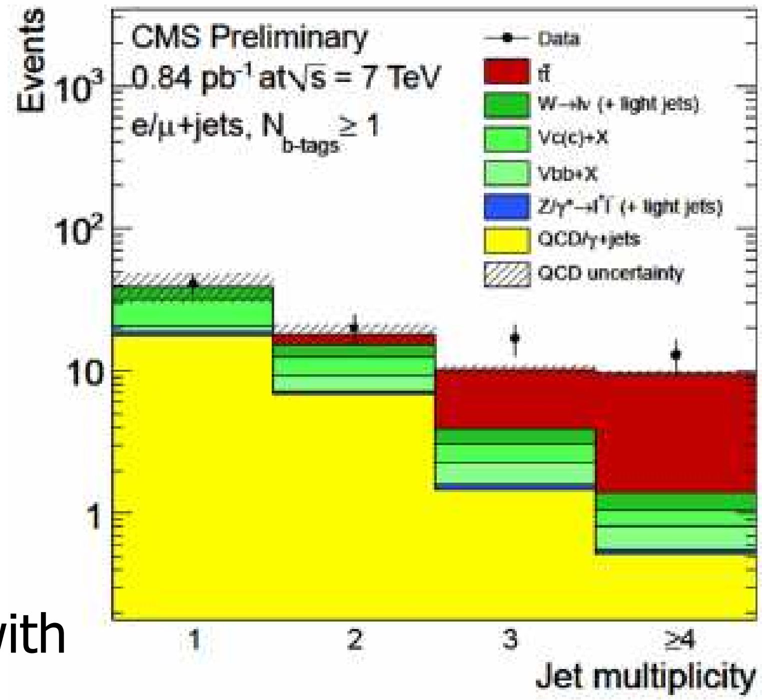
- Alljets $(2b + 4q)$

Top pair observation: lepton + jets channel



Top signal established in CMS with L_{int} = 0.84 pb^{-1}

tt → lνb q qbar b → lepton + 4 jets + MET



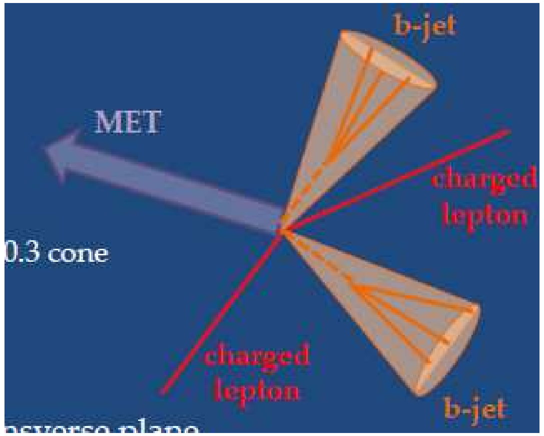
High-pt, isolated lepton, at least 1 b-tagged jet (secondary vertex tagger with ≥ 2 tracks; ~ 80% eff. with small fake rate)

- ttbar will favor the 3,≥4-jet bins (30 evts observed with ≥ 3 jets)
- QCD, W+jets the 1,2-jet bins (predicted total bckgd ~5 evts)

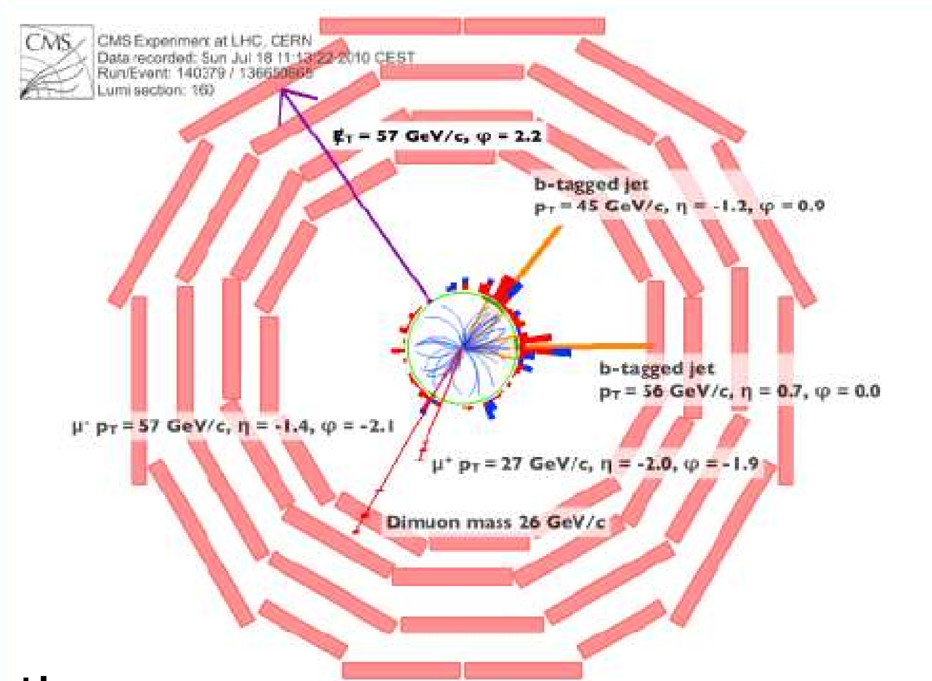
Top pair cross section: dilepton channel

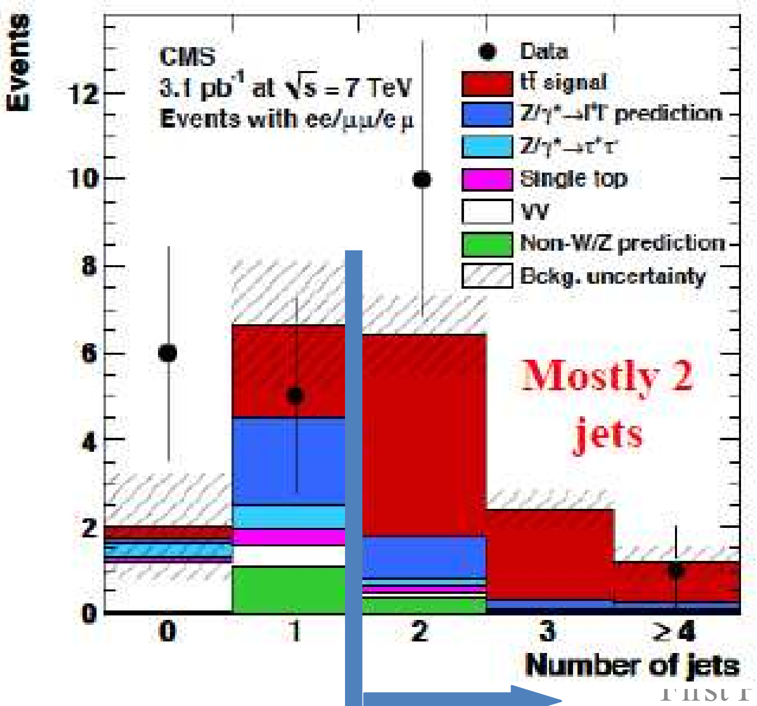
Phys. Lett. B 695 (2011) 424

$L_{int} = 3.1\ pb^{-1}$



$tt \rightarrow l\nu b\ l\nu b \rightarrow 2$ leptons + 2 b-jets + MET





Selection:

Two isolated high-p_T leptons (e, μ), MET (>20-30 GeV), at least 2 hard jets (E_T> 30 GeV)

Top pair cross section: dilepton channel

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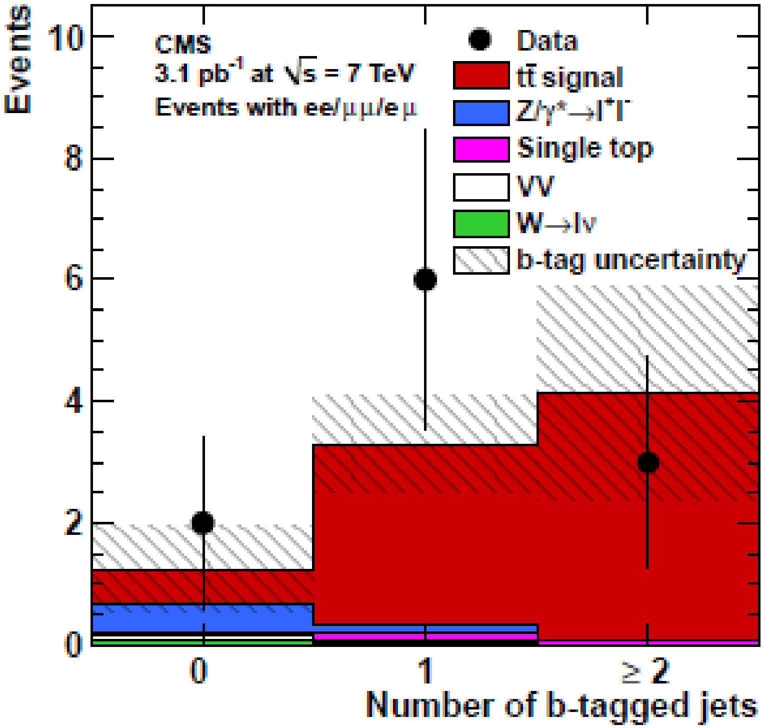
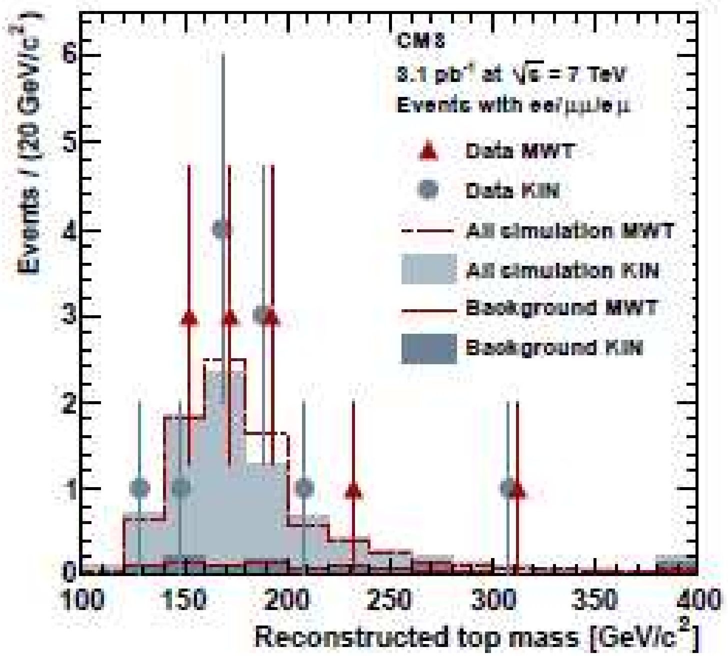




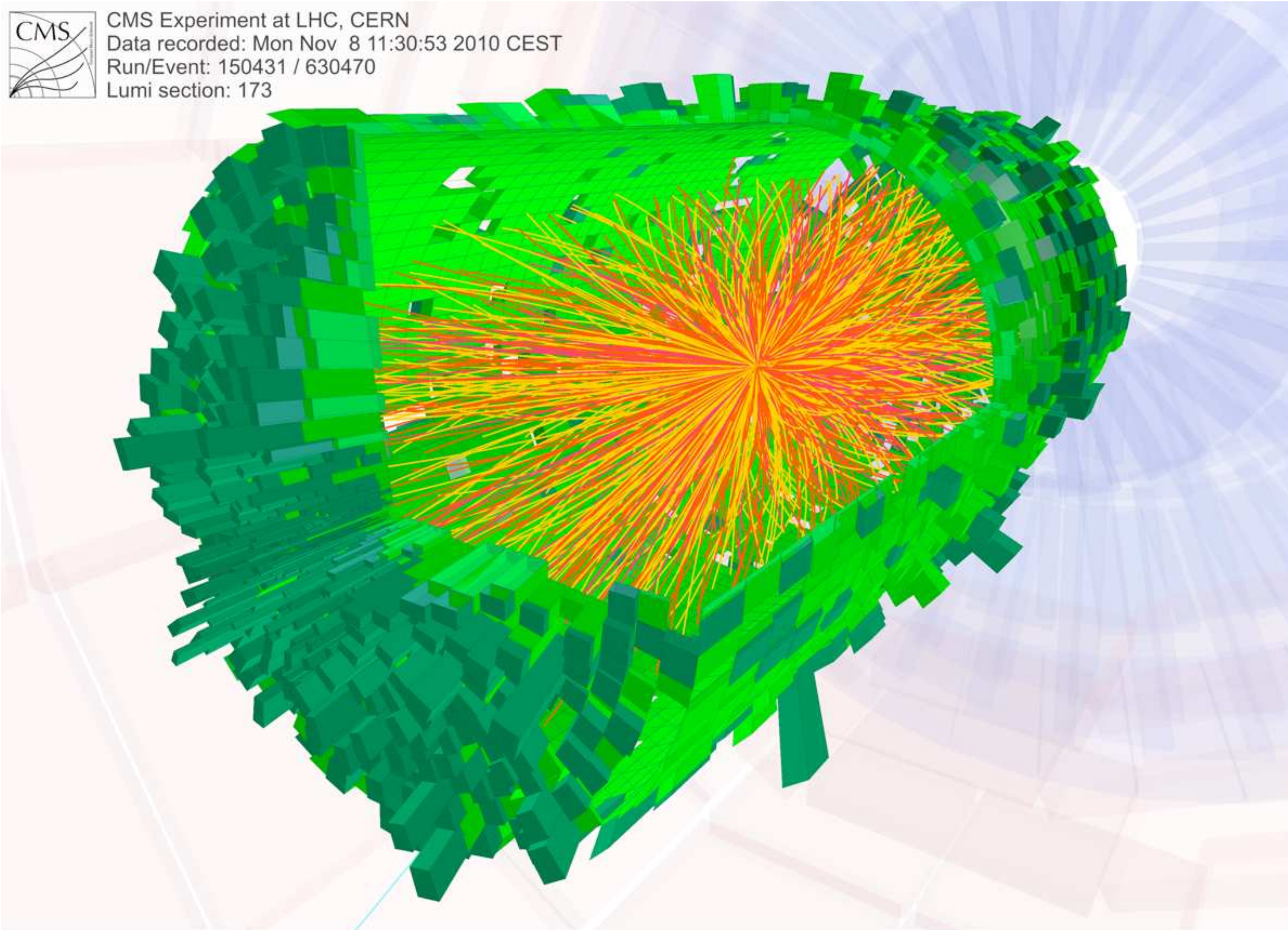
B tagging in Jets not even used to select signal, but as a cross-check for signal consistency

Reconstructed top mass, consistent with a top-quark mass of 172.5 GeV

σ (pp $\rightarrow$ ttbar) = 194 ± 72 (stat) ± 24 (syst) ± 21 (lumi) pb

σ Predicted MCFM NLO = 158 ± 23 pb

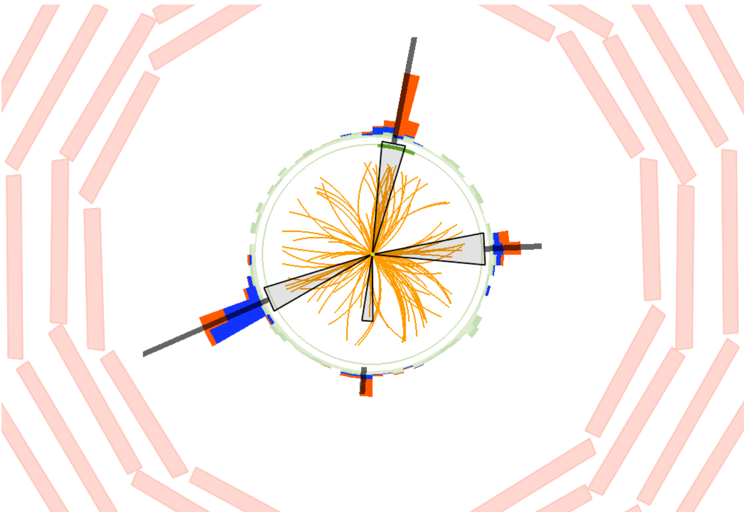
Heavy Ions: Pb-Pb Collisions @ LHC



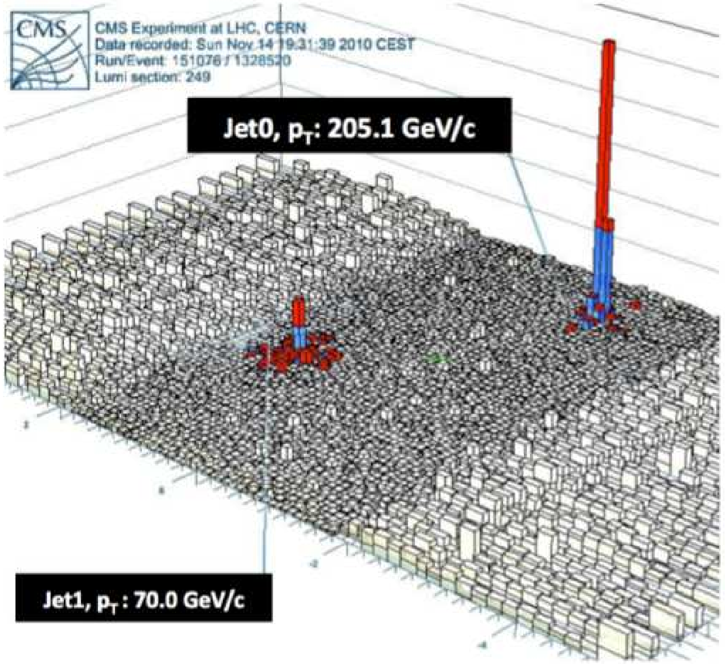
- Pb-Pb collisions at 2.76 TeV / nucleon, 6.7 μb^{-1} collected in late 2010
- Plenty of new interesting effects in this dense environment

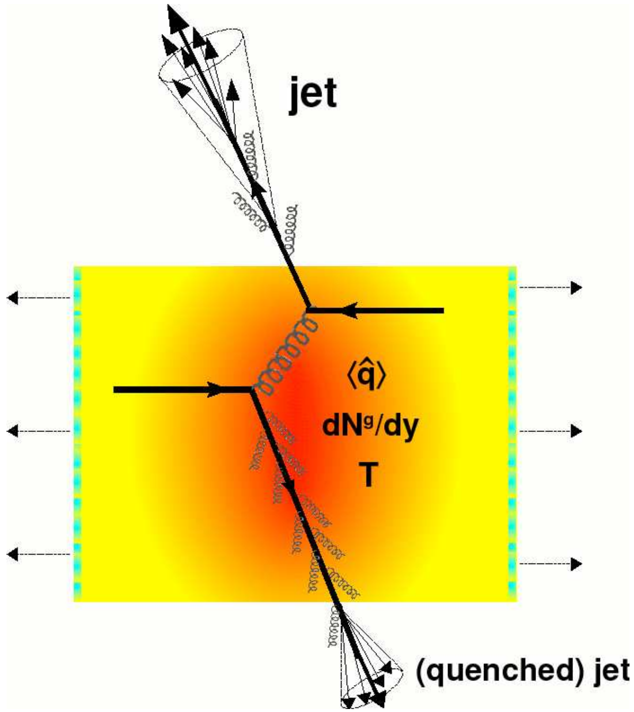
First time such good 4π-coverage and excelllent tracking performance experiment in HI

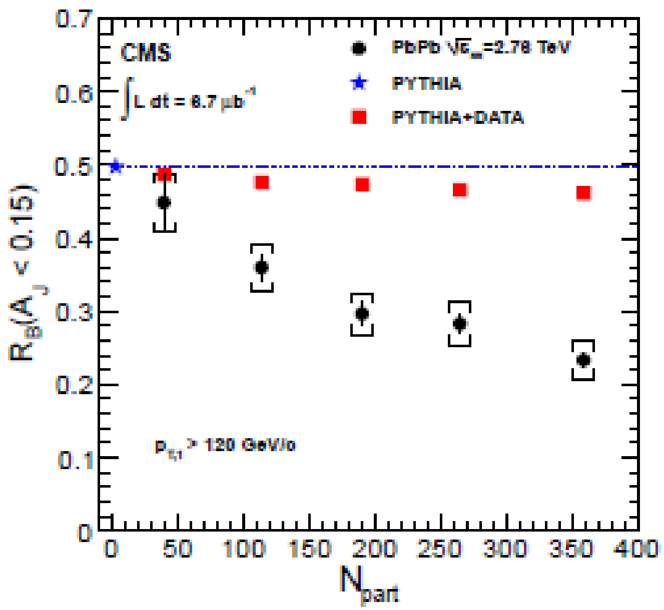
Heavy Ions: Jet Quenching



Indirect evidence of strong Jet Quenching measured at RHIC in single particle spectra and particle correlations



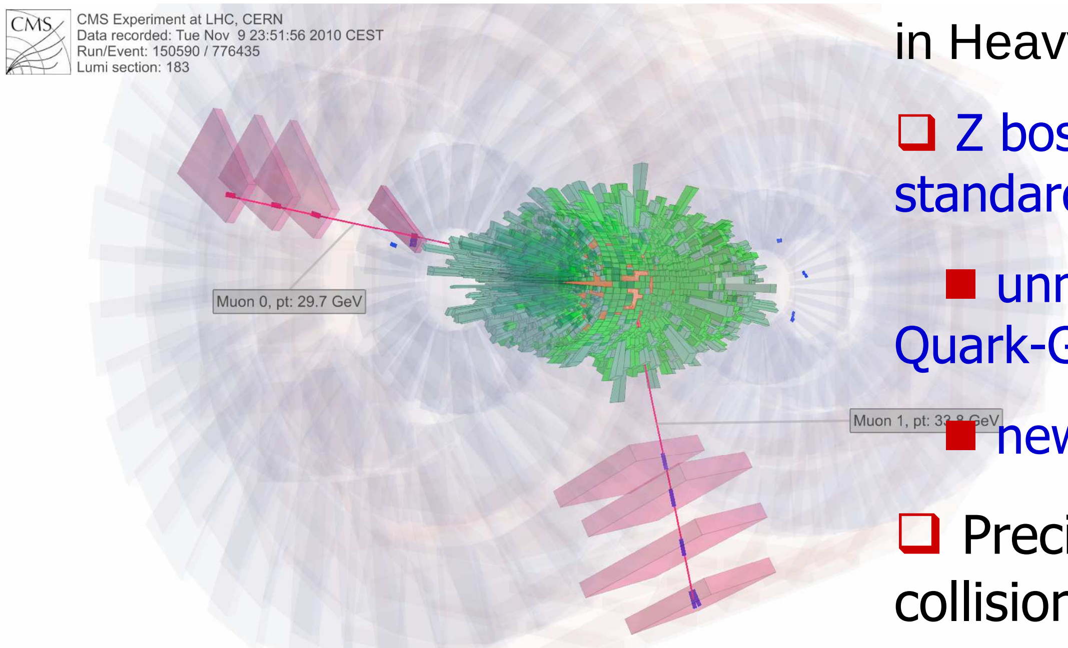




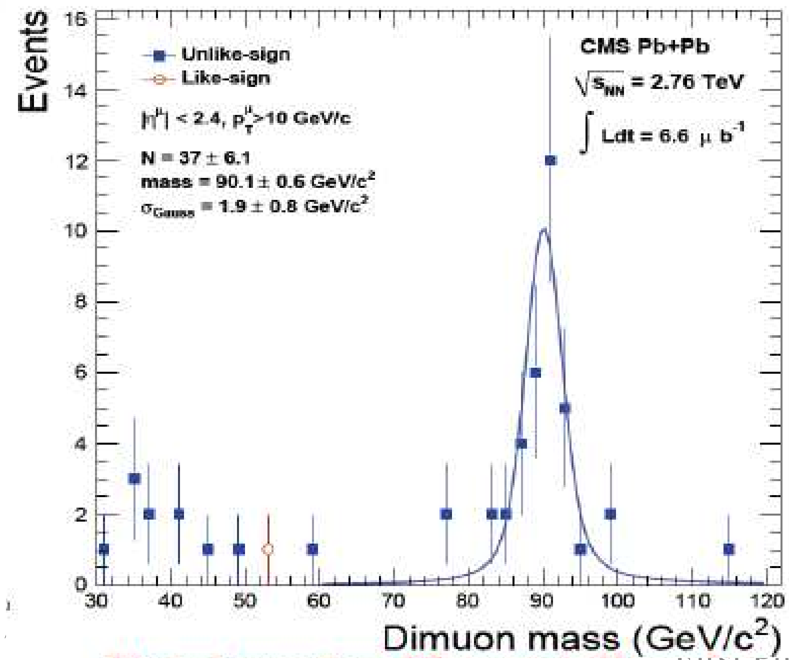
First direct evidence of strong jet quenching observed in LHC HI collisions (by CMS and ATLAS).

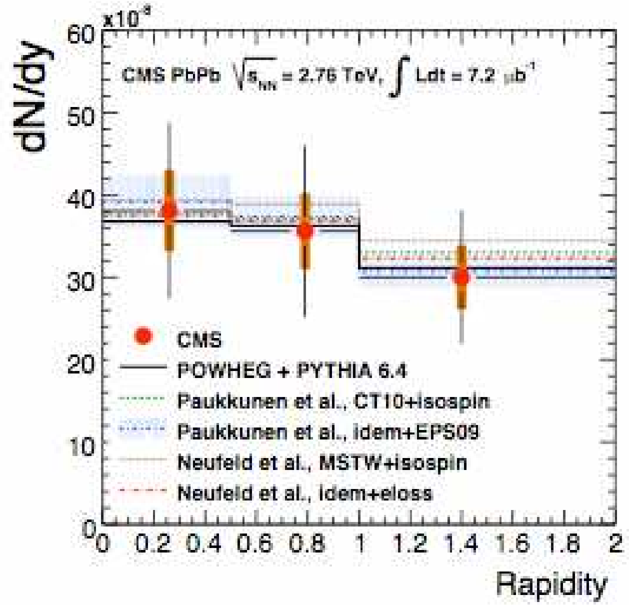
Heavy Ions: First observation of Z0 boson

arXiv:1102.5435



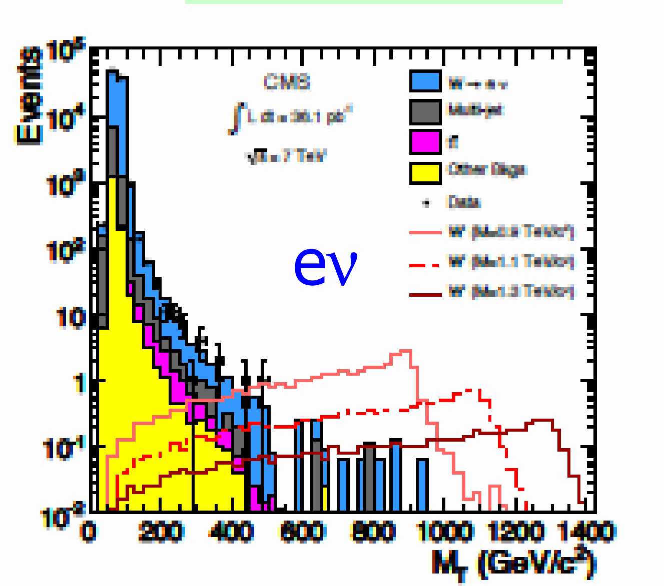
- ❑ First time (ever) an EW boson (Z0) has been observed in Heavy Ion collisions.
- ❑ Z bosons (decaying into leptons) can be used as a standard reference of the initial state.
  - ■ unmodified by the medium, (allows studying the Quark-GluonPlasma at the TeV scale).
  - ■ new & cleaner reference than photons.
- ❑ Precise measurements of Z production in heavy-ion collisions can help constrain nuclear PDFs.





Exotica: Heavy resonances: W’

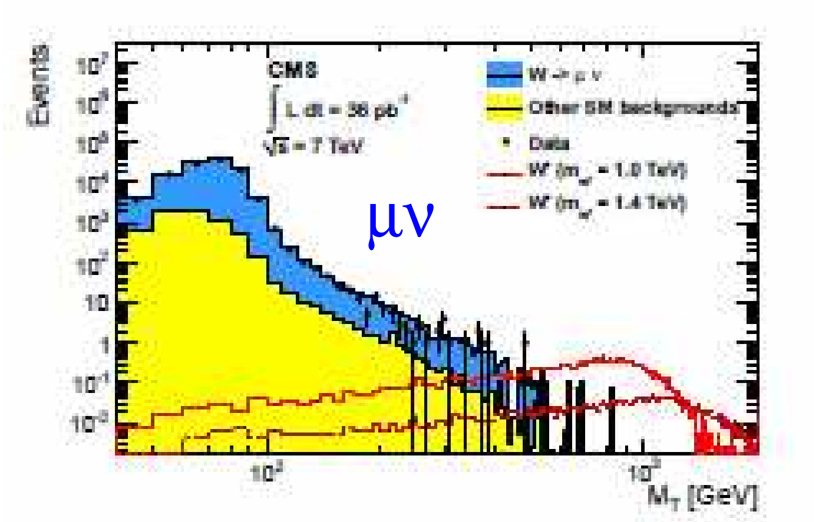
arXiv-1012.5945

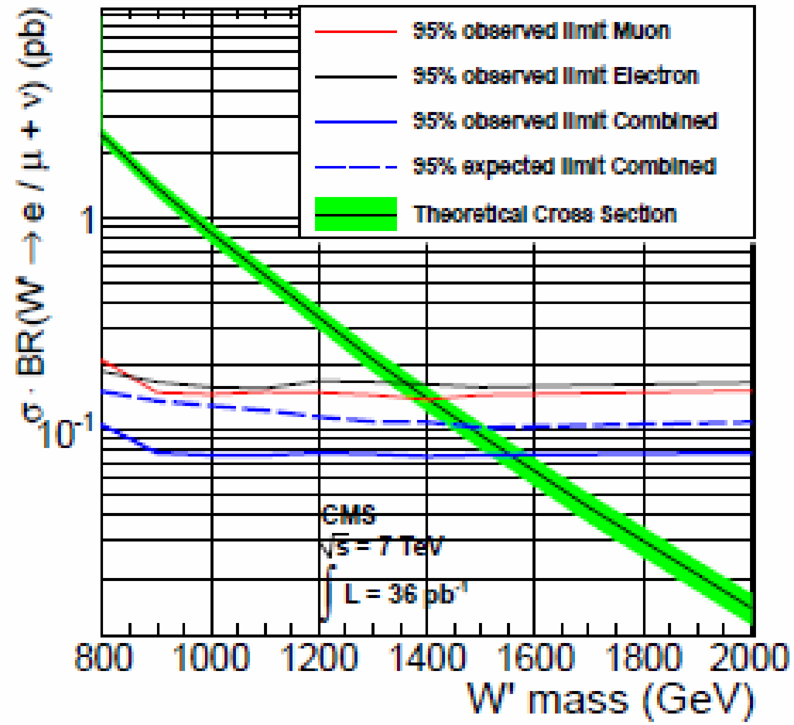


Search for W’ $\rightarrow \mu\nu$, eν

- Backgd: W $\rightarrow \mu$/e ν, QCD multijet evts, ttbar, Drell-Yan & Cosmic muons
- Essential good reconstruction of high p_T (~1 TeV) muons

arXiv-1103.0030





W’ excluded up to M=1.58 TeV at 95% CL (e+μ channels combined)

Exotica: Searches

Many other search channels :

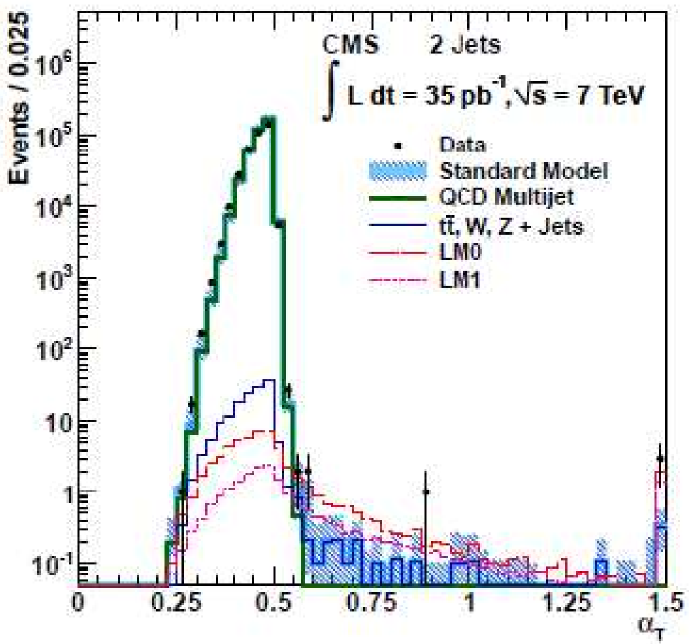
- Excited Leptons
- Heavy Stable Charged Particles
- Stopped Gluinos
- 4th generation
- LeptoQuarks
- MultiJet Resonances
- ExtraDimensions
- …..

In many channels LHC has started to surpass Tevatron sensitivity

Supersymmetry

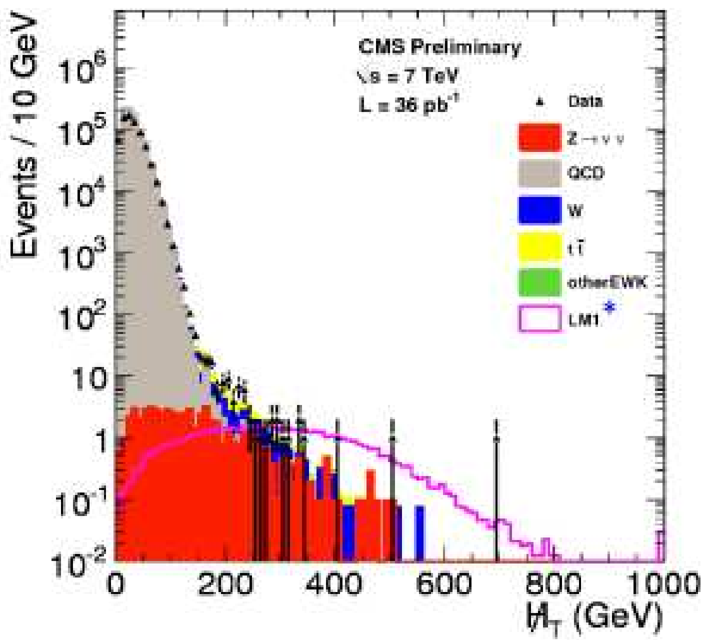
- Searches focus on large MET + significant hadronic activity (high E_T jets) +leptons
- Data driven methods used to control experimental effects and SM backgds.
- Excellent agreement with SM predictions, both yields and shapes
  - Tails of distributions
  - Define convenient variables to distinguish SM from SUSY events

CERN-PH-EP-2010-084



$\alpha_T = E_T^{j2} / M_T$

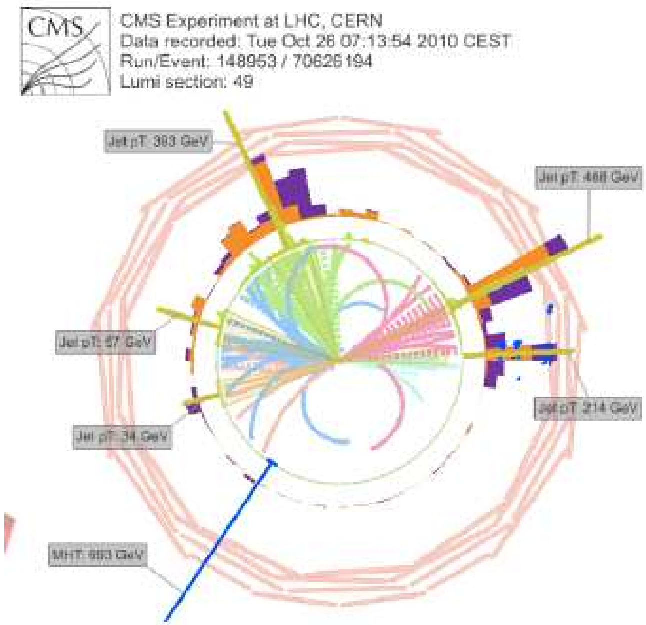
CMS-SUS-10-005



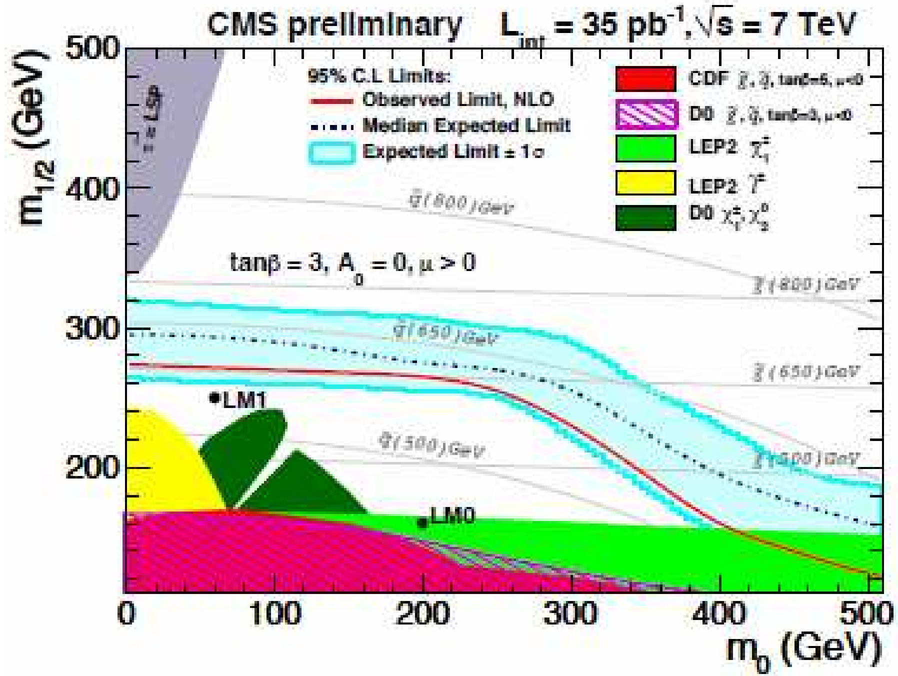
Supersymmetry

- Searches based on different final event topologies
  - Hadronic (JETs+MET) **arXiv-1101.1628** **CMS-SUS-10-005**
  - 1 lepton (+JETs+MET), 2 leptons (Same Sign, Opposite Sign) (+JETs+MET) **arXiv-1103.1348**
  - Multilepton events **CMS-SUS-10-008**
  - Di-photon, photon+lepton (+JETs+MET) **arXiv-1103.0953** **CMS-SUS-11-002**
- Interpret in the context of several SUSY models ➔ set limits, already improving those of past experiments

No SUSY observed, but pretty bckgd evts

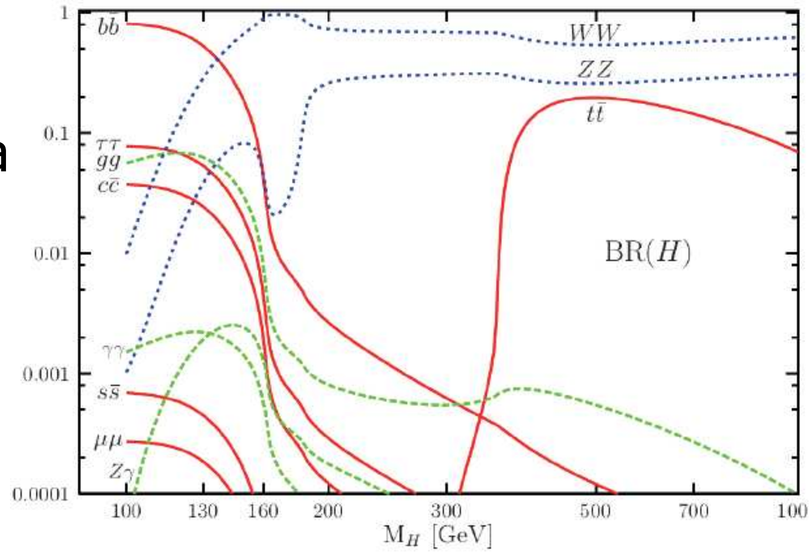


arXiv-1101.1628



Higgs

- No sensitivity to SM Higgs with current data sample
- Strategy for 2011-2012 run; add channels with potentia sensitivity, not just "golden ones" ➔ Approach "Many drops fill the bucket"
- As seen, most tools are already in place : leptons, jets, taus, photons, MET, b-tagging



Channel	Physics Objects	Higgs mass range used in analysis (GeV)
H→γγ	photons	115-150
qqH, H→ττ	taus, MET	115-145
VH, H→bb (highly boosted)	b-tagging	115-125
VH, H→WW→lvjj	jets, MET, W's	130-200
H→WW→2l2v + 0/1 jets	μ, e, MET, W's	120-600
qqH, H→WW→2l2v	μ, e, MET, jets, W's	130-500
H→ZZ→4l	μ, e, Z's	120-600
H→ZZ→2l2v	μ, e, MET, Z's	200-600
H→ZZ→2l2b	μ, e, b-tagging	300-600

Higgs decays dominated by dibosons

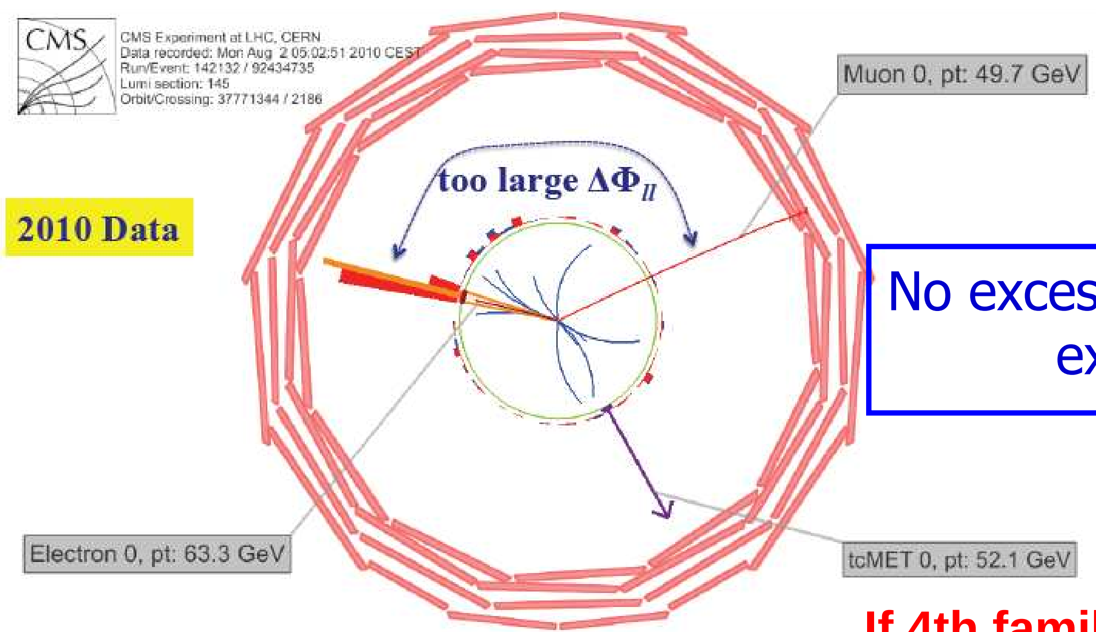
Higgs: $WW \to 2l\ 2\nu$

Signal: 2 isolated leptons with small $\Delta\phi$ + MET+ jet veto

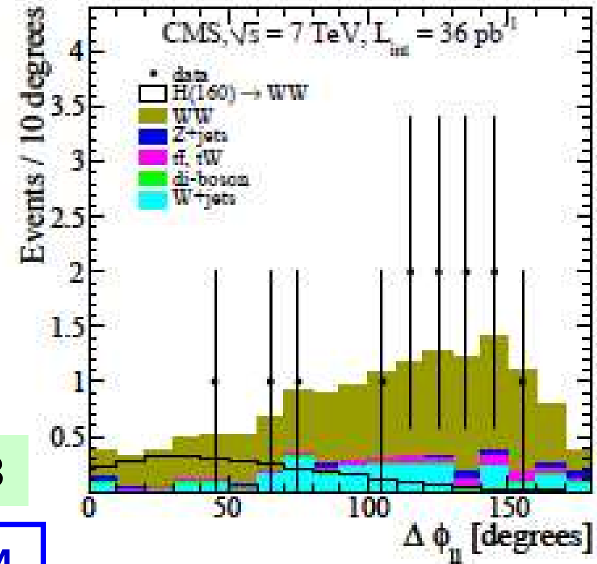
Backgrounds: WW: $\Delta\phi$ + m_{ll}, ttbar: jet veto, $\Delta\phi$ + mll, W+jets:light lepton Id, Drell Yan: MET + mll, WZ, ZZ: 2 lepton in final state + MET + mll

Look for excess above cut in NN distribution (see paper)

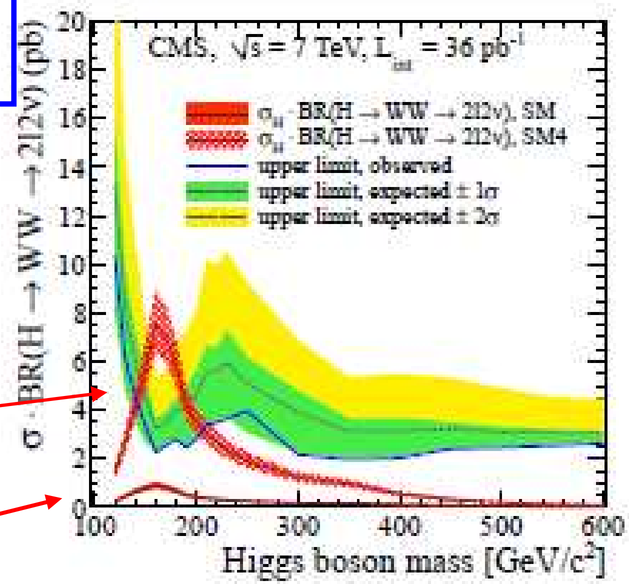
Irreducible WW backgd evt.



CMS-HIG-10-003



No excess found above SM expectations

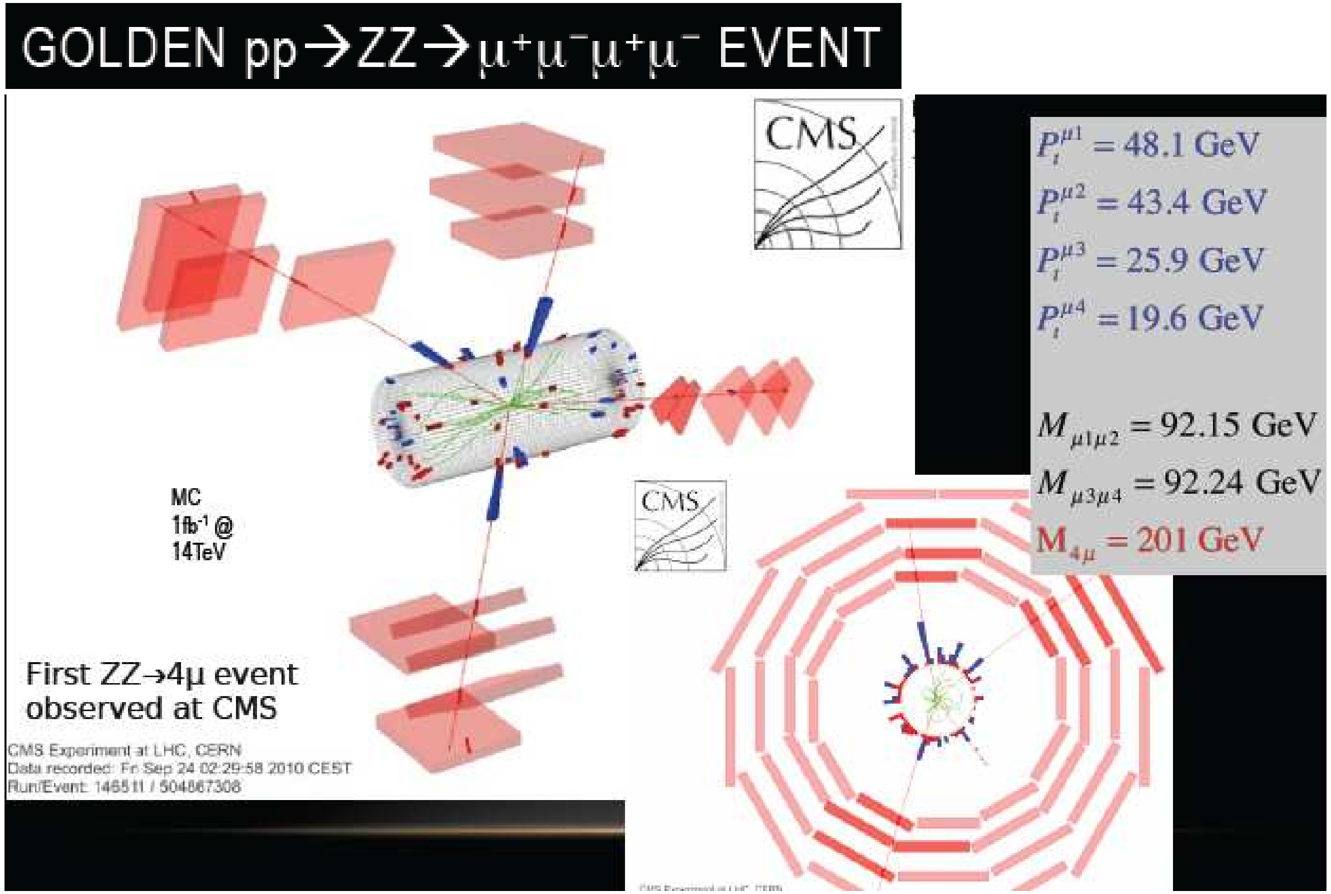


If 4th family fermions exists & Higgs has SM couplings → $144 < M_H < 207$ GeV excluded

SM Higgs expectations

Higgs: ZZ→4 leptons (e,μ)

- Signal: 4 high-p_T isolated leptons fully reconstructed → Higgs mass peak
- Backgrounds: ZZ irreducible, ttbar & Zbb removed by lepton isolation + impact param. cut
- Low background, but low yield



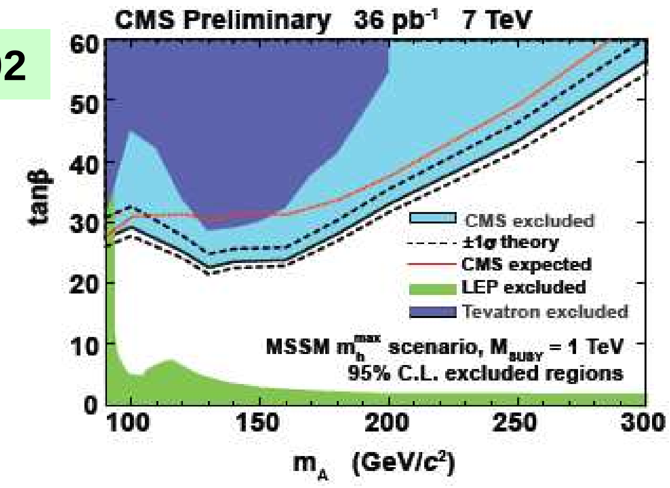
Add other ZZ decay modes: 2l2ν, 2l2b,2l2j

Higgs: Sensitivities

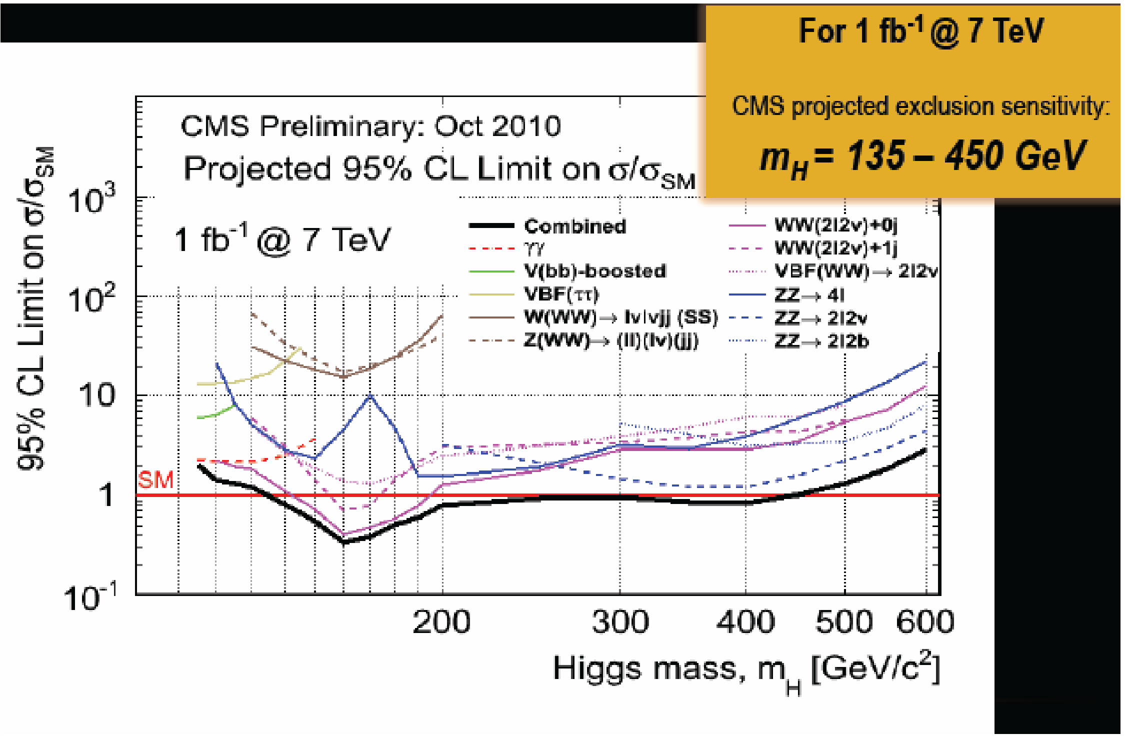
Other channels:

- H→ γγ,
- In MSSM, Φ → ττ **CMS-HIG-10-002**
- $H^+ \to \tau\nu$, or $H^{++} \to$ 2leptons **CMS-HIG-10-001**

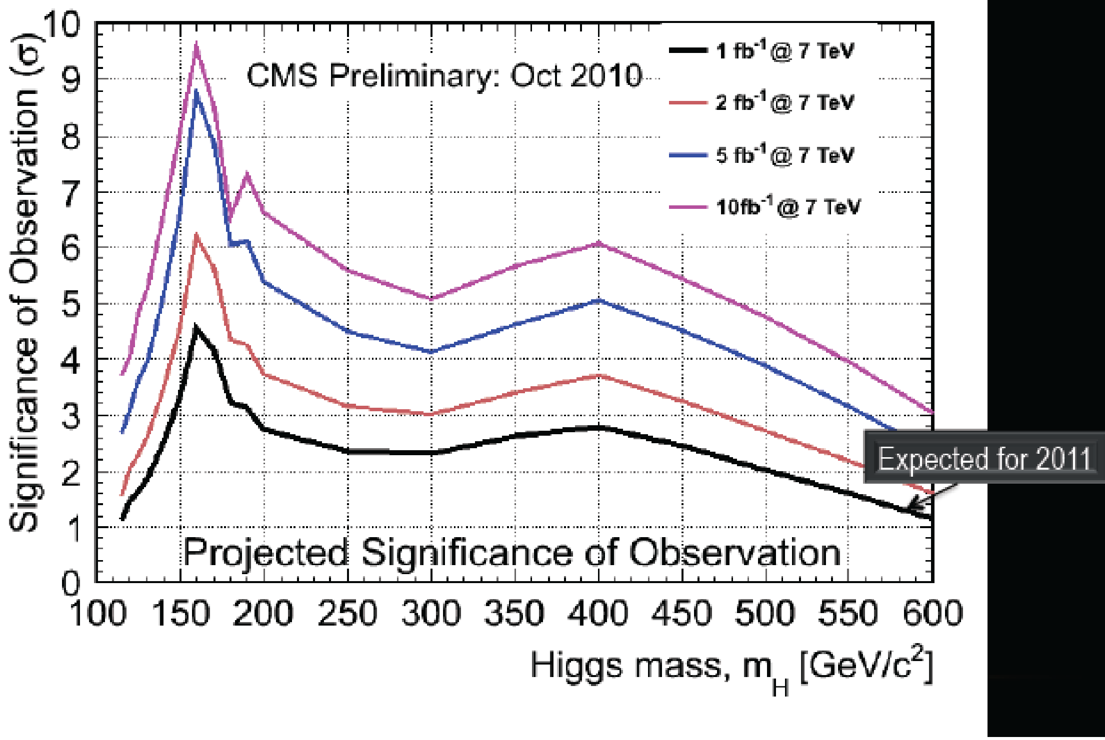
CMS-HIG-10-002



Exclusion Sensitivity



Observation Sensitivity



Outline

- LHC collider
- CMS experiment and subdetectors performance
- First Physics results with 2010 data
- Perspectives 2011-2012

Perspectives 2011-2012

- A reduced review of some CMS physics results published or in the final phase of analysis have been presented. For more details and info

  https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults

- Last week new luminosity determination during 2010 Run was made public. Cross section values to be increased by 1.007. Lumi uncertainty reduced from 11% to 4%.
- Since last weekend (13 March) LHC is providing again stable proton beams and collisions in CMS
- Run2011 will take place at $\sqrt{s}$ = 7 TeV (no increase to 8 TeV for the moment) with a goal of Lint = 1 fb^{-1} by end 2011.
- LHC will continue running during 2012, aiming for $\approx$5fb^{-1} (or even more), depending on collider performance.
- During 2013 there will be a long technical shutdown to consolidate the whole machine for E_b=6-7 TeV

Outlook

LHC had a wonderful start in 2010

- The detectors and accelerator working well
- The Standard Model is well established at 7 TeV scale
- Early searches yield no surprises, going beyond Tevatron
- Look forward to several fb^{-1} data at 7 TeV in 2011-2012
- Be prepared for possibly unambiguous discoveries of higgs, SUSY and exotic new physics
- LHC already providing collisions for the 2011-2012 period.

Wishing for a successful and enriching 2011 year at LHC!!