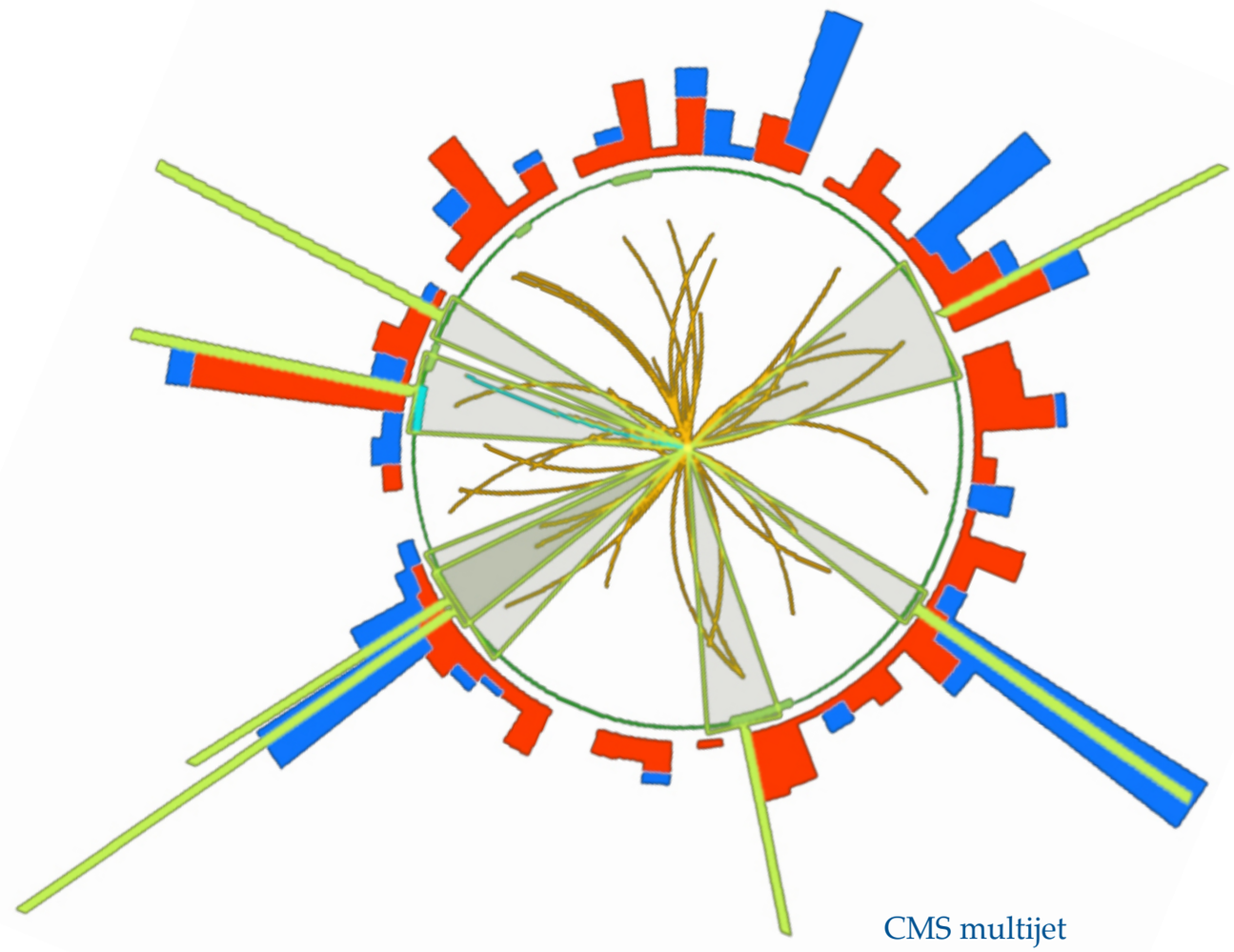
CMS Status and First Results

Dave Newbold (University of Bristol)
on behalf of the CMS Collaboration

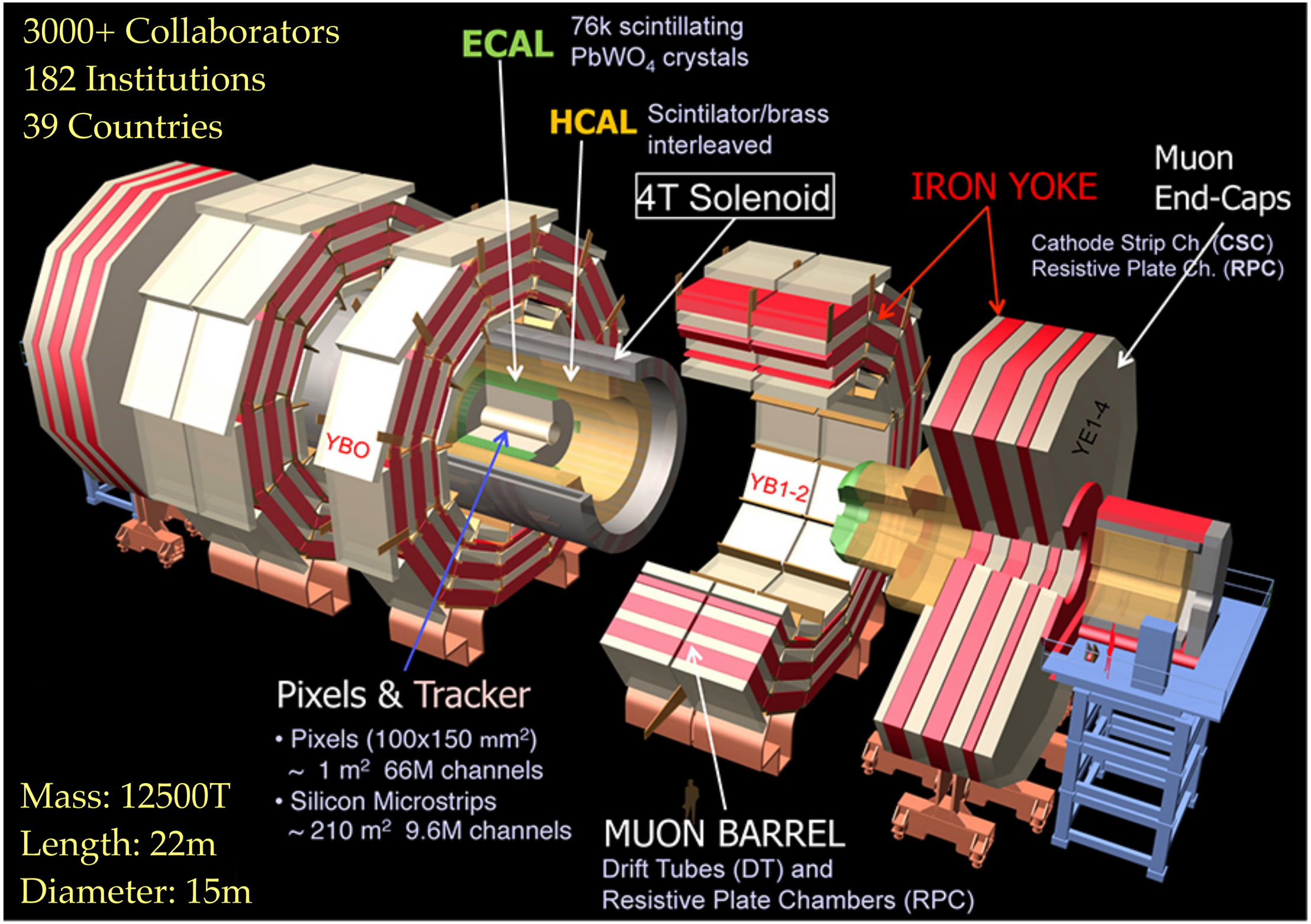
- CMS detector
- Commissioning
- Detector performance
- First QCD results
- First electroweak data
- Prospects for 2010 -11



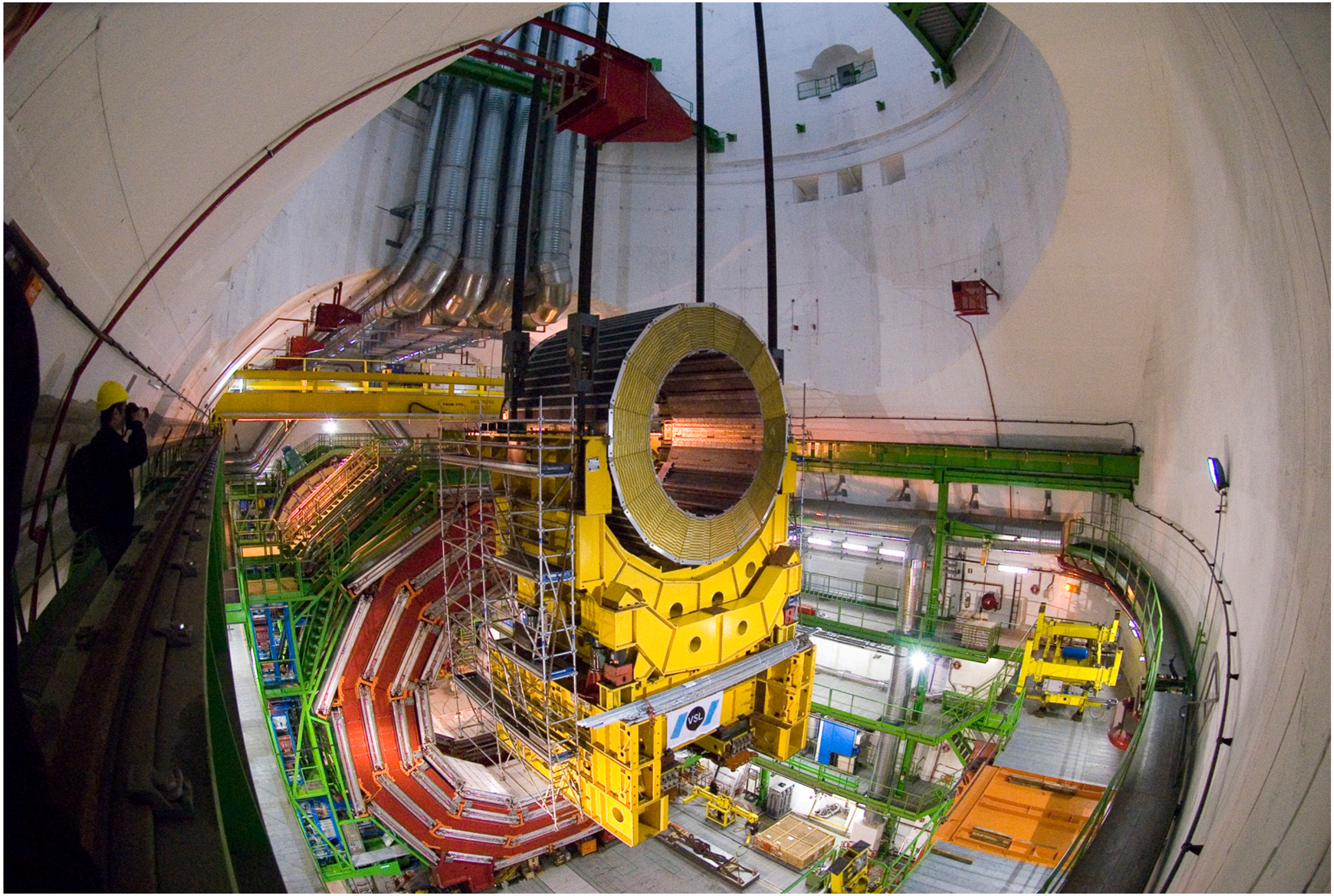
CMS multijet candidate - 7TeV data

BOOST2010 Workshop, June 2010

The CMS Detector

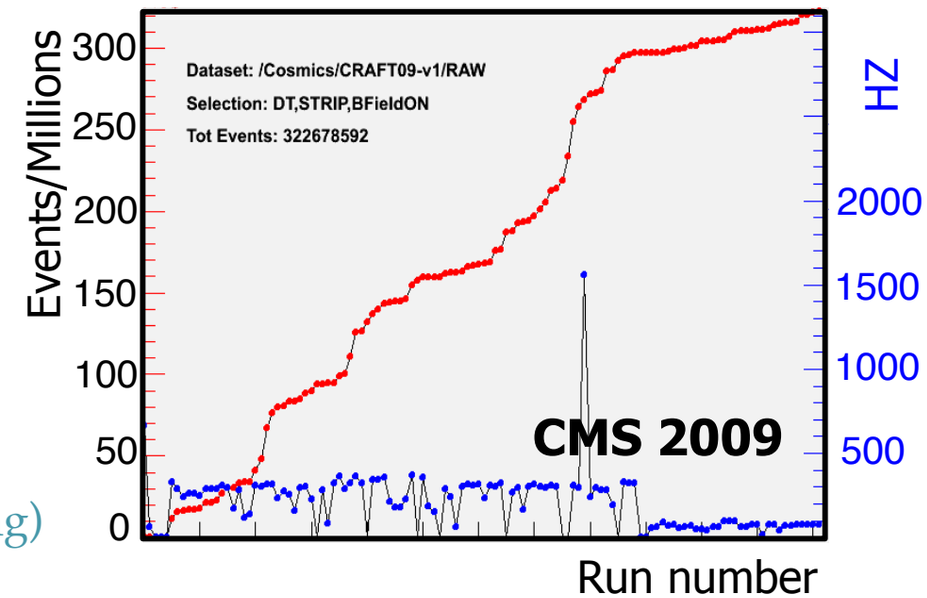


CMS in February 2007



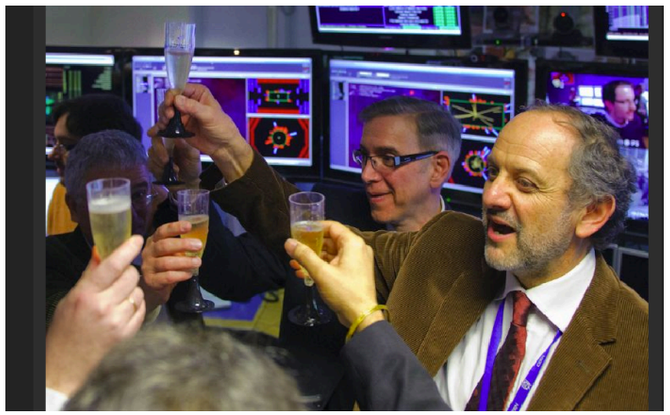
CMS Data-Taking Periods

- Cosmics runs:
  - MTCC '06: 25M cosmic muons
  - CRAFT '08: 470M cosmic muons
  - CRAFT '09: 300M cosmic muons
  - Detailed detector studies during commissioning
    - Operation of all data-taking systems (trigger, DAQ, computing)

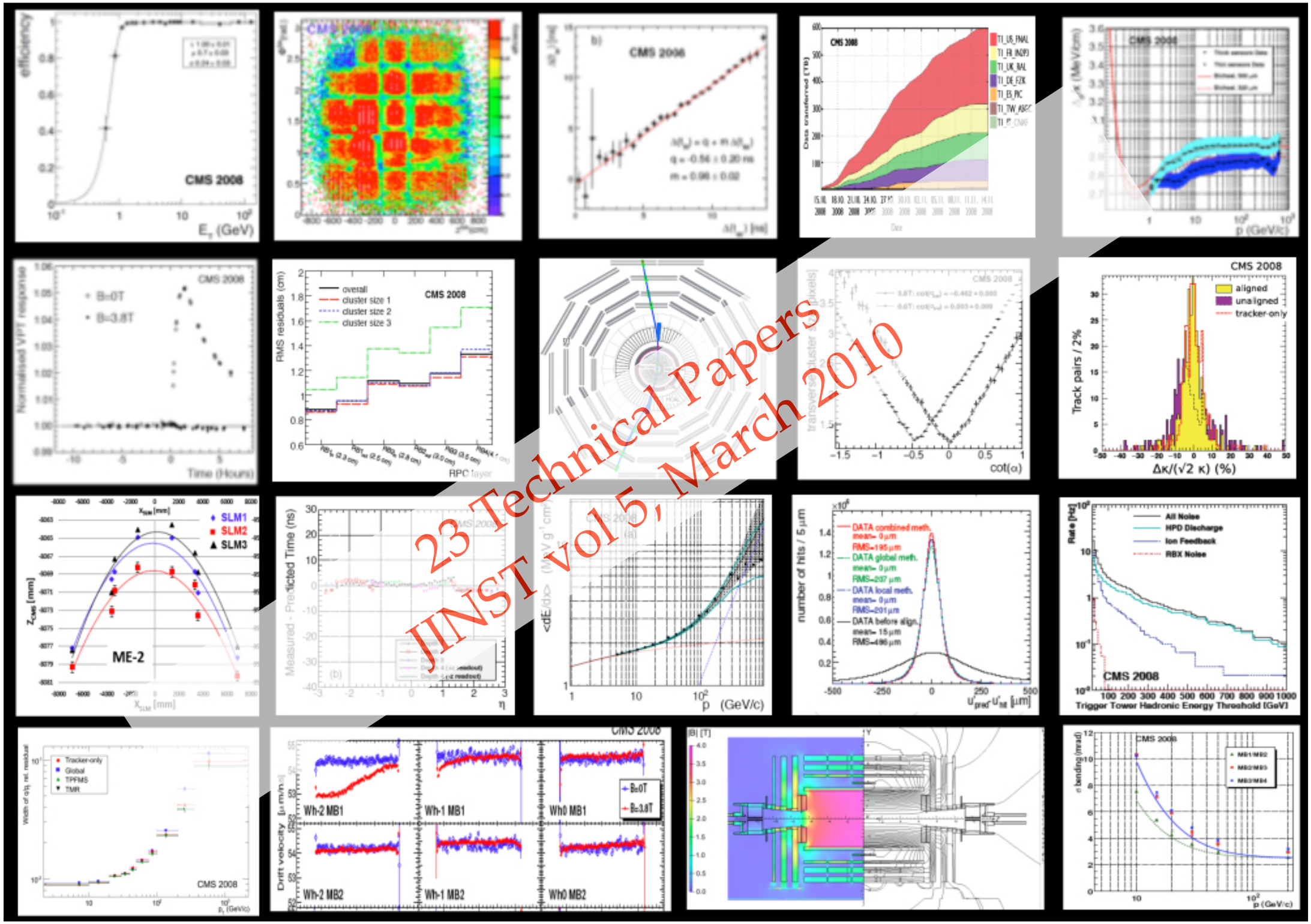


- Collision runs:
  - $\sqrt{s}$ = 900GeV (LHC injection energy): 300k events →
    - Delivered / recorded: 15μb^{-1} / 10μb^{-1}
    - First LHC collision run, many lessons learnt about detector operations and performance
    - First physics papers based on this data

  - $\sqrt{s}$ = 2.36TeV: 20k events
    - Delivered / recorded: 1.2μb^{-1} / 0.4μb^{-1}
    - Short run, paving the way to real high-energy operation
  - $\sqrt{s}$ = 7TeV: "LHC Run 1" →
    - Running since 30th march 2010, ~20nb^{-1} delivered so far

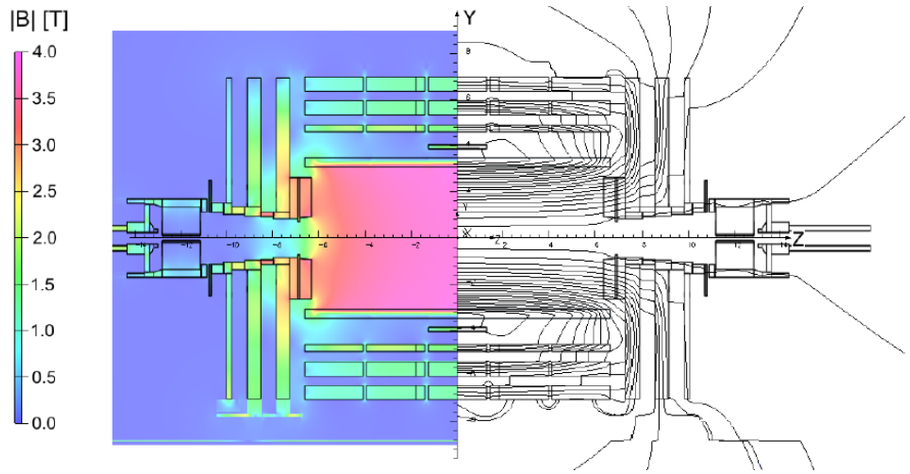


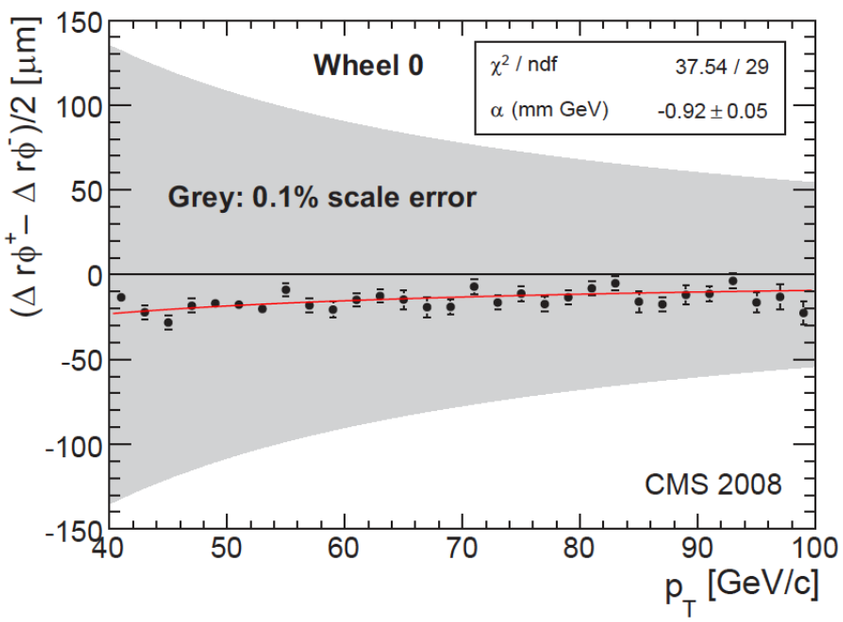
CRAFT - Cosmic Runs at Four Tesla



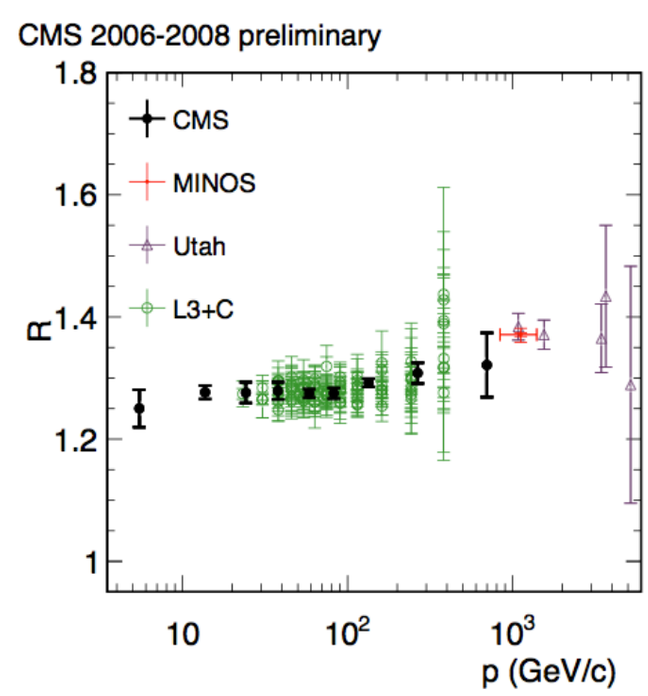
23 Technical Papers
JINST vol 5, March 2010

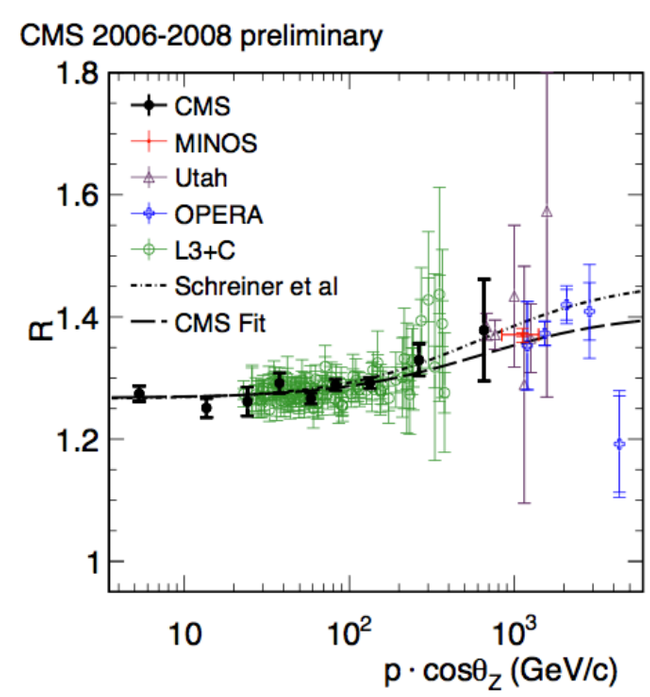
CRAFT Achievements





- Field map fully understood
  - Extrapolate tracks, tracker to muon chambers -> field known to 0.1% within solenoid
- Tracker alignment
  - Alignment precision matches that originally expected for ~10pb^{-1}
- In good shape for physics runs



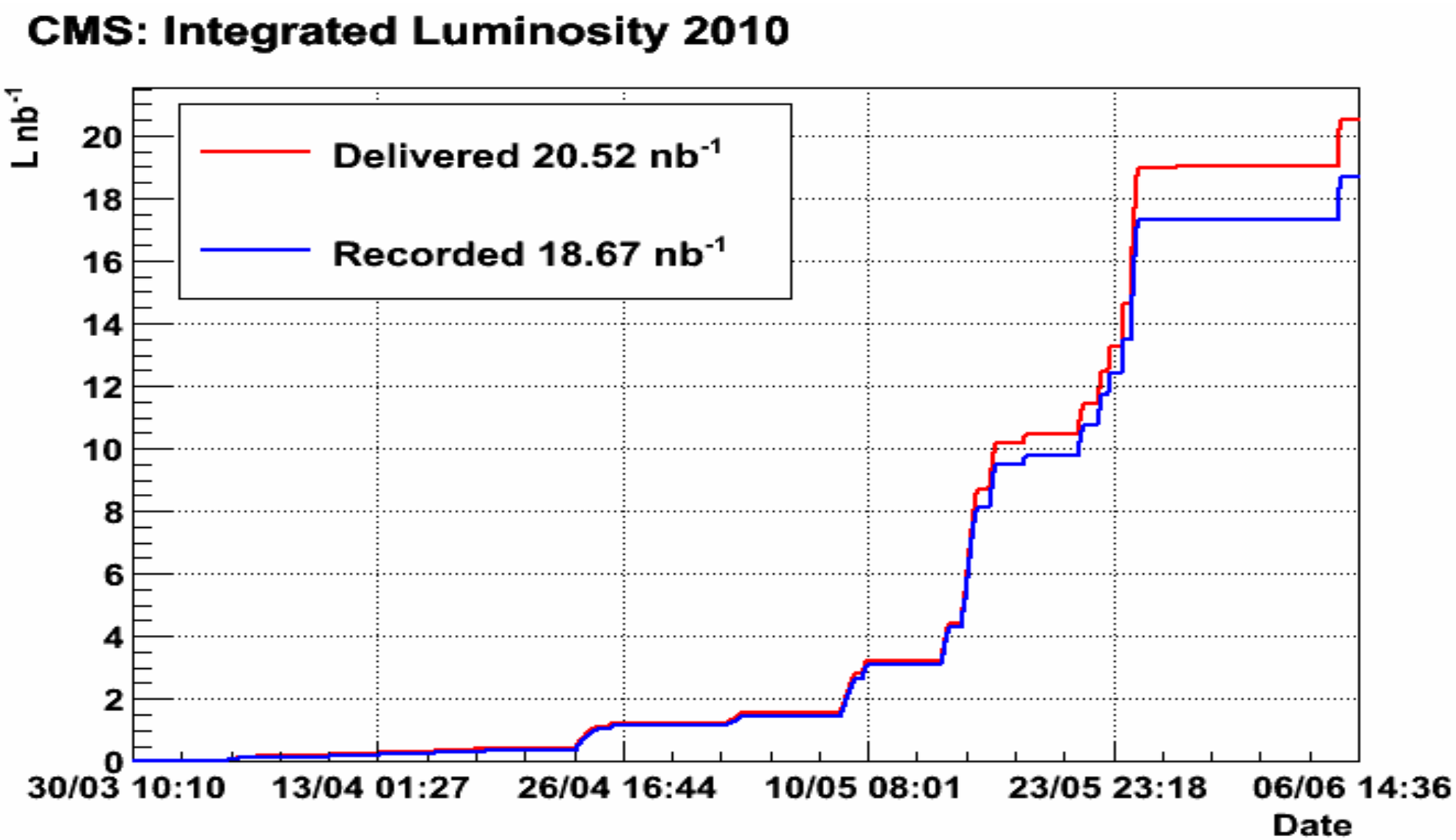


- TeV muons without LHC
  - Most precise measurement of charge ratio over wide p range
  - Submitted to PLB

LHC Luminosity Profile for 7TeV

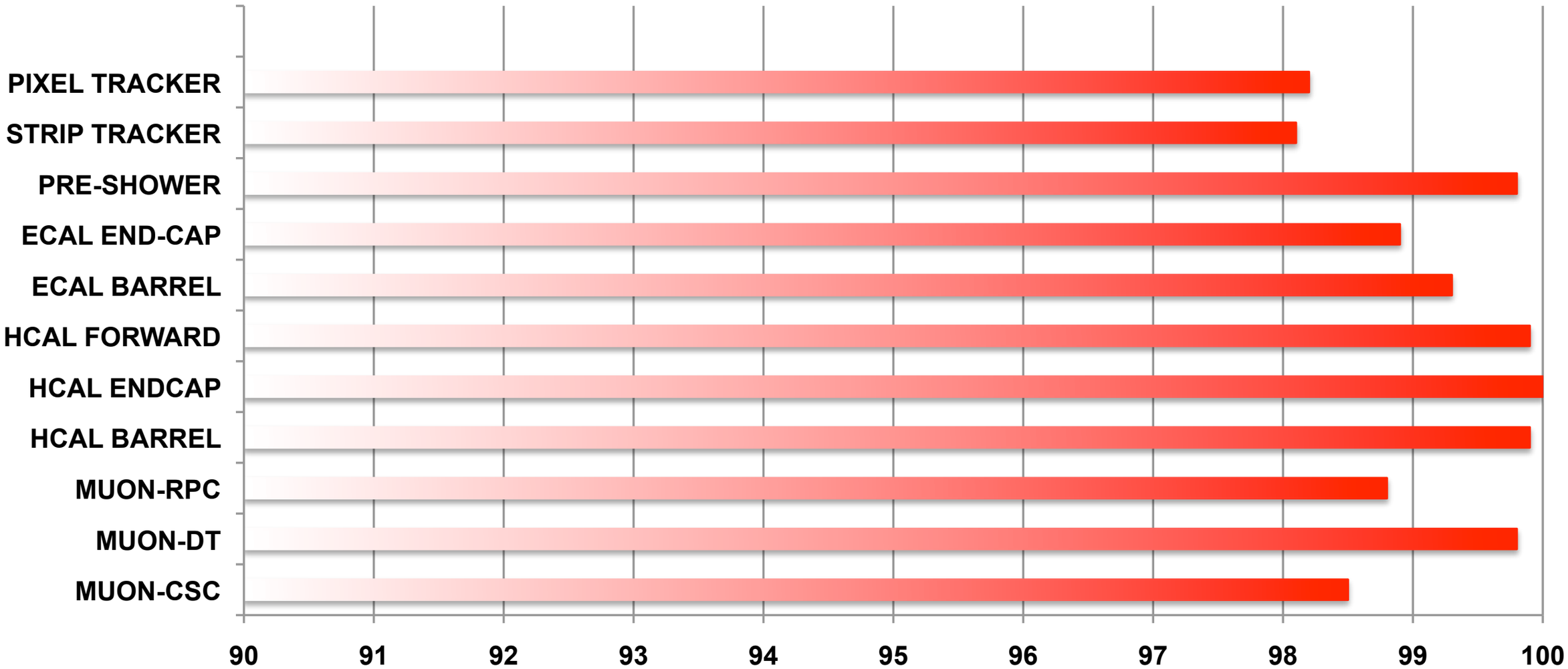
Delivered by LHC: 20.5nb^{-1}; collected by CMS: 18.7nb^{-1}

Data taking efficiency: 91%; high quality data for 90% of runs



CMS 7TeV data sample to date: 17nb^{-1}

CMS Operating Efficiency

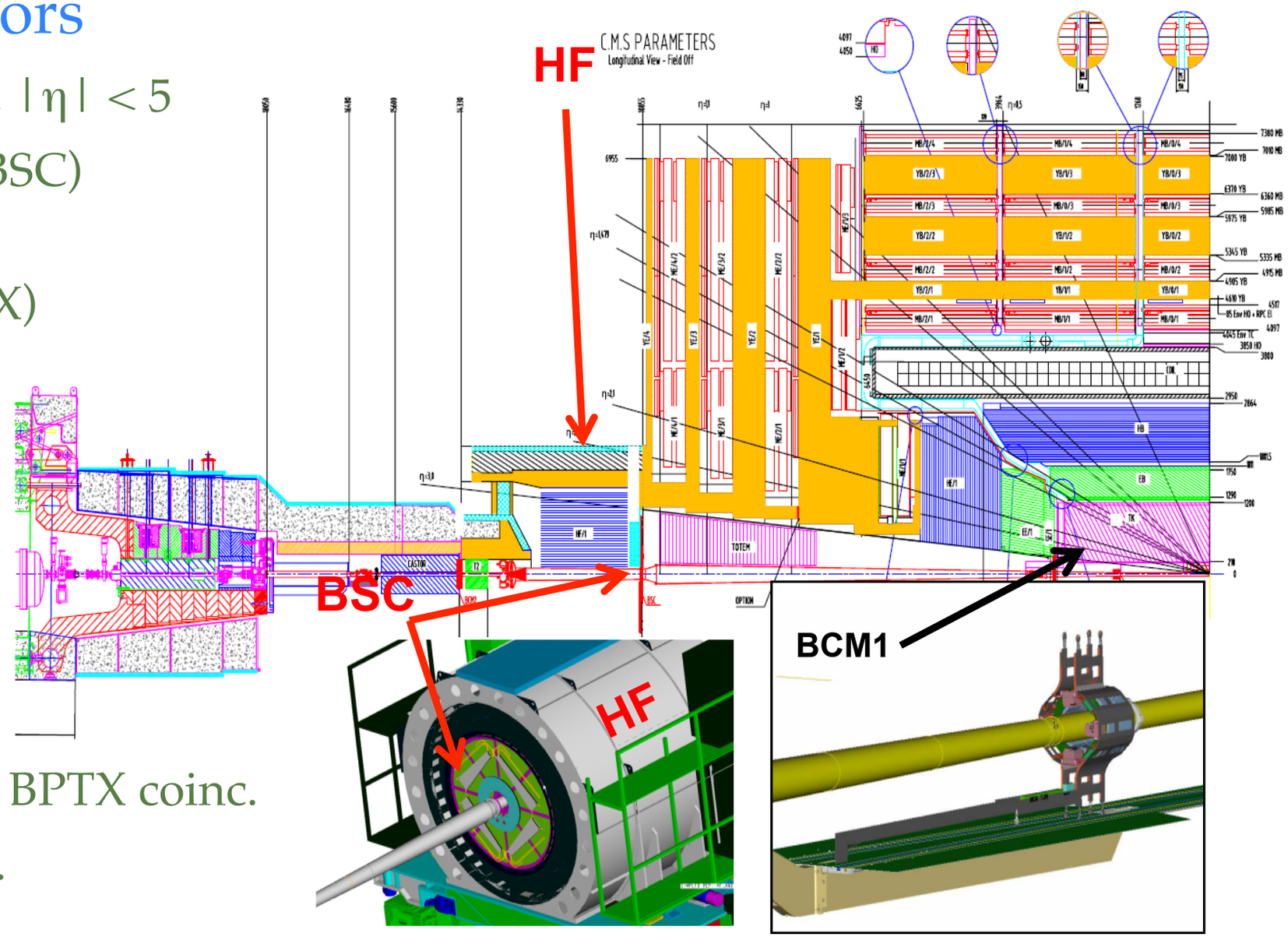


	MUON-CSC	MUON-DT	MUON-RPC	HCAL BARREL	HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER	
Series1	98.5	99.8	98.8	99.9	100	99.9	99.3	98.9	99.8	98.1	98.2	

- All subsystems >98% functional – CMS is operating efficiently

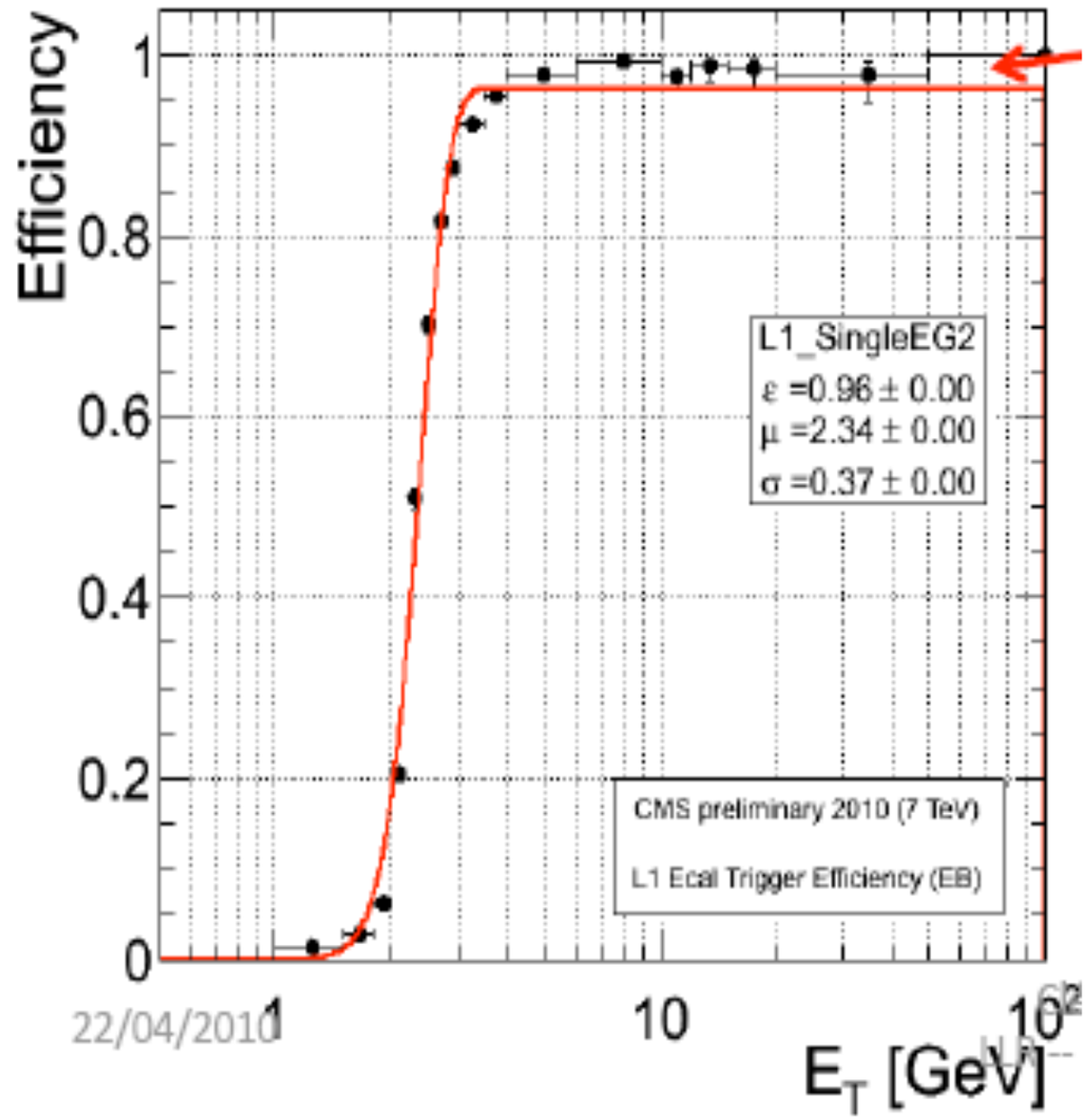
Triggering at Low Luminosity

- L1 trigger detectors
  - Forward calos: $2.5 < |\eta| < 5$
  - Beam scintillators (BSC)
    - ±10.5m from IP
  - Beam pickups (BPTX)
    - ±175m from IP



- Triggers
  - Zero bias, prescaled BPTX coinc.
  - Min bias, BSC coinc.
- Minbias offline selection
  - BSC (OR of 2 planes) + good vertex, $\varepsilon \sim 90\%$
  - HF ($E > 3$GeV both sides): $\varepsilon \sim 90\%$

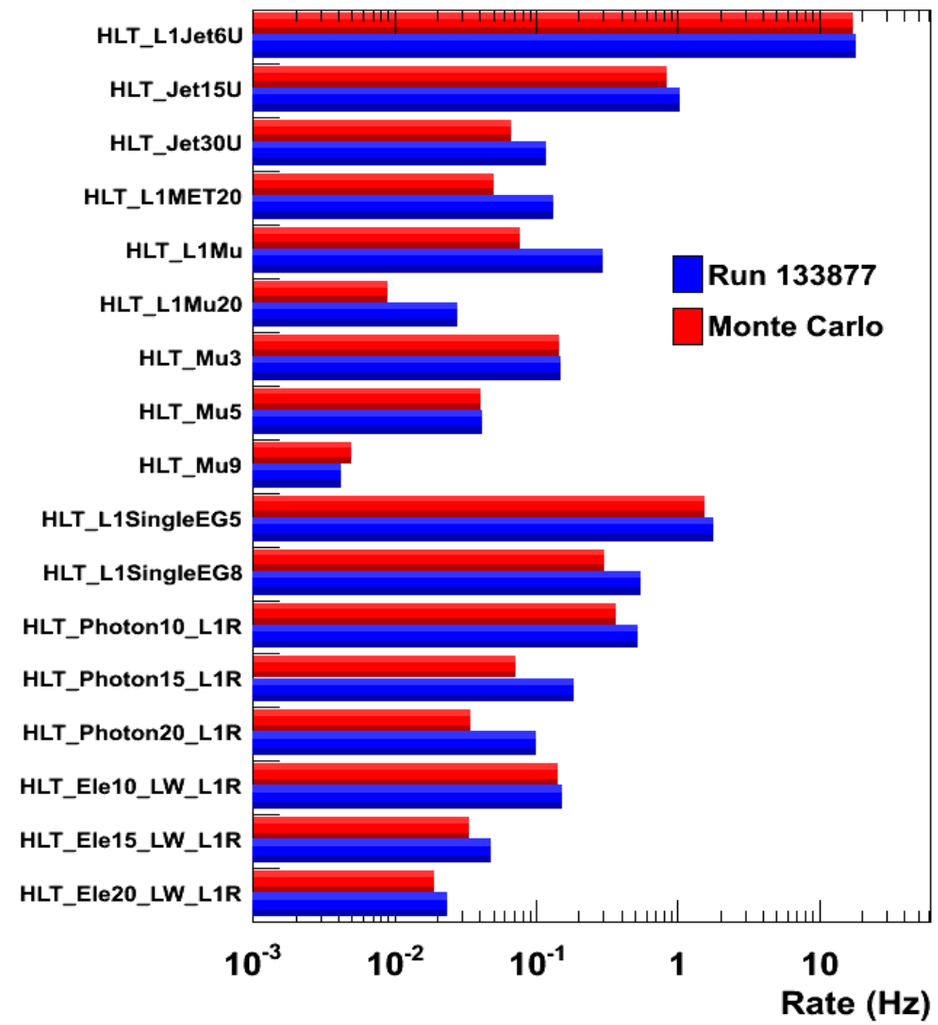
Trigger Commissioning

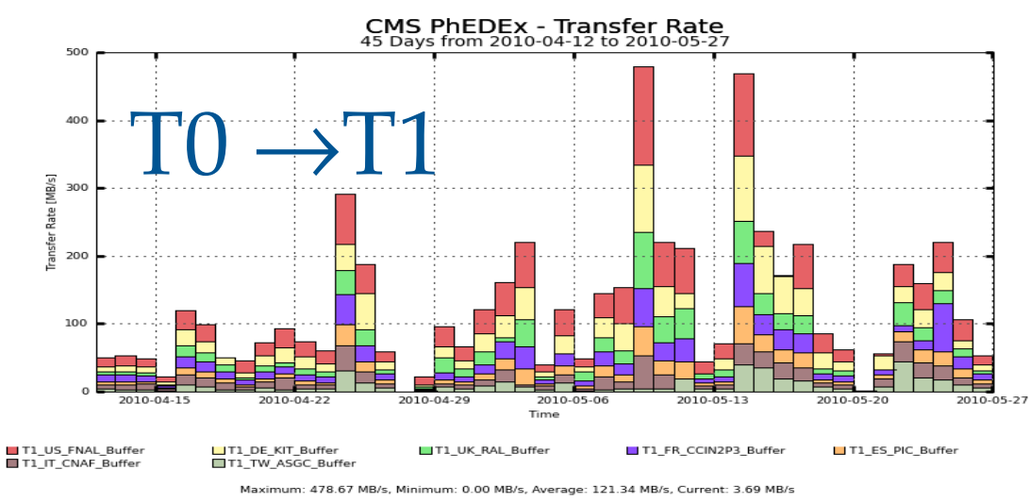


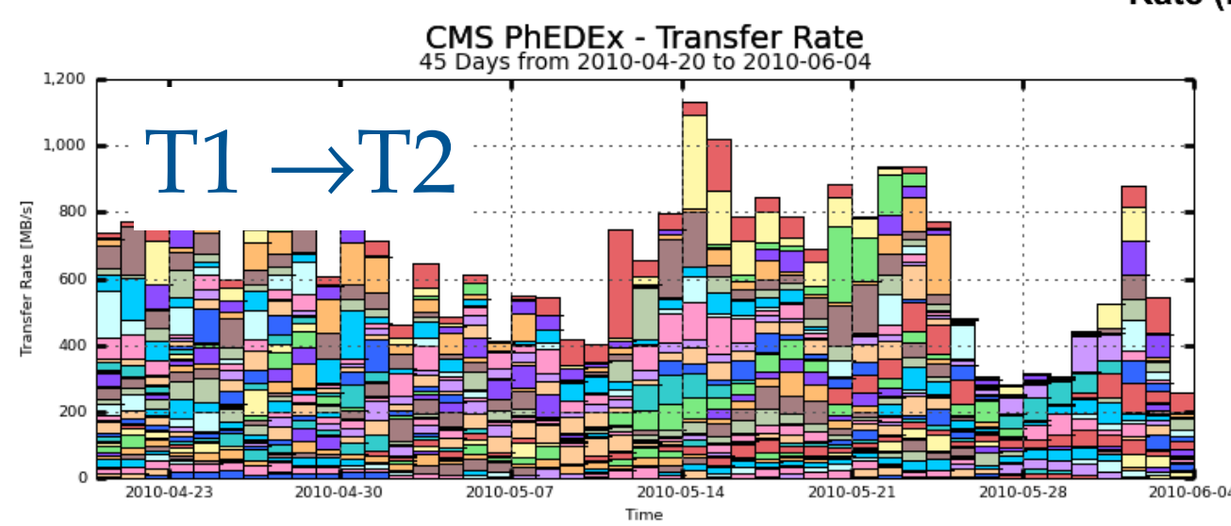
- High-level trigger in 'mark and pass' mode for MB running
  - Allows validation of first low threshold muon / calo trigger paths
  - Higher lumi trigger performance can later be estimated in the same way

DAQ & Offline Performance

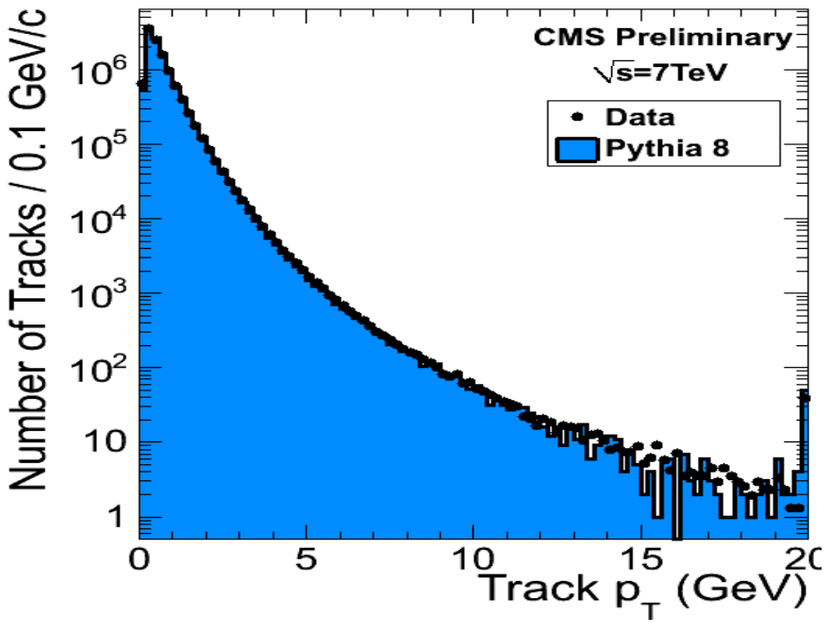
- Excellent efficiency from HLT, DAQ
  - HLT compute farm ~2% loaded
  - Can cope with ~100ms/evt load
  - Currently predict <40ms/evt for $\mathcal{L}=10^{30}$
- Computing system
  - Data processing proceeds smoothly
  - Many reprocessing cycles complete at T1
  - >60 centres (T1 & T2) participating
  - ~500 users submitting jobs for analysis

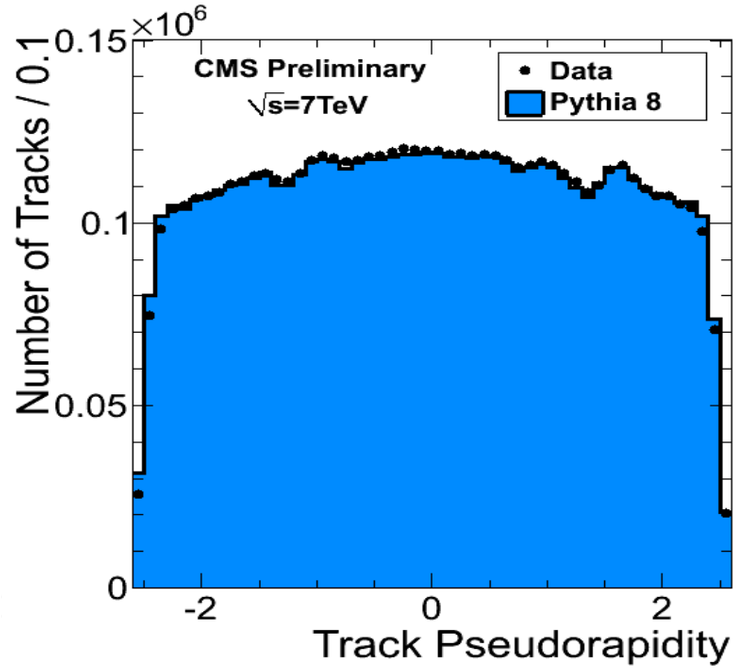


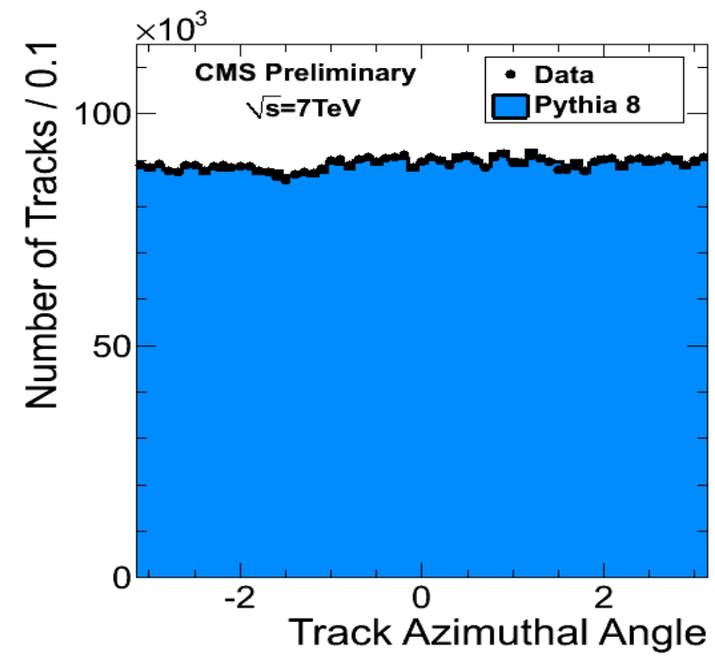


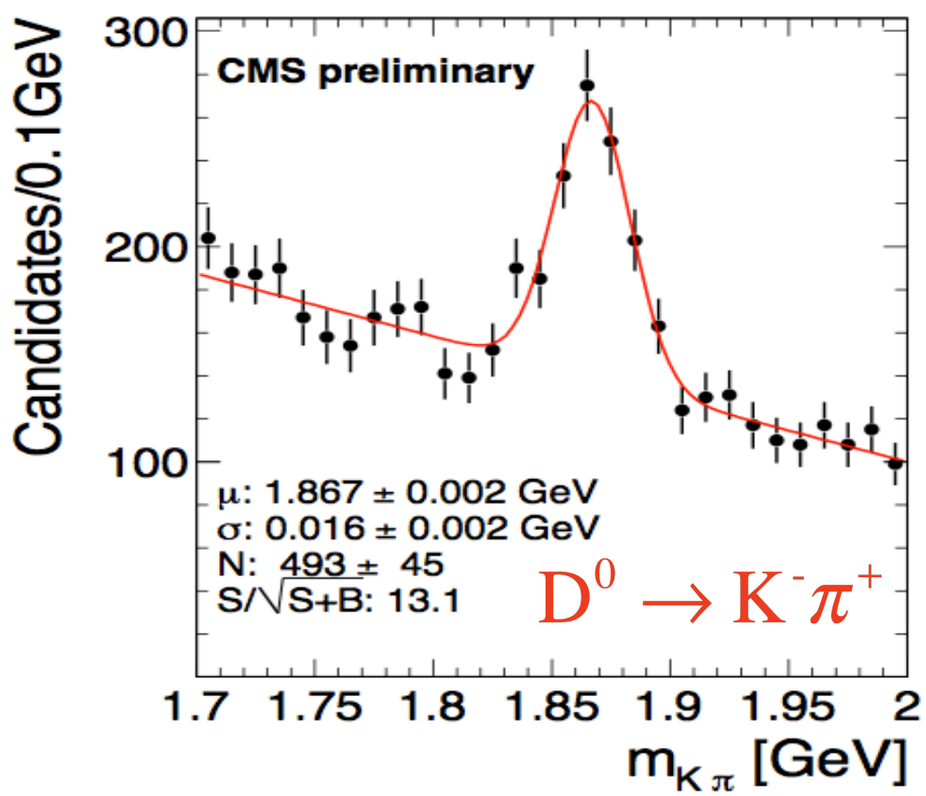


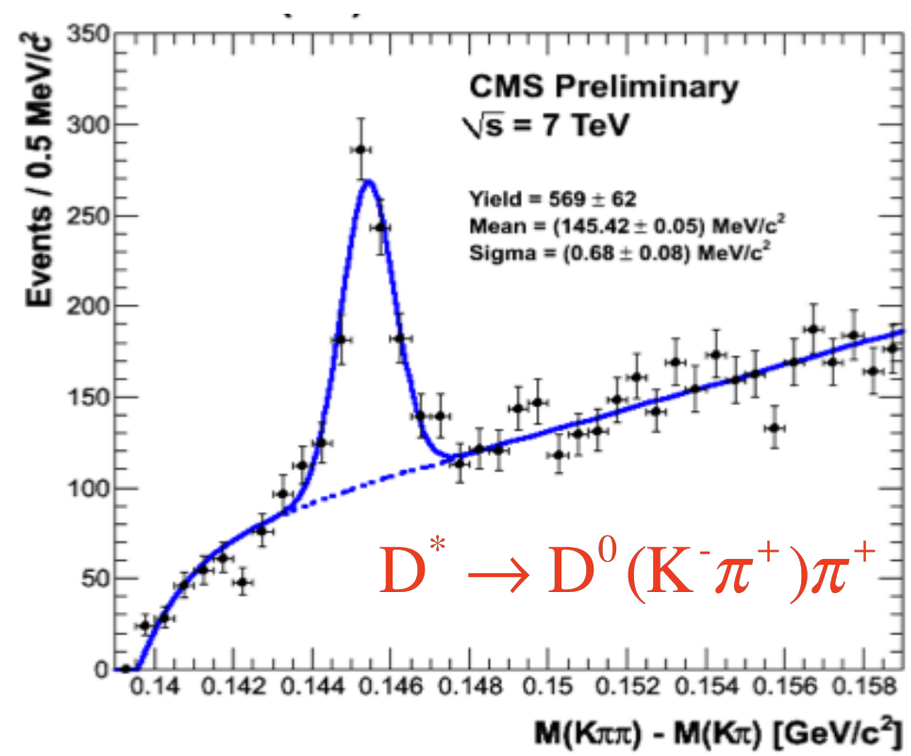
Tracking Performance



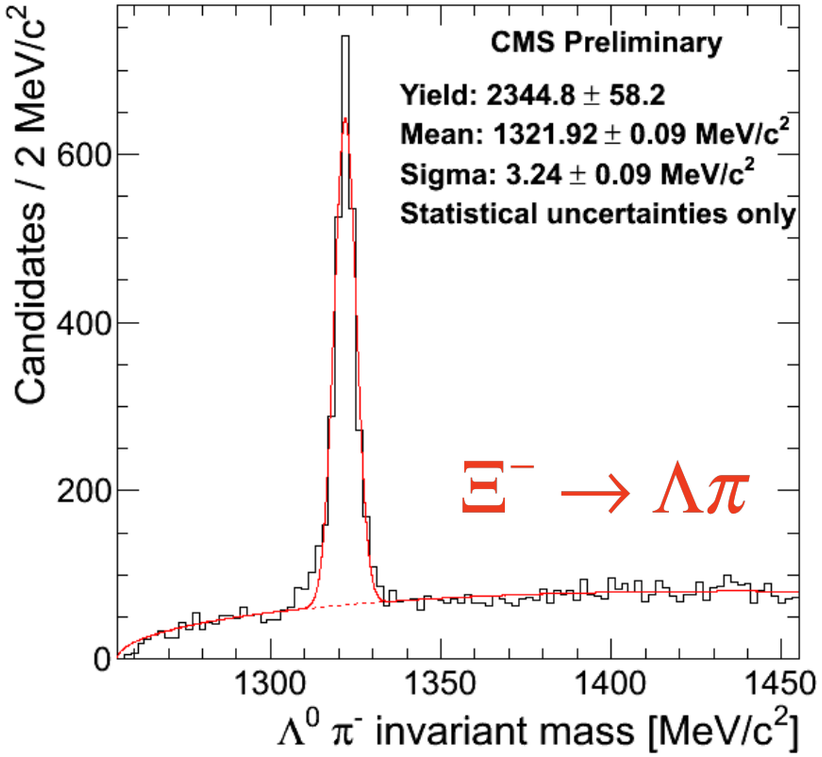


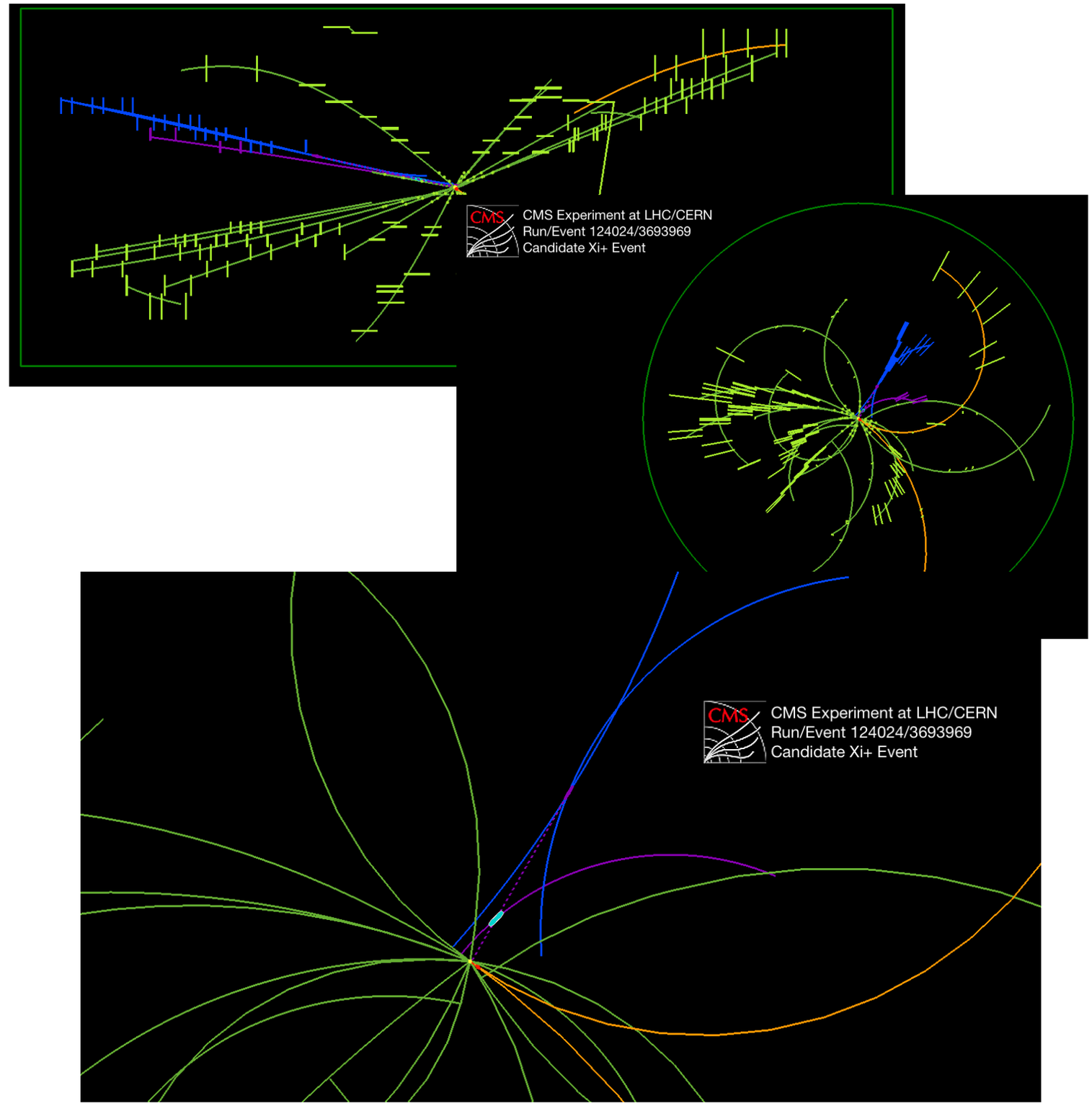


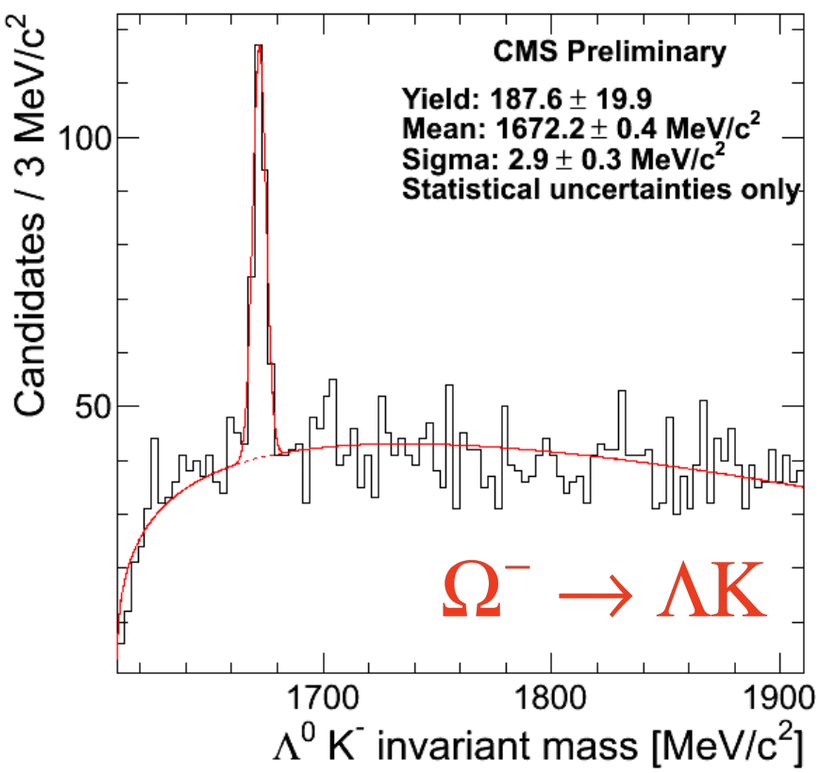




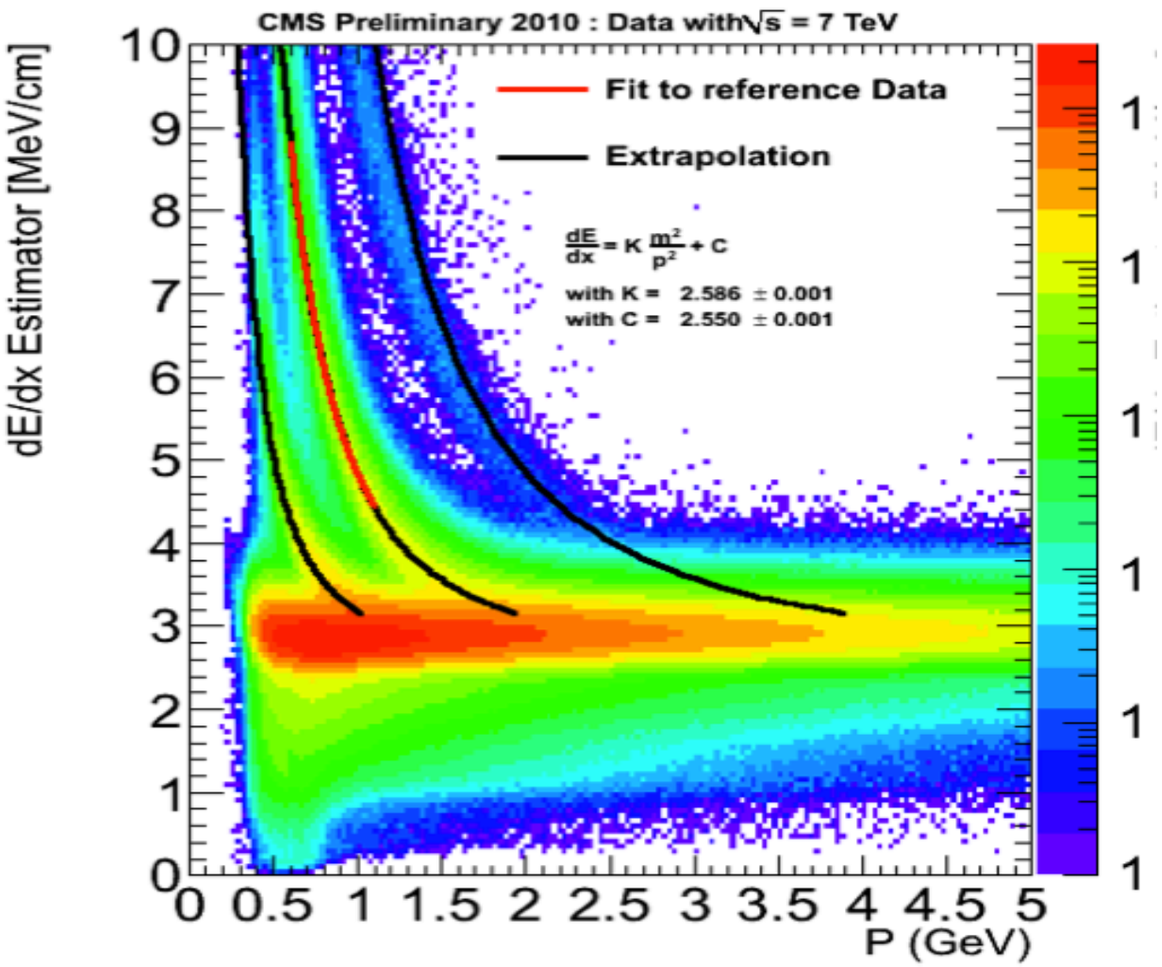
Tracking Performance

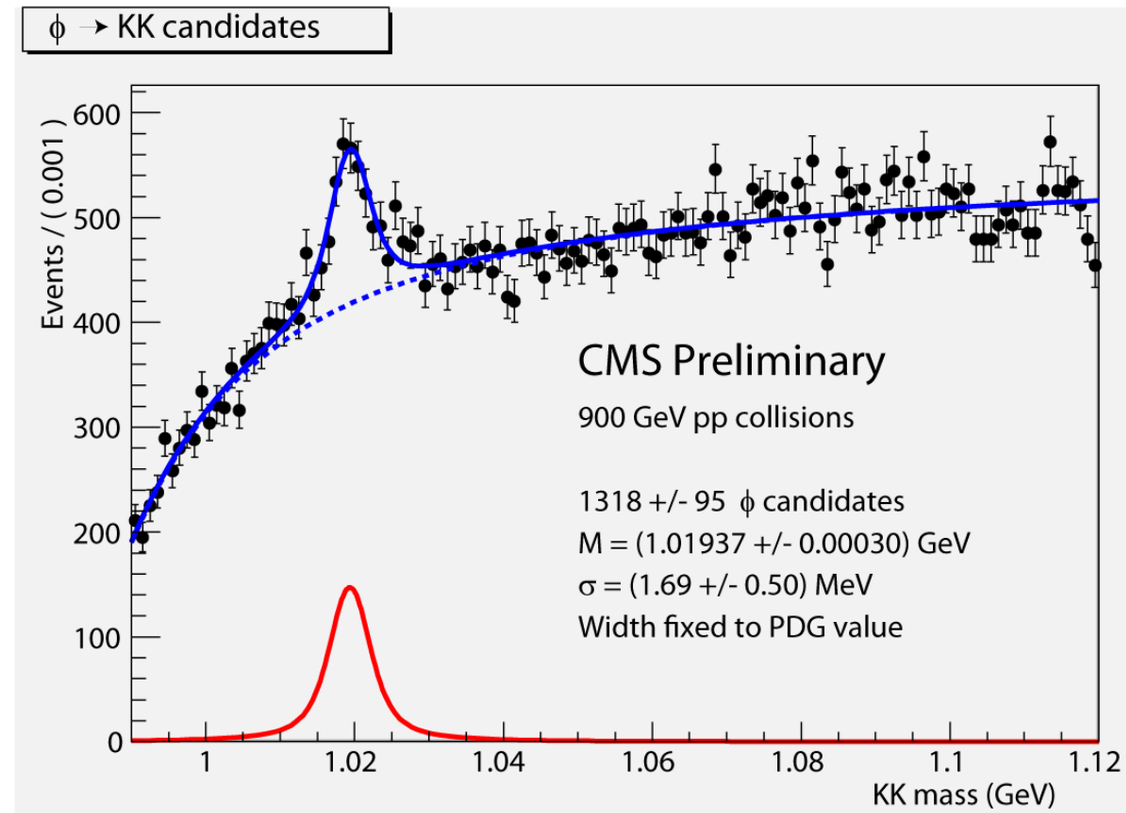






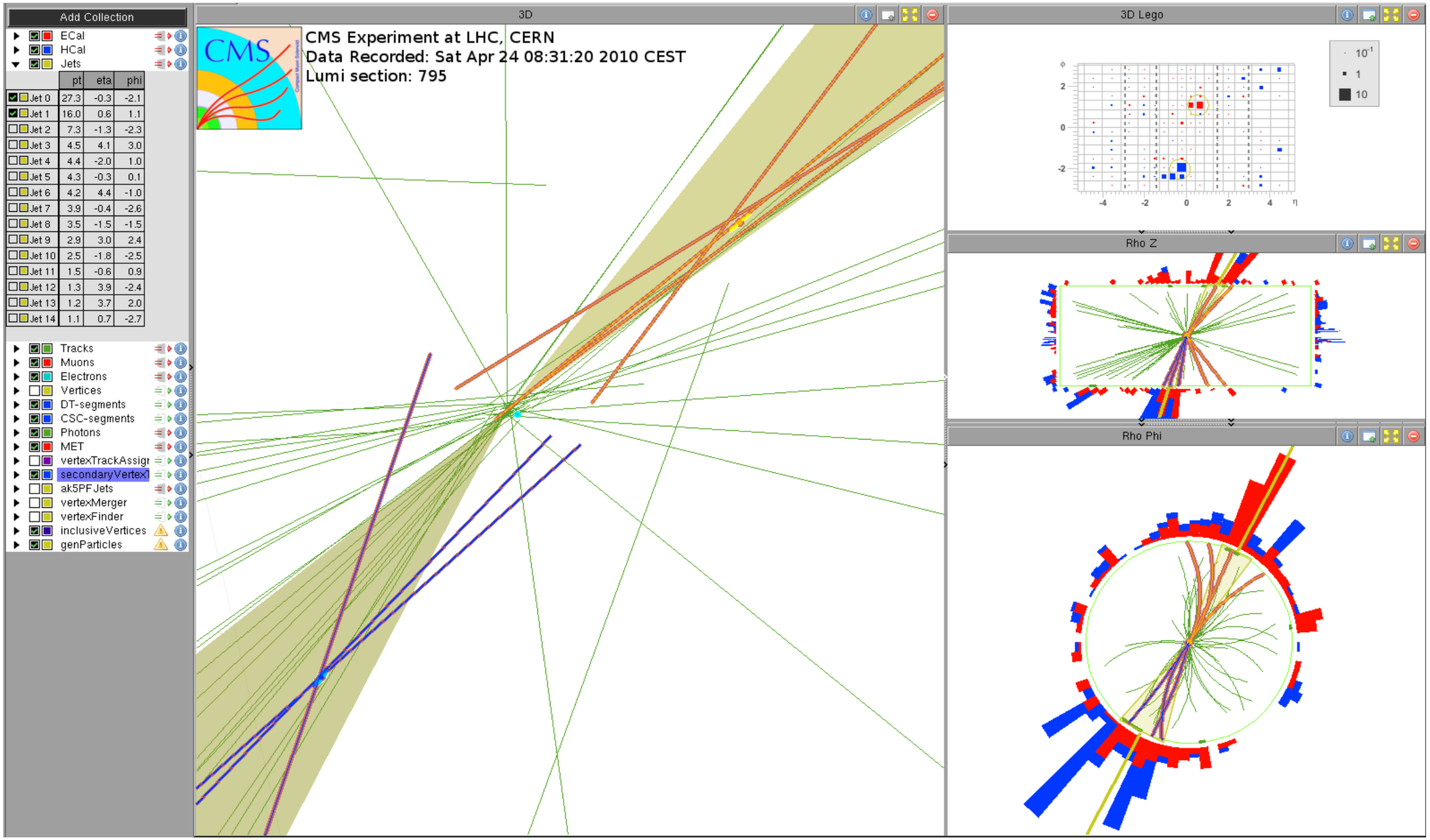
Tracking Performance





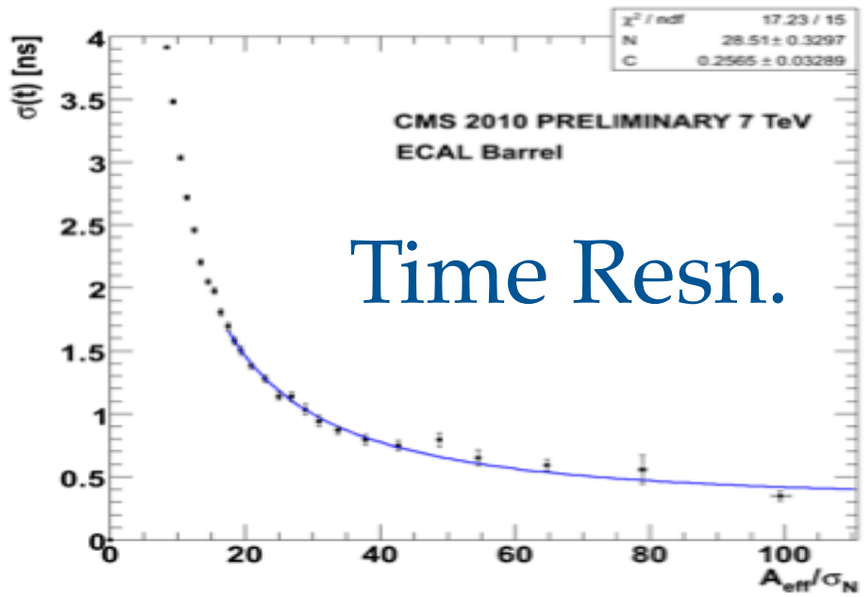
- Tracking performance validated
  - Momentum scale, alignment, primary / secondary vertex ID
  - Simulation of material distribution being fine-tuned

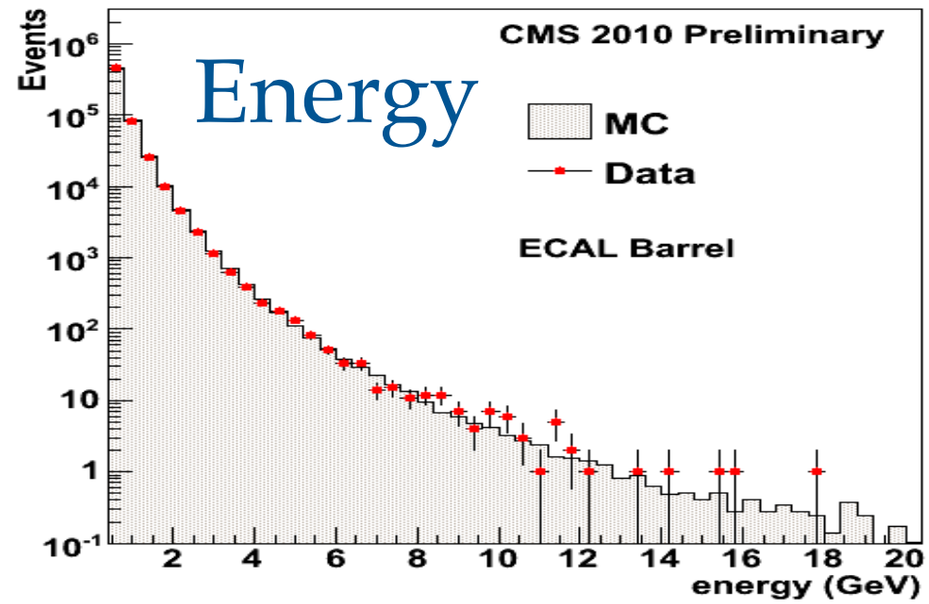
b-Tagging

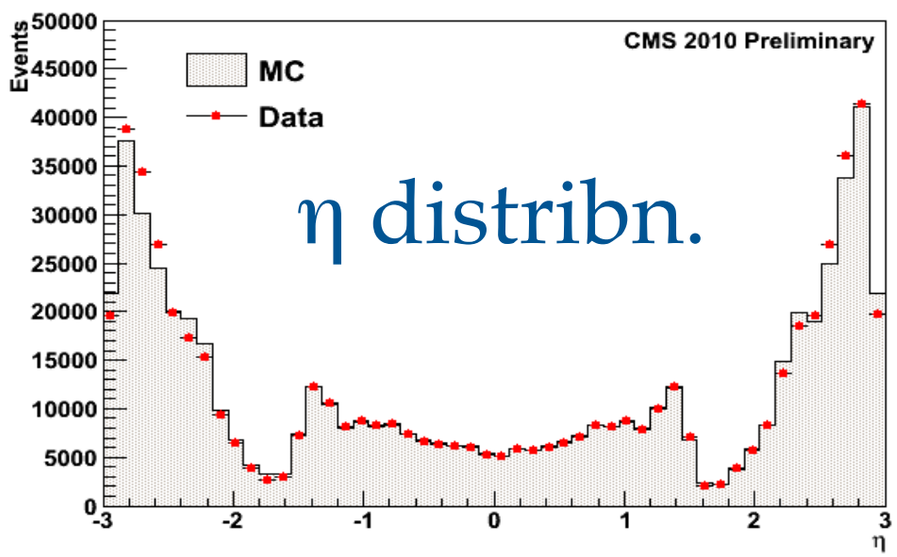


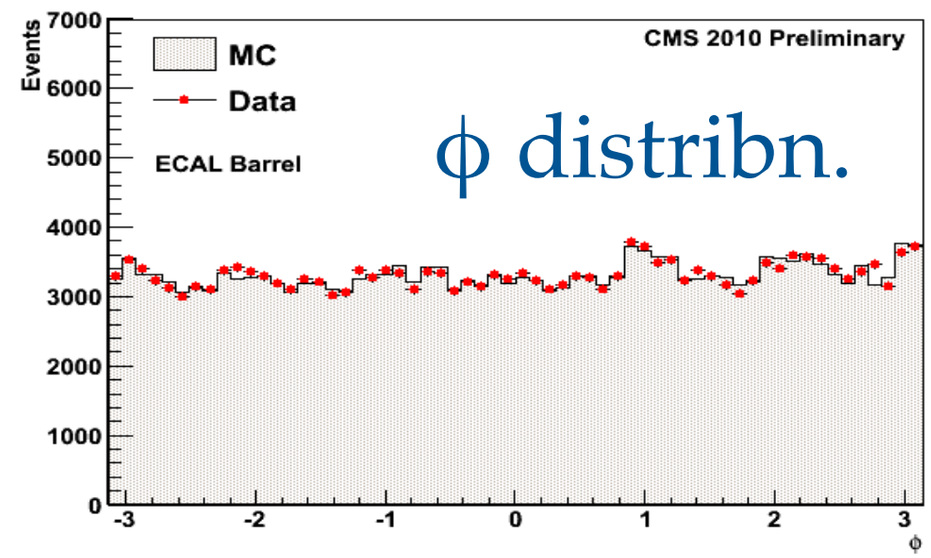
- Example double b-jet candidate
  - b-tagging currently being commissioned

ECAL Cluster-Level Performance









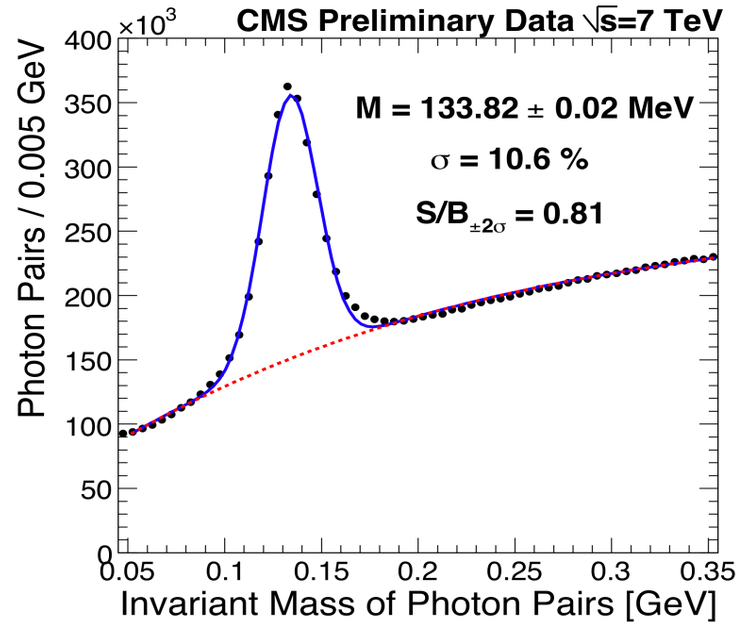
- Distributions for highest cluster in ECAL barrel
  - Good agreement with MC; performance well understood
  - Note that CMS ECAL was not be re-calibrated during CRAFT

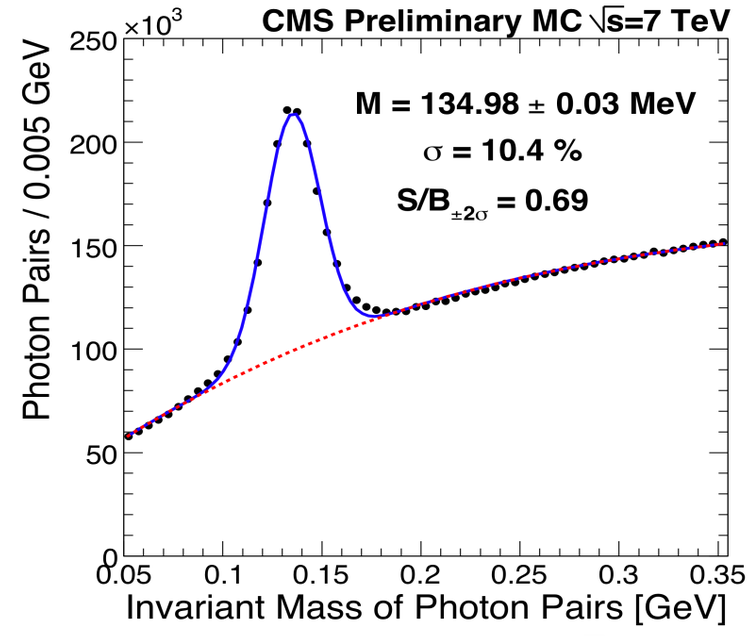
γγ Resonances

1.46M $\pi^0 \rightarrow \gamma\gamma$

$p_t(\gamma) > 0.4$GeV

$p_t(\pi) > 1$GeV

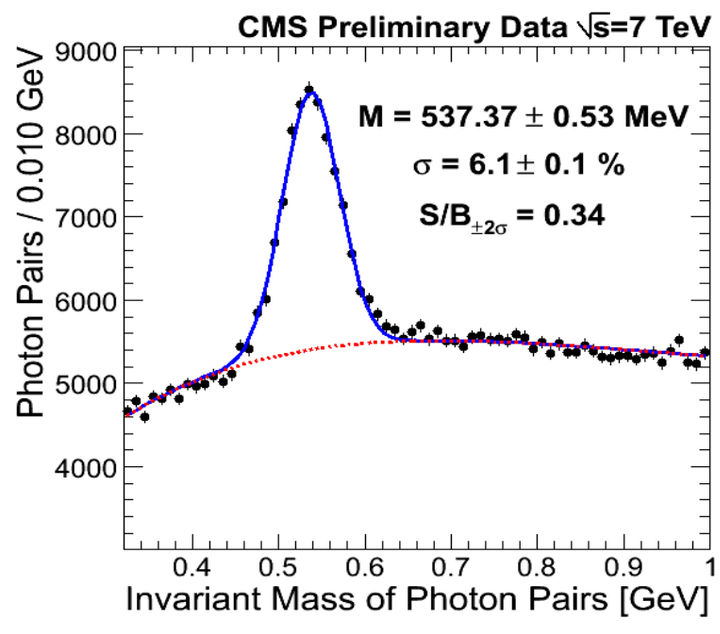


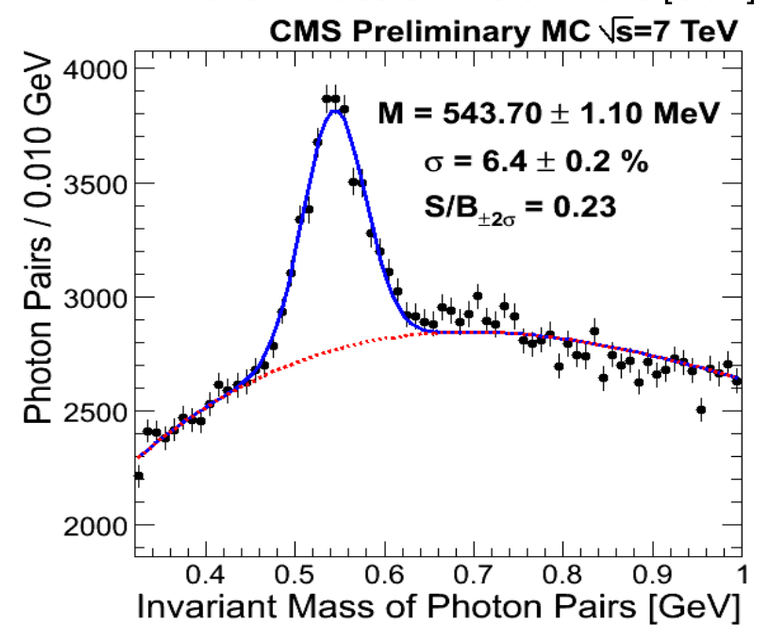


25.5k $\eta^0 \rightarrow \gamma\gamma$

$p_t(\gamma) > 0.4$GeV

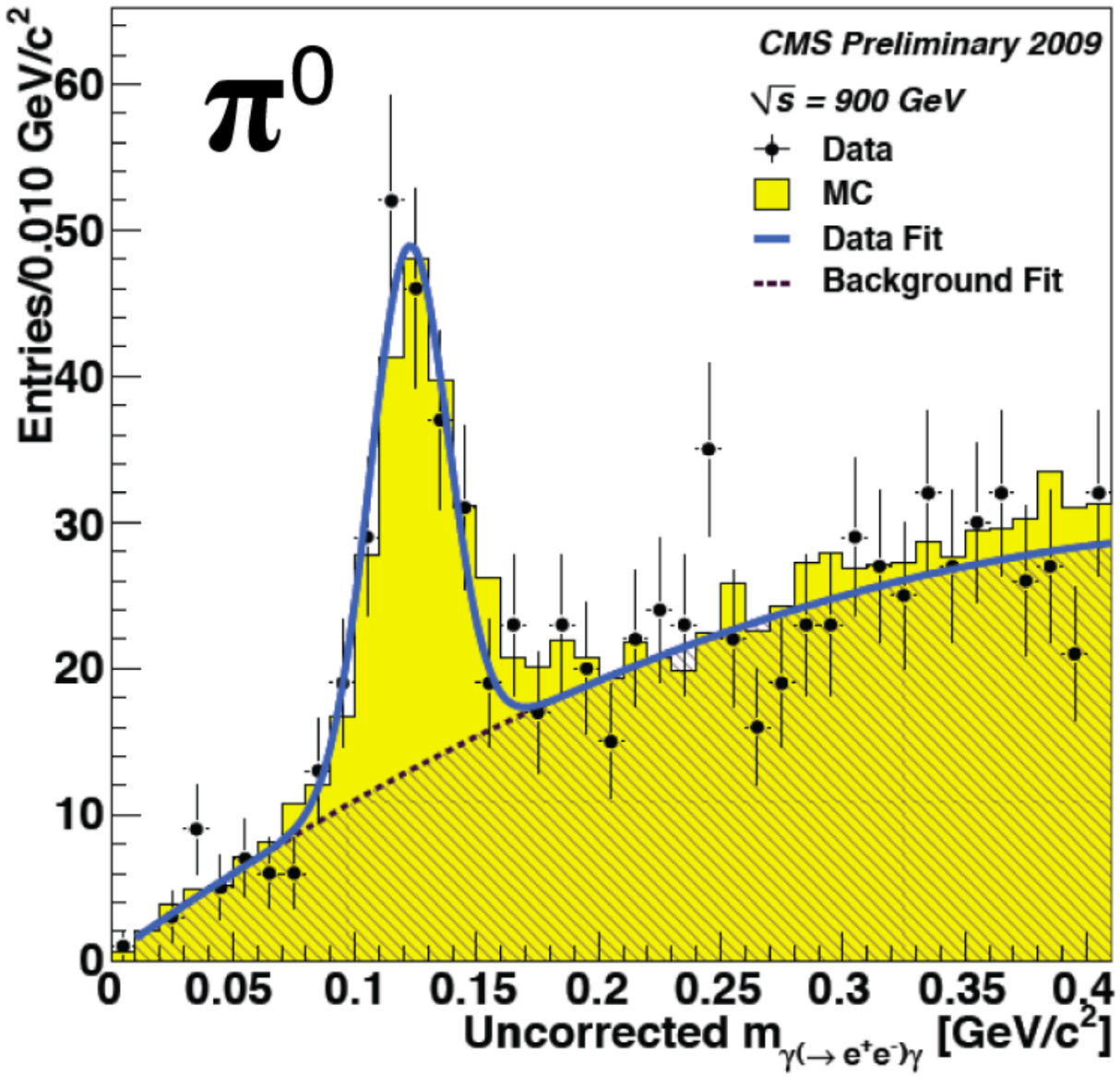
$p_t(\pi) > 1$GeV





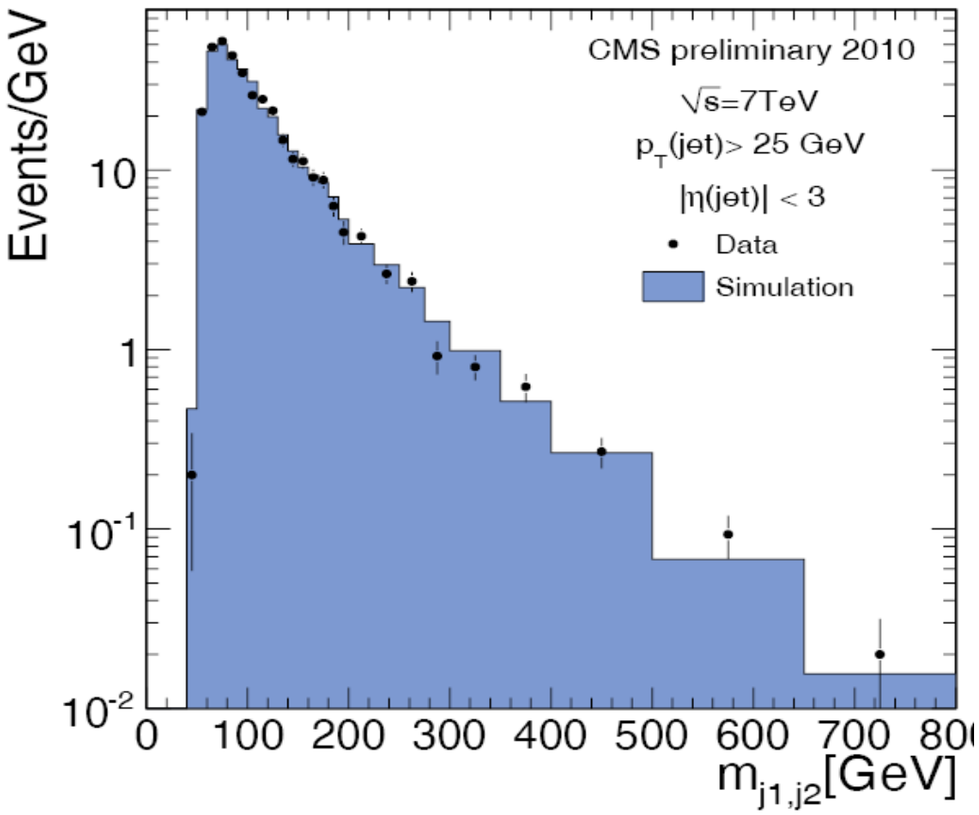
- Only around 10% of stats in these plots; useful tool for intercalibration of ECAL

Recovered Photons



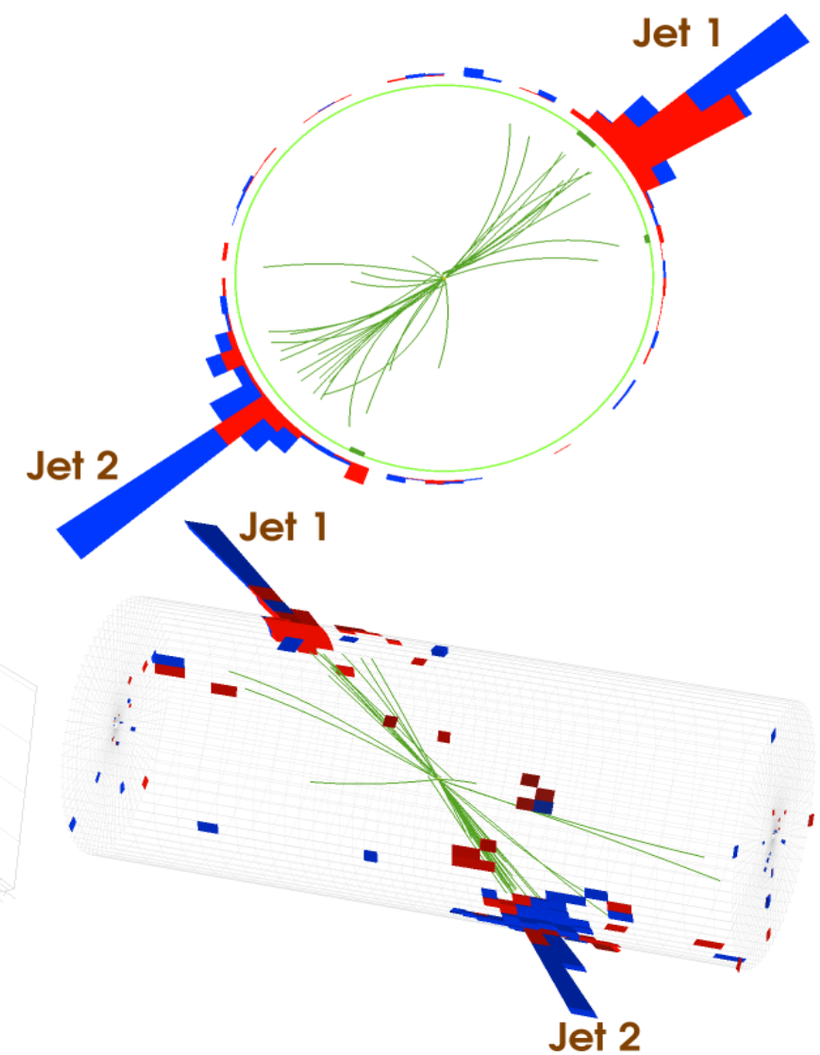
- Pi-0 mass plot with one leg reconstructed as a conversion
  - Tracker and ECAL are working well together – essential for efficiency in γ channels

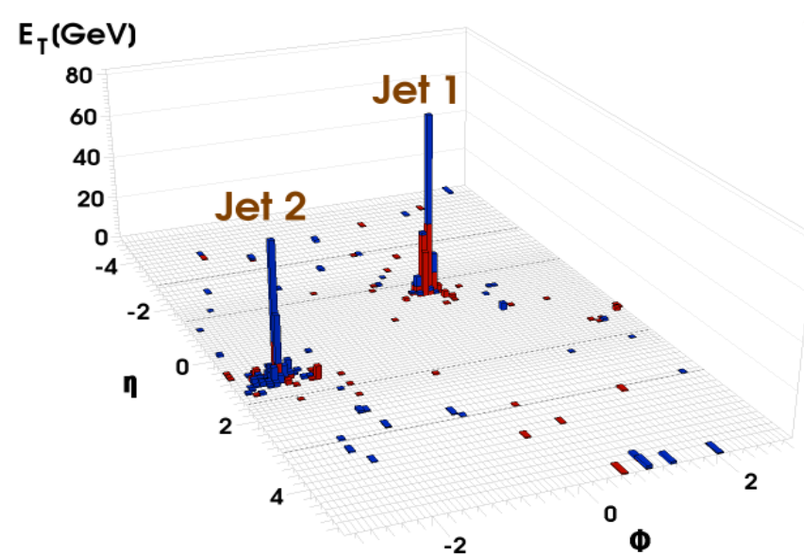
Jets



- Dijet spectrum approaching 1TeV
  - Sensitivity to strongly produced BSM particles / contact interactions, etc

CMS Experiment at LHC, CERN
Run 133450 Event 16358963
Lumi section: 285
Sat Apr 17 2010, 12:25:05 CEST





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

Jet Spectrum for Different Reco

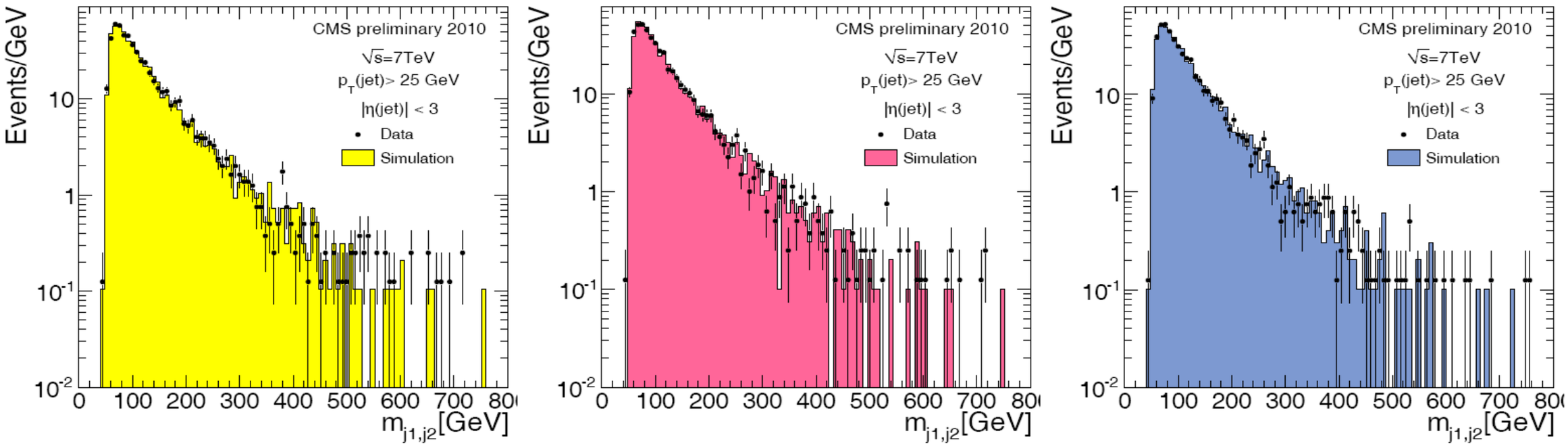
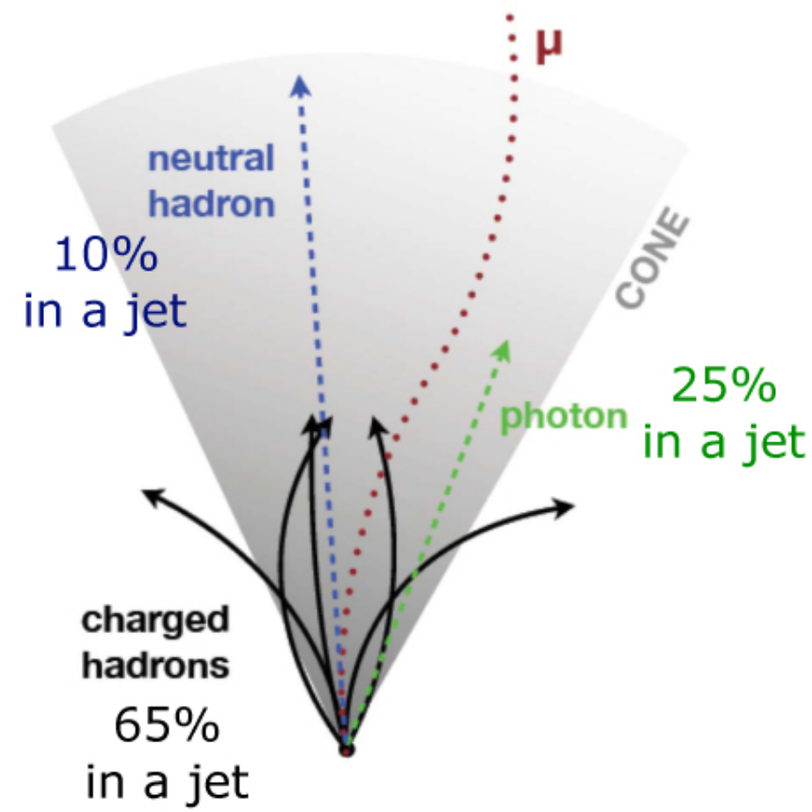
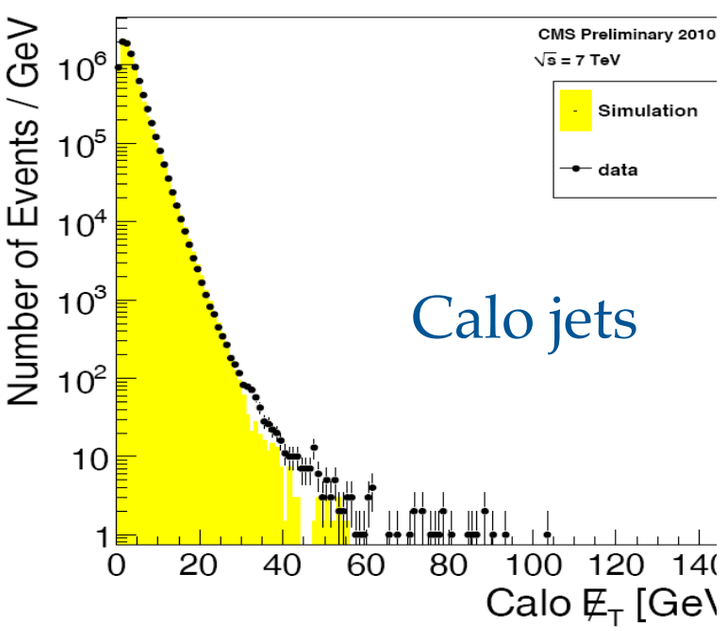


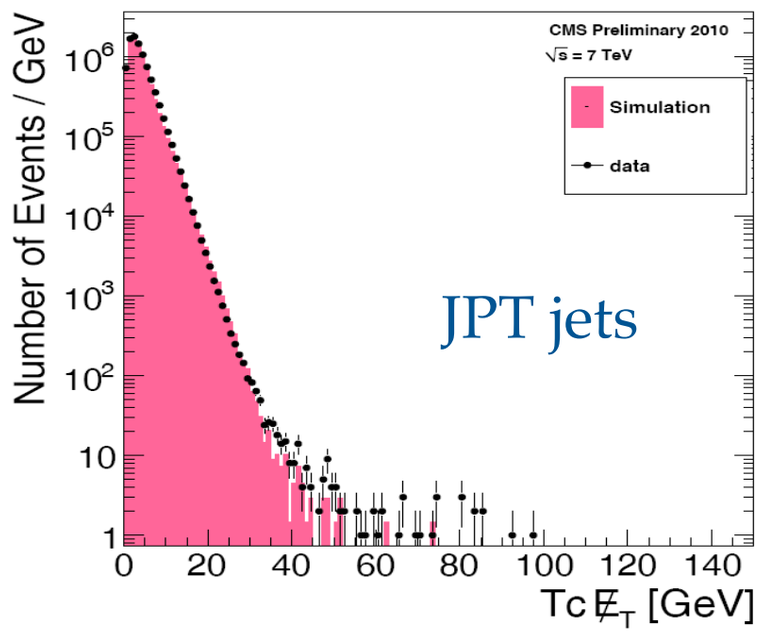
Figure: Data vs MC: Di jet mass $m_{j1,j2}$ for Cal
jets, PFjets.

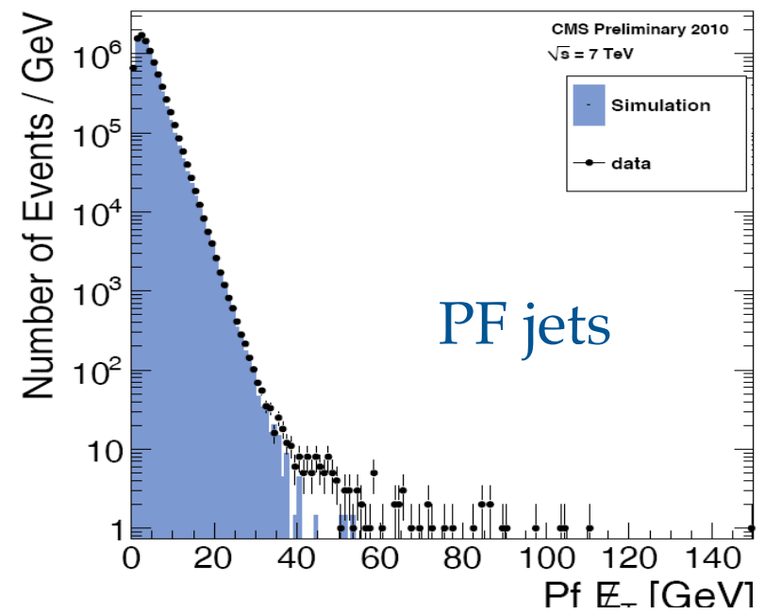
- Three jet reconstruction methods
  - Calo jets / 'Jet plus track' / Full particle flow
  - Particle flow takes advantage of full detector granularity & relative strengths
  - Already showing good consistency with MC & promising performance



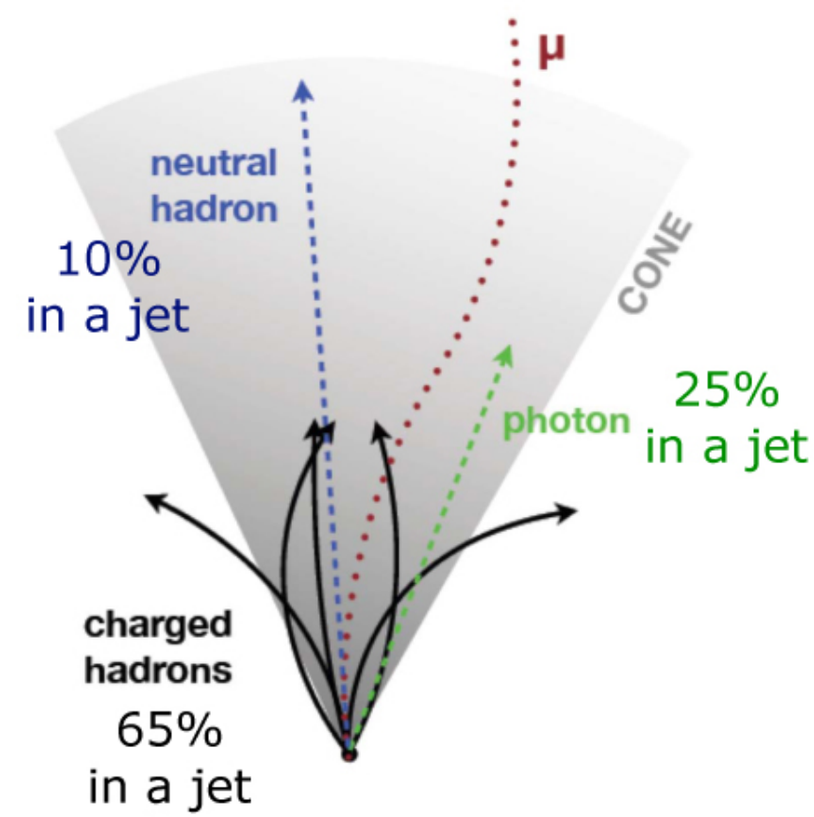
Missing Et



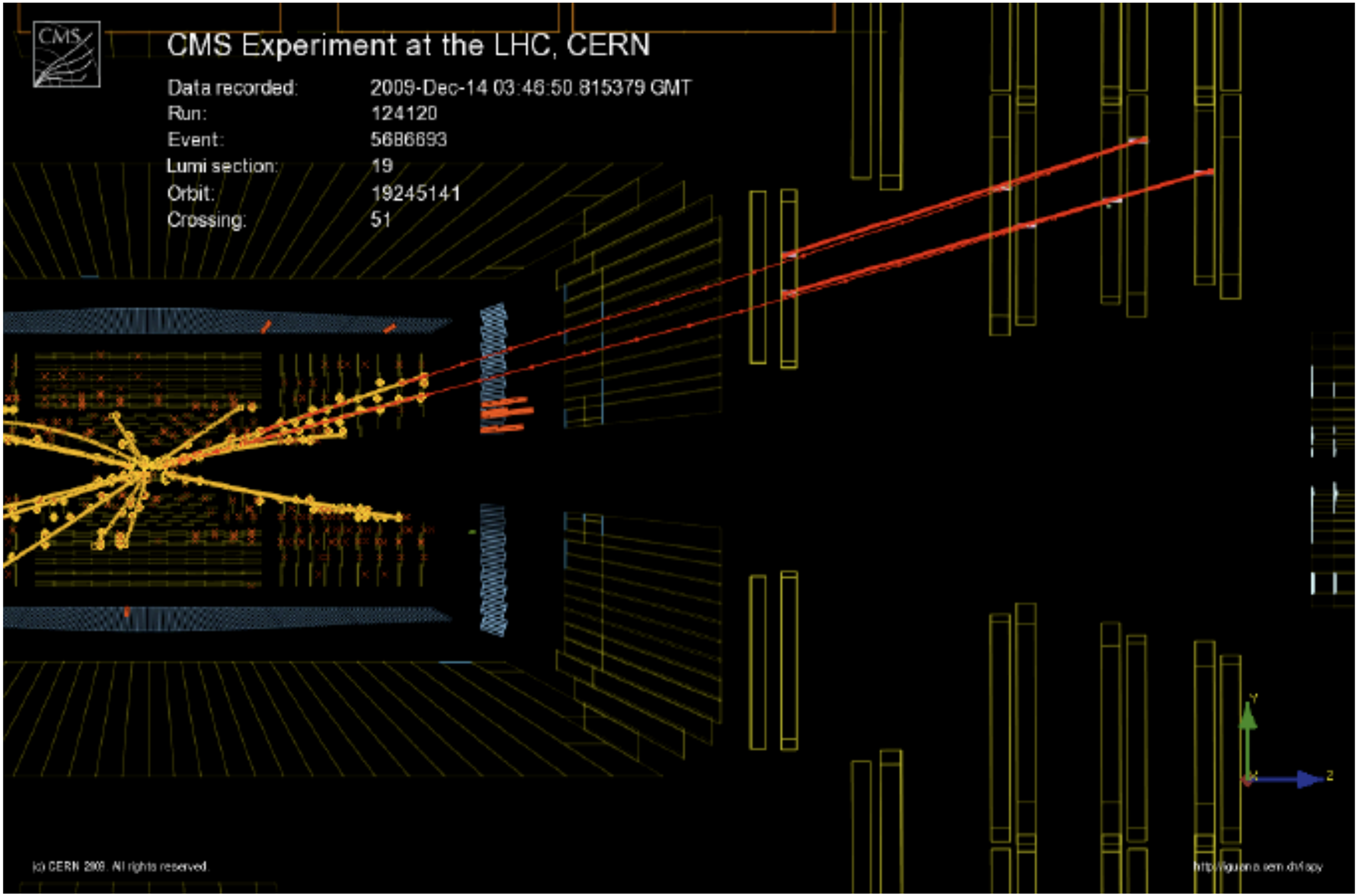




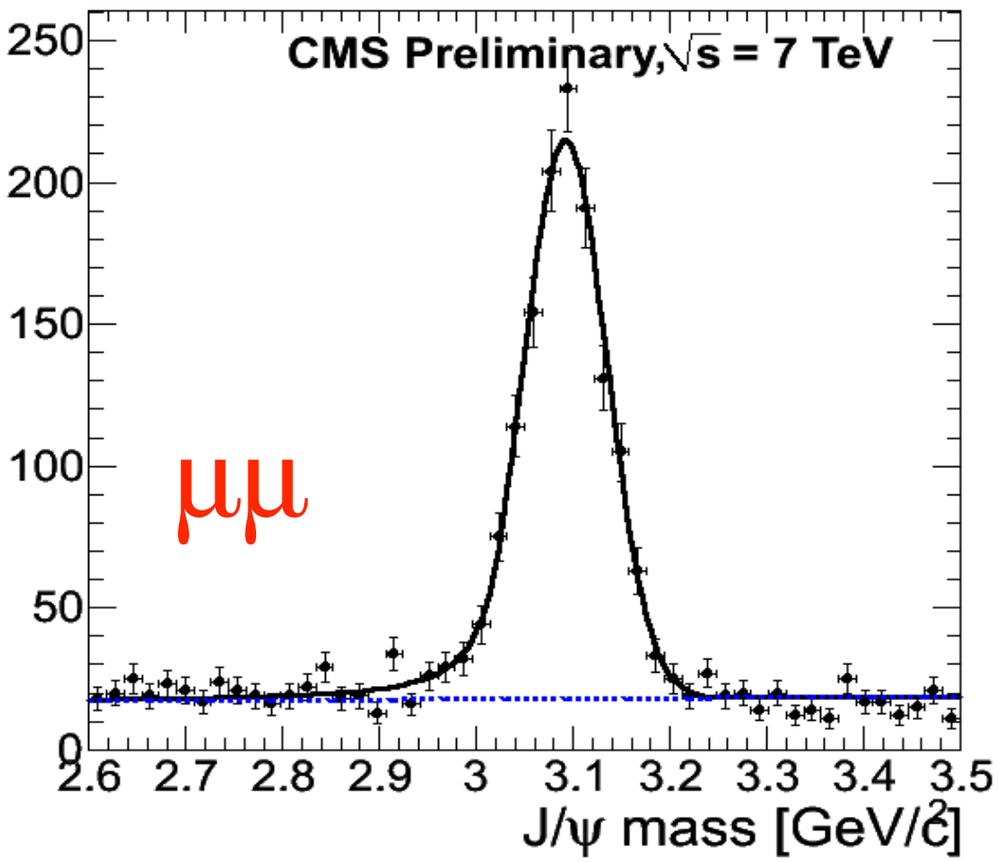
- This is a dijet sample
  - Since ~no true MET, can examine tails
- Good agreement with simulation
  - Five orders of magnitude range
  - Tails still under study – work in progress
  - MET measurement is crucial to many early searches; under intensive development

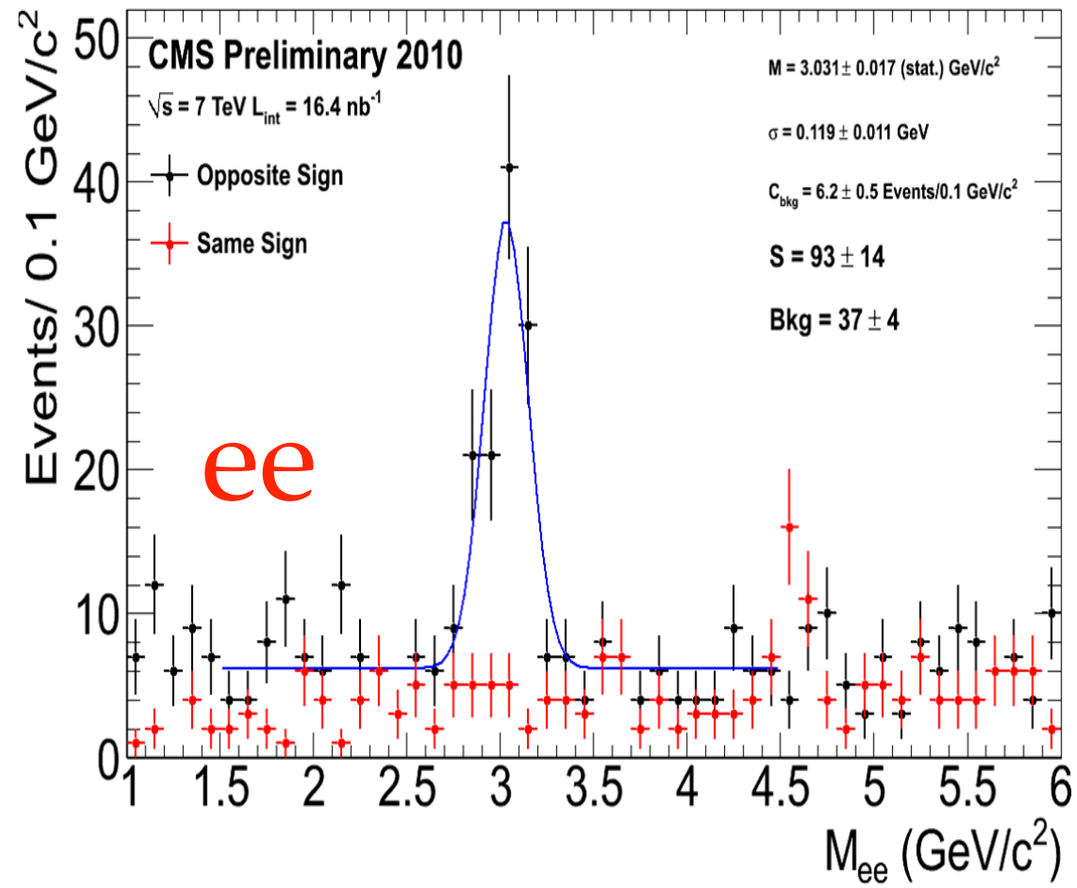


Muon Performance

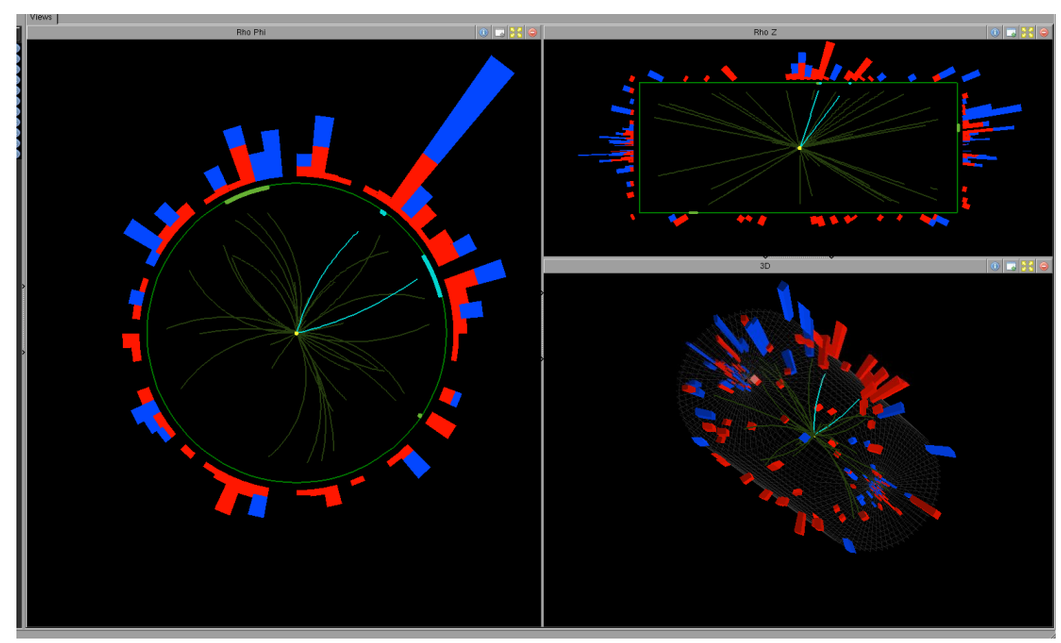


J/ψ Observation





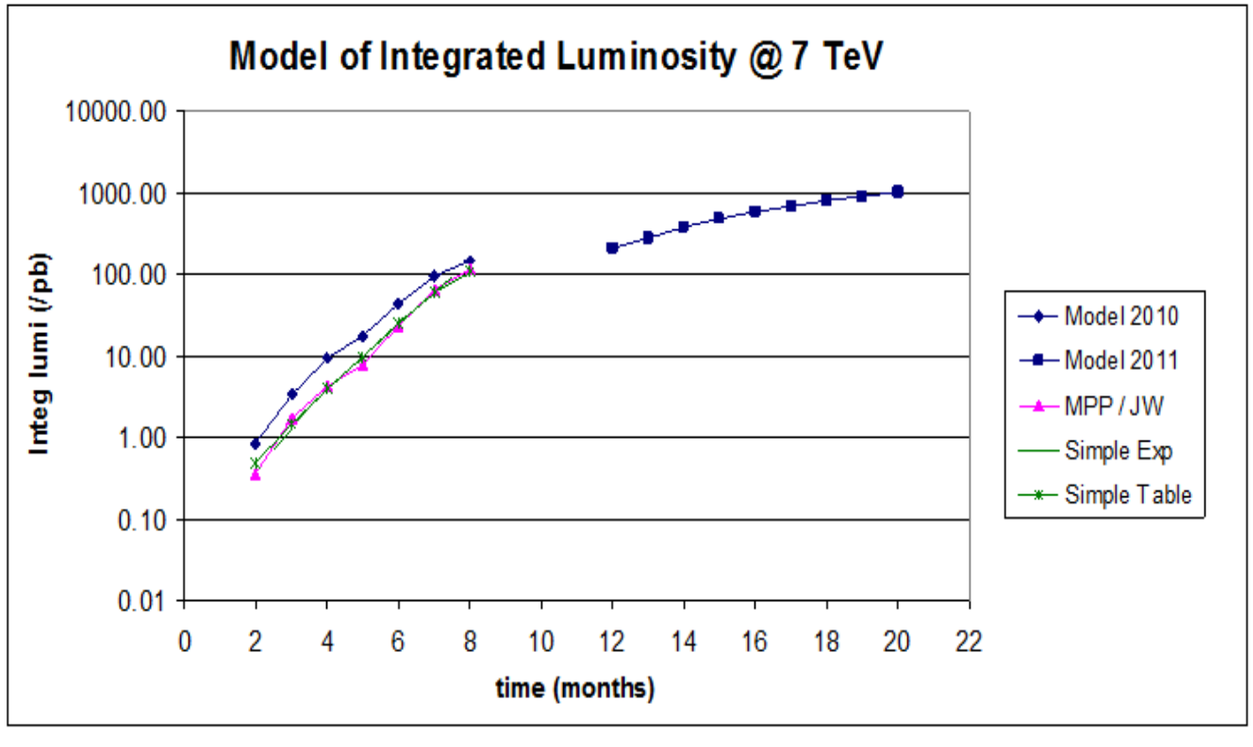
- 'Tag and probe' technique
  - Can be used to estimate lepton efficiencies (and fake rates)
  - Low mass resonances constrain muon momentum scale
  - Challenging analysis at low masses



CMS Physics Goals

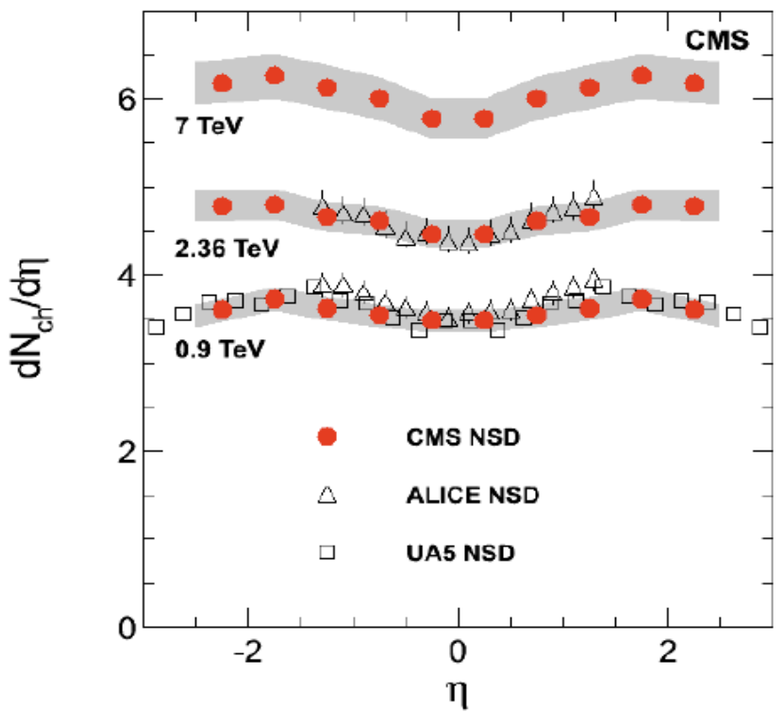
We are here ->

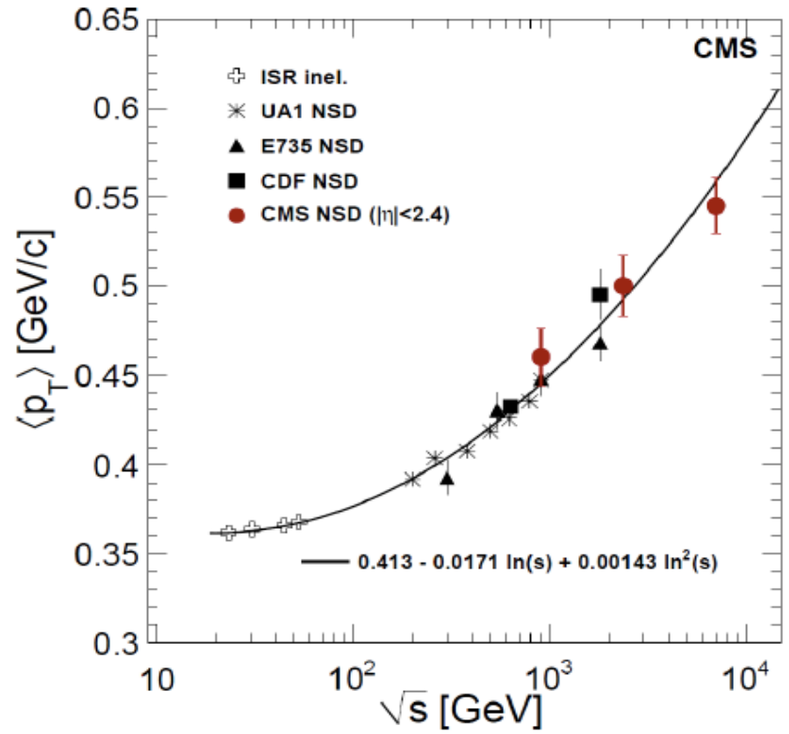
Integrated L	SM Object	SM Use	Search Strategy
mb^{-1} (1)	UE, MB	Tune MC	
ub^{-1} (10^3)	Jets, Heavy flavor	Align. dE/dx Calib, trigger valid, MET c, b tag leptons	
nb^{-1} (10^6)	W Z	Cross section, charge Mass scale, resolution	
1 pb^{-1} (10^9)	Top pairs	Leptons + J + true MET	Black holes
10 pb^{-1}			Dijet M > 2 TeV HSCP, leptoquarks
100 pb^{-1} (2010)			M > TeV W' , Z' New range for SUSY
1000 pb^{-1} (2011)			SUSY – TeV mass scale Higgs @ 95% CL, (140,190) GeV

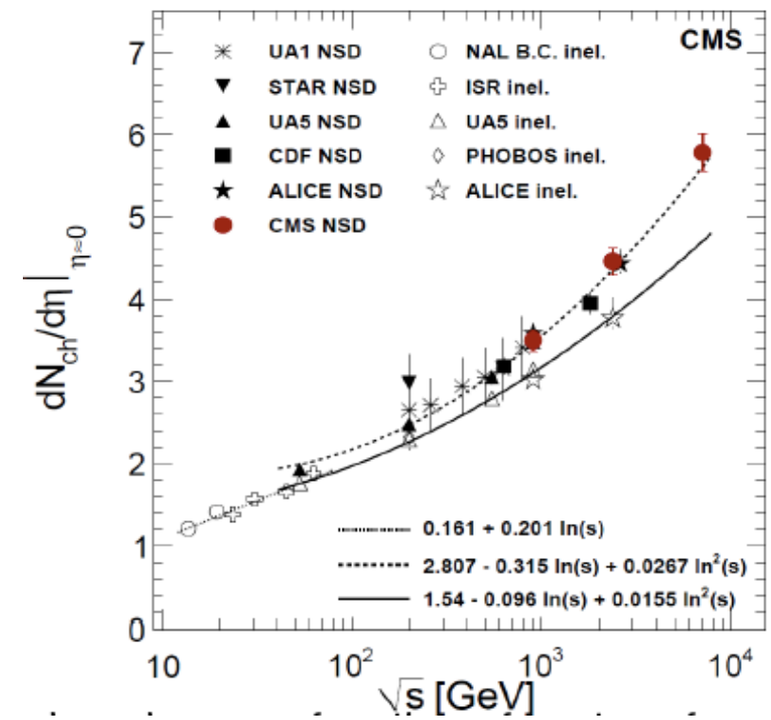


- At ~20nb^{-1}, expect:
  - 100 W -> μ / e
  - 10 Z -> μμ / ee
  - 1 ttbar ?

QCD: Charged Particle Distributions







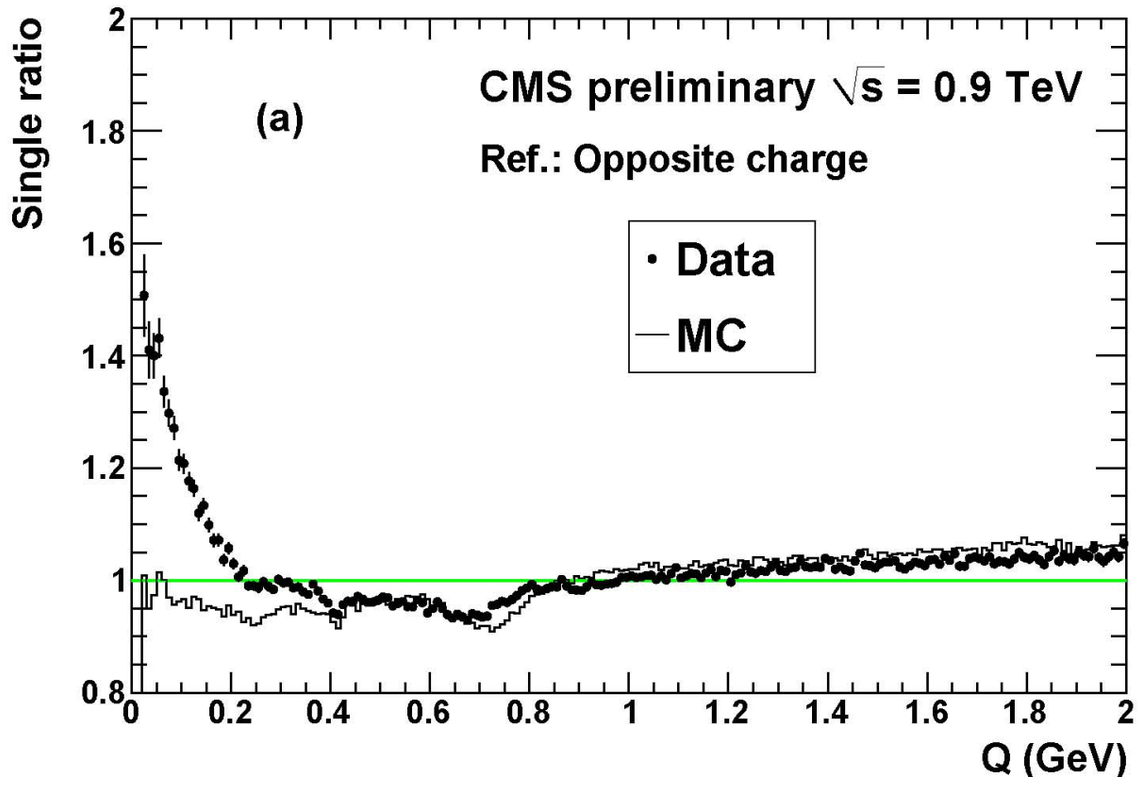
- Two publications on charged particle distribution in minbias
  - 900GeV paper published last year
  - 7TeV paper accepted for PRL start of June
  - Both analyses use three methods of estimation for cross-checking
- Tuning of MC generators is under way
  - Rise of particle density at 7TeV is steeper than predicted by generators

QCD: Bose-Einstein Correlations

- Measure correlation between identical bosons

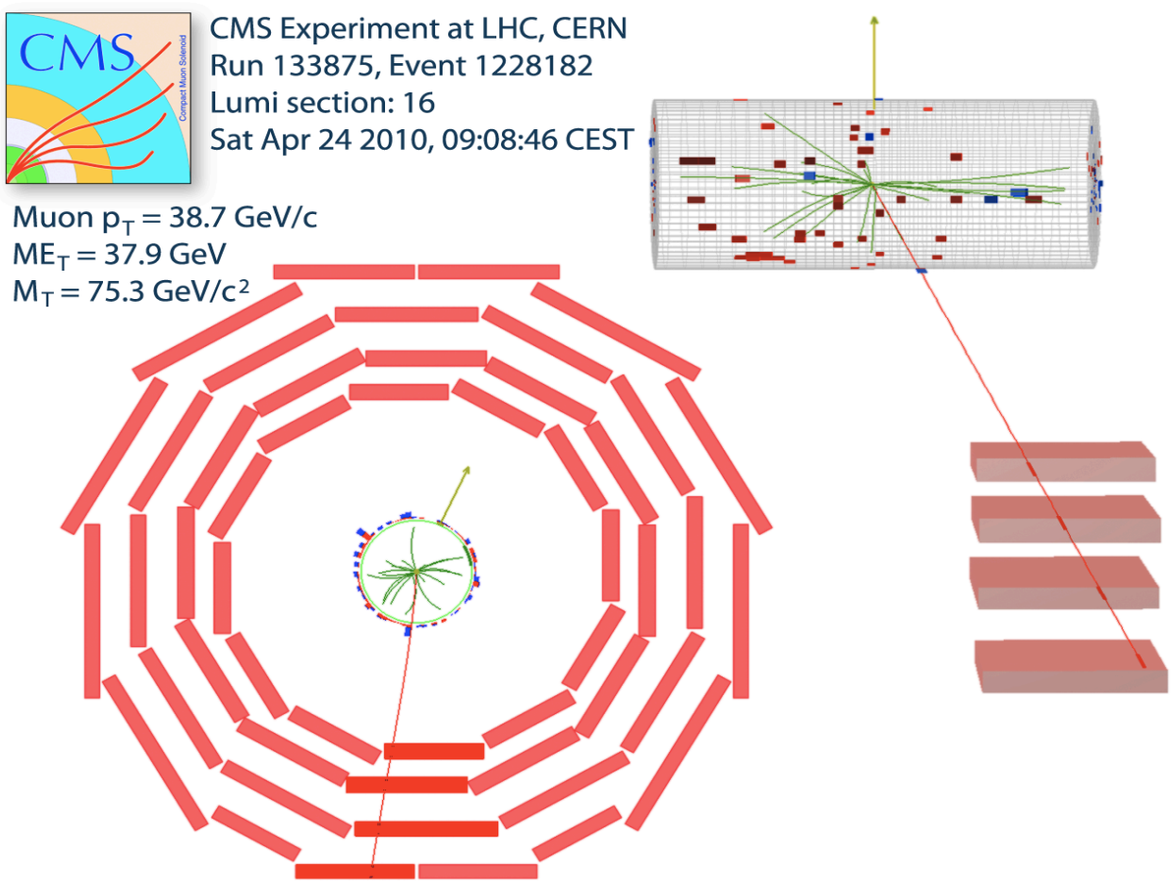
$$R = \frac{P(p1,p2)}{P(p1)P(p2)} = \frac{dN/dQ}{dN/dQ_{ref}} \qquad Q = \sqrt{m_{\pi\pi}^{\ 2} - 4m_{\pi}^{\ 2}}$$

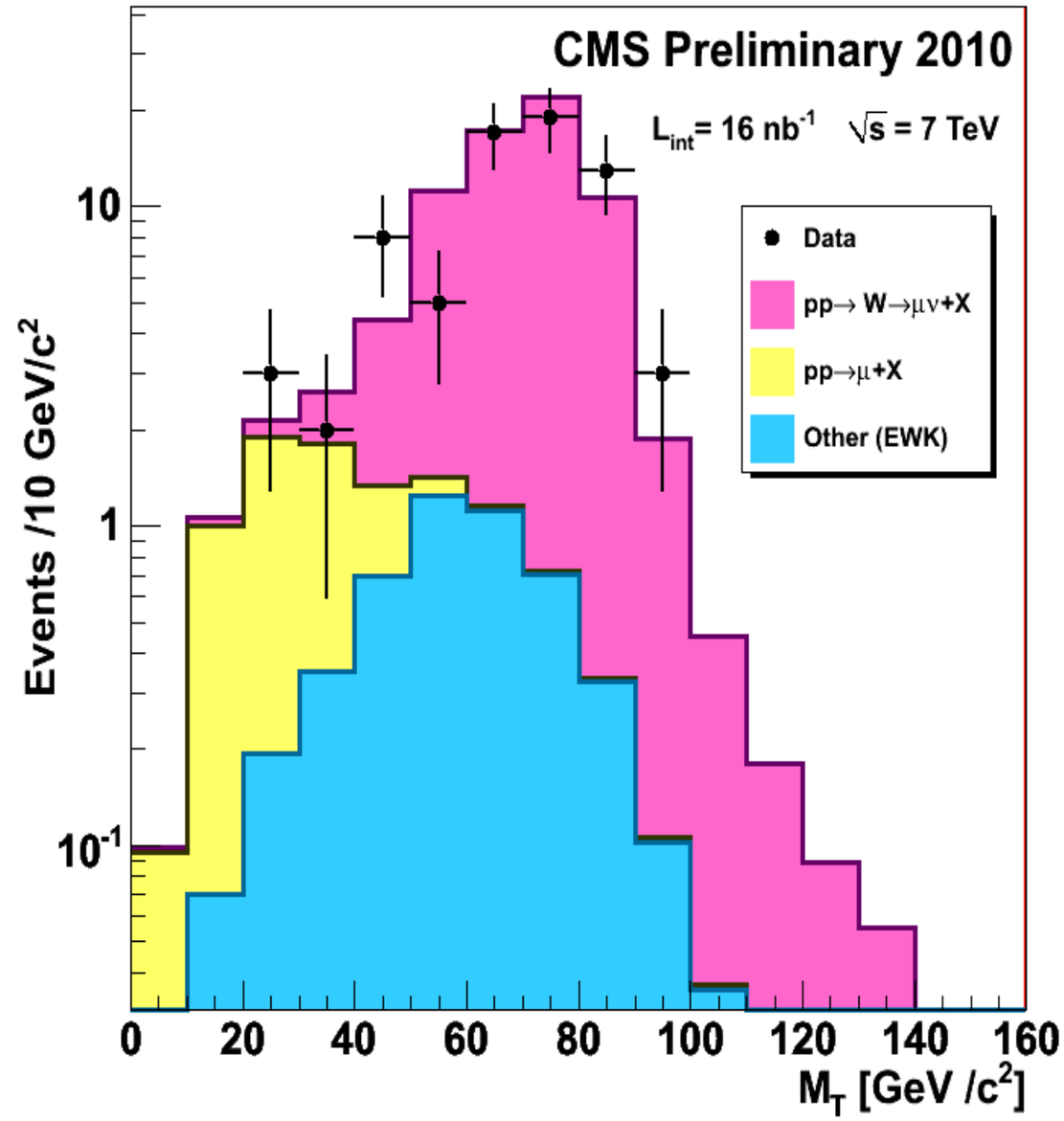
- Use several reference samples for normalisation
  - Dilute the correlation via opposite charge pairs; rotated events; mixed events; opposite hemisphere pairs
- Results
  - Clear evidence of BEC observed
  - May obtain the effective size of the emission source:
  - **$r = 1.59 \pm 0.05_{stat} \pm 0.19_{sys}$ (900 GeV)**
  - **$r = 1.99 \pm 0.18_{stat} \pm 0.24_{sys}$ (2.36 TeV)**
    - These results use several different reference samples combined
  - Available as arXiv:1005.3294v1



W→μν

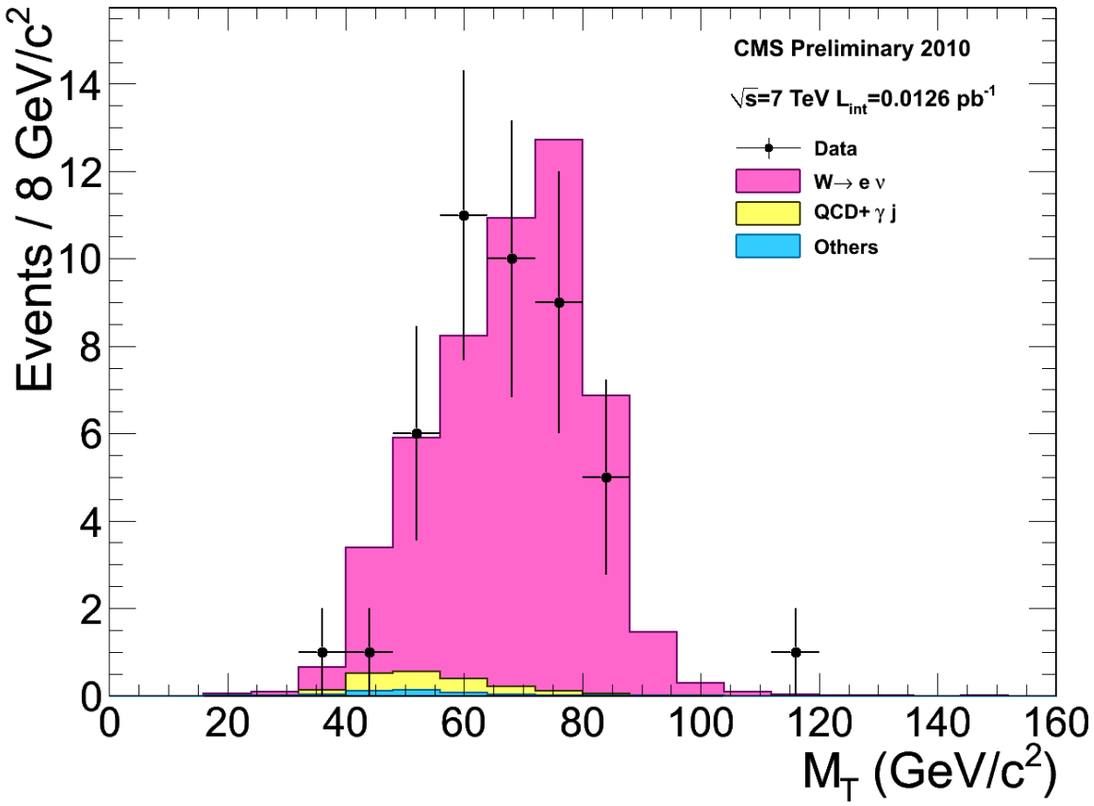
Event selection: *Muon id cuts (global and tracker muons), Isolation, pT cut and MET*
Monte Carlo : *Cross section normalized to 16 nb^{-1} integrated luminosity*

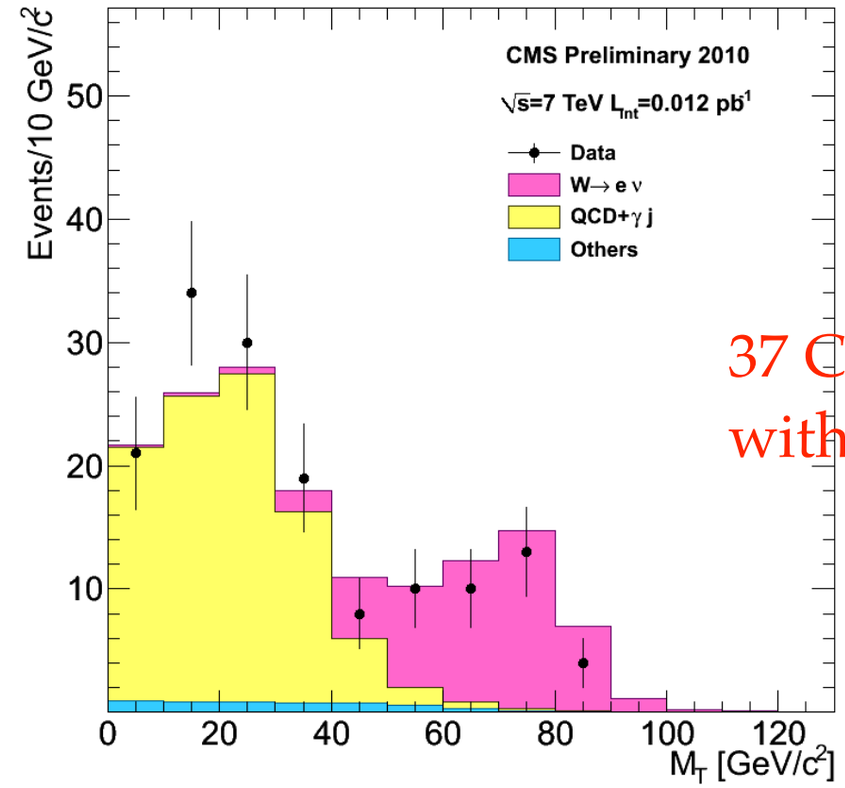




57 Candidates with M_t > 50GeV

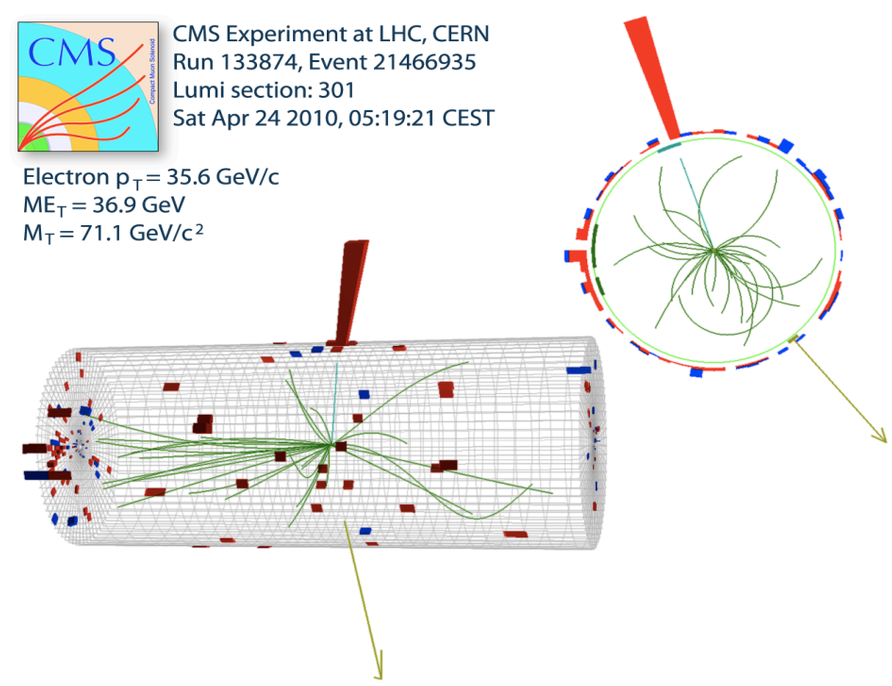
W→eν





37 Candidates
with $M_t > 50$GeV

40 Candidates
with $M_t > 50$GeV

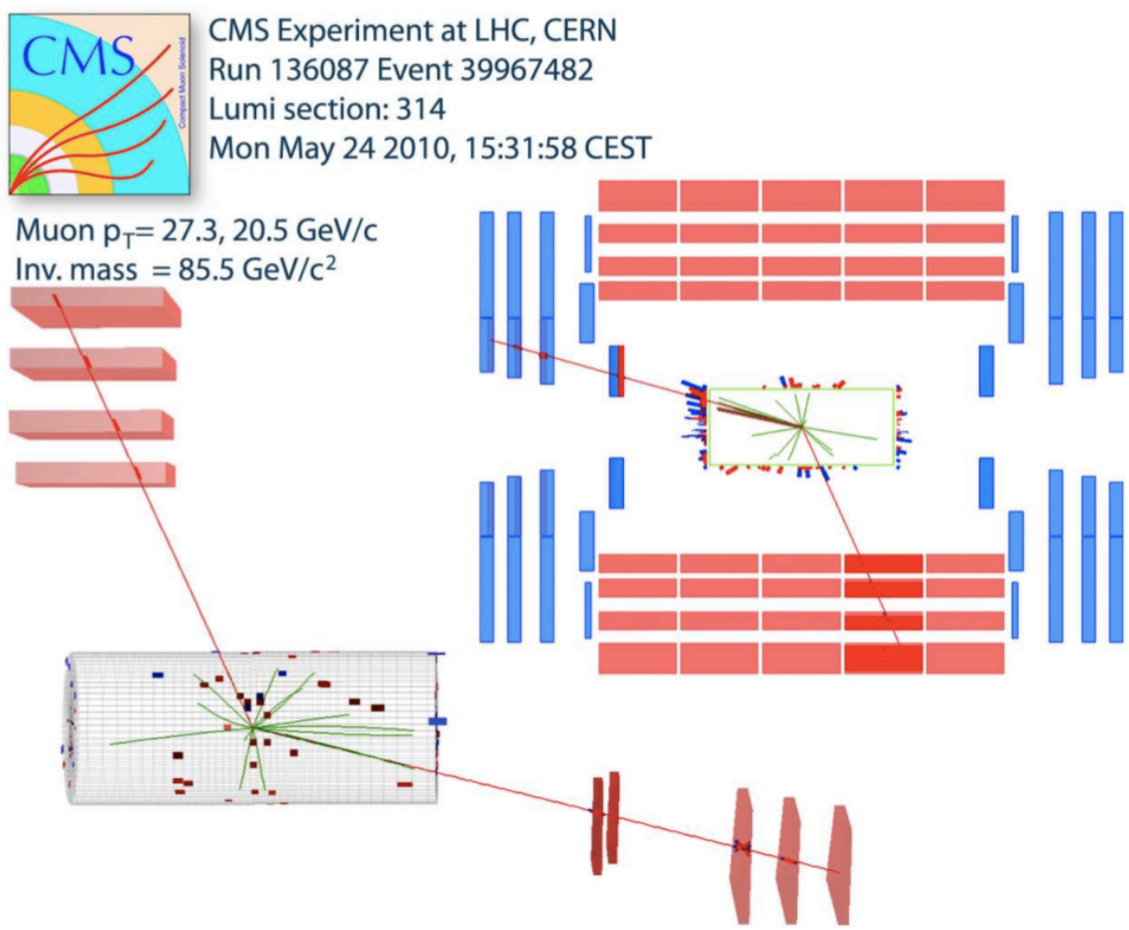


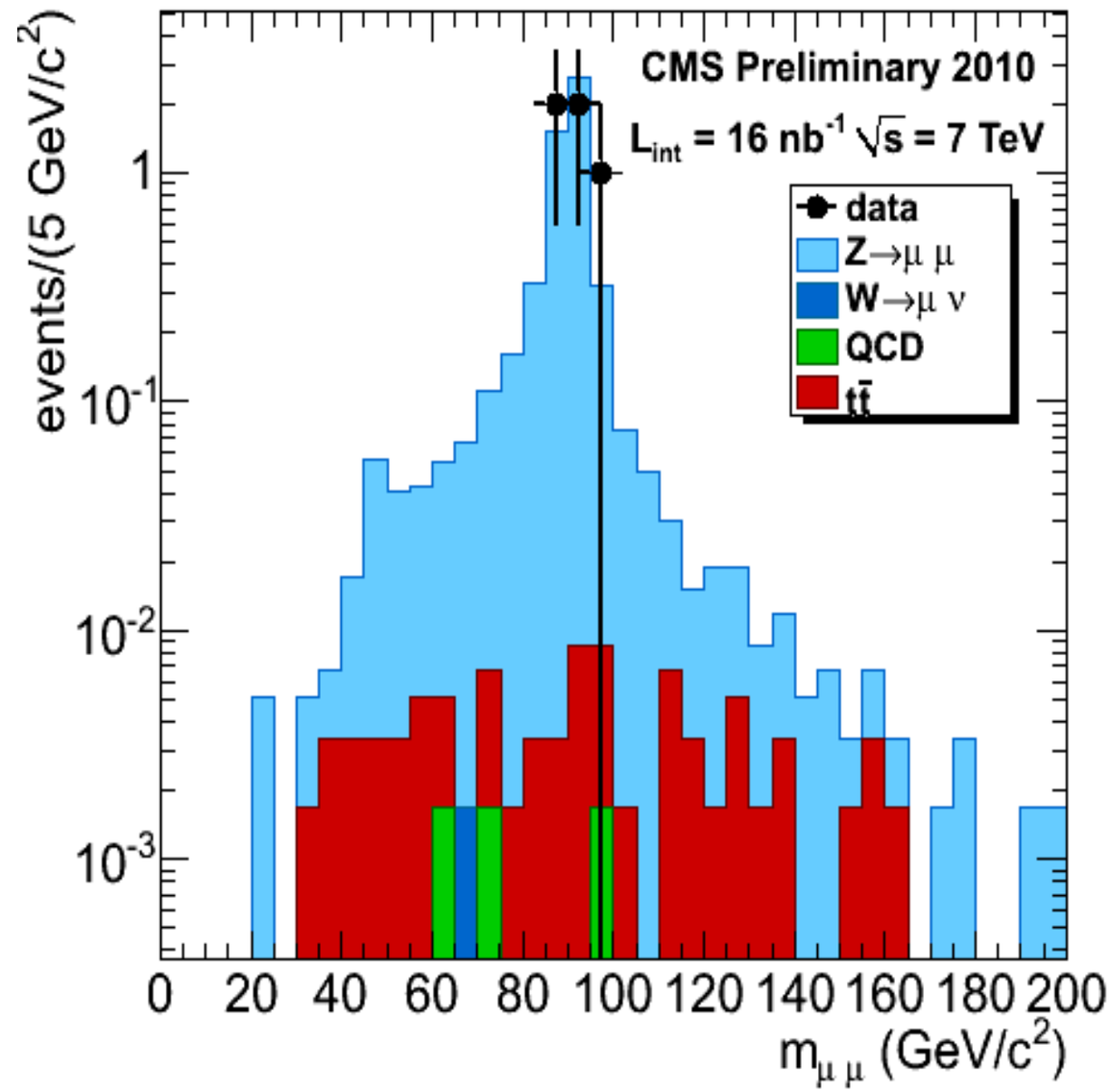
Two event selections :

- *basic electron id and no MET cut*
- *more complex electron id, cuts on ET, MET and ΣET*
- *Cross section normalized to 12 nb^{-1}*

Z→μμ

Event selection : *muon id selection (global and tracker muons) ; loose Isolation, pT cut.*
Monte Carlo : *cross section normalized to 16 nb^{-1} integrated luminosity*

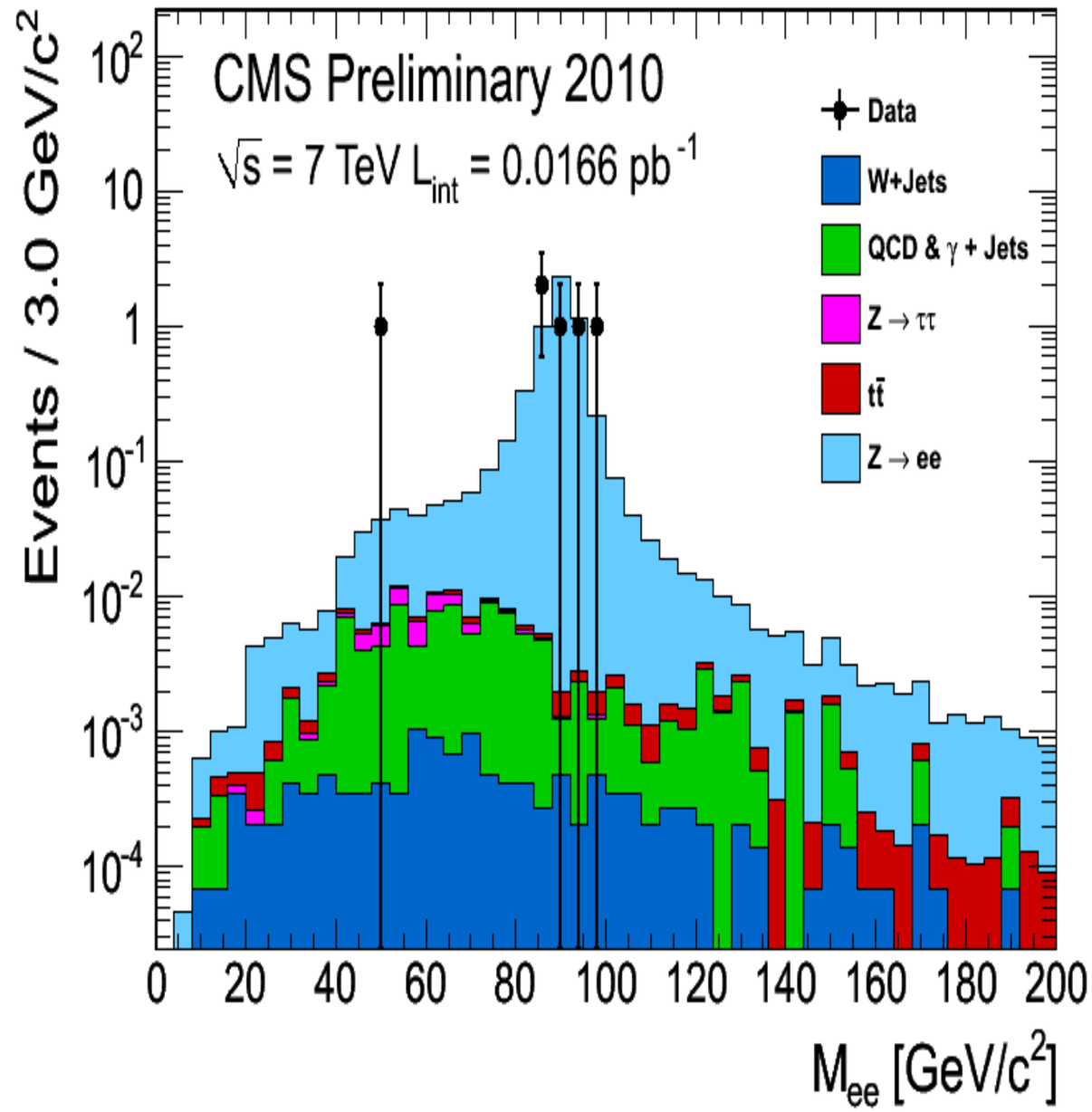




5 Candidates

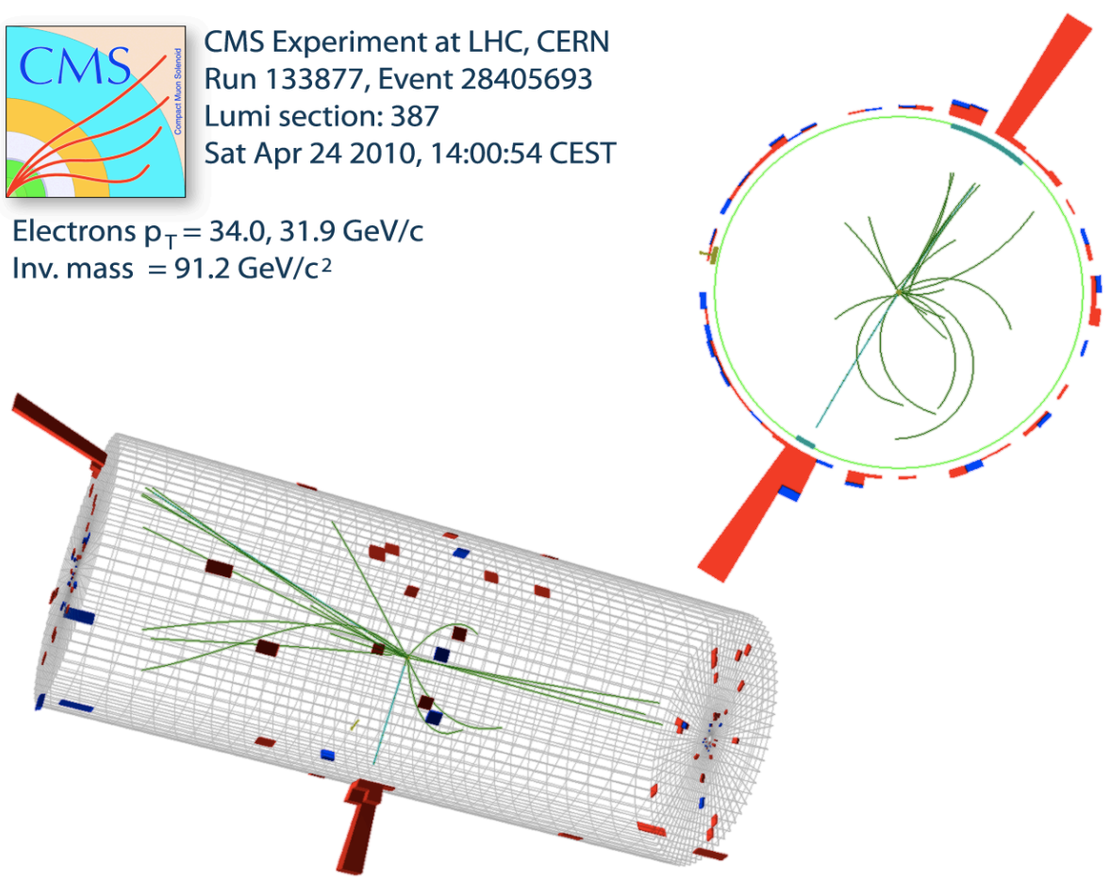
Z→ee

Event selection: *both electrons with a SuperCluster with Et > 20 GeV*
Monte Carlo : *cross section normalized to 17 nb^{-1} integrated luminosity*



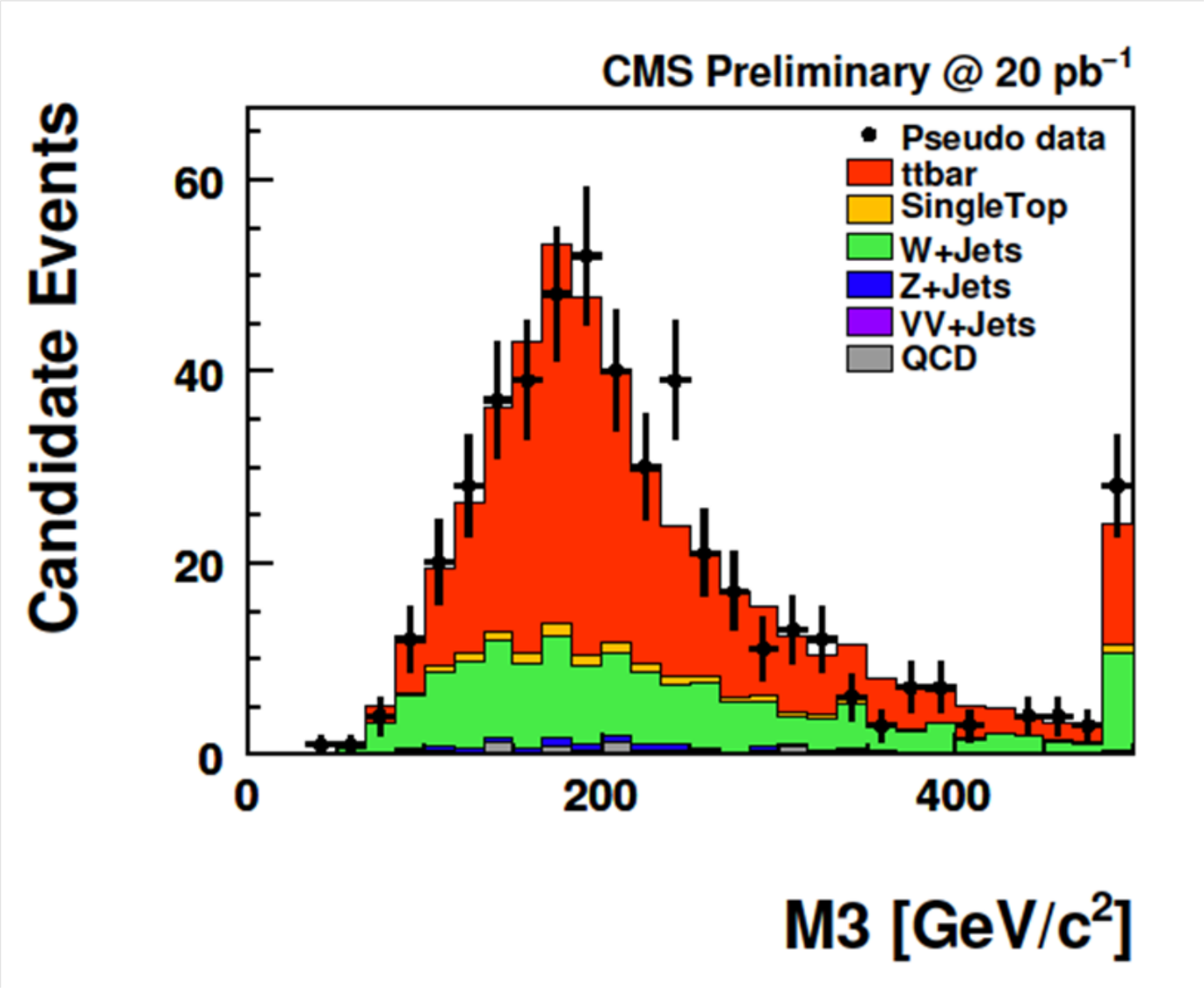
CMS Experiment at LHC, CERN
Run 133877, Event 28405693
Lumi section: 387
Sat Apr 24 2010, 14:00:54 CEST

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



5 Candidates

Prospects: 10pb^{-1}

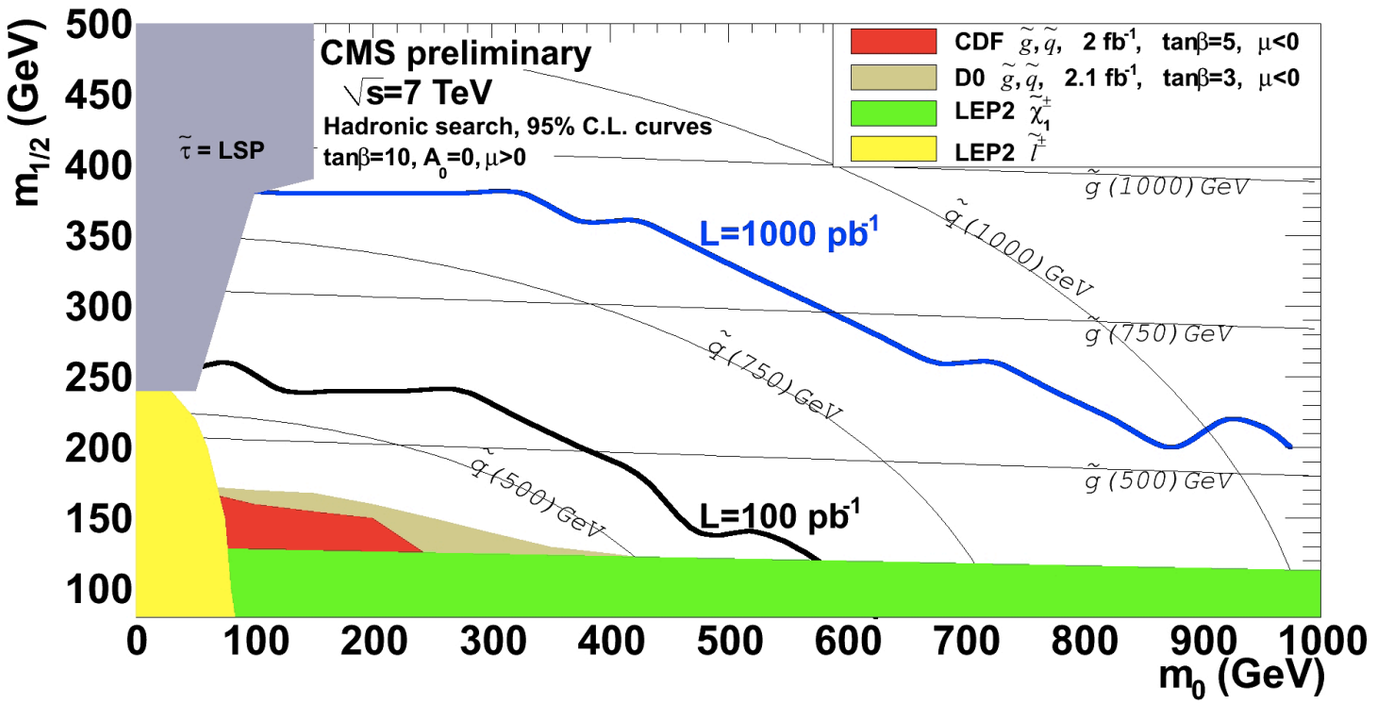


Monte Carlo

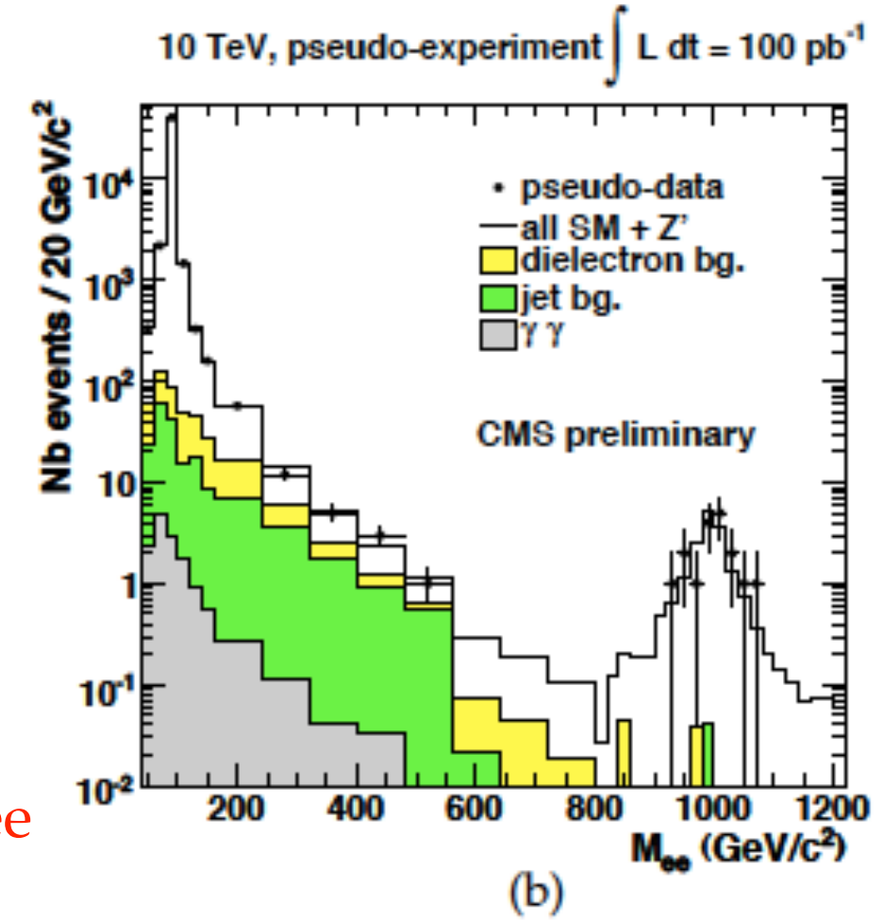
M3 = highest invariant mass combination of three jets from the event

- Top physics will soon become accessible
  - Autumn 2010?
  - Completes 'rediscovery' of the standard model
  - Commission top-tagging procedures at CMS

Prospects for 100pb^{-1}

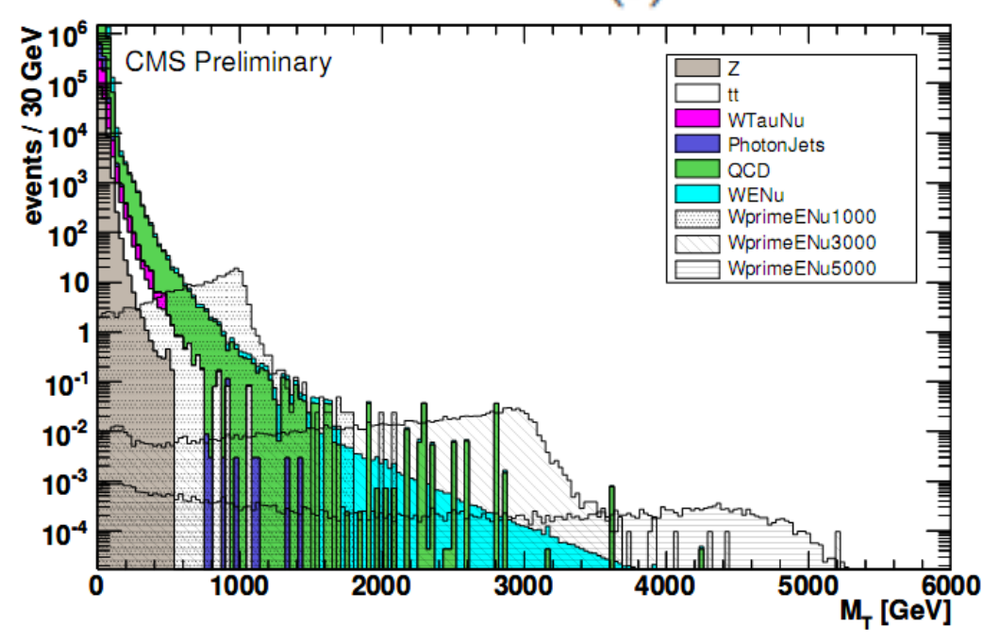


All-hadronic SUSY search reach



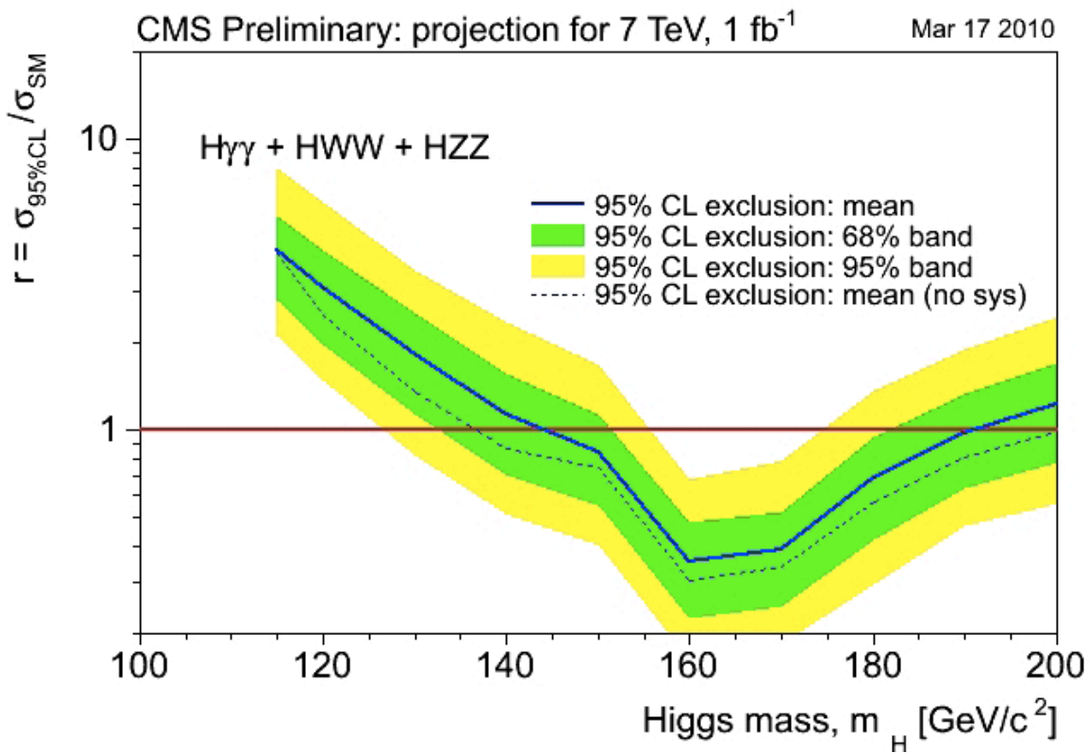
Z′ (1TeV) -> ee

- New physics searches begin in earnest at this stage
  - End of 2010?
- SUSY, Z′, W′

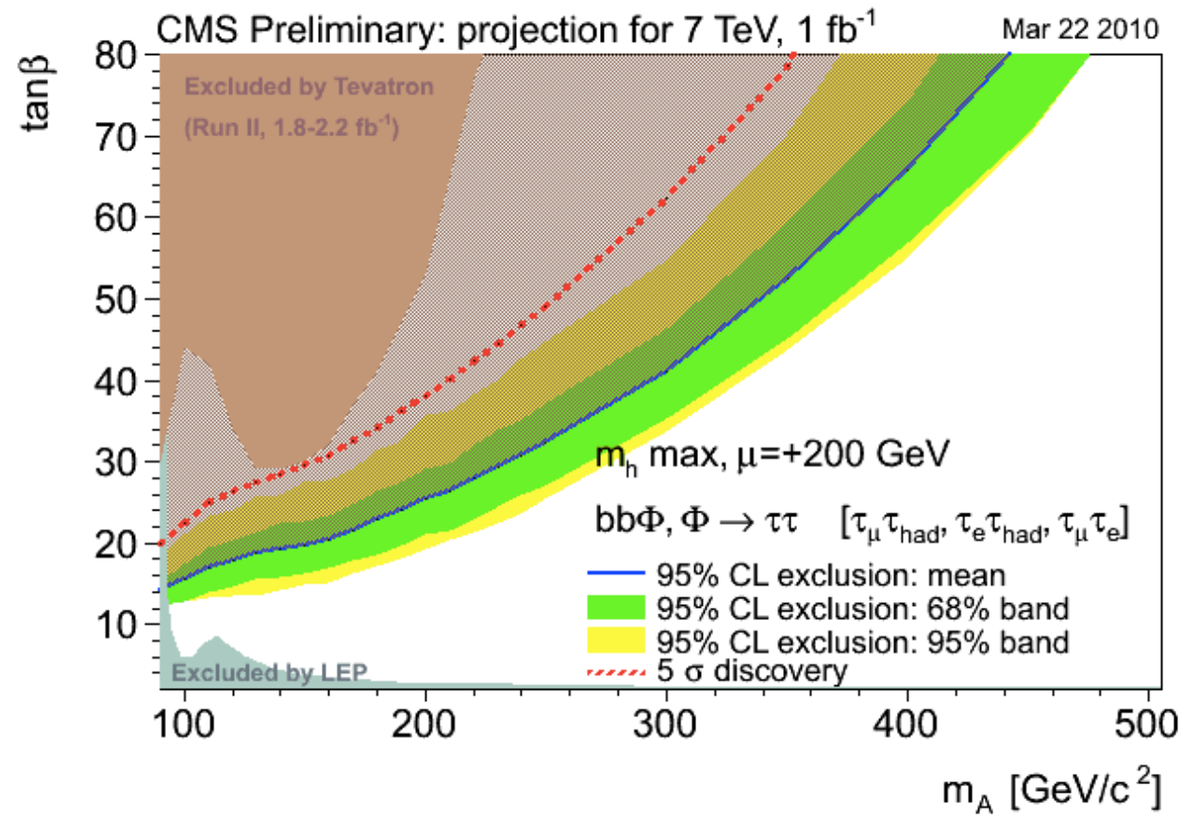


W′ (1,3,5TeV) -> eν

Prospects for 1fb^{-1}



SM Higgs exclusion, 1fb^{-1}



SUSY Higgs exclusion, 1fb^{-1}

- Completion of the standard model (or alternative)
  - Current LHC planning has 1fb^{-1} reached by December 2011
  - It will be an interesting 18 months ahead

Summary

- CMS is operational for physics
  - Commissioning phases with cosmics and beam were successful
  - All components performing incredibly well, and with high efficiency
  - Turnaround of commissioning and physics analyses is extremely rapid
- Current status
  - Taking data at $\sqrt{s} = 7$TeV with exponentially increasing luminosity
  - Papers already published on first measurements, more to come soon
  - First W and Z candidates have been observed
- Plans for 2010 – 11
  - Clear prospects for exciting physics very soon
  - Many new results will be announced this summer
  - 'Rediscovery' of the standard model in 2010
  - Possibility of new physics in 2011
- Stay tuned: things are moving fast!