Commissioning of CMS and early SM Measurements with Jets, Photons and Missing-E_T at the LHC

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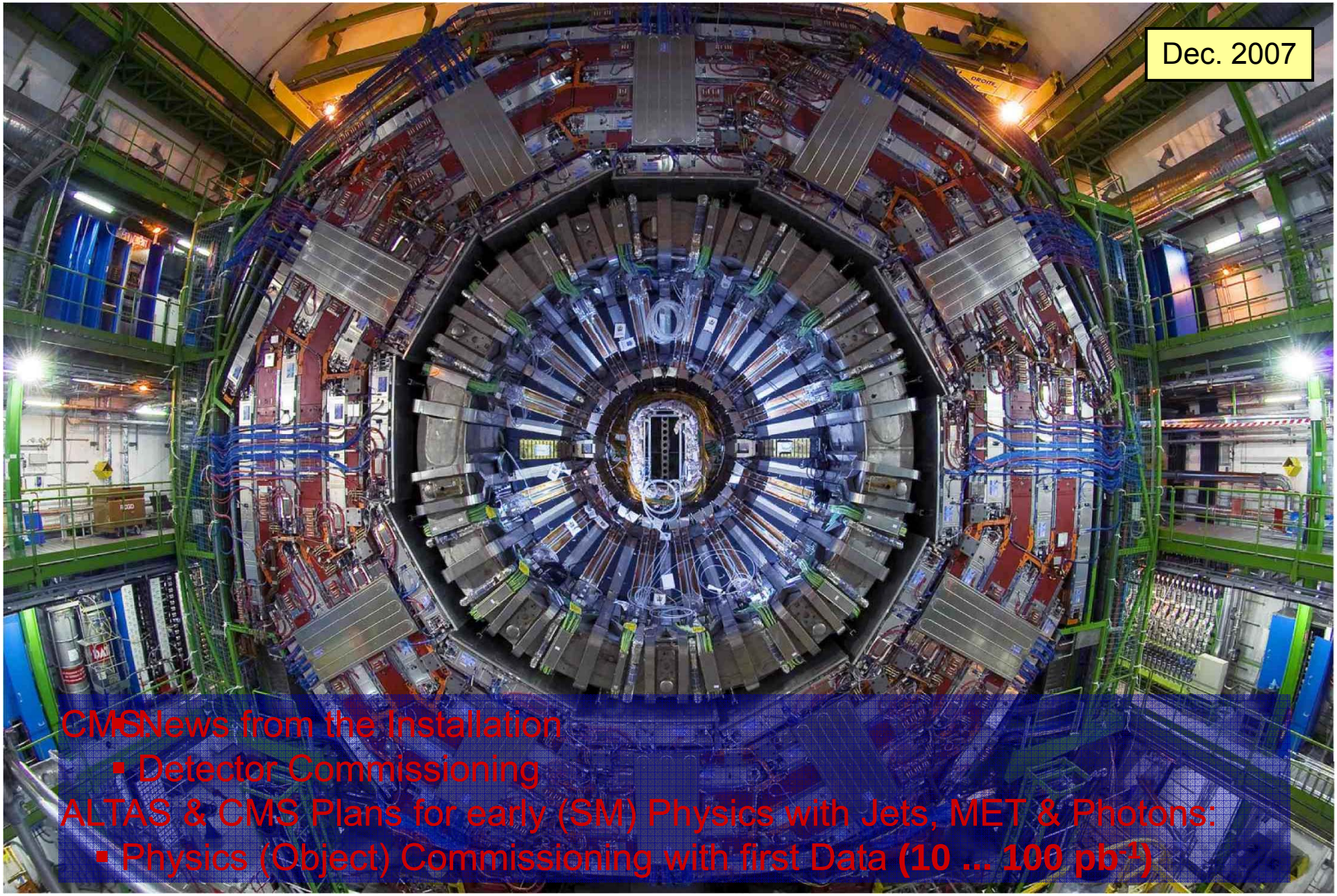
for ATLAS & CMS

Rencontres de Moriond EW 2008

March 1-8, 2008, La Thuile, Italy

Outline

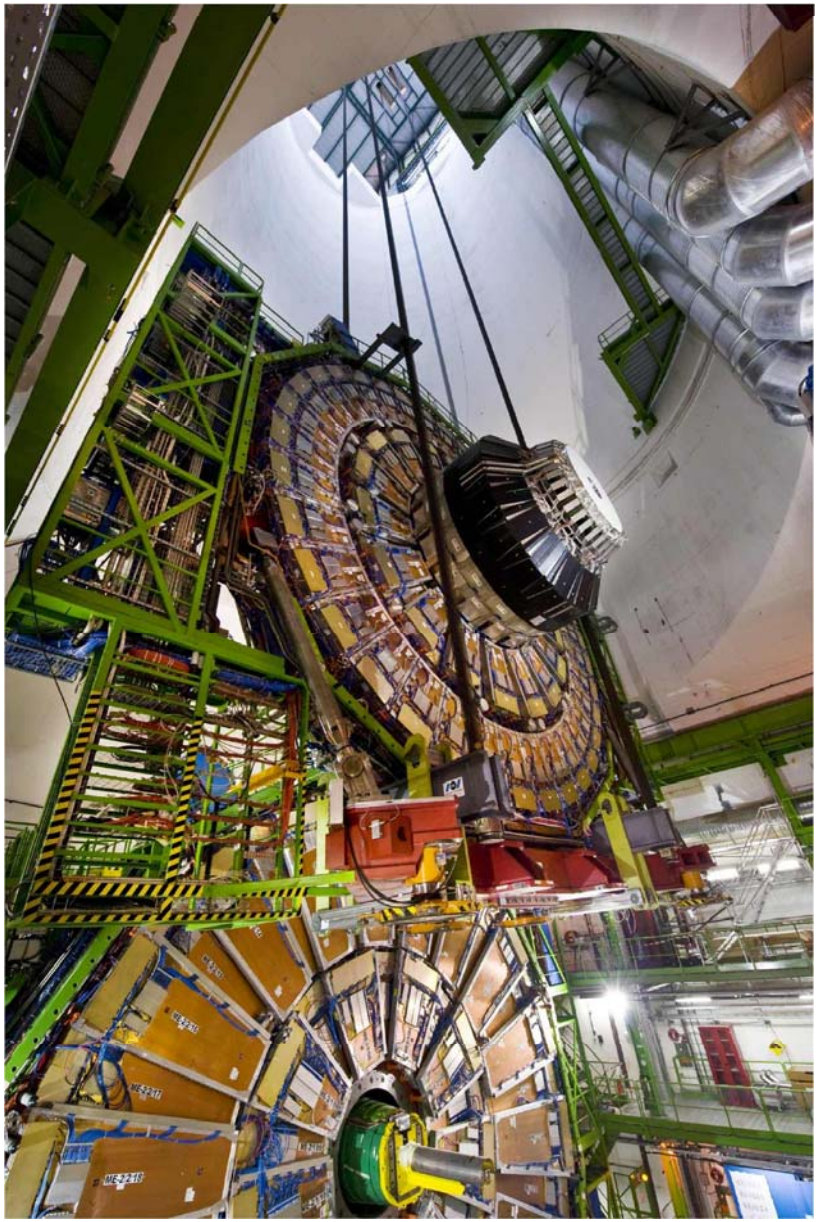


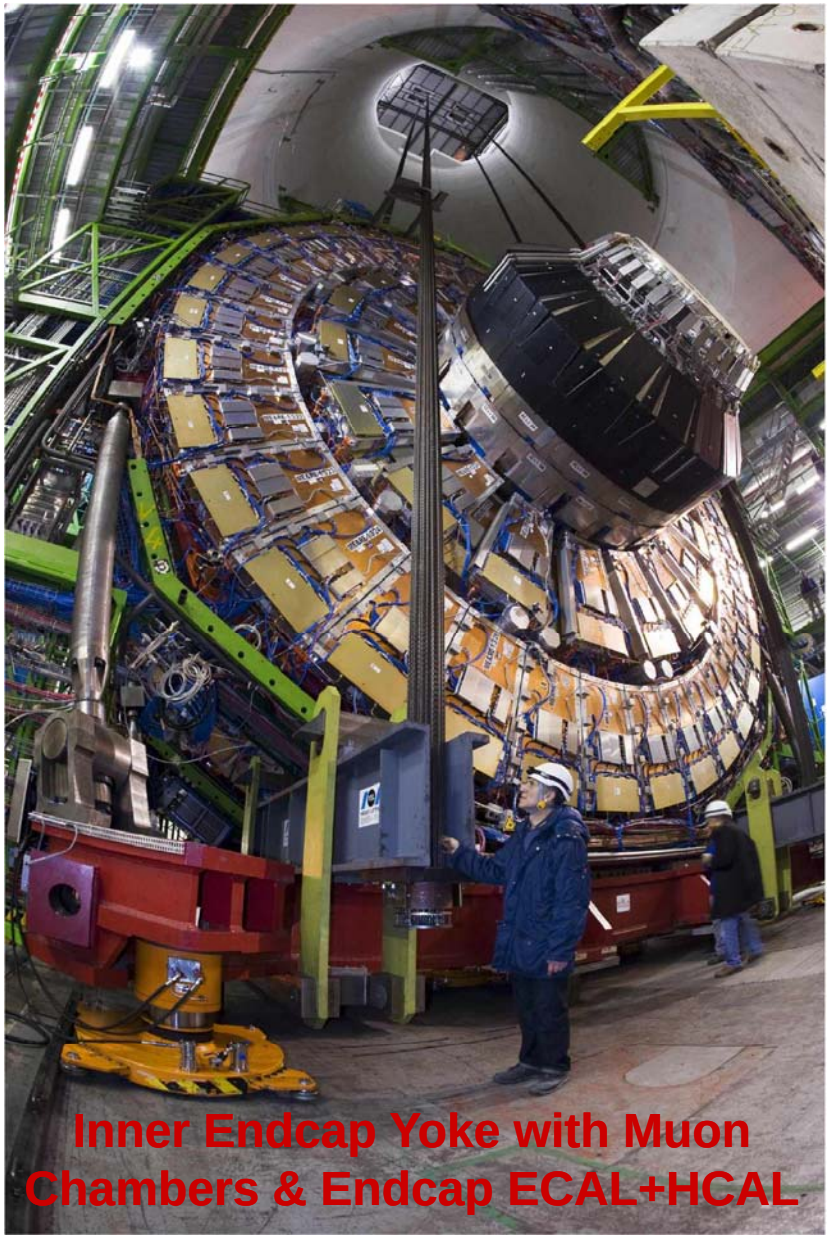
CMS News from the Installation
- Detector Commissioning

ALTAS & CMS Plans for early (SM) Physics with Jets, MET & Photons:
- Physics (Object) Commissioning with first Data **(10 ... 100 pb^{-1})**

Touch-down for the last heavy Structure of CMS

January 2008



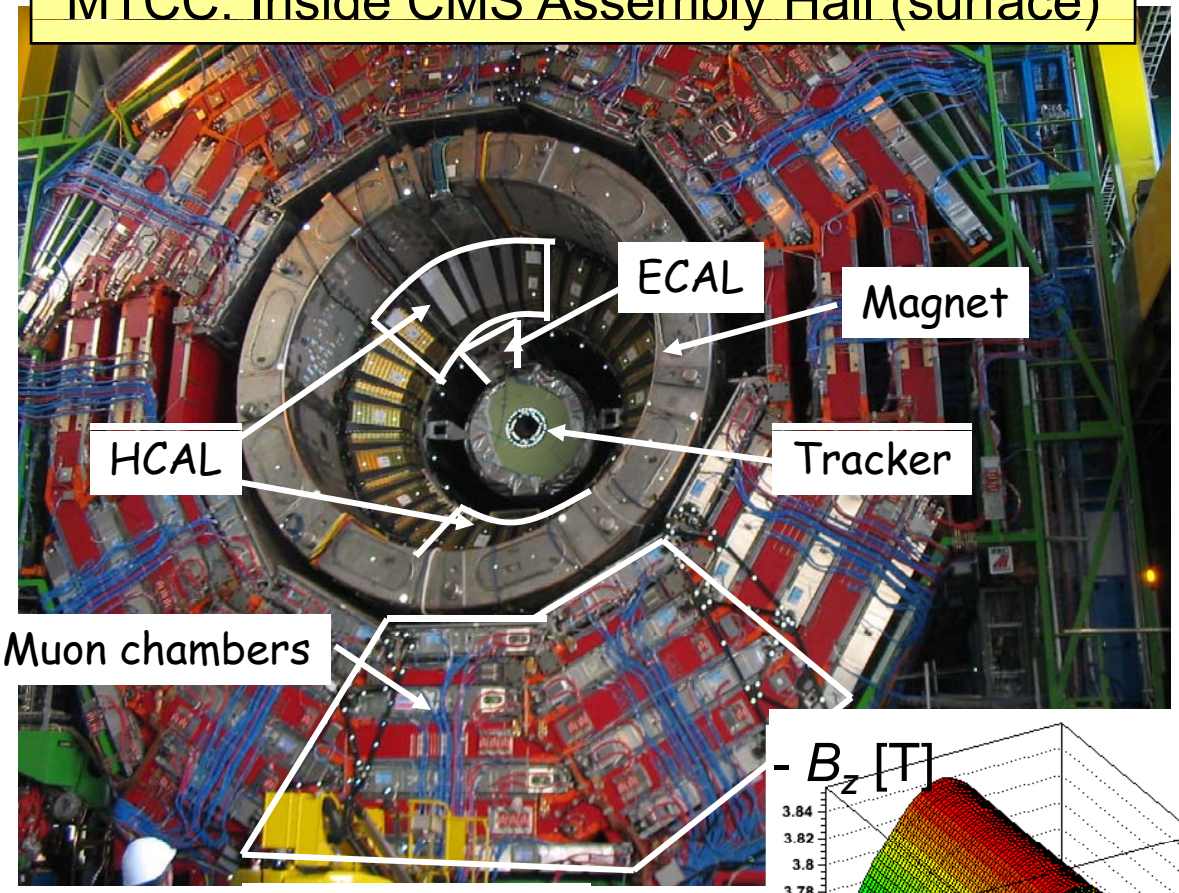


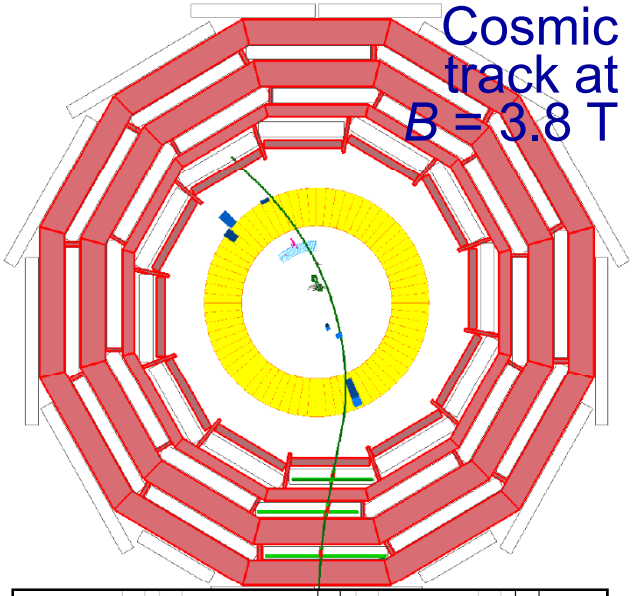
Inner Endcap Yoke with Muon Chambers & Endcap ECAL+HCAL

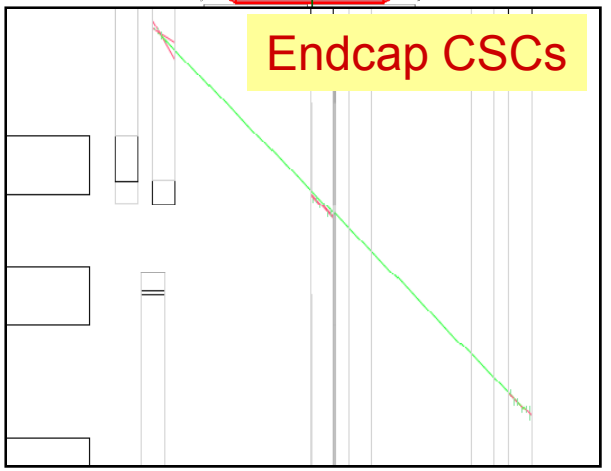
2006: Magnet Test & "Cosmic Challenge"

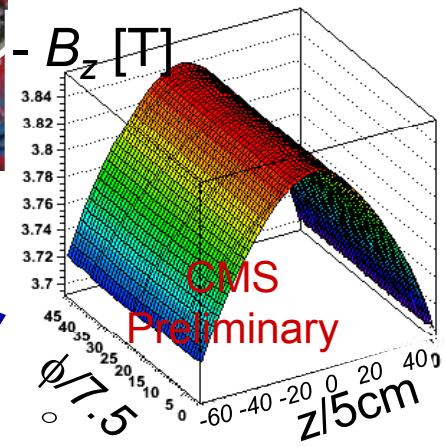
MTCC: Inside CMS Assembly Hall (surface)

Summer/Autumn 2006





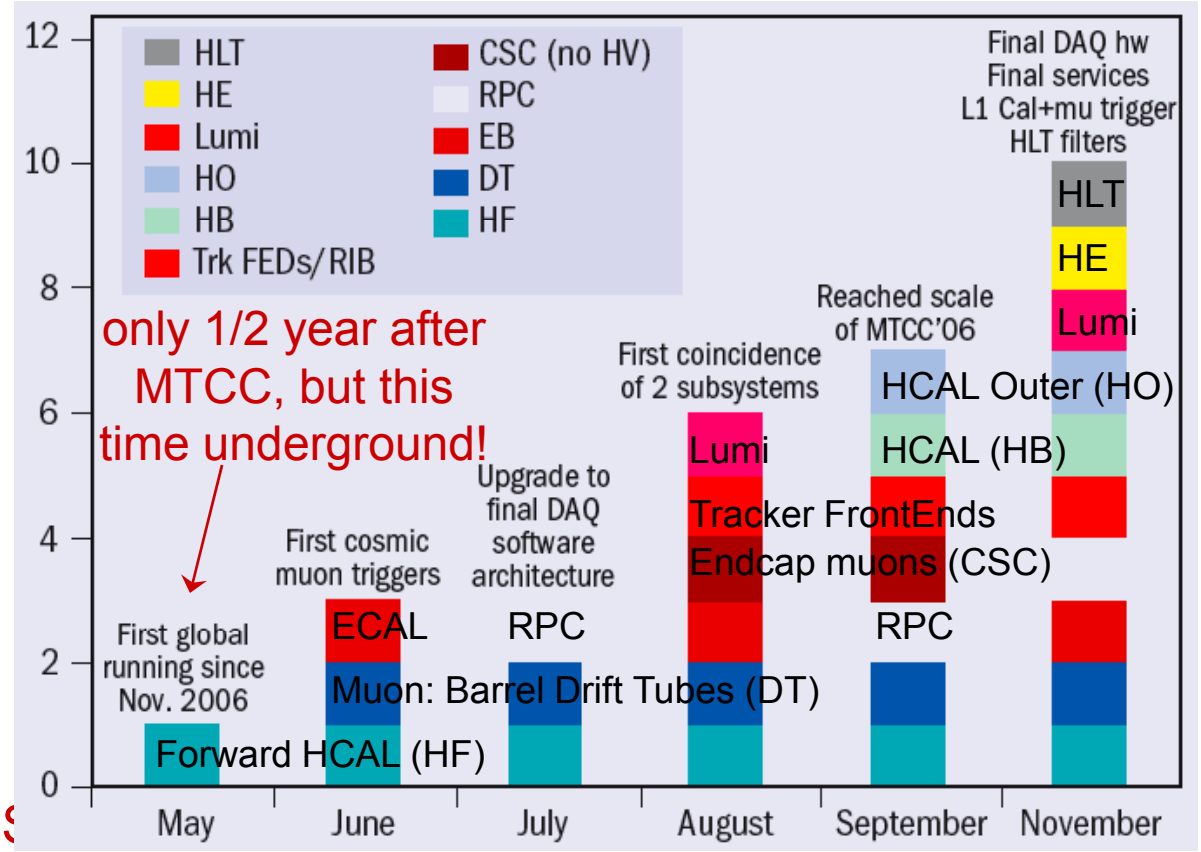




Solenoid:
- tested to B = 4T
- mapped field

CMS '07 Commissioning Highlights

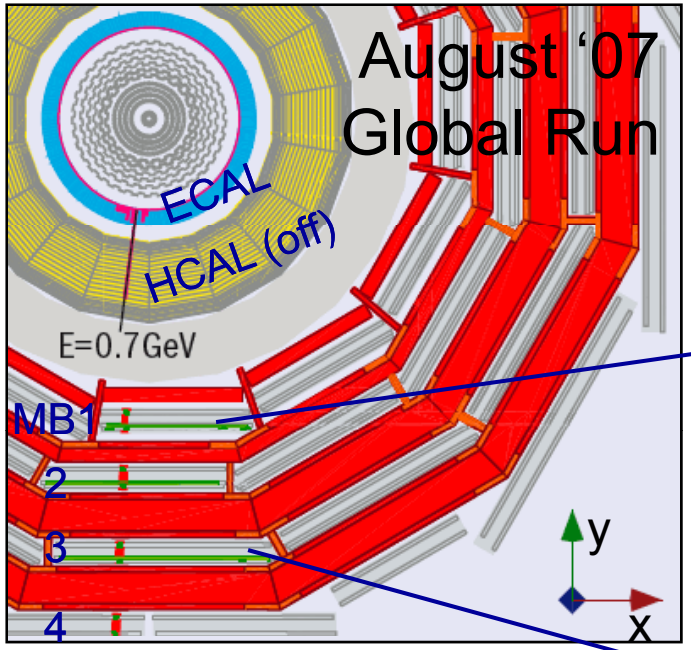
- Systems Integration
  - Power, cooling, detector electronics, trigger, DAQ, run-control, slow-control
  - Automated, reproducible and safe procedures
  - Pre-synchronization (cosmics triggers)
- Demonstrated Level-1 triggers from all muon detectors (DT, CS RPC) and calorimeters (ECAL, HCAL)
- Deployed HLT filtering
- Life data flow to Tier-0,1,2's
- Integrated real-time monitoring …



Increasing complexity of the 2007 Global Runs

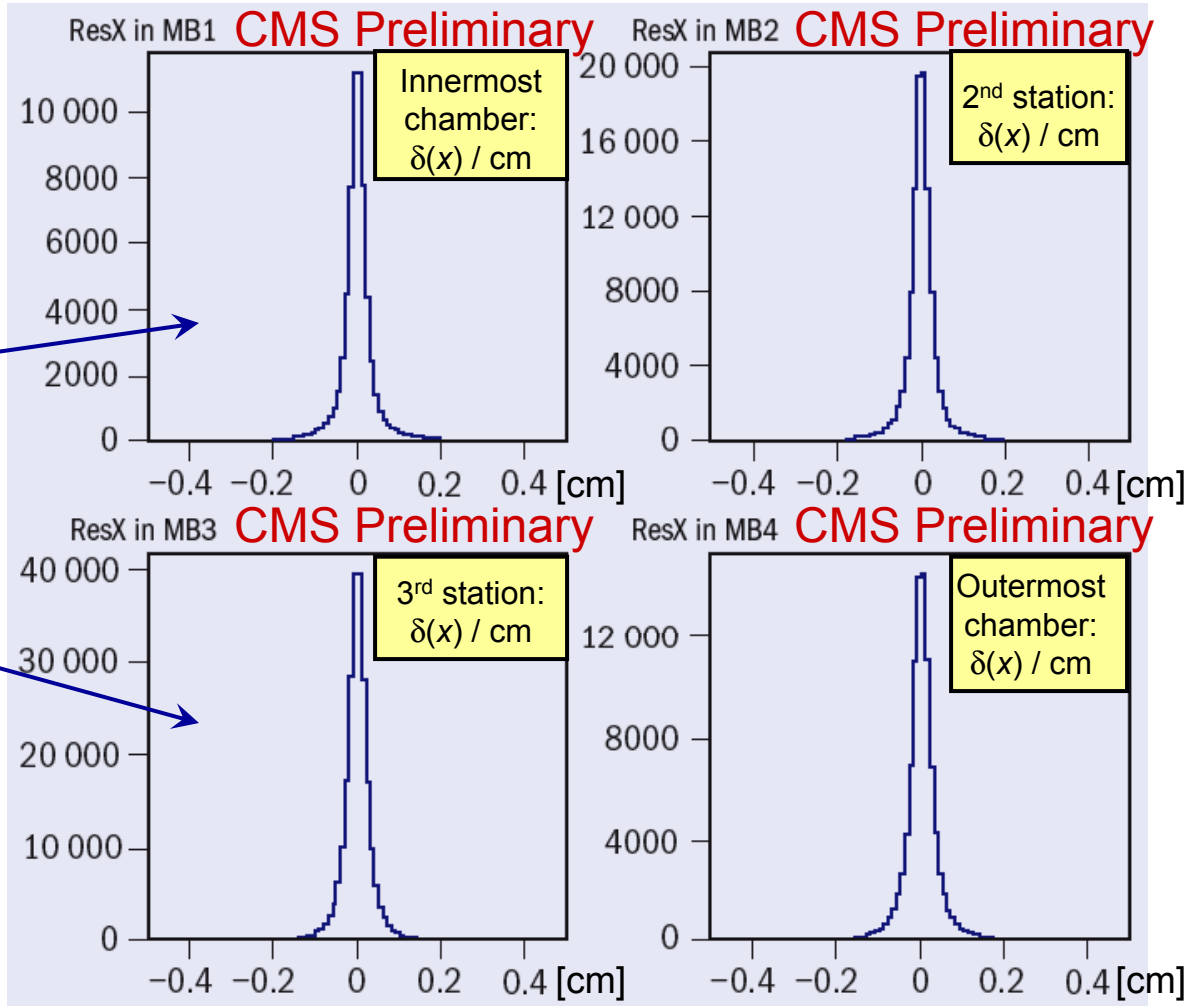
Next: With final Tracker, ~100% of CMS, with magnet on, ... collisions.

Some CMS Commissioning Results...



Cosmic m.i.p. signal in ECAL (DT trigger)

Up to end of 2007:
Synchronized triggers from parts of all trigger detectors (CAL & Muon). Parts of all in readout, except Tracker (≥Mar '08) & Preshower



First results from cosmic data: single-hit resolution of barrel drift tubes (DT): < 280 μm

Physics Commissioning with the first Collision Data

Likely LHC Startup Scenario

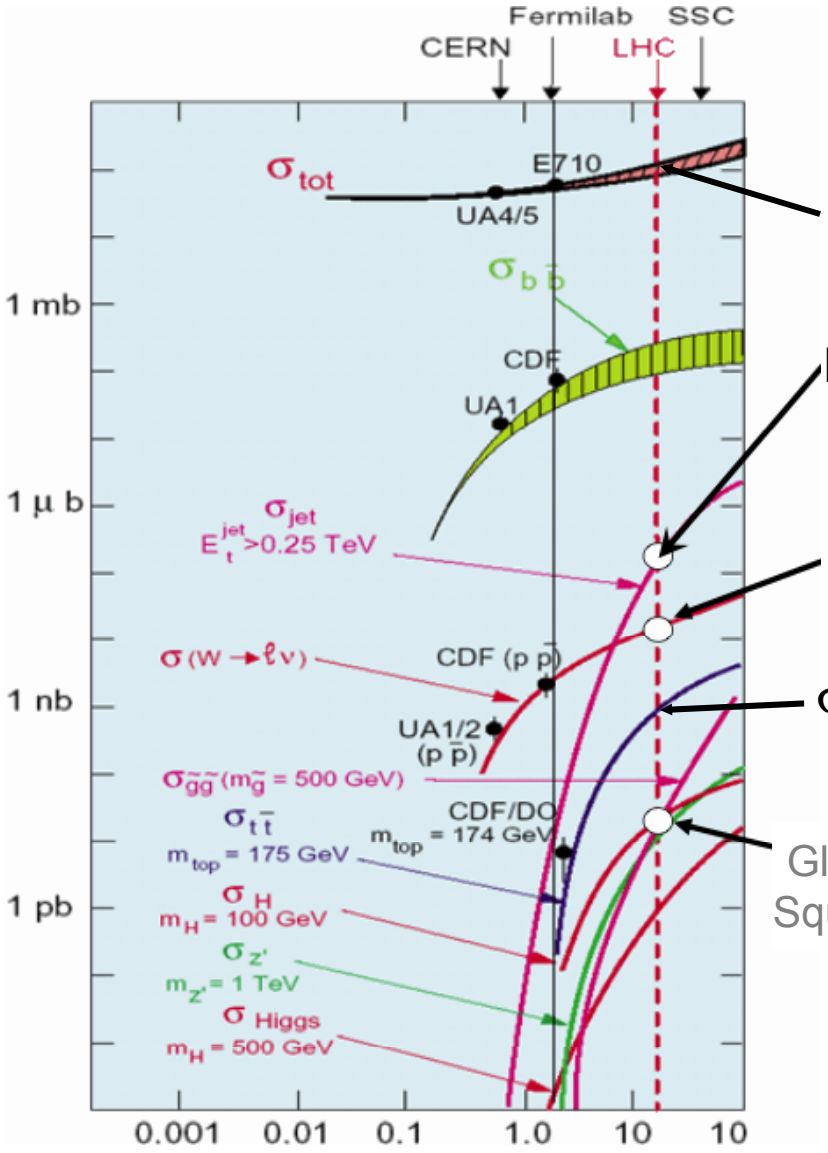
- Approximately 30 days of beam to establish first collisions
- Pushing gradually one or all of:
  - Bunches per beam (1 to 43 to 156)
  - Squeeze
  - Bunch Intensity

IP 1 & 5

Bunches	β*	I_b	Luminosity	Pileup	Min. bias rate	$\int L\,dt$:
1 x 1	18	10^{10}	10^{27}	Low	55 in ~10^4 xings	
43 x 43	18	3 x 10^{10}	3.8 x 10^{29}	0.05	20 kHz in 5.10^5	
43 x 43	4	3 x 10^{10}	1.7 x 10^{30}	0.21	60 kHz in 5.10^5	~ 0.1 pb^{-1}
43 x 43	2	4 x 10^{10}	6.1 x 10^{30}	0.76	200 kHz in 5.10^5	
156 x 156	4	4 x 10^{10}	1.1 x 10^{31}	0.38	400 kHz in ~10^7	~ 1 pb^{-1}
156 x 156	4	9 x 10^{10}	5.6 x10^{31}	1.9	2MHz in ~10^7	
156 x 156	2	9 x 10^{10}	1.1 x10^{32}	3.9	4MHz in ~10^7	~ 10 pb^{-1}

(each step takes about 1 week)

Towards Precision Measurements ...



"Minimum-bias"

High-p_T QCD jets

W, Z production

$\sigma(t\bar{t})$ ~ 100 times larger than at the Tevatron

Gluon-to-Higgs fusion (light)
Squarks, Gluinos (m ~ 1 TeV)

Huge statistics for SM physics:
~ 10^7 W evts/100 pb^{-1}
~ 10^6 Z evts/100 pb^{-1}
~ 10^5 $t\bar{t}$ evts/100 pb^{-1}

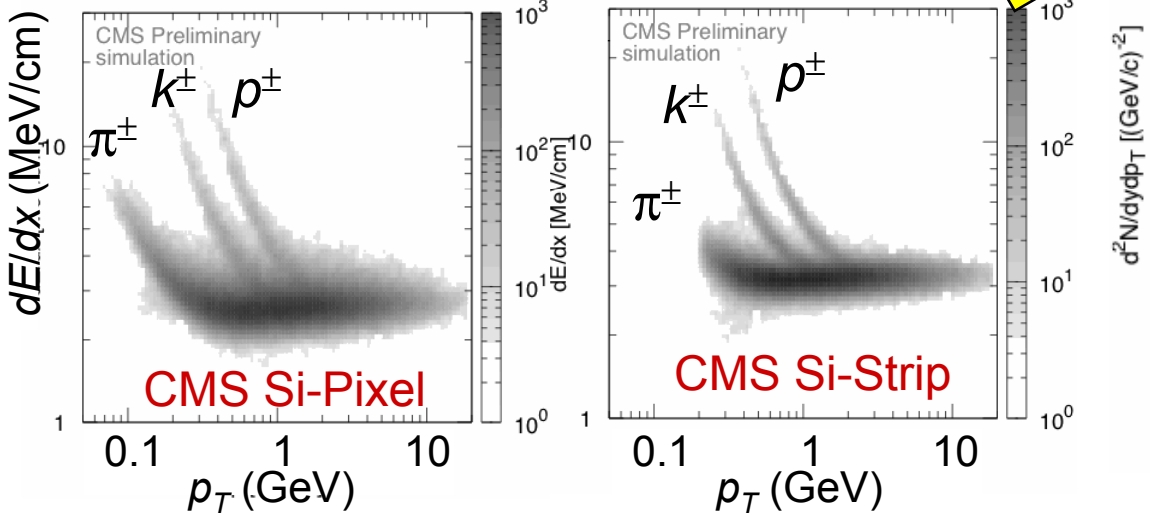
Alignment/Calibration:
- ECAL uniformity
- e/γ-E scale
- HCAL uniformity
- jet-E scale (JES)
- Tracking alignment
- Muon alignment

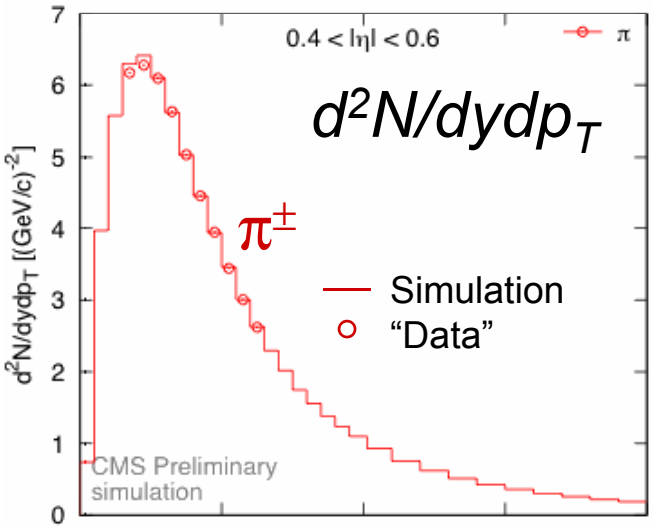
improve

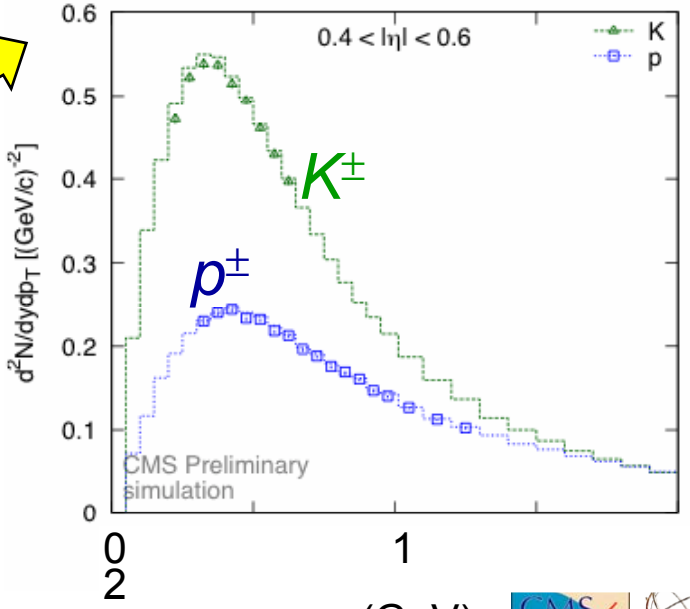
Early data:
$Z \to ee$, $Z \to \mu\mu$, QCD jets,
Z/γ+jet(s), $W \to jj$ in $t\bar{t}$, ...

Charged-Hadron Spectra

- One of the first measurements to be done: charged-hadron spectrum
  - Never before explored at $\sqrt{s} > 2$ TeV
  - Important tool for calibration & understanding of detector response
- Min-bias and/or Zero-bias trigger
- Statistics: ~ 1 month (at 70%) with 1Hz allocated trigger bandwidth

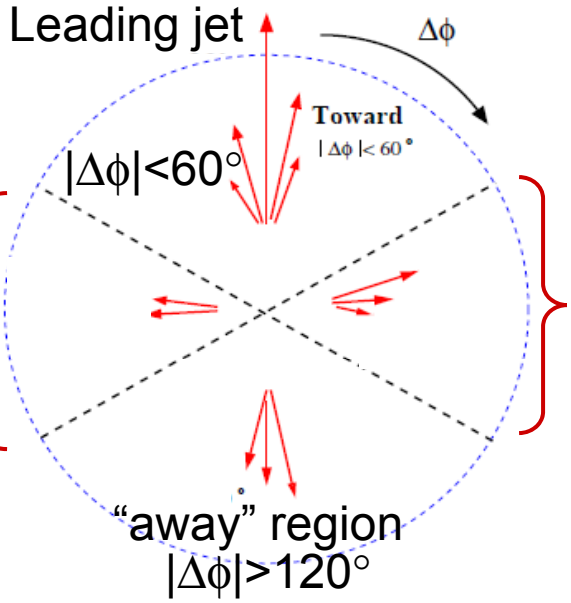




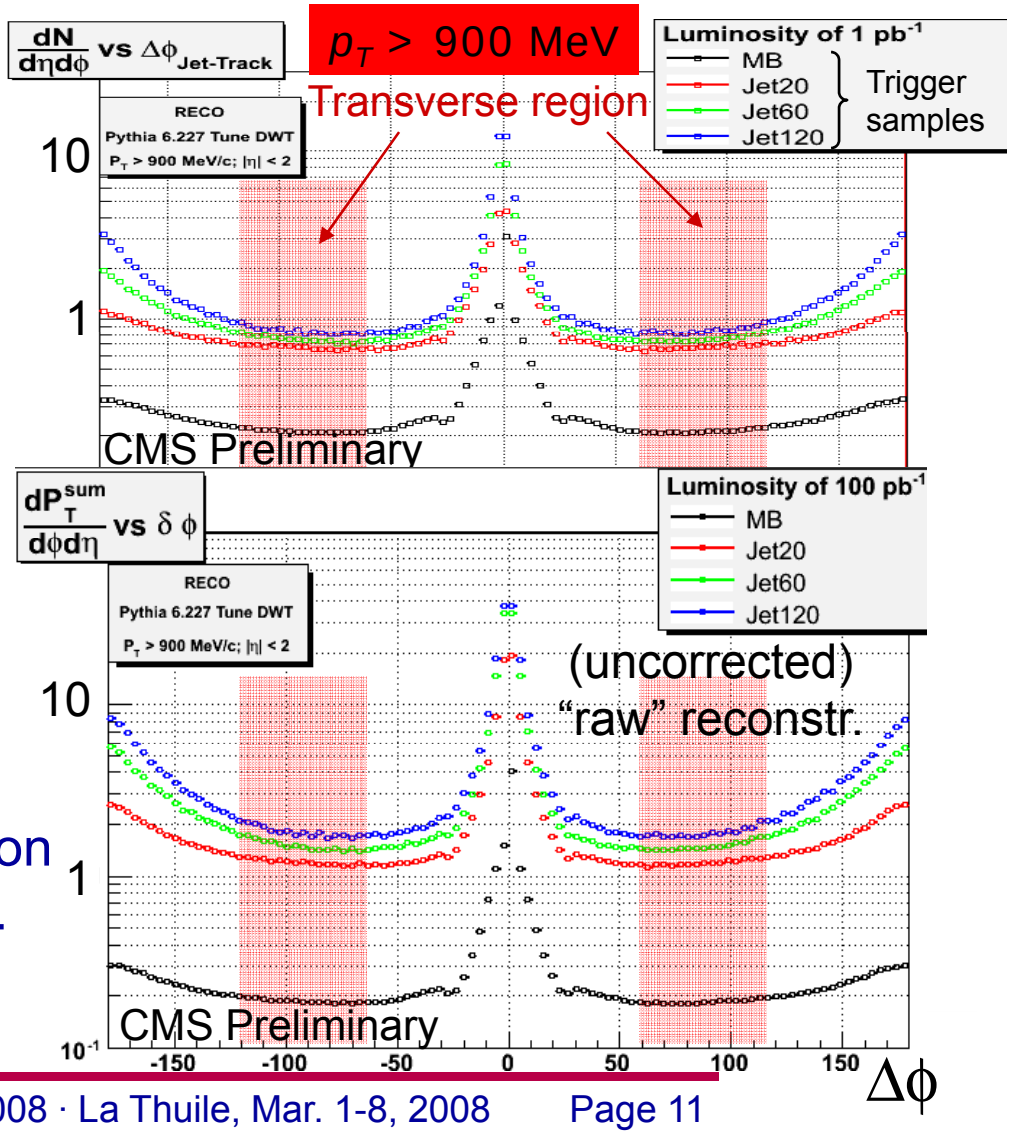


Event Structure: Underlying Event

- Measuring the underlying event activity
  - Observe $d^2N/d\eta d\phi$ and $d^2p_T^{sum}/d\eta d\phi$



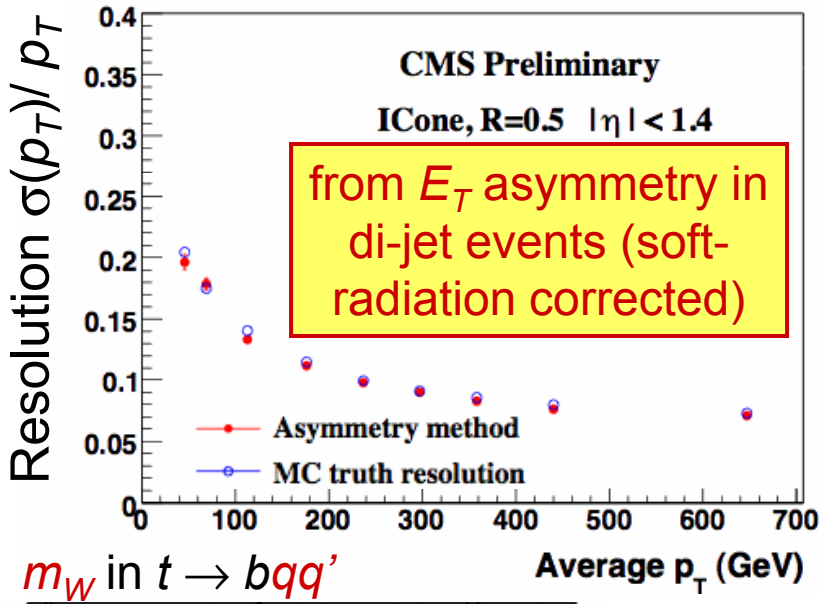
Look in region ⊥ to jet activity: transverse region

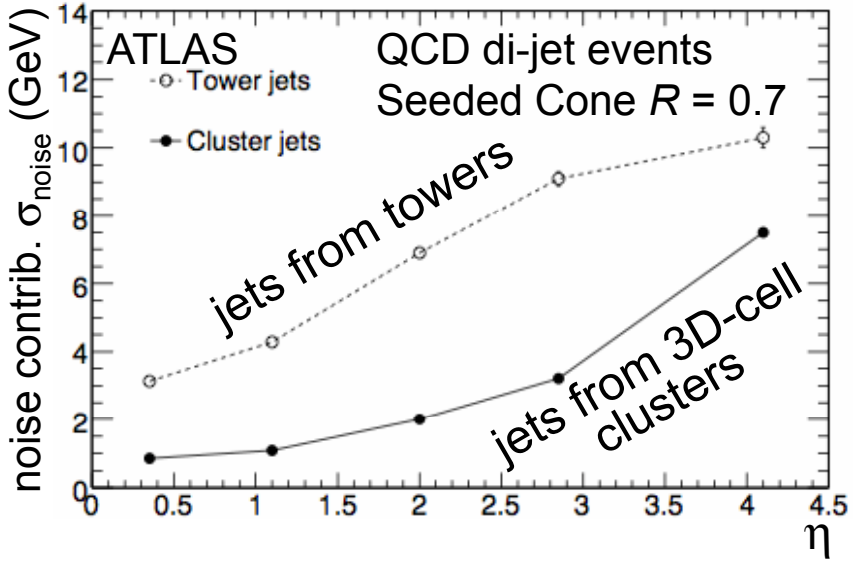


→ Important ingredient for jet & lepton isolation, energy flow, jet-tagging, …
→ sensitive to test multiple-parton interaction (MPI) tunes of QCD …

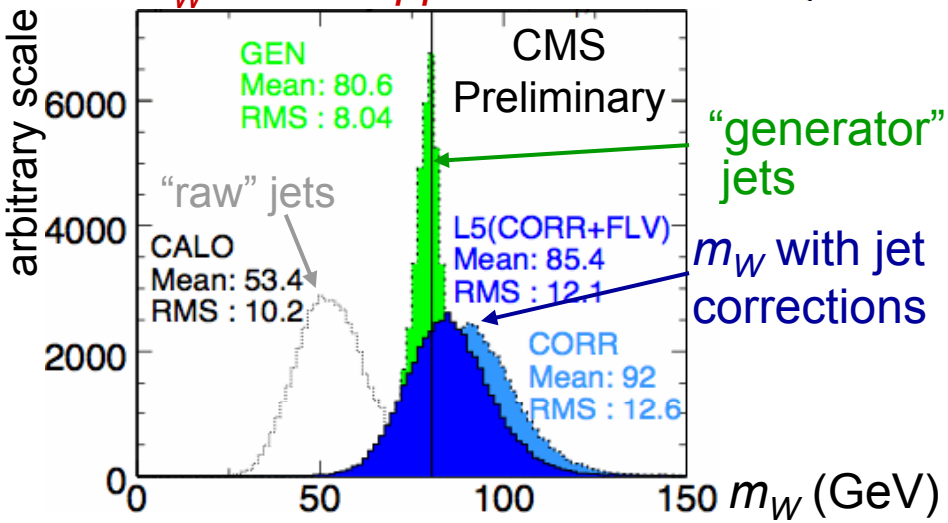
Jets at the LHC

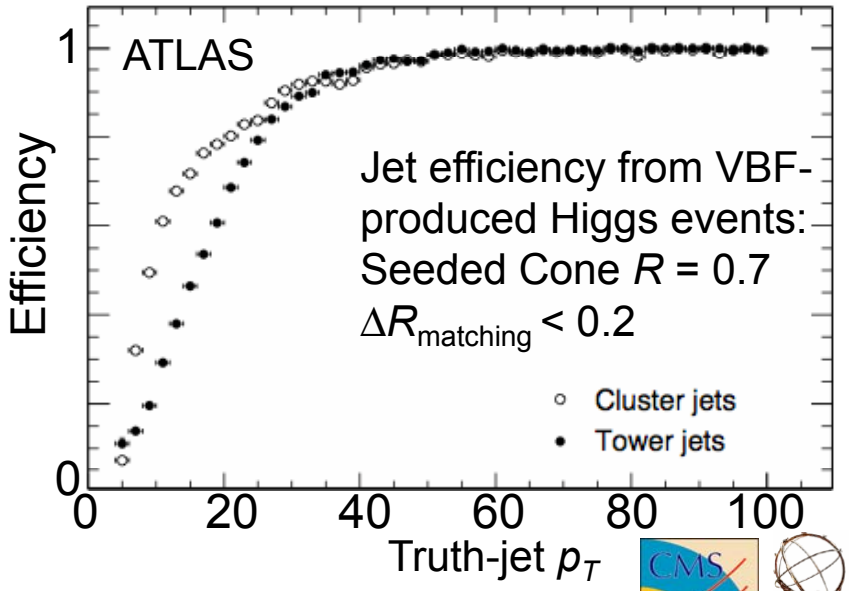
Data-driven method vs. MC-truth:



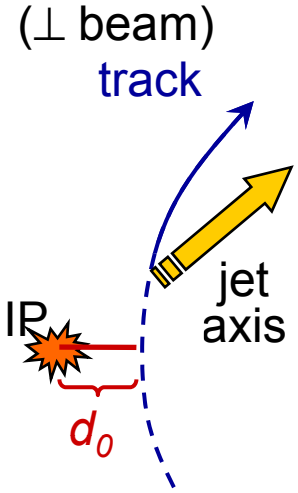


m_W in $t \to bqq'$

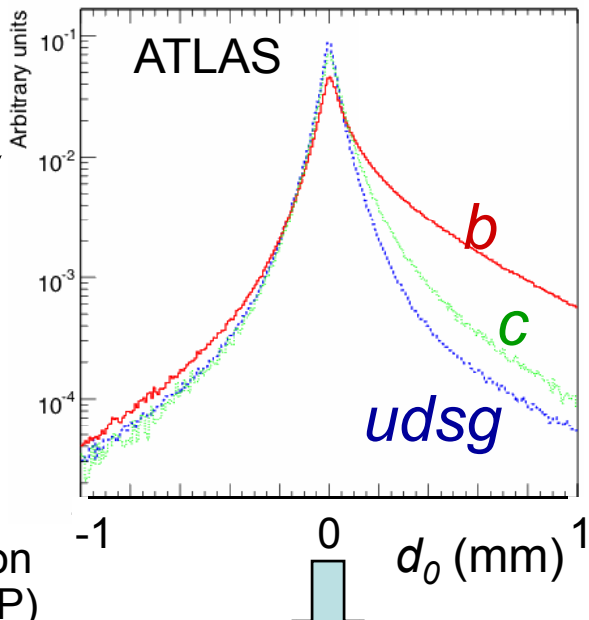




From B-Tagging ...



(d_0<0 if track crosses jet-axis on opposite side of IP)



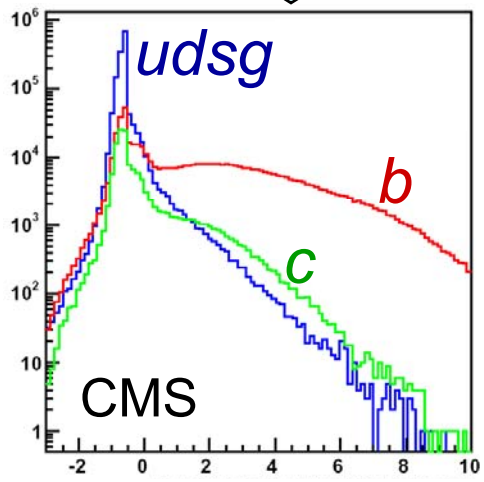
→ significance $d_0/\sigma(d_0)$
→ all jet tracks → Likelihood
→ also 3D, vertex finding ...

N.B.: Life-time *b*-tags work even with misaligned tracker

b-tag efficiency with independent (from *tt*) sample: semi-leptonic *bb*

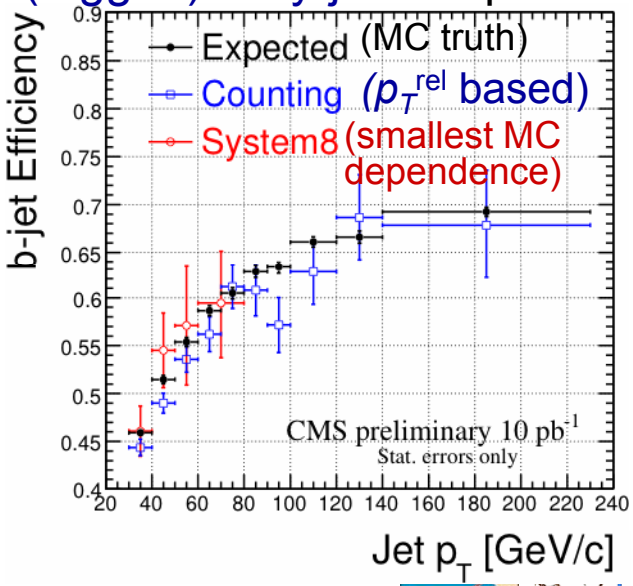
Use μ-jet + (tagged)away-jet samples:

Algorithm for combined 2ndary-vertex tagging (incl. topological & kinematical observables)



Measure eff. with first data rather than trust MC only:

Tested methods developed at the Tevatron



... to Top (Re-)Discovery

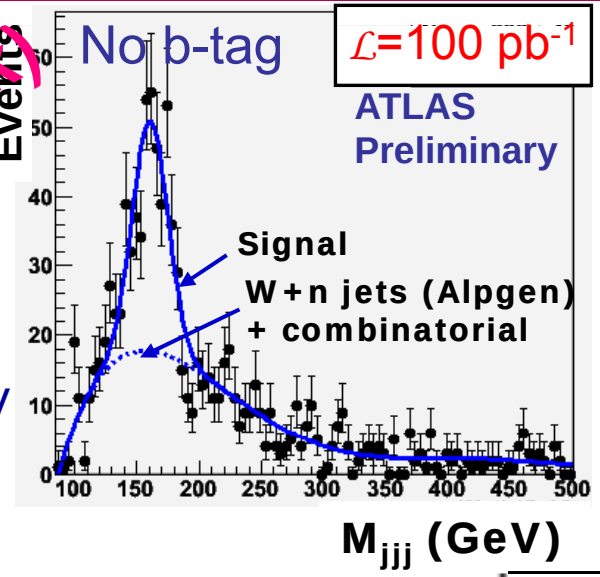
Event selection (ATLAS):
- No *b*-tagging at start-up
- 3 jets with $\max(\Sigma p_T) \rightarrow M_{jjj}$

isol. lepton, p_T>20GeV
→ Trigger

3+1 jets
p_T>40 GeV

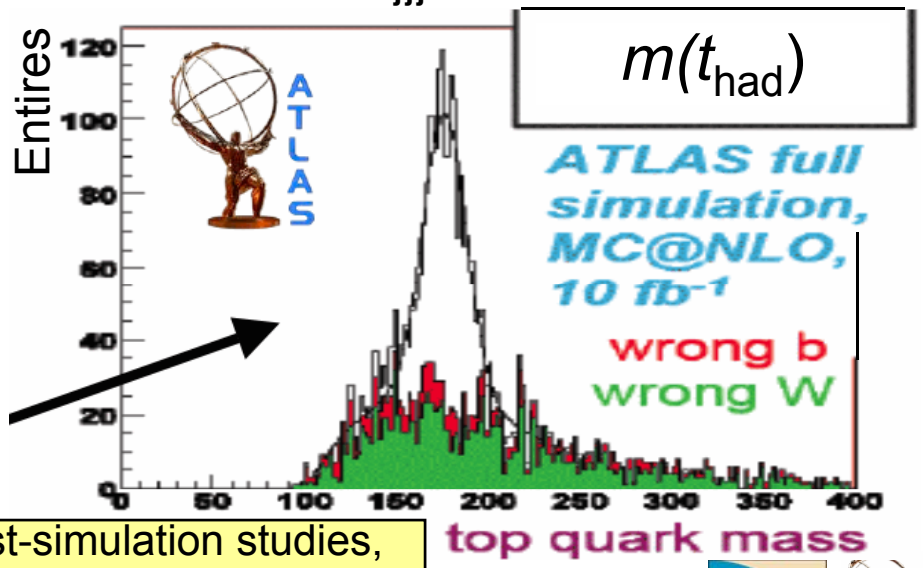
$\not{E}_T$ > 20 GeV

(→ see M. Plamondon's talk)



Lepton-tagged *tt* sample perfect to validate *b*-tagging!

Use this *tt* sample to
- complement γ/Z+jets sample for JES correction: $W \rightarrow jj$ in *tt*
- study *b*-tagging

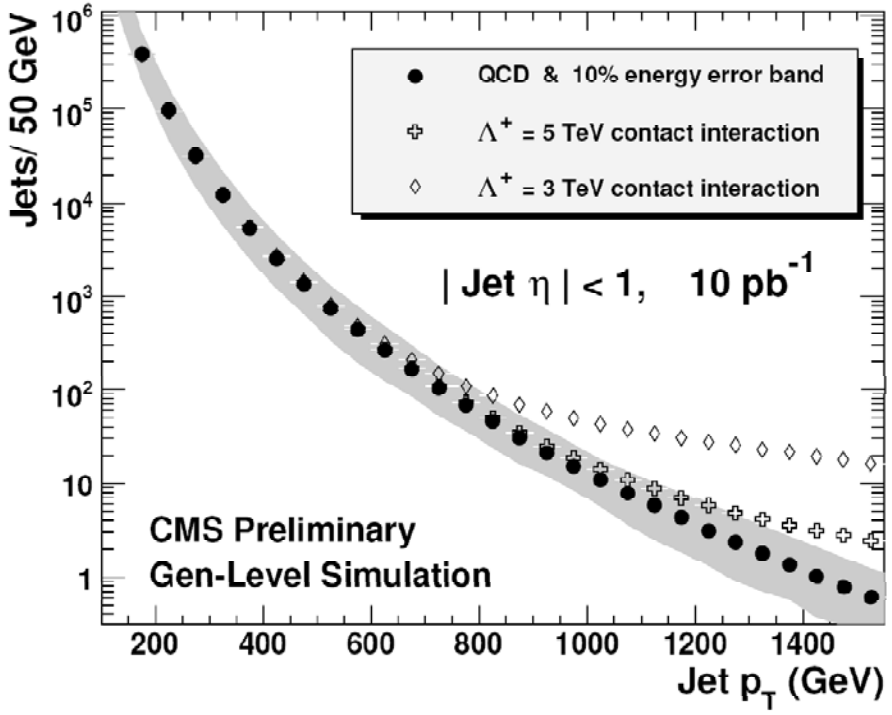


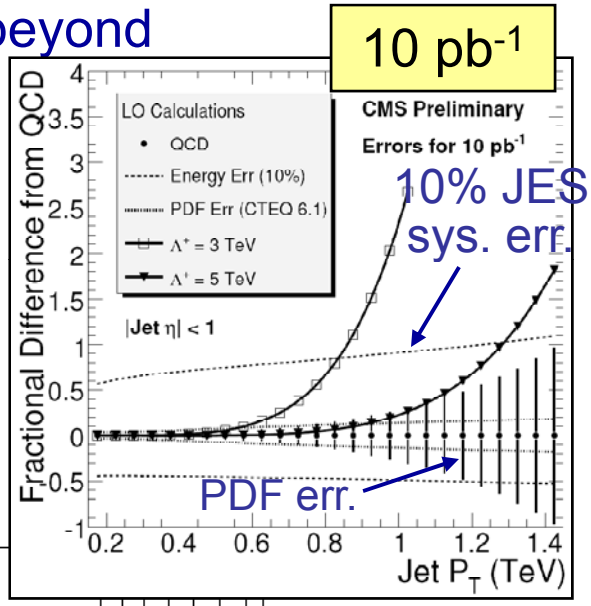
Ultimate aim – after JES and with *b*-tagging – for 10fb^{-1}:
Statistical uncertainty: 0.05-0.2 GeV
Systematics: 0.9-1.6 GeV

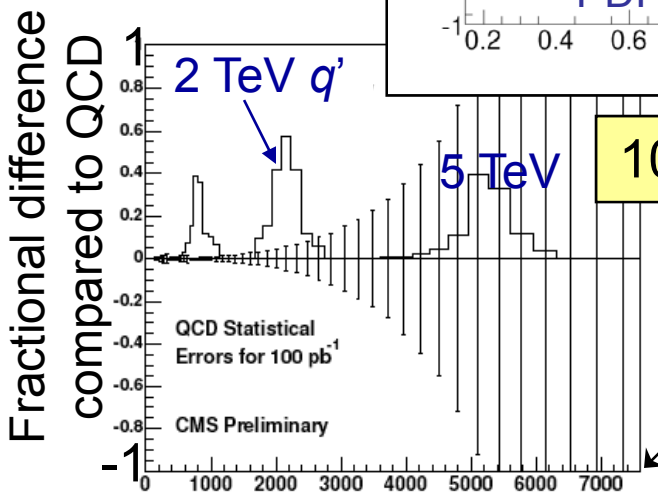
N.B.: fast-simulation studies, QCD is likely not well modeled.

QCD High-E_T Jets

- Jet-*E* scale will dominate error:
  - ~ 10% JES uncertainty for 10 pb^{-1}
  - Measure QCD jet-p_T spectra up to 1 TeV and beyond
  - Contact interactions: large rate at high-p_T, with 10pb^{-1} sensitive to 3 TeV scale C.I. …further use di-jet ratios, *m*(*jj*) …







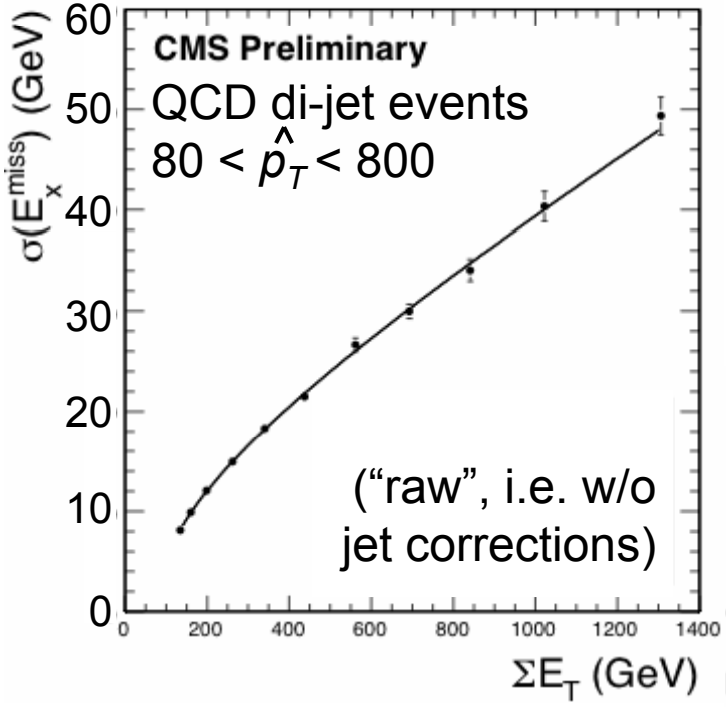
100 pb^{-1}

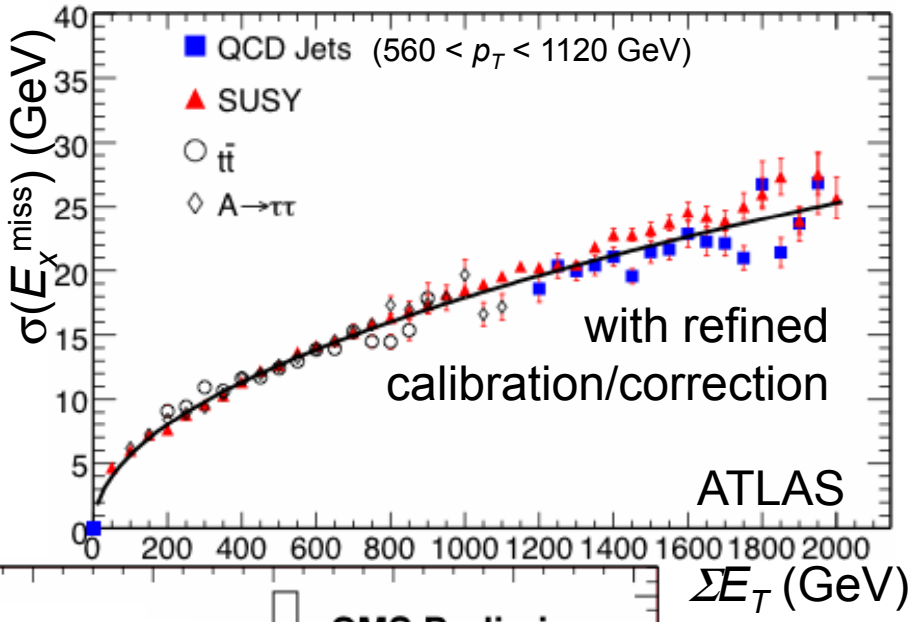
excited quarks?

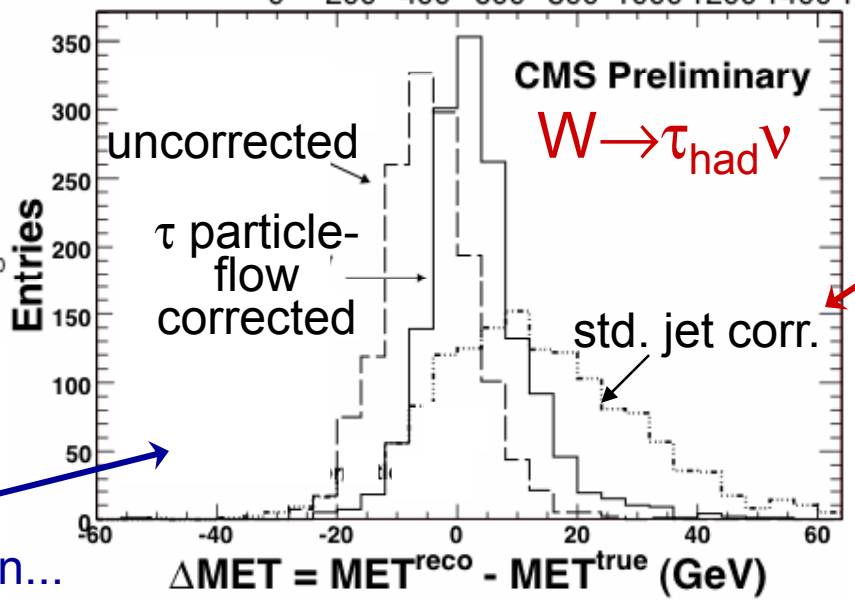
Di-jet mass

Missing Transverse Energy

Updated results from pTDR with realistic detector simulation (e.g. gains from sourcing, etc.)



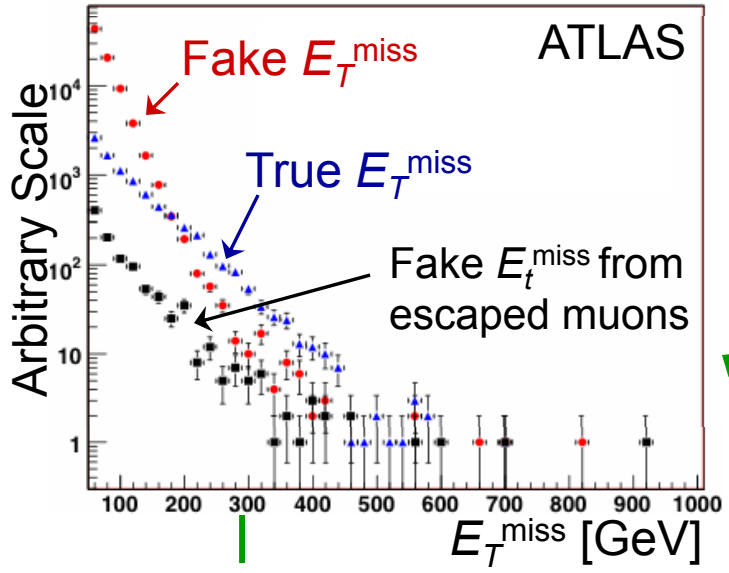




Standard jet correction not optimal here due to different jet properties & flavor composition

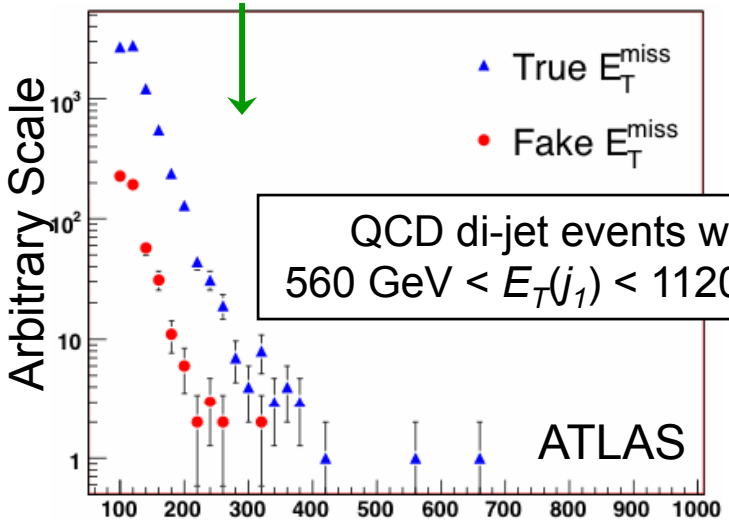
Corrections from particle-flow are promising to improve resolution, see here for τ-jets; further P.F. studies in preparation...

Missing Transverse Energy

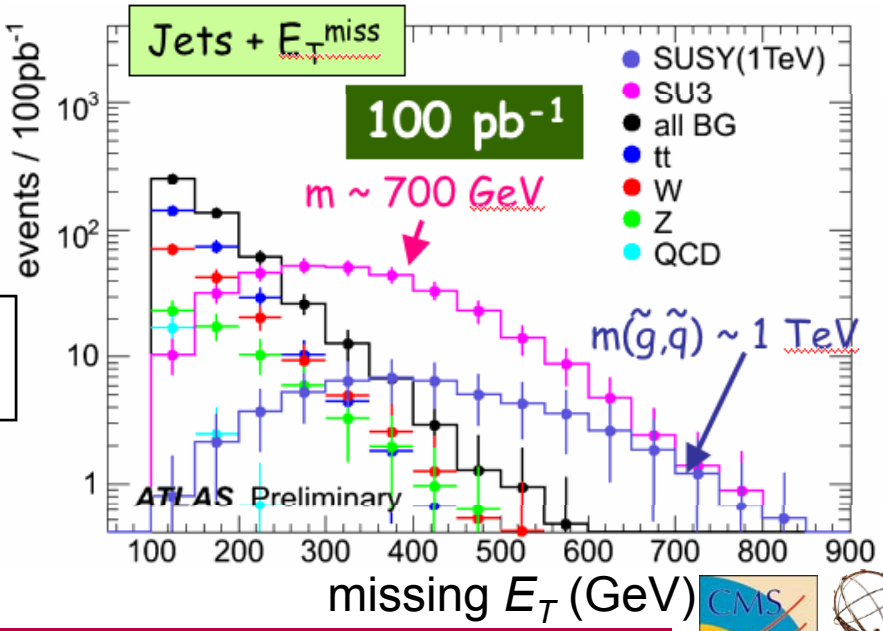


- Fake E_T^{miss} comes from:
  - Beam-gas interactions, machine bgd.
  - Displaced I.P.
  - Hot/dead/noisy cells or regions
  - non-linearity in hadronic response
  - finite energy resolution
  - High-p_T muons escaping fiducial region
  - E losses in cracks or passive material

Isolation: $\Delta\phi(E_T^{miss}, \text{high-}E_T \text{ jet}) > 17^o$



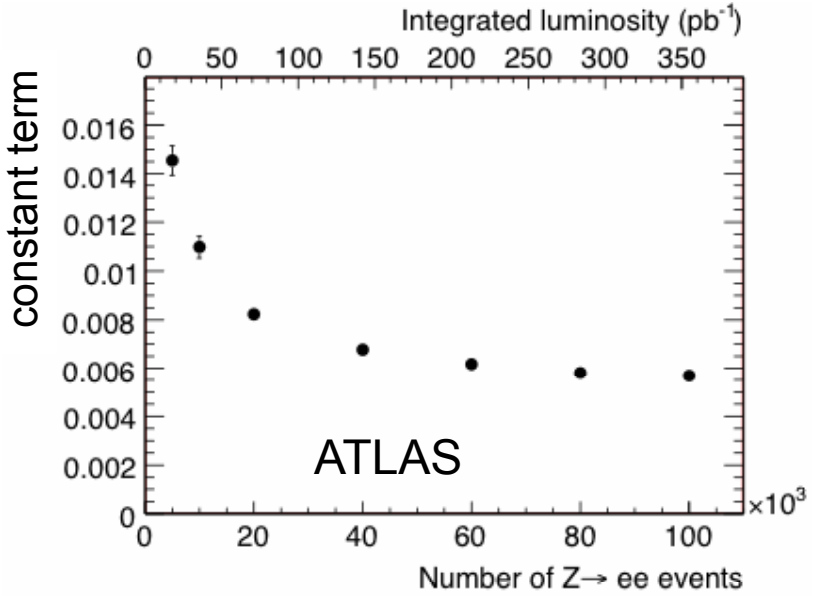
QCD di-jet events with
560 GeV < $E_T(j_1)$ < 1120 GeV

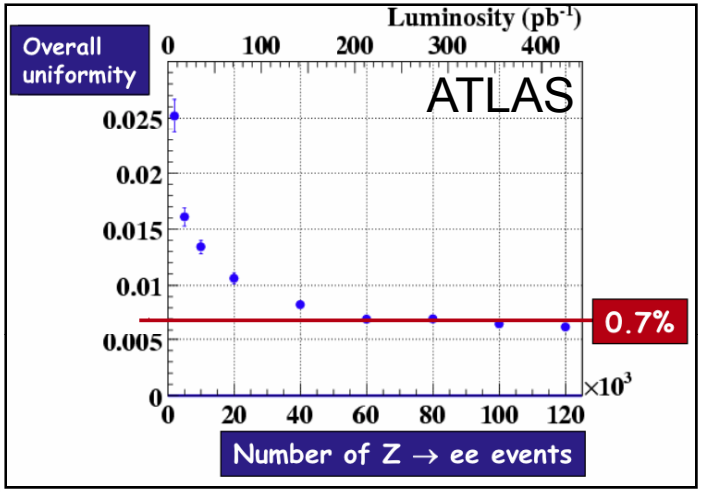


Some Comments on Photons ...

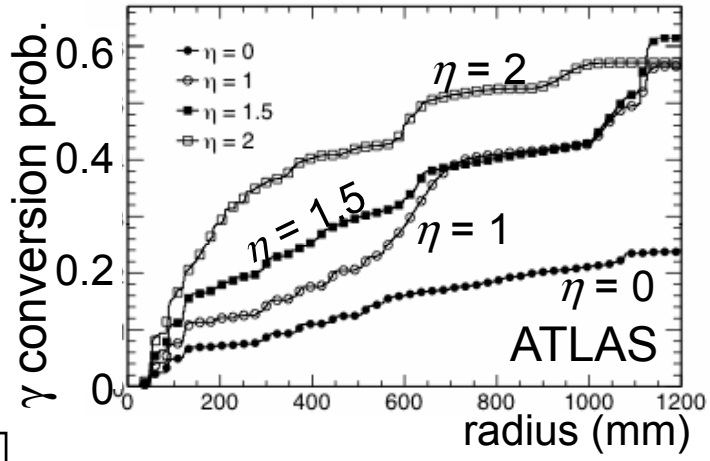
... require good understanding of ECAL: uniformity/calibration

First with π^0, then with electrons from $Z \rightarrow ee$:





Photons are much harder to extract from jet background than certain isolated electrons, e.g. from $Z \rightarrow ee$ (due to π^0) ...



Photon conversion in material before the ECAL !...

Also use γ/Z+jet data for JES:
$\rightarrow \gamma$/Z recoil $\rightarrow$ Jet-E scale (JES) to 1%

Summary

- The commissioning of CMS is well advanced
- Physics (object) commissioning:
  - Early data of 10 - 100 pb^{-1} will allow first studies Standard Model processes in order to understand the detectors and optimize the performance of particle-ID
  - New (updated) studies focusing on early data have been discussed

(CMS)	Expected at $t = t_0$	Goal for Physics
Tracker alignment	20-200 μm in $R\phi$	O(10 μm)
ECAL uniformity	4%	< 1%
HCAL unif.	2-3 %	< 1%
JES	< 10%	2-3 %

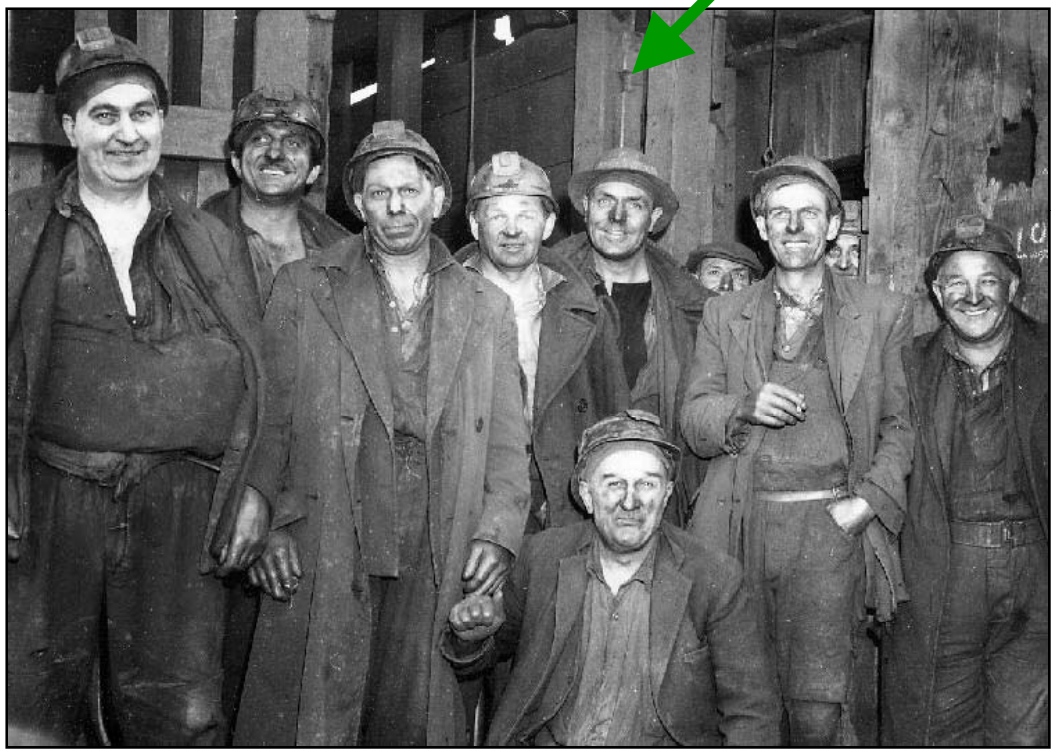
ECAL, HCAL: intercalibration using azimuthal symmetry (minimum bias).

ECAL: π^0 calibration, then electrons from $Z \rightarrow ee$

JES: di-jet balancing, γ/Z+jet, $W \rightarrow jj$ in tt events

Summary II

Exhausted but happy physicists after a long shift (of data taking)



(even without collisions, the experiments are already taking loads of interesting data to commission their detectors)

Both, ATLAS & CMS, are eagerly awaiting the LHC collisions in summer ‘08!