Commissioning di CMS

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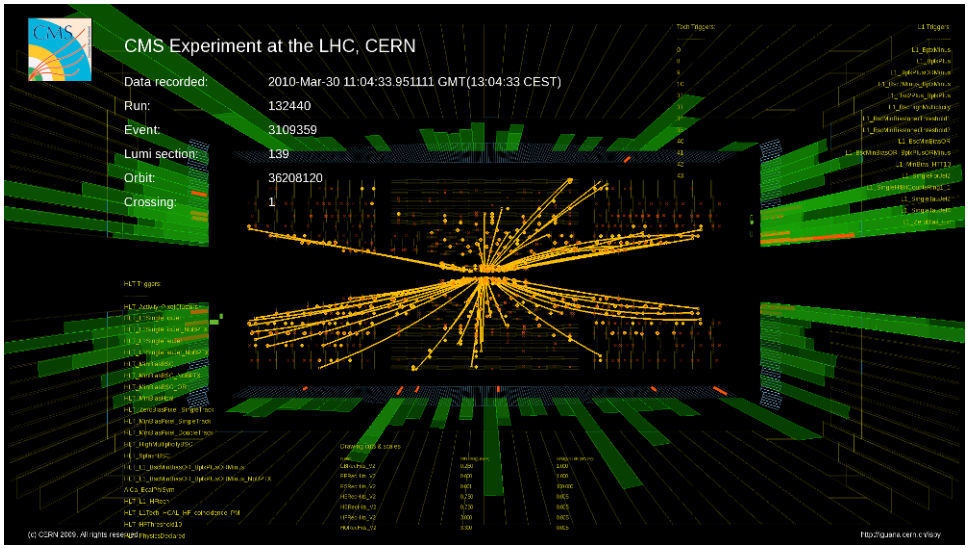
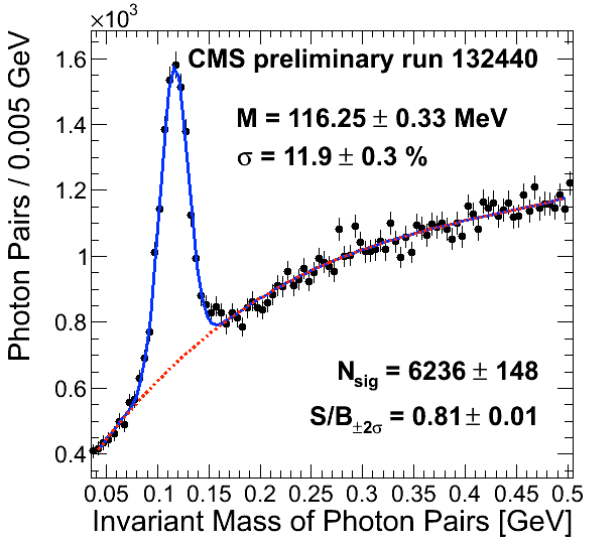
IFAE 2010

Roma - 08/04/2010

Just off the press: 7 TeV @ CMS





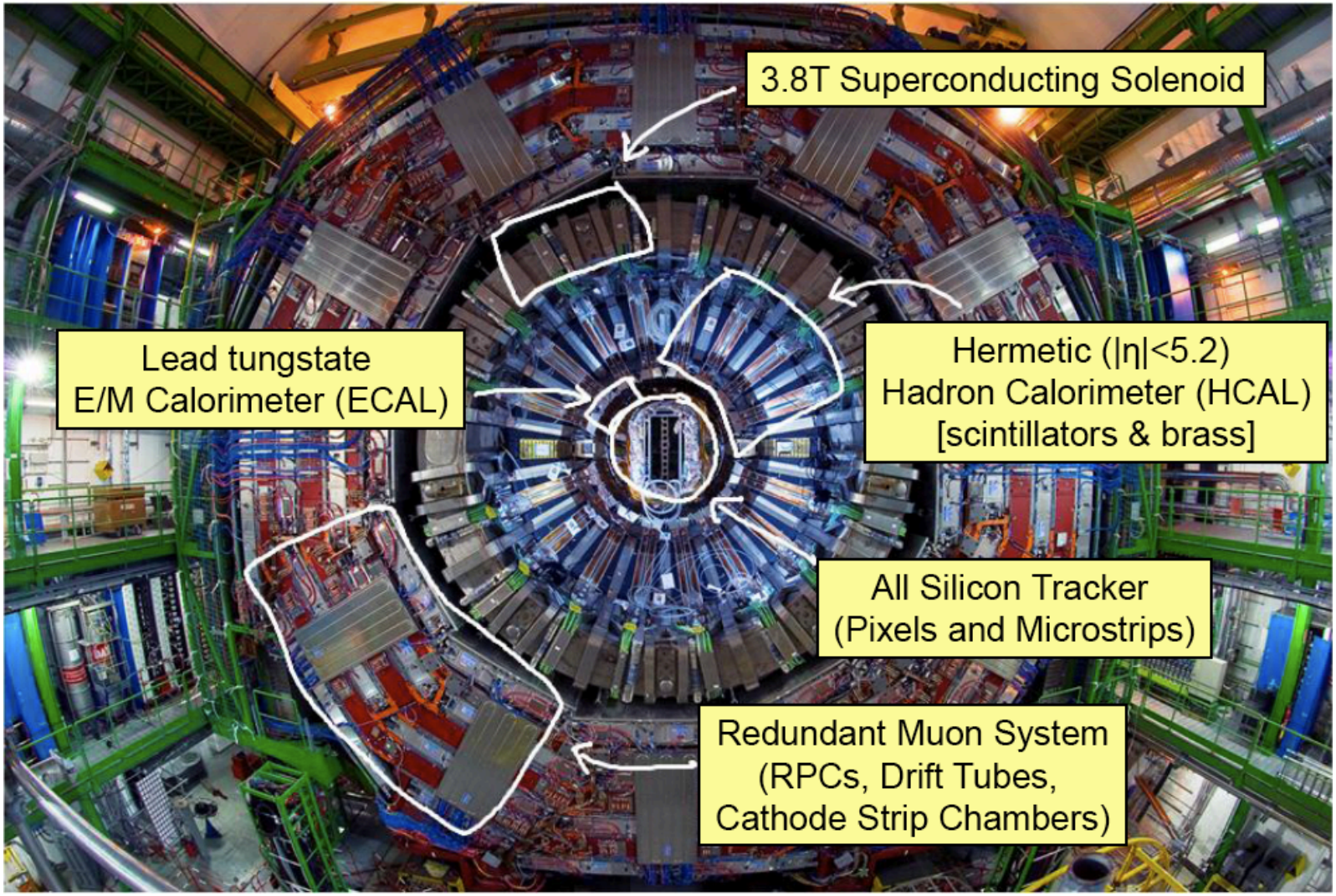
Since 30th March:
Recorded ~0.15 nb^{-1}

Outline

CMS Detector status and commissioning

- Preparation for beam (Sept08/Nov9): cosmic runs
- Commissioning with beam: the 900 GeV run
  - First performance plots and comparison with MC

CMS in a nutshell

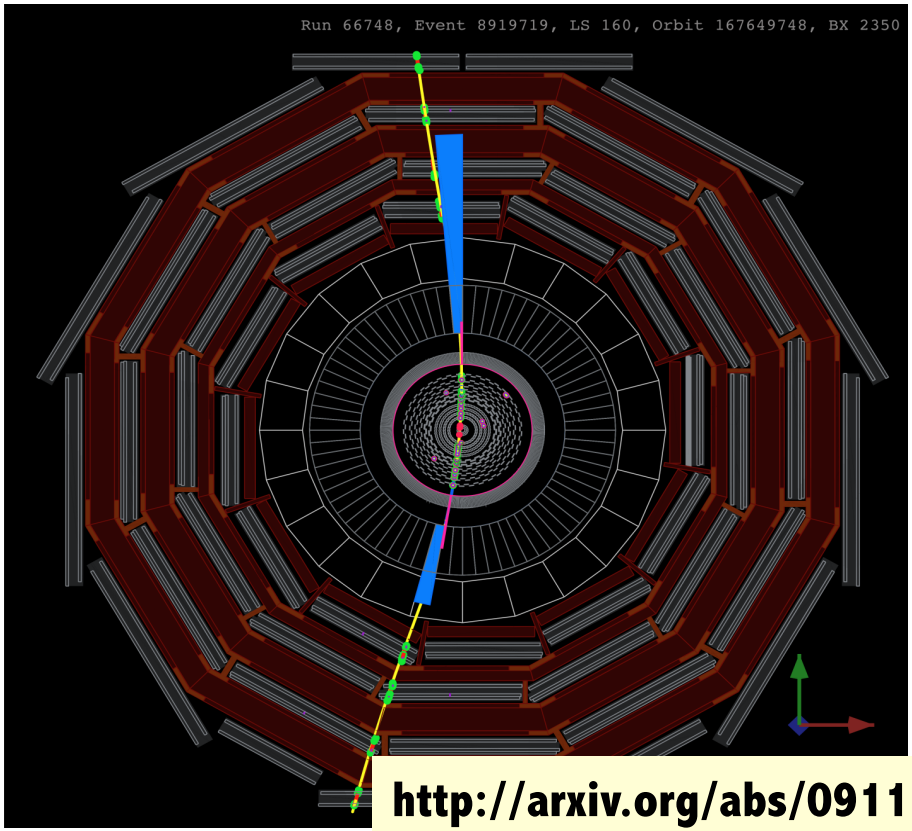


CMS comprises
66M pixel channels,
~10M Si microstrip ch,
~75k crystals,
150k Si preshower ch,
~15k HCAL ch,
250 DT chambers
(170k wires),
450 CSC chambers
(~250k wires),
~ 500 Barrel RPCs
~ 400 endcap RPCs,
100 kHz DAQ system
(~ 10k CPU cores),
Grid Computing (~ 50 k cores),
offline (> 2M lines of source code).

182 Institutions
>3000 scientists and engineers
~ 2000 Authors (including students)

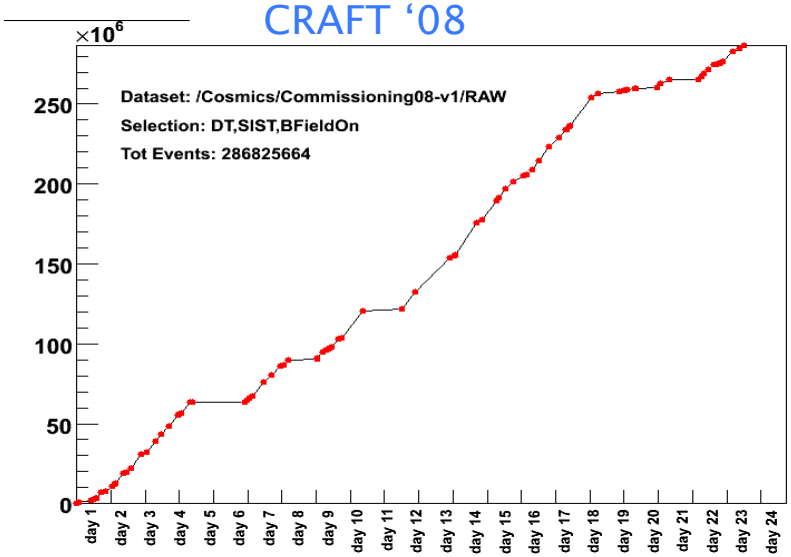
Last year of preparation (sept 08 – nov 09)

Cosmic Runs At Four Tesla

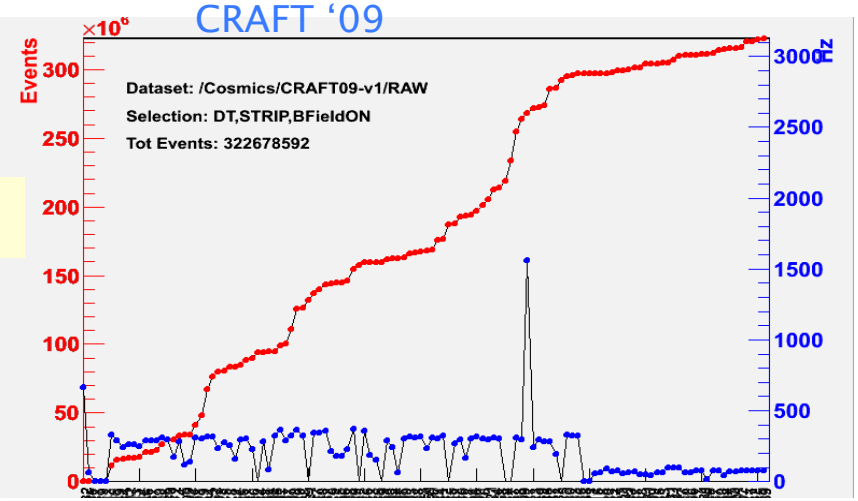


http://arxiv.org/abs/0911.4845

CRAFT '08



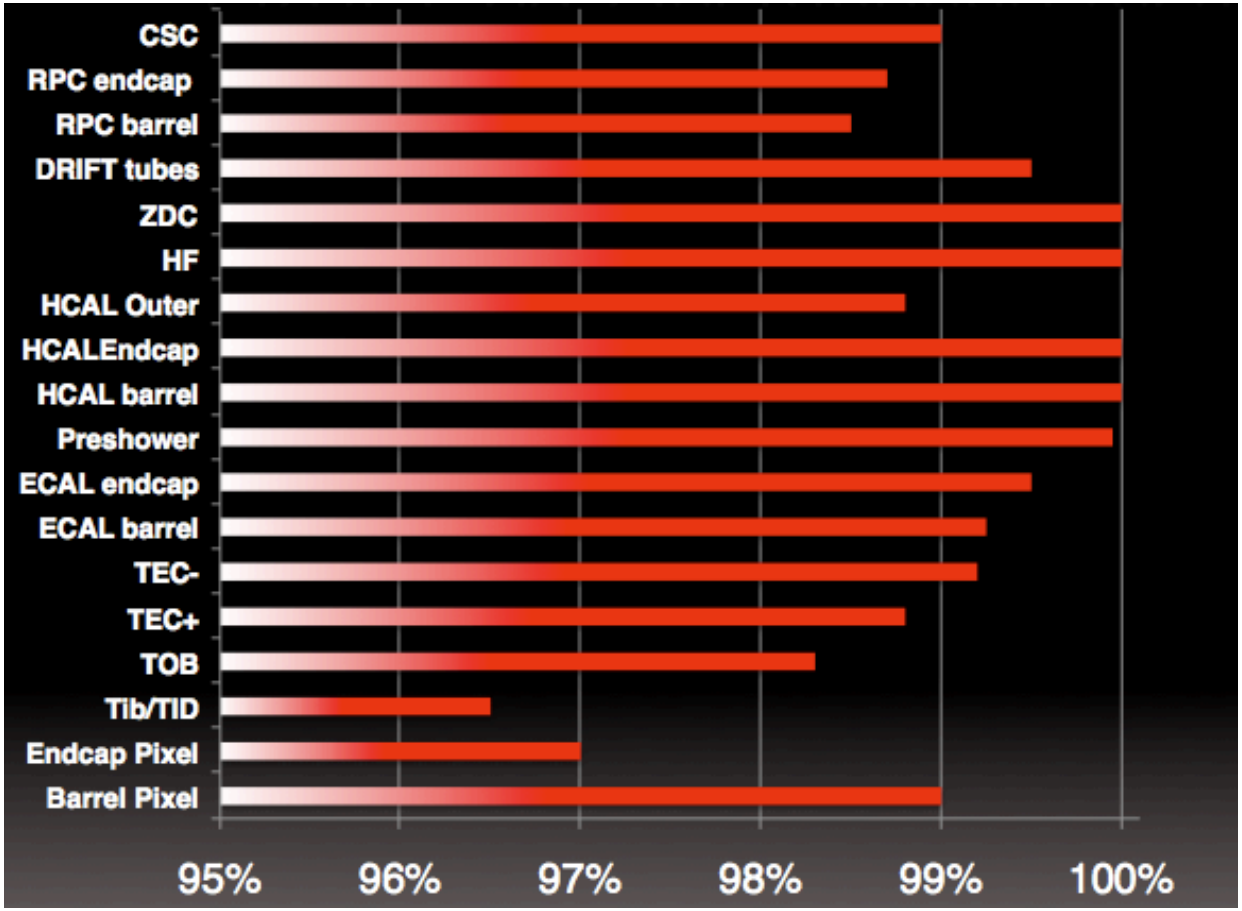
CRAFT '09



600M cosmics collected with magnetic field and all subdetectors on

- 300M in Autumn08
- 300M in Summer09

CMS operation



CMS is in good shape

>99% is operational

Good data taking efficiency

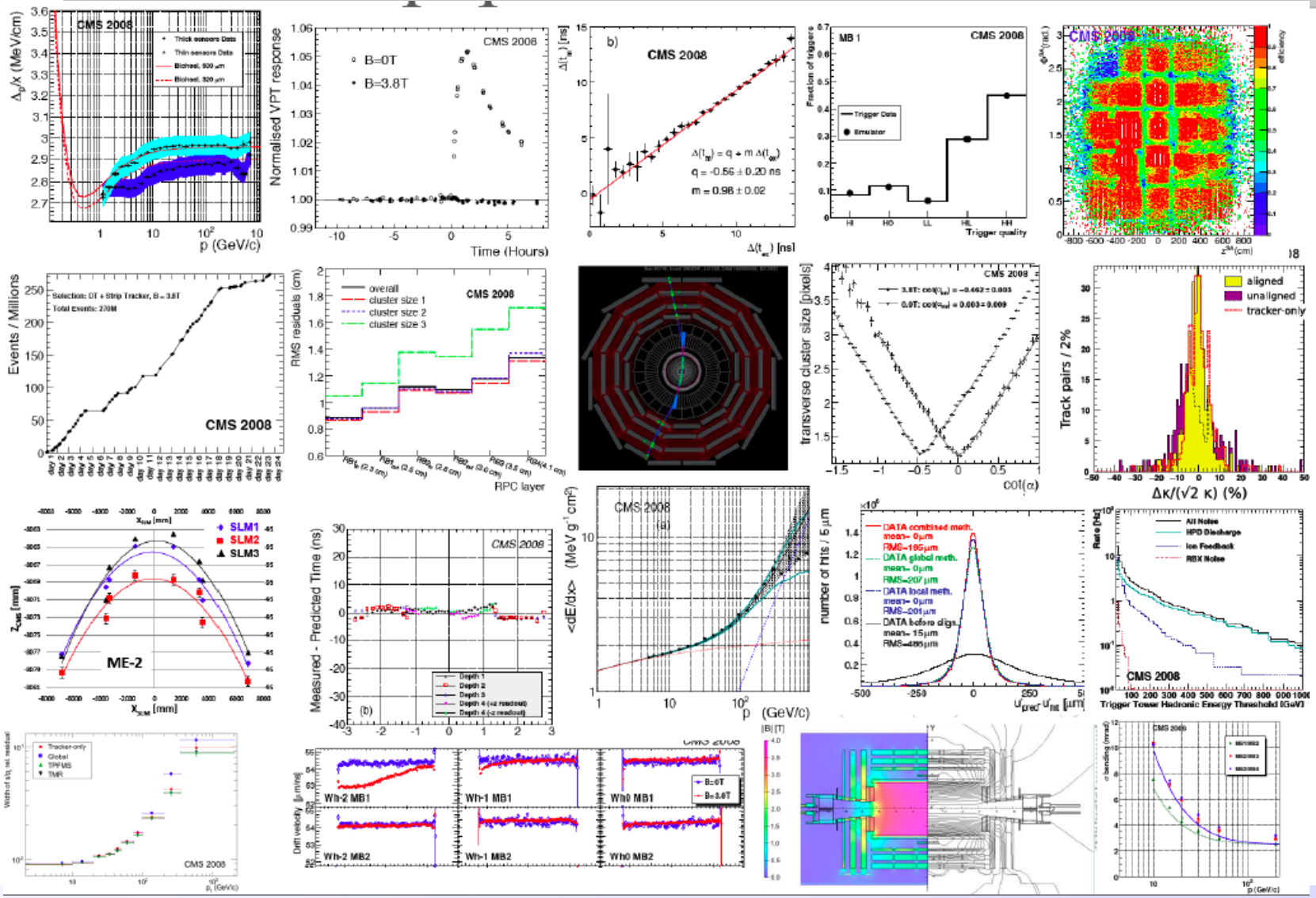
CRAFT09 ≈ 80% (reaching 90% during weekends)

And during LHC first beams was 85%

Rewards

- Continuous preparation while waiting for the beam
  - Improved stability and reliability of all online operational aspects (services/DAQ/Trigger)
  - Improved reconstruction software robustness
  - Test software & computing workflows
- Deeper understanding of detector performance
  - 23 articles resulted in a dedicated JINST volume (**2010 J. Inst 5**)
  - Invested the maximum effort to understand the basic detector performance before LHC startup (especially for tracker and muon system) “profiting” from the shutdown…

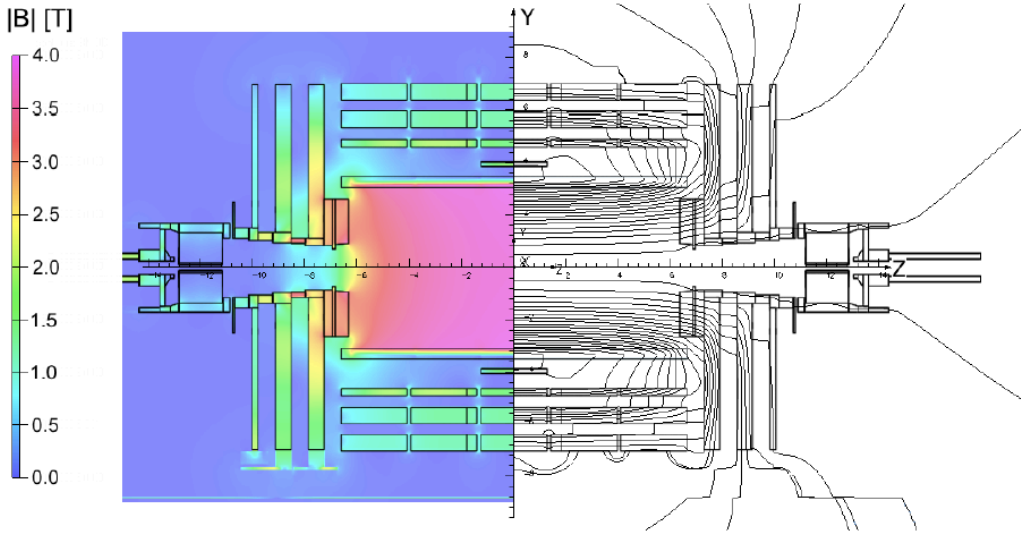
From the 23 papers submitted to JINST…



CRAFT: Measurement of B field

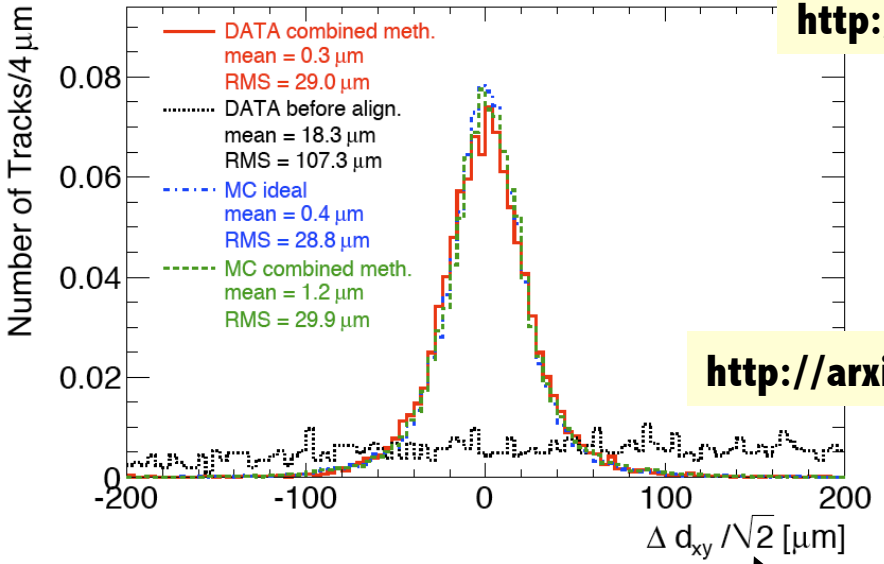
- Good understanding of the solenoid B field in the tracker region and in the return yoke
  - **Map in the tracker volume**
    - Measured by probes in 2006 at 0.005%
    - Verified in situ with cosmics at 0.1%
  - **Field map in the yoke** at first found over-estimated by 20% looking at muon residuals in bending plane
    - Too tight physical boundaries were imposed in the finite-element model (radius,z)
    - New model implemented, now **accuracy @ 3-8% level** (ok for physics)

http://arxiv.org/abs/0910.5530



CRAFT: Muon/Tracker

http://arxiv.org/abs/0910.2505



Approaching MC ideal alignment

3-4 μm @ module level in the barrel

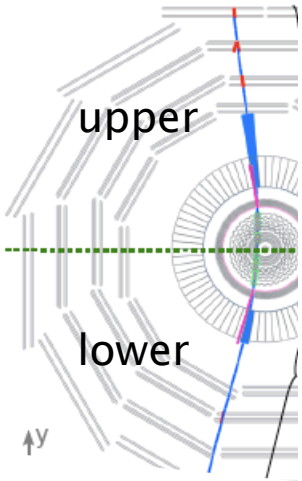
3-14 μm in the endcap

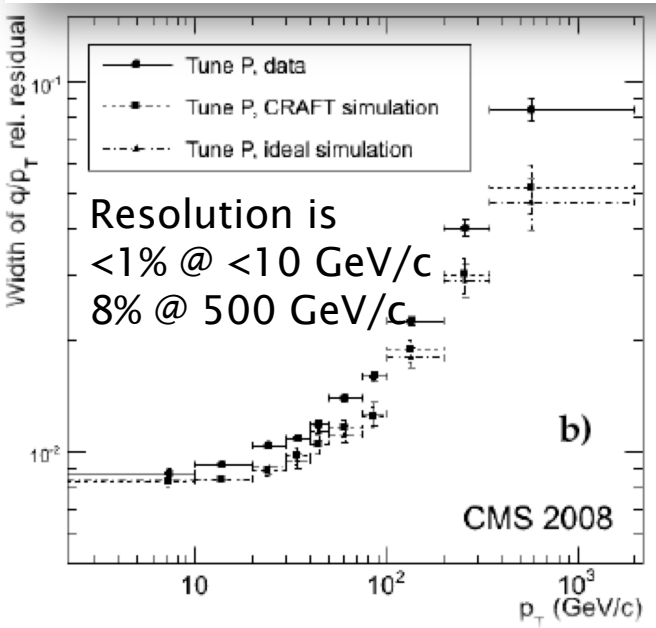
http://arxiv.org/abs/0911.4994

$$R(q/p_T) = \frac{(q/p_T)^{upper} - (q/p_T)^{lower}}{\sqrt{2}(q/p_T)^{lower}}$$

Splitting muons tracks in "upper"/"lower"part and comparing

- transverse impact parameter
- Measured p_T

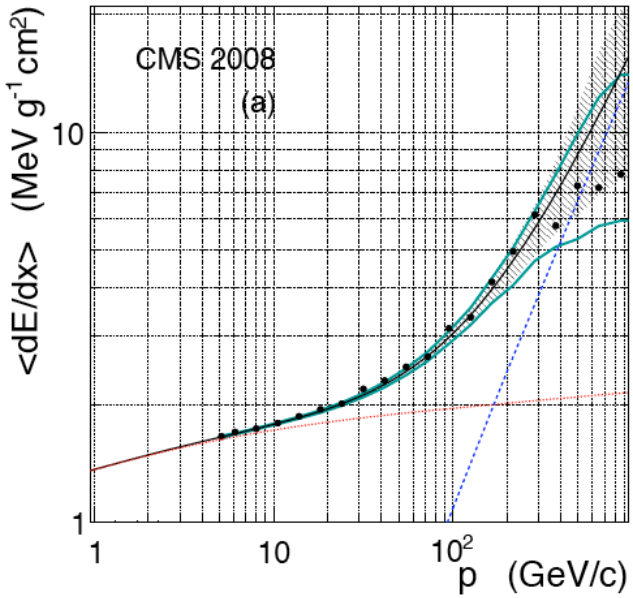




CRAFT: Calorimeters

First measurement of muon critical energy in lead tungstate $160^{+5}_{-6} \pm 8$ GeV

Using only bottom half of ECAL
Angle between muon and crystal axis < 0.5 radians
Scale measured in TB confirmed at 2% accuracy

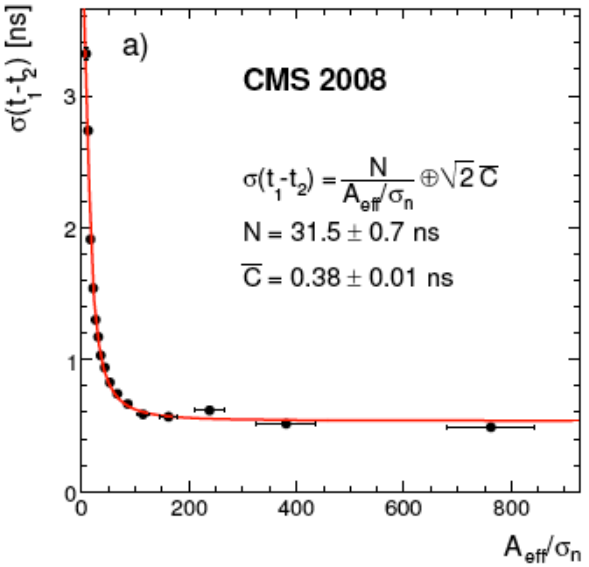


Muon stopping power as a function of muon momentum

http://arxiv.org/abs/0911.5397

Improved understanding of noise and synchronization in ECAL and HCAL

http://arxiv.org/abs/0911.4044



ECAL time resolution as a function of effective amplitude (amplitude/noise). **Sub-ns synchronization** between channels is achieved

For HCAL time spread measured to be ±2ns

http://arxiv.org/abs/0911.4877

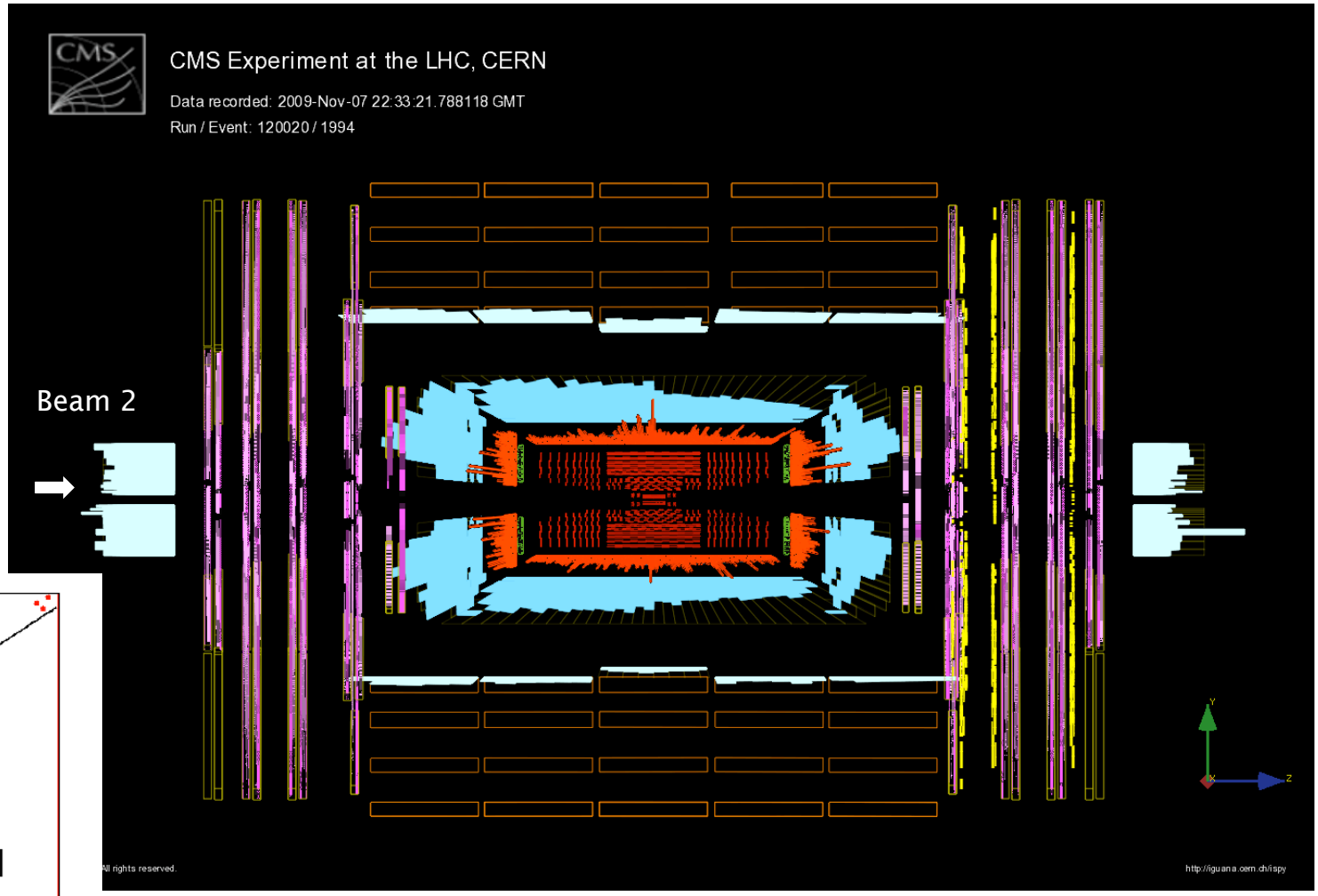
Commissioning with beam

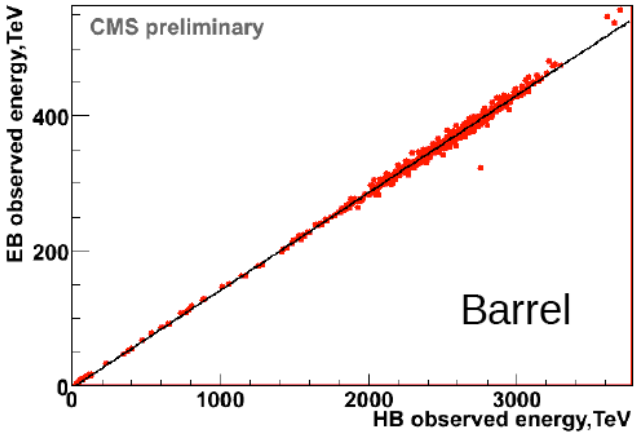
Appetizer: the LHC sector test

Dump LHC beam on collimators upstream to CMS

2 series of “splash events” in Sept08 and Nov09 (in 2009 collected 1105 shots)

Allow to check/improve synchronization of individual channels in calorimeters (tracking off, muons at reduced HV)

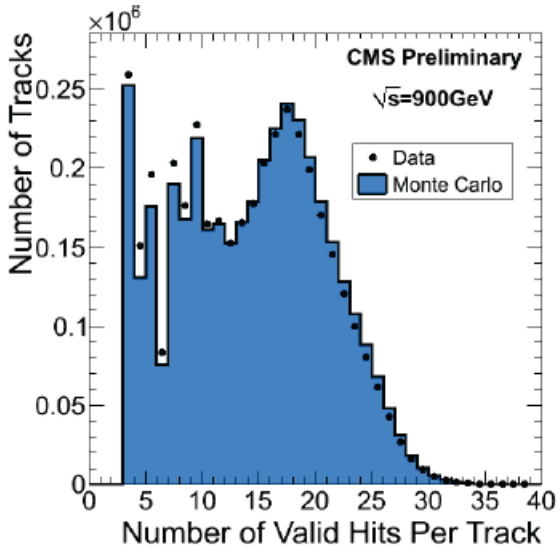


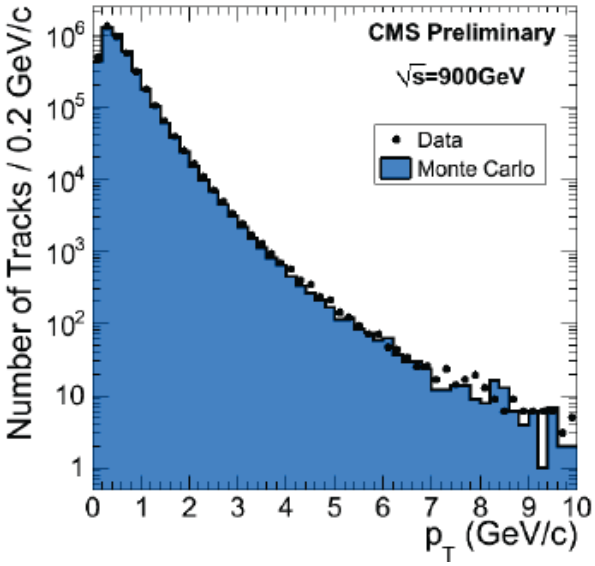


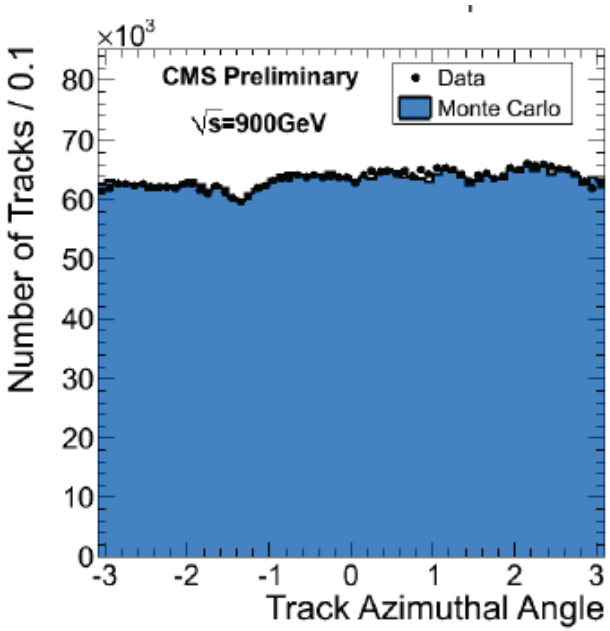
Correlation between energy measured in ECAL and HCAL barrel

First tracks from collisions @ 900 GeV

Commissioning of track reconstruction algorithm:







Tracks are seeded either by pixel triplets or pairs with constraint on the beam spot
Track selection applied here:
$|d_z/\sigma| < 10$
$\sigma_{pT}/p_T < 10\%$

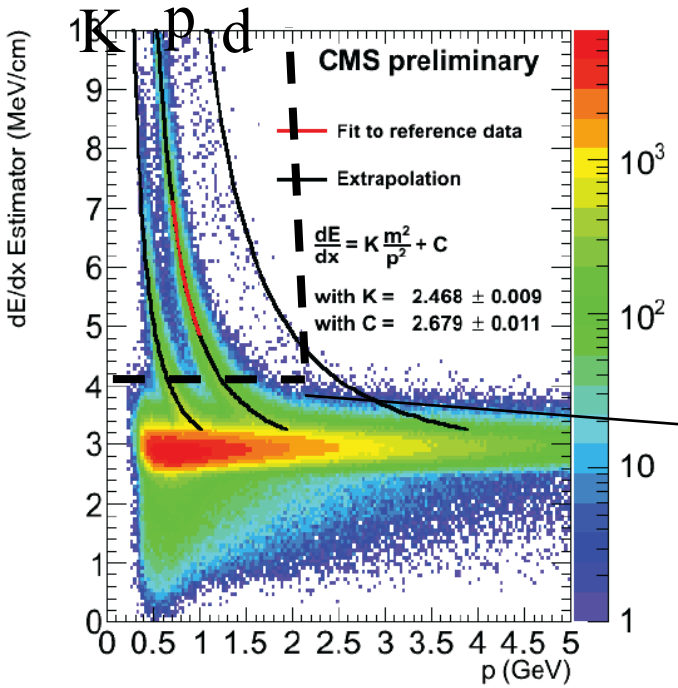
Dips in azimuthal distribution ($\phi = -1.2$) are due to inactive modules and are well reproduced in MC (affecting only low p_T tracks)

More advanced tools: dE/dx

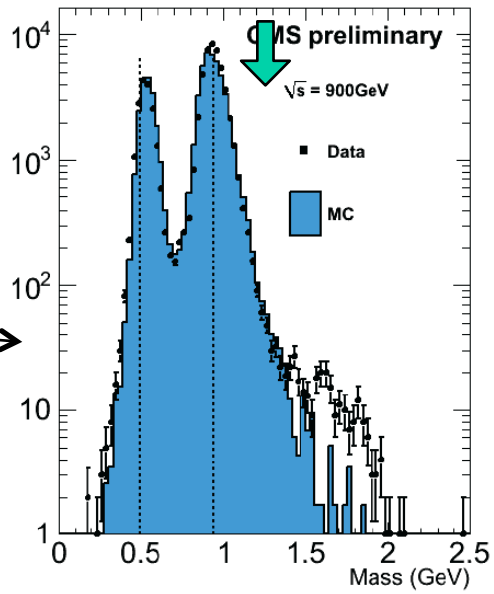
CMS Silicon tracker has analog readout

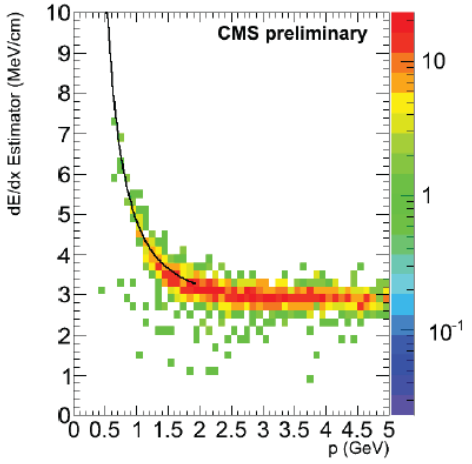
$$dE/dX = \left(\frac{1}{N} \sum_i c_i^k \right)^{1/k} \quad k = -2$$

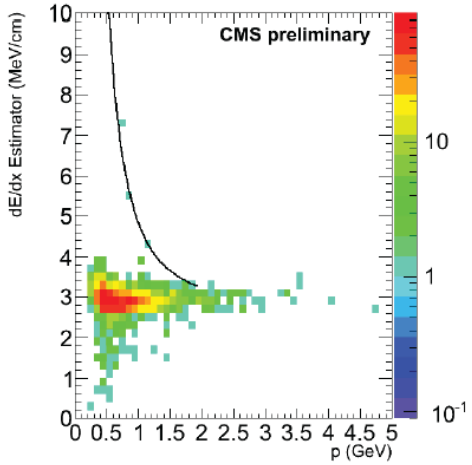
dE/dX computed for tracks:
- ≥ 10 Strip Hits
- compatible with primary vertex $|d_{xy}|<2$cm, $|d_z|<15$cm



p < 2 GeV
dE/dX > 4.15 MeV/cm





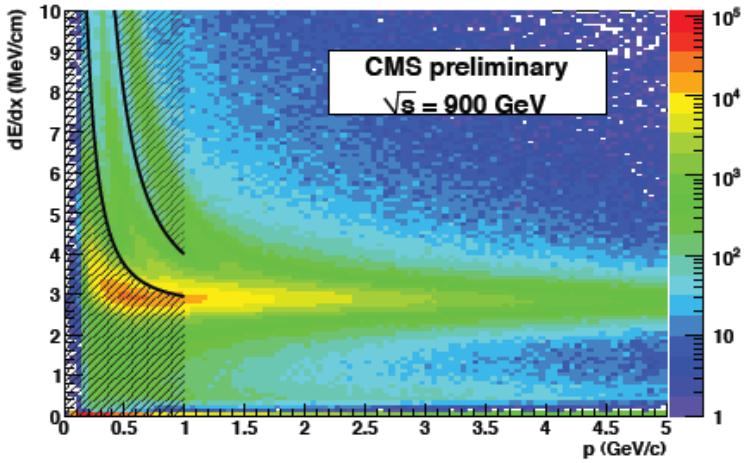


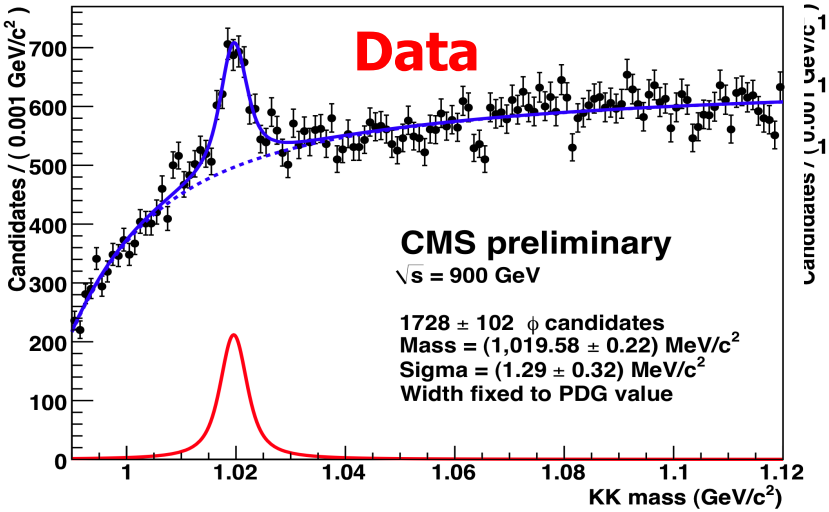
Validated using higher and lower momentum track from selected Λ^0 ➔pπ decays

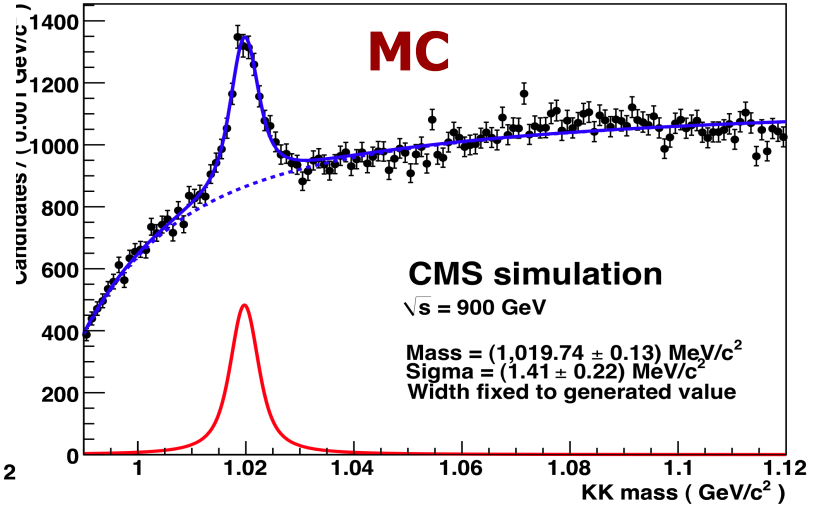
dE/dX @ work: ϕ(1020)➔K^+K^-

Φ →KK:

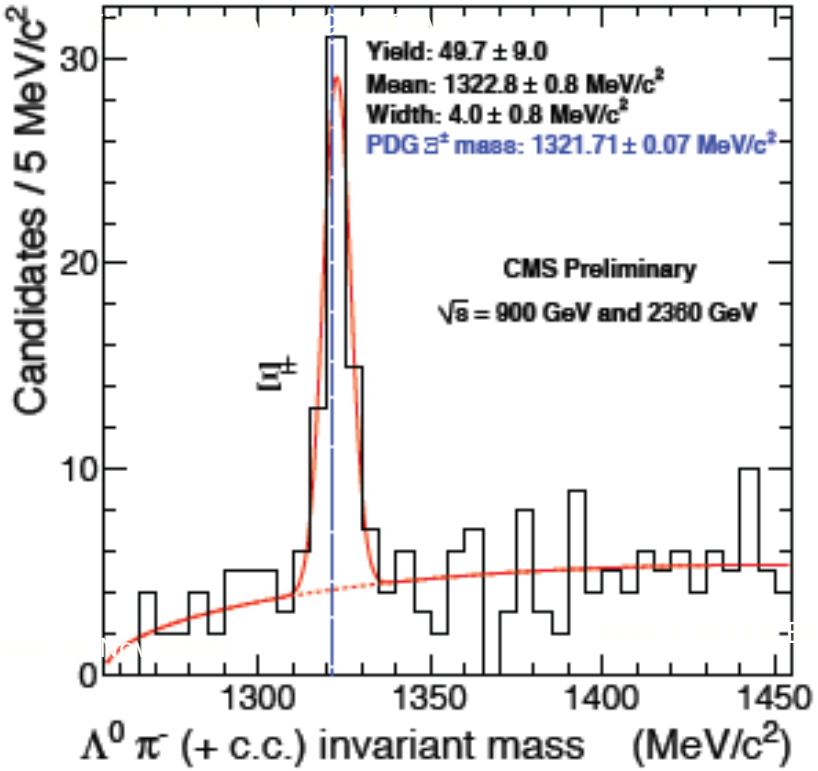
Kaons with tracks
≥5hits, $\chi^2_{norm} < 2$, d_{xy}<3mm,
p_T>0.5 GeV
Particle ID:
p>1GeV OR
dE/dx inside kaon range



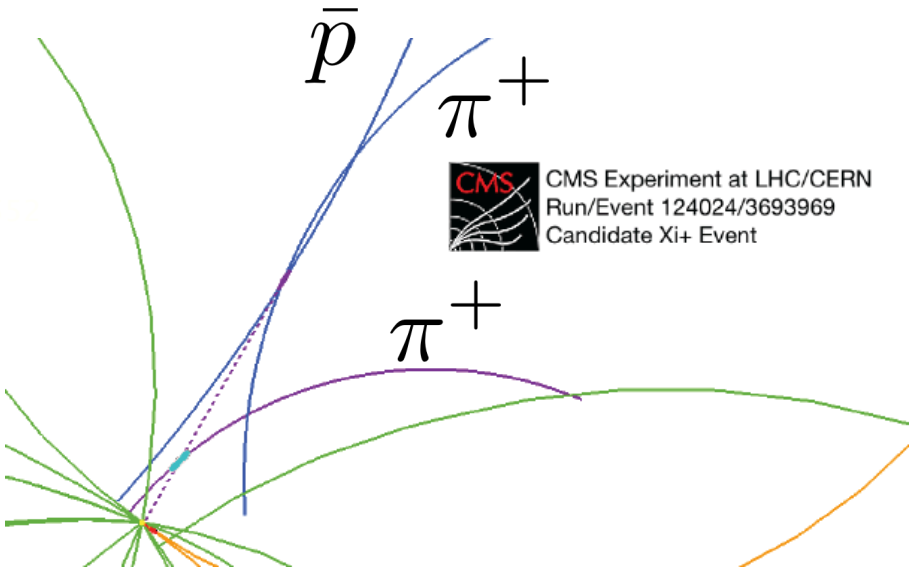




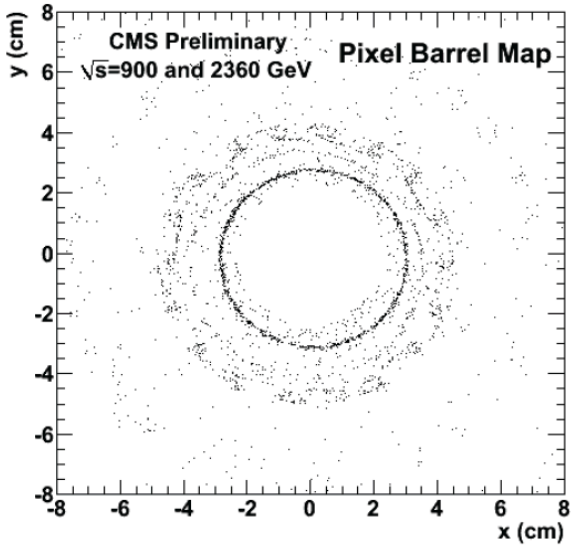
Secondary vertex @ work

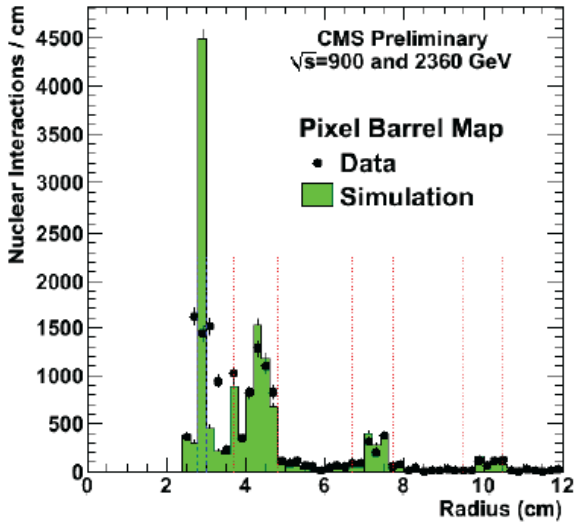


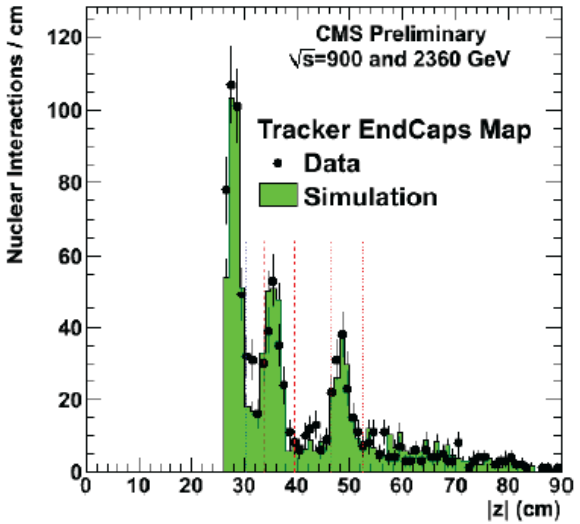
Selection for Ξ:
Lambda mass within 8 MeV
Lambda-pion vertex fit probability > 1%
Both pions have the same sign charge
3D impact parameter significance > 3



Nuclear interactions







Beam pipe slightly off-center

Inner carbon fiber shielding of the pixel visible

About 5% of charged pions interact in the tracker volume

Resolution of the nuclear interaction vertex is about 50 μ m (vertices associated to V_0 and conversions are removed)

Calorimetry @ work: jets @ CMS

Redundant way of reconstructing jets in CMS

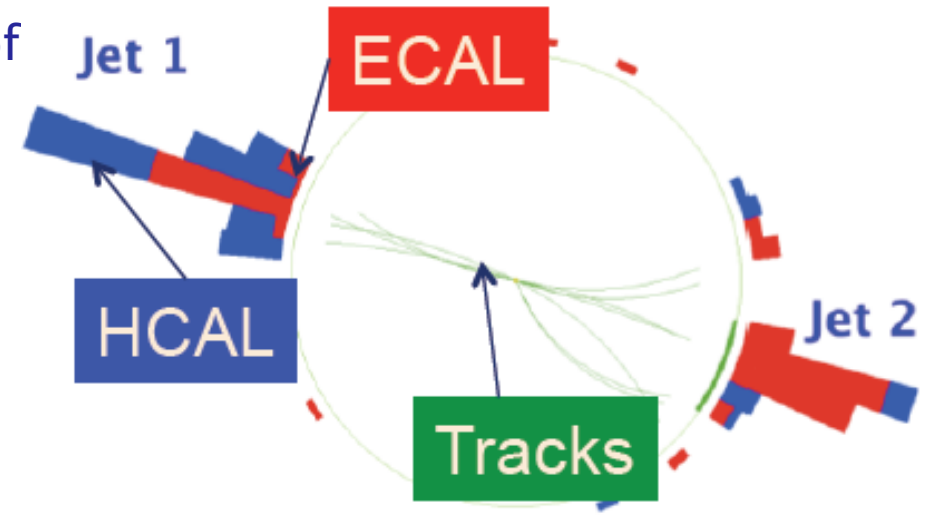
CaloJets: using CaloTower constituents

Track Corrected Jets (Jet + Tracks): replacing for charged particles calorimetric response with corresponding tracks and adding out of cone tracks

Particle Flow Jets: exploiting at best redundancy and granularity of the CMS detector. PF aims to reconstruct individual particles, then cluster them in jets

For these first studies focused only on the antiKT=0.5 algorithm
JHEP04(2008)063

Montecarlo based energy corrections are applied in what follows



Inclusive & Di-jets selections @ 900 Gev

Di-Jet selection

Loose JetId is applied, high purity achieved with topological requirement

	CaloJets	JPTJets	PFJets
p_T^{min}	10 GeV	8 GeV	8 GeV
η^{max}	3.0	2.0	3.0

Selection	$\sqrt{s} = 900$ GeV		
	CaloJets	JPTJets	PFJets
$p_T > p_T^{min}$, $\lvert\eta\rvert < \eta^{max}$	574	418	719
$\lvert\lvert\Delta\varphi(j_1, j_2)\rvert - \pi\rvert < 1.0$	339	268	556
loose JetID	246	218	531

#Events passing selection

Inclusive Jet selection

No topological cut: more sensitive to instrumental bkg

Tighter JetId is applied

	CaloJets	JPTJets	PFJets
p_T^{min}	15 GeV	13 GeV	10 GeV
η^{max}	2.6	2.0	3.0

Selection	$\sqrt{s} = 900$ GeV		
	CaloJets	JPTJets	PFJets
$p_T > p_T^{min}$, $\lvert\eta\rvert < \eta^{max}$	1462	588	2499
tight JetID	459	302	2088

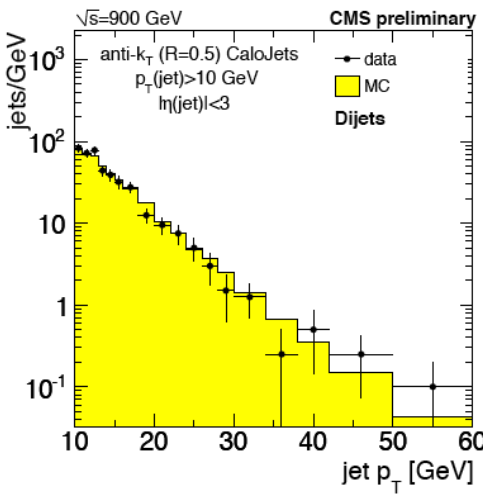
#Jets passing selection

Observed spectra @ 900 GeV: Di-Jets and Inclusive Jets

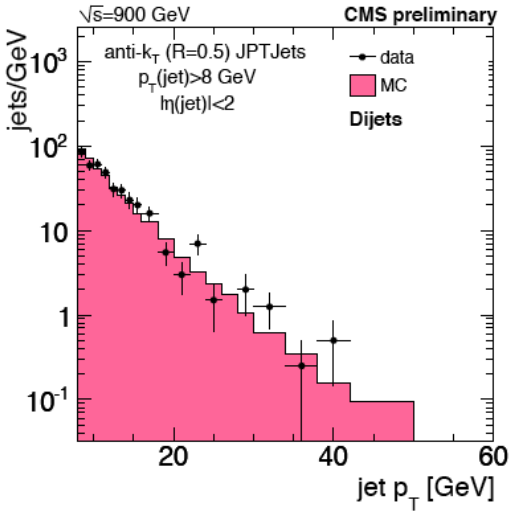
Di - Jets

Good agreement with MC

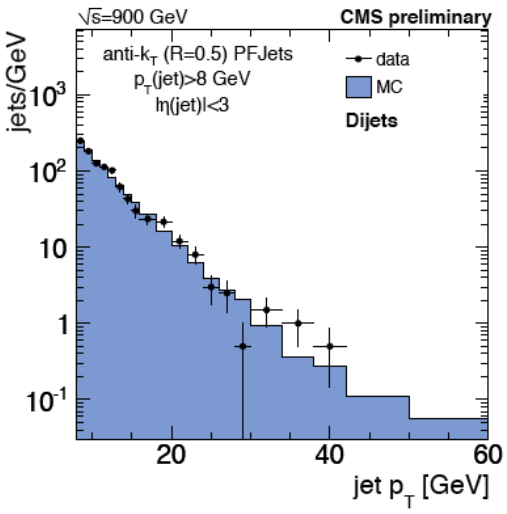
Inclusive -jets



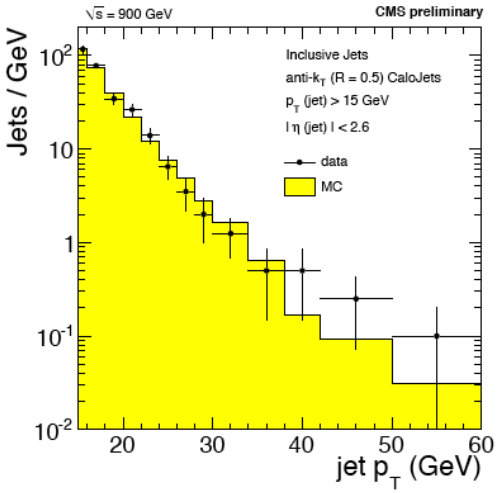
CaloJets

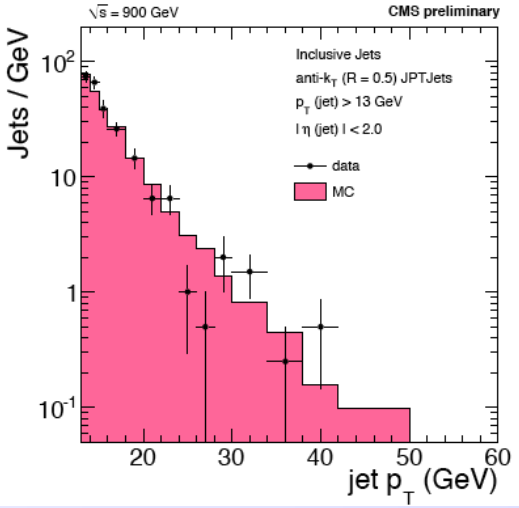


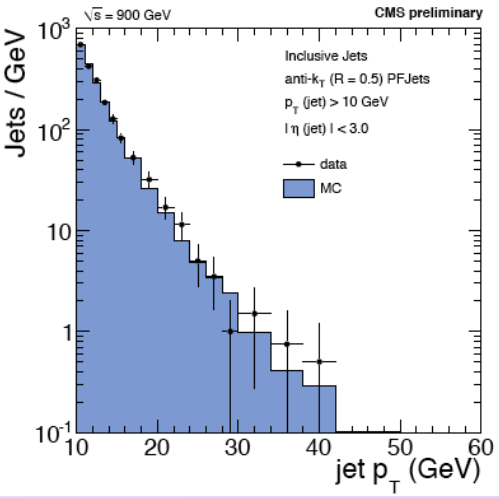
JPT



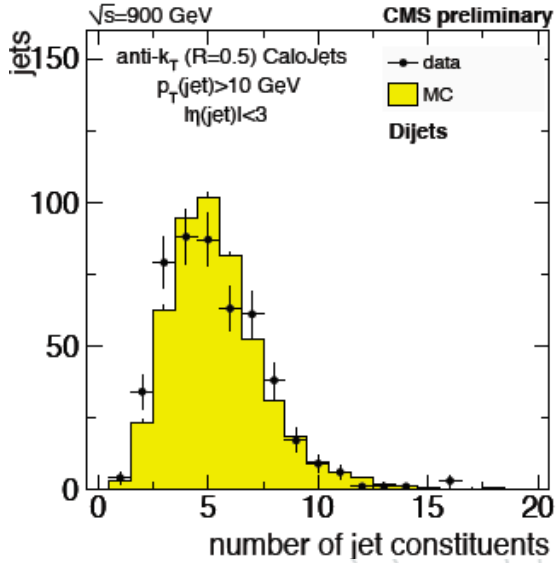
PFJets

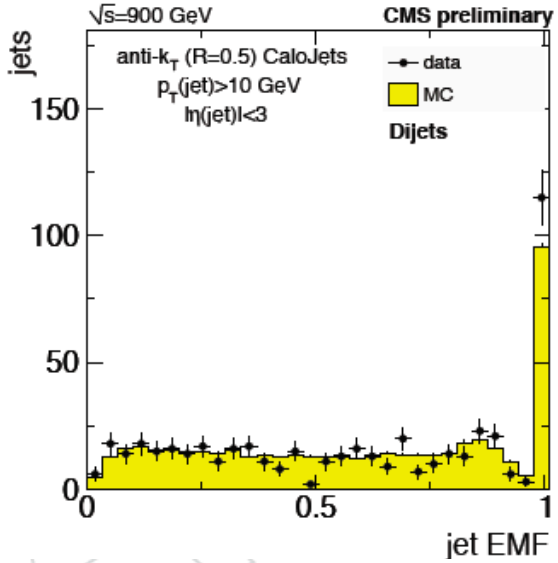


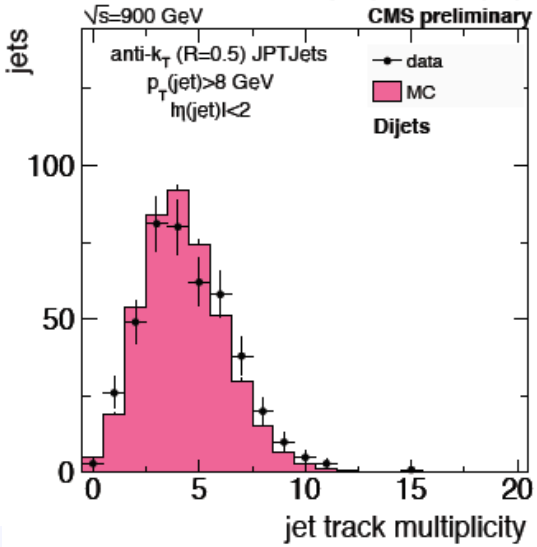


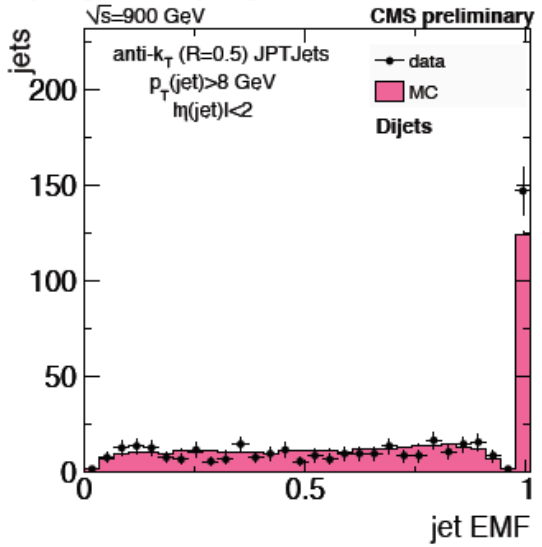


Some Jet properties





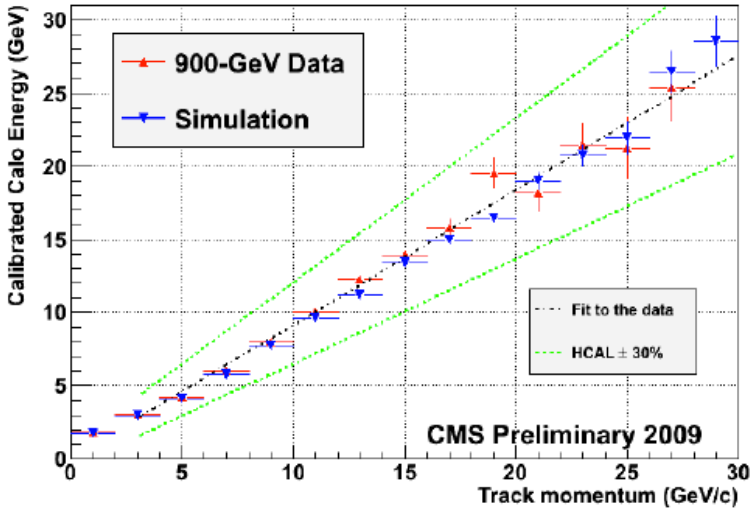




Distributions are for jets selected in di-jet events

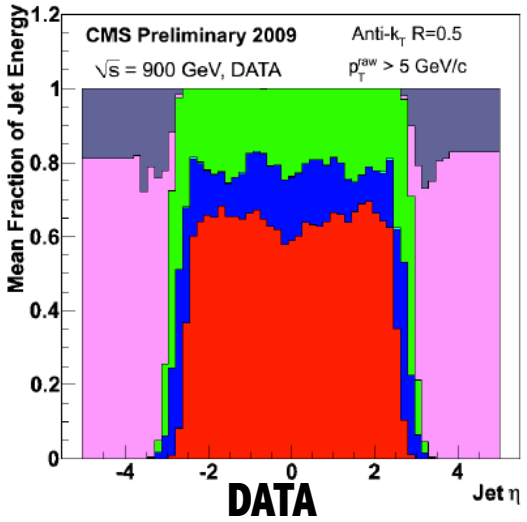
Confident to look at jets at higher Et in 7 TeV data

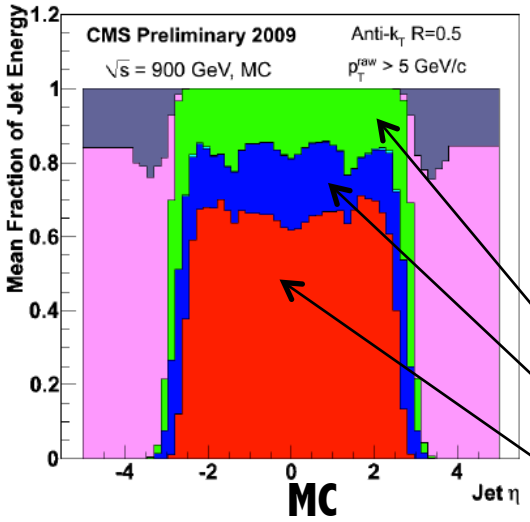
PF commissioning



Single particle response in the calorimeter seems to be well reproduced by MC. Fundamental ingredient for the ParticleFlow and Jet+Tracks algorithm

$|\eta|<2.4$, $1<p_T<30$ GeV, calorimeter calibration obtained for the moment from MC





Inclusive PF jets uncorrected p_T> 5 GeV (no further cut is applied!)

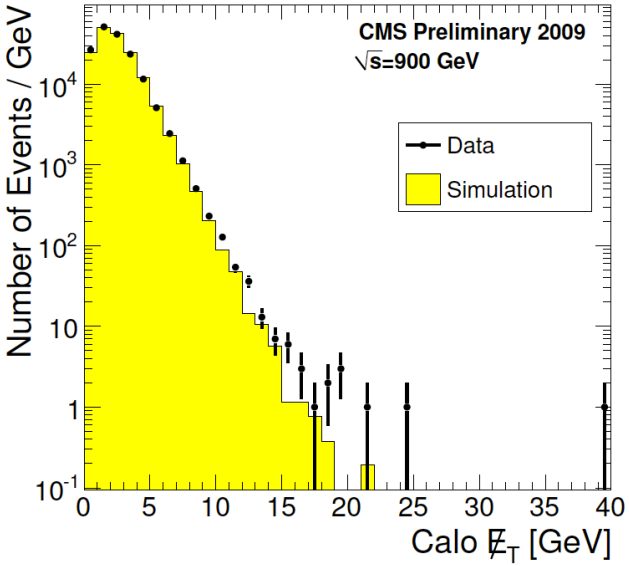
Different jet components as a function of η

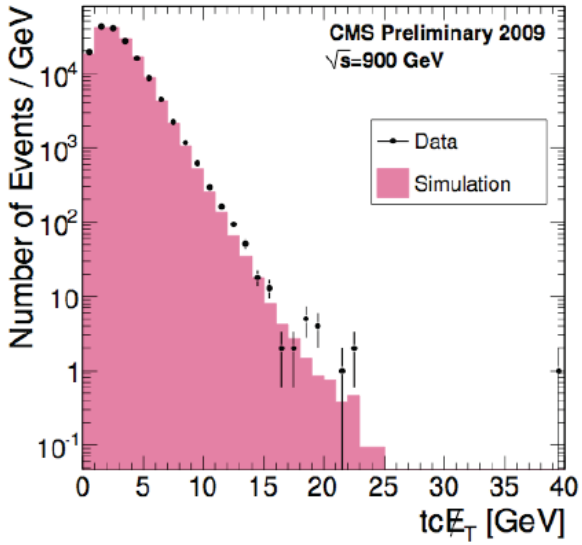
Neutral hadrons
Photons
Charged hadrons

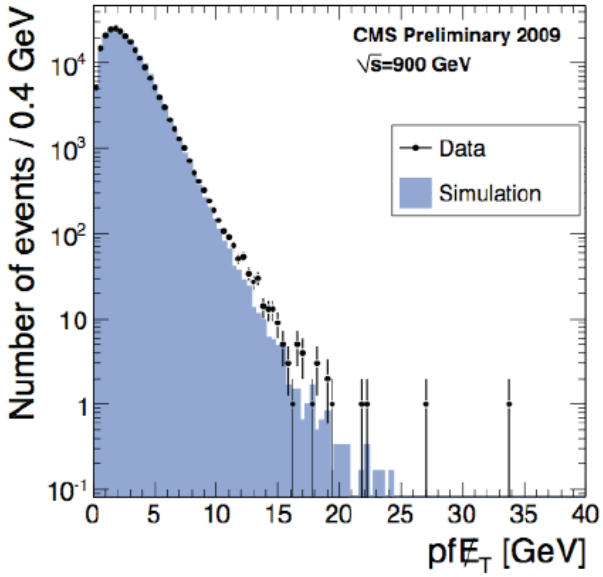
Commissioning of Missing Transverse Energy

- Most sensitive variable to instrumental background
- 3 MET calculation methods
  - CaloMET
  - Tracker corrected MET
  - MET from Particle Flow
- 900 GeV data have been used to start commissioning the calorimeter noise removal algorithms. Tools are in place for:
  - Particle Hits in HF PMT windows and fibers (known since test beam)
  - Coherent noise in HB/HE due HPD discarges and pedestal shifts (known since Cosmic runs, random occurrence)
  - Isolated anomalous signals in EB
  - Beam halo signals in calorimeters

MET distributions

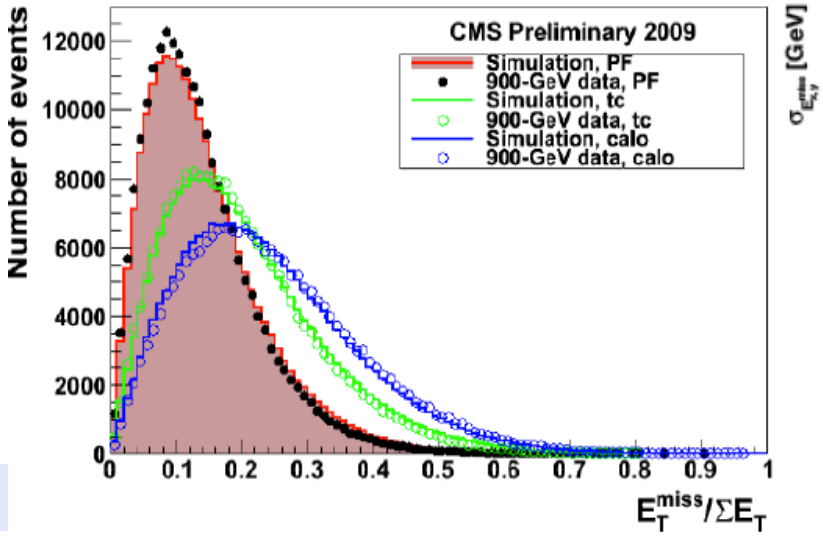




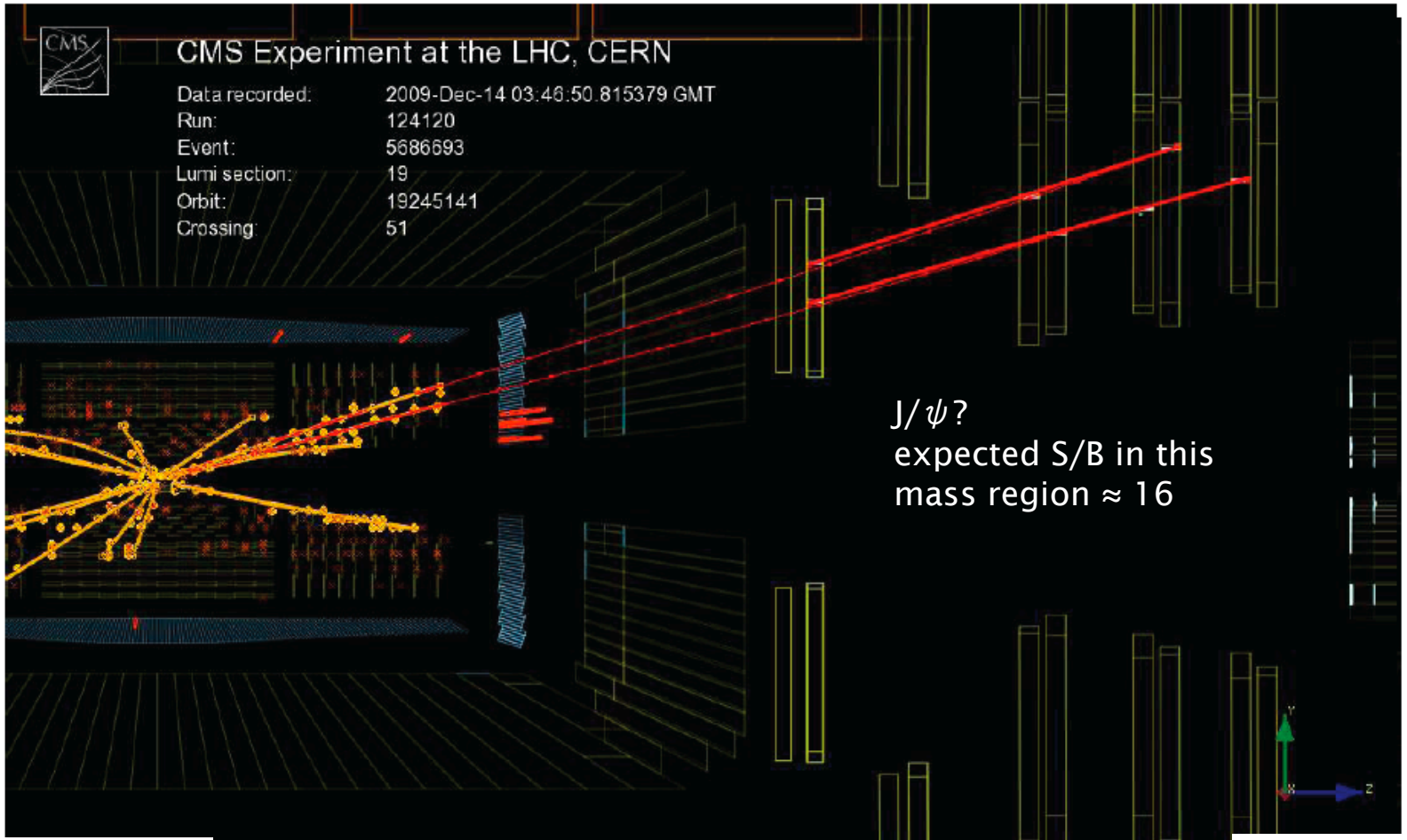


Calorimeter noise cleaning applied for all the 3 methods. MC agreement satisfactory

Particle flow MET quite promising!



Towards lepton commissioning: Di-muon event @ 2.36 TeV



Dimuon vertex prob = 89.5%
$c\tau = (- 31 \pm 46)\ \mu m$

Mass resolution is 37 MeV

$p_T(\mu_1) = 3.6$ GeV/c, $p_T(\mu_2) = 2.6$ GeV/c, $m(\mu\mu) = 3.03$ GeV/c^2

Summary

- CMS commissioning is well underway
  - Cosmic runs allowed us to have a good understanding of our detector before beam
  - Good agreement between first data @ 900 GeV and MC in several areas: tracking, calorimeters, jets, MET…
  - Understanding of noise, calibration and alignment already at a level that allows first physics studies to be done
- But still lot of work ahead of us:
  - Not many signal electrons and muons have been observed @ 900 GeV (mostly fakes). First observations of J/ψ, Y, W, Z signals are not far… We need these signals to fully commission lepton reconstruction (study efficiencies, identification and fake rate)
  - And also: improve calibration of calorimeters, electromagnetic energy scale, jet energy scale, tracker material…