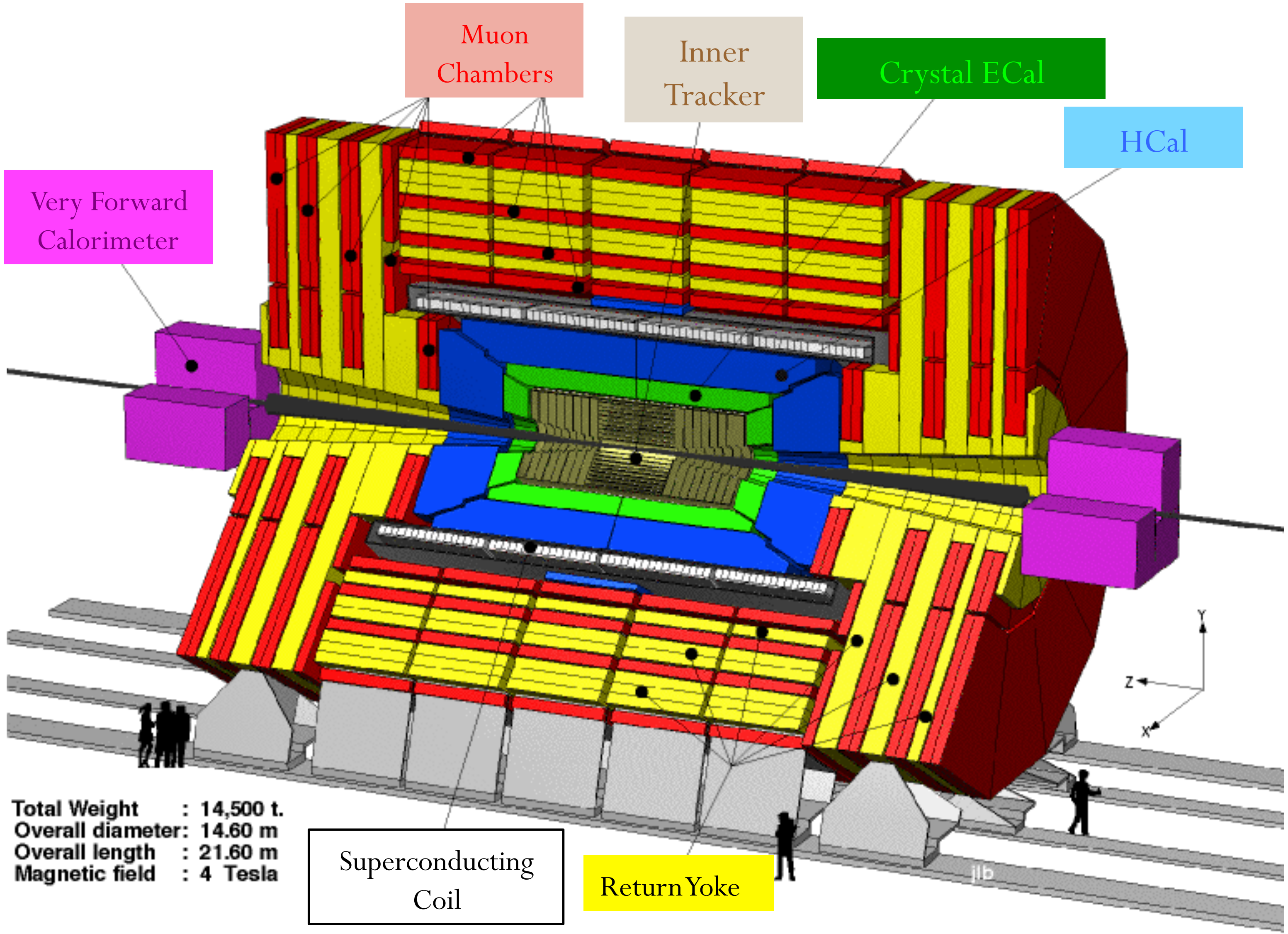
Status and first results on proton-proton collisions at 900 GeV and 2.36 TeV in CMS

Lamia Benhabib

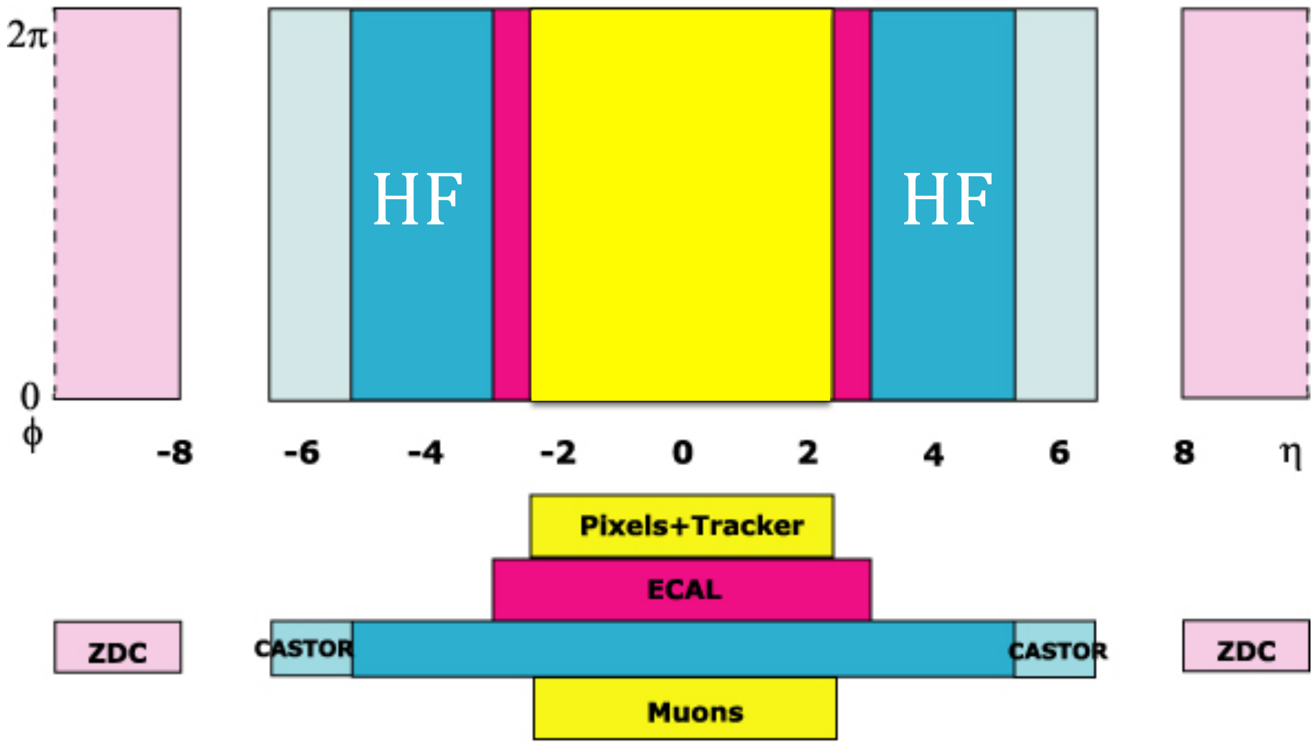
Rencontre ions lourds /heavy-ion meeting
IPN Orsay
09.04.2010

The CMS detector layout

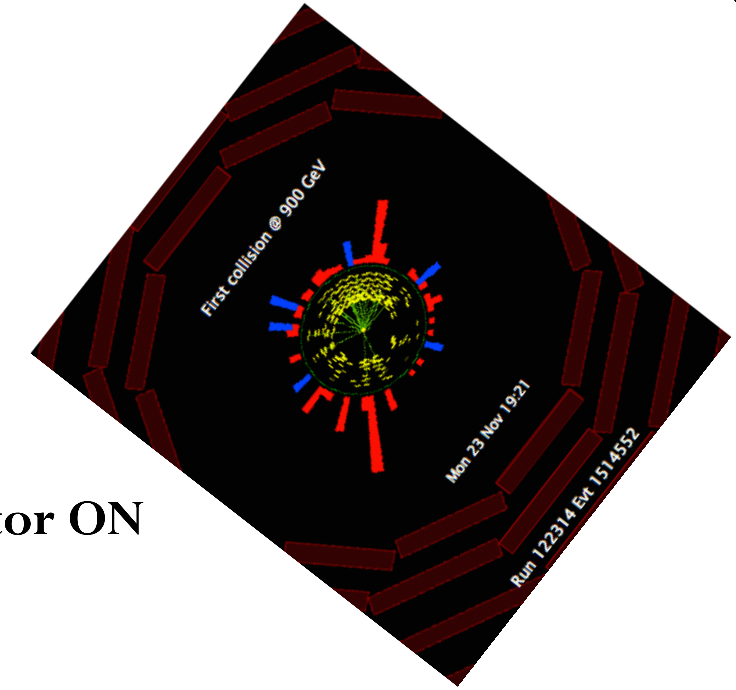


CMS phase-space coverage

- CMS: full ϕ and almost full η acceptance at the LHC
- Charged tracks and muons: $|\eta| < 2.4$
- Electrons and photons: $|\eta| < 3$
- Jets, energy flow: $|\eta| < 6.7$ (plus $|\eta| > 8.3$ for neutrals, with the ZDC)



Introduction



- First LHC collisions : Nov 23rd
- First stable beams $\sqrt{s}$ = 900 GeV : Dec 6th
- First collisions $\sqrt{s}$ = 2.36 TeV : Dec 14th
- First collisions $\sqrt{s}$ = 7 TeV : Mar 30th

- **Luminosity recorded by CMS with the full detector ON**
  - $\sim 10\ \mu b^{-1}$ $\sqrt{s}$ = 900GeV
  - $\sim 0.4\ \mu b^{-1}$ $\sqrt{s}$ = 2.36 TeV

  Normalized to $\sigma_{\mathrm{MinBias}} = 52$ mb

- **High data taking efficiency**

- **Trigger :** Inclusive configuration to accept Minimum Bias events (Beam Scintillator Counter)

- **In 2009 CMS recorded :** 350k MB events from p+p collisions $\sqrt{s}$ = 900 GeV
  20k MB events from p+p collisions $\sqrt{s}$ = 2360 GeV
- **Different measurements :** resonances, electrons, muons, jets…

The first CMS physics paper

PUBLISHED FOR SISSA BY SPRINGER
RECEIVED: *February 4, 2010*
ACCEPTED: *February 7, 2010*
PUBLISHED: *February 10, 2010*

Transverse-momentum and pseudorapidity distributions of charged hadrons in pp collisions at $\sqrt{s} = 0.9$ and 2.36 TeV

CMS Collaboration

ABSTRACT: Measurements of inclusive charged-hadron transverse-momentum and pseudorapidity distributions are presented for proton-proton collisions at $\sqrt{s} = 0.9$ and 2.36 TeV. The data were collected with the CMS detector during the LHC commissioning in December 2009. For non-single-diffractive interactions, the average charged-hadron transverse momentum is measured to be 0.46 ± 0.01 (stat.) $\pm$ 0.01 (syst.) GeV/c at 0.9 TeV and 0.50 ± 0.01 (stat.) $\pm$ 0.01 (syst.) GeV/c at 2.36 TeV, for pseudorapidities between -2.4 and $+2.4$. At these energies, the measured pseudorapidity densities in the central region, $dN_{ch}/d\eta|_{|\eta|<0.5}$, are 3.48 ± 0.02 (stat.) $\pm$ 0.13 (syst.) and 4.47 ± 0.04 (stat.) $\pm$ 0.16 (syst.), respectively. The results at 0.9 TeV are in agreement with previous measurements and confirm the expectation of near equal hadron production in $p\bar{p}$ and pp collisions. The results at 2.36 TeV represent the highest-energy measurements at a particle collider to date.

JHEP02(2010)041

arXiv:1002.0621v2 [hep-ex]

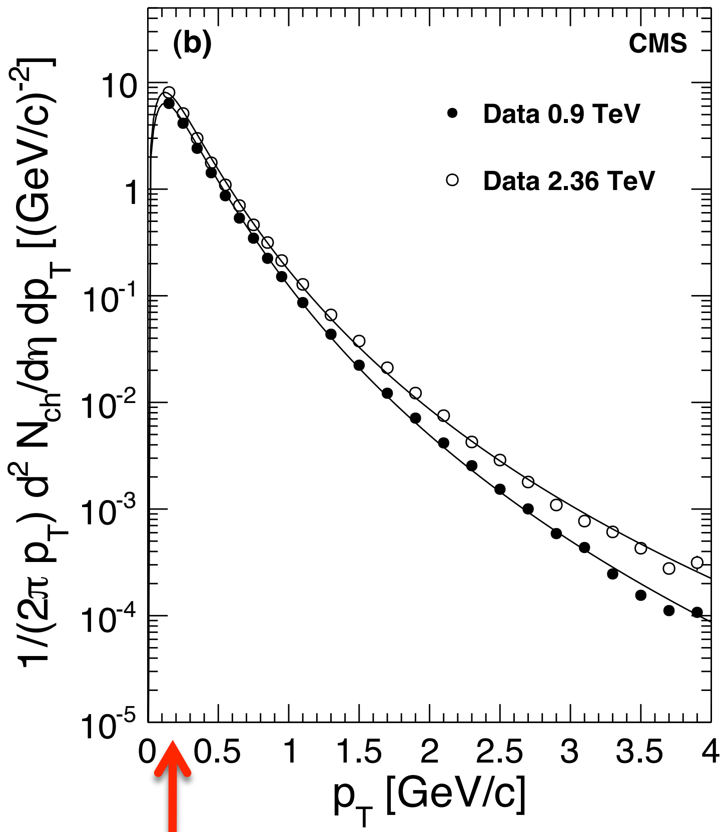
Charged hadron dN/dη and dN/dp $_T$

- Important for high-luminosity LHC runs with pile-up and relevant as reference for heavy ion physics

- Various processes involved :
- elastic
- single-diffractive,
- non-single- diffractive(NSD)

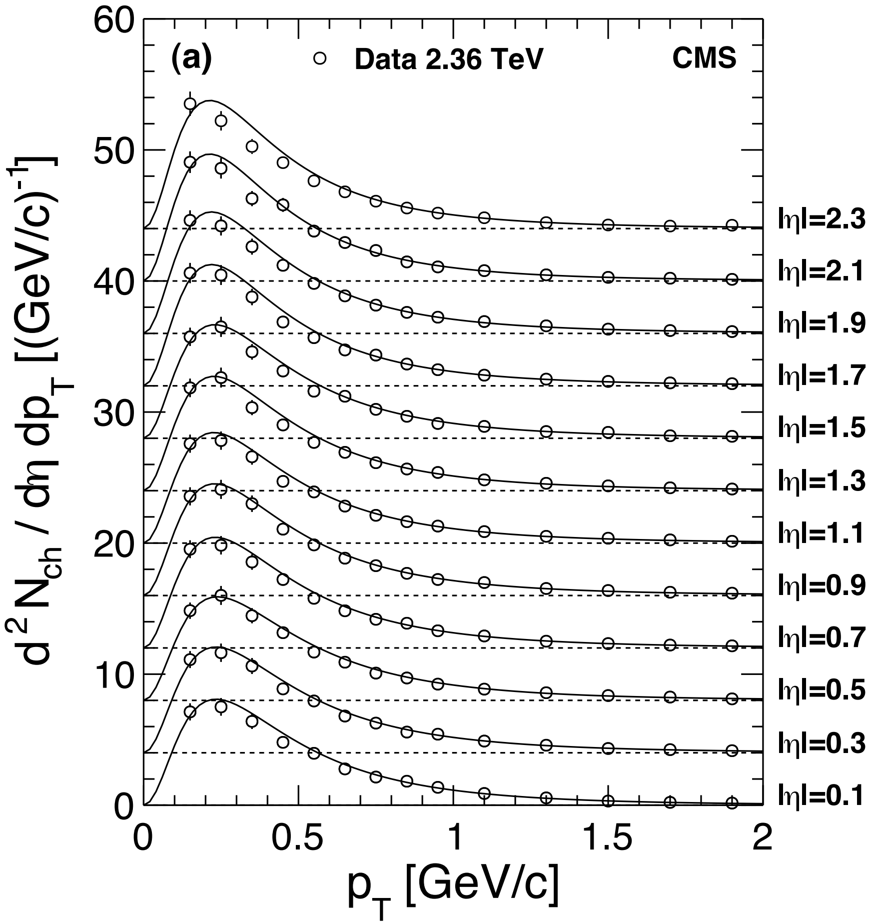
= double diffractive + non-diffractive

→ aim to measure the NSD component

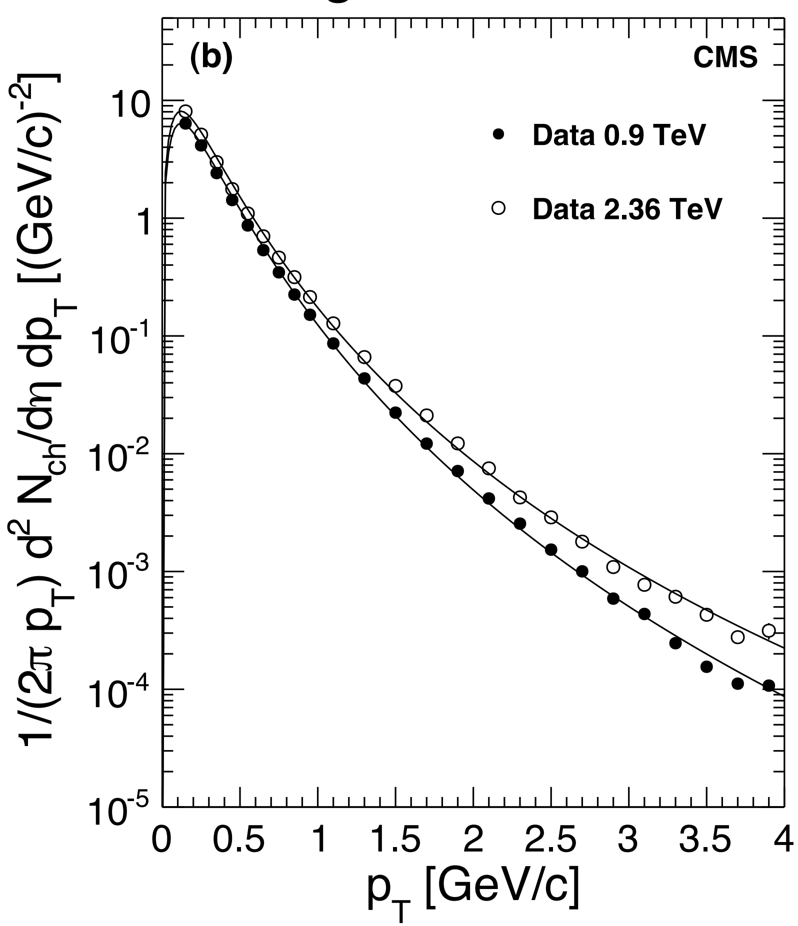


At very low pT, a big challenge for the tracking : 0.1 GeV/c in a B field of 3.8T corresponds to a beding radius of 8 cm

dN/dP $_T$ results



Integral for | η |<2.4



For 900 GeV p+p collisions (72637 events) and for 2.36TeV (18074 events)

Fitted with the empirical Tsallis function (exponential at low pT, power law at high pT)

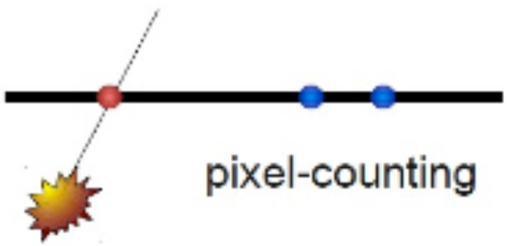
Integral used for dN/d η particle count (5% correction at low pT)

$<p_T> = 0.46 \pm 0.01(\text{stat}) \pm 0.01(\text{syst})$ 0.9TeV

$<p_T> = 0.50 \pm 0.01(\text{stat}) \pm 0.01(\text{syst})$ 2.36TeV

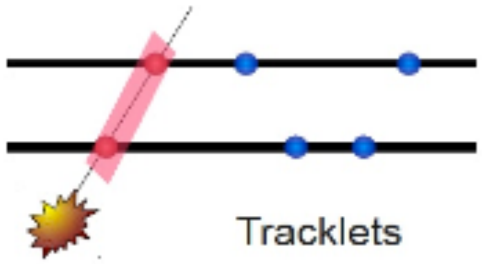
Three methods for dN/dη

- Pixeldetector: 53.3cm long, 3 layers with radii: 4.4, 7.3, 10.2 cm



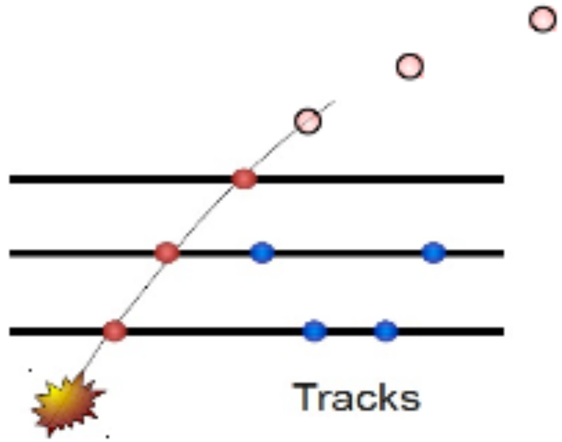
$p_T > 30$ MeV/c

- Clusters per layer
- $|\eta| < 2$
- 3 measurements of dN/dη
- Immune to mis-alignment
- Simplest method



$p_T > 75$ MeV/c

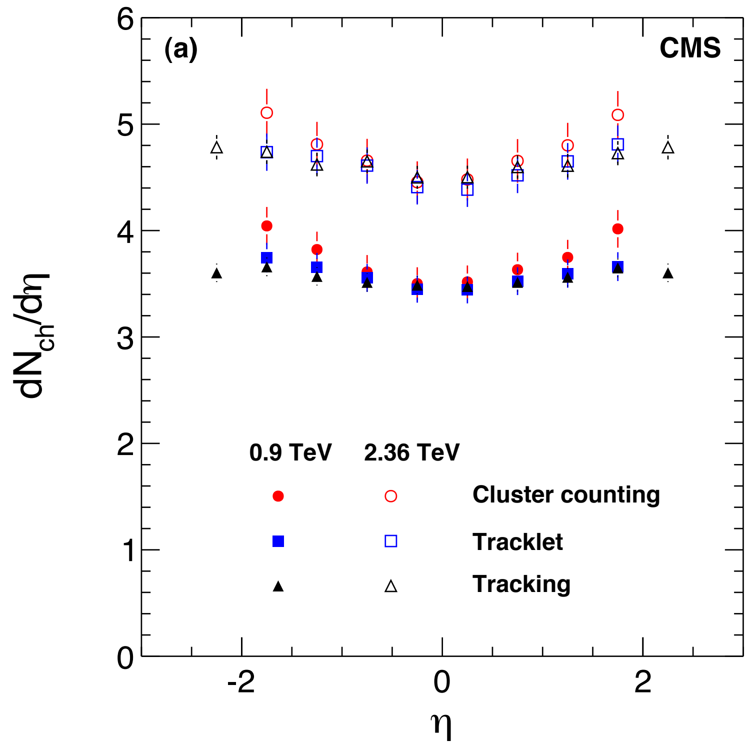
- 2 of 3 pixel layers
- $|\eta| < 2$
- 3 measurements of dN/dη
- Sensitive to mis-alignment

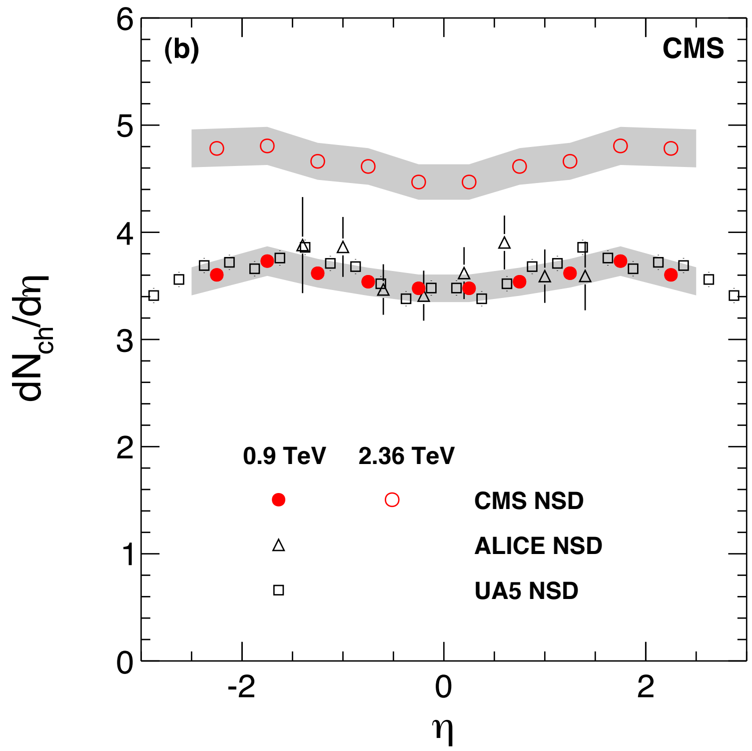


$p_T > 100$ MeV/c

- Full tracks (pixel and strips)
- $|\eta| < 2.4$
- dN/dη and dN/dpT
- Sensitive to mis-alignment
- Most complex

Results for dN/dη



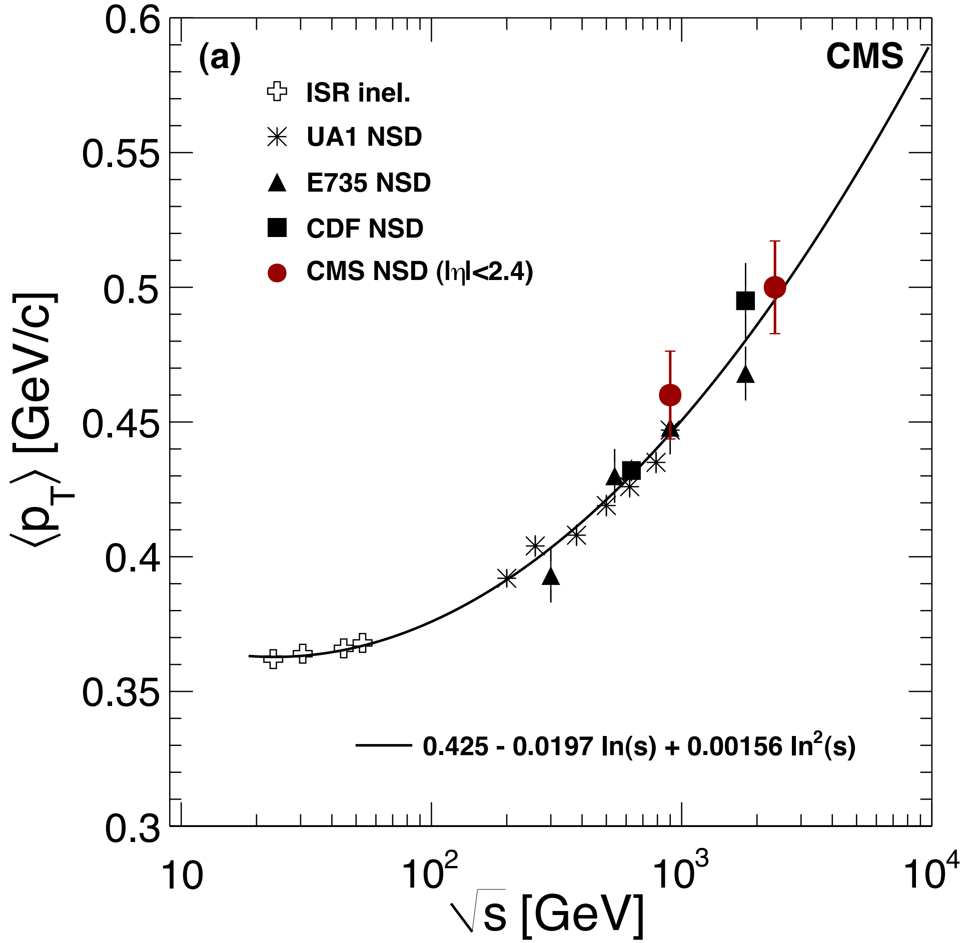


- 3 methods give consistent results
- Error bars show systematic errors (ranging from 4.4% to 2.4%)

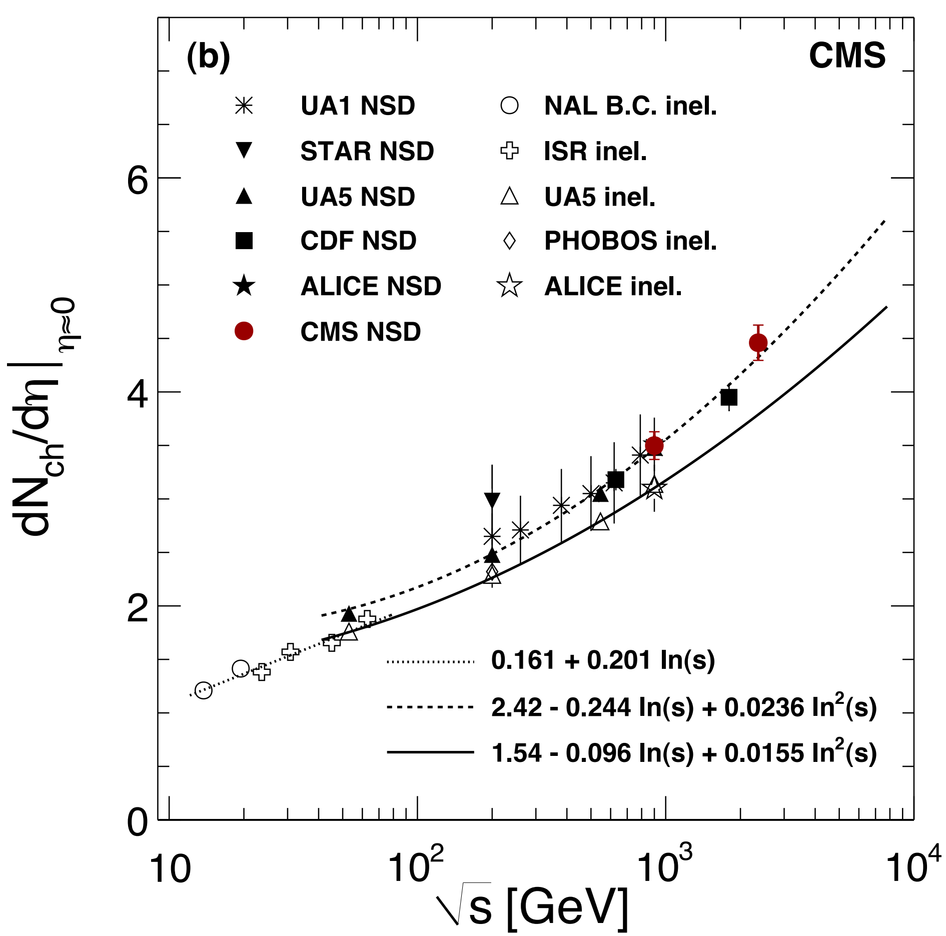
- 3 CMS methods are averaged
- Shaded band indicates systematic error
- Largest part is due to uncertainty in SD/DD contamination (2%).

UA5 and CMS results are symmetrized in η

Results: scaling with Energy



Variation of average p_T with center-of-mass energy



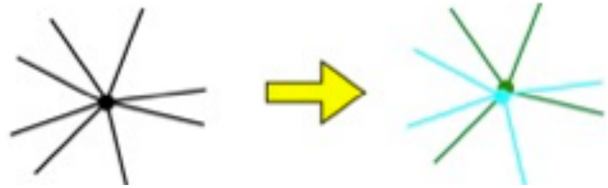
Variation of $dN/d\eta$ with center-of-mass energy

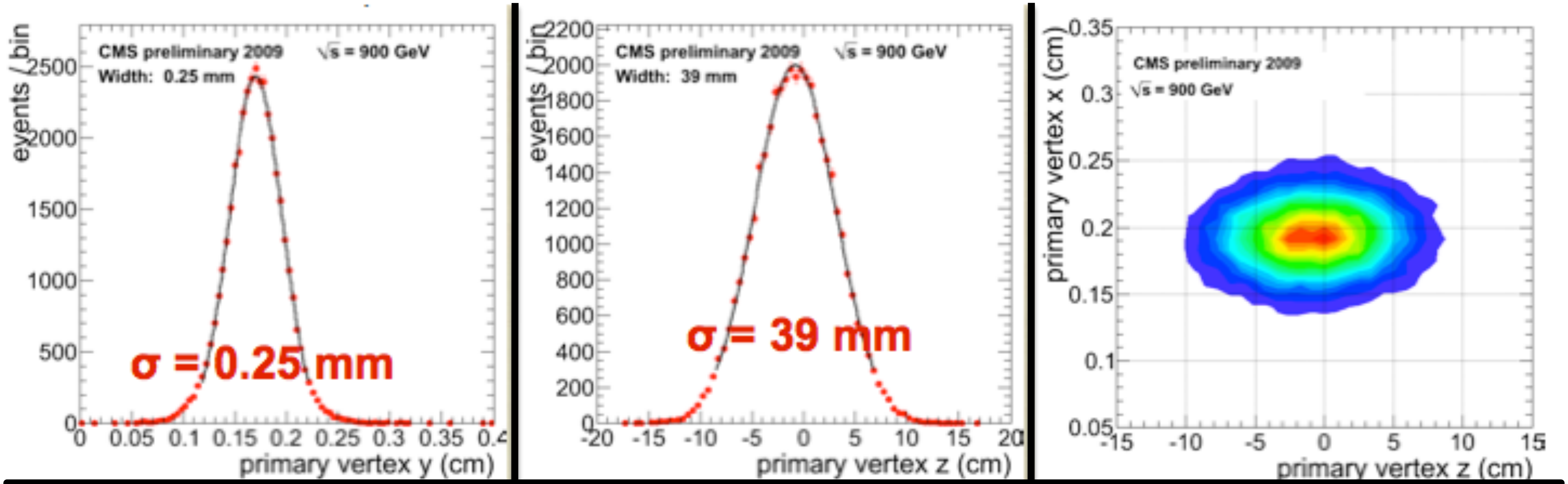
$dN/d\eta$ (2.36TeV) / $dN/d\eta$ (0.9TeV) = 28.4 % ±1.4 ± 2.6
significantly larger than prediction from PYTHIA&PHOJET resp. 18.4% & 14.5%

Other (yet unpublished) results…

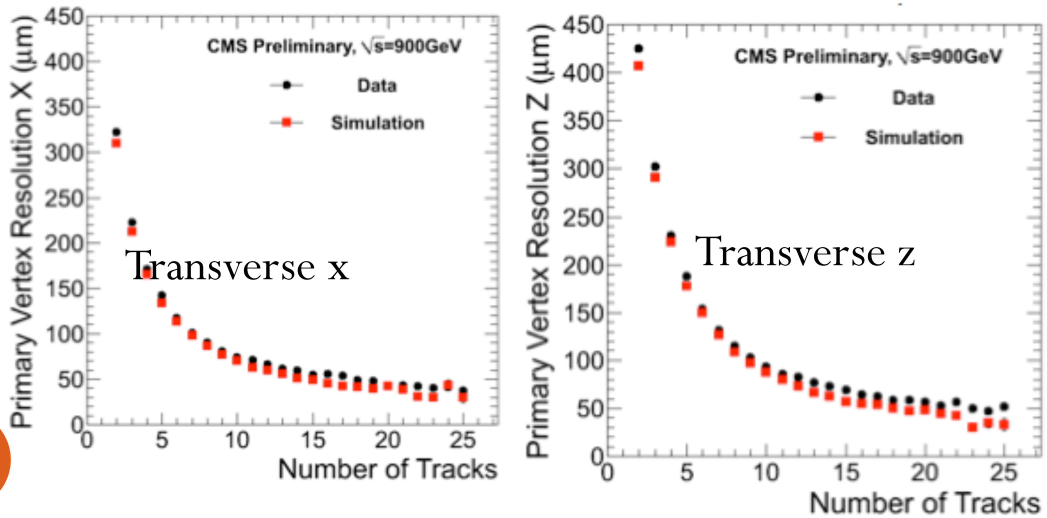
- Primary vertex reconstruction
- First CMS resonances: π^0 and η
- K_s and Λ^0 Mass and Lifetime
- Electrons
- Muons
- Jets
- Missing E_T

Primary vertex reconstruction



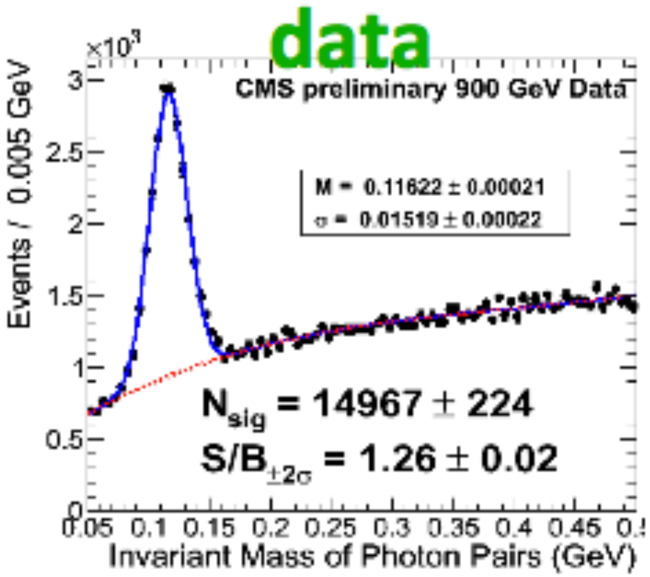


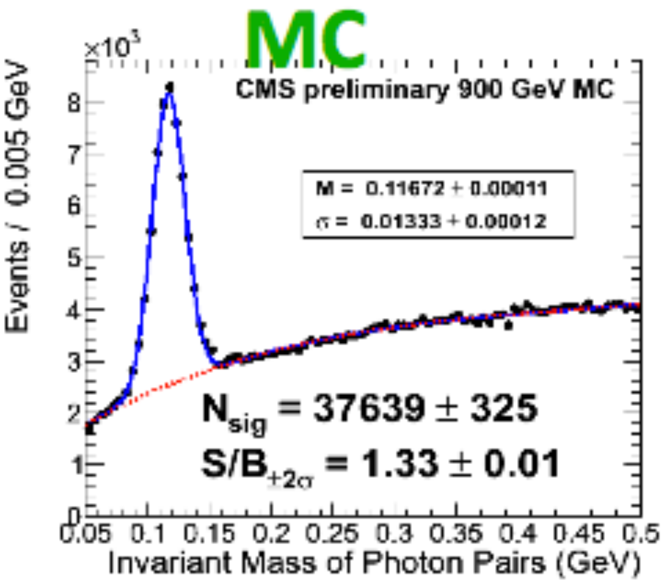
Primary vertex distribution for a single run : beam width estimated from a gaussian fit



- Separating tracks in two independent sets
- Comparing the fit
- Very good agreement with MC

First CMS resonances: π^0 and η



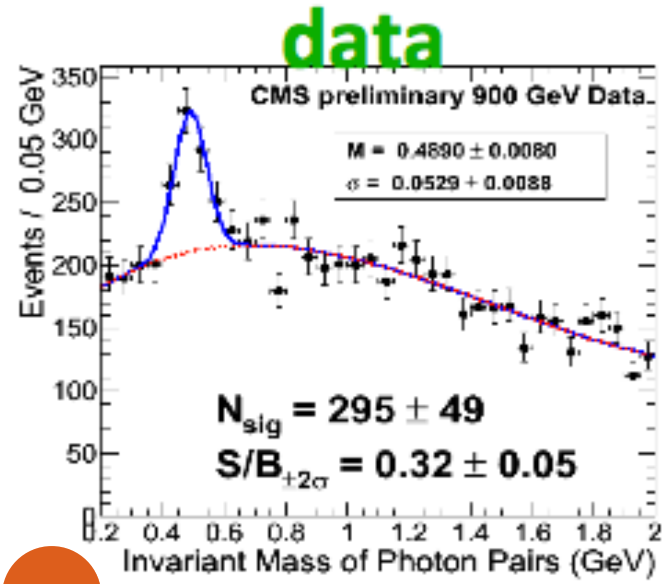


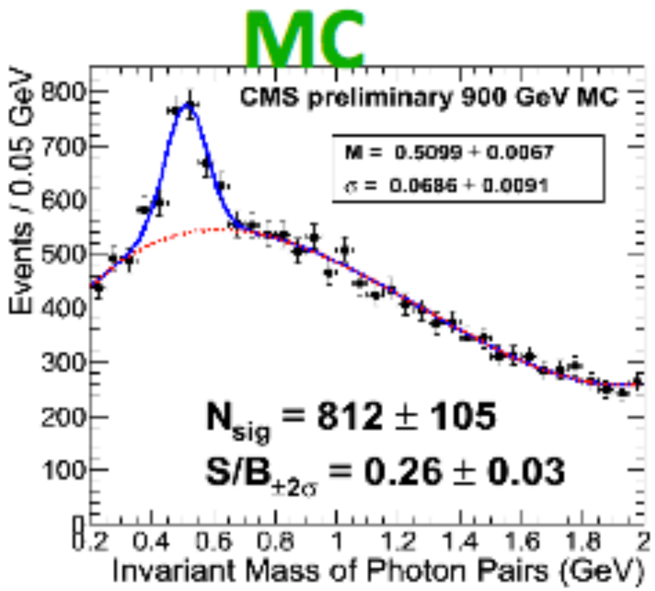
$\pi^0 \rightarrow \gamma\gamma$

- ECAL barrel ($|\eta|<1.479$)
- $E_T(\gamma) > 300$ MeV
- $E_T(\pi^0) > 900$ MeV
- shower shape

No all the corrections applied

→ mass is a bit low



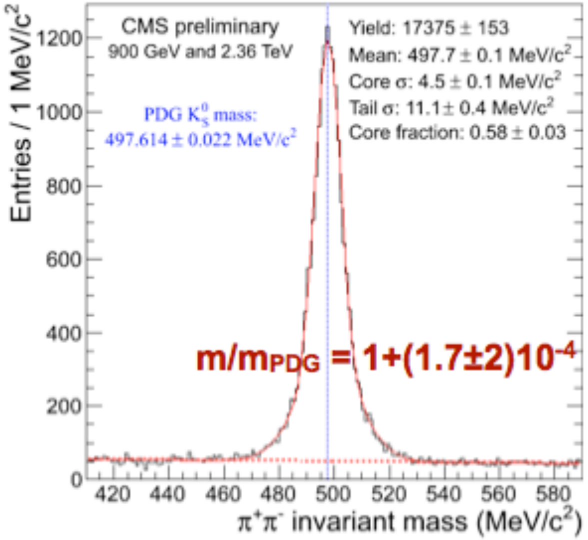


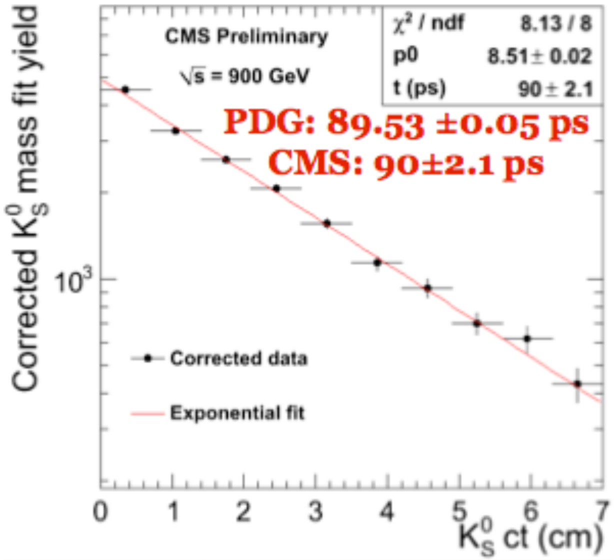
$\eta \rightarrow \gamma\gamma$

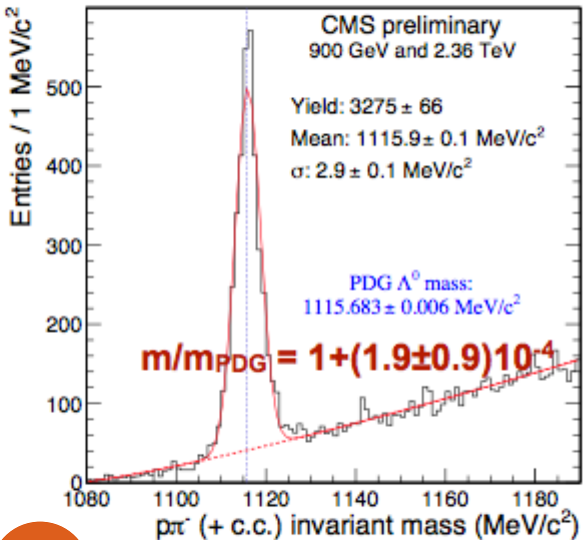
- Photon pairs in barrel
- $E_T(\gamma)$>400 MeV;
- $E_T(\eta)$>2.0 GeV;
- shower shape

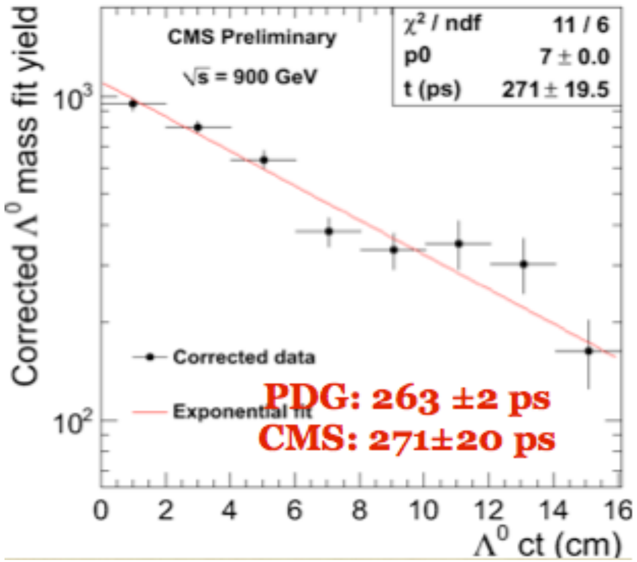
Good agreement data and MC: peak position and S/B

K_s and Λ_0 Mass and Lifetime



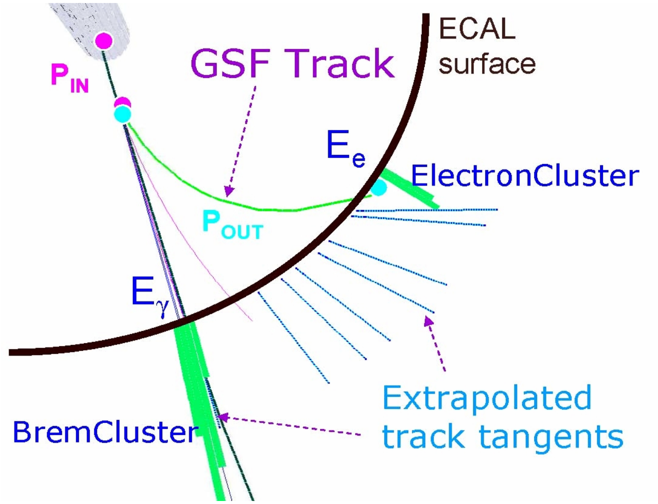






- Resolution of the mass fit:
  Ks : 7.99±0.14 MeV
  Λ_0: 3.01±0.08 MeV
- Agreement Data/MC
  Ks : 7.62 ± 0.03 MeV
  Λ_0 : 2.99 ± 0.04 MeV
- Measured lifetime in agreement with PDG
- Other Reconstructed resonances
  $\Xi \rightarrow \Lambda_0 \pi^-$ (+c.c.)
  $K^*(892)\pm \rightarrow K_0\, \pi\pm$

Electron reconstruction



- Electron reconstruction: affected by
- Material in front of ECAL
- Magnetic field

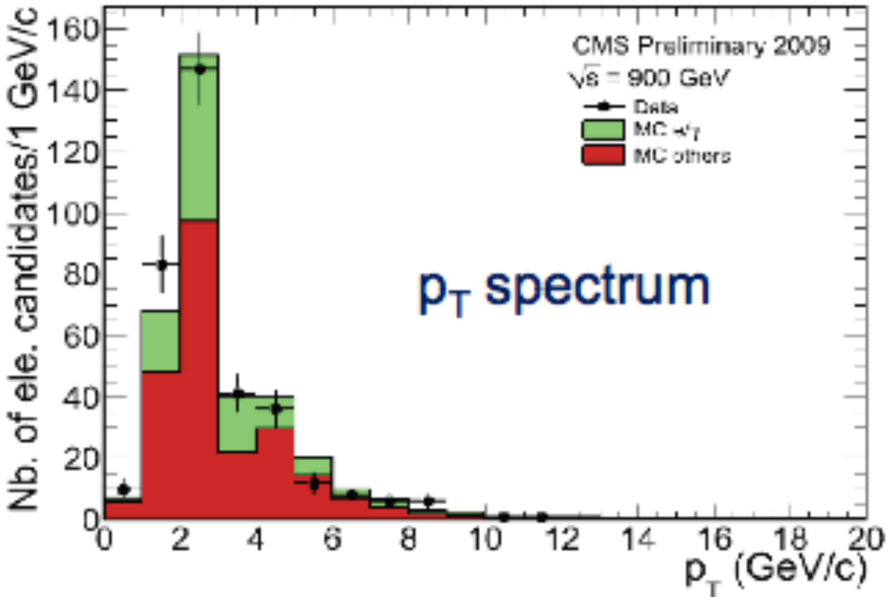
Energy clustering to recover bremsstrahlung

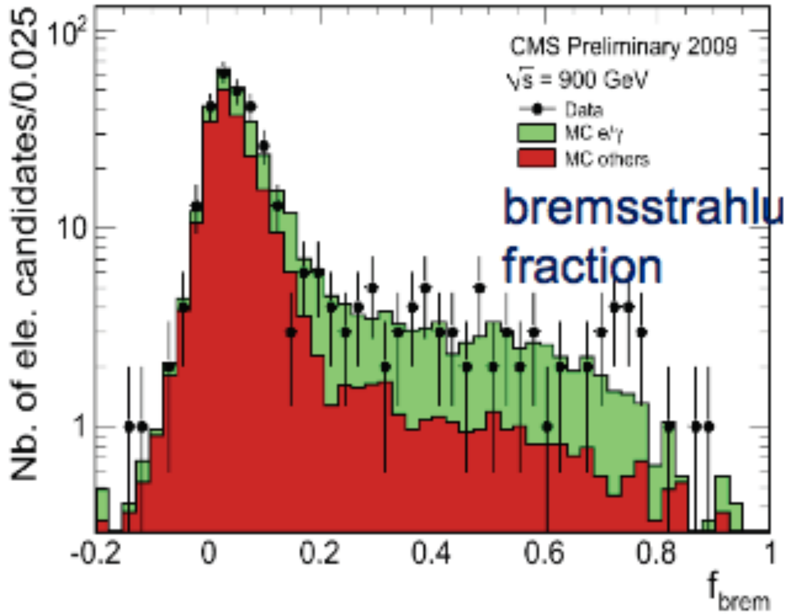
Electron track seeding (2 approaches)

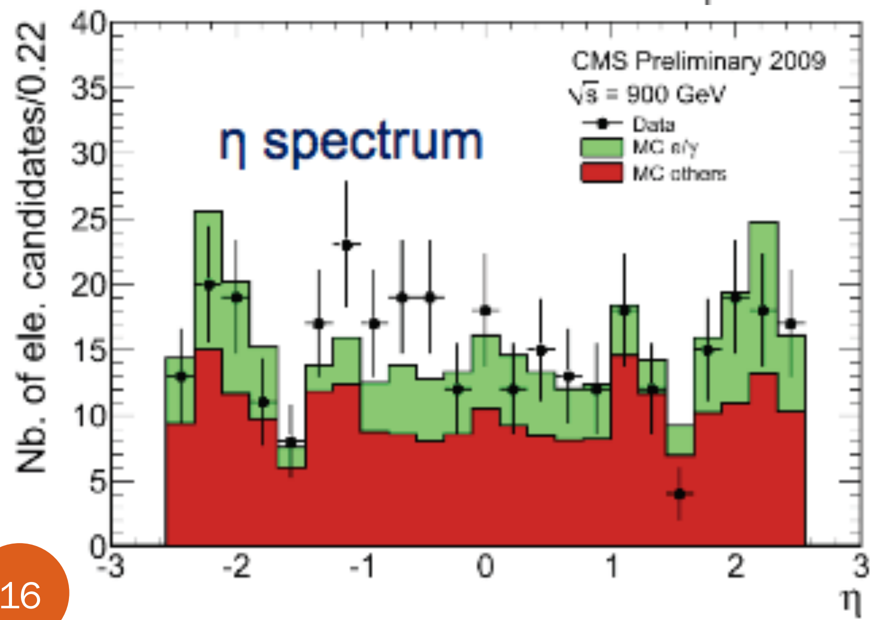
- Start from ECAL superclusters and searchfor compatible hits in the tracker (Ecal Driven)
- Use all tracks as starting point (Tracker Driven)

- Tracking for electrons:
  - Loose match with tracker seeds
  - Bremsstrahlung energy loss modeled with a mixture of Gaussians in the track fit
  - Final energy / momentum combination
  - Bremsstrahlung estimate using tracks : $f_{brem} = (P_{IN} - P_{OUT}) / P_{IN}$

Electron commissioning at 900 GeV







- Low pT electron candidates expected, mainly non-prompt from γ conversions
- 351 candidates reconstructed in 2009 collision data at 900 GeV

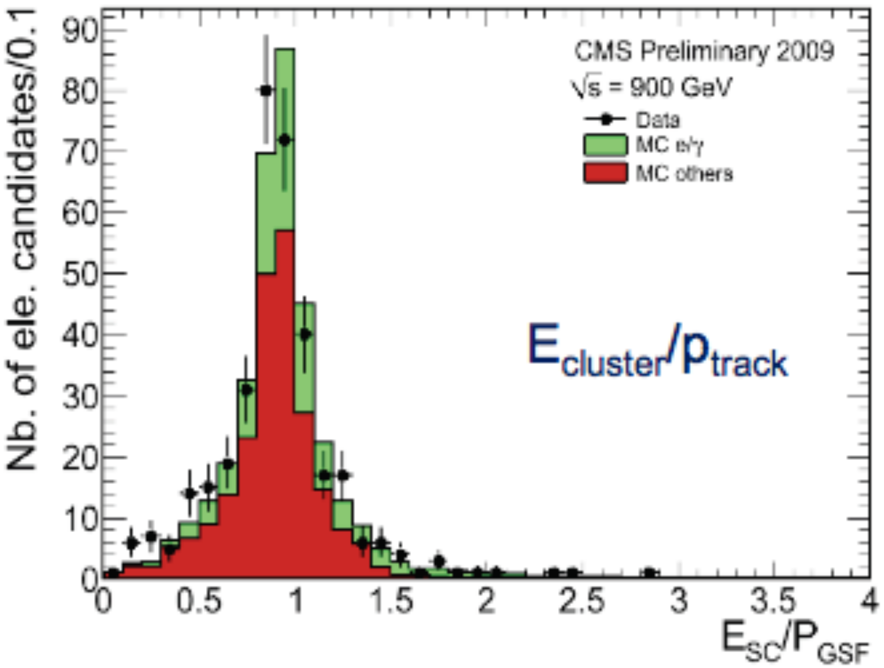
From MC, 40% are expected to be real electrons

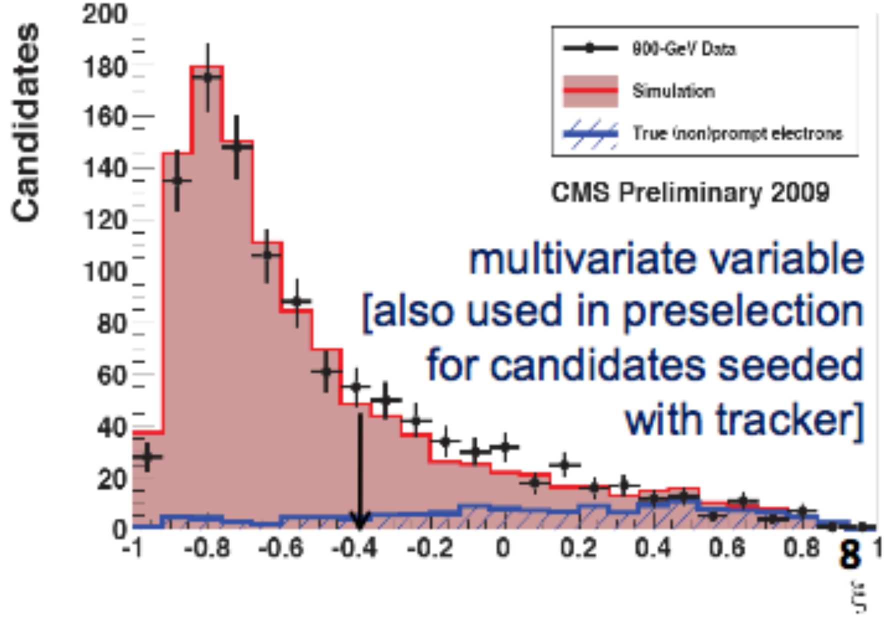
Electron Identification

- Electron tracking tuned to have good efficiency more than high purity
- 10^3-10^5 rejection power needed against jets depending on physics analysis
- Remaining background due to conversions, π^0 Dalitz decays, isolated hadrons

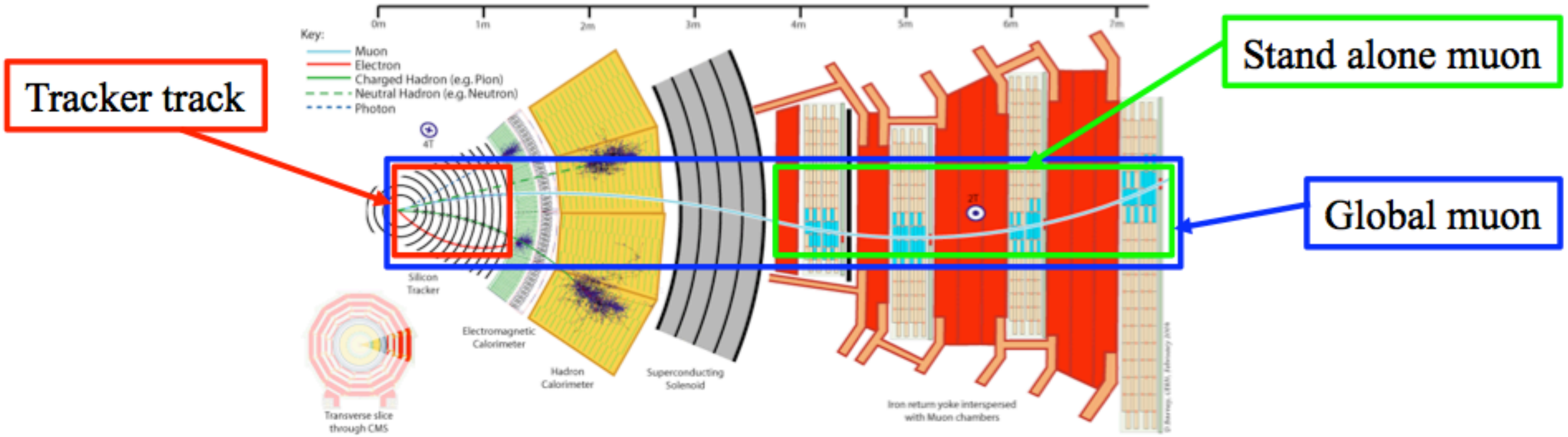
  - Geometrical matching ECAL/tracker
  - Energy / momentum matching
  - Deposits in ECAL vs HCAL

⇒ **(mva)Multivariate Variable Analysis for electrons**





Muon reconstruction

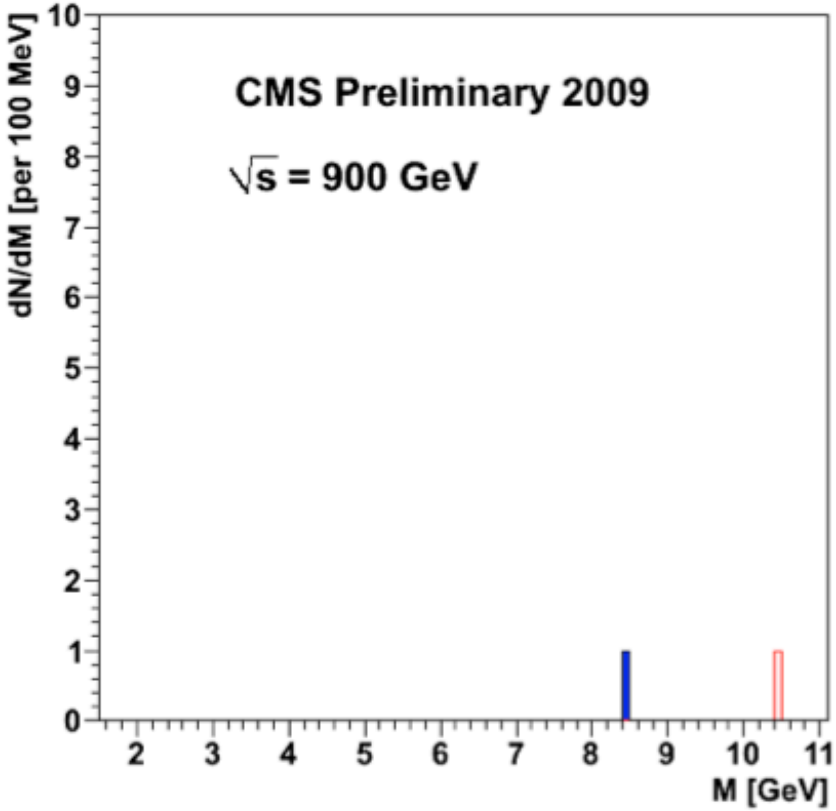


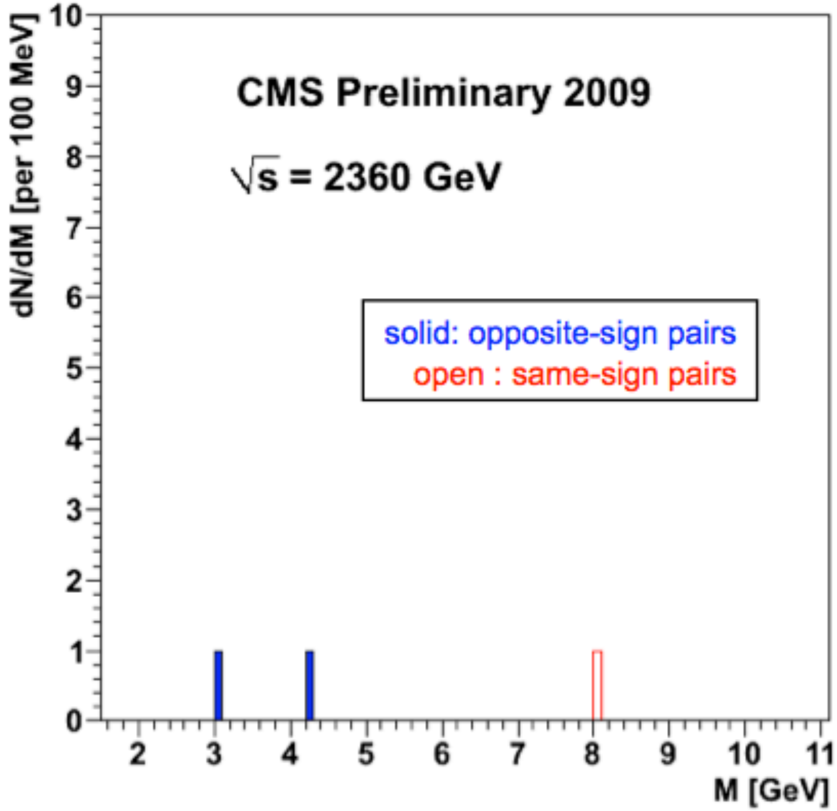
2 complementary approaches

- Stand alone muon based (outside-in) : the algorithm fits all the hits in the muon system and search for compatible tracks in the tracker system

- Tracker based (inside-out) : starting from all the tracks in the tracker system and identify the muon associating the tracker tracks with the segments in the muon system

Dimuons in CMS at 900 and 2360 GeV



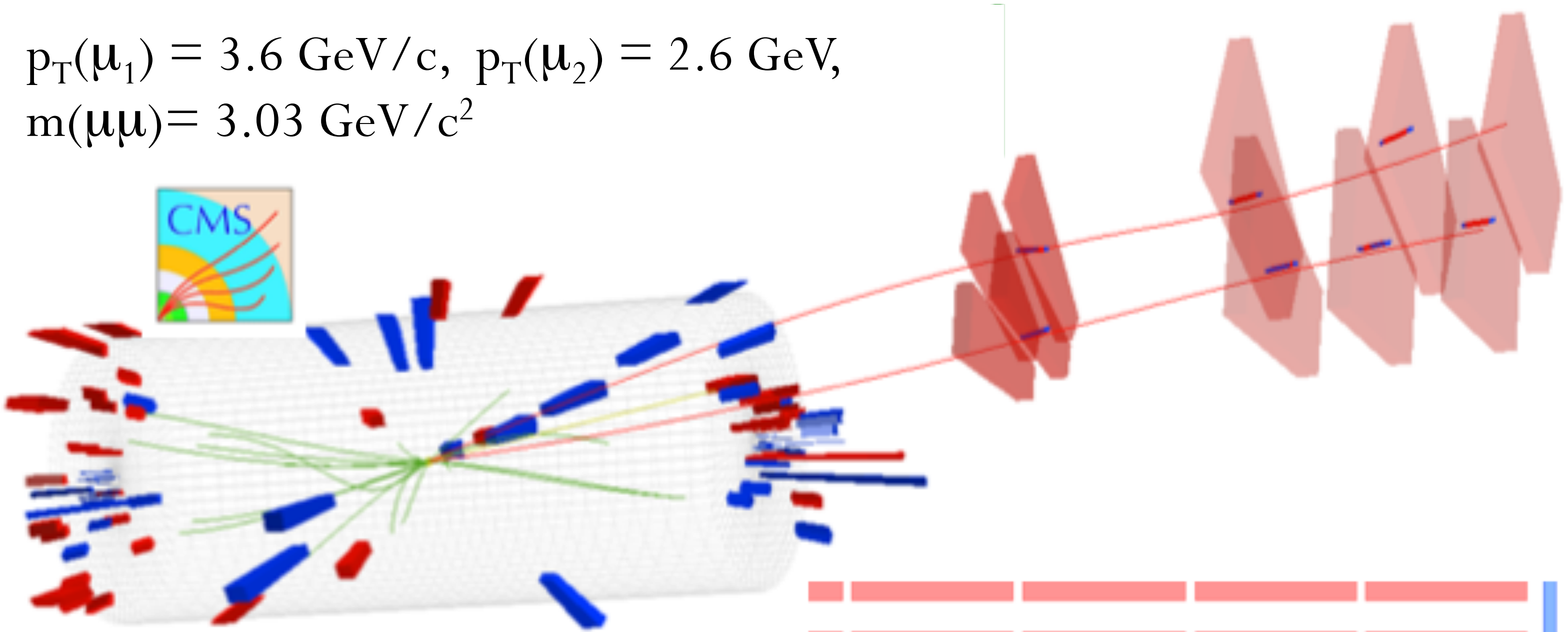


The 2.36 TeV data set contains two opposite-sign dimuons :

- $M = 3.04 \pm 0.04$ GeV/c^2, dimuon vertex $\chi 2$ prob.= 57%, c$\tau = -17 \pm 81\ \mu$m (a J/ψ?)
- $M = 4.26 \pm 0.04$ GeV/c^2, dimuon vertex $\chi 2$ prob.= 6%, c$\tau = -51 \pm 106\ \mu$m

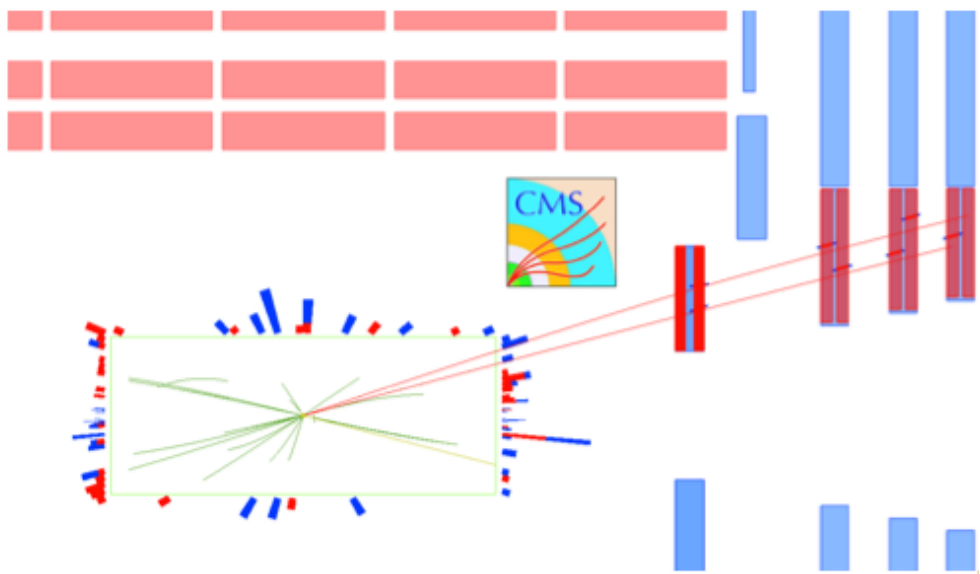
A nice event display

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



CMS Experiment at the LHC, CERN

Data recorded:	2009-Dec-14 03:46:50.815379 GMT
Run:	124120
Event:	5686693
Lumi section:	19
Orbit:	19245141
Crossing:	51



Jet reconstruction in CMS

3 methods to reconstruct jets

Calorimeter jets

Reconstruction using energy deposits in the ECal and HCal cells (calorimeter tower)

Calorimeter tower : one or more HCAL cells and the geometrically corresponding ECALcrystals.

The Jet-Plus-Tracks (JPT) algorithm

Corrects the energy and the direction of a calorimeter jet by exploiting the excellent performance of the CMS tracker to improve the p_T response and resolution of calorimeter jets

Particle Flow jets

Reconstruct, identify and calibrate each individual particle in the event by combining the information from all CMS sub-detector systems, then cluster to jets

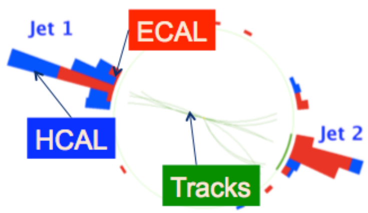
Dijet

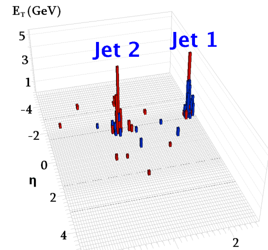
	CaloJets	JPTJets	PFJets
PT min	10 GeV	8 GeV	8 GeV
η max	3.0	2.0	3.0

Inclusive

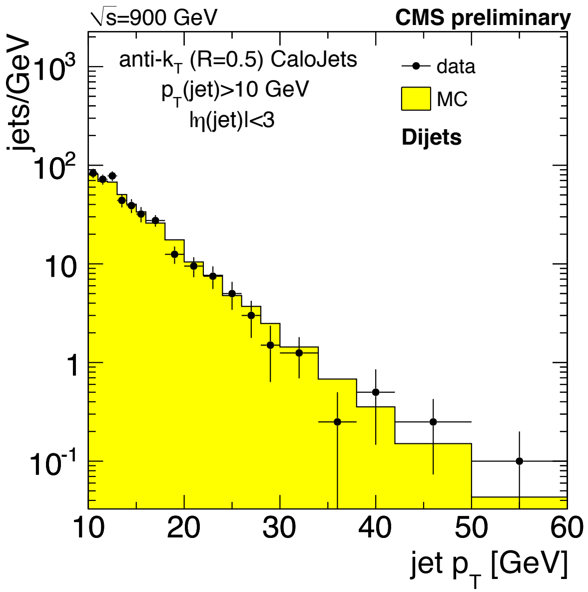
	CaloJets	JPTJets	PFJets
PT min	15 GeV	13 GeV	10 GeV
η max	2.6	2.0	3.0

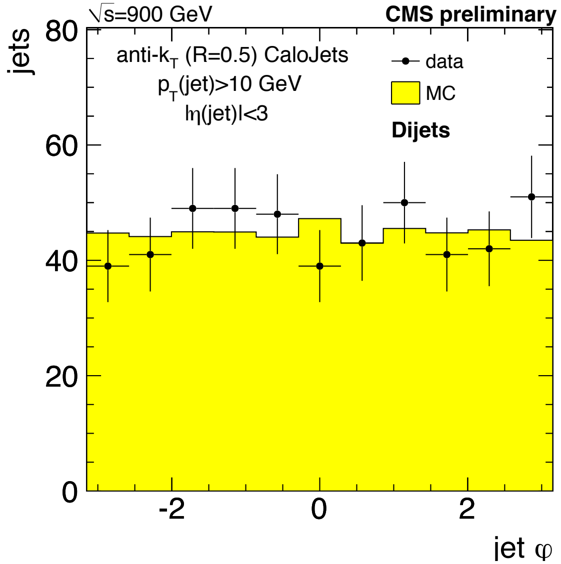
Jets in CMS at 900 GeV

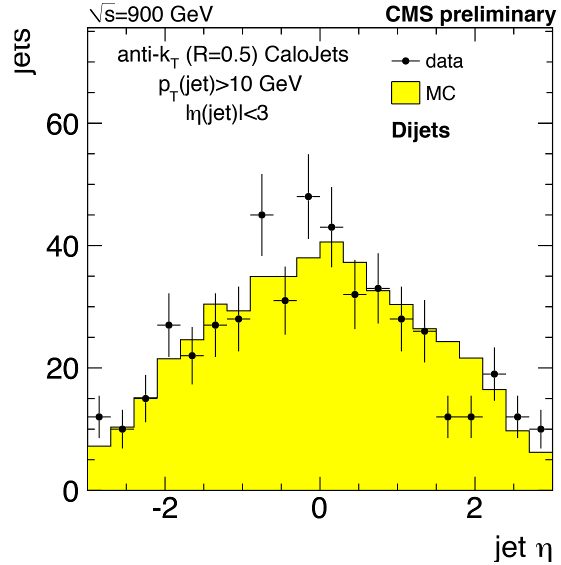




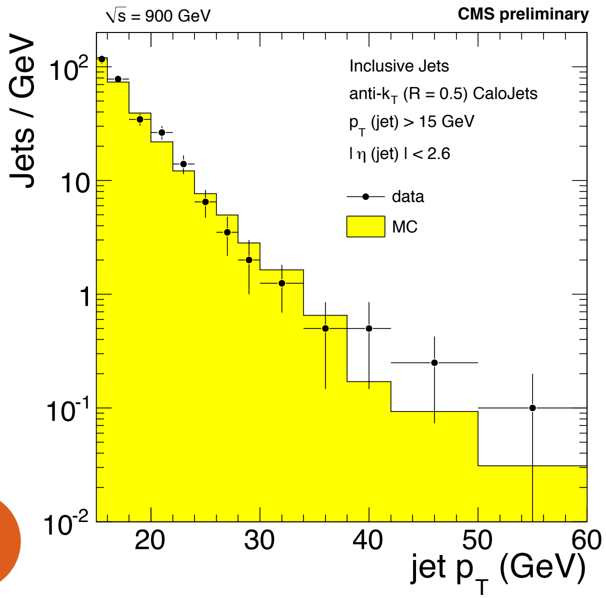
Dijet

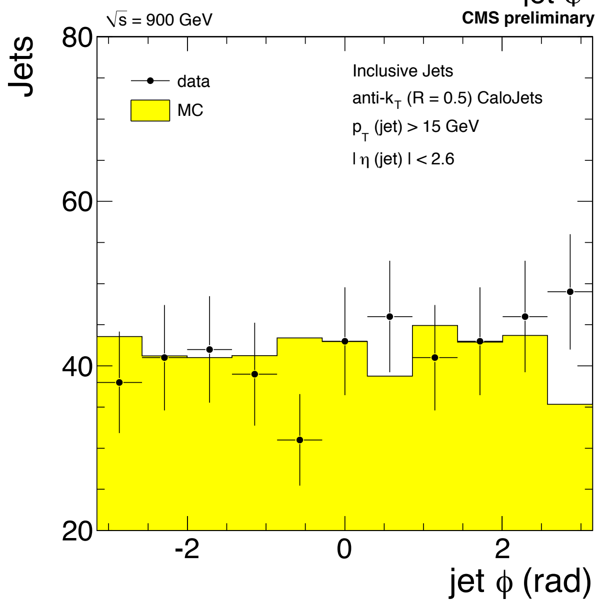


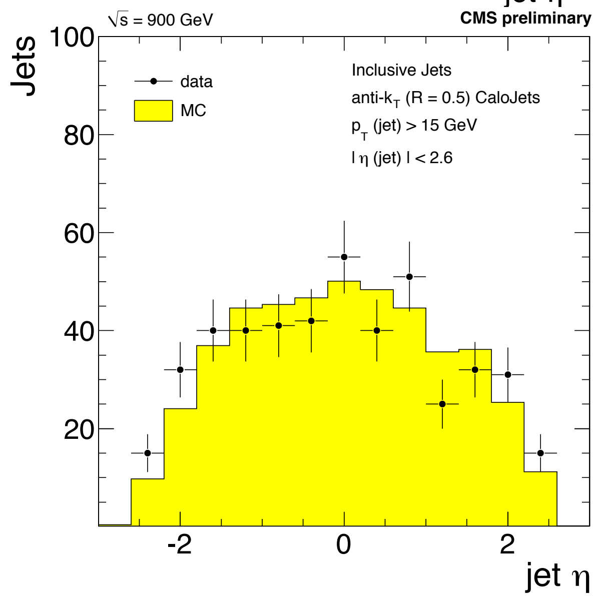




Inclusive

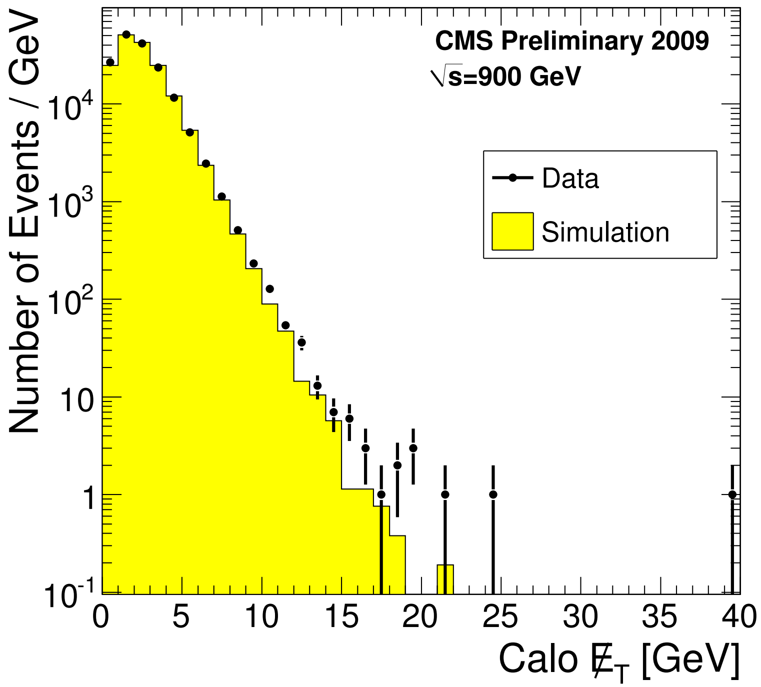


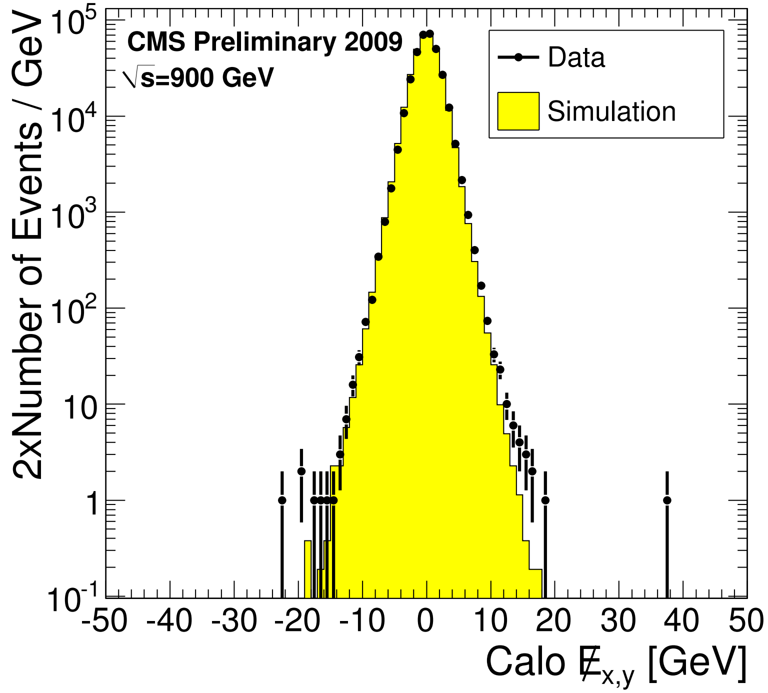




Missing ET in CMS

3 methods to reconstruct jets : Calorimeter jets, the Jet-Plus-Tracks (JPT) algorithm, particle flow jets





The missing ET is well described in simulation, and tails are small …
Even without final detector calibration)

Conclusion

- CMS arrived prepared to first collision data and was ready to quickly analyze the data and to produce physics results
- Very good agreement with simulation without further need of tuning, thanks to preparation with test beams and cosmic runs
- First paper on collision data is published, 5 other papers are in preparation
- Excellent detector performance shown with high data quality
- Exploring 7 TeV data…

Geneva, March 30th 2010.

....

At 12:58:34 the LHC Control Centre declared stable colliding beams: the collisions were immediately detected in CMS. Moments later the full processing power of the detector had analyzed the data and produced the first images of particles created in the 7 TeV collisions traversing the CMS detector

....