Highlights from CMS

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for the CMS Collaboration

DIS'2010, Firenze, Italy
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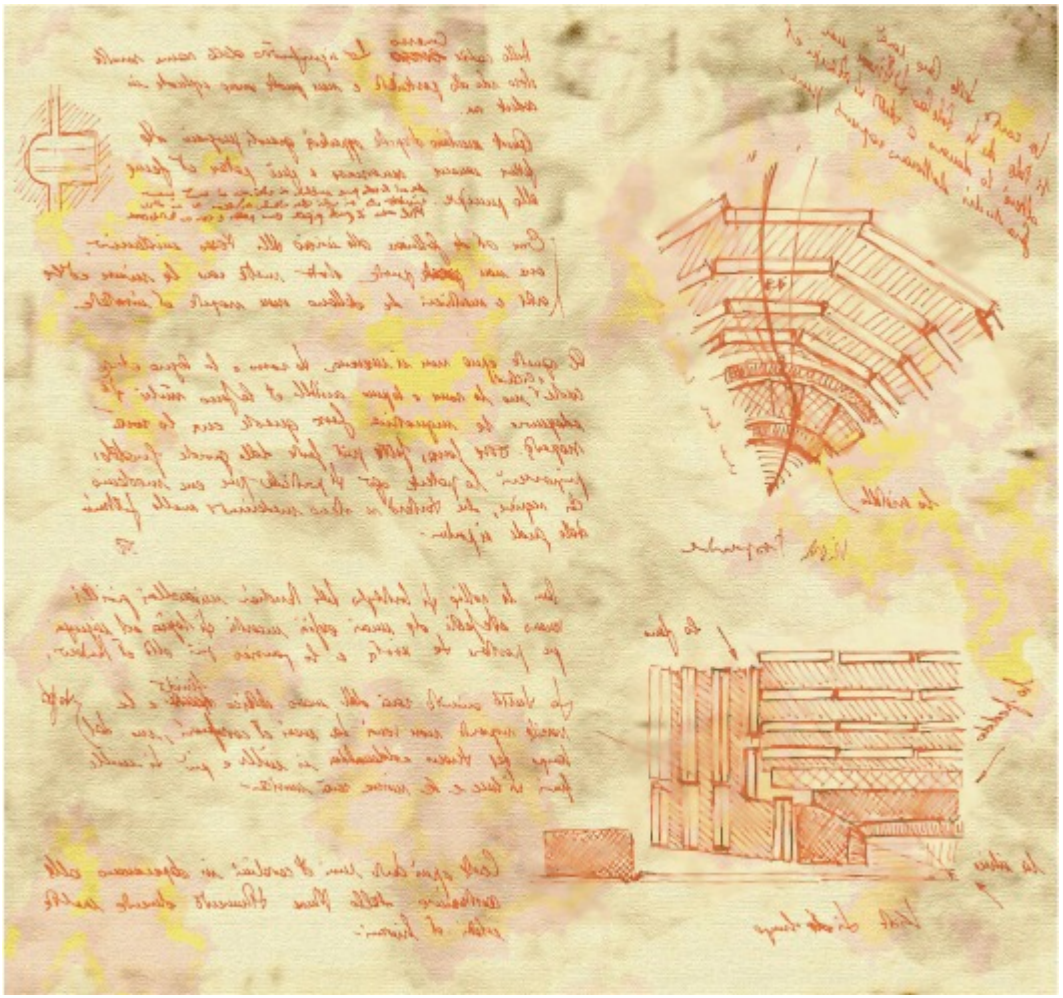
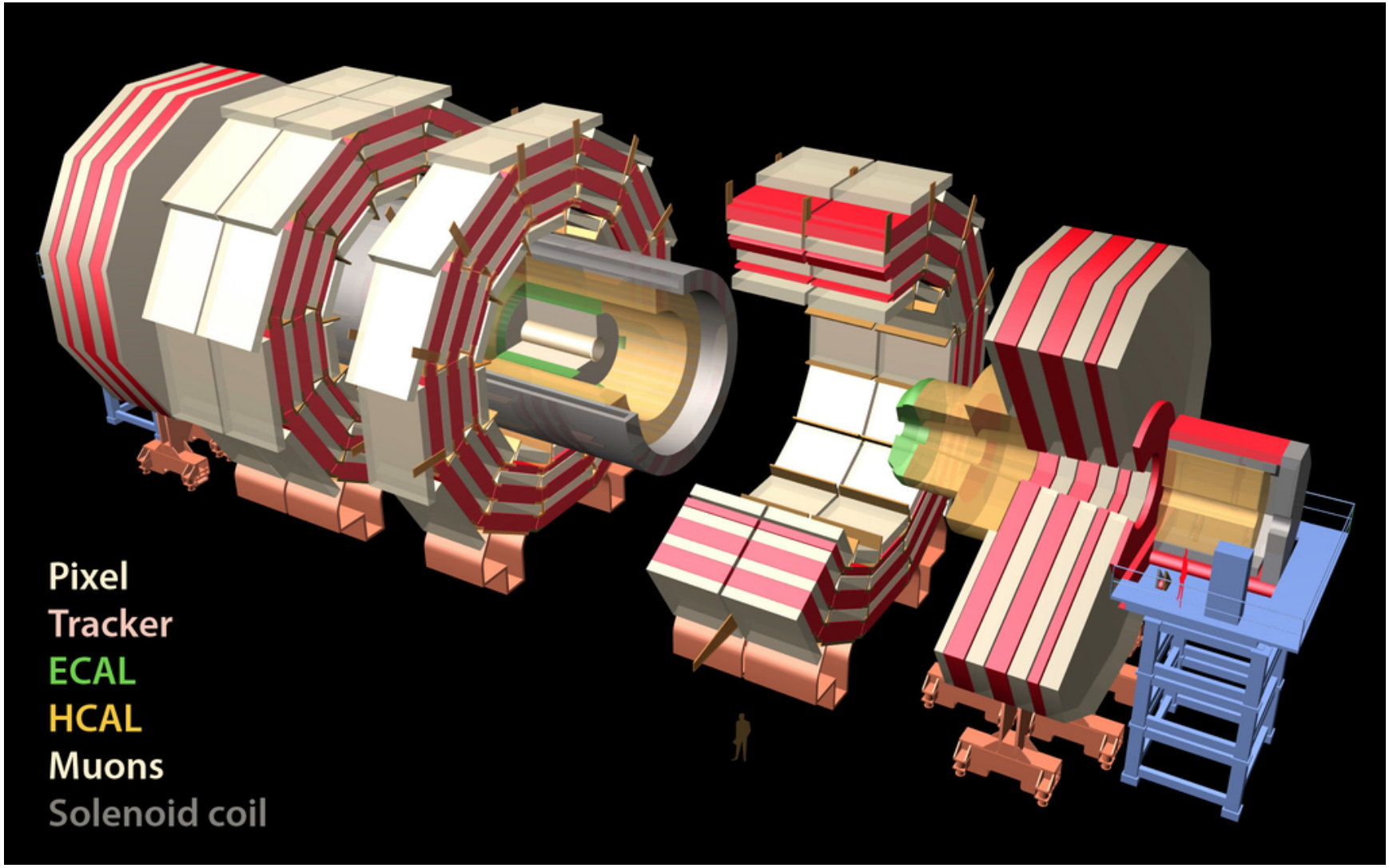


CMS technical proposal in style of Leonardo da Vinci

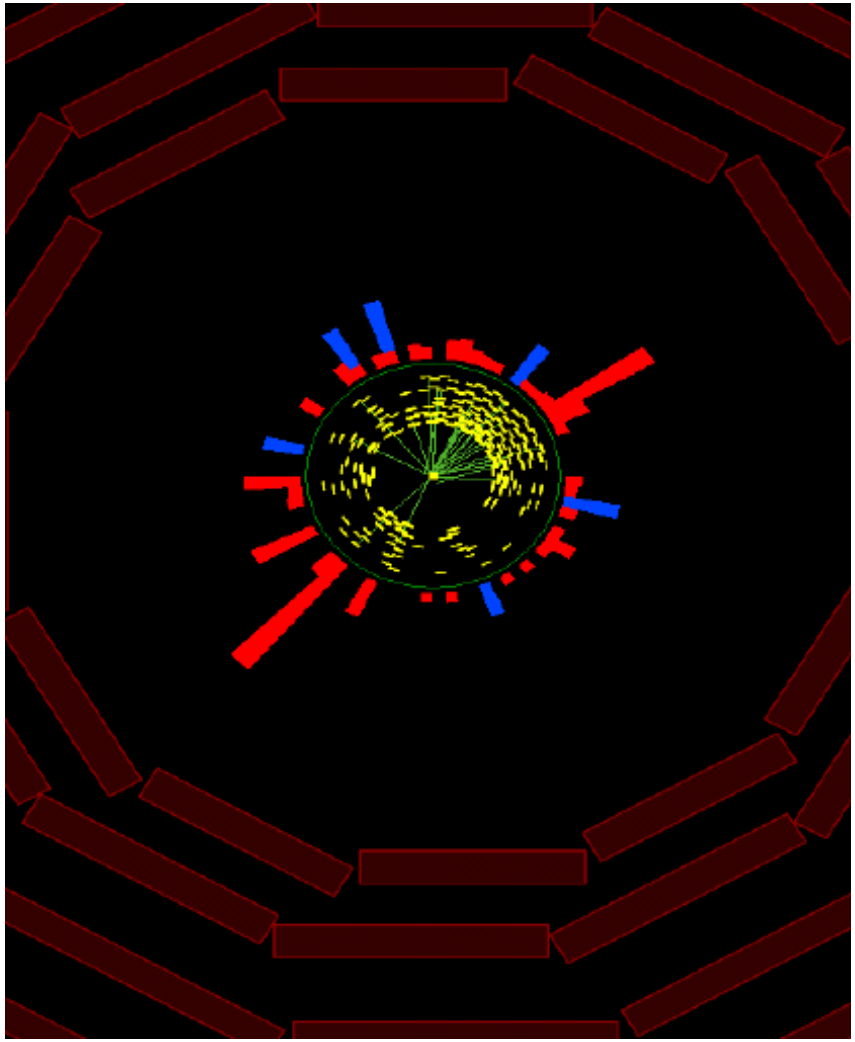
- The CMS detector
- Performance results
  - Tracking and vertexing
  - Jets
  - Missing E_T
  - Electrons and photons
  - Particle flow
- Physics results
  - QCD
- The CMS menu for DIS'2010

The CMS detector



Silicon tracker (pixels+strips) Lead tungstate crystal ECAL
Hermetic ($|\eta| < 5.2$) HCAL Muon system (RPC, DT, CSC) 3.8 T field

CMS timeline and energies



- 0.9 TeV

  ⇐ First collisions: 23 Nov 2009
  - First stable beams: 6 Dec 2009
  - More than 300 k events collected

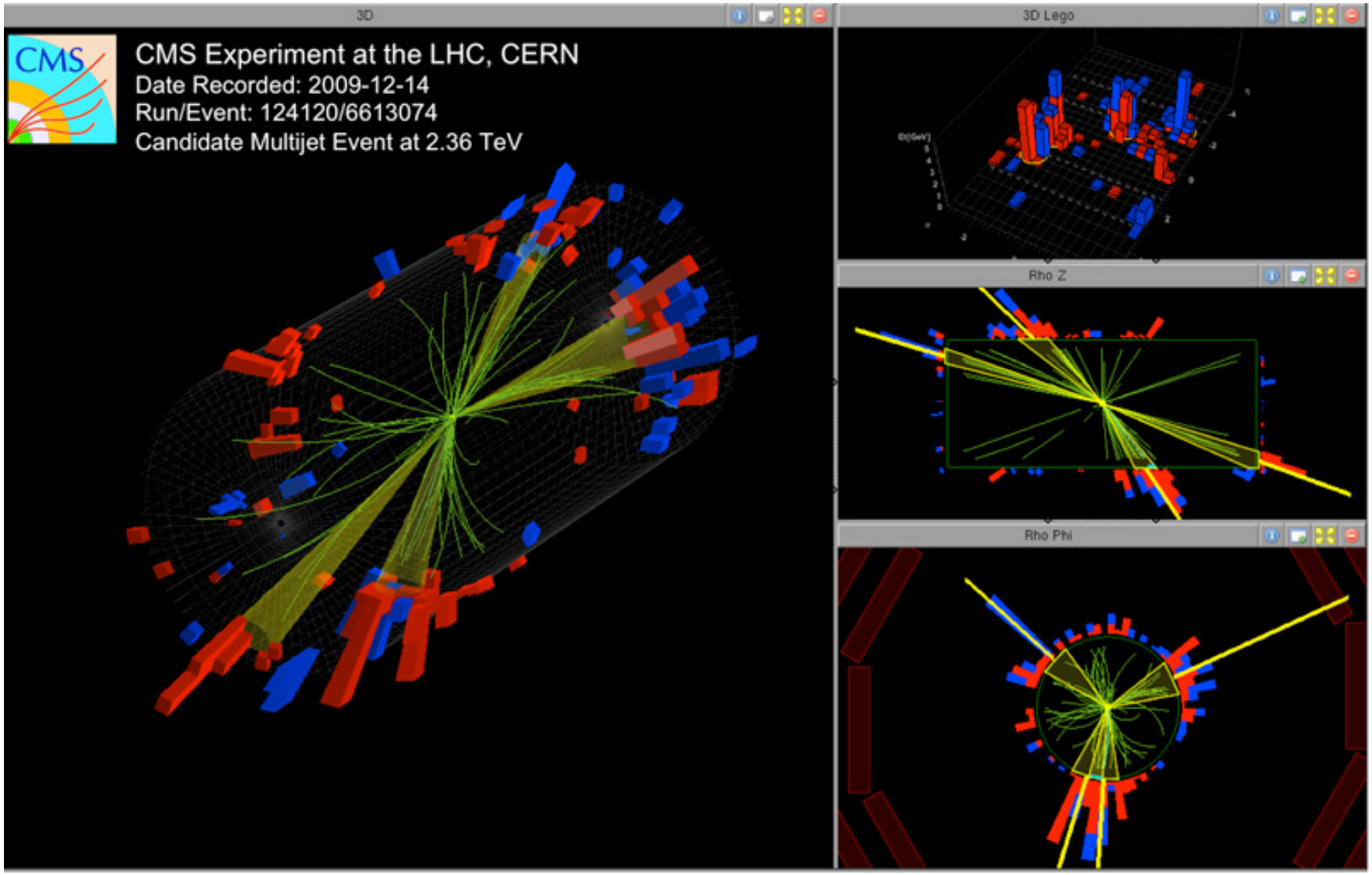
- 2.36 TeV
  - First collisions: 14 Dec 2009
  - About 20 k events collected

- 7 TeV
  - First collisions: 30 Mar 2010
  - Several million events so far
  - Very many ongoing analyses

Fully open minimum bias trigger, now with typical rates of 50-100 Hz

First results produced in very short time, shown in this talk

The detector at work

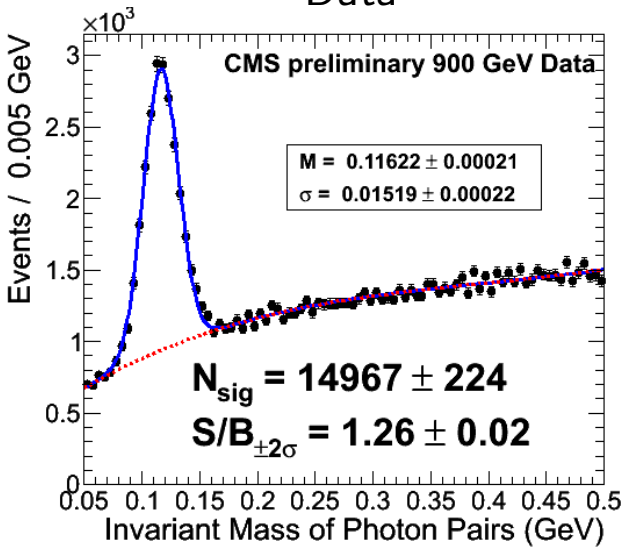


Tracks, calorimeter towers and jet candidates at 2.36 TeV

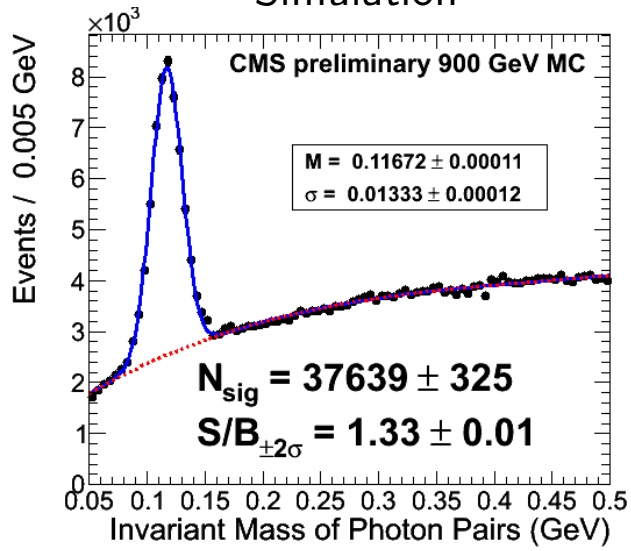
Performance results

Neutrals decaying to $\gamma\gamma$

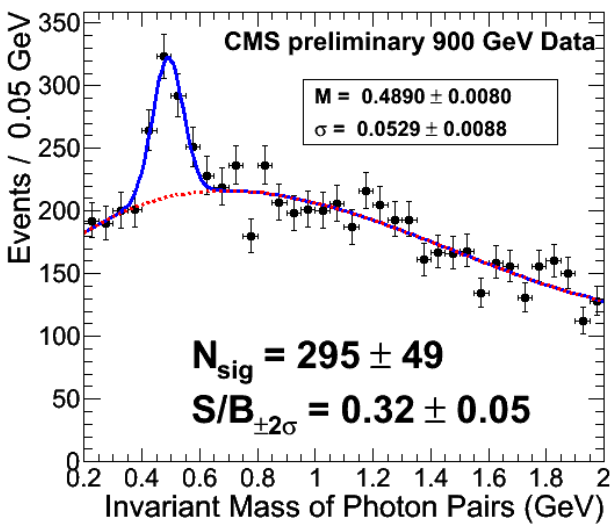
Data

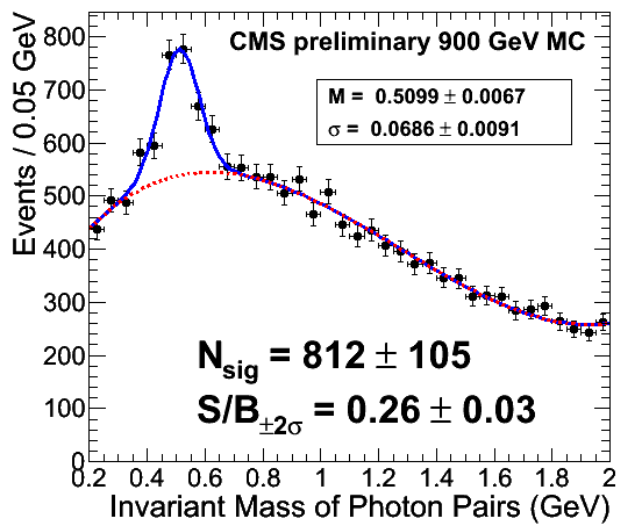


Simulation



$\pi^0 \to \gamma\gamma$
No corrections
(for shower containment, thresholds, energy loss)



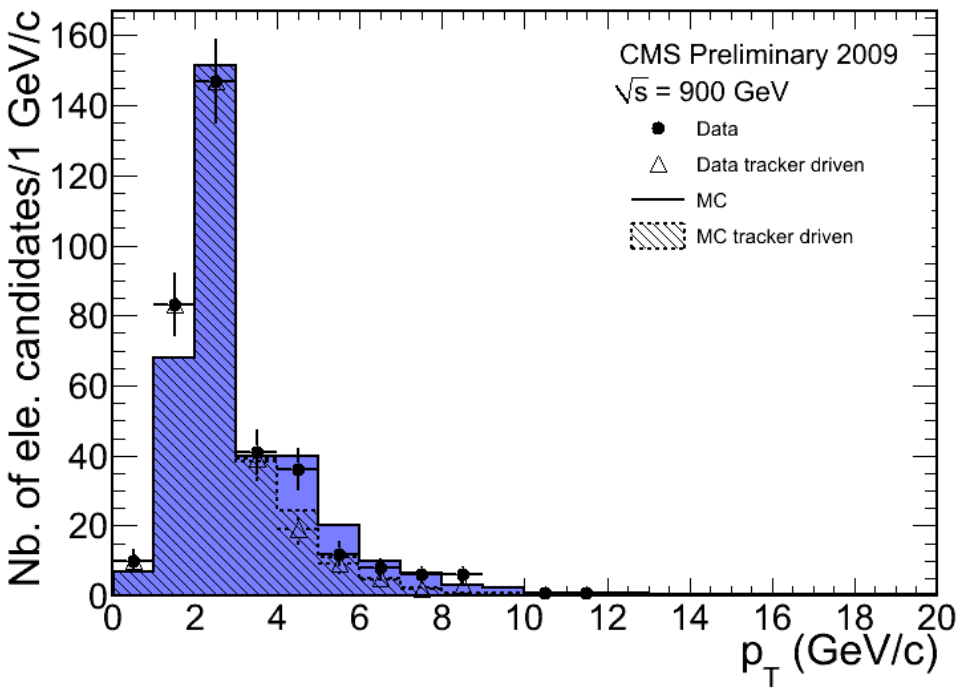


$\eta \to \gamma\gamma$
Corrected,
good agreement:
peak position and S/B

ECAL photons: energy scales now in data and MC agree within 2%

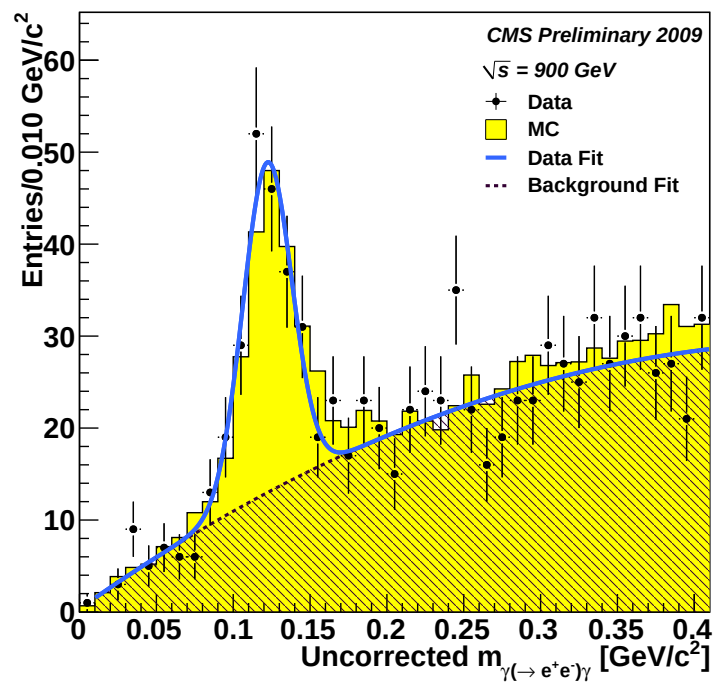
Electrons and conversions

Electrons



p_T distribution of electron candidates
Tracker or ECAL driven

π^0 with conversion

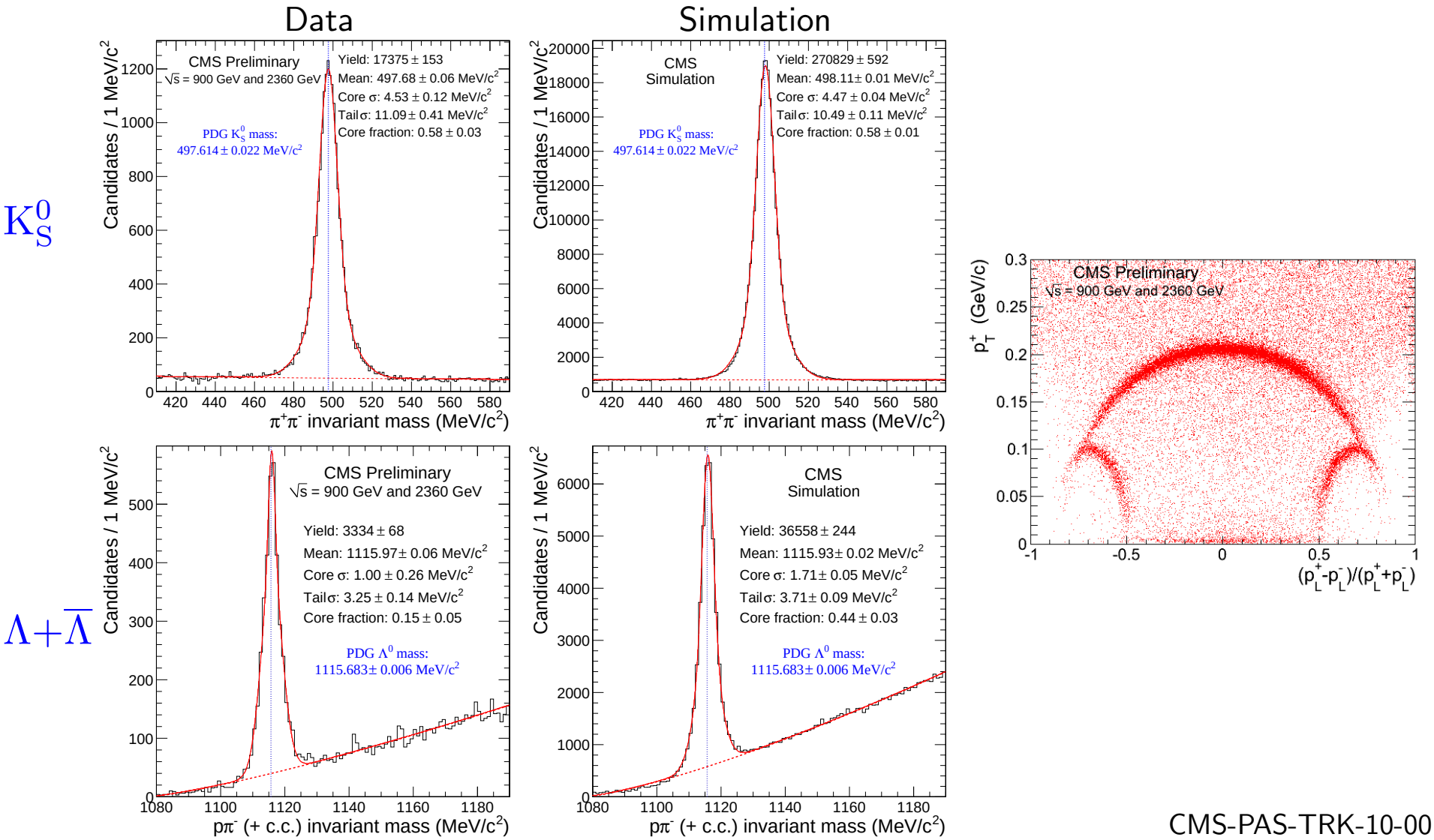


CMS-PAS-EGM-10-001

Observation of $\pi^0 \to \gamma\gamma$
One leg reco'd from conversion

Good agreement between data and MC

Tracking – long lived resonances

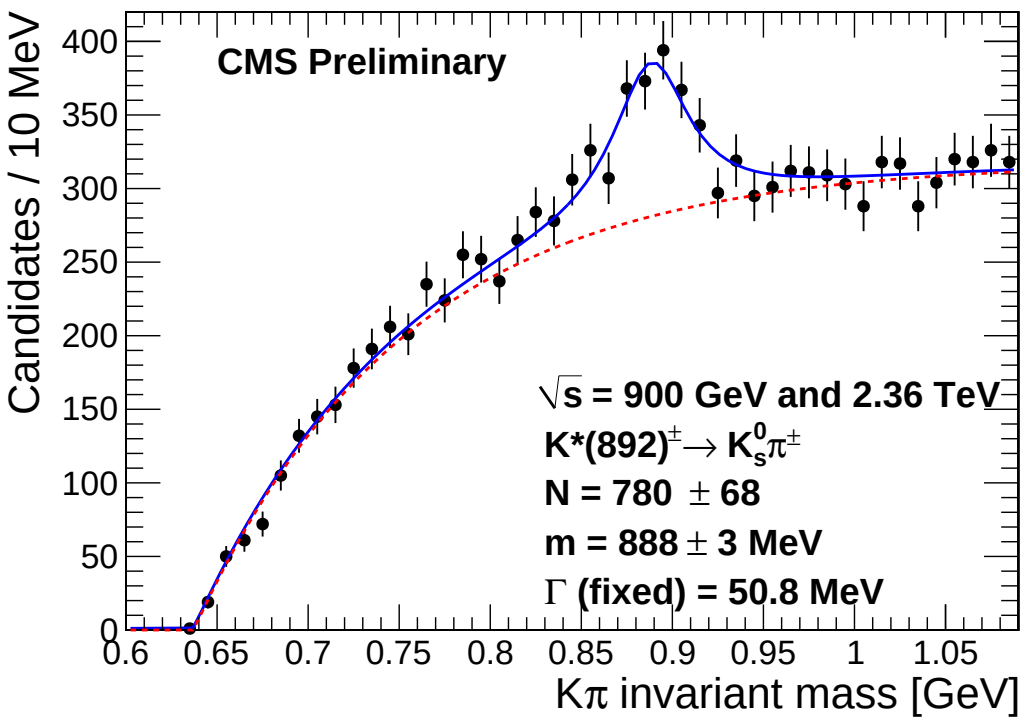


CMS-PAS-TRK-10-001

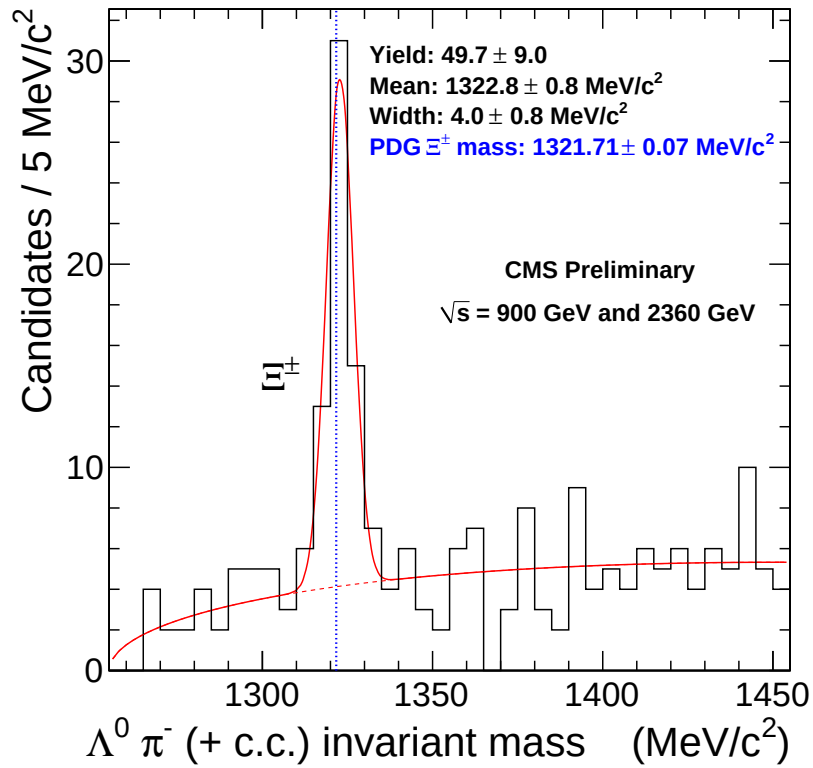
Peak shape and S/B agrees beautifully: per mille precision in momentum

Tracking – on-vertex resonances

$K^*(892)$



$\Xi^- + \overline{\Xi}^+$



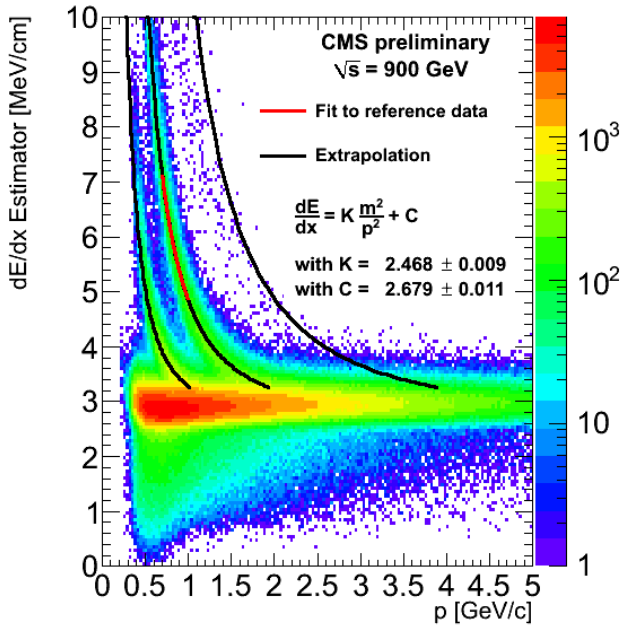
CMS-PAS-TRK-10-001

One step further: cascade decays with three charged hadrons in the final state

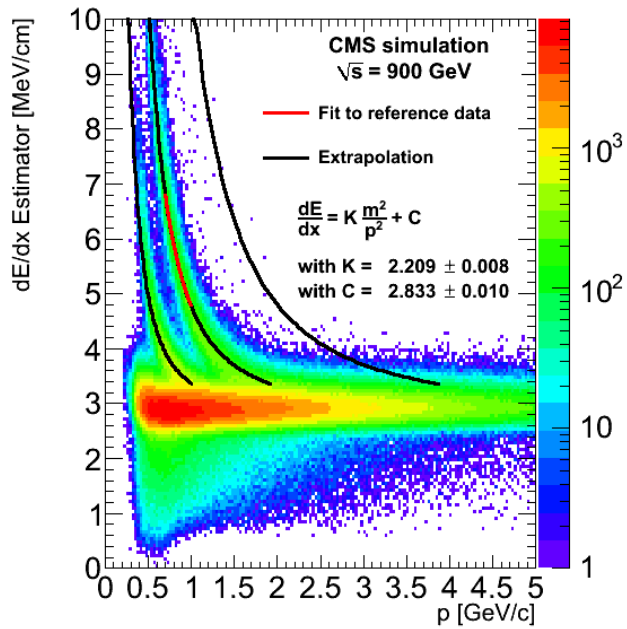
Mass peaks: excellent agreement with PDG

Tracking – particle identification

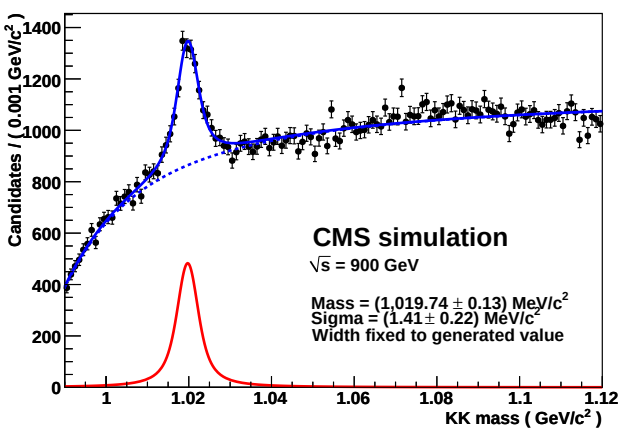
Data

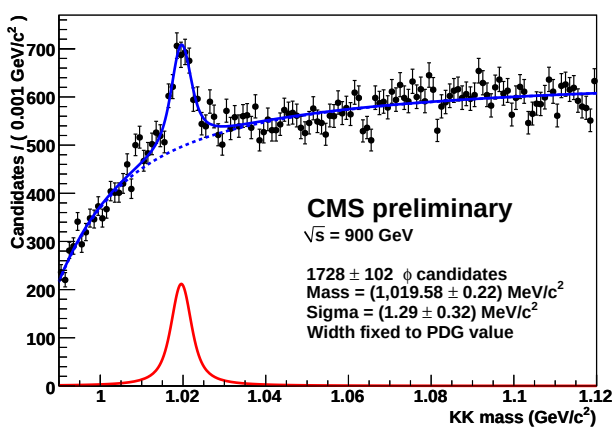


Simulation



Energy loss
in the silicon layers
(power mean)
vs momentum



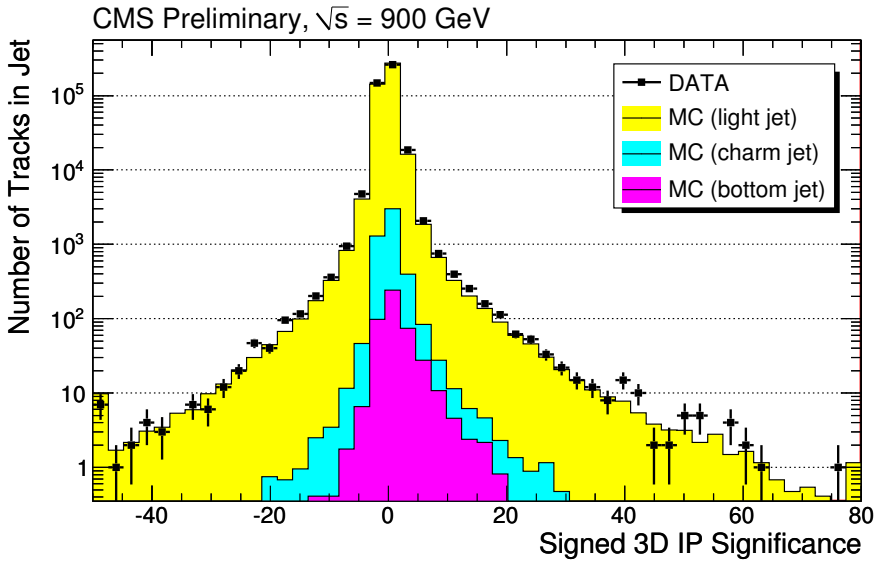


Reconstruction of
$\phi(1020) \to K^+K^-$
with help of dE/dx

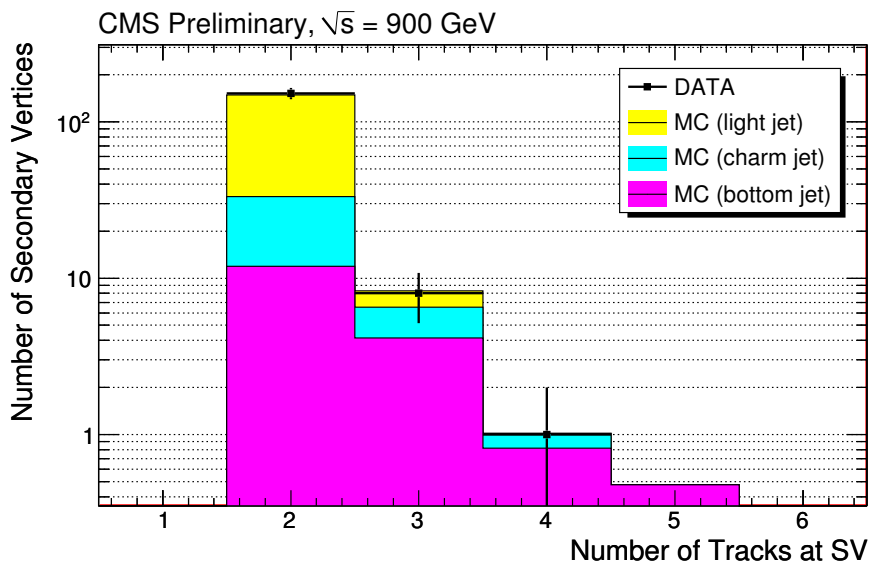
CMS-PAS-TRK-10-001

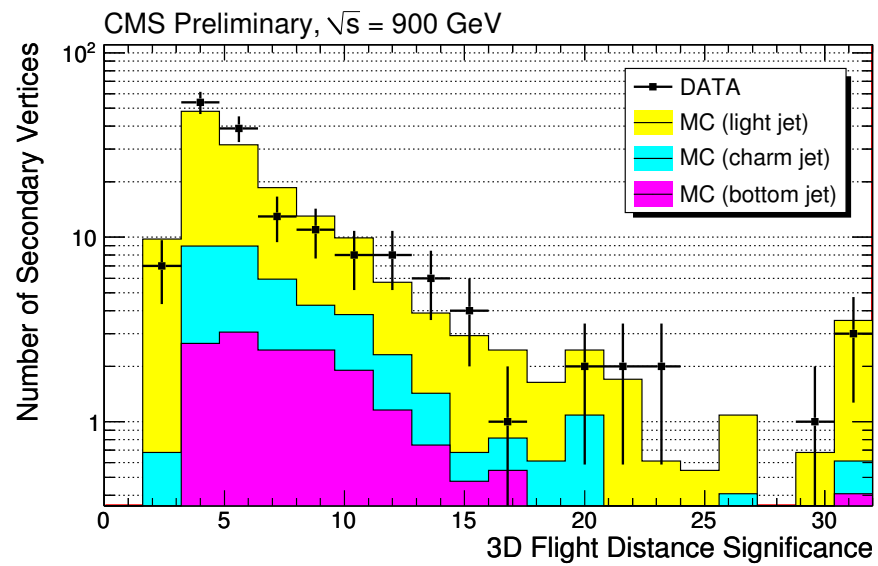
Particle identification at low momentum

Vertexing – b-tagging



- Variables
  - Impact parameter significance tracks with at least 7 hits, associated to a jet, impact given wrt the primary vertex
  - Number of tracks at seco vertex
  - Decay length significance

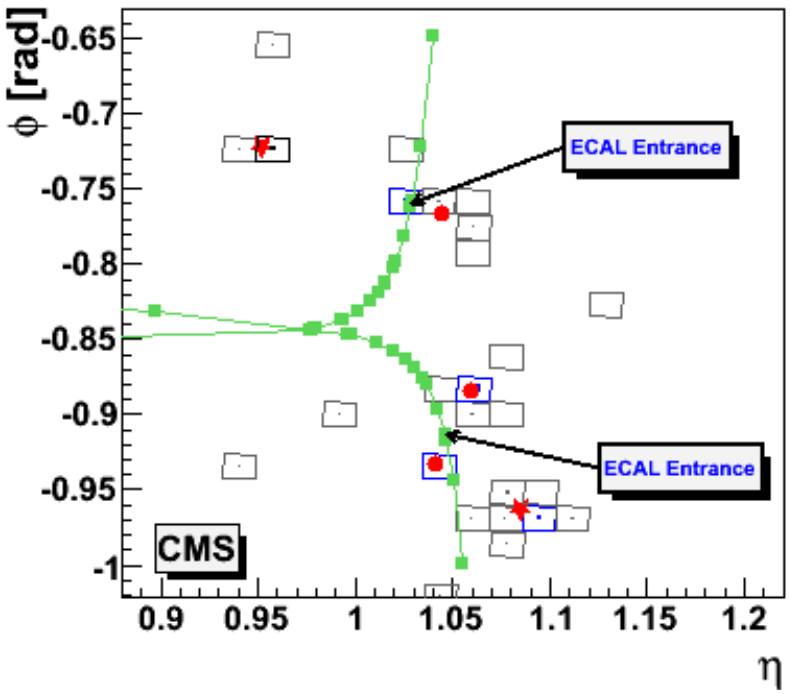




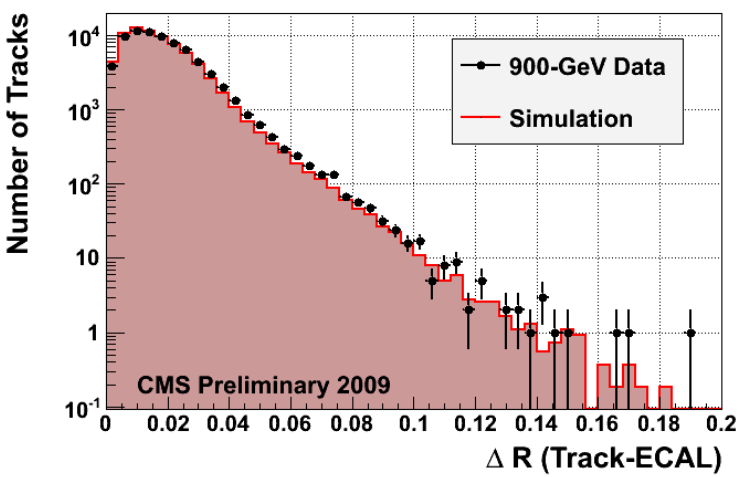
CMS-PAS-TRK-10-001

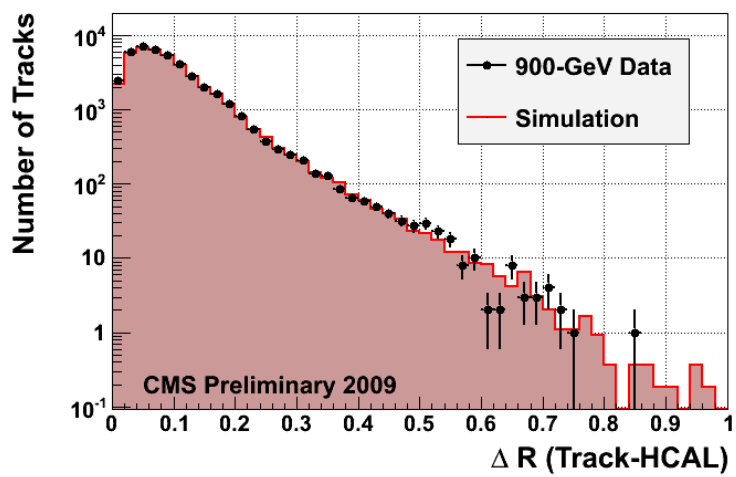
Basic b-tagging related variables are well described

Particle flow

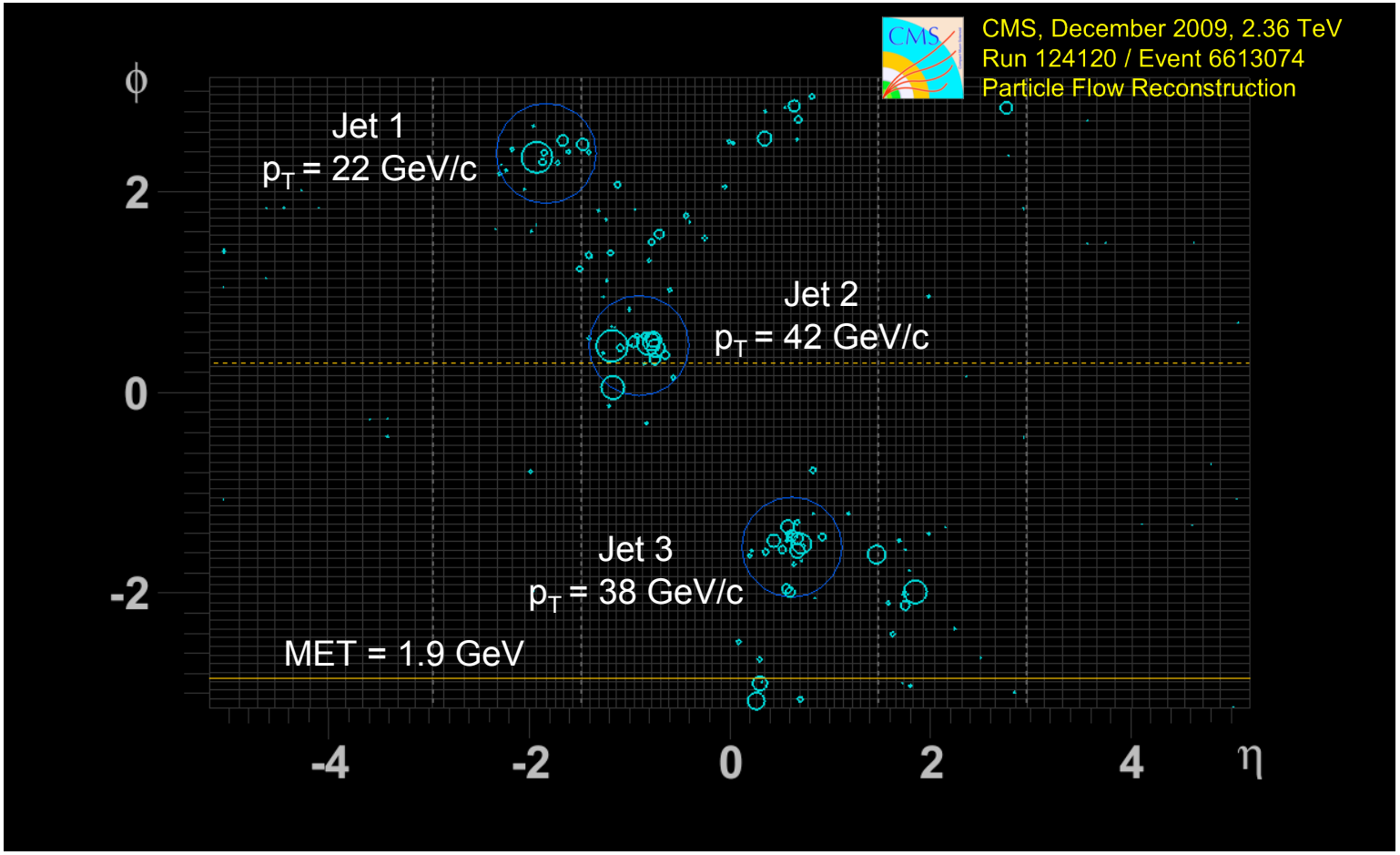


- New approach
  - Extract and properly combine informations from several sources
  - Link tracks and calorimeter clusters based on their distance ΔR
  - Improved performance for photons, charged and neutral hadrons, jets and missing E_T
  - Optimized energy resolution and particle identification

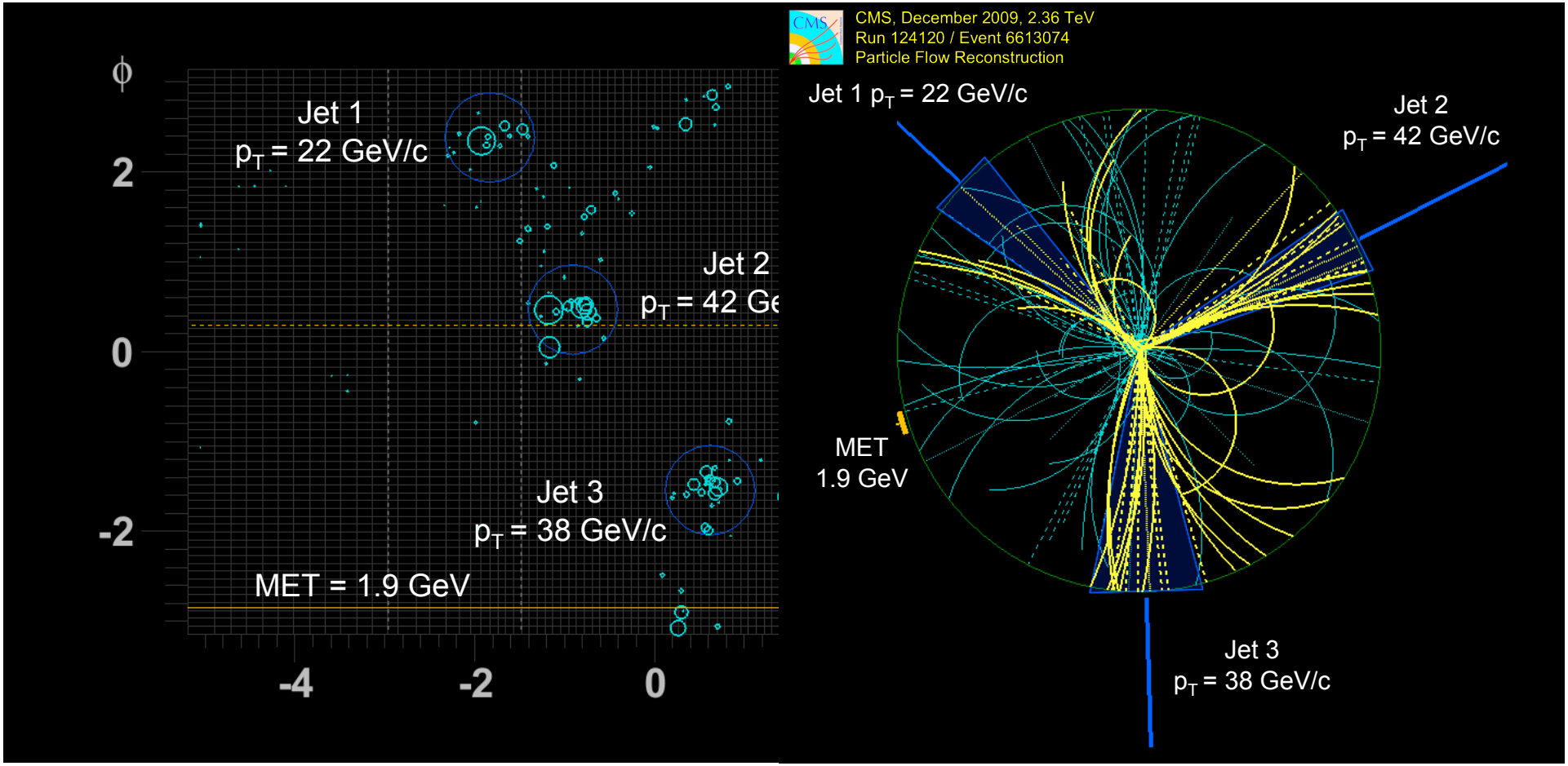




Particle flow



Particle flow

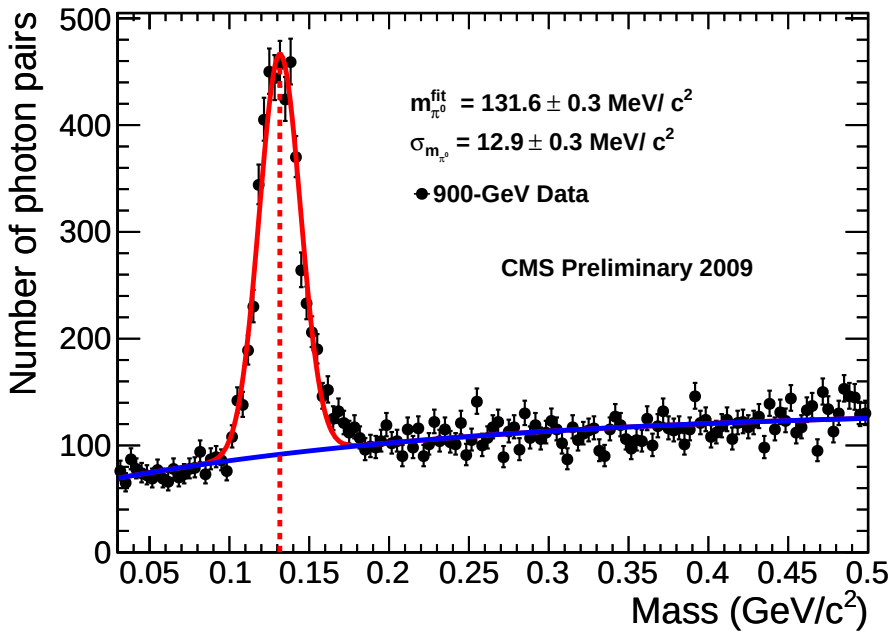


CMS-PAS-PFT-10-001

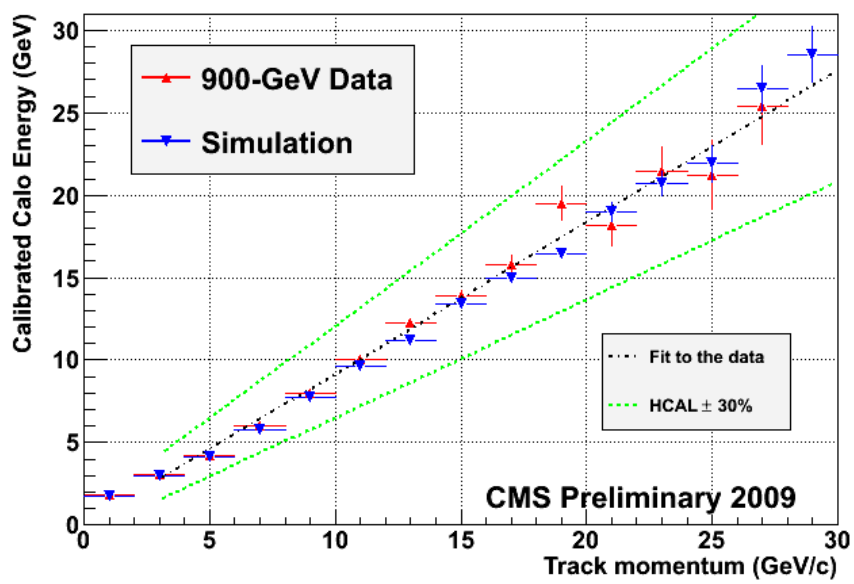
A particle-flow reconstructed event at 2.36 TeV

Circles – particle p_T Thinner circles – jets with $p_T > 20$ GeV/c

Particle flow – examples



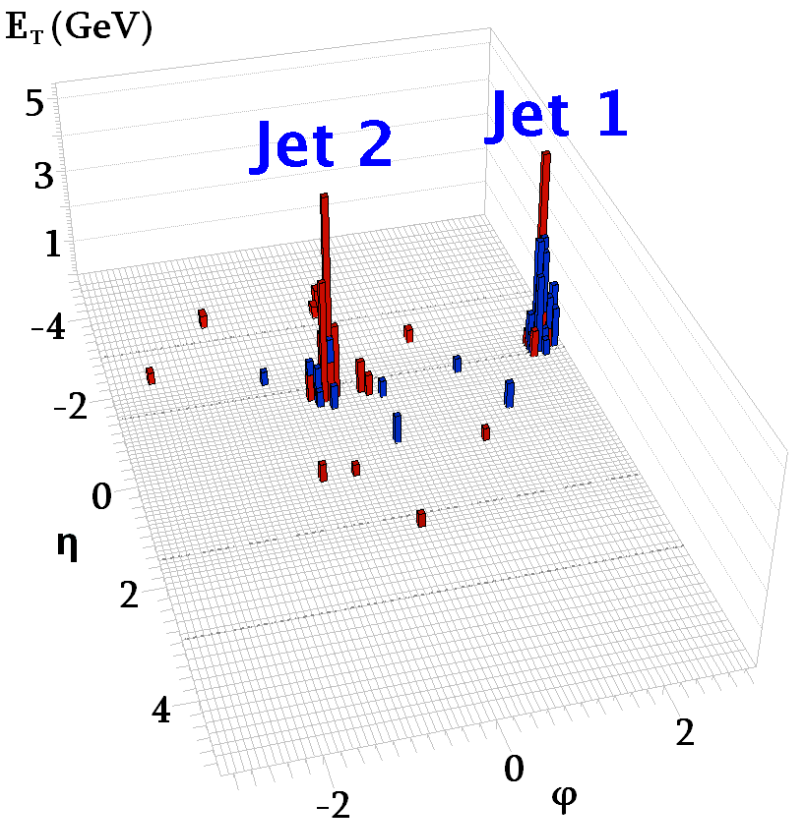
- π^0 reconstruction
  - ECAL barrel region $|\eta| < 1.0$
  - Correct mass position, 13 MeV/c^2 resolution

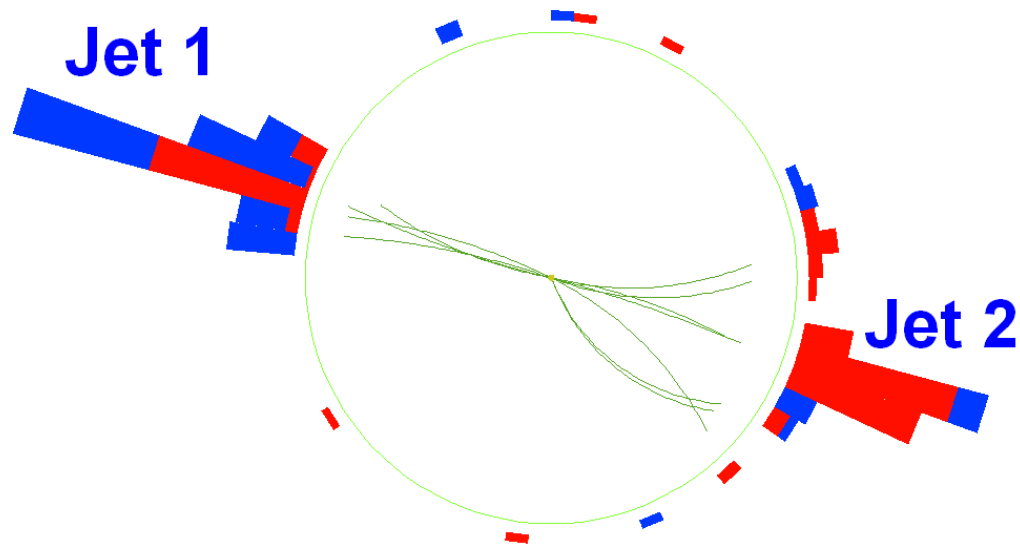


- HCAL calibration
  - Calorimeter cluster energy and track momentum
  - Calibration scale agrees within ∼5%

CMS-PAS-PFT-10-001

Jets



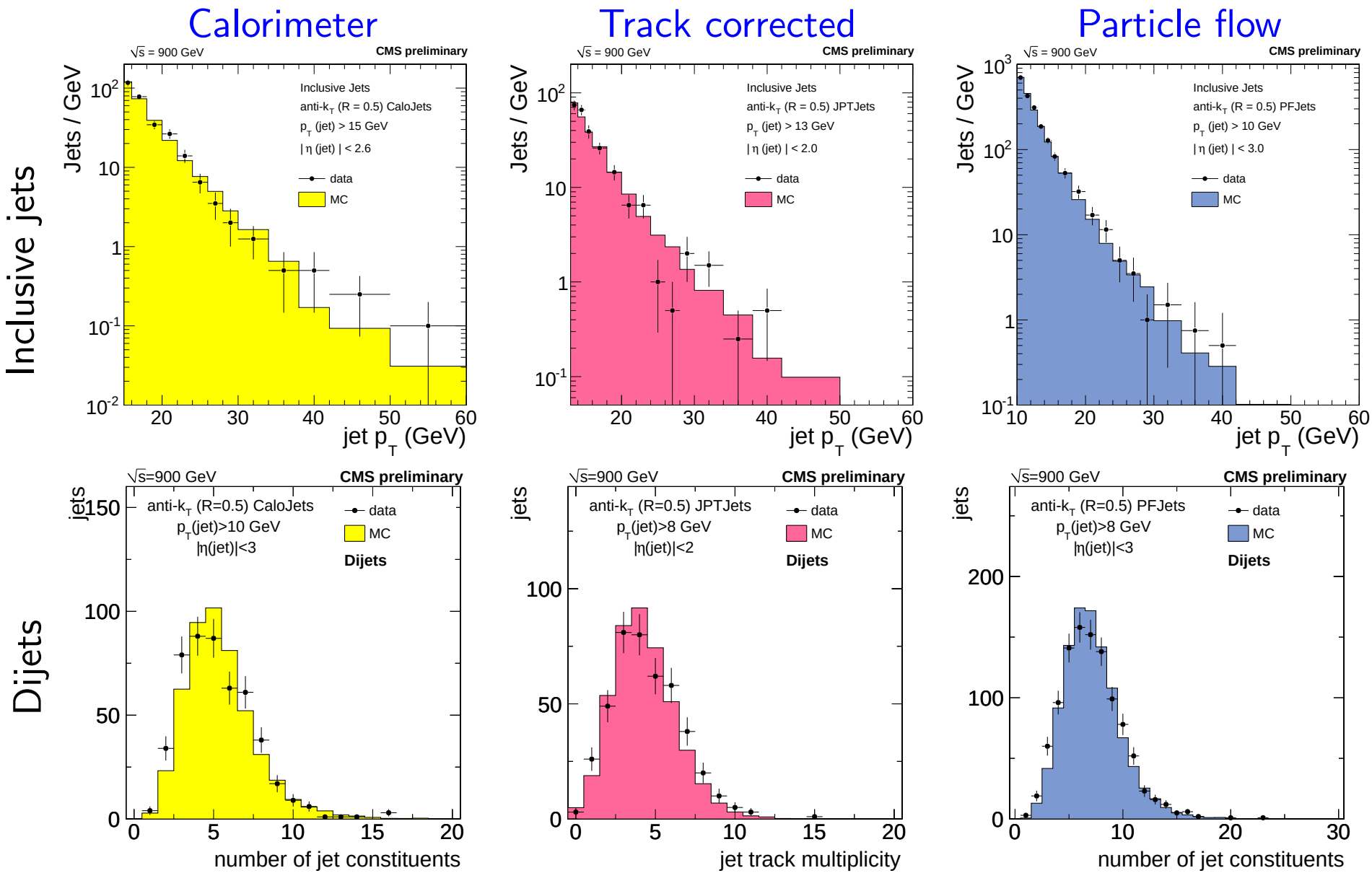


CMS-PAS-JME-10-001

Tracks with $p_T > 1$ GeV/c and calorimeter towers with $E_T > 0.3$ GeV
Jet transverse momenta are measured to be 39-45 GeV and 31-37 GeV

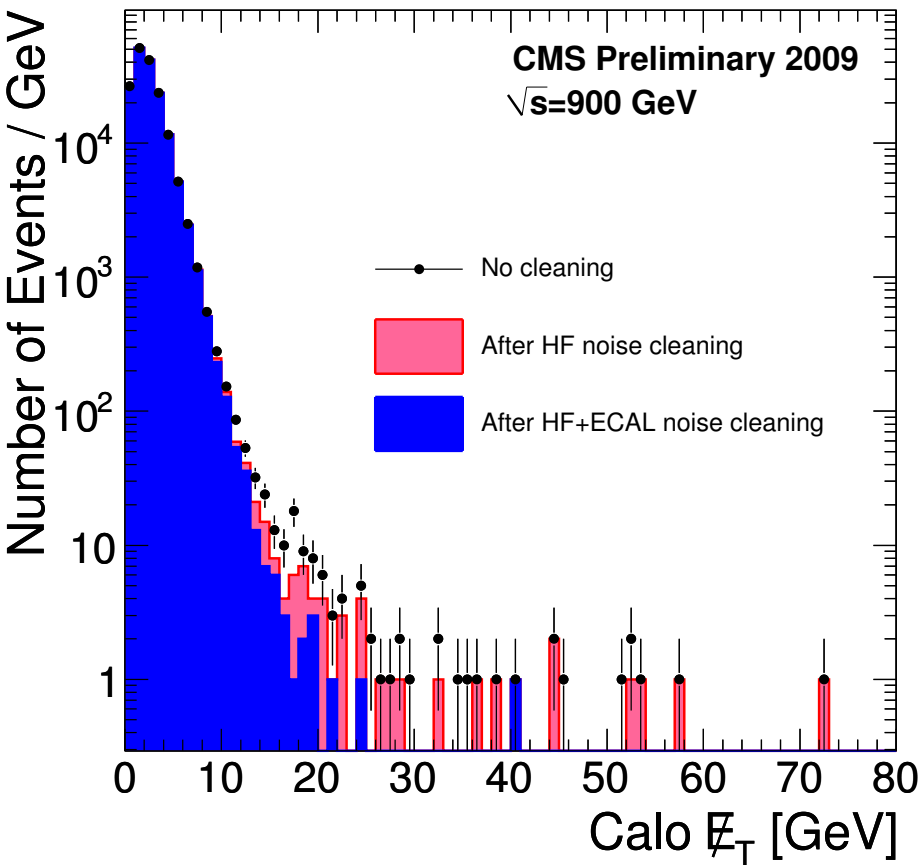
Dijet candidate event at $\sqrt{s} = 900$ GeV

Jets – p_T and composition



CMS-PAS-JME-10-001

Missing E_T



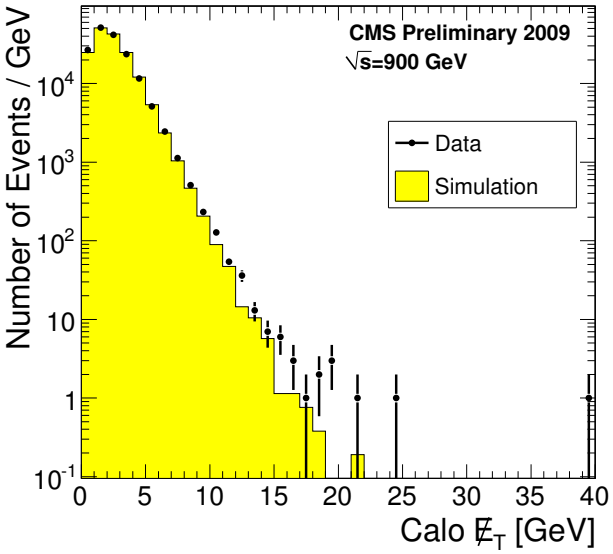
- Corrections
  - Robust missing E_T measurement over the full data-taking period
  - Anomalous noise in HCAL
    - hybrid photo diodes
    - photo-multiplier window hits
  - Anomalous noise in ECAL
    - single crystals, "spikes"
  - Beam-halo muons

CMS-PAS-JME-10-002

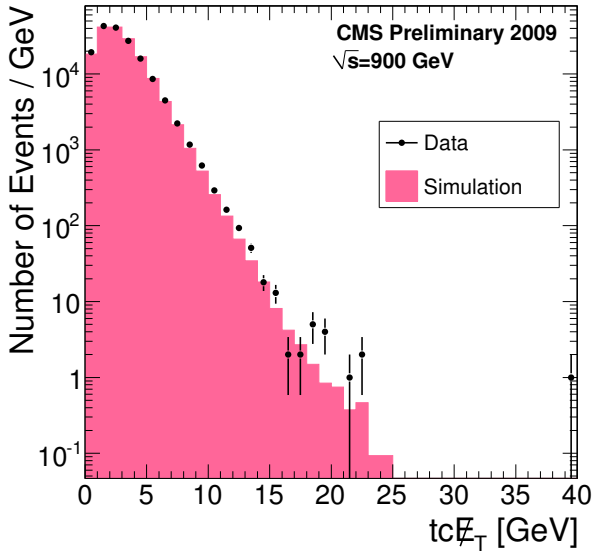
Very efficient cleaning procedure: reduction of the E_T tail

Missing E_T

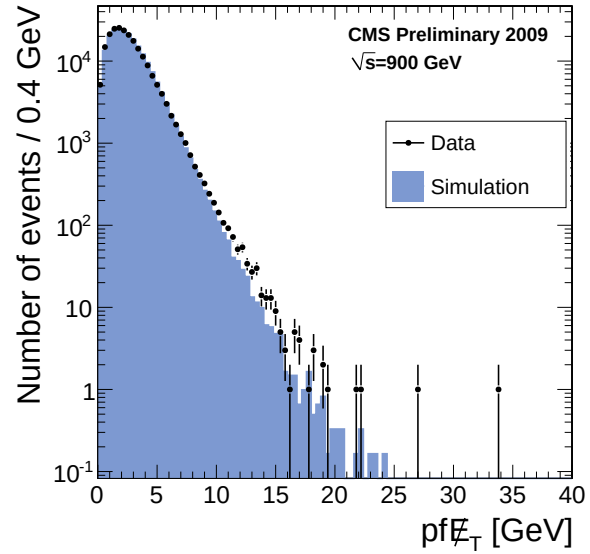
Calorimeter



Track corrected

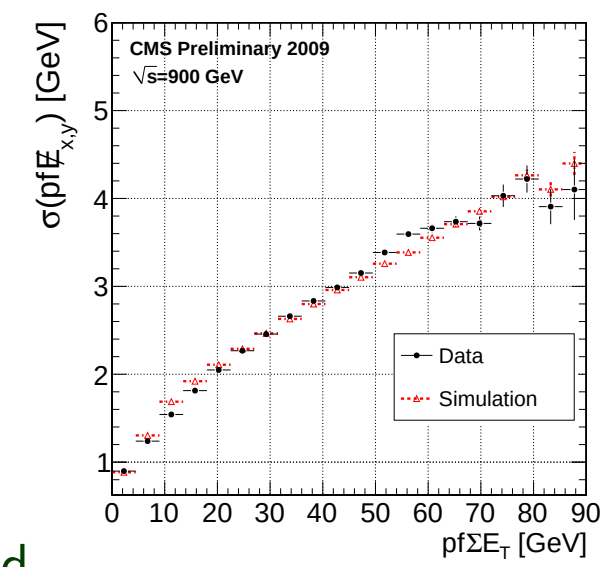


Particle flow



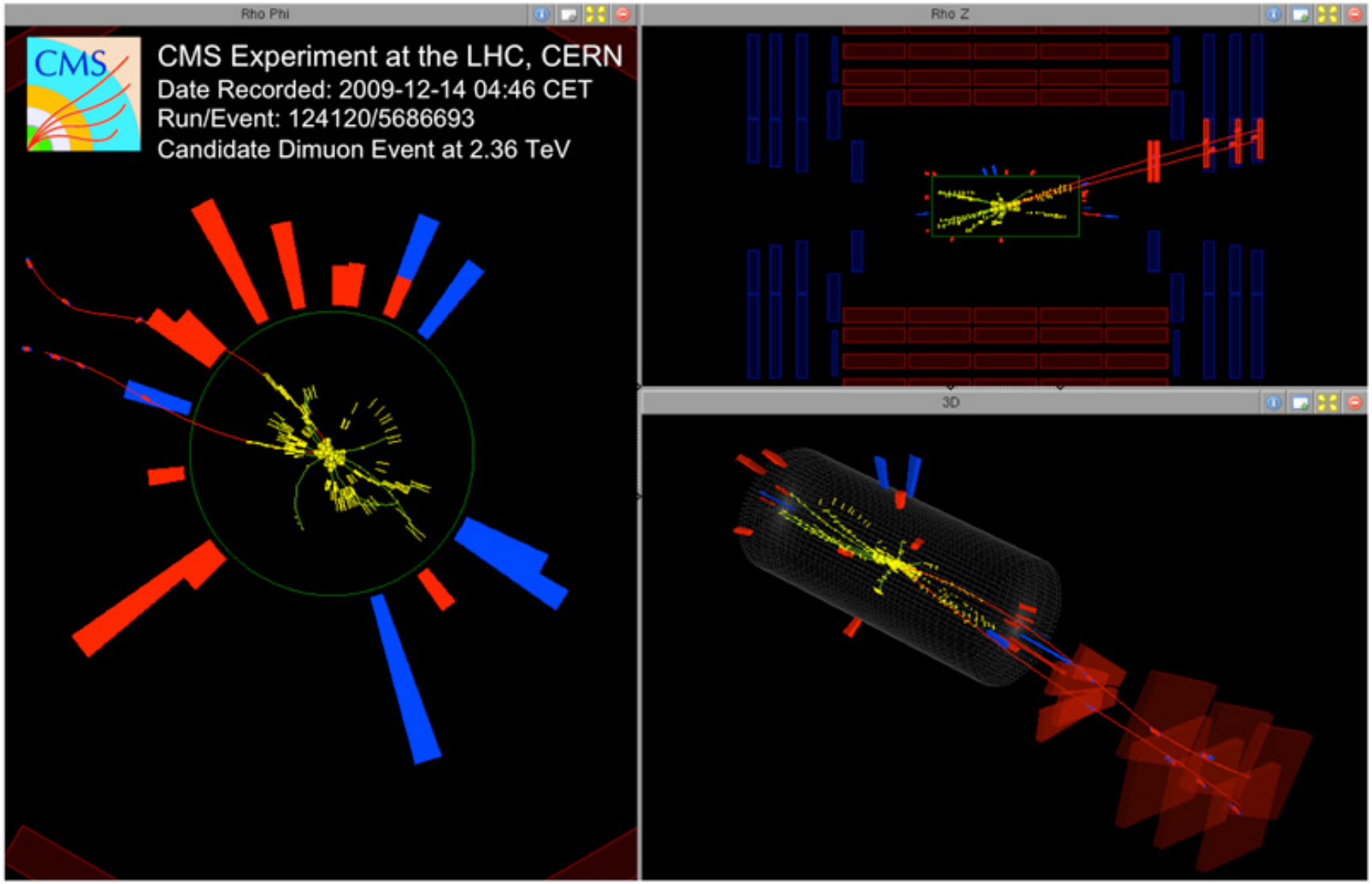
- Performance
  - Tails are small thanks to the cleaning
  - Three methods to compare
  - Since no signal is expected yet, resolution can be measured
  - Better resolution with Particle flow than for calorimeter-only

$$\sigma_{E_T} = 0.55 \text{ GeV} \oplus 0.45 \sqrt{\sum E_T}$$



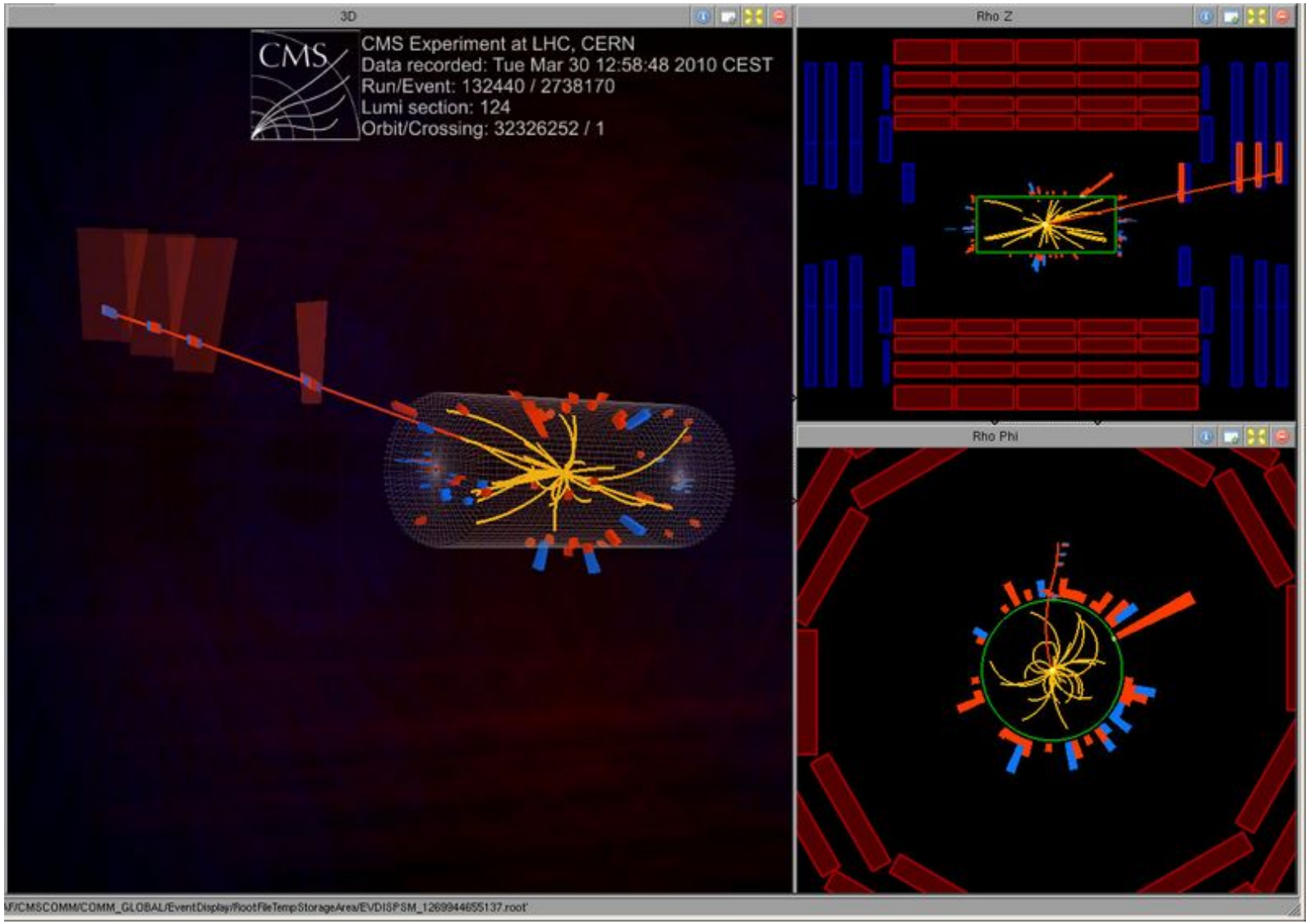
Missing E_T is well described

Muons



Muon pair at $\sqrt{s} = 2.36$ TeV

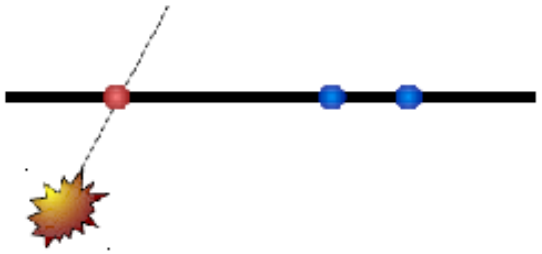
Muons



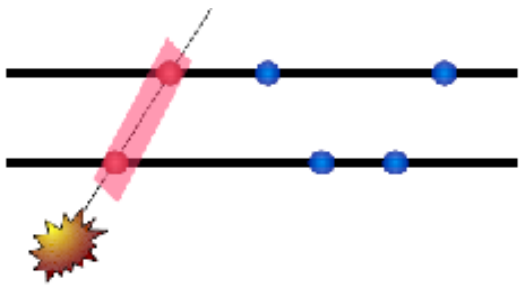
Forward muon at $\sqrt{s} = 7$ TeV

Physics results

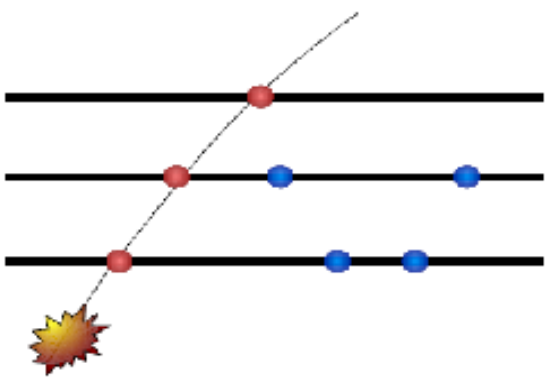
Spectra of charged hadrons – methods



- Pixel hit counting (1 hit)
  - Using the primary vertex, calculate η for each cluster
  - Immune to detector mis-alignment, simplest
  - $p_T > 30$ MeV/c, $|\eta| < 2$



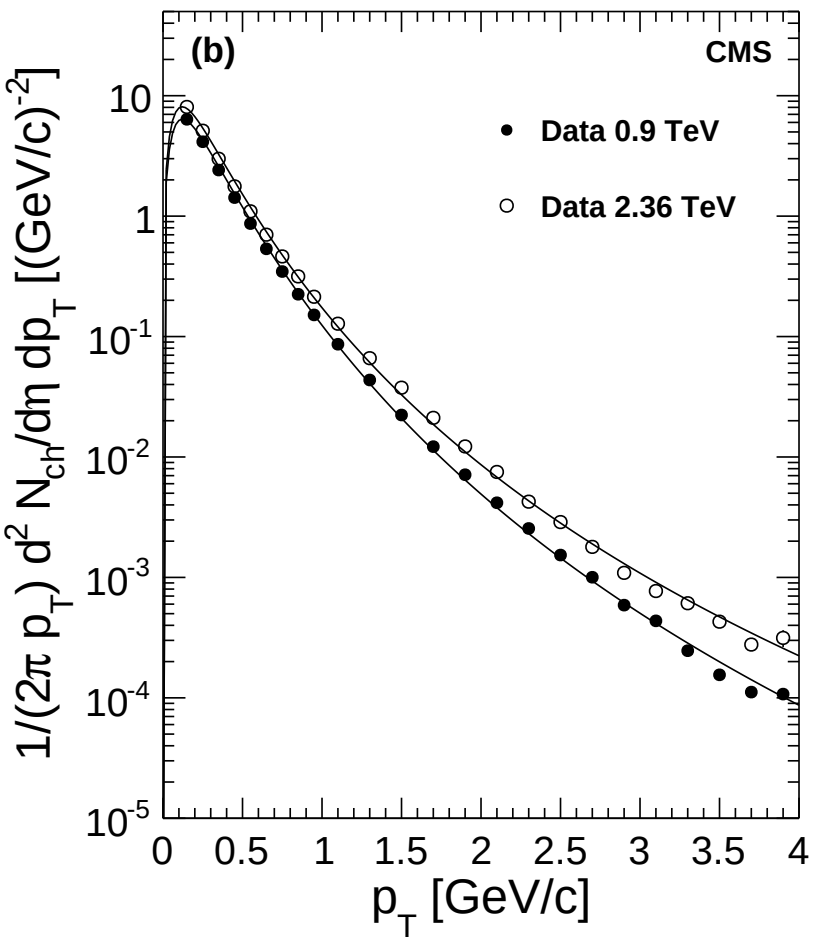
- Tracklets (2 hits)
  - Form hit pairs, calculate η
  - Data-driven background subtraction
  - $p_T > 50$ MeV/c, $|\eta| < 2$

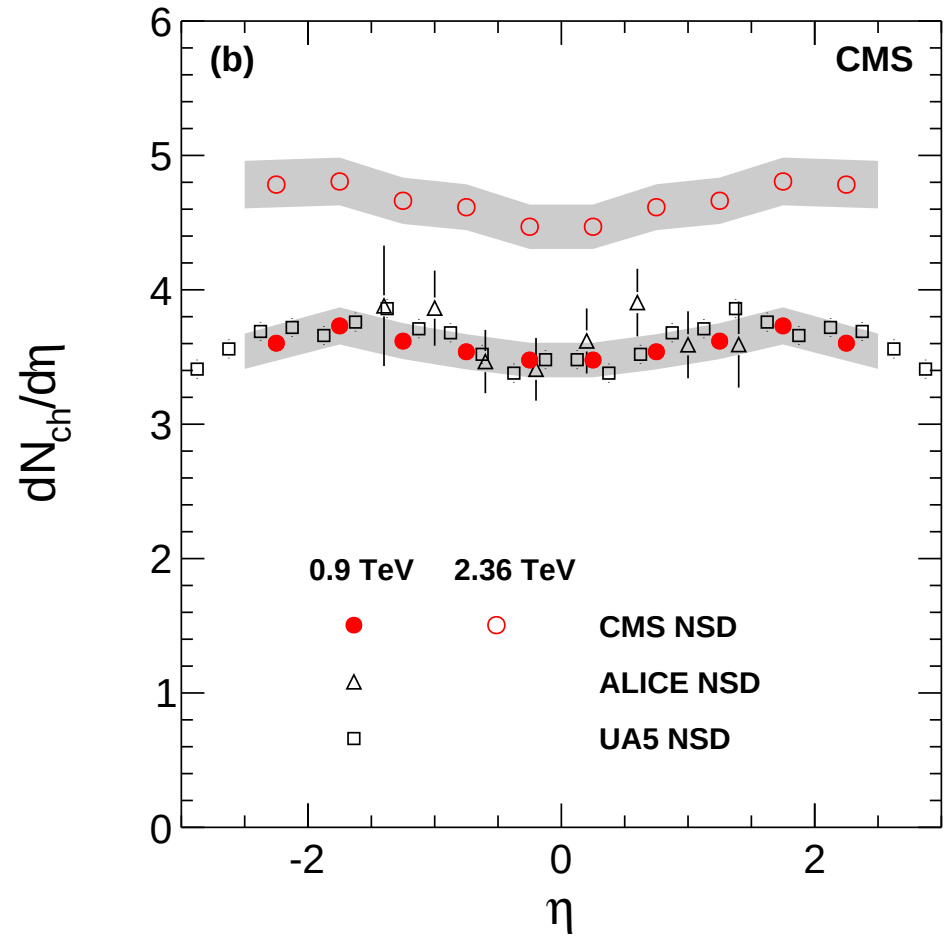


- Full tracks
  - Use all pixel and strip hits, provide η and p_T
  - Sensitive, most complex
  - $p_T > 100$ MeV/c, $|\eta| < 2.4$

Measure η and p_T of charged hadrons with the silicon tracker

Spectra of charged hadrons – spectra





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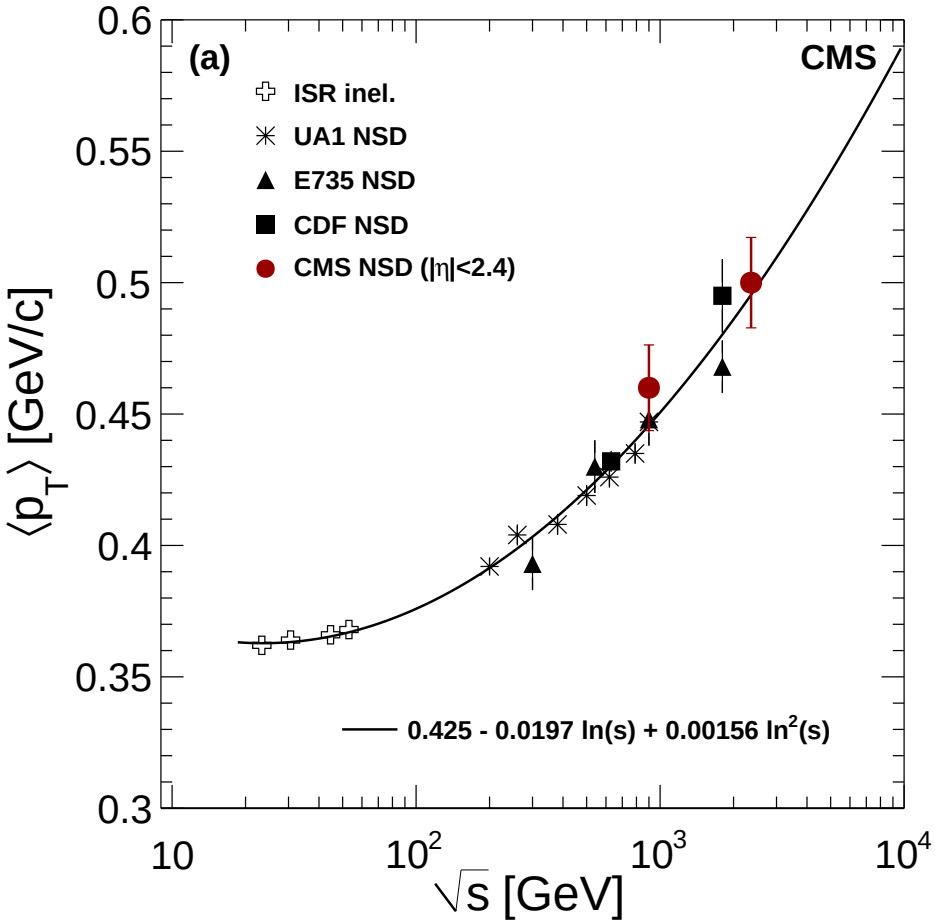
Three methods: full tracks; tracklets with bckg subtraction; hit counting with corr's

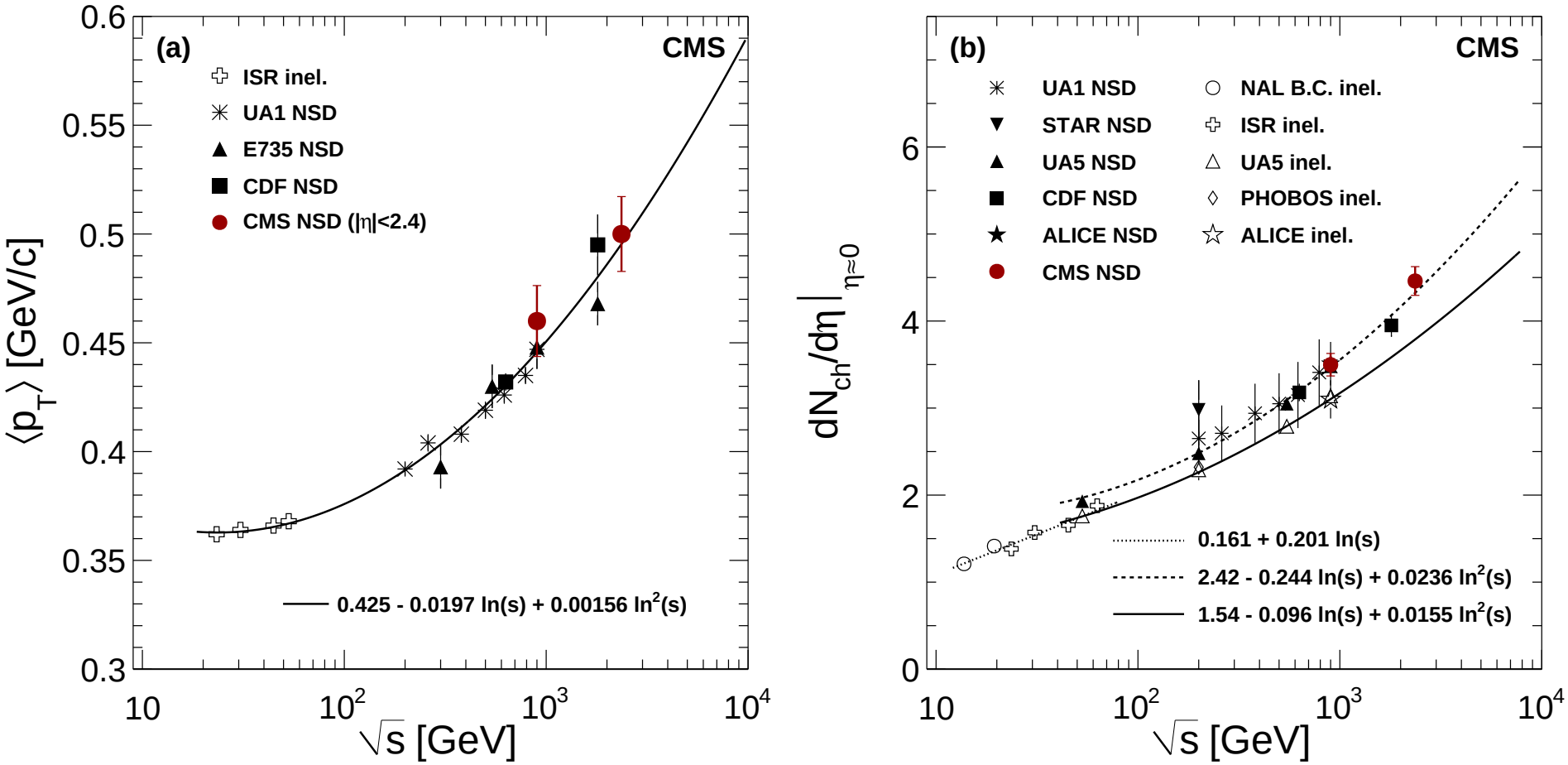
Tsallis fits: combination of low-p_T exponential and high-p_T power law

First published momentum distribution, first 2.36 TeV results, 8 citations

Spectra of charged hadrons – $\sqrt{s}$ dependence



Spectra of charged hadrons – $\sqrt{s}$ dependence



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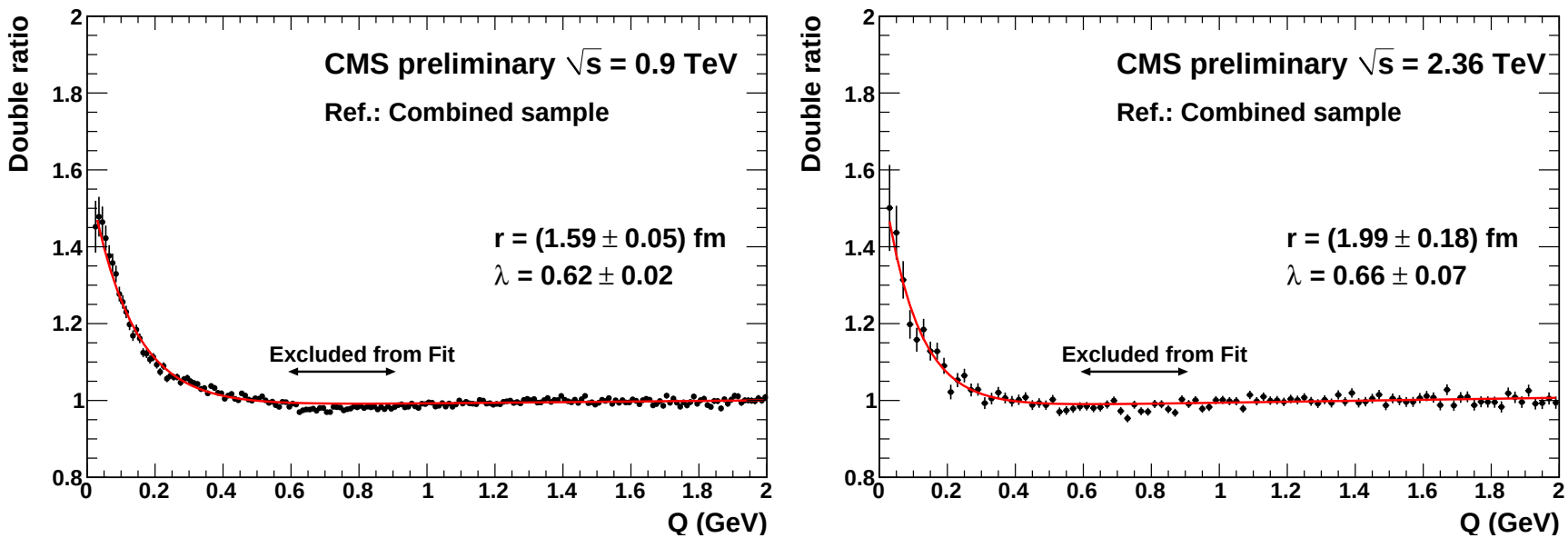
Higher $\langle p_T \rangle$, accelerated increase of $dN_{ch}/d\eta$ density

Input for theory, numbers soon also at 7 TeV

Bose-Einstein correlation of charged hadrons

- The effect
  - Correlation between identical bosons
  - The size of the correlated emission region can be inferred
  - What to measure? Difference of four-vectors, $Q = \sqrt{-(p_1 - p_2)^2}$



Measurement of Bose-Einstein correlations with first CMS data, CMS-PAS-QCD-10-003

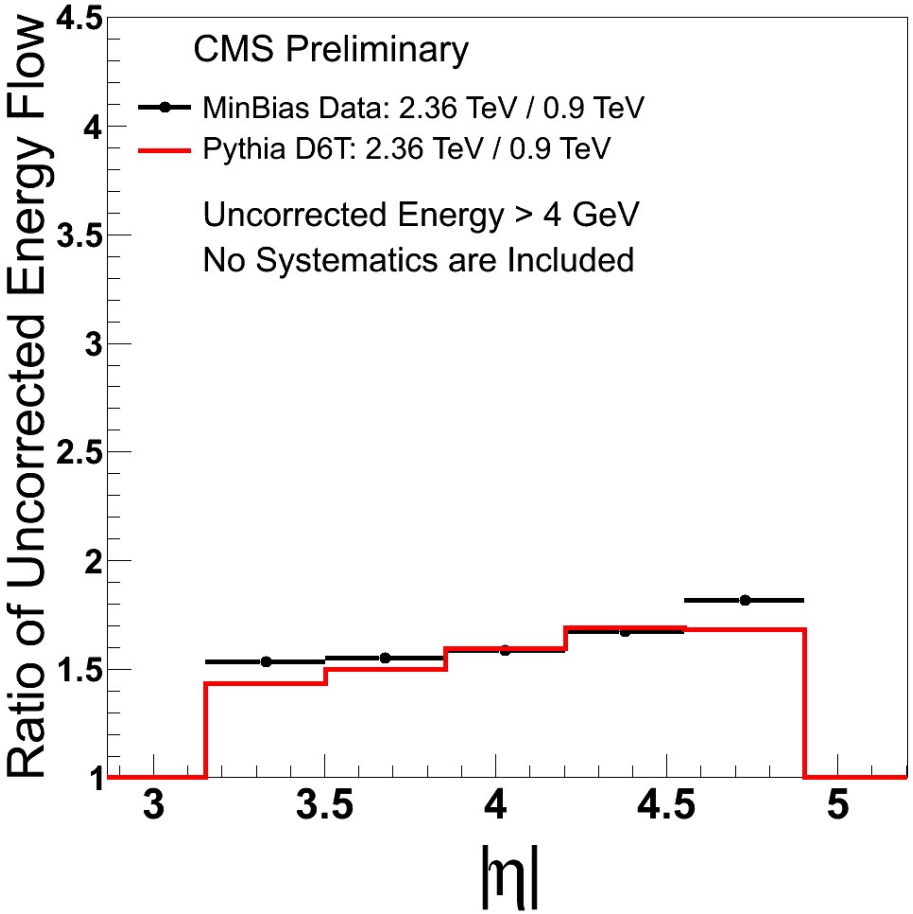
Ratio of signal and uncorrelated background distributions

Exponential behavior, extracted radius and correlation strength λ

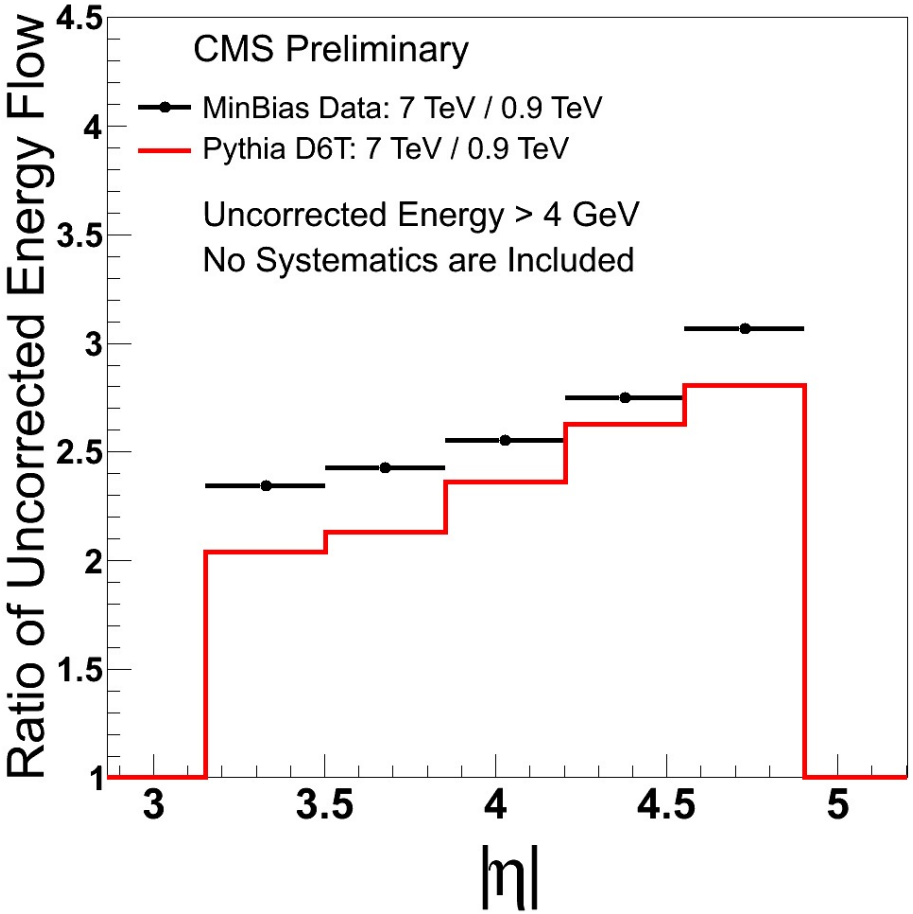
Much more in parallel talk "QCD physics from CMS", Thu 11:15

Forward physics – ratio of energy flow

2.36 TeV/0.9 TeV



7 TeV/0.9 TeV

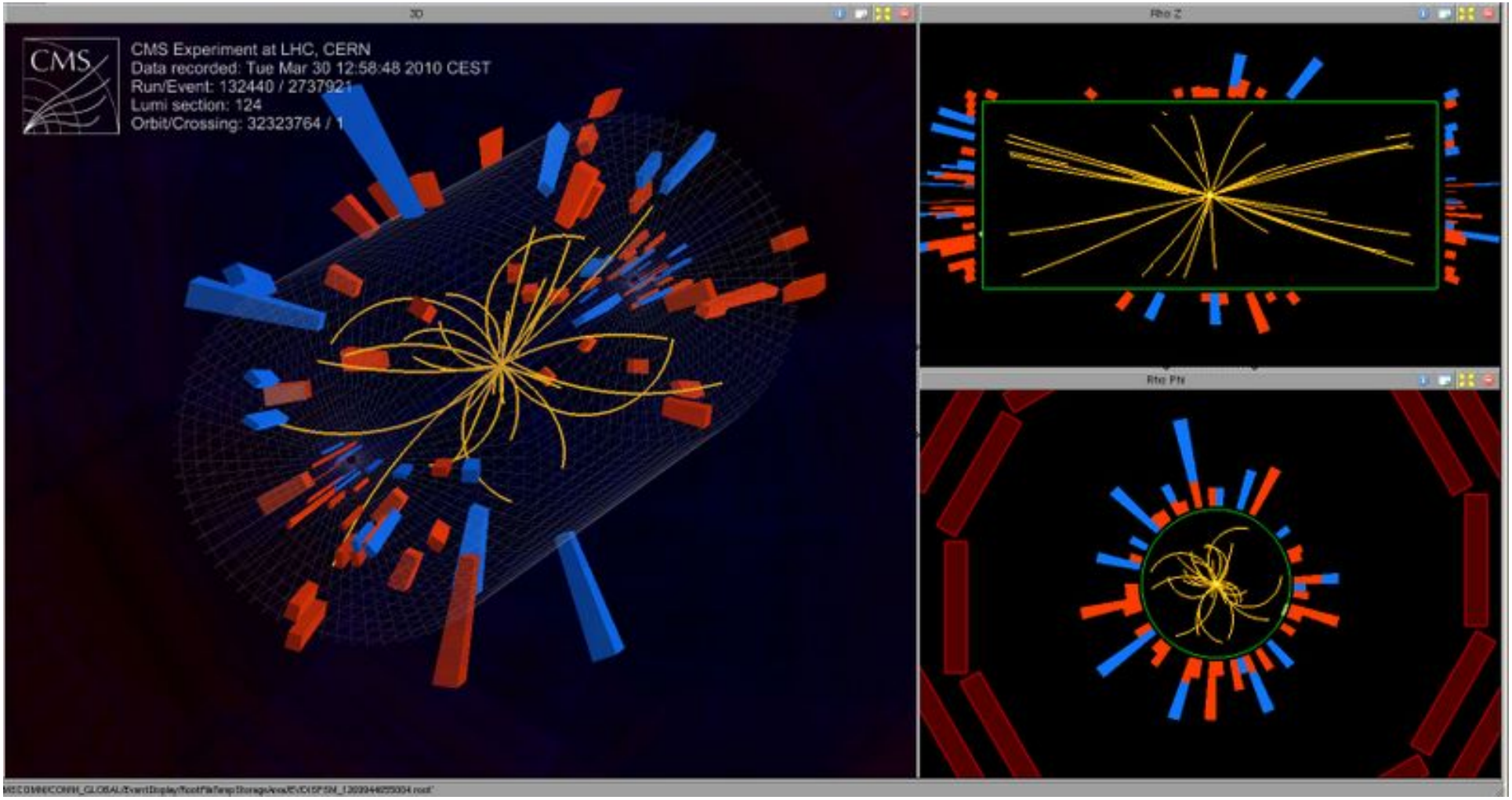


Can be important when studying multiple parton interactions

Valuable input for model tuning in the forward region

See parallel talk "Measurements of the transverse energy flow and forward jets", Wed 12:40

First 7 TeV collisions



A minimum bias pp event at CMS

First 7 TeV collisions

CMS Control Room at P5

Starting the long march towards 1 fb^{-1} and possible discoveries

The CMS menu for DIS'2010

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- Forward
  - **Measurement of the transverse energy flow and forward jets [data]**
    Wed 12:40, *Joint QCD and final states and Diffraction*, Sercan Sen
  - **Exclusive production at LHC (CMS)**
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- Top
  - **Expectations for first single-top studies in CMS**
    Tue 14:50, *EWK and searches*, Jeannine Wagner-Kuhr
  - **Top rediscovery at the LHC (CMS + ATLAS)**
    Wed 12:35, *Heavy flavors*, Julien Donini

The CMS menu for DIS'2010 (cont'd)

- EWK
  - **Studies of the Z→ee diff cross-section as a function of Z rapidity**
    Wed 12:20, *Parton densities*, Bryan Dahmes
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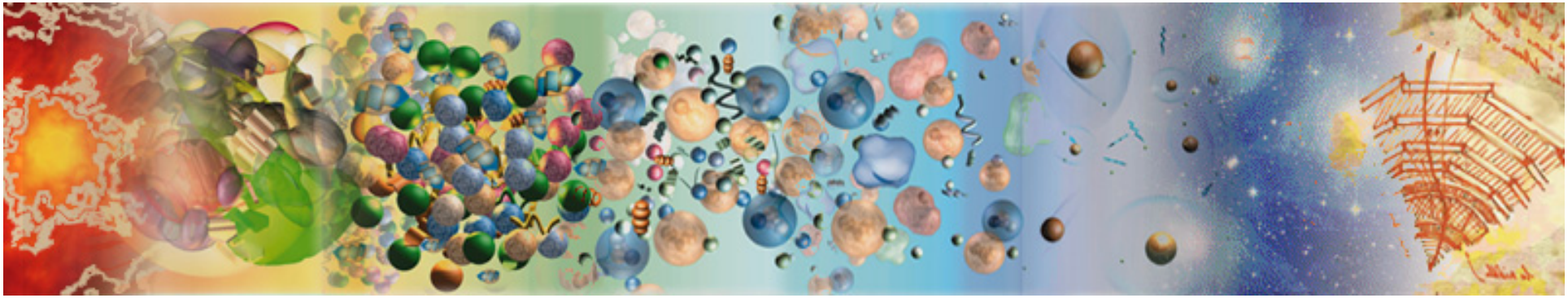
- B physics
  - **First beauty measurements at CMS**
    Thu 12:15, *Heavy flavors*, Roberto Covarelli

Summary

- Performance
  - Results from a small data sample
  - Many aspects are already commissioned (tracking, calorimeters)
  - Excellent performance seen

- Physics
  - First physics analyses and publication at 0.9 and 2.36 TeV



Much more to come