





# First results from the 13 TeV data with the CMS Experiment

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#### First collisions at 13 TeV



## Welcome to the 13 TeV era

Here: results using the early data with luminosity from  $nb^{-1}$  to  $42pb^{-1}$ 

CMS Integrated Luminosity, pp, 2015,  $\sqrt{s}=$  13 TeV



## Measuring from the lightest to the heaviest particles

#### $\dots$ in the SM



#### Top quark physics: $t\overline{t}$ and single top cross section



## Measuring from the lightest to the heaviest particles

#### $\ldots$ in the SM



#### Top quark physics: $t\overline{t}$ and single top cross section



#### ... and beyond: Heavy resonance searches



## Plethora of studies with the 13 TeV data



# Dimuons spectroscopy [CMS-DP-2015-018]

#### [CMS-DP-2015-016]



#### Resonance searches

#### [CMS-DP-2015-037]



#### SUSY Commissioning

#### [CMS-DP-2015-035]



## Soft QCD

- The understanding and modeling of QCD interactions necessary for precision measurements and searches for new physics
- Soft particle production cannot be calculated reliably using pQCD: generally described by phenomenological models
   → Monte Carlo tunes



#### Pseudorapidity distribution of charged hadrons [PLB 751 (2015) 143]

- Inclusive production of charged hadrons  $dN/d\eta$  gives a handle on the relative weight of soft and hard scattering contributions  $\rightarrow$  Important for precise modeling of pile-up collisions
- Collect minimum bias data in low pile up (PU) runs
  - Data taken on June 7, average PU~0.2-5%, B=0T (straight tracks)
- Strategy: Use different techniques with different sensitivities to misalignment, material detector response, background contamination





Two hits in different pixel layers

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Tracks from pixel hits triplets: three aligned hits fitted to a straight line

#### Results [PLB 751 (2015) 143]



- Corrected to a sample of inelastic collisions:  $dN/d\eta(|\eta| < 0.5) = 5.49 \pm 0.01 \text{ (stat)} \pm 0.17 \text{ (syst)}$
- Collision energy dependence as expected
- $\rightarrow$  First LHC publication with 13 TeV data

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## Long-range near-side two-particle angular correlations

arXiv:1510.03068, submitted to PRL



• High-multiplicity events show long-range correlations at  $\Delta \Phi \sim 0$  (near-side ridge)

- Associated yield extracted as a function of charged particle multiplicity and pT
  - Linear raise of the associated yield is observed as a function of number of tracks

## The top quark

Top quark production mainly in pairs  $(t\bar{t})$  and via gluon fusion at LHC



• Measuring  $\sigma_{t\bar{t}}$  is the first fundamental step for understanding top physics

- Test QCD predictions and help constraining the PDFs (especially gluon distribution)
- Main background for Higgs and many searches for New Physics
- May provide insight into physics BSM
- Measure  $t\bar{t}$  in different regions of the phase space: further understanding of QCD, enhance sensitivity to new physics

## First 13 TeV top quark candidates

#### $t\bar{t} e\mu + 2 b jets$ single top quark CMS Experiment at LHC\_CERN Data recorded: Tac Jul 14 11:47:11 2015 CEST Run/Event: 251721 / 22303468 CMS (im) section: 21 CMS Experiment at LHC, CERN CMS, Data recorded: Wed Jul 8 19:26:24 2015 CEST Run/Event: 251244 / 83494441 Lumi section: 151 Orbit/Crossing: 39572626 / 358 MET untagged jet MET= 164.0 GeV b-tagged j muon Jet p, = 81.6 GeV CMS Experiment at LHC. CERN Electron CMS Hats recorded' Thu Jul 9 01/29 2: Run/Event: 251252765011478 p, = 57.7 Lumi section: 140 Orb //Crossing 38595725 / 2078 Jet p. = 56.8 GeV Muon p. = 53.8 GeV muon jet from W jet from W biet extra jet $t\bar{t} \ \mu + \ge 4$ jets C. Diez Pardos (DESY) 03.11.2015 11/28

#### Inclusive cross section

## $t ar{t} \ e \mu \ {\sf channel}$ [arXiv:1510.05302, submitted to PRL]



 $\sigma_{t\bar{t}} = 769 \pm 60(\text{stat}) \pm 55(\text{syst}) \pm 92(\text{lumi}) \text{ pb}$ (16% precision)

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03.11.2015

42 pb<sup>-1</sup> (13 TeV)

Non W/Z

Number of jets 42 pb<sup>1</sup> (13 TeV)

Non W/Z VV tW

> 250 300 m<sub>ey</sub> (GeV)

Data

Data

ZIN

## $t\bar{t}$ : I+jets channel [CMS-PAS-TOP-15-005]



## Grand summary $t\bar{t}$ cross sections



Good agreement among all measurements, also with NNLO+NNLL theory  $_{\rm 03.11.2015}$ 

## Differential cross section: analysis strategy

- Event selection
- 2 Top quark kinematic reconstruction



- Bin-wise cross section measurement:
- ◊ Subtract background
- ◊ Unfolding: correct for detector effects & acceptance to particle or parton level in full or visible phase space
- ${f 9}$  Normalised to measured  $\sigma$  in the same phase space
- Sompare to theory predictions/calculations



#### $t\bar{t}$ and top quark kinematics [CMS-PAS-TOP-15-005/10]

- Results measured in full phase space at parton level
- Measurements are dominated by the statistical uncertainty



• In general good agreement between data and predictions

Results as a function of global event variables (MET, HT, etc.): CMS-PAS-TOP-15-013

## tī: jet multiplicity [CMS-PAS-TOP-15-005/10]

Large fraction of  $t\bar{t}$  produced with high energetic jets from initial and final state radiation

- Stringent test of QCD perturbation series to higher orders
- Reveal presence of new physics in tt
  +jets final states, background for ttH



• Measured at particle level in fiducial phase space



Single Top

## Single top production via EWK interaction



## Single top t-channel production

Why are single tops interesting?

#### ... in the Standard Model

 Direct probe of Wtb coupling, V<sub>tb</sub> in CKM matrix.

$$\left(\begin{array}{ccc} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{array}\right)$$

- Constrain u/d PDF models (ratio of top/anti-top cross-sections)
- ... as probe for new physics:
  - 4th generation of quarks, FCNC, contributions from additional bosons (W'), charged Higgs, dark matter associated production
  - anomalous EWK couplings (corrections from higher energies)



#### t-channel inclusive cross section [CMS-PAS-TOP-15-004]

q q'foward b t l

- Selection: 1 isolated high-p<sub>T</sub> muon, 1 central b-tagged jet, 1 forward light jet, M<sub>T</sub>(W)
- Template fit to the pseudorapidity of the forward jet



#### Single Top

## t-channel inclusive cross section [CMS-PAS-TOP-15-004]

- σ = 274 ± 98(stat) ± 52(syst) ± 33pb(lumi), constrained |V<sub>tb</sub>| > 0.7 at 95%CL
- Significance: 3.5 (2.7) observed (expected)



## **Resonant Di-jet Candidate** (5.4 TeV!)



#### Dijet resonances [CMS-PAS-EXO-15-001]

- Search for heavy particles decaying into 2 jets
- For narrow resonances : search for a bump in the di-jet mass spectrum.





- $\bullet$  Simple and striking signature  $\rightarrow$  sensitive to any resonance coupling to quarks/gluons
- New energy scale reachable, expected to have already a better sensitivity for masses > 5 TeV!

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#### Selection [CMS-PAS-EXO-15-001]

• Wide jets improve dijet mass resolution





- Fit to the dijet invariant mass
- No evidence of dijet resonances: data agree with background fit function

#### Results [CMS-PAS-EXO-15-001]



- Exclusion limits are calculated for gluon-gluon, quark-gluon and quark-quark.
- Exclusion from 2.3 to 5.1 TeV (best exclusion), depending on the model.

Model	Final State	Obs. Mass Limit [TeV]	Exp. Mass Limit [TeV]
String Resonance (S)	qg	5.1	5.2
Excited Quark (q*)	qg	2.7	2.9
Scalar Diquark (D)	qq	2.7	3.3
Axigluon (A)/Coloron (C)	φą	2.7	2.9
Color Octet Scalar (s8)	gg	2.3	2.0

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#### Prospects at 13 TeV

CMS Integrated Luminosity, pp, Run 2  $\sqrt{s} = 13$  TeV



## Some prospects at 13 TeV



- Measure the couplings of the top quark to  $Z,\gamma$  and top-Yukawa coupling
- Higgs: first measurement of VBF, VH
- Highest dijet mass bin >7 TeV
- Hopefully first discoveries!

### Summary

- A new challenging time just started at LHC 13 TeV Run2
- First measurements from 13 TeV with a luminosity  $\leq$ 50 pb<sup>-1</sup> are already public
- $\bullet\,$  First competitive searches at 13TeV  $\rightarrow\,$  Nothing found yet
- Many new results (EWK, searches for BSM, SUSY) expected before the end of the year!
- CMS public Physics results available from: http://cms-results.web.cern.ch/cms-results/public-results/publications/

# BACK UP

## CMS after Long Shutdown 1



#### Some Prospects at 13 TeV

- For high mass searches parton luminosity counts!
- With 3 fb<sup>-1</sup> all searches with  $M_x > 2$  TeV are competitive



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## Magnet Criogenics

- The restart of the CMS magnet after LS1 was more complicated than anticipated due to problems with the cryogenic system in providing liquid Helium.
- Inefficiencies of the oil separation system of the compressors for the warm Helium required several interventions and delayed the start of routine operation of the cryogenic system.
- Currently the magnet can be operated, but the continuous up-time is still limited by the performance of the cryogenic system requiring more frequent maintenance than usual.
- A comprehensive program to re-establish its nominal performance is underway. These
  recovery activities for the cryogenic system will be synchronized with the accelerator
  schedule in order to run for adequately long periods.
- A consolidation and repair program is being organized for the next short technical stops and the long TS at the end of the year.