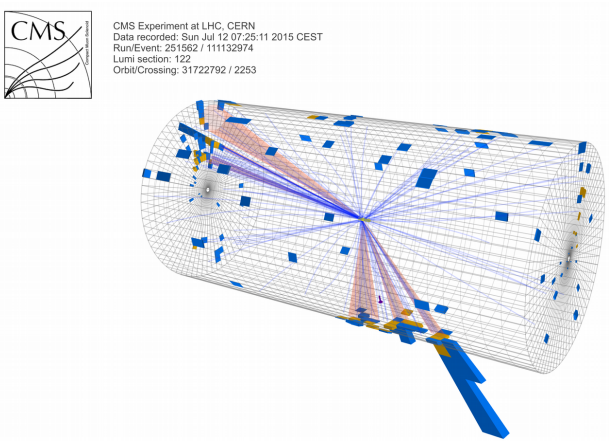
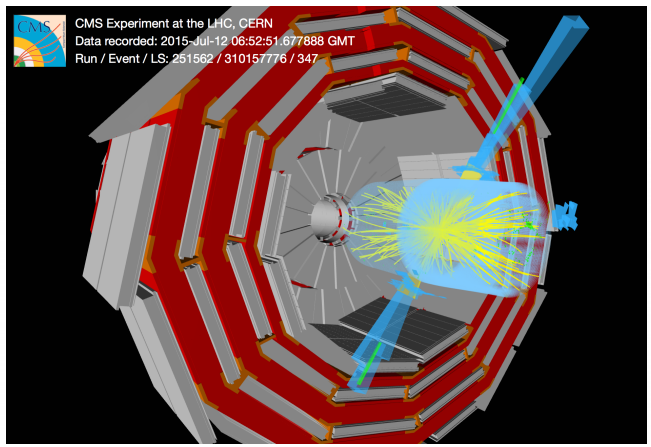
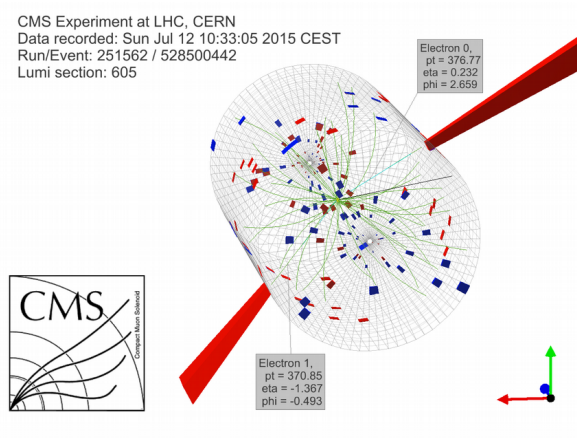
First results from the 13 TeV data with the CMS Experiment

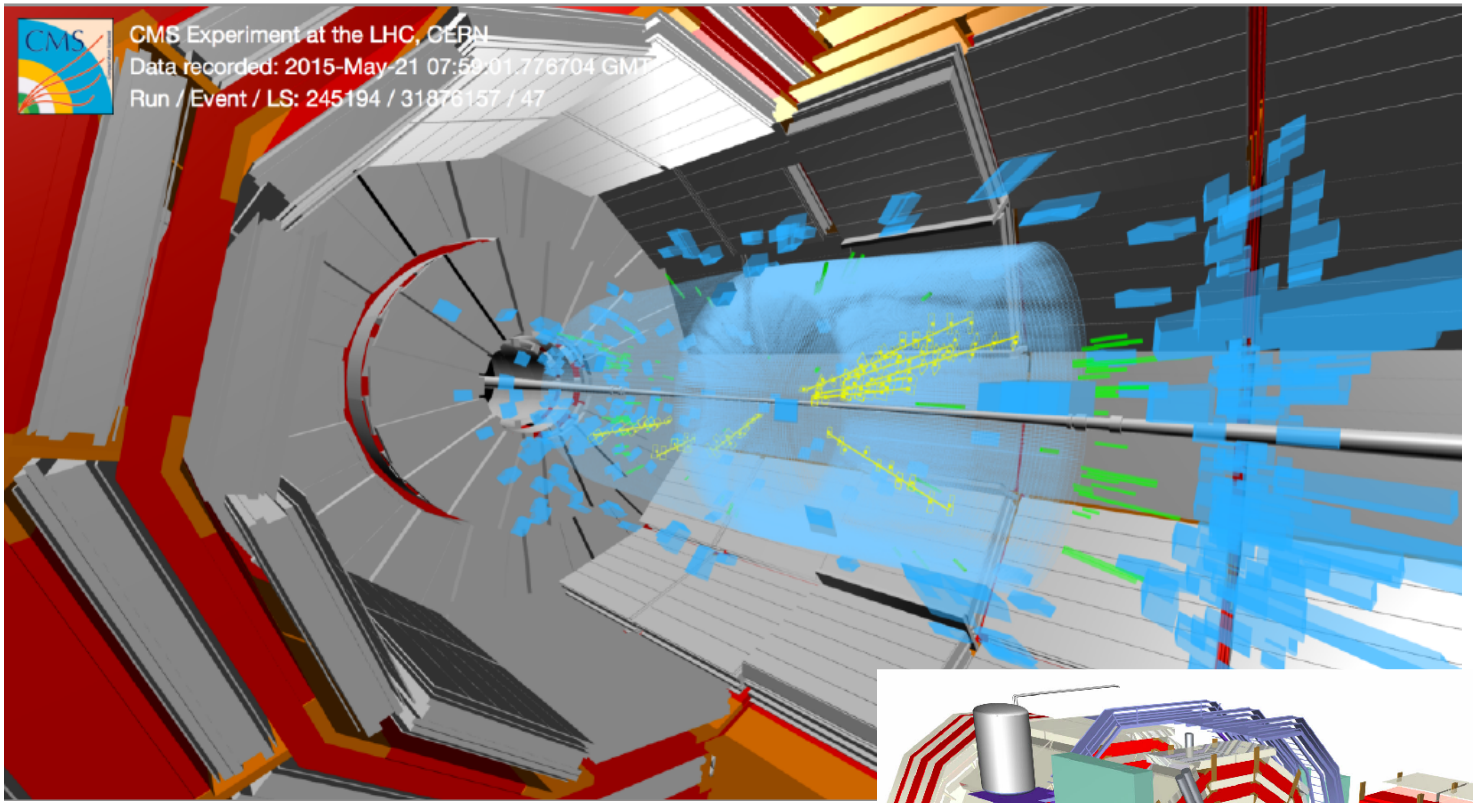
Carmen Diez Pardos
DESY Hamburg

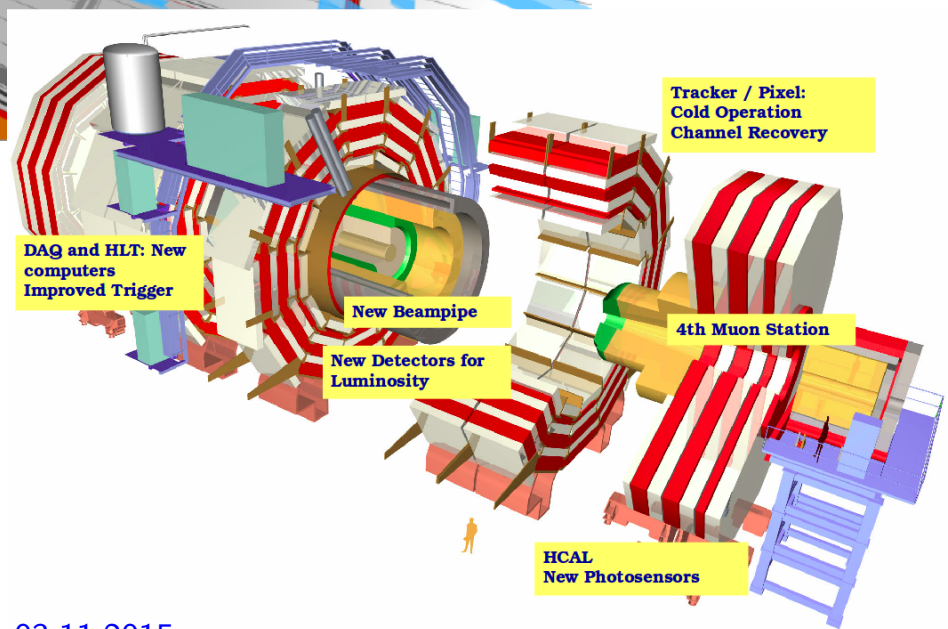






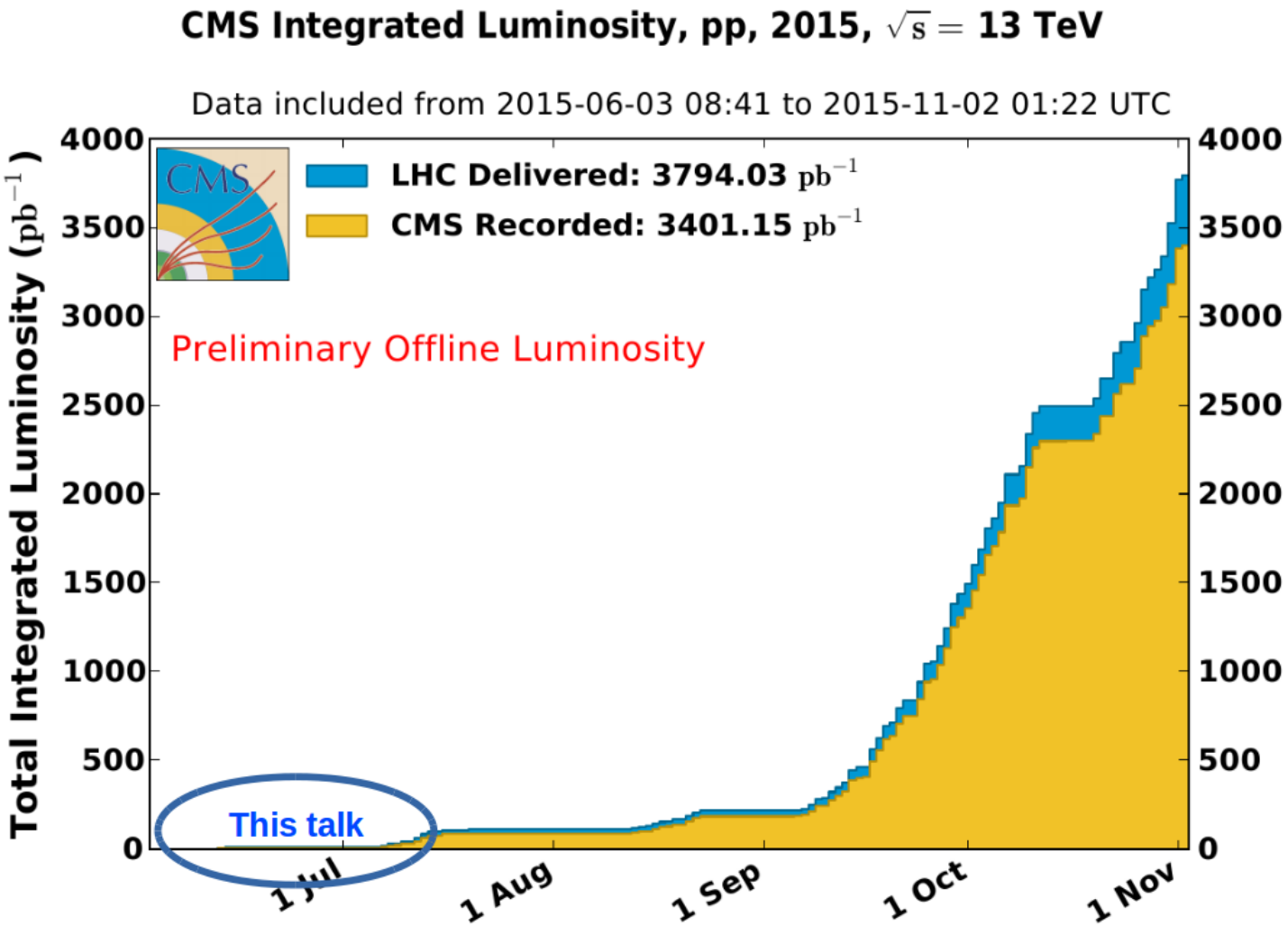
First collisions at 13 TeV





Welcome to the 13 TeV era

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



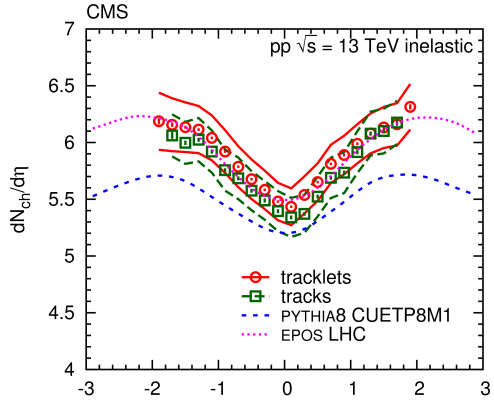
Measuring from the lightest to the heaviest particles

...in the SM

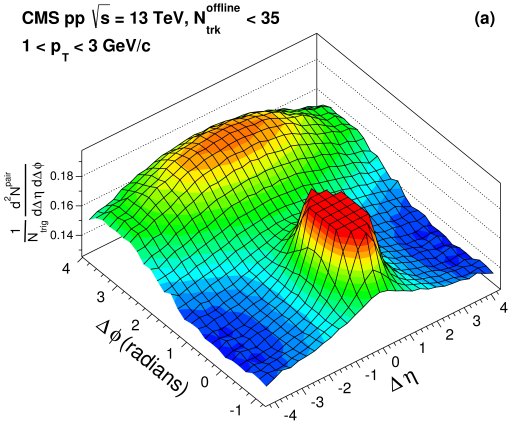
QCD

η charged hadrons

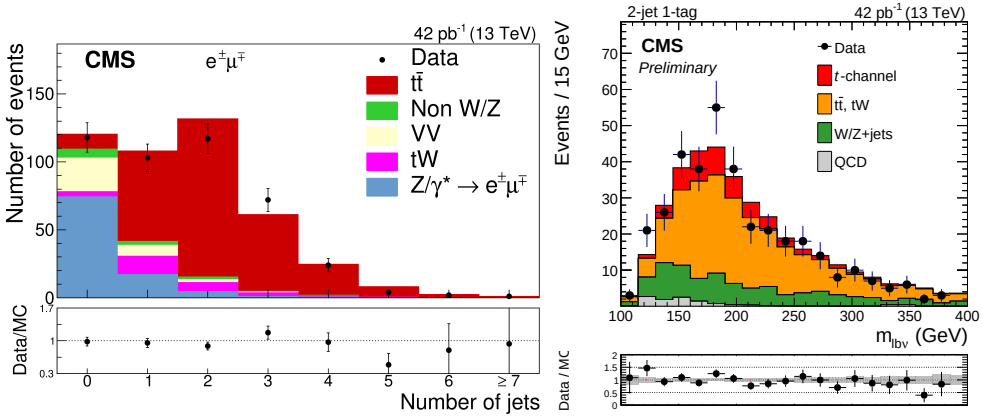
arXiv:1510.03068



two-particle angular correlations arXiv:1510.03068



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



arXiv:1510.05302, CMS-PAS-TOP-15-004/005/010/013

Measuring from the lightest to the heaviest particles

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QCD η charged hadrons

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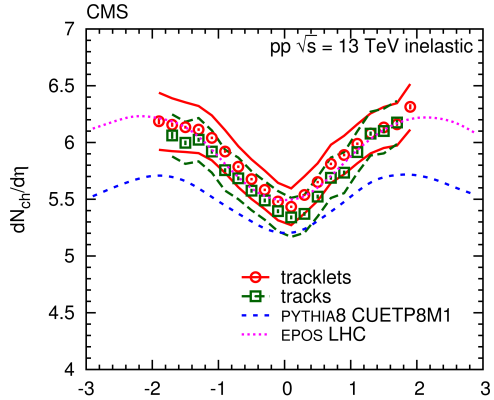

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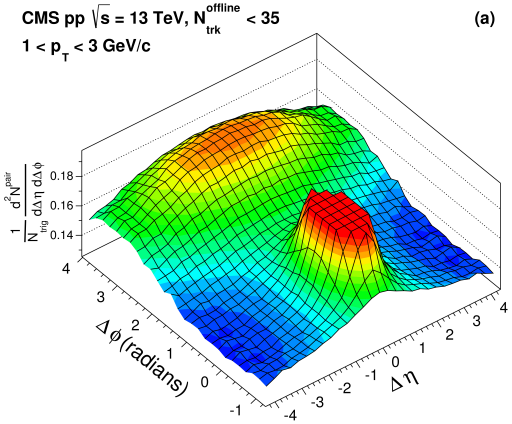
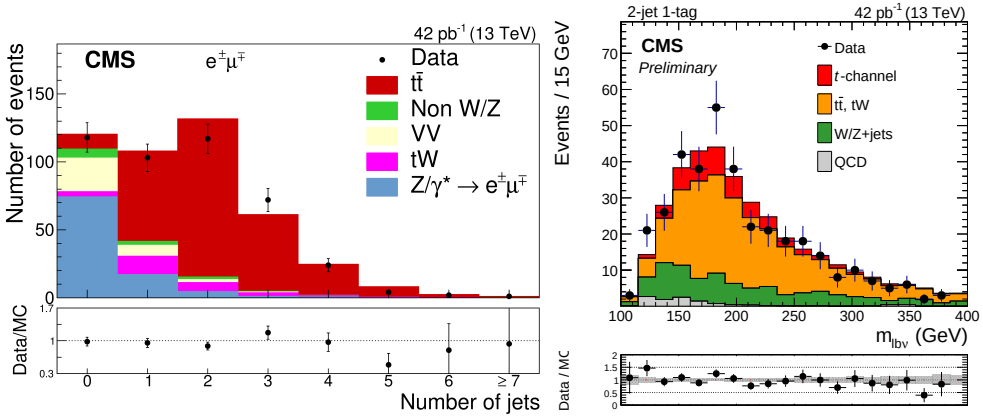
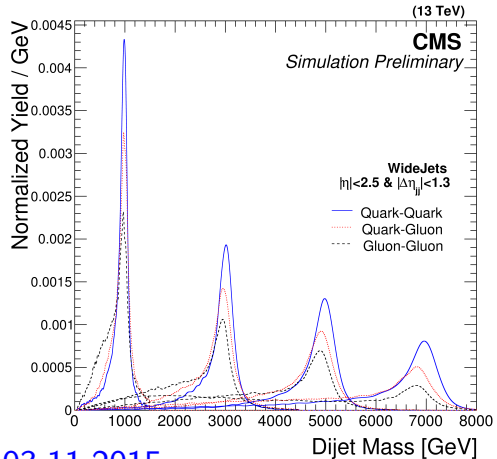


Top quark physics: $t\bar{t}$ and single top cross section



arXiv:1510.05302, CMS-PAS-TOP-15-004/005/010/013

... and beyond: Heavy resonance searches

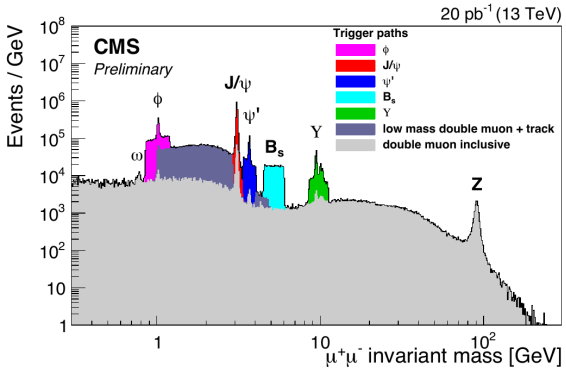


CMS-PAS-EXO-15-001

Plethora of studies with the 13 TeV data

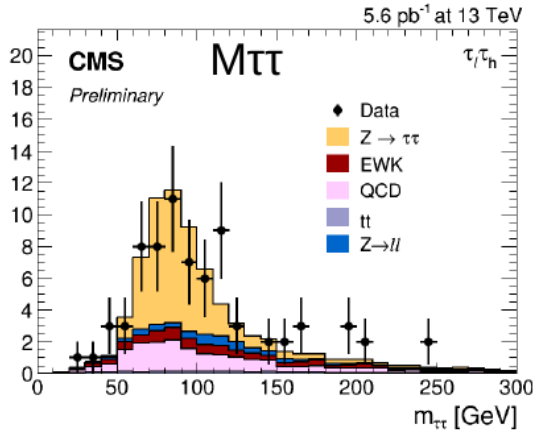
Dimuons spectroscopy

[CMS-DP-2015-018]



EWK commissioning

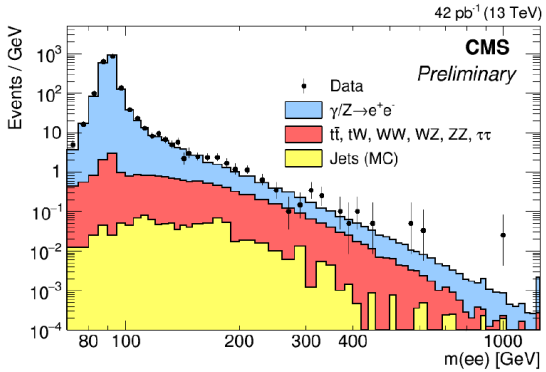
[CMS-DP-2015-016]



ZZ → 2e2μ candidate

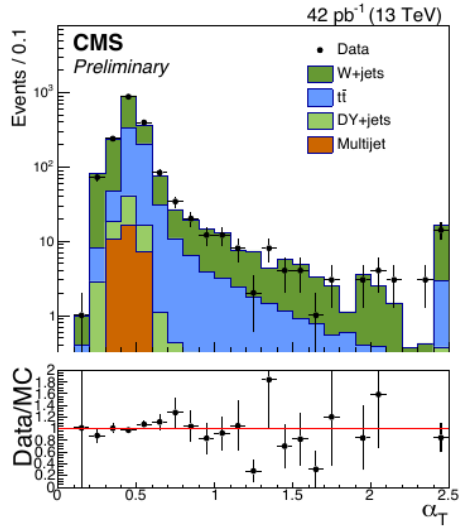
Resonance searches

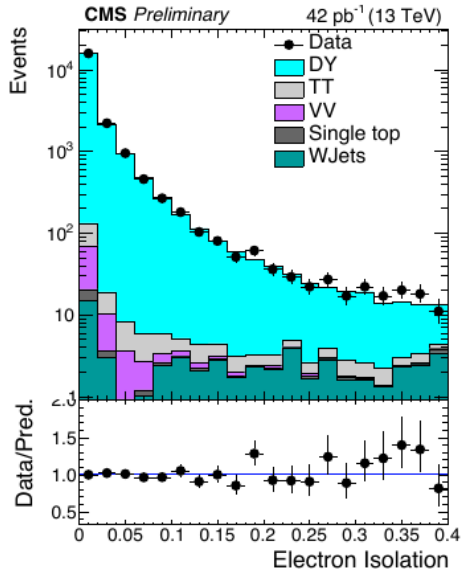
[CMS-DP-2015-037]



SUSY Commissioning

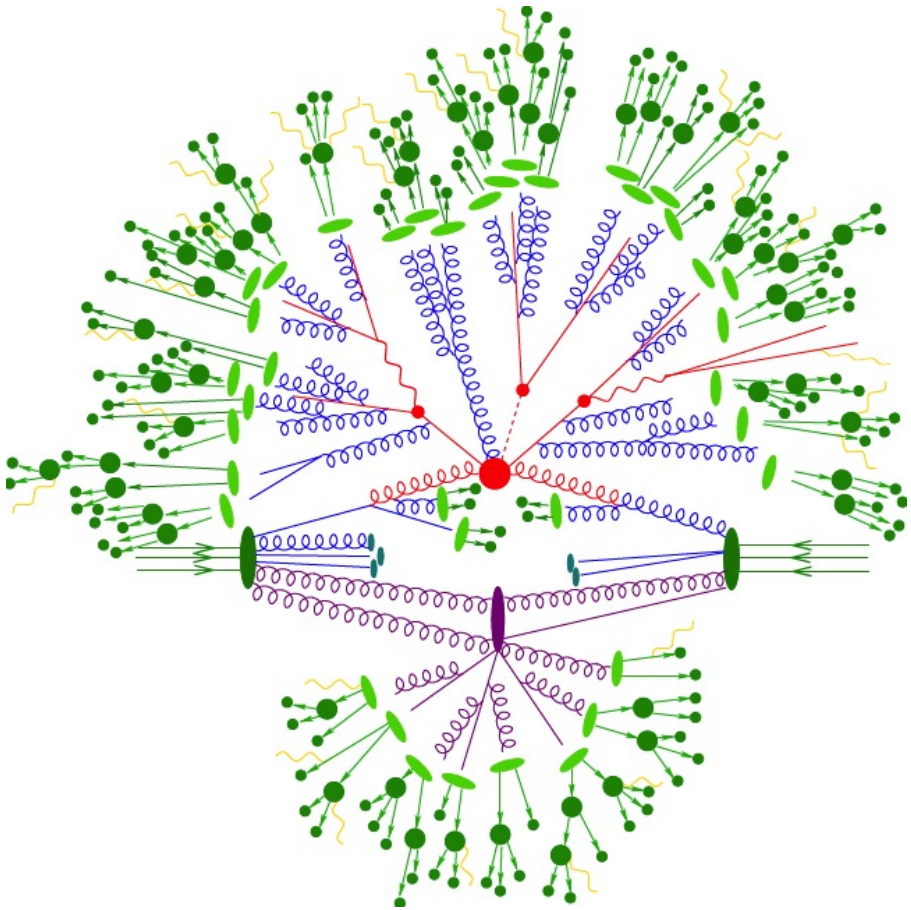
[CMS-DP-2015-035]





Soft QCD

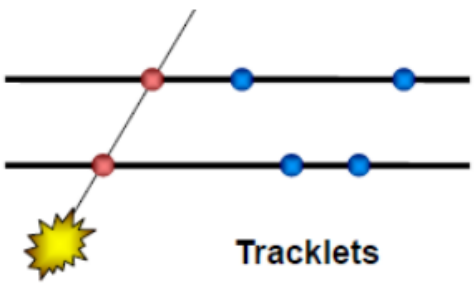
- The understanding and modeling of QCD interactions necessary for precision measurements and searches for new physics
- Soft particle production cannot be calculated reliably using pQCD: generally described by phenomenological models
  $\rightarrow$ Monte Carlo tunes



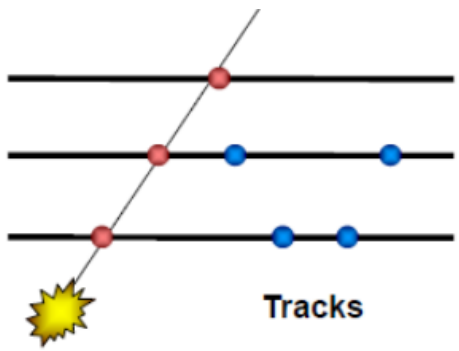
Pseudorapidity distribution of charged hadrons

[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$\sim$0.2-5%, **B=0T (straight tracks)**
- Strategy: Use different techniques with different sensitivities to misalignment, material detector response, background contamination

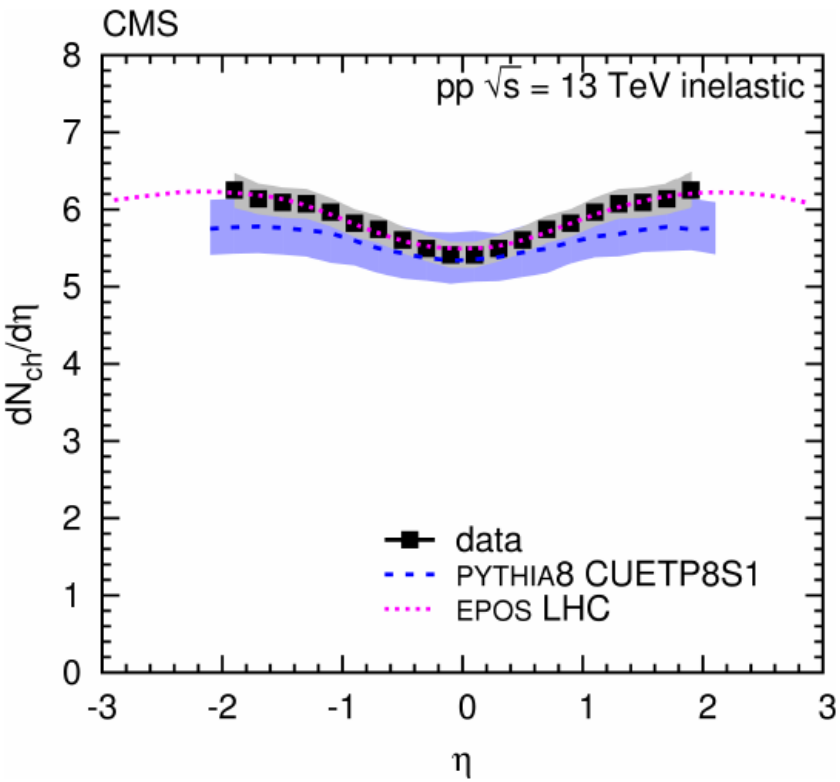


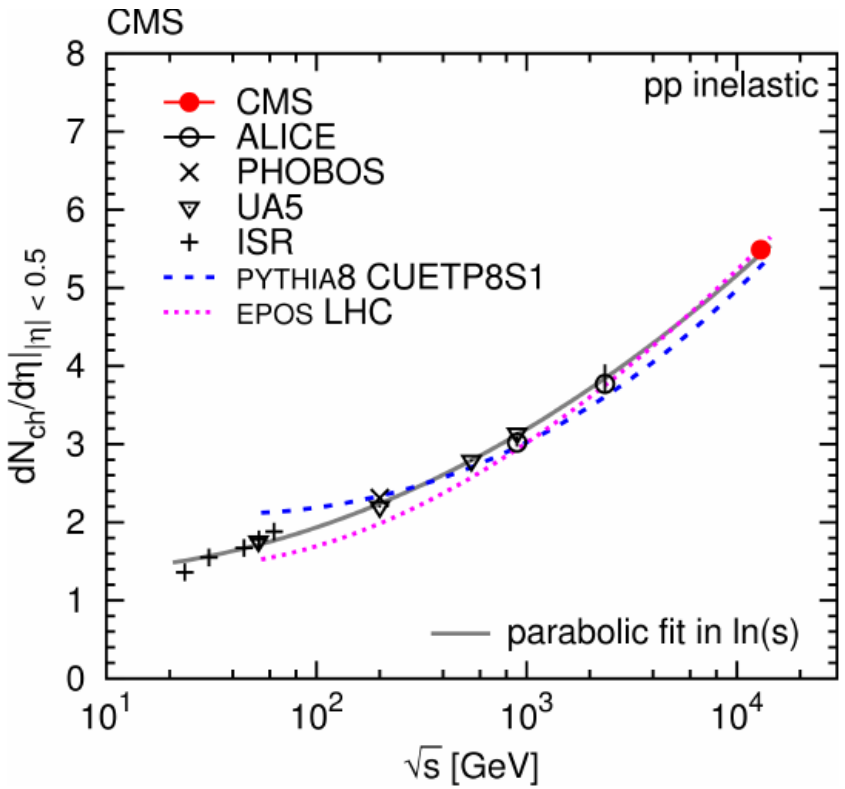
Two hits in different pixel layers



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

Results [PLB 751 (2015) 143]



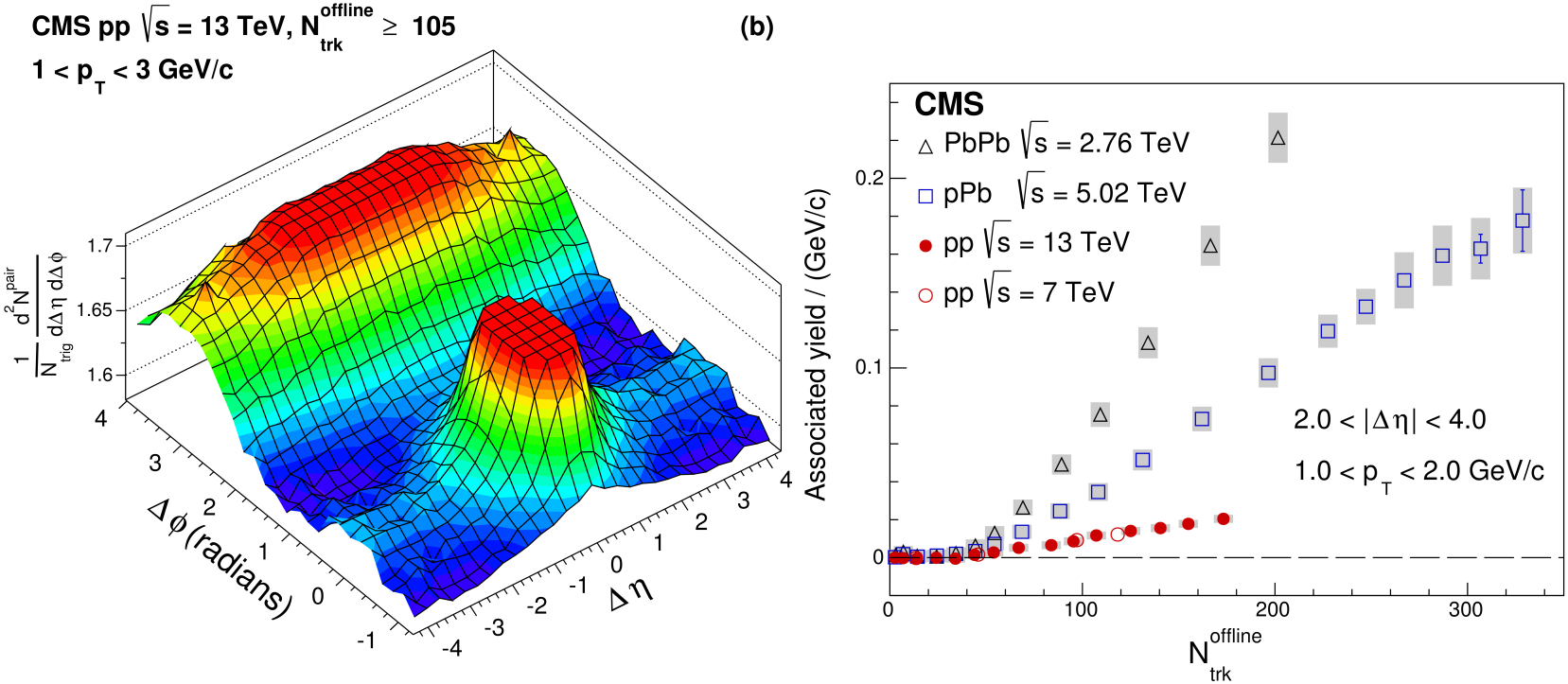


- Corrected to a sample of inelastic collisions:
  $dN/d\eta(|\eta| < 0.5) = 5.49 \pm 0.01$ (stat) $\pm$ 0.17 (syst)
- Collision energy dependence as expected

$\rightarrow$ First LHC publication with 13 TeV data

Long-range near-side two-particle angular correlations

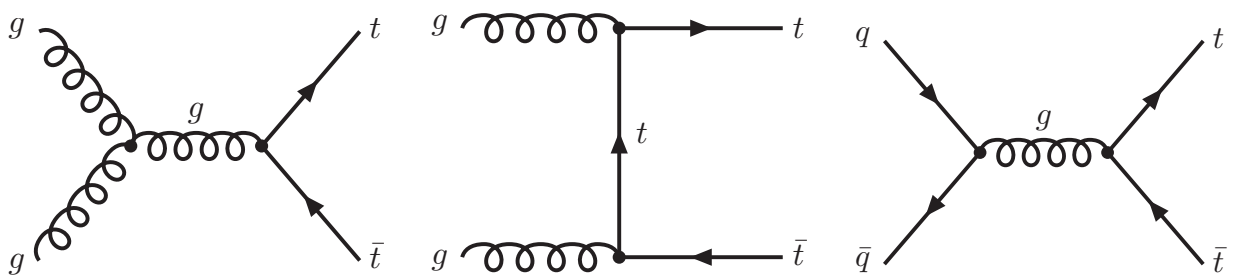
arXiv:1510.03068, submitted to PRL



- 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 p_T
  - Linear raise of the associated yield is observed as a function of number of tracks

The top quark

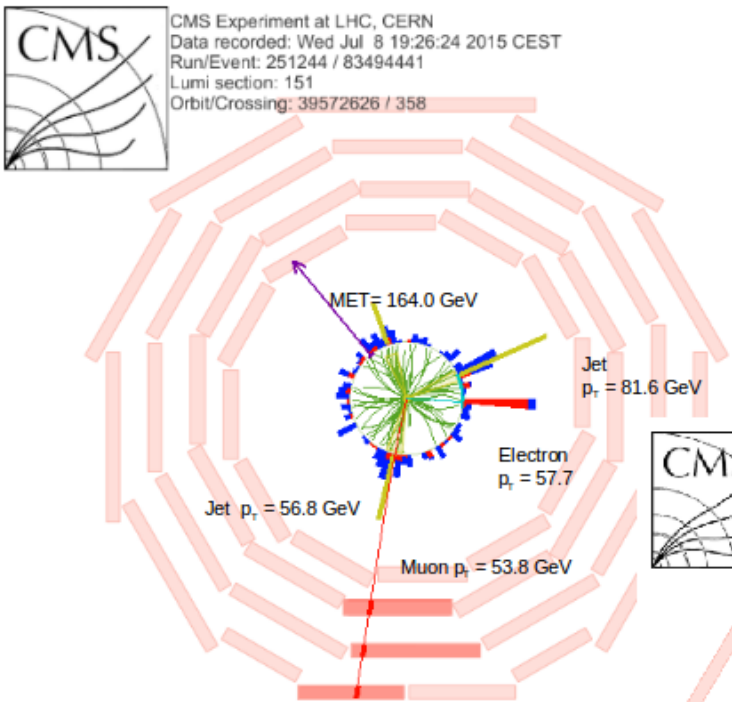
Top quark production mainly in pairs ($t\bar{t}$) and via gluon fusion at LHC



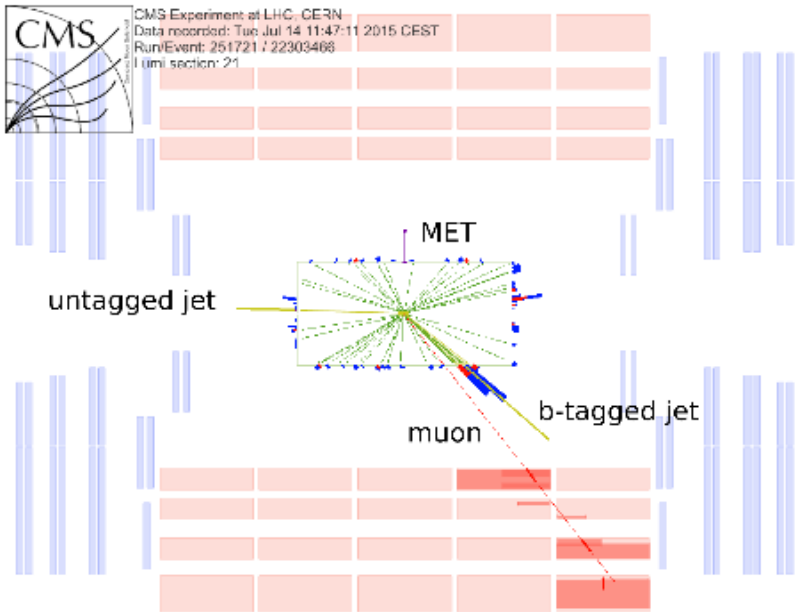
- Measuring $\sigma_{t\bar{t}}$ is the first fundamental step for understanding top physics
  - Test QCD predictions and help constraining the PDFs (especially gluon distribution)
  - Main background for Higgs and many searches for New Physics
  - May provide insight into physics BSM
- Measure $t\bar{t}$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

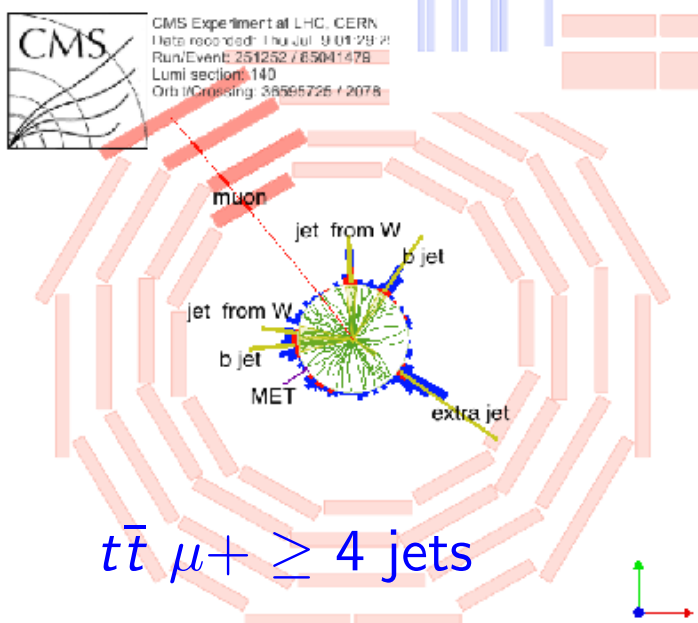
First 13 TeV top quark candidates

$t\bar{t}$ $e\mu$ + 2 b jets



single top quark

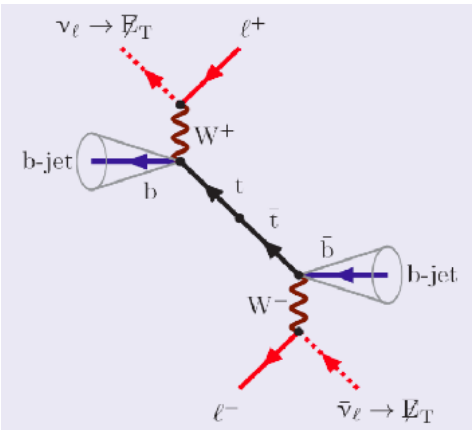




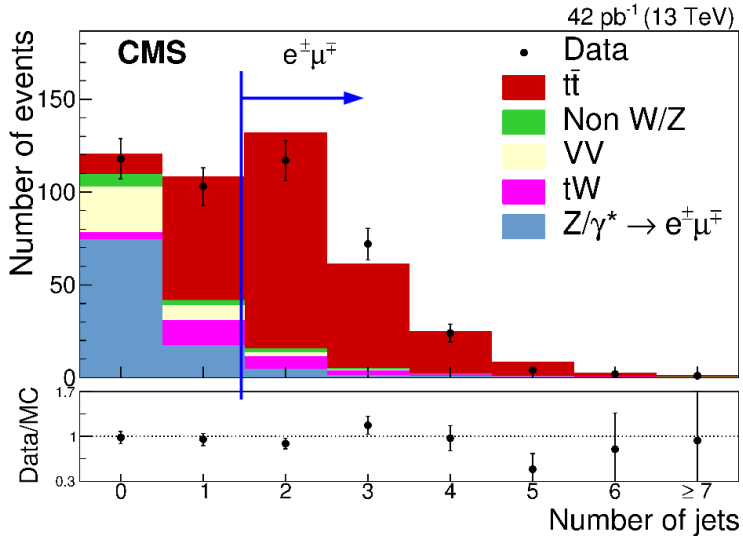
$t\bar{t}$ $\mu+ \geq 4$ jets

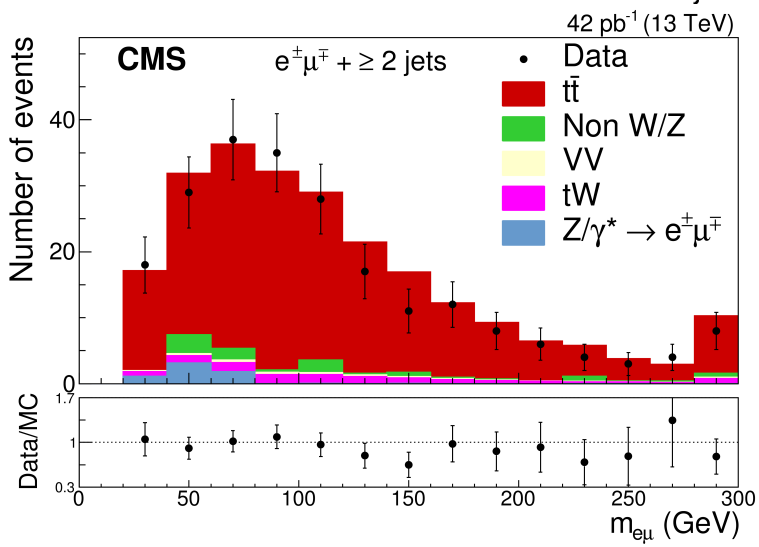
$t\bar{t}$ $e\mu$ channel [arXiv:1510.05302, submitted to PRL]

$$\sigma = \frac{N_{data} - N_{bkg}}{\epsilon_{t\bar{t}} \int \mathbf{L} dt}$$



1. One isolated opposite charge $e\mu$ pair ($m_{e\mu} > 20$GeV)
2. $\geq$2 jets



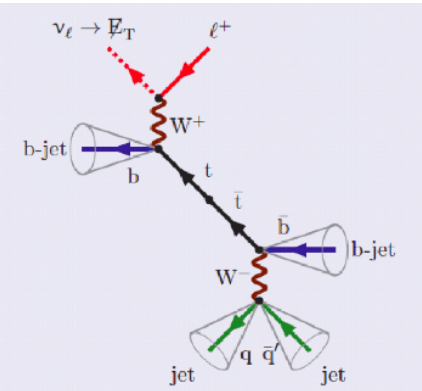


$\sigma_{t\bar{t}} = 769 \pm 60(\text{stat}) \pm 55(\text{syst}) \pm 92(\text{lumi})$ pb

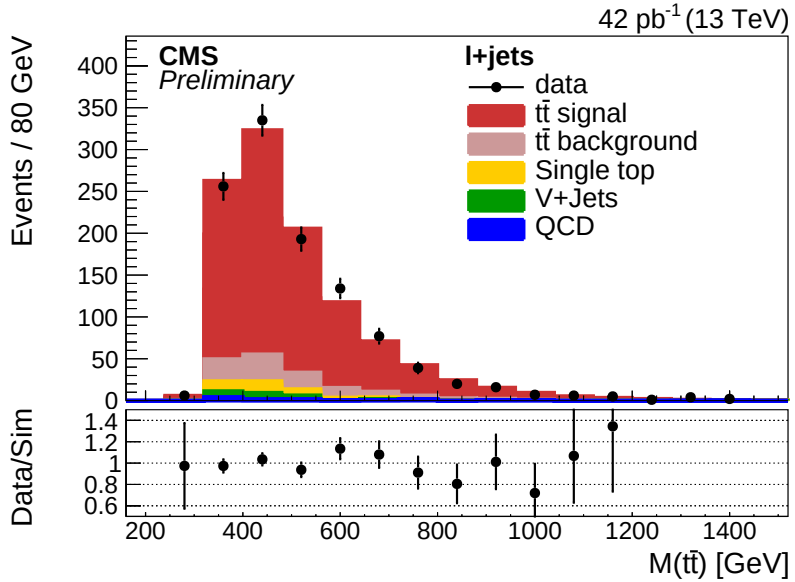
(16% precision)

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

1. One isolated high-p_T lepton
2. $\geq$4 jets
3. Veto additional leptons
4. $\geq$1 b-tagged jet

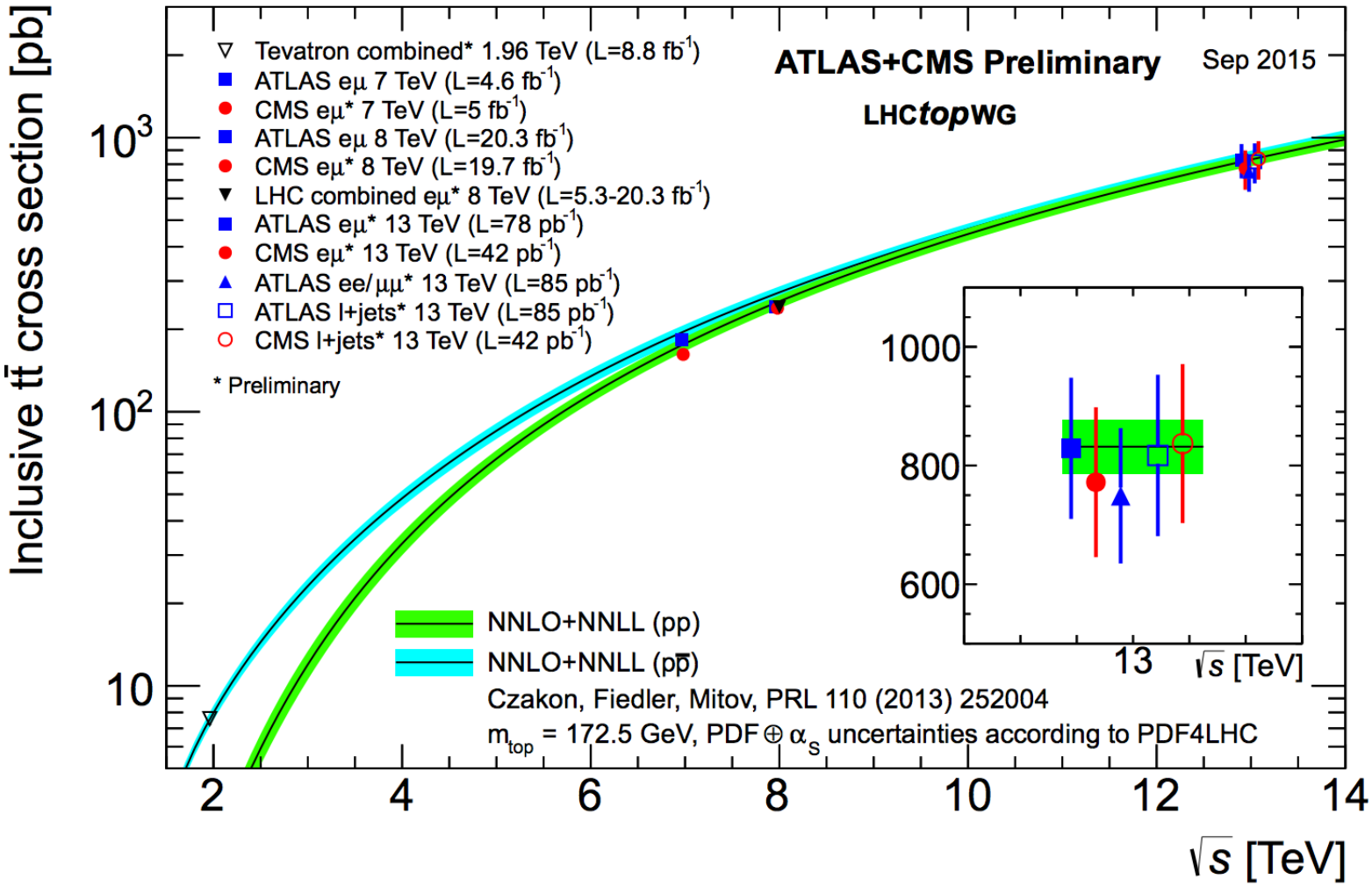


+ Kinematic reconstruction of top quarks



$\sigma_{t\bar{t}} = 836 \pm 27(\text{stat}) \pm 88(\text{syst}) \pm 100(\text{lumi})$ pb
(16% precision)

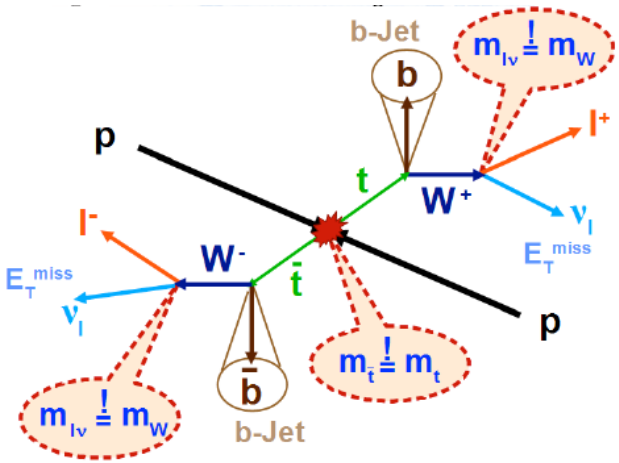
Grand summary $t\bar{t}$ cross sections

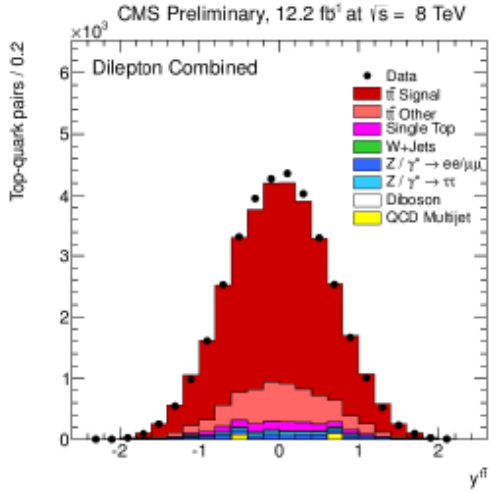


Good agreement among all measurements, also with NNLO+NNLL theory

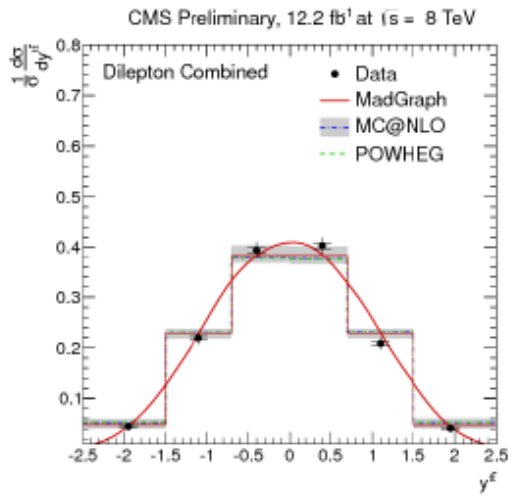
Differential cross section: analysis strategy

1. Event selection
2. Top quark kinematic reconstruction





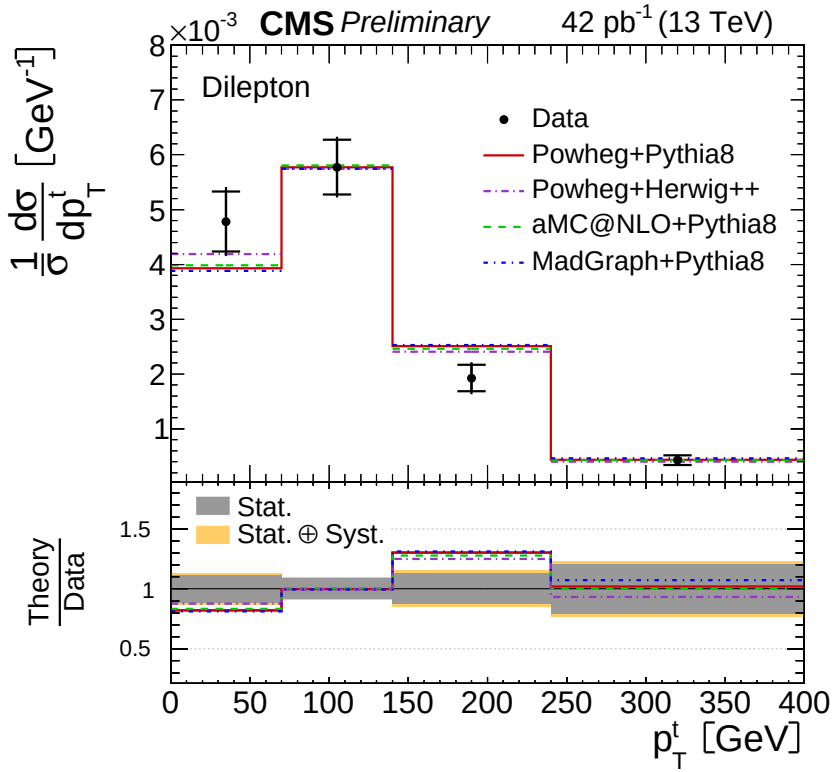
$$\frac{1}{\sigma}\frac{d\sigma^i}{dX} = \frac{1}{\sigma}\frac{N^i_{\text{Data}} - N^i_{\text{BG}}}{\Delta^i_X \epsilon^i L}$$

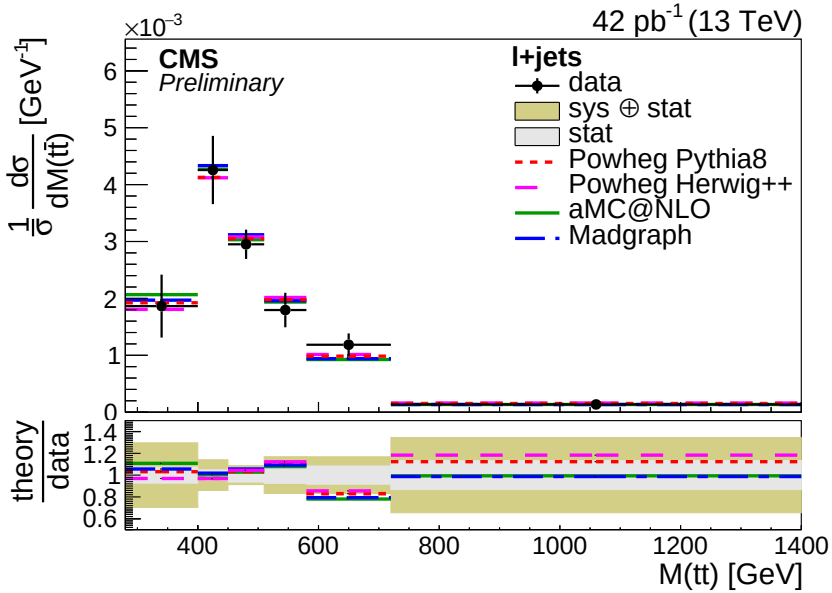


3. Bin-wise cross section measurement:
   - ◇ Subtract background
   - ◇ Unfolding: correct for detector effects & acceptance to particle or parton level in full or visible phase space
4. Normalised to measured σ in the same phase space
5. Compare to theory predictions/calculations

$t\bar{t}$ 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





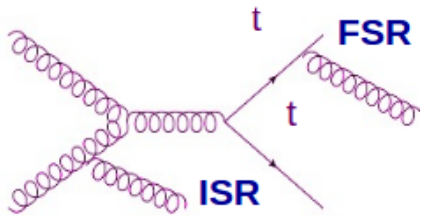
- In general good agreement between data and predictions

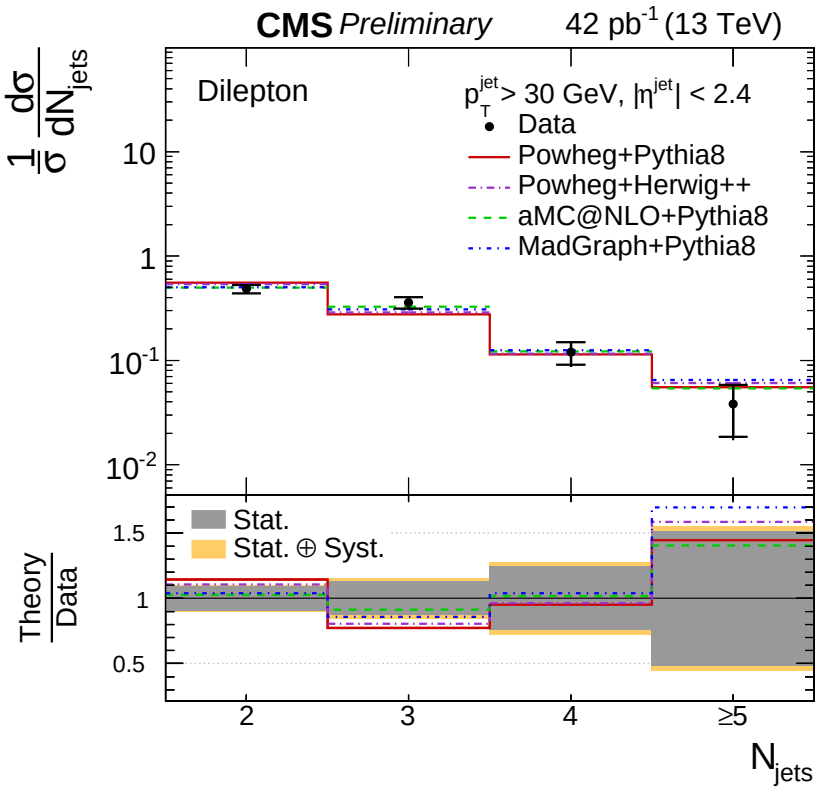
Results as a function of global event variables (MET, HT, etc.): CMS-PAS-TOP-15-013

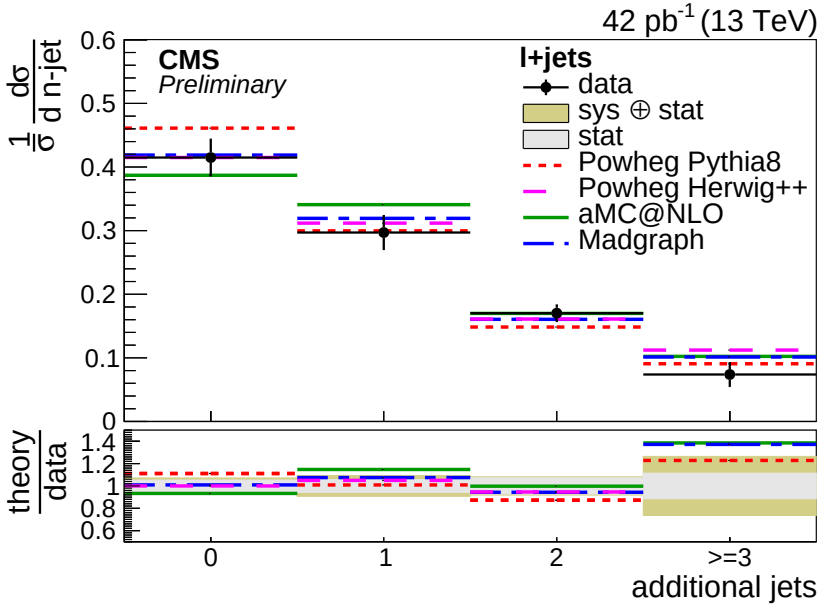
$t\bar{t}$: jet multiplicity [CMS-PAS-TOP-15-005/10]

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 $t\bar{t}$+jets final states, background for $t\bar{t}H$
- Measured at particle level in fiducial phase space

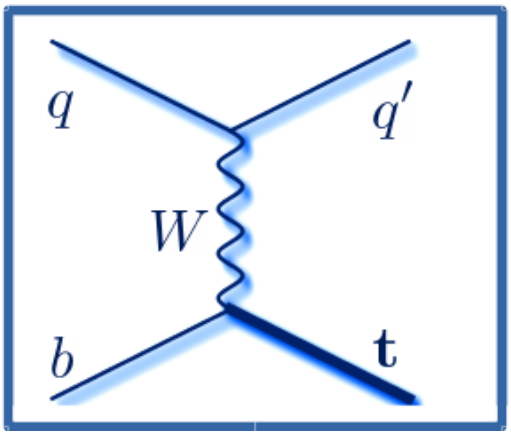




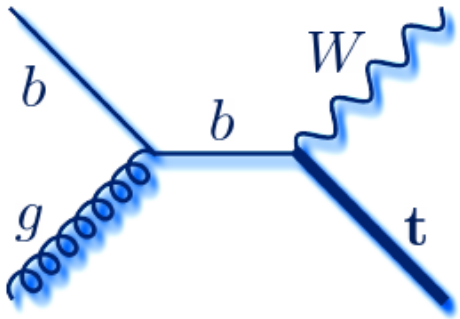


Single top production via EWK interaction

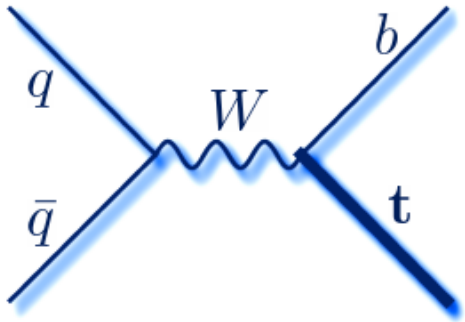
t-channel

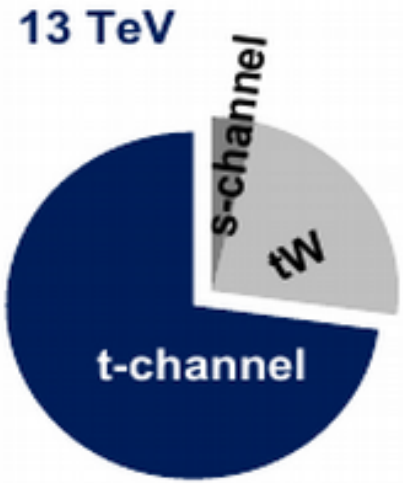


W associated production (tW)



s-channel





$$\sigma_{t-ch}^{8\,TeV} = 86.5^{+2.8}_{-1.0}(\text{scale})^{+2.0}_{-2.2}(\text{PDF})\text{pb}$$

$$\sigma_{t-ch}^{13\,TeV} = 218 \pm 5(\text{scale}) \pm 5(\text{PDF})\text{pb}$$

Cross section calculated at NLO+NNLL

Single top t-channel production

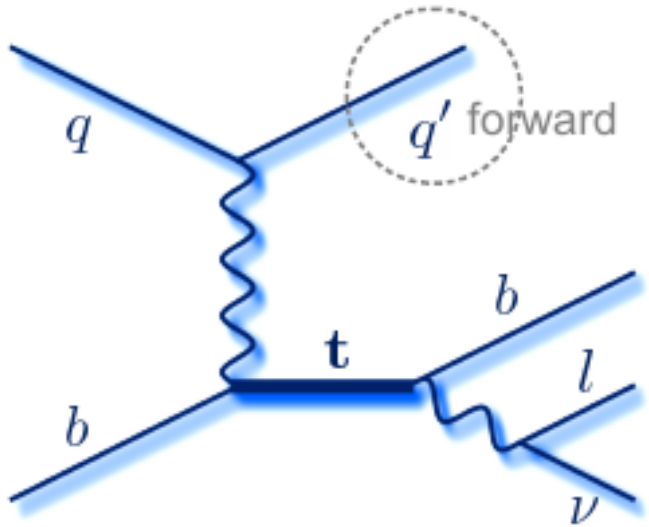
Why are single tops interesting?

... in the Standard Model

- Direct probe of Wtb coupling, V_{tb} in CKM matrix.

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

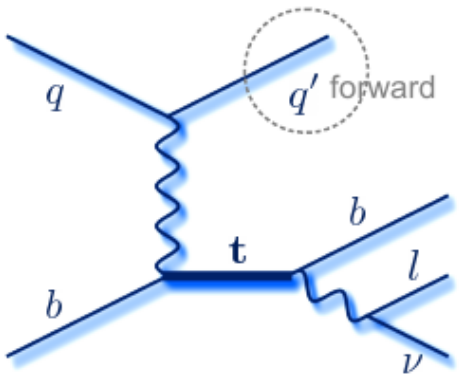
- Constrain u/d PDF models (ratio of top/anti-top cross-sections)



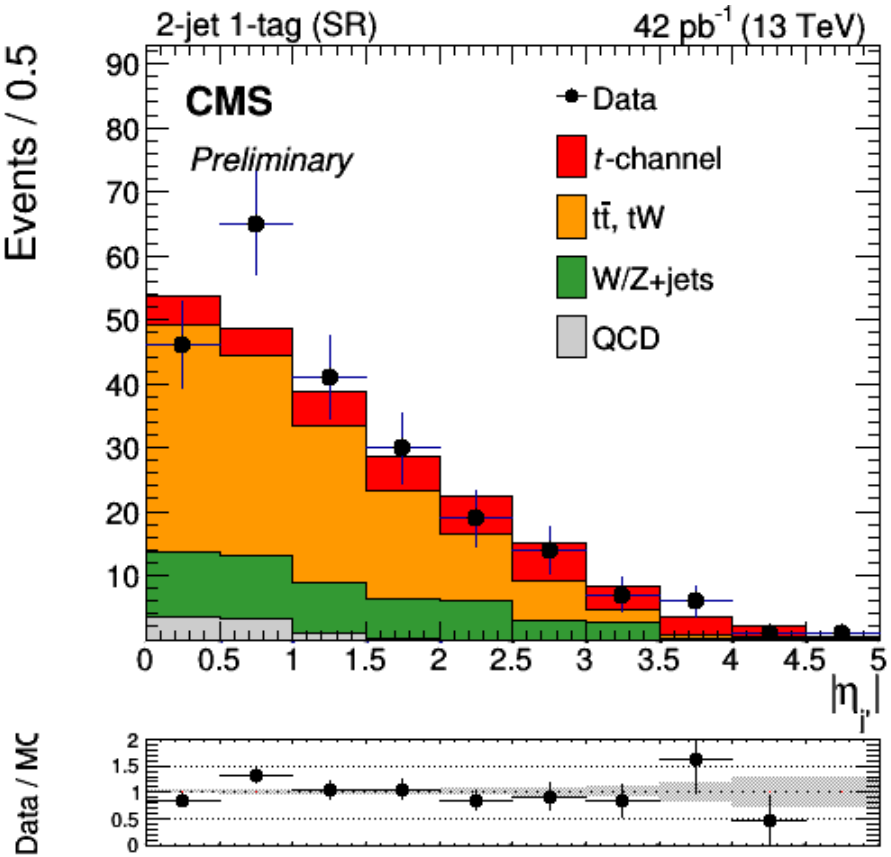
... as probe for new physics:

- 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]

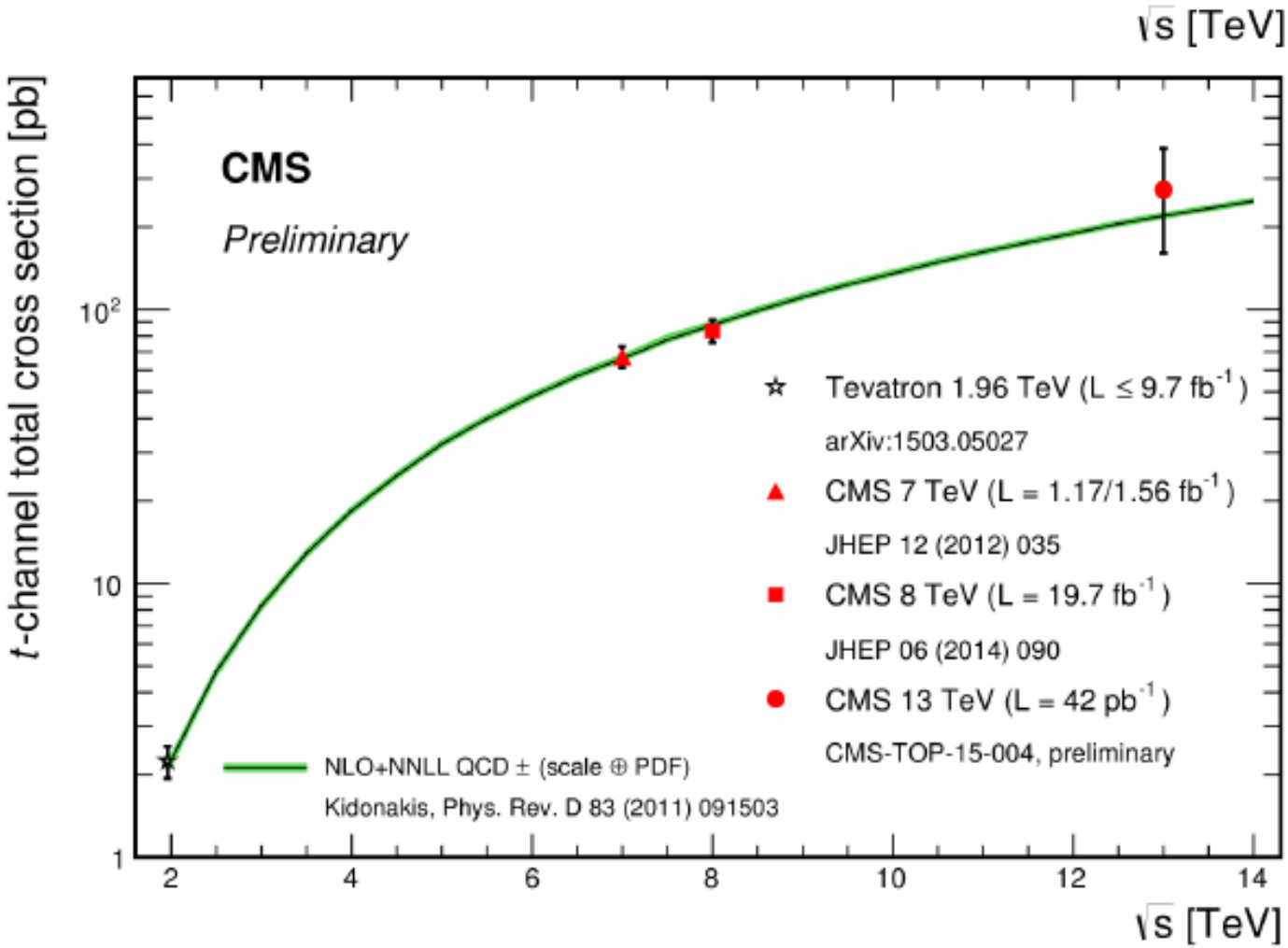


- Selection: 1 isolated high-p_T muon, 1 central b-tagged jet, 1 forward light jet, M_T(W)
- Template fit to the pseudorapidity of the forward jet

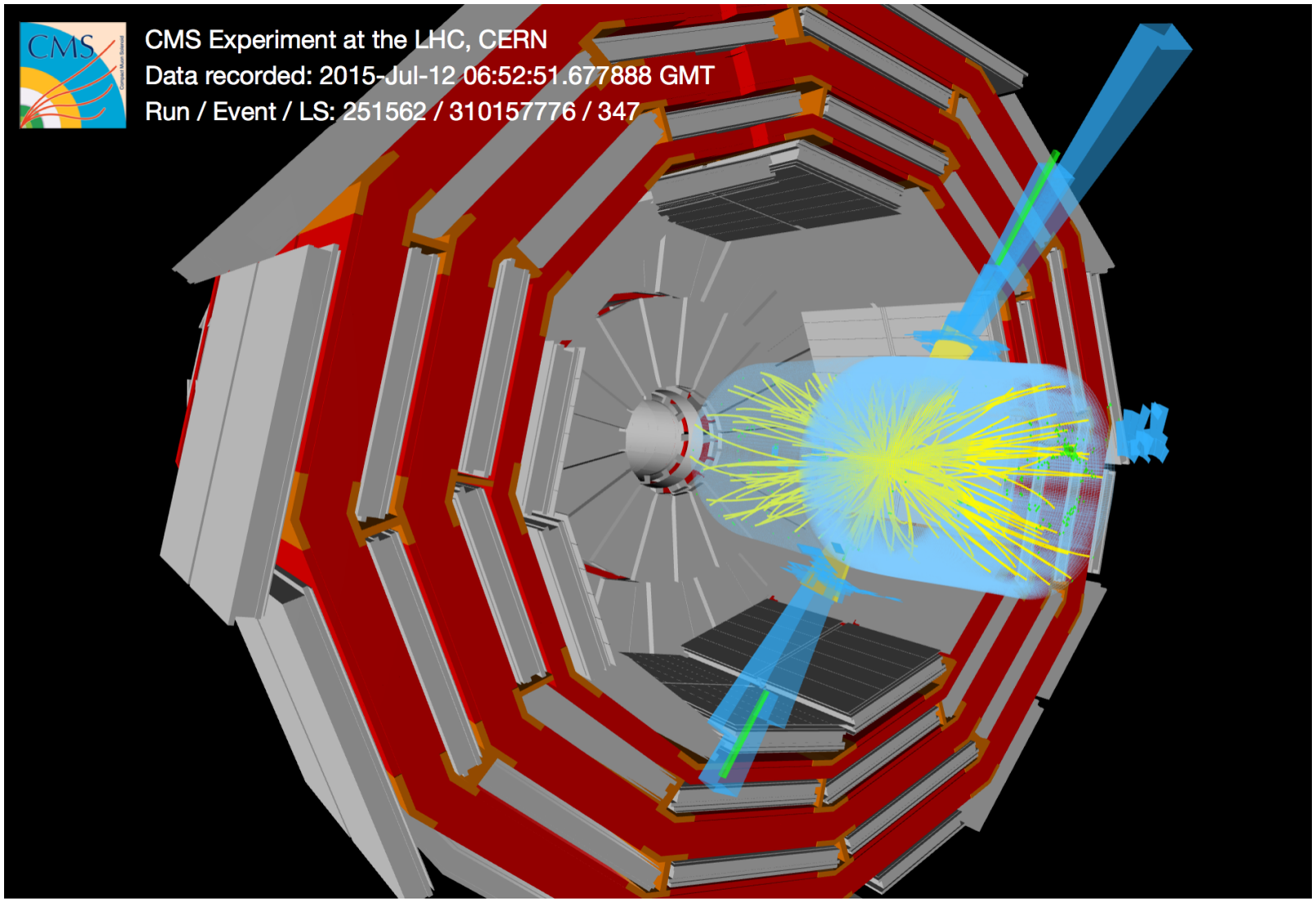


t-channel inclusive cross section [CMS-PAS-TOP-15-004]

- $\sigma = 274 \pm 98(\text{stat}) \pm 52(\text{syst}) \pm 33\text{pb}(\text{lumi})$, constrained $|V_{tb}| > 0.7$ at 95%CL
- Significance: 3.5 (2.7) observed (expected)

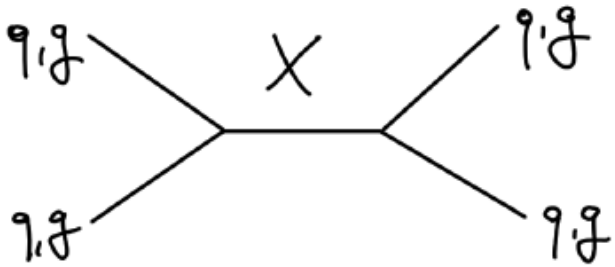


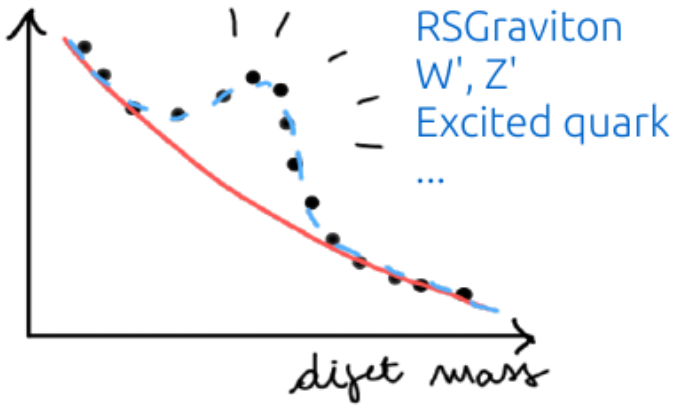
Resonant Di-jet Candidate (5.4 TeV!)



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.



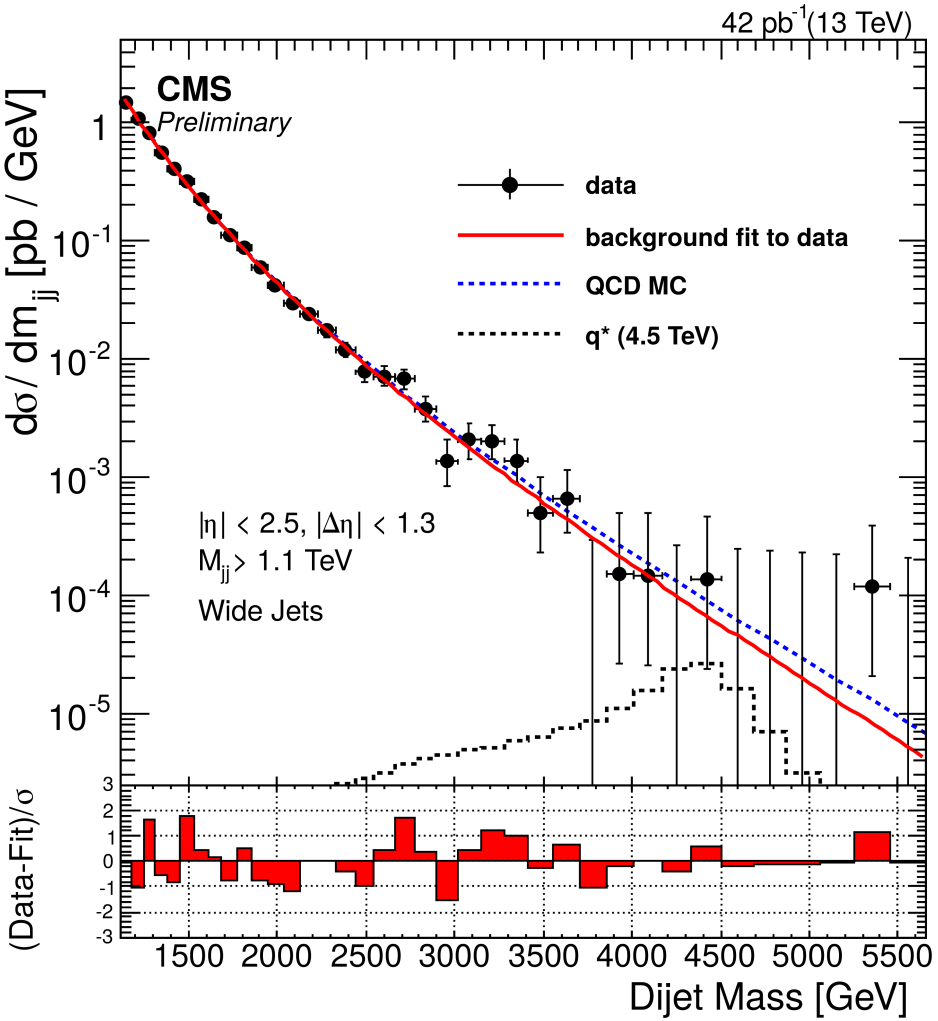


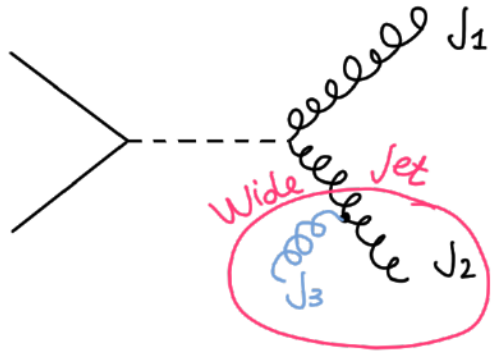
[G. D'Imperio]

- 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!

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

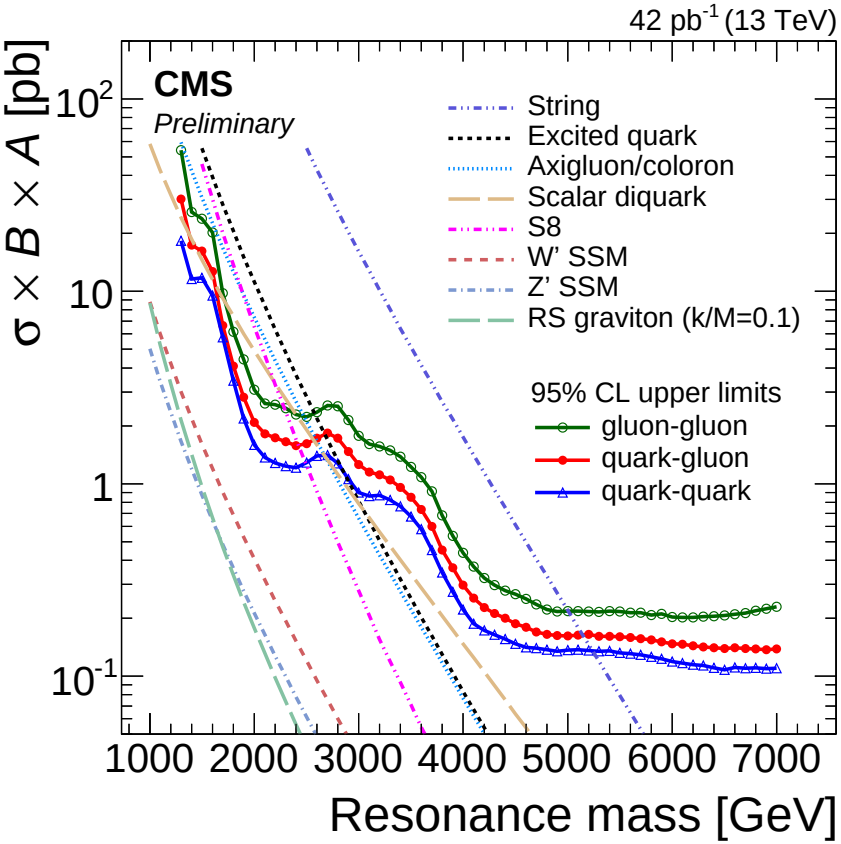
- Wide jets improve dijet mass resolution





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

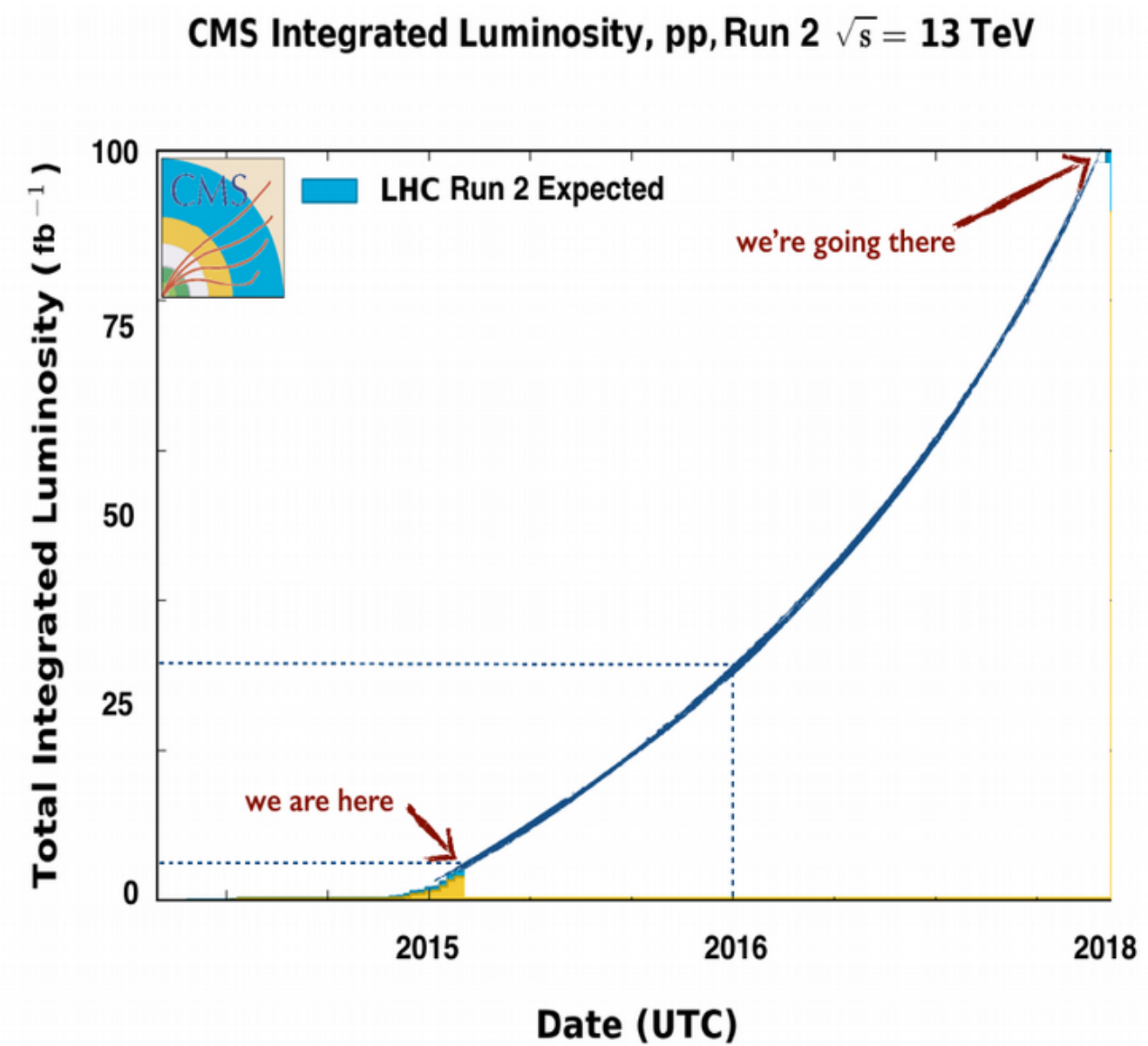
Results [CMS-PAS-EXO-15-001]



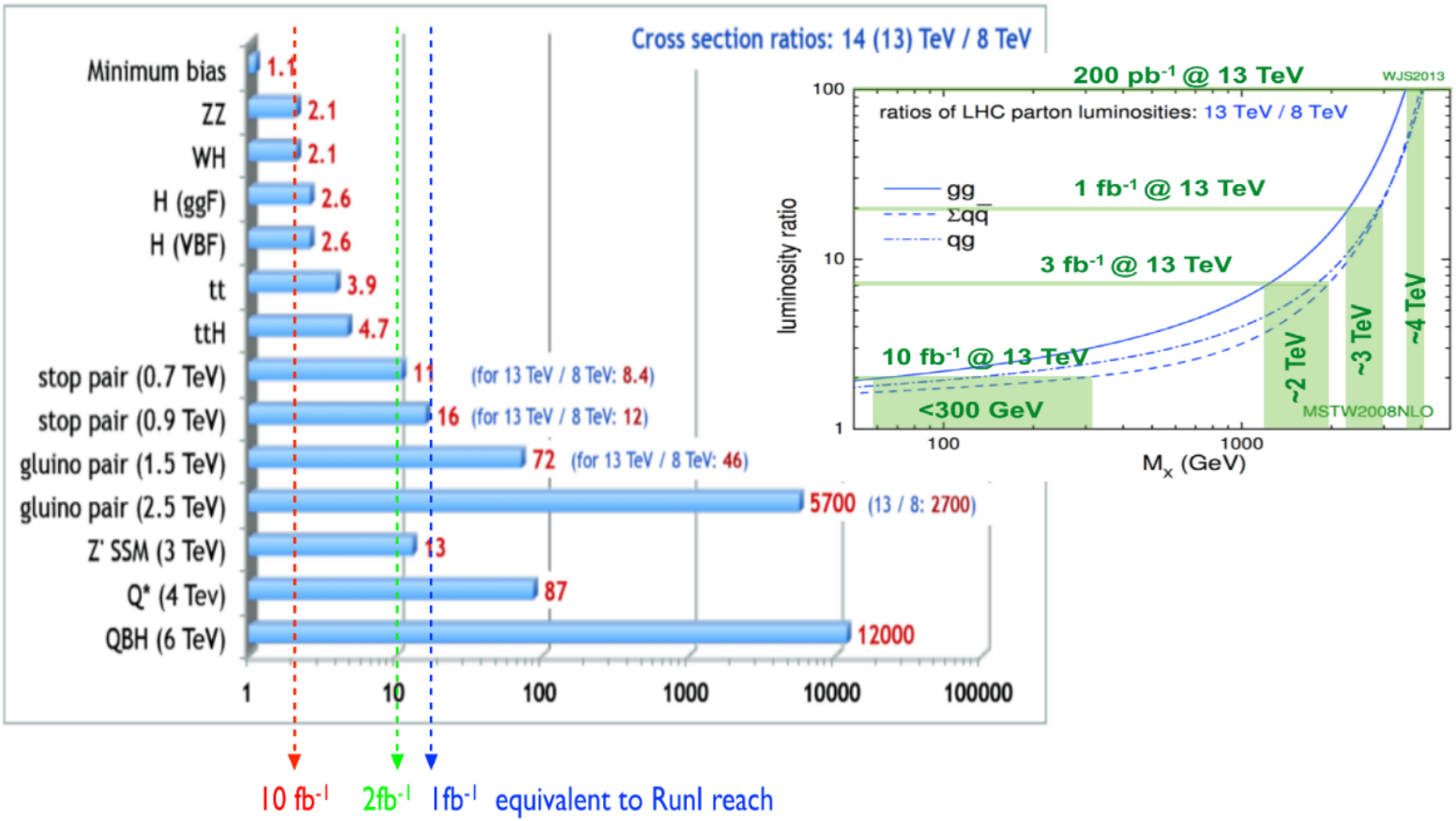
- Exclusion limits are calculated for gluon-gluon, quark-gluon and quark-quark.
- Exclusion from 2.3 to 5.1 TeV (best exclusion), depending on the model.

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)	$q\bar{q}$	2.7	2.9
Color Octet Scalar (s8)	gg	2.3	2.0

Prospects at 13 TeV



Some prospects at 13 TeV



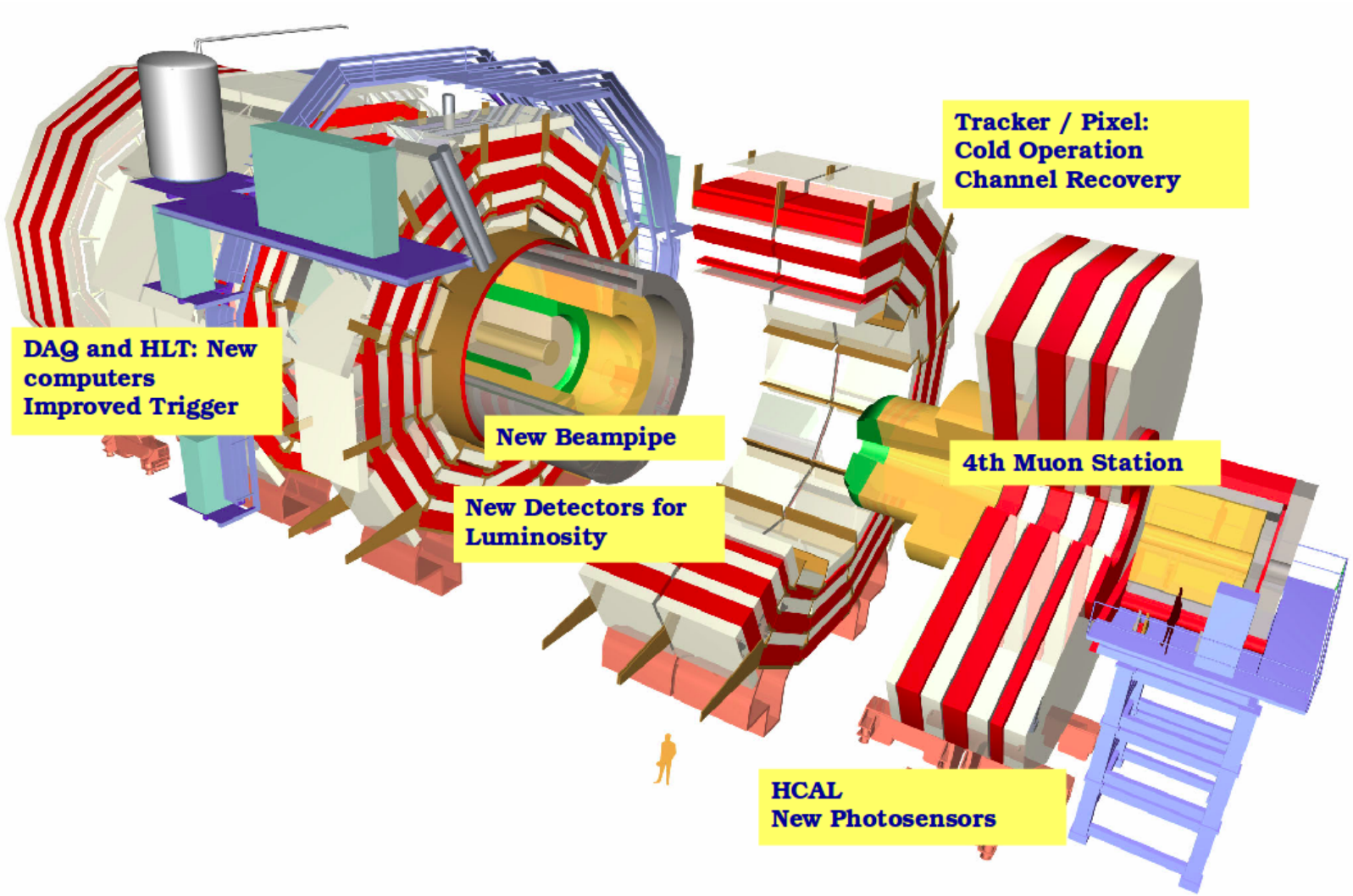
- Measure the couplings of the top quark to Z,γ and top-Yukawa coupling
- Higgs: first measurement of VBF, VH
- Highest dijet mass bin >7 TeV
- Hopefully first discoveries!

Summary

- A new challenging time just started at LHC 13 TeV Run2
- First measurements from 13 TeV with a luminosity $\leq$50 pb^{-1} are already public
- 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/

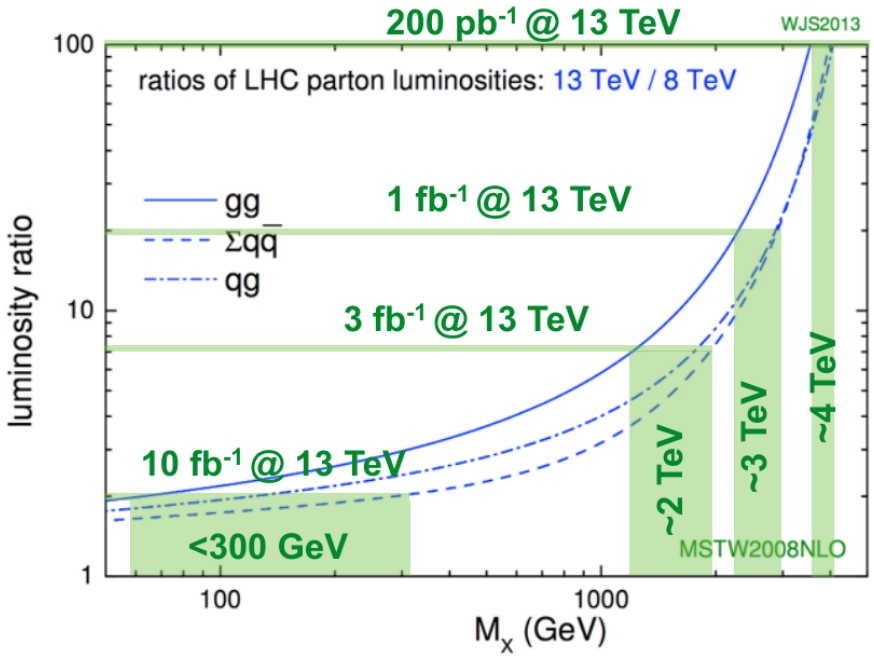
BACK UP

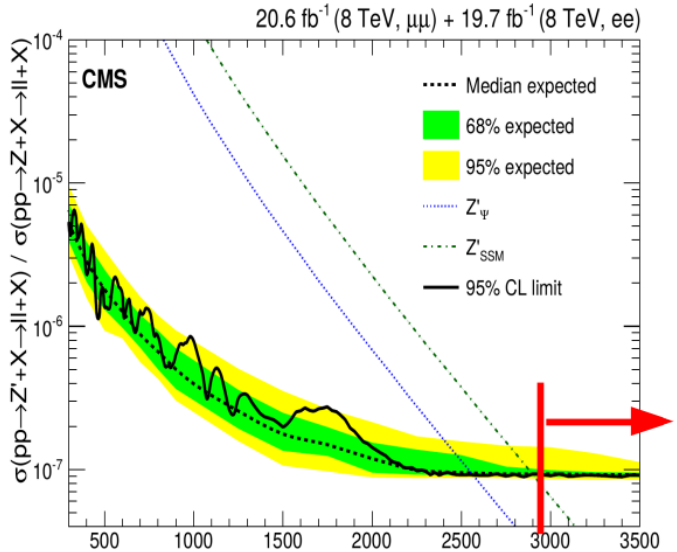
CMS after Long Shutdown 1

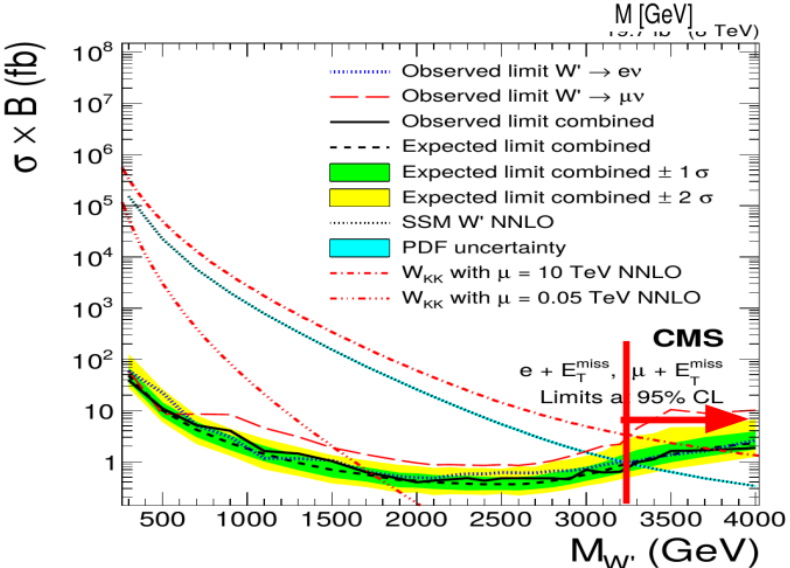


Some Prospects at 13 TeV

- For high mass searches parton luminosity counts!
- With 3 fb^{-1} all searches with M_x >2 TeV are competitive







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.