

Standard model measurements & Exotic Searches at CMS/LHC

Dr. Georgios Daskalakis

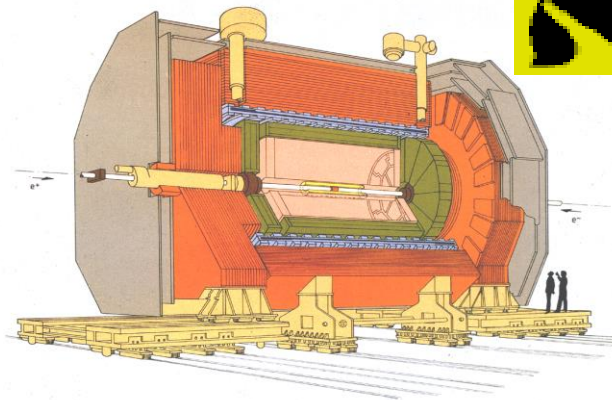
Institute of Nuclear & Particle Physics

NCSR "DEMOKRITOS, Athens, Greece

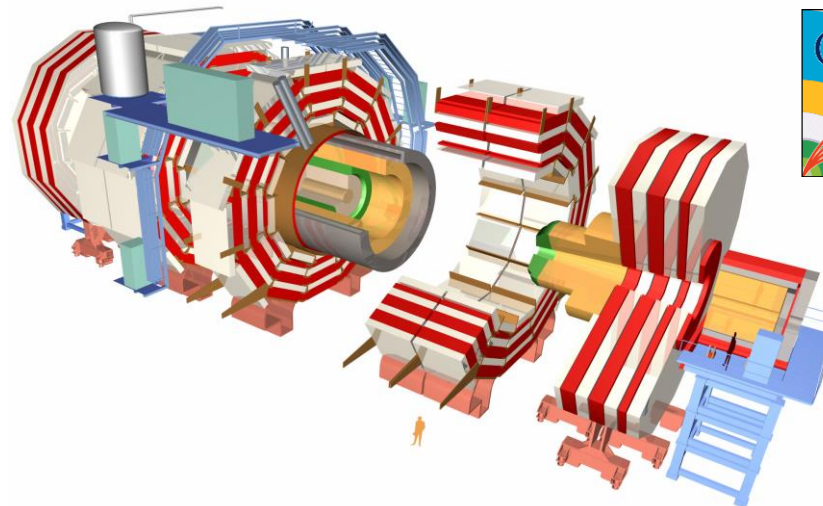
18 July 2019

Carrier Path

- Jan 13 – today (CMS) Researcher Grade B', Institute of Nuclear & Particle Physics, NCSR "D"
- Apr 07 – Dec 12 (CMS) Researcher Grade C', Institute of Nuclear Physics, NCSR "D"
- May 05 – Apr 07 (CMS) Research Associate, Imperial College, London, UK
- Apr 03 – Apr 05 (CMS) Research Fellow, CERN (CMS ECAL Group)
- Jan 02 – Mar 03 (CMS) Post Doctoral Associate, University of Athens, Greece
- Mar 00 – Jan 02 Military Service (Greek Navy)
- Jul 99 – Feb 00 Private Sector (Software Company)
- Jan 95 – Jun 99 (ALEPH) Ph.D Thesis, DEMOKRITOS & NTUA, Greece
(supervisor : C. Markou)
- Sep 88 – Jul 93 - Diploma, Univ. of Athens, Greece



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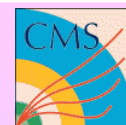


ALEPH / LEP

(1995-1999 INP DEMOKRITOS)

Tri-linear Gauge Boson Couplings (TGCs)

ALEPH data @ 172 GeV



CMS / LHC

(2002 – 2007 UoA-GR, CERN-CH, IC-UK)

electrons & photons

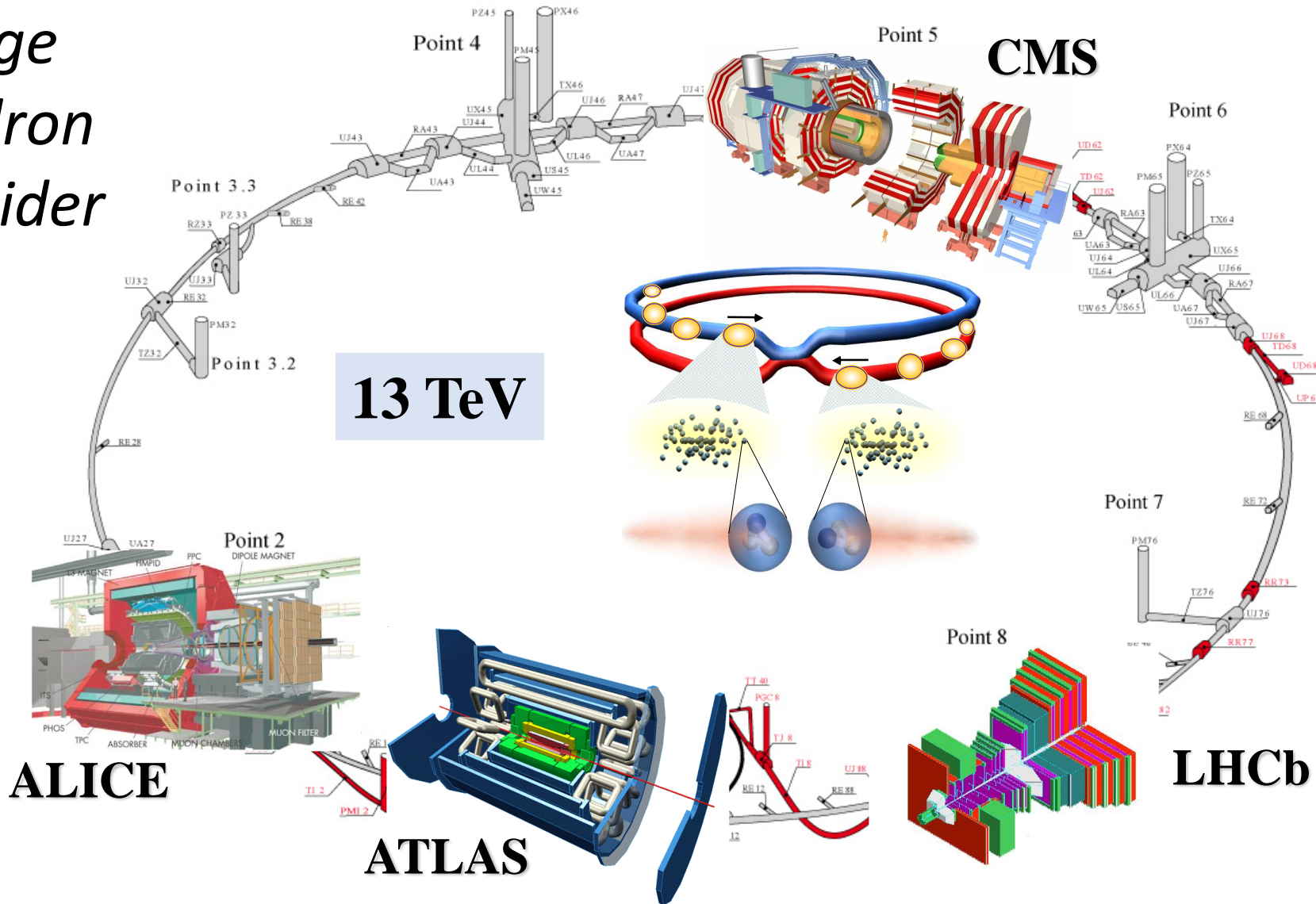
- Reconstruction
- Triggers
- ECAL Calibration
- Test Beam

Higgs Boson Physics

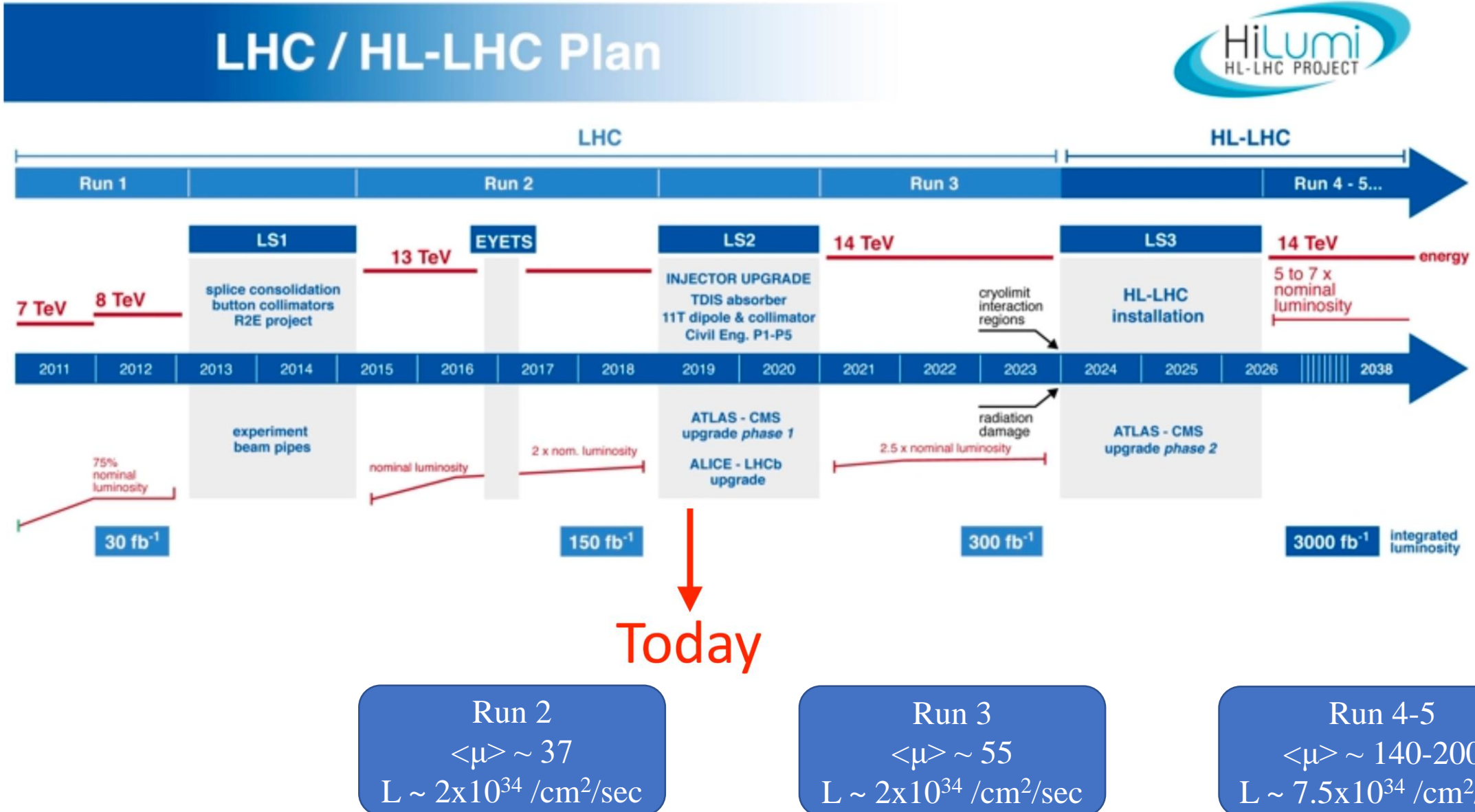
- Standard Model (SM) $H \rightarrow \gamma\gamma$
- Minimal SuperSymmetric $A \rightarrow Zh$

LHC

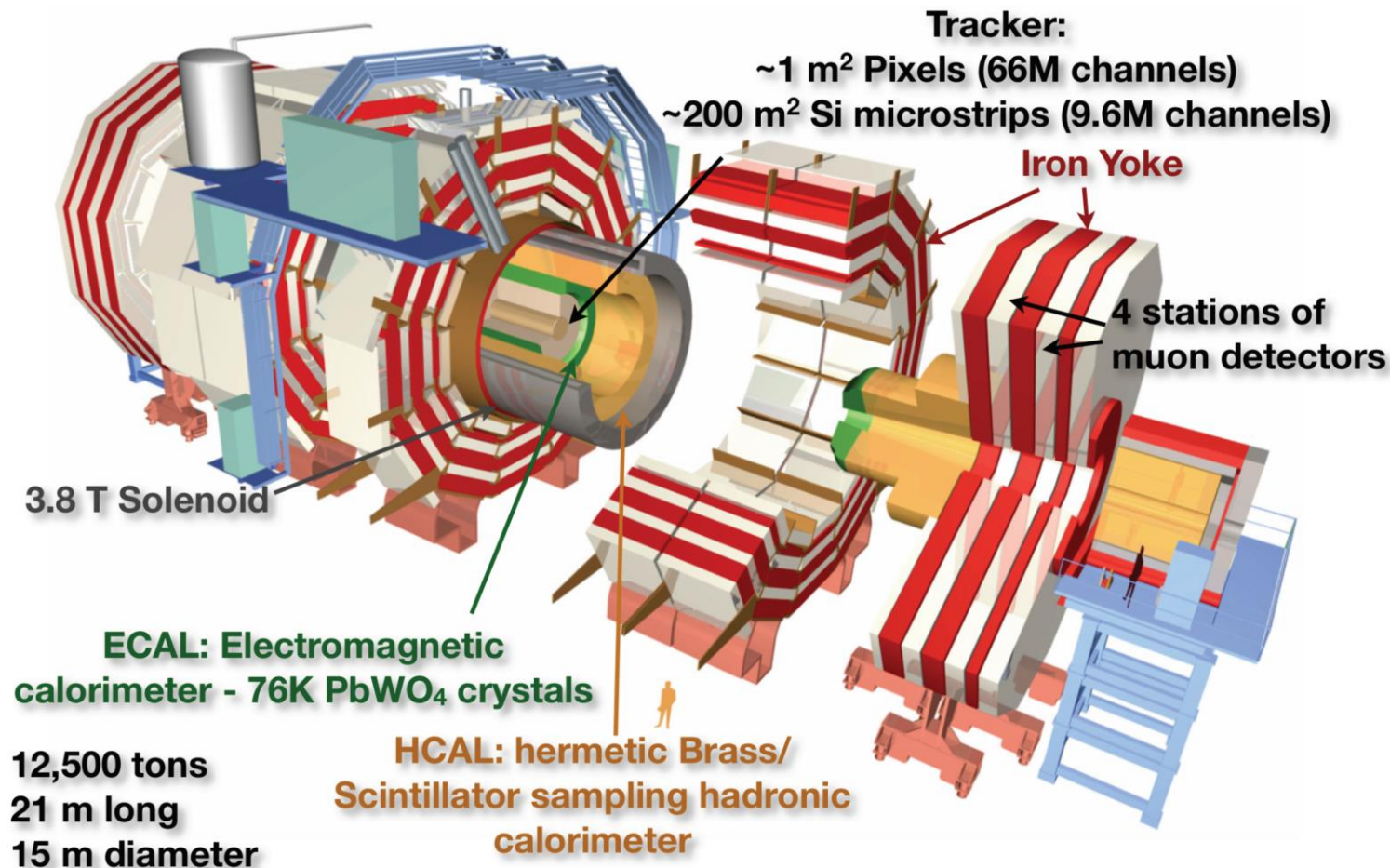
Large
Hadron
Collider



The LHC plan



The CMS experiment

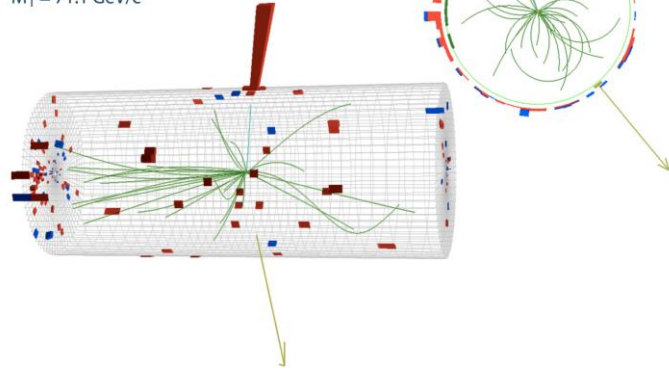


51 Countries
229 Institutes
281 Technicians
1065 Engineers
2942 Physicist (PHD+PHD students)
1906 PhD Physicists
1036 Physics Doctoral Students
1110 Undergraduates



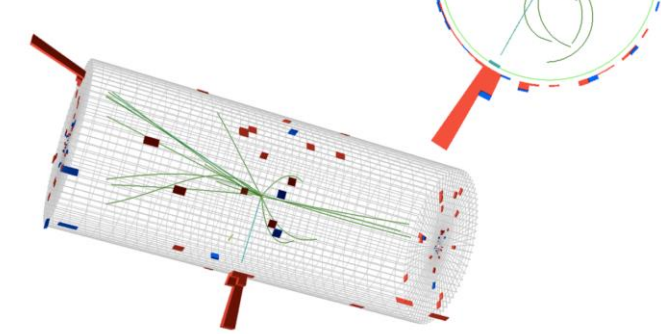
CMS Experiment at LHC, CERN
Run 133874, Event 21466935
Lumi section: 301
Sat Apr 24 2010, 05:19:21 CEST

Electron $p_T = 35.6$ GeV/c
 $ME_T = 36.9$ GeV
 $M_T = 71.1$ GeV/c²



CMS Experiment at LHC, CERN
Run 133877, Event 28405693
Lumi section: 387
Sat Apr 24 2010, 14:00:54 CEST

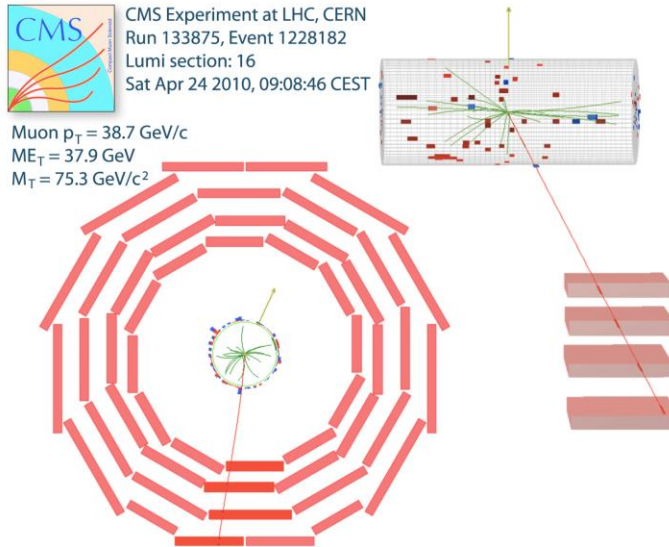
Electrons $p_T = 34.0, 31.9$ GeV/c
Inv. mass = 91.2 GeV/c²



Measurement of the $W \rightarrow \ell \nu$ & $Z \rightarrow \ell \ell$ cross sections with the first (2.9) 36 pb⁻¹ at 7 TeV

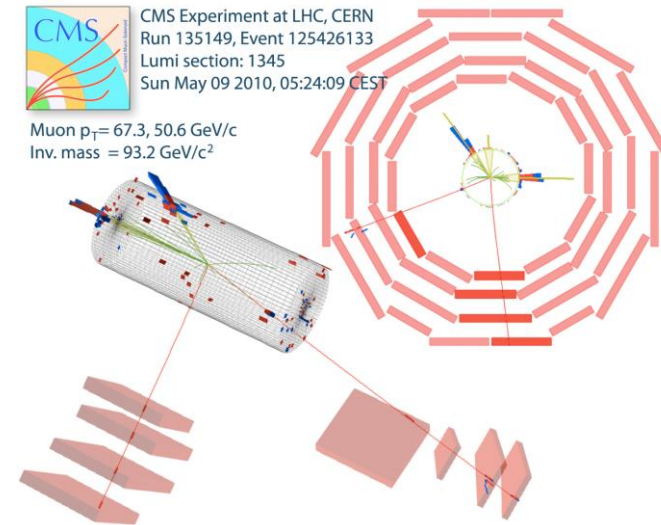
CMS Experiment at LHC, CERN
Run 133875, Event 1228182
Lumi section: 16
Sat Apr 24 2010, 09:08:46 CEST

Muon $p_T = 38.7$ GeV/c
 $ME_T = 37.9$ GeV
 $M_T = 75.3$ GeV/c²



CMS Experiment at LHC, CERN
Run 135149, Event 125426133
Lumi section: 1345
Sun May 09 2010, 05:24:09 CEST

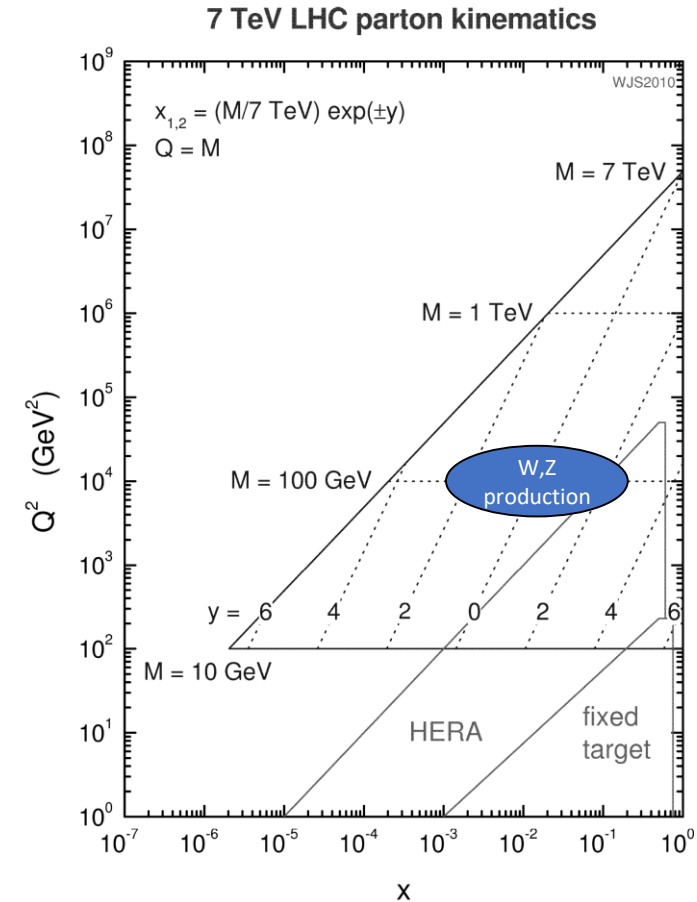
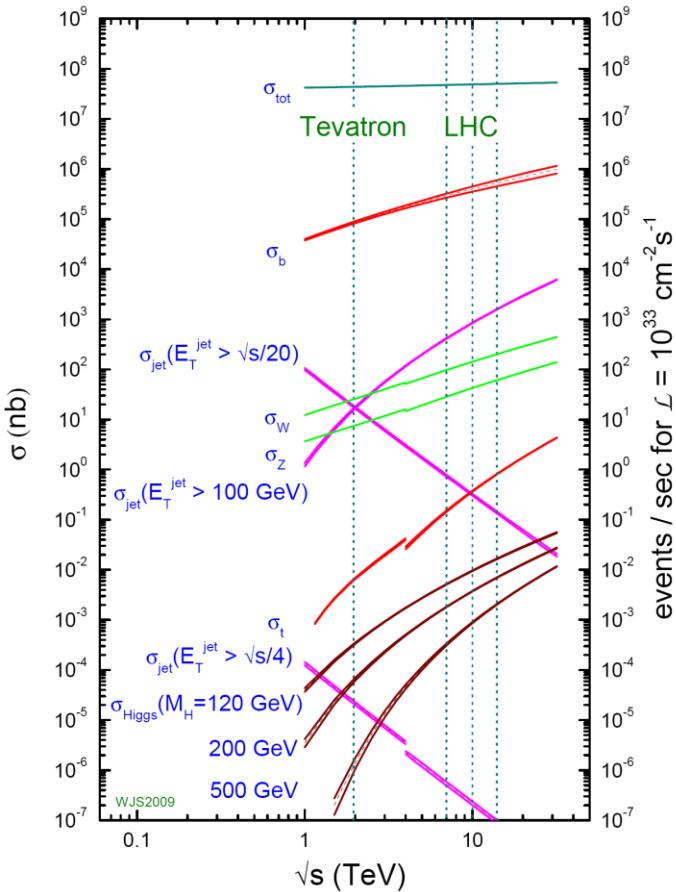
Muon $p_T = 67.3, 50.6$ GeV/c
Inv. mass = 93.2 GeV/c²



Motivation

Measurement of the known “unknowns” in the new Energy frontier :

- is an excellent way to understand and commission “physics objects”
- provides a good understanding of SM processes improving our knowledge on PDFs, pQCD, ...
- SM processes are backgrounds to searches for new Physics, so SM measurements are themselves by default “searches”.



W & Z production is theoretically well understood, has high rates and distinctive signatures.

The first publications for W & Z cross sections



PUBLISHED FOR SISSA BY SPRINGER

RECEIVED: December 13, 2010

ACCEPTED: December 27, 2010

PUBLISHED: January 19, 2011

2.9 pb⁻¹

Measurements of inclusive W and Z cross sections in pp collisions at $\sqrt{s} = 7$ TeV

The CMS collaboration

ABSTRACT: Measurements of inclusive W and Z boson production cross sections in pp collisions at $\sqrt{s} = 7$ TeV are presented, based on 2.9 pb⁻¹ of data recorded by the CMS detector at the LHC. The measurements, performed in the electron and muon decay channels, are combined to give $\sigma(\text{pp} \rightarrow \text{WX}) \times \mathcal{B}(\text{W} \rightarrow \ell\nu) = 9.95 \pm 0.07$ (stat.) ± 0.28 (syst.) ± 1.09 (lumi.) nb and $\sigma(\text{pp} \rightarrow \text{ZX}) \times \mathcal{B}(\text{Z} \rightarrow \ell^+\ell^-) = 0.931 \pm 0.026$ (stat.) ± 0.023 (syst.) ± 0.102 (lumi.) nb, where ℓ stands for either e or μ . Theoretical predictions, calculated at the next-to-next-to-leading order in QCD using recent parton distribution functions, are in agreement with the measured cross sections. Ratios of cross sections, which incur an experimental systematic uncertainty of less than 4%, are also reported.

KEYWORDS: Hadron-Hadron Scattering

ARXIV EPRINT: [1012.2466](https://arxiv.org/abs/1012.2466)

JHEP01(2011)080



PUBLISHED FOR SISSA BY SPRINGER

RECEIVED: July 23, 2011

REVISED: September 13, 2011

ACCEPTED: October 11, 2011

PUBLISHED: October 27, 2011

36 pb⁻¹

Measurement of the inclusive W and Z production cross sections in pp collisions at $\sqrt{s} = 7$ TeV with the CMS experiment

The CMS collaboration

E-mail: cms-publication-committee-chair@cern.ch

ABSTRACT: A measurement of inclusive W and Z production cross sections in pp collisions at $\sqrt{s} = 7$ TeV is presented. The electron and muon decay channels are analyzed in a data sample collected with the CMS detector at the LHC and corresponding to an integrated luminosity of 36 pb⁻¹. The measured inclusive cross sections are $\sigma(\text{pp} \rightarrow \text{WX}) \times \mathcal{B}(\text{W} \rightarrow \ell\nu) = 10.31 \pm 0.02$ (stat.) ± 0.09 (syst.) ± 0.10 (th.) ± 0.41 (lumi.) nb and $\sigma(\text{pp} \rightarrow \text{ZX}) \times \mathcal{B}(\text{Z} \rightarrow \ell^+\ell^-) = 0.974 \pm 0.007$ (stat.) ± 0.007 (syst.) ± 0.018 (th.) ± 0.039 (lumi.) nb, limited to the dilepton invariant mass range 60 to 120 GeV. The luminosity-independent cross section ratios are $(\sigma(\text{pp} \rightarrow \text{WX}) \times \mathcal{B}(\text{W} \rightarrow \ell\nu)) / (\sigma(\text{pp} \rightarrow \text{ZX}) \times \mathcal{B}(\text{Z} \rightarrow \ell^+\ell^-)) = 10.54 \pm 0.07$ (stat.) ± 0.08 (syst.) ± 0.16 (th.) and $(\sigma(\text{pp} \rightarrow \text{W}^+X) \times \mathcal{B}(\text{W}^+ \rightarrow \ell^+\nu)) / (\sigma(\text{pp} \rightarrow \text{W}^-X) \times \mathcal{B}(\text{W}^- \rightarrow \ell^-\bar{\nu})) = 1.421 \pm 0.006$ (stat.) ± 0.014 (syst.) ± 0.029 (th.). The measured values agree with next-to-next-to-leading order QCD cross section calculations based on recent parton distribution functions.

KEYWORDS: Hadron-Hadron Scattering

JHEP10(2011)132

VBTF & INPP contributions

GD & J. Berryhill (electrons)

L. Lista & J.A. Maestre (muons)

were **leading** the **Vector Boson Task Force** group

(part of the EWK group)

4 analyses in 1 paper

INPP contributions

The team:

GD, S. Kesisoglou (postdoc), I. Manolakos (student)

GD was

- leading the VBTF group (electrons),
- editor and contact person for the analysis.

“Electron” analysis

- analysis software,
- electron efficiencies,
- ‘working points’ definitions
- combination of channels
- fiducial/full phase space results

Measurements:

Inclusive W and Z production cross section

- Separately for electrons and muons, and combined.
- Comparison with theoretical NNLO predictions.

Ratio of W^+/W^- and W/Z production cross sections

- Insensitive to luminosity and other sources of uncertainties.

Measurement Strategy

Signal yield extracted from
W: mainly MET, with data-driven methods
for the QCD background estimation
Z: di-lepton invariant mass

Integrated Luminosity:
(largest source of systematic uncertainty)
• 4.0%

$$\sigma \times \text{BR} = \frac{N_{\text{candidates}} - N_{\text{background}}}{\text{Acceptance} \times \text{Efficiency} \times L}$$

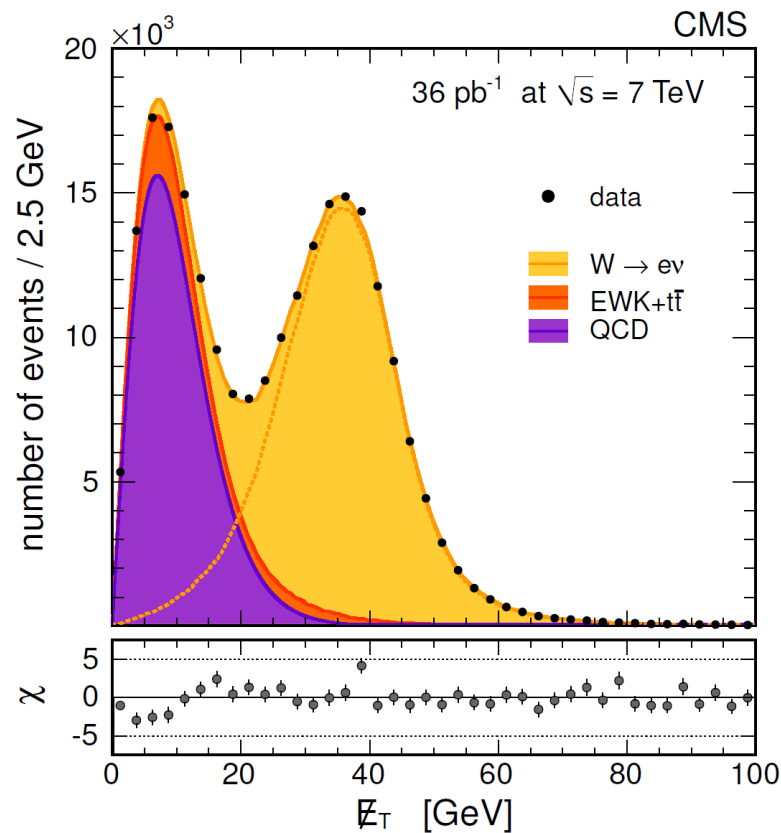
Determined from simulation.
Source of theoretical uncertainties

Selection efficiency for signal falling within the acceptance

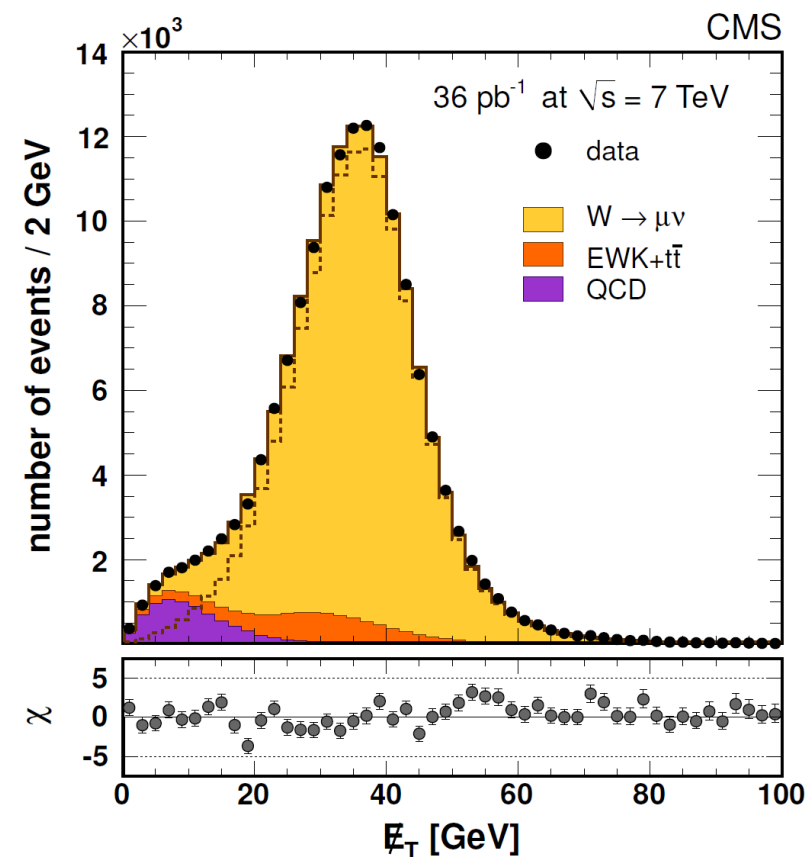
- Obtained from simulation
- Corrected using efficiencies measured in data and MC with a T&P technique

$$\varepsilon = \varepsilon_{\text{MC}} \times \rho_{\text{eff}}, \quad \rho_{\text{eff}} = \varepsilon_{\text{T\&P}}(\text{data}) / \varepsilon_{\text{T\&P}}(\text{MC})$$

Distributions after selection ($W \rightarrow l\nu$)



$W \rightarrow e\nu$	$W \rightarrow \mu\nu$
Candidates	
236 K	166 K
Signal	
136 K	141 K
Acceptance × Efficiency (%)	
36.3	38.5



Signal shape:

MC + $Z \rightarrow ll$ data for Recoil tuning

Signal extraction:

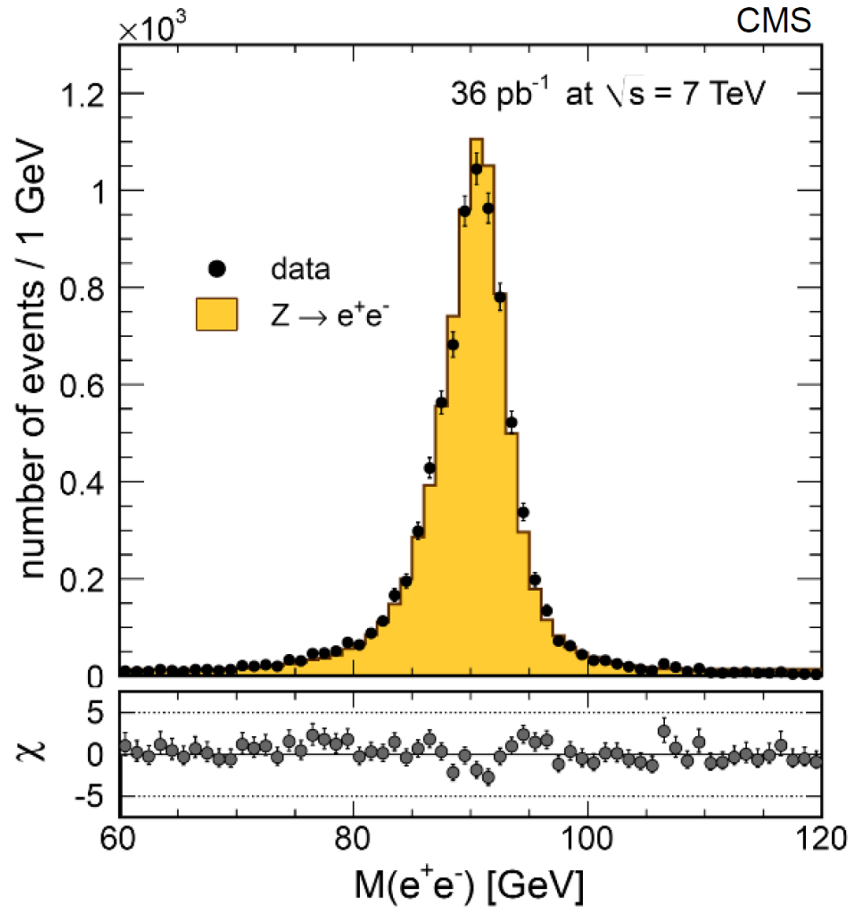
fits to missing transverse energy (MET)

QCD bkgd shape:

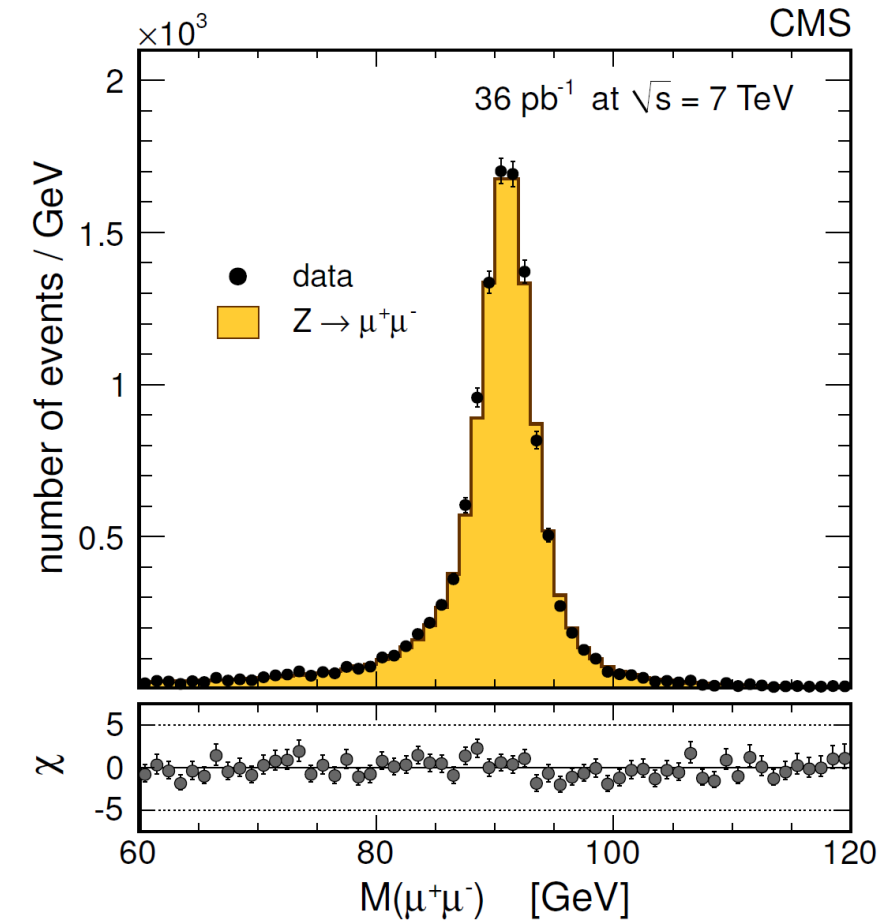
From data with lepton ID criteria reversed

Modeling with templates or analytical functions, ABCD method

Distributions after selection ($Z \rightarrow ll$)



$Z \rightarrow e^+e^-$	$Z \rightarrow \mu^+\mu^-$
Candidates	
8.4 K	13.8 K
Signal	
8.4 K	13.7 K
Acceptance \times Efficiency (%)	
23.6	39.4
BACKGROUND Almost negligible	



Signal Extraction

Cut & count, Fits to M_{ll} for Signal yield and efficiencies

Systematics

	W→ev (%)	W→μν (%)	Z→ee (%)	Z→μμ (%)
Experimental	1.5	1.1	1.8	0.7
Theoretical	0.9	1.1	1.7	2.0
Total (Exp. + Th.)	1.7	1.6	2.5	2.1
Luminosity	4.0			

Experimental : Lepton reconstruction & ID , Trigger pre-firing, Momentum/Energy scale & resolution, MET scale and resolution, Background subtraction/modeling, Pileup

Theoretical : PDF & HO corrections uncertainties on acceptance & MC efficiencies

NLO POWHEG+CT10 PDF, PDF4LHC (68% CL) with [MSTW08, CT10, NNPDF2.0] , α_s errors, scale unc.

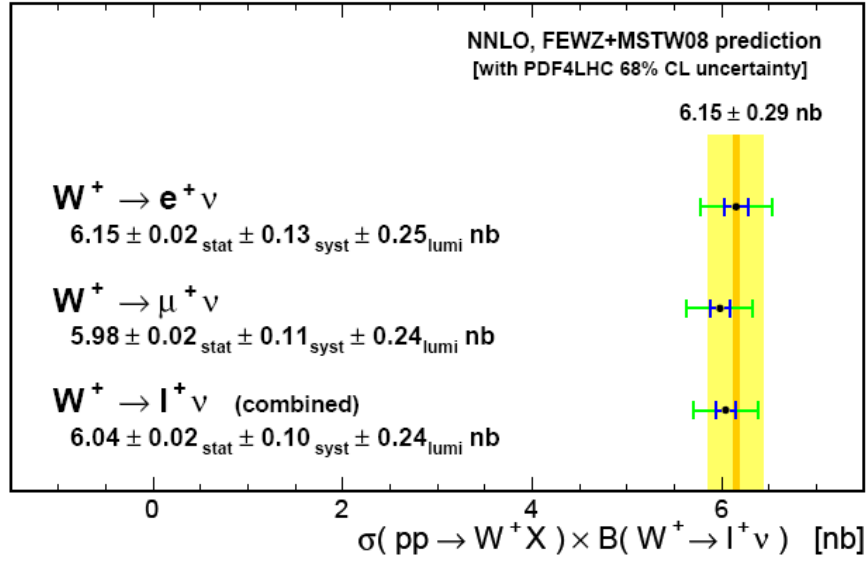
For W^+/W^- ratios special attention on:

- Lepton charge mis-measurement (only for electrons: 0.1-0.4%)
- Relative efficiencies between l^+ and l^-

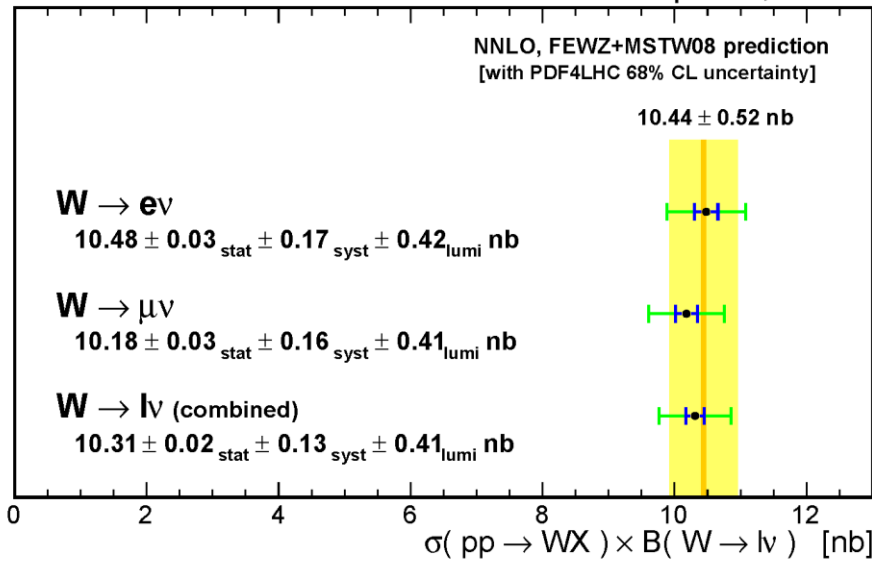
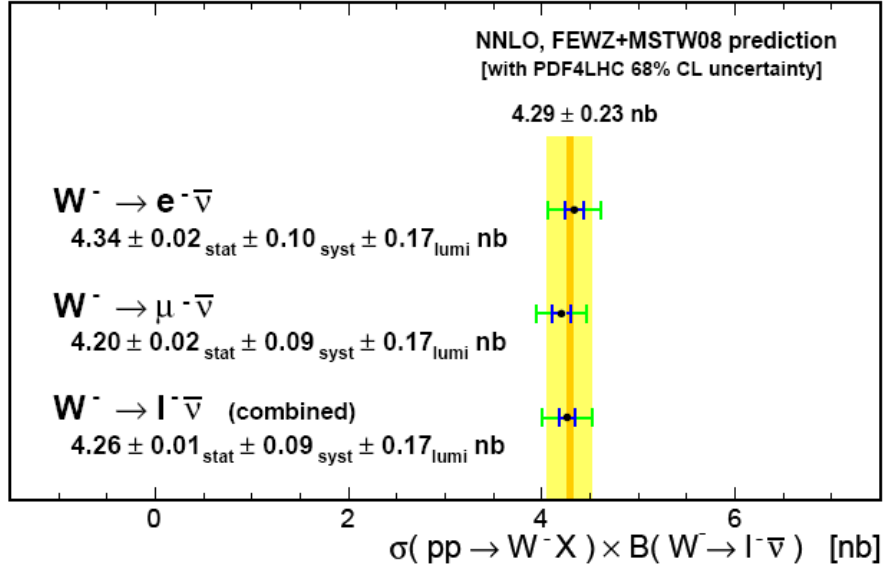
Both measured from data using a clean sample of $Z \rightarrow ll$ events.

Measured Cross sections

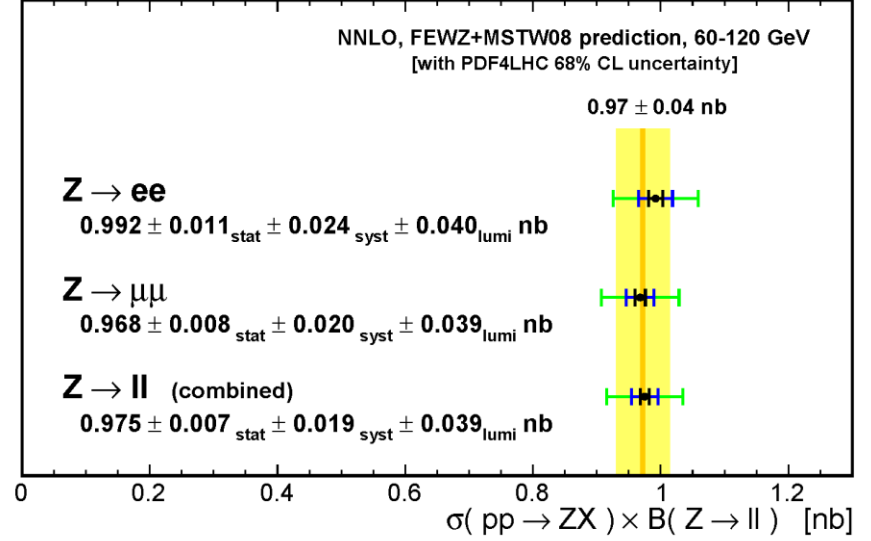
CMS 36 pb⁻¹ at $\sqrt{s} = 7$ TeV



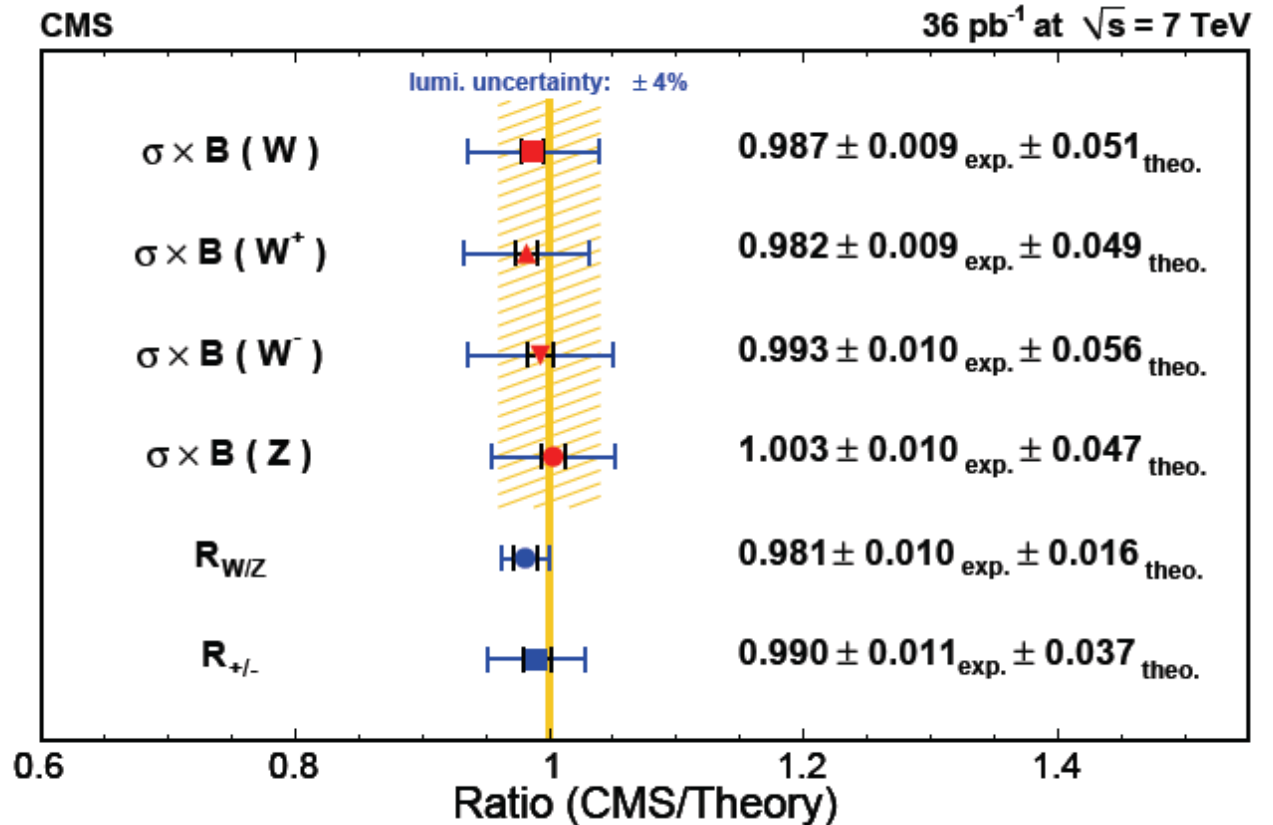
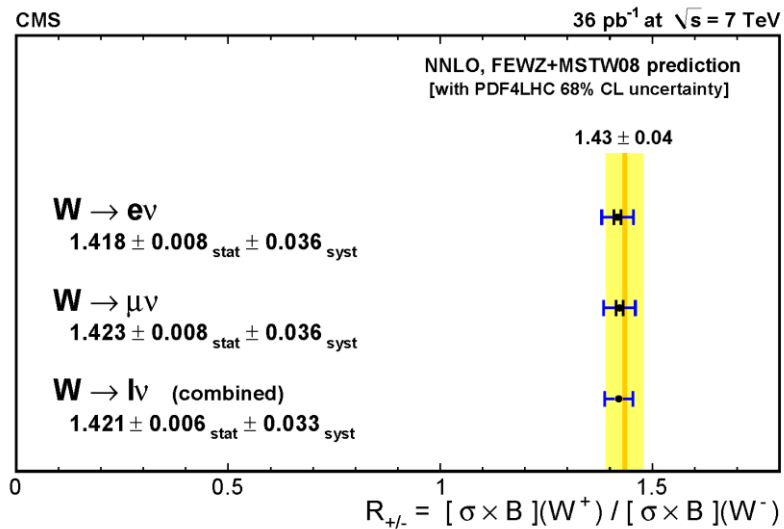
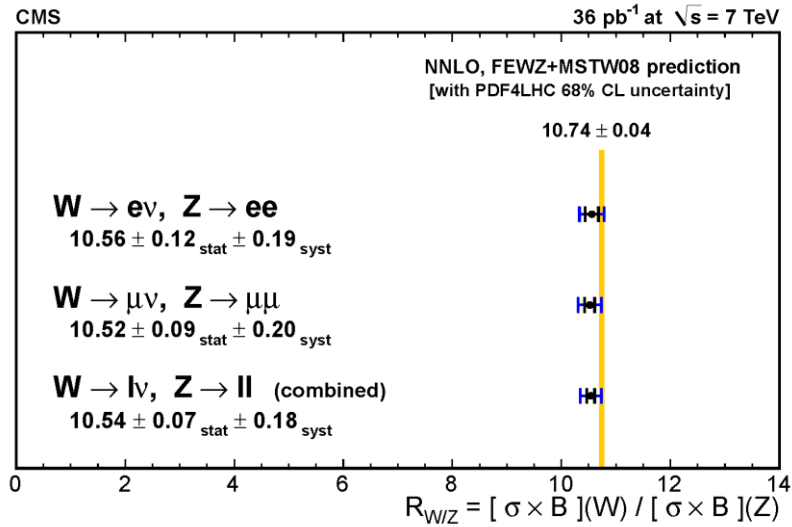
CMS 36 pb⁻¹ at $\sqrt{s} = 7$ TeV



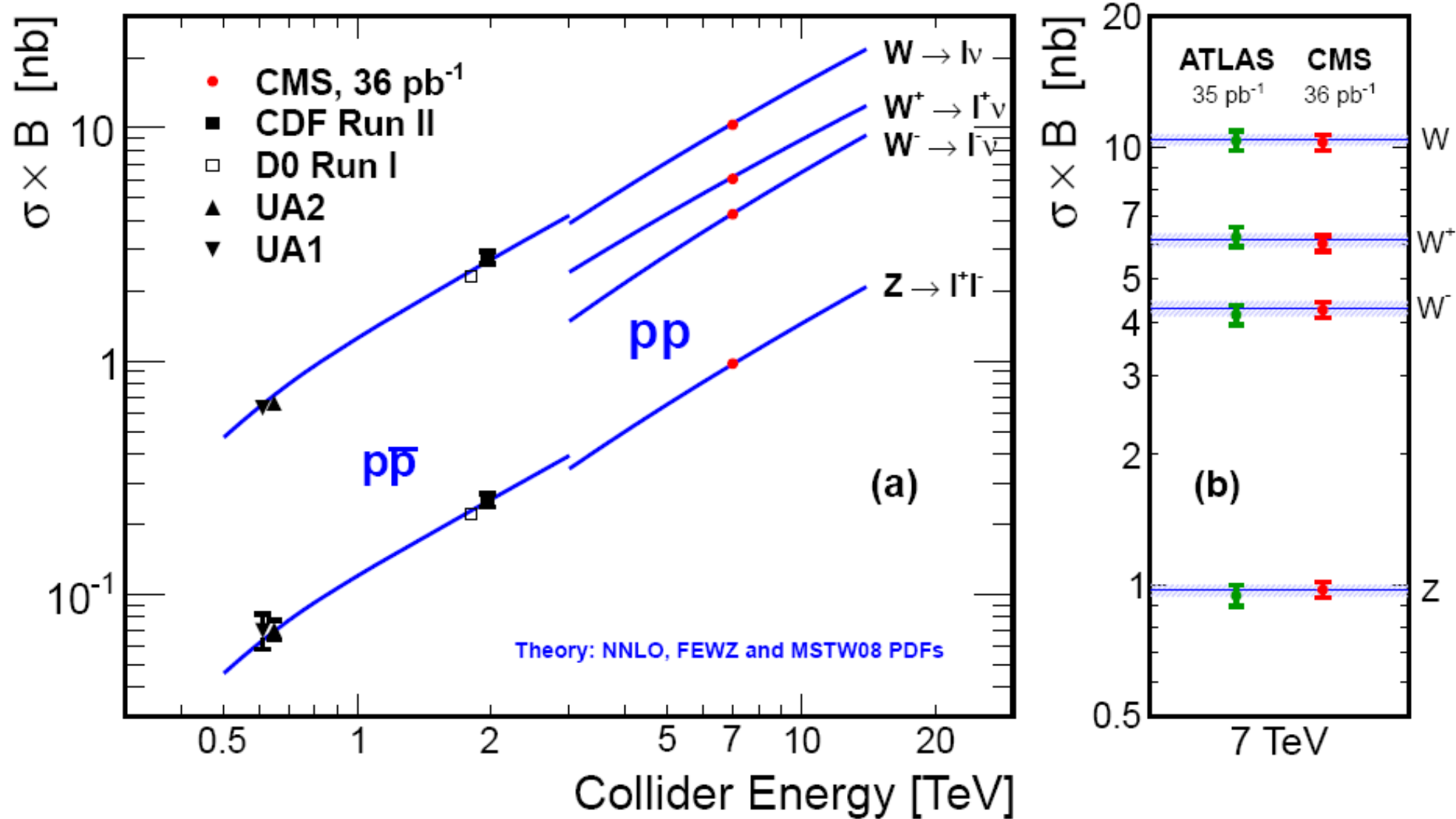
CMS 36 pb⁻¹ at $\sqrt{s} = 7$ TeV

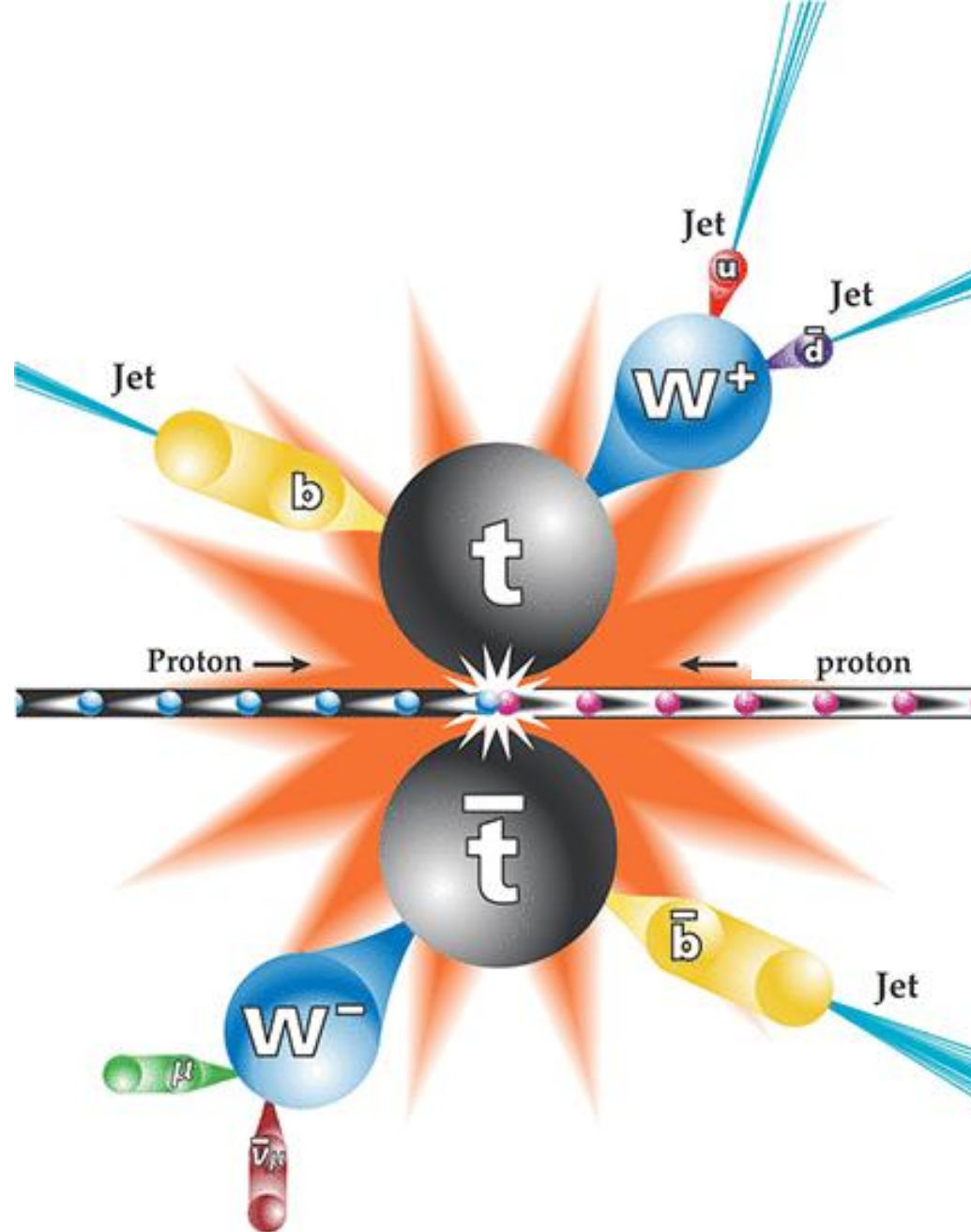


Measured Cross section Ratios



Cross sections versus Collider Energy



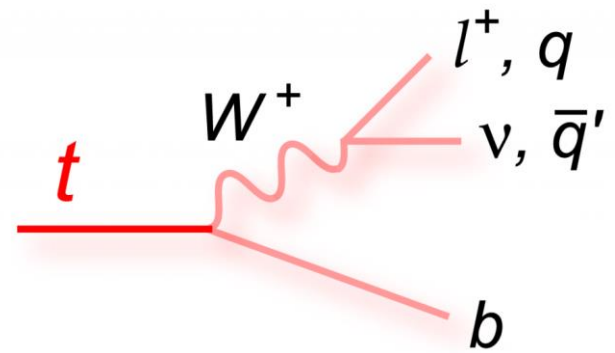


$tt + N_{\text{jets}}$

8 TeV
20 fb⁻¹

Why bother with t-quark

$t \rightarrow Wb$ almost 100%



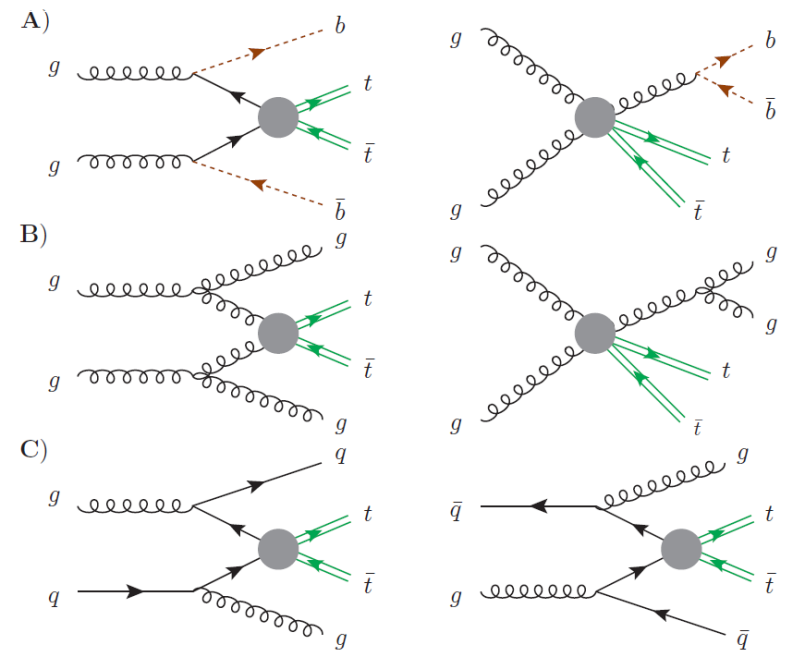
- Most massive particle known. Same mass scale as W,Z,H
 - ◆ Largest Yukawa coupling among fermions ($y_t \sim 1$)
 Special role in EWSB ?

- Very short lifetime $\tau(t) = 1/\Gamma(t) \sim 3.3 \times 10^{-25}$ s

$\tau(t) < \tau$ (hadronization) $\sim 10^{-24}$ s \rightarrow No hadronic bound states

Top-pair (tt) cross-section as a function of number of jets.

- test of pQCD.
- $tt + N$ jets is an irreducible background to $tt + H$ ($H \rightarrow bb$).



The measurement

Jet multiplicity

reconstructed jets
in $t\bar{t}$ events



particle-level jets
in $t\bar{t}$ events

results in **visible** phase space.

allows a RIVET analysis → for **tests of MC generators**.

Additional-jet multiplicity

Cumulative cross sections ($t\bar{t}$ + at least N additional **particle-level** jets)

→ compare with theoretical calculations of $t\bar{t}$ + $\geq 0, 2$ additional jets



G. Bevilacqua and M. Worek, JHEP 07 (2014) 135, arXiv:1403.2046

CMS Physics Analysis Summary

Contact: cms-pag-conveners-top@cern.ch

2016/07/14

Measurement of the differential production cross section for top-quark pairs as a function of jet multiplicity in the lepton+jets final state at $\sqrt{s} = 8$ TeV with the CMS detector

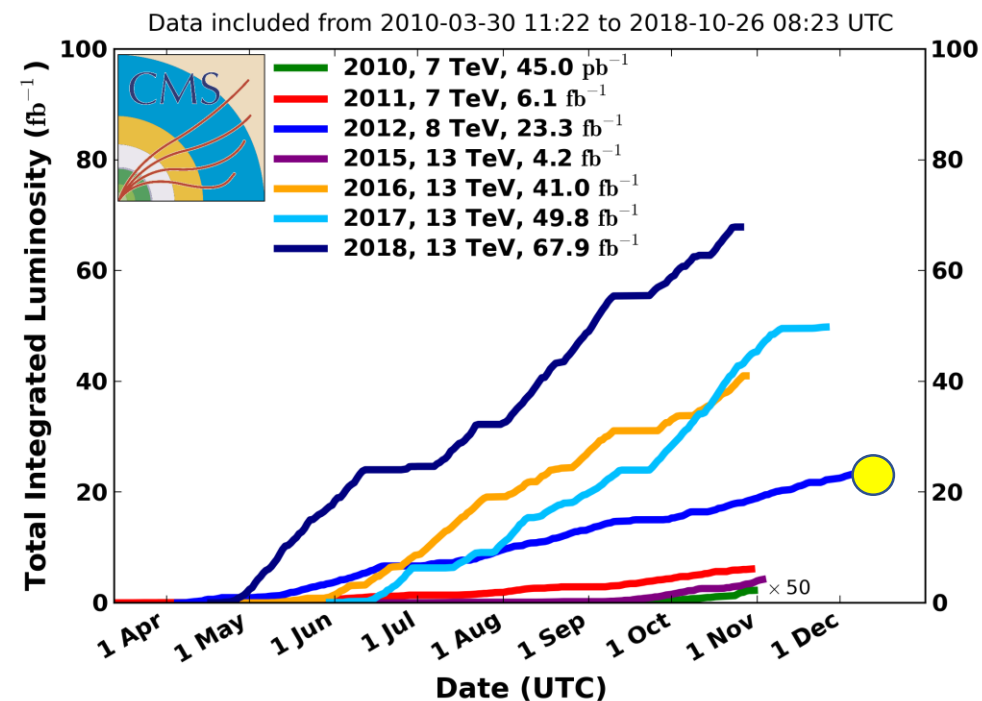
The CMS Collaboration

Abstract

The top-quark pair differential production cross section in pp collisions at $\sqrt{s} = 8$ TeV as a function of the number of jets is measured in the lepton+jets (e/μ +jets) final state for an integrated luminosity of 19.7 fb^{-1} . The cross section is presented in the visible phase space of the measurement as well as extrapolated to the full phase space. The results are compared with theoretical predictions at next-to-leading order. The comparisons show good agreement between the data and the predictions within the experimental and theoretical uncertainties.

**INPP team funded
by KRIPIS-I
(ORASY , ΟΠΣ 448332)**

CMS Integrated Luminosity Delivered, pp



Authors

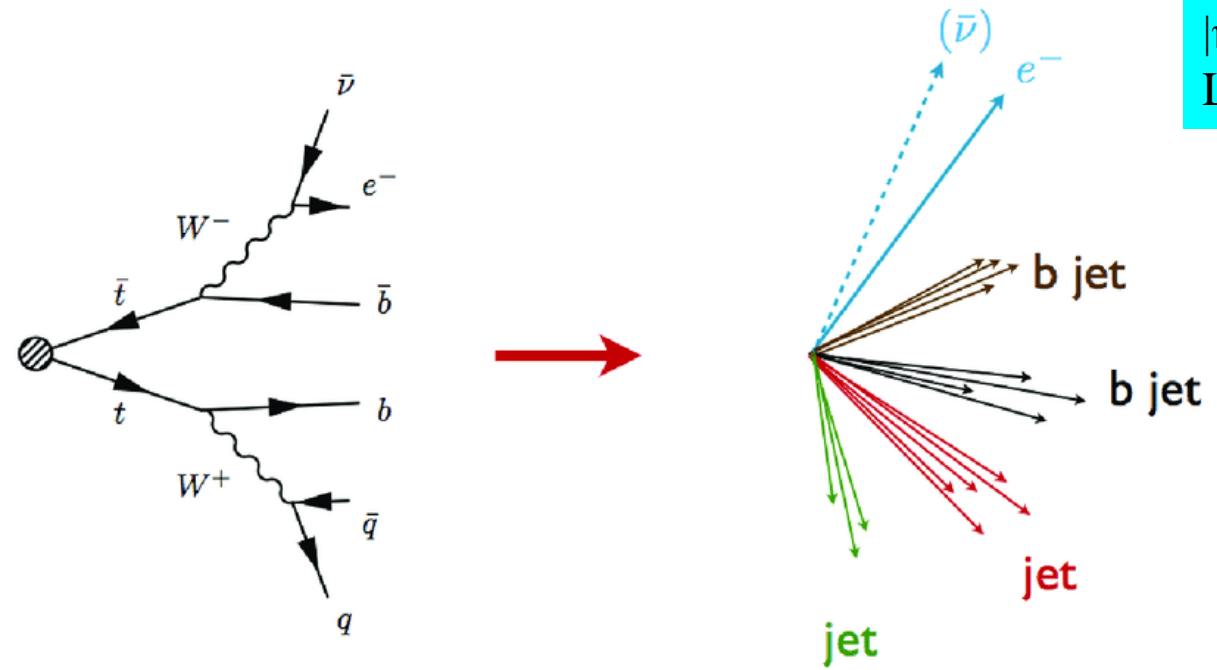
A. Descroix, U. Husemann (KIT) + INPP

The INPP team:

GD, G. Anagnostou, T. Diakonidis (postdoc), E. Elmalis (student)
GD was editor and contact person of the analysis.

Selection criteria

Single lepton triggers (electrons / muons)



one isolated lepton
 $p_T > 30$ GeV.
 $|\eta| < 2.5$ (electrons), *excluding the barrel/endcap region*
 $|\eta| < 2.1$ (muons)
Loose lepton veto

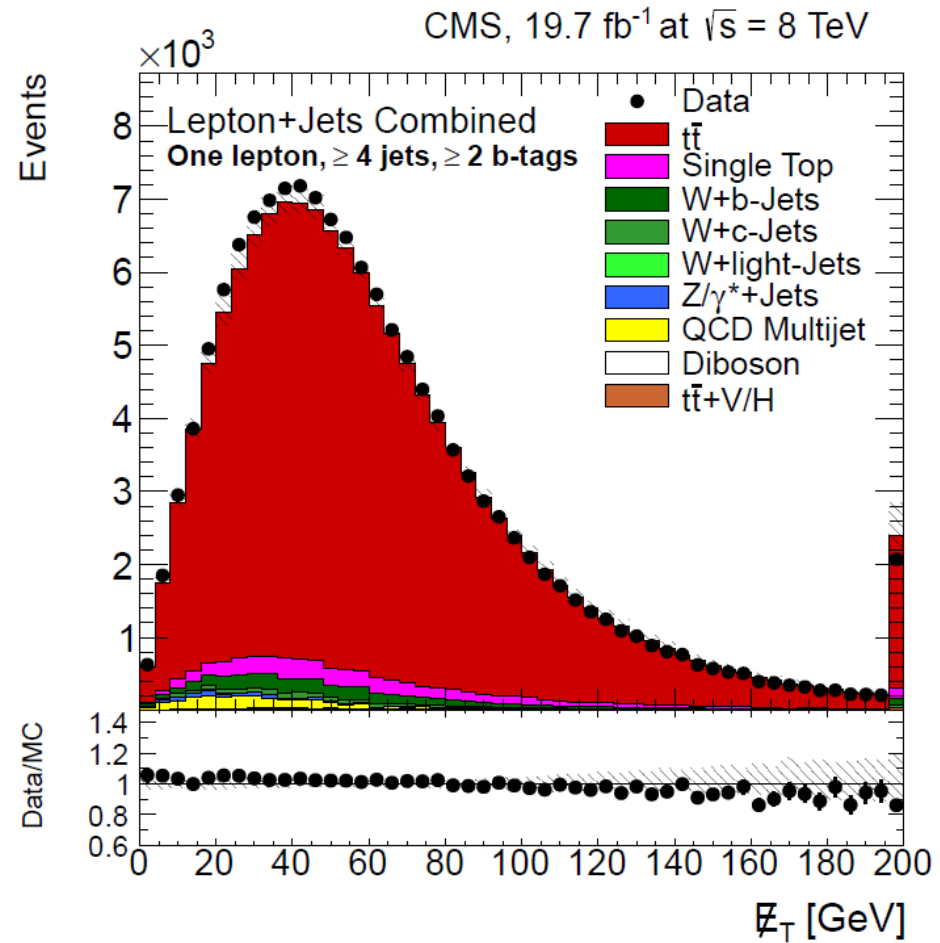
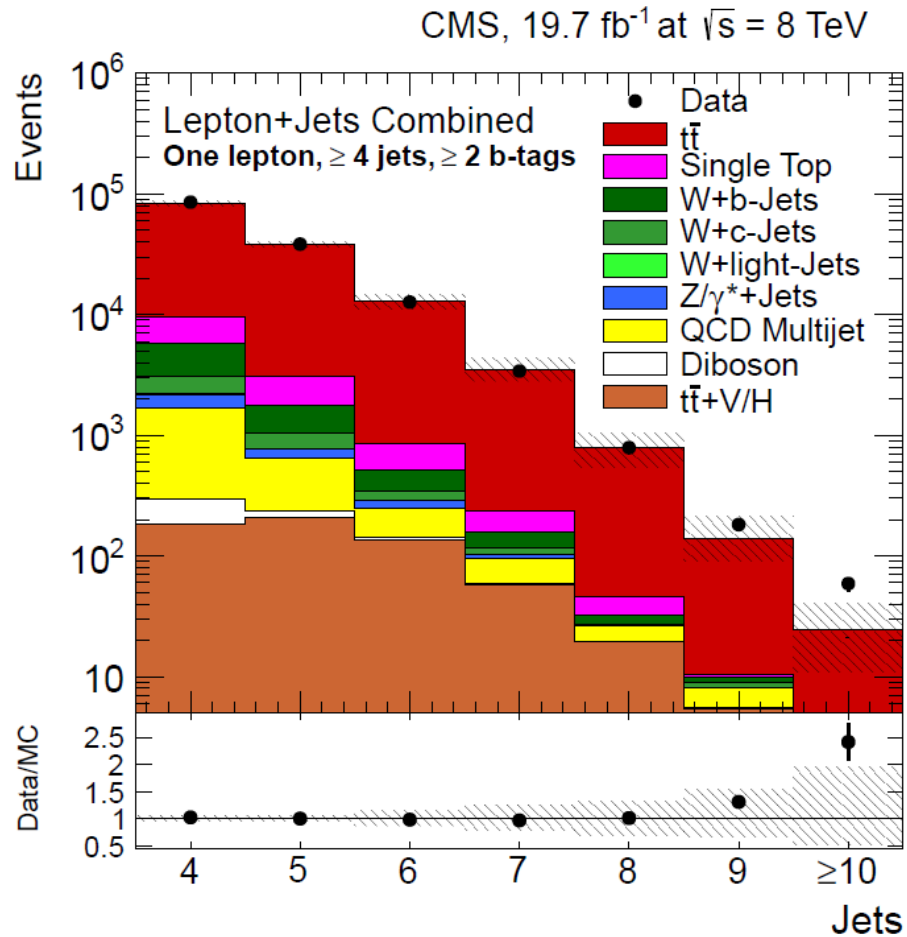
≥ 4 jets (ak5 CHS)
 $p_T > 30$ GeV ; $|\eta| < 2.5$
 ≥ 2 jets b-tagged (CSV medium)

eliminate jets when $\Delta R(\text{lepton-jet}) < 0.5$

High signal purity (90%).

All backgrounds estimations are based on MC predictions except W +jets and QCD multijets (data-driven).

After event selection



- Combined e+jets & μ +jets channels
- QCD-multijet and W+jets background from data
- The $t\bar{t}$ MC sample (red) is scaled to the measured inclusive cross section

ingredients of the measurement

Jet Multiplicity: Measurement in visible phase space

Unfold the jet multiplicity:
reco-level to particle-level

Subtract non-ttbar
backgrounds in each
bin (4 to ≥ 10 reco-jets).

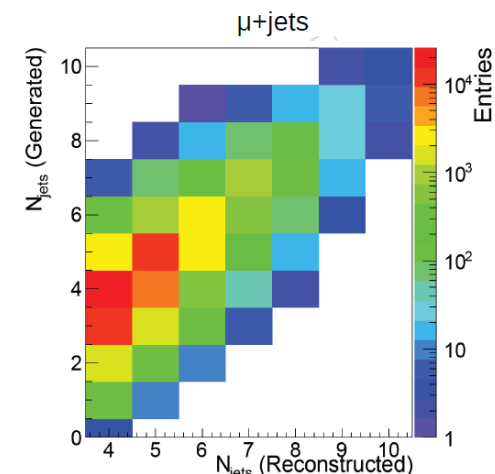
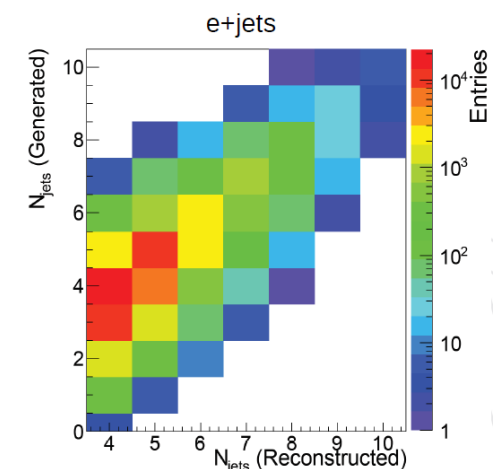
$$\frac{d\sigma_i}{dN_{\text{jets}}} = \frac{\sum_j U_{ij} (n_j^{\text{data}} - n_j^{\text{non-tt}})}{\mathcal{L} \cdot \frac{(A \cdot \epsilon)_i^{\text{detec}}}{(A \cdot \epsilon)_i^{\text{visible}}}}$$

Bin-by-bin
acceptance
correction

- Inversion of the migrations from reco-jet to particle-level jets by unfolding:
 - Singular Value Decomposition.
 - Regularization against fluctuations, optimal point at minimum of global correlation.
 - Purity and stability drop below 50% for highest multiplicities.

- Main uncertainties arise from:
 - Jet Energy Scale (JES): 3-18%, increasing with the jet multiplicity.
 - Q^2 and jet-matching: 0.2-18.0% and 1.0-40.3%
 - "MadGraph-Powheg" : 0.2-25.2%
 - PDF uncertainty: 0.4-11.3%
 - Top- p_T reweighting: 2.8-11.0%

Migration Matrices - Unfolding



Systematic Uncertainties

Jet Multiplicity: Systematics (e+jets) %

	$e + 4$ jets	$e + 5$ jets	$e + 6$ jets	$e + 7$ jets	$e + 8$ jets	$e + 9$ jets	$e + \geq 10$ jets
$d\sigma/dN_{\text{jets}}$ [pb]	4.16	1.91	0.61	0.15	0.036	0.013	0.004
JES	3.42	6.39	7.83	11.75	13.82	12.65	17.71
JER	0.17	0.58	0.45	1.87	2.43	2.09	4.35
b-Tagging (b,c)	4.33	3.65	3.20	2.74	1.92	2.05	2.24
b-Tagging (light)	0.37	0.27	0.22	0.15	0.16	0.20	0.17
Pile-up	0.71	0.39	0.25	0.23	1.30	1.80	3.59
Lepton Efficiency	0.55	0.51	0.49	0.50	0.46	0.50	0.39
Luminosity	2.92	2.81	2.84	2.85	2.79	2.79	2.79
Q^2 ($t\bar{t}$)	2.22	4.74	4.62	5.40	3.63	9.51	14.79
Matching ($t\bar{t}$)	1.03	2.46	2.15	6.44	18.52	16.36	20.73
Q^2 (W +jets)	1.91	0.84	1.48	1.58	0.51	1.96	3.33
Matching (W +jets)	3.64	2.54	1.63	1.71	4.50	4.14	2.58
MADGRAPH-POWHEG	0.28	0.49	0.24	1.57	4.05	19.55	11.25
Top- p_T Reweighting	2.85	4.97	7.00	8.44	9.18	11.00	10.83
PDF	0.41	0.63	0.78	0.77	1.28	1.12	3.54
Single Top CS	0.31	0.19	0.19	0.13	0.14	0.02	0.03
W +Jets CS	1.22	0.45	0.62	0.47	0.11	0.56	0.54
B/C in W +jets	1.38	0.49	0.50	0.65	0.03	0.67	1.08
QCD CS	0.43	0.21	0.18	0.53	0.49	0.59	0.03
QCD Shape (e +jets)	0.28	0.52	0.33	3.21	1.51	3.13	0.08
Z +Jets CS	0.02	0.01	0.01	0.03	0.03	0.002	0.004
Diboson CS	0.01	0.002	0.003	0.003	0.01	0.002	0.03
$t\bar{t}$ + H / W / Z CS	0.03	0.07	0.15	0.24	0.37	0.29	0.24
Syst. unc.	8.66	11.17	12.71	17.86	26.30	32.78	35.81
Stat. unc.	1.20	1.56	3.72	8.42	18.26	20.21	25.22
Total unc.	8.74	11.28	13.24	19.75	32.02	38.50	43.80

Jet Multiplicity: Systematics (μ +jets) %

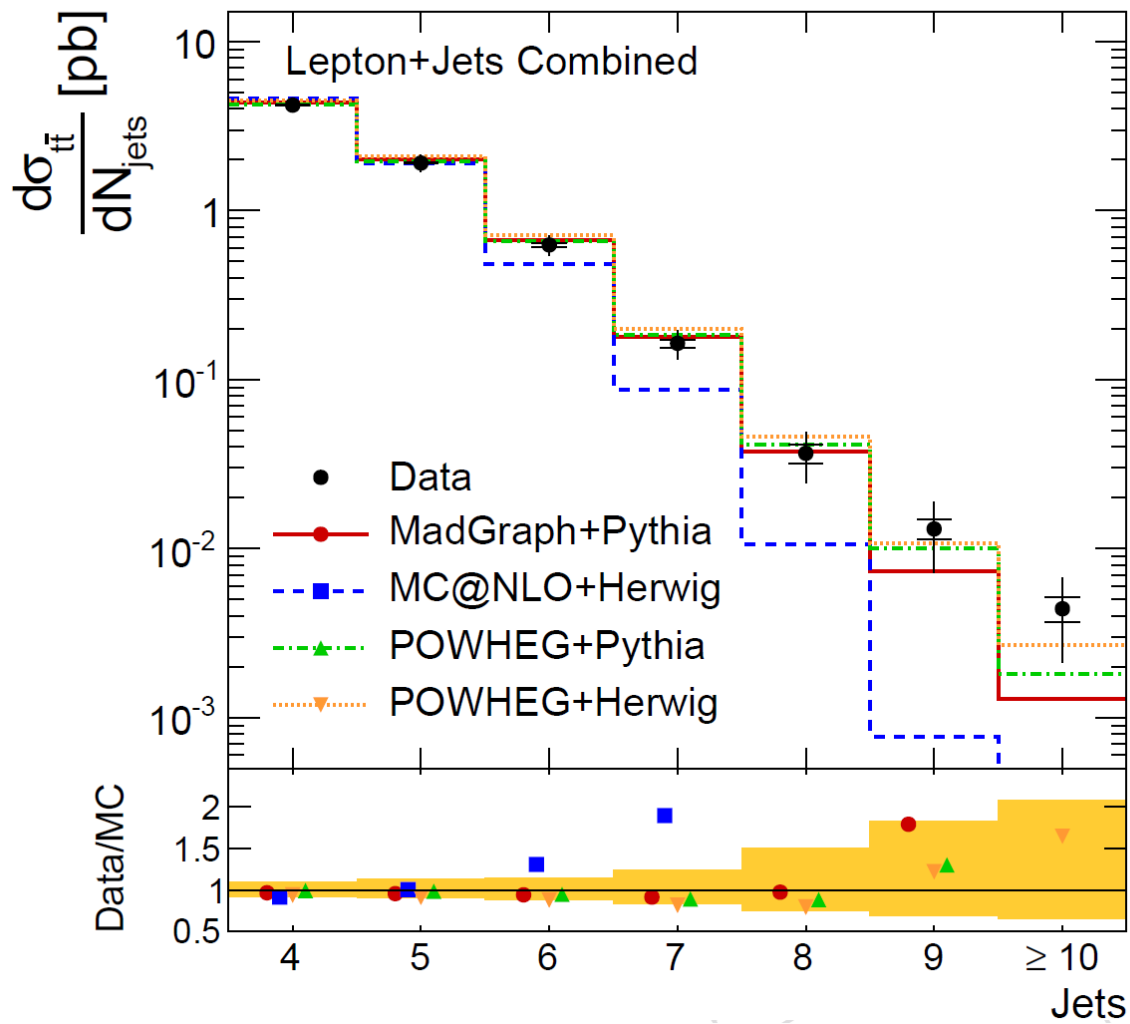
	$\mu + 4$ jets	$\mu + 5$ jets	$\mu + 6$ jets	$\mu + 7$ jets	$\mu + 8$ jets	$\mu + 9$ jets	$\mu + \geq 10$ jets
$d\sigma/dN_{\text{jets}}$ [pb]	4.25	1.92	0.64	0.17	0.037	0.013	0.005
JES	3.69	6.29	7.81	11.83	14.79	10.27	16.71
JER	0.25	0.29	0.76	1.10	1.17	0.56	4.37
b-Tagging (b,c)	4.30	3.64	3.11	2.74	2.11	1.72	2.30
b-Tagging (light)	0.36	0.26	0.19	0.19	0.06	0.10	0.20
Pile-up	0.86	0.17	0.40	0.19	2.86	0.47	1.59
Lepton Efficiency	0.68	0.70	0.74	0.73	0.79	0.75	0.72
Luminosity	2.92	2.82	2.81	2.85	2.76	2.78	2.71
Q^2 ($t\bar{t}$)	1.55	3.86	3.92	4.88	9.59	14.55	17.62
Matching ($t\bar{t}$)	0.97	1.92	1.81	5.62	21.69	31.05	40.30
Q^2 (W +jets)	1.94	1.36	0.53	1.67	2.04	1.84	0.37
Matching (W +jets)	3.88	2.27	1.72	2.33	2.57	3.25	2.55
MADGRAPH-POWHEG	0.66	0.82	1.24	8.35	6.43	18.91	4.80
Top- p_T Reweighting	2.85	5.09	6.83	7.84	10.70	10.34	9.65
PDF	0.47	0.73	0.83	0.58	0.93	1.40	1.29
Single Top CS	0.31	0.21	0.14	0.18	0.09	0.08	0.02
W +Jets CS	1.28	0.58	0.35	0.75	0.49	0.42	0.08
B/C in W +jets	1.43	0.66	0.52	0.79	0.67	0.29	0.10
QCD CS	0.08	0.03	0.03	0.02	0.07	0.02	0.09
QCD Rellso (μ +jets)	0.08	0.08	0.11	0.40	1.23	0.59	1.00
Z +Jets CS	0.01	0.001	0.02	0.01	0.004	0.0004	0.0006
Diboson CS	0.01	0.002	0.003	0.001	0.005	0.004	0.0008
$t\bar{t}$ + H / W / Z CS	0.03	0.07	0.16	0.22	0.34	0.35	0.19
Syst. unc.	8.74	10.71	12.28	18.81	31.19	42.12	48.72
Stat. unc.	1.08	1.42	3.26	7.02	17.24	18.26	21.43
Total unc.	8.81	10.80	12.70	20.07	35.63	45.91	53.22

Measured Production cross section

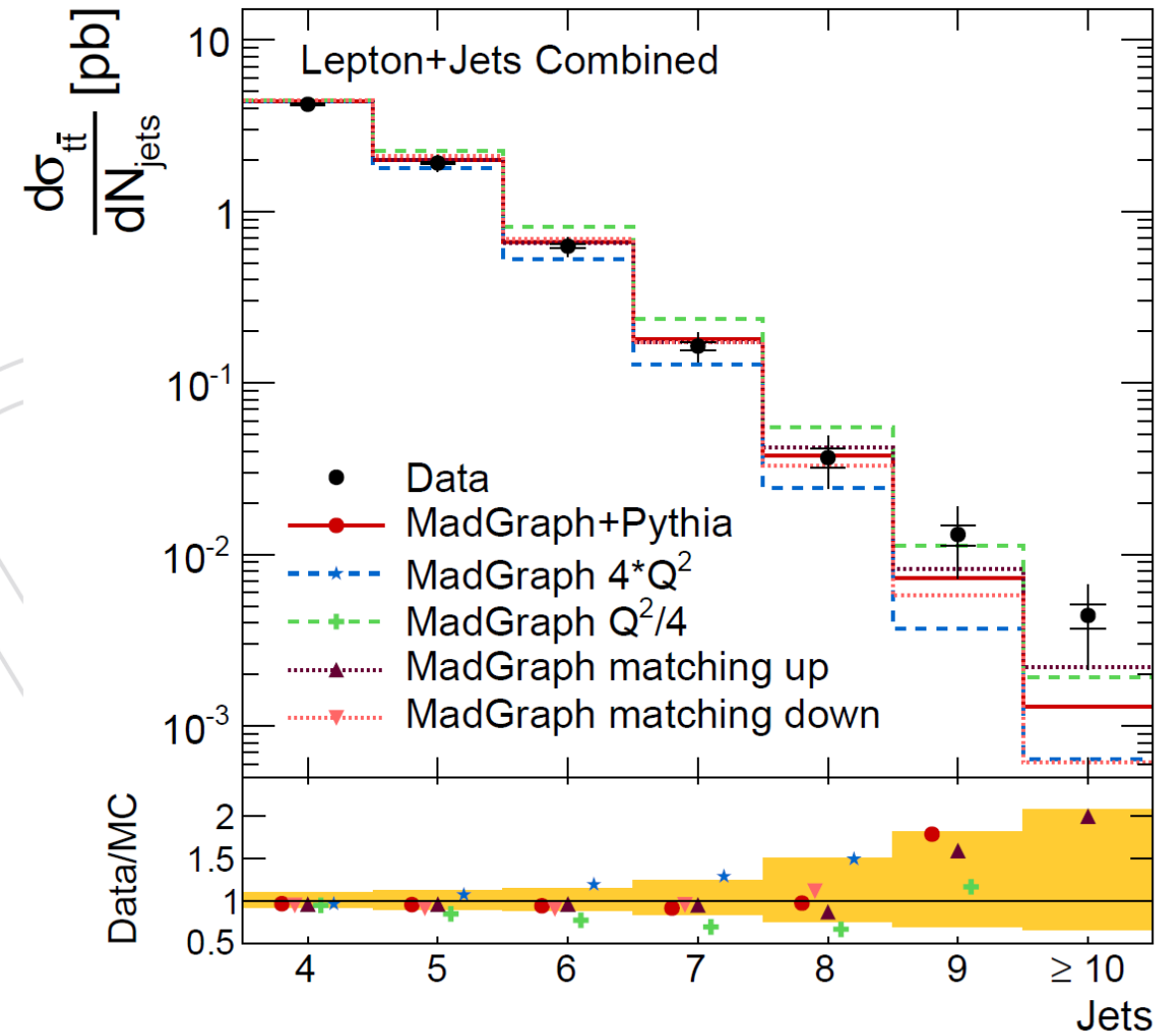
Category	$d\sigma/dN_{\text{jets}}$ [pb]	Stat.	Exp.	Theor.	Total
$t\bar{t} \rightarrow \ell + 4$ jets	4.21	0.8%	6.2%	5.6%	8.8%
$t\bar{t} \rightarrow \ell + 5$ jets	1.91	1.0%	7.5%	7.8%	11.2%
$t\bar{t} \rightarrow \ell + 6$ jets	0.627	2.5%	8.6%	9.0%	12.9%
$t\bar{t} \rightarrow \ell + 7$ jets	0.164	5.4%	12.3%	14.0%	19.6%
$t\bar{t} \rightarrow \ell + 8$ jets	0.0366	12.5%	15.4%	27.0%	33.6%
$t\bar{t} \rightarrow \ell + 9$ jets	0.0131	13.5%	13.2%	40.7%	45.0%
$t\bar{t} \rightarrow \ell + \geq 10$ jets	0.00441	16.4%	18.8%	45.4%	51.8%

Comparison with Generators

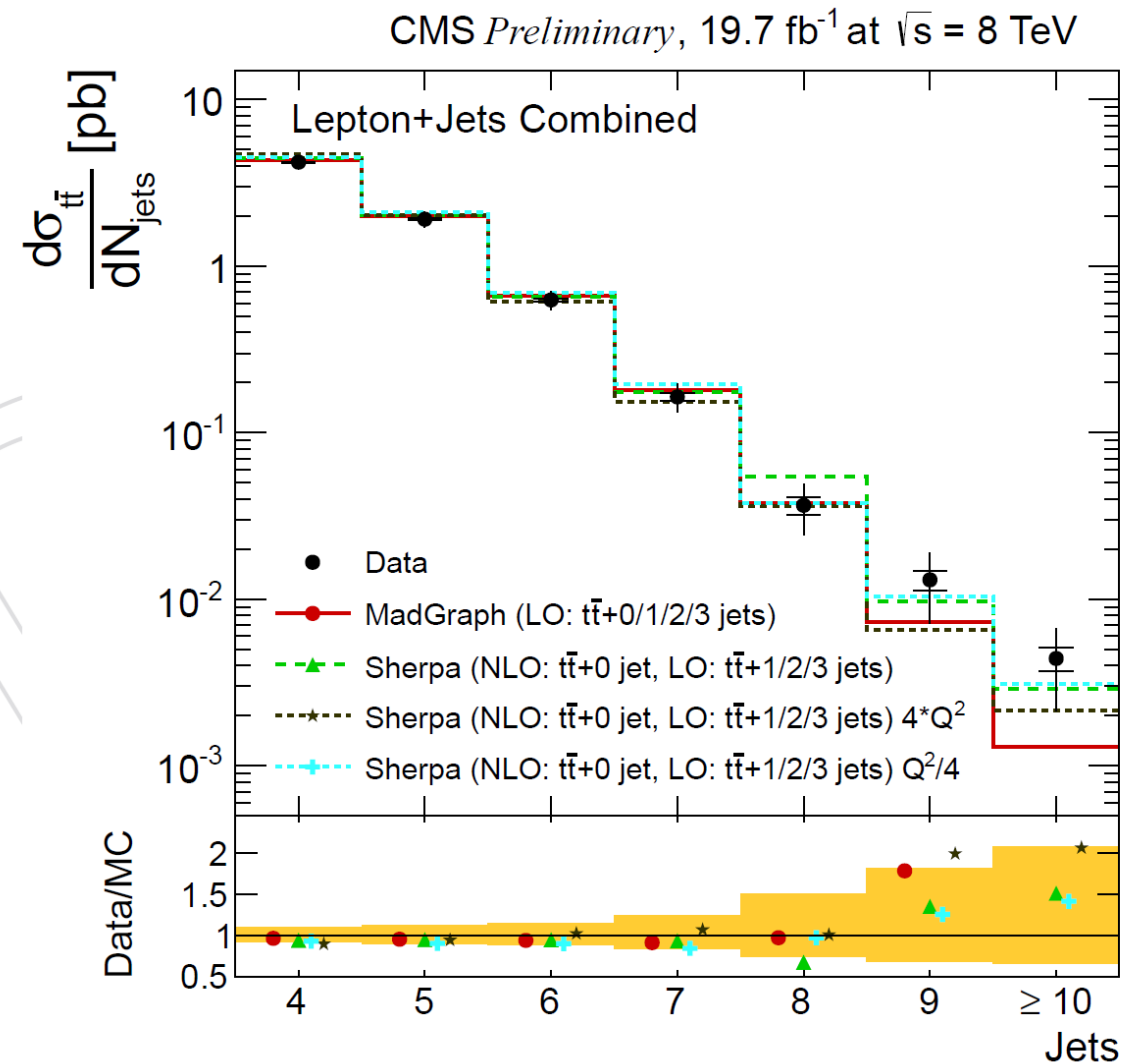
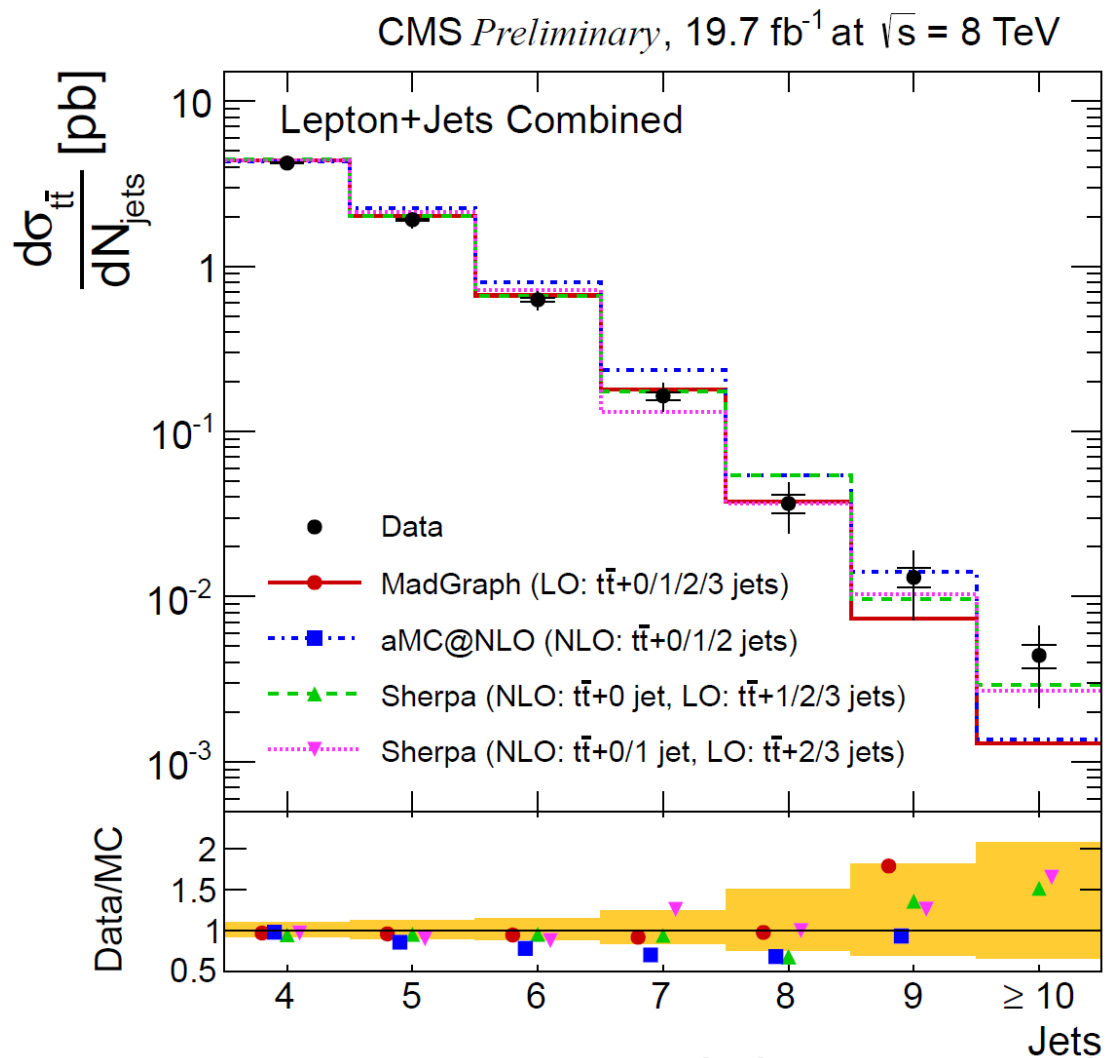
CMS Preliminary, 19.7 fb⁻¹ at $\sqrt{s} = 8$ TeV



CMS Preliminary, 19.7 fb⁻¹ at $\sqrt{s} = 8$ TeV



Comparison with Generators

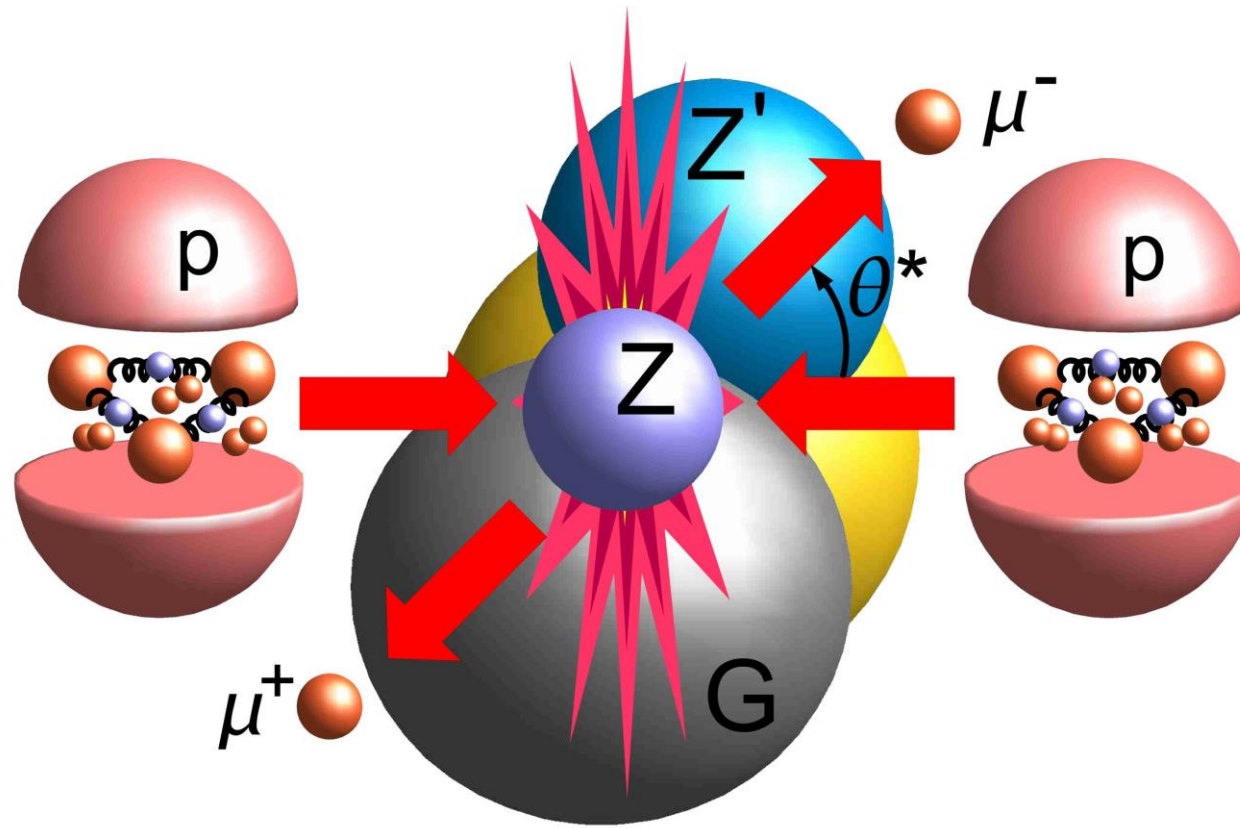


Results

Top++2.0 (Comput. Phys. Commun. 185 (2014) 2930) , $M_t = 172.5\text{GeV}$.

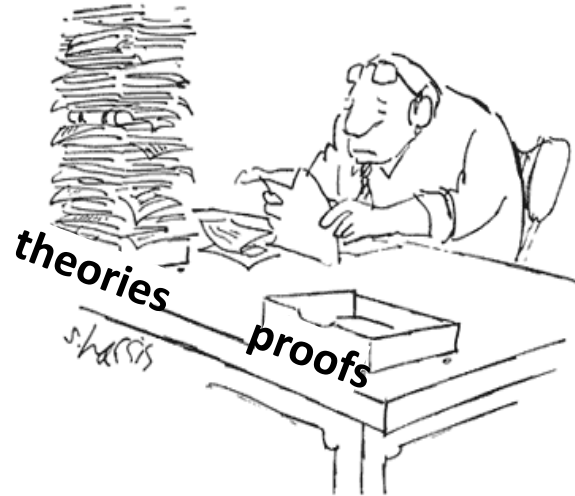
	$d\sigma/dN$ [pb]	Stat.	Exp.	Theo.	Total	Prediction [pb]
$t\bar{t} + \geq 0$ jet	239.9	0.3%	6.2%	11.2%	13.0%	$252.9^{+2.5\%}_{-3.4\%}(\text{scale}) \pm 4.6\%(\text{PDF}+\alpha_s)$
$t\bar{t} + \geq 1$ jet	81.4	0.5%	7.2%	11.7%	14.0%	-
$t\bar{t} + \geq 2$ jets	20.1	0.8%	8.5%	13.6%	16.3%	$20.97^{+15.5\%}_{-13.3\%}(\text{scale})$
$t\bar{t} + \geq 3$ jets	4.06	1.6%	10.3%	18.4%	21.3%	-
$t\bar{t} + \geq 4$ jets	0.71	3.4%	13.1%	30.5%	33.4%	-

G. Bevilacqua and M. Worek, JHEP 07 (2014) 135, arXiv:1403.2046

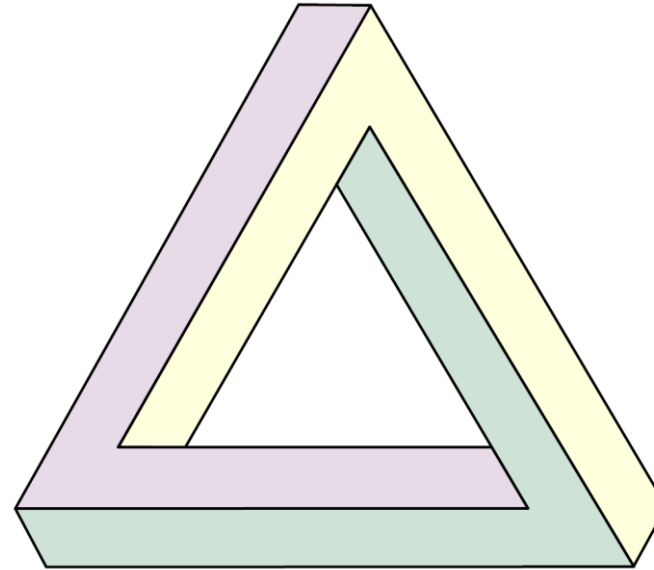


Searches for
Narrow Di-lepton resonances
at 8 & 13 TeV

where we stand



the Questions



Hierarchy problem
Unification of forces
Origin of flavor
Origin of dark matter
Gravity, dark energy
Neutrino masses
...

the SM extensions

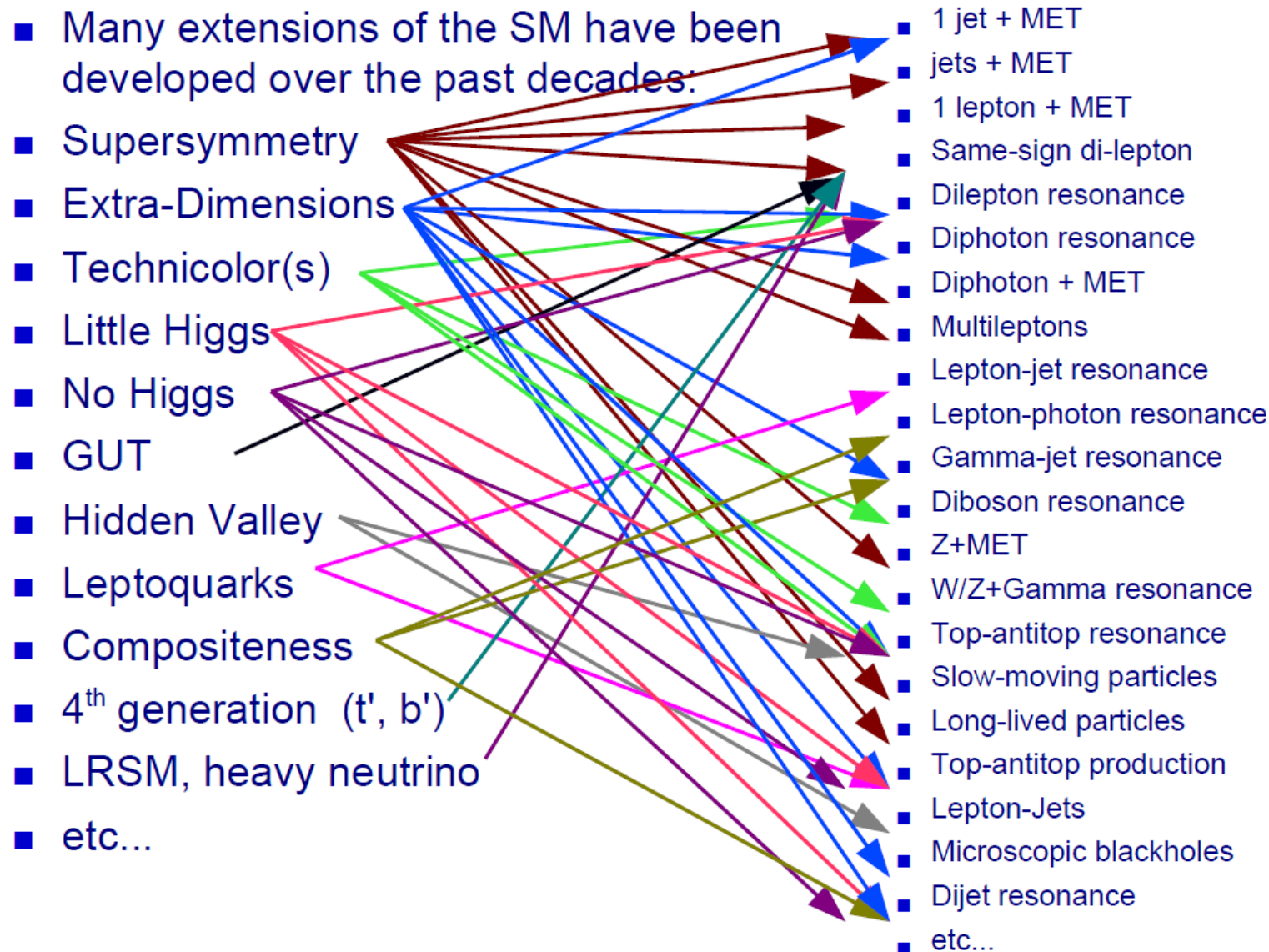
SUSY, Extra-Dimensions, New Gauge Bosons, Contact Interactions, Leptoquarks, Excited fermions, 4th generation, Type III seesaw, ...

the Proofs *(experiments)*

(jets, lepton, $\gamma\gamma$, Z)+ E_T^{miss} , (ee , $\mu\mu$, $\tau\tau$, $\gamma\gamma$, jj , lepton-jet, lepton- γ , γ -jet, VV , tt) resonances, slow-moving or long-lived particles, ...

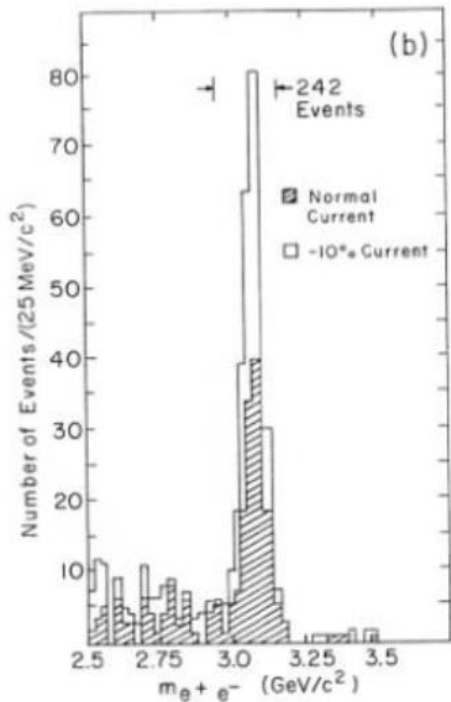


Models vs Final-States

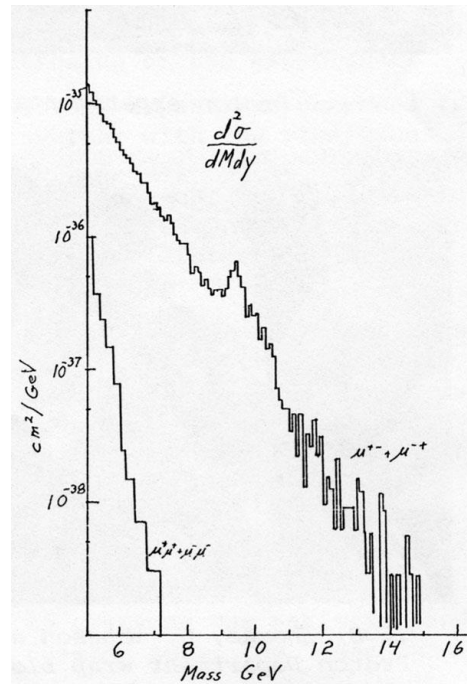


Why di-lepton resonances?

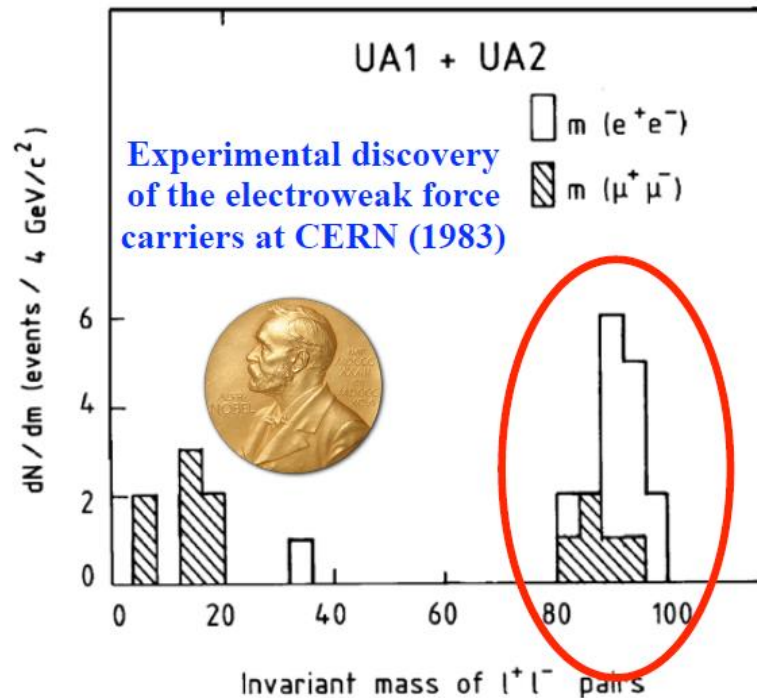
SLAC/BNL, 1974



Fermilab, 1977



CERN, 1983

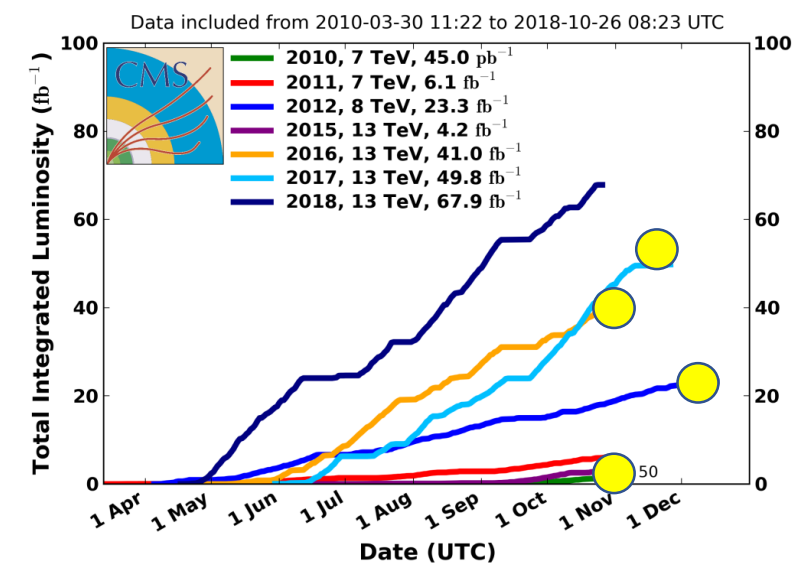


... great success story in the past ...

- Heavy resonance decaying to di-leptons in several NP models
- Simple final state (express stream, always in the list of first analyses when new data appear)
- Use the accumulated experience on the Standard Model W, Z physics (together with my expertise on electrons) in searches for Z' decaying to electron pairs (HEEP group).

Published results

CMS Integrated Luminosity Delivered, pp



CMS INPP joint the di-lepton searches at the end of **2011**
 The team : **GD**, V. Giakoumopoulou (postdoc), S. kesisoglou (postdoc)

Co-financed by Greece and the European Union

ΘΑΛΗΣ-Ε.Μ.Π. : 68/1127

Αναζήτηση της Προέλευσης της Μάζας και Νέας Φυσικής στον Επιταχυντή LHC

Available on the CERN CDS information server CMS PAS EXO-16-031

CMS Physics Analysis Summary

Contact: cms-pag-conveners-exotica@cern.ch 2016/08/05

Search for a high-mass resonance decaying into a dilepton final state in 13 fb⁻¹ of pp collisions at $\sqrt{s} = 13$ TeV

Available on the CERN CDS information server CMS PAS EXO-18-006

CMS Physics Analysis Summary

Contact: cms-pag-conveners-exotica@cern.ch 2018/03/12

Search for high mass resonances in the dielectron final state

The CMS Collaboration

Abstract

A search for high mass resonances in the dielectron final state is performed using proton-proton collision data at a center-of-mass energy of 13 TeV collected by the CMS experiment at the LHC in 2017. The integrated luminosity corresponds to 41 fb⁻¹. No evidence for a significant deviation from standard model expectation is observed. The sensitivity of the search is increased by combining these data with a previously analysed set of data obtained in 2016 and corresponding to a luminosity of 36 fb⁻¹. Upper bounds are set on the masses of hypothetical particles that arise in new-physics scenarios.

JHEP06(2018)120

Physics Letters B 768 (2017) 83–82

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Search for heavy narrow dilepton resonances in pp collisions at $\sqrt{s} = 7$ TeV and $\sqrt{s} = 8$ TeV

HEP

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PUBLISHED: April 7, 2017

Search for physics beyond the standard model in dilepton mass spectra in proton-proton collisions at $\sqrt{s} = 8$ TeV

Physics Letters B 768 (2017) 57–60

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Search for narrow resonances in dilepton mass spectra in proton-proton collisions at $\sqrt{s} = 13$ TeV and combination with 8 TeV data

The CMS Collaboration*

ABSTRACT: Dilepton mass spectra in proton-proton collisions at $\sqrt{s} = 13$ TeV and combination with 8 TeV data are presented. The search is performed using proton-proton collision data collected by the CMS experiment at the LHC in 2016 and 2017. The integrated luminosity is 41.0 fb⁻¹ at $\sqrt{s} = 13$ TeV and 36.1 fb⁻¹ at $\sqrt{s} = 8$ TeV. Upper bounds are set on the masses of hypothetical particles that arise in new-physics scenarios.

HEP

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RECEIVED: March 16, 2018

ACCEPTED: June 11, 2018

PUBLISHED: June 22, 2018

Search for high-mass resonances in dilepton final states in proton-proton collisions at $\sqrt{s} = 13$ TeV

The CMS Collaboration

ABSTRACT: A search is presented for new high-mass resonances decaying into electron or muon pairs. The search uses proton-proton collision data at a center-of-mass energy of 13 TeV collected by the CMS experiment at the LHC in 2016, corresponding to an integrated luminosity of 36 fb⁻¹. Observations are in agreement with standard model expectations. Upper limits on the product of a new resonance production cross section and branching fraction to dileptons are calculated in a model-independent manner. This permits the interpretation of the limits in models predicting a narrow dilepton or dimuon resonance. A scan of different intrinsic width hypotheses is performed. Limits are set on the masses of various hypothetical particles. For the Z_{SM} (Z_{SM}) particle, which arises in the sequential standard model (superstring-inspired model), a lower mass limit of 4.50 (3.90) TeV is set at 95% confidence level. The lightest Kaluza-Klein graviton arising in the Randall-Sundrum model of extra dimensions, with coupling parameters k/Λ_{Pl} of 0.01, 0.05, and 0.10, is excluded at 95% confidence level below 2.10, 3.65, and 4.25 TeV, respectively. In a simplified model of dark matter production via a vector or axial vector mediator, limits at 95% confidence level are obtained on the masses of the dark matter particle and its mediator.

KEYWORDS: Beyond Standard Model, Hadron-Hadron scattering (experiments), Lepton production, Particle and resonance production

ARXIV EPRINT: 1803.06292

* E-mail address: cms-publication-committee-chair@cern.ch

OPEN ACCESS, Copyright CERN, for the benefit of the CMS Collaboration. Article funded by SCOAP³.

https://doi.org/10.1007/JHEP06(2018)120

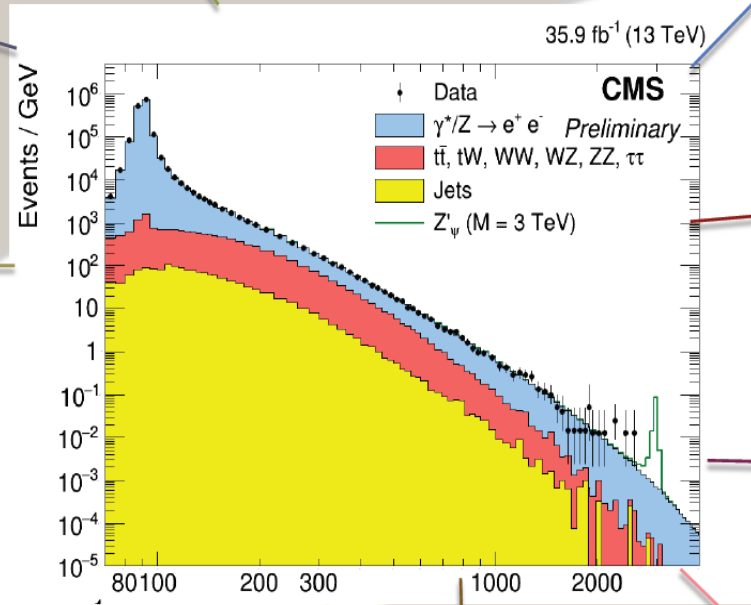
Search Strategy

Develop a simple, ET independent ID

Maintain a robust high efficient trigger
Keep low E_T threshold

Understand ID efficiency in data and MC from Z peak to high E_T

Normalize cross sections to Z peak
All ET independent effects are included



Understand mass scale and resolution

Measure and understand backgrounds

Set limit on the cross section of various new physics models

Parameterization of signal and background shapes

$$R_\sigma = \frac{\sigma(\text{pp} \rightarrow Z' + X \rightarrow \mu^+ \mu^- + X)}{\sigma(\text{pp} \rightarrow Z + X \rightarrow \mu^+ \mu^- + X)}$$

CMS INPP contributions/responsibilities

- NNLO corrections and theory uncertainties for the DY background.
- Detailed study on the impact of the resonance width and interference
- Limits setting and significance estimation at 8 TeV searches
- Energy corrections for non-responding ECAL crystals
- Editor of 'Z' publications (most recent one : **JHEP 1806 (2018) 120**).

Available on the CMS information server CMS AN-11-268

CMS Analysis Note

The content of this note is intended for CMS internal use and distribution only

2013/12/20

Development of algorithms for the energy recovery of problematic ECAL channels.

S. Kesisoglou, V. Giakoumopoulou, G. Daskalakis
Institute of Nuclear & Particle

Available on the CMS information server CMS AN AN-12-348

CMS Analysis Note

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2013/04/30

The energy of electrons and electromagnetic calorimeter that the readout electronics energy resolution and decrease of this note is to document remedy such problems by the energy deposits in their

PDF Uncertainties for Z' searches at 8 TeV

Available on the CMS information server CMS AN-16-053

¹ Institute of Nuclear

CMS Draft Analysis Note

The content of this note is intended for CMS internal use and distribution only

2018/01/31
Head Id: 375684
Archive Id: 443475M
Archive Date: 2016/12/02
Archive Tag: trunk

A full study at NLO and NNLO in QCD on the PDF uncertainties for the DY cross sections as well as the normalized DY cross sections to the Z' peak is presented at 13 TeV. The cross sections were obtained with FEWZ3 (FEWZ 3.1.1b2) by using the PDF4LHC15 set of parton distribution functions. As a cross check three more individual PDF sets (MSTW2008, CT10Q2, NNPDF21) were used to calculate the PDF uncertainties and make comparisons between the different predictions. Possible correlations between the cross section PDF uncertainties were taken into account in the calculation of the cross section ratios. The relative uncertainty at NNLO for the normalized cross section at 250 GeV is around 1% while it increases to 7% for normalized cross sections around 4 TeV.

PDF Uncertainties for Z' searches at 13 TeV with Electron Pair or Muon Pair Final States

D. Bourilkov¹ and G. Daskalakis²

¹ University of Florida, Gainesville, Florida, USA
² Institute of Nuclear & Particle Physics, NCSR "Demokritos", Aghia Paraskevi, Greece

Abstract

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This box is only visible in draft mode. Please make sure the values below make sense.
PDFAuthor: Georgios Daskalakis, Dimitri Bourilkov
PDFTitle: PDF Uncertainties for Z' searches at 13 TeV with Electron Pair or Muon Pair Final States
PDFSubject: CMS
PDFKeywords: CMS, physics, software, computing
Please also verify that the abstract does not use any user defined symbols

Z' Stats Meeting

Wednesday 22 Apr 2015, 14:00 → 17:00 Europe/Zurich

40/R-A10 (CERN)

Georgios Daskalakis (Nat. Cent. for Sci. Res. Demokritos (GR))

Description: vidyo pin 3141

Slides

14:00	→ 14:10	Introduction
14:10	→ 15:00	Z' Limit Setting Review Speaker: Viktoria Athina Giakoumopoulou (Nat. Cent. for Sci. Res. Demokritos (GR)) Slides
15:00	→ 16:00	Narrow Width Approximation Review Speaker: Claire Shepherd-Themistocleous (STFC - Rutherford Appleton Lab. (GB)) Slides
16:00	→ 16:30	DY k-factors and higher order effects Speakers: Dr Dimitri Bourilkov (University of Florida (US)), Dimitri Bourilkov (U) Slides
16:30	→ 16:50	Z' Discovery tools Speaker: Sam James Harper (STFC - Rutherford Appleton Lab. (GB)) Slides



PUBLISHED FOR SISSA BY SPRINGER

RECEIVED: March 16, 2018
ACCEPTED: June 11, 2018
PUBLISHED: June 22, 2018

Search for high-mass resonances in dilepton final states in proton-proton collisions at $\sqrt{s} = 13$ TeV



The CMS collaboration

E-mail: cms-publication-committee-chair@cern.ch

ABSTRACT: A search is presented for new high-mass resonances decaying into electron or muon pairs. The search uses proton-proton collision data at a centre-of-mass energy of 13 TeV collected by the CMS experiment at the LHC in 2016, corresponding to an integrated luminosity of 36 fb^{-1} . Observations are in agreement with standard model expectations. Upper limits on the product of a new resonance production cross section and branching fraction to dileptons are calculated in a model-independent manner. This

JHEP06(2018)120

CMS INPP contributions/responsibilities

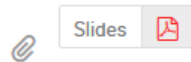
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Description vidyo pin 3141



Victoria Giakoumopoulou

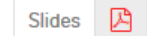
Outline



14:00 → 14:10 Introduction

14:10 → 15:00 Z' Limit Setting Review

Speaker: Viktoria Athina Giakoumopoulou (Nat. Cent. for Sci. Res. Demokritos (GR))



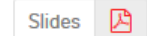
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16:00 → 16:30 DY k-factors and higher order effects

Speakers: Dr Dimitri Bourilkov (University of Florida (US)), Dimitri Bourilkov (U)



16:30 → 16:50 Z' Discovery tools

Speaker: Sam James Harper (STFC - Rutherford Appleton Lab. (GB))



- modeling data
 - signal pdfs and its parameters
 - background pdfs and its parameters
 - the data
- the likelihood function
 - the parameter of interest POI
 - combining channels
 - systematic uncertainties
 - the extended form of the likelihood
- the configuration file
- limit calculations
 - the procedure
 - the code
 - timing
 - stability tests
- presence of signal (???)
- Run I & Run II combination (???)

NNLO corrections and theory uncertainties for the DY background

Available on the CMS information server

CMS AN AN-12-348

CMS Analysis Note

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2013/04/30

PDF Uncertainties for Z' searches at 8 TeV

D.

Available on the CMS information server

CMS AN-16-053

¹University
²Institute of Nuclear & Parti

CMS Draft Analysis Note

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2018/01/31
Head Id: 375684
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PDFTitle: PDF Uncertainties for Z' searches at 13 TeV with Electron Pair or Muon Pair Final States
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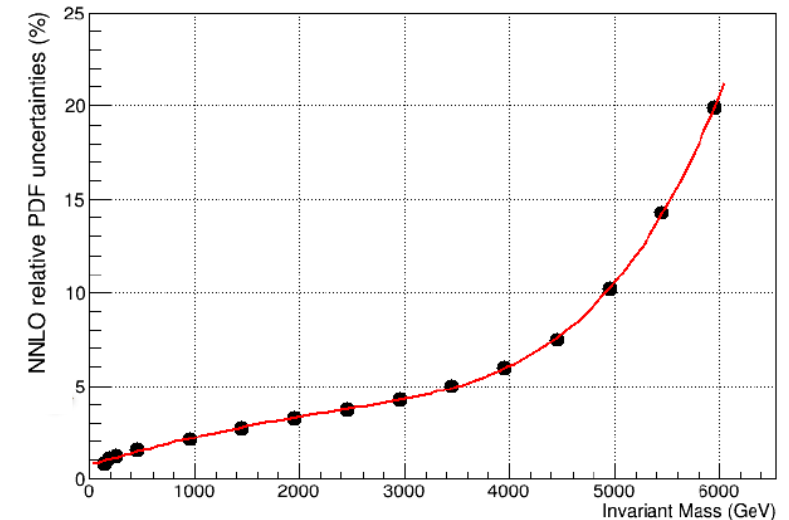
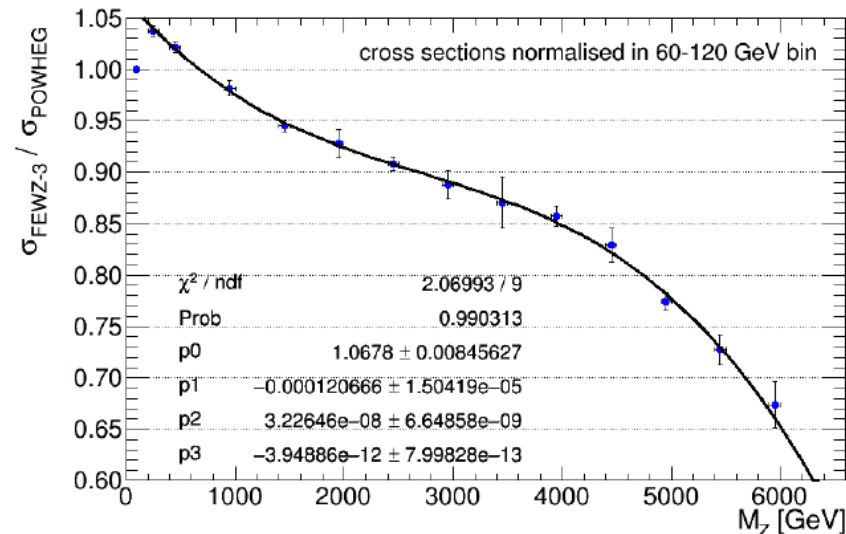
PDF uncertainties for a) DY cross sections b) the normalized DY cross sections to the Z peak, at 13 TeV, at NLO and NNLO in QCD

Fully Exclusive W and Z package

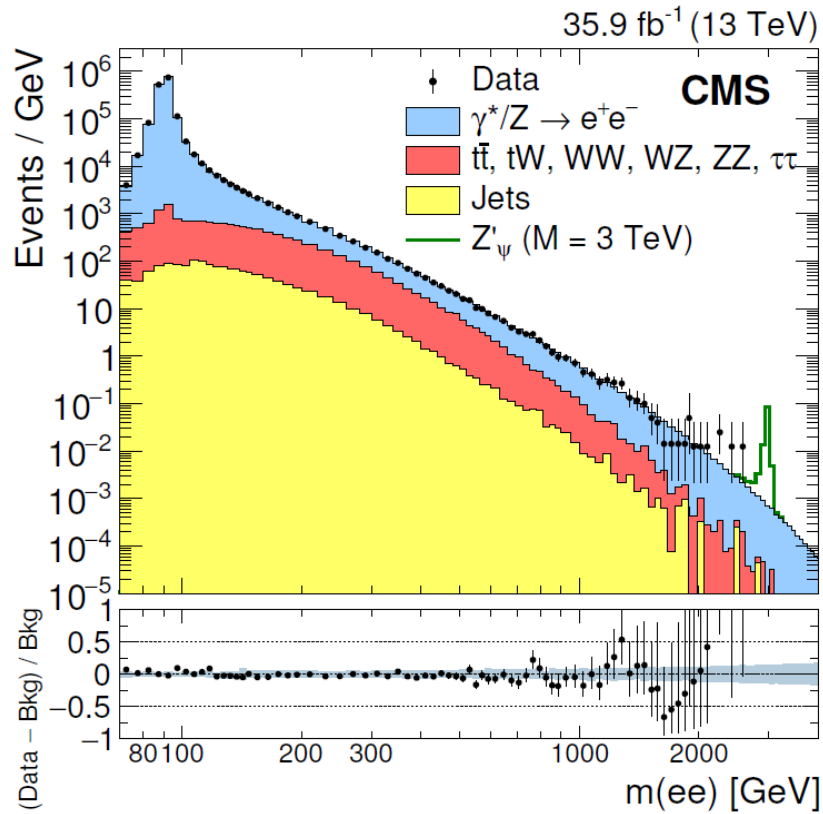
FEWZ 3.1.b2 by using the LUXqed+PDF4LHC15 set of PDFs
LUXqed (photon parton distribution function inside the proton)

Cross check with three more individual

PDF sets : MSTW2008, CTEQ12, NNPDF21

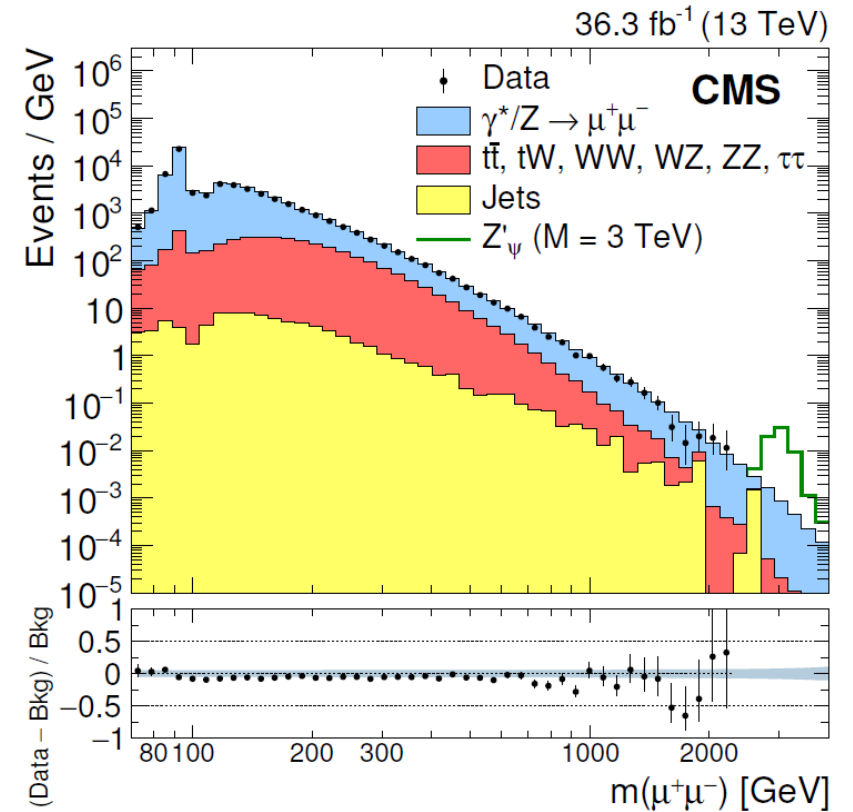


distributions after selection



Data samples:
 36 fb^{-1}
 (13 TeV ; full **2016** dataset)

The full **Run-II** dataset
 $\sim 140 \text{ fb}^{-1}$ is now analyzed.



Results:

No evidence for a heavy narrow resonance is observed.

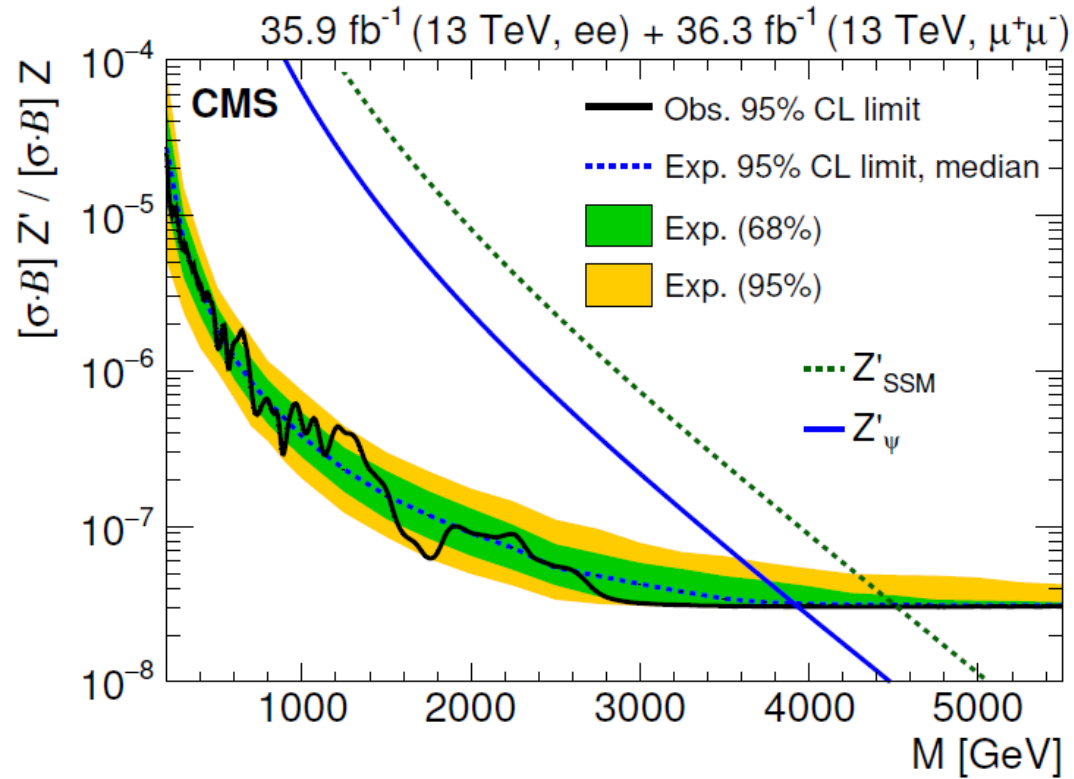
Selection:

Di-electron trigger, offline $p_T > 35 \text{ GeV}$, $|\eta| < 2.5$ in ECAL fiducial, isolation
 Single muon trigger, offline $p_T > 53 \text{ GeV}$, $|\eta| < 2.1$, isolation

Backgrounds:

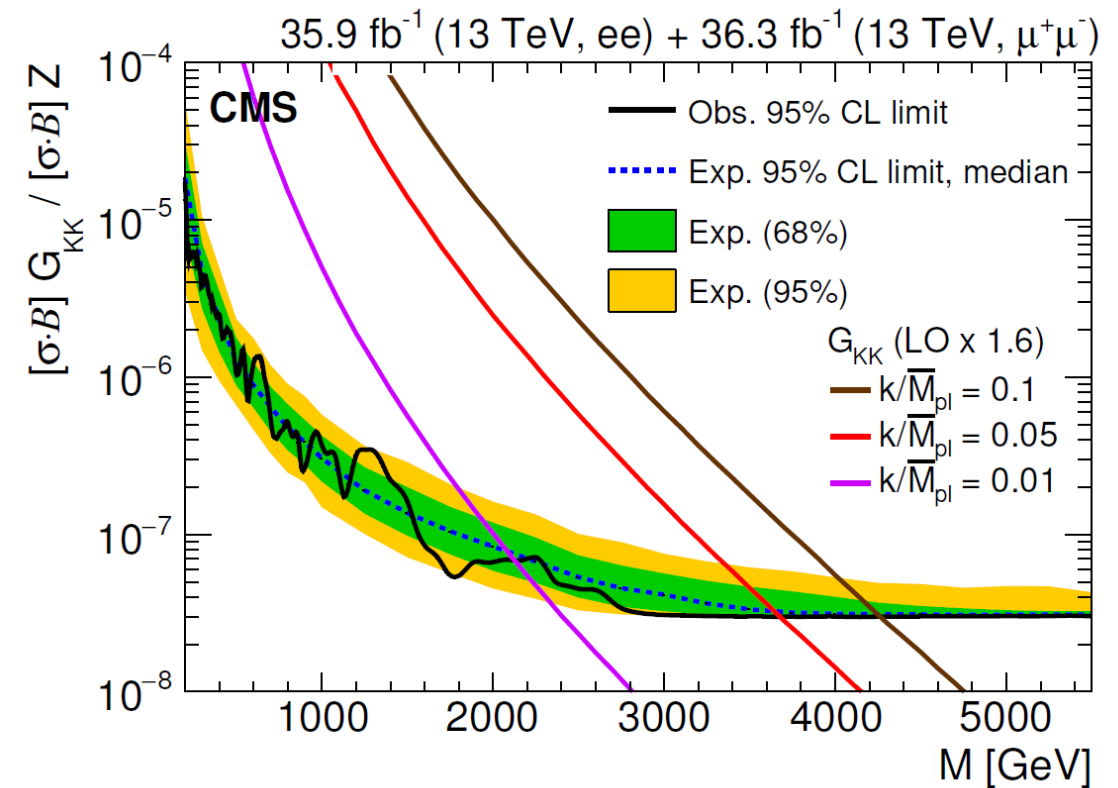
DY, tt, VV, multijets

Results



Spin-1

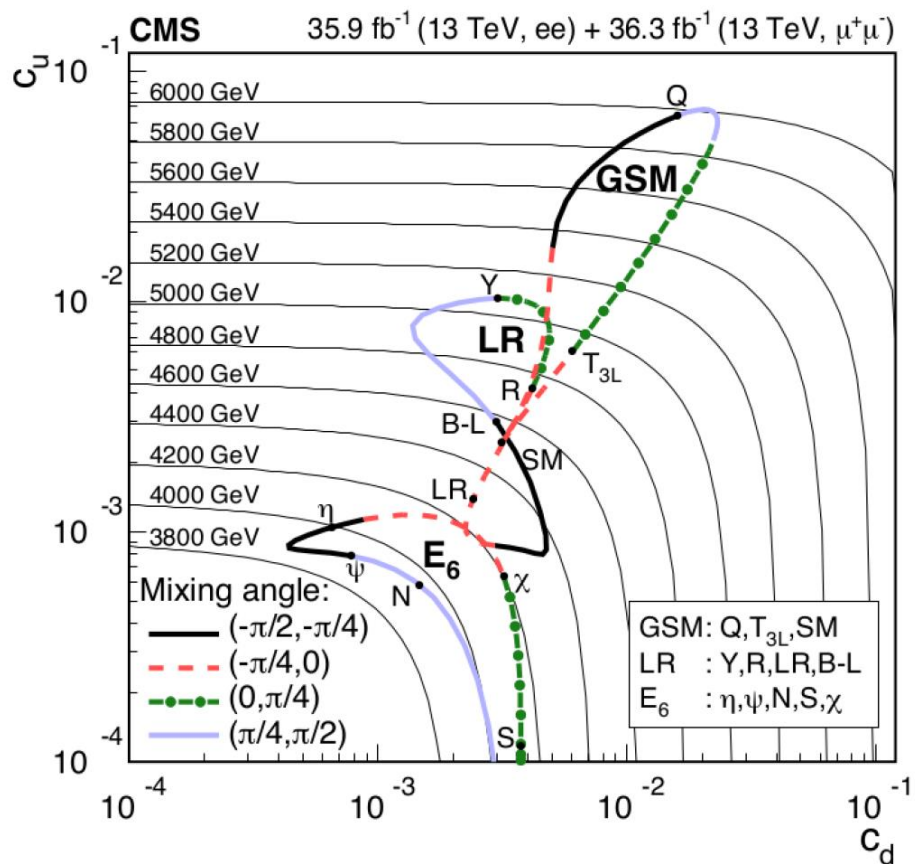
Channel	Z'_{SSM}		Z'_ψ	
	Obs. [TeV]	Exp. [TeV]	Obs. [TeV]	Exp. [TeV]
ee	4.10	4.10	3.45	3.45
$\mu^+\mu^-$	4.25	4.25	3.70	3.70
ee + $\mu^+\mu^-$	4.50	4.50	3.90	3.90



Spin-2

Channel	$k/\bar{M}_{Pl} = 0.01$		$k/\bar{M}_{Pl} = 0.05$		$k/\bar{M}_{Pl} = 0.1$	
	Obs. [TeV]	Exp. [TeV]	Obs. [TeV]	Exp. [TeV]	Obs. [TeV]	Exp. [TeV]
ee	1.85	1.85	3.30	3.30	3.90	3.90
$\mu^+\mu^-$	2.05	2.00	3.50	3.50	4.05	4.05
ee + $\mu^+\mu^-$	2.10	2.05	3.65	3.60	4.25	4.25

Results on Generalized Models



$U'(1)$ model	Mixing angle	$\mathcal{B}(\ell^+\ell^-)$	c_u	c_d	c_u/c_d	$\Gamma_{Z'}/M_{Z'}$
E ₆						
U(1) _χ	0	0.061	6.46×10^{-4}	3.23×10^{-3}	0.20	0.0117
U(1) _ψ	0.5π	0.044	7.90×10^{-4}	7.90×10^{-4}	1.00	0.0053
U(1) _η	-0.29π	0.037	1.05×10^{-3}	6.59×10^{-4}	1.59	0.0064
U(1) _S	0.129π	0.066	1.18×10^{-4}	3.79×10^{-3}	0.31	0.0117
U(1) _N	0.42π	0.056	5.94×10^{-4}	1.48×10^{-3}	0.40	0.0064
LR						
U(1) _R	0	0.048	4.21×10^{-3}	4.21×10^{-3}	1.00	0.0247
U(1) _{B-L}	0.5π	0.154	3.02×10^{-3}	3.02×10^{-3}	1.00	0.0150
U(1) _{LR}	-0.128π	0.025	1.39×10^{-3}	2.44×10^{-3}	0.57	0.0207
U(1) _Y	0.25π	0.125	1.04×10^{-2}	3.07×10^{-3}	3.39	0.0235
GSM						
U(1) _{SM}	-0.072π	0.031	2.43×10^{-3}	3.13×10^{-3}	0.78	0.0297
U(1) _{T3L}	0	0.042	6.02×10^{-3}	6.02×10^{-3}	1.00	0.0450
U(1) _Q	0.5π	0.125	6.42×10^{-2}	1.60×10^{-2}	4.01	0.1225

Table 1. Various benchmark models with their corresponding mixing angles, their branching fraction (\mathcal{B}) to dileptons, the c_u and c_d parameter values and their ratio, and the width to mass ratio of the associated Z' boson.

Models:

- E₆** : GUTs inspired
- LR** : left-right symmetric extensions of SM
- GSM** : Sequential SM, SM-like couplings

$$\sigma(Z') \sim C_u W_u + C_d W_d \quad \begin{array}{l} \text{Phys. Rev. D } \mathbf{70} \text{ (2004) 093009} \\ \text{Phys. Rev. D } \mathbf{83} \text{ (2011) 075012} \end{array}$$

c_u (c_d) : information about the model-dependent Z' boson couplings to the up-type (down-type) quarks,
 w_u (w_d): depends on the up-type (down-type) quark PDFs

EXOTICA Workshop 2018

 **CMS EXO WORKHOP 2018**
1st- 3rd November 2018
National Kapodistrian University of Athens (NKUA) Greece 

Local Organizing Committee
Charis-Kleio Koraka, NKUA
Niki Saoulidou, NKUA
Georgios Anagnostou, NCSR Demokritos
Georgios Daskalakis, NCSR Demokritos
Kostas Kousouris, NTUA

Scientific Organizing Committee
Oliver Buchmuller, Imperial College, UK
Ivan Mikulec, HEPHY, Austria
Adish Vartak, CERN



Email /contact : cms-exo-athens-2018@cern.ch
Indico Page : <https://indico.cern.ch/event/733957/>



Ongoing Projects

Ongoing Projects (2019-2020)

EXO

Z' Searches *final paper*

data : 2016-2017-2018
13 TeV , 140 fb⁻¹

Analysis is finished and approved few days ago.

There is a long paper (legacy) to be written
Work not started yet.

CMS PAS EXO-19-019

DRAFT CMS Physics Analysis Summary

The content of this note is intended for CMS internal use and distribution only

2019/07/12
Archive Hash: 363b55d-D
Archive Date: 2019/07/12

Search for a narrow resonance in high-mass dilepton final states in proton-proton collisions using 140 fb⁻¹ of data at $\sqrt{s} = 13$ TeV

The CMS Collaboration

Abstract

A search for physics beyond the standard model is presented using electron or muon pairs with high invariant mass. A data set of proton-proton collisions collected by the CMS experiment at the LHC at $\sqrt{s} = 13$ TeV recorded in years 2016 to 2018 and corresponding to a total integrated luminosity of up to 140 fb⁻¹ is analyzed. No significant deviation is observed with respect to the expectation from the standard model backgrounds. Upper limits are set on the ratio of the production cross section times branching ratio of a new narrow dilepton resonance to that of the Z boson and converted into lower limits on the masses of various hypothetical particles. A Z'_{SSM} (Z'_p) particle, arising in the sequential standard model (superstring-inspired model) is excluded below a mass of 5.15 (4.55) TeV at 95% confidence level.

This box is only visible in draft mode. Please make sure the values below make sense.

PDFAuthor: Laurent Thomas and Jan-Frederik Schulte for Z' to ee and mumu teams
PDFTitle: Search for new physics in high mass dilepton final state
PDFSubject: CMS
PDFKeywords: CMS, physics, dileptons, resonance

Please also verify that the abstract does not use any user defined symbols

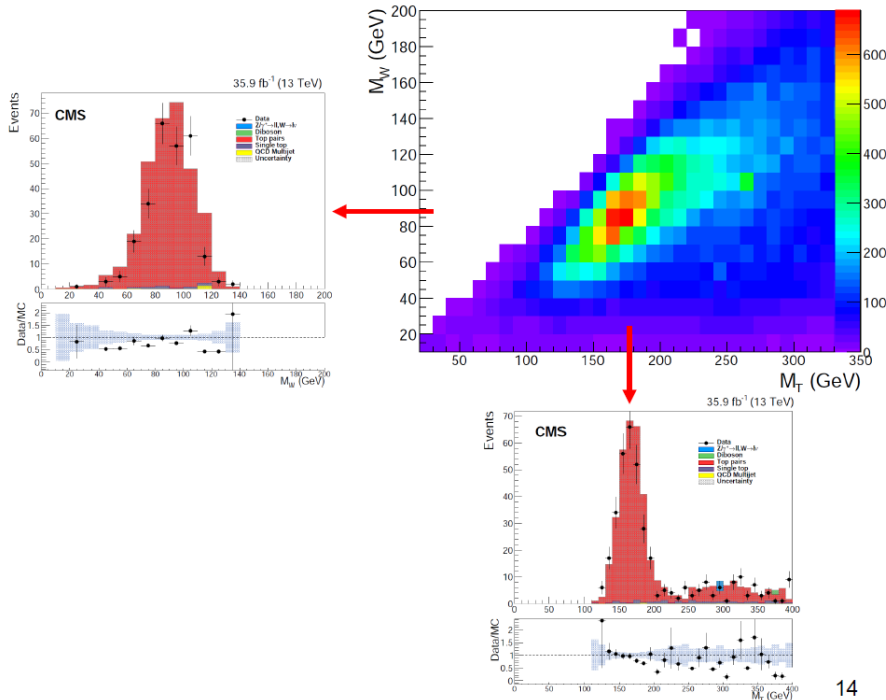
Ongoing Projects (2019-2020)

T'T' Searches

B2G

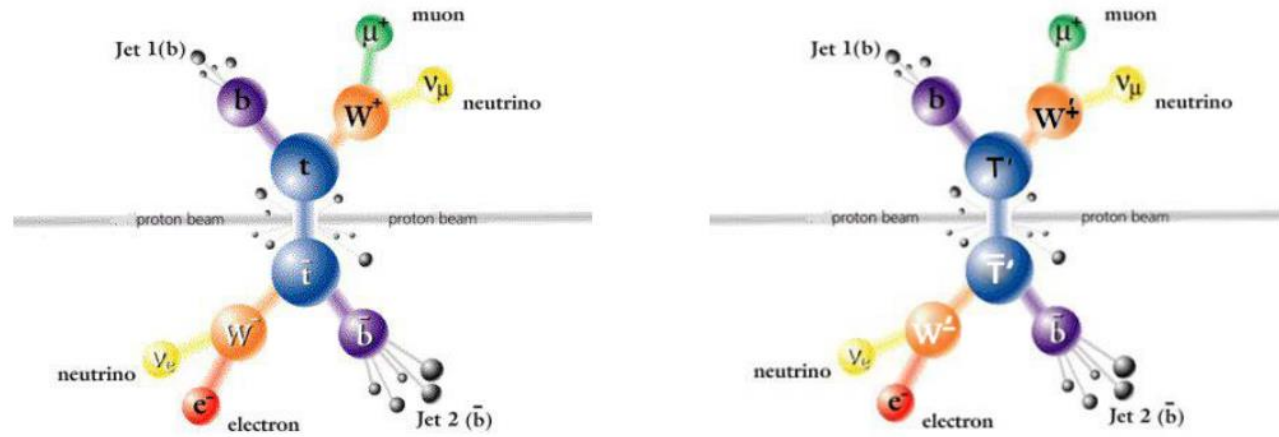
data : 2016-2017-2018
13 TeV , 140 fb⁻¹

Data 2016 – control region



14

2-Dimensional mass search



generic topology with 2 unknown particles

Searching **simultaneously** for both a heavy top partner T' and a new gauge boson W' .

Many BSM models predict both for cancelations in M_{Higgs} – e.g Little Higgs – susy, extra dimensions etc

Method is currently documented in a paper using a Delphes production of 200M events.

The team :
Georgios Anagnostou , GD, (student ?)

Ongoing Projects (2019-2020)

HIGGS

ttH, $H \rightarrow b \bar{b}$

data : 2016-2017-2018
13 TeV , 140 fb⁻¹

The team :

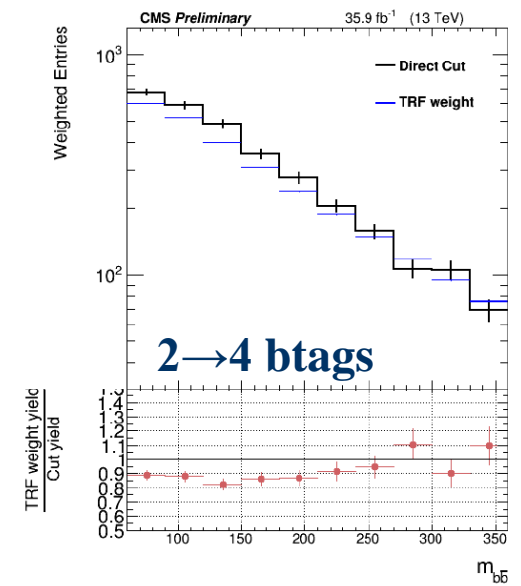
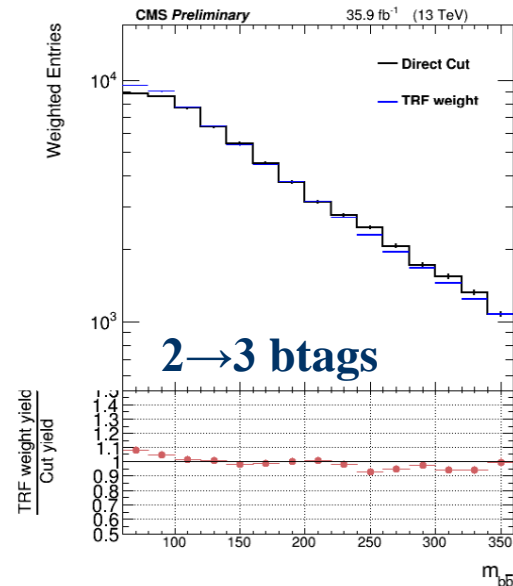
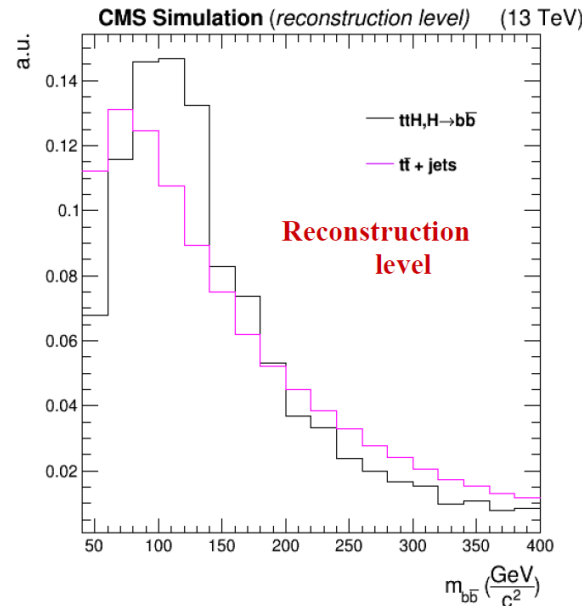
Niki Saoulidou,
Georgios Anagnostou , GD,
Charis Kleio Koraka (student)

We have started with
presentations in the relevant
Higgs working group

The idea : Study of the di-leptonic ttH(bb-bar) channel reconstructing the Higgs mass and using a data-driven background prediction method

The mass reconstruction is performed by simultaneously solving analytically the ttH dileptonic decay system while scanning the M_t vs M_W mass plane searching for solutions.

Data-driven background: From events with exactly 2 b-tagged jets (ttbar enriched + Higgs contamination small) predict the shape and normalization of the $m_{b\bar{b}}$ distribution of events with exactly 3 / 4 b-tagged jets by applying probability weights.



Ongoing Projects (2019-2020)

TOP

W helicities from $t\bar{t}$ events

data : 2016 (full Run-II)
13 TeV , 36 (140) fb⁻¹

The team :

M. Soares, J. Brochero (postdoc),
G. Anagnostou, GD,
A. Stakia (student)

Analysis quite advanced.
Shown at TOP meetings.

Now:

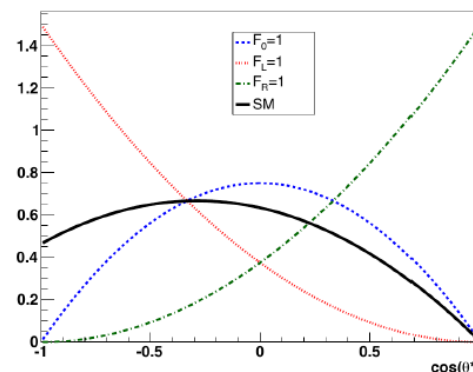
- Try to estimate systematics for 2016 data
- Process 2017 / 2018 datasets

Motivation:

- The measurement is sensitive to the Wtb vertex structure;
new physics from anomalous Wtb couplings
- New methodology** to improve systematic uncertainties w.r.t. **7 & 8 TeV** analyses

Previous Measurements

- Based on $\cos(\theta^*)$ → Strong discriminant power



- $\cos(\theta^*)$ needs the reconstruction of the top process ($t\bar{t}$ or single top)
- $t\bar{t}$ kinematic fit introduces a dependency of top mass.

$\cos(\theta^*)$: in the t -quark rest frame, the angle between the **down-type fermion momentum in the W rest frame** and the **W momentum in the top-quark rest frame**

$$\frac{1}{\Gamma} \frac{d\Gamma}{d\cos\theta^*} = \frac{3}{8} (1 - \cos\theta^*)^2 F_L + \frac{3}{8} (1 + \cos\theta^*)^2 F_R + \frac{3}{4} \sin^2\theta^* F_0$$

in SM:

$$F_0=0.6902$$

$$F_L=0.3089$$

$$F_R=0.0009$$

- We propose a different approach to extract the W-helicity

- $\Delta\Phi(\ell, \text{jet})$
- $M_{\ell b}$

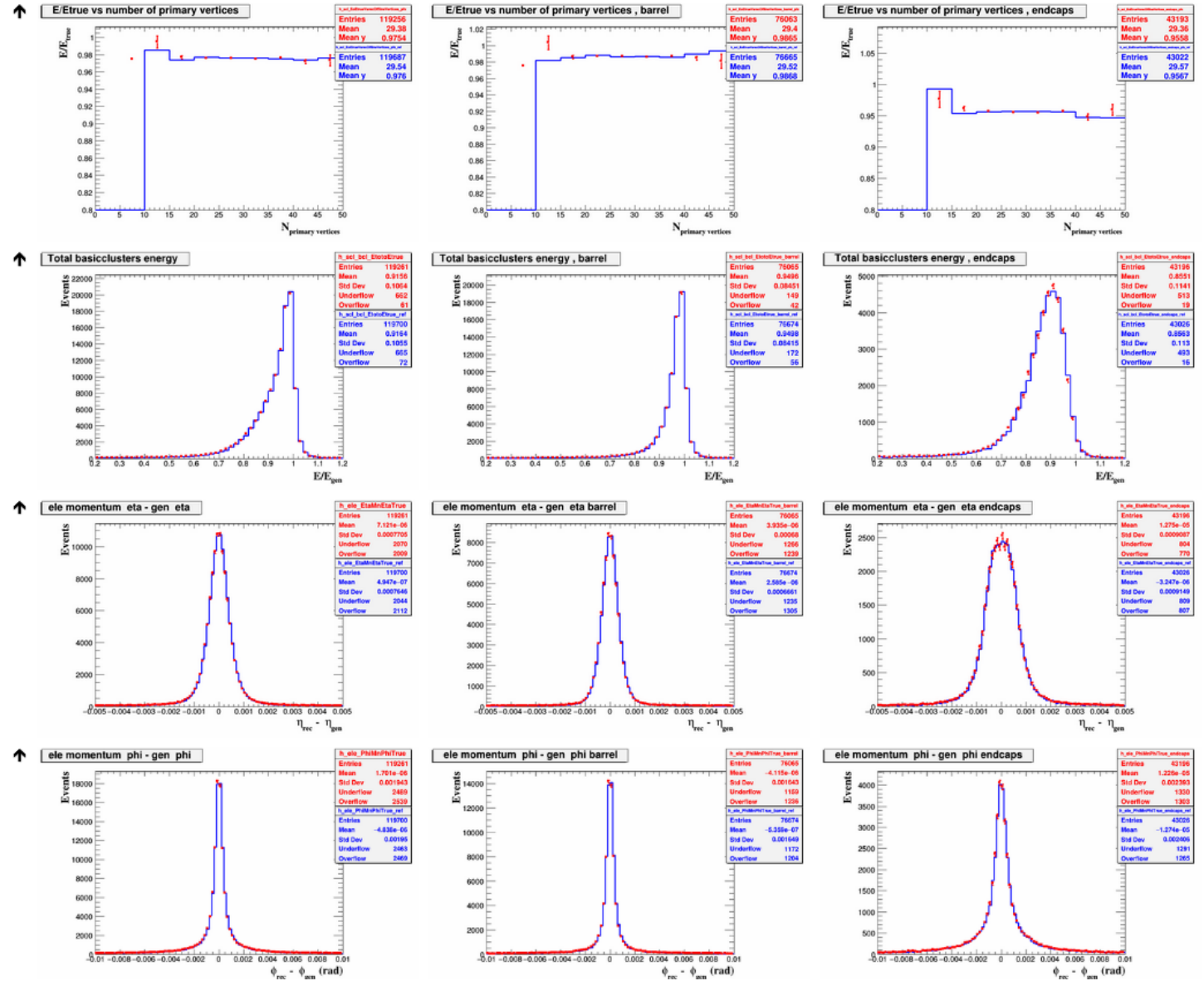
Analysis Review Committees in CMS (ARCs)

1. CMS Collaboration, “*Search for dark matter in $H(bb)+MET$ final state (full 2016 dataset)*”, **CMS EXO-16-050**
2. CMS Collaboration, “*Search for dark matter in $Z(ll)+MET$ final state using the 2016 dataset*”, **CMS EXO-16-038**
3. CMS Collaboration, “*Search for dark matter, extra dimensions, and unparticles in $Z(ll)$ MET final state at 13 TeV*”, **CMS EXO-16-010**
4. CMS Collaboration, “*Photon-jet fragmentation function in PbPb*”, **CMS HIN-16-014**
5. CMS Collaboration, “*Inclusive W/Z cross section at 13 TeV*”, **CMS SMP-15-004**
6. CMS Collaboration, “*Study of Z boson production in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV*”, **CMS HIN-15-002**
7. CMS Collaboration, “*Drell-Yan differential cross section measurement at 8 TeV*”, **CMS SMP-14-003**
8. CMS Collaboration, “*Study of W boson production in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV*”, **CMS HIN-13-007**
9. CMS Collaboration, “*Measurement of the electron charge asymmetry in inclusive W production in pp collisions at $\sqrt{s} = 7$ TeV*”, **CMS SMP-12-001**
10. CMS Collaboration, “*Search for the associated production of unparticles and a Z boson in pp collisions at $\sqrt{s} = 7$ TeV in the final state containing muons and missing transverse energy*”, **CMS EXO-11-043**
11. CMS Collaboration, “*A Search for Resonances in Semileptonic Top Pair Production at $\sqrt{s} = 7$ TeV*”, **CMS TOP-11-009**
12. CMS Collaboration, “*Electromagnetic physics objects commissioning with first LHC data*”, **CMS EGM-10-001**
13. Alemany R. et. al. “*Discovery potential for Universal Extra Dimensions signal with four leptons in the final state.*”, **CMS NOTE AN 2006/008.**
14. Clerbaux B. et. al. “*TeV electron and photon saturation studies*”, **CMS NOTE 2006/004.**
15. Collard C., Lemaire Cl., “*Search with the CMS Detector for Randall-Sundrum Excitations of Gravitons Decaying Into Electron Pairs*”, **CMS NOTE 2004/024.** Also published in **Eur. Phys. J. C40 (2005) 15.**
16. Voutilainen M., Lassila-Perini K., “*Jet Rejection for Electrons and Photons Using Track Isolation*”, **CMS NOTE 2004/002.**

Institutional Reviews in CMS

1. CMS Collaboration, “Search for Heavy Majorana Neutrino in $2l2j$ final state”, **CMS EXO-17-028**
2. CMS Collaboration, “Search for the J/Ψ plus gamma rare decay of Z and Higgs bosons with 13 TeV data”, **CMS SMP-17-012**
3. CMS Collaboration, “Search for VV resonances in the all-hadronic final state”, **CMS B2G-17-001**
4. CMS Collaboration, “Search for high-mass resonances in dijet final state (full 2016 dataset)”, **CMS EXO-16-056**
5. CMS Collaboration, “Search for SUSY using the razor variables in 0L and 1L events at $\sqrt{s} = 13$ TeV”, **CMS SUS-16-017**
6. CMS Collaboration, “Measurement of the top pair-production in association with a W or Z boson in pp collisions at 13 TeV”, **CMS TOP-16-016**
7. CMS Collaboration, “Top quark pair differential cross sections at particle level in the dilepton channel at 13 TeV”, **CMS TOP-16-007**
8. CMS Collaboration, “Measurement of the $\Lambda(b)$ polarization and the angular parameters of the $\Lambda(b)$ to $J/\psi \Lambda^0$ decays in pp collisions at $\sqrt{s} = 7$ and 8 TeV”, **CMS BPH-15-002**
9. CMS Collaboration, “Matrix Element search for $t\bar{t}H$ with $H \rightarrow b\bar{b}$ ”, **CMS HIG-14-010**
10. CMS Collaboration, “Search for neutral MSSM Higgs bosons decaying to a pair of tau leptons in pp collisions”, **CMS HIG-13-021**
11. CMS Collaboration, “Heavy Neutrinos with OS+SS dileptons”, **CMS EXO-13-008**
12. CMS Collaboration, “Upsilon(nS) cross-section measurement in pp collisions at $\sqrt{s}=7\text{TeV}$ ”, **CMS BPH-12-006**

Service work (Fast Simulation)



Validation of Fast Simulation Software Releases

(260 distributions per Release)

125 Releases validated

Conferences

- 2019** **HEP-2019:** Conference on Recent Developments in High Energy Physics and Cosmology, 17-20 Apr 2019, Athens (Greece)
Talk: "Exotic searches at CMS/LHC"
- 2019** **LaThuile2019:** XXXIII Les Rencontres de Physique de la Vallée d'Aoste, 10-16 Mar 2019, La Thuile (Italy)
Talk: "Searches for heavy resonances at the LHC"
- 2016** **ICNFP2016** 5th International Conference on New Frontiers in Physics,
Talk: "TOP PHYSICS (CMS)"
- 2015** **HEP 2015:** Conference on Recent Developments in High Energy Physics and Cosmology, 15-18 Apr 2015,
Talk: "Search for physics beyond the standard model in dilepton mass spectra in proton-proton collisions at $\sqrt{s} = 8$ TeV"
- 2014** **HSSHEP 2014:** Conference on Recent Developments in High Energy Physics and Cosmology, 8-10 May 2014,
Talk: "Exotic Searches in CMS"
- 2012** **Standard Model @ LHC 2012** , Copenhagen, Denmark
Talk: "Inclusive W & Z measurements in CMS"
- 2011** **Blois2011:** 23rd Rencontres de Blois on "Particle Physics and Cosmology" , Blois, France
Talk: "Inclusive W/Z cross section and W charge asymmetry measurements at the LHC" for for both ATLAS & CMS Collaborations
CMS CR-2011/167
- 2008** **4th Conference On Physics at LHC – 2008**, Split, Croatia
Talk: "Inclusive W and Z production at LHC start-up"
Proceedings: PoS(2008LHC)041
- 2006** **CALOR 2006**, XII International Conference on Calorimetry in High Energy Physics, Chicago, Illinois, USA
Talk: "CMS ECAL Calibration Strategy."
Proceedings: American Institute of Physics (AIP)
- 2006** **Lake Louise Winter Institute Conference, 2006**, Alberta, CANADA
Talk: "Searches for the Higgs boson in CMS"
Proceedings: World Scientific
- 2004** **Meeting of the Division of Particles and Fields of the American Physical society**, APS, Riverside, California, USA
Talk: "ECAL Performance – Testbeam results."
Proceedings: International Journal of Modern Physics A20 (2005) 3823-3825
- 2004** **CALOR 2004**, XI International Conference on Calorimetry in High Energy Physics, Perugia, ITALY
Talk: "Electron and Photon reconstruction with fully simulated events in the CMS/LHC experiment."
Proceedings: "Perugia 2004, Calorimetry in Particle Physics", 355-361

Funding

1) KRIPIS (ORASY , ΟΠΣ 448332)

(May 14)

The INPP funded with the amount of **1,400,000.00 euros**

Scientific responsible of the work package EE 4.1 “Measurement of the $pp \rightarrow tTq\bar{q}$ cross section (t:top quark; T:anti-top quark)”.

Budget of EE 4.1 : **84,117 euros**

Hired for two years E. Elmalis (physicist) and Th. Diakonidis (postdoctoral associate).

2) TECHNOLOGY/THEPIS/0609(BE)/18

(Dec 11)

Budget : **137,000 euros**.

Project “Search for neutral SM & MSSM Higgs bosons in the decay channel $H/A/h \rightarrow \tau\tau$ ”. The duration of the project is 36 months.

3) Research Program “THALIS”, Project: “GENESIS@LHC” , 68/1127

(Nov 11)

Budget : **600 000 euros**

Project: “Αναζήτηση της Προέλευσης της Μάζας και Νέας Φυσικής στον Επιταχυντή LHC”

4) Estimate the lost energy of non-functioning ECAL channels

(Jan 06)

University of Cyprus

Budget: 43 000 euros

Project: “Development of a Computational Algorithm for the Dead Crystals calibration of the Electromagnetic Calorimeter in the CMS experiment”.

1) PhD Committees

- Dimitris Karasavvas (University of Athens, Greece; ongoing))
- Ariadni Antwnaki (University of Athens, Greece; 2012)
- Maria Cepeda Hermida (Universidad Complutense de Madrid, Spain; 2011)

2) Master/Diploma Committees

- Dimitris Perdikis, “Training of classification algorithms for the identification of hadronic jets in the CMS/LHC experiment”, (National Technical University of Athens, Dec 2017)
- George Bakas, “Study of differential cross section of the $t\bar{t}$ production in the CMS detector”, (National Technical University of Athens, Jan 2018)
- Dimitris Karasavvas, “A Data-Driven QCD-background approximating technique for events resulting on two jets in the final state with the CMS experiment”, (University of Athens, Nov 2017)

3) Student supervision

- Loukas Ksaplanteris (University of Patras ,Dec 2015)
practice work : “Methods for the estimation of QCD background in $t\bar{t}+N$ jets processes.”
- Marios Maroudas (University of Patras, Greece, Jan 2013)
practice work : “Theories that predict additional heavy Z' and W' bosons”.
- Aggelos Anastopoulos (University of Patras, Greece; November 2011)
undergraduate thesis work with title “Modern techniques of data analysis in the CMS/LHC experiment”.
- Antonios Agapitos (University of Athens, Greece; July 2011)
master thesis work with title “Electron charge identification studies & applications in the measurement of the background for the process $pp \rightarrow \gamma^*/Z \rightarrow e^+e^-$ ”.

1) Speaker at NCSR «DEMOKRITOS» Summer Schools

From 2007, I continuously participate at the Summer Schools organized at the NCSR “DEMOKRITOS” by presenting to the audience, in a simplified way, CERN, the LHC experiments and their role in the search for New Physics.

2) European Researchers' Night

Almost every year I participate in Researcher’s night, presenting the CMS/LHC experiment to the wide audience and explaining the high energy experiments as well as the goals of particle physics in general.

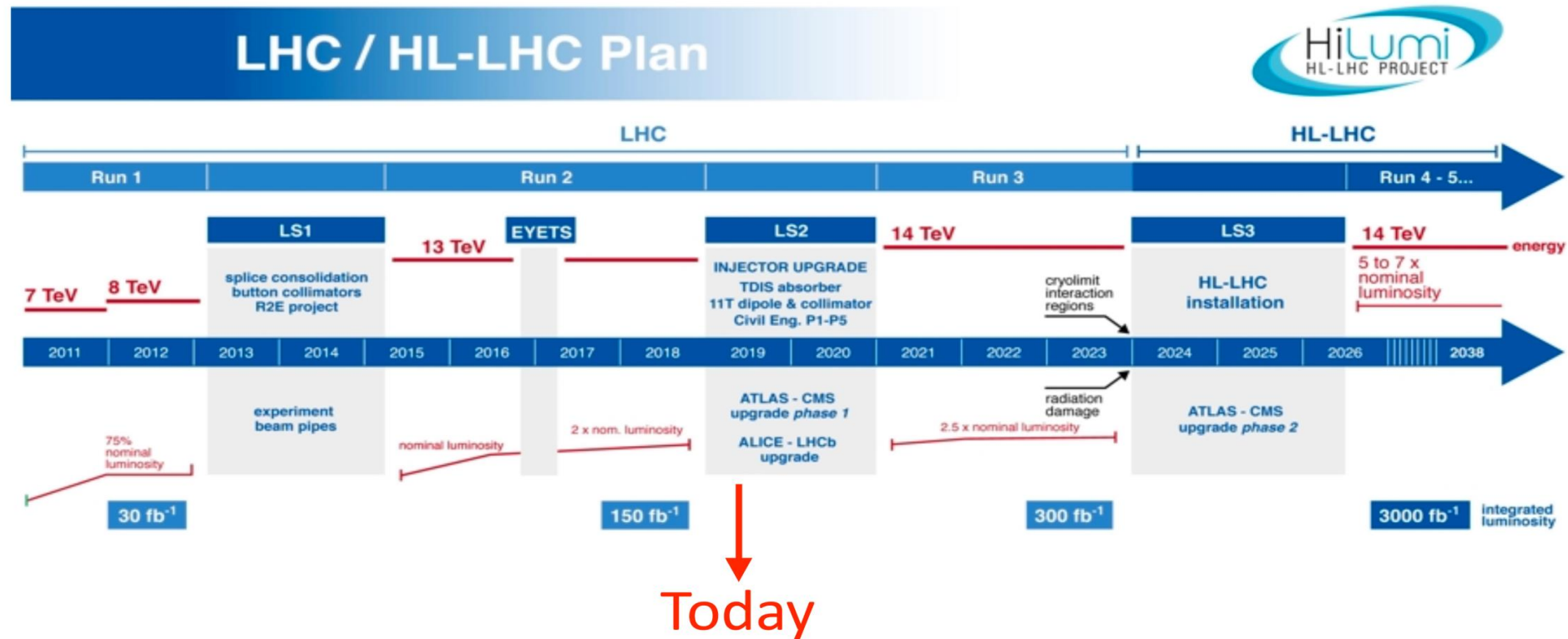
3) Invited Speaker to Summer Schools organized for students from High Schools

Every year I give around 5 talks to high Schools or to Summer Schools organized for students from high Schools, in which I explain Particle Physics, CERN, the LHC experiments and the benefits of the society from the High Energy experiments.

Future Plans

- Many beautiful results from CMS. More to come soon including the full RUN-2 luminosity.
- Observations are in agreement with standard model expectations.

Necessary to continue the broad search program for New Physics



Future Plans

I have established strong collaborations with colleagues both **inside** and **outside** Greece. Working with a strong team makes things easier and more productive.

LHC plans to provide $\sim 300 \text{ fb}^{-1}$ during 2021-2023 (x2 what we collected in Run-2)

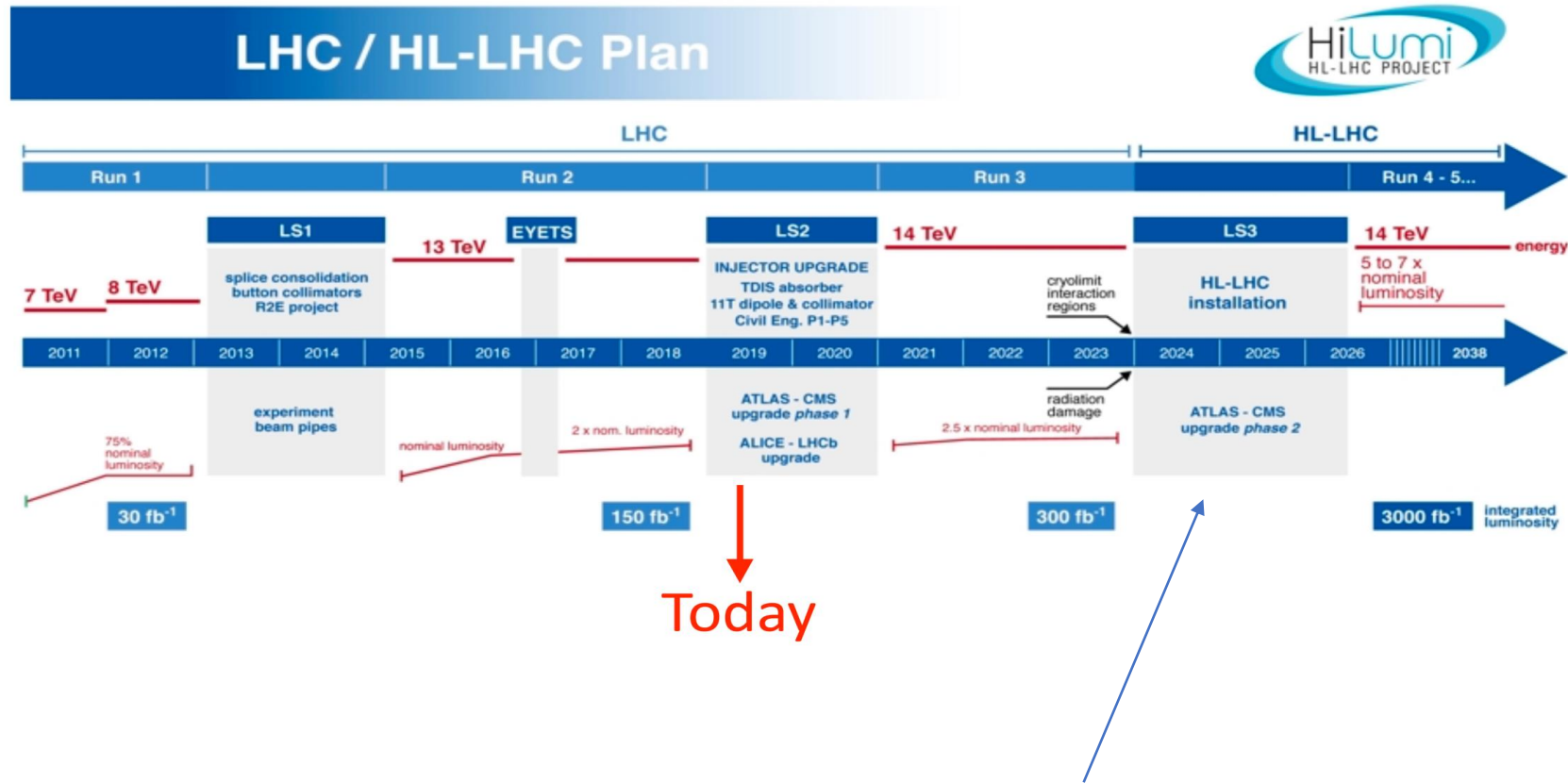
We are in a very good position to continue the analysis work both in terms of experience and personnel.

I would like to continue the efforts both in

Standard Model
&
Searches

Especially for Searches, input from our 'theorists' would be great !

Future Plans



CMS INPP has a commitment on the Phase-II Upgrade of the Tracker. I plan to be more actively engaged to Phase-II (under investigation for a project that we could fit in)

BACKUP