CMS Physics

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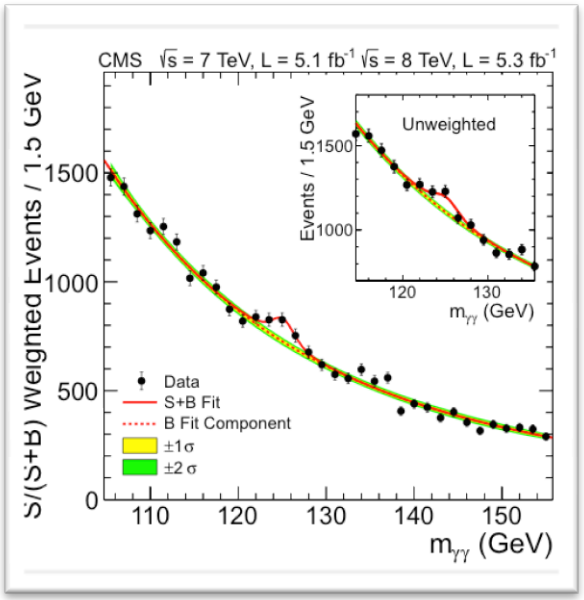
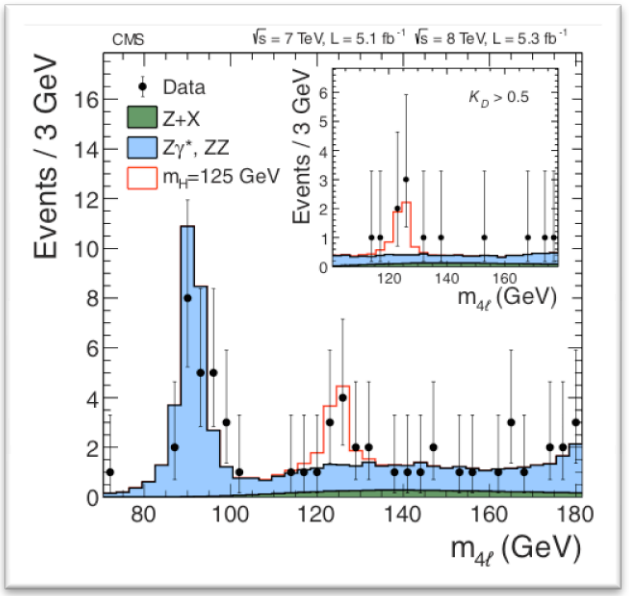
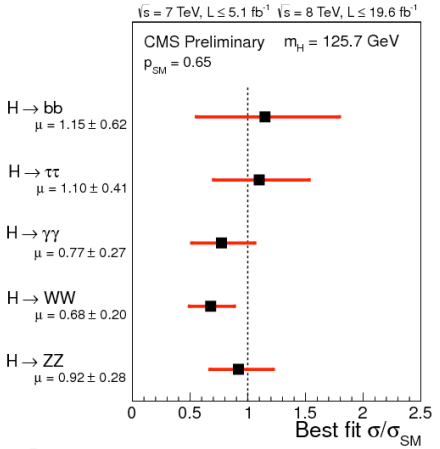
INFN - Napoli





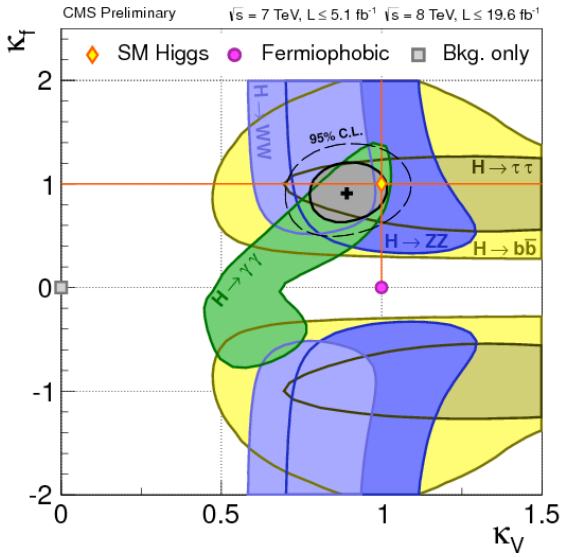
CMS Physics Achievements

- CMS results have been awarded with a Nobel prize to P. Higgs and F. Englert
  - *"for the theoretical discovery […] which recently was confirmed through the discovery […] by the ATLAS and CMS experiments at CERN's Large Hadron Collider"*



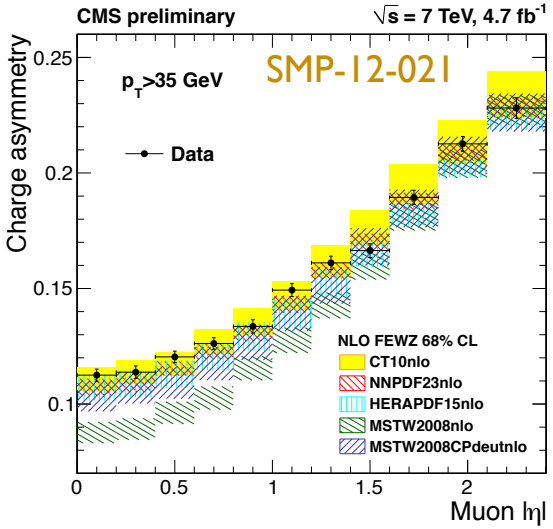
- This is the –*so far*– the most important of the many results produced by CMS throughout its first years of running

- INFN, including Naples, gave a great contribution to the experiment and to this discovery



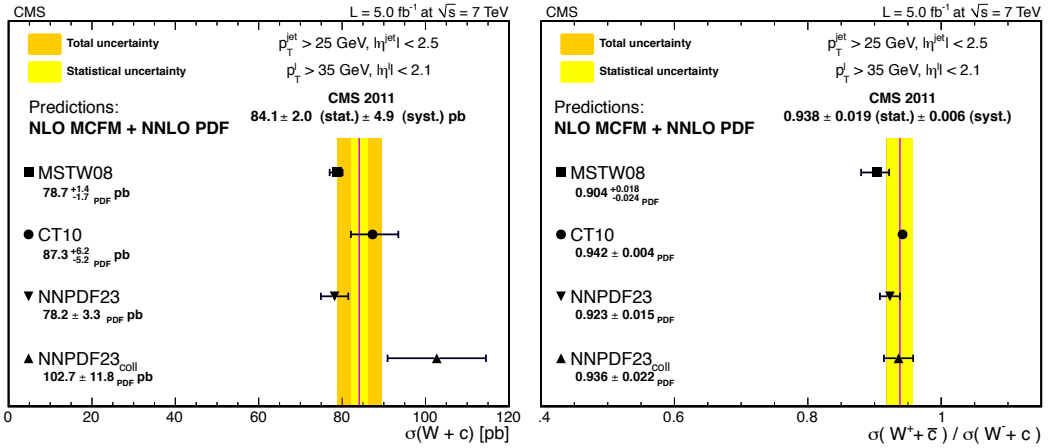
Standard Model

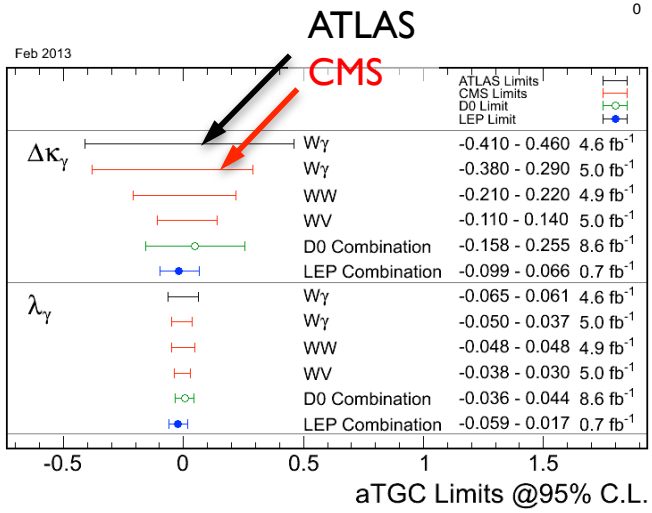
- Constraints on PDF from SM measurement can improve the knowledge of Higgs and other processes



- Z+b(b), W+bb, W+c measured: probes of sea quark PDF and background to searches
- Stringent limits set to anomalous couplings from multiboson final states

SMP-12-002

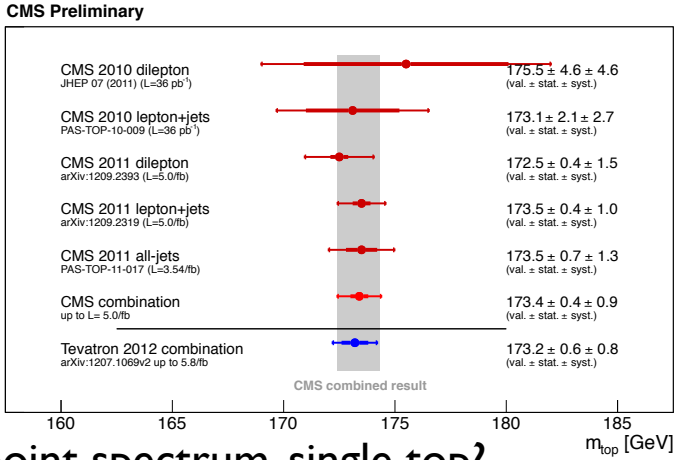


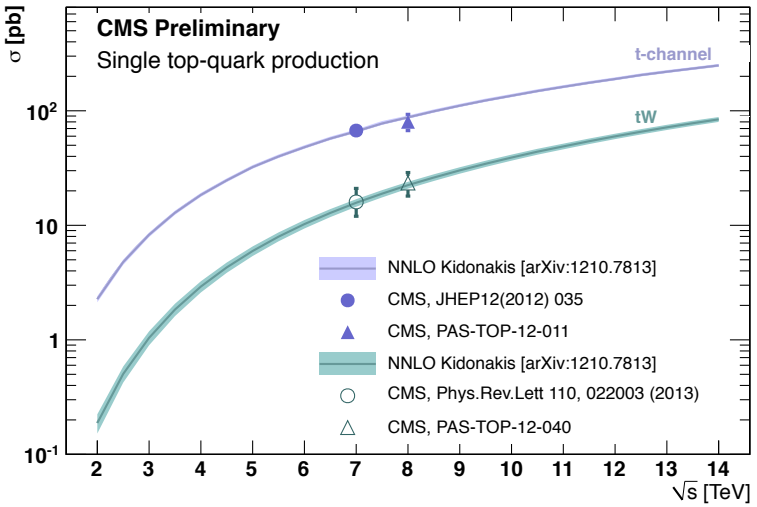


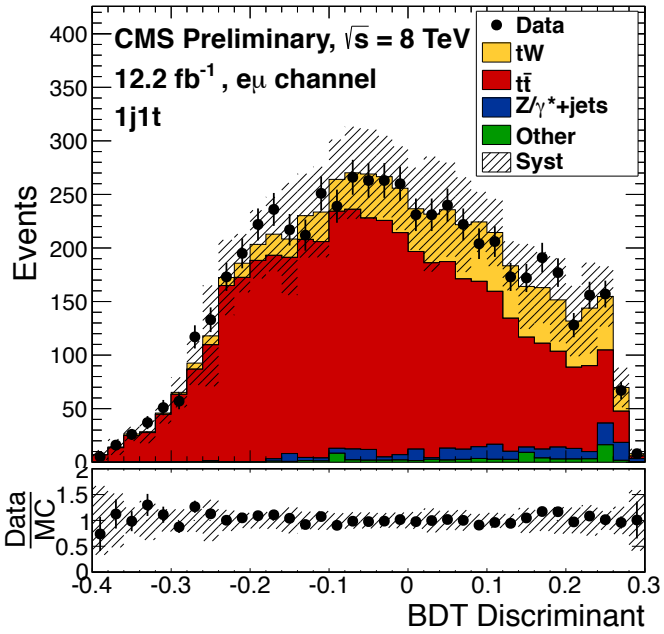
- Higgs and other measurements would benefit of a better knowledge of gluon PDF
- Precision physics program at LHC is fully part of a wider comprehension of the Standard Model and search for possible deviations

Top physics

- Top-quark mass measurements reached Tevatron precision
  - Complementary mass measurements could further reduce the uncertainty: endpoint spectrum, single top?
- Differential studies are possible thanks to the large available data sample (very good generator description found so far)
- Access to rare channels permits to probe new physics in the top sector. E.g.: observation of tW (TOP-12-040)
- CMS has better precision compared to ATLAS in most of the cases

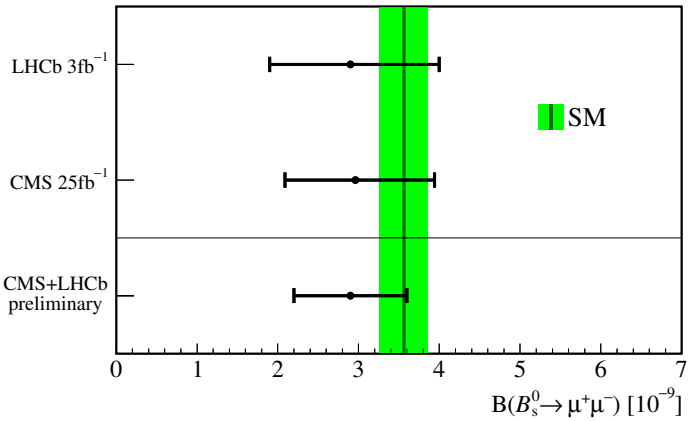


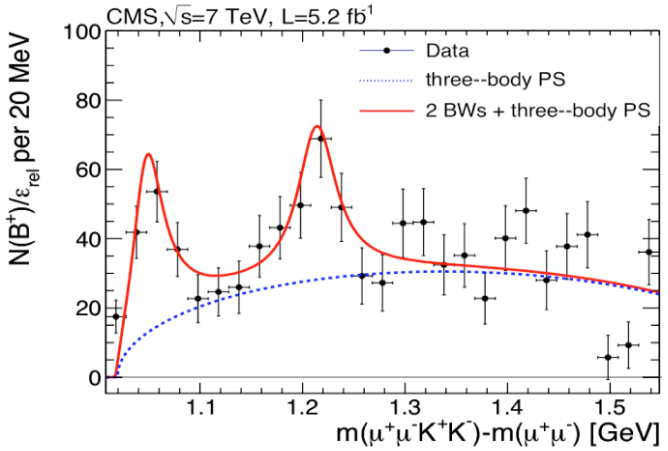




B Physics

- $B(B_s \rightarrow \mu\mu)$ result competitive with LHCb (BPH-13-004)
  - Combination with LHCb approved (BPH-13-007)
  - Run-II higher luminosity can bring further improvement, but trigger and reconstruction should be adequate
- CMS found a new peaking structures in the $J/\psi\ \varphi$ mass from $B^+ \rightarrow J/\psi\ \varphi\ K^+$ (BPH-11-026) already observed at CDF at slightly different mass
  - More studies are needed to confirm the nature of those structures
- LHCb presented a 3.7σ angular distribution anomaly in $B \rightarrow K^* \mu\mu$
  - Work in progress in CMS





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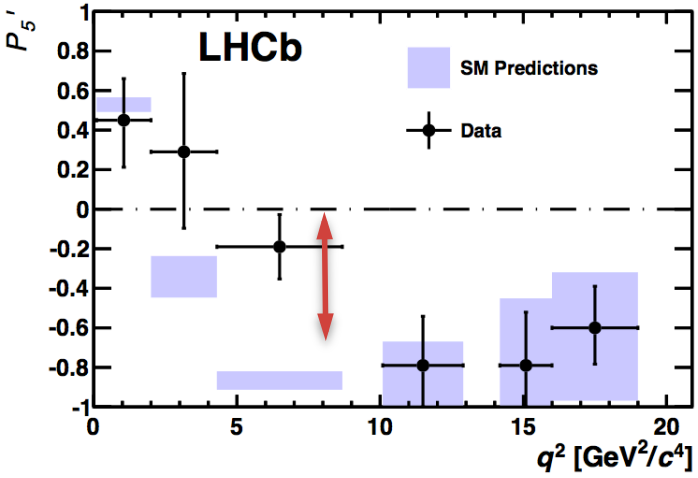
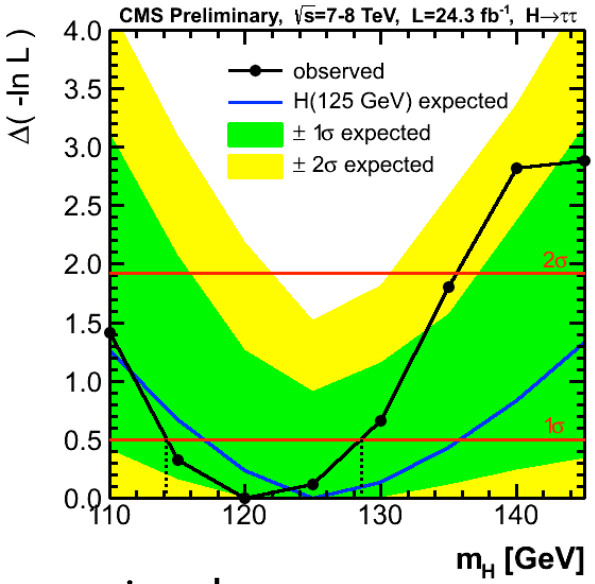
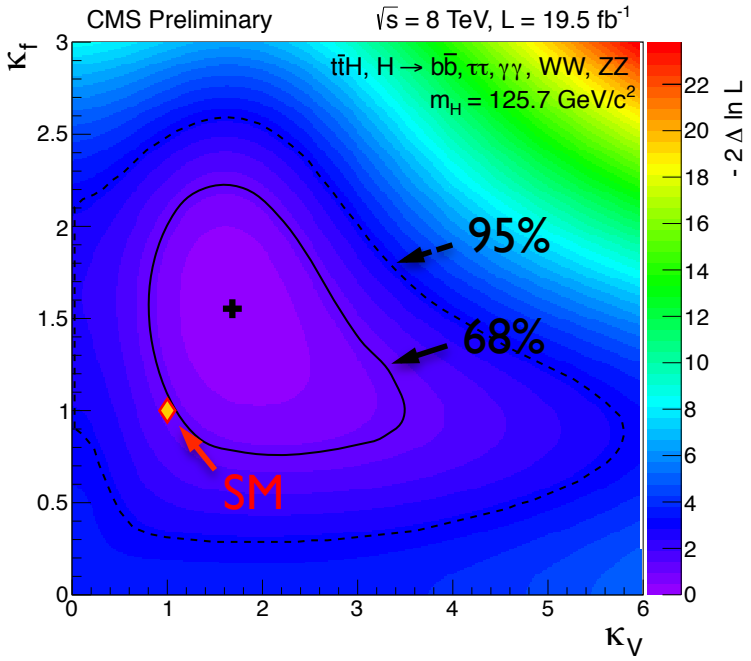
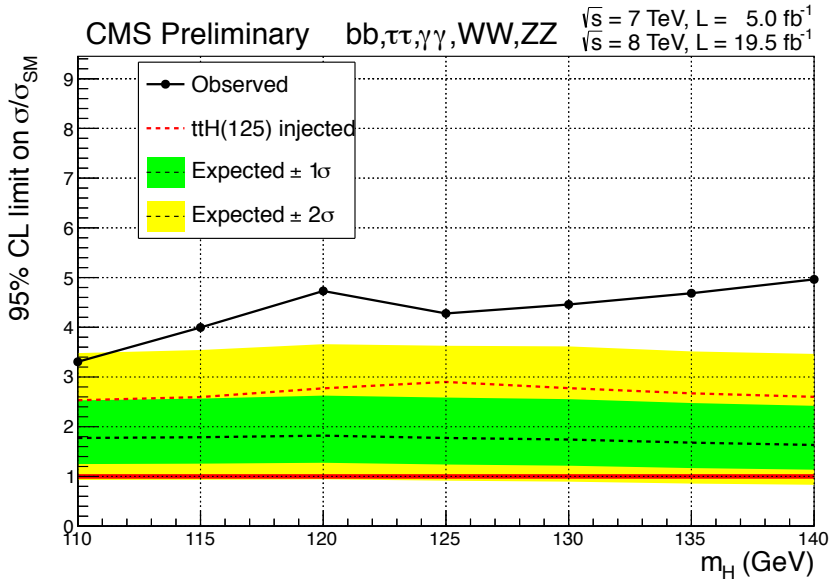


Higgs



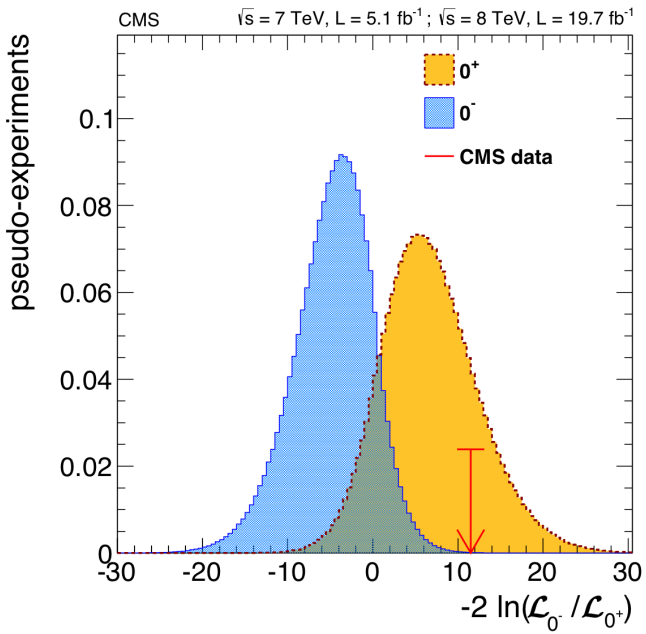
- Most of the results have been published, still "legacy" papers are in progress
- Recent result from ttH with H decaying to leptonic channels, and combination with the other channels. Slight excess w.r.t. SM, but still low sensitivity: $\sigma=(2.5\pm1.0)\times\sigma_{SM}$
- Part of the Higgs group program is devoted to improving the property measurements, part to search for non-minimal Higgs bosons (SuSy or other models)
- $H\rightarrow \tau\tau$: 3σ excess (preliminary), now under final approval

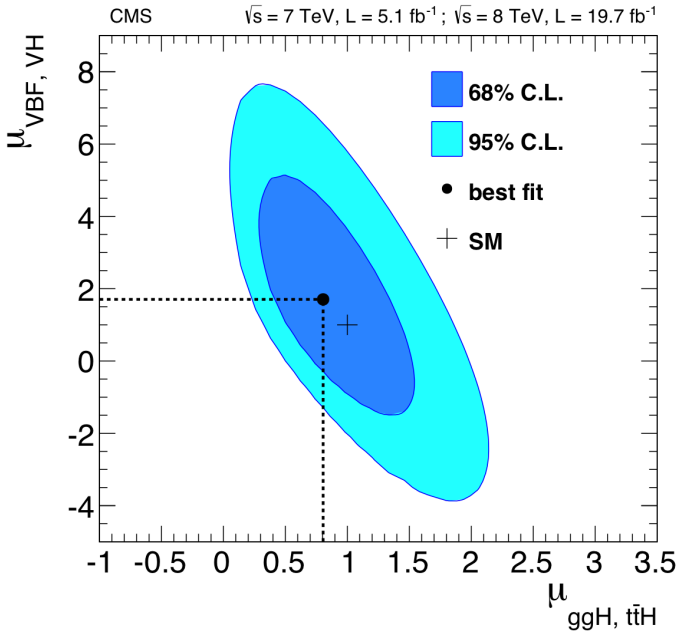




Higgs - Properties

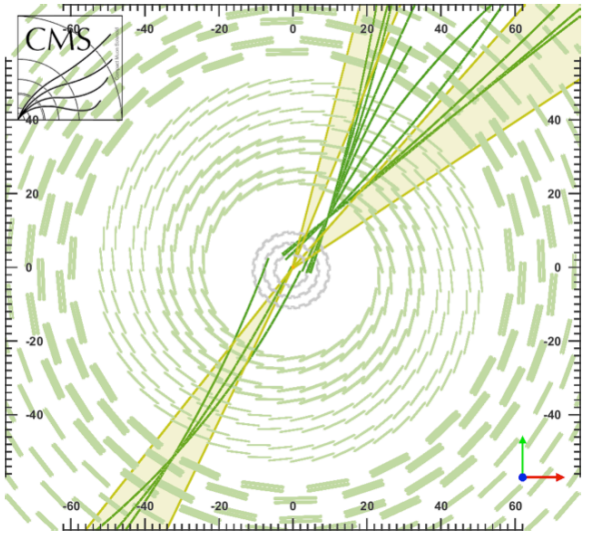
- The properties of a Higgs boson candidate are measured in the H→ZZ→4l decay channel, with with l=e, μ.
- The production cross section of the new boson times the branching fraction to four leptons is measured to be $0.93^{+0.26}_{-0.23}$ (stat.)$^{+0.13}_{-0.09}$ (syst.) times that predicted by the standard model.
- Its spin-parity properties are found to be consistent with the expectations for the standard model Higgs boson (pseudoscalar spin-1 boson hypotheses are excluded at a 99% CL, spin-2 boson hypotheses are excluded at a 95% CL).

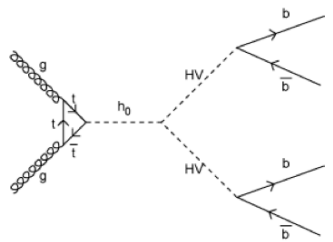


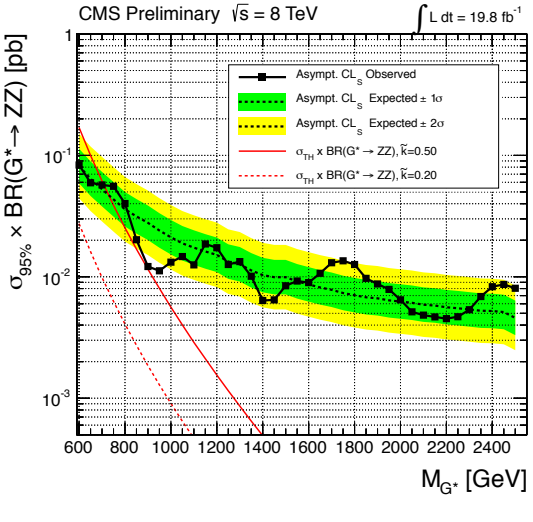


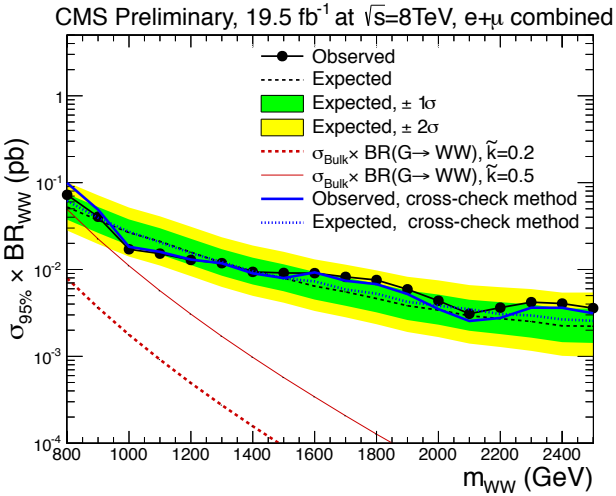
Exotica

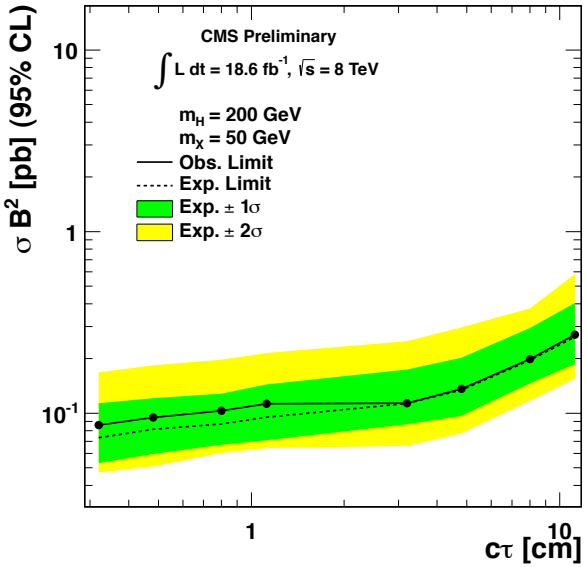
- Exotica papers are in general less numerous than in the past
  - Many analyses finalized shortly after the end of run I
- Still some new results show interesting applications of non-trivial analysis techniques, e.g.: search for displaced jet resonances (EXO-12-038)
  - ATLAS studied "out-of-time" jets
- Search for resonances decaying to ZZ (EXO-12-022) and WW (EXO-12-021), interpreted as limits to graviton production cross section × BR to searched final states





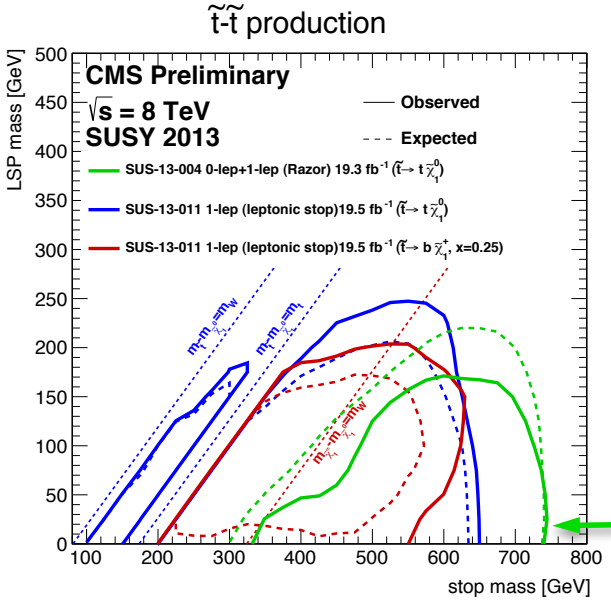


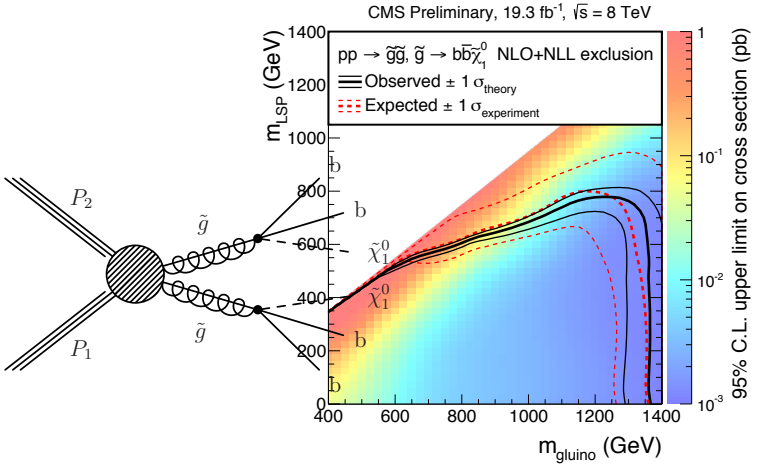


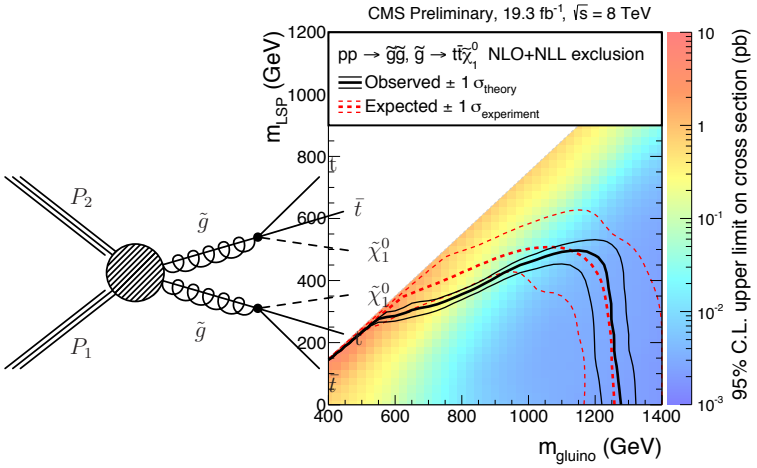


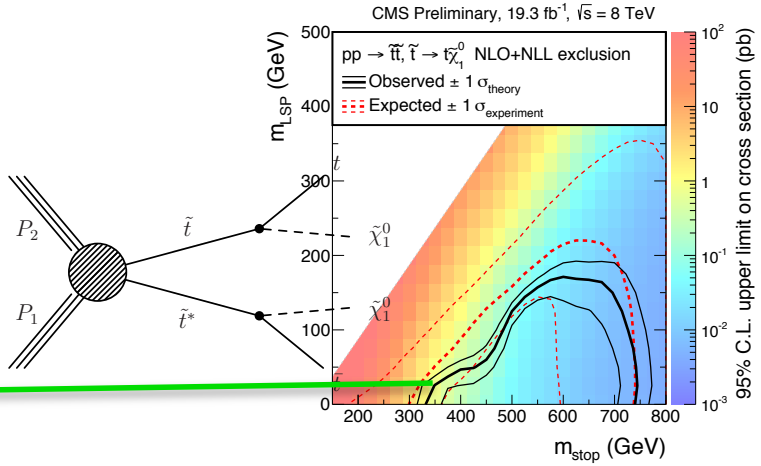
SuSy

- Specific SuSy searches address topologies uncovered by other searches with generic topologies
- E.g.: search for final states with b jets using razor variables (SUS-13-004)



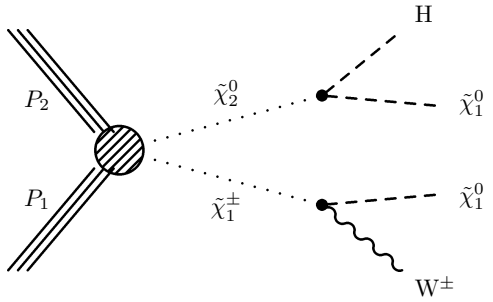


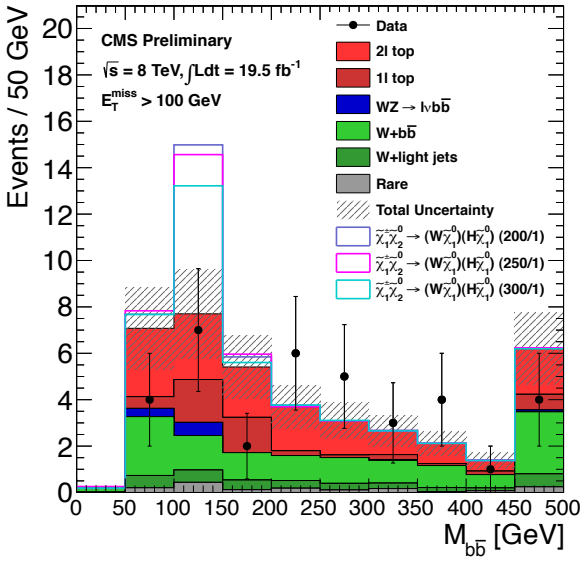


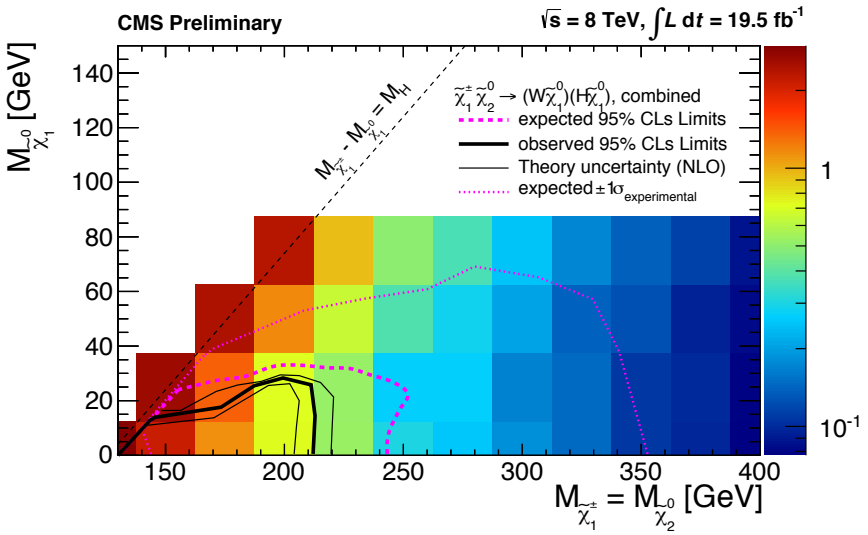


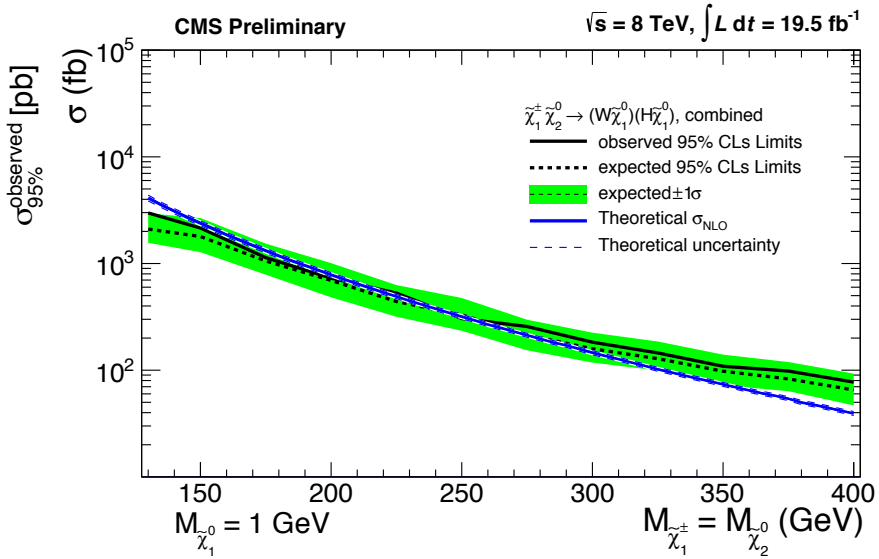
SuSy: Higgs as a tool!

- Search for decays with Higgs bosons in the final state (SUS-13-017)
- Several decay modes explored: H→bb, WW, ZZ, ττ









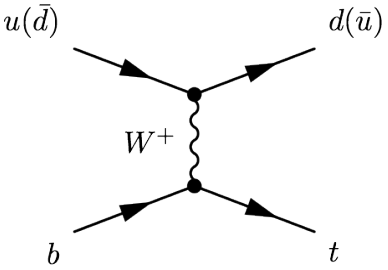
What's next?

- "Legacy" papers should be mostly completed by winter
- It's time to get ready to run II
- Prepare the strategy to analyze the first data:
  - What channels are more promising?
  - What results would be more interesting?
  - Precision measurements (including Higgs properties) and/or searches?
  - Can we approach new channel profiting from signatures we already have analyzed?
- In order to get ready we have to prepare the ingredients:
  - Trigger: different selection (e.g.: isolation applied on leptons) will put constraints on how to study control samples from data
  - Physics objects: PAG need to work closely with POG in order to exploit the best available tools
  - Different background compositions, at higher energy
  - Pile-up conditions
  - Definition of new events selections
  - …
- Studies of channels at high energy are also a starting point to explore the scenarios for the phase-II upgrade and for high luminosity LHC

Naples group: data analysis

- 2010: analysis of the very first data
  - $Z \rightarrow \mu\mu$ inclusive cross section
  - Vector Boson Task Force convenership
- 2011:
  - Z and W inclusive cross section paper (CMS top cite)
  - Single-top production: first measurements (→ PRL)
- 2012:
  - Higgs boson search: $H \rightarrow ZZ \rightarrow llqq$
  - Single-top longer paper on t channel (→JHEP)
  - Single-top convenership
  - National physics coordinator
- 2013:
  - Higgs boson properties: $H \rightarrow ZZ \rightarrow llll$, via VBF
  - First s-channel single-top measurement
  - Physics validation convener (Francesco)
- 2014:
  - Single-top convenership (Orso)

t channel: cross section

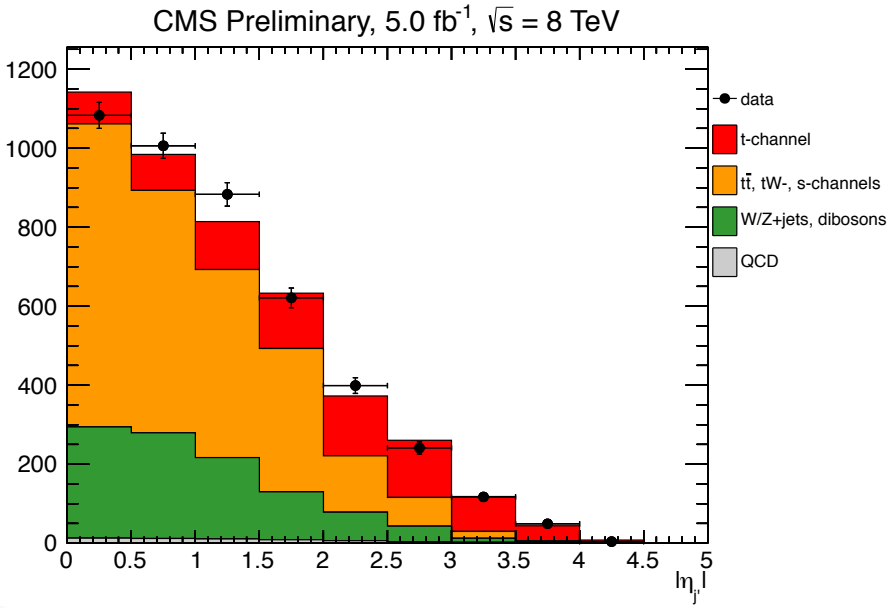


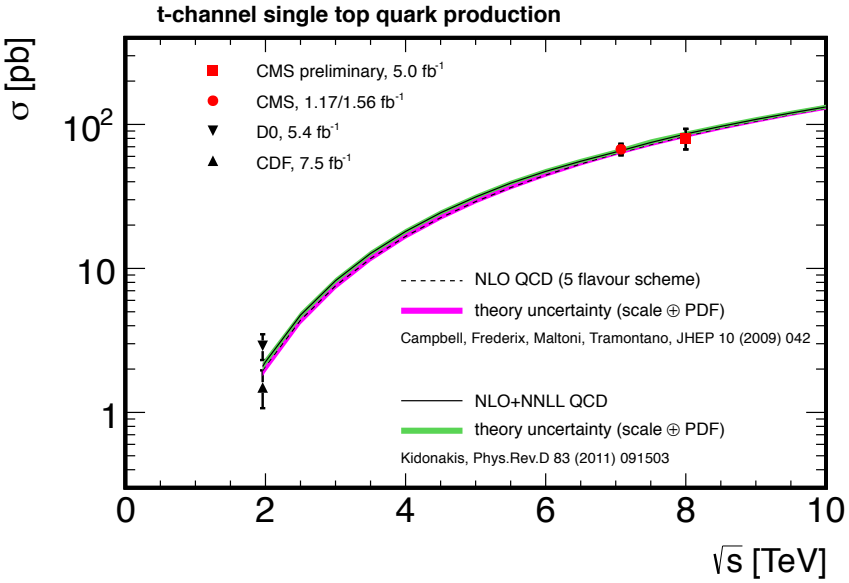
- Inclusive cross section measured at 7 and 8 TeV
- **7 TeV**, 1.17/1.56 fb^{-1}: three analyses combined: NN, BDT and fit to $|\eta_{j'}|$ distribution; exactly one e or μ

  $\sigma_{t\text{-ch.}} = 67.2 \pm 3.7(stat) \pm 3.0(syst) \pm 3.5(th) \pm 1.5(lumi)$ pb [JHEP12(2012) 035]
  $\sigma_{t\text{-ch.}}^{SM} = 64.6$pb

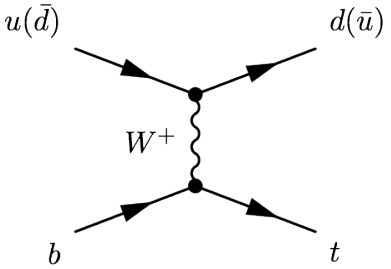
- **8 TeV**, 12.2 fb^{-1}: fit to $|\eta_{j'}|$ distribution in 2jets+1b-tag, signal region from reconstructed top mass. Exactly one μ

  $\sigma_{t\text{-ch}} = 80.1 \pm 5.7(stat) \pm 11.0(syst) \pm 4.0(lumi)$ pb [TOP-12-011]
  $\sigma_{t\text{-ch.}}^{SM} = 87.6$pb

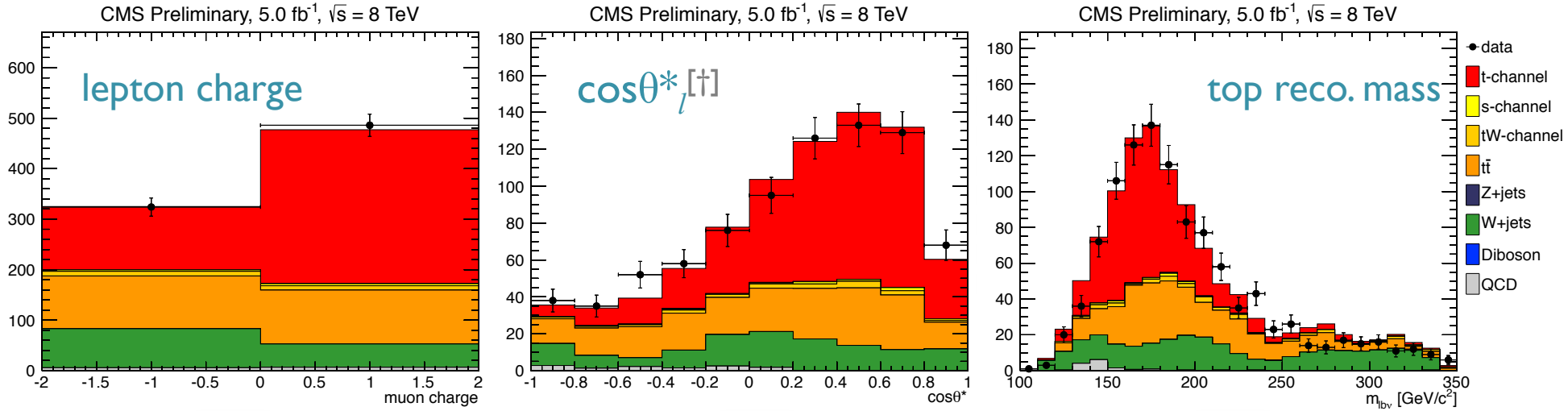




t channel: distributions



- The t-channel data sample is large enough to start studying distributions
  - → differential cross sections
- Signal can be enhanced by requiring large forward jet pseudorapidity, e.g.: $|\eta_{j'}| > 2.0$



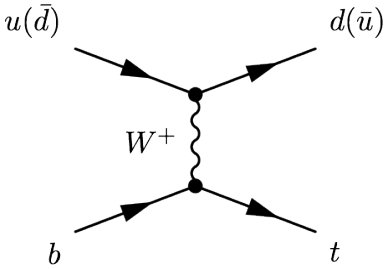
Top/antitop cross-section ratio

Top polarization

Top mass from single top (uncovered so far!)

[†] θ^*_l = angle between lepton in W rest frame and the W in top rest frame.

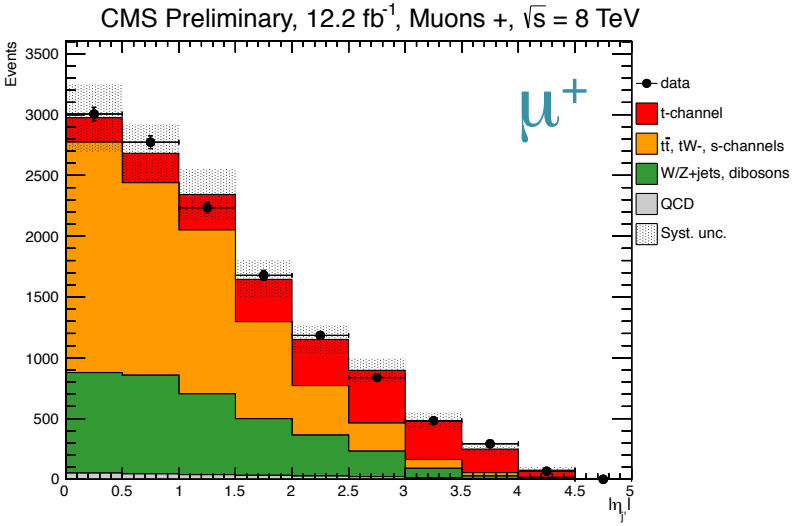
Top antitop, separately

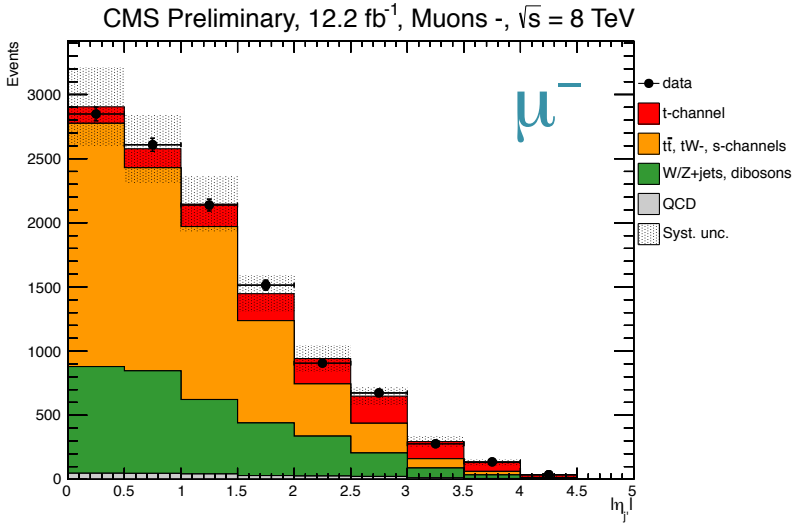


- Top and antitop cross sections can be measured separately, based on the lepton charge [TOP-12-038]
- Their ratio and total cross section can be determined, alternatively
- Slightly different selection with both e and μ, to optimize uncertainty on the ratio; electron channel added to the analysis

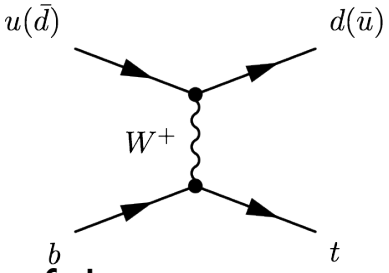
- σ_{top} = 49.9 ± 1.9(stat) ± 8.9(syst) pb
- $\sigma_{anti\text{-}top}$ = 28.3 ± 2.4(stat) ± 4.9(syst) pb

SM expectation
σ_{top}= 43.0 ($^{+1.6}_{-0.2}$) ±0.8 pb $\sigma_{anti\text{-}top}$= 22.9±0.5 ($^{+0.7}_{-0.9}$) pb
http://arxiv.org/abs/1210.7813v2





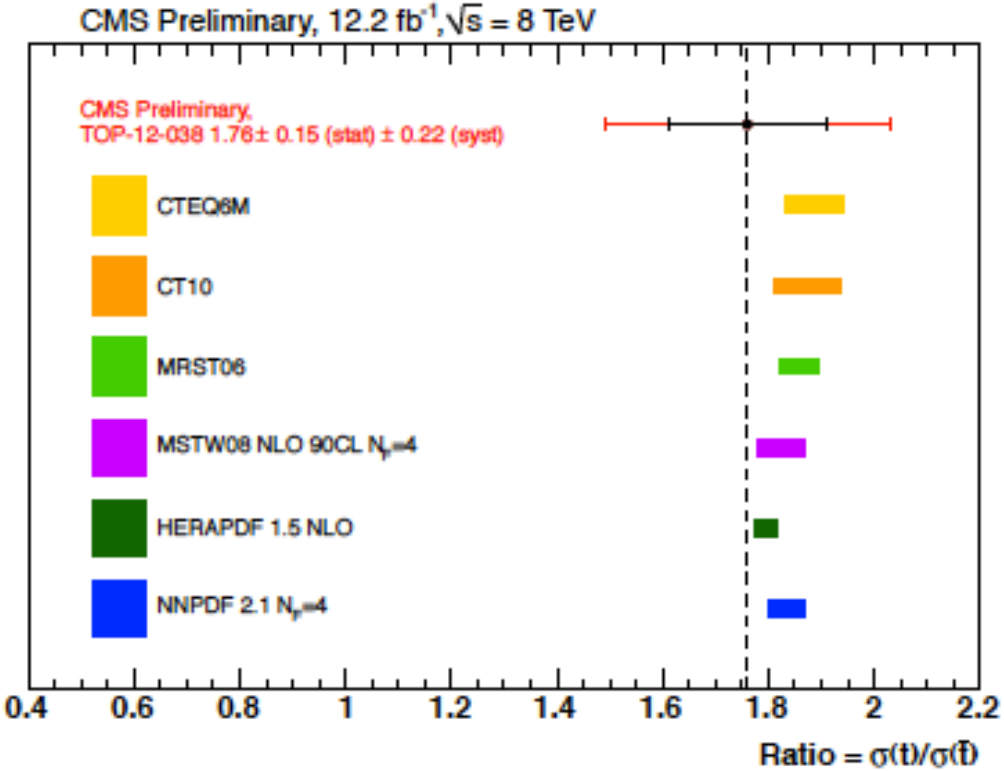
Top-antitop ratio



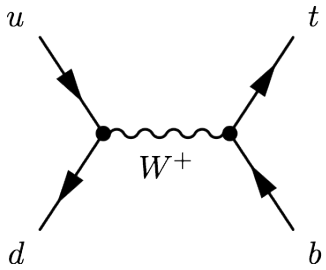
- Top-antitop ratio $R_{t/t\sim}$ probes the different u and d content of the proton
- Potentially sensitive to PDF

- $R_{t/t\sim} = 1.76 \pm 0.15(stat) \pm 0.22(syst)$

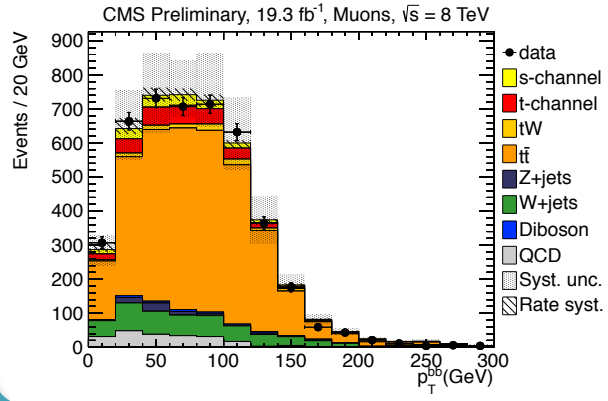
- Uncertainty is still large to discriminate PDF models
- Combination with ATLAS should be pursued, but measurements are available at different $\sqrt{s}$
- Can we achieve a better sensitivity combining some observables at $\sqrt{s}$ = 7 TeV and 8 TeV (and eventually at 14 TeV)?
- ..or it is a job for PDF global fits?

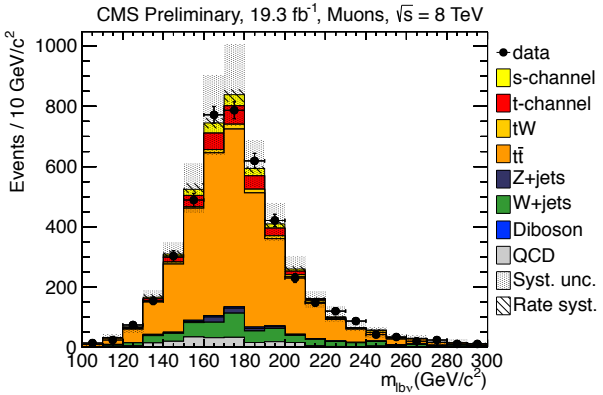


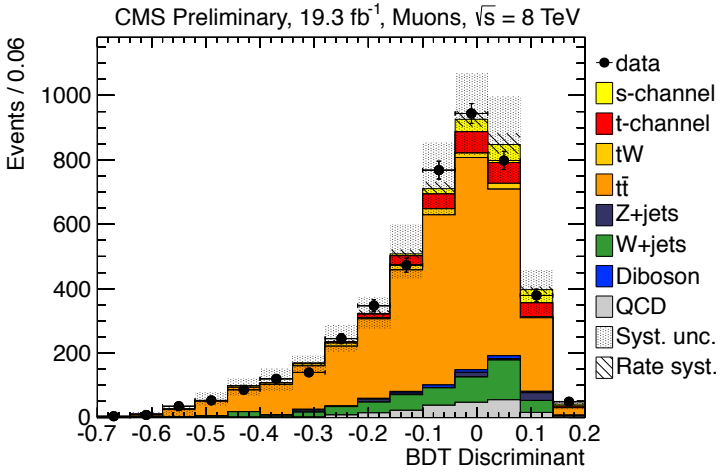
s channel

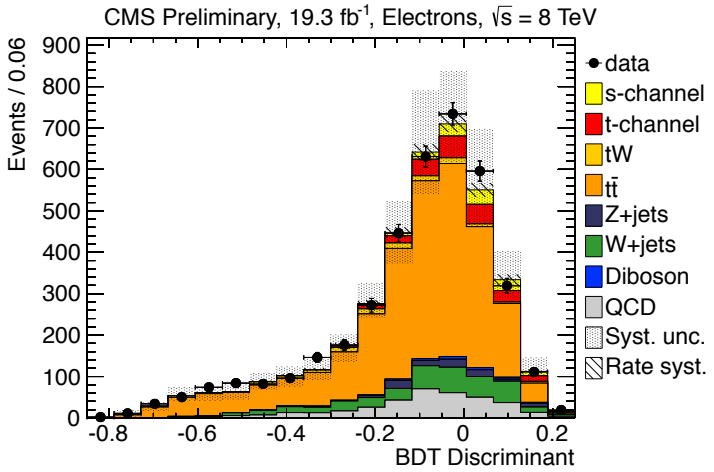


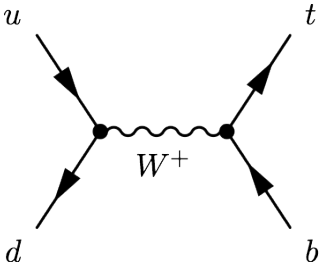
- Most unfavorable cross section and signal/background
- Signal determined using a multivariate approach to increase sensitivity (BDT, 10/11 variables for μ/e)
- Data/simulation agreement was checked for each variable











s channel results

- First CMS result approved by PASCOS (**8 TeV**, 19.3 fb^{-1})
- Upper limit: $\sigma_{s\text{-ch.}} < 2.1 \times$ SM cross section [TOP-13-009]

exp. w/ signal exp. w/o signal

$$\begin{aligned}
\sigma_{s\text{-ch.}} &< 12.4 \quad (18.4,\ 10.5)\ \text{pb} \quad \text{muon channel} \\
\sigma_{s\text{-ch.}} &< 14.7 \quad (23.2,\ 15.4)\ \text{pb} \quad \text{electron channel} \\
\sigma_{s\text{-ch.}} &< 11.5 \quad (17.0,\ 9.0)\ \text{pb} \quad \text{combined}
\end{aligned}$$

- Sensitivity still limited (0.9σ exp, 0.7σ obs), mainly by theory systematics
- Keeping under control uncertainties like renorm./factor scale (83%!!) would reduce dramatically the uncertainty (➪ TOPLHCWG)
- Cross section determined anyway from fit to data yield ($\sigma_{s\text{-ch.}}^{SM} = 5.6$pb):

$$\begin{aligned}
\sigma_{s\text{-ch.}} &= 5.9 \pm 7.1(\text{exp.}) \pm 5.0(\text{th.}) \\
\sigma_{s\text{-ch.}} &= 6.9 \pm 5.6(\text{exp.}) \pm 6.5(\text{th.}) \\
\sigma_{s\text{-ch.}} &= 6.2 \pm 5.4(\text{exp.}) \pm 5.9(\text{th.})
\end{aligned}$$

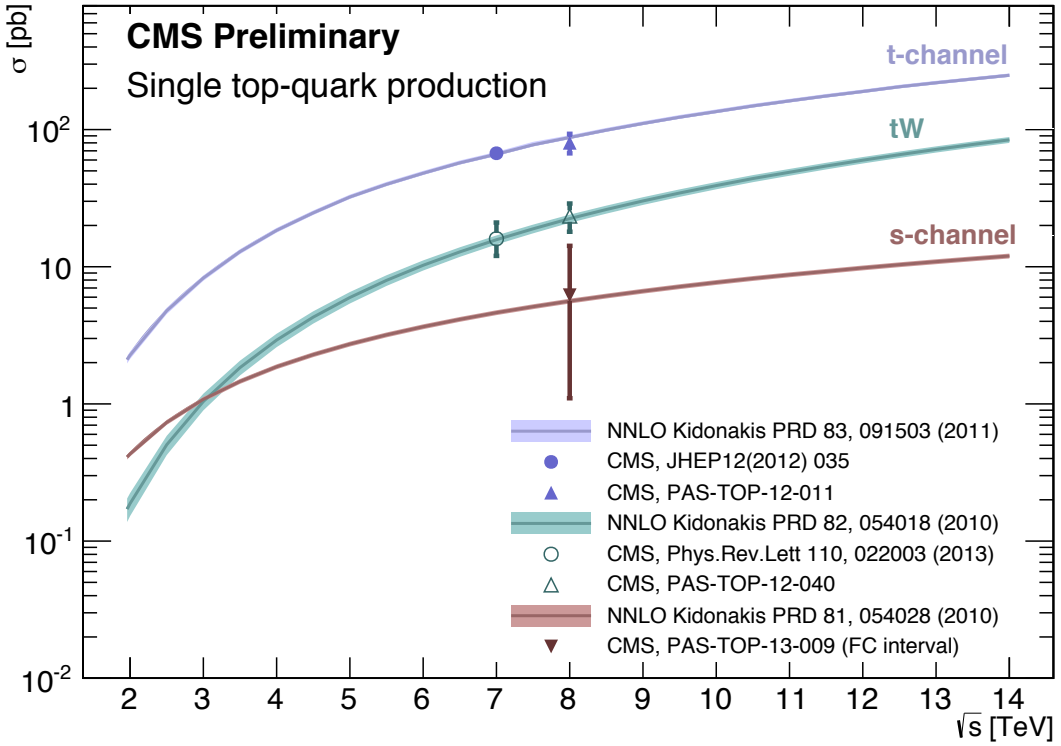
Feldman-Cousins

$$\begin{aligned}
\sigma_{s\text{-ch.}} &= 5.9^{+8.6}_{-5.1}\ \text{pb} \quad \text{muon channel} \\
\sigma_{s\text{-ch.}} &= 6.9^{+8.7}_{-5.7}\ \text{pb} \quad \text{electron channel} \\
\sigma_{s\text{-ch.}} &= 6.2^{+8.0}_{-5.1}\ \text{pb} \quad \text{combined}
\end{aligned}$$

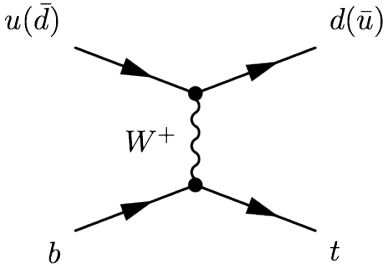
- The analysis at 7 TeV is interesting: the better S/B ratio may compensate the smaller data sample
  - ATLAS limit available at 7 TeV, 0.70 fb^{-1}: $\sigma_{s\text{-ch.}} < 26.5$pb = 5.7 × SM cross section [ATLAS-CONF-2011-118]

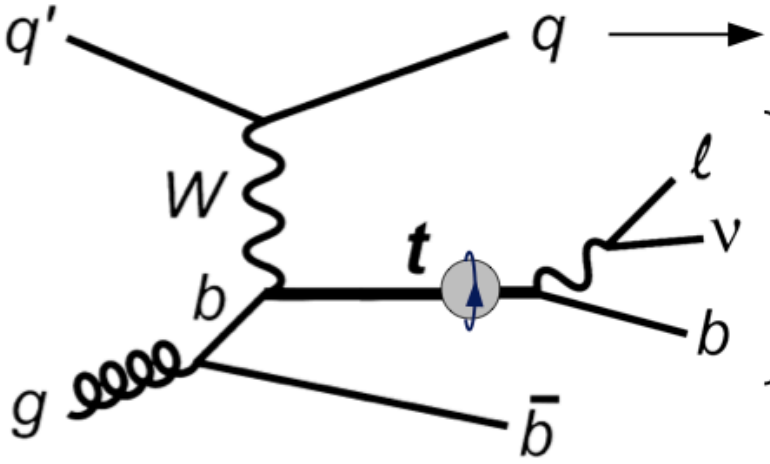
Cross section summary

- t channel and tW measured at 7 and 8 TeV
  - t channel reached 16% precision, 14% if combined with ATLAS
- s channel, upper limit at 8 TeV
  - Fit from data allows to determine the cross section, yet with poor precision so far



Differential measurements and top polarization





SM: top ~100% polarized along light quark

Wtb coupling structure encoded in kinematics of decay products (SM: V-A coupling structure)

- Selection very similar to cross section measurement
- Extract distribution of angle between light quark & lepton in the top-quark rest frame:

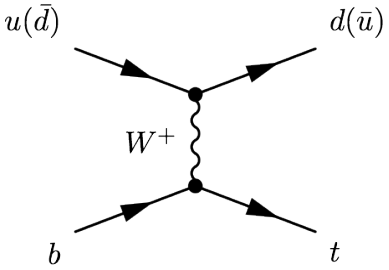
$$\cos\theta^* = \frac{\vec{p}^{\,*}_{\ell} \cdot \vec{p}^{\,*}_{\ell \mathrm{q}}}{|\vec{p}^{\,*}_{\ell}| \cdot |\vec{p}^{\,*}_{\ell \mathrm{q}}|}$$

- Determine the asymmetry

$$A = \frac{N(\cos\theta^* > 0) - N(\cos\theta^* < 0)}{N(\cos\theta^* > 0) + N(\cos\theta^* < 0)}$$

- Probe coupling structure

Differential studies

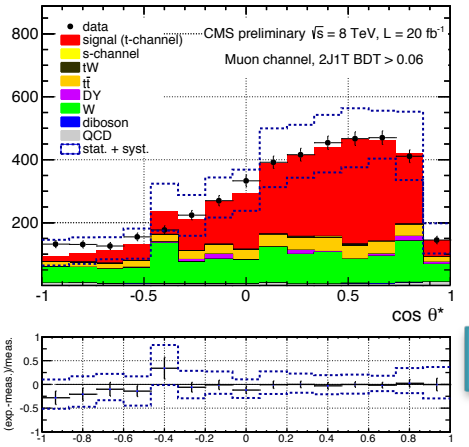


- Regularized unfolding of cosθ* distribution removes experimental effects
- Top spin asymmetry: A_l = 0.41±0.06(stat)±0.16(syst)
- Top polarization: P_l = 0.82±0.12(stat)±0.32(syst)

$$A_l \equiv \frac{1}{2} \cdot P_t \cdot \alpha_l = \frac{N(\uparrow) - N(\downarrow)}{N(\uparrow) + N(\downarrow)}$$

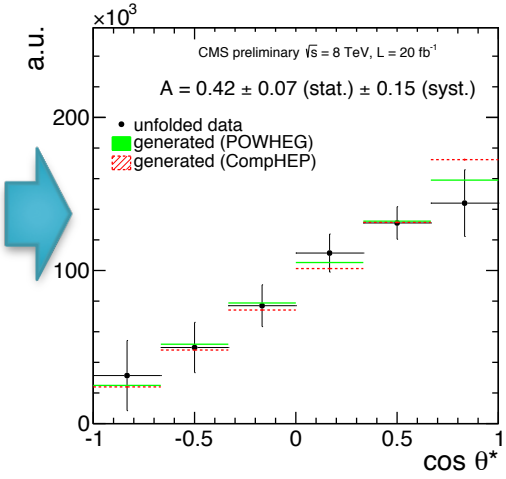
α_l =1 in the SM, modified in case of tWb anomalous coupling

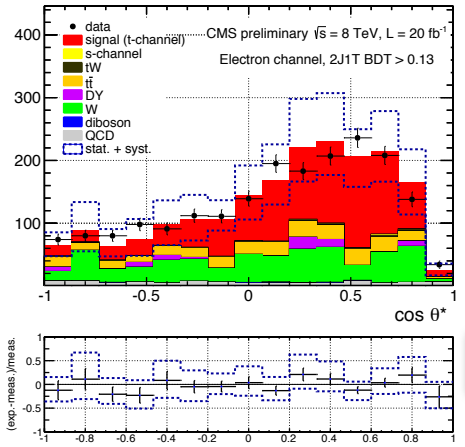
- First of several possible differential cross-section measurements



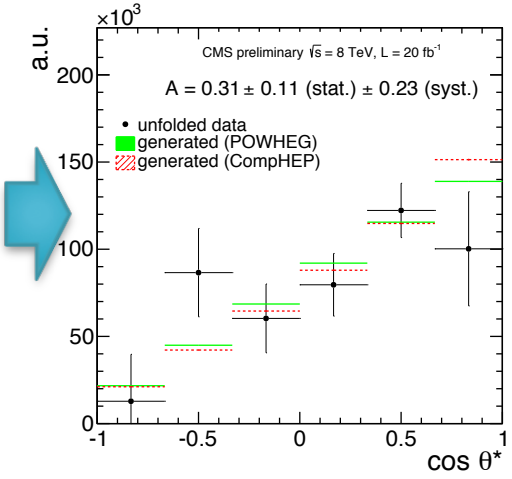
muons

[TOP-13-001]

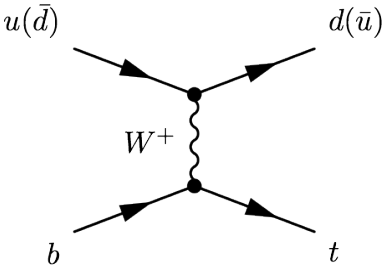




electrons



W helicity

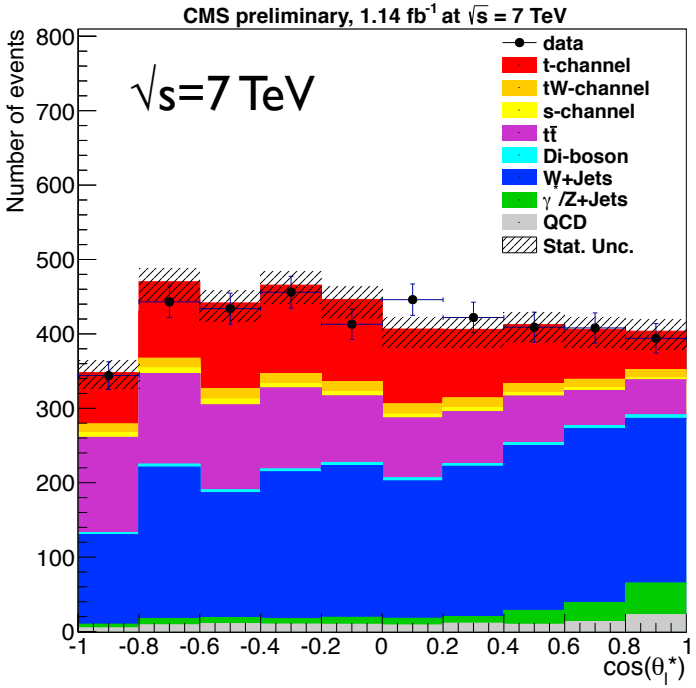


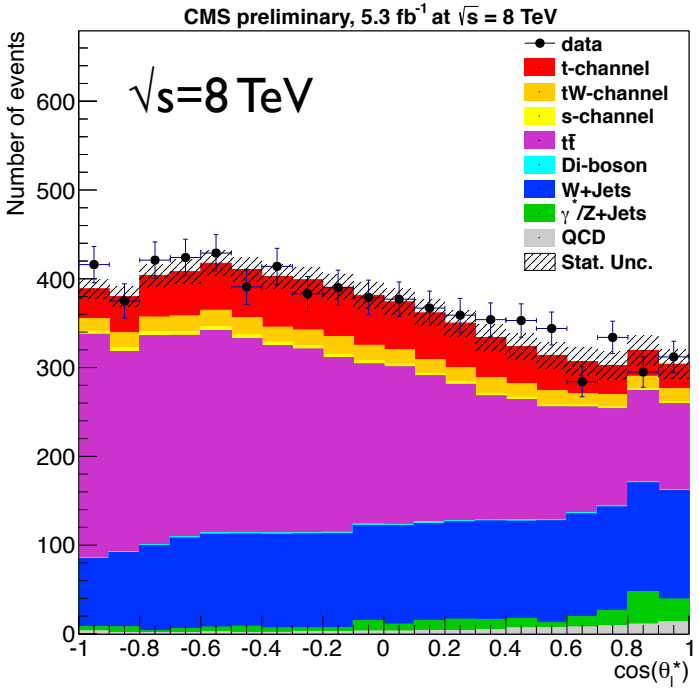
- W helicity from top decay studied from $\cos\theta^*_l$[†] distribution

[†] θ^*_l = angle between lepton in W rest frame and the W in top rest frame.

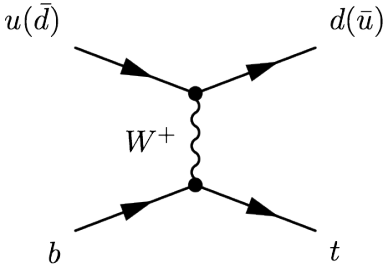
$$\rho(\cos\theta^*_\ell) = \frac{1}{\Gamma}\frac{\mathrm{d}\Gamma}{\mathrm{d}\cos\theta^*_\ell} = \frac{3}{8}(1+\cos\theta^*_\ell)^2 F_R + \frac{3}{8}(1-\cos\theta^*_\ell)^2 F_L + \frac{3}{4}\sin^2\theta^*_\ell F_0$$

- Single-top selection provides a sample enriched in single-top event, where the tt~ fraction is anyway sizable, in particular at 8 TeV
- Orthogonal selection w.r.t. W helicity analysis in tt~, suitable for a possible combination





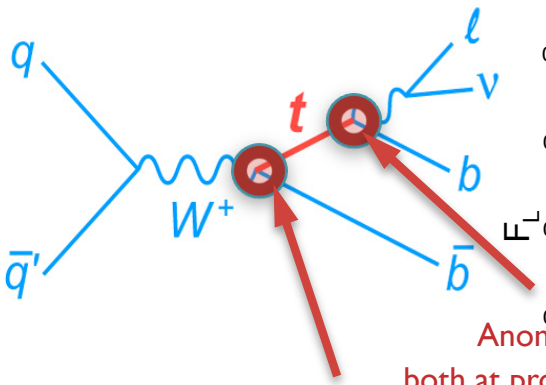
W helicity



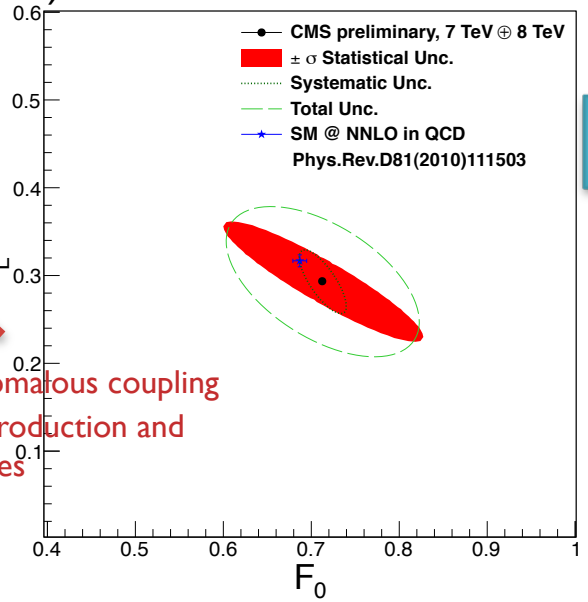
- Preliminary result with **7+8 TeV** (1.14fb^{-1} + 5.3fb^{-1}, μ only) [TOP-12-020]:
  - F_L = 0.293 ± 0.069(stat) ± 0.030(syst)
  - F_0 = 0.713 ± 0.114(stat) ± 0.023(syst)
  - F_R = −0.006 ± 0.057(stat) ± 0.027(syst)
- Limits set on anomalous tWb couplings

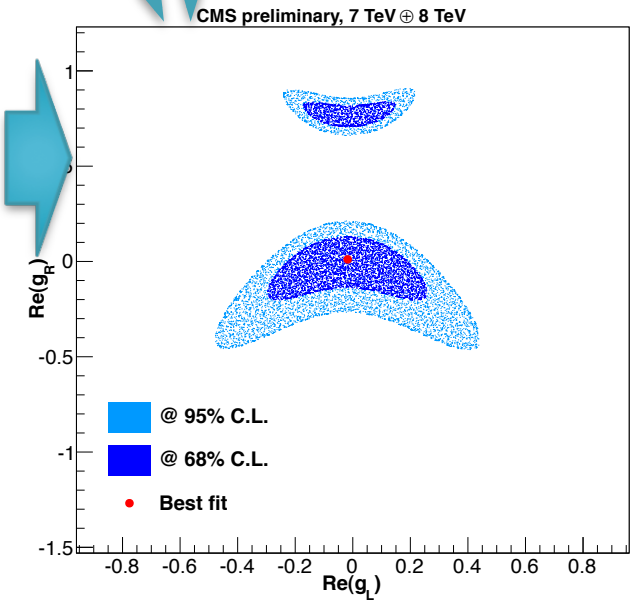
$$\mathcal{L}_{tWb}^{anom.} = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}(V_L P_L + V_R P_R)tW_{\mu}^{-} - \frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}q_{\nu}}{m_W}(g_L P_L + g_R P_R)tW_{\mu}^{-} + H.C,$$

- Anomalous coupling at production vertex not taken into account explicitly in the analysis method, but effects on the measurement determined with dedicated simulated samples: null (V_R=0) or negligible bias, if V_L = 1 and $|V_R|^2 < 0.3$ (D0 limit).



Anomalous coupling both at production and decay vertices





Naples group

1	Buontempo Salvatore	Dipendente	Dirigente di Ricerca	80%
2	Cavallo Nicola	Associato	Prof. Ordinario	100%
3	De Nardo Guglielmo	Associato	Ricercatore	20%
4	Di Guida Salvatore	Associato	Dottorando	100%
5	Dogangun Oktay	Associato	Dottorando	100%
6	Esposito Marco	Associato	Dottorando	100%
7	Fabozzi Francesco	Associato	Ricercatore	100%
8	Iorio Alberto Orso Maria	Associato	Assignista di ricerca	100%
9	Lista Luca	Dipendente	Primo Ricercatore	95%
10	Meola Sabino	Associato	Ricercatore	100%
11	Merola Mario	Associato	Assegnista	100%
12	Paolucci Pierluigi	Dipendente	Primo Ricercatore	100%
13	Sciacca Crisostomo	Associato	Prof. Ordinario	0%
Totale			**13**	**FTE: 11.0**

Francesco Tramontano (researcher, type "A") recently joined CMS as theorist affiliated

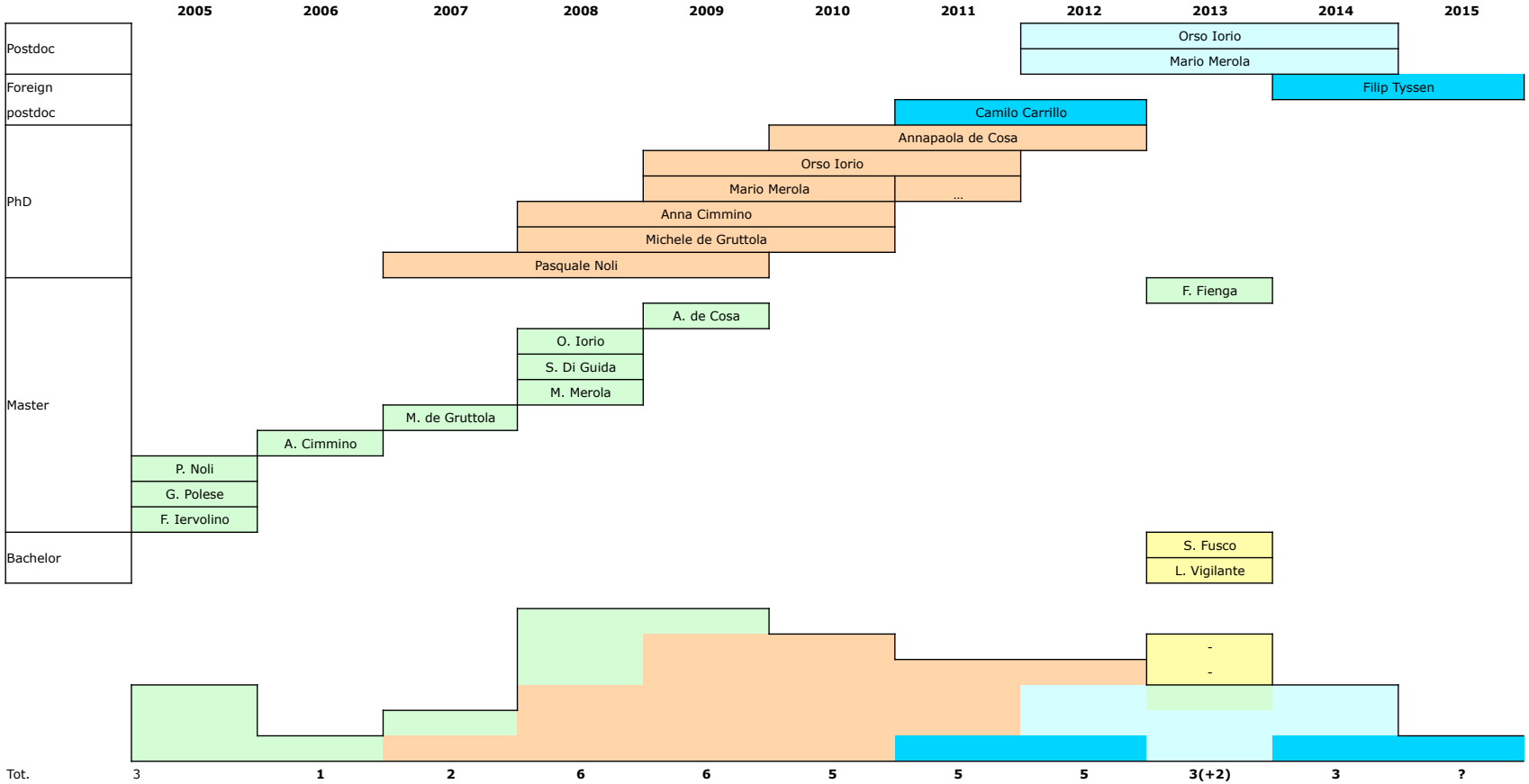
2014 Budget

Sigla loc.	Capitolo	Riunione	Note alla richiesta	Rich.	Rich. SJ	Assegn.	Assegn. SJ	Assegn. Dot.	Commento alla assegnazione
NA	MISS	Assegnazioni	RPC: project manager: 6mu x 3.95k€/mu	24.0	0.0	94.0			include tutte le voci
		Assegnazioni	RPC: technical coordinator: 4mu x 3.95k€/mu	16.0	0.0	0.0			
		Assegnazioni	RPC: resp. supermoduli: 2mu x 3.95k€/mu	8.0	0.0	0.0			
		Assegnazioni	RPC: resp. database: 2mu x 3.95k€/mu	8.0	0.0	0.0			
		Assegnazioni	PPD: liason con gruppi di analisi: 2k€ x 3.95k€/mu	8.0	0.0	0.0			
		Assegnazioni	Physics/TOP: single top group convener: 2mu x 3.95k€/mu	8.0	0.0	0.0			
		Assegnazioni	Coordinatore italiano della fisica: 2mu x 3.95k€/mu	8.0	0.0	0.0			
		Assegnazioni	RPC link board: missioni al CERN di tecnici: 12mu x 3.95k€/mu	47.5	0.0	0.0			
		Assegnazioni	RPC: sistema di potenza e riparazioni, missioni di tecnici al CERN: 2mu x 3.95k€/mu	8.0	0.0	0.0			
		Assegnazioni	RPC: RE4, sistema di potenza: missioni al CERN di tecnici: 4mu x 3.95k€/mu	16.0	0.0	0.0			
		Assegnazioni	RPC: turni al CERN: 7mu x 3.95k€/mu	27.5	0.0	0.0			
		Assegnazioni	Metabolismo: 11 FTE x 3.95k€/FTE	43.5	0.0	0.0			
		Totale MISS		**222.5**	0.0	**94.0**	0.0	0.0	
	CON	Assegnazioni	Metabolismo: 11 FTE x 1.5k€/FTE	16.5	0.0	14.0			
		Totale CON		**16.5**	0.0	**14.0**	0.0	0.0	
	APP	Assegnazioni	4 distributori HV per il sistema presente: totale 4180€	4.0	0.0	4.0			fuori tetto
		Assegnazioni	Connettori Fibre LB: totale di 1500€	1.5	0.0	1.5			fuori tetto
		Assegnazioni	Kit per il montaggio delle LB (custom): 2500€	2.5	0.0	2.5			fuori tetto
		Assegnazioni	Set di componenti spare per il sistema LB (spartan III e memorie associative): 3150€	3.0	0.0	3.0			fuori tetto
		Assegnazioni	fibre ottiche per linkboard RPC	10.0	0.0	0.0			Nuova richiesta anticipata 2013
		Totale APP		**21.0**	0.0	**11.0**	0.0	0.0	
	SERVIZI	Assegnazioni	Auto al CERN	4.0	0.0	0.0			
		Totale SERVIZI		4.0	0.0	0.0	0.0	0.0	
Totale NA				**264.0**	0.0	**119.0**	0.0	0.0	

Relevant cuts applied: being re-discussed within the Italian community

Students and postdocs

- The number of young physicists is decreasing in the last years, after a positive trend
  - Positive sign: two bachelor theses ongoing



Naples: analysis next years

- Higgs analysis moving to and end
- Consolidating single-top analysis
- Possibly investigate new physics channels with single-to signature
- The strategy will be defined in a forthcoming group meeting being scheduled shortly
- Contact with university is vital for the future of the group