CMS $H \rightarrow WW$ toy model

for the ATLAS+CMS combination exercise

Assumptions for the current round

- 3 di-lepton channels, 0-jet bin, simple event counting after cuts
- numbers approx. correspond to 7 TeV, 1 fb^{-1}
  - some are reasonable projections from 14 TeV studies, some are plainly made up
  - we provide two mass points
    with two plausible "observations" for each, assuming Higgs presence (plan A) and absence (plan B)
    - m_H=160: sweet spot for the HWW analysis; challenge in evaluating very large significance at 1 fb-1 (and, from practical point of view, hardly needed—we would be already beyond the "discovery" stage)
    - m_H=140: aprox. the SM exclusion cross-over at 1 fb-1 (combining two experiments makes a difference); role of systematic errors is significantly larger than at mH=160 (good for crosschecking tools)
- nuisance parameters (currently 37)
  - no truncated Gaussians, anymore

    they are not physical and known to be pathological in Bayesian calculations
  - for this round, all have lognormal pdf's

    For simplicity, statistical errors related to finite event statistics in MC samples and "Data" control samples are also treated as lognormal.
    Later, they will be replaced by Gamma distributions or by adding corresponding Poisson terms to the likelihood function
    [we will try both to see the difference]

Input tables

- txt tables are attached to the agenda
- snippet:

```
Date: June 22, 2010
Description: HWW-->2l2v, 0jets, cut-and-count for 3 channels: mumu, ee, emu; made-up numbers for a ATLAS+CMS combination exercise
mH    160  Higgs mass hypothesis
comE  7.0   center of mass energy
lumi  1  luminosity in fb-1
----------------------------------------------------------------------------------------------------------------------------
imax   3  number of channels
jmax   6  number of backgrounds
kmax  37  number of nuisance parameters
----------------------------------------------------------------------------------------------------------------------------
Observation   15  7  13
----------------------------------------------------------------------------------------------------------------------------
bin          1     1     1     1     1     1     1     2     2     2     2     2     2     2     3     3     3     3     3     3     3
process      H    Wj    Zj    tX    WW    WZ    ZZ     H    Wj    Zj    tX    WW    WZ    ZZ     H    Wj    Zj    tX    WW    WZ    ZZ
process      0     1     2     3     4     5     6     0     1     2     3     4     5     6     0     1     2     3     4     5     6
----------------------------------------------------------------------------------------------------------------------------
rate      10.5  0.01  0.05  0.94  3.39  0.01  0.01  5.39  0.01  0.05  0.46  1.50  0.05  0.04  10.0  0.01  0.05  1.37  1.88  0.01  0.01
----------------------------------------------------------------------------------------------------------------------------
 1  lnN   1.00  2.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  2.00  1.00  1.00  1.00  1.00  1.00
 2  lnN   1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  2.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
 3  lnN   1.00  1.30  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
 4  lnN   1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.30  1.00  1.00  1.00  1.00  1.00  1.00  1.30  1.00  1.00  1.00  1.00  1.00
```

- comments will help understand which nuisance parameter corresponds to what:

```
Control sample 1/sqrt(N) error           Observed 1 W-->munu + fakeable muon (preselection cuts)
Control sample 1/sqrt(N) error           Observed 1 W-->enu + fakeable electron (preselection cuts)
a1a2 error (muon fake rate)              Judgment from MC (jet- vs. gamma-triggers, different ET thresholds)
a1a2 error (electron fake rate)          Judgment from MC (jet- vs. gamma-triggers, different ET thresholds)
Control sample 1/sqrt(N) error           Observed 2500 Z-->2mu around Z peak (preselection cuts)
```

although for technical combination all we need to know is which ones have to be correlated between ATLAS and CMS

Likelihood Model

$$L_{b+rs} = \prod_i \left(\frac{\left(\sum_{j=0,1,..} \tilde{n}_{ij} \cdot \kappa_{ijk}^{\theta_k} \right)^{N_i}}{N_i\,!} \cdot \exp\left(-\sum_{j=0,1,..} \tilde{n}_{ij} \cdot \kappa_{ijk}^{\theta_k} \right) \right) \cdot \prod_k f(\theta_k)$$

$$L_b = \prod_i \left(\frac{\left(\sum_{j=1,..} \tilde{n}_{ij} \cdot \kappa_{ijk}^{\theta_k} \right)^{N_i}}{N_i\,!} \cdot \exp\left(-\sum_{j=1,..} \tilde{n}_{ij} \cdot \kappa_{ijk}^{\theta_k} \right) \right) \cdot \prod_k f(\theta_k)$$

$i = 1, 2, 3$ counts channels to be combined

$j = 0, 1, 2, \ldots$ counts signal (0) and all backgrounds (1,2,...) in channel i

$k = 1, 2, 3, \ldots$ counts all independent sources of uncertainties

N_i number of observed events in channel i

$\tilde{n}_{ij}$ our best estimate of event rates;

for bkgd's $(j \neq 0)$, $\tilde{n}_{ij} = \tilde{b}_{ij}$;

for signal $(j = 0)$, $\tilde{n}_{i0} = r \cdot \tilde{s}_i$, where r is a common signal strength modifier

κ_{ijk} estimate of systematic error (lognormal scale factor) associated with k-th source of uncertainties

θ_k neusance parameter associated with k-th source of uncertainties

$f(\theta)$ normal distribution (Guassian with mean=0 and sigma=1)

Preliminary results

mH=160, plan B (no signal) with systematics

“95%” C.L. exclusion limits on signal strength modifier $r = \sigma/\sigma_{SM}$

Tools	Bayesian	Simple LR (LEP)	Profiled LR (Tevatron)	Profile LR	Profile Likelihood*
RooStats	**0.312±TBD**				**0.218**
LandS**	**0.315±0.001**	**0.290±0.003**		n/a	n/a

Timing

RooStats	5 chains, 30K iterations 15 min				**<10 s**
LandS**	20K toys **2 s**	100K toys per distrib. **30 s**			

* PL is known to be a poor approximation for cases with low statistics
** LandS (Limits-and-Significance): a standalone tool used for crosschecks, plan to absorb in RooStats later
https://mschen.web.cern.ch/mschen/LandS/index.html

preliminary results

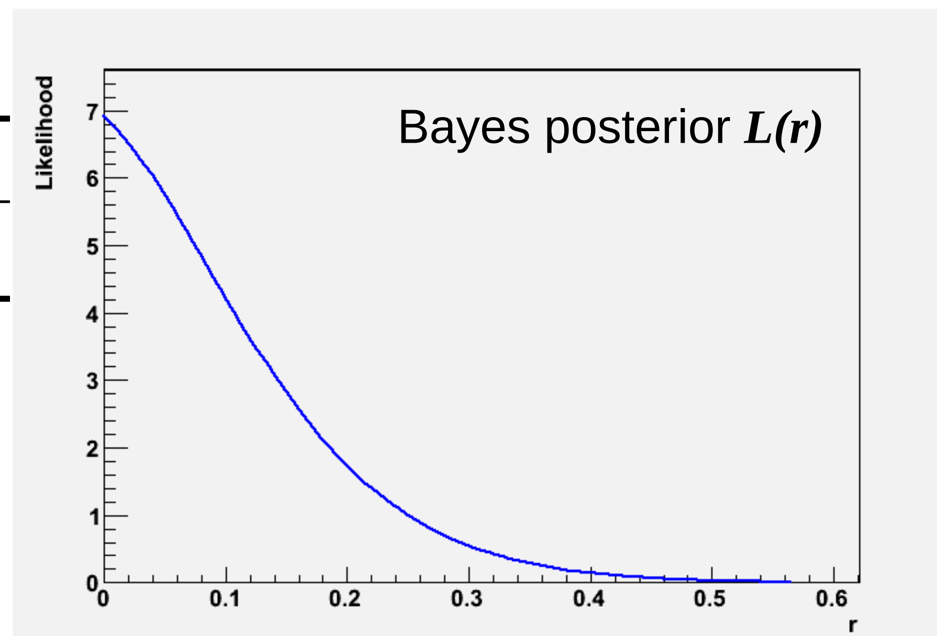
mH=160, plan B (with signal), no systematics

“95%” C.L. exclusion limits on signal strength modifier $r = \sigma/\sigma_{SM}$

Tools	Bayesian	Simple LR (LEP)	Profiled LR (Tevatron)	Profile LR	Profile Likelihood*
RooStats					
LandS**	**0.282±0.000**	**0.271±0.003**		n/a	n/a

Timing

RooStats		
LandS**	no toys needed **<1 ms**	100K toys per distrib. **3 s**



preliminary results

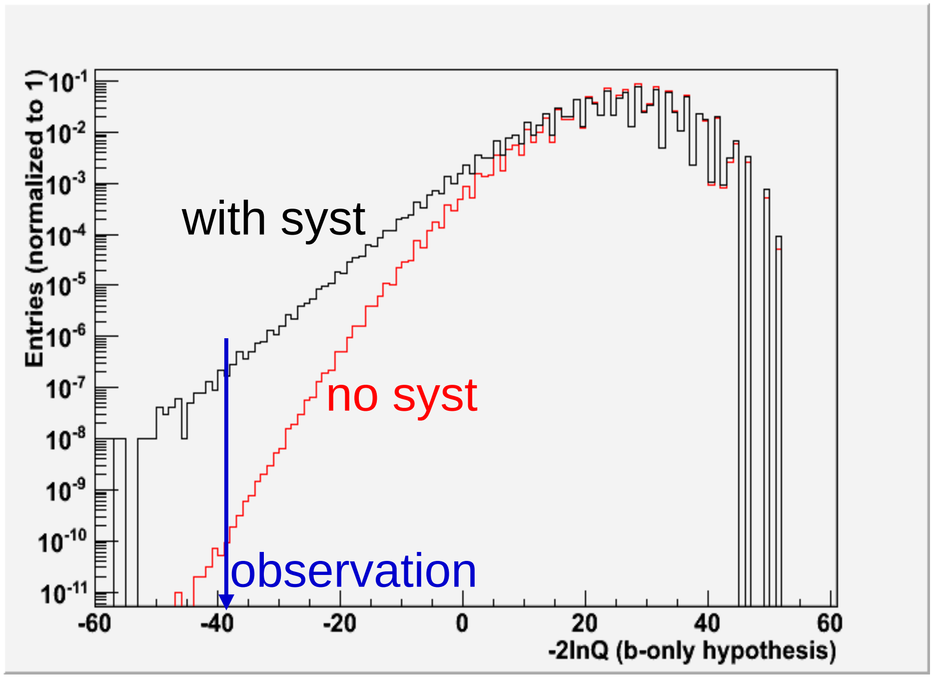
mH=160, plan A (with signal) with systematics

Significance of an event excess

Tools	Hybrid	Profile Likelihood*
RooStats		**4.89**
LandS	**4.77±0.02**	n/a

Timing

RooStats		<10 s
LandS	100M toys **2.5 hr**	



* PL is known to be a fairly good approximation even for small statistics

preliminary results

mH=160, plan A (with signal) without systematics

Significance of an event excess

Tools	Hybrid	Profile Likelihood*	Exact**
RooStats			
LandS	**6.22±0.02**	n/a	**6.24481**

Timing

RooStats		
LandS	100B toys **11 min x 1000**	

* PL is known to be a fairly good approximation even for small statistics

** Exact analytical: can be easily done for a small number of channels with low event count and no systematics, but not really scalable outside of this corner of “phase space”

CMS RooStats Workspace

- Set up, but a little slow at the moment (working on re-optimization); should be ready to exchange with ATLAS in a few days
- Which nuisance parameters should we correlate at the beginning? Luminosity?
- Need to use a common pdf—we suggest lognormal