Looking at LHC Results

following Uli's advice

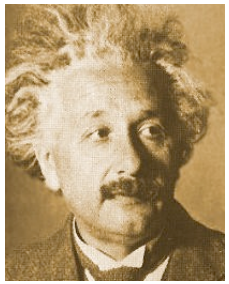
Tilman Plehn

Heidelberg

Buffalo, 9/2011

The LHC

On physics mission for a while now



- Einstein:
  smash 3.5 TeV protons onto 3.5 TeV protons
  produce anything that interacts with quarks and gluons
  search for it in decay products
  repeat every 25 ns
- huge detectors, soldering, exciting data... $\longrightarrow$ experiment
  deep knowledge, fun, workshops in nice places... $\longrightarrow$ theory
  best of both words (Uli et al) $\longrightarrow$ phenomenology

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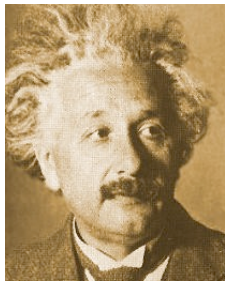

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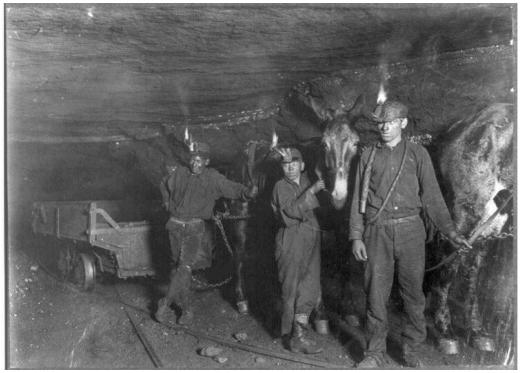

life as a theorist

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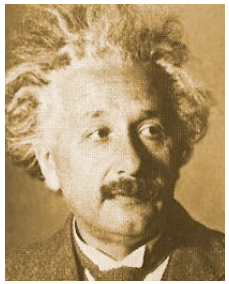

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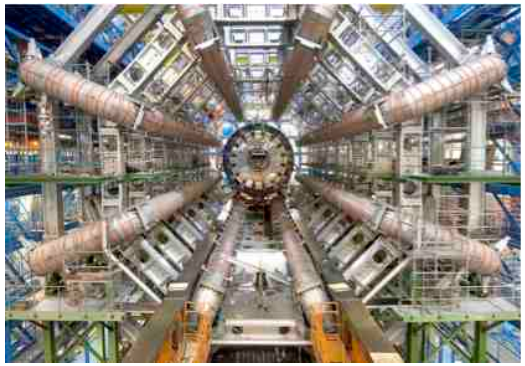

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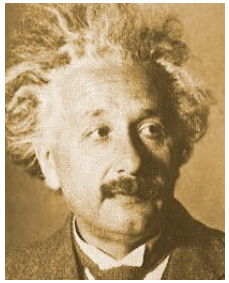

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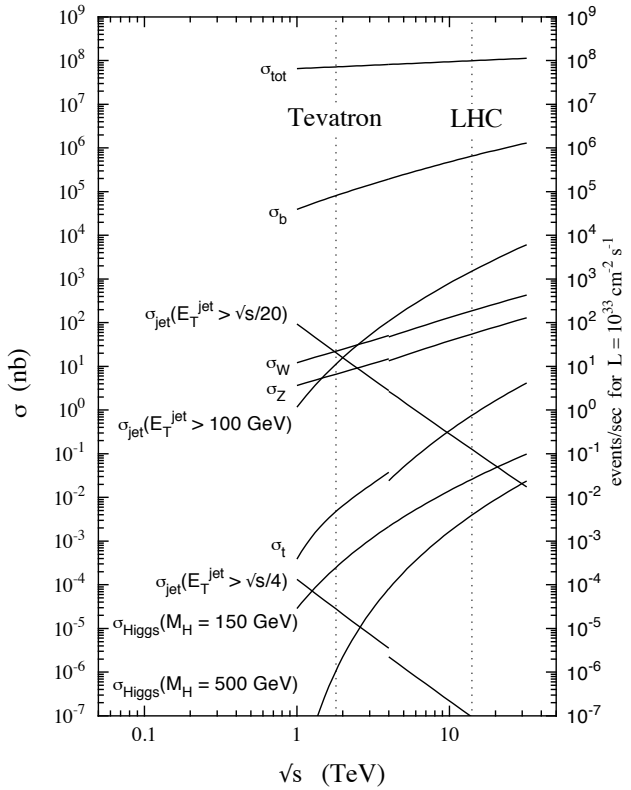
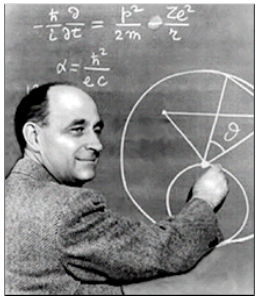
In short

- signal: everything new, exciting and rare
  background: yesterday's signal
- Standard Model: theory of background
  QCD: evil background theory trying to kill us
- jet: everything except for leptons/photons
  crucial: what is inside a jet $[q, g, b, \tau, W, H, t]$



Standard–Model effective theory

A brief history of Uli's favorite (Standard) model



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  (2 $\to$ 2) transition amplitude $\mathcal{A} \propto G_F E^2$
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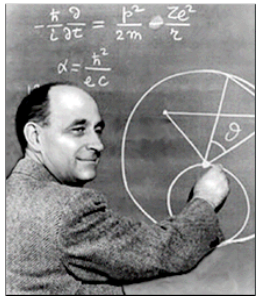

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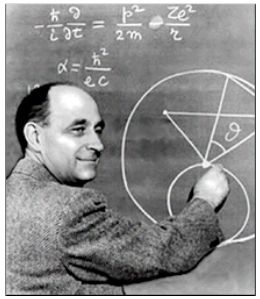

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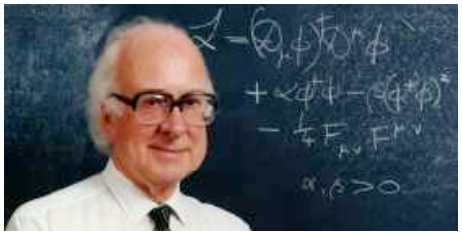

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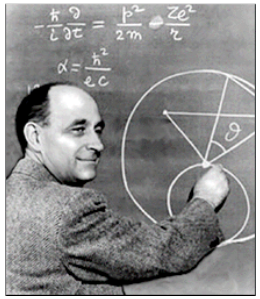

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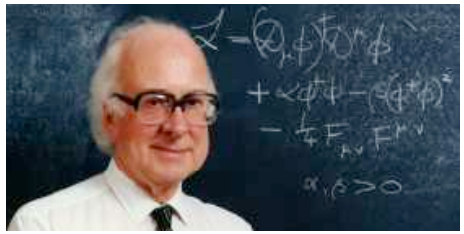

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  theory valid to high energy
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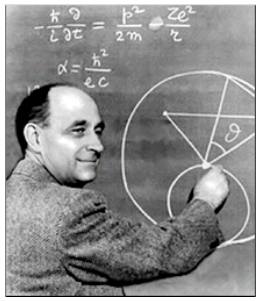

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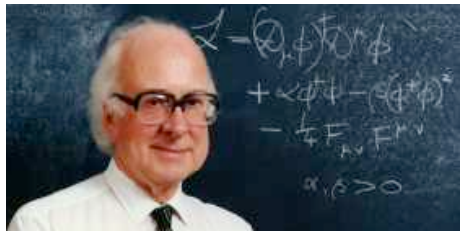

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- but experimentally incomplete — effective theory

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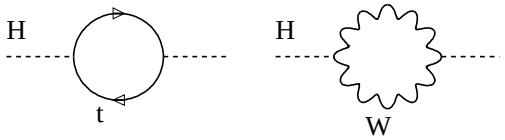

Theorists worrying

- Heisenberg: quantum corrections to Higgs mass... [$\Delta t\, \Delta E < 1$]
  ...imply effective field theory problem

$$m_H^2 \longrightarrow m_H^2 - \frac{g^2}{(4\pi)^2}\,\frac{3}{2}\,\frac{\Lambda^2}{m_W^2}\left[m_H^2 + 2m_W^2 + m_Z^2 - 4m_t^2\right] + \cdots$$

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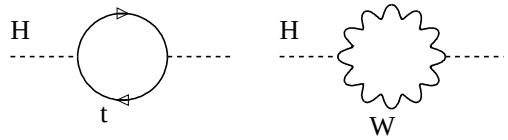
$\Rightarrow$ hierarchy problem — Higgs without stabilization incomplete

Standard–Model effective theory



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Starting from data which...

...indicates light Higgs [e-w precision data]
...indicates large cutoff to effective Standard Model

- easy solution: counter term — but against idea of symmetries
- or new physics at TeV scale: supersymmetry
  extra dimensions
  little Higgs
  composite Higgs, TopColor
  YourFavoriteNewPhysics...

$\Rightarrow$ beautiful concepts, contrived models

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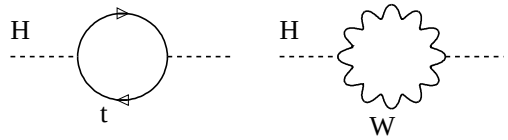

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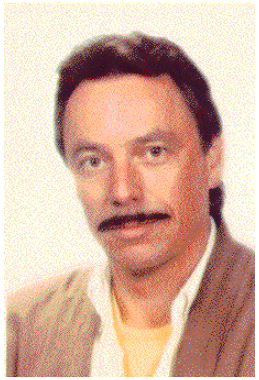

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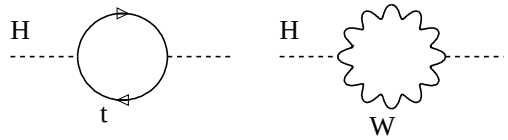

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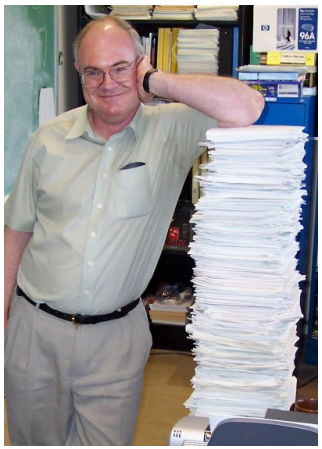
Uli: theoretists obviously have too much time

- there is always new physics at higher scales
- means for the LHC:

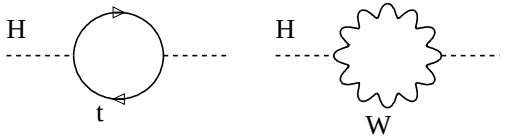
  find light Higgs?
  find new physics stabilizing Higgs mass??
  see dark–matter candidate???

$\Rightarrow$ imagining Uli's advice

let's instead find something totally unexpected!!



Things we have not (yet) seen: supersymmetry



Against Uli's advice: look for supersymmetry

- partner for each Standard Model particle
- cancellation because of different spins
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$\Rightarrow$ LHC: measure spectrum with missing energy

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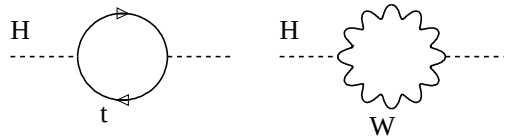

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Particle spectrum

		spin	d.o.f.	
fermion	f_L, f_R	1/2	1+1	
$\longrightarrow$ sfermion	$\tilde{f}_L$, $\tilde{f}_R$	0	1+1	
gluon	G_μ	1	n-2	
$\longrightarrow$ gluino	$\tilde{g}$	1/2	2	Majorana
gauge bosons	γ, Z	1	2+3	
Higgs bosons	h^0, H^0, A^0	0	3	
$\longrightarrow$ neutralinos	$\tilde{\chi}_i^0$	1/2	$4 \cdot 2$	dark matter
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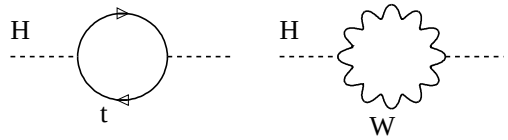

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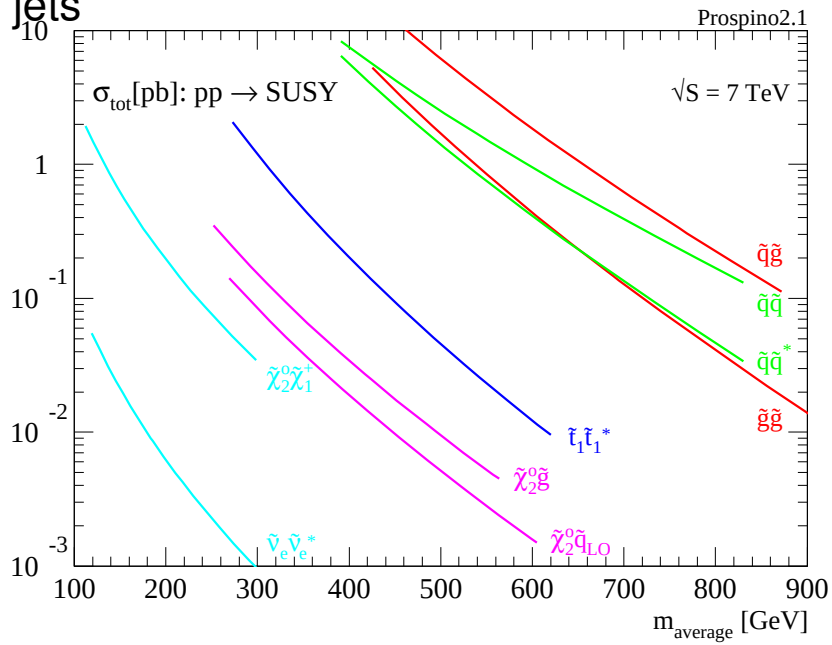
- production of squarks and gluinos
  cascade decay to DM candidate and jets
- general theme: try to survive QCD



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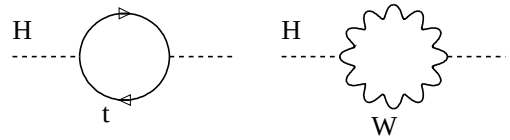

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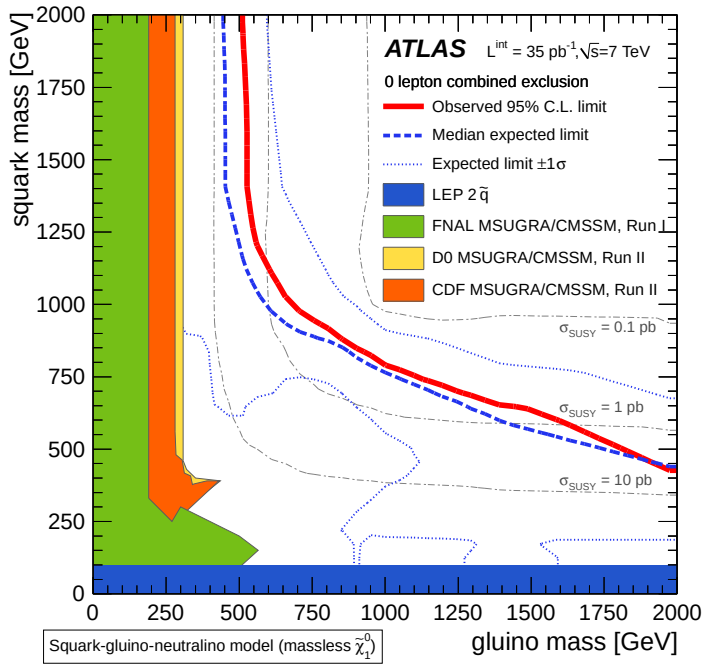

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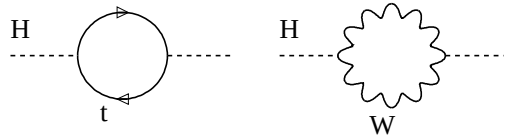

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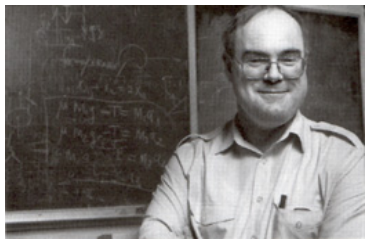
$\Rightarrow$ Uli recommending:

work on what we actually see!



Things we might have seen: Higgs

Standard Model Higgs searches

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- heavy Higgs: $H \to ZZ$ pretty boring
  light Higgs: tough and fun

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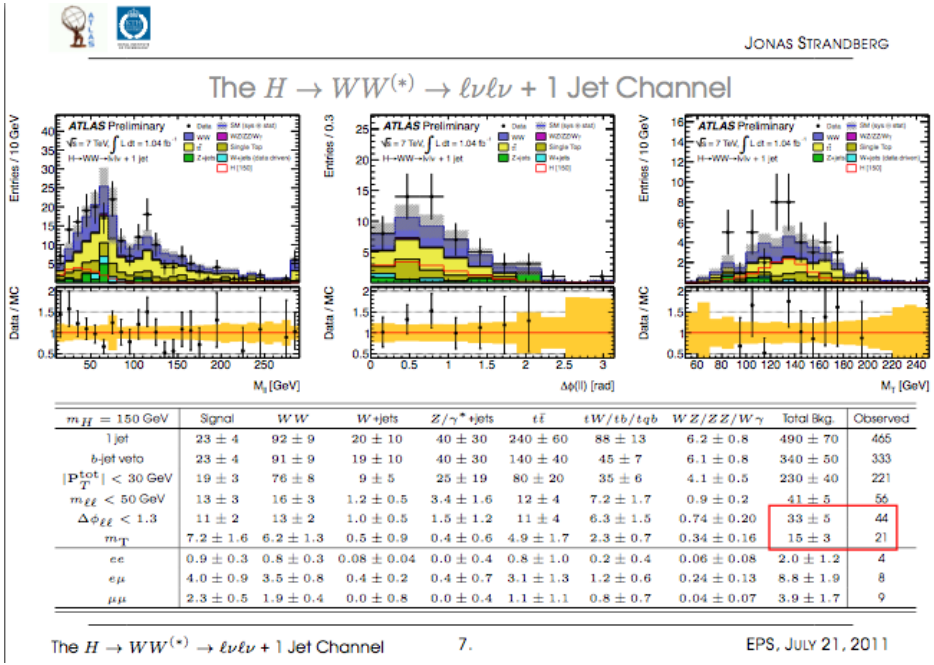

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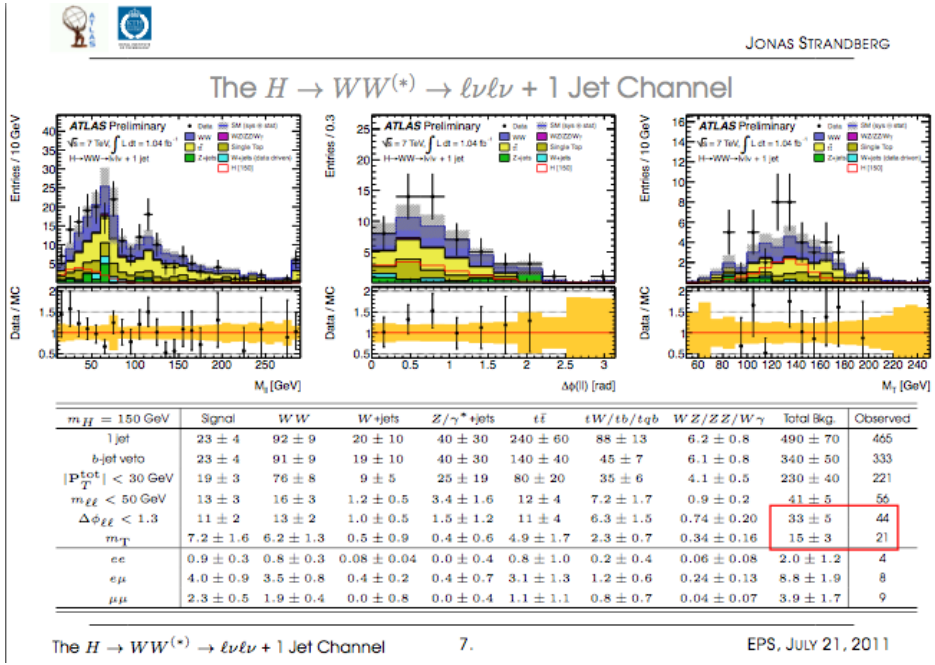
- since then kind of vanishing...



$m_H = 150$ GeV	Signal	WW	W+jets	Z/γ^*+jets	$t\bar{t}$	$tW/tb/tqb$	$WZ/ZZ/W\gamma$	Total Bkg.	Observed
1 jet	23 ± 4	92 ± 9	20 ± 10	40 ± 30	240 ± 60	88 ± 13	6.2 ± 0.8	490 ± 70	465
b-jet veto	23 ± 4	91 ± 9	19 ± 10	40 ± 30	140 ± 40	45 ± 7	6.1 ± 0.8	340 ± 50	333
$\lvert\mathbf{p}_T^{\text{tot}}\rvert < 30$ GeV	19 ± 3	76 ± 8	9 ± 5	25 ± 19	80 ± 20	35 ± 6	4.1 ± 0.5	230 ± 40	221
$m_{\ell\ell} < 50$ GeV	13 ± 3	16 ± 3	1.2 ± 0.5	3.4 ± 1.6	12 ± 4	7.2 ± 1.7	0.9 ± 0.2	41 ± 5	56
$\Delta\phi_{\ell\ell} < 1.3$	11 ± 2	13 ± 2	1.0 ± 0.5	1.5 ± 1.2	11 ± 4	6.3 ± 1.5	0.74 ± 0.20	33 ± 5	44
m_T	7.2 ± 1.6	6.2 ± 1.3	0.5 ± 0.9	0.4 ± 0.6	4.9 ± 1.7	2.3 ± 0.7	0.34 ± 0.16	15 ± 3	21
ee	0.9 ± 0.3	0.8 ± 0.3	0.08 ± 0.04	0.0 ± 0.4	0.8 ± 1.0	0.2 ± 0.4	0.06 ± 0.08	2.0 ± 1.2	4
$e\mu$	4.0 ± 0.9	3.5 ± 0.8	0.4 ± 0.2	0.4 ± 0.7	3.1 ± 1.3	1.2 ± 0.6	0.24 ± 0.13	8.8 ± 1.9	8
$\mu\mu$	2.3 ± 0.5	1.9 ± 0.4	0.0 ± 0.8	0.0 ± 0.4	1.1 ± 1.1	0.8 ± 0.7	0.04 ± 0.07	3.9 ± 1.7	9

Things we might have seen: Higgs

Standard Model Higgs searches

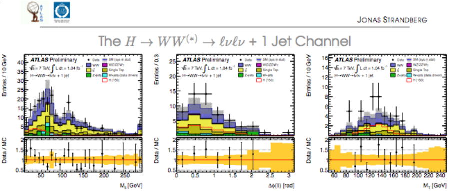
– remember: we know everything about it
  except: does it exist?
  and what is its mass?
– heavy Higgs: $H \to ZZ$ pretty boring
  light Higgs: tough and fun
– decays $H \to b\bar{b}, \tau^+\tau^-, W^+W^-$
– production $pp \to H + 0, 1, 2$ jets [Baur & Glover]

$\Rightarrow$ Higgs phenomenology really all QCD...

LHC results

– let me focus on EPS 2011
  very boring until Friday
  then very exciting
– since then kind of vanishing...

$\Rightarrow$ more good advice by Uli:
  experimenters are smart people, give them time!



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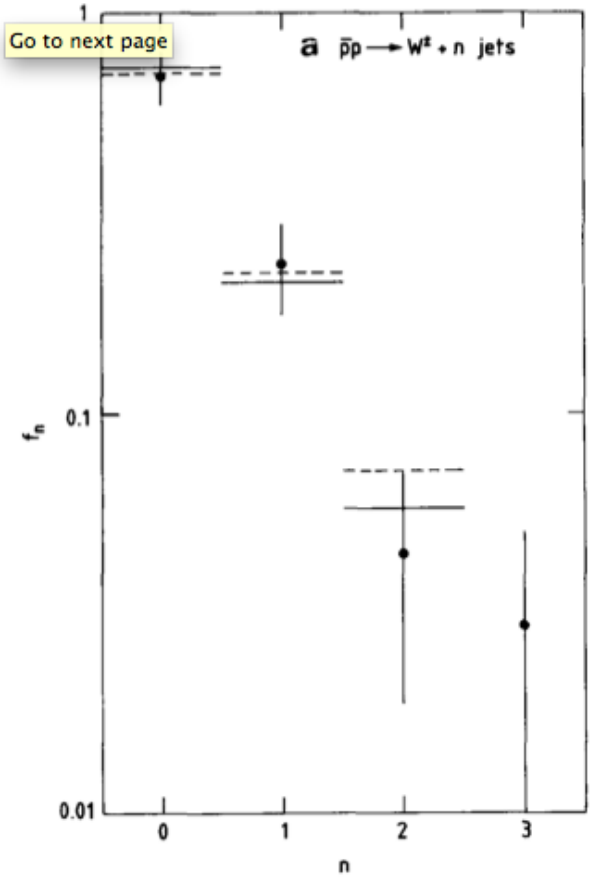
The $H \to WW^{(*)} \to \ell\nu\ell\nu$ + 1 Jet Channel 7. EPS, JULY 21, 2011

Jets we do see!

Exclusive jet counting [challenge to LHC-QCD]

- Peskin & Schroeder: soft photons with Poisson s
- UA2 to ATLAS: staircase scaling [Ellis, Kleiss, Stirling]

$$R_{(n+1)/n} = \frac{\sigma_{n+1}}{\sigma_n} = \text{const}$$



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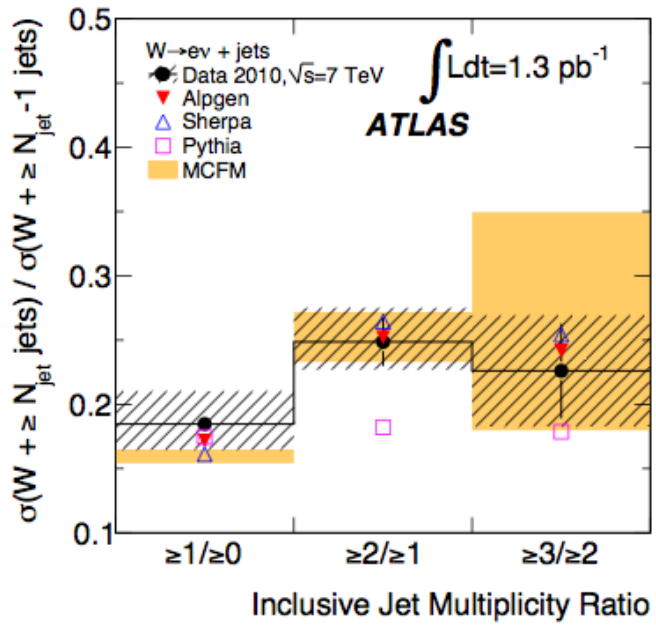

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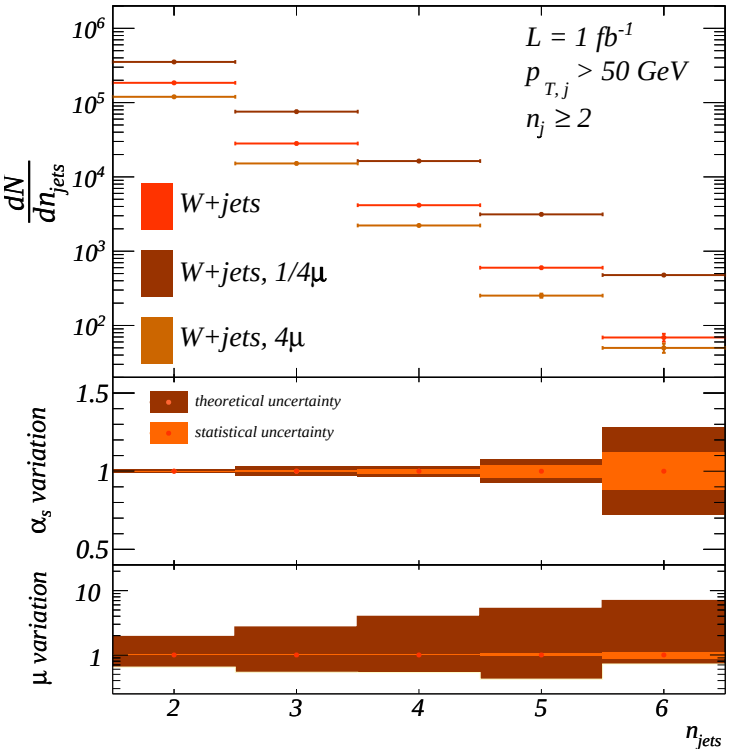
  and predict the WBF Higgs veto rate



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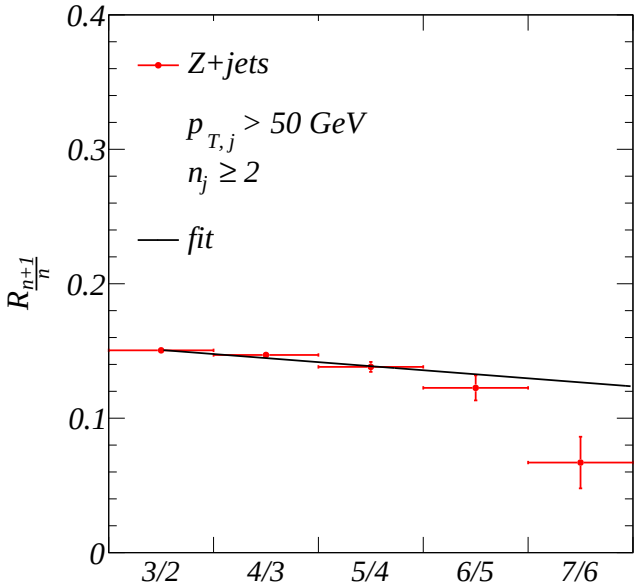

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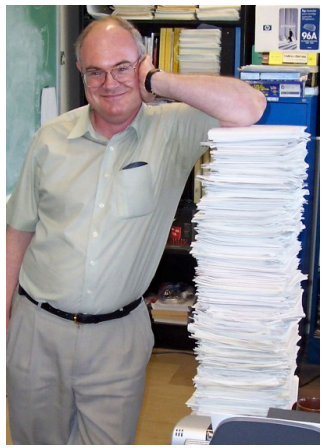
$\Rightarrow$ Uli?
nice calculation, but we really knew that all along!



Fat jets

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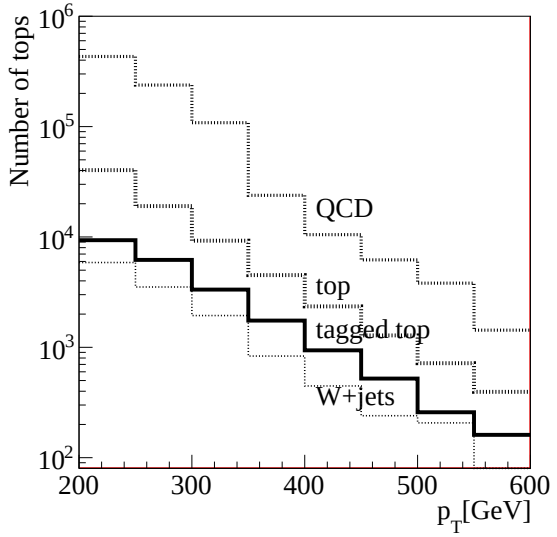

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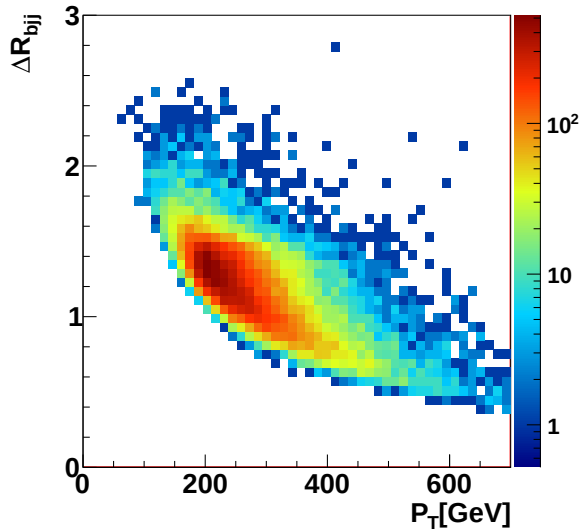

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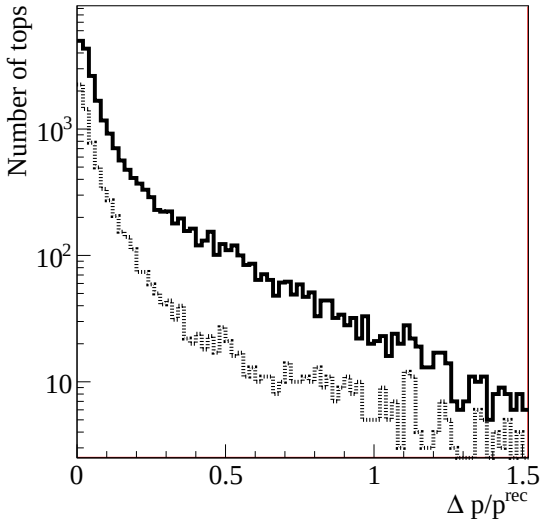

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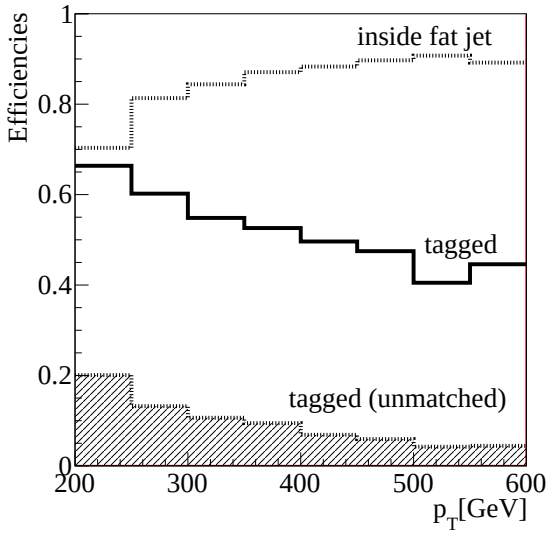

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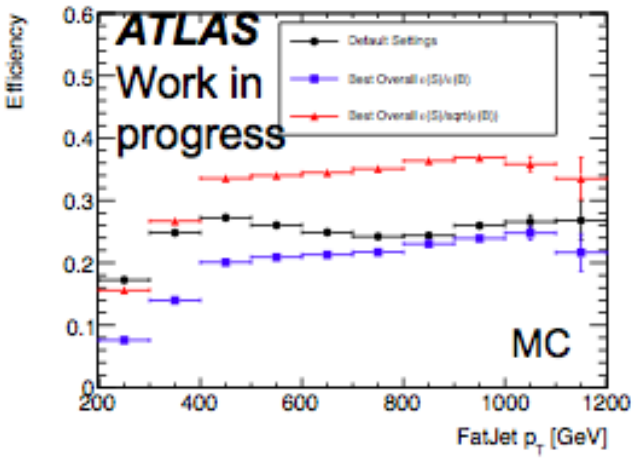

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$\Rightarrow$ I think Uli liked that

```
TP: So if you are just doing what you like - what do you like these days?
   Any cool new physics models?  Some more top pair production?  ...

UB: Yes, I do top production.  And what I call electroweak jets ...

TP: Electroweak jets - is that something I can read about?

UB: No.  This is the biggest secret in the universe.  (8/11/2010)
```

Thank you, Uli

Uli's final advice:

and for next time update all these old experimental plots!!