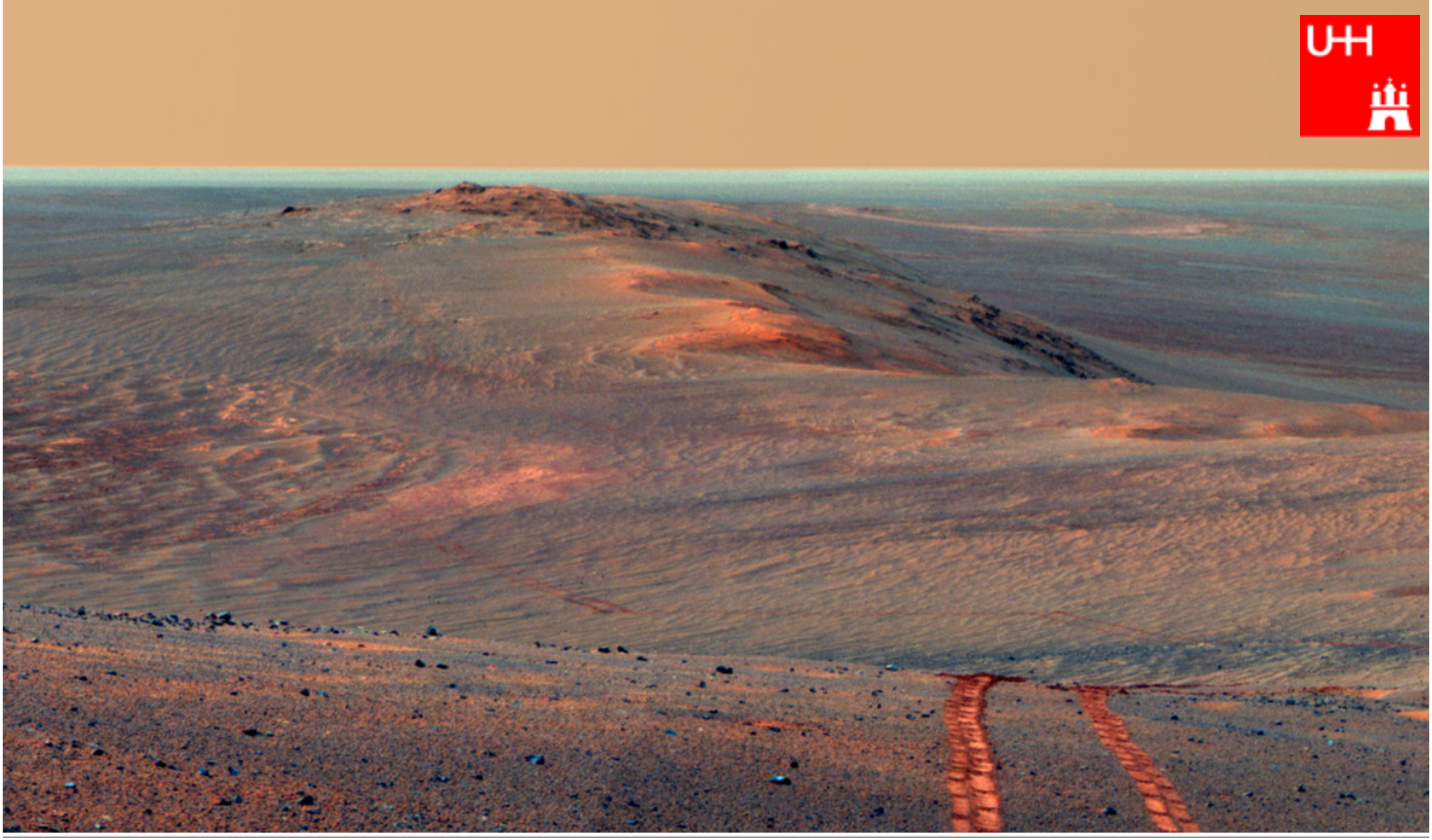


Physics Intro
JetMet workshop

Peter Schleper

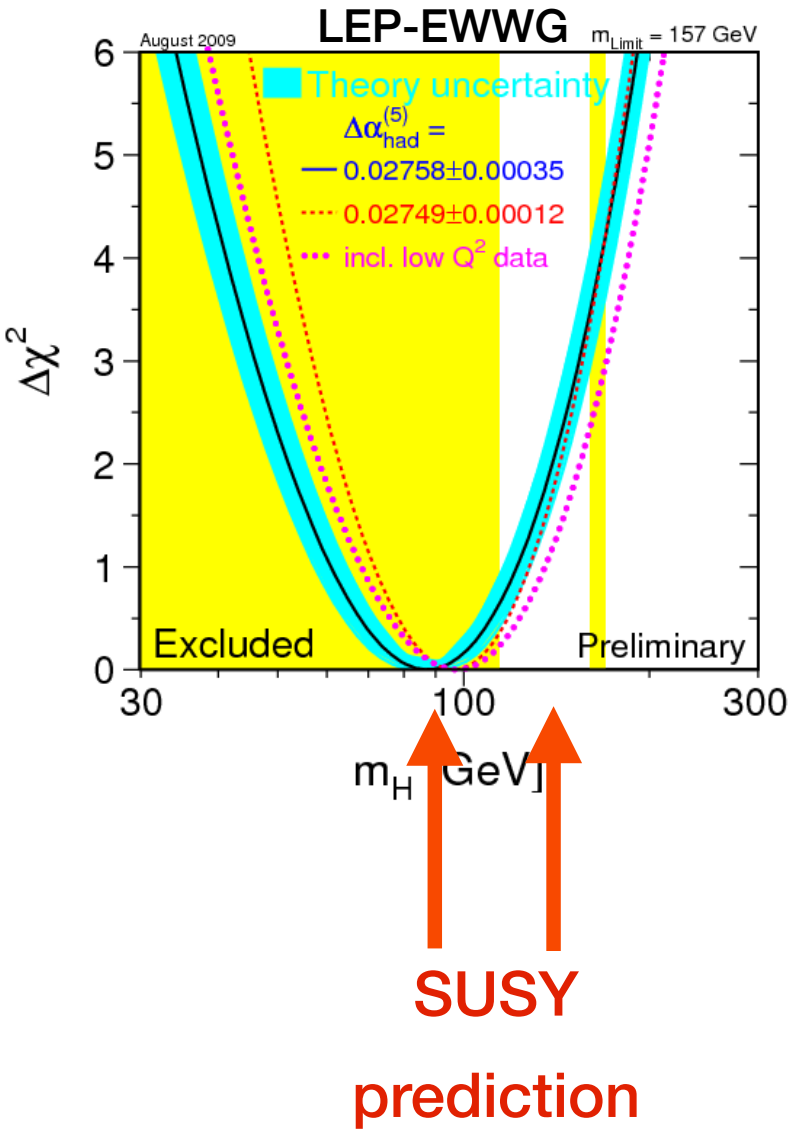
peter.schleper@physik.uni-hamburg.de

Universität Hamburg

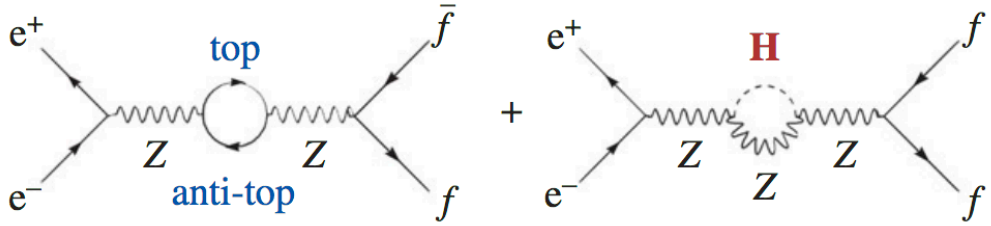
15.4.2019

https://mars.nasa.gov/news/8414/six-things-to-know-about-nasas-opportunity-rover/

The Quest for Blue Band Plots



Higgs mass as predicted from SM & LEP-data



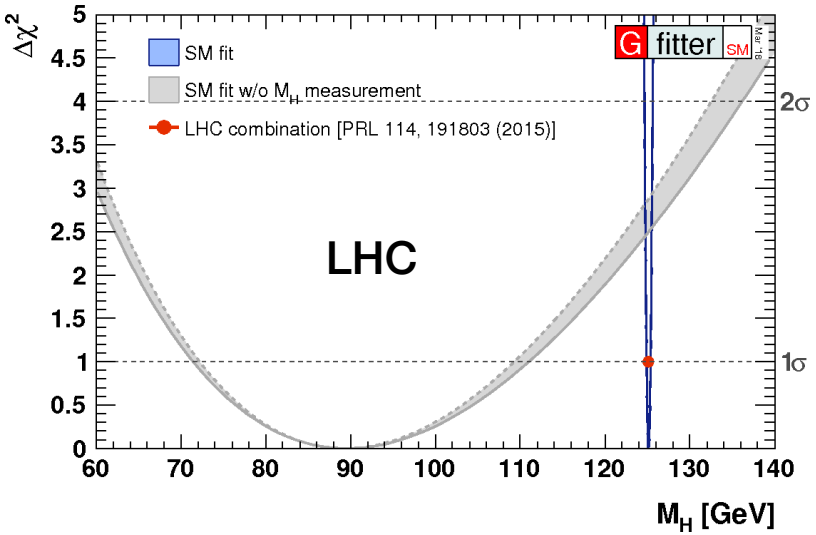
Blue band plots:

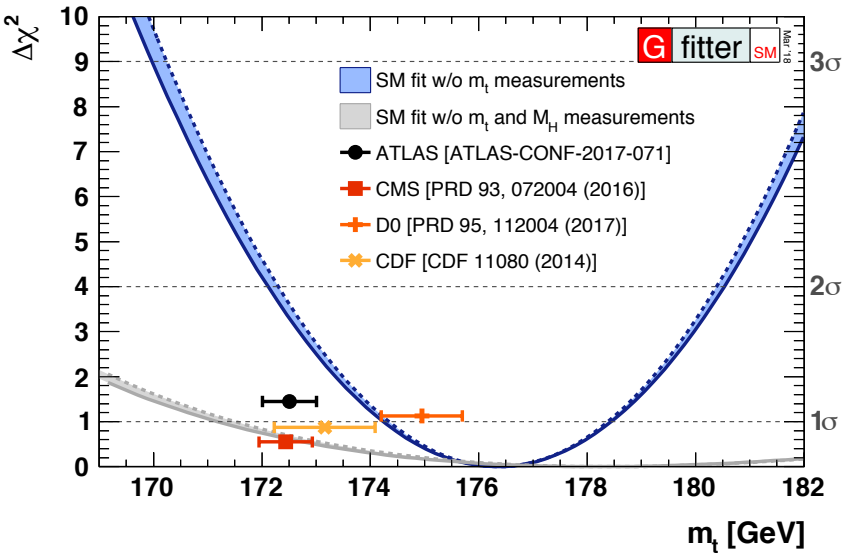
➜ constraints from precision data on multi-dimensional space of possibilities

➜ often at edge of what can be done / discovered

Blue Band Plots

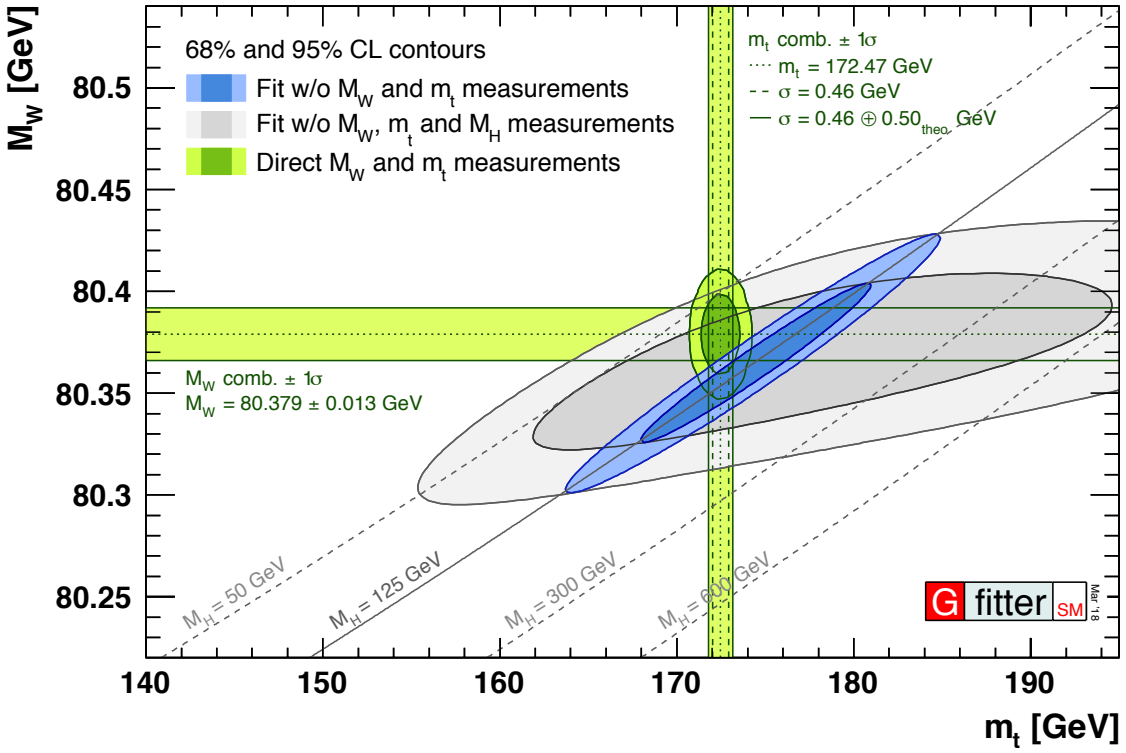
LHC direct mass measurements





yes! ➜ SUSY predicted it !

SM also ok … ➜



Blue Band Candidates

LHC direct mass measurements:

➜ top and W ➜ overconstrain electroweak sector

Higgs sector:

➜ overconstrain couplings ➜ BSM contributions

vacuum stability

➜ BSM ?

Dark Matter:

➜ cosmology constrains Ω_{DM} ➜ $\sigma(XX \rightarrow SM)$ - mass relation

➜ direct detection would fix $\sigma(Xp \rightarrow Xp)$

➜ LHC discovery would fix $\sigma(SM \rightarrow X)$

g-2 muon:

➜ upper bound on new physics ?

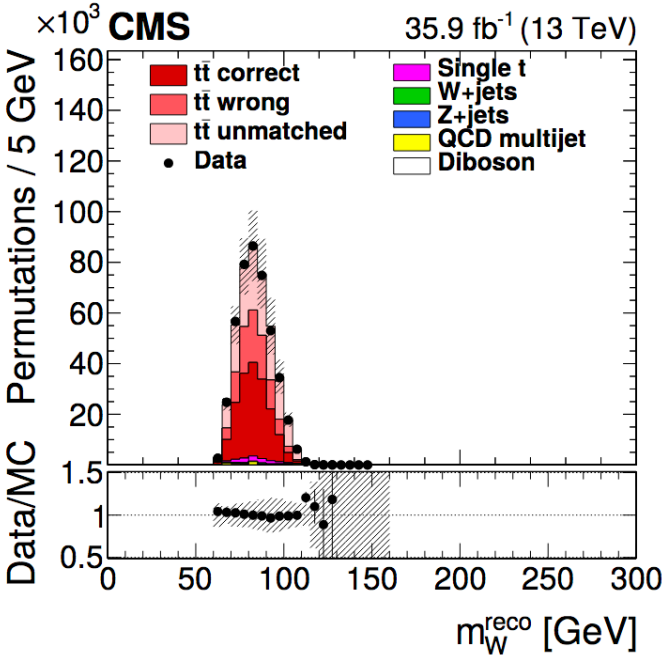
LHC BSM searches:

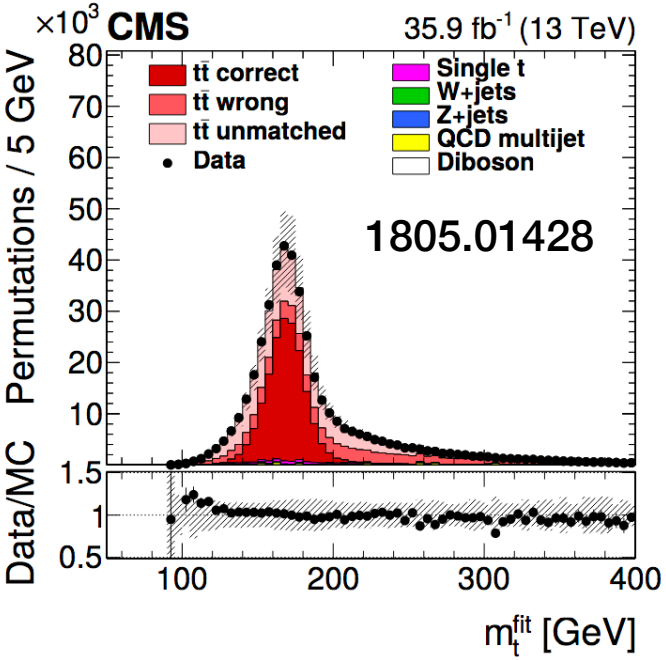
➜ lower bound or breakthrough

R_K lepton universality (LHCb)

… add your favourite …

Top Mass Measurement

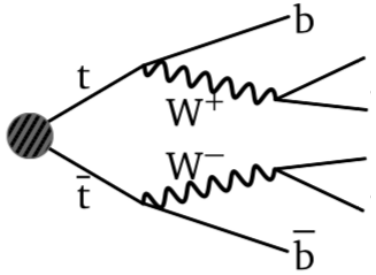


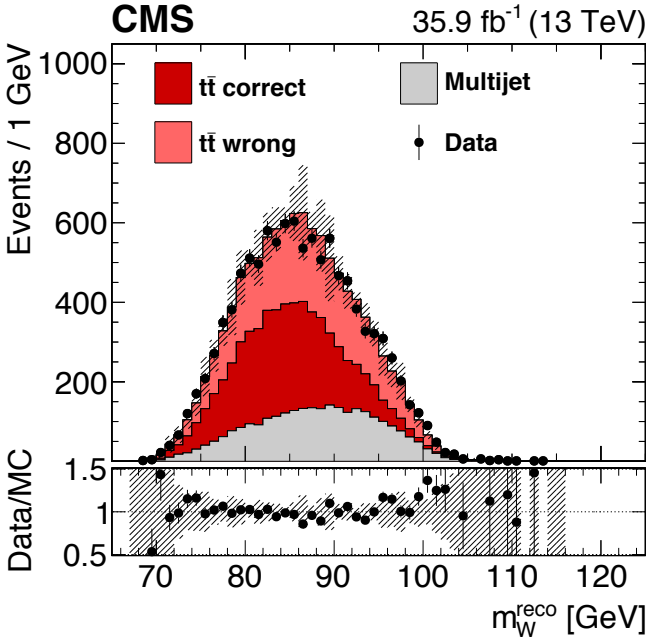


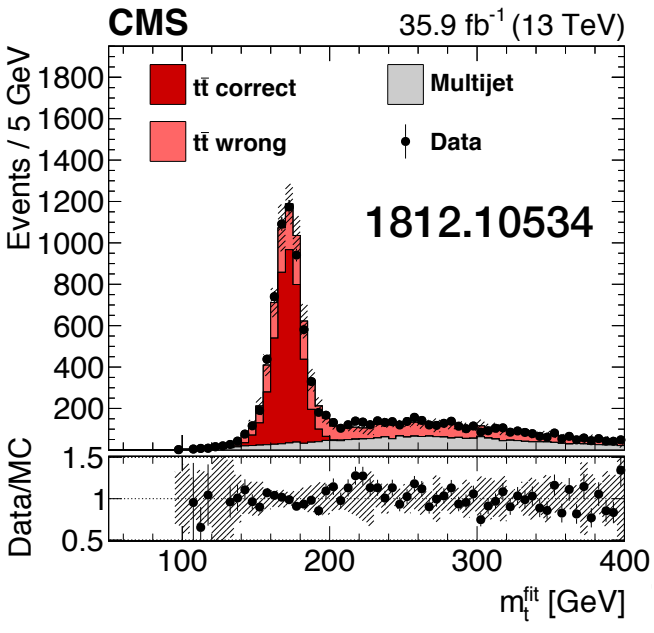
tt ➜ bb + l + qq

use $M_{qq}=M_W$, MET, $M_t=M_t$

template fits for JES and M_t







tt ➜ bb + qq + qq

same technique

no MET dependence

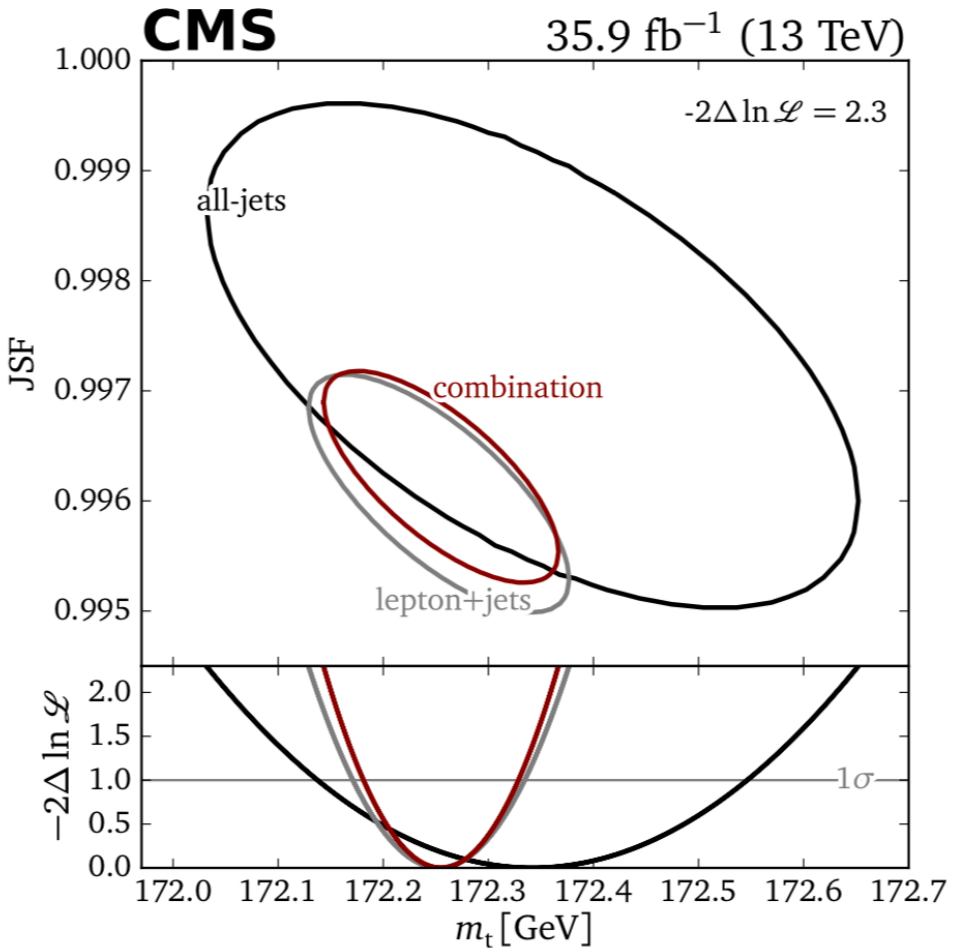
some QCD bkg

higher jet thresholds

Top Mass Measurement

$$m_t^{\text{hyb}} = 172.26 \pm 0.07\,(\text{stat+JSF}) \pm 0.61\,(\text{syst})\ \text{GeV},$$

$$\text{JSF}^{\text{hyb}} = 0.996 \pm 0.001\,(\text{stat}) \pm 0.007\,(\text{syst})$$



	δm_t^{hyb} [GeV]		
	all-jets	ℓ+jets	combination
Experimental uncertainties			
Method calibration	0.06	0.05	0.03
JEC (quad. sum)	0.15	0.18	0.17
– Intercalibration	−0.04	+0.04	+0.04
– MPFInSitu	+0.08	+0.07	+0.07
– Uncorrelated	+0.12	+0.16	+0.15
Jet energy resolution	−0.04	−0.12	−0.10
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– light quarks (uds)	+0.07	+0.06	+0.07
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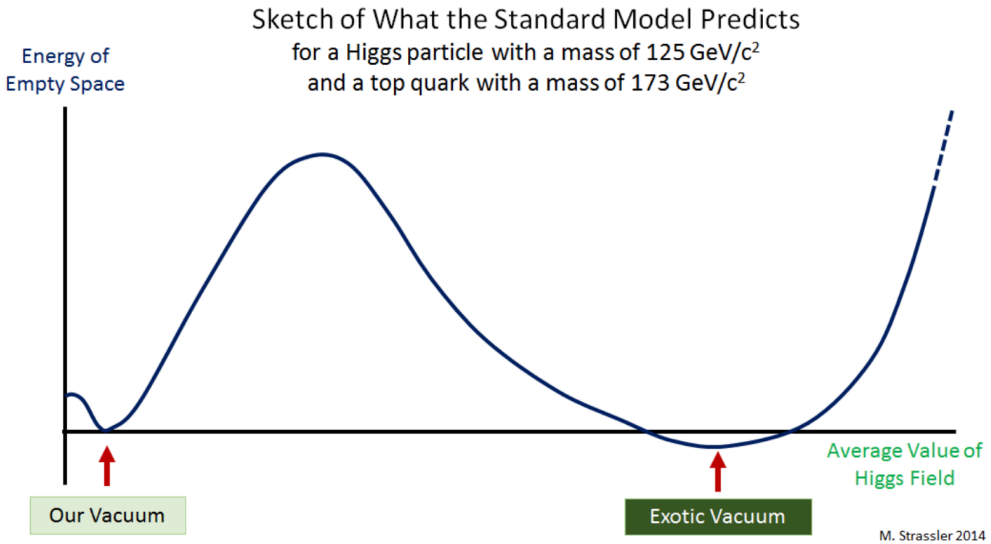
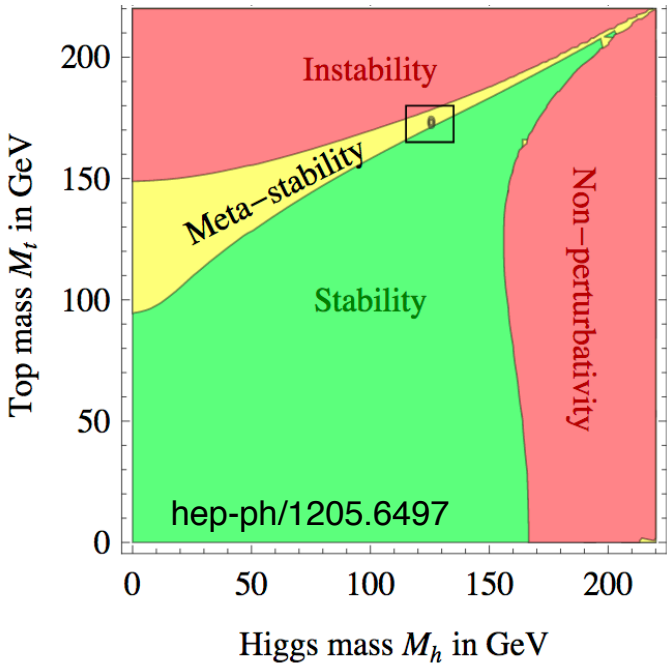
– b frag. Bowler–Lund	−0.07	−0.05	−0.05
– b frag. Peterson	−0.05	+0.04	−0.02
– semileptonic b hadron decays	−0.03	+0.10	−0.04
...			

Vacuum Stability

running higgs couplings (λ) ➜ higgs potential



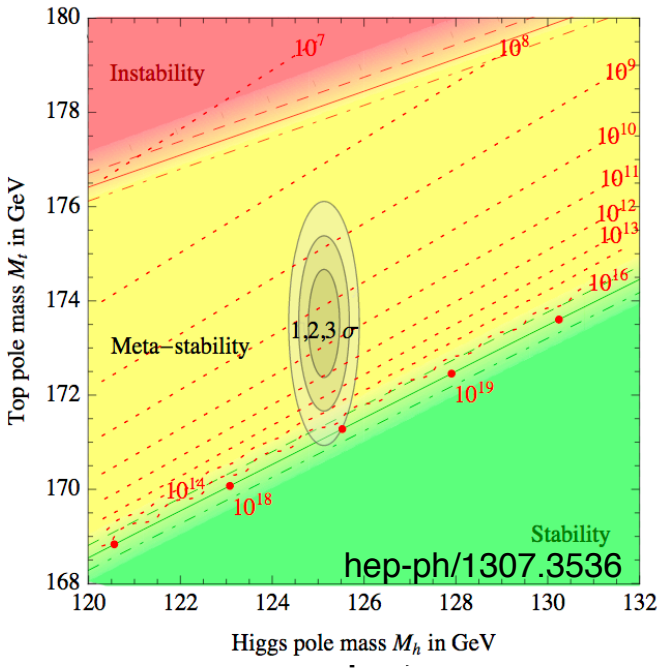


cosmology with LhC data

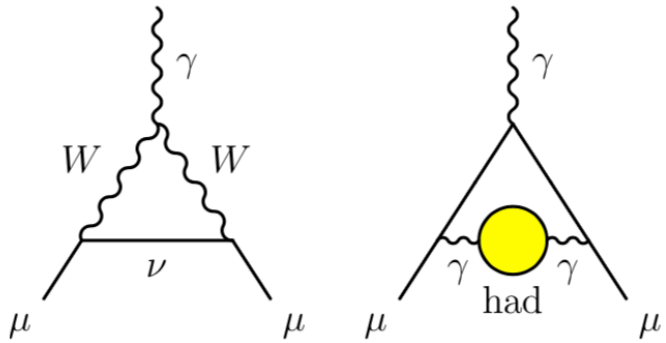
tunneling from current to true vacuum

➜ was: constraint on SM top and higgs mass

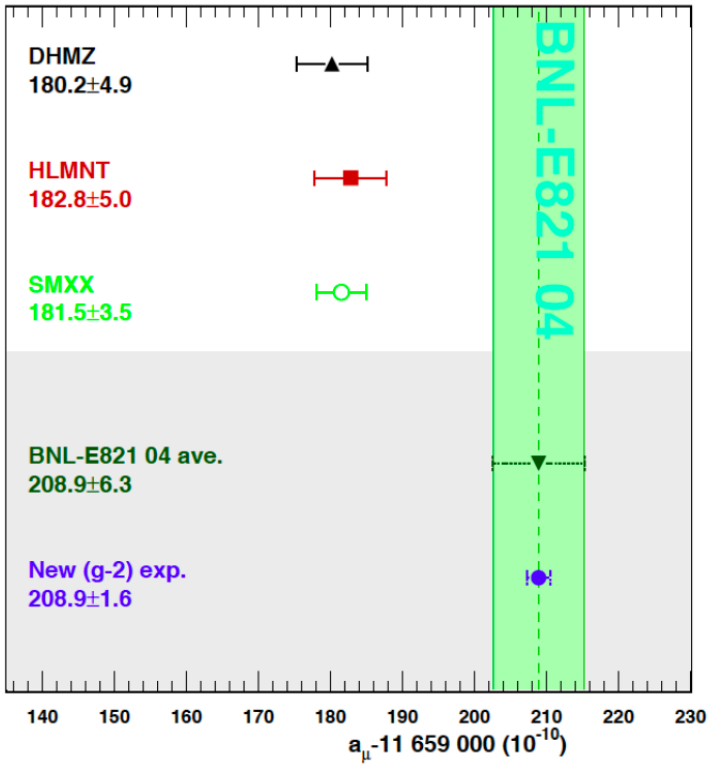
➜ is: constraint on BSM



μ anomalous magnetic moment $a_\mu = (g-2)/2$



T. Blum et al. (arXiv:1311.2198)



$$a_\mu^{exp} - a_\mu^{SM} = (268 \pm 63 \pm 43) \cdot 10^{-11}$$

$$W, Z, H: \; 253 \cdot 10^{-11} = c \left(\frac{M_\mu}{M_W} \right)^2$$

Deviation SM - Experiment:

3.5 σ

New experiments at Fermilab and J-PARC

➜ aim for factor 2 to 4 improvement

➜ would correspond 5 σ

New theory calculations

➜ hadronic contribution in SM

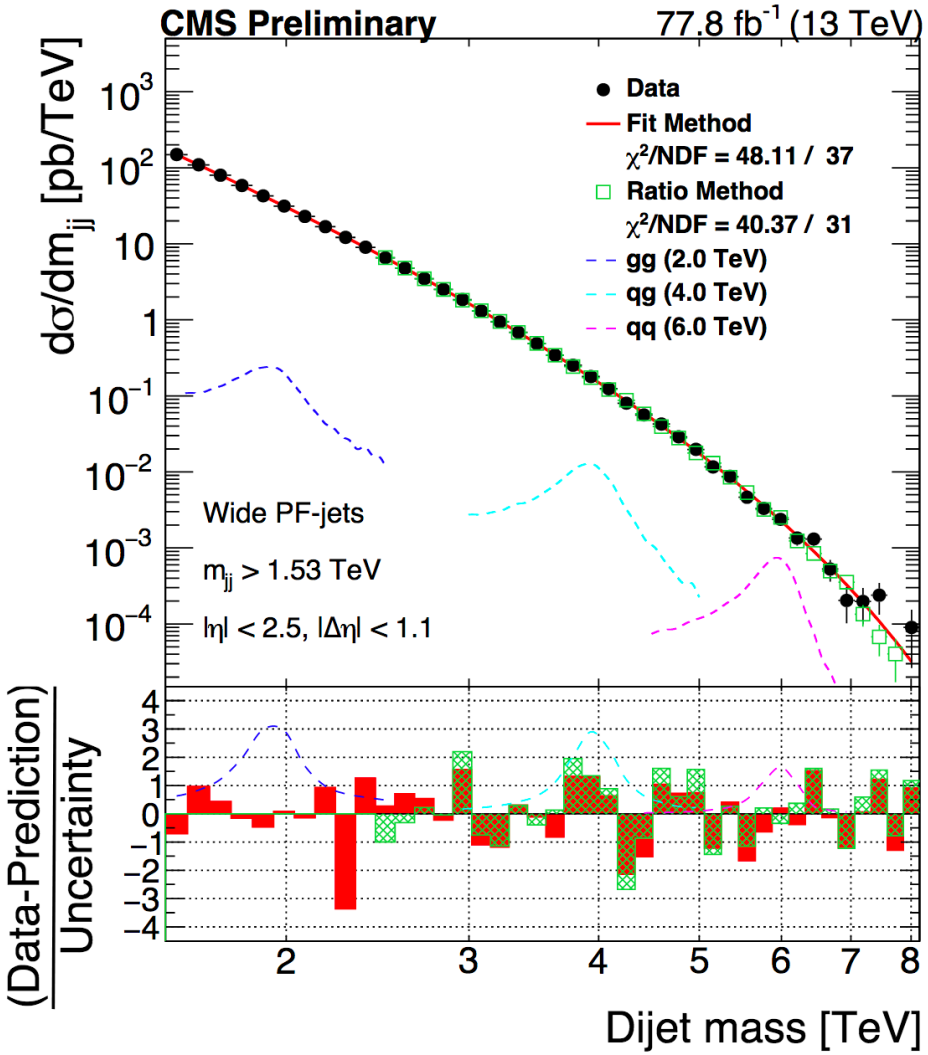
Hint to new physics ?

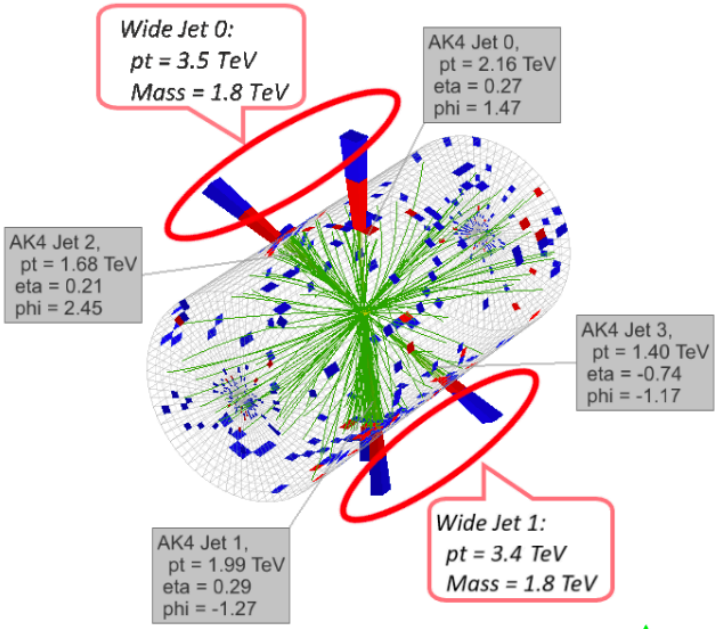
➜ low mass SUSY with SM coupling ?

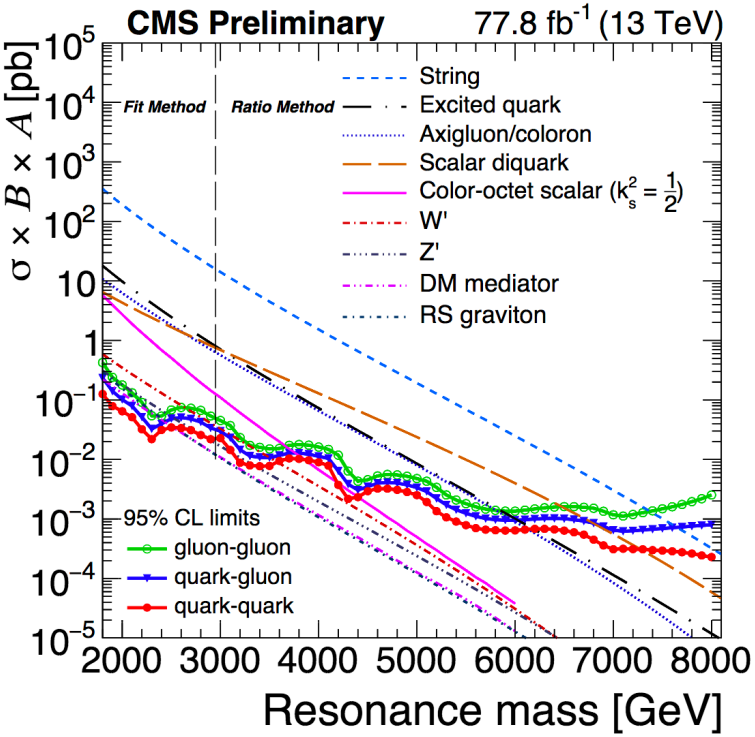
➜ new physics with small coupling ?

$$SUSY: \; \pm 130 \cdot 10^{-11} \cdot \left(\frac{100\,GeV}{M_{SUSY}} \right)^2 \tan\beta$$

High Pt Physics







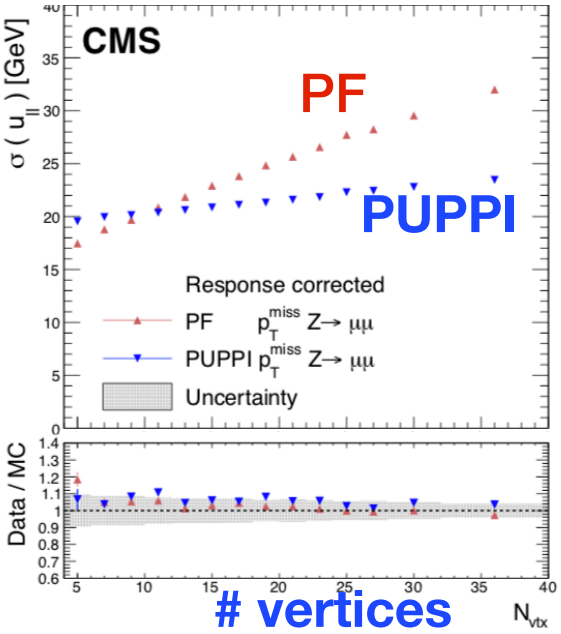
CMS @ High Luminosity: Systematics

Assumed / hoped for uncertainties as used for Higgs Projections

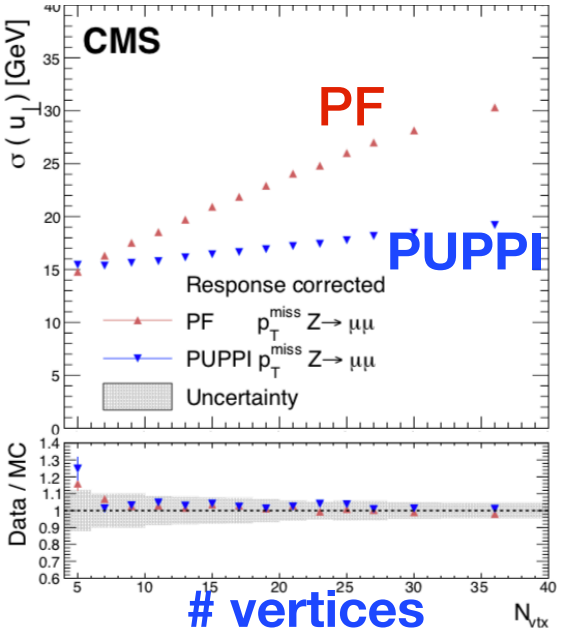
Source	Component	Run 2 uncertainty	Projection minimum uncertainty
Muon ID		1–2%	0.5%
Electron ID		1–2%	0.5%
Photon ID		0.5–2%	0.25–1%
Hadronic tau ID		6%	2.5%
Jet energy scale	Absolute	0.5%	0.1–0.2%
	Relative	0.1–3%	0.1–0.5%
	Pileup	0–2%	Same as Run 2
	Method and sample	0.5–5%	No limit
	Jet flavour	1.5%	0.75%
	Time stability	0.2%	No limit
Jet energy res.		Varies with p_T and η	Half of Run 2
MET scale		Varies with analysis selection	Half of Run 2
b-Tagging	b-/c-jets (syst.)	Varies with p_T and η	Same as Run 2
	light mis-tag (syst.)	Varies with p_T and η	Same as Run 2
	b-/c-jets (stat.)	Varies with p_T and η	No limit
	light mis-tag (stat.)	Varies with p_T and η	No limit
Integrated lumi.		2.5%	1%

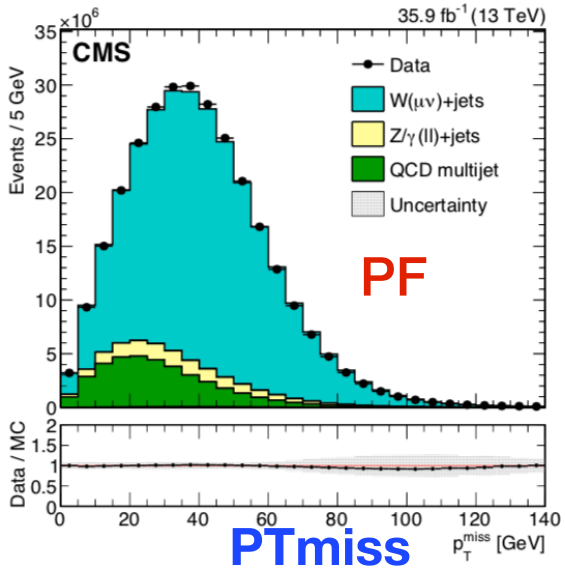
Pileup mitigation

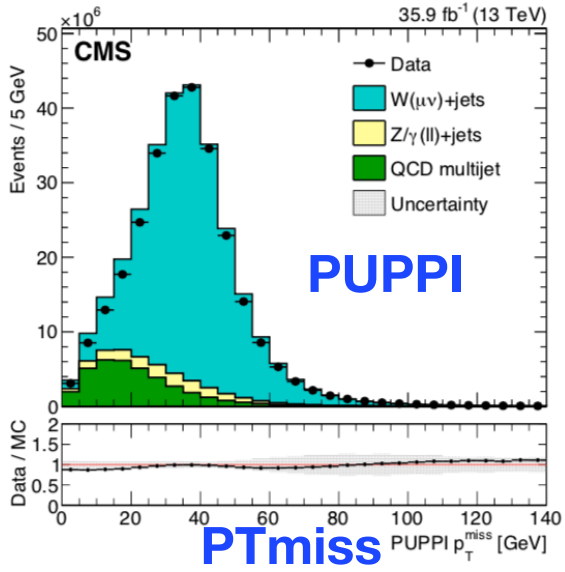
MET-parallel resolution



MET-perp resolution







Particle flow

Charged Hadron Substraction

PUPPI

pileup per particle identification

for neutral particles: weight based on local environment

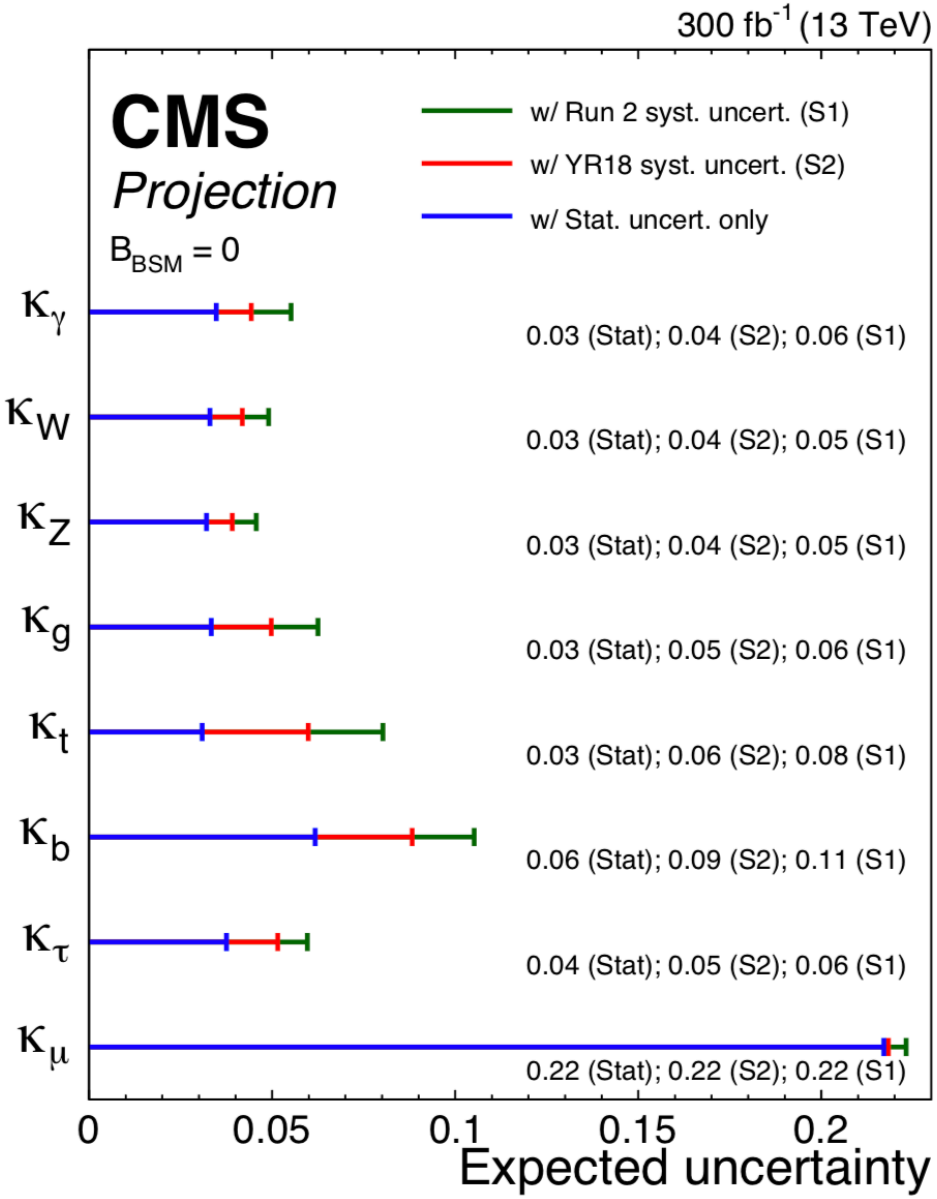
➜ much less dependent on PU

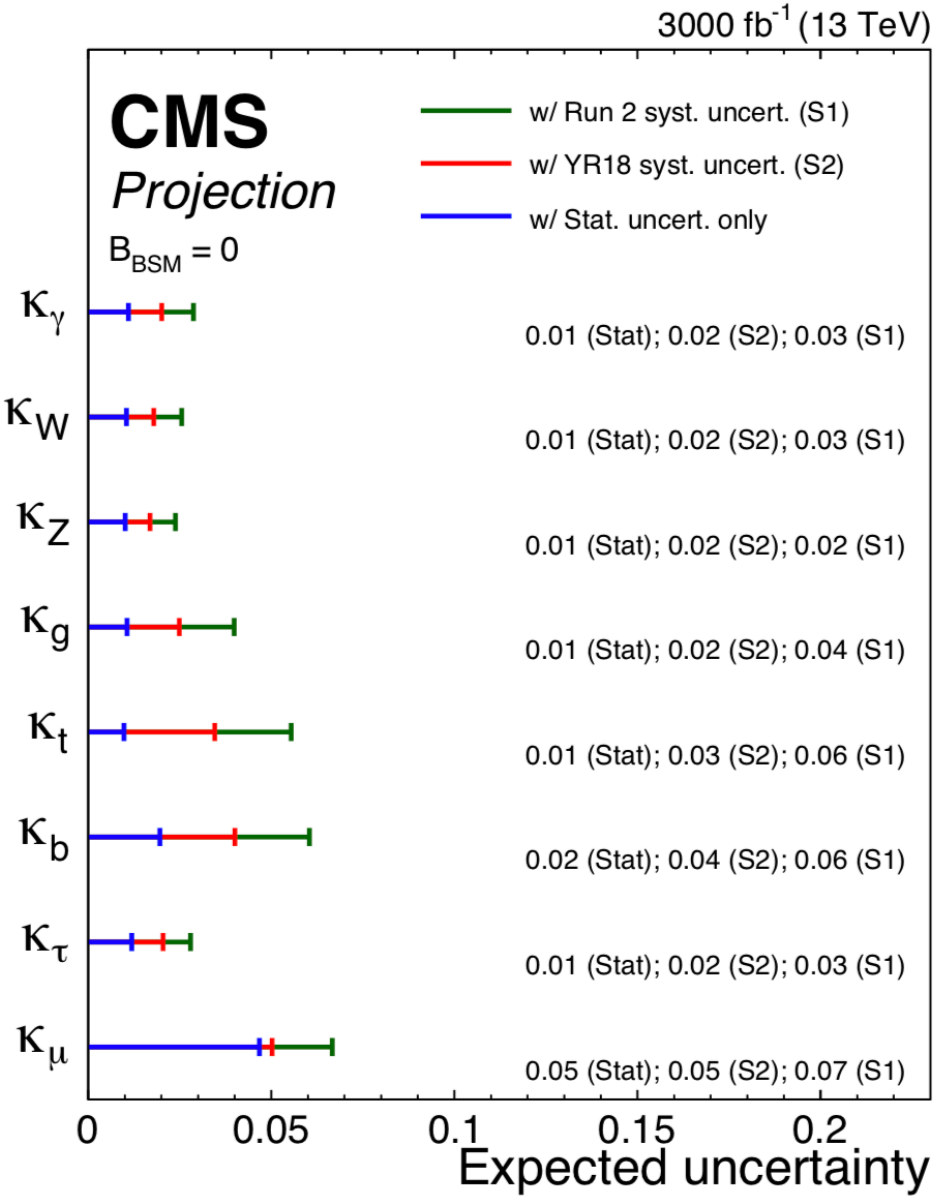
➜ better resolution for MET and PT-jet

➜ modifies jet shapes, …, ?

Higgs future @ HL-LHC

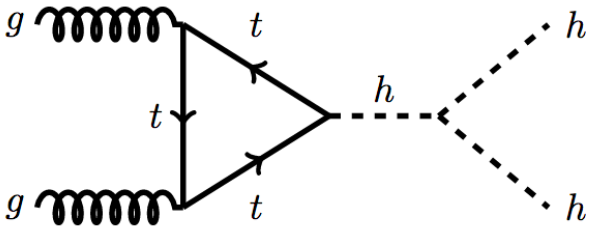
Statistics helps !

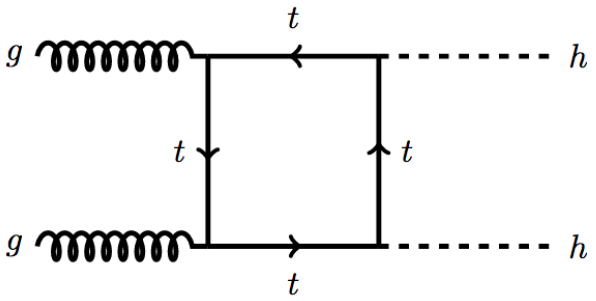


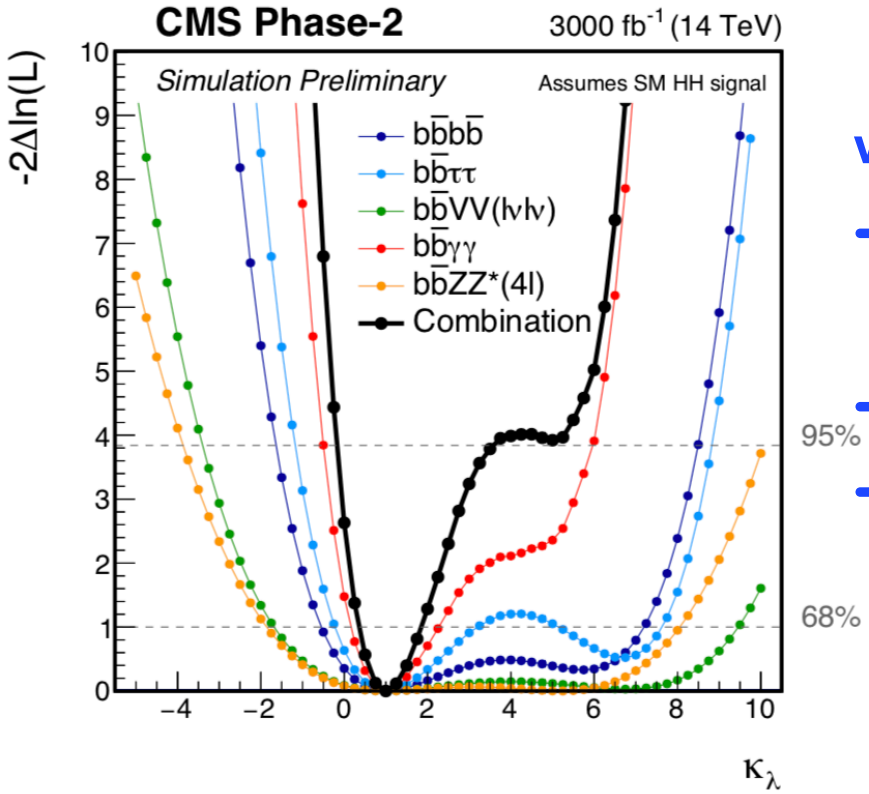


Higgs selfcoupling

SM prediction: HHH coupling and HHHH coupling







very sensitive to low-pt thresholds for b-jets

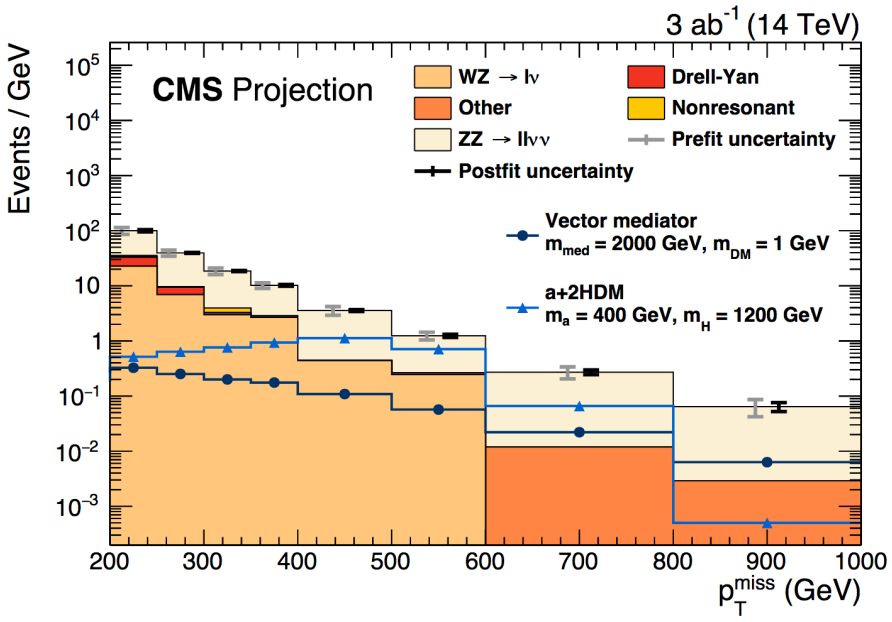
➜ 45 GeV

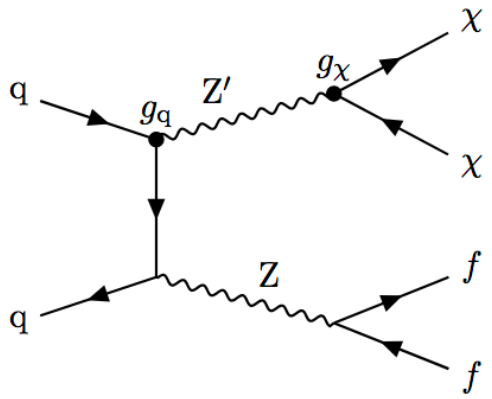
➜ for SM: 2,6 σ significance of observation

➜ BSM: could be much different

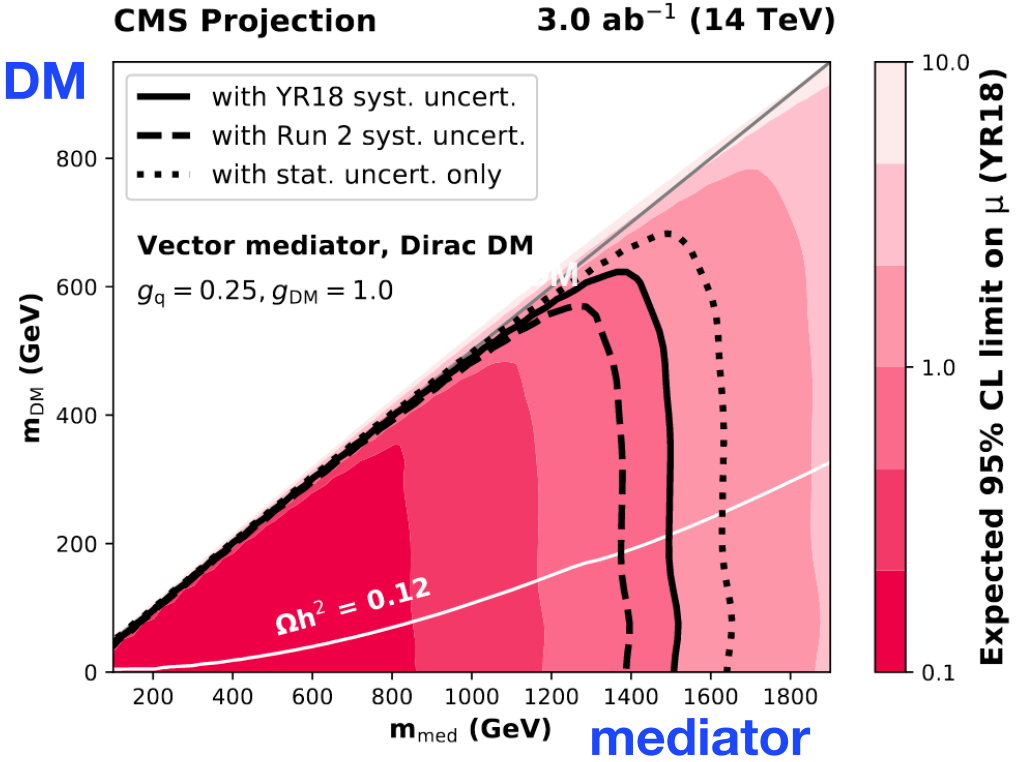
Dark Matter future @ HL-LHC

e.g.: SUSY: > 100 parameters, many ways to modify DM production
many combinations of parameters allow for correct relic density
simplified models: SM - mediator - DM





CMS PAS FTR-18-007

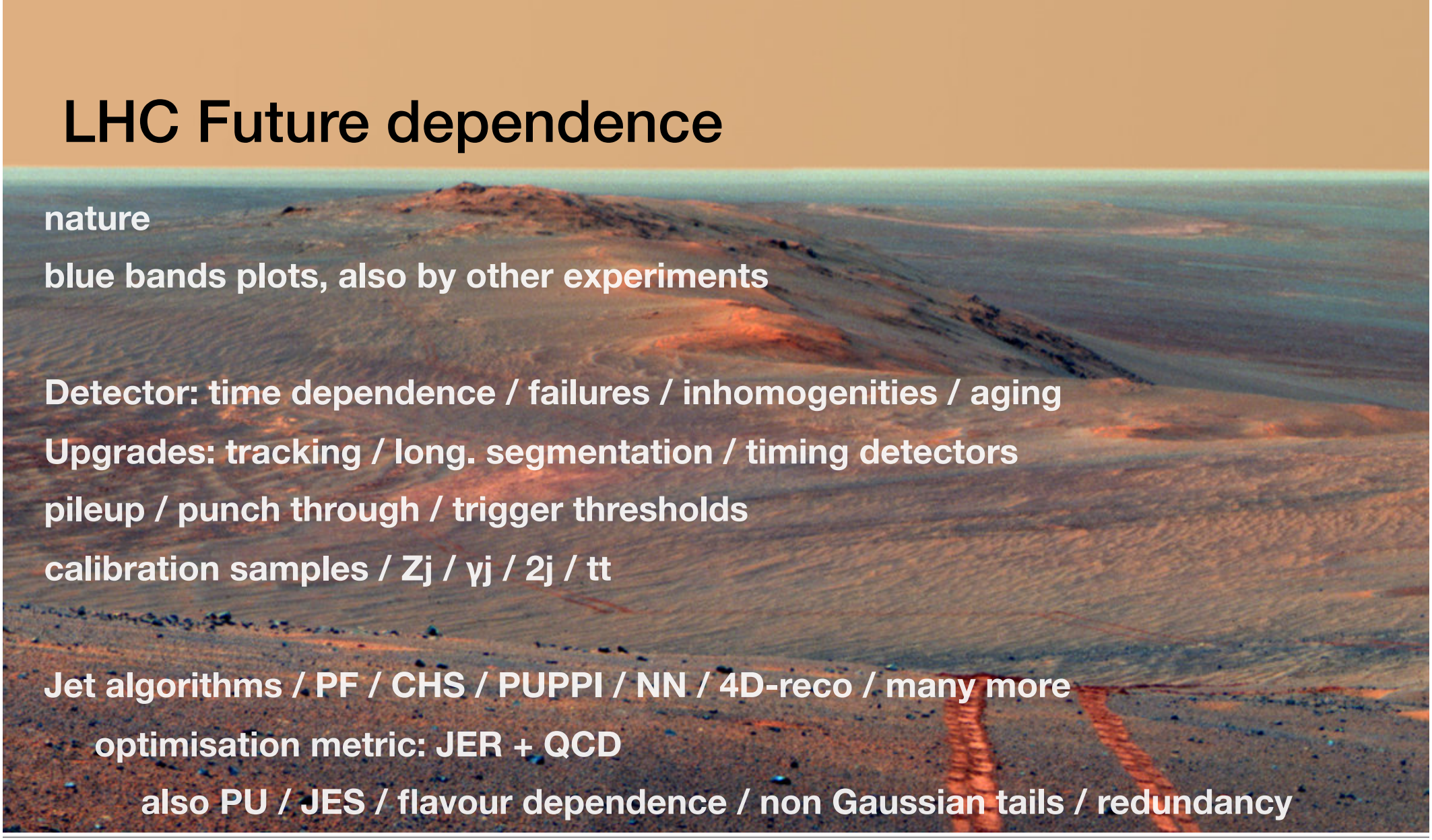


Tail of PTmiss distr.

➜ PU / resolution/ systematics

factor 2.3 in mass relative to run-2

LHC Future dependence



nature

blue bands plots, also by other experiments

Detector: time dependence / failures / inhomogenities / aging

Upgrades: tracking / long. segmentation / timing detectors

pileup / punch through / trigger thresholds

calibration samples / Zj / γj / 2j / tt

Jet algorithms / PF / CHS / PUPPI / NN / 4D-reco / many more

optimisation metric: JER + QCD

also PU / JES / flavour dependence / non Gaussian tails / redundancy

Top Mass Measurement

	δm_t^{hyb} [GeV]		
	all-jets	ℓ+jets	combination
Experimental uncertainties			
Method calibration	0.06	0.05	0.03
JEC (quad. sum)	0.15	0.18	0.17
– Intercalibration	−0.04	+0.04	+0.04
– MPFInSitu	+0.08	+0.07	+0.07
– Uncorrelated	+0.12	+0.16	+0.15
Jet energy resolution	−0.04	−0.12	−0.10
b tagging	0.02	0.03	0.02
Pileup	−0.04	−0.05	−0.05
All-jets background	0.07	−	0.01
All-jets trigger	+0.02	−	+0.01
ℓ+jets background	−	+0.02	−0.01
Modeling uncertainties			
JEC flavor (linear sum)	−0.34	−0.39	−0.37
– light quarks (uds)	+0.07	+0.06	+0.07
– charm	+0.02	+0.01	+0.02
– bottom	−0.29	−0.32	−0.31
– gluon	−0.13	−0.15	−0.15
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– b frag. Peterson	−0.05	+0.04	−0.02
– semileptonic b hadron decays	−0.03	+0.10	−0.04
PDF	0.01	0.02	0.01
Ren. and fact. scales	0.04	0.01	0.01
ME/PS matching	+0.24	−0.07	+0.07
ME generator	−	+0.20	+0.21
ISR PS scale	+0.14	+0.07	+0.07
FSR PS scale	+0.18	+0.13	+0.12
Top quark p_T	+0.03	−0.01	−0.01
Underlying event	+0.17	−0.07	−0.06
Early resonance decays	+0.24	−0.07	−0.07
CR modeling (max. shift)	−0.36	+0.31	+0.33
– "gluon move" (ERD on)	+0.32	+0.31	+0.33
– "QCD inspired" (ERD on)	−0.36	−0.13	−0.14
Total systematic	0.70	0.62	0.61
Statistical (expected)	0.20	0.08	0.07
Total (expected)	0.72	0.63	0.61