Model Unspecific Search in CMS: Results with latest data

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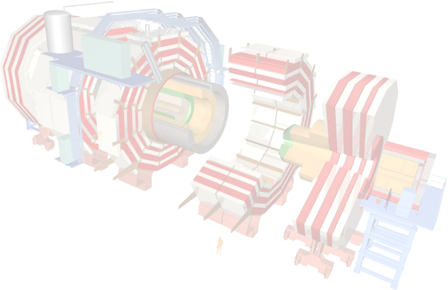
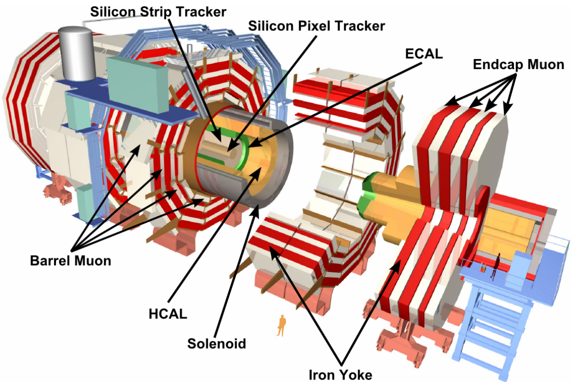
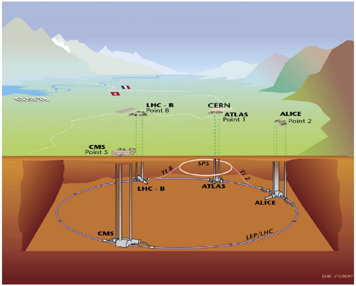
Outline

1. Introduction
2. Implementation
3. Looking at Data
4. Summary/Outlook



CMS @ LHC

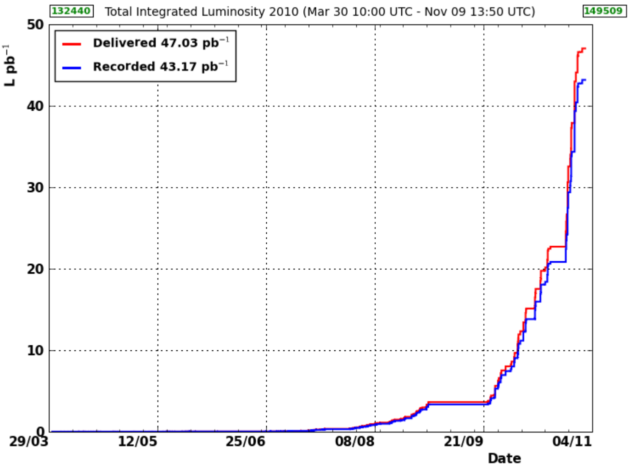




CMS

- length ≈ 21 m
- diameter ≈ 16 m
- mass ≈ 12500 t
- solenoid up to ≈ 4 T

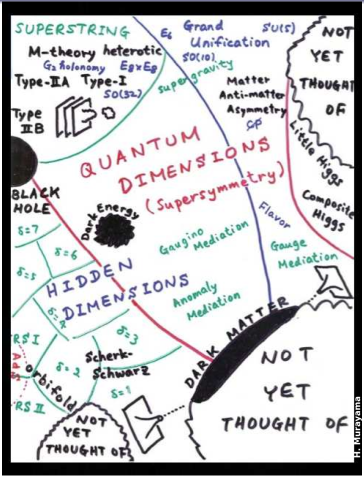
Integrated Luminosity



Data:

- Delivered: 47 / pb
- Recorded: 43 / pb
- Certified: 34 / pb

Motivation



Challenge

Many competing models!
Can we have (dedicated) analyses for all of these?
What are the models no one has thought of yet?

Example: SUSY

A whole “model framework” with many free parameters.

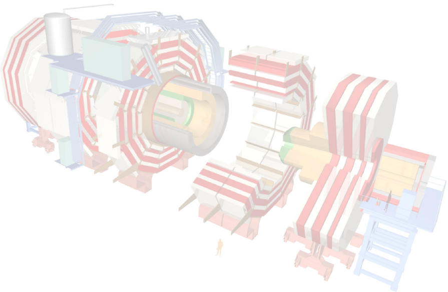
Idea:

Model independent search!

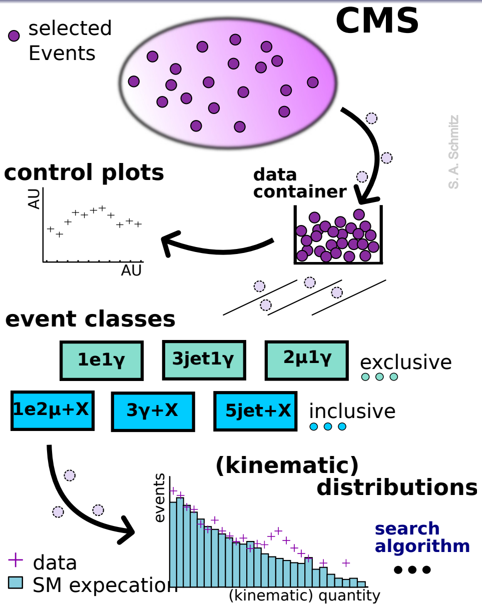
Minimise the theoretical bias:

- Assume only one model: The **Standard Model**
- Search for deviations from the SM expectation in many final states

Outline

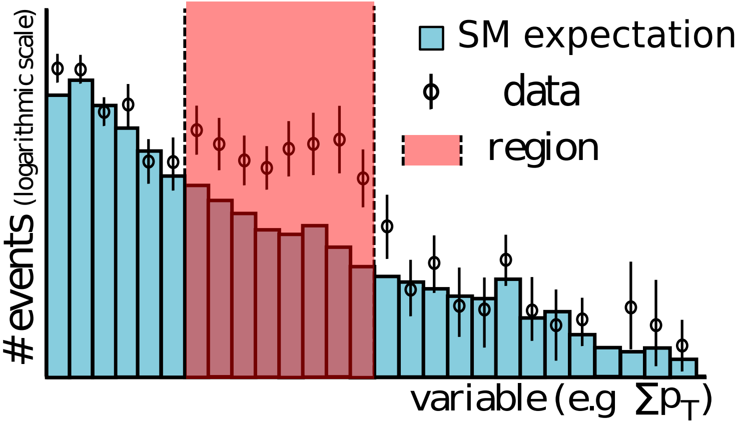


MUSiC Concept



- **Select** good events and objects
- Sort events by their physics object content (μ, e, γ, (b-)jets, $\not{E}_T$) into **event classes**
- **Kinematic distributions** of interest: $\sum p_T$, M_{inv} (, $\not{E}_T$)
- Run the **search algorithm** on these distributions
- Find the most significant **connected bin region** in every distribution

Search algorithm



Most significant region:

In **every distribution** of **every event class**: Find the region with the lowest probability of MC to deviate even more, i. e. the smallest p-**value**.

MUSiC's p-value

Standard treatment:

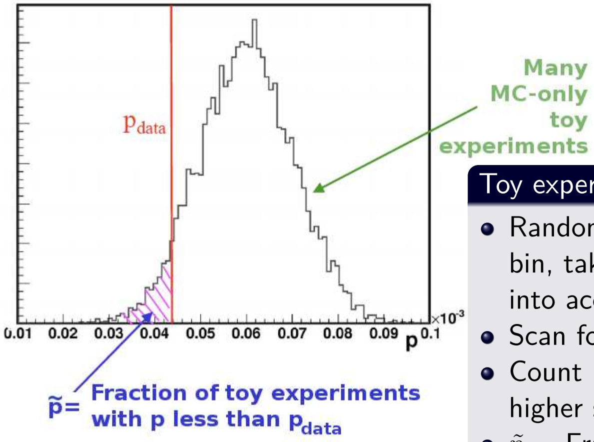
Convolute a Poisson (statics) with a **Gaussian** (systematics) to model the uncertainties on the mean.

Alternative approach:

Use a **Lognormal** prior.
$\rightarrow$ Better treatment of some uncertainties, worse for others.
$\rightarrow$ Good cross check.

"Look-elsewhere effect"

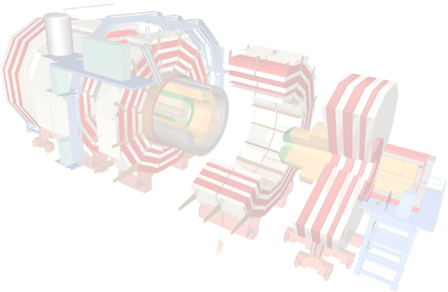
Considering **many regions** in **many distributions** it becomes more probable to see a deviation by chance due to statistical fluctuations.



Toy experiments:

- Randomise MC expectation bin by bin, taking all known uncertainties into account
- Scan for most significant region
- Count pseudo experiments with higher significance than data
- $\tilde{p}$ = Fraction of toy experiments with $p_{\text{toy}} < p_{\text{data}}$

Outline



MUSiC on 7 TeV data

Data:

Used SM backgrounds: Multijet, electroweak, top, γ + Jets, low mass resonances

Major systematic uncertainties:

MC statistics, luminosity (11 %), cross section (5 %), PDF, JES (5 %)

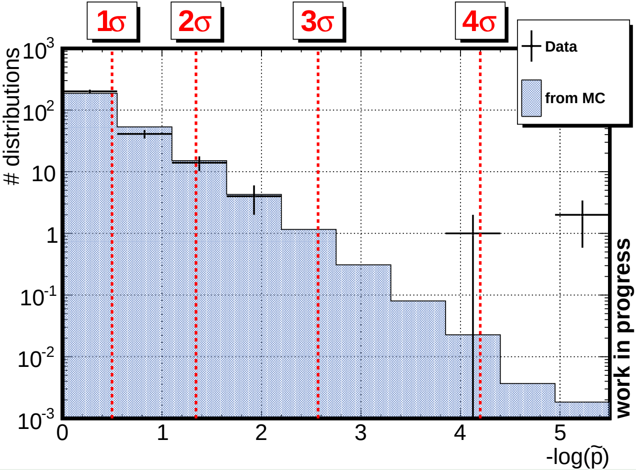
Cuts:

Require at least one e ($p_T > 60$ GeV) **or** μ ($p_T > 25$ GeV)
Allows **loose p_T**-Selection for other objects

Object	p_T^{min} / GeV
e	25
γ	25
μ	18
Jet	50
(MET	30)

$\tilde{p}$ distribution

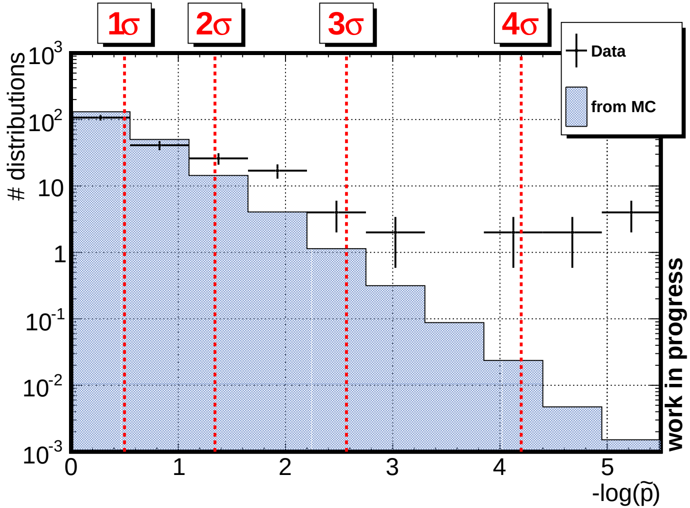
Without MET: Good agreement with MC prediction!



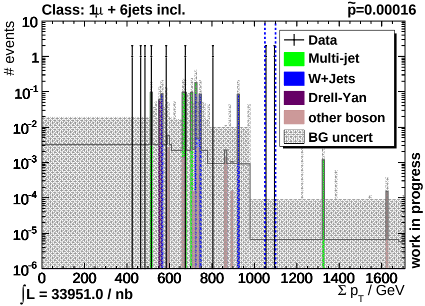
Few discrepant event classes can be explained by instrumental effects or simulation

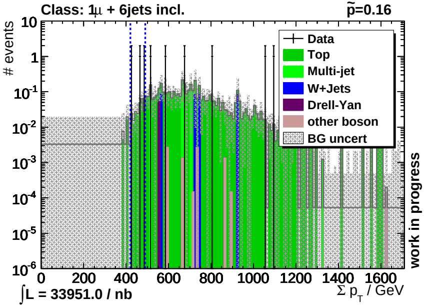
Cross check: Rediscovering the Standard Model

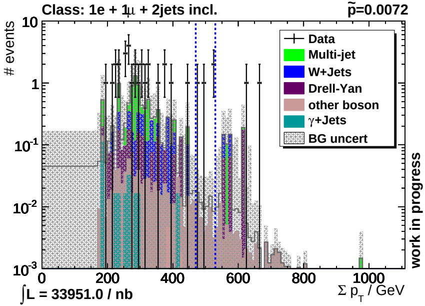
Removed the top quark MC samples:
excess in a wide range of event classes.

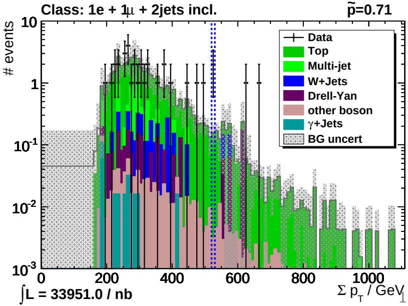


$t\bar{t}$ “most significant”



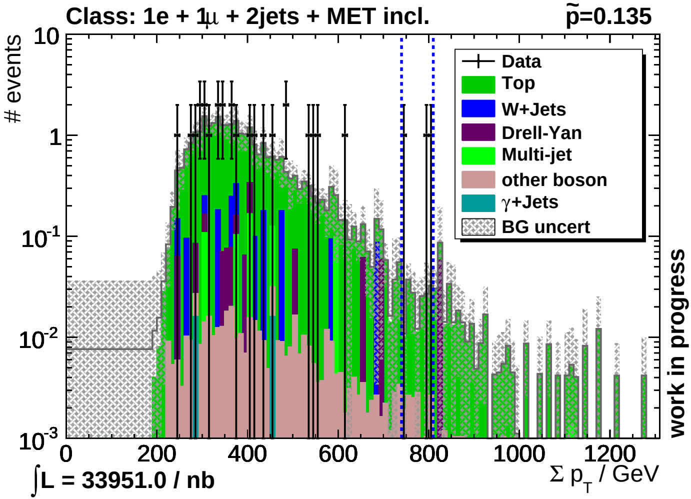






Preview: MET

MET not yet fully implemented in MUSiC but:
Promising first results



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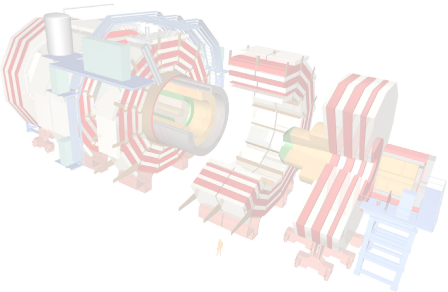


Summary and outlook

Today:

- Model independent search that looks for deviations from the SM
- Complementary to dedicated analyses
- Possible deviations need detailed investigation

Data results:

- Globally good agreement
- Few deviations left (under control)
- Able to rediscover SM physics (in non-standard final states)

Future:

- Analyse more final states

Thank you for your attention!

backup

p-value

Definition:

$$p \equiv \mathcal{P}(T(\boldsymbol{X}) \geq T(\boldsymbol{x}) \,|\, H_0)$$

With:

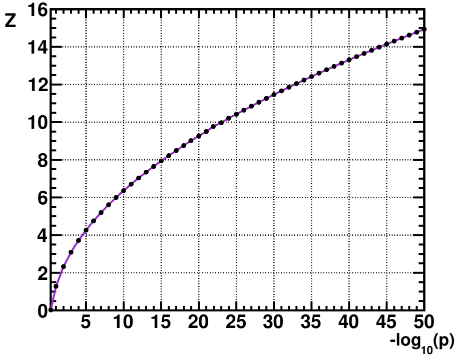
$\boldsymbol{X}$ = Possible data set

$\boldsymbol{x}$ = Observed data set

T = Test statistic

= (number of entries in our case)

H_0 = Null hypothesis = SM



Often p-values are expressed in terms of **standard deviations**.

MUSiC's p-value

Use a **Gaussian prior** to model the uncertainties on the mean of a *Poisson counting experiment* $\Rightarrow$ prior predictive p-value.

$$p^{\mathsf{N}} = \begin{cases} \underbrace{\sum_{i=N_{\text{data}}}^{\infty} C}_{\text{normalisation}} \cdot \int_0^\infty \mathrm{d}\lambda \, \underbrace{\exp\left(-\frac{(\lambda - N_{\text{SM}})^2}{2\,\sigma_{\text{SM}}^2}\right)}_{\text{systematics}} \cdot \underbrace{\frac{\mathrm{e}^{-\lambda}\,\lambda^i}{i!}}_{\text{statistics}} & \text{if } N_{\text{data}} \geq N_{\text{SM}} \\ \sum_{i=0}^{N_{\text{data}}} C \cdot \int_0^\infty \mathrm{d}\lambda \, \exp\left(-\frac{(\lambda - N_{\text{SM}})^2}{2\,\sigma_{\text{SM}}^2}\right) \cdot \frac{\mathrm{e}^{-\lambda}\,\lambda^i}{i!} & \text{if } N_{\text{data}} < N_{\text{SM}} \end{cases}$$

with:

N_{SM} = Pure SM (Monte Carlo) expectation in this region

$\sigma_{\text{SM}} = \sqrt{\sigma_{\text{stat}}^2 + \sum_i \sigma_{i,\text{syst}}^2}$ = Uncertainty on the MC prediction for the SM

Region with the smallest p-value: **Region of Interest**

Another approach: **Lognormal** prior

The "look-elsewhere effect"

Considering **many regions** in **many distributions** it becomes more probable to see a deviation by chance due to statistical fluctuations.

The single region p-value alone is not a good significance estimator.
$\Rightarrow$ Compute "new" estimator $\tilde{p}$:

$$\tilde{p} = \frac{\text{number of } H_0 \text{ experiments with a region featuring } p < p_{\text{data}}}{\text{total number of } H_0 \text{ experiments}}$$

Easy (toy) example: all regions **statistically independent**

$$\tilde{p} = 1 - (1 - p_{\text{data}})^n \;; \quad n = \text{number of regions}$$

In realistic cases regions are correlated due to shared bins and/or **correlated** systematic uncertainties!

Solution:

Dice a sufficiently large number of pseudo experiments in order to determine $\tilde{p}$.

Determination of $\tilde{P}$

① In every distribution the data gives **one most significant region**, i. e. smallest p-value (p_{data}).

② Dice the MC expectation according to uncertainties many times (pseudo experiments) to get a distribution of p-values.

③ Get the "relative number of pseudo experiments with $p < p_{\text{data}}$" $= \tilde{p}$.