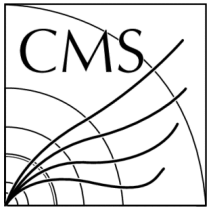


Search for stops with the CMS experiment

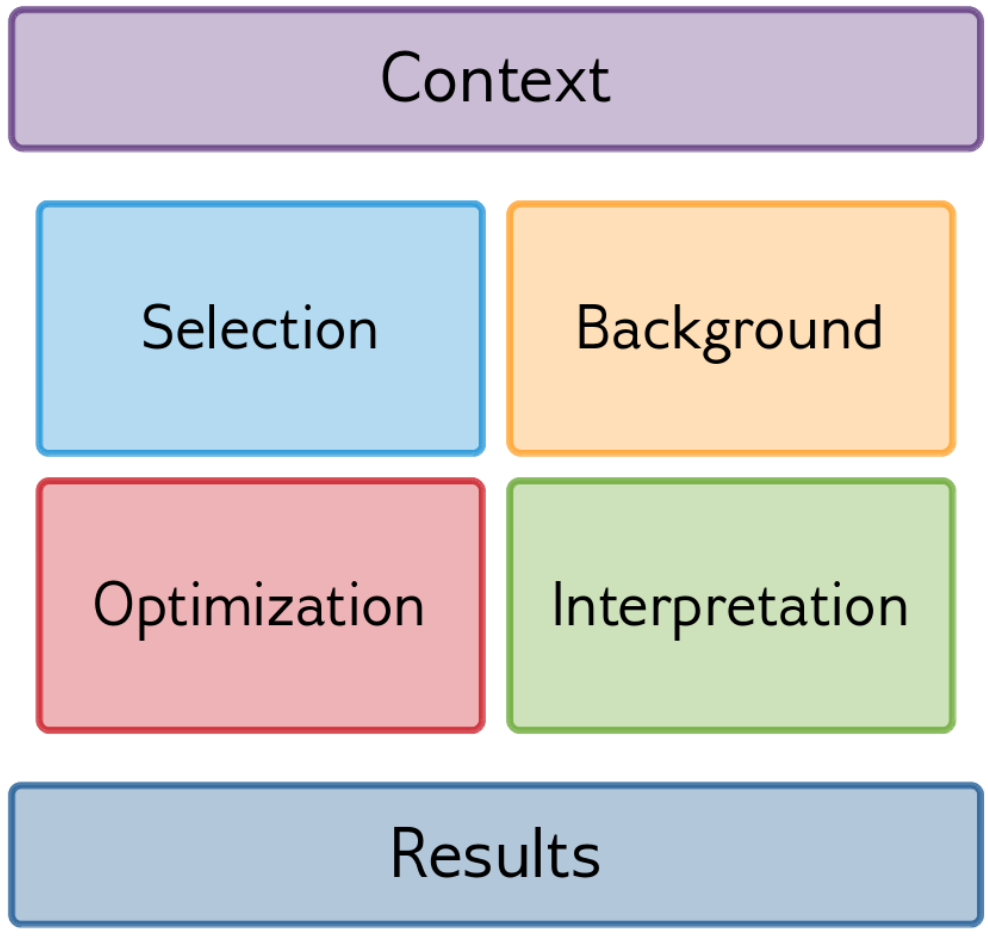
Journées de Rencontre des Jeunes Chercheurs

December 4th, 2013

Alexandre Aubin

Supervisors : Caroline Collard, Eric Chabert

Institut Pluridisciplinaire Hubert Curien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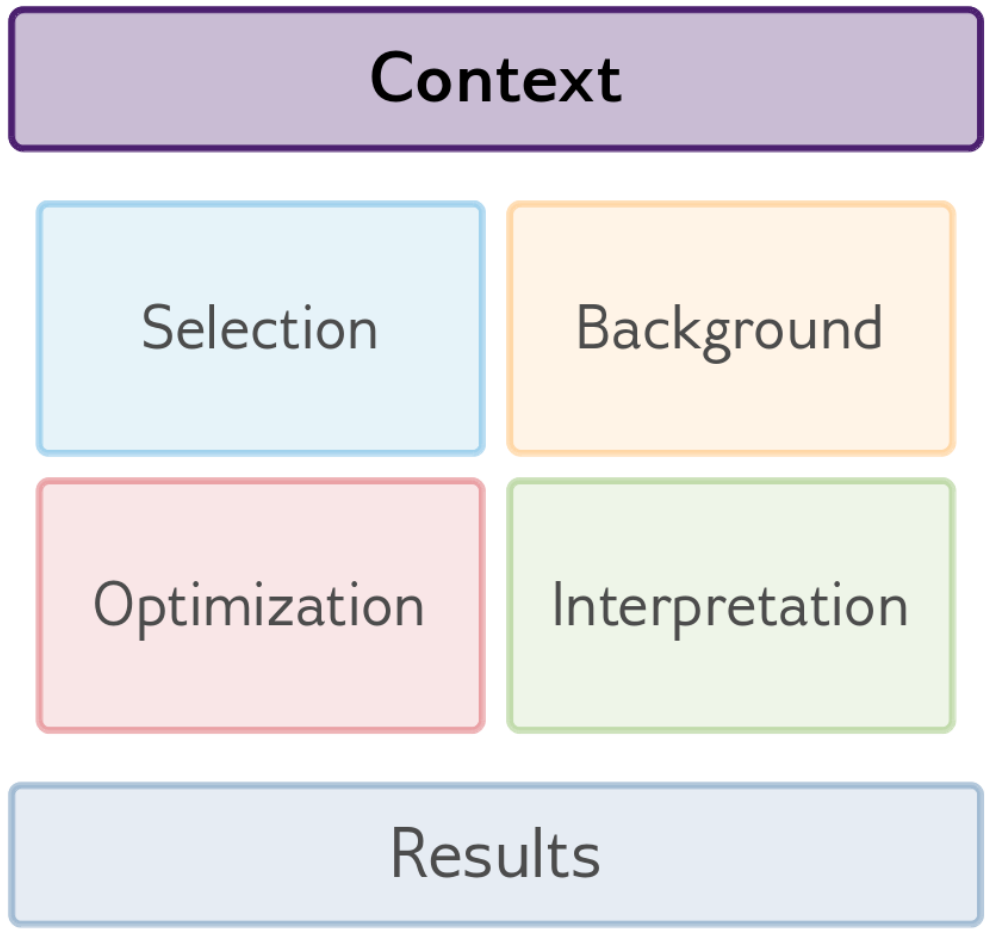
Context
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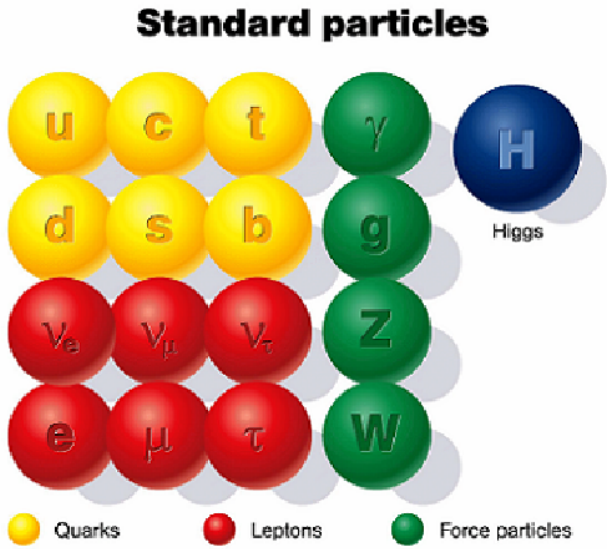
Context

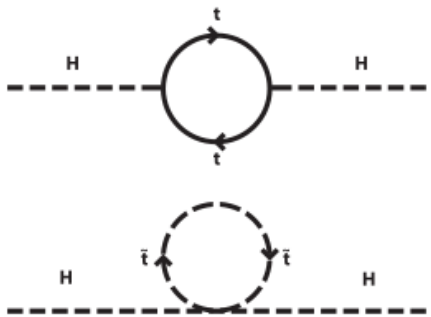
Super-symmetry

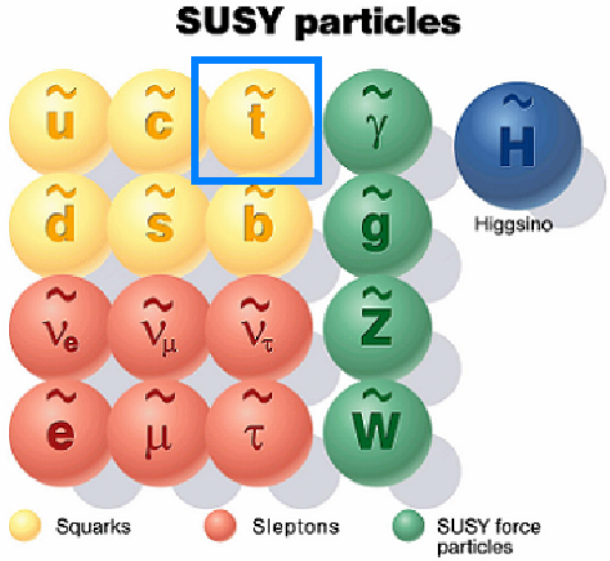
- Standard-Model extension
- Boson $\leftrightarrow$ fermion symmetry
- Provides dark matter candidate
  (in RP conservative models)
- Solves the hierarchy problem



Why top squarks?

- "Natural" SUSY $\Rightarrow m_{\tilde{t}} \sim 1$ TeV

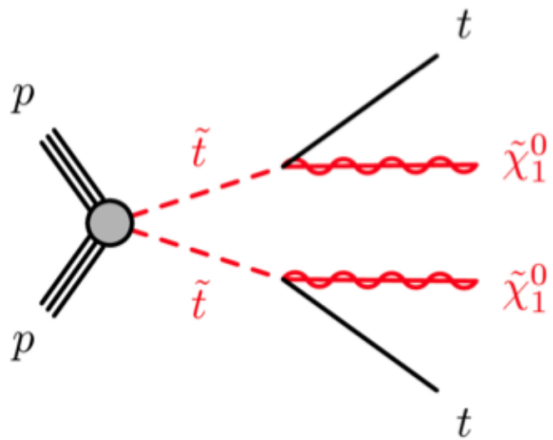




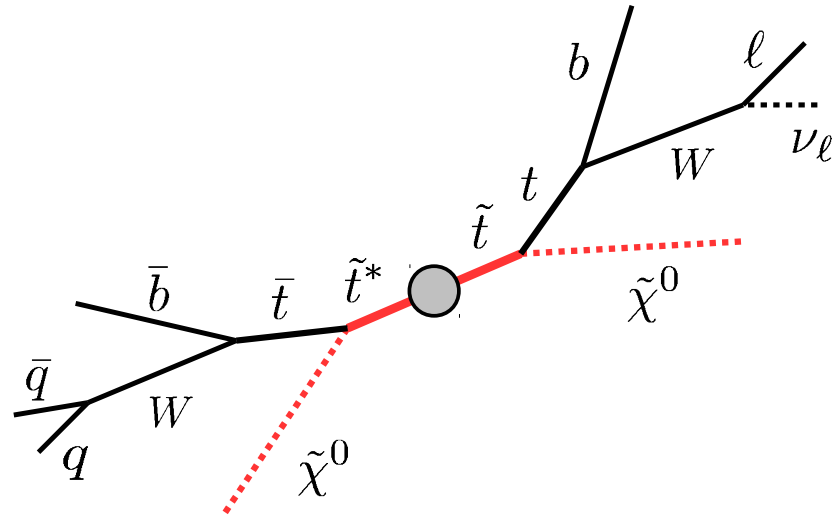
Context

$$\tilde{t} \to t\tilde{\chi}^0$$

Feynman diagram



Transversal view

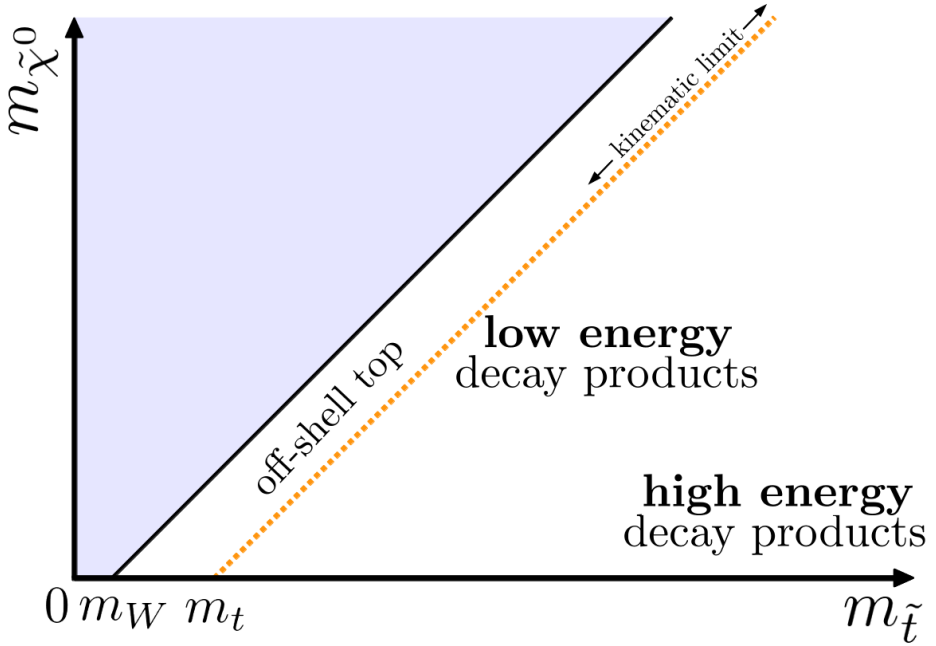


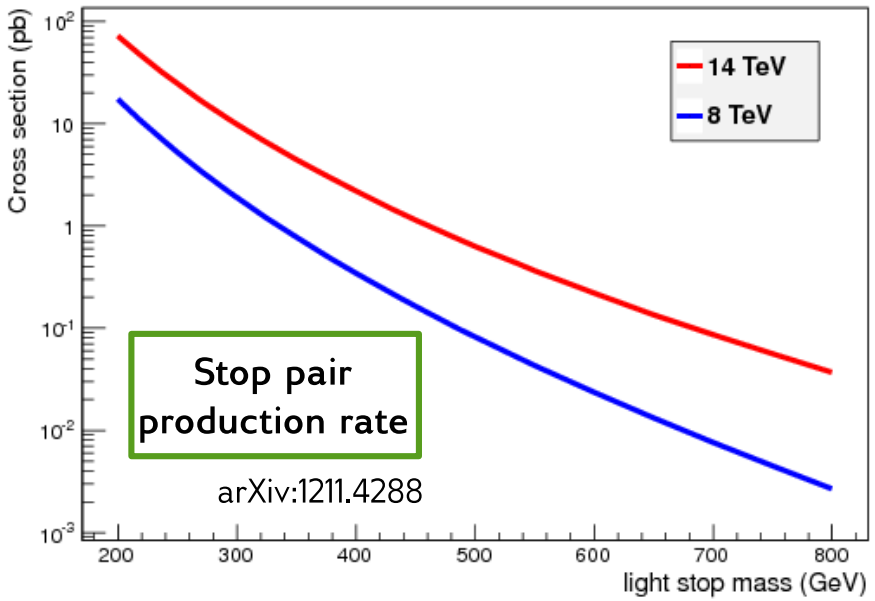
Stop pair production

(1-lepton channel)

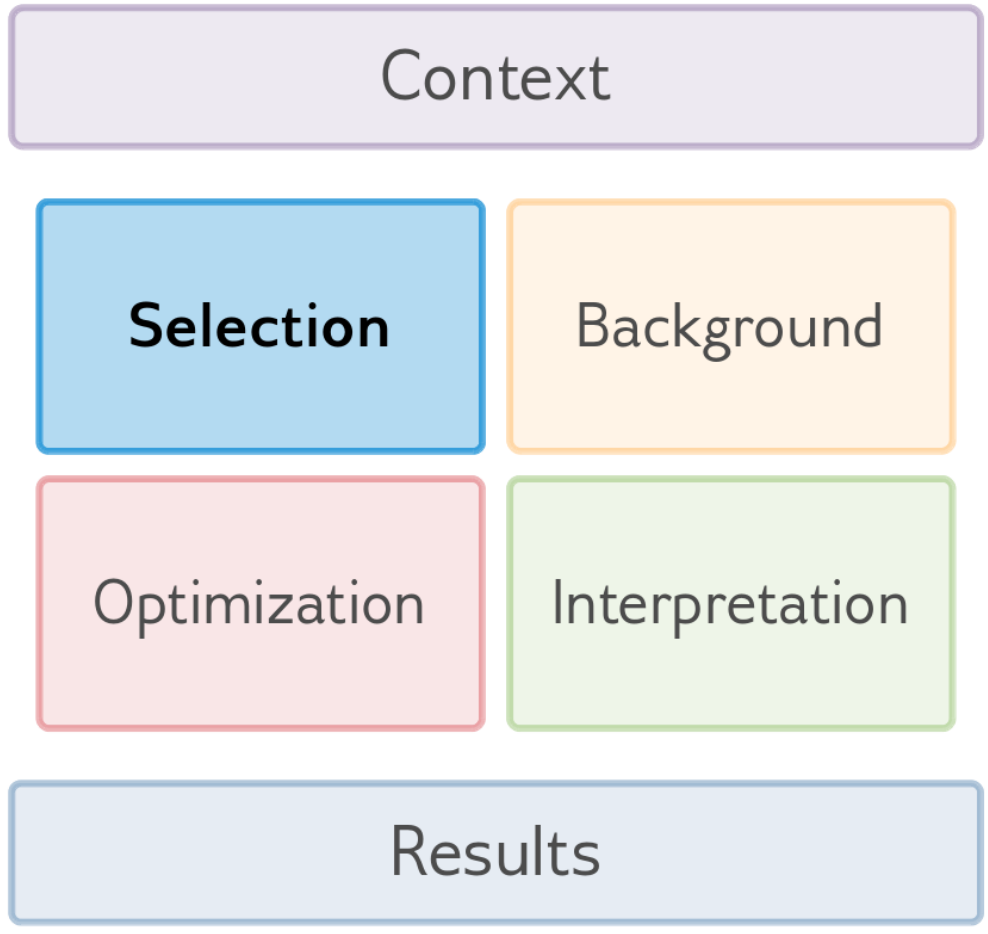
$$\begin{aligned} pp \to \tilde{t}\tilde{t}^* &\to \tilde{\chi}^0\tilde{\chi}^0 + tt \\ &\to \tilde{\chi}^0\tilde{\chi}^0 + bbWW \\ &\to \tilde{\chi}^0\tilde{\chi}^0 + bb + \ell\nu_\ell + q\bar{q} \end{aligned}$$

Context





- Study in the frame of simplified SUSY models (generic result)
- Production rate divided by 10 every $\sim$ 200 GeV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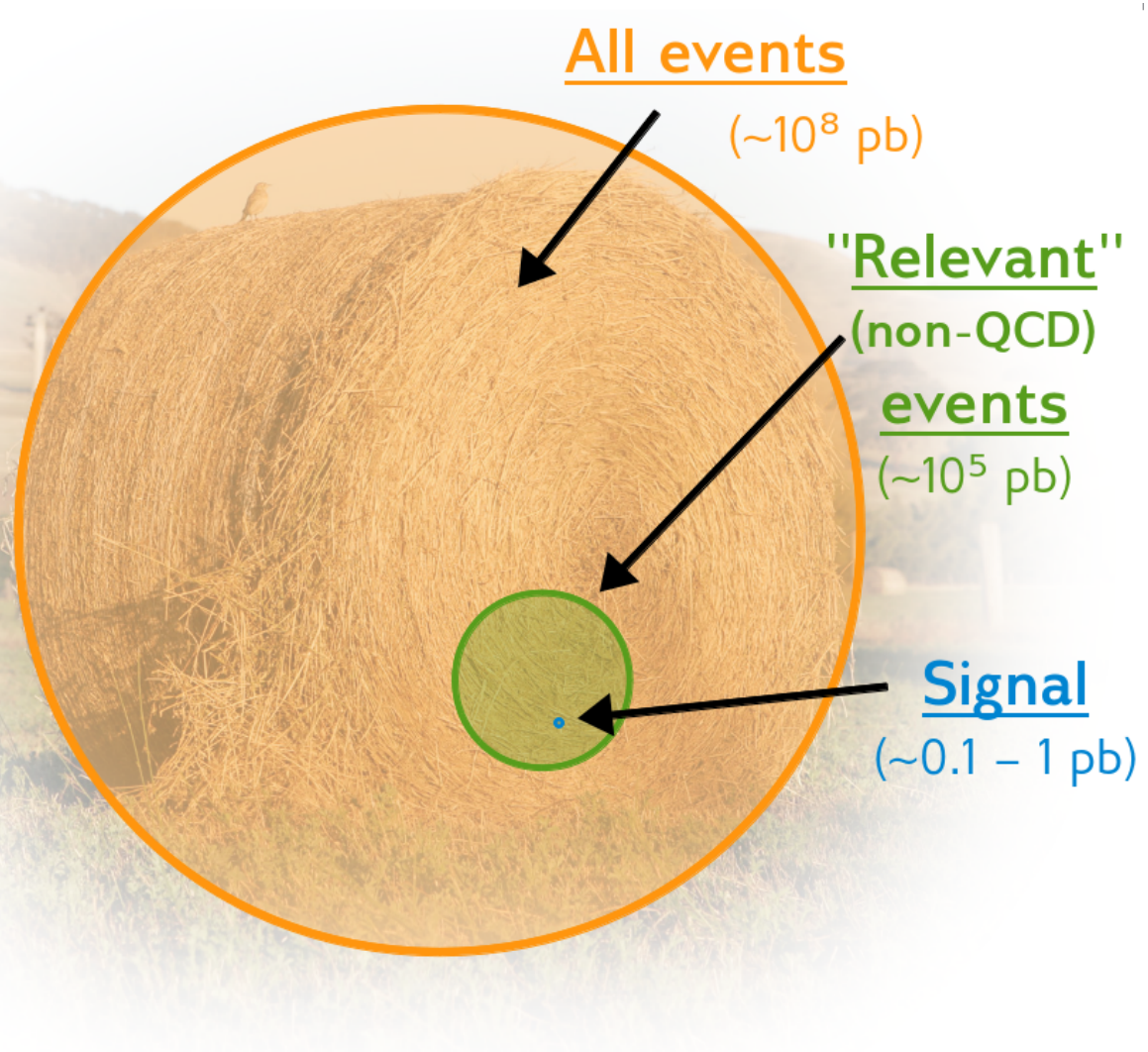
Selection

Looking for a needle in a haystack

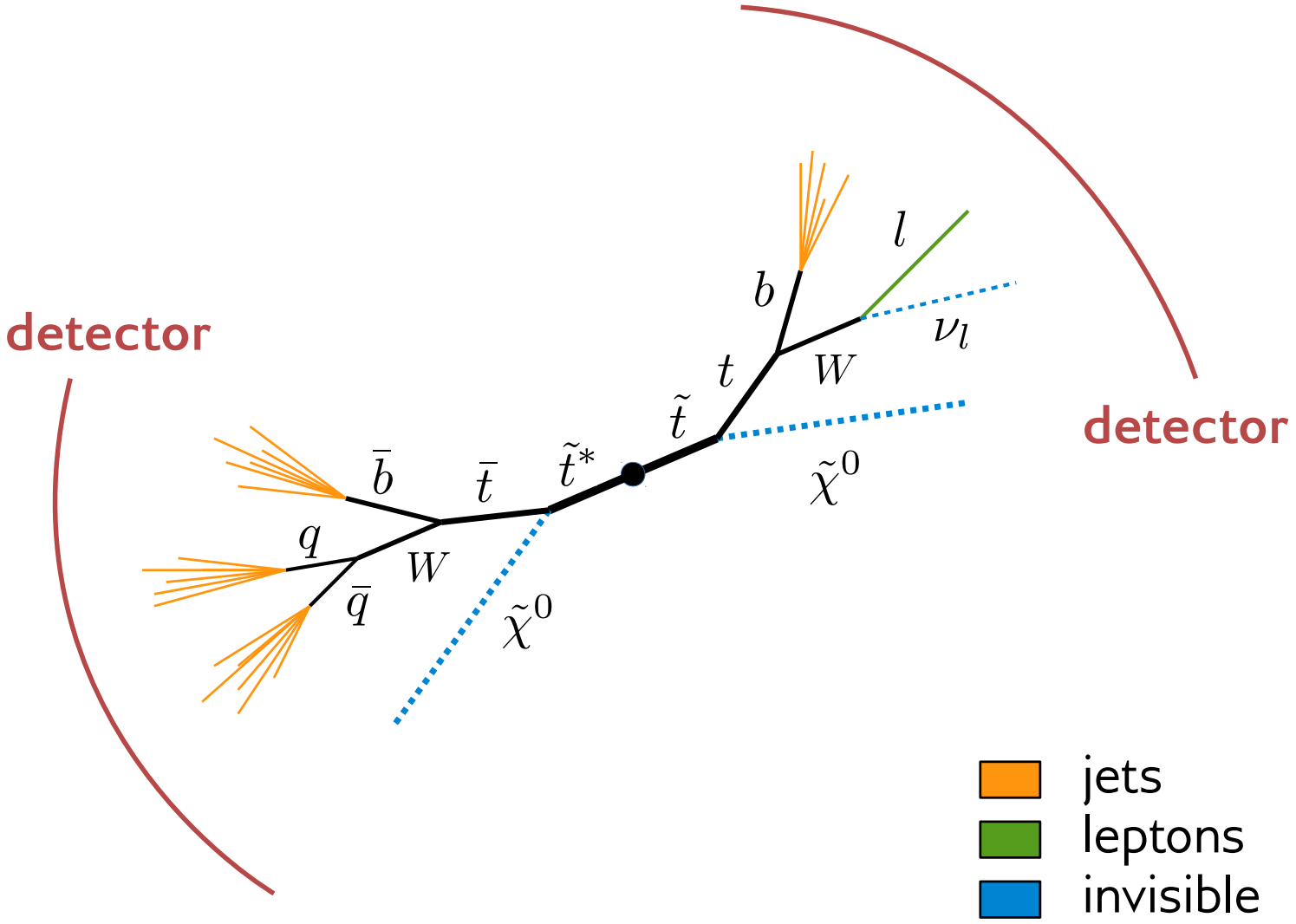
Selection



Looking for a needle in a haystack
About 1 signal event among 100 millions !

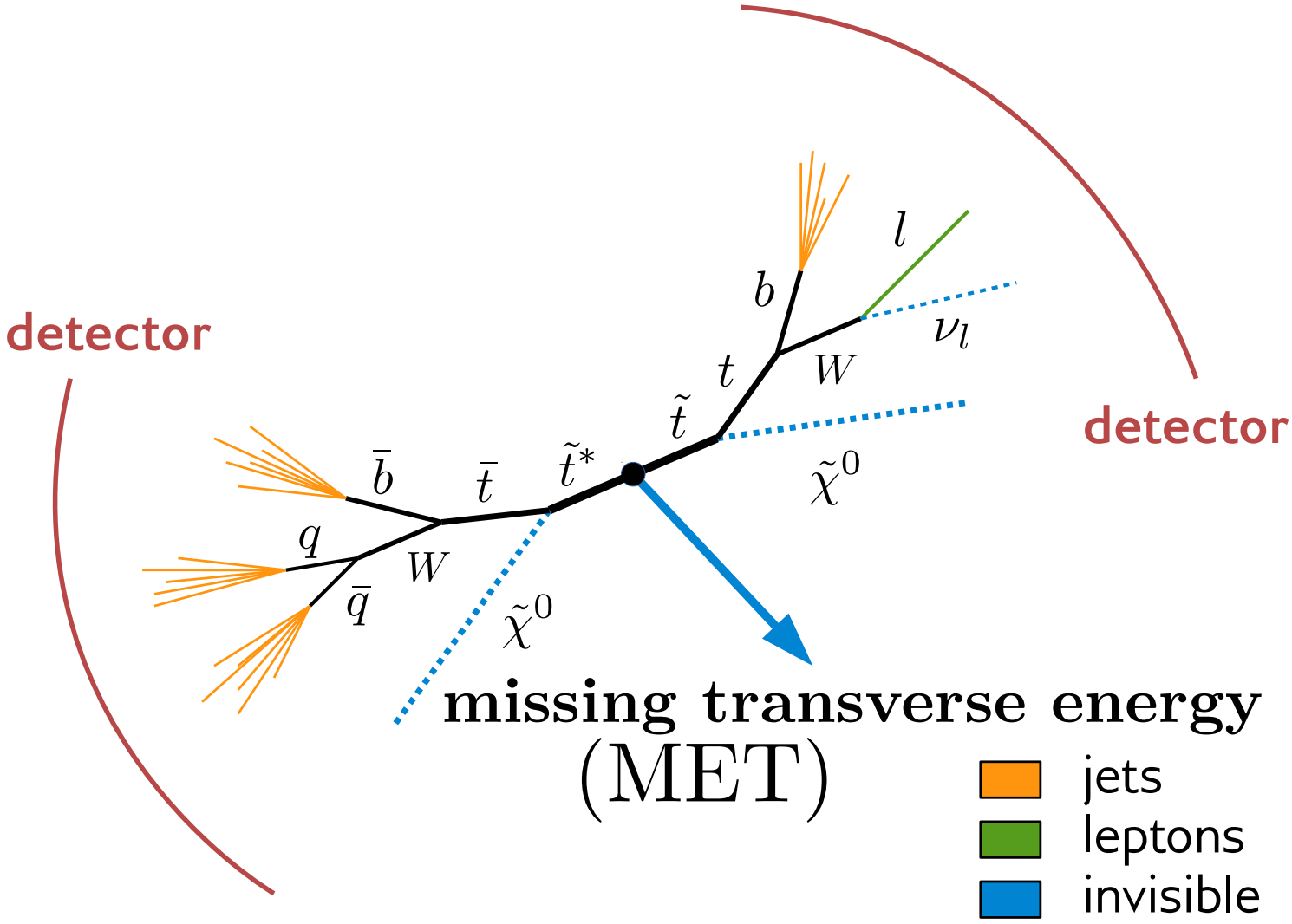
Selection

$$pp \to \tilde{t}\tilde{t}^* \quad \to bbWW + \tilde{\chi}^0\tilde{\chi}^0$$
$$\to \ell + qqbb + \nu_\ell\tilde{\chi}^0\tilde{\chi}^0$$



Selection

$$pp \to \tilde{t}\tilde{t}^* \quad \to bbWW + \tilde{\chi}^0\tilde{\chi}^0$$
$$\to \ell + qqbb + \nu_\ell\tilde{\chi}^0\tilde{\chi}^0$$



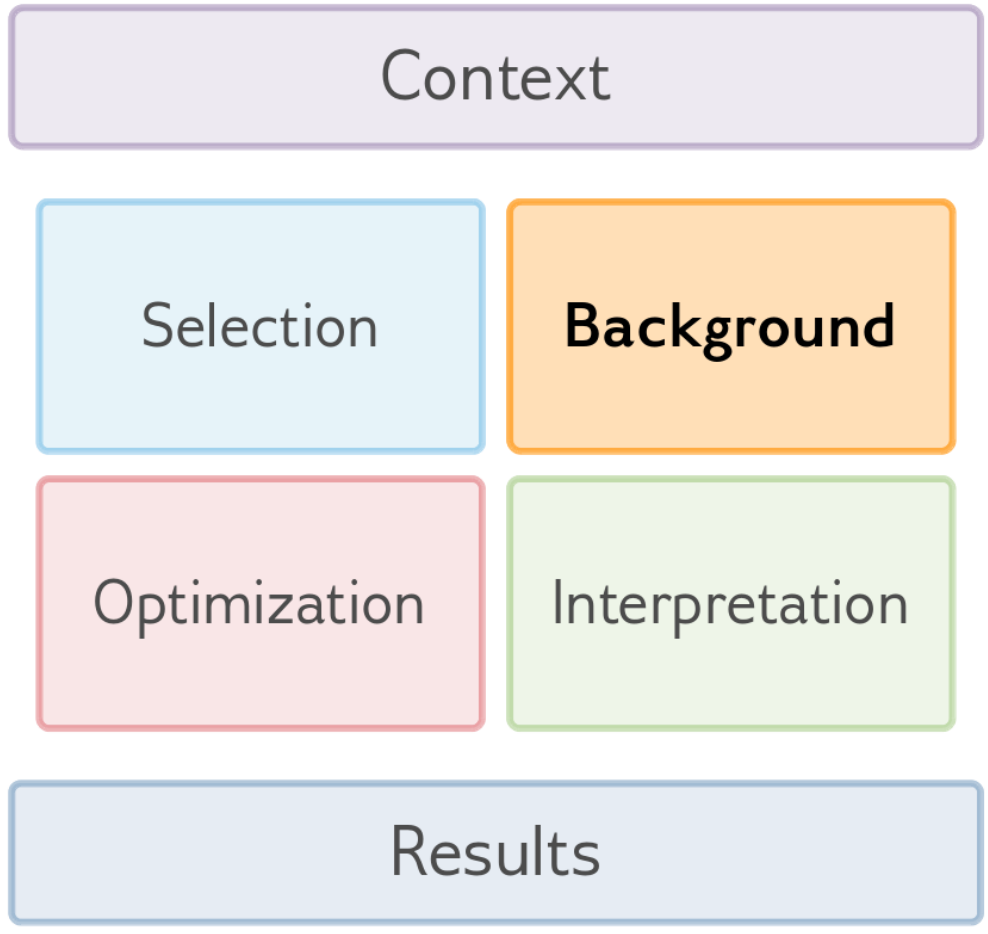
Selection

$$pp \to \tilde{t}\tilde{t}^* \quad \to bbWW + \tilde{\chi}^0\tilde{\chi}^0$$
$$\to \ell + qqbb + \nu_\ell\tilde{\chi}^0\tilde{\chi}^0$$

Selection

- 1 lepton (e/μ)
- $\geq$ 4 jets, $\geq$ 1 b-jet
- MET $\geq$ 100 GeV
- second-lepton vetos
  (isolated track, hadronic τ)

$\Rightarrow$ signal-to-noise ratio increased to $\sim$ 1 per 15000 !
(good, but still not enough)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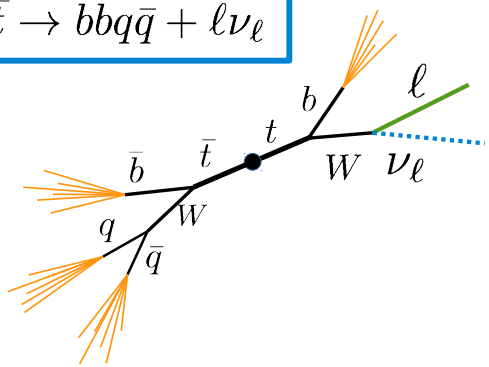
Backgrounds

- Other Standard-Model processes have **similar final state**

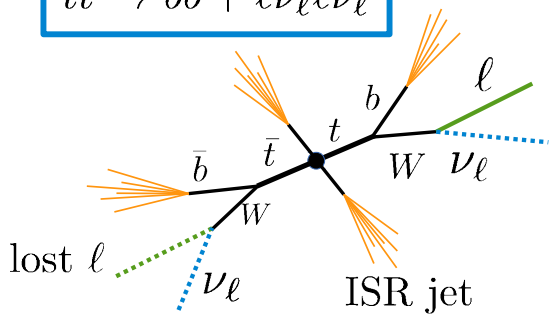
1-lepton $t\bar{t}$

$t\bar{t} \to b\bar{b}q\bar{q} + \ell\nu_\ell$



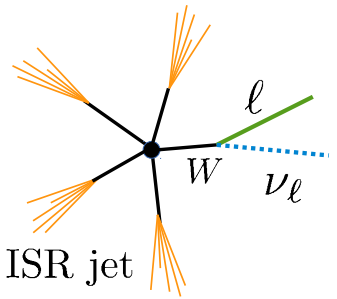
2-lepton $t\bar{t}$

$t\bar{t} \to b\bar{b} + \ell\nu_\ell\ell\nu_\ell$

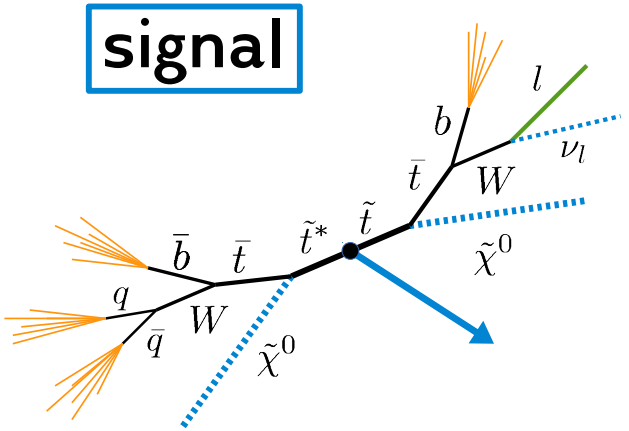


W + jets

$W \to \ell\nu_\ell$



signal

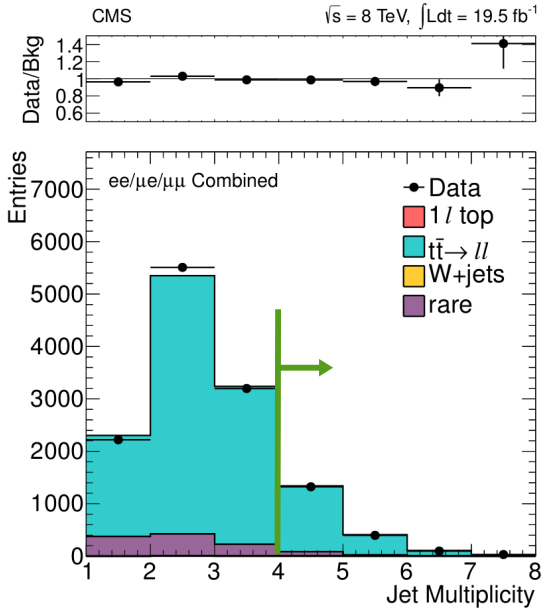


- **Understanding** these processes is crucial **to spot and exploit second-order differences**

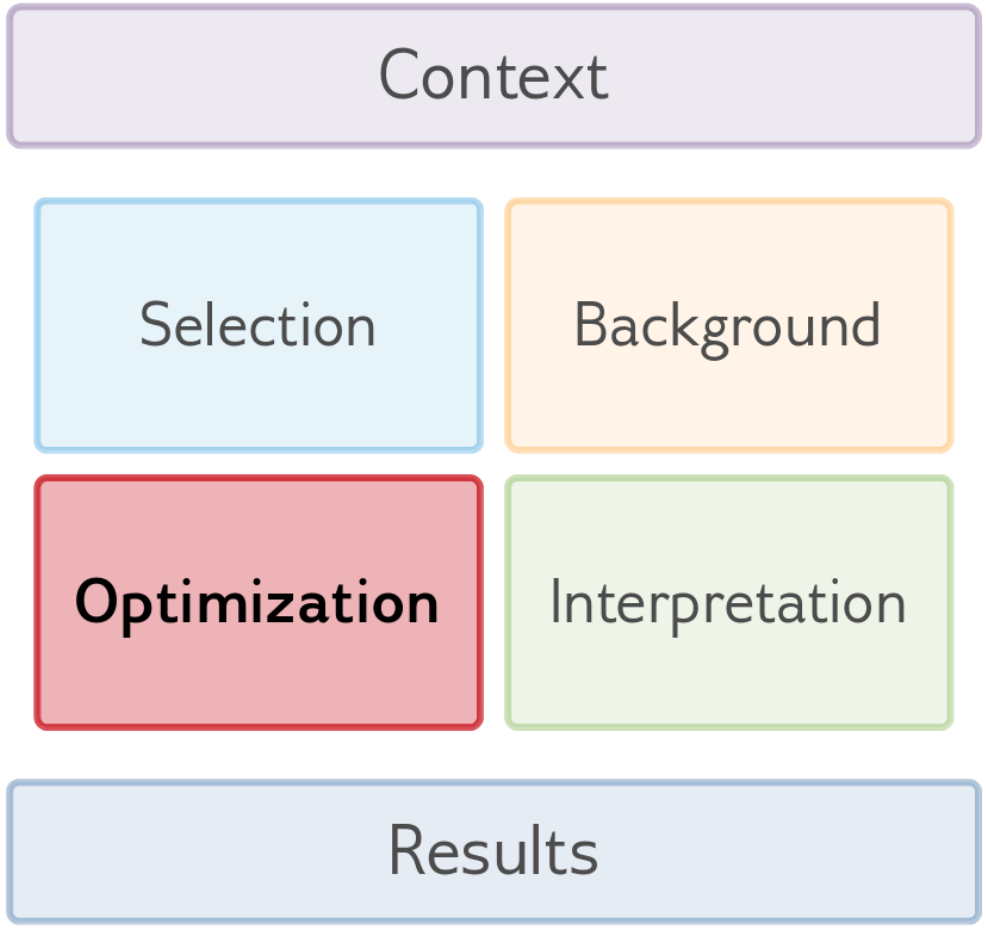
Backgrounds

Need for precise background prediction

- Reliance on Standard-Model measurements and Monte-Carlo generator
- Estimation and checks from the data



Selection criteria	1ℓ	$\geq 2\ell$
0 b-jet	**W+jets** dominated	-
≥1 b-jet	**Signal region**	**tt** → $\ell\ell$ dominated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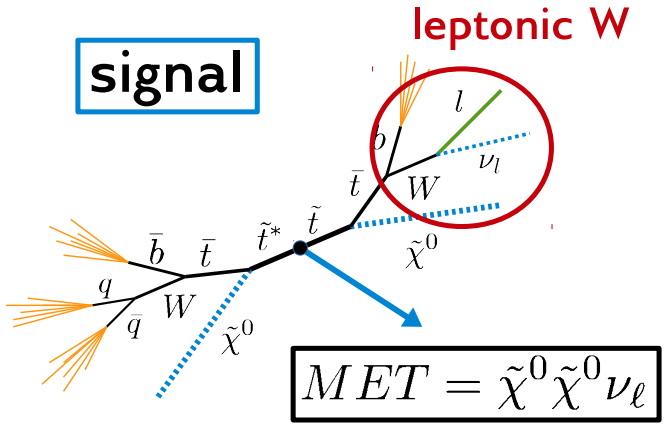
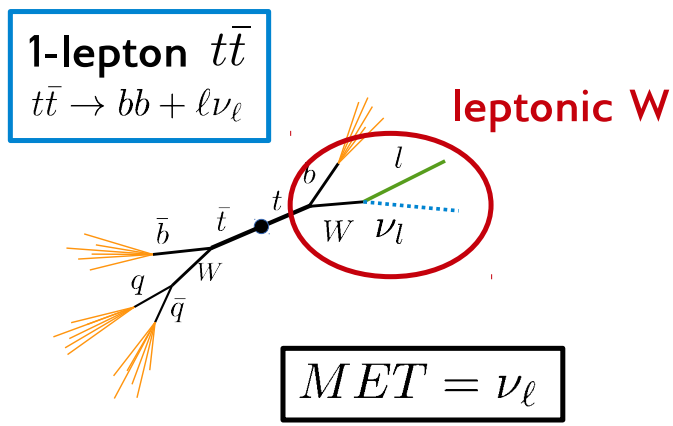
Optimization

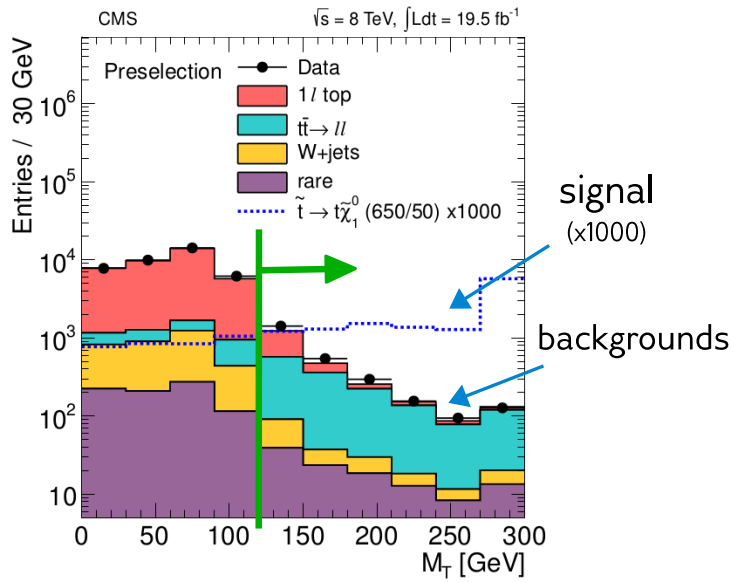




$W_{leptonic}$ = lepton + neutrino mass(W) ~ 80 GeV

The M_T variable

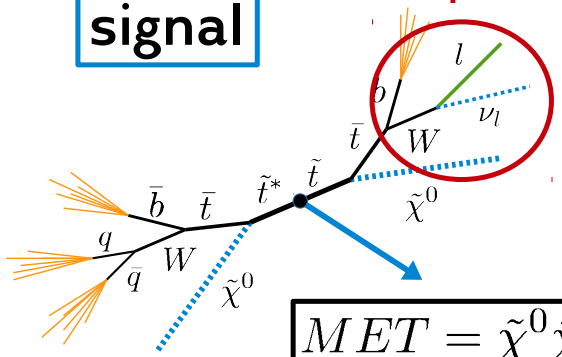
- $M_T = mass(\ell + MET)$
- try to exploit the leptonic W to discriminate signal and background



Optimization

signal

leptonic W

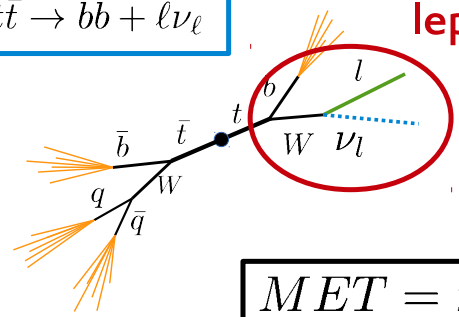


$MET = \tilde{\chi}^0\tilde{\chi}^0\nu_\ell$

1-lepton $t\bar{t}$

$t\bar{t} \rightarrow bb + \ell\nu_\ell$

leptonic W

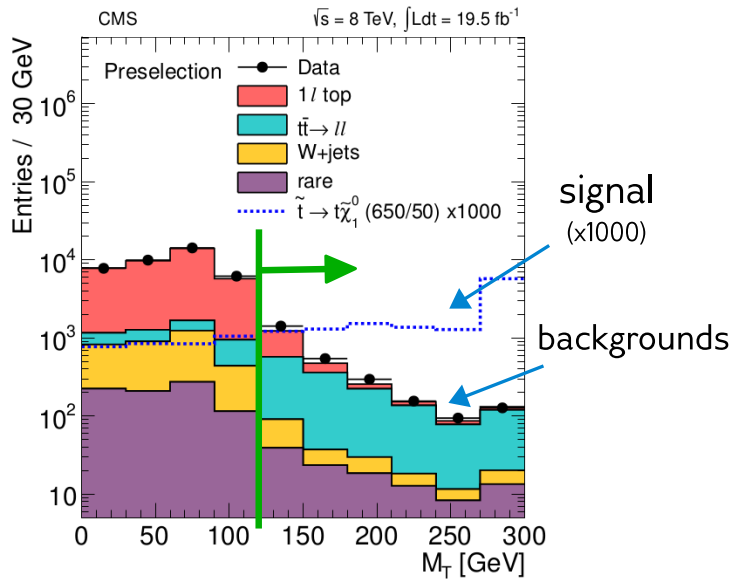


$MET = \nu_\ell$

$W_{leptonic}$ = lepton + neutrino mass(W) ~ 80 GeV

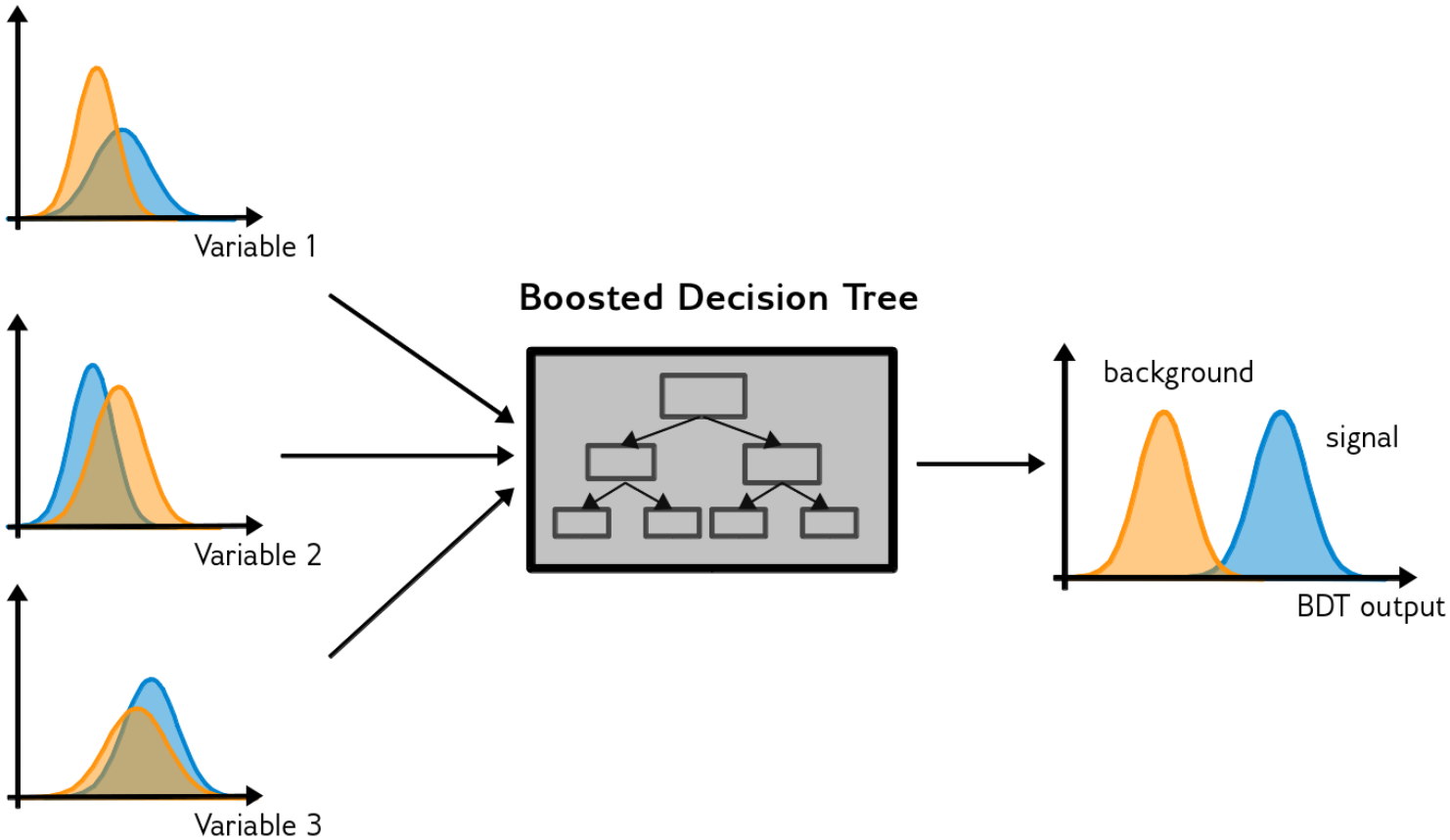
$$M_T > 120 \text{ GeV}$$

$\Rightarrow$ signal-to-noise ratio increased to
$\sim$ **1 per 200**!
(good, but can do better)



Optimization

Use boosted decision tree
to combine variables into one



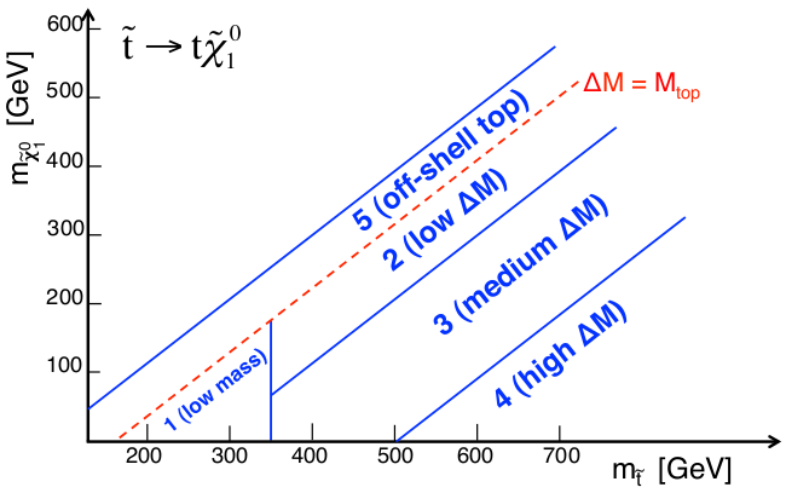
Optimization

Use boosted decision tree to combine variables into one

- Use $\sim$ 6 different variables in the BDT

Variable	Usage
MET	✓
M_{T2}^{W}	✓
min$\Delta\Phi$	✓
HT_{T}^{ratio}	✓
hadronic top χ^2	on-shell t
leading b-tagged jet p_T	off-shell t

- Split the $(m_{\tilde{t}}, m_{\tilde{\chi}^0})$ space in different regions

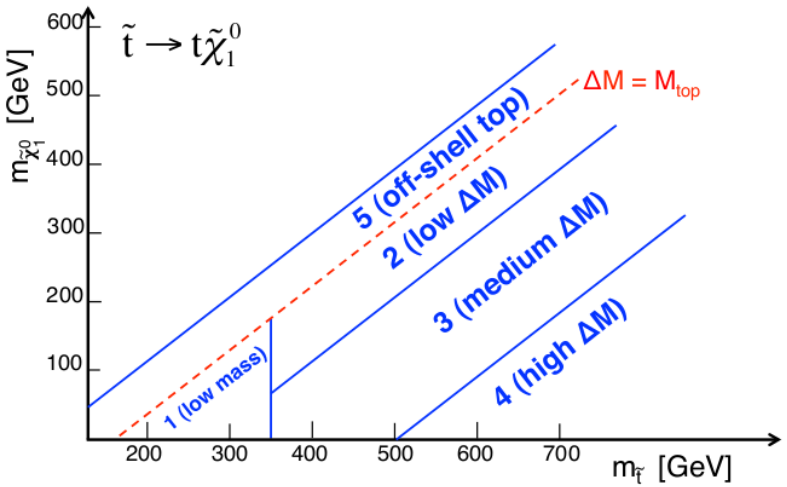


Optimization

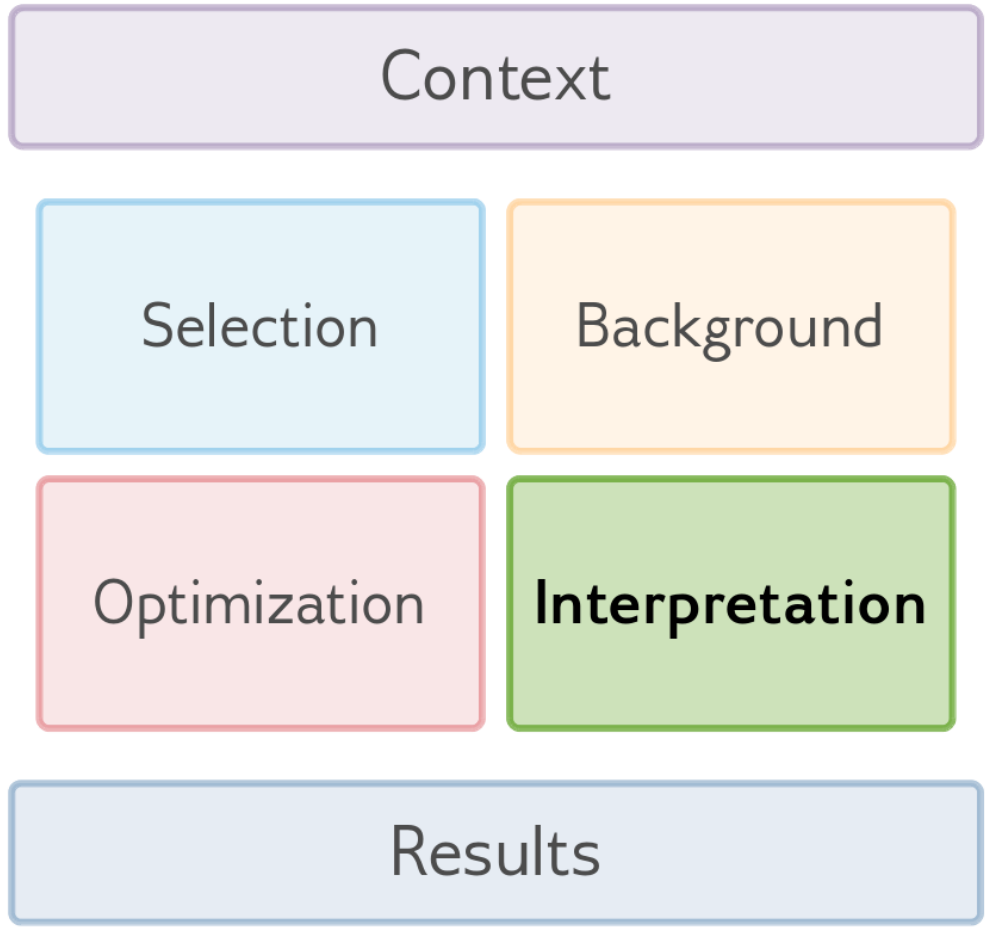
- Use $\sim$ 6 different variables in the BDT

Variable	Usage
MET	✓
M_{T2}^{W}	✓
min$\Delta\Phi$	✓
HT_{T}^{ratio}	✓
hadronic top χ^2	on-shell t
leading b-tagged jet p_T	off-shell t

- Split the $(m_{\tilde{t}}, m_{\tilde{\chi}^0})$ space in different regions



$\Rightarrow$ signal-to-noise ratio increased to **1 per 0.5 $\sim$ 2**!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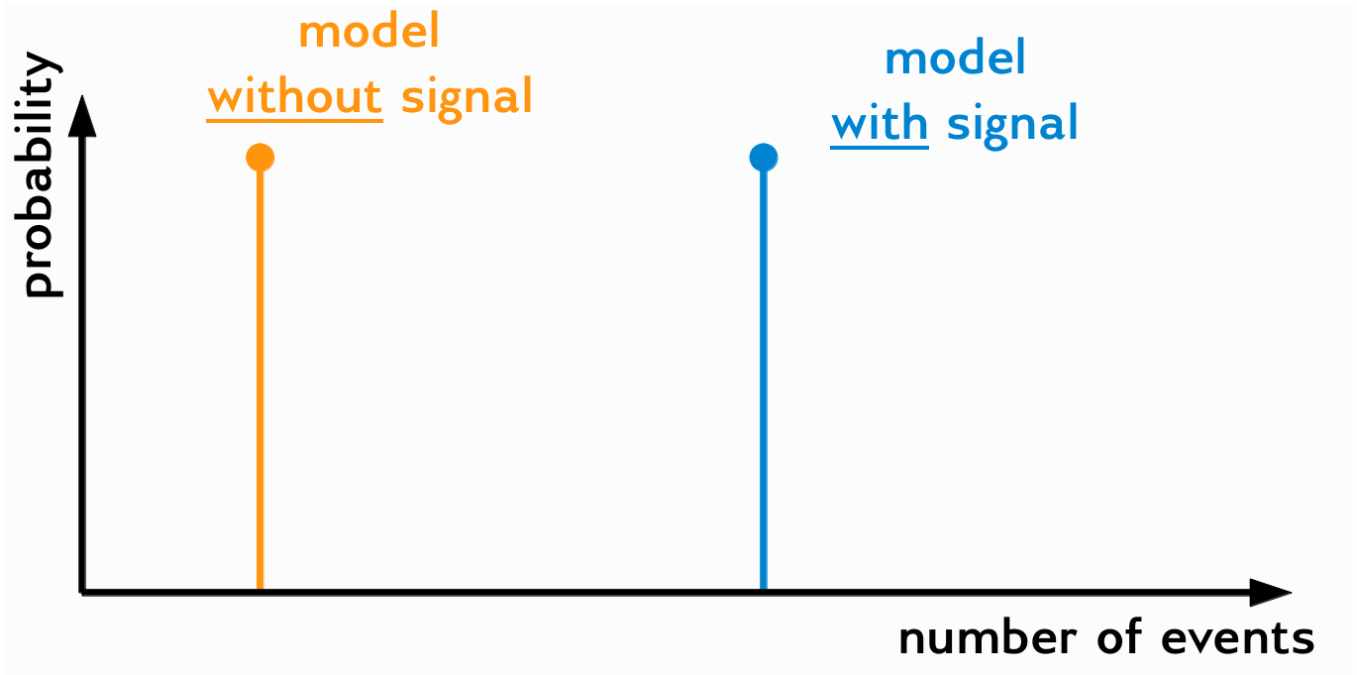
Interpretation

At the end, what you measure is a number of event



Interpretation

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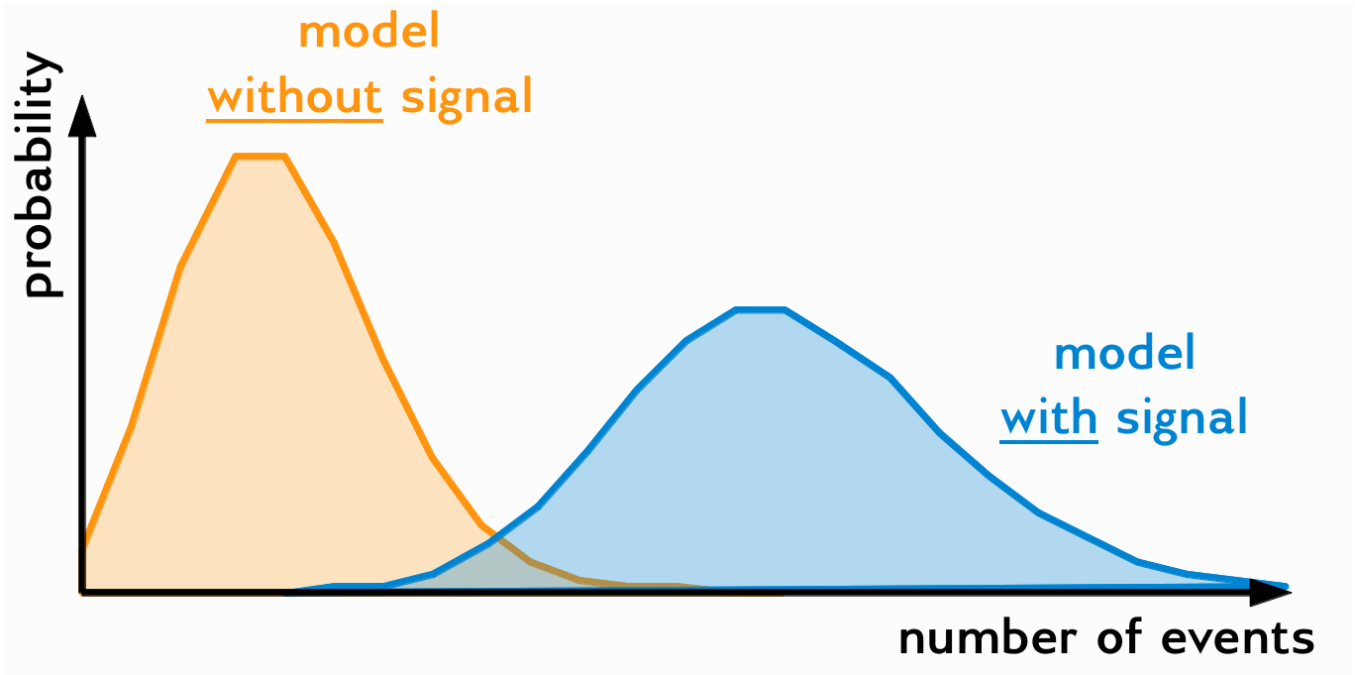
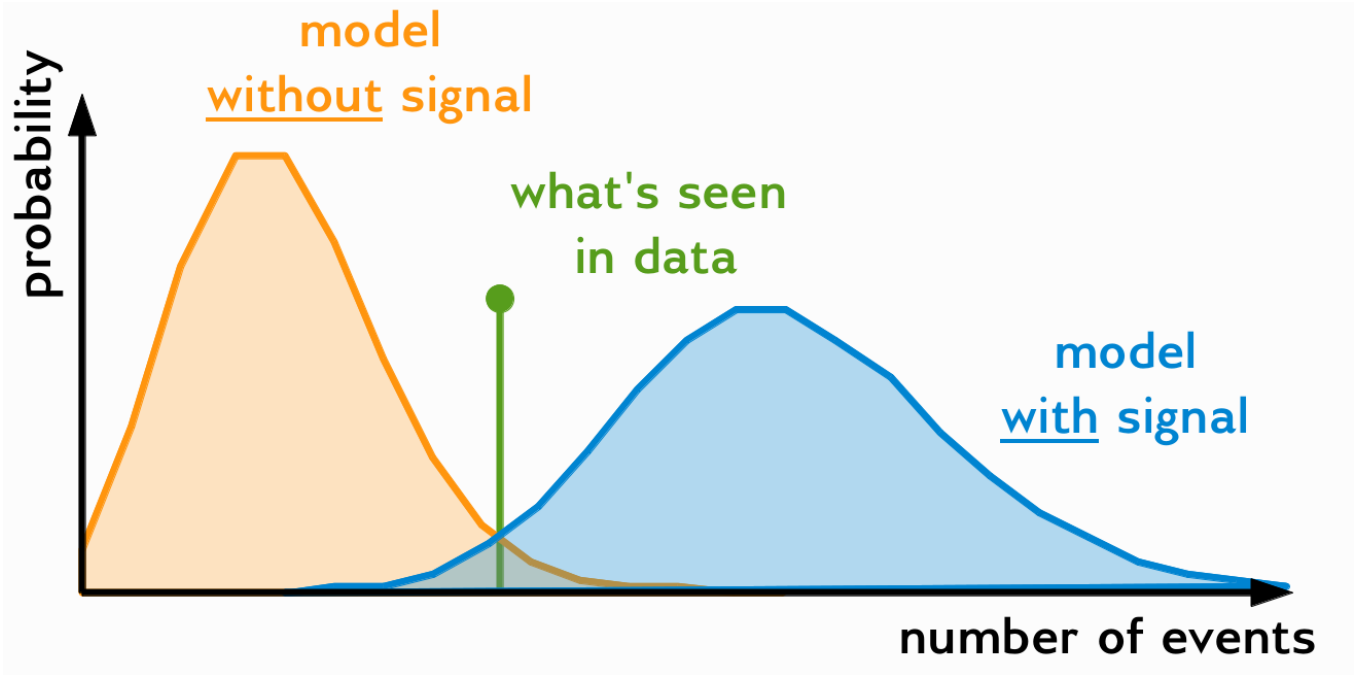
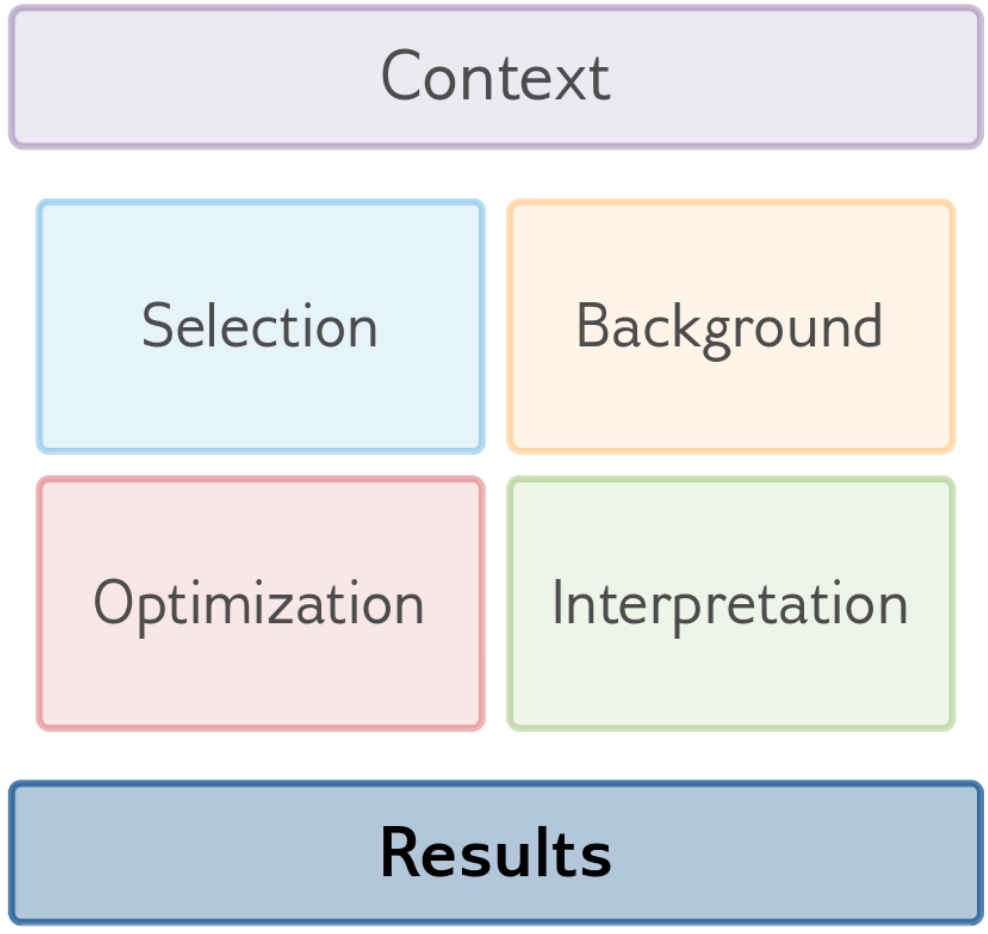


Interpretation

At the end, what you measure is a number of event
$\rightarrow$ what can you really say about the existence
or non-existence of the signal ?



Not a trivial problem
Need use of statistical tools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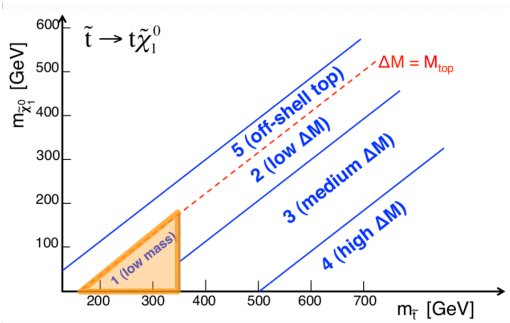
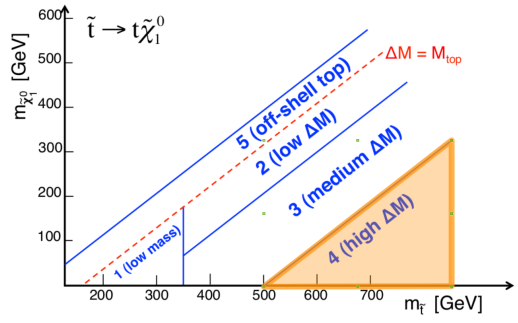
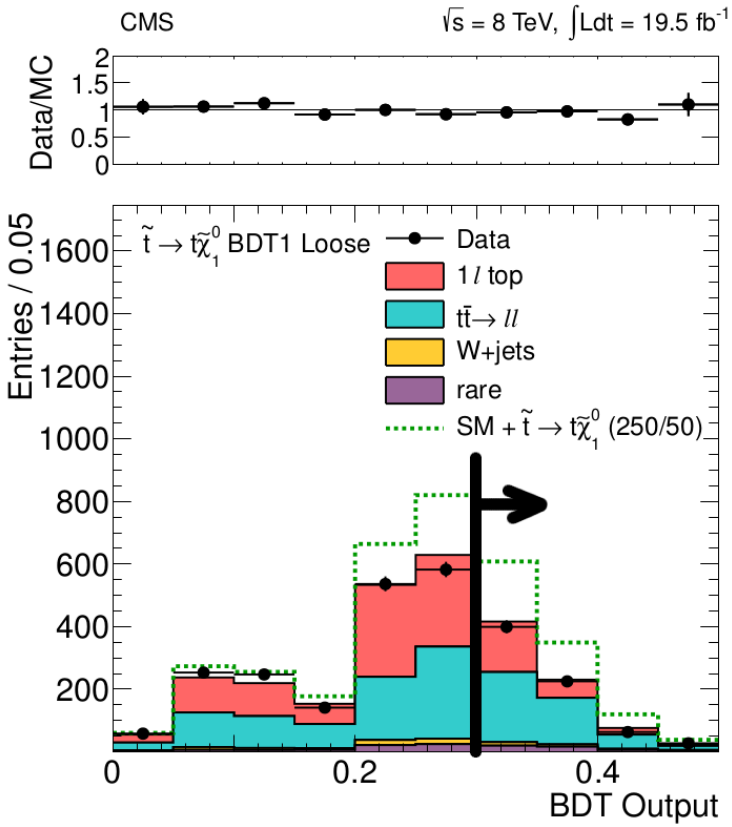
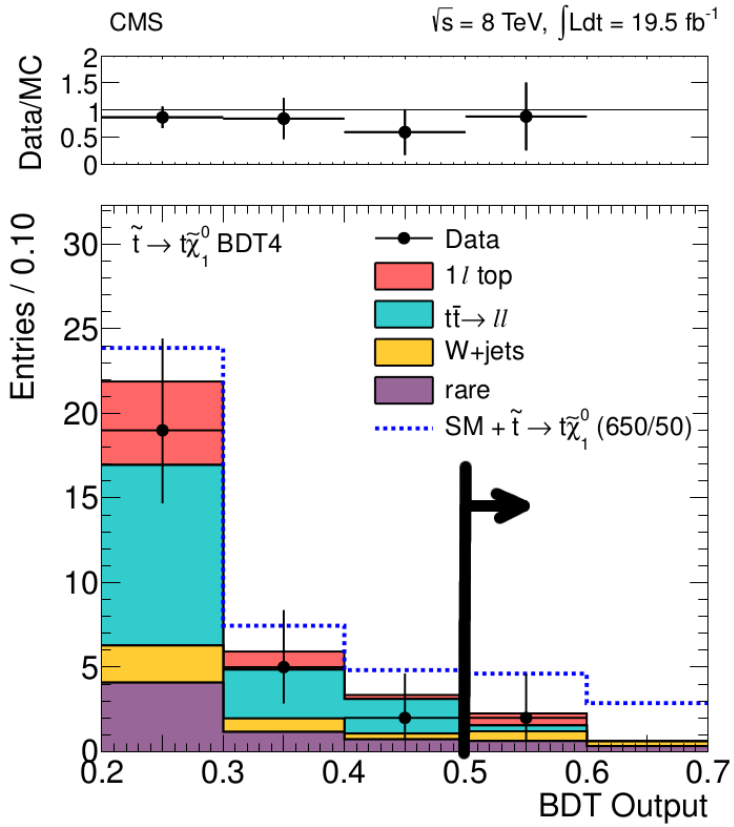
Results





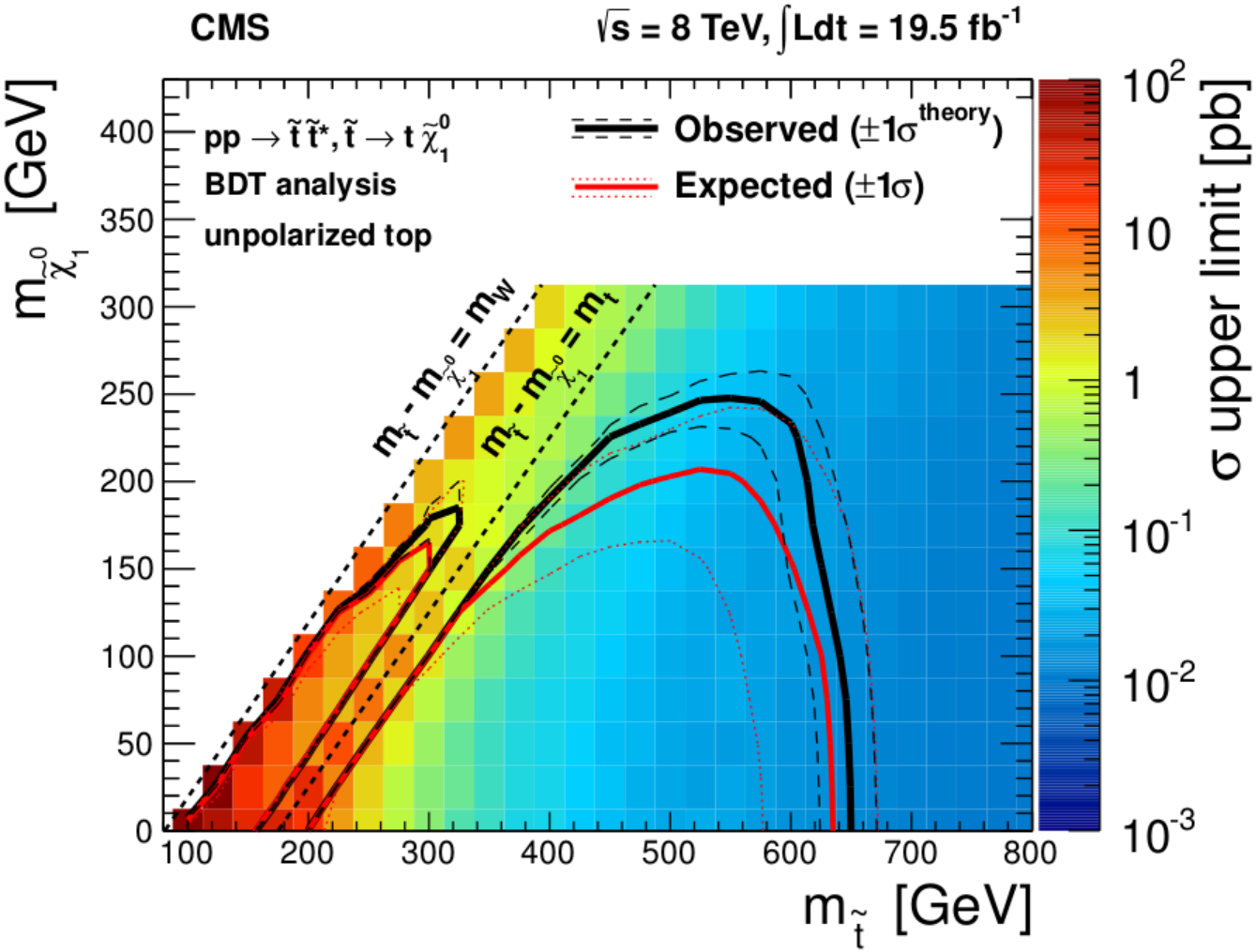




⇒ **no excess is observed**

Results

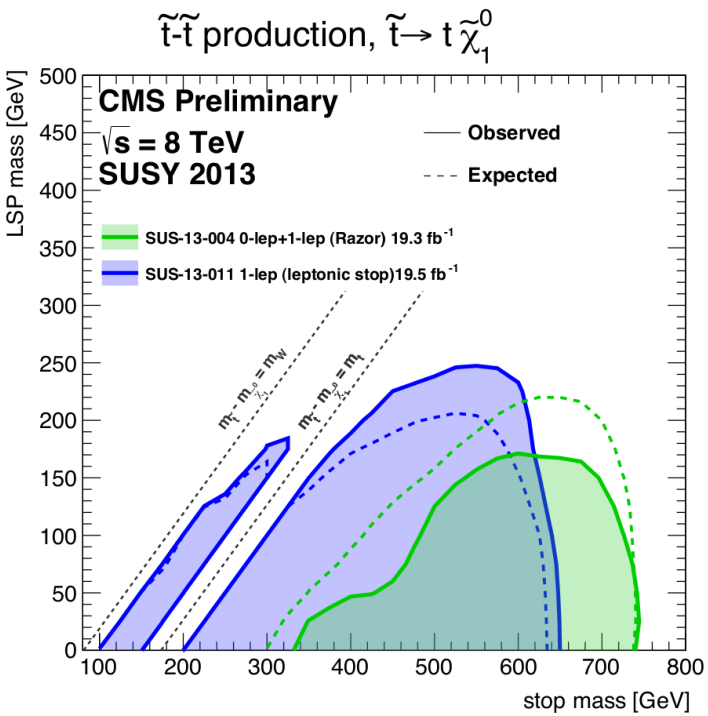
Excluded parameter space

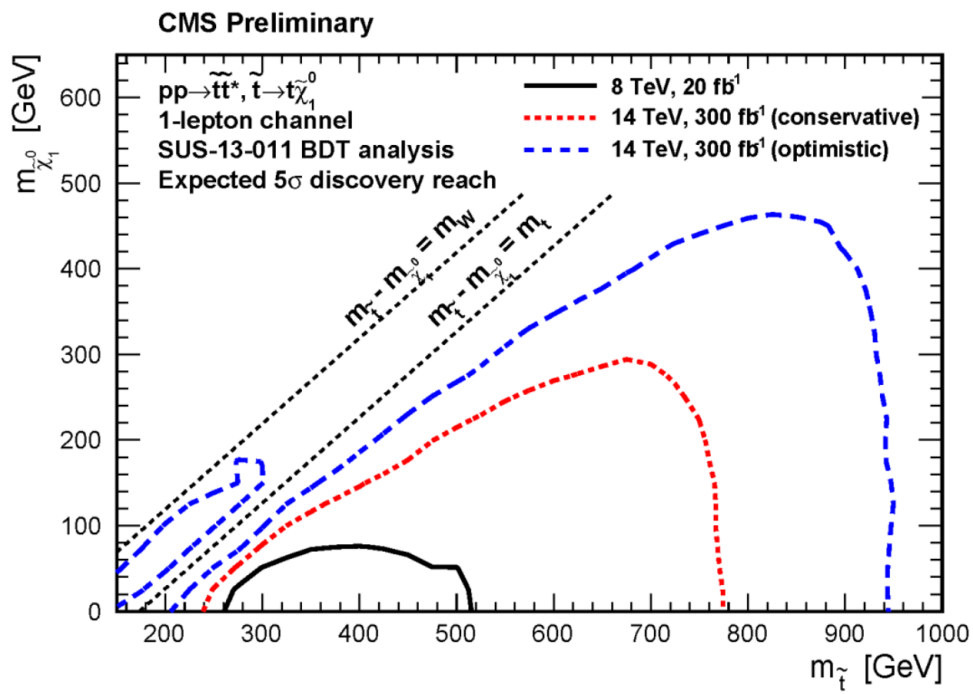


Results

Results

- Other analysis providing complementary results
- Ongoing combination with 0ℓ and 2ℓ channels
- 14 TeV projections predicts 5σ discovery potential up $m_{\tilde{t}} \sim$ 750-950 GeV





Conclusion

- Hope you understand a bit better **the different aspects of a search** at the LHC
- Stop search : **hot topic to search and constrain SUSY**
- So far, we probe stop masses up to $\sim$ **650 GeV**.
- Now working on **combination with 0-ℓ and 2-ℓ** channels, + looking forward to the **13-14 TeV**.

Conclusion

- Hope you understand a bit better **the different aspects of a search** at the LHC
- Stop search : **hot topic to search and constrain SUSY**
- So far, we probe stop masses **up to $\sim$ 650 GeV**.
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Thanks !

Any questions ?