# Towards a new approach for stop quark searches

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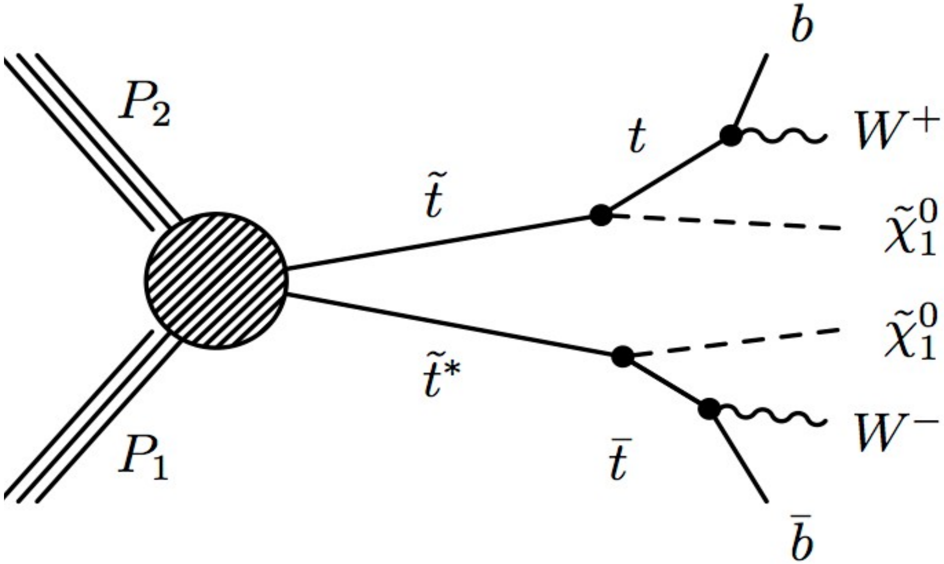
Lieselotte Moreels & Thomas Fitoussi

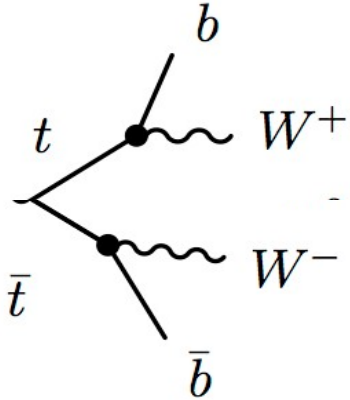
*Work in progress!*

# ttbar is the main background for stop quark searches




$$pp \to \tilde{t}\tilde{t}^* \to t\bar{t}\tilde{\chi}_1^0\tilde{\chi}_1^0 \to b\bar{b}W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0$$

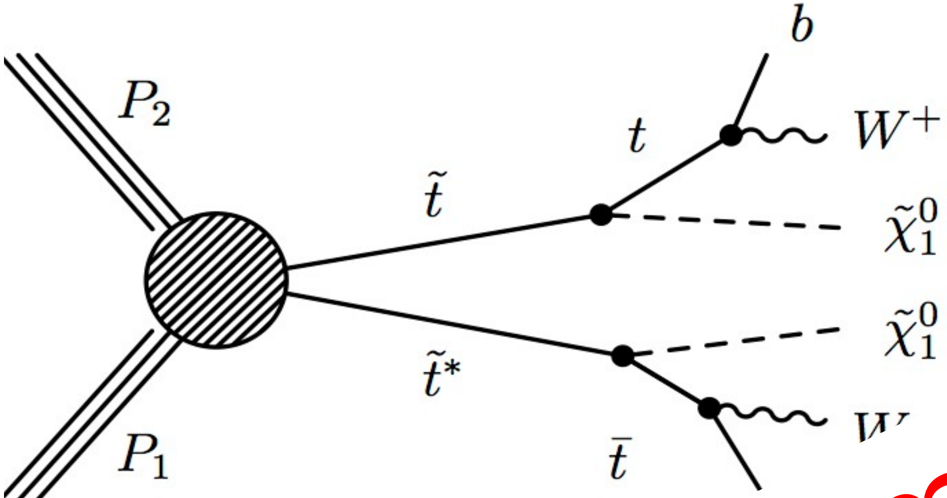
$\chi^0$ is the stable lightest supersymmetric particle (LSP)
→ missing transverse energy (MET)




ttbar:
- less missing transverse energy
- more boosted

Typically stop searches use MET, $H_T$, angles between objects, ...

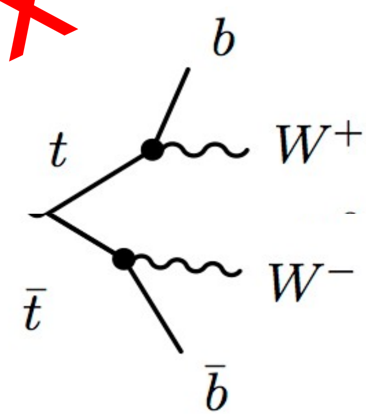
# ttbar is the main background for stop quark searches




$pp \to \tilde{t}\tilde{t}^*$ … $bW^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0$

**Matrix element method?**

…s the stable lightest supersymmetric particle (LSP)
→ missing transverse energy (MET)




ttbar:
- less missing transverse energy
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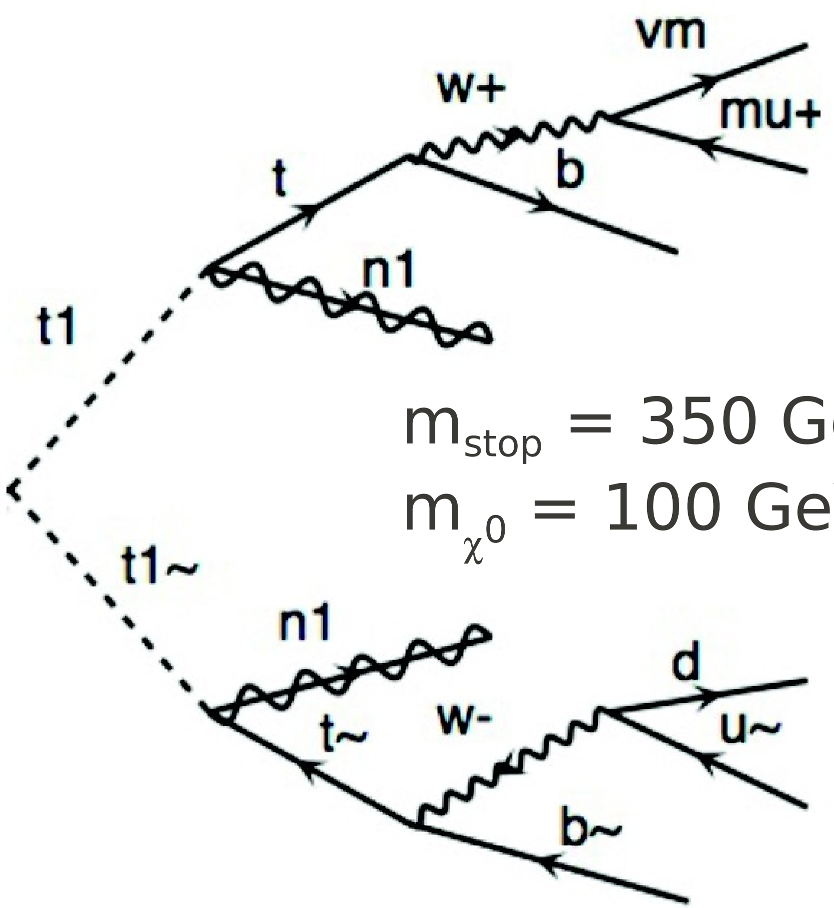
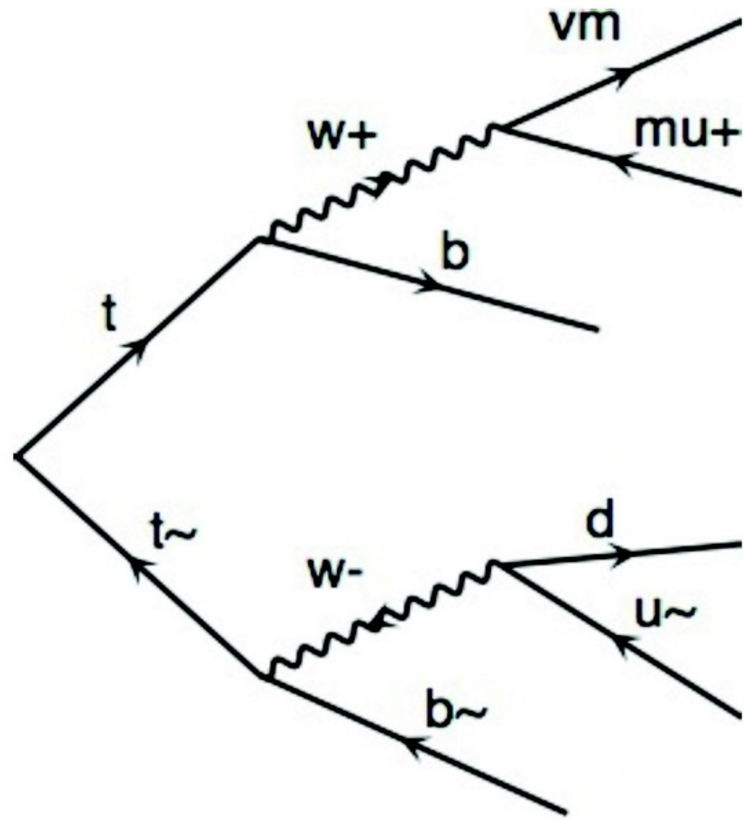
Typically analyses use MET, $H_T$, angles between objects, ...

# Case study on muon+jets+MET decay channel with sqrt(s) = 8 TeV

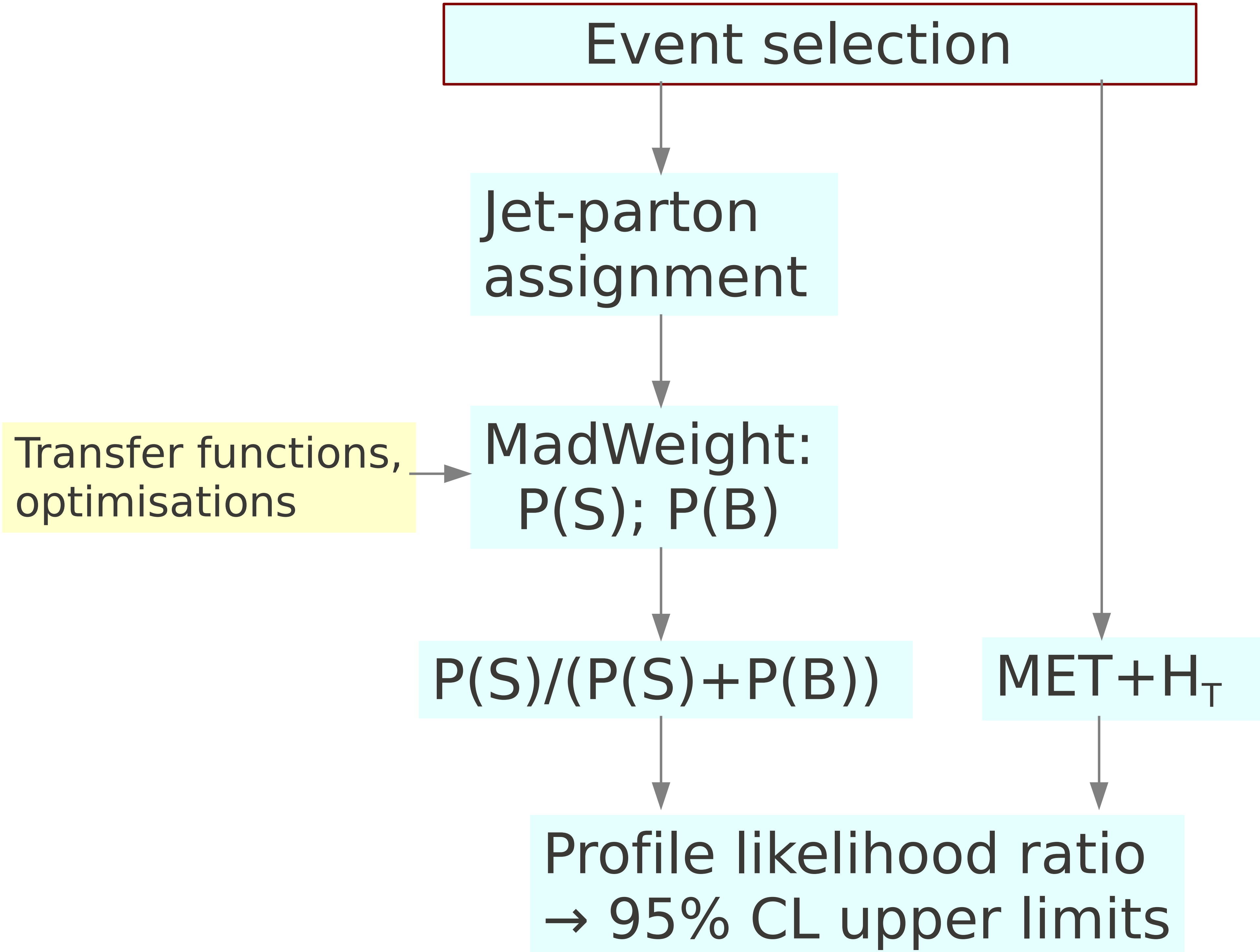



$m_{stop}$ = 350 GeV
$m_{\chi^0}$ = 100 GeV

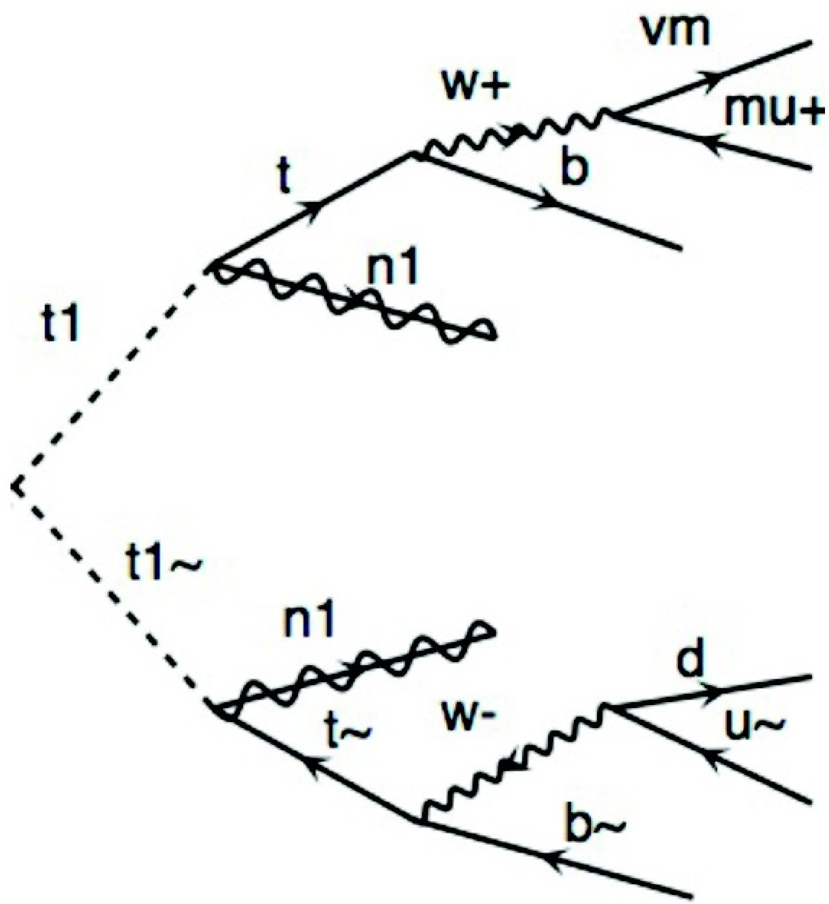
generate p p > t t~ , t > b mu+ vm , t~ > b~ j j




generate p p > t1 t1~ / sch sq , t1 > b mu+ vm n1 / sch sq , t1~ > b~ j j n1 / sch sq
→ exclude diagrams involving charginos (sch) and other squarks (sq)!


Event selection
Jet-parton assignment
Transfer functions, optimisations
MadWeight: P(S); P(B)
P(S)/(P(S)+P(B))
MET+$H_T$
Profile likelihood ratio → 95% CL upper limits

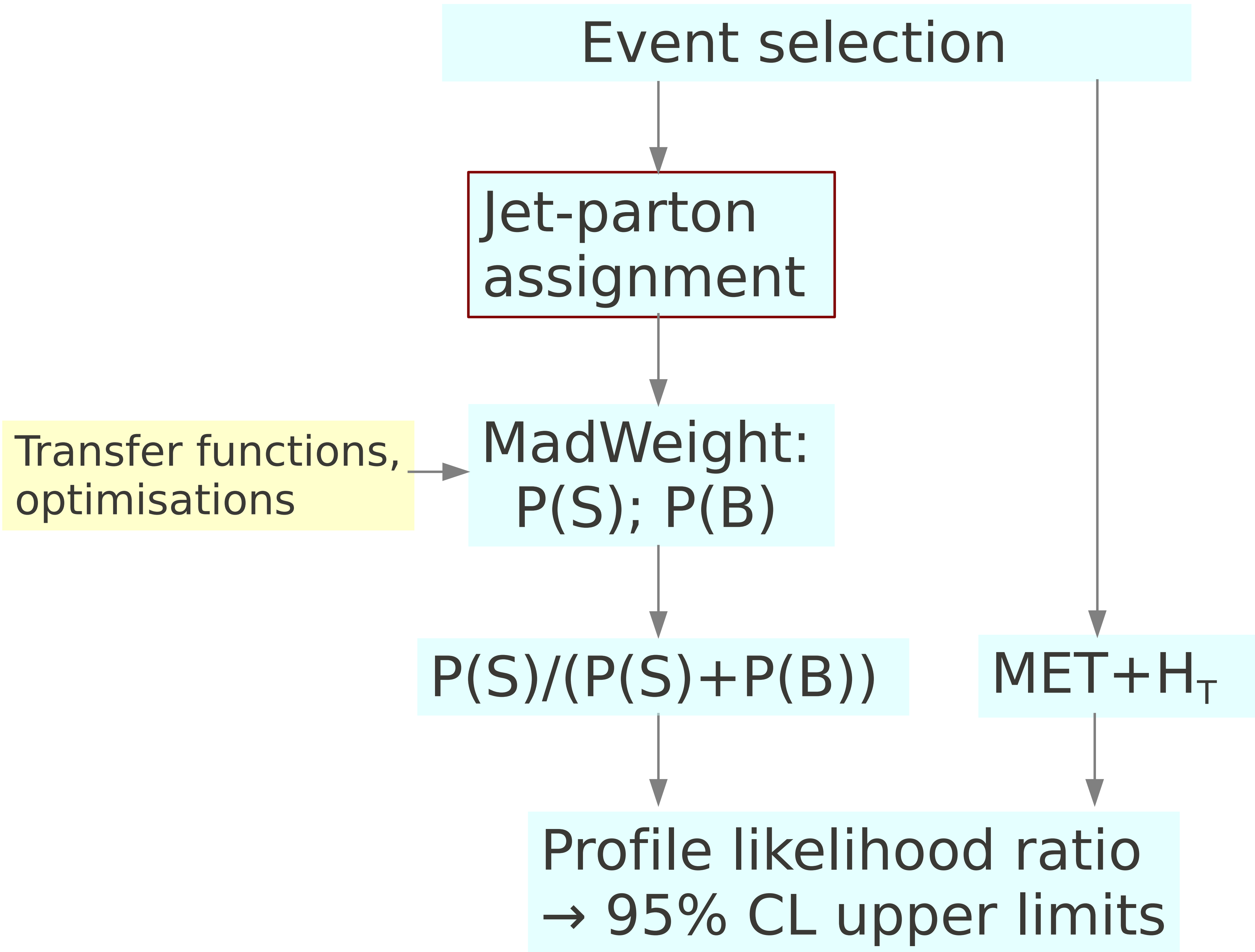
# The event selection reduces non-ttbar backgrounds to a small fraction




- =1 isolated muon:
  $p_T$ > 25 GeV, $|\eta|$<2.1
- ≥ 4 jets: 2 b-tagged
  $p_T$ > 30 GeV, $|\eta|$<2.4
- MET > 70 GeV
- $H_T$ > 250 GeV

→ S/B ~ 260/19000 (1.4%)

B = 94% ttbar + 6% other (mainly W+jets and single top)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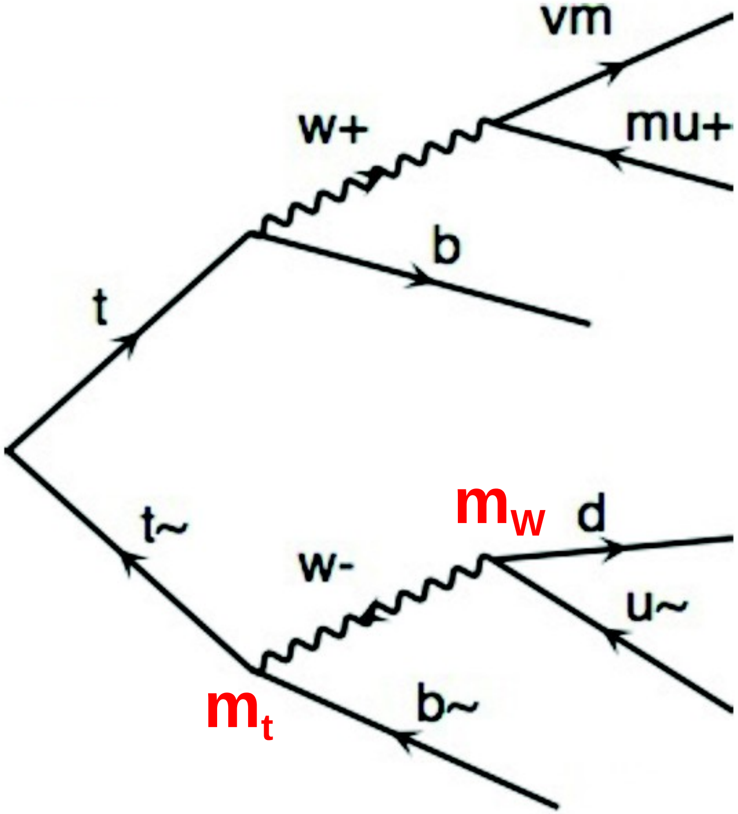
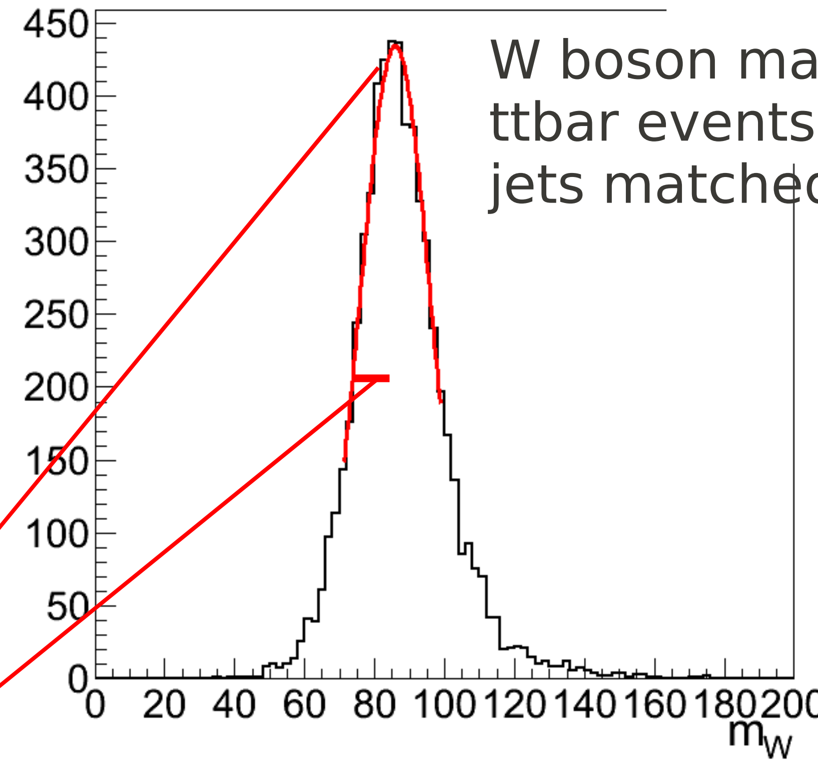
# Reduce the number of jet-parton assignments from 24 to 2



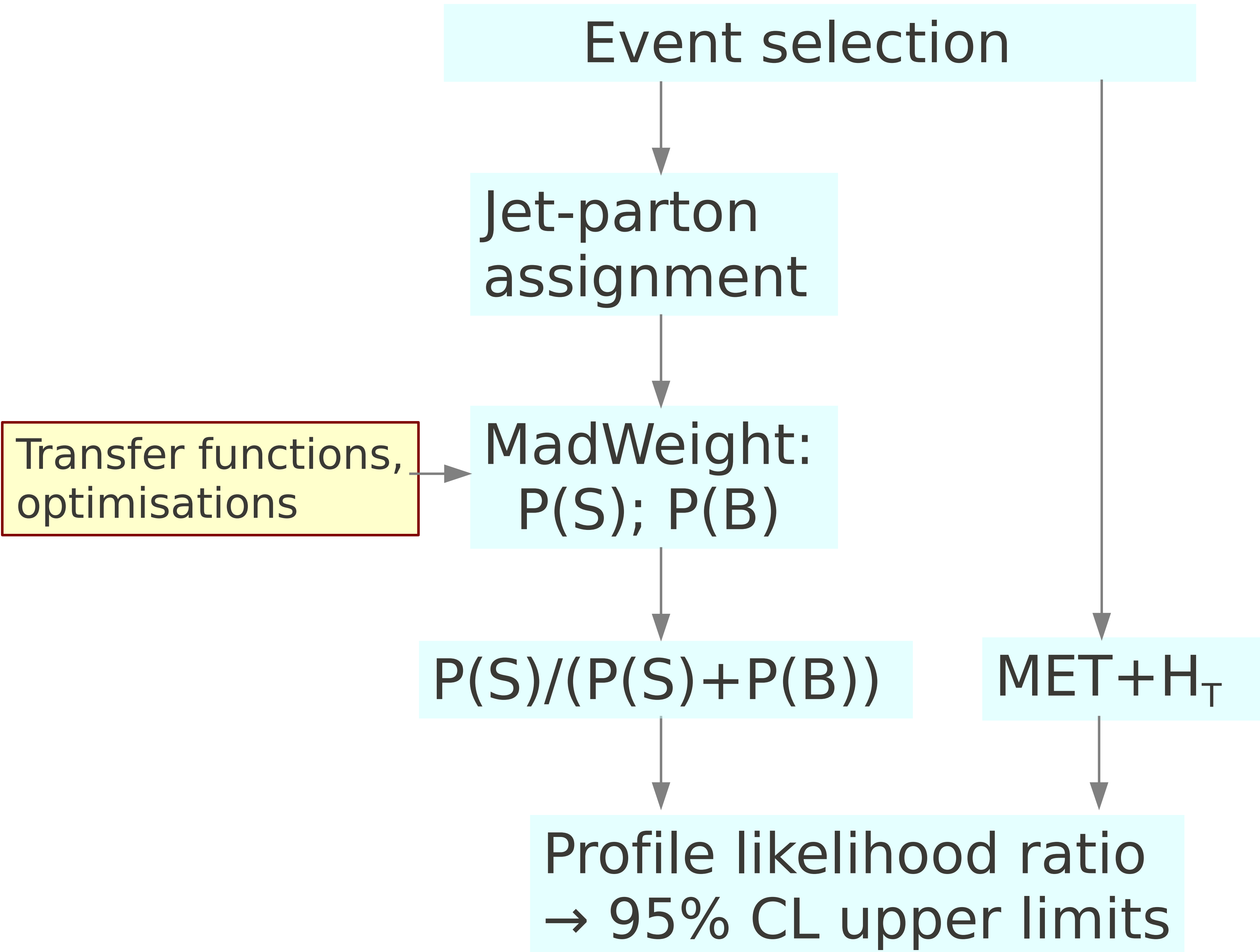

W boson mass from ttbar events using jets matched to quarks

Use the 4 highest $p_T$ jets; for each permutation, calculate:

$$\chi^2 = \left(\frac{m_{j_1,j_2} - m_W}{\delta m_W}\right)^2 + \left(\frac{m_{j_1,j_2,j_3} - m_t}{\delta m_t}\right)^2$$

one of the b jets

→ choose the 2 assignments with the smallest $\chi^2$
(~74% the correct assignment is one of those 2)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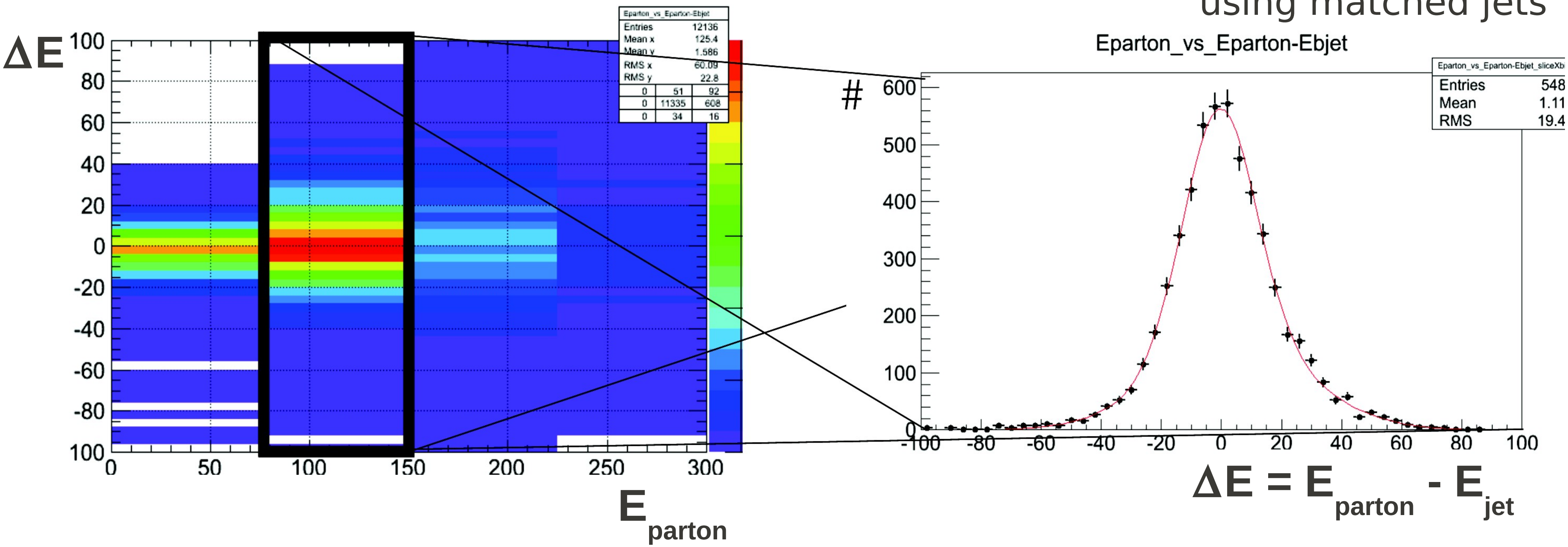
# Transfer function for jet energies

from ttbar events
using matched jets

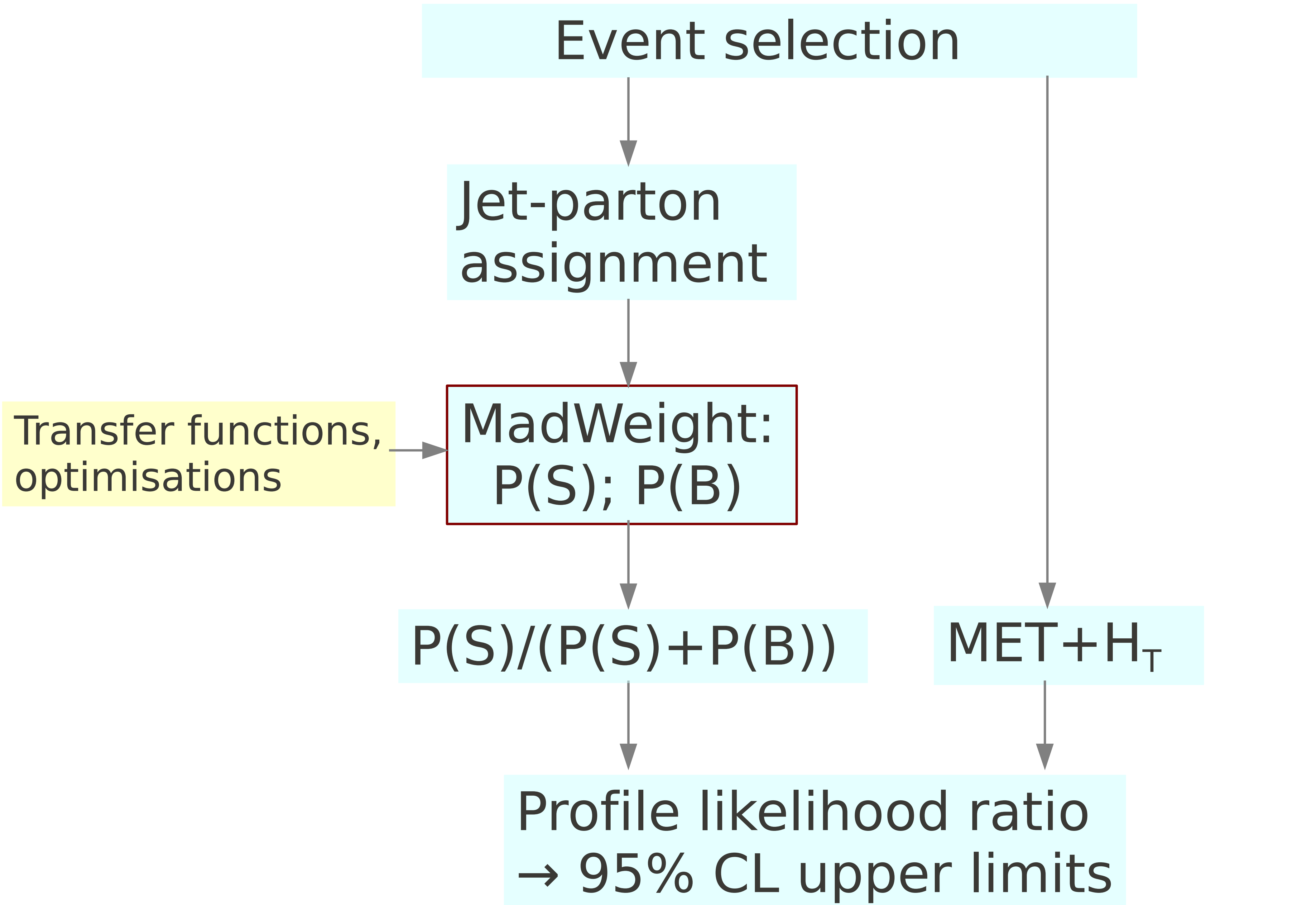



- Different for b jets and non-b jets
- Double gaussian with 6 parameters $p_i$

  $p_3\exp[-(\Delta E-p_1)^2/(2p_2{}^2)] + p_6\exp[-(\Delta E-p_4)^2/(2p_5{}^2)]$
- Parametrized as a function of $E_{parton}$:

  $p_{i,0} + p_{i,1}\mathrm{sqrt}(E_{parton}) + p_{i,2}E_{parton}$

  → 18 (6*3) parameters
- Assume angles and muon energy perfectly measured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# Calculate the probability for signal (stops) and background (ttbar)

For each event, compute the probability (MadWeight) that it is a:

- ttbar event (i.e. background “B”) → P(B)
- stop quark event (i.e. signal “S”) → P(S)

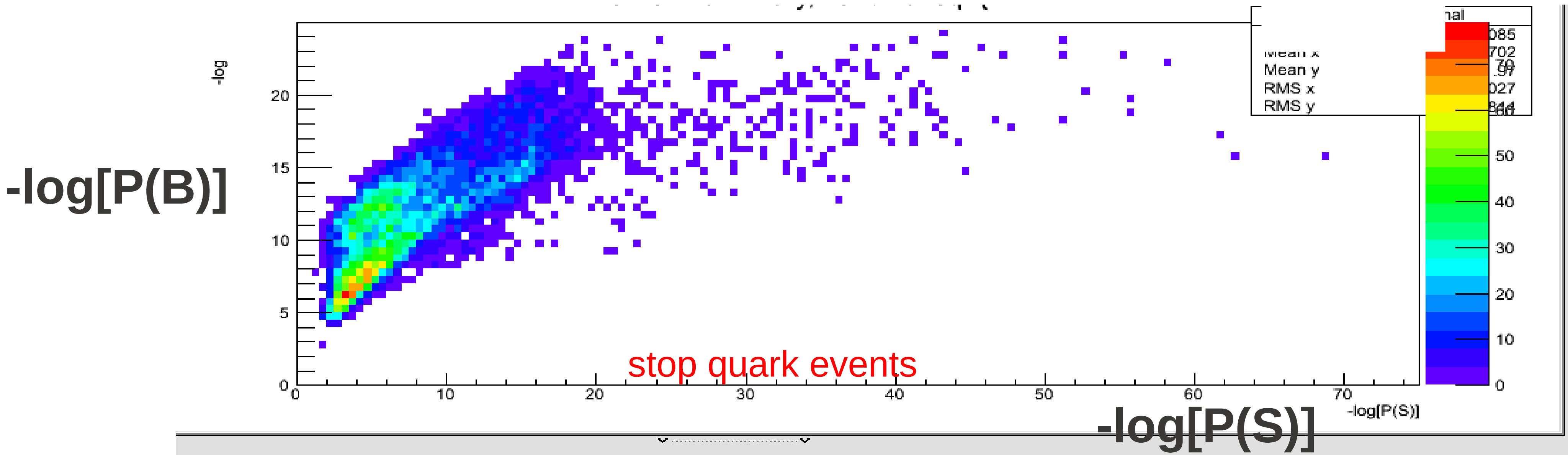
$$\mathcal{P}(p^{obs}|\vec{\theta}) = \frac{1}{\sigma(\vec{\theta})} \int dp^{true} |M(\vec{\theta}, p^{true})|^2 W(p^{true}, p^{obs})$$

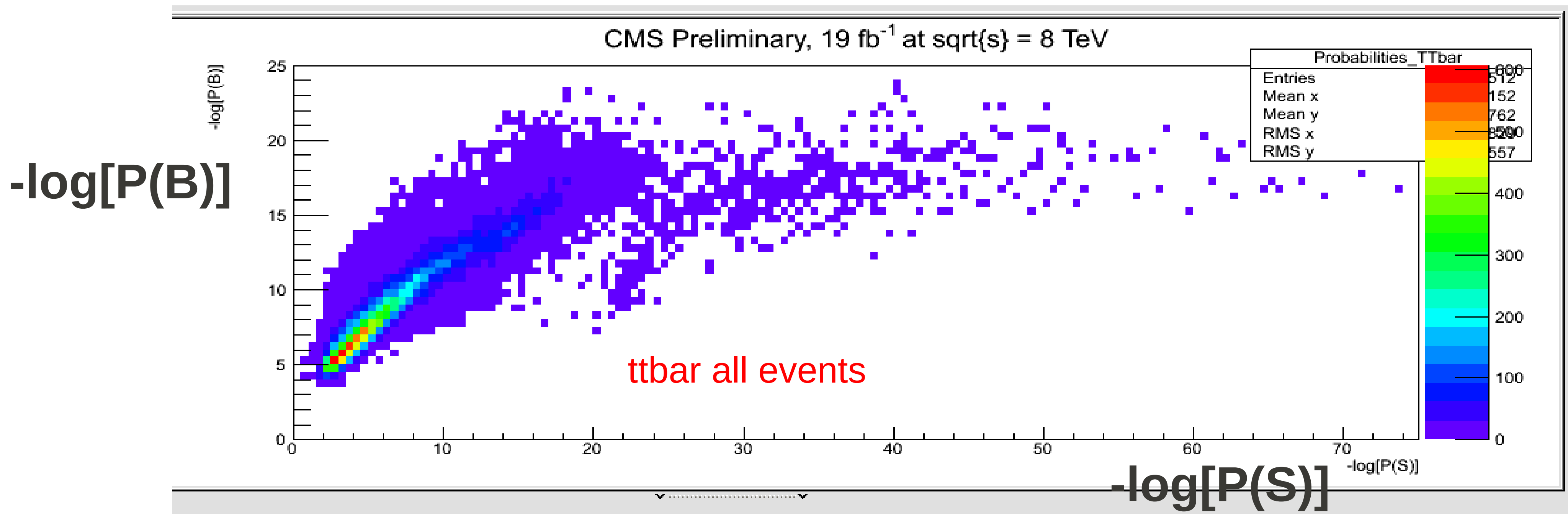
P(B) and P(S) are obtained for the 2 jet-parton assignments → take the average

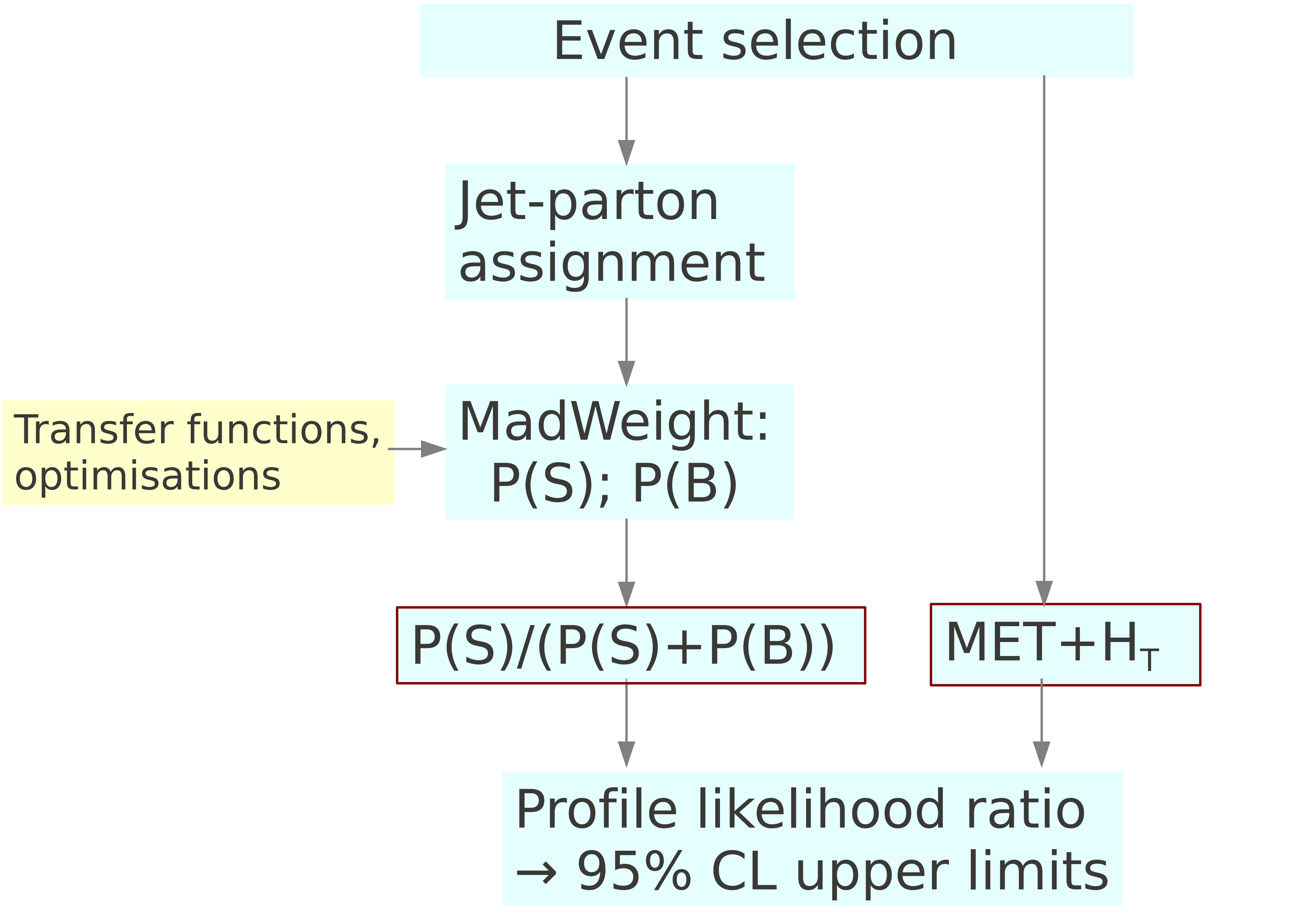
→ ultimately obtain for each event:

$$LR = \frac{\mathcal{P}(S)}{\mathcal{P}(S) + \mathcal{P}(B)}$$

# The probability for signal (stops) and background (ttbar)





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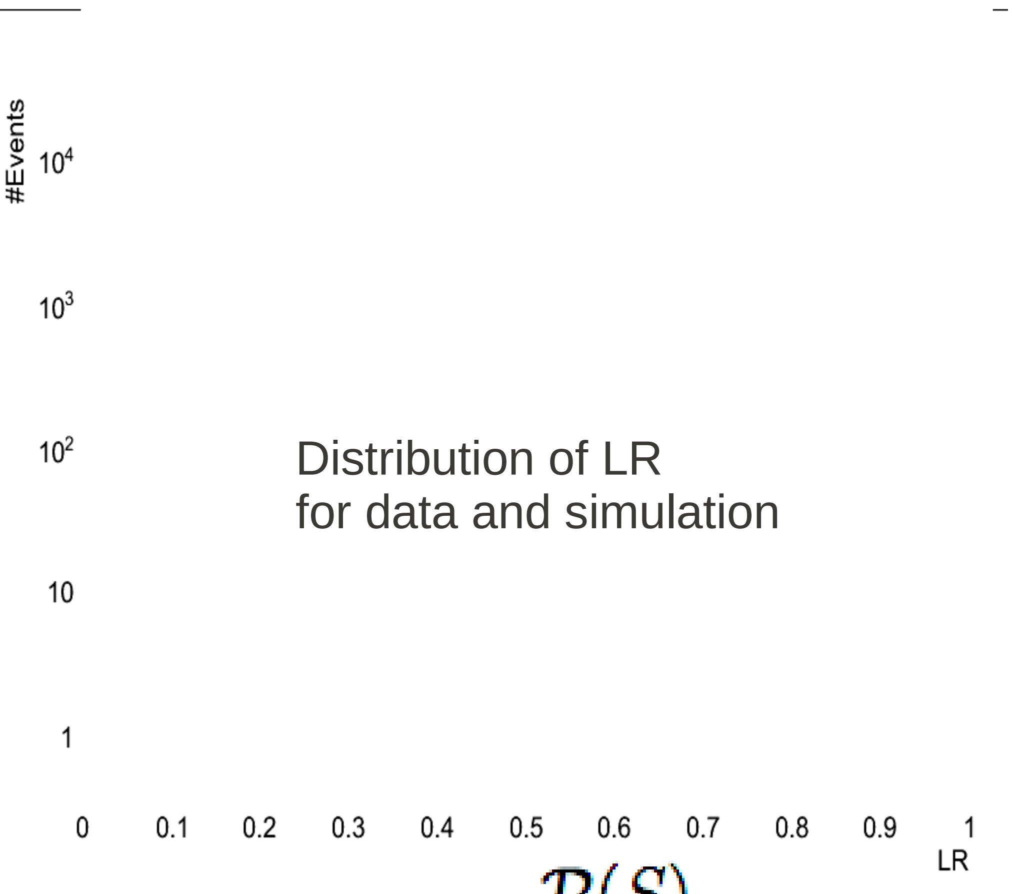
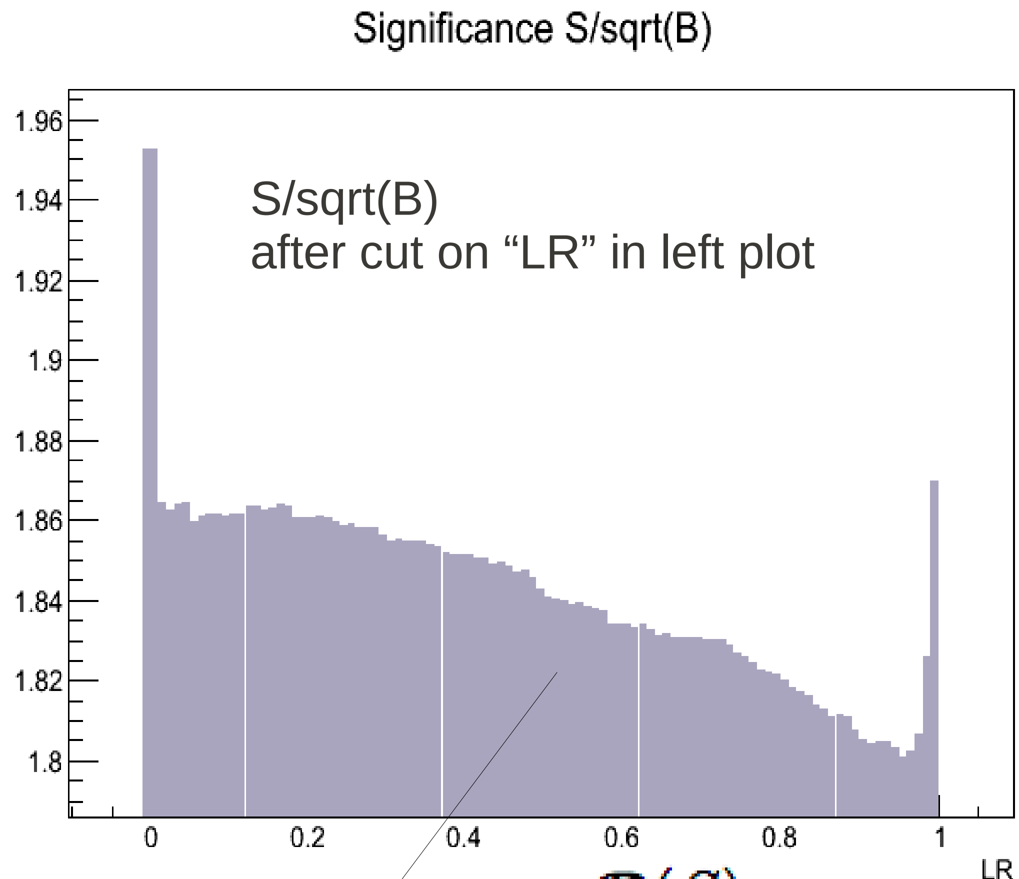
# The discriminator distribution




Distribution of LR
for data and simulation

$$LR = \frac{\mathcal{P}(S)}{\mathcal{P}(S) + \mathcal{P}(B)}$$

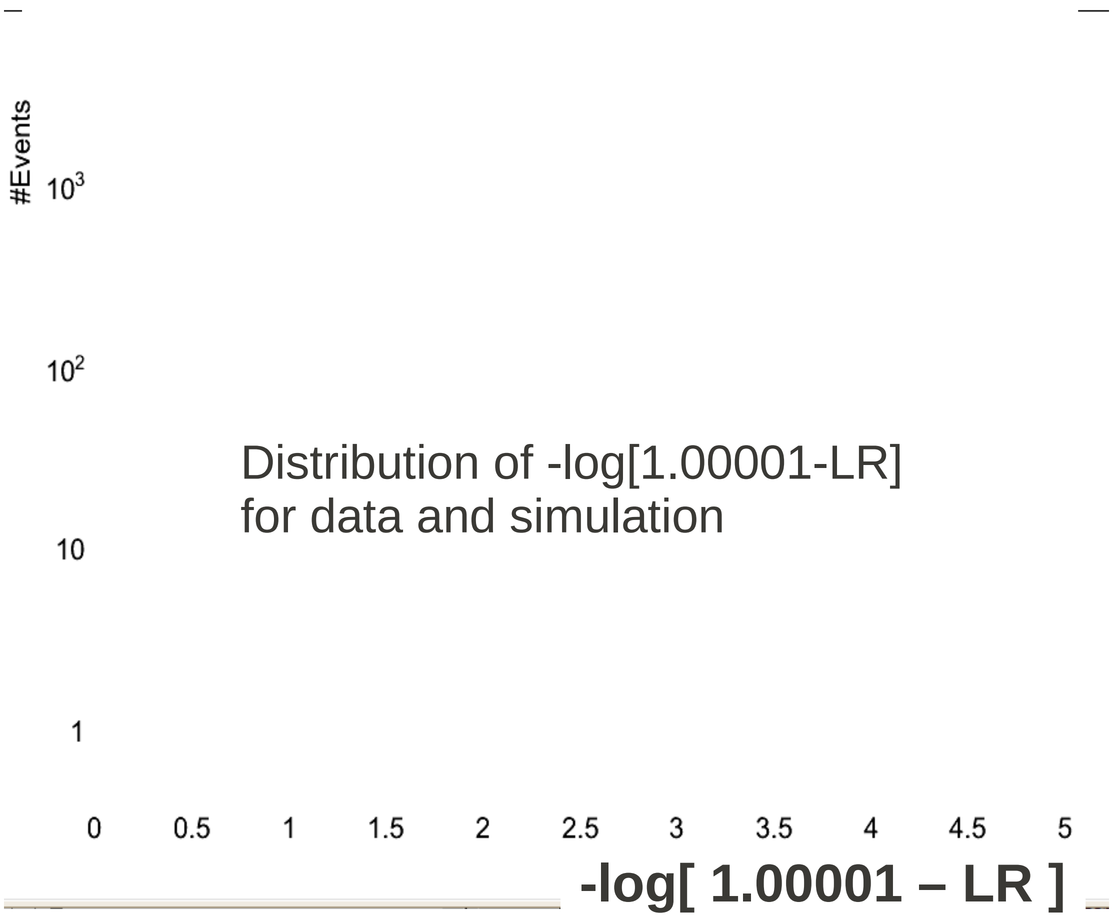


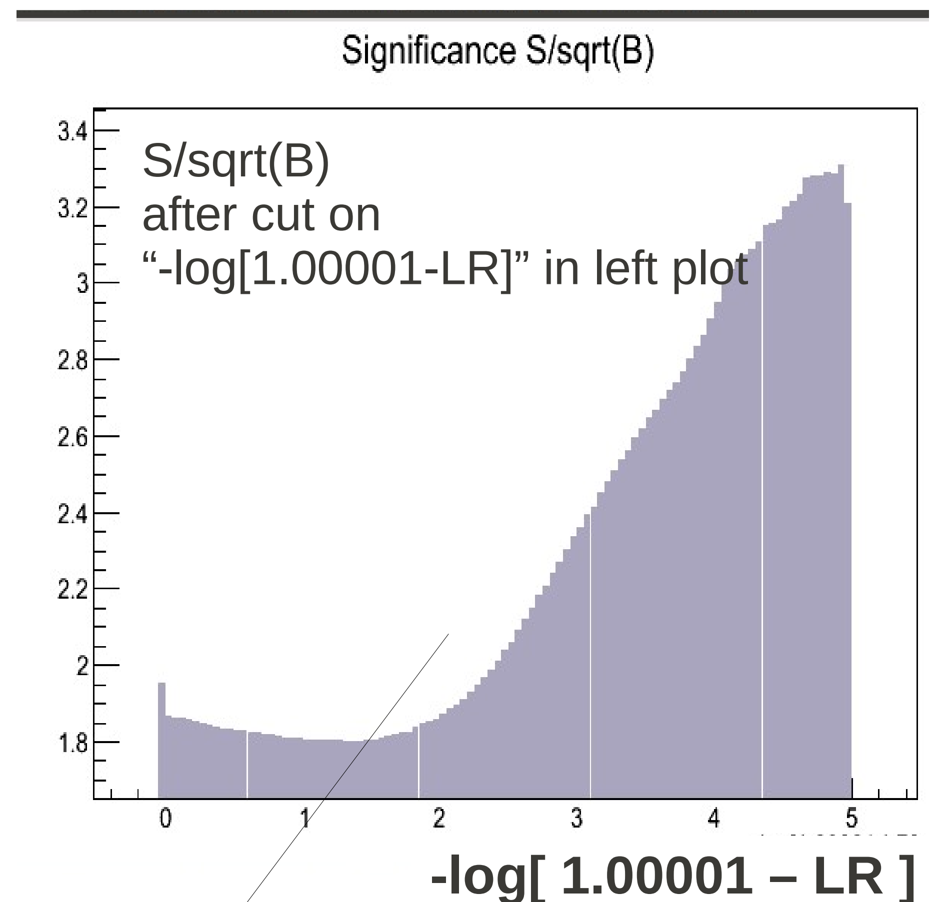

S/sqrt(B)
after cut on “LR” in left plot

$$LR = \frac{\mathcal{P}(S)}{\mathcal{P}(S) + \mathcal{P}(B)}$$

Provides a first idea of the sensitivity

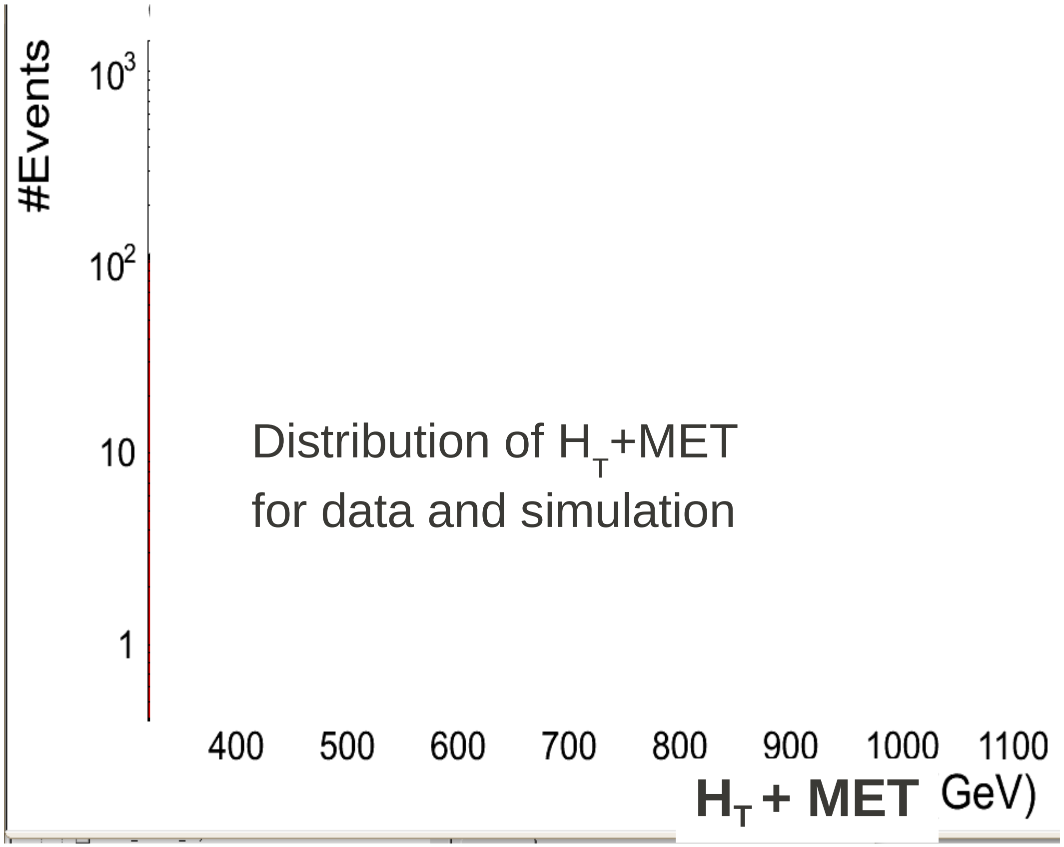
# The transformed discriminator has more sensitivity

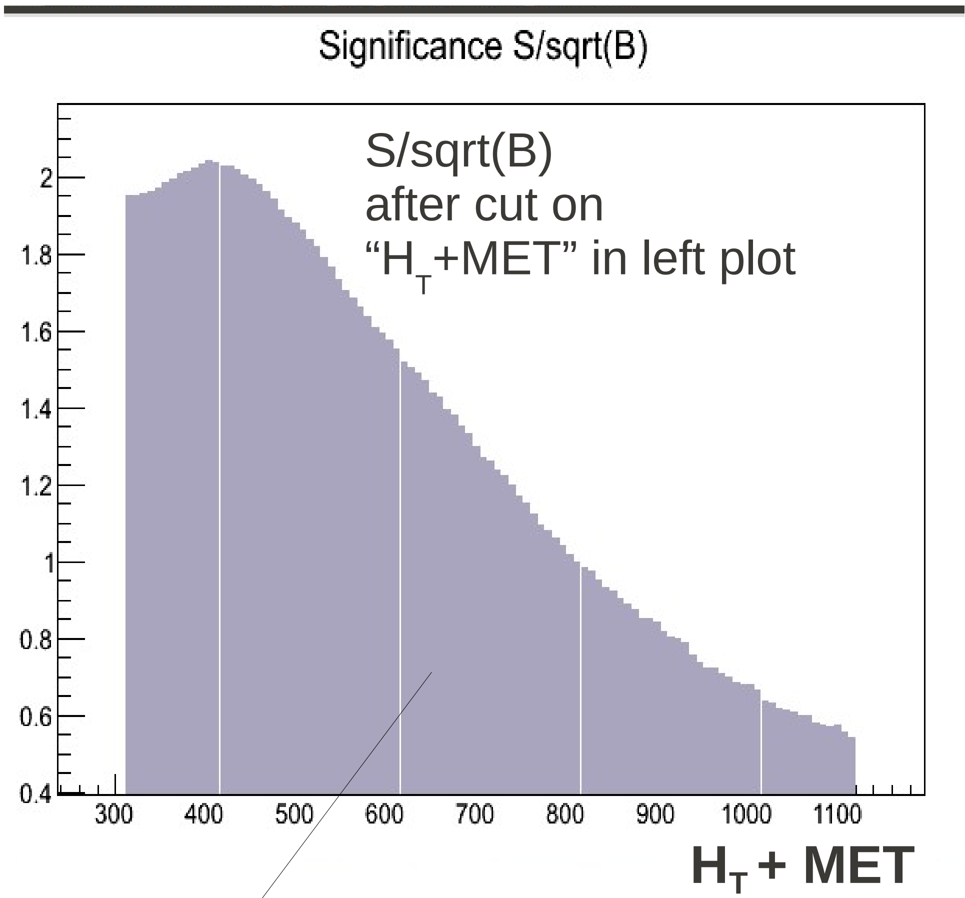


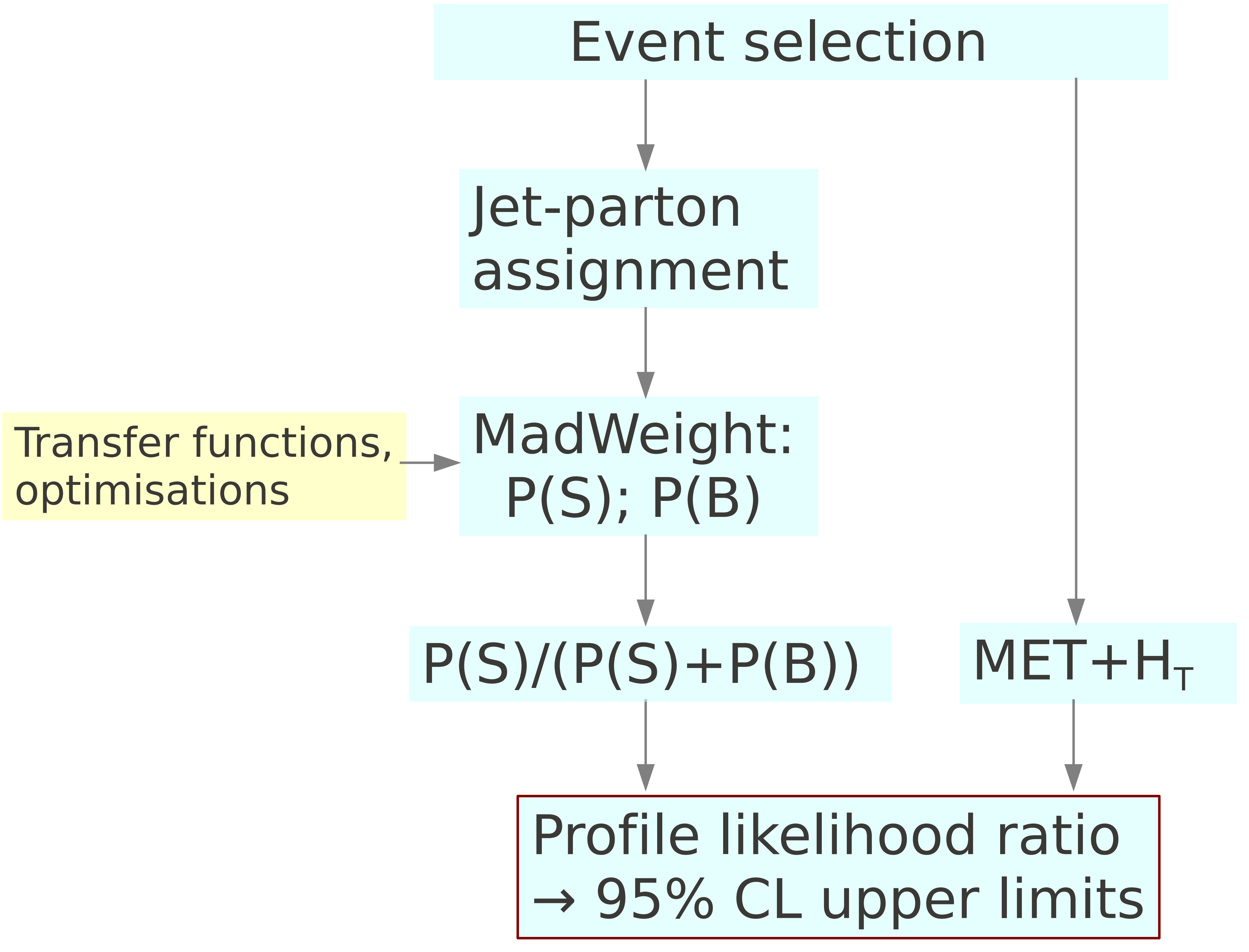

Provides a first idea of the sensitivity

# Simple analysis using HT+MET




Provides a first idea of the sensitivity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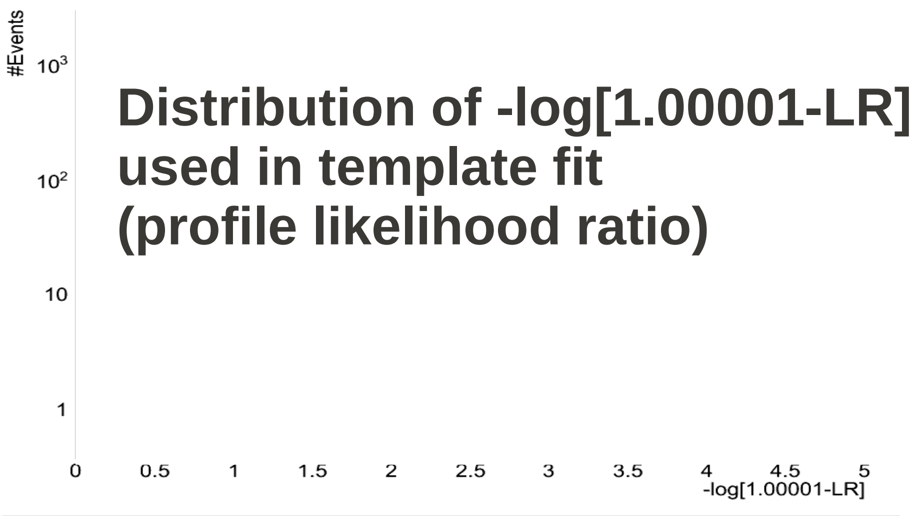
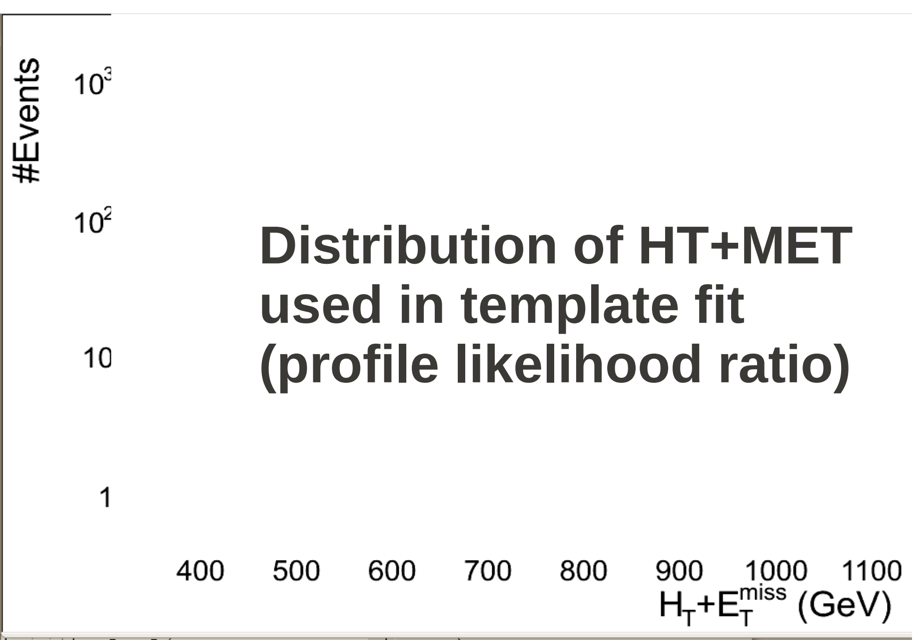
MET+H_T
Profile likelihood ratio → 95% CL upper limits

# The matrix element method clearly has a lot of potential in this search




Signal strength needed for 95%CL exclusion:
~0.6 (from initial rough studies)

Factor 3!




Signal strength needed for 95%CL exclusion:
~1.9 (from initial rough studies)

# The “quick” case study is promising

The first study is promising: factor of 3 improvement
(madweight versus 'simple' $H_T$+MET)

Time for the real work & detailed studies:

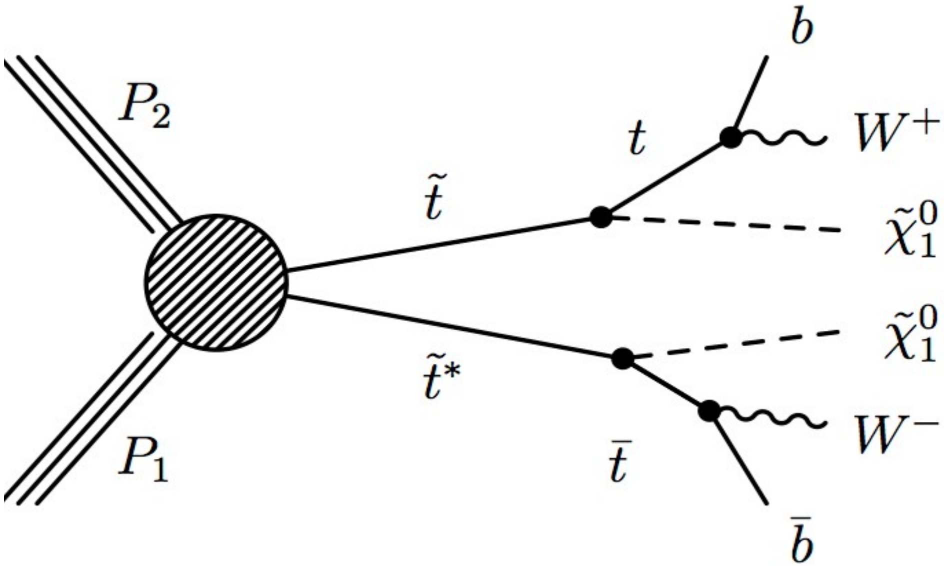
- Closer look at transfer functions:
  η-dependent, less parameters, also muon energy
- Further reduce the cpu time (~7 minutes/event ?)
- Permutations now done 'by hand'
- Normalization factor → interpret weights as probabilities
- What is required to run MadWeight on the grid?

Real experimental analysis:

- Perform a scan on $(m_{stop}, m_{\chi^0})$
- Include systematics
- ...

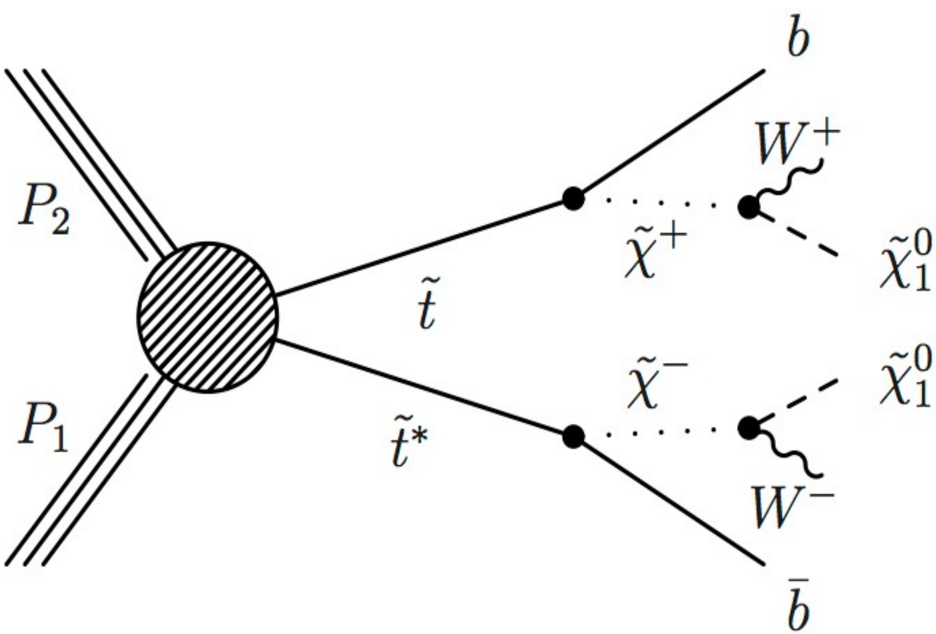
# Additional material

# Ultimately: search simultaneously for 2 signal decay channels with MEM!



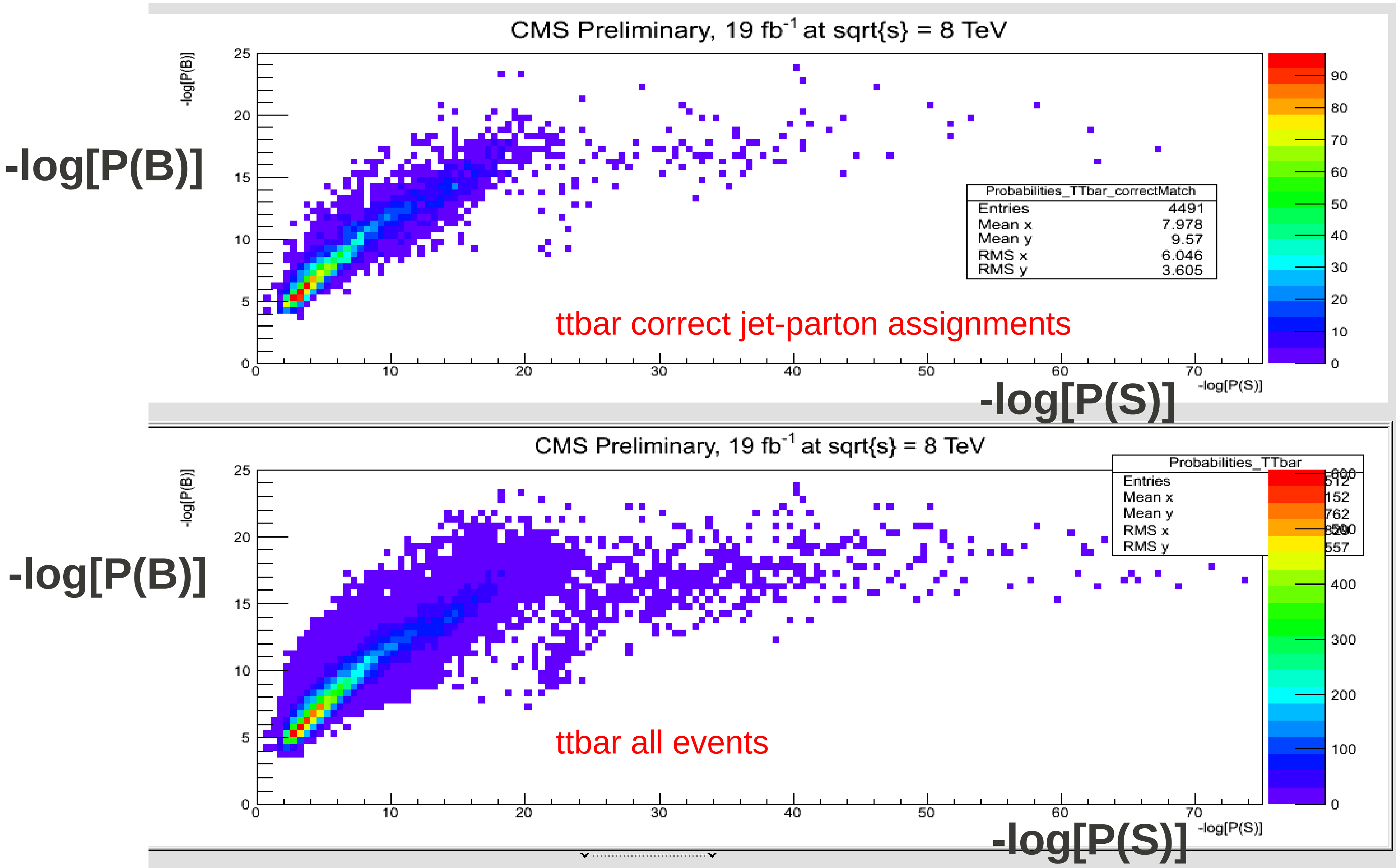

$$pp \to \tilde{t}\tilde{t}^* \to t\bar{t}\tilde{\chi}_1^0\tilde{\chi}_1^0 \to b\bar{b}W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0$$

Enhance our chance to find stops: use both signal decay channels!

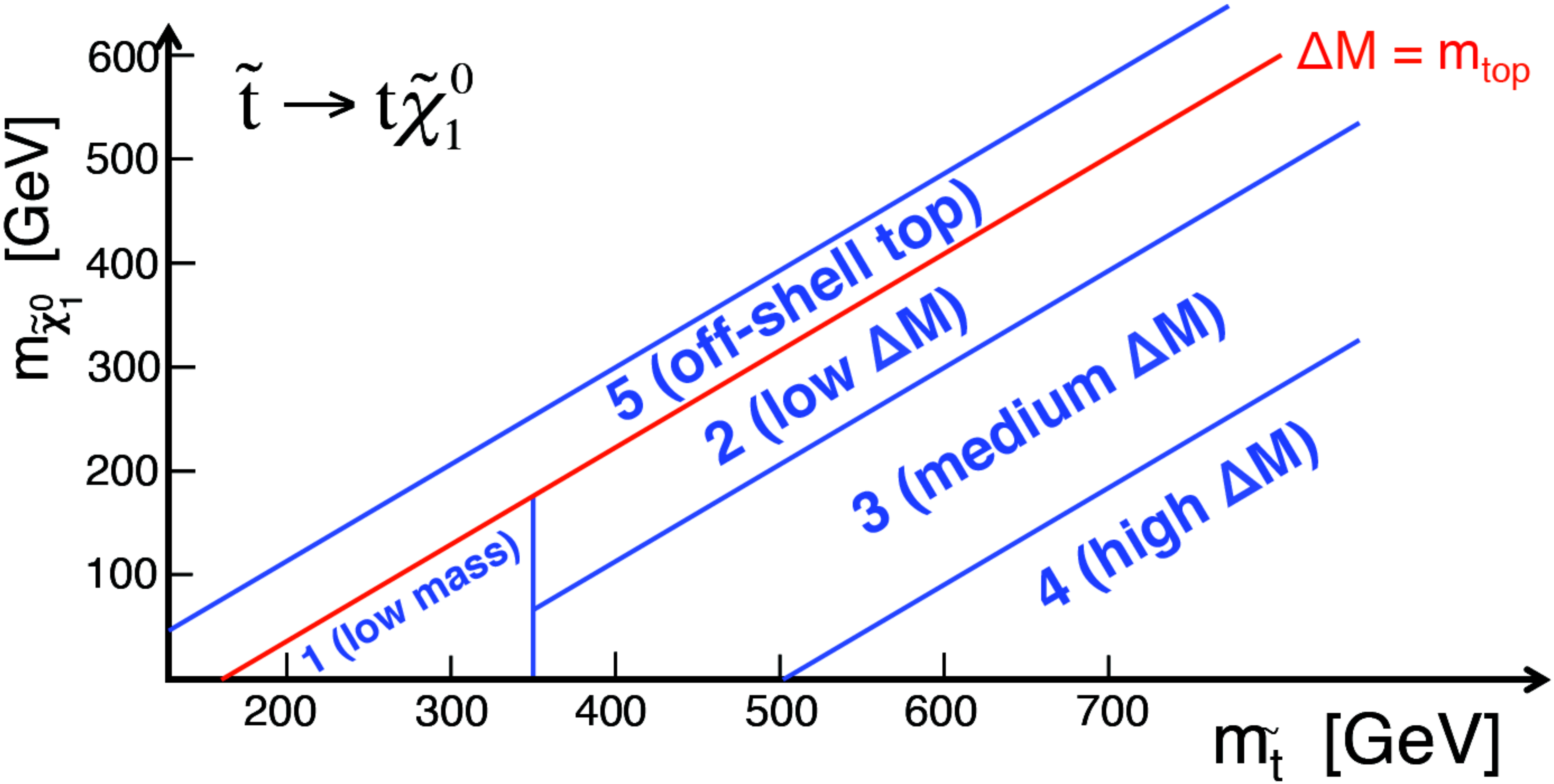



$$pp \to \tilde{t}\tilde{t}^* \to b\bar{b}\tilde{\chi}_1^+\tilde{\chi}_1^- \to b\bar{b}W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0$$

# The “probability” for signal (stops) and background (ttbar)



# The parameter space



# The CMS official exclusion limit