A New Approach To Matrix Element Re-Weighting

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CP3

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P.Artoisenet, V.Lemaître, F. Maltoni, OM: JHEP 1012:068

Motivations

- Both LHC and Tevatron search for Higgs and NP !
  - How to identify new particles?
  - How to measure particle properties?
- Especially difficult in presence of missing Energy
- Is there a way to optimise the information which can be extracted from a event sample?

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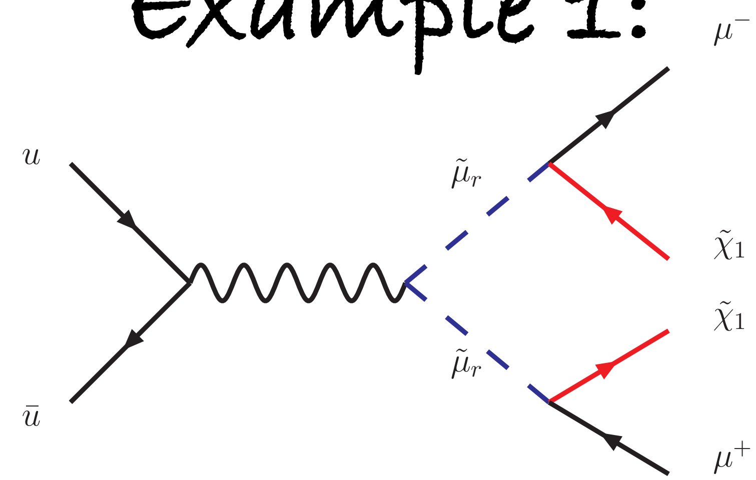
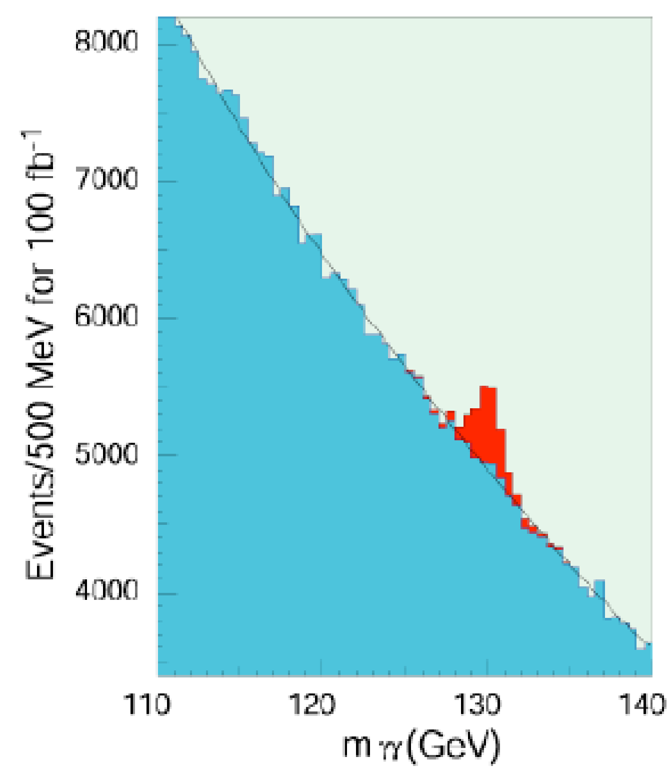


Example 2:



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YES Many

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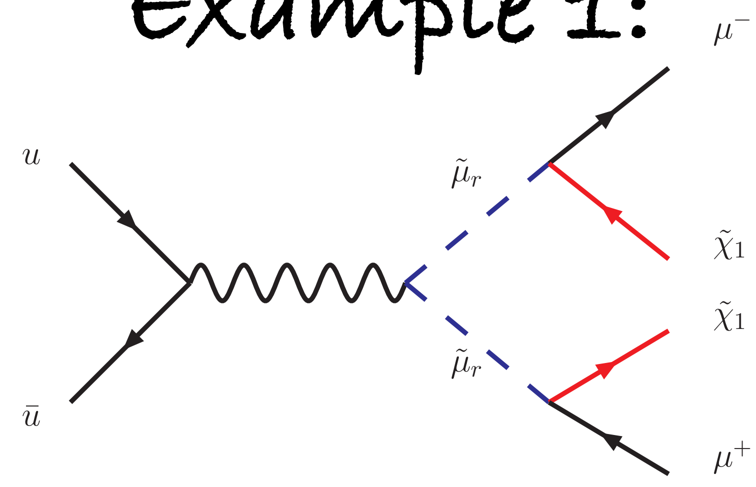

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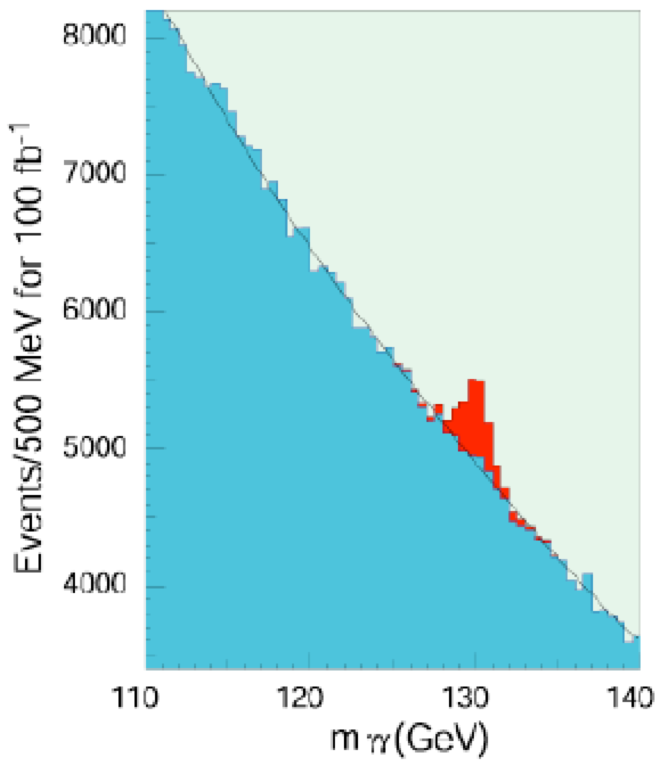

Outline

- Introduction to Matrix Element re-weighting
- Examples of studies / investigations
  - mass determination : smuon pair production
  - Spin analysis
  - ISR effects: pp > H > W+ W-
  - DMEM: $m_{t\bar{t}}$ in fully leptonic channel
- Conclusions

Matrix Element Re-weighting

- Associate to each experimental event characterised by $\boldsymbol{p}^{vis}$, the probability $\mathcal{P}(\boldsymbol{p}^{vis}|\alpha)$ to be produced and observed following a theoretical assumption α

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- $|M_\alpha(\boldsymbol{p})|^2$ is the squared matrix element

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- $W(\boldsymbol{p}, \boldsymbol{p}^{vis})$ is the transfer function
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- σ_α^{vis} is the cross-section (after cuts)

Matrix Element Method

- Most common and important use is to combine those in a Likelihood

$$L(\alpha) = \prod_{i=1}^{N} \mathcal{P}(\boldsymbol{p}_i^{vis}|\alpha)$$

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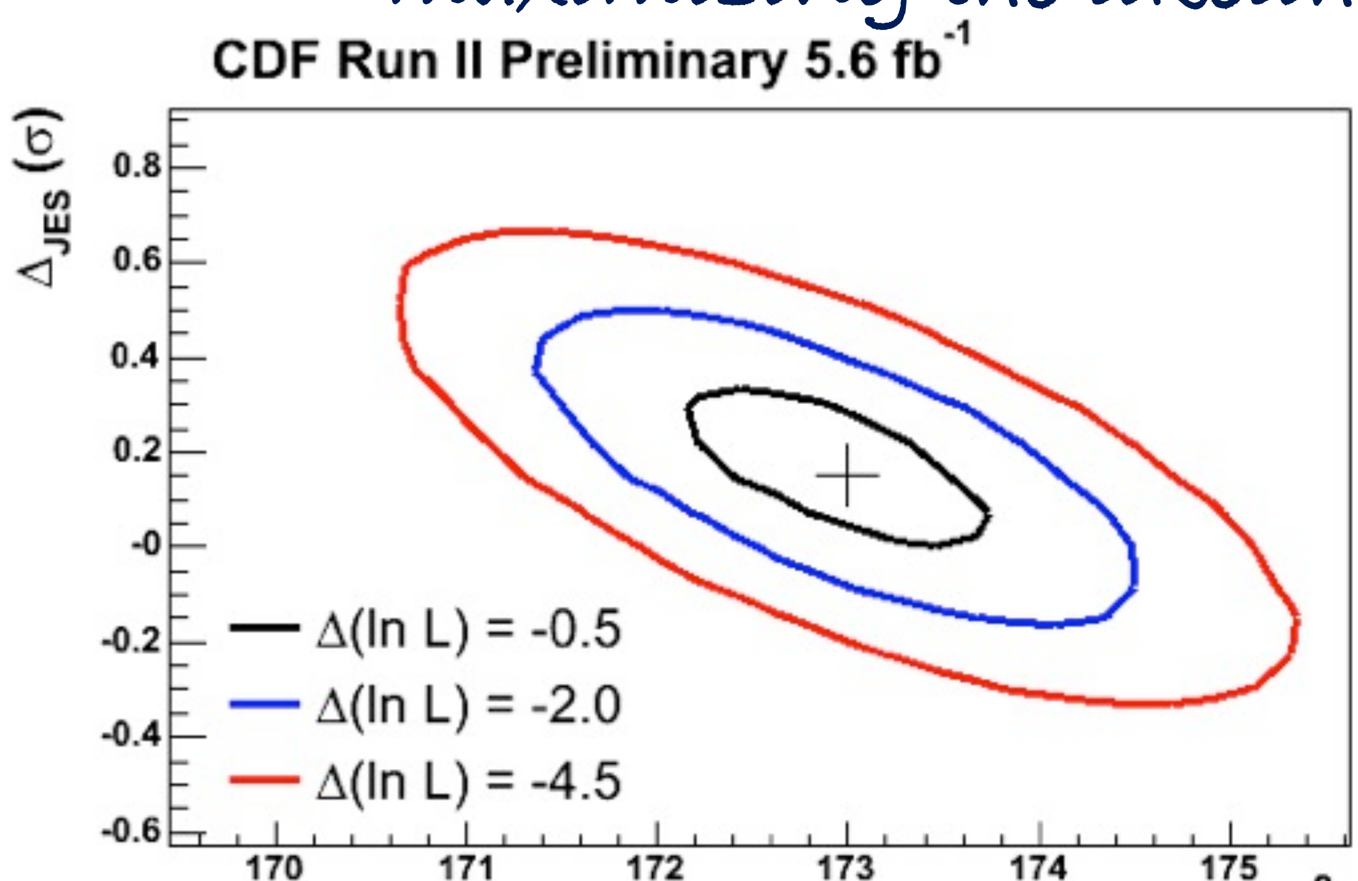

Semi-leptonic decay

$$m_{top} = 173.0 \pm 1.2 \text{GeV}$$

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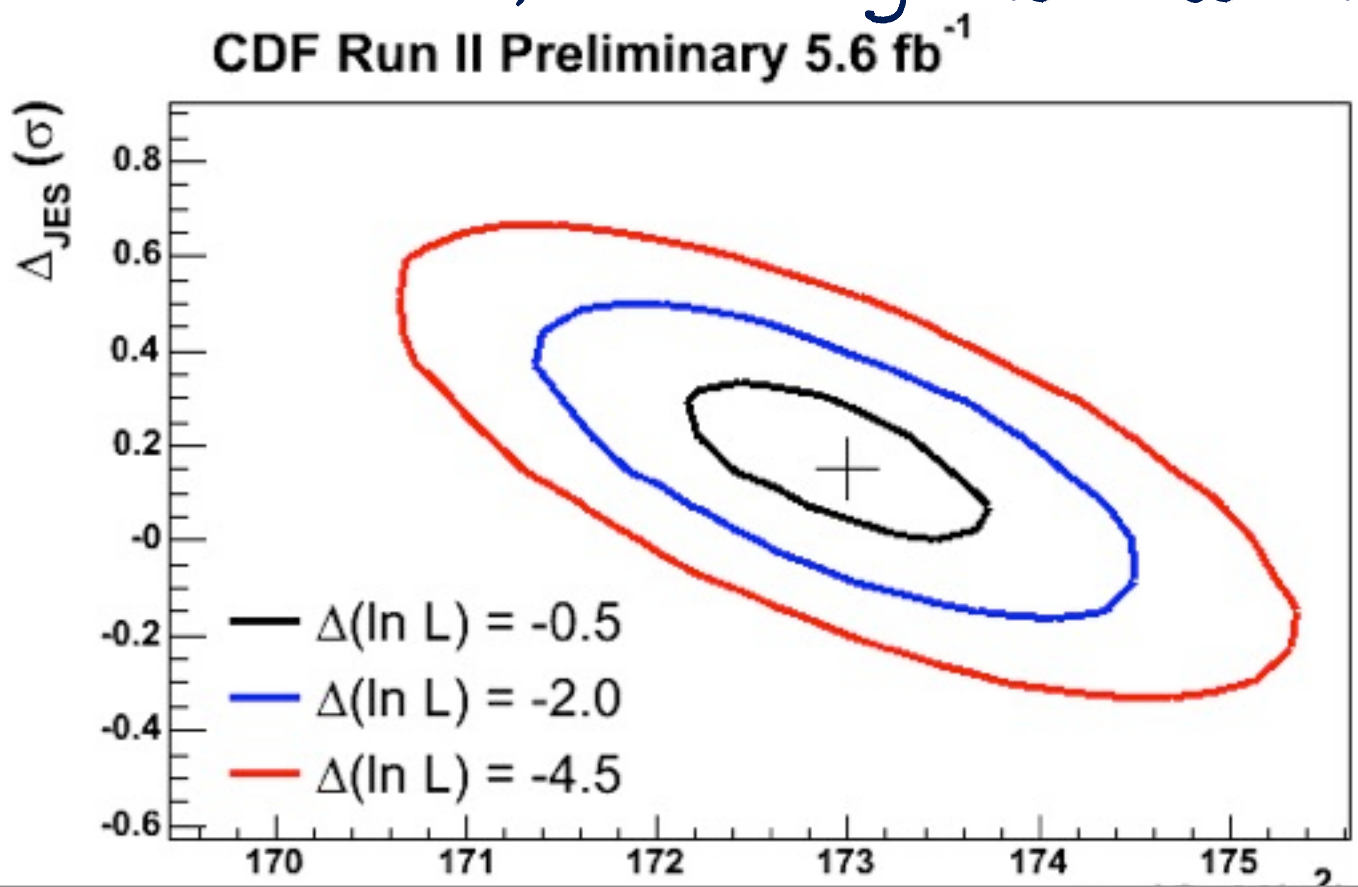

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Also use for

- Higgs Exclusion
- single top cross observation

CRITICS OF THE METHOD

- The Likelihood methods builds the BEST discriminating variable
- Fully Model dependant
- Pure LO approximation
- Transfer Function approximation
  - Factorize for each parton
  - Not valid for hard radiation
- Strong sensitivity in analysis cut
- Computing time ($N_{event} * N_{th}$ integrals)

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How to evaluate those weights?

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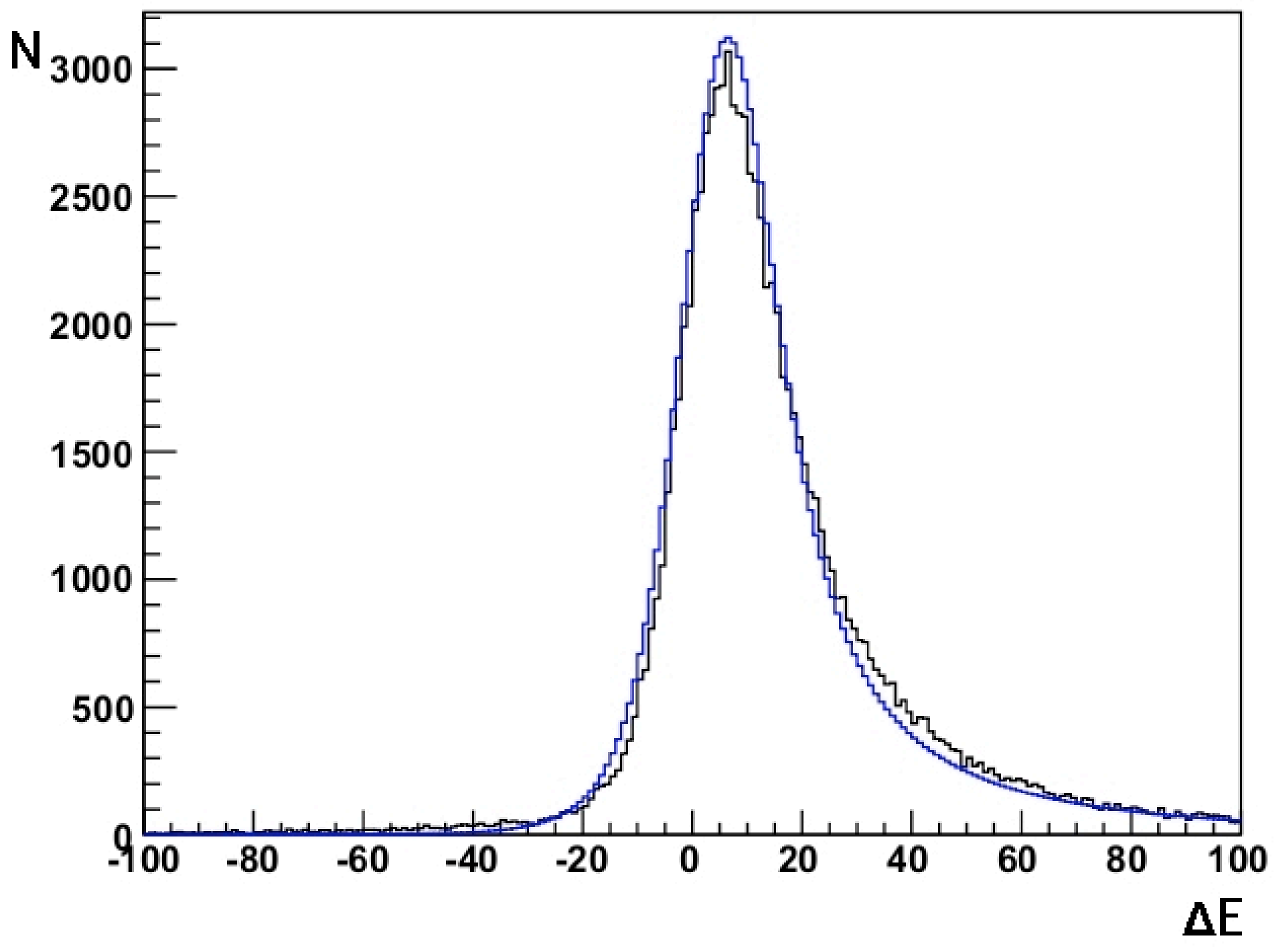

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- Need a specific integrator: MadWeight

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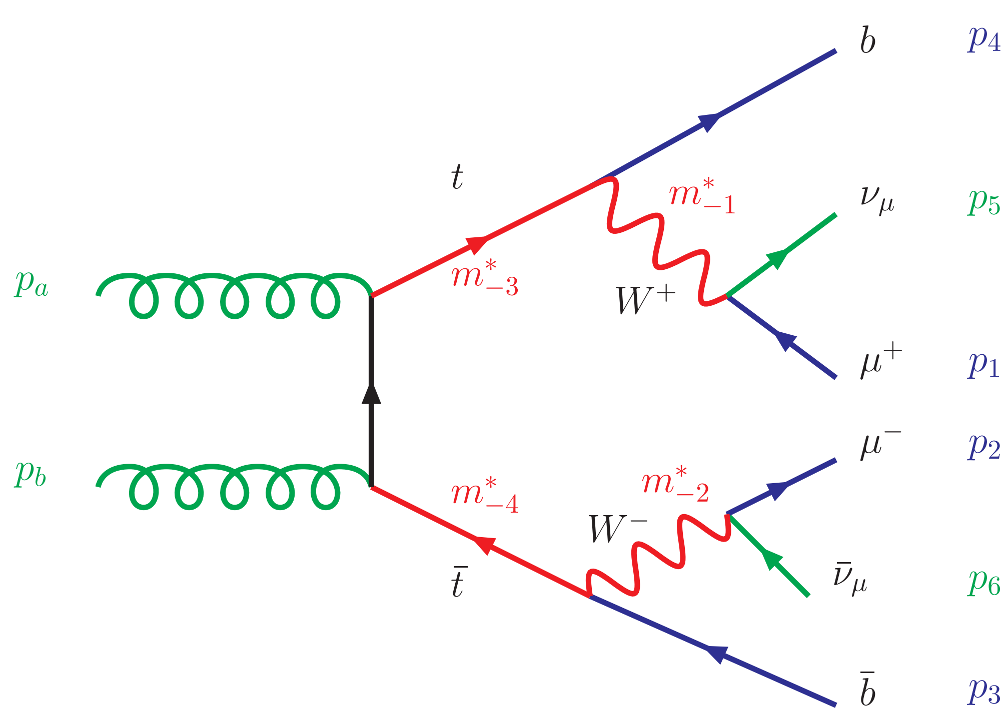
- Presence of sharp functions
  - Breit-Wigner
  - TF linked to angular observables

MADWEIGHT

- First Example: di-leptonic top quark pair



- degrees of freedom 16
  - 2: pdf
  - 3 x 6: final states
  - -4: energy-momentum conservation
- peaks 16
  - 4: Breit-Wigner
  - 3 x 4: visible particles

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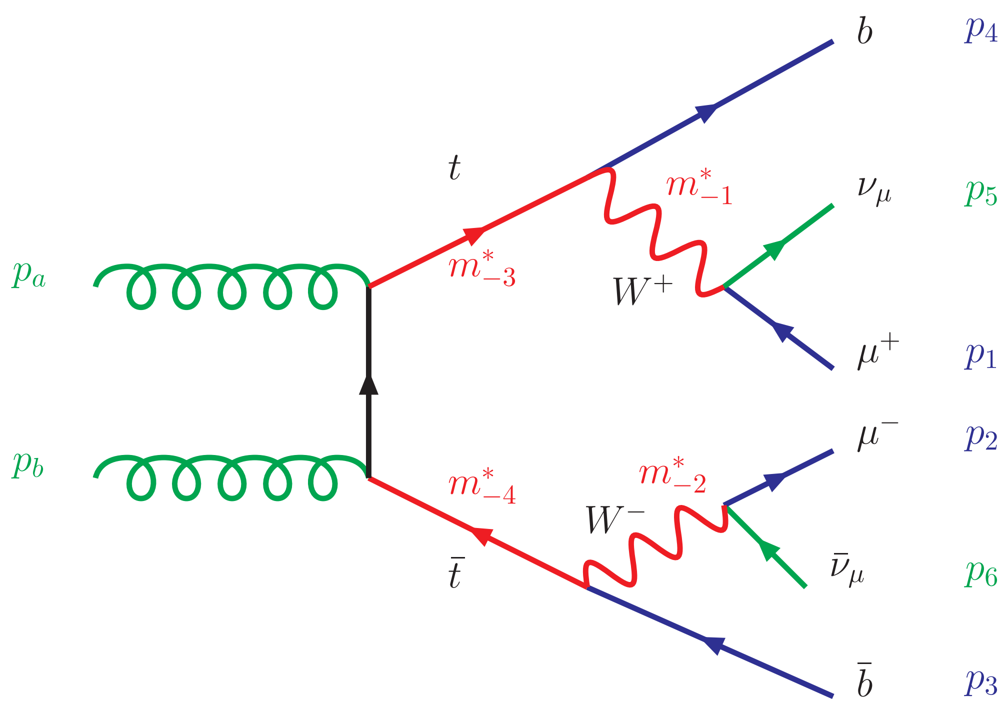

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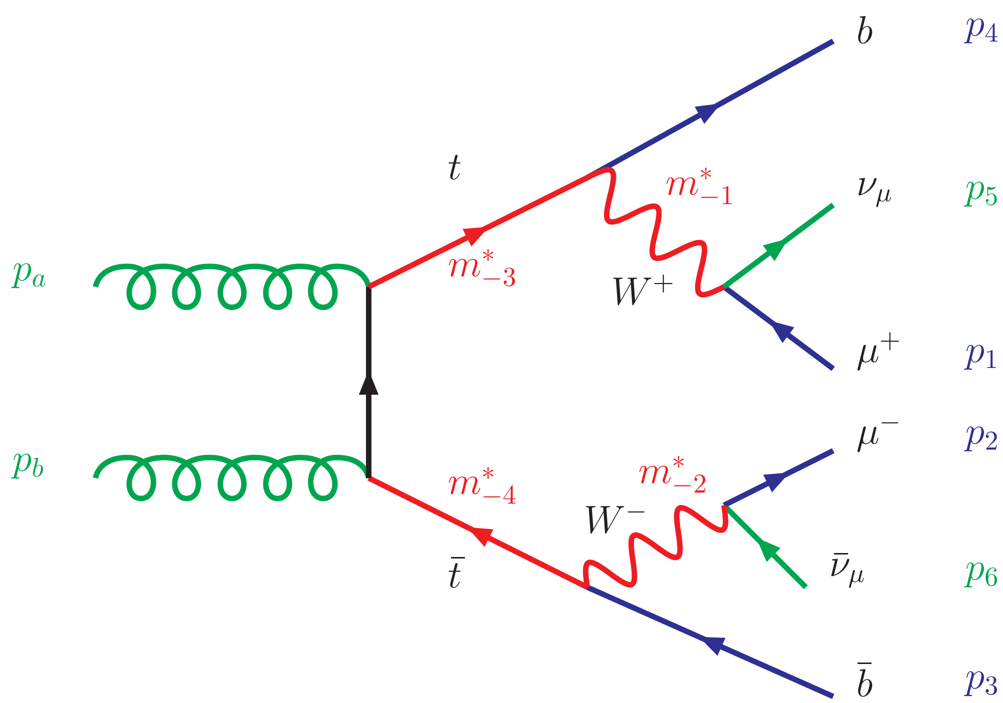

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$$d\phi = \prod_{i=1}^{4} \frac{d^3 p_i}{(2\pi)^3 2E_i} \prod_{i=5}^{6} \frac{d^3 p_i}{(2\pi)^3 2E_i} dx_1 dx_2 \delta^4 \left(p_a + p_b - \sum_j p_j \right)$$

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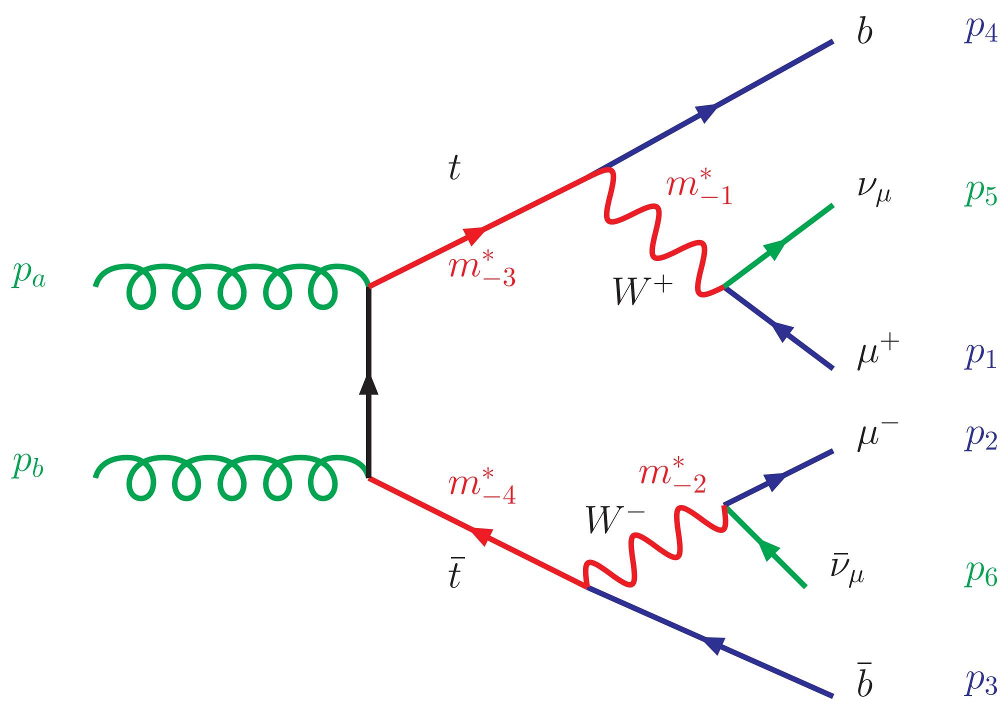

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Pass to →

$$d\phi = \prod_{i=1}^{4} d\theta_i d\phi_i d|\boldsymbol{p}_i| \prod_{j=1}^{4} dm^{*2}_{-j} \times J$$

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MADWEIGHT

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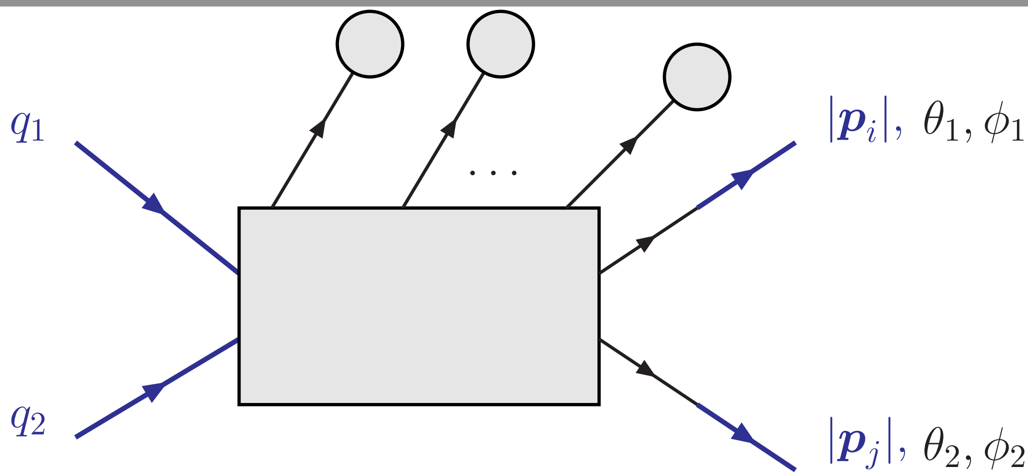
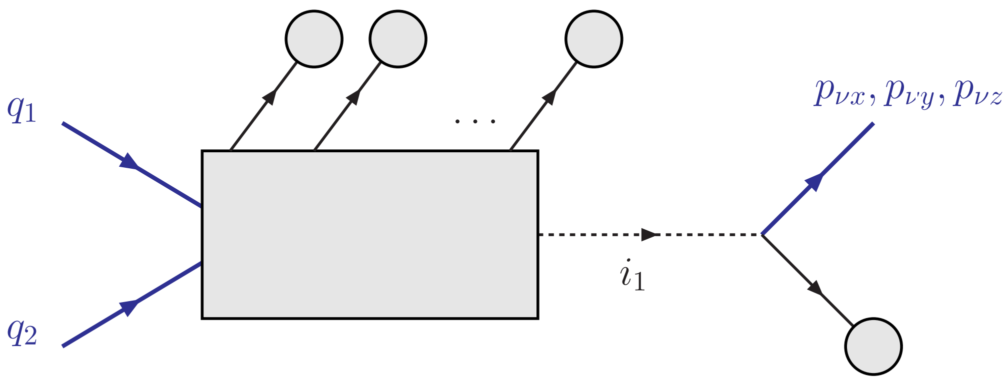
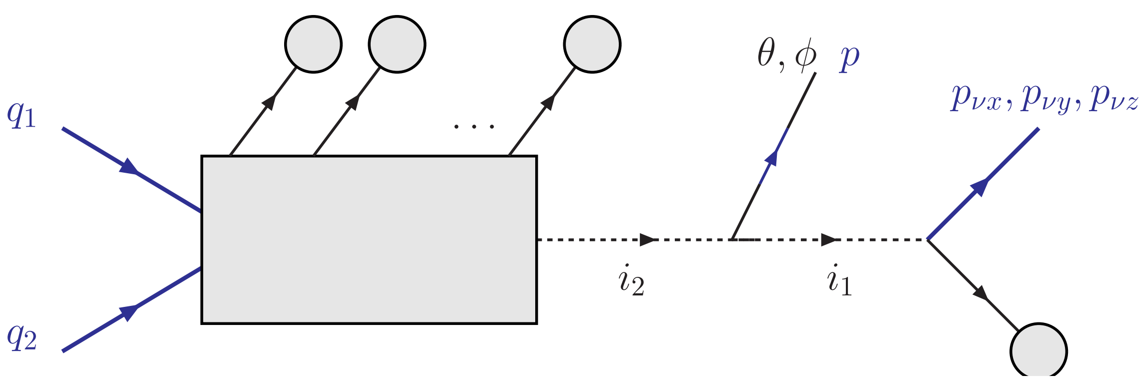
MadWeight



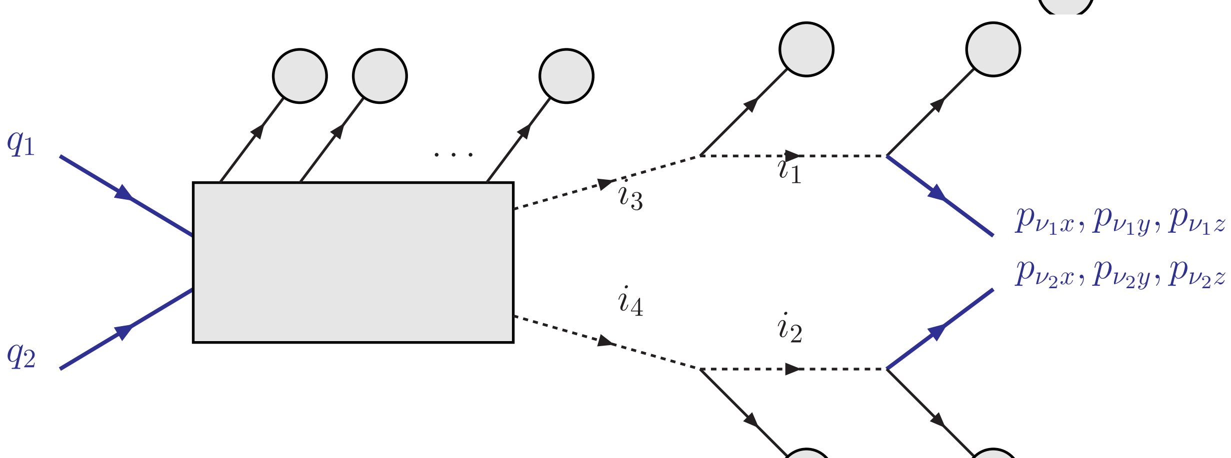
fully hadronic / leptonic process



W production

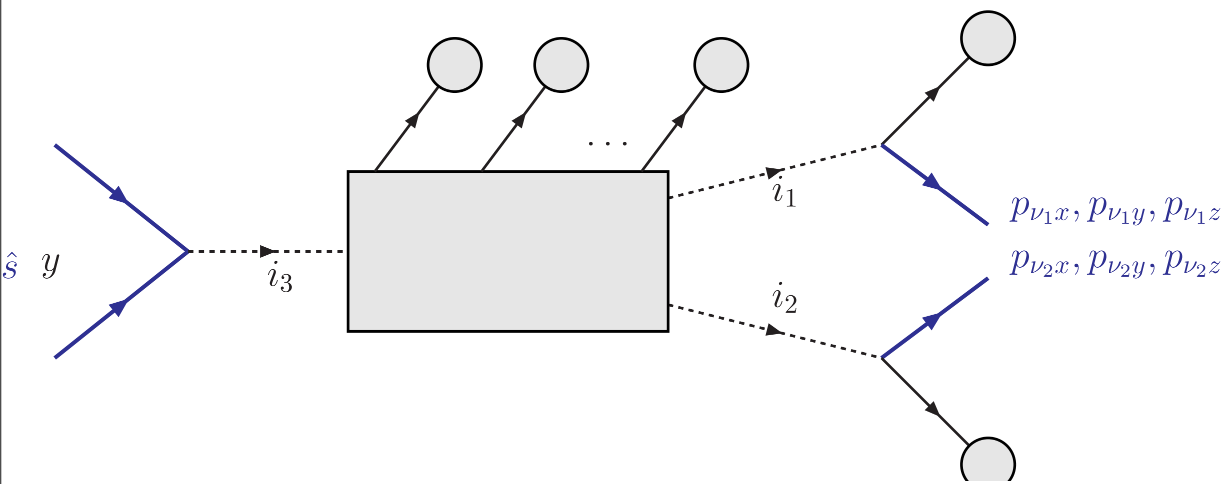


semi-leptonic top quark pair

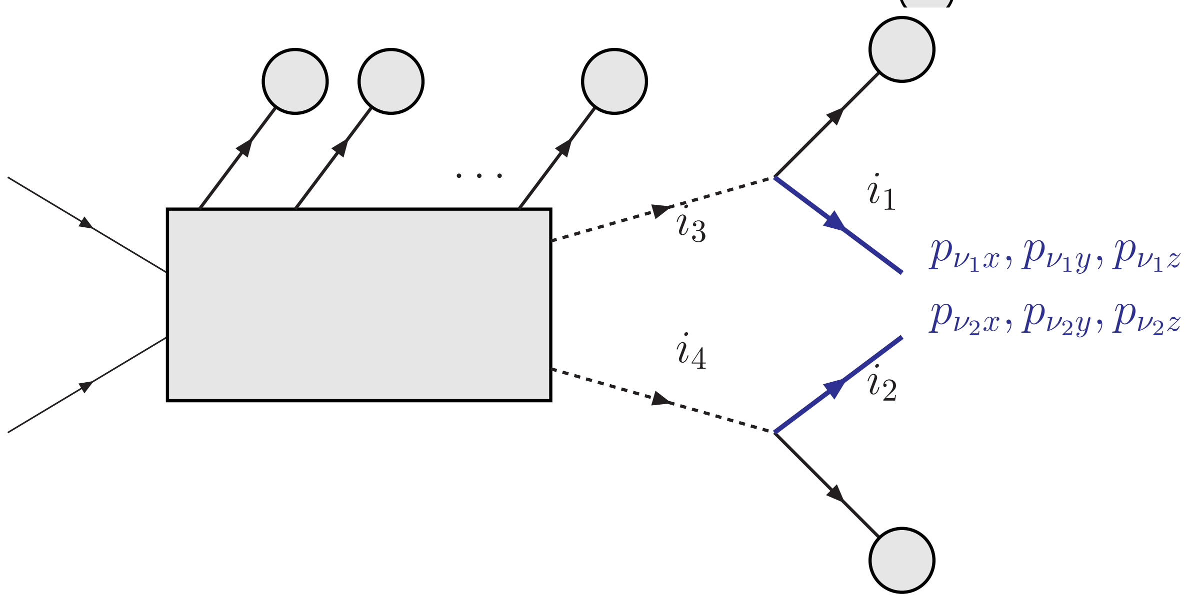


Fully leptonic top quark pair

MadWeight

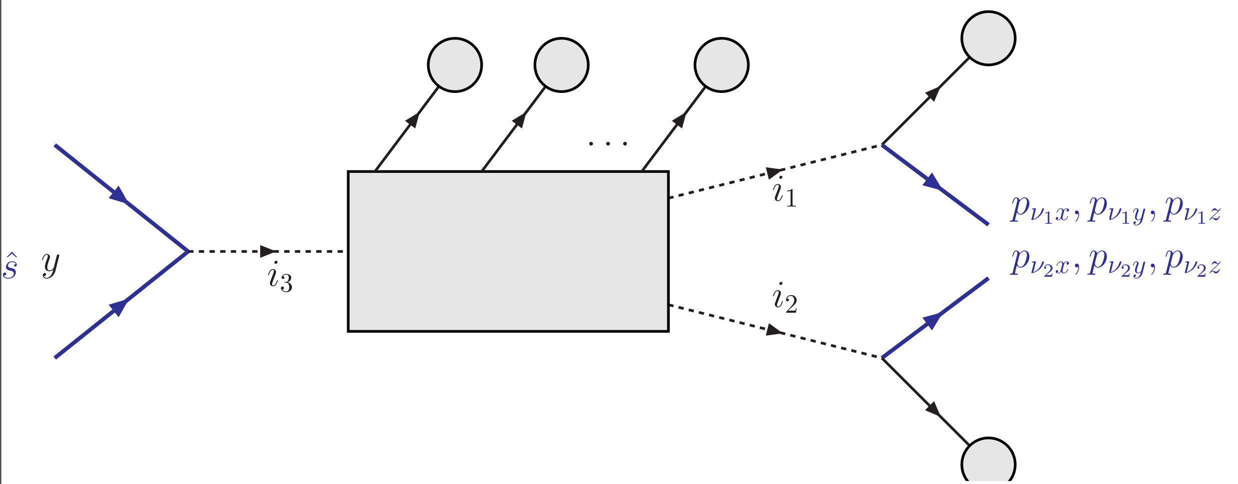


Higss production decaying in W



Class F

W+ W- production



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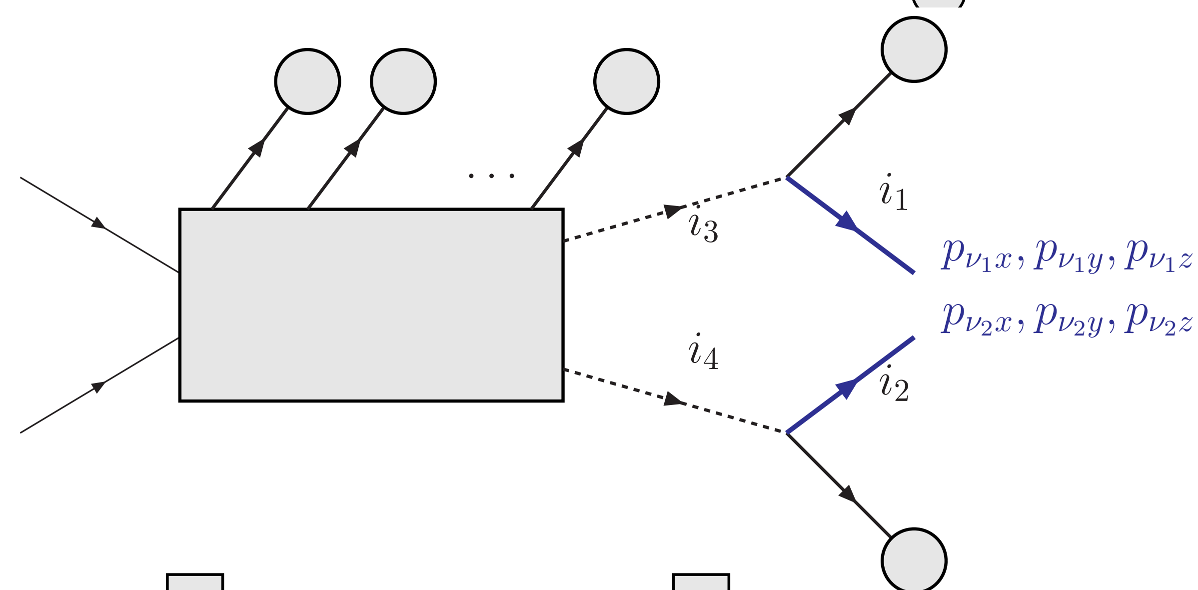

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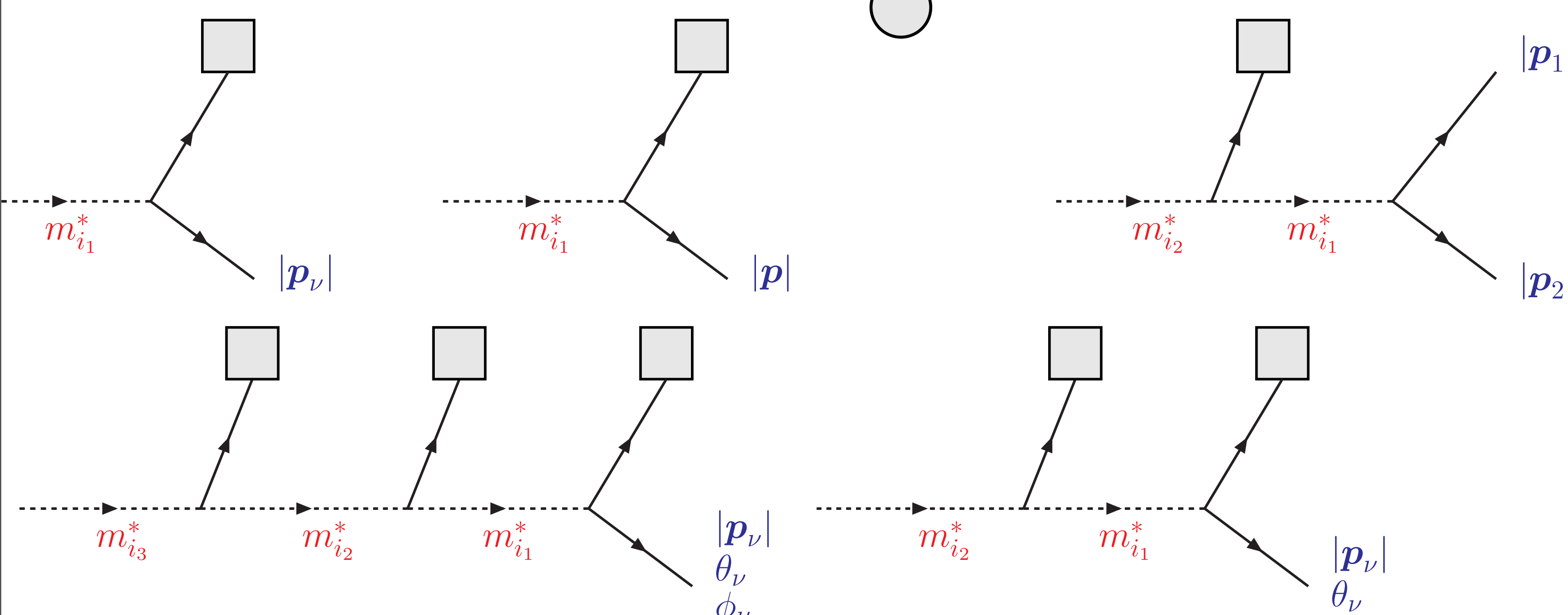

Lot of possibility to have more complex process

+1 W

+1 Z

+ ...

- Examples of studies / investigations
  - mass determination : smuon pair production
  - Spin Analysis
  - ISR effects: pp > H > W+ W-
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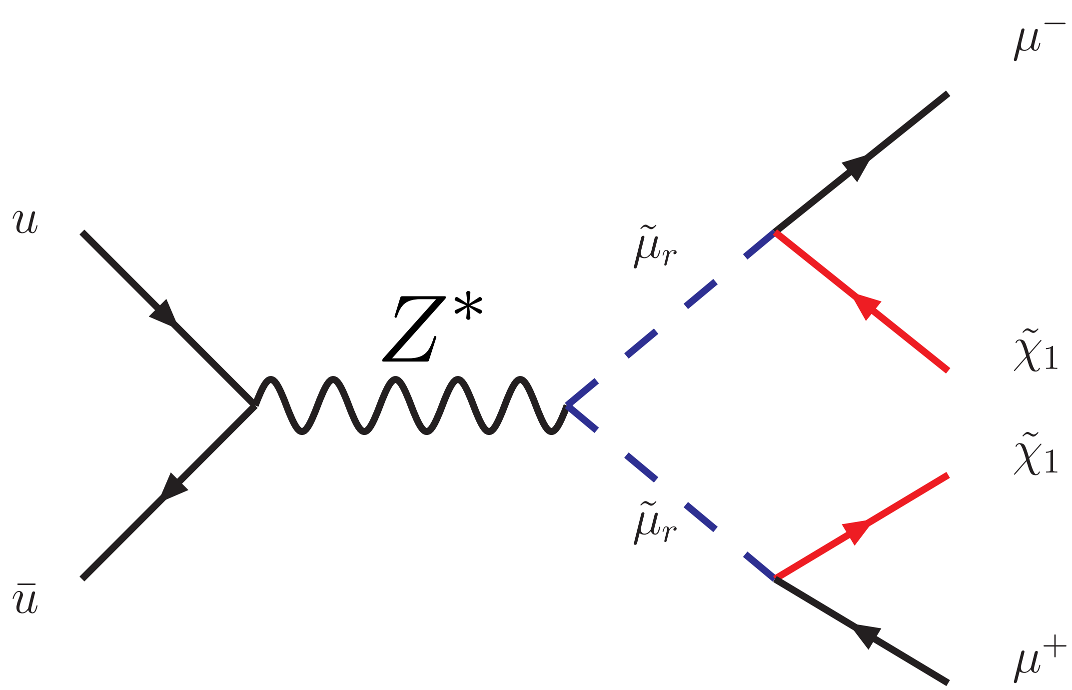
Mass determination

(Crazy?) scenario: We observe only Two muon + MET



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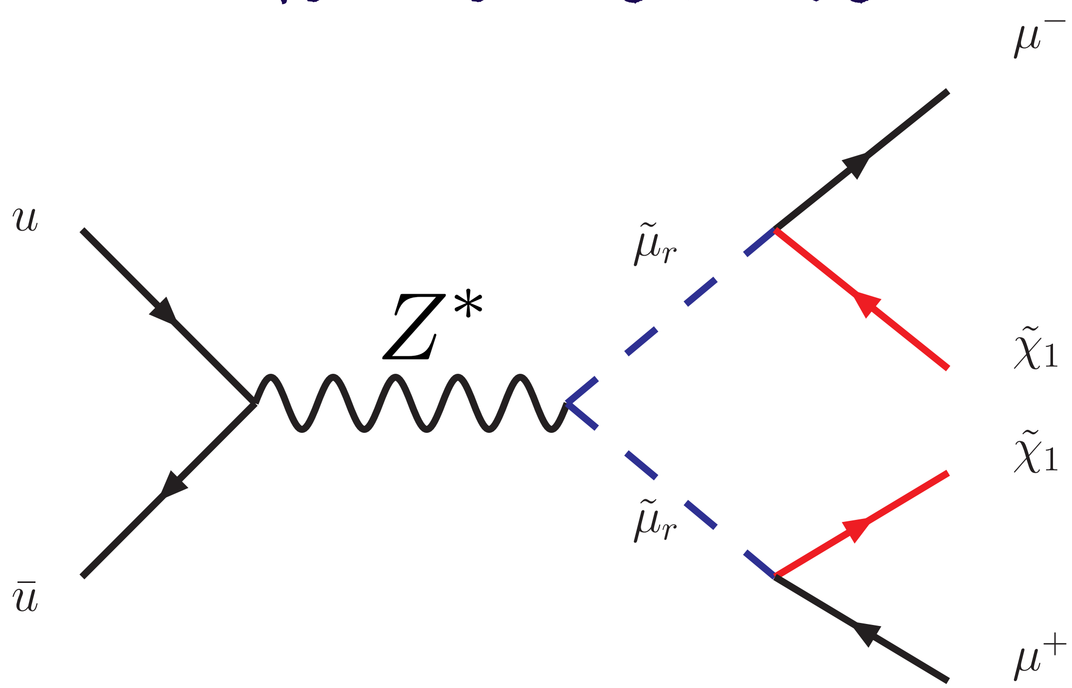
How to measure smuon mass and LSP mass?



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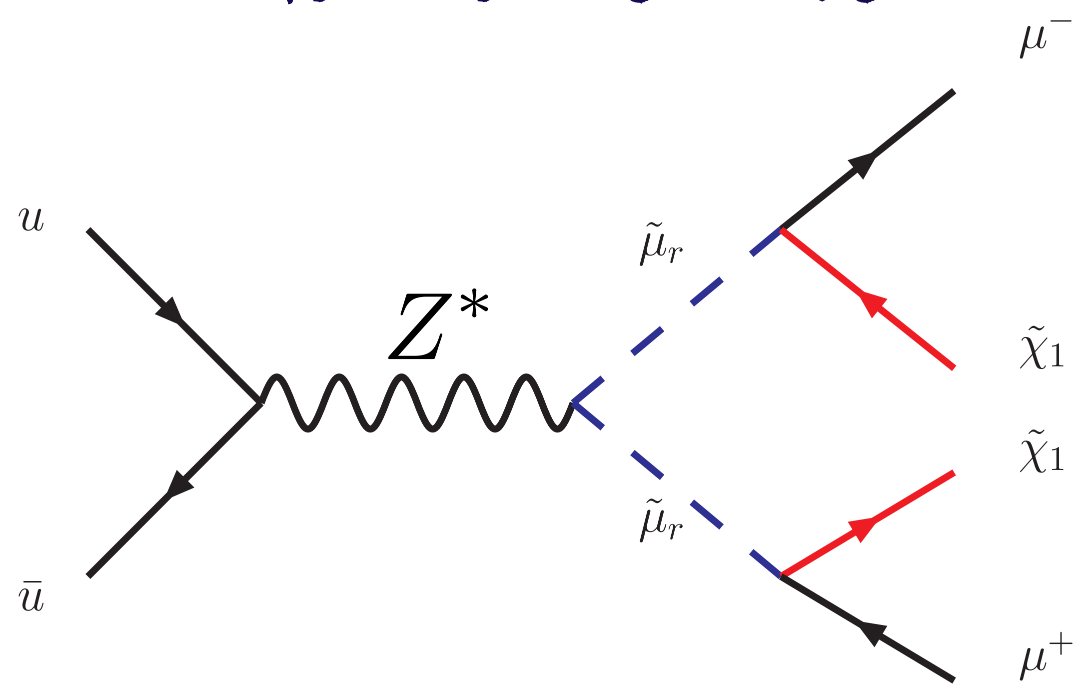

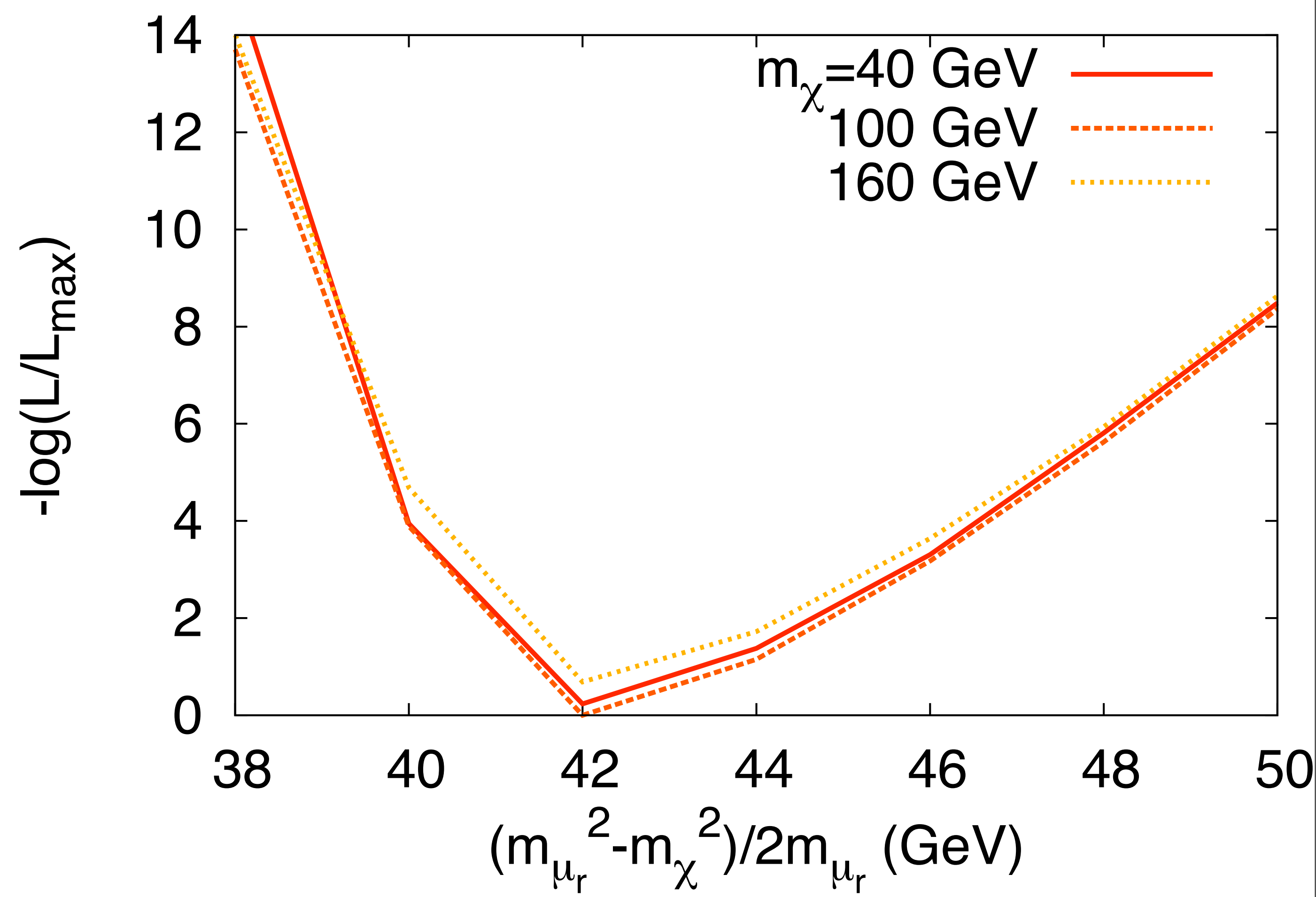

- 50 (Monte-Carlo) events

$$M_{\tilde{\mu}} = 150\text{GeV}$$
$$M_{\tilde{\chi}} = 100\text{GeV}$$

$$(M_{\tilde{\mu}}^2 - M_{\tilde{\chi}}^2)/2M_{\tilde{\mu}} = 42\text{GeV}$$

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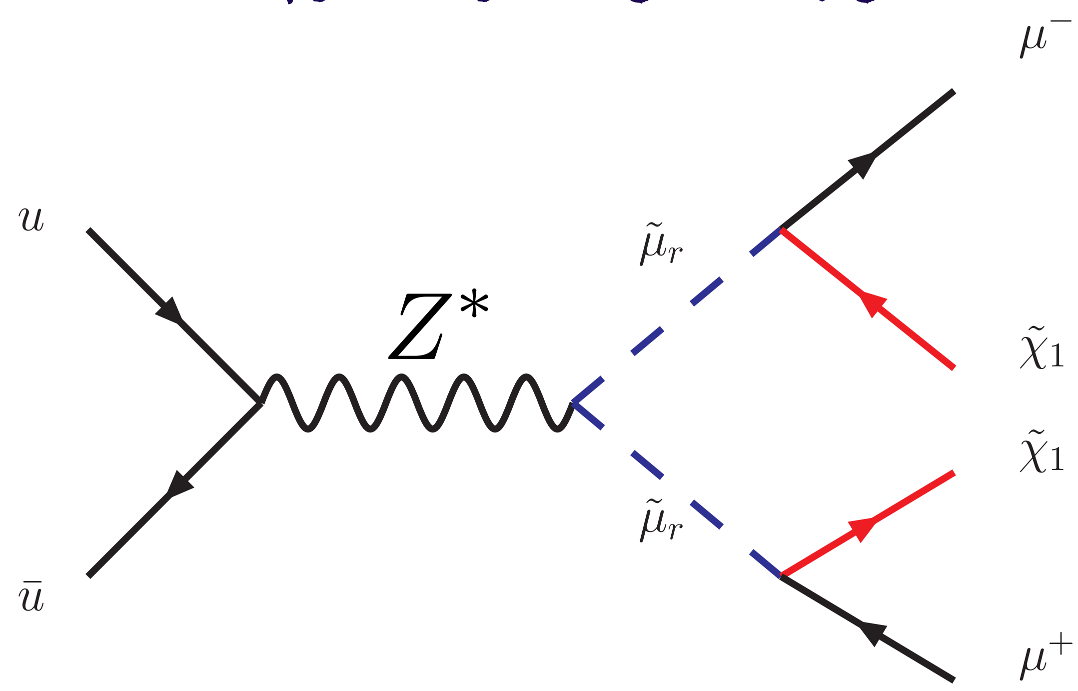

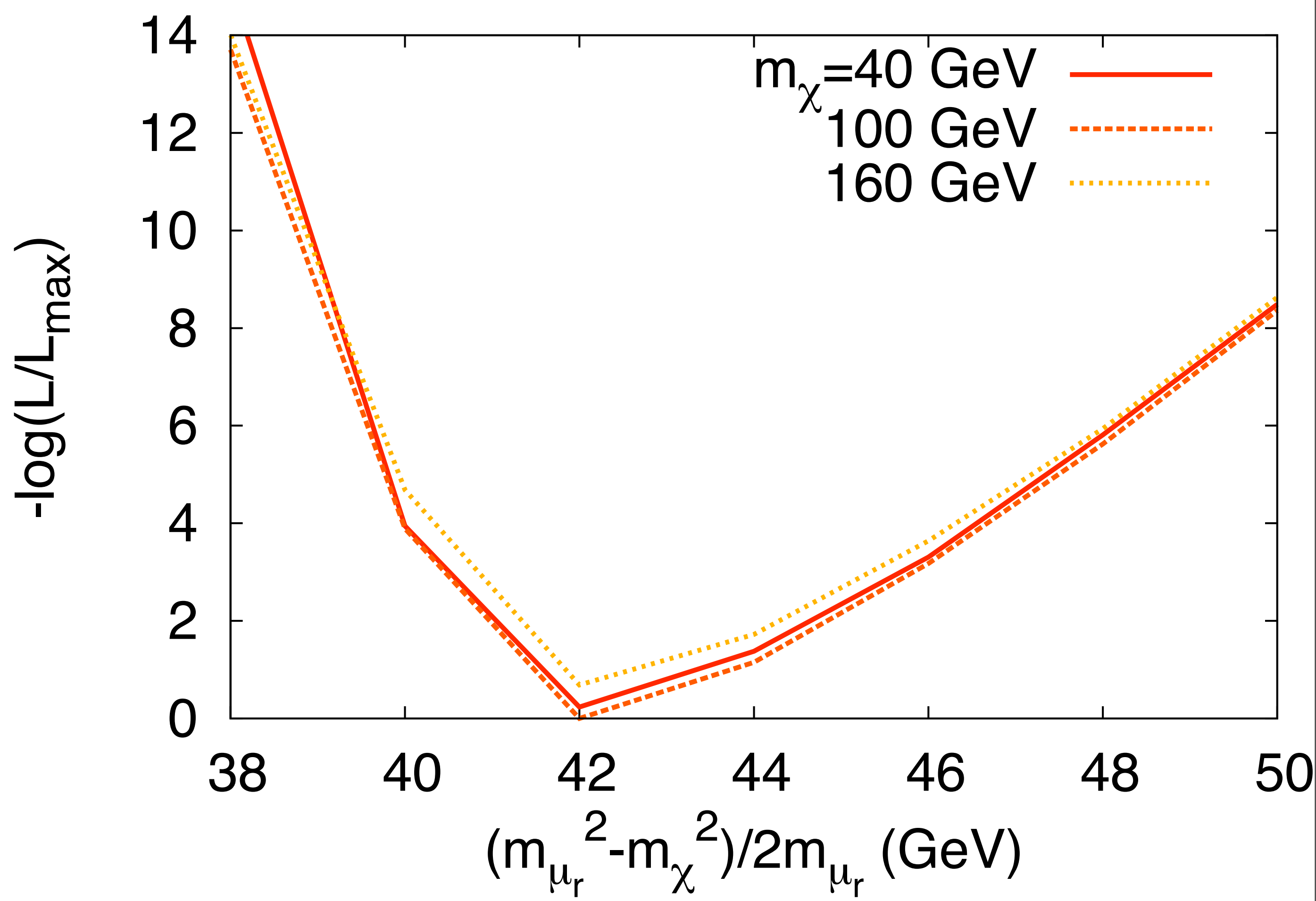

Energy in the rest frame

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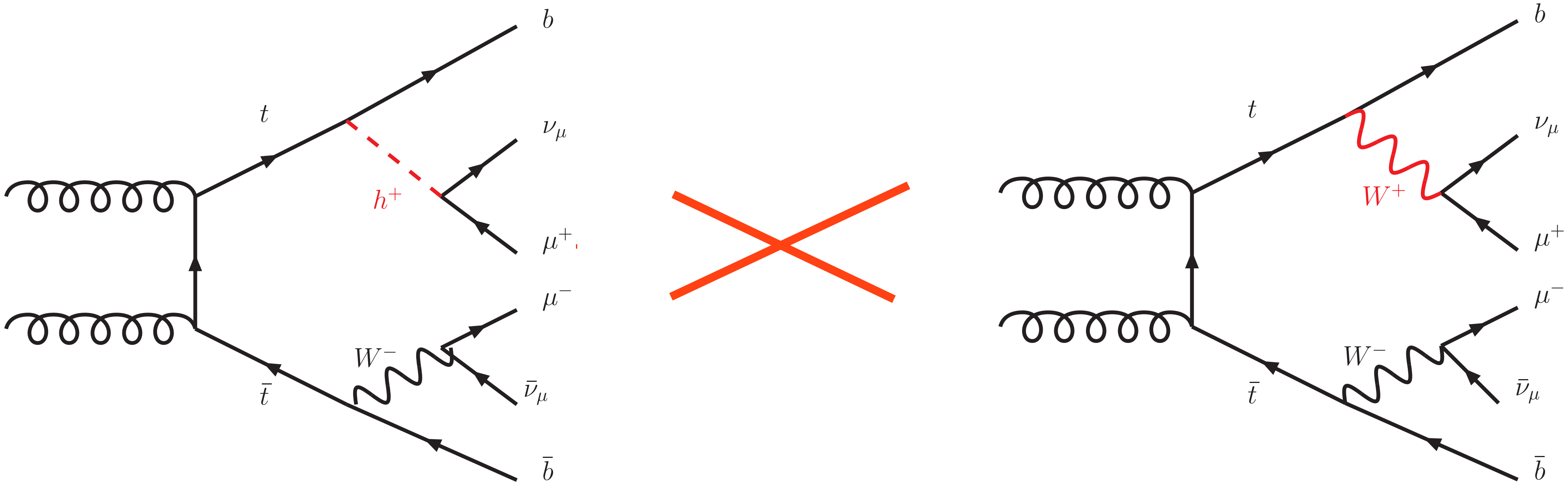
Signal/Background

- Estimate Charged Higgs contribution



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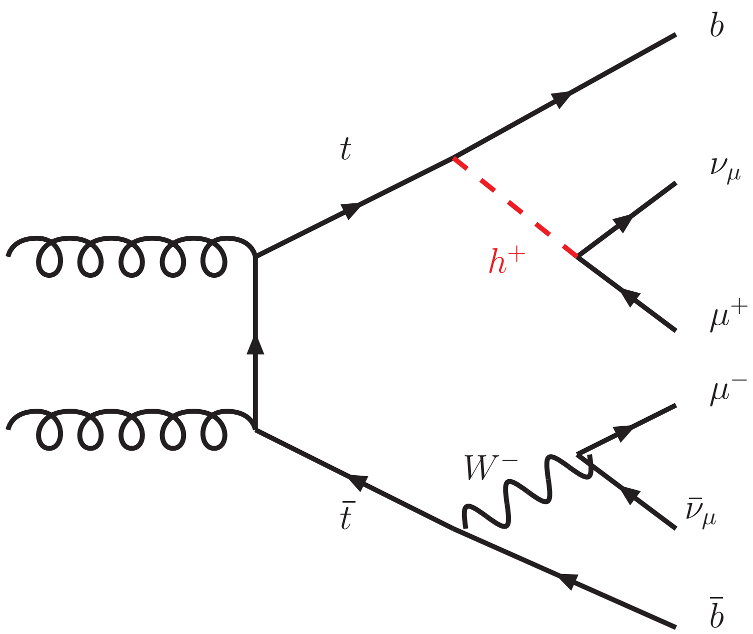

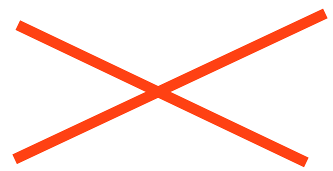

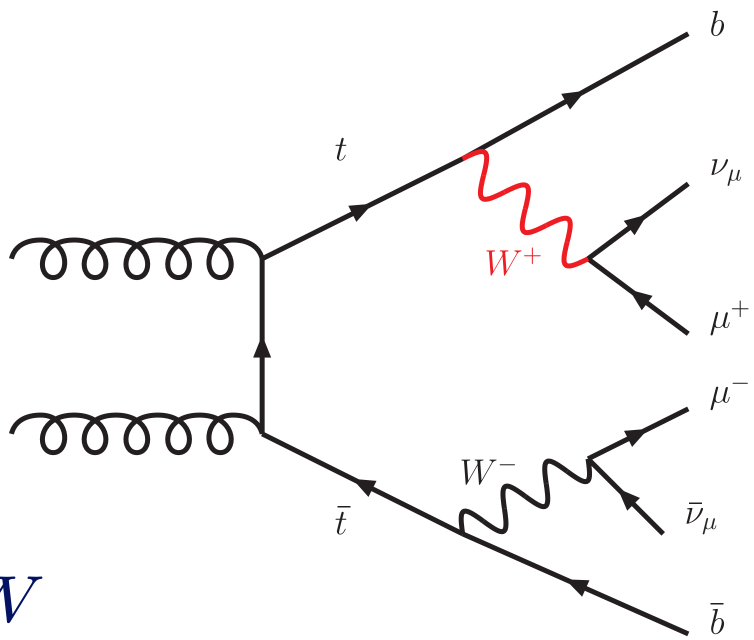

$$M_{H^+} = M_W$$

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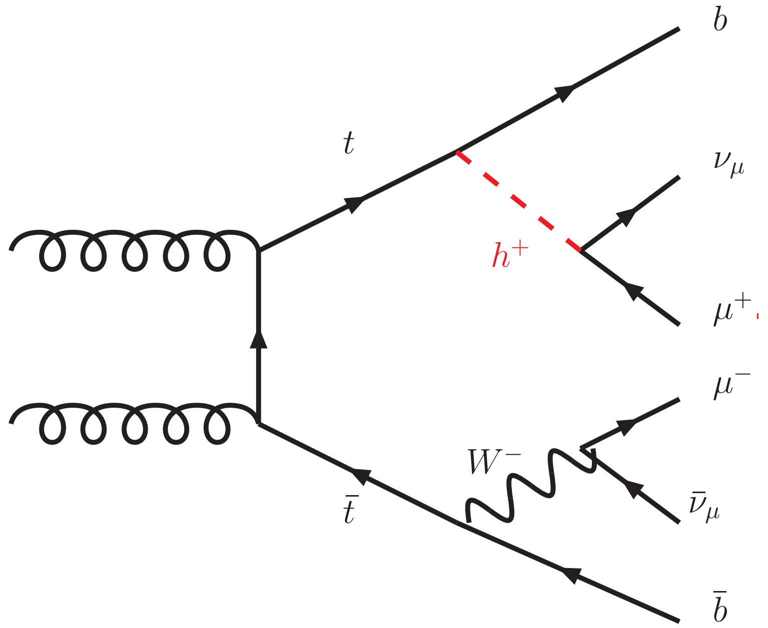

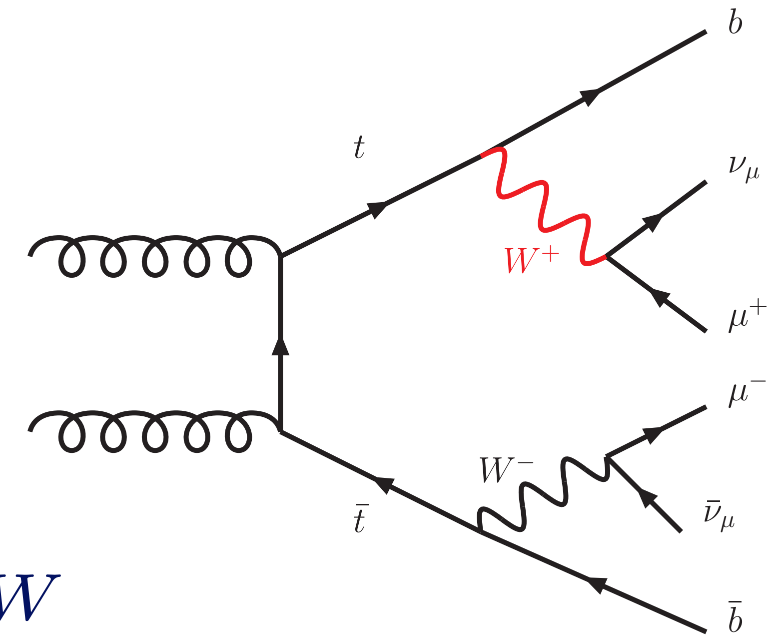

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- define discriminant:

$$d = \frac{P_S}{P_S + P_{BG}}$$

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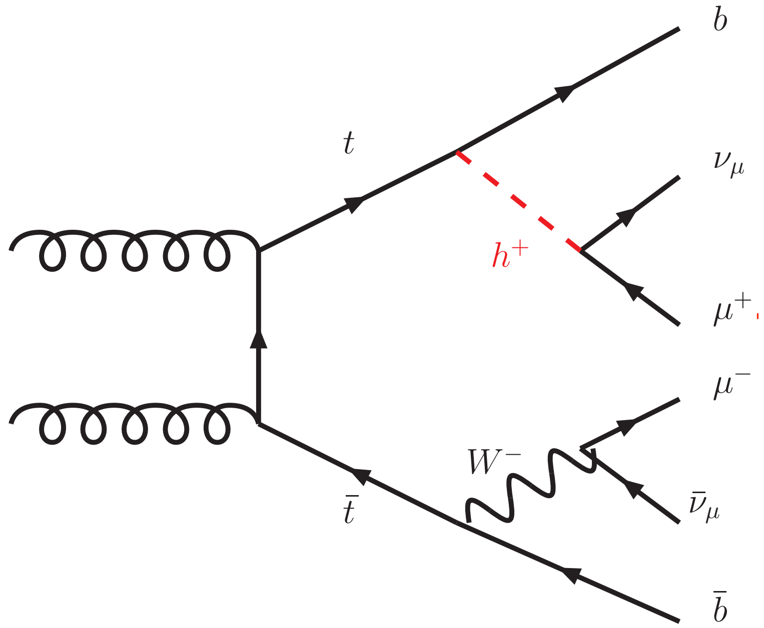

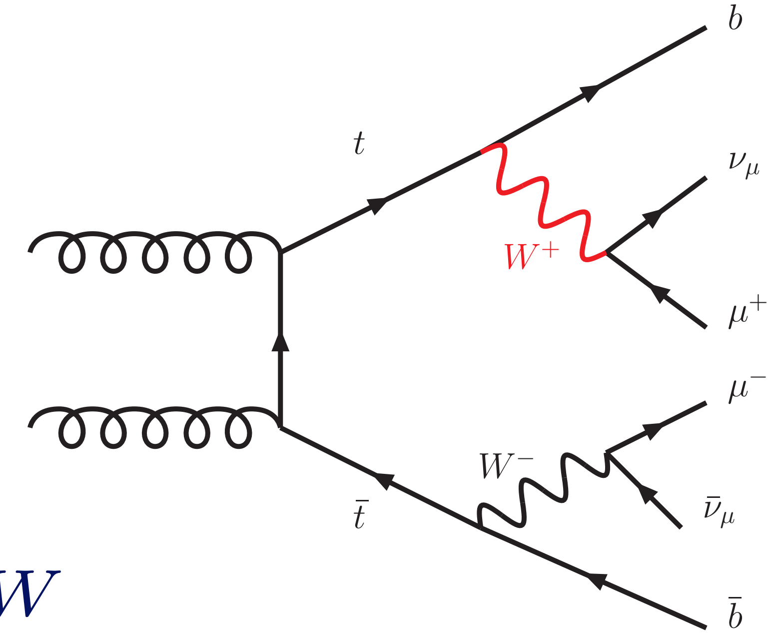

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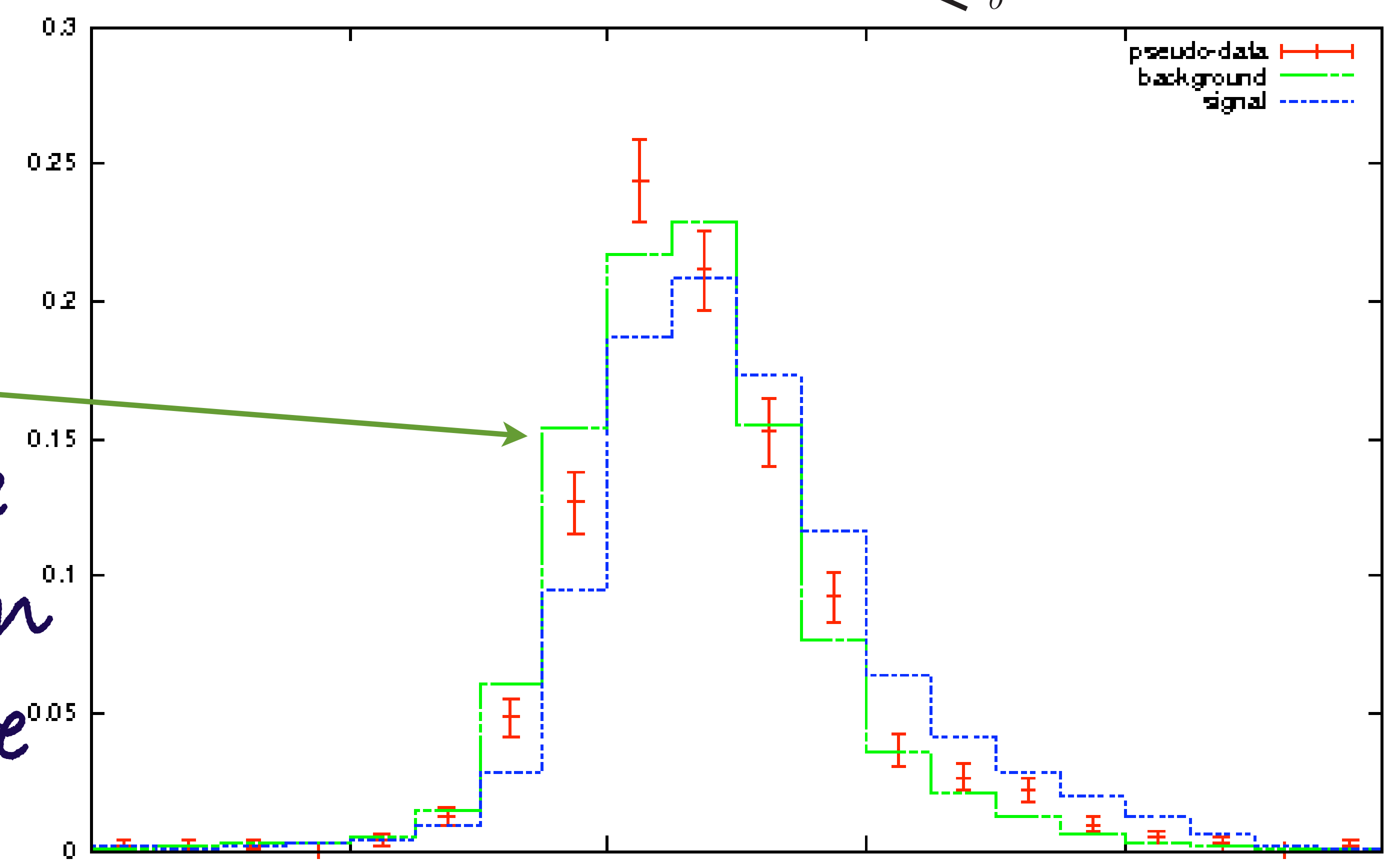
- SM Monte-Carlo:

  Probability for one event to have a given discriminant value



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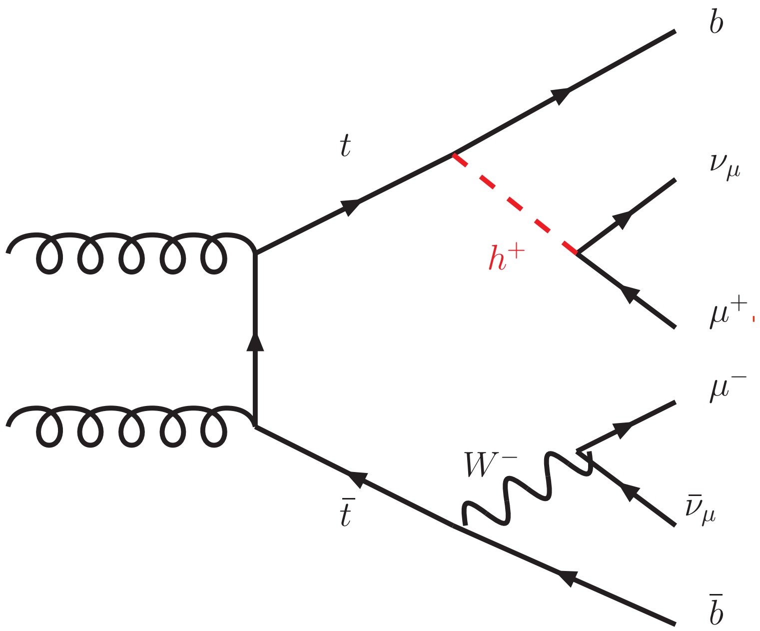

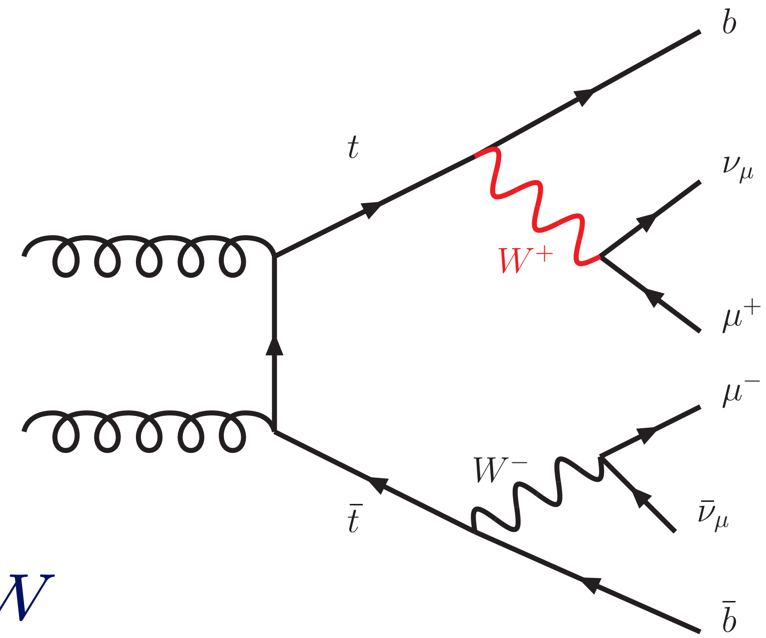

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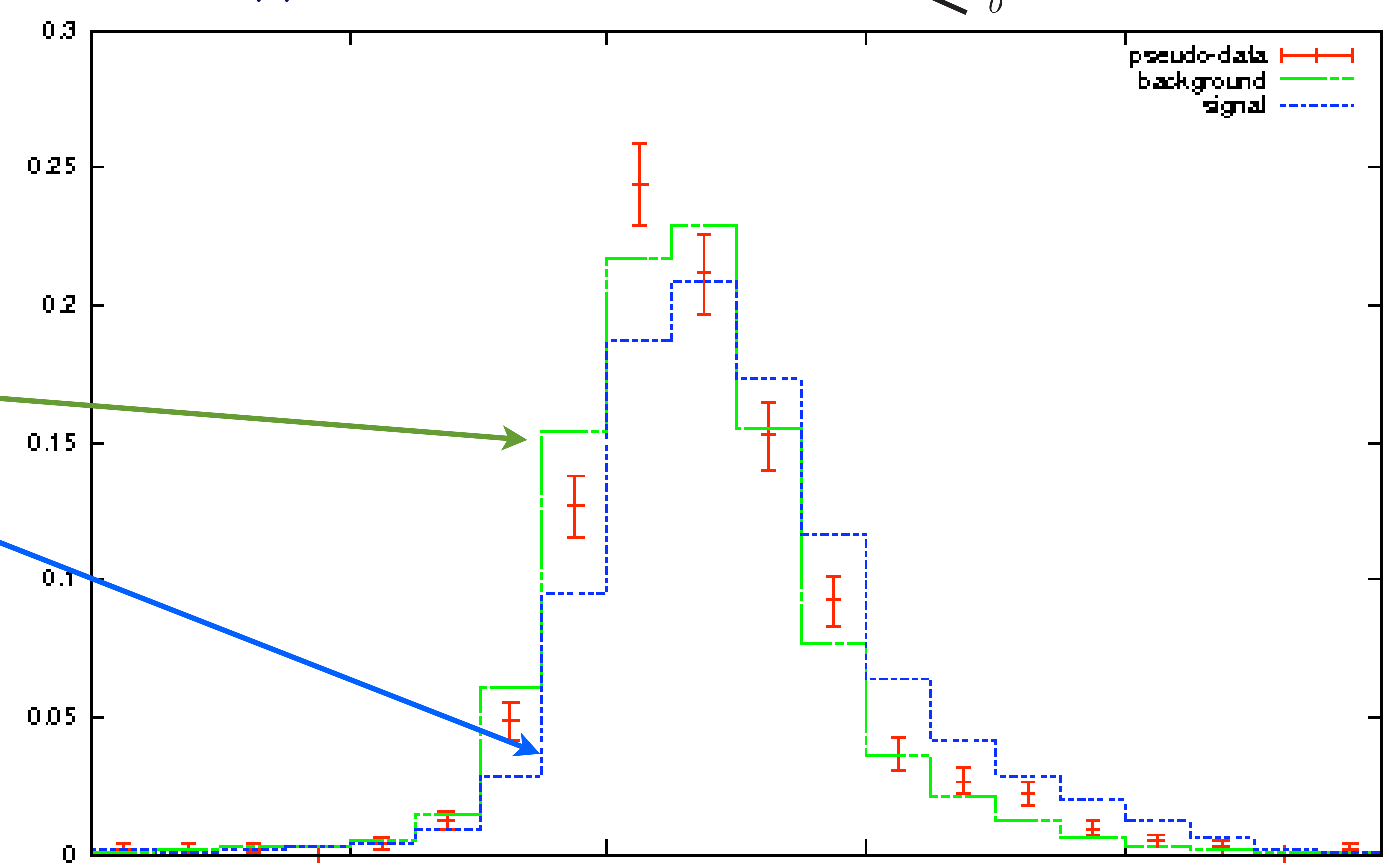

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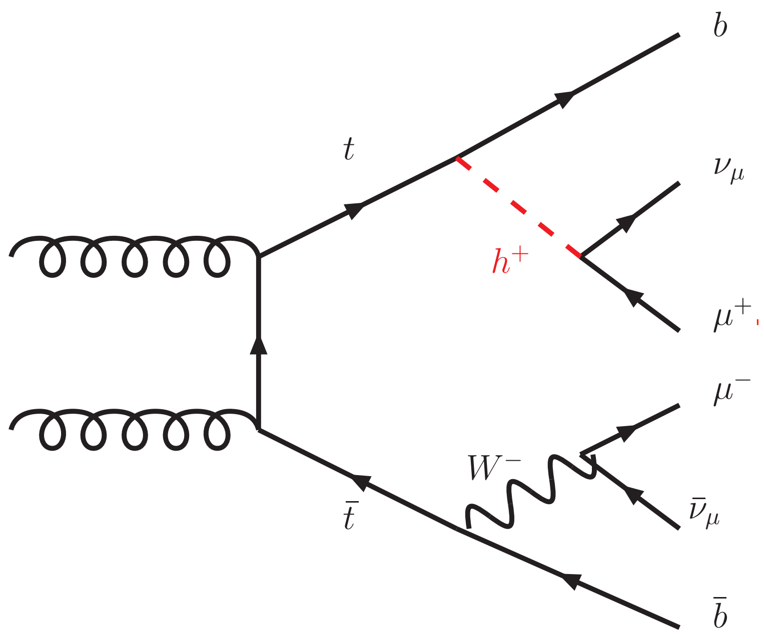

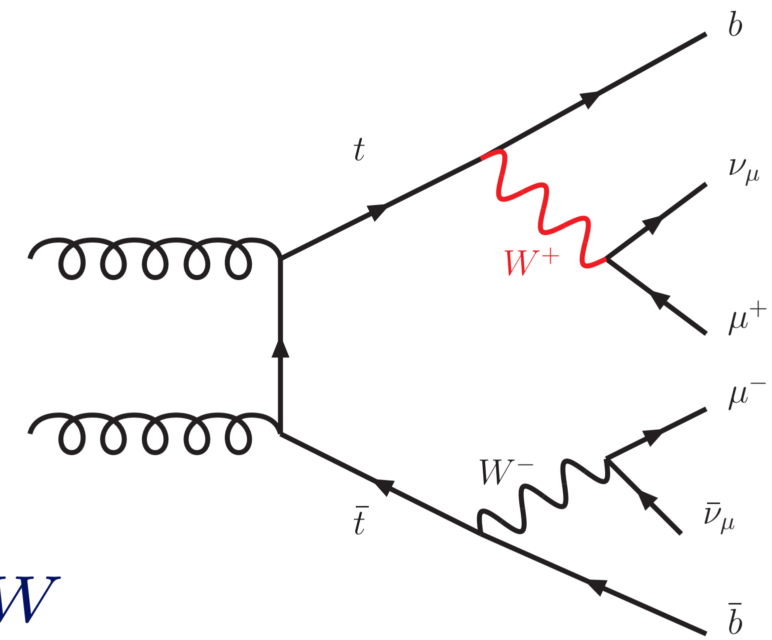

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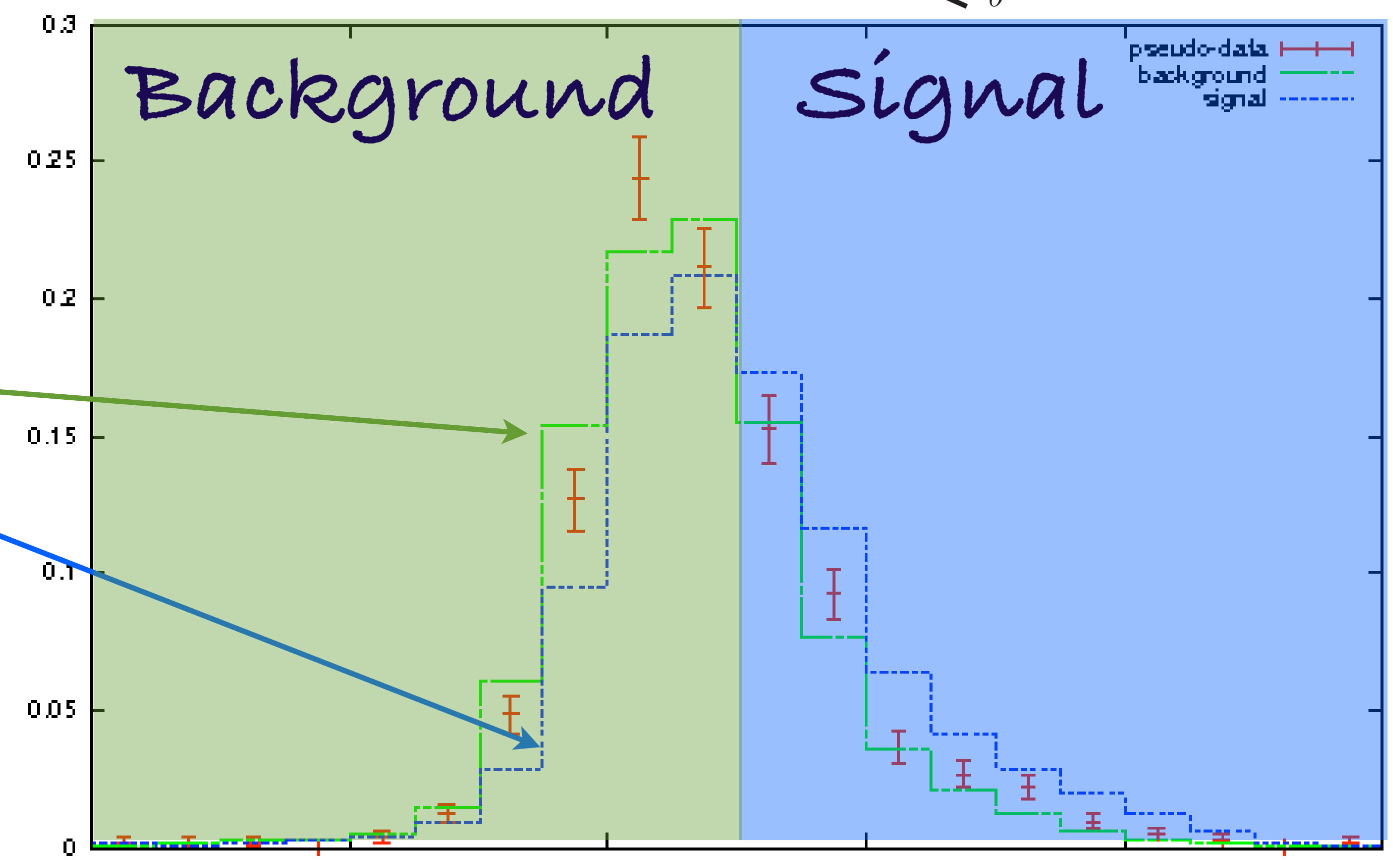
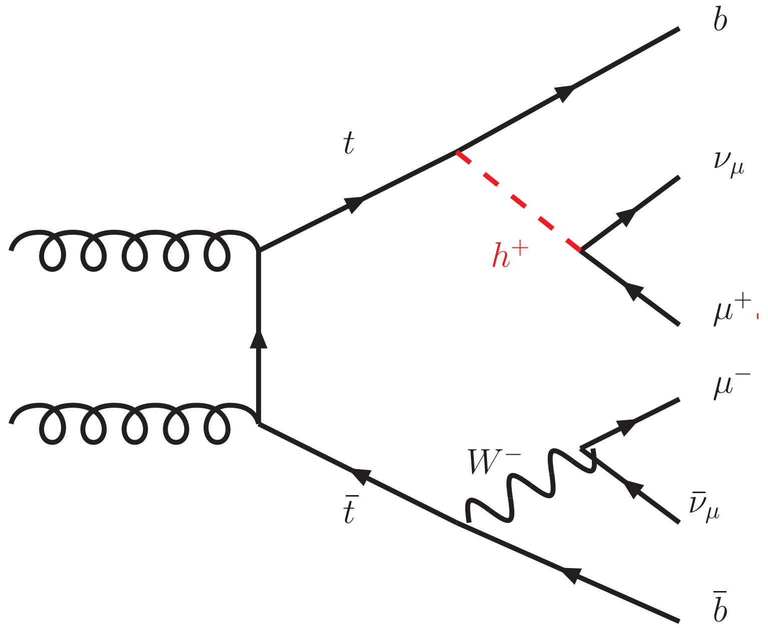
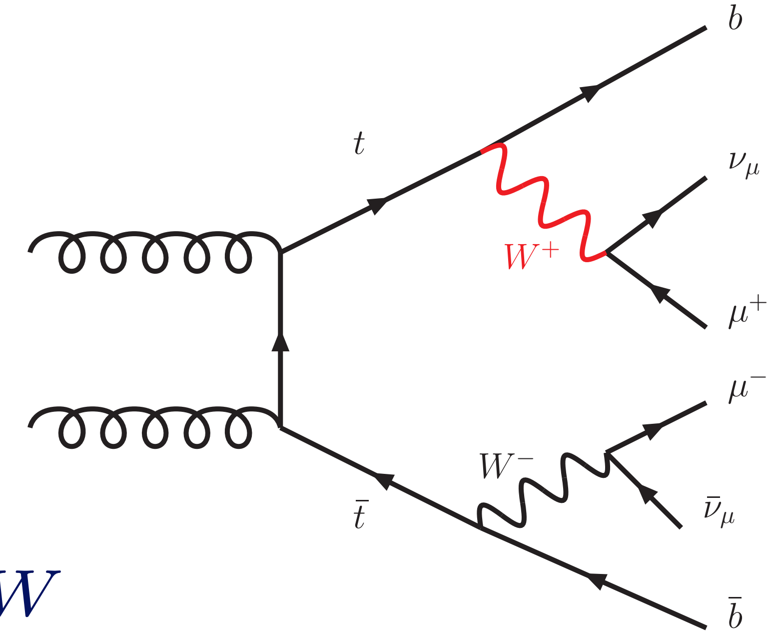


Signal/Background

- Estimate Charged Higgs contribution





$$M_{H^+} = M_W$$

- define discriminant:

$$d = \frac{P_S}{P_S + P_{BG}}$$

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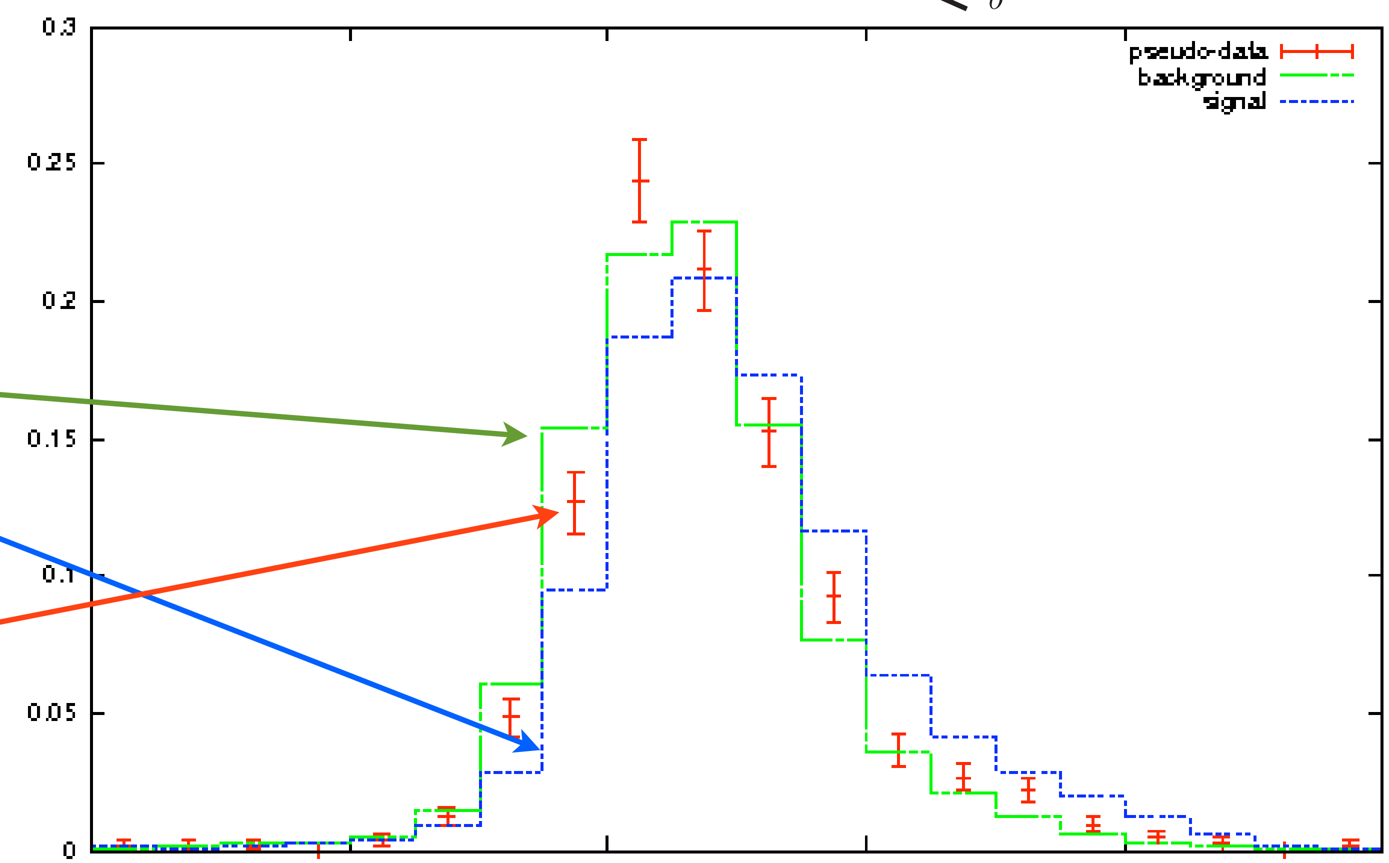
- Pseudo-events



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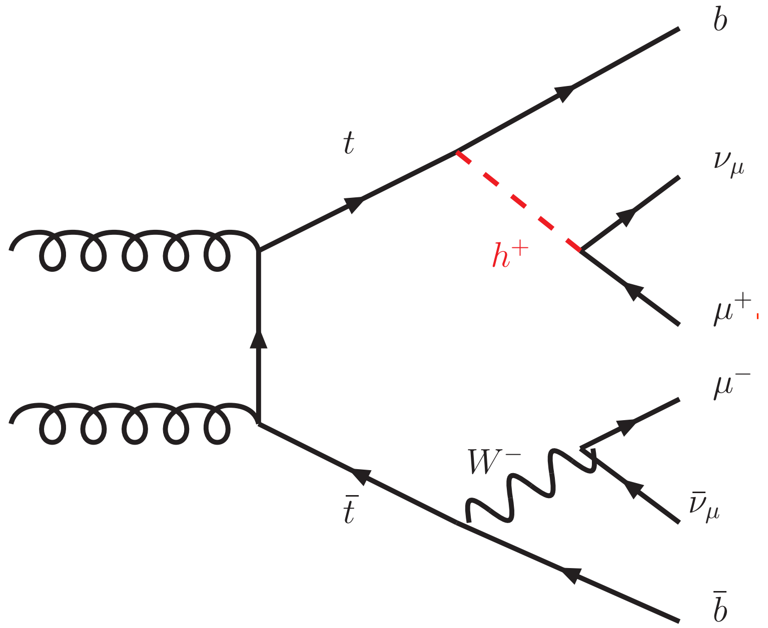

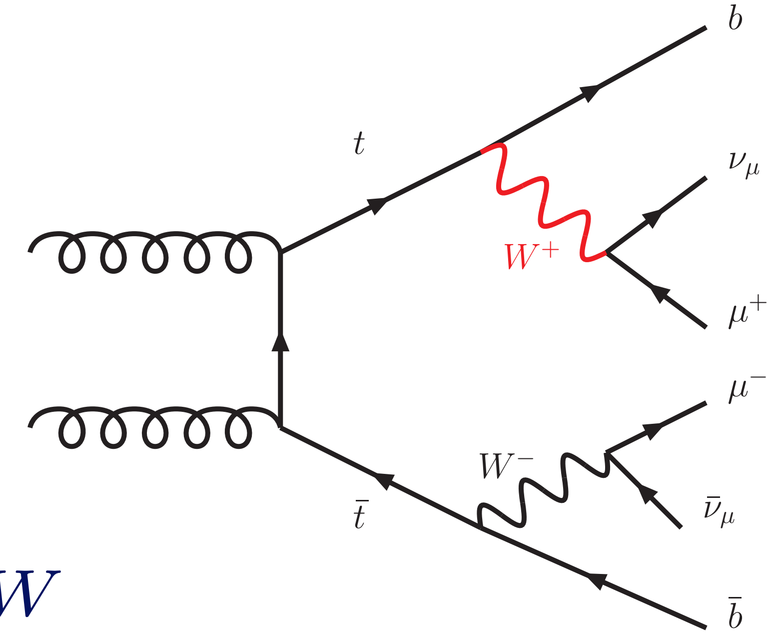

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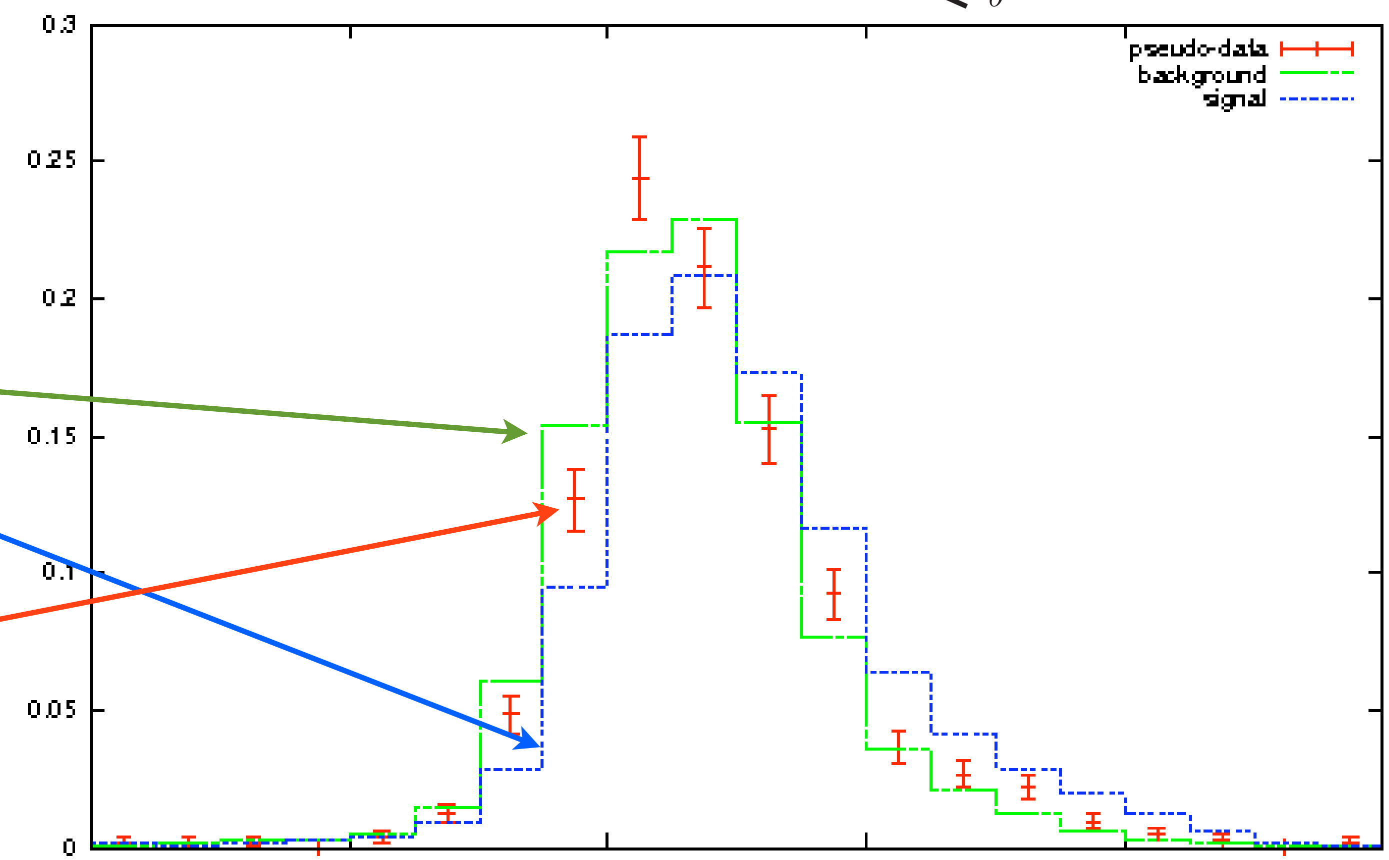
$$\sigma_S = 1.7 \pm 0.4 pb$$



- Examples of studies / investigations
  - mass determination : smuon pair production
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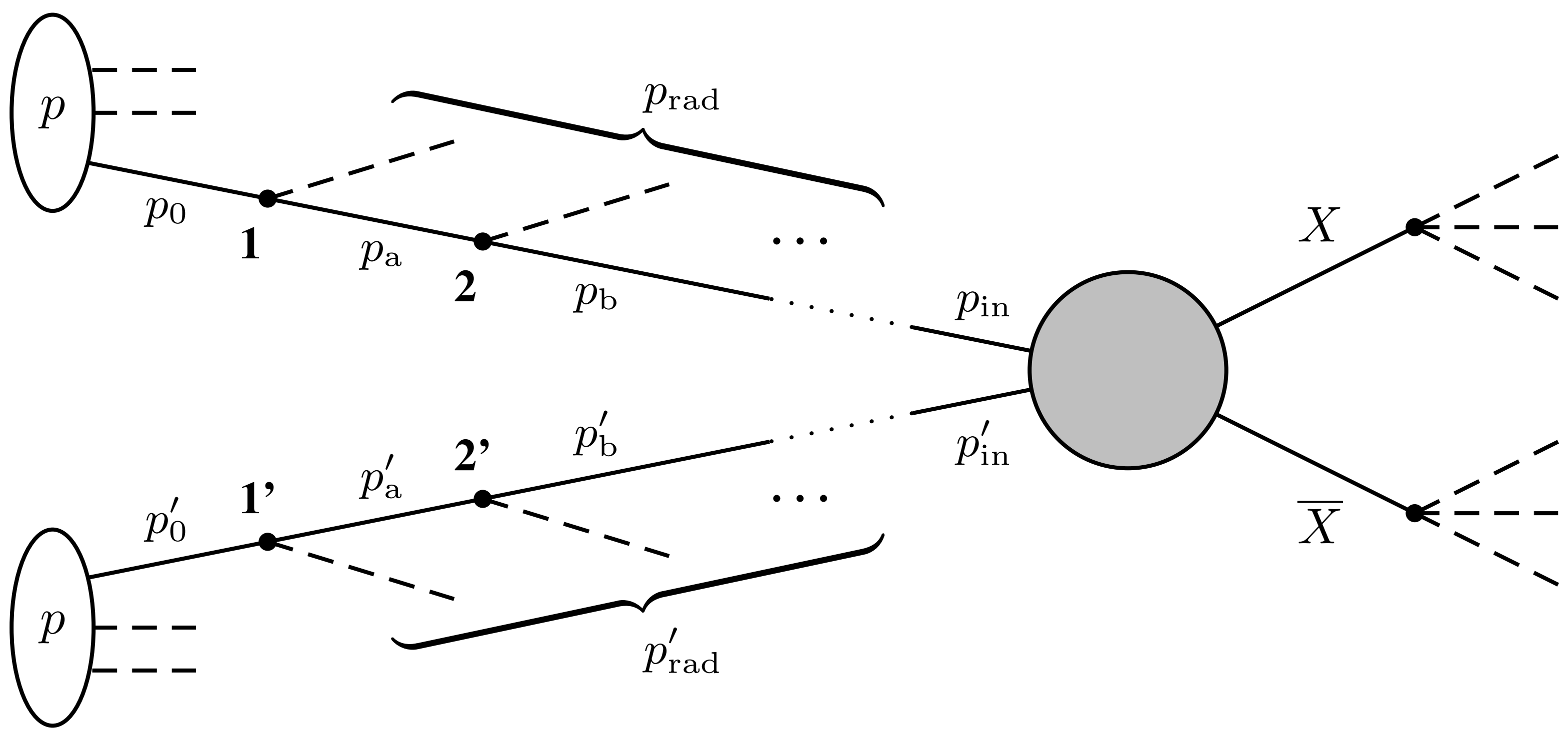
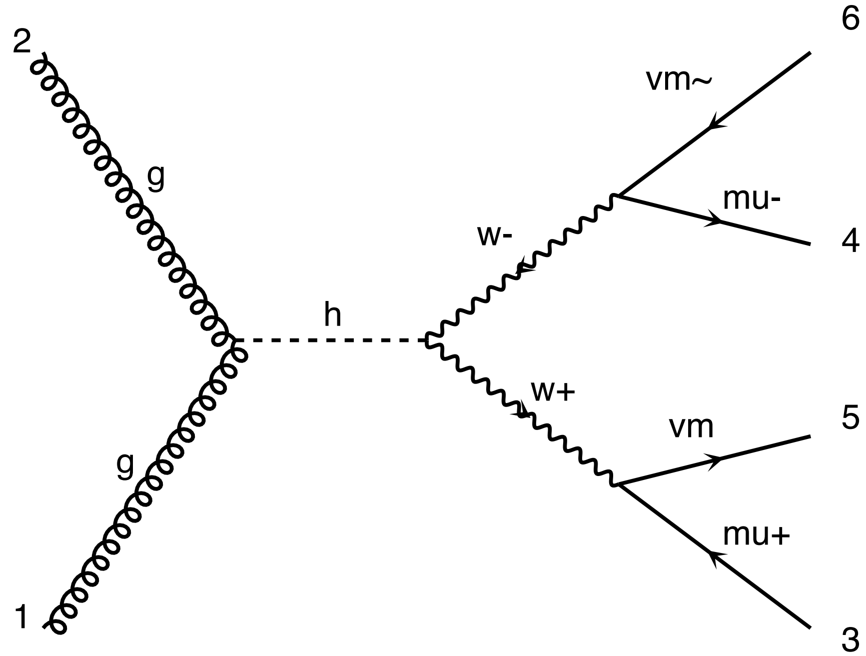
  - ISR effects: pp > H > W+ W-
  - DMEM: in fully leptonic channel

Initial State Radiation



- Main effect: induce a total transverse momentum

Initial State Radiation



- Study the ISR on Higgs production at LHC (14 TeV) at parton level (no hadronization)

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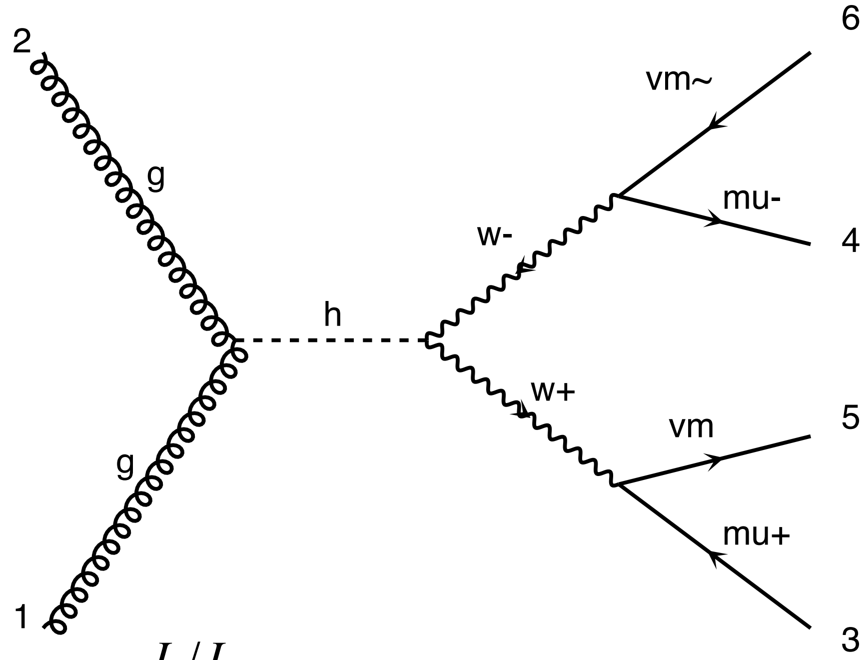
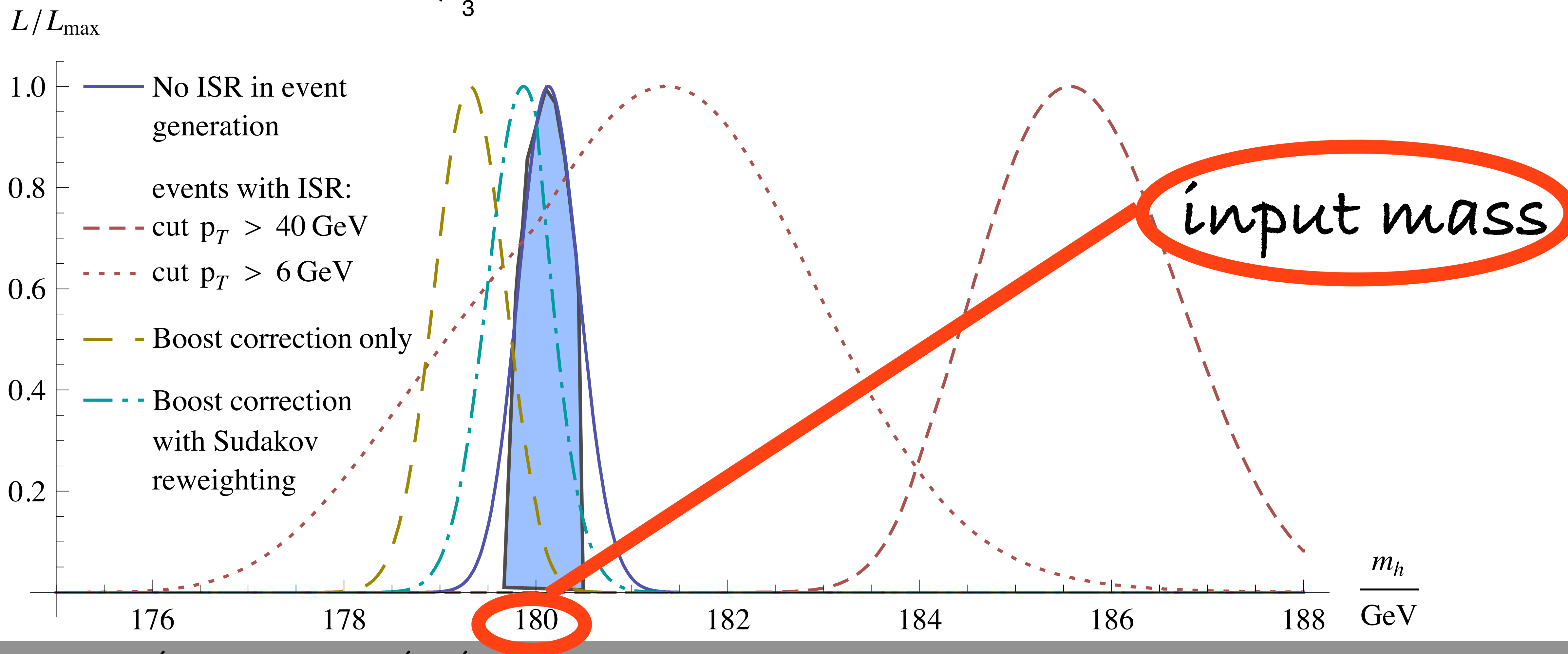


- Study the ISR on Higgs production at LHC (14 TeV) at parton level (no hadronization)
- No ISR → No Bias



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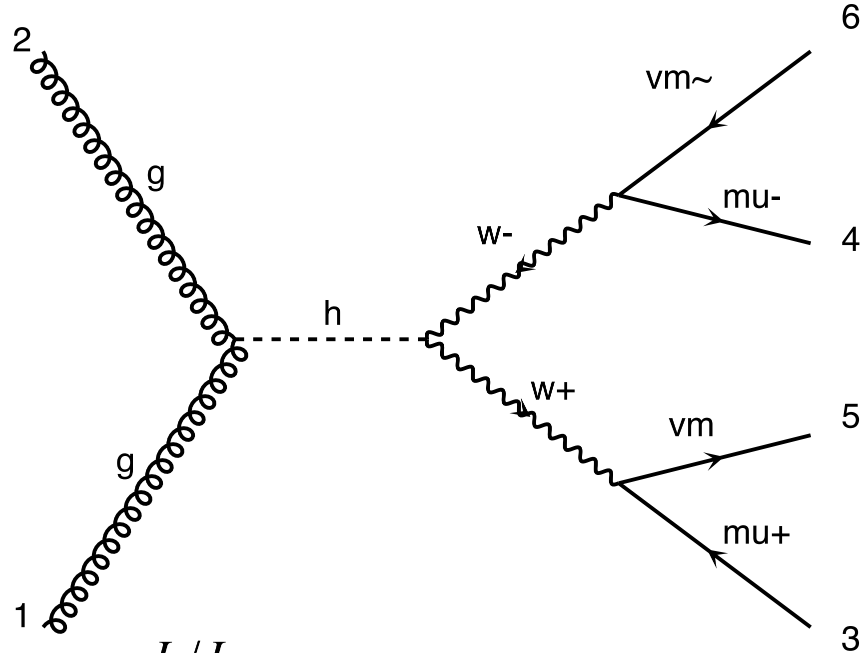
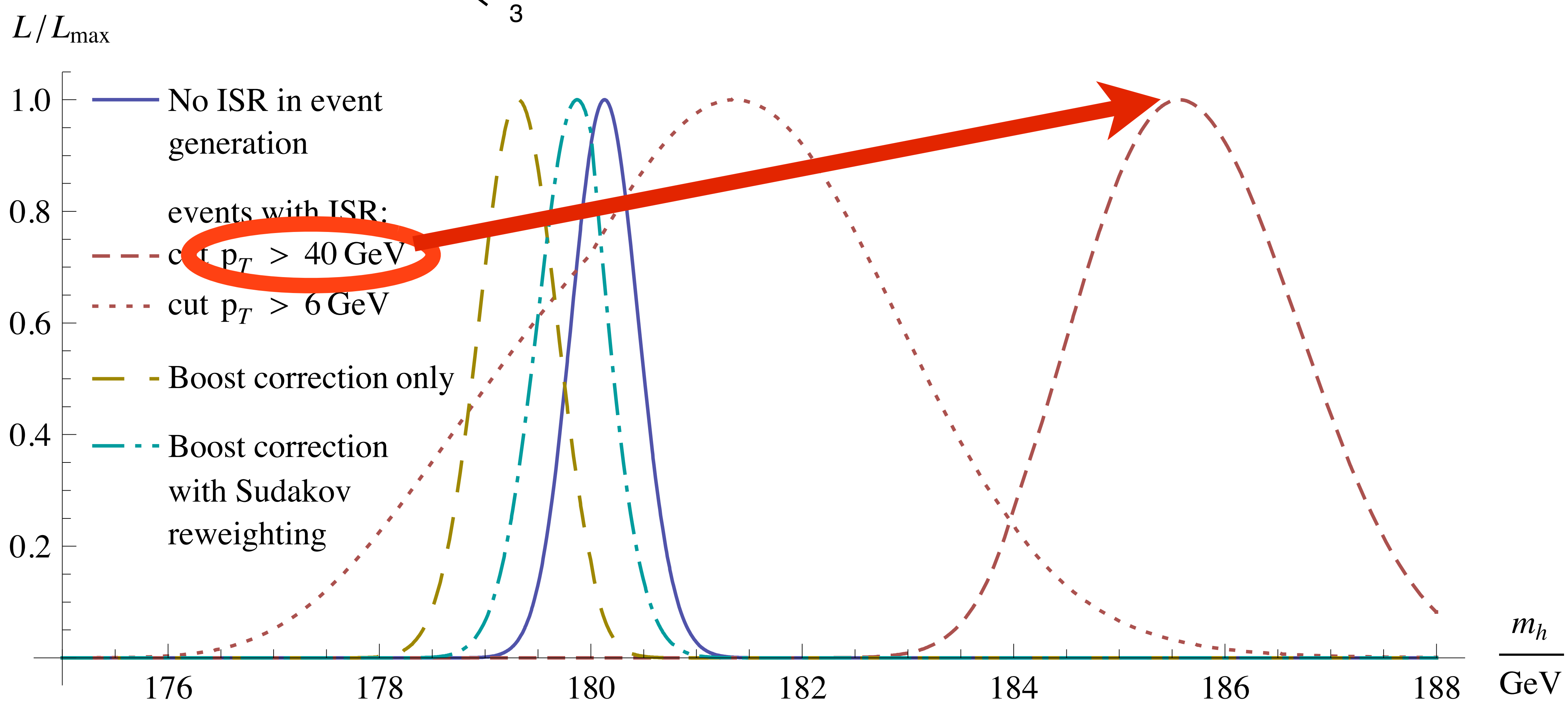


- Study the ISR on Higgs production at LHC (14 TeV) at parton level (no hadronization)
- Large Veto → Large bias



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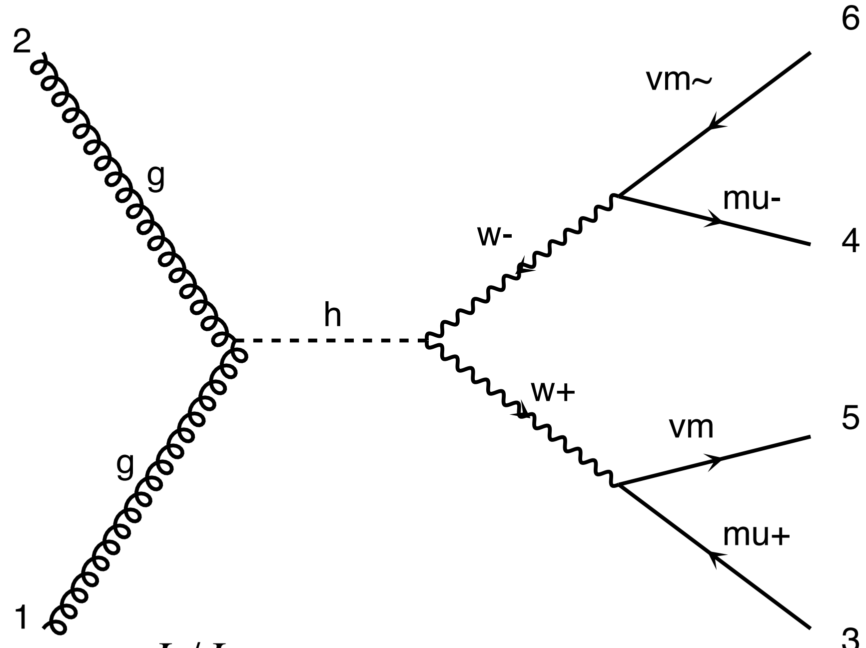
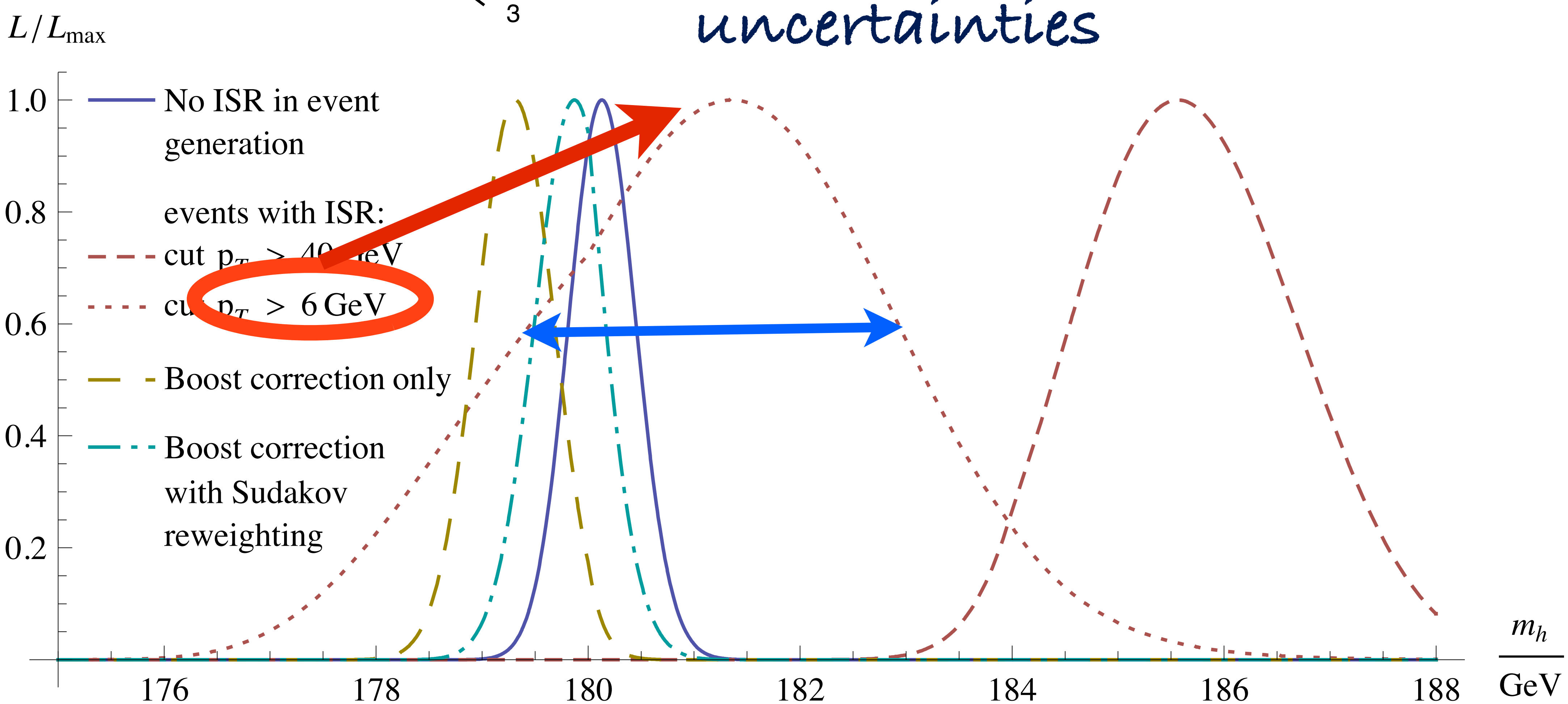


- Study the ISR on Higgs production at LHC (14 TeV) at parton level (no hadronization)
- smaller veto → smaller bias but larger statistical uncertainties



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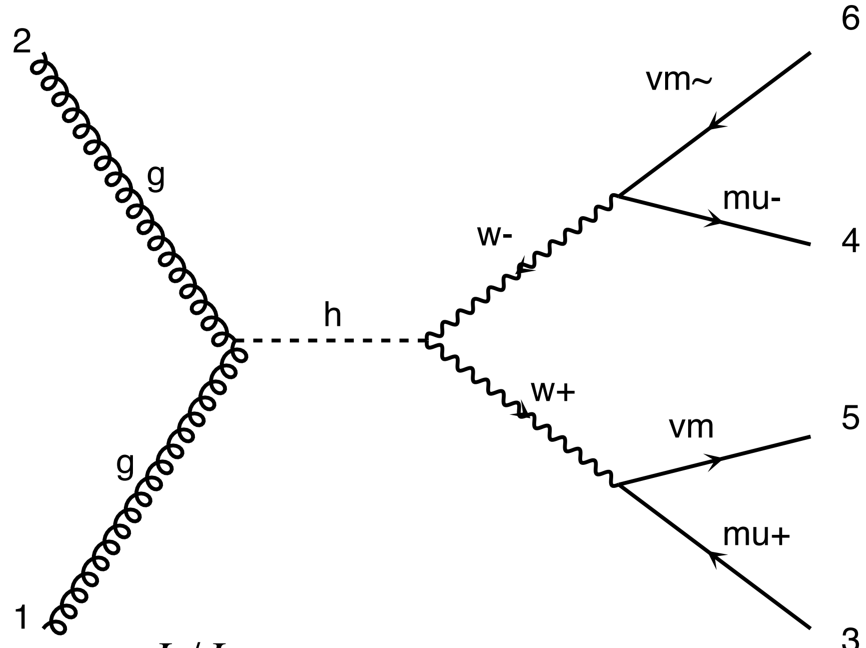
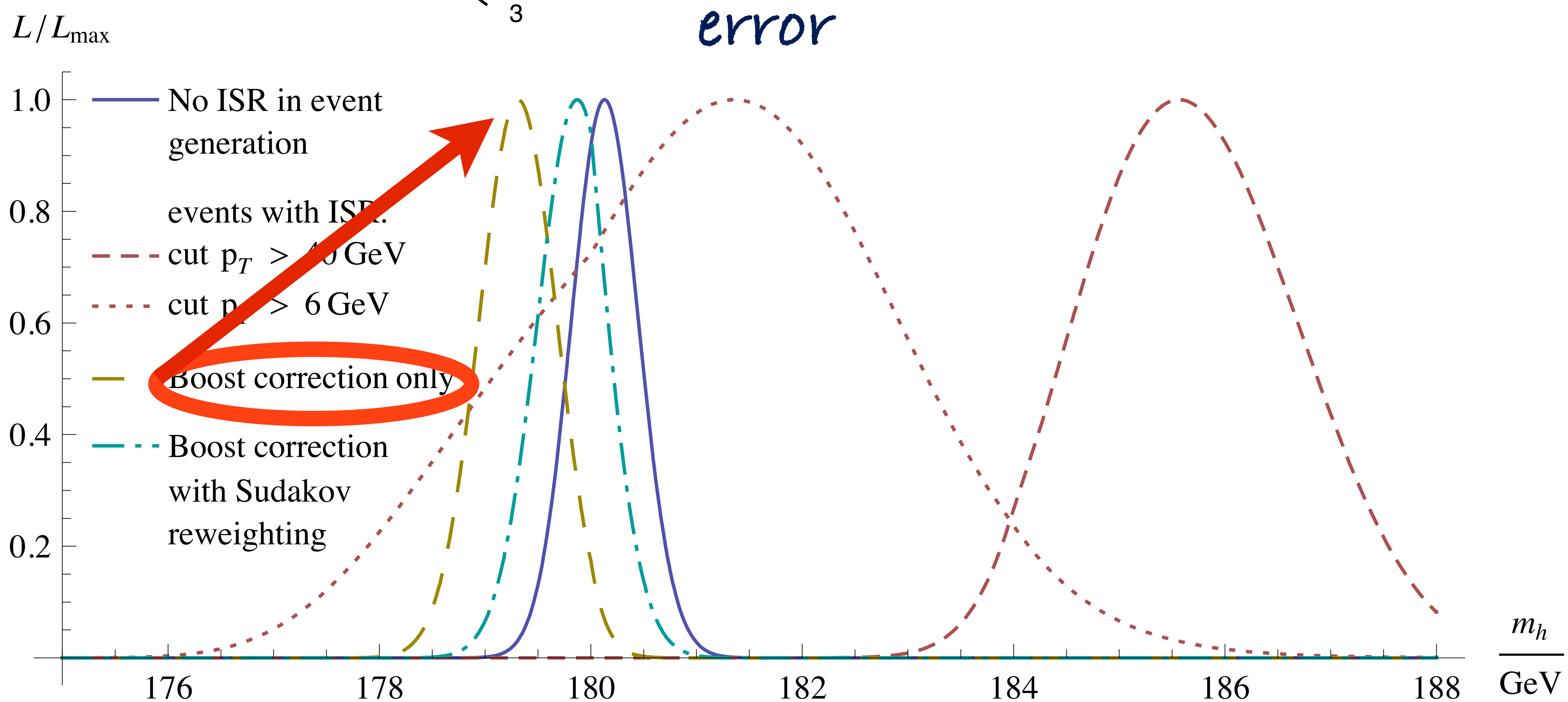
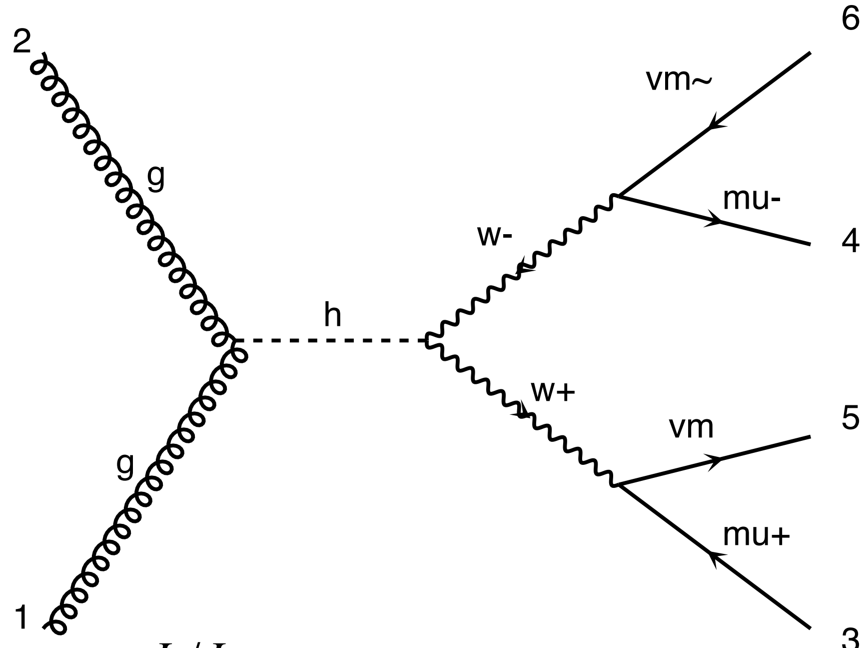


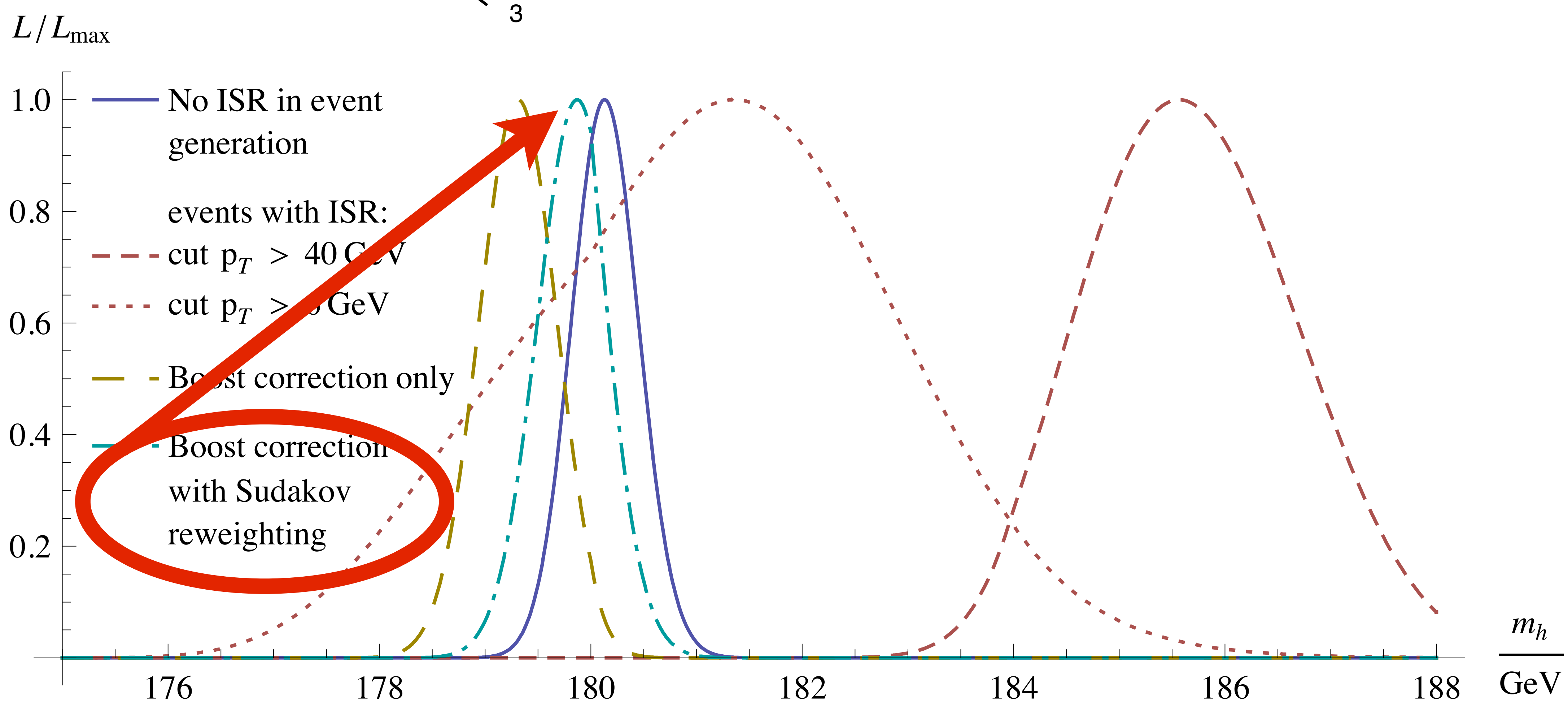
- Study the ISR on Higgs production at LHC (14 TeV) at parton level (no hadronization)
- Use the ISR to boost the momenta ➔ small bias/ error



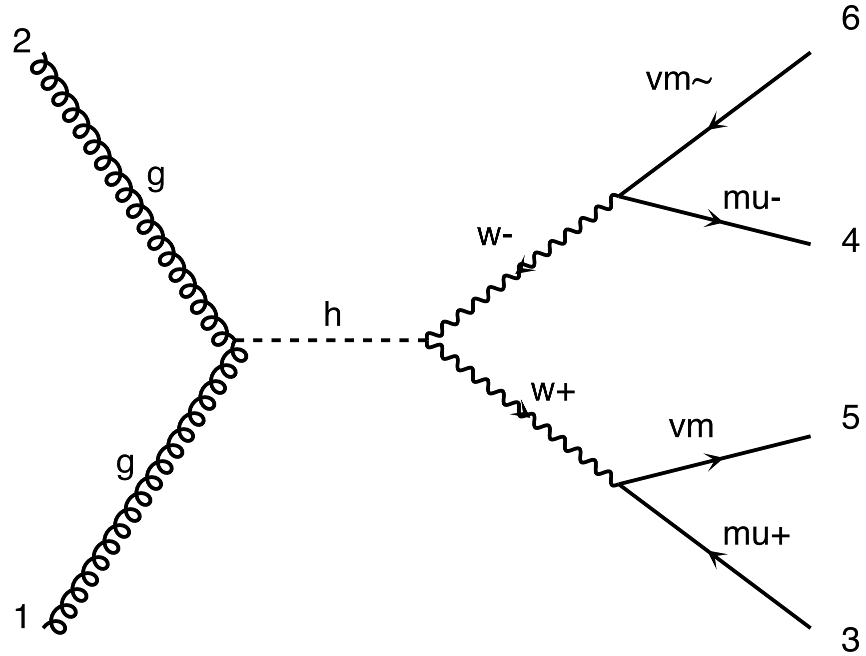
Initial State Radiation



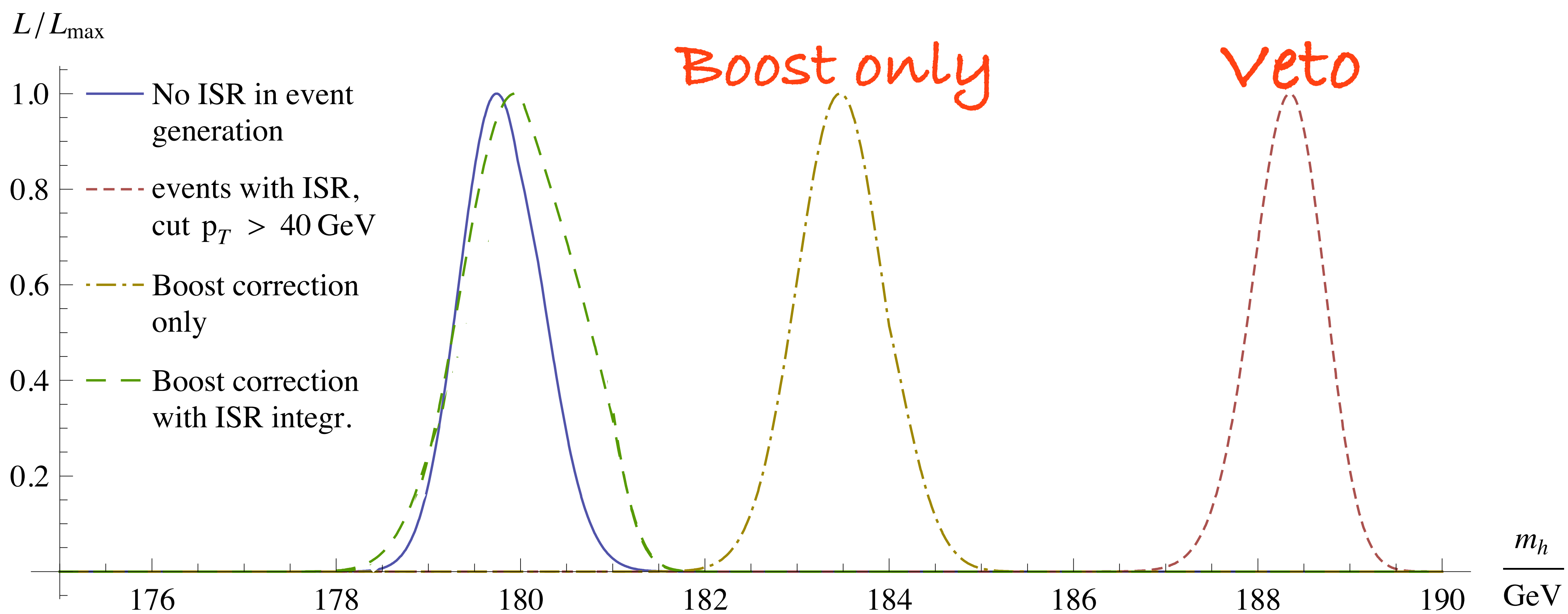
- Study the ISR on Higgs production at LHC (14 TeV) at parton level (no hadronization)
- Add the Sudakov Factor
  → No significative bias



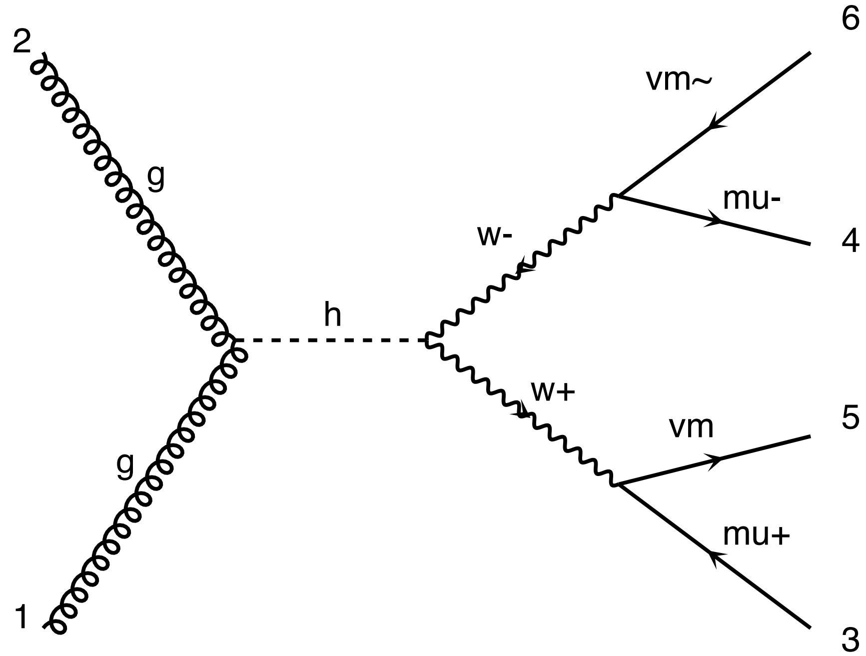
Initial State Radiation



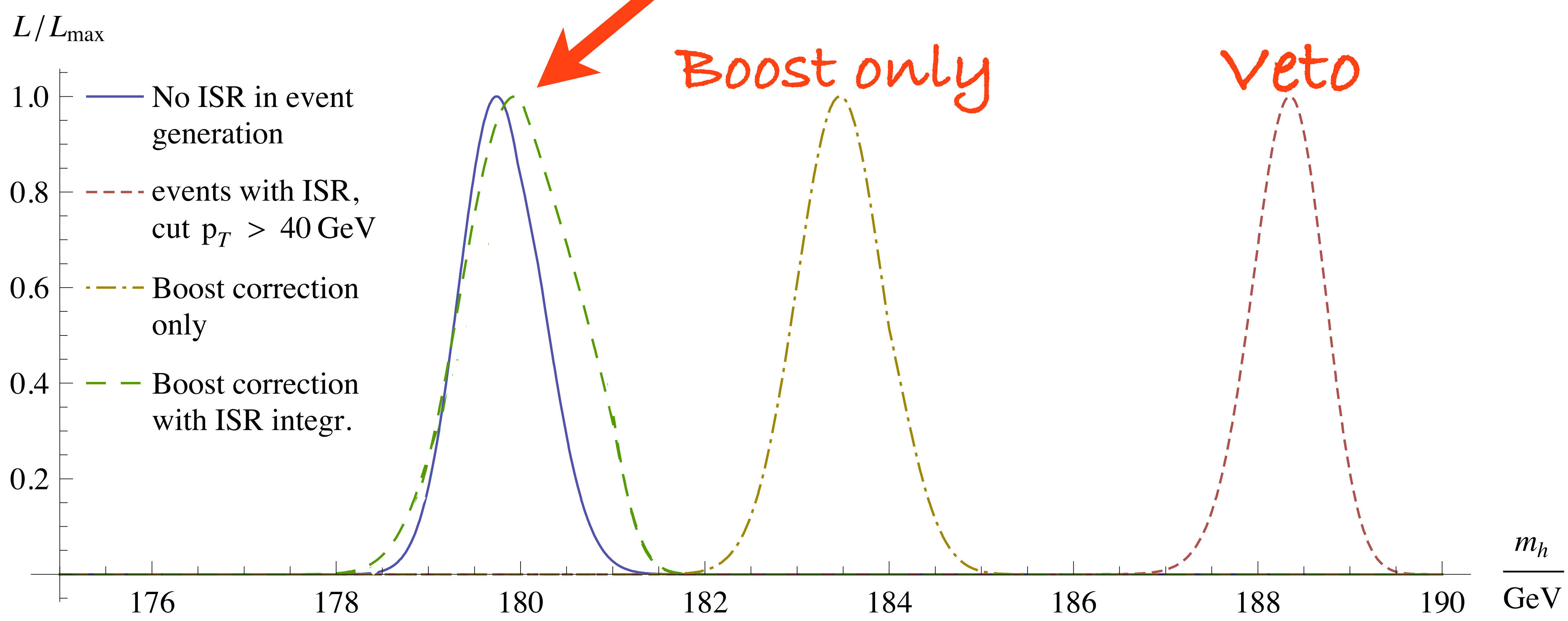
- Study the ISR on Higgs production at LHC (14 TeV) at detector level



Initial State Radiation



- Study the ISR on Higgs production at LHC (14 TeV) at detector level
- Introduce ISR transfer functions



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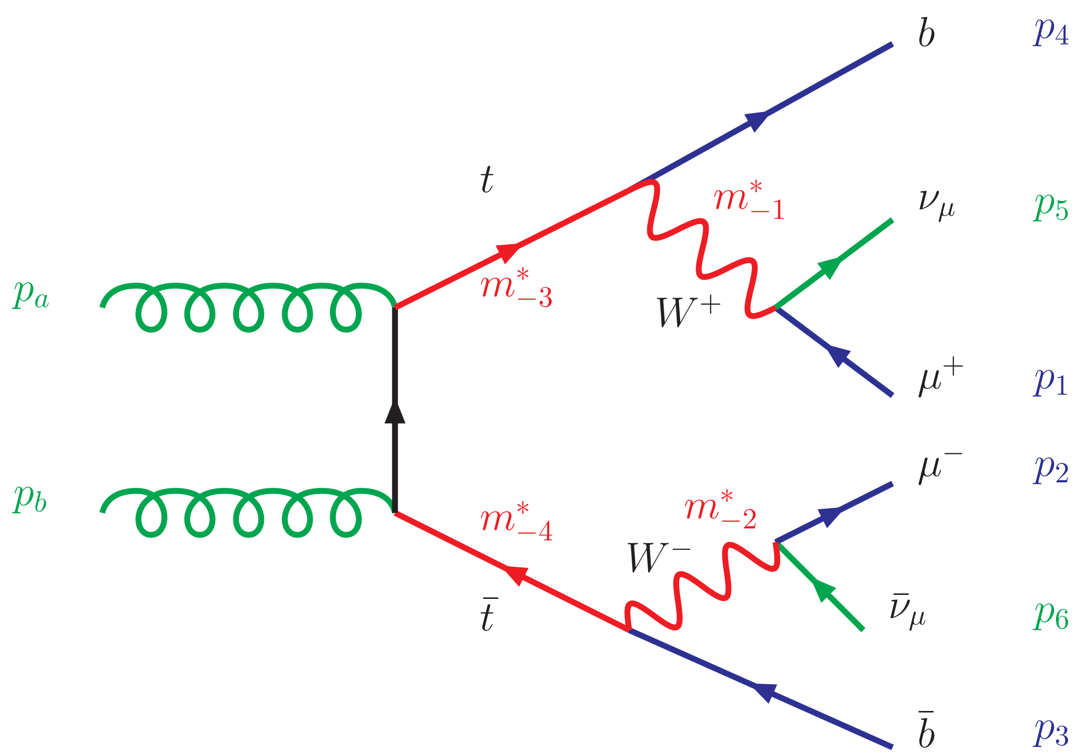
  - **DMEM: $m_{t\bar{t}}$ in fully leptonic channel**

Differential Cross Section



- Need the parton configuration
- uses a series of constraints (kinematical fit)
- use $\frac{1}{\mathcal{P}}\frac{\partial \mathcal{P}}{\partial Z}$ as discriminator

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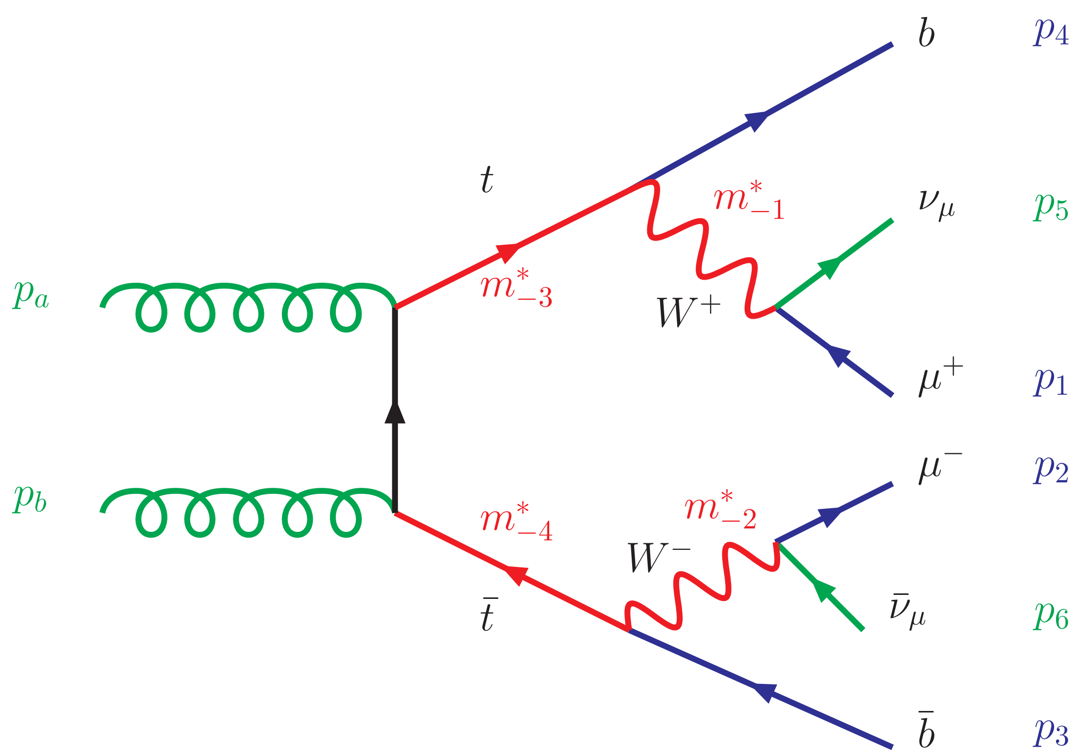

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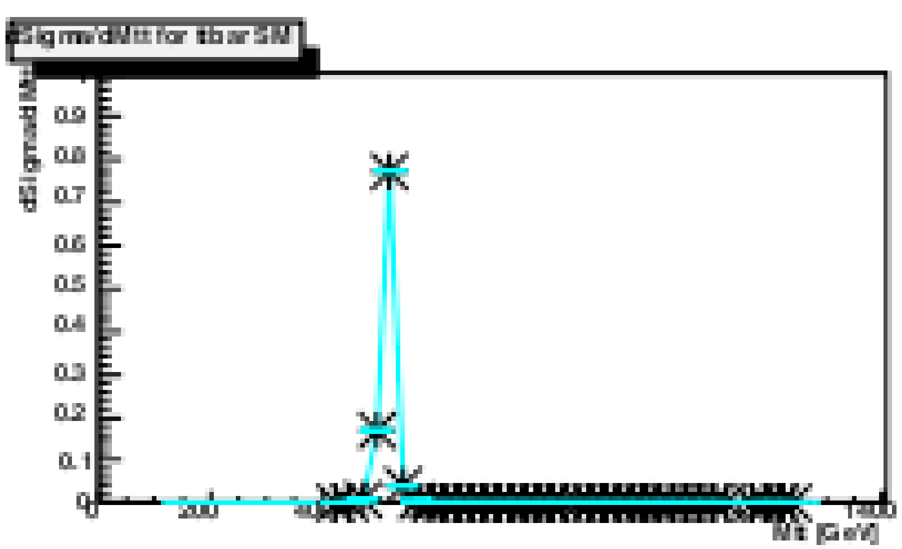
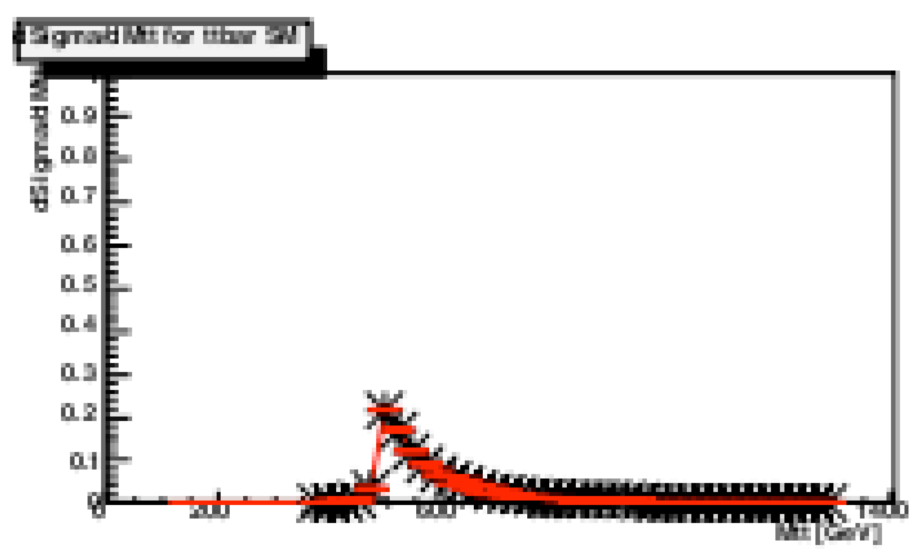
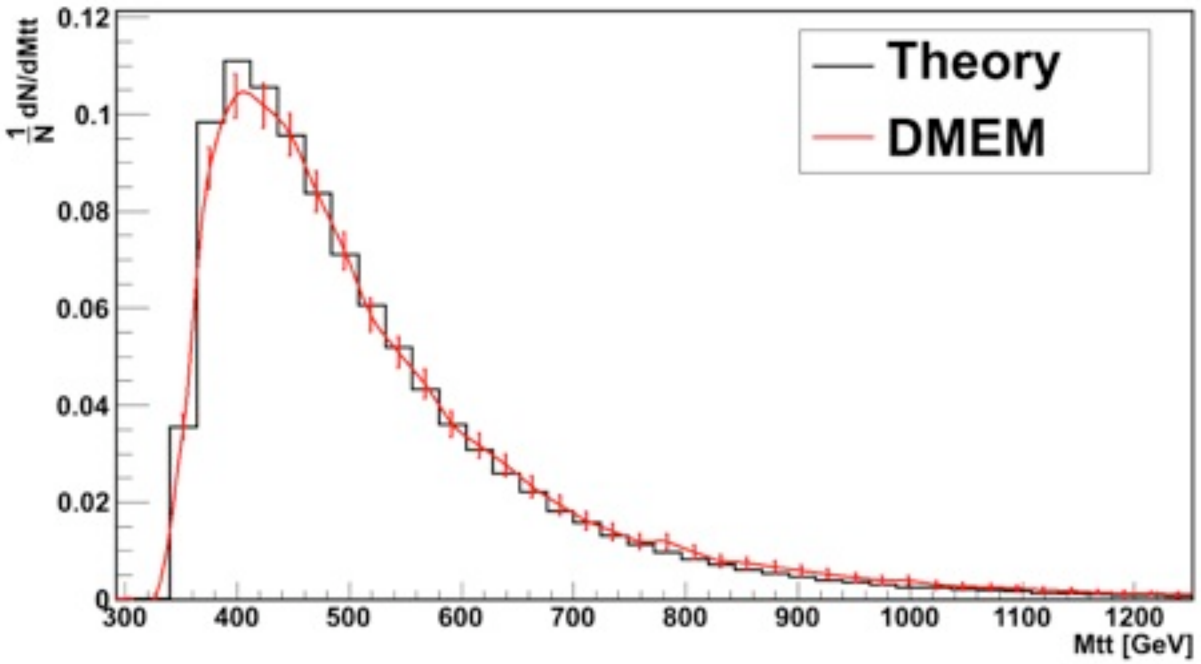
We use the full inference



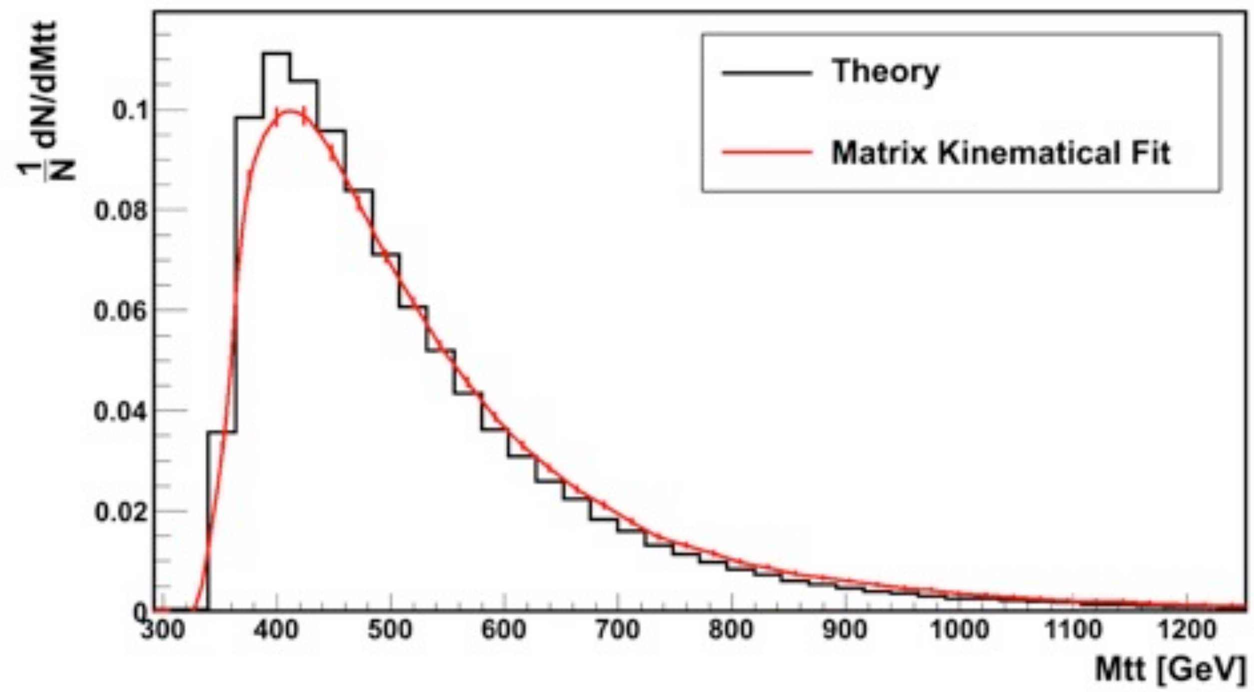


DMEM Validation

partonic level

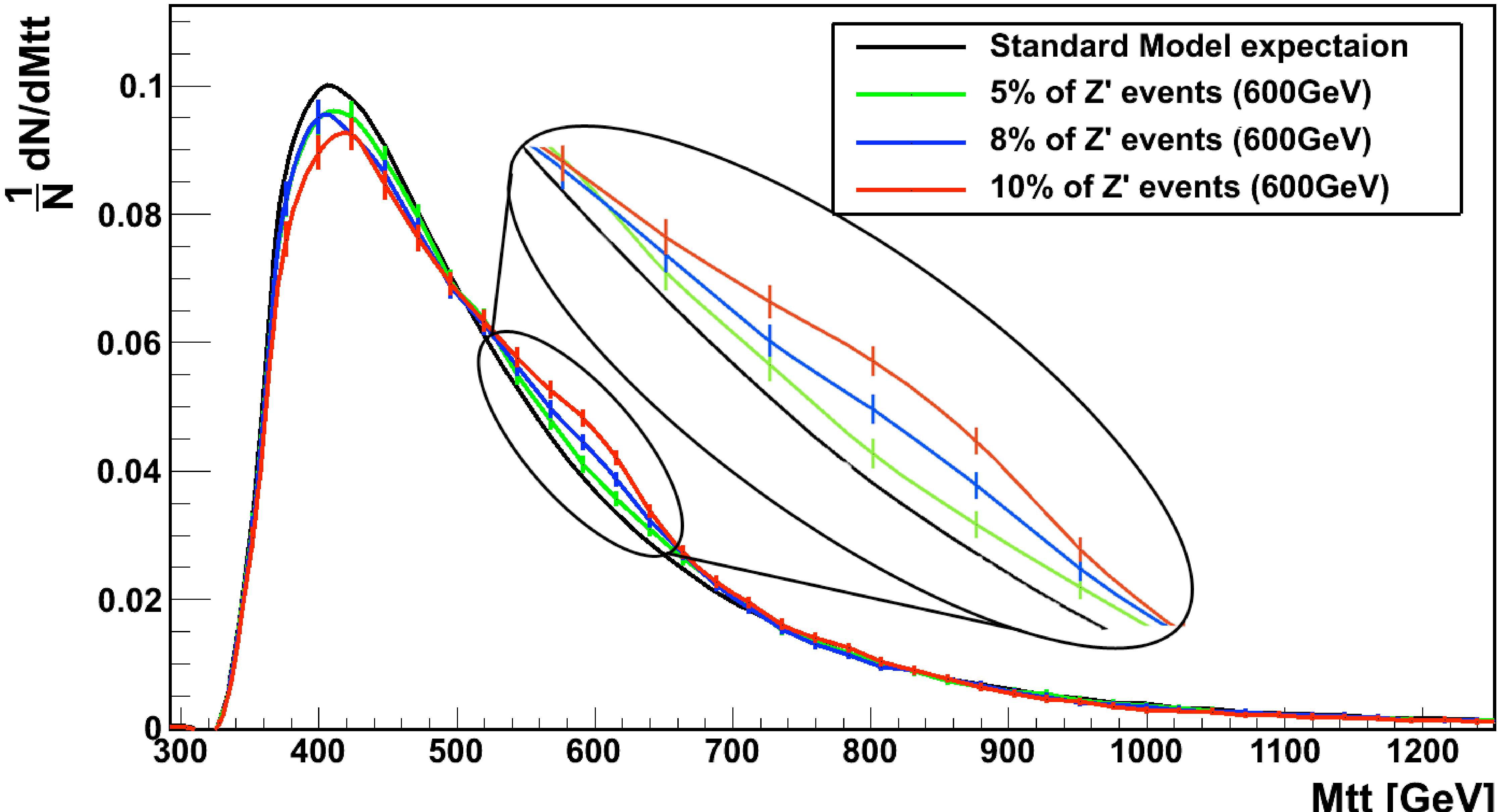


reconstructed level



DMEM

- What if the sample is not a SM one? For example if a heavy Z exists (600 GeV).



Only use SM matrix Element!!!

Conclusion

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BUT

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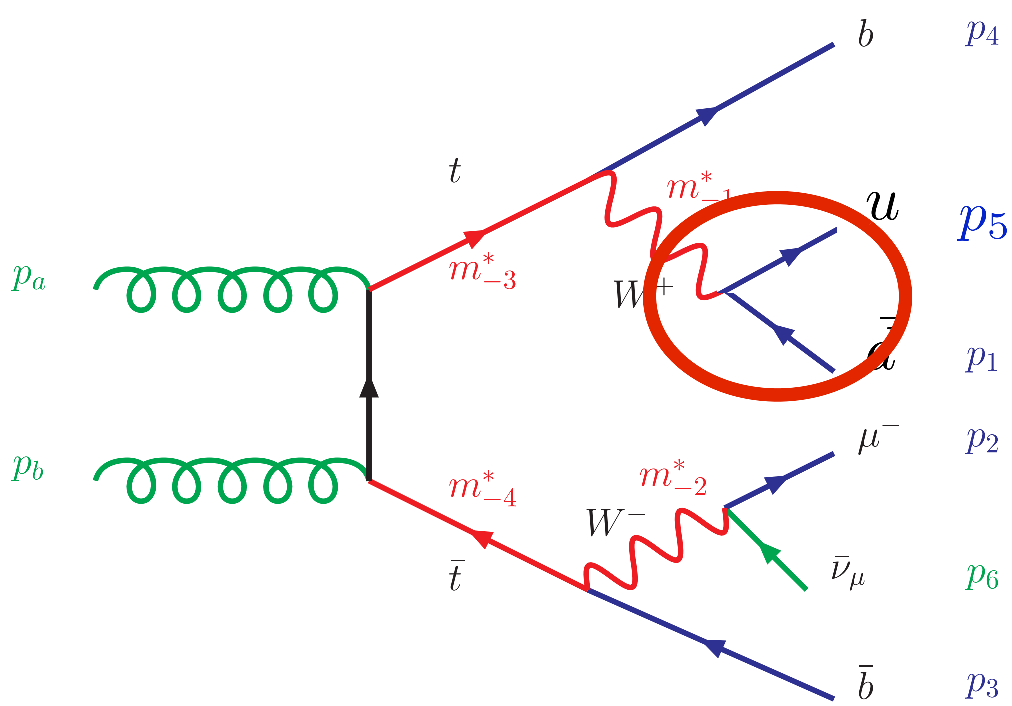
Backup slide

MADWEIGHT

- Second Example: semi-leptonic top quark pair



- degrees of freedom 16
- peaks 19

MADWEIGHT

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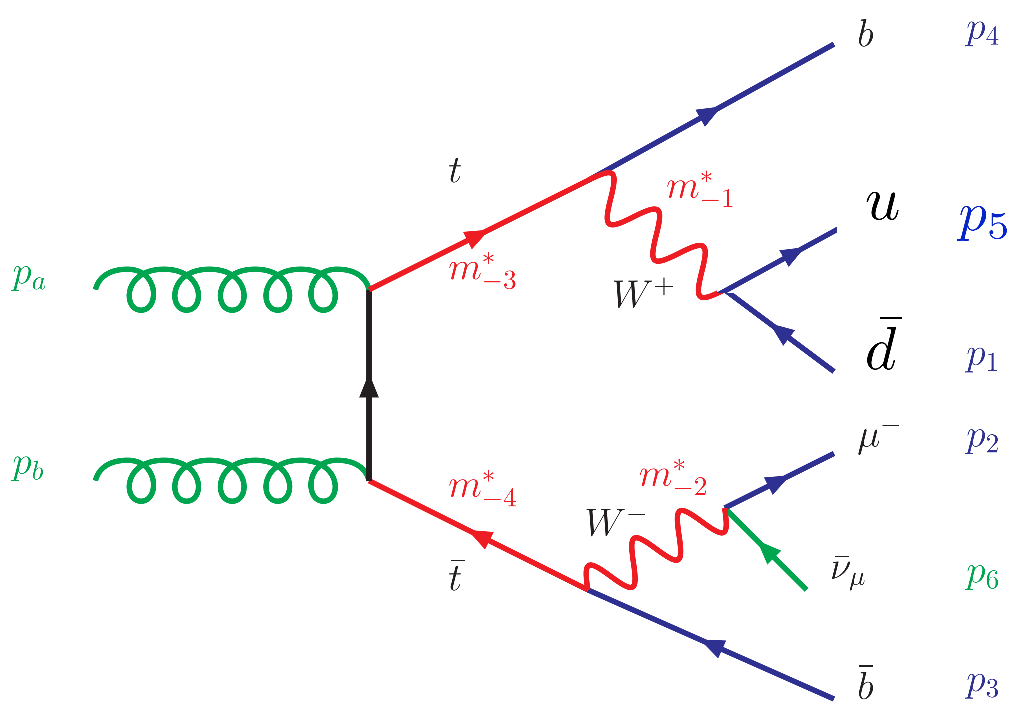

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MADWEIGHT

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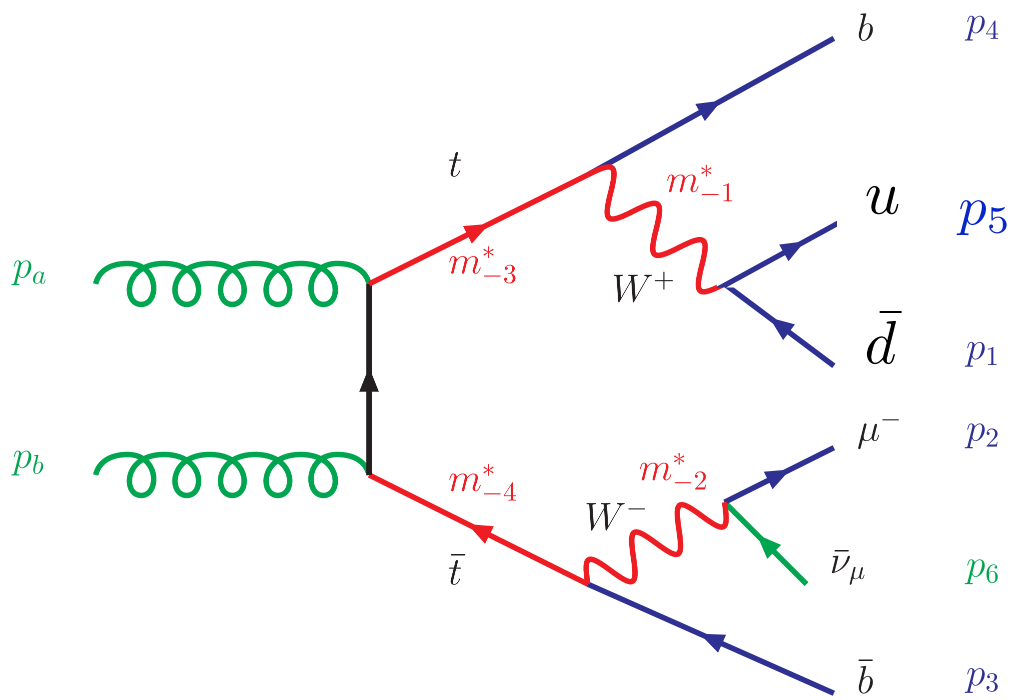

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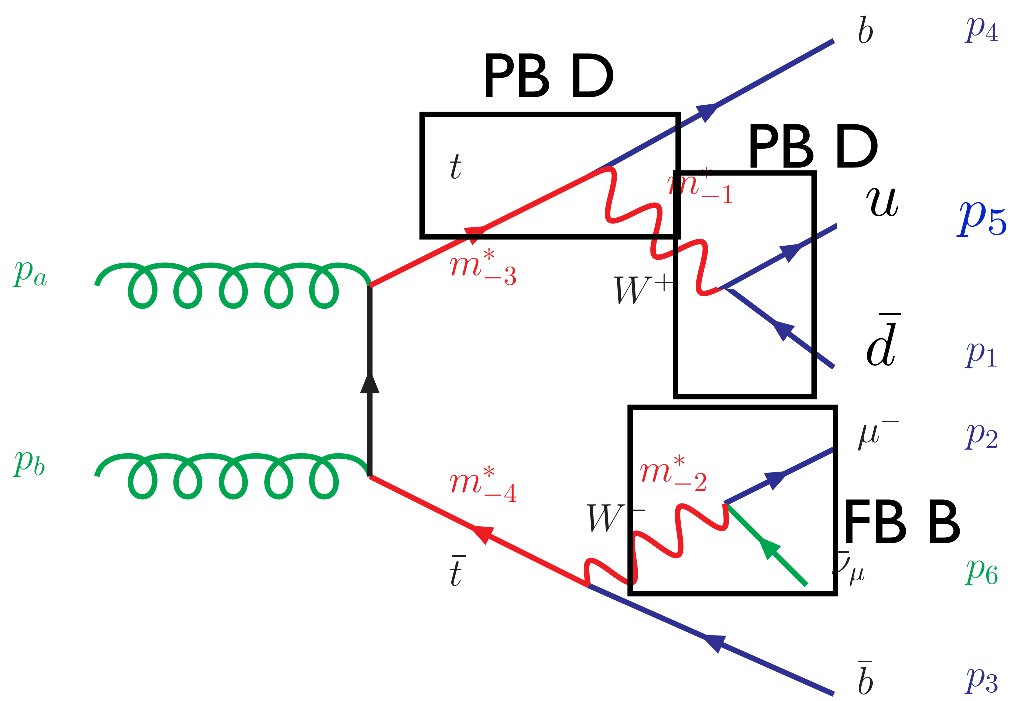

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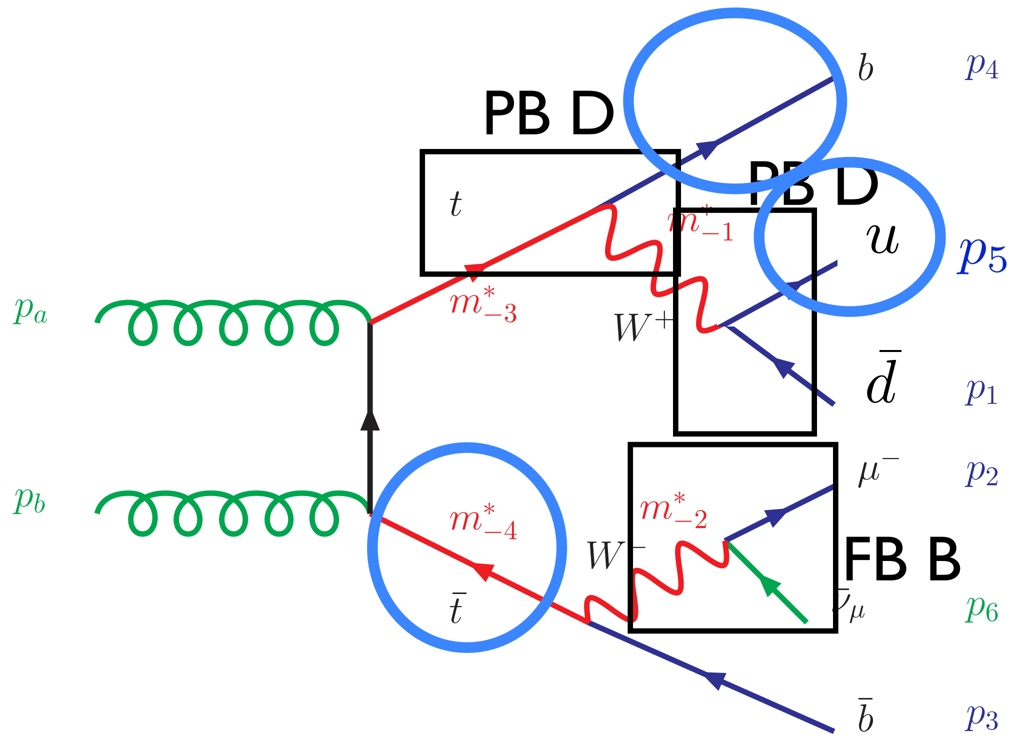

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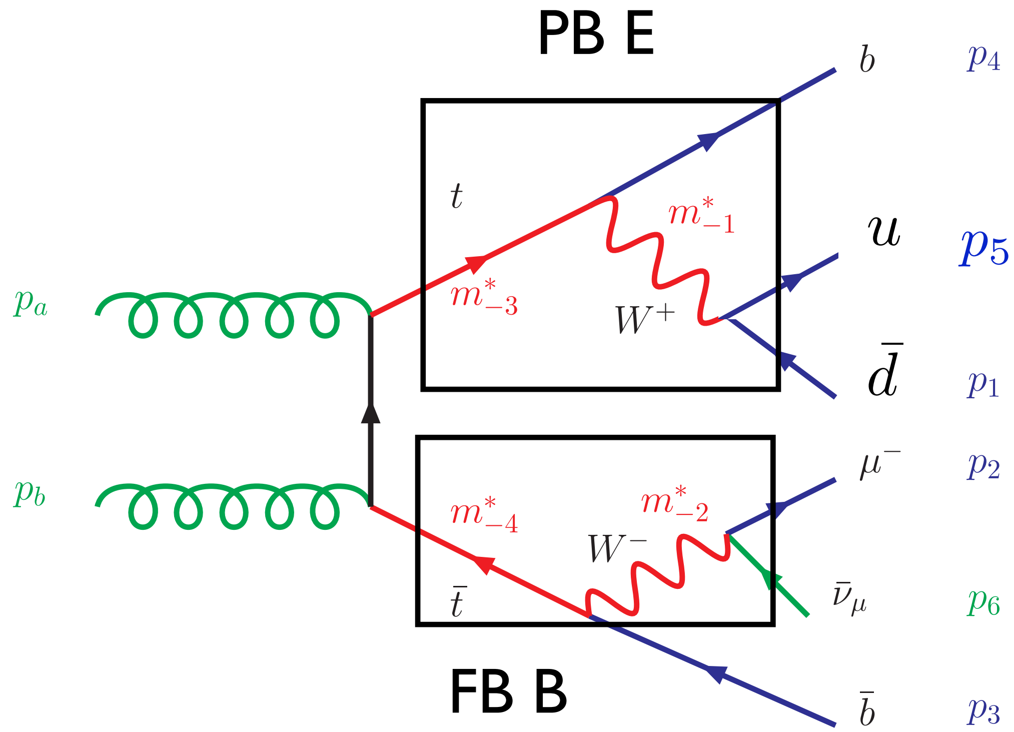

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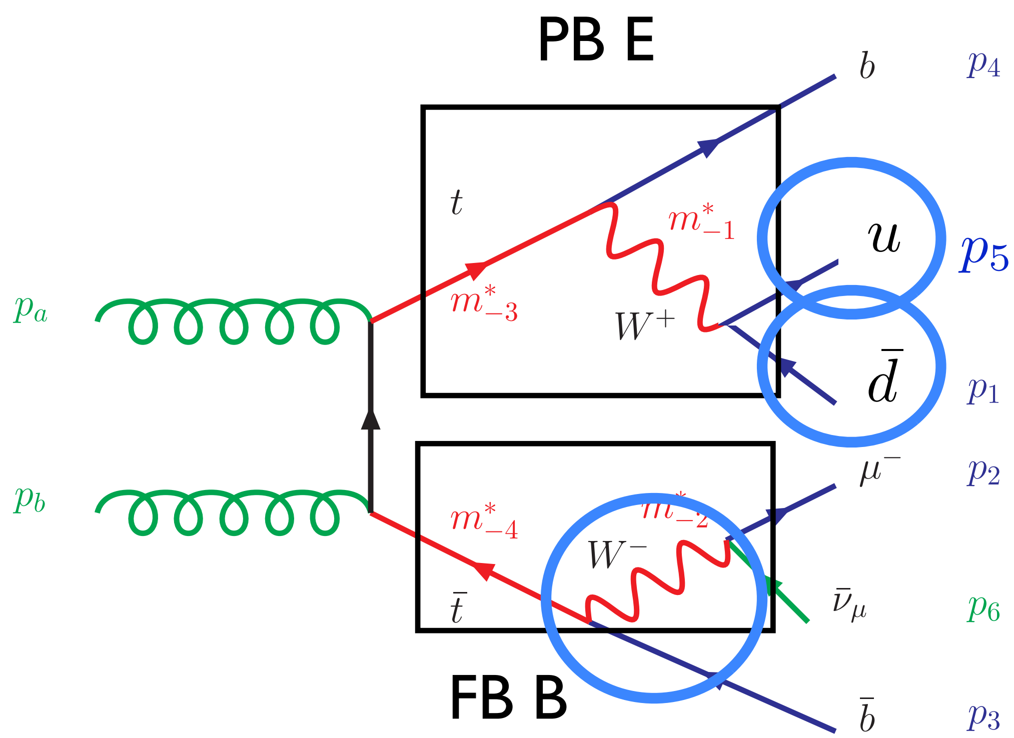

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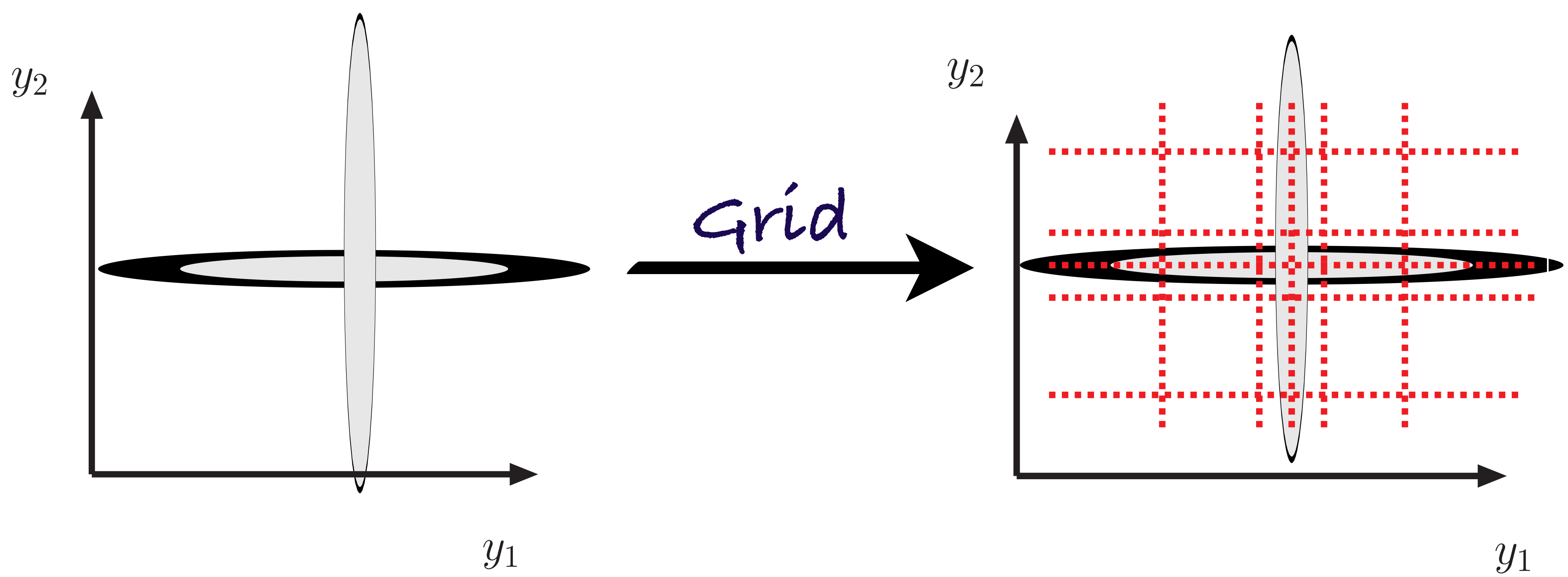
MadWeight

- the phase-space is split into blocks, each of them is associated to a specific local change of variables
- 12 blocks, i.e. 12 analytic changes of variables have been defined in our code.
- MadWeight finds automatically
  - the optimal partition of the PS into blocks
  - computes the weights using the corresponding PS parametrisation

Monte-Carlo Integration

- The choice of the parameterisation has a strong impact on the efficiency



- The adaptive Monte-Carlo Technique picks point in interesting areas
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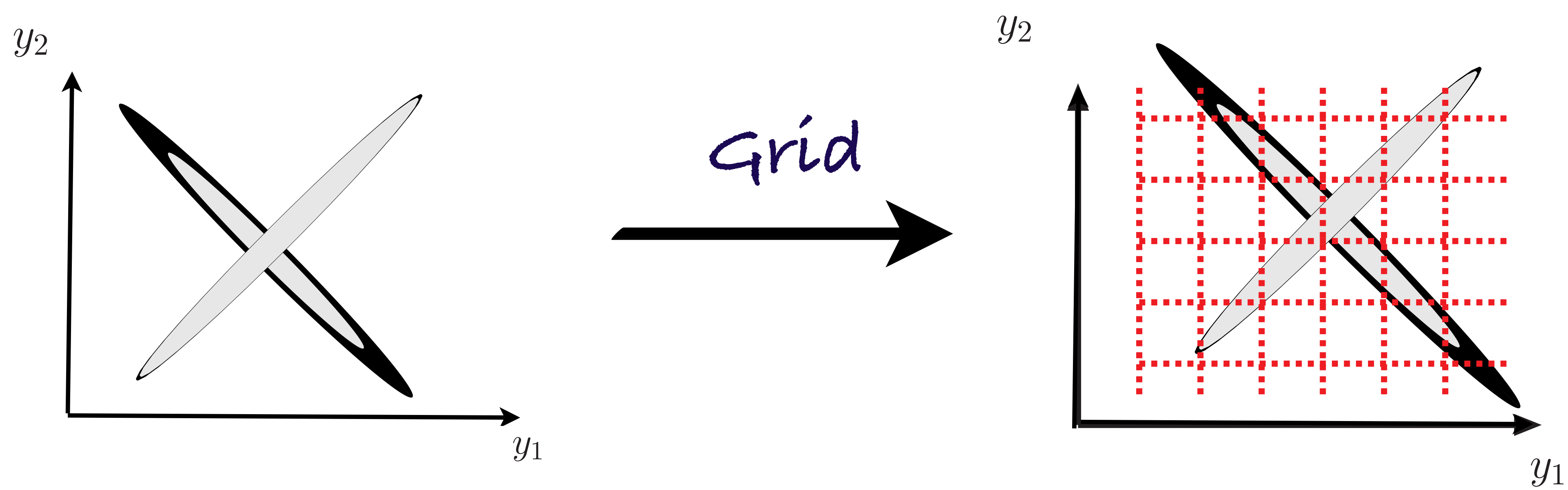

- The adaptive Monte-Carlo Techniques picks points everywhere
  → The integral converges slowly

Monte-Carlo Integration

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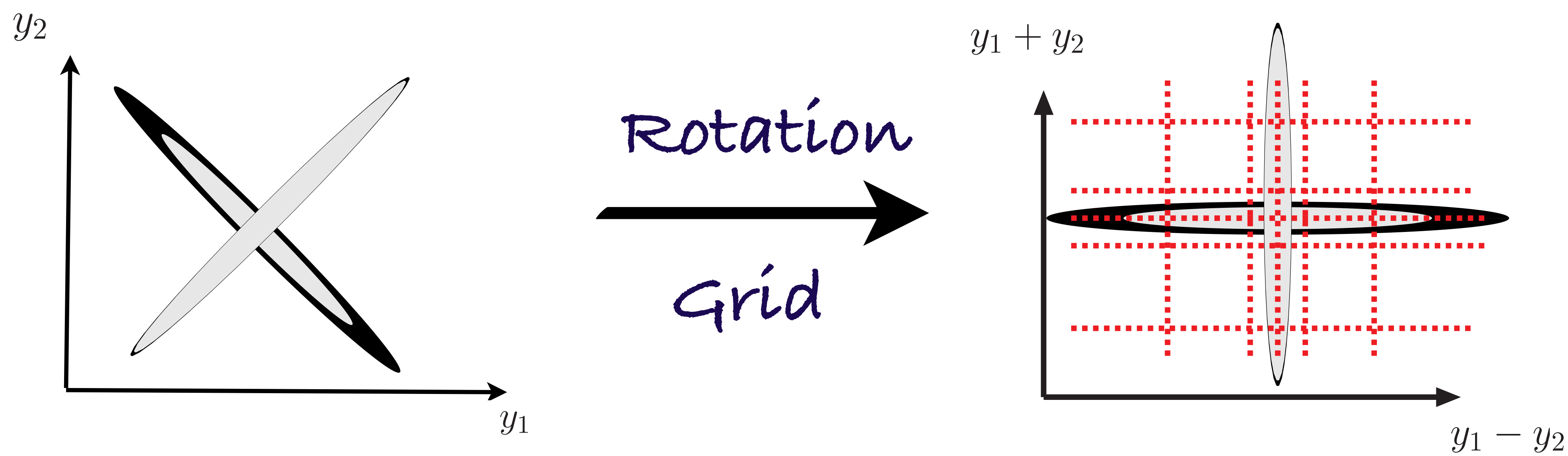

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Demo

Terminal — bash — bash

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