

A New Approach To Matrix Element Re-Weighting

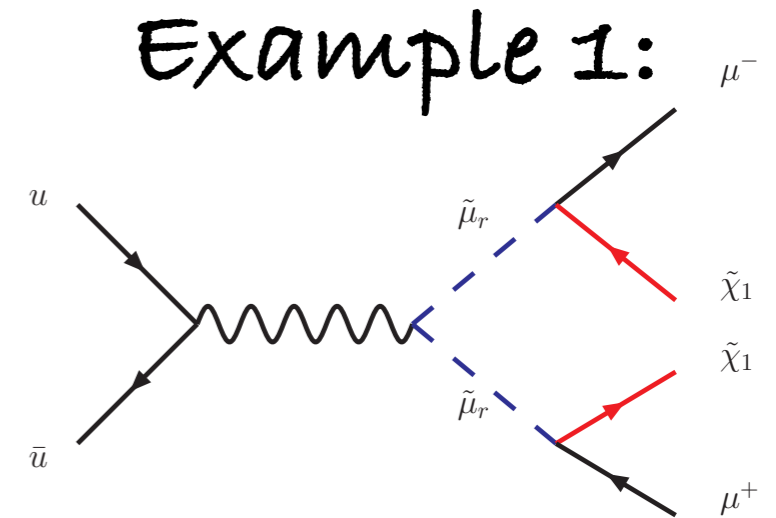
Olivier Mattelaer
Université Catholique de Louvain
CP3

J. Alwall, A. Freytas, OM: [arxiv:1010.2263](https://arxiv.org/abs/1010.2263)

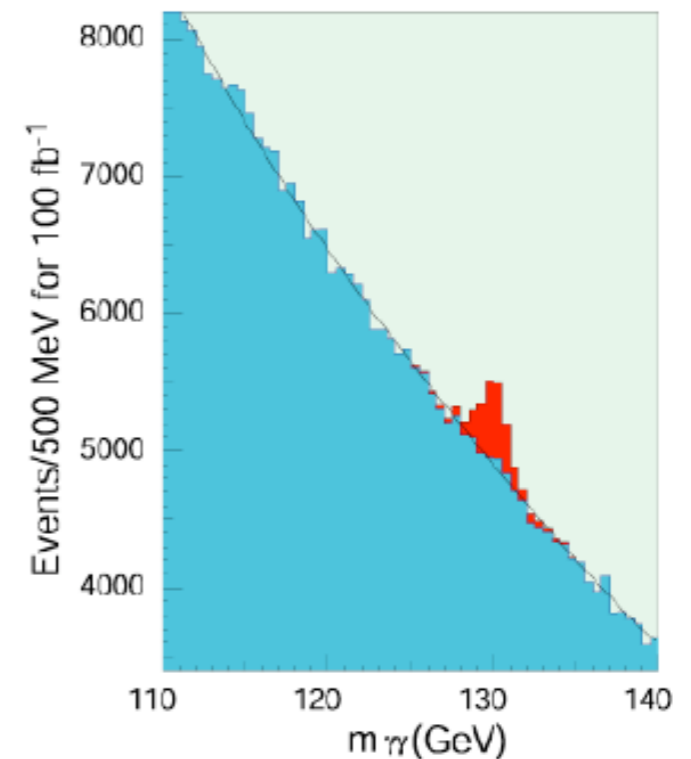
P.Artoisenet, V.Lemaître, F. Maltoni, OM: [JHEP 1012:068](https://arxiv.org/abs/1012.068)

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?



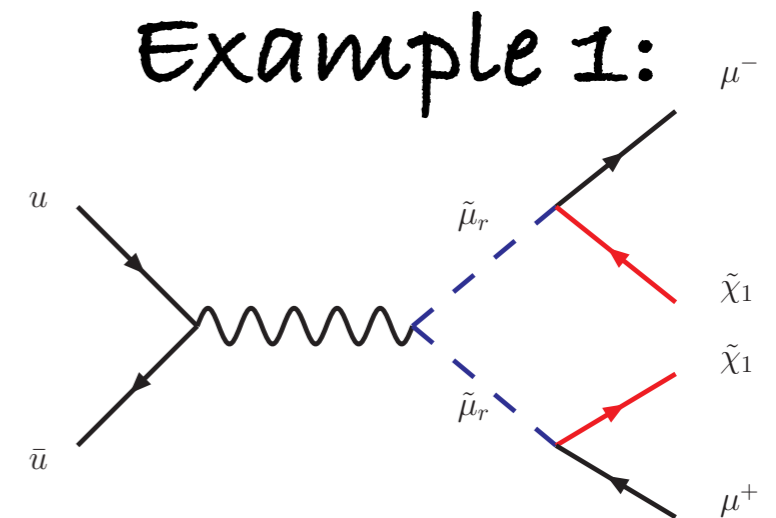
Example 2:



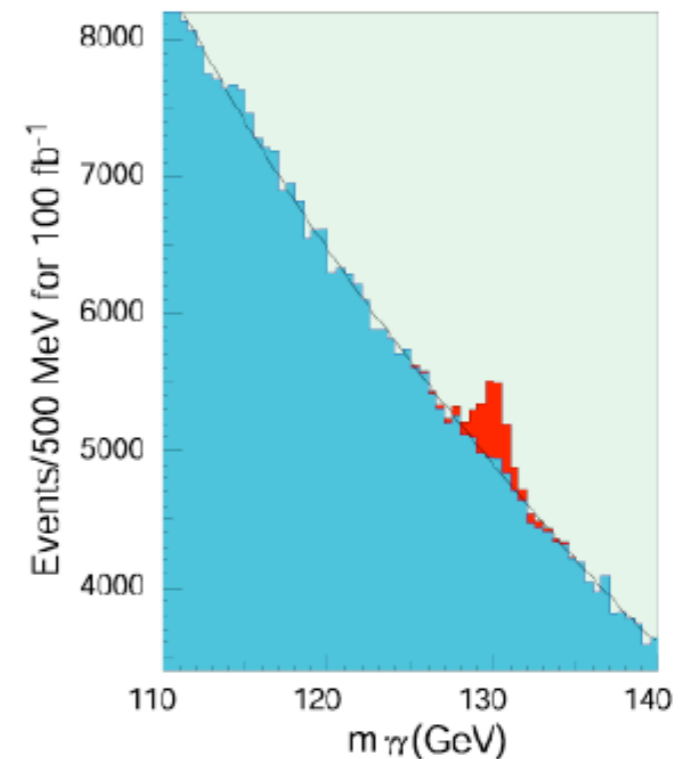
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YES MANY



Example 2:



Outline

- Introduction to Matrix Element re-weighting
- Examples of studies / investigations
 - mass determination : smuon pair production
 - 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 p^{vis} , the **probability** $\mathcal{P}(p^{vis}|\alpha)$ to be produced and observed following a theoretical assumption α

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$$\mathcal{P}(\mathbf{p}^{vis}|\alpha) = \frac{1}{\sigma_\alpha} \int d\Phi dx_1 dx_2 |M_\alpha(\mathbf{p})|^2 W(\mathbf{p}, \mathbf{p}^{vis})$$

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- σ_α is the cross-section

Matrix Element Method

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

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

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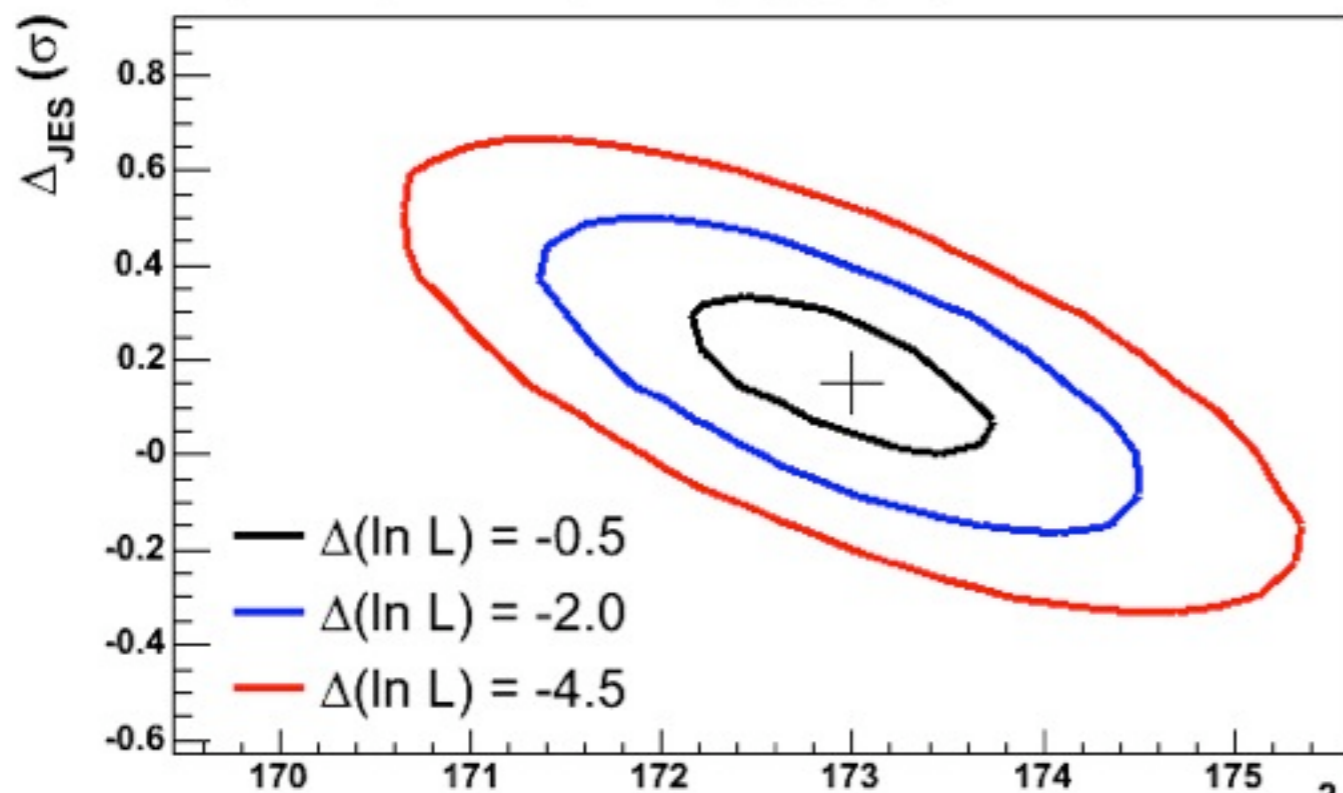
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CDF Run II Preliminary 5.6 fb⁻¹



Semi-leptonic decay

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

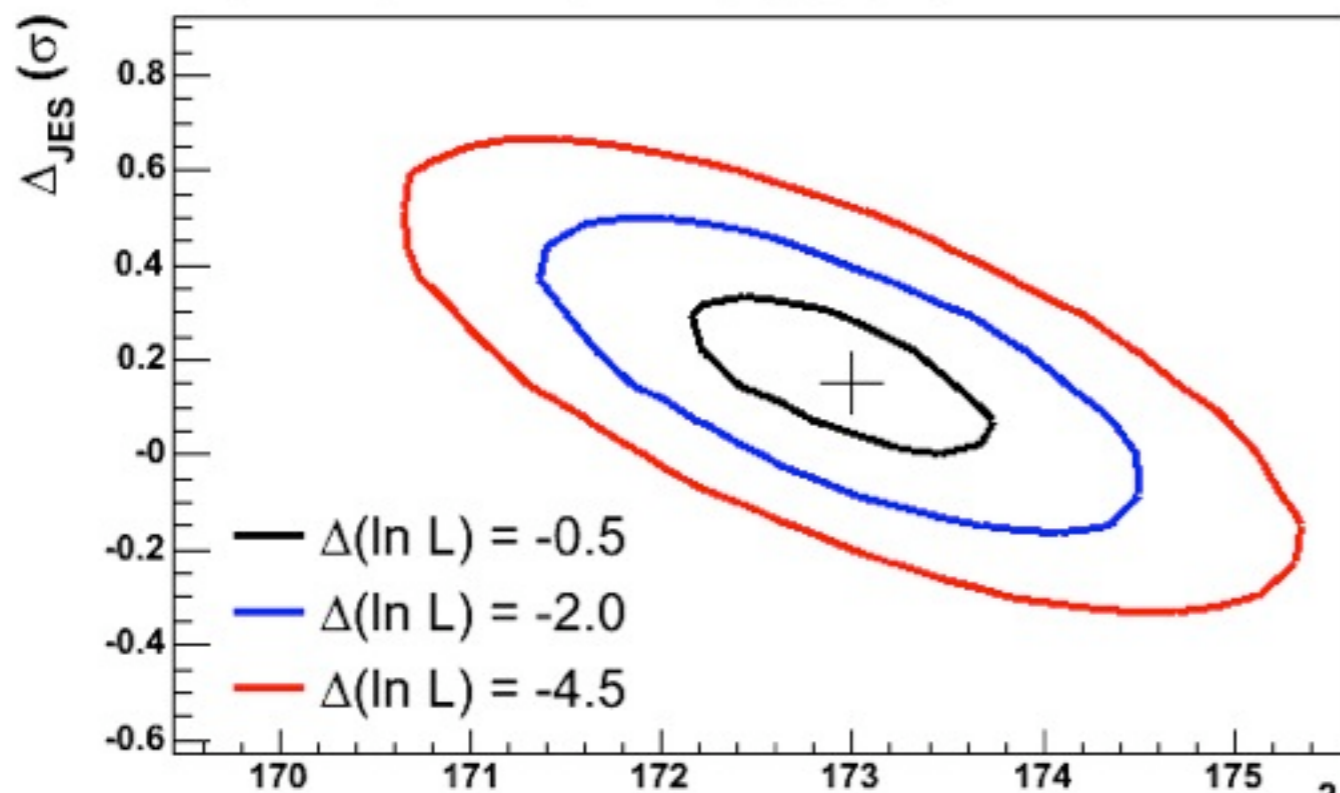
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Also use for

- Higgs Exclusion
- single top cross observation

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Difficult point: Numerical integration

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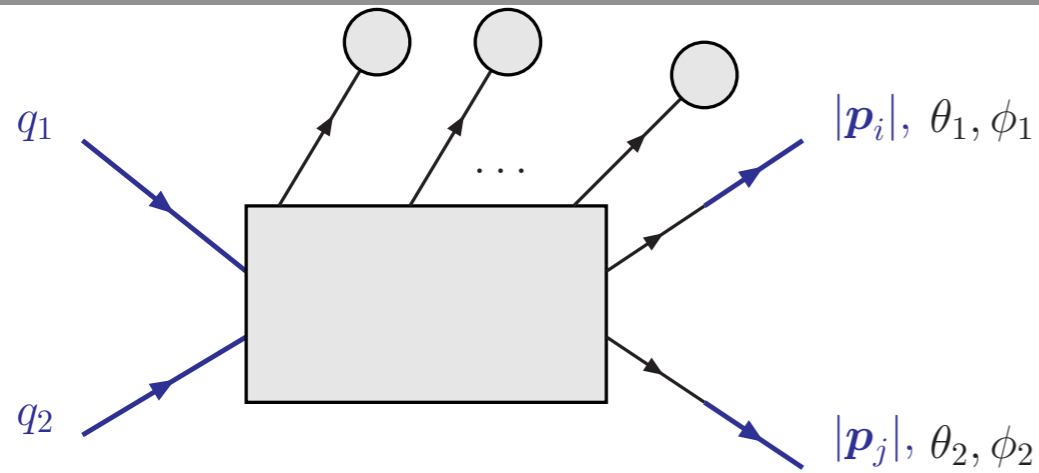
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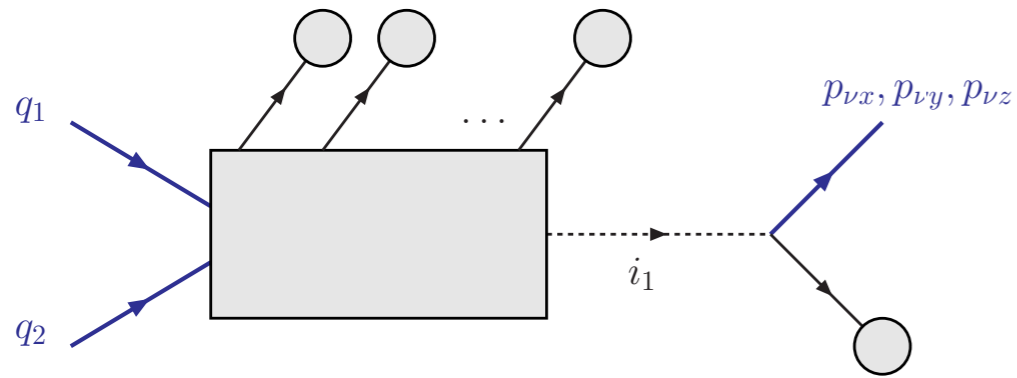
MADWEIGHT

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

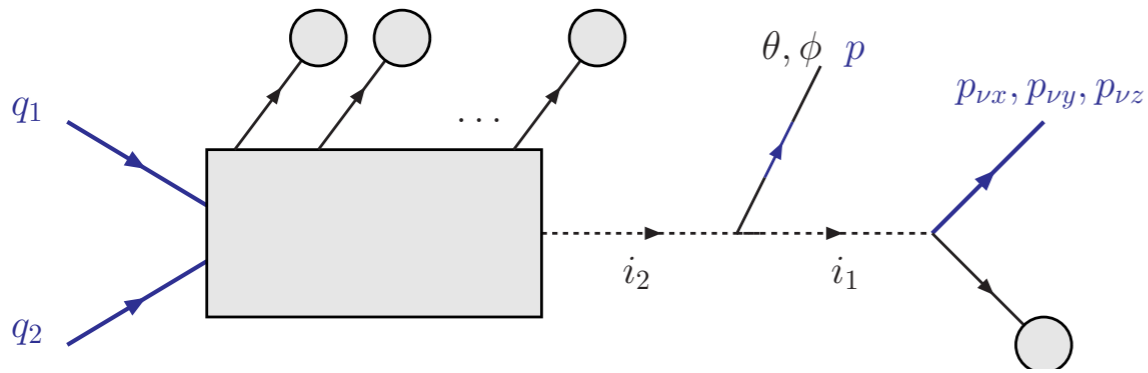
MadWeight



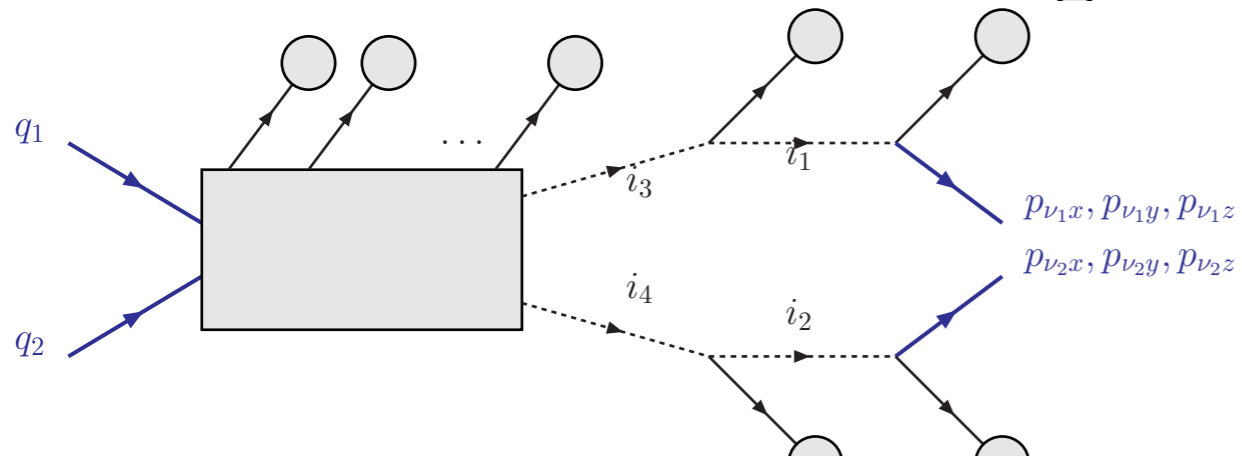
fully hadronic / leptonic process



W production

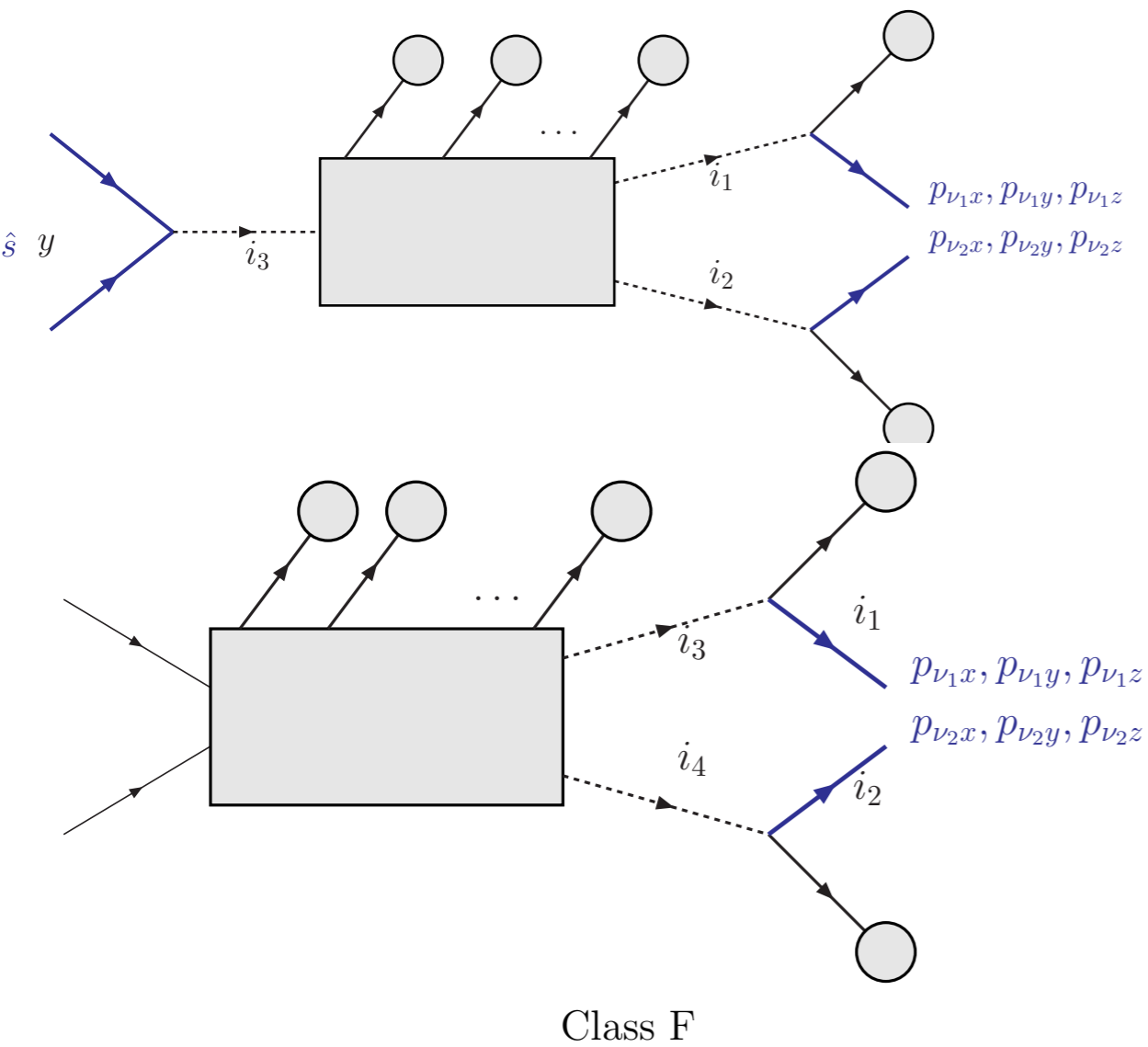


semi-leptonic top quark pair



Fully leptonic top quark pair

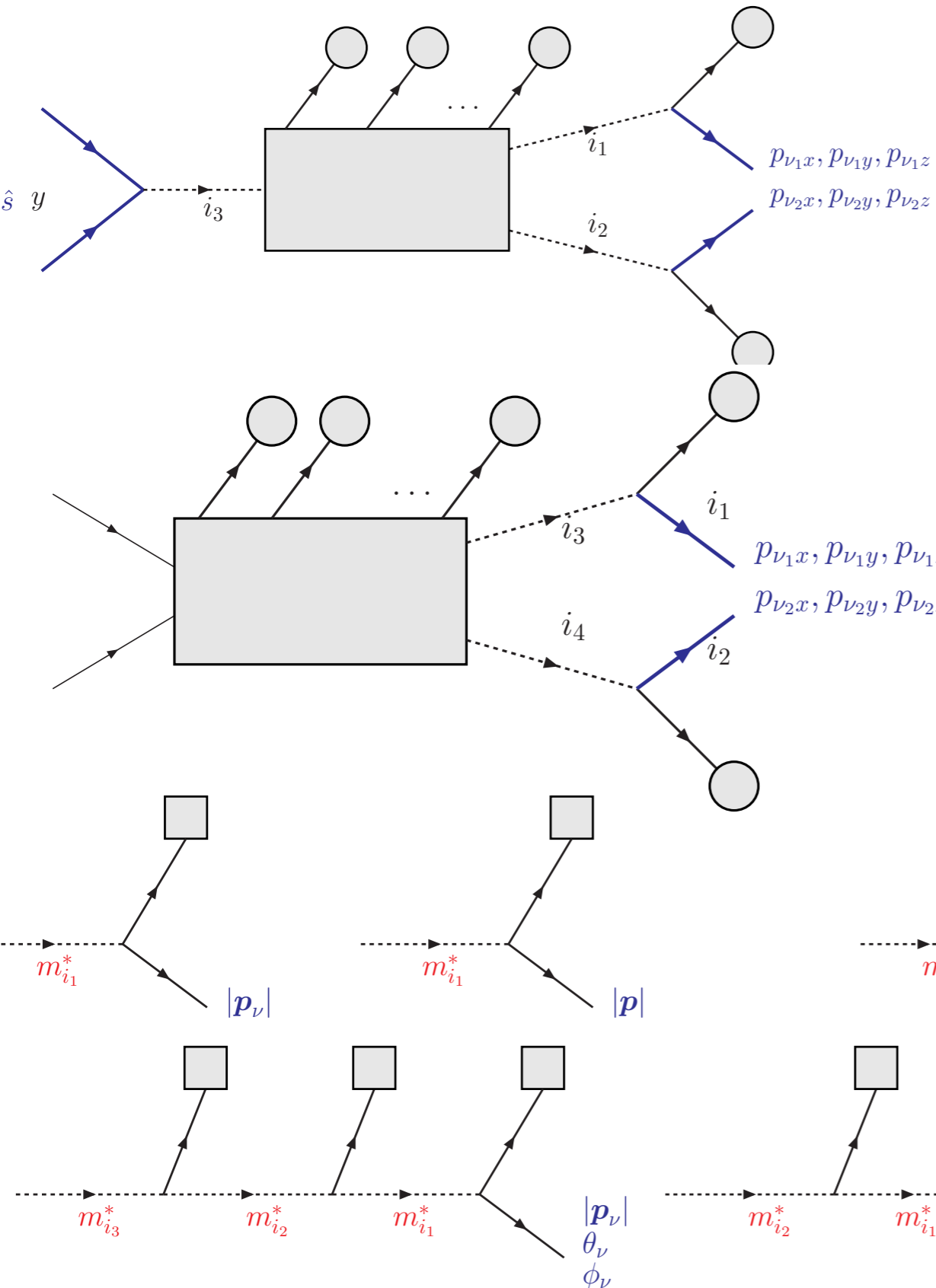
MadWeight



Higgs production decaying in w

$w + w$ -production

MadWeight



Higgs production decaying in w

$w + w^-$ production

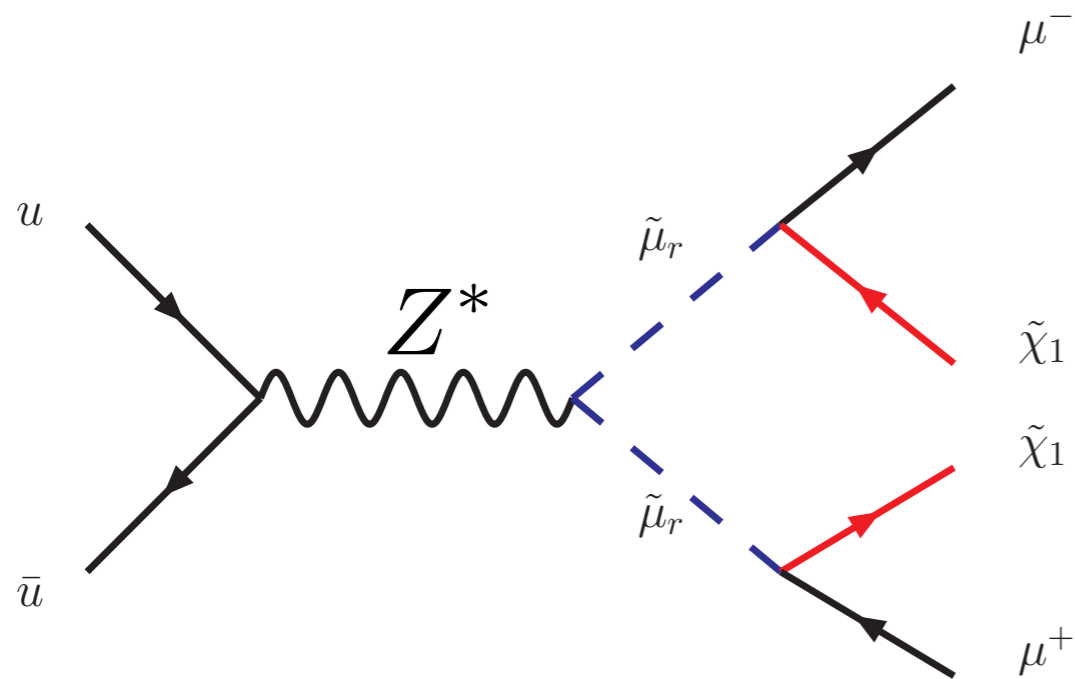
Lot of possibility to have more complex process

- +1 w
- +1 Z
- + ...

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Mass determination

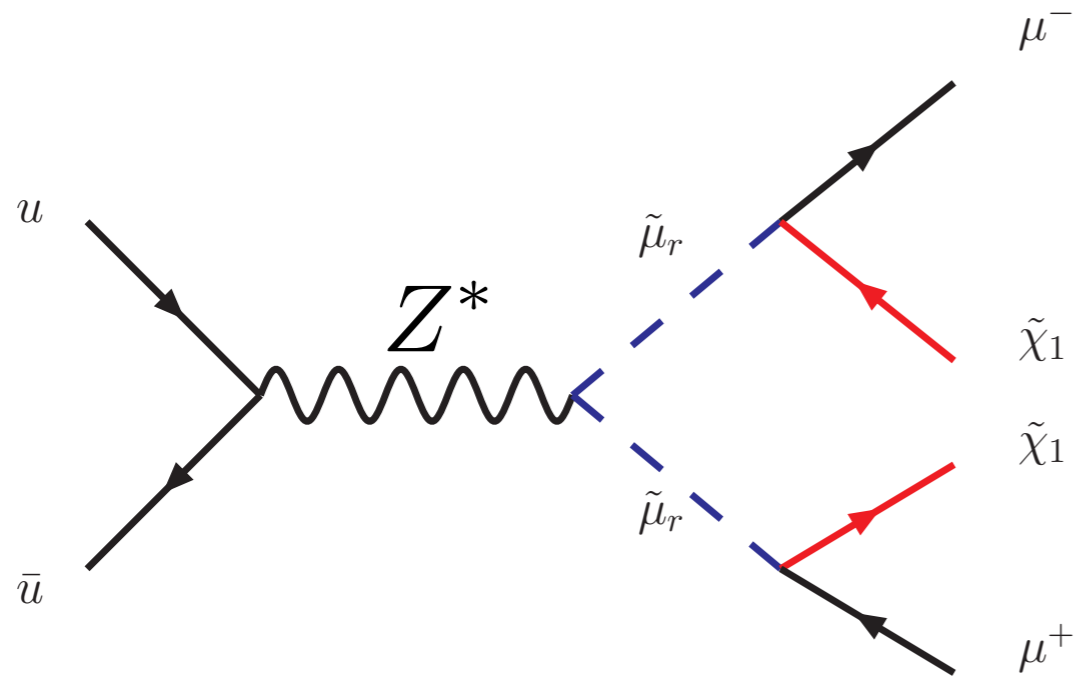
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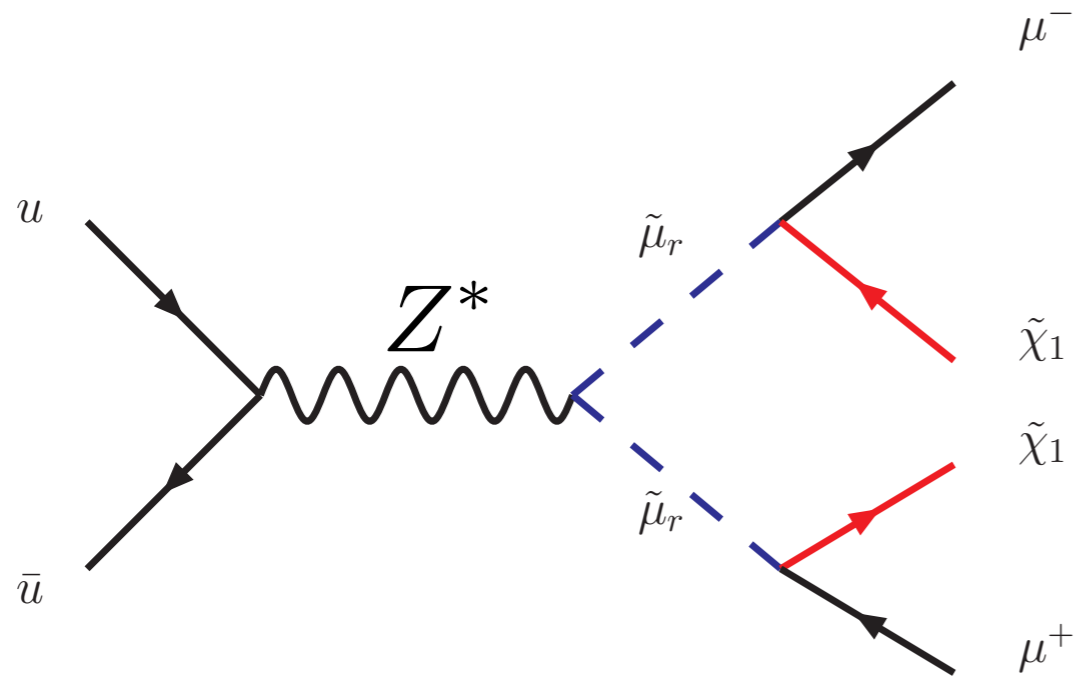
How to measure smuon mass and LSP mass?



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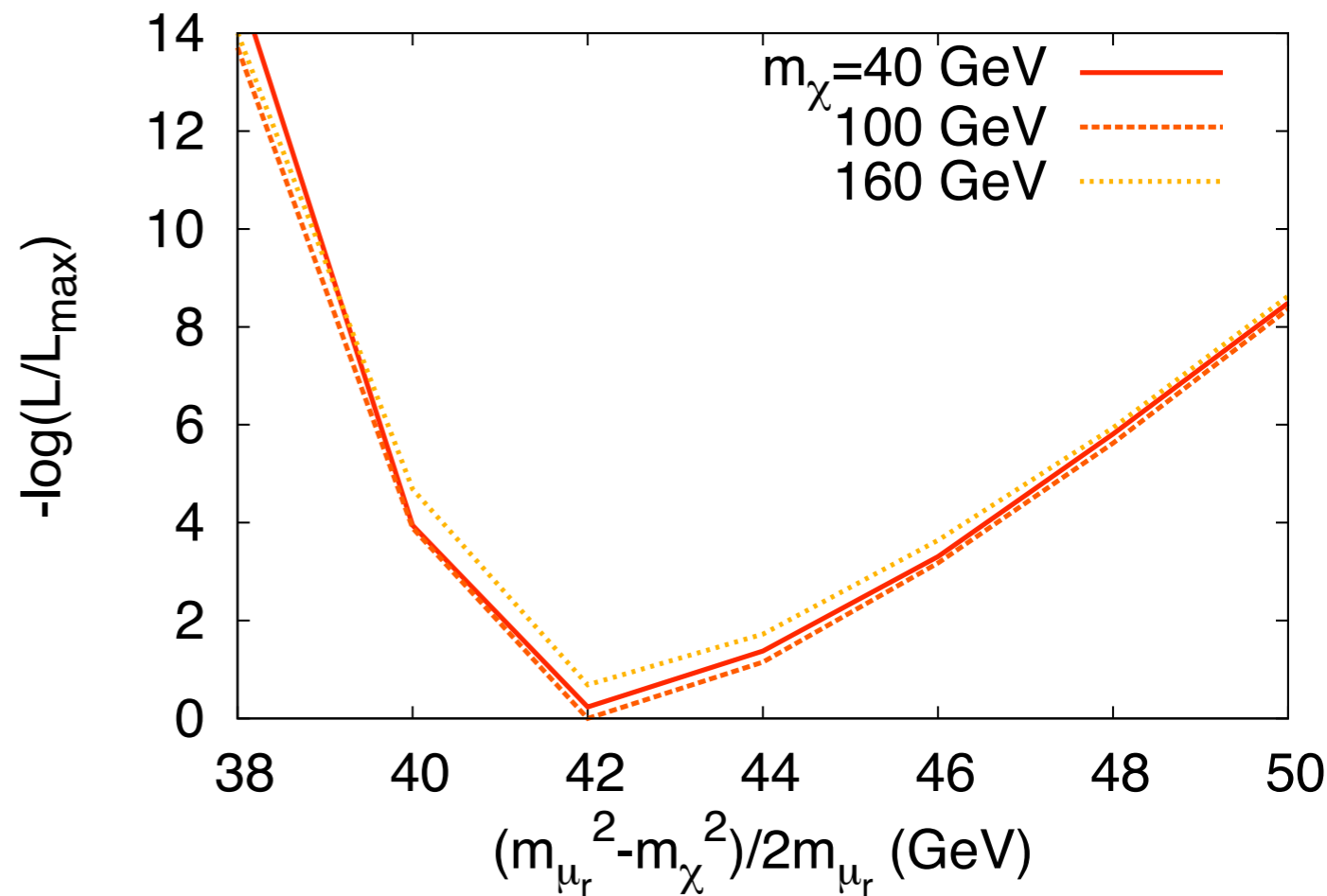


□ 50 (Monte-Carlo) events

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

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

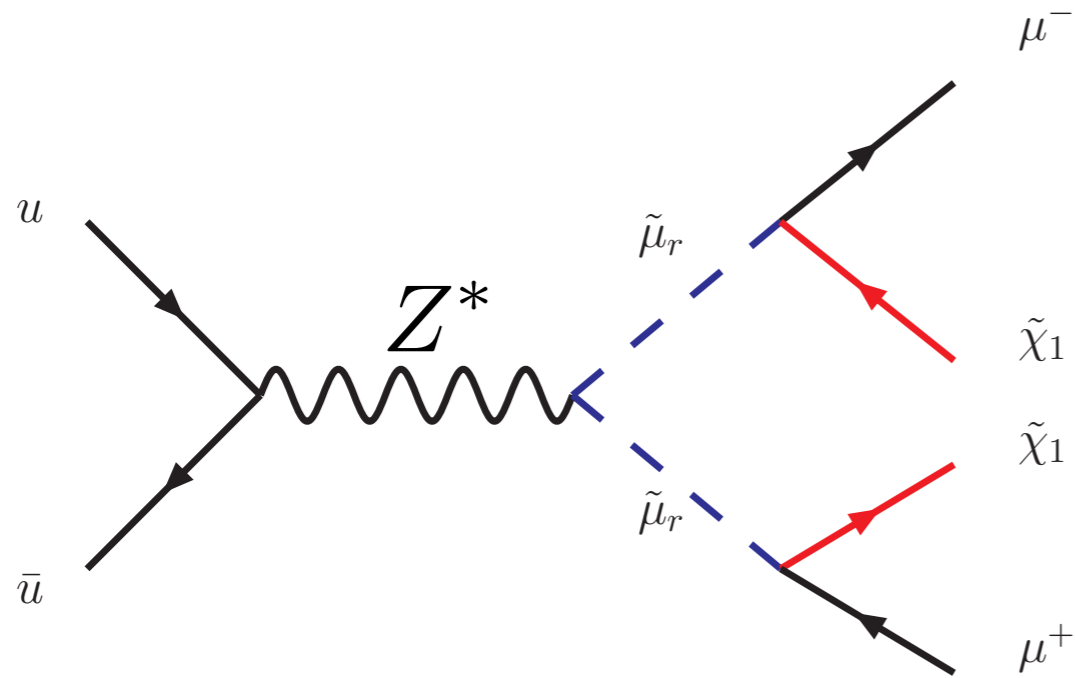
$$(M_{\tilde{\mu}}^2 - M_{\tilde{\chi}}^2) / 2M_{\tilde{\mu}} = 42 \text{ GeV}$$



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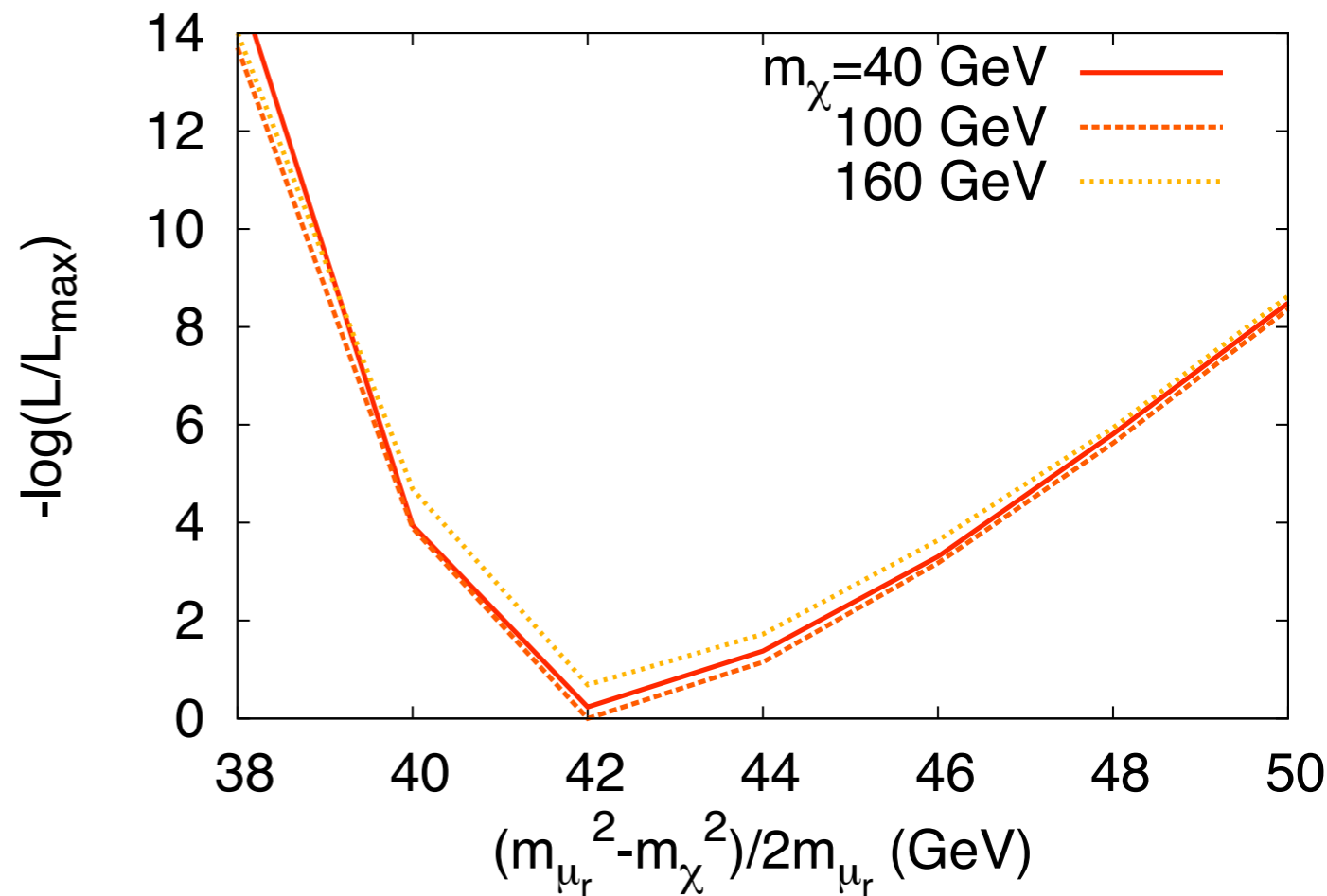


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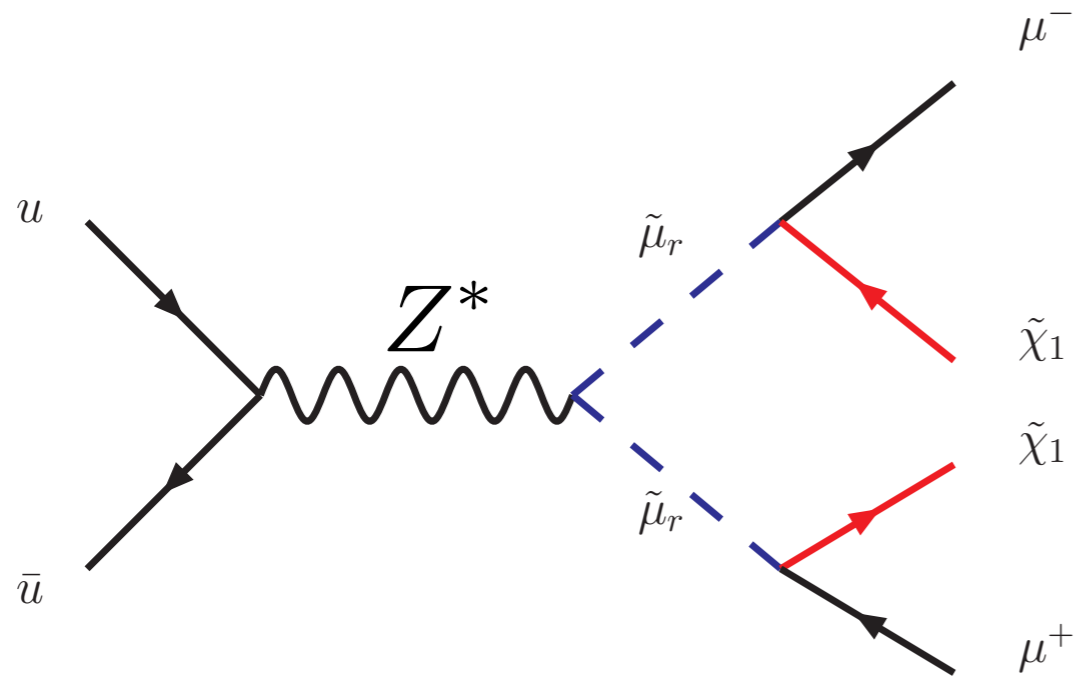


Energy in the rest frame

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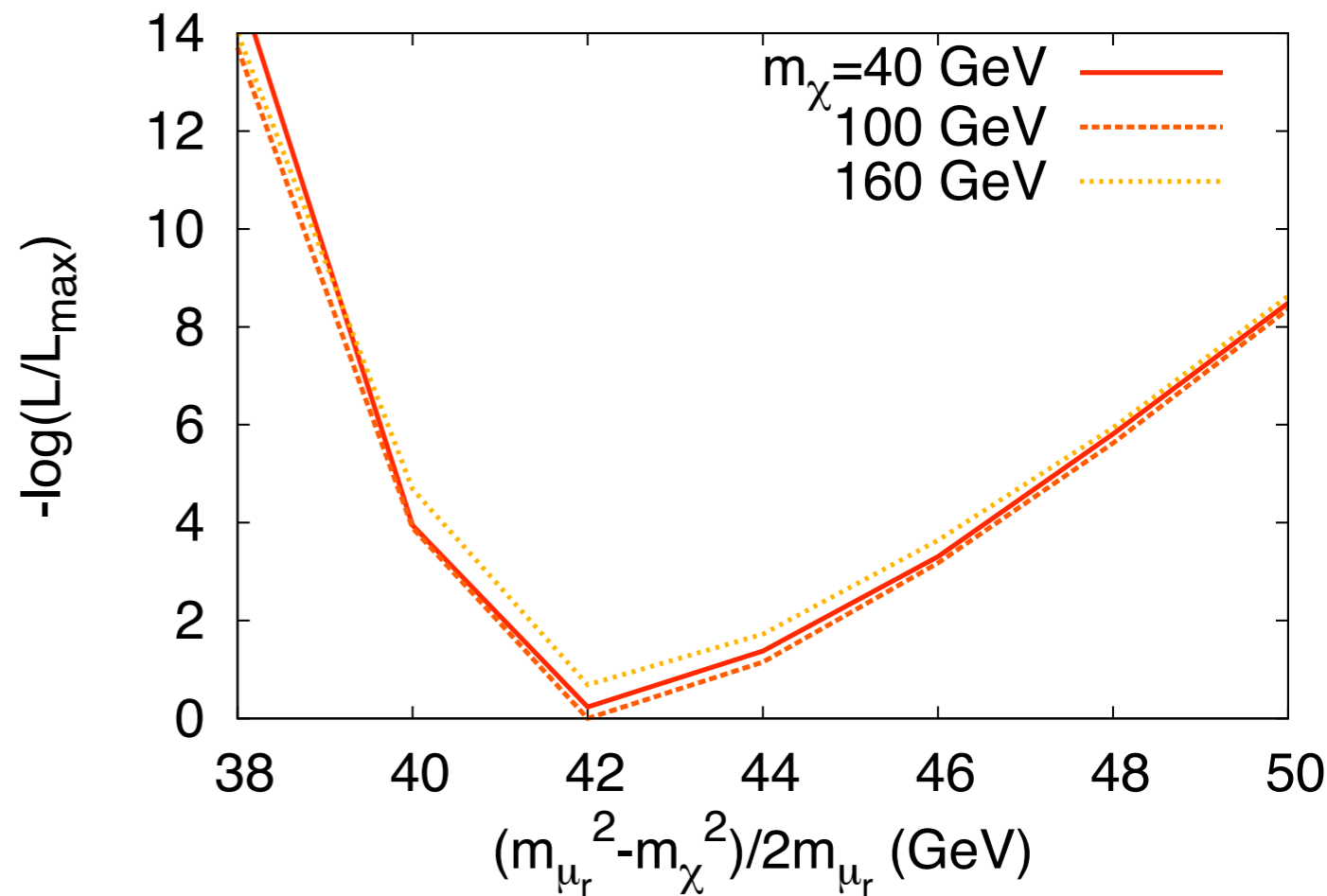


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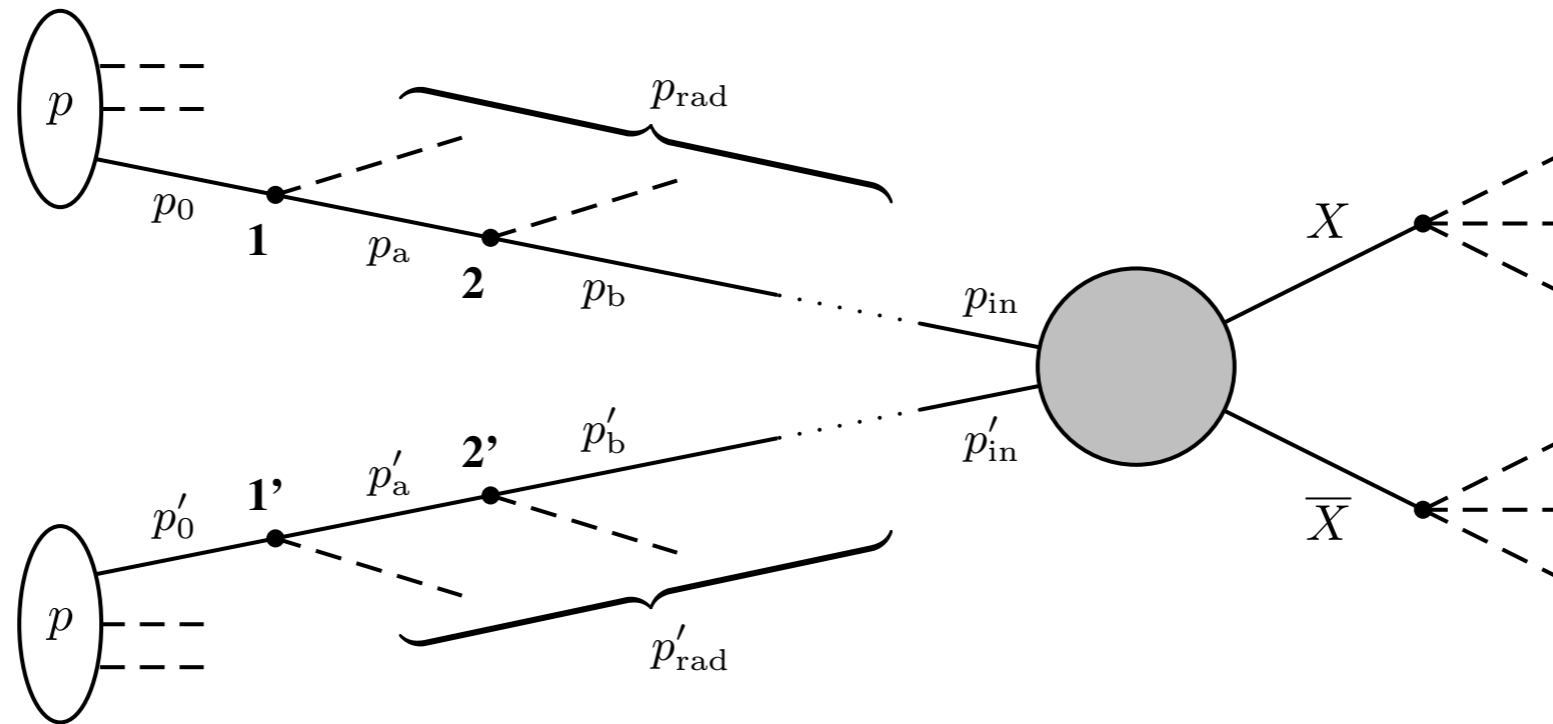


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No Free Launch

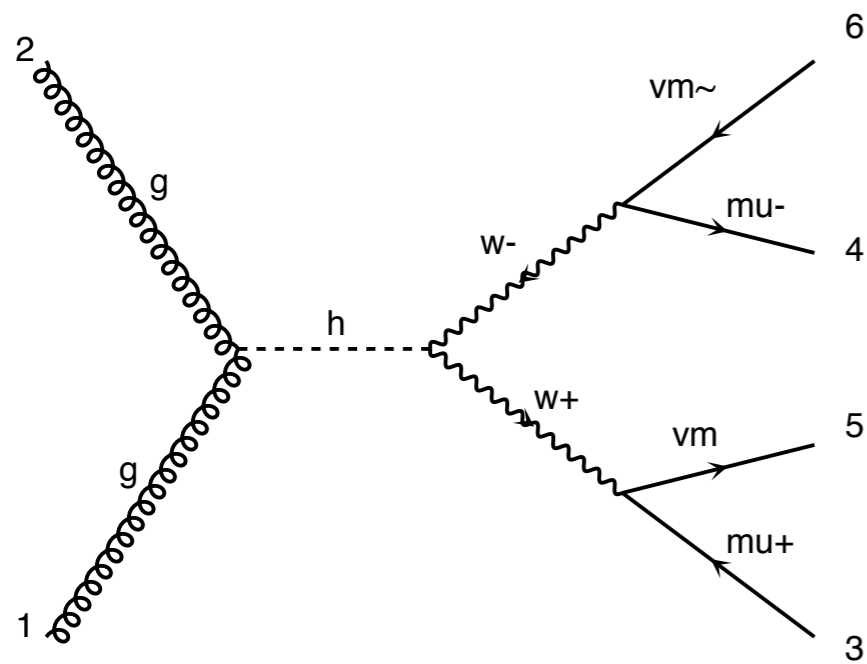
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Initial State Radiation



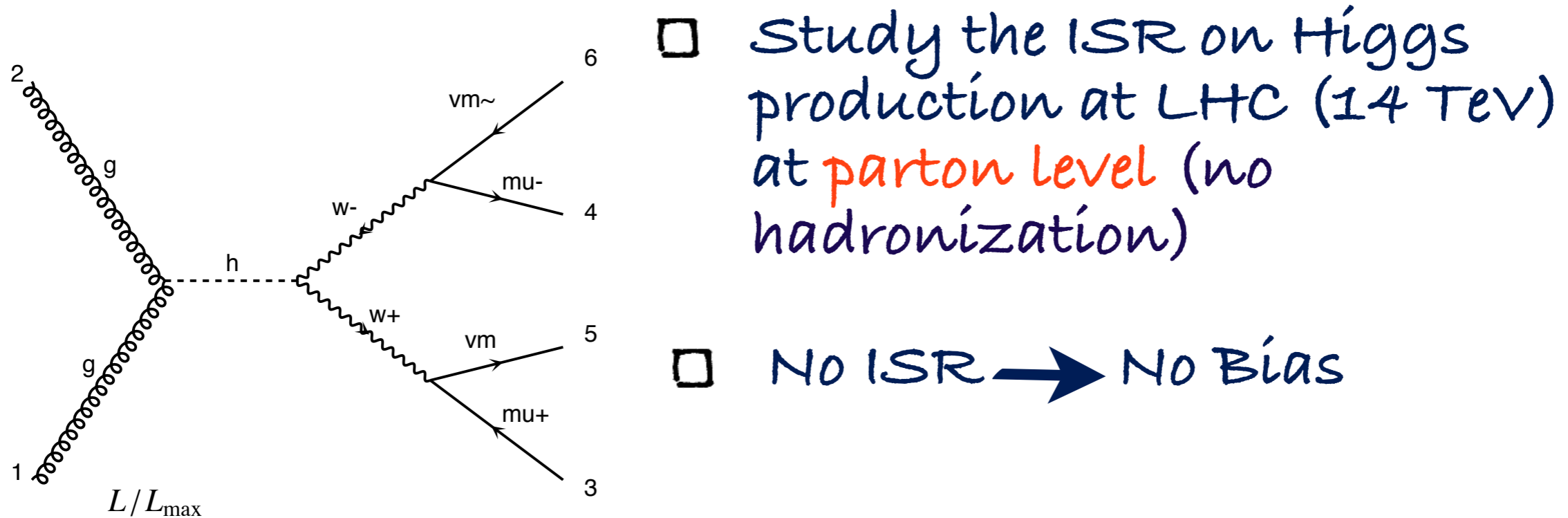
- Main effect: induce a total transverse momentum

Initial State Radiation



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

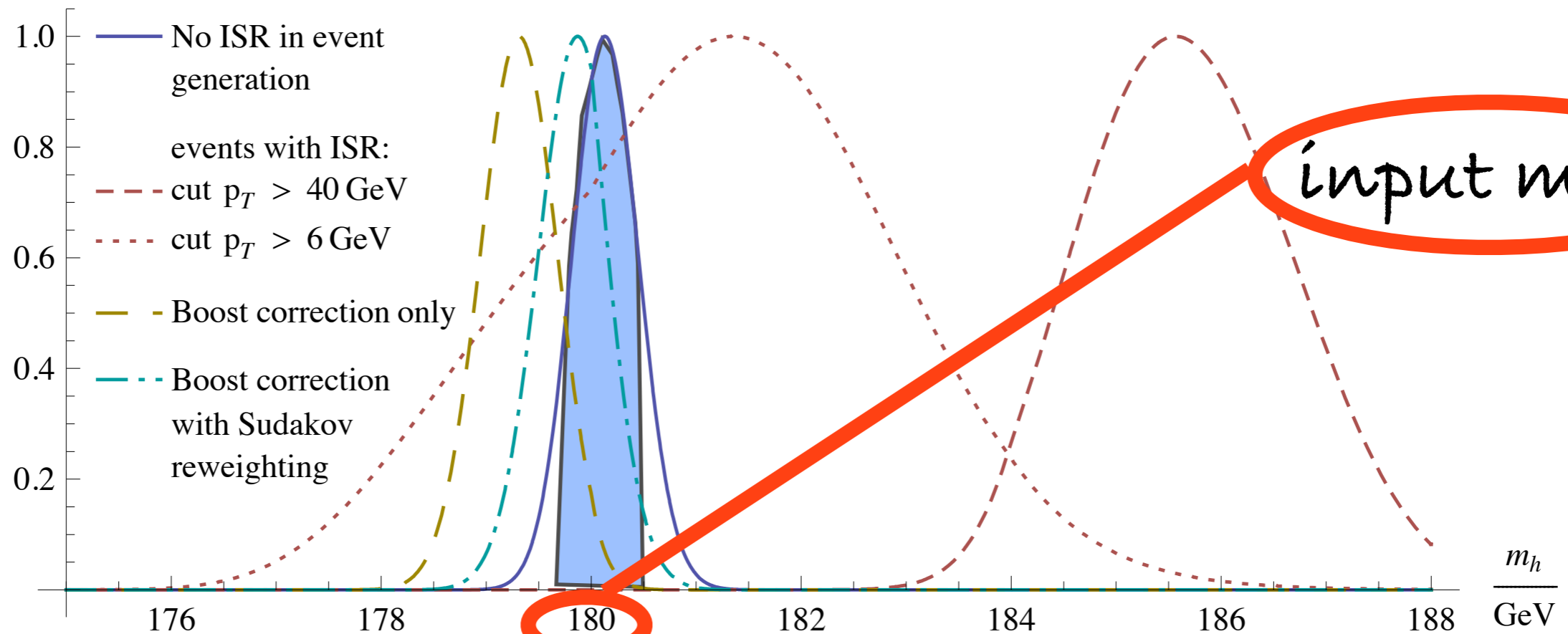
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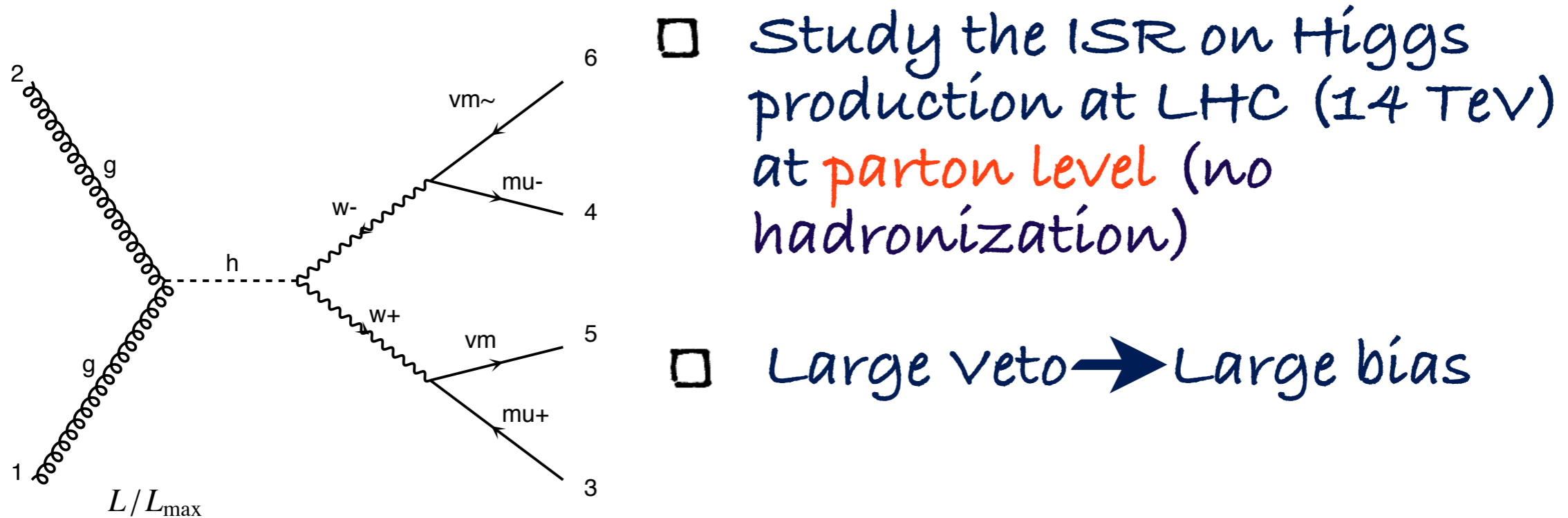
□ NO ISR \rightarrow NO Bias

L/L_{\max}



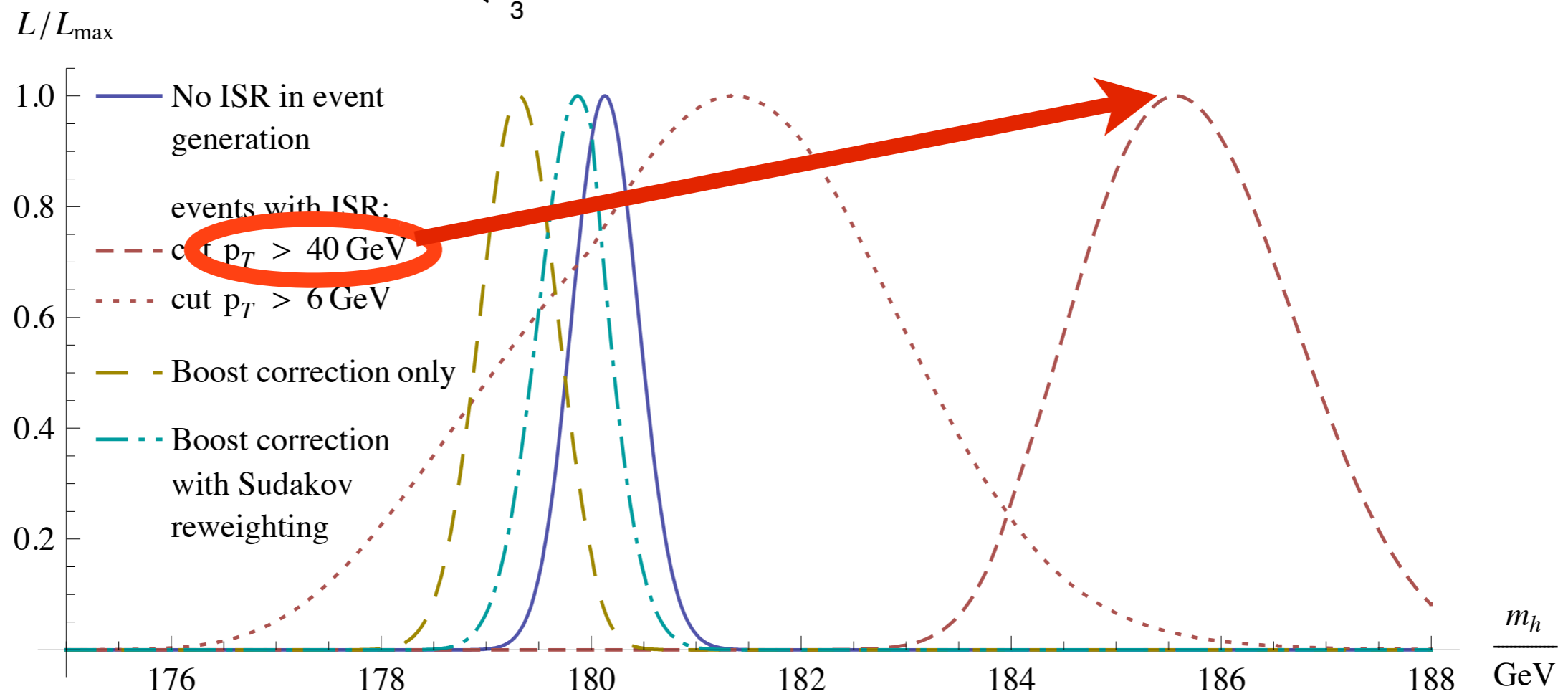
input mass

Initial State Radiation

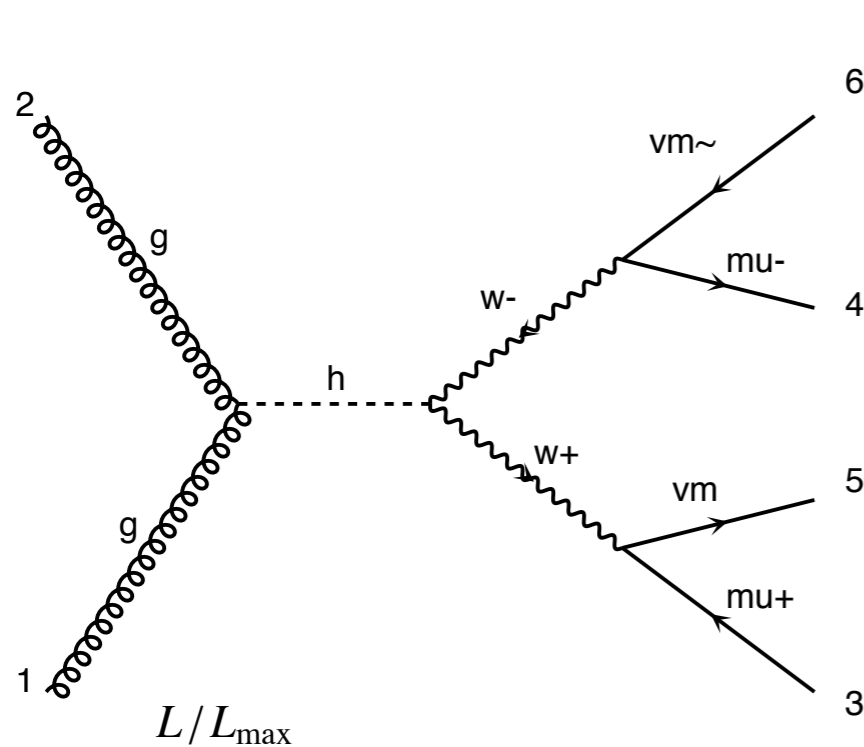


□ Study the ISR on Higgs production at LHC (14 TeV) at **parton level** (no hadronization)

□ Large veto \rightarrow Large bias

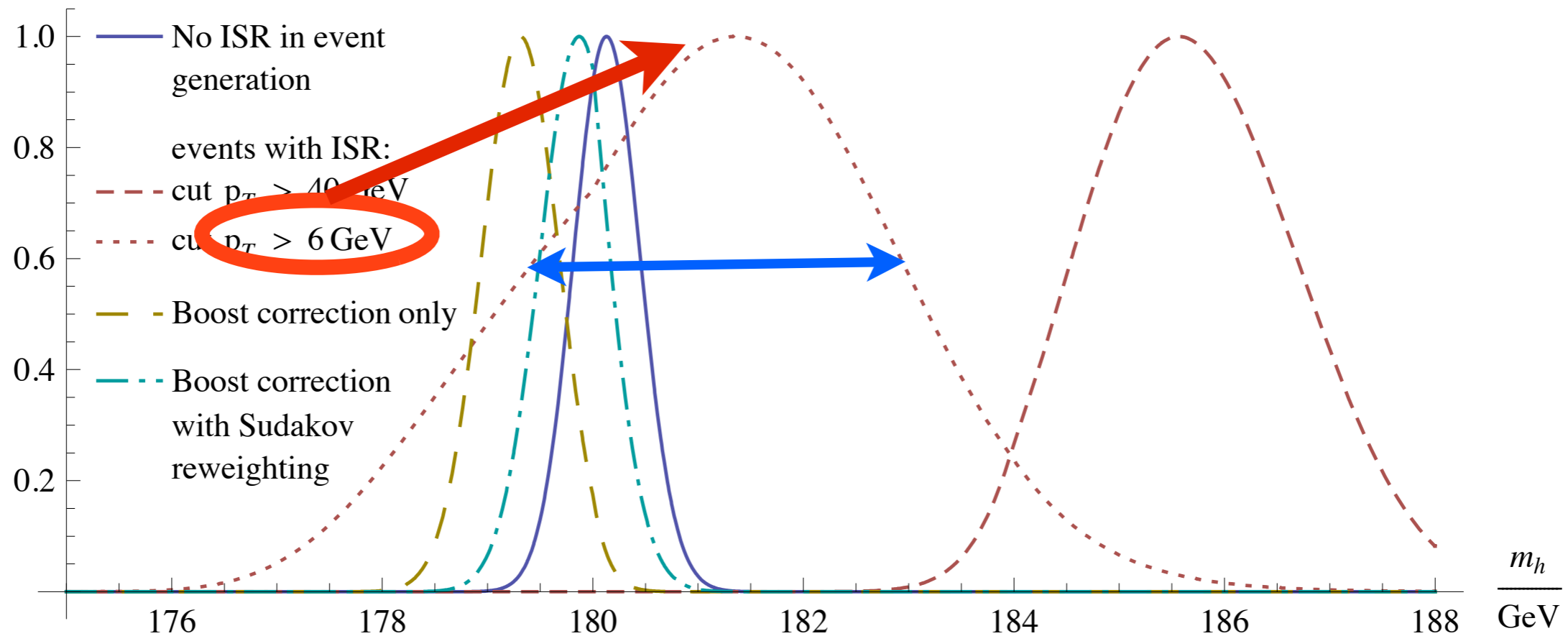


Initial State Radiation

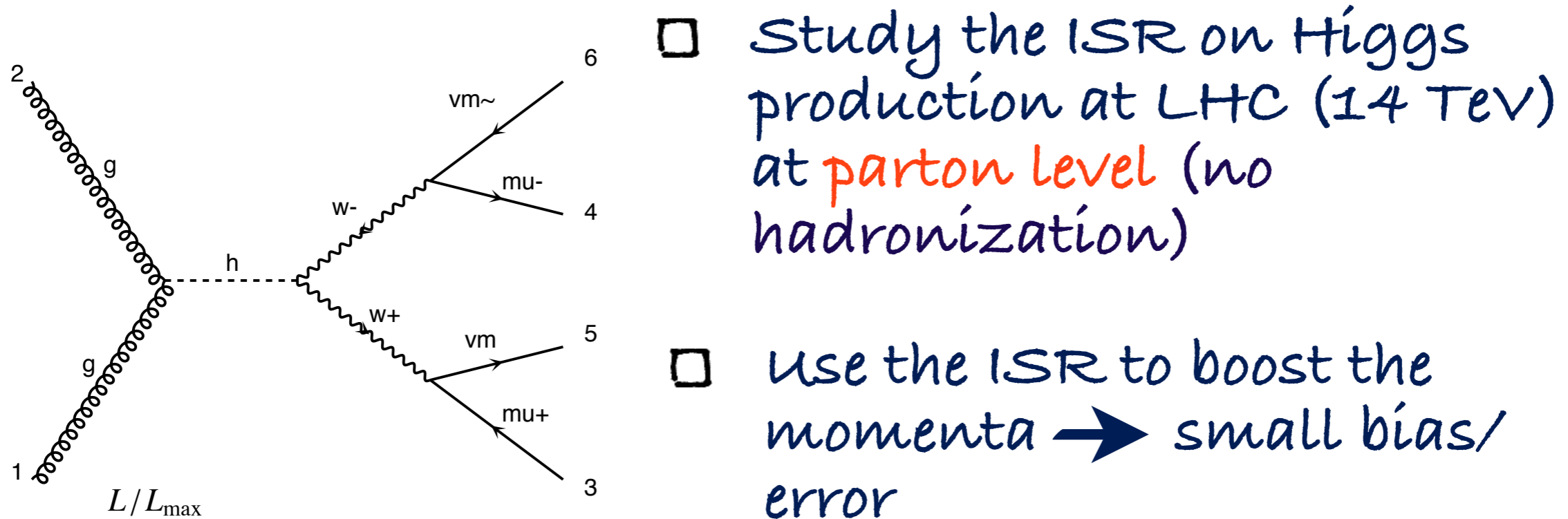


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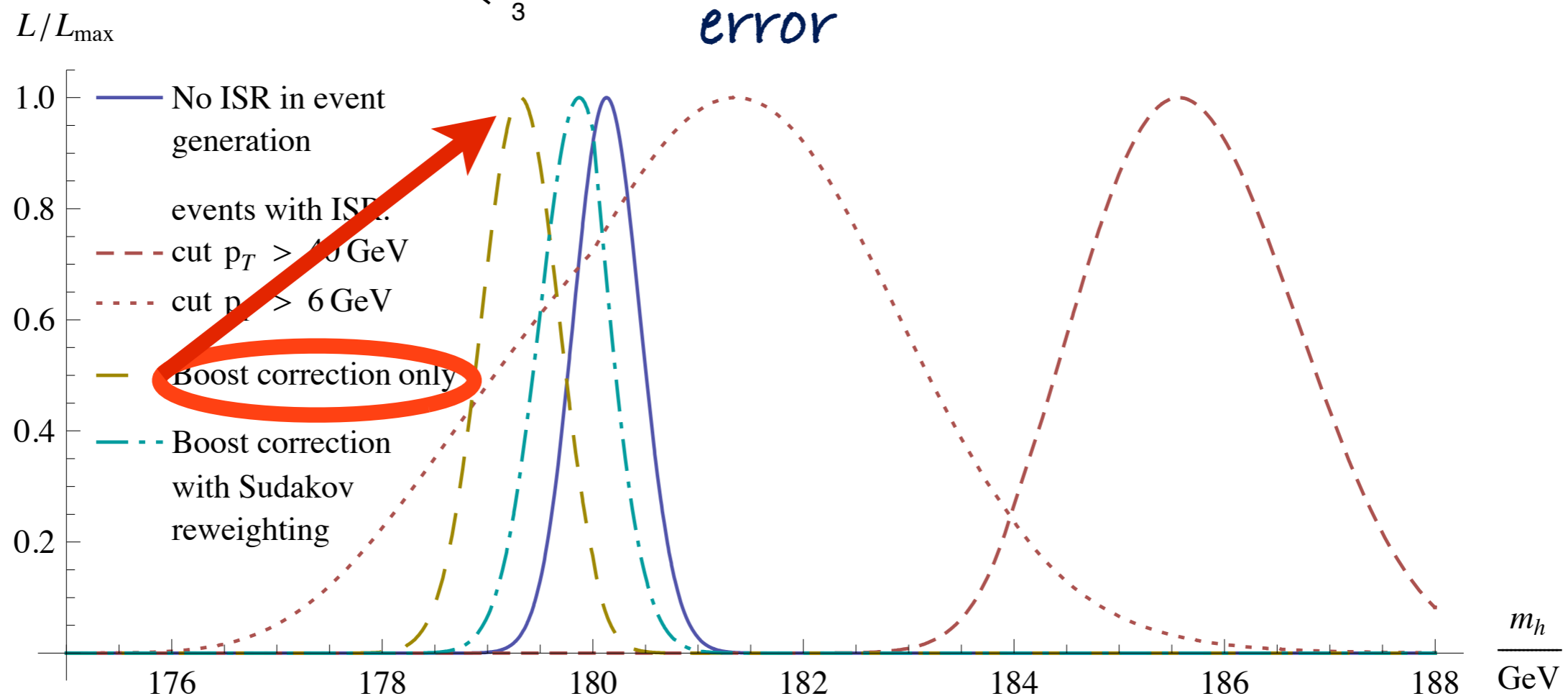
□ smaller veto \rightarrow smaller bias but larger statistical uncertainties



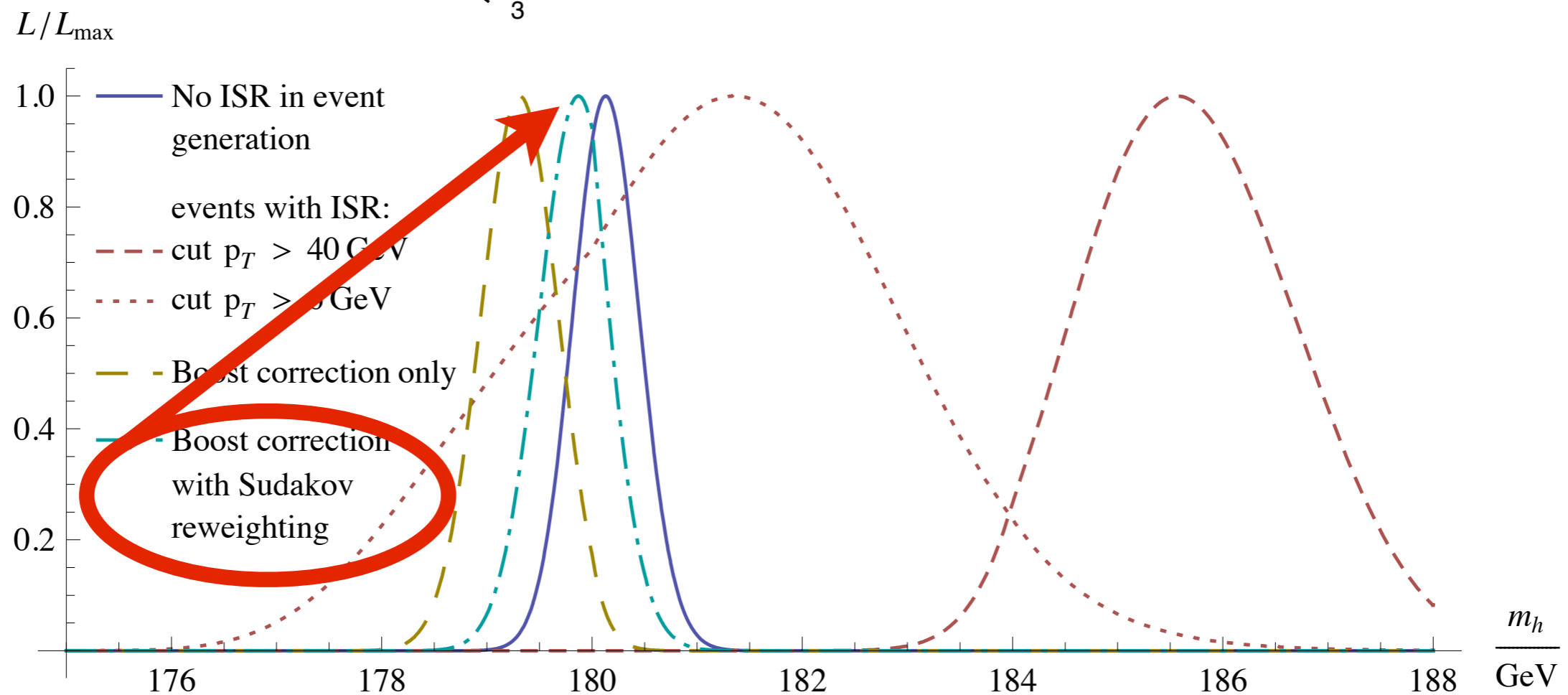
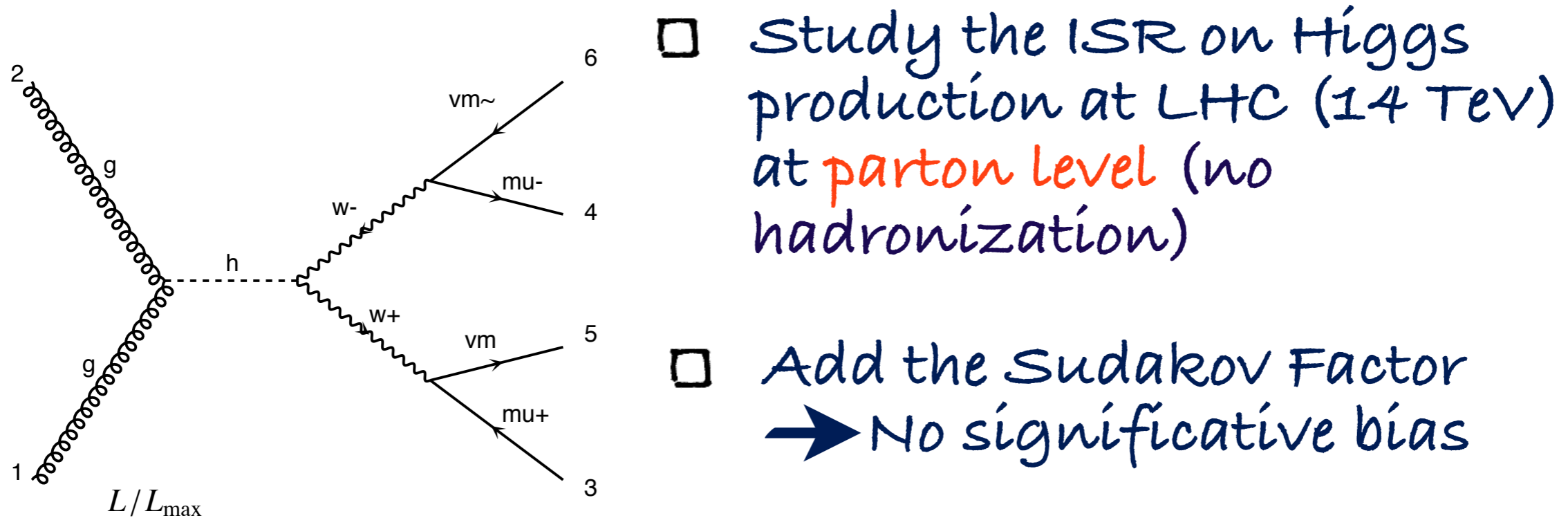
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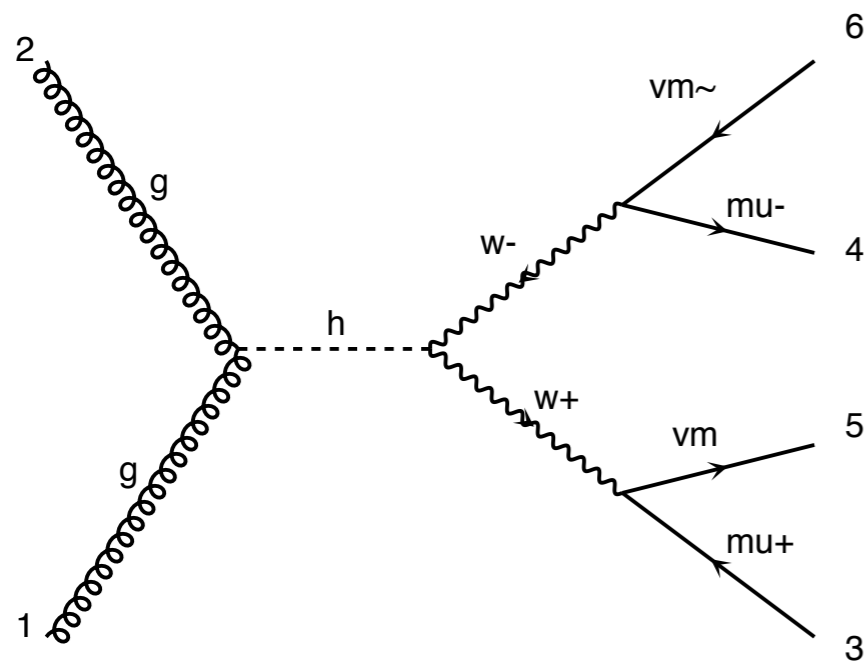
- Study the ISR on Higgs production at LHC (14 TeV) at **parton level** (no hadronization)
- Use the ISR to boost the momenta \rightarrow small bias/error



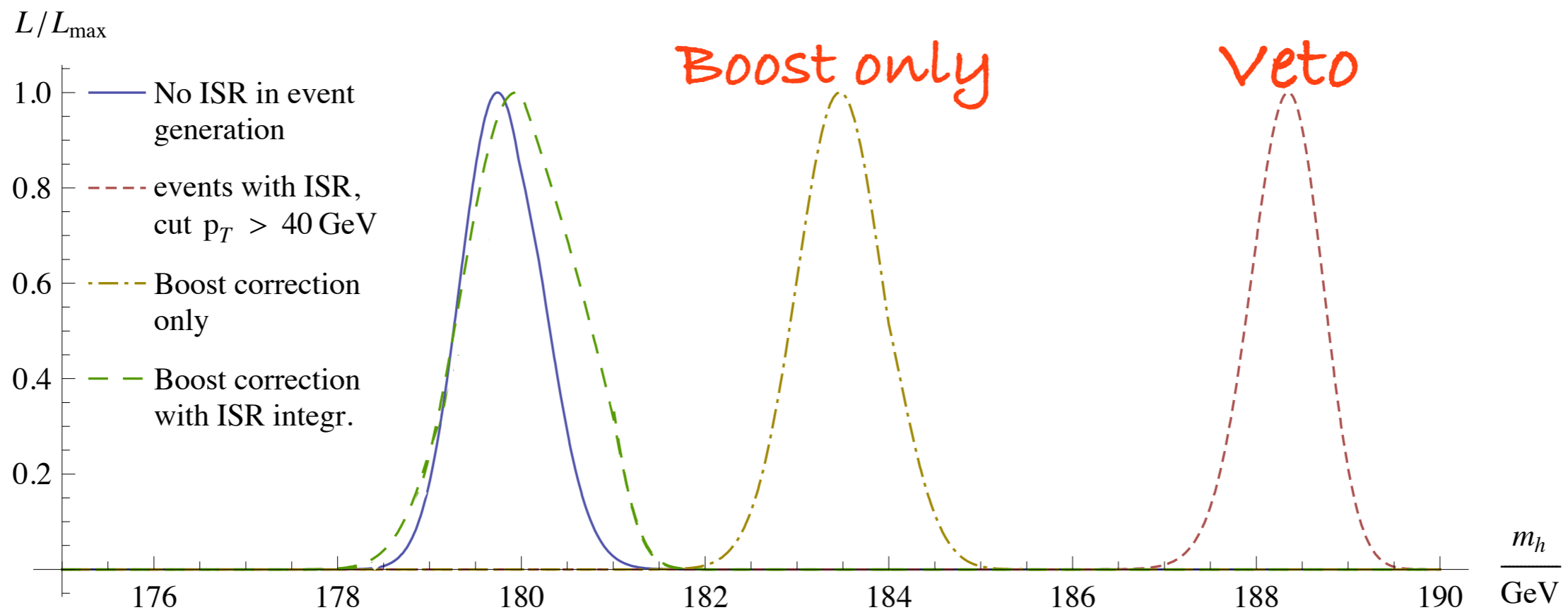
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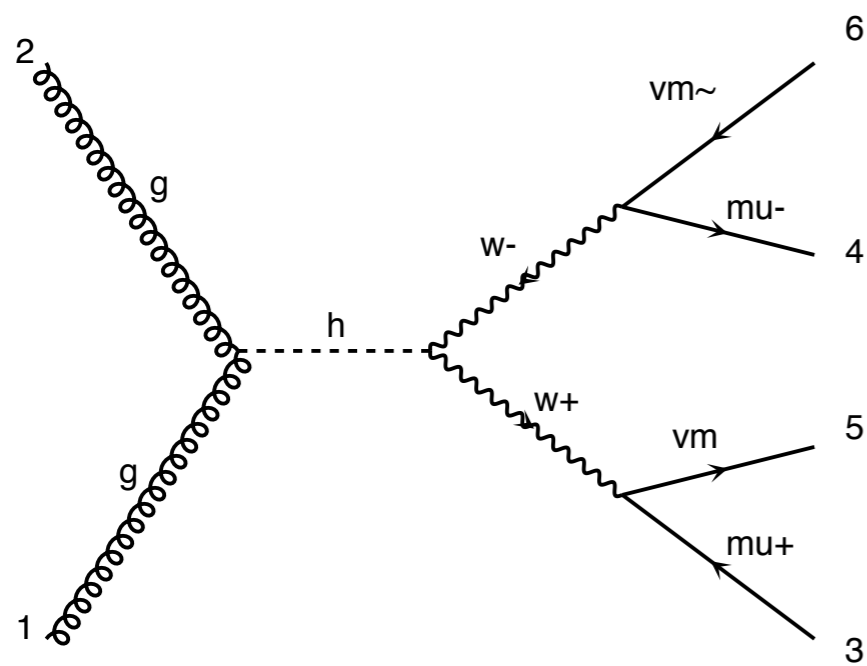
Initial State Radiation



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

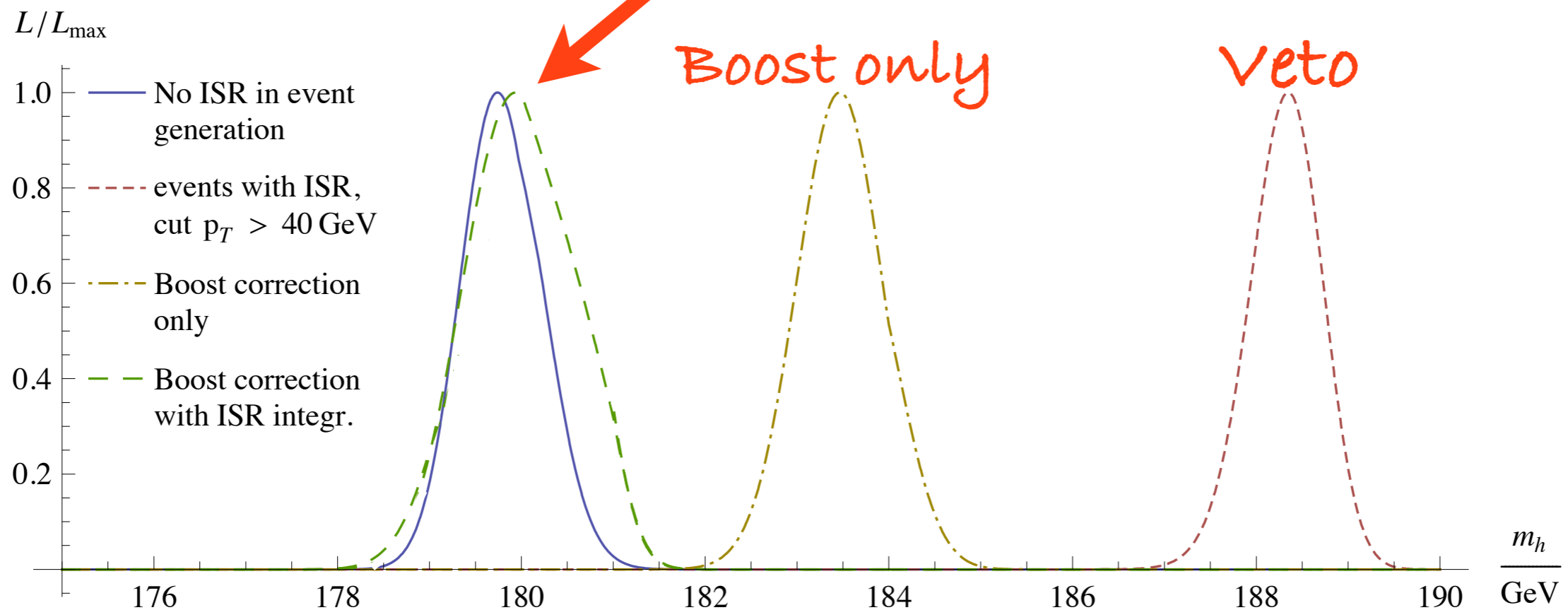


Initial State Radiation



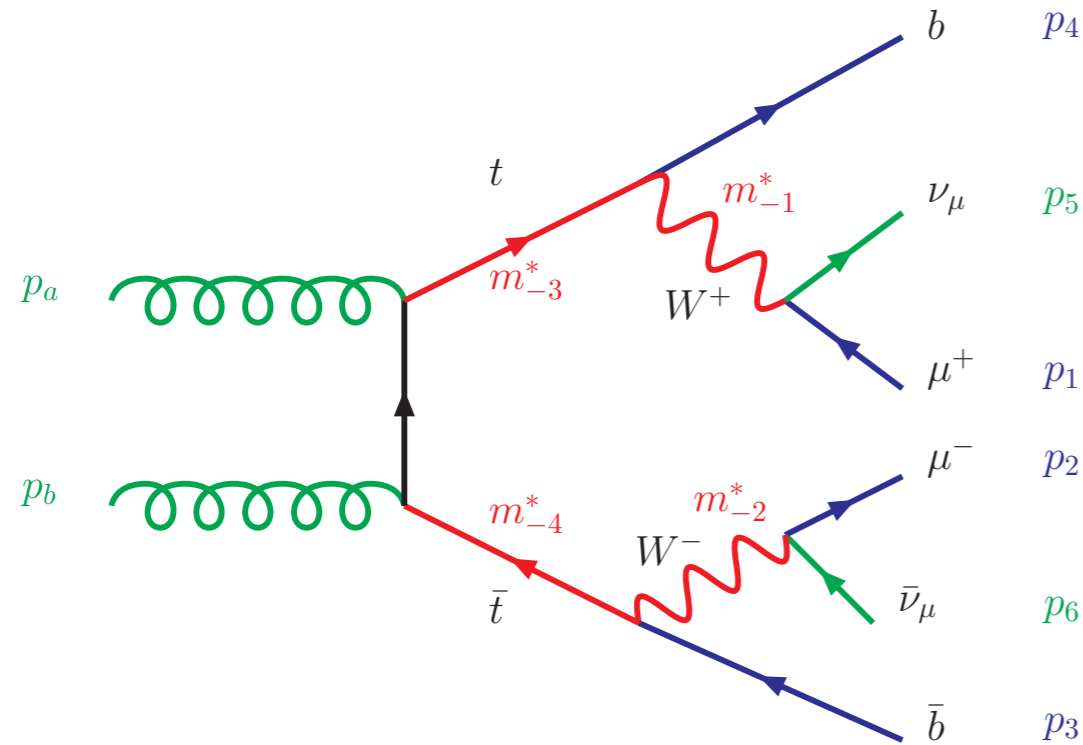
□ Study the ISR on Higgs production at LHC (14 TeV) at **detector level**

□ Introduce ISR transfer functions



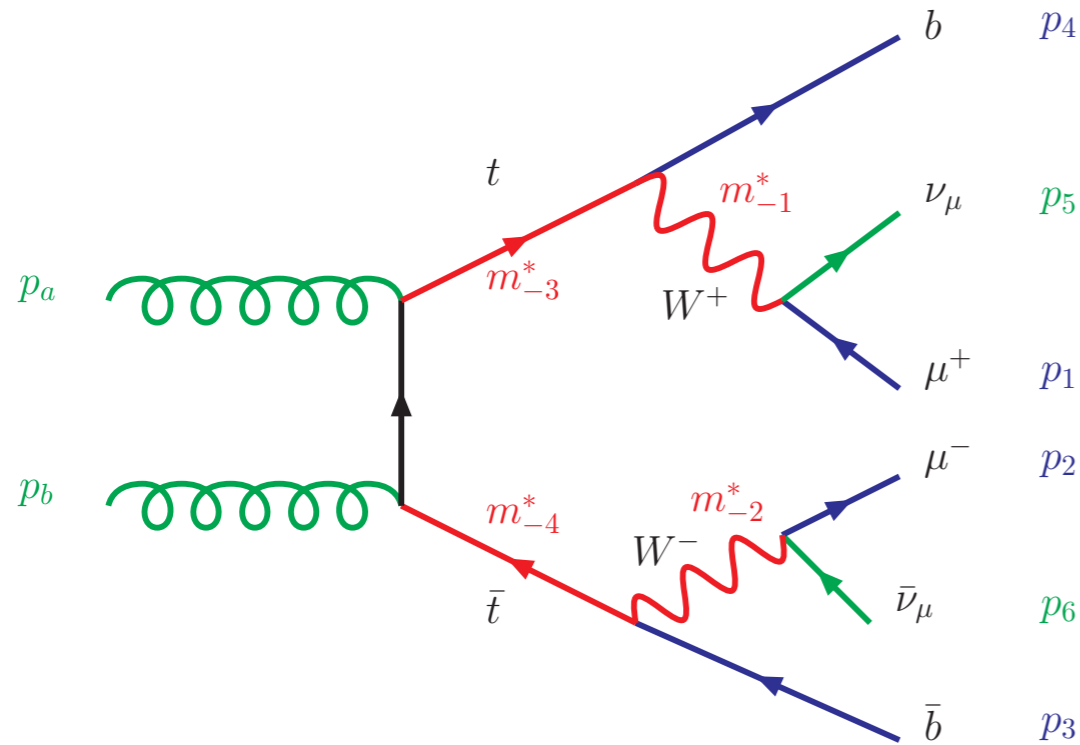
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Differential Cross Section



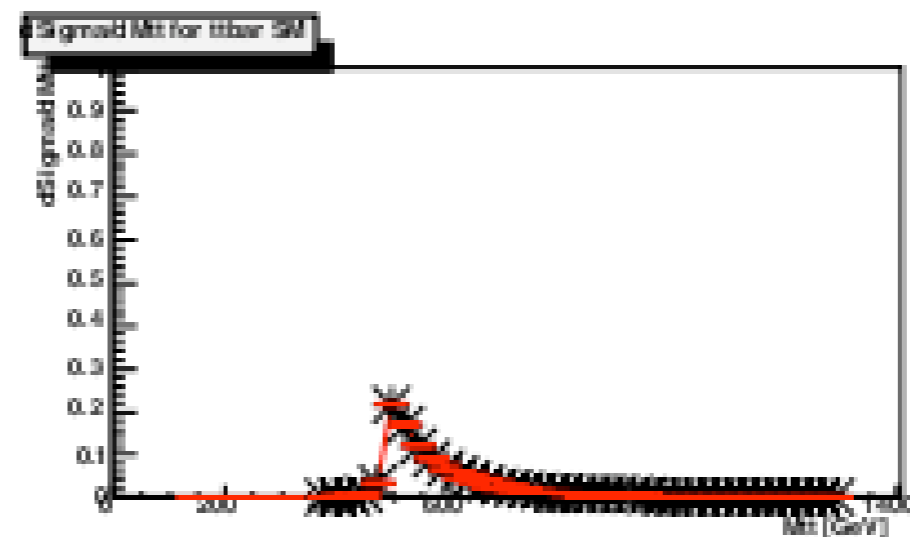
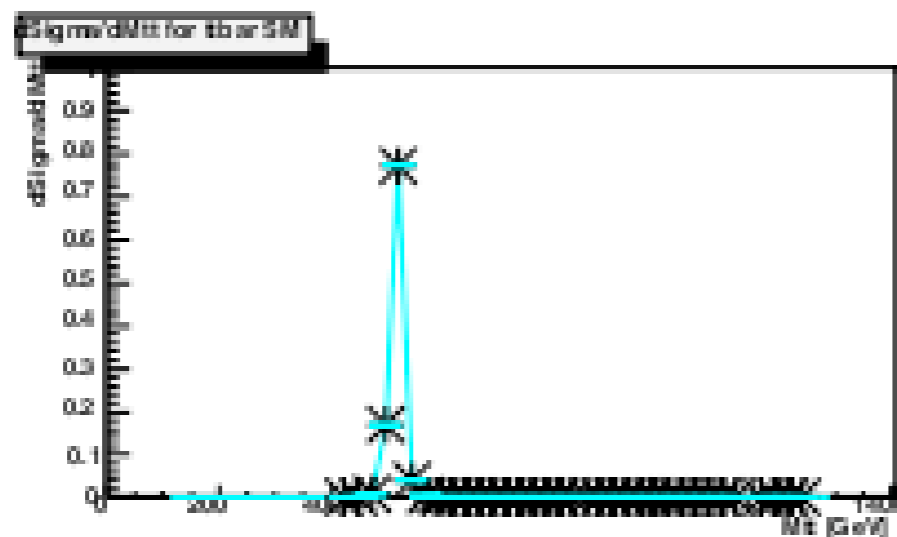
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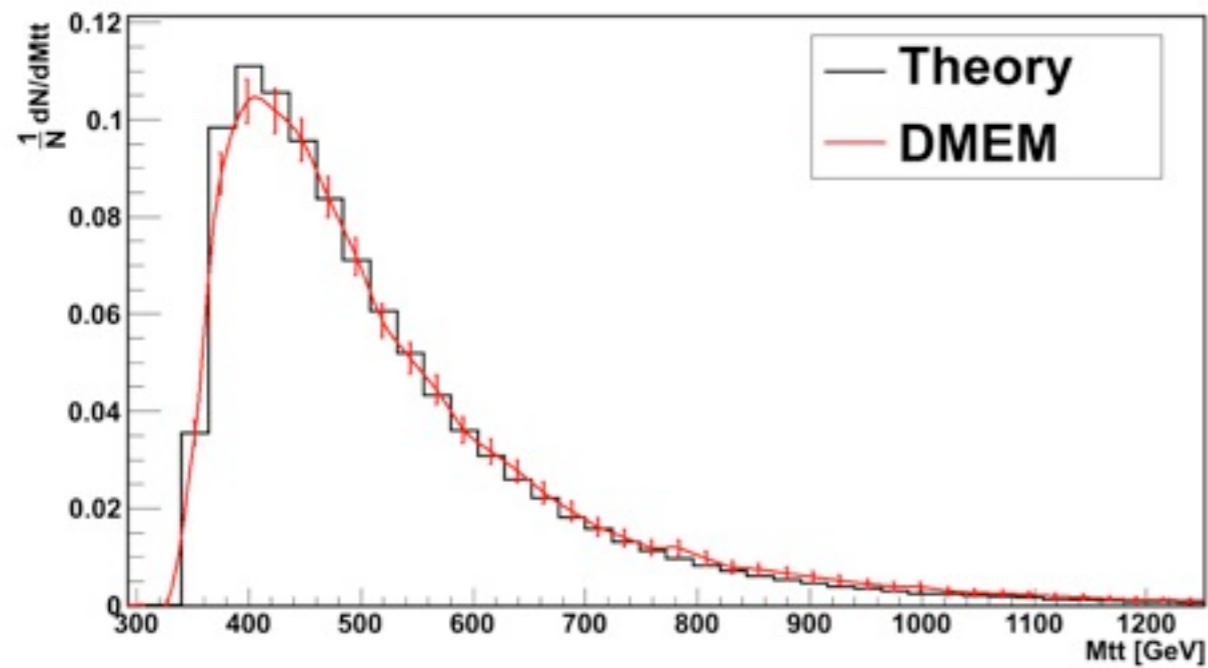
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We use the full inference

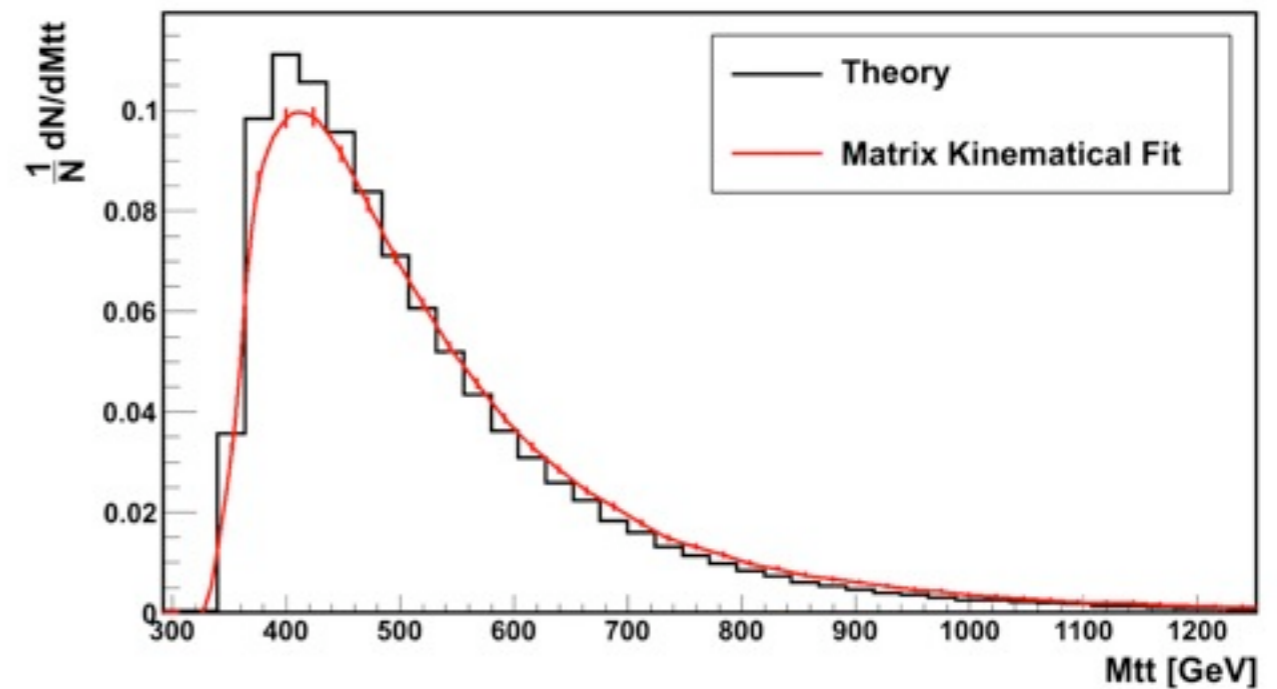


DMEM Validation

partonic level

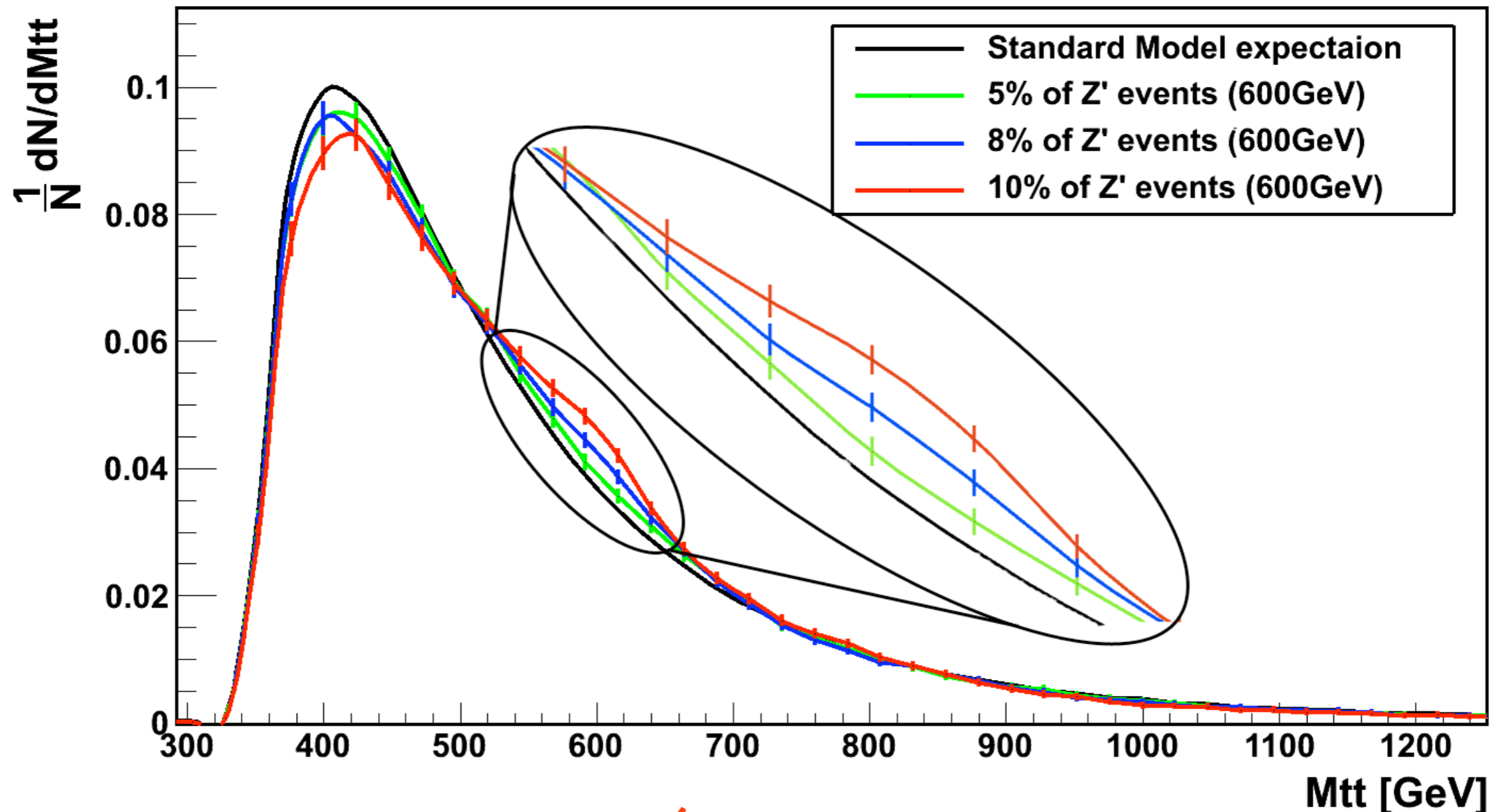


reconstructed level



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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That's only the beginning!
- Promote to NLO

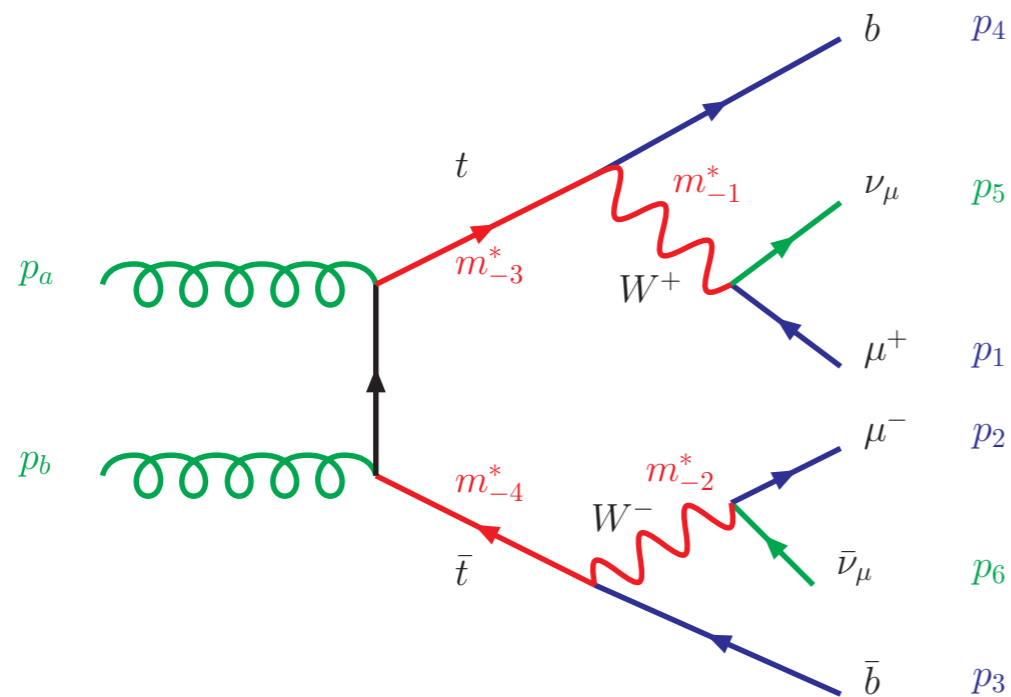
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- *That's only the beginning!*
- Promote to NLO
- New assessments of systematic

Backup slide

MADWEIGHT

□ First Example: di-leptonic top quark pair



□ degrees of freedom **16**

□ **2: pdf**

□ **3 x 6: final states**

□ **-4: energy-momentum conservation**

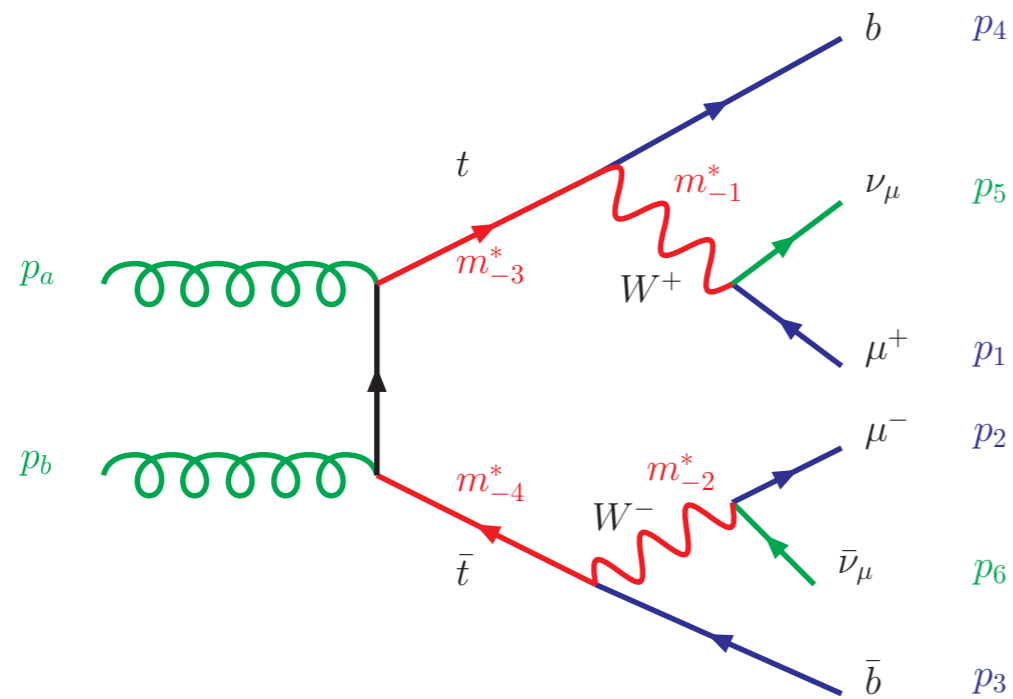
□ peaks **16**

□ **4: Breit-Wigner**

□ **3 x 4: visible particles**

MADWEIGHT

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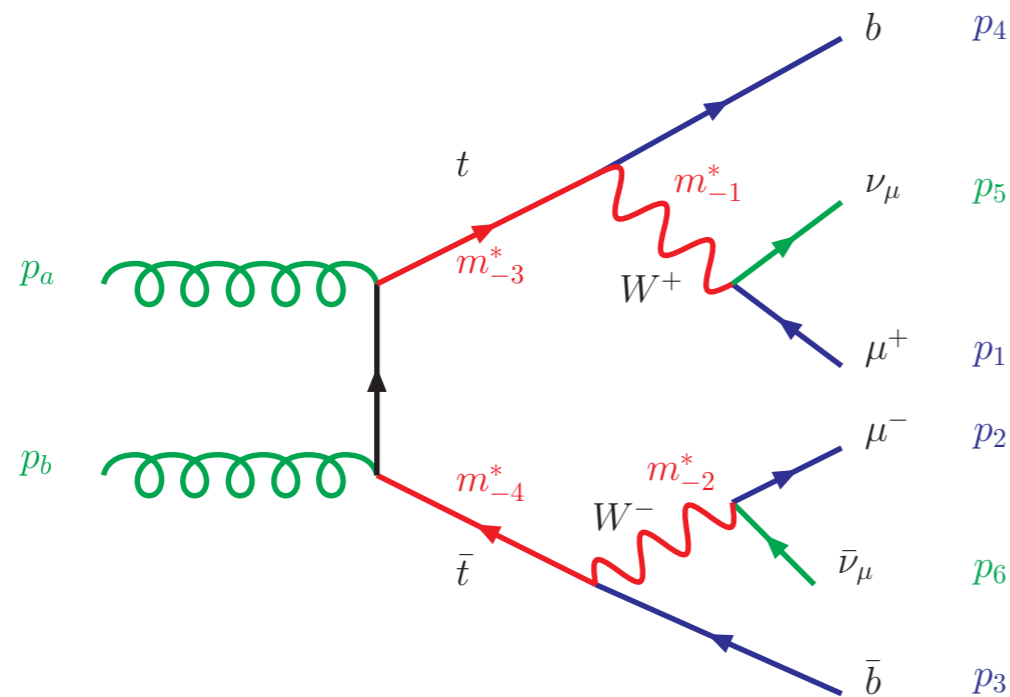
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→ All peaks aligned

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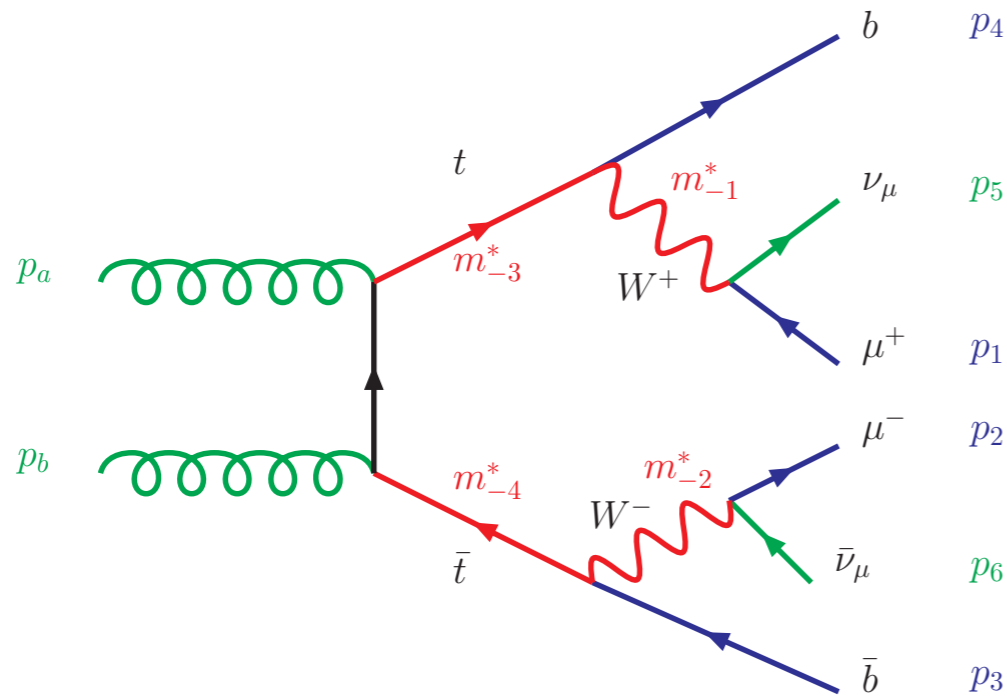
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$$d\phi = \prod_{i=1}^4 \frac{d^3 p_i}{(2\pi)^3 2E_i} \prod_{i=5}^6 \frac{d^3 p_i}{(2\pi)^3 2E_i} dx_1 dx_2 \delta^4 \left(p_a + p_b - \sum_j p_j \right)$$

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□ peaks 16

→ All peaks aligned

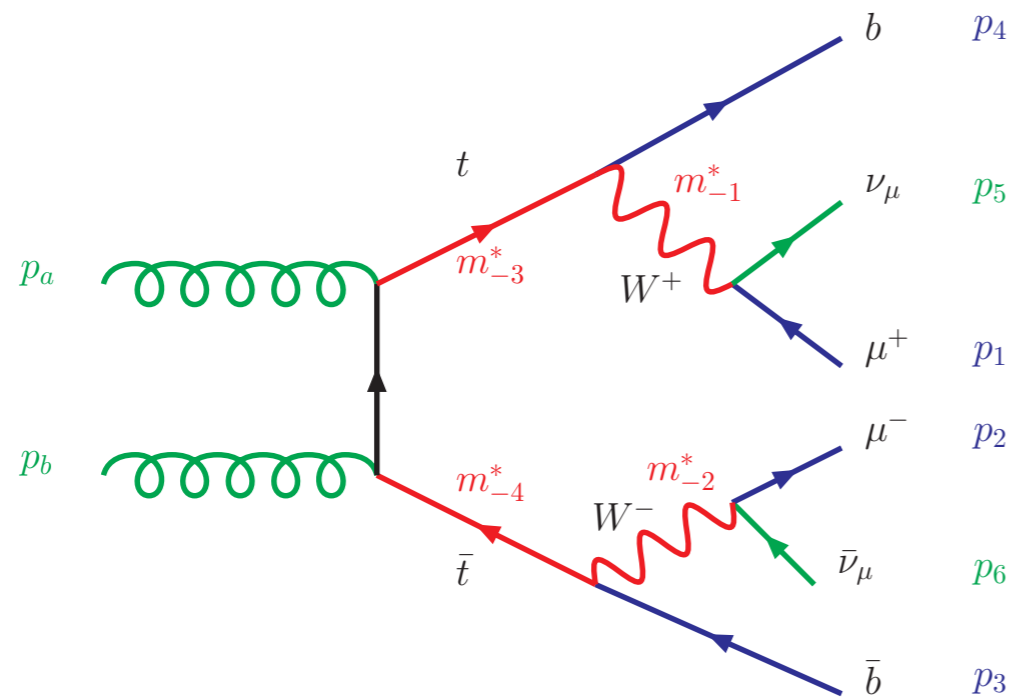
$$d\phi = \prod_{i=1}^4 \frac{d^3 p_i}{(2\pi)^3 2E_i} \prod_{i=5}^6 \frac{d^3 p_i}{(2\pi)^3 2E_i} dx_1 dx_2 \delta^4 \left(p_a + p_b - \sum_j p_j \right)$$

Pass to →

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

MADWEIGHT

□ First Example: di-leptonic top quark pair



□ degrees of freedom 16

□ peaks 16

→ All peaks aligned

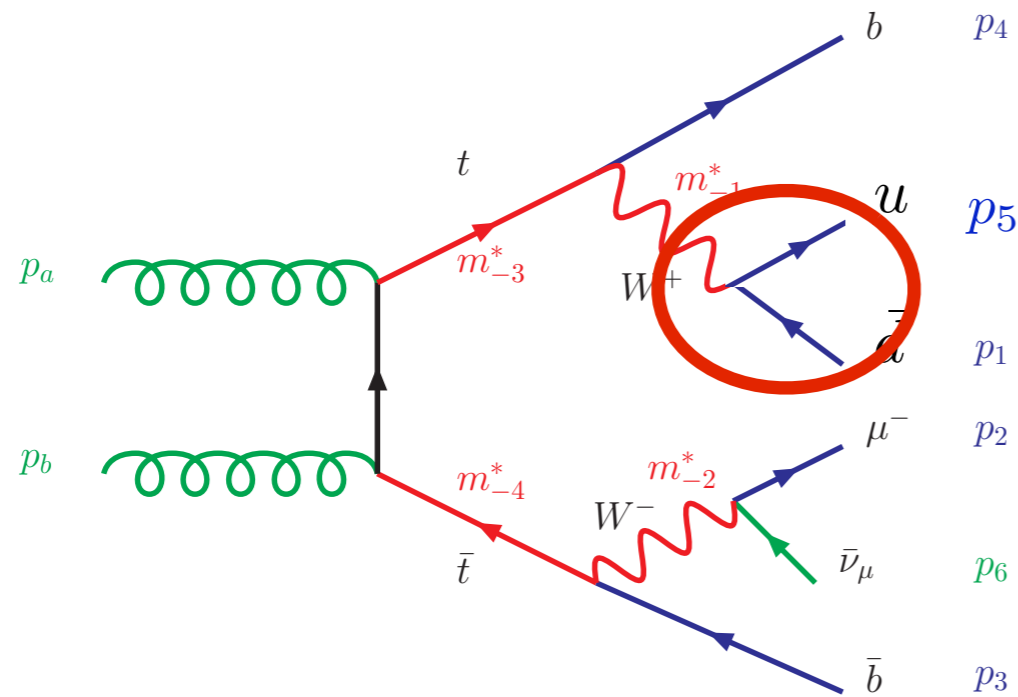
$$d\phi = \prod_{i=1}^4 \frac{d^3 p_i}{(2\pi)^3 2E_i} \prod_{i=5}^6 \frac{d^3 p_i}{(2\pi)^3 2E_i} dx_1 dx_2 \delta^4 \left(p_a + p_b - \sum_j p_j \right)$$

Pass to Final Block D →

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

MADWEIGHT

□ Second Example: semi-leptonic top quark pair

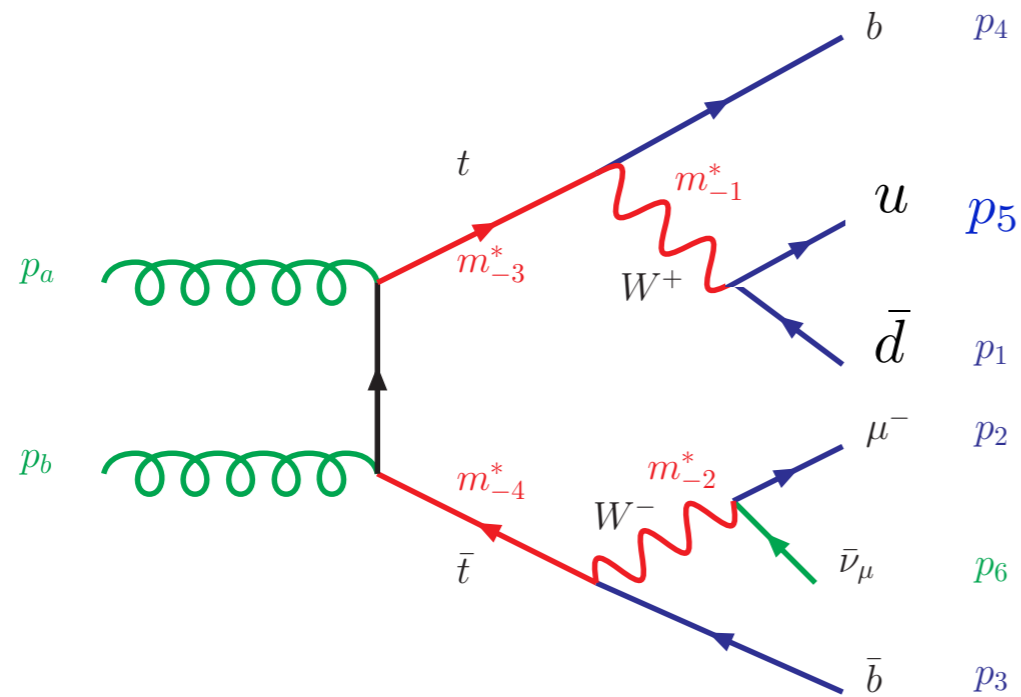


□ degrees of freedom 16

□ peaks 19

MADWEIGHT

□ Second Example: semi-leptonic top quark pair



□ degrees of freedom 16

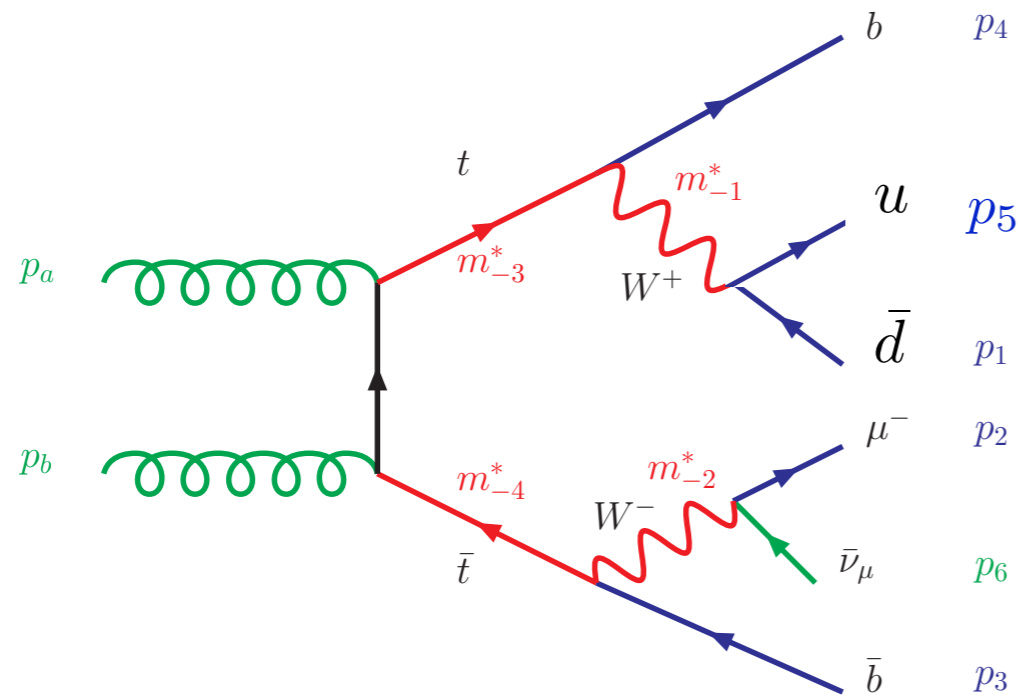
□ peaks 19

→ 3 peaks unaligned

→ Multi-channel

MADWEIGHT

□ Second Example: semi-leptonic top quark pair



□ degrees of freedom **16**

□ peaks **19**

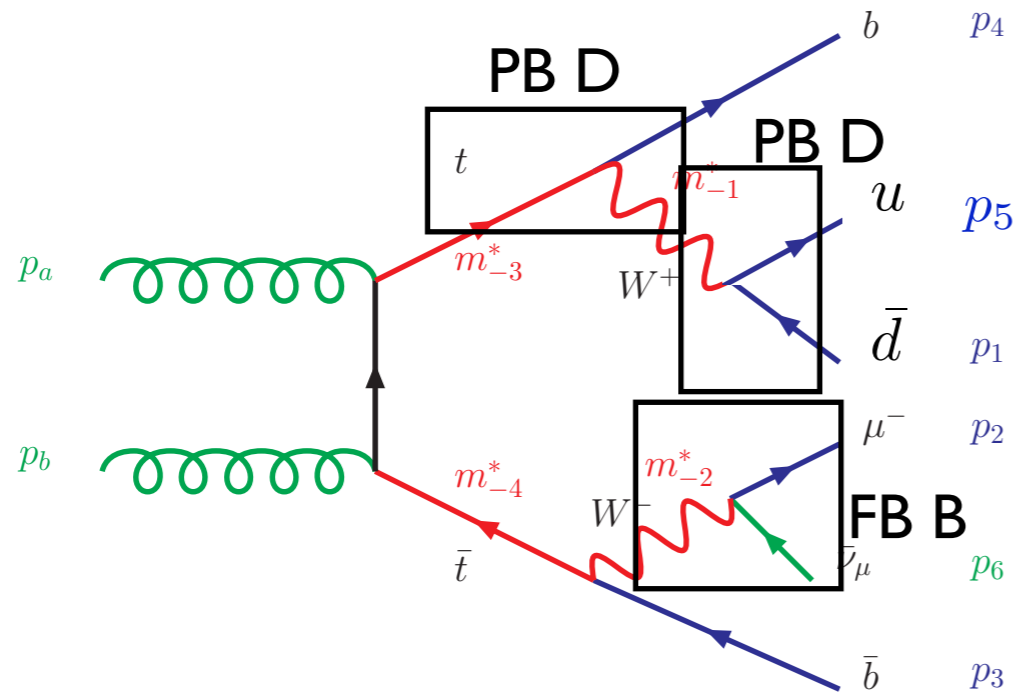
→ **3 peaks unaligned**

→ **Multi-channel**

$$d\phi = \prod_{i=1}^5 \frac{d^3 p_i}{(2\pi)^3 2E_i} \frac{d^3 p_6}{(2\pi)^3 2E_6} dx_1 dx_2 \delta^4(p_a + p_b - \sum_j p_j)$$

MADWEIGHT

□ Second Example: semi-leptonic top quark pair



□ degrees of freedom **16**

□ peaks **19**

→ **3 peaks unaligned**

→ **Multi-channel**

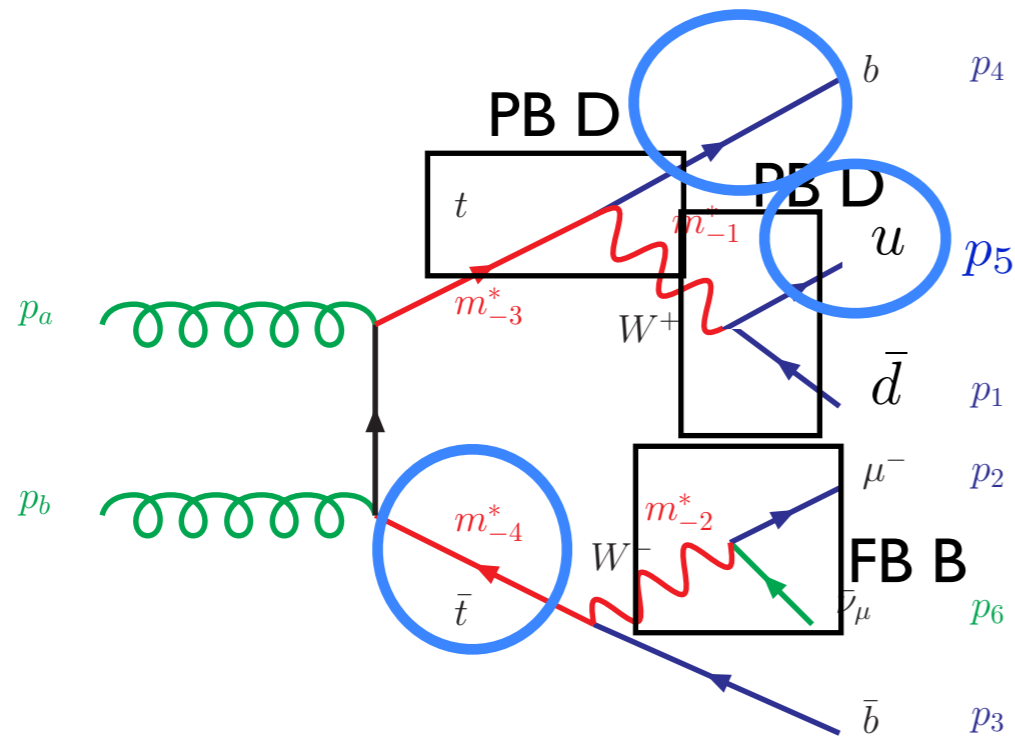
$$d\phi = \prod_{i=1}^5 \frac{d^3 p_i}{(2\pi)^3 2E_i} \frac{d^3 p_6}{(2\pi)^3 2E_6} dx_1 dx_2 \delta^4(p_a + p_b - \sum_j p_j)$$

Pass to →

$$d\phi = \prod_{i=1}^5 d\theta_i d\phi_i \prod_{j=1}^3 d|p_j| \prod_{k=1}^3 dm_{-k}^{*2} \times J$$

MADWEIGHT

□ Second Example: semi-leptonic top quark pair



□ degrees of freedom **16**

□ peaks **19**

→ **3 peaks unaligned**

→ **Multi-channel**

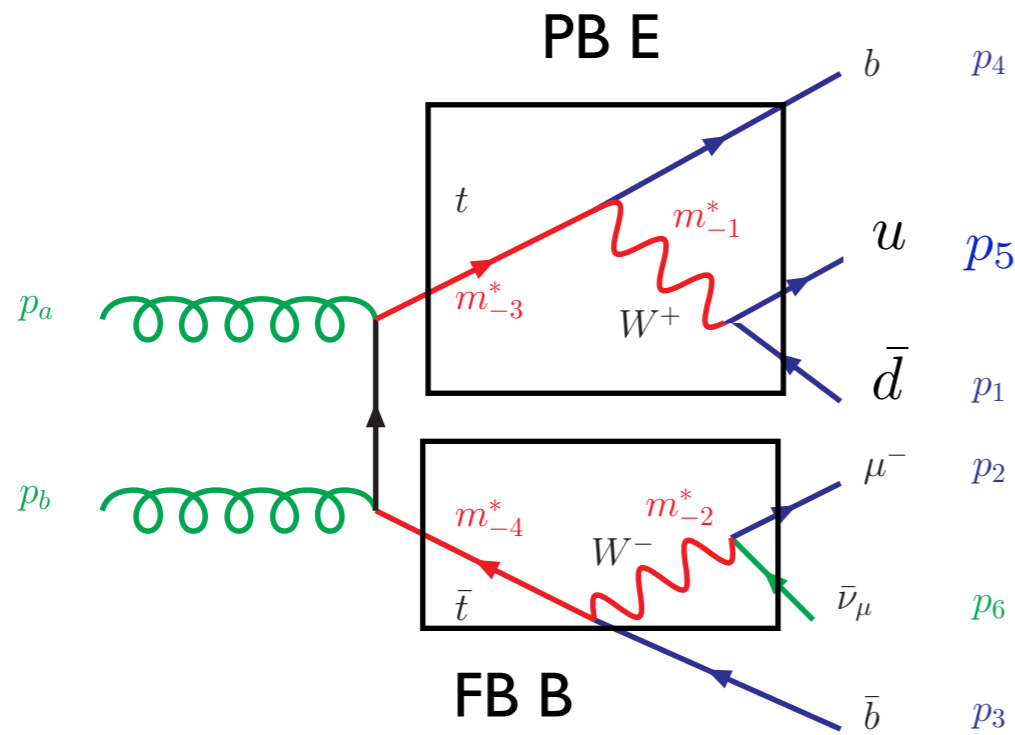
$$d\phi = \prod_{i=1}^5 \frac{d^3 p_i}{(2\pi)^3 2E_i} \frac{d^3 p_6}{(2\pi)^3 2E_6} dx_1 dx_2 \delta^4(p_a + p_b - \sum_j p_j)$$

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MADWEIGHT

□ Second Example: semi-leptonic top quark pair



□ degrees of freedom 16

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→ Multi-channel

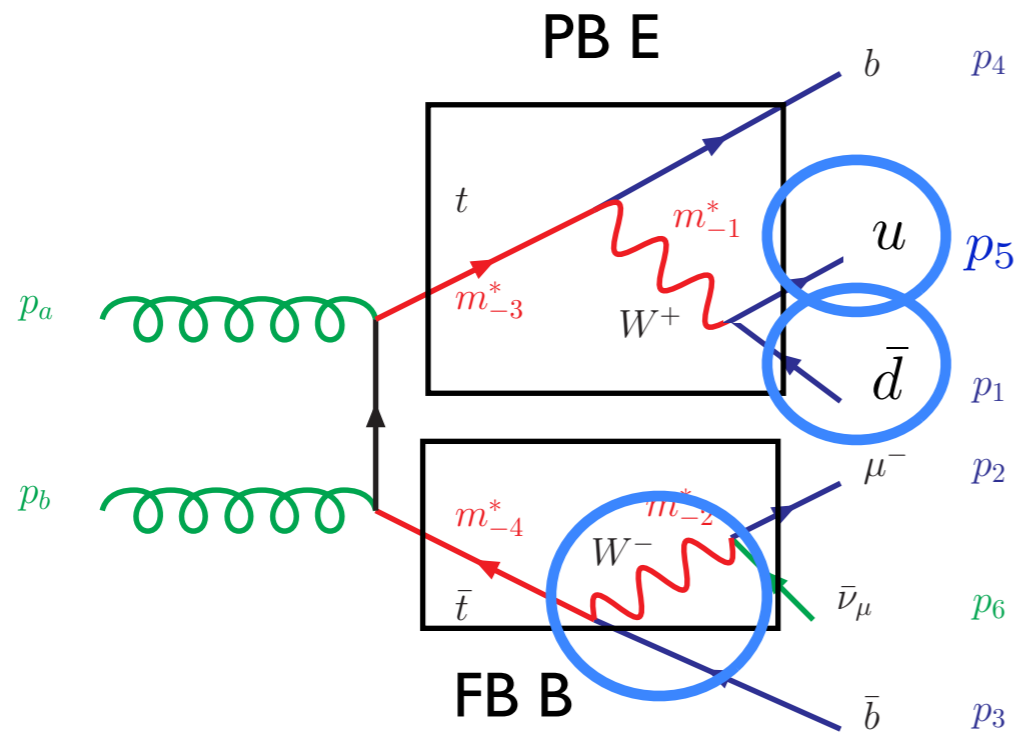
$$d\phi = \prod_{i=1}^5 \frac{d^3 p_i}{(2\pi)^3 2E_i} \frac{d^3 p_6}{(2\pi)^3 2E_6} dx_1 dx_2 \delta^4(p_a + p_b - \sum_j p_j)$$

Pass to →

$$d\phi = \prod_{i=1}^5 d\theta_i d\phi_i \prod_{j=2}^4 d|\mathbf{p}_i| \prod_{k=1, k \neq 2}^4 dm_{-k}^{*2} \times J$$

MADWEIGHT

□ Second Example: semi-leptonic top quark pair



□ degrees of freedom **16**

□ peaks **19**

→ **3 peaks unaligned**

→ **Multi-channel**

$$d\phi = \prod_{i=1}^5 \frac{d^3 p_i}{(2\pi)^3 2E_i} \frac{d^3 p_6}{(2\pi)^3 2E_6} dx_1 dx_2 \delta^4(p_a + p_b - \sum_j p_j)$$

Pass to →

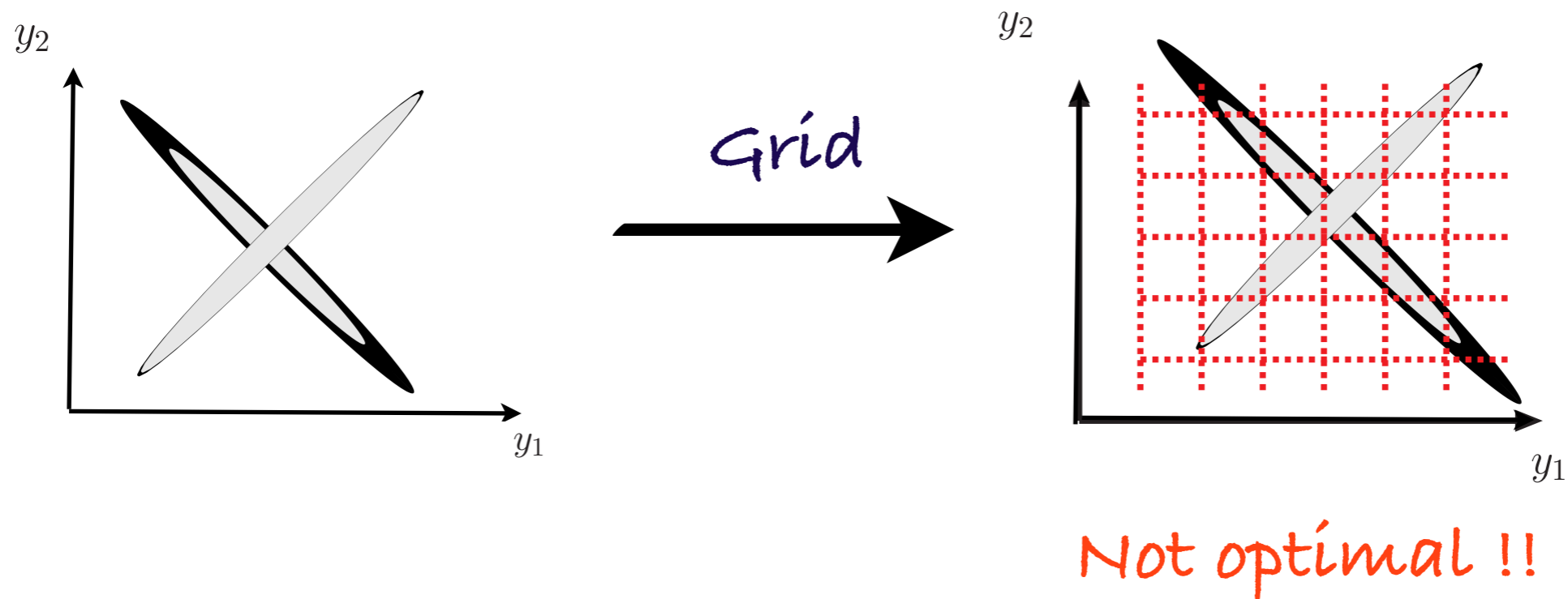
$$d\phi = \prod_{i=1}^5 d\theta_i d\phi_i \prod_{j=2}^4 d|\mathbf{p}_j| \prod_{k=1, k \neq 2}^4 dm_{-k}^{*2} \times J$$

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

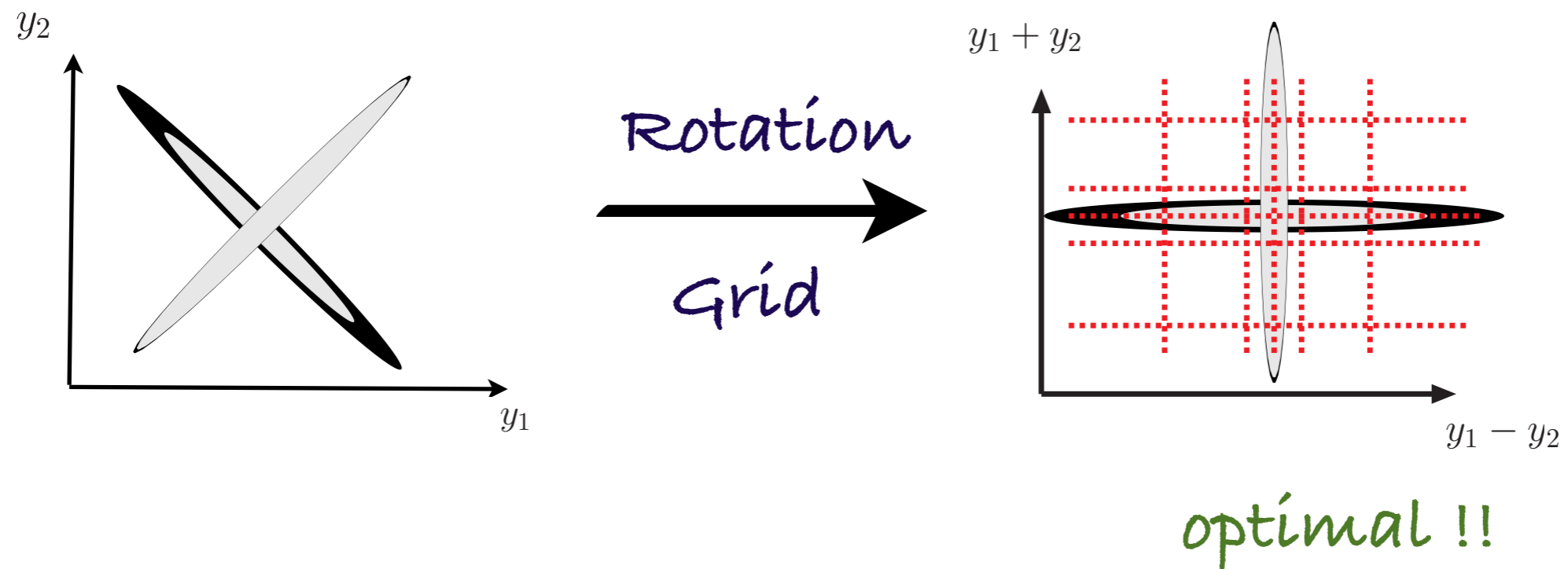
- The choice of the parametrization has a strong **impact** on the efficiency



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Monte-Carlo Integration

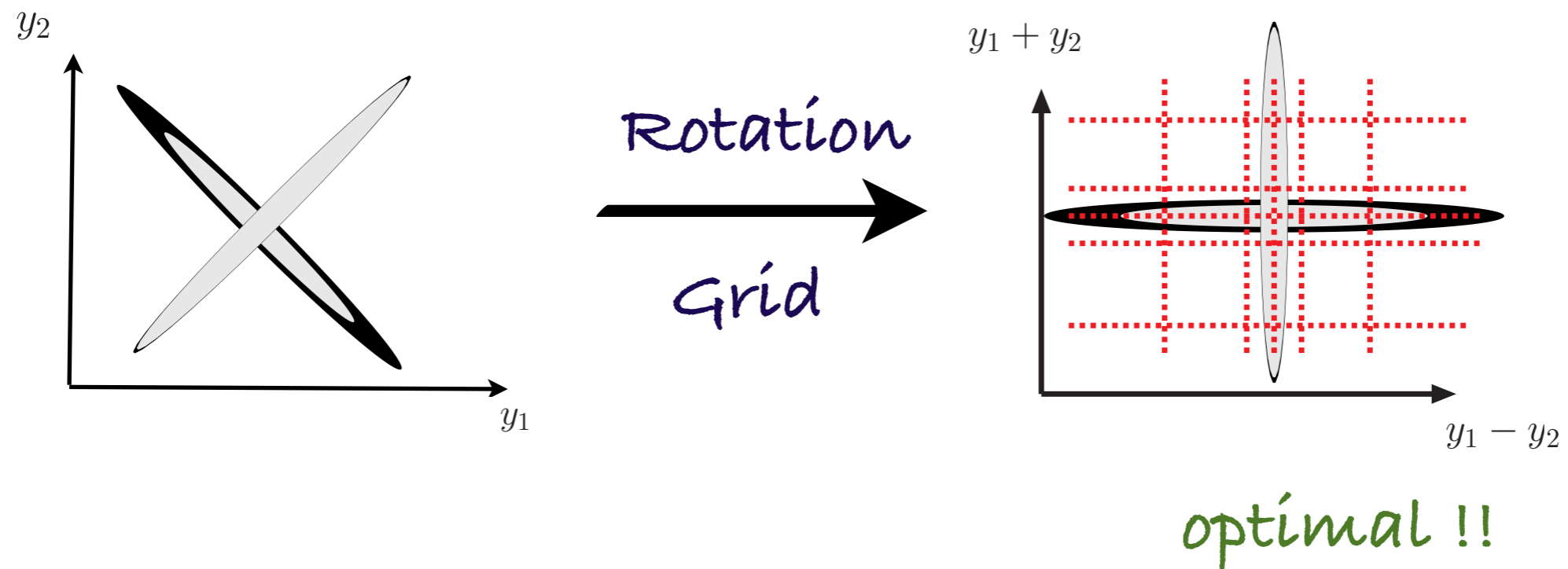
- The choice of the parametrization has a strong **impact** on the efficiency



JHEP 1012:068

Monte-Carlo Integration

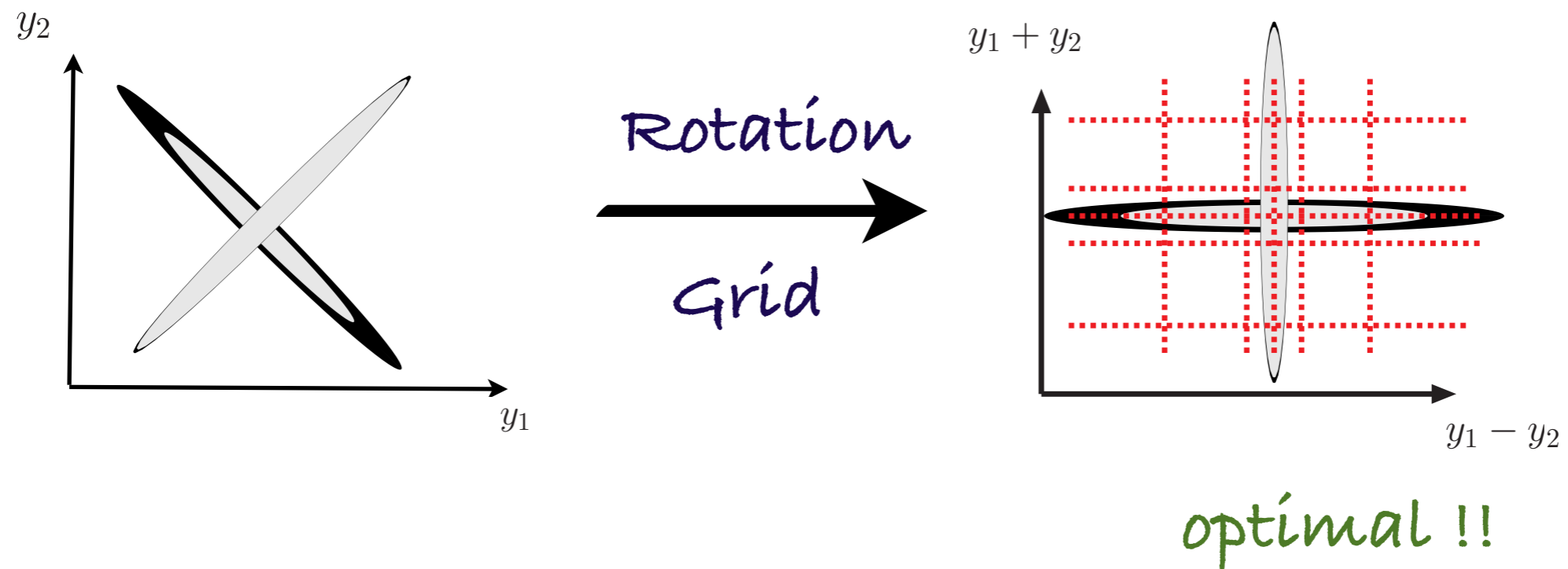
- The choice of the parametrization has a strong **impact** on the efficiency



Is it possible to optimize for any topology?

Monte-Carlo Integration

- The choice of the parametrization has a strong **impact** on the efficiency



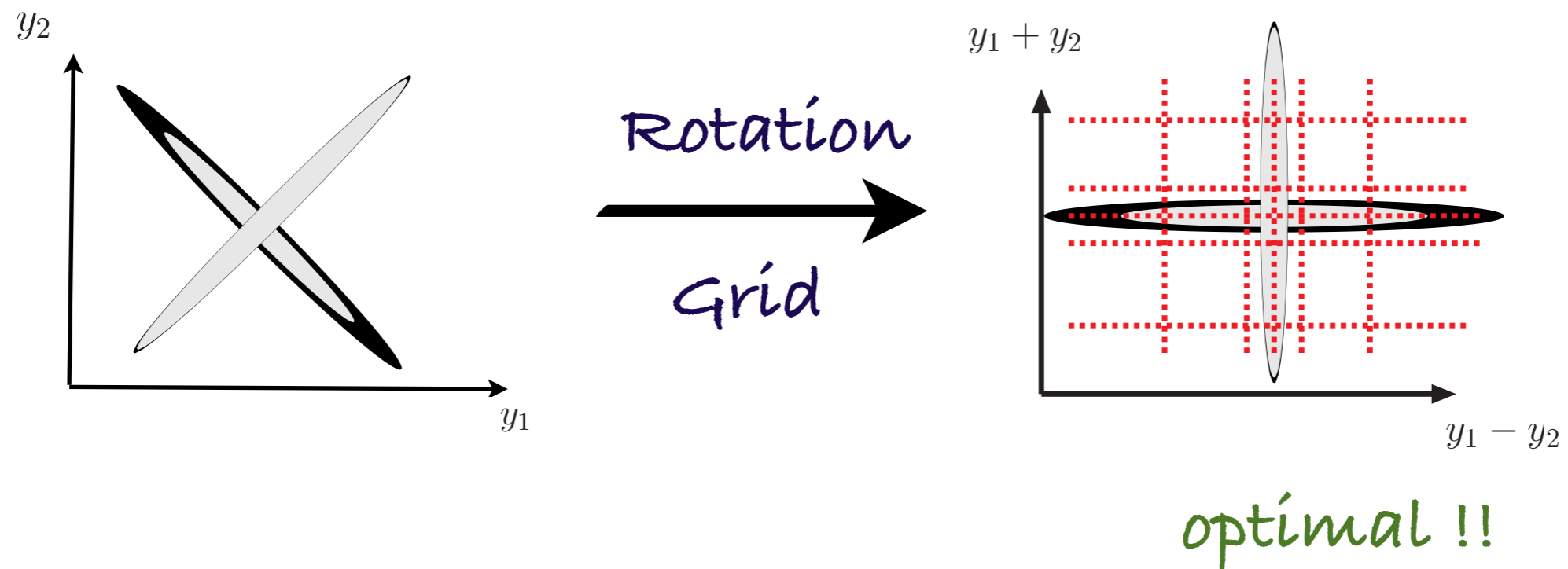
Is it possible to optimize for any topology?

YES

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Monte-Carlo Integration

- The choice of the parametrization has a strong **impact** on the efficiency



Is it possible to optimize for any topology?

YES \longrightarrow **Madweight**

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