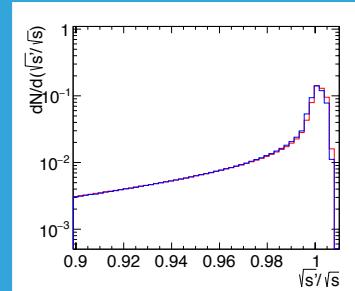


# OUTLINE

## UNCERTAINTY ON THE CLIC LUMINOSITY SPECTRUM

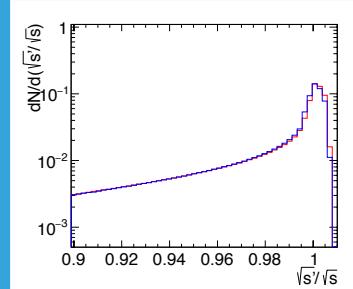


WHAT IS THE IMPACT ON PHYSICS(\*)?

(\*) HERE BY PHYSICS WE MEAN THE TOP MASS MEASUREMENT FROM RADIATIVE EVENTS BUT I AM WILLING TO SEE IT THROUGH MORE ANALYSIS

# OUTLINE

## UNCERTAINTY ON THE CLIC LUMINOSITY SPECTRUM



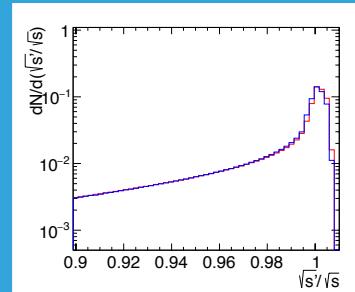
WHAT IS THE IMPACT ON PHYSICS(\*)?

IN ORDER TO DETERMINE THE LUMINOSITY SPECTRUM YOU NEED A GUESS (MATHEMATICAL MODEL) AND A DETECTOR SIMULATION  
(PLUS DATA - BHABHA SCATTERING - BUT NOT COVERED YET)

# OUTLINE

ASSUMING IMPERFECT GUESS ON THE LUMINOSITY SPECTRUM BUT PERFECT SIMULATION OF THE DETECTOR

## UNCERTAINTY ON THE CLIC LUMINOSITY SPECTRUM

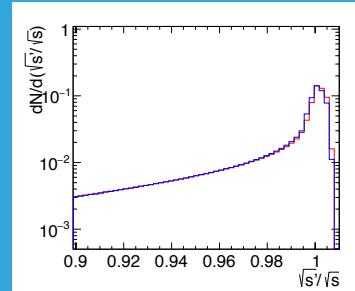


WHAT IS THE IMPACT ON PHYSICS?

**1st Part of the talk :** study made by  
Pablo Gomis who apologizes for not  
being here and I am presenting it in his  
behalf

# OUTLINE

## UNCERTAINTY ON THE CLIC LUMINOSITY SPECTRUM



WHAT IS THE IMPACT ON PHYSICS?

ASSUMING A PERFECT GUESS ON THE LUMINOSITY SPECTRUM BUT **IMPERFECT SIMULATION** OF THE DETECTOR

**2nd Part of the talk** : study made by Philipp Zehetner as part of his Summer Student project that Pablo propagated to the top mass uncertainty



# CLIC DETECTOR AND PHYSICS 2018

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# TOP MASS MEASUREMENT FROM RADIATIVE EVENTS

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M. BORONAT\*, E. FULLANA\*, J. FUSTER\*, I. GARCÍA\*, P. GOMIS\*, A. H. HOANG°,  
V. MATEU+, M. PERELLÓ\*, E. ROS\*, M. A. VILLAREJO\*, M. VOS\*, A. WIDL°

\* IFIC (UNIVERSITAT DE VALÈNCIA/CSIC)

+ UNIVERSIDAD DE SALAMANCA

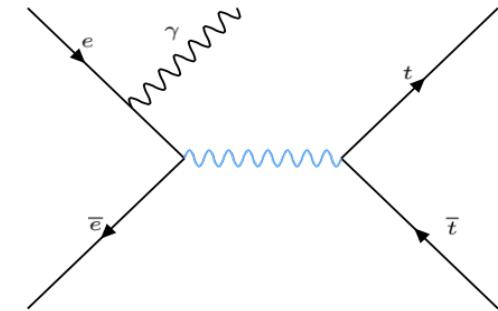
° UNIVERSITÄT WIEN

WITH MUCH APPRECIATED CONTRIBUTIONS FROM A. SAILER

# INTRODUCTION TO THE OBSERVABLE

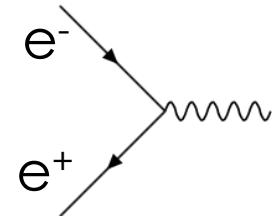
6

- ▶ The idea is to measure the top-quark mass ( $m_t$ ) measuring the differential cross section of the process  $e^+e^- \rightarrow t\bar{t}\gamma_{\text{ISR}}$ .



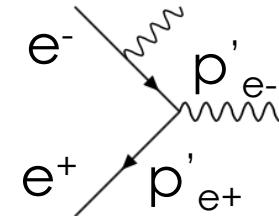
- ▶ The  $t\bar{t}$  production cross section is sensitive to the center of mass energy and  $m_t$ :

$$\sigma(e^+e^- \rightarrow t\bar{t}) = f(s, m_t)$$



$$s = (p_{e^-} + p_{e^+})^2$$

$$\sigma(e^+e^- \rightarrow t\bar{t}\gamma) = f(s', m_t)$$



$$s' = (p'_{e^-} + p'_{e^+})^2$$

- ▶ The emitted  $\gamma_{\text{ISR}}$  reduces the available phase space for the  $t\bar{t}$  production.
- ▶ Therefore the  $t\bar{t}\gamma_{\text{ISR}}$  production cross section is sensitive to the emitted ISR photon energy.

# INTRODUCTION TO THE OBSERVABLE

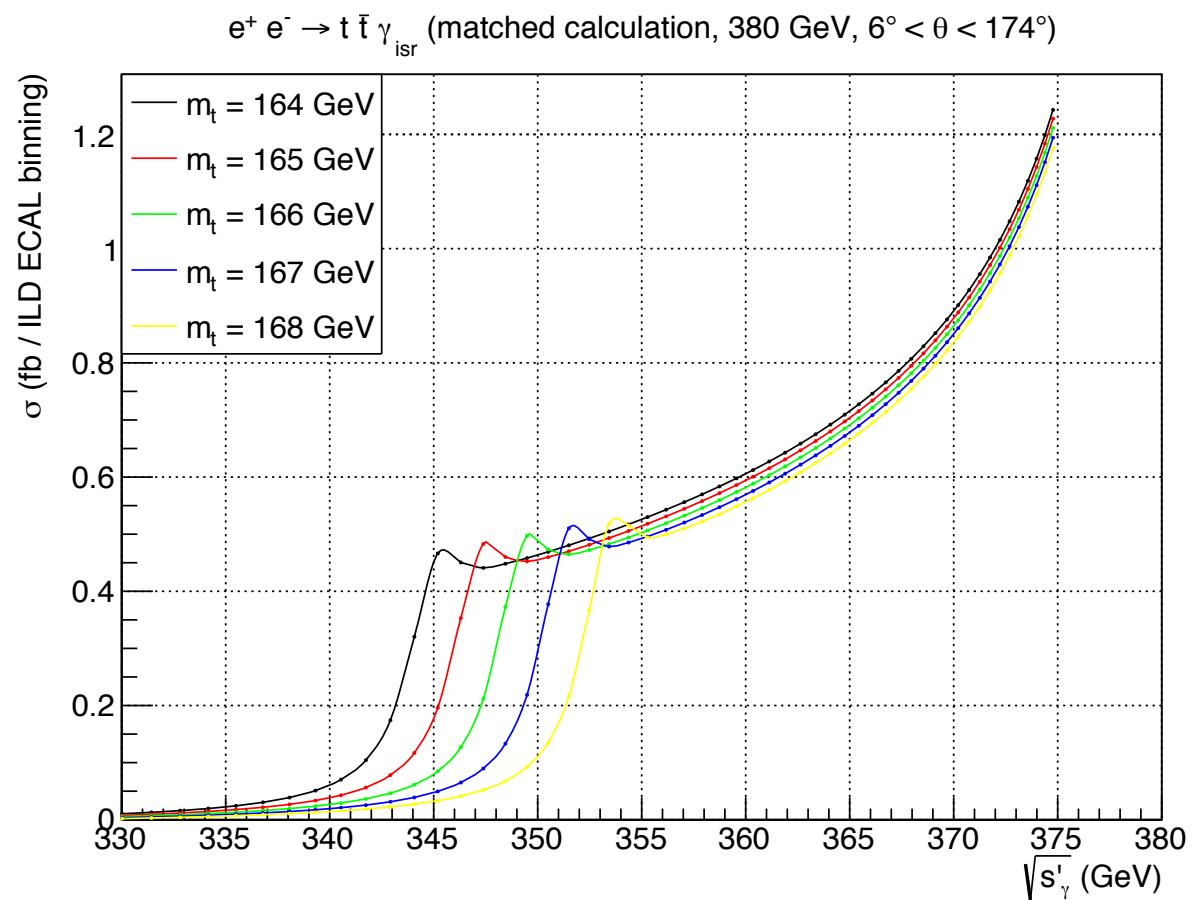
7

- ▶  $m_t$  can be measured by counting the  $t\bar{t}$  events produced for a certain  $s'$  (i.e ISR energy photon):

$$s' = s \left(1 - \frac{2E_\gamma}{\sqrt{s}}\right)$$

- ▶ Our observable is the differential cross section of the  $t\bar{t}$  production as a function of  $\sqrt{s'}$ .

- ▶ The observable is more sensitive to  $m_t$  near the top production threshold, and the dependence diminishes as  $\sqrt{s'}$  grows.



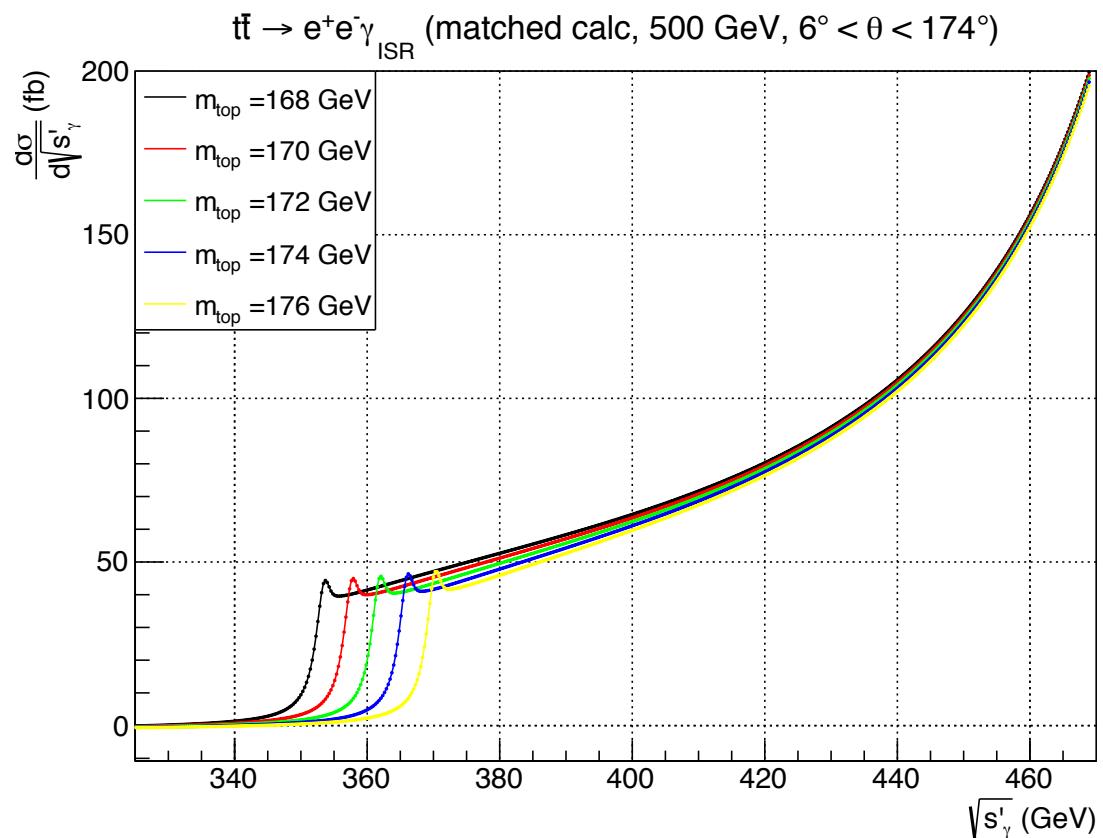
# THEORETICAL MODEL: MATCHED CALCULATION

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- ▶ A factorization theorem valid at  $O(\alpha_{QED})$  and to all orders in  $\alpha_s$  (beyond perturbation theory) has been established by A. H. Hoang and V. Mateu in which the observable can be calculated analytically:

$$\sigma_{t\bar{t}\gamma_{ISR}}(m_t, s') = \sigma_{ISR}(E_\gamma) * \sigma_{t\bar{t}}(m_t, s')$$

- ▶ The model convolutes the ISR calculation with the threshold - continuum matched calculation by A. H. Hoang et al.
- ▶ The model outputs the differential cross section of the  $e^+e^- \rightarrow t\bar{t}\gamma_{ISR}$  as a function of the photon energy and polar angle respect to the head-on collision, for a given top mass.
- ▶ The input mass can be chosen to be any short-distance mass scheme, in this case we chose the  $\overline{MS}$  scheme. For the calculation itself the 1S and MSR masses are used.



- ▶ For more information and details on the matched calculation:

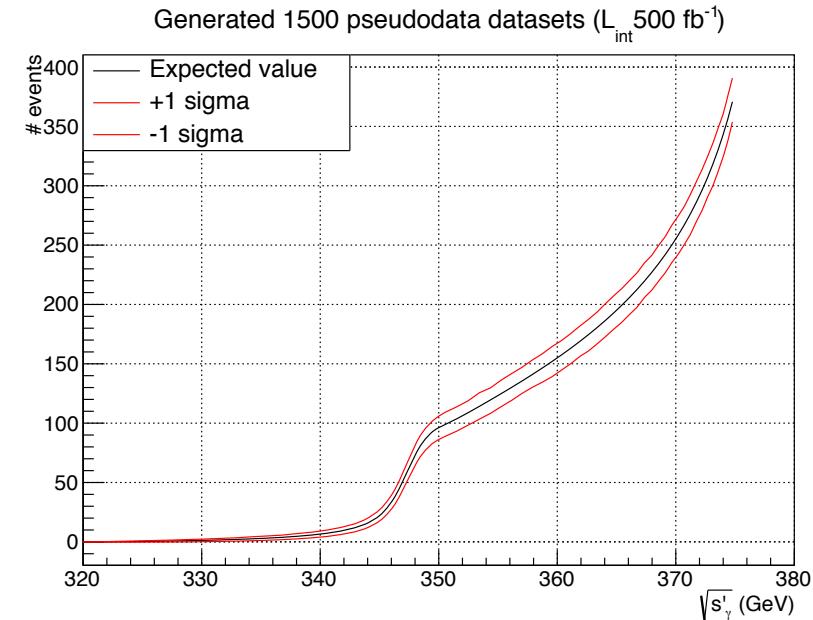
ANGELIKA WIDL LCWS17 TALK

# UNCERTAINTY ON THE TOP MASS (STATISTICS)

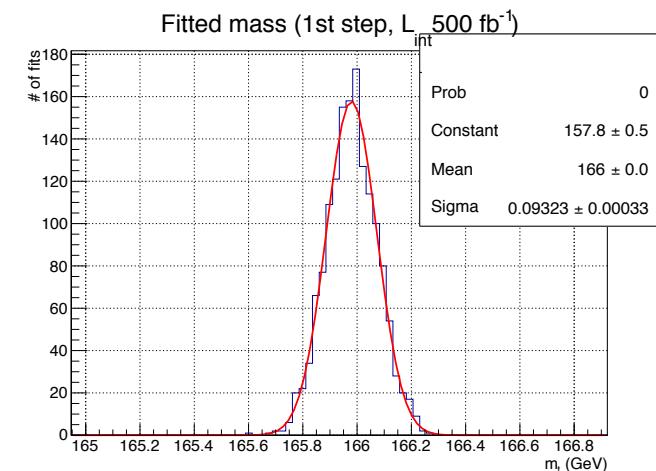
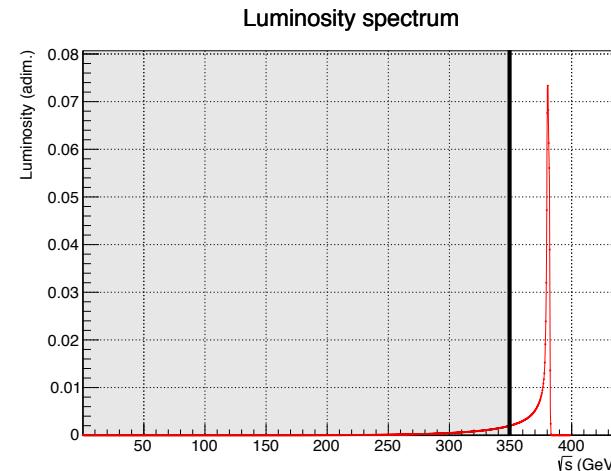
9

- ▶ Propagation of the statistical uncertainty into the top mass though pseudo experiments
- ▶ The Luminosity spectrum is propagated into the observable though a weighted sum
- ▶ Shift of ~30MeV when you include the Luminosity Spectrum in the observable

	$6^\circ < \theta < 174^\circ$	$8^\circ < \theta < 172^\circ$	$10^\circ < \theta < 170^\circ$
CLIC Spectrum @ 500 fb <sup>-1</sup>	75 MeV (50 MeV w/o)	93 MeV (60 MeV w/o.)	104 MeV (65 MeV w/o. s.)



- ▶ Part of this loss in sensitivity is due to a loss of statistics ( $t\bar{t}$ bar threshold acceptance). The other part, concerns the change in the shape due to bin migrations.
- ▶ Work in progress: by taking into account the correlations between these bins we expect to improve the sensitivity prospect.

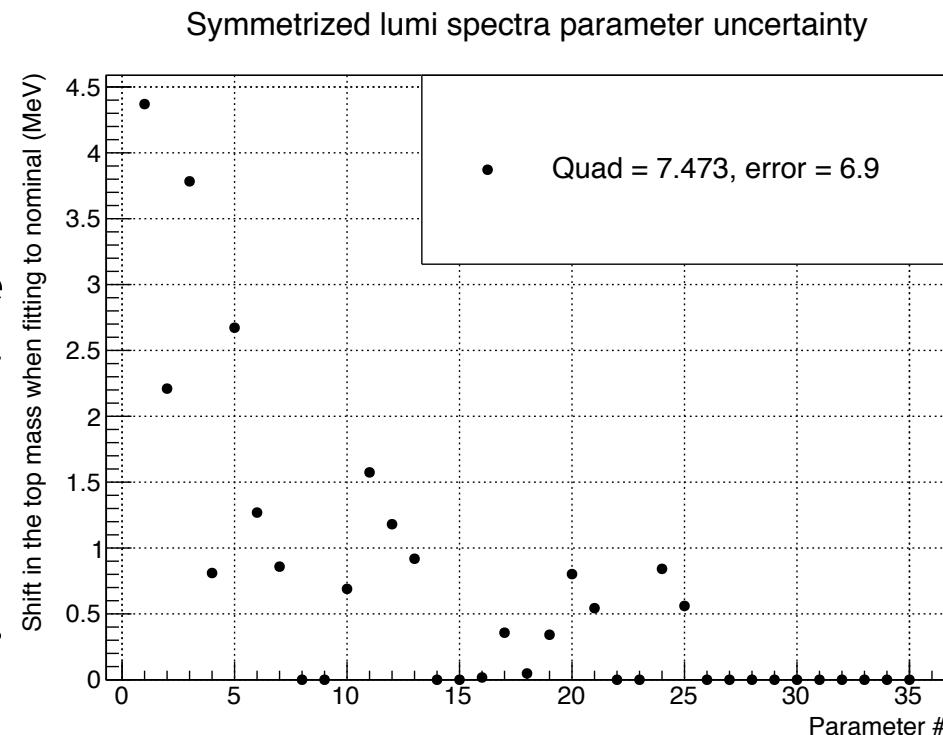


# PROPAGATION OF THE UNCERTAINTY ON THE LUMINOSITY SPECTRUM INTO THE TOP MASS

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- ▶ To estimate the effect of the luminosity spectrum uncertainty in our study we propagate the error from its 19 free parameters.
- ▶ Using the 19 parameter errors from the luminosity spectrum reconstruction we generate 38 (19 parameters  $\times 2\sigma$  up,  $\sigma$  down) spectrums.
- ▶ We weight the spectrums with the observable and we fit it to the model weighted with the “nominal” reconstruction.

- ▶ The propagated error for each parameter is taken as the symmetrisation ( $\sigma$  up,  $\sigma$  down) of the mass shifts obtained through the fits.
- ▶ The total uncertainty is found by performing  $E = E_p \text{Cov} E_p^T$ .
- ▶ We find a total uncertainty of **7 MeV**.



# THIS IS THE END OF THE FIRST PART OF THE TALK

# Luminosity Spectrum Reconstruction - Impact of Detector Resolution Mismodelling

Philipp Zehetner  
Ludwig-Maximilians-Universität München

CERN Summer Student  
Supervised by Esteban Fullana and Andre Sailer

August 28, 2018

# Analysis Steps

What if we don't know the exact resolution of our detector?

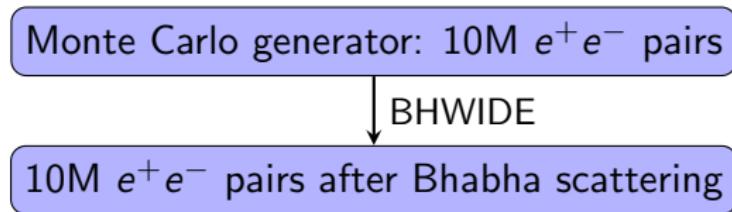
# Analysis Steps

What if we don't know the exact resolution of our detector?

Monte Carlo generator: 10M  $e^+e^-$  pairs

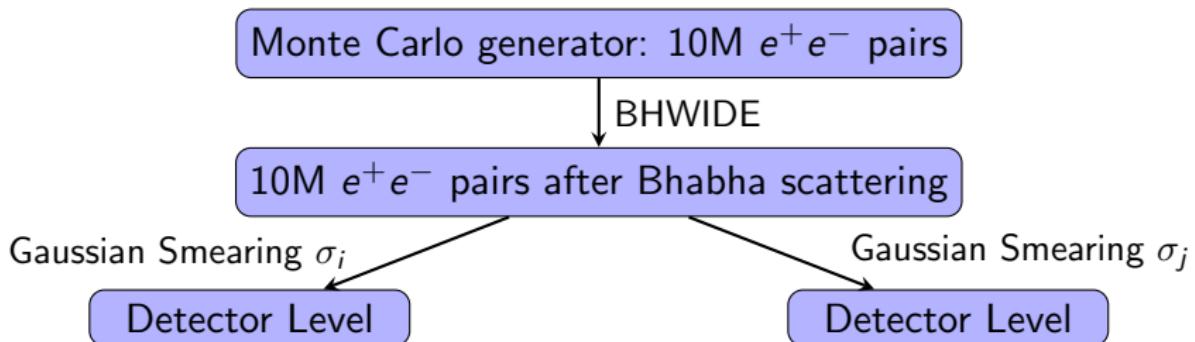
# Analysis Steps

What if we don't know the exact resolution of our detector?



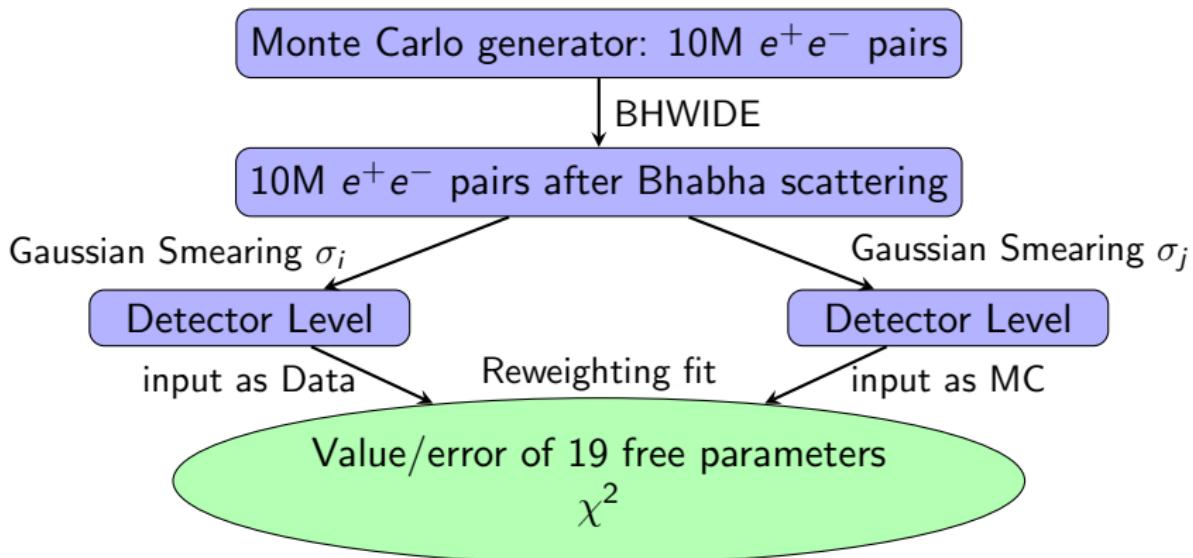
# Analysis Steps

What if we don't know the exact resolution of our detector?

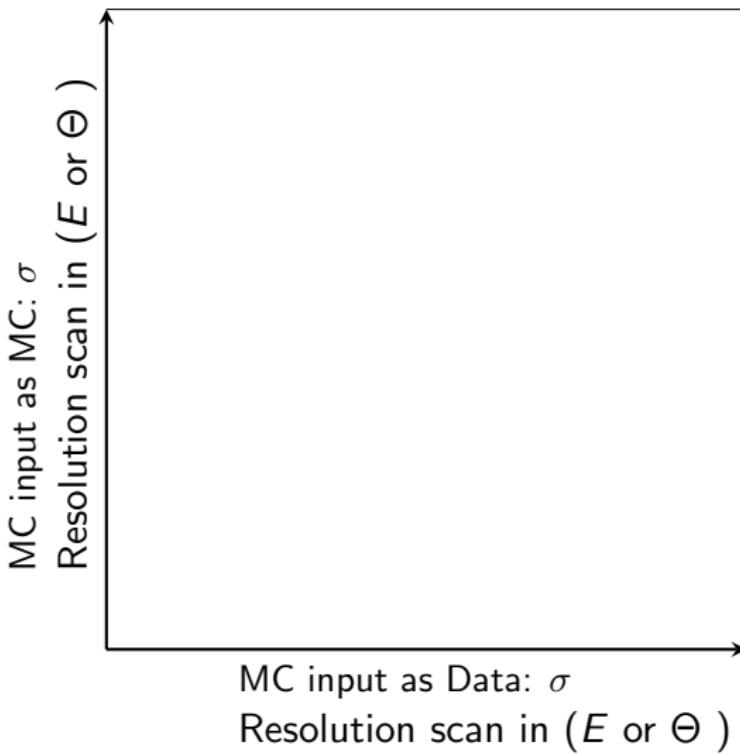


# Analysis Steps

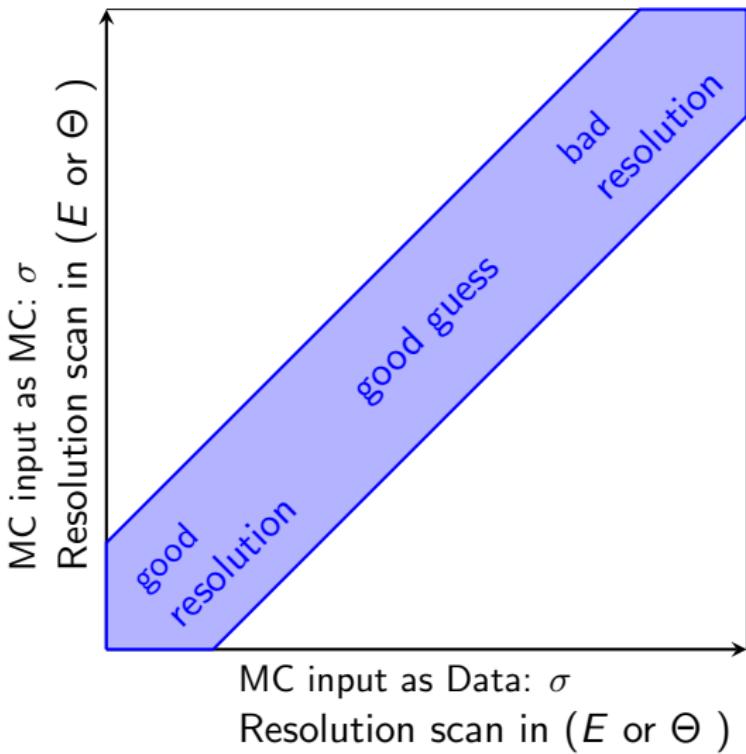
What if we don't know the exact resolution of our detector?



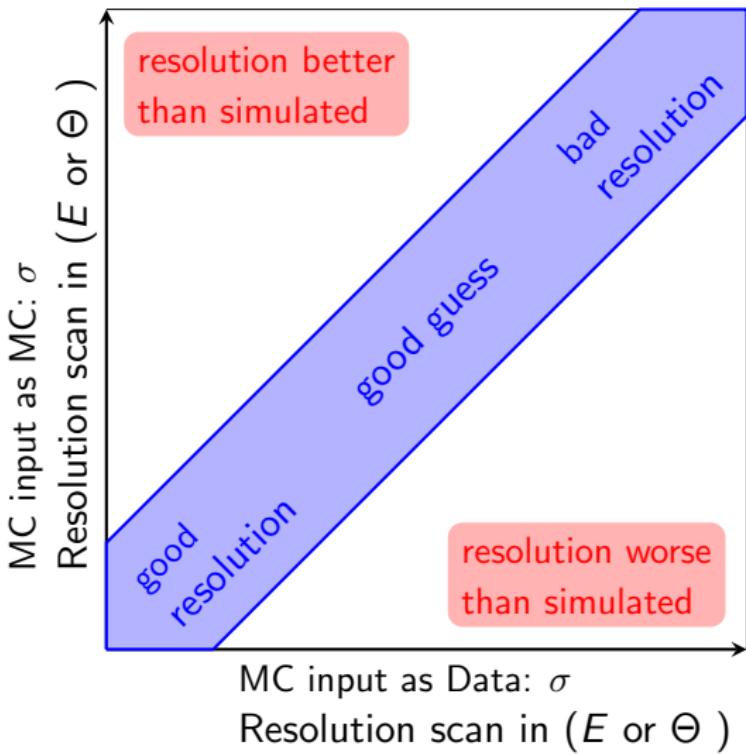
# Plot Structure



# Plot Structure

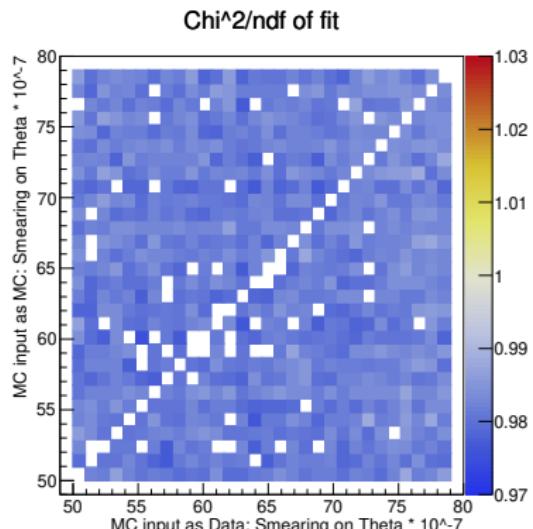


# Plot Structure

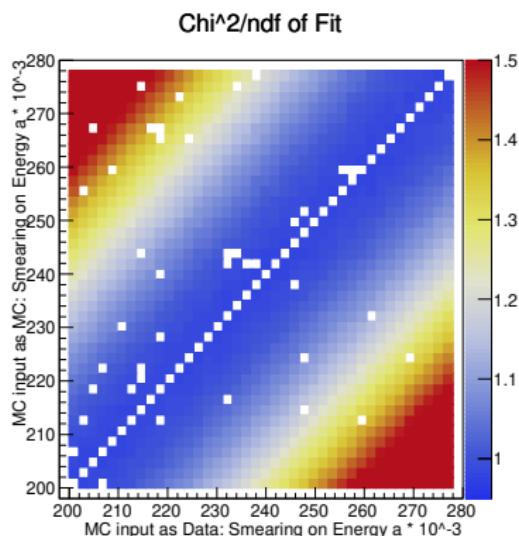


# $\chi^2$ results for $\Theta$ and Energy resolution scan

$\Theta$



Energy

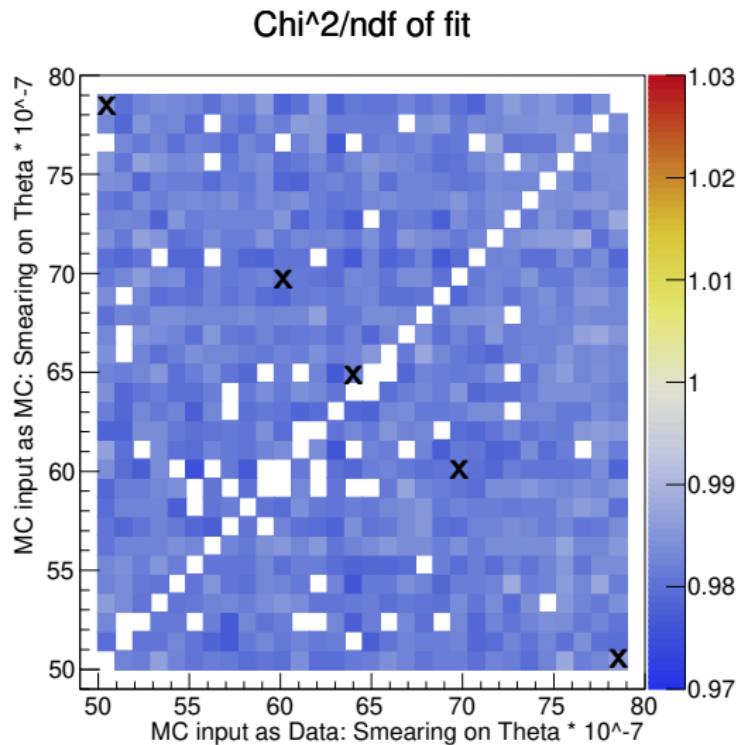


$31 \times 31 = 961$  data points

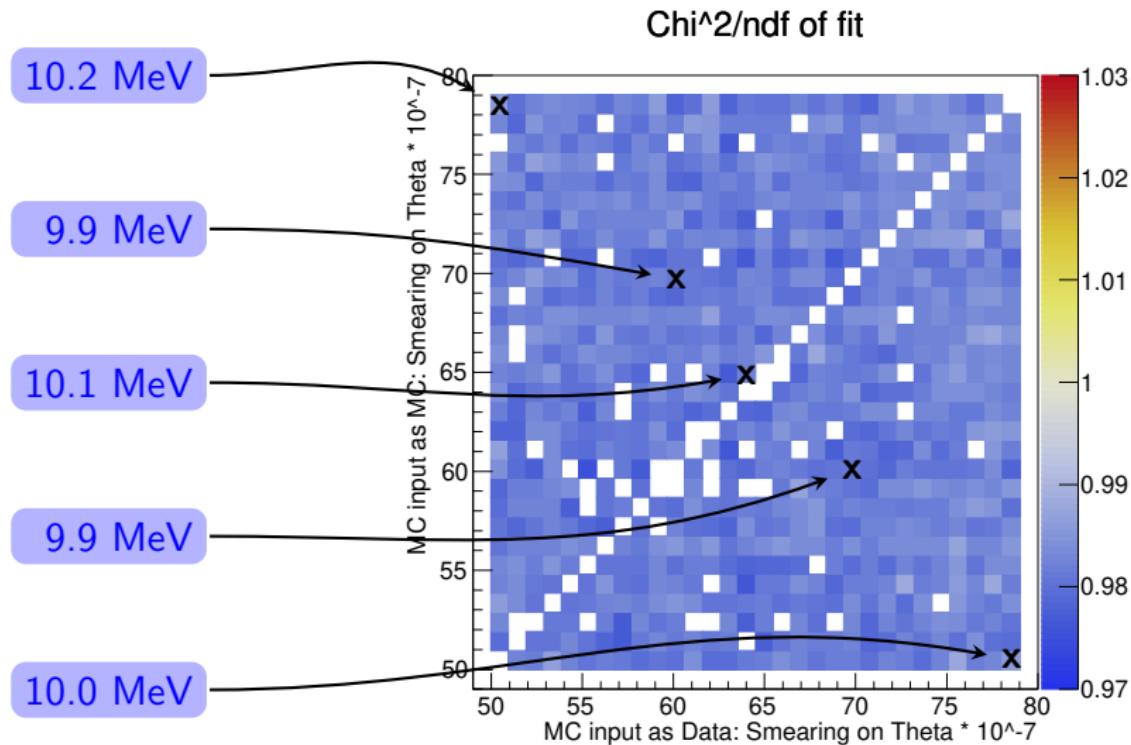
$41 \times 41 = 1681$  data points

$$\sigma_E = \frac{a}{\sqrt{E}} \oplus b$$

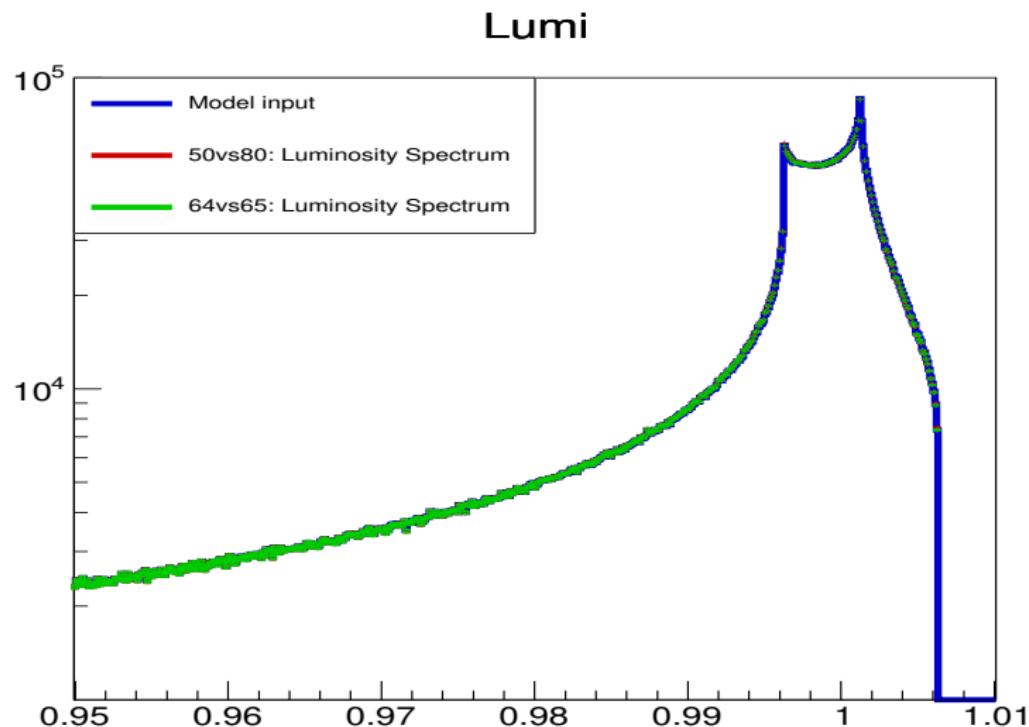
# Impacts on top mass measurements: Theta



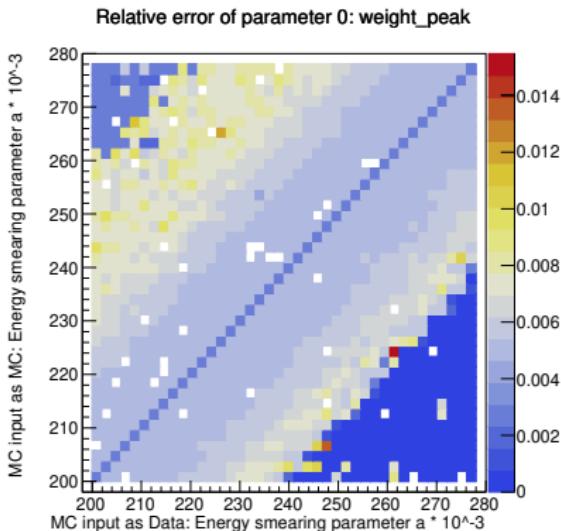
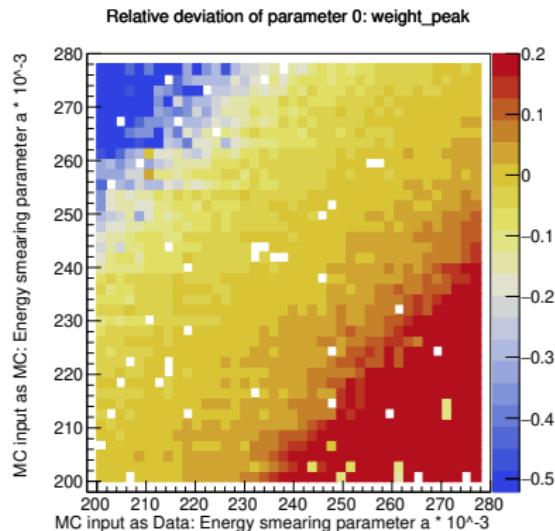
# Impacts on top mass measurements: Theta



# Luminosity Spectrum for mismodelling $\Theta$

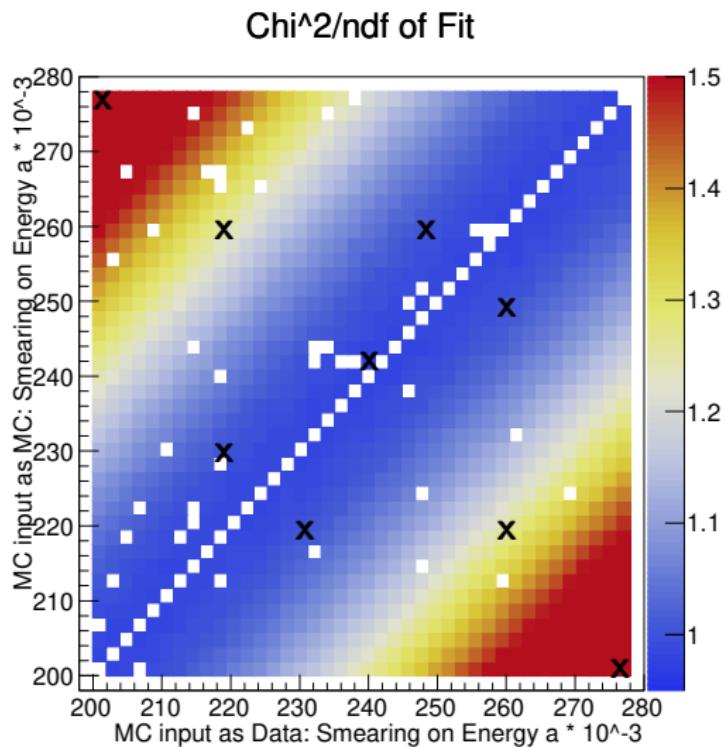


# Problematic Missmodelling: Energy resolution

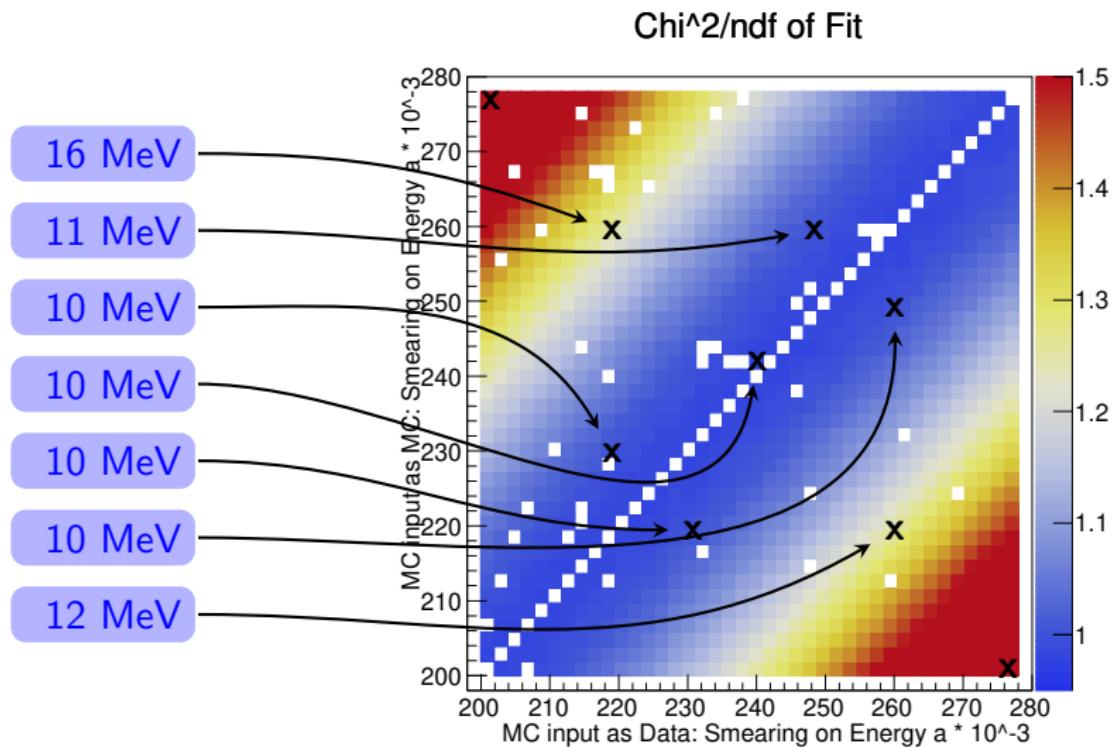


- ① 'Stable zone' around diagonal: small error and little deviation
- ② off-diagonal corners: large deviation, errors drop to zero

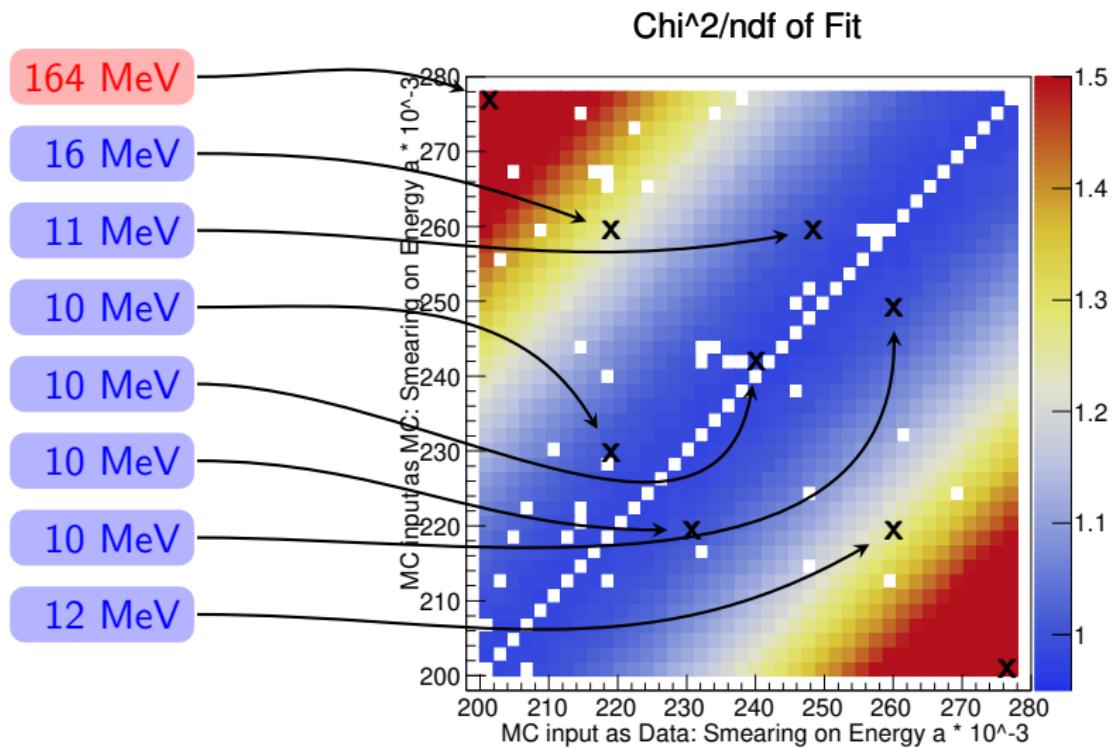
# Impacts on top mass measurements: Energy



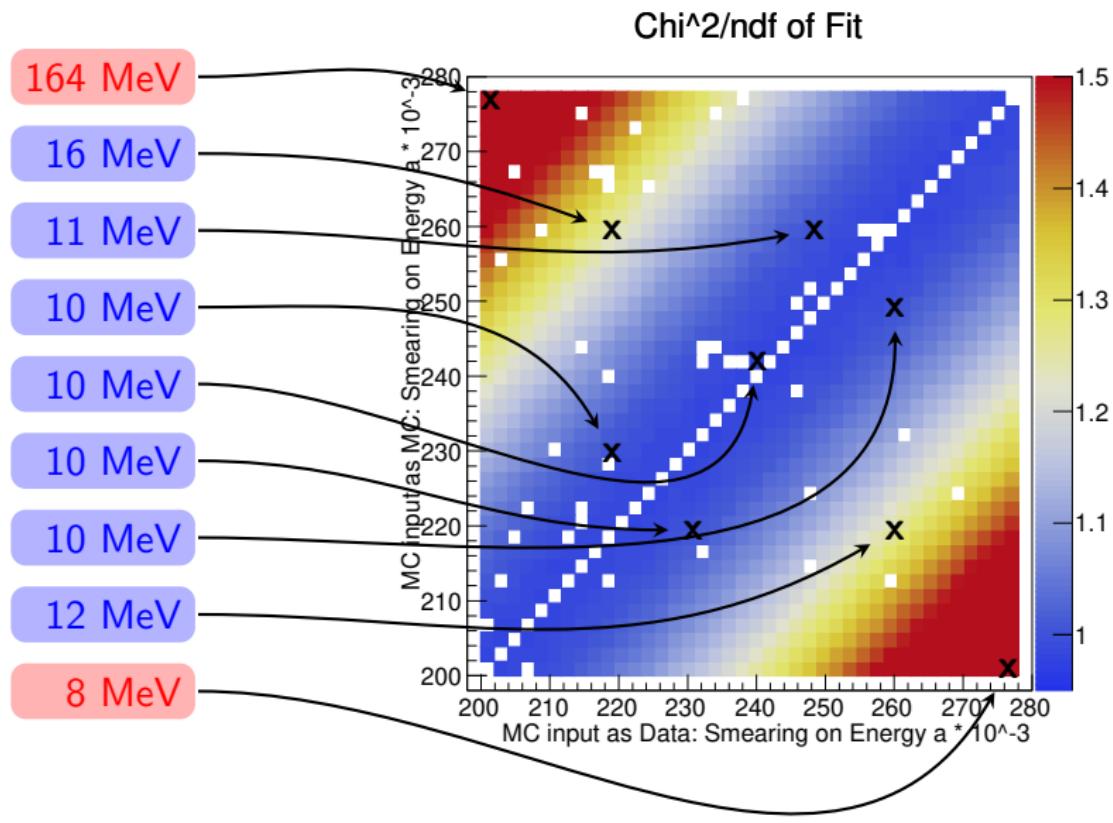
# Impacts on top mass measurements: Energy



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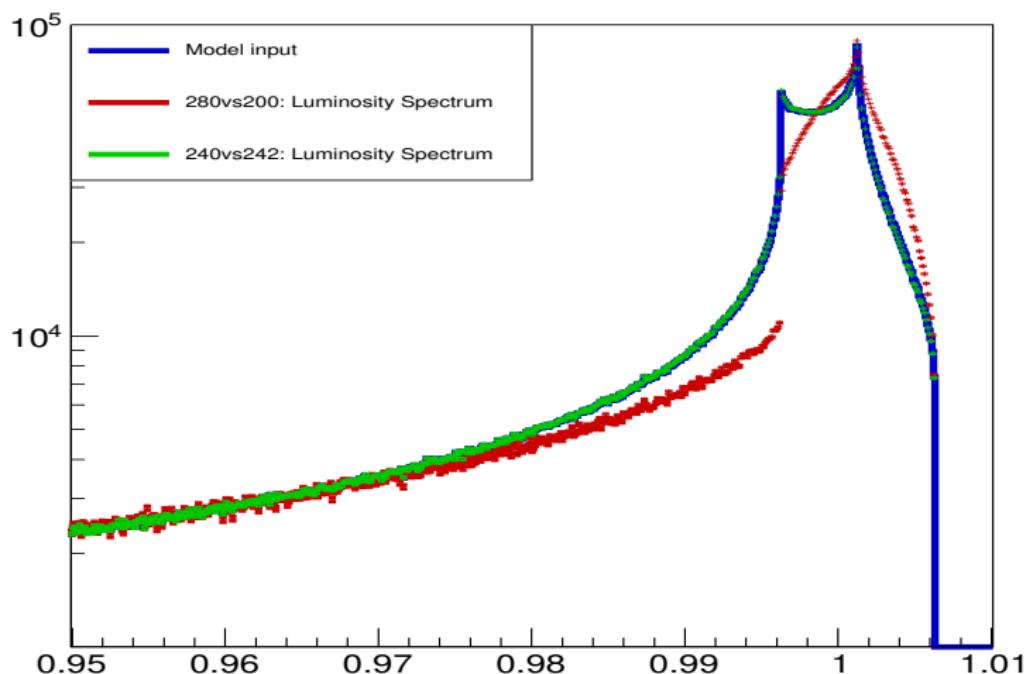


# Impacts on top mass measurements: Energy



# How reliable are the 8 MeV?

Lumi



# Conclusions

- ① If the resolution on  $\Theta$  is reasonably well modelled, resulting errors on the top quark mass measurement are small

# Conclusions

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# Conclusions

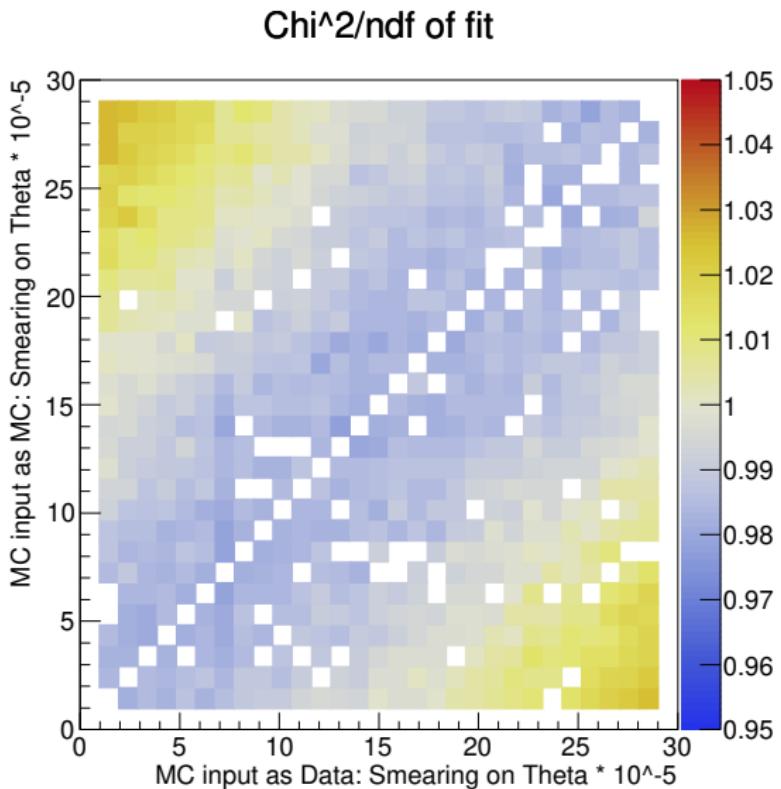
- ① If the resolution on  $\Theta$  is reasonably well modelled, resulting errors on the top quark mass measurement are small
- ② The energy resolution is more sensitive.
- ③ Errors stay relatively small, when mismodelling the resolution by  $\pm 15\%$

# Conclusions

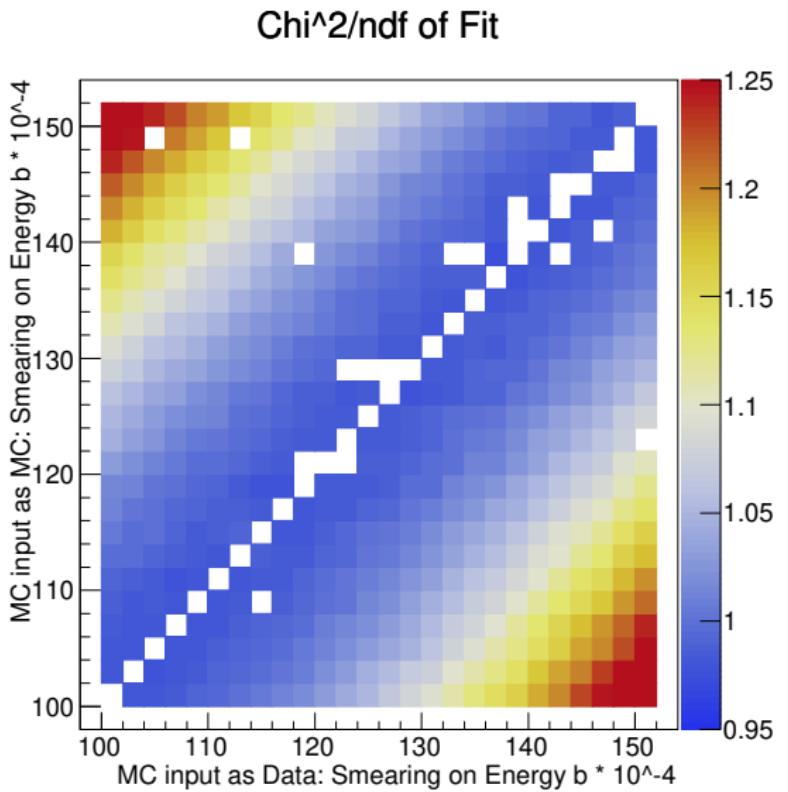
- ① If the resolution on  $\Theta$  is reasonably well modelled, resulting errors on the top quark mass measurement are small
- ② The energy resolution is more sensitive.
- ③ Errors stay relatively small, when mismodelling the resolution by  $\pm 15\%$
- ④ Larger deviations either drastically increase the error, or yield unreliable results on error propagation

- ① Luminosity Spectrum Reconstruction at Linear Colliders  
Authors: Stéphane Poss, André Sailer  
<https://arxiv.org/abs/1309.0372>
- ② Errors on top quark mass provided by Pablo Gomis  
Link to his Presentation

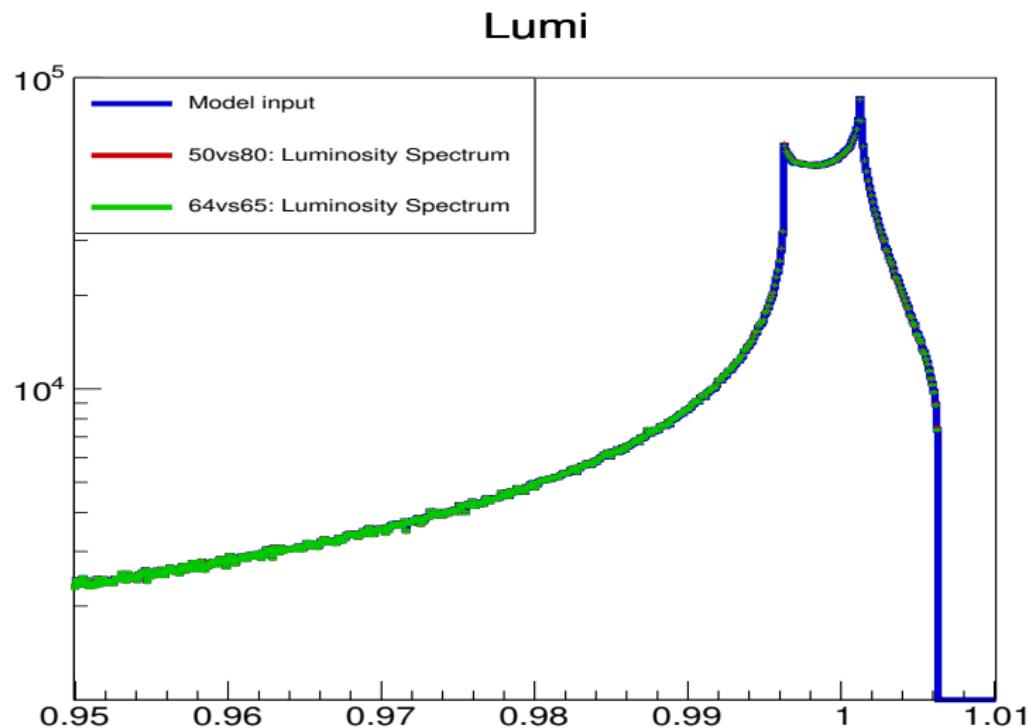
# BackUp 1: $\chi^2$ for larger range for $\Theta$



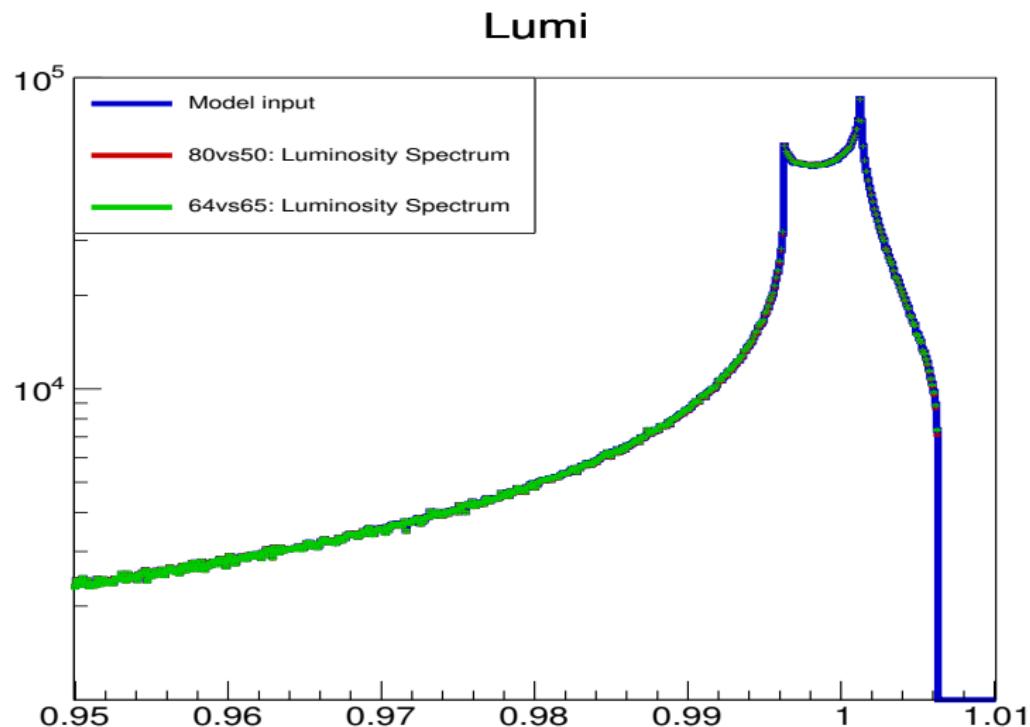
# BackUp 2: $\chi^2$ for parameter b



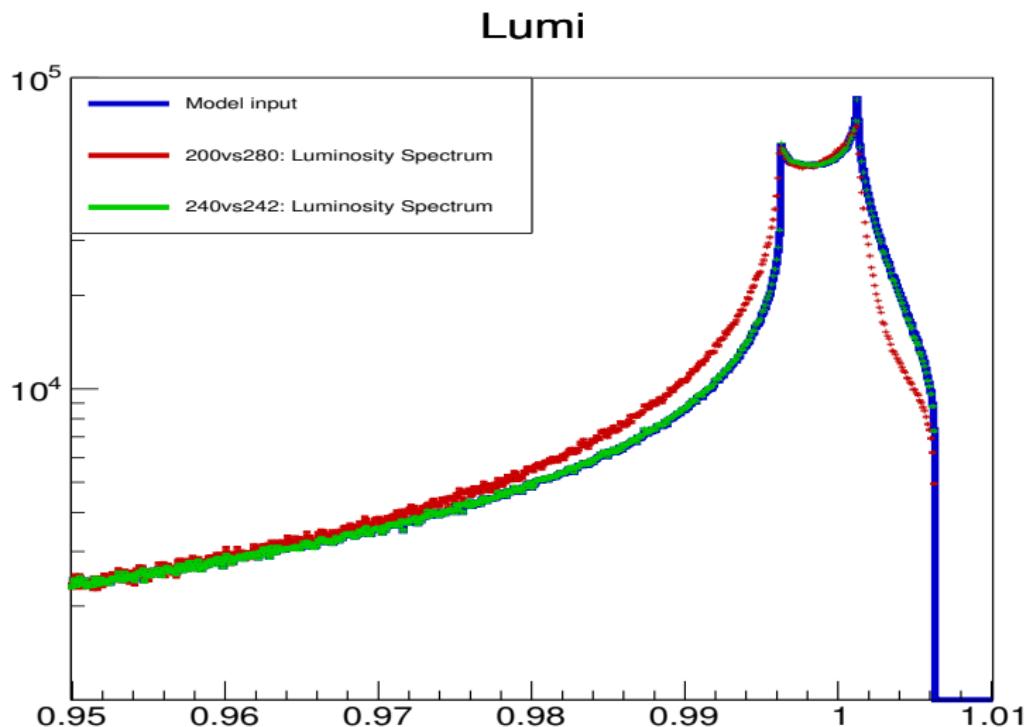
# BackUp 3: Luminosity: 50vs80



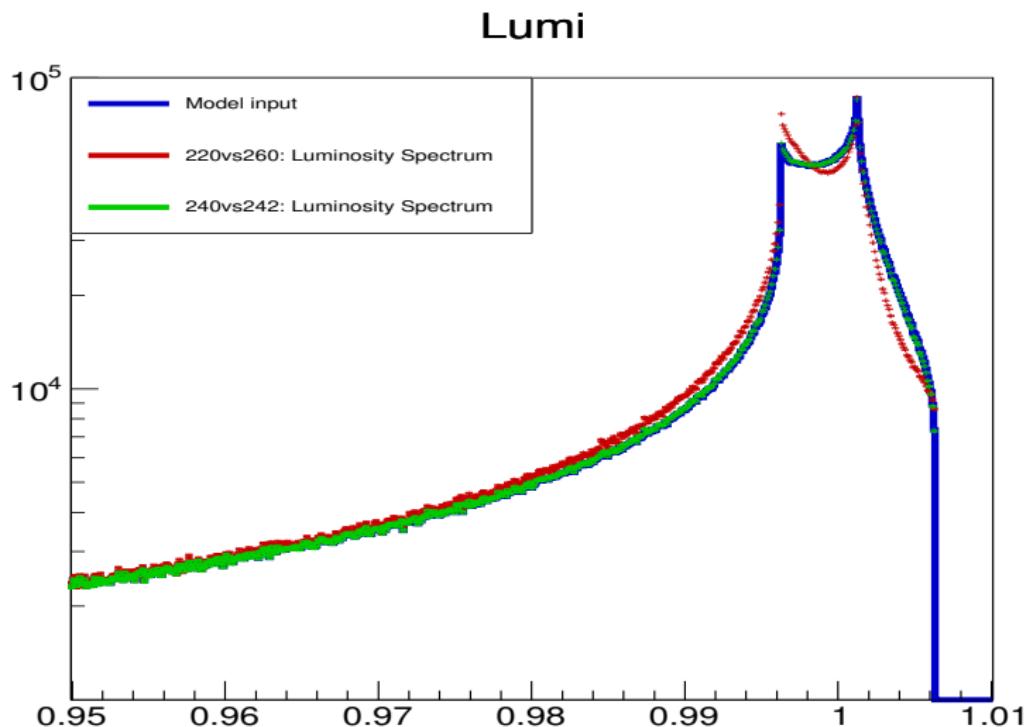
# BackUp 4: Luminosity: 80vs50



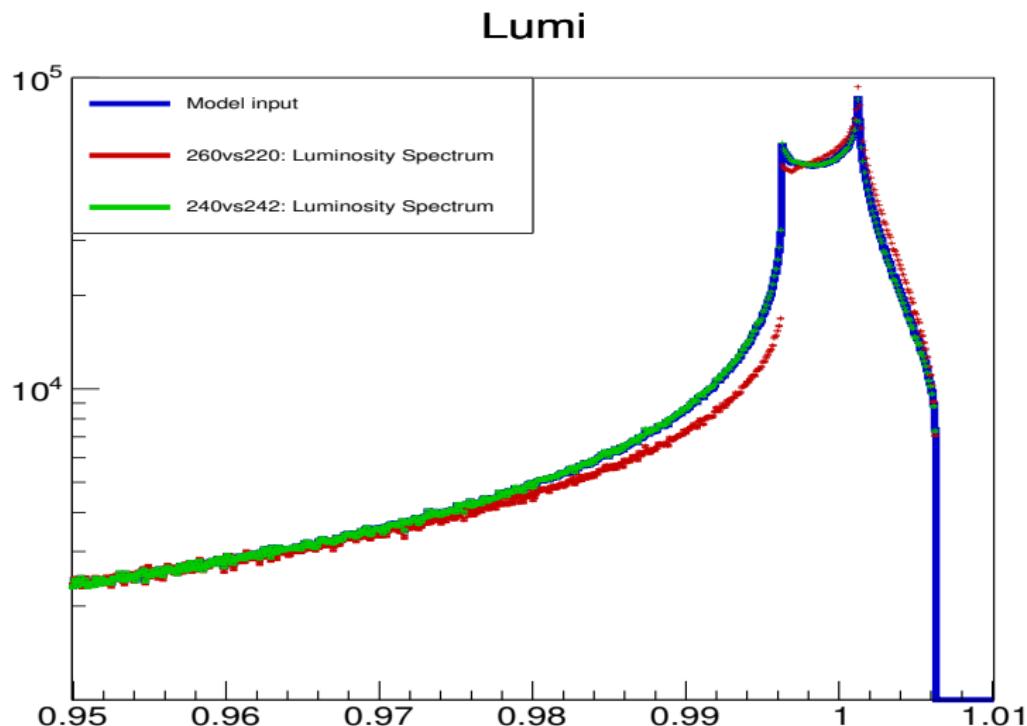
# BackUp 5: Luminosity: 200vs280



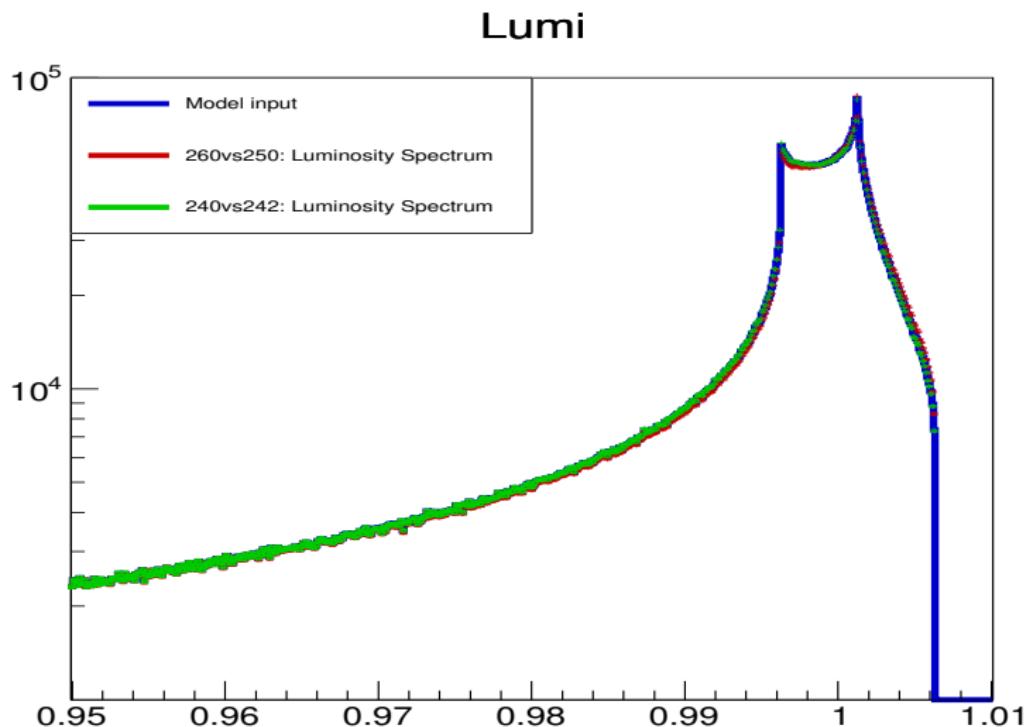
# BackUp 6: Luminosity: 220vs260



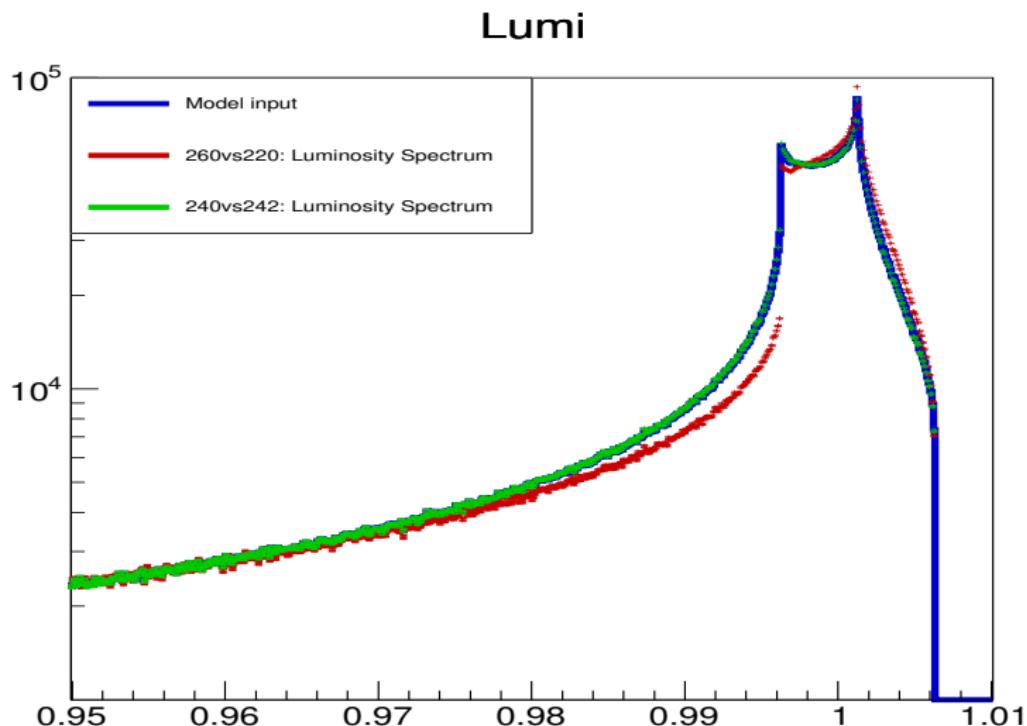
# BackUp 7: Luminosity: 260vs220



# BackUp 8: Luminosity: 260vs250



# BackUp 9: Luminosity: 220vs230



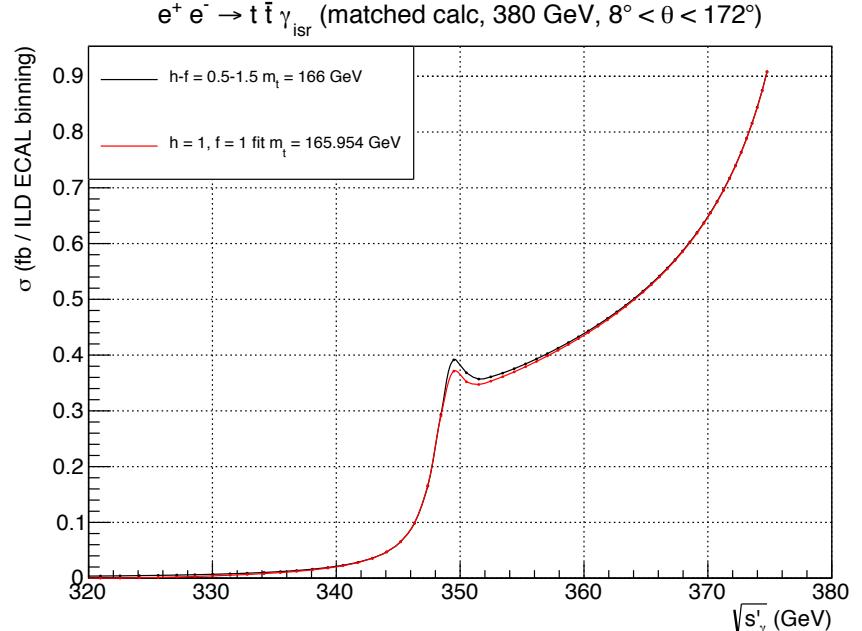
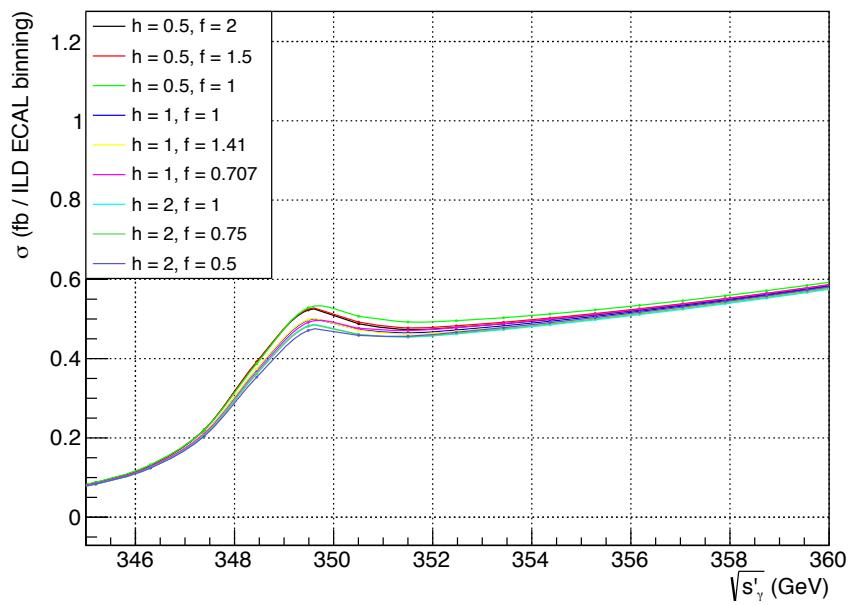
# THEORETICAL MODEL UNCERTAINTY

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- The main sources of uncertainty in the matched calculation come from the hard, soft and ultra soft scales in the NRQCD calculation, which can be parametrized as a function of the  $h$  and  $f$  parameters.

\* results for  $8^\circ < \theta < 172^\circ$

Proposed scale parameters variations ( <a href="#">A. Hoang , M. Stahlhofen</a> )									
$h$	1/2	1/2	1/2	1	1	1	2	2	2
$f$	2	3/2	1	1	$\sqrt{2}$	$\sqrt{1/2}$	1	$3/4$	$1/2$
$\Delta m$ (MeV) @380 GeV	-44	-46	-43	0	-1	8	29	30	45
$\Delta m$ (MeV) @500 GeV	-55	-58	-54	0	-2	12	32	34	51

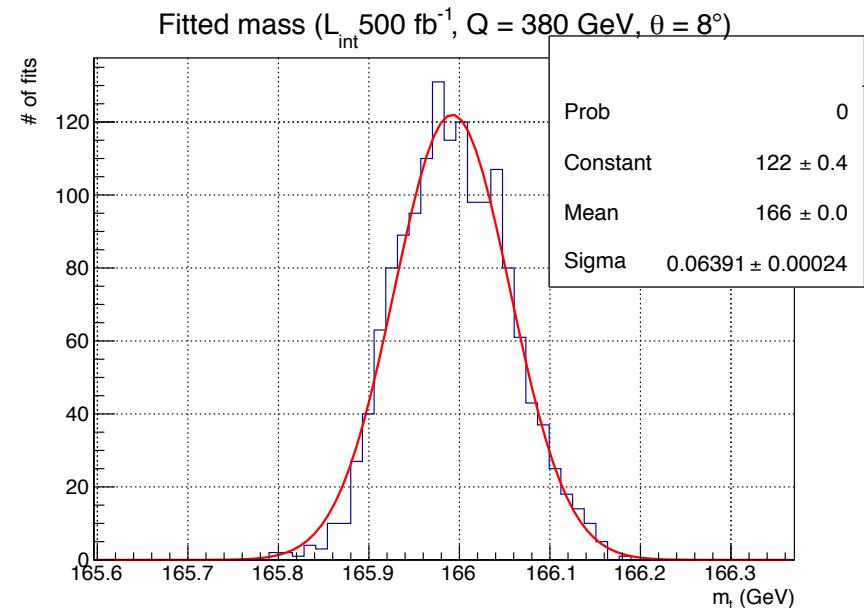
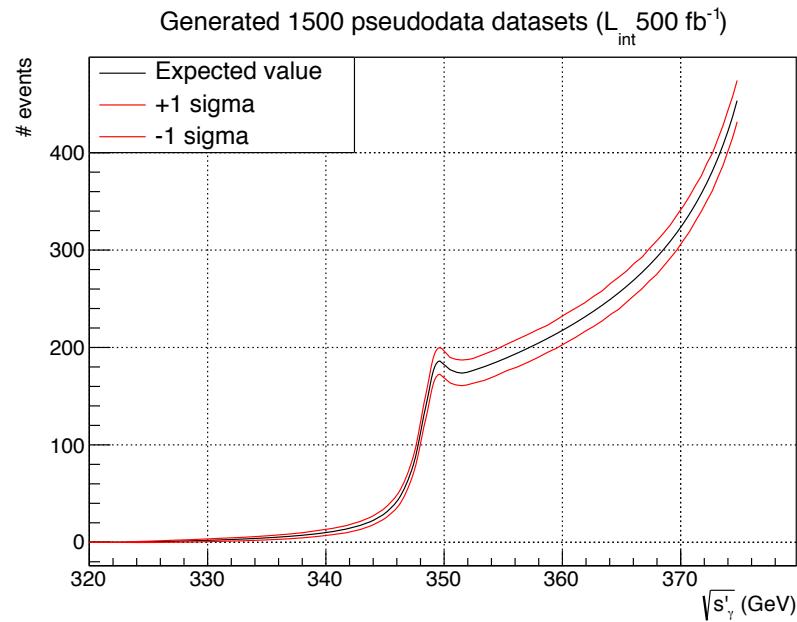


- We evaluate the theoretical uncertainty by fitting the model (at 380/500 GeV, 500 fb<sup>-1</sup>) with modified scales and a given top mass (166 GeV) to the same model with the nominal scales and with the top mass as a fit parameter.
- The fits lead to an estimation of ~50 MeV theoretical uncertainty for the model at both energies.

# SENSITIVITY TO THE TOP QUARK MASS

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- In order to evaluate the sensitivity of the observable to the top mass we generate pseudo data of certain luminosities.
- We assume that the real number of events in that bin will follow a Poisson distribution with a mean equal to the multiplication of the cross section expected for each of the bins by the integrated luminosity.
- By generating thousands of datasets and fitting them to the theoretical model we obtain thousands of values for the mass, which then are used to fill a histogram.
- Then we fit the histogram to a gaussian and we estimate the precision for the mass measurement as its sigma.



# SENSITIVITY TO THE TOP QUARK MASS (II)

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Considering a detector coverage of  $6^\circ < \theta < 174^\circ$

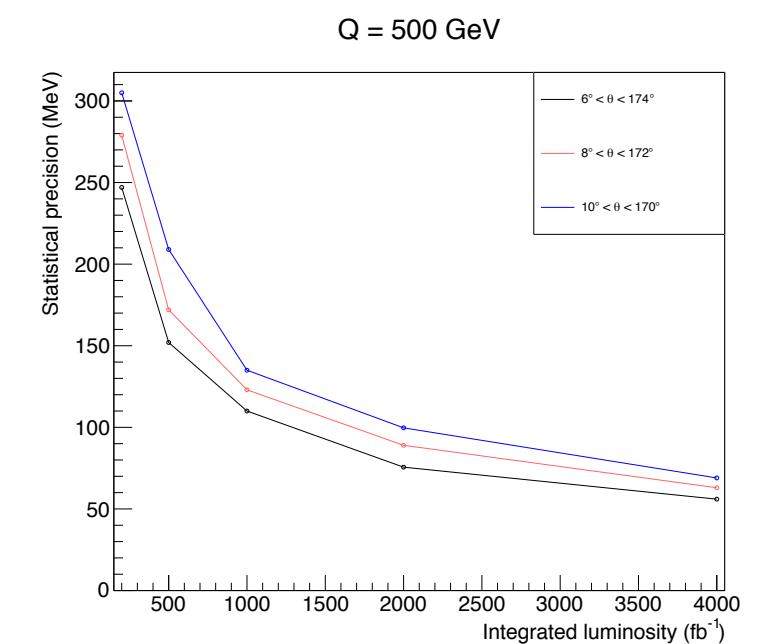
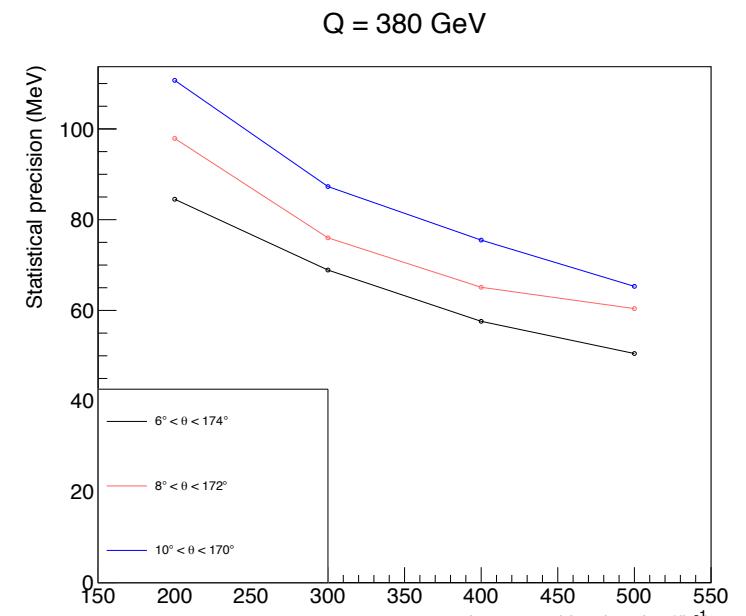
	200 fb $^{-1}$	500 fb $^{-1}$	1000 fb $^{-1}$	4000 fb $^{-1}$
$\sigma_m$ (MeV) @380 GeV	85	50		
$\sigma_m$ (MeV) @500 GeV	247	152	110	56

Considering a detector coverage of  $8^\circ < \theta < 172^\circ$

	200 fb $^{-1}$	500 fb $^{-1}$	1000 fb $^{-1}$	4000 fb $^{-1}$
$\sigma_m$ (MeV) @380 GeV	98	60		
$\sigma_m$ (MeV) @500 GeV	279	172	123	63

Considering a detector coverage of  $10^\circ < \theta < 170^\circ$

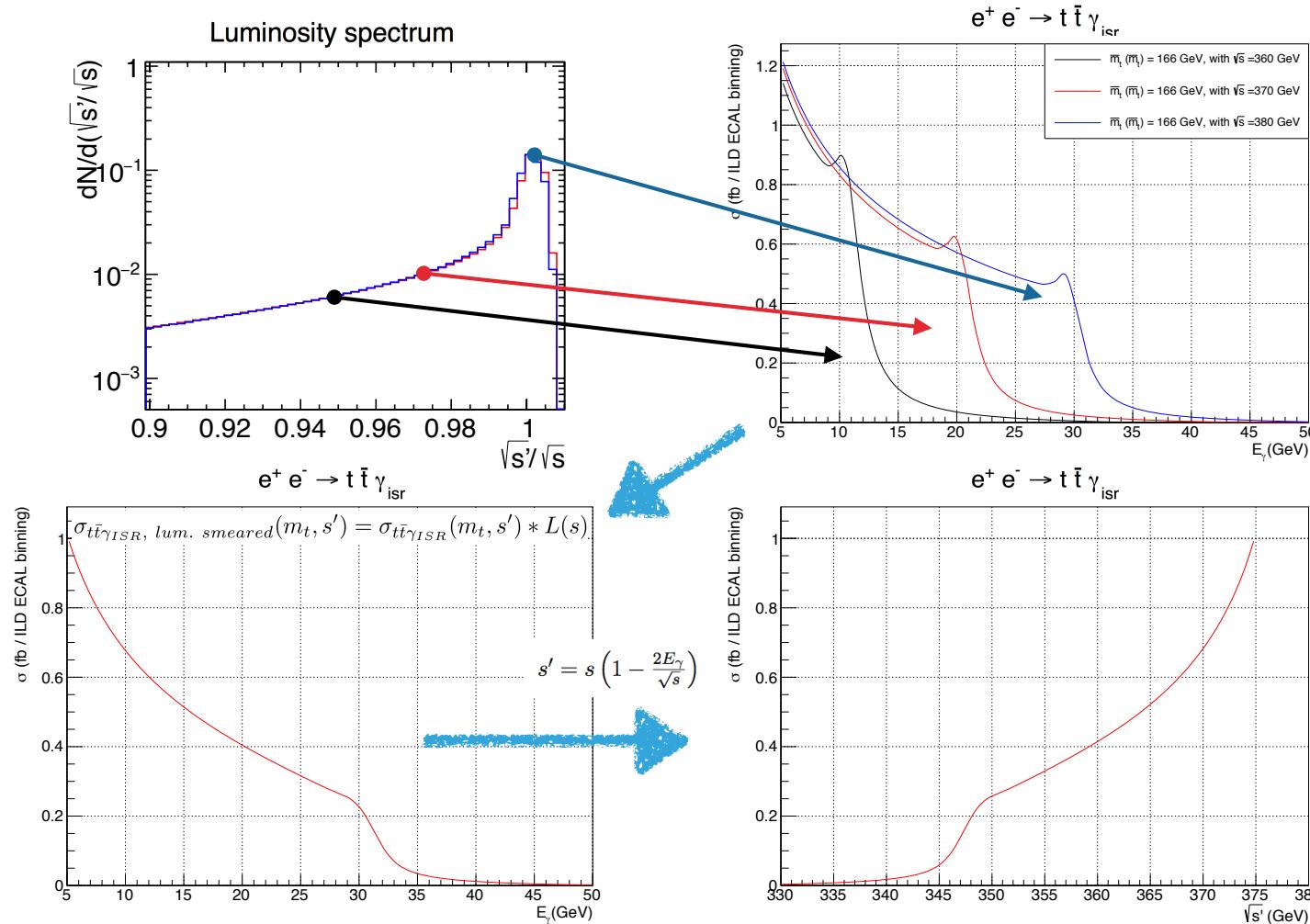
	200 fb $^{-1}$	500 fb $^{-1}$	1000 fb $^{-1}$	4000 fb $^{-1}$
$\sigma_m$ (MeV) @380 GeV	111	65		
$\sigma_m$ (MeV) @500 GeV	305	209	135	69



# LUMINOSITY SPECTRUM WEIGHTING

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- In the experiment,  $s$  isn't fixed to 380 GeV, but instead, it has a spectrum. To account for that, we fold our model with the luminosity spectrum.



- We weight our observable distributions of a given  $Q$  with the luminosity spectrum.