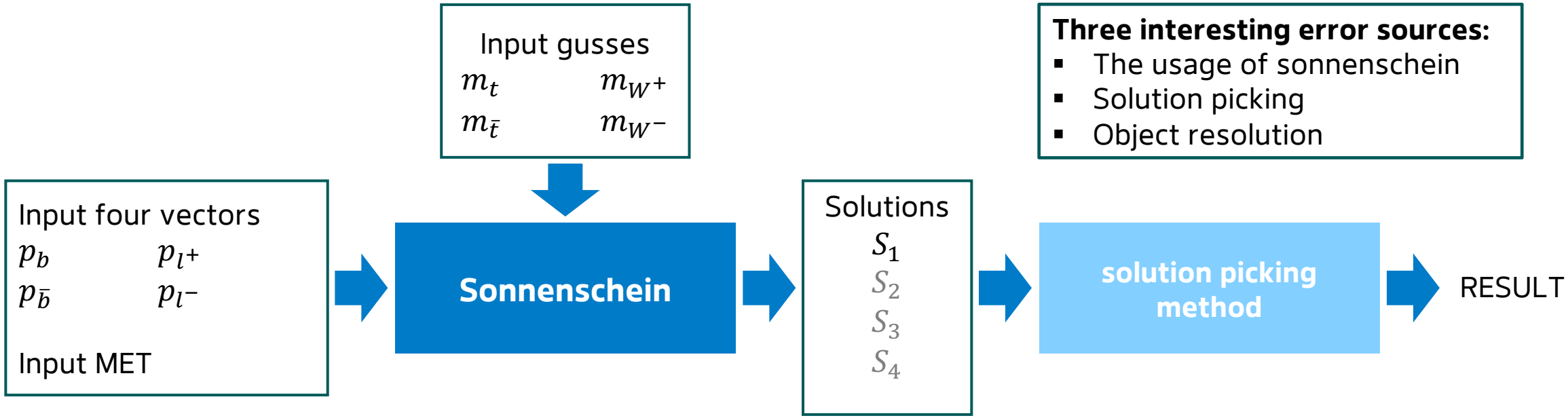
Introduction

Underling task: Investigation on reconstructing ttbar system from dilepton decay channel using the sonnenschein algorithm

Problem: Escape of the neutrinos leads to six unknown components (momenta)

Sonnenschein: analytical method to solve for the neutrino momenta exactly without any numerical/iterative fitting



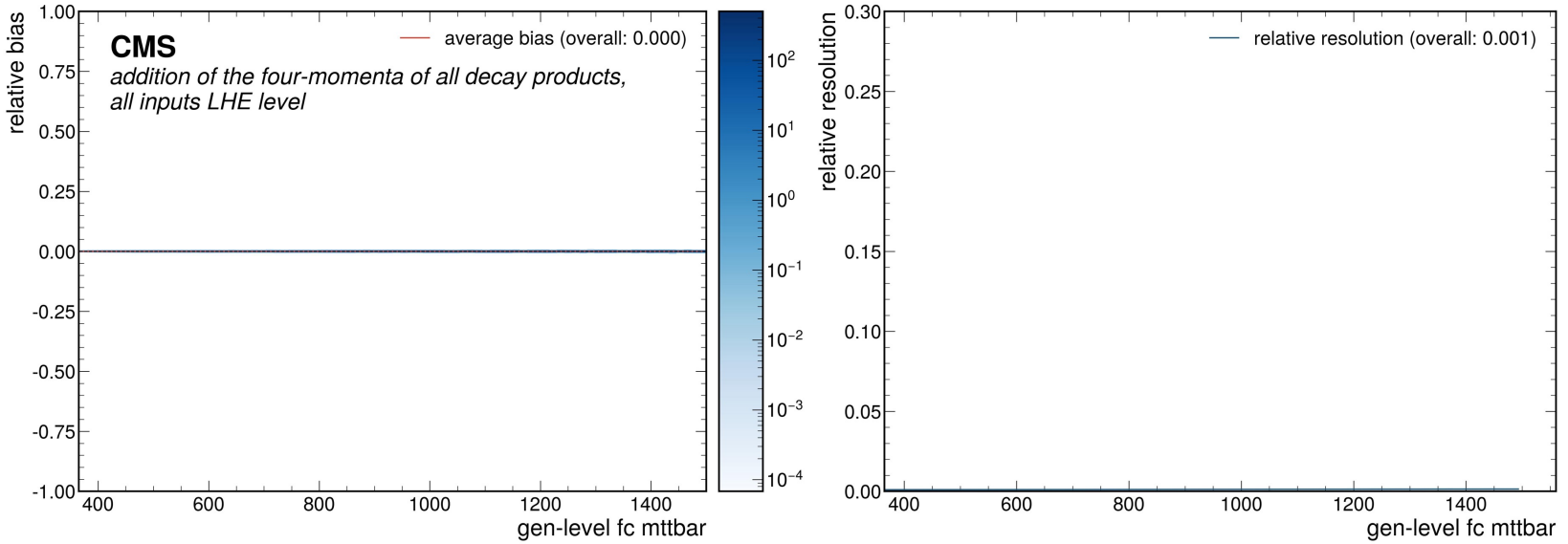
Source One: The algorithm

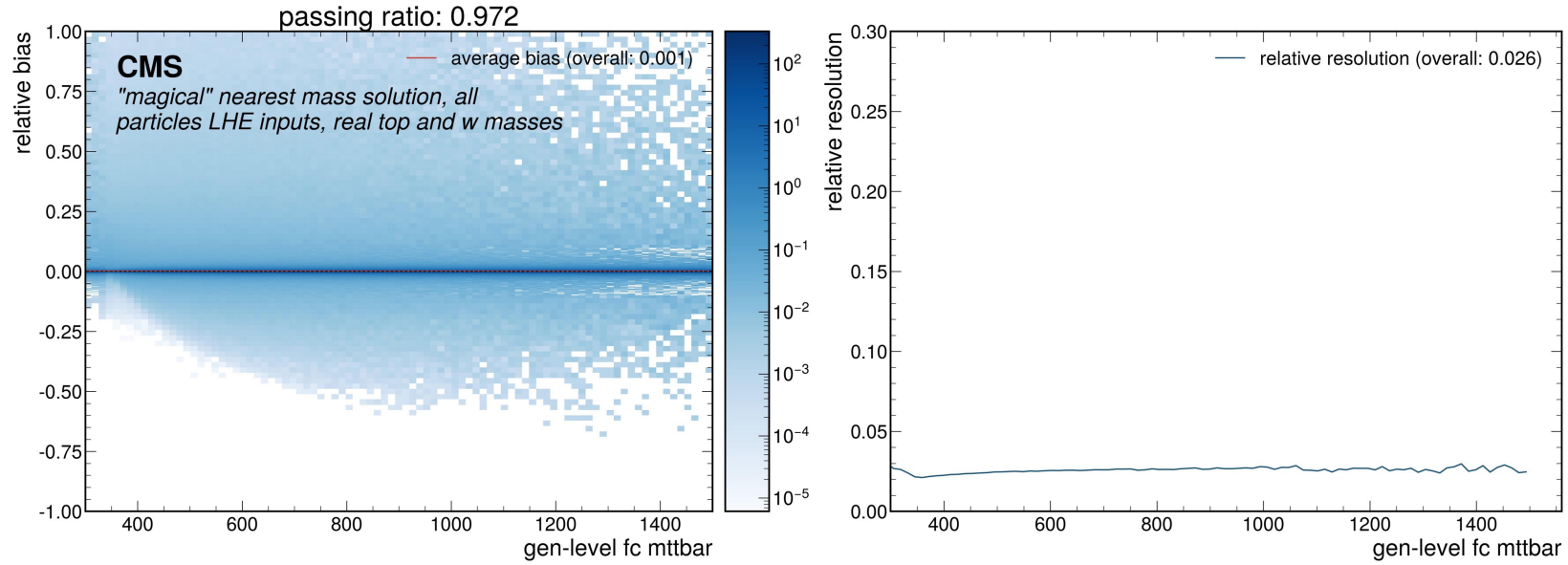
Perfect circumstances:

- POWHEG LHE level four vectors for b, $\bar{b}$, l^+, l^-
- MET from the LHE four vectors of neutrinos
- "perfect guess" for m_t, $m_{\bar{t}}$, m_{W^+}, m_{W^-} (truth level values)
- "magic" solution picking of closest-to-truth-mass solution

Four momenta addition leads to near perfect reconstruction

Usage of sonnenschein with the same input leads to some misreconstruction





Source one: The algorithm

Adding up the four momenta leads to perfect precision, but taking these same four momenta as inputs for sonnenschein leads to misreconstructions

Examination of some misreconstructed events showed:

- **Tiny rounding** (due to inherent limitation of finite floating points) are irrelevant for the addition of the four momenta
- In the multitude of calculations in the sonnenschein algorithm they can **multiply** quite heavily
- This **numerical effect** leads to misreconstruction

There is one particular problem in case of multiple solutions:

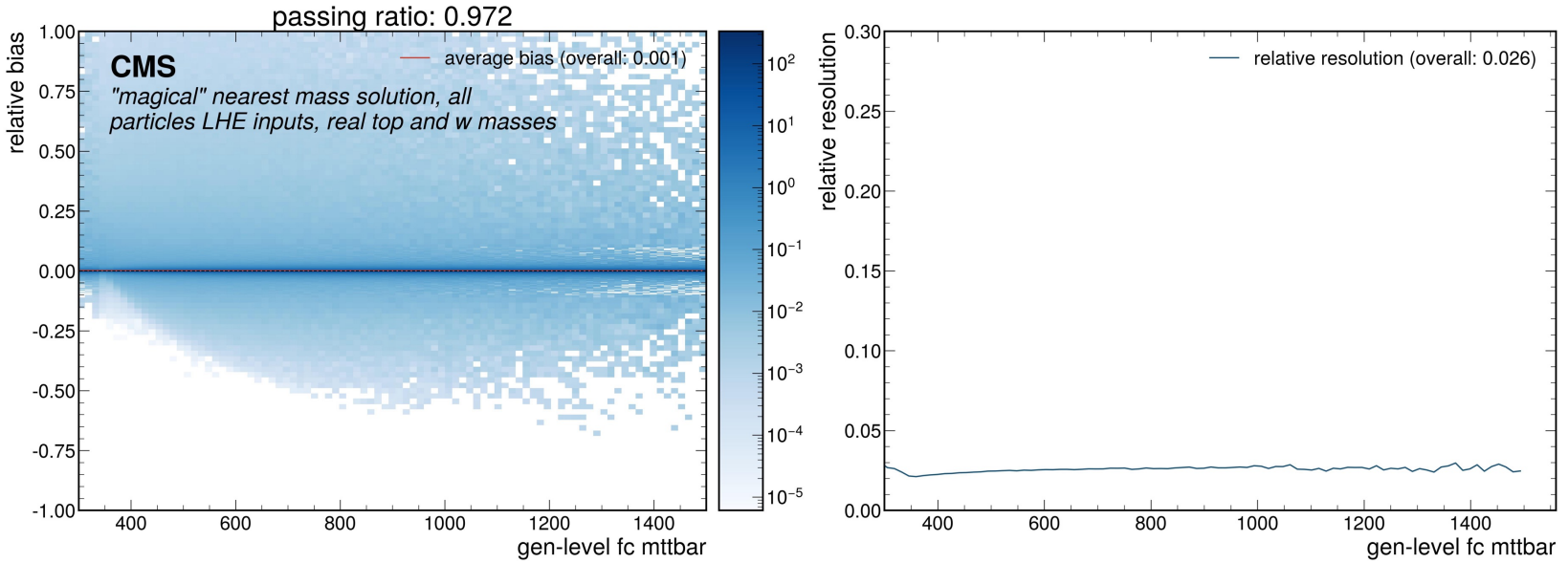
- For the calculation of the neutrino momentum a **root** is taken
- Due to the numerical effects the radicand of the true solution can get negative leading to **imaginary momentum**
- Because this is unphysical sonnenschein is built to **ignore** these solutions
- The true **solution is lost** completely
- Left with the other solutions sonnenschein **selects the next closest solution** which is wrong

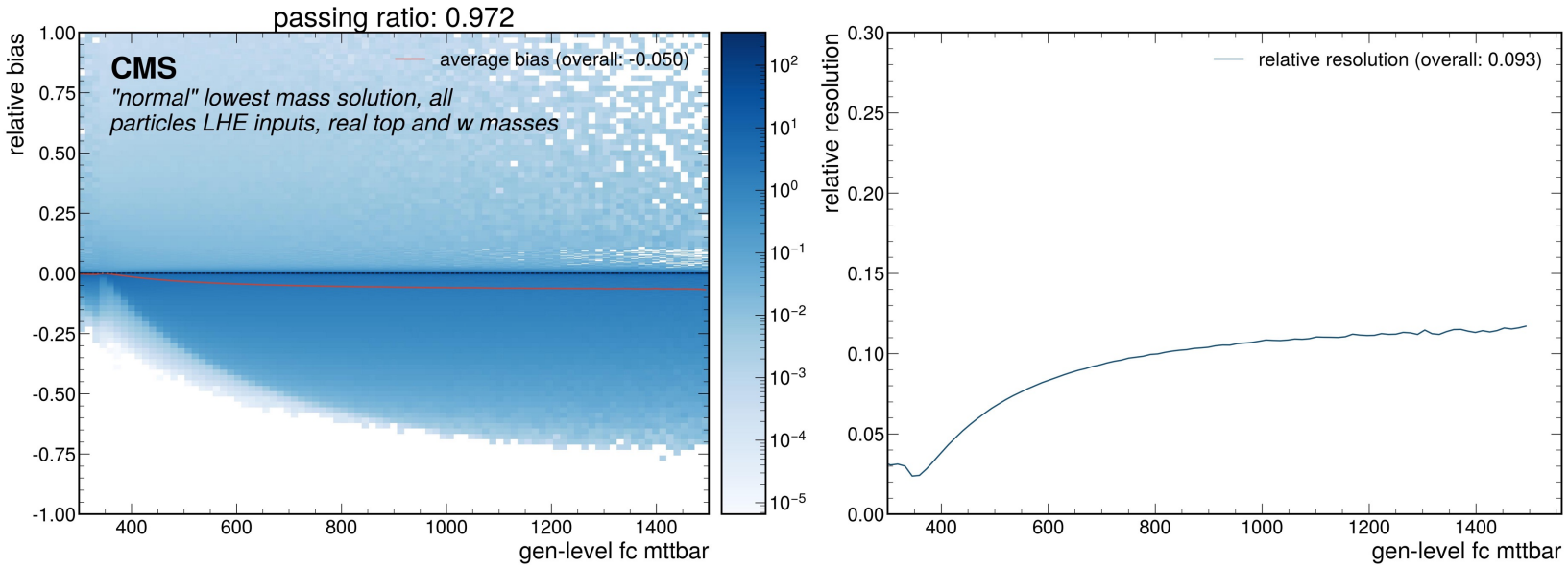
Source Two: The solution picking

- Quadric equation can result in up to four solutions for the system
- A selection of one solution must be performed

"Magical" method:
Calculate mttbar for all solutions
Take the one with min($m_{pred} - m_{real}$)

"Normal" method:
Calculate mttbar for all solutions
Take the one with min(m_{pred})





Source two: The solution picking

The method of solution picking currently used has an understandable and easy implementable criterion on selecting one solution but performs badly especially in high mass regimes of mttbar

- Small to no difference in low mttbar regimes between magic and normal solution picking
- Relevant difference in high mttbar regimes

Reason for this relevance of mttbar:

- The reconstruction with sonnenschein has one bound for the resulting mttbar
- This is a lower bound: at least the resting mass of the input top mass guesses
- Irrelevant in cases where mttbar is in principle just the addition of the top resting masses
- Relevant in high mass regimes where mttbar is not just the addition of the tops resting masses

Source three: Object resolution

Increase in object resolution increases the resolution and decreases the passing ratio. Most relevant is the resolution increase on the b quarks. Jets perform better in reconstruction then last copy quarks

Central top mass, 100 times sampled W mass, magic solution

l^+	LHE		l^+	Gen lc		l^+	Gen lc		l^+	Gen lc		l^+	detector	
l^-	LHE		l^-	Gen lc		l^-	Gen lc		l^-	Gen lc		l^-	detector	
b	LHE		b	Gen lc		b	GenJets		b	GenJets		b	detector	
$\bar{b}$	LHE		$\bar{b}$	Gen lc		$\bar{b}$	GenJets		$\bar{b}$	GenJets		$\bar{b}$	detector	
MET	LHE neut add		MET	Gen lc neut add		MET	Gen lc neut add		MET	GenMET		MET	detector	
Bias		0.1%	Bias		5.6%	Bias		5.3%	Bias		6.7%	Bias		-2.0%
Resolution		2.6%	Resolution		19.2%	Resolution		17.5%	Resolution		19.1%	Resolution		23.7%
Passing ratio		97.2%	Passing ratio		87.9%	Passing ratio		87.0%	Passing ratio		82.5%			

Increasing realism, increasing object resolution

- Most relevant change: LHE to Gen lc
- Detailed analysis shows most impactful effect is change from LHE b quarks to GenJets
- Gen lc in most realistic form with normal solution picking reaching resolution of 23%
- Effect of detector nearly irrelevant

Possible improvements

There are possible improvements to be made with the sonnenschein algorithm by usage of neural networks for different tasks, take some of the beauty of sonnenschein away but improving the reconstruction

Figure out a way of making sonnenschein numerically robust: The numerical artifacts in idealized circumstances shows the numerical sensitivity of the algorithm to small changes in input parameters

Implementing a magic solution finder: Outsource the task of picking a solution in case of multiple solutions to a neural network, which could fit the presumably high-level criterion on what makes a right solution