Interferences in the $t\bar{t}$ invariant mass spectrum

Markus Mechtel

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Motivation

- $t\bar{t}$ resonances predicted by many models
- $t\bar{t}$ resonances influence shape of $t\bar{t}$ invariant mass spectrum

$\Rightarrow$ study $t\bar{t}$ invariant mass spectrum to look for signals of resonances

- many models predict interference between resonance production and SM processes
- interference hardly respected yet

$\Rightarrow$ **How does an interference change the significance ?**

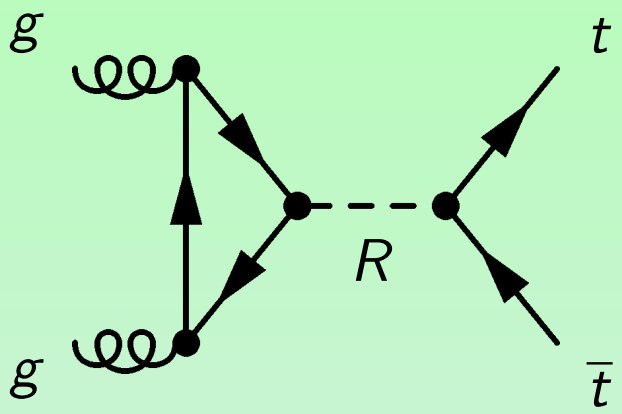
Candidates for Resonance

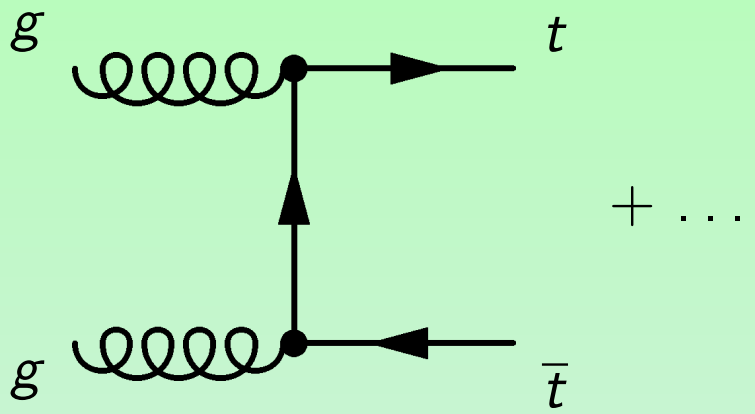
Spin	color	parity $(1,\gamma_5)$	some examples	Interf.
0	0	(1,0)	SM, MSSM, 2HDM	×
0	0	(0,1)	MSSM, 2HDM	✓
0	8	(1,0), (0,1)	techni-π^0	×
1	0	(SM,SM)	Z'	×
1	0	(1,0), (0,1), (1,$\pm$1)	vector	✓
1	8	(1,0)	coloron, KK gluon	✓
1	8	(0,1)	axigluon	×
2	0	–	KK graviton	✓

[Frederix, Maltoni: JHEP01(2009)047]

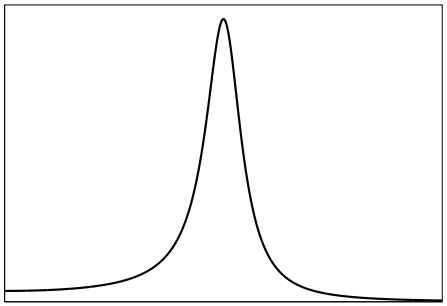
- interference depends on resonance properties and model
- strongest interference with vector/pseudoscalar resonances

Usual Approach without Interference

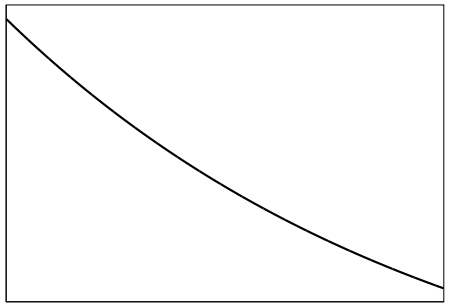




Signal

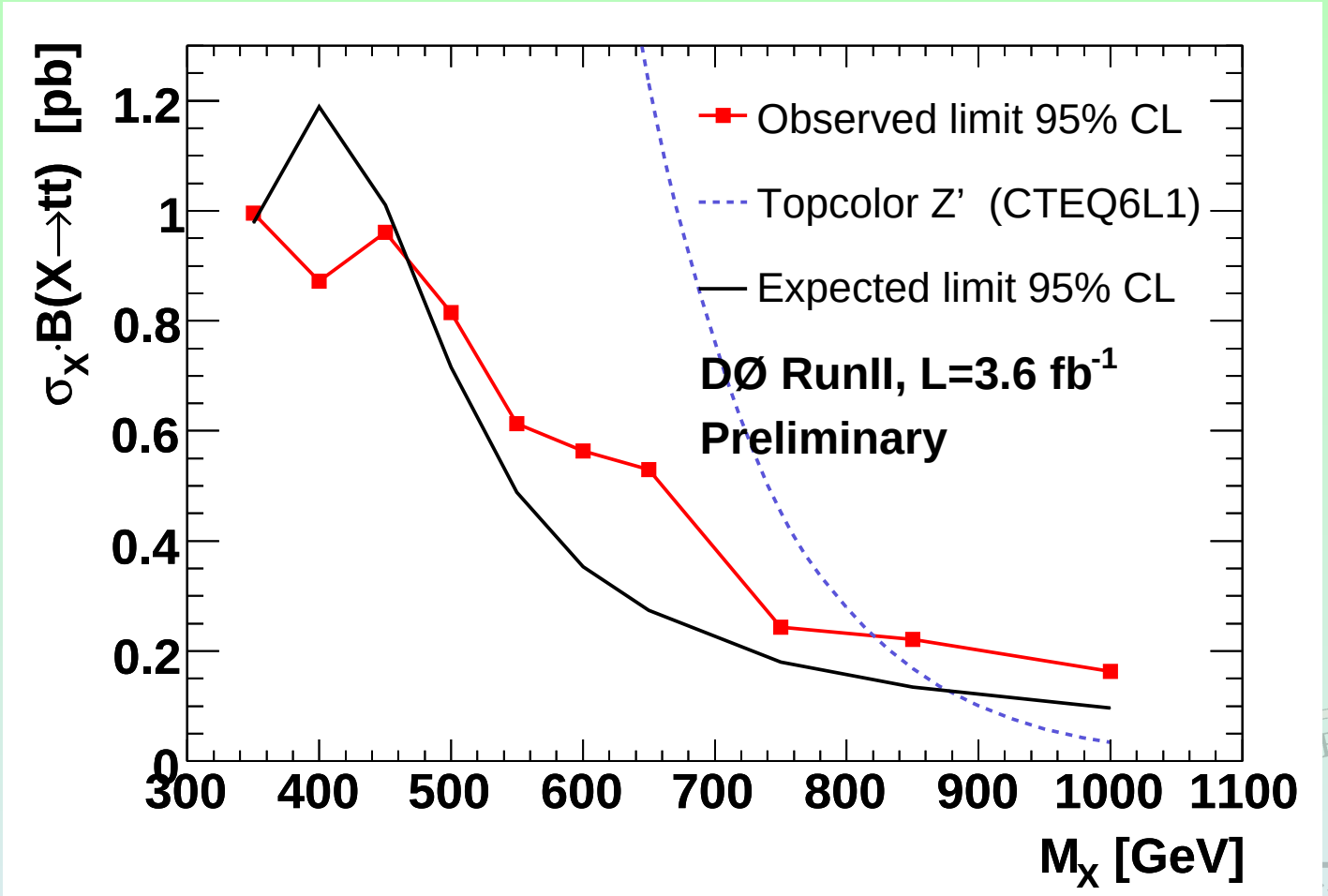


Background



separate calculations for signal and background processes

$t\bar{t}$ Resonances at DØ

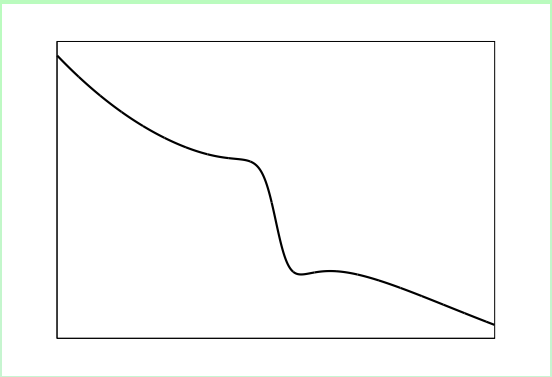


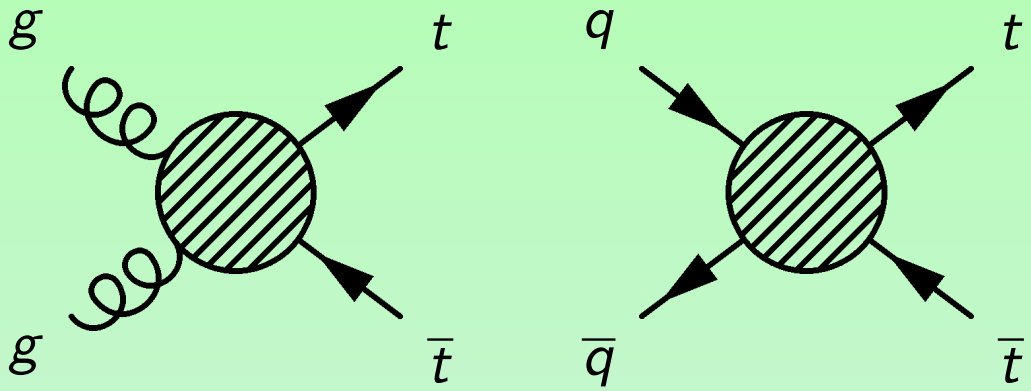
$M_{Z'} < 820$ GeV excluded at 95% CL

$\Gamma_{Z'} = 0.012 M_{Z'}$
no interference for Z'

[Schliephake, Wicke]
DØ note 5882-CONF

Interference





Processes with identical initial and final states require common handling in matrix element

$$\begin{aligned} |\mathcal{M}|^2 &= |B+S|^2 \\ &= |B|^2 + |S|^2 + \underbrace{2 \cdot \mathrm{Re}\left(B\overline{S}\right)}_{\text{Interference}} \end{aligned}$$

Interference (QCD $\leftrightarrow$ resonance) usually ignored, but may be large and have to be taken into account for some models

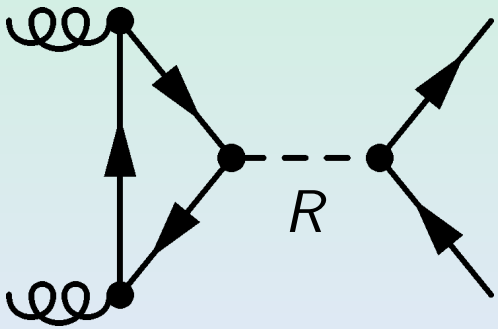
e.g. [Bernreuther, J. Phys. G **35** (2008) 083001]

Considered Models

This talk concentrates on two models with large interferences.

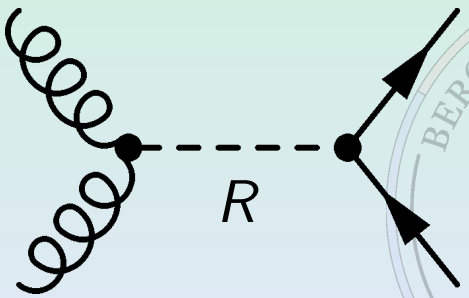
pseudoscalar Higgs

- pseudoscalar particle
- SM Higgs coupling
- no color charge
- mass 400 GeV
- width 4 GeV
- "narrow resonance"
- main production process



Coloron

- vector particle
- SM strong coupling
- color octet
- mass 1 TeV
- width 10 GeV
- "heavy gluon"
- main production process

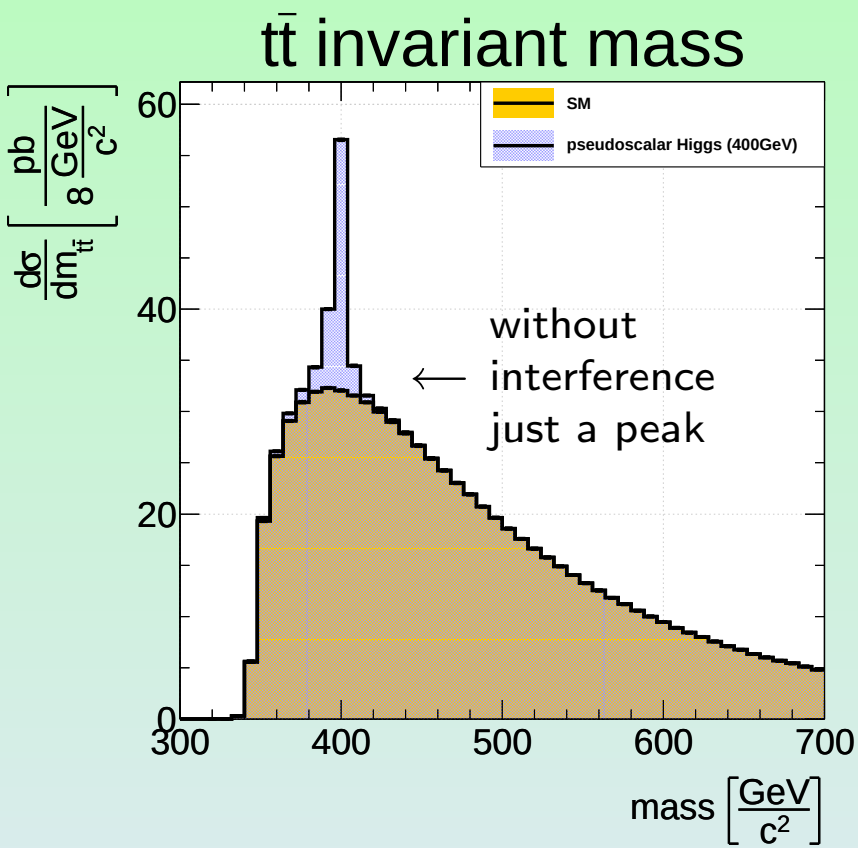


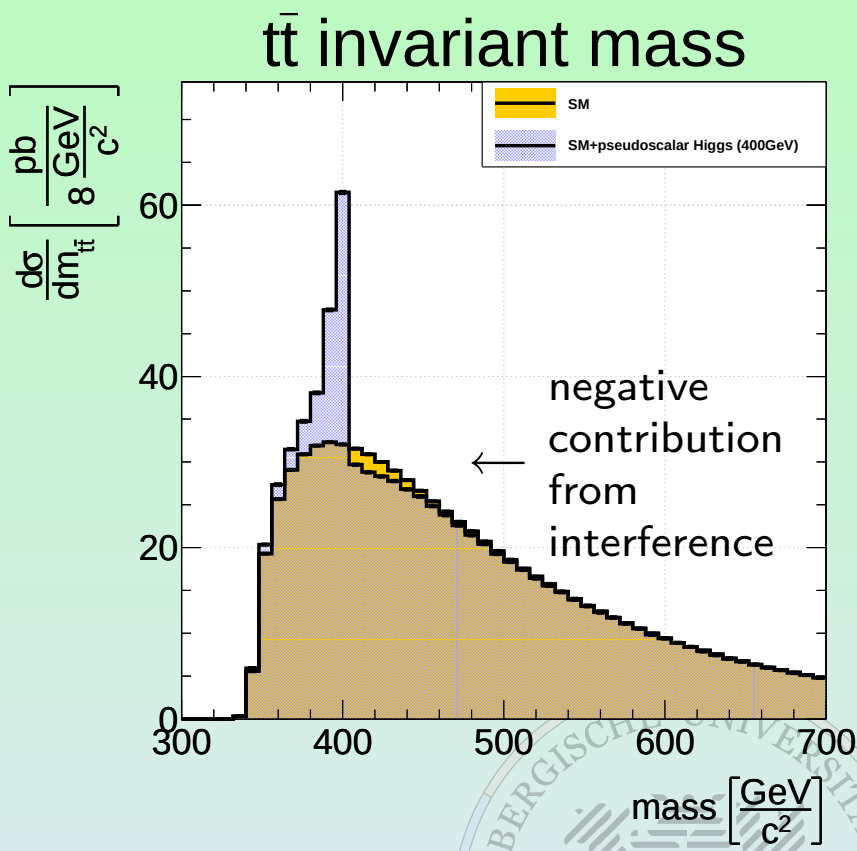
MC Calculations done with Herwig++ 2.4.0

Influence of Interference

example: SM $t\bar{t}$ + pseudoscalar Higgs (400 GeV)

at $t\bar{t}$ parton level

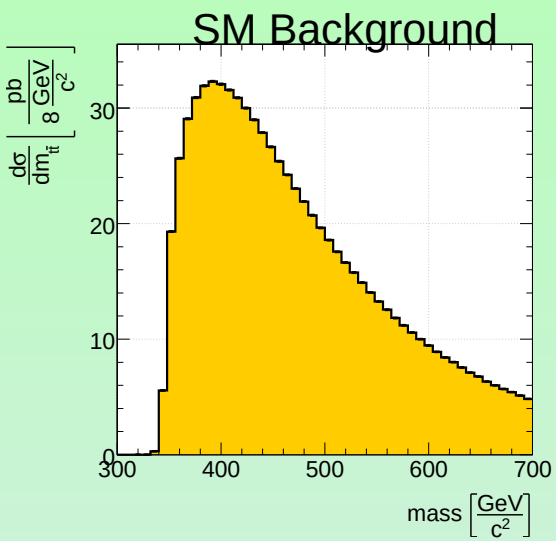




- interference leads to peak-dip-structure
- peak appears enhanced

$\Rightarrow$ interference can have strong impact on spectrum

Pseudoscalar Higgs (400 GeV) – $t\bar{t}$ parton level



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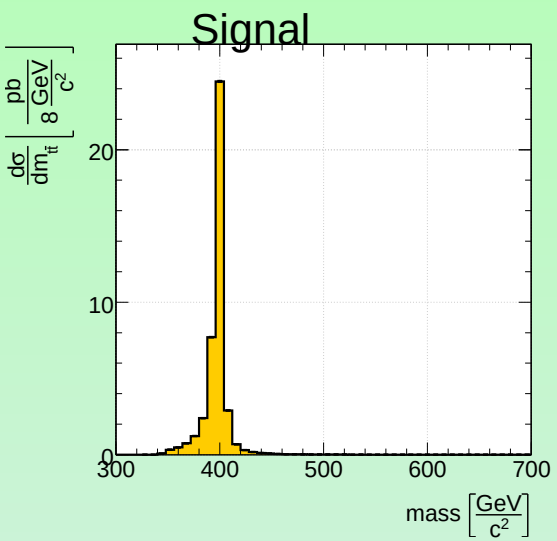

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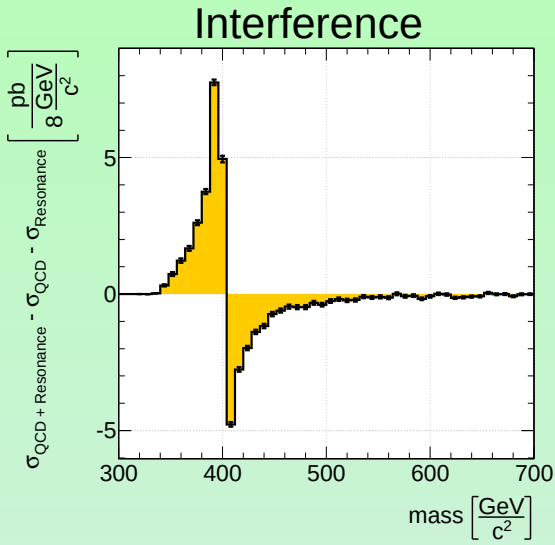

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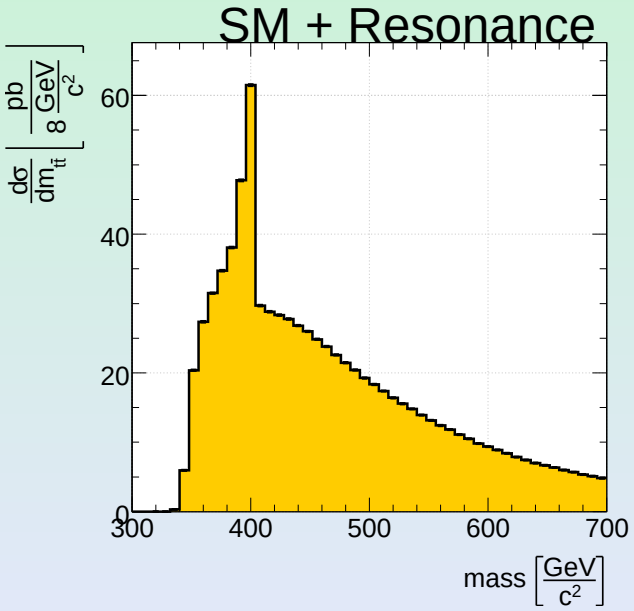
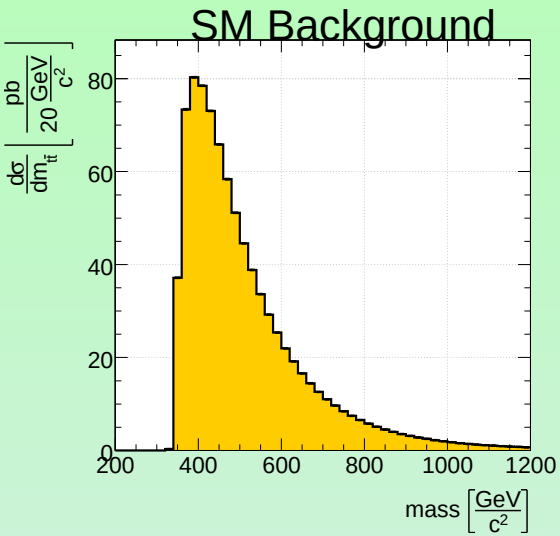


- decomposition
  $|B+S|^2 =$
  $|B|^2 + |S|^2 + 2 \cdot \mathrm{Re}\left(B\overline{S}\right)$
- additional contribution from interference
- size of interference comparable to signal

Coloron (1 TeV) – $t\bar{t}$ parton level



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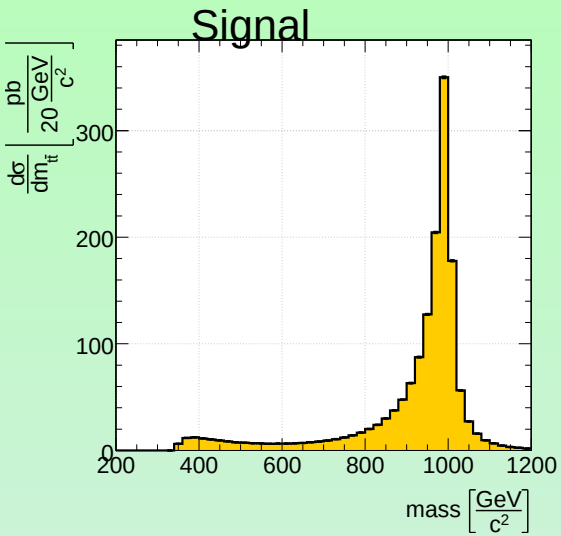

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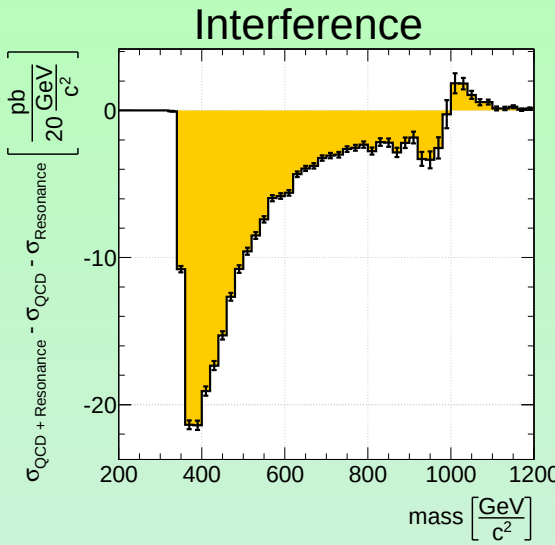

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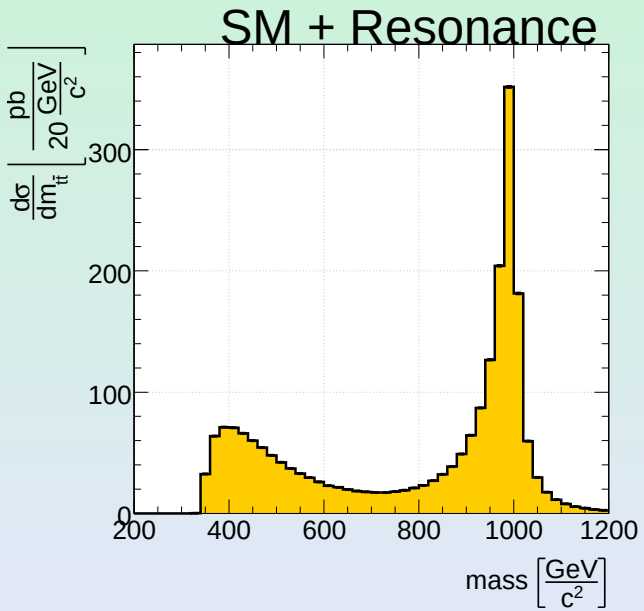


- negative interference with SM $t\bar{t}$ continuum decreases total cross section

$$\sigma_B + \sigma_S = 2386\text{pb}$$
$$\sigma_{B+S} = 2169\text{pb}$$

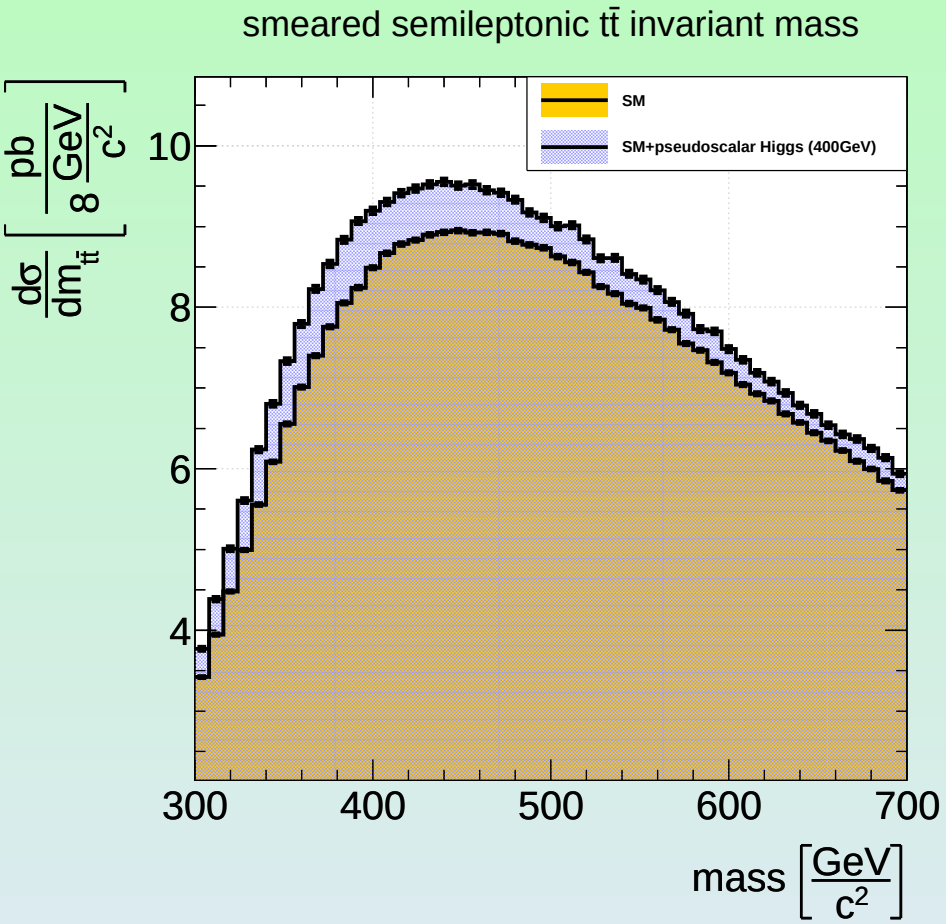
- dip-peak structure near resonance mass

Estimation of Detector Effects

- simulation of detector energy resolution
  - Anti-K_T jet algorithm from particle momenta
  - smearing MC jet energy
  - $(\not{E}_T)_{x,y} = (\sum p_\nu)_{x,y}$

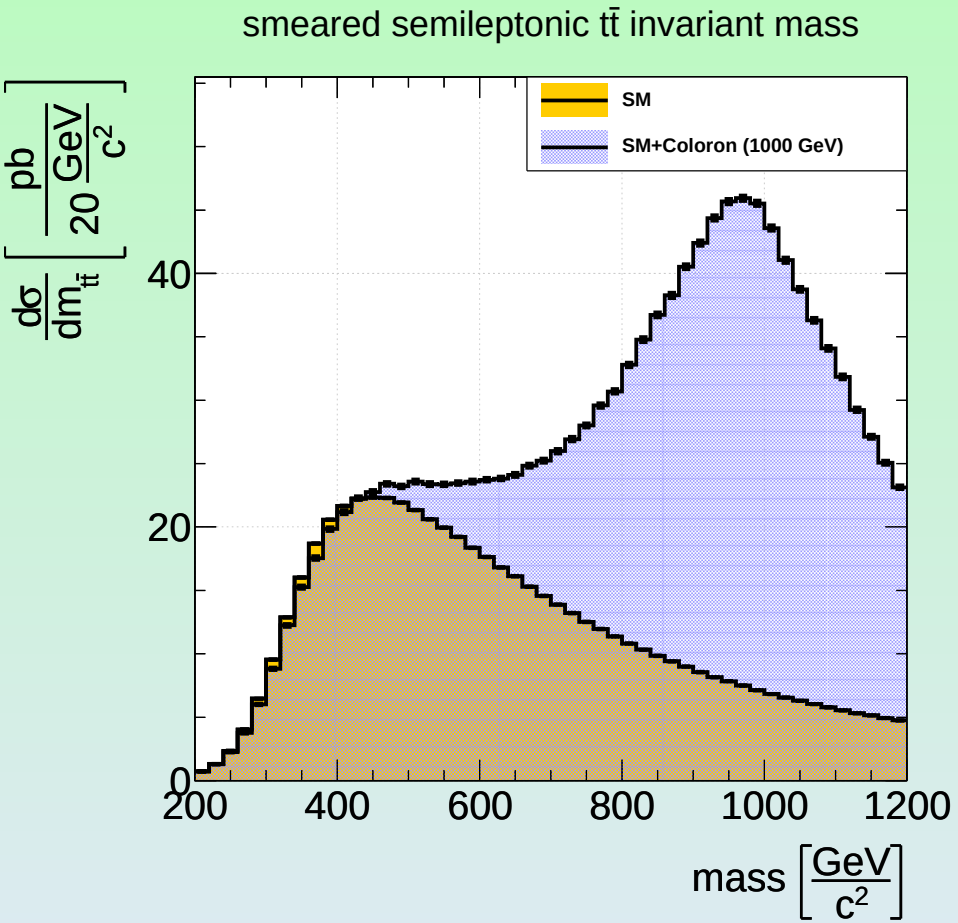
  $\longrightarrow$ to be improved by generic detector simulation
- semileptonic $t\bar{t}$ reconstruction
  - e, μ with highest p_T
  - kinematic fit for leptonic W momentum
  - 4 jets with highest p_T

Pseudoscalar Higgs (400 GeV) – Reconstruction



- negative interference does not survive semileptonic reconstruction
- main difference: increased cross section
- Interference also causes increased difference in shape

Coloron (1 TeV) – Reconstruction



- negative interference decreases total cross section

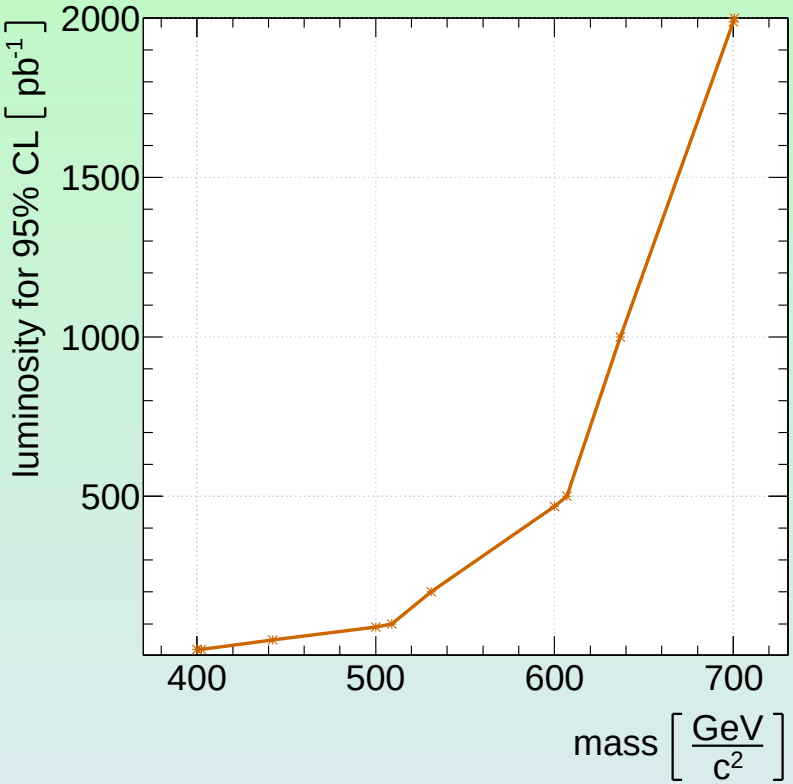
$$\sigma_B + \sigma_S = 2386\text{pb}$$
$$\sigma_{B+S} = 2169\text{pb}$$

- huge signal allows exclusion of colorons up to $m \lesssim 5$ TeV even with $\sim 100 pb^{-1}$ (no systematics included)

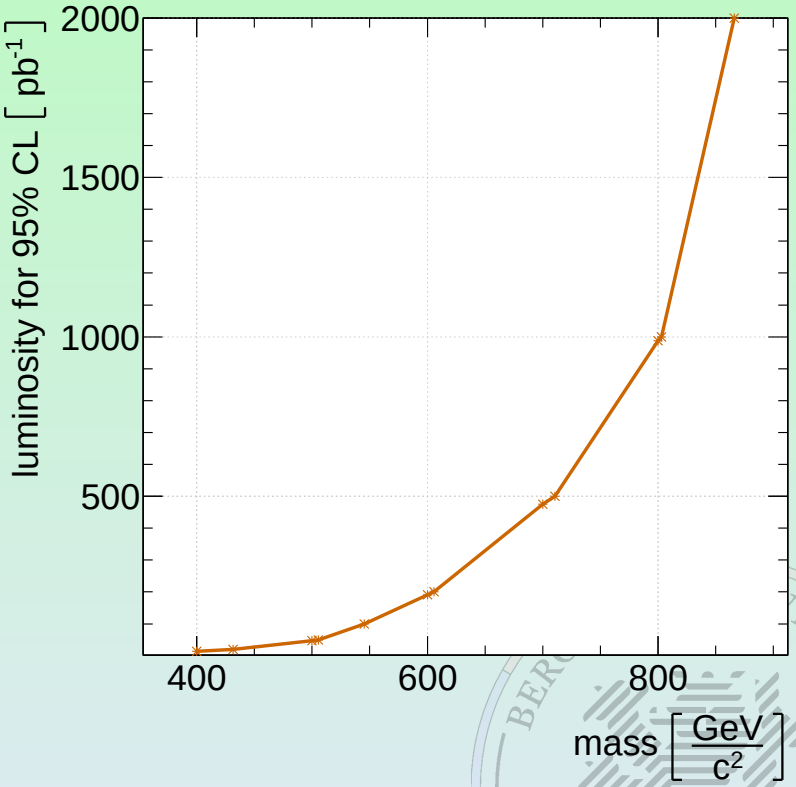
Pseudoscalar Higgs – Limit Calculation

exclusion limits based on a modified frequentist approach

without interference



with interference



- efficiency: 10%
- no systematic uncertainties

expected exclusion limit with $100 pb^{-1}$ @ 95% CL

- without interference: $m \lesssim 510$ GeV
- with interference: $m \lesssim 550$ GeV

Summary & Outlook

Summary

- $t\bar{t}$ resonances can interfere with Standard Model $t\bar{t}$ processes
- interference affects measured $t\bar{t}$ invariant mass spectrum
- interference can increase/decrease significance of a resonance signal

Outlook

- generic detector simulation
- investigation of detector effects on sensitivity
- systematic uncertainties will decrease sensitivity