FCC-hh Physics meeting summary

Michele Selvaggi
CERN

Agenda

15:30 → 15:45 **Introduction** 15m

Speakers: Filip Moortgat (CERN) , Heather Gray (LBNL)

FCC_Intro_April28.p...

15:45 → 16:00 **Status of MC samples** 15m

Speaker: Michele Selvaggi (CERN)

sampleprod_280420...

16:00 → 16:20 **Higgs properties** 20m

Speaker: Michele Selvaggi (CERN)

higgs_28042017.pdf

16:20 → 16:40 **Update on HH->bbWW** 20m

Speaker: Biagio Di Micco (Universita' degli Studi di Roma Tre e Istituto Nazionale di Fisica Nucleare (INFN))

Pres_FCC_hh_WS.pdf

16:40 → 17:00 **Disappearing Track studies** 20m

Speaker: Masahiko Saito (University of Tokyo (JP))

DisappearingTrack_...

FCC week

Filip Moortgat
Heather Gray

We have been assigned a 90' slot at the FCC week in Berlin (Thursday morning)

https://indico.cern.ch/event/556692/timetable/#20170601

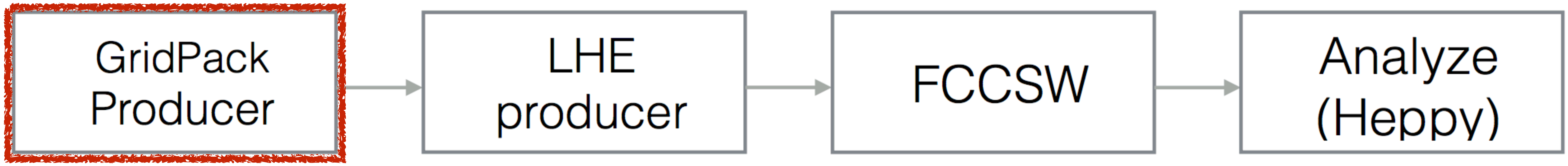
First draft of the agenda:

0) Introduction (5'): Filip/Heather
1) Dark Matter searches (overview + recent progress): Phil Harris (20')
2) Di-Higgs studies (bbgg + bbWW): Biagio Di Micco (tbc) (15')
3) Higgs properties : Michele Selvaggi (20')
4) Stop Searches: speaker from Incandela group (10')
5) Top FCNC: (tbc) (10')
6) Disappearing Track: Ryu Sawada (10')

Note: All results shown in Berlin should be (or have been) presented in a WG meeting first.

GridPacks

Clement Helsens
Michele Selvaggi



Samples

H_T bins

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```

All "HT-binned" and "inclusive" gridpacks have been produced !

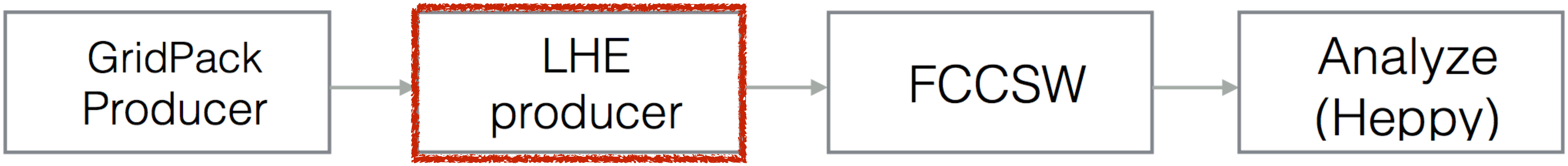
/eos/fcc/hh/generation/mg5_amcatnlo/gridpacks/

123 gridpacks in total

87 binned in HT -> 36 different processes

Les Houches Events

Clement Helsens
Michele Selvaggi



- ## LHE Producer[1]
  - Produces Les Houches Event (LHE) files using GridPacks using lxbatch queues (working on extending to HTCondor)
  - Procedure has been made more robust to allow multiple users
  - Comprehensive list of generated events can be found here:

http://fcc-physics-events.web.cern.ch/fcc-physics-events/LHEevents.php

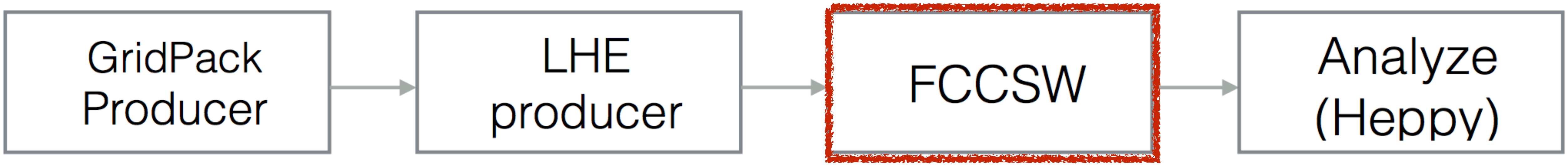
/eos/fcc/hh/generation/mg5_amcatnlo/lhe

  - With the intent of covering a large spectrum of processes, **mostly inclusive samples** have been generated but HT binned on the way
  - More than 440M events generated so far!

[1] https://github.com/clementhelsens/EventProducer

Pythia/Delphes events

Clement Helsens
Michele Selvaggi



- FCCSW Producer[1] (NEW!)
  - Runs FCCSW (**Pythia8+Delphes**) on LHE files using lxbatch queues
  - produces FCCSW n-tuples that can be analysed with Heppy

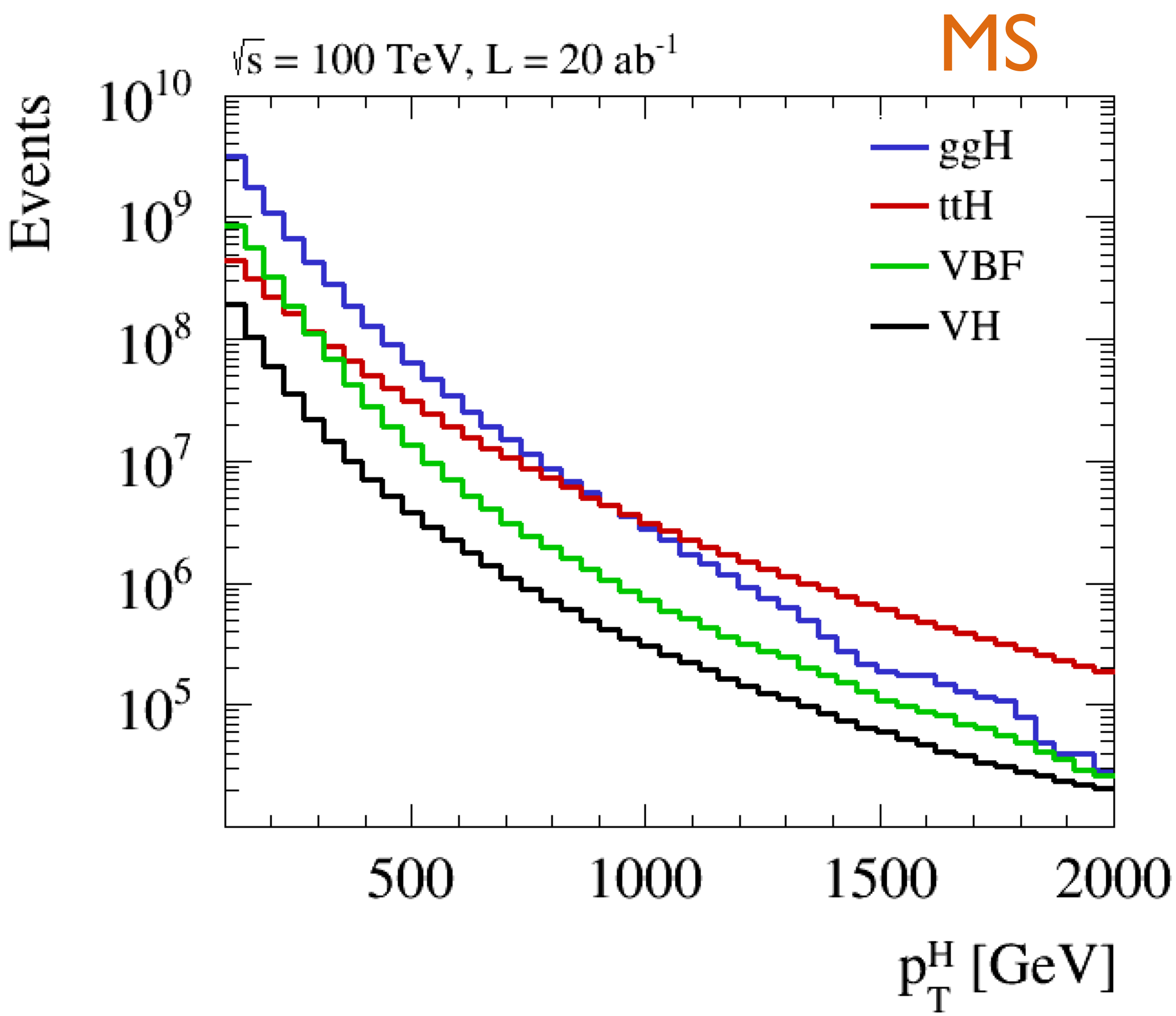
/eos/fcc/hh/generation/DelphesEvent/v0_0/

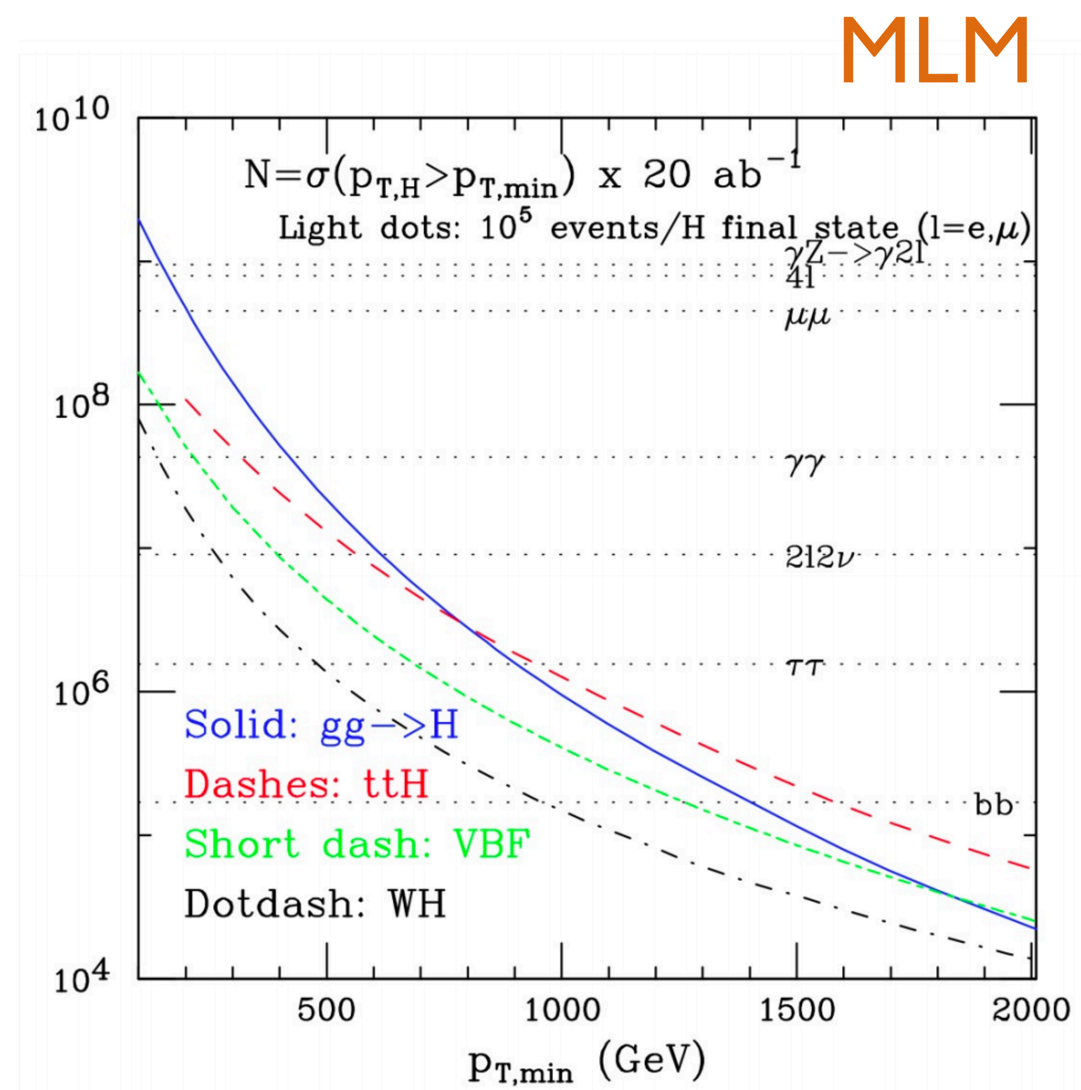
  - With the intent of covering a large spectrum of processes, **mostly inclusive samples** have been generated so far
  - More than 100M events generated!

[1] https://github.com/clementhelsens/EventProducer

Higgs $N(p_T > p_{T,min})$ (I)

Michele Selvaggi

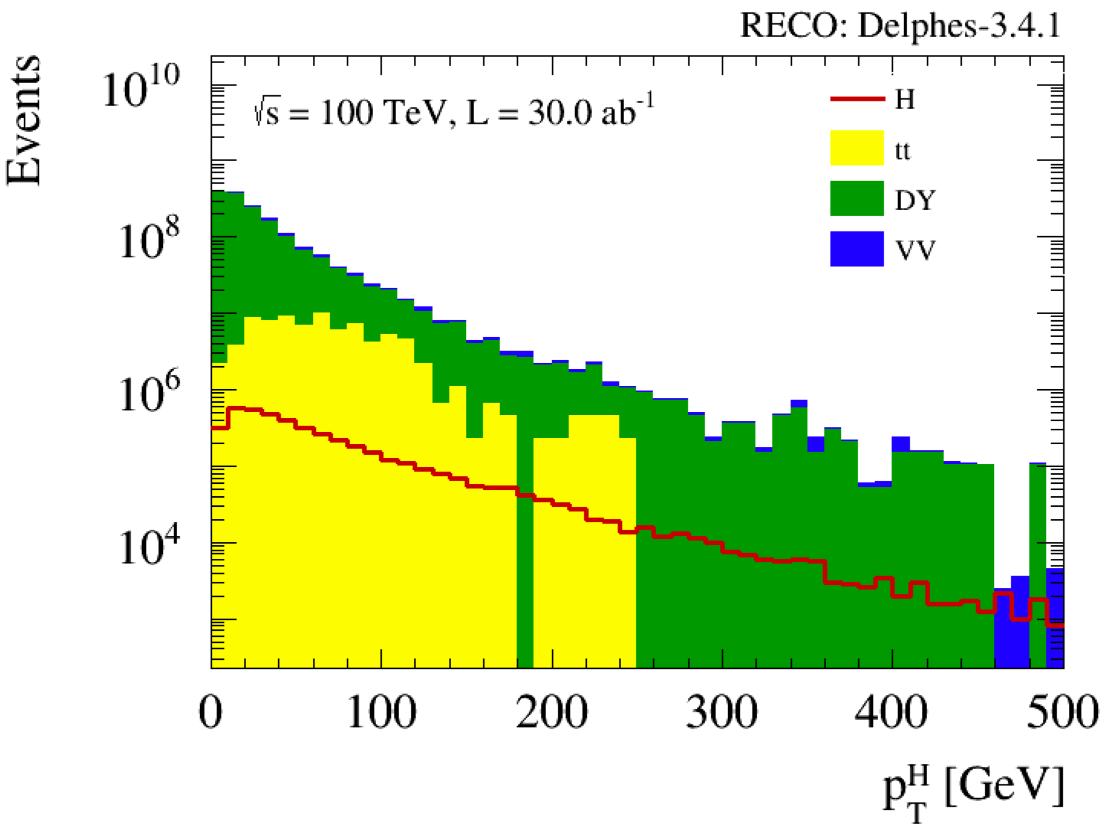


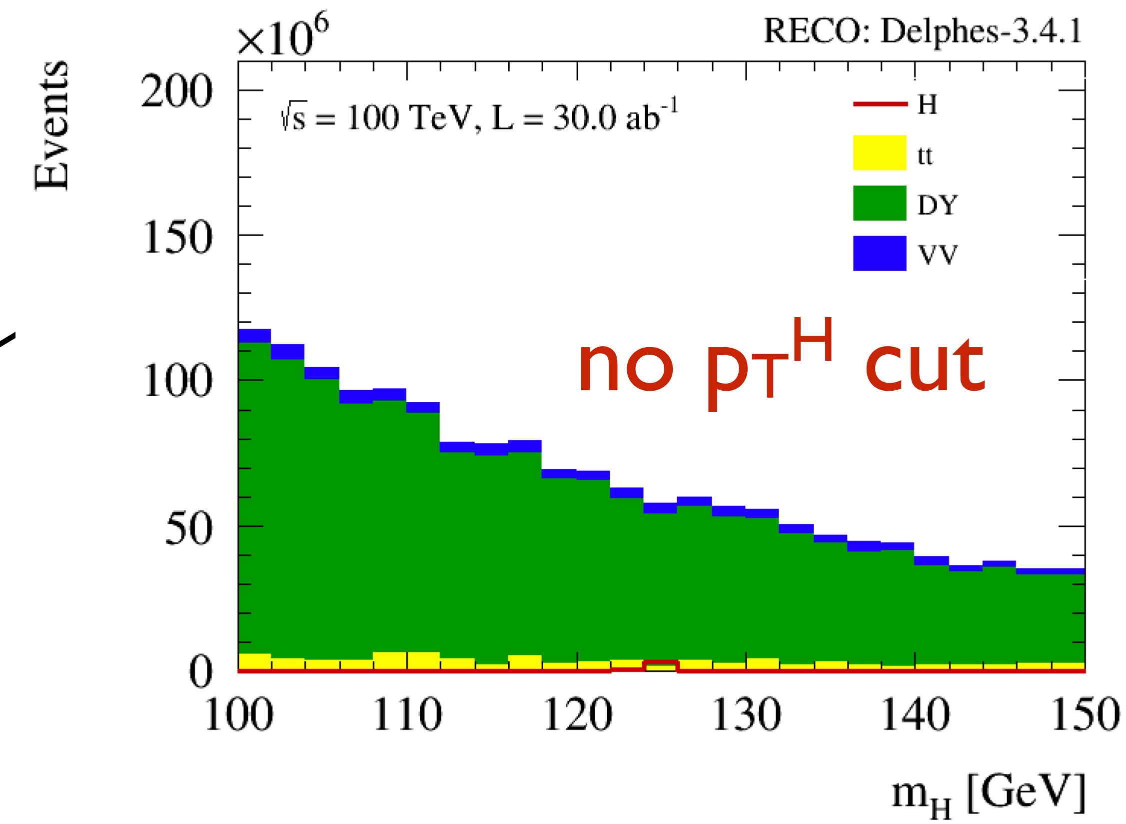


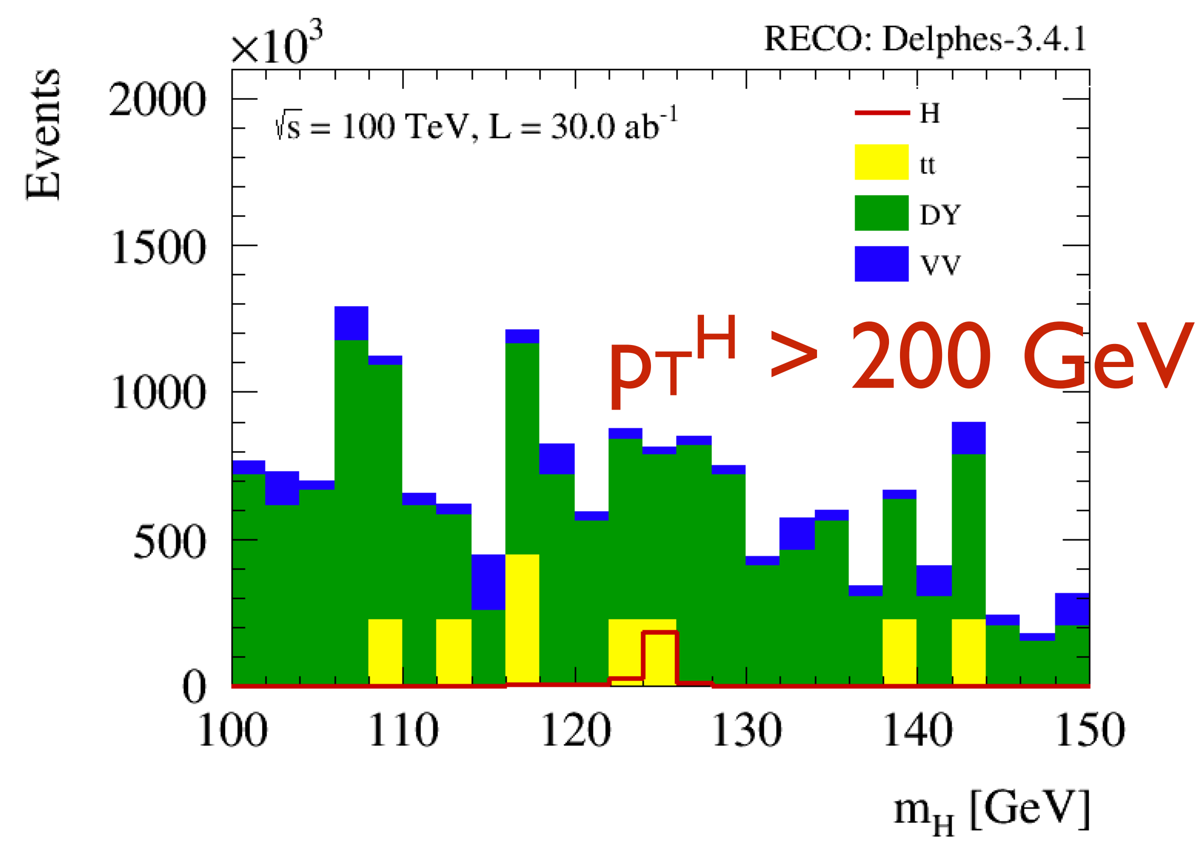
- ggH comparable
- **ttH becomes dominant at p_T > 800-900 GeV**, has slightly harder spectrum (matching?)
- similar spectra for VH (note VH vs WH)
- VBF seems off (wrong matching ?)

H → μμ - Plots

Michele Selvaggi







- previous selection applied except window cut around Higgs mass
- **can gain in background rejection at high p_T(H)**

H → μμ - Expected sensitivity

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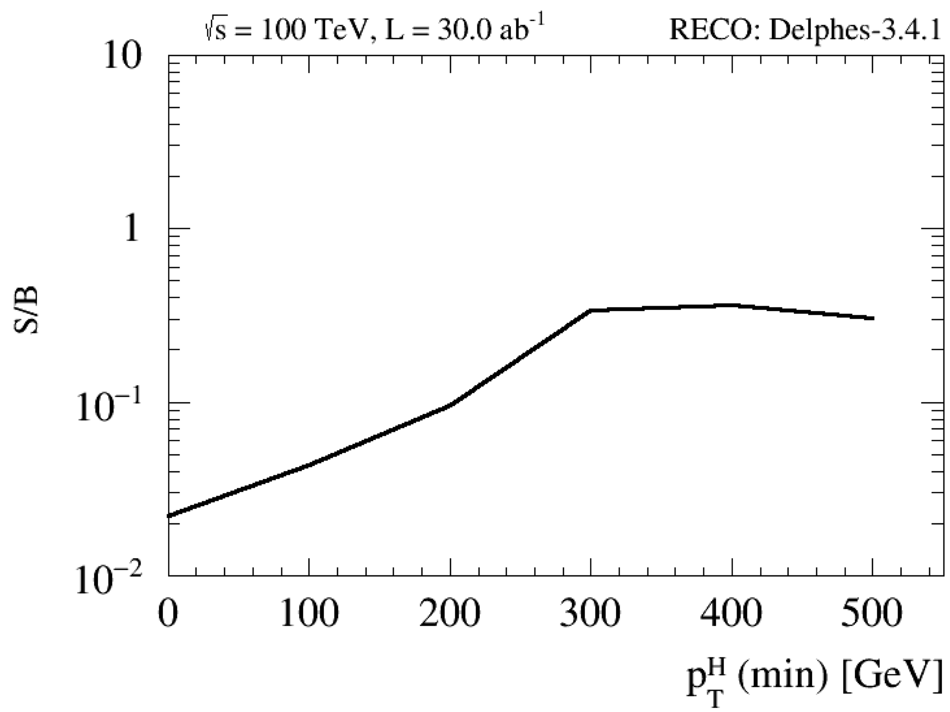
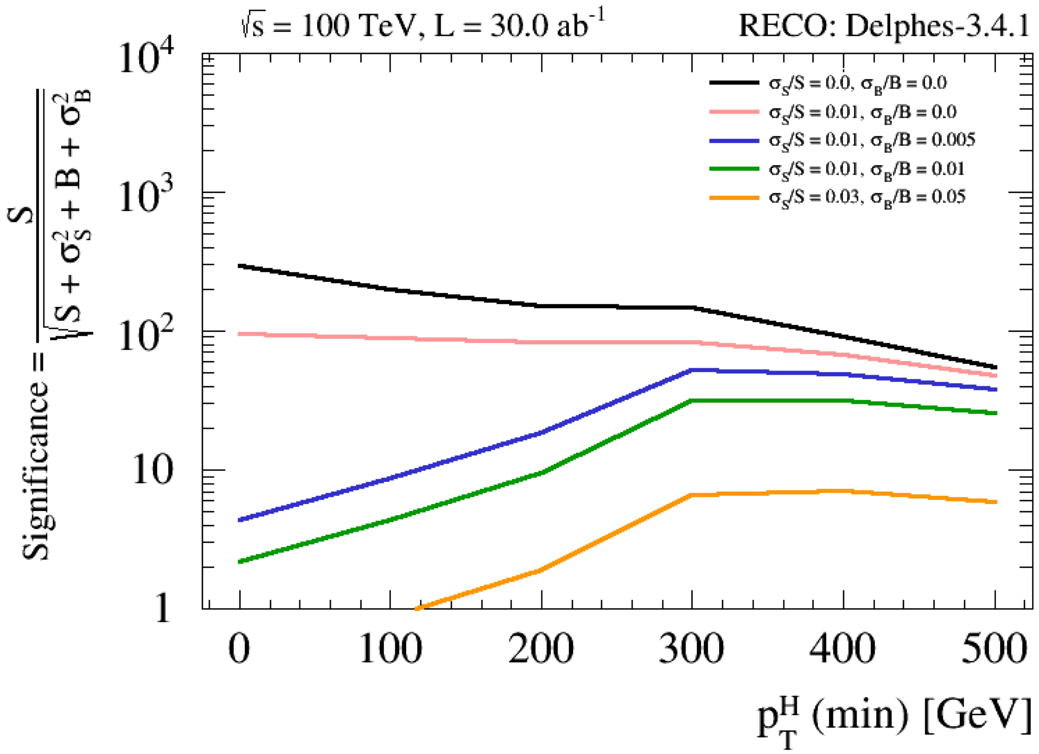
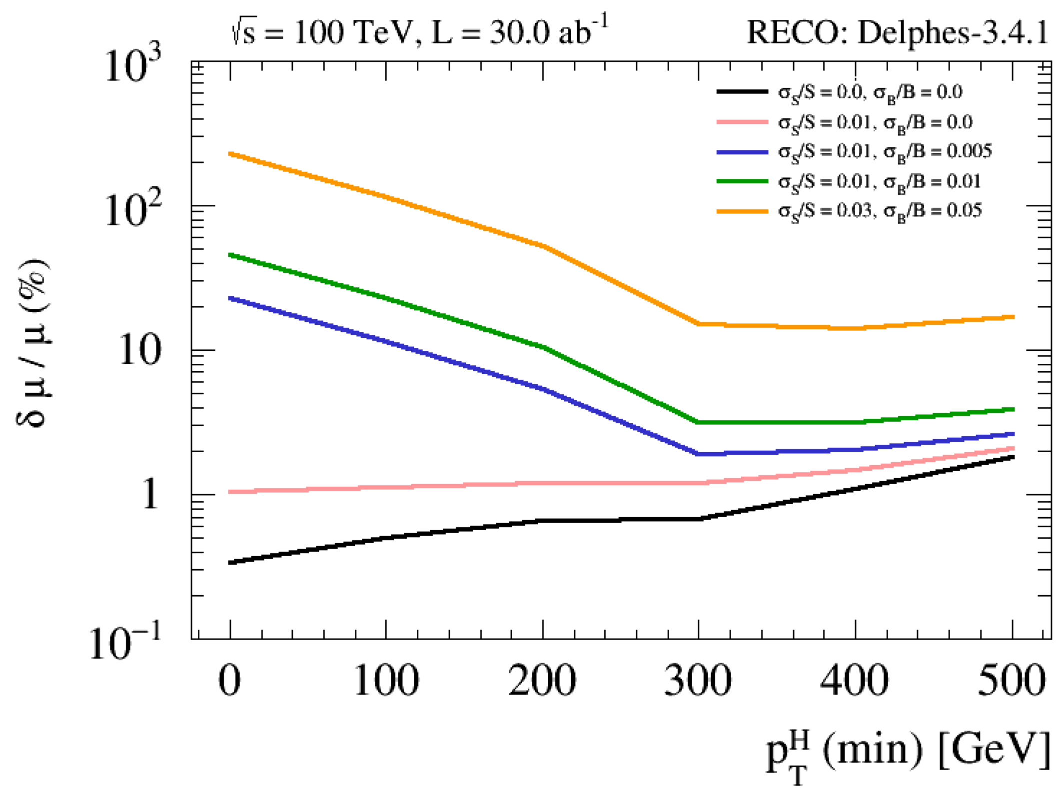




- **O(1) % precision** on signal strength can be achieved
- more **background MC stats** needed to conclude at **high p_T**
- this study far from being optimised:
  - fit on m(μμ)
  - including photon FSR to improve mass reso.
  - apply b-jet veto (tricky, suppresses ttH)?
  - …



$H \rightarrow \gamma\gamma$ - Plots

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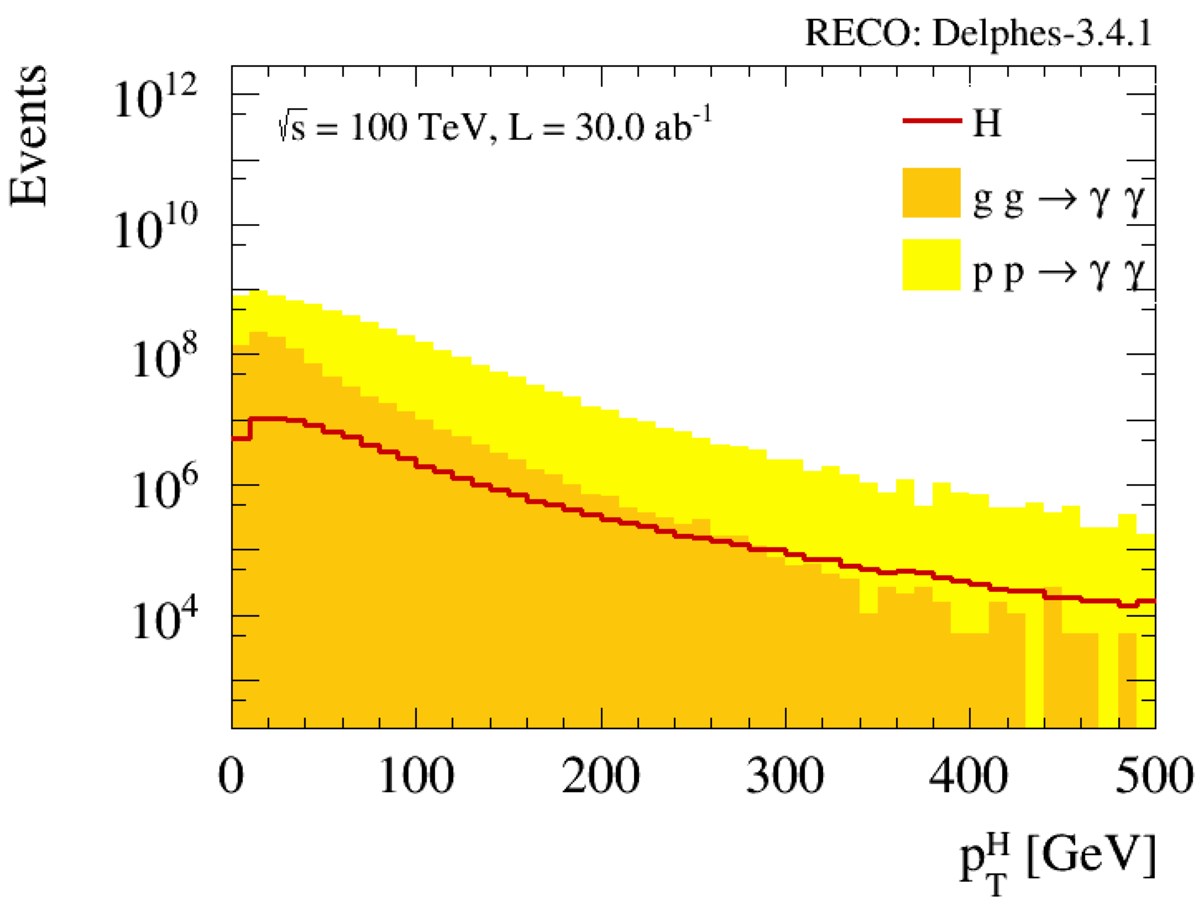

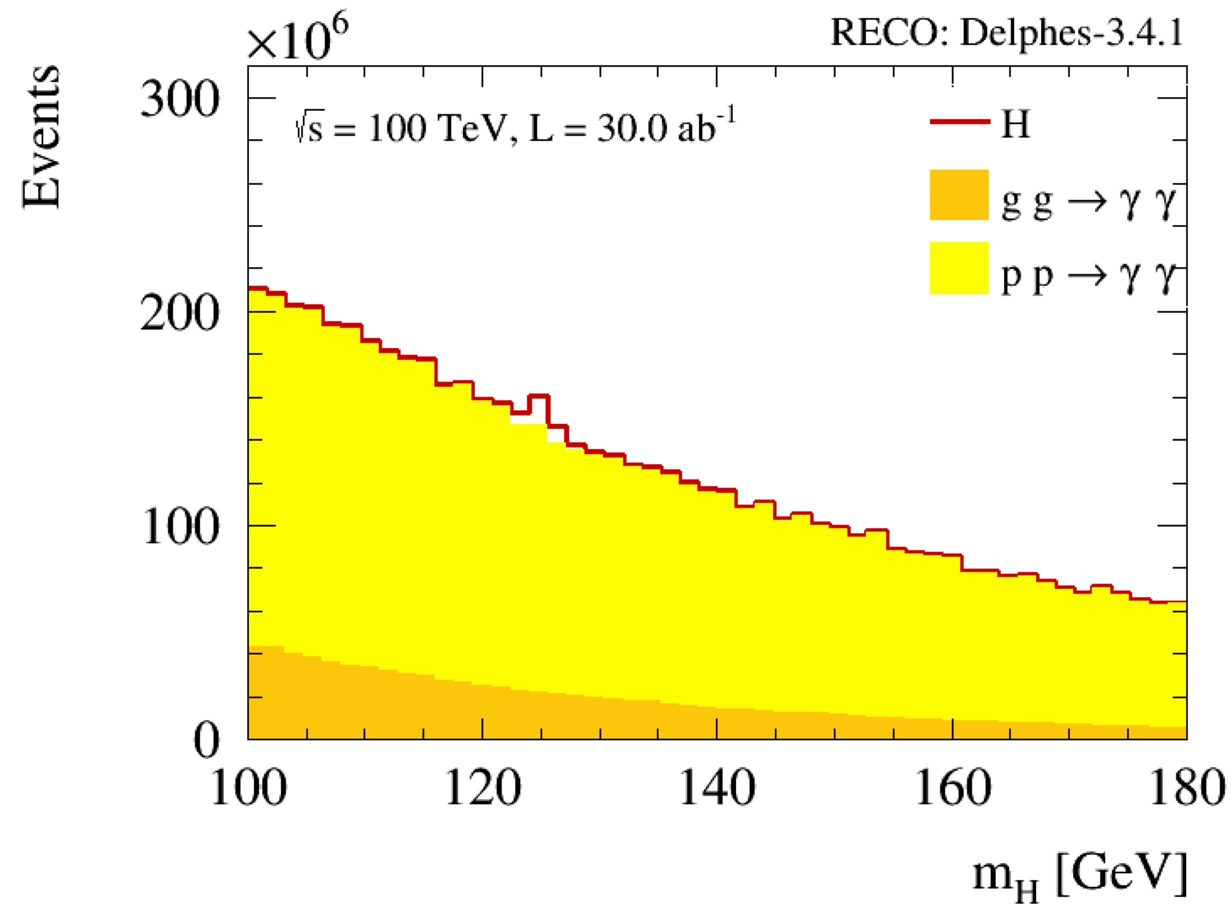

H → γγ - Expected sensitivity

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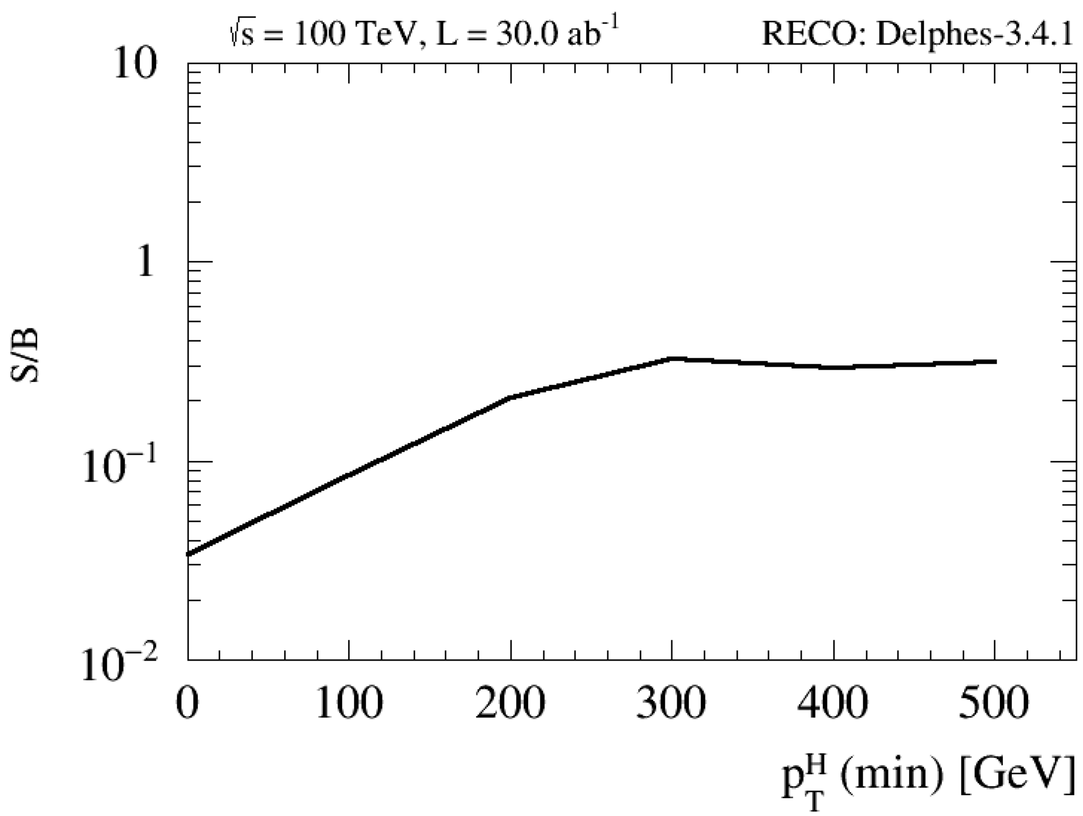

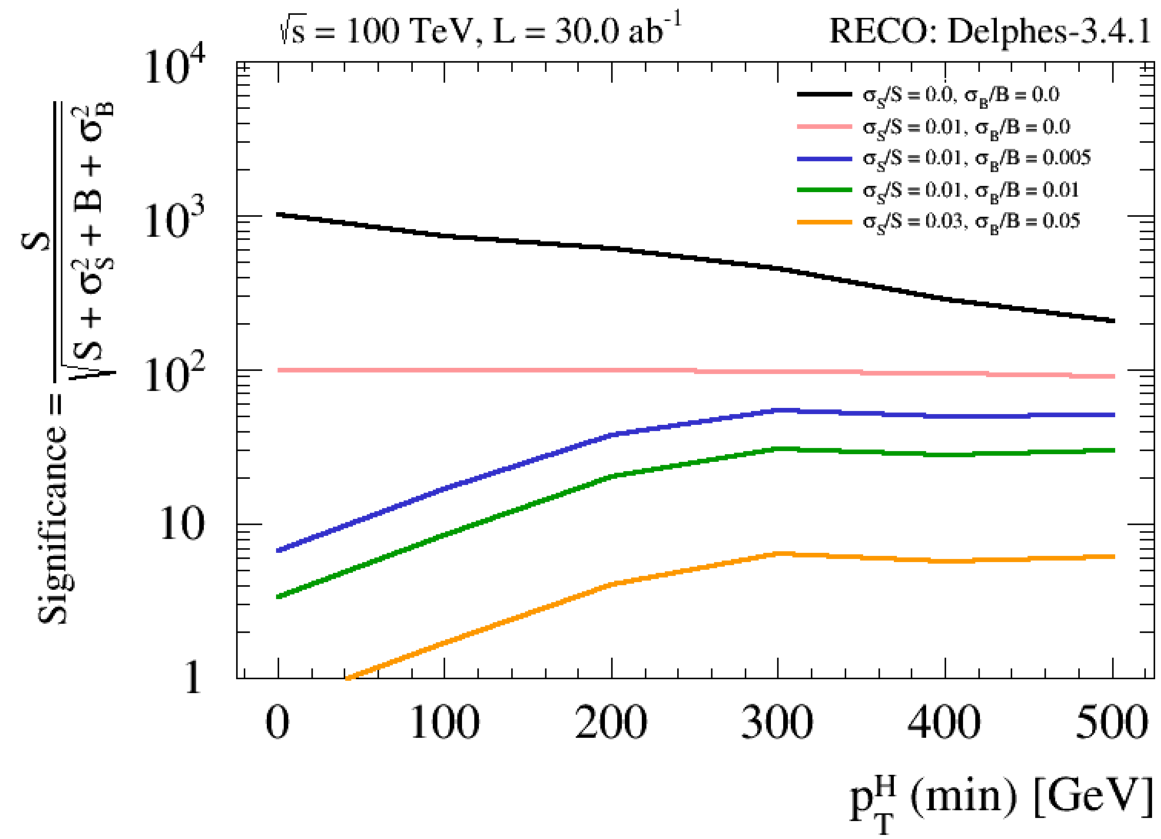

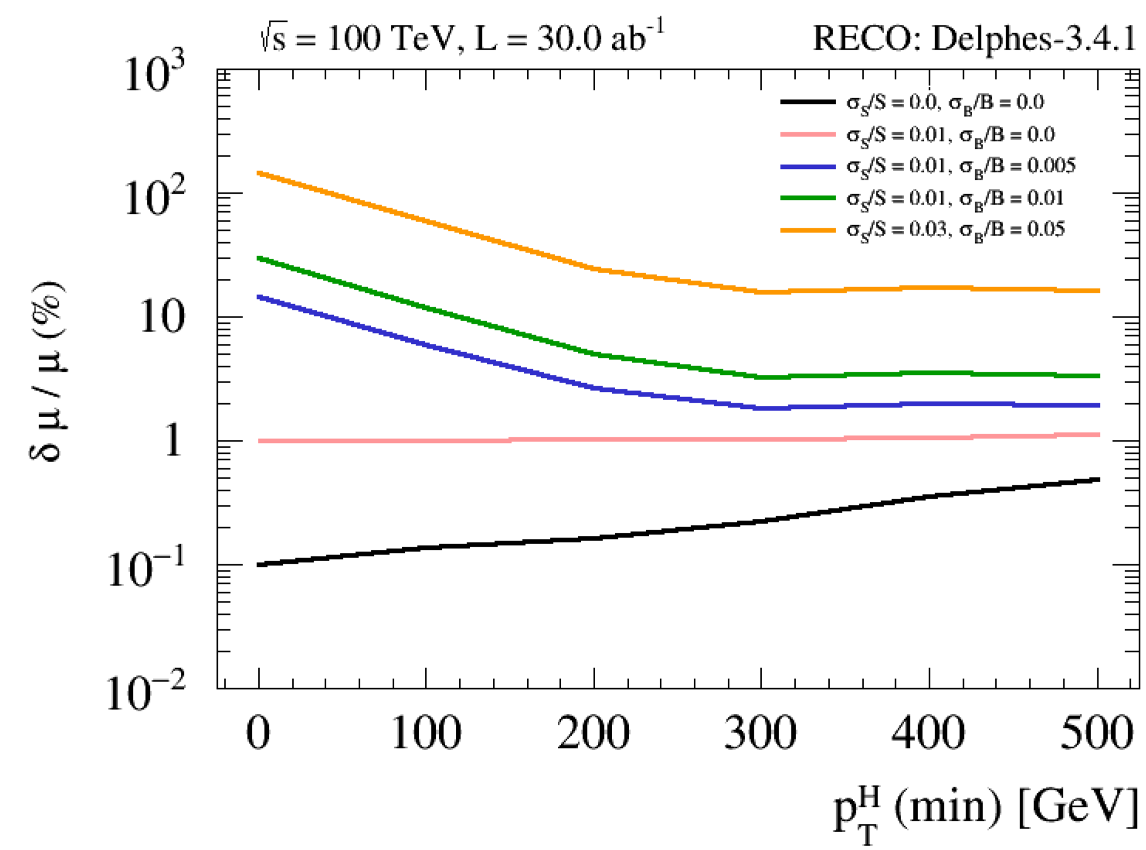

- **O(1) % precision** on signal strength can be achieved
- increase in sensitivity seems to reach plateau at $p_{T,H}$ ~ 300 GeV
- Possible improvements:
  - background K-factors
  - include photon fake rate
  - …

H → ZZ* → 4l - Plots

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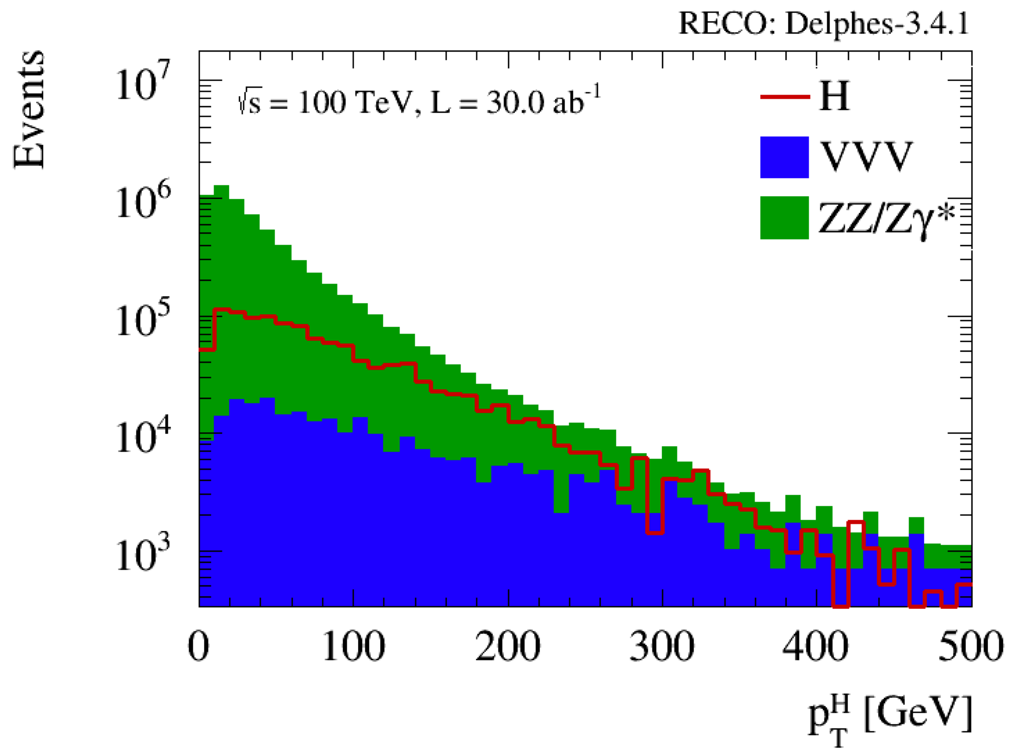
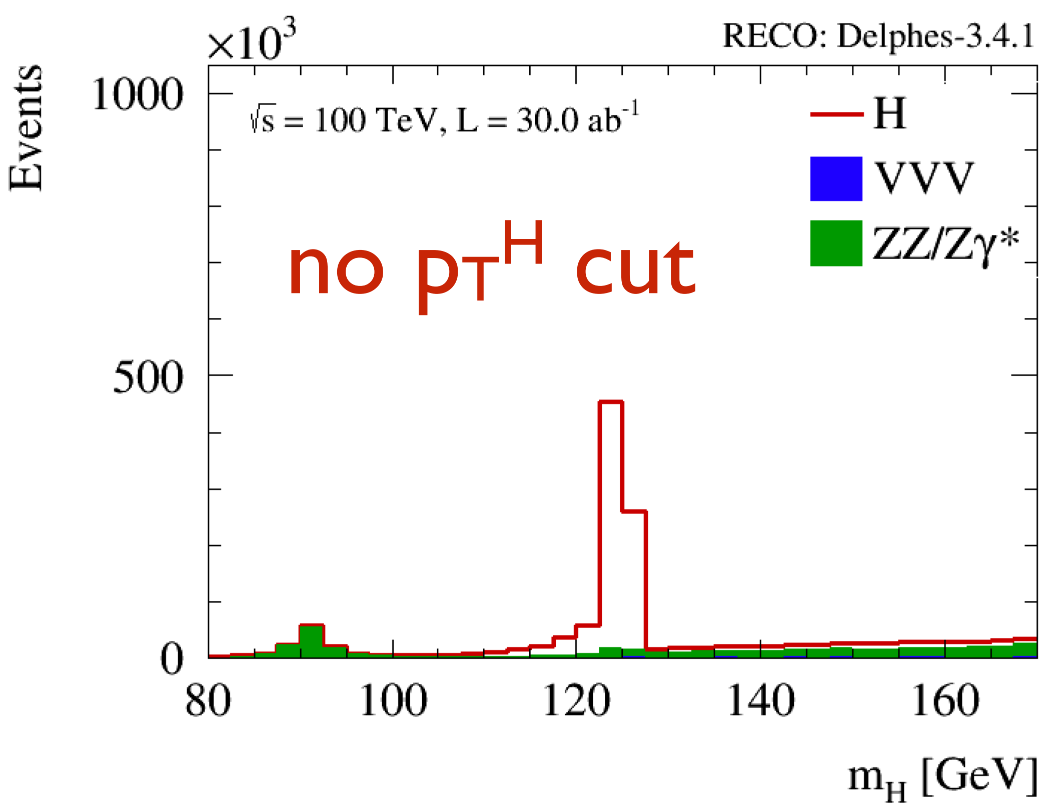
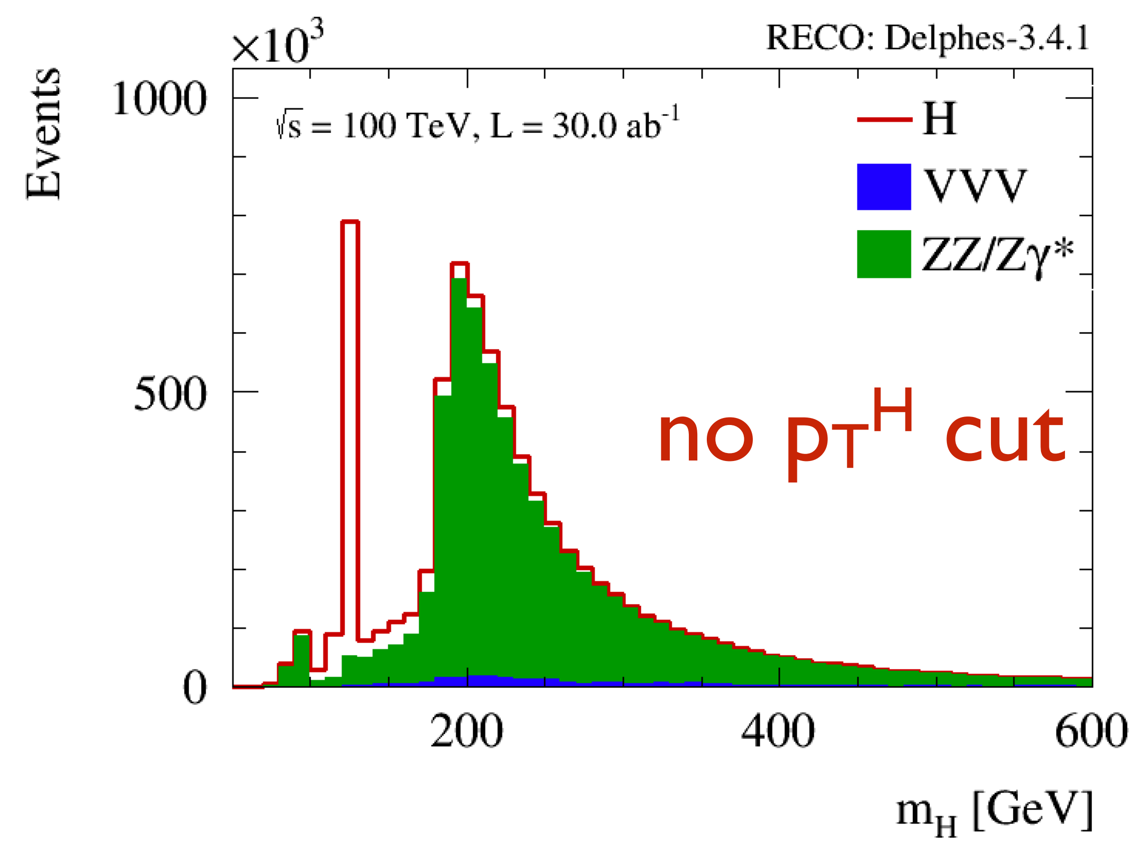
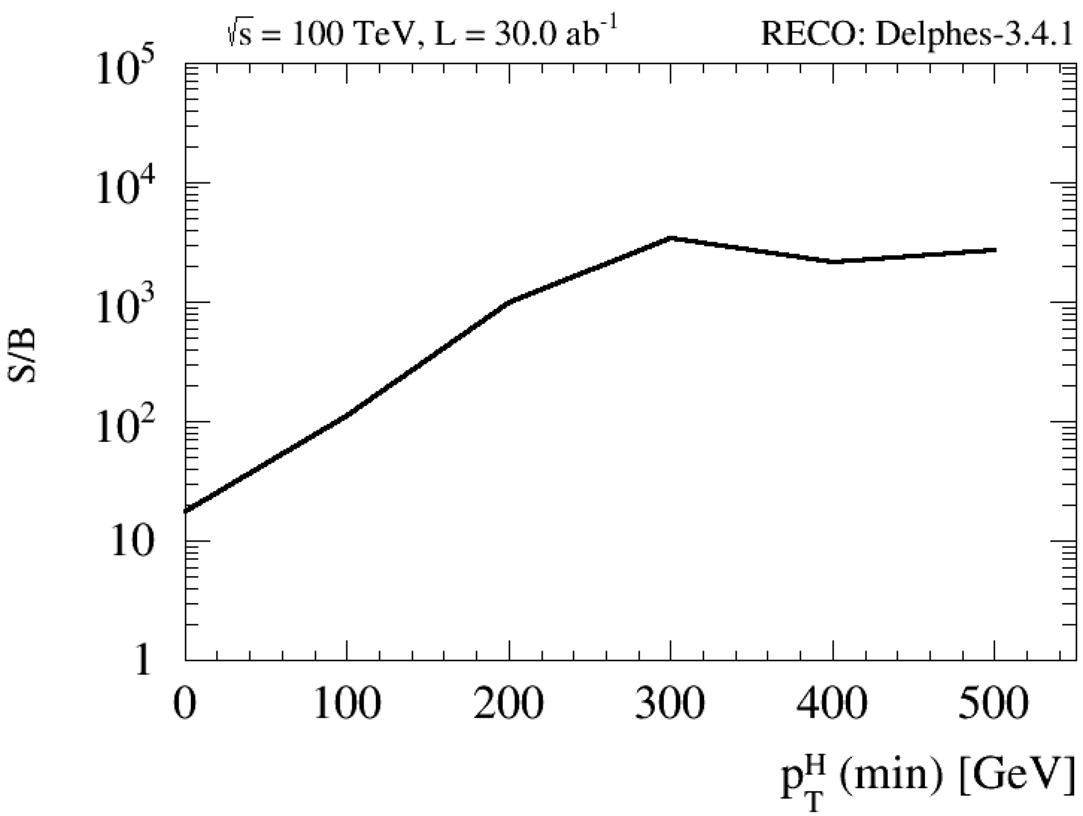


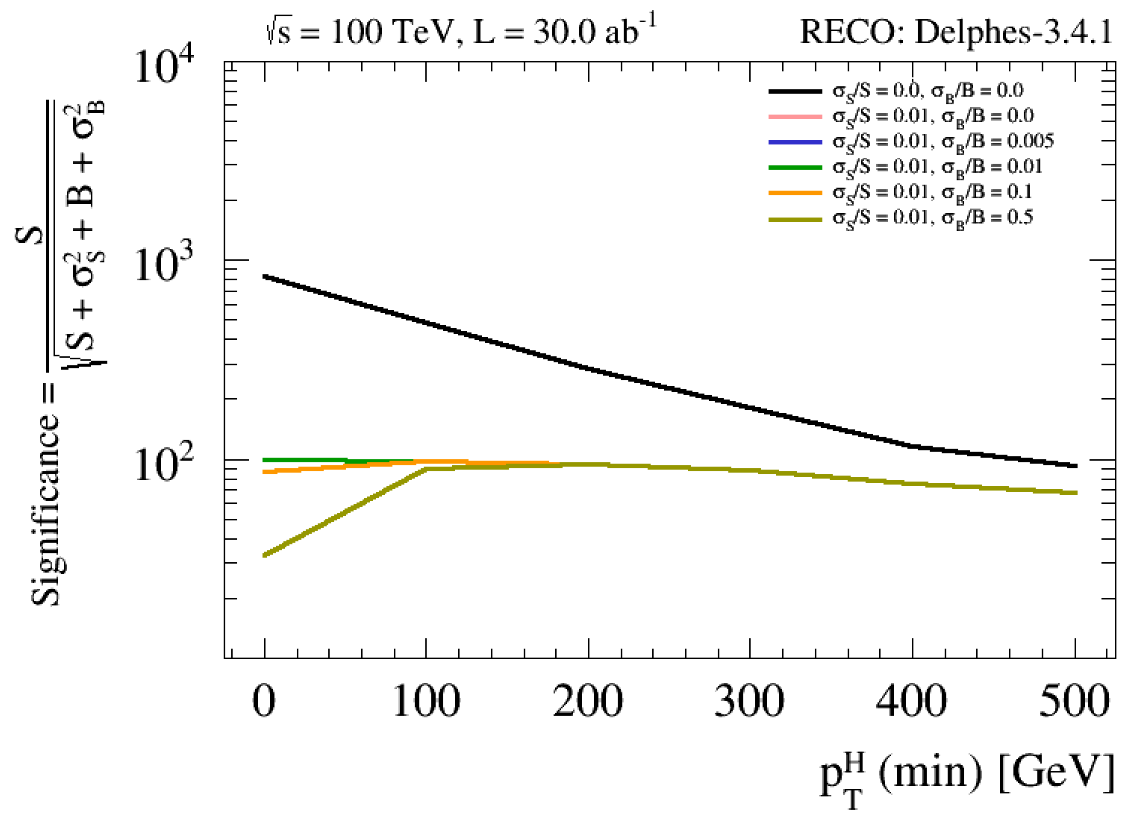
- Z/γ* peak highly suppressed
  → due to cuts?
  → or simply normalization bug



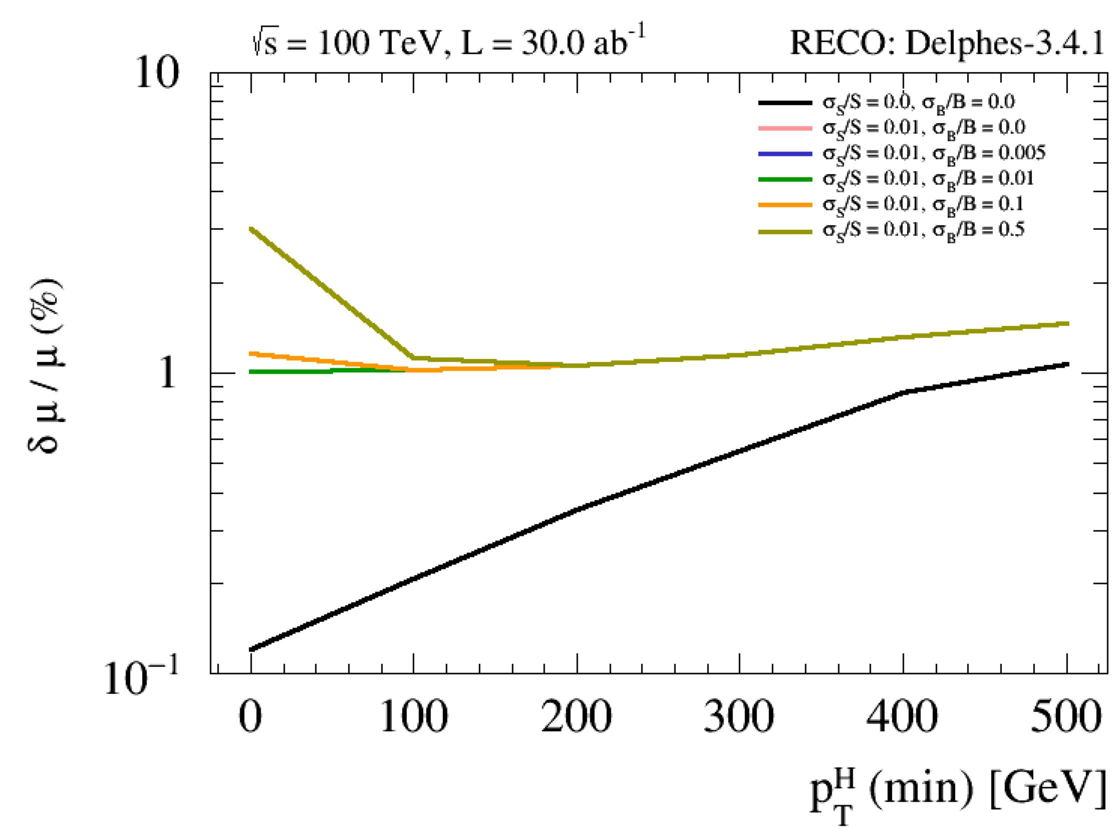


H → ZZ* → 4l - Expected sensitivity





- **O(1) % precision** on signal strength can be achieved
- increase in sensitivity seems to reach plateau at $p_{T,H}$ ~ 100 GeV
- only limited by uncertainty on signal
- this study far from being optimised:
  - fit on m(4l)
  - including photon FSR to improve mass reso.
  - apply b-jet veto (tricky, suppresses ttH)?
  - …



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$H \rightarrow WW^* \rightarrow 2l2\nu$ - Selection

Michele Selvaggi

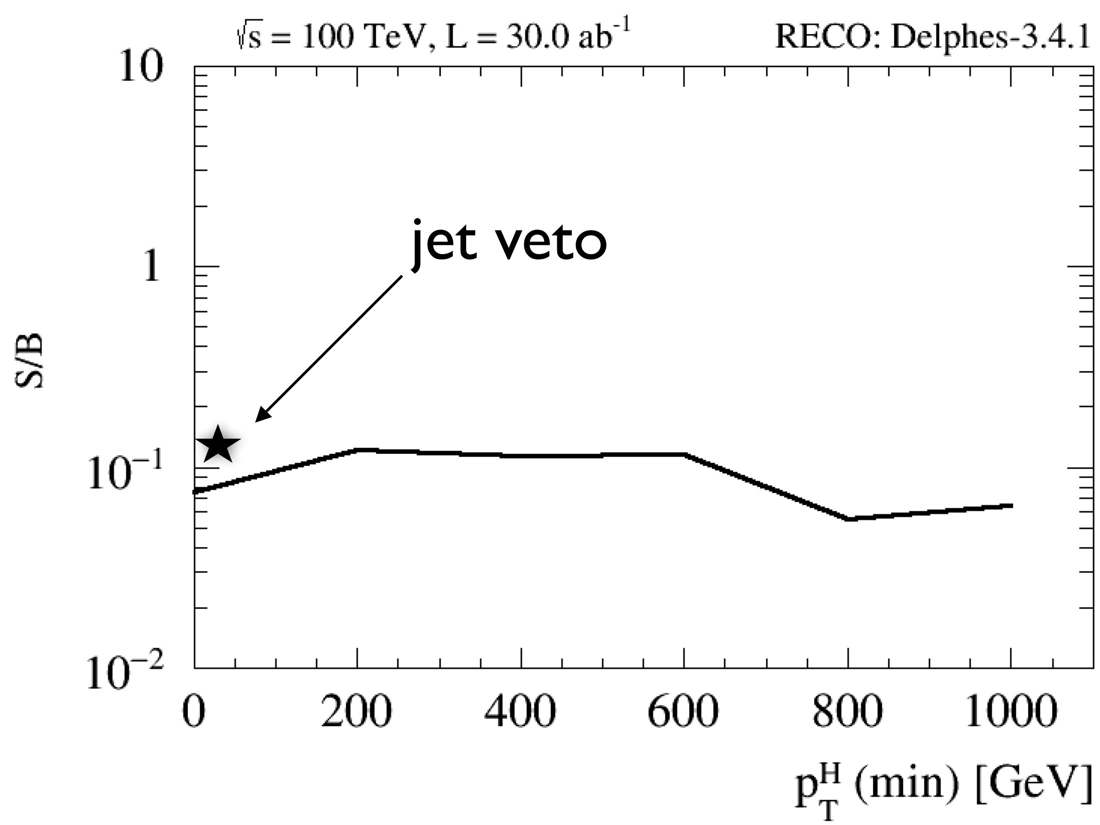
- BR($H \rightarrow WW^* \rightarrow 2l2\nu$) ~ 8.52e-3,
- **irreducible:** WW^* (only qq WW here)
- **reducible.** : ttbar, tW, VVV, DY, W+jets (fakes, not included here)

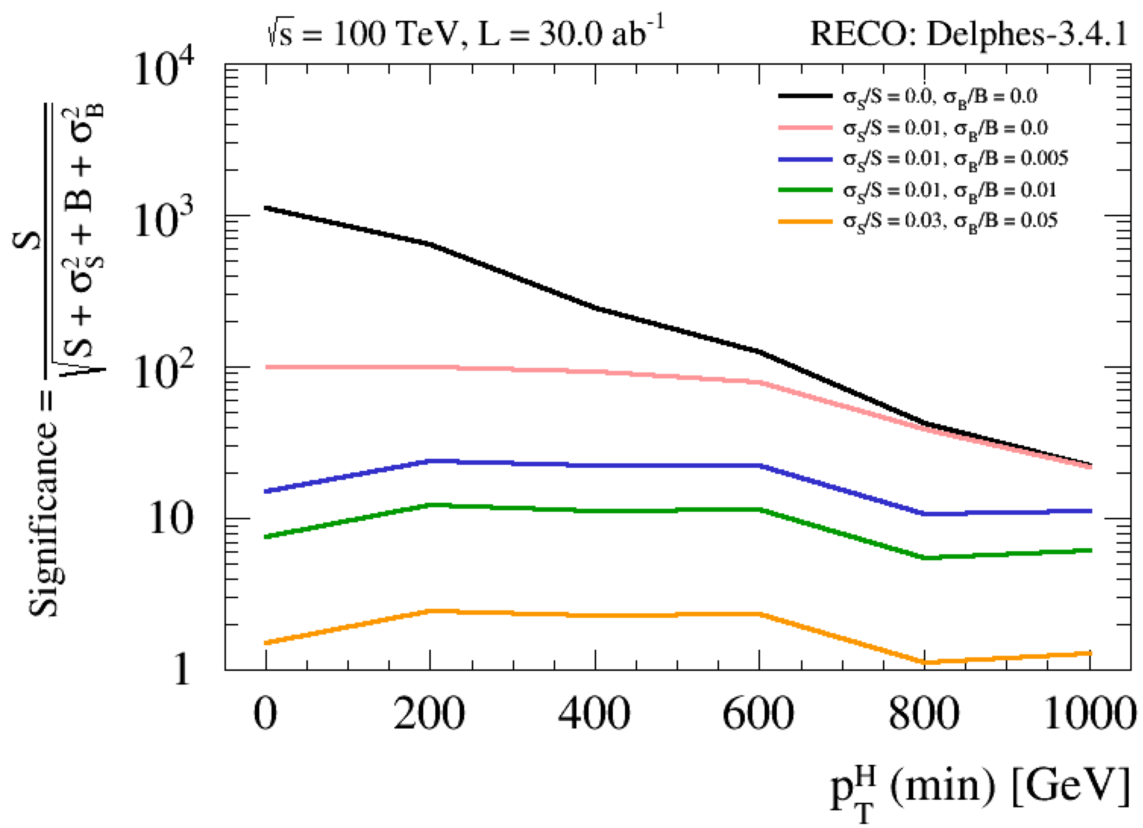
Simple cut and count strategy:

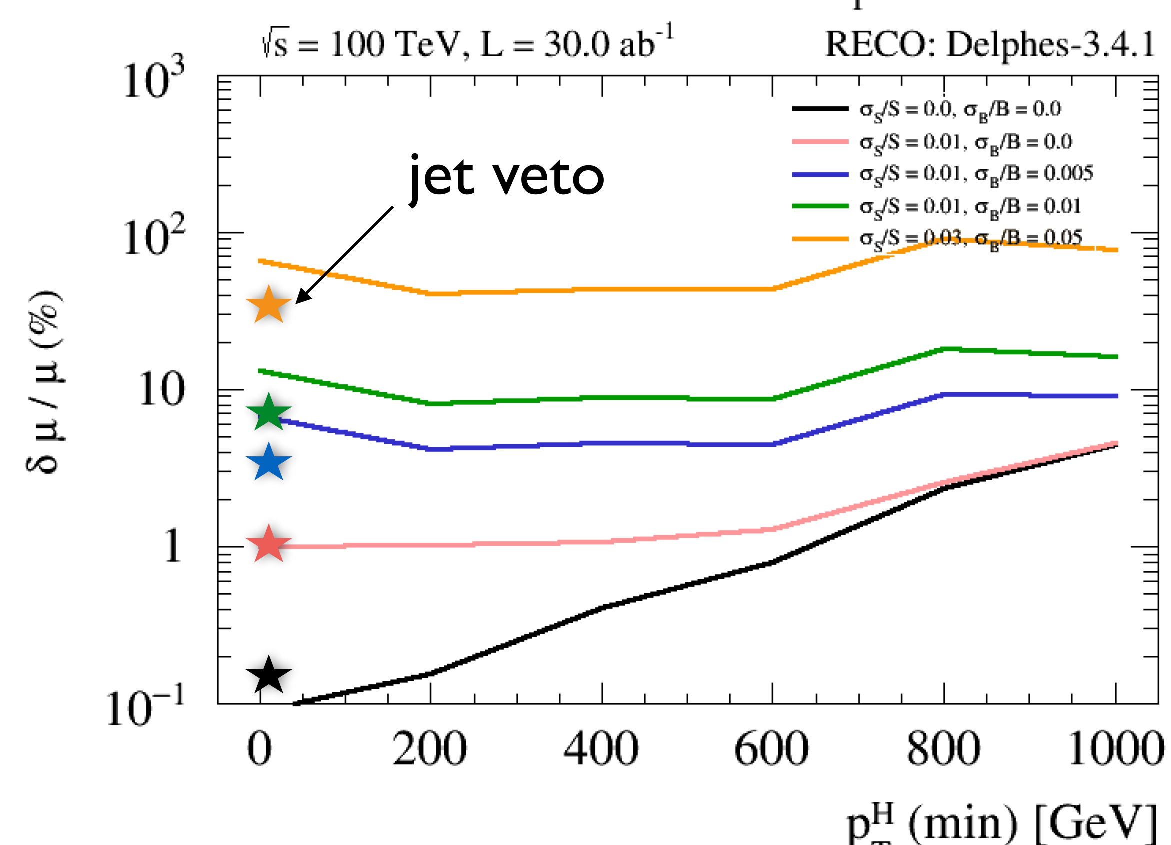
- only consider opposite flavor eμ final state (no DY)
- crucial part of this analysis is **jet veto** against ttbar:
  - relax jet veto and take advantage of H high pT spectrum?
  - or apply jet veto and study H at threshold?

- $p_T(l_1) > 25$ GeV, $p_T(l_2) > 15$ GeV, $|\eta(l_i)| < 4.0$
- $N_{bjets} = 0$
- $pT_{ll} > 45.$
- $\Delta\phi_{ll} < 90$ deg.
- $50 < m_R < 200$

$H \rightarrow WW^* \rightarrow 2l2\nu$ - Expected sensitivity







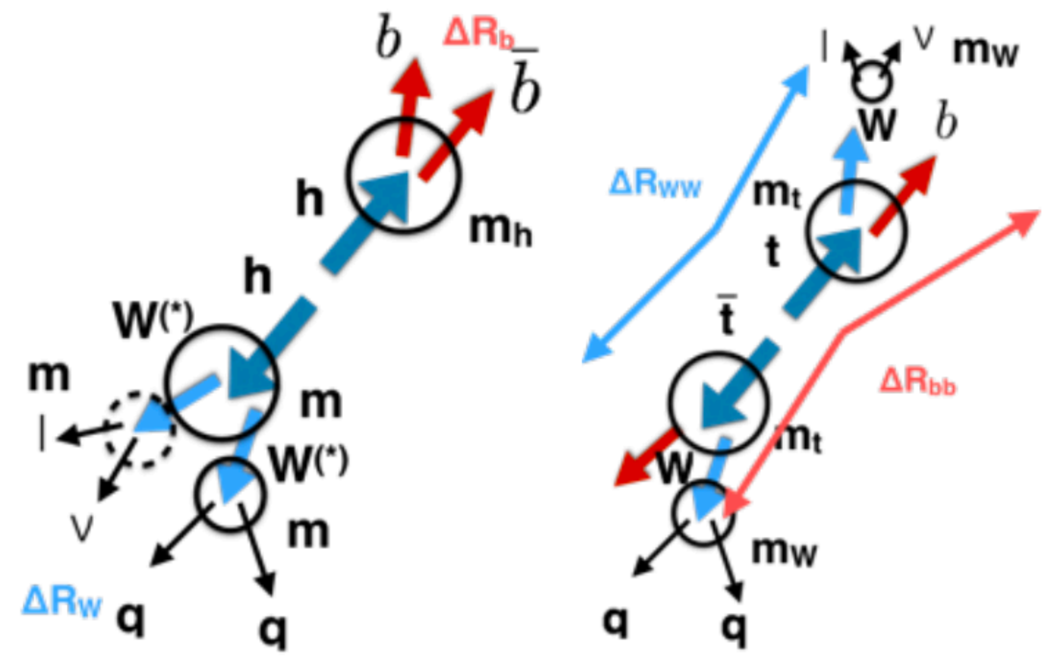
- **O(1) % precision** on signal strength can be achieved
- Suprisingly (without uncertainties), jet veto does not help much
  - because b-jet veto already applied
  - signal is very jetty
- high p_T moderately helps

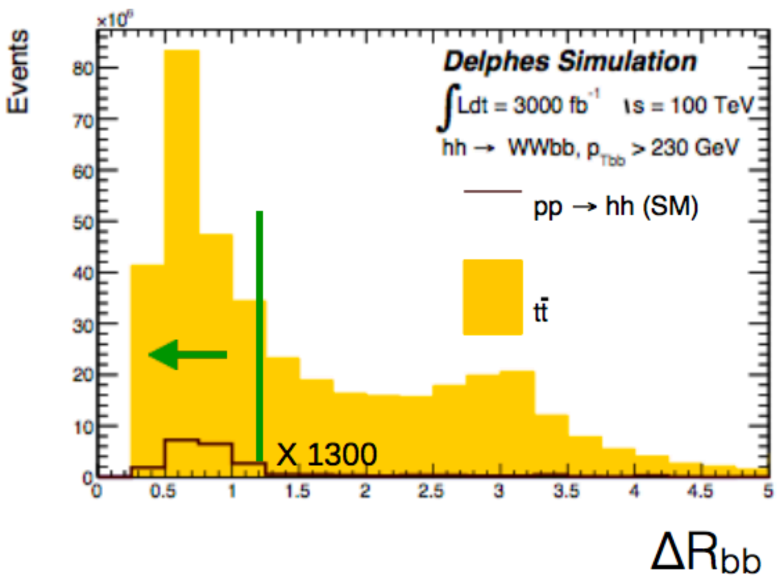
Michele Selvaggi

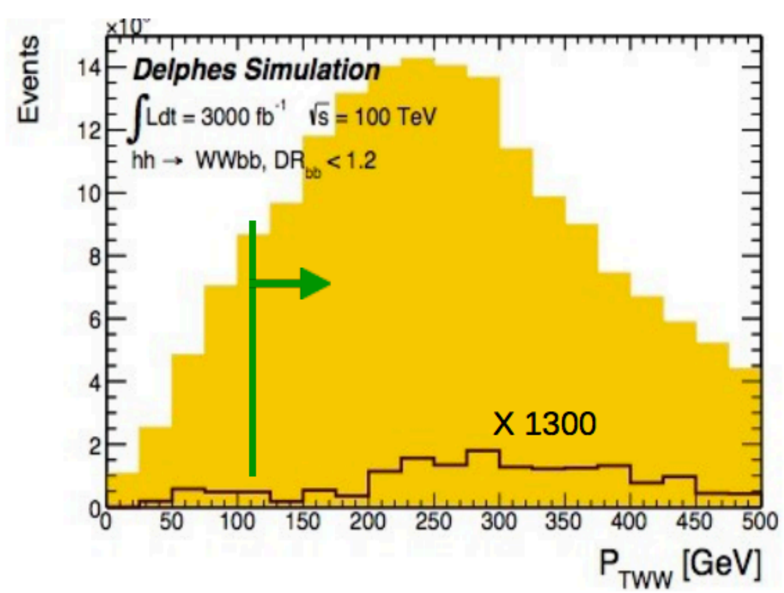
Biagio di Micco

The hh→WWbb→lνbb channel

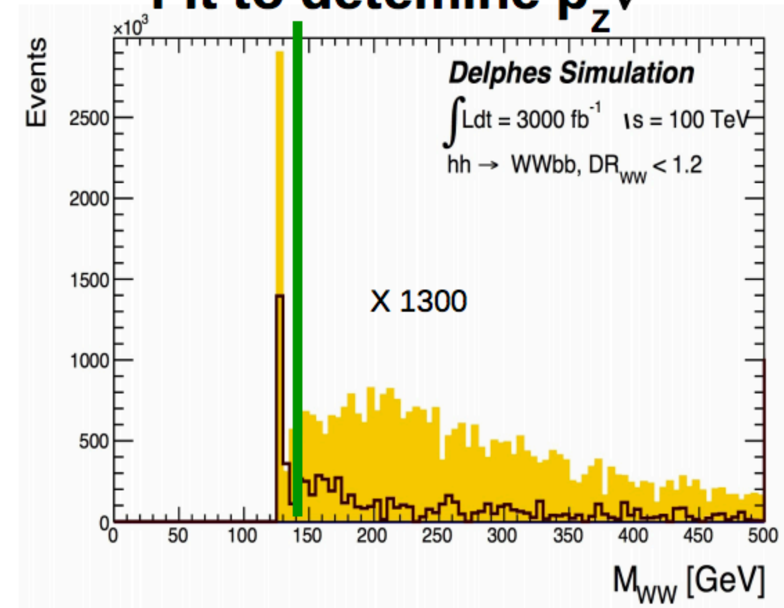
- Final state very close to the ttbar background, possible to disentangle the two only through the use of many variables
- Ideal analysis would exploit all mass constraints through a kinematic fit, profit of different angular and spin correlation through an MVA analysis
- This is just the first attempt, tried to use a simple cut based analysis, to train the machinery
    - at least one isolated lepton with $p_T > 15$ GeV, $|\eta| < 2.5$ use the Higgs mass constraint to compute the neutrino longitudinal momentum
    - at least 4 jets with $p_T > 20$ GeV $|\eta| < 2.5$
    - at least 2 b-jets





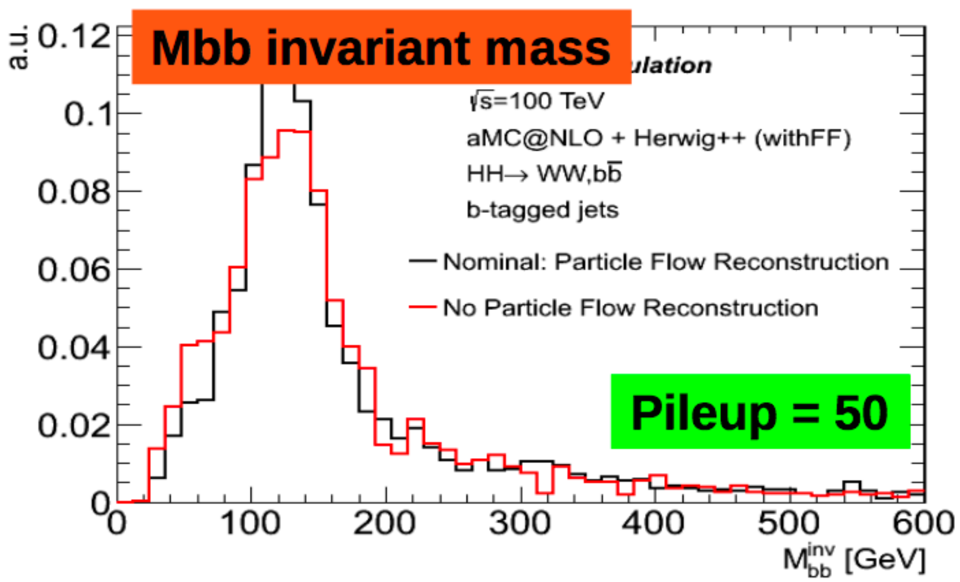


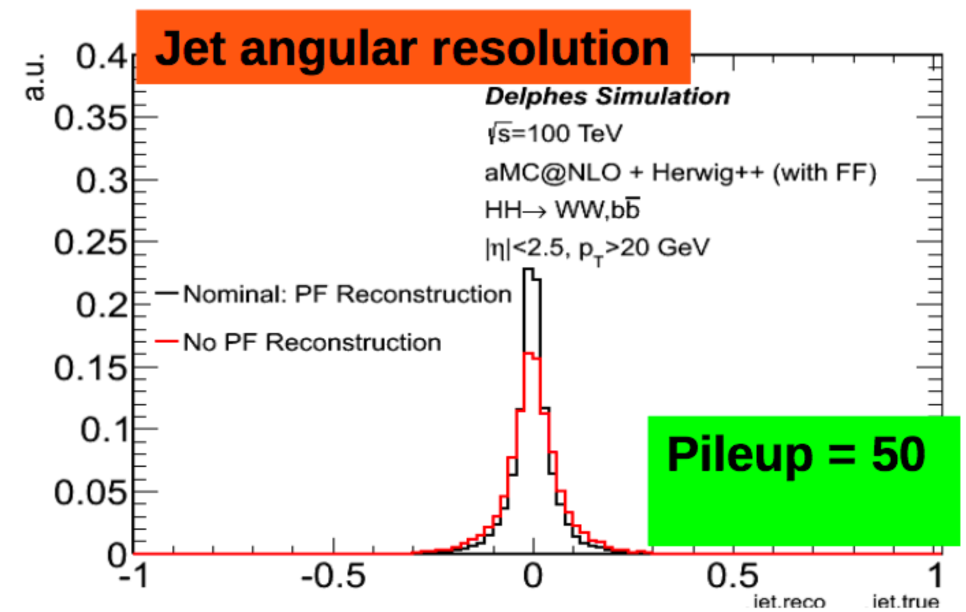
Fit to detemine $p_z\nu$

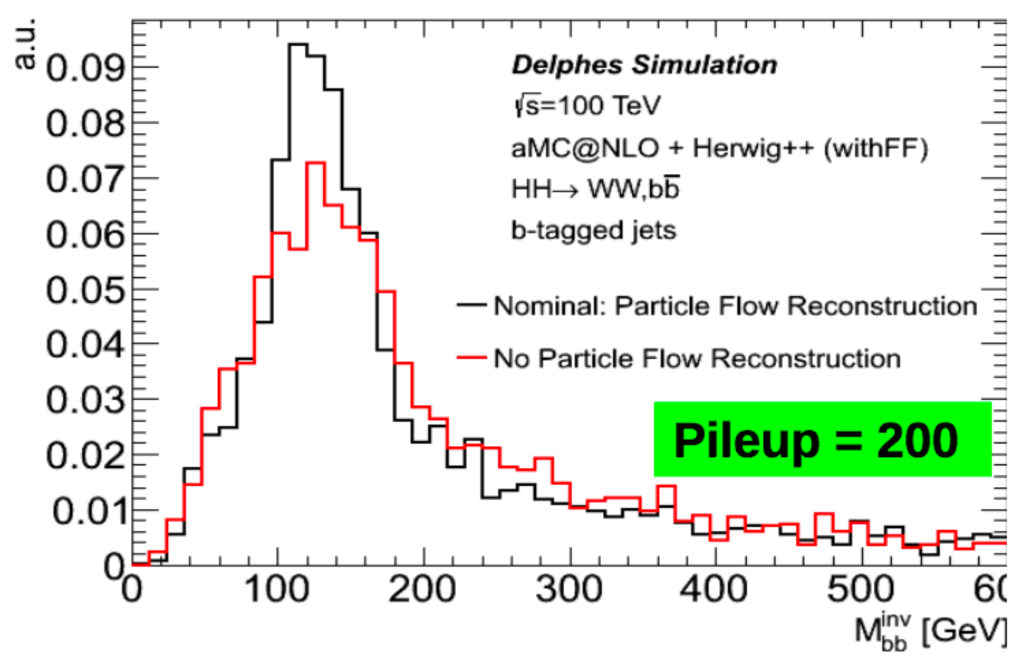


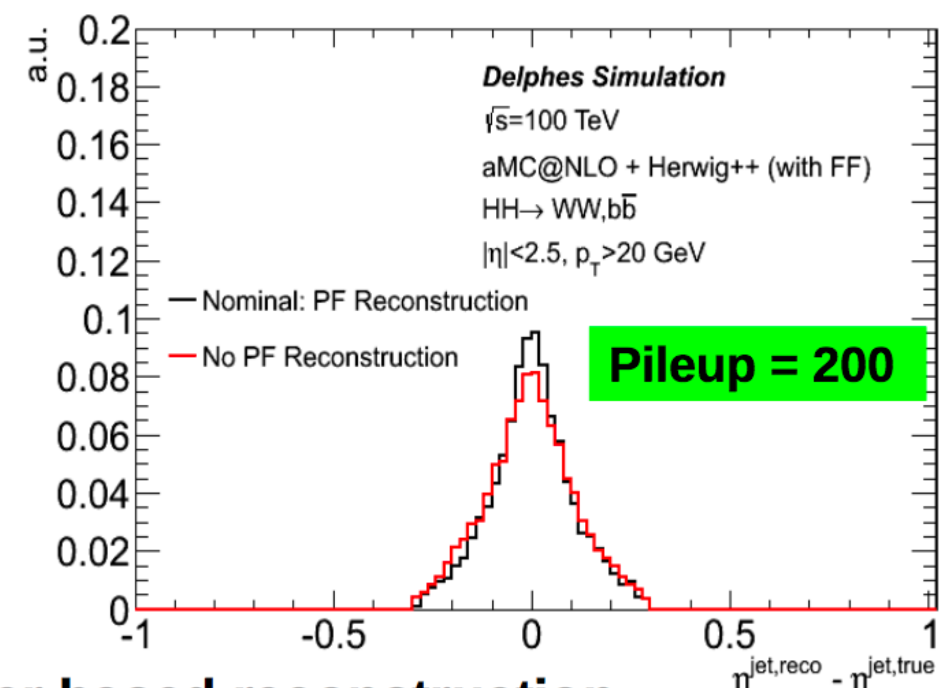
Biagio di Micco

Particle flow versus calorimeter tower jets







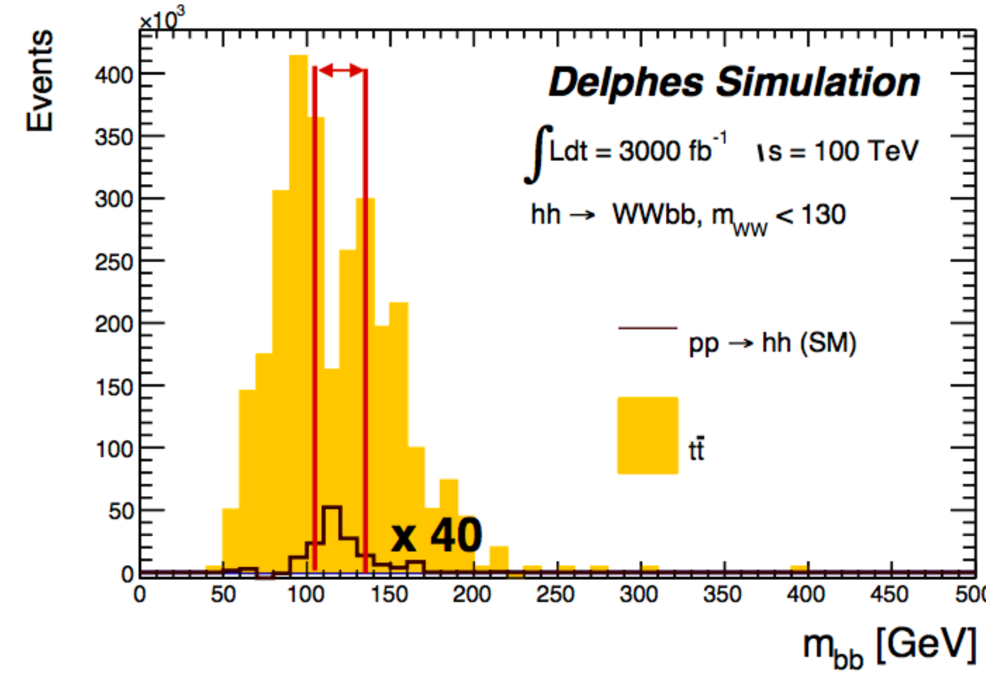


- **Deterioration using calorimeter based reconstruction**

The hh→ WWbb→ lνbb channel, analysis cuts and results

Analysis cuts

Variable	Cut
$p_T(bb)$	> 230 GeV
ΔRbb	< 1.2
$p_T(WW)$	> 140 GeV
ΔR_{WW}	< 1.2
m_{WW}	< 130 GeV
m_{bb}	105 – 135 GeV

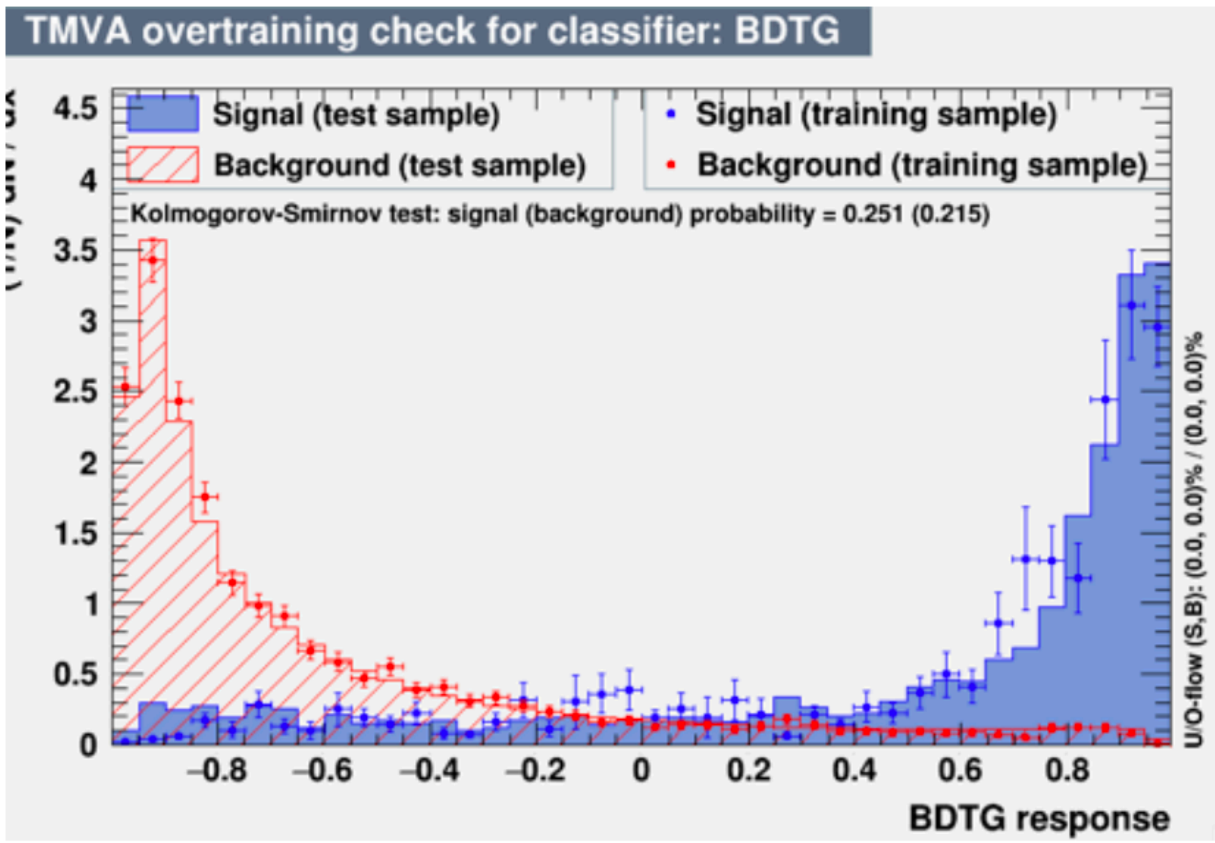


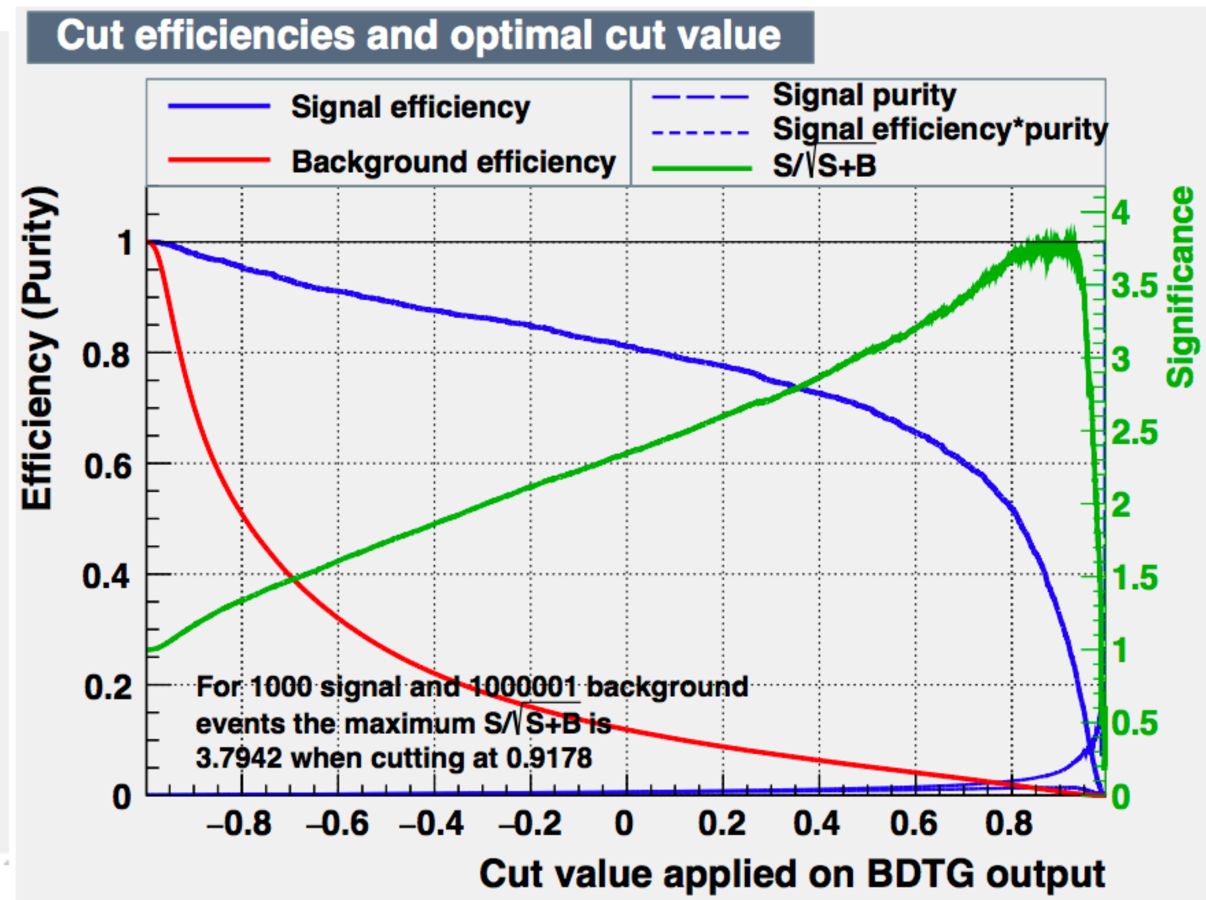
3 ab^{-1} PU 50	Object selection	Final selection	ε
hh-WWbb	7084	803	$2.5 \cdot 10^{-3}$
t-t_{bar}	$5.4 \cdot 10^{9}$	$7.9 \cdot 10^{5}$	
S/B_{kg}	$1.3 \cdot 10^{-6}$	$1.0 \cdot 10^{-3}$	

3 ab^{-1} PU 200	Object selection	Final selection	ε
hh-WWbb	$5.4 \cdot 10^{4}$	273	$8.5 \cdot 10^{-4}$
t-t_{bar}	$3.6 \cdot 10^{9}$	$3.4 \cdot 10^{5}$	
S/B_{kg}	$1.5 \cdot 10^{-5}$	$8.0 \cdot 10^{-4}$	

S/B quite low , need to work more on analysis selection implementing more variables and using a MVA approach.

BDT performance



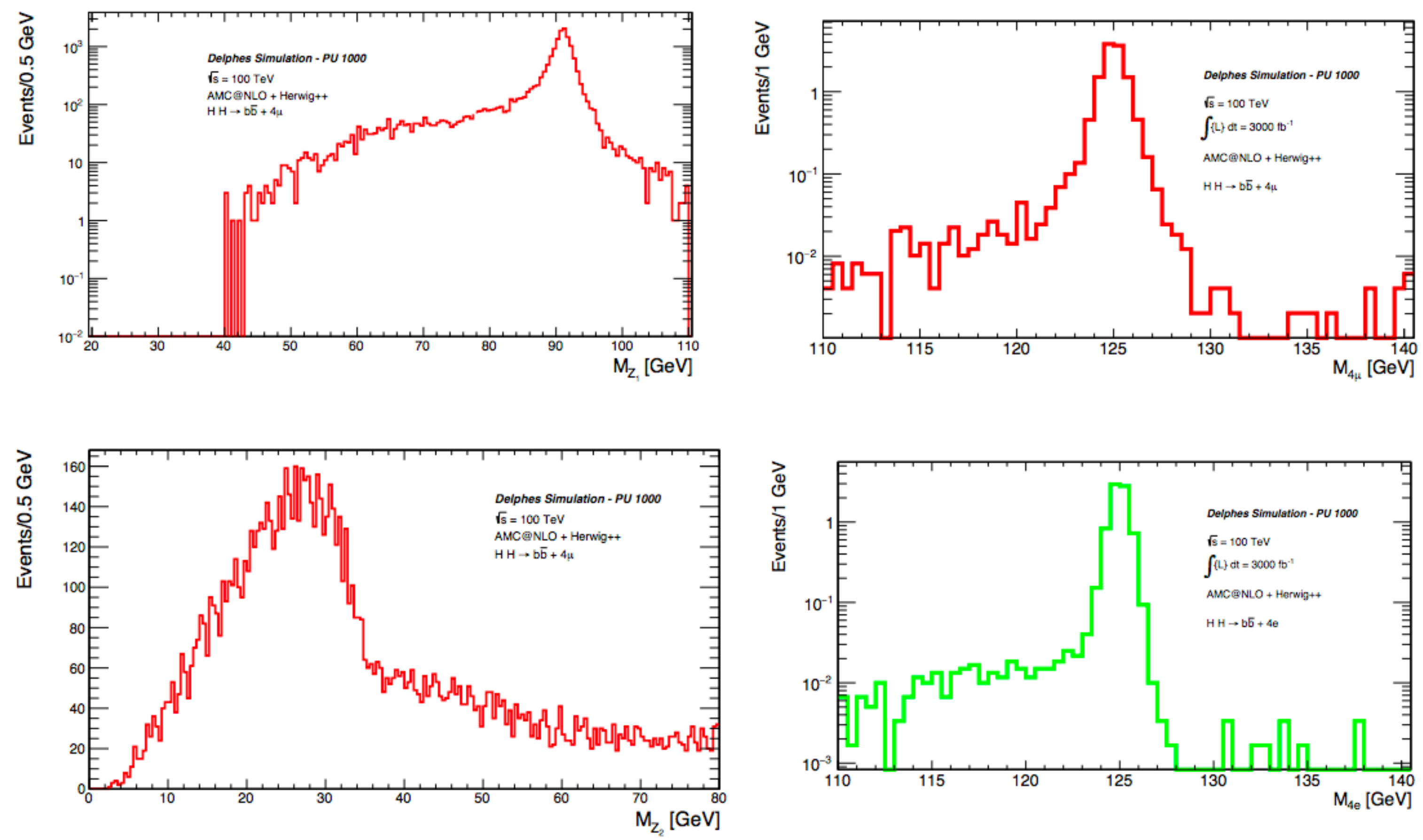


Poor performance at the moment, need to work on adding more variables, include preselection cuts and so on.

Biagio di Micco

The hh→ZZbb→4lbb channel

- ≥ 4 muons with $p_T > 5$ GeV, $|\eta| < 4.0$
- ≥ 4 electrons with $p_T > 7$ GeV, $|\eta| < 4.0$
- Z_1 selection: $\ell^+\ell^-$ pair with mass closest to the nominal Z boson mass
  40 GeV < m_{Z1} < 120 GeV
- Z_2 selection: second $\ell^+\ell^-$ pair
  12 GeV < m_{Z2} < 120 GeV
- Among the 4 selected leptons: at least one with p_T>20 GeV and one with p_T>10 GeV
- QCD suppression: $m(\ell^+\ell^-)$ > 4 GeV
- Kinematic cuts: $m_{4\ell}$ > 120 GeV, $m_{4\ell}$ < 130 GeV
- At least 2 b-jets with p_T > 30 GeV



$$\mathcal{L} = 3\,\mathrm{ab}^{-1}$$

	σ·L·Br(hh→ZZbb→4lbb	no b-jet req.	with b-jet	ε (no b-jet)	ε (b-jet)
4μ	161	61	12.1	38%	7.4%
4e	161	40	7.7	25%	4.8%
Tot	322	101	20	31%	6.2%

- forward b-tagging can be an important ingredient of the analysis, need to test configuration with fwd dipole
- big impact from lepton isolation cut (not presented here), need to optimise isolation criteria

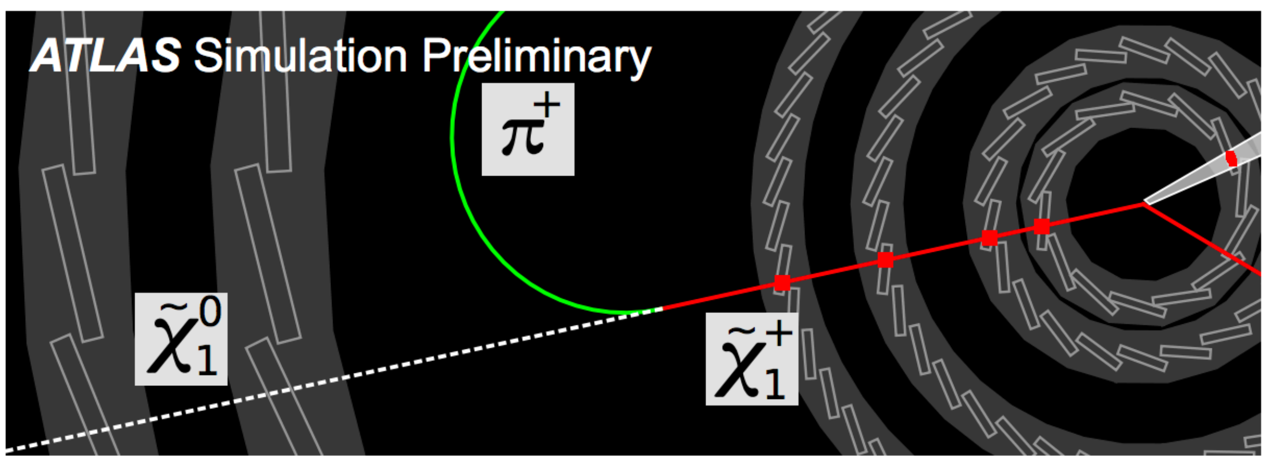
Disappearing tracks

Masahiko Saito

Charged wino is nearly mass-degenerate with neutral wino

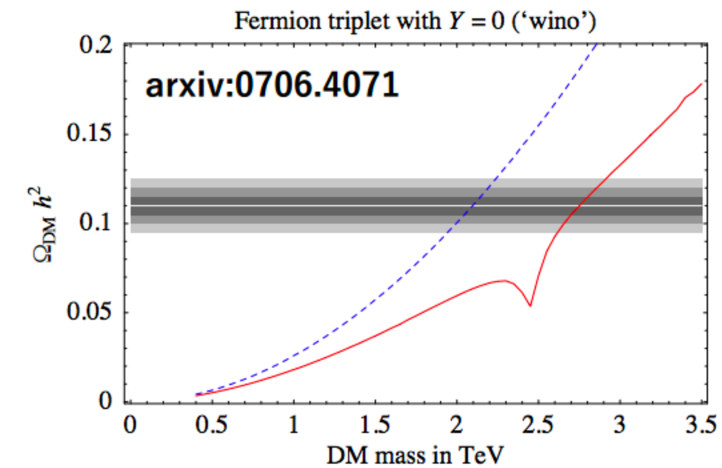
$$m_{\chi^{\pm}} - m_{\chi^{0}} \sim 165 \text{ MeV}$$

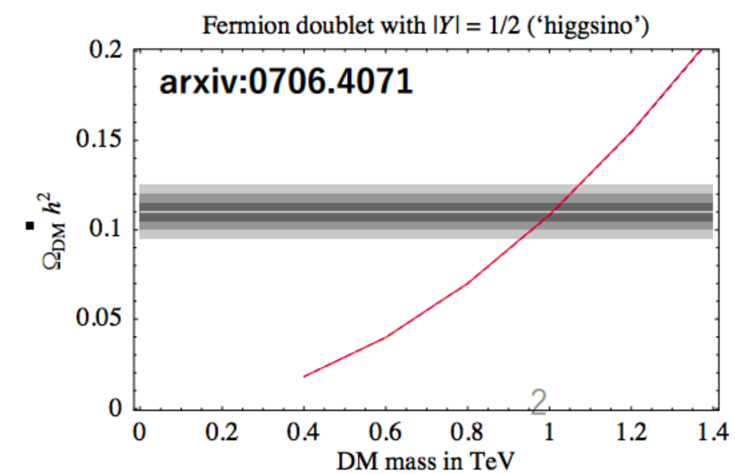
- Wino LSP leads **meta-stable chargino** (τ =**0.2 nsec**) due to very small mass splitting.
  - c τ ~ 6 cm → directly detectable
  - chargino tracks disappear in the tracker.



- We searched long-lived chargino from run-1.
  - preliminary exclusion limit is 430 GeV (ATLAS run-2 36 fb^{-1}).
- We're also interested in disappearing track analysis at FCC.

3





Disappearing tracks

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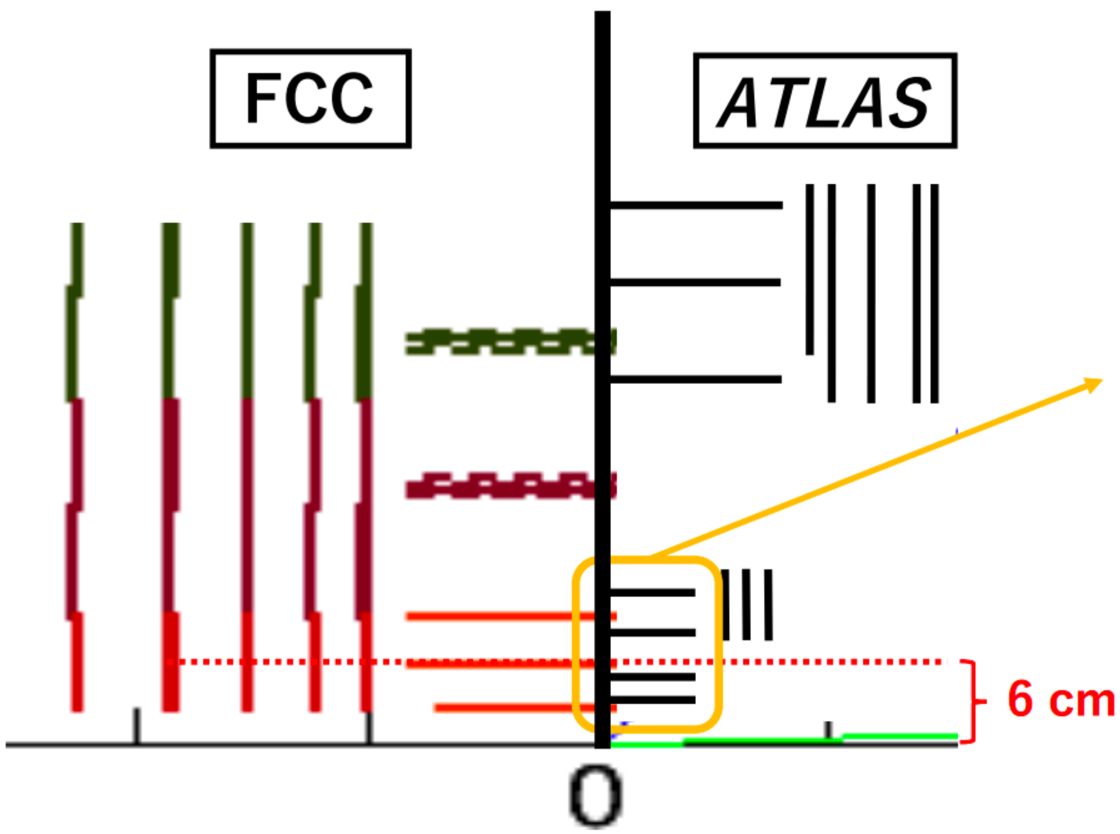
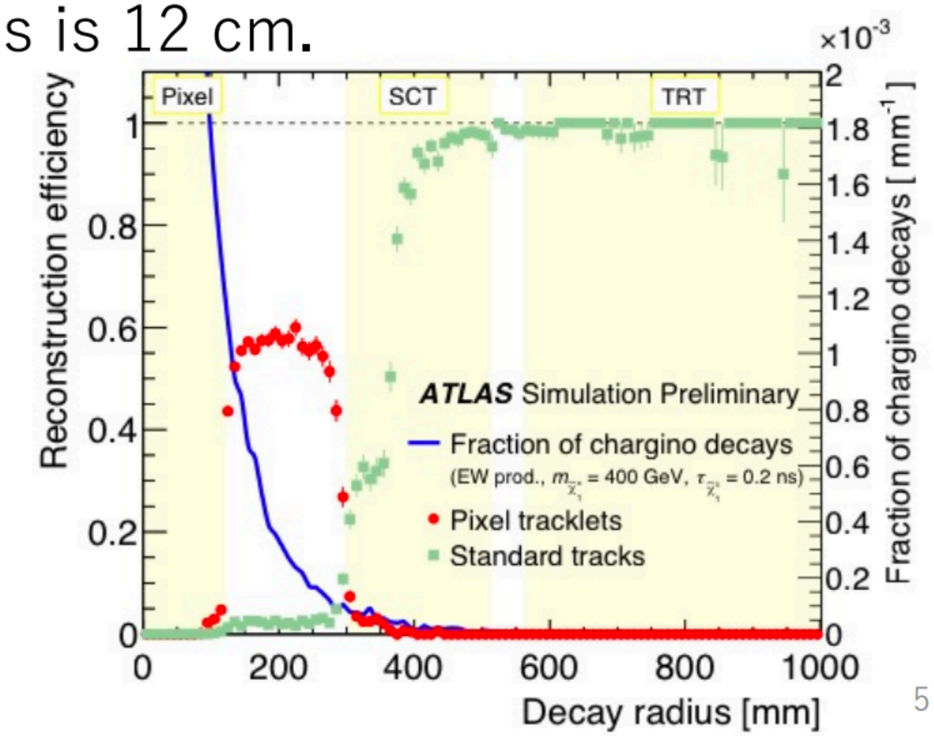
Difference between ATLAS & FCC inner detector



- Charged wino have 0.2 nsec lifetime. This corresponds to **6 cm.**
  - Short track reconstruction is important

- Now we use **only four layers** to reconstruct disappearing tracks. The radius is 12 cm.



Disappearing tracks

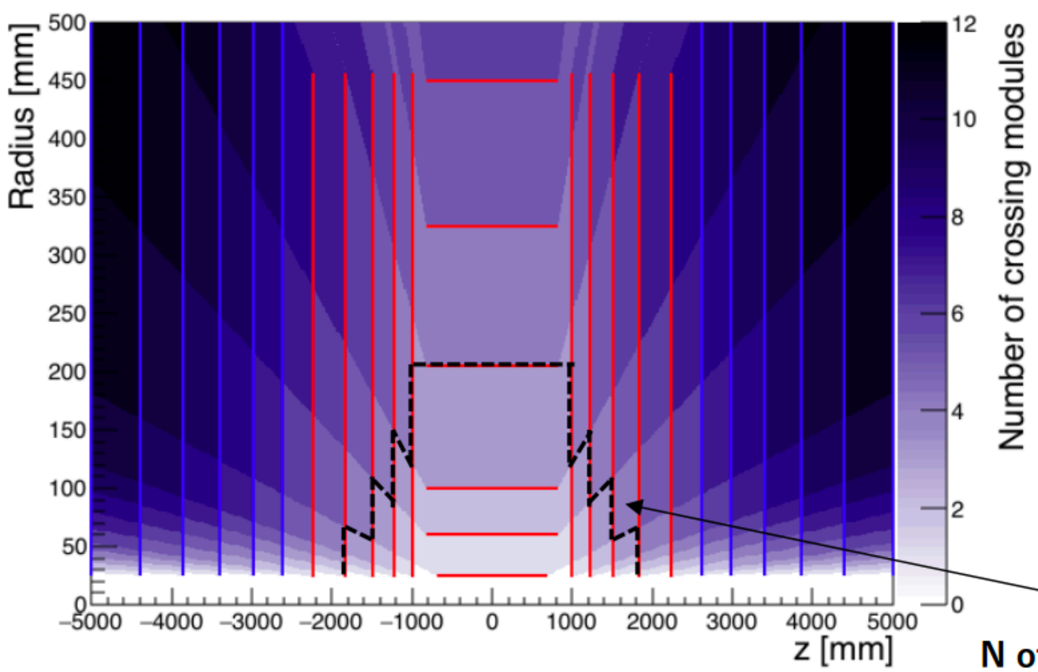
Masahiko Saito

Selection

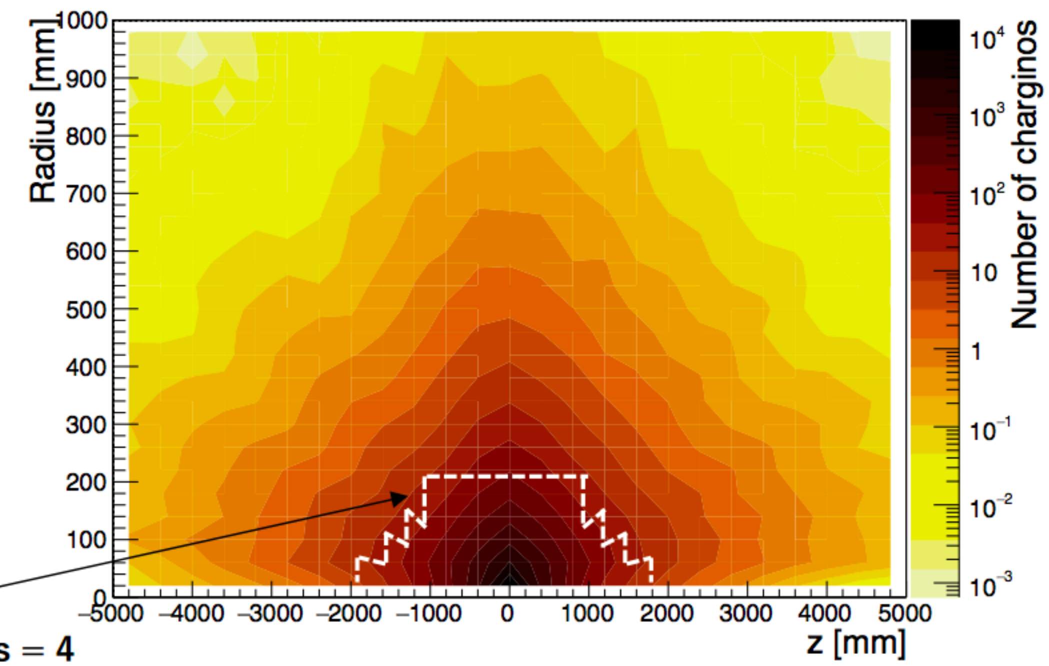
mass [TeV]

- Require MET > 1 TeV. (**tentative threshold**)
- Require at least one disappearing track.
  - Use "option3 ver2" layout (http://fcc-tklayout.web.cern.ch/fcc-tklayout/)
  - Assume we can reconstruct signal tracks if charginos go through **at least 4 silicon layers** before the decay.

FCC Inner detector



Decay position of chargino (m=1TeV, τ =0.2nsec)



N of crossing modules = 4

- **Require four module crossings to reconstruct tracks**
- **The position at 4th layer is important for track reconstruction and signal acceptance**

- **Charginos decay according to exponential.**

$$w = \exp\left(-l_{\text{decay}}/\beta\gamma c\tau\right)$$

Disappearing tracks

Masahiko Saito

Expected number of Signal at 100 fb^{-1}

wino mass [TeV]	all events	MET > 1 TeV	MET > 1 TeV & 4 layer crossing
1	2.1e+4	1.1e+3	9.5e+1
2	1.2e+3	1.1e+2	4.5e+0
2.6	3.7e+2	3.4e+1	1.1e+0

- O(1) events per 100 fb^{-1} remains after selection.
- But current selection is very preliminary. We need to optimize it.

- We can observe disappearing track events from ~3 TeV winos!

Disappearing tracks

Masahiko Saito

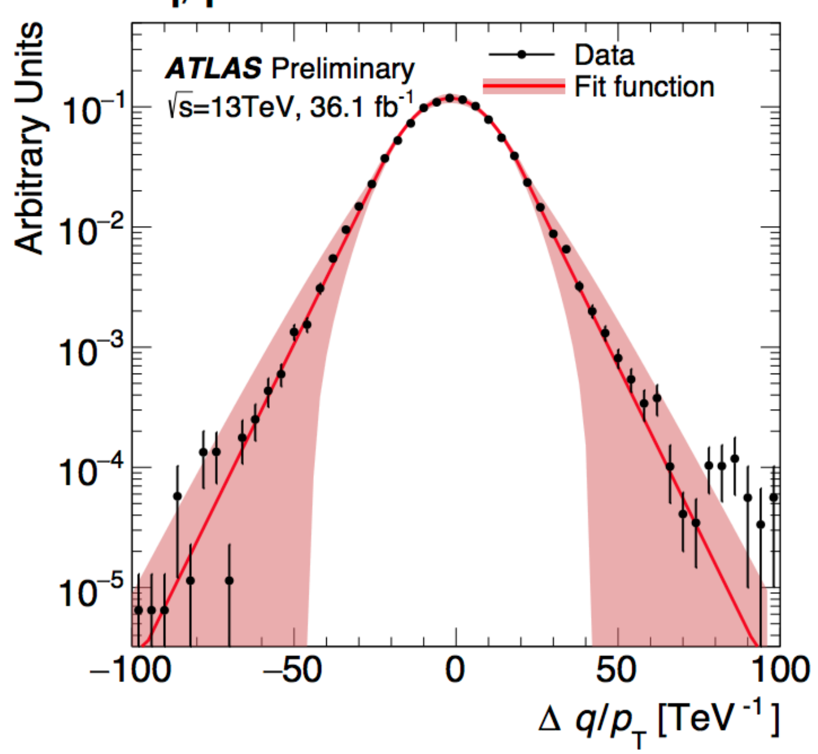
$\sigma(p_T)/p_T = 10 * p_T$ (TeV)

pT resolution of short tracks

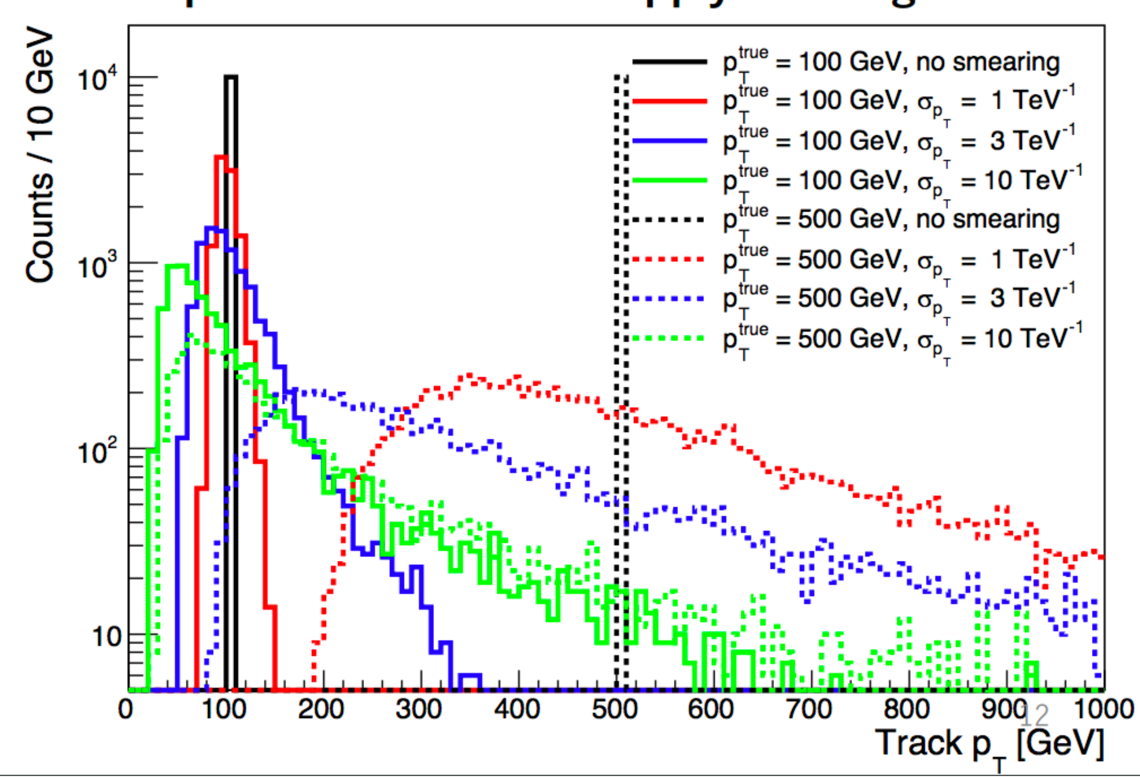
- Very short tracks have very bad resolution because of the lever arms.
- Current resolution is about 10 /TeV. This means we cannot discriminate 100 GeV curvature tracks and linear tracks.
- In this study we ignore this resolutions. However this is very important.

➡ **We would like to check this by full simulation**

q/pT resolution of 4-hits-track



track pT distribution after apply tracking resolution



Disappearing tracks

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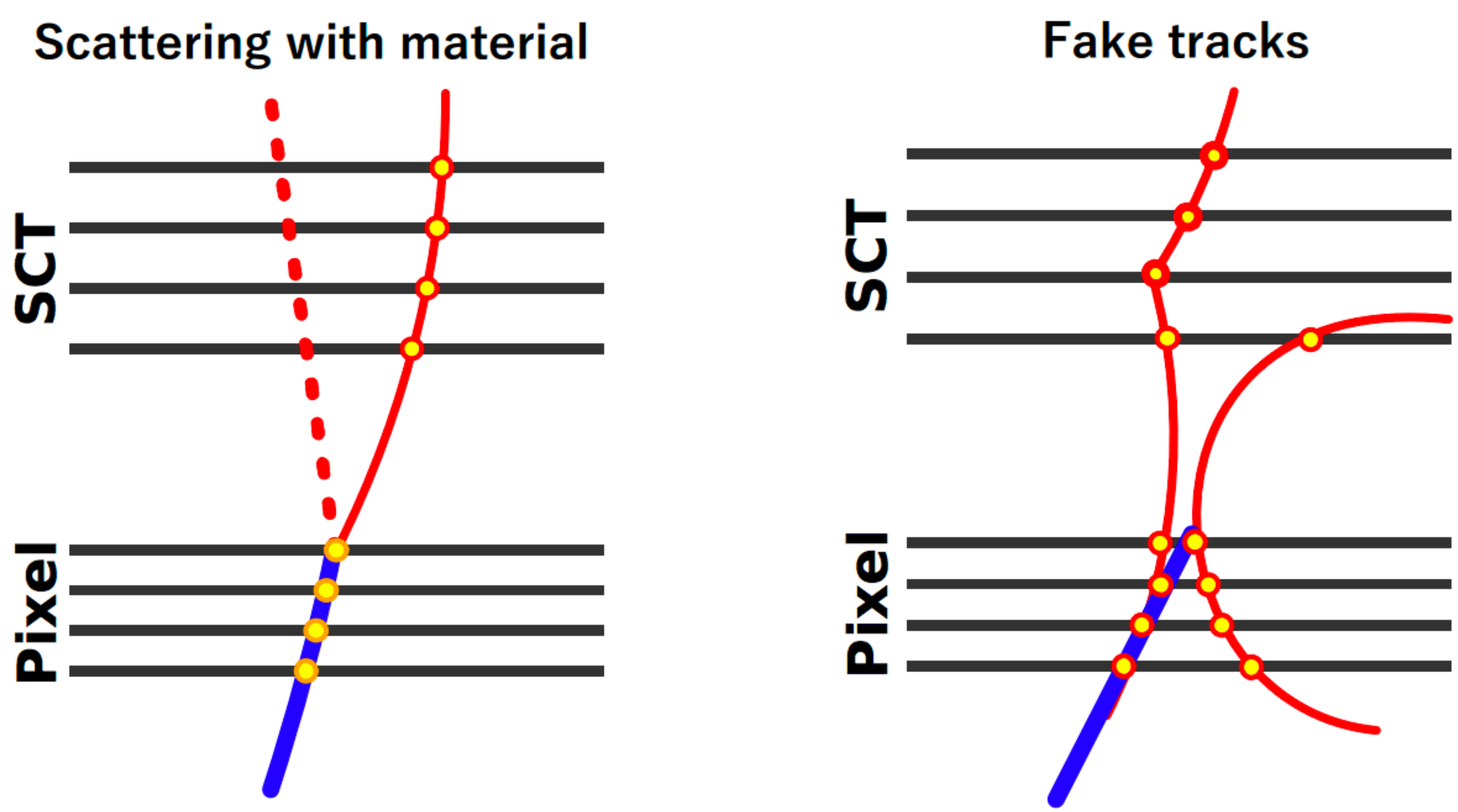
Background strategy



- Backgrounds categorize roughly two components.
  - physical background : Missing hits due to material interaction
  - unphysical background : Random combination of hits
- Background strongly depends on detector. So need simulation