Exotic top decays and top mass interpretation at FCC: progress report

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1. Introduction
2. Exotic top decays
3. Top-flavoured hadrons and m_t
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In collaboration with B.Mele and D.Sengupta and A.P.Lind (top mesons/mass)

Thanks to B.Mele (talks at FCC/TLEP '14 and 2nd FCC Italy and France '24 workshops)

FCC-ee unprecedented clean environment to study top physics

Heavy top mass allows it to decay into a number of BSM final states:

$t \to H^+ b \to \tau\nu b$, $t \to H^+ s \to cs\bar{s}$ (2HDM)

$t \to Z' u$, $t \to Z' c$ (light Z')

$t \to \chi\chi u$, $t \to \chi\chi u$ (DM candidates)

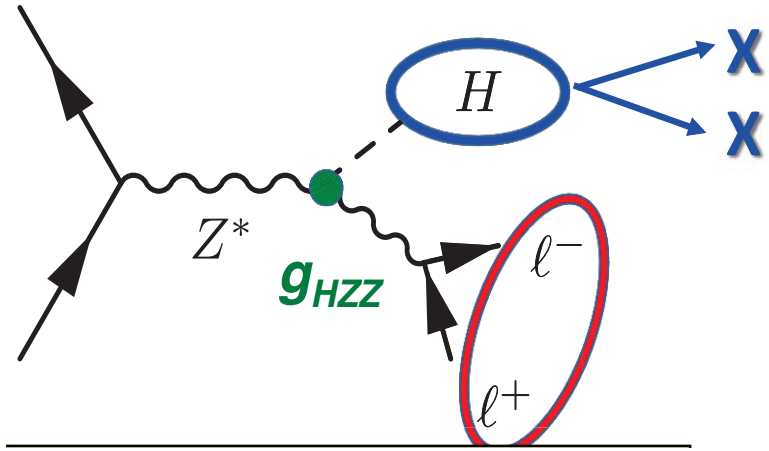
$t \to nj \neq t \to bW \to bjj$

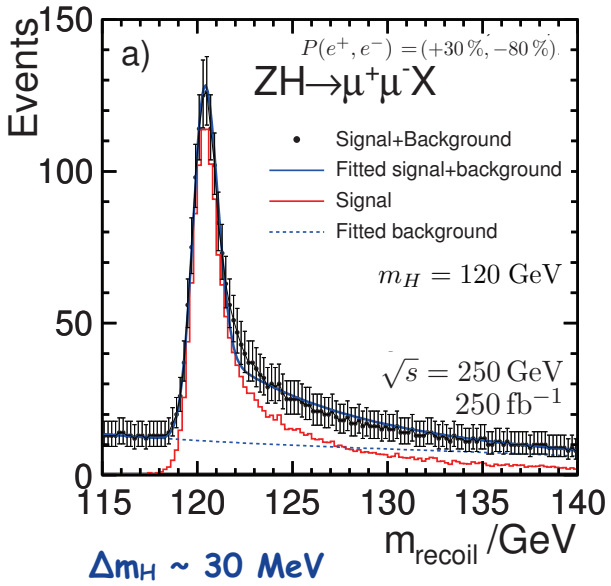
Rare SM decays (CKM suppressed): $t \to Ws$, $t \to Wd$

While at LHC one has to make assumption on exotic decays and models, FCC-ee offers the chance to set bounds in a model-independent manner

Top mass interpretation using T-hadrons: non-perturbative effects are partially suppressed at FCC-ee and T-mass can be related to pole mass

Learning from $e^+e^- \to ZH$ (B.Mele's talks)





One tags Z decay products, i.e. $Z \to \ell^+\ell^-$

From the measurement of $\sigma_{\rm tot}$ one can infer g_{HZZ}

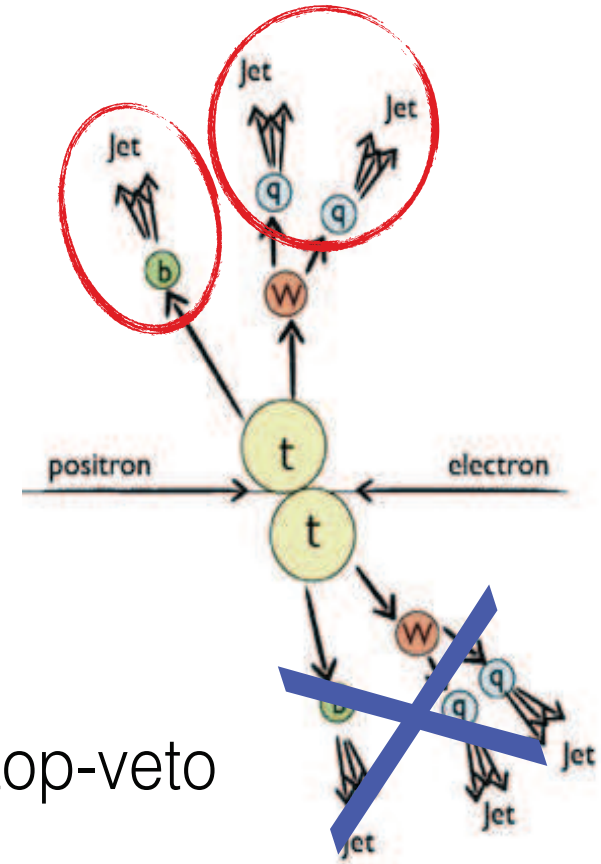
Inclusive Higgs decay as Z recoil system

Sensitivity to all Higgs decays, including the rare ones, such as $H \to c\bar{c}$, $H \to gg$

The recoil mass correctly peaks at the m_H value in the simulation

How about using this method for $t\bar{t}$ events at FCC-ee?

Our strategy: tag one top, e.g. $t \to b(jj')$, and inclusive with respect to the other one



Define a strategy to assign a given final state (bjj') to a SM top quark

One top passes the selection criteria

Recoiling system does not pass the selection (veto on 2nd top)

1) SM decay outside the acceptance region or detector range; 2) exotic decays

Our goal: setting model-independent bounds on exotic BR(top)

Starting point: running Standard Model $t\bar{t}$ events using Madgraph+PYTHIA+DELPHES in all channels (dilepton, ℓ+jets, all jets)

Implement FCC selection criteria: acceptance cuts, efficiencies, ...

Investigate fraction of (SM) events which do not pass the selection

Getting started with FCC simulations: technical issues to be discussed even offline (D.Sengupta, acknowledgements to M.Selvaggi)

https://fcc-physics-events.web.cern.ch/FCCee/delphes/winter2023/idea/

Delphes FCC-ee physics events from winter 2023 production (IDEA Detector)

It works well when using the root files provided by the authors, problems with files generated by ourselves

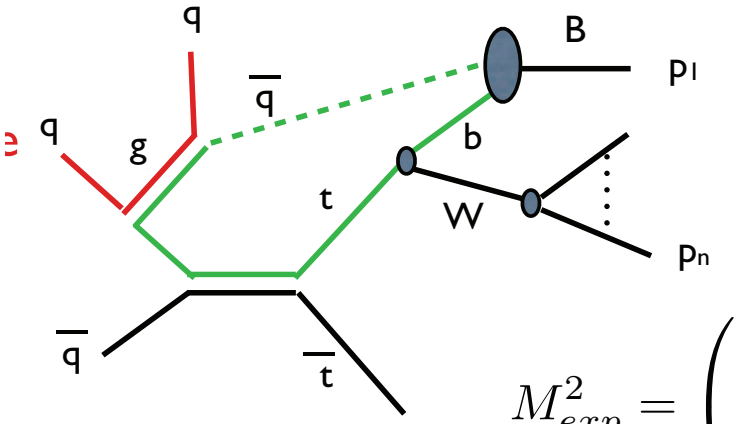
Similar results when trying $e^+e^- \to ZH$ samples

Long-standing debate on interpretation of the top mass measurements

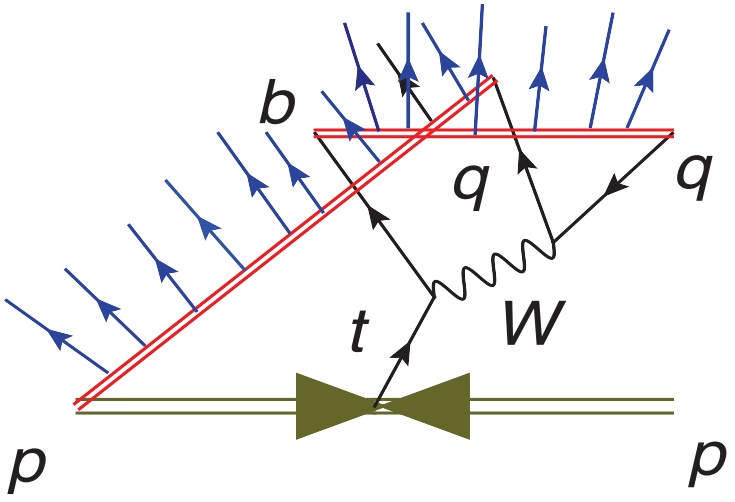
Much work to understand uncertainty/discrepancy in the extracted m_t (MC generators) in terms of pole mass (G.C.'19, A.Hoang'20, P.Nason'17)

It is well understood that, as m_t is extracted from top-decay products, it must be close to the top pole mass

Non-perturbative effects (colour reconnection, underlying event, etc.) spoil this picture): effects of $\mathcal{O}(\Lambda_{\rm QCD})$: $m_t = m_t^{\rm pole} + \mathcal{O}(\Lambda_{\rm QCD})$



$$M^2_{exp} = \left(\sum_{i=1,\ldots,n} p_i \right)^2$$



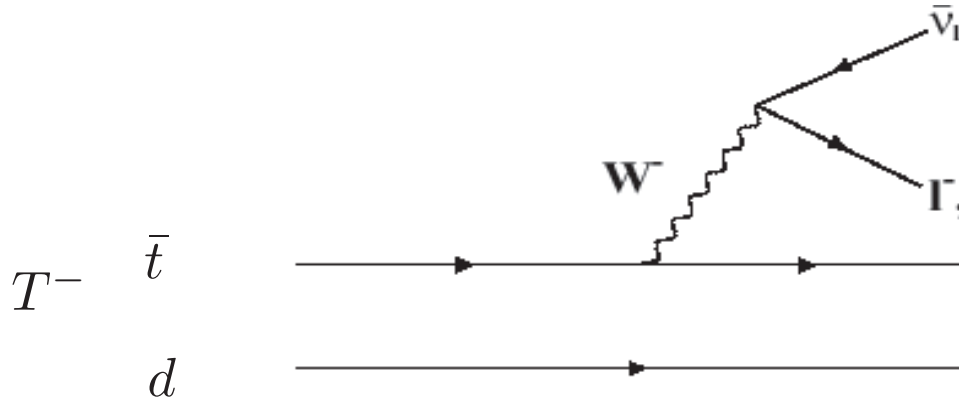
Left: M.L.Mangano, TOP 2013 workshop, Right: S.Argyropoulos, LNF'15 workshop

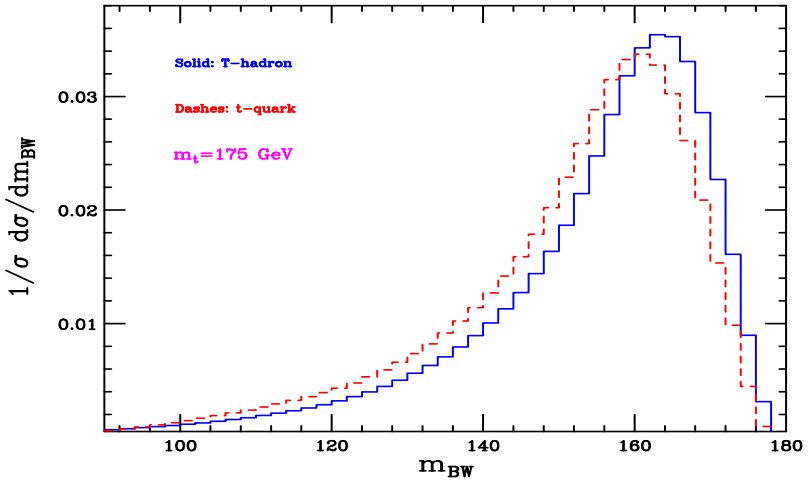
Simulation of top hadrons T: $m_T = m_{\rm pole} + \Delta$ (lattice, HQET, NRQCD)

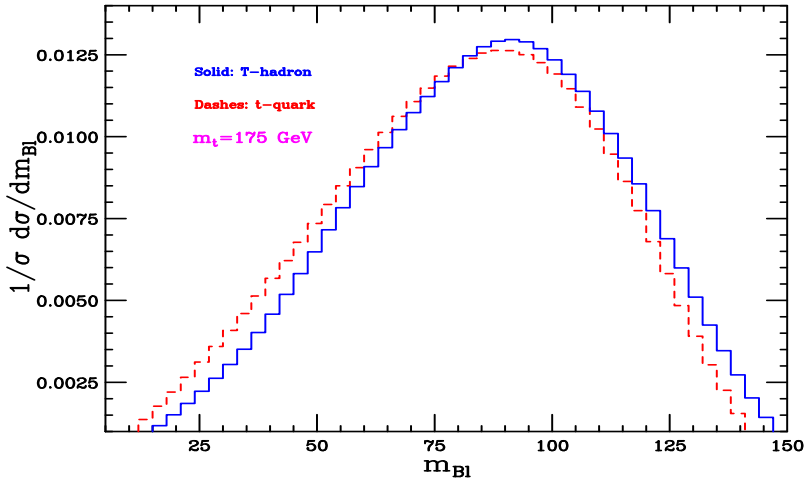
Compare $t\bar{t}$ and T-hadron events and fit m_t (G.C., A.P.Lind and D.Sengupta)

FCC-ee ideal environment as it suppresses ISR, underlying event, colour reconnection between initial/final states

Strategies to discriminate T from standard $t\bar{t}$ final states







Preliminary results: HERWIG 6.510 for m_{BW} (left) and m_{Bl} (right) $\sqrt{s} = 500$ GeV

Conclusions

FCC-ee offers unprecedented opportunities for precise measurements of top-quark properties

Unlike LHC it allows one to explore rare SM and exotic top decays model-independently

Work in progress on bounding exotic top decays exploiting recoiling system (analogy with $e^+e^- \to ZH$)

Simulation of top-flavoured mesons T: interpreting m_t using lattice or HQET to relate pole mass to m_T and eventually m_t

Possible strategy to detect/exclude top mesons?