[Work in Collaboration with L Apolinario, G Milhano, G Salam]

Boosted tops and the time-structure of the QCD medium

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@CASSalgado @HotLHC

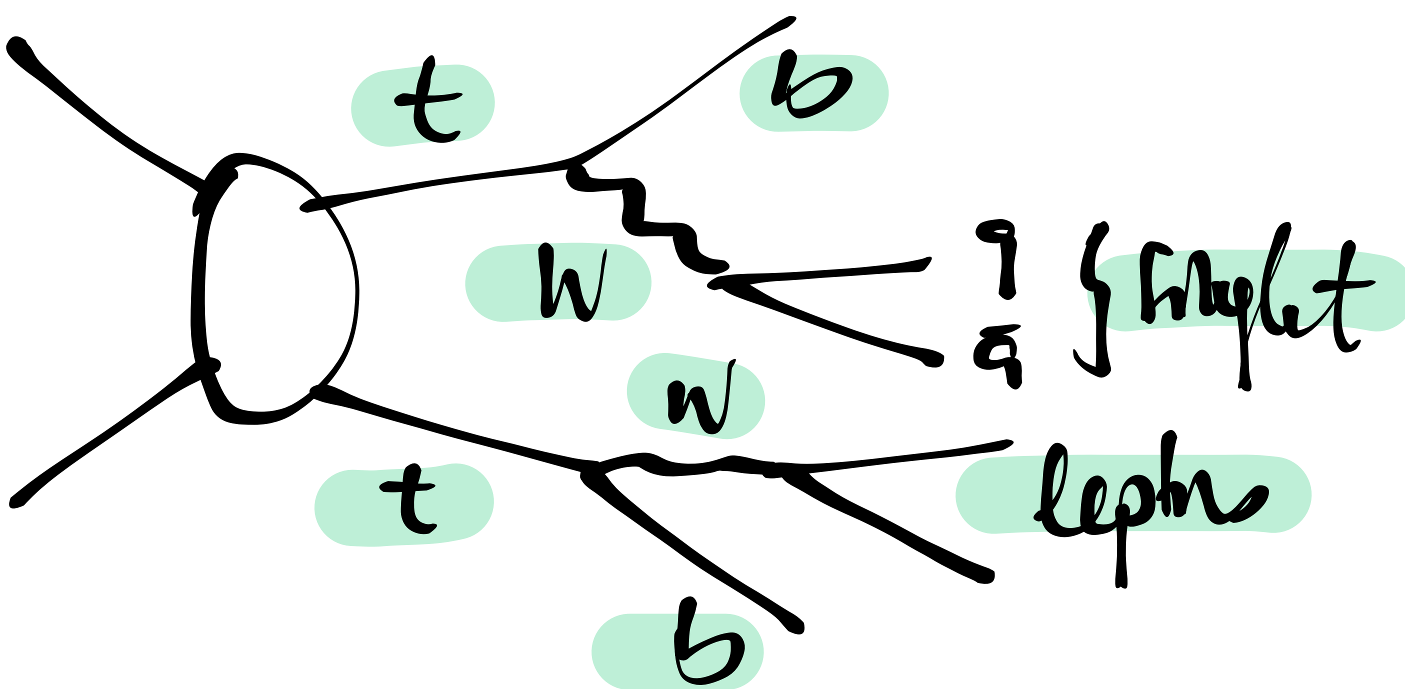
European Research Council
Established by the European Commission

Simple question

Can we **more directly measure the space-time** development of the medium with jet observables? - including **late times**

Switch-off the cascade for some time

Use **color-singlet** configurations



Boosted tops a possibility

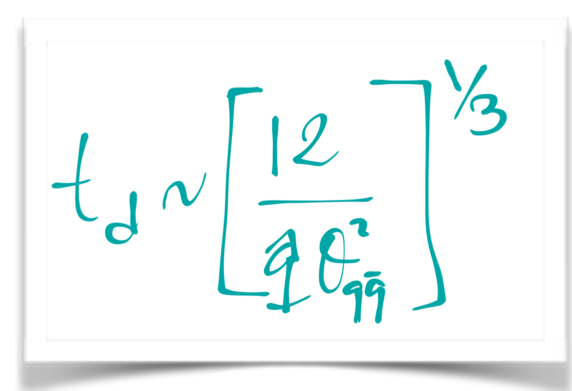
Main limitation: very rare - **high statistics needed (HL-LHC & FCC studied here)**

Lifetimes [W's and tops]

Tops and W's have finite lifetimes - and decay into jets

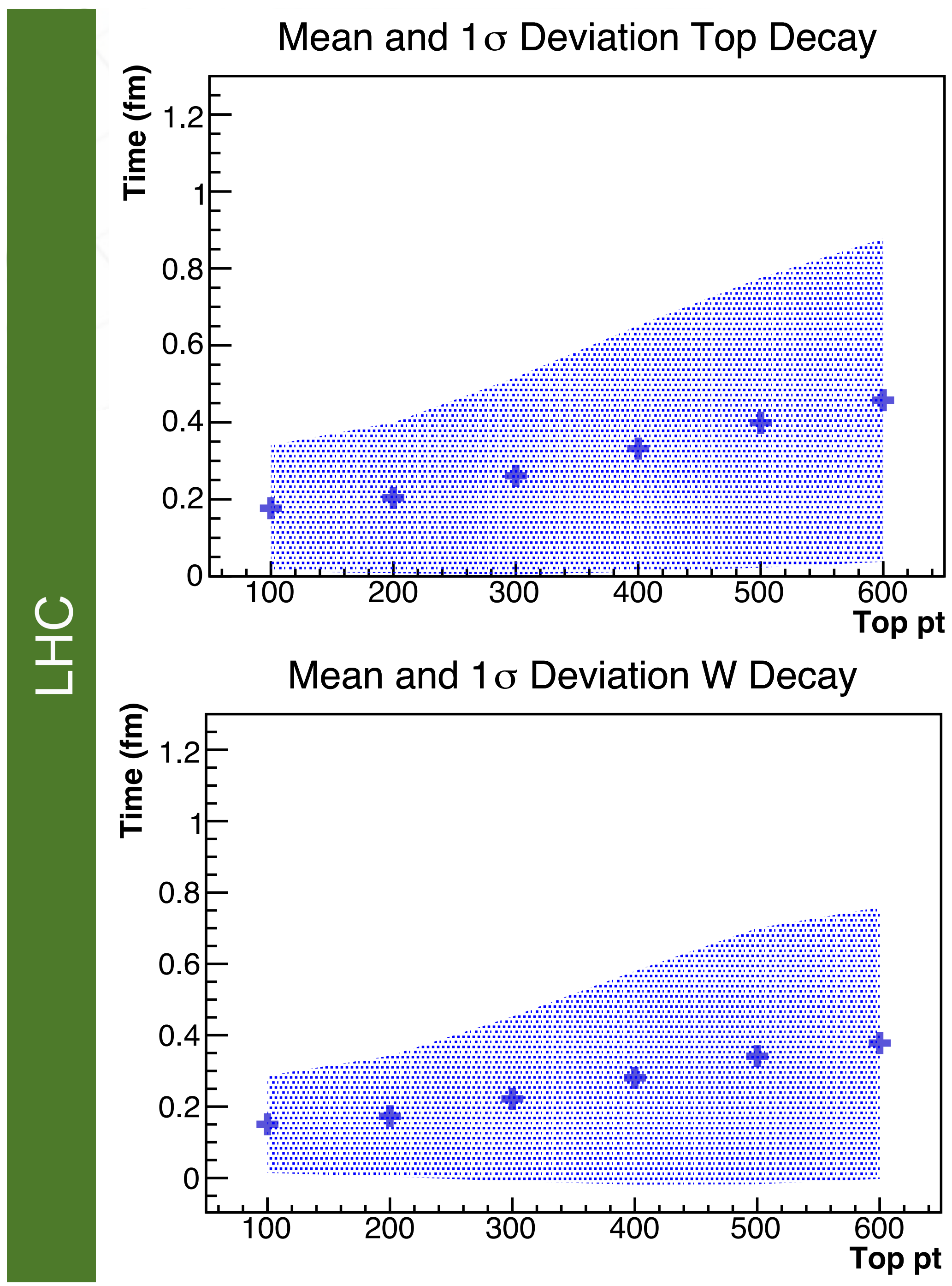
top quark at rest	**~0.15 fm/c**
W boson at rest	**~0.10 fm/c**

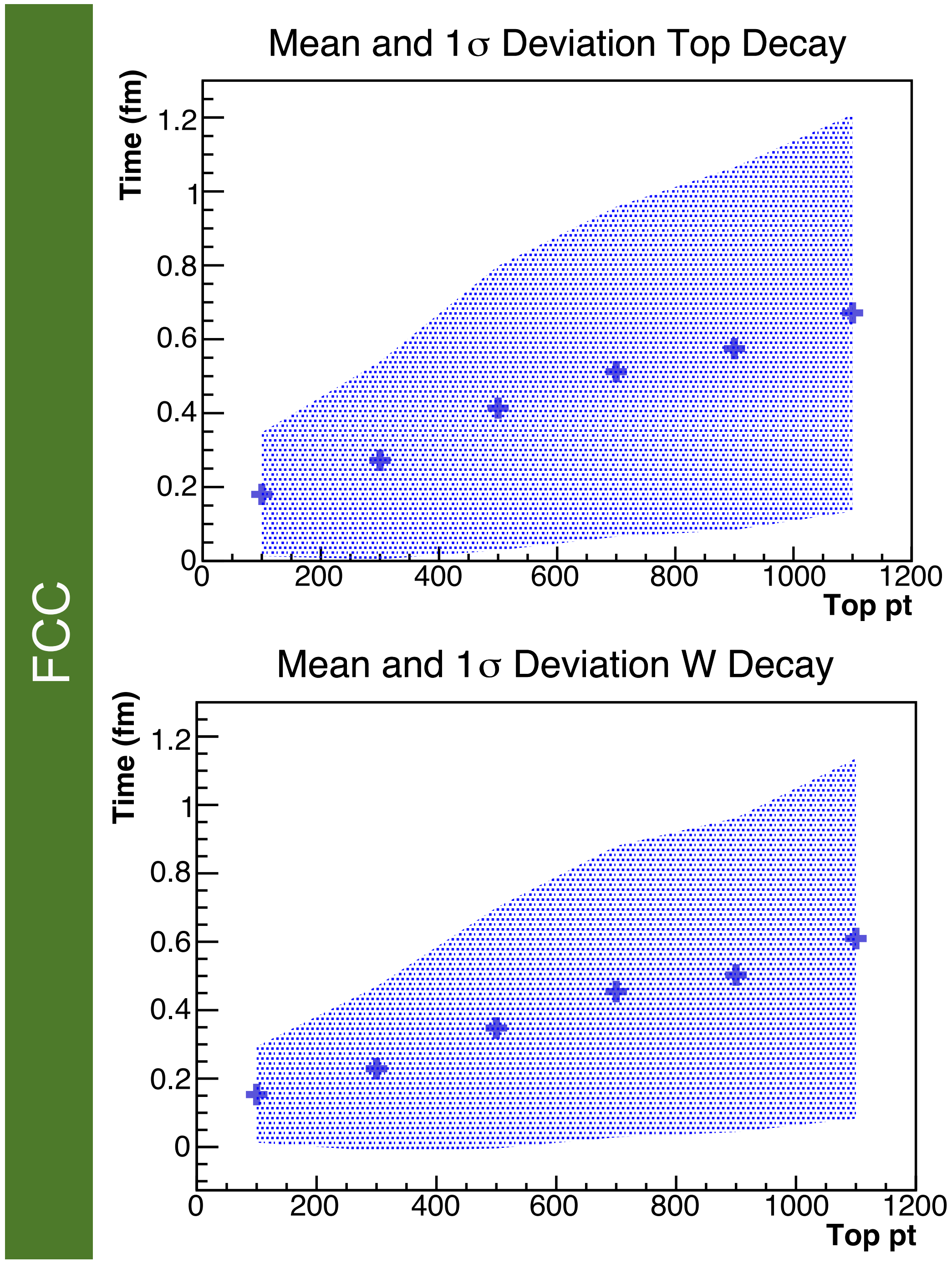
- Enhance these times **by boost** - high-pT top/W
- **Color coherence** - color singlet object for longer time



[Mehtar-Tani, Salgado, Tywoniuk; Casalderrey-Solana, Iancu]

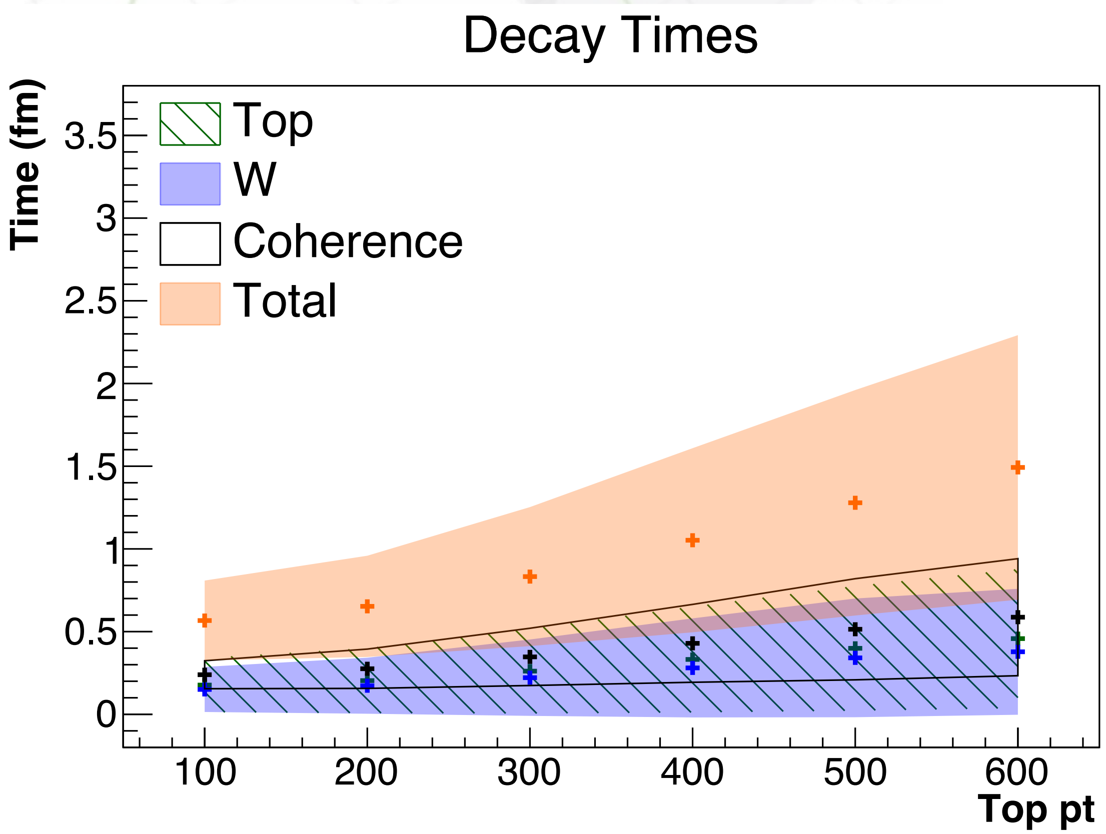
Yoctosecond cronometer





Boosted lifetimes

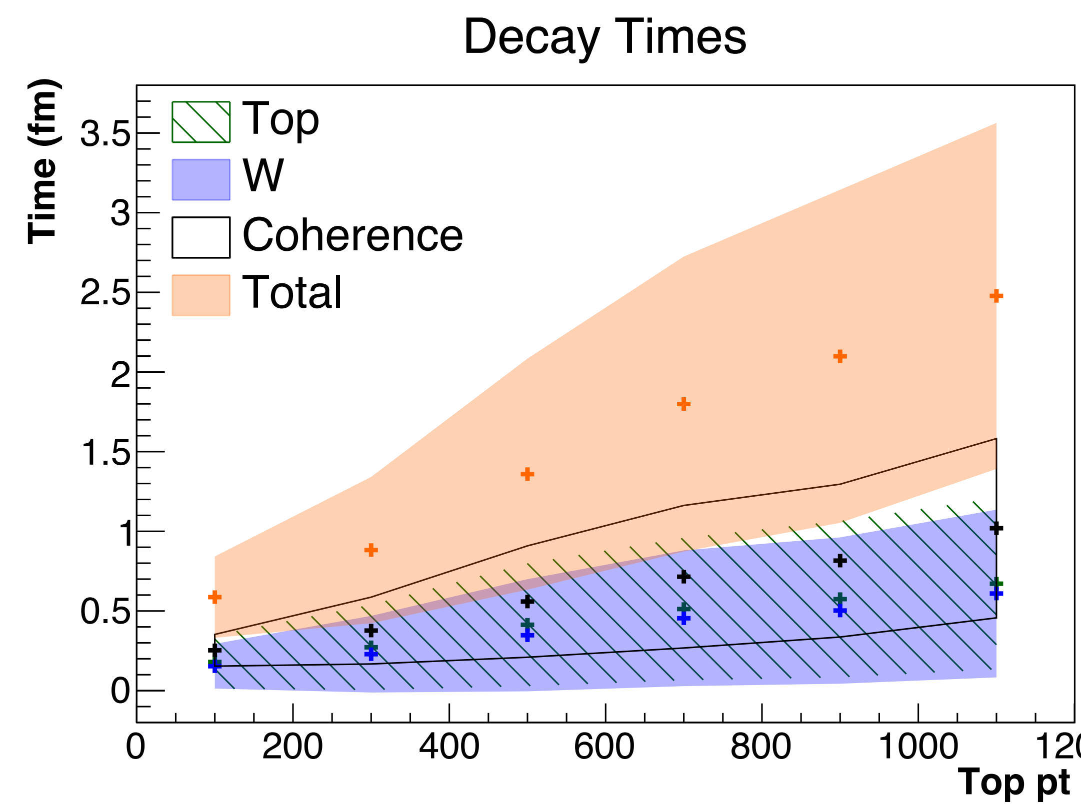
LHC



→ not enough statistics

Probe 0.4<t<1.2 fm

FCC



(Here most of the results for FCC)

Probe 0.5<t<3.5 fm

Proof of principle analysis

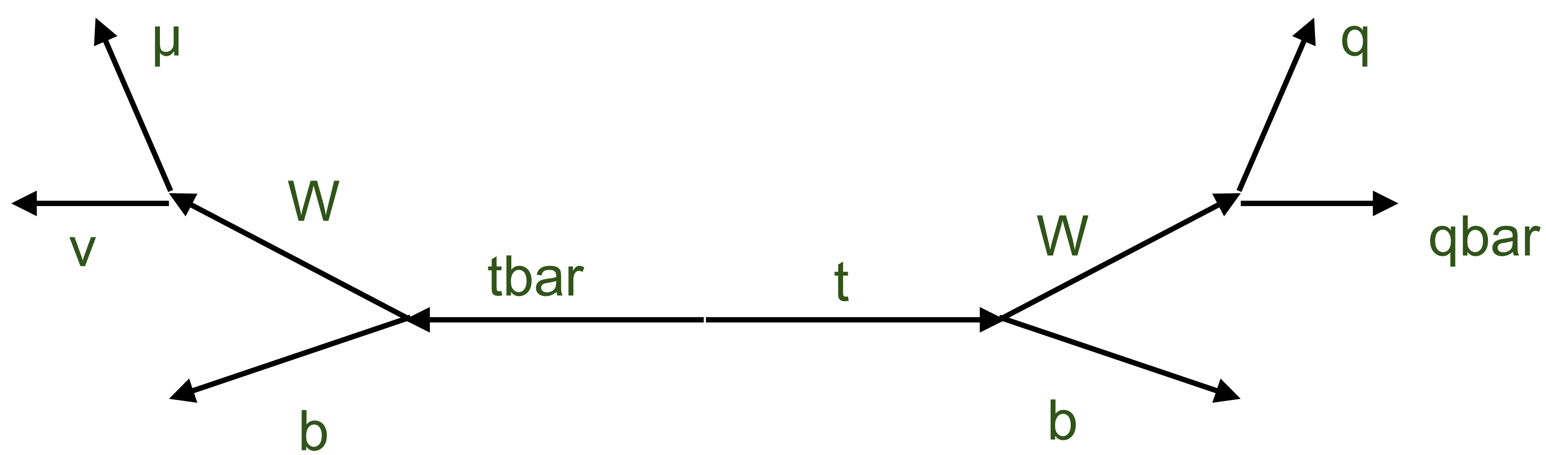
Simulation by POWHEG (hard event) + PYTHIA 8 (parton shower)

LHC - HL	FCC
5.5 TeV/nucleon	39 TeV/nucleon
Lint = 10 nb-1	Lint=30 nb-1
A=208 (Pb)	A=208 (Pb)
0-10% centrality (42% of ttbar events)	0-10% centrality (42% of ttbar events)

For this proof of principle analysis we **do not include** HI background or detector effects

Reconstruction method

Event with at least
- 1 muon, pT>25, |eta|<2.5 (in real world require MET?)
- 2 b-jets (assumed 70% efficiency)
- 2 or more jets



[Stolen from L Apolinario - Paris 2016]

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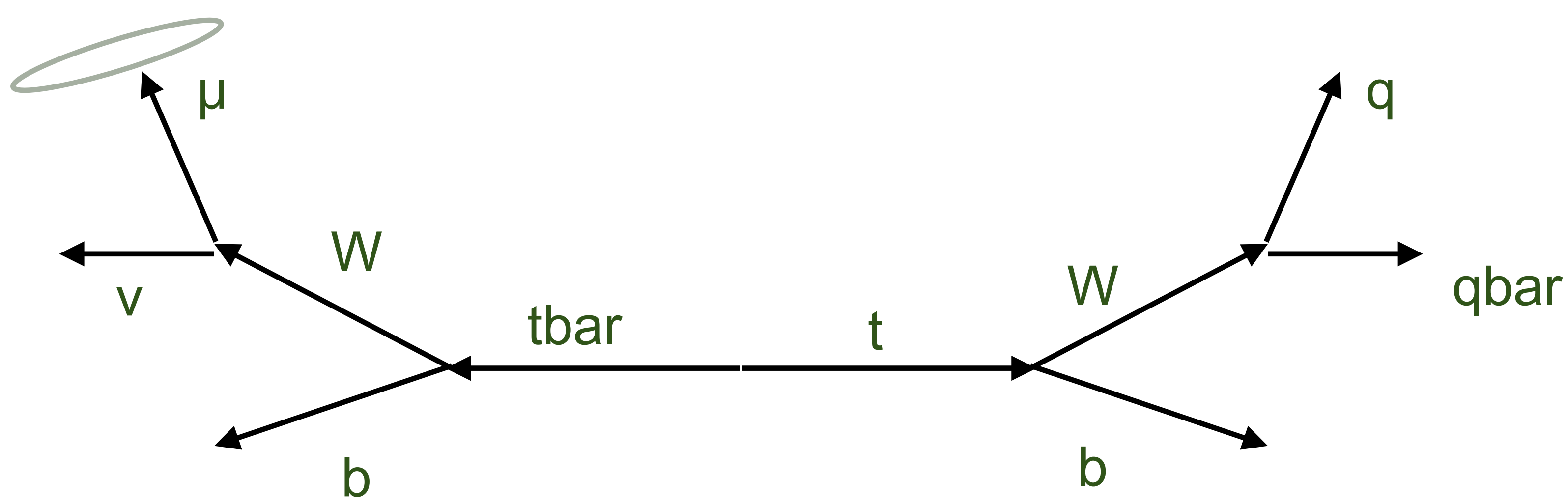

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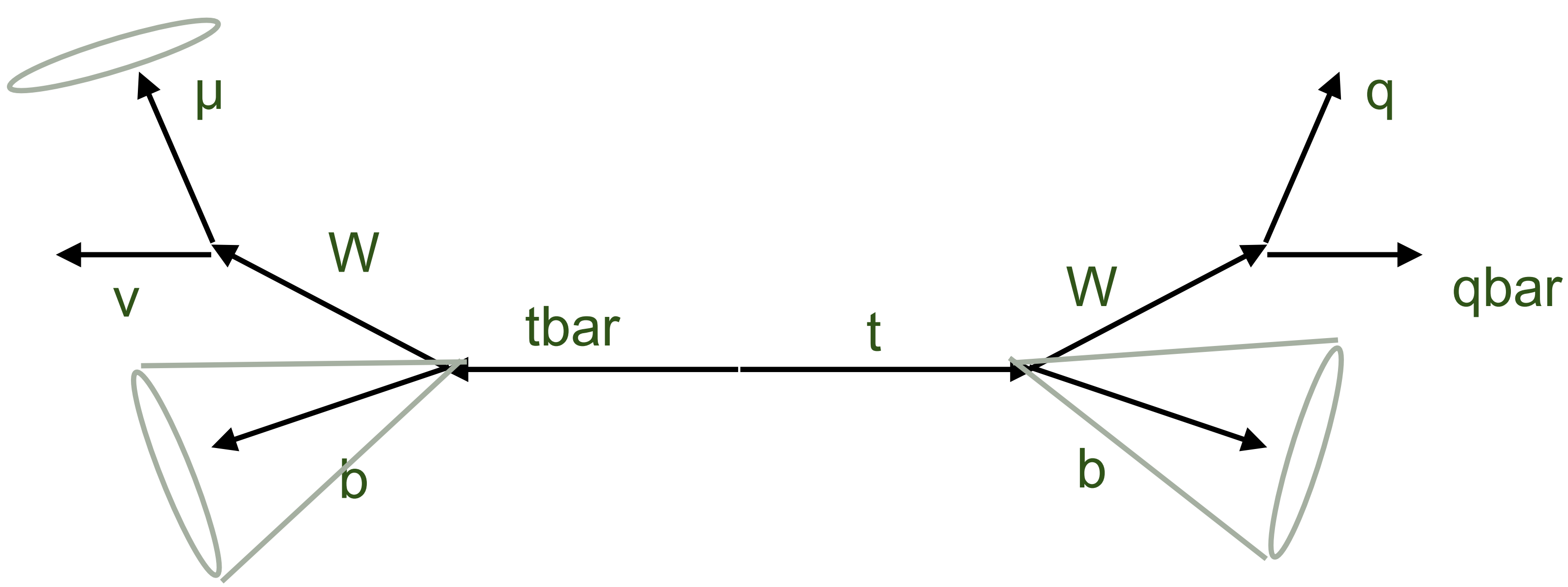

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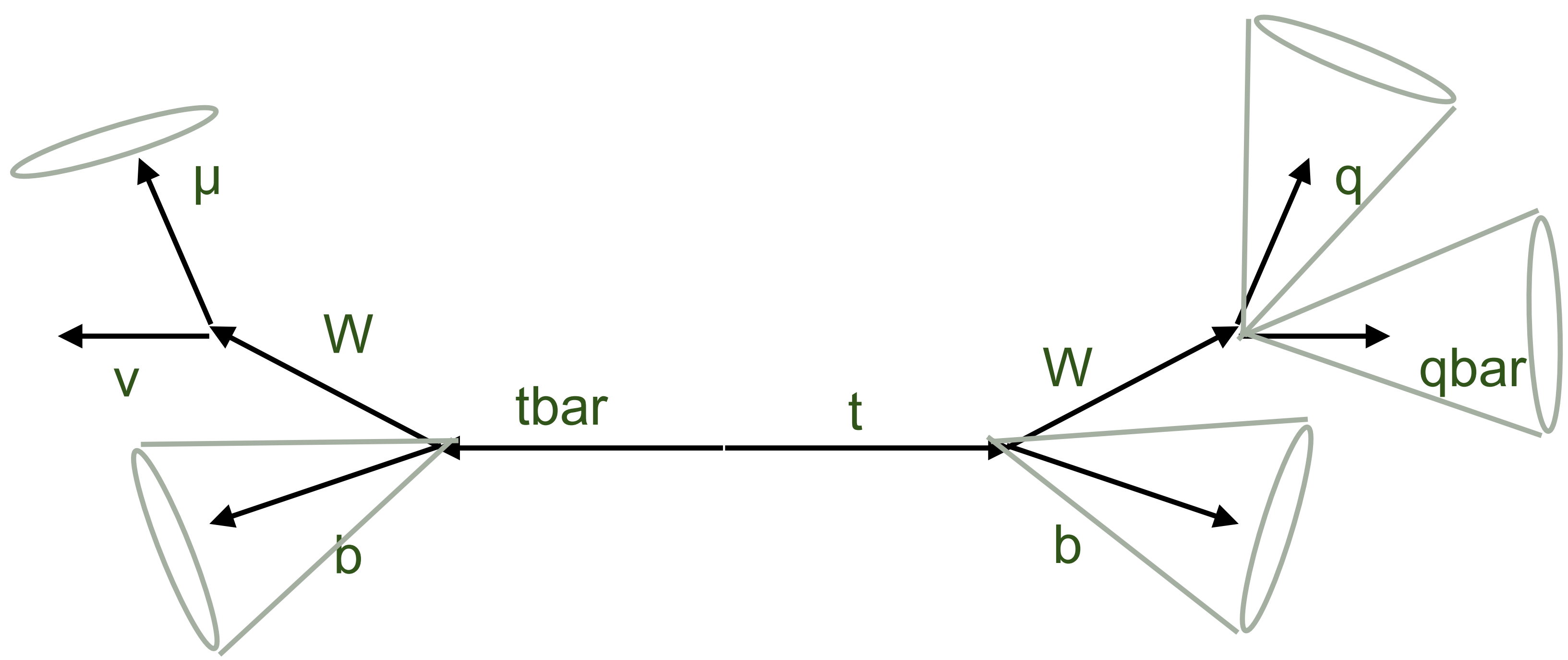
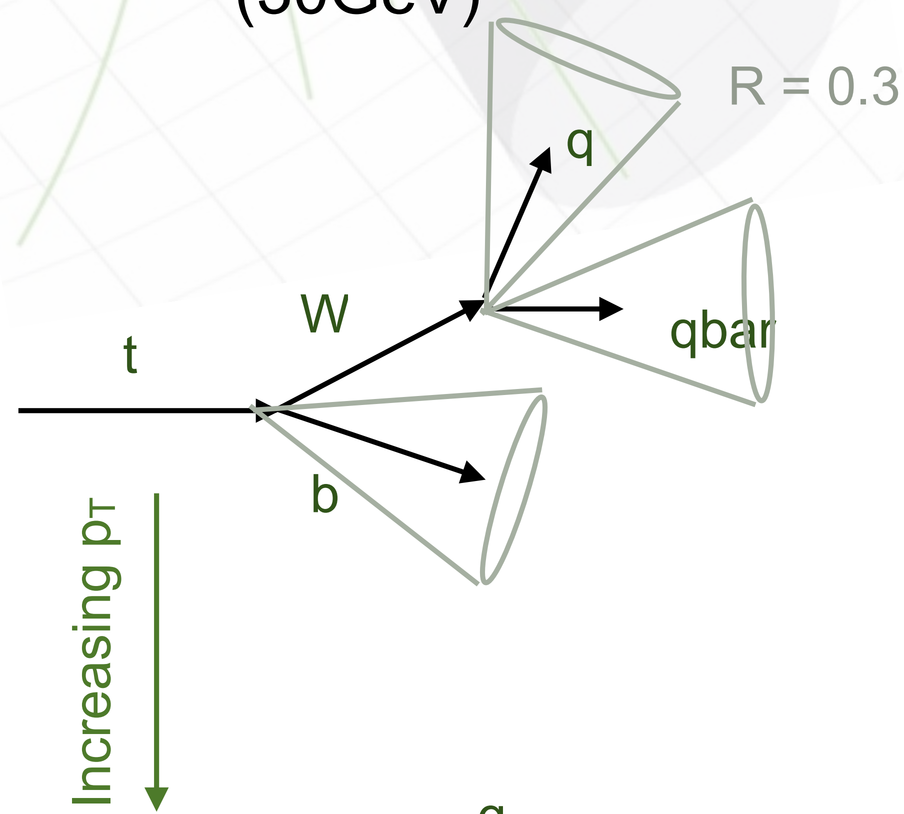
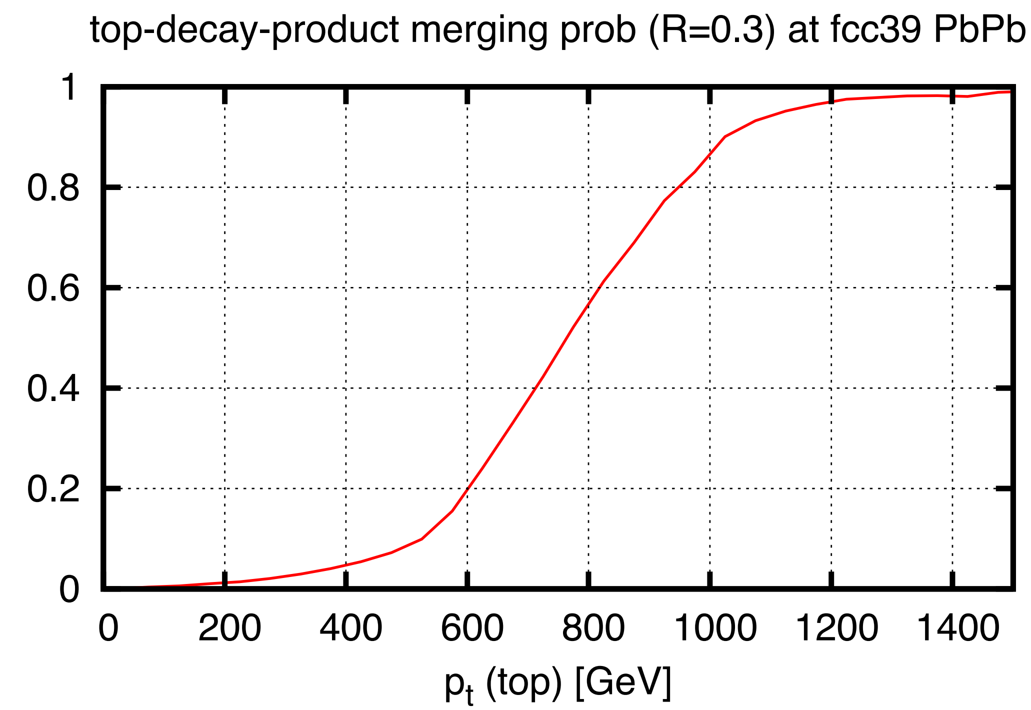


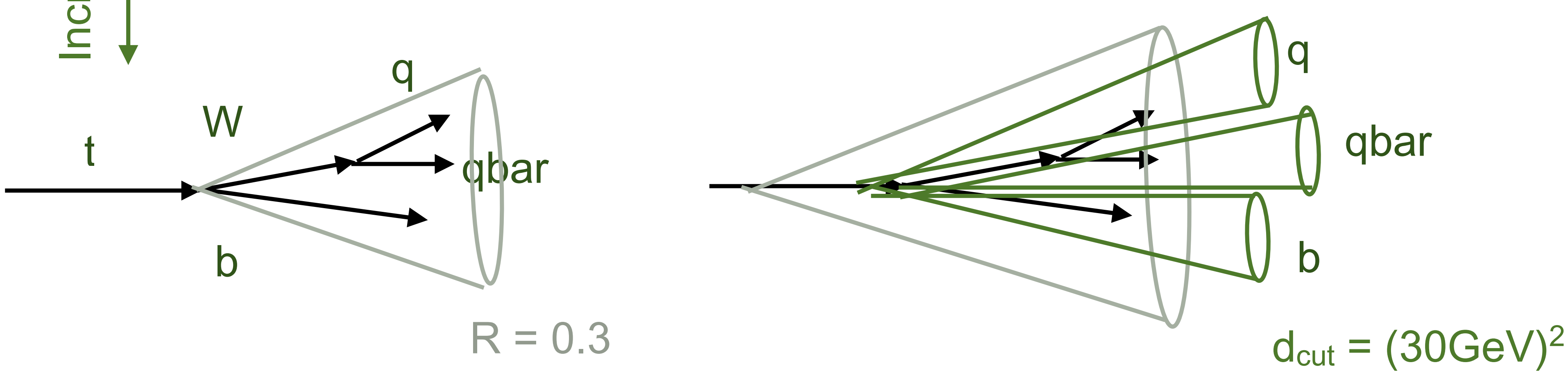
[Stolen from L Apolinario - Paris 2016]

Reconstruction method

- Anti-k_T jets with R = 0.3, p_T > 30 GeV, |η| < 2.5.
  - Recluster with k_T algorithm, R = 1.0 and decluster with dcut = $(30\text{GeV})^2$





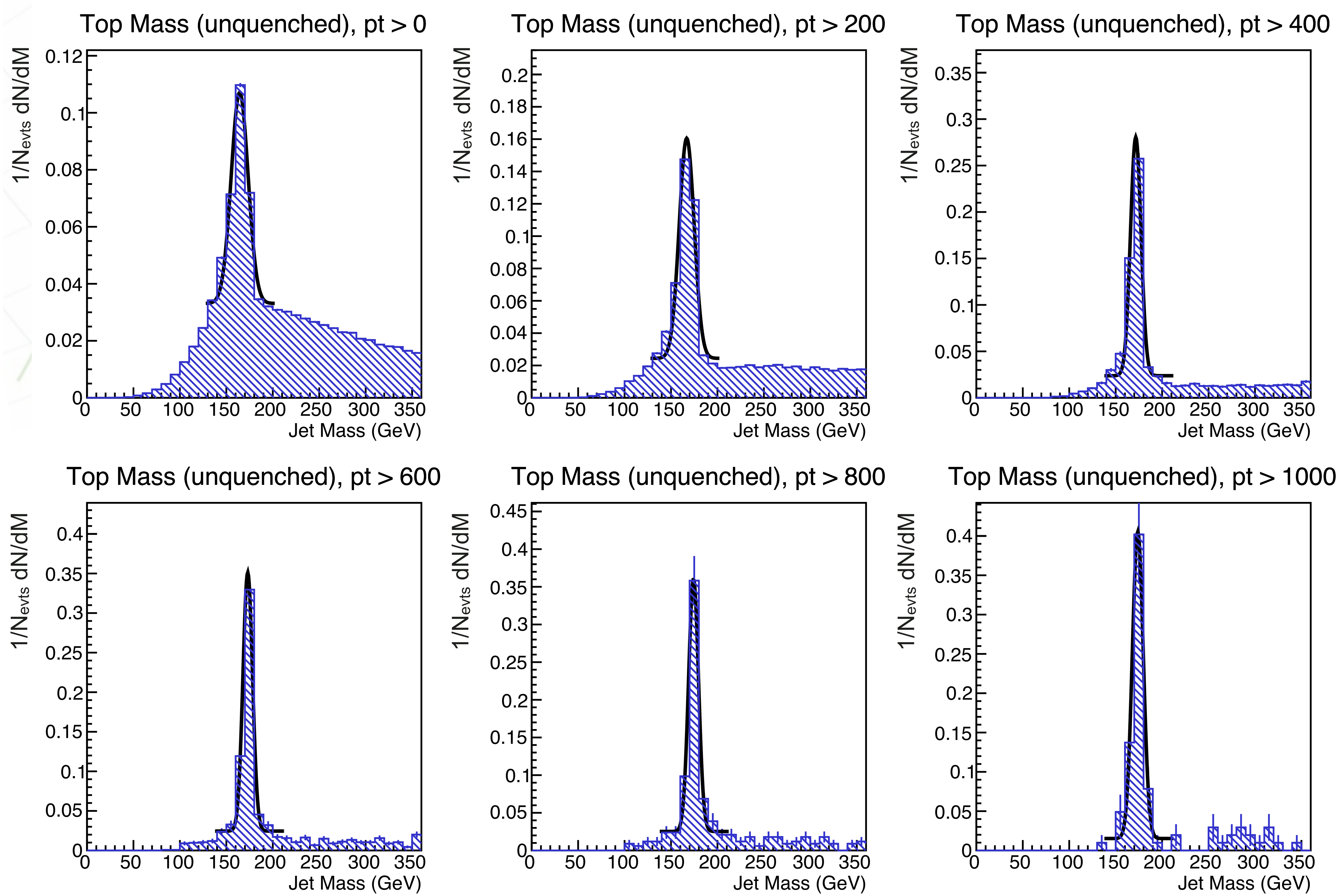


Reclusters with larger R and find sub-jets with $p_{T,rel} > \sqrt{(d_{cut})}$

[Stolen from L Apolinario - Paris 2016]

Reconstructed top mass

Simple Energy loss scenario



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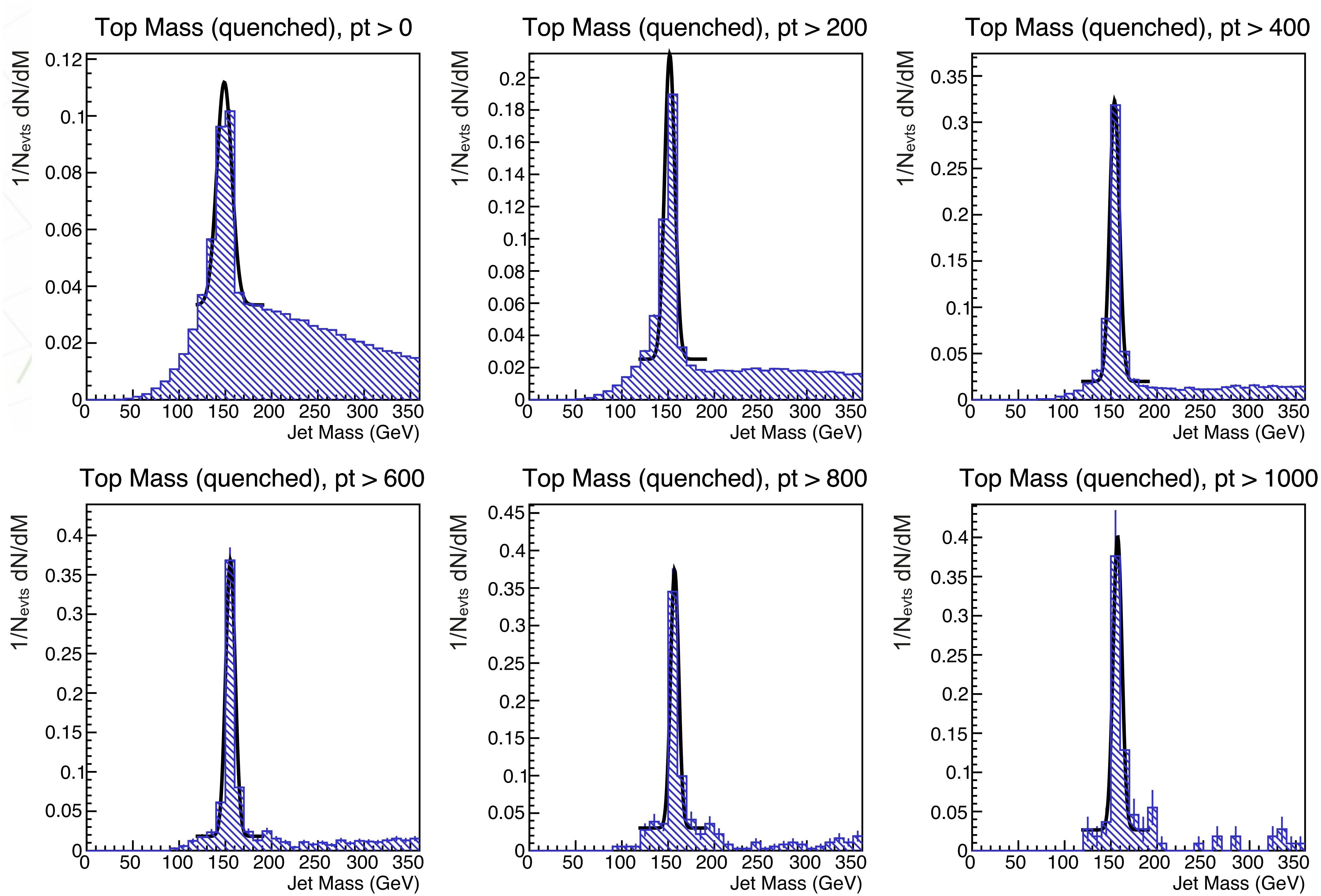
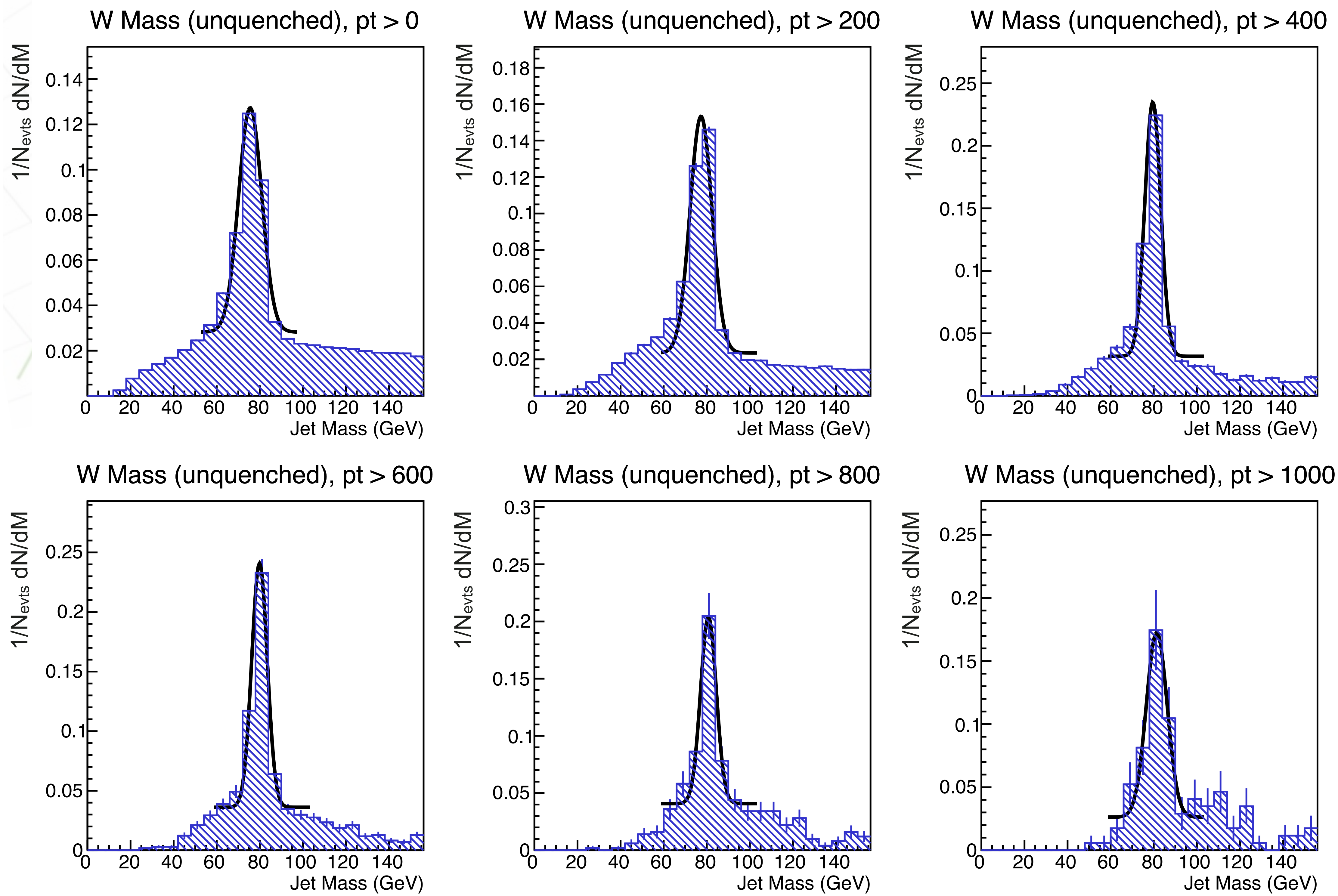
Simple Energy loss scenario



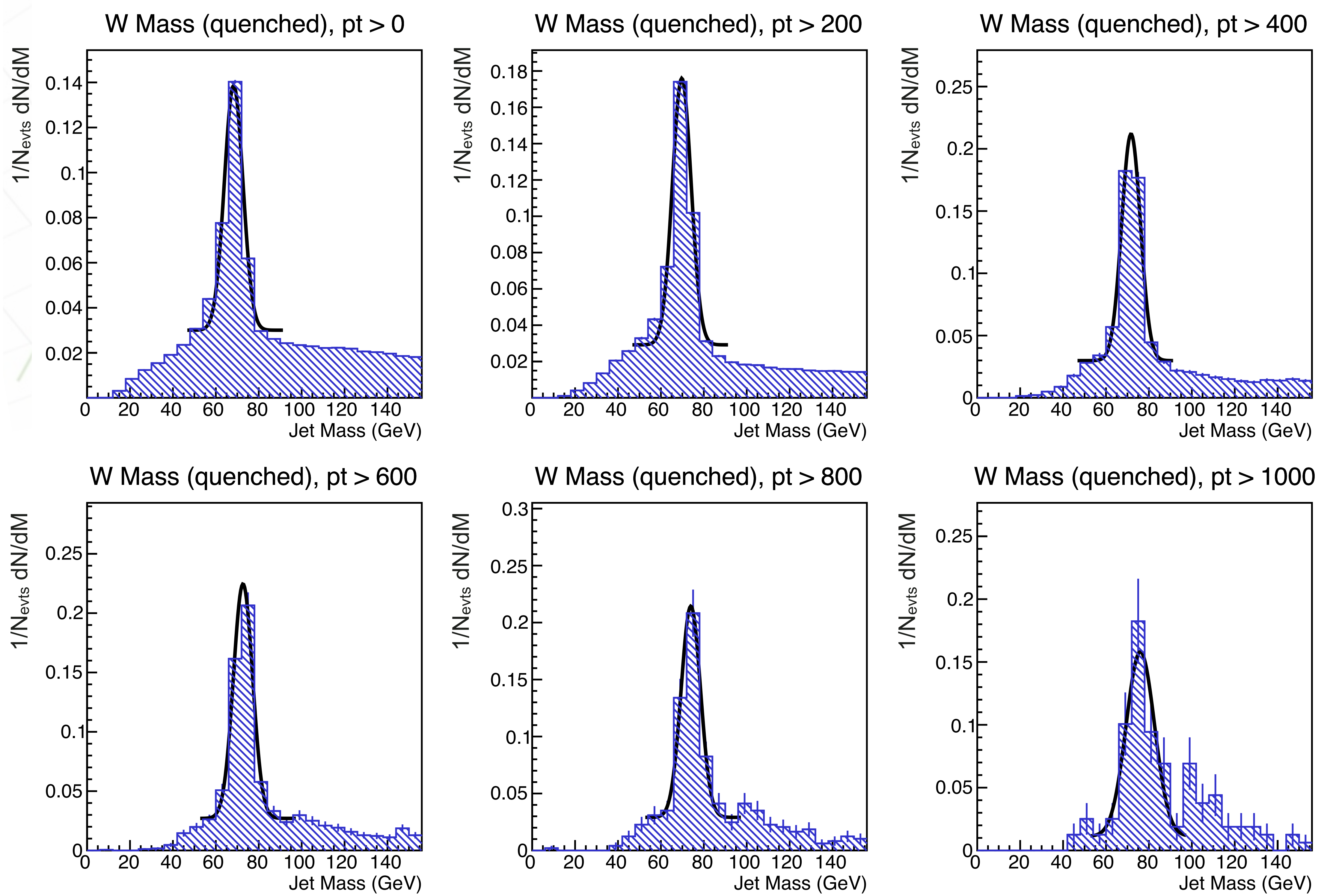
Reconstructed W mass

Simple Energy loss scenario



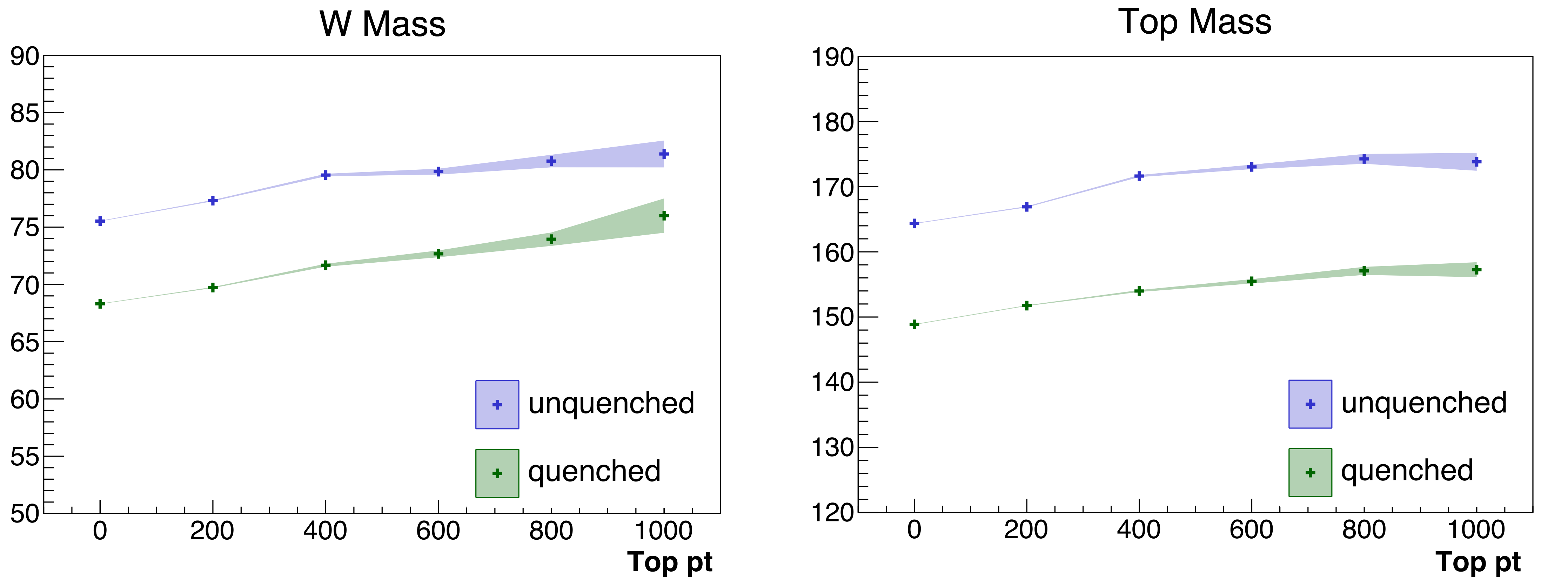
Reconstructed W mass

Simple Energy loss scenario



Rec masses vs Energy loss

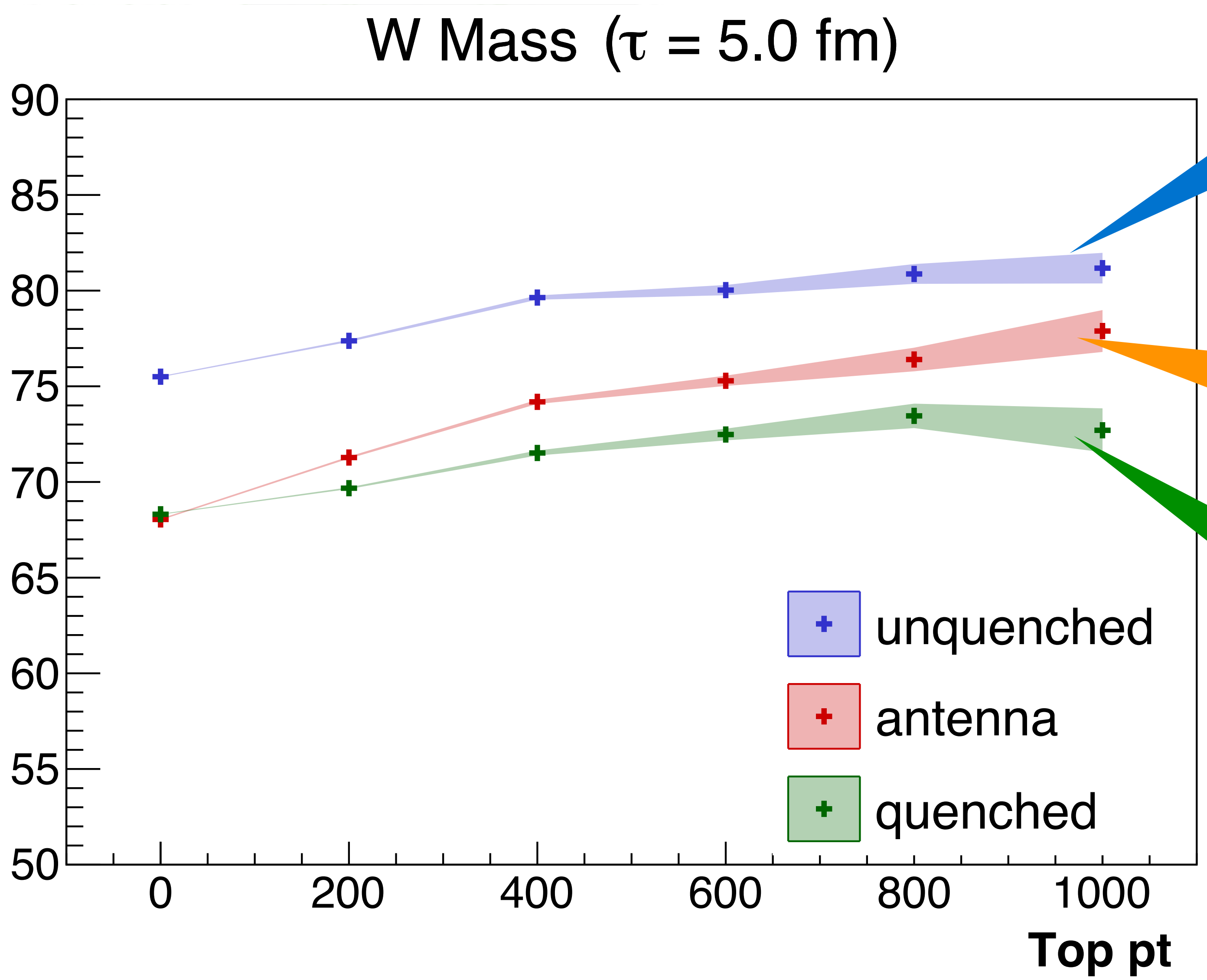
All partons lose a 10% of energy



A very simplified energy loss scenario
but reconstructed masses clearly different with jet quenching

Color coherence

Simplified implementation of color coherence



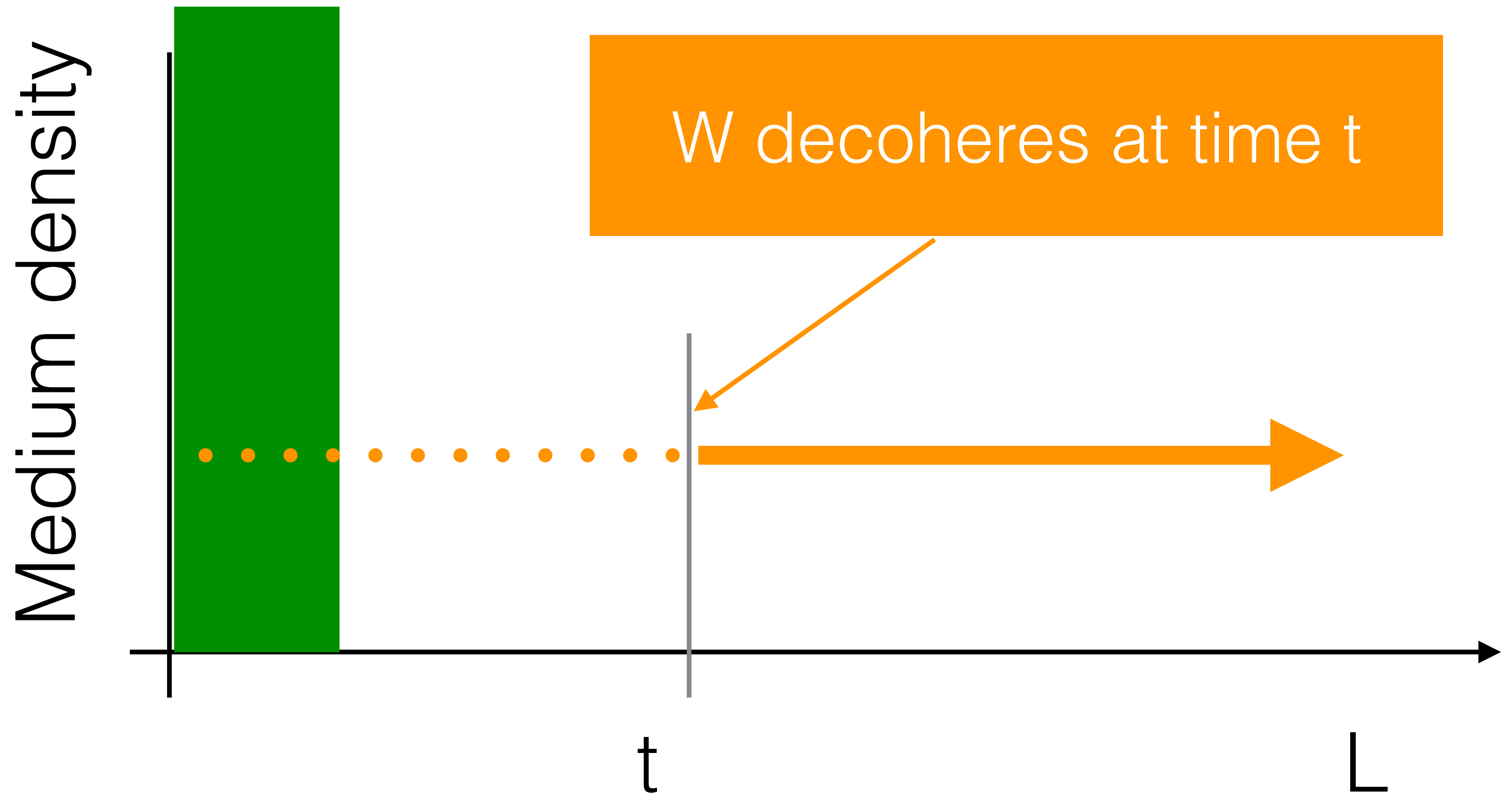
Unquenched

Partons from the decay of the W do not lose energy (totally coherent singlet antenna). All other 10% Energy loss

All partons 10% Energy loss

Time-dependent Eloss

Toy model to study the effect of “switching-off” the jet interaction for some time t



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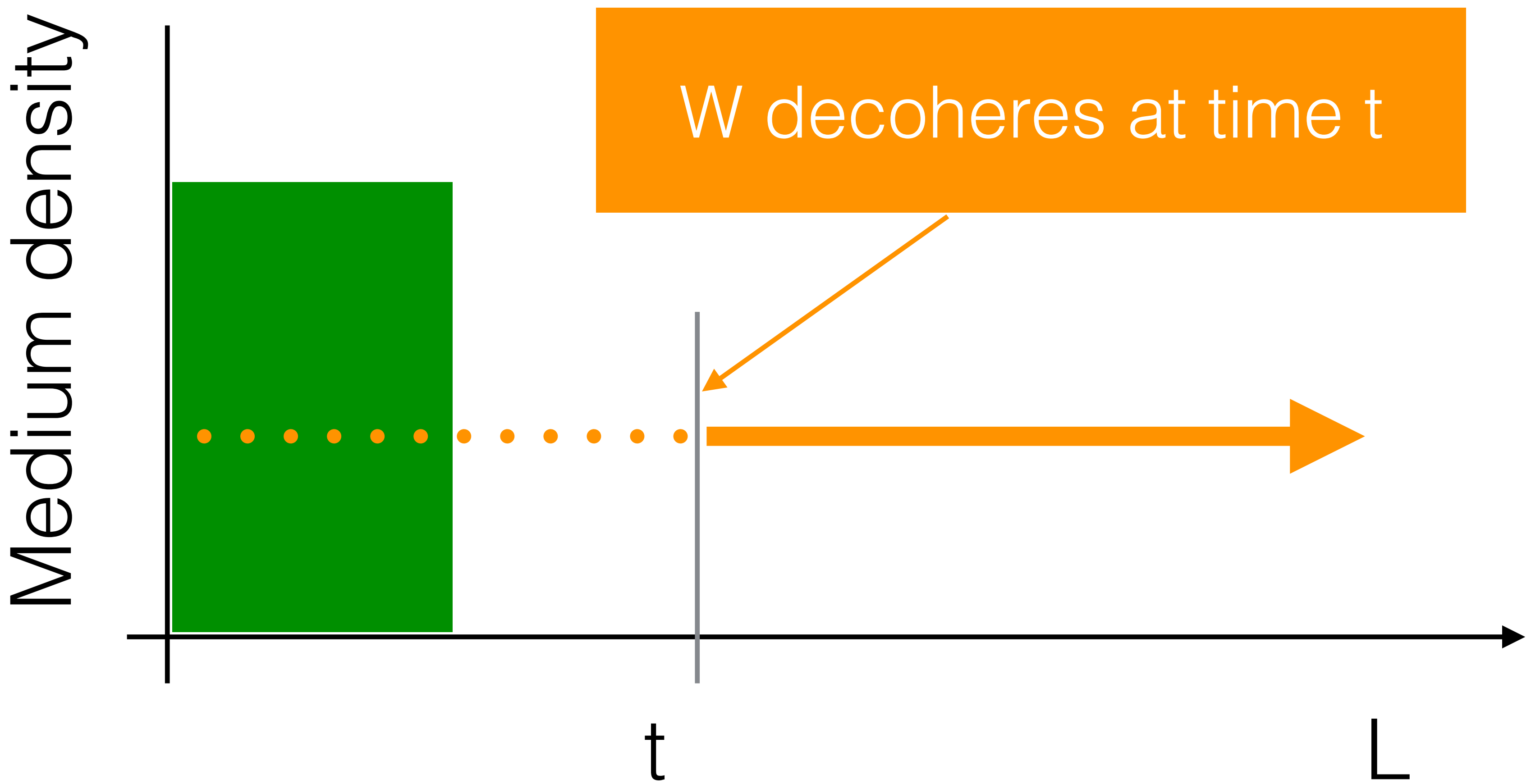

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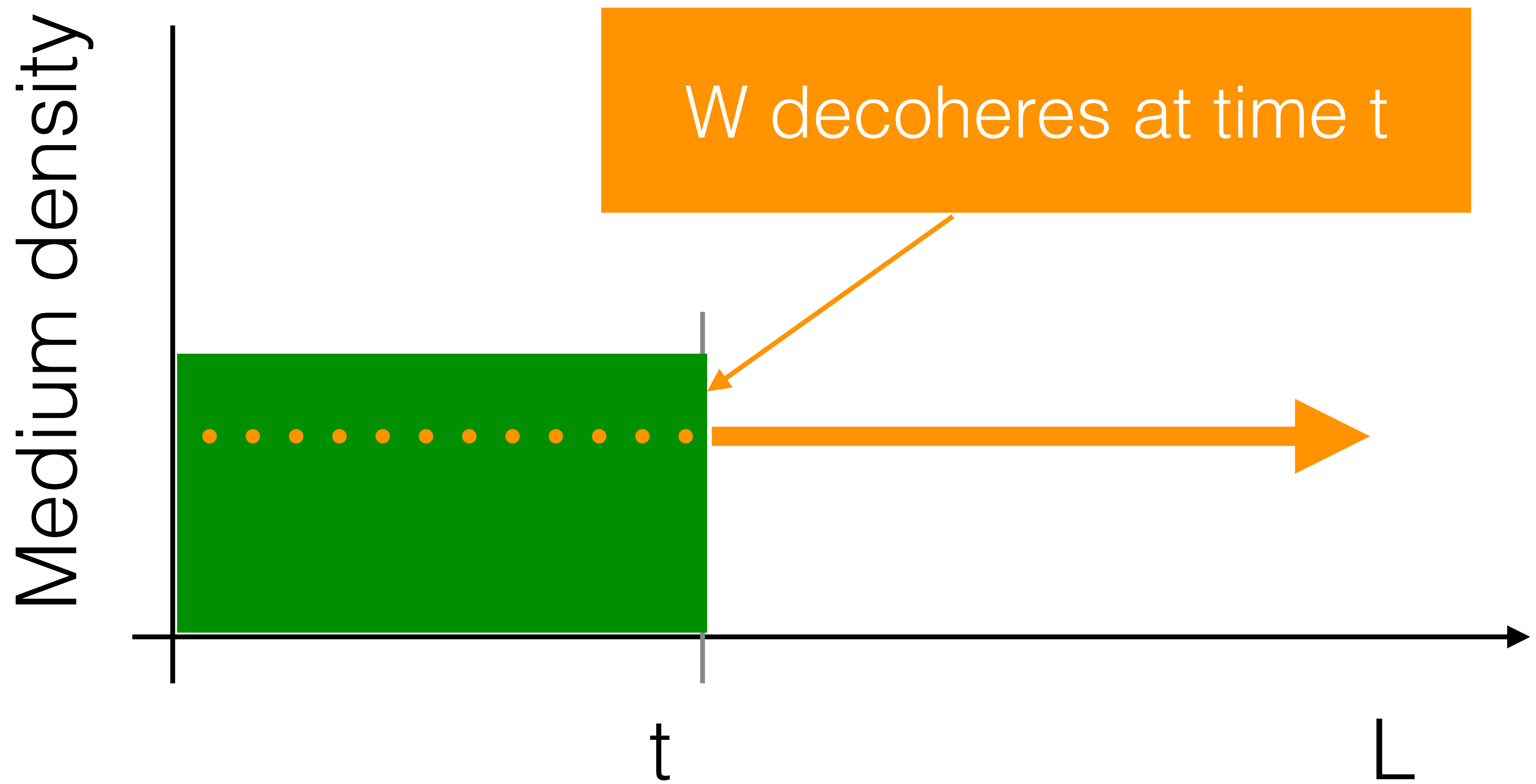

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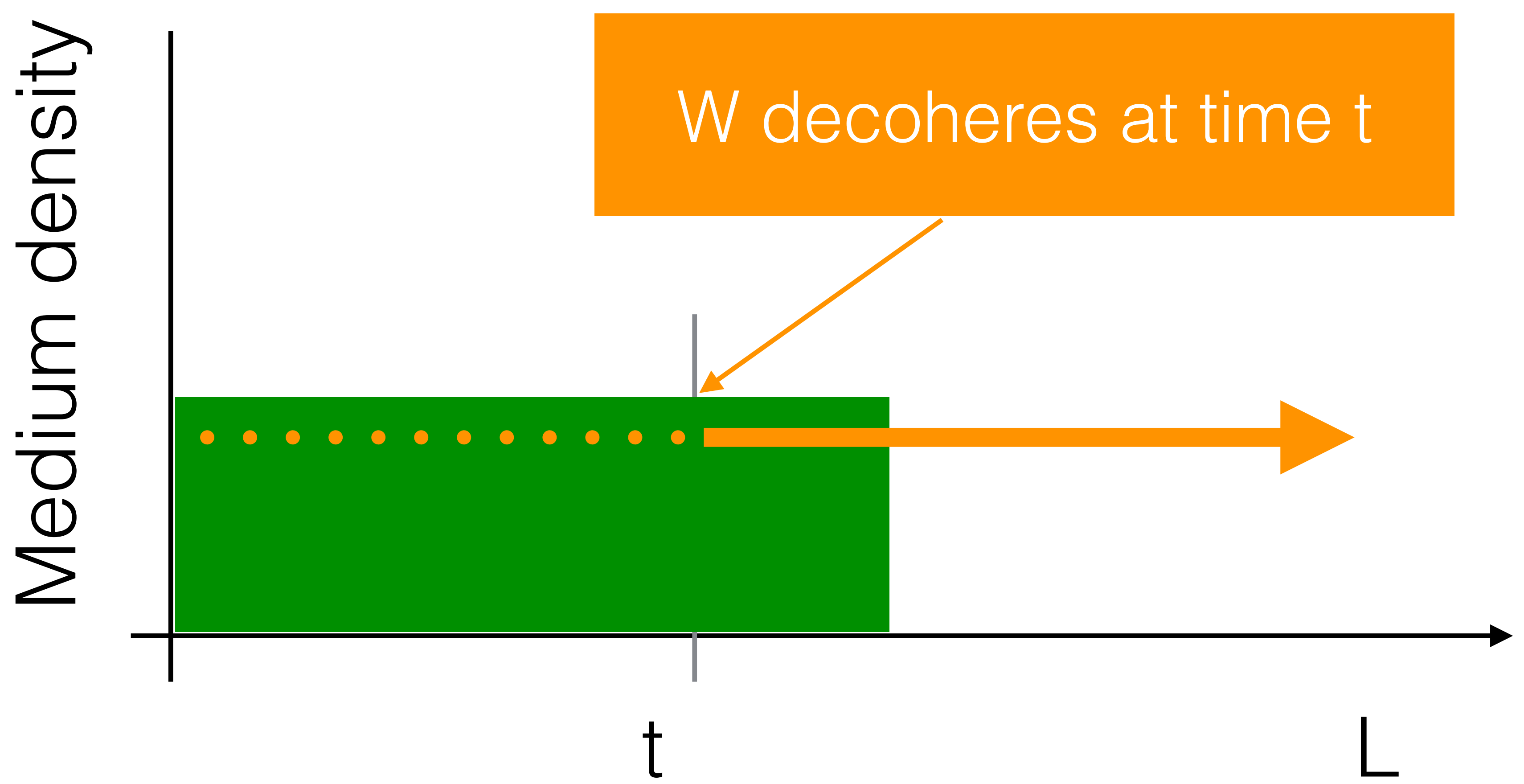

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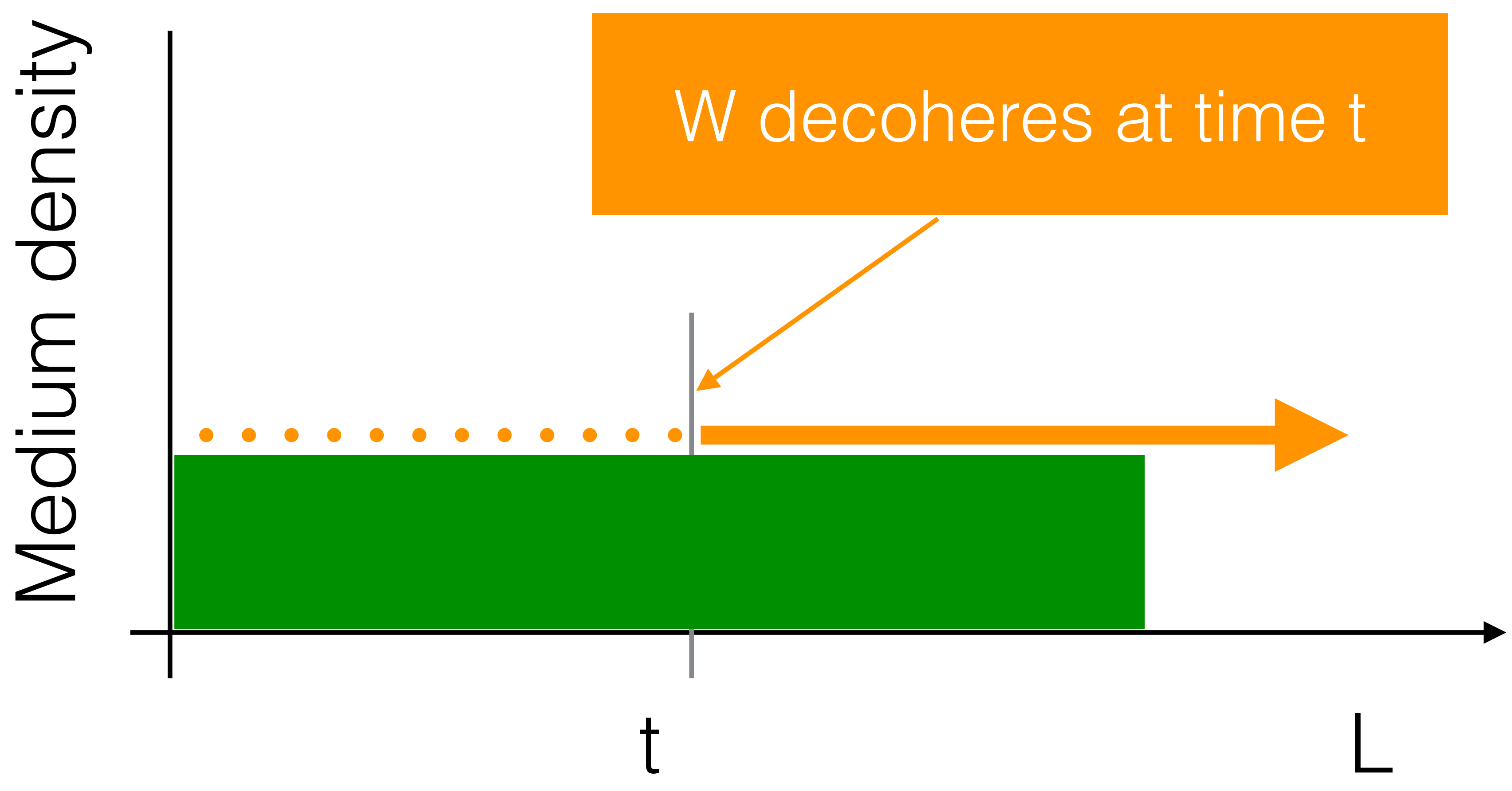
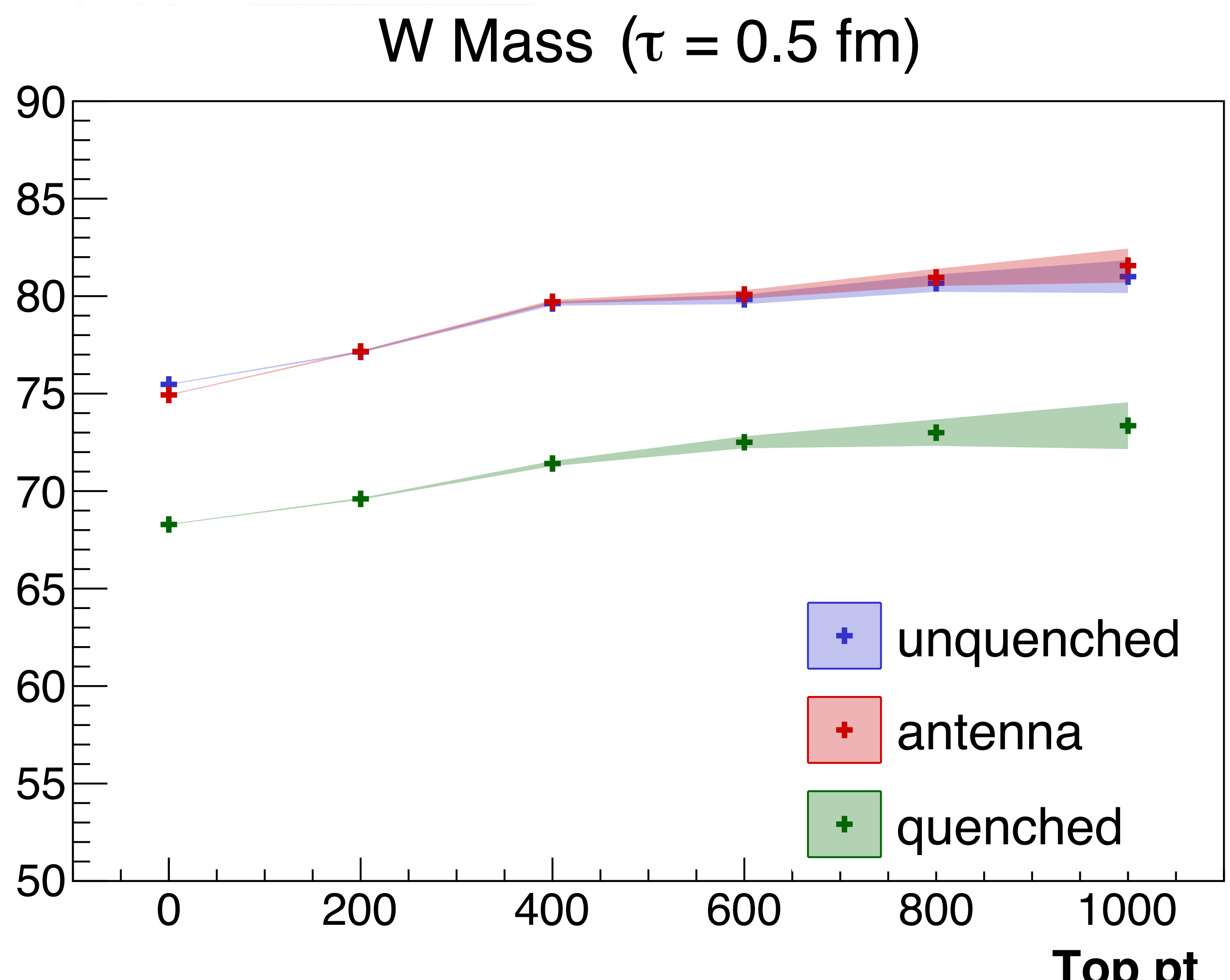
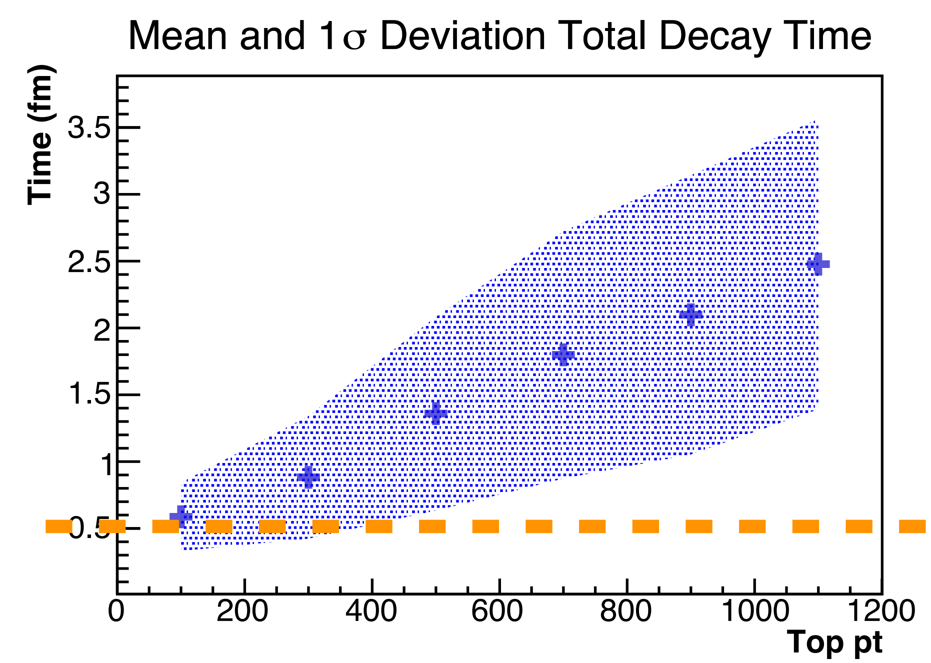
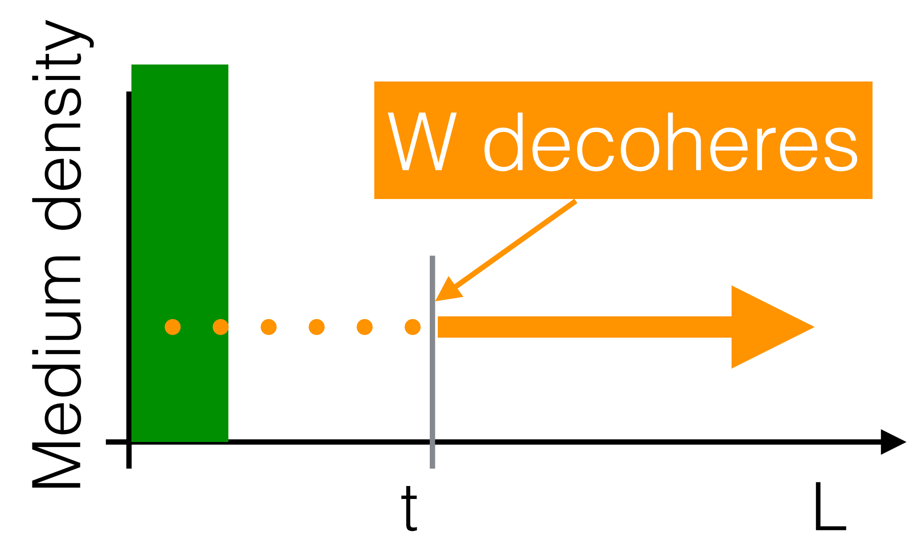


Time-dependent Eloss

Simple form: $\frac{\Delta E}{E} = \frac{L-t}{L} \times 10\%$







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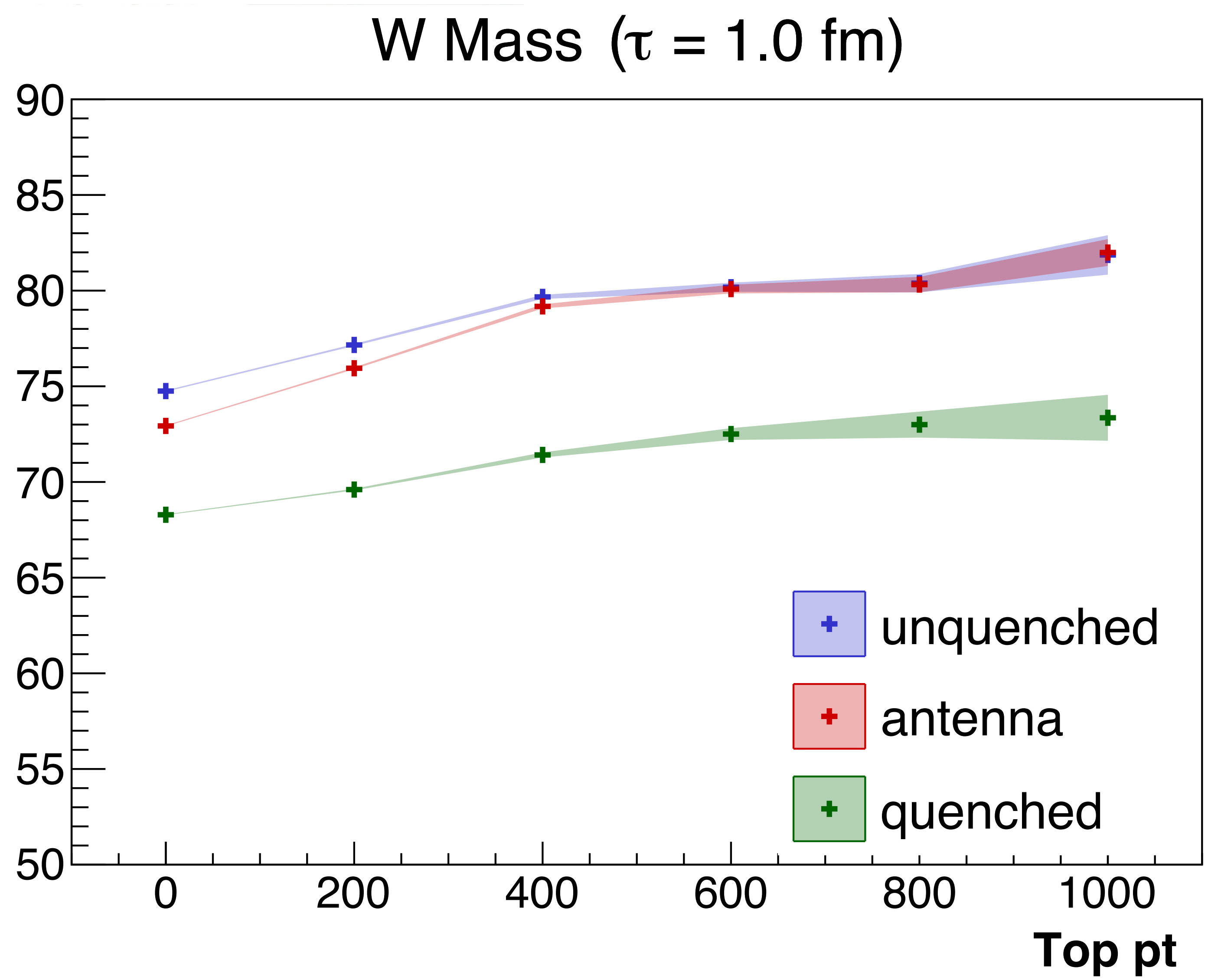

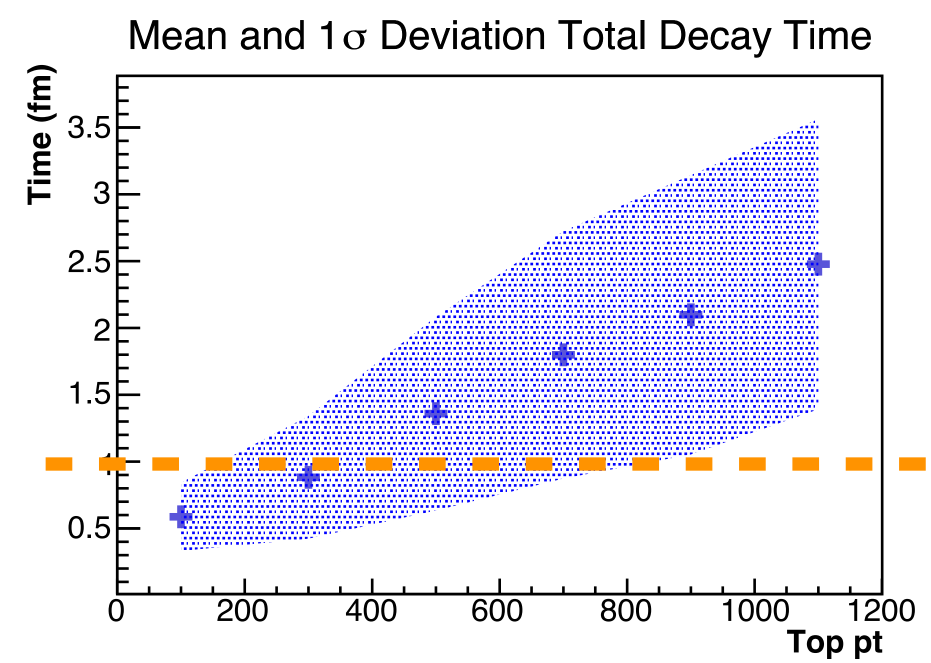

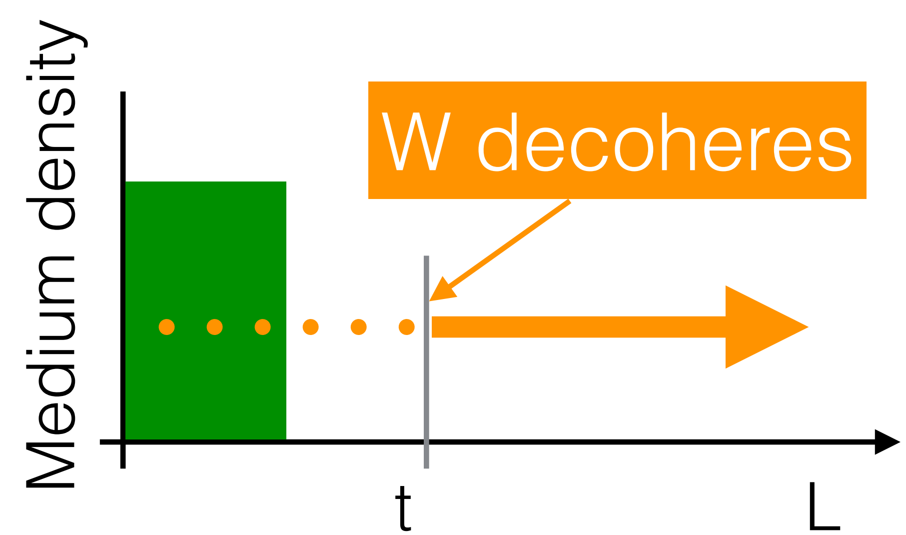

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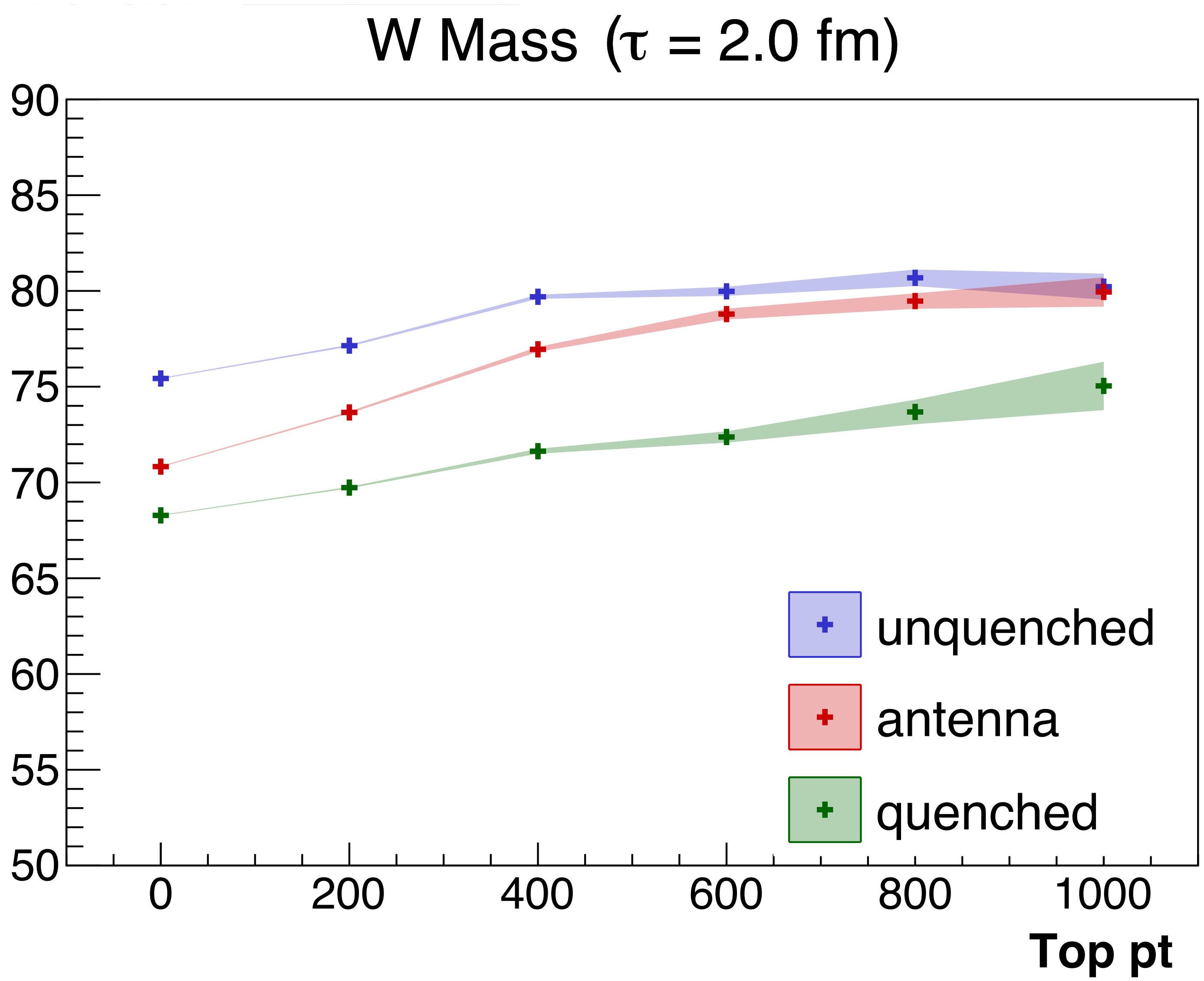

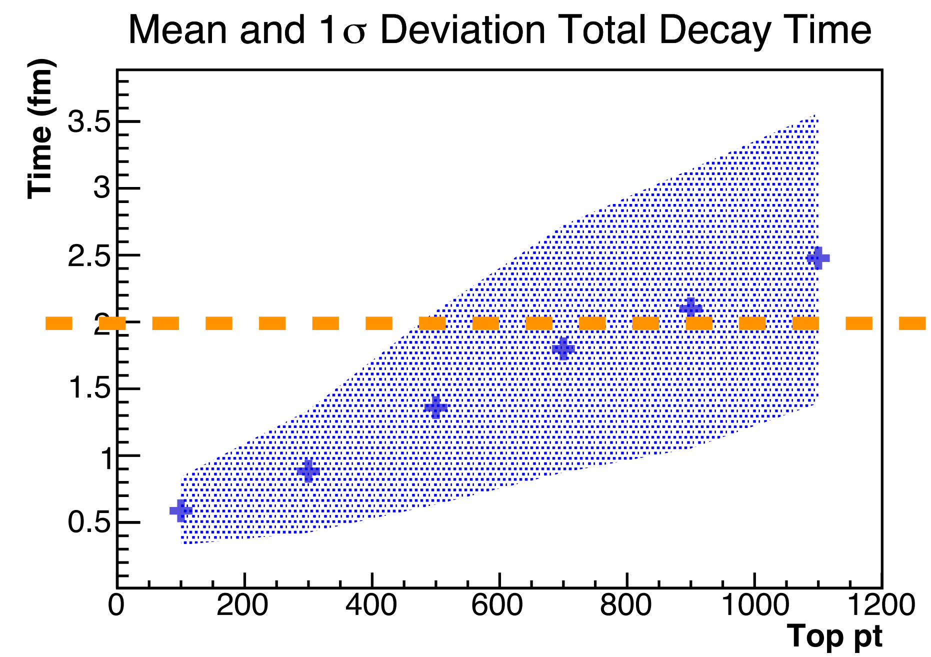

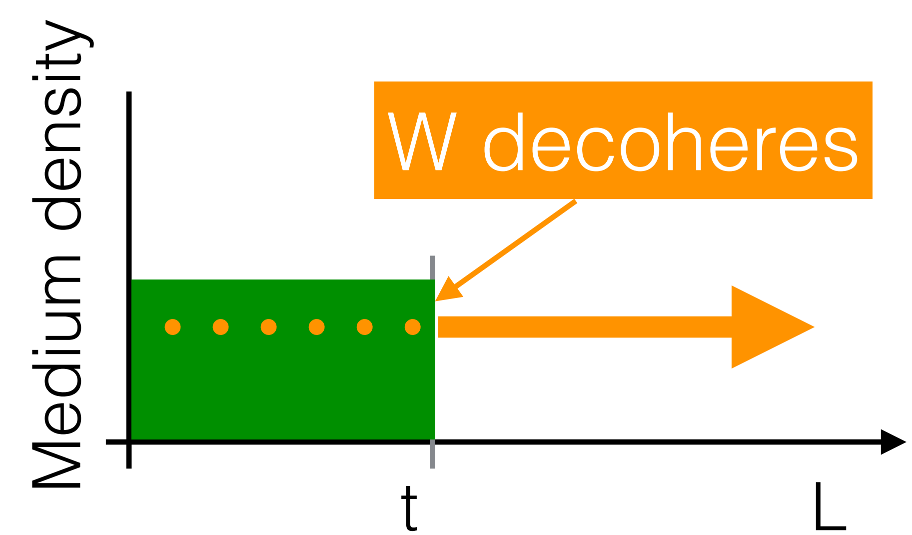

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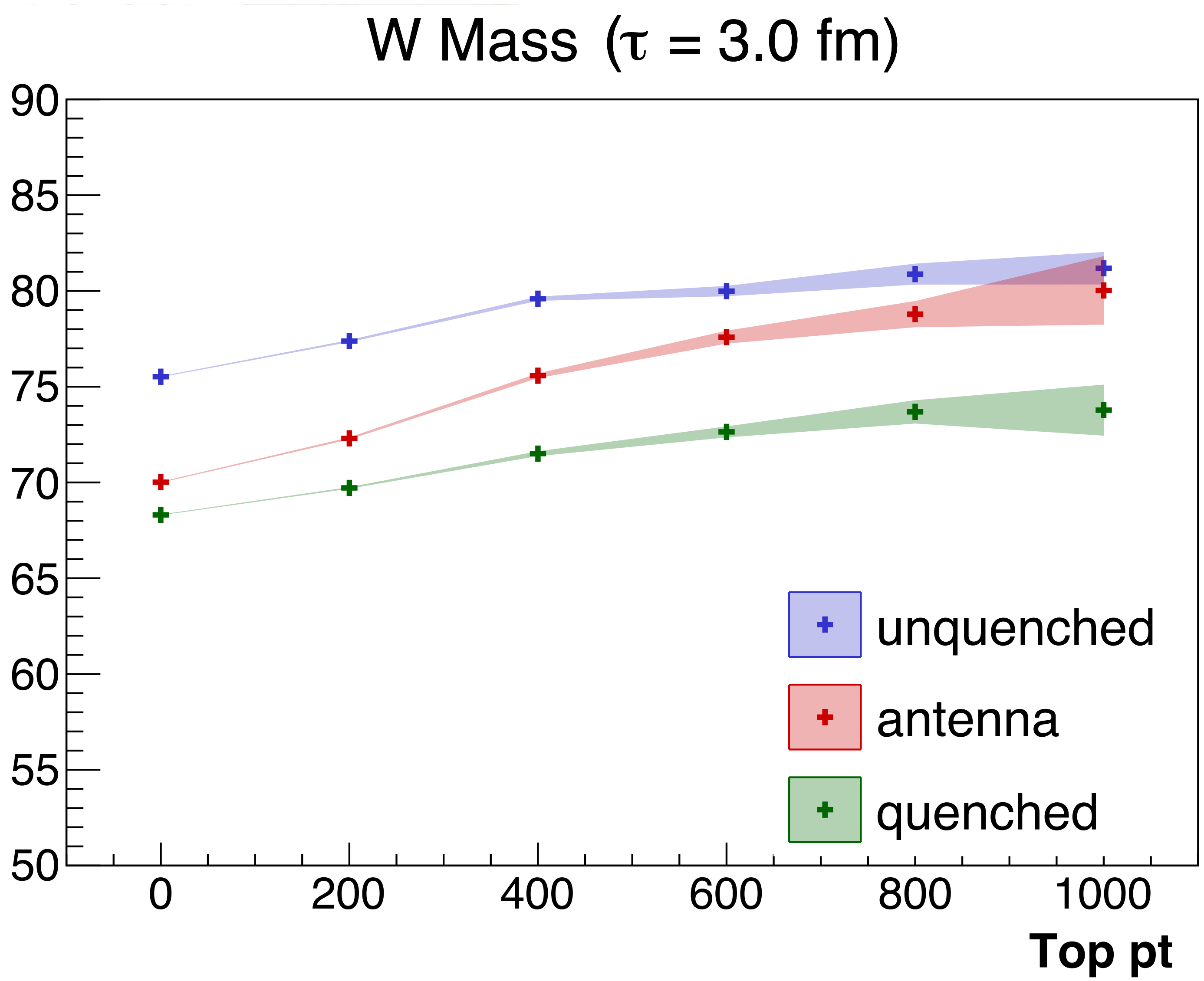

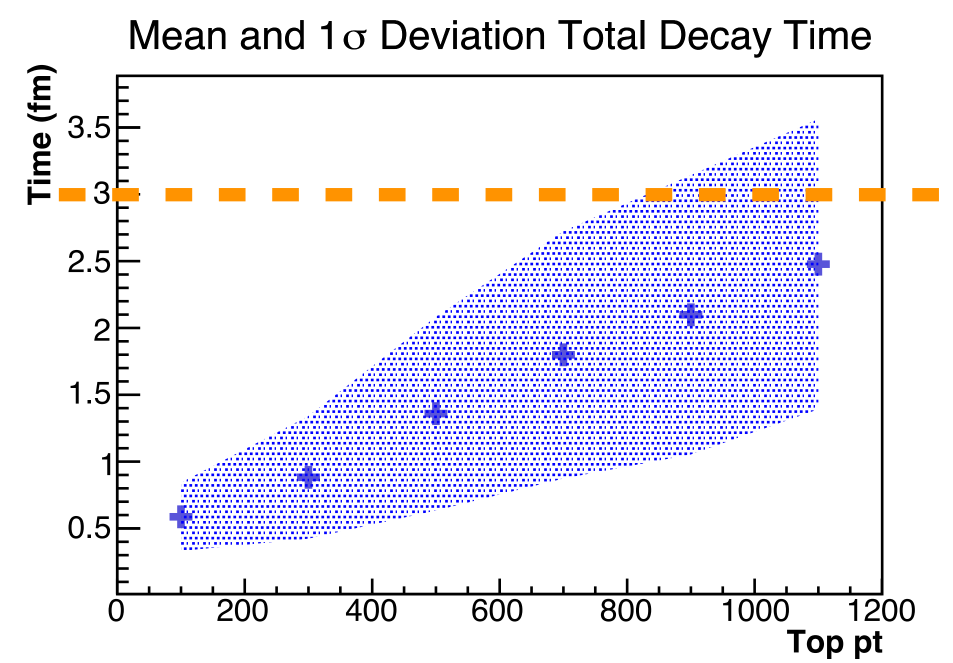

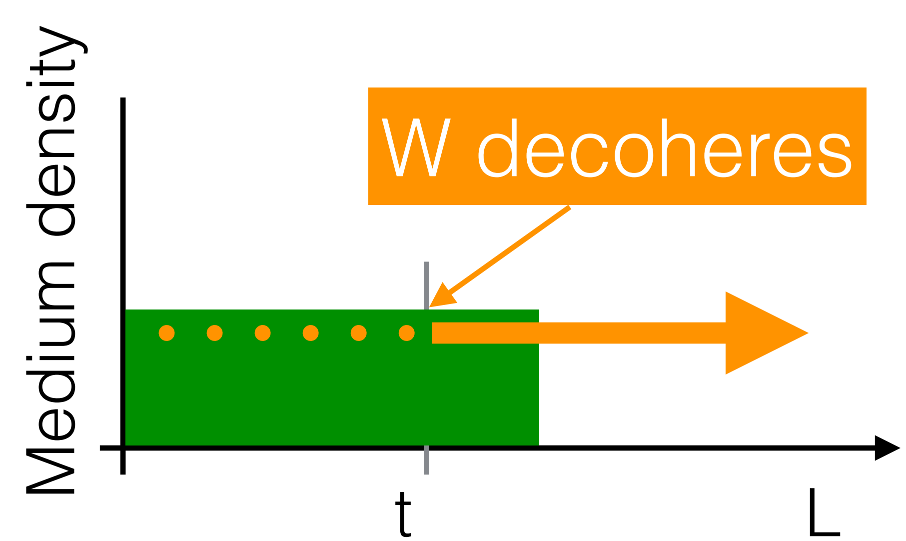

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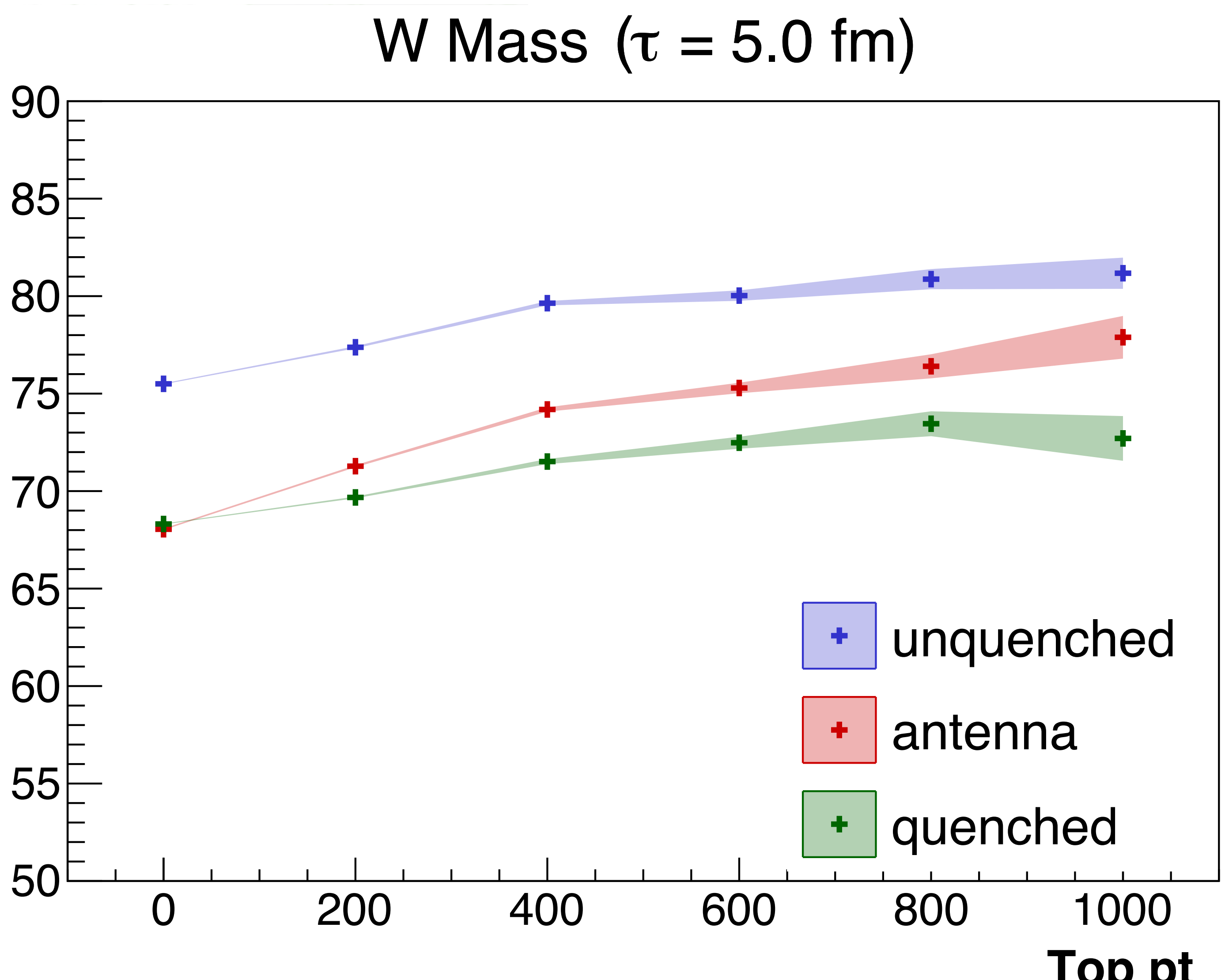
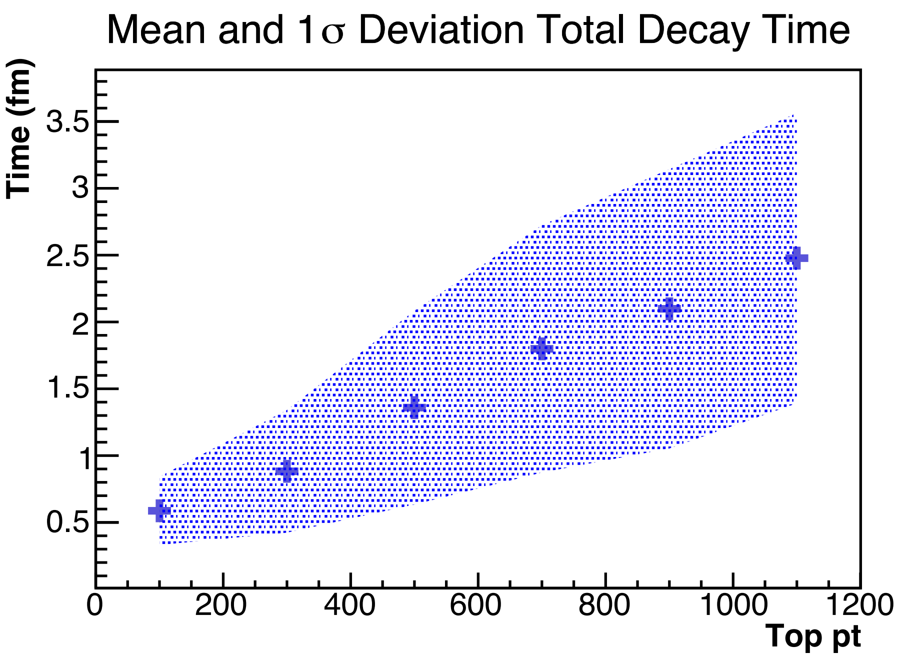
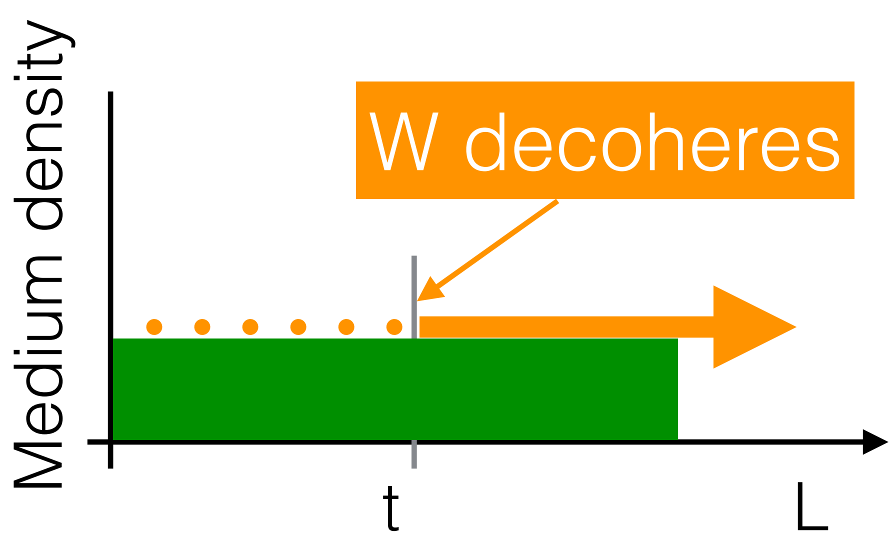
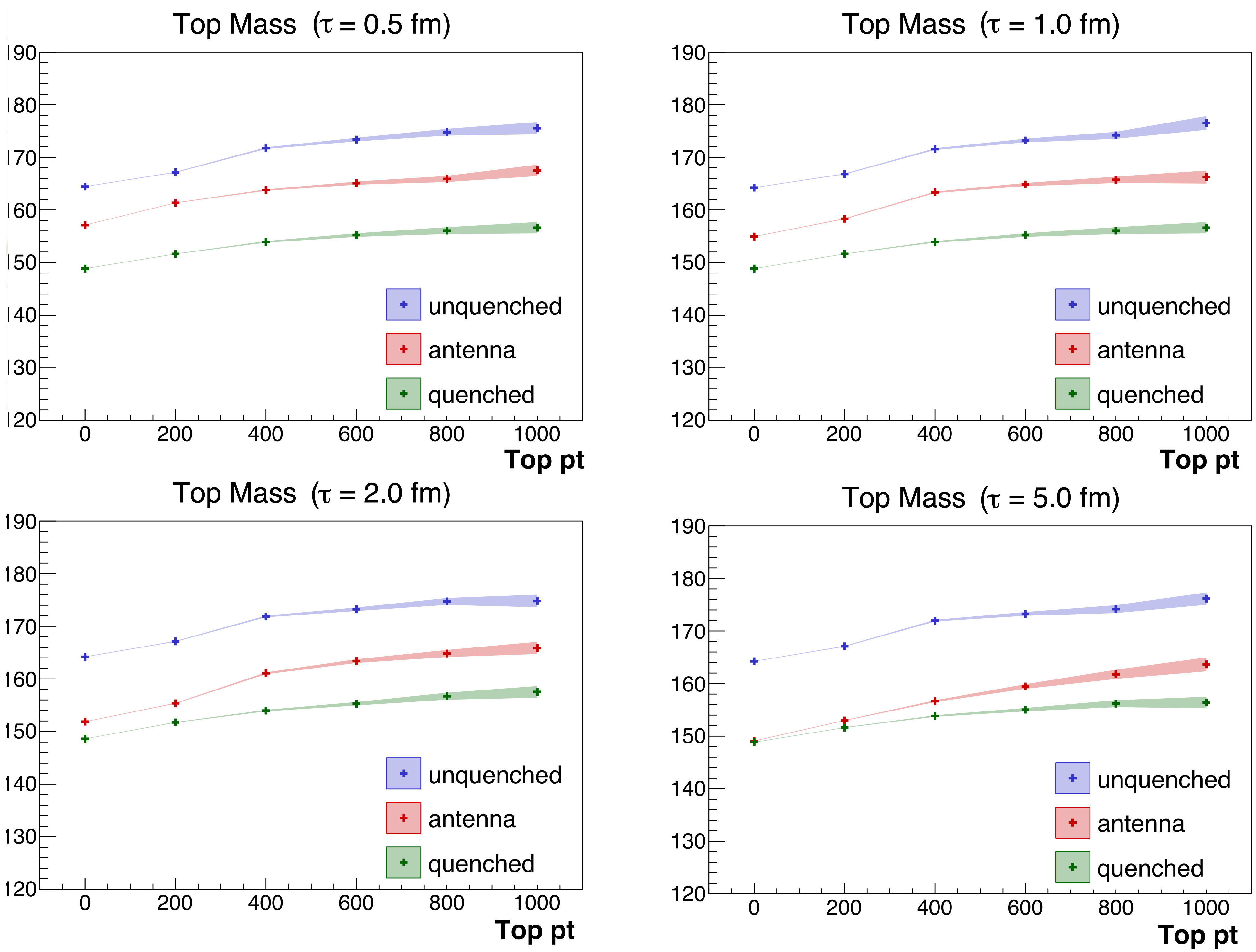




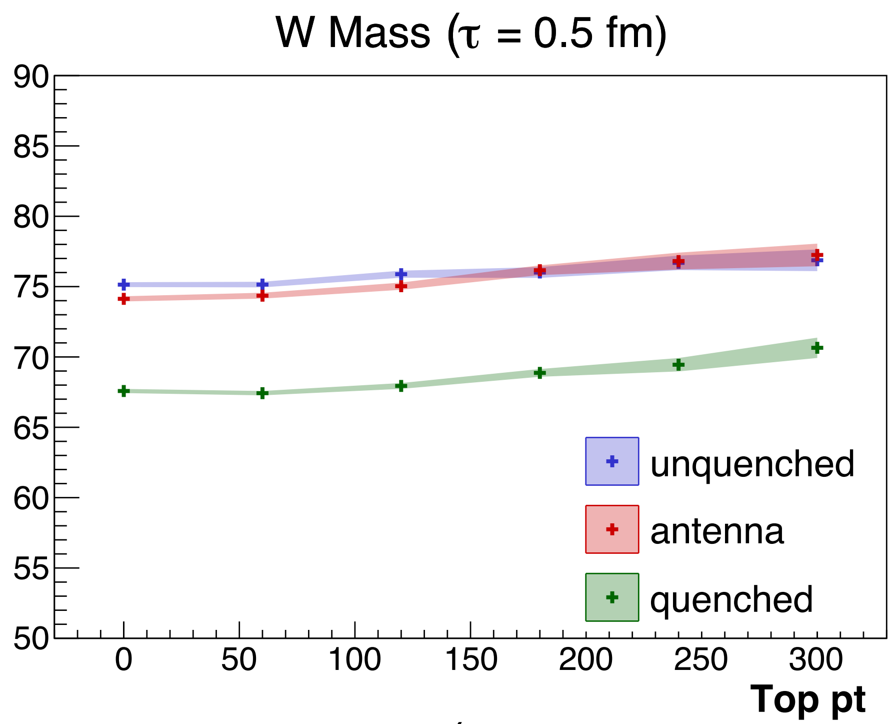


Top masses

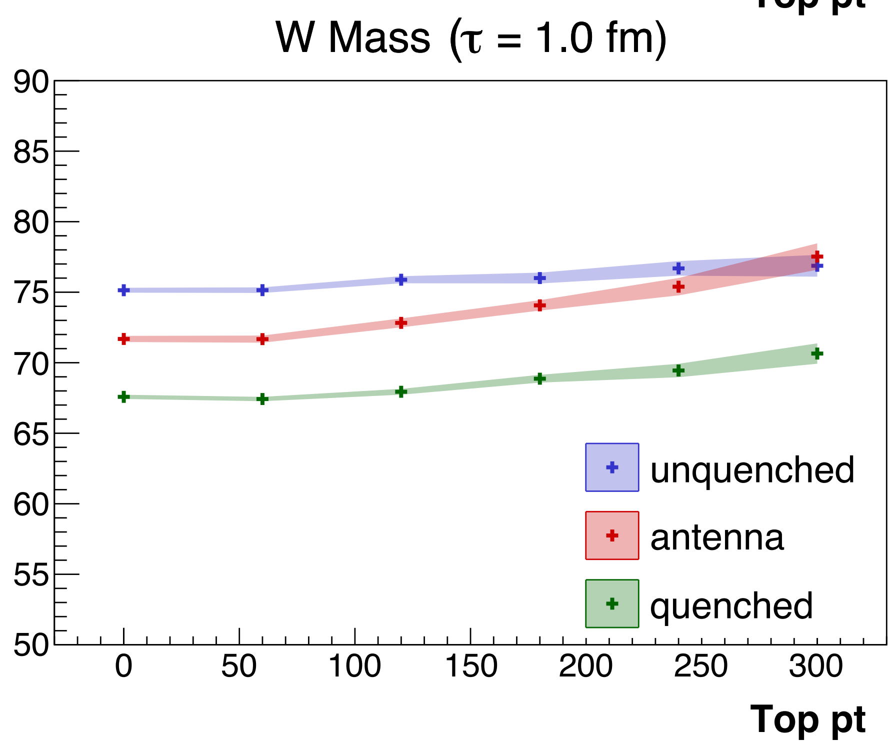


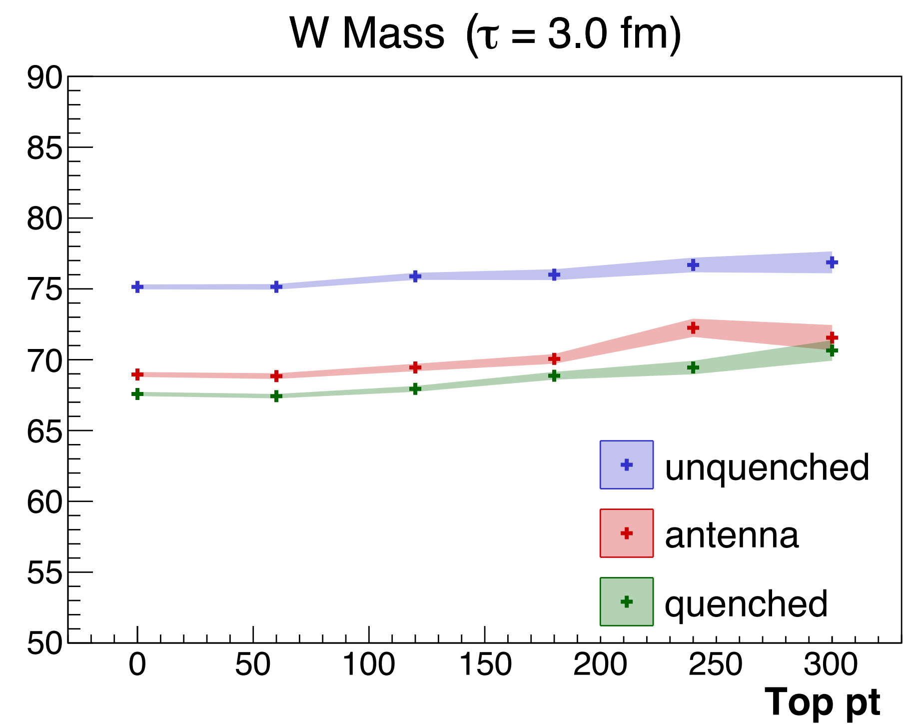
Top Mass (τ = 0.5 fm)
Top Mass (τ = 1.0 fm)
Top Mass (τ = 2.0 fm)
Top Mass (τ = 5.0 fm)
190
180
170
160
150
140
130
120
0
200
400
600
800
1000
Top pt
unquenched
antenna
quenched

HighLuminosity-LHC



Statistics limit the range of times to t~1.2 fm/c (pT<200-300GeV)





Conclusions

- First proof-of-principle analysis of boosted tops in HI
- Different boosts measure different evolution times
  - Quenching is modified
- Large boosts effectively **"*switch-off the medium*"** for some fm - color singlet W+qqbar antenna
  - Controls when jets start to interact with medium
- Access to **both small and large times** of the medium evolution with jet quenching

0.5<t<3.5 fm/c @ FCC
0.4<t<1.5 fm/c @ HL-LHC