Update on boosted tops

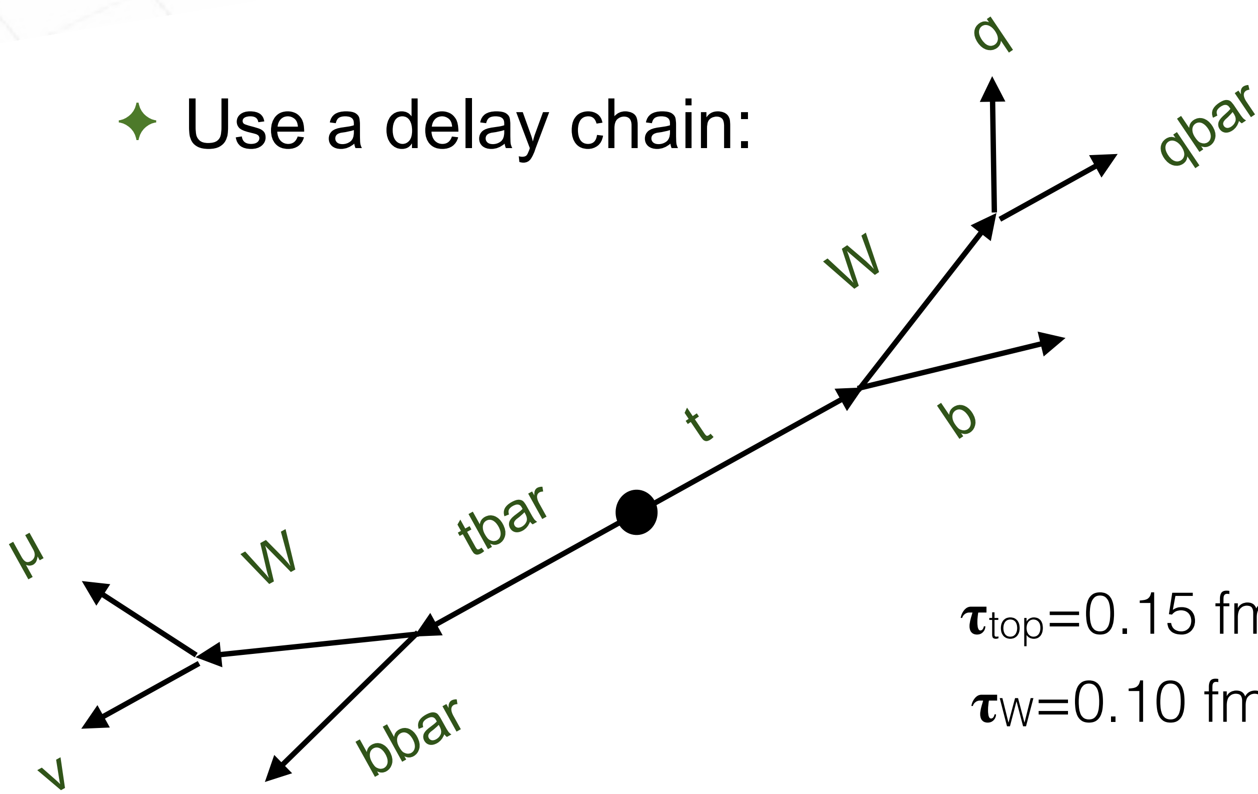
Liliana Apolinário
(LIP)

Guilherme Milhano, Carlos Salgado and Gavin Salam
(LIP, USC, CERN)

Work partially included in FCC-hh report
arXiv:1605.01389

Introduction

- Main goal:
  - Use probes that had a delayed interaction with the medium (in contrast with observables that are the result of the whole medium evolution)
    - Use a delay chain:



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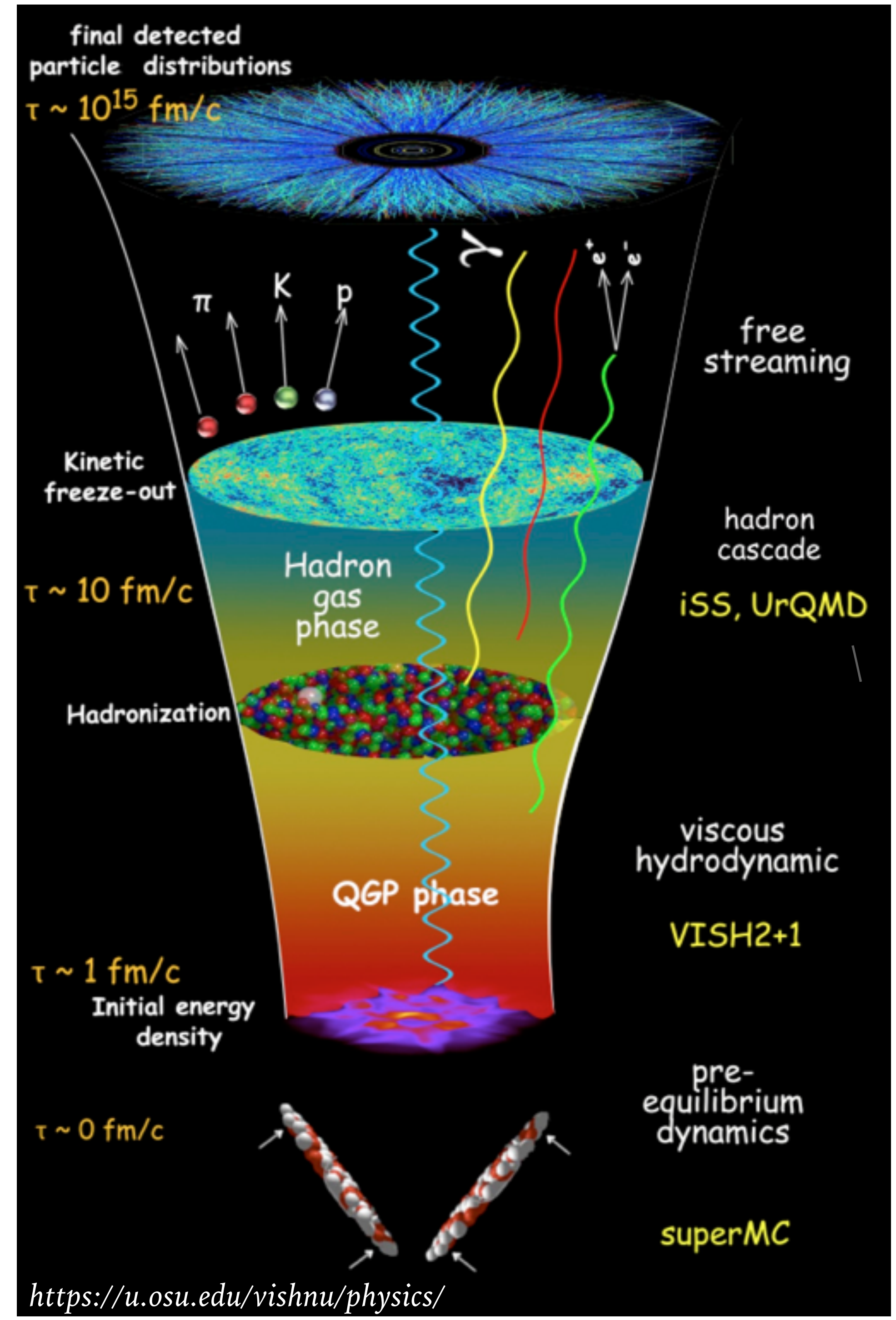
τ_{W}=0.10 fm/c



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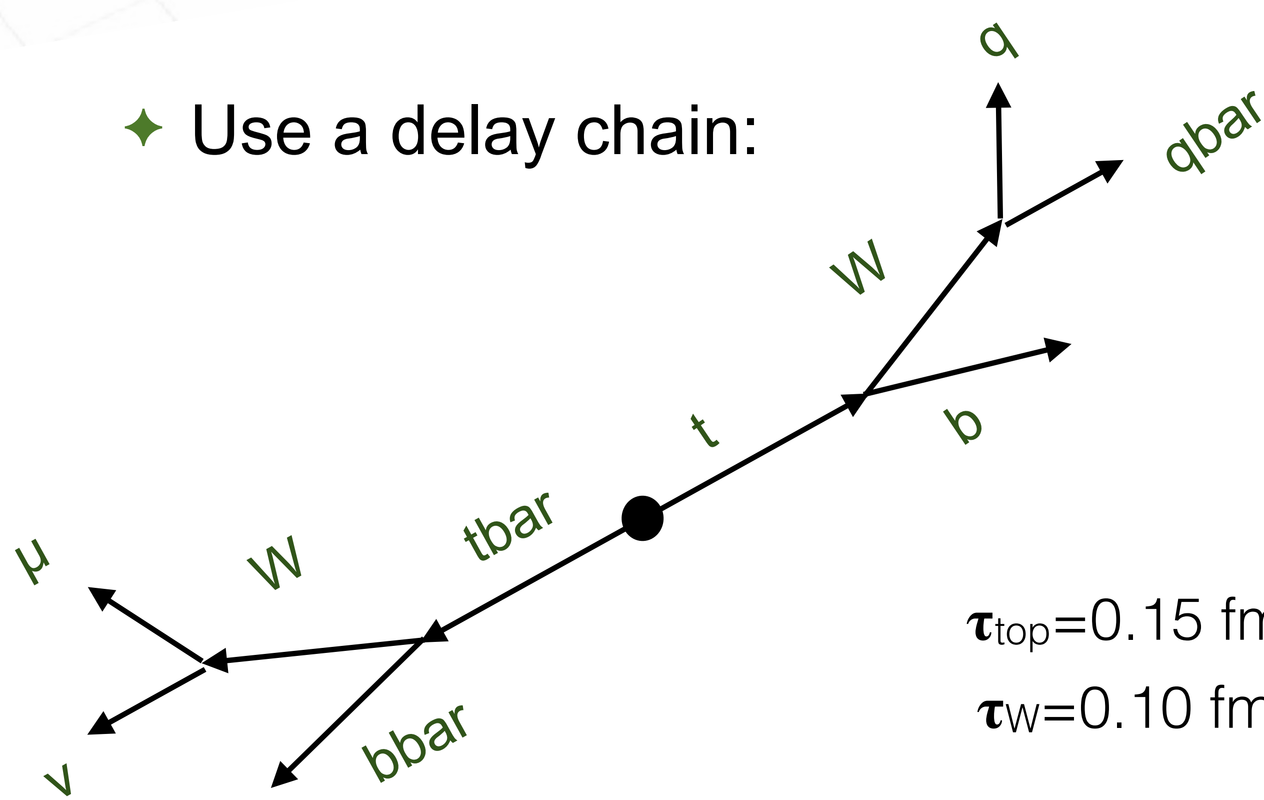

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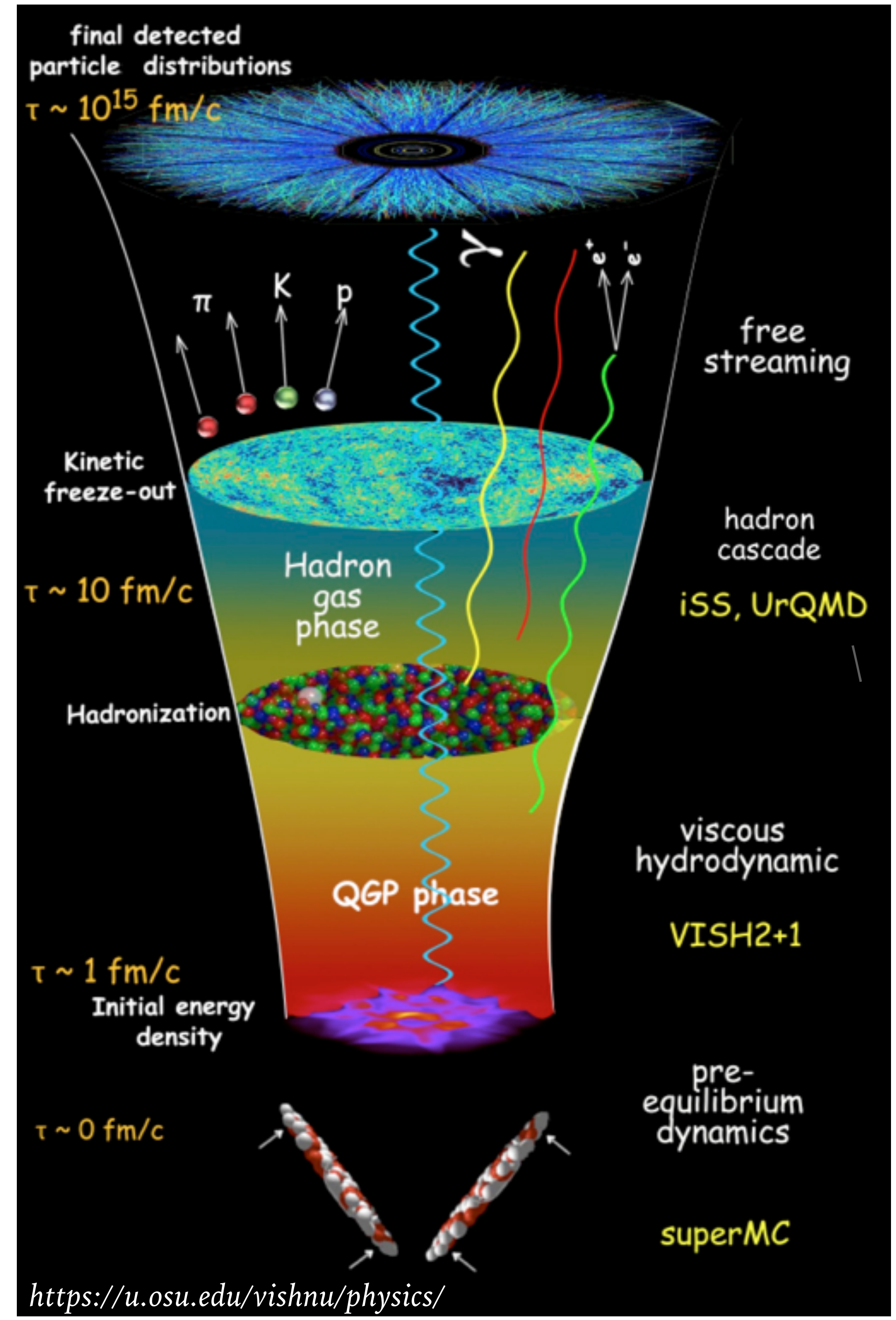

- First measurement in pPb: CMS-HIN-17-002

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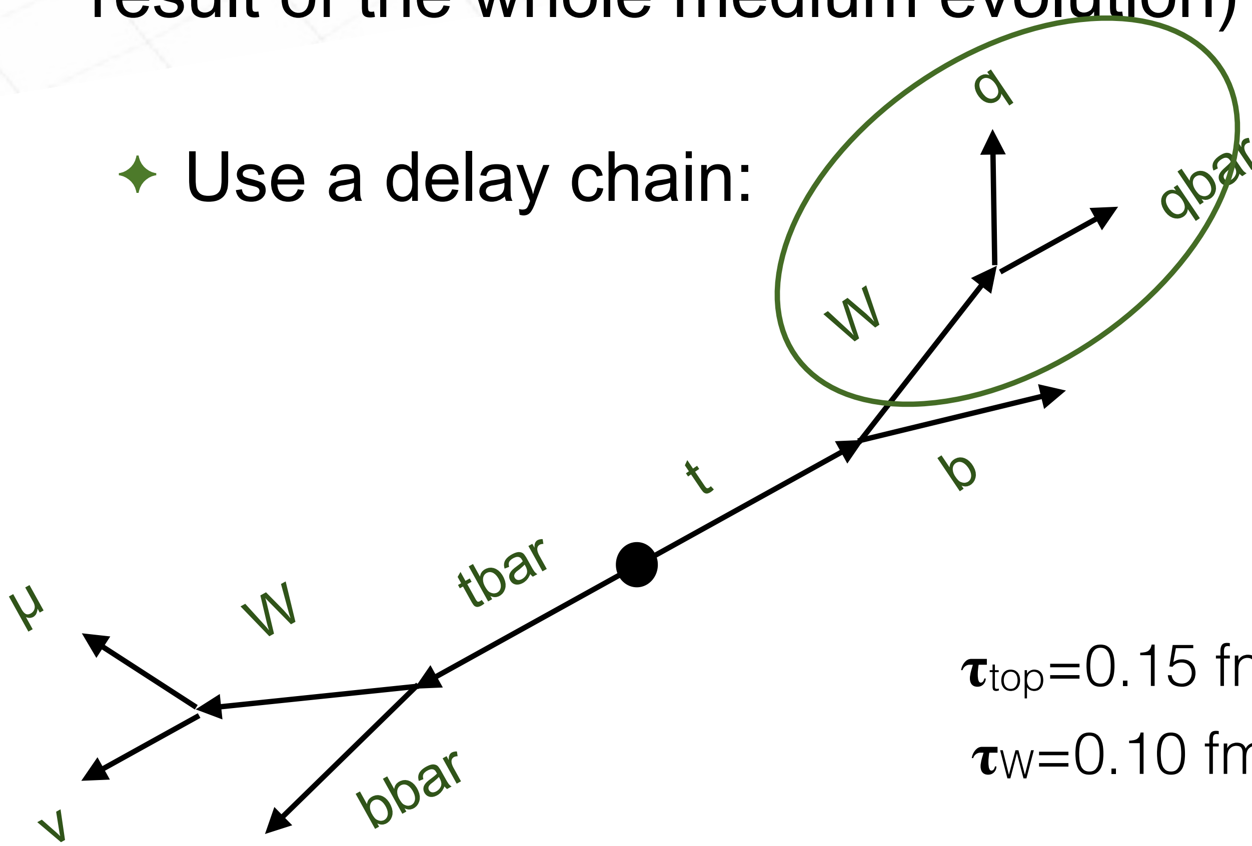

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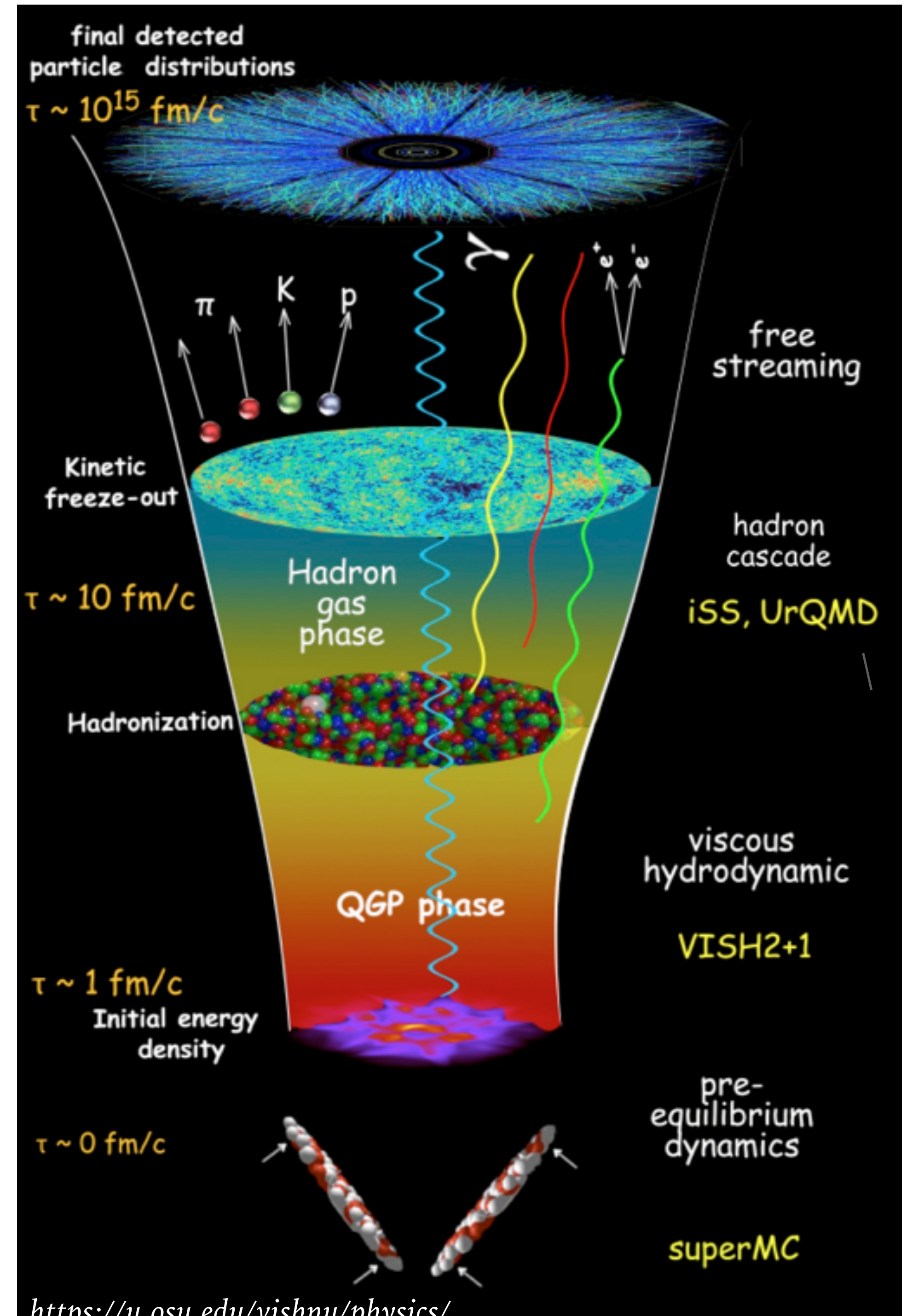

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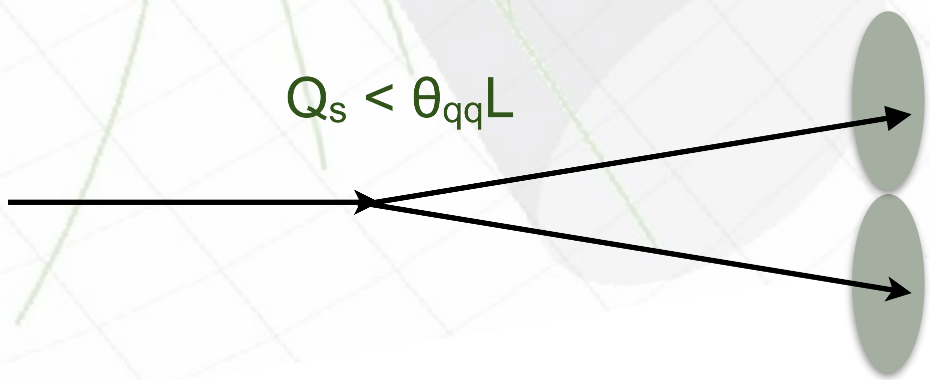
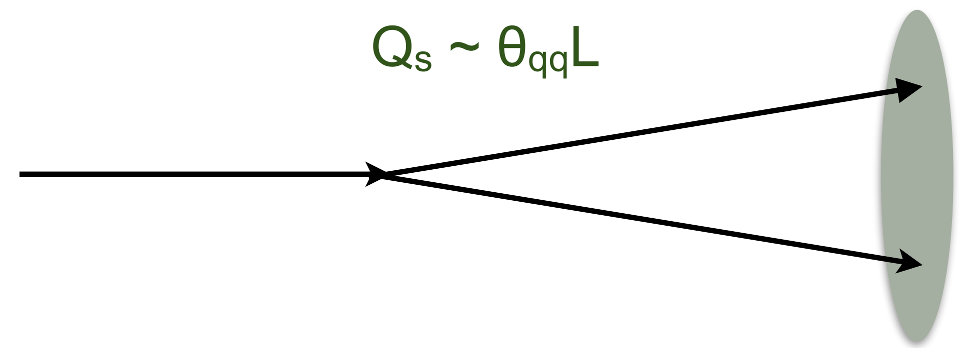
Color coherence

- Moreover, W boson hadronic decay is the natural setup to study coherence effects:



Medium able to "see" both particles
Color correlation is broken
Both particle emit independently



Medium "sees" both particles as one single emitter
Particles emit coherently

Saturation scale: $Q_s^2 = \hat{q}\, L$

Transport coefficient: $\hat{q}$

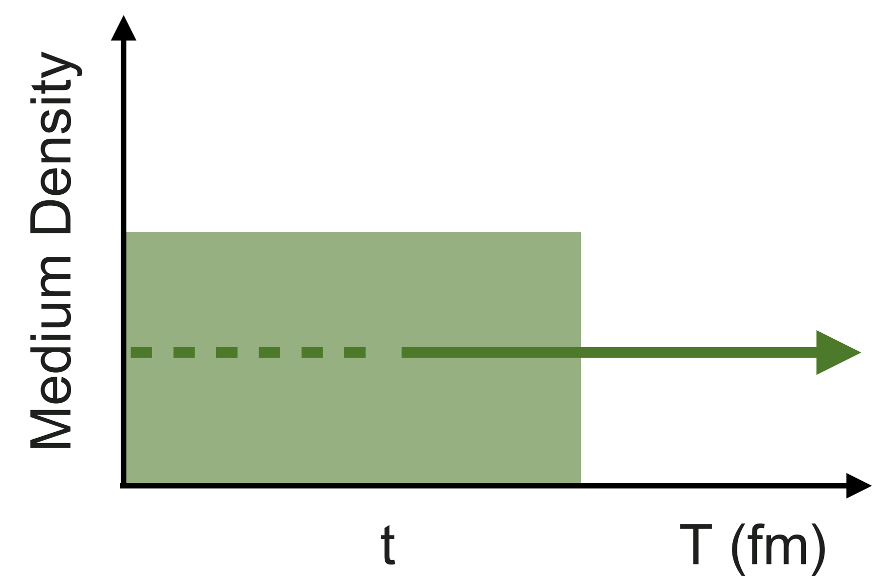
Medium length: L

- Increase even more the time delay allowing to have a complete mapping of the QGP evolution:
  - Stay in colourless singlet state during: $t_d = \left(\frac{12}{\hat{q}\theta_{q\bar{q}}^2} \right)^{1/3}$

Mehtar-Tani, Salgado, Tywoniuk (2010-2011)
Casalderrey-Solana, Iancu (2011)

A first proof of principle

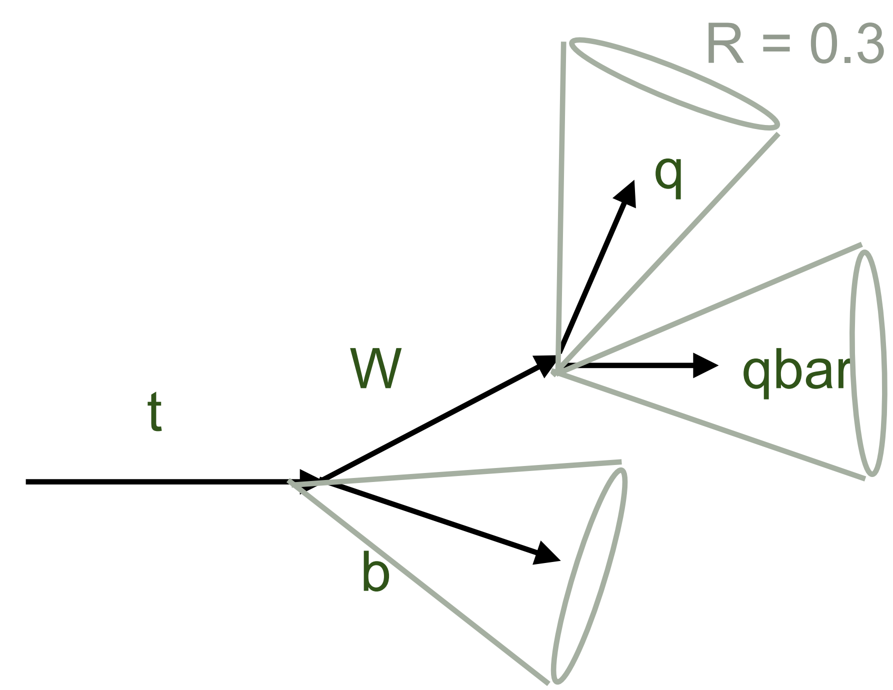
- Very simple naive model:
  - No fluctuations;
  - 10% energy loss to all coloured particles that travel the whole medium length, L. (CMS Z+jet CMS-PAS-HIN-15-013)
    - Antenna particles (only proportional to the medium length that is left after the total delay time, t):



$$\frac{\Delta E}{E} = -0.1\left(\frac{L-t}{L}\right)$$

A first proof of principle

- Focus on FCC-hh (A = 208; [0-10]%)
  - $\sqrt{s_{NN}}$ = 39 TeV; $\mathscr{L}$ = 30nb^{-1}
  - $p_{T,\mu}$ > 25 GeV + 2 bjets + >= 2 non-bjets
  - Anti-k_T R = 0.3, p_T > 30 GeV, $|\eta|$ < 2.5. (recluster with k_T, R = 1.0 and decluster with dcut = $(20\text{GeV})^2$)
  - W jets = 2 highest-p_T non-b jets.
  - “Muonic” W is the one closest to the muon in Delta R (ATLAS 1502.05923)



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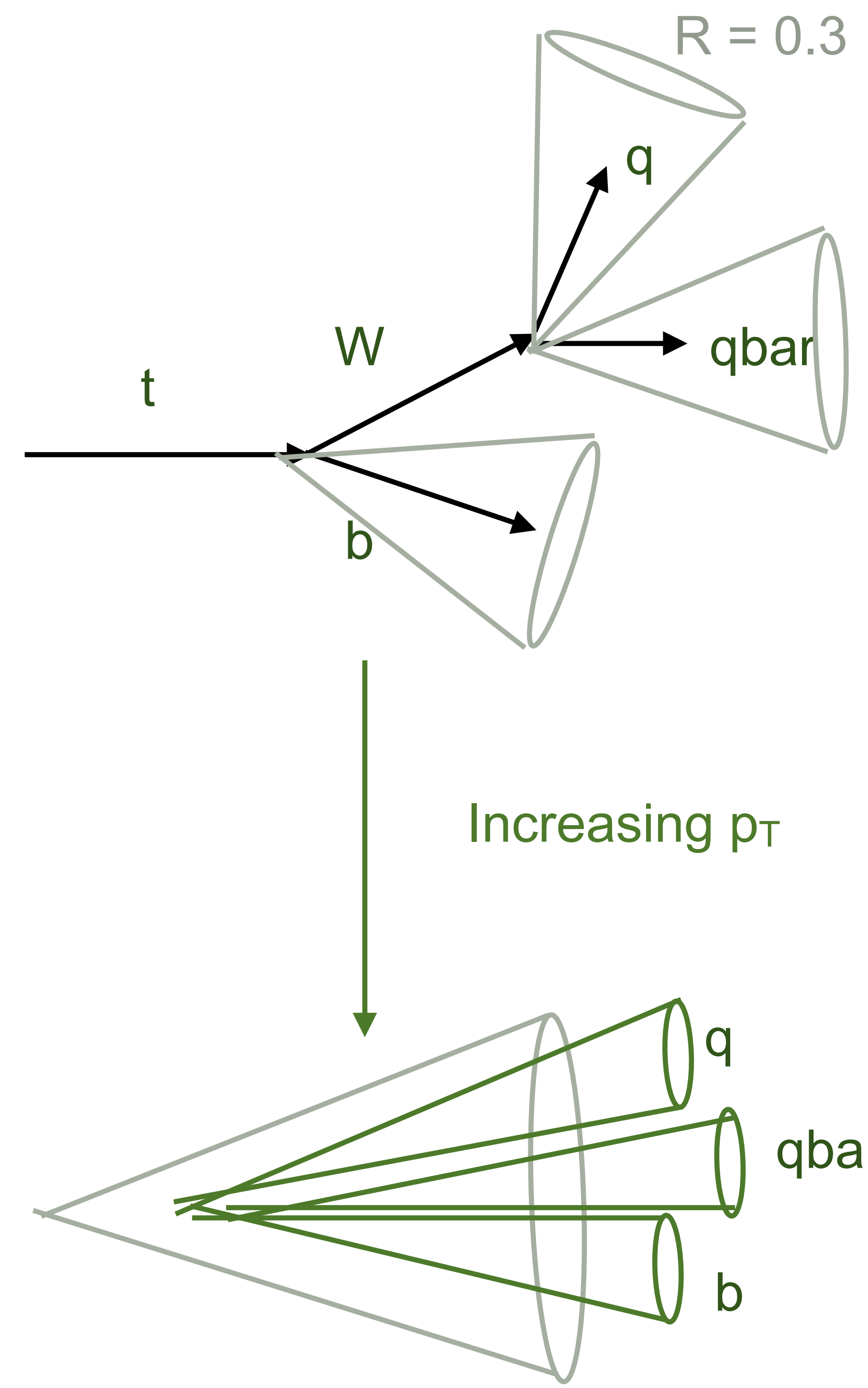
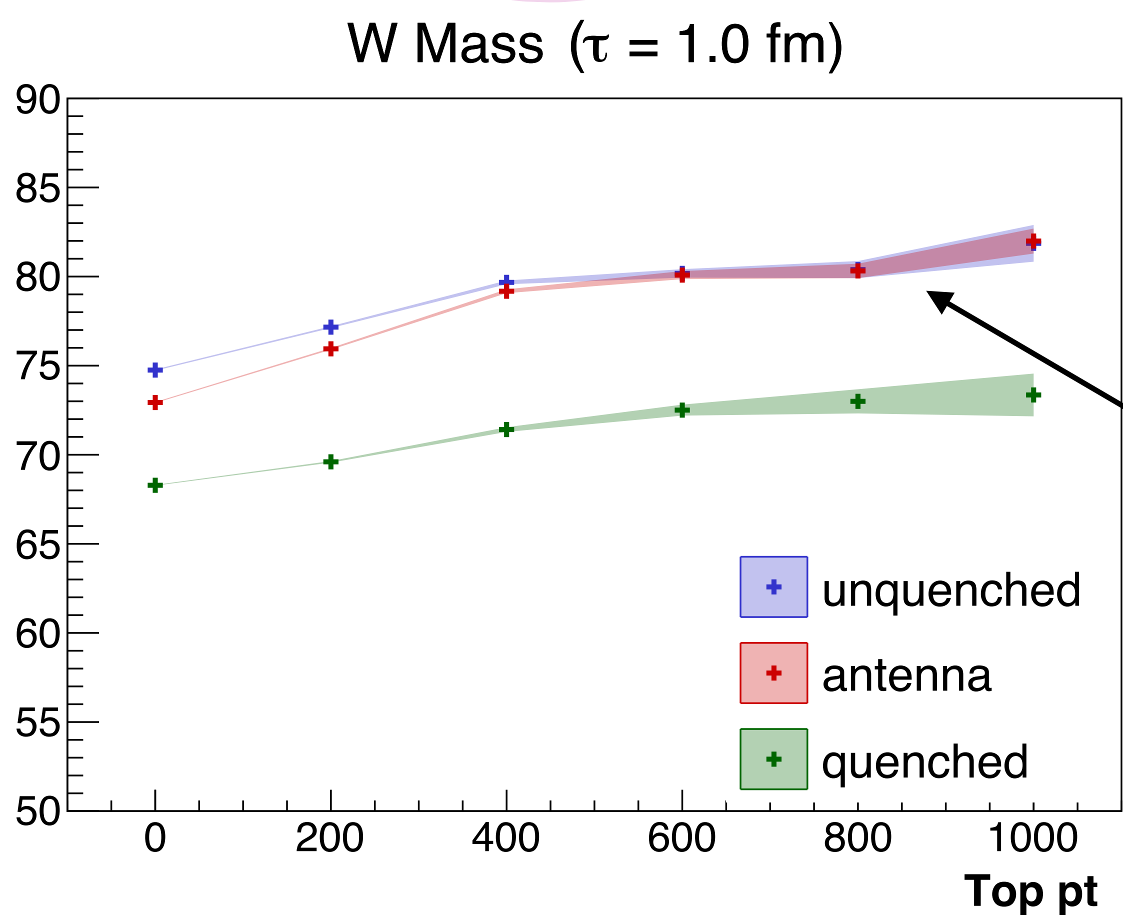


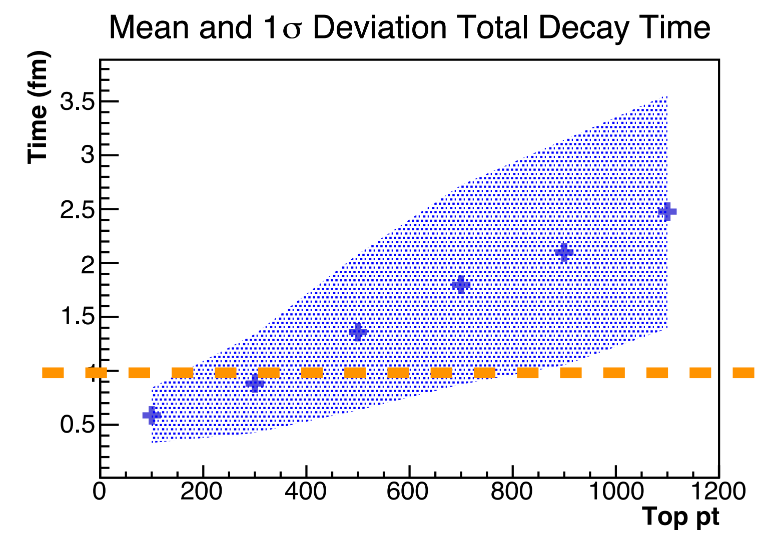
A first proof of principle

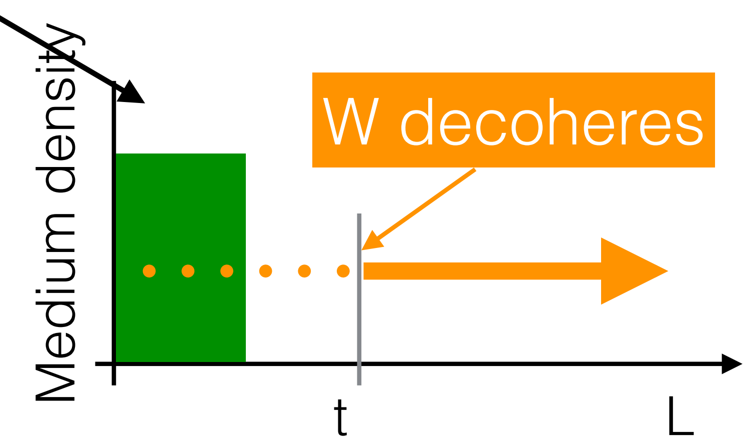
C. Salgado, Hard probes 2016

Time-dependent Eloss

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







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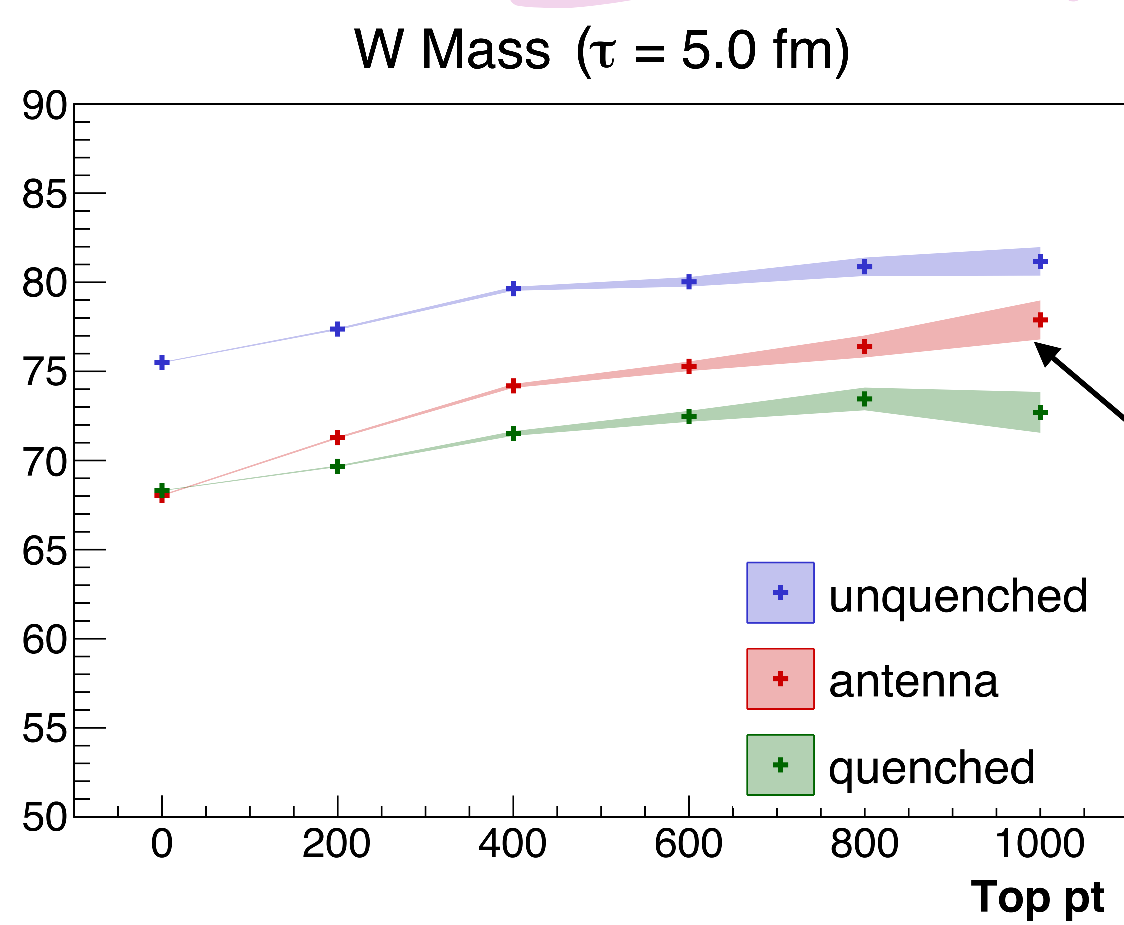

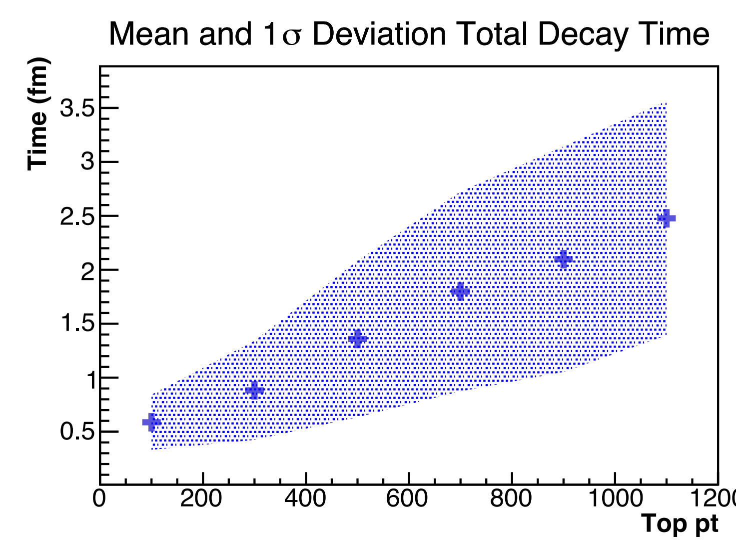

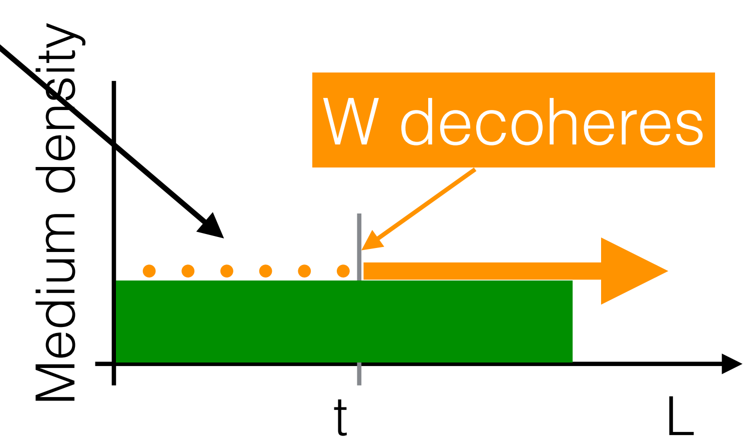

And it works!

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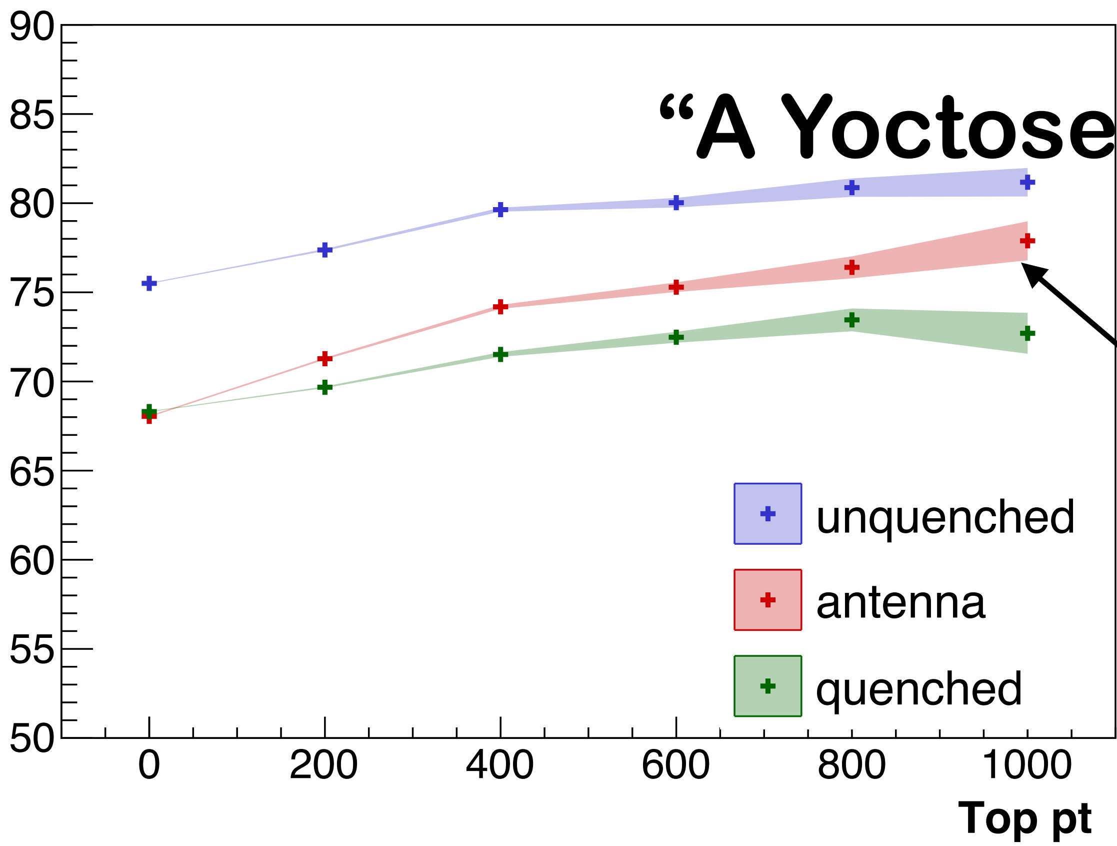
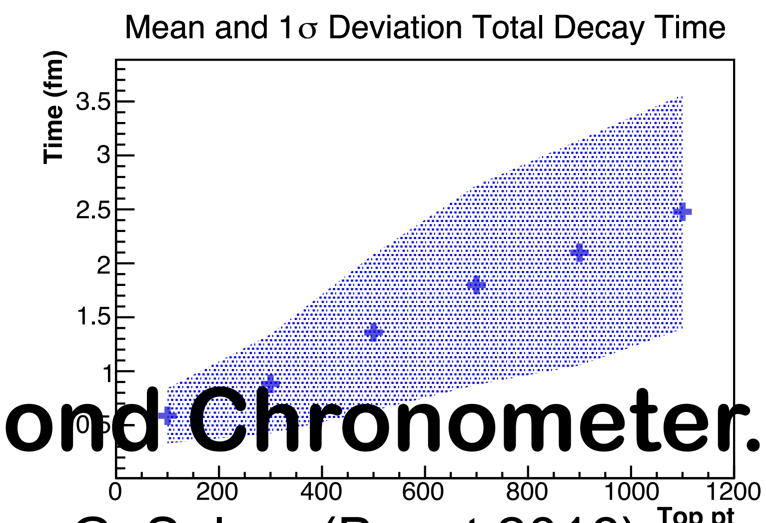
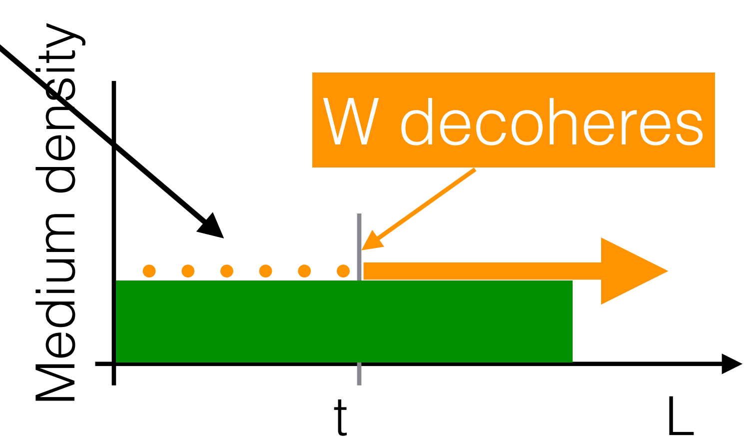




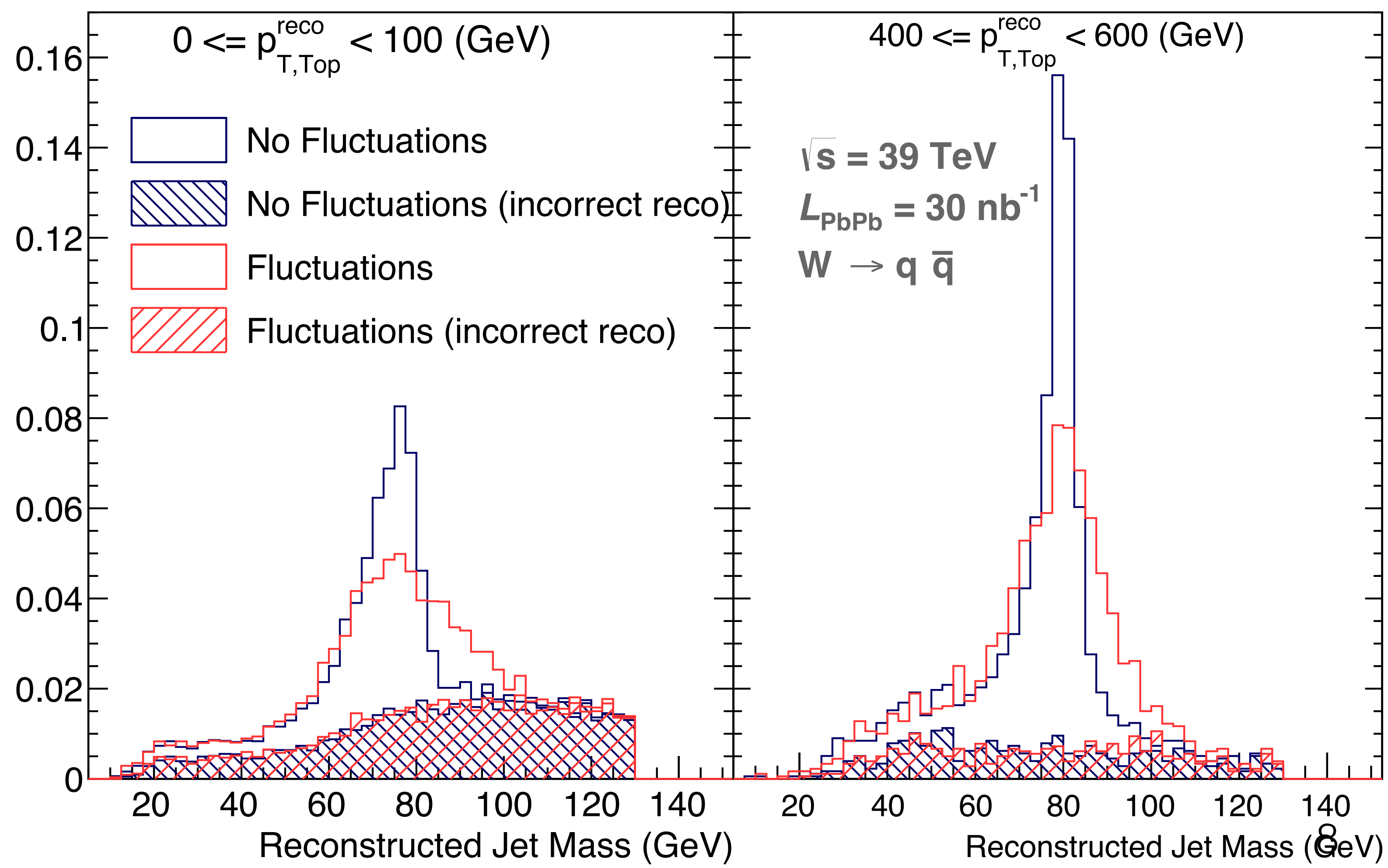
“A Yoctosecond Chronometer.”

– G. Salam (Boost 2016)



A (not so) first proof of principle

- Assess statistical significance of this study for the FCC:
  - Introduce Gaussian Fluctuations (at particle level) as 150%/sqrt(p_T) ≡ 15% at 100 GeV
  - Improved reconstruction method:
    - W candidate is reconstructed by considering all pairs of non-b jets with m_{jj} < 130 GeV; the highest scalar pt sum pair is selected



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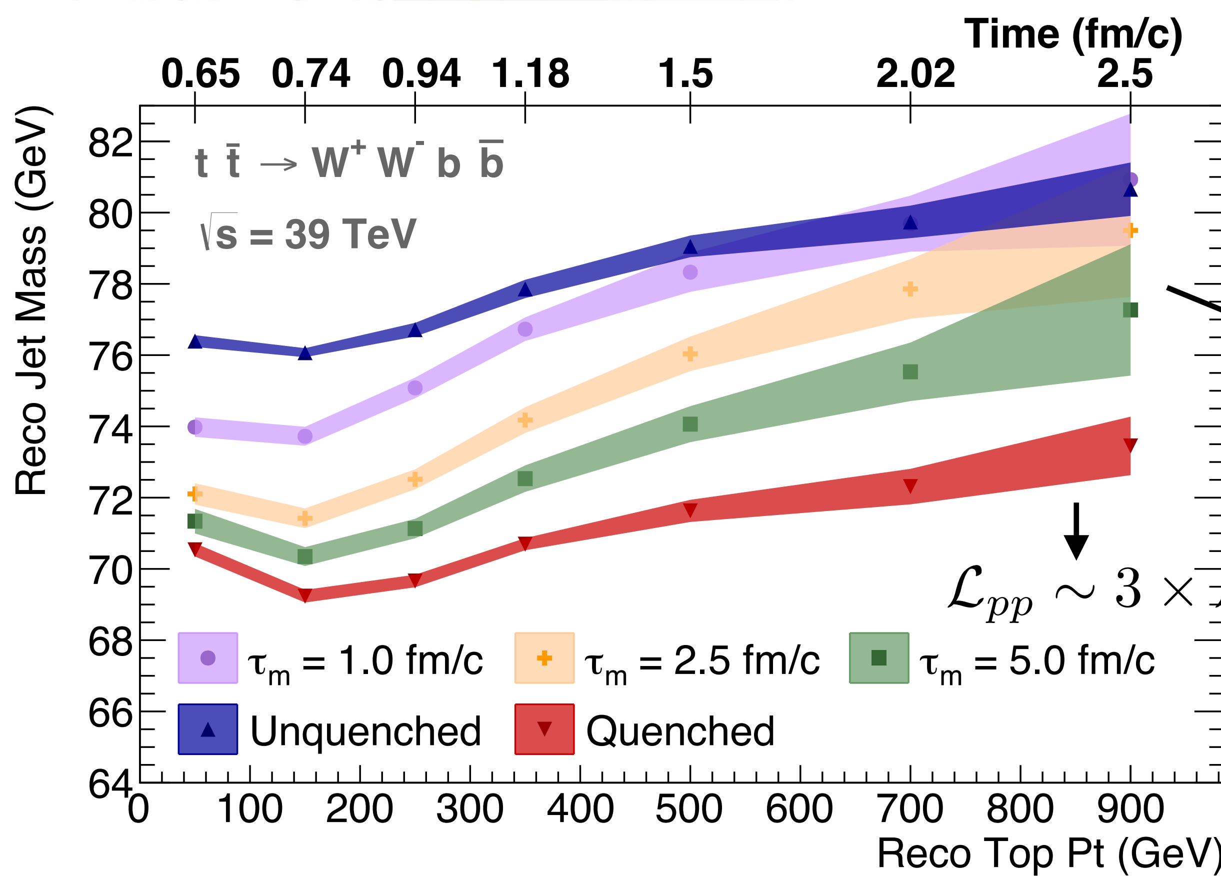
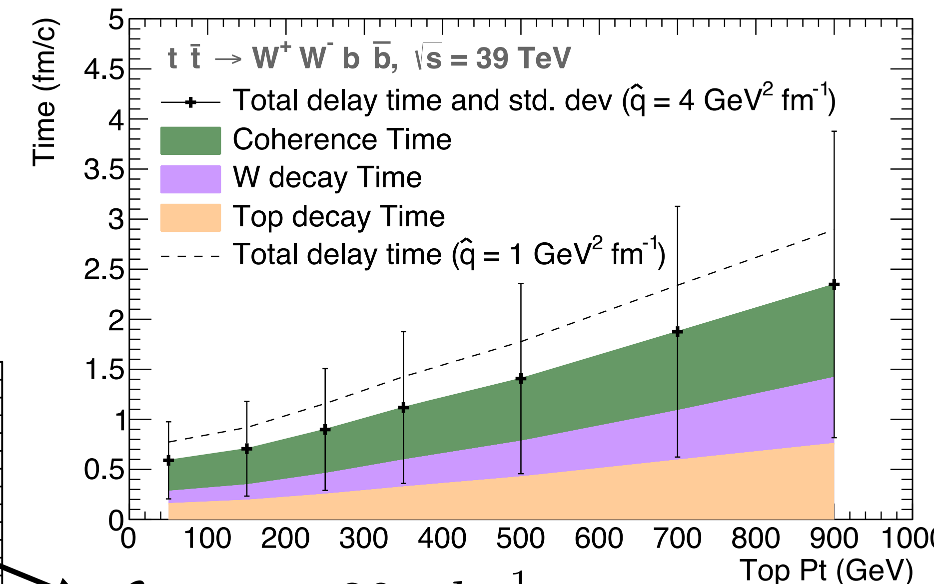
L. Apolinário, INT Workshop, 2017

- Reconstructed W Jet Mass:
  - “Antenna” model only:



$$\mathcal{L}_{pp} \sim 3 \times \mathcal{L}_{PbPb}$$



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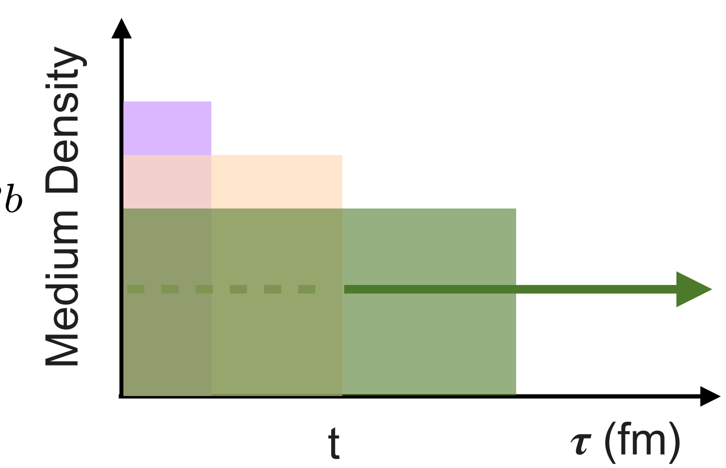

Depending on the chosen p_T, the antenna may still lose some energy.
Knowing the energy loss, it is possible to build the density evolution profile of the medium!

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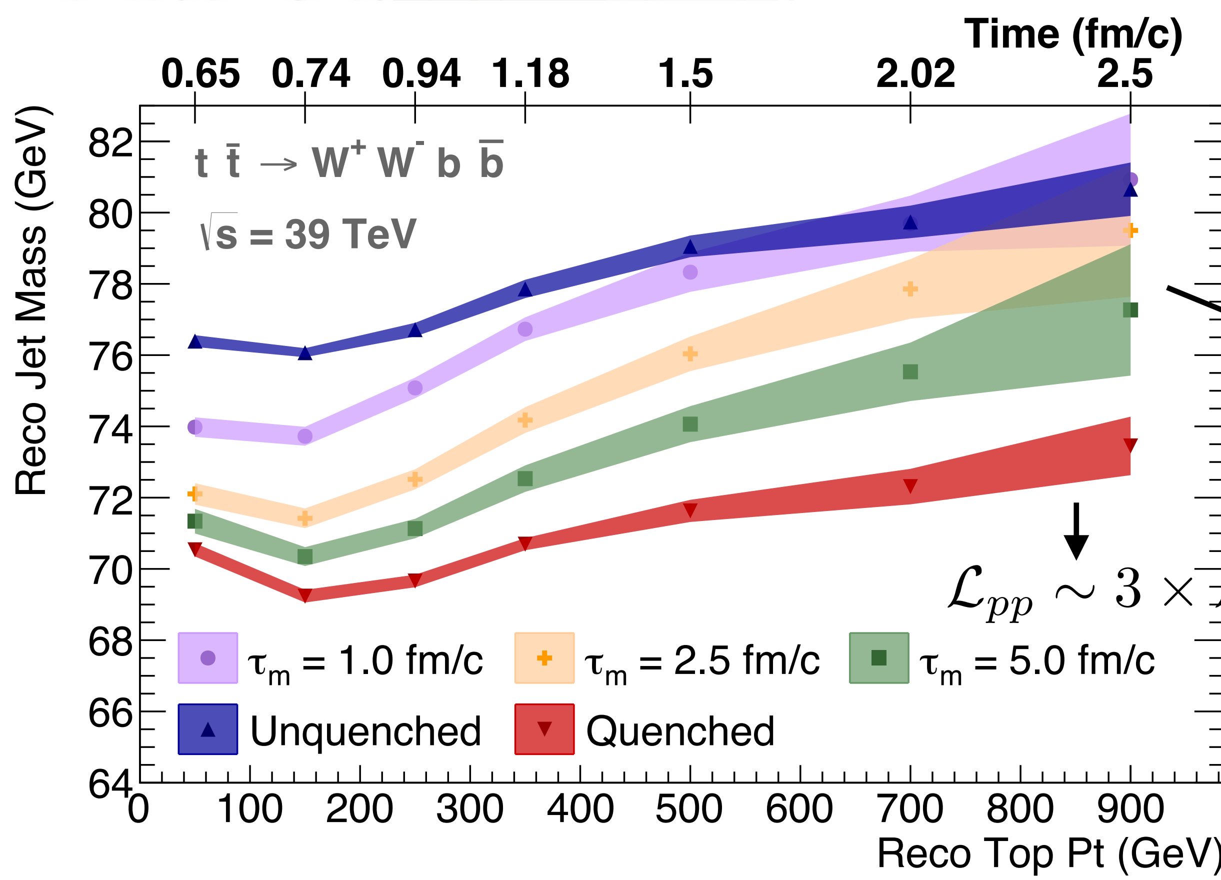

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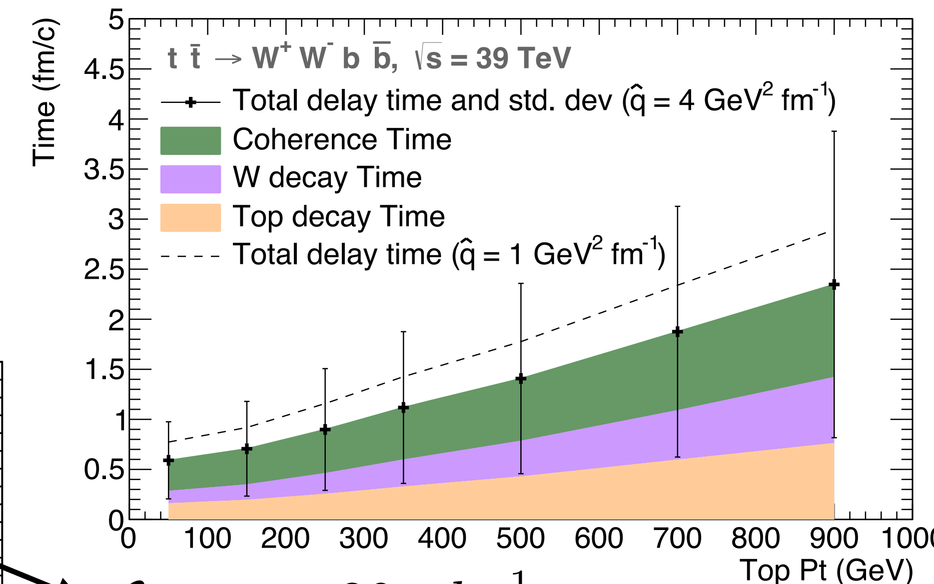

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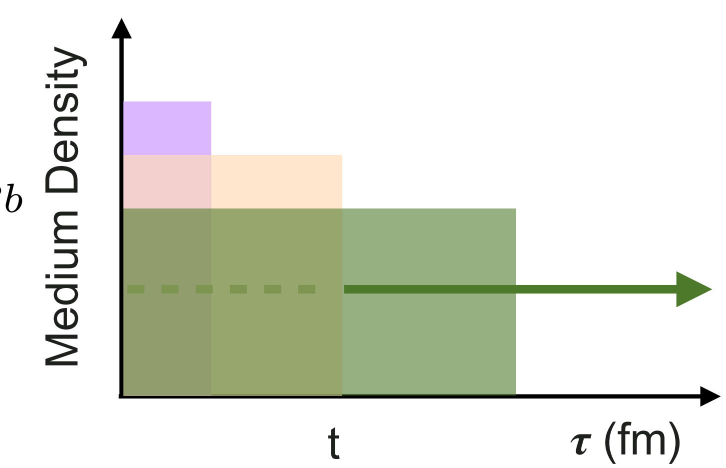

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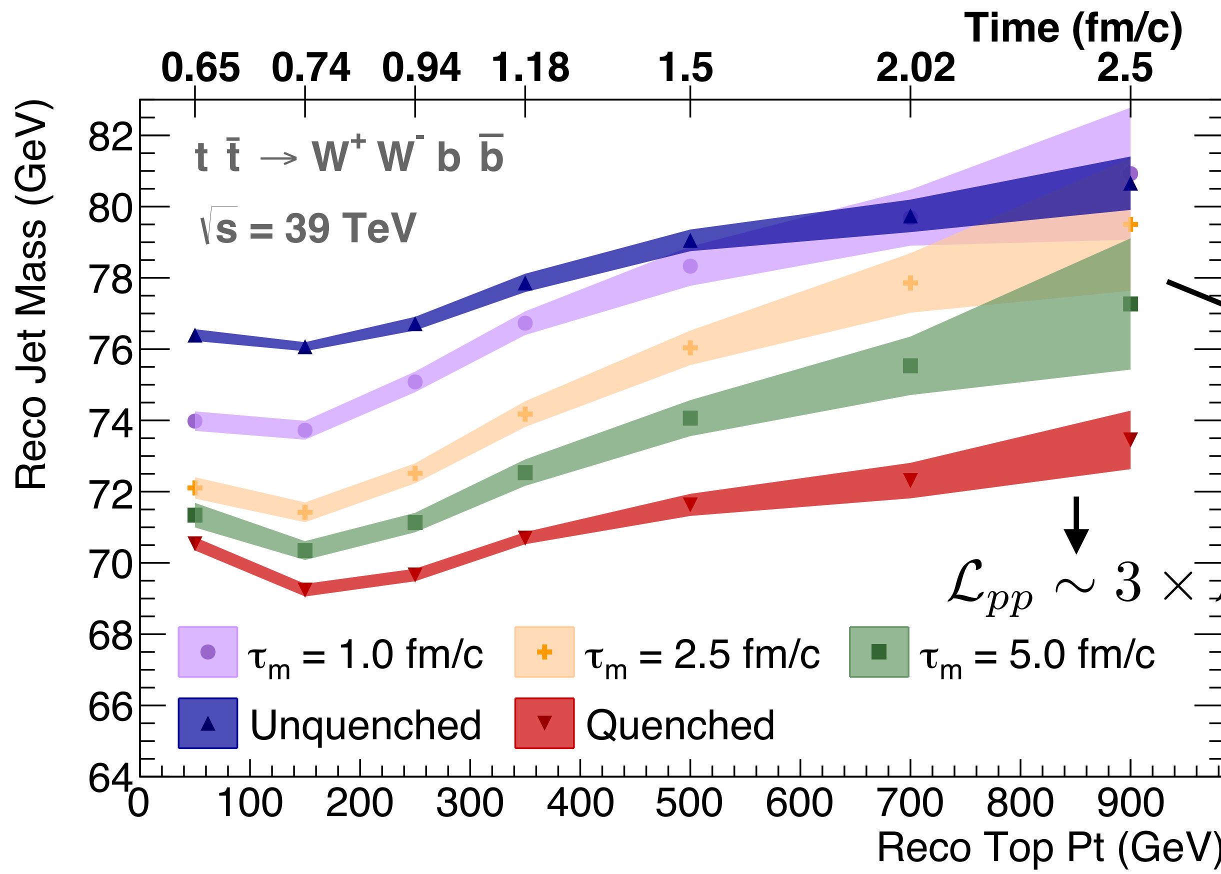

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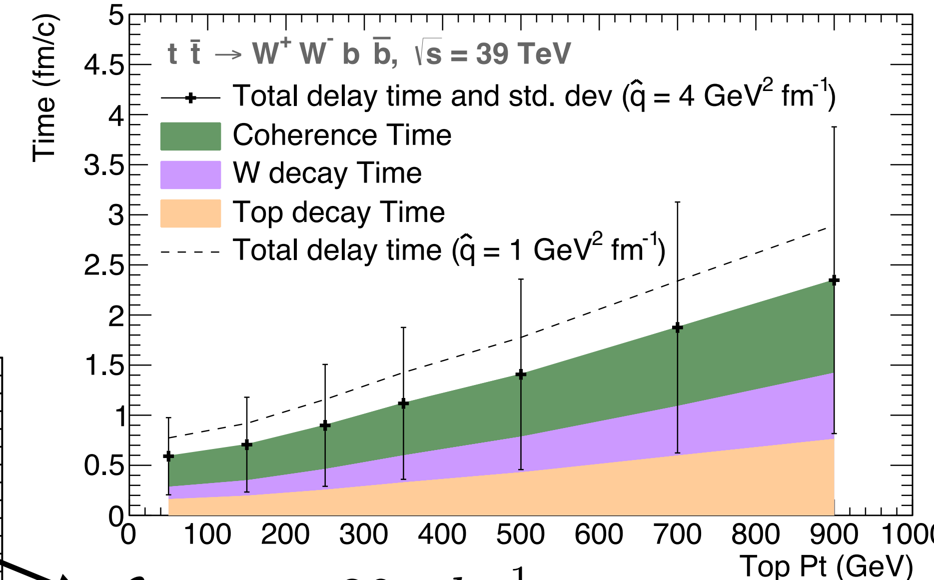

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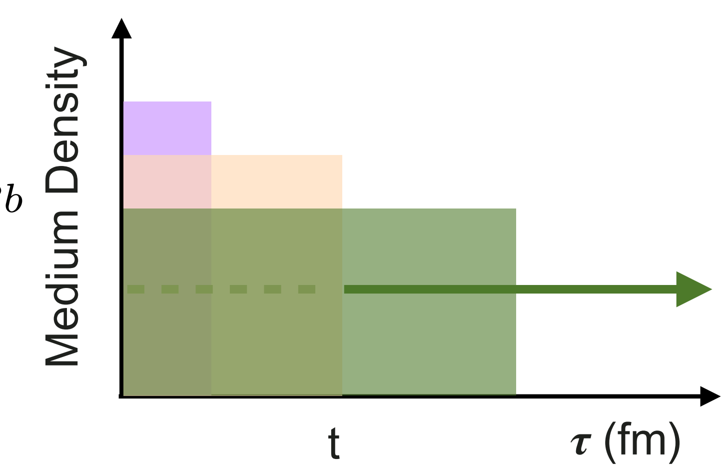

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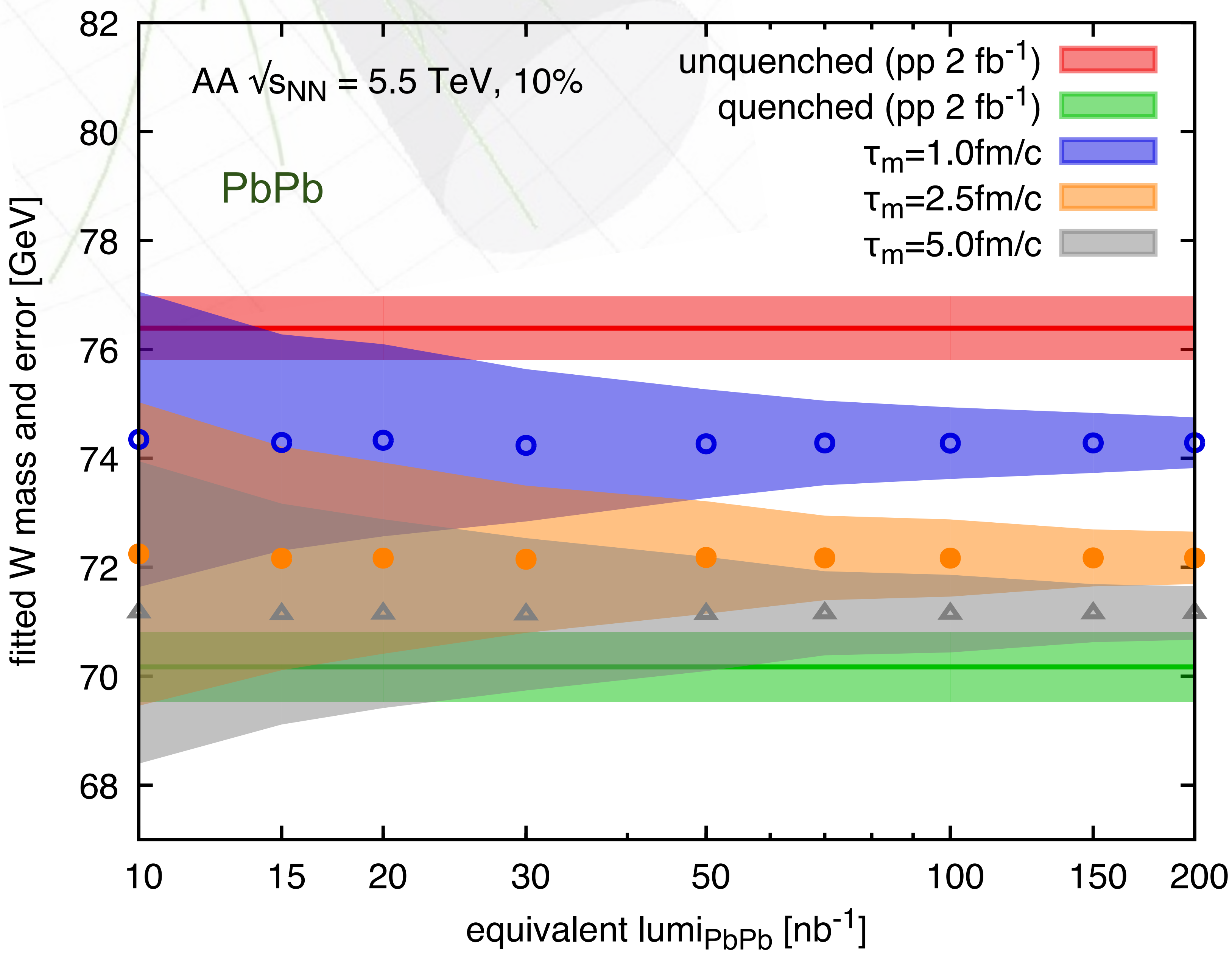
How about the LHC?

From FCC to HL-LHC

- Needed luminosity for LHC (PbPb) run?

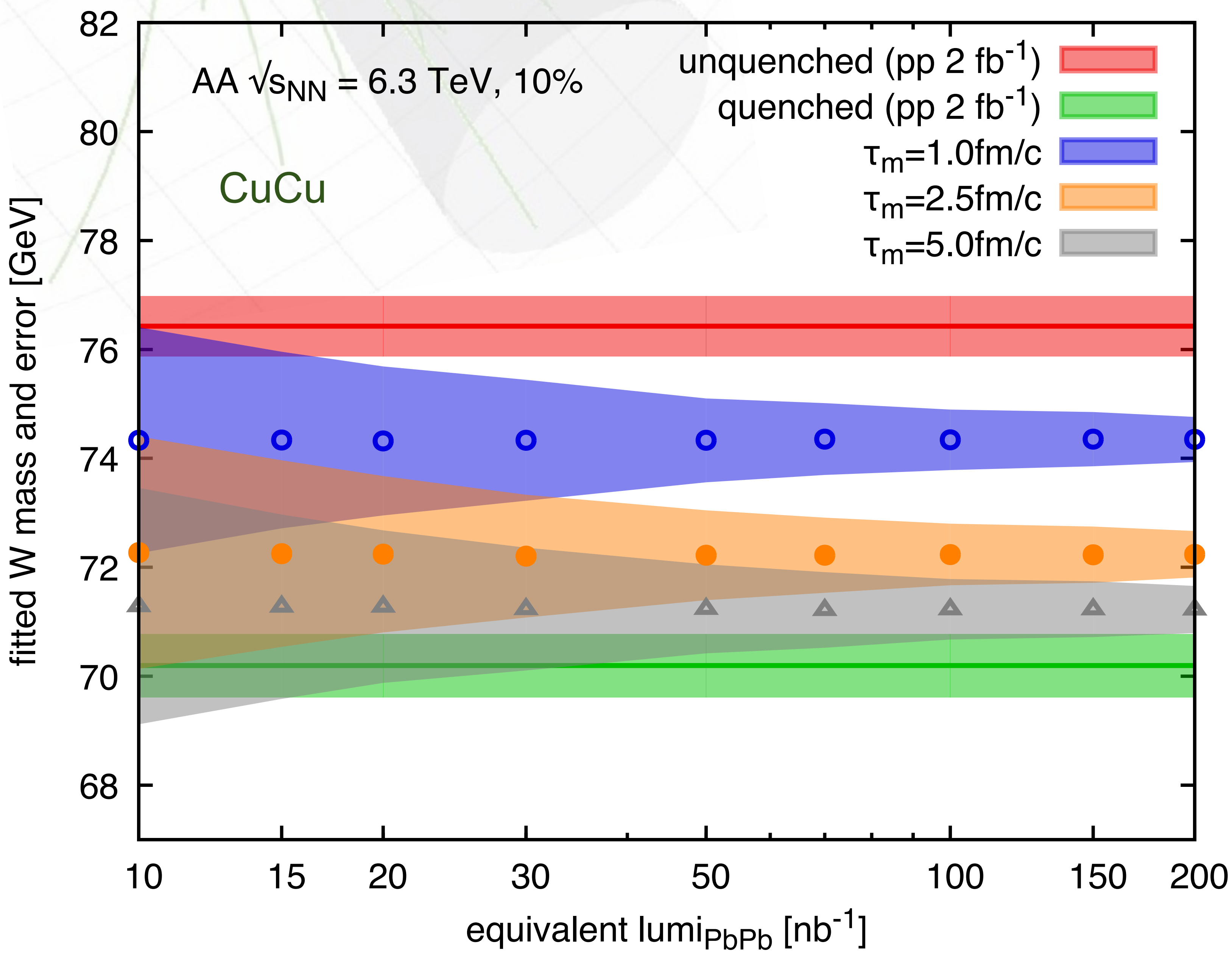


- Not possible to do this study differentially in top p_T bins (not enough statistics)
- Inclusive distributions, at $\mathscr{L}$ = 10 nb^{-1} also limited…

From FCC to HL-LHC

- How about lighter nuclei? CuCu?

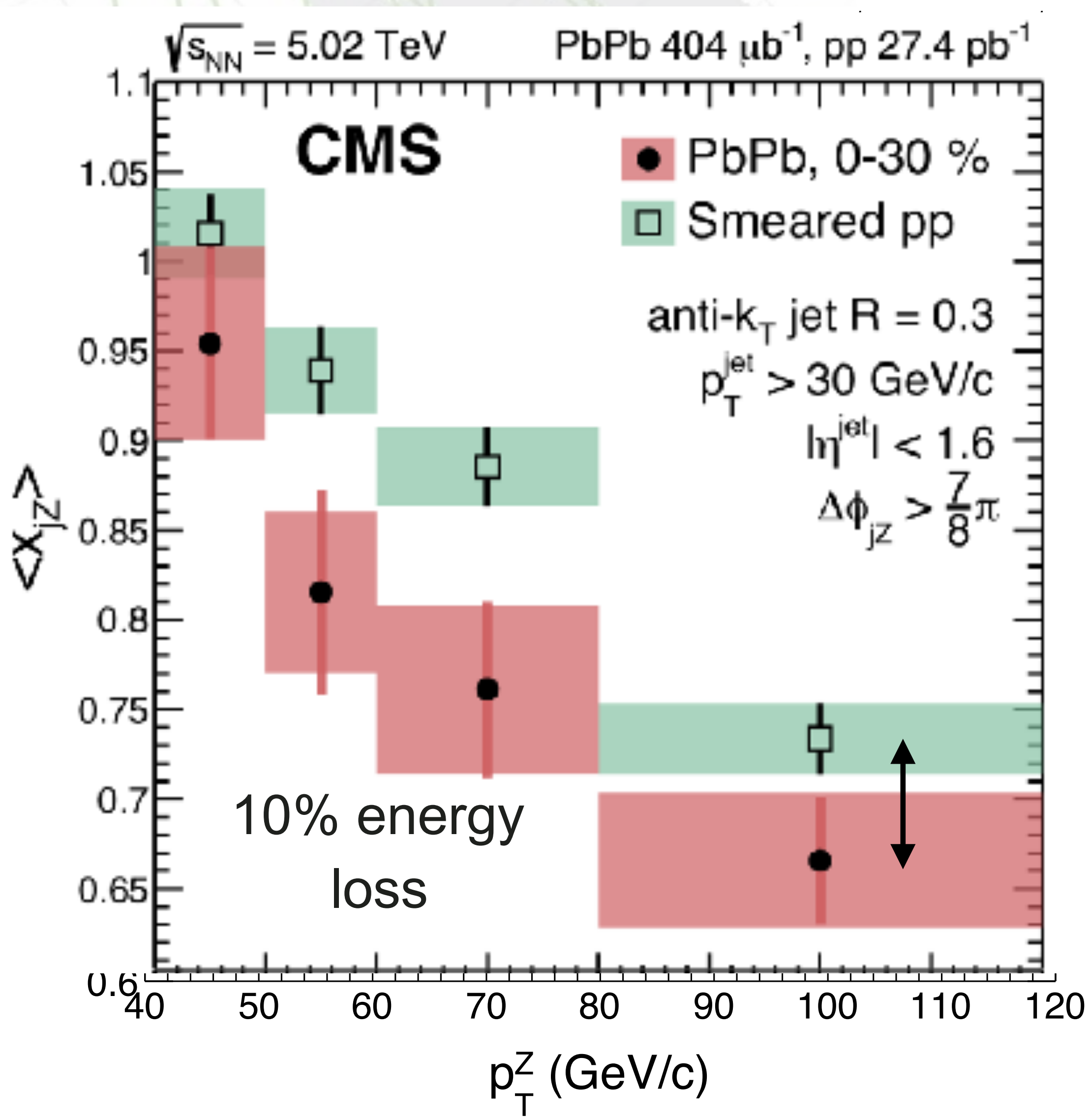
Thank to J. Jowet!



- Increase of energy together provides a slight decrease in the statistical uncertainty at the same equivalent PbPb luminosity
- Lighter nuclei can go higher in luminosity.
- Energy loss for lighter systems?

Energy Loss: Light vs Heavy

- Z+Jet: (CMS PRL 2017)



(Average momentum imbalance Z + Jet)

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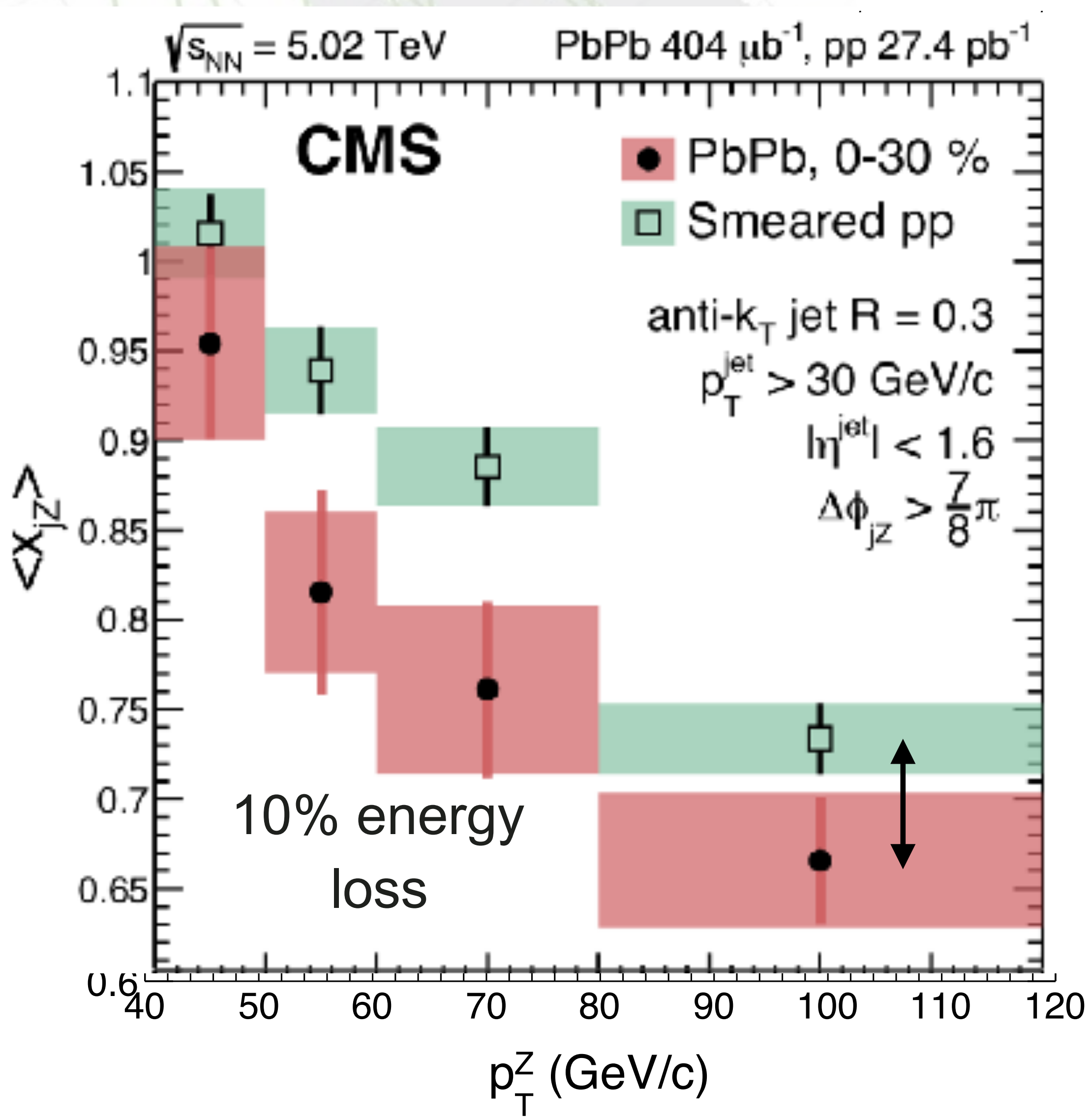

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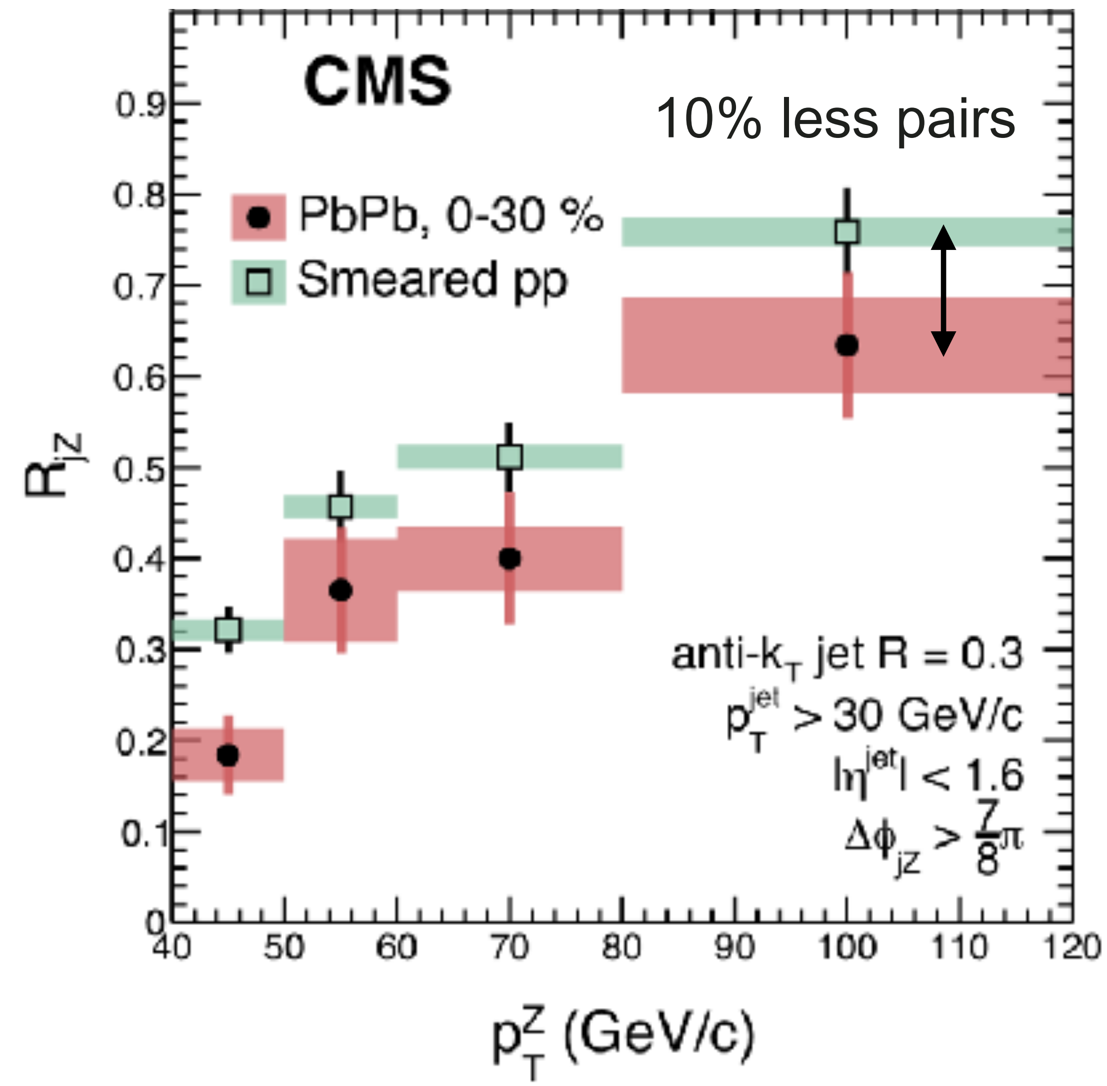

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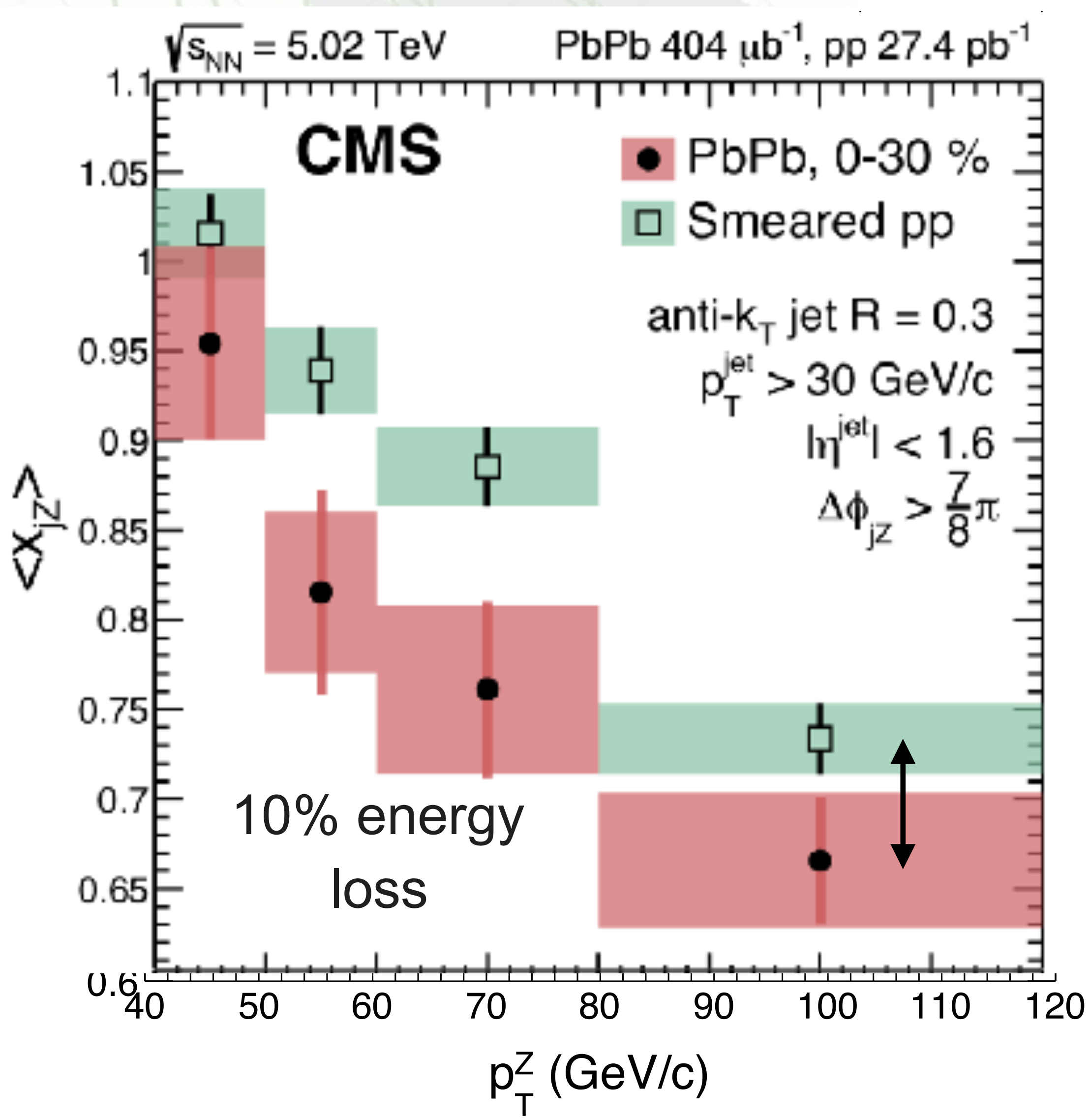

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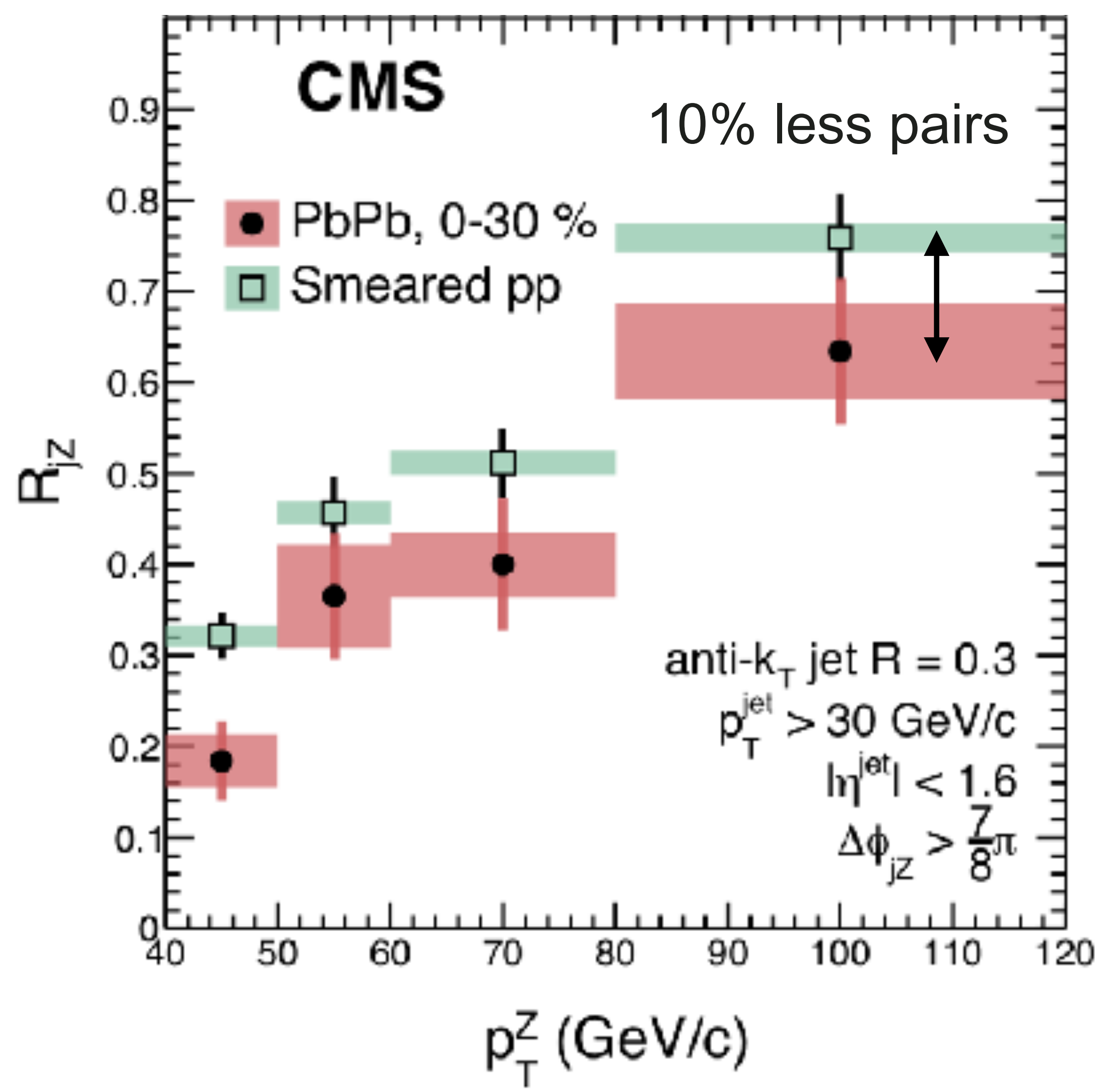

PbPb: $$\frac{\Delta E}{E} = -0.1 \Rightarrow \frac{\Delta E}{E} = -0.15$$

CuCu: $$\frac{\Delta E}{E} = -0.1$$

Energy Loss: Light vs Heavy

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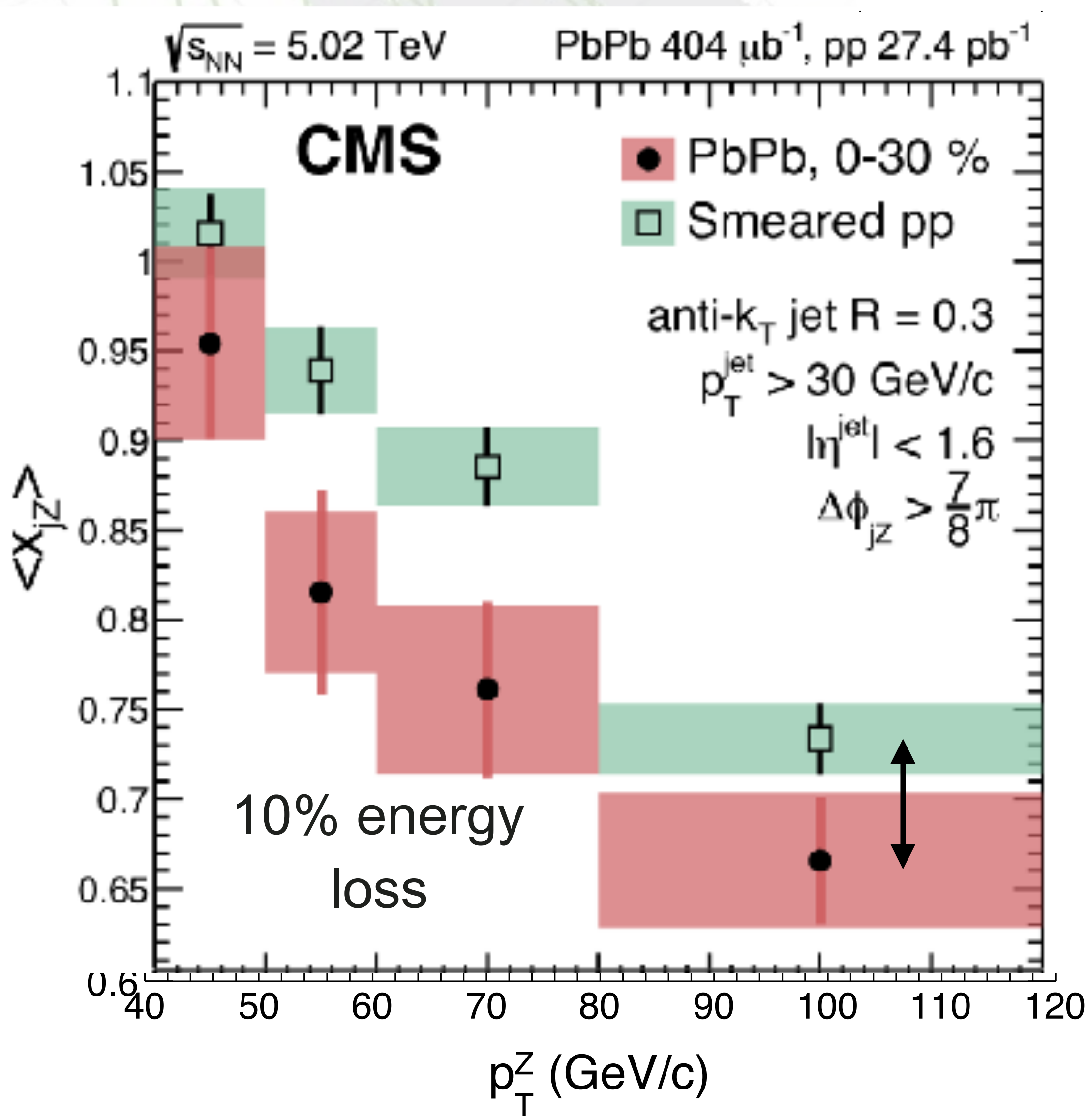

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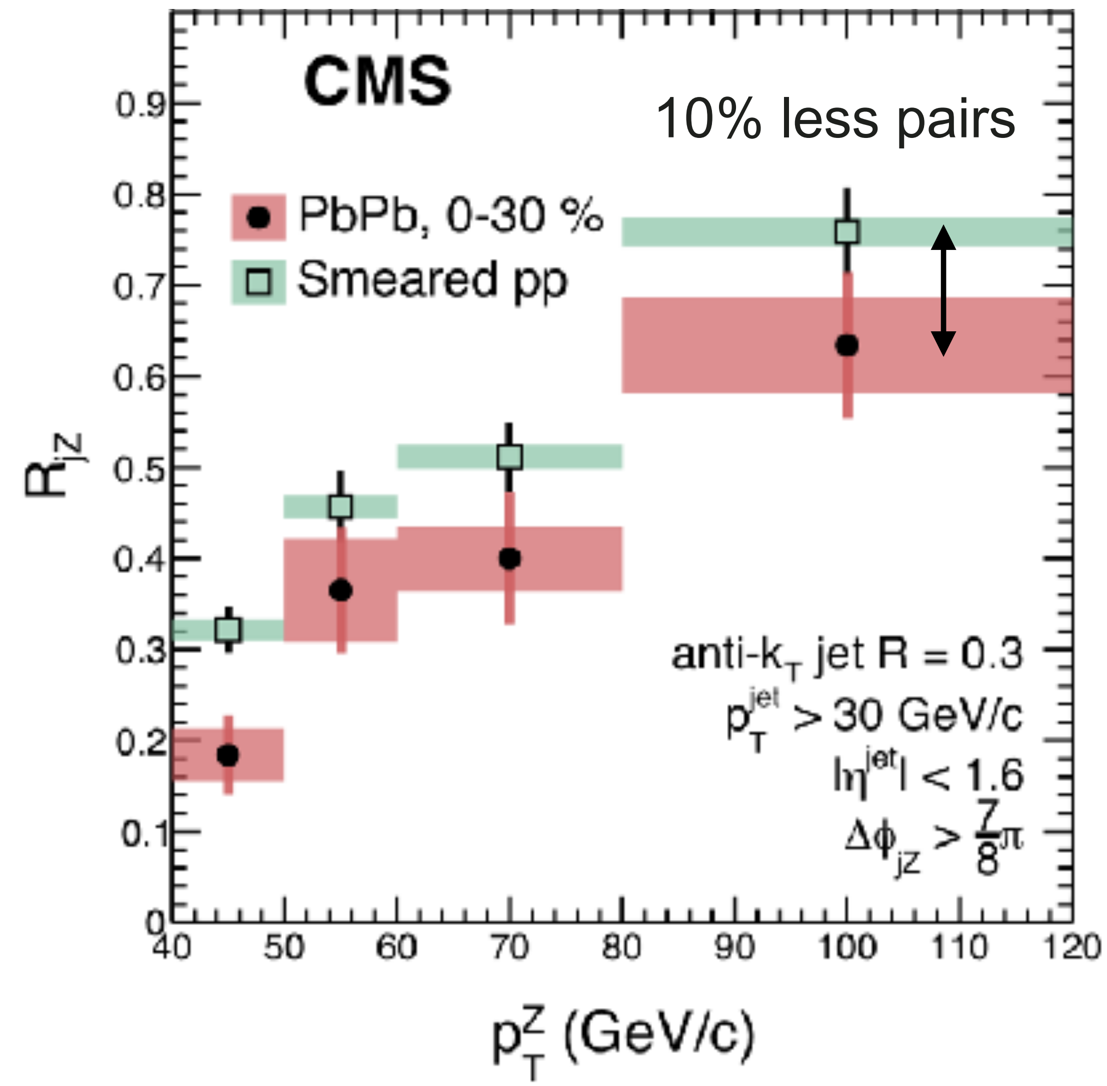

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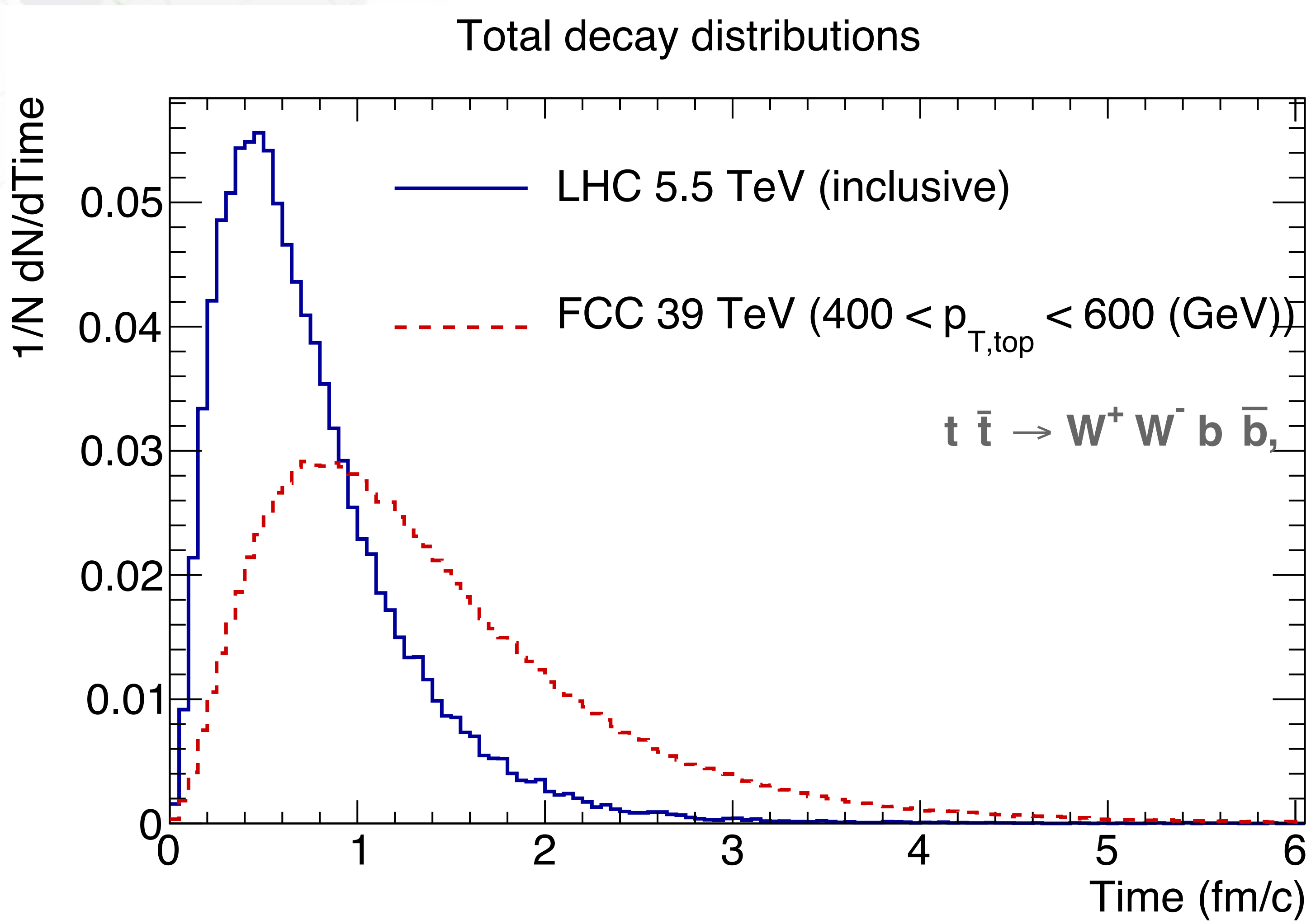
We were being conservative…

Our standard from now on!

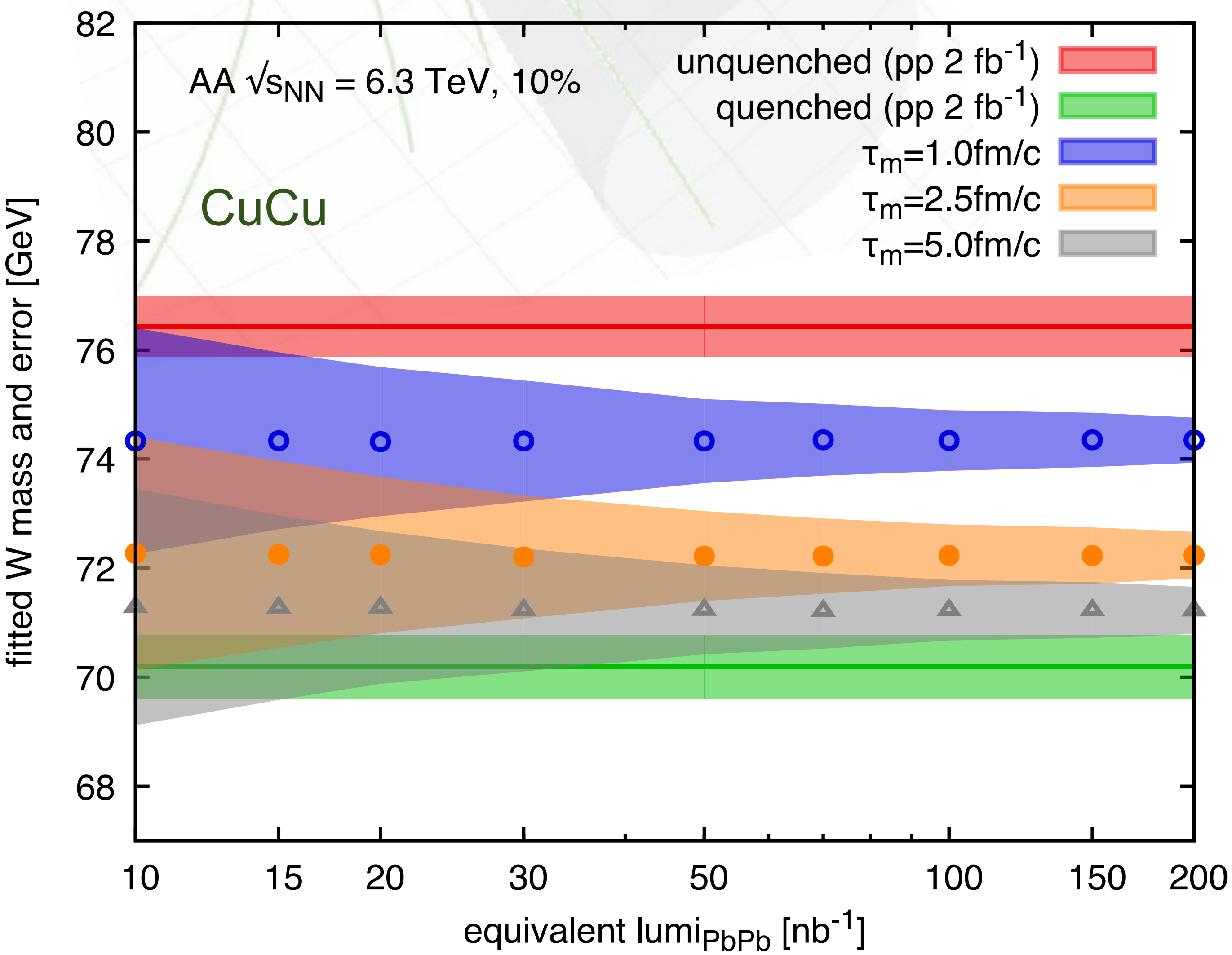
Timescales: HL-LHC vs FCC

- Average total delay time at the LHC is very smal…
  - But there is a large dispersion that one can play with.



Statistical significance

- Define separation from fully quenched to a “brick” of size τ_m by the number of σ at a fixed luminosity, $\mathscr{L}$.



- Unquenched reference: pp
- Quenched reference: assumed what would give a “normal quenched scenario” the band width + 1% extra error;
- Look at the significance of one of the other curves with respect to “quenched” reference.

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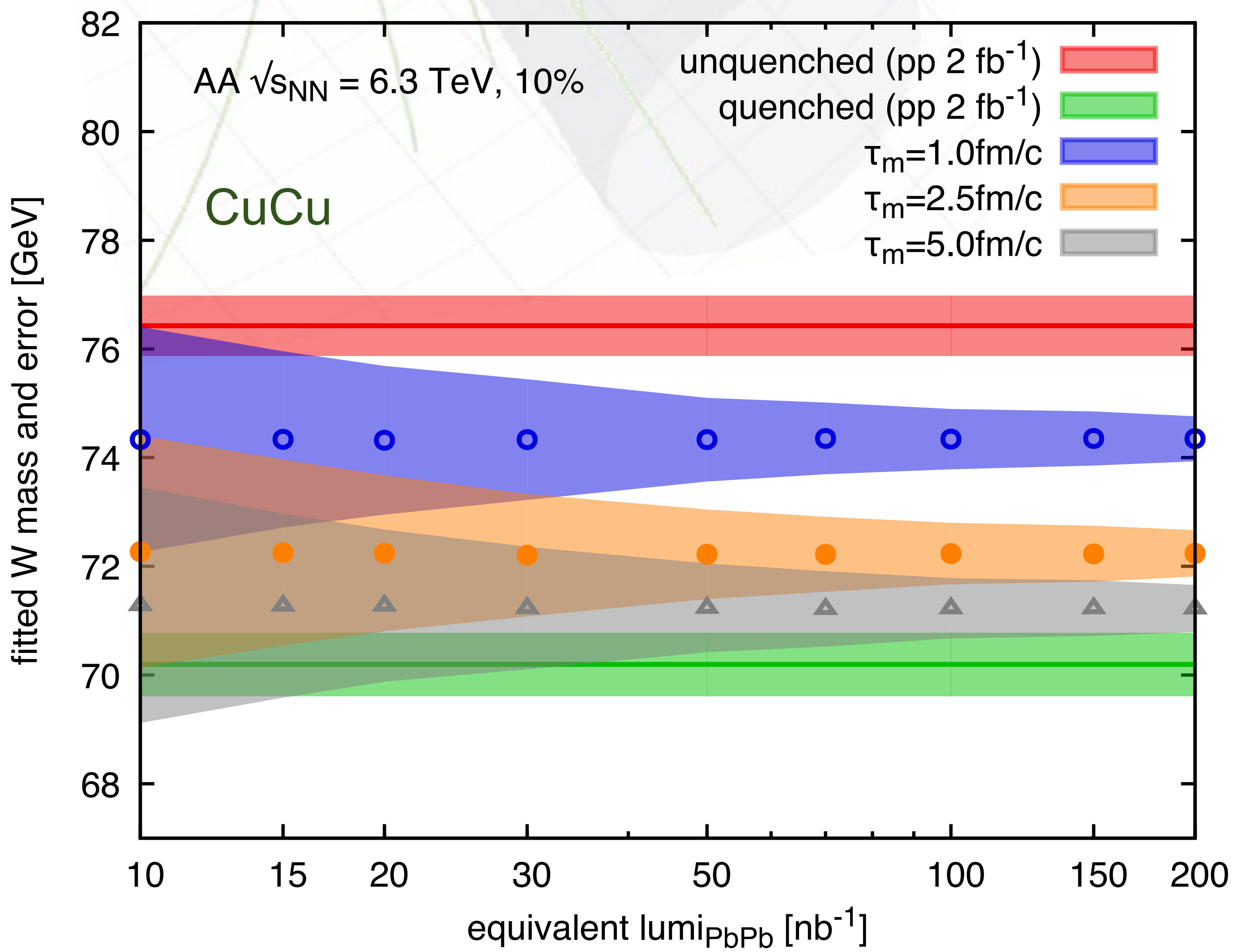

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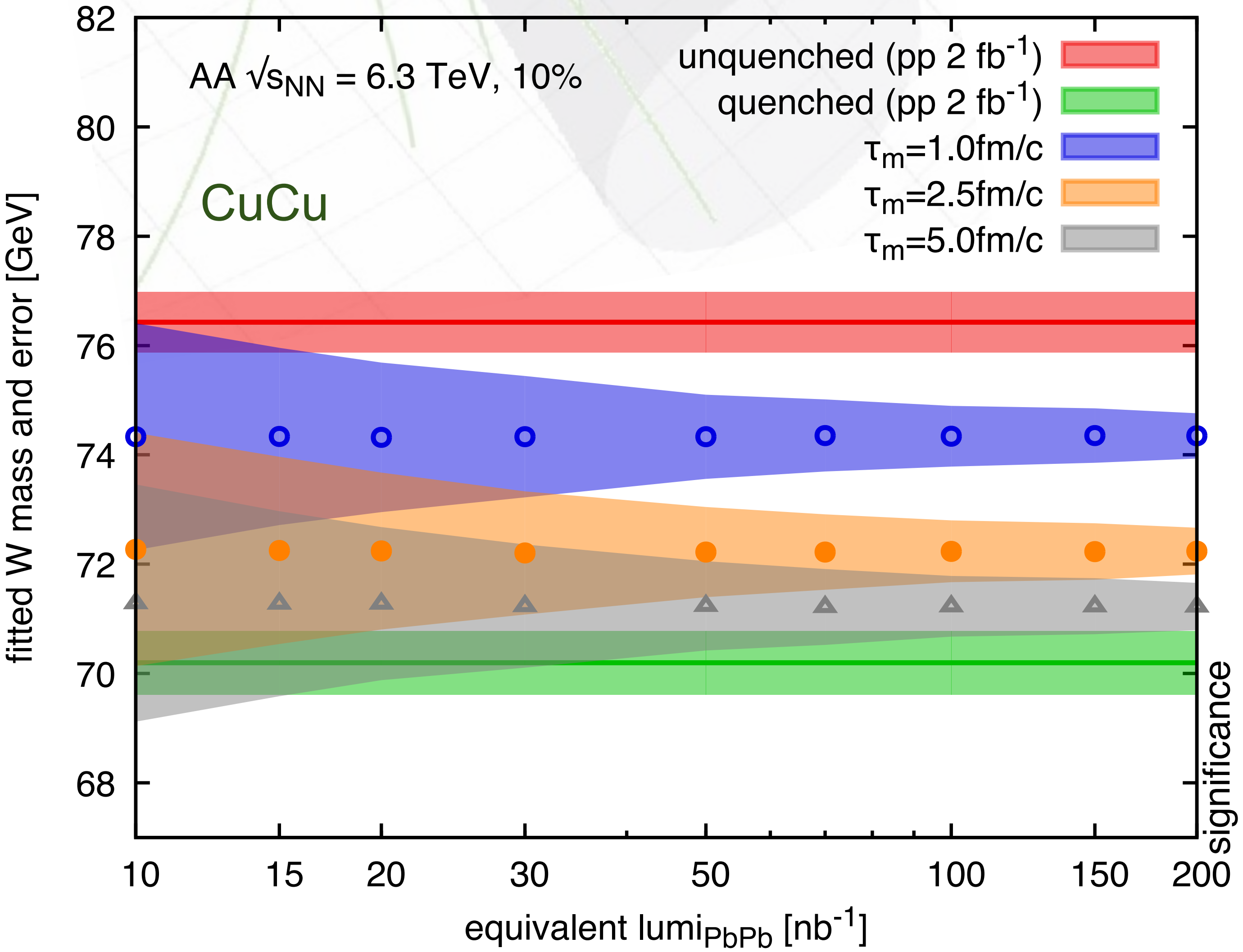

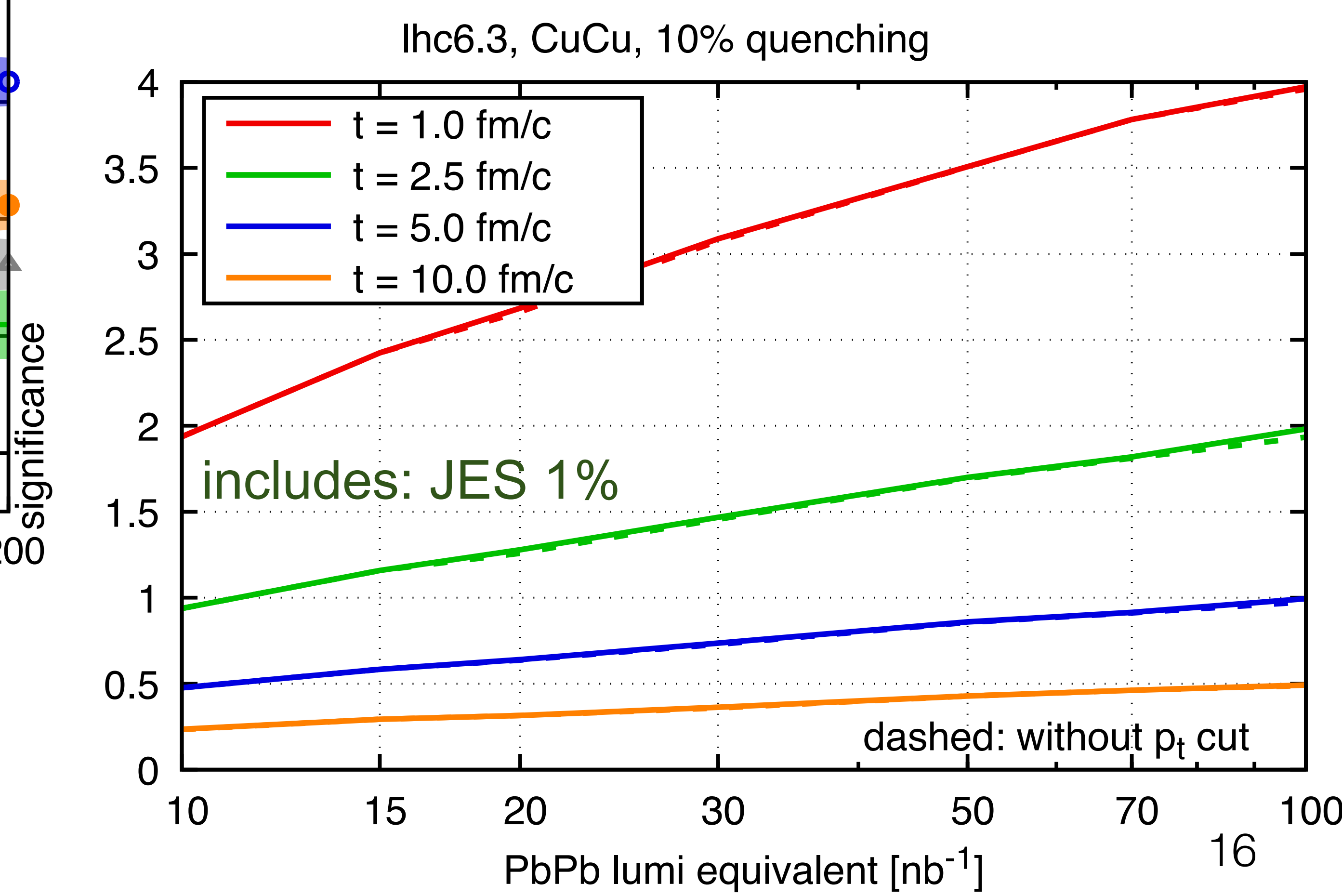

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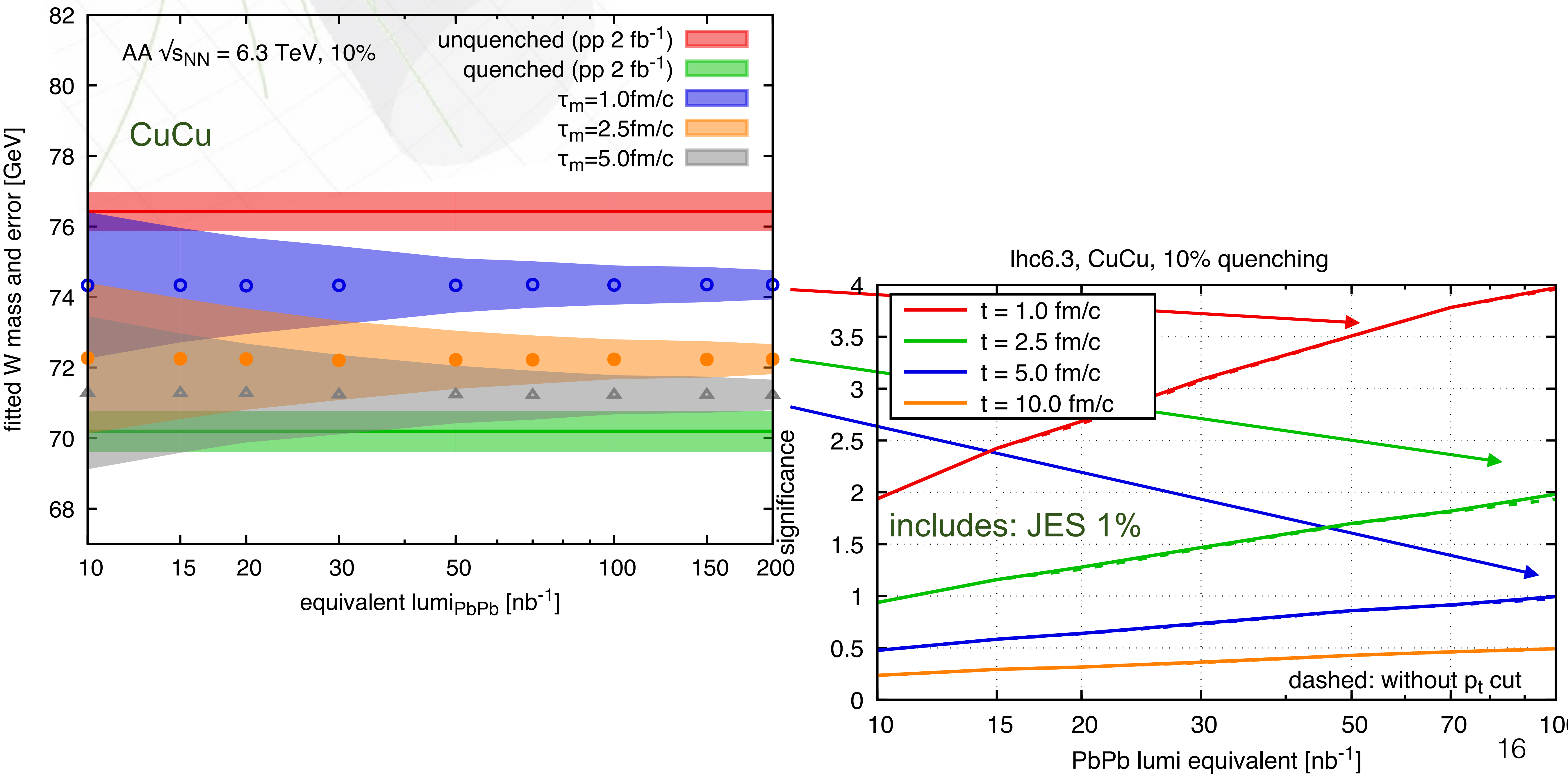

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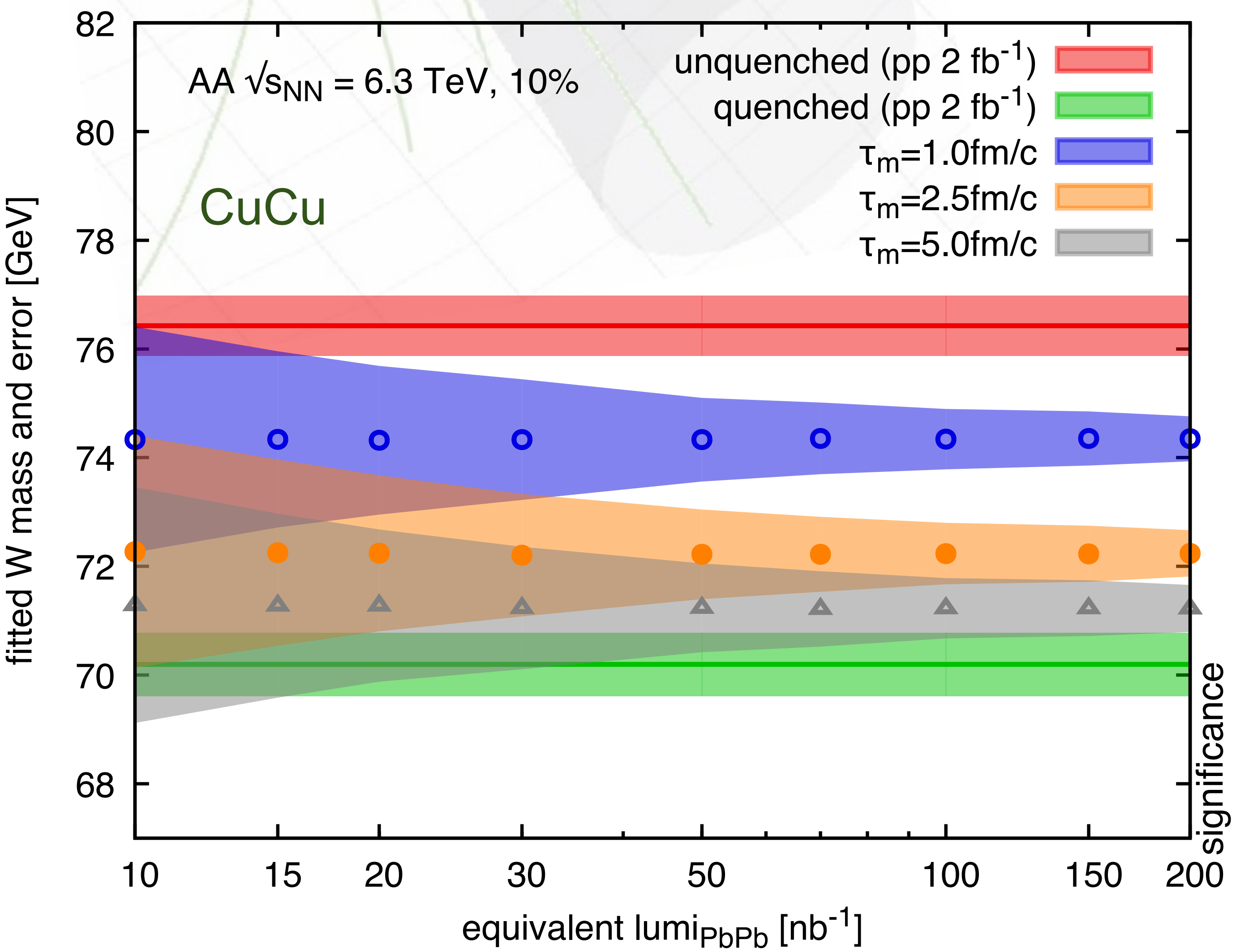
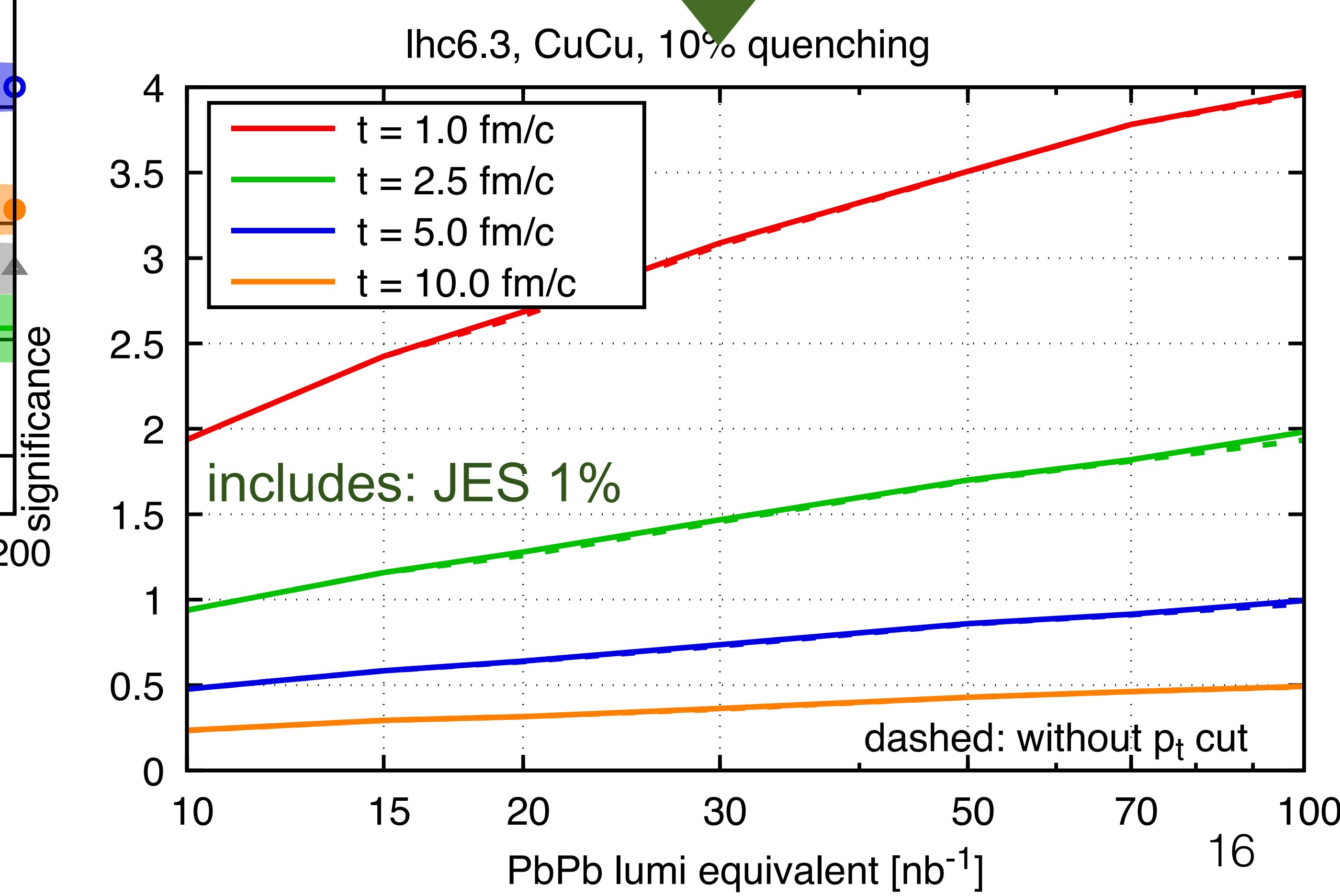


- Possible to distinguish with 3σ a scenario in which the quenching dominates in the first 1fm/c and 1.5σ for 2.5 fm/c



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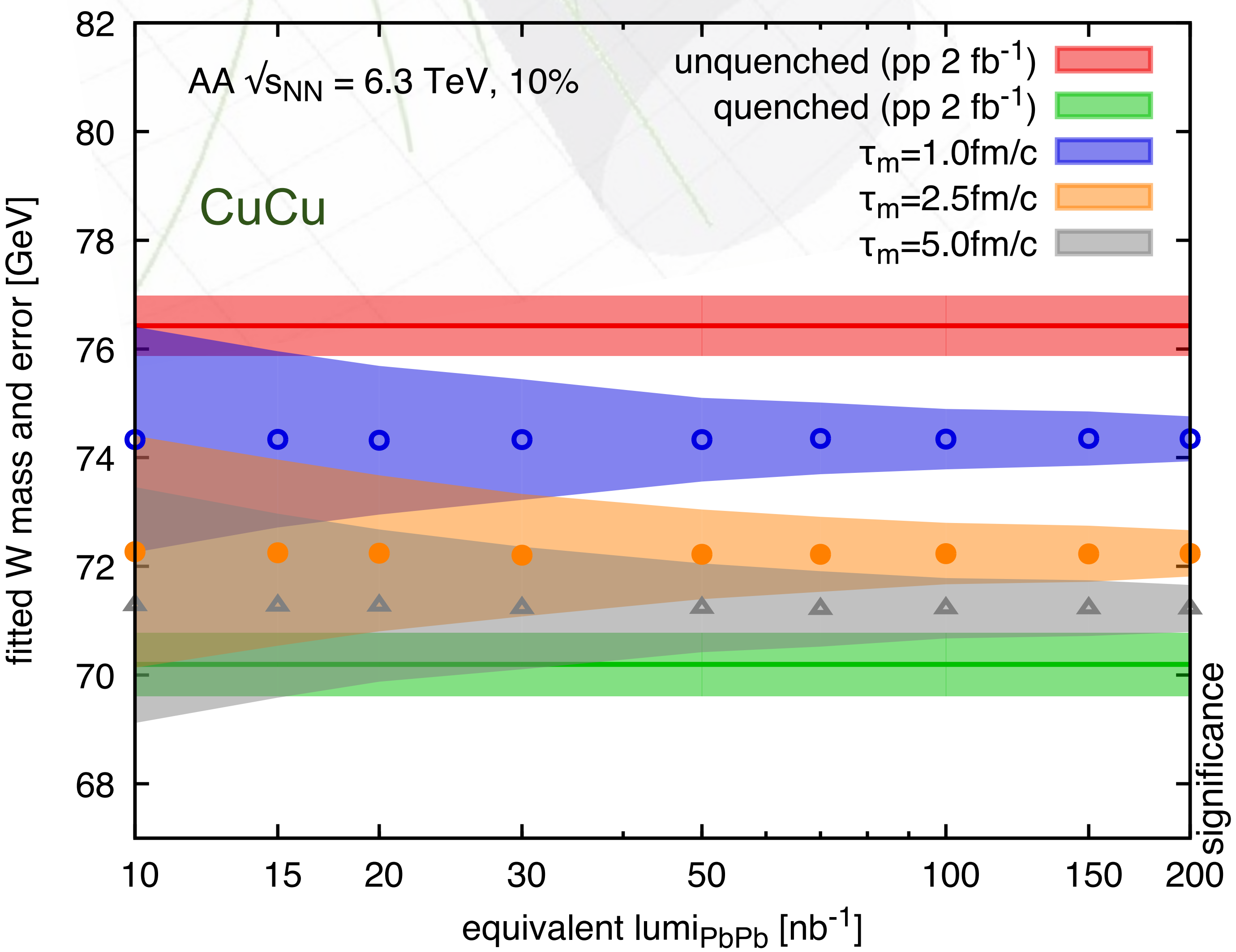

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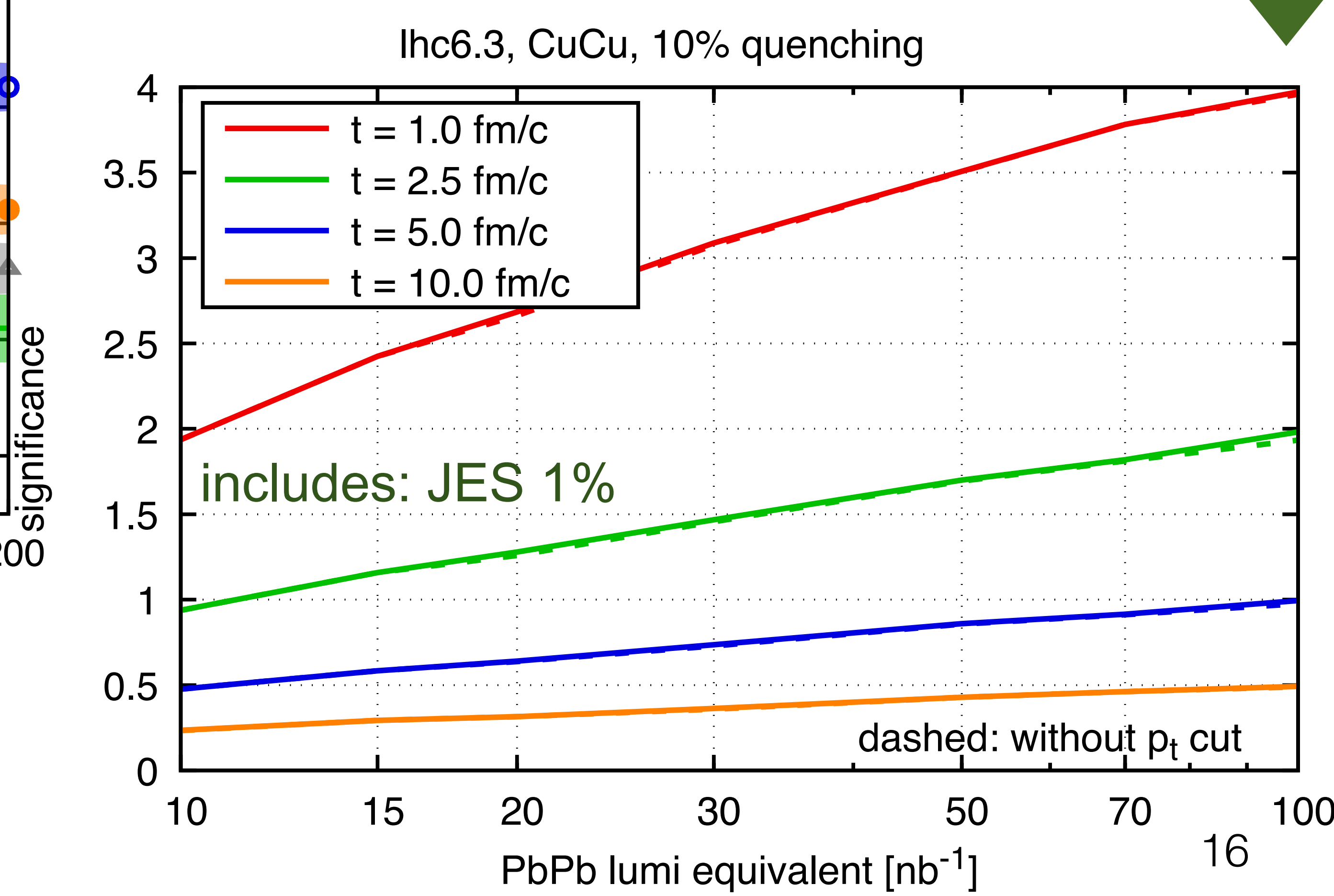

- Distinction between 1 and 2.5 fm/c with 2σ possible only at 100 nb^{-1}

Statistical significance

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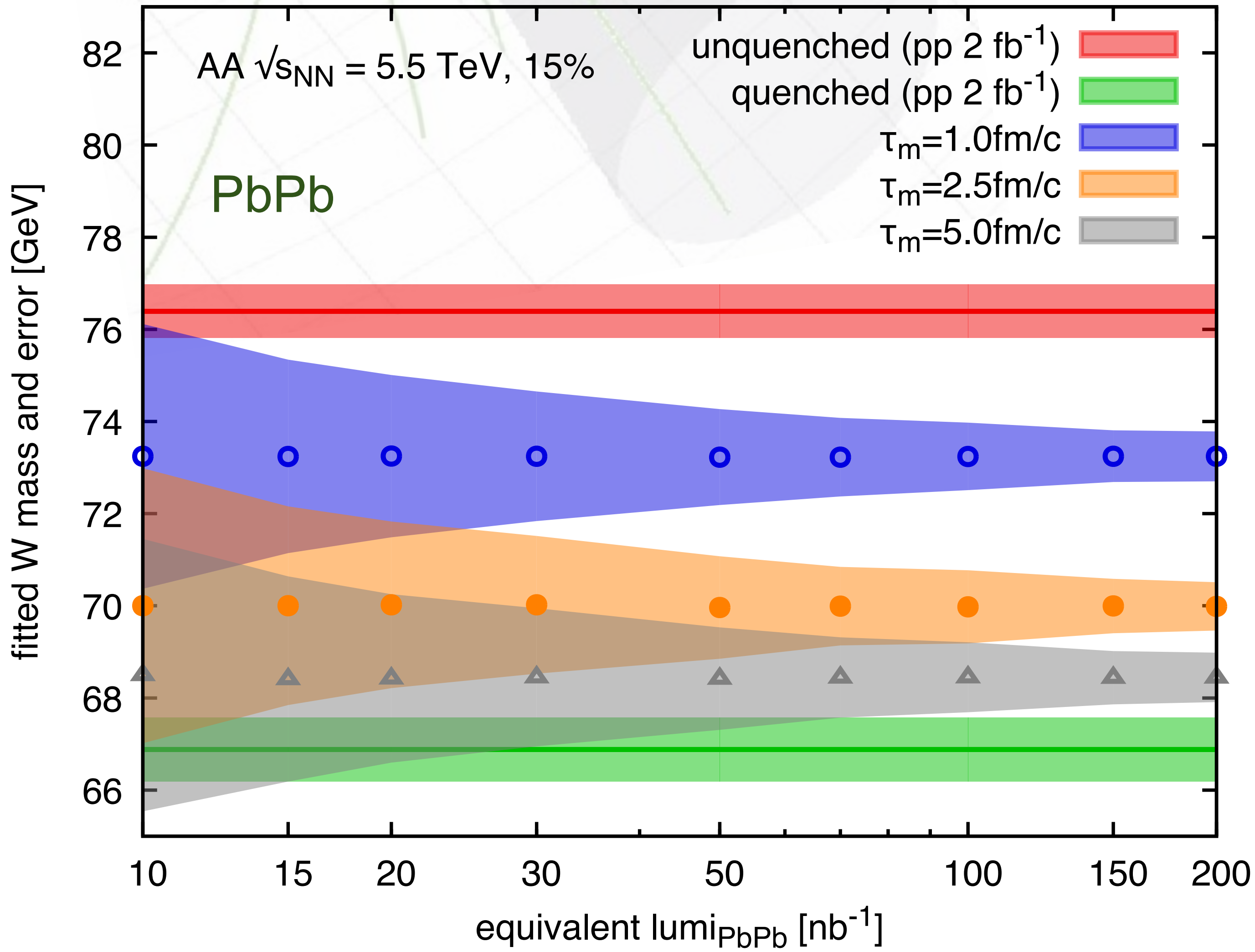
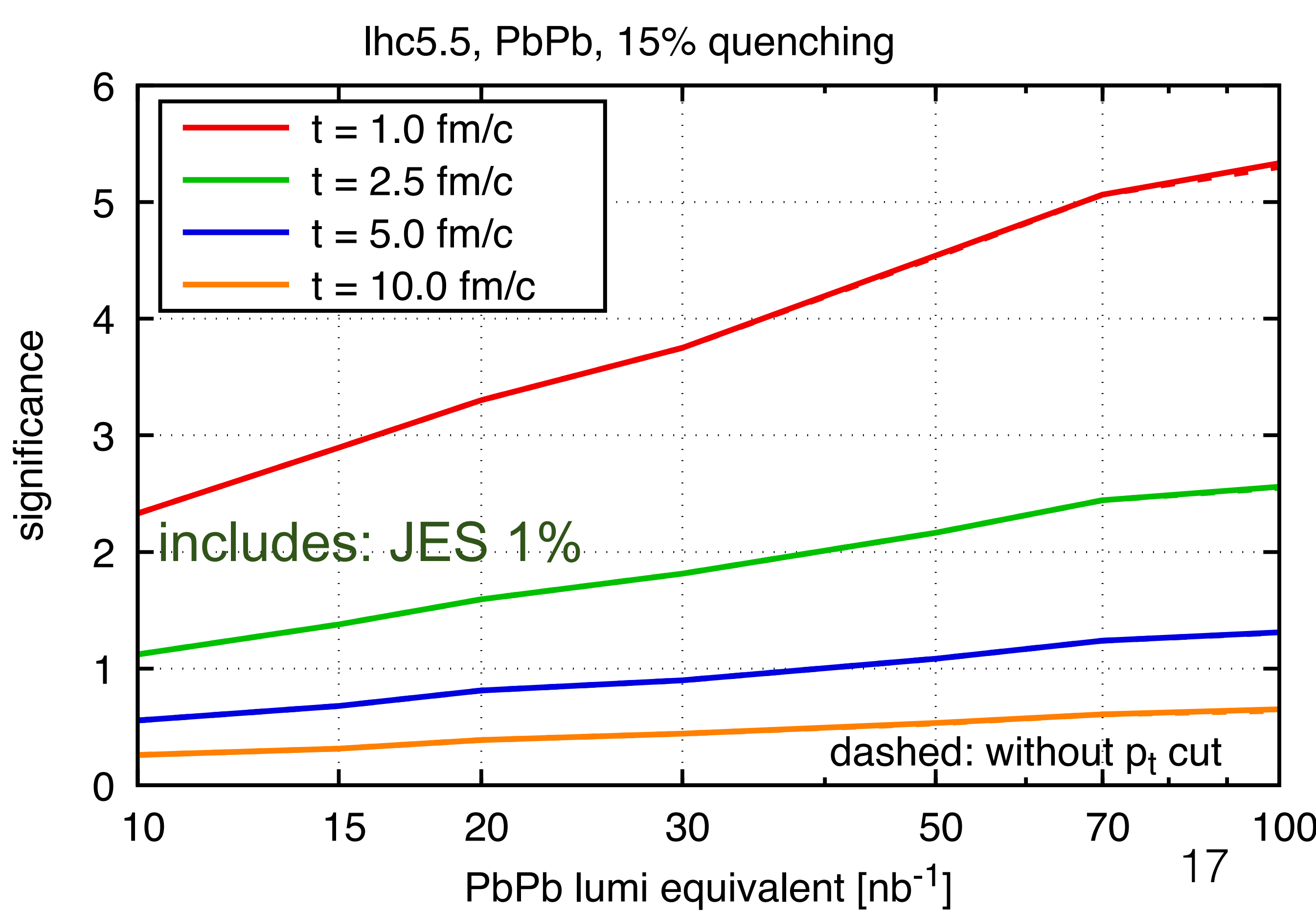
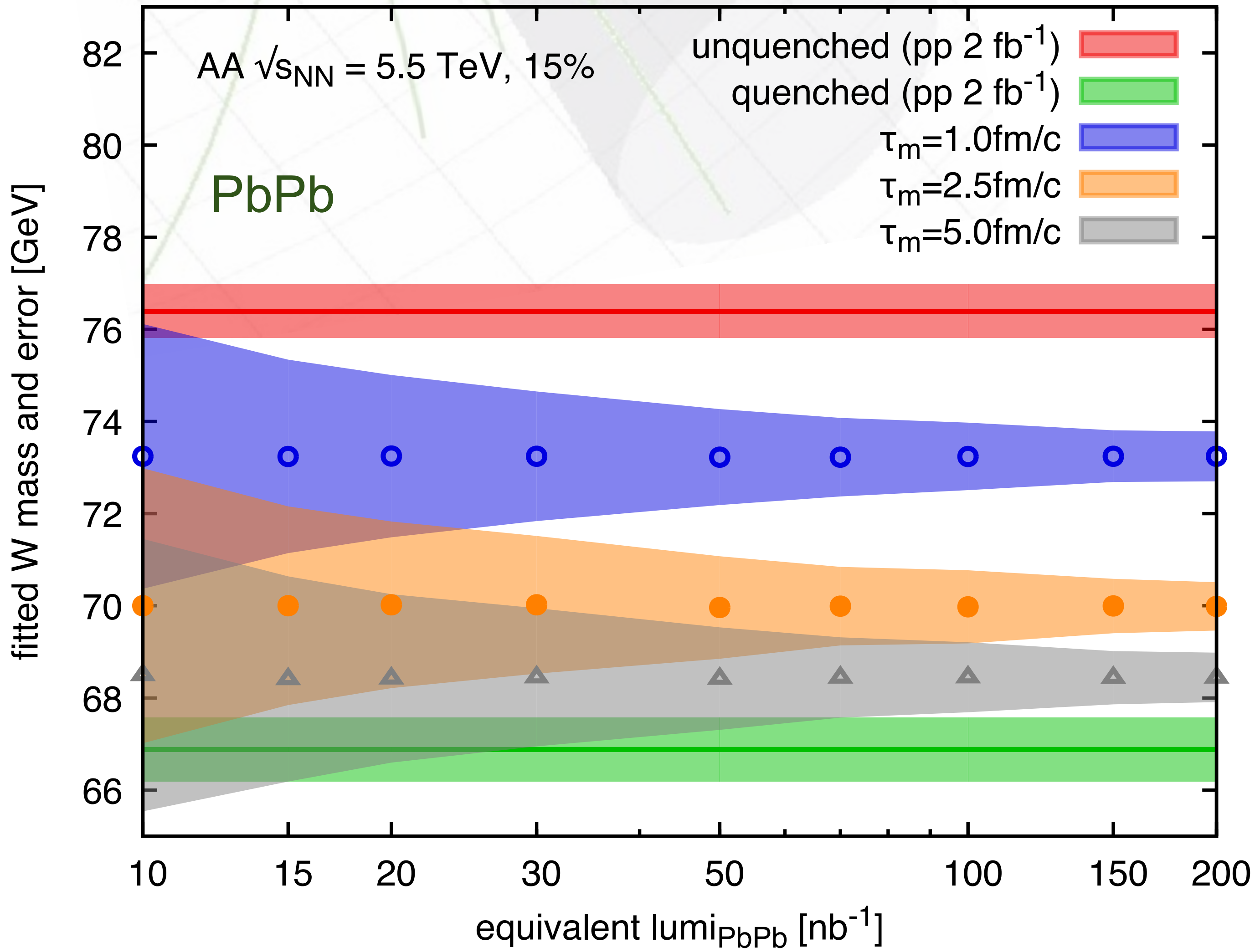
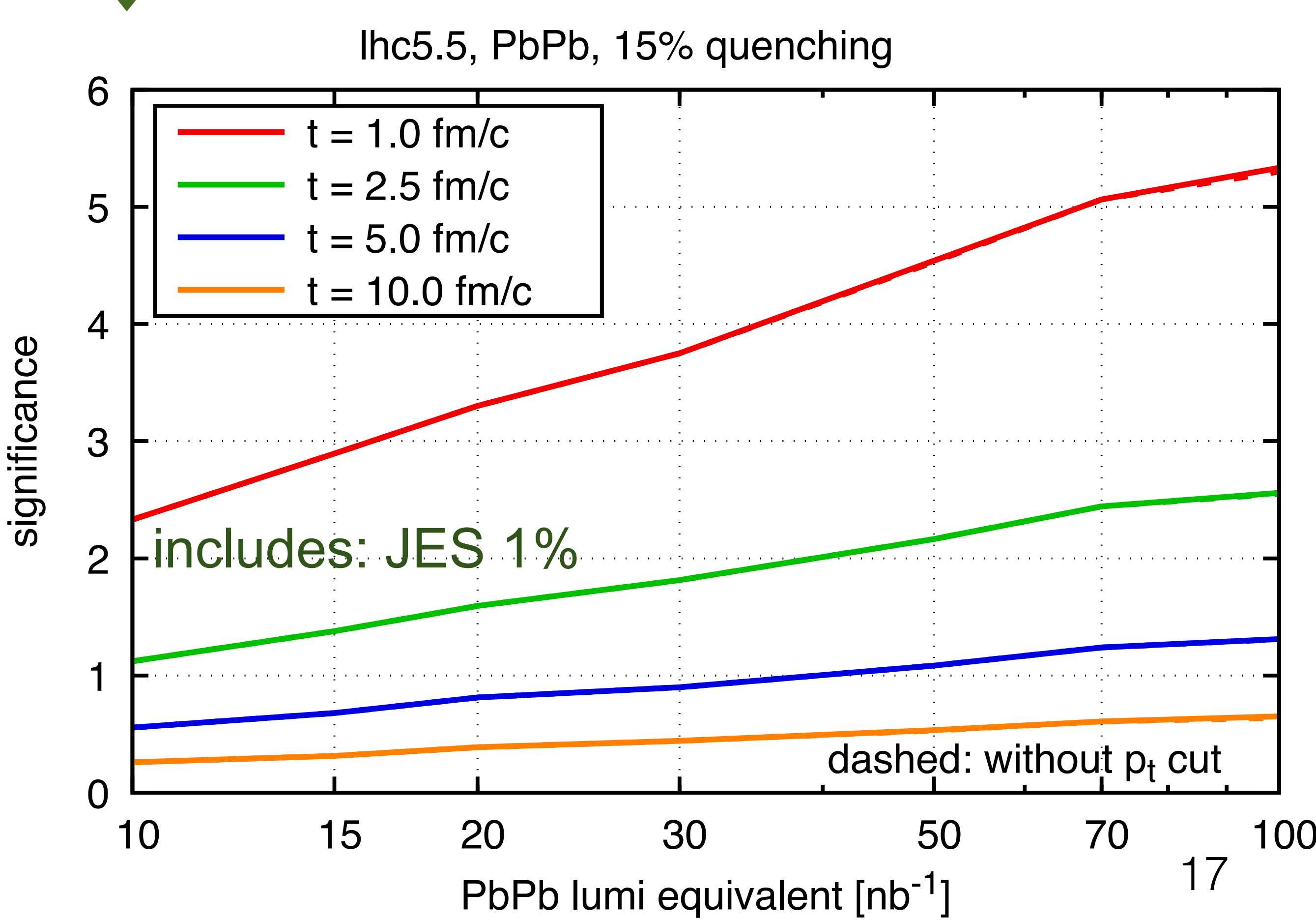




Statistical significance

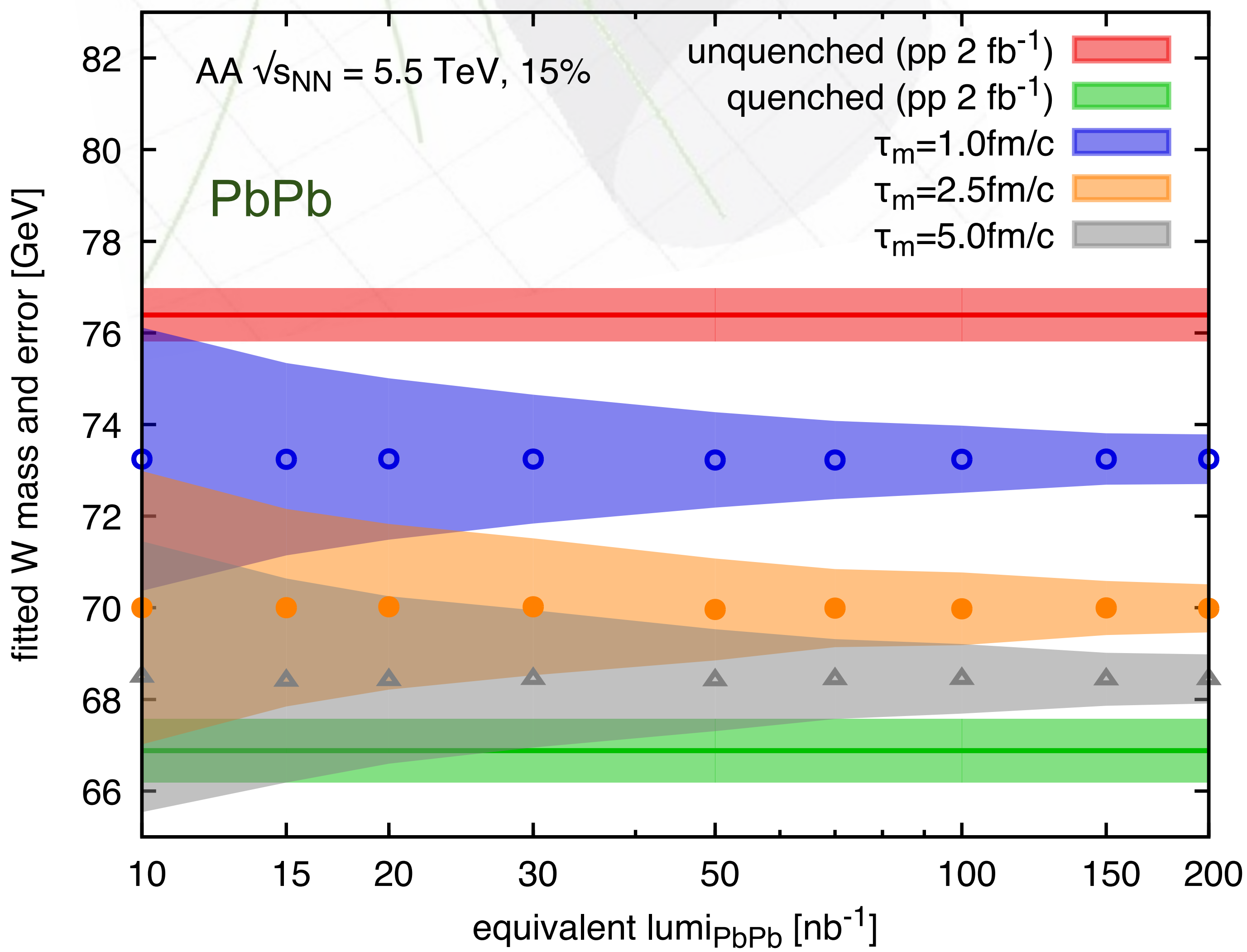
- Define separation from fully quenched to a “brick” of size τ_m by the number of σ at a fixed luminosity, $\mathscr{L}$.
- Only 2.5σ for a scenario in which quenching dominates in the first 1 fm/c and 1σ for 2.5 fm/c





Statistical significance

- Define separation from fully quenched to a “brick” of size τ_m by the number of σ at a fixed luminosity, $\mathscr{L}$.



- 2σ only at 30 nb^{-1}

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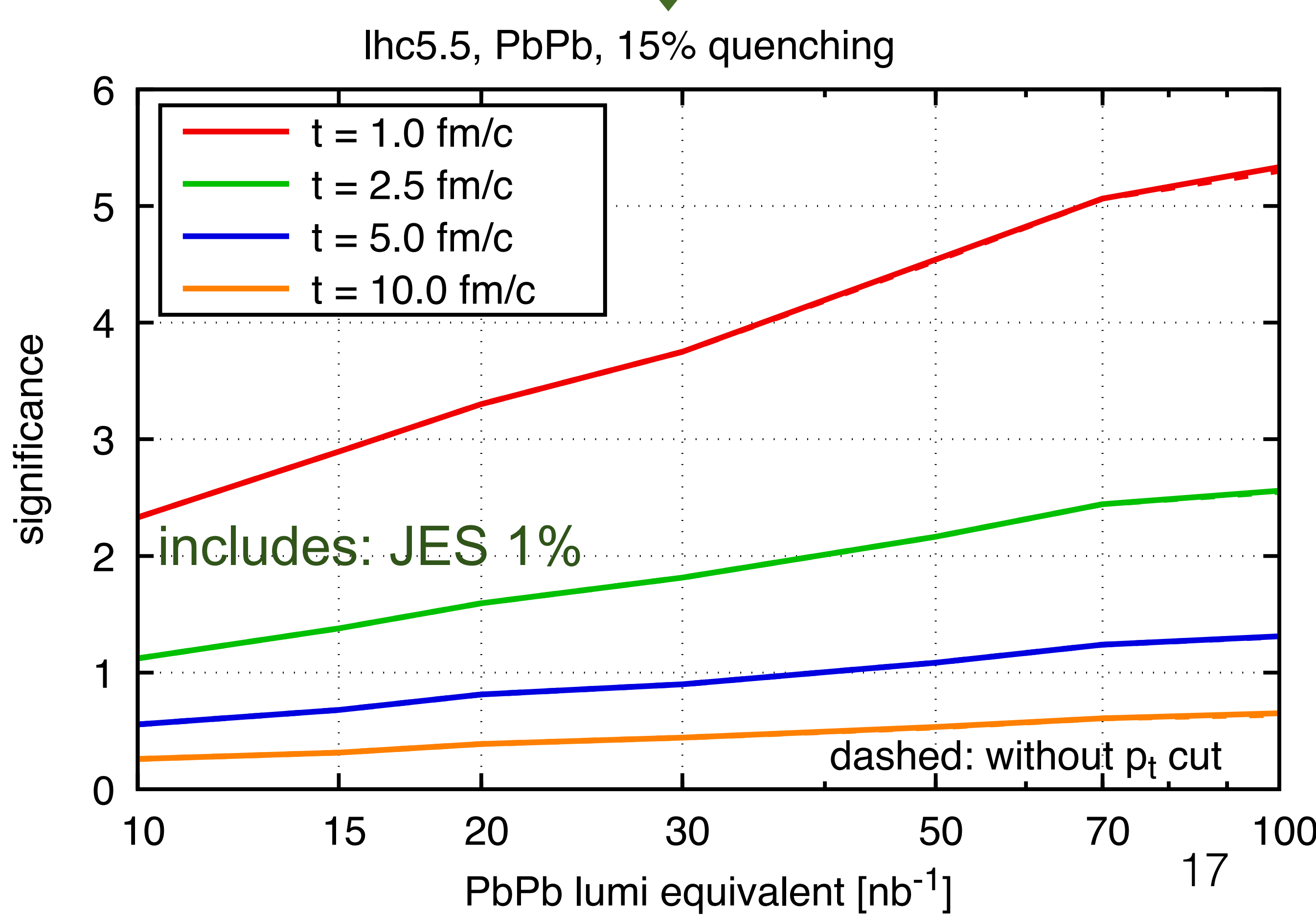
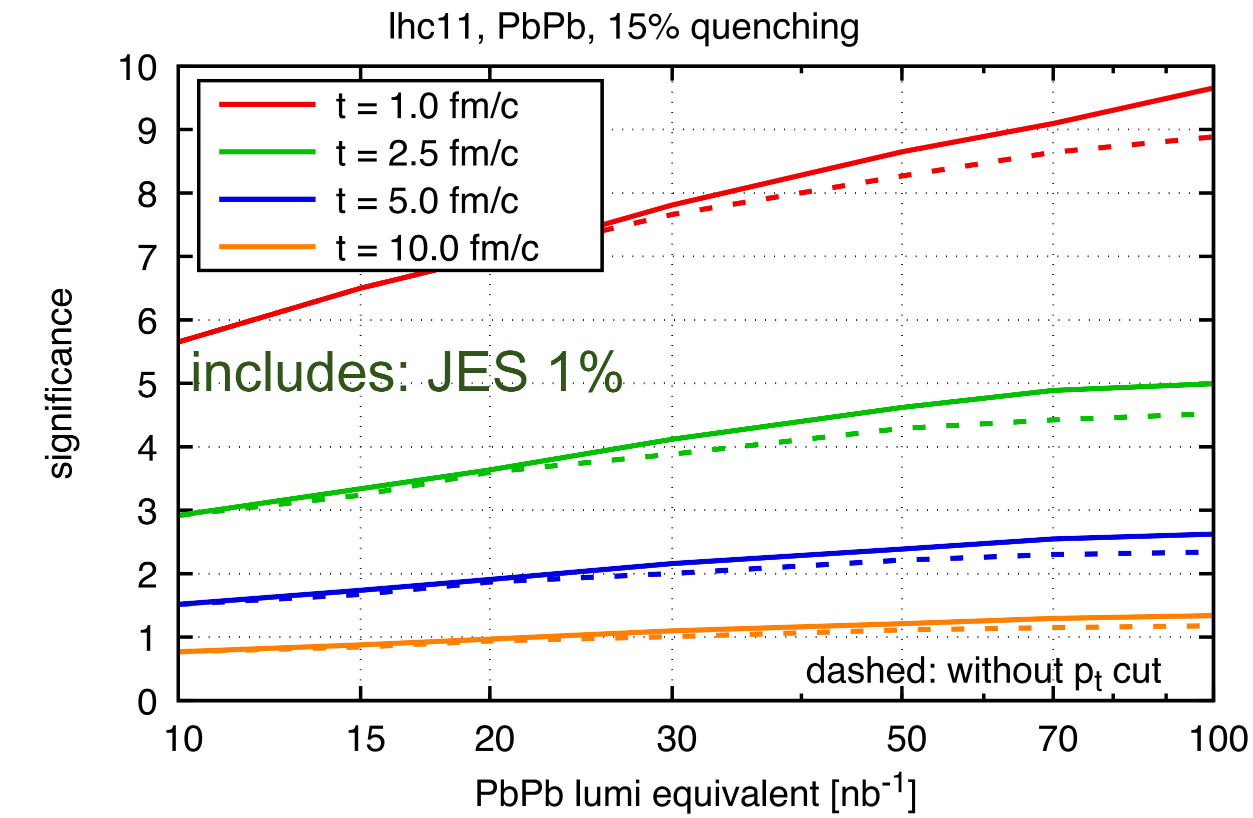
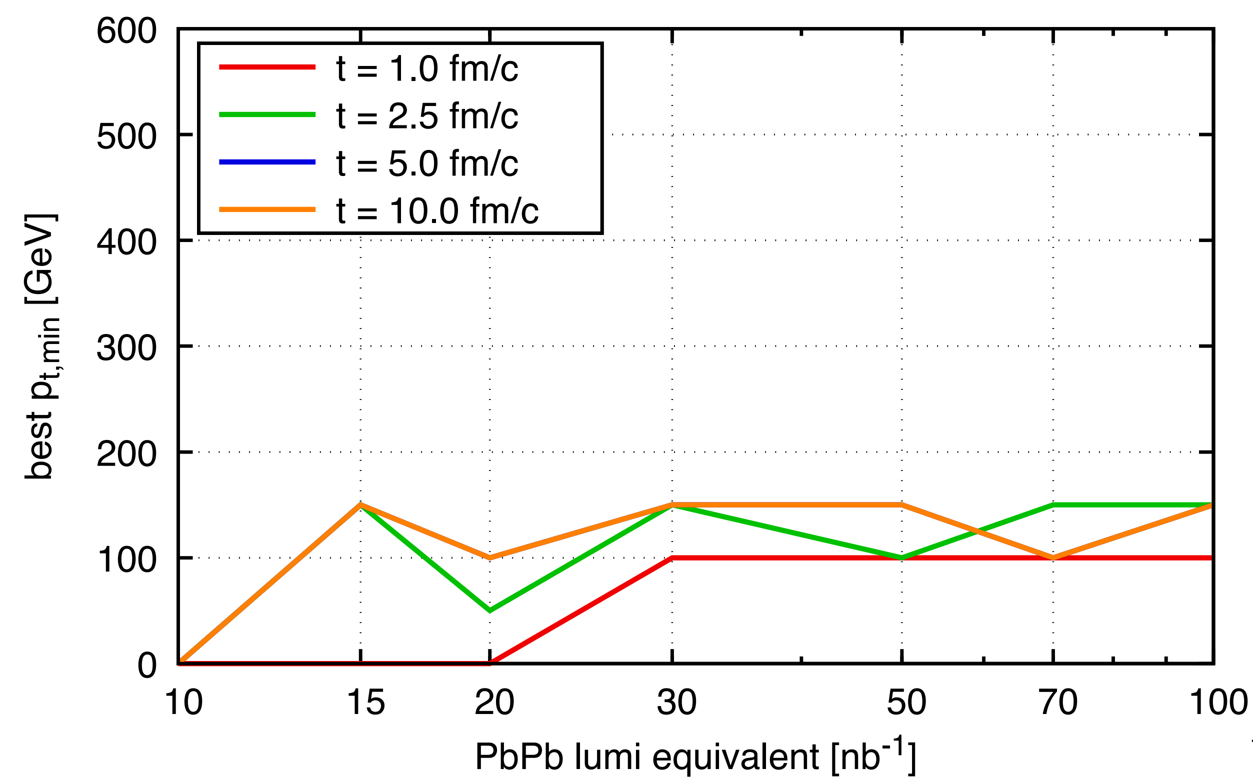


HE-LHC

- Assuming:
  - $\sqrt{s_{NN}}$ = 11 TeV;
  - $\mathscr{L}$ = 30 nb^{-1};
  - $\frac{\Delta E}{E} = -0.15 \left(\frac{L-t}{L} \right)$
  - 15% Gaussian fluctuations





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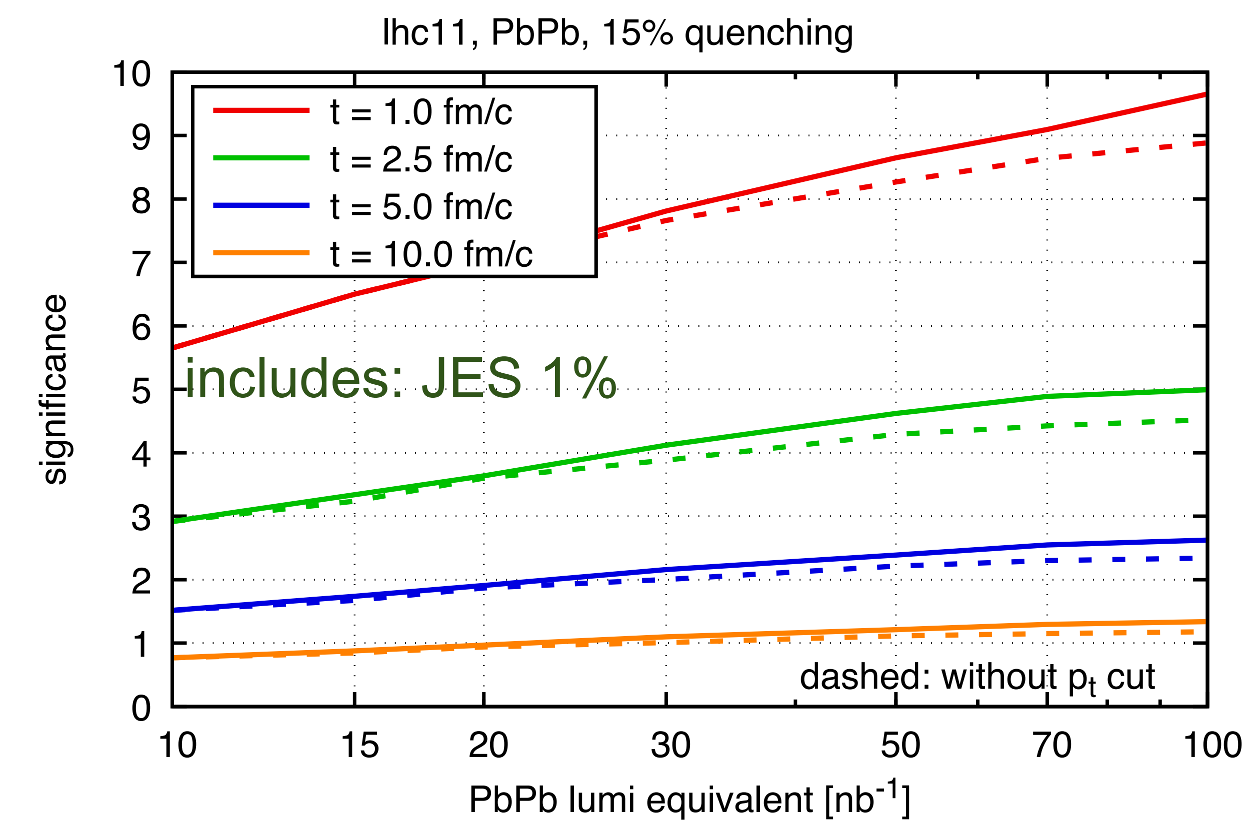

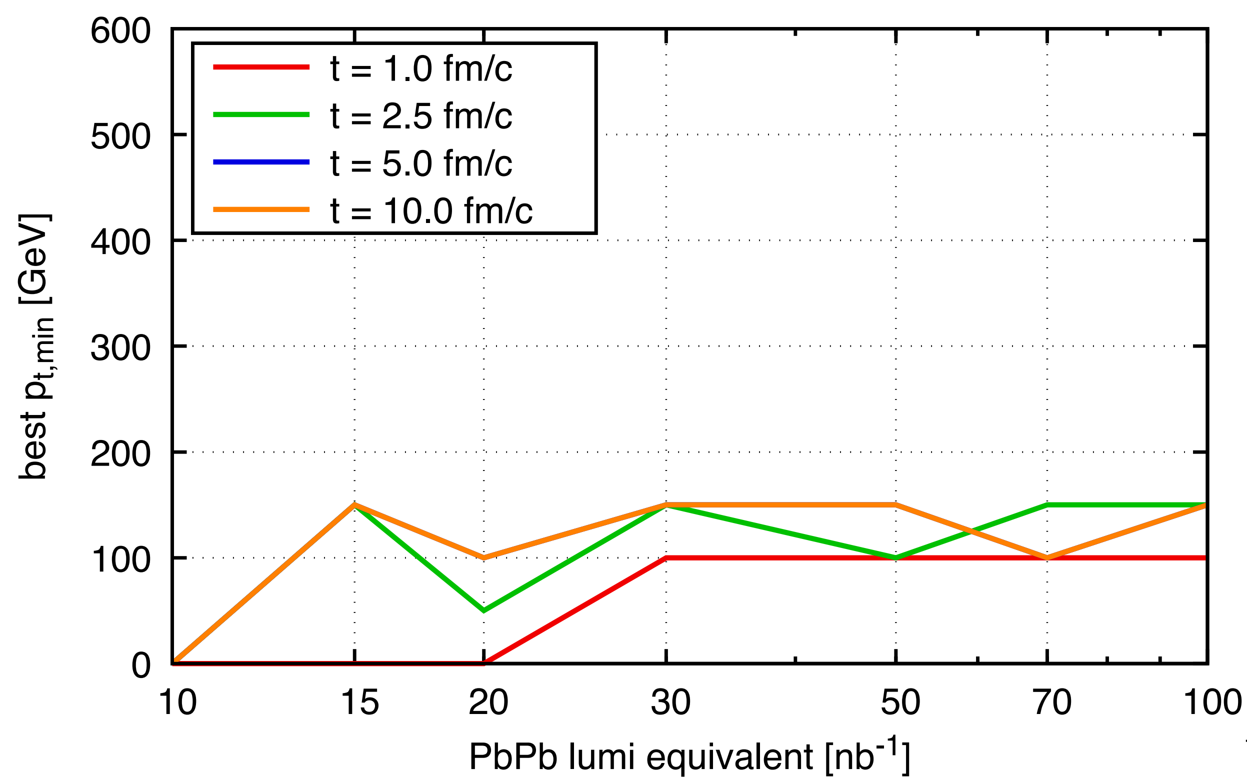

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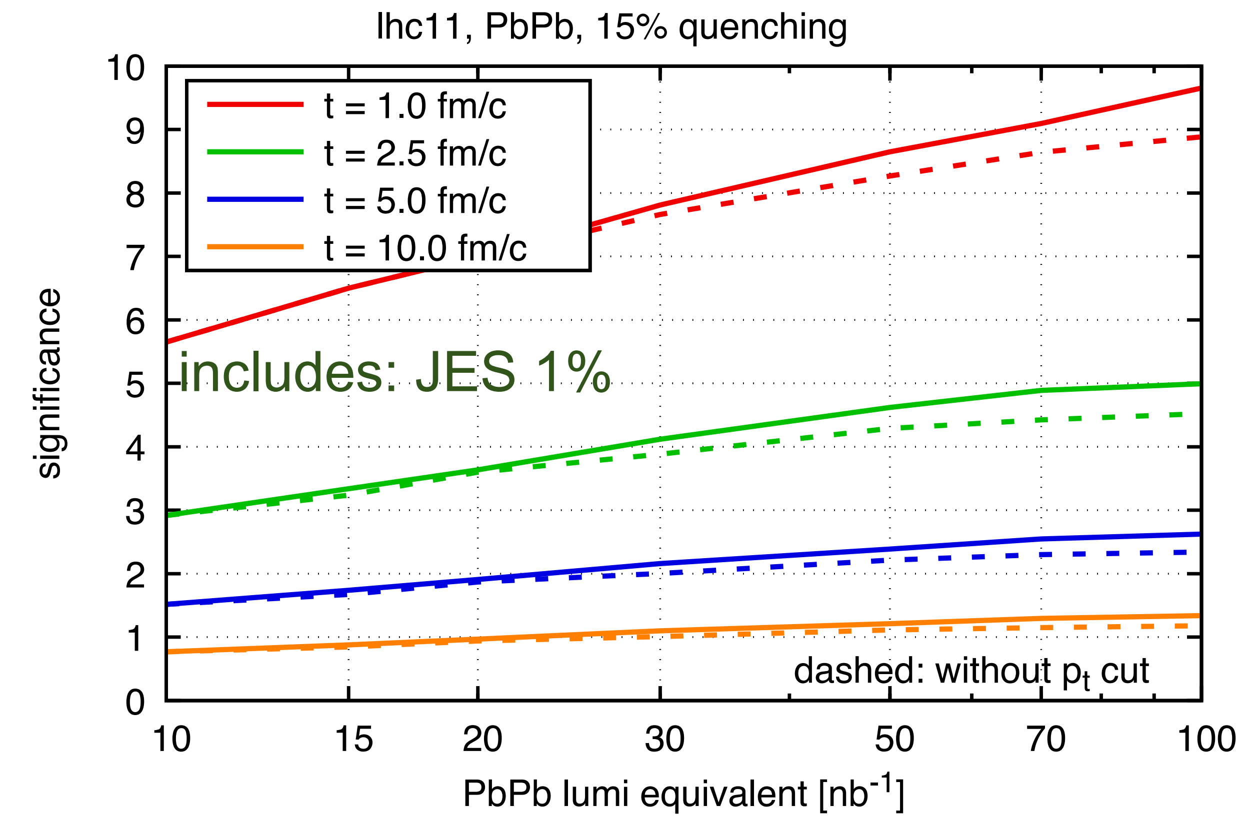
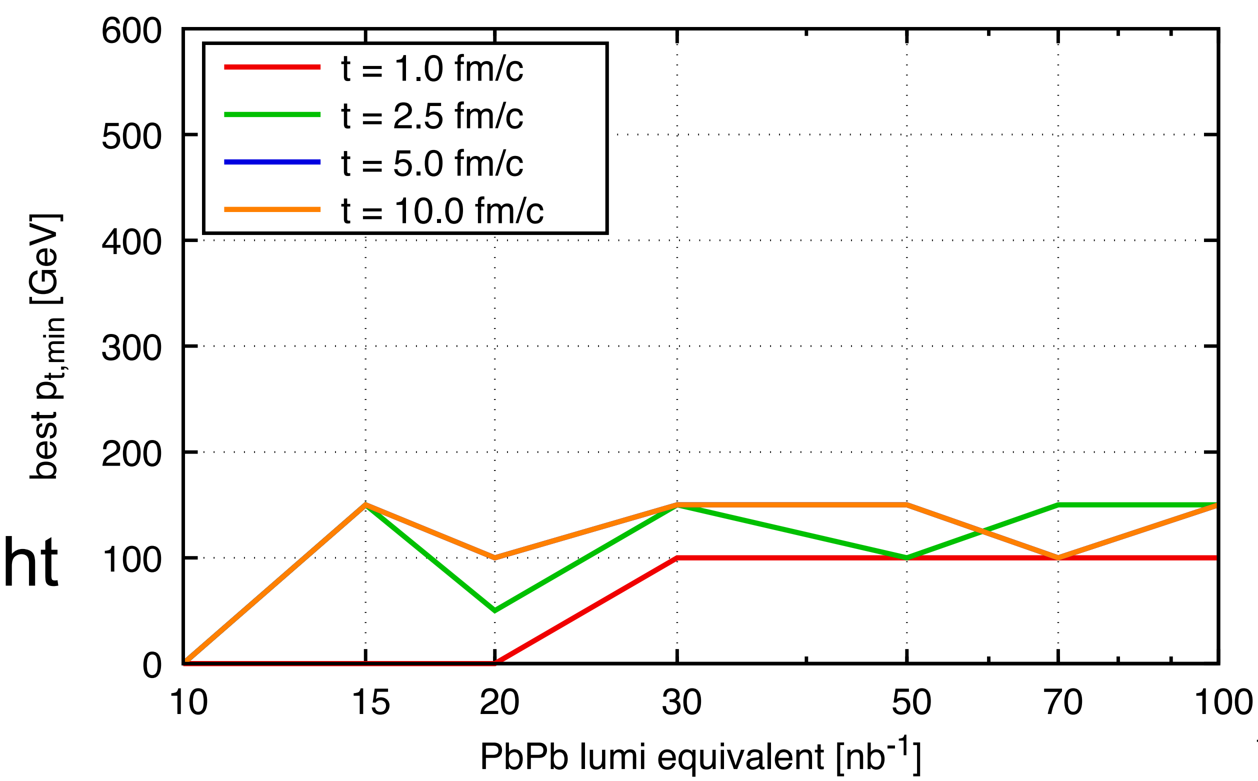
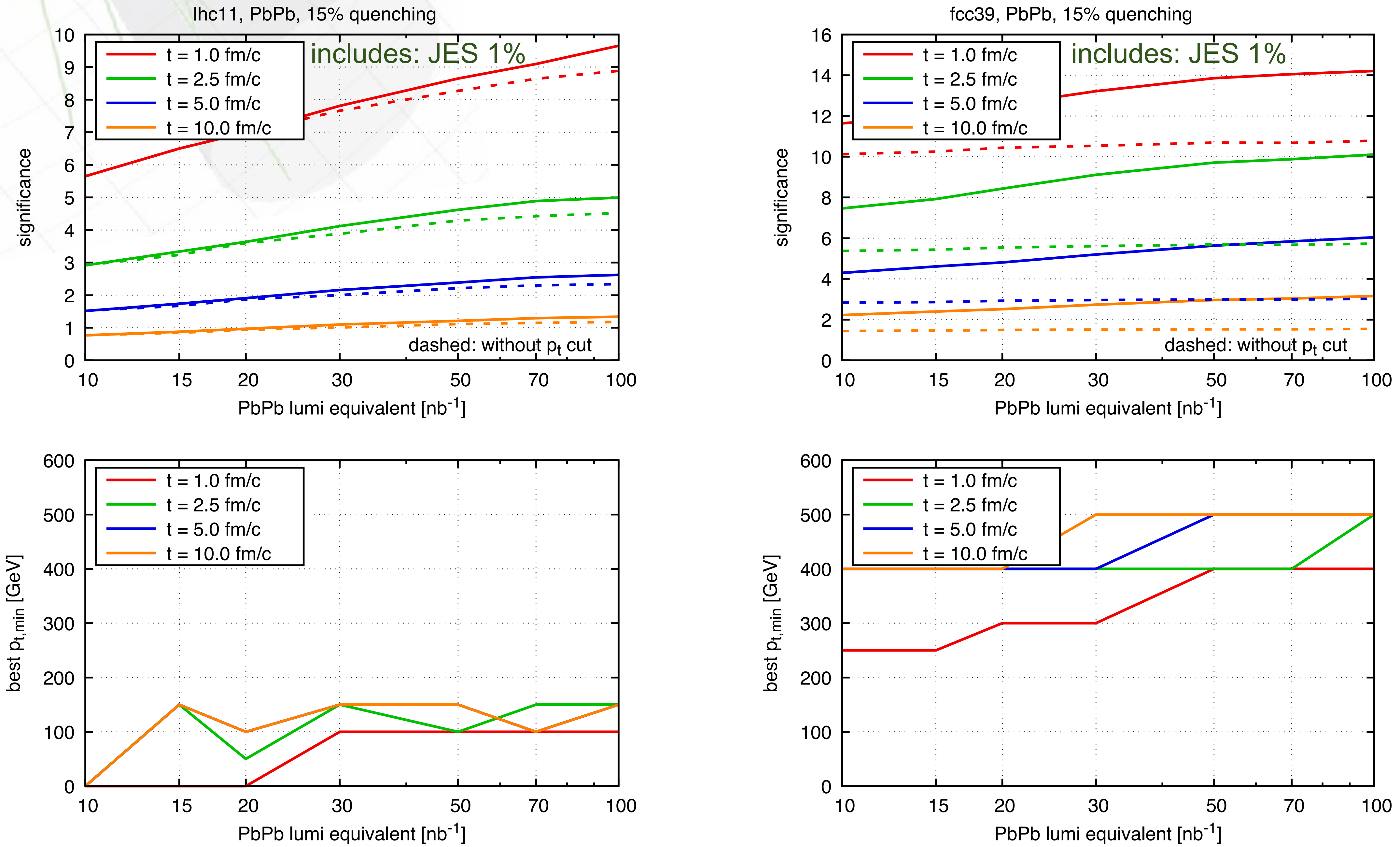
- Introducing a minimum p_T cut might help to improve the statistical significance





HE-LHC vs FCC-39TeV

- For completeness, we can do the same exercise for the FCC, at a centre-of-mass energy of $\sqrt{s_{NN}}$ = 39 TeV;



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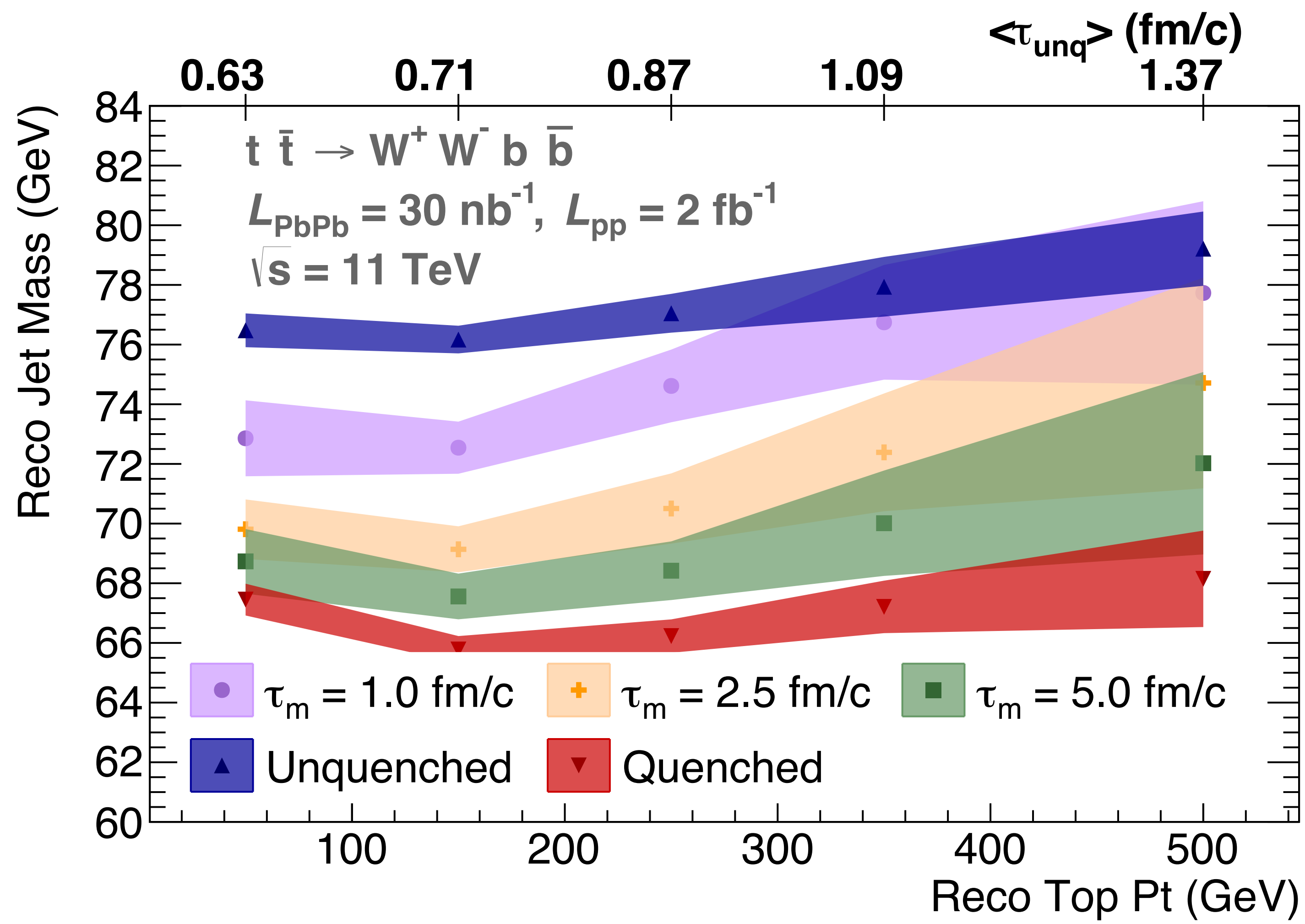

HE-LHC vs FCC-39TeV

- Available timescales to probe:

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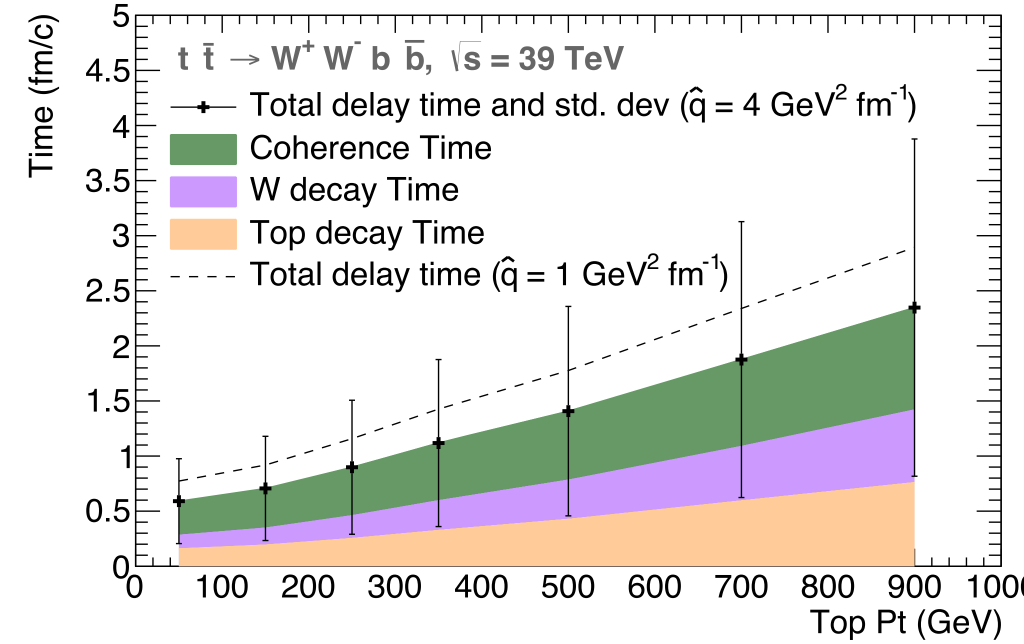

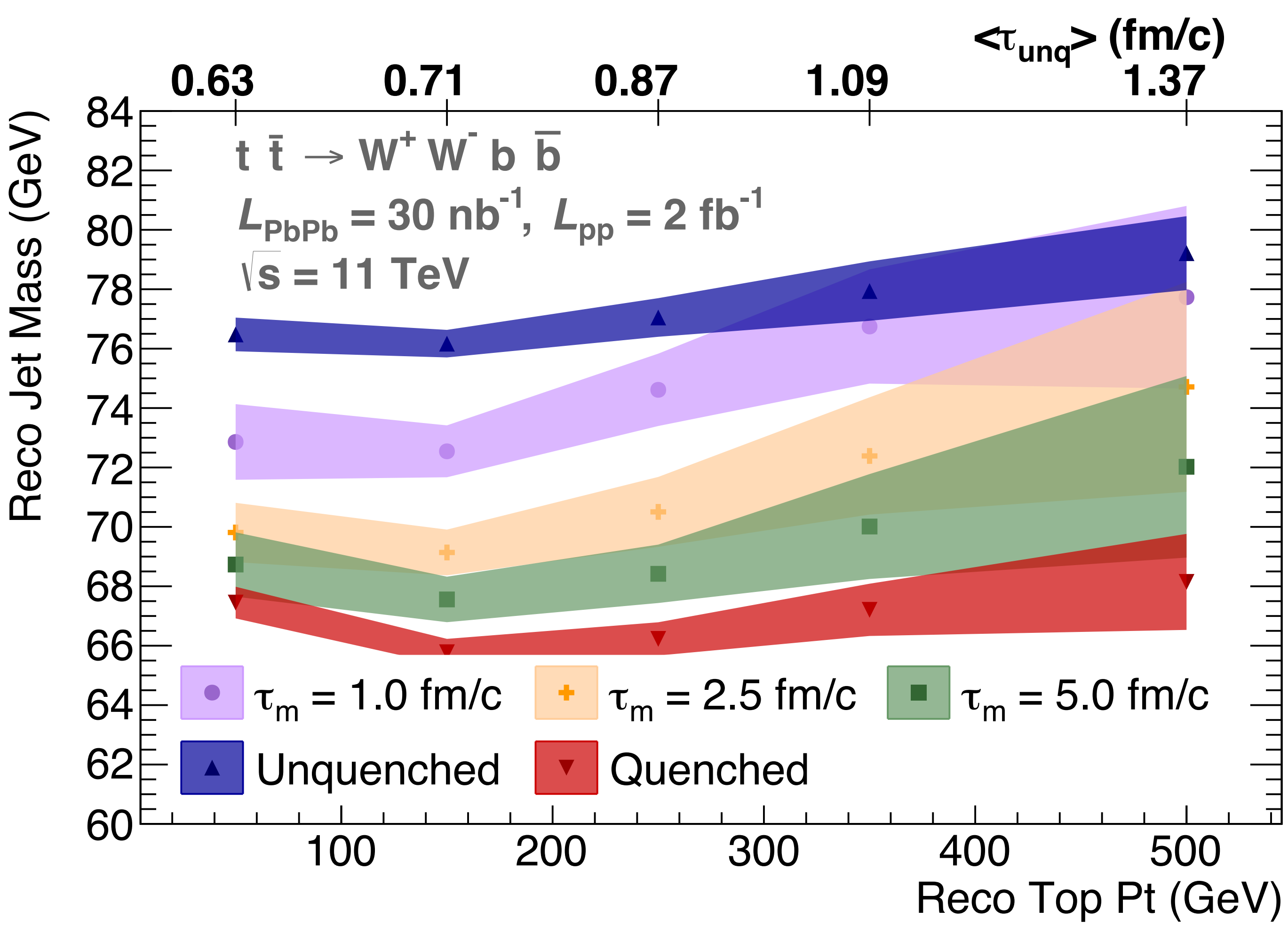

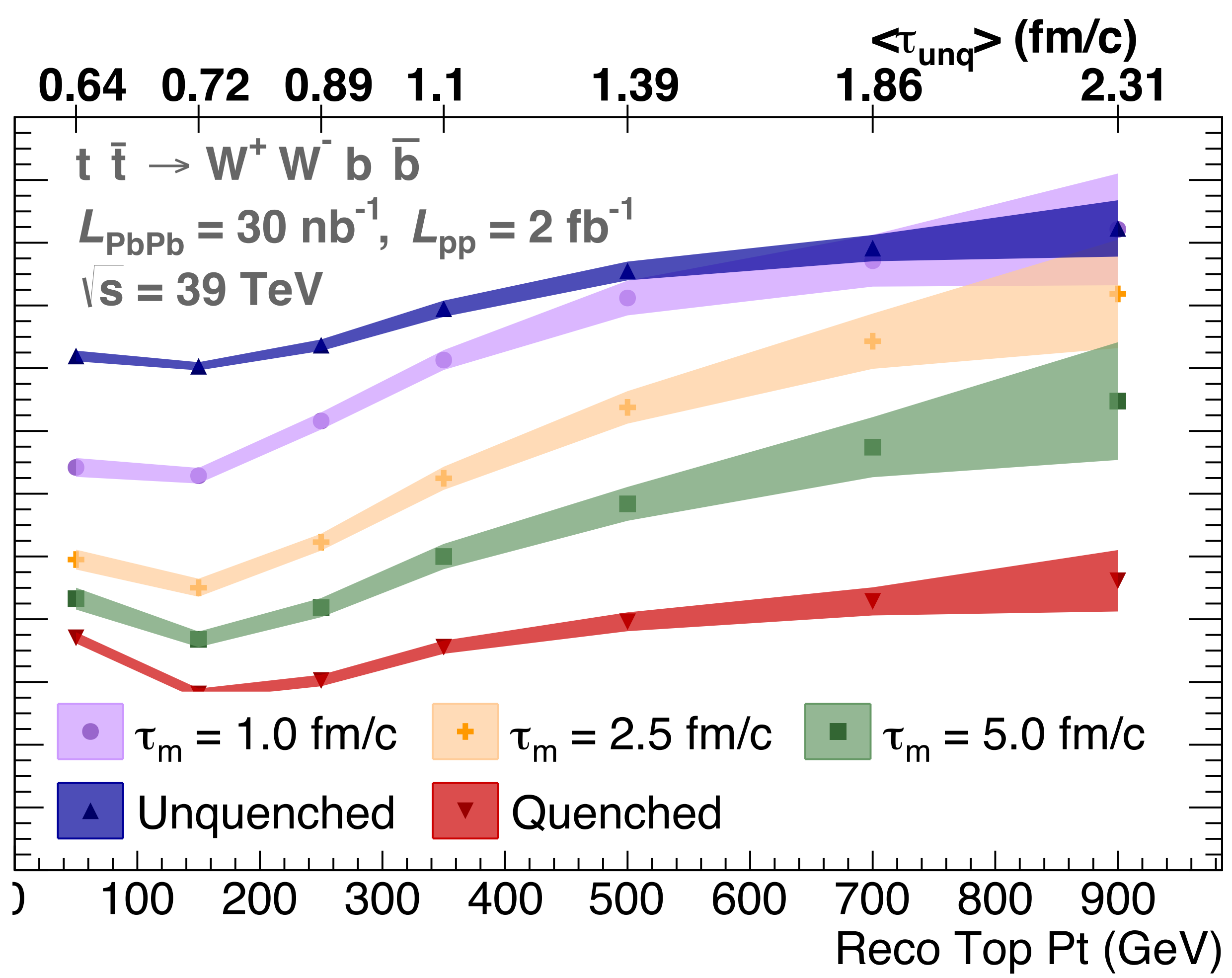

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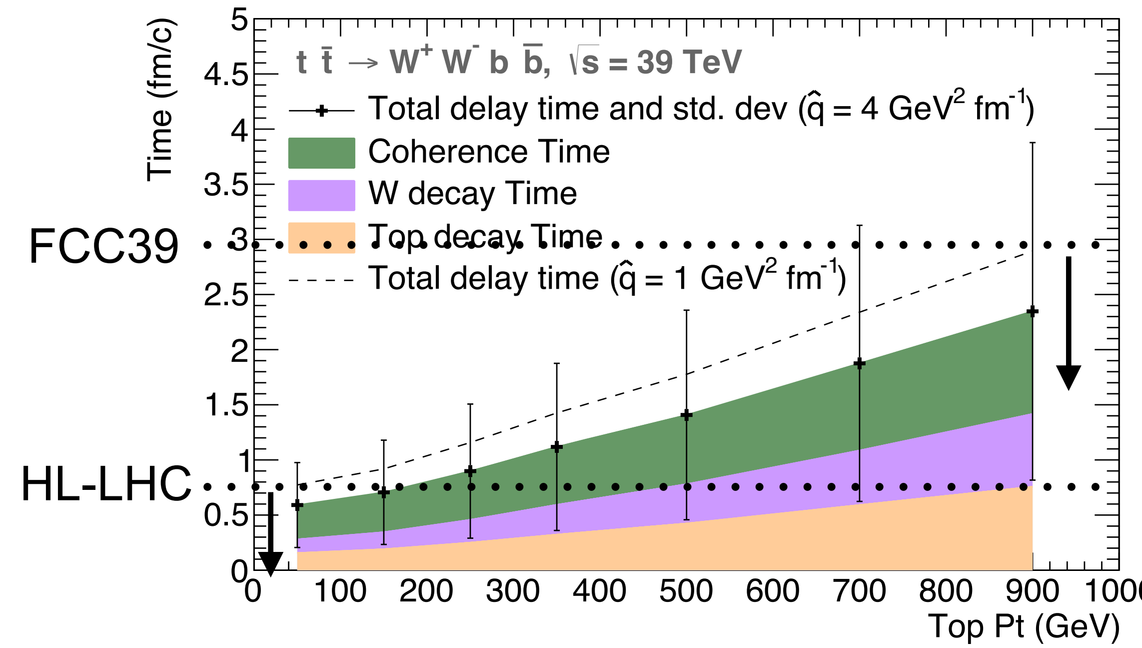

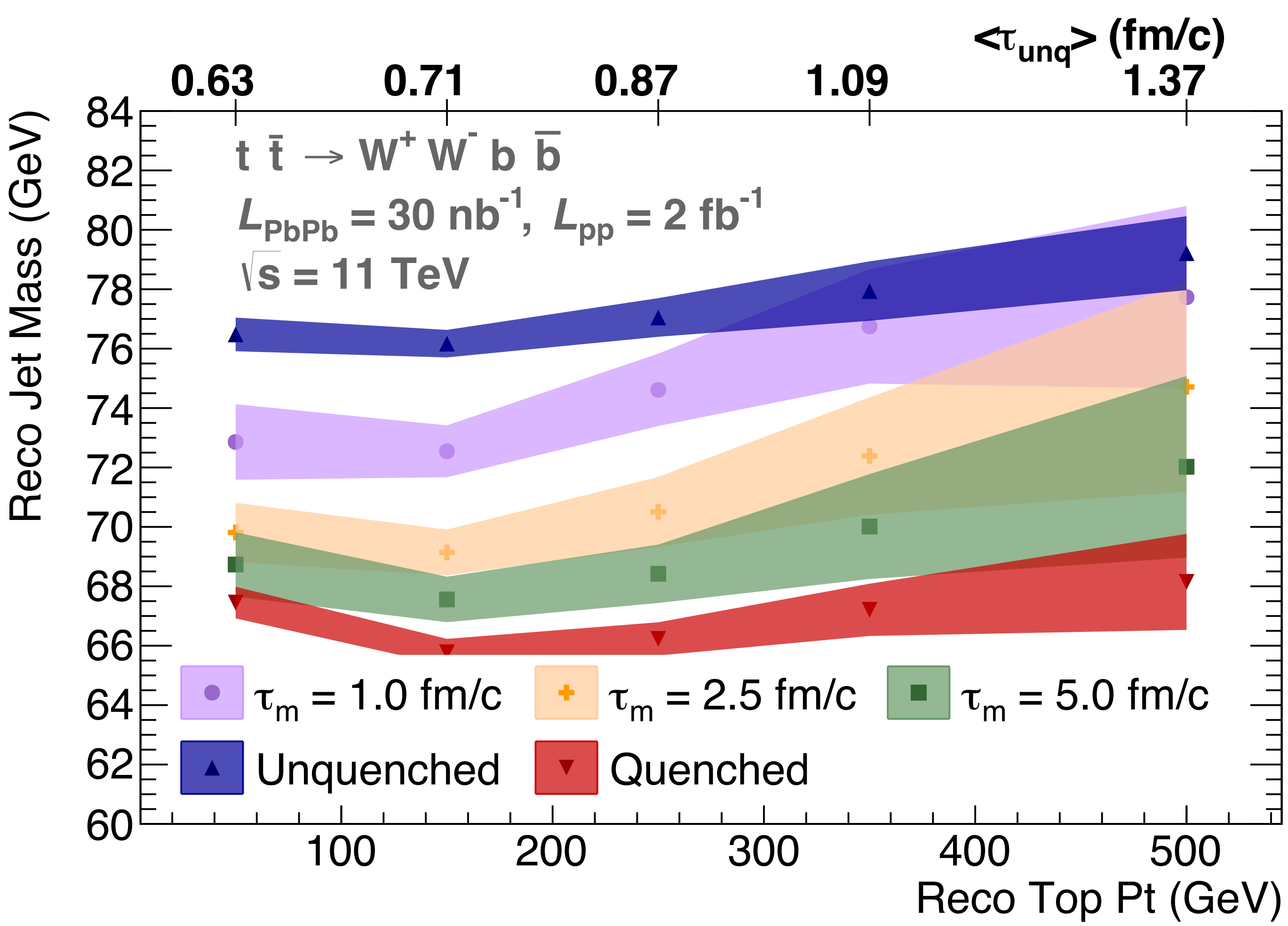

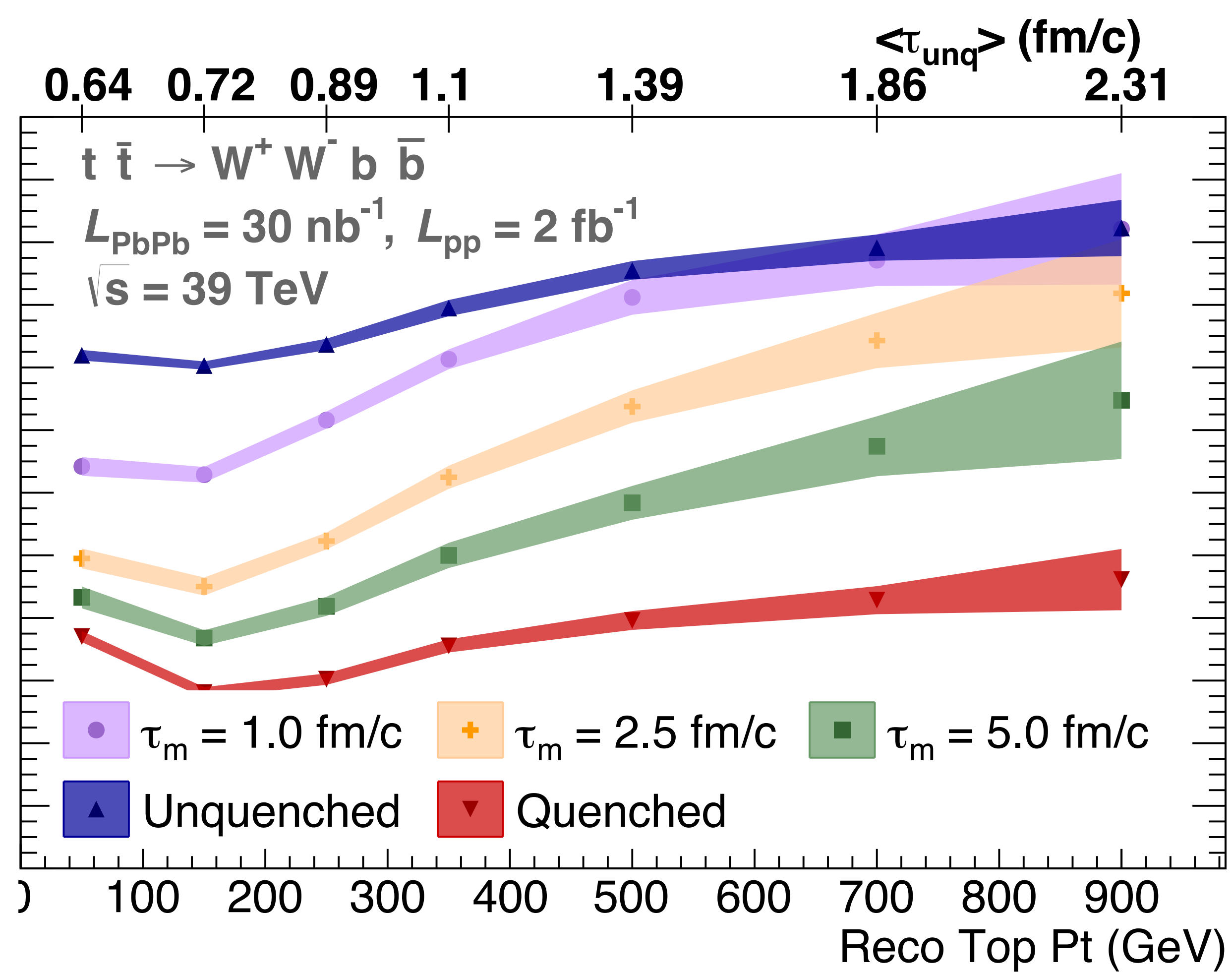

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Thank you!

Backup

√sNN Comparisons

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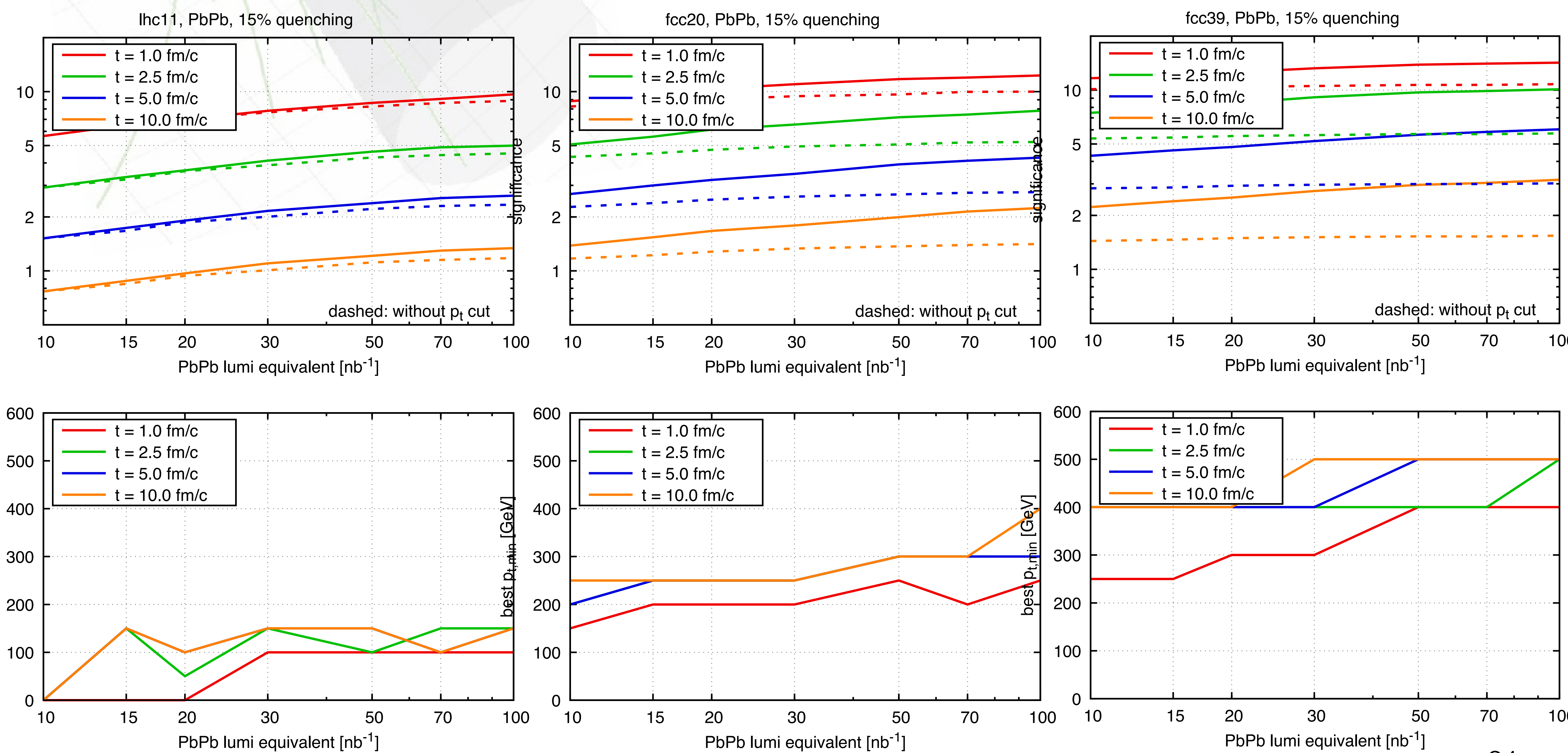

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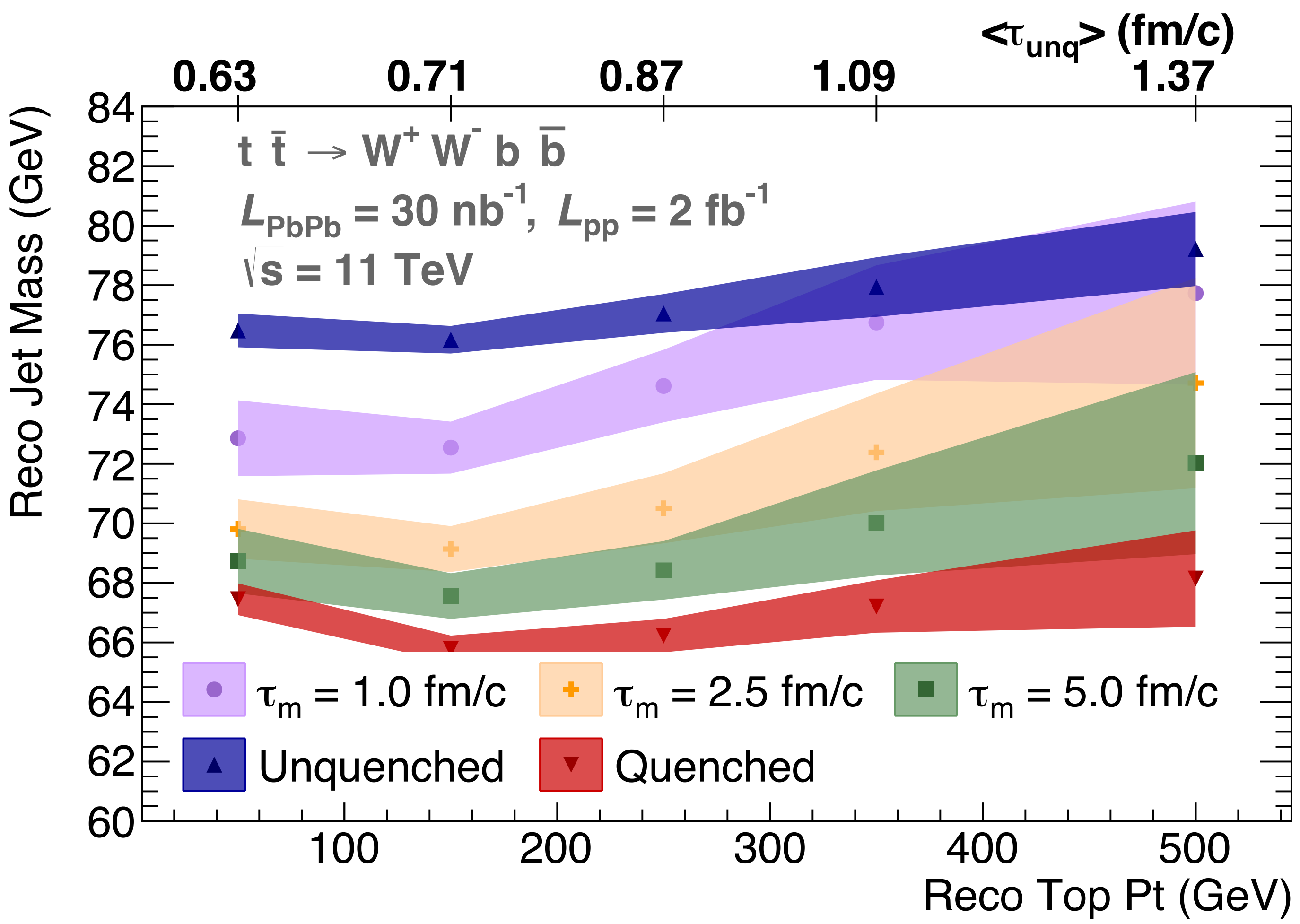

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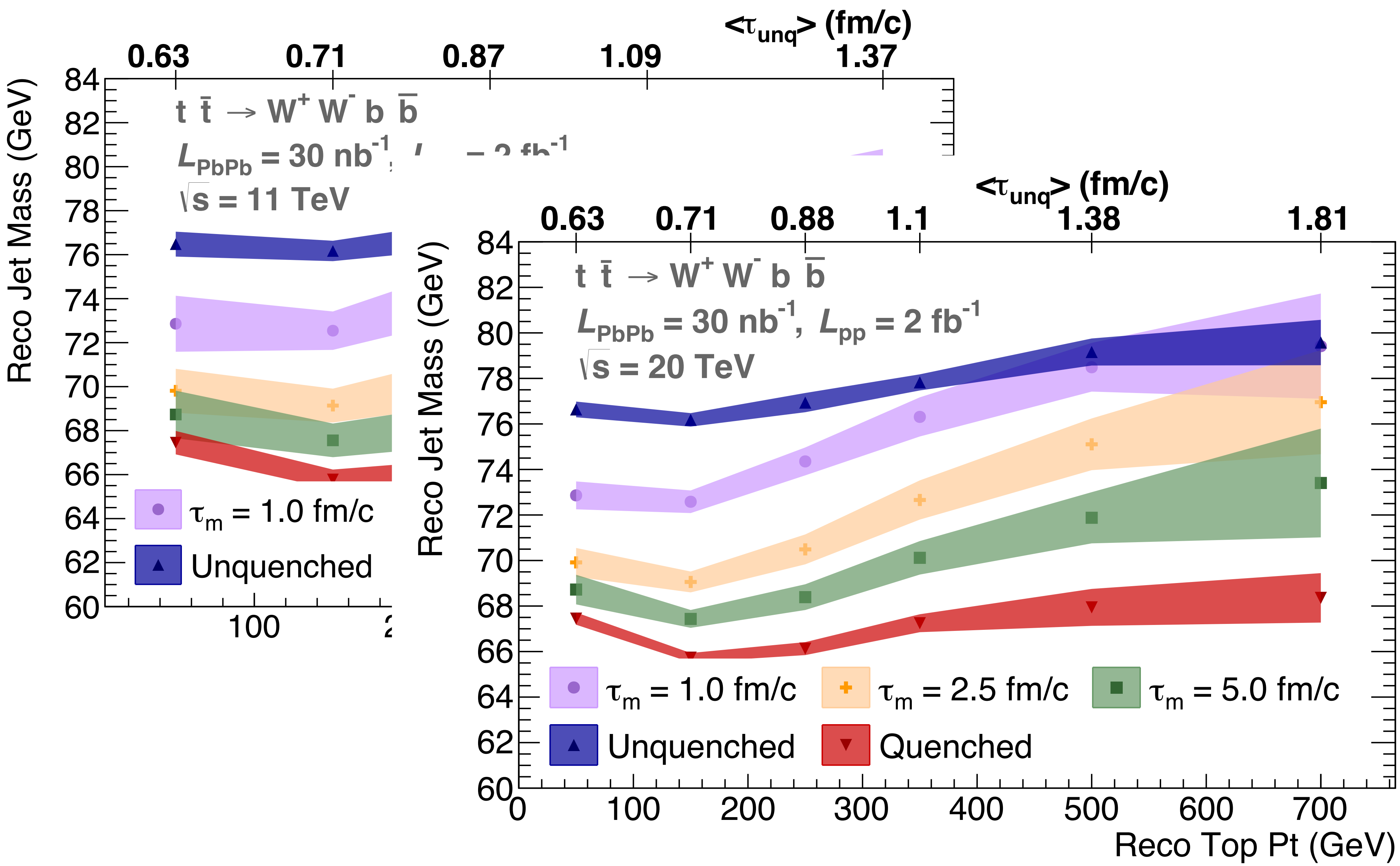

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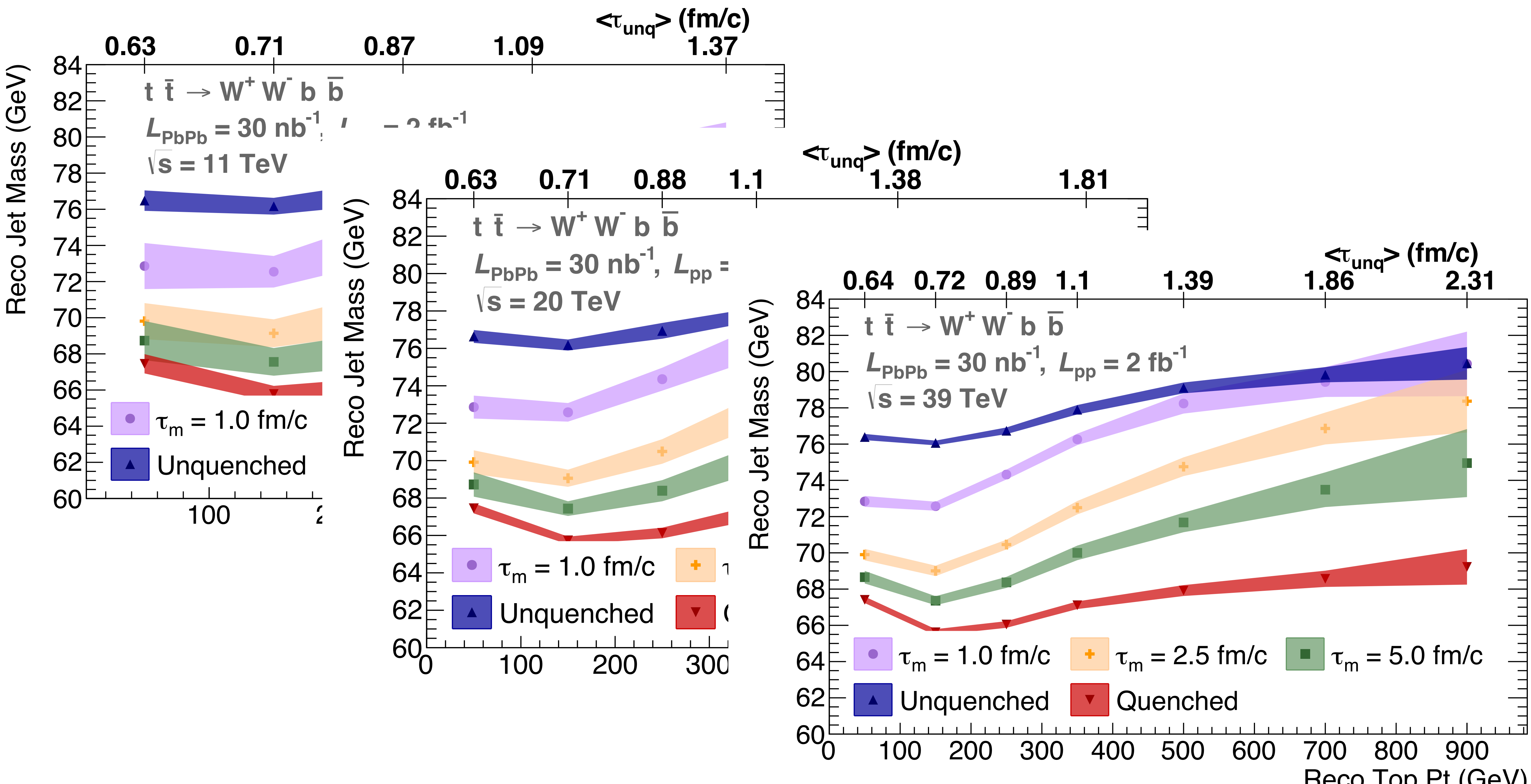

Energy loss rescaling

- Number of participants according to a Glauber model:
  - $N_p^{CuCu} \sim 107$ [0-10]%
  - $N_p^{PbPb} \sim 356$ [0-10]%
- BDMPS Energy Loss for an expanding medium:
  - $\Delta E \sim L$ (medium length)
- Since:
  - $L \sim A^{1/3} \Rightarrow \Delta E^{CuCu} \sim (N_p^{CuCu}/N_p^{PbPb})^{1/3}\, \Delta E^{PbPb}$
  - $\Delta E^{PbPb} \sim 0.15 \Rightarrow \Delta E^{CuCu} \sim 0.1$

Complete set of cuts

- POWEG NLO + Pythia8 Shower
- Reconstruction of the event (at parton level)
  - 1μ with $p_T > 25$ GeV and $|\eta| < 2.5$
  - Jet reconstruction with anti-k_T R = 0.3, $p_T > 30$ GeV, $|\eta| < 2.5$. (recluster with k_T, R = 1.0 and decluster with dcut = $(20\text{GeV})^2$)
  - 2 b-jets + >= 2 non-bjets
- Quenching + energy loss fluctuations at parton level

Reconstruction procedures

- Our “old”
  - 1μ with $p_T > 25$ GeV and $|\eta| < 2.5$
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  - “muonic” W candidate is the one closest to the muon in Delta R (ATLAS 1502.05923)
- Our “new”
  - 1μ with $p_T > 25$ GeV and $|\eta| < 2.5$
  - Jet reconstruction with anti-k_T R = 0.3, $p_T > 30$ GeV, $|\eta| < 2.5$ (recluster with k_T, R = 1.0 and decluster with dcut = $(20\text{GeV})^2$)
  - “hadronic” W candidate is reconstructed by considering all pairs of non-b jets with $m_{jj} <$ 130 GeV; the highest scalar pt sum pair is selected
- CMS:
  - 1μ with with $p_T > 30$ GeV and $|\eta| < 2.1$
  - Jet reconstruction with anti-k_T R = 0.4, pT > 25 GeV and $|\eta| < 2.5$
  - Reconstructed jets must be separated by at least $\Delta R = 0.3$ from the selected muon
  - “hadronic” W candidate is reconstructed by considering the pair with the with the smallest separation in (η,φ) plane