$\sqrt{\hat{s}_{min}}$: a global inclusive variable

mass scale determination at LHC

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In a work with: K.C.Kong, K.Matchev and M. Park

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Mass measurement in missing energy e

- Missing transverse energy BSM signatures are most exciting and well motivated from theoretical perspective.

- Mass measurements are quite challenging task at the hadron collider experiment.
  - BSM (SUSY) events always contain two or more invisible particles.
  - Number of missing particles and their identities are unknown.
  - The masses of invisible particles are a priori unknown.
  - The masses of their parents are also unknown.
  - CM energy and boost along beam direction is unknown.
  - No masses can be reconstructed directly.
- Several methods (and variants) for mass determination

Mass measurement in missing energy e

- Endpoint method, Invariant mass edge

  Rely on the kinematic endpoint or shapes of various invariant mass distributions constructed out of visible(SM) decay products in the cascade decay chain. *Hinchliffe, Paige, Bachacou, Allanach, Lester, Parker, Webber, Gjelsten, Miller, Osland, Matchev, Park, Burn..*

- Polynomial method, On shell mass relation

  Attempt to extract event reconstruction using the measured momenta of the visibles and the measured missing transverse momentum. *Nojiri, Polesello, Tovey, Cheng, Gunion, Han, McElrath, Marandella..*

- Cambridge variable method, kink

  Explore the transverse invariant mass variable M_{T2} and the end point of the M_{T2} distribution. *Lester, Summers, Barr, Stephens, Tovey, Cho, Choi, Kim, Park, Kong, Matchev, Park, Burn...*

- Hybrid method

  Combining two or more of these techniques. *Nojiri, Polesello, Tovey, Ross, Serena...*

Mass measurement in missing energy e

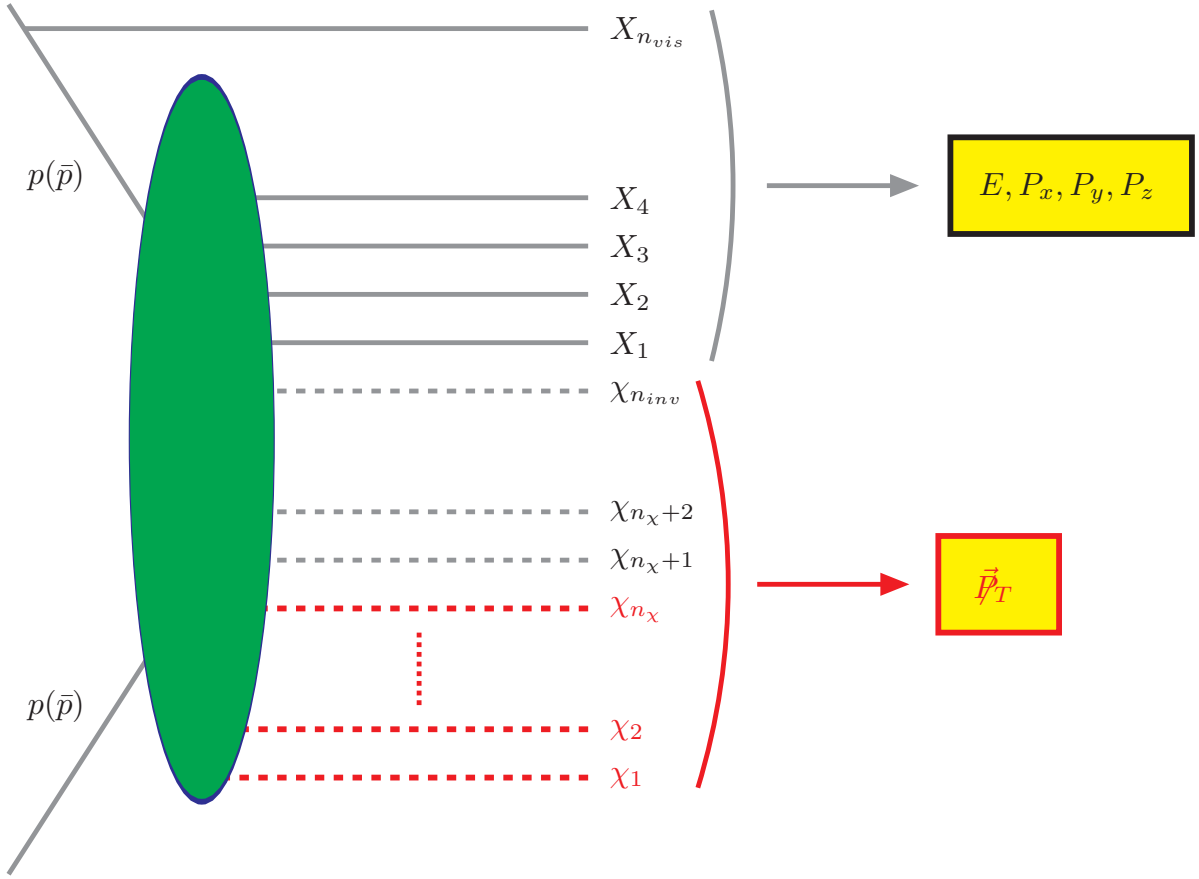
⊙ Basic characteristics for most of these studies:

- A particular BSM scenario and investigated its consequences in a rather model-dependent setup.
- one must attempt at least some partial reconstruction of the events, by assuming a particular production mechanism, and then identifying the decay products from a suitable decay chain.
- one inevitably encounters a combinatorial problem whose severity depends on the new physics model and the type of discovery signature.

complex event topologies with a large number of visible particles, and/or a large number of jets but few or no leptons, will be rather difficult to decipher, especially in the early data.

$\sqrt{\hat{s}_{min}}$ – Derivation

Any typical event in hadron collider:



Q. Can one say something about the newly discovered physics and in particular about its mass scale, using only inclusive and global event variables?

Q. Even before attempting any event reconstruction ?

$\sqrt{\hat{s}_{min}}$ – Derivation

we get the minimum value:

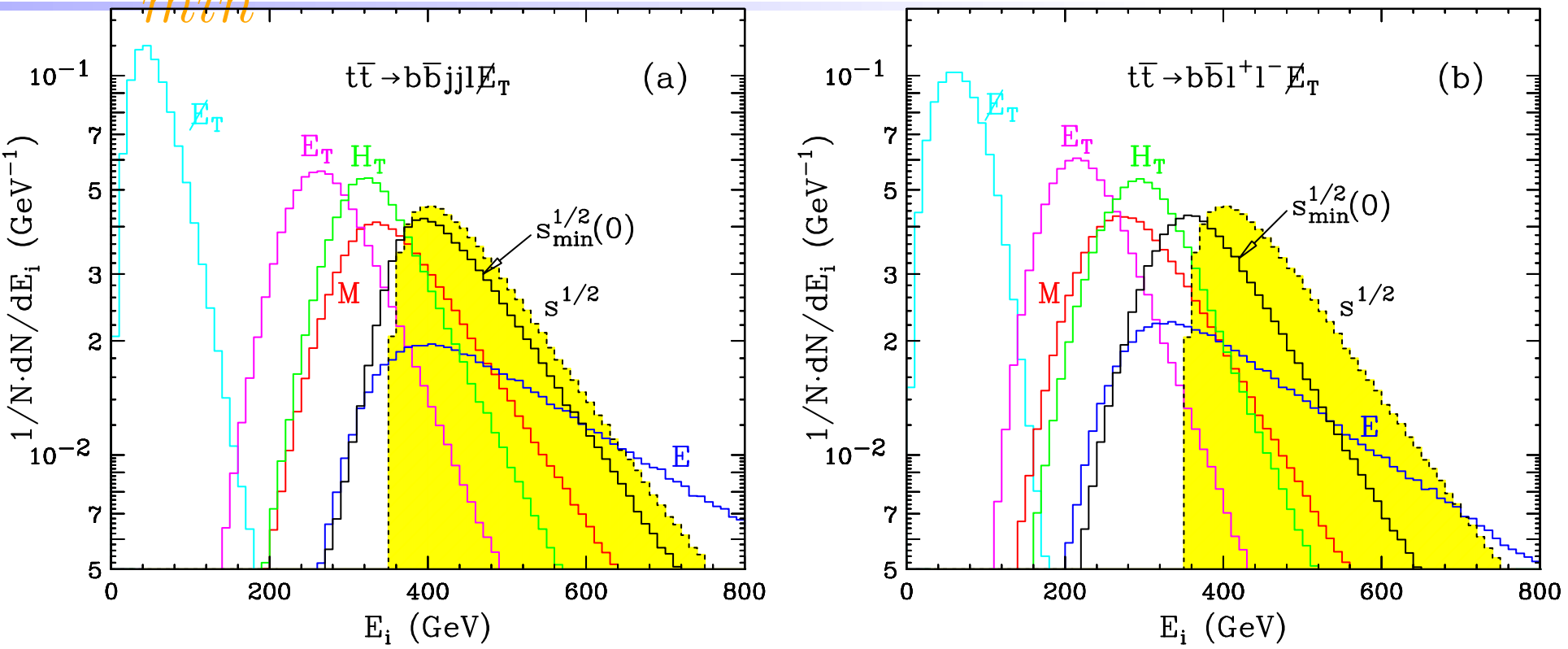
$$\sqrt{\hat{s}_{min}} \equiv \hat{s}_{min}^{1/2}(M_{inv}) = \sqrt{E^2 - P_z^2} + \sqrt{\not{P}_T^2 + M_{inv}^2}$$

$\hat{s}_{min}^{1/2}$ is the *minimum* parton level center-of-mass energy, which is required in order to explain the observed values of E, P_z and $\not{E}_T$.

Feature

- simplicity and Clear physical meaning.
- True for completely general types of events - any number and/or types of missing particles.
- Uses all available information (not just transverse quantities).
- Model-independent: No need for any event reconstruction.
- $\hat{s}_{min}^{1/2}$ defined in terms of the global and inclusive event quantities E, P_z and $\not{E}_T$.

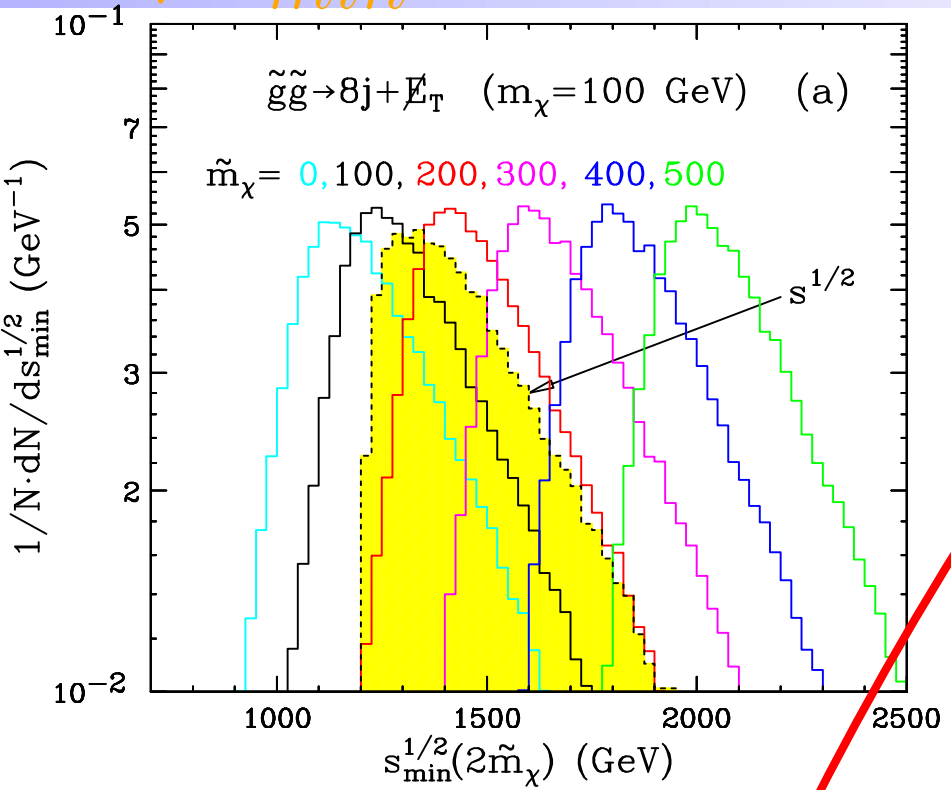
$\hat{s}_{min}^{1/2}$ and other inclusive variables

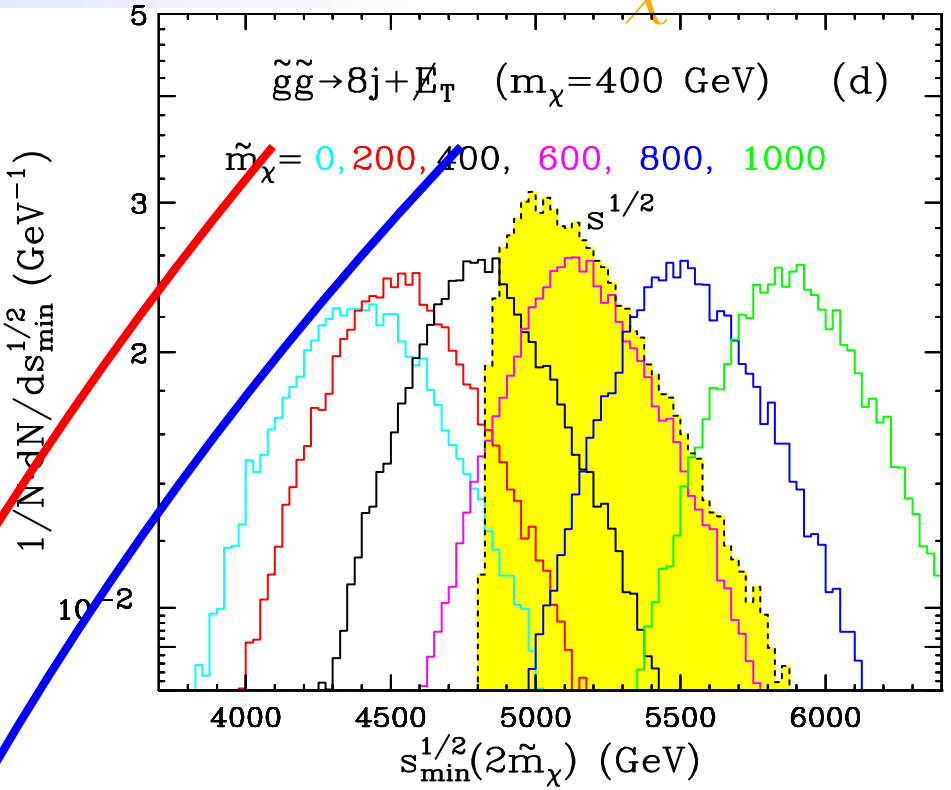


Distributions of the various energy scale variables in (a) single-lepton and (b) dilepton $t\bar{t}$ events.

- An approximate measurement to the true value of $\hat{s}$?
- Better indicator of the relevant energy scale.

$\sqrt{\hat{s}_{min}}$ and unknown masses $\tilde{m}_\chi$





distributions of the $\hat{s}^{1/2}_{min}(M_{inv})$ variable for several different SUSY mass spectra

True mass

Trial mass

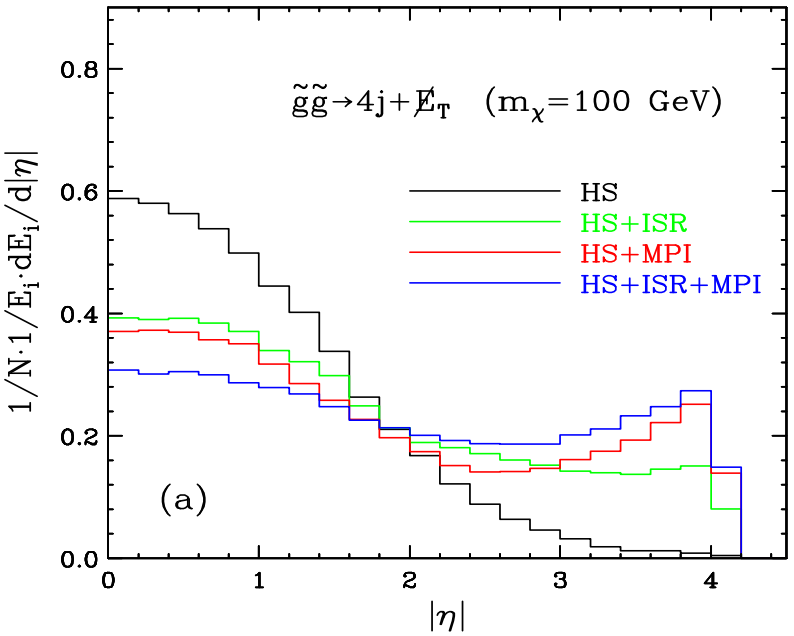
- Can one measure SUSY masses in terms of LSP mass ?

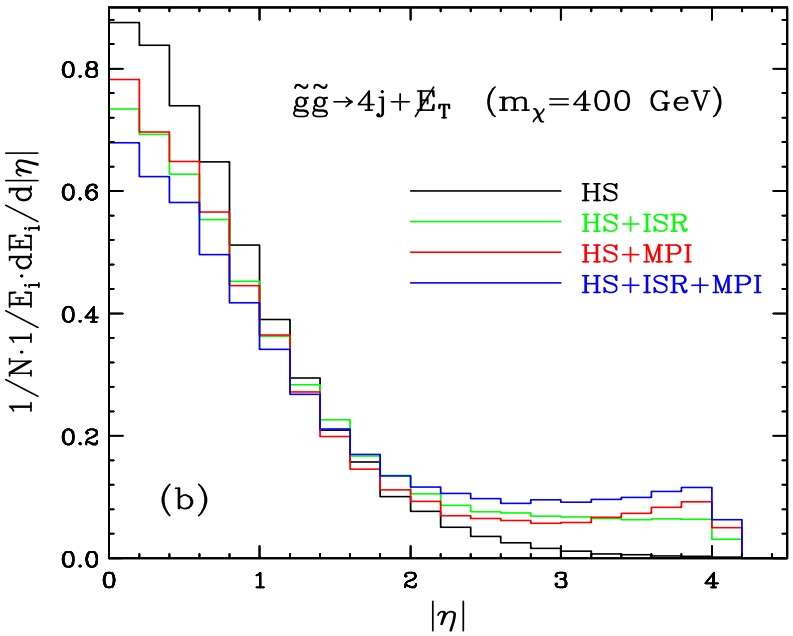
$$\left(\hat{s}^{1/2}\right)_{thr} \approx \left(\hat{s}^{1/2}_{min}(2m_\chi)\right)_{peak}$$

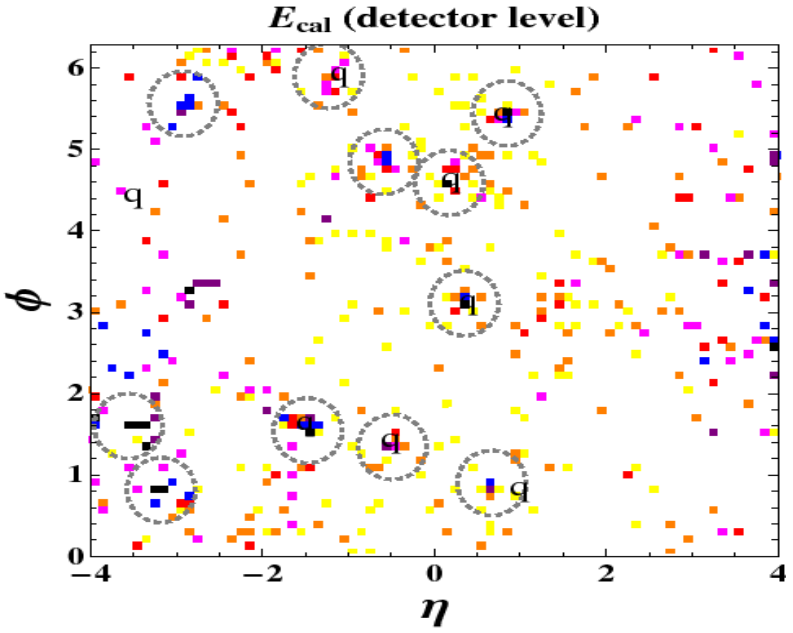
$\sqrt{\hat{s}_{min}}$ and mother mass :ISR effect

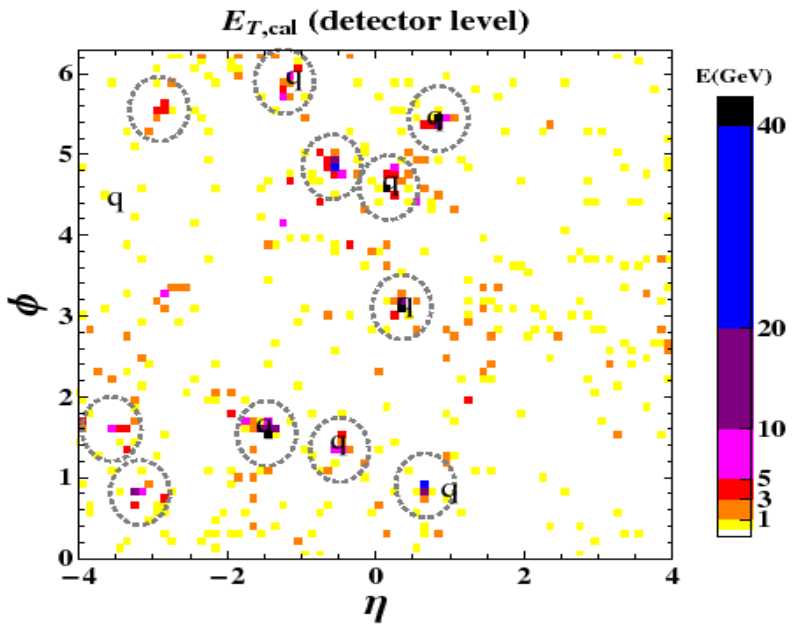
- Ideally, we want to measure $\sqrt{\hat{s}}$ coming from hard scattering.
- BSM comes with unknown missing particles.
- $\sqrt{\hat{s}_{min}}$ introduced to deal situation with correlation with new physics mass scale.
- But, Real event can have Initial state radiation (ISR), multiple parton interactions (MPI) and pile-up.
- If not controlled, these extra contributions can increase $\sqrt{\hat{s}}$.
- Easily resolved, when ISR and/or MPI products may be reliably identified and excluded.
- For generic method, we can try to compensate for the ISR/MPI effects by measuring from real data, using well measured Standard Model process.
- Alternatively, we can design and apply cuts which would minimize the ISR and MPI effects.

$\sqrt{\hat{s}_{min}}$ and mother mass :ISR effect









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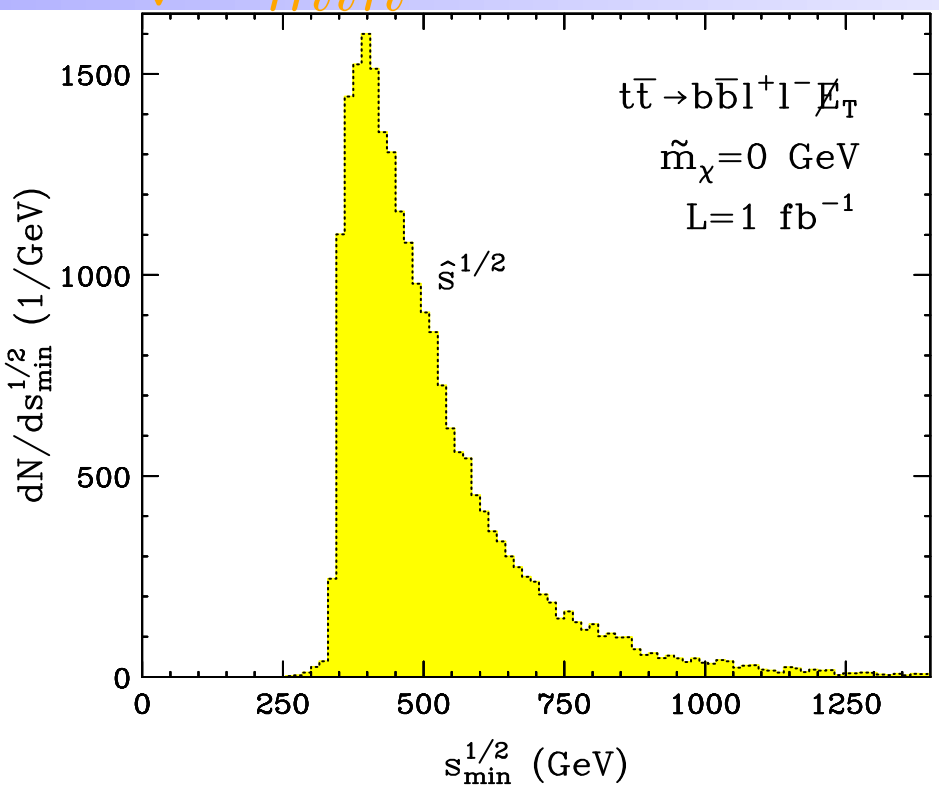
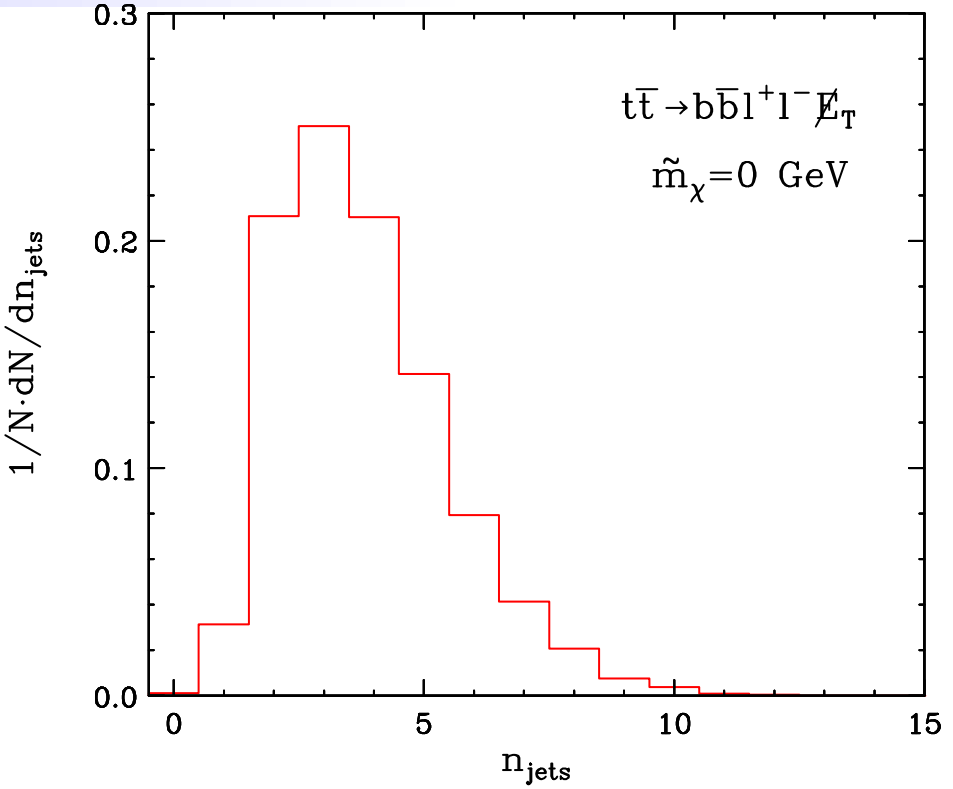
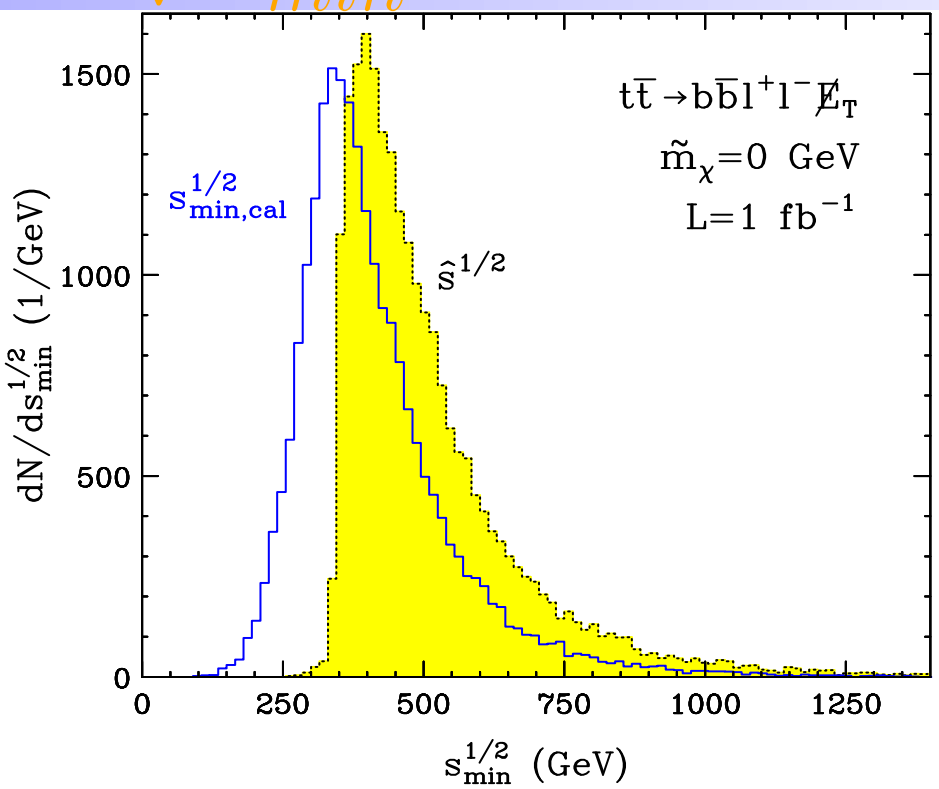
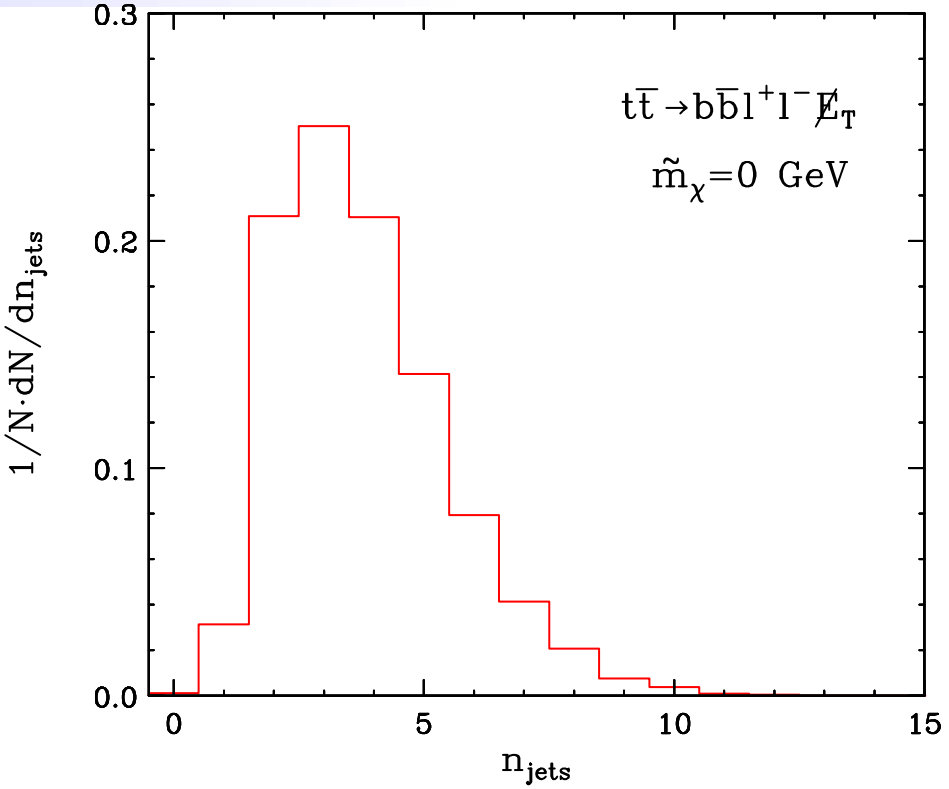




- Extra contribution from ISR, MPI can be devastating.
- At LHC, typical event reconstructed with number of ISR jets.
- Most of the cal energy from ISR cannot form jet, low PT.
- PT threshold as regulator.

$\sqrt{\hat{s}_{min}}$ and mother mass :ISR effect





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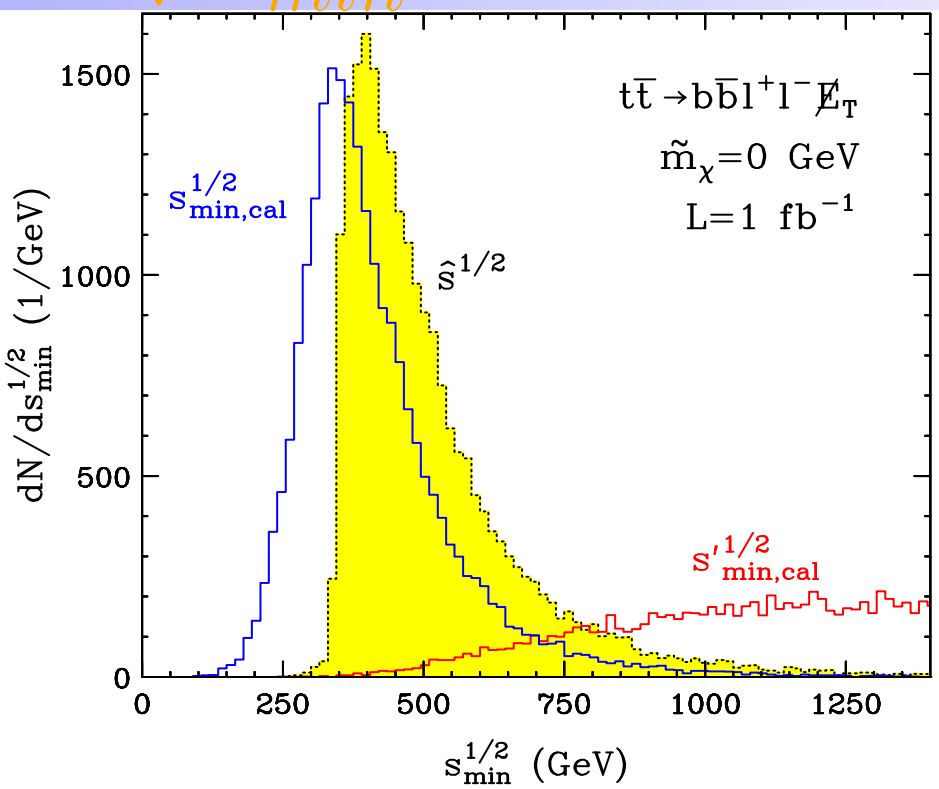

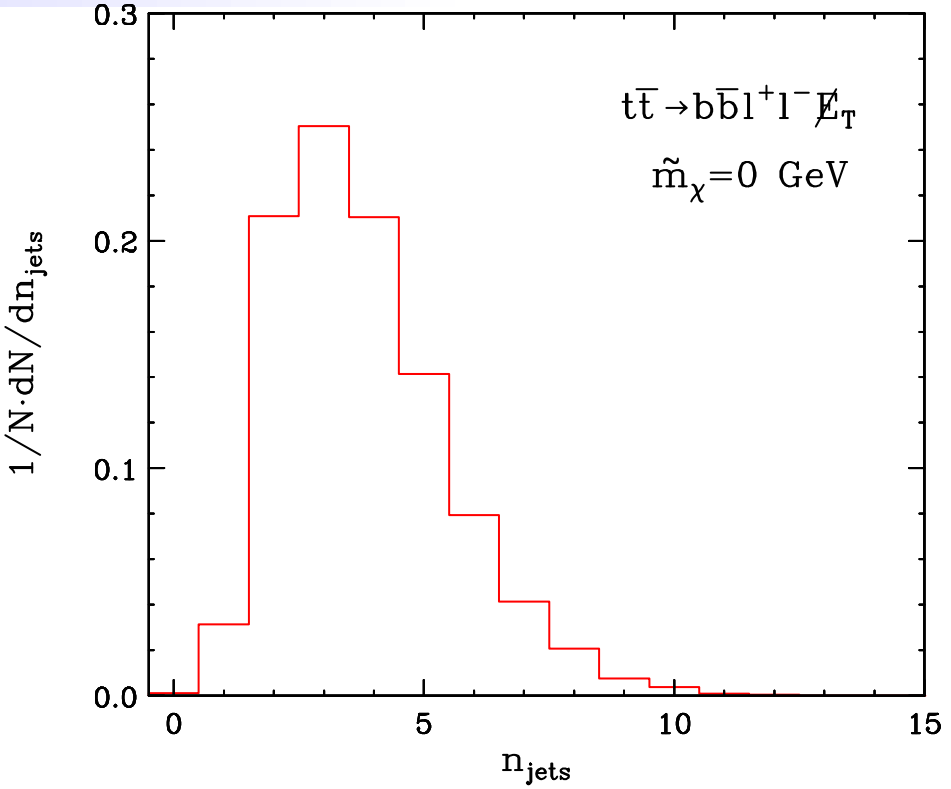

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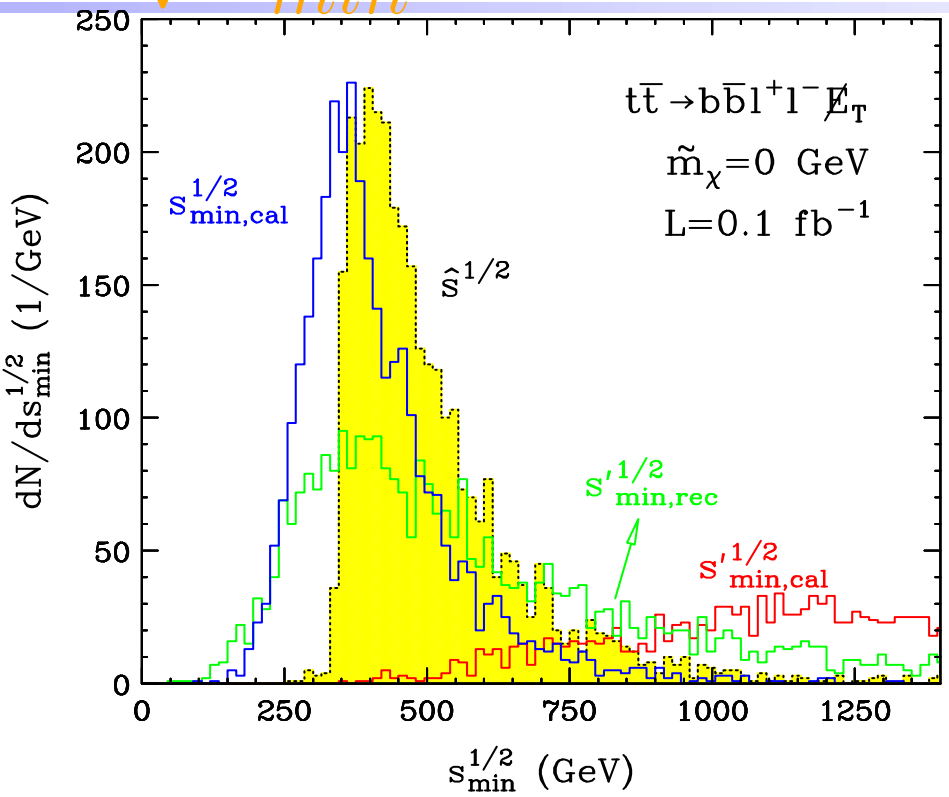

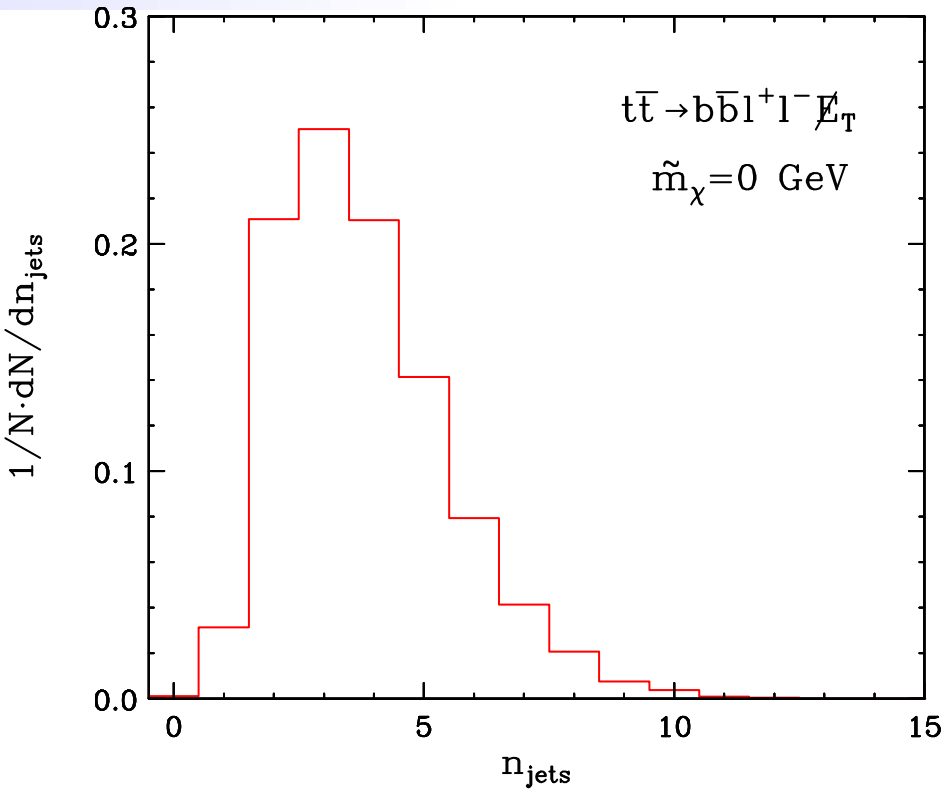

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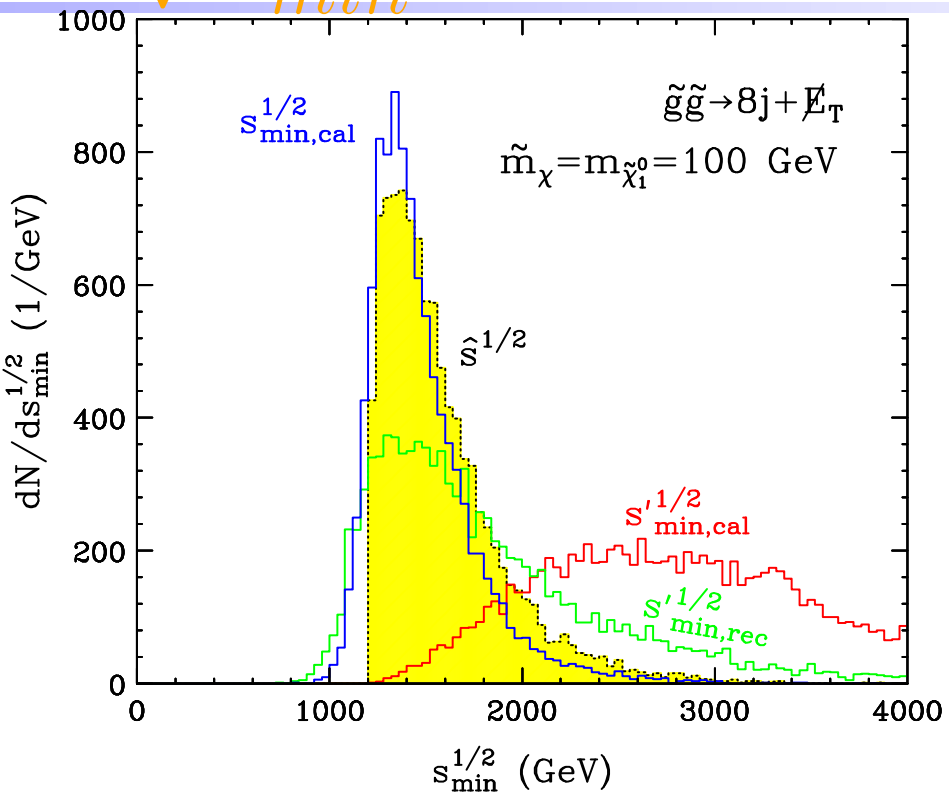
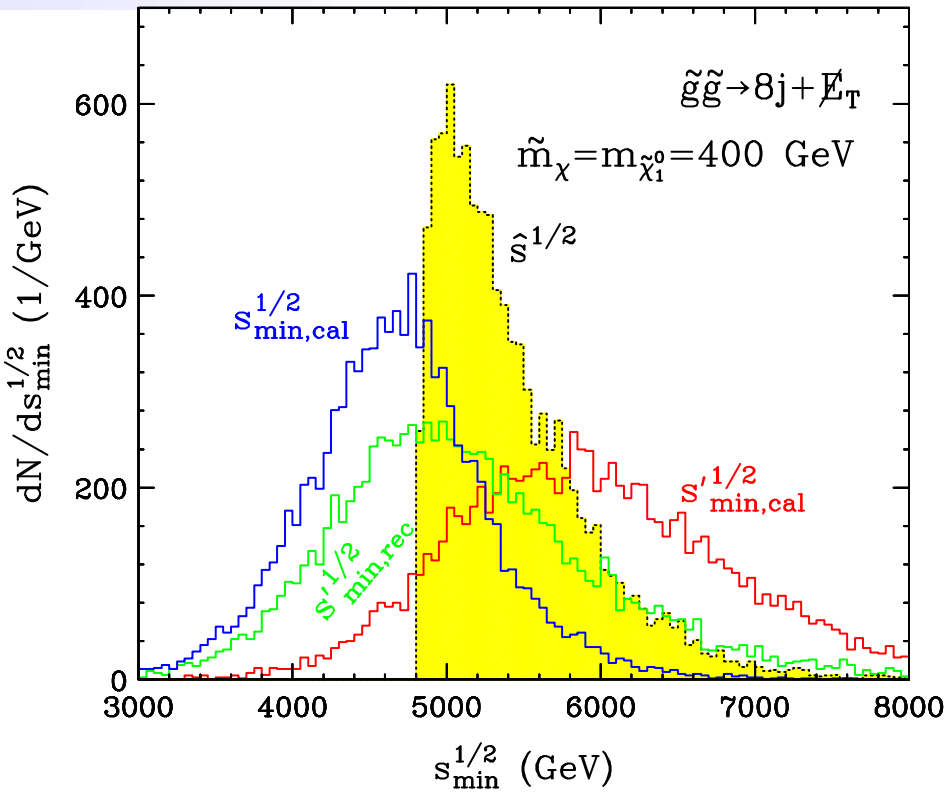
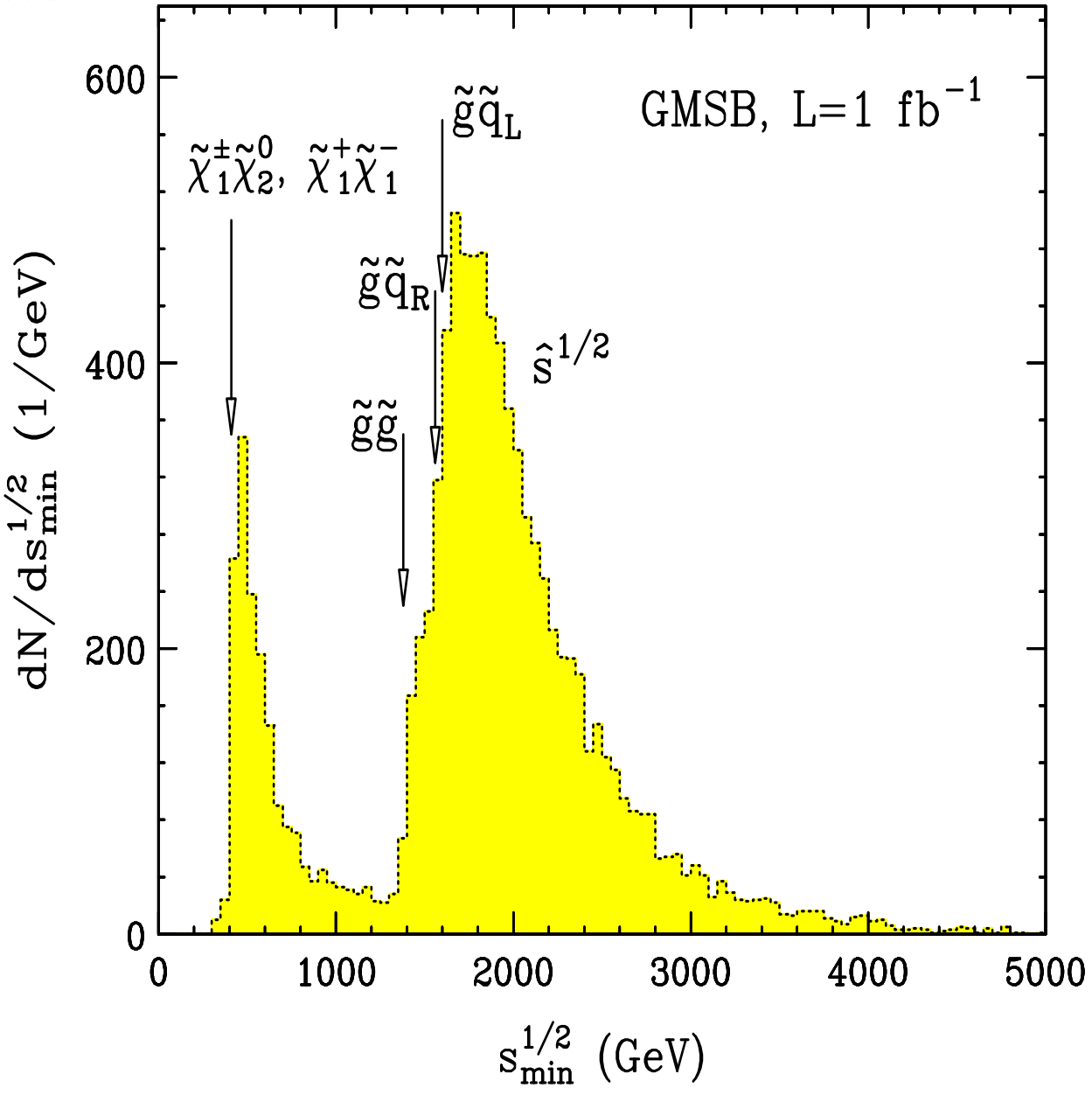




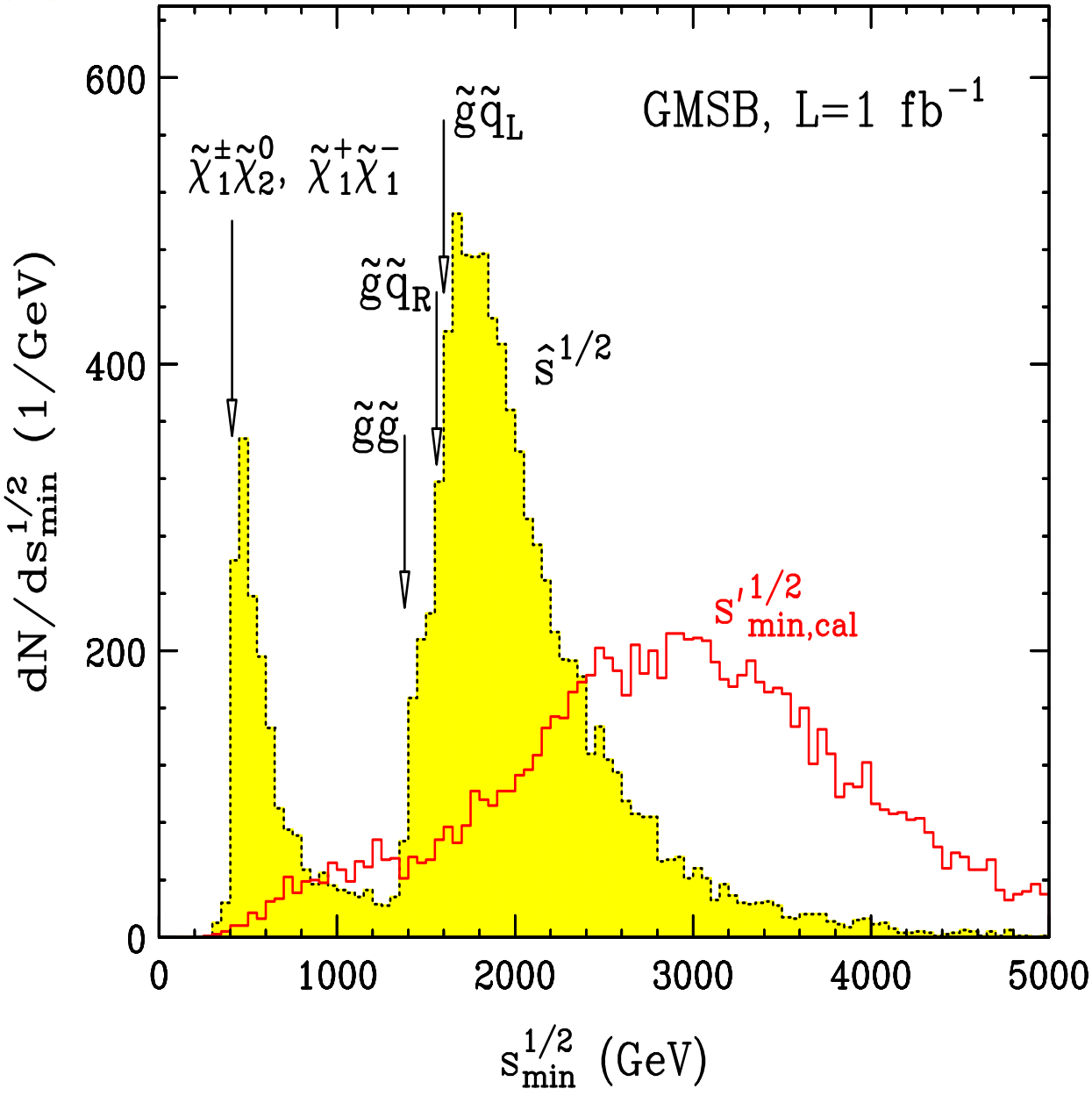
- Strong production = dominant production!
- One of the complex but common type event topology.

$\sqrt{\hat{s}_{min}}$ and mother mass :ISR effect



- Inclusive search : EW and strong Production

$\sqrt{\hat{s}_{min}}$ and mother mass :ISR effect



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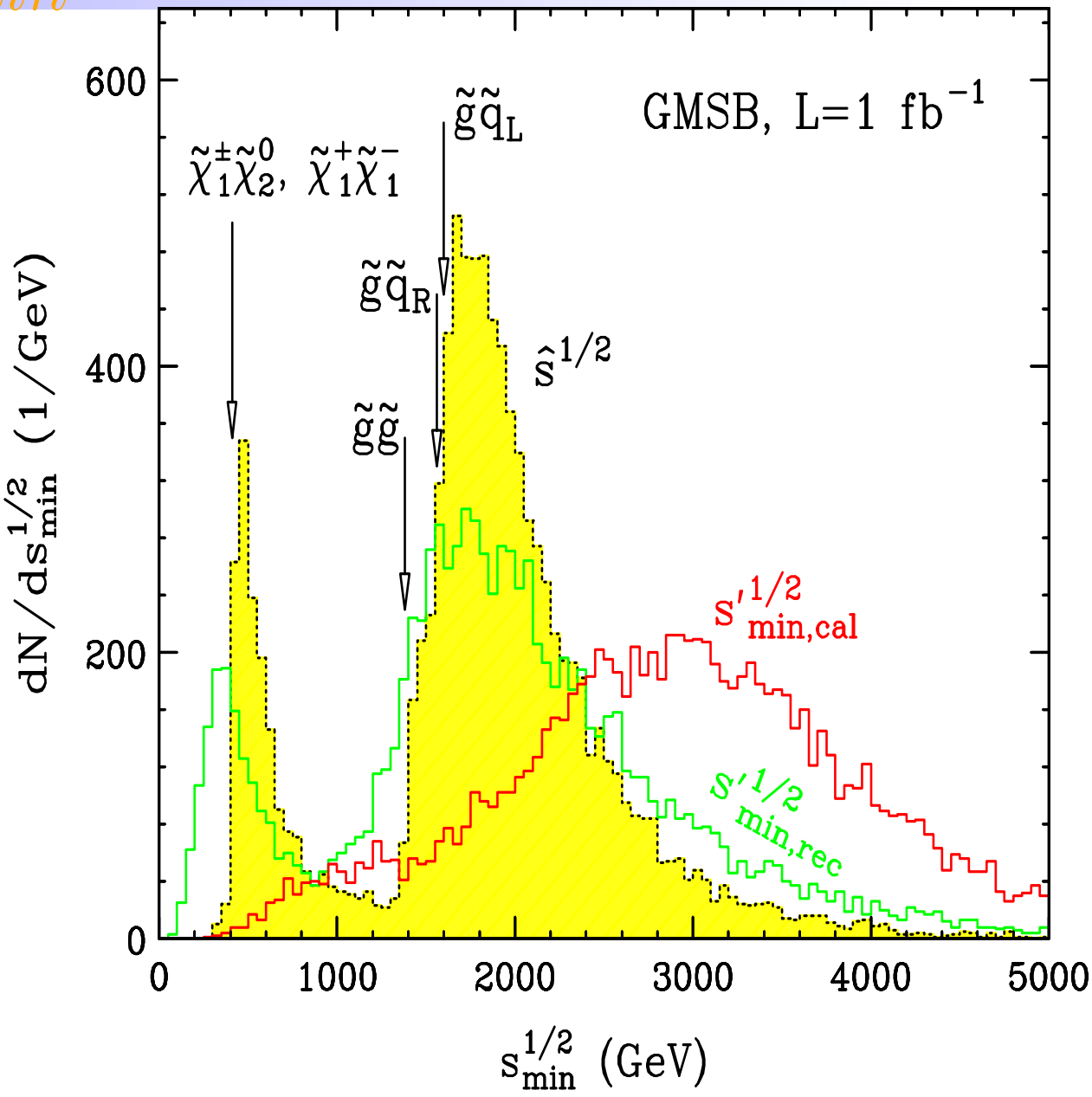

- Inclusive search : EW and strong Production

$\sqrt{\hat{s}_{min}}$ @ LHC – Summary

- Expect an early discovery of a missing energy signal at LHC.
- May involve a signal topology which is too complex for a successful and immediate exclusive event reconstruction
- $\hat{s}_{min}^{1/2}$ is a new global and inclusive variable.
- it is the minimum required center-of-mass energy, given the measured values of the total calorimeter energy E, total visible momentum $\vec{P}$, and/or missing transverse energy $\not{E}_T$ in the event.
- completely general, and is valid for any generic event with an arbitrary number and/or types of missing particles - symmetric or asymmetric.
- its shape matches the true $\hat{s}^{1/2}$ distribution better than any of the other global inclusive quantities $\rightarrow$ identifying the scale of the hard scattering.

$\sqrt{\hat{s}_{min}}$ @ LHC – Summary

- ISR and MPI can pose as serious problem
- Reconstruction works as regulator
- $\hat{s}^{1/2}(M_{inv})$ distribution with the true value of the invisible mass M_{inv}, its peak is very close to the mass threshold of the parent particles originally produced in the event.
- $\hat{s}^{1/2}_{min}(0)$ can already be used for background rejection and increasing signal to noise, just like $M_{T2}(0)$
- Farther possibility to use it at the trigger level.

$\sqrt{\hat{s}_{min}}$ @ LHC – Summary

Thank You