Higgs searches with rest frame subjet algorithm and N-subjettiness.

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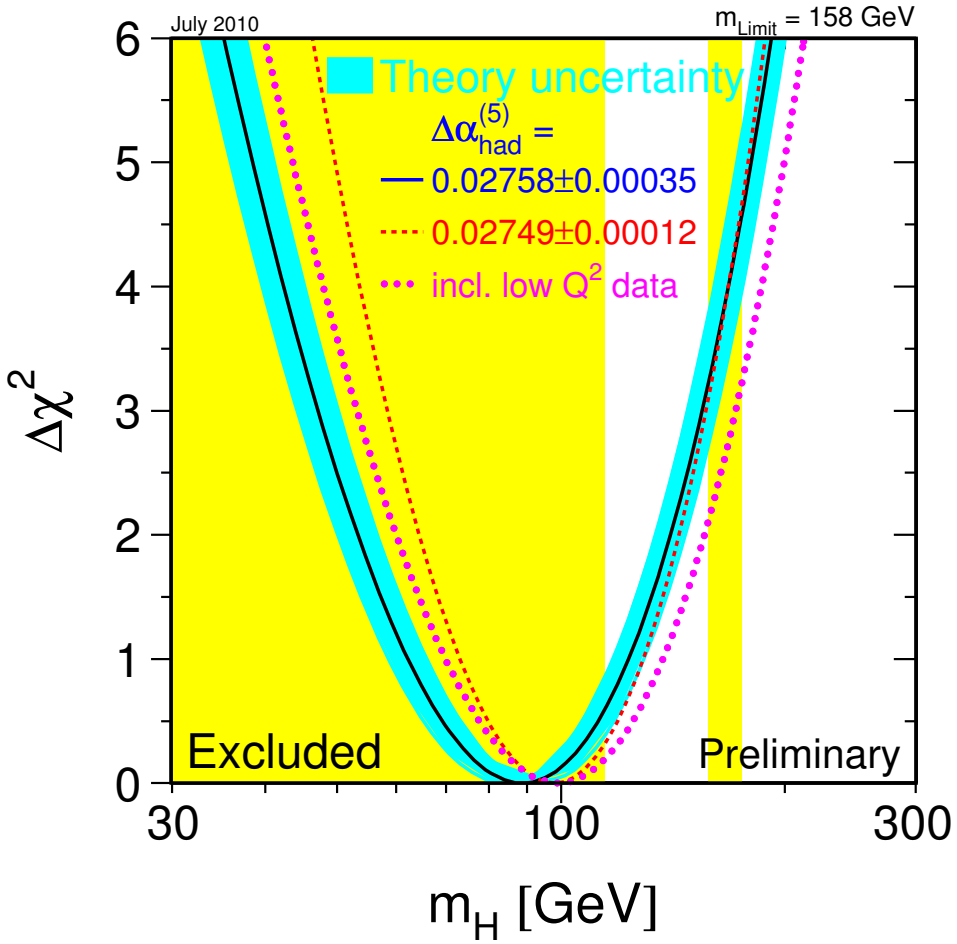
12 January 2011

Main Objectives

- Finding Higgs via fully hadronic decay channels of $pp \to H + W/Z$.
- N-subjettiness : to identify fat-jets.
- Rest frame subjet : to provide a subjet definition for N-subjettiness.
- The jet rest frame : to define the rest frame subjet.

This talk is based on arXiv:1011.1493.

Constraints on the SM Higgs

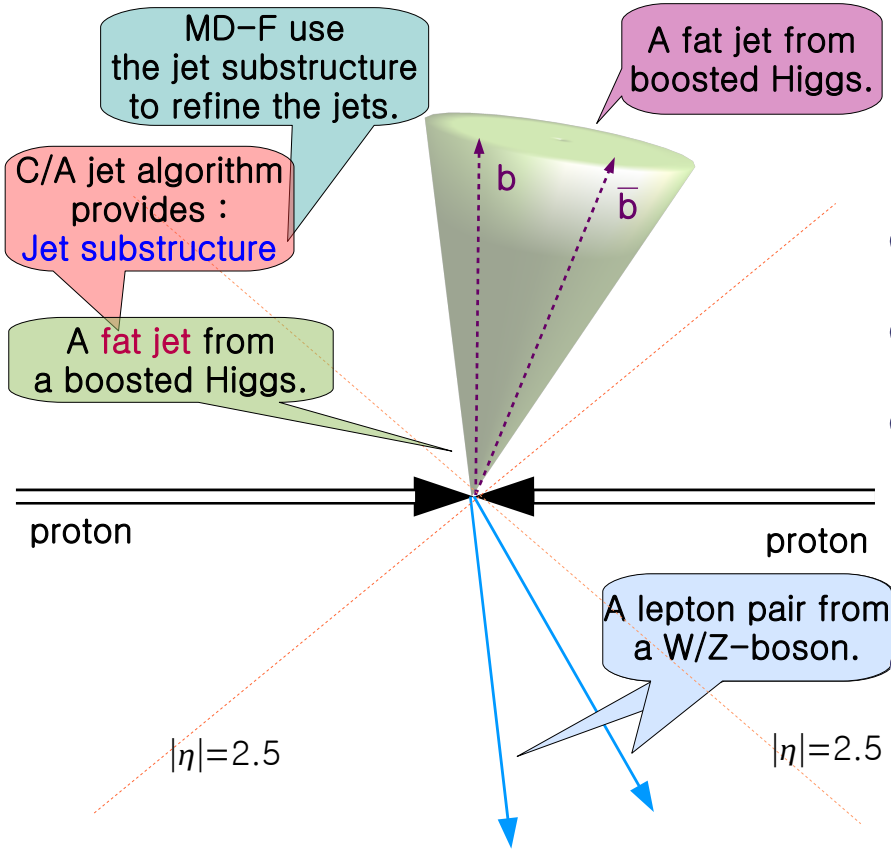


$m_H \sim 120\mathrm{GeV}$ is preferred.
$\Rightarrow H \to b\bar{b}$ becomes a dominant decay channel.
$\Rightarrow$ huge QCD background.

Figure: from arXiv:1012.2367

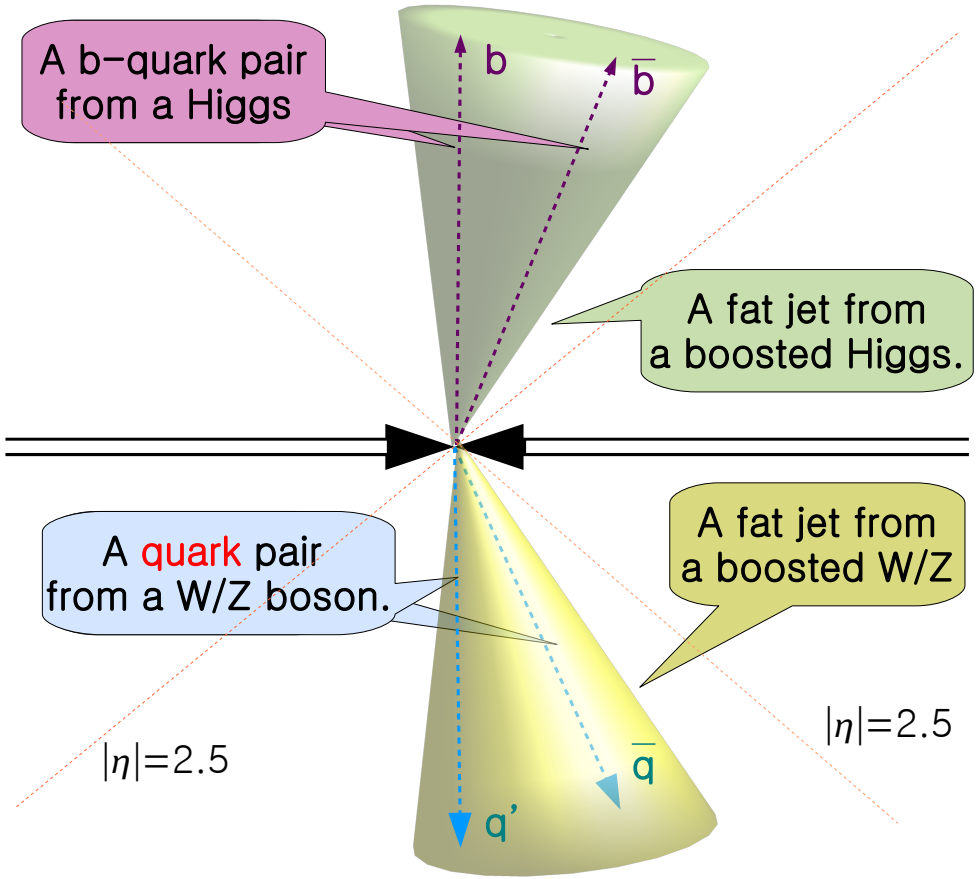
Fat jet signals from boosthed Higgs via $pp \to H + W/Z$

Pioneered by Jonathan M. Butterworth, Adam R. Davison, Mathieu Rubin, Gavin P. Salam, Phys.Rev.Lett.100:242001,2008 (BDRS).



- Cluster jets with C/A MD-F algorithm.
- Seeking one fat jet, instead two b-jets.
- Mass drop & filtering (MD-F) : remove soft particles from underlying event, and pileup.
- ATLAS public note 2009-088 suggests the statistical significance of the $S/\sqrt{B}$ is about 3.7σ.

Another fat jet signals from $pp \to H + W/Z$.



- Two fat jets, instead of one fat jet + one lepton pair $\Rightarrow$ involves higher uncertainties.
- $\sigma_{hadronic}(pp \to H + W/Z)$: several times larger than $\sigma_{(semi)leptonic}(pp \to H + W/Z)$ $\Rightarrow$ large σ compensates the uncertainties of the jets.

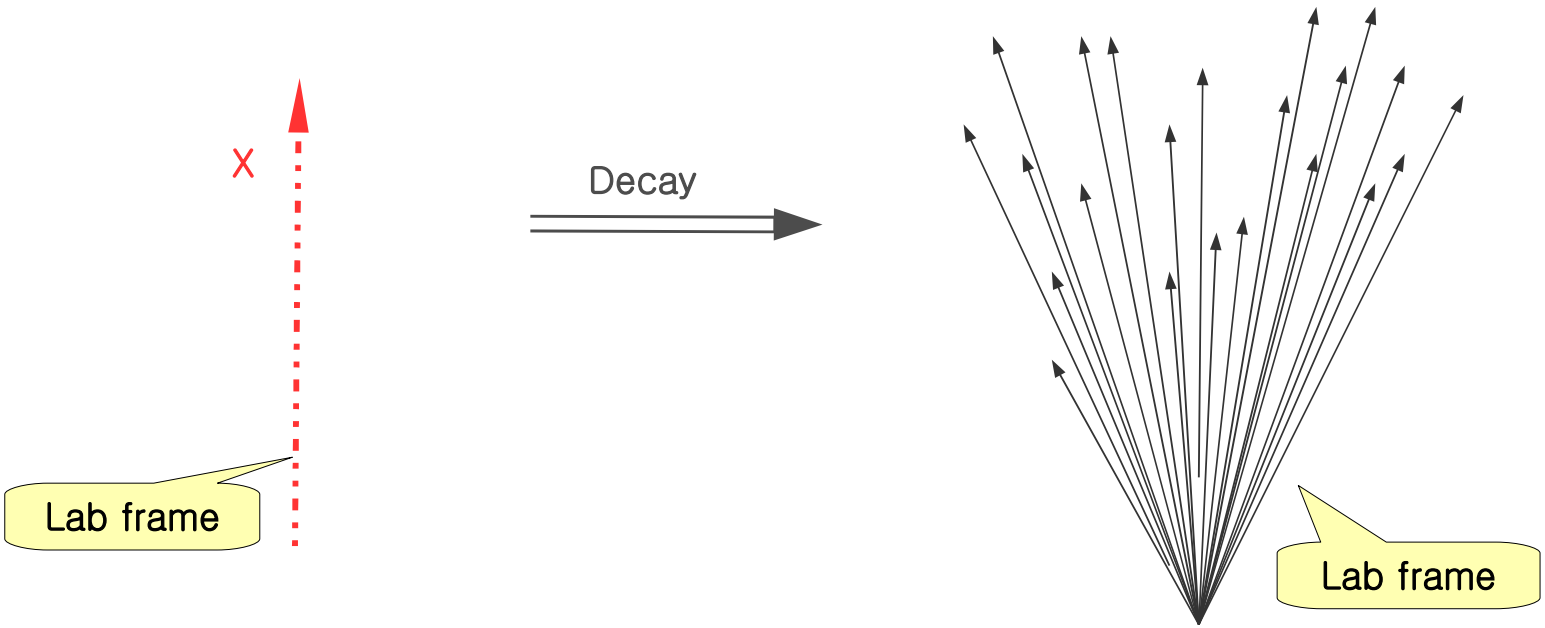
The problem is that QCD background is too large even if existing jet substructure algorithms are applied.

N-subjettiness : brief introduction

- A variation of 'N-jettiness', a global event shape introduced by Iain W. Stewart, Frank J. Tackmann, Wouter J. Waalewijn, Phys.Rev.Lett.105:092002,2010.
- A jet shape observable.
- Identify boosted heavy particles which decay to N partons.
- Discriminates the fat jets from QCD jets.
- Defined in terms of constituent particles and rest frame subjets of a jet.

This talk focuses on 'two'-subjettiness with SISCone jet for the standard model Higgs searches via $pp \to H + W/Z$:

Boosted color singlet particle in the jet rest frame.



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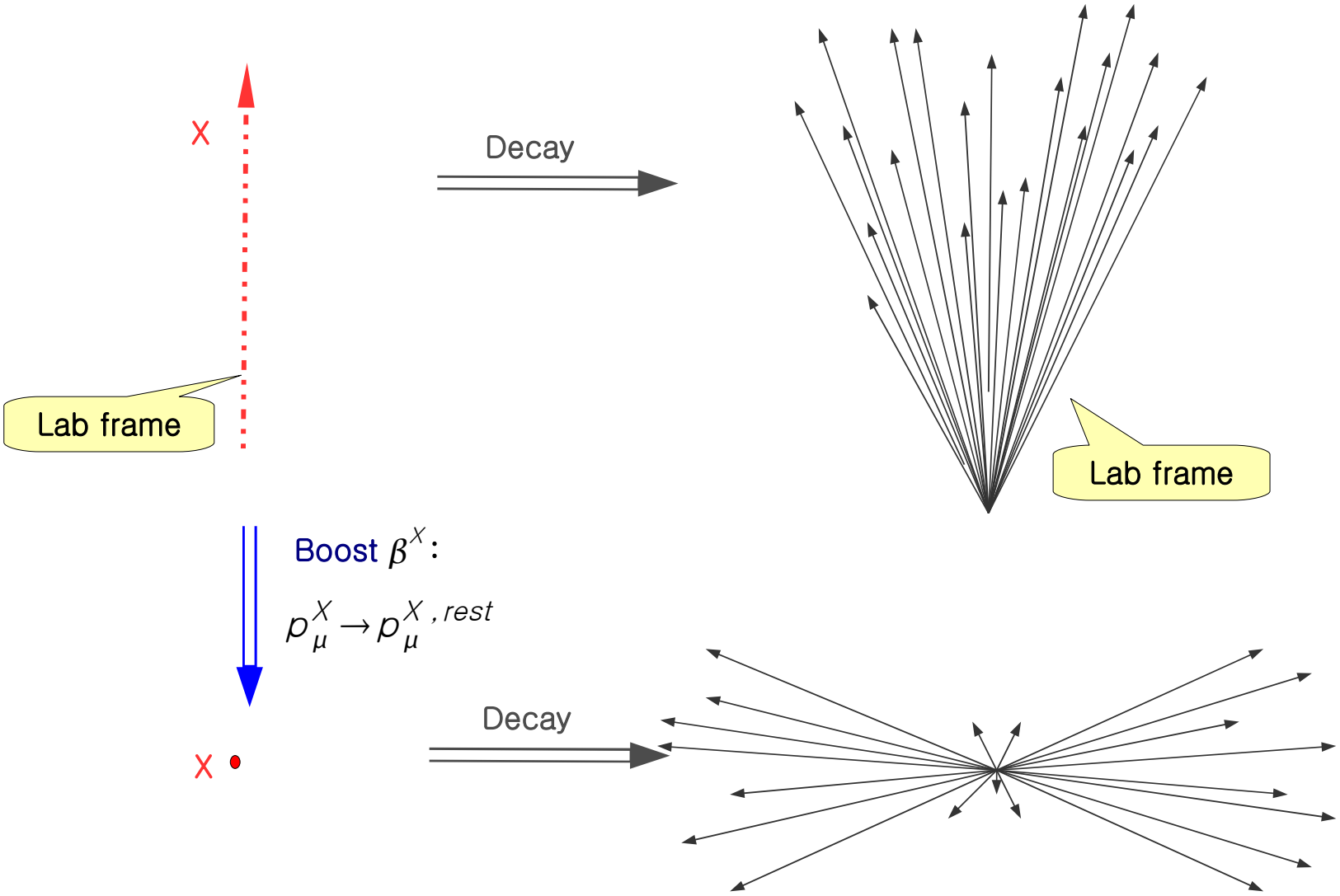

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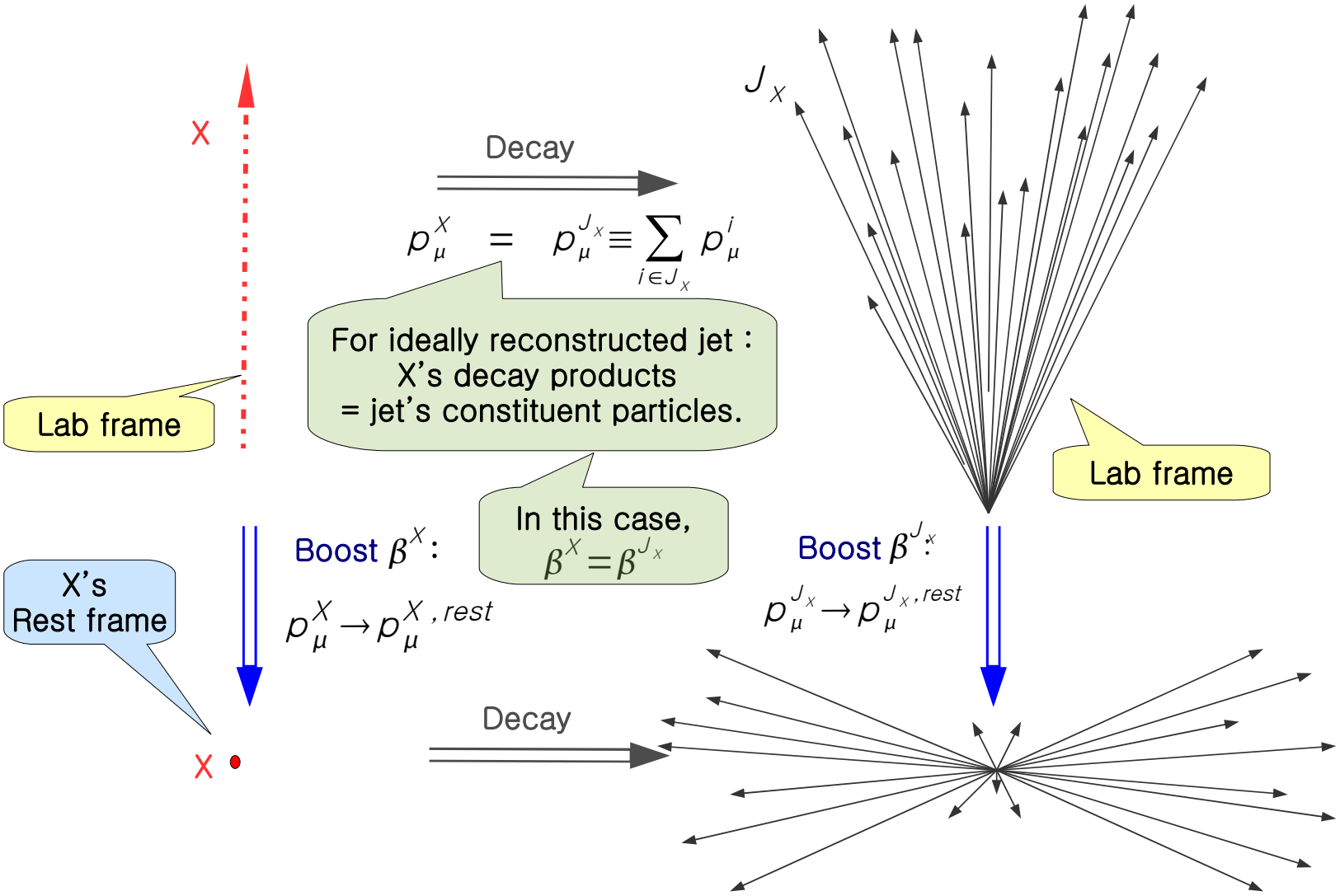

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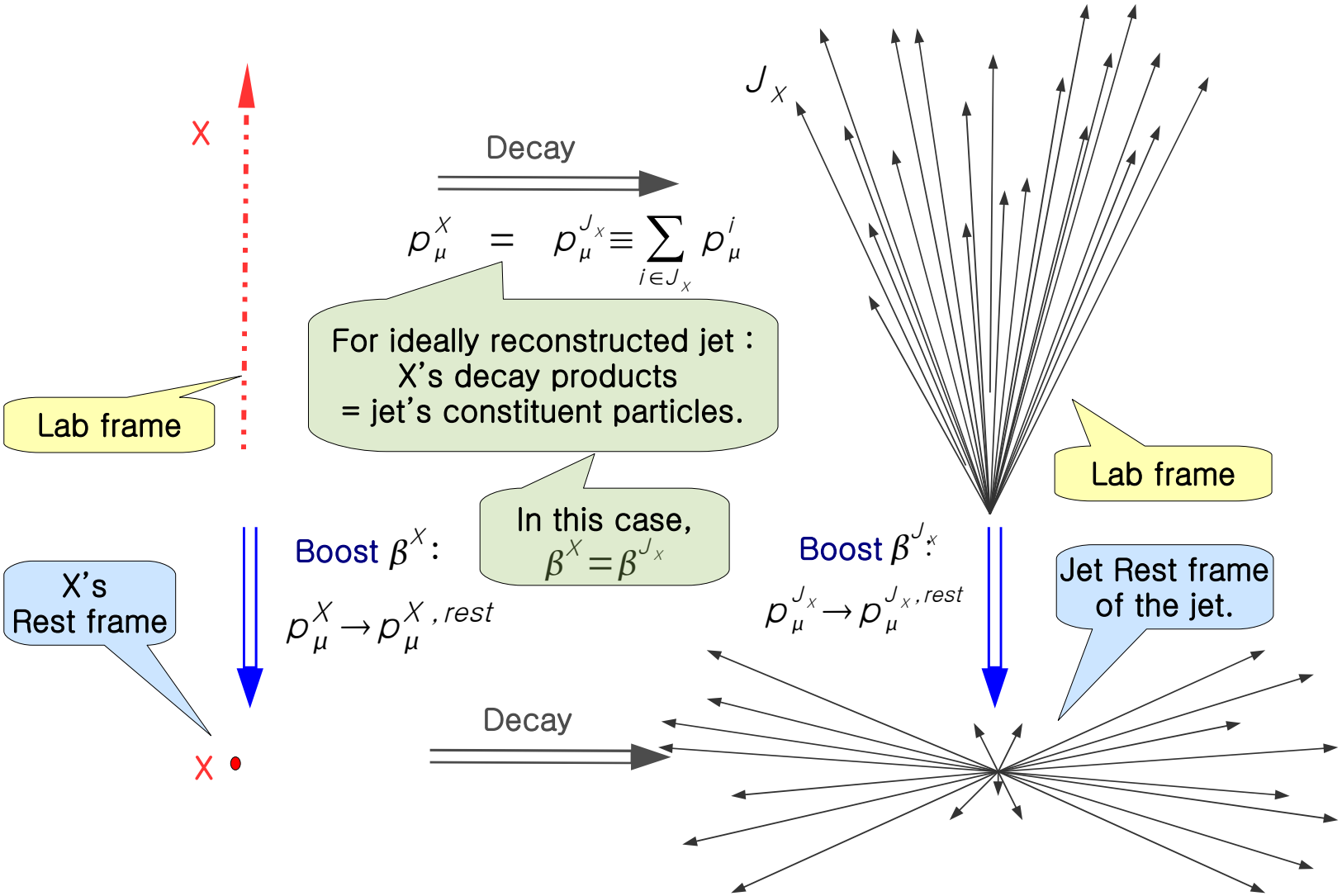
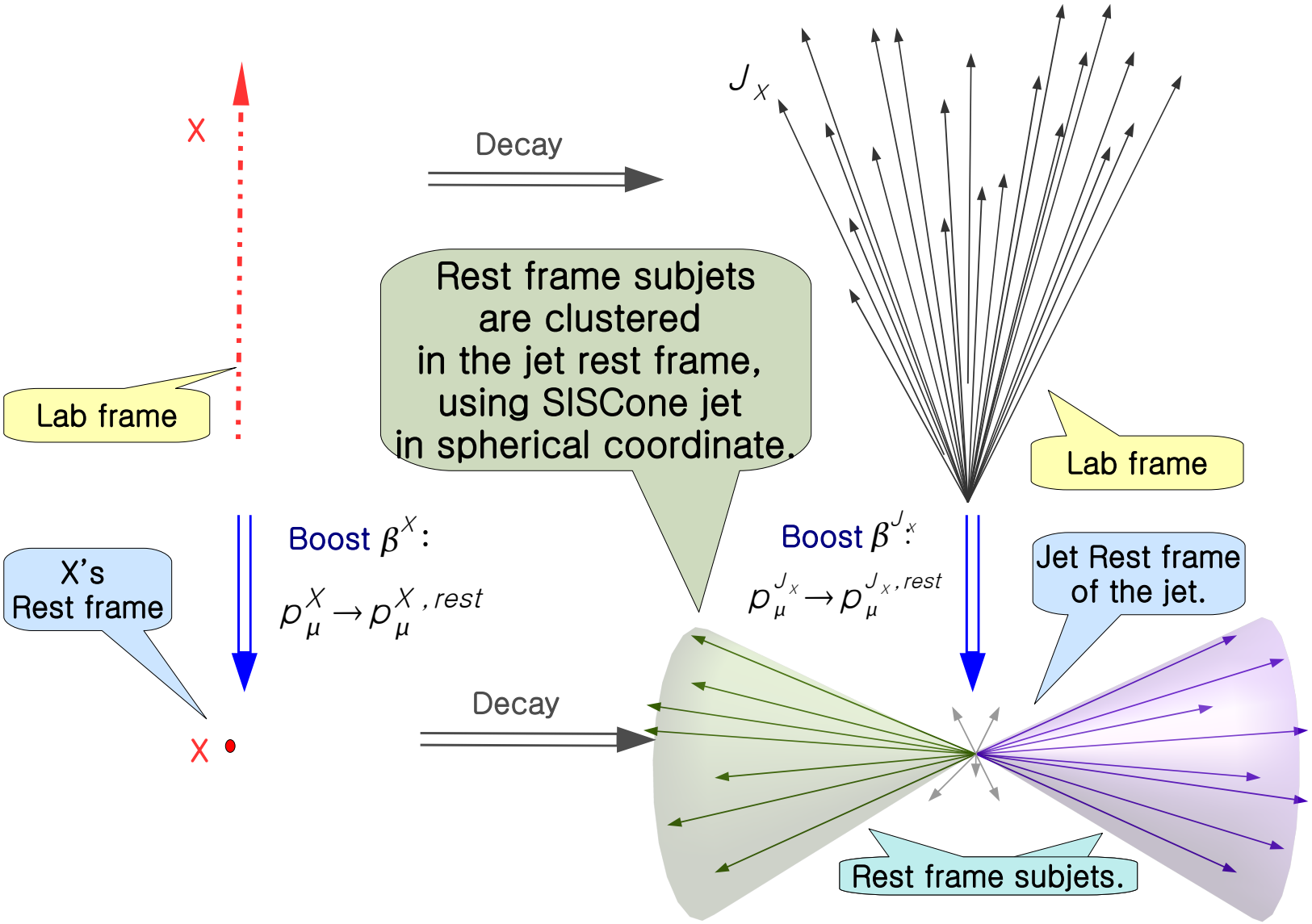
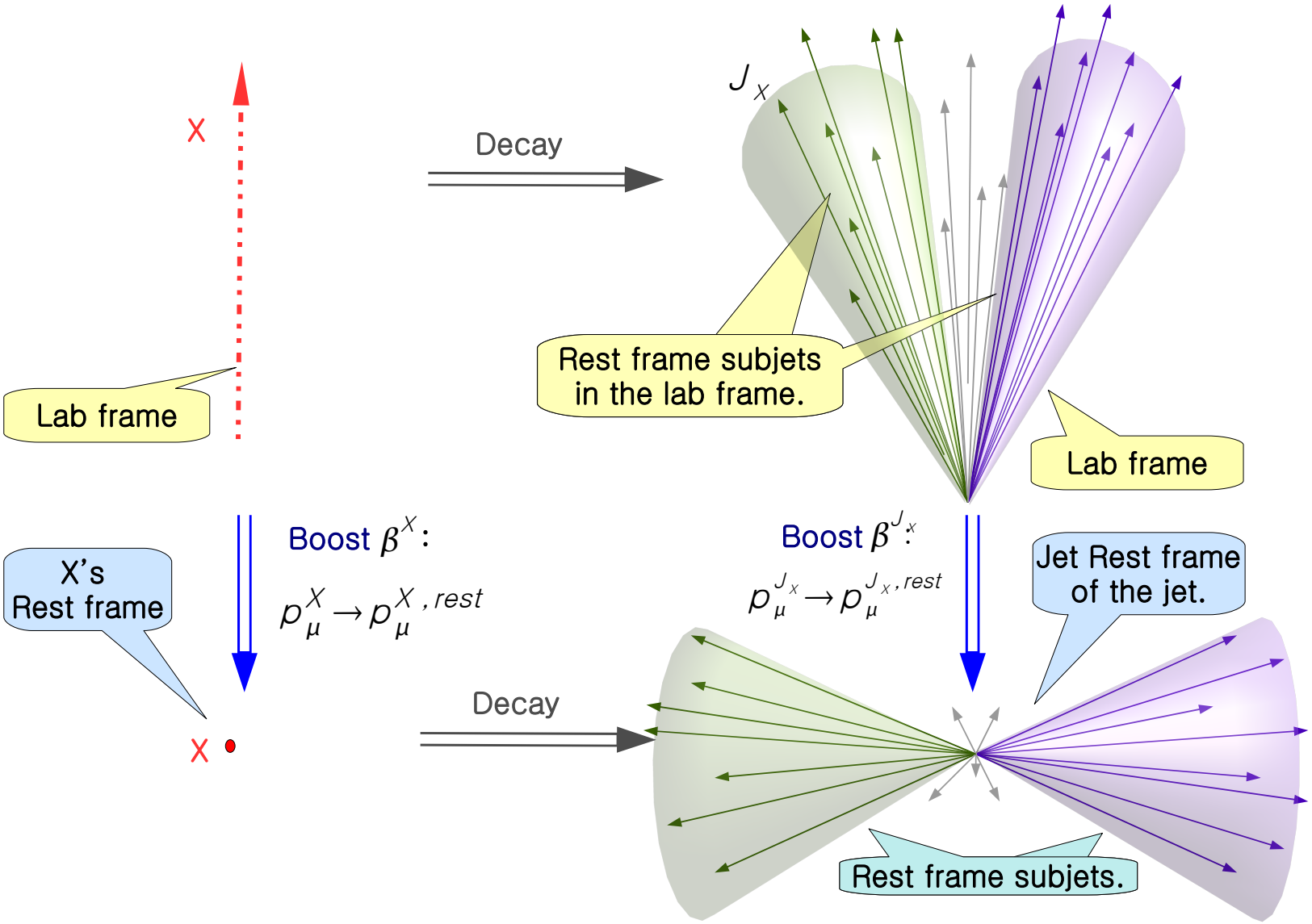


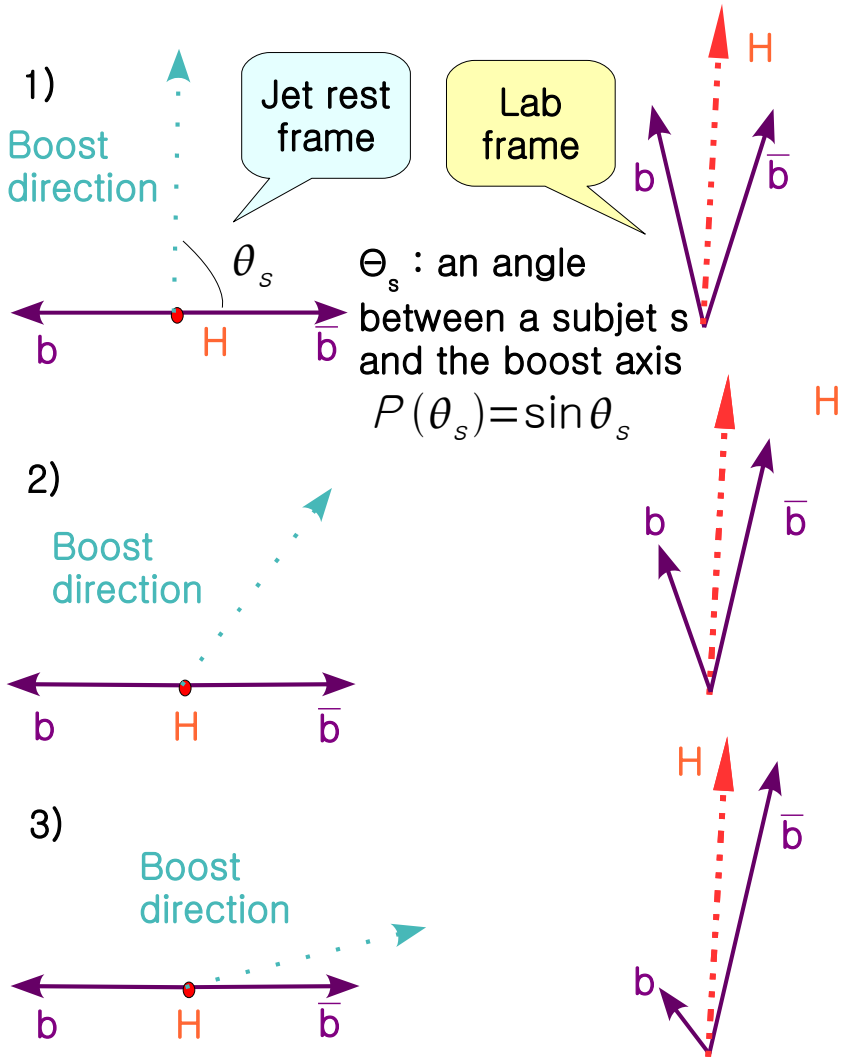
Rest frame subjet : definition.



Rest frame subjet.



Rest frame subjet : Higgs jet case.



Most probable &
⇒ Likely to be reconstructed properly

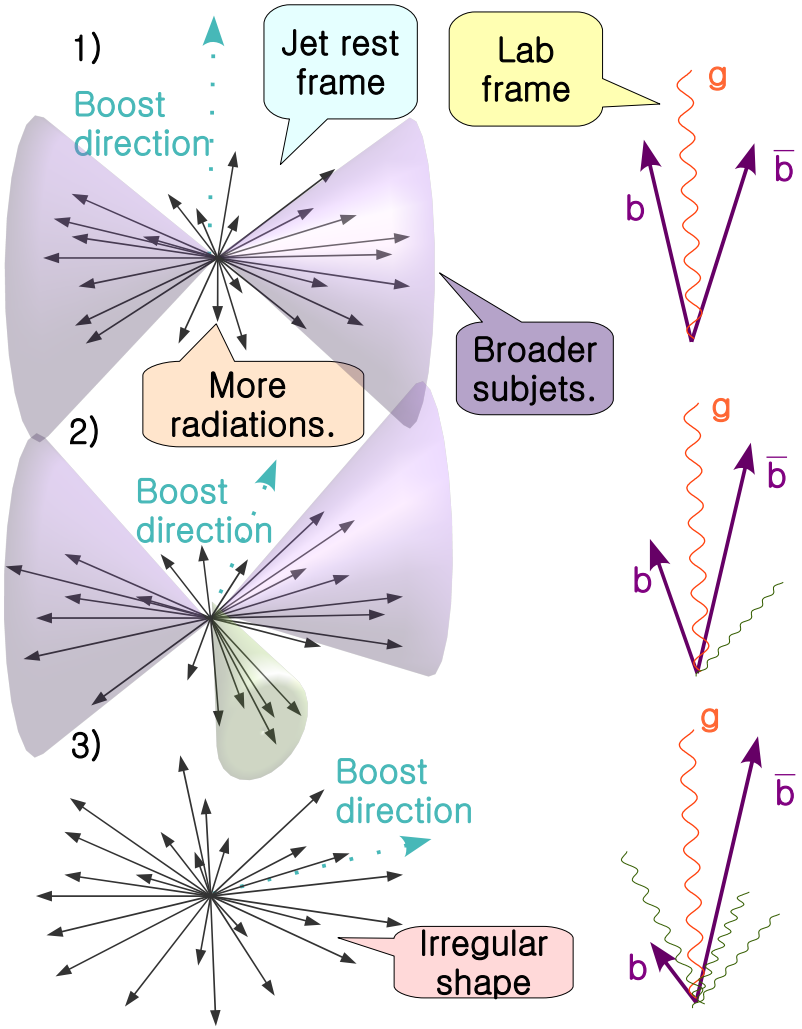
Less probable &
⇒ Less likely to be reconstructed properly

Least probable &
⇒ Unlikely to be reconstructed properly

The jet rest frame : QCD jet case

Colored partons hadronize

$\Rightarrow$ causes their shape in the jet rest frame more irregular. Moreover,



Corresponds to
hard gluon splitting &
$\Rightarrow$ no more hard radiation.
Least probable.

Less hard gluon splitting &
$\Rightarrow$ additional radiation.
More probable.

Soft gluon splitting &
$\Rightarrow$ additional radiations.
Most probable.

Difference between fat jets and QCD jets.

Boosted H / W / Z jets are likely to give

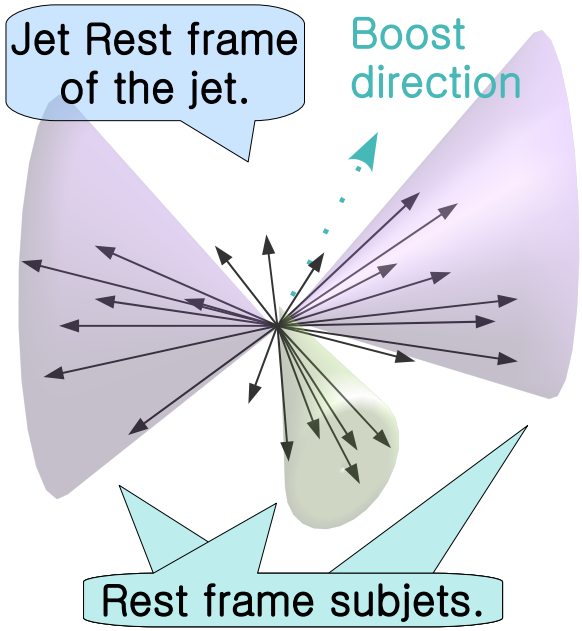
- Two energetic subjets
- Narrower subjets.
- $\theta_s \sim \pi/2$.

QCD jets are likely to give

- Several subjets.
- Broader subjets.
- $\theta_s \sim 0$, or π.

How to identify fat jets which have 'two' 'narrow' subjets?

N-subjettiness, τ_N^{rest}.



$$\tau_N^{rest} = \frac{2}{M_{jet}^2} \sum_{i \in J} min(p_i \cdot q_1, p_i \cdot q_2, \ldots, p_i \cdot q_N)$$

$$M_{jet}^2 \equiv (p_\mu^{jet})^2$$

q_k : momenta of subjets.

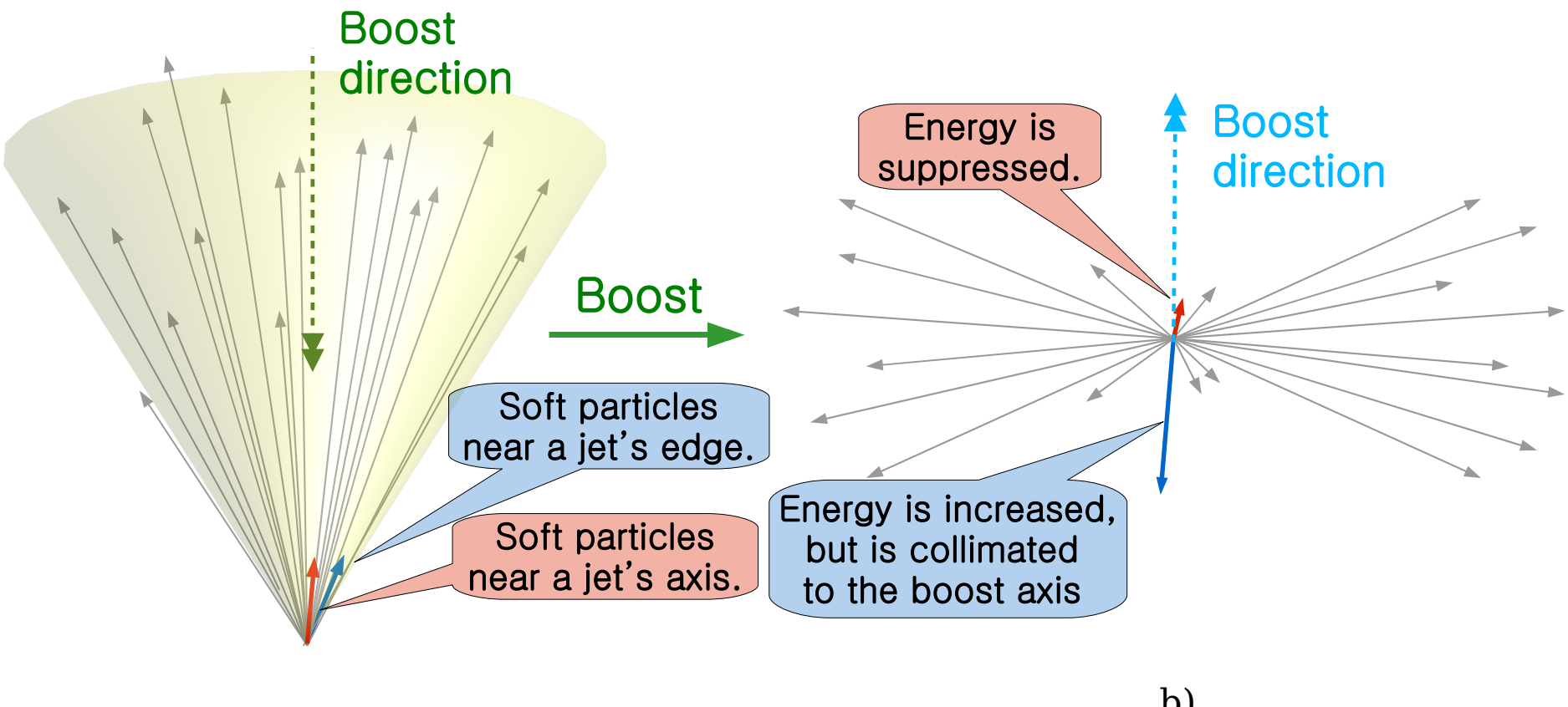
p_i : momenta of the constituents particles.

- N infinitely narrow subjets
  $\Rightarrow \tau_N^{rest} \rightarrow 0$.
- Broader subjets
  $\Rightarrow$ larger τ_N^{rest}.
- Additional undesired subjets
  $\Rightarrow$ larger τ_N^{rest}.

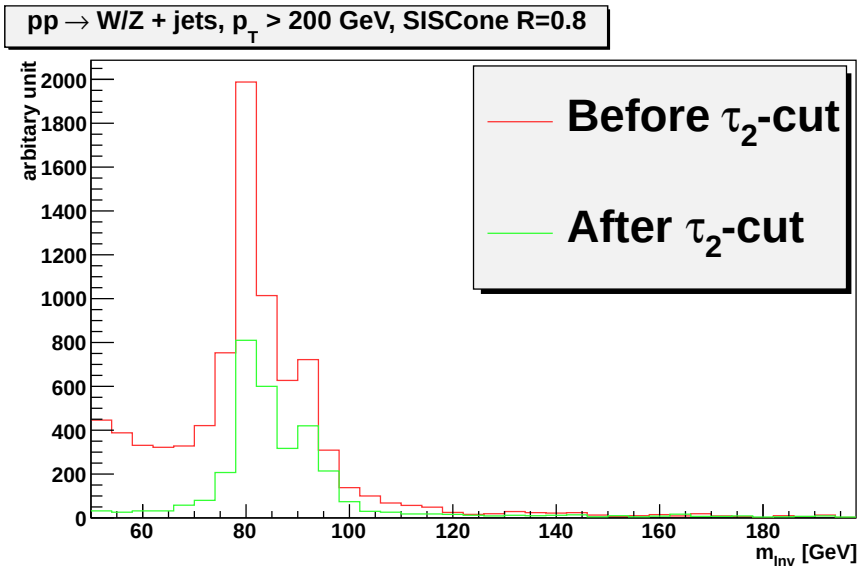
Boosted H/W/Z jets : small τ_2^{rest}.
QCD jets : large τ_2^{rest}.

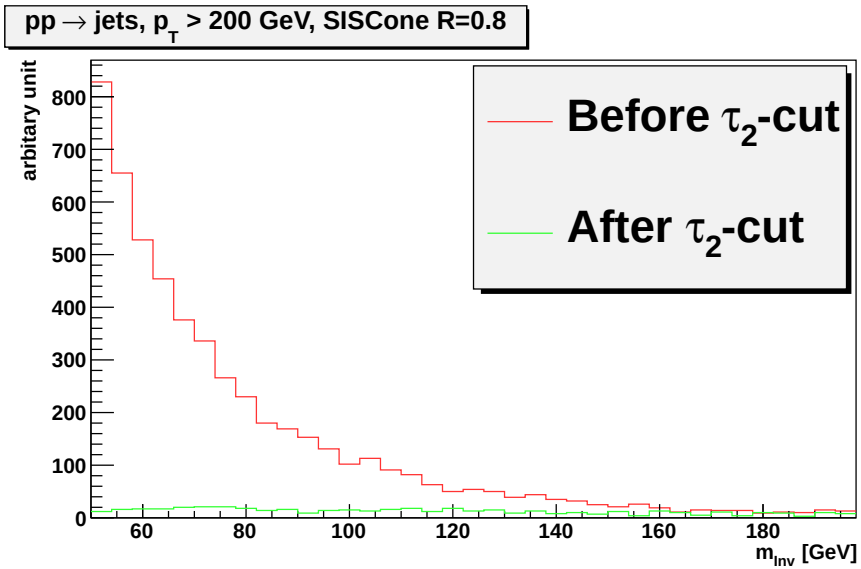
Effects of underlying event, plieup on N-subjettiness.

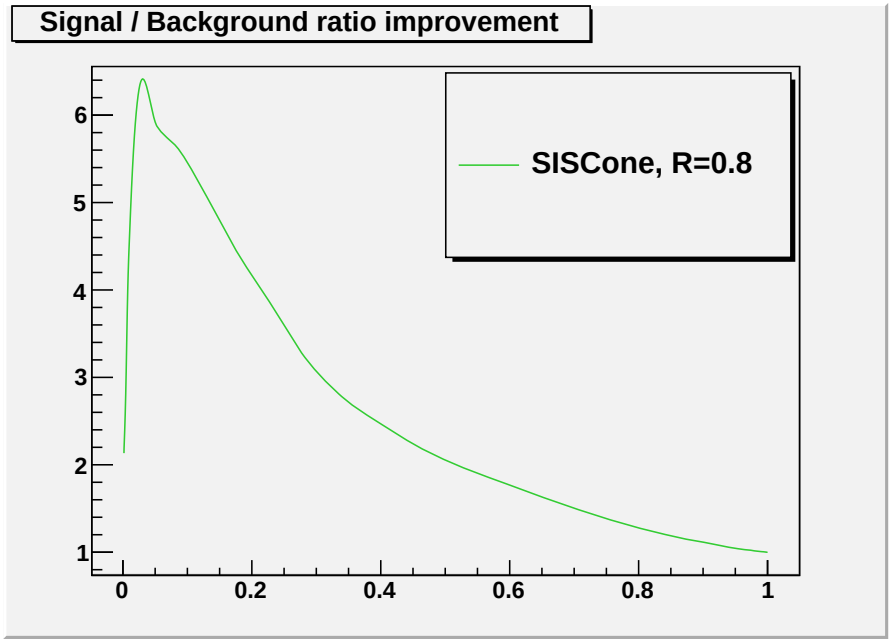
- Leading subjets are less affected by underlying event, and pileup.
- 10% changes of jet mass $\Rightarrow$ 20% changes of τ_N^{rest}.
- Note that, very soft particles can change τ_N^{rest} only a little bit : τ_N^{rest} is infra red safe.



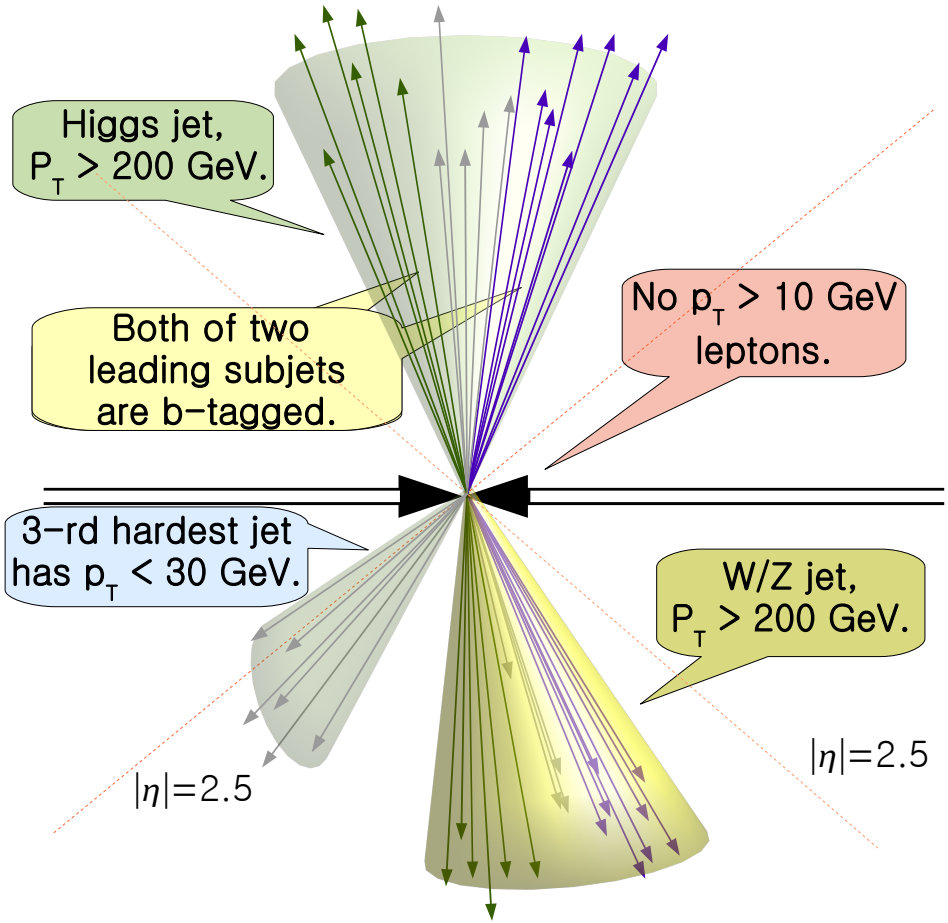
Before and after τ_N^{rest}-cut : $W/Z + jets$ case.







Higgs searches : event selection scheme.



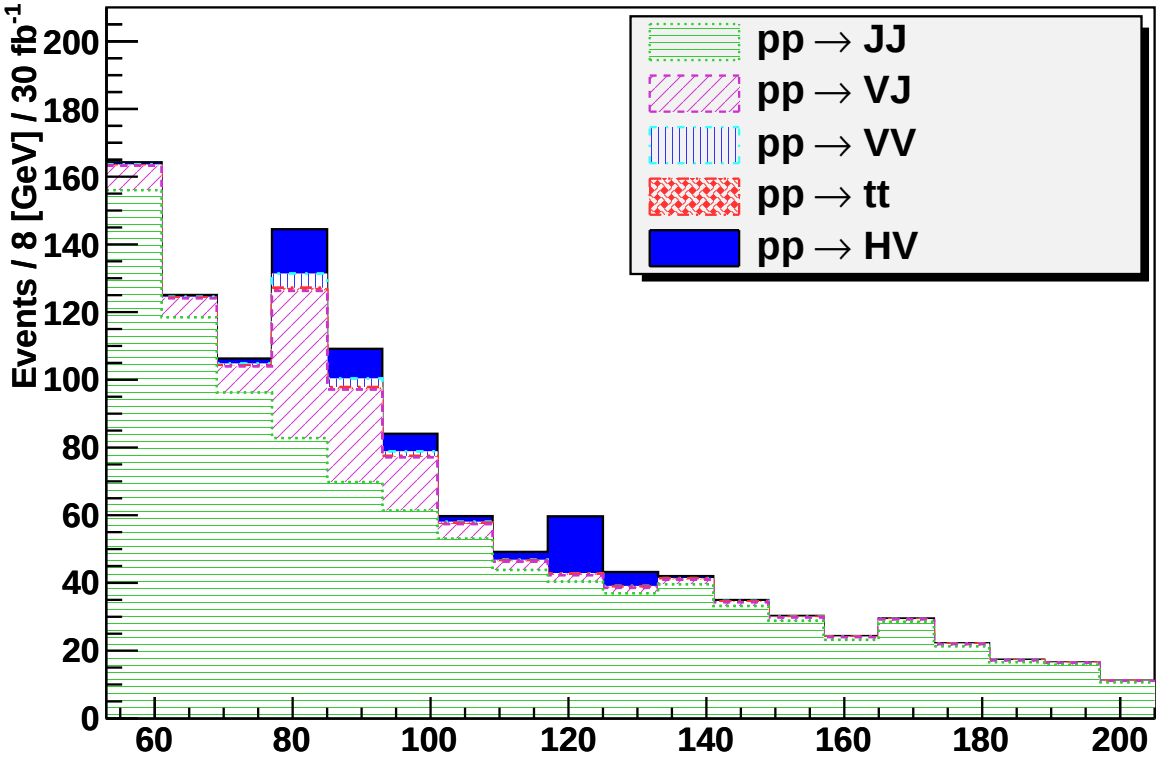
Both of two leading jets are required to satisfy :

- $\tau_2^{rest} < 0.08$ cut.
- $\cos\theta_s < 0.8$ cut.

And two leading subjets of the Higgs candidate jets are required to be b-tagged.

The results

PYTHIA 6.4.23 + ATLAS MC09 parameter tune.
Jet clustering : SISCone jet, R = 0.8, f = 0.75 (f = overlab threshold).
Subjet clustering : SISCone jet in spherical coordinate, R = 0.7, f = 0.75.



- $30 fb^{-1}$ of LHC 14 TeV,
- With a jet mass resolution $\pm 10 GeV$:
  $S/B \sim 30/200$ and
  $S/\sqrt{B} \sim 2\sigma$.

Summary

- τ_2^{rest} cut, $\cos\theta_s$ cut identify boosted H / W / Z jet.
- Rest frame subjet algorithm provides
  a subjet definition for SISCone jet and any jet algorithm.
- With τ_2^{rest}, $\cos\theta_s$, the statistical significance of the signals
  from $pp \to H + W/Z$ is expected to be about 2σ
  for $30 fb^{-1}$ at LHC 14 TeV.
- The scheme is rather a proof of concept version. It will be improved further to increase the significance : work in progress.
- Rest subjet algorithm can also be combined with other subjet techniques.