LCFIVertex Status and Updates in Flavor Tagging Studies for Linear Colliders

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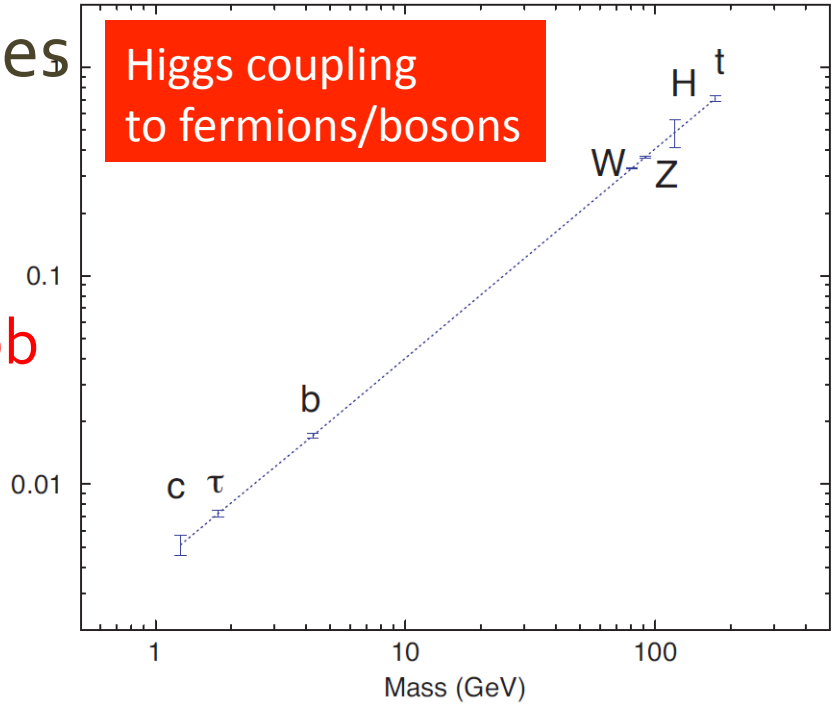
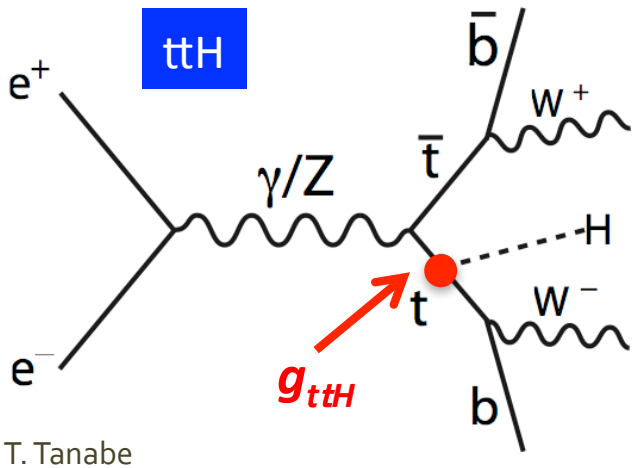
outline

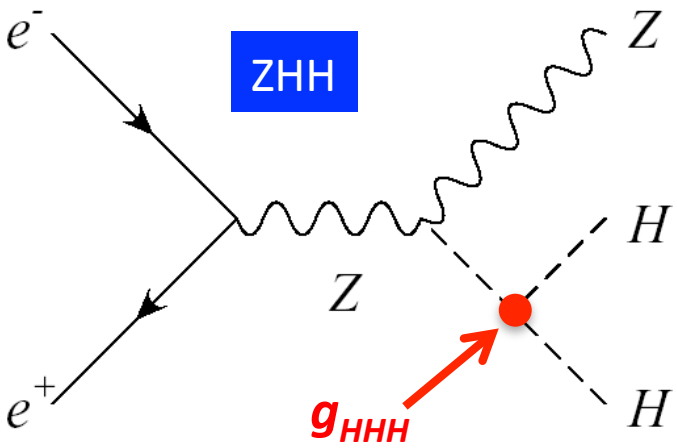
- introduction
  - flavor tagging @ LC
  - LCFIVertex status
  - vertex finding algorithms
  - detector simulation and data samples
- discrimination variables
  - track/vertex variables
  - event categories (discrete variables)
- summary

physics motivation

- Many important physics processes have multiple heavy flavor jets
  - Higgs BF : H -> bb, H -> cc
  - Higgs self-coupling : ZHH -> qqbbbb
  - top-Yukawa : ttH -> bWbWbb
  - top physics : tt -> bWbW



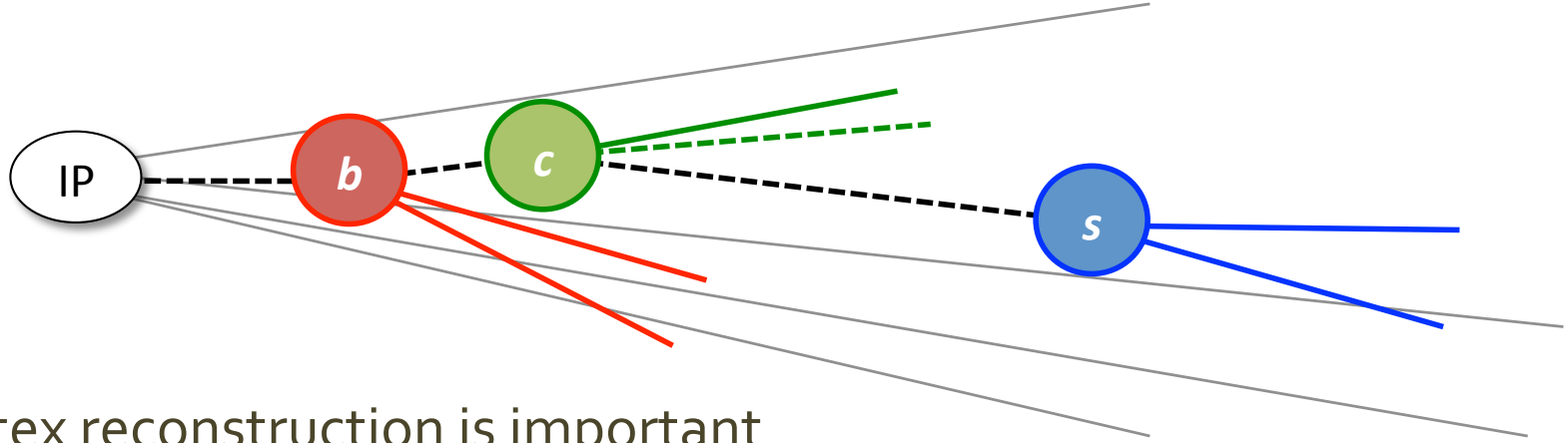




Z→qq (70%)
ll (30%)
W→qq (65%)
lν (35%)
H→bb (65%)
(m_H=120GeV)

ideal flavor tagging

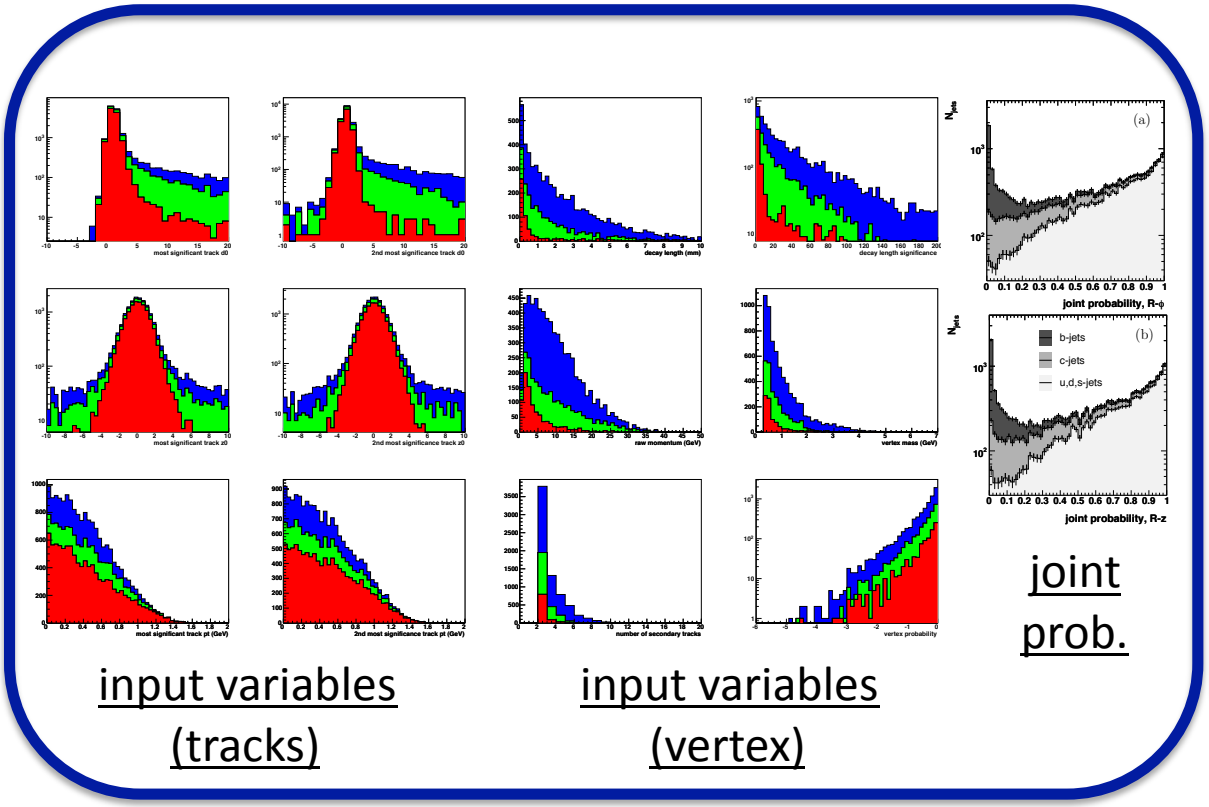
- reconstruct the entire decay chain (b -> c -> s) in a jet



  - vertex reconstruction is important
    - but vertices cannot be made from a single track
      - use track measurements (impact parameter)
  - presence of neutral particles
    - missing correction by using p_T
  - lepton ID: energetic/isolated leptons is a sign of heavy quark decays
- variable combination
  - likelihood, neural net
  - event categorization (discrete variables)

LCFIVertex

LCFIVertex is a collection of algorithms for flavor tagging and parton charge identification.



neural net

b-likeness
c-likeness
parton charge

LCFI collaboration: NIM A 610 (573) [arxiv:0908.3019]

LCFIVertex Package

Tracking → Particle Flow (Pandora) → Jet Clustering (Durham) → Vertex Finder (ZVTOP) → Flavor Tagging with Neural Net → Charge Reconstruction

flavor tag optimization strategy

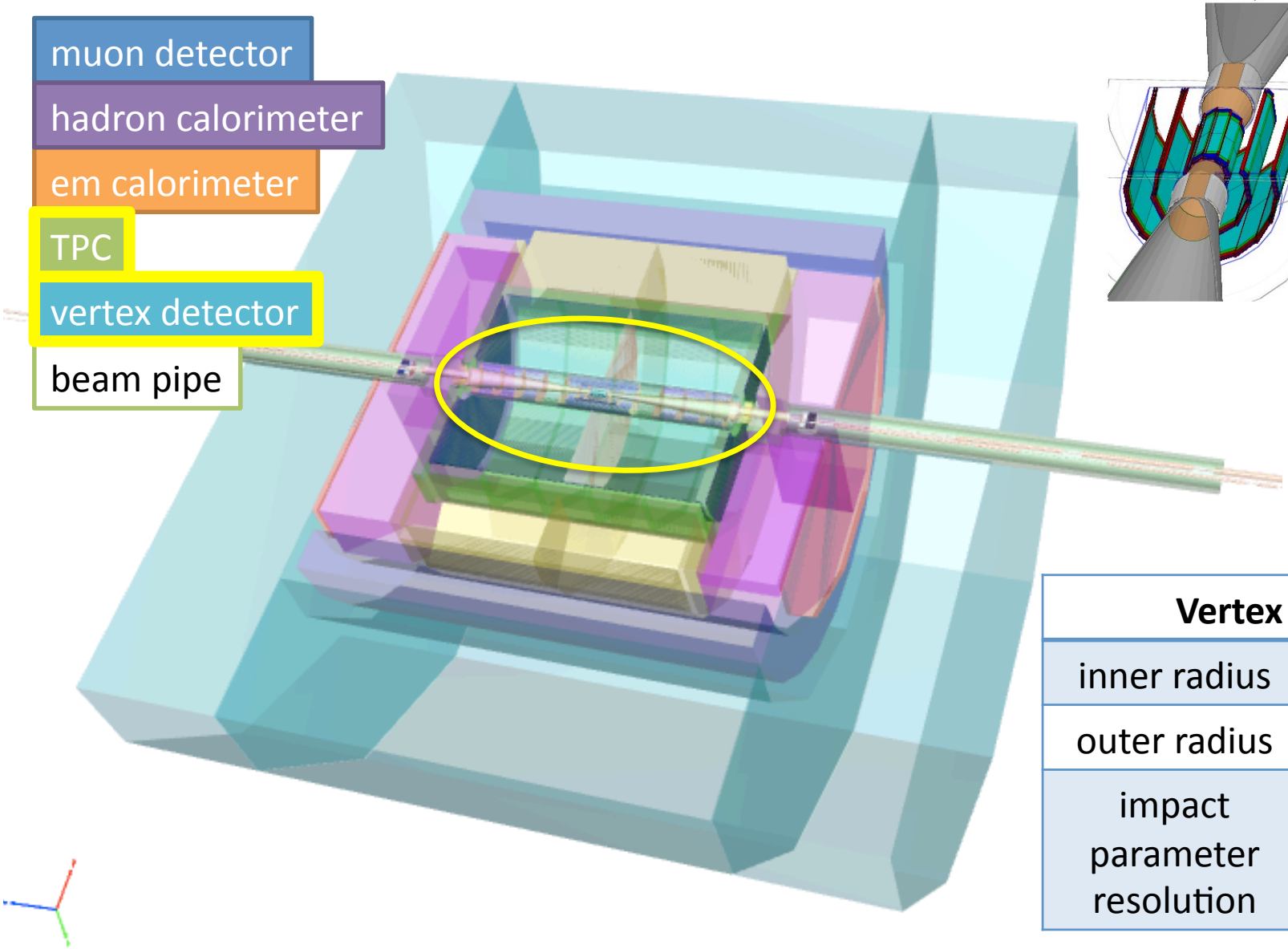
- from basic checks to algorithm tuning
  - ✓ vertex hits
  - ✓ track reconstruction
  - ✓ track residual & track errors
  - ➔ track quality & track selection
  - ➔ vertex reconstruction
  - ➔ combination of input variables
  - ➔ optimization for multi-jet environment

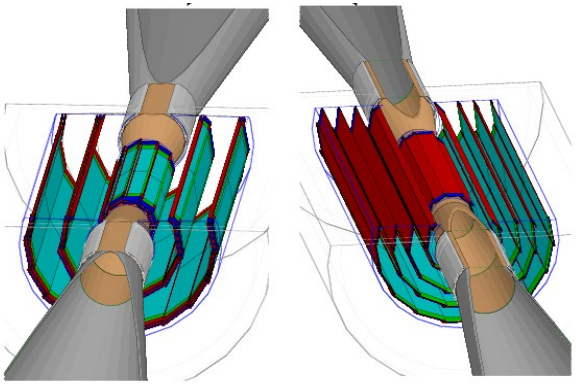
Presented at ILD workshop, July 2010

Today's talk

See talk by T. Suehara on Thursday

ILD Detector





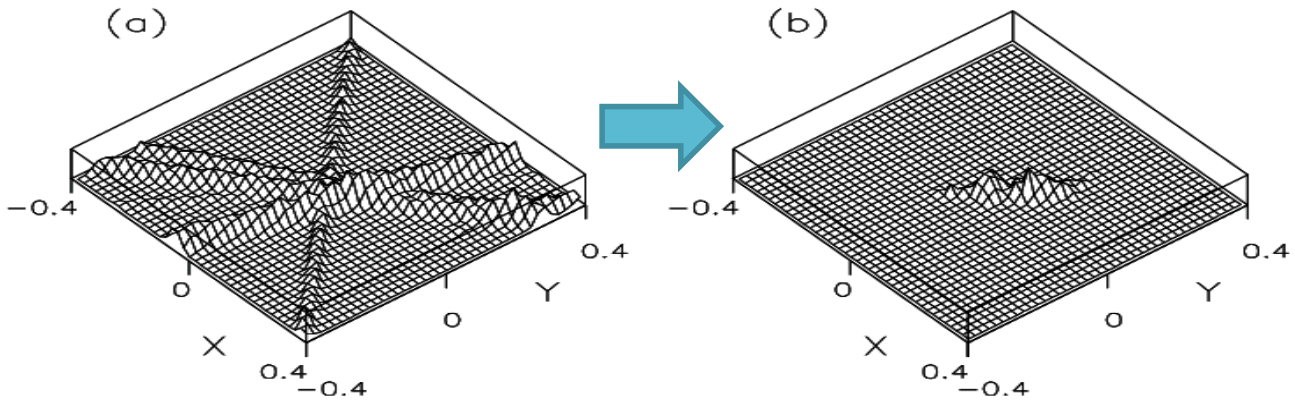
Vertex Detector	
inner radius	15 mm
outer radius	60 mm
impact parameter resolution	< 5 μm (high momentum)

vertex finding algorithms

- topological vertex finder

track probability tubes

vertex function: overlapping tubes -> high values

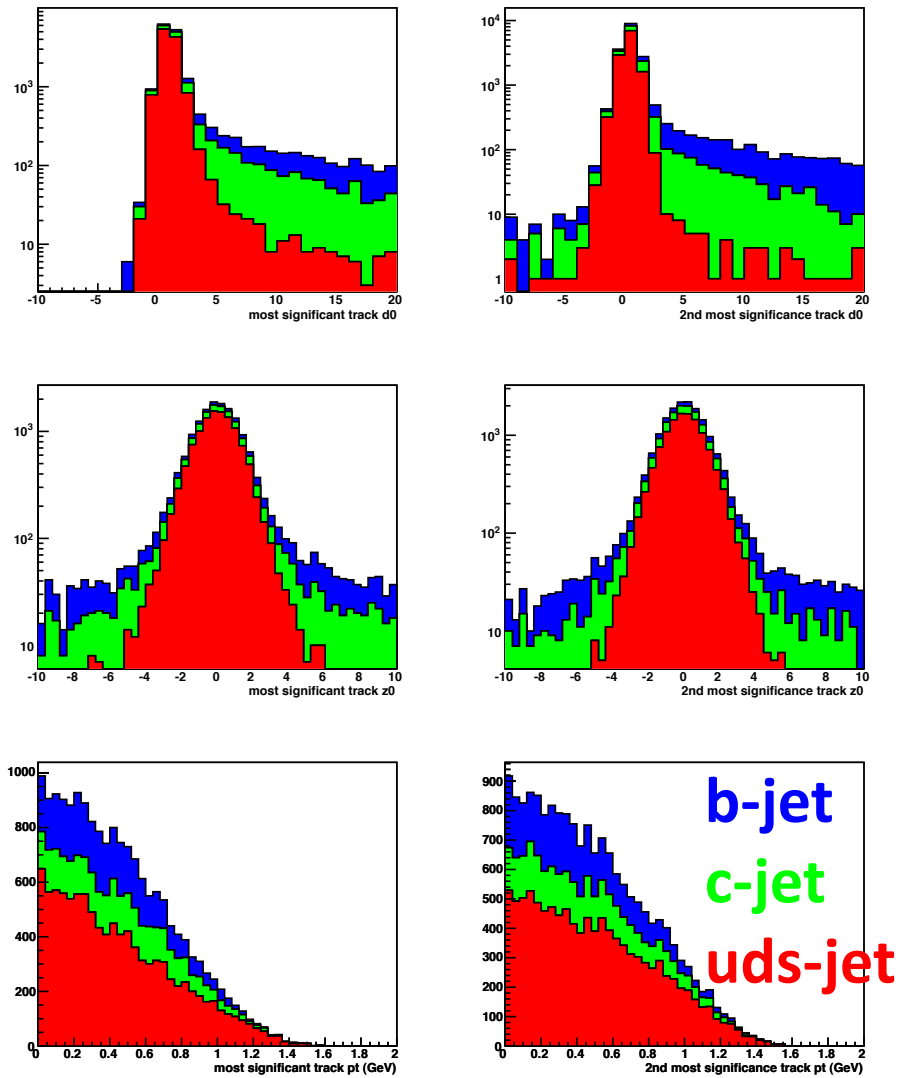


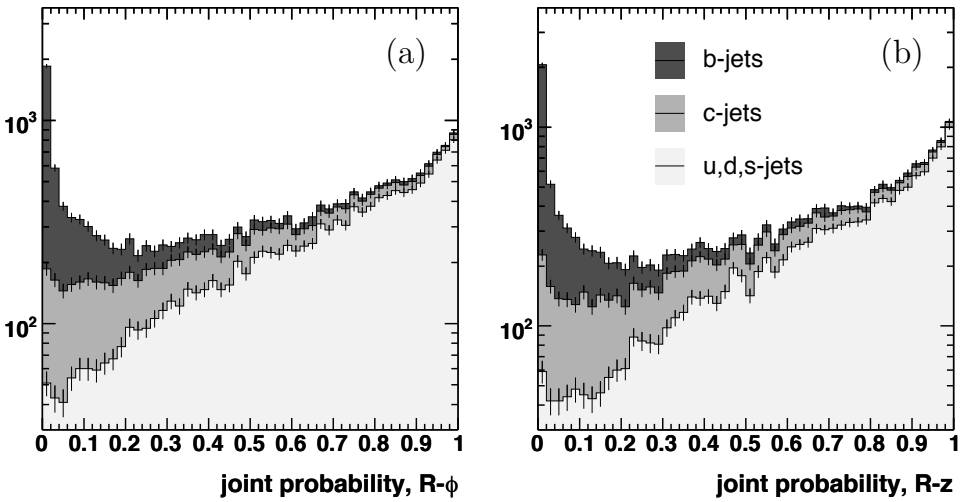
  - can find vertices for arbitrary topology with any number of tracks（must be separated from the primary vertex）
  - it takes lots of CPU time due to having to evaluate the vertex function at many points in space
- tear-down
  - starting from a set of tracks, remove tracks which are inconsistent (large chi-squared contribution)
  - if the primary tracks are properly removed, vertices can be found with high efficiency
- build-up
  - using track pairs as seed, attach other tracks
  - good seeds lead to good vertices

combination of variables

- LCFIVertex currently uses:
  - # of reconstructed vertices as categories
    - #vtx = 0, #vtx = 1, #vtx >=2
  - neural nets to combine variables derived from tracks & vertices
    - 6 variables for each category above
- we revisit both:
  - track/vertex variables
  - the event categorization (discrete variables)
- in this talk, we present some of the variables/categories we are considering using

input variables for tracks

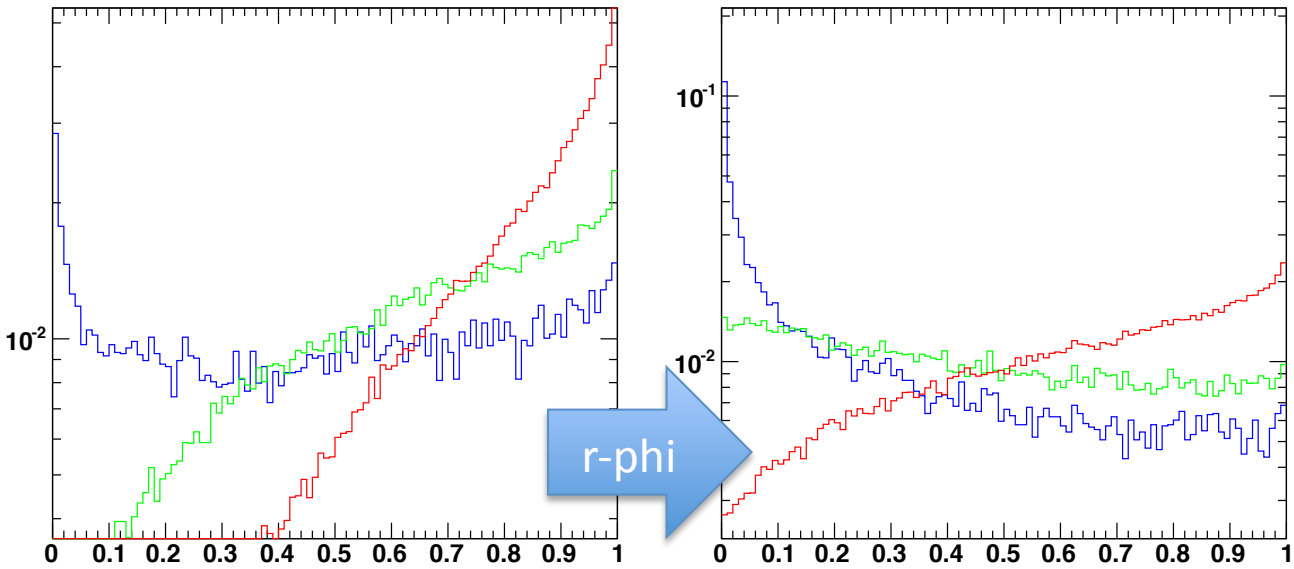




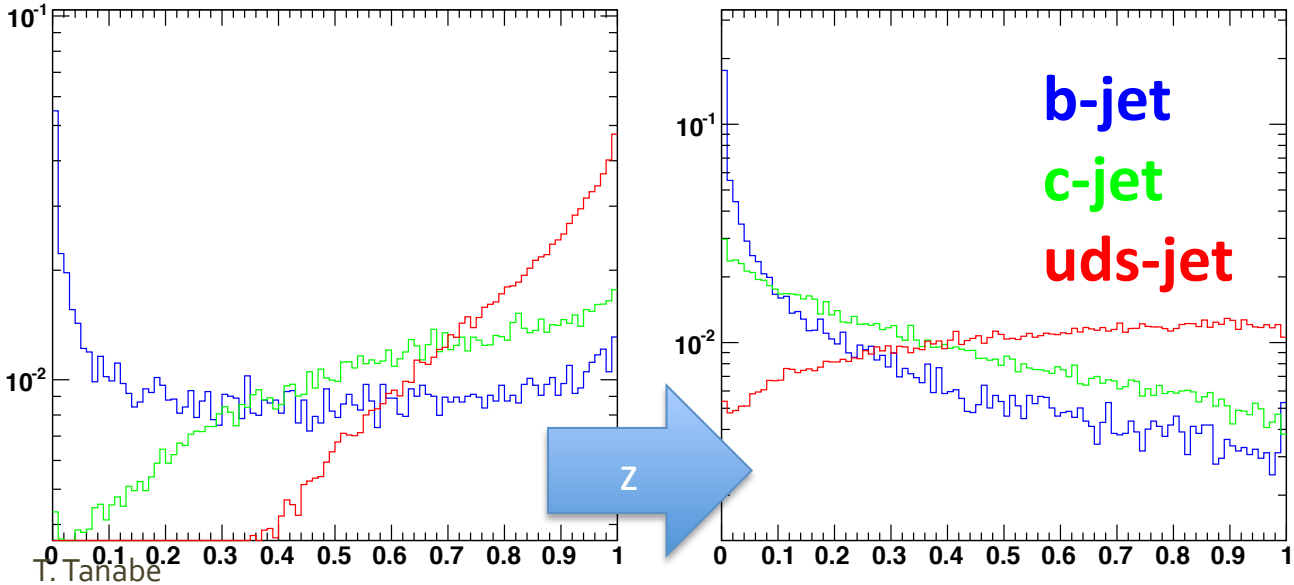
LCFIVertex uses:

- impact parameter
- impact parameter significance
- track momentum
- joint probability

joint probability

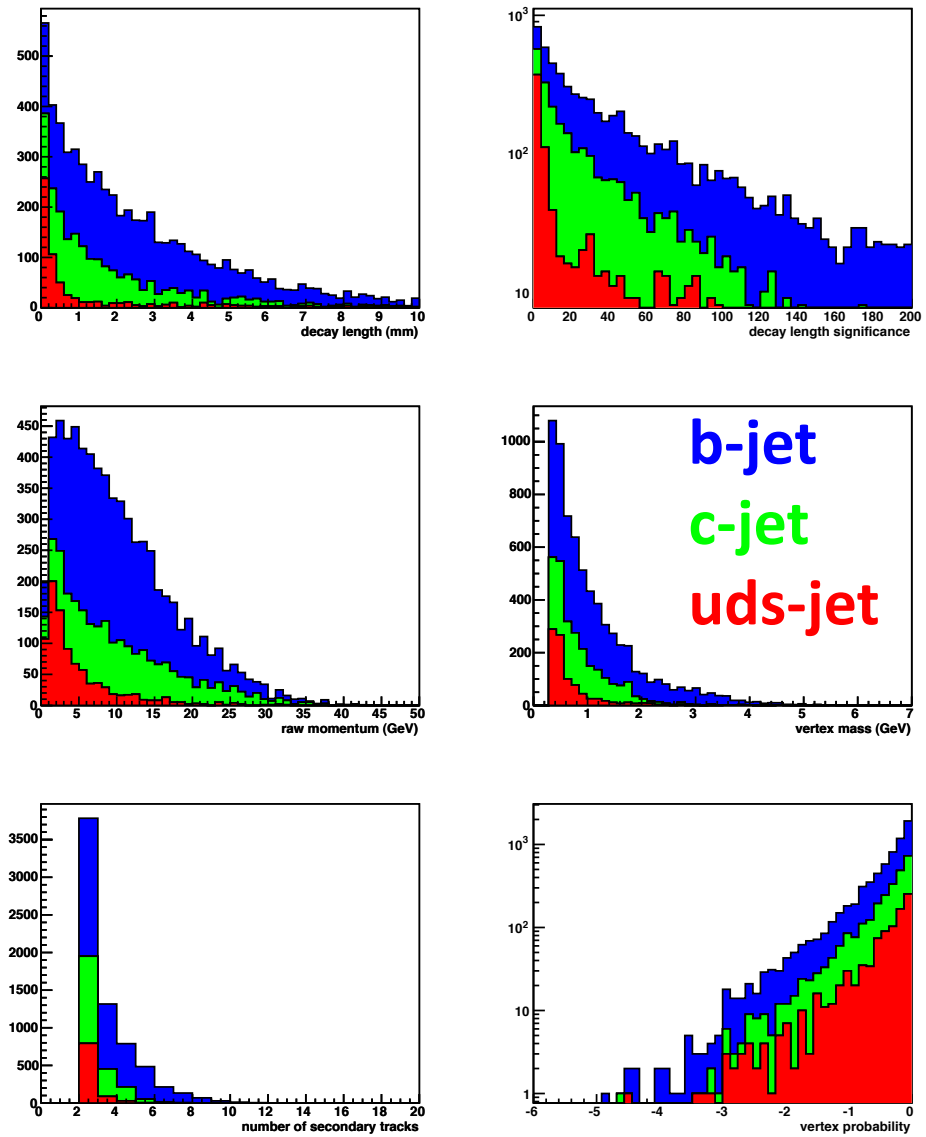


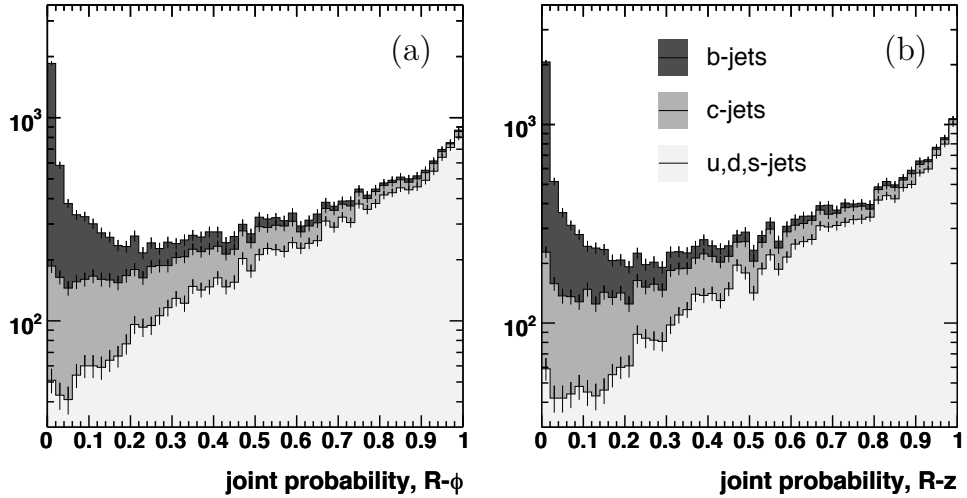
- joint probability = product of track probability to come from the primary
- parameterized using impact parameter significance



- we now remove the track with the highest impact parameter significance
- should be more stable (safeguard against spurious fake tracks)

input variables for events with vertices



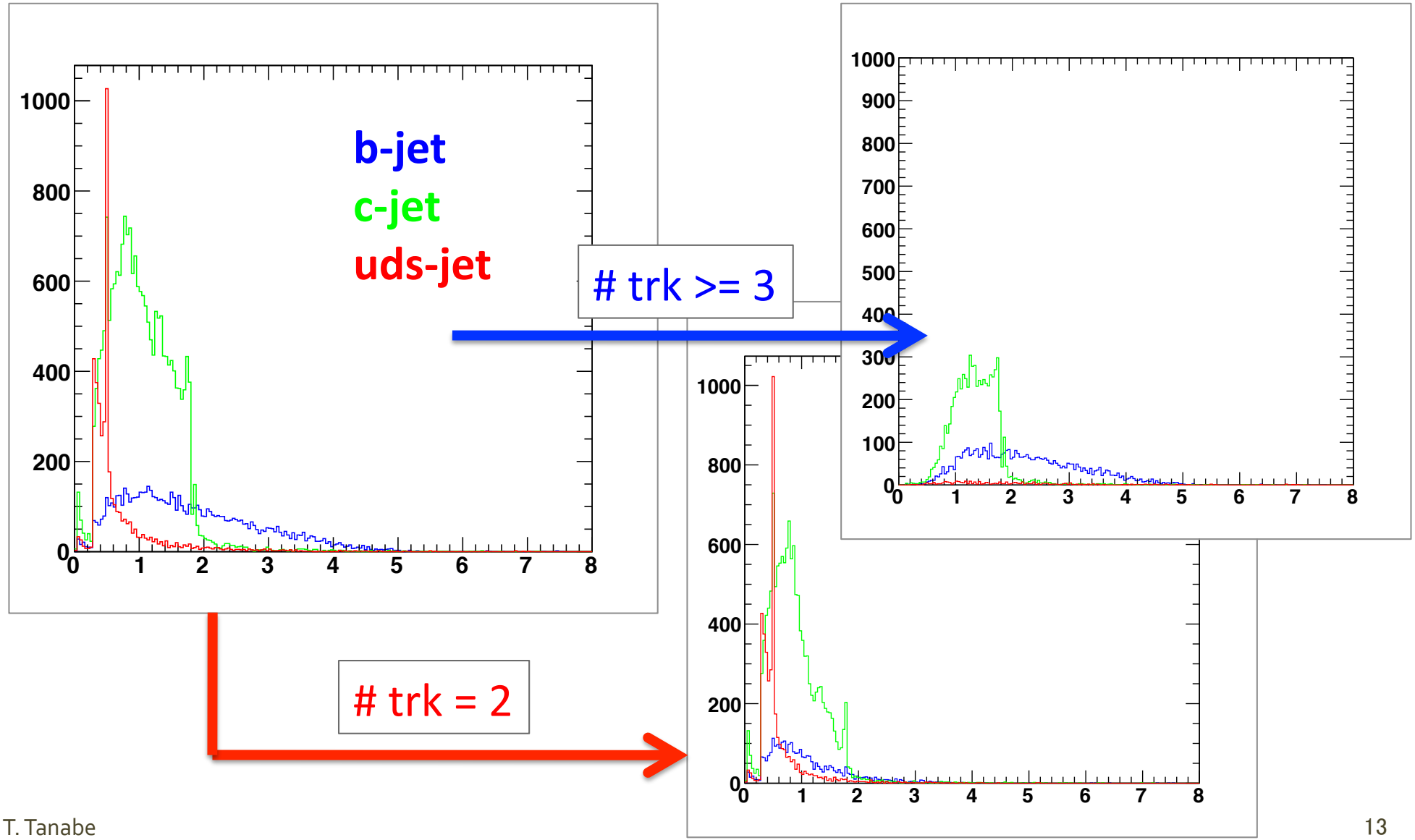


LCFIVertex uses:

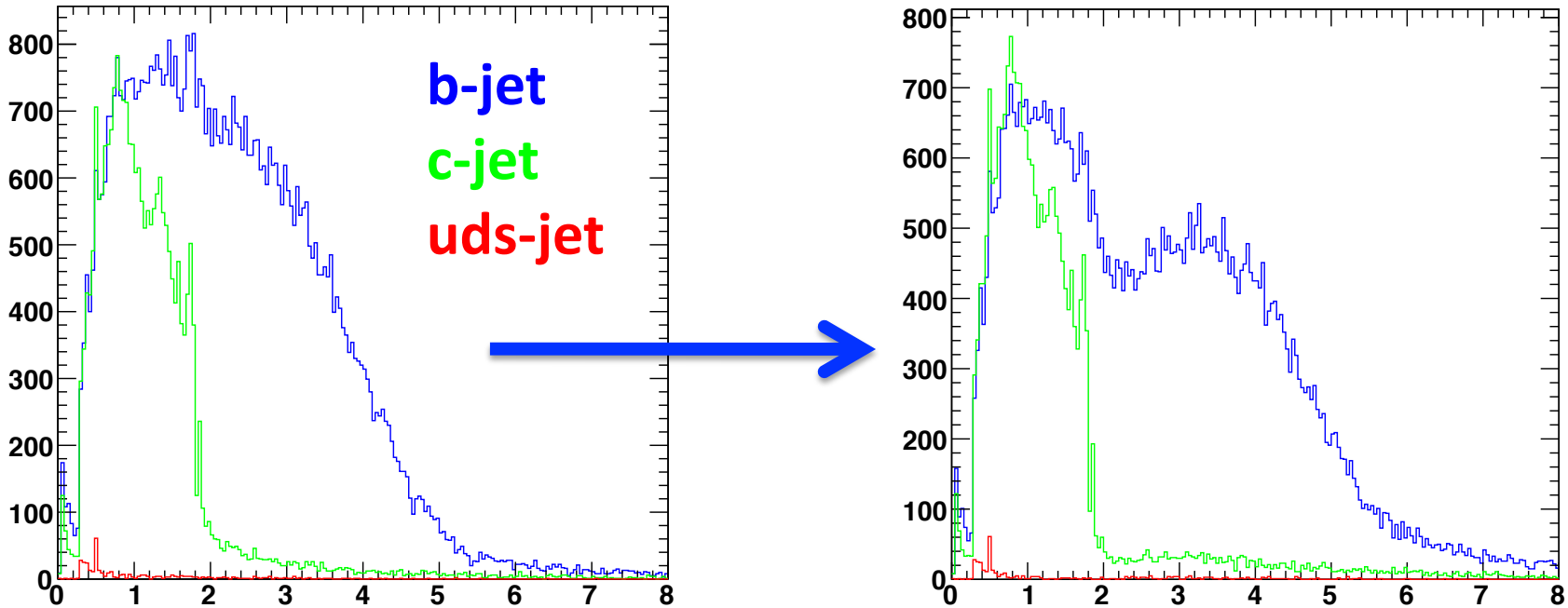
- decay length
- decay length significance
- vertex momentum
- vertex mass
- track multiplicity
- vertex probability
- joint probability

vertex mass (#vtx = 1 case)

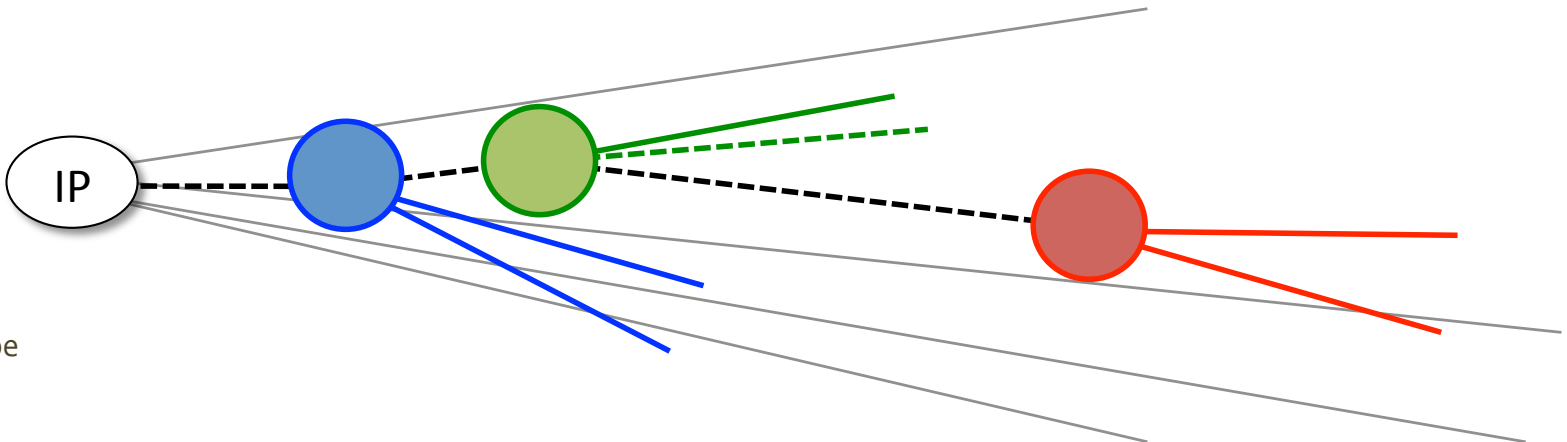
categorization based on the multiplicity of the leading vertex



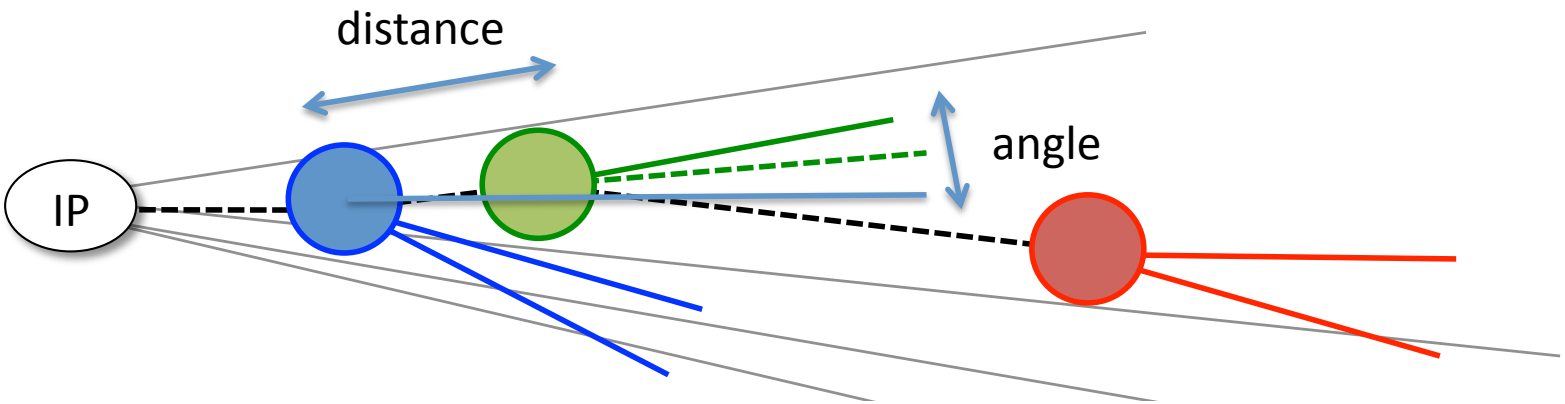
vertex mass (#vtx >= 2 case)

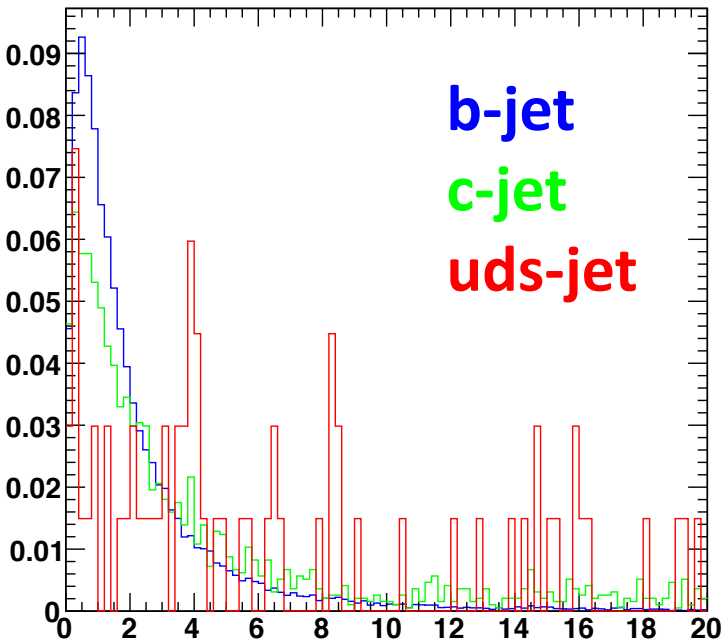


second vertex is constrained to have the D meson mass
(if the resulting combined mass exceeds)

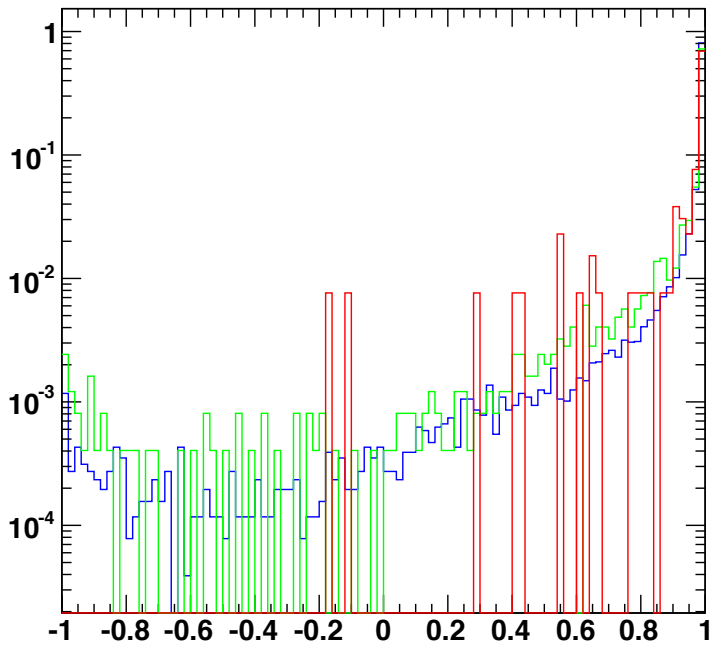


secondary vertex separation (#vtx >= 2)





distance



angle

leptons

- the presence of leptons (energetic, isolated) is a sign of semileptonic decays of heavy quarks

	bb	cc	uds
all events	97211	99015	97029

separate events by the presence of leptons*
(* assumes perfect lepton tagger)

	bb	cc	uds
# leptons = 0	36525	51458	64743
# leptons > 0	60686	47557	32286

<u>good lepton tagging algorithm is urgently needed</u>

leptons

- for events *without* reconstructed vertices:

	bb	cc	uds
all events	16950	50476	92135

separate events by the presence of leptons*
(* assumes perfect lepton tagger)

	bb	cc	uds
# leptons = 0	6178	25745	62351
# leptons > 0	10772	24731	29784

more ideas: lepton track impact parameters with respect to the secondary vertices (significant deviation is a sign of an additional flavor-changing decay)

summary

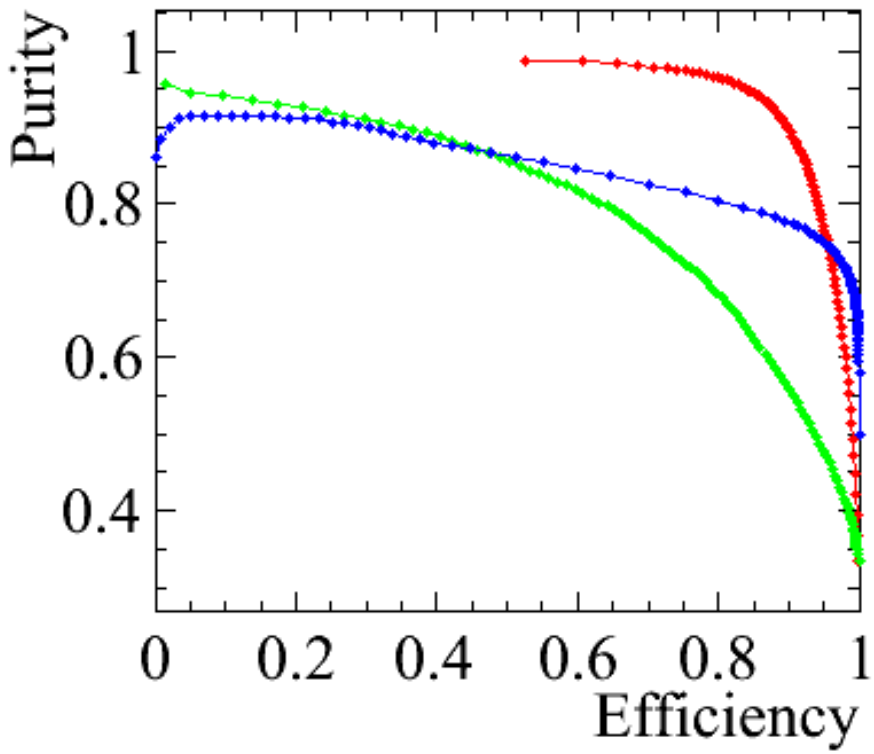
- performance of flavor tagging is critical to the ILC physics program particularly for processes involving many heavy flavor jets
- the procedure for flavor tagging is being revisited
  - many new variables & categories are being considered
- time scale ~ reconstruction software freeze for DBD studies
- flavor tagging optimization in *multi-jet environments*
  - see talk by T. Suehara on Thursday

ILC-CLIC collaboration

- our ideas are being tested using the ILD detector @ ILC
- we would be happy to look at other detector configurations e.g. CLIC detectors
- if you're interested, please provide us with MC samples
  - special note for the CLIC configuration:
    - the longer b-flight and its resulting material interaction should be properly addressed in the samples
    - please document the changes in geometry (e.g. VXD, B-field, beam spot size)
  - samples:
    - Z->qq @ E_{cm} = 91.2 GeV for comparison
    - Z->qq @ E_{cm} = 1 TeV and 3 TeV without ISR

back up

flavor tagging performance



LCFIVertex (ilcsoft v01-06)