

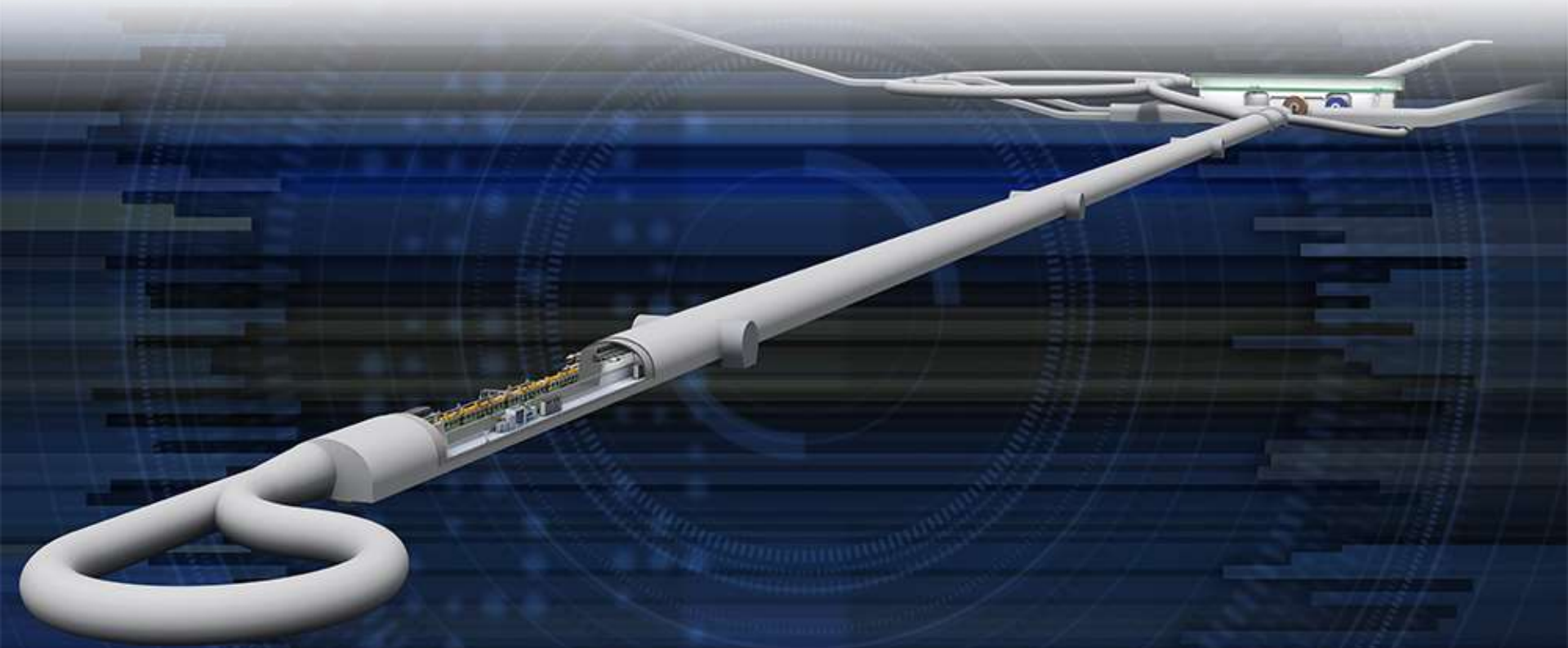
# News on LCFIPlus

Tomohiko Tanabe

(on behalf of LCFIPlus Collaboration)

March 2, 2015

TYL/FJPPL Workshop on Top Physics at the ILC at LAL



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## **Advertisements:**

- ALCW2015
- #mylinearcollider

## **LCFIPlus:**

- Introduction
- Implementation
- Performances (DBD)
- Current Plans



Asian Linear Collider Workshop | under  
**ALCW**  
**2015**  
 20-24 April '15 KEK Tsukuba, Japan

**Asian Linear Collider Workshop 2015**  
**KEK, Tsukuba, April 20-24**

International workshop co-hosted by KEK, ACFA and LCC, to study the physics and detectors and the implementation of future linear electron positron colliders.

On April 22, a special symposium "LC Tokyo Event" at the University of Tokyo as a part of the workshop.

**ILC Tokyo Event :**  
**Wednesday, April 22, 2015**

- Main plenary session of ALCW2015
- Lectures and a panel discussion for ILC in Japan
- ILC Food Festa: enjoy the cuisine from the countries of the signatories to the ILC TOR



Illustration: Ray Chen

For those of you who have already registered to ALCW2015, thank you!!

If you know colleagues who are still deciding, or visiting Japan at the time, please try to convince them to attend.

Please don't miss the Wednesday event in Tokyo. This is going to be important, with many participants outside the field.

**International Organizing Committee**

Ties Bethe (DESY)  
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 Katsuki Fuji (KEK)  
 Ji Guo (IHEP, Beijing)  
 Christophe Griean (Barcelona / DESY)  
 Michael Harrison (BNL)  
 Wei-Shu Hou (NTU, Taipei)  
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 Kajari Maitland (TPP)  
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<http://www-conf.kek.jp/alcw2015/>



# #mylinearcollider campaign

The **Linear Collider Collaboration** is collecting **video messages** of physicists supporting the **ILC**.

The purpose is to tell the world that there are real people with names and faces who are supporting the **ILC**. We consider this effort to be very important.



In the video, please state:  
your **name** and **institution** with a **short message** (~1 min) about *e.g.* why you think the ILC should be built.

Your message will get uploaded to YouTube.

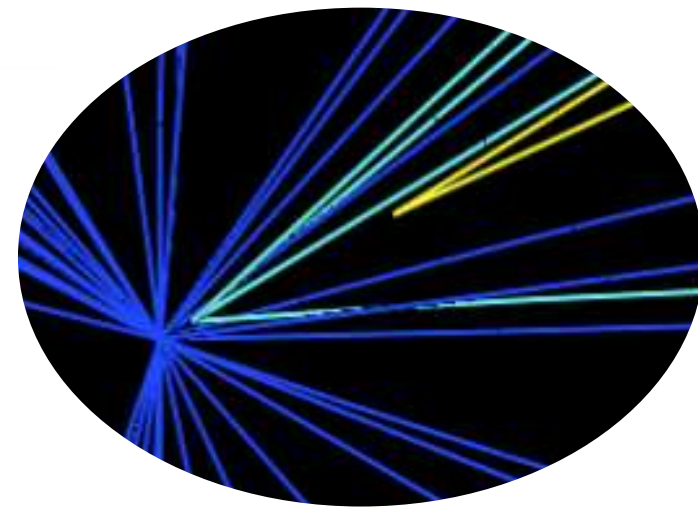
Search "**mylinearcollider**" to see some examples.

**Many thanks to those (500+) who have already contributed!  
Please help spread the word!**



**THANK YOU!!**

# Introduction



- Flavor tagging crucial at ILC:
  - e.g.  **$h \rightarrow bb/cc$ ,  $t \rightarrow bW$ ,  $H^0 A^0 \rightarrow bbbb$**
- Challenges:
  - reconstructing **secondary** and **tertiary** decays
  - environment with **many jets** (new for  $e^+e^-$  at ILC energies)
- LCFIPlus:
  - Package of algorithms to perform secondary vertex finding, jet finding, and flavor tagging optimized for ILC analyses
    - In particular: Higgs self-coupling at 500 GeV
    - Synergistic with **vertex charge measurement**

# Introduction

- Historical context:
  - **LCFIVertex** [NIM A 610 573 (2009)]
    - used in ILC LOI and CLIC CDR
  - Evolved into **LCFIPlus** (2010~)
    - used successfully by **both SiD and ILD** in DBD studies
    - publication currently under preparation
- LCFIPlus group was recently expanded.
  - Current list of developers: M.Kurata, T.Suehara, J.Strube, TT

# Detector Requirements

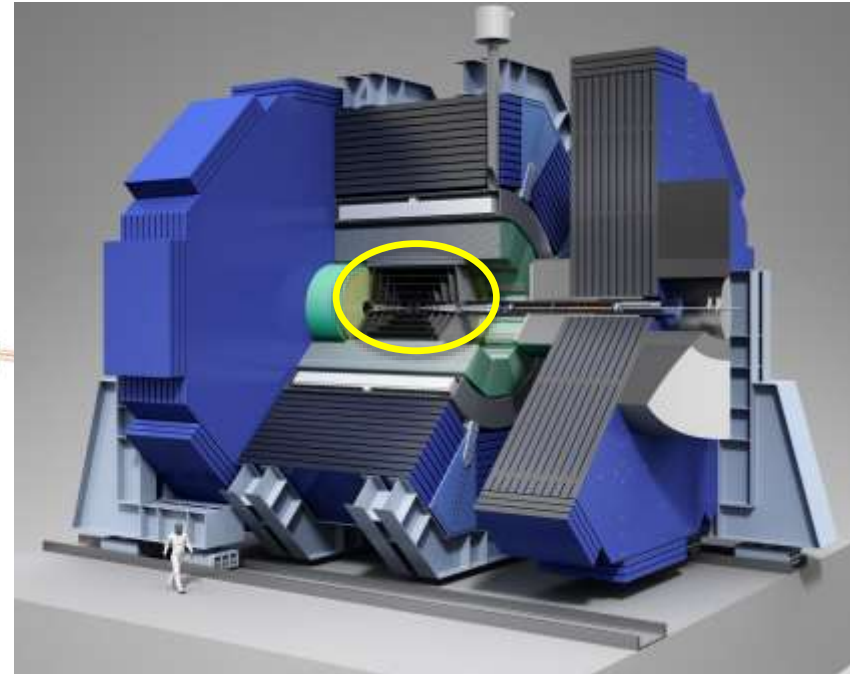
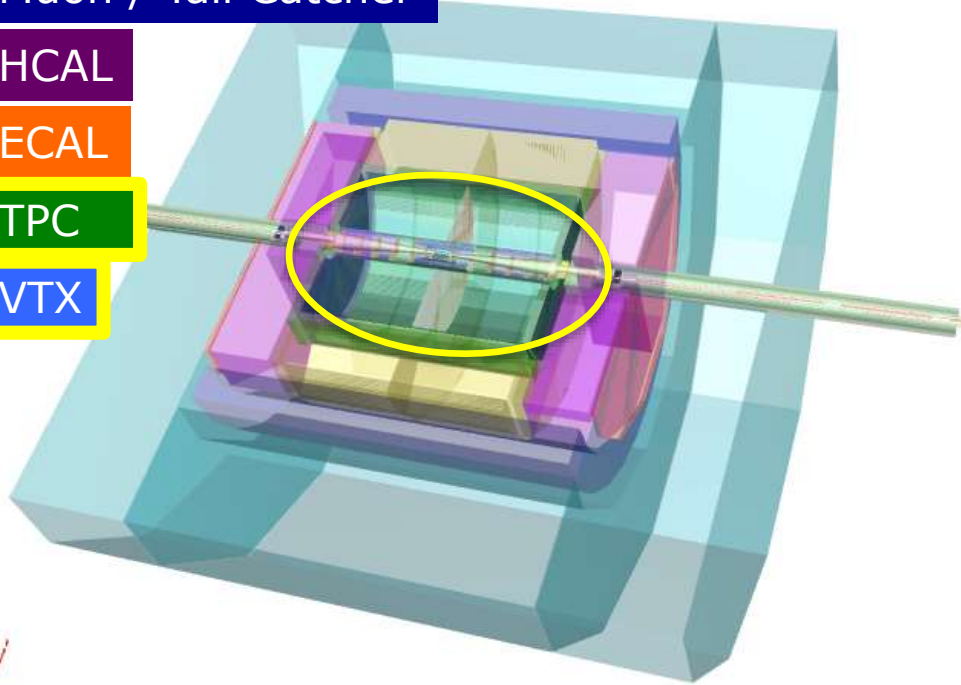
Muon / Tail Catcher

HCAL

ECAL

TPC

VTX



## Vertex Detector (ILD / SiD)

inner radius	15 / 14 mm
outer radius	60 mm
impact parameter resolution	< 5 $\mu\text{m}$ (high mom.)

**Vertex:** Impact parameter resolution

**Tracker:** Track quality selection /  $V^0$  rejection

**Calorimeters:** Lepton identification / PFA object selection



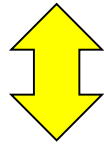
# Software Implementation

“LCFIPlus world”

## LCFI+ Data

**Tracks, Neutrals, Vertices, Jets, ...**

- Automatic type identification  
(Allow one name with multiple types)
- Automatic creation/deletion  
(using ROOT class dictionary)



## Algorithms

**Vertex Finder, Jet Finder,  
Flavor Tagger, ...**

- Parameters class used for type-safe configuration

“LCIO world”

## LCIO Data

- Automatic conversion from LCIO to Lcfiplus classes
- Conversion to LCIO invoked by processor

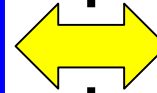
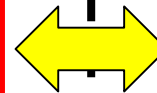


configure

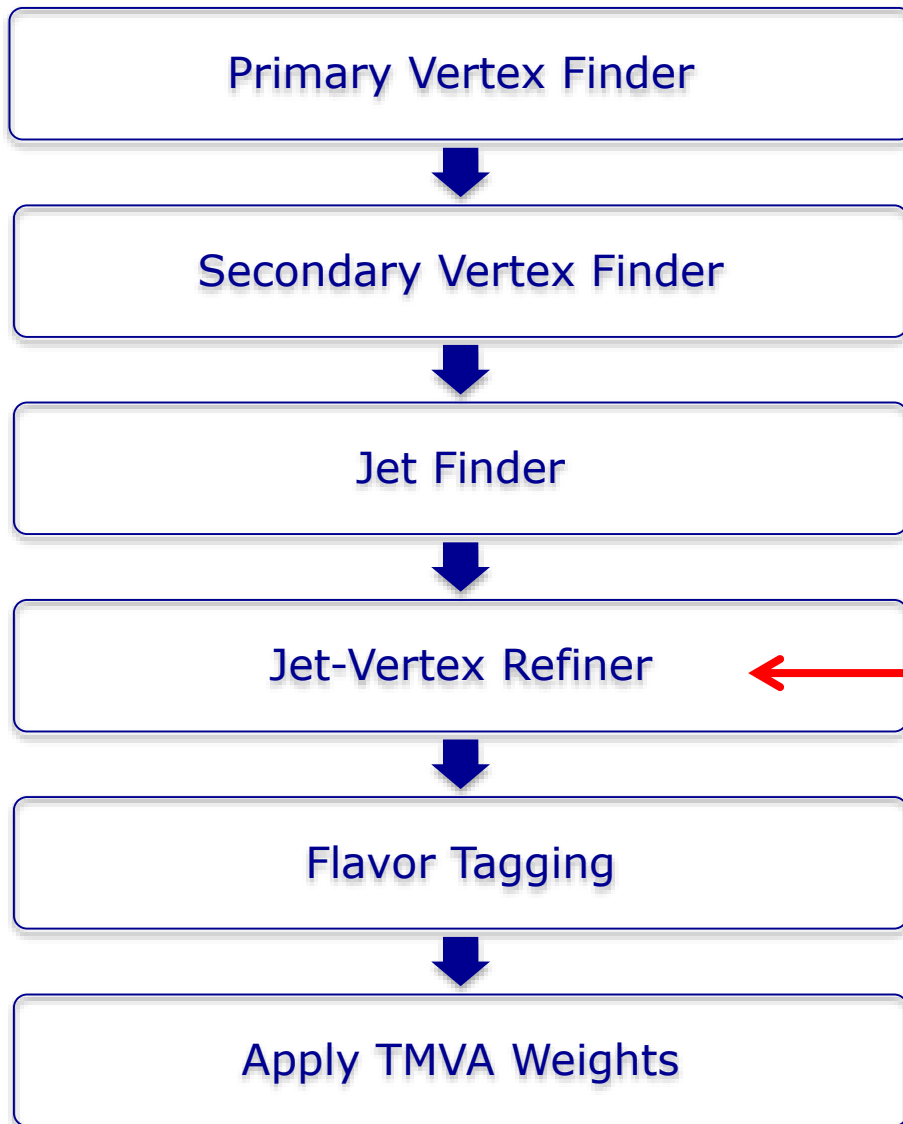
## LcfiplusProcessor

**Marlin processor**

- Marlin parameters control algorithms
- LCIO I/O configuration



# Reconstruction Flow



**Vertex finding first,  
Jet finding second**

**Vertex charge optimization  
could go here**

# Vertex Finder

Motivated by *vertex-first, jet-second* approach, a high purity vertex finder was developed. Compared to LCFIVertex, the LCFI+ vertex finder gives:

- fewer rate of primary tracks
- better efficiency of secondary tracks
- improved  $V^0$  rejection

*in realistic multi-jet environment*

(a) $ZHH \rightarrow qqbbbb$	Track origin			
	Primary	$b$ hadron	$c$ hadron	Other
Number of all reconstructed tracks	67575	12912	15246	4087
Number of tracks used by ZVTOP ...in <i>good</i> vertices	[ 1162 -	[ 8534 8248	[ 10404 10103	[ 999 -
Number of tracks used by our original vertex finder ...in <i>good</i> vertices	[ 617 -	[ 8717 8551	[ 10529 10333	[ 358 -
(b) $t\bar{t} \rightarrow bbqqqq$	Track origin			
	Primary	$b$ hadron	$c$ hadron	Other
Number of all reconstructed tracks	74504	8945	12602	4219
Number of tracks used by ZVTOP ...in <i>good</i> vertices	[ 920 -	[ 5999 5830	[ 8353 8137	[ 1024 -
Number of tracks used by our original vertex finder ...in <i>good</i> vertices	[ 420 -	[ 6161 6060	[ 8447 8279	[ 341 -

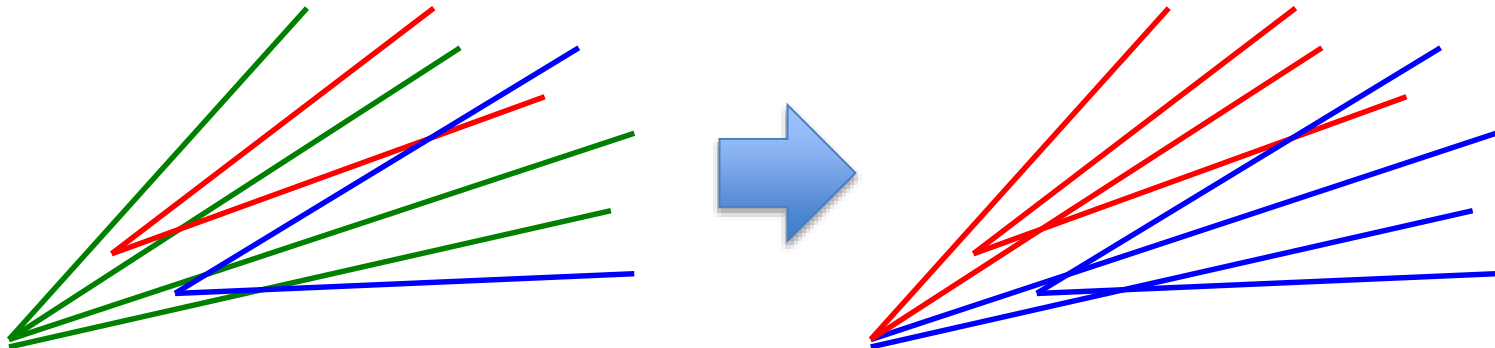
Good performance is obtained in reasonable computing time without the help of jet finders.

# Jet Finder

## Procedure optimized for discrimination of b and c jets, taking advantage of vertex information.

- Find secondary vertices first → Prevent secondary particles to go into different jets
- Cluster vertices based on angle / distance
- Divide particles into jets, keeping vertices intact → Boost b tagging efficiency
- Find single tracks from secondary decays in proximity of secondary vertices → improve b/c separation in one vertex category

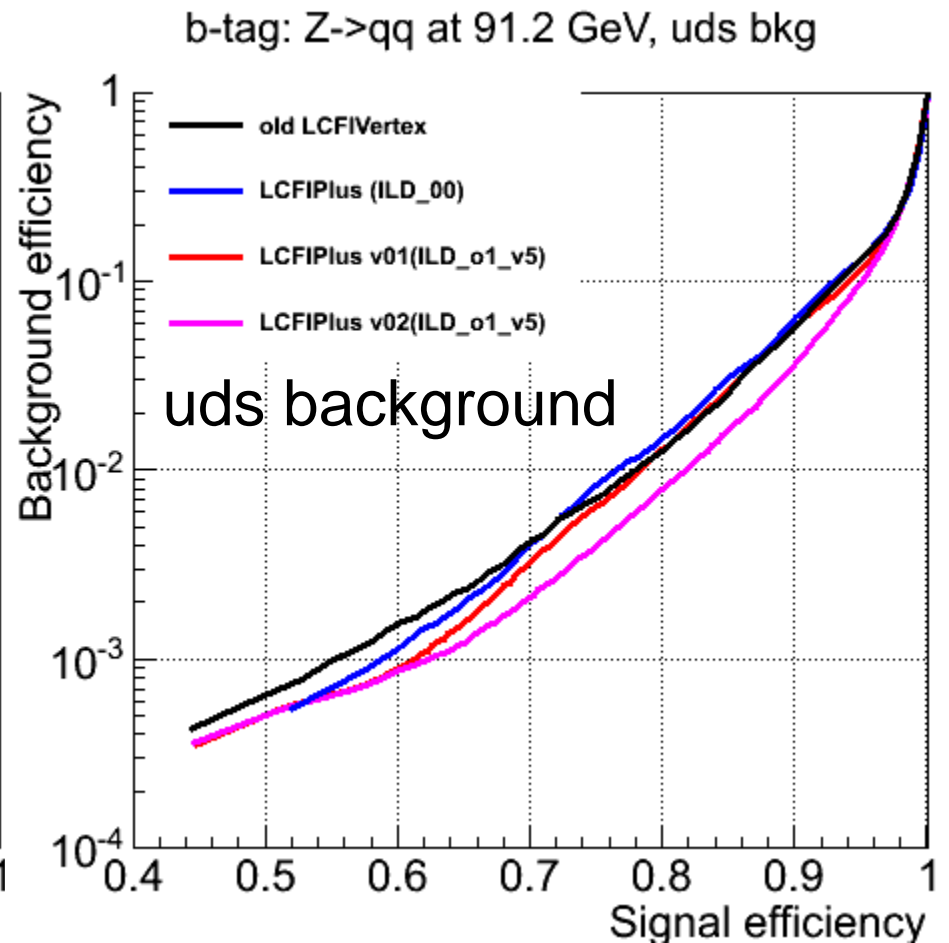
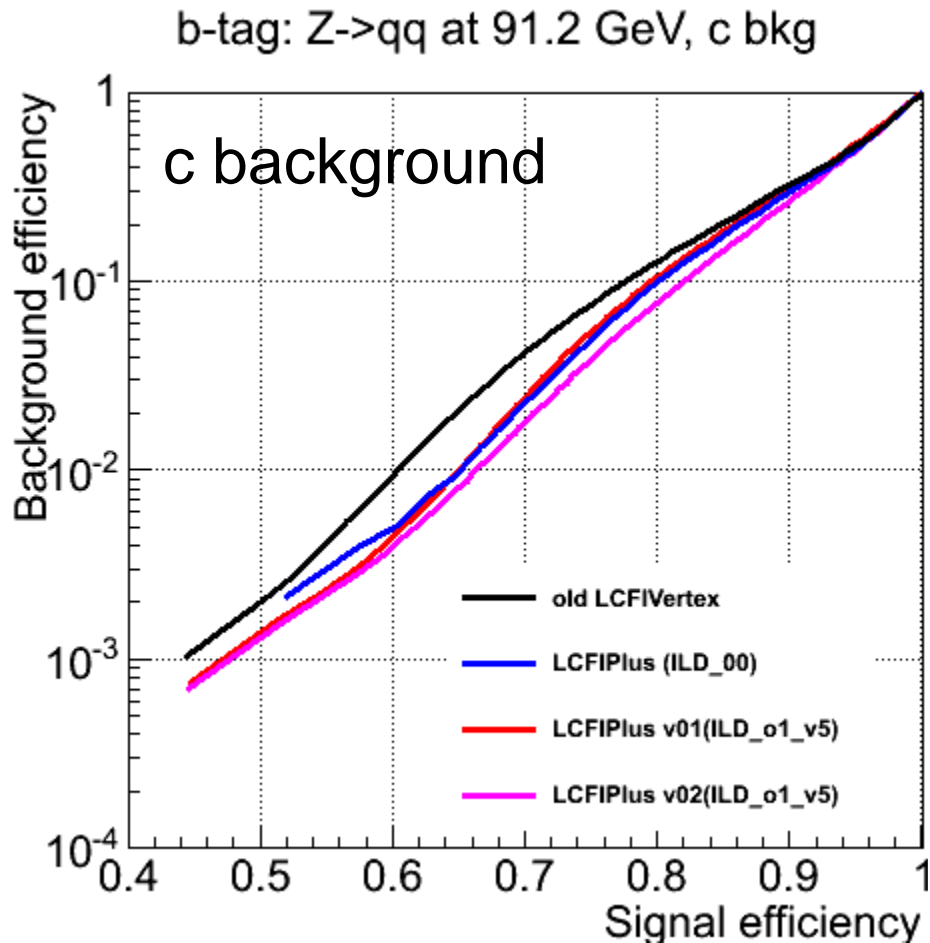
	1+1 vtx	2 vtx
bb	20.4%	22.2%
cc	0.73%	0.16%
qq	0.06%	0.04%





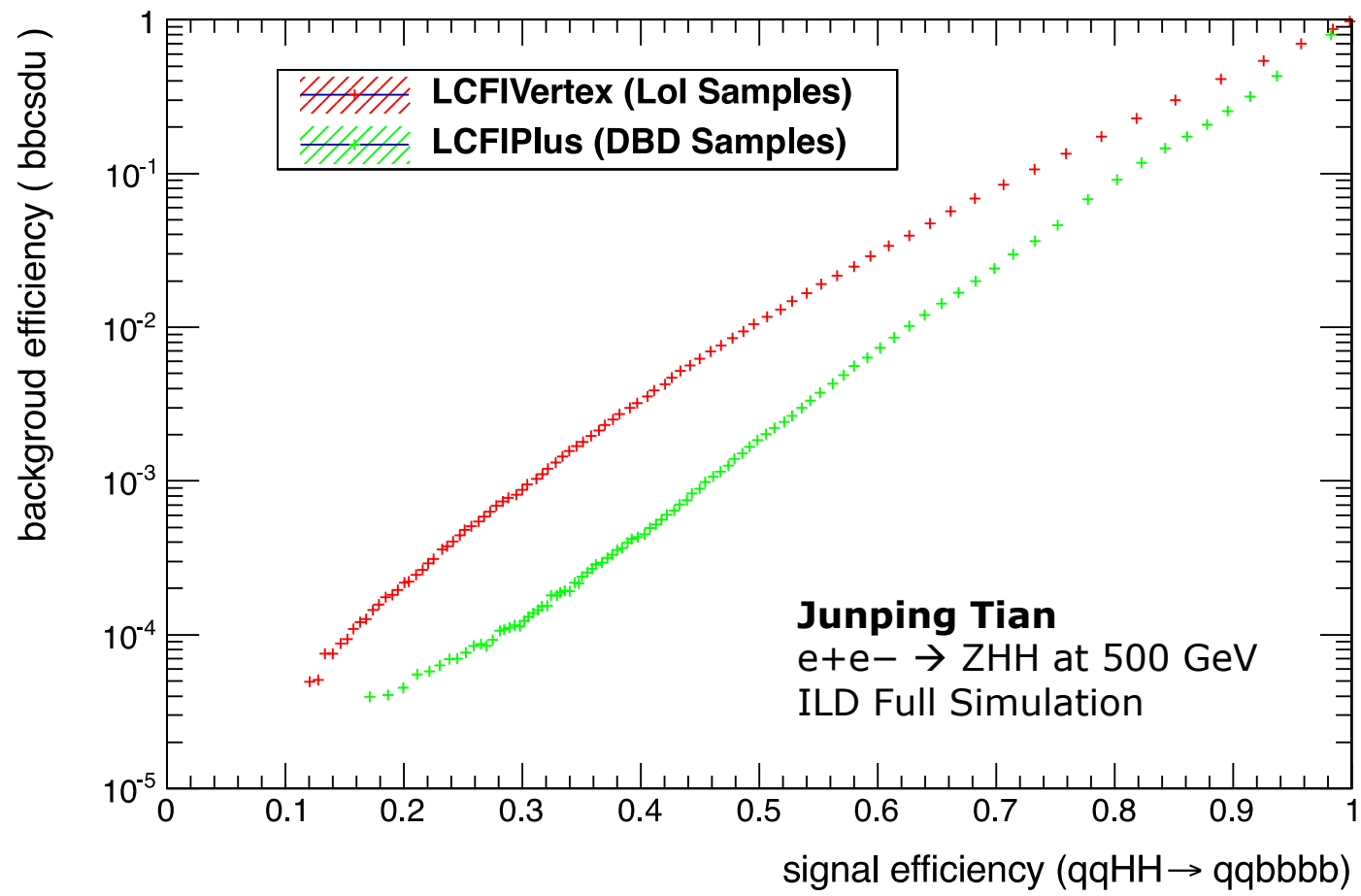
- Use of TMVA multiclass classification with boosted decision trees (BDT)
  - 3 classes: b, c, uds
  - 4 categories: #vtx = 0, 1, 1+single, 2
  - 20-30 input variables
  - 2 indep. output: b-likeness, c-likeness
- Training typically performed with 2, 4, 6 jet events
  - e.g. ZZZ → bbbbbb, cccccc, qqqqqq
  - O(100k) jets per class sufficient for training

# Performance at Z-pole (LoI vs. DBD)



Improved all efficiency regions.

# Performance: ZHH at 500 GeV



Improvement in 6 jet events

# Current Plans

- Automatic creation of joint probability histograms
  - Assigned to T. Suehara (Done)
- Dealing with pair backgrounds
  - Assigned to J. Strube (In progress)
- Inclusion of new jet finders: hadron kt, Valencia, etc.
  - Assigned to TT (In progress)
- Improving particle ID / vertex mass
  - Assigned to M. Kurata (→ See later talk)
- Vertex charge optimization
  - **Looking forward to fruitful collaboration with LAL**
- Areas that could still be improved
  - Flavor tagging in 1-vertex + 1-track category
  - Reoptimization of secondary vertex finder
    - Current cutoff at 300  $\mu\text{m}$ , not energy-dependent



# Repositories & Documentation

- DESY repository (ilcsoft release)
  - <https://svnsrv.desy.de/viewvc/marlinreco/LCFIPlus/>
- **(NEW)** Git repository (development version)
  - <https://github.com/lcfiplus/LCFIPlus>
- Documentation
  - <https://confluence.slac.stanford.edu/display/ilc/LCFIPlus>