Top mass measurement with the CLIC_ILD detector at 500 GeV

Stephane Poss[1], Frank Simon[2,3], Katja Seidel[2,3]

[1]CERN, Geneva, Swizerland
[2]MPI for Physics, Munich, Germany
[3]Excellence Cluster 'Universe', Munich, Germany

LCWS 2011

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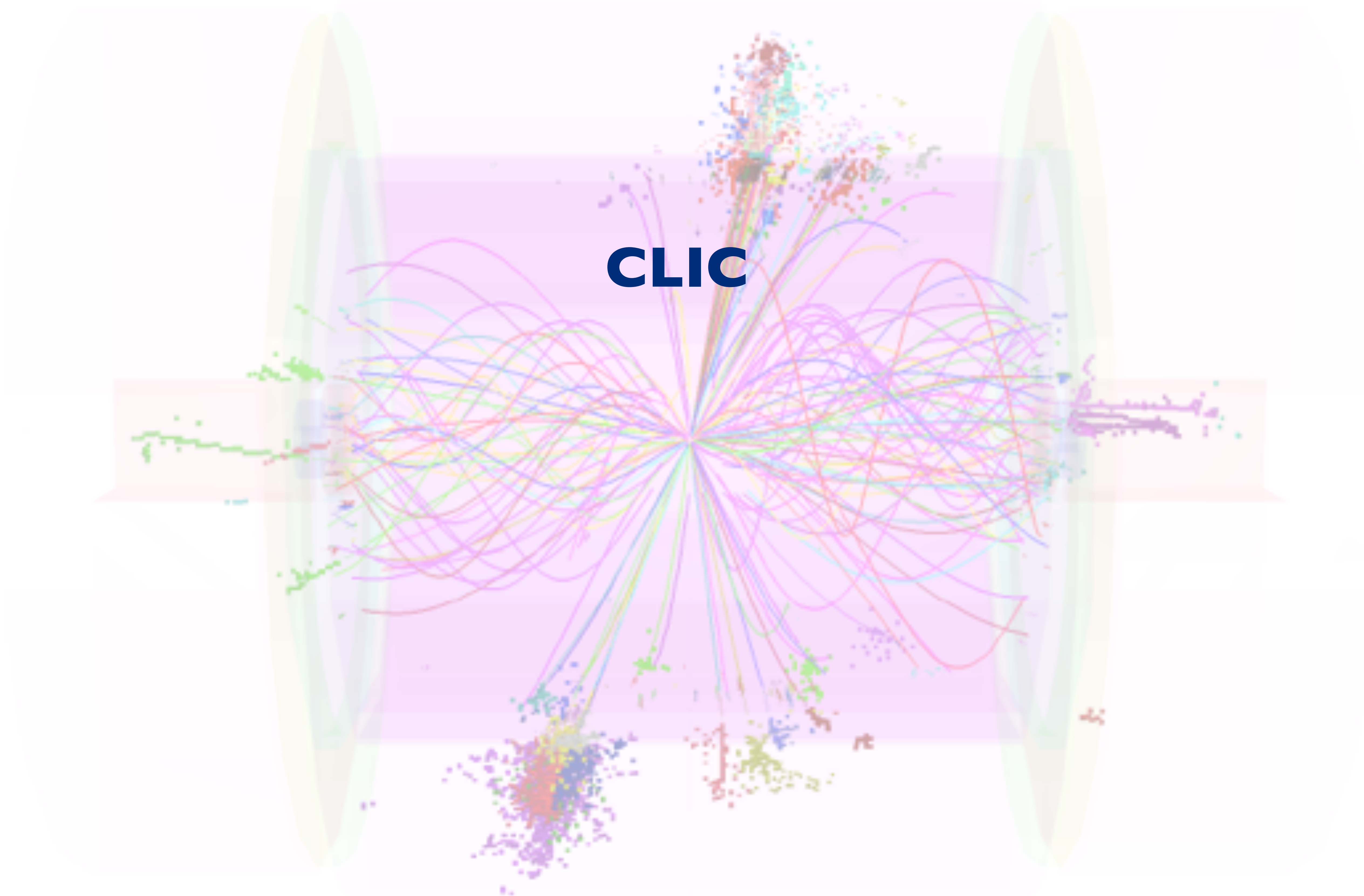
Outline

- CLIC Introduction
  - Machine and Detector
  - CLIC background conditions
  - Event simulation and reconstruction
- Analysis Chain
  - Decay channel selection
  - Event topology reconstruction
  - Physical Background rejection
- Final results for CLIC CDR
- Summary

CLIC



CLIC and CLIC_ILD

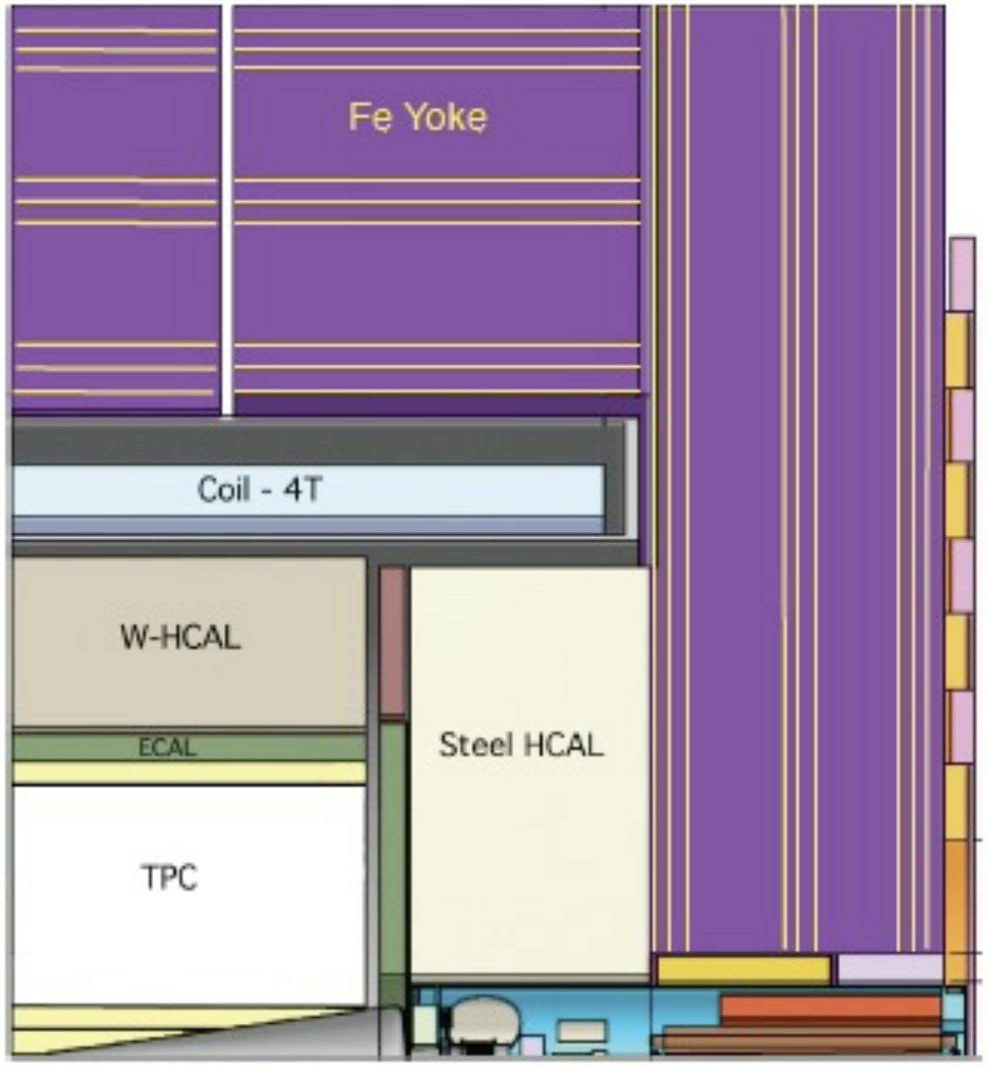
Machine:

- e+e- machine
- design $\sqrt{s}$ = 3 TeV
- different energies possible
- staged construction

→ test SM and LHC results with high precision
search for physics beyond SM / LHC

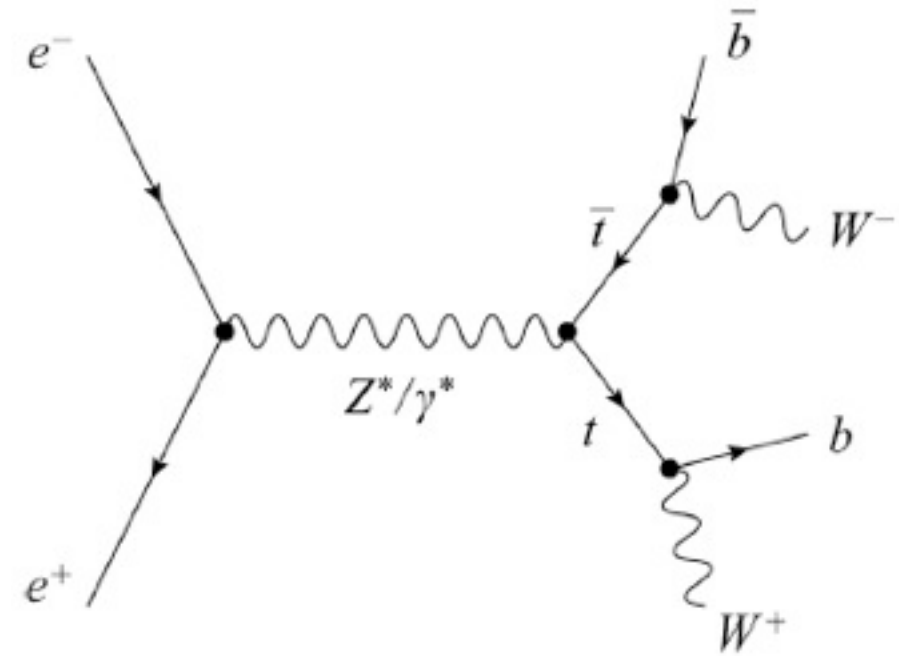
Detector:

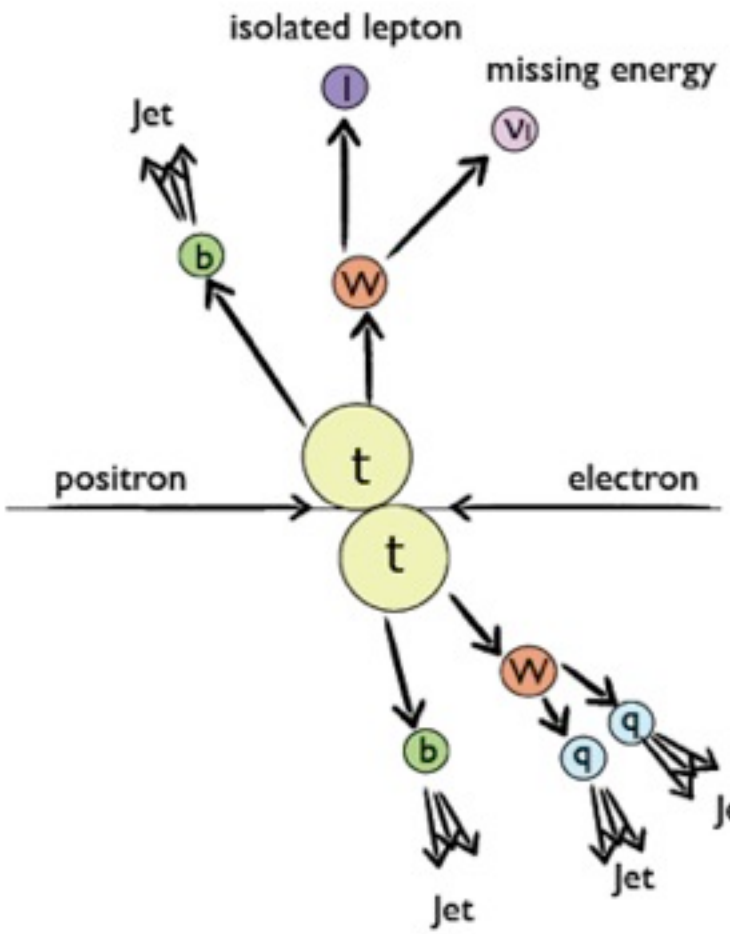
- Here: CLIC_ILD
- Optimized for Particle Flow
  - excellent tracking detectors
  - high granular calorimeter
  - time stamping capability
- See talk by M. Thomson (LCWS Plenary, Monday 17:35)

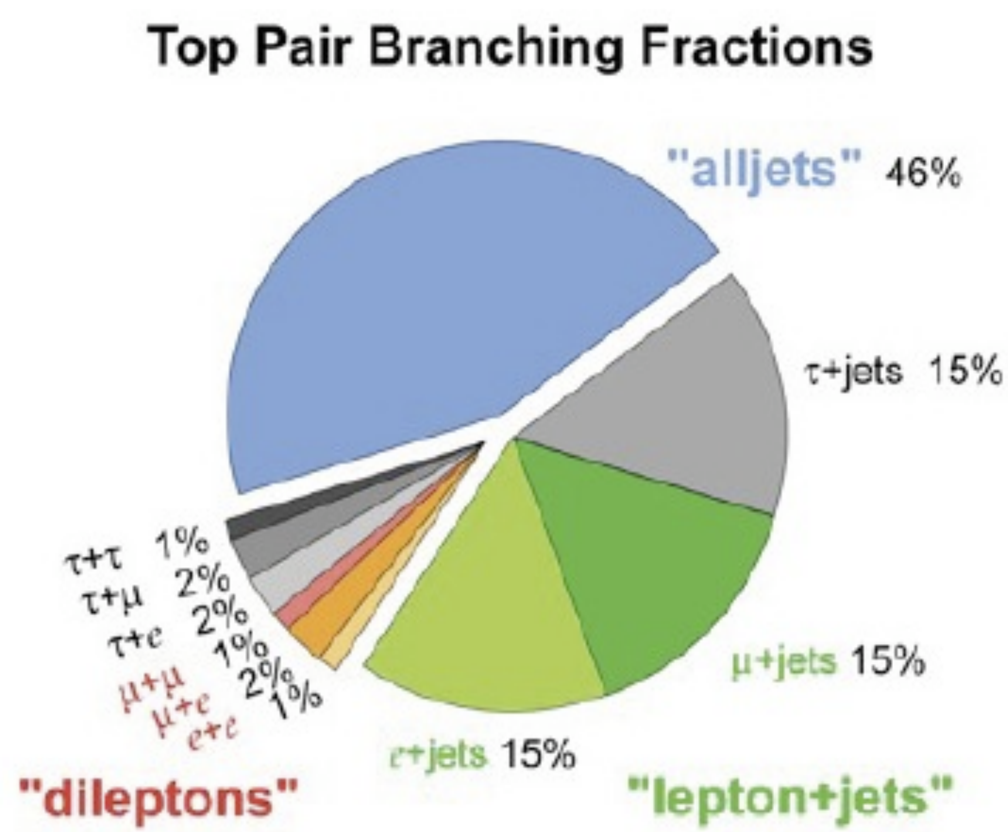


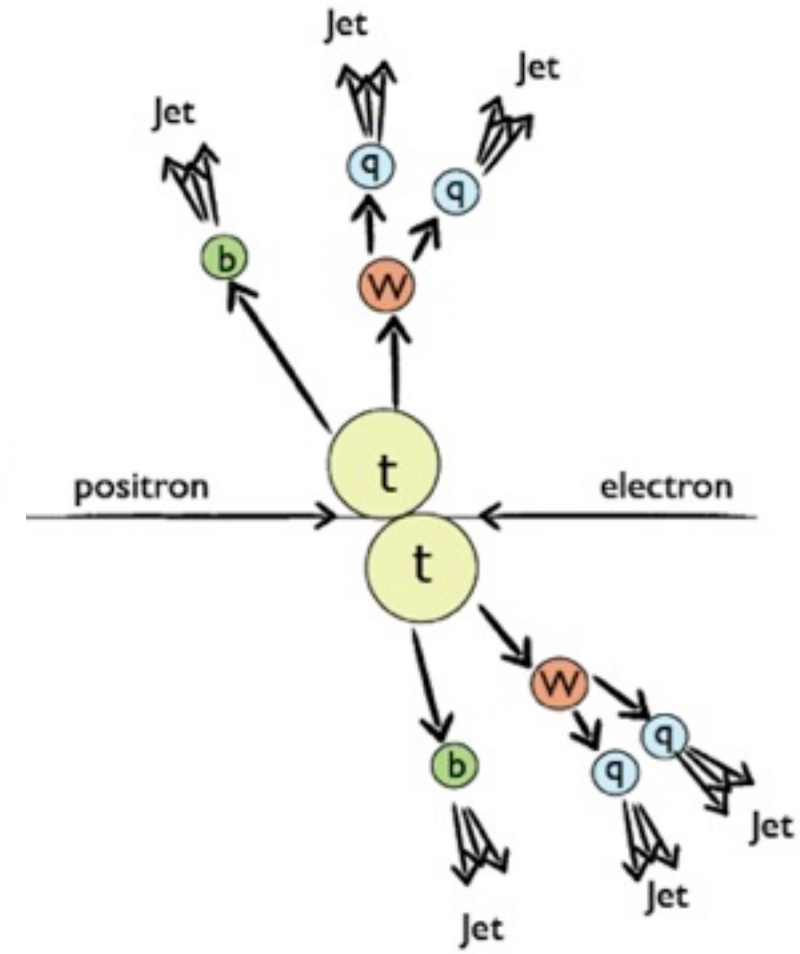
Top physics at CLIC

- Staged construction mode possible: 500 GeV
- Analysis part of the CLIC conceptual design report
- Analysis: Top mass measurement from top pair production
  - full-hadronic channel
  - semi-leptonic channel





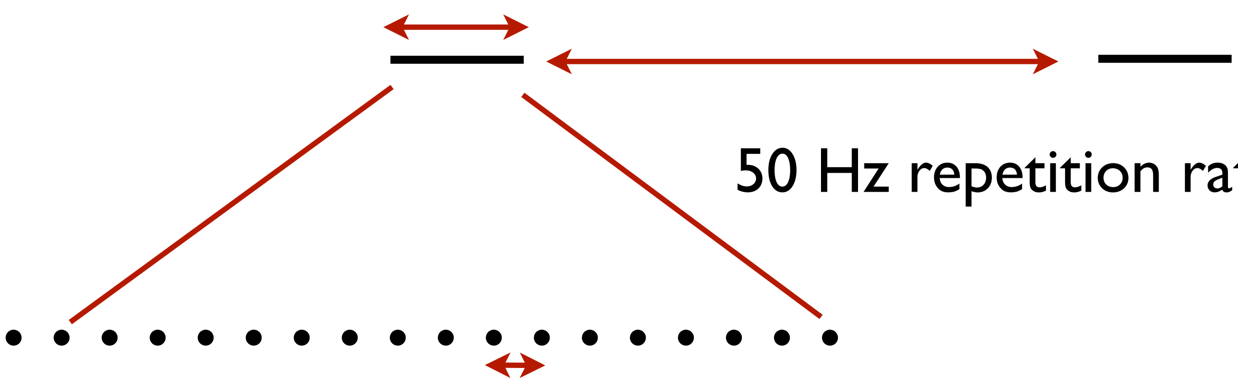


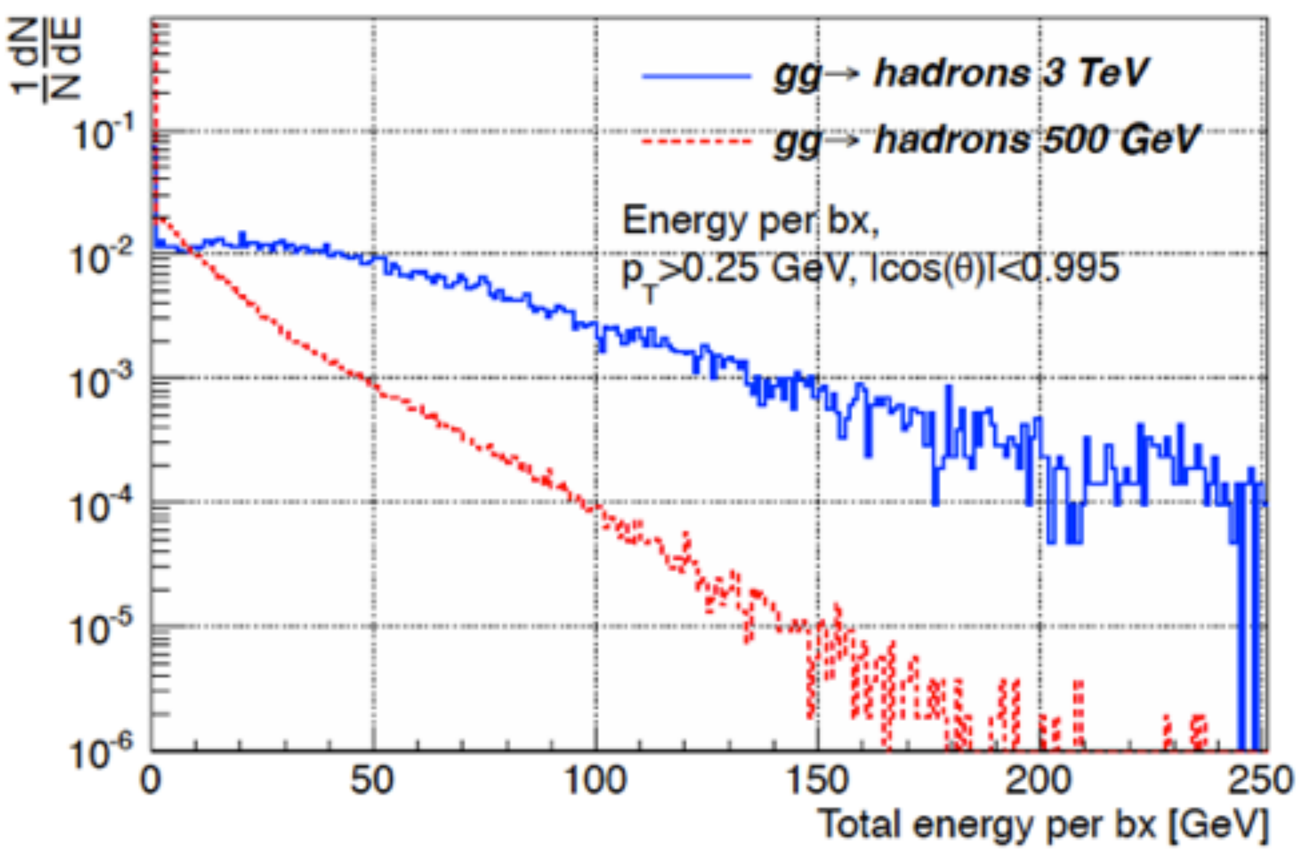


Conditions at CLIC

The bunch structure at CLIC

- 0.5 ns bunch spacing
- 312 bunches per train



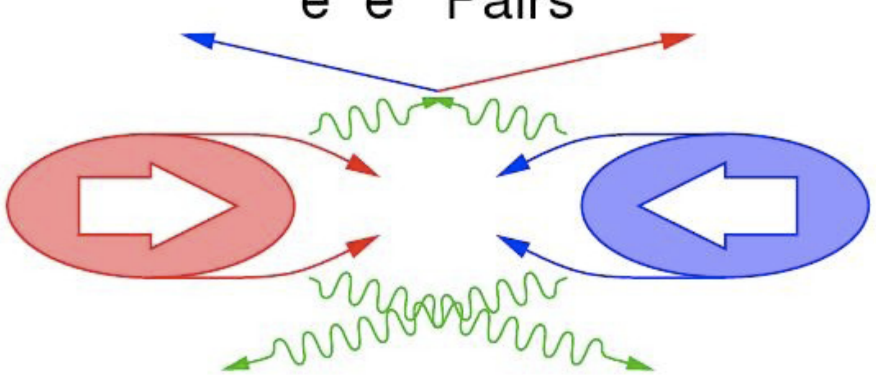


Beamstrahlung driven by energy and focusing

For 500 GeV:

- mean bunch:
  - ΔE/E ~ 7%
- coherent e^+e^- pairs:
  - 2.0 x 10^2 / bunch crossing
- incoherent e^+e^- pairs:
  - 8.0 x 10^4 / bunch crossing

γγ → hadrons interactions:
  - 0.2 / bunch crossing



CLIC Event Reconstruction

CLIC event:

Integration over a full bunch train

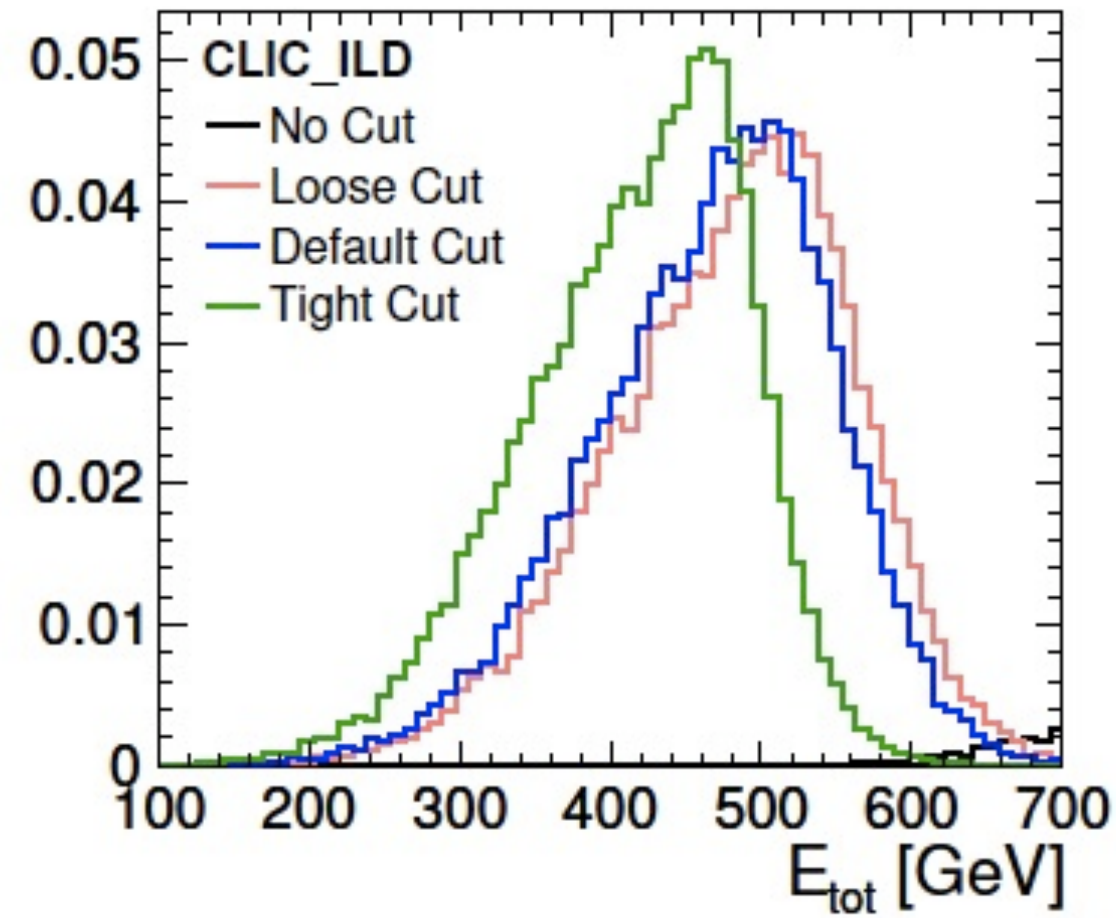
- 312 bunches

Reconstruction challenge:

Suppress pile up from γγ → hadrons interactions

- adds significant energy to events
- in particular in the forward region
- not in time with the physics event

Effect of timing and p_t cut strengths



Reconstruction Technique: Particle Flow

- Pandora Particle Flow event reconstruction based on geometrical hit assignments
- Application of a combination of timing and pt cuts specially for low p_t particles to reject γγ → hadron background events
- Different strength of cuts are available for 3 TeV and 500GeV center-of-mass energy

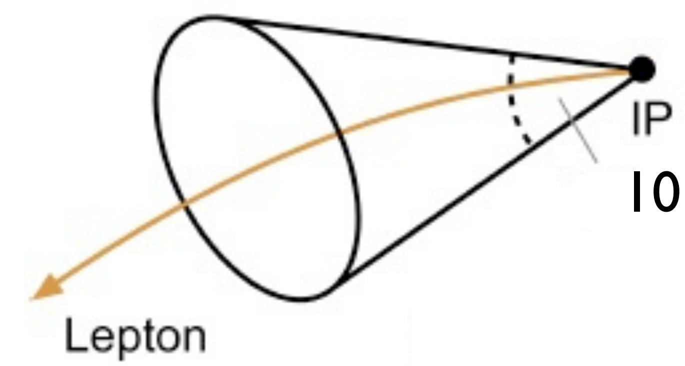
Analysis Chain

$\sqrt{s} = 500\,\text{GeV}$

type	$e^+e^- \rightarrow$	cross section σ	number of events generated for $100\,\text{fb}^{-1}$
Signal	$t\bar{t}$	550 fb	$5.5 \cdot 10^4$
Background	WW	7.1 pb	$7.1 \cdot 10^5$
Background	ZZ	410 fb	$4.1 \cdot 10^4$
Background	$q\bar{q}$	2.6 pb	$2.6 \cdot 10^5$
Background	WWZ	40 fb	$4.0 \cdot 10^3$

Lepton Finder

- Classification of decay branch for each event
- Search for isolated leptons in a cone
  - 10 degree cone opening angle
  - Lepton energy > 10 GeV
  - Particles in cone: charged, energy > 2.5 GeV



Lepton Finder

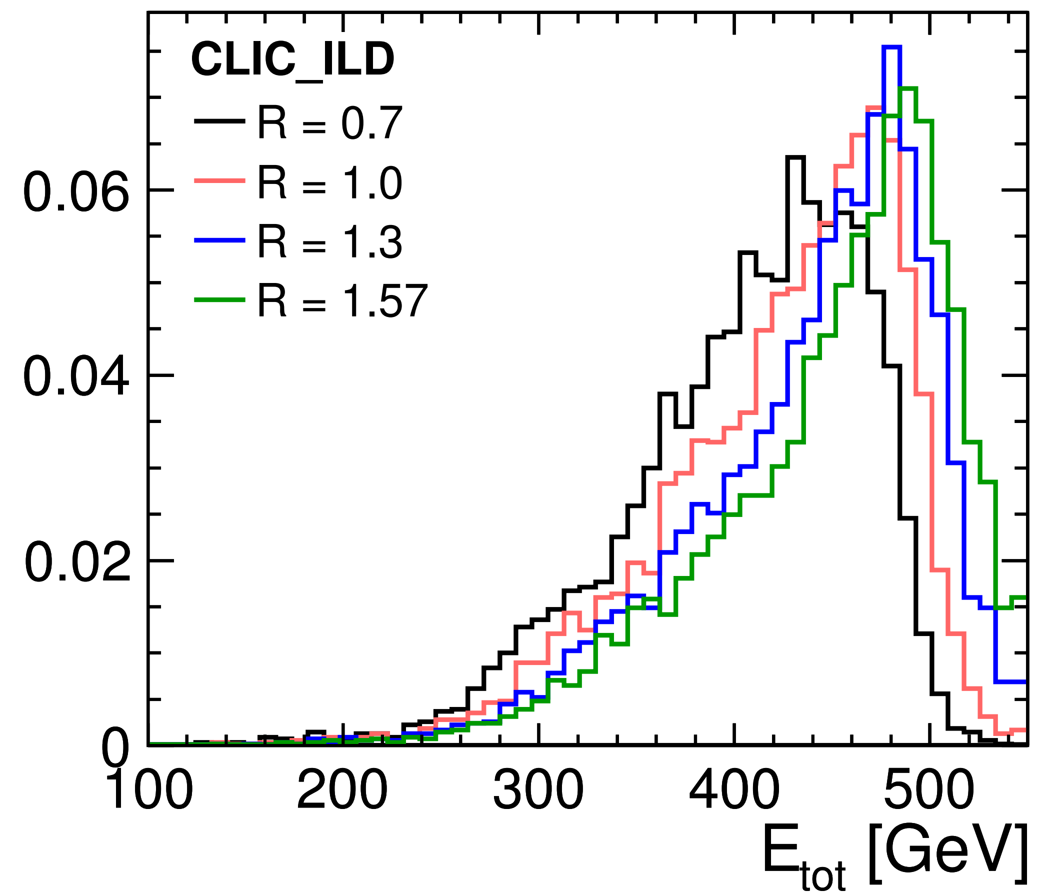
No isolated lepton found
- Full-hadronic decay branch
- 6 jets

One isolated lepton found
- Semi-leptonic decay branch
- 4 jets, isolated lepton, neutrino

> 1 isolated lepton found
- Full-leptonic decay branch
- Events rejected

Jet clustering and Flavor Tagging

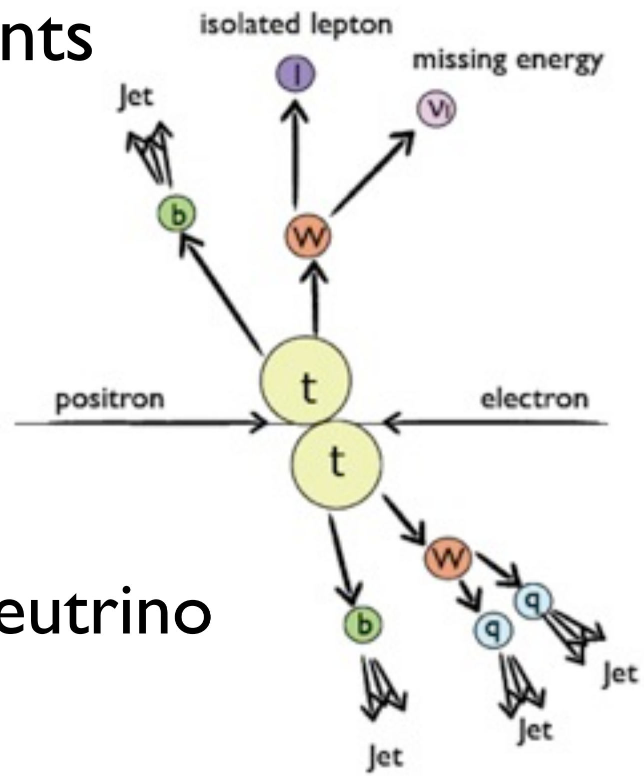
- Hadron k_t algorithm
  - Exclusive Mode: Force to 4 or 6 jets
  - Jet algorithm helps to reject background
  - R value defines size of jet, cross checked with distribution of events without machine background



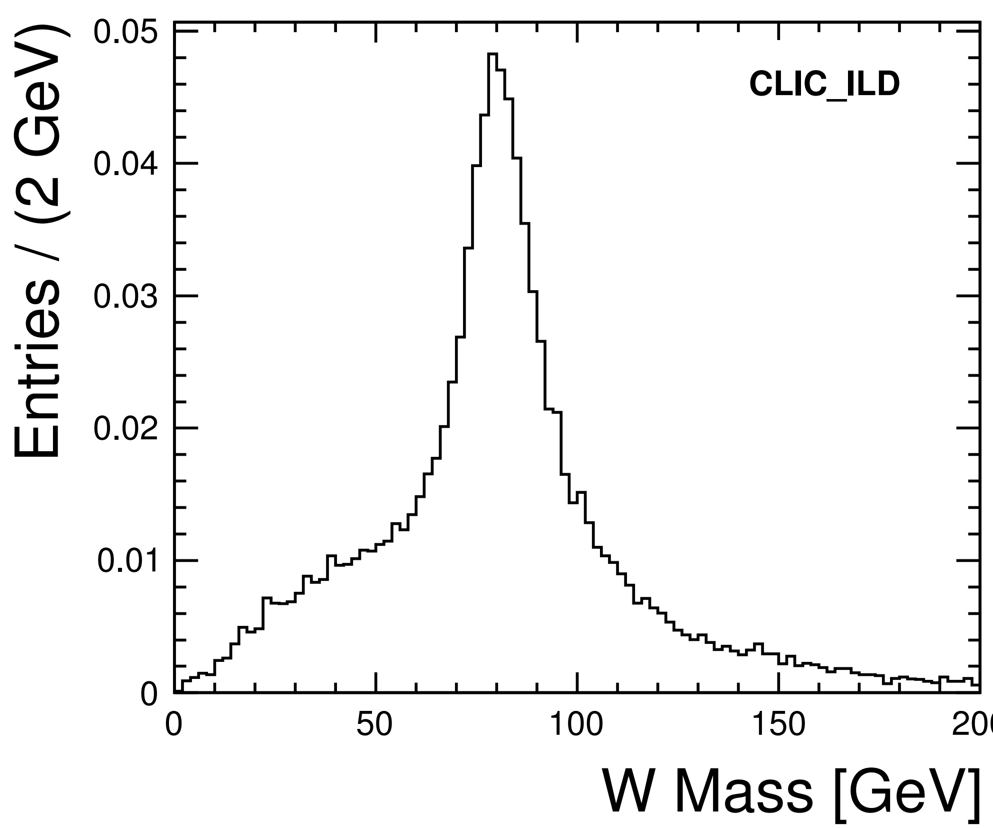
- Flavor tagging based on LCFI Vertex Package
  - Dedicated flavor tagging talk by J. Strube (R&D5, Wednesday, 15:50)
  - Flavor Tagging is based on a neural net
  - Every jet gets assigned with a b-tag value
  - Jets with highest two b-tag values are chosen to be b-jets

Jet combinatorics

Semi-Leptonic events



- 2 b-jets
- 2 light-jets
- 1 lepton
- missing energy / neutrino

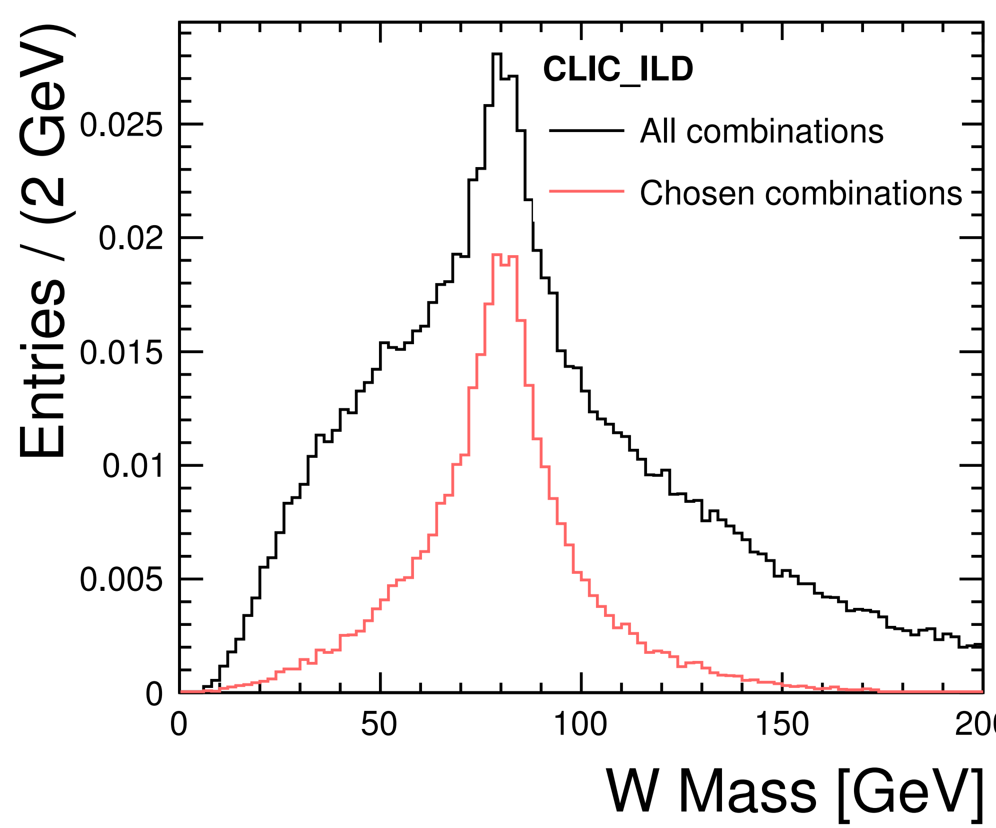


Full-Hadronic events

- 4 light-jets
- 2 b-jets
- Calculation:

$$|m_{ij} - m_W| + |m_{kl} - m_W|$$

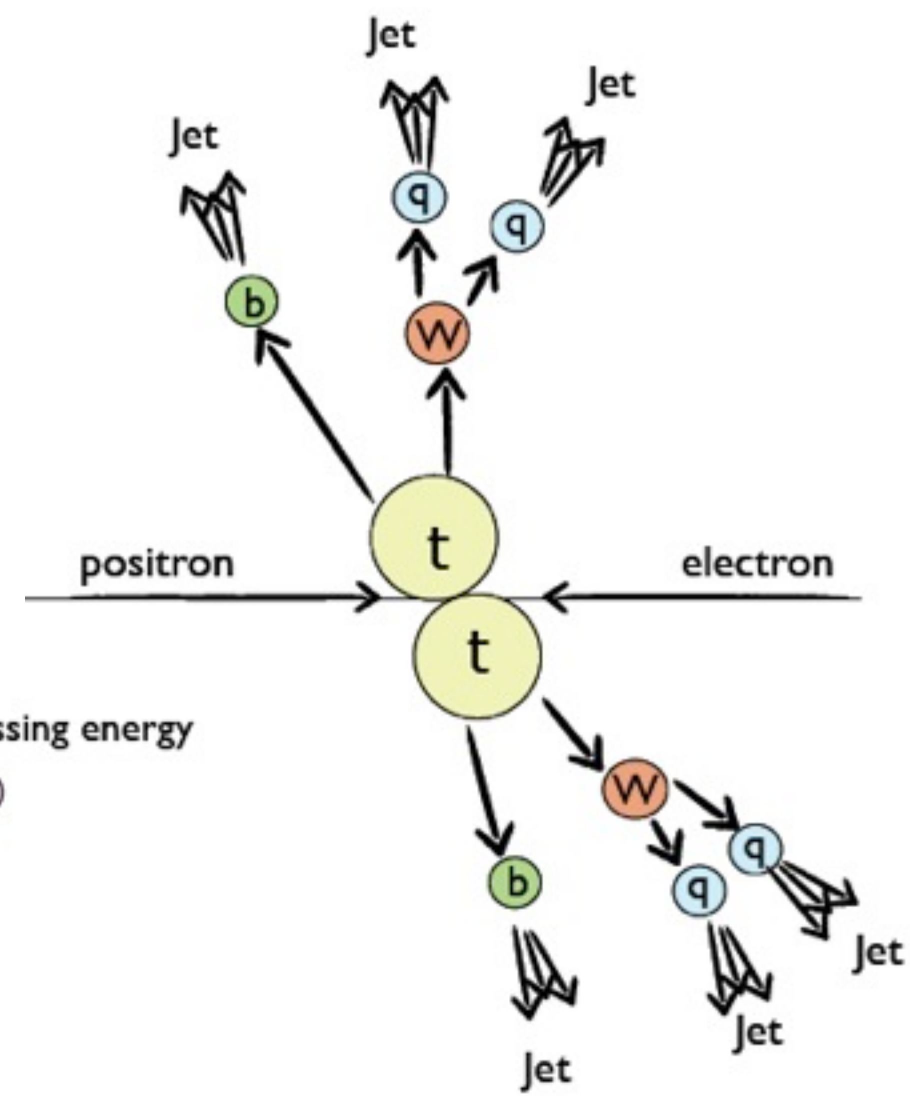
- Minimum value defines best permutation

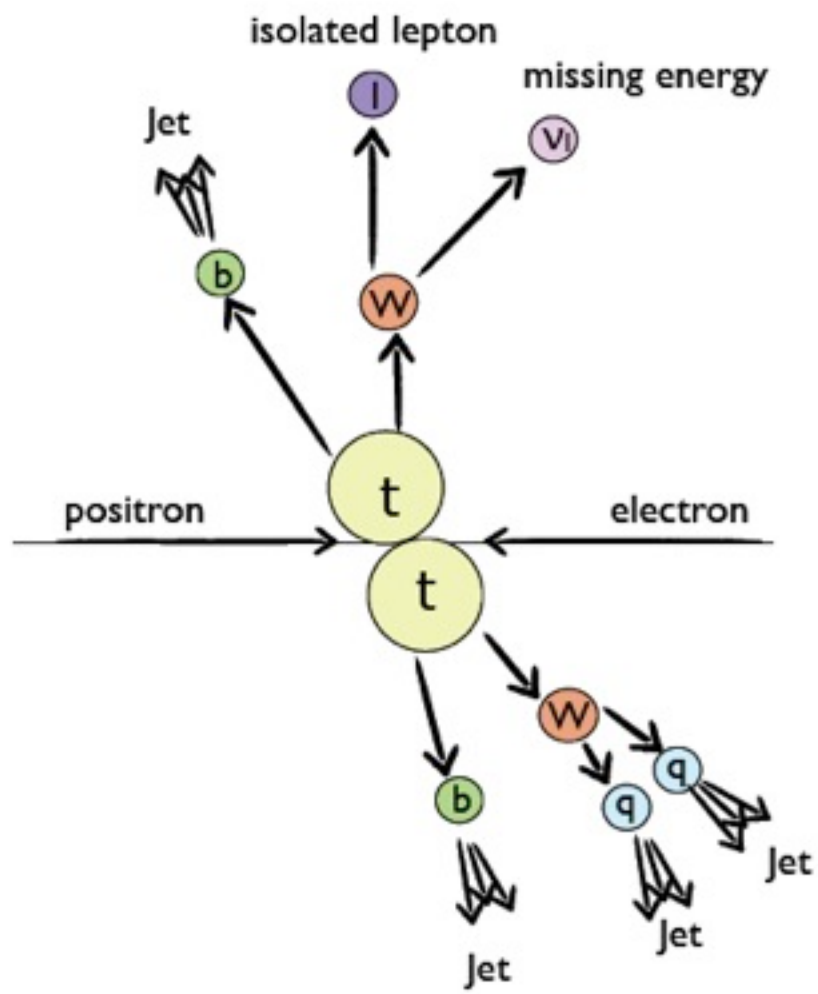


Kinematic Fit

Kinematic fit uses constraints from signal event topology to correct measured properties of decay products

- Constraints for four and six jet events:
  - Energy conservation
  - Momentum conservation
  - W mass equals 80.4 GeV
  - Equal top masses





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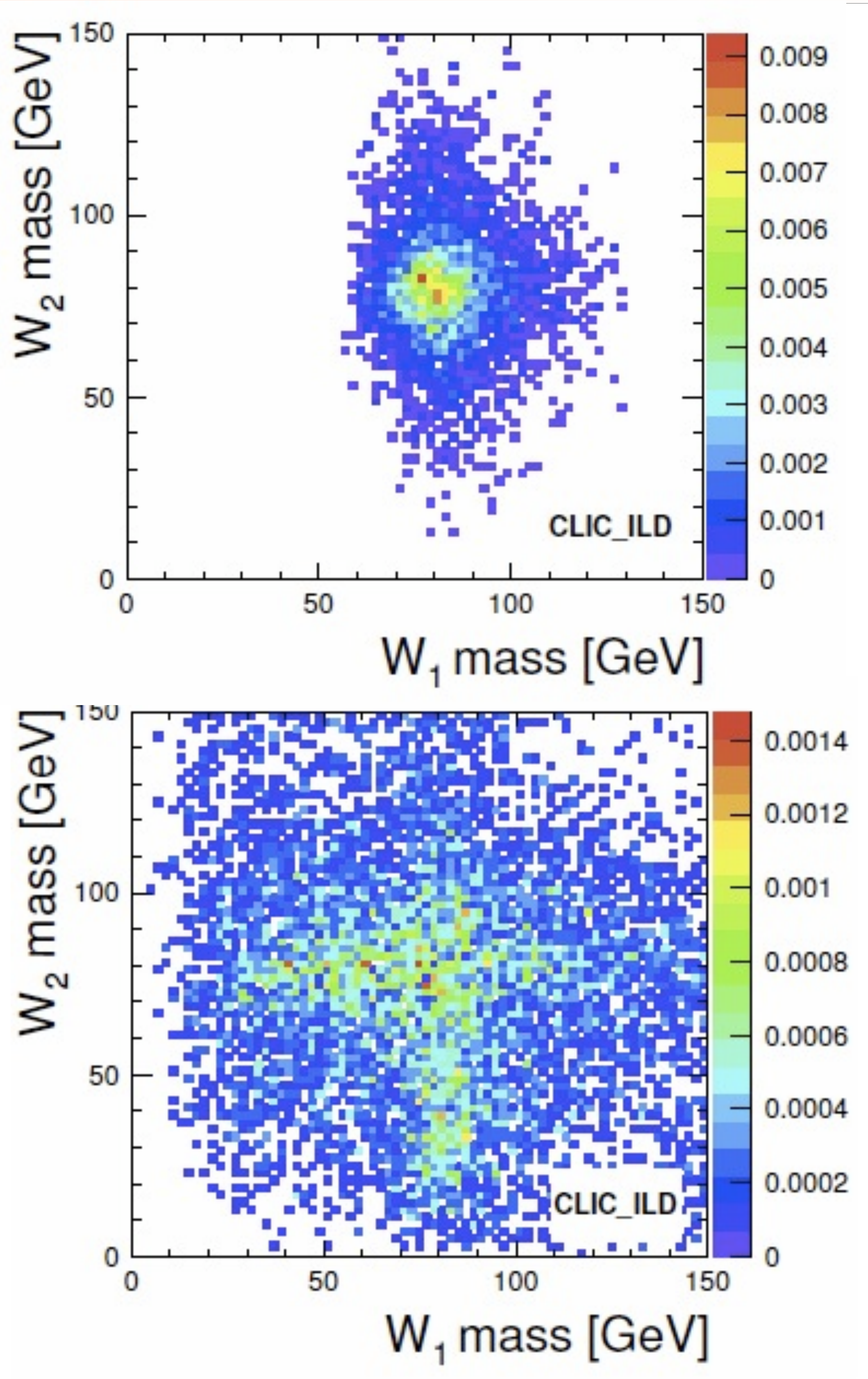
- Use kinematic fit for final Wb pairing
- Only very clean events pass kinematic fit



Kinematic Fit and Background Rejection

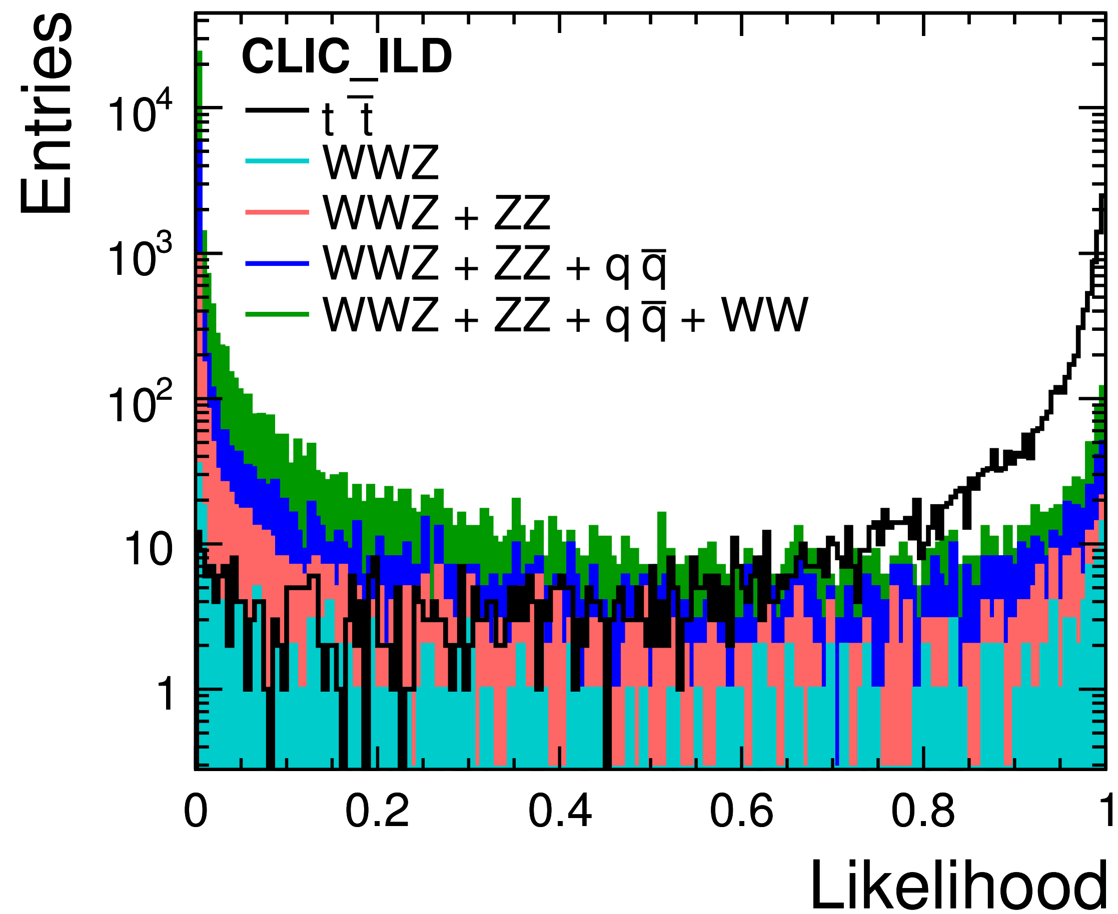
Kinematik Fit

- Powerful Background Rejection for qq, WW, ZZ
- Rejection of unwanted signal events: full-leptonic events, tau- events

Binned likelihood rejection

- Seven input variables (Number of particles in event, value of b-tags, sphericity, ...)
- Likelihood cut of 0.6 chosen
- Training with independent sample

Full-Hadronic



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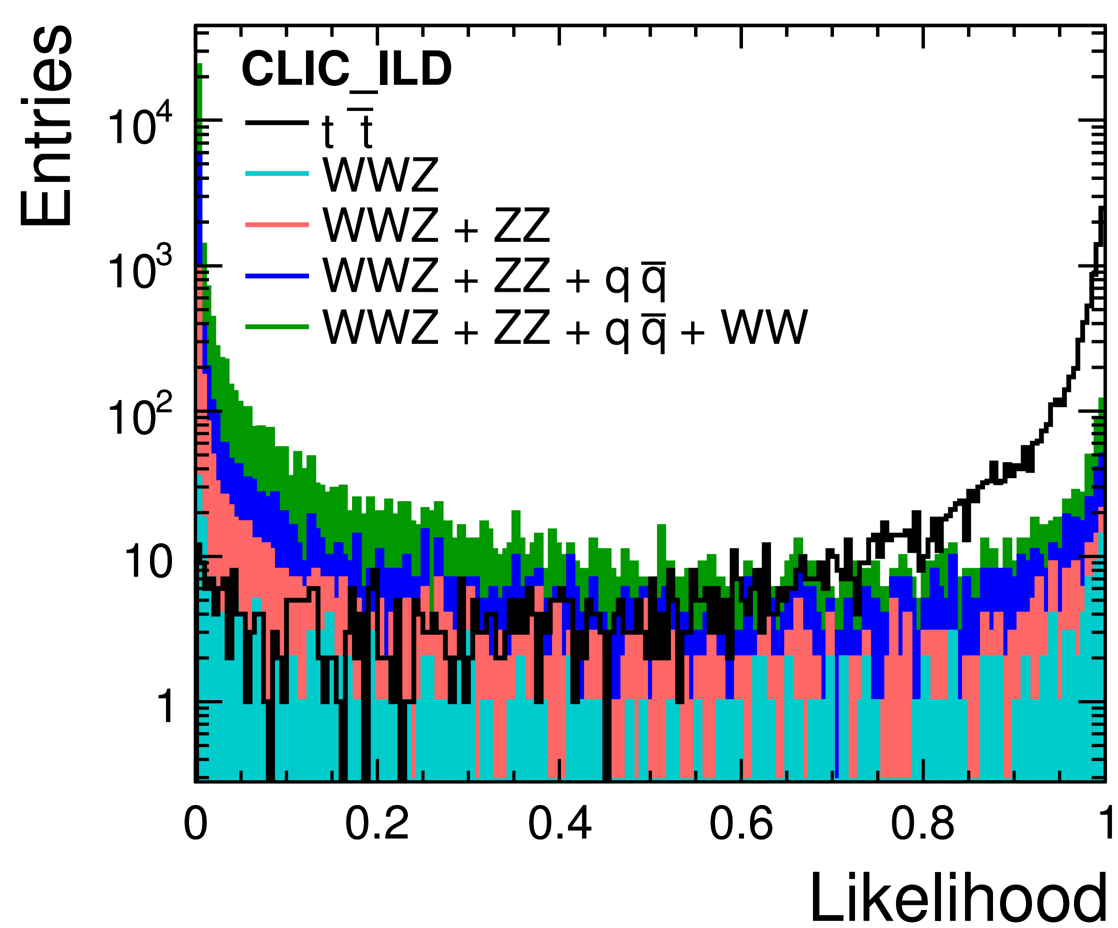
- Likelihood cut of 0.6 chosen
- Training with independent sample

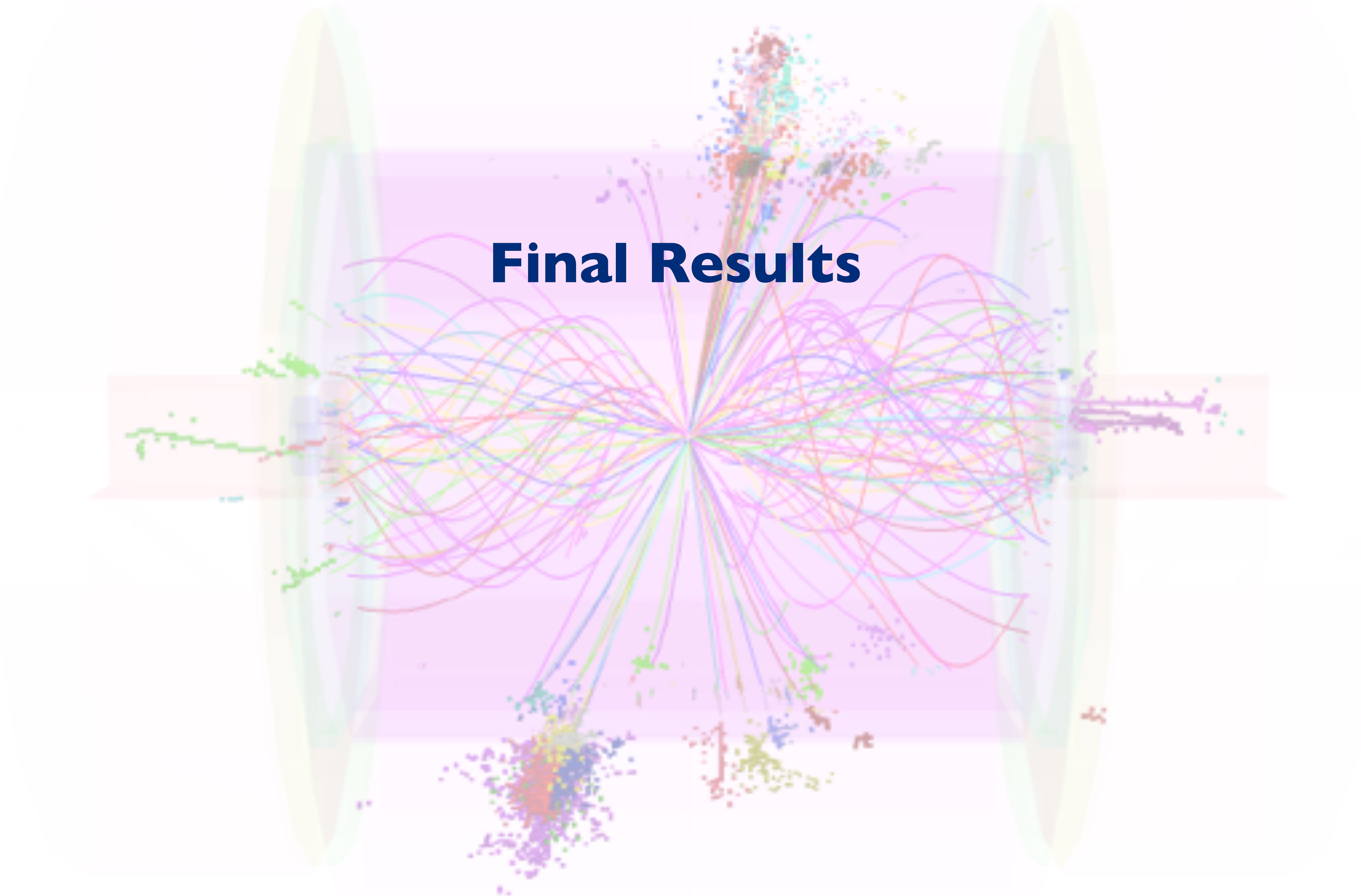
Overall background rejection: > 99%
Overall signal selection:
Full-Hadronic: 35%
Semi-Leptonic: 56%

- Signal efficiency could be improved
- Analysis goal: clean events not amount of statistic

Full-Hadronic



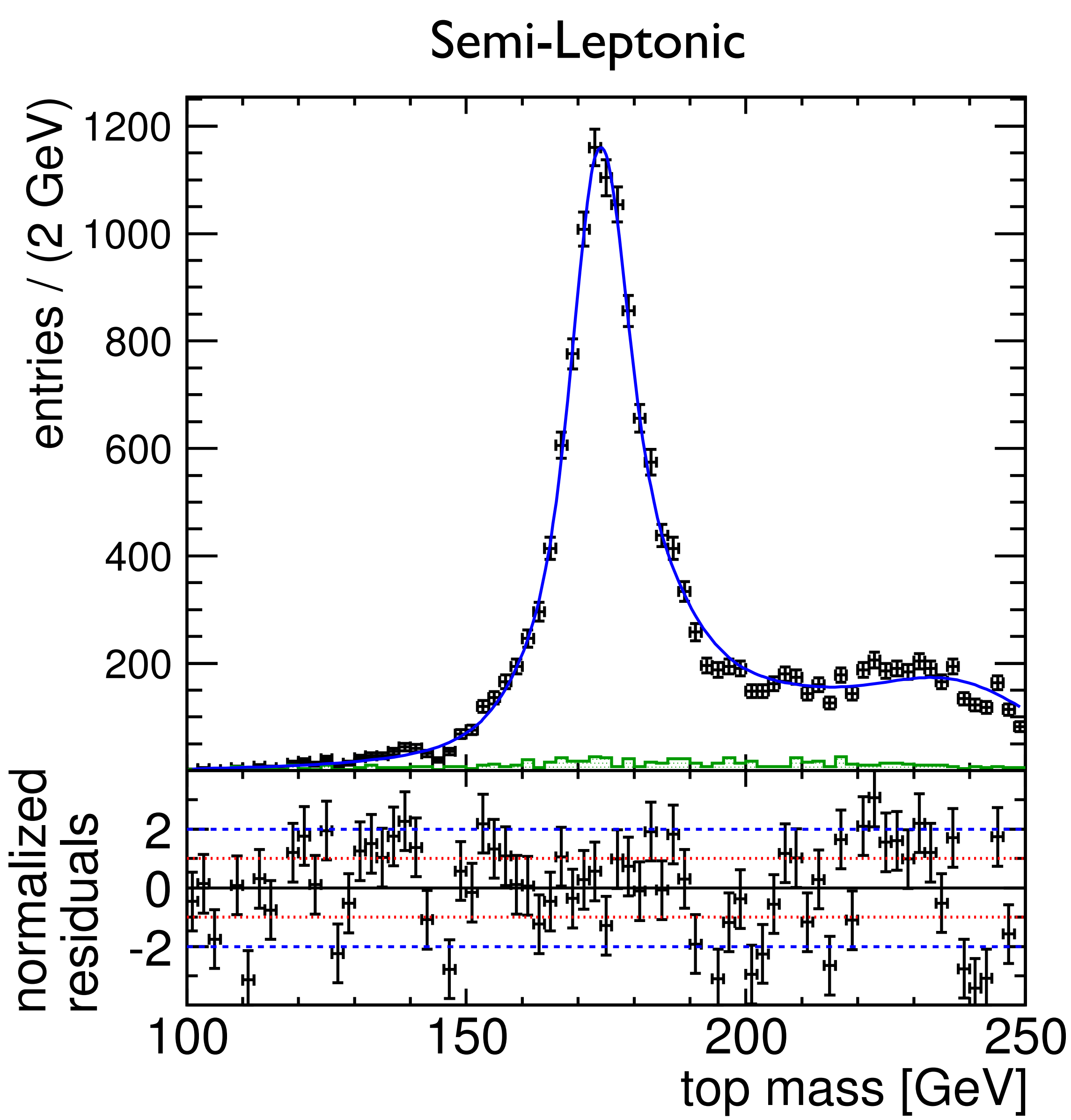
Final Results

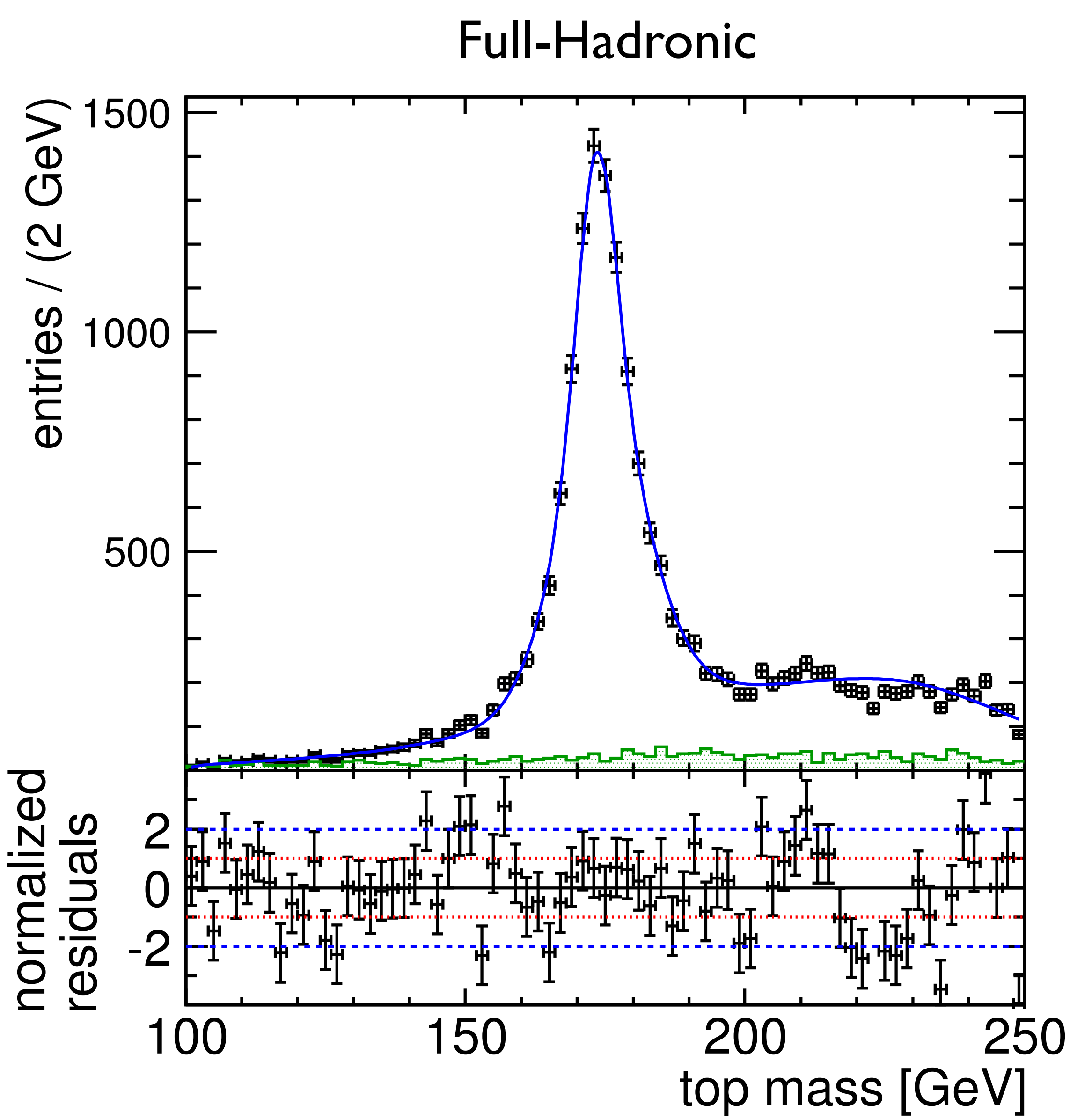


Fit of final distribution

Un-binned maximum likelihood fit over full range

- Combination of signal and background pdf
- Signal pdf is a convolution of a Breit Wigner and a detector resolution function



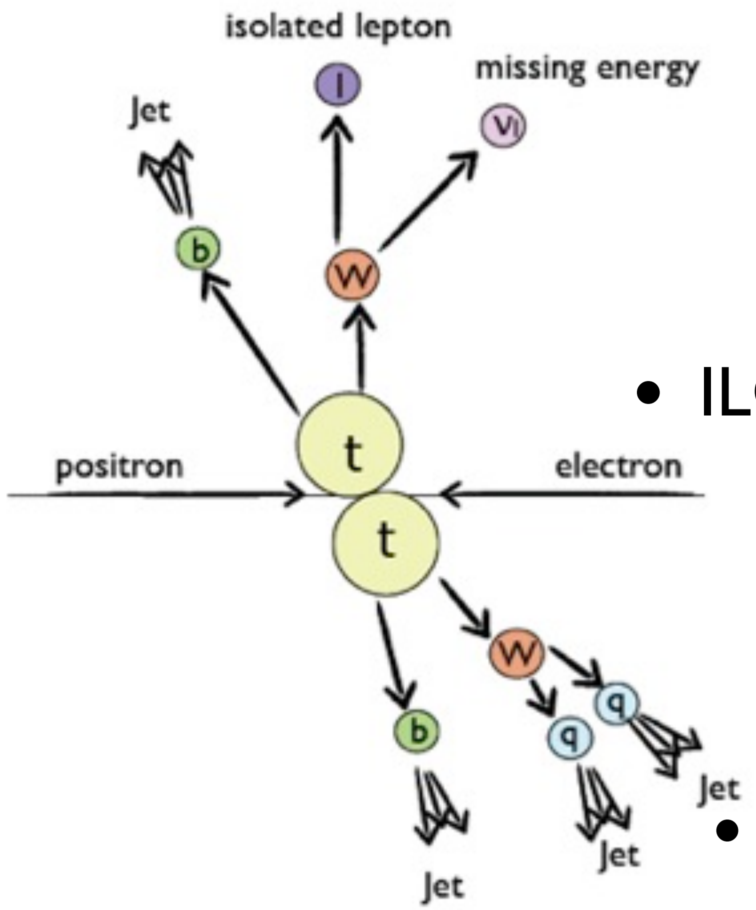


Top Mass for 100 fb^{-1} with CLIC_ILD at 500 GeV

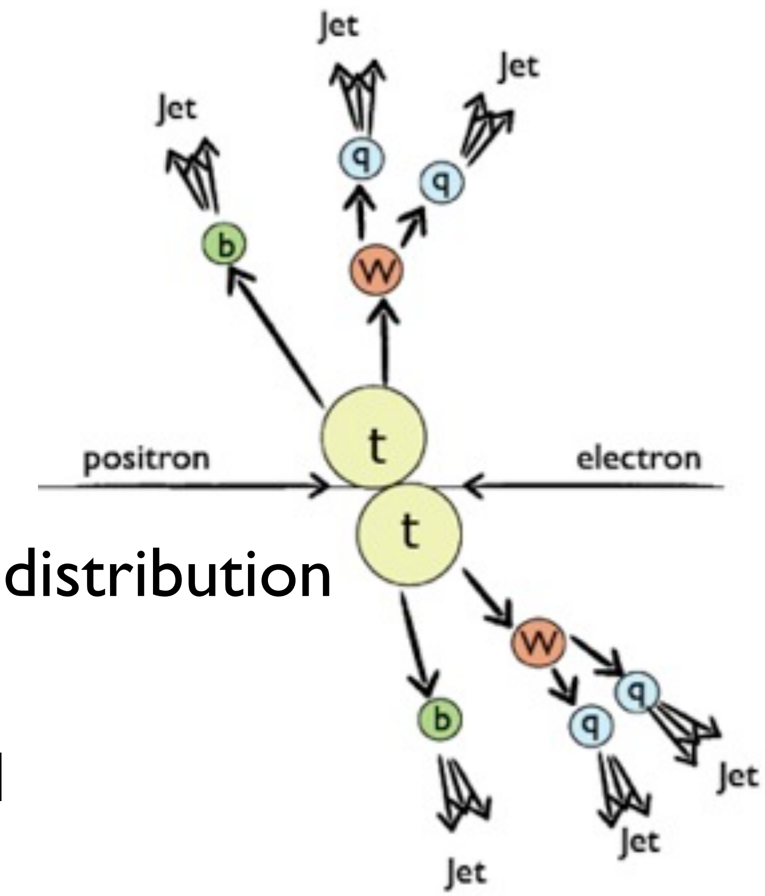
- Results of the overall fit:
  - Full-Hadronic : m_{top} = 174.08 ± 0.08 GeV (stat)
  - Semi-Leptonic: m_{top} = 174.30 ± 0.09 GeV (stat)

generator values:

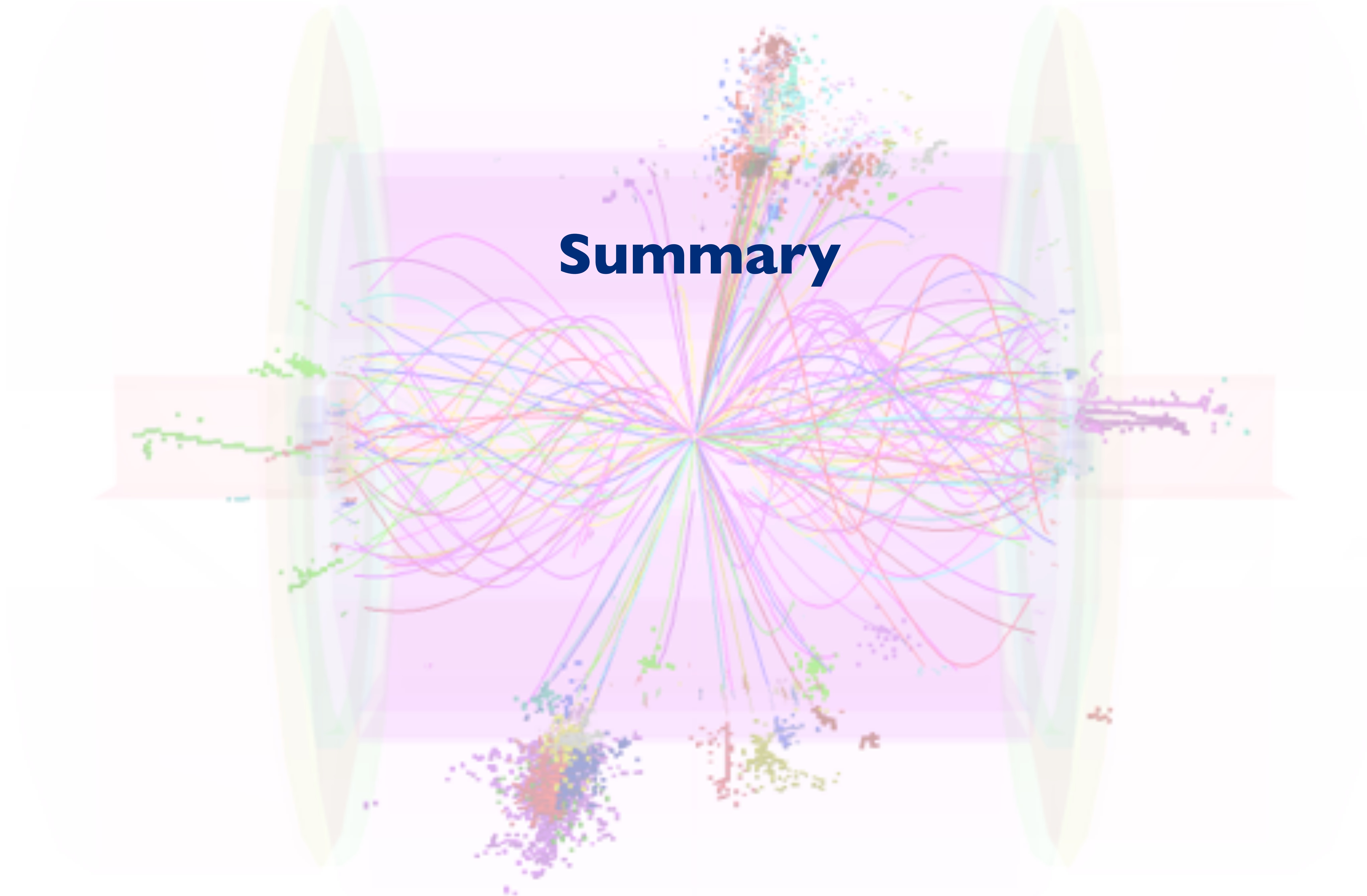
mtop = 174 GeV, width: 1.37 GeV



- ILC ILD top mass analysis for 100 fb^{-1}:
  - statistical error:
    - Full-Hadronic: 0.11 GeV
    - SemiLeptonic: 0.14 GeV
  - Full-Hadronic: Similar statistics in final distribution for ILD and CLIC_ILD study
  - Semi-Leptonic: Higher statistics in final distribution in CLIC_ILD study



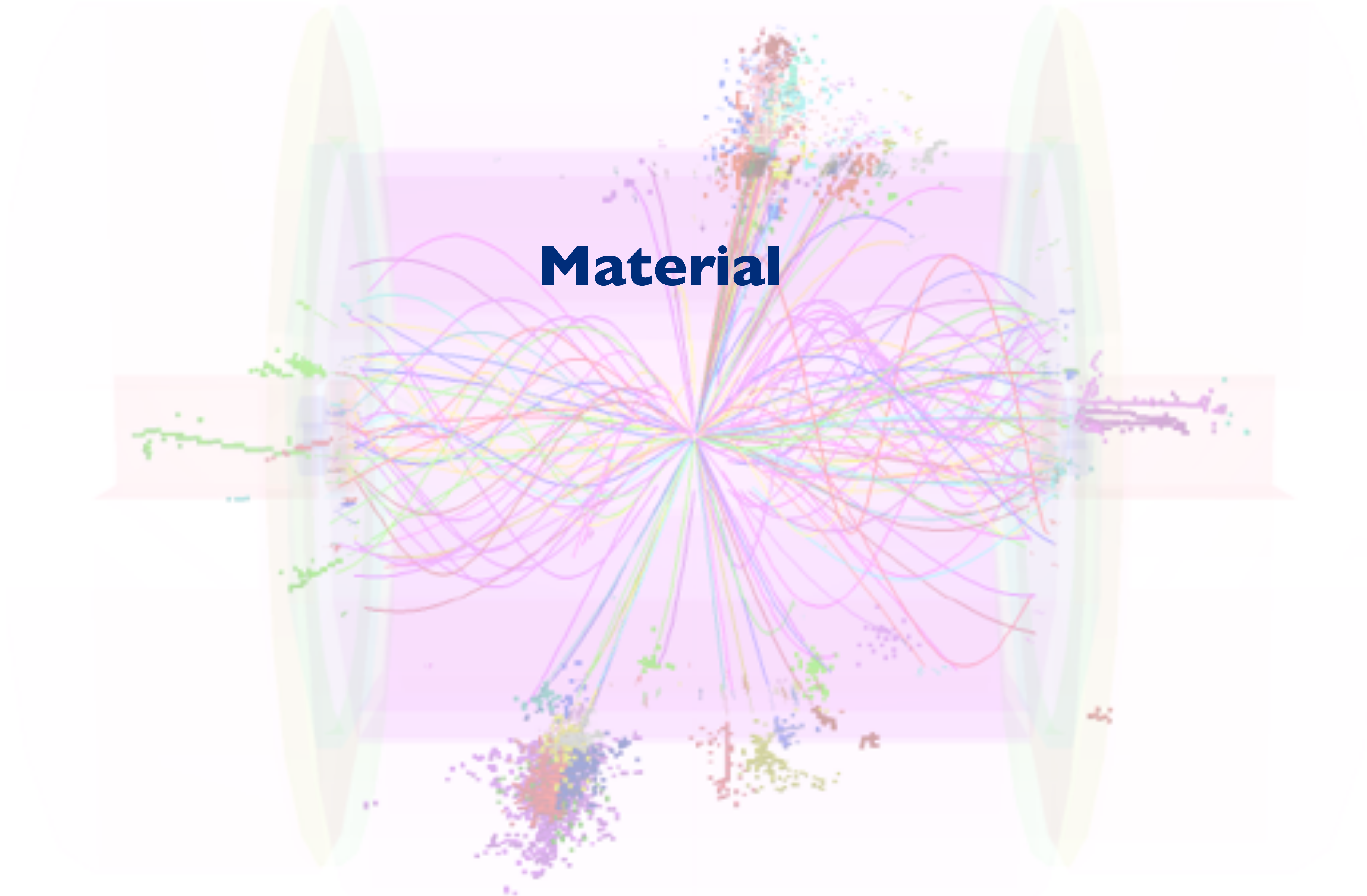
Summary



Summary:

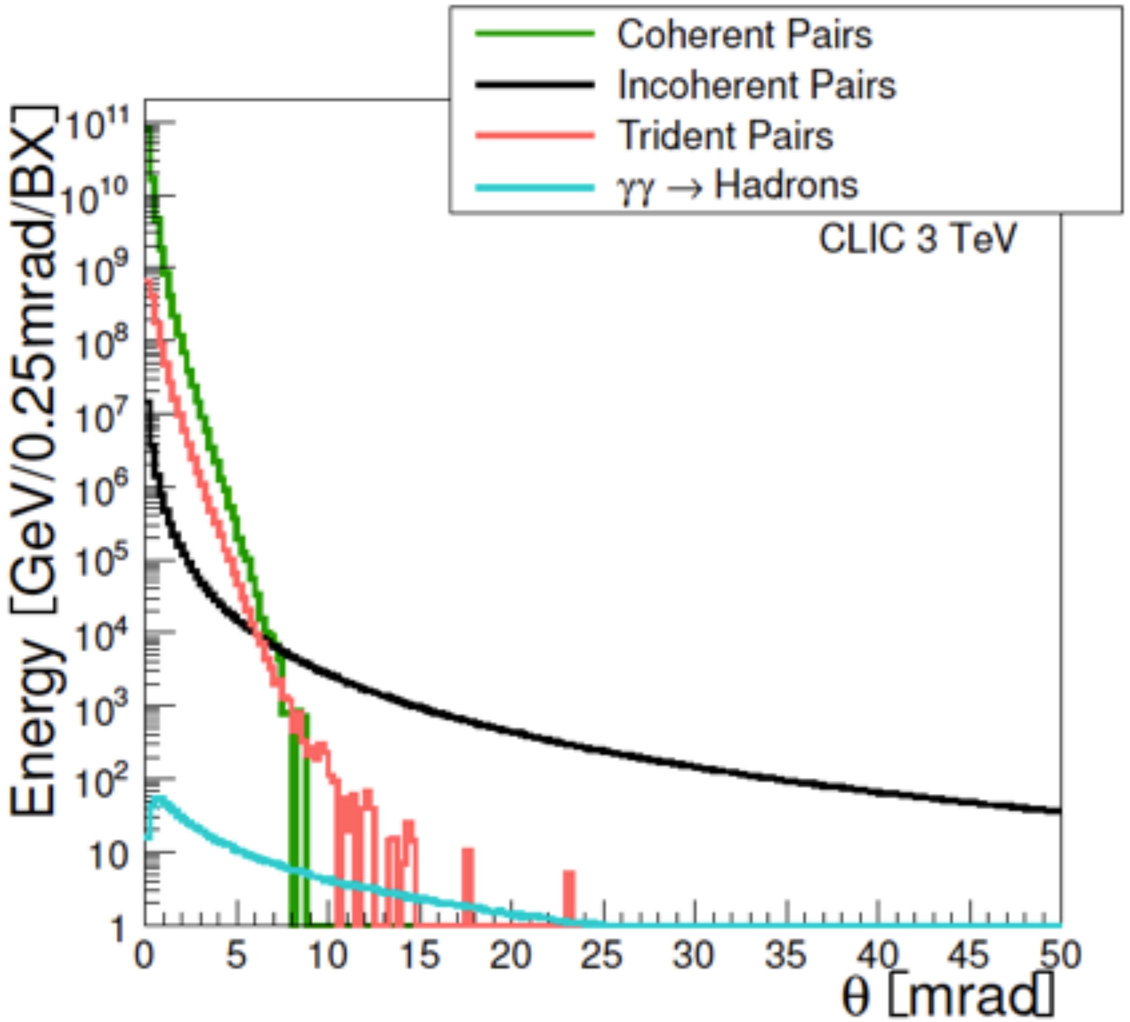
- Low energy version of CLIC also suitable for high precision measurements
  - More details in the CLIC_CDR:
    http://lcd.web.cern.ch/LCD/CDR/CDR.html

- Machine background conditions and pile up under control
- Analysis of tt events at 500 GeV with the CLIC_ILD detector for 100 fb^{-1} gives a statistical error of 80-90 MeV on top mass
- Analysis of top mass for full-hadronic and semi-leptonic decay chain of top pairs
- Result comparable with studies for ILD and SiD for ILC at 500 GeV
- All details about this analysis:
  https://edms.cern.ch/document/1158626/1



Material

Conditions at CLIC: Beamstrahlung Details



- Coherent e^+e^- pairs with angles < 10 mrad
  - Crossing angle and beam pipe opening at CLIC: 20 mrad
  - Outgoing beam: coherent pairs disappear in beampipe
- Incoherent pairs: reduced by solenoidal field, constrain innermost radius of vertex detector

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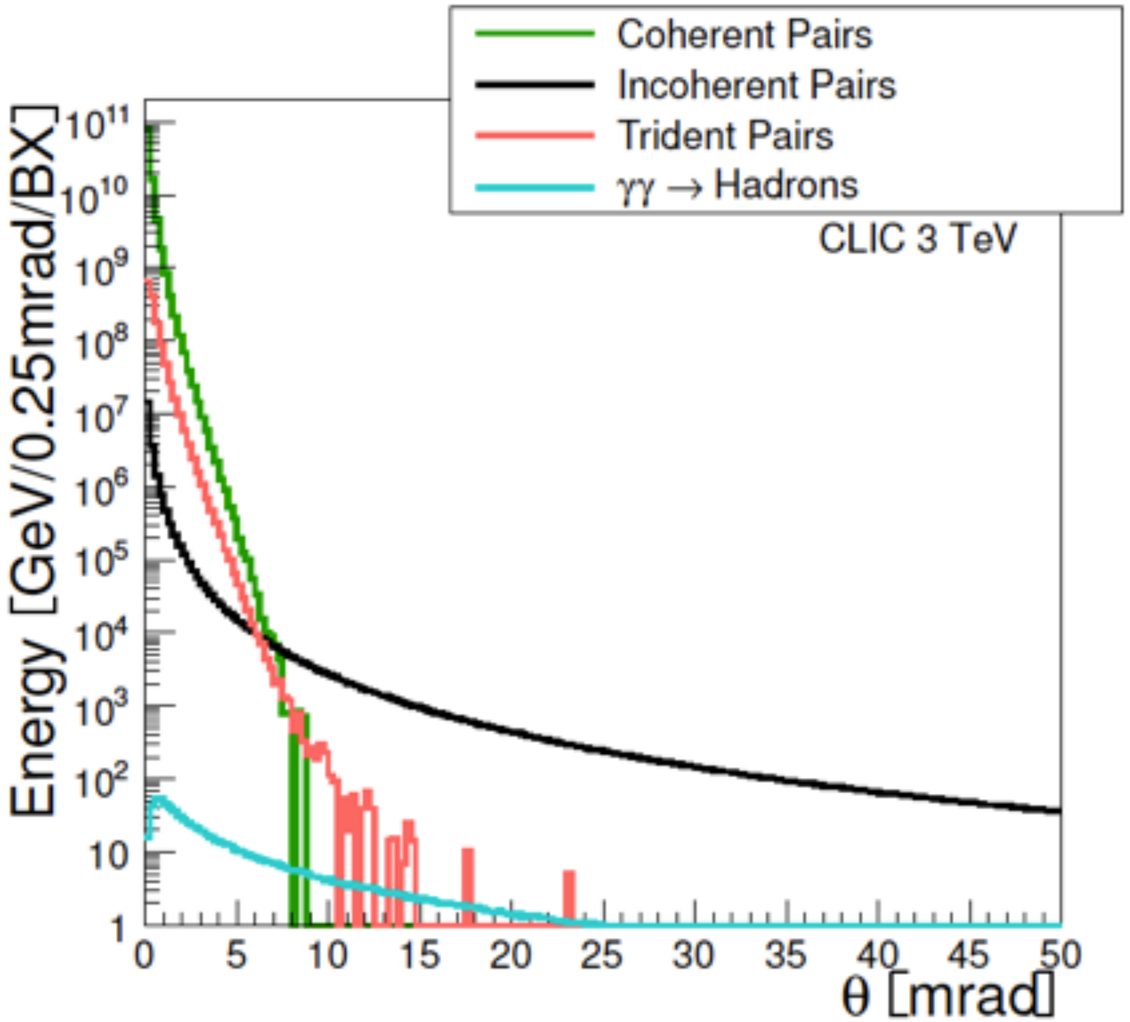

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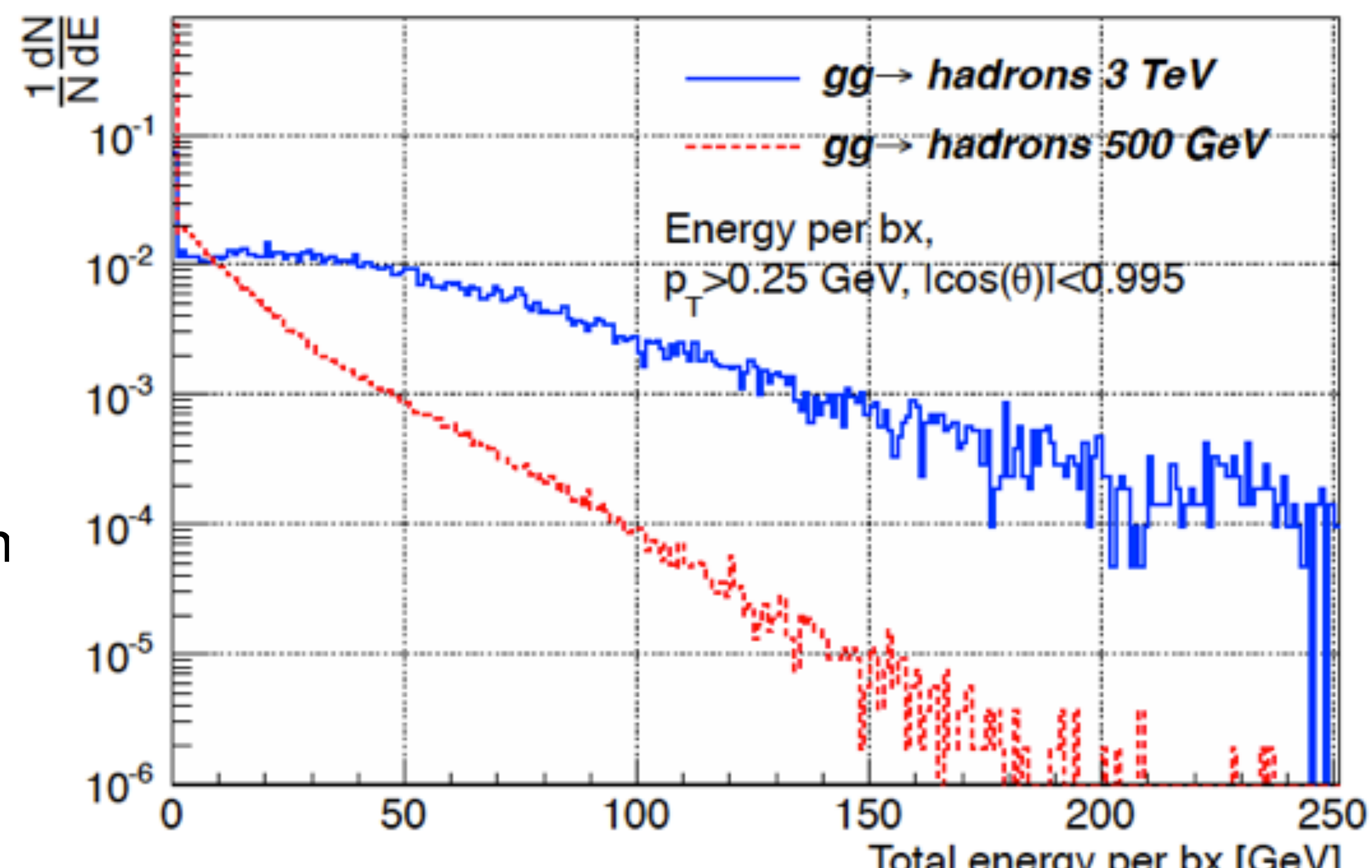
- γγ → hadrons: ~ 3.2 events / bx, ~ 28 ch. particles in detector acceptance
  ➫ 15 TeV in detector during bunch train forward peaked
  ➫ Requires precise time stamping and clever event reconstruction

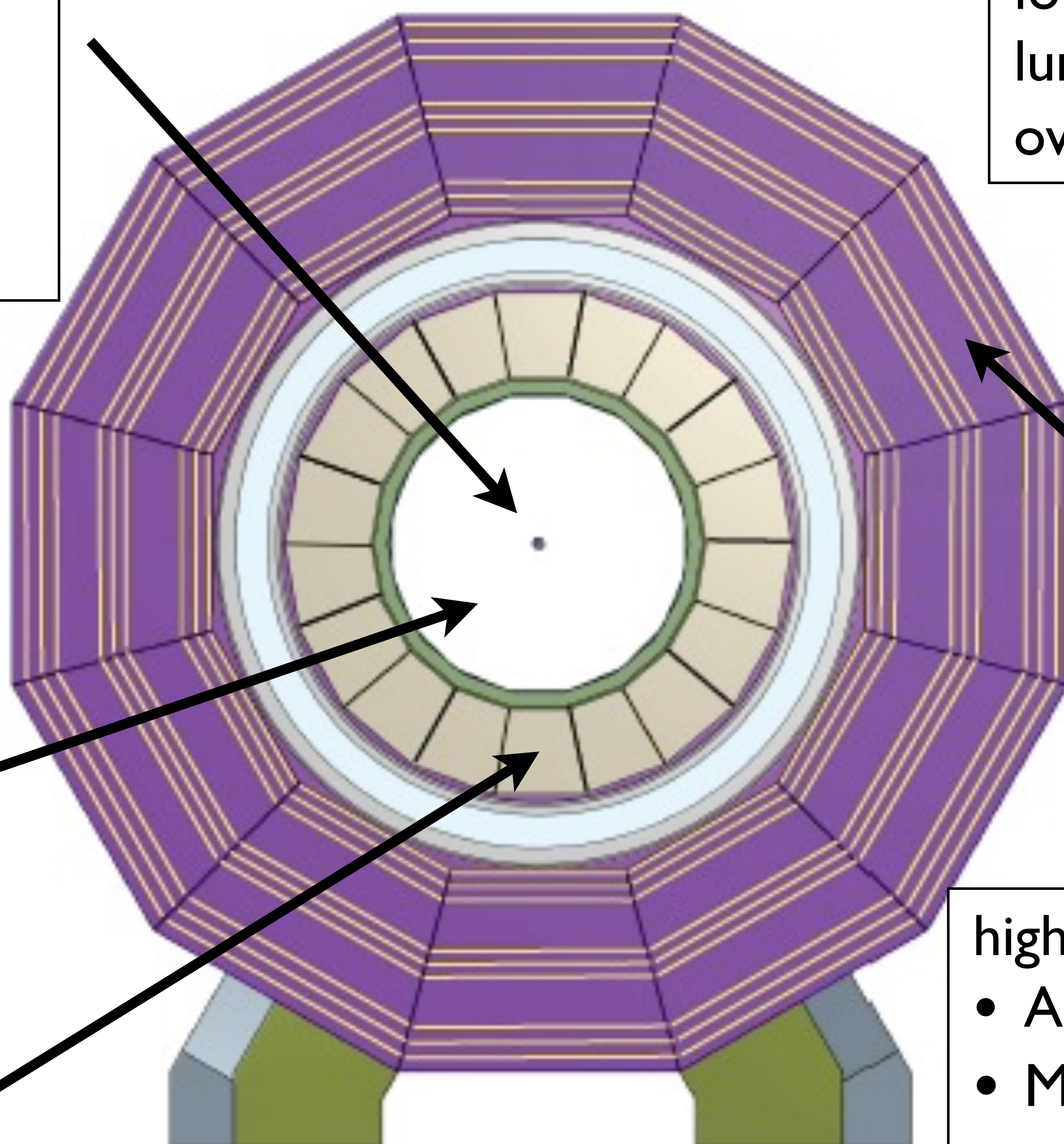


CLIC_ILD Detector - Main Features

Detectors concept follows the ILC designs: CLIC_ILD

low-mass, high precision vertex detector:
Si pixel detector
Si strip inner tracker
ILD (500GeV): 15mm
CLIC_ILD (500GeV): 25mm
CLIC_ILD (3TeV): 31mm

forward calorimeters for luminosity measurements and overall detector hermeticity



magnet yoke with muon detector / tail catcher

precision tracking:

- SiD: Si strip main tracker
- ILD: TPC main tracker

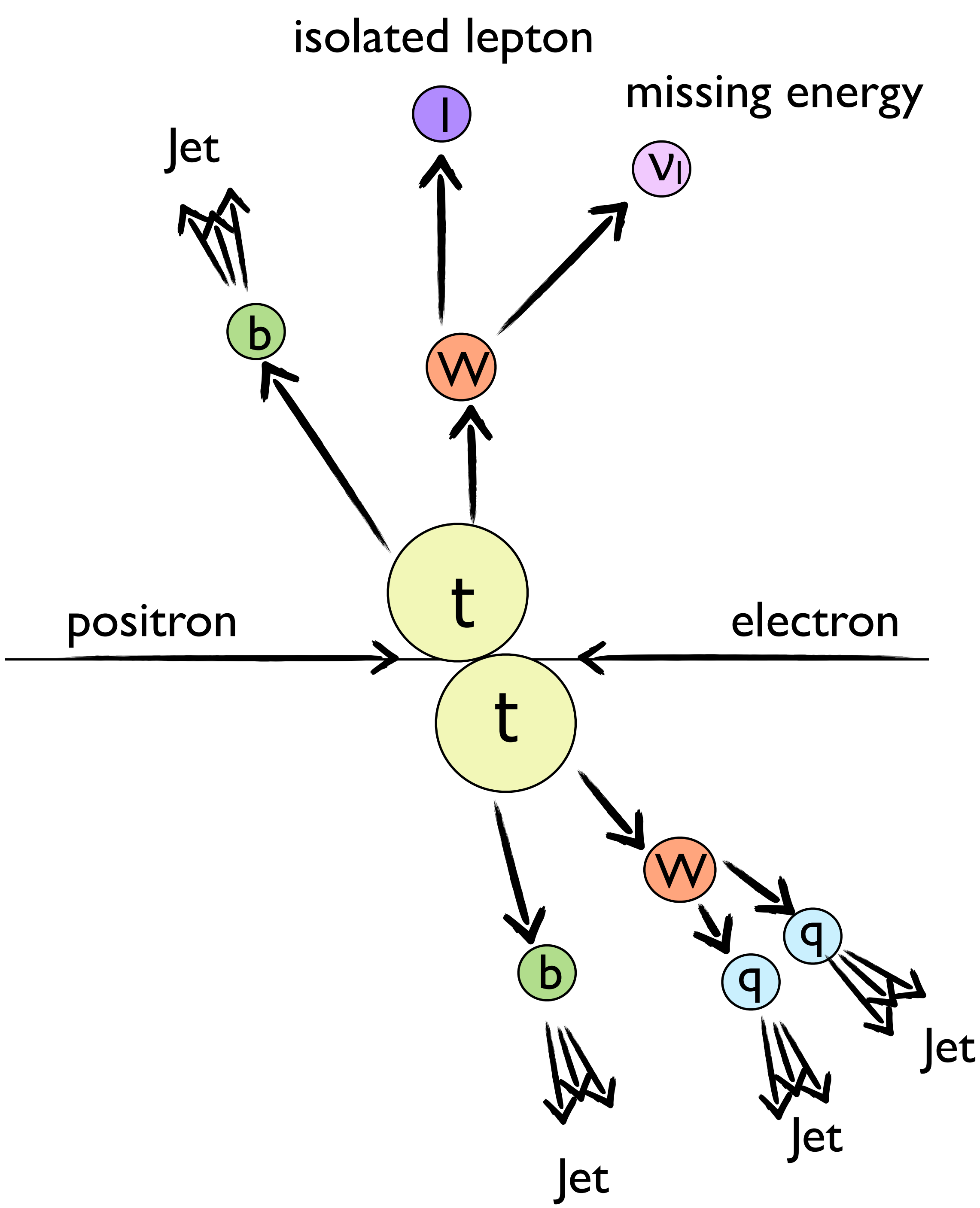
high-field solenoid

- All detectors inside solenoid
- Magnetic field:
  CLIC_ILD at 4 T

highly granular calorimeters for particle flow

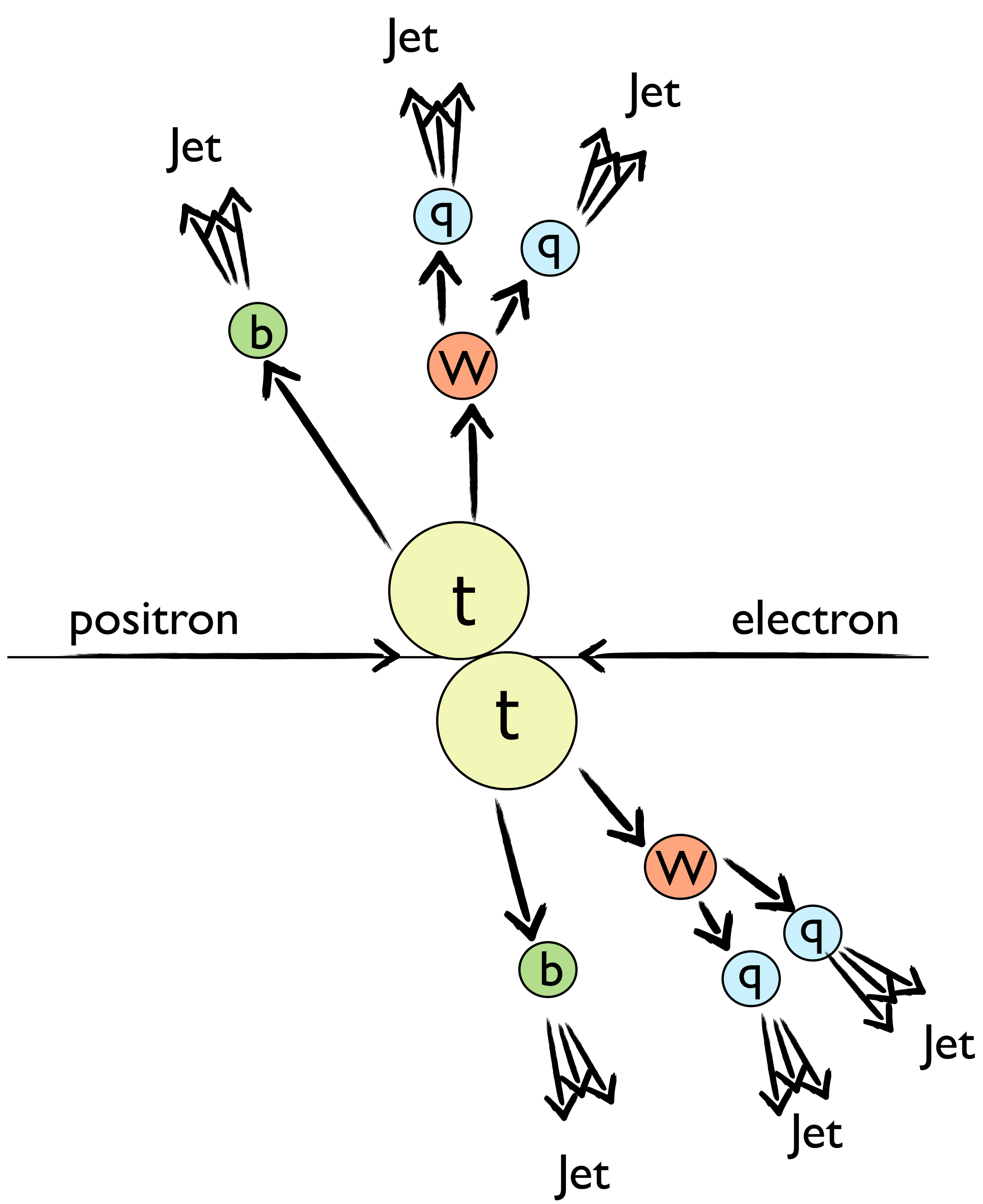
- Hcal: 7.5 λ, steel in endcap, tungsten in barrel

Event topology



Semi-Leptonic decay channel

Event topology



Full-Hadronic decay channel