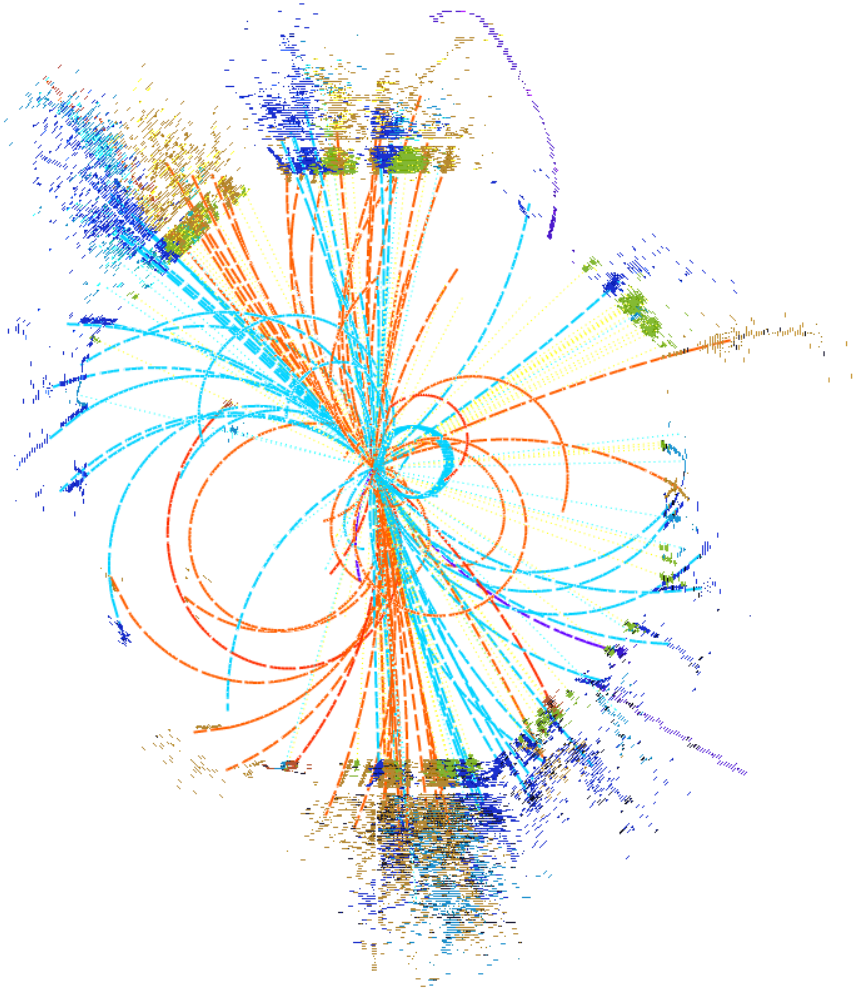
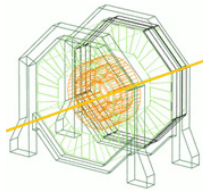
Measurement of the top Yukawa coupling at 1 TeV

Philipp Roloff (CERN)



SiD Workshop Meeting, 22/08/2012



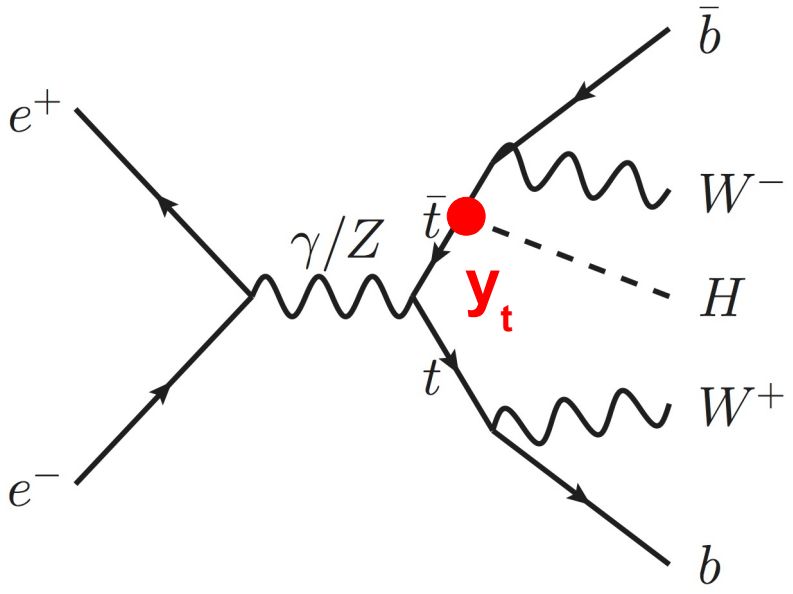
Introduction

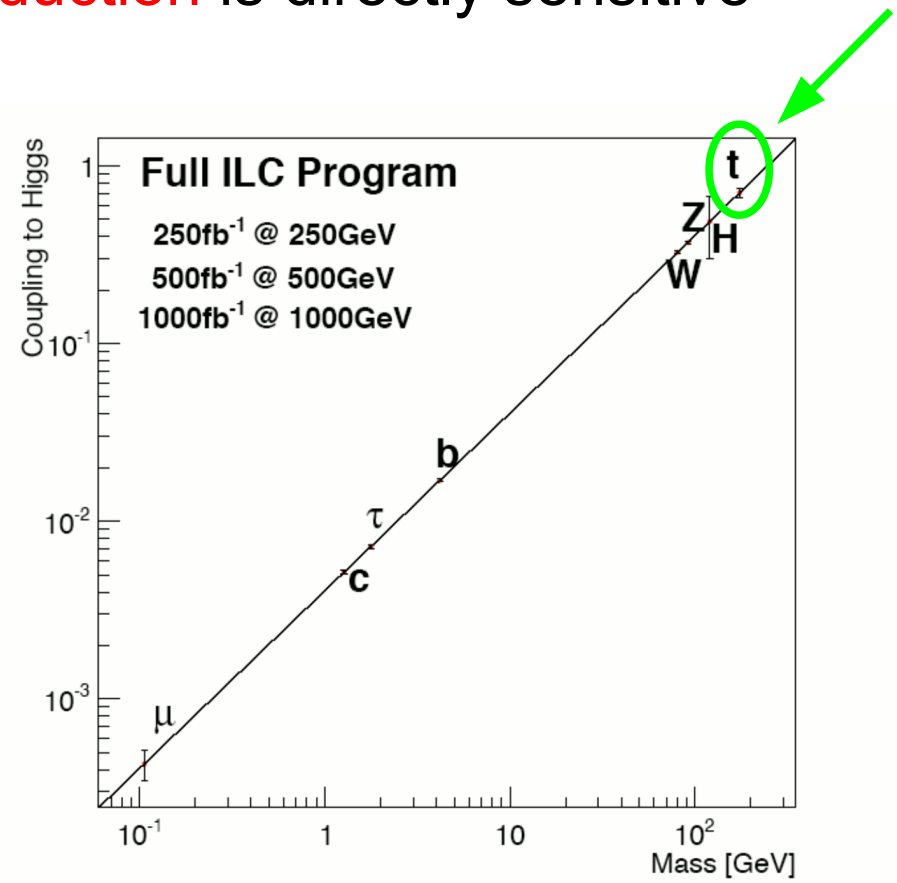
- **Physics motivation**
- **Extraction of the top Yukawa coupling**

Introduction

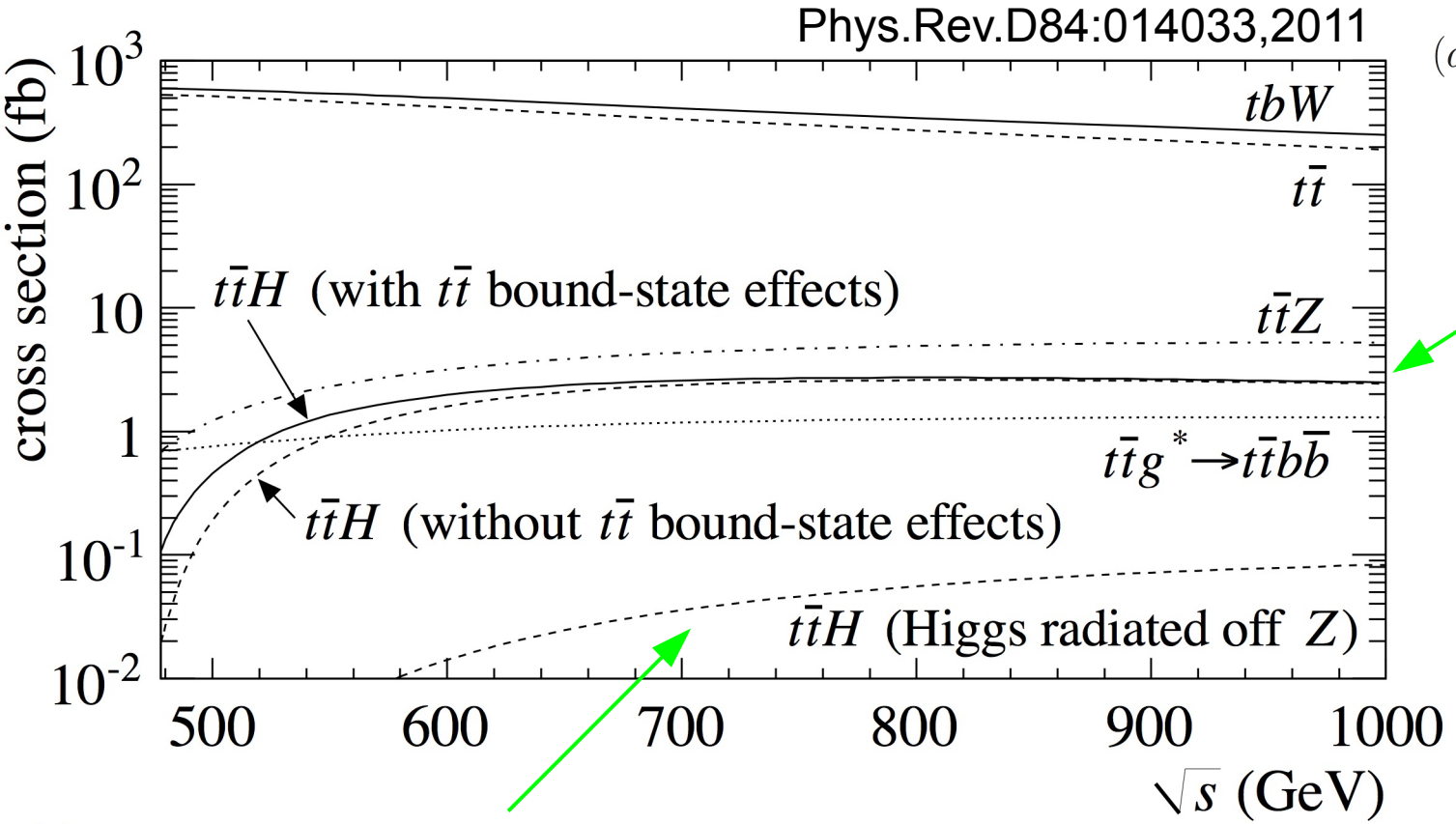
Manpower:
- Jan Strube, Philipp Roloff (CERN)
- cooperation with Tomohiko Tanabe (ILD analysis)

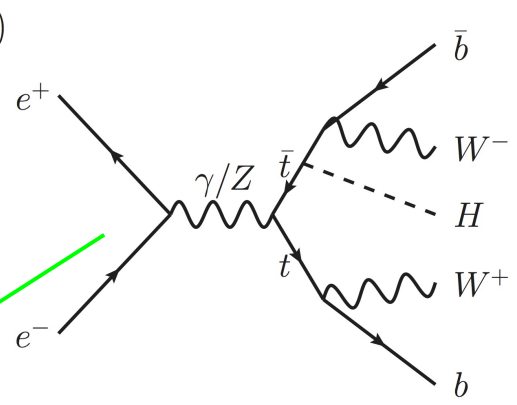
Motivation: Cross section for $t\bar{t}h$ production is directly sensitive to the top Yukawa coupling, y_t:



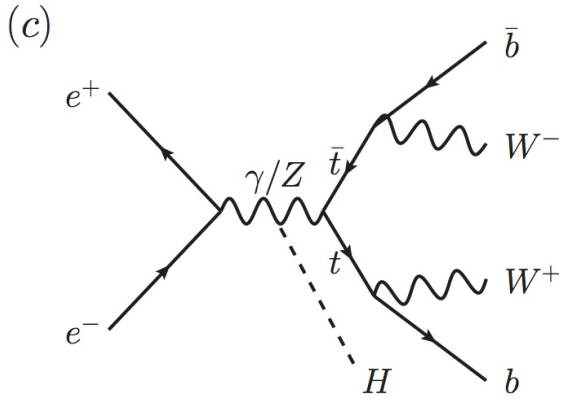


Signal cross sections



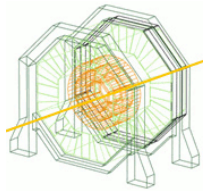


At 1 TeV:
- σ ≈ 2.2 fb
- $t\bar{t}$ bound-state effects can be neglected



Higgs radiated off Z:
- σ ≈ 0.08 fb
- Not sensitive to y_t

Impact of Higgsstrahlung on y_t

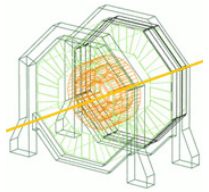


- Modified event generator (PHYSIM) to apply scaling the SM coupling, e.g.: 0.8 * y_t(SM), 1.2 * y_t(SM)
- The cross section was calculated for different y_t values
- The distribution was parameterised by a parabolic function
- The slope at the SM value was extracted:

$$\left(\frac{\sigma / y_t}{|d\sigma / dy_t|} \right)_{y_t = y_t(SM)}$$

(0.5 without contribution from Higgsstrahlung off Z)

Impact of Higgsstrahlung on y_t



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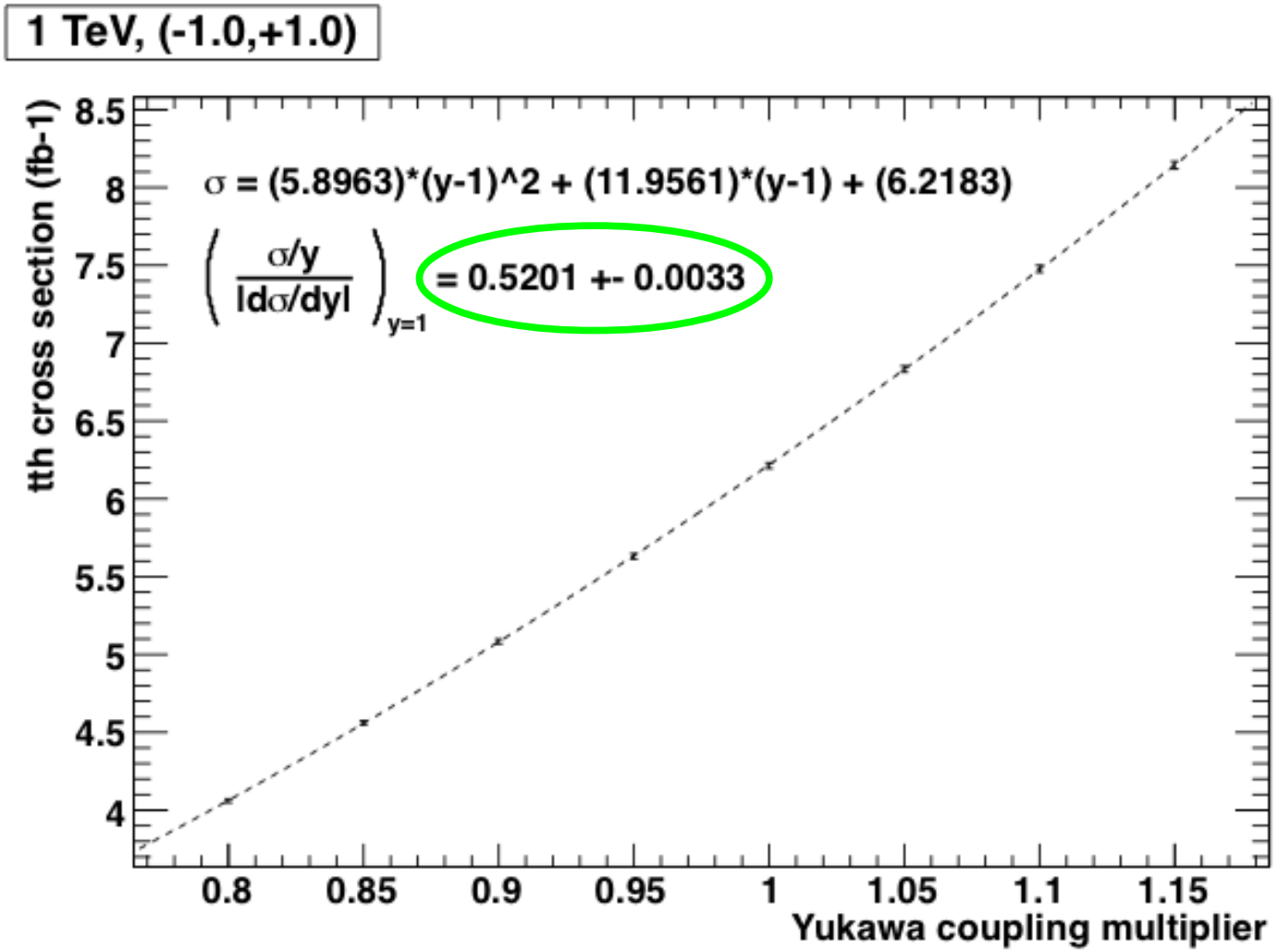
$$\left(\frac{\sigma / y_t}{|d\sigma / dy_t|}\right)_{y_t = y_t(SM)} \qquad \frac{\Delta y_t}{y_t} = (\ldots)\frac{\Delta\sigma}{\sigma}$$

(0.5 without contribution from Higgsstrahlung off Z)

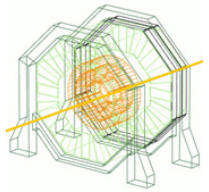
Cross section as function of y_t



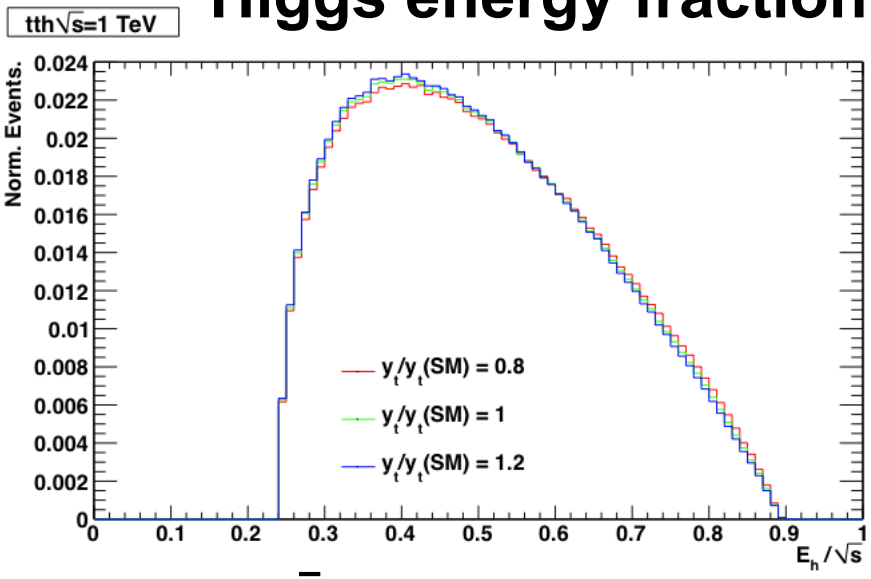
4% deviation from 0.5 observed

→ relevant given the precision expected at 1 TeV!

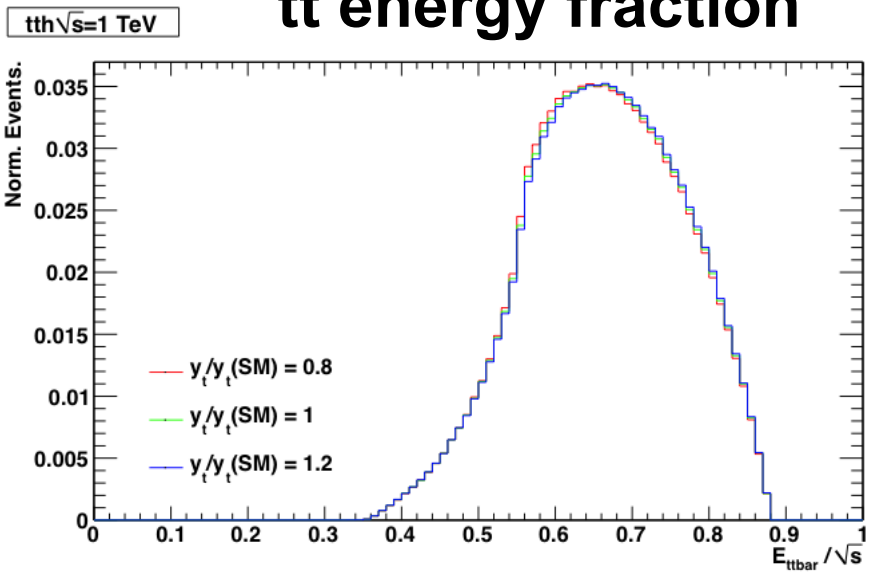
Impact on event kinematics



Higgs energy fraction



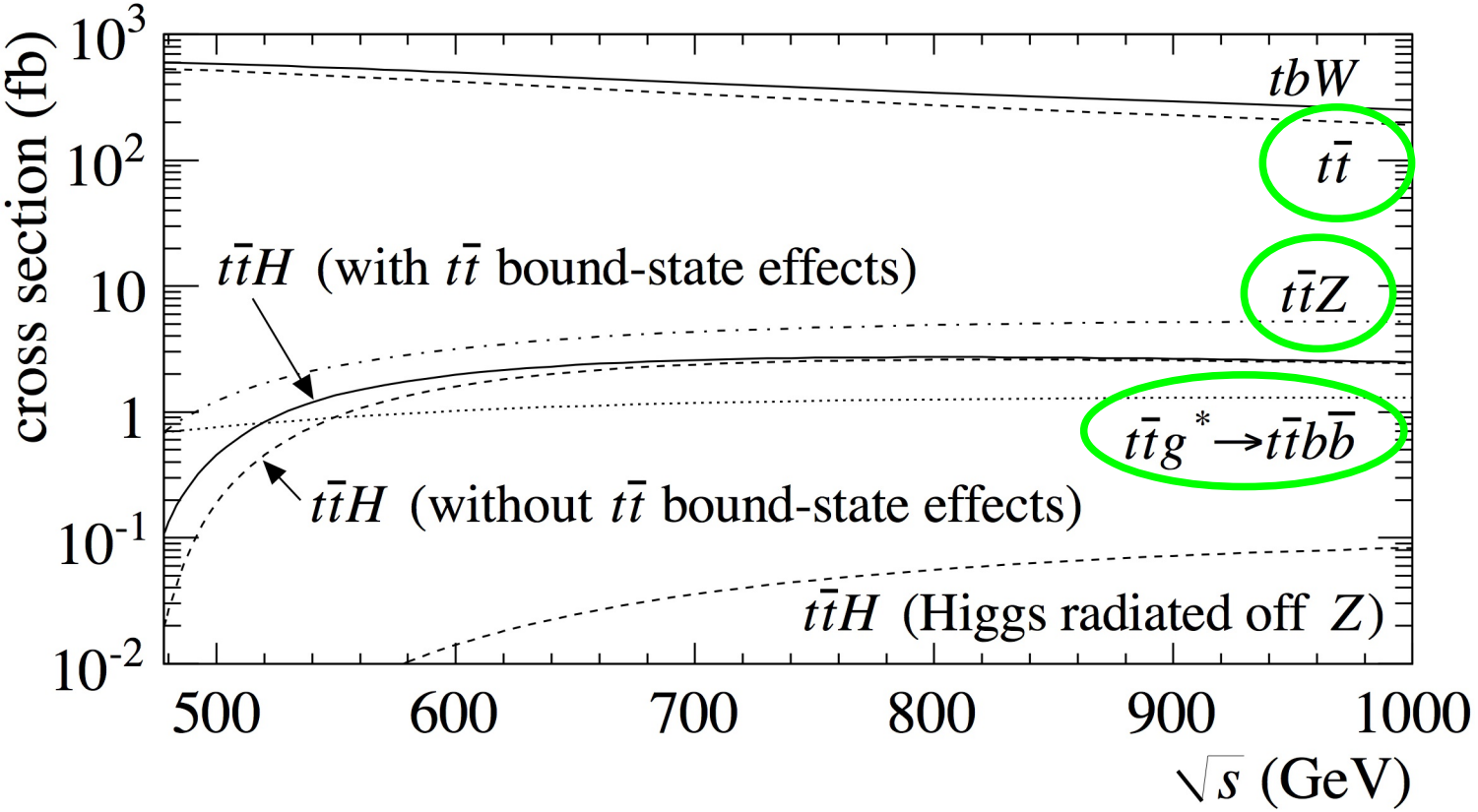
$t\bar{t}$ energy fraction



- Small difference in the shapes visible

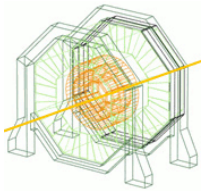
- Additional correction due to possible effect on detector acceptance probably not necessary

Background processes



- **$t\bar{t}$ pair production:** 6-fermion final state (WHIZARD)
- **$t\bar{t}Z$ production:** 8-fermion final state (PHYSIM)
- **$t\bar{t}g^* \to t\bar{t}b\bar{b}$**, 8-fermion final state, splitting of hard gluons (PHYSIM)

Software tools



Main software tools used in the analysis stage:

- **LCFIPlus:** Vertex finder and flavour tagging

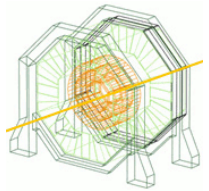
- Based on LCFI (used for LOI studies)
- Improved for multi-jet events:

Avoid splitting up of tracks from b/c decay into different jets

- Implemented as Marlin processor
- Works now also for SiD (available since v00-05-01-pre)

- **FastJet:** Jet reconstruction

- Includes implementations of several jet finding algorithms
- Written in C++, wrapper for Marlin exists
- Used successfully by LHC experiments and for CLIC CDR analyses



Event reconstruction

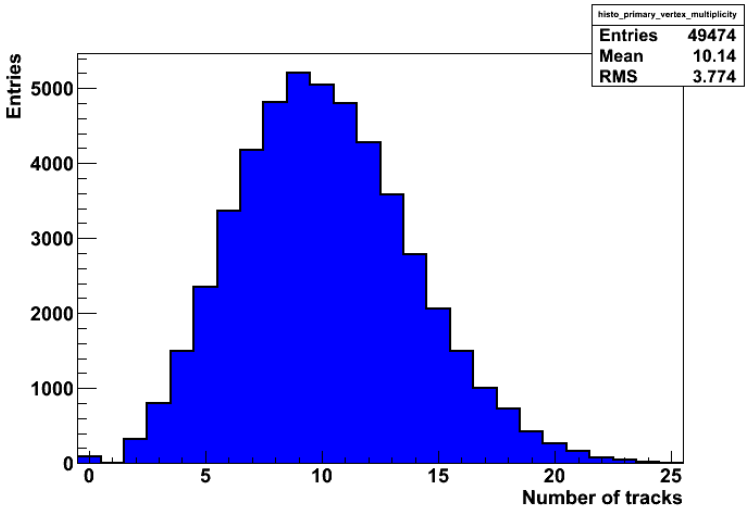
- **Flavour tagging performance**
- **Jet reconstruction**

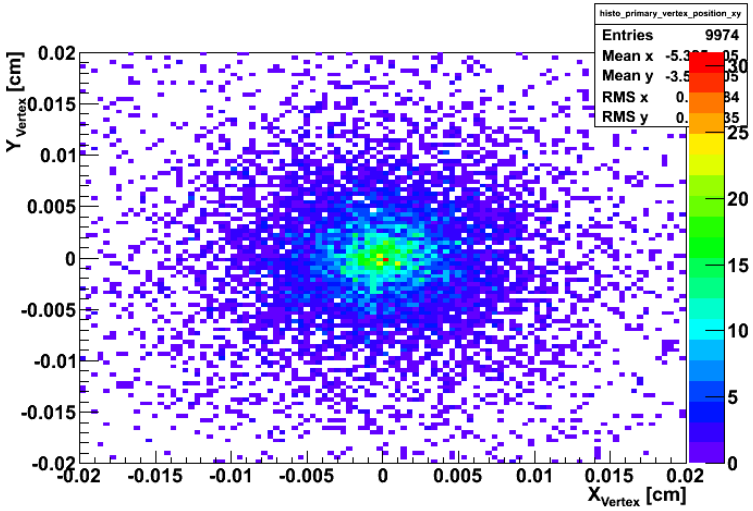
Cross check: vertex resolution

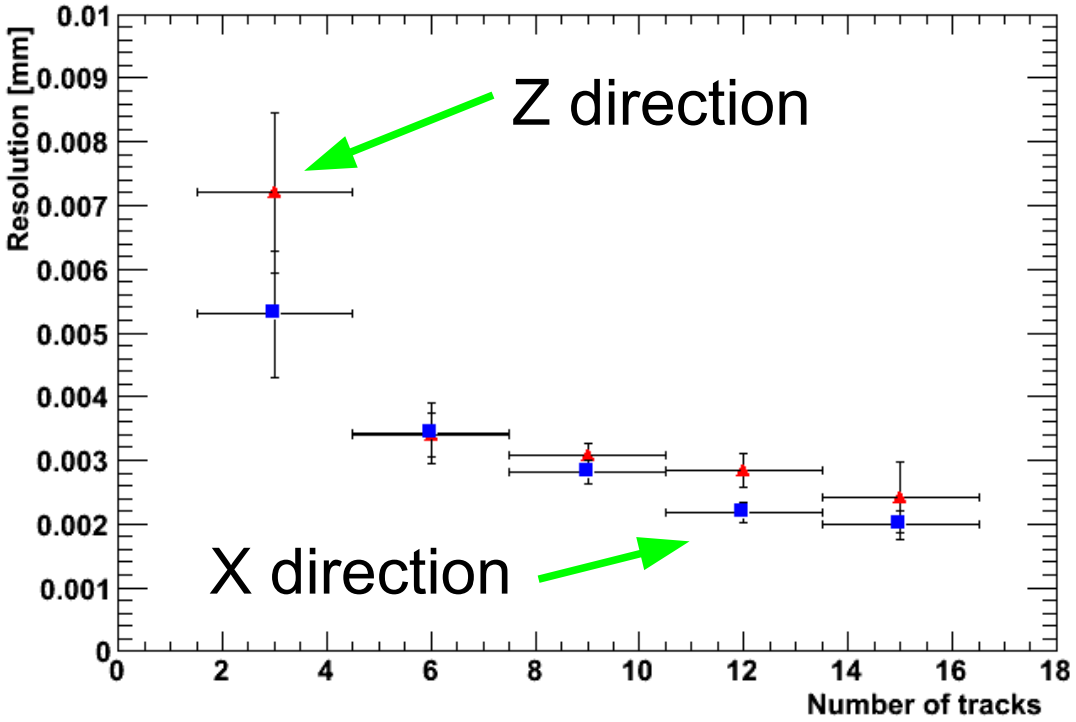
- Using Z → uds events at 91 GeV
- Beam constraint in vertex fit switched off
- Smearing of vertex position switched off

→ True primary vertex always at (0,0,0)

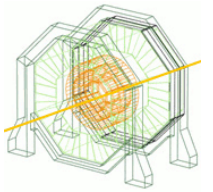
→ Can obtain resolution directly from width residual distribution

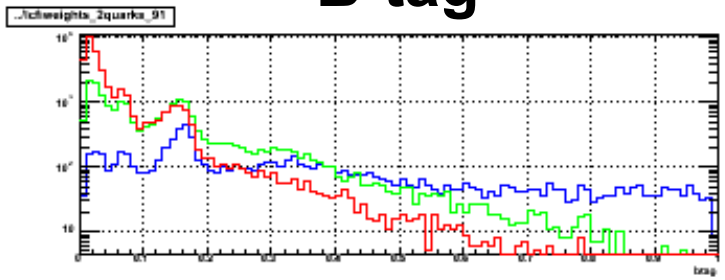
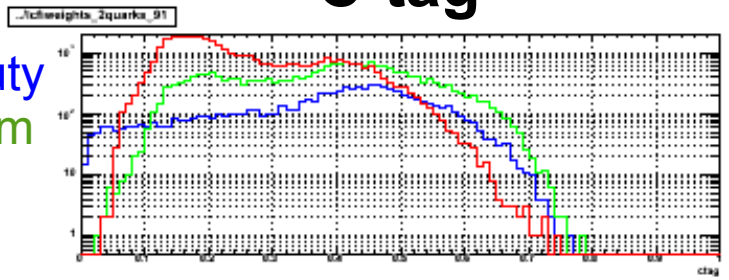
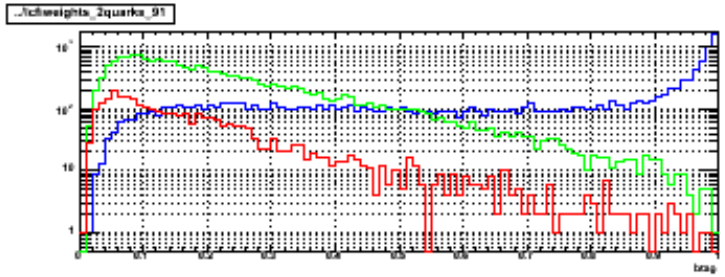
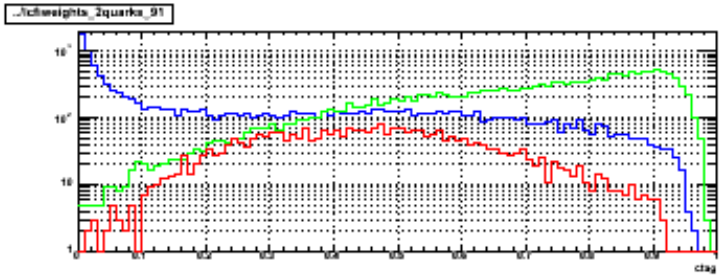
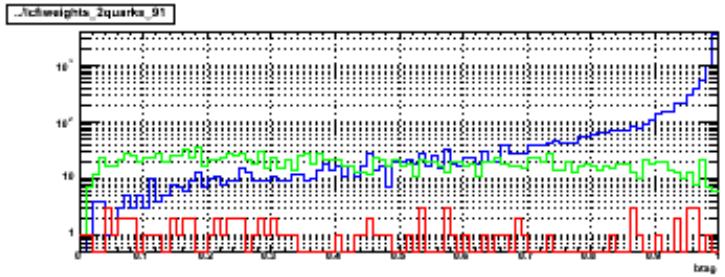
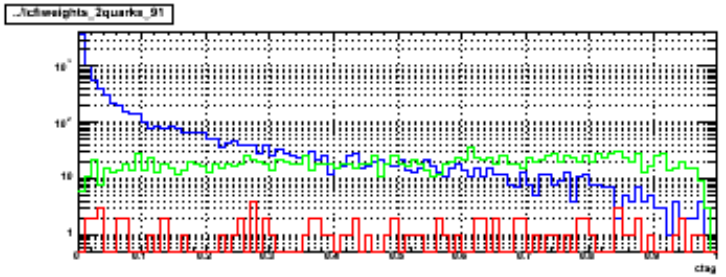
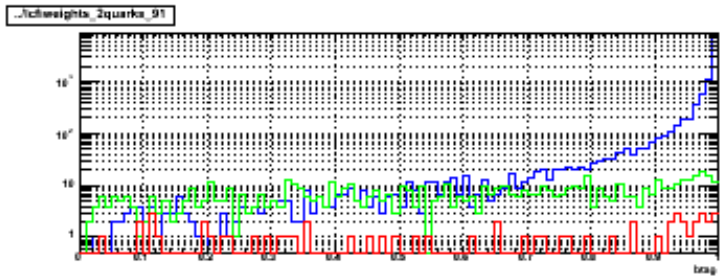
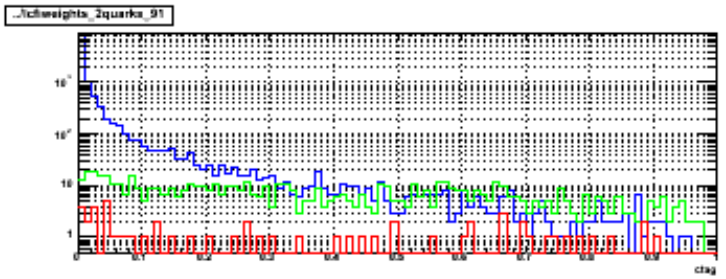






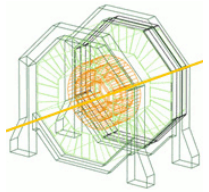
Flavour tagging: Z pole

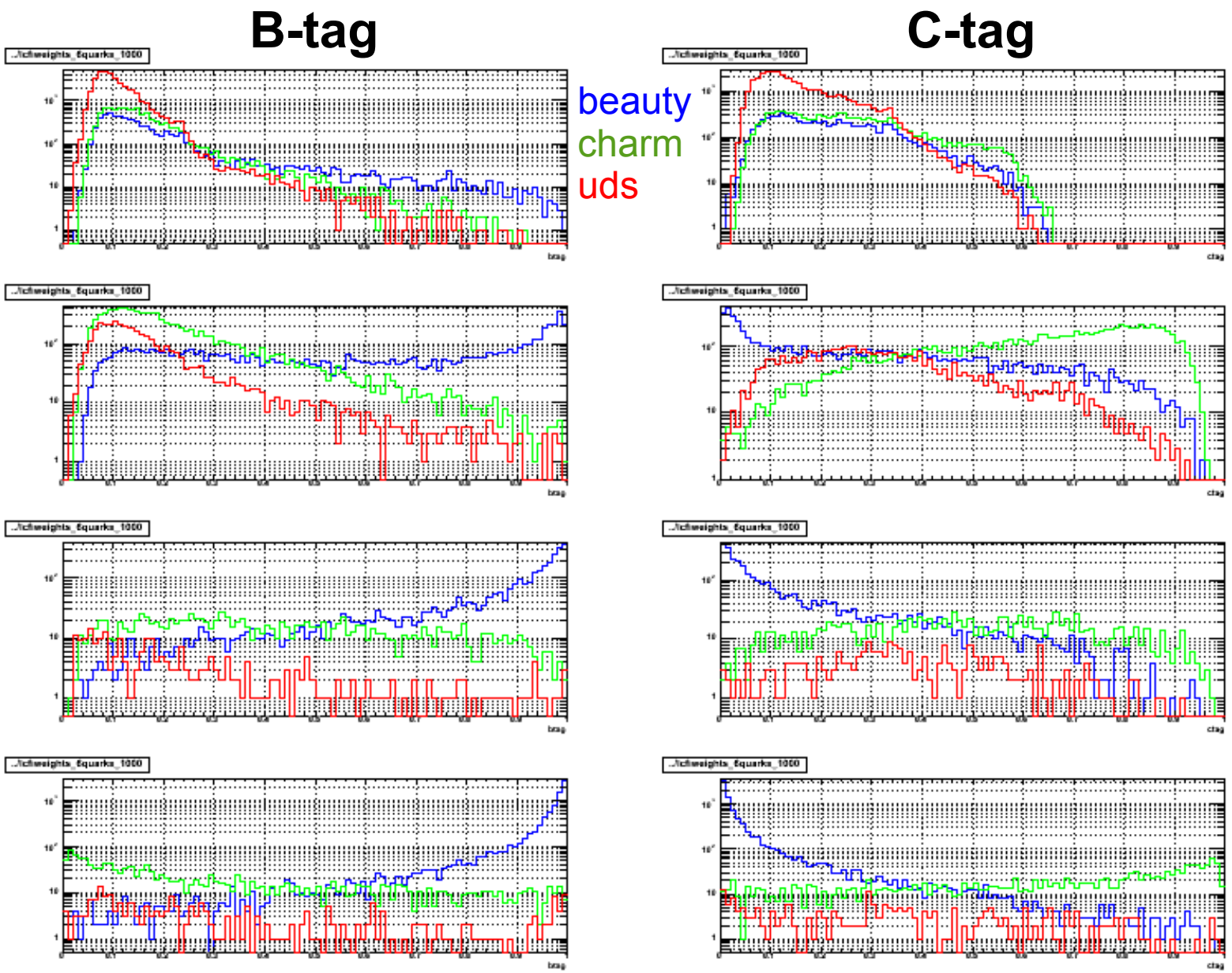


	B-tag	C-tag
No vertex		
1 vertex		
1 vertex + 1 pseudo-vertex		
2 vertices		

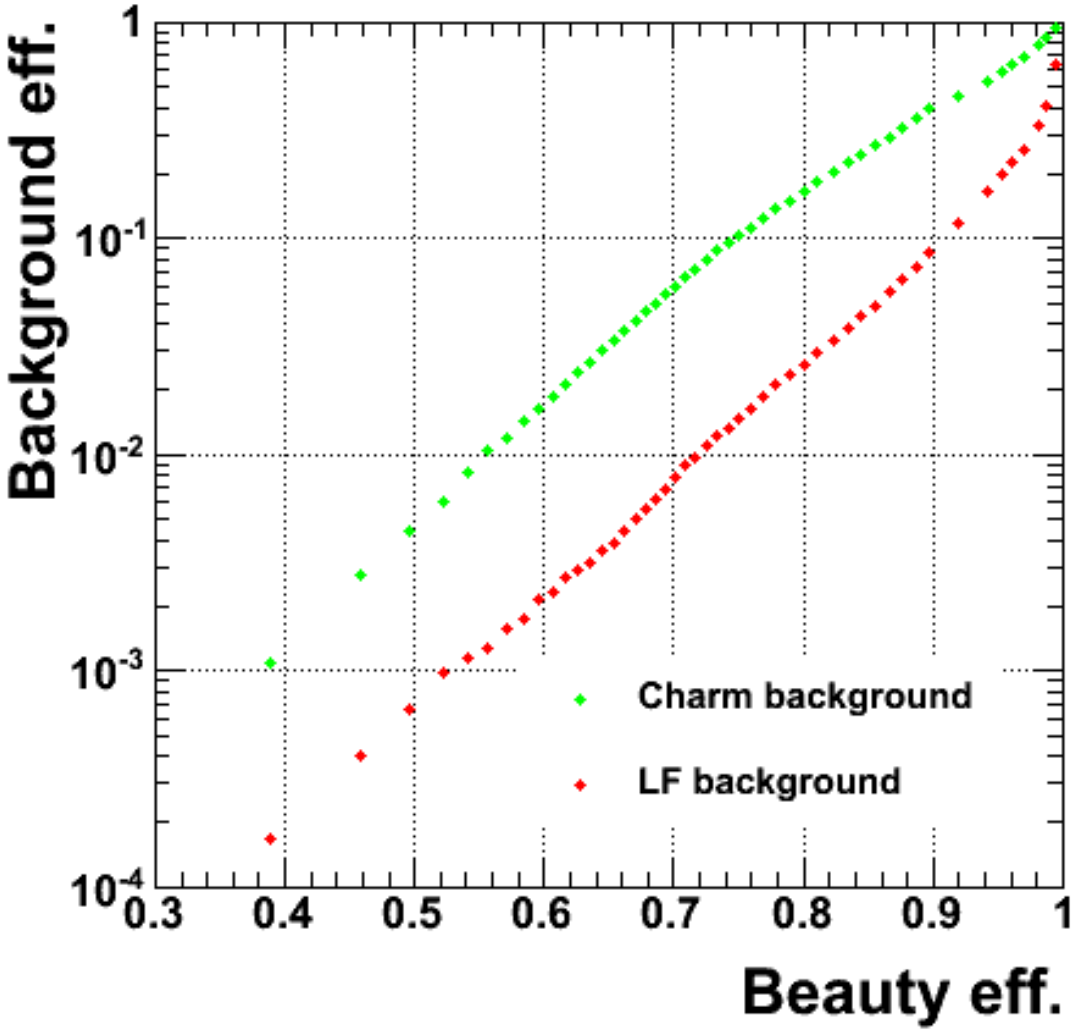
beauty
charm
uds

Flavour tagging: 6-jet samples at 1 TeV



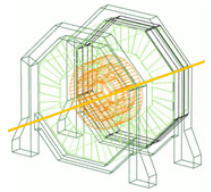


Beauty eff. vs. background eff.



Z pole

Jet reconstruction strategy



Fully simulated signal events (no beam-related backgrounds yet):
- 1000 events tth → 6jets (4b jets) + lepton + missing E
- 1000 events tth → 8jets (4b jets)

1.) Remove identified isolated leptons from PFO list
(using IsolatedLeptonFinderProcessor in Marlin)

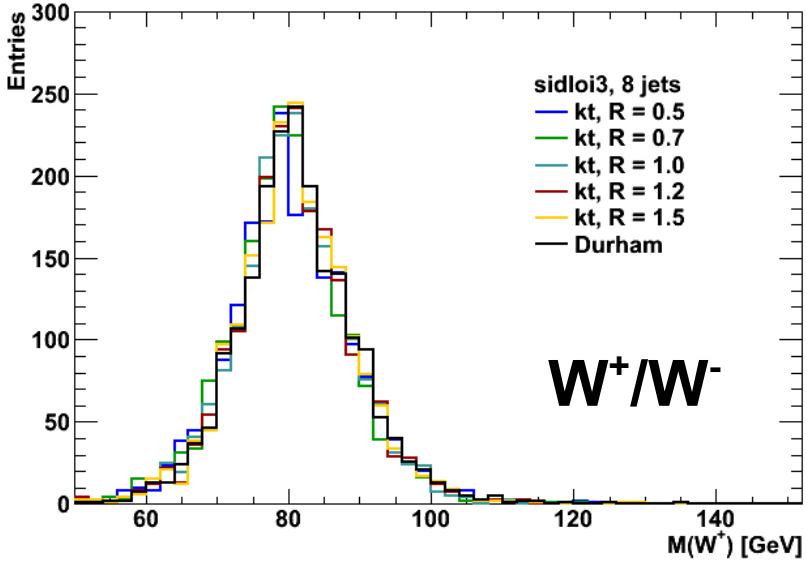
2.) Perform jet clustering using Durham or hadron-collider type kt
(R = 0.5, 0.7, 1.0, 1.2, 1.5) in the exclusive mode with 6 or 8 jets

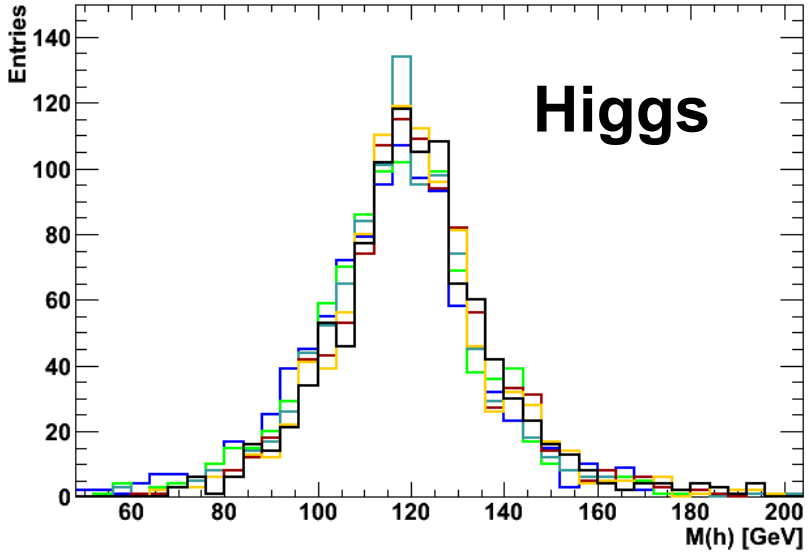
3.) Minimise:

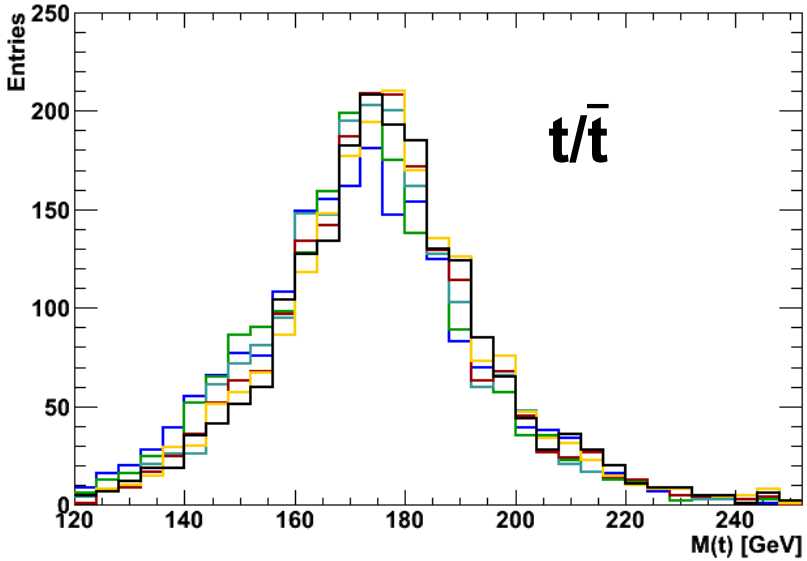
8 jets: $(M_{12} - M_W)^2 / \sigma_W^2 + (M_{123} - M_t)^2 / \sigma_t^2 + (M_{45} - M_W)^2 / \sigma_W^2$
$+ (M_{456} - M_t)^2 / \sigma_t^2 + (M_{78} - M_H)^2 / \sigma_H^2$

6 jets: $(M_{12} - M_W)^2 / \sigma_W^2 + (M_{123} - M_t)^2 / \sigma_t^2 + (M_{45} - M_H)^2 / \sigma_H^2$

Comparison of jet algorithms: 8-jet final state



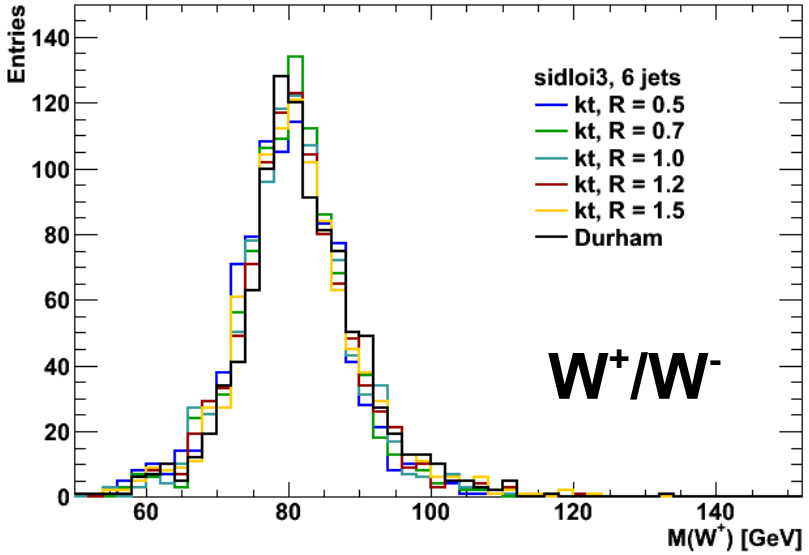


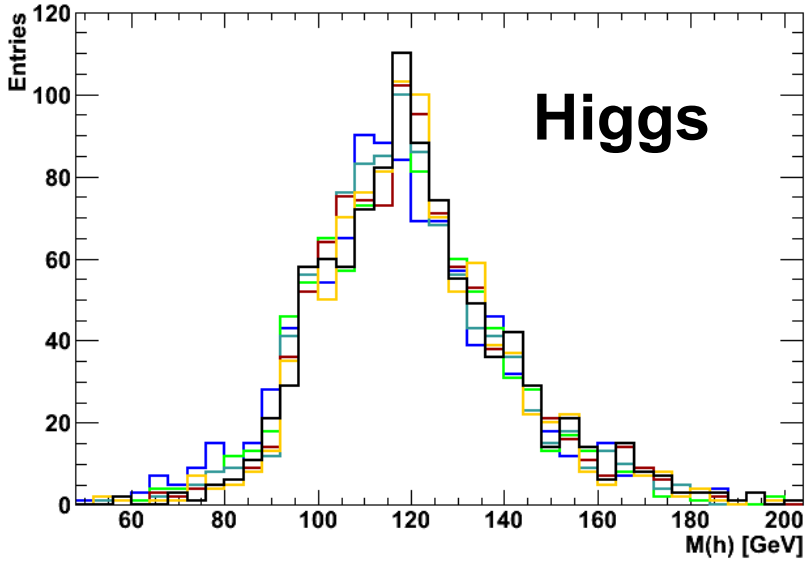


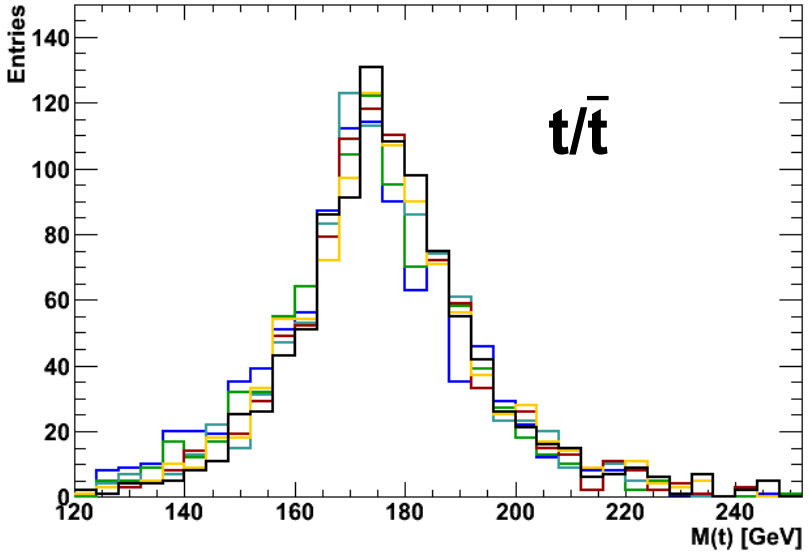
- Durham and hadron collider k_t algorithm show very similar performance

- Slight shift towards lower masses for decreasing R

Comparison of jet algorithms: 6-jet final state





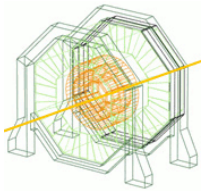


- Durham and hadron collider k_t algorithm show very similar performance

- **Further improvement possible if needed**:

  - Use of b-tagging information
  - Kinematic fit

Cross section and y_t measurement



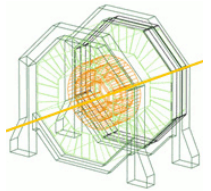
- **Apply event selection based on:**

  - M(t/$\bar{t}$)
  - M(H)
  - Four highest jet b-tag values
  - Thrust
  - Jet transition values: $Y_{7\to8}$ or $Y_{4\to5}$
  - …

- Use of multivariate classifier like boosted decision tree?

- Cross section from counting events $\rightarrow y_t$

Summary and conclusions



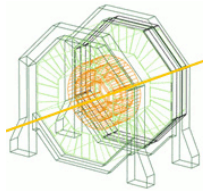
- The measurement of the $t\bar{t}h$ final state allows to measure the top Yukawa coupling directly

- Allows to benchmark several crucial aspects of the detector performance:

  - Reconstruction of multi-jet final states
  - Flavour tagging
  - Lepton identification

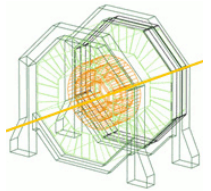
- All tools for the analysis are available now

- Waiting for the samples from the ongoing MC production



Backup slides

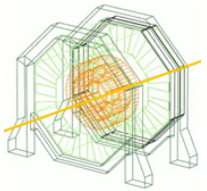
Samples for training of flavour tagging



final state:	#events:	status:
Z → bb	50000	sim&reco done
Z → cc	50000	sim&reco done
Z → qq	50000	sim&reco done
Z' → bb (200 GeV)	50000	sim&reco done
Z' → cc (200 GeV)	50000	sim&reco done
Z' → qq (200 GeV)	50000	sim&reco done
bbbb	10000	sim&reco done
cccc	10000	sim&reco done
qqqq	10000	sim&reco done
bbbbbb	10000	sim&reco done
cccccc	10000	sim&reco done
uuuuuu	10000	sim&reco done
dddddd	10000	sim&reco done
ssssss	10000	sim&reco done

→ The 4q and 6q samples are also be used by the ILD analysis

Changes to LCFIPlus package



Adapted the LCFIPlus package for SiD:

• The magnetic field is now read from the steering file instead of GEAR (ILD geometry package).

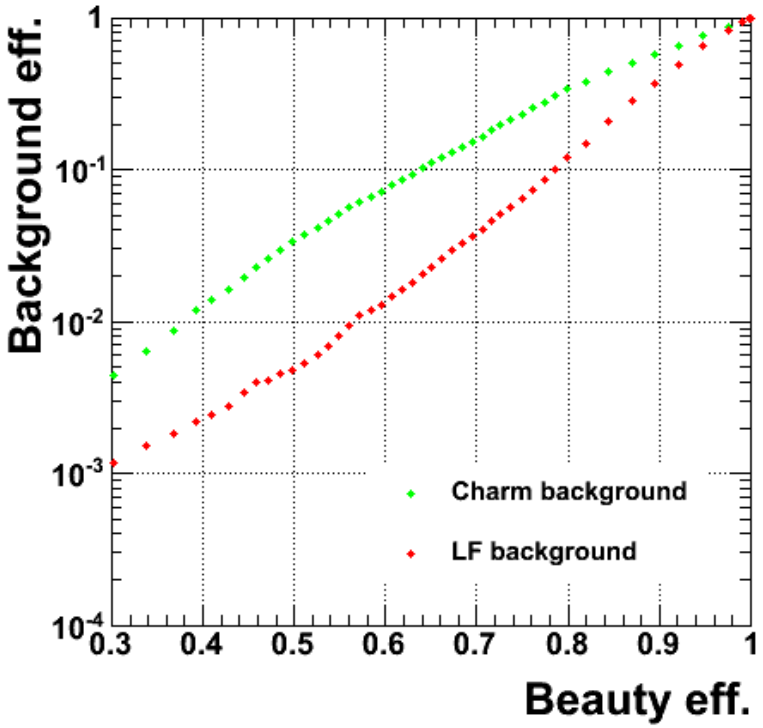
• The beam constraint in the primary vertex fit can be switched off (to measure the vertex resolution).

• The beam size can be set in the configuration file.

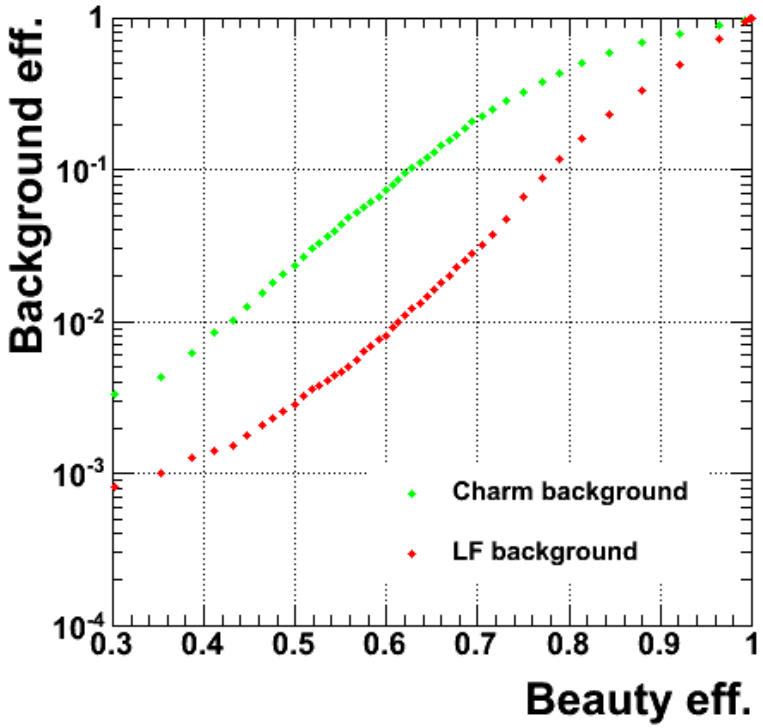
• Several hard-coded cuts can now be adjusted in the steering file to account for the different geometry of the SiD vertex detector.

Beauty eff. vs. background eff.

4-quarks



6-quarks



→ Need to check with training works best in the analysis