Reconstruction of heavy flavour jets for Higgs physics at future e^+e^- colliders

DPG Spring Meeting, Aachen

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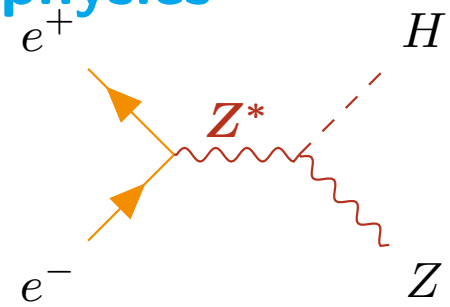
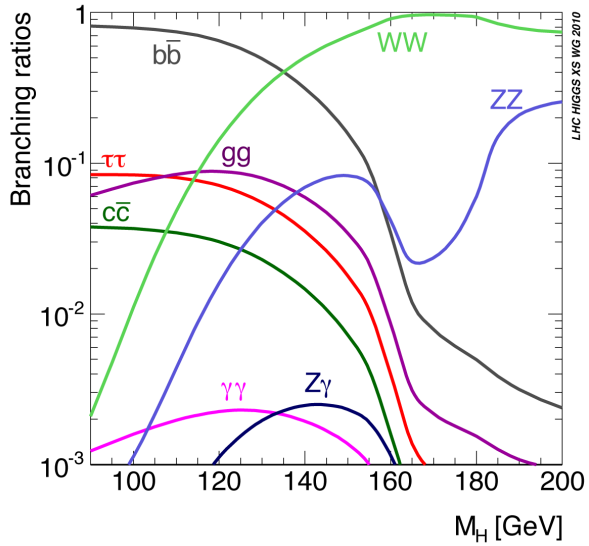
HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Motivation, heavy flavours in particle physics

- We can do precision measurements at lepton colliders
  - $H \to b\bar{b}$ and $H \to c\bar{c}$ decays





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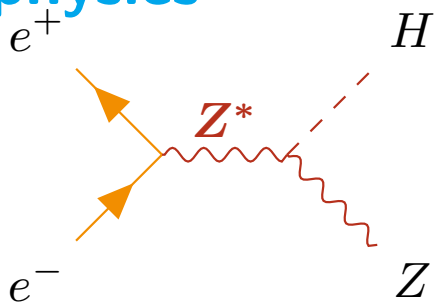
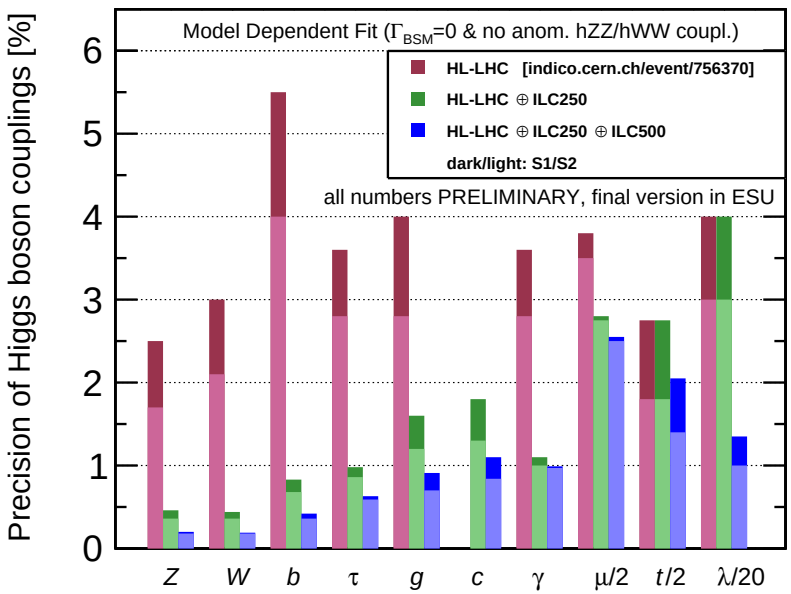
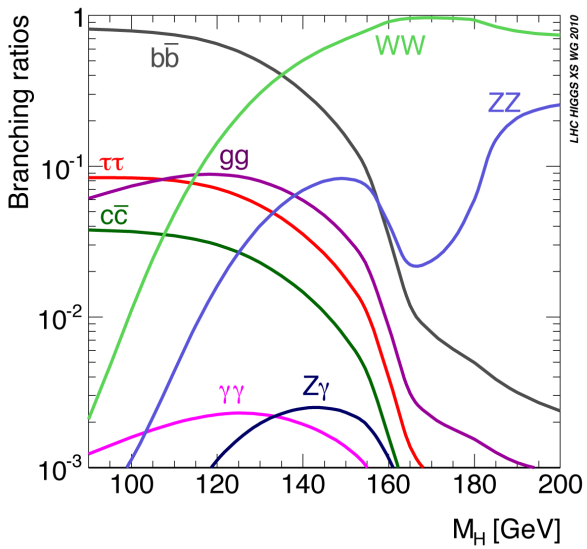
- Improvement of heavy flavour jet reconstruction and identification







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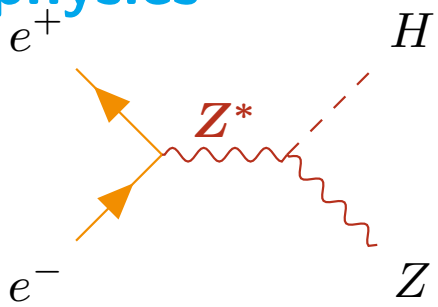
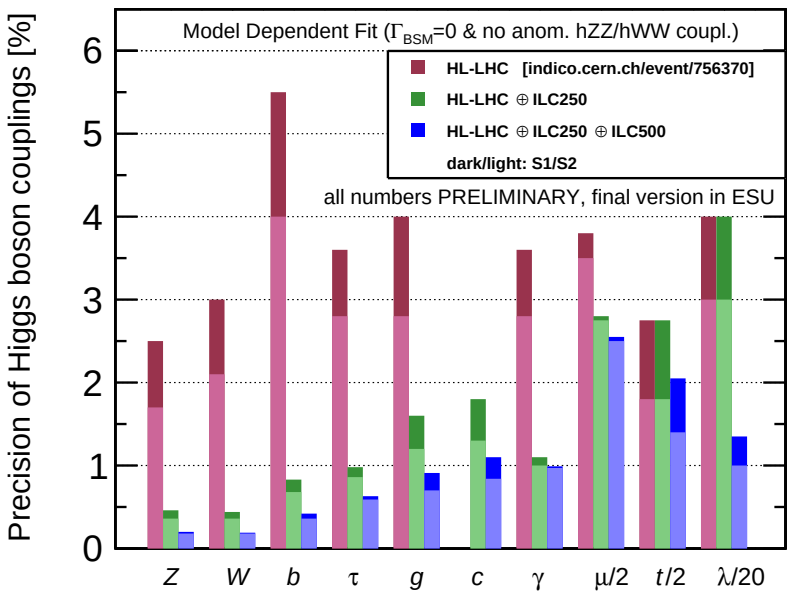
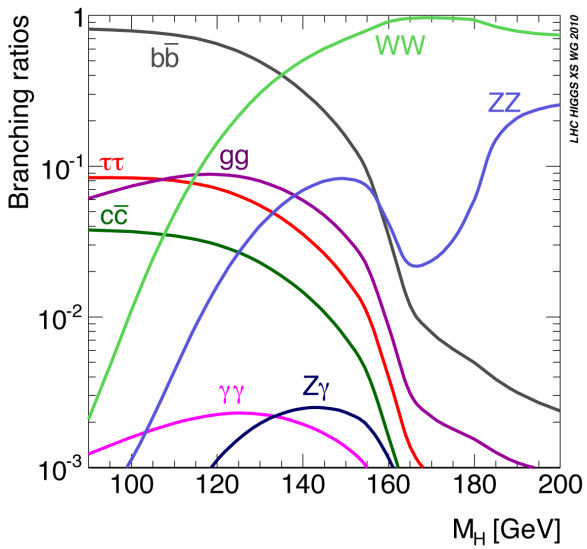




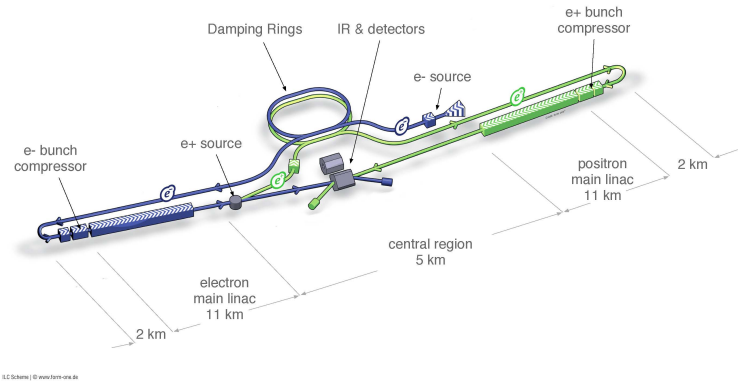


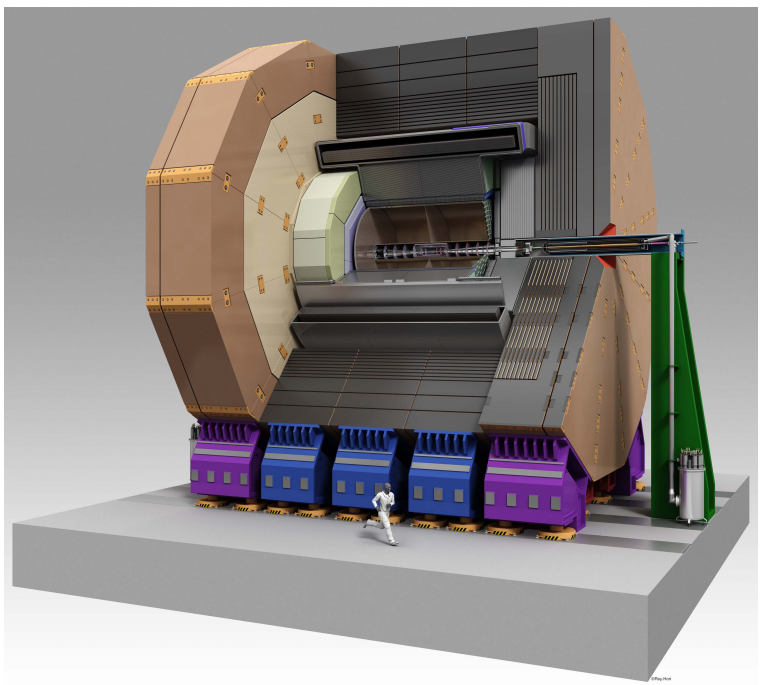
- Precision and Model independent measurement could be possible → **@ ILC**

International Linear Collider

and ILD Detector concepts

- Polarized e^+e^- beams colliding at $\sqrt{s} = 250\text{GeV}$ (upgrades: 500GeV and 1TeV)
  - detailed knowledge of initial states
  - more clear environment compared with hadron colliders

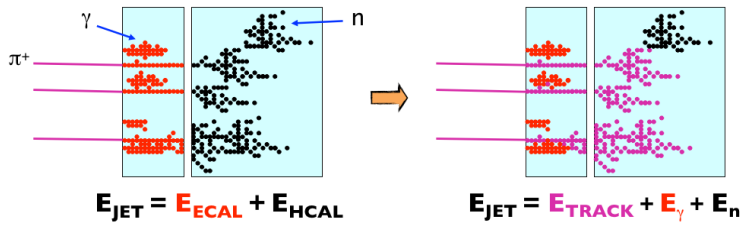




- International Large Detector
  - designed and optimized for Particle flow

Particle Flow Algorithm (PFA) and particle composition of jets

- Particle flow approach to calorimetry
  - fine granularity detectors
  - sophisticated software algorithm (Pandora)



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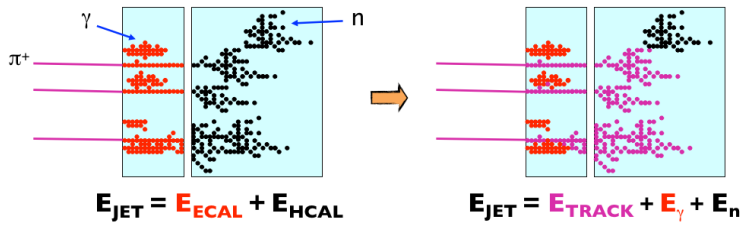
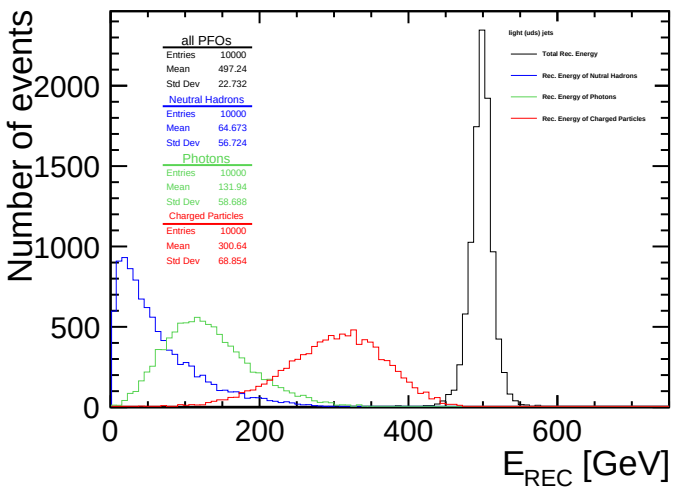


- Particle composition of a jet



$$E_{\text{REC}}^{\text{charged particles}} \approx 60\%\ E_{\text{REC}}^{\text{total}}$$

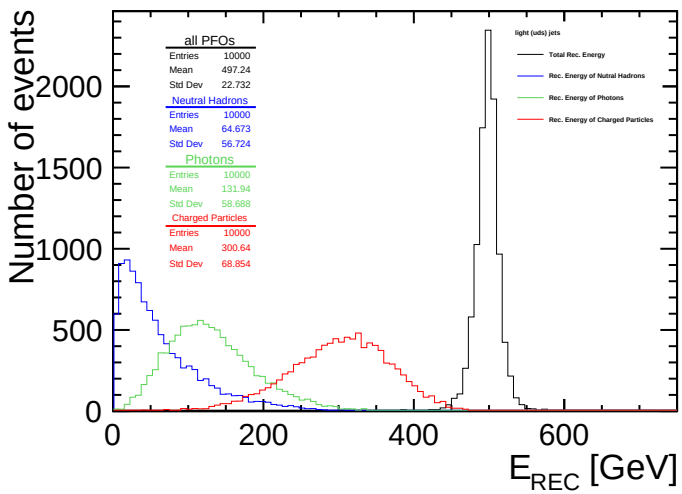
$$E_{\text{REC}}^{\text{neutral hadrons}} \approx 13\%\ E_{\text{REC}}^{\text{total}}$$

$$E_{\text{REC}}^{\text{photons}} \approx 26\%\ E_{\text{REC}}^{\text{total}}$$

Jet Energy Study of light quarks

- $e^+e^- \to q\bar{q}$ events
  - Fixed $\sqrt{s} = 40, 91, 200, 350, 500$ GeV
  - Standard di-jets: d, u and s quarks
  - Total Energy method:

$$E_{jet} \approx \frac{E_{tot}}{2} \quad \sigma_{E_{jet}} \approx \frac{\sigma_{E_{tot}}}{\sqrt{2}} \quad \frac{\sigma_{E_{jet}}}{E_{jet}} \approx \sqrt{2}\frac{\sigma_{E_{tot}}}{E_{tot}}$$



Jet Energy Resolution:

$$\frac{\sigma_E}{E} = \frac{22.732}{497.24} \times \sqrt{2} = 6.465\%$$

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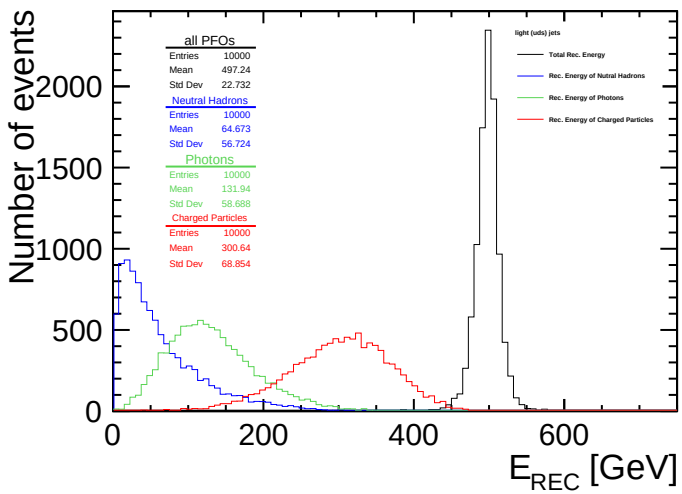

Jet Energy Resolution:

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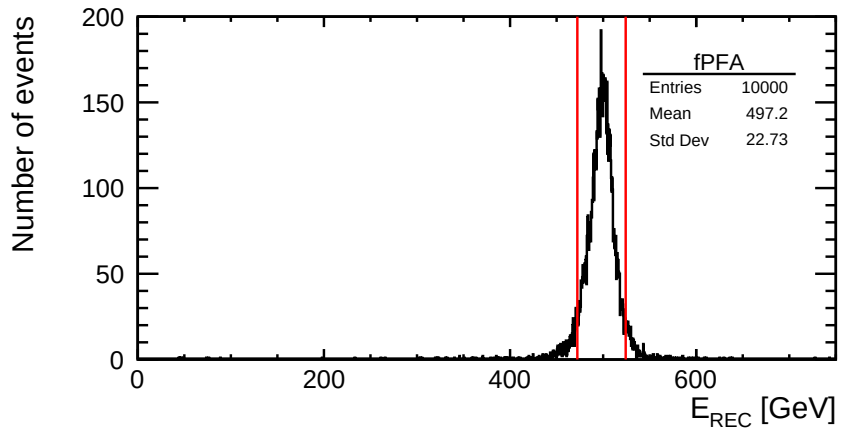
- Taking 90% of events to minimize the RMS

$$\frac{\sigma_{E_{tot}}}{E_{tot}} = \frac{\text{RMS}(E_{90\%})}{\text{MEAN}(E_{90\%})}$$



for $\sqrt{s} = 500$ GeV

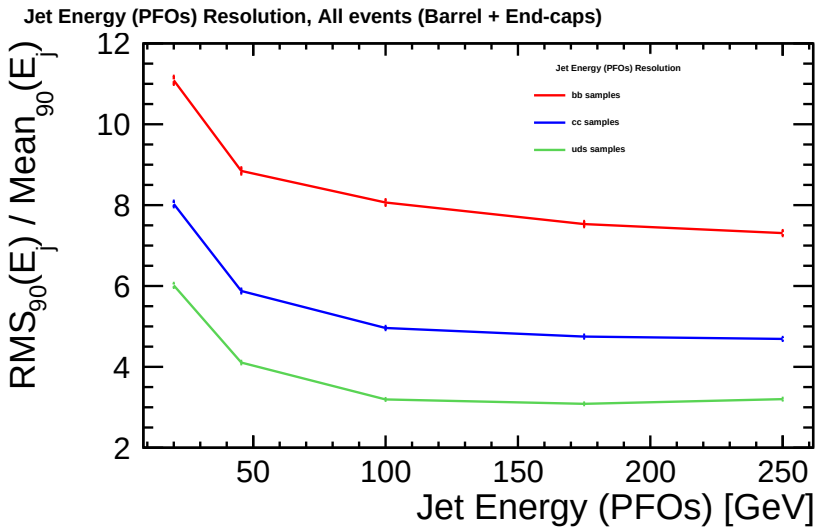
$$RMS(90\%) = 11.282 \ (472.278 : 524.226)$$

$$MEAN(90\%) = 498.375$$

$$\frac{\sigma_E(90\%)}{E(90\%)} = 3.2016\% \pm 0.032\%$$

Jet energy Study of b and c quarks

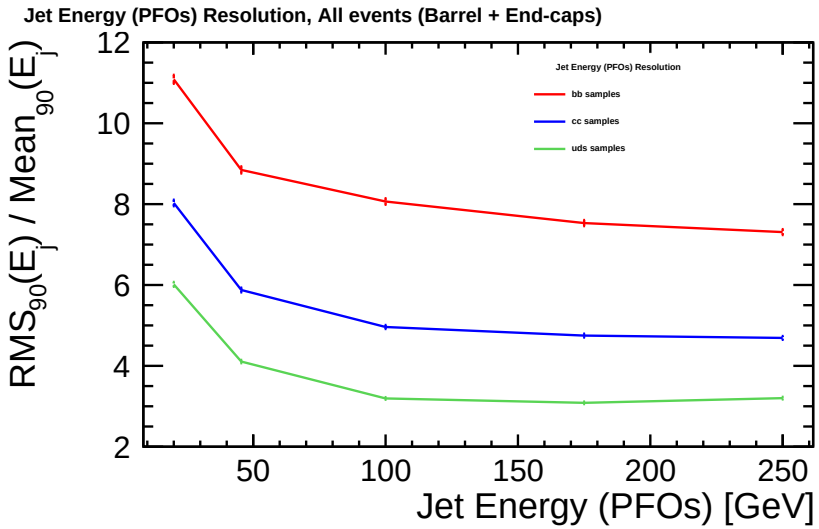
- Jet energy resolution



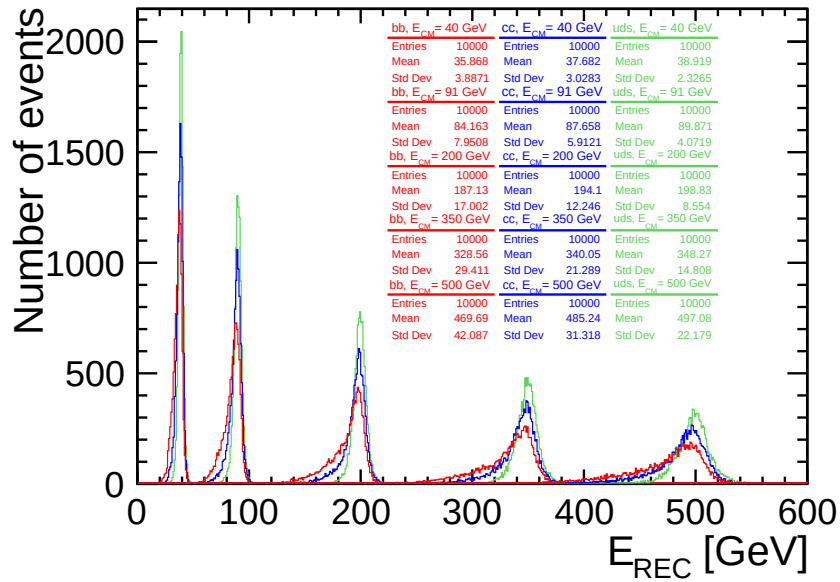
- Semi-leptonic decays cause different behaviour:

Jet energy Study of b and c quarks

- Jet energy resolution

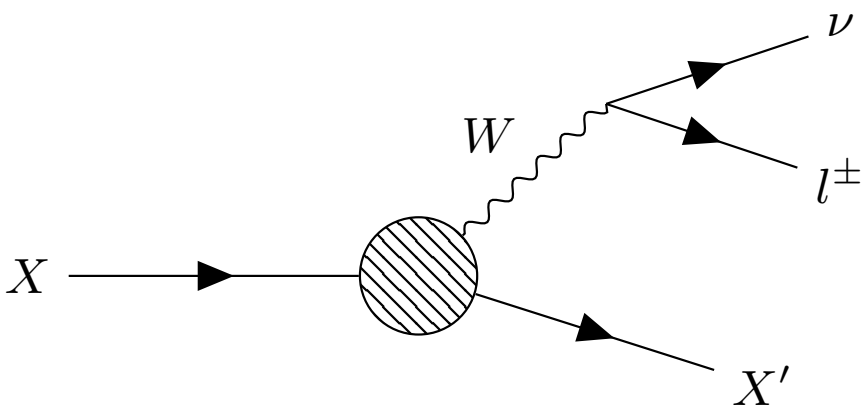


- Jet energy distribution



- Semi-leptonic decays cause different behaviour:
  - a lot of events with missing energy in heavy flavours

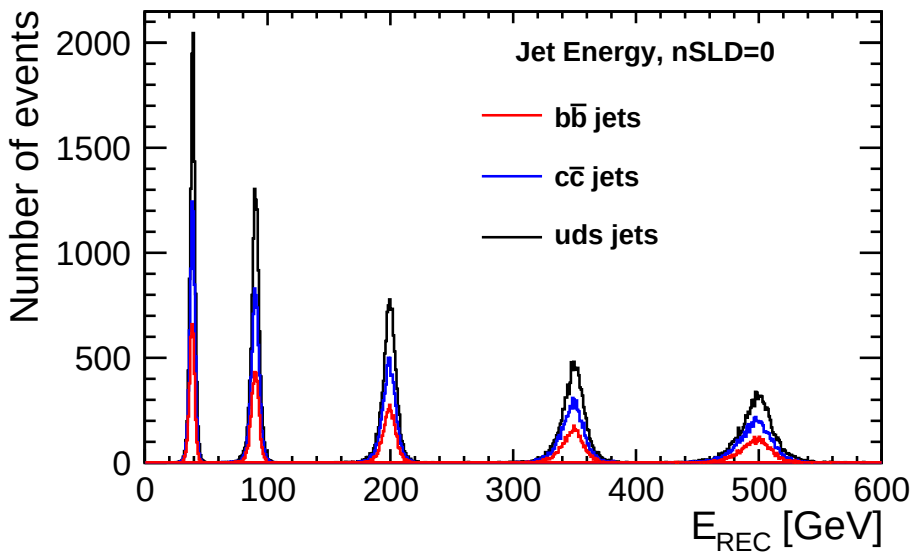
Semi-leptonic decays in heavy flavour jets



		nBSLD		
		0	1	2
nCSLD	0	34%	24%	4%
	1	18%	12%	2%
	2	3%	2%	0%

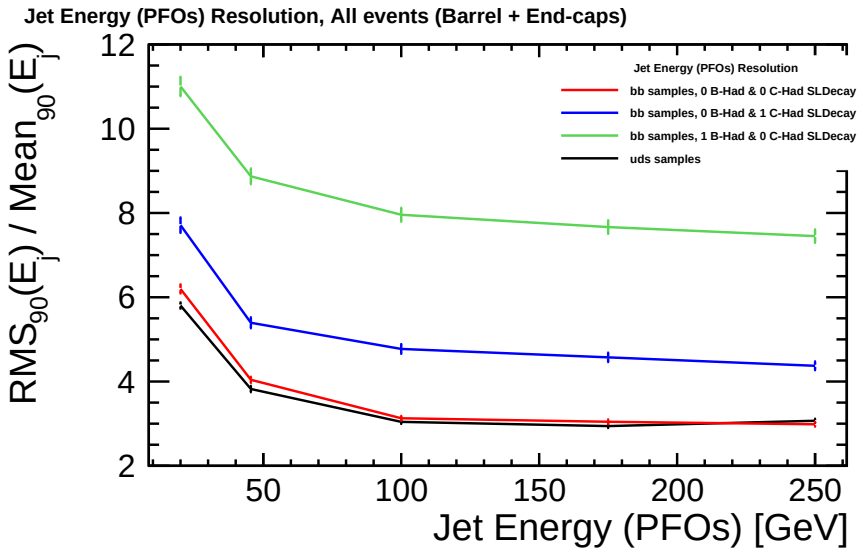
nBSLD: number of B-hadron semi-leptonic decay
nCSLD: number of C-hadron semi-leptonic decay

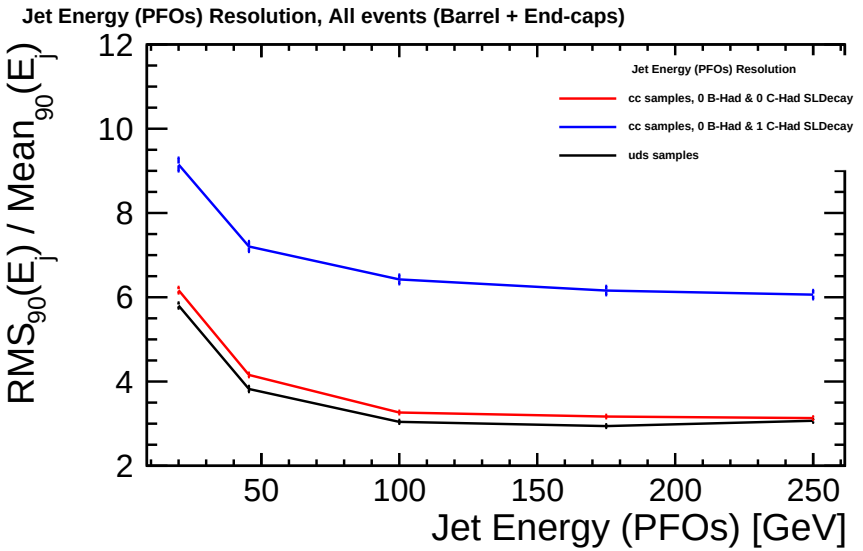
- $b\bar{b}\rightarrow$4(max) semi-leptonic decay
  - $BR(B \rightarrow l\nu) \approx 25\%$
- $c\bar{c}\rightarrow$2(max) semi-leptonic decay
  - $BR(C \rightarrow l\nu) \approx 21\%$
- $\frac{1}{3}$ of events without semi-leptonic decay



Semi-leptonic decays degrade JER

in heavy flavour jets





- Jet Energy Resolution is improved by excluding semi-leptonic decays
- Neutrinos from B-hadron semi-leptonic decay are more energetic

Conclusion

- study of $b\bar{b}/c\bar{c}$ jets is crucial for Higgs precision measurements
- ILD design and optimization: PFlow JER : 3-4%
- Due to neutrino from semi-leptonic decays:
  - $c\bar{c}$: 50% worse than uds
  - $b\bar{b}$: $>$ 2x worse than light quarks
  - Better JER for events without semi-leptonic decays

BACKUP