ILC detector optimization, reconstruction and physics analysis

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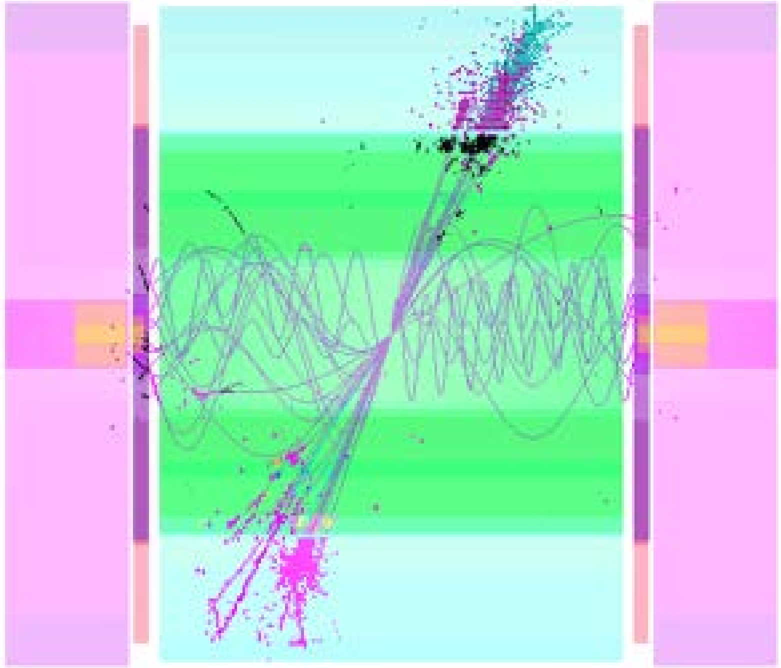
S. Green
See S. Green talk in LCWS15

Calorimeter Optimisation

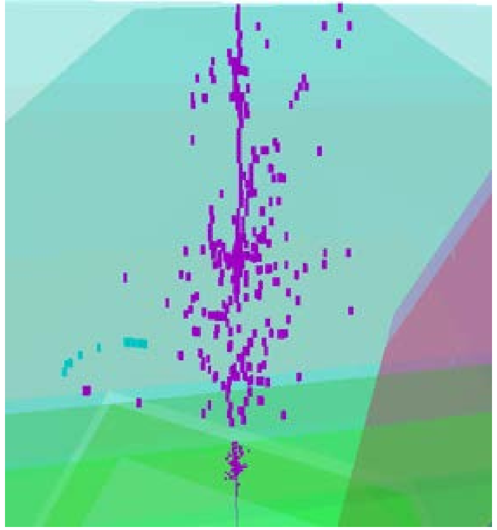
- Calorimeter optimisation
  - Access physics performance as a function of detector performance, i.e. Jet energy resolution
- Calorimeters must be designed to aid:
  - Intrinsic energy resolution
  - Pattern recognition performance.
- Pattern recognition is an essential aspect of detector performance in PFA.



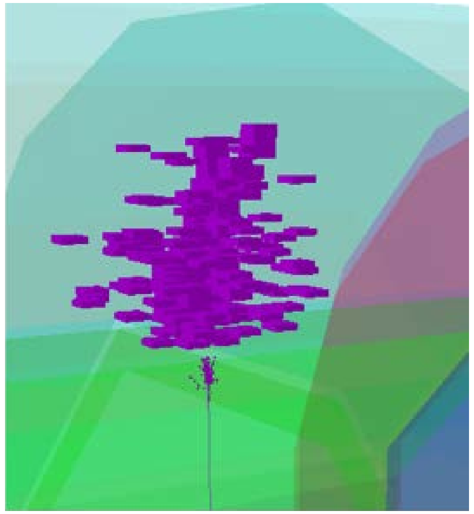
500 GeV Z’ bosons decay

Calorimeter Optimisation

- Metric for Calorimeter optimisation:
  - Jet energy resolution: $\frac{\sigma_{90\%}}{\langle E_{jets} \rangle}$, typically Z'->u/d/s jets
- Global parameters:
  - B-Field, R_0 Ecal
- ECal parameters: (ongoing)
  - Cell size, N_{layer}, active material, Silicon /Scintillator, Transverse granularity as a function of depth
- HCal parameters:
  - Cell size, N_{layer}, absorber material, N_{X^0}, sampling faction

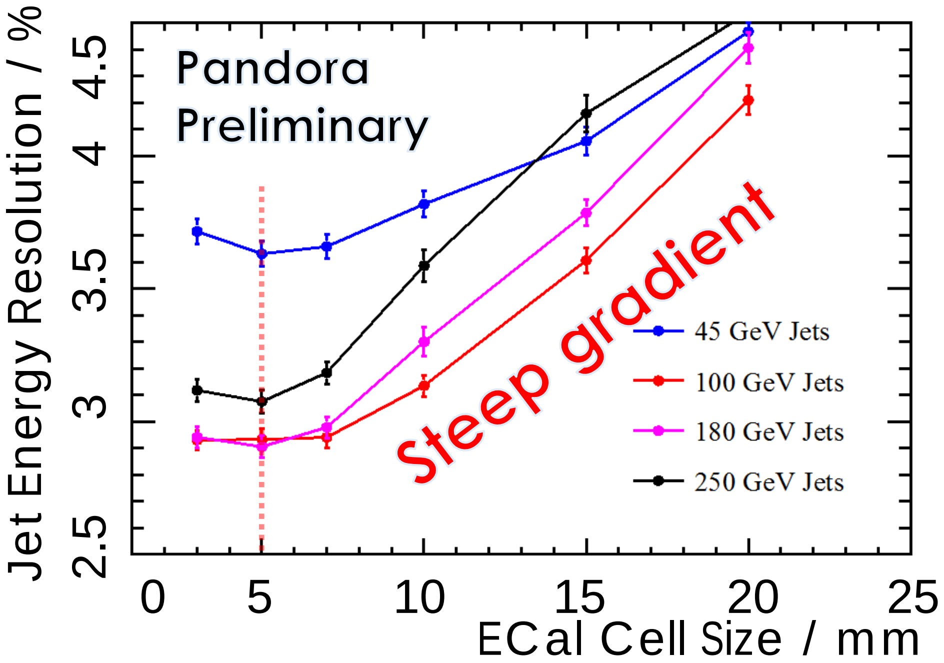


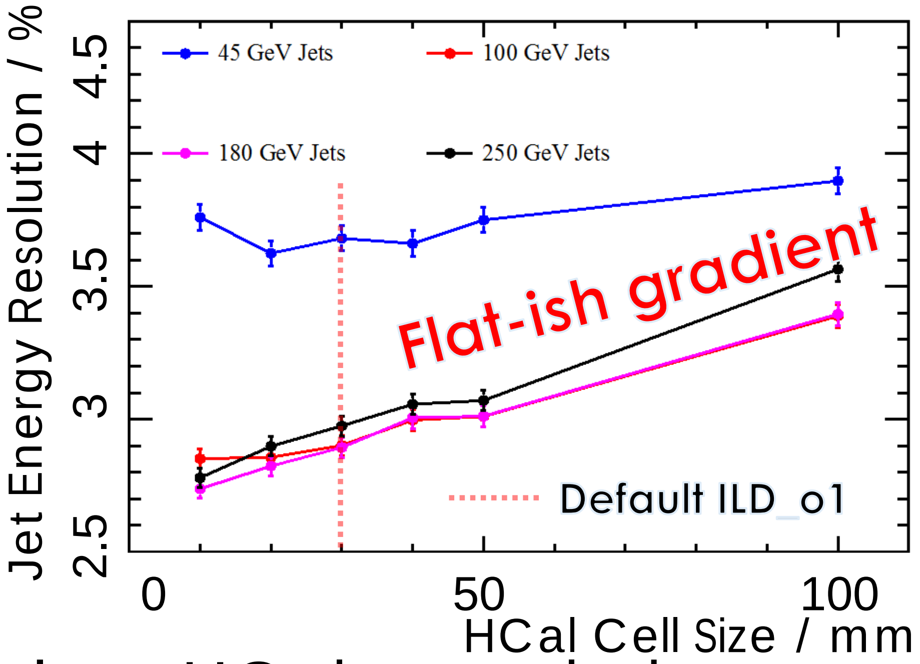
HCal Cell size changes



Calorimeter Optimisation

HCal Timing Cuts : 100 ns
ECal Timing Cuts : 100 ns
HCal Hadronic Cell Truncation: Optimised for detector model
Software : ilcsoft_v01-17-07, including PandoraPFA v02-00-00
Digitiser : ILDCaloDigi,enable realistic ECal and HCal digitisation
Calibration : PandoraAnalysis toolkit v01-00-00

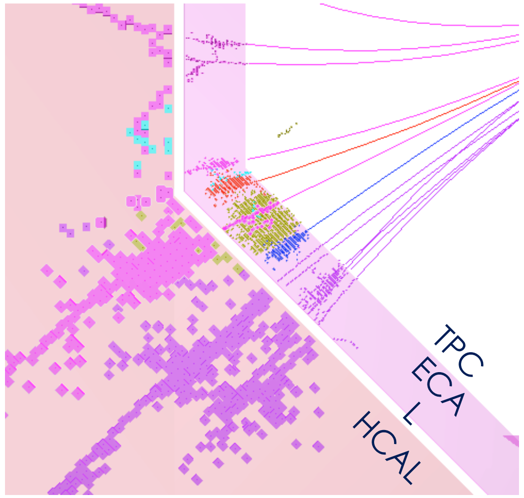




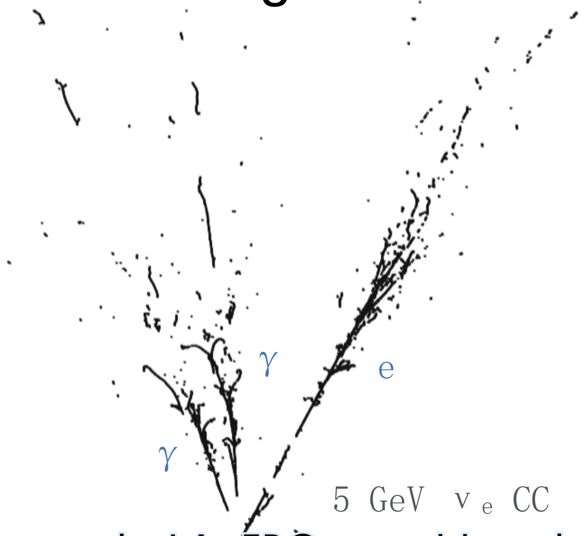
- ECal granularity is more important than HCal granularity
  - Pattern recognition algorithms can separate individual particles in the ECal, seeding the pattern recognition in the HCal.
  - Reclustering, examining consistency of cluster energy and associated track momentum, also significantly aids HCAL pattern recognition.

PandoraPFA

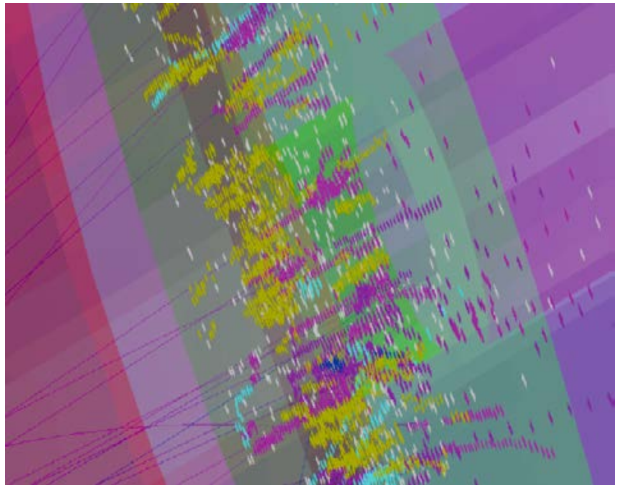
- Pandora software development kit designed in, implemented in and supported by Cambridge.
  - Sophisticated pattern recognition framework that supports a multi algorithm approach to solving complex problems.
  - Provides advanced reclustering and recursive functionality.



ILC/CLIC event topology



Example LAr TPC event topology



Showers in CMS HGCAL

Current major use-cases: ILC (NIMA.2009.09.009), CLIC (NIMA.2012.10.038), LAr TPC reco at DUNE/MicroBooNE (arXiv:1307.7335, 1506.05348) and CMS HGCAL upgrade (LHCC-P-008).

PandoraPFA

- Pandora SDK is now well documented (EPJC publication)
- Github page provides all source, detailed documentation and seminar-style overviews of reconstruction use-cases.

The Pandora Software Development Kit for Pattern Recognition

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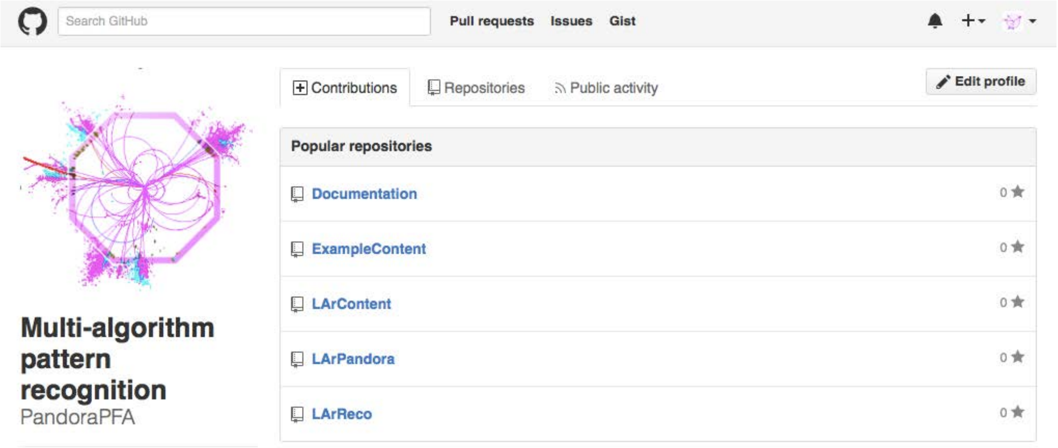
Abstract

The development of automated solutions to pattern recognition problems is important in many areas of scientific research and human endeavour. This paper describes the implementation of the Pandora Software Development Kit, which aids the process of designing, implementing and running pattern recognition algorithms. The Pandora Application Programming Interfaces ensure simple specification of the building-blocks defining a pattern recognition problem. The logic required to solve the problem is implemented in algorithms. The algorithms request operations to create or modify data structures and the operations are performed by the Pandora framework. This design promotes an approach using many decoupled algorithms, each addressing specific topologies. Details of algorithms addressing two pattern recognition problems in High Energy Physics are presented: reconstruction of events at a high-energy e^+e^- linear collider and reconstruction of cosmic ray or neutrino events in a liquid argon time projection chamber.

Keywords: Software Development Kit, Pattern recognition, High Energy Physics

http://arxiv.org/abs/1506.05348 or EPJC.75.439
or PandoraPFA github page

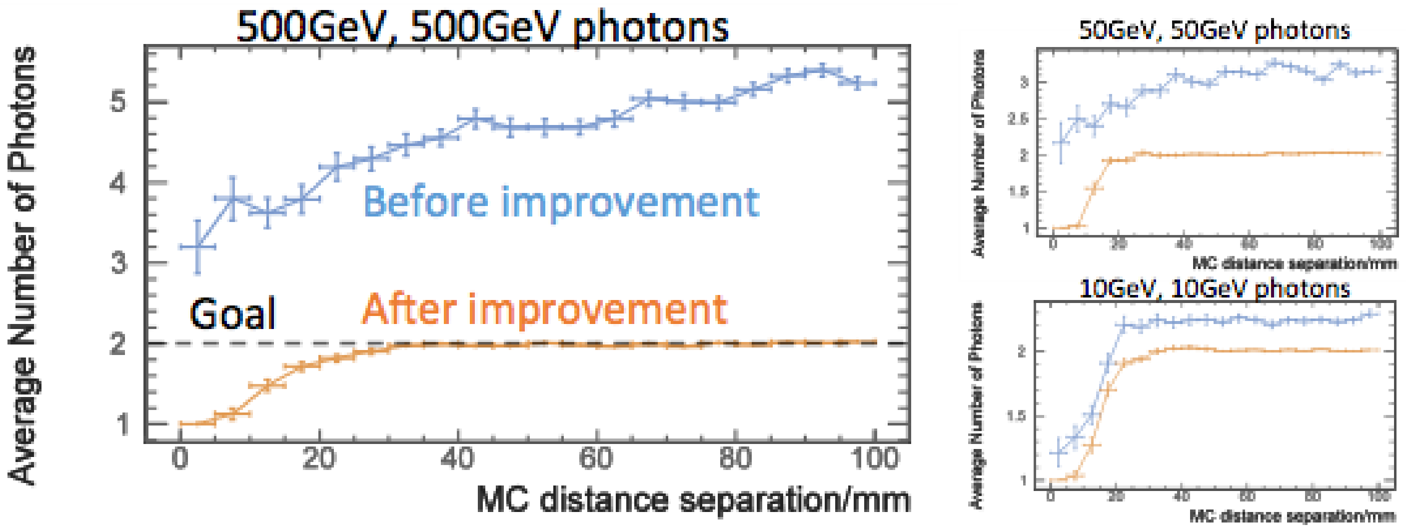


https://github.com/PandoraPFA

B. Xu
See B. Xu talk in LCWS15

Improvements to Photon reconstruction

- Improve completeness of reconstructed photons, particularly at high energies
  - Small fragments of EM showers could often be reconstructed as separate particles.
- Three new Pandora algorithms carefully merge fragments, based on cluster separation and energy profiles.

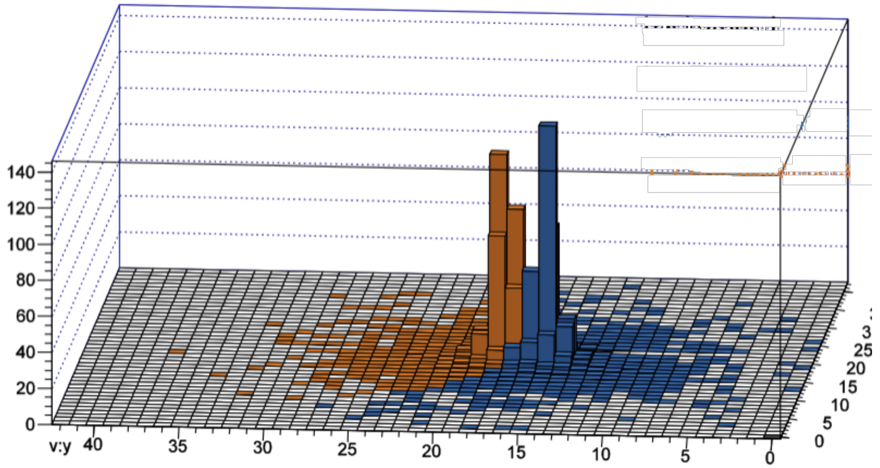


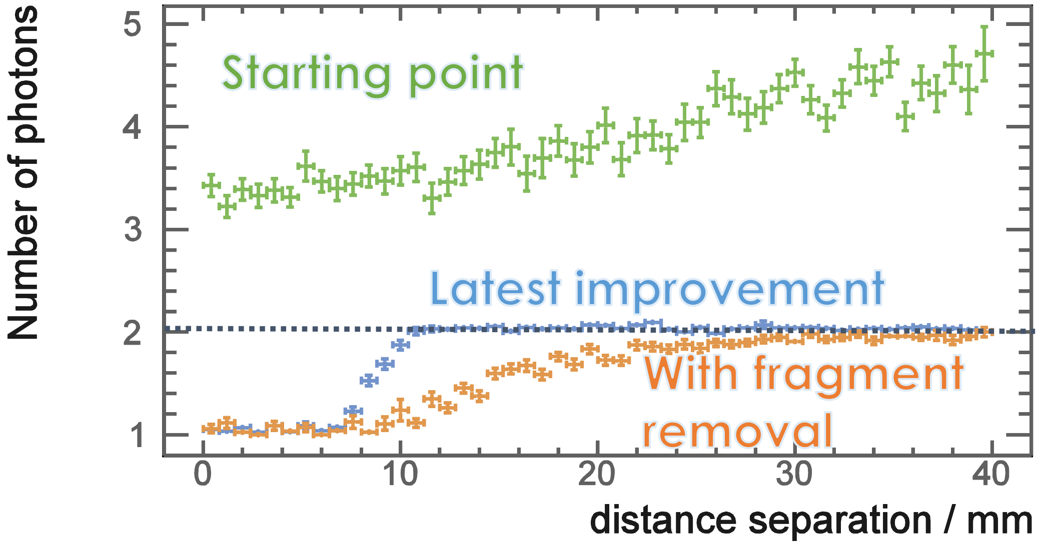
Average number of reconstructed photons (as a function of true separation) for samples consisting of two photons, generated with random directions

B. Xu
See B. Xu talk in LCWS15

Improvements to Photon reconstruction

- Improvements to photon reconstruction, reduce confusion in jet reconstruction and improve jet energy resolution
  - Identify EM shower cores by projecting ECAL energy deposits into a transverse plane. Apply algorithm to identify energy deposition peaks and to collect hits contributing to each peak.

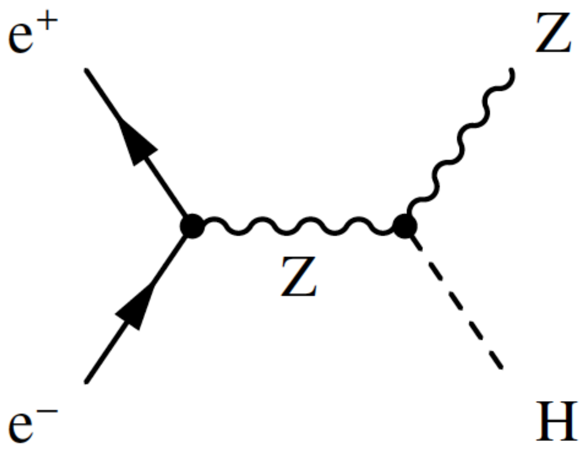




M. Thomson
See arxiv 1509.02853 accepted by EPJC

HZ(Z->qq) cross section analysis

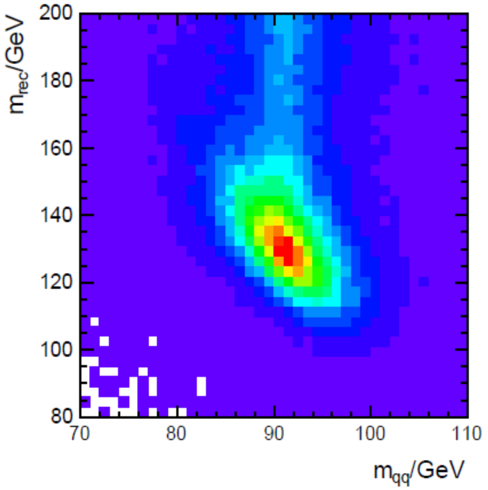
- Model-independent measurement of the e+e-> HZ(Z->qq) cross section
- Analysis strategy
  - i) separate all simulated events into candidates for Higgs decays to
    - “invisible” long-lived neutral particles
    - visible final states
  - ii) identify the di-jet system that is the best candidate for the Z->qq decay
  - iii) veto background events with event shape parameters



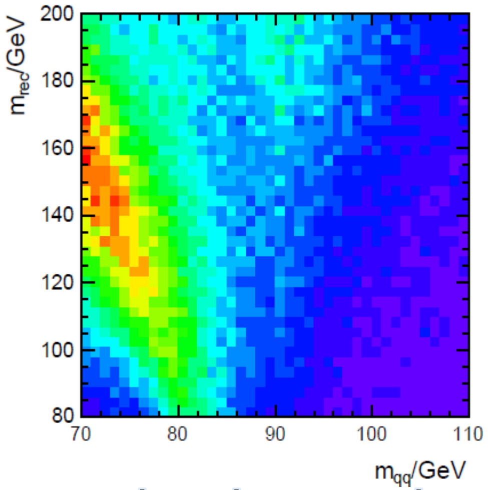
M. Thomson
See arxiv 1509.02853 accepted by EPJC

HZ(Z->qq) cross section analysis

- Analysis strategy
  - iv) identify HZ(Z->qq) events solely based on the properties from the candidate Z->qq decay, for visible and invisible Higgs decays
  - v) combine the results into a single measurement of σ(HZ)
- Plots show all events passing the visible Higgs preselection for CLIC operating at $\sqrt{s}$ = 350GeV. Distributions for ILC are very similar



HZ(Z -> qq) events



background

HZ(Z->qq) cross section analysis

√s = 350GeV (Z->qq)	$P(e^-,e^+)$	$\Delta\sigma_{vis.}$	$\Delta\sigma_{invis.}$	$\Delta\sigma(HZ)$
ILC 500fb^{-1}	0,0	±1.57%	±0.48%	±1.63%
ILC 350fb^{-1}	-0.8,+0.3	±1.68%	±0.52%	±1.76%
ILC √s = 250GeV 250fb^{-1} **Z->l^+l^-*** *To compare*	-0.8,+0.3	-	-	±2.6%

- For the polarised beam at √s = 350GeV with Z->qq, $\Delta\sigma(HZ)$=1.8% is comparable to √s = 250GeV with Z->l^+l^-, $\Delta\sigma(HZ)$=2.6%
- This conclusion weakens the motivation for operating a future linear collider significantly below the top-pair production threshold
- *ILC LOI / TDR / H. Li, arXiv:1007.3008.

Thank you!