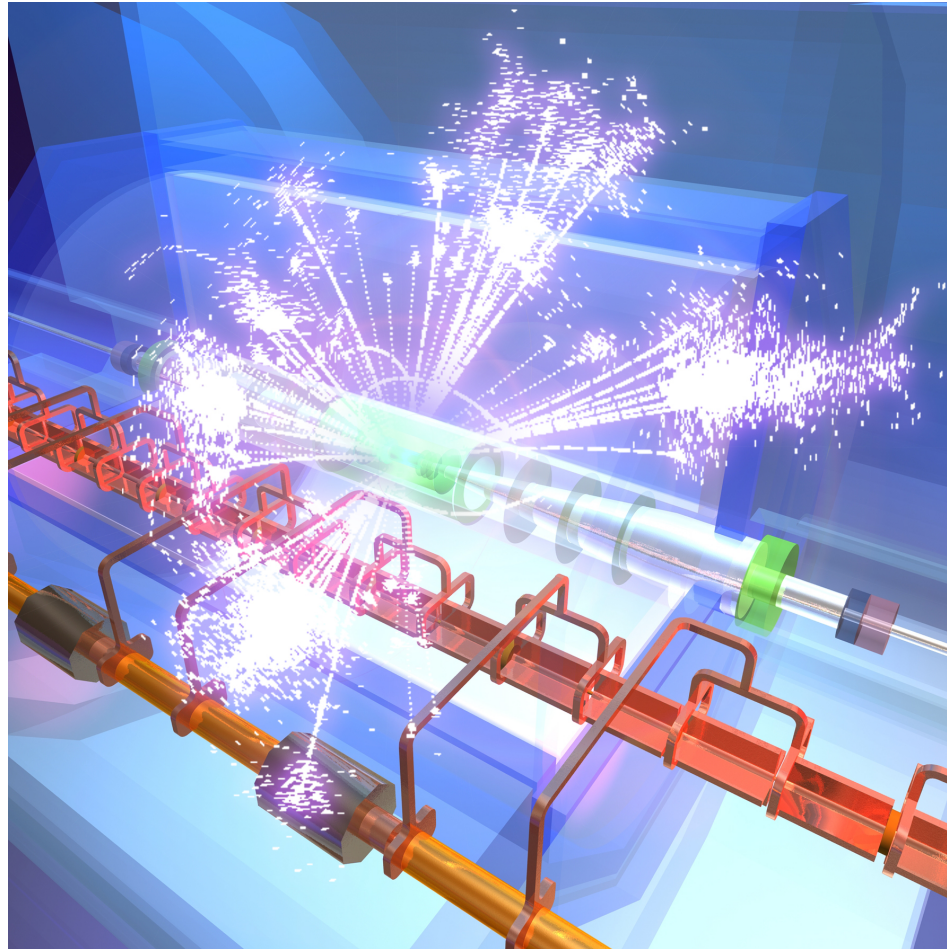




# Physics at CLIC



**Mark Thomson**  
**University of Cambridge**



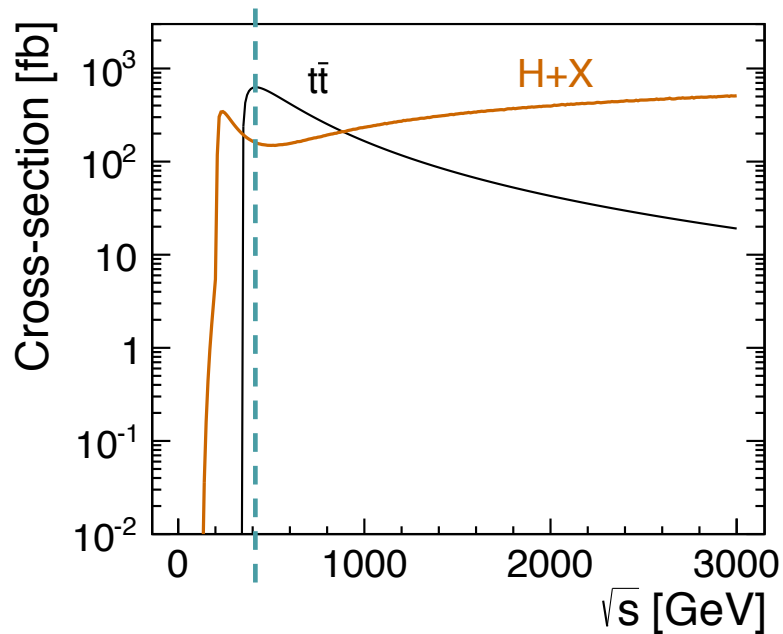


# CLIC Physics Landscape I



**CLIC is foreseen as a **staged** machine:**

- ★ **First stage would focus on **precision SM physics****
  - **propose ~350-375 GeV : Higgs **and** top**



- ★ **Not the peak of Higgs cross section**
  - **But, luminosity scales with  $\sqrt{s}$**
- ★ **250 GeV and 350 GeV give **similar precision** for coupling measurements**
- ★ **But 350 GeV as a first stage:**
  - **provides access to top physics**

- ★ **Energies of subsequent stages motivated by physics**
  - **results from ~14 TeV LHC operation**
  - **direct dark matter searches,**
  - **...**



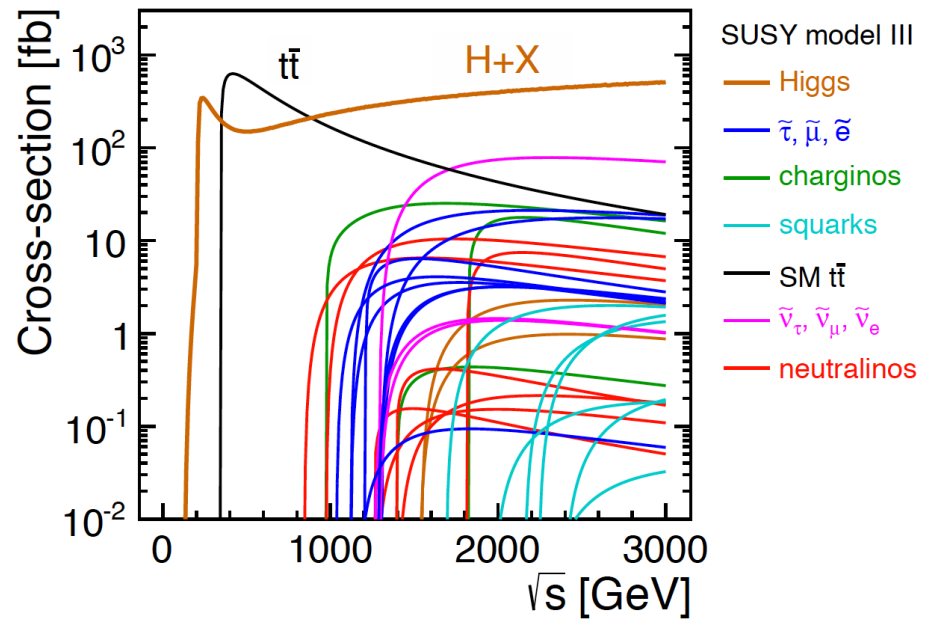
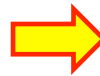
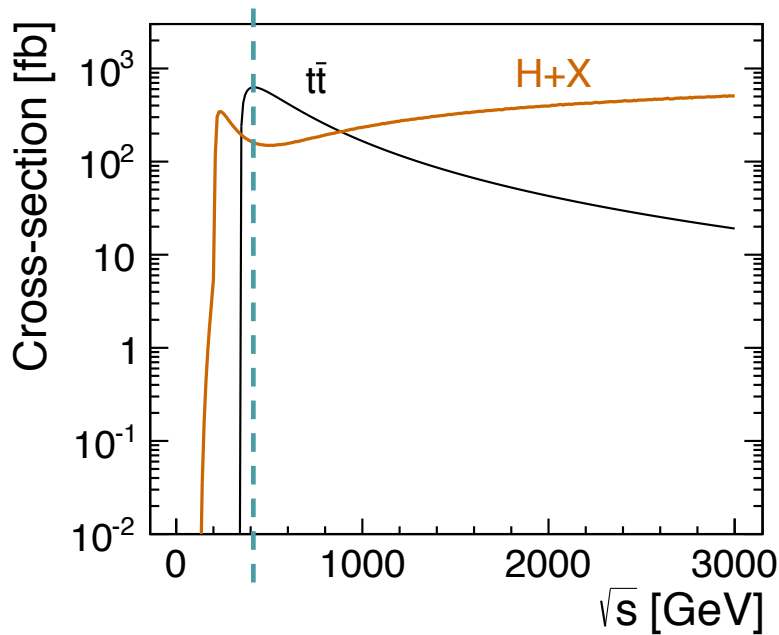
# The Physics Landscape II



★ For example, illustrative SUSY “Model III\*” of Vol.3 of CLIC CDR

- Gauginos and sleptons at  $\sqrt{s} \sim 1.5$  TeV
- Squarks at  $\sqrt{s} \sim 2.5$  TeV

Precision measurements at CLIC



\*mSUGRA with non-universal squark masses with  $\tan\beta = 10$ , Allanach *et al.*, CERN LCD-Note 2012-003



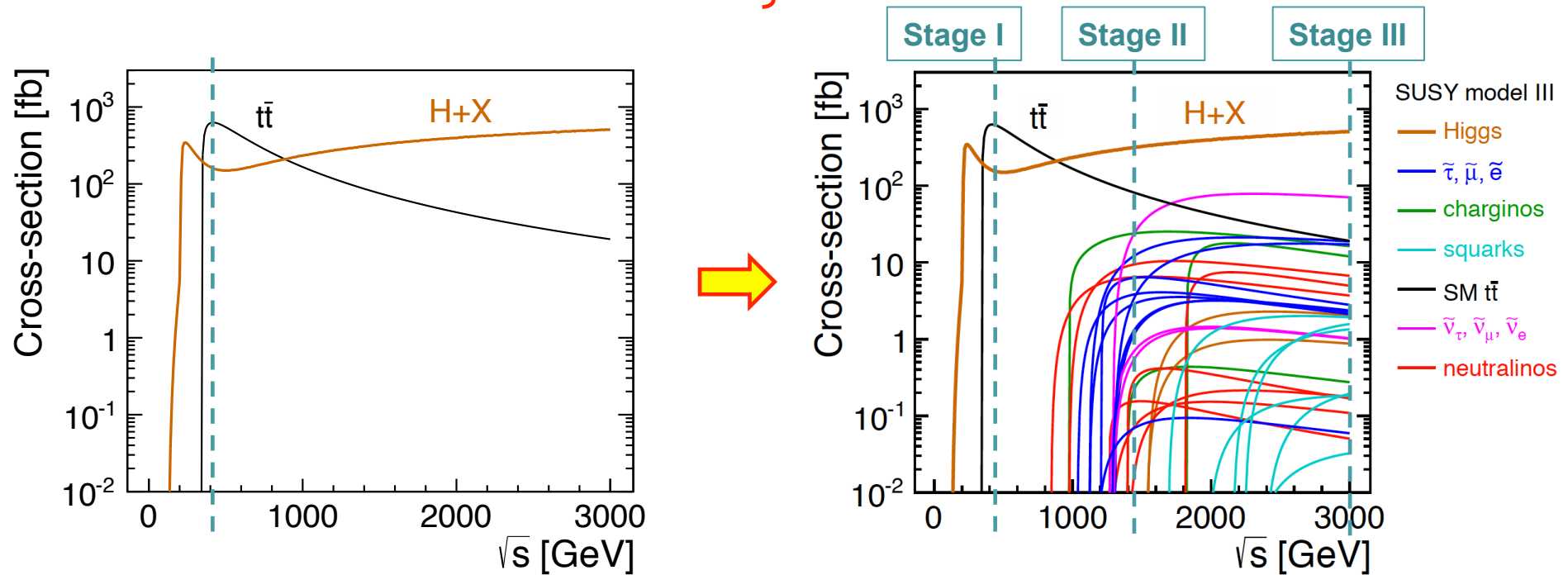
# The Physics Landscape II



★ For example, illustrative SUSY “Model III\*” of Vol.3 of CLIC CDR

- Gauginos and sleptons at ~1.5 TeV
- Squarks at ~2.5 TeV

Precision measurements at CLIC



For example:

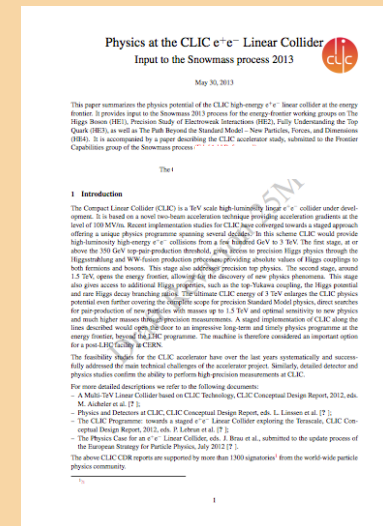
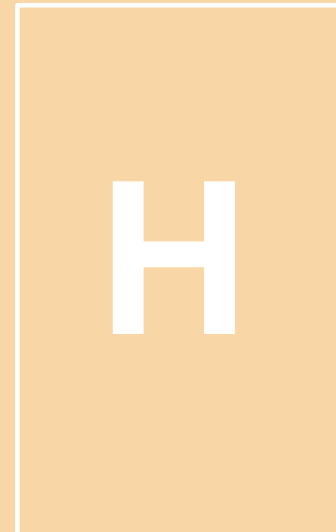
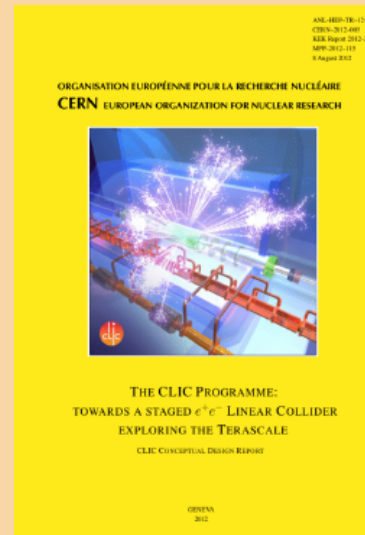
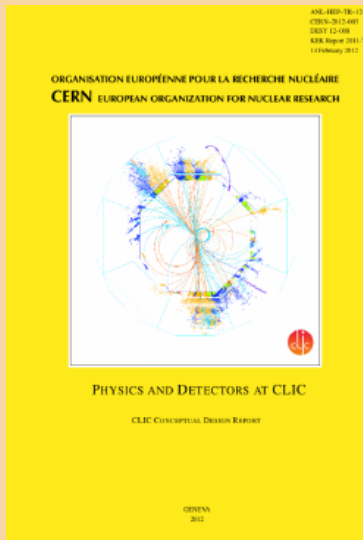
Stage I	~350 GeV	Higgs, Top
Stage II	~1.5 TeV	Higgs, gauginos, sleptons
Stage III	~ 3 TeV	Higgs, squarks, ?



# CLIC Physics Studies



- ★ A very active area in past few years
- ★ Recent CLIC studies focussed around 4 documents
  - CLIC CDR Vol. 2: CLIC physics at 3 TeV
  - CLIC CDR Vol. 3: CLIC physics for a staged machine
  - Higgs paper studies: Overview of Higgs physics 350 GeV – 3 TeV
  - CLIC Physics Snowmass Whitepaper (draft version)





# Higgs Physics at CLIC

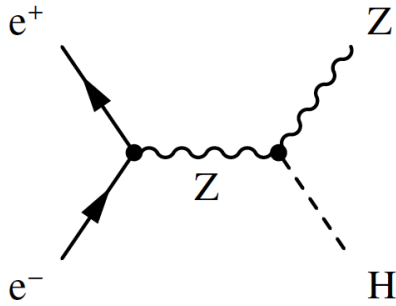


# Standard Model Higgs

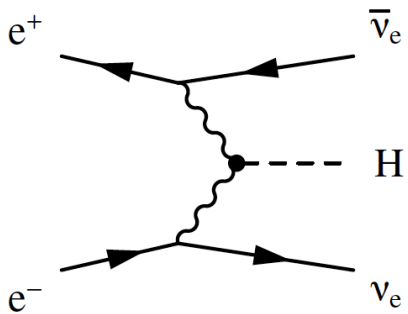


★ A number of SM Higgs processes accessible at CLIC

★ Below  $\sqrt{s} \sim 300$  GeV  
Higgs-strahlung dominates



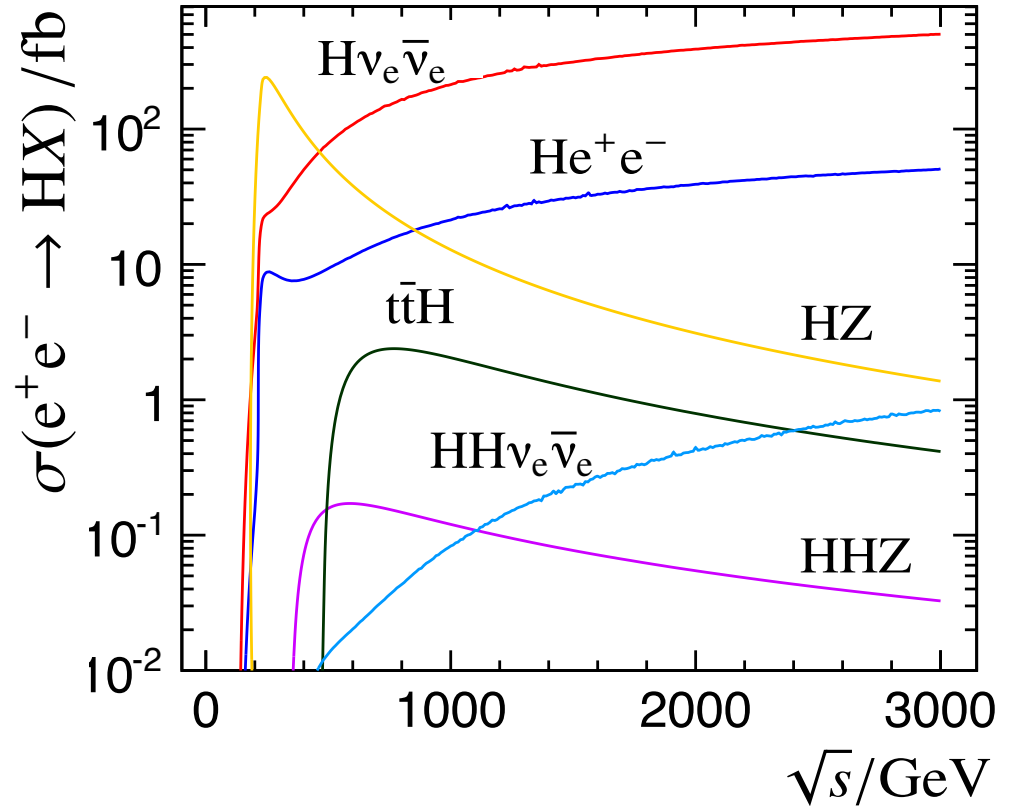
★ Above  $\sqrt{s} \sim 500$  GeV  
WW fusion dominates



★ At  $\sqrt{s} = 350$  GeV both contribute

★ CLIC energy stages, provide a rich programme of precision Higgs physics

$m_H = 125$  GeV



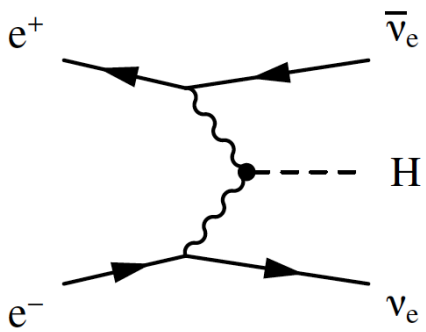


# Higgs at Higher Energy

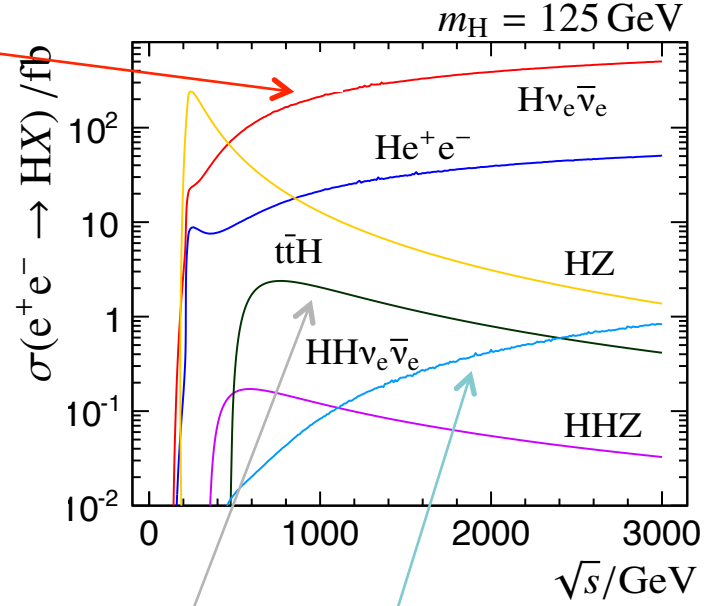


★ In a higher energy stage of CLIC...

- Fusion cross section becomes large
  - + luminosity  $\sim$ scales with  $\sqrt{s}$
- Large numbers of  $H\nu_e\bar{\nu}_e$  events



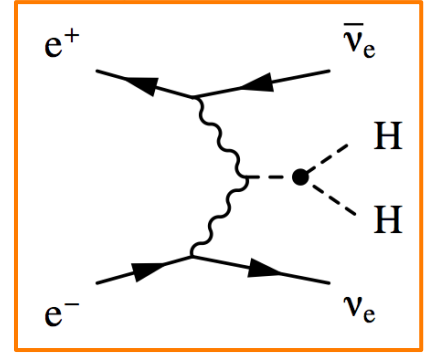
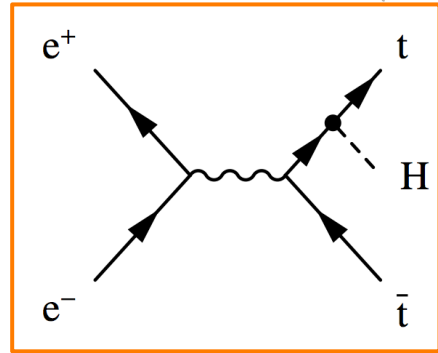
	$\sqrt{s} =$	
	1.5 TeV	3 TeV
Int Lumi [ $\text{fb}^{-1}$ ]	1500	2000
Cross section	309 fb	510 fb
$N(H\nu\nu)$	460,000	970,000



➡ Precise BR measurements

★ + Rarer processes give access to

- top Yukawa coupling
- Higgs self-couplings







# Higgs Study Assumptions



- ★ For Snowmass white paper and Higgs publication
  - Study evolution of precision on Higgs properties over different stages
  - Assumptions:

	350 GeV	1.4 TeV	3 TeV
$\sigma(e^+e^- \rightarrow ZH)$	133 fb	6 fb	1 fb
* $\sigma(e^+e^- \rightarrow Hv_e\bar{\nu}_e)$	52 fb	244 fb	415 fb
Int. $\mathcal{L}$	500 fb <sup>-1</sup>	1500 fb <sup>-1</sup>	2000 fb <sup>-1</sup>
# ZH events	66,500	7,500	2,000
# $H\nu_e\bar{\nu}_e$ events	26,000	366,000	830,000

- ★ Many Higgs analyses in progress at 350 GeV and 1.4 TeV
  - most final states covered (a few holes)
  - + some updates of 3 TeV analyses (e.g. for  $m_H = 125$  GeV)

\*unpolarised cross sections



# What next ?



★ After Higgs paper, the focus will shift...

★ Higgs: still loose ends...

- Parameter fitting
- $H \rightarrow ZZ$  at 350 and 1.4 TeV
- Additional effort needed for  $H \rightarrow WW$

★ Plenty of other opportunities for new people



# What next ?



## ★ Top:

- $A_{\text{FB}}$  and  $\sin^2\theta_W$
- Top coupling to  $W, Z, \gamma, H$
- CP violation in top decays
- FCNCs

## ★ Precision SM:

- $M_W$
- TGCs and QGCs, e.g.  $WW \rightarrow WW$  scattering

## ★ BSM

- A **major focus** of CLIC physics at  $> 1.4$  TeV
- List of possible topics will be defined
- Open to suggestions...



# How to get involved



## ★ Regular analysis meetings at CERN

- <http://indico.cern.ch/categoryDisplay.py?categId=3222>
  - **always possible to attend by webex**
- **Meetings typically quite full**
  - **always interesting...**
- **If interested, please contact us:**
  - [mark.thomson@hep.phy.cam.ac.uk](mailto:mark.thomson@hep.phy.cam.ac.uk)
  - [philipp.roloff@cern.ch](mailto:philipp.roloff@cern.ch)



# Summary



## ★ CLIC Physics:

- **Very active area**
  - **lively and full bi-weekly analysis meetings**
- **Contributions from many people/groups**
- **Recent focus on Higgs physics**
- **Strong central support from CERN group**
  - **event generation, analysis advise, ...**
- **Plenty of opportunities to contribute...**