Summary:
BSM + Top/QCD/Loopverein

A.F.Żarnecki

on behalf of the BSM and Top/QCD/Loopverein group conveners

FACULTY OF PHYSICS
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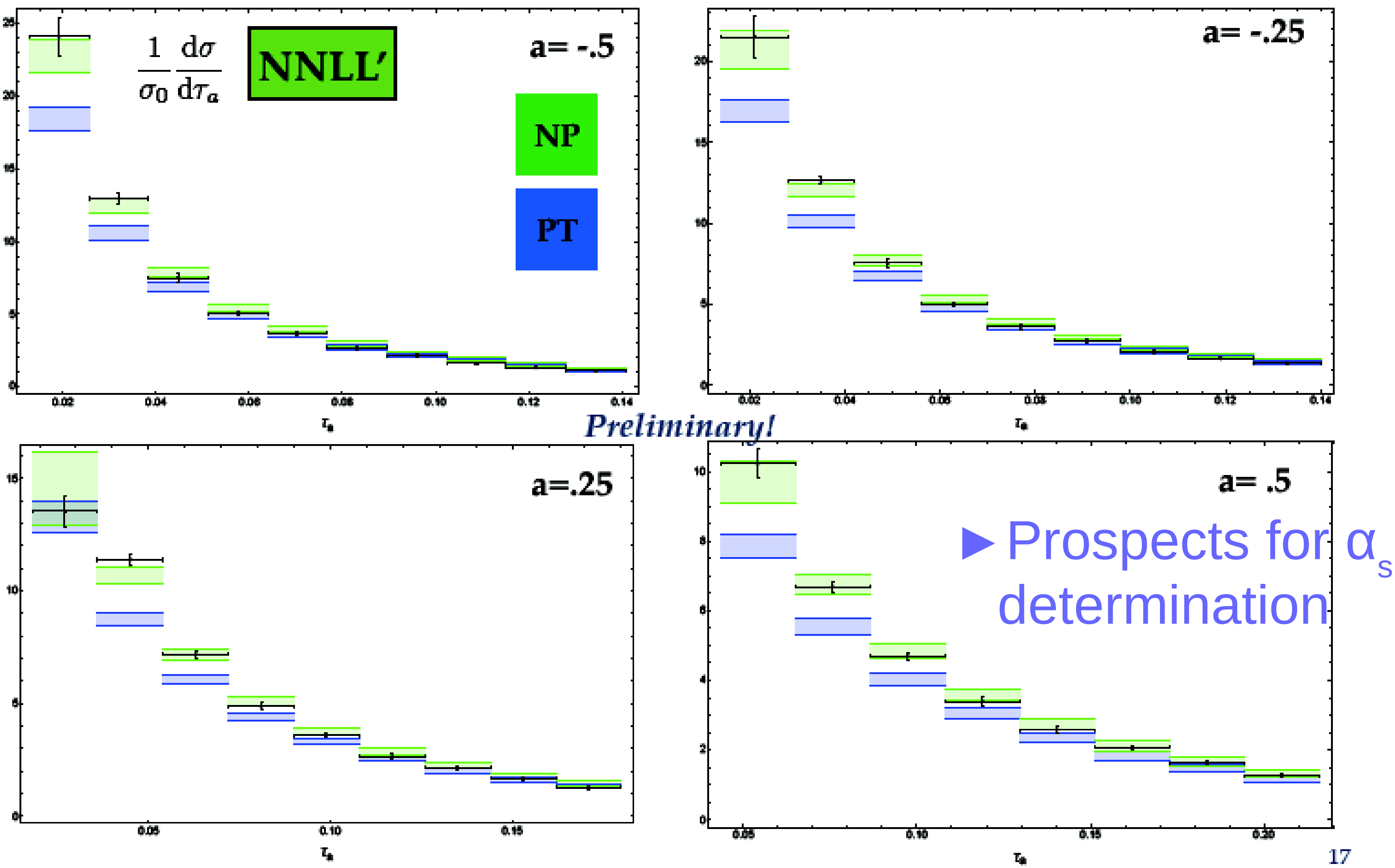
QCD: progress in event shape variable description in e^+e^-

Comparison with LEP data (L3)

NNLL' + $\mathcal{O}(\alpha_s^2)$ results [Q = mz]

$A = .283 \quad \alpha_s(m_Z) = .1161$

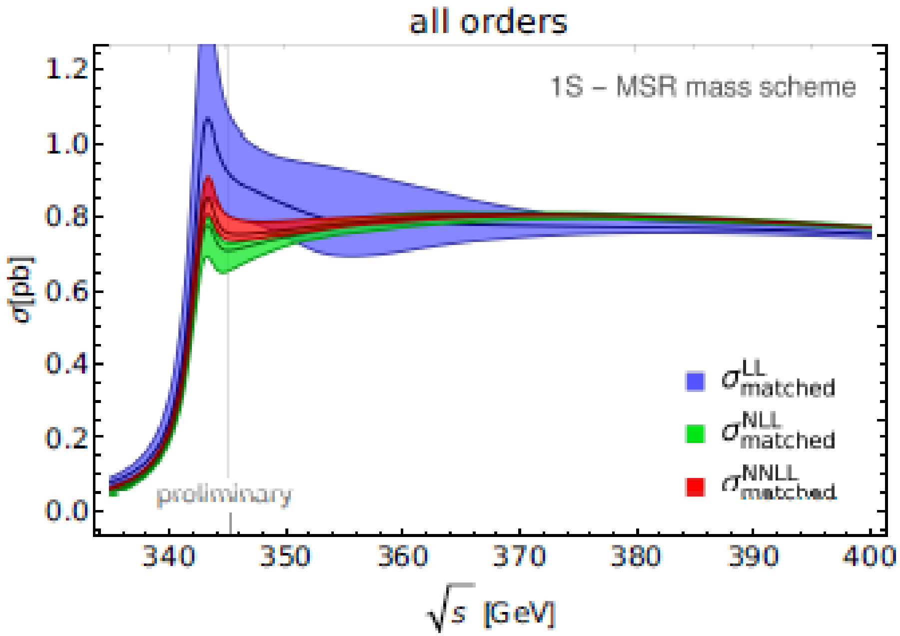


► Prospects for α_s determination

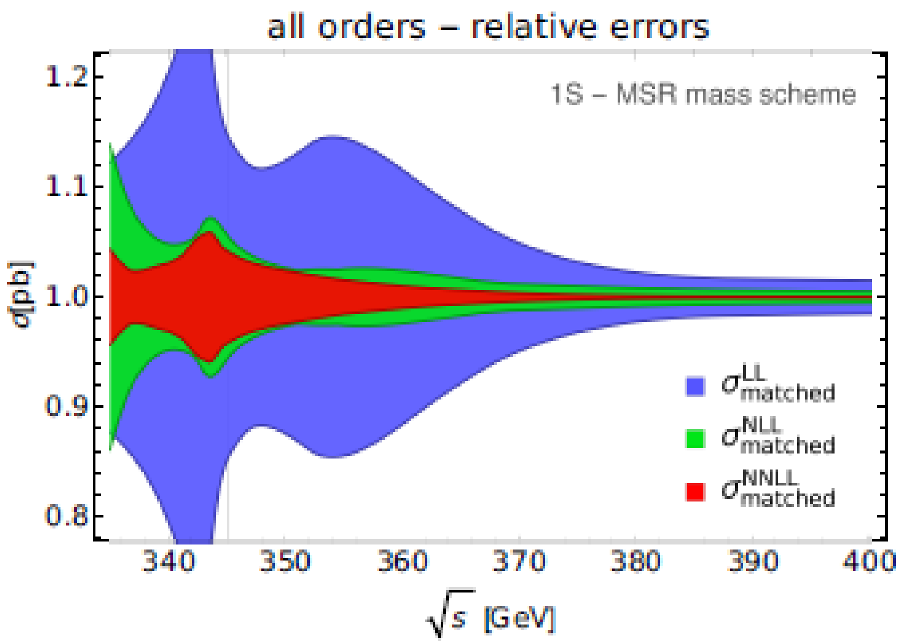
James Talbert et al. *Event shapes for precision QCD studies at lepton colliders*

QCD: progress in top threshold modeling

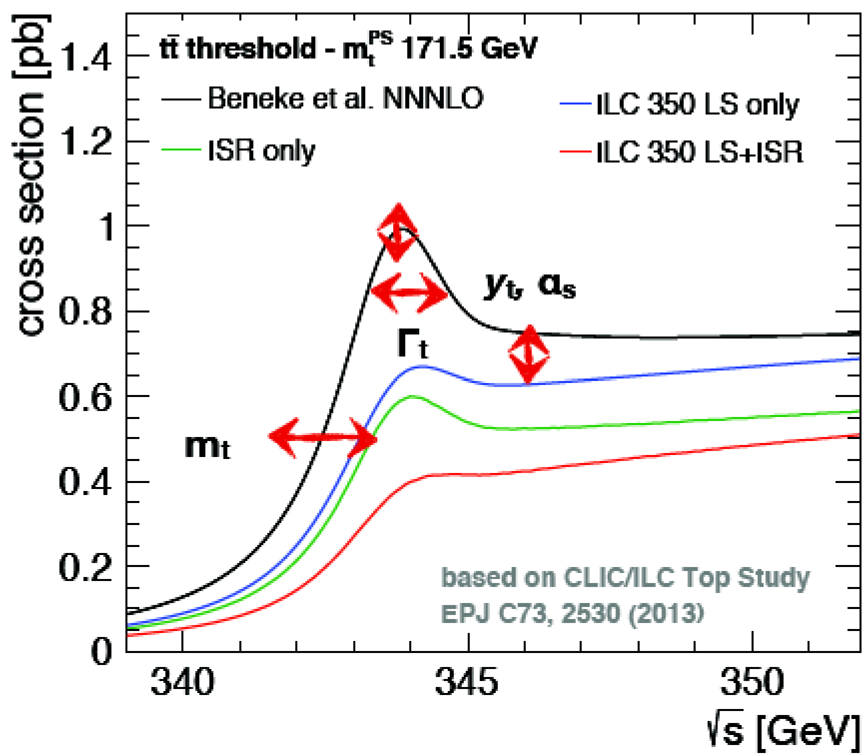
▶ reduced systematic uncertainties



$\sigma_{matched}$	σ_{NRQCD}		σ_{QCD}
LL	LL	⟷	NLO
NLL	NLL	⟷	NNLO
NNLL	NNLL	⟷	$N N^3LO$



Frank Simon, *Top threshold scan*



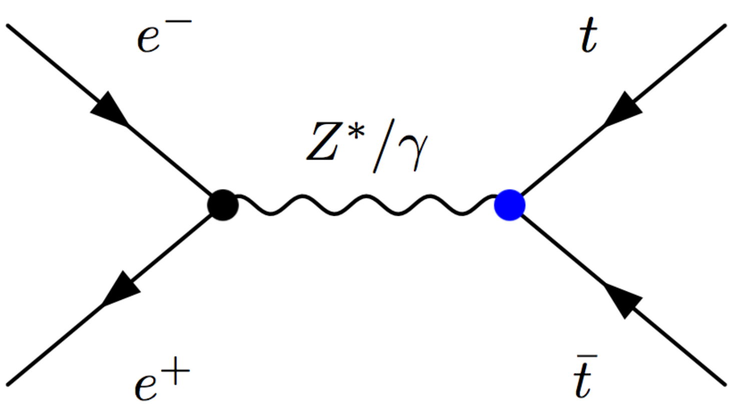
Angelika Widl *Threshold - Continuum Matching at NNLL*

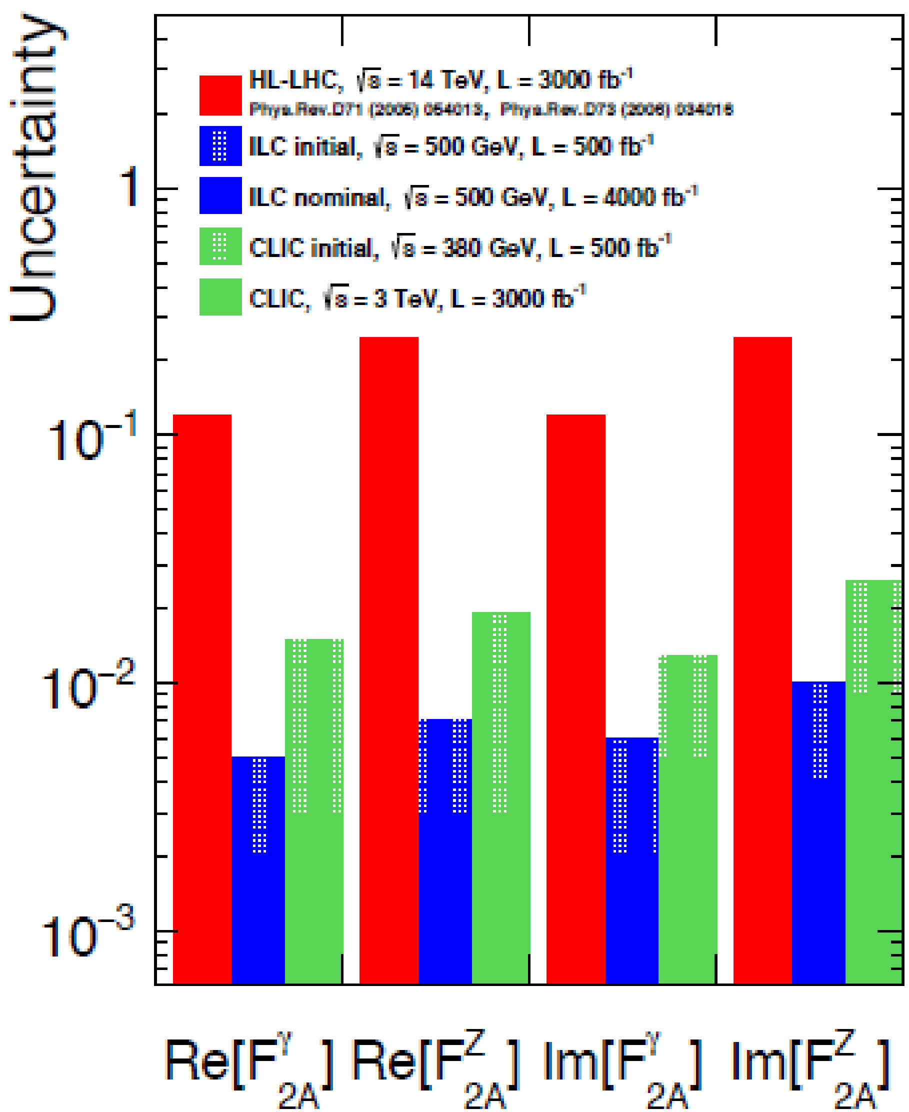
Top: Prospects of CPV optimal observables

arXiv:1710.06737

- **ILC500** and **CLIC380** have a very similar sensitivity to form factors, reaching **limits of |F_{2A}^{γ}| <0.01.**

- Assuming that systematic uncertainties can be controlled to the required level, a luminosity upgrade of both machines **may bring a further improvement.**

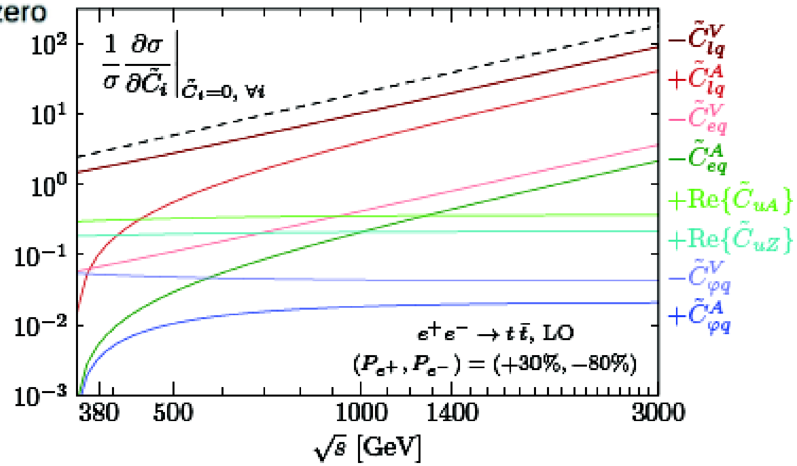




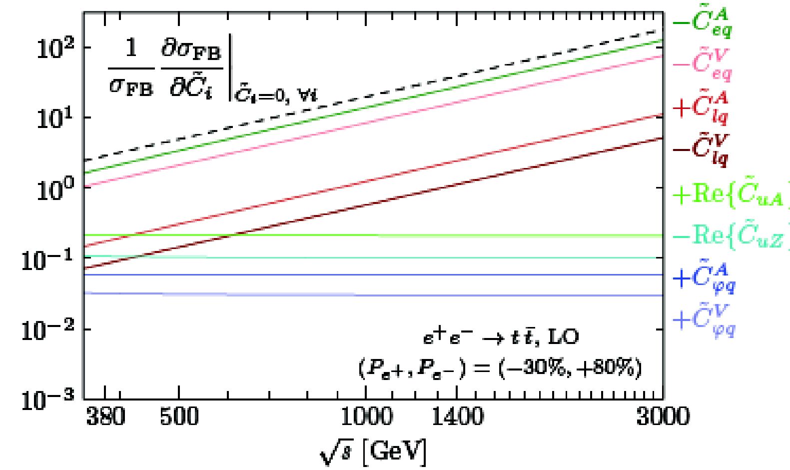
EFT analysis of top couplings

Sensitivity:
Relative change in cross-section due to non-zero operator coefficient
Δσ (C) / σ / ΔC

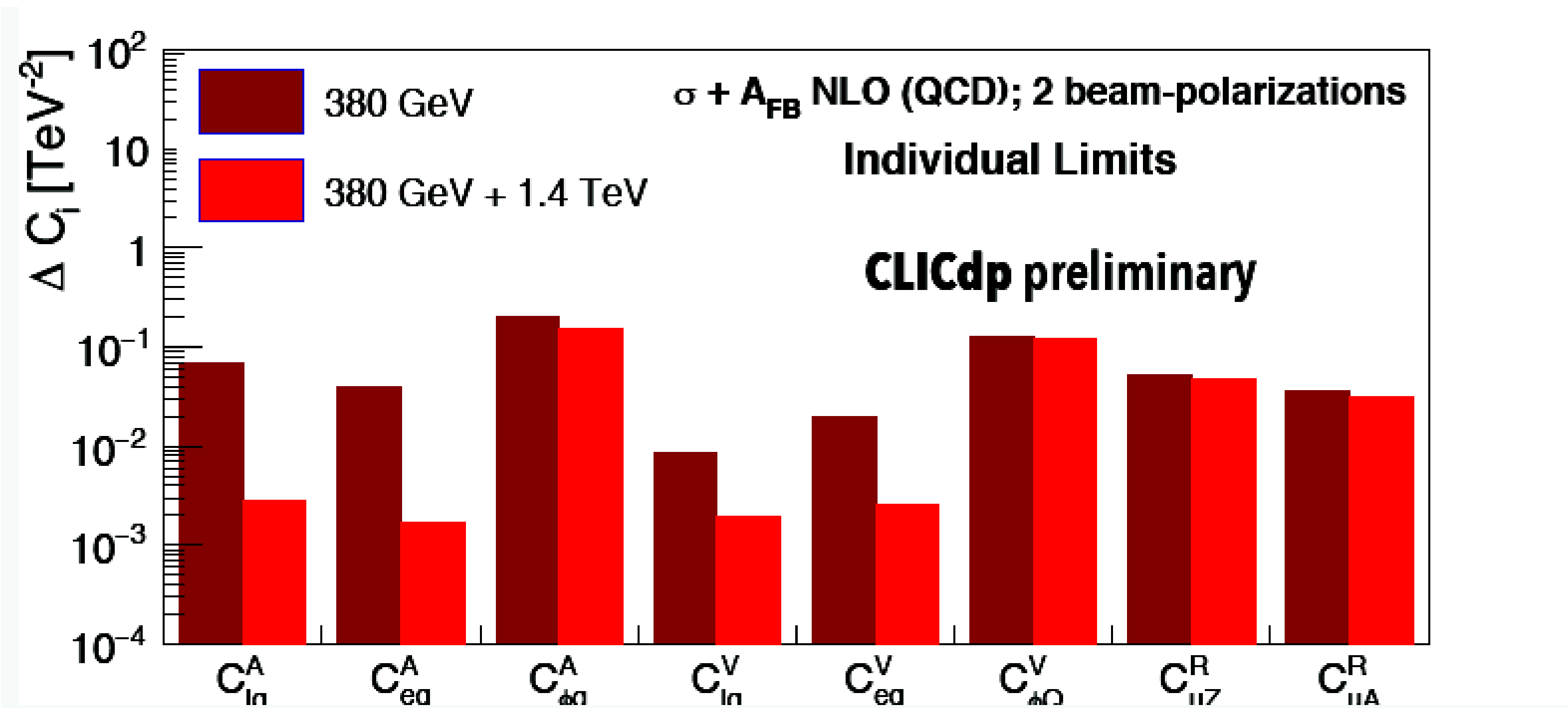
Cross-section



Forward-backward asymmetry

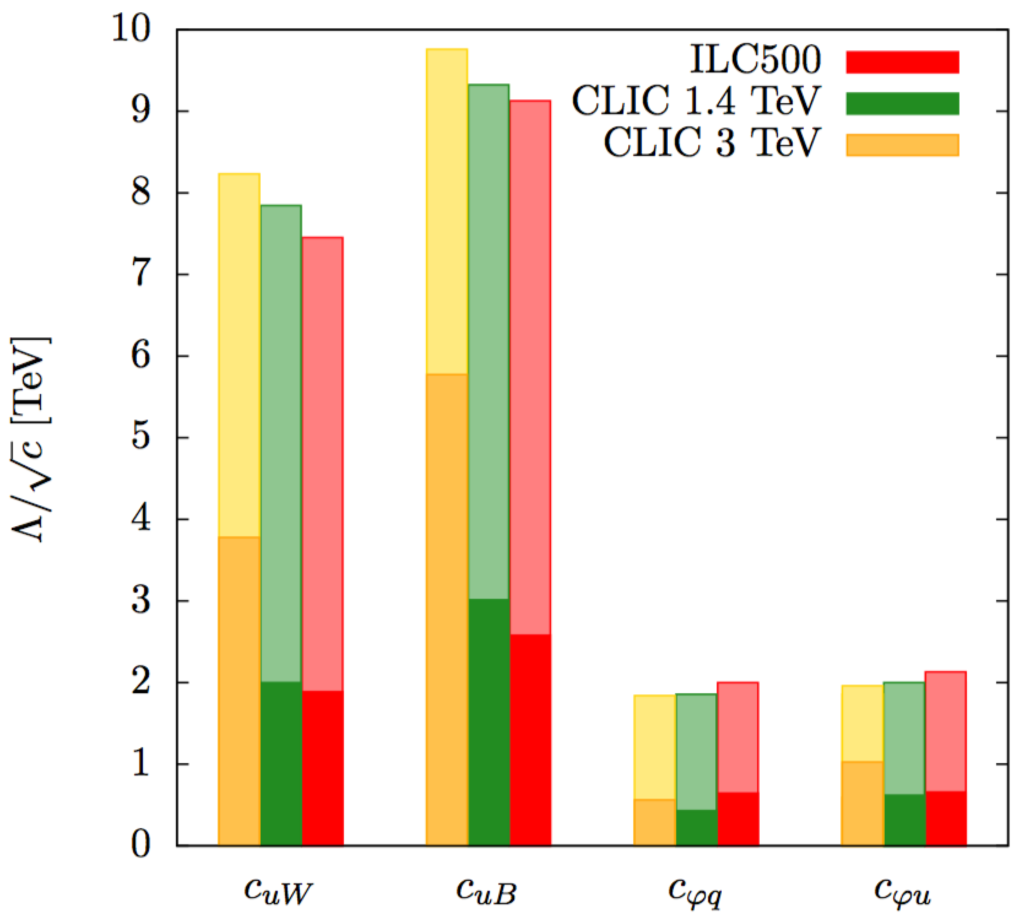


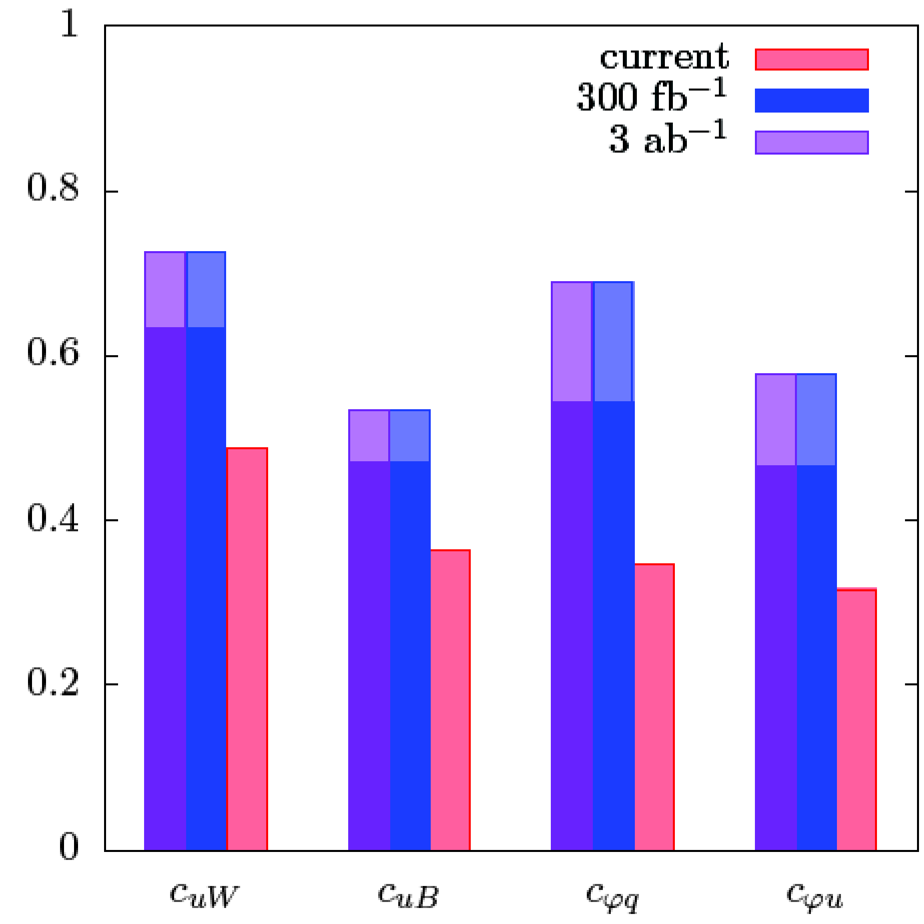
Full-simulation at CLIC@1.4 and CLIC@3 TeV



EFT analysis of top couplings

Comparison of LC sensitivity with HL-LHC estimates for top EW couplings





Michael Russell, *Top electroweak couplings at future lepton colliders*

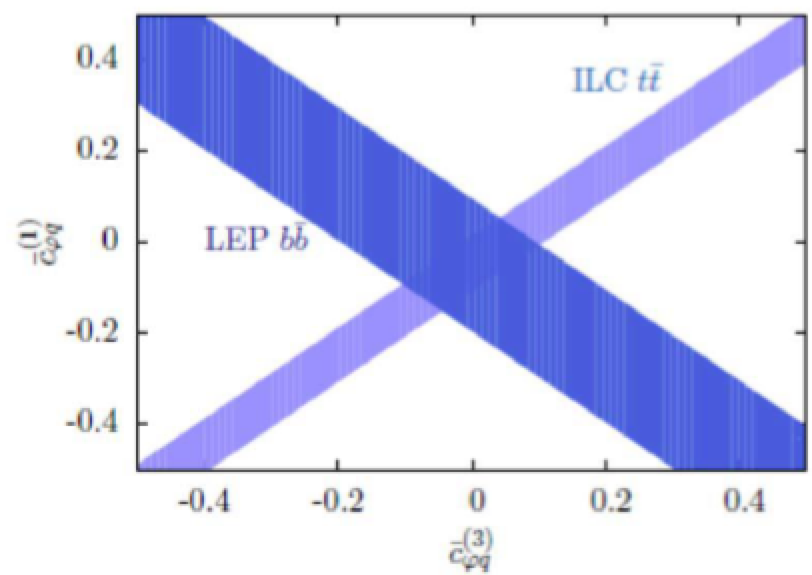
Measurements in the top sector can not constrain all EFT operators.

Compementary information need to be obtained from *b* sector !

Top at LHC and Tevatron

- As illustrated by the **EFT analysis**, the top and b sectors are fully complementary
- EW top interactions can be measured in various ways
- AFBt at **Tevatron** and charge asymmetry ACt at **LHC**
- **ttZ**, (ttW), ttH
- Top decay distribution (not discussed)
- Single top production (not discussed)

$$C_{1V} = \frac{v^2}{\Lambda^2}\Re\left[c^{(3)}_{\varphi q} - c^{(1)}_{\varphi q} - c_{\varphi u}\right]^{33}$$
$$C_{1A} = \frac{v^2}{\Lambda^2}\Re\left[c^{(3)}_{\varphi q} - c^{(1)}_{\varphi q} + c_{\varphi u}\right]^{33}$$
$$C_{2V} = \sqrt{2}\frac{v^2}{\Lambda^2}\Re\left[\cos\theta_W c_{uW} - \sin\theta_W c_{uB}\right]^{33}$$
$$C_{2A} = \sqrt{2}\frac{v^2}{\Lambda^2}\Im\left[\cos\theta_W c_{uW} + \sin\theta_W c_{uB}\right]^{33}$$

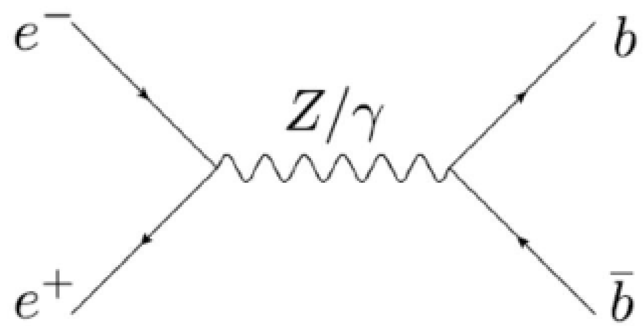


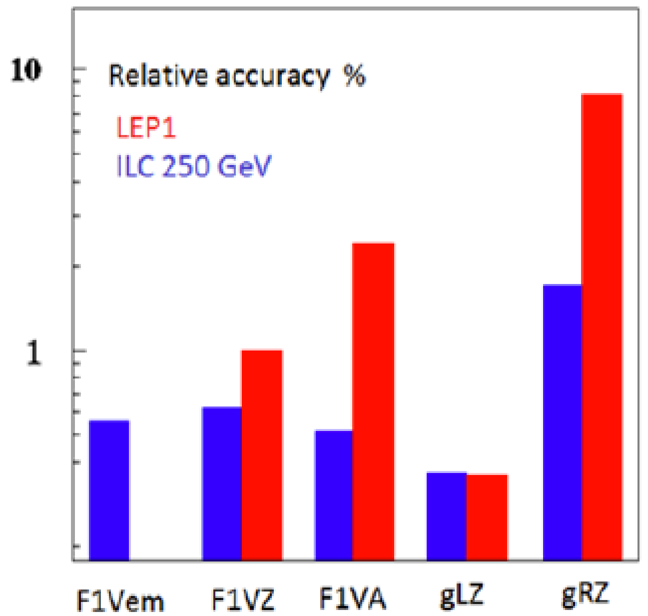
1505.06020

ILC250 can significantly improve *b measurements* from LEP

- **10^3** times higher luminosity
- beam **polarisation**
- better detector and reconstruction tools

What can be expect at ILC250 on ee->bb





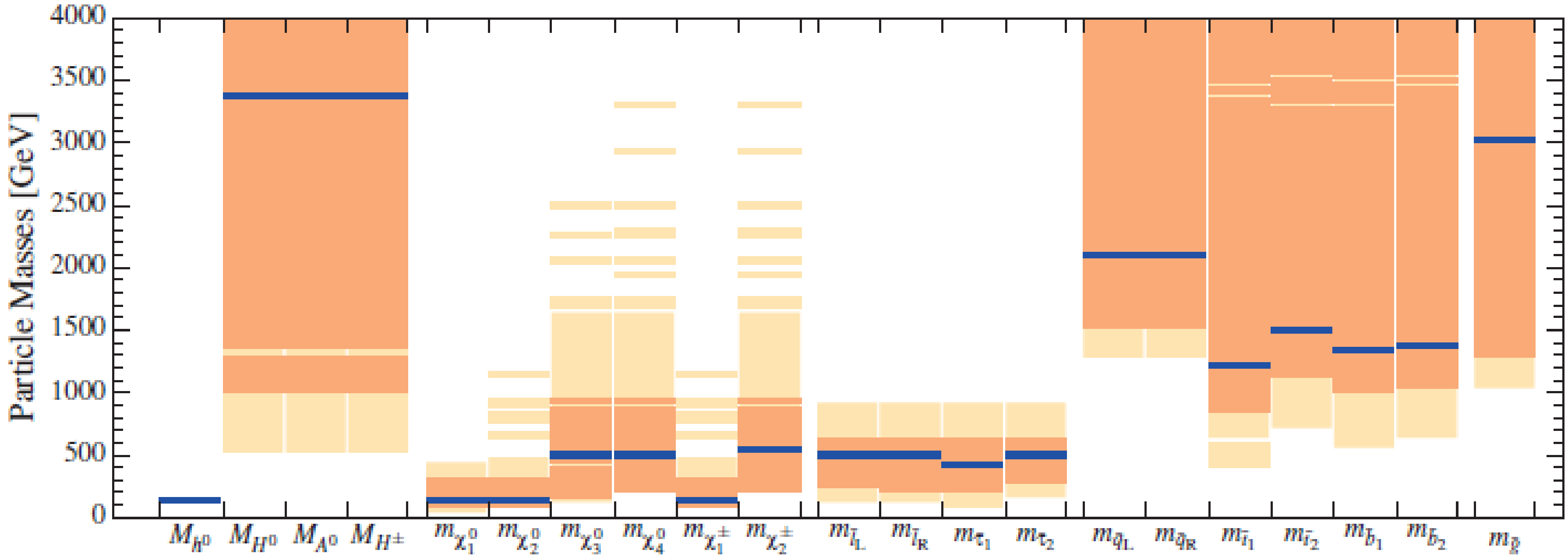
1709.04289

- $\delta g_{RZ}/g_{RZ}$ **~2%** sufficient to **confirm at >5σ** or to **discard** the LEP1 effect which is at the **25%** level
- Recall the sign uncertainty on LEP1 solutions **dg_{RZ}/g_{RZ}=25%** or **dg_{RZ}/g_{RZ}=-225%**
- Not a problem at 250 GeV to make the right choice for the sign
- ILC measurements with **beam polarisation** provide model independent access to **vector** and **tensor** couplings

BSM: prospects for direct searches at ILC250

e^+e^- prospects for pMSSM10:

[2015]



⇒ high colored masses

⇒ relatively low electroweak masses

partially with not too large ranges

⇒ clear prediction for ILC and CLIC

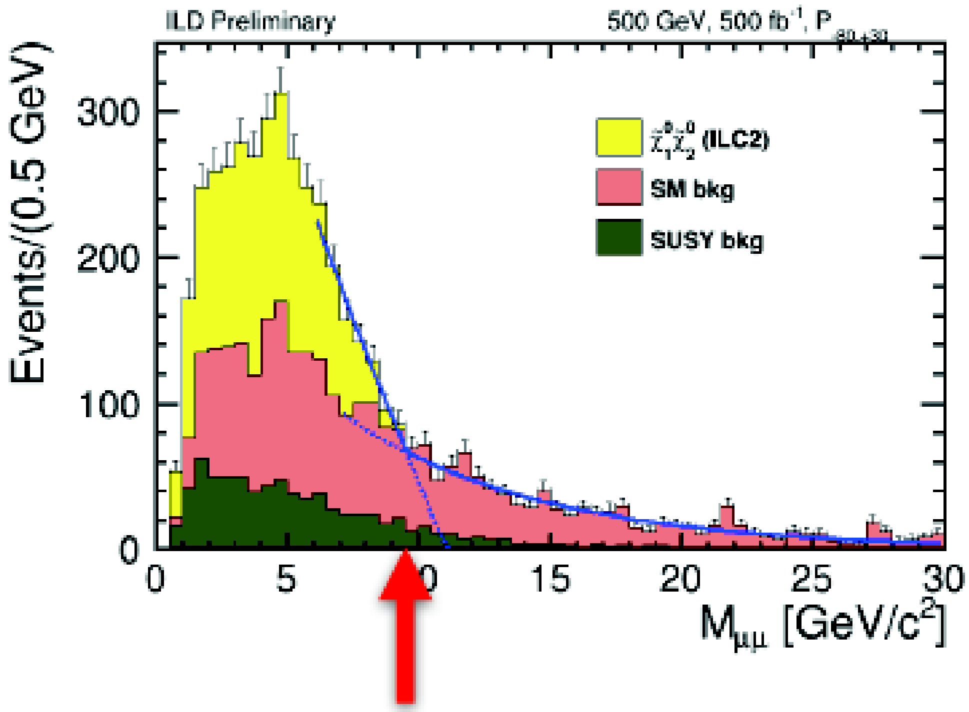
Mass Extraction

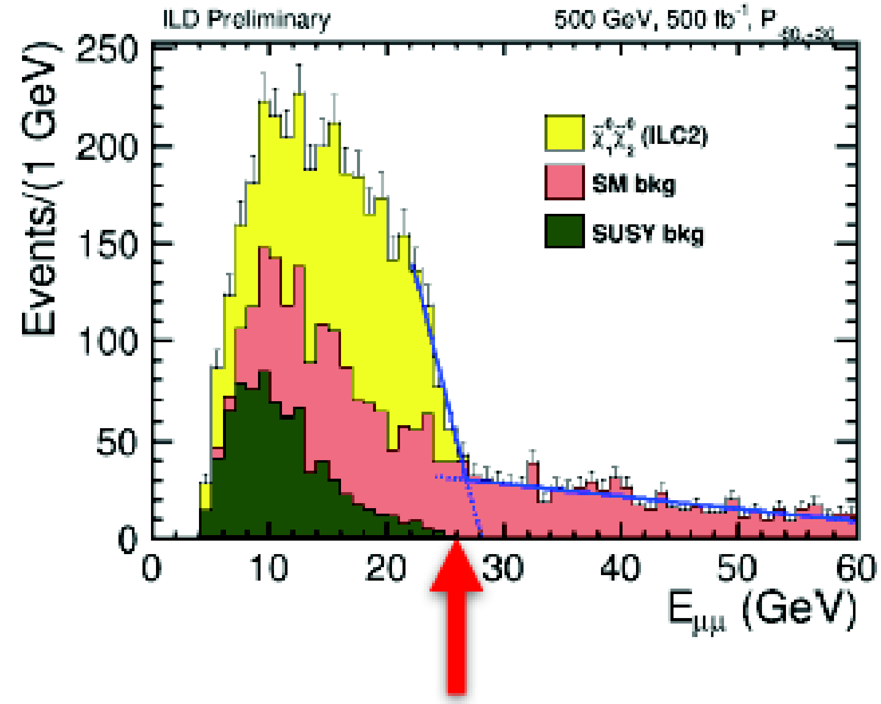
$$e^+e^- \to \tilde{\chi}_1^0 \tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 \ell^+ \ell^-$$

Mass extraction is done separately for each channel (N1N2 and C1C1)
Example for N1N2 channel:

- The maximum invariant mass gives mass splitting ΔM=**M(N2)-M(N1)**
- The maximum di-lepton energy is a function of **M(N1)** and **M(N2)**

→ Solve for **M(N1)** and **M(N2)**





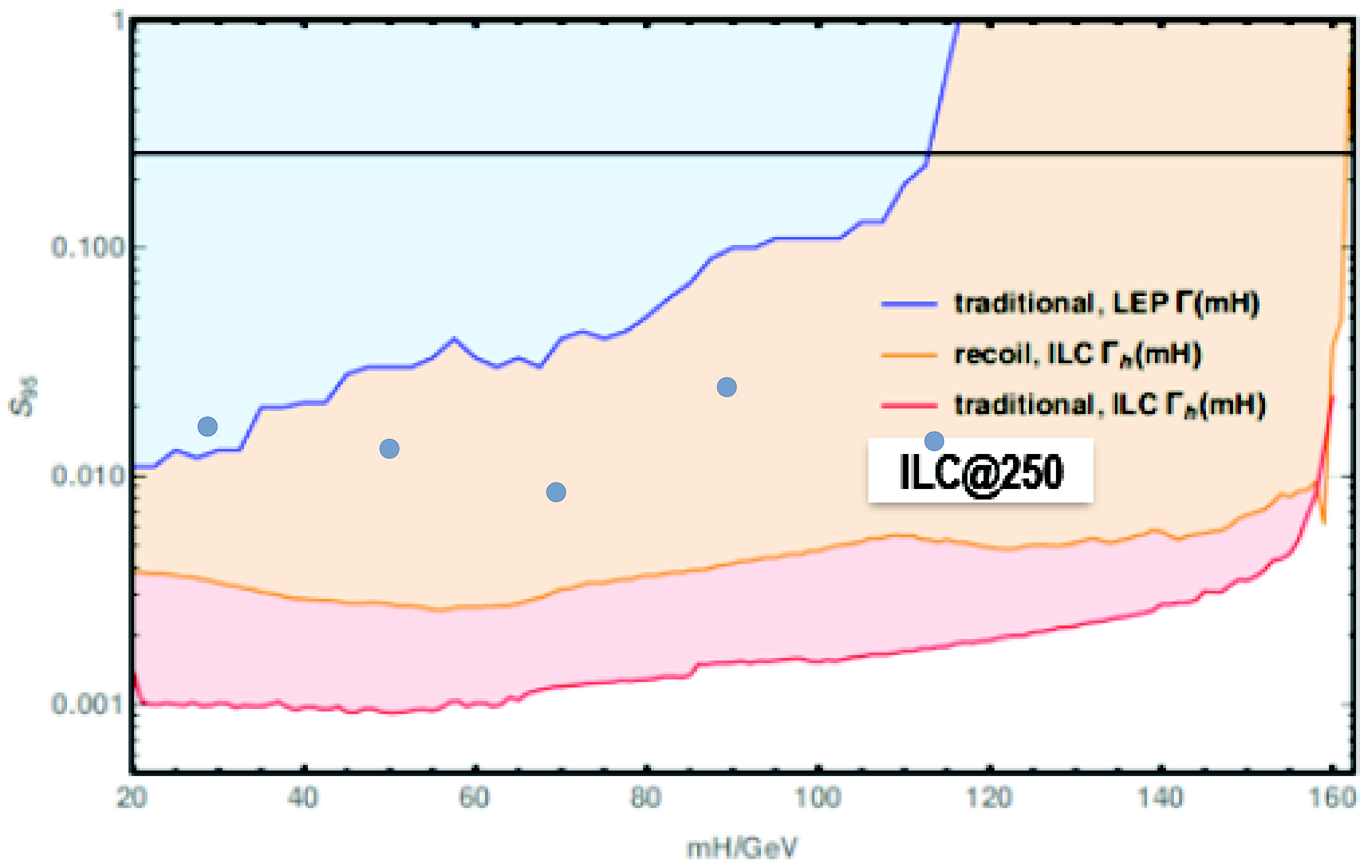
Edge extraction is key

M(N1), M(N2) can be extracted at the 1% level
Similar precision for charginos

Tomohiko Tanabe, *Characterizing Light Higgsinos from Natural SUSY at the ILC*

Application to ILC

- Combined limits for ILC at $\sqrt{s}$=250 GeV, (-80%,+30%), $\mathscr{L}$=2000fb^{-1}



Projection from future LHC accuracy on couplings of state at 125 GeV

Klute ea '13,Lopez-Val ea '13

- Yan Wang *Searching for new light scalars at the ILC*

- *S95 ∈ [0.001-0.002] ('traditional' ILC) and [0.003-0.005] ('recoil',ILC)*

→ $g_{h1Z}/g^{SM}_{HZ} \in$ *[0.032-0.045] and [0.055- 0.071]*

Christian Drews

Study of charged Higgs bosons search at the ILC for a collision energy of 1 TeV

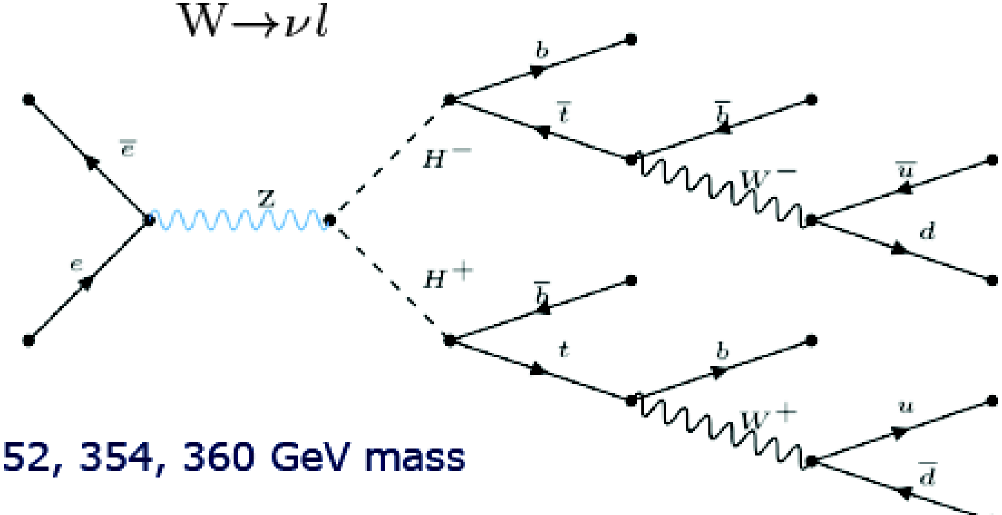
TECHNISCHE UNIVERSITÄT DRESDEN

TOHOKU UNIVERSITY

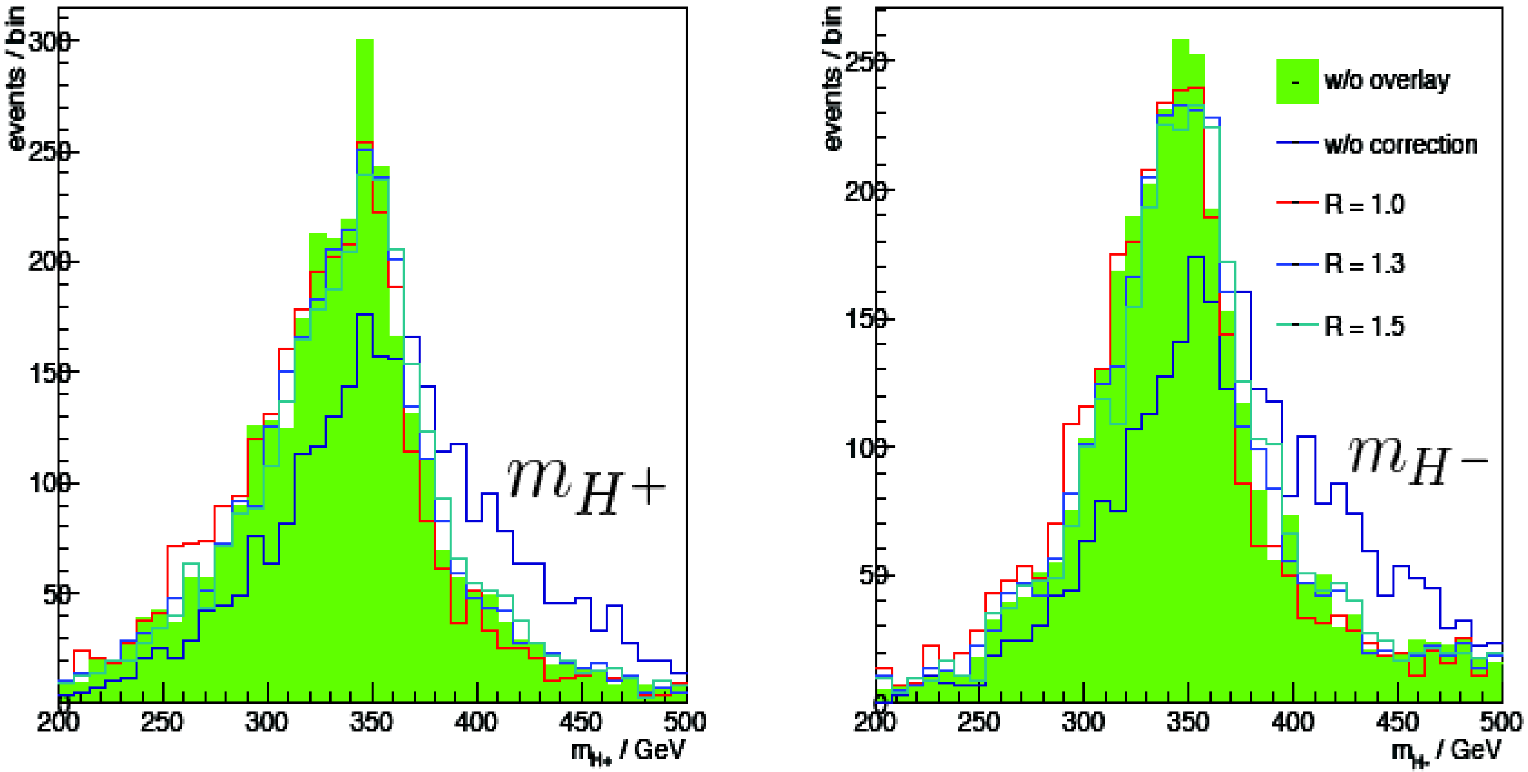
Overview

- Full simulation study of ILC/ILD
- $m_{H\pm}$ = 350 GeV   cross section = 9 fb   BR(H±→bt) = 90%
- E^+e^- -> H^+H^- -> tb tb -> Wbb Wbb $\xrightarrow{W\to 2\text{ jets}}$ 8 jets (hadronic)

  Wbb Wbb $\xrightarrow[W\to\nu l]{W\to 2\text{ jets}}$ 6 jets + lepton (semi-lep.)
- Major background:
  - ttH/ttZ/ttg -> ttbb
  - tt -> bWbW
  - HA -> bbbb (SUSY)
  - H/A -> tt at resonance
  - Ignoring SUSY background
- Goal: $m_{H\pm}$ meassurment
  - Samples with 340, 346, 348, 350, 352, 354, 360 GeV mass



Beam background reduction with kt-Algorithm

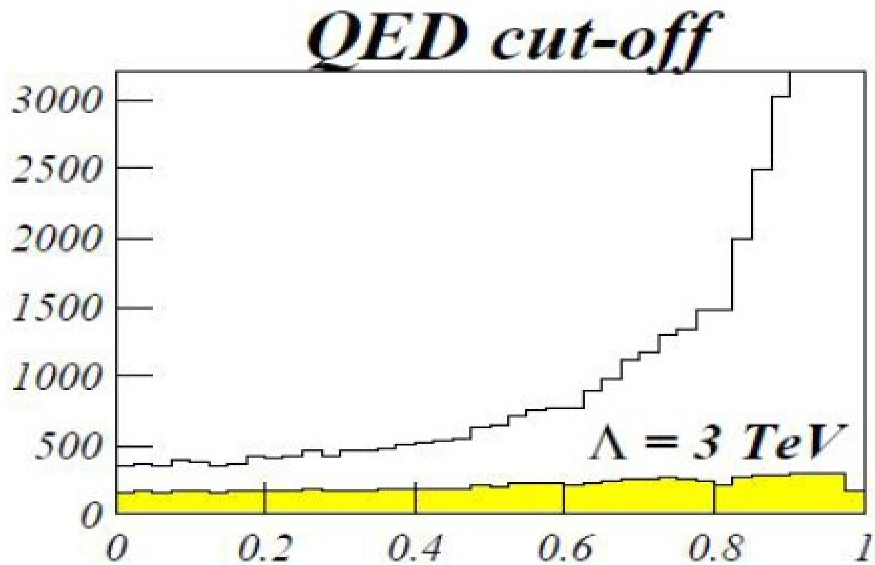


Reconstructed H^+ and H^- mass with realistic clustering and pairing with generator information

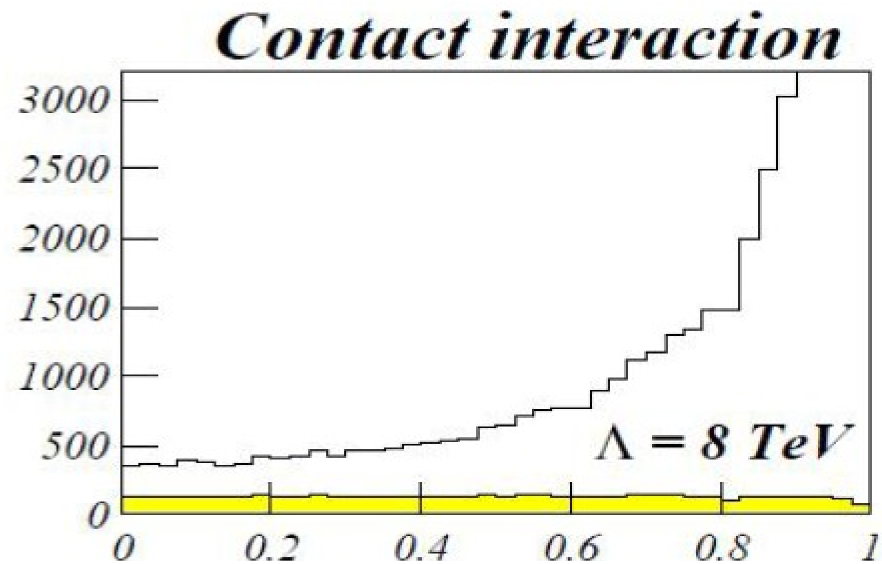
R chosen to be 1.3

0.5 GeV mass precision expected

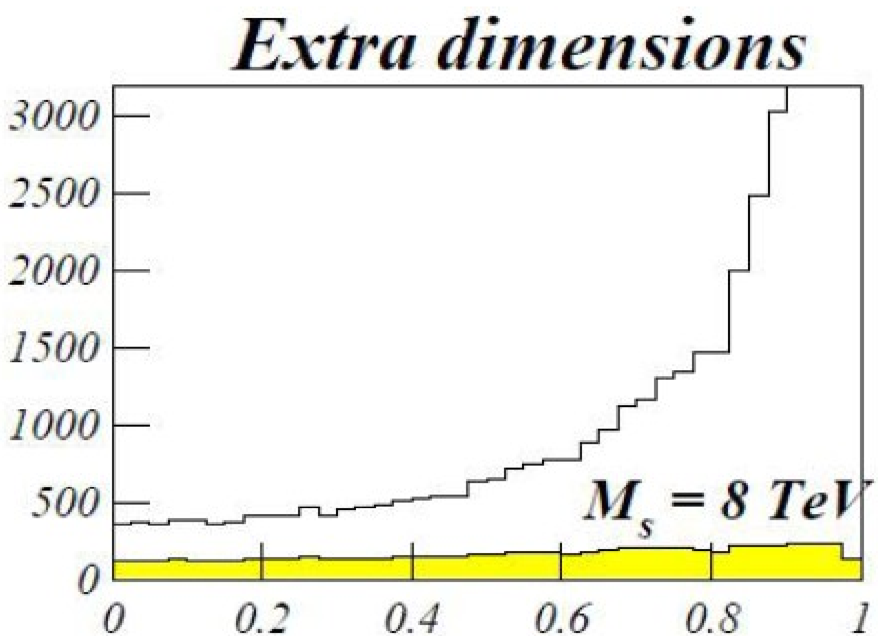
Searches for BSM physics in $e^+e^- \rightarrow \gamma\gamma$ events



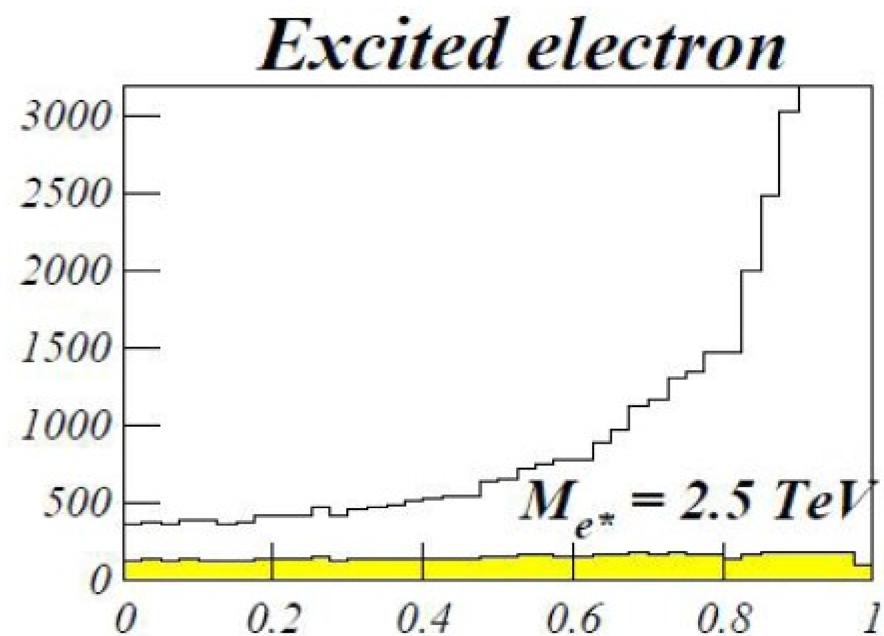
QED cut-off 6-6.3 TeV (LEP 400 GeV)



Contact interaction 19-21 TeV (LEP 800 GeV)

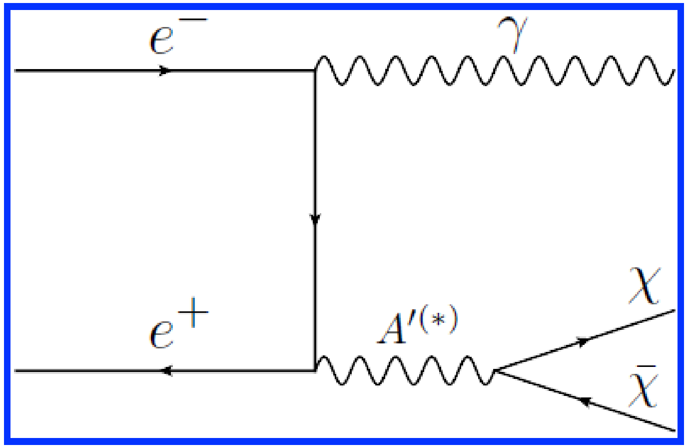


Extra dimensions 15-16 TeV (LEP 1000 GeV)

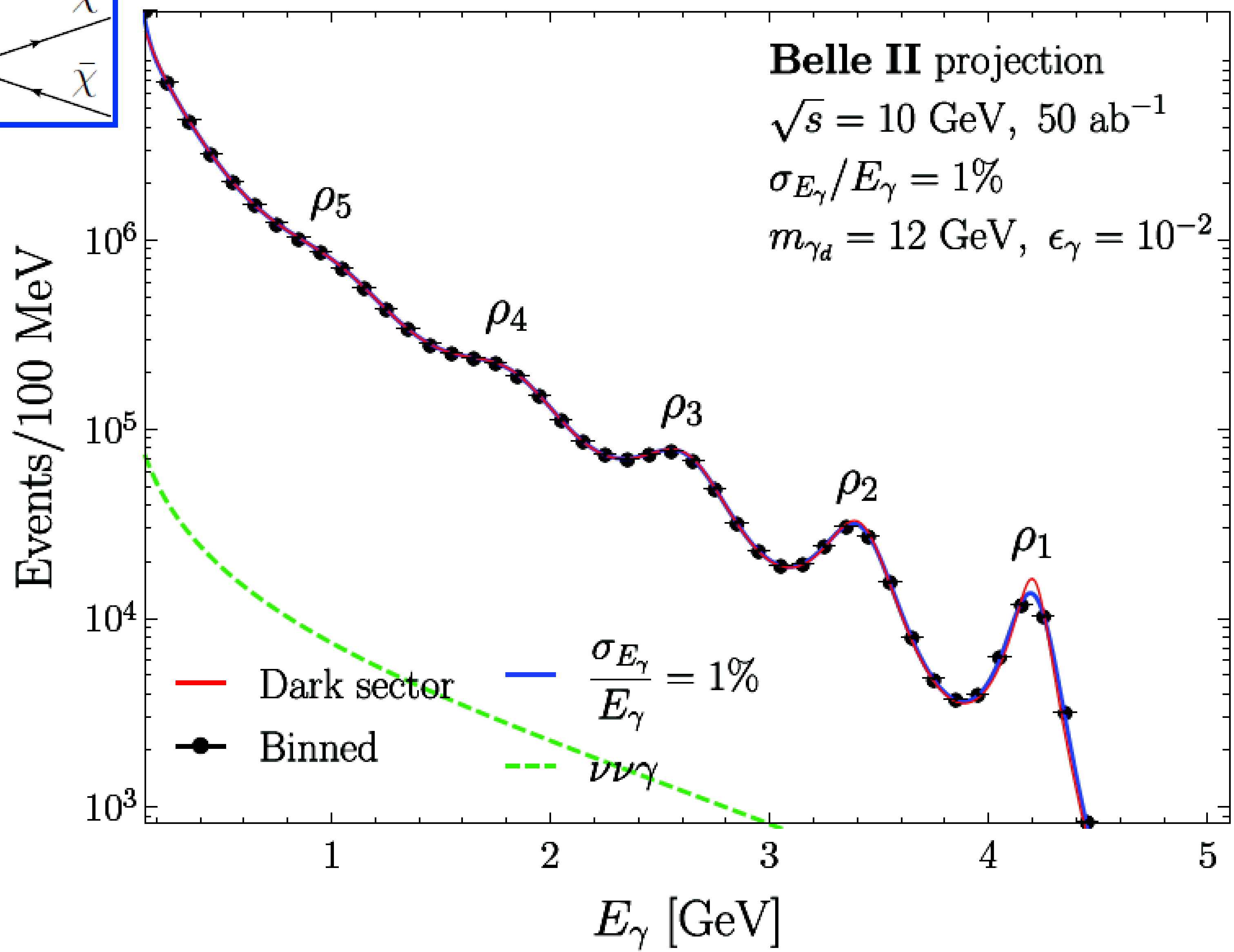


Excited electron 4.7-5.0 TeV (LEP 250 GeV)

Igor Boyko, *Search for new physics with ee→γγ at CLIC*



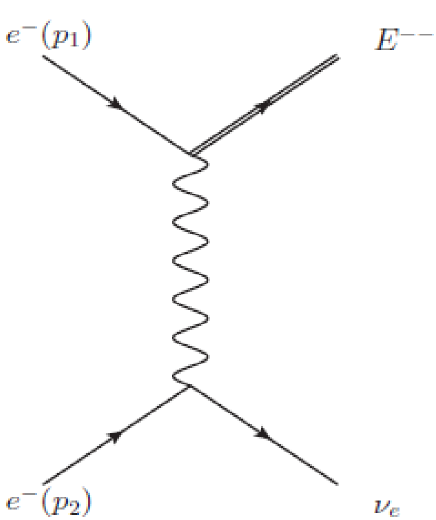
DM searches with $e^+e^- \rightarrow \gamma$ events

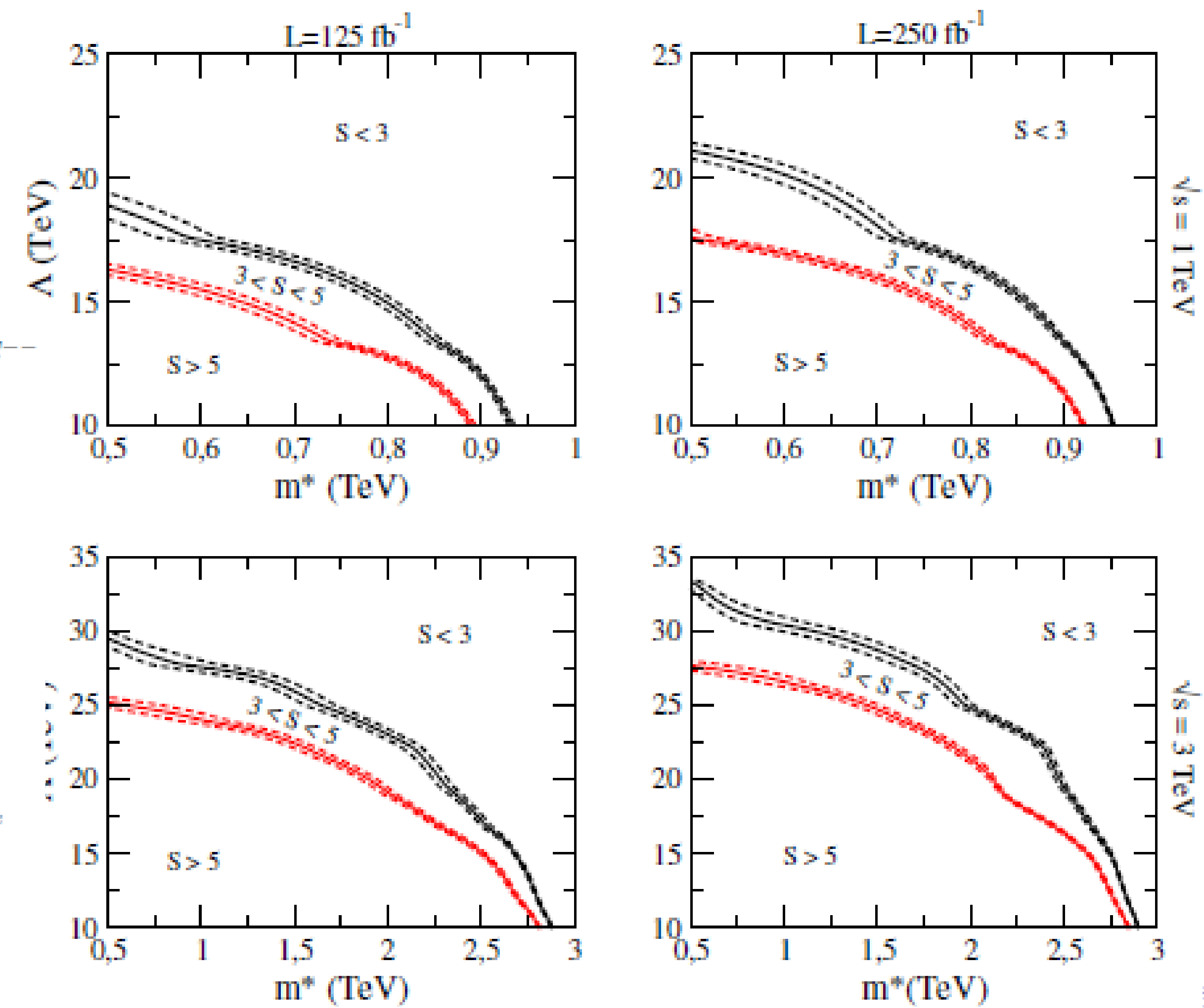


Hitoshi Murayama, *Dark Spectroscopy – a proposal for an ILC study*

Statistical significance for e^-e^- collisions

- $S = \frac{N_s}{\sqrt{N_s+N_b}}$, given $N_s = L\sigma_s$ and $N_b = L\sigma_b$ as function of m^* and Λ
- Reduced luminosity: $L_{e^-e^-} = \frac{1}{4} L_{e^+e^-}$ D. Shulte, Int. J. Mod. Phys. A 18 2851 (2003)





Conclusions

- LC will allow for precise measurements in top and bottom quark sectors
  - Significant improvement compared to LEP/LHC
  - Should help to resolve “flavour anomalies”
  - Indirect constraints on BSM beyond LHC reach
- Direct BSM searches profit from high energy
  - Significant discovery reach already at 250 GeV
  - SUSY still in good shape, many scenarios accessible at e^+e^-
  - We need to be prepared for unexpected signatures
- Improved precision and new theoretical ideas open new research possibilities
- Beam polarisation crucial for SM precision and BSM sensitivity

Many thanks to:

- **BSM conveners**:
  Mikael Berggren (DESY), Igor Boyko (JINR),
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  Jose Santiago (Granada),Tomohiko Tanabe (Tokyo)
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  Yoshimasa Kurihara (KEK),
  Sonny Mantry (N. Georgia), Roman Poeschl (LAL)
- **All speakers of both sessions**