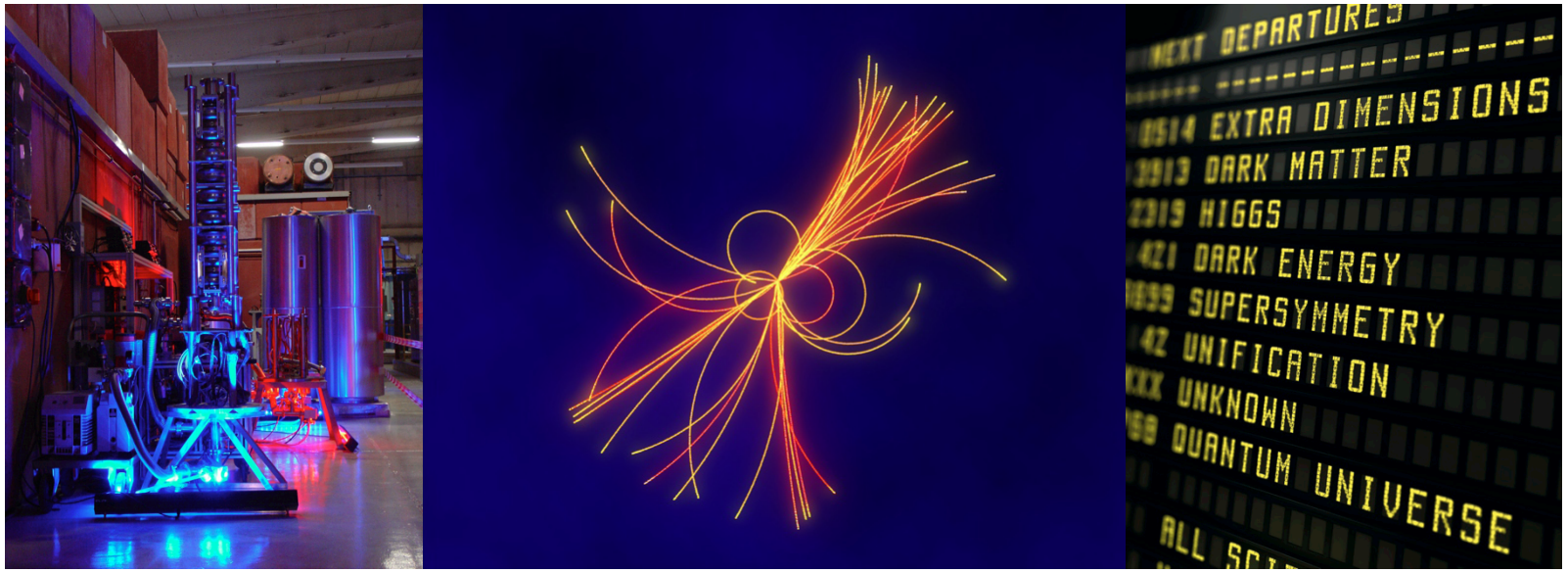
# ILC Project at DESY




Jenny List

79. Physics Research Committee

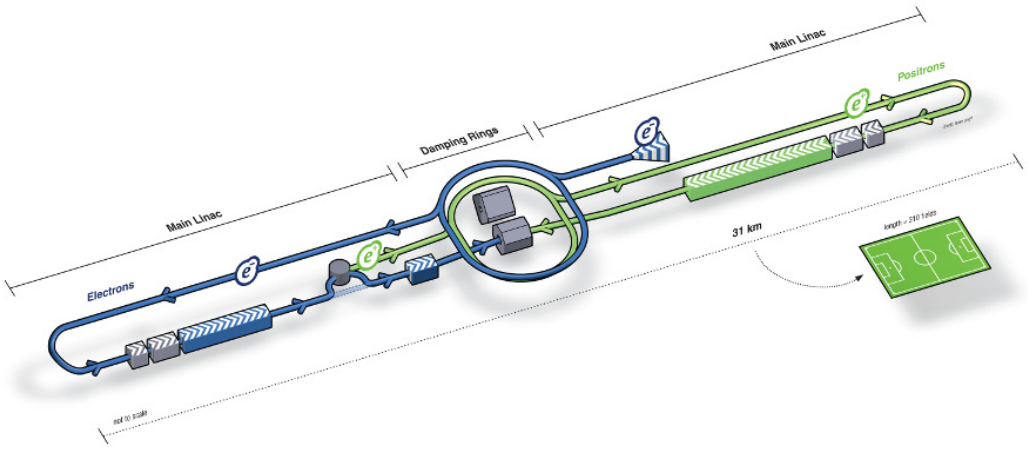
DESY, May 11, 2015

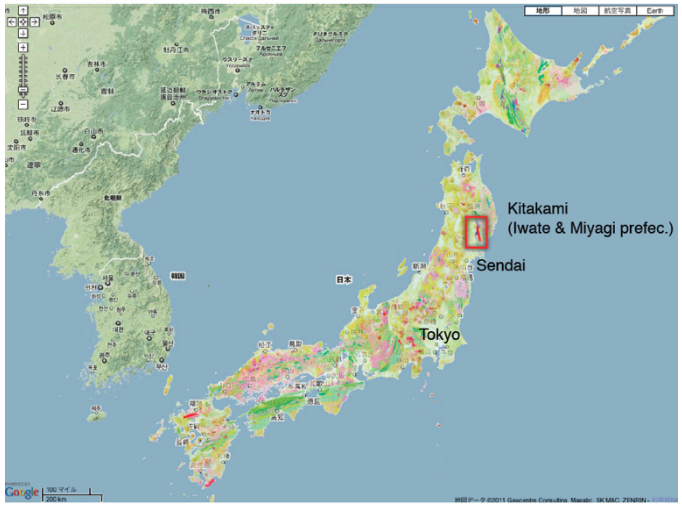
HELMHOLTZ ASSOCIATION

DESY

# The International Linear Collider

- $e^+e^-$ collider with $\sqrt{s}$ = 250 – 500 GeV, upgradable to $\sqrt{s}$ = 1 TeV
- L ~$2 \times 10^{34}$ $cm^{-2}$ $s^{-1}$
- 31 km long, SCRF technology
- global collaboration (~130 institutes)

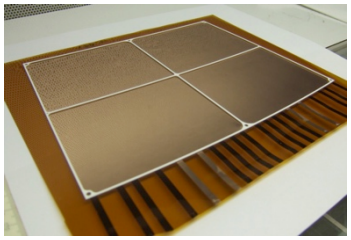


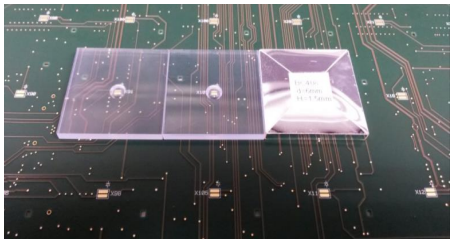




- since August 2013: Kitakami in northern Japan is candidate site
- following the recommendation by the Science Council of Japan, MEXT currently investigates hosting the ILC

# DESY ILC Activities

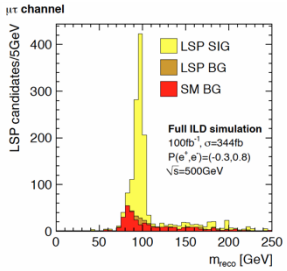
- **strong contributions in a (selected) number of technical systems**
  - **HCAL**
  - **TPC**
  - FCAL (Zeuthen)
  - Polarimetry

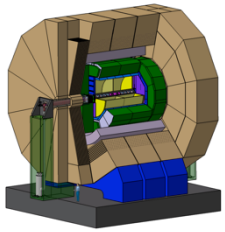


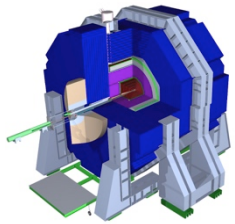


- **strong contribution to the physics case for the ILC:**
  - important basis for students / education
  - very important at the moment to continue to sharpen the case for the ILC

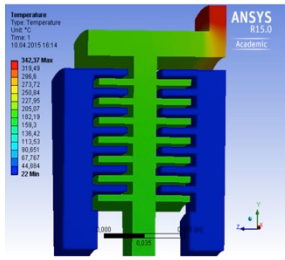
Main topic for today!





- **detector integration and overall management**
- **central support for the ILC community**
  - test beam and prototype integration
  - central software
  - MDI
  - central documentation facilities
- **accelerator**
  - SCRF (cf last PRC)
  - **positron source (Zeuthen)**



# Selected R&D Topics

**TPC**

**HCAL**

**Positron Source**

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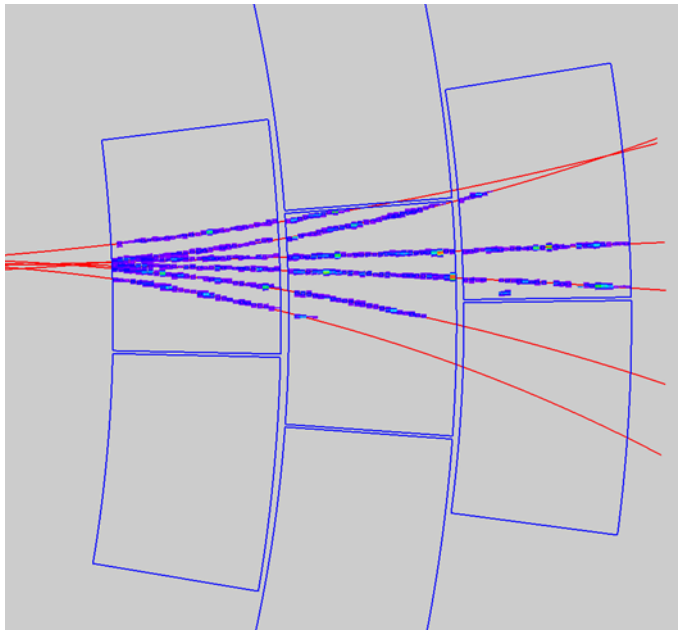
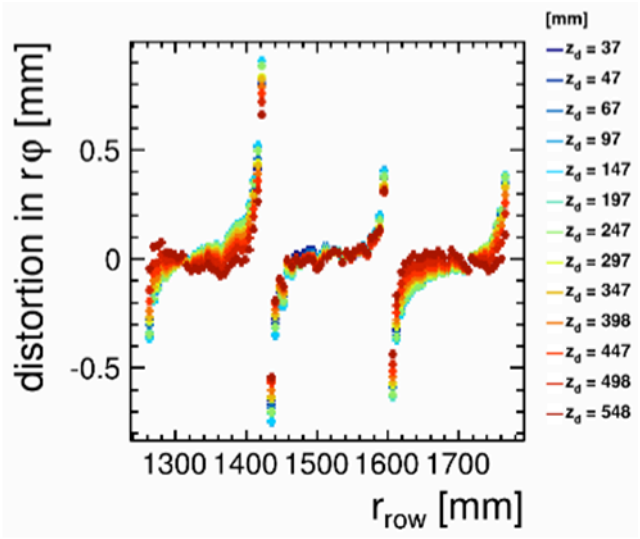
# TPC R&D at DESY



picture of an event recorded
at the DESY testbeam with the
DESY module (GEM based)




measured distortions after
alignment, but with local field distortions

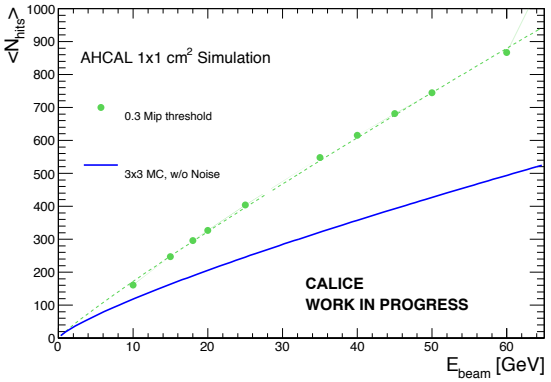
focus of the studies:

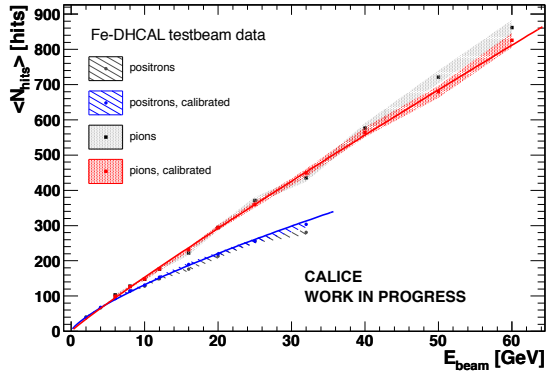
- understanding field distortions
- understanding calibration and alignment
- understanding reliability issues

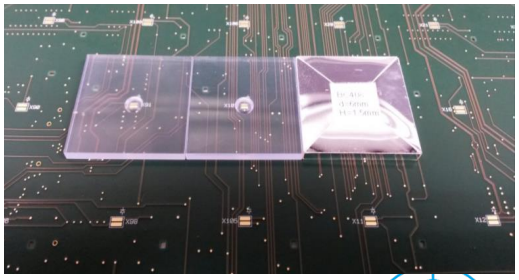
goal: design the next generation of modules
closer cooperation with Japanese groups intended: common module?

# Hadron Calorimeter R&D at DESY

- finishing analysis of first prototype data
  - drive and validate Geant 4 improvements
  - **common analysis analogue *and* digital HCAL data**
- major steps towards second generation prototype
  - **first round of beam tests at CERN with partially instrumented ILD-like module**
  - sector integration: data concentrator, powering and cooling for 2 full modules
  - scalable DAQ prototype for ILD and with good test beam performance
- technological frontier
  - drastic improvement of SiPM parameters dark noise, inter-pixel cross-talk, temperature stability, device uniformity
  - **towards automated assembly: surface-mounted SiPMs**
- site-dependent detector integration
  - earth-quake stability studies for absorber structure



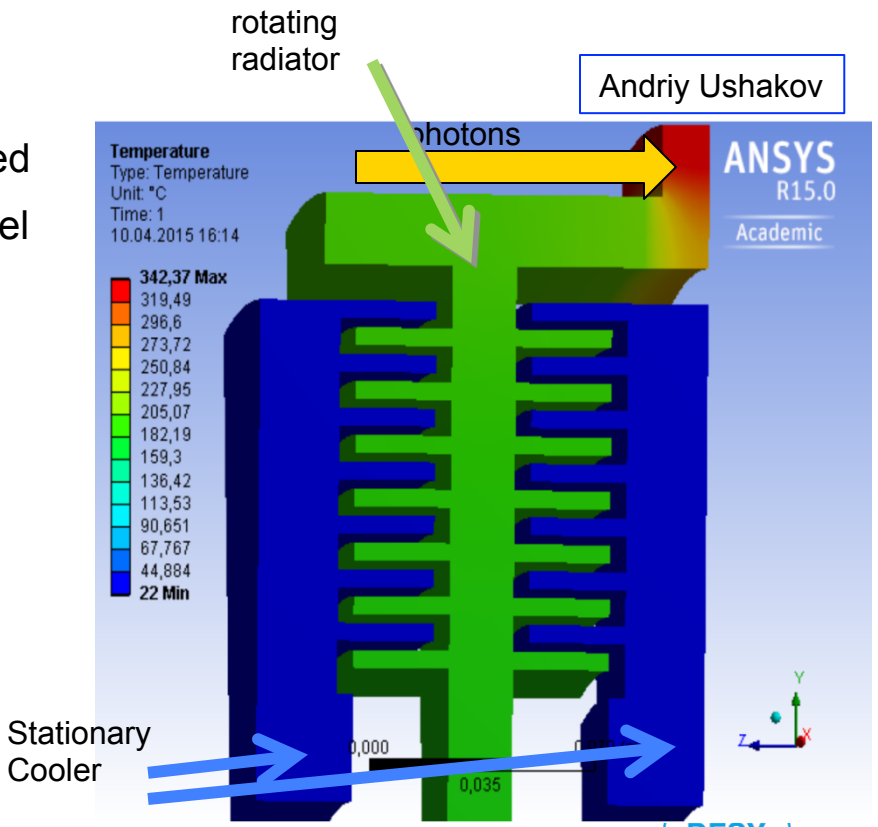



# Positron Source R&D at DESY

- one of *the* remaining R&D issues for the ILC
- helical undulator: the only way to get polarized positron beam (P≈30%)
- positron target wheel prototyping (at LLNL)
  - Ø 1m, rapidly rotating (100m/s) in vaccuum
  - Vacuum seal problem not yet solved
- alternative: cooling by thermal radiation
  - very promising option, no showstopper identified
  - optimize design of rotating radiator+target wheel and stationary cooler
  - optimize material for best heat transfer
  - cyclic load: fatigue load limits including particle irradiation ⇔ material degradation
  - engineering design
  - desired: experimental mock up in real size to test the whole system
- unique Zeuthen expertise and activity
- resources are stretched

ALCW 2015: radiative $e^+$ target cooling
Riemann, Dietrich,Sievers, Ushakov



# The Physics Case for the ILC

**Higgs**

**SUSY**

**Running Scenarios**

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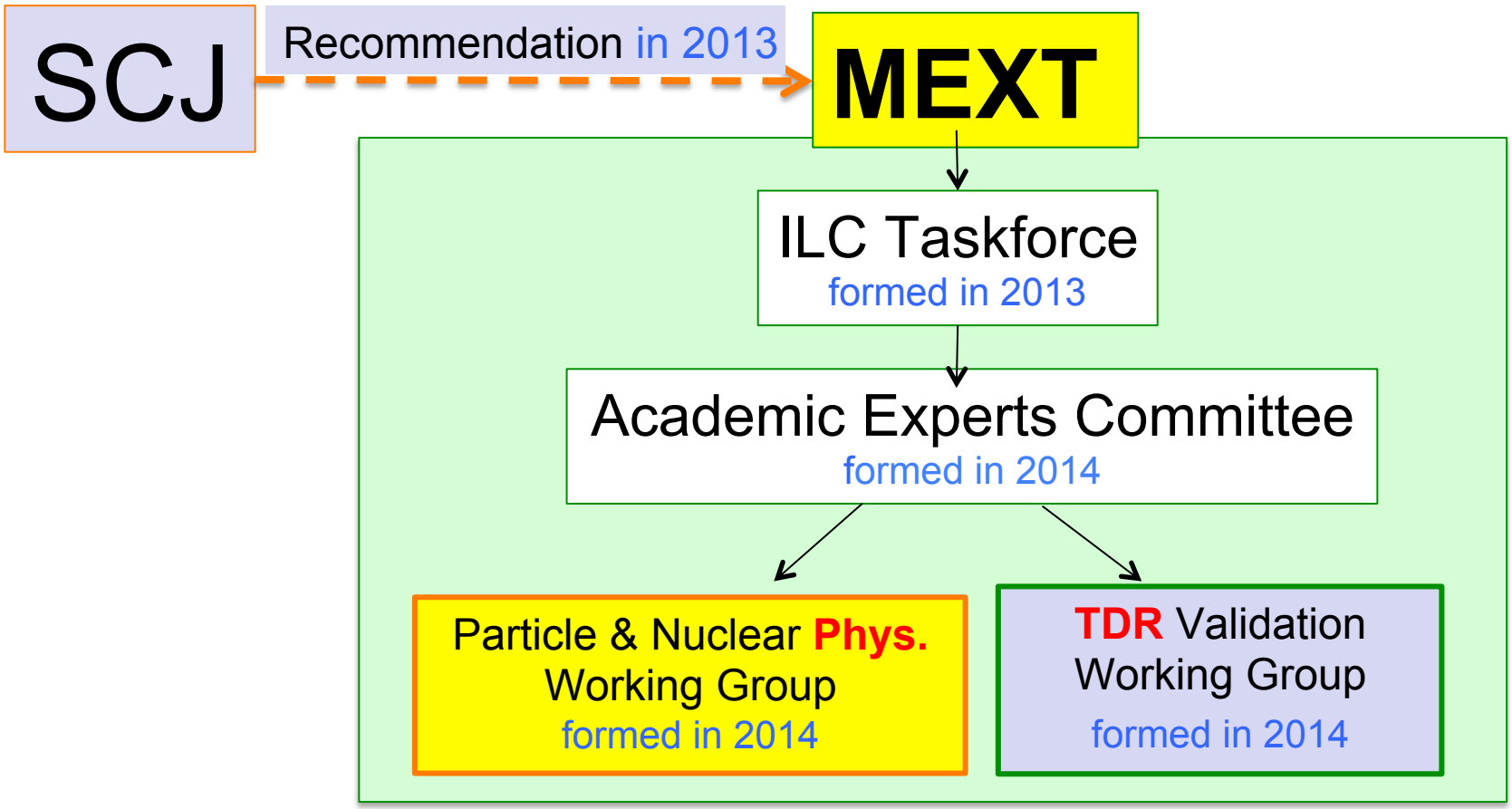
# Why talk once again about the ILC Physics Case?

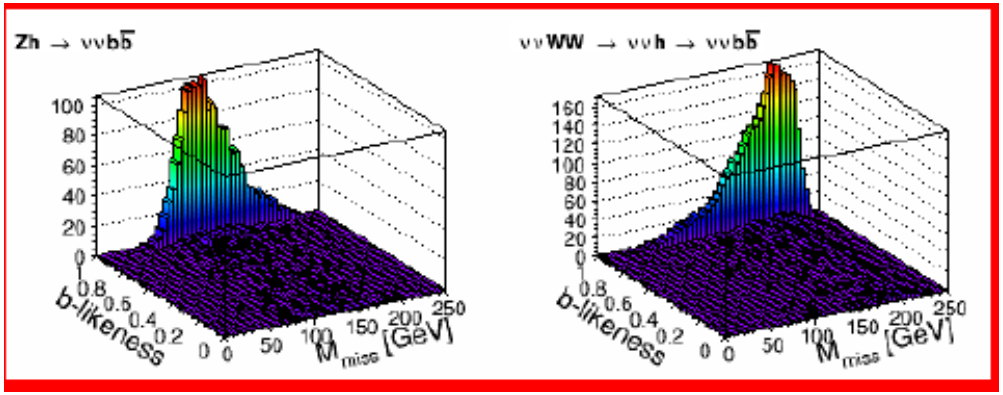



- during the past year, Particle & Nuclear Physics WG scrutinized physics case
- LCC Physics Group (2 DESY members): provided input over the last year
- **significant contributions from DESY**

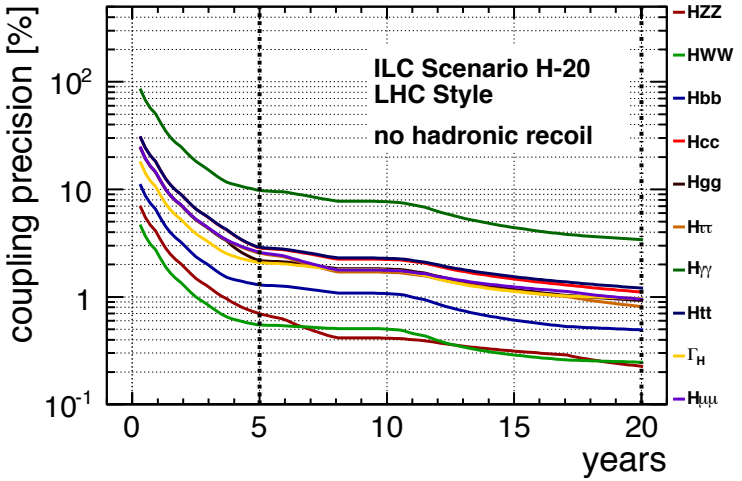
# Higgs Branching Ratios

[work in progress]

- close collaboration with Japanese groups
- BR(H->bb / cc / gg) :
  - separate ZH and WW-fusion contributions in vvH mode
  - impact of vertex detector geometry and low momentum tracking on H->cc identification



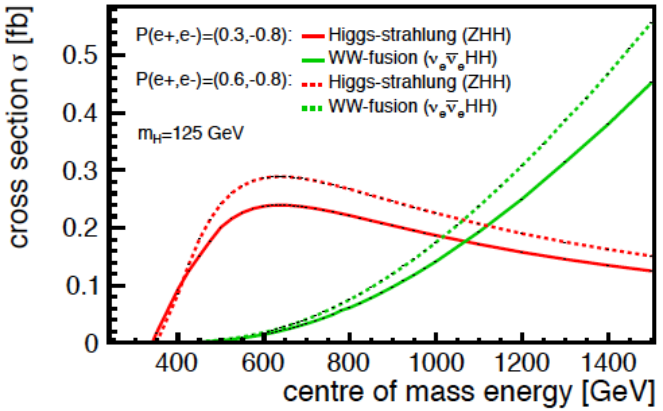

- global coupling fit of all Higgs σxBR measurements at various centre-of-mass energies: DESY/KEK collaboration
  - **evaluate combination of measurements at different centre-of-mass energies & polarisations as function of time**
  - fully model-independent or “LHC-style”
  - with / without experimental & theoretical uncertainties
  - to come: include covariance between (partially) correlated measurements / systematics



# Higgs Self-Coupling

[work in progress]

- crucial to fully establish Higgs mechanism
- first stage ILC @ 500 GeV: access via ZHH
- again close collaboration with Japan
- DESY: ZHH -> Z bbbb




**Preliminary results presented at LCWS14 (without overlay)**

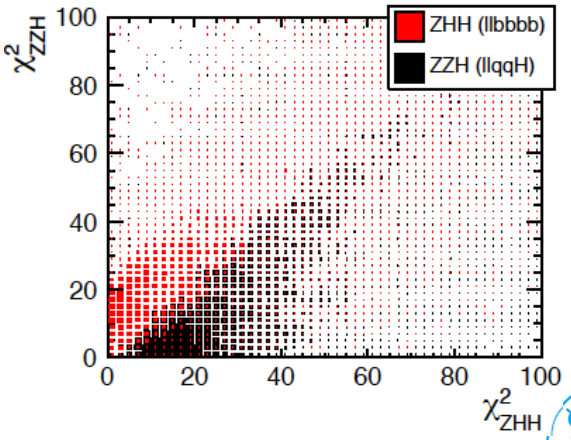
| decay channel | signal | background | significance | |
|---|---|---|---|---|
| | | | excess | measurement |
| ZHH → $l^-l^+$HH | 3.0 | 4.3 | 1.16σ | 0.91σ |
| | 3.3 | 6.0 | 1.12σ | 0.91σ |
| ZHH → $\nu\bar{\nu}$HH | 5.2 | 6.9 | 1.63σ | 1.37σ |
| ZHH → $q\bar{q}$HH | 9.2 | 20.9 | 1.82σ | 1.64σ |
| | 7.7 | 23.5 | 1.45σ | 1.31σ |

cross section: $\frac{\Delta\sigma_{ZHH}}{\sigma_{ZHH}} = 32.6\%$

Higgs self-coupling: $\frac{\Delta\lambda}{\lambda} = 53.5\%$

$m_H$ = 125 GeV
L = 2 ab$^{-1}$
P($e^+$,$e^-$)=(0.3,-0.8)

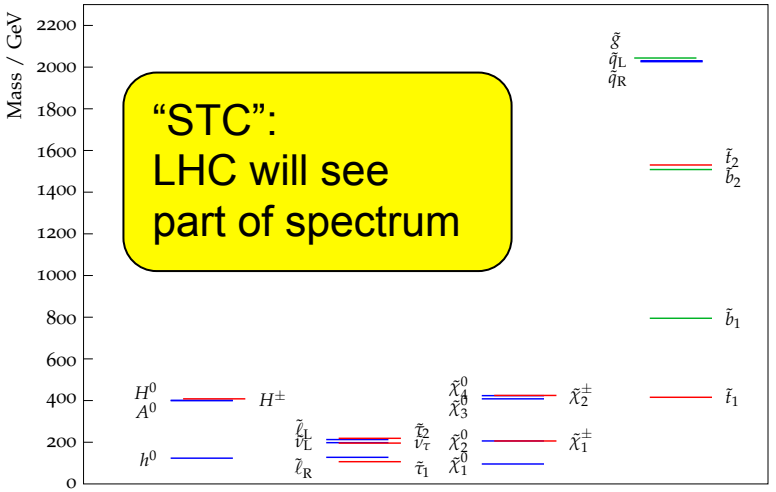
- long list of possible improvements
- first try: kinematic fitting
  - already achieved without much optimisation
    **20% relative improvement in Z->ll channel**
  - other channels to come...

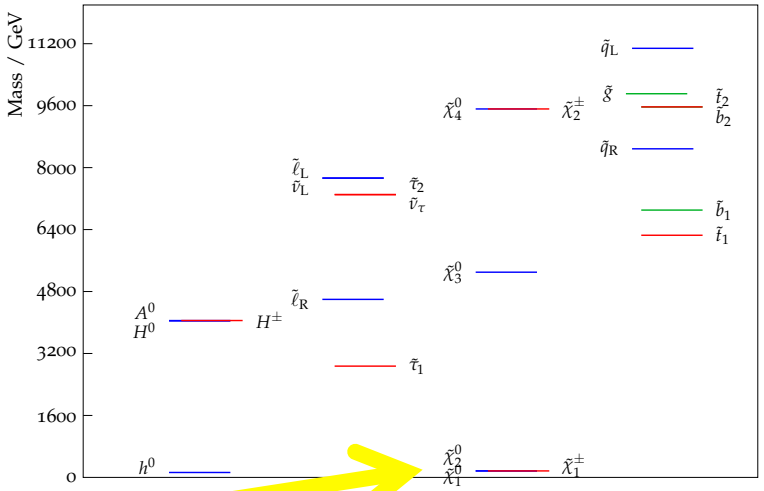


# Post LHC-8 Benchmarks for ILC Physics

[PRD88 (2013) 055004]

- New Physics potential of the ILC ?
  => review implications of LHC results!
- 10 SUSY benchmarks compatible with LHC 8 TeV and low energy constraints
  - (radiative) Natural SUSY, NUHM2, NUGM, mSugra, NMH, pMSSM, ...
- conclusions:
  - after LHC-8, there is lot's of stuff left
  - in some cases LHC-13/14 will discover part of spectrum
  - **even if no SUSY-like signal at LHC-13/14: well motivated phase-space for ILC**



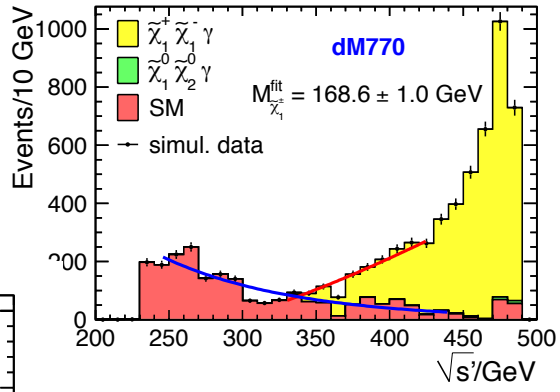



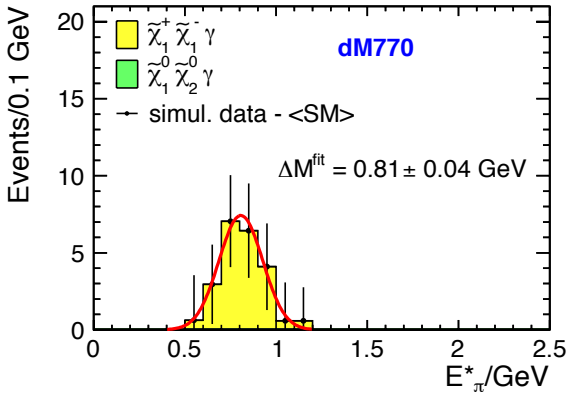

"BB":
nothing at LHC
ILC will see light
Higgsinos!

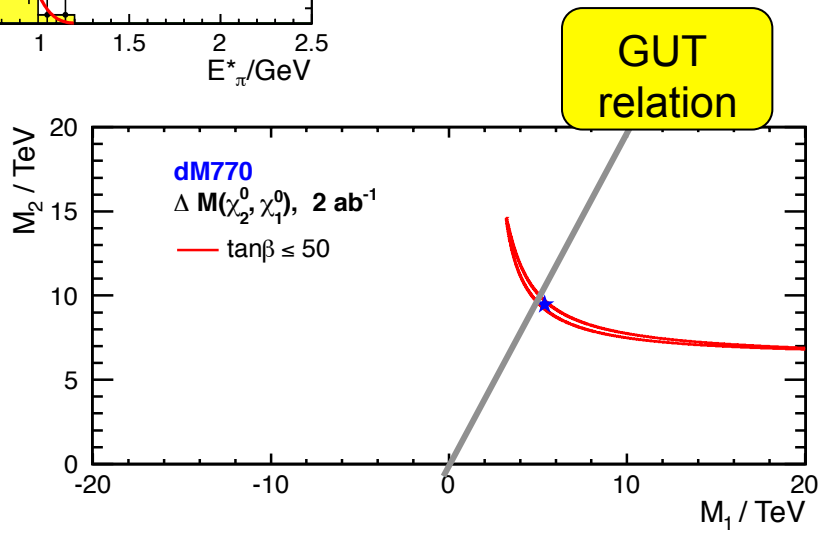
# Natural SUSY & Light Higgsinos

[EPJ C73 (2013) 12, 2660]

- Natural SUSY: $\mu << M_1, M_2$
  => three light, near-degenerate Higgsinos
- typical mass splittings few GeV or sub-GeV
- ILC fast simulation study:
  - cross-sections to few %
  - mass scale to 1-2 GeV
  - mass splitting to 40 MeV (!)
- **allows to constrain $M_1$, $M_2$ even if in multi-TeV regime**
- currently: re-do in full simulation
- very interesting detector performance benchmark:
  - low momentum tracking, PID
  - hermeticity



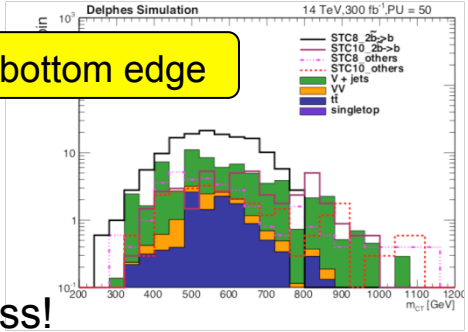



# LHC – ILC Interplay

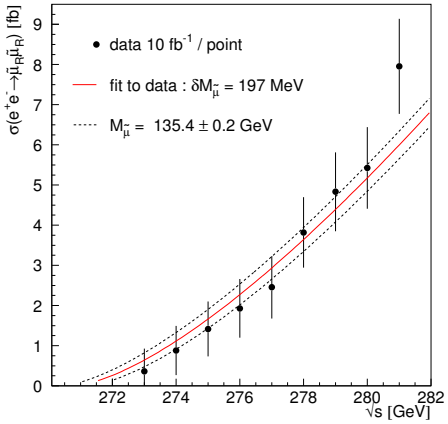
[work in progress]

- joint study with DESY CMS SUSY group – STC benchmark:
  Dark Matter motivated pMSSM scenario with stau-LSP co-annihilation
- (HL-)LHC: signals of
  - stop, sbottom, gluino mix
  - electroweakino mix
  - able to isolate sbottom signal
    => upper edge in contransverse mass!

LHC sbottom edge

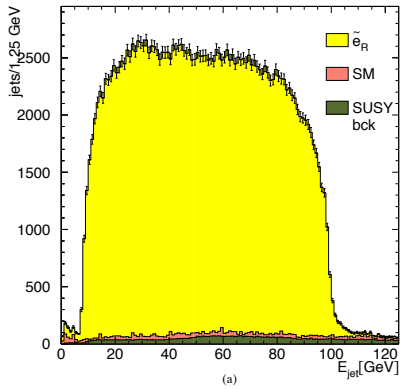



ILC smuon threshold scan

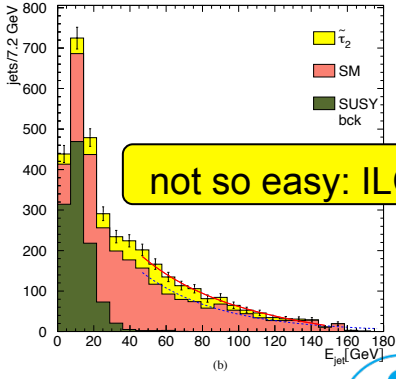



- ILC: full disentangling and precision profiling of
  - all sleptons
  - lighter electroweakinos
  - continuum vs threshold scans ?
- **feeds back into LHC analysis:**
  - determine sbottom mass
  - identify heavier electroweakinos

easy: ILC selectron-R



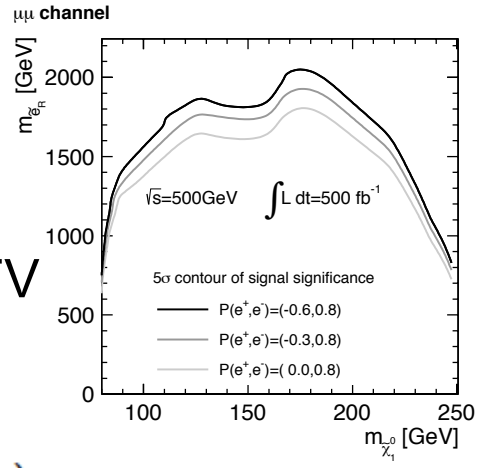

not so easy: ILC stau-2



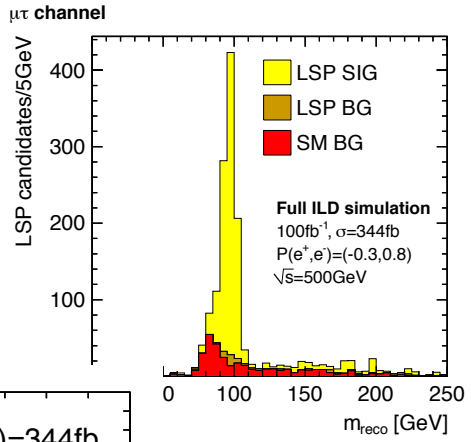
# Neutrino Physics at the ILC

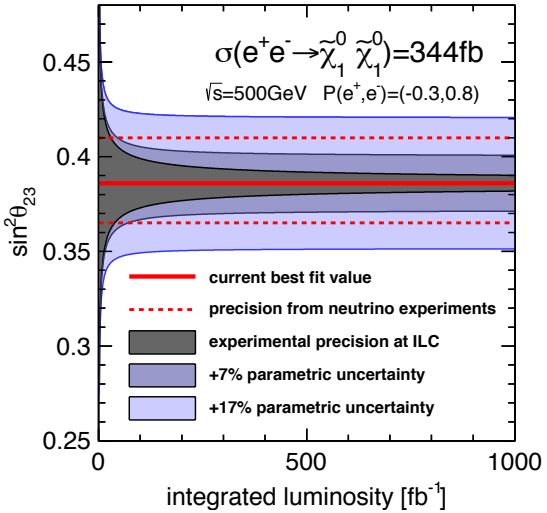
[EPJ C74 (2014) 2720]

- bi-linear R-parity violating SUSY: neutrino masses via high-scale see-saw mechanism
- ILC: precision measurements of LFV neutralino decays give access to neutrino mixing
  - measure $BR(\tilde{\chi}_1^0 \to W\mu)/BR(\tilde{\chi}_1^0 \to W\tau)$
- full ILD simulation study yields
  - with $100\,\mathrm{fb}^{-1}$: $\delta M_{\tilde{\chi}_1^0} = 0.13\,\mathrm{GeV}$
  - with $500\,\mathrm{fb}^{-1}$: $\delta BR = 6.5\%$
  - $\sin\theta_{23}$ is accessible with (at least) similar precision as in neutrino oscillations
- verify / falsify bRPV SUSY as origin of neutrino masses!




probes selectron masses up to ~2 TeV

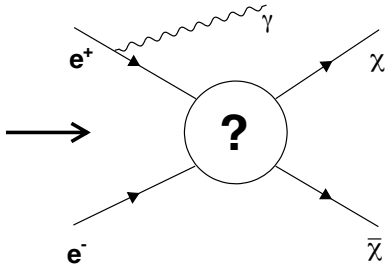


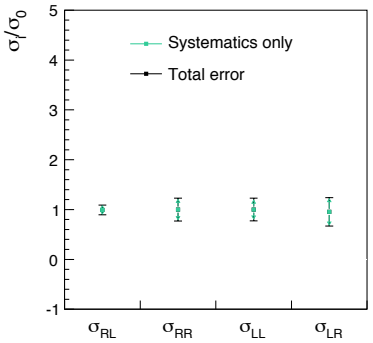



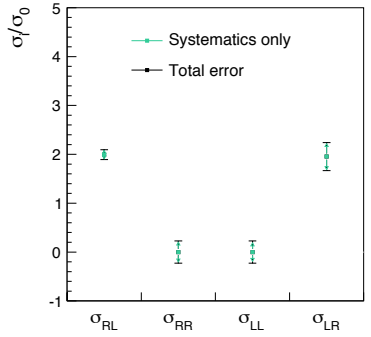
# WIMP Dark Matter

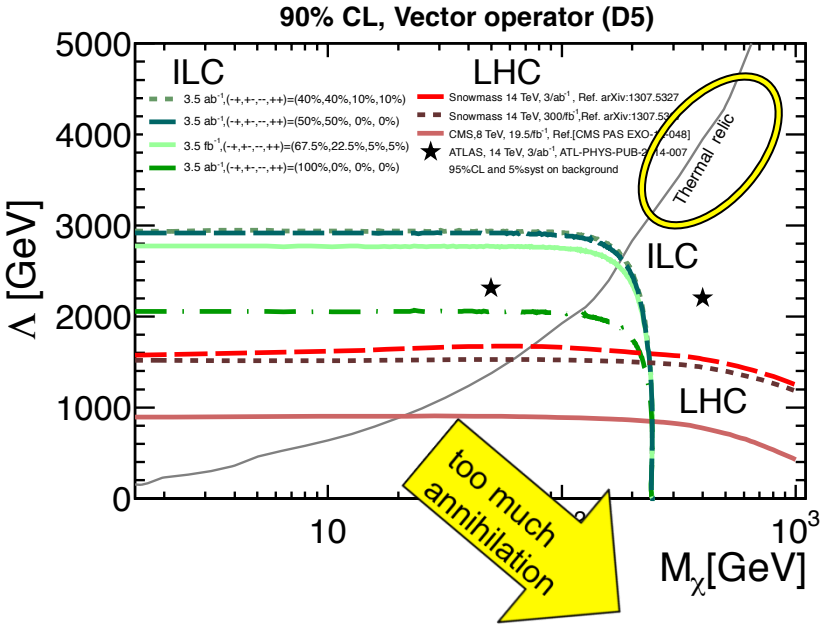
[EPJ C72 (2012) 2213 + update in prep.]

- mono-photon signature: $e^+e^-$ -> γ X X
- LHC & direct detection: test X-proton coupling
- ILC: tests X-electron coupling – **fully complementary!**
- %-level mass & polarised cross-sections => chiral structure of interaction
- reach in effective operator framework....

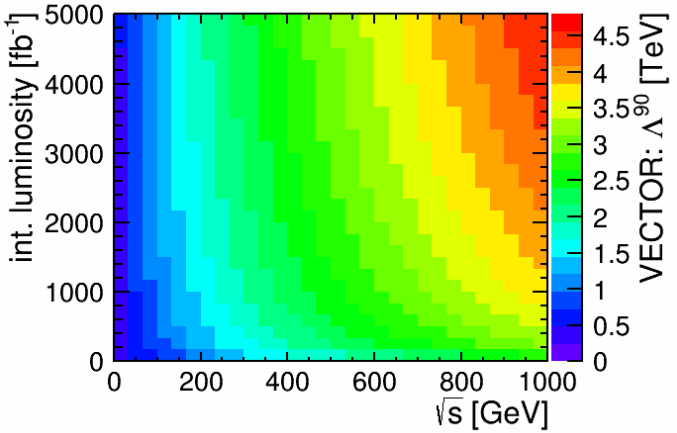



... and extra-polation to other sqrt(s)



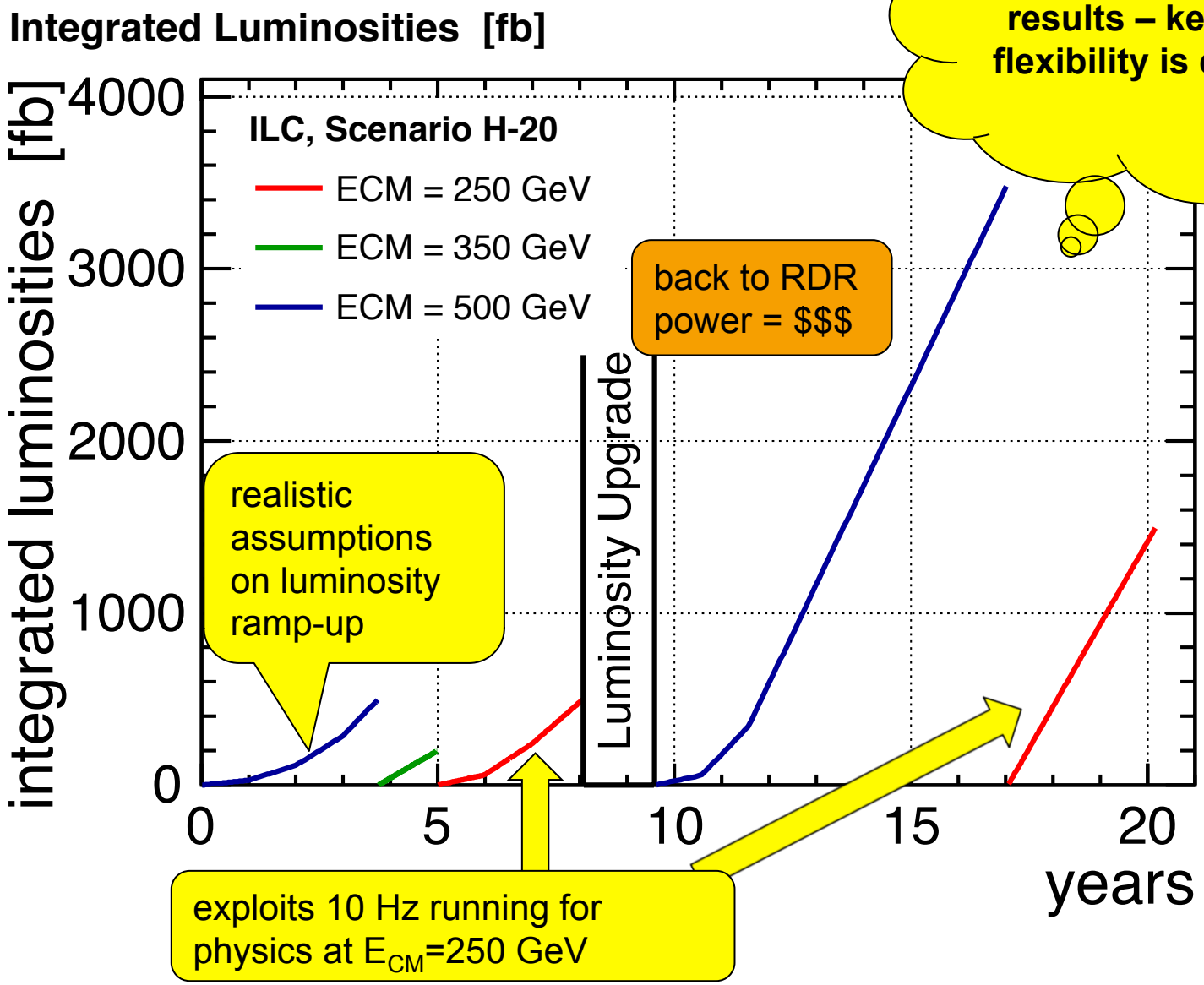
# Status of Physics Case Review

- interim reports from MEXT review process in April 2015
- Particle & Nuclear Physics WG:
  - well received (thanks to continuous input of LCC Physics Group)
  - in particular:
    **BSM potential recognized, whether LHC find New Physics or not**
- TDR WG:
  - TDR costing ~confirmed, additions for beyond-TDR items
  - new working group on
    human resources to be established
- final report ~March 2016 reconfirmed
- during ALCW2015: “Tokyo Event”
  - positive impression, Japan seriously interested
  - inofficial discussions with US started
  - EU more complex, starting with France

# LCC Joint WG on ILC Beam Parameters

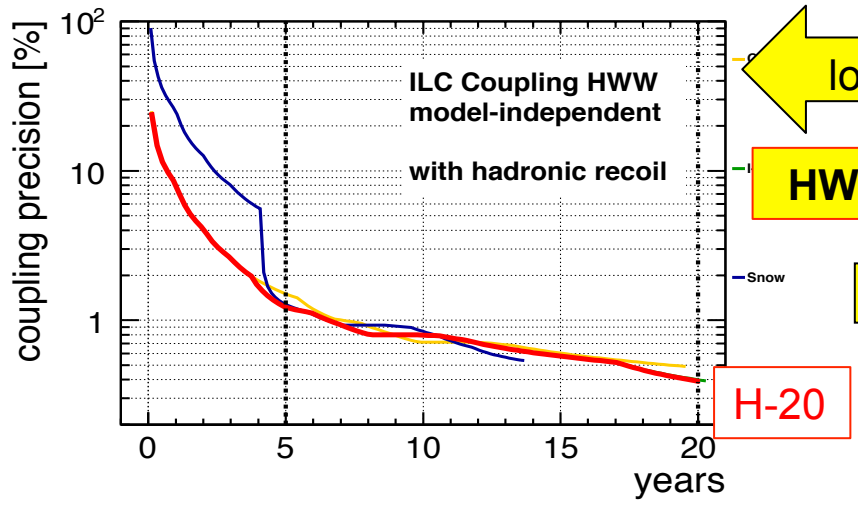
- established in spring 2014 to work out running scenarios for the ILC
- "Joint WG": particle *and* accelerator physicists
- strong DESY participation: 2 out of 7 members
- objectives:
  - define assumptions on **real-time** luminosity accumulation
  - define amount of integrated luminosity at various centre-of-mass energies
  - optimise for early (~5 years) and final (~20 years) physics potential
- first task: prepare for staged ILC construction
  - staging scenarios presented at LCWS 2014
  - report available as ILC-NOTE-2015-066
- second task: running scenarios for full TDR baseline machine
  - running scenarios presented at ALCW 2015
  - currently waiting for comments / approval by LCB

# A New ILC Running Scenario




**will be influenced by further LHC & ILC results – keeping full flexibility is essential!**

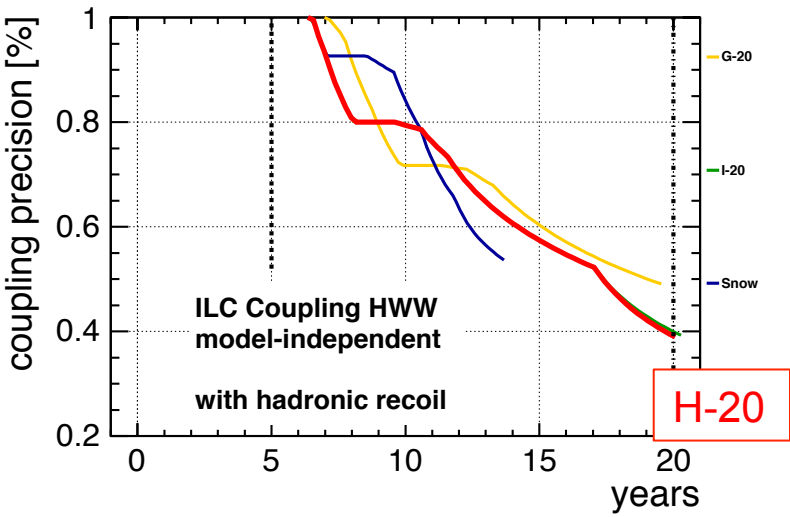
# Higgs-Vector Boson Couplings in var. Running Scenarios

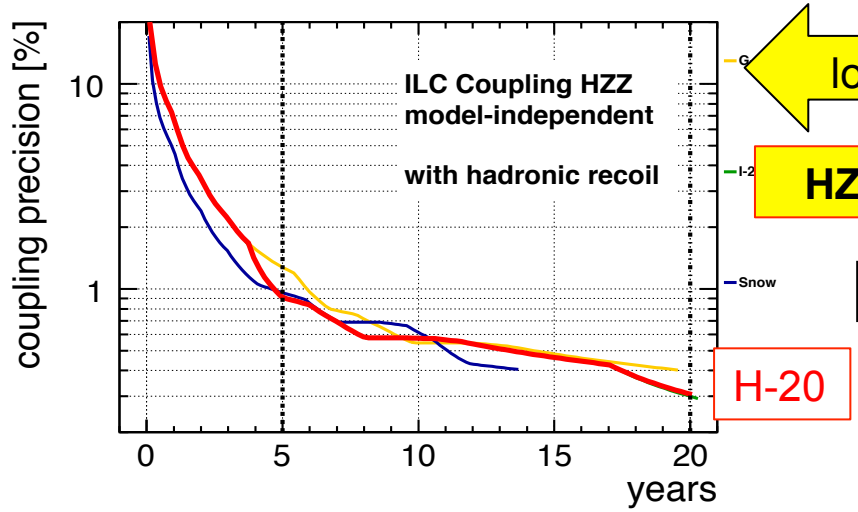



log scale

**HWW coupling**

lin scale

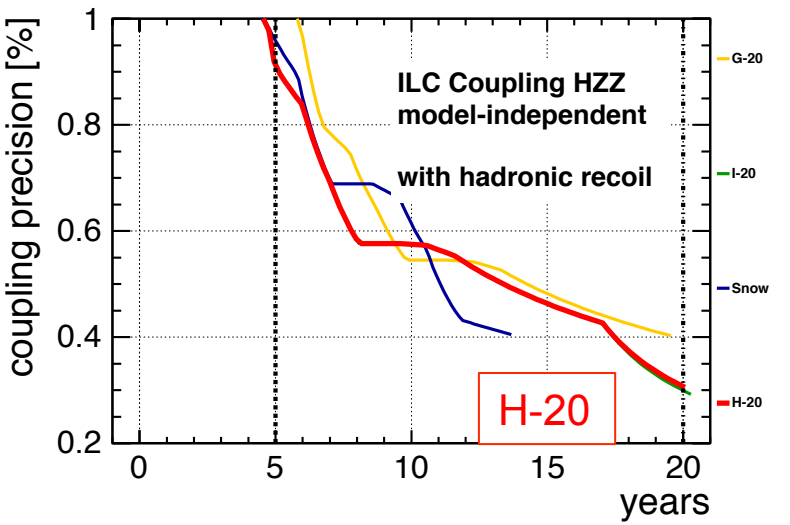


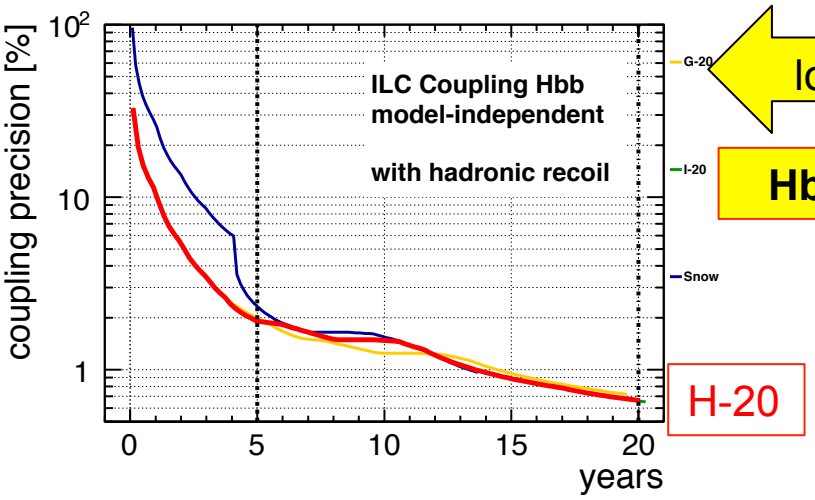

log scale

**HZZ coupling**

lin scale



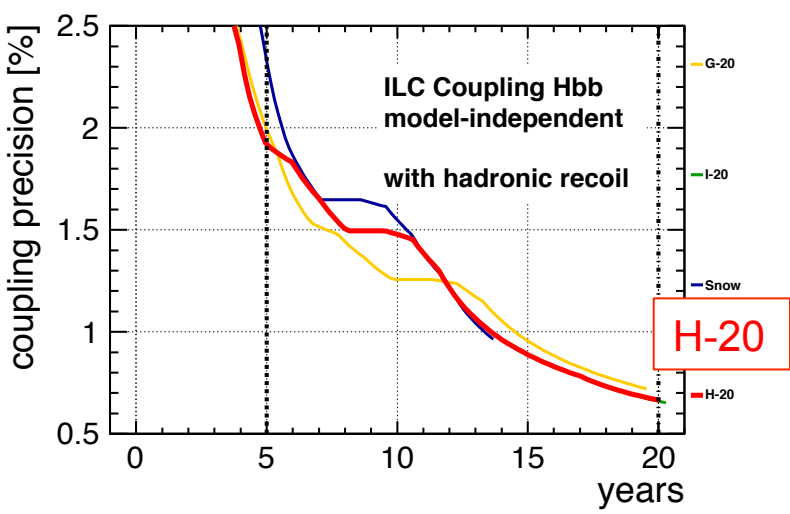
# Higgs-Fermion Couplings in var. Running Scenarios

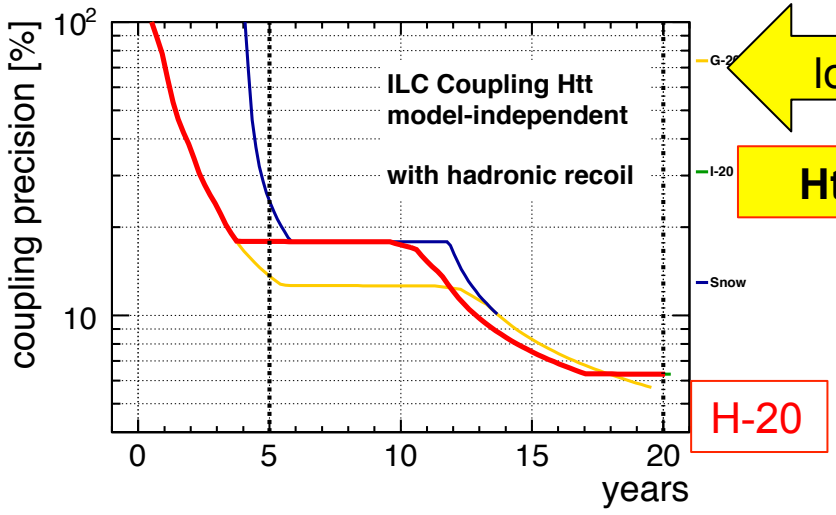



log scale

**Hbb coupling**

lin scale

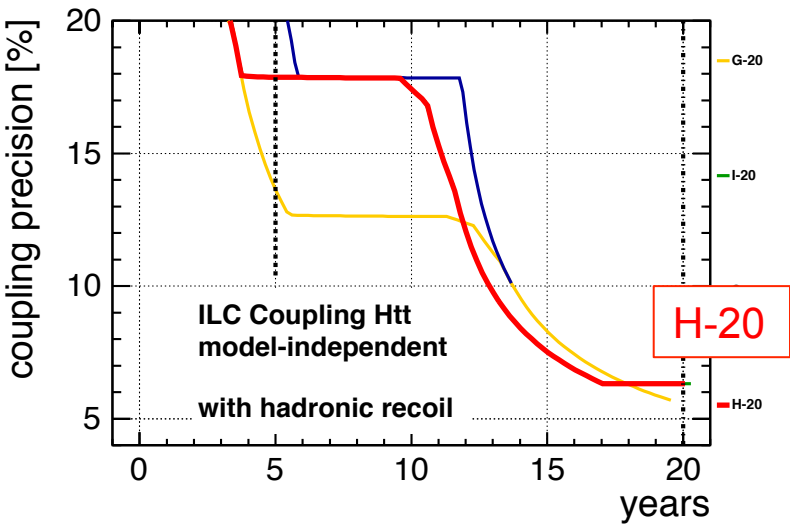



log scale

**Htt coupling**

lin scale



# Summary

- DESY has a strong in-house ILC programme and is in an excellent position to support this project
- DESY contributions are essential for ILC in key areas
  - detector and accelerator R&D
  - detector design & integration, MDI and overall management
  - **physics case**
  - **new running scenario => update physics projections to higher luminosities!**
- unique contributions to ILC BSM physics case
- important input to MEXT review process (and earlier: Snowmass)
  - physics case got “green light”
  - new working group on human resources to be established
- Japan is seriously investigating the idea of hosting the ILC:
  - original evaluation schedule re-confirmed: March 2016
  - inofficial discussions with other countries have started

# Back Up

# Outlook on Physics Case

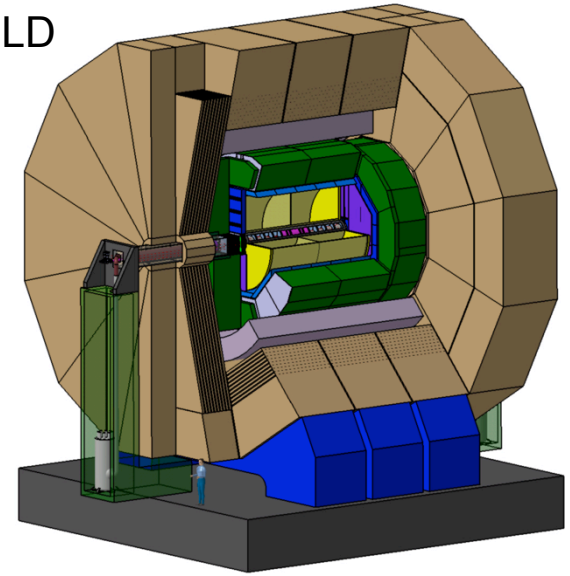
- Update physics projections
  - from benchmarking luminosities (250 $fb^{-1}$ / 500 $fb^{-1}$)
  - to full H-20 luminosities (2 $ab^{-1}$ / 4 $ab^{-1}$)
- Continue to improve tricky cases (eg Higgs Self-Coupling)
- Watch upcoming LHC results
- More detailed estimates of systematic uncertainties wherever statistical uncertainty < 1%
  => implications on detector design???

# Concept News

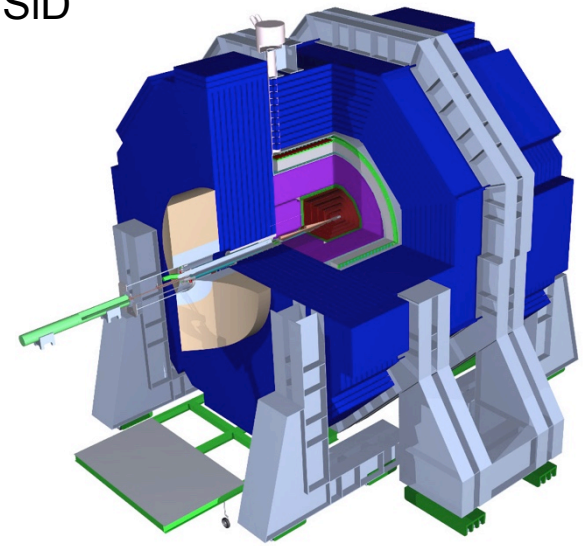
- ILD Reorganisation:
  - establishing a new, more collaboration-like structure
  - currently on-going: election of spokesperson
- ILD Detector Optimisation:
  - Started to evaluate potential for cost saving
  - Investigating consequences of new L* requested by accelerator
    => redesign of forward region
- ILD & SiD joint with Accelerator & MDI group:
  - study of machine-related backgrounds with new accelerator parameters
- SiD:
  - DESY coordinates SiD part for all EU proposals (RanDALF, etc)

# ILC Detector Concepts

ILD



SiD



- 2 detector concepts for ILC: ILD and SiD
  - both optimised for particle flow algorithms
  - complementary technologies
  - DESY has strong role in ILD
- Within the concepts
  - Simulation and reconstruction software
  - Engineering and integration
  - Detector optimisation
  - Physics analysis studies
- Detector R&D
  - R&D collaborations inform the concepts:
    - •LCTPC: Time Projection Chamber (ILD)
    - •CALICE: calorimetry (ILD &SiD)
    - •FCAL: very forward calorimetry (ILD & SiD)
  - Polarimetry
  - Vertex detector