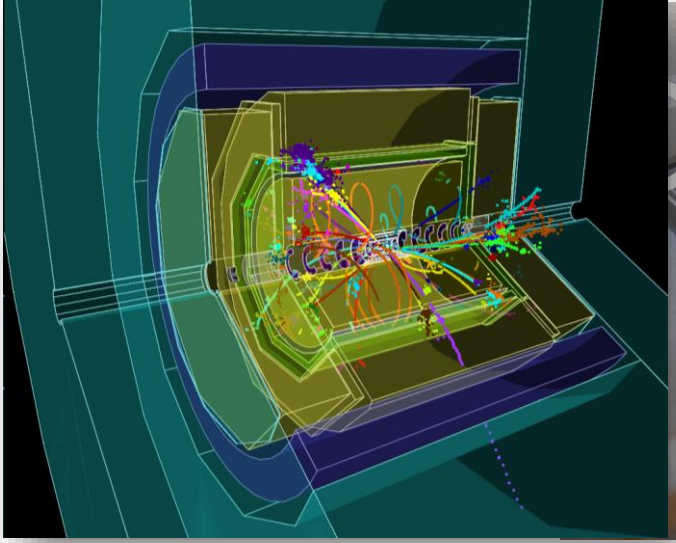
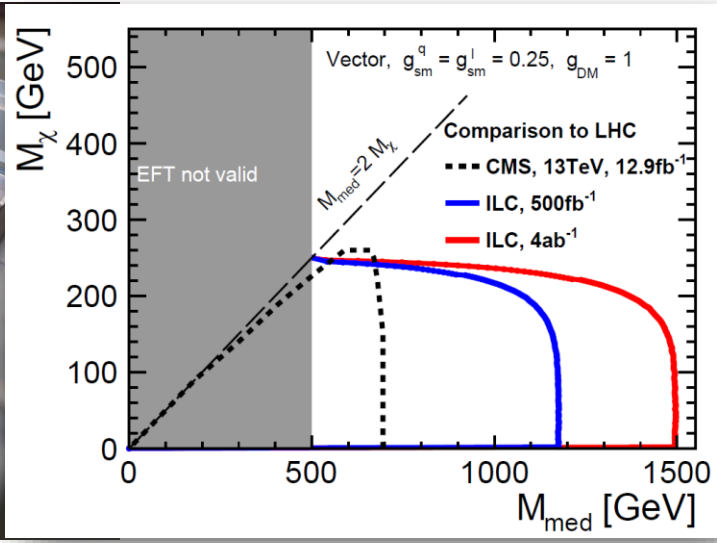




Future Collider at DESY: Local activities

Ties Behnke

Future Colliders at DESY

The starting point

- Electron Positron collisions are high on the list of priorities in Europe for the next project. DESY has had and wants to continue to have a strong involvement in future collider options
- DESY has in the past contributed strongly on many aspects of future colliders
  - Theory: strong support of making the science case for a future collider
  - Development of central accelerator technologies, in particular, ILC technology
  - Development of detector technologies needed for future colliders
  - Development of analysis strategies for lepton colliders
  - Development and operation/ maintenance of central software for future collider studies
  - Participation in the international organization of different future collider activities
    - ILC in many different roles
    - FCC in different roles
    - Global efforts: GDE (until 2014), LCC (until 2020), IDT (current)

A bit of history…

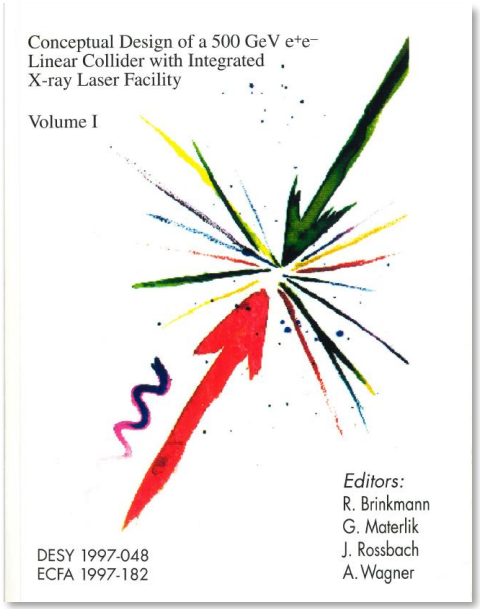
DESY and its role in future colliders

1990

Early 1990: Bjoern Wiik:

- Invest into superconducting acceleration technologies
- Increase gradient by factor of 10, reduce cost by factor of 10

1997 Publication of TESLA CDR: conceptual design study



- Strong DESY involvement in ILC technology: shift of emphasis by 2010 away from particle physics, to XFEL accelerator
- Strong DESY leadership in detector concept development for future collider, science studies, and software for future colliders

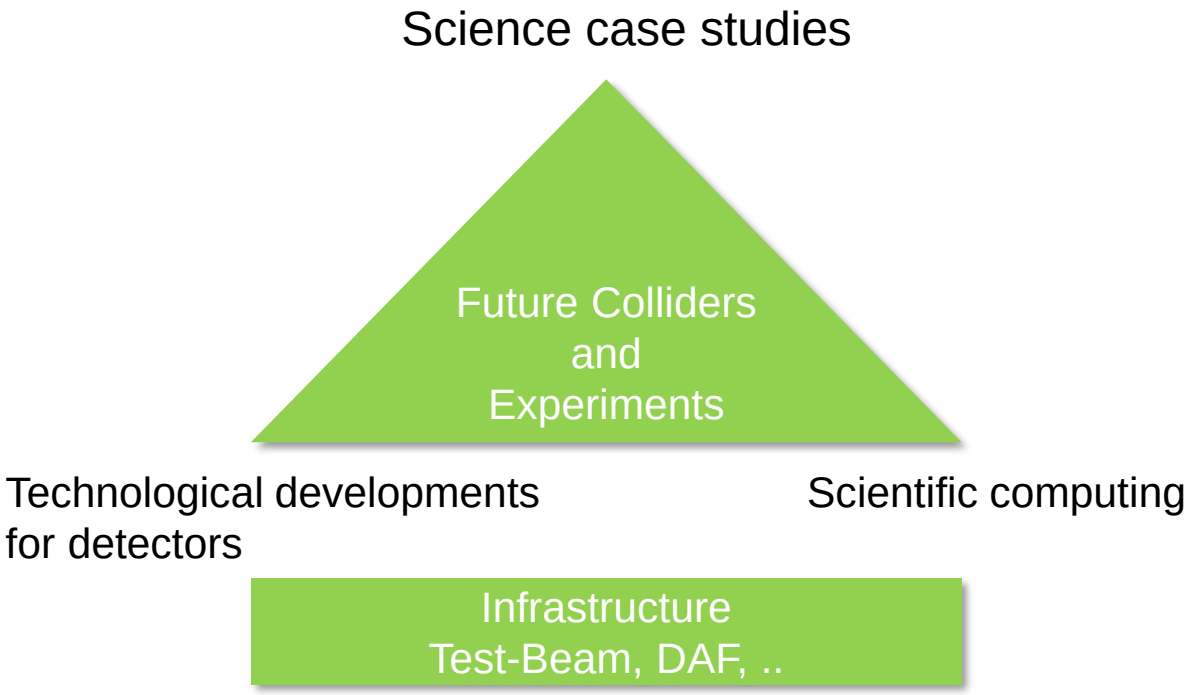
- Diversification, expansion to include other Higgs factory concepts, ramping up of FCC effort, participation in FCC-hh and FCC-ee effort

- Trigger studies on Higgs factory based on advanced accelerator concepts (HALHF)

2024

The essentials

Making the case

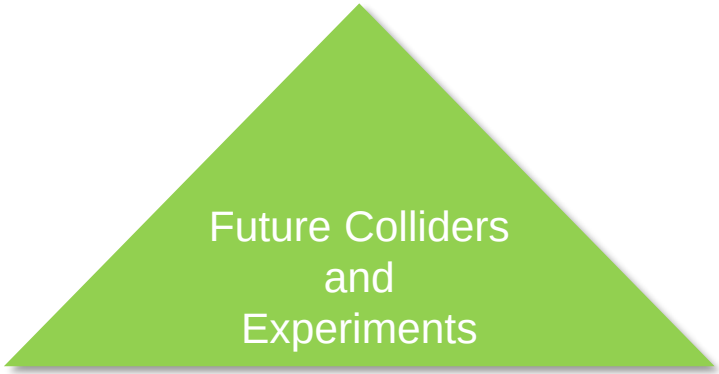


The essentials

Making the case

Science independent of particular collider option
But not collider blind

Science case studies



Cooperation with “local” partners,
Quantum Universe

Embed strongly in lab-wide effort to grow scientific computing

Technological developments for detectors

Scientific computing

Integration into interntl. R&D effort (DRD, etc)

Infrastructure
Test-Beam, DAF, ..

Integration into Helmholtz effort (MT, MU)

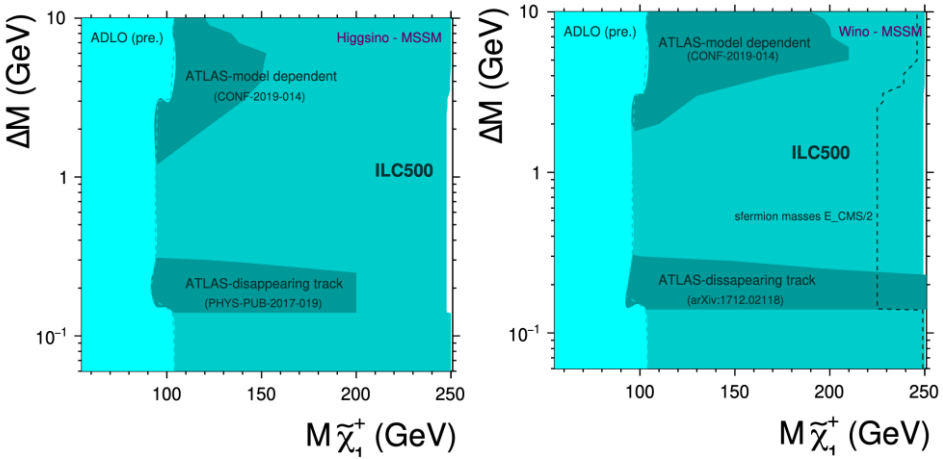
Science

A broad effort to understand the science of a future collider

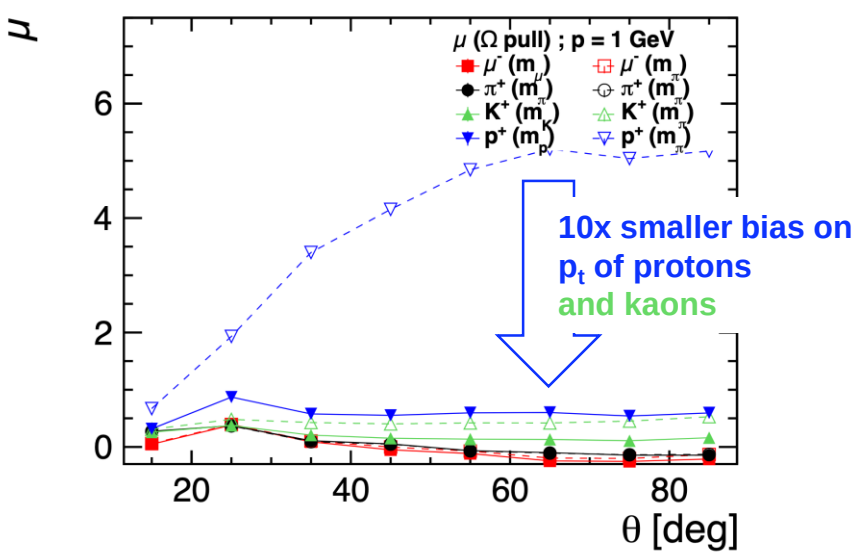
See talk by Jenny earlier today

- ILC as a natural SUSY discovery machine and precision microscope: From light Higgsinos to tests of unification
- WIMP Dark Matter at the International Linear Collider

Extrapolation of LEP (ADLO) chargino searches for ILC500 [arXiv:2002.01239]



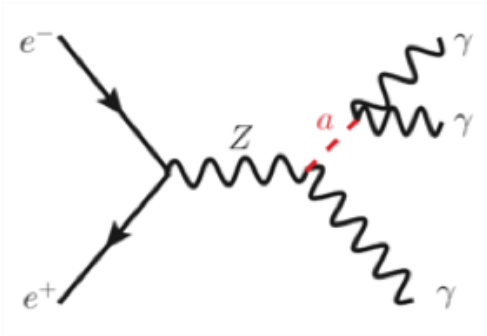
Track re-fitting with correct mass hypothesis (=>dE/dx in TPC)

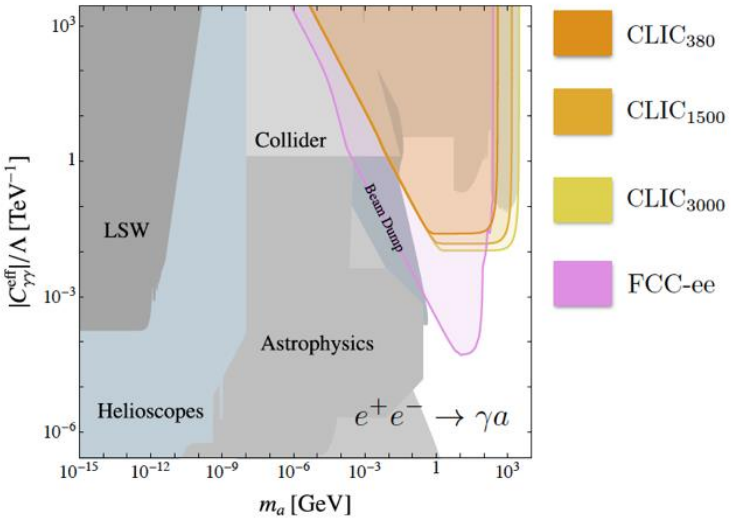


BSM at the FCC-ee

An example of a concrete project

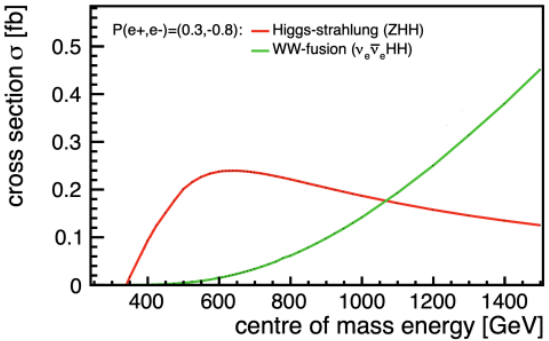
- Effort led by Juliette Alimena
  - Integrated into activities of the FCC BSM group
  - Juilette plays coordinating role
- BSM group focusing on 3 physics cases:
  - Heavy Neutral Leptons (HNLs)
  - Axion-like Particles (ALPs)
  - BSM Higgs
- Contributed to FCC midterm report, Snowmass, and the BSM group has a long history of producing Masters theses
- Work at DESY in BSM has focused on ALPs
  - Get long-lived ALPs when couplings and mass are small
  - At the FCC-ee, orders of magnitude of parameter space accessible. Especially sensitive to final states with at least 1 photon
  - Ukrainian Winter Student (Yuliia Borisenckova): Feb-Mar 2023, MIT bachelors student (Merlin Gogolin): Summer 2024

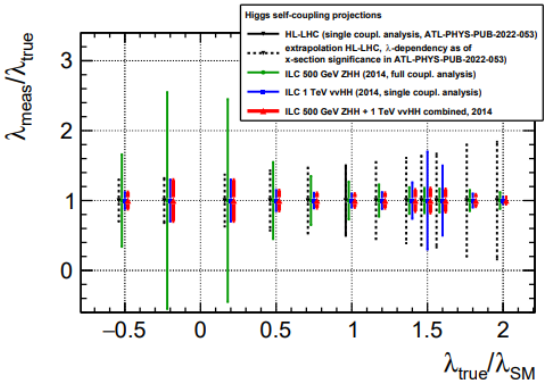




Higgs Self Coupling at the ILC

Energy counts: J. List etal.





Recent re-analysis of ZHH reaction
- J. Torndal, J. List

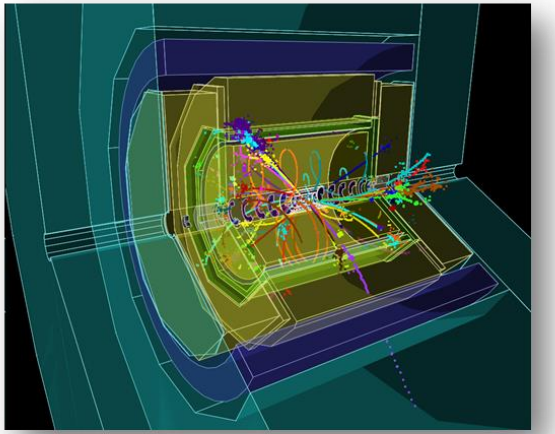
arXiv:2307.16515

E(cms) 500 GeV and 1 TeV

Comparison of different collider options

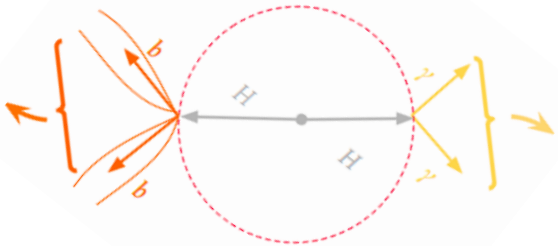
Comprehensive study done to explore the science potential of a linear Higgs factory (and beyond)

- Fully simulated events, detailed detector simulation
- Full realistic event reconstruction scheme
- Backgrounds partially simulated



Higgs Self-Coupling at the FCC-hh

E. Gallo etal.



$30ab^{-1}$ of integrated luminosity, about 10x the one at the end of HL-LHC

centre-of-mass energy of 100 TeV

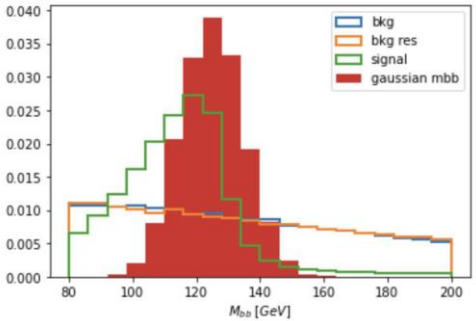
(2/fb per day initially and up to 8/fb day for nominal parameters)

Study based on fast simulation
DELPHES
Parametrized MC

LHC-like detector model
Parameterized particle flow performance

- Include pileup

Elisabetta Gallo, etal
Final state H->bb and H->gamma gamma



Study dependence of result on b-mass resolution:

Improvement of m(bb) (Z) to 2% would allow a measurement
at the LHC-hh of 2% on k(λ)

at a 100 TeV hadron collider

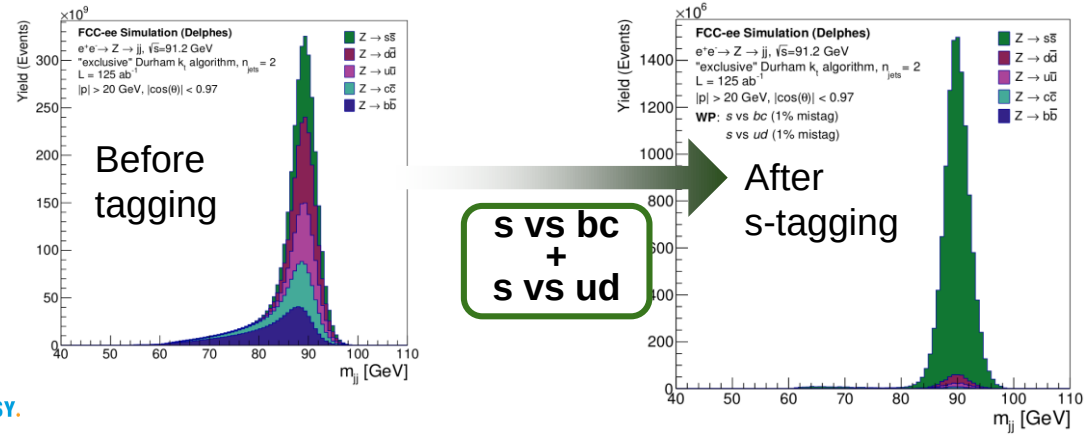
collider	Indirect-h	hh	combined
HL-LHC [78]	100-200%	50%	50%
ILC_{250}/C^3-250 [51, 52]	49%	–	49%
ILC_{500}/C^3-550 [51, 52]	38%	20%	20%
$CLIC_{380}$ [54]	50%	–	50%
$CLIC_{1500}$ [54]	49%	36%	29%
$CLIC_{3000}$ [54]	49%	9%	9%
FCC-ee [55]	33%	–	33%
FCC-ee (4 IPs) [55]	24%	–	24%
FCC-hh [79]	-	3.4-7.8%	3.4-7.8%
μ(3 TeV) [64]	-	15-30%	15-30%
μ(10 TeV) [64]	-	4%	4%

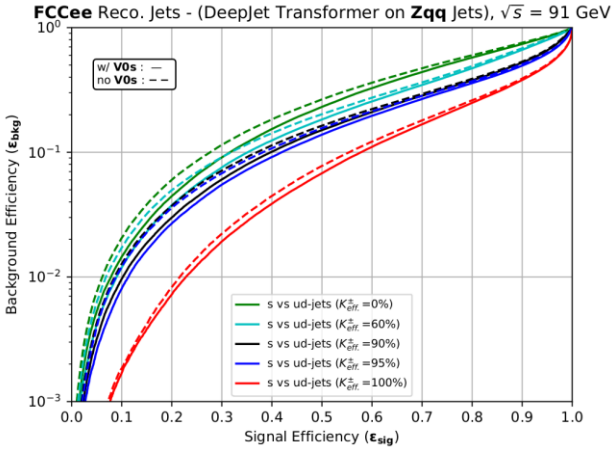
Jet Flavour Tagging at the Z resonance for FCC-ee

F. Blekmann etal

- **DeepJetTransformer** (DJT)
  - multi-node jet flavour tagger that simultaneously tags u,d,s,c,b jets (also has gluon jet tag capability)
  - **transformer-based deep neural network**
    - Cutting edge also for LHC
    - Relatively lightweight (trains fast also with many inputs) for deep learning NN
  - Excellent performance for b and c jets, but also s, u, d jet identification

- Paper "Jet Flavour Tagging at FCC-ee with a Transformer-based Neural Network: DeepJetTransformer"
  - provides network structure, multiple working points and examination of detector peformance (incl. particle ID and V0 reconstruction scenarios)
  - Benchmark: **Z→ss** can be isolated at **5σ significance** with **60 nb^{-1}**
    = **a second** of the FCC-ee at 91 GeV





Strange jet tagging is highly dependent on **$K^{\pm}/\pi^{\pm}$ identification** and **V^0 reconstruction**

https://arxiv.org/abs/2406.08590

Existing collaboration F. Blekman with VUBrussel and UniZurich. K. Gautam and E. Ploerer at DESY for remaining duration of PhD.

DESY's role in FC Worldwide

Central participation in the
FCC study (C. Grojeans etal)

HALHF

Long tradition of contribution

Participation in IDT group
Strong role in detector development for ILC

DESY among the proposers of
HALHF

Important role in the int'nl design study
towards a muon collider

Connection to detector development activities (DRD)
Connection to accelerator developments

Muon Colliders

People to talk to @DESY: Yee Chinn Yap, Thomas Madlener, Federico Meloni, Priscilla Pani, Juergen Reuter, David Spataro

MuCol

Co-funded by the European Union

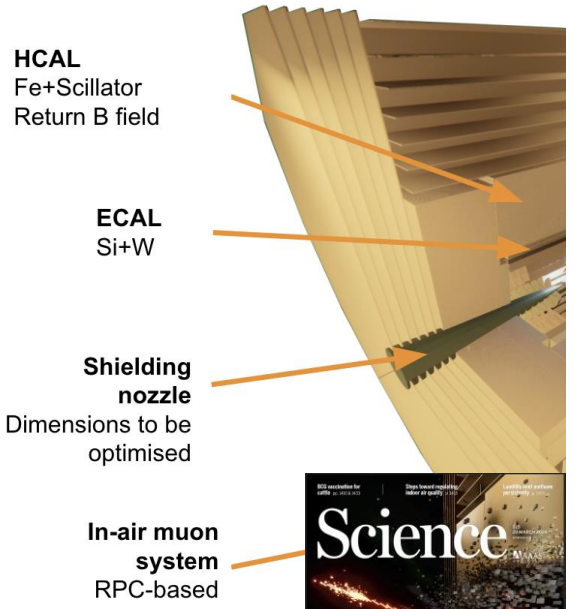
Focus on: design of **new detector concept**
exploring the **physics case**

Major roles in:

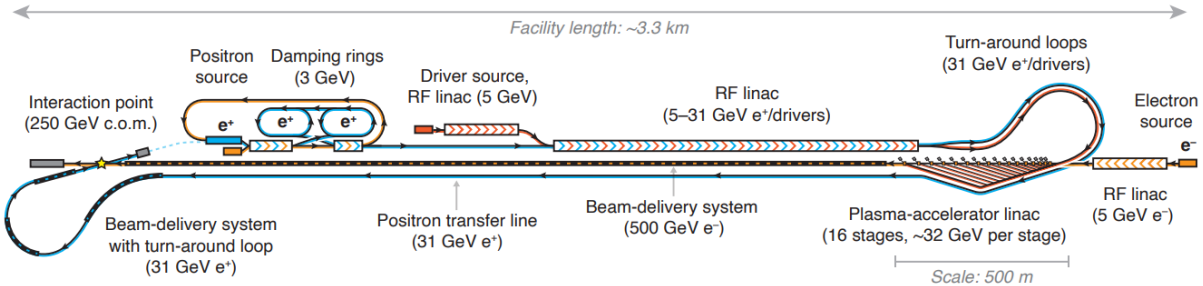
- **core software** (Chair + 1 member of IMCC task force)
- development of track reconstruction **algorithms** (synergies with key4hep, LUXE and DESY.Quantum)

Supported by EU INFRA-DEV grant **MuCol**

DESY will host **IMCC week in 2025**



HALFH concept

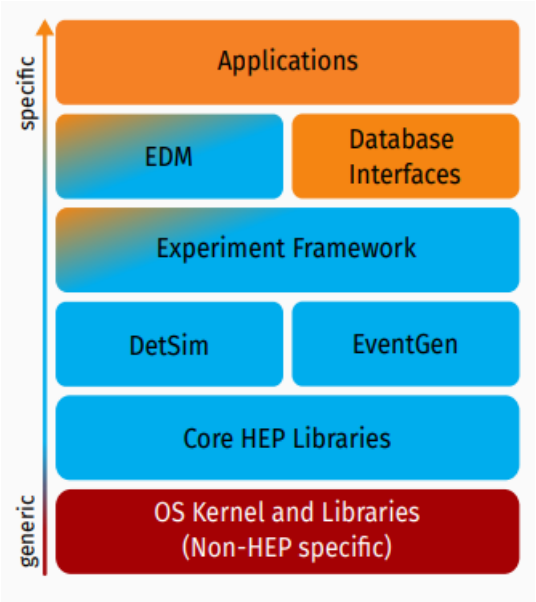


- Advanced novel acceleration concept: CA. Lindstroem/ RD Archy/ Brian Foster
- Based on plasma acceleration: significant R&D is needed
- DESY involved in accelerator design/ detector design/ physics impact

Tools for working at future colliders

Enabling work on the future

Central tools as a basis to enable studies at a range of collider options



Event data model

Event generation framework

Detector description language

Simulation framework
Fast ---------- Full

Full reconstruction software

Analysis algorithms

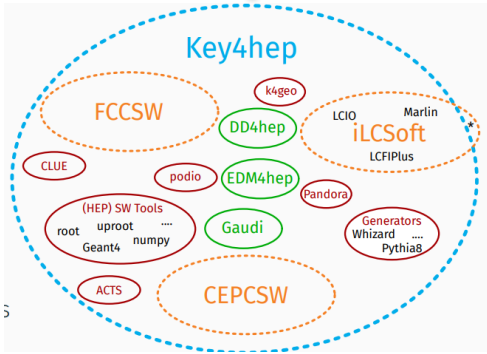
dd4hep – key4hep

Detector models

Generator software

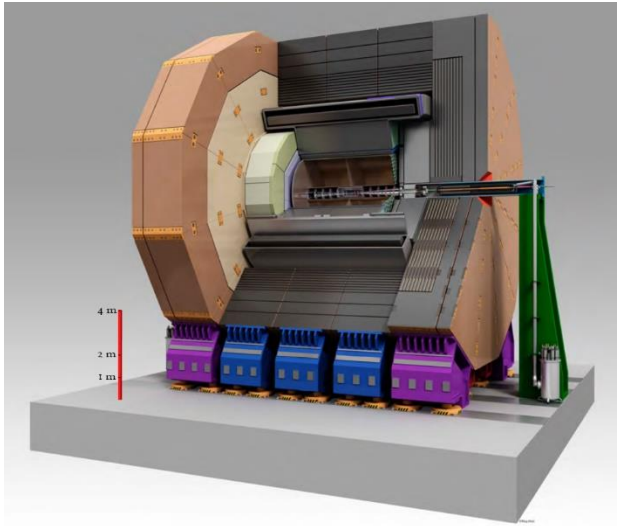
Reconstruction chains

Simulated data samples (full – DST)



Detector concepts as central integration platforms

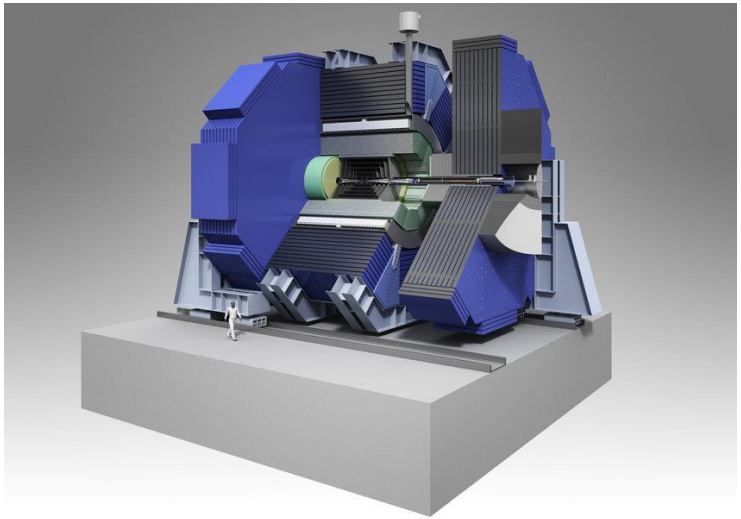
ILD and SiD as prototype detector concepts



ILD and SiD developed for the ILC

ILD in particular has a strong DESY participation

Have developed into variants:
CLIC DP
CLD@FCC-ee
CEPC Det



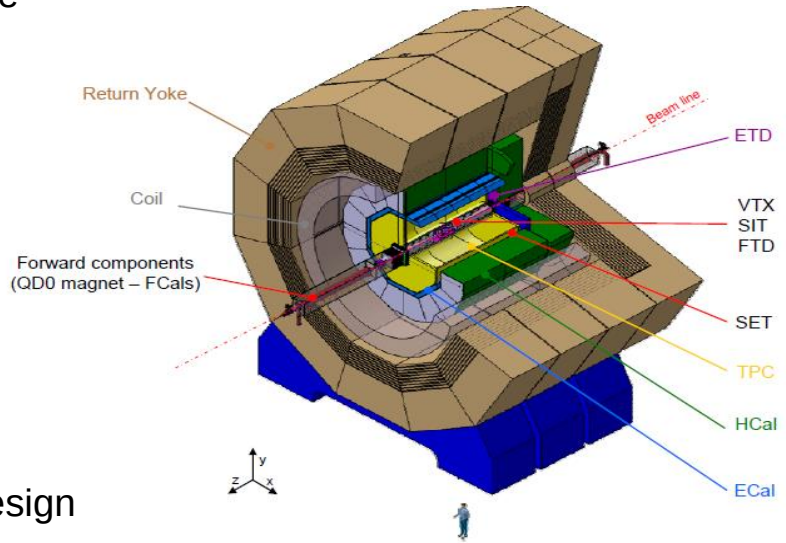
A Detector for a Future Collider

Requirement from Science

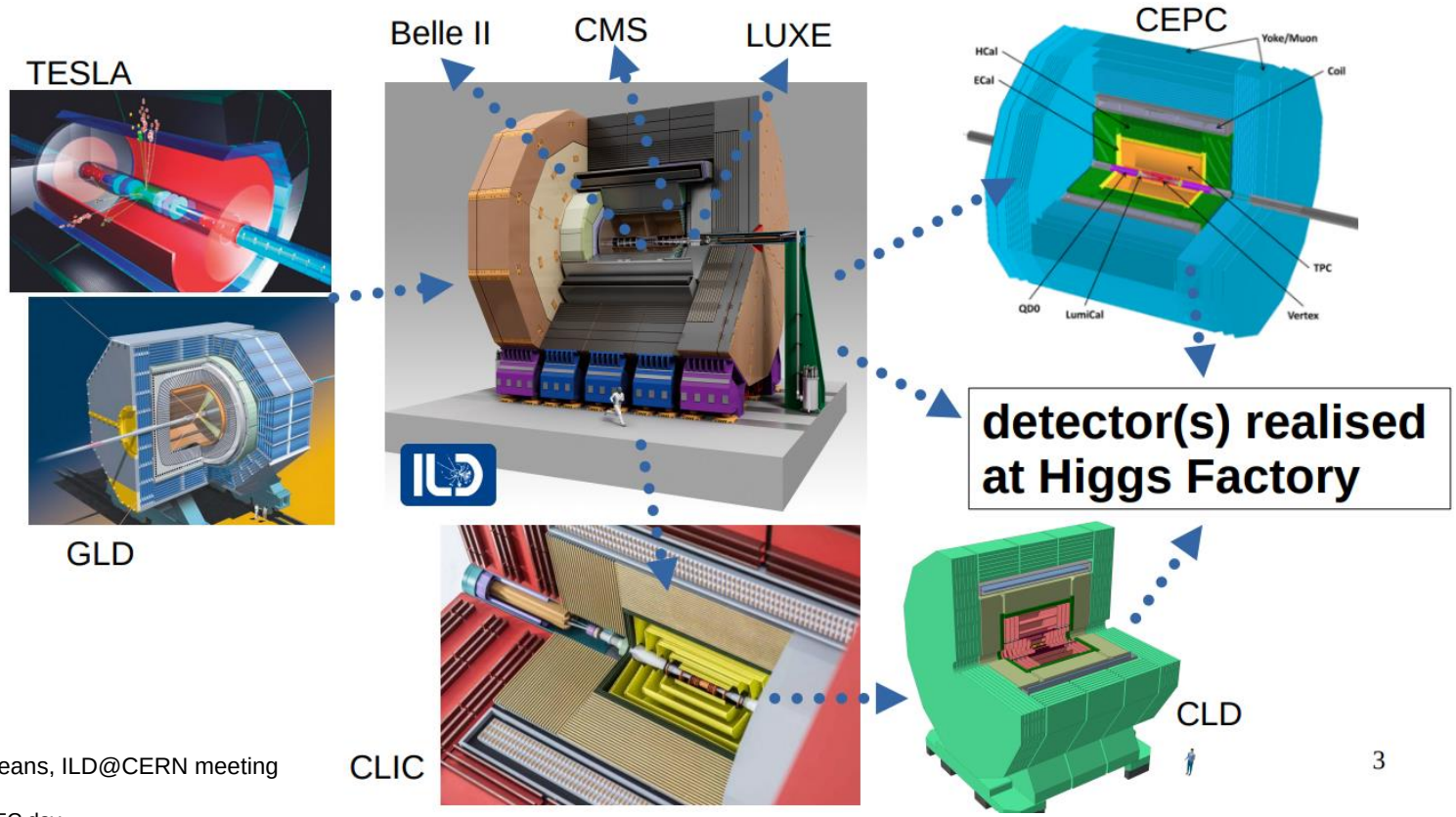
Find / develop technologies
to meet the requirements

Validate the technologies

Integrate technologies
into a coherent detector design



The ILD anchestry

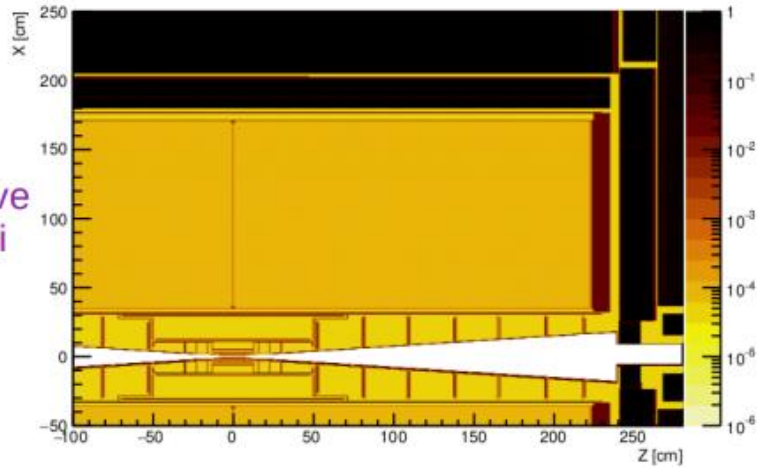


Slide from D.Jeans, ILD@CERN meeting

Expanding the scope

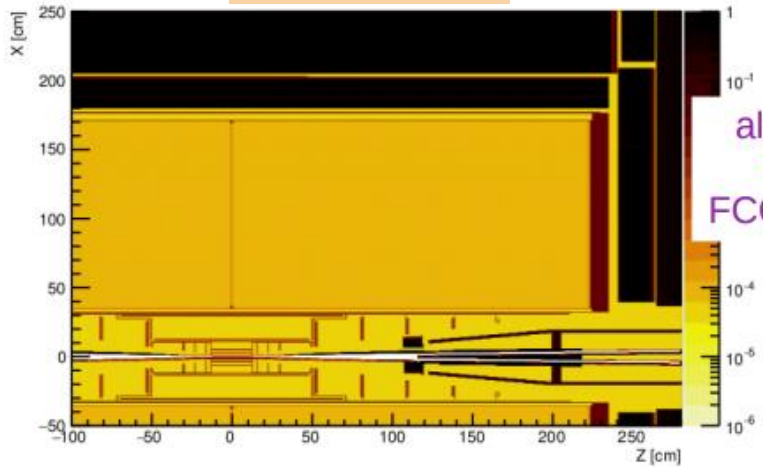
Exploring options: ILC and FCC-ee

ILD at ILC



alternative inner Si

ILD at FCC-ee



alt. inner Si & FCCee MDI

12

Future collider activities at DESY

- Broad range of activities at DESY
- Last years have seen a significant broadening of activities
- Most activities are small: few people, as sideprojects
- There is a lot of room for people to get involved at a “small” scale

HALHF