

# Research Unit *Experimental Particle Physics*

Experimental Particle Physics at DESY

Helmholtz Program: Matter and the Universe (MU)

PoF III Topic: Fundamental Particles and Forces

DESY Research Unit: Experimental Particle Physics

Beate Heinemann

Center Evaluation DESY, 5 – 9 February 2018

**HELMHOLTZ** RESEARCH FOR  
GRAND CHALLENGES

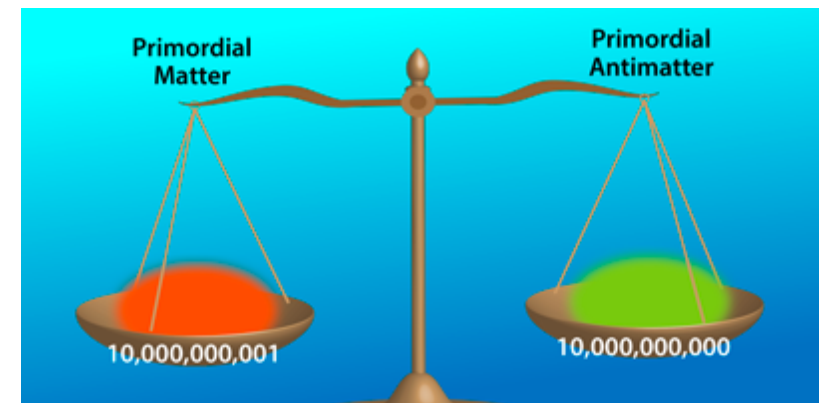
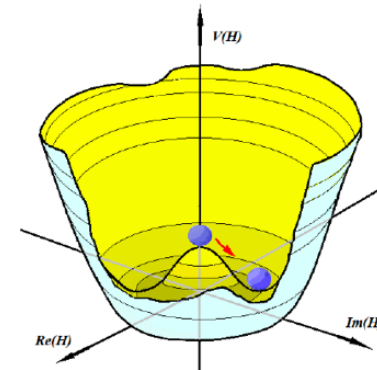


# Particle Physics Landscape

Open questions challenge the standard model

**The Standard Model is amazingly successful – but ...**

- What is the structure of the vacuum? Is there only one Higgs field? What stabilizes it?
- Is there new physics at the weak scale?
- What is dark matter and dark energy?
- What is the reason for the matter-antimatter asymmetry?



# Particle Physics Landscape

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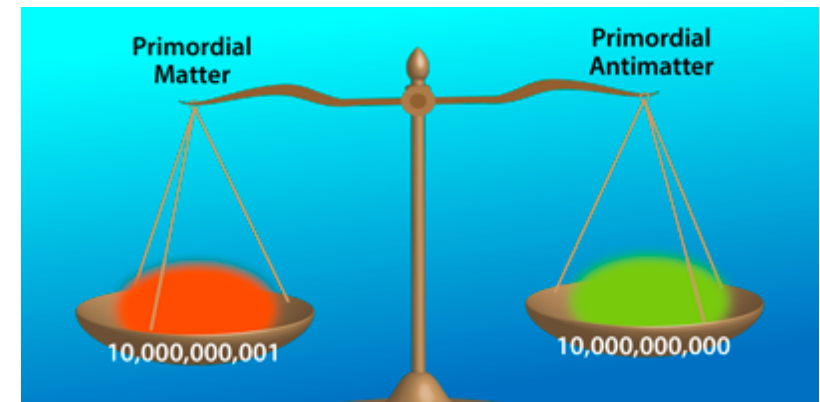
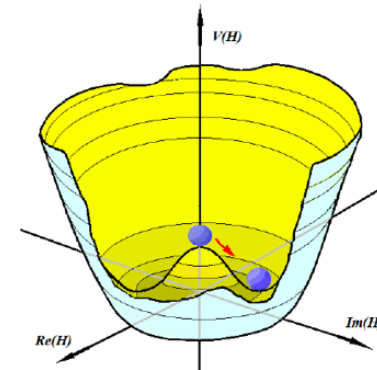
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→ Key science drivers of experimental particle physics

→ Two complementary ways to experimentally address these questions

- Precision measurements of known particles / processes
- Direct searches for new particles and phenomena

**Mandatory: Close interaction between experiment and theory**





# Particle Physics Experiments

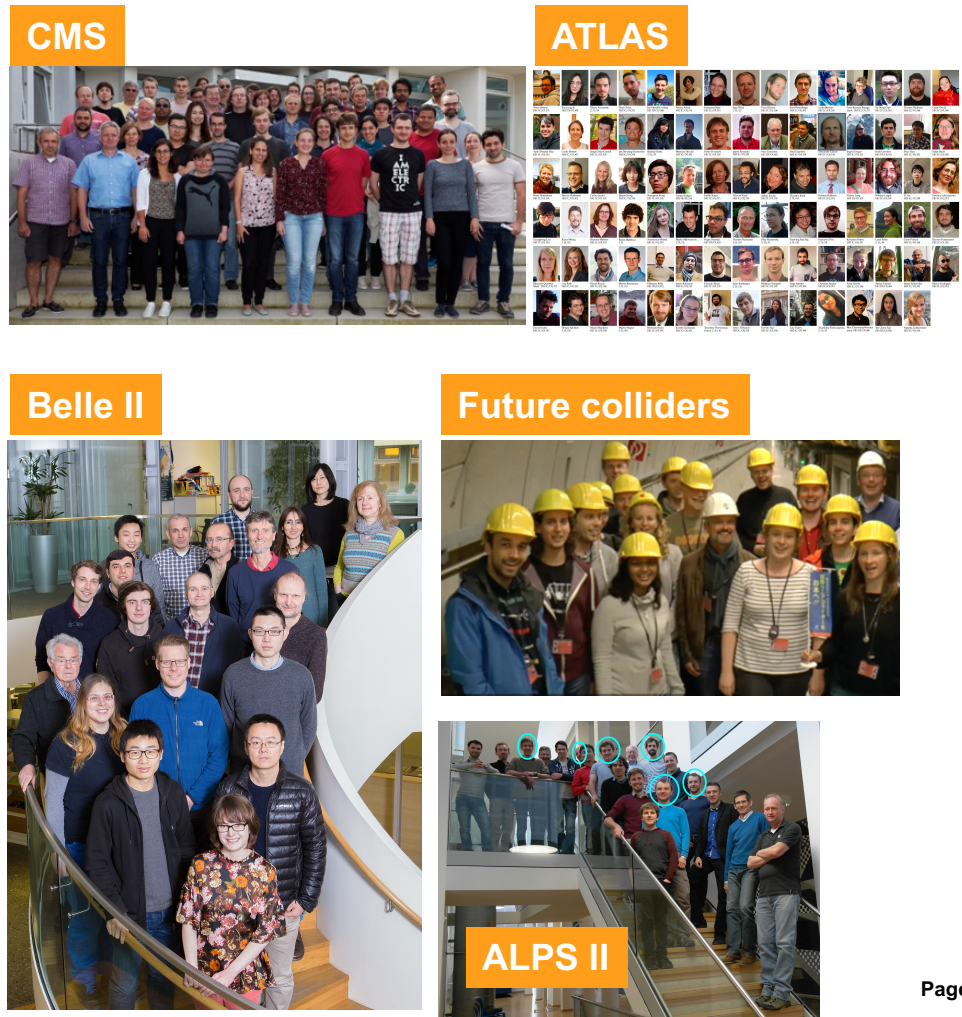
## Experiments with DESY engagement

**DESY is participating in several international experiments which address these questions**

- ATLAS and CMS at Large Hadron Collider (CERN)
  - Higgs boson & other precision measurements
  - Searches for new physics (e.g. dark matter)
- Belle II at SuperKEKB (KEK in Japan)
  - Precision measurements of B-mesons and taus
  - Searches for new physics
- Future colliders
  - E.g. ILC at  $\sqrt{s} = 250$  GeV in Japan?
  - Higgs factory (+some new physics searches)

## On-site experiments

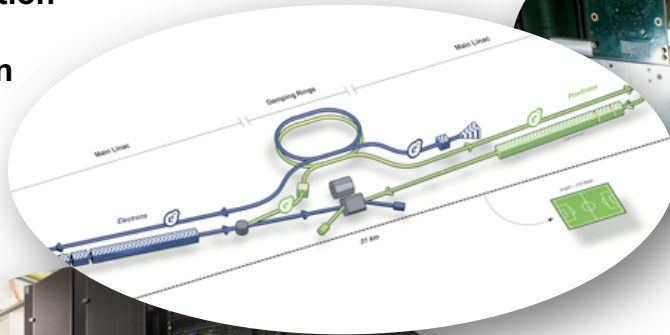
- HERA ep collider: 1992-2007
- OLYMPUS at DORIS in 2012
- Axions: ALPS I (2007-2010) and ALPS II (2020+)





# Experimental Particle Physics – Lifecycle Competence

Conception  
Design  
Decision



R&D

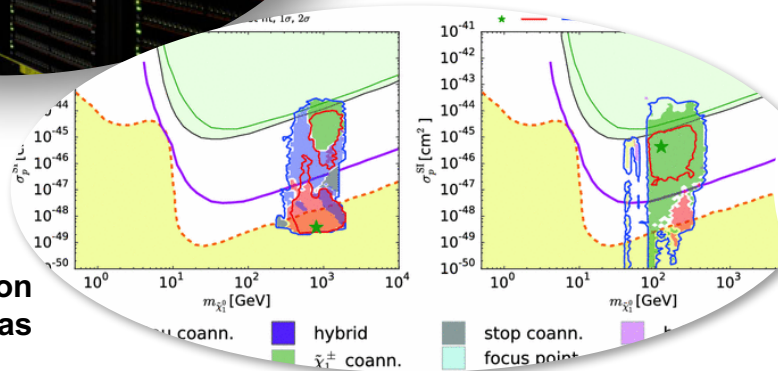


Construction  
Commissioning

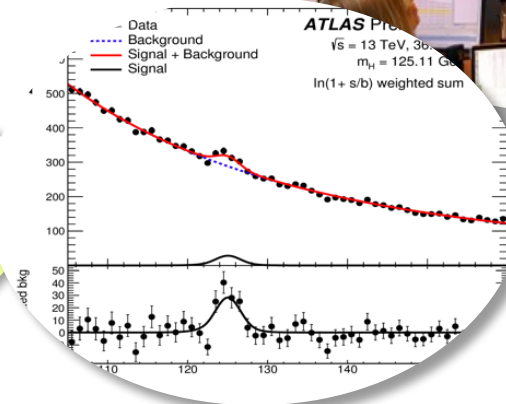


Data preservation  
Outreach into society

Interpretation  
New ideas



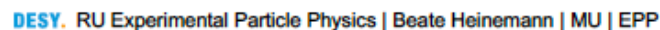
Operation



Physics analysis  
Analysis strategy

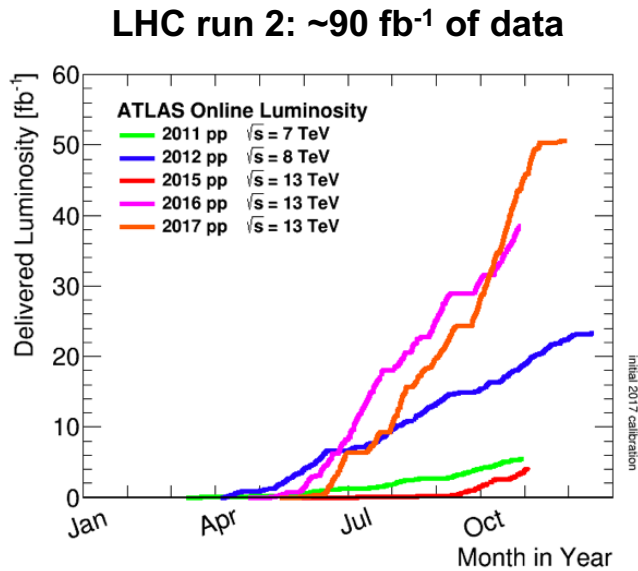
Each plot comes from a separate PhD thesis (50+ PhD thesis total)

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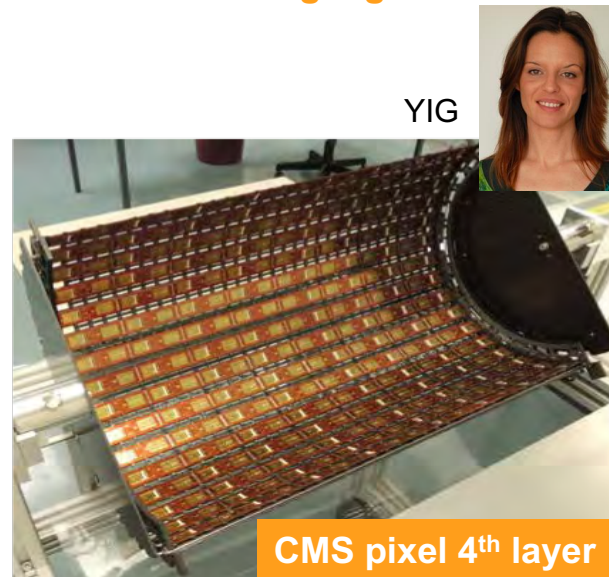
# Achievements during Review Period

Technical contributions to ATLAS and CMS: selected highlights

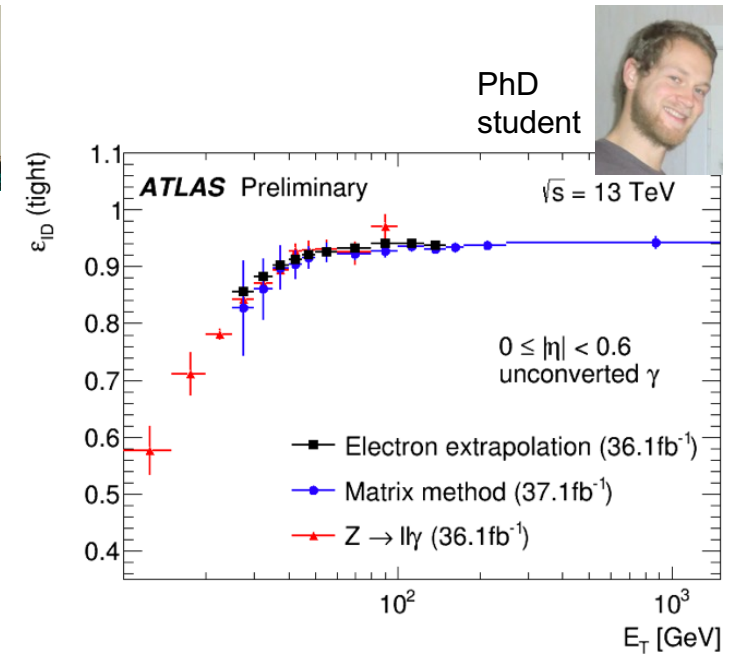


DESY contributions to **detector operation, data taking, ....**

Luminosity measurement



**Construction of 287 modules** for 4<sup>th</sup> layer of CMS pixel detector at DESY, installed in early 2017

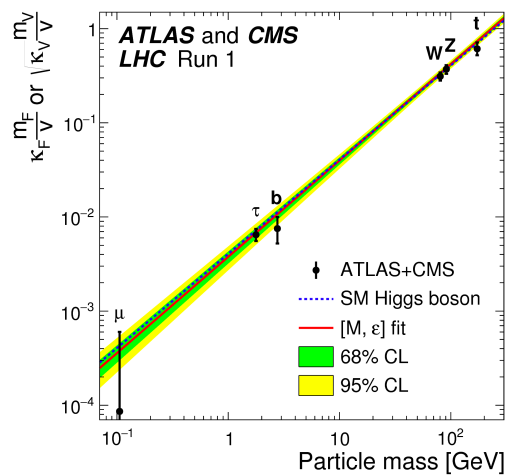


Many DESY contributions to **calibration, performance optimisation, and measurements**

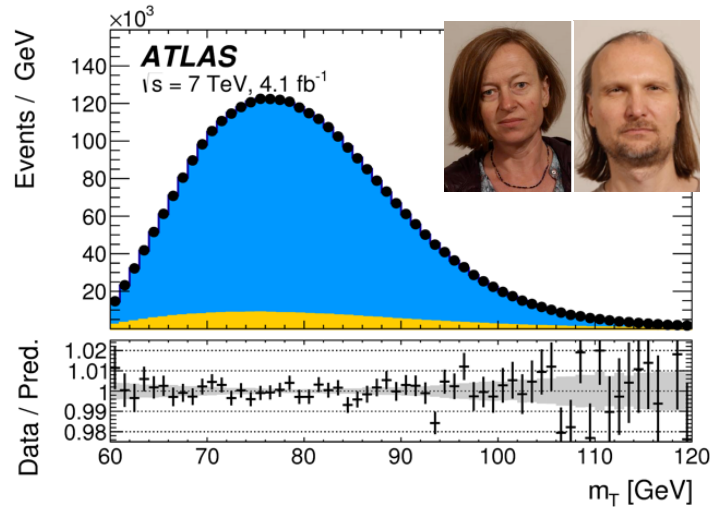
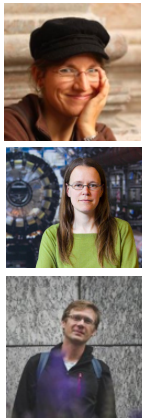


# Achievements during Review Period

## LHC measurements and searches with DESY contributions: selected highlights



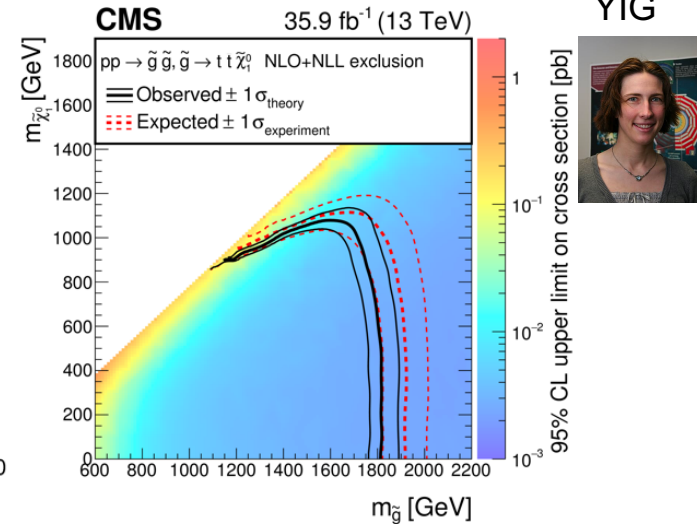
YIGs



### W mass determination at the LHC

$$m_W = 80370 \pm 19 \text{ MeV}$$

Major DESY contributions on modeling of W production.



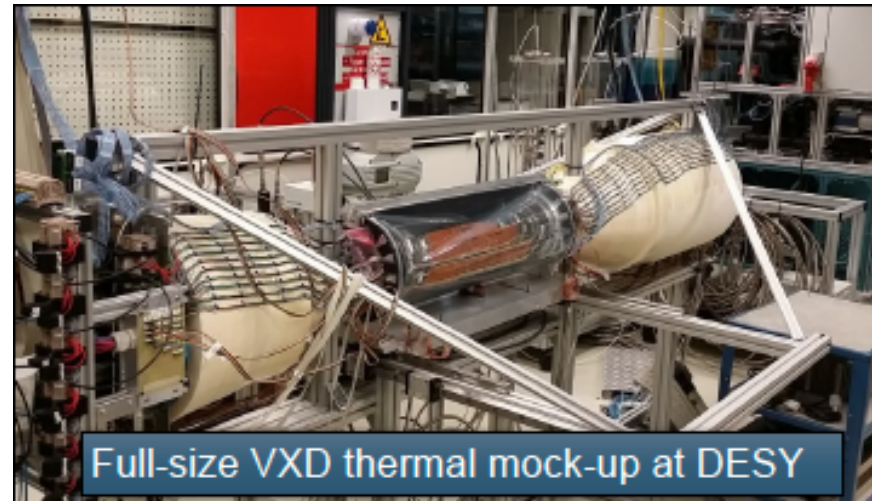
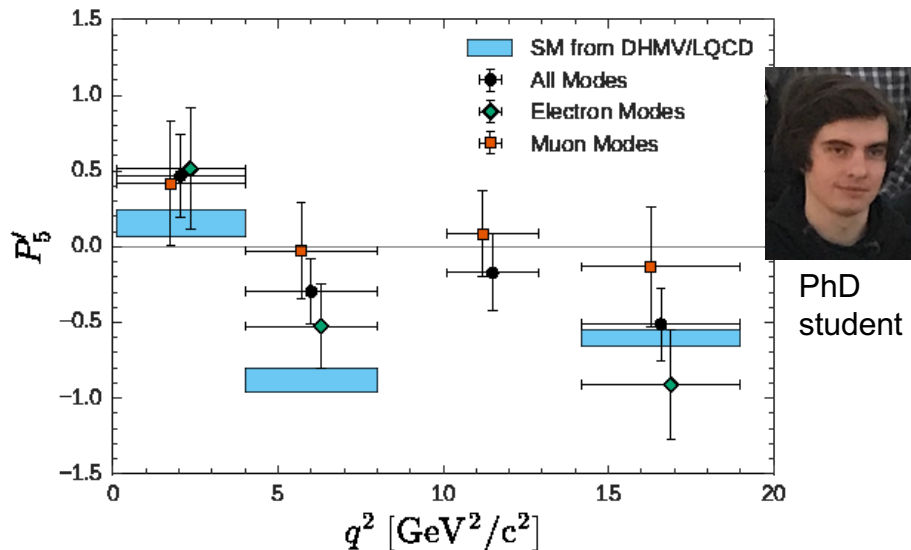
### Supersymmetry and dark matter searches

YIG



# Achievements during Review Period

## Precision and flavour physics with Belle / Belle II: selected highlights



### B->K\*II analysis

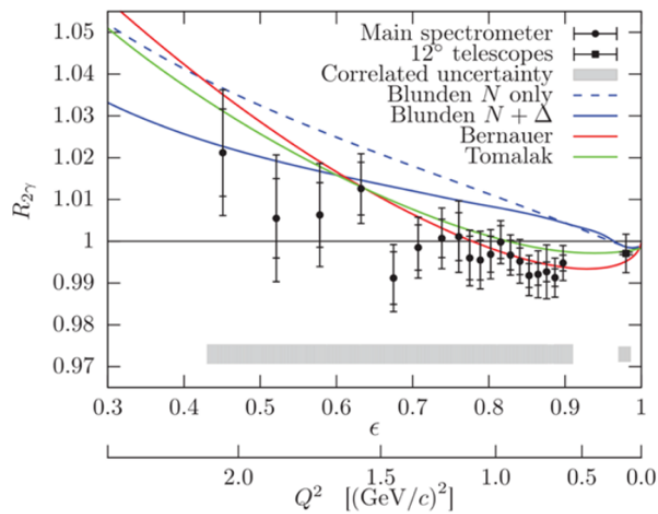
- Analysis motivated by anomaly seen by LHCb ( $3.4\sigma$ )
- Belle analysis also sees anomaly in muon channel ( $2.6\sigma$ ) → More data needed!

### Construction of Belle II detector

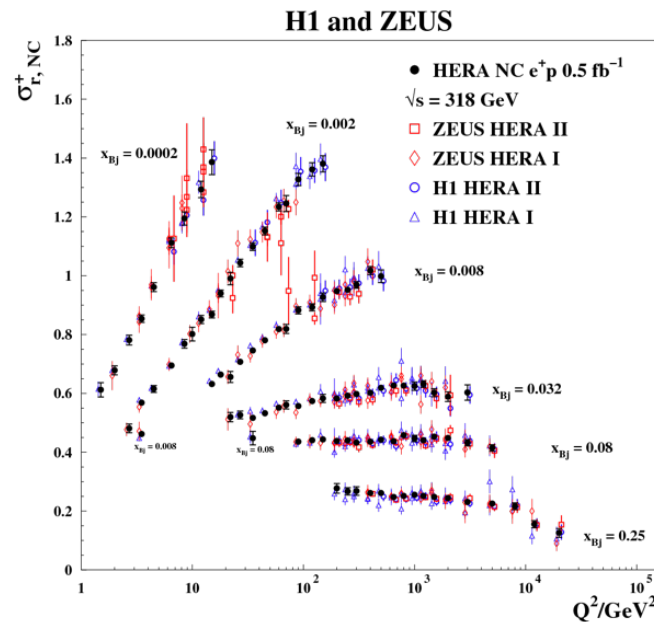
- Expect 50 times more lumi than Belle
- Vertex detector build in Germany; assembly and commissioning at DESY
- Machine-detector interface (e.g. remote vacuum connection)

# Achievements during Review Period

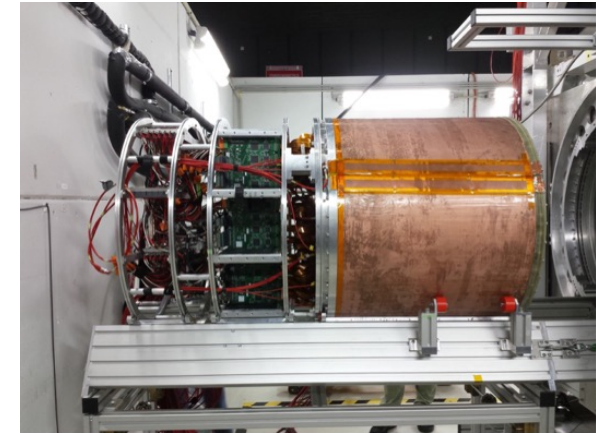
OLYMPUS, HERA, future colliders ILC: selected highlights



**Final analysis of data from OLYMPUS** experiment, shedding light on the two-photon exchange contribution to elastic electron-proton scattering.



**Final combination of HERA data**  
Critical input to determining parton distribution of proton



**ILC detector development and physics studies**, e.g.

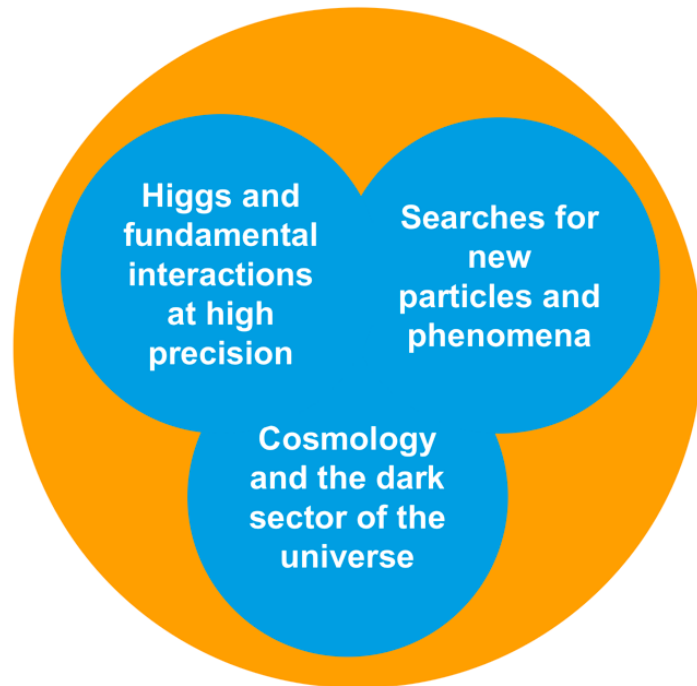
- TPC prototype
- Particle flow calorimetry (CALICE concept used for CMS HGCal upgrade)
- Physics studies for ILC



# Strategy for Experimental Particle Physics at DESY

Outcome of the “DESY-2030” strategy process: 2018-2030

## Science Drivers



## Explore the LHC and beyond

- Upgrade ATLAS and CMS for HL-LHC
- Prepare leading participation at a future global collider project

## Harvest at Belle II

- Data taking and analysis until ~2027

## On-site experiment

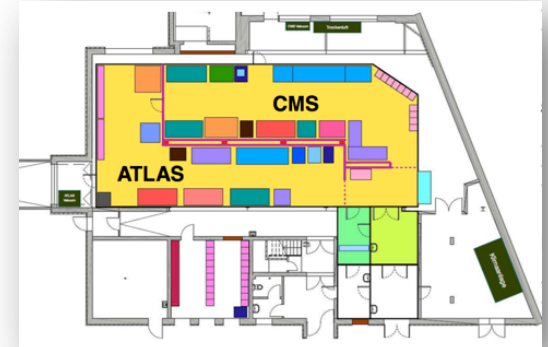
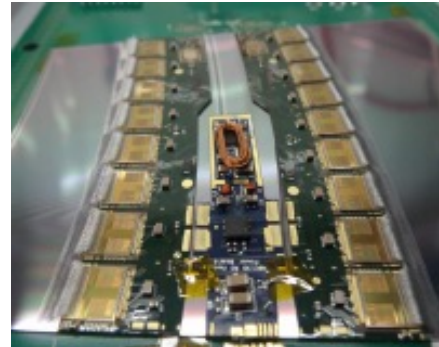
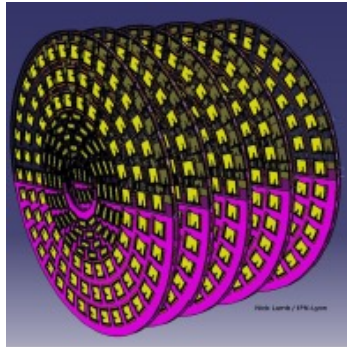
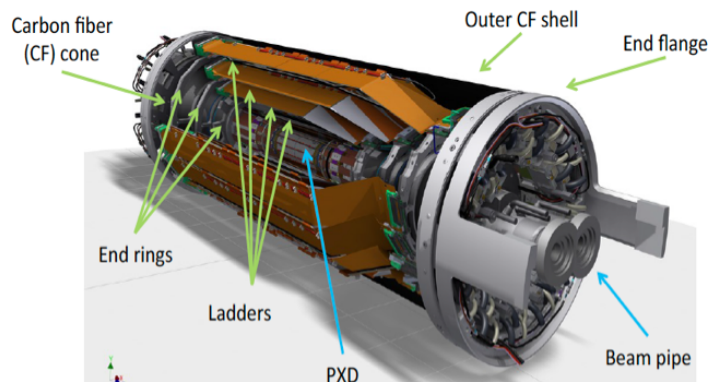
- Prepare a future on-site experiments after ALPS-II
- Detector R&D & testbeam operation

## DESY as a “hub”:

- Support projects with large German participation

# Future Plans: Belle II and LHC

## Construction of vertex and tracking detectors & data exploitation phase



### Belle II: 2019-2027

- Assembly and commissioning of vertex detector at DESY during 2018
- Physics analyses:
  - excl. ( $K^*\text{II}$ ) and incl. ( $X_u\text{II}$ ) B-decays, dark sector, tau decays (LFV, LNV), ...

### CMS and ATLAS: upgrade LHC to collect 3000 fb<sup>-1</sup> by 2035

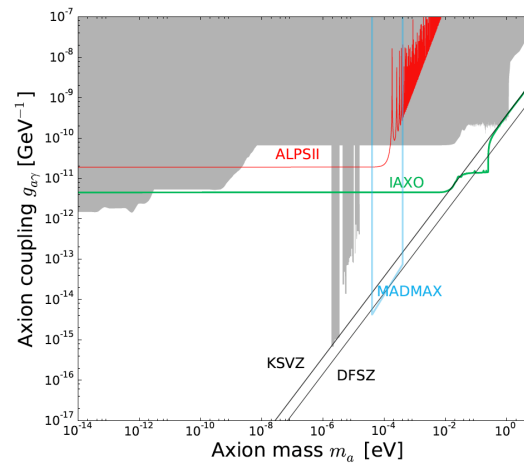
- Construction of new ATLAS & CMS tracker endcaps (now – 2025)
  - All components built at German institutes (universities & DESY)
  - Integration of full endcap at DESY in new detector assembly facility (DAF)
- Operation, calibration, alignment of current detectors and physics analyses:
  - Precision Higgs and SM physics
  - Searches for new physics (particularly dark matter)

# Future Plans: On-Site Experiments



## ALPS II

- Search for axion-like particles coupling to photons (dark matter candidate)
- Use 20 HERA magnets
- Data taking 2020+

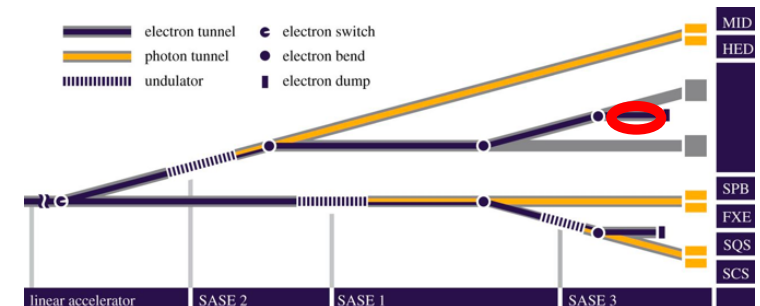


## MADMAX and/or IAXO

- Two other approaches for axion searches
- IAXO: axions from sun
- MADMAX: axions from DM halo

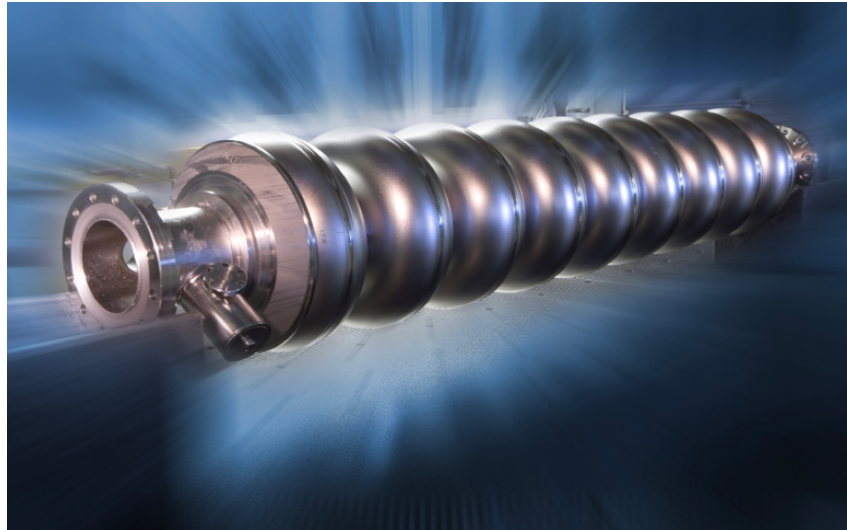
## LUXE

- Explore strong-field QED using XFEL electron beam + laser
- Feasibility study ongoing





# Future Plans: Future Colliders



## **ILC based on cavities as built for XFEL**

- Under consideration as global project hosted in Japan
- Strong effort in detector R&D for e+e- colliders (ILC or others)

**Engaged in physics studies to evaluate scientific potential**

**Engaged in decision processes on future priorities (e.g. European Strategy)**

## Conclusions

**Experimental particle physics at DESY has been very successful; we have been a pivotal contributor to international projects**

**We have the expertise and critical mass to make a difference and to shape the present and the future of the field, together with international partners**

**Many interesting activities are planned for the future, including major on-site detector construction with German universities and international partners**

# Backup

# Some Numbers

Core-funded plus third-party-funded scientists (FTE) without Ph.D. students

Core-financed costs (2016): 21.118 MEUR

Third-party funding (2016): 2.288 MEUR

