Future Experiments

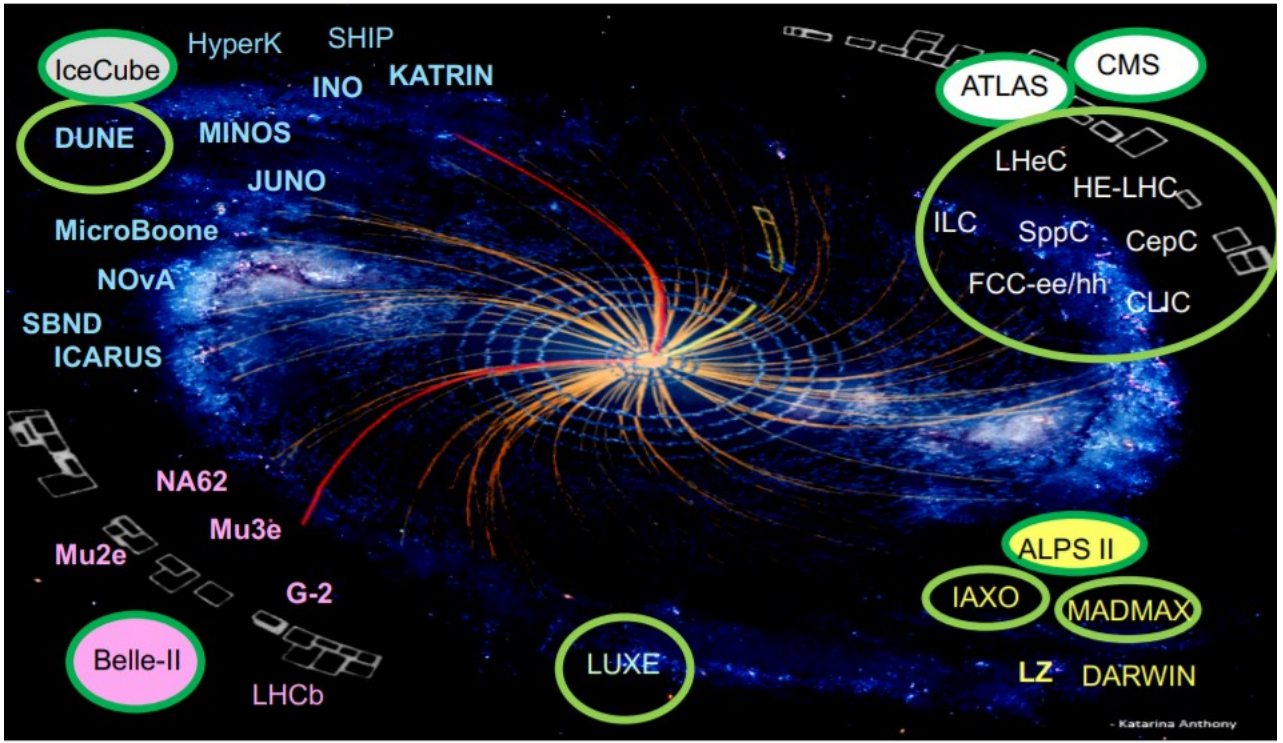
Looking beyond the LHC

Ties Behnke, FLC

The “HEP” world

Neutrino Frontier

Energy Frontier



Intensity Frontier

Cosmic Frontier

Picture shown by Beate in the DESY 2030 process

The (collider) future of our field

LHC (HL-LHC) will remain the key collider for the near future

Scientifically:

- Exploitation of the Higgs as a portal to new physics is a central task
- Exploit the top as a window of opportunity for new physics
- Search for the unexpected (discovery reach is significant and complementary to the LHC)

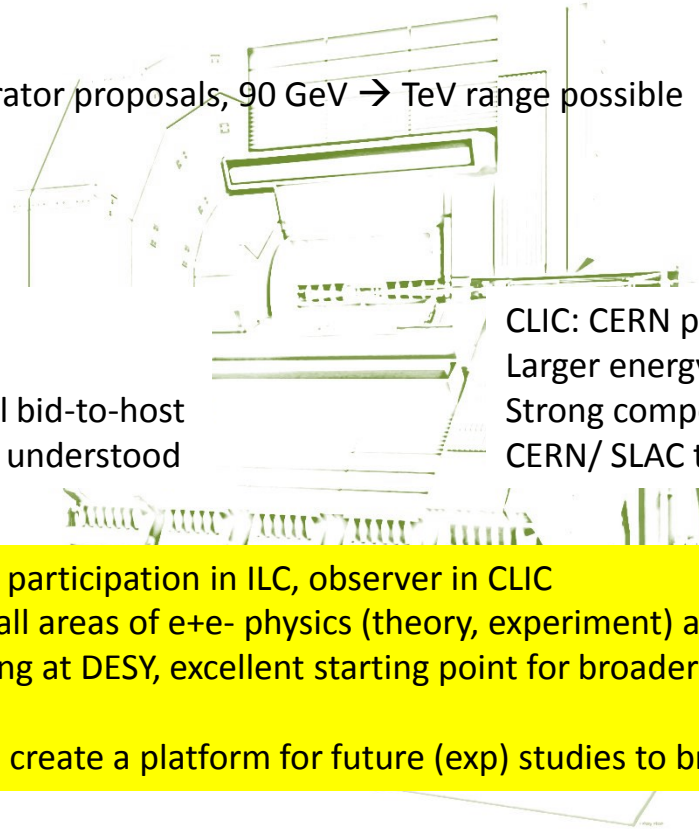
Hadron Colliders

- HL-LHC
- HE-LHC?
- FCC-HH?

Lepton Colliders

- ILC?
- CLIC?
- FCC-ee?
- CEPC?
- Muon Collider??

ILC/ CLIC: Status and Prospects



- ILC/ CLIC: two linear accelerator proposals, 90 GeV → TeV range possible
- First phase: Higgs factory
  - 250 GeV ILC
  - 380 GeV CLIC

ILC: strong push in Japan
Political support
But not enough (yet) for a formal bid-to-host
"DESY" technology, mature, well understood

CLIC: CERN project
Larger energy reach than ILC
Strong competition at CERN from FCC
CERN/ SLAC technolgy, demonstrator missing

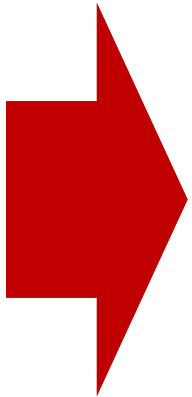
Long standing DESY participation in ILC, observer in CLIC
Large expertise for all areas of e+e- physics (theory, experiment) available locally
ILC community strong at DESY, excellent starting point for broader studies

Within DESY should create a platform for future (exp) studies to bring together all expertise

Future Detectors

Our competence:

- LHC upgrade (DAF): Silicon detector (mostly strip)
- ILC detectors
  - Concepts
  - Particle flow calorimeters
  - Gaseous tracking
  - Software
- BELLE
  - Pixel vertex detector
  - Integration



Broad expertise

Apply to future projects which are on the table

Partipate in the definition and shaping of future projects

Contribute centrally to the definition of experiments at future projects

Common effort of the Helmholtz Programms Matter and the Universe and Matter and Technologies
Significant community at DESY on detector development

Non-Collider Accelerator Based

Opportunities beyond the LHC and Belle:

- Collider projects: uncertain future and time-line
- Experiments in non-collider projects
    - In-house experiments (LUXE)
    - Neutrino Experiments
    - Others? Fixed target experiments?

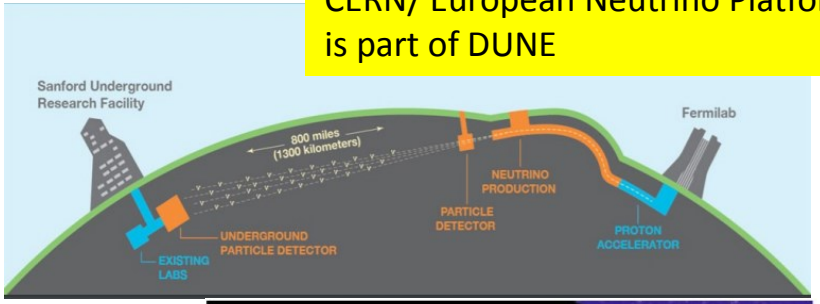
Non-Collider Physics

Neutrino physics:

- Precise measurement of ν_e appearance
- Precise meas. of ν_μ disappearance
- Measure CP symmetry, contribution to mass hierarchy determination
- Neutrino interaction cross section measurement
- …

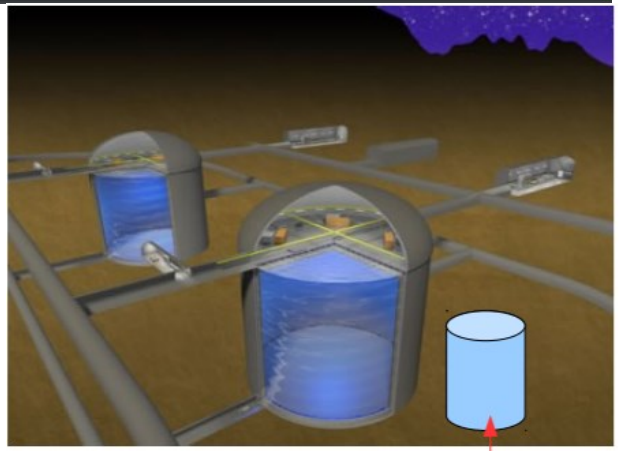
CERN/ European Neutrino Platform is part of DUNE

Dune



lAr TPC

Water Cerenkov



Hyper-Kamiokande (Japan)

Comparison with LBNF/DUNE

	Energy	Protons per pulse	Rep. period	Power	Operation time /year	Off-axis	Peak energy
J-PARC	30 GeV	3.2×10^{14}	1.16sec	1.3MW	1×10^{7} sec	2.5deg.	0.6GeV
LBNF	120GeV	7.5×10^{13}	1.2sec	1.2MW	1.8×10^{7} sec	0deg.	2-3 GeV

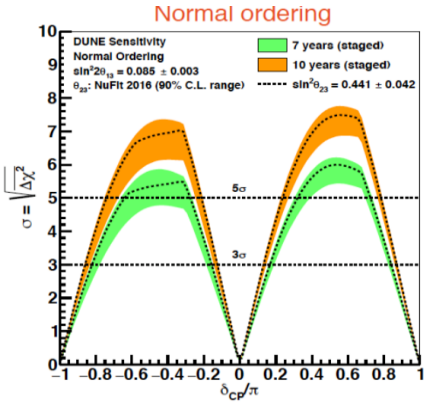
	Baseline length	Far det. fiducial	nue events / year	nuebar events / year
HK	295km	187kton	657	157
DUNE	1300km	40kton	300	54

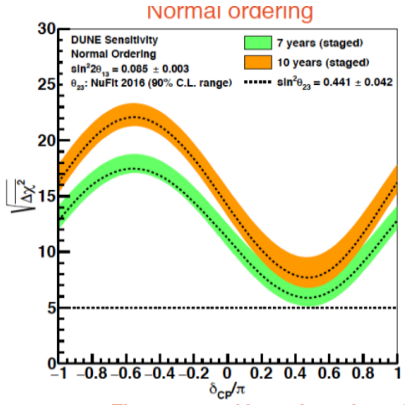
(assuming normal ordering)

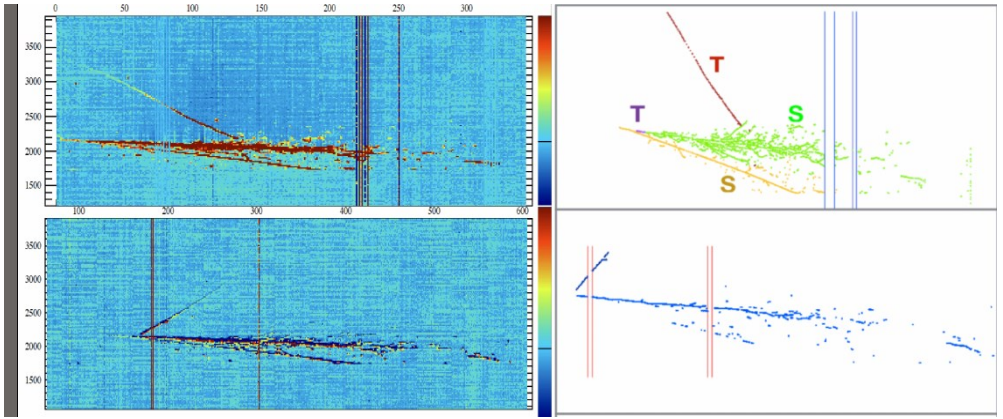
Assuming maximal CP violation phase

DUNE Physics Program

- Neutrinos have been a source of surprises since two decades
  - Clear evidence for BSM physics
- Neutrino Oscillations
  - Search for leptonic CP violation
  - Determine neutrino mass hierarchy
  - Precision PMNS mixing matrix measurements
- Supernova Physics
- Proton decay
- Liquid Argon TPC Technology to maximize sensitivity







The DUNE Near Detector

A LAr TPC

- Measure reactions on Ar (mostly inclusive)
- Constrain detector effects

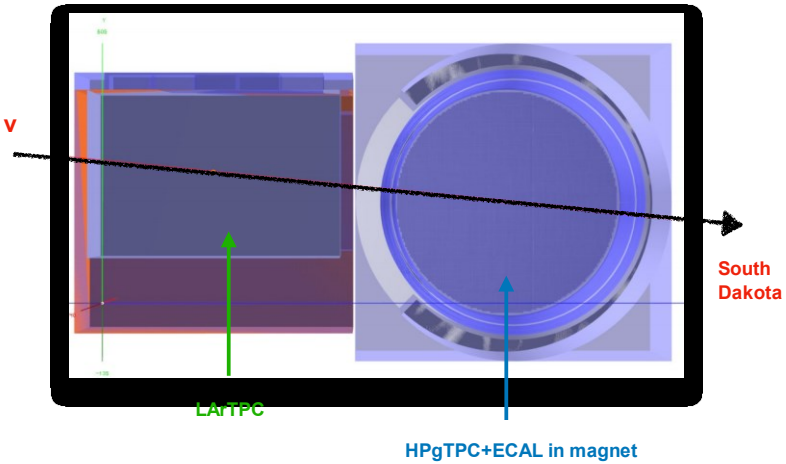
A capable Multi-Purpose Detector (MPD)

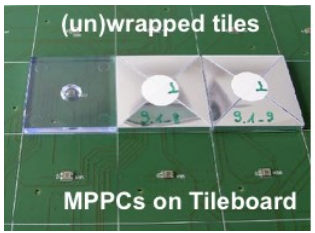
- Measure neutrino flux
- As many different differential X-sections as possible
- Sensitive to pions, protons, neutrons, electrons, photons

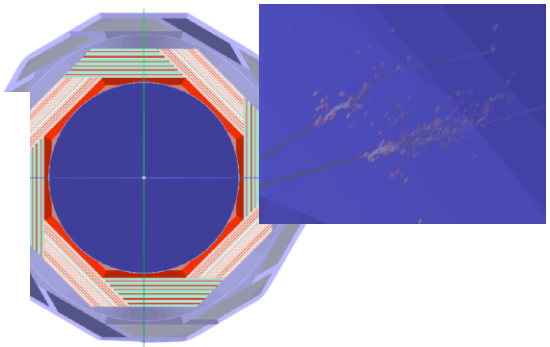
Highly Granular ECAL surrounding HPgTPC

- Granularity for electron and π0 ID
- Cu / Fe absorber, SiPM+Scintillator read-out
- Using of DESY expertise and infrastructure from LC R&D and CMS upgrade
- First conceptual simulation studies done

- Cooperation with German Universities?







Local vs Global

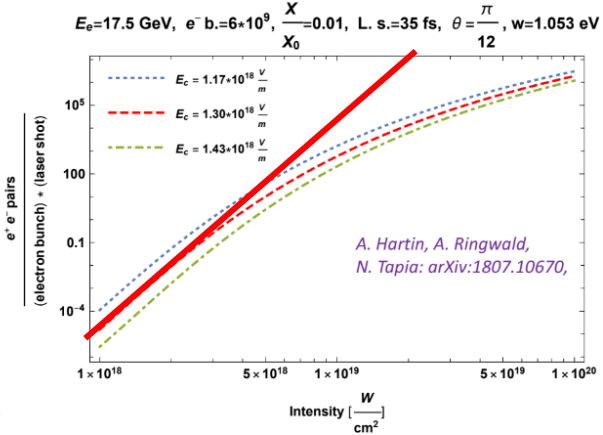
Vibrant on-site program is important

- Well established: ALPS (see Andreas' presentation)
- Proposal stage: LUXE
- Dicusssion state: IAXO/ Baby-IAXO (see Andreas' presentation)

Test beam and detector development are part of the on-site program and are central for our field and division.

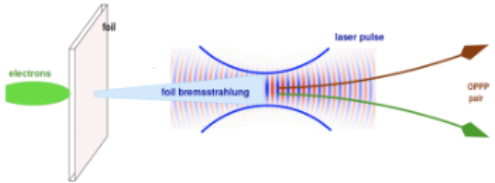
LUXE@XFEL

An experiment to test non-perturbative QED up to the Schwinger Limit:



LASER AND PHOTON BEAM

- Use Laser to generate electric field
- Use high energy electron beam to create high-energy photons



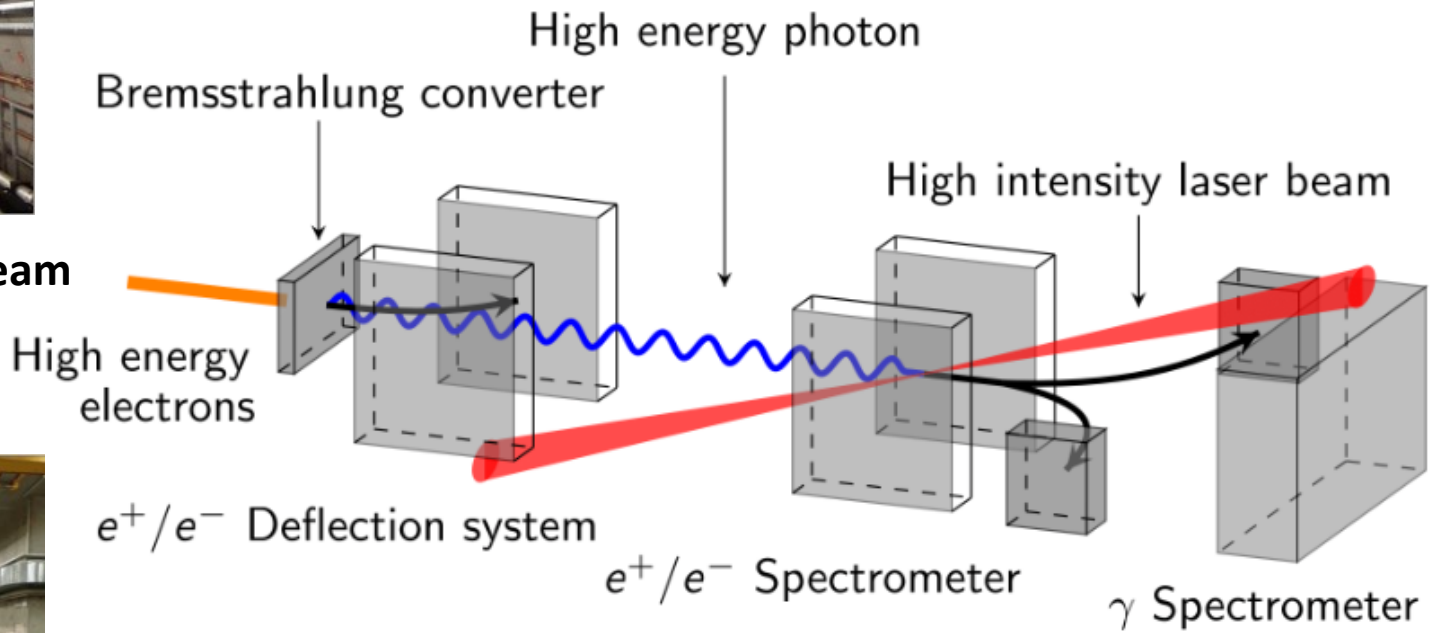
$$\xi = \frac{eE_L}{m_e\omega_L c} \qquad \chi \approx \gamma\frac{\varepsilon}{\varepsilon_S} \propto \gamma\sqrt{E_L}$$

- Laser power required to reach Schwinger field ($\chi_\gamma \sim 1$):
  - Non-relativistic photons: I=2x10^{29} W/cm^2 => Much beyond currently achievable values
  - EU.XFEL, $E_\gamma \approx$10 GeV: I≳10^{20} W/cm^2 => Can use well-tested laser technology
  - ELI-NP, $E_\gamma \approx$GeV: I≳10^{22} W/cm^2 => State-of-the-art laser needed

Beate Heinemann et.al.

LUXE@XFEL Conceptual Design

XFEL beam



LUXE

Feasibility study has started
Funding currently from the DESY Strategy Fund
Proposal will be presented to XFEL SAC

Preliminary timeline:

- **Summer 2019:**
  - Determine feasibility, work plan and possible time scales for the two locations in XFEL tunnel
- **November 2019**
  - Application for ERC synergy grant (synergies of laser, particle physics and accelerator physics)
  - Obtain letter of support by management and council of EU.XFEL
- **Nov/Dec 2020**
  - Start of installation (?): May extend over two shutdowns (should know in summer 2019)
- **2021-2022 or 2022-2023: prototype experiment (stage-0)**
  - About 2-3 weeks per year likely sufficient but would try to take as much data as possible
- **2023/2024:**
  - Install more powerful laser
  - Publish results of phase-0 experiment
- **2025-2027: Data taking with high-power laser (stage-1)**
  - Interesting to run at different energies, currents,… configurations
  - Plan to benefit from requirements of other experiments

Current group small

Collaboration is forming

Outlook

- DESY remains a strong player defining the future of our field
- We have the capacity and the capabilities for central contributions for future projects like ILC, CLIC, FCC-ee, etc.
- A strong on-site program is taking shape.