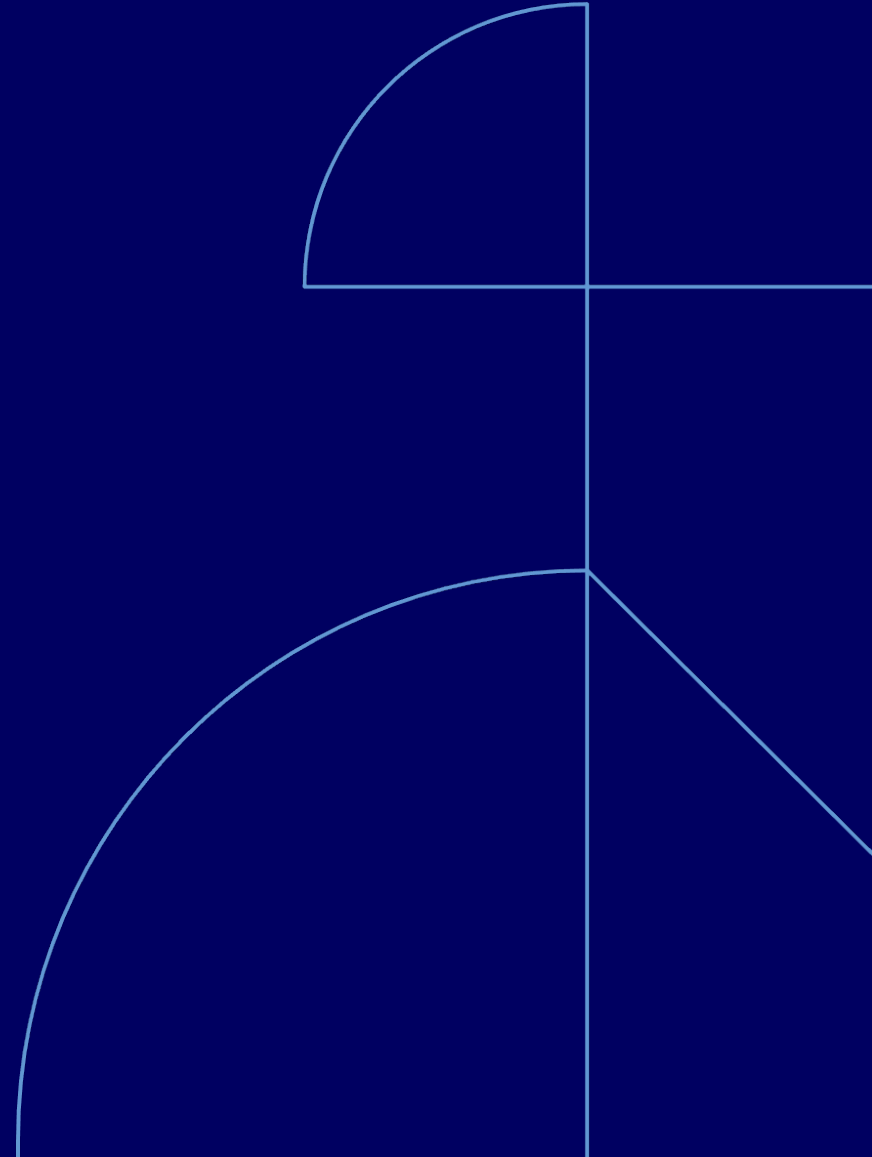




Summary of future collider activities in the Nordics

Magdalena Vande Voorde
Young Nordic Future-Collider day
14th of May 2024



Future collider work in Denmark, Sweden, Norway and Finland

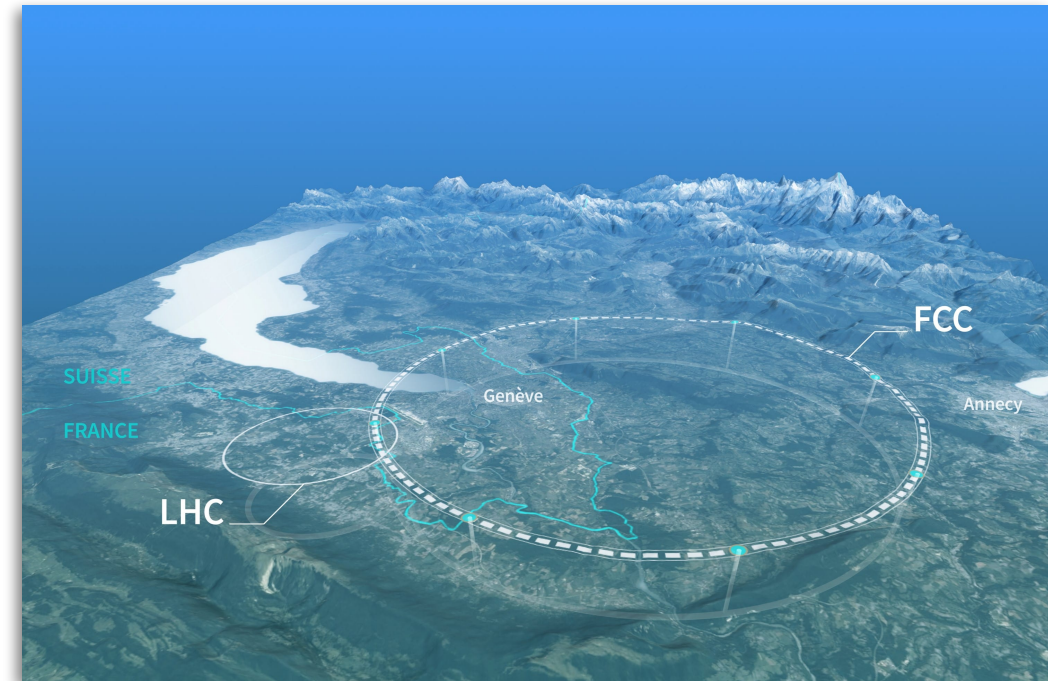
- We in the Nordics are involved in several future collider projects!
 - Circular colliders - FCC
 - Linear colliders - CLIC, ILC
 - Novel accelerators - muon collider and plasma accelerators
 - Other future colliders - EIC
- In a range of topics
 - Accelerator development
 - Detector development
 - Theoretical/phenomenological studies
 - Experimental physics studies



FCC - Future Circular Collider

Physics studies and detector design

- **Mogens Dam (Niels Bohr Institute)** engaged in the FCC-ee developments since very early stages
- Co-convener of the Detector Concept Working Group of the Feasibility Study since 2016, working with the detector design for FCC-ee
- Key involvements for the design of the luminosity measurements
 - Aim to measure the absolute luminosity with a precision of 10^{-4}
 - **Master student Johanna.** working on the full simulation of the luminosity monitors
- Pioneering work for tau measurements at FCC-ee
 - Precise measurement of the tau properties can rigidly test lepton universality
 - **Master student Jonathan** working on tau lifetime measurements





- Extensive studies of long-lived particles (LLPs) at FCC-ee led by **Rebeca Gonzalez Suarez (Uppsala University)**
 - FCC-ee can be utilized for direct BSM searches!
 - Currently the BSM co-convener for the FCC-ee Feasibility study as well as the BSM co-convener in the ECFA Higgs/Top/EW Factories study
 - **Postdoc Giulia Ripellino, PhD student Axel Gallén** and me are finalizing a sensitivity study of exotic Higgs decays to LLPs at FCC-ee, paper soon
- Calorimeter design studies of the noble liquid calorimetry for ALLEGRO (A Lepton-Lepton collider Experiment with Granular Read-Out) by a Finnish CERN Fellow in the EP-R&D department, **Juska Pekkanen**
 - Similar to ATLAS ECAL detector, aim to have at least an order of magnitude higher granularity than in ATLAS
 - Main focus on the development of the readout electrode, vital component for achieving the very high granularity

References:

- arXiv:2401.07564
- arXiv:2209.13128
- arXiv:2203.08039
- arXiv:2203.06520
- arXiv:2203.05502
- arXiv:2106.15459

References:

- CERN EP-R&D annual report
- Presentation at 2nd ECFA WS
- Presentation at the 7th FCC Physics WS



- Snowmass contribution on event generators for High-Energy Physics Experiments by **Lund University**
- Input to CERN proceeding related to parton radiation and fragmentation from LHC to FCC-ee by **Christian Bierlich and Torbjörn Sjöstrand (Lund University)**
- Cryomodule development by **ESS in Sweden, led by Paolo Pierini**
 - Assembly and testing of FCC-ee Cryo Modules in the Superconducting Radio Frequency facility
- Simulation studies of thin film growth on superconducting cavities under different deposition conditions by **Finnish material physicists**



References:

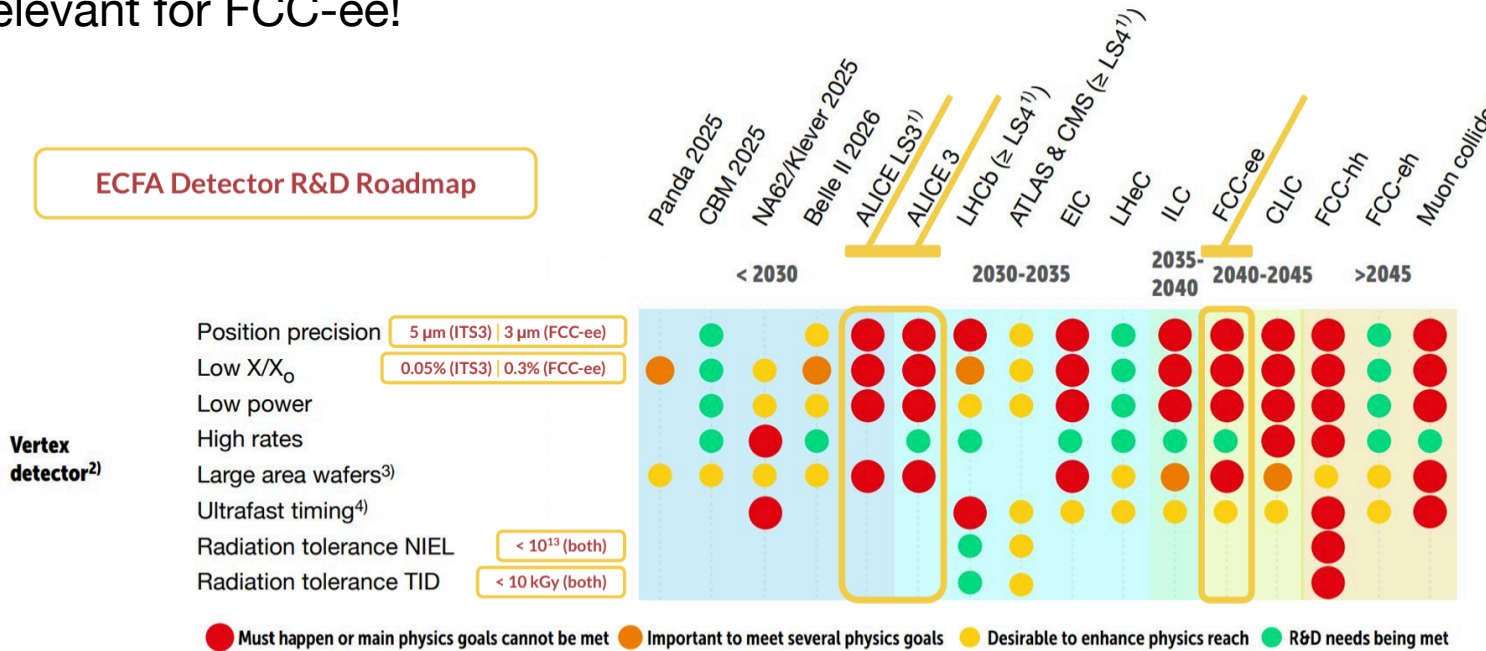
- Snowmass review
- Cern proceeding

FCC - possible future contributions

Detector and accelerator development



- The current main detector development activity from the ALICE group in Lund are on the ALICE Si-tracking upgrades for ALICE 3, called ITS3
- The vertex detector requirements of ITS3 and FCC-ee are similar → work on ITS3 and ALICE3 are very relevant for FCC-ee!



References:

- ALICE ITS3 TDR
- Figure: talk at 7th FCC Physics WS by K. Gunal
- Original table: ECFA Detector R&D Roadmap

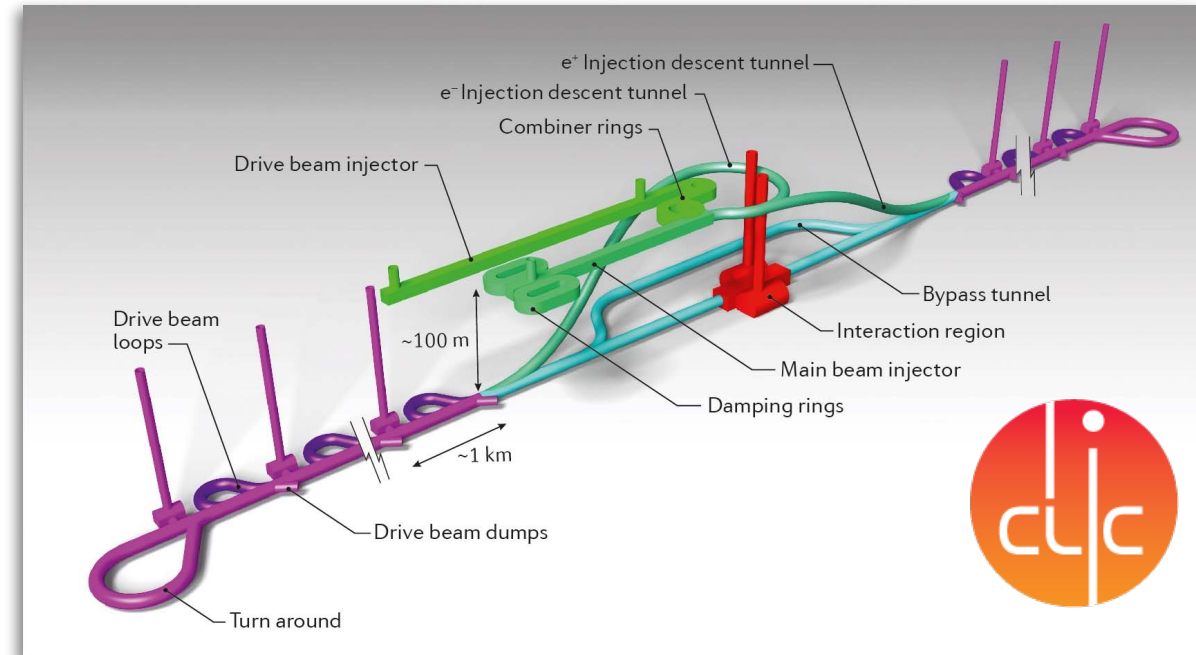
- The FREIA lab at Uppsala University, with capabilities for R&D on superconducting accelerator technology, are keen to start working with FCC!

CLIC - Compact Linear Collider

Accelerator development

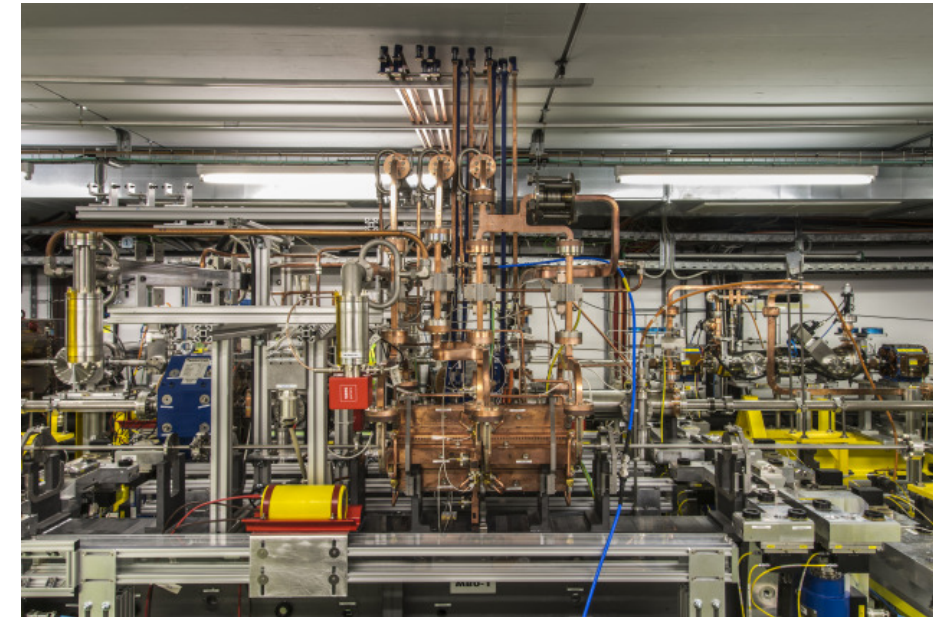


- Over 10 years involvement from the **Finnish community**
- Major work from **Kenneth Österberg** and the group at **Helsinki University** includes
 - Detailed physics model of the mechanism of vacuum arc in CLIC RF cavities
 - Mechanical modelling, assembly and prototyping of the full CLIC module
 - Micromechanical manufacturing and assembly of CLIC RF cavities
- Also, long standing contributions from **Norway** with **Steinar Stapnes**, who is the CLIC project leader at CERN, and **Erik Adli** and **Kyrre Ness Sjøbæk**
 - Recently, main contribution in experimental and theoretical work on the wakefield monitors





- Work from **Uppsala University**, led by **Marek Jacewicz** and **Maja Olvegård**
 - Contributed to the CLIC feasibility study with development of the two-beam test stand, part of the CLIC Test Facility 3 (CTF3) led by **Roger Ruber**
 - Designed a beam diagnostics systems for CLIC and CTF3
 - Collaborating with **Finnish colleagues** (and others) to investigate vacuum breakdown in high-gradient acceleration cavities, highly relevant for CLIC
 - **One PhD student** developing a simulation framework for the drive beam complex, applied for beam performance studies.
 - Code can also be used for the muon collider study!



Two beam acceleration module from CT3

References:

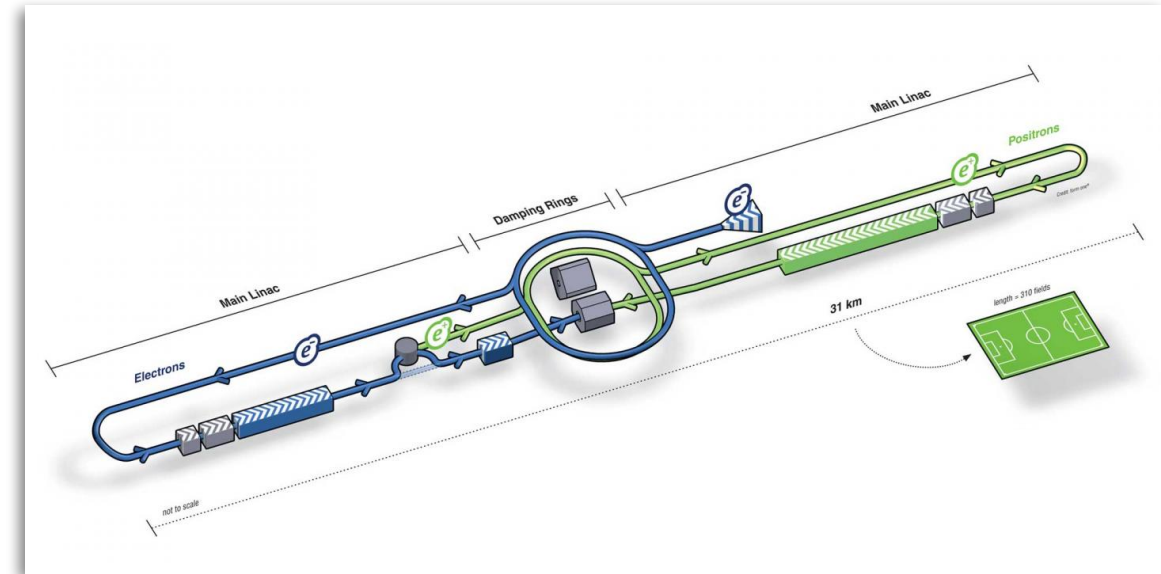
- arXiv:2403.03198
- J. Phys.: Conf. Ser. 2687 062027, 2024
- NIM A Vol 729, pp 546-553, 2013
- NIM A Vol. 797, pp. 234-246, 2015

ILC - International Linear Collider



Detector development

- Leif Jönsson and Anders Oskarsson from Lund University, with major roles in the LCTPC collaboration
 - Working on a tracking solution for the ILD that involves high resolution time projection chamber (TPC)
 - Lund responsible for the readout electronics and the data acquisition system for the LCTPC development
- No recent physics studies for ILC
- Linear collider activities are ramping down due to the plans for FCC-ee and CEPC
 - Name change of collaboration to International *Lepton* Collider
 - Studies ongoing to investigate the use of TPC at FCC-ee



References:

- [arXiv:2311.09181](https://arxiv.org/abs/2311.09181)

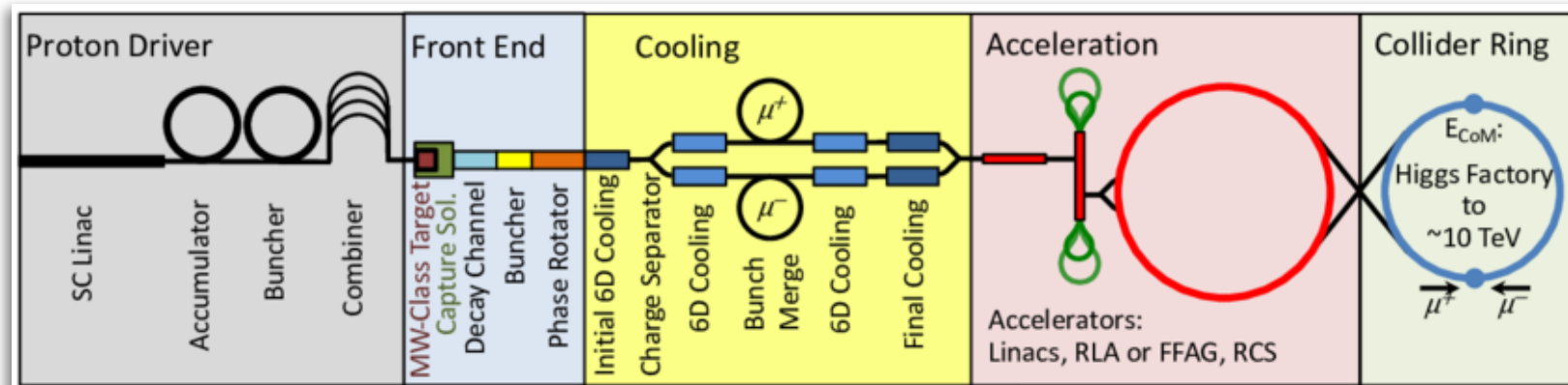


Muon Collider

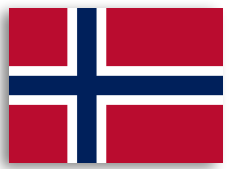
Accelerator development



- Uppsala University and ESS are part of the European Consortium MuCol
 - Working towards one or more demonstrators of the main feasibility issues of a muon collider
- ESS is the lead institute of WP3 (working project focused on Proton Driver), coordinated by **Natalia Milas**
 - Responsible for delivering a very short pulse of intense protons to the target for pion to muon production
 - 3 ESS physicists, one PhD student and one Postdoc in the working group
- ESS and Uppsala University (**Vitaliy Goryashko and Maja Olvegård**) collaborates on the design of a proton accumulator and compressor to produce a proton beam that in turn can generate the muon beam
 - Uppsala University co-supervise an ESS Postdoc in this



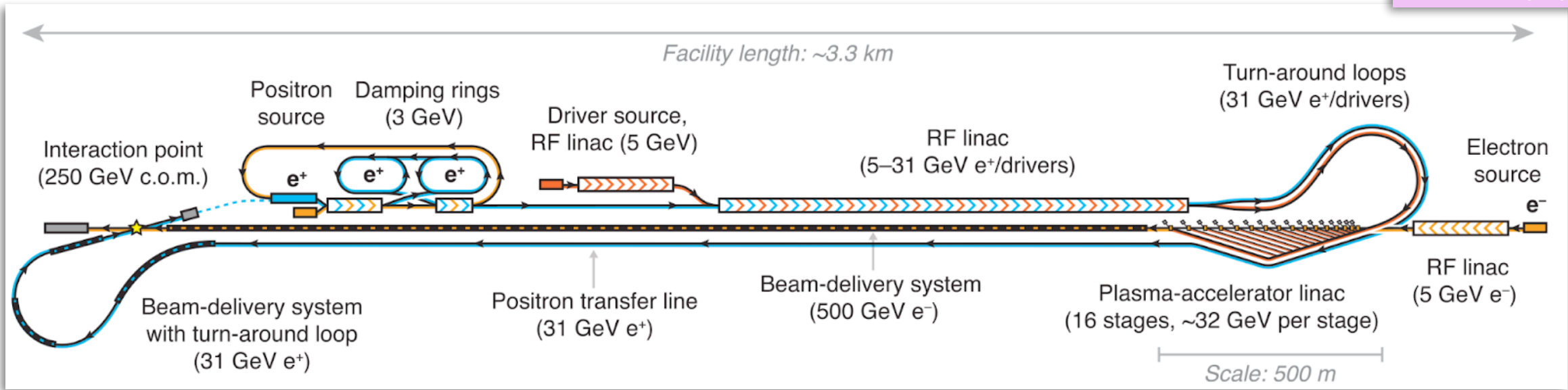
HALHF - Hybrid Asymmetric Linear Higgs Factory



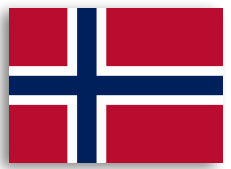
Accelerator development

- Proposed in 2023 by Carl Andreas Lindstrøm (University of Oslo) with collaborators, built upon previous plasma-wakefield-acceleration linear collider (PWFA-LC) concepts, such as that proposed by Erik Adli (University of Oslo) in 2013
 - Combines the best of plasma-wakefield and RF accelerators into a 3-km long Higgs factory
 - Avoids the difficult plasma acceleration of positrons by a mixture of plasma-wakefield acceleration to high energy electrons, and conventional RF acceleration to low energy positrons
 - High-risk, high-reward alternative to the FCC-ee, at a fraction of the cost for FCC
 - If the FCC is built, naturally take part in those activities

References:
• PWFA-LC paper
• HALHF paper



Other plasma-based accelerator concepts



Accelerator development

- Several contributions from the **University of Oslo** to plasma accelerator studies
- Prospective study of gamma–gamma colliders with plasma-based accelerators led by **Erik Adli** and funded by the Norwegian Research Council
 - Converts two electron beams into photon beams via Compton scattering of a laser pulse just before the collision point
 - Can be fairly compact even at multi-TeV energies if built with plasma-based accelerators!
- ERC starting grant for project Staging of Plasma Accelerators for Realizing Timely Applications ([SPARTA](#)) led by **Carl Andreas Lindstrøm**
 - Project aiming to demonstrate a solution to the difficult problem of staging plasma accelerators with plasma lenses
- Involved in demonstrating plasma accelerators in experiments at DESY, SLAC and CERN

References:

- PhysRevLett.121.194801
- PhysRevLett.126.014801
- Plasma Phys. Control. Fusion 58 034017
- Nature 561, 363–367 (2018)

EIC - Electron-Ion Collider and RHIC - Relativistic Heavy Ion Collider



Theoretical studies and detector development

- Historic involvement on the ALICE Time Projection Chamber (TPC) fronts from **Lund University** has led to a spin-off by **David Silvermyr** for the sPHENIX TPC at RHIC
- The **ALICE group at Lund University** might join EPIC (or the future 2nd experiment) at EIC, but no ongoing work on EIC or EPIC yet
- Several model developments in PYTHIA, for future EIC collisions:
 - **Ilkka Helenius (University of Jyväskylä)** extending and implementing a VMD model.
 - **Christian Bierlich (Lund University)** Monte Carlo initial states in electron-ion collisions
 - Both: MC validation studies (Rivet) for including HERA data and EIC simulation infrastructure.
- Large contributions to EIC from the theory group at **University of Jyväskylä** led by **Tuomas Lappi**
 - Presented earlier today in [Tuomas talk!](#)



References:

- arXiv:2112.12598
- JHEP 10 (2019) 026

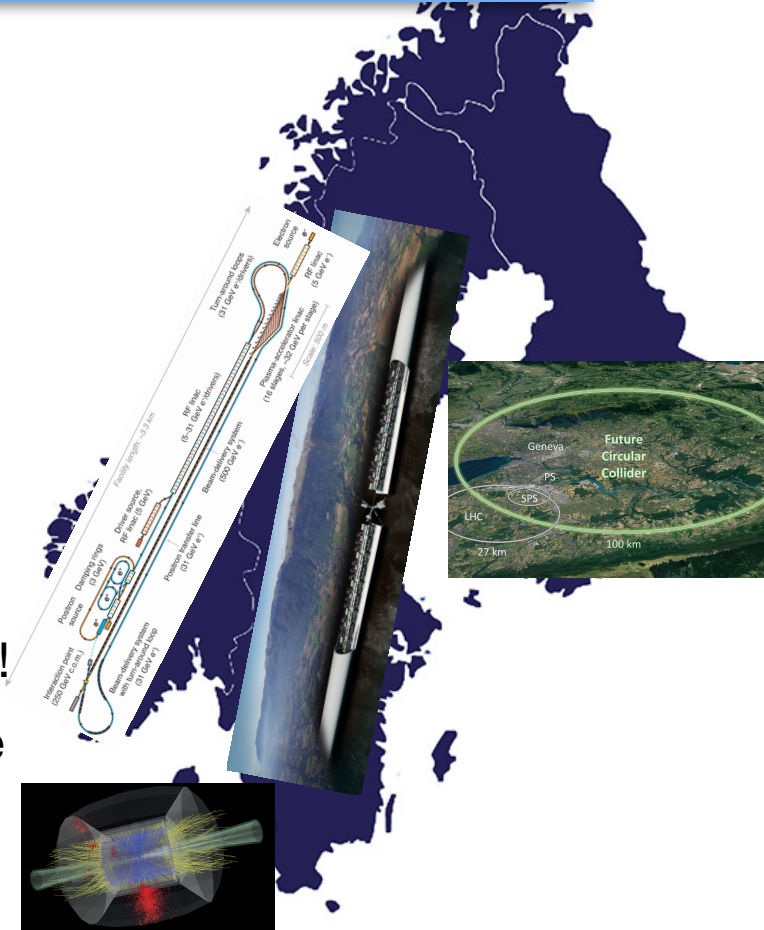
References:

- EIC Yellow Report

Summary

Maybe in a multiverse somewhere we are building all the future collider projects ... one in each Nordic country ...

- The Nordic community is involved in many exciting future collider projects
 - Swedish contributions in accelerator- and detector development, experimental and theoretical studies for FCC-ee, muon collider, CLIC, ILC and EIC/RHIC
 - Finnish contributions in detector- and accelerator development, and theoretical studies for FCC-ee, CLIC and EIC
 - Norwegian contributions in accelerator developments for plasma accelerators and CLIC
 - Danish contributions to detector design and physics studies for FCC-ee
- Not to forget, our neighbors in the Baltics are working for the future as well!
 - E.g some studies done with Key4HEP for CLIC, planned to be re-done for FCC-ee, by Mario Kadastik and Joosep Pata (HEPC Estonia)
- A huge thank you to everyone who shared their material with me!



Thank you for your attention!

The future is bright! 