HEP / KEAL
@
NICPB / KBFI



CERN @ Estonia - State of Play

Torben Lange on behalf of CERN groups in Estonia
Nordic-Baltic post ESPPU meeting | 13.11.2026
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Euroopa Liit
Euroopa Sotsiaalfond
Eesti tuleviku heaks
Euroopa Liit
Siseministeerium
Eesti Teadusagentuur
Estonian Research Council
PRG2502, Taristu24-TK10 & TK202 "Fundamental Universe"

CERN in Estonia







- Radiation hard electronics/ FPGAs / DRD7
- CMS Phase 2 + BRIL
- Power electronics lab
- Newer focus on FCC

- CMS Analysis
- Particle Theory
- Machine learning
- Cosmology
- CERN Tier 2 (WLCG)

- Accelerator technology CLIC/FCC
- Scintillators CCC
- AMBER hadron physics
- CLOUD atmospheric aerosols

The road to CERN membership

- First Bilateral agreement in 1996
- Part of CMS since 1997 (through KBFI)
- Hosts its own Tier-2 datacenter of the WLCG
- Participation in several other CERN experiments including CLOUD, COMPASS, NA66, BRIL and TOTEM
- Studies for CLIC and now FCC!
- Part of the Crystal Clear R&D collaboration (CCC) since 2013!
- Associated membership agreed in 2020, realized in 2021
- **Full membership since August 2024!**



Estonian CERN Science consortium

- Consortium of KBFI (lead), TalTech and UTartu to coordinate and further CERN-related research in Estonia
- Goals:
  - Ensure continuation of Estonian CERN research
  - Improve CERN research capacity in R&D institutions
  - Ensure participation in active CERN experiments
- Forms the CERN scientific advisory board to Estonia's Ministry of Economic Affairs and policy makers
- Dedicated funding to increase related research infrastructure

Estonian CERN Science consortium

Estonia's CERN vision

Participation of the science, education, and business sectors in CERN activities stimulates innovation and provides a direct path to new knowledge and skills.

Estonia's CERN mission

- Contribute through CERN to the development of global and Estonian science and industry.
- Actively make use of the opportunities associated with CERN membership.
- Maintain a high scientific standard and educate scientists and engineers.

CERN is part of Estonia's Infrastructure roadmap! CERN strategy is ready! Three focus goals: CMS, Quantum Computing **and FCC!**

CERN contributions at KBFI (overview)

CMS Analysis

- Higgs physics, HH production and the Higgs boson potential, BSM Higgs Sector extensions
- 3 Convenerships in CMS (Higgs combinations, Modelling and Interpretations, Offline Reconstruction)
- Dedicated group grant (5 years) on HH
- 1 PI, 2(3) PostDocs, 1 PhD, 3 BSc.

Particle Theory

- Quantum information in HEP, Scalar models, Phase transitions in the early universe
- Dedicated group grant from next year
- Group: 3 PIs, 3 PostDocs and 1 PhD students
- Additional activity in Gravitational waves and Cosmology not listed here (~25 people in total)

ML in HEP

- ML challenges both inside and outside CMS, object reconstruction at FCC, ML in astrophysics
- Convenership for tau reconstruction at the FCC
- Associate scientist at CERN openlab and Visiting PostDoc grant in Hamburg, PhD shared with CMS analysis

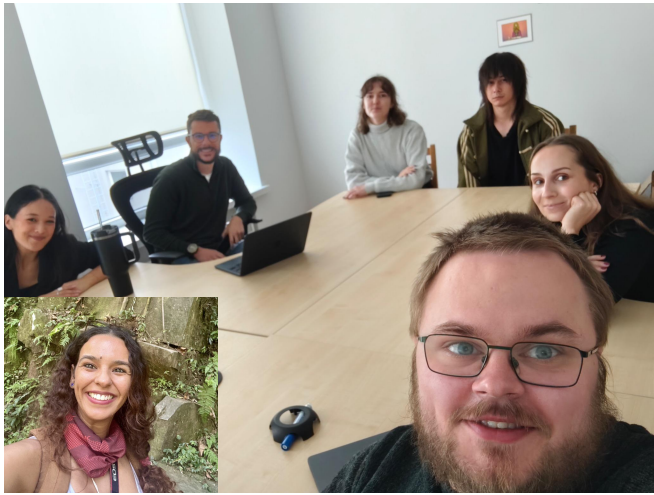
KBFI Computing (T2)

- Hosting the Estonian T2 with ~3000 cores and 8 PB of storage, part of WLCG
- 1-2% of CMS Tier2 computing
- Recently upgraded (cooling, power, storage, compute)

Cosmology

- Cosmology and gravitational waves (theory)
- Part of several GW detector collaborations including Terrestrial Very-Long-Baseline Atom Interferometry (TVLBAI) at CERN

KBFI Focus: Higgs physics



- Increasingly large sub-group focussed on HH pair Production and the Higgs self coupling
- Strong visibility in the form of convenerships and Leadership roles in all recent combinations

+ New postDoc

- Strong interest in EFT and extended Higgs sector studies
- If it has Higgs, HH, EFT, taus or leptons in it, we are likely interested!
- Continuation of these efforts for HL-LHC and extension to precision Higgs physics at the FCC are the natural next steps
- HL-LHC will find HH production and HL-LHC + FCC will measure the Higgs self coupling with increasing precision, probing the Higgs potential directly!

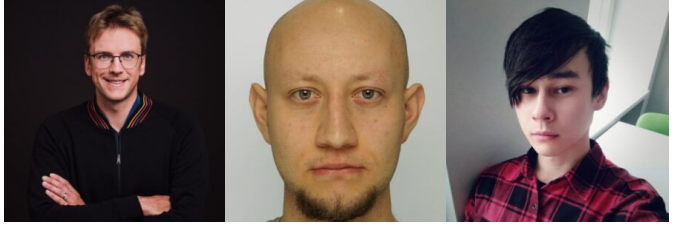
Upcoming event!

COMETA workshop on Future VBS and HH prospects

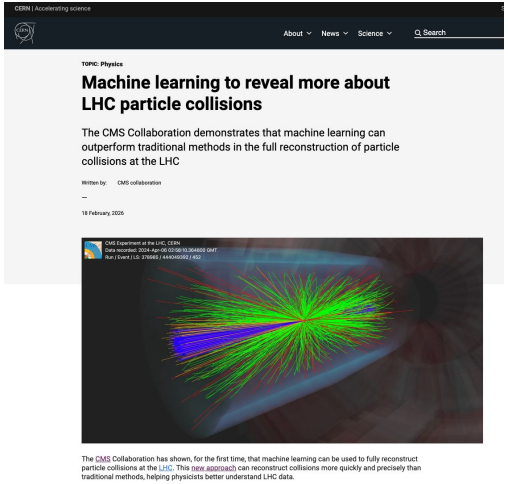
- 2.5 Day workshop on the current state of VBS and HH physics in Run3 and the prospects for the HL-LHC
- Overlap with Cosmology and Gravitational Waves!
- 15.02-17.02 in Tallinn!

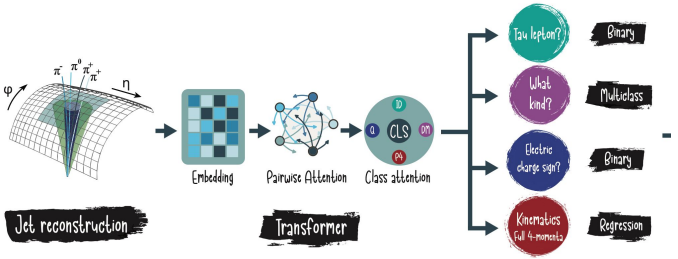
https://indico.cern.ch/event/1736329/

KBFI Focus II: Object reconstruction for future colliders



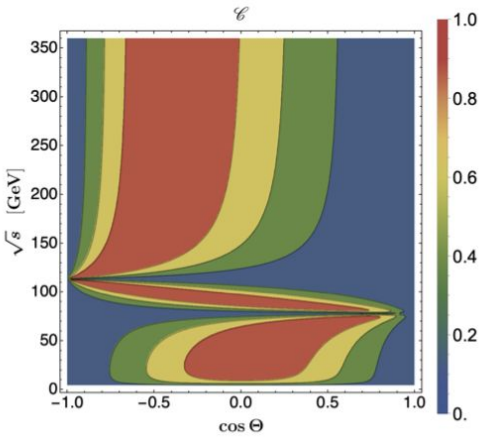
- Strong contributions to even reconstruction and concurrent and future colliders:
  - Development of ML based particle reconstruction: MLPF now commissioned for CMS simulation in Run3 and beyond [link], also tested as a foundation model [1, 2], **featured on CERN main page!**
  - Heavy involvement in tau reconstruction for the FCC-ee, two new papers with jet foundation models [link] and a transformer for multi-task tau reconstruction: classification, decay mode, charge and kinematic regression [link] (Normans talk)
  - **Tau results part of this years FCC week in Helsinki!**





KBFI Focus III: Quantum Tomography

- Strong activity in study of quantum observables in collider physics, testing **quantum entanglement and bell conditions**
- Several **papers on entanglement studies with taus for the FCC-ee** [link][link] and **Belle2** [link]
- Convenership for bell nonlocality at CERN Quantum Observables workshop
- Plans:
  - Study Z' models at the HL-LHC and FCC-ee (quantum tomography)
  - Feasibility studies of Tau pair ellipsoid reconstruction at the FCC-ee and Belle 2
  - Expansion to study of the Higgs boson self coupling through Tomography







\+ New postDoc

CERN contributions at TalTech (overview)

FCC detector activities

- Conceptual design of radiation-hard electronics (FCC)
- Focus on Signal processing, and system-level analysis
- MoU with FCC signed 2022

Power electronics lab

- Collaboration with the CERN Electrical Power Converters group
- Energy-storage converters for FCC magnet powering / other power solutions
- Contact point to the DRD7 program (Detector electronics R&D)

CMS Phase 2/BRIL

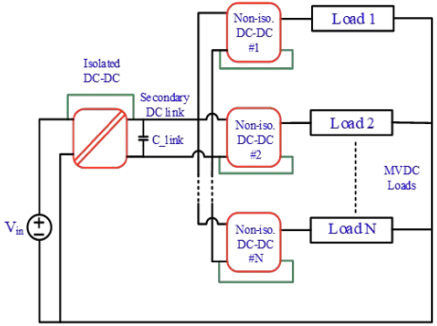
- CMS associated member since 2022
- FPGA firmware development
- L1 tau trigger for phase 2 (Collaboration with KBFI)
- Test system for the Fast Beam Condition Monitor luminometer (FBCM ASIC)
- Now shift from prototype to validation and integration

TalTech Focus I: Efficient RF powering for future colliders

A route to smaller converters and lower conversion losses

Partial power regulation

Zeeshan Haider, PhD researcher

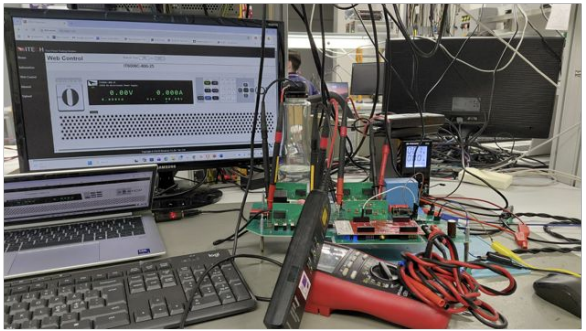


2–5% of load power through the shared converter

Simulation: 45 kV bus, 3 × 500 kW loads.
Individual RF supply regulation at 40–50 kV.

Precise klystron voltage control

Vinod Kumar Yadav, postdoctoral researcher



±1 kV electrode trim target for multibeam klystrons

Second-stage prototype tested at 100 V input.
Electrostatic trim with near-zero steady current.

Next milestone: full-voltage hardware and system validation

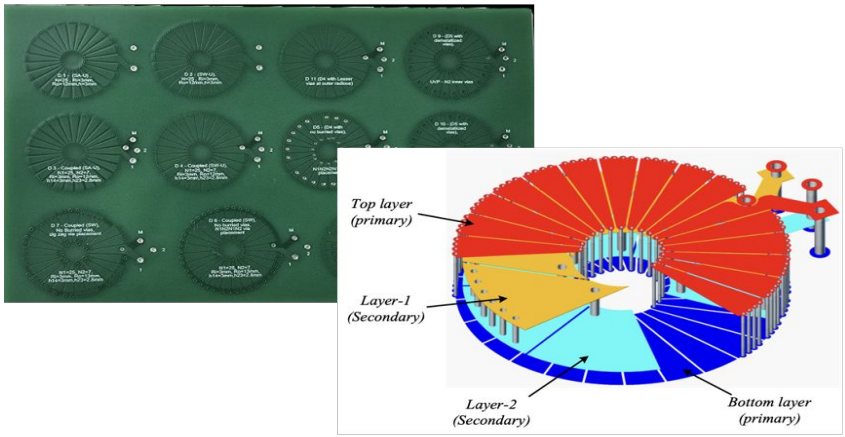
Kindly provided by A. Chub

TalTech Focus II: Less conversion hardware inside detectors

Single-stage conversion targets lower losses and a smaller footprint

Abdul Majid Bhat, PhD researcher

Air-core PCB inductors



Fabricated prototypes for MHz operation

Next milestone: validate the complete 48 V converter

Converter design target

48 V to 2.5 V

in a single conversion stage

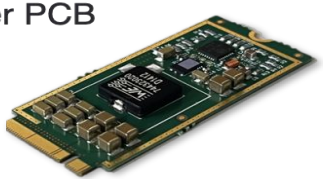
12.5 W output, >80% efficiency target

For radiation exposure and
strong magnetic fields

Measured inductor coupling

k = 0.75

Air-core design in a four-layer PCB



Kindly provided by A. Chub

CERN contributions at UTartu (overview)

Accelerator Technology

- Focus on vacuum electrical breakdowns
- Multiscale models of defect evaporation
- Part of the MATTER group
- Originally studied for CLIC
- MoU with FCC signed in 2022

AMBER

- Full member of AMBER
- Fixed target experiment at SPS
- New DAQ commissioned/used in 2025 and 2026
- Heavy-flavour theory: to be measured at upcoming Drell-Yan run [UTartu]

CLOUD

- Research of Atmospheric aerosols (CLOUD) including the role of cosmic-ray ionisation
- CERN beam at the PS to mimic cosmic rays
- Studies of the effect of CO2 on atmospheric ion chemistry [UTartu]
- Contributions to CLOUD with two instruments [UTartu]

CCC

- Part of the Crystal Clear Collaboration (CCC) since 2013
- Cooperation with CERNs DRD6 program (calorimetry R&D)
- Research and development of ultrafast scintillators and crystal growth techniques [UTartu]

UTartu Focus: Accelerators technologies for FCC

- Expanding developments for FCC:
  - Electron sources,
  - kicker magnets
  - electromagnetic separators
- The groups work on field emission of electrons is especially important for the electron sources
- Existing expertise of vacuum electrical breakdowns adds to kicker magnets and electromagnetic separator development

For more contact Veronika Zadin!

Summary

- Estonia despite its small size offers a broad spectrum of CERN related efforts
- This includes physics analysis with CMS (KBFI) and particle physics theory (KBFI / UTartu)
- But also participation in smaller experiments such as CLOUD (UTartu)
- And more engineering focused work:
  - Radiation hard electronics for detectors (TalTech)
  - Crystals and Calorimeters (UTartu)
  - Accelerator technologies (UTartu)
  - Power systems for magnet systems (TalTech)
- Further we are also involved in algorithmic work such as object reconstruction for future colliders
- **This and the engineering of course also allows Estonia also too already look into the future and contribute to the FCC!**