UPPSALA UNIVERSITET

Future Accelerators

Accelerator Research & Development

and

Swedish Competence & Involvement

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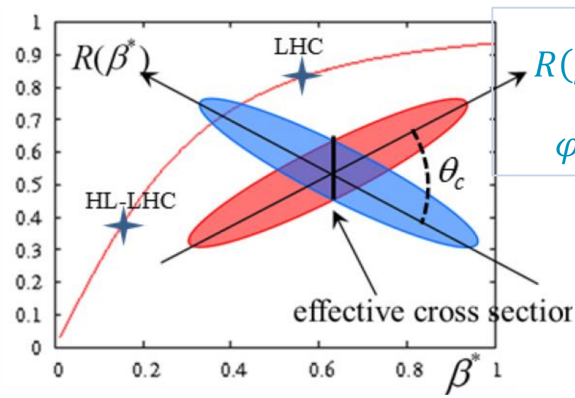
Swedish PP Strategy Meeting

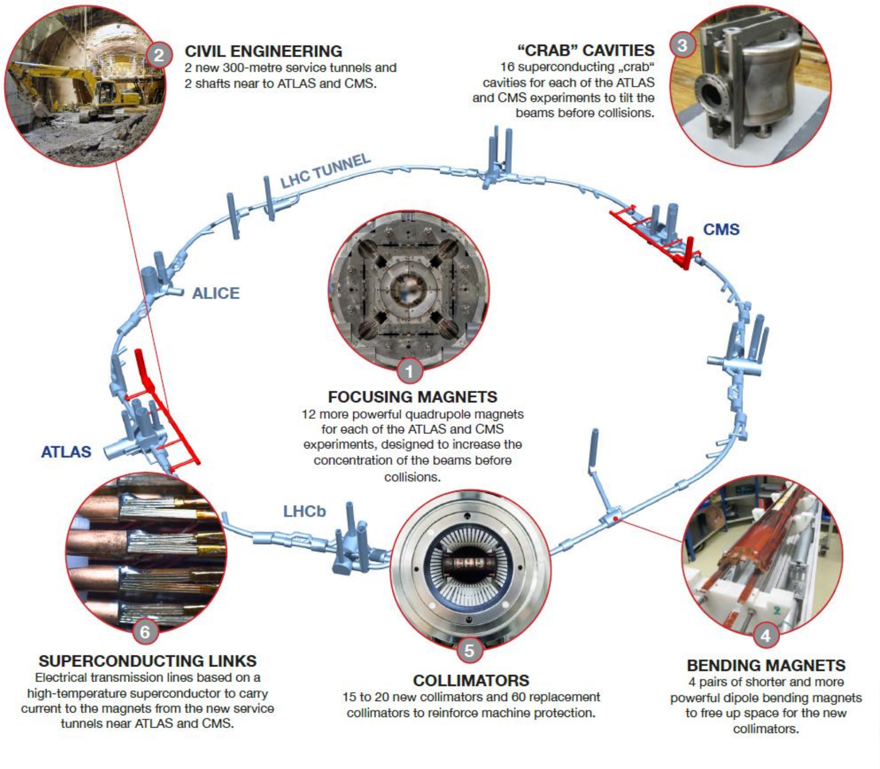
Uppsala University, 13 March 2018

High Luminosity LHC (HL-LHC)

- Increase the LHC luminosity with a factor 5
  - Peak luminosity L_{peak} = **5×10^{34} cm^{-2}s^{-1} with levelling**, allowing:
    - an integrated luminosity of **250 fb^{-1} per year**,
    - enabling the goal of **L_{int} = 3000 fb^{-1}** twelve years after the upgrade.
    - this luminosity is more than **ten times** the luminosity reach of the first 10 years of the LHC lifetime.
- Increase brightness by reduced β* and crabbing
  - new insertion triplet & crab cavities
  - modify some collimators & bending dipoles

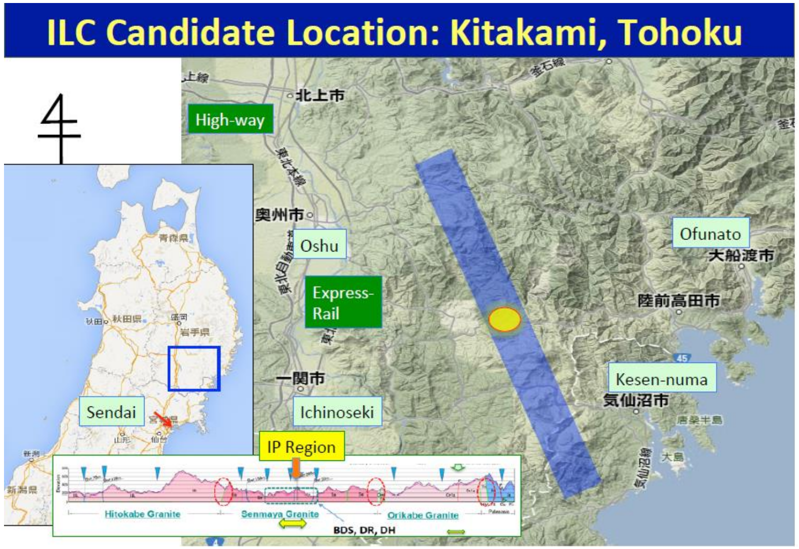


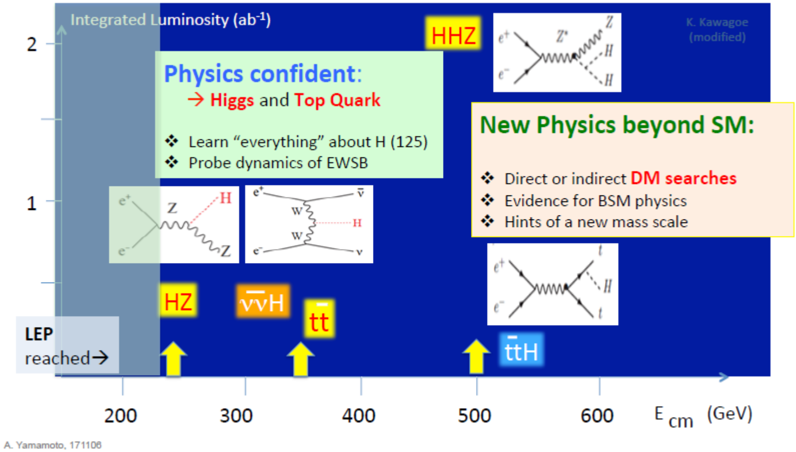
$$R(\beta) = \frac{1}{\sqrt{1+\varphi^2}}$$
$$\varphi = \theta_c\sigma_z/2\sigma_x$$

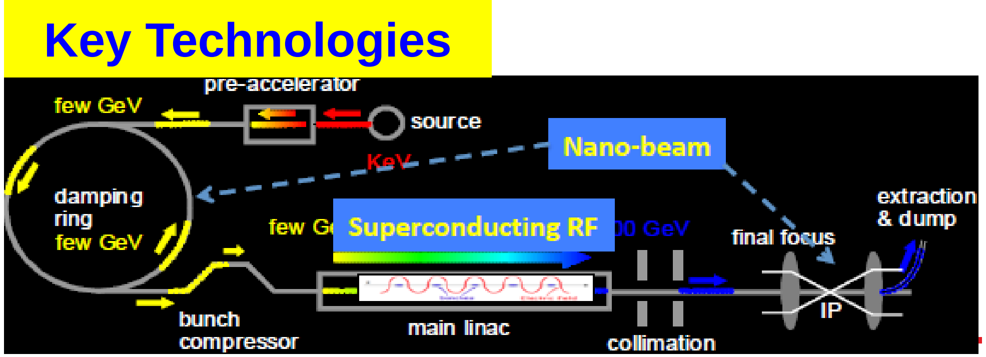


International Linear Collider (ILC)

- **Energy frontier electron-positron collider, starting as Higgs-factory**
  - c.m. energy 250 GeV for precision Higgs physics → **~13 years after decision**
  - staging to 500 GeV for precision top physics
  - staging to 1 TeV for BSM searches
  - $\geq 1 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ Luminosity
  - cost-reduction R&D in JP-US collaboration
    - superconducting RF technology
      - large grain Nb, N-doping, vertical EP
    - input power coupler fabrication

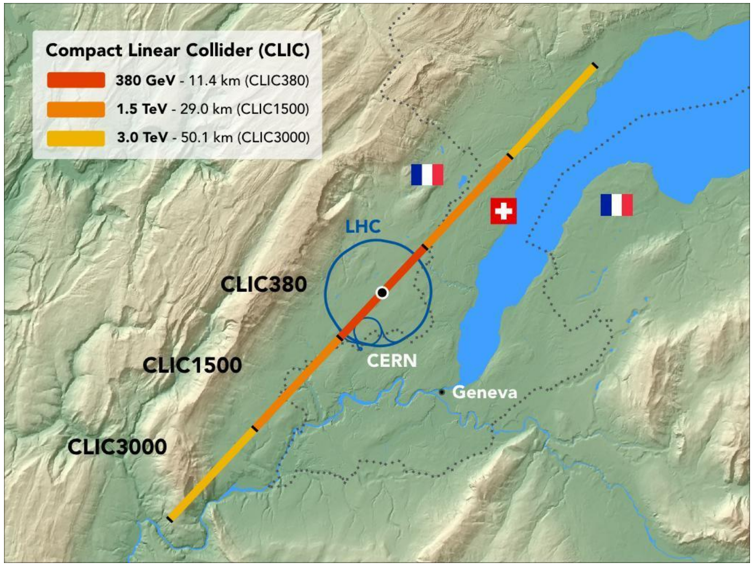


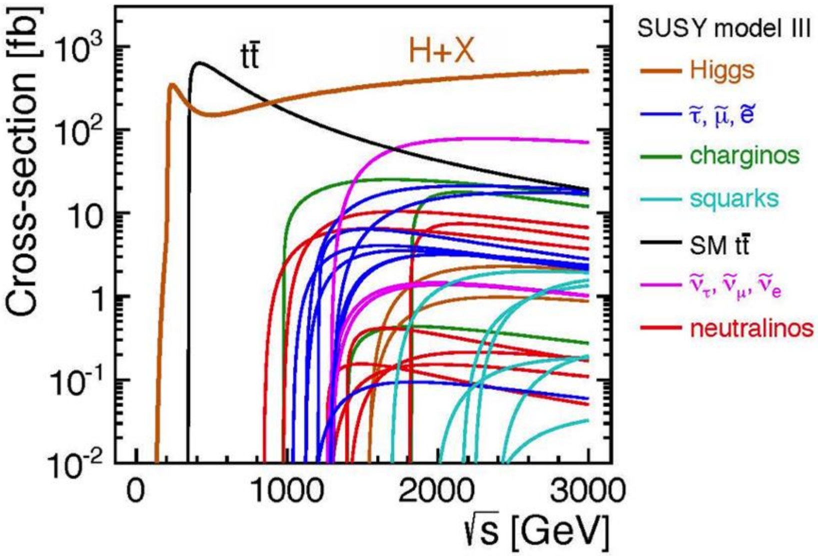




Compact Linear Collider Study (CLIC)

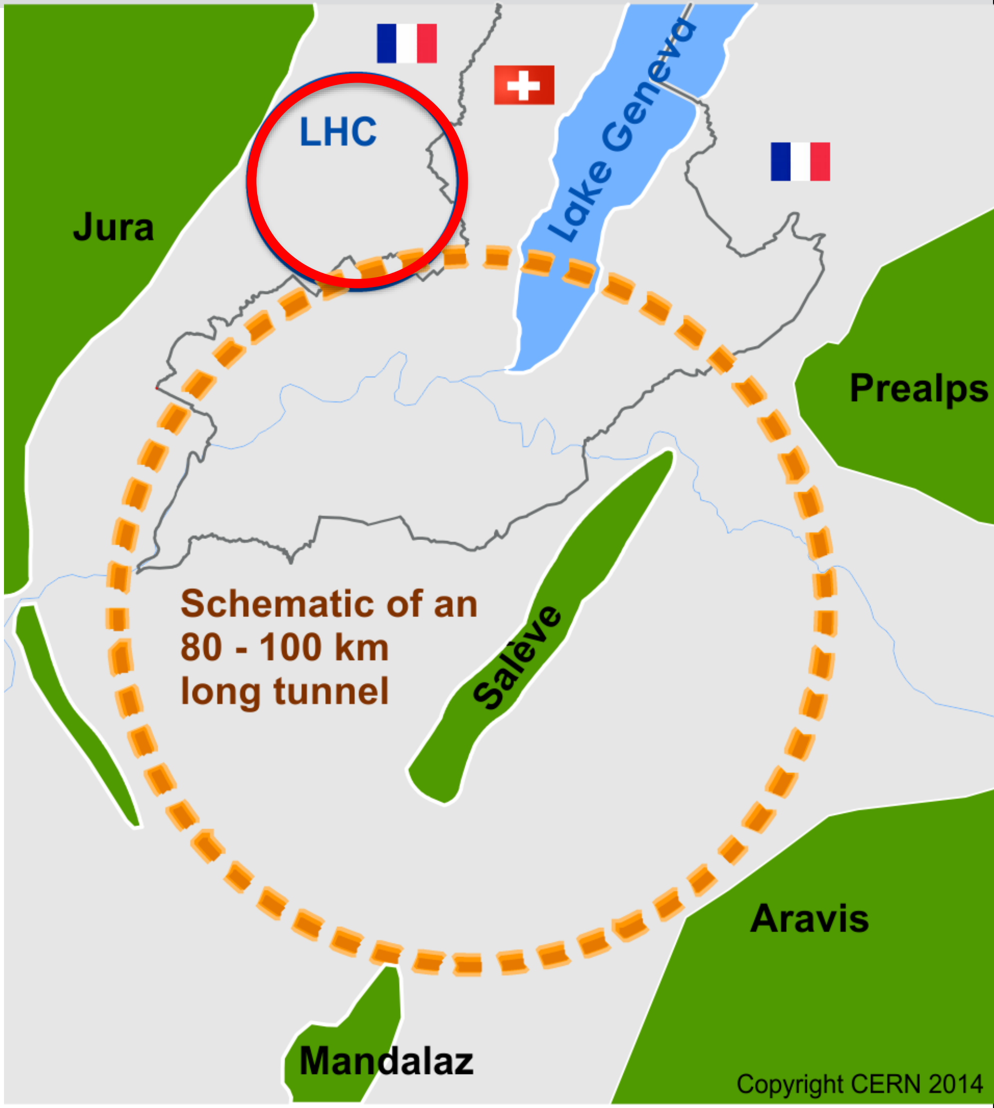
- **Energy-frontier capability for electron-positron collisions, for precision exploration of potential new physics that may emerge from LHC**
  - 380 GeV, 600 fb^{-1} for precision Higgs and top physics → **no later than 2035**
  - 1.5 TeV, 1.5 ab^{-1} for BSM searches, Higgs-Top and Higgs self-coupling
  - 3 TeV, 3 ab^{-1} for BSM searches, Higgs self-coupling
- Reasonable cost profile, targeting existing CERN budget possibilities
- Normal conducting high gradient technology, two-beam acceleration





Future Circular Collider Study (FCC)

- International FCC collaboration (CERN as host lab) to study:
  - pp-collider (FCC-hh) → main emphasis, defining infrastructure requirements
- **~16 T ⇒ 100 TeV *pp* in 100 km**
  - ~100 km tunnel infrastructure in Geneva area, site specific
  - e+e- collider (FCC-ee), as potential first step → **start operation 2039**
  - HE-LHC with FCC-hh technology → **start operation 2040**
  - p-e (FCC-he) option, IP integration, e- from ERL

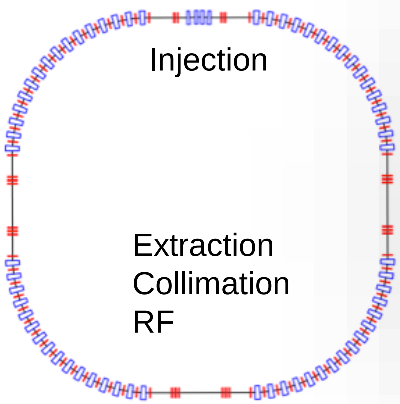


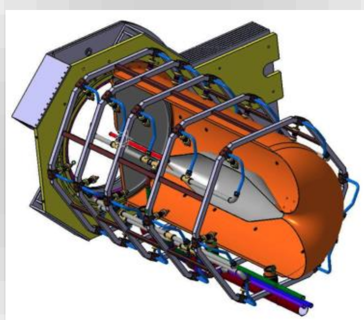
FCC

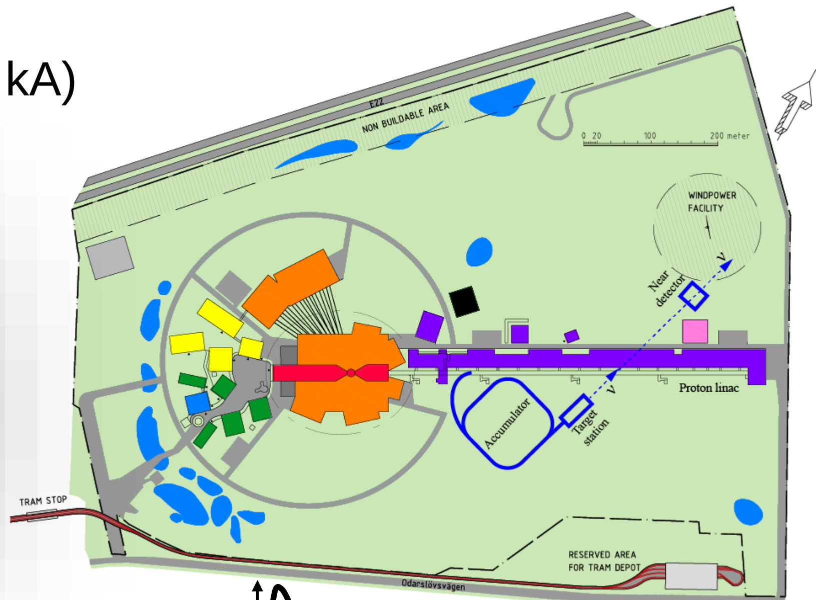
- **FCC-ee:**
  - c.m. energy from 45 to 183 GeV for Z, WW, H and ttbar production
  - Exploration of 10 to 100 TeV energy scale via couplings with precision measurements
  - ~20-50 fold improved precision on many EW quantities (equiv. to factor 5-7 in mass) (m_Z, m_W, m_{top} , $\sin^2\theta_w^{eff}$, R_b , $\alpha_{QED}(m_z)$, $\alpha_s(m_z\ m_W\ m_\tau)$, Higgs and top quark couplings)
  - Machine design for highest possible luminosities at Z, WW, ZH and ttbar working points
- **FCC-hh:**
  - Highest centre of mass energy for direct production up to 20 - 30 TeV
  - Huge production rates for single and multiple production of SM bosons (H,W,Z) and quarks
  - Machine design for 100 TeV c.m. energy & integrated luminosity ~ 20ab^{-1} within 25 years
- **HE-LHC:**
  - Doubling LHC collision energy with FCC-hh 16 T magnet technology
  - c.m. energy = 27 TeV ~ 14 TeV x 16 T/8.33T, target luminosity ≥ 4 x HL-LHC
  - Machine design within constraints from LHC civil engineering and based on HL-LHC and FCC technologies

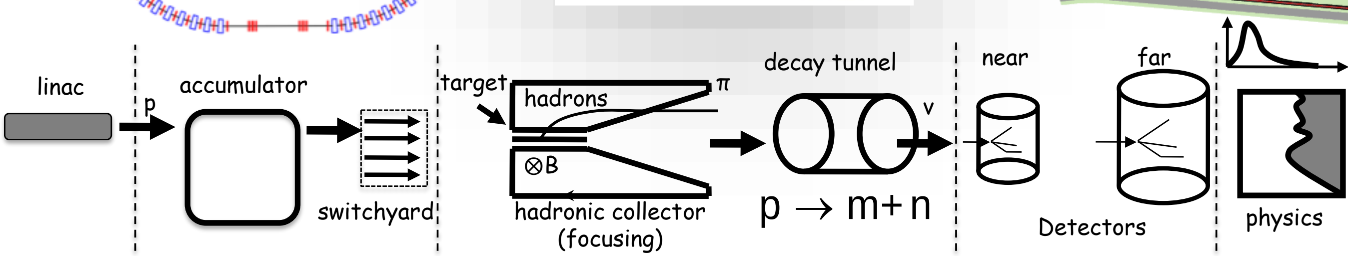
ESS Neutrino Super Beam (ESSnuSB)

- Doubling the ESS beam power for a second target
  - linac duty cycle doubling to 8 % (RF sources, cooling)
    - using new H^- source
  - accumulator ring (~400 m circ.) compress 2.86 ms beam pulse to few μs
    - multi-turn injection, stripping $H^- \rightarrow H^+$
  - 2nd target station with magnetic horn (350 kA)
    - to deliver ~300 MeV neutrinos



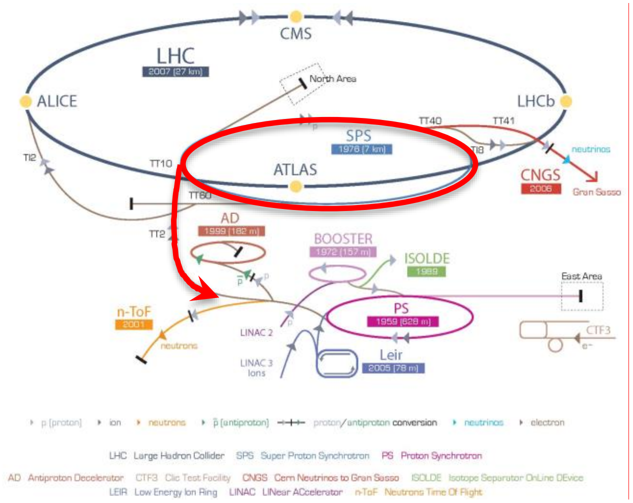


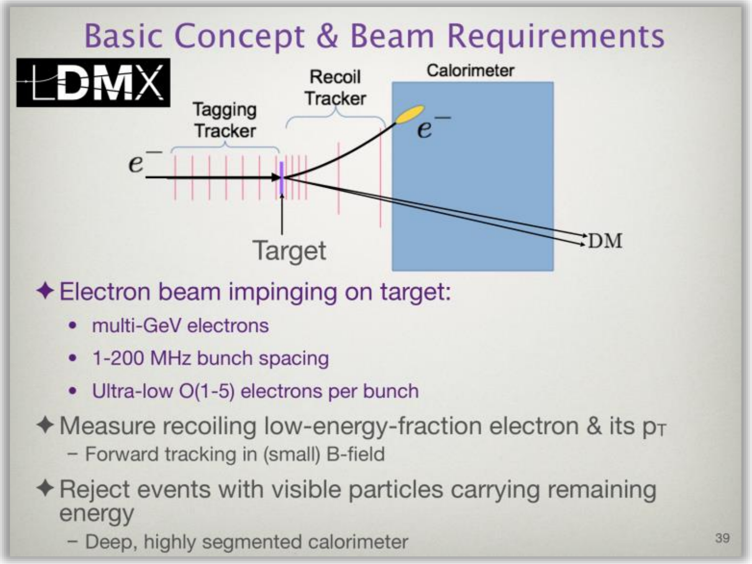


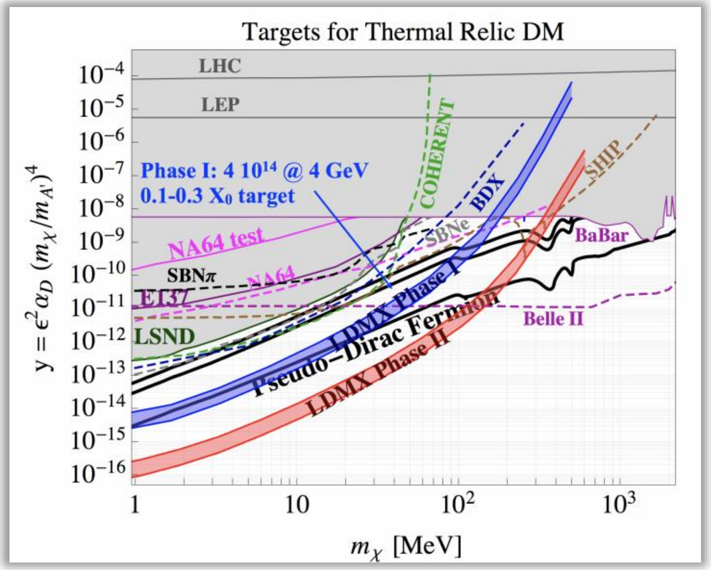


CERN e-beam Facility for DM Searches

- **Implementation of an LDMX type beam**
  - X-band based 60m LINAC to 3 GeV in TT4-5
  - Fill the SPS in 2s (bunches 5ns apart) via TT60
  - Accelerate to ~10 GeV in the SPS
  - Slow extraction to experiment in 10s as part of the SPS super-cycle
  - Experiment(s) considered in UA2 area or bring beam back on Meyrin site using TT10







Swedish Academic Contributions

- **FREIA Laboratory, Uppsala University**
  - **Accelerator physics**
    - CLIC beam dynamics, RF breakdown
    - ESSnuSB accumulator ring, beam dynamics
    - HL-LHC machine protection
  - **Accelerator technology**
    - SCRF for ESS, LHC, ILC, FCC (spoke, elliptical, crab)
    - NCRF for CLIC
    - SC magnets for LHC, FCC (CCT correctors)
    - RF sources for all projects
- **Lund University**
  - **Civil engineering** (with MAXlab & ESS)
    - fire safety for FCC

Swedish Industrial Contributions

- **Swedish industrial return = 0.45 for ”supplies” and 0 for ”services”**
  – recent 4 years > 5 MCHF sold to CERN
    - 2 MCHF by top 4: Scanditronix Magnets, Kompressortechnik, ScandiNova, The Svedberg Lab

  – new contract with Sandvik for 3.6 MEUR (Dec.'17)
  – other sales through subsidiaries or as sub-contractor
- **Requires active policy to cross "Valley of Death" of funding → FREIA Laboratory and its staff**
  – SC & NC magnets (HL-LHC, CLIC, FCC, HE-LHC)
  – cryostats and cryogenic distribution
  – RF sources & high voltage pulse modulators
  – cables, copper and fiber
  – high power RF distribution
  – signal processing and CE instrumentation (mass flow)
  – UHV vacuum baking products
  – ...