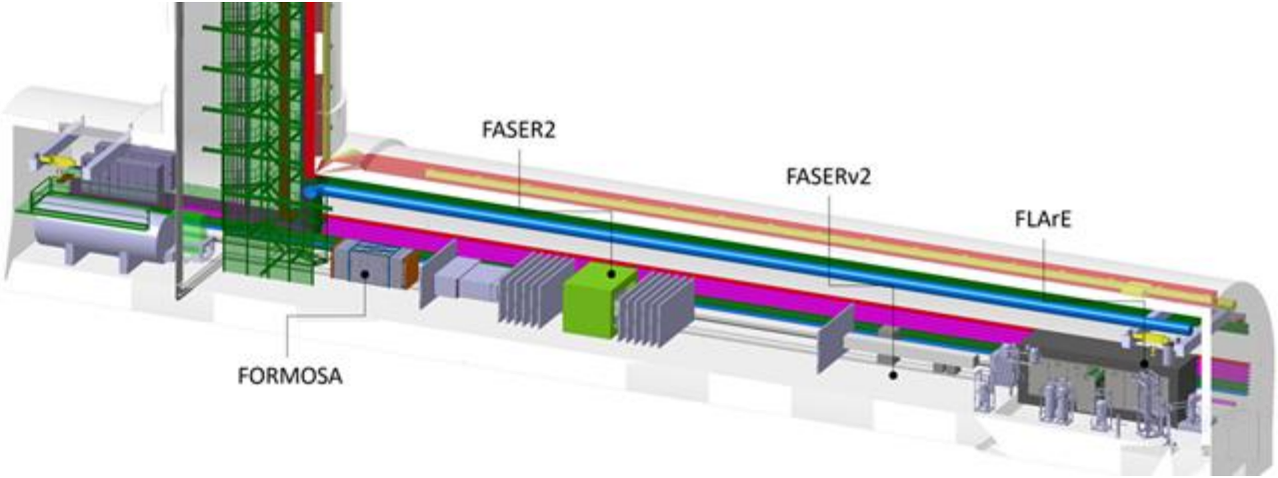
FPF UK ESSU
Drafting input
(focus: FASER2, FLArE)



Inputs required

- Key physics deliverables (name up to 5). Be quantitative where relevant/possible.

  Wide-ranging and deep physics programme spans:
  - **Dark Matter**: FIMPs, inelastic DM, and DM scattering
  - **New Particles**: millicharged particles, and quirks
  - **Neutrino physics:** O(10^6) muon neutrinos, O(10^5) electron neutrinos, O(10^4) tau neutrinos at TeV energies
  - **QCD:** constraining proton PDFs through neutrino DIS at high-x, measuring flavour production at $x \sim 10^{-7}$, investigating gluon saturation
  - **Astroparticle physics**: solve long-standing issues: cosmic ray muon puzzle and atmospheric neutrino fluxes

  Quantitative details in plots in *[EPPSU preparation document draft]*

- Please quote the datasets and running/exposure time required for the numbers above
  - Plots calculated with 3000/fb of integrated luminosity (HL-LHC)

- Environmental cost of construction (in units of tonnes of CO2 equivalent)
  - Beam: no modification required to LHC (zero)
  - Construction: concrete for 1 shaft + 1 experimental cavern

- Environmental cost of operation per year (in units of tonnes of CO2 equivalent)
  - Uses existing LHC beam (no additional cost)
  - Detector cryo power requirements ~100 kW electrical

- Estimate of financial costs (provide separate numbers for R+D phase, construction phase and operations phase)
  - FPF all experiments CHF40M (core costs, all experiments, of which CHF11.6M for FASER2)
  - FPF facility CHF49M (class-4 estimate, includes outfitting, integration, electrical, cryo, safety)
  - Detailed table below

- Does your project plan dedicated submission(s) for the ESPPU (if so, give details)
  - Yes, a FPF submission will be made

- Comparison of physics goals with the current state of the art in the area
    - Generally yields and sensitivity factor of ~1000 larger than FASER (or SND)
    - Can discover a wide variety of new particles that cannot be discovered at fixed target facilities or other LHC experiments

- List the project's main advantages compared to competitor projects
    - Deep and wide-ranging science programme spanning BSM, Dark Matter, neutrino, QCD, and astroparticle physics
    - Highly complementary physics to LHC general-purpose detectors
    - Pathfinder experiments in world-leading science exploitation
    - Intermediate timescale ideal for maintaining skilled workforce
    - Cost-effective: exploits CERN's existing accelerator infrastructure
    - Environmental impact minimal: exploits existing LHC beam
    - UK industry engaged in largest capital items (spectrometer magnet)

- Preferred location for the project
    - Extensive site selection study was conducted by CERN Civil Engineering. The site is 627–702 m west of the ATLAS IP. Shielded from the ATLAS interaction point (IP) by over 200 m of concrete and rock. Vibration, radiation, and safety studies show that the FPF can be constructed independently of the LHC without interfering with LHC operations.

- Project timeline (if possible provide separate by the R&D, construction and exploitation periods)
    - Should be ready for physics in the HL-LHC era as early as possible in Run 4. A possible timeline is for the FPF to be built during Long Shutdown 3 from 2026-29, the support services and experiments to be installed starting in 2029, and the experiments to begin taking data during Run 4.

- Main risks/obstacles for realisation of physics goals (e.g. development of new technologies, construction of a new facility)
    - Technology mature for all experiments
    - Experiments require FPF Facility

- Anticipated area(s) of UK involvement
    - FASER2 spectrometer and UK industry for the spectrometer magnet. Some interest in aspects of FLArE.

- Total number of FTE /year required for construction/operation. What is the expected UK FTE?
    - There are 7 UK institutes involved to date, including RAL. Construction/operation FTE profile to be agreed.

Construction costs

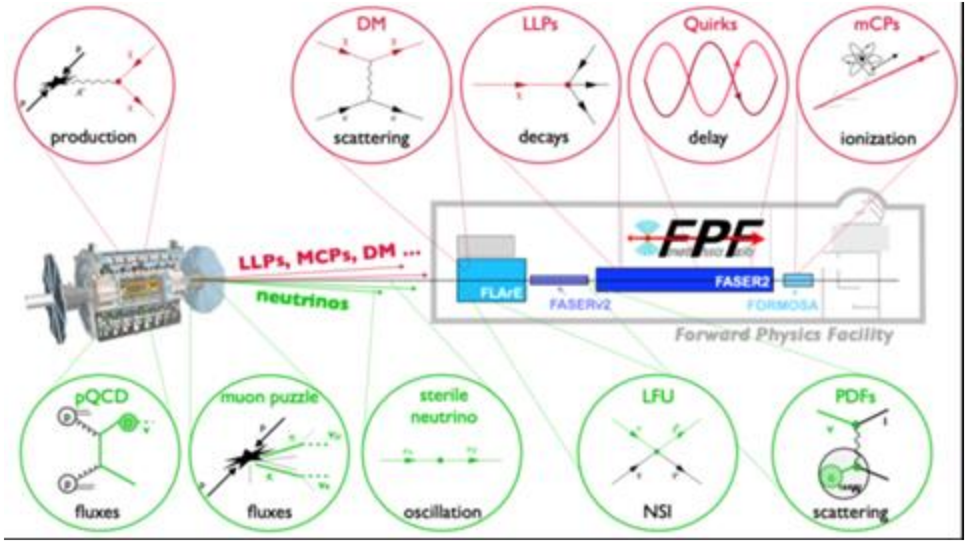
Component	Cost Range	Comments
Facility Costs		
FPF civil construction	35.3 MCHF	Construction of shaft and cavern
FPF outfitting costs	10.0 MCHF	Electrical, safety, and integration
Cryogenic infrastructure	3.8 MCHF	Cryogen storage and cooling systems
Total	**49.1 MCHF**	Includes integration for infrastructure
Experiment Costs		Core costs only
FASER2	11.6 MCHF	3+3 tracker layers, SAMURAI-style magnet, dual-readout calorimeter
FASERν2	15.4 MCHF	
FLArE	10.8 MCHF	Cryostat, proximity cryogenics, detectors
FORMOSA	2.3 MCHF	
Total	**40.1 MCHF**	Core cost experimental program

TABLE I. Cost for components of the FPF and the experimental program. Costs of the infrastructure at CERN are Class 4 estimates according to international standards; they have a range from −30% to +50%. The costs for experimental components are estimated as core costs, which consist of direct costs of materials and contracts only. Each core cost was computed with conservative technical choices; as new ideas and designs are considered, the costs are expected to change.

Motivation and deliverables - FASER2

The **Forward Physics Facility** has a rich and **broad** physics programme

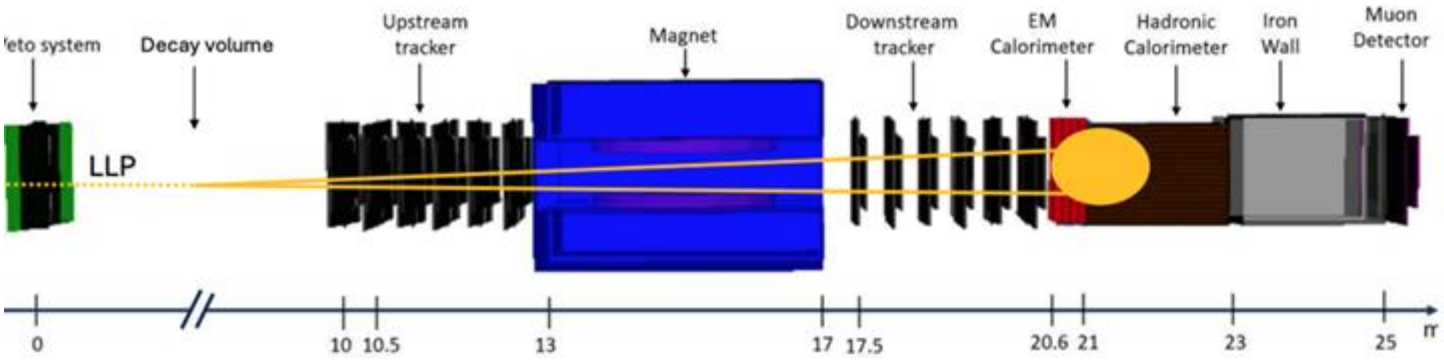
- Three main physics motivations
  - Beyond Standard Model (BSM) “dark sector” searches
  - TeV-energy Neutrino physics
  - QCD physics



FASER2 design

FASER2 scaled up version of **FASER** experiment.

Designed to search for decaying **BSM LLPs** (**100x larger** transverse size to FASER, and 7x longer decay volume) and to measure charge/momentum of muons from **neutrino interactions** in FLArE and FASERv2)



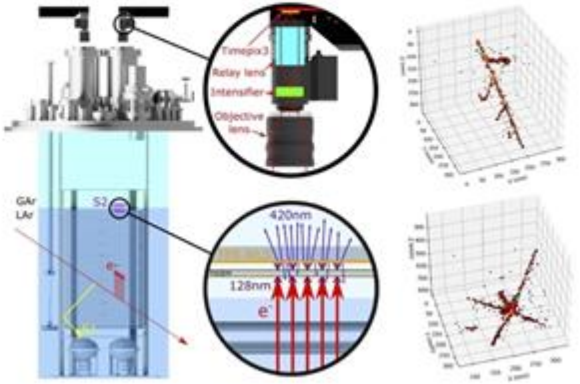
Baseline tracker – **SciFi tracker**

Two options for magnet:

- Custom made **super-conducting dipole** (2Tm bending power 1.7x1.7m^2 square air-core apperture): Prelimiary quote from Toshiba: 4.1MCHF 3-4y lead-time
- 4 off-the-shelf **crystal-puller magnet** units (2Tm (central) bending power 1.6m diameter air-core apperture): Prelimiary quote from Toshiba: 2.3MCHF 1-2y lead-time

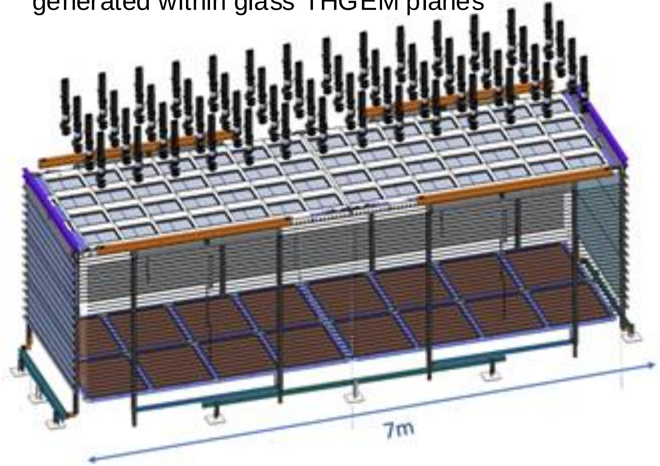
FLArE -Fast Optical LArTPC Design Option

- Great opportunity to implement a **cutting edge fast 3D optical TPC** readout developed within the **Liverpool ARIADNE program**
- Brings **high temporal and spatial resolution** to liquid argon interactions, utilizes **fast TPX cameras**
- **Simplifies design** for TPC and cryostat as well as **reduces costs**
- Liverpool is interested in delivering the light readout plane and the optical system for FLArE

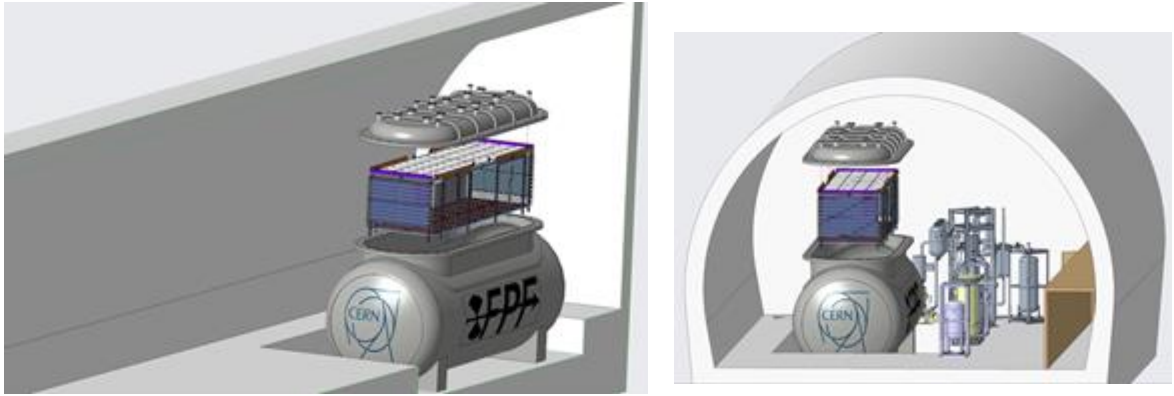


ARIADNE detection principle and LAr interactions

56 TPX3 cameras capturing the S2 light generated within glass THGEM planes



FLArE TPC optical readout option



FLArE cylindrical cryostat option within the FPF cavern

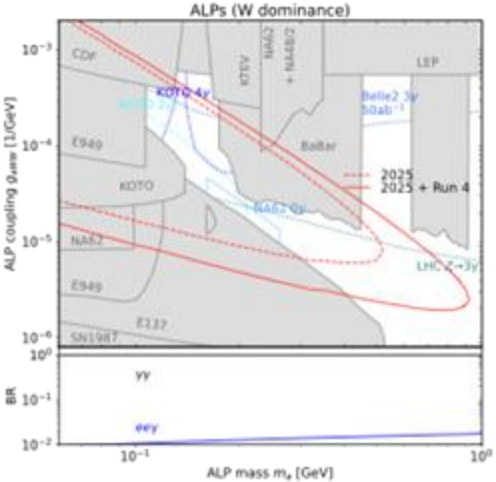
(default) FASER @ HL-LHC

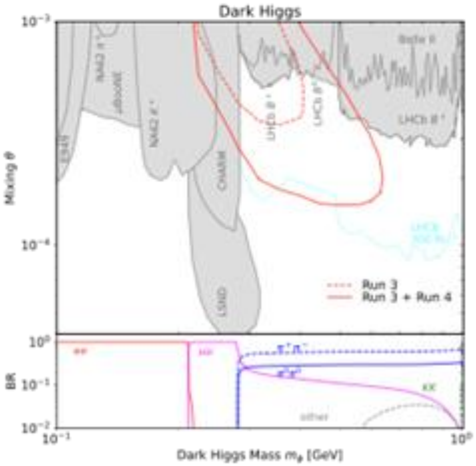
Regardless of FPF, FASER has already been approved for operation in Run 4 → new pre-shower in preparation for 2025 and no major upgrades foreseen for Run 4

Great additional physics potential in studies of hidden sectors and measurements of high-energy neutrino.

Current UK composition:

4 universities
6.3% of FASER authors
5(6) Physicists, **5** current doctoral students





FASERnu emulsion detector not as efficient – discussions about replacements/alternatives in progress with UK institutes interested in pushing for some specific options to reutilise SCT modules (**limited costings expected**)