FASER

ForwArd Search ExpeRiment

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20th May 2022
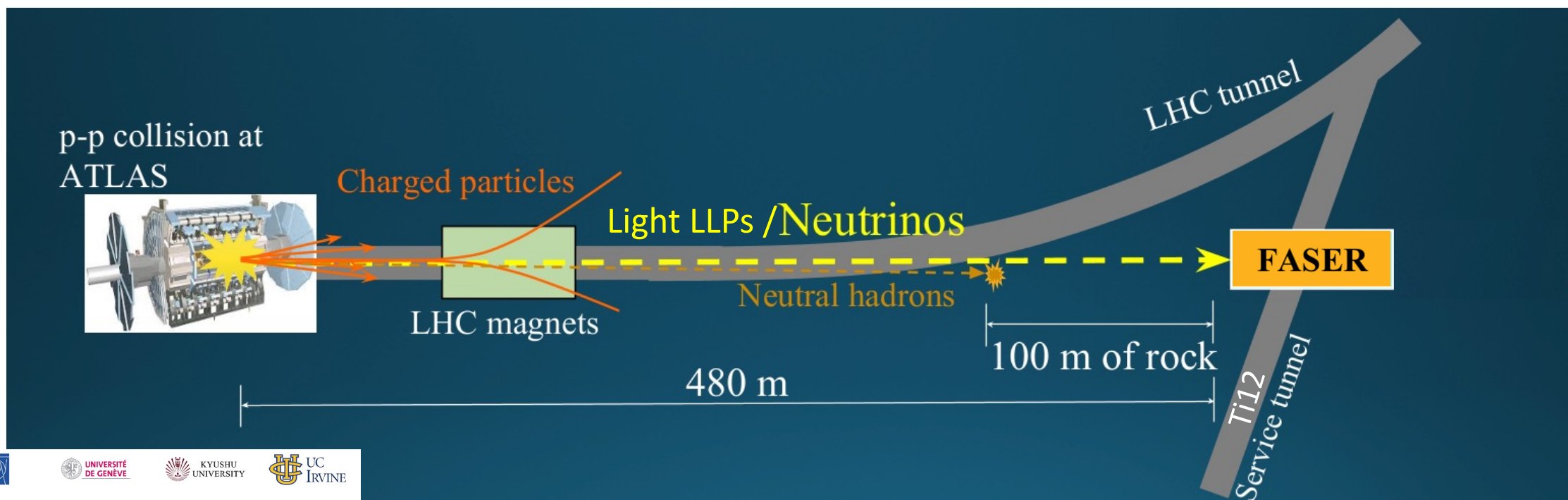
Liverpool HEP Annual meeting

FASER Experiment and Collaboration

- New LHC run-3 experiment located 480 m downstream of ATLAS in Ti12 side service tunnel
  - Along line-of-sight after LHC curves away behind 100 m rock → low background rate

- 75 members from 22 institutes (3 UK) across 9 countries
  - Liverpool joined in 2020 as first UK HEP institute
    - RHUL on accelerator side and Manchester joined recently

Physics Motivation

- Designed to search for light, weakly interacting particles (from IP1)

pp → LLP, LLP travels ~480m, LLP → ee, γγ, μμ, …

- Probes large range of BSM models that predict long-lived particles
  - Dark photons, ALPS, HNL, B-L

- Complementary to ATLAS/non-collider
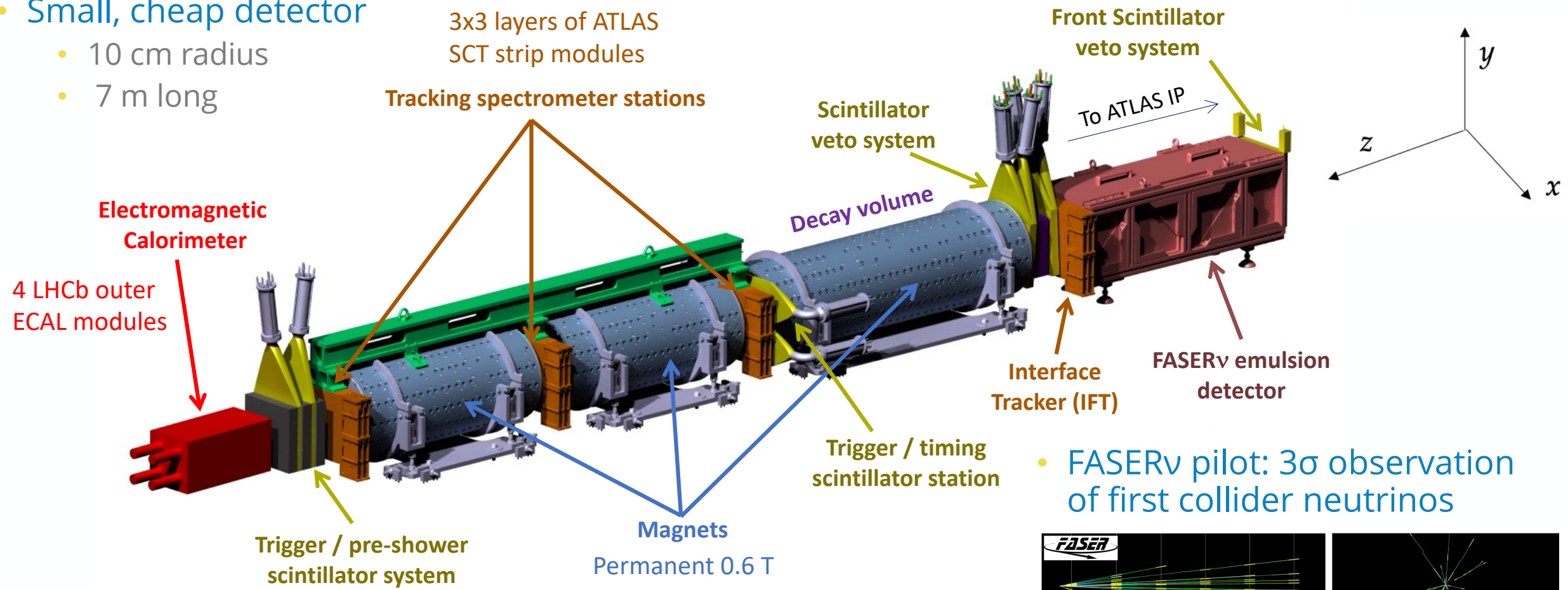 - Sensitivity to unique parameter space
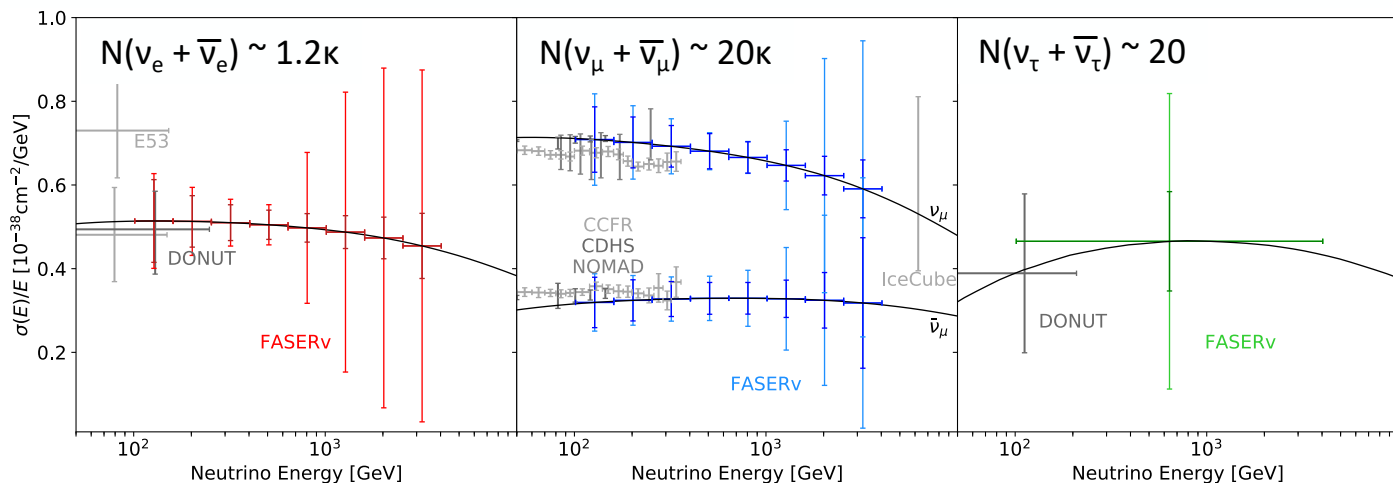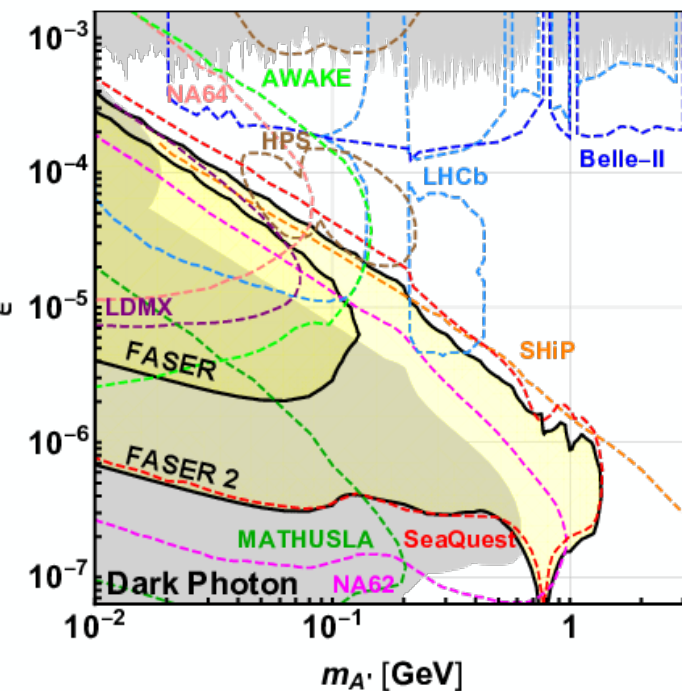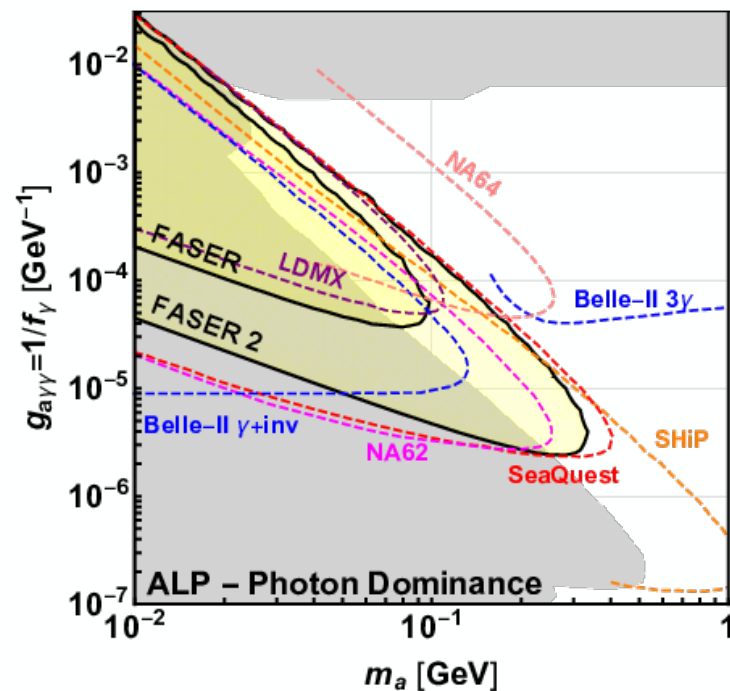
- FASERNu adds neutrino program
  - First observation of collider neutrinos

- Cross-section measurement in E range from ~ 100 GeV to ~1 TeV
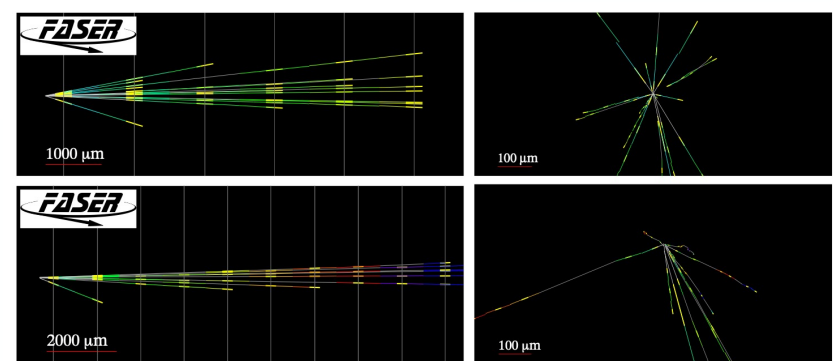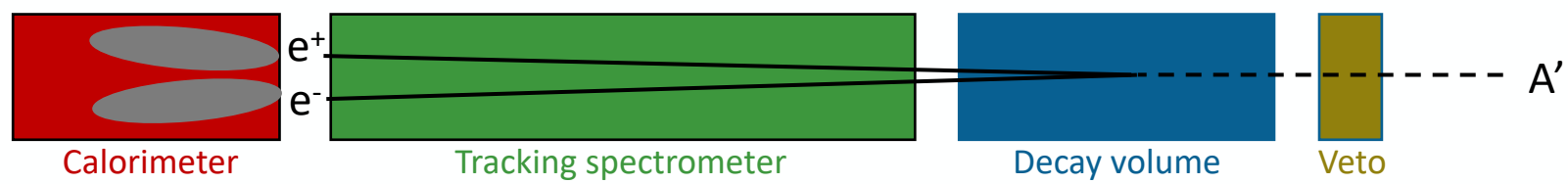 - Unconstrained region of phase space

FASER Detector

- Small, cheap detector
  - 10 cm radius
  - 7 m long

3x3 layers of ATLAS SCT strip modules

Tracking spectrometer stations

Front Scintillator veto system

To ATLAS IP

Scintillator veto system

Decay volume

Electromagnetic Calorimeter

4 LHCb outer ECAL modules

Interface Tracker (IFT)

FASERν emulsion detector

Trigger / timing scintillator station

Magnets
Permanent 0.6 T

Trigger / pre-shower scintillator system

- FASERν pilot: 3σ observation of first collider neutrinos

e⁺

e⁻

A'

Calorimeter

Tracking spectrometer

Decay volume

Veto

1000 μm

100 μm

2000 μm

100 μm

Successfully Commissioned and Installed in Ti12

- Further commissioning with cosmics and beam splashes / single beams

From ATLAS

FASERnu

Veto

Decay volume

Trackers

Preshower

Calorimeter

- Detector paper being finalised for publication
  - Monica is co-editor

EM Calorimeter and Test Beam

LHCb
(3x3 version)

- Liverpool responsible for simulation and digitisation of ECAL
  - 66 layers of lead-scintillator plates read by 2x2 array of PMTs

Electron

Muon
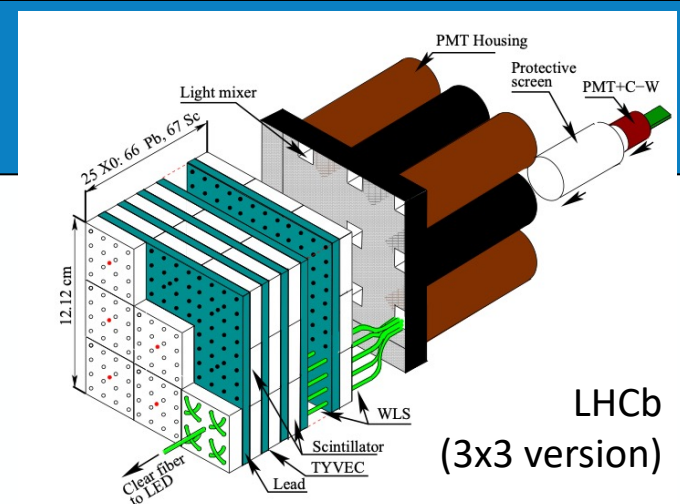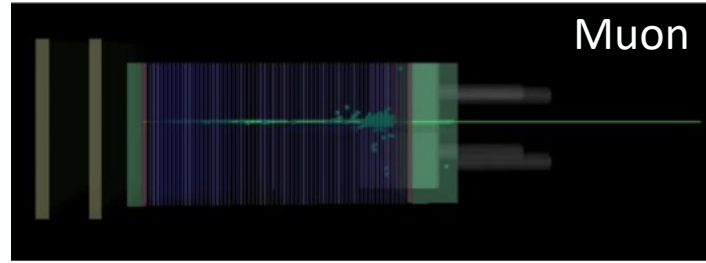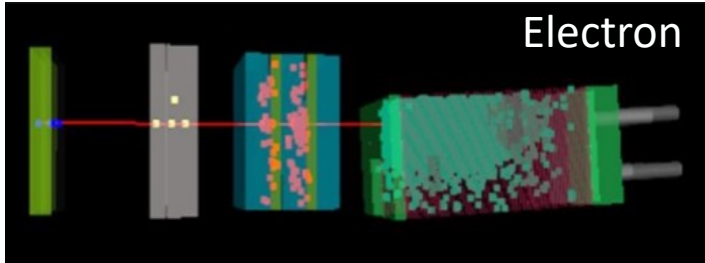
- Sim compares reasonably with data from recent Test Beam
  - Proposed by Liverpool amongst others

- Implemented first version of digi
  - Now compare sim+digi to TB data

FASER Preliminary

- Test Beam Data (Corrected)
- Fit of form: $\sqrt{0.01^2 + 0.093^2/E}$
- Test Beam Simulation (Corrected)
- LHCb Parameterisation
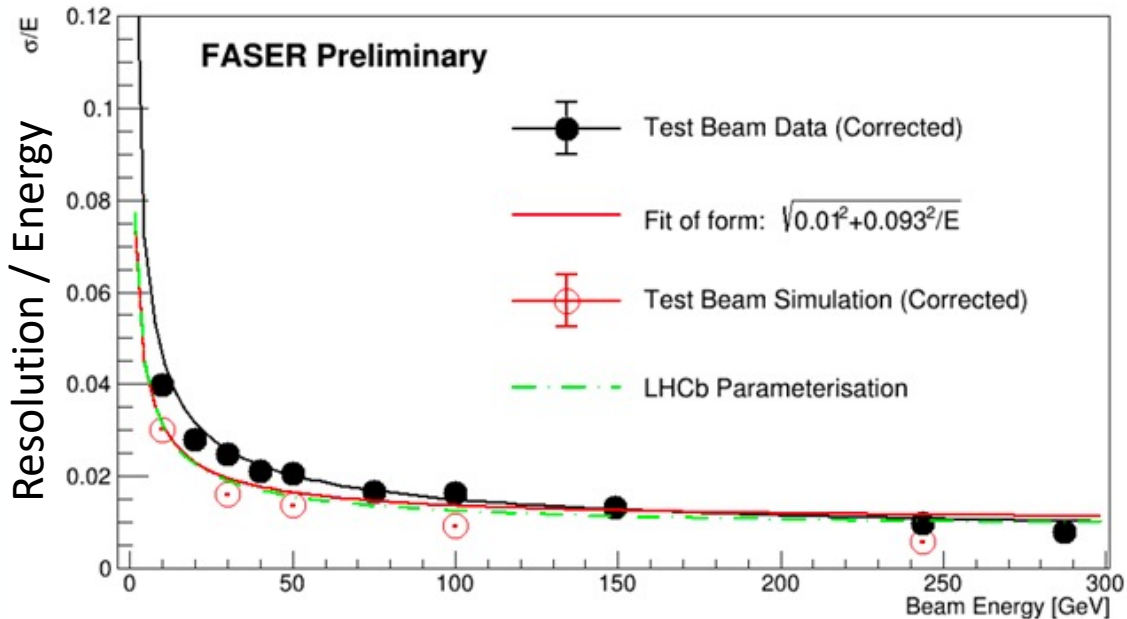
- Higher-order effects to be added from TB measurements
- See Lottie's talk yesterday for more details
- Test beam paper In preparation

Signal

Time [ns]
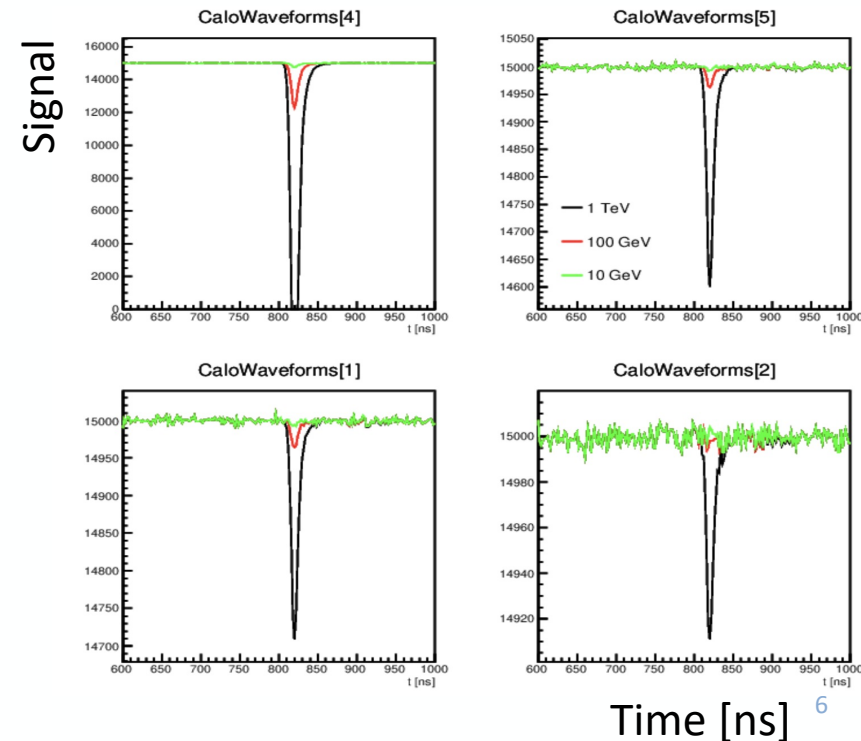
First 6.8 TeV Beam Data!

- FASER able to see particles from recent 6.8 TeV beam optics tests
  - First particles traversing full detector, including interface tracker
  - Of order 50 such events → studying these in detail
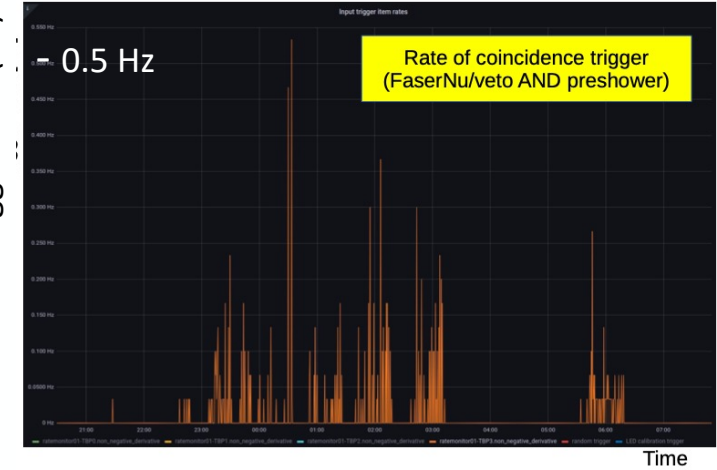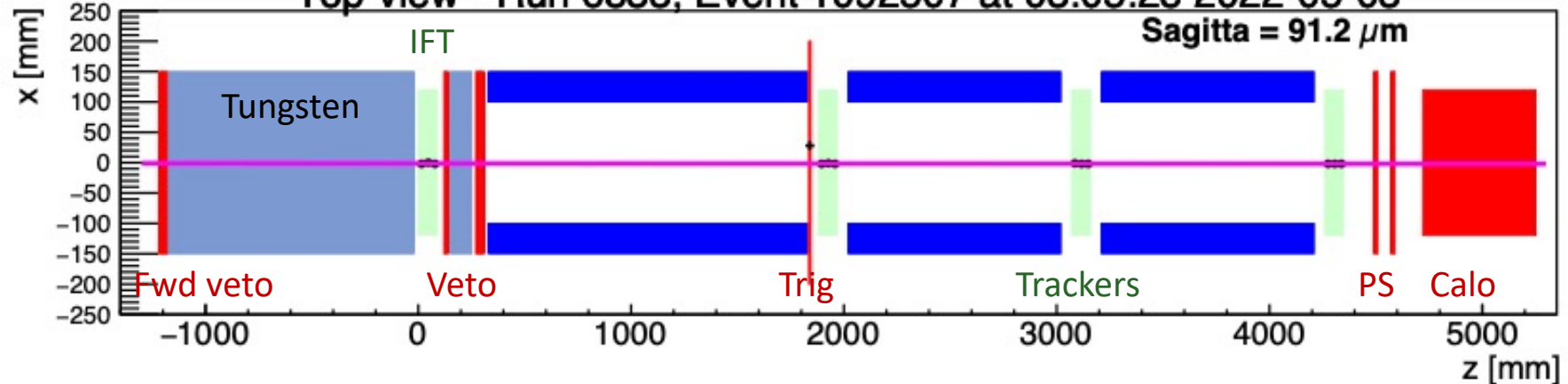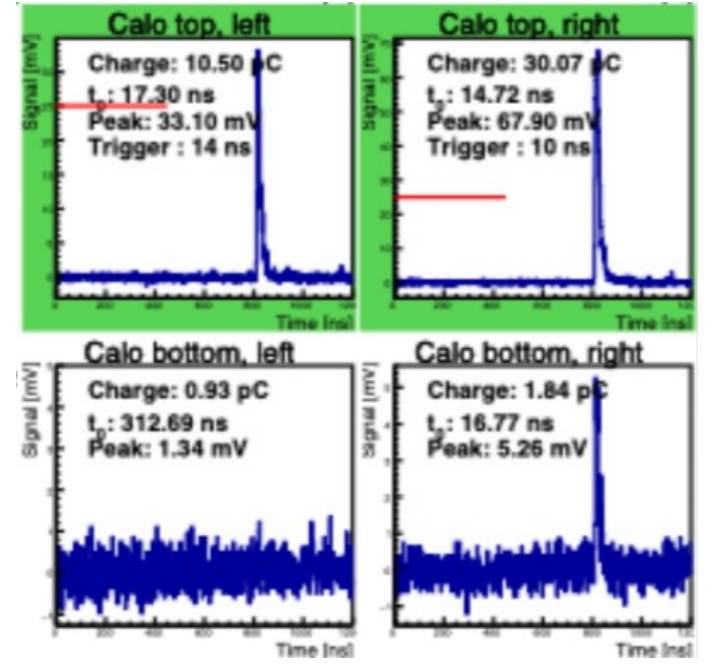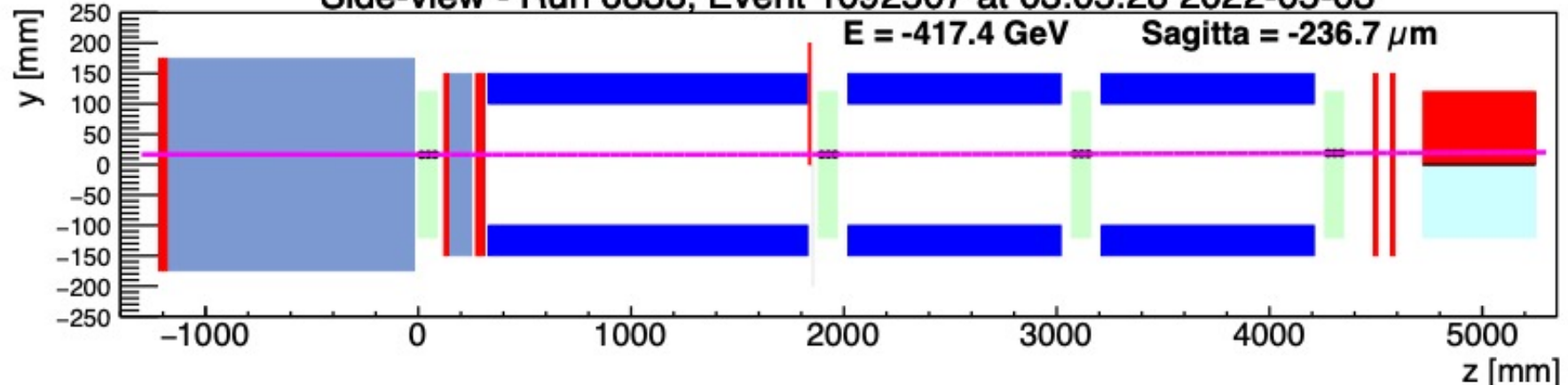
Mock Data Challenge

- Physics Coordination structure set up in January 2022 and Carl appointed as Co-coordinator
  - Ensure timely, high-quality physics output that is well documented and reproducible

- Setup Mock Data Challenge (MDC) to ensure readiness for data-taking:
  - Test full production chain from generation all the way through to analysis
  - Exercise organisation structure and communication procedures

- Goal is to demonstrate end-to-end analysis workflow
 - Focus effort on finalising software → significant progress
  - Determine readiness and uncover missing pieces
  - In addition, jump start analysis effort

- Representative signal and background processes have been generated
  - Currently undergoing simulation, digitisation and reconstruction
  - Analysis part starting imminently and will run till ~end of July
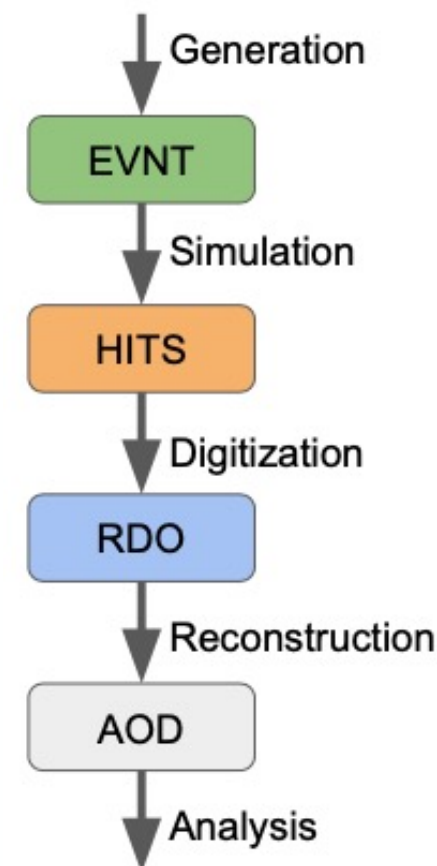
Forward Physics Facility (FPF)

- Proposal to build a new dedicated forward physics facility
  - Hosting a suite of far-forward experiments at the HL-LHC
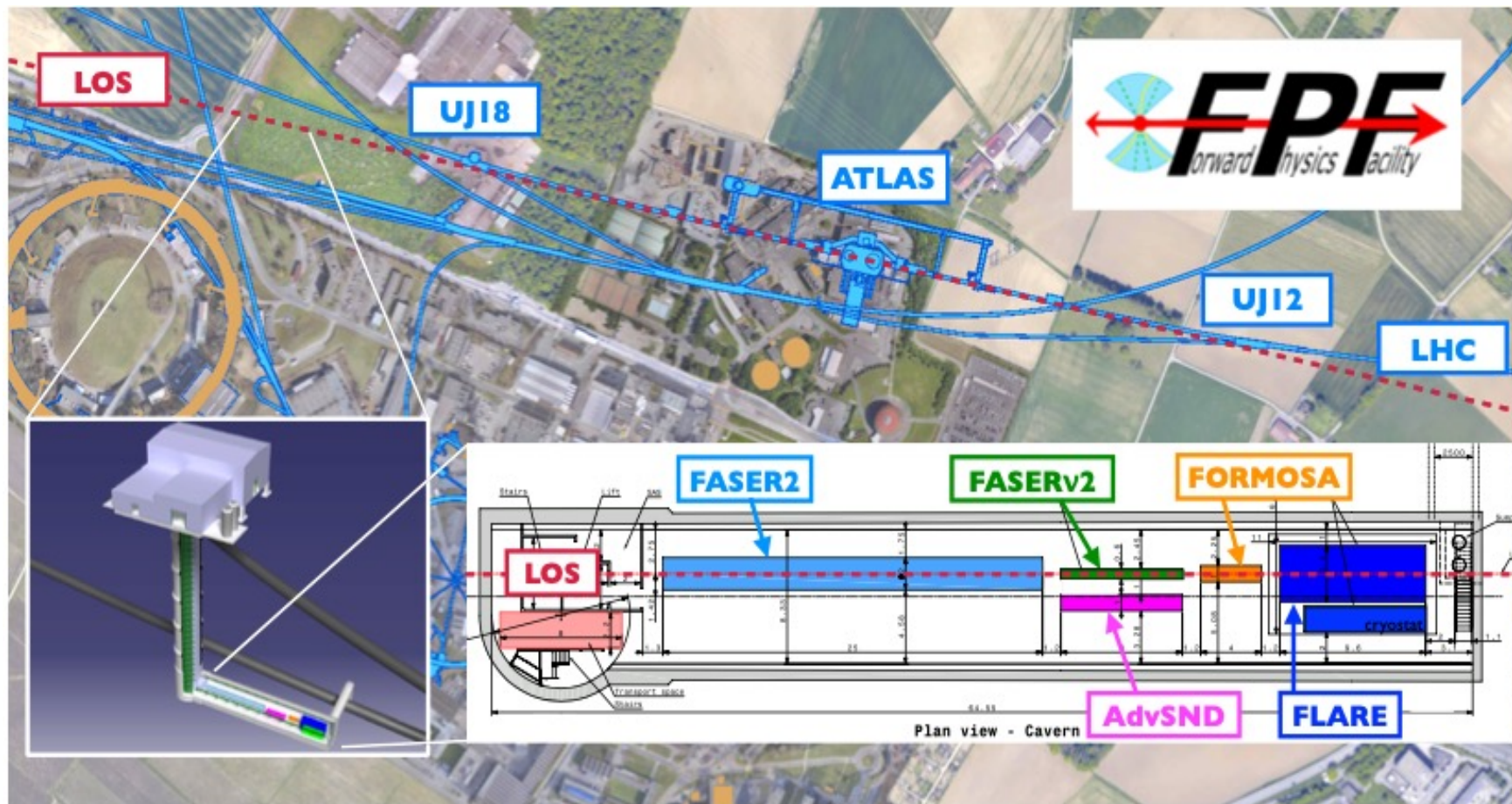
- Current planned detectors
- **FASER2**
  - FASER scaled to r=1m
  - Light dark sector parts.
- **FASERnu2**
  - ~20t emulsion + tungsten detector
  - Mainly ν_τ
- AdvSND
  - Off axis ν detector
  - Fwd charm + low-x gluon
- FORMOSA
  - Scintillating bars
  - Millicharged particles
- FLArE
  - ~10t LAr TPC
  - DM + ν physics

- Detailed (429pp) paper submitted as part of Snowmass: https://arxiv.org/abs/2203.05090

FPF Physics

- Benefits from inc. HL-LHC lumi by allowing
  - Longer detectors
    - Increased target/decay volume
  - Wider detectors
    - Increased sensitivity to HF production
  - New detectors
    - Complementary physics capabilities

- FPF has a rich + broad physics program
  - Across a variety of areas …

- Main physics motivations
  - BSM dark sector searches
  - Neutrino physics
    - ~10^5 ν_e, 10^6 ν_μ, 10^3 ν_τ
  - QCD physics
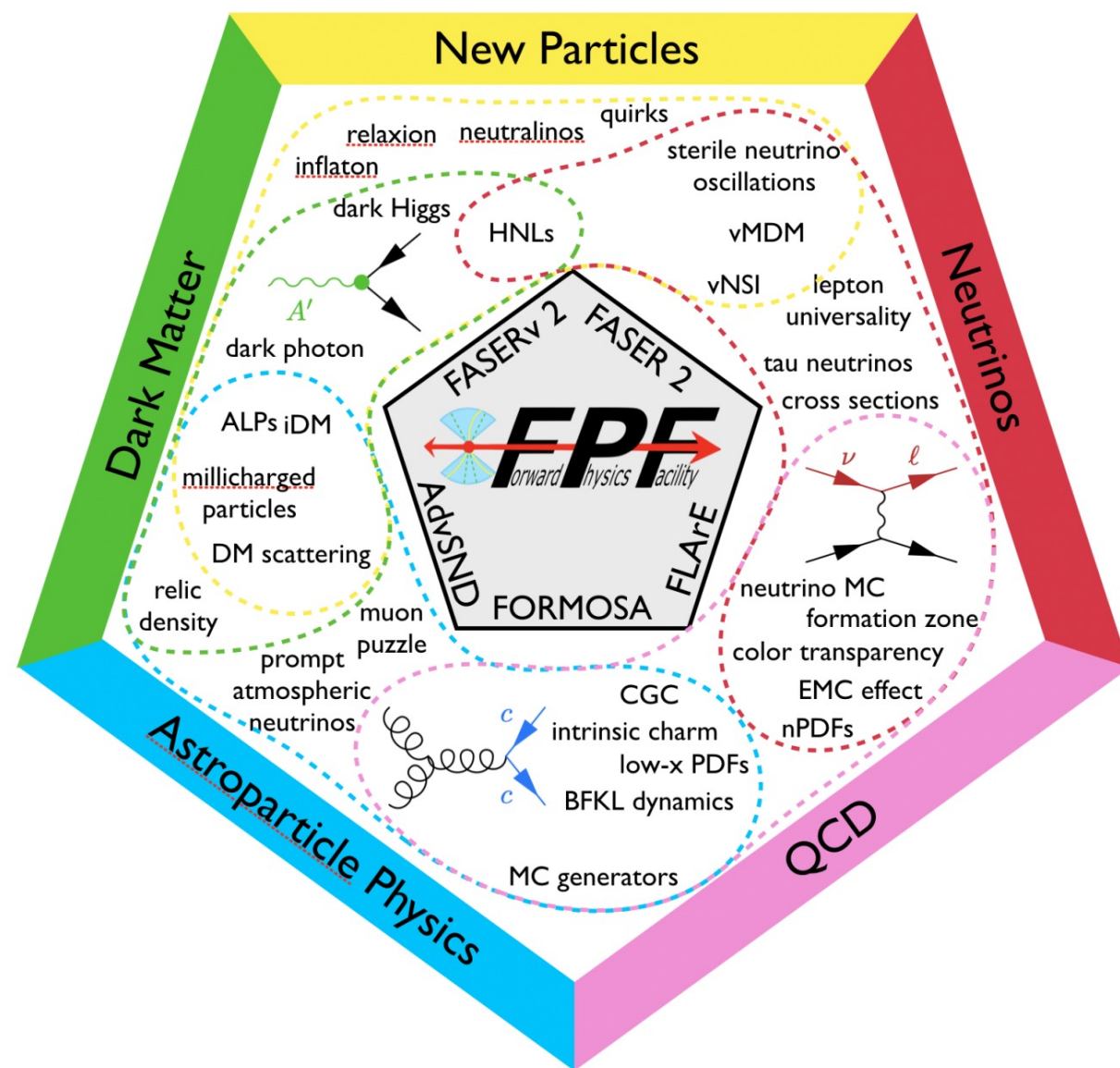
FASER(nu)2

- Conceptually a scaled up version of FASER2
  - Veto: similar scintillator-based
  - Magnets: Superconducting with B = 1 T
  - Tracker: much larger → considering SiFi/SiPM
  - Calo/Muon: enhanced PID & position resolution
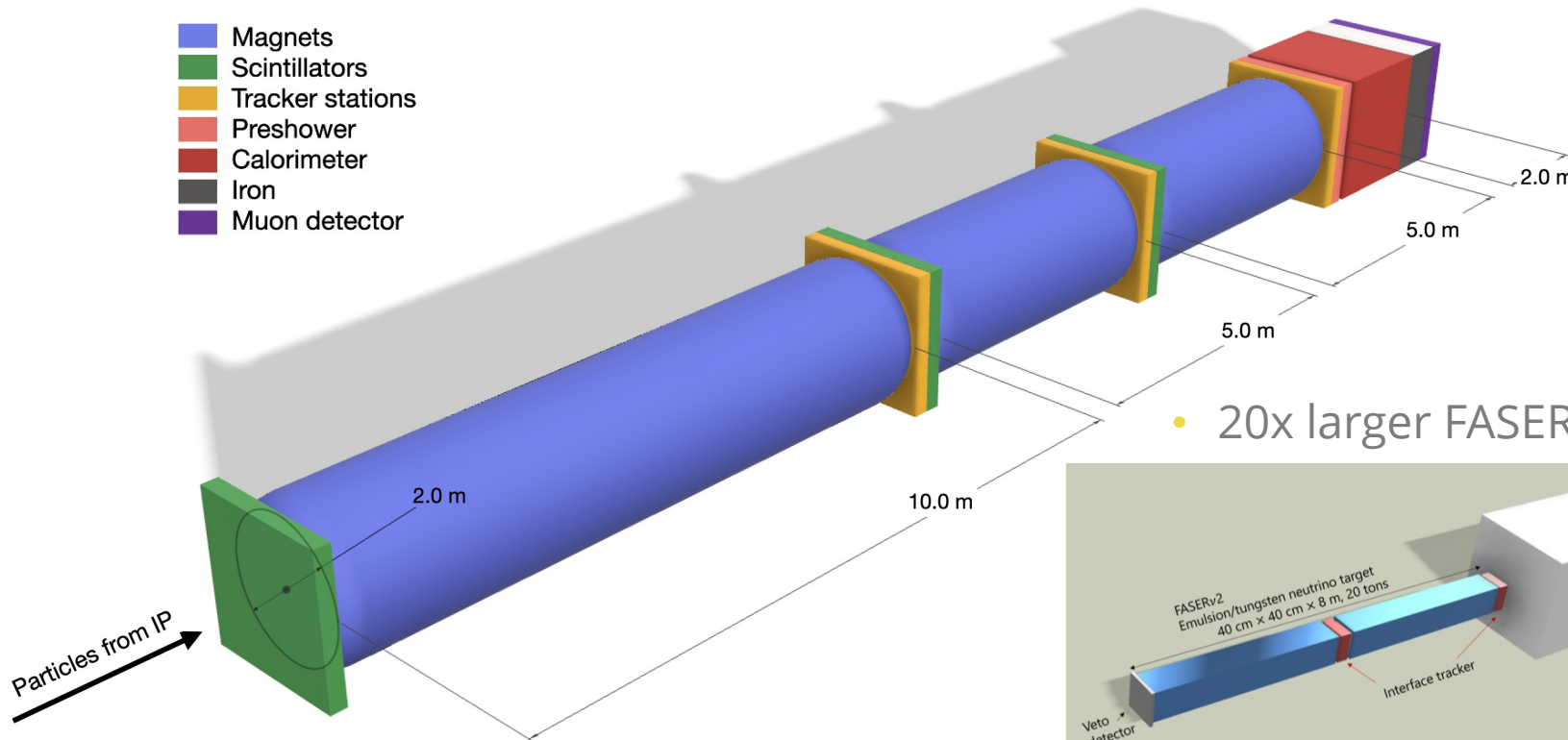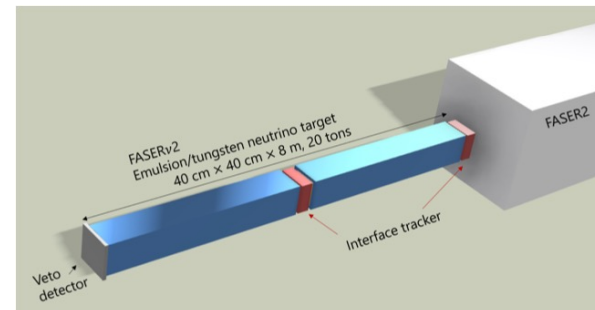
	FASER	FASER2
R [m]	0.1	1
DV [m}	1.5	10
TS [m]	2.6	10

Active area x ~100

- Wider LLP physics program
  - Probing up to higher mass

Benchmark Model	FASER	FASER 2
Dark Photons	✓	✓
$B - L$ Gauge Bosons	✓	✓
$L_i - L_j$ Gauge Bosons	—	—
Dark Higgs Bosons	—	✓
Dark Higgs Bosons with hSS	—	✓
HNLs with e	—	✓
HNLs with μ	—	✓
HNLs with τ	✓	✓
ALPs with Photon	✓	✓
ALPs with Fermion	—	✓
ALPs with Gluon	✓	✓
Dark Pseudoscalars	—	✓

Magnets
Scintillators
Tracker stations
Preshower
Calorimeter
Iron
Muon detector

2.0 m

5.0 m

5.0 m

2.0 m

10.0 m

Particles from IP

- 20x larger FASERNu

FASERv2
Emulsion/tungsten neutrino target
40 cm × 40 cm × 8 m, 20 tons

FASER2

Interface tracker

Veto detector
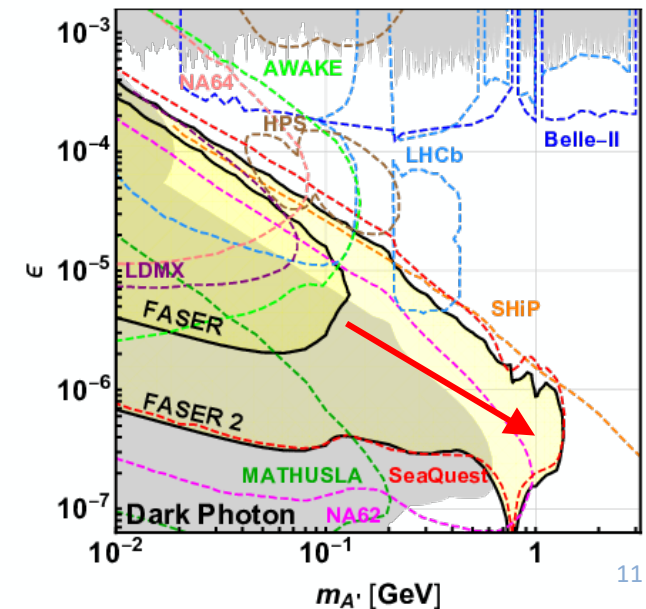
Summary + Outlook

- FASER detector successfully commissioned and installed in TI12 ready for run-3
  - Already observed high-energy first collision events passing through full detector

- Currently finalising and validating software in readiness for imminent data taking
  - Dedicated Mock Data Challenge

- Liverpool have played a major role across the collaboration
  - Simulation and digitisation for ECAL
  - Analysing test beam data
  - Detector paper editor
  - Physics coordination

- Well placed to make the most of first data-taking
  - Expect to probe new ground already with 2022 data
  - Planning for first results at conferences next year

- In the longer term, proposal for dedicated forward physics facility
  - If approved, we are interested in detector development towards FASER2 and FASERnu2

Happy

Christmas
World Bee Day