

FASER

ForwArd Search ExpeRiment

Monica D'Onofrio, [Carl Gwilliam](#), Lottie Cavanagh

20th May 2022

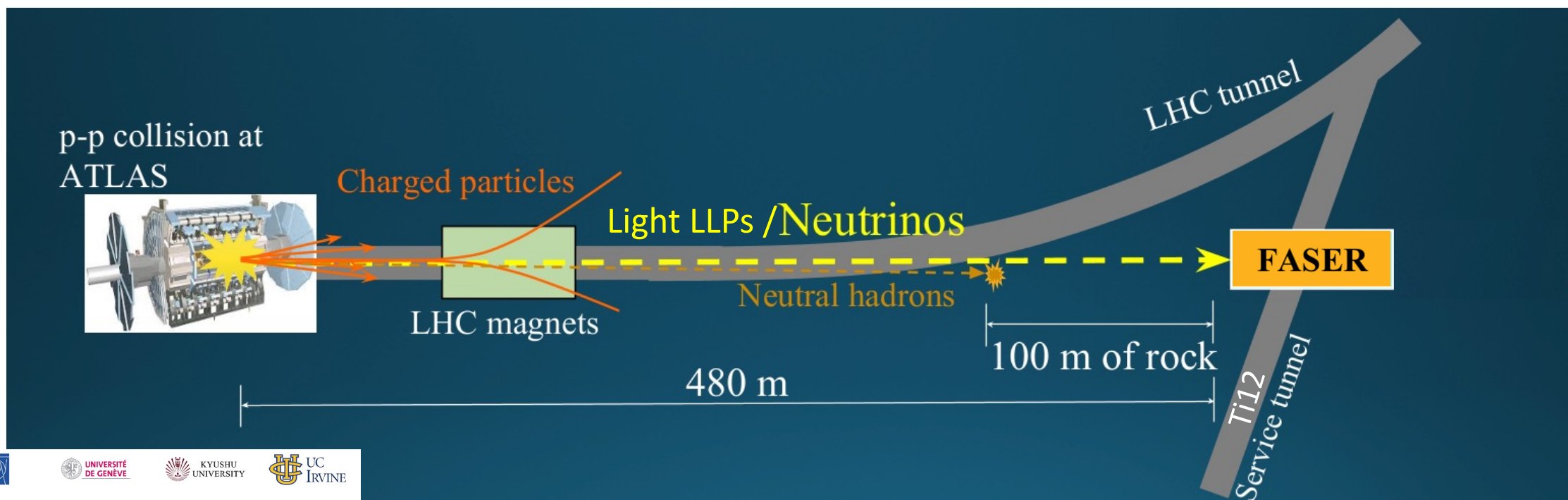
Liverpool HEP Annual meeting



UNIVERSITY OF
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FASER Experiment and Collaboration

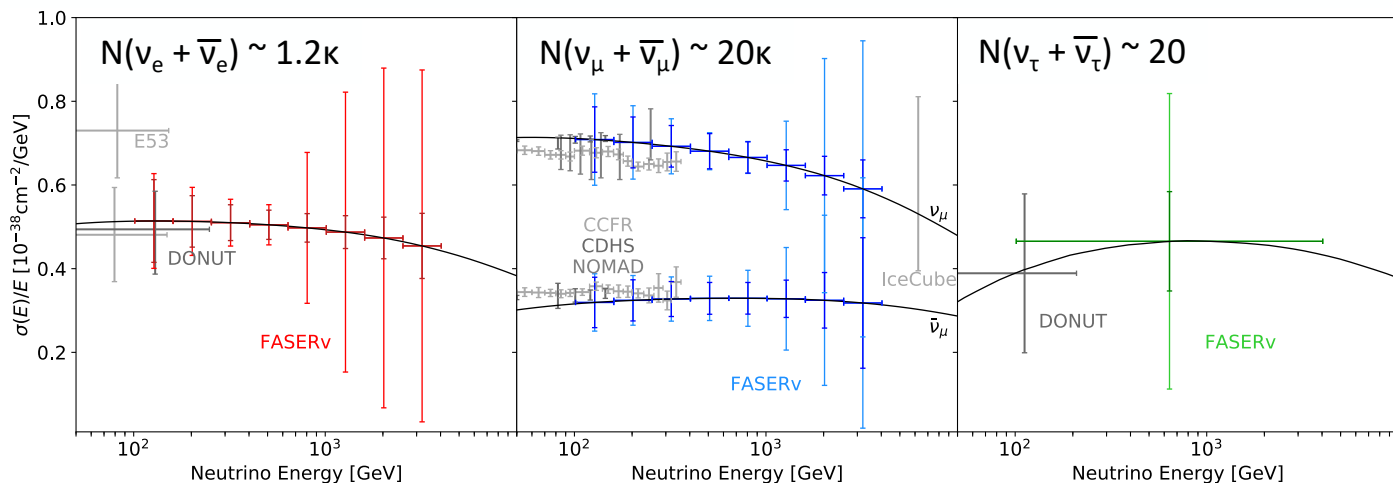
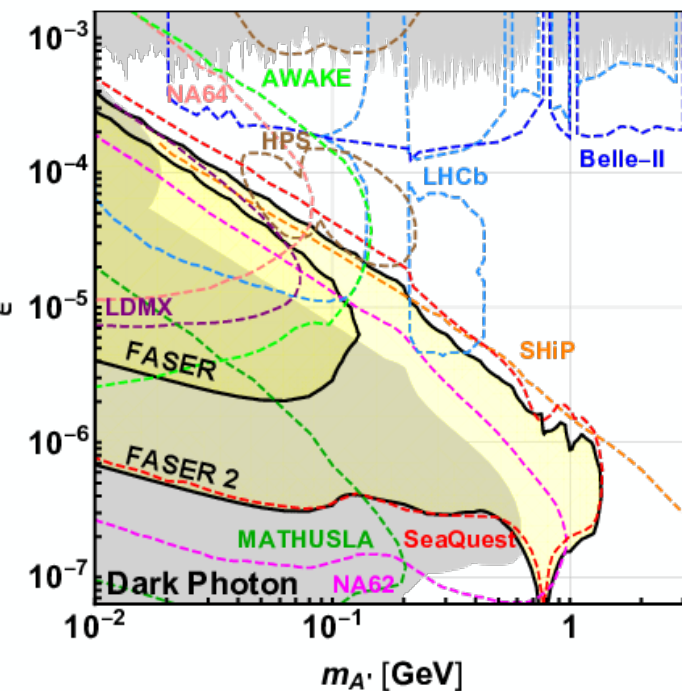
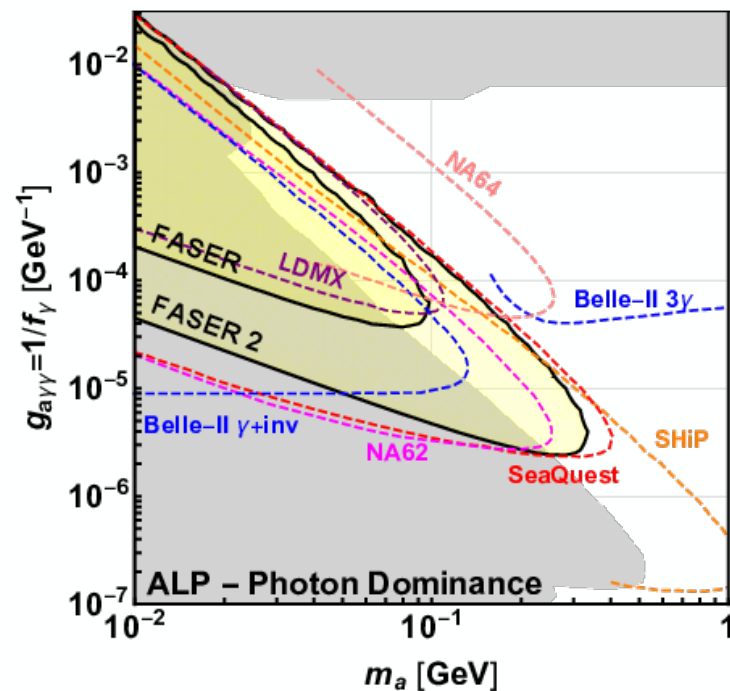
- New LHC run-3 experiment located 480 m downstream of ATLAS in Ti12 side service tunnel
 - Along line-of-sight after LHC curves away behind 100 m rock → low background rate



- 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 \rightarrow LLP, LLP travels $\sim 480\text{m}$, LLP \rightarrow ee, $\gamma\gamma$, $\mu\mu$, ...
- 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

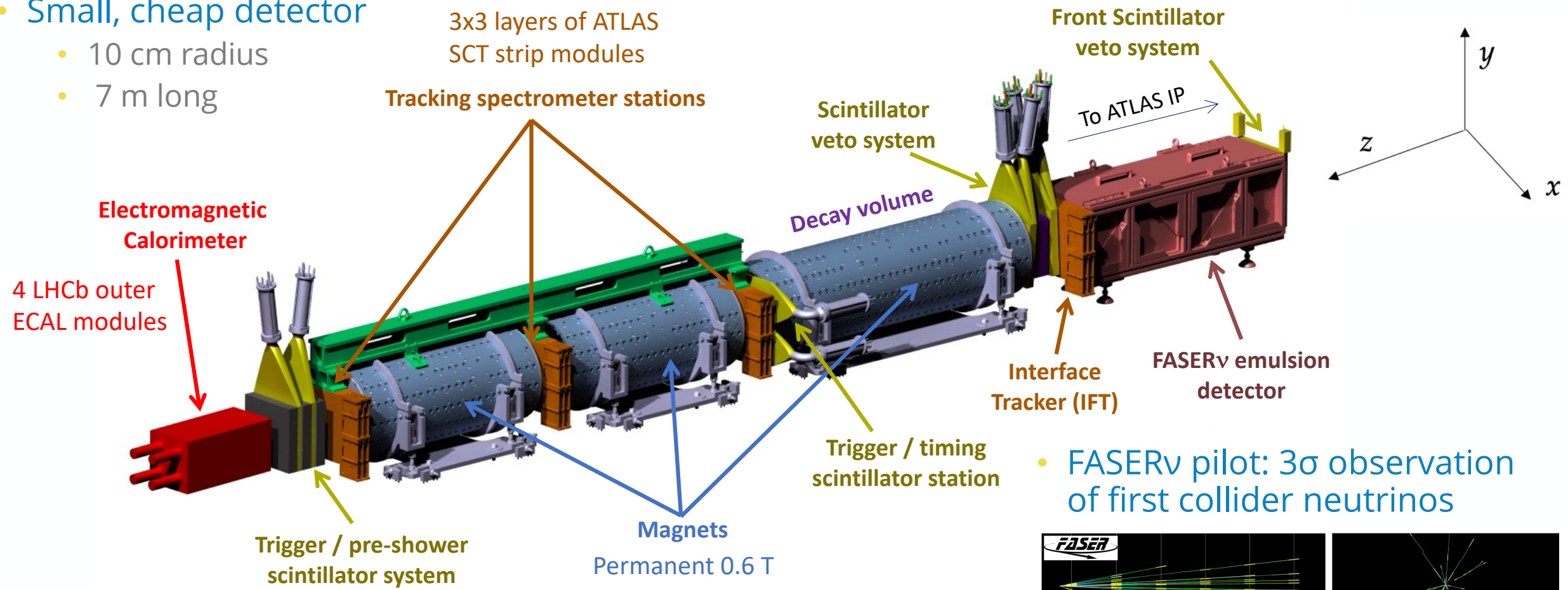


- FASERnu adds neutrino program
 - First observation of collider neutrinos
- Cross-section measurement in E range from ~ 100 GeV to ~ 1 TeV
 - Unconstrained region of phase space

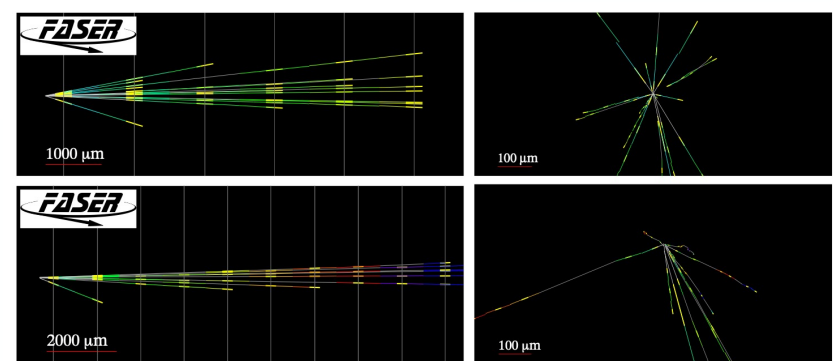
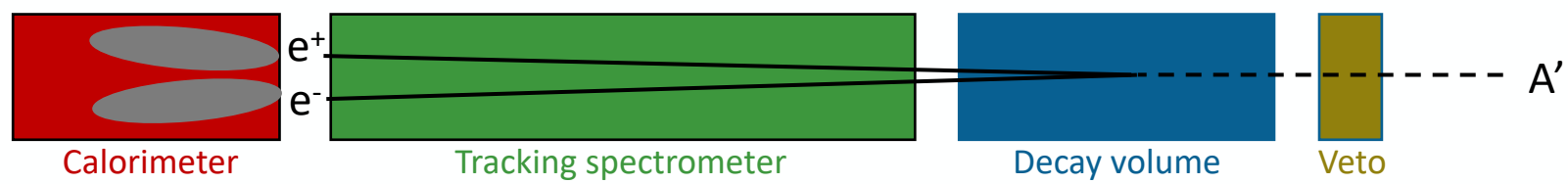
FASER Detector

- Small, cheap detector

- 10 cm radius
- 7 m long



- FASERv pilot: 3σ observation of first collider neutrinos



Successfully Commissioned and Installed in Ti12

- Further commissioning with cosmics and beam splashes / single beams



1 PREPARED FOR SUBMISSION TO JINST
2 ©2021 CERN FOR THE BENEFIT OF THE FASER COLLABORATION.
3 VERSION 1

4 **The FASER Detector**

5 **FASER Collaboration**

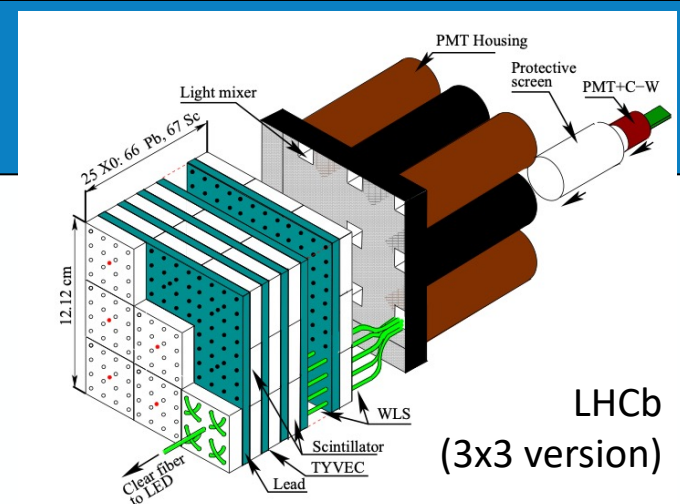
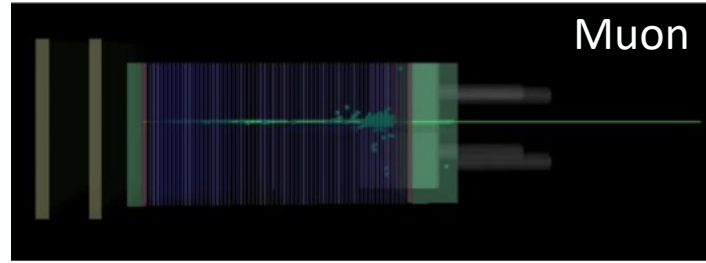
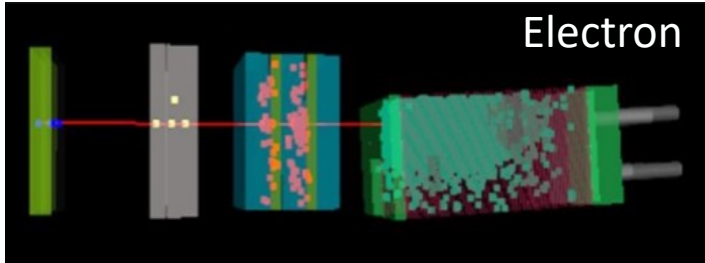
6 **Henso Abreu¹, Elham Amin Mansour², Claire Antel², Akitaka Ariga^{3,21}, Tomoko Ariga⁴, Florian Bernlochner⁵, Tobias Boeckh⁵, Jamie Boyd⁶, Lydia Brenner⁶, Franck Cadoux², David W. Casper⁷, Charlotte Cavanagh⁸, Xin Chen⁹, Andrea Coccaro¹⁰, Olivier Crespo-Lopez⁶, Stéphane Déblieux², Sergey Dmitrievsky¹¹, Monica D'Onofrio⁸, Liam Dougherty⁶, Candan Dozen⁹, Abdallah Ezzi²³, Yannick Favre², Deion Fellers¹², Jonathan L. Feng², Didier Ferrere², Edward Karl Galantay², Jonathan Gall⁶, Enrico Gamberini⁶, Stephen Gibson¹³, Sergio Gonzalez-Sevilla², Yuri Gornushkin¹¹, Carl Gwilliam⁸, Daiki Hayakawa¹¹, Shih-Chieh Hsu¹⁴, Zhen Hu⁹, Giuseppe Iacobucci², Tomohiro Inada⁹, Sune Jakobsen⁶, Elliott Johnson², Enrique Kajomovitz², Felix Kling¹⁵, Umut Kose⁶, Rafaella Kotitsa⁶, Jesse Krusse^{24,25}, Susanne Kuehn⁶, Helena Lefebvre¹³, Lorne Levinson¹⁶, Ke Li¹⁴, Jinfeng Liu⁹, Chiara Magliocca², Josh McFayden¹⁷, Sam Meehan², Matteo Milanese², Manato Miura²¹, Dimitar Mladenov², Théo Moretti², Magdalena Munker², Mitsuhiro Nakamura¹⁸, Toshiyuki Nakano¹⁸, Marzio Nesi^{6,2}, Friedemann Neuhaus¹⁹, Laurie Nevay¹³, Hidetoshi Otono⁴, John Osborne⁶, Carlo Pandini²⁰, Hao Pang⁹, Lorenzo Paolozzi^{6,2}, Brian Petersen⁶, Francesco Pietropaolo⁶, Markus Prim⁵, Michaela Queitsch-Maitland⁶, Filippo Resnati⁶, Chiara Rizzi², Hiroki Rokujo¹⁸, Elisa Ruiz-Cholz¹⁹, Jakob Salfeld-Nebgen⁶, Francisco Sanchez Galan⁶, Osamu Sato¹⁸, Paola Scamporrì²², Kristof Schmiedner¹⁹, Matthias Schott¹⁹, Anna Styrla², Savannah Shively⁷, Roland Sipek⁶, John Spencer¹⁴, Yosuke Takubo²⁰, Noshin Tarannum², Ondrej Theiner², Pierre Thonet⁶, Eric Torrence¹², Serhan Tufanli⁶, Svetlana Vasina¹¹, Camille Vendevour⁶, Benedikt Vormwald⁶, Di Wang⁹, Stefano Zambito², Gang Zhang⁹**

27 ¹Department of Physics and Astronomy, Technion—Israel Institute of Technology, Haifa 32000, Israel
28 ²Département de Physique Nucléaire et Corpusculaire, University of Geneva, CH-1211 Geneva 4, Switzerland
29 ³Albert Einstein Center for Fundamental Physics, Laboratory for High Energy Physics, University of Bern, Sidlerstrasse 5, CH-3012 Bern, Switzerland
30 ⁴Kyushu University, Nishi-ku, 819-0395 Fukuoka, Japan
31 ⁵Universität Bonn, Regina-Pacis-Weg 3, D-53113 Bonn, Germany
32 ⁶CERN, CH-1211 Geneva 23, Switzerland
33 ⁷Department of Physics and Astronomy, University of California, Irvine, CA 92697-4575, USA

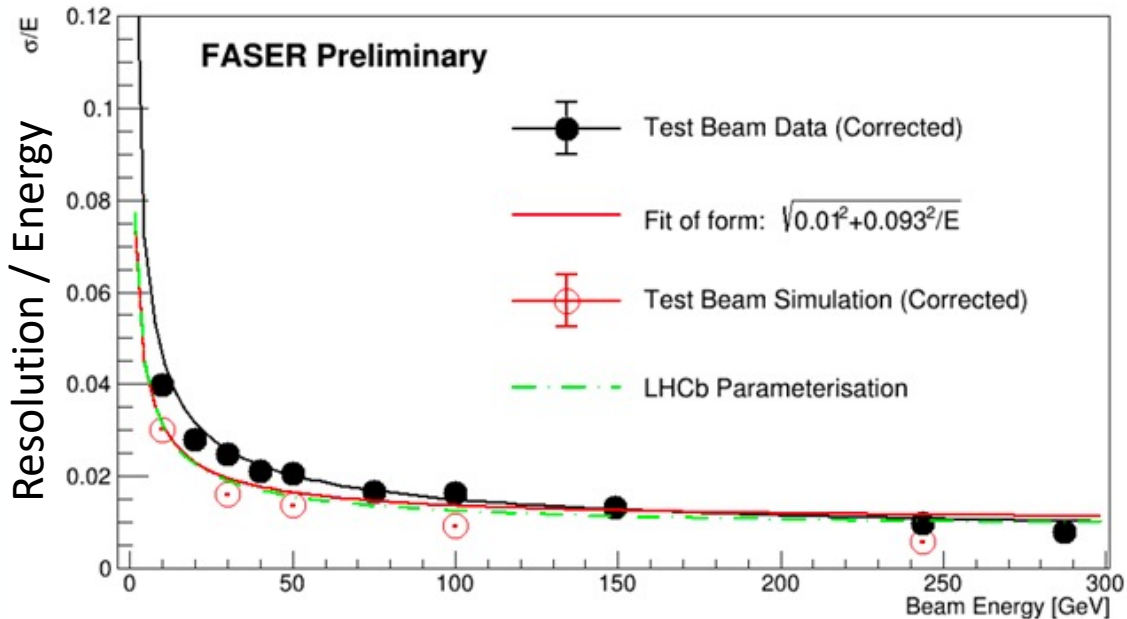
- Detector paper being finalised for publication
- Monica is co-editor

EM Calorimeter and Test Beam

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

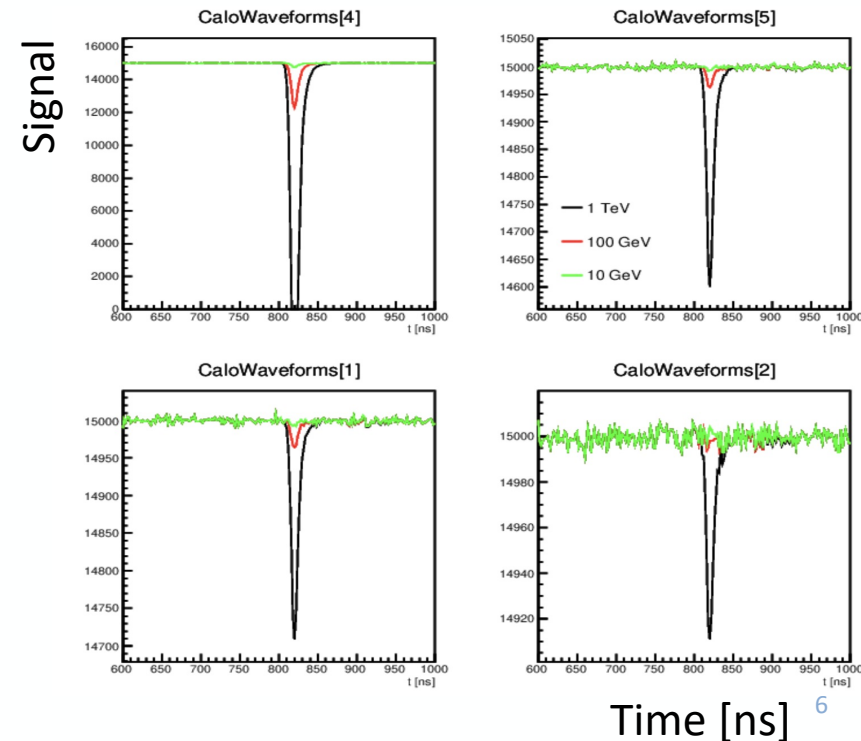


- Sim compares reasonably with data from recent Test Beam
 - Proposed by Liverpool amongst others



- Higher-order effects to be added from TB measurements
- See [Lottie's talk](#) yesterday for more details
- Test beam paper In preparation

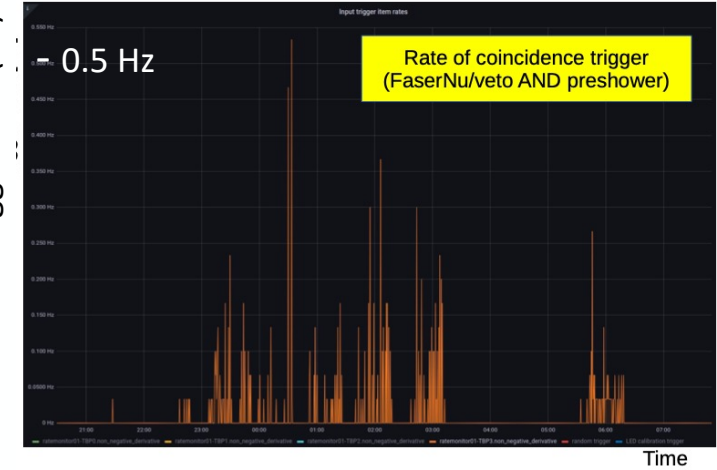
- Implemented first version of digi
 - Now compare sim+digi to TB data



First 6.8 TeV Beam Data!

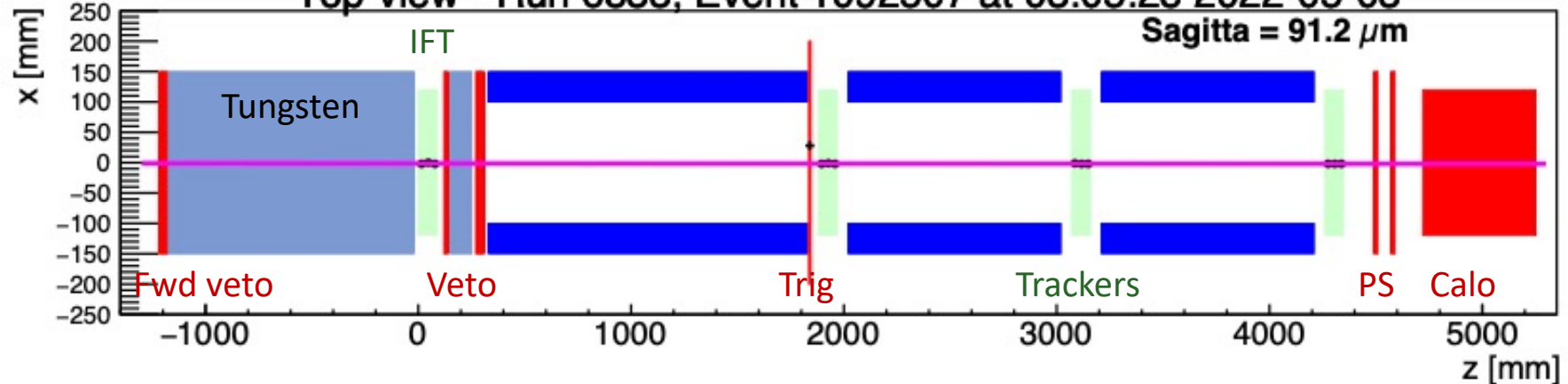
- FASER able to see particles from recent 6.8 TeV beam optics tests
 - First particles traversing full detector, including interface tracker
 - Of order 50 such events \rightarrow studying these in detail

Trigger rate (Hz)



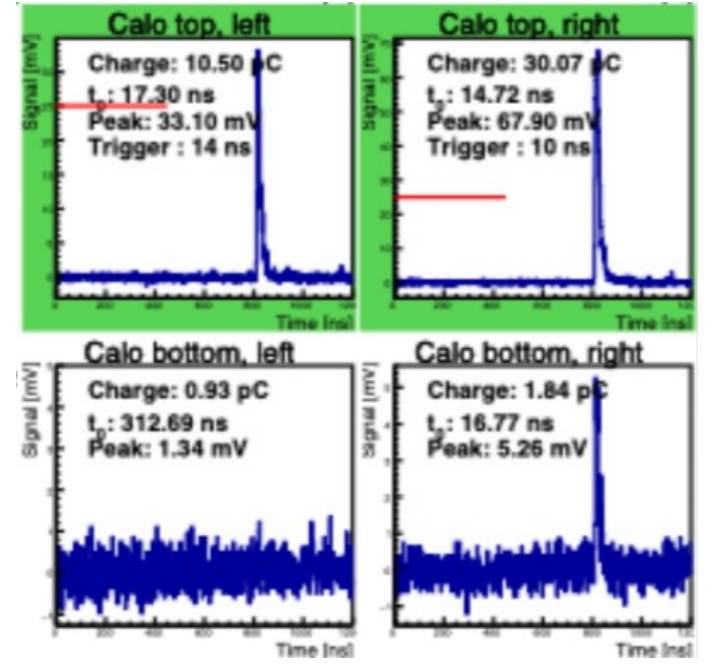
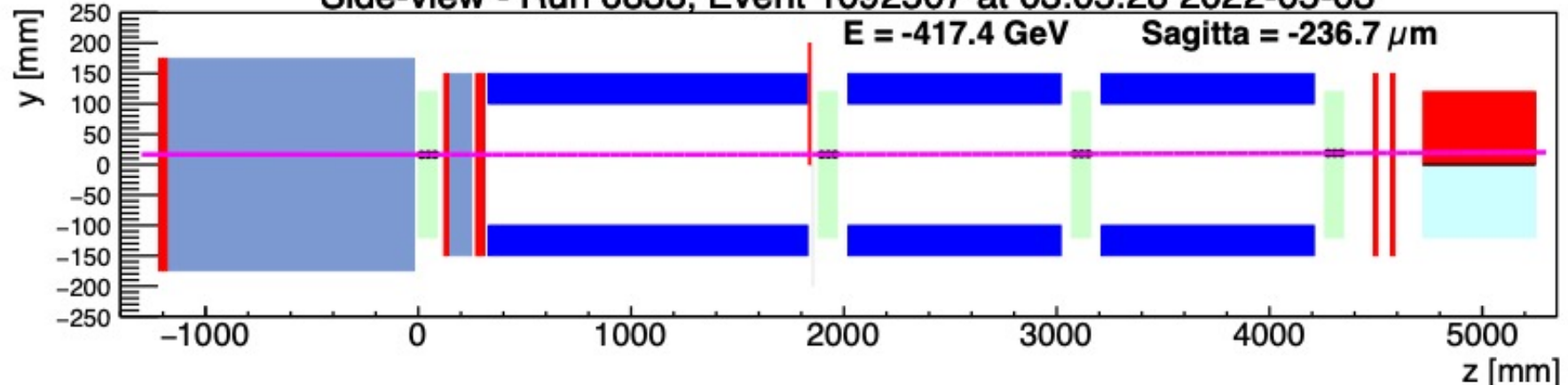
Top-view - Run 6833, Event 1092507 at 03:05:28 2022-05-03

Sagitta = $91.2 \mu\text{m}$



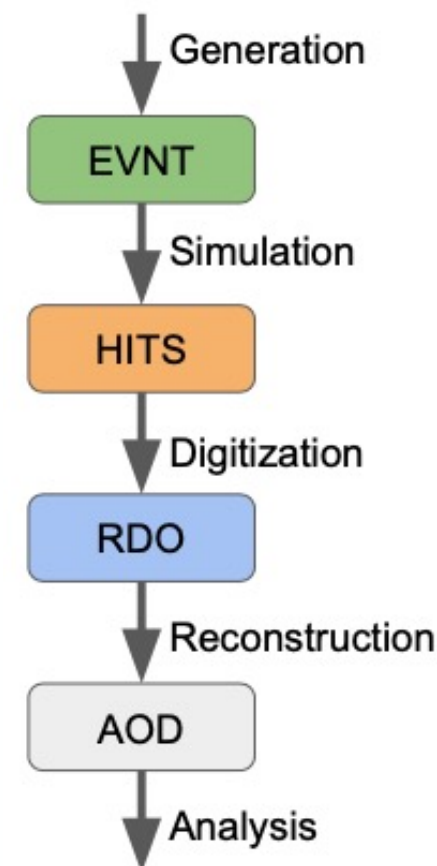
Side-view - Run 6833, Event 1092507 at 03:05:28 2022-05-03

E = -417.4 GeV Sagitta = $-236.7 \mu\text{m}$



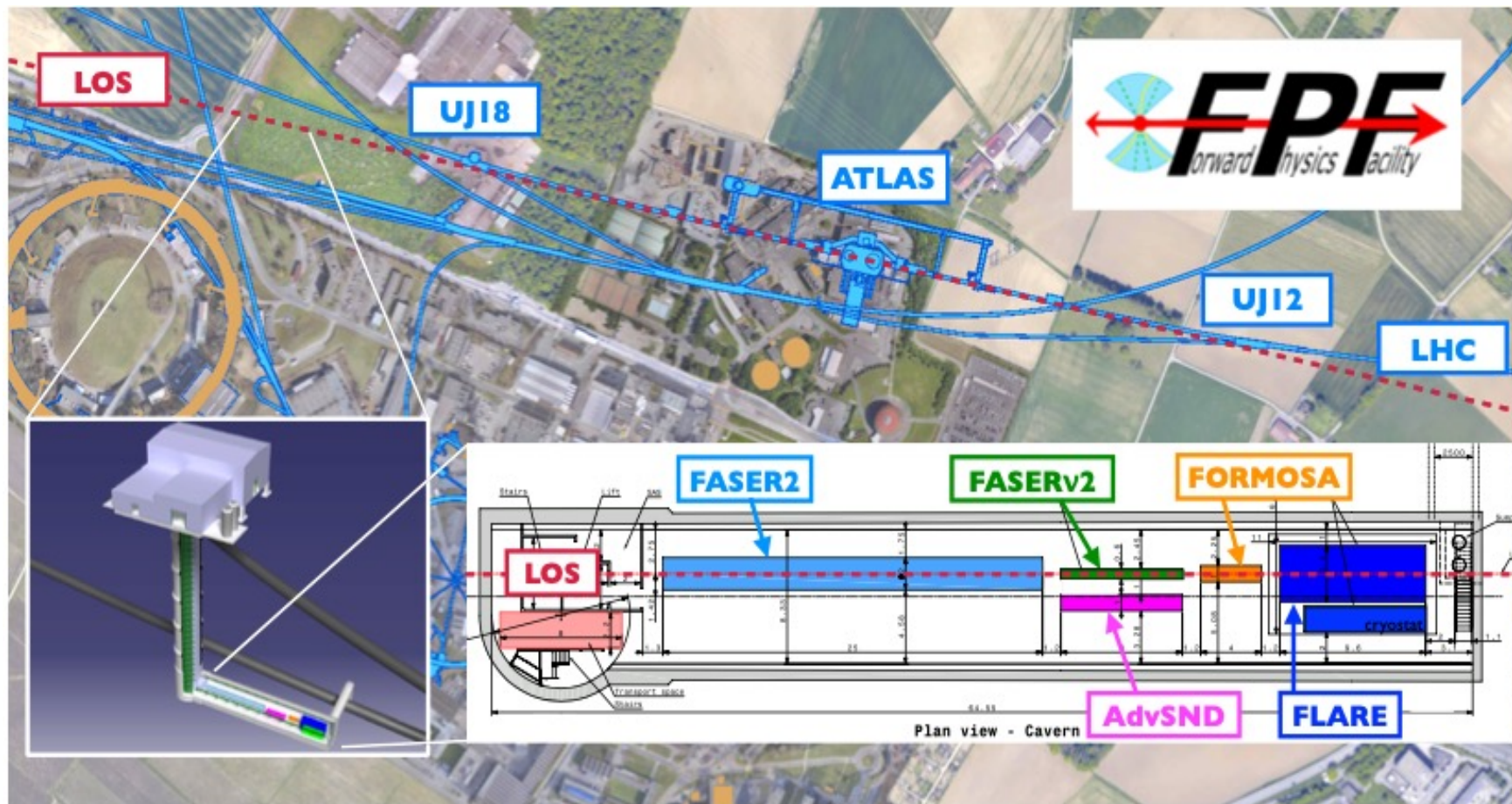
Mock Data Challenge

- 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

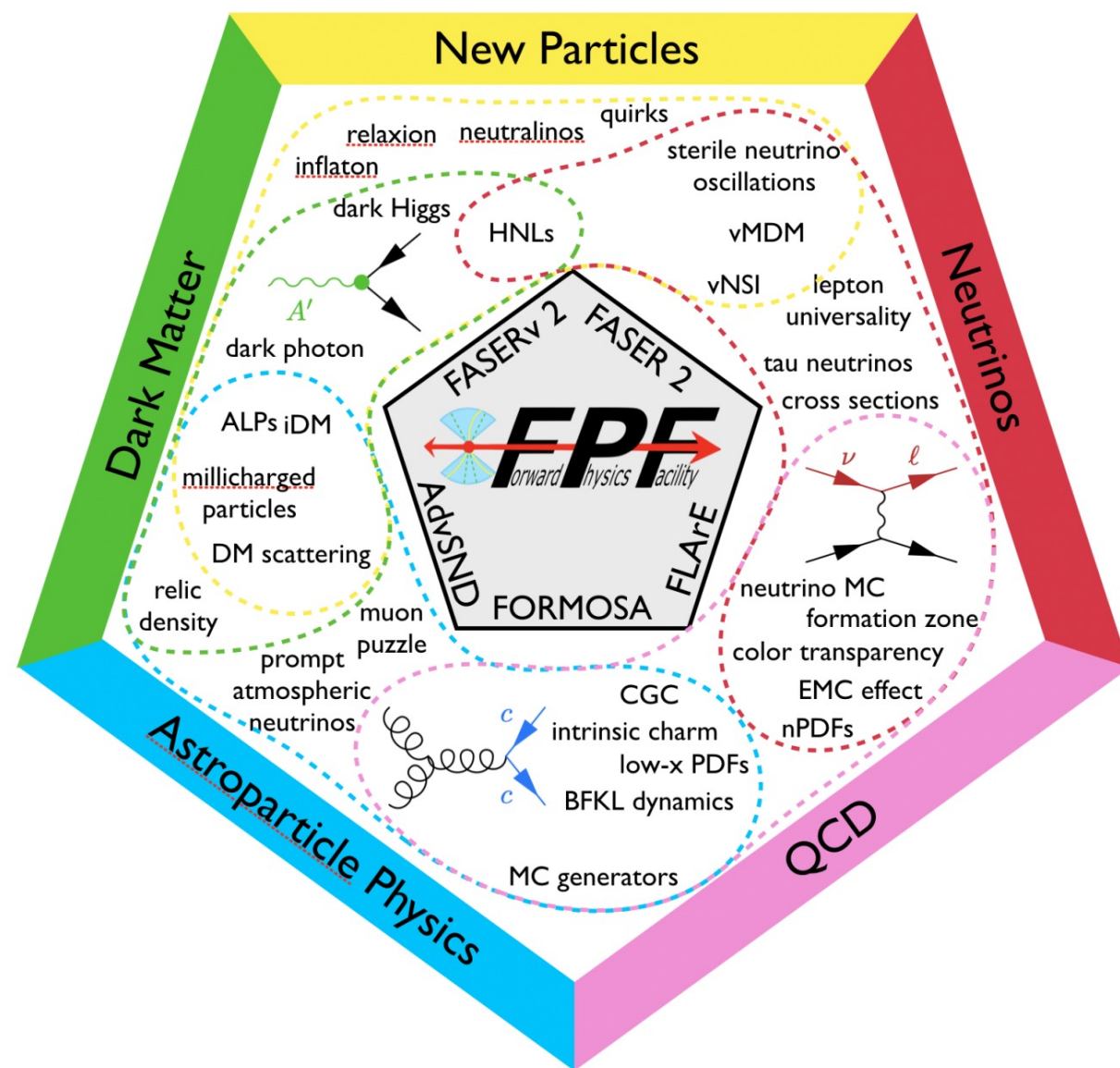


- Current planned detectors
- **FASER2**
 - FASER scaled to $r=1\text{m}$
 - Light dark sector parts.
- **FASERnu2**
 - $\sim 20\text{t}$ emulsion + tungsten detector
 - Mainly ν_τ
- AdvSND
 - Off axis ν detector
 - Fwd charm + low-x gluon
- **FORMOSA**
 - Scintillating bars
 - Millicharged particles
- **FLArE**
 - $\sim 10\text{t}$ 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
 - $\sim 10^5 \nu_e, 10^6 \nu_\mu, 10^3 \nu_\tau$
 - QCD physics



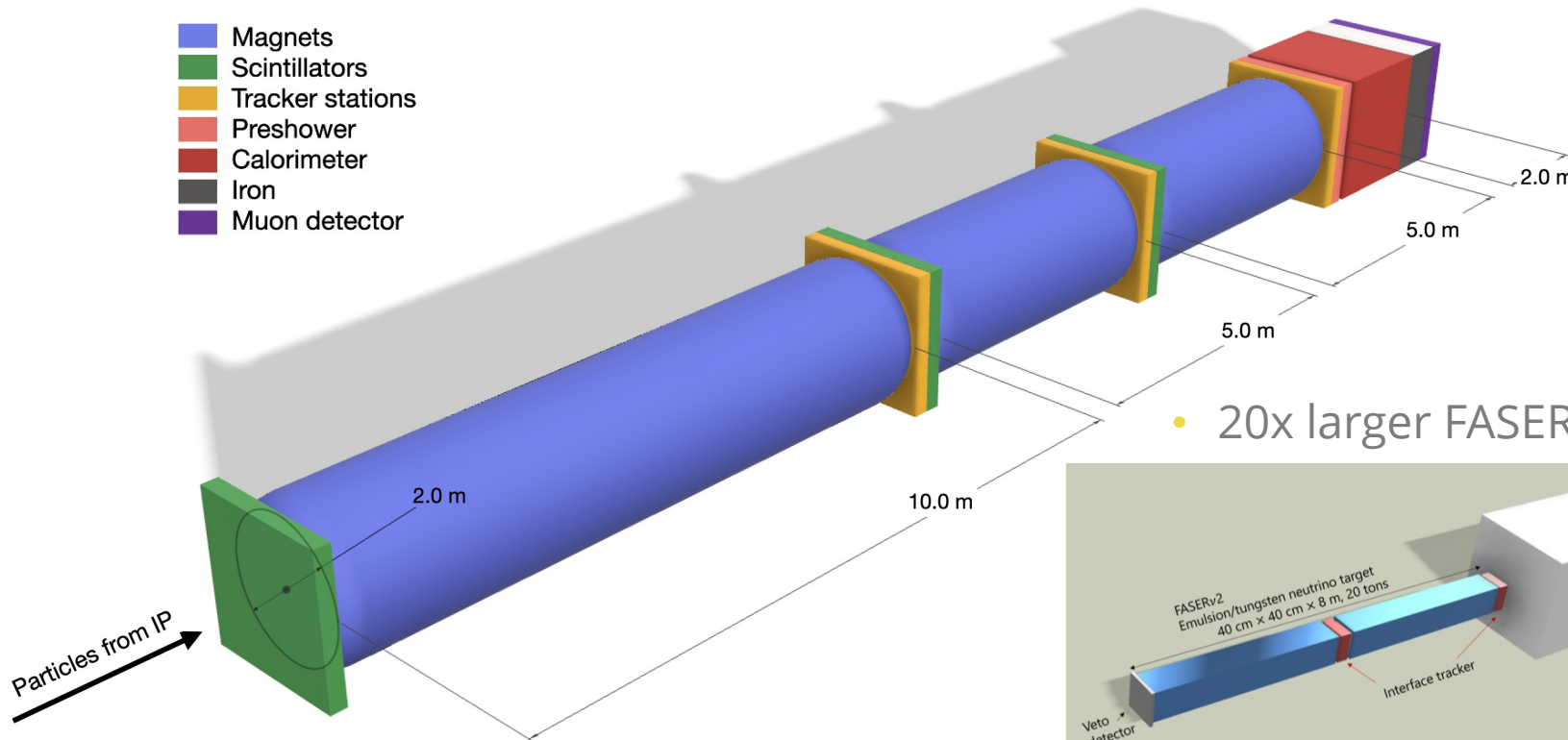
FASER(nu)2

- Conceptually a scaled up version of FASER2
 - Veto: similar scintillator-based
 - Magnets: Superconducting with $B = 1$ T
 - Tracker: much larger \rightarrow considering SiFi/SiPM
 - Calo/Muon: enhanced PID & position resolution

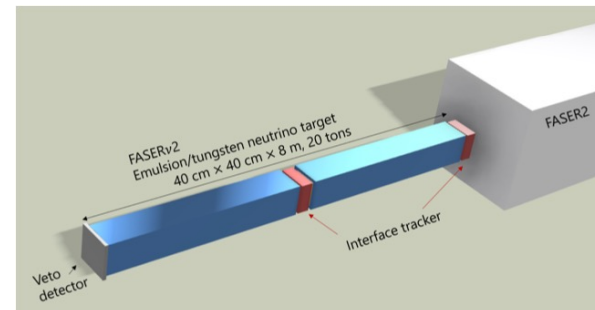
	FASER	FASER2
R [m]	0.1	1
DV [m]	1.5	10
TS [m]	2.6	10

Active area $\times \sim 100$

- Magnets
- Scintillators
- Tracker stations
- Preshower
- Calorimeter
- Iron
- Muon detector

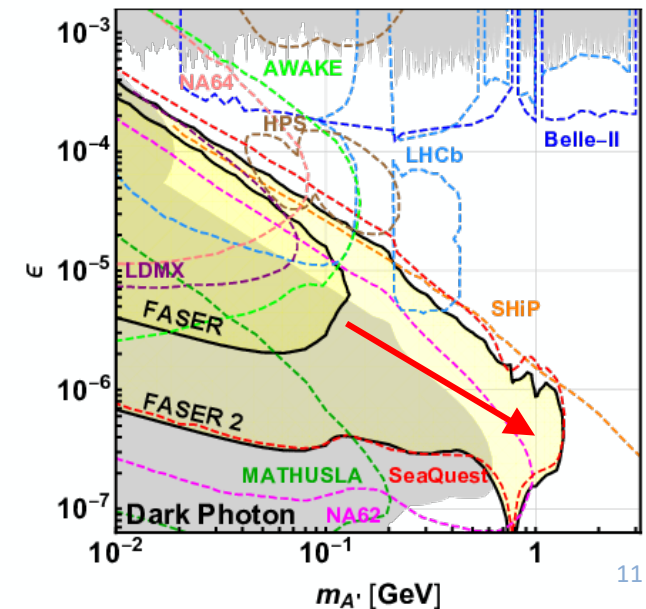


- 20x larger FASERnu



- 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	—	✓



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
 - Detector paper editor
 - Analysing test beam data
 - 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

