FASER: Forward Search Experiment at the LHC

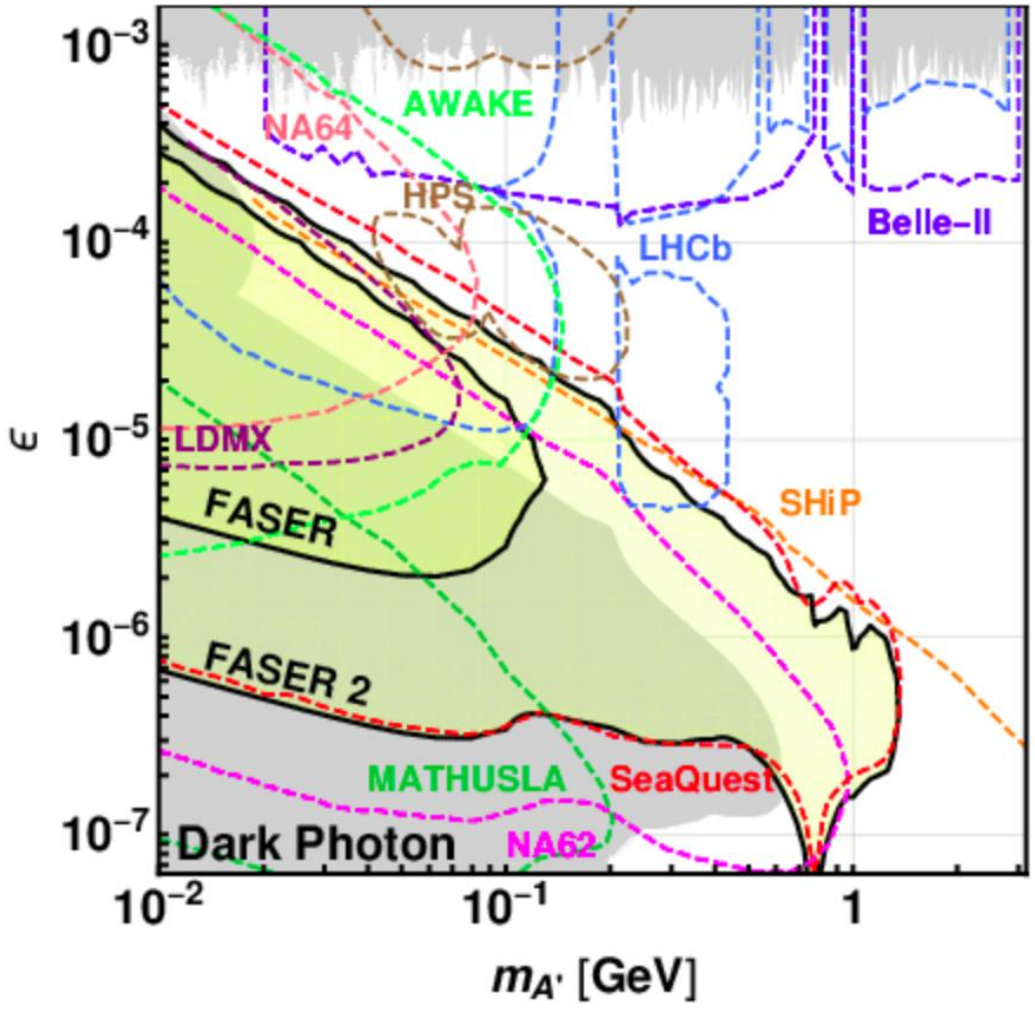
Di Wang (Tsinghua University)

For the FASER Collaboration

EPS-HEP 2021

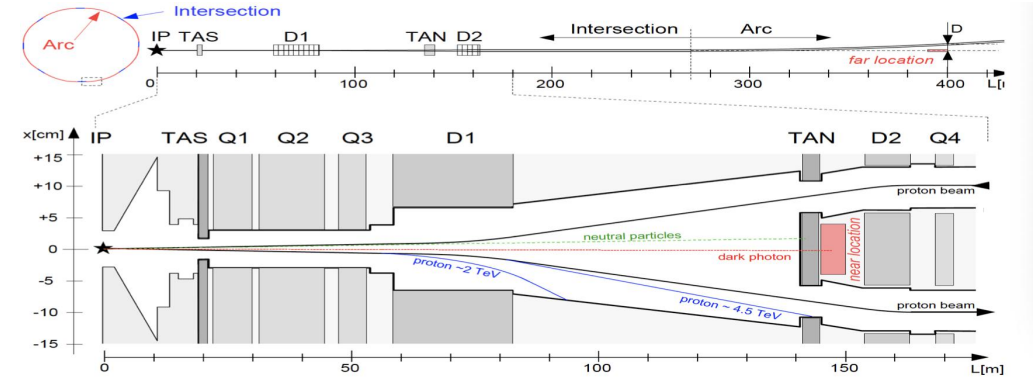
The Physics Prospects

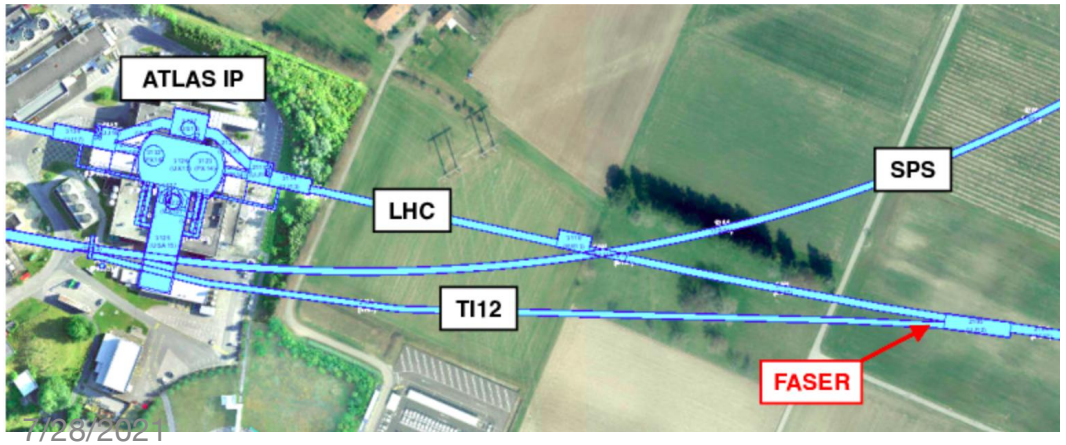
- Most LHC experiments focus on heavy, strongly interacting particles
- The physics goal of FASER(the Forward Search Experiment) is light long-lived particles (LLPs) related to physics beyound the Standard Model
- These new particles are related to many important and basic questions, such as dark matter



The Physics Prospects

- The FASER experiment is a small and inexpensive experiment located at TI12 side tunnel (480 m from ALTAS IP)
- Charged particles produced from the IP are deflected by LHC magnets
- Neutral hadrons are absorbed by LHC infrastructure (TAS/TAN) or 100m of rock between the IP and FASER
- LLPs pass through the LHC infrastructure/rock without interacting





The Physics Prospects

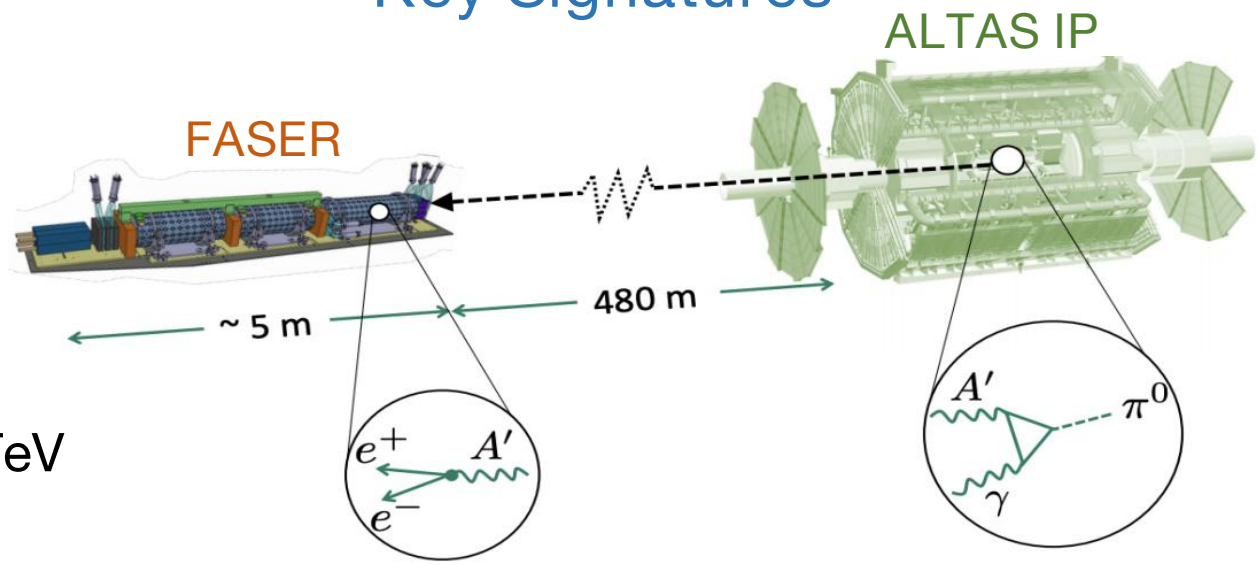
- LLPs will arrive at the FASER main detector and decay into visible Standard Model particles

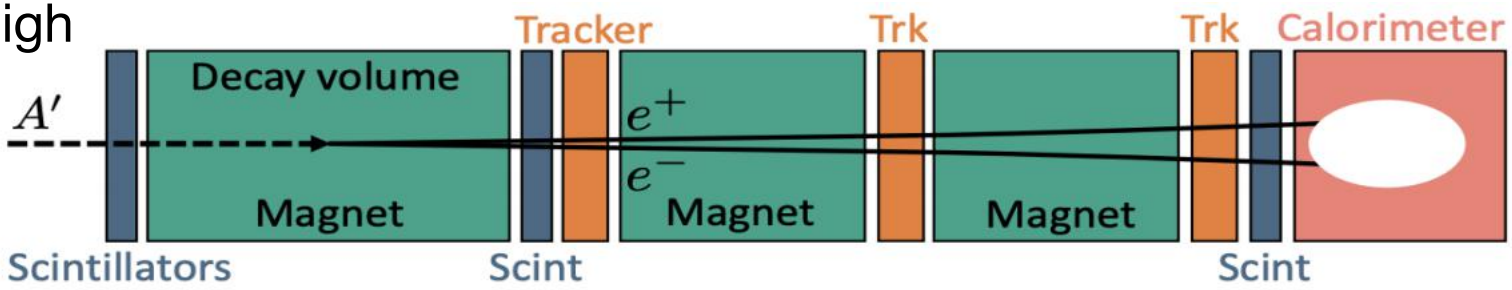
$$PP \rightarrow LLP + X$$ LLP travels for ~480m

$$LLP \rightarrow ChargedTracks + X$$

- Dark Photon (A')
- Ballpark number for A': momentum of 1 TeV and mass of 100MeV
- Decay products collimated for A': Requirements for magetic field & high resolution tracker

Key Signatures



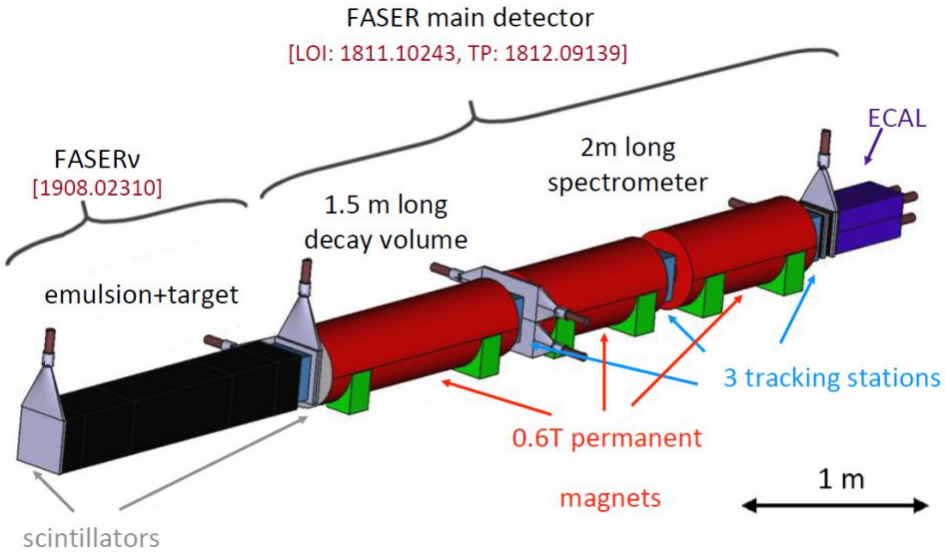


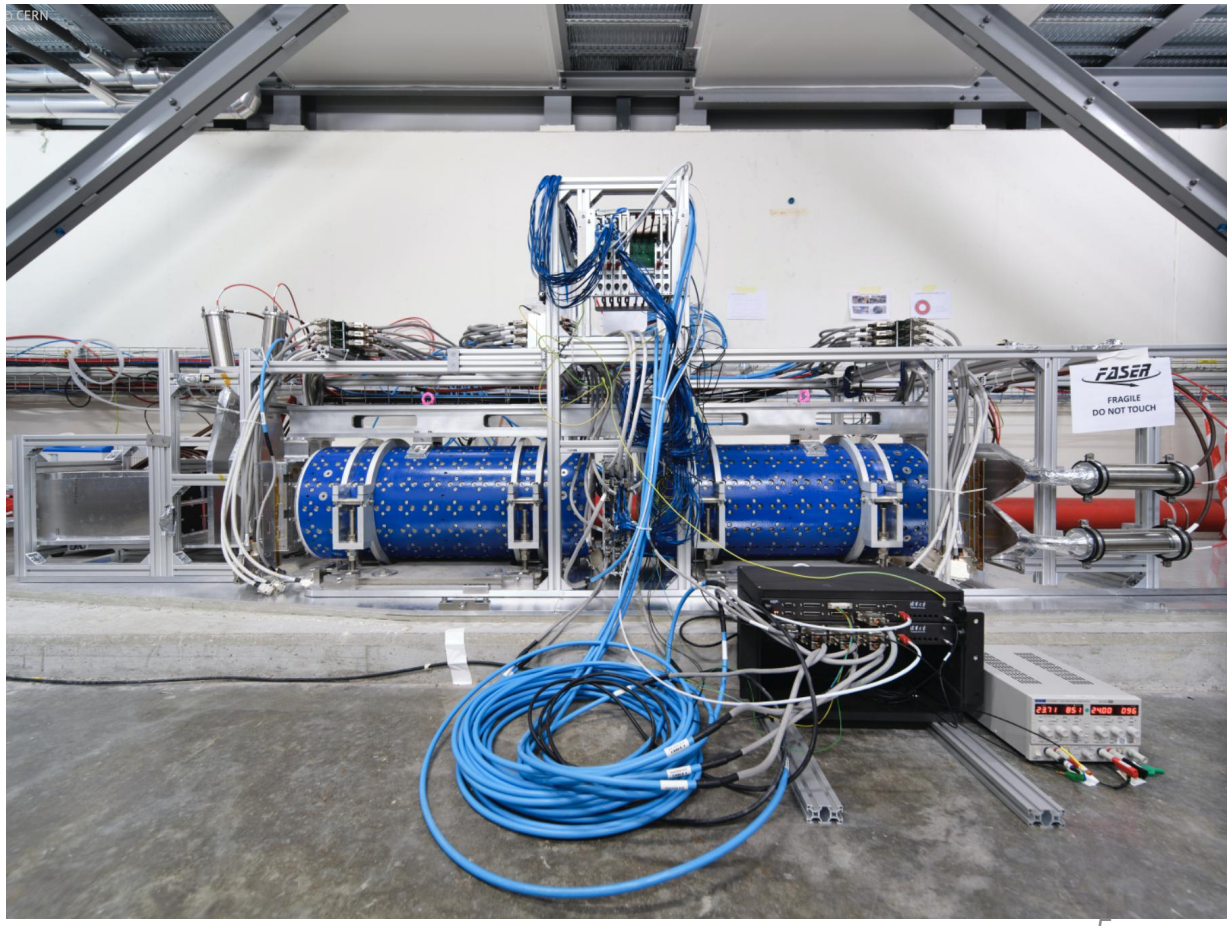
Anna Sfyrla

2019 Physics potential: Phys. Rev. D 99, 095011

The FASER Detector

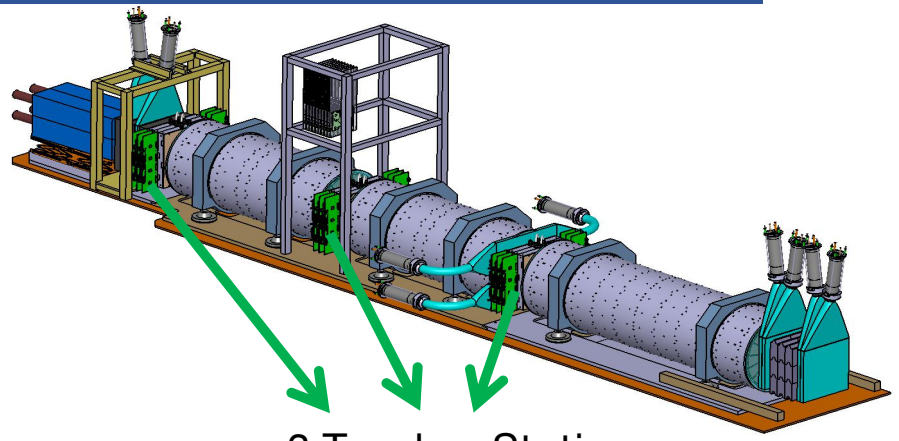
- The FASER detector is composed of scintillators, a decay volume, a spectrometer, tracker stations and an electromagnetic calorimeter
- The radius of the FASER main detector is 0.1m and the total length is 5m
- Besides the main detector, there is a subdetector named FASERν, which will study neutrinos produced at the LHC





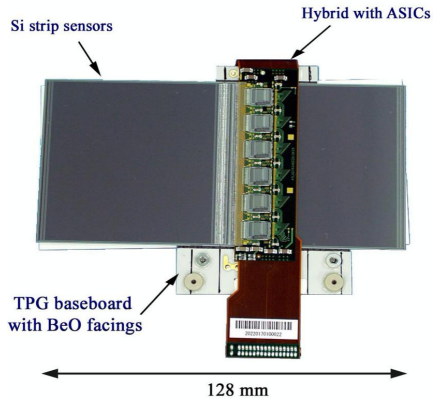
Tracker of the FASER Detector

- 3 Tracker stations are installed on the FASER main detector to track the charged particles produced by goal particles decay
- Each tracker station consists of 3 tracker planes
- 8 semiconductor strip tracker (SCT) modules are installed on 1 tracker plane. The SCT modules are spares from the ATLAS experiment
- 3 Tracker Interlock and Monitoring (TIM) boards are installed to monitor the status of the 3 tracker stations of the FASER main detector

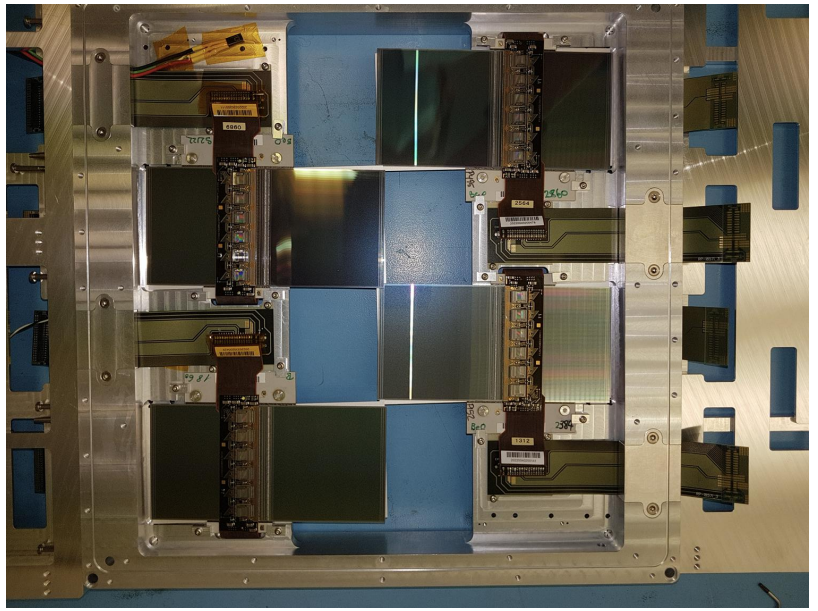


3 Tracker Stations

TIM board



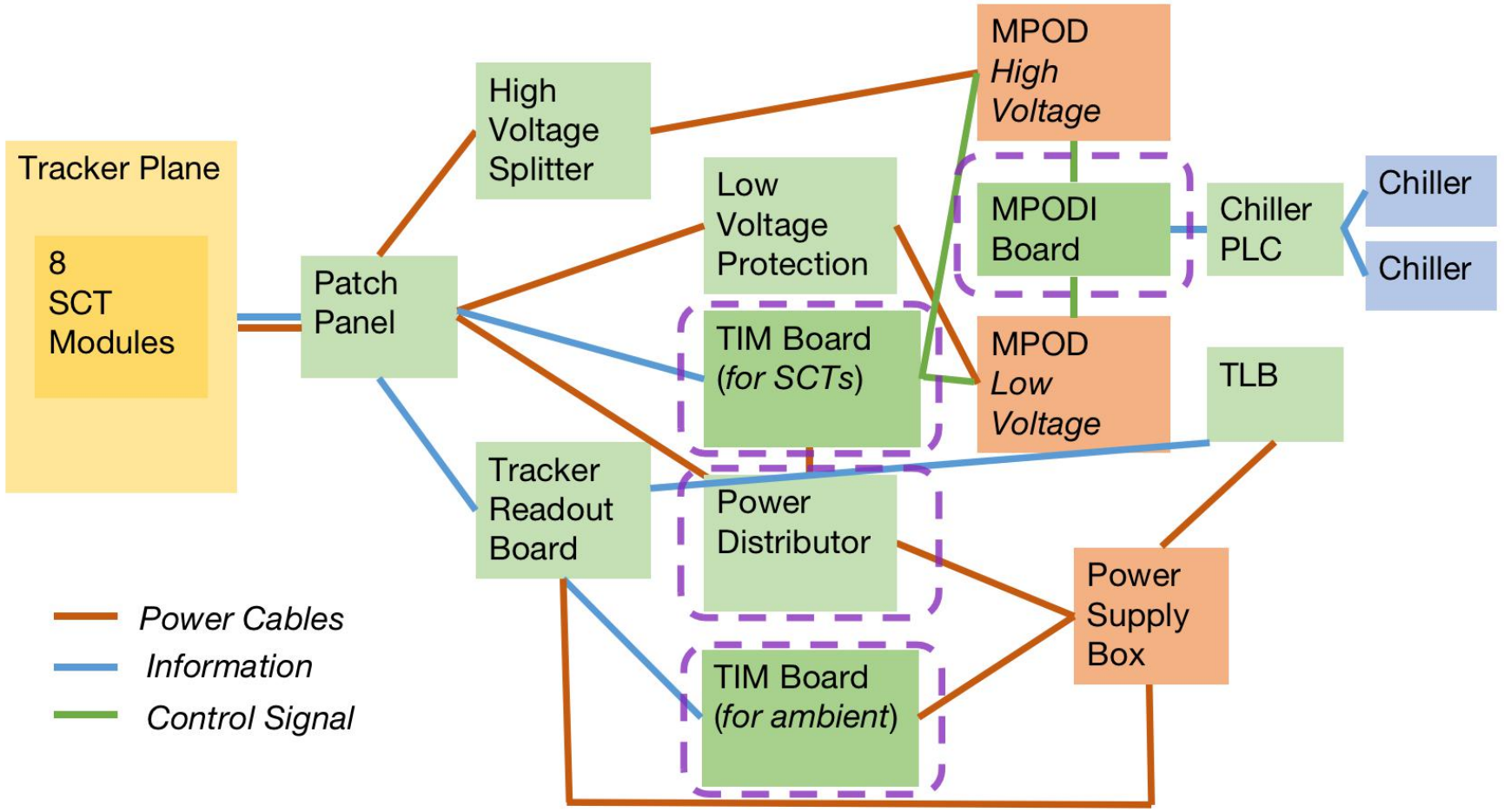
SCT modules



Tracker Plane

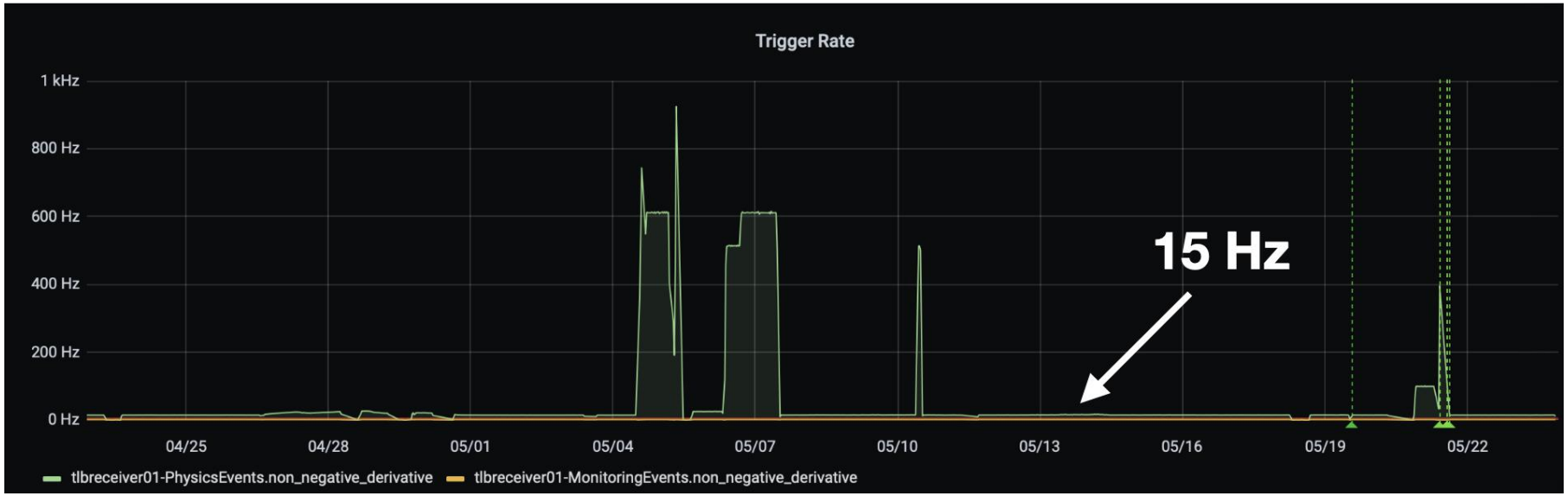
Tracker of the FASER Detector

- Here is the sketch of the FASER tracker station



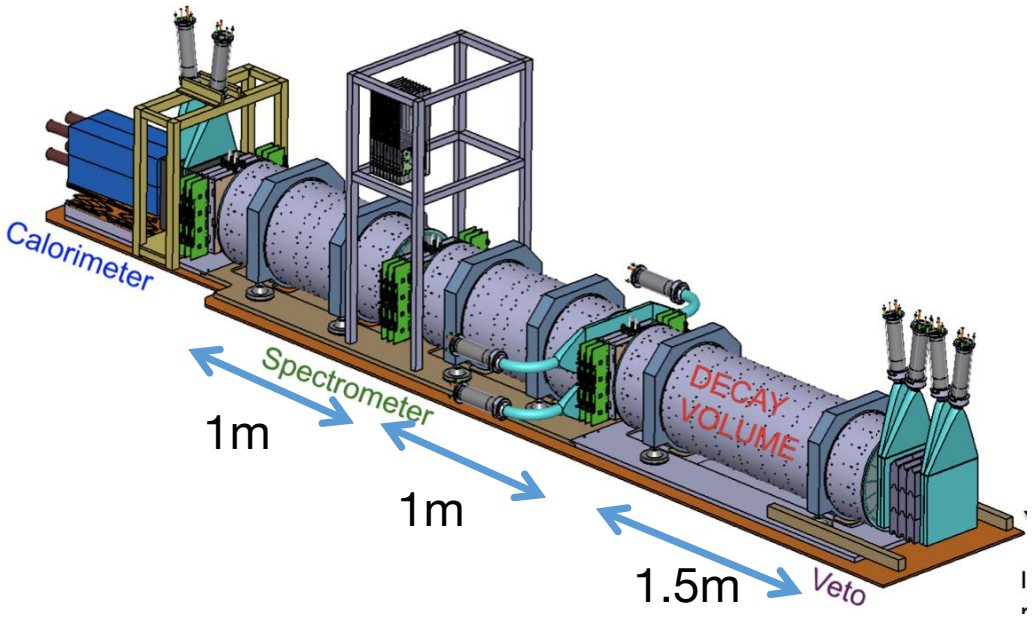
Tracker of the FASER Detector

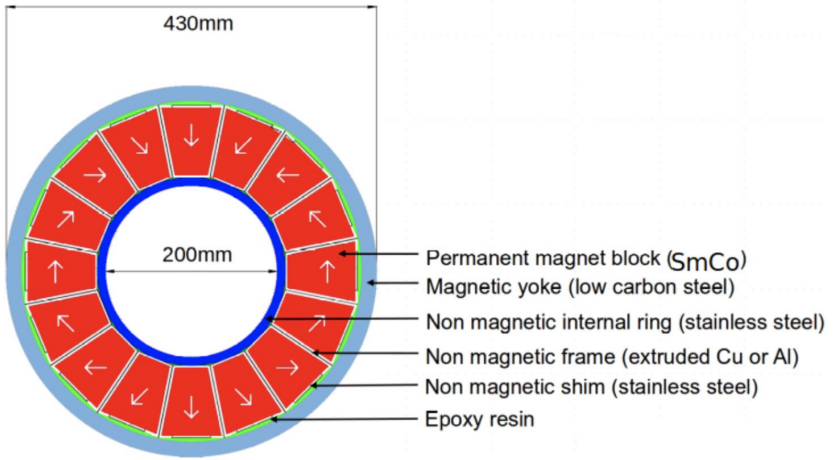
- Tracker commissioning has been ongoing during last few months
- Remote operation and monitoring are tested
- For the cosmic test:
- 10-15 Hz trigger rate requiring 2-scintillator coincidence
- Very long runs (days) achieved with few problems
- High rate (600Hz) tests are also successfully performed

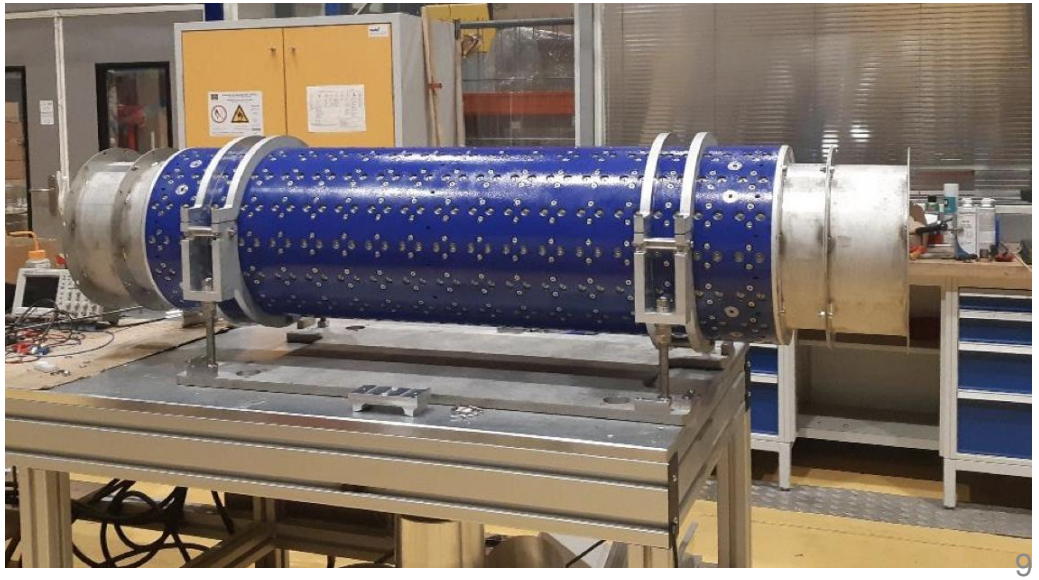


Magnets of the FASER Detector

- FASER uses 0.55 T permanent dipole magnets
- 1.5m long magnet for decay volume
- Two 1m long magnets for spectrometer

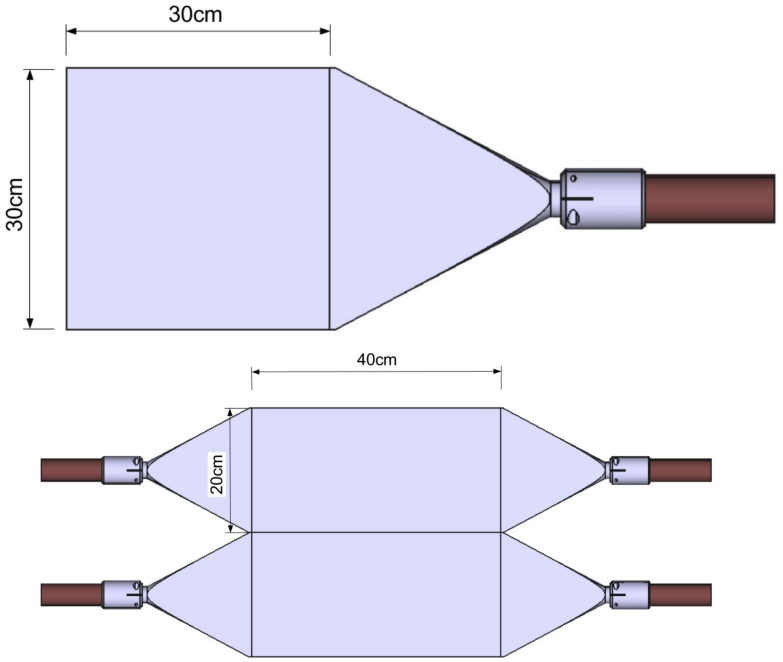






Calorimeter and Scintillator of the FASER Detector

- 4 scintillator stations are installed to veto charged particles entering the decay volume
- The first two stations are the veto stations located in front of the dipole magnets used to suppress events with charged particles (for example. muons) produced externally
- The final trigger/preshower station is located in front of the calorimeter. This station provides an additional trigger signal which can be used in a coincidence with the first trigger station to reduce the rate of non-physics triggers
- The scintillator efficiency has been measured with cosmic rays to be >99.99%



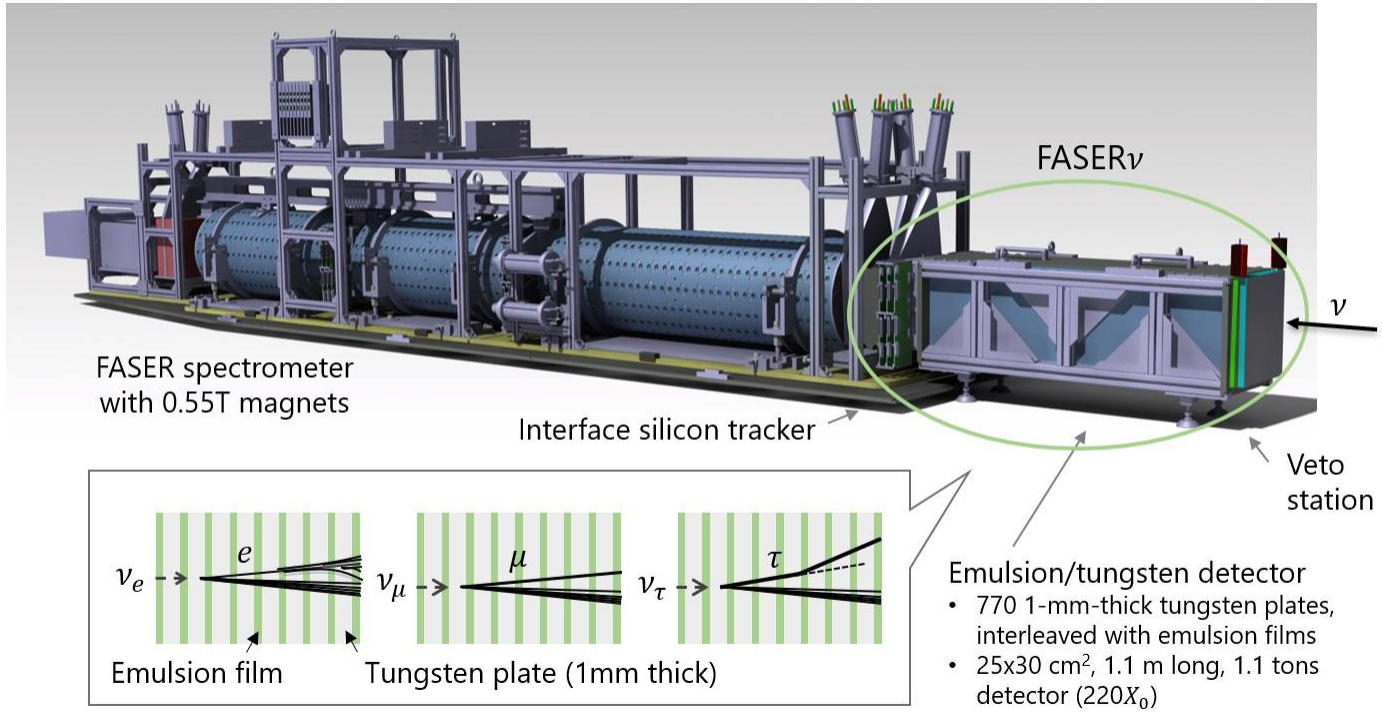
- The electromagnetic calorimeter is designed to stop high-energy electrons and photons, identify them, and measure their energies
- The calorimeters modules are spares from the LHCb experiment.
- The modules are being calibrated in a test beam at CERN this week

FASER ν

for more details see Tomoko's talk (28th in T04)

- FASERν is a emulsion/tungsten detector
- 1.1m long, 25x30cm, 1.1tn detector
- interface silicon tracker and veto station
- Made from 770 1mm thick tungsten plates, interleaved with emulsion films

- Detect and measure collider neutrinos
- A huge number of neutrinos produced in the LHC collisions (hadron decay) traverse the FASER location
- Measure SM collider neutrinos for the first time and bridge gaps in neutrino cross-section measurements
- measure also electron neutrinos and tau neutrinos

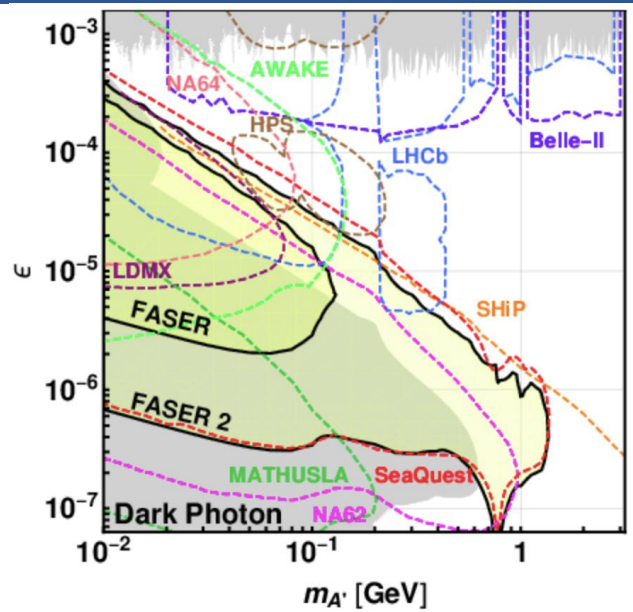


FASERnu LOI, Eur. Phys. J. C 80 (2020) 61, arXiv:1908.02310

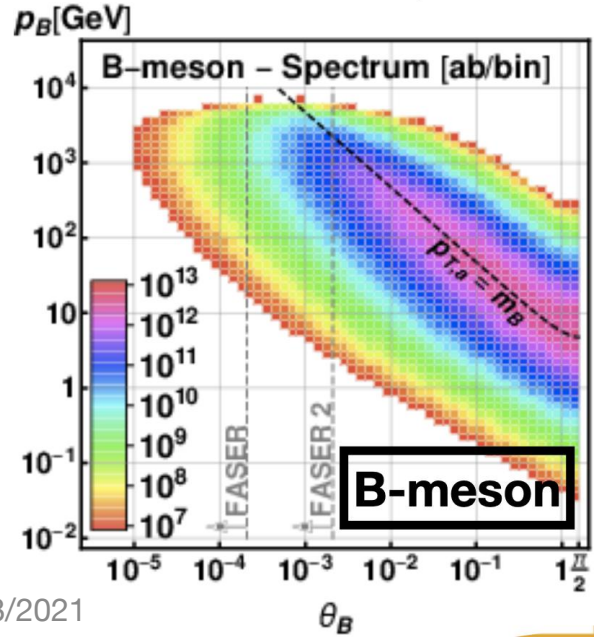
First neutrino interaction candidates at the LHC, arXiv:2105.06197

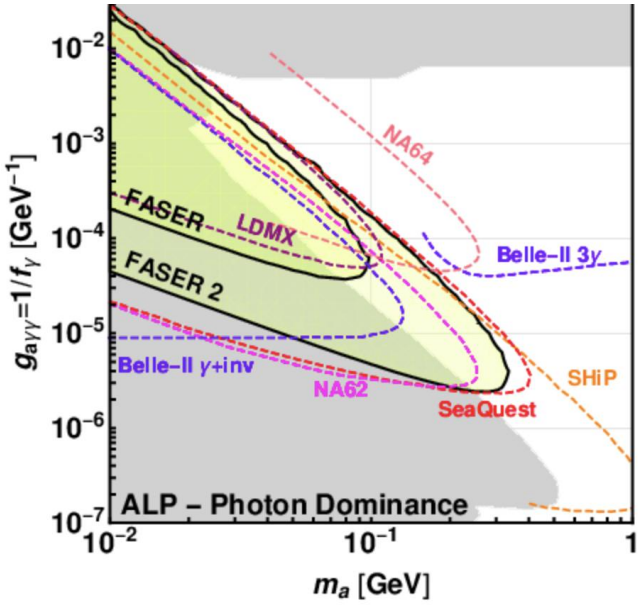
FASER 2

- FASER2: A possible future upgrade after Run 3
- radius R=1m, length of deacy volume D = 5m
- luminosity: $3ab^{-1}$
- good sensitivity to particles produced in heavy meson decays (B,D)



FASER: 10 cm radius, 150 fb^{-1} ,
FASER 2: 1 m radius, 3 ab^{-1}





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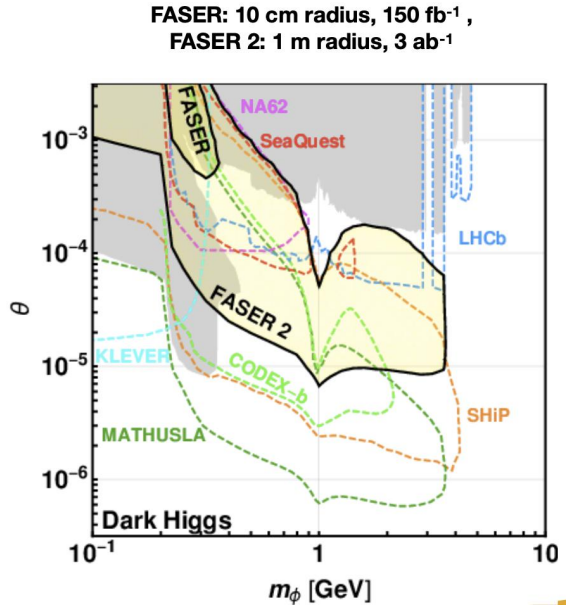


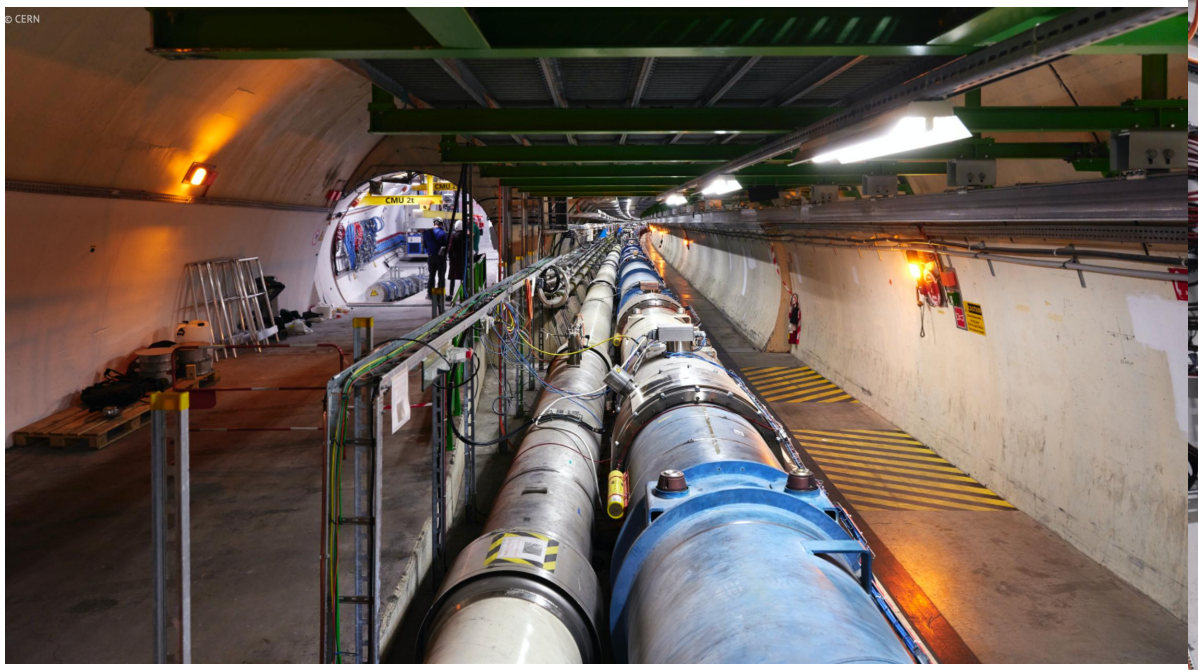
FASER 2

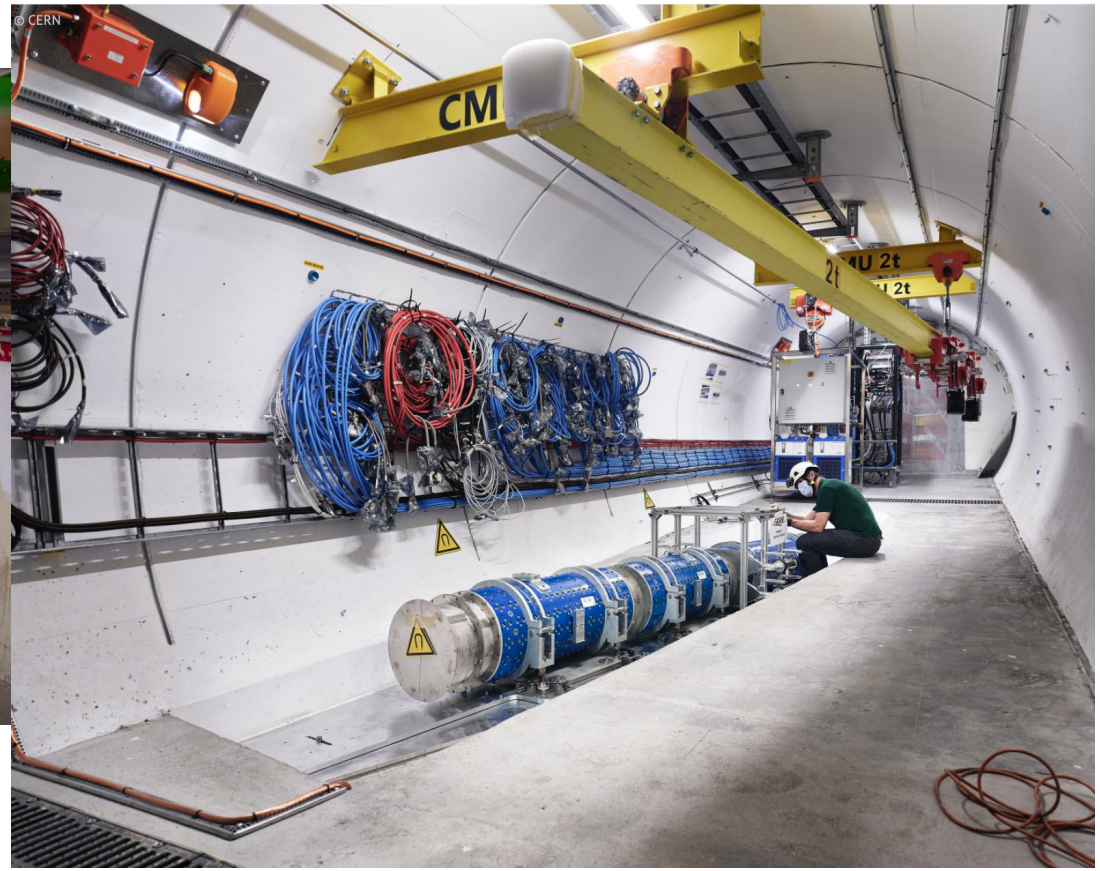
- FASER (Run 3)： sensitive to unexplored phase spaces for a range of hidden sector physics
- FASER 2 (HL-LHC)： opportunity to probe more benchmarks (e.g. new particles produced in heavy meson decay (D, B))

Benchmark Model	Label	Section	PBC	Refs	FASER	FASER 2
Dark Photons	V1	IV A	BC1	[7]	√	√
$B-L$ Gauge Bosons	V2	IV B	—	[30]	√	√
$L_i - L_j$ Gauge Bosons	V3	IV C	—	[30]	—	—
Dark Higgs Bosons	S1	V A	BC4	[26, 27]	—	√
Dark Higgs Bosons with hSS	S2	V B	BC5	[26]	—	√
HNLs with e	F1	VI	BC6	[28, 29]	—	√
HNLs with μ	F2	VI	BC7	[28, 29]	—	√
HNLs with τ	F3	VI	BC8	[28, 29]	√	√
ALPs with Photon	A1	VII A	BC9	[32]	√	√
ALPs with Fermion	A2	VII B	BC10	—	—	√
ALPs with Gluon	A3	VII C	BC11	—	√	√
Dark Pseudoscalars	P1	VIII	—	[36]	—	√

Timeline

- Refurbishment of TI12 to be an experiment site was completed in winter 2020
- All detectors have been installed in TI12
- Data taking will start at LHC RUN-3 2022



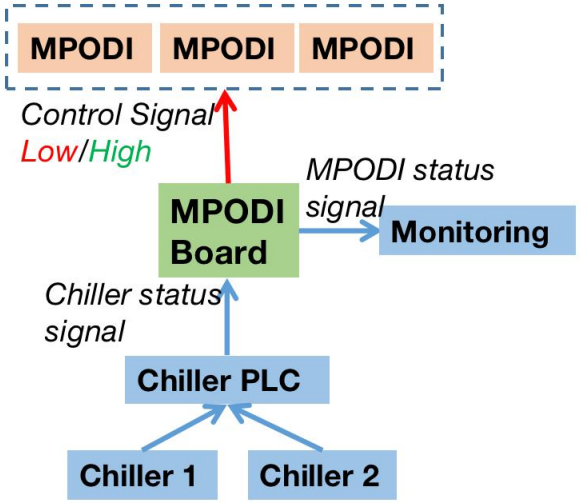


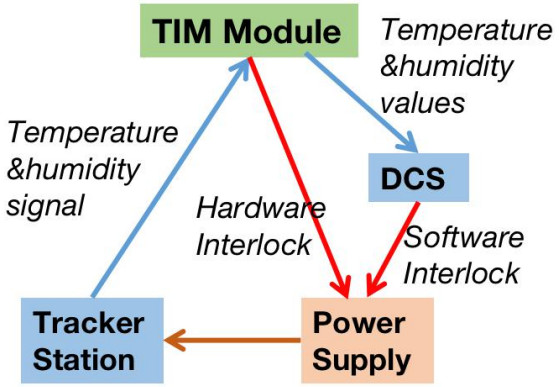
Thanks For Listening

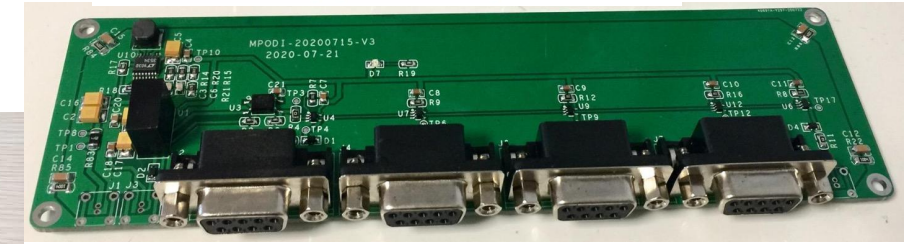
Backup

Tracker of the FASER Detector

- The Tracker Interlock and Monitoring (TIM) module produced by Tsinghua University team is the core of the interlock system of the FASER tracker.
- The main functions of the TIM boards are:
- Collecting temperature and humidity information from the tracker
- Sending all information to DCS for further processing
- Hardware interlock based on temperature







- The function of the MPOD Interlock (MPODI) board produced by Tsinghua team is to turn the MPOD off when two chillers stop working to avoid possible damages due to high temperature