



<https://twiki.cern.ch/twiki/bin/view/FASER/WebHome>

Forw**A**rd **S**earch **E**xpe**R**iment at the LHC

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for the FASER Collaboration



UCIRVINE

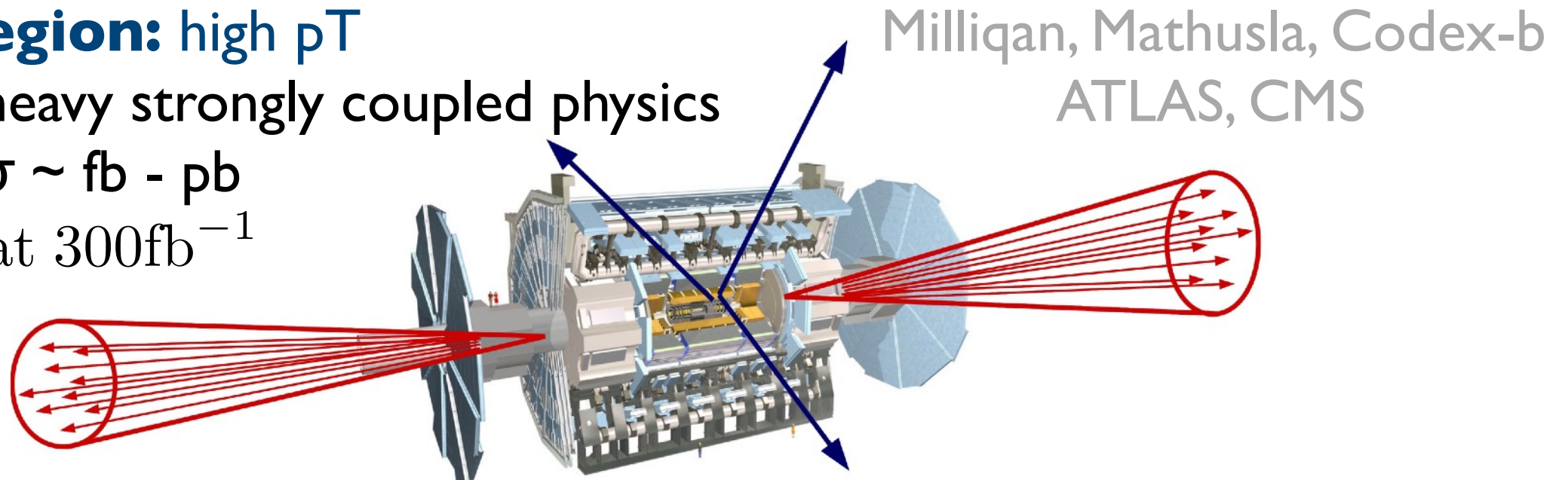
PBC Annual Workshop 2019

January 16th 2019

The Idea

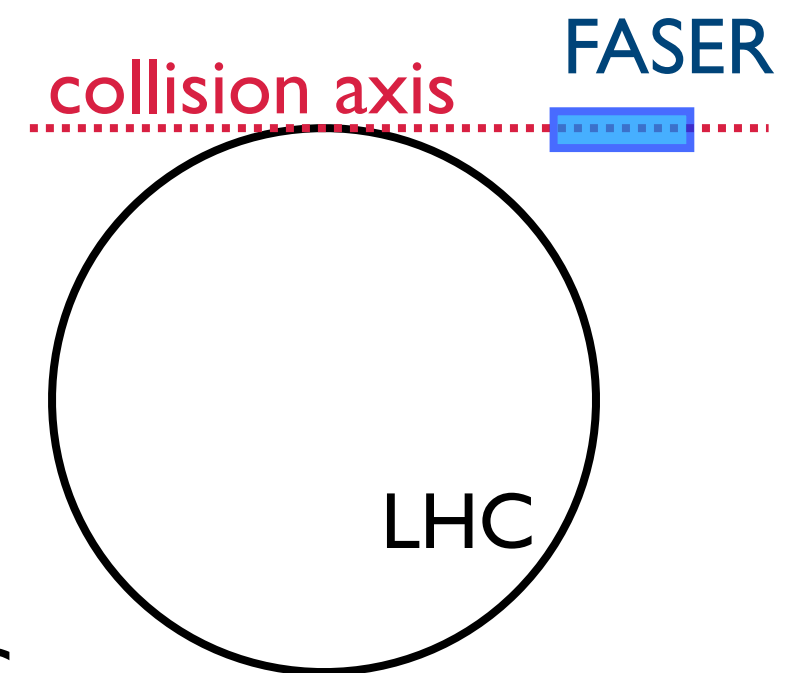
transverse region: high p_T

- searches for heavy strongly coupled physics
- typical rates $\sigma \sim \text{fb} - \text{pb}$
 $N_H = 10^7$ at 300fb^{-1}



forward region

- **enormous** event rates $\sigma_{\text{inel}} \sim 100\text{mb}$: $N_\pi = 10^{17}$ at 300fb^{-1}
 - extremely weakly-coupled particles may be produced sufficiently
- most particles have small $p_T \sim \Lambda_{\text{QCD}}$ and high $E \sim \text{TeV}$
 - particles highly **collimated** $\theta \sim \Lambda_{\text{QCD}}/E \sim \text{mrad}$
- weakly coupled particles can be **long-lived**
 - decays outside downstream from IP
- we propose small ($\sim 1\text{m}^3$) inexpensive ($\sim 1\text{M}\$$) detector $\sim 500\text{m}$ downstream to search for LLP
 - **FASER: ForwArd Search ExpeRiment** at the LHC



Status and Timeline

05/2017 - first idea on blackboard

09/2017 - original FASER paper [arXiv:1708.09389](https://arxiv.org/abs/1708.09389)

01/2018 - FASER joins PBC

spring 2018 - FASER collaboration forms

identification of location / FLUKA background study
first detector design

07/2018 - Letter of Intent [arXiv:1811.10243](https://arxiv.org/abs/1811.10243)

Technical Proposal - **11/2018**

location in TI-12 / in-situ measurements

civil engineering, transport, and integration

technical details of FASER detector components

11/2018 - LLP Physics Potential

[arXiv:1811.12522](https://arxiv.org/abs/1811.12522)

12/2018 - Funding

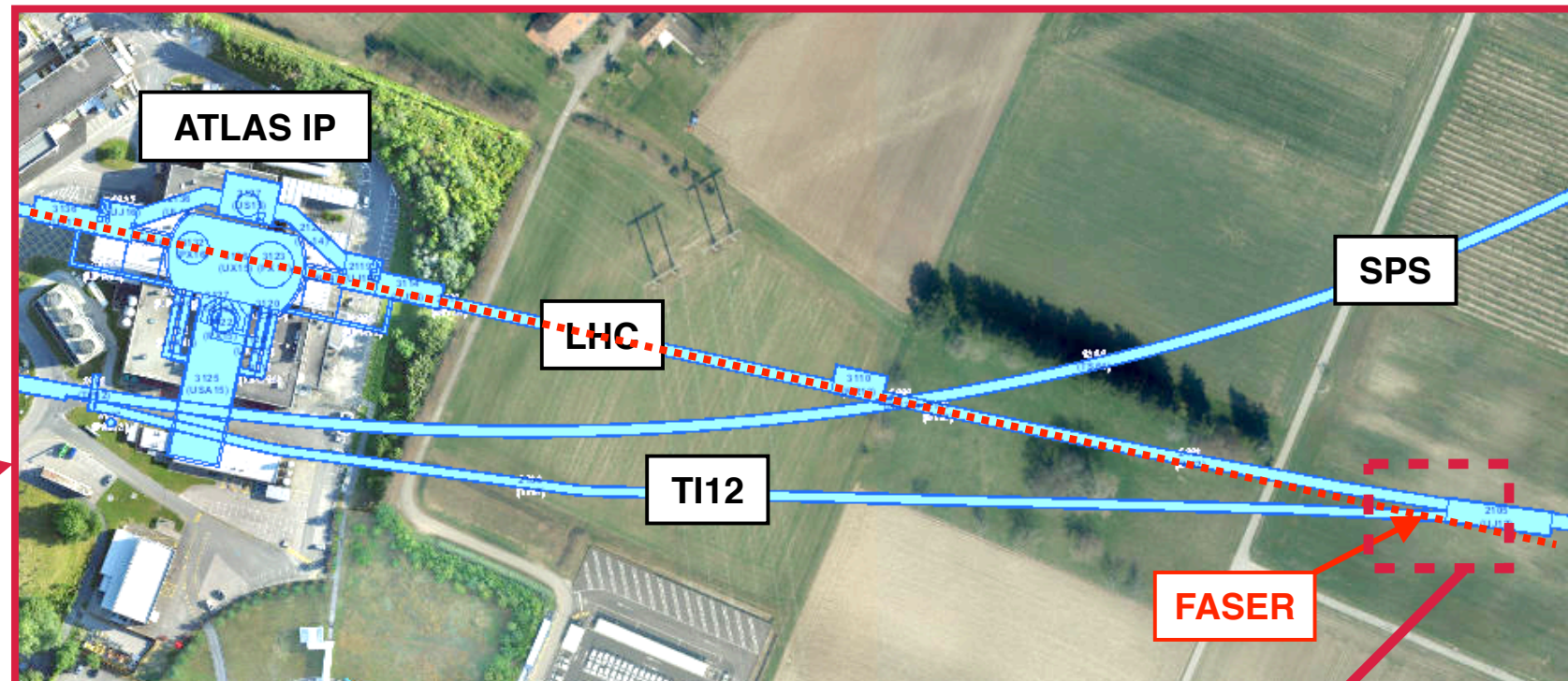
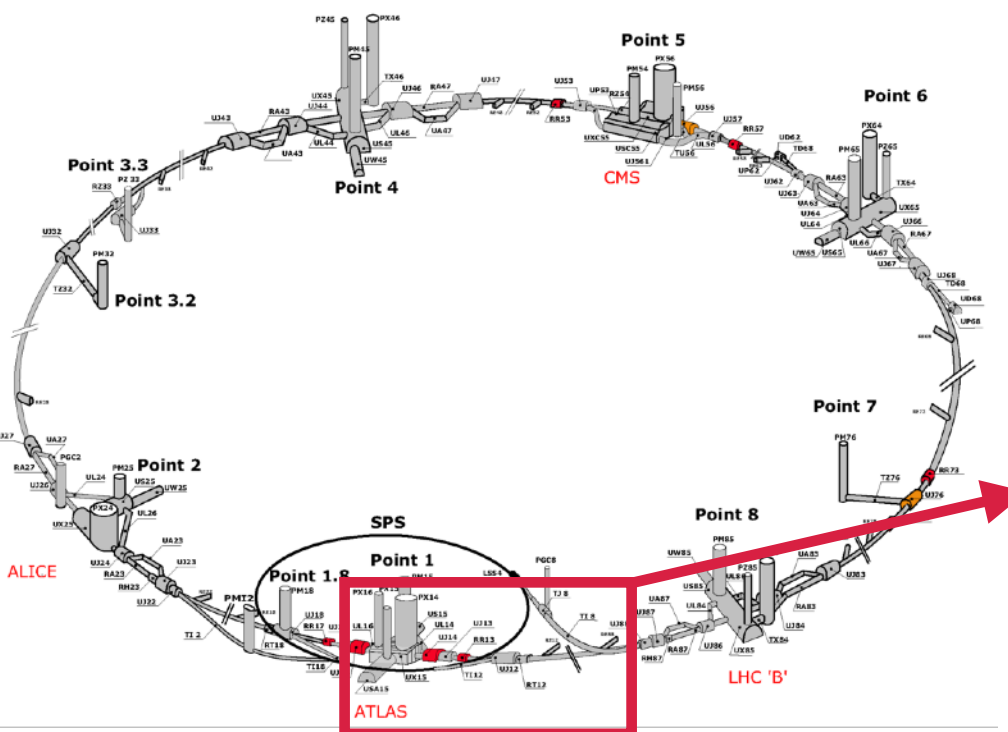
Detector Construction and Integration - **2019-2020**

Collecting Data - **2021-2023**

FASER 2 Upgrade - **HL-LHC era**

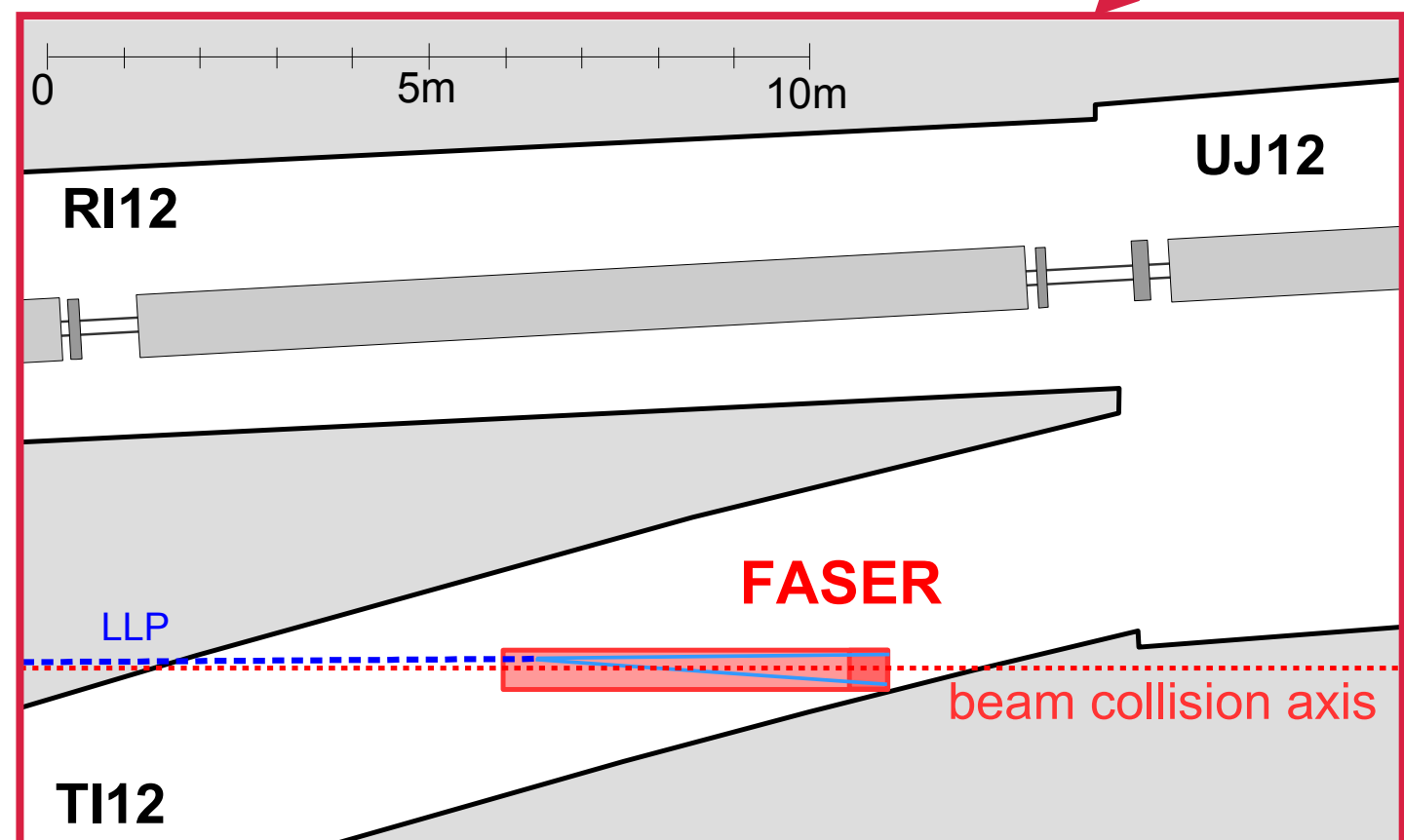


FASER's Location



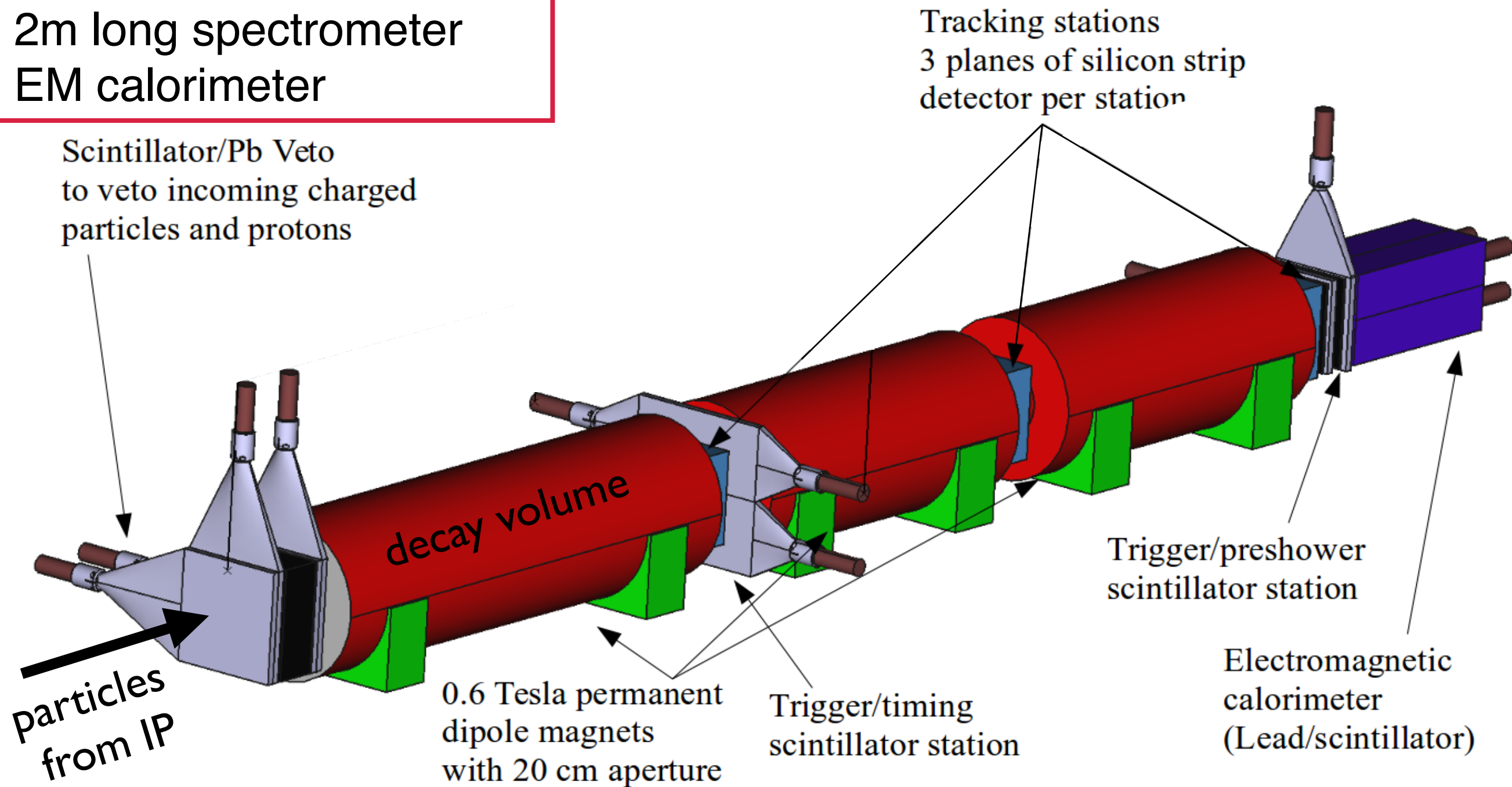
Cylindrical Decay Volume

	FASER	FASER 2
Radius	10cm	1m
Length	1.5m	5m
Luminosity	150fb^{-1}	3ab^{-1}



Detector Design

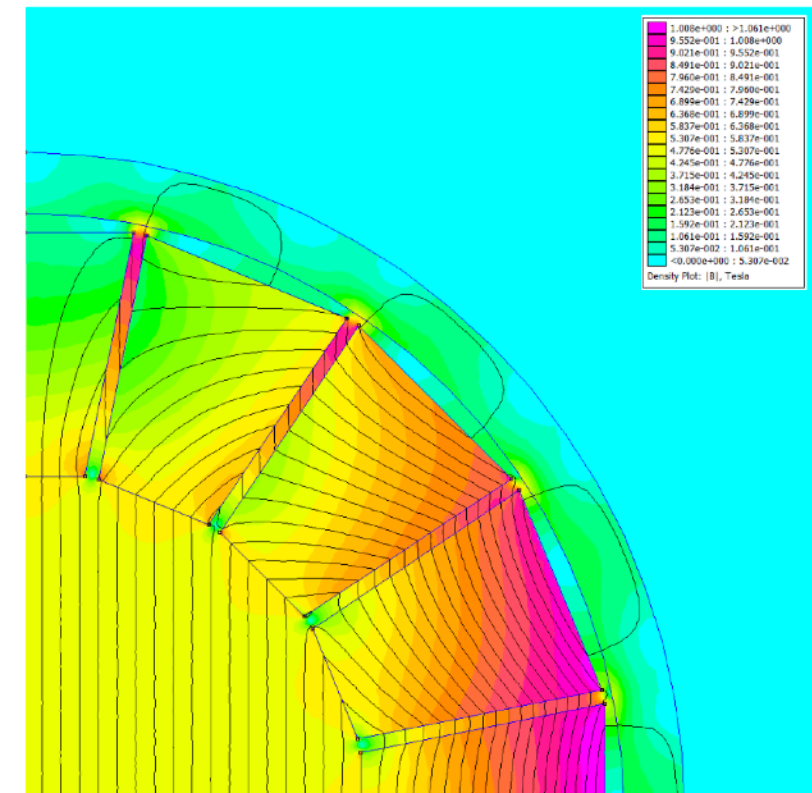
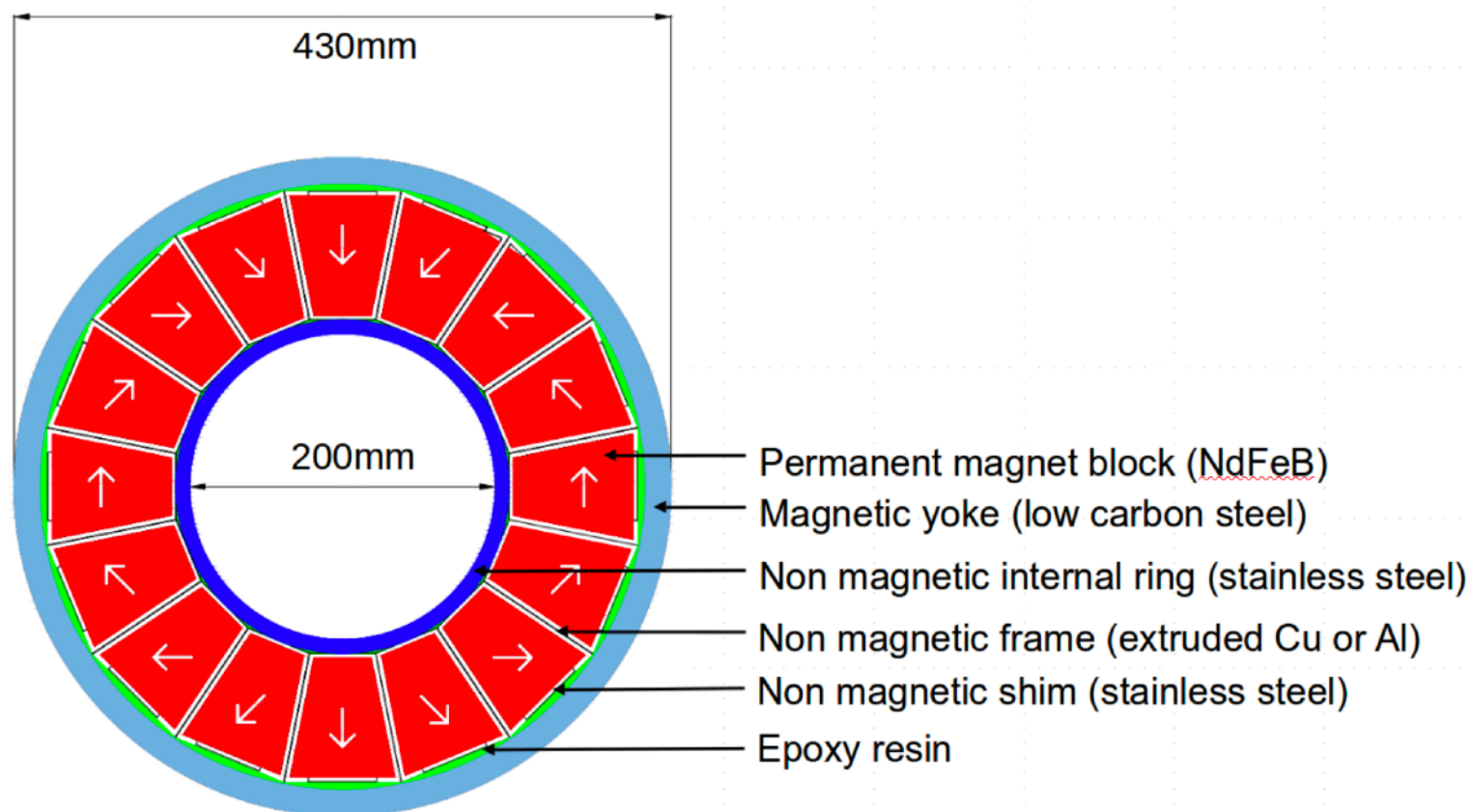
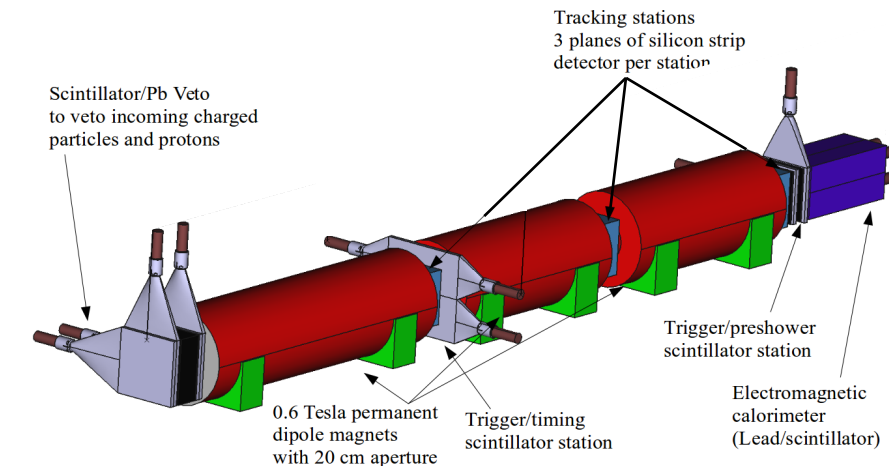
- The detector consists of:
- scintillator veto
 - 1.5m long decay volume
 - 2m long spectrometer
 - EM calorimeter



Detector Design

FASER Magnet

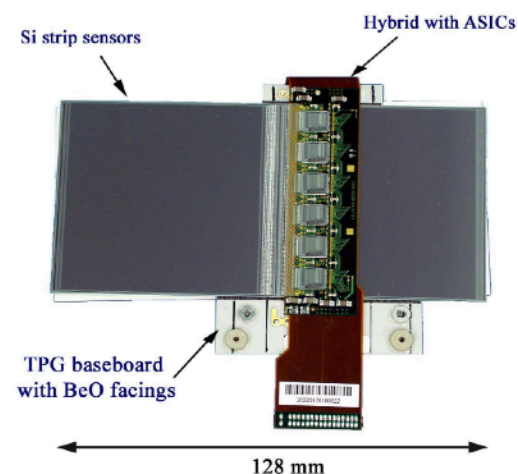
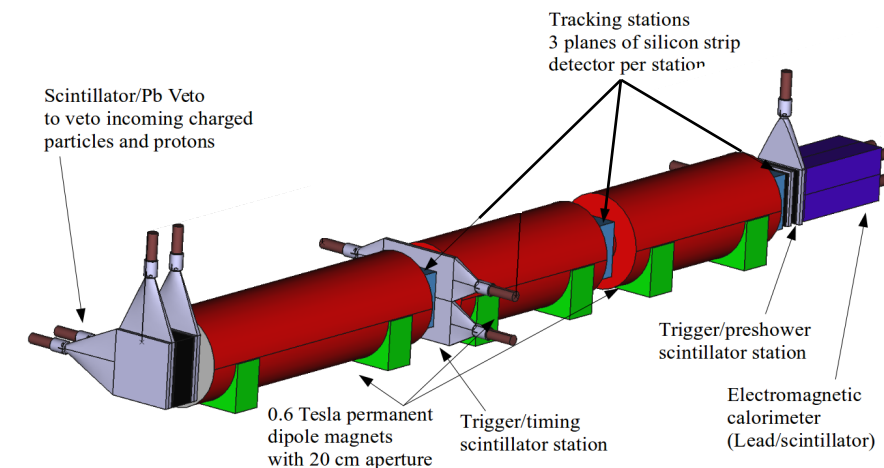
- 0.6T permanent dipole magnets
- Halbach array design
 - LOS to passes through the magnet center
 - minimum digging to the floor in T112
 - minimized needed services (power, cooling etc..)
- to be constructed by the CERN magnet group



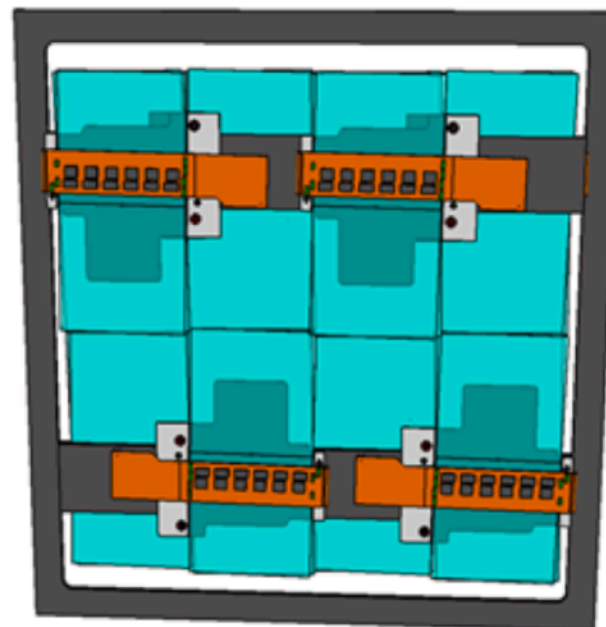
Detector Design

FASER Tracker

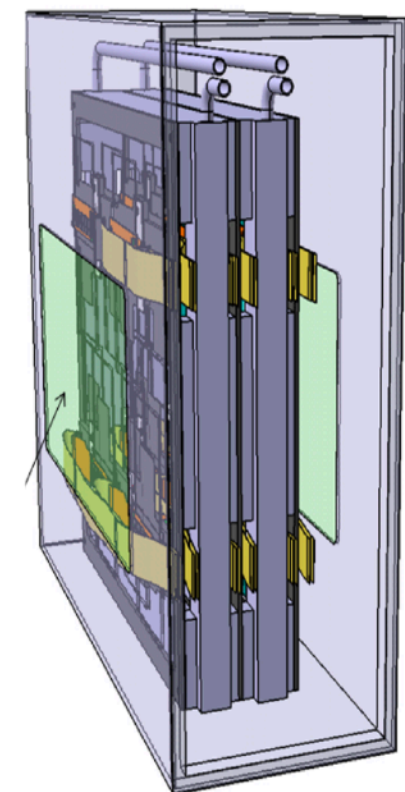
- 3 tracking stations, each with 3 tracking layers
- double sided silicon micro-strip detectors
- ATLAS SCT spare modules will be used
 - 80 μ m strip pitch, 40mrad stereo angle
 - many thanks to the ATLAS SCT collaboration!
 - 72 SCT modules for the full tracker



SCT module



Tracking layer

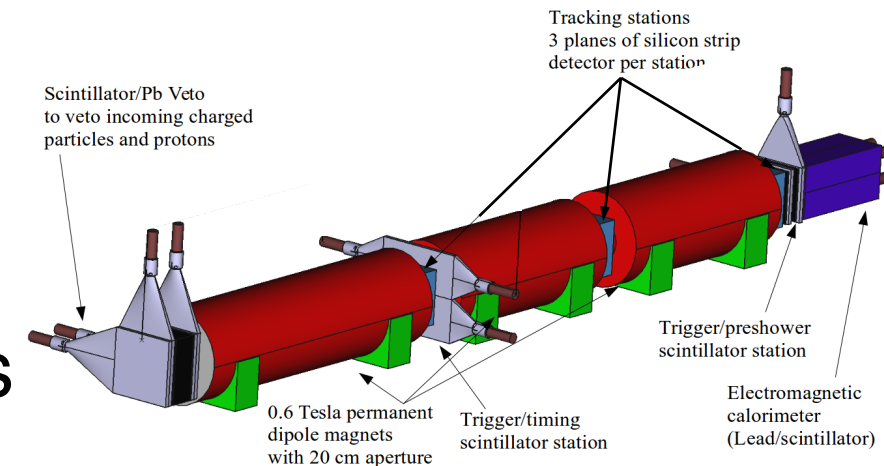


Tracking station

Detector Design

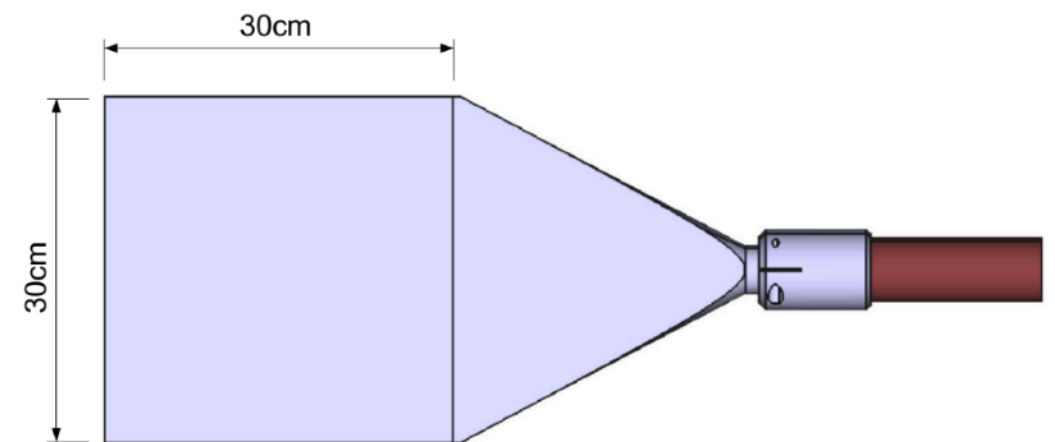
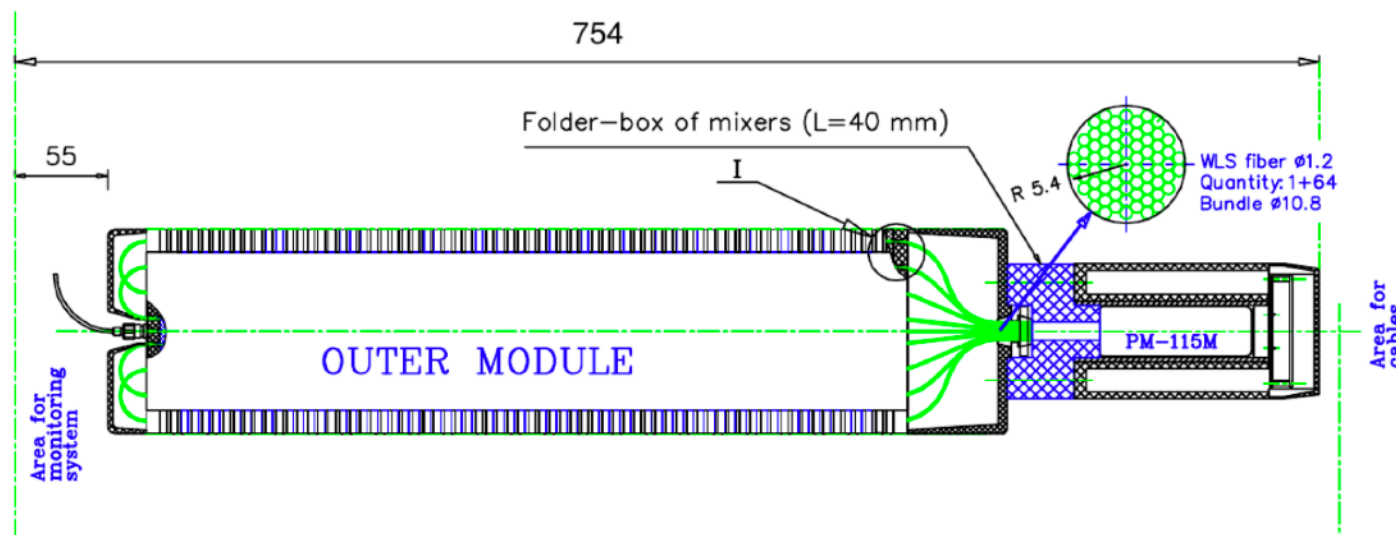
FASER ECAL

- EM energy measuring / triggering / electron/photon identification
- FASER will use spare LHCb outer ECAL modules
 - $\sim 1\%$ energy resolution for 1 TeV electrons
 - Many thanks for LHCb for allowing us to use these!



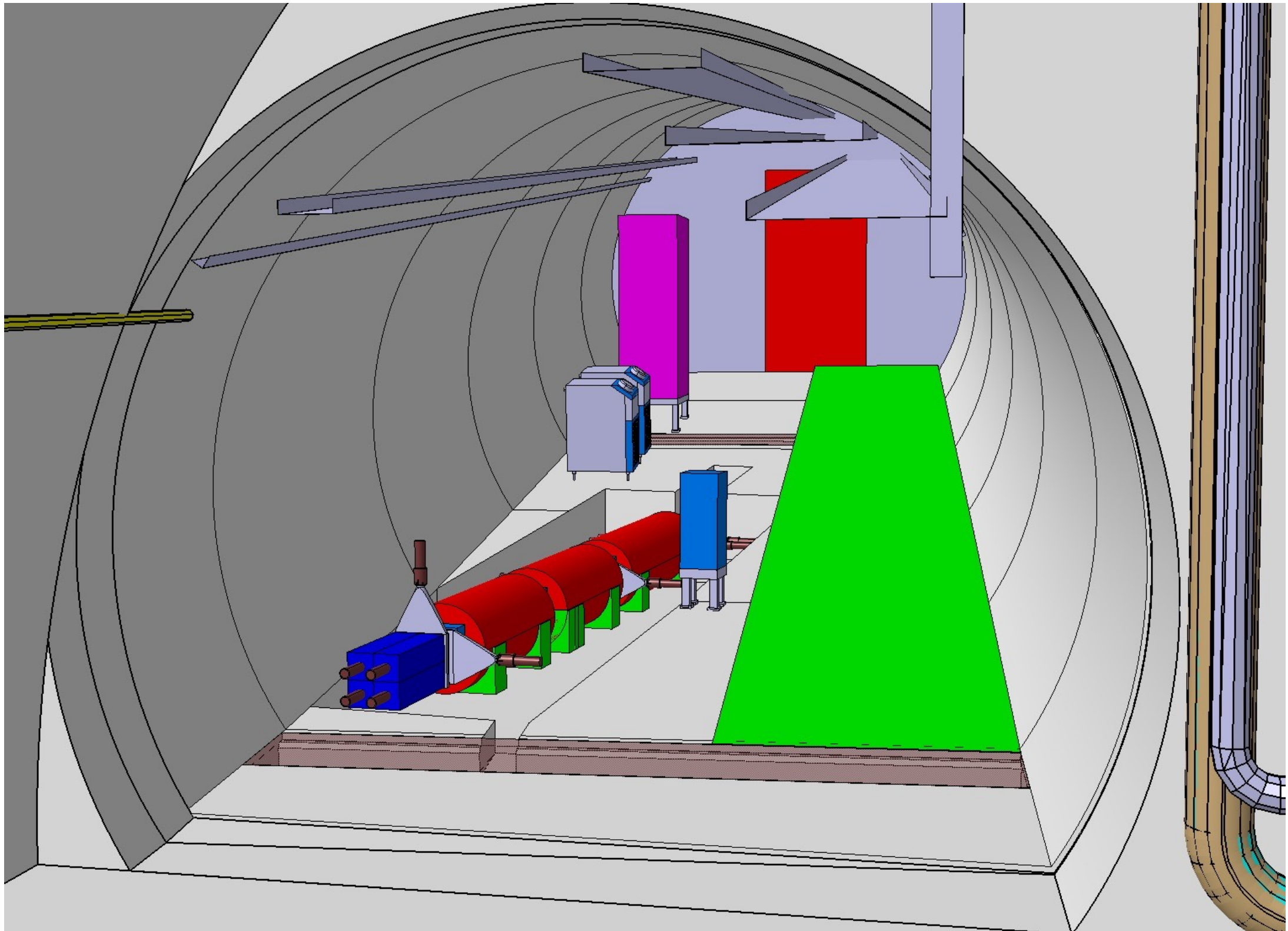
FASER Scintillators

- vetoing charged particles entering the decay volume / triggering
- to be produced at CERN scintillator lab



Detector Design

FASER Integration in T112



Backgrounds

Signal is striking

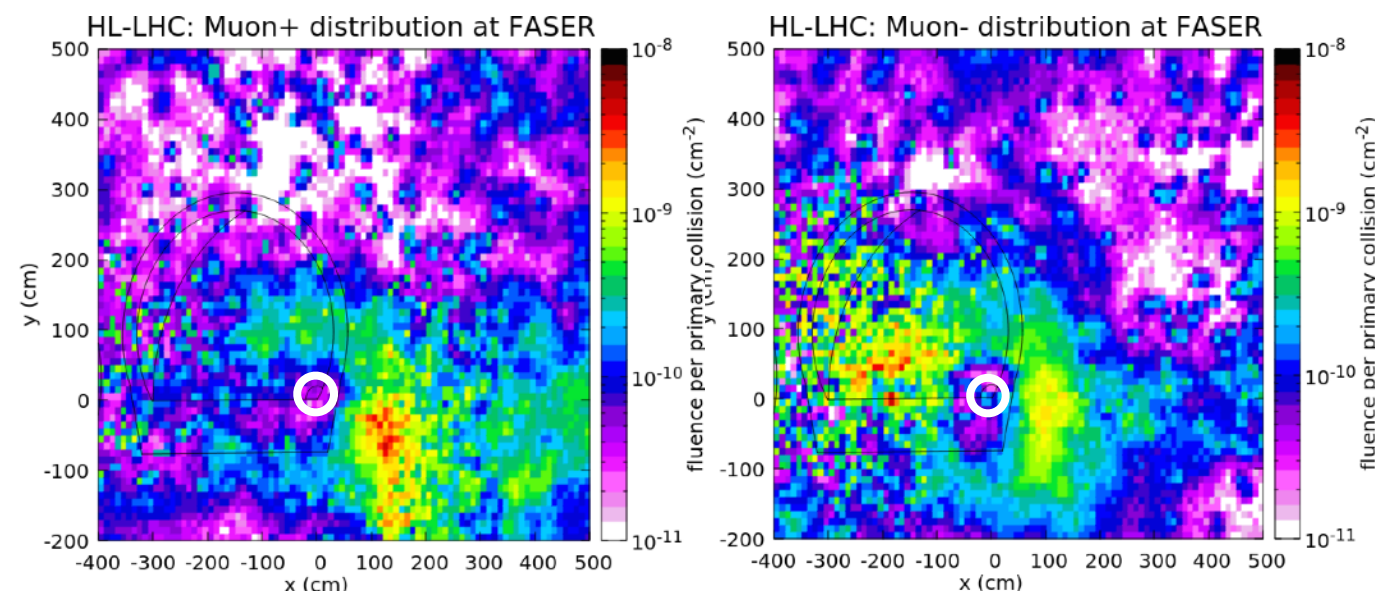
- two opposite-sign, high energy ($E > 500$ GeV) charged particles
- originate from a common vertex in a small, empty decay volume
- point back to the IP through 90 m of rock

Background considerations

- shielding: natural (rock) and LHC infrastructure (concrete, magnets, absorbers)
- only muons/neutrino can transport TeV energies through ~ 100 m rock

FLUKA Study

- CERN STI group performed FLUKA simulation
- most backgrounds associated with muon from collision debris
 - estimated flux: 0.2 Hz/cm^2 for $E > 100 \text{ GeV}$
 - can be vetoed with scintillators



Backgrounds

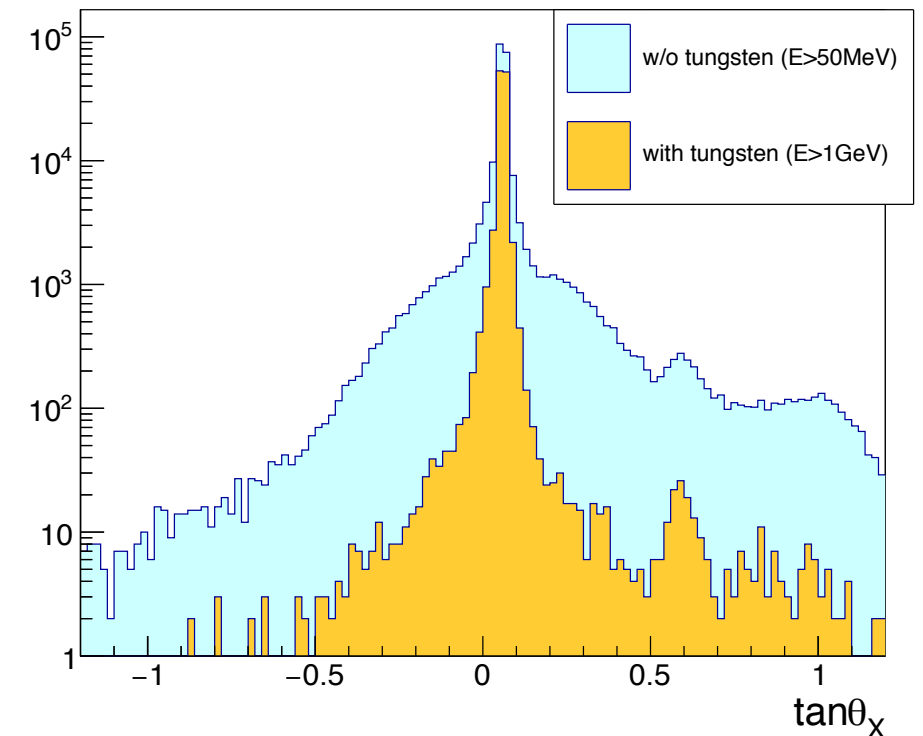
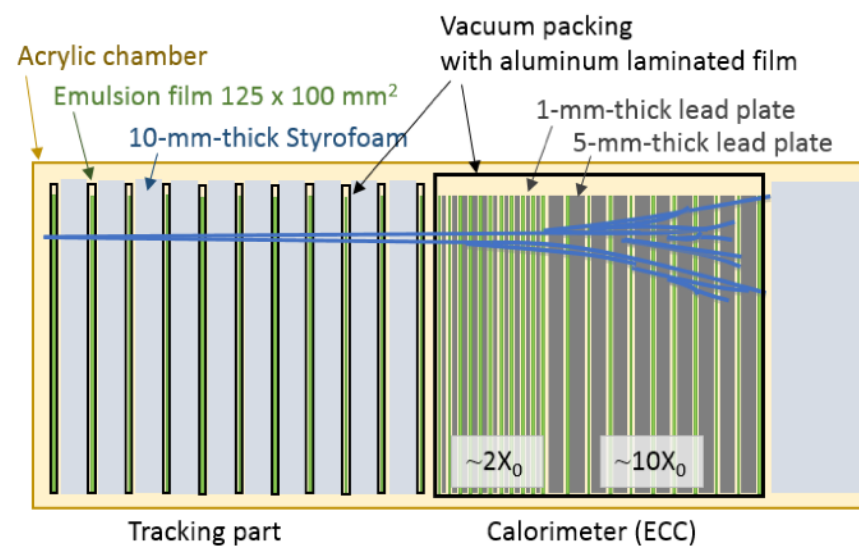
In-Situ Measurements

- using emulsion detectors
- first measurements already performed in T118 and T112
- consistent with FLUKA simulations

FLUKA: $2 \cdot 10^4 \text{ fb/cm}^2$

Emulsion Detector: $(1.2-1.9) \cdot 10^4 \text{ fb/cm}^2$

- data analysis on-going



FASER's Physics Potential

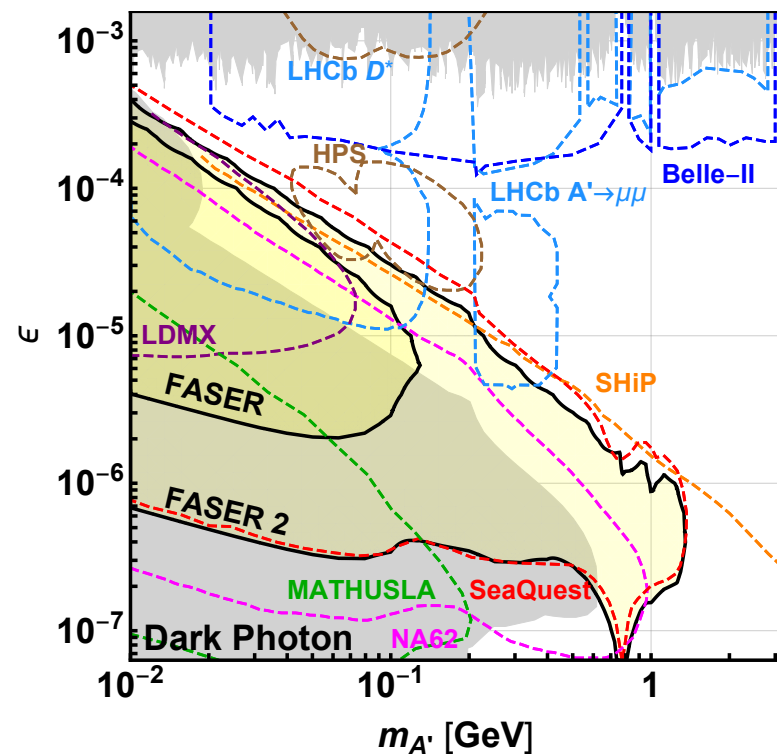
LLP Searches at FASER

- FASER has a full physics program: Dark photon, dark Higgs, HNL, ALPs

Dark Photon

$$\epsilon F^{\mu\nu} F'_{\mu\nu}$$

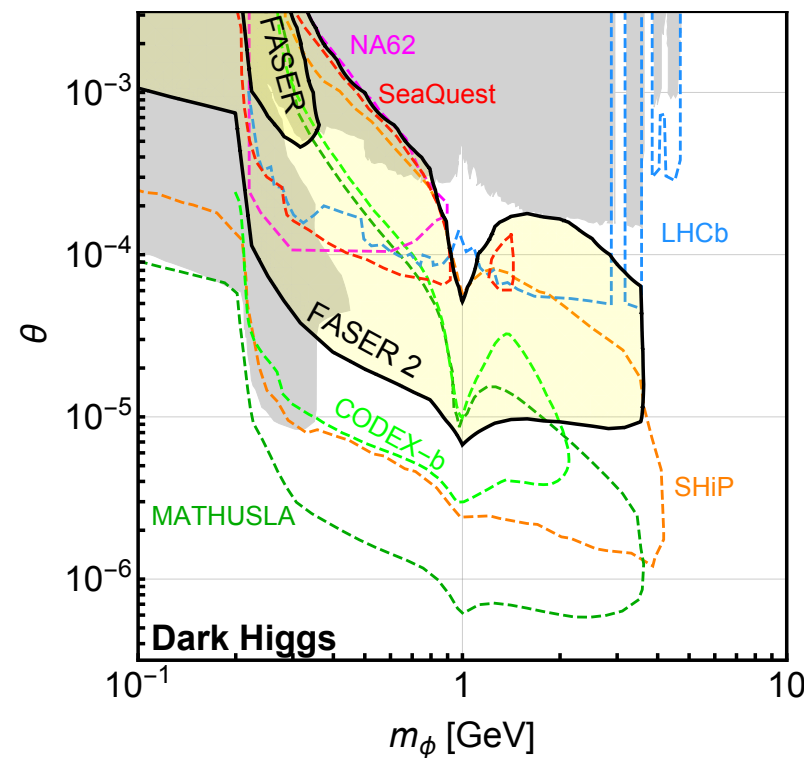
[1708.09389]



Dark Higgs

$$\epsilon |H|^2 \phi^2$$

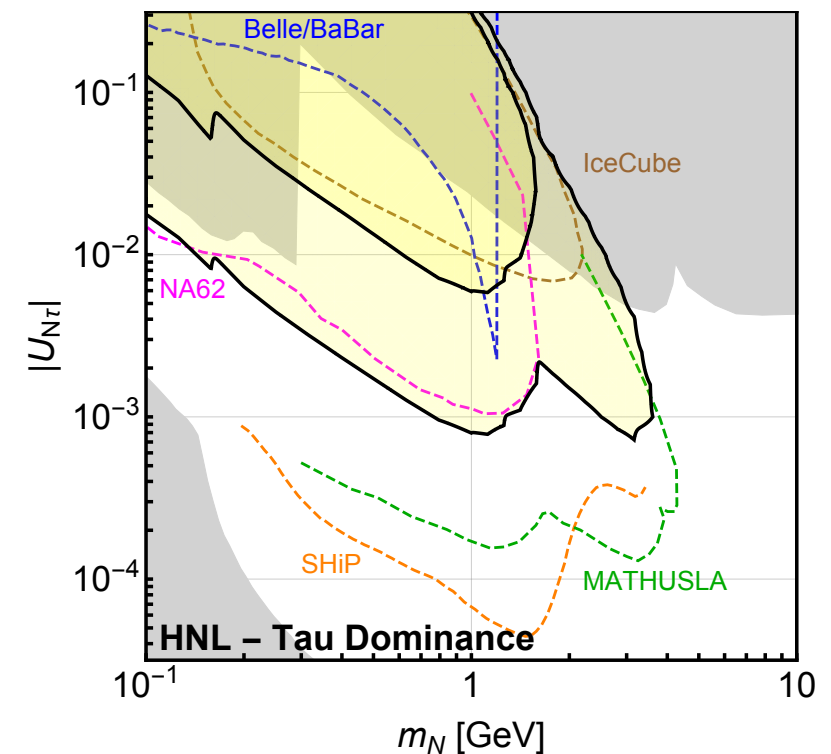
[1710.09387]



HNL

$$y L H N$$

[1801.08947]



FASER's Physics Potential

LLP Searches at FASER

- FASER has a full physics program: Dark photon, dark Higgs, HNL, ALPs
- contribution to PBC study
- FASER LLP physics potential study: [arXiv:1811.12522](#)

Benchmark Model	PBC	FASER	FASER 2
Dark Photons	BC1	✓	✓
$B - L$ Gauge Bosons	—	✓	✓
$L_i - L_j$ Gauge Bosons	—	—	—
Dark Higgs Bosons	BC4	—	✓
Dark Higgs Bosons with hSS	BC5	—	✓
HNLs with e	BC6	—	✓
HNLs with μ	BC7	—	✓
HNLs with τ	BC8	✓	✓
ALPs with Photon	BC9	✓	✓
ALPs with Fermion	BC10	✓	✓
ALPs with Gluon	BC11	✓	✓

+ inelastic DM

[Berlin, FK: 1810.01879]

+ RPV Susy

[Dercks, de Vries, Dreiner,
Wang: 1810.03617]

Possible additional physics applications

- large neutrino flux: neutrino measurements
- coverage $\eta > 10$: forward SM physics, eg. Monte Carlo validation

under investigation

Current Status

The FASER collaboration: 27 collaborators, 15 institutions, 8 countries

Akitaka Ariga,¹ Tomoko Ariga,^{1,2} Jamie Boyd,³ Franck Cadoux,⁴ David W. Casper,⁵ Yannick Favre,⁴ Jonathan L. Feng,⁵ Didier Ferrere,⁴ Iftah Galon,⁶ Sergio Gonzalez-Sevilla,⁴ Shih-Chieh Hsu,⁷ Giuseppe Iacobucci,⁴ Enrique Kajomovitz,⁸ Felix Kling,⁵ Susanne Kuehn,³ Lorne Levinson,⁹ Hidetoshi Otono,² Brian Petersen,³ Osamu Sato,¹⁰ Matthias Schott,¹¹ Anna Sfyrla,⁴ Jordan Smolinsky,⁵ Aaron M. Soffa,⁵ Yosuke Takubo,¹² Eric Torrence,¹³ Sebastian Trojanowski,^{14,15} and Gang Zhang¹⁶



The University Of Sheffield.



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WEIZMANN INSTITUTE OF SCIENCE



KEK



UNIVERSITY of WASHINGTON

JOHANNES GUTENBERG
UNIVERSITÄT MAINZ



清华大学

Tsinghua University



Acknowledgements

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We are grateful to the ATLAS SCT project and the LHCb Calorimeter project for letting us use spare modules as part of the FASER experiment. In addition, FASER gratefully acknowledges invaluable assistance from many people, including the CERN Physics Beyond Colliders study group; the LHC Tunnel Region Experiment (TREX) working group; Rhodri Jones, James Storey, Swann Levasseur, Christos Zamantzas, Tom Levens, Enrico Bravin (beam instrumentation); Dominique Missiaen, Pierre Valentin, Tobias Dobers (survey); Jonathan Gall, John Osborne (civil engineering); Caterina Bertone, Serge Pelletier, Frederic Delsaux (transport); Francesco Cerutti, Marta Sabaté-Gilarte, Andrea Tsinganis (FLUKA simulation and background characterization); Pierre Thonet, Attilio Milanese, Davide Tommasini, Luca Bottura (magnets); Burkhard Schmitt, Christian Joram, Raphael Dumps, Sune Jacobsen (scintillators); Dave Robinson, Steve McMahon (ATLAS SCT); Yuri Guz (LHCb calorimeters); Salvatore Danzeca (Radiation Monitoring); Stephane Fartoukh, Jorg Wenninger (LHC optics), Michaela Schaumann (LHC vibrations); Marzia Bernardini, Anne-Laure Perrot, Katy Foraz, Thomas Otto, Markus Brugger (LHC access and schedule); Simon Marsh, Marco Andreini, Olga Beltramello (safety); Stephen Wotton, Floris Keizer (SCT QA system and SCT readout); Liam Dougherty (integration); Yannic Body, Olivier Crespo-Lopez (cooling/ventilation); Yann Maurer (power); Marc Collignon, Mohssen Souayah (networking); Gianluca Canale, Jeremy Blanc, Maria Papamichali (readout signals); Bernd Panzer-Steindel (computing infrastructure); and Mike Lamont, Fido Dittus, Andreas Hoecker, Andy Lankford, Ludovico Pontecorvo, Michel Raymond, Christoph Rembser, Stefan Schlenker (useful discussions).

Summary and Outlook

FASER

- search for light weakly coupled particles at LHC
- quick, small and inexpensive experiment



Status

- Letter of Intent and Technical Proposal submitted
- funding from Heising-Simons Foundation and Simons Foundation
- advanced stage of CERN approval

SIMONS
FOUNDATION



Envisioned Timeline

- build/install FASER in LS2 (2019-20)
- take data during Run 3 (2021-23, 150 fb⁻¹)
- upgrade to FASER 2 in LS3 (2023-25) for HL-LHC (2026-35, 3 ab⁻¹)

For more information, see

<https://twiki.cern.ch/twiki/bin/view/FASER/WebHome>

We look forward to feedback and suggestions