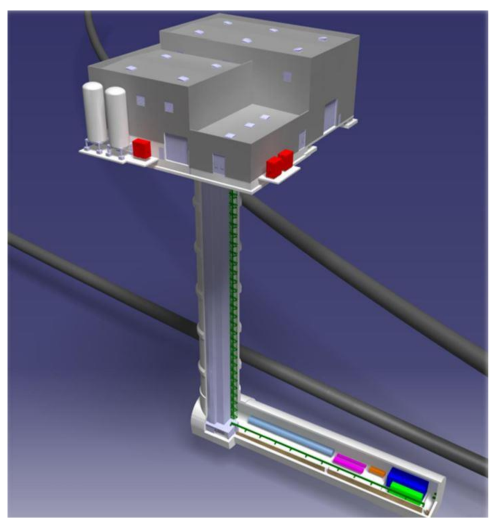
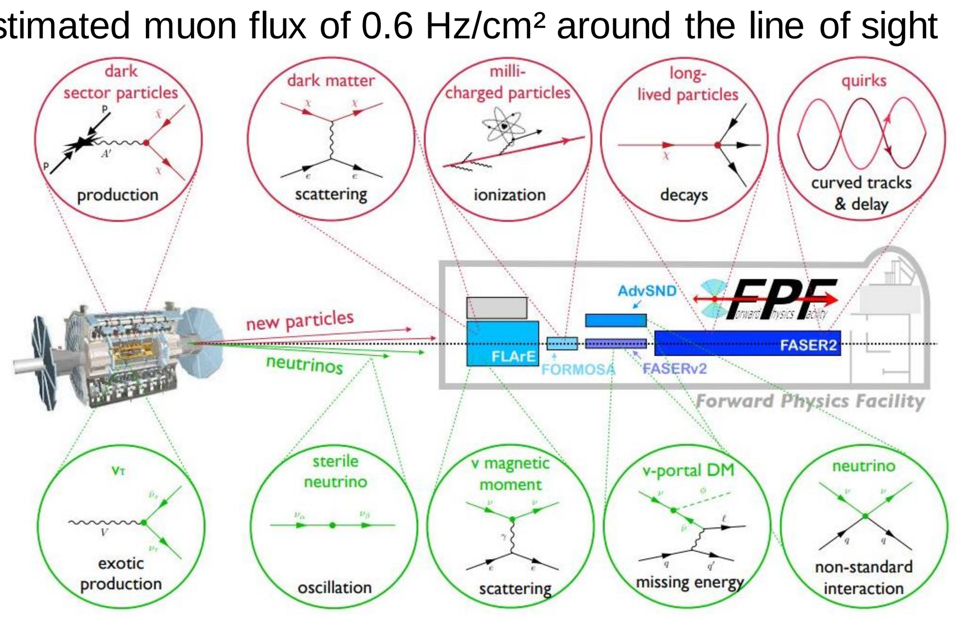
Development of tracking software and detector design studies for the proposed FASER-2 experiment at the LHC

Forward Physics Facility

- Forward Physics Facility[1] (FPF) - proposed underground cavern for far-forward experiments during the High-Luminosity LHC era
- Physics Potential: Detecting ~10^6 neutrino interactions (TeV), searches for light dark matter, and many other new particles
- Location: 617-682 m west of ATLAS IP along the beam collision axis
- Dimension : 65 m long and 9 m wide, 88 m-deep shaft
- Shielded by 200+ m of rock→ Estimated muon flux of 0.6 Hz/cm² around the line of sight



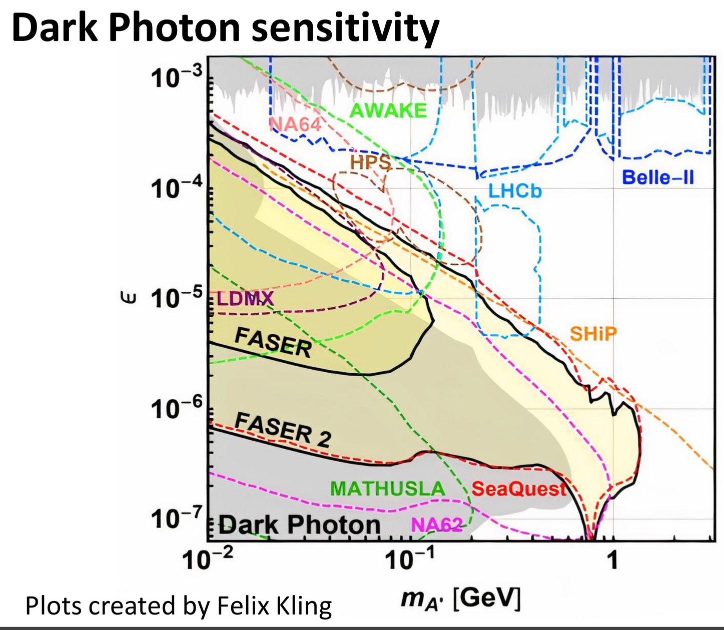


FPF discussed in more detail in talk by R. Abraham in BSM2 session

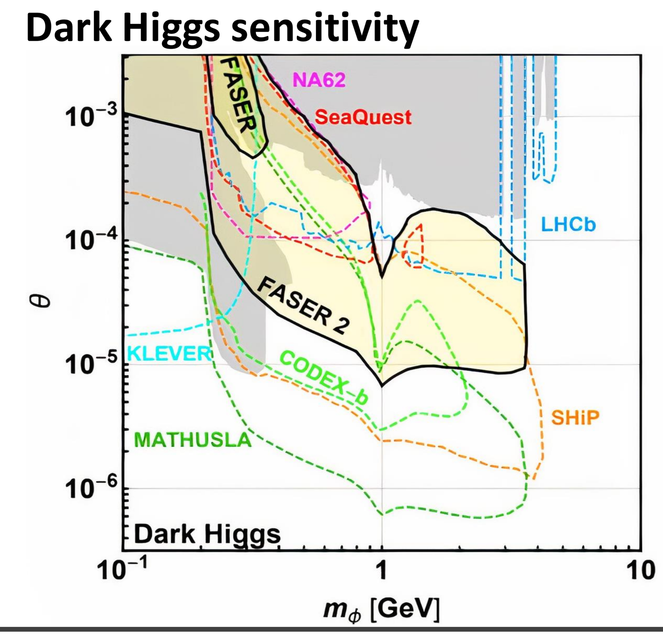
FASER2 Physics Sensitivity

- FASER2 upgrade to the FASER experiment[2], larger detector, increased sensitivity to BSM physics
- Search for Long-Lived Particles (LLPs) decaying into visible final states :
  - Dark Photons, Dark Higgs bosons
  - Axion-like particles, Heavy neutral leptons
- Measure momentum of muons from neutrino interactions in dedicated neutrino detectors FASERv2 and FLArE

Dark Photon sensitivity



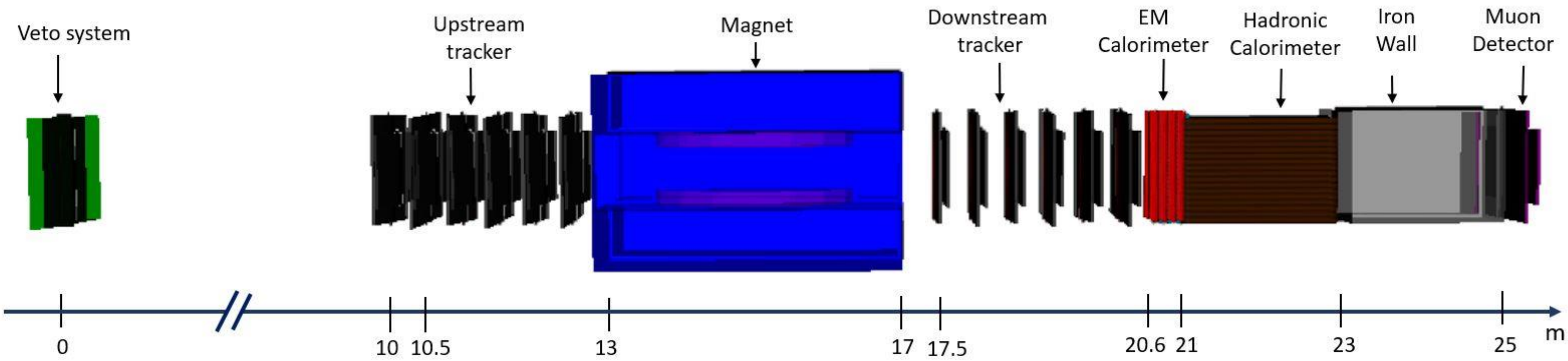
Dark Higgs sensitivity



Plots created by Felix Kling

FASER2 Detector Conceptual Design

FASER2 detector simulation created with pyg4ometry[3] in GDML :



Veto

- Plastic scintillator-based veto system
- Expected to reject muon rates of ~ 20kHz

Tracker

- Silicon photomultiplier and scintillating fiber tracker technology
- Based on LHCb's SciFi[4] tracker
- Spatial resolution of ~ 100 µm
- Each station consists of vertical and horizontal SciFi modules

Magnet

- Rectangular aperture: 1 m in height, 3 m in width, 4 m depth
- Superconducting magnet technology
- Based on SAMURAI[5] experiment magnet
- BField 4 Tm bending power for particle separation, momentum resolution, and charge ID

EM Calorimeter

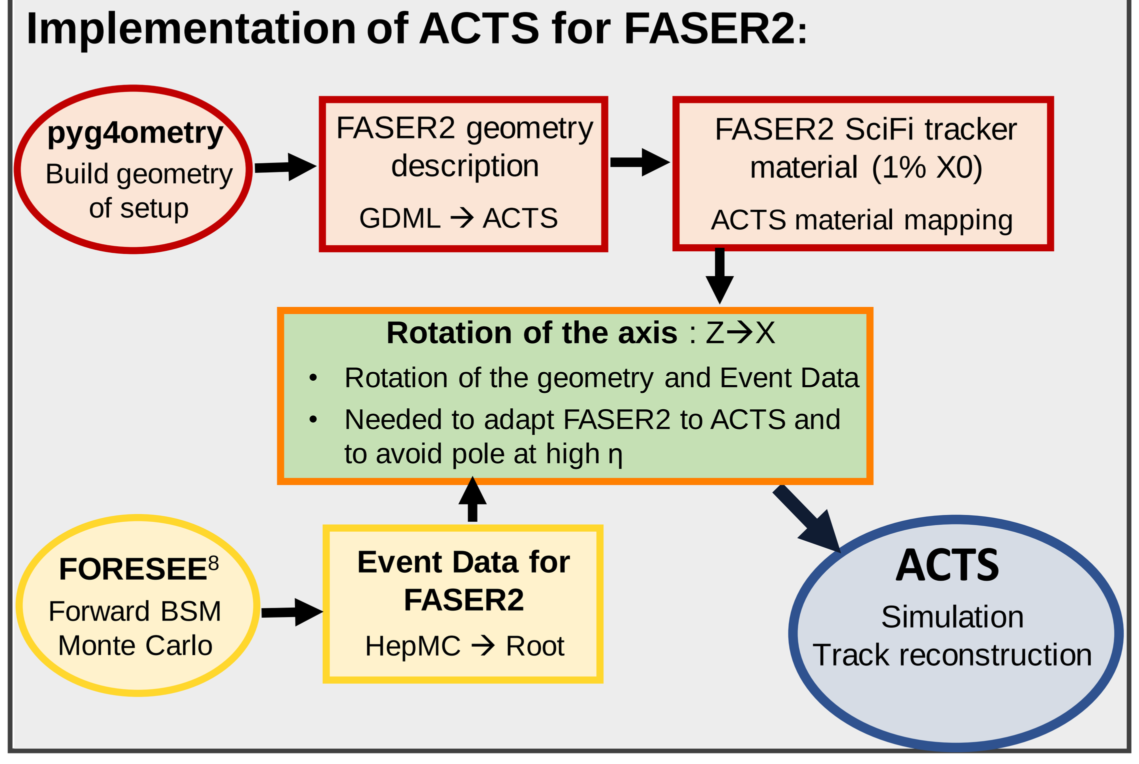
Hadronic Calorimeter

- Dual-readout calorimetry[6] technology
- Spatial resolution for particle identification at ~ 1-10 mm separation
- Particle identification capabilities

A Common Tracking Software

- **ACTS**[7]: Experiment-independent toolkit for charged particle track reconstruction in HEP experiments
- Implemented in modern C++ and python
- Features:
  - Event data model
  - Tracking geometry description based on surface
  - Track propagation and fitting algorithms
  - Basic seed finding algorithms
  - Common vertexing algorithms

Implementation of ACTS for FASER2:

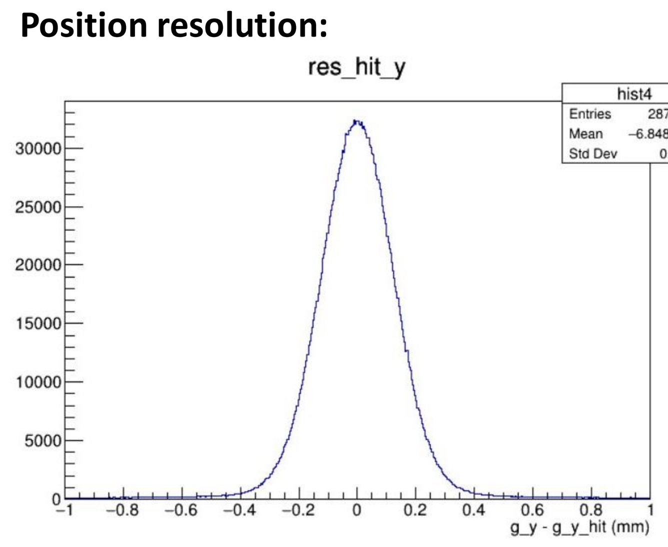


Preliminary Results

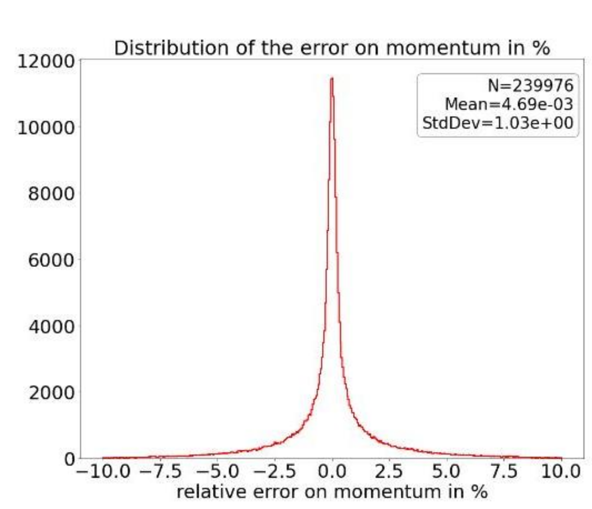
Results from using ACTS tracking software to the FASER2 geometry :

- Tracks fitted by ACTS's Kalman Fitter using truth information for seeding
- 120 000 BSM Monte Carlo FORESEE events simulated Dark Higgs m = 0.81 GeV decay in $\mu^+\mu^-$
- Detector resolution simulated by Gaussian smearing of the real x and y-hit positions with σ_{res}= 100 µm
- Track efficiency very close to 1

Position resolution:



Momentum resolution plot :

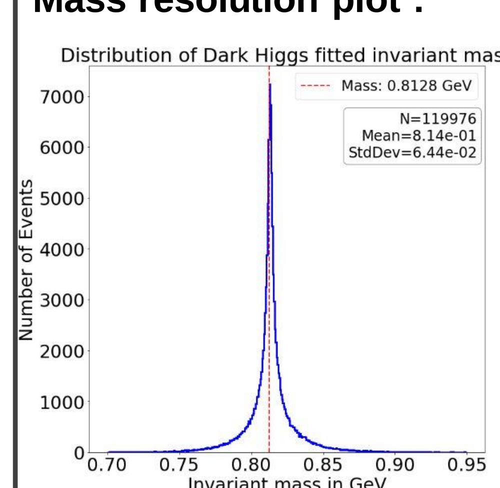


- Momentum resolution is mainly influenced by the resolution of the detector
- Other factors on the momentum resolution: Value of the B field, material effects, length of FASER2 geometry and tracker alignment

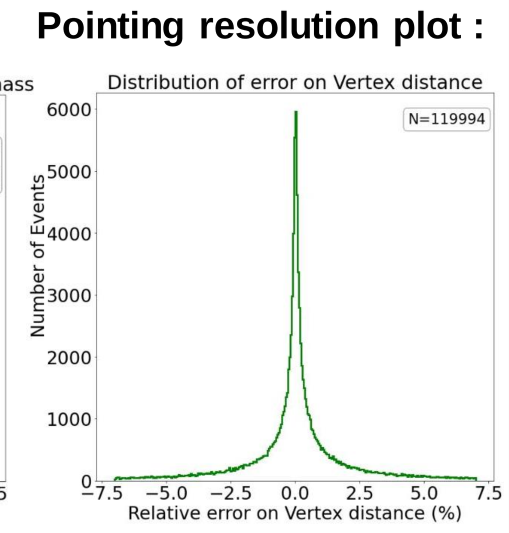
Mass/Pointing resolution plot

Track reconstruction with ACTS :
120 000 events Dark Higgs decay in $\mu^+\mu^-$ m = 0.81 GeV

Mass resolution plot :



Pointing resolution plot :



Future studies

- Comparing reconstruction performance for different possible layouts of FASER2 detector
- Alignment studies
- Charge ID performance for neutrino studies (neutrino/anti-neutrino separation)
- Study of the muon background and impact of the veto for reconstruction

References :

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8. Felix Kling et Sebastian Trojanowski. "Forward experiment sensitivity estimator for the LHC and future hadron colliders". In : Physical Review D 104.3. doi :10.1103/physrevd.104.035012.

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Acknowledgements: This poster was possible because of the work of Josh McFayden, Jamie Boyd et al. from the FASER2 Collaboration and FPF Collaboration and the support from the ACTS developers A. Salzburger, C.Allaire, A.Stefl et al.