

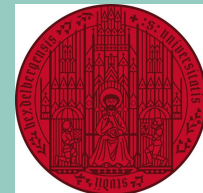
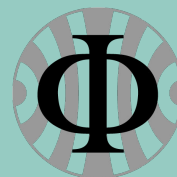


The SHADOWS Experiment

Search for Hidden And Dark Objects With Sps

Shreya Roy, on behalf of the SHADOWS Collaboration
Physikalisches Institut
University of Heidelberg

SHADOWS



SHADOWS

Search for Hidden And Dark Objects With the SPS

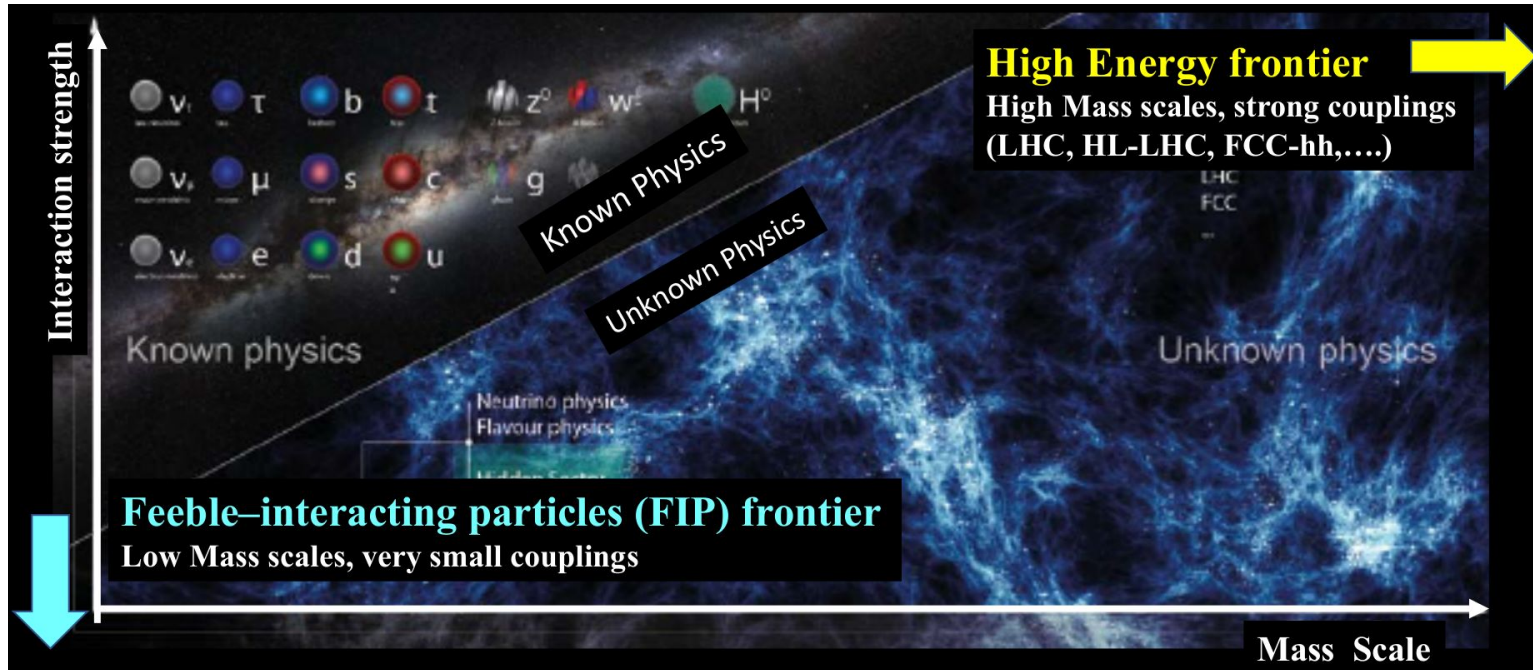
Technical Proposal

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Status

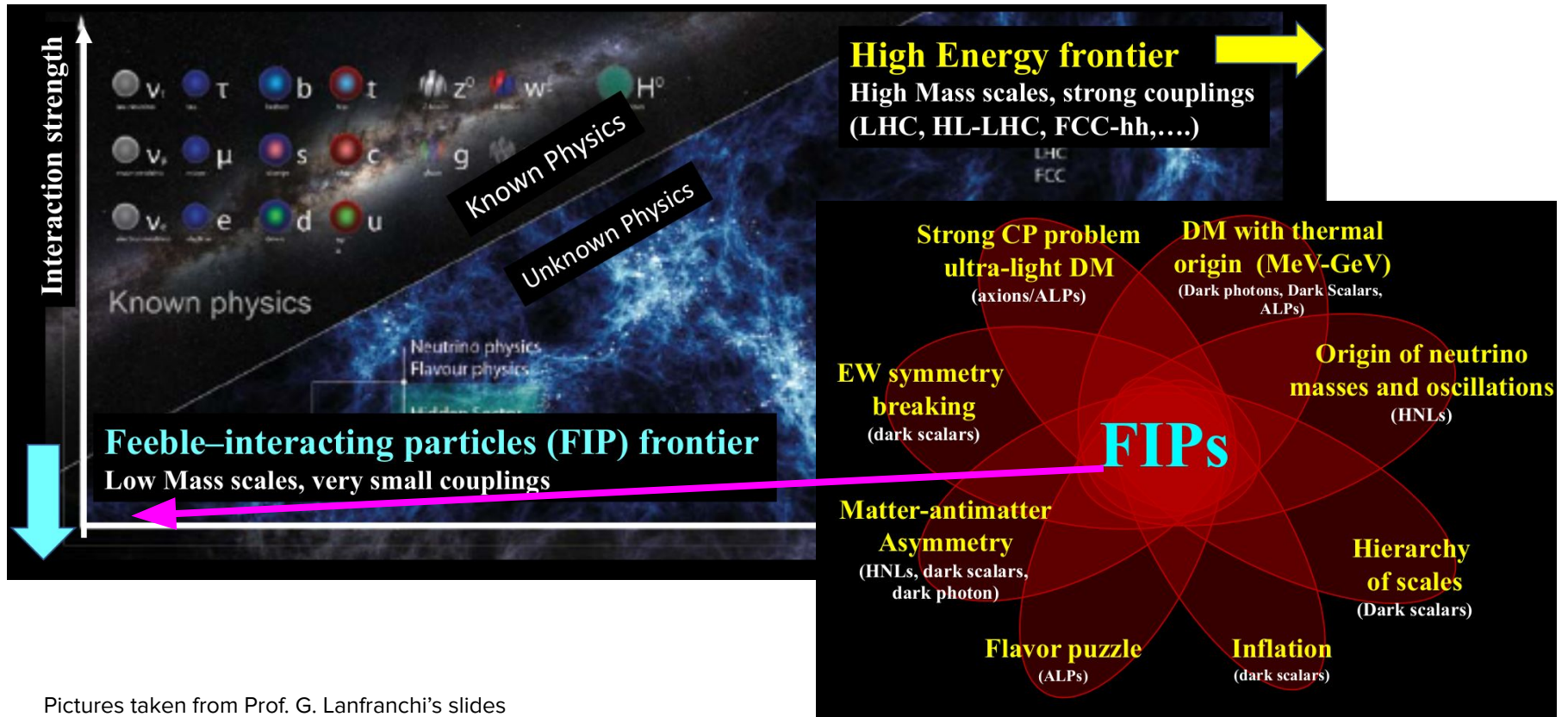
- The technical proposal has been submitted to the SPSC in August 2023
- Decision will be by the end of this year 2023

What are Feebly Interacting Particles (FIPs)?




Pictures taken from Prof. G. Lanfranchi's slides

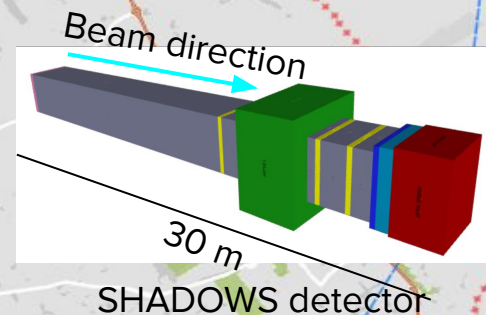
What are Feebly Interacting Particles (FIPs)?



Pictures taken from Prof. G. Lanfranchi's slides

SHADOWS experiment

- SHADOWS is a **new off-axis beam dump experiment**
- ◆ exploiting the SPS primary proton beam currently serving the NA62 experiment  **CERN North area**
- ◆ planned to be operated concurrently with the HIKE experiment (NA62 successor)

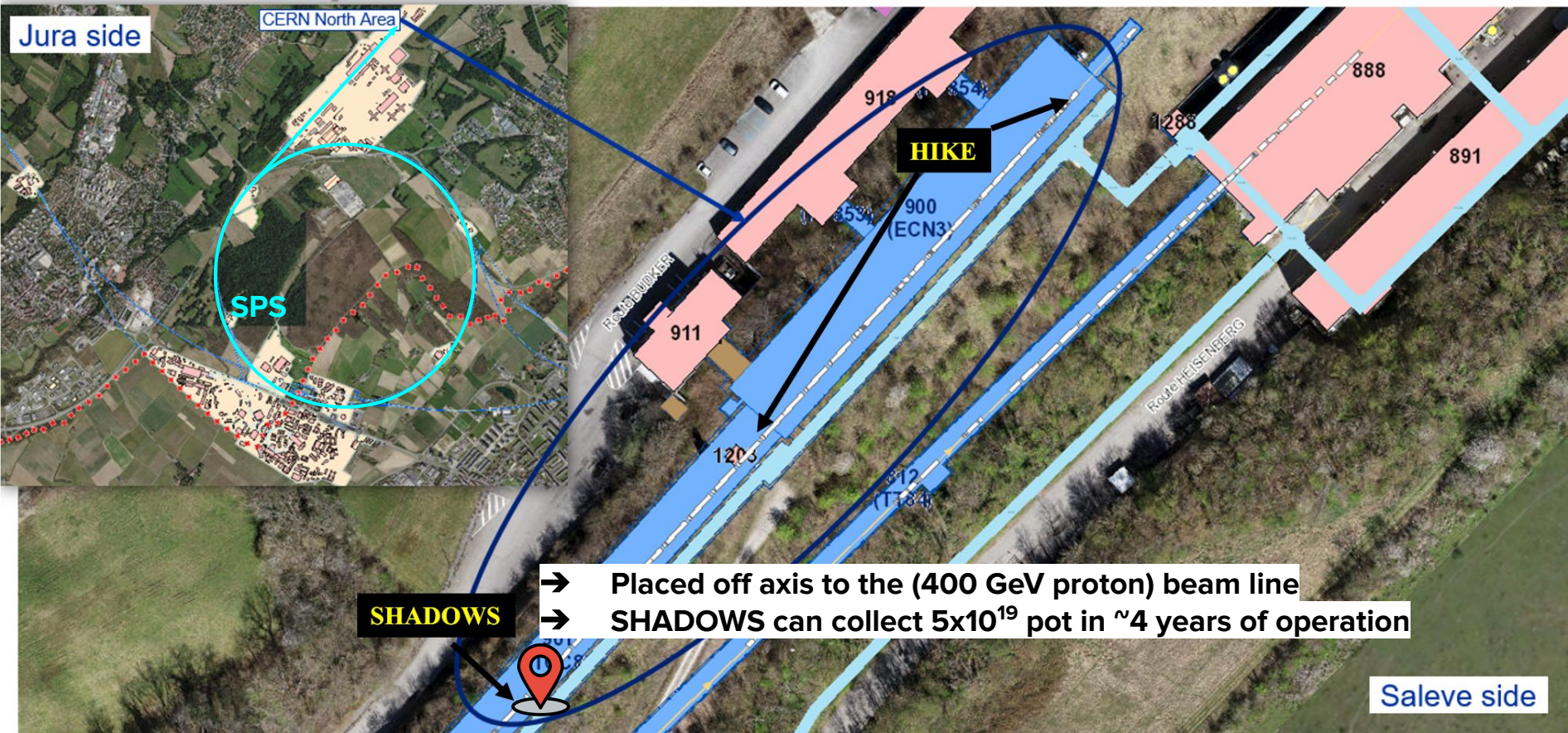


- **Main goal : search for feebly-interacting particles (FIPs) emerging from charm and beauty decays**

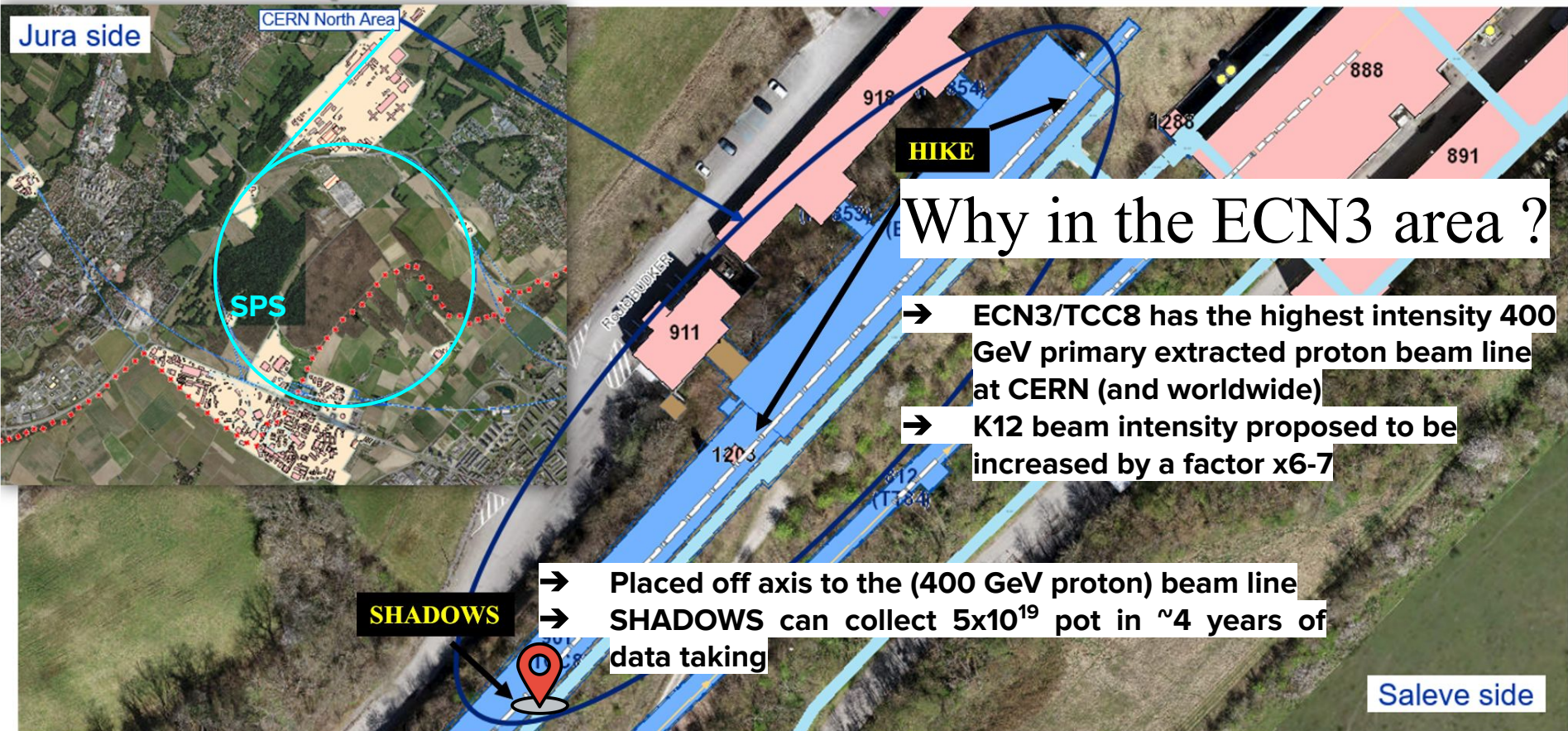
The visible final states of FIPs decays :

Scalar portal	$l^+l^-, \pi^+\pi^-, K^+K^-$
Pseudo-scalar portal	$l^+l^-, \gamma\gamma, \pi^+\pi^-, K^+K^-$
Vector portal	$l^+l^-, \pi^+\pi^-, K^+K^-$
Fermion (neutrino) portal	$l^\pm\pi^\mp, l^\pm K^\mp, l^\pm\rho^\mp (\rho^\mp \rightarrow \pi^\pm\pi^0), l^+l^-\nu$

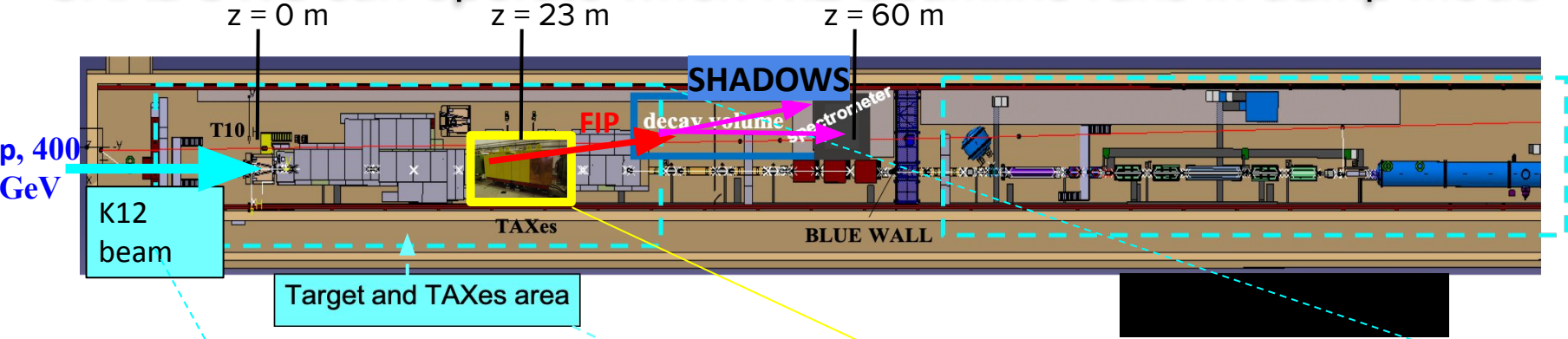
SHADOWS detector location (satellite view)



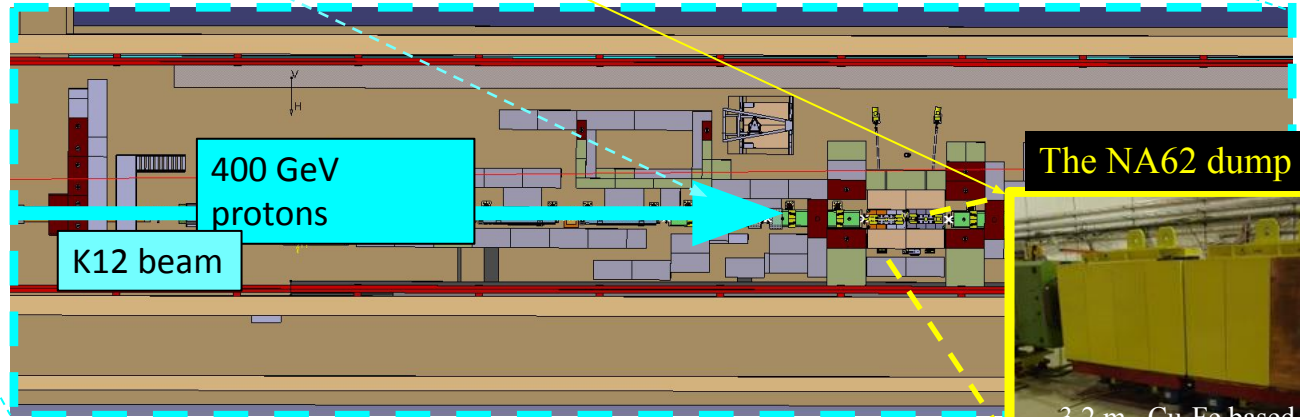
SHADOWS detector location (satellite view)



SHADOWS can operate when K12 beamline runs in dump mode

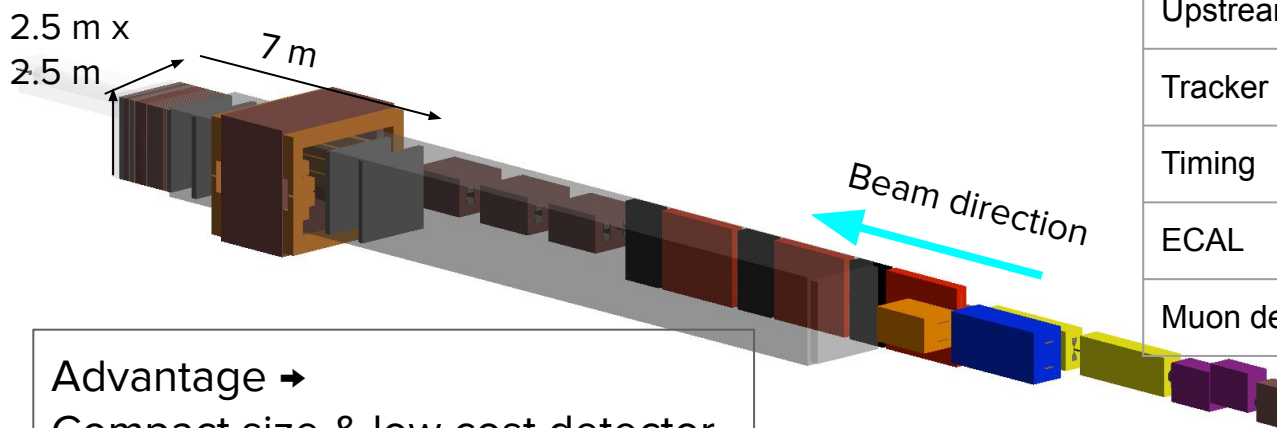
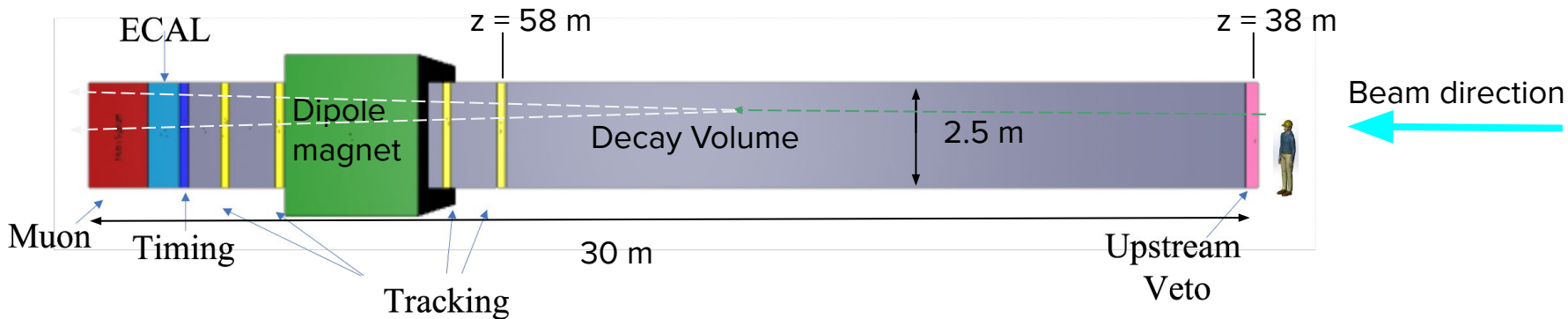


T10 target is moved out and the 400 GeV primary p beam is sent onto the dump (TAX)



NB: TAX to be replaced in the high-intensity ECN3 era

SHADOWS detector : Overview

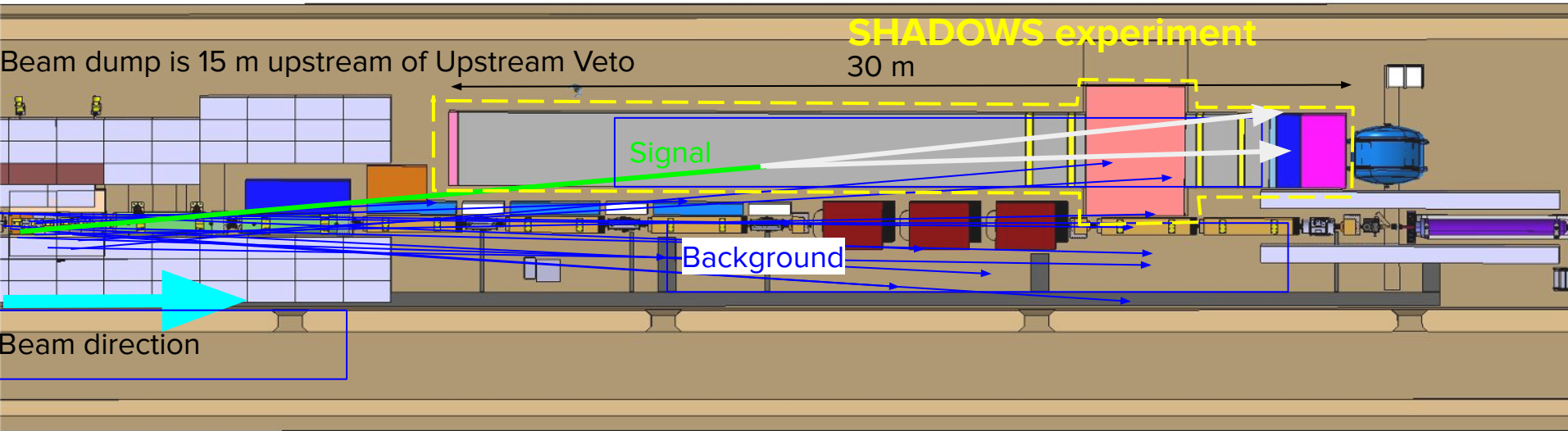


Upstream Veto	Micromegas
Tracker	Straw tube detectors
Timing	Scintillating bars
ECAL	StripCal
Muon detector	Scintillating tiles

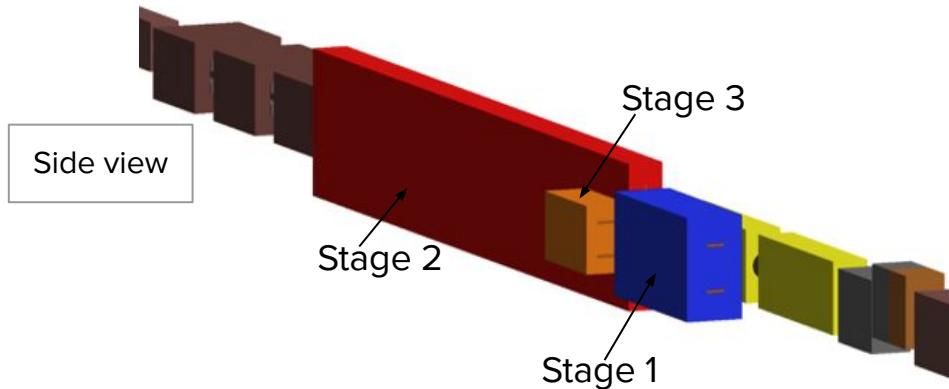
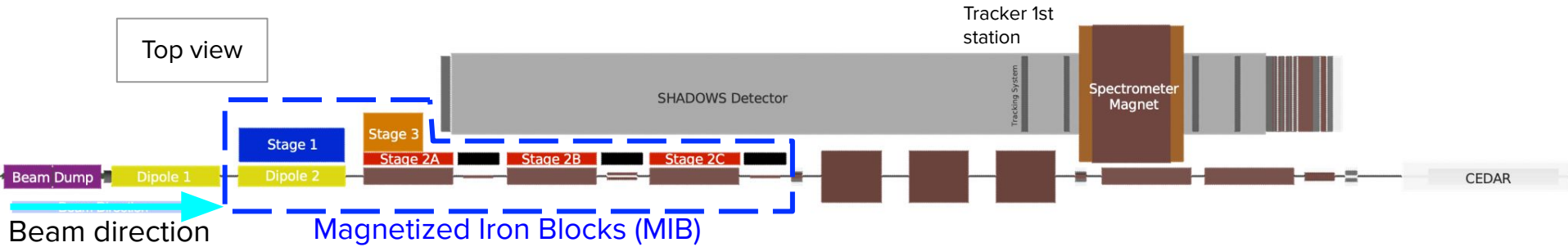
Advantage →
Compact size & low cost detector

Why is SHADOWS an off-axis detector?

- There is another experiment on axis (but far downstream of the beam dump)
- Although off-axis, SHADOWS is closer to the beam dump, hence has increased acceptance
- Reduced background compared to on-axis experiments

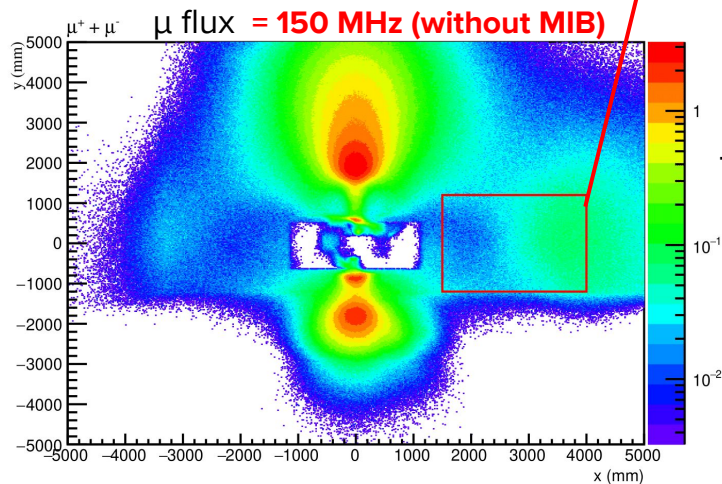
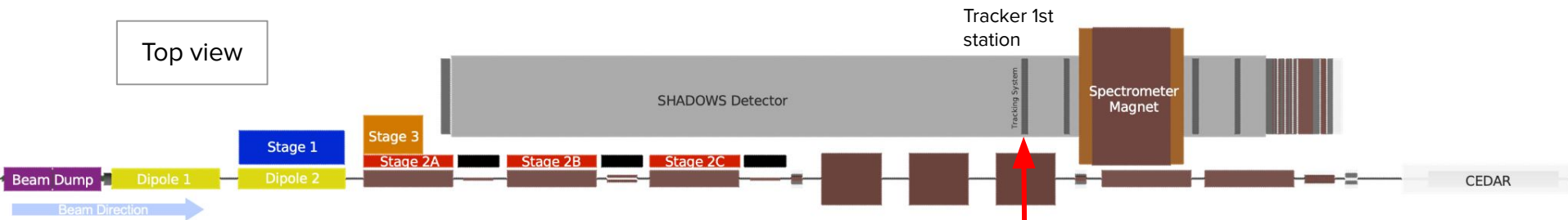


The muon sweeping magnets (MIB): a clever design

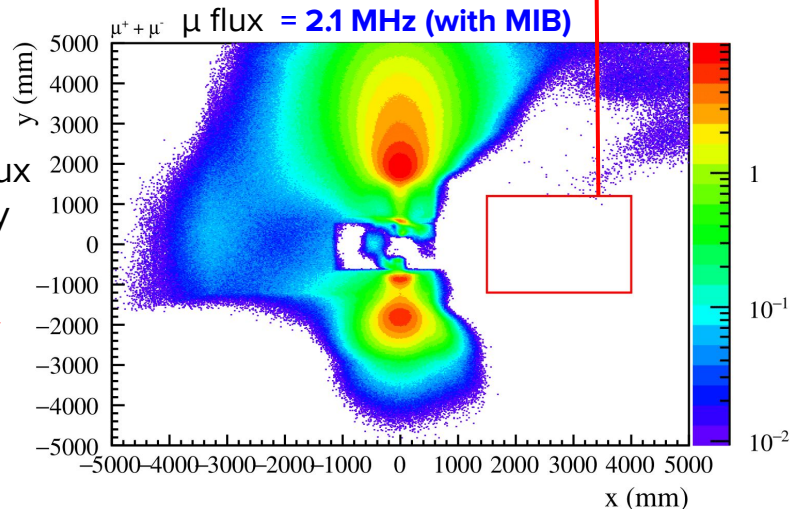


The MIBs bend the muons away in the horizontal and vertical plane → reduces muon flux approaching SHADOWS

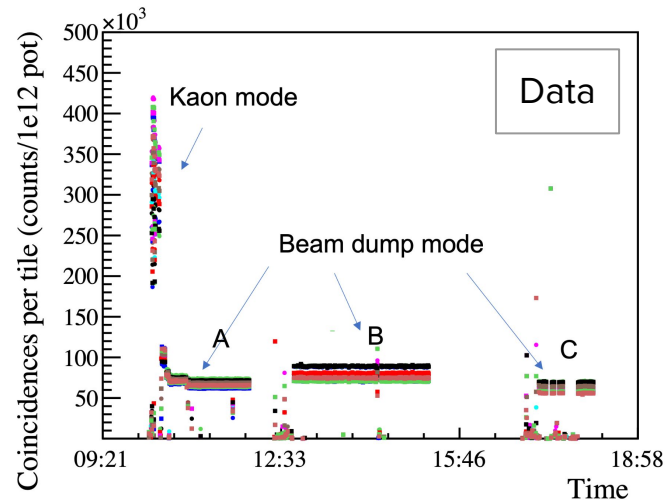
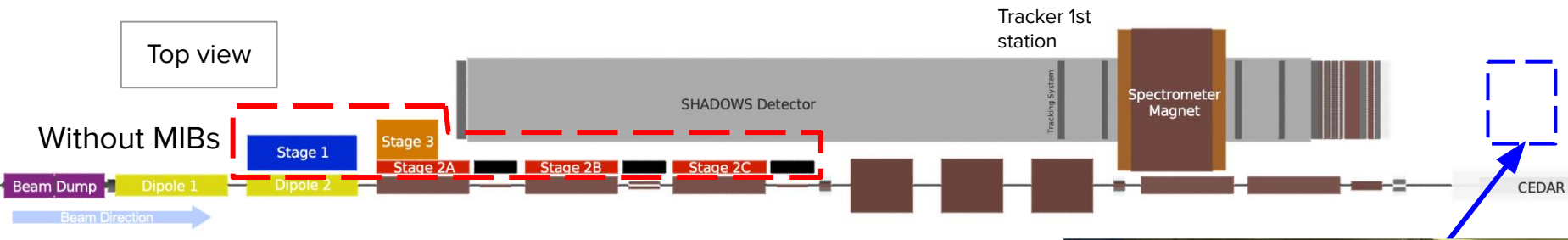
The muon sweeping magnets (MIB): a clever design



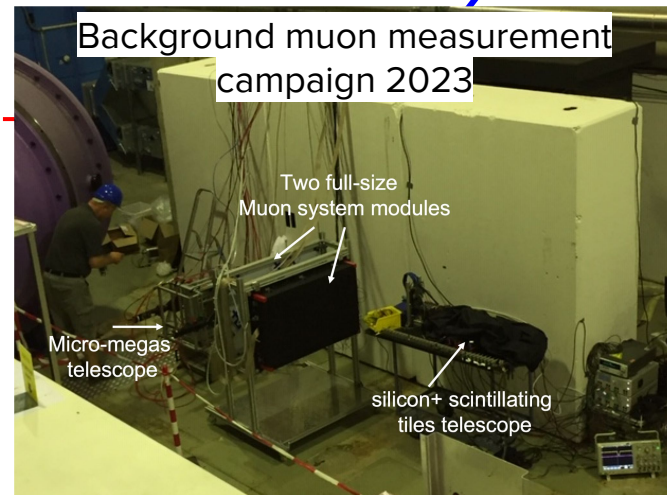
Total muon flux
reduction by
factor 70



Measurement of the “off-axis” muon flux in 2023



“Measured μ flux is a factor 3 higher than simulated μ flux” - well known fact from NA62



Other ways to reduce the muon background

Upstream Veto
(99.8% efficiency)

Timing detector
(Time resolution $\sigma_t = 100$ ps)

Decay Volume

Tracking System

Spectrometer Magnet

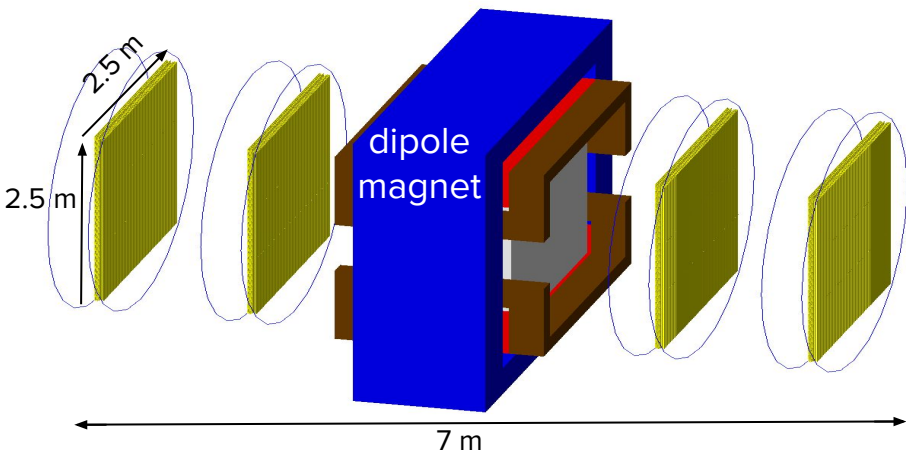
Lateral Veto

Stage 2B

Stage 2C

Timing detector - selects dimuon events within a time difference $\delta T \leq \pm 3 \sigma_t = \pm 300$ ps

SHADOWS Spectrometer



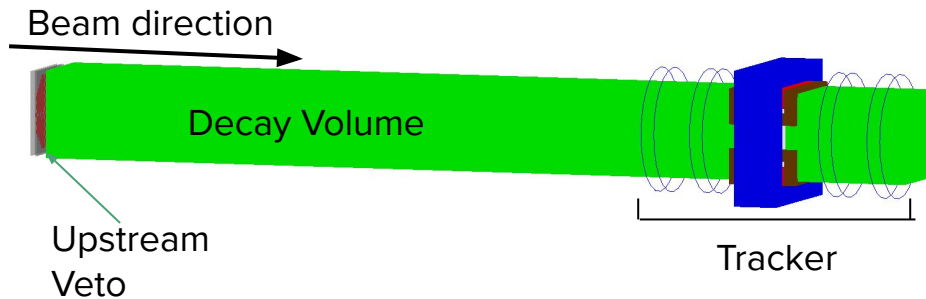
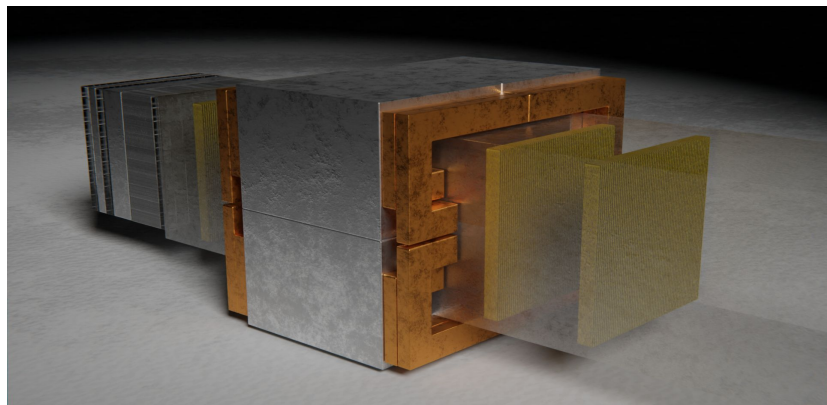
Straw tube tracker chamber



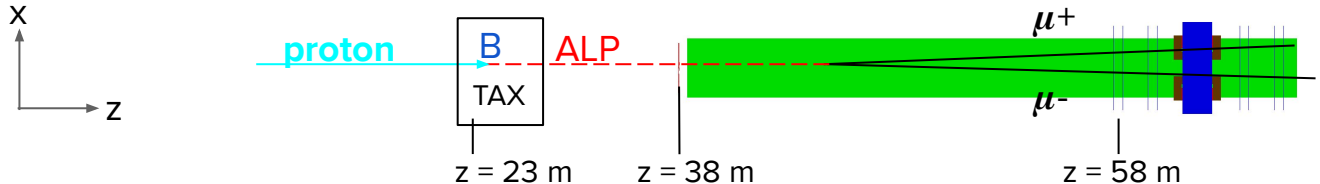
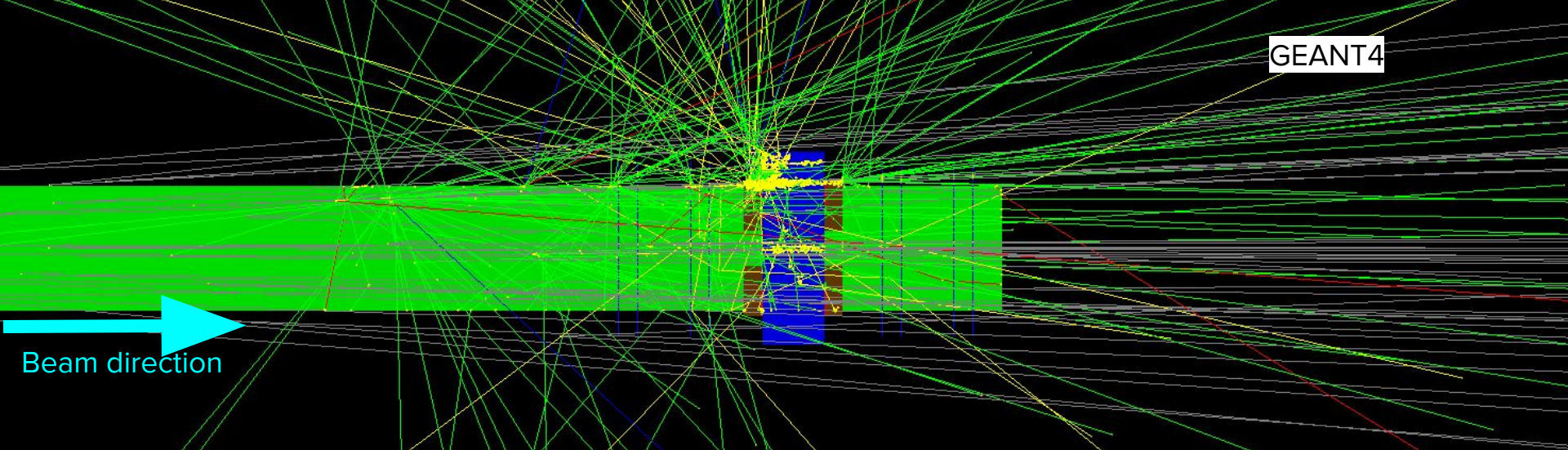
4 planes in x, 4 planes in y



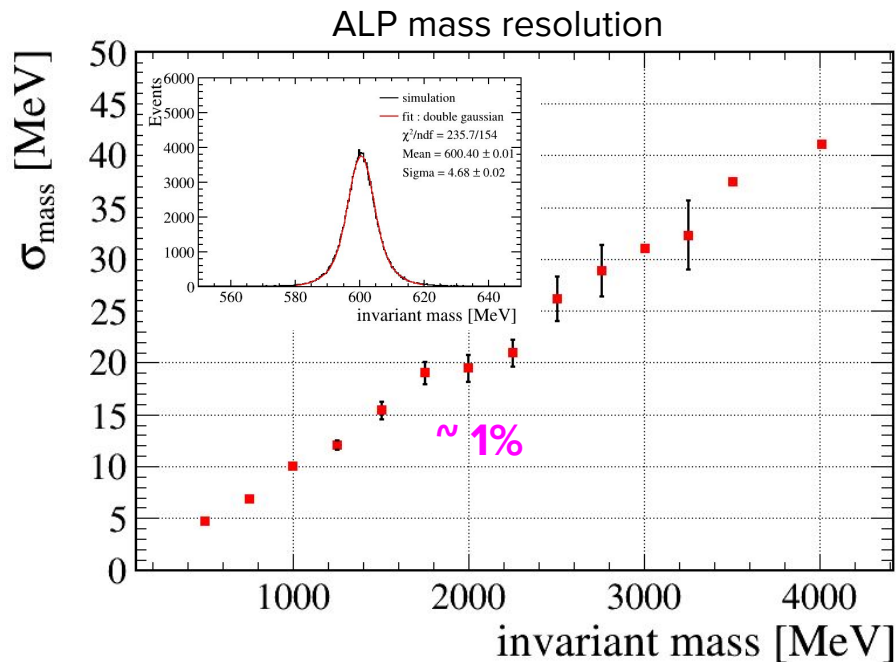
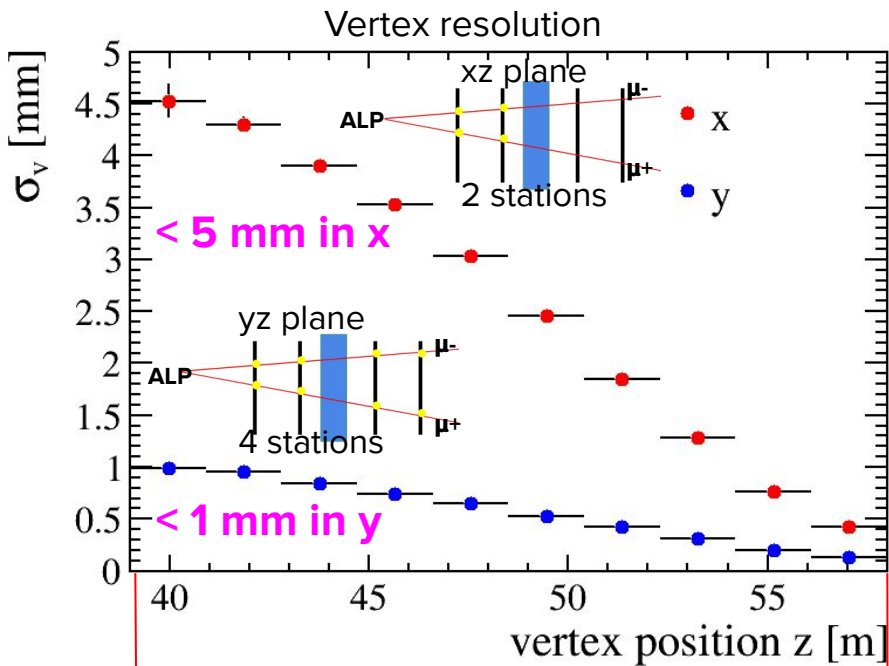
Straw tube detectors (NA62)



Signal reconstruction and selection



Preliminary SHADOWS tracker performance



Signal reconstruction and selection

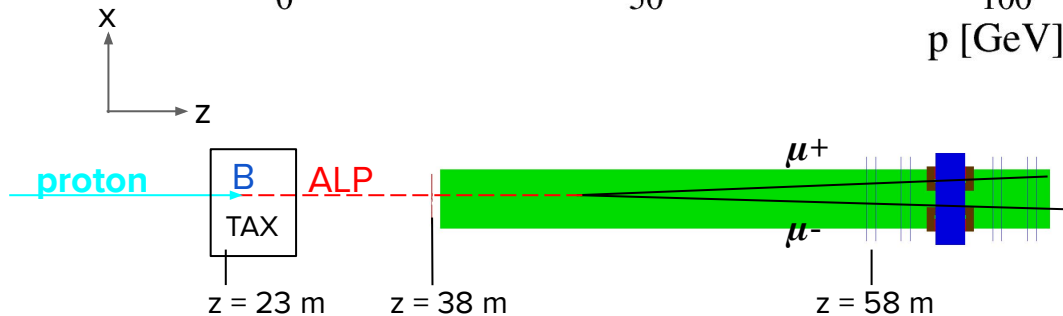
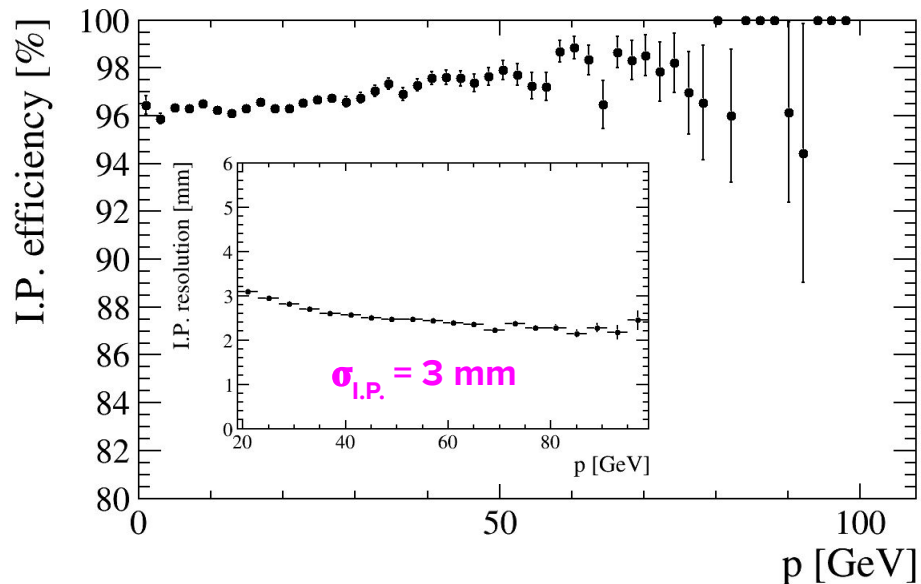
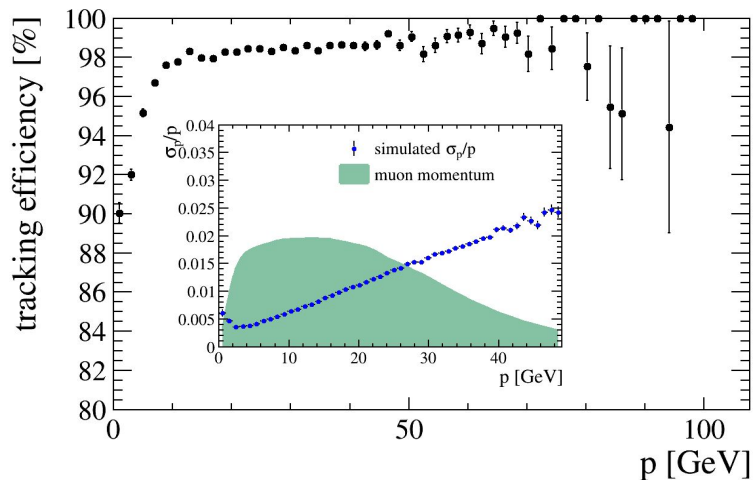
FIP signal used for the simulation : ALP $\rightarrow \mu^+ \mu^-$

\rightarrow Signal selection with efficiency cuts

- ◆ Tracking efficiency = 98 %
- ◆ Vertex efficiency = 89.2 %
- ◆ Impact parameter efficiency = 96.6 %

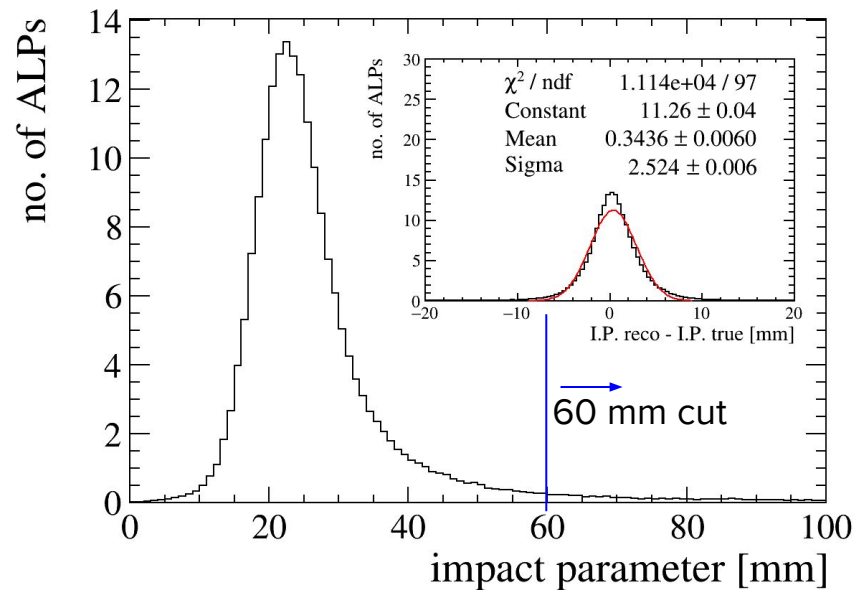
Total ALP reconstruction efficiency = 83%

(for tracks in acceptance)



Combinatorial muon background

Muon background	2160M / spill*
MIB reduction	10M / spill
Timing detector requirement	3000 / spill
Upstream Veto requirement	1.2×10^{-2} / spill
Vertex requirements	6×10^{-6} / spill
Pointing or (I.P. < 60 mm)	6×10^{-10} / spill



Total combinatorial dimuon background events after all cuts = 6×10^{-10} /spill x 2.4×10^6 spills in SHADOWS lifetime (4 years) = 0.001. Estimated background for muon inelastic interaction < 0.9

→ The selection of cuts results in a muon **background of less than 1 dimuon event** throughout the entire lifespan of SHADOWS

* 1 spill = 4.8 sec

SHADOWS timeline



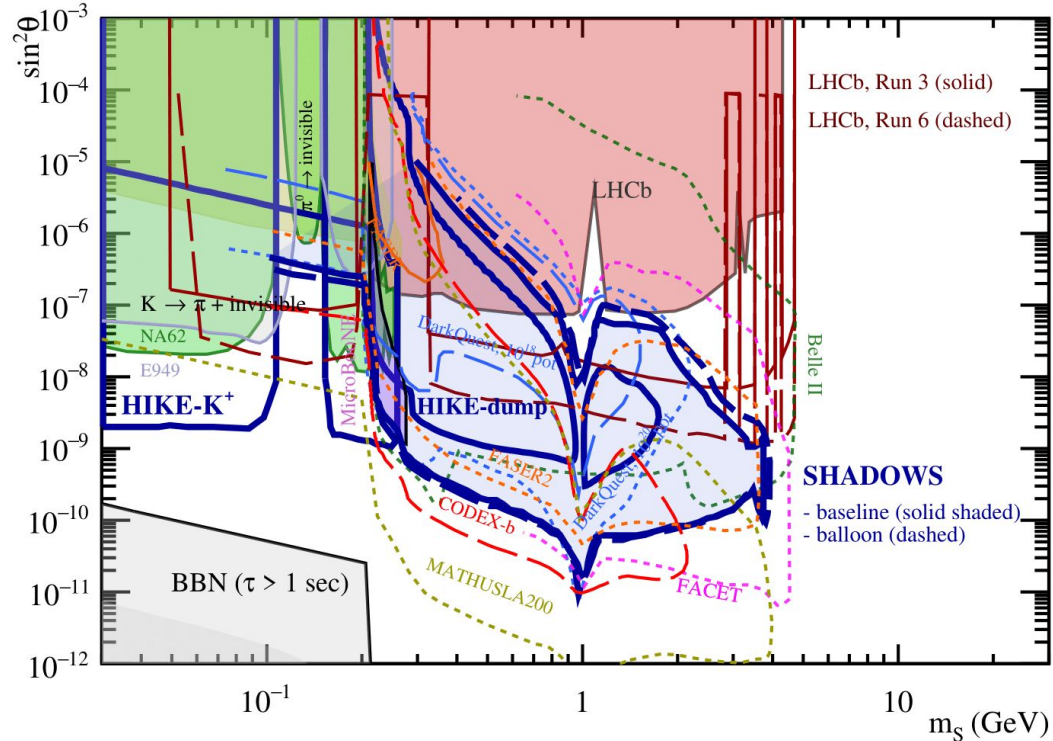
2031 onwards : Expected data taking with beam 50% of the time in beam-dump mode (for HIKE and SHADOWS) and 50% of the time in kaon mode (for HIKE phase I, no SHADOWS)

2023	2024	2025	2026	2027	2028	2029	2030	2031
NA62 Run			LS3	LS3	LS3	ECN3/HI Installation/ commissioning	ECN3/HI Installation/ commissioning	ECN3/HI run
Proposal	TDR	TDR	TDR/PRR	Production	Production	Production/ Installation	Installation/ Pilot Run	SHADOWS run
2032	2033	2034	2035	2036	2037	2038	2039	2040
ECN3/HI run	LS4	ECN3/HI Run					LS5	
SHADOWS run	consolidation	SHADOWS run	SHADOWS run	SHADOWS run	SHADOWS run	SHADOWS run	consolidation	SHADOWS run

SHADOWS physics goals

HIKE in K⁺ mode will explore the lower mass regime

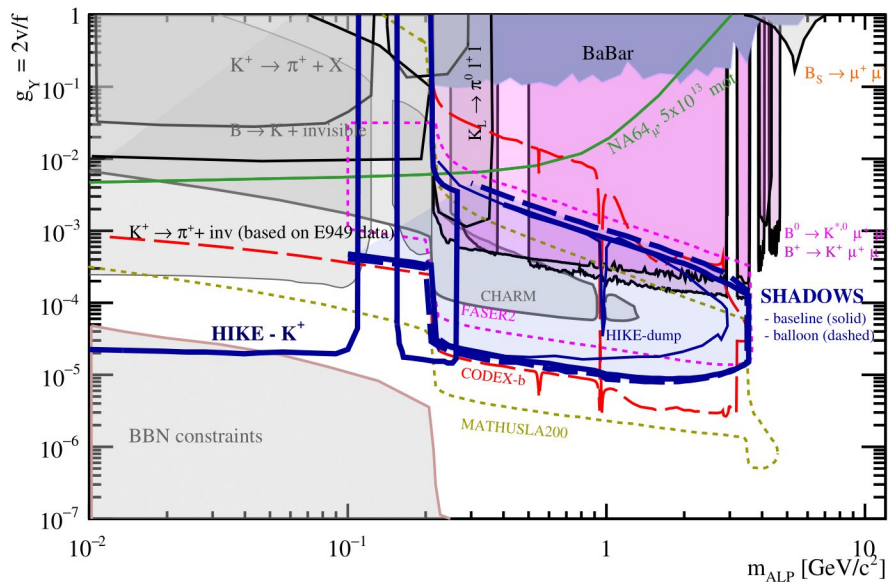
Sensitivity to light dark scalar



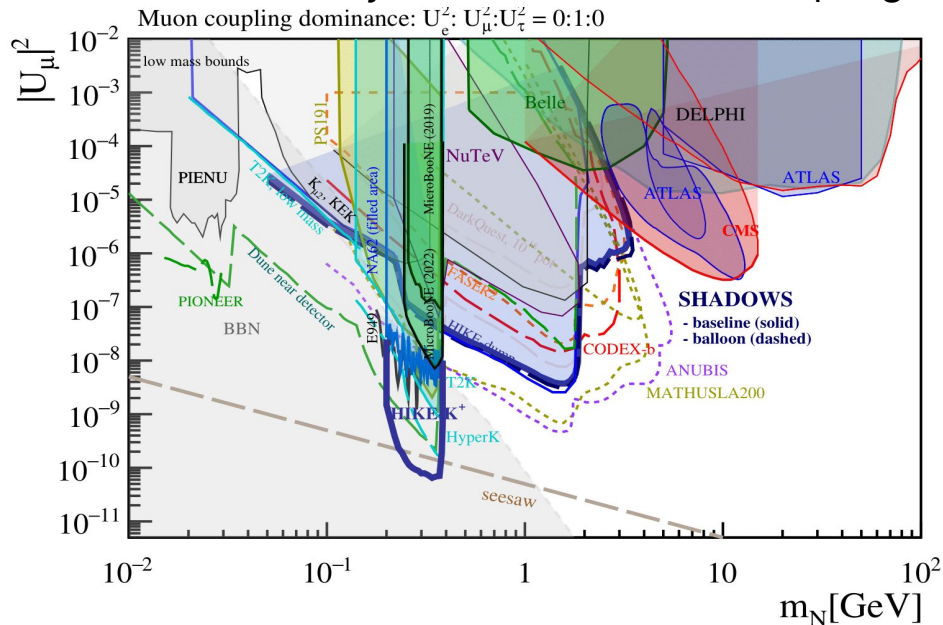
SHADOWS + HIKE in beam-dump mode will explore the mass range from few MeVs to few GeVs

SHADOWS physics goals

Sensitivity to ALPs with fermion couplings



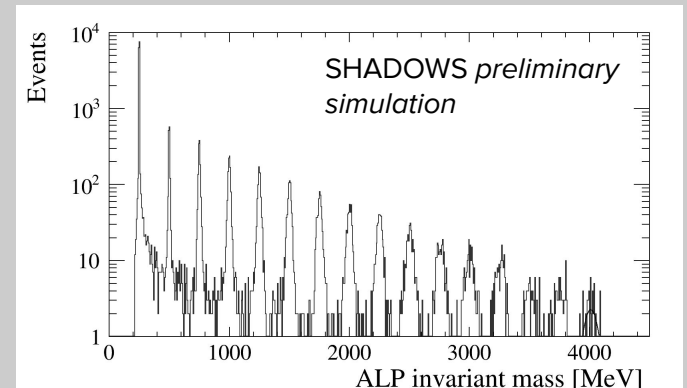
Sensitivity to HNL with muon coupling



→ Anticipate achieving the FIP physics results by 2040 at the latest, solidifying competitiveness of SHADOWS + HIKE in the global FIP exploration landscape

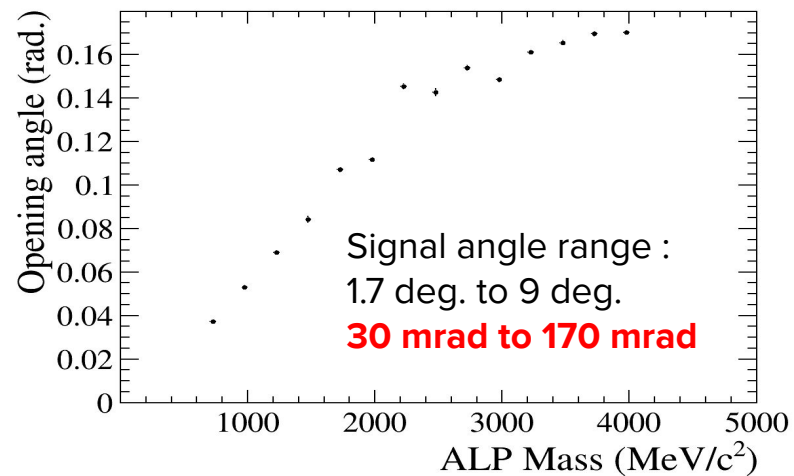
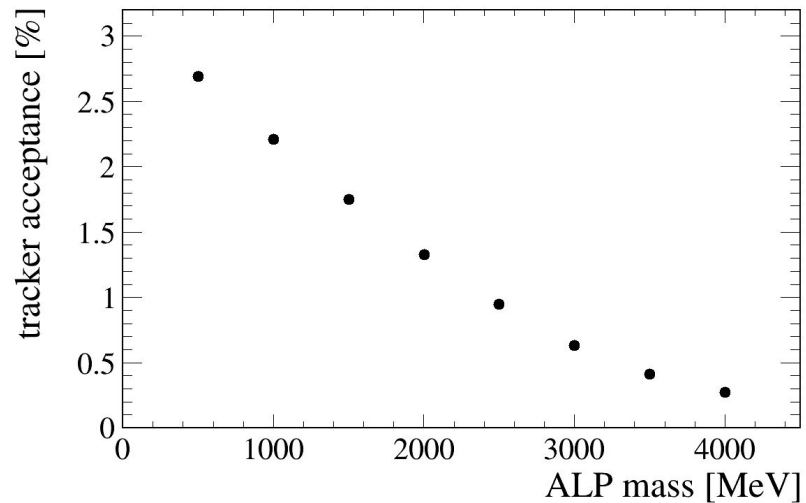
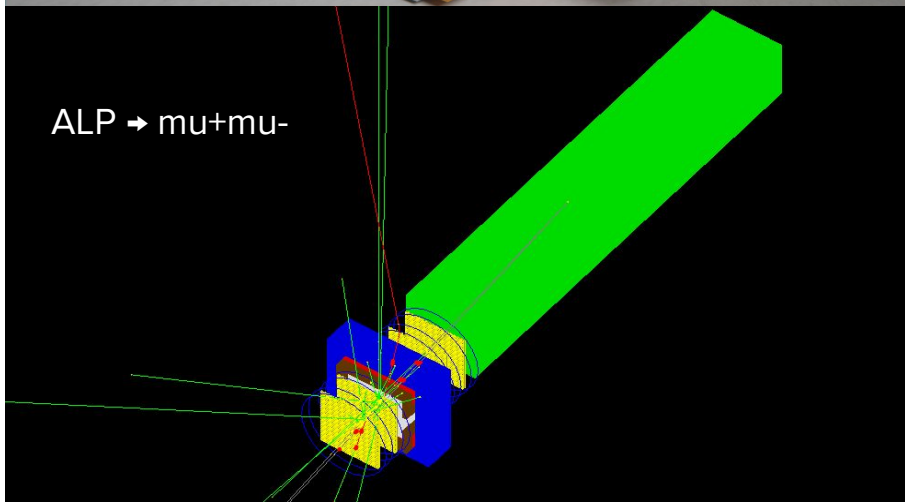
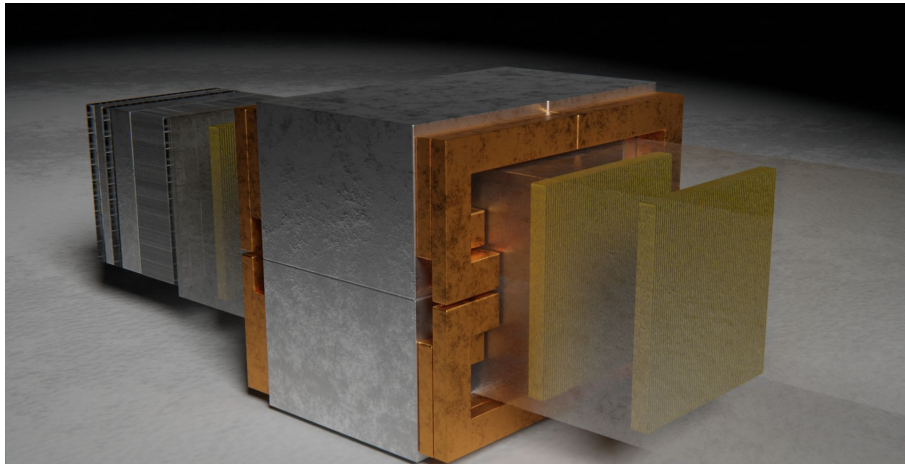
Summary

- **SHADOWS** - is a **new beam dump experiment** at the **CERN North Area** searching for **FIPs** within a mass range of **MeV to few GeV**
- It seeks to **exploit** the **400 GeV primary protons** from the **SPS** and is planned to **operate concurrently with HIKE experiment**
- SHADOWS is foreseen to begin **data collection by 2031**
- The **(ALP) signal efficiency is 83%** in the acceptance of SHADOWS
- **SHADOWS+HIKE are competitive** within mass range of few MeVs to few GeVs with other proposed experiments

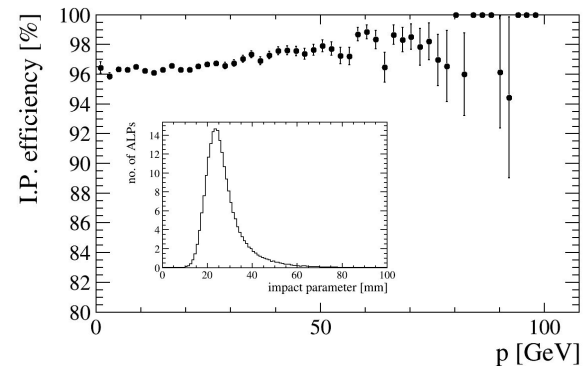
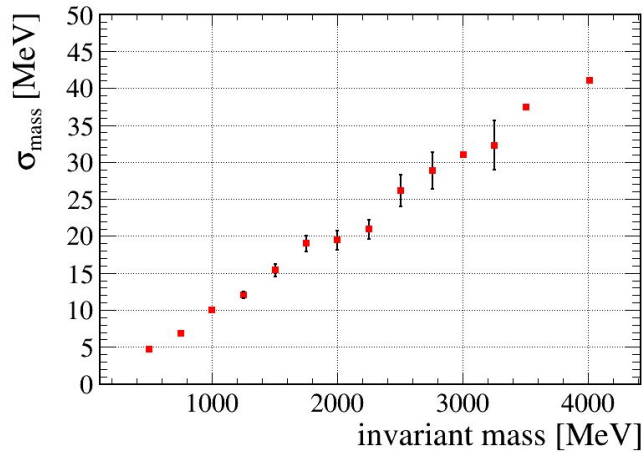
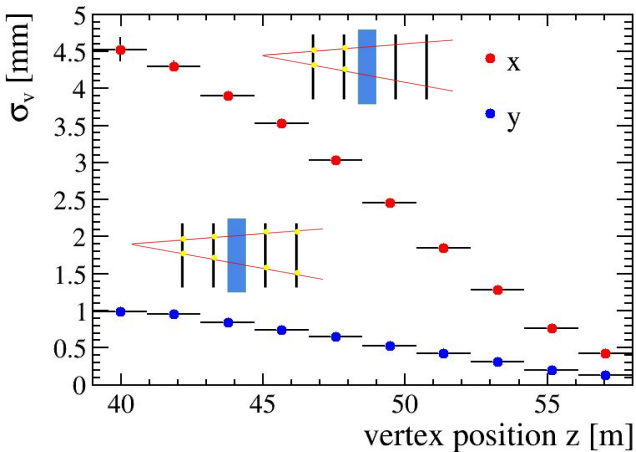
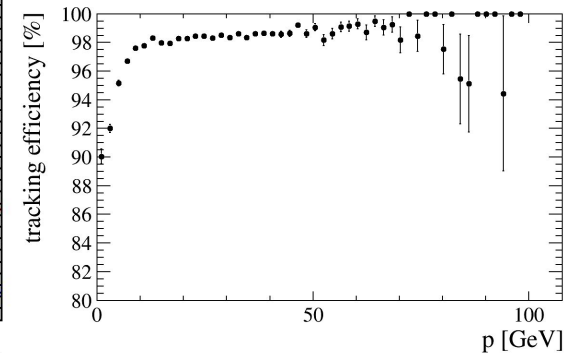
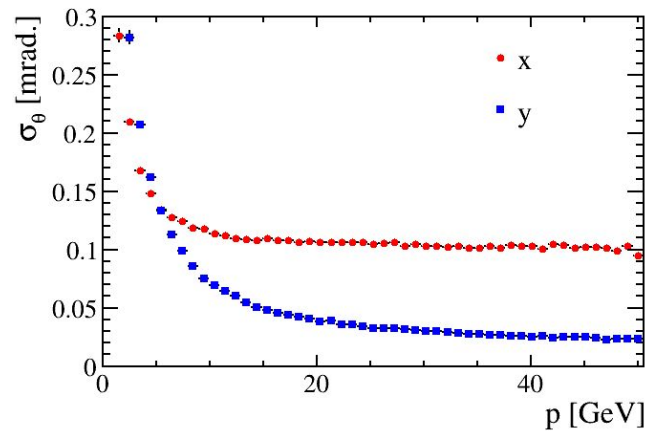
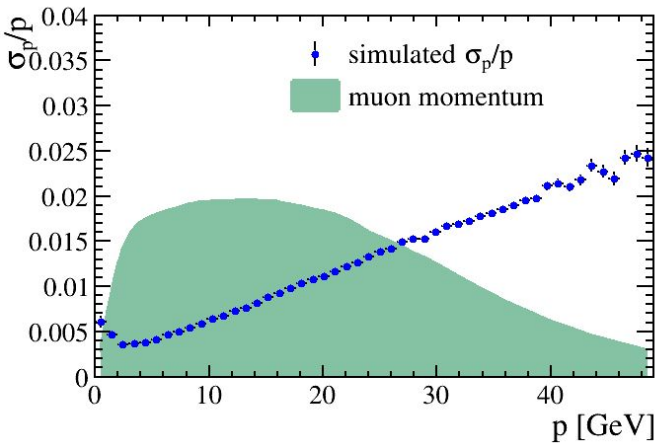


Back up

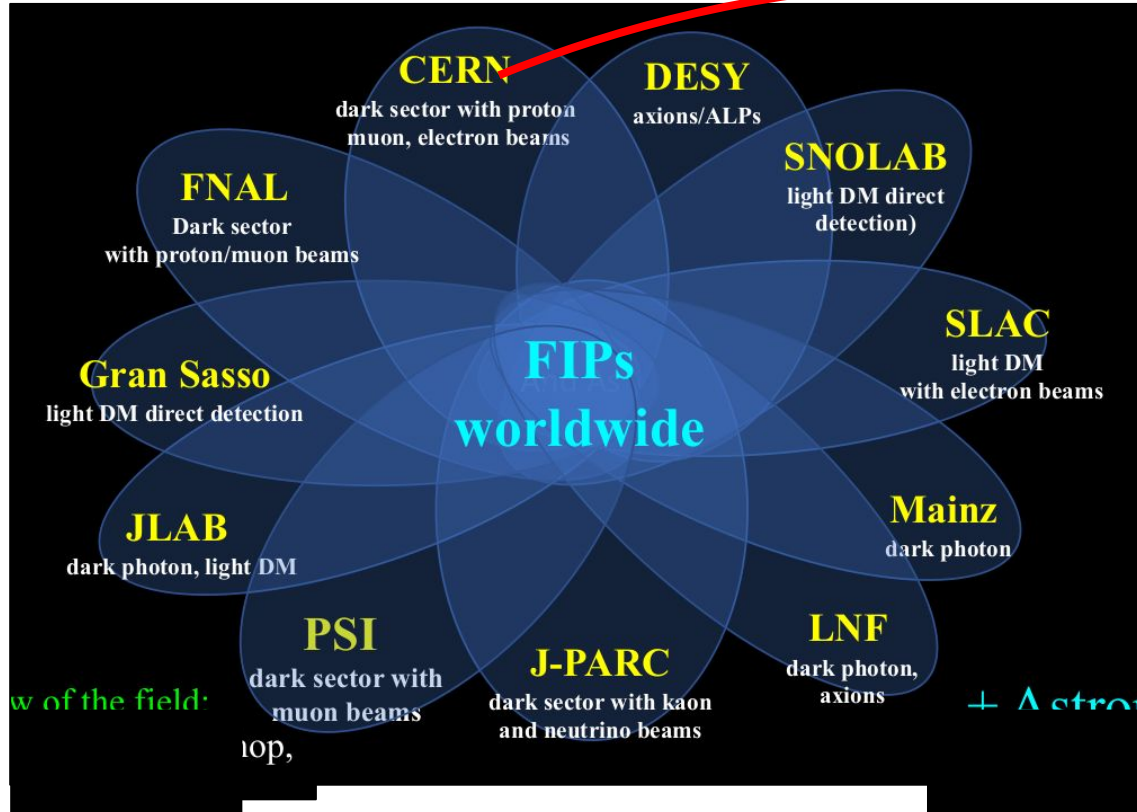
SHADOWS Spectrometer



Tracking performance : SHADOWS Preliminary



Search for FIPs in labs worldwide



New experiment : SHADOWS

Search for Hidden And Dark Objects With Sps : proton beam dump experiment

Aim → search for FIPs (ALPs) emerging from charm and beauty decays, in the range of MeV to a few GeV