LHCP2018 Bologna, 08 June 2018

Claude Vallée (CPPM/DESY)

PHYSICS BEYOND COLLIDERS at CERN

Study Group mandated by the CERN Management
to prepare the next European HEP strategy update (2019-20)

coordination: J. Jäckel, M. Lamont, C.V.

Excerpt from the PBC mandate:

"Explore the opportunities offered by the CERN accelerator complex to address some of today's outstanding questions in particle physics through experiments complementary to high-energy colliders and other initiatives in the world."

Time scale: next 2 decades

PBC KICK-OFF WORKSHOP, CERN, Sept. 6-7, 2016

Call for abstracts → 33 abstracts submitted, 20 selected for presentation

1st GENERAL WORKING GROUP MEETING, CERN, March 1-2, 2017

Identification of main issues to be studied

FOLLOW-UP WORKSHOP, CERN, November 21-22, 2017

Working groups project reports

New call for abstracts → 10 abstracts submitted, 7 selected for presentation

2nd GENERAL WORKING GROUP MEETING, CERN, June 13-14, 2018

Status of studies for PBC deliverables

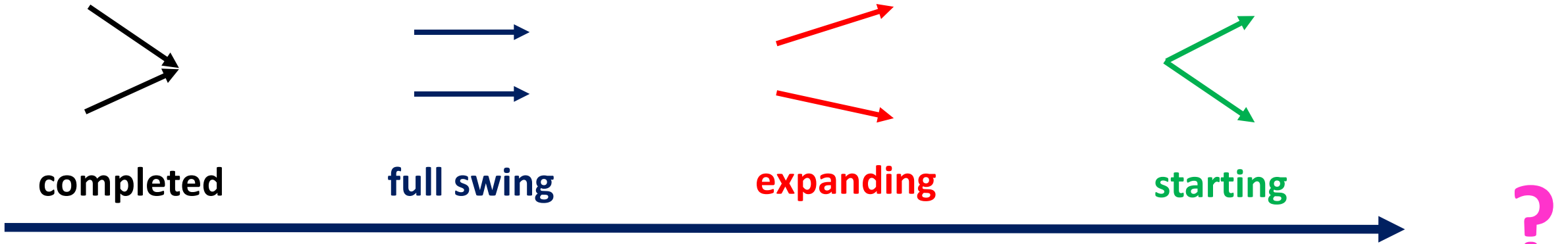
CLOSE-OUT WORKSHOP FORESEEN AT CERN early-2019

NB: PBC meetings and activities documented on pbc.web.cern.ch

(credit to Collaborations for the plots shown in this presentation)

A DECADE OF VIBRANT "DIVERSITY" PHYSICS AT CERN !

~1000 physicists on ~20 experiments



completed	full swing	expanding	starting	
CNGS (ν) DIRAC (QCD)	COMPASS (QCD) NA61 (QCD)	ANTIMATTER FACTORY (CPT)	NA62 & NA64 (BSM) ν Platform (det. R&D) AWAKE (acc. R&D)	PBC

…+ CAST, OSQAR, etc…

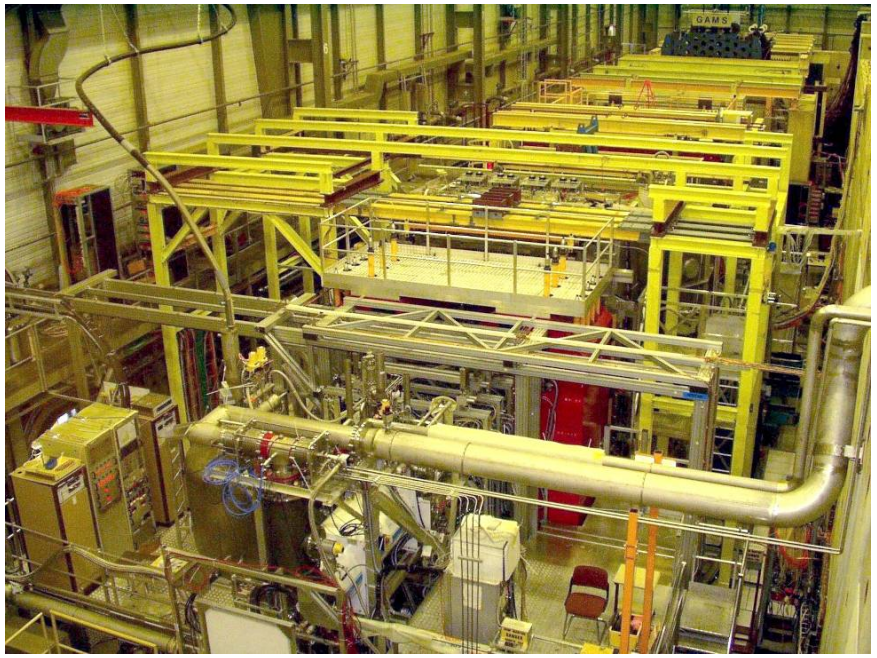
Recent stop of major programs (e.g. CNGS) leaves room to new significant initiatives

PBC PROJECTS UNDER STUDY

1) QCD–oriented

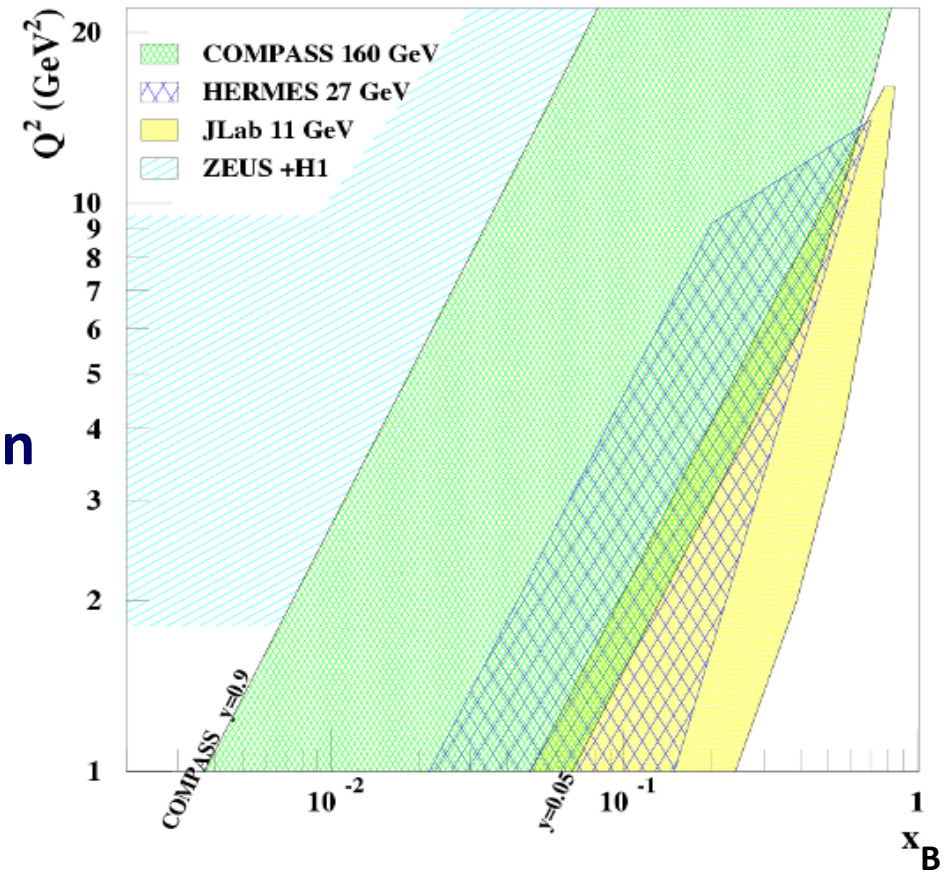
2) BSM-oriented

3) Some new long term facilities



COMPASS

a large acceptance spectrometer in the intermediate x-domain between H1/ZEUS and HERMES/JLAB

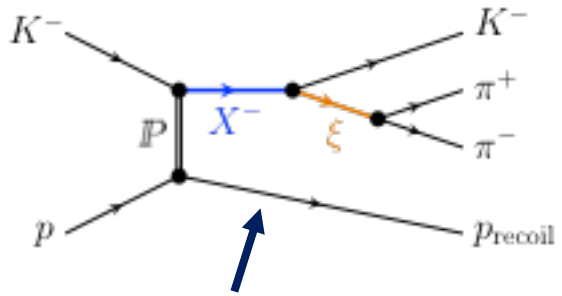


COMPASS I (< 2012): Spin content of the proton constituents with polarized DIS

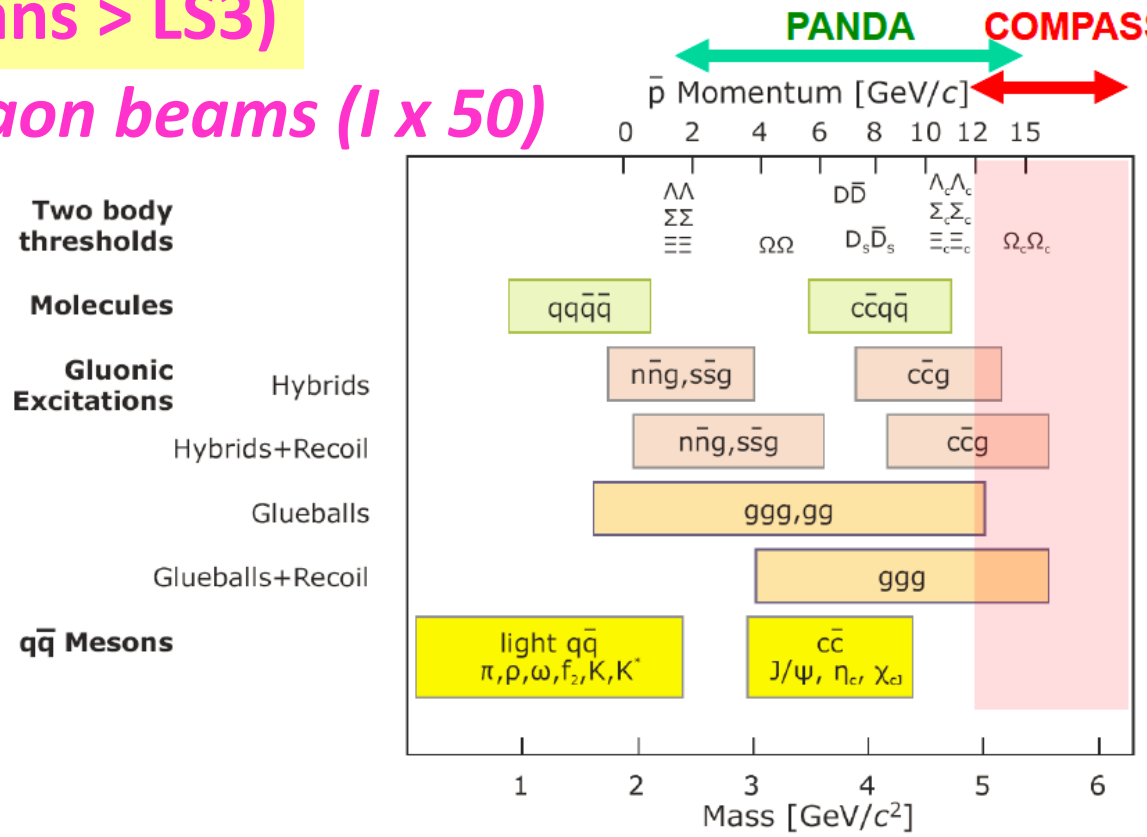
COMPASS II (2014-18): Orbital momentum with DVCS
Transverse Momentum Dependent effects with polarized DY

COMPASS++ (long term plans > LS3)

Wish RF separated antiproton and kaon beams (I x 50)



- **High statistics strange meson spectroscopy**
- **Exotic states spectroscopy complementary to LHCb/PANDA**
- **Kaon and antiproton structure**



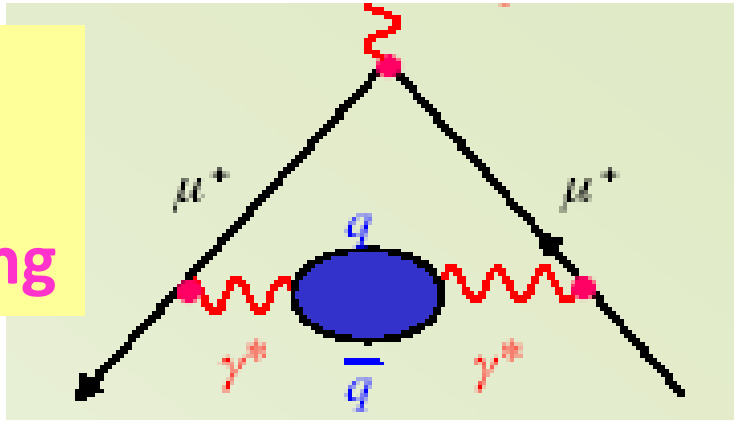
DY statistics	NH_3	Al (7cm)	W	NA3	NA10	E537	E615
K^- beam	14,000	2,800	29,600	700			
$\bar{p}$ beam	15,750	2,750	22,500			387	

<u>Main issues</u>: Competition, cost/schedule of RF separated beam, Collaboration support

→ Shorter term LS2↔LS3 program under definition

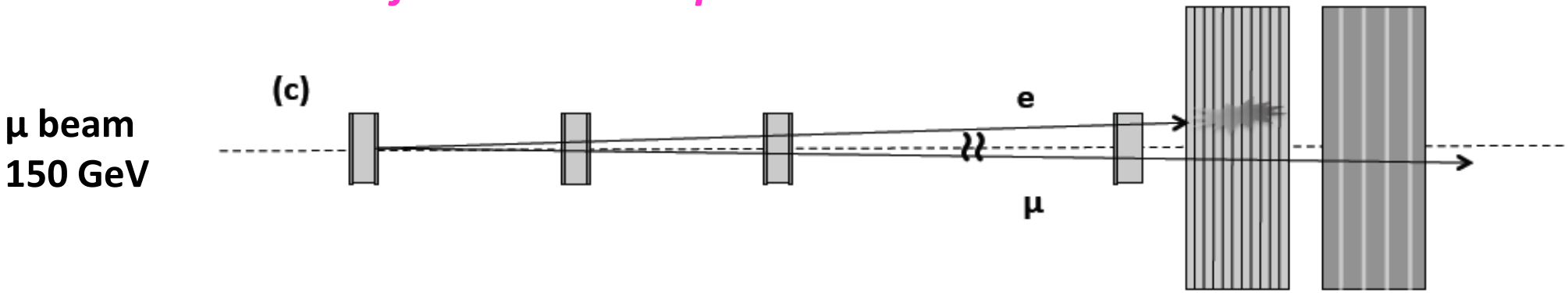
MUonE

Direct measurement of the dominant contribution to the theoretical error on $(g-2)_\mu$ from μ-e elastic scattering



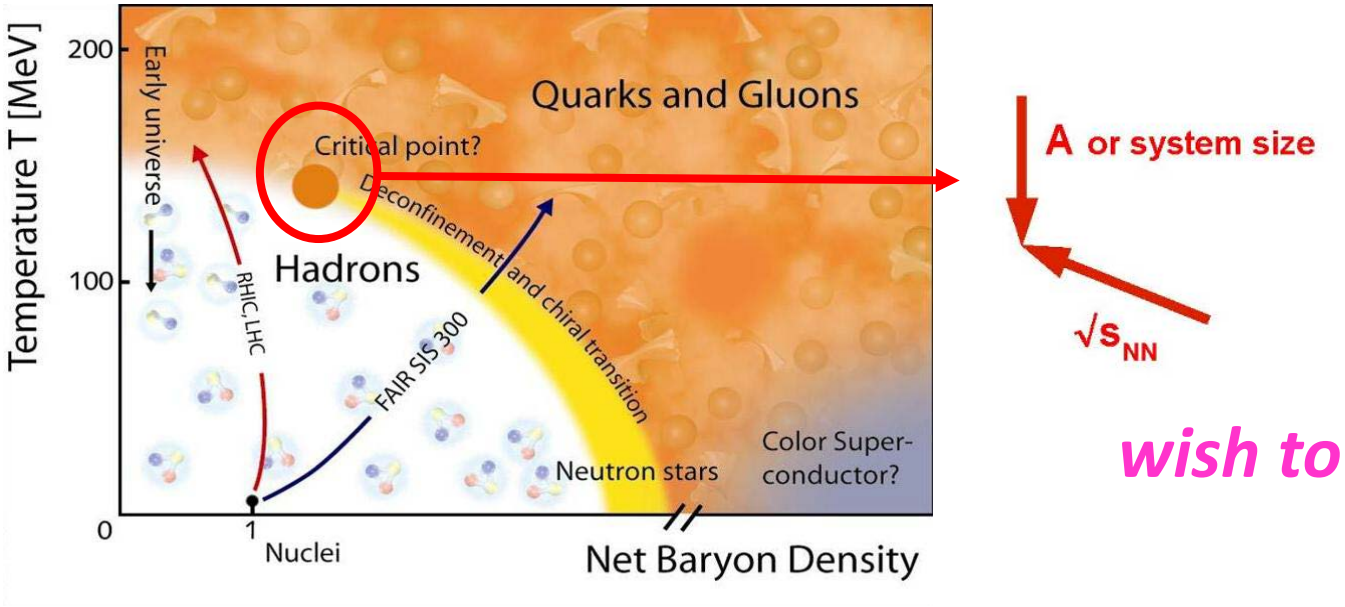
Vacuum polarisation

High statistics space-like measurement could reduce by factor 2 the current error derived from time-like processes



Full t range accessible thanks to high energy μ beam boost, self normalized measurement
Might be feasible with reasonable resources within the (modified) COMPASS setup

<u>Main issue</u>: systematic effects (control needed at 10^{-5} level)

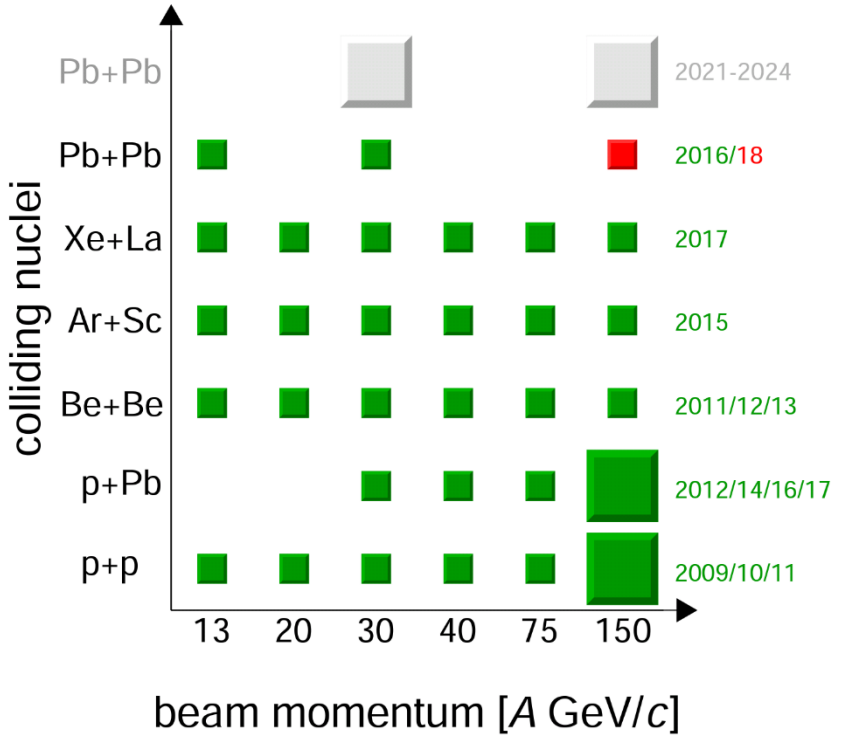


NA61/SHINE

Search for QCD Critical Point by scan in the (T, μ_B) plane

AFTER LS2:

wish to further study QCD deconfinement with open charm



Clear motivation to revisit QCD phase transition with charm [Zhang]

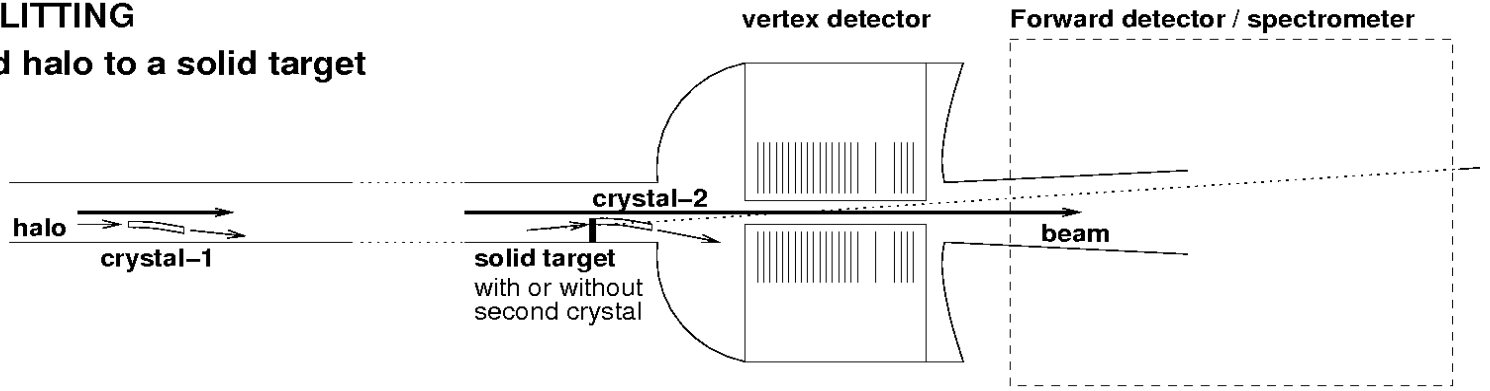
Main issues:

factor 10 increase in beam intensity and high rate data taking

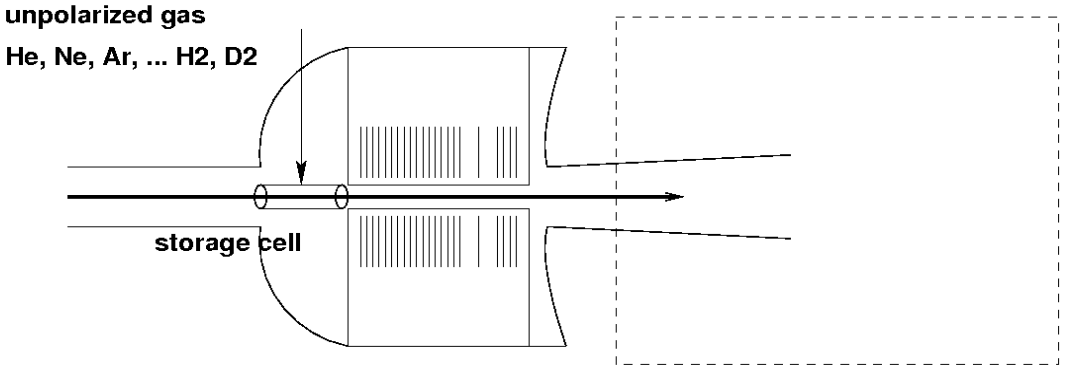
NB: NA61 large acceptance TPC still unique after LS2 to constrain ν beam fluxes (T2K⁺, HK, LBNF)

Fixed Target physics with LHC beams

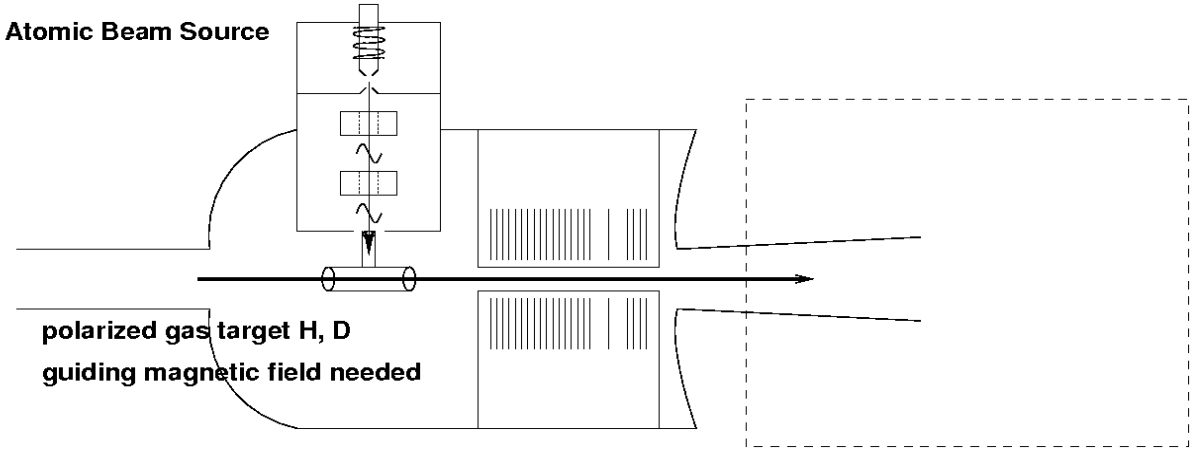
BEAM SPLITTING
channeled halo to a solid target



STORAGE CELL



POLARIZED TARGETS



3 options under study by LHCb and ALICE

[Martinez-Vidal]

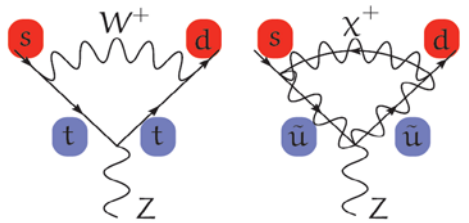
Opens a unique new kinematical domain to structure & deconfinement measurements

<u>Main issue of LHC internal fixed targets</u>: compatibility with other LHC programs/goals

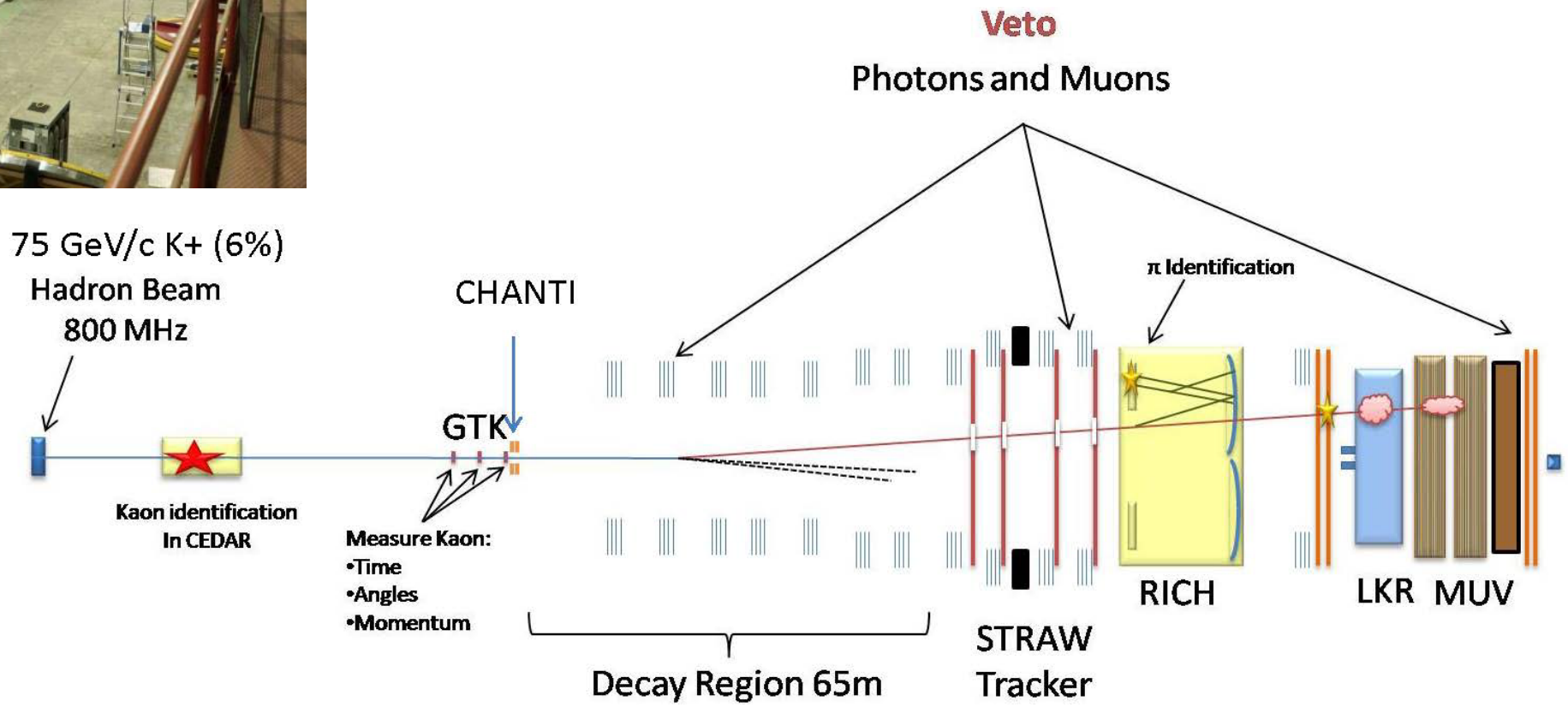
$K \to \pi\nu\bar{\nu}$ (BR ~ 10^{-10})

NA62

Rare K decays



Regular data taking started after many years of intensive construction and commissioning



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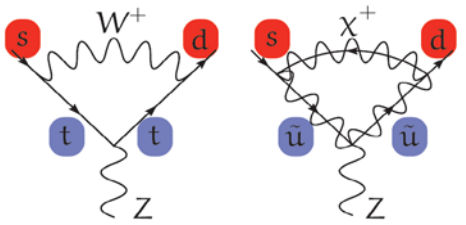
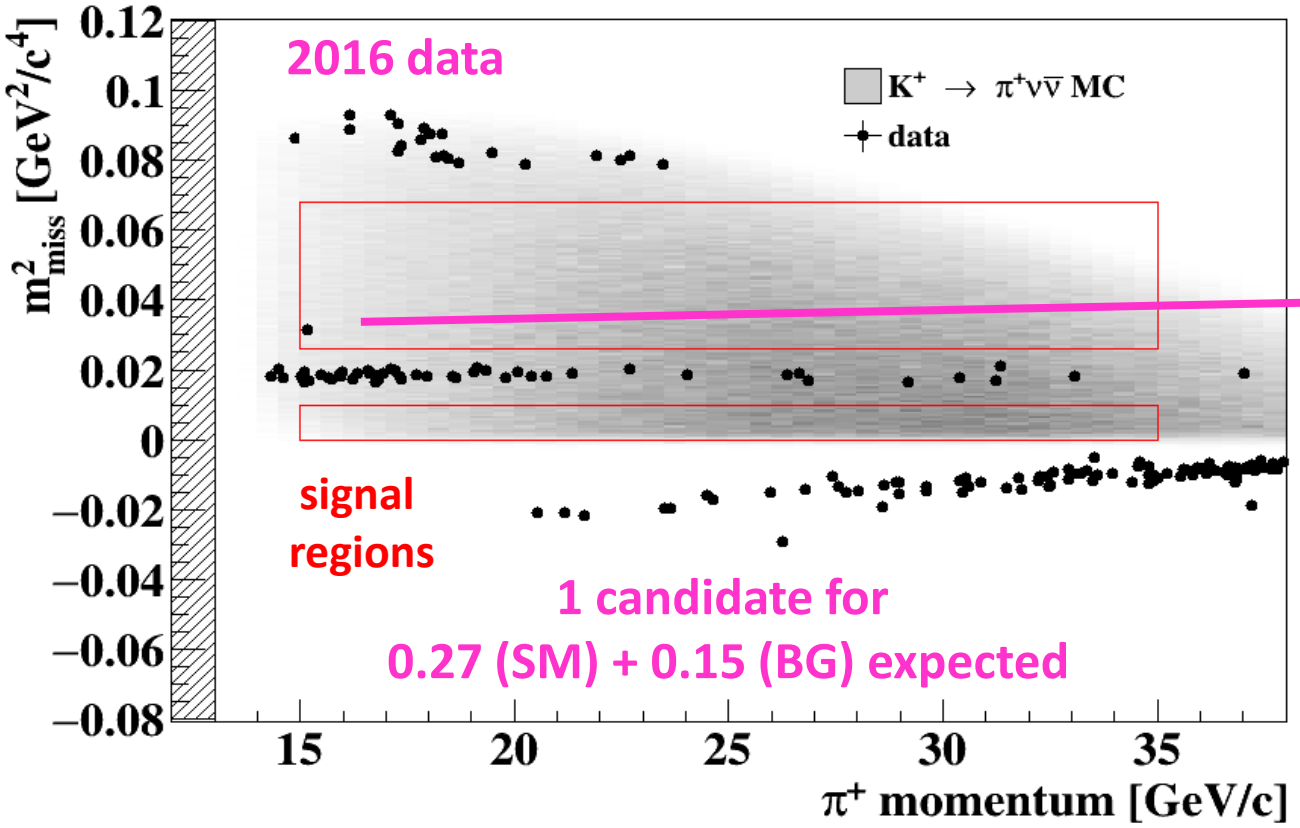
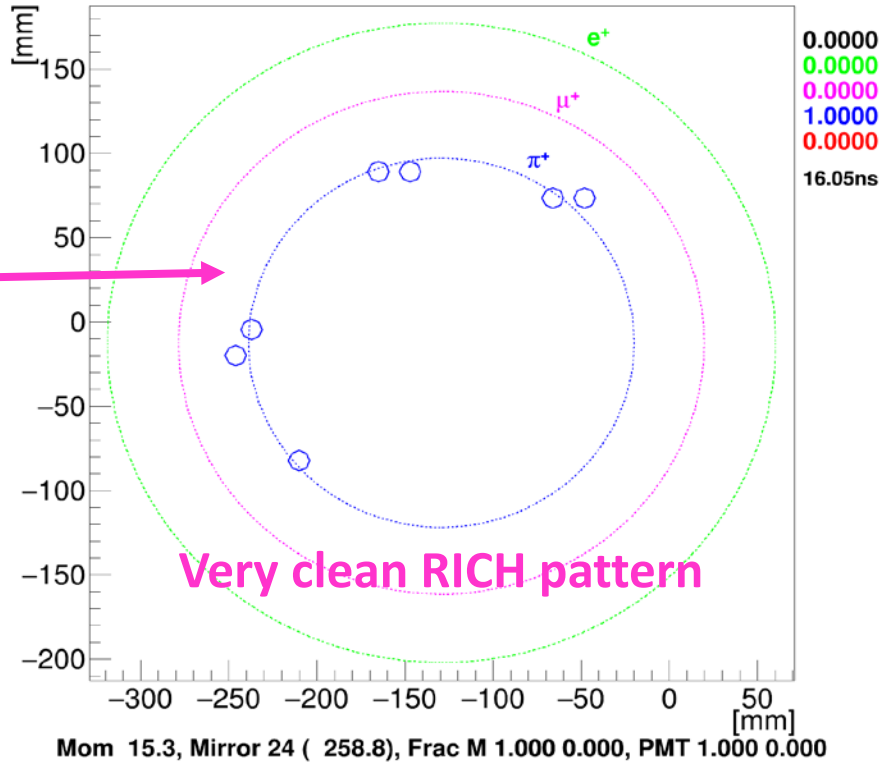




Run 6646, Burst 953, Event 543854, Track 1



Promising result with 2016 data proves validity of the in-flight method for the future

~20 signal events expected until LS2

KLEVER: $K^o \rightarrow \pi^o\nu\nu$ rare decay

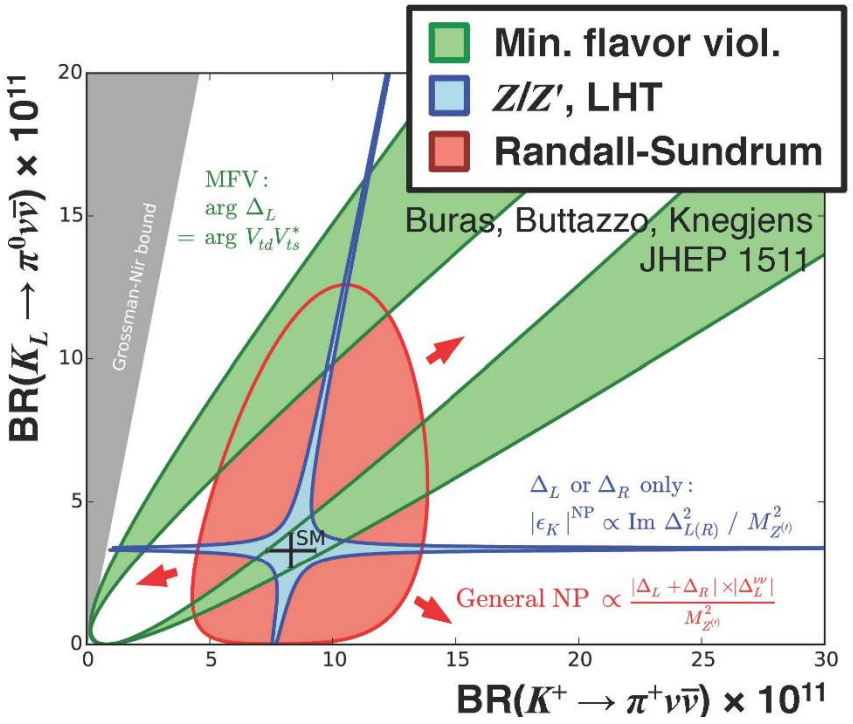
K^0 decays complementary to K^+ decays for the CKM matrix and BSM searches.

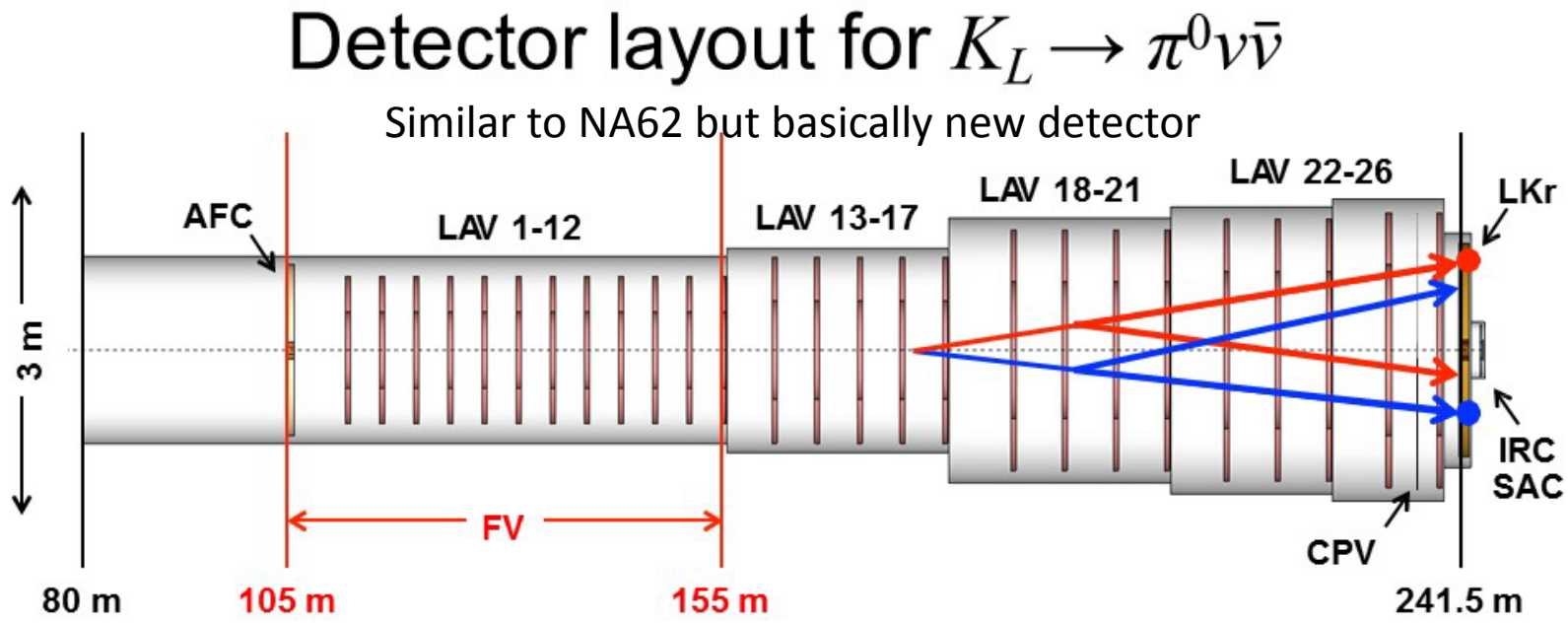
Would require a new high intensity K^o beam.

~50 events could be collected with a similar but basically new detector.

Competition from starting KOTO at JPARC:

few events expected in coming years, upgrade by factor ~10 foreseen > 2025





<u>Main issues</u>: actual sensitivity vs competition, cost of new beam and upgraded detector

SHiP

Flagship program for a comprehensive investigation of the Hidden Sector in the few GeV domain

Similar layout as NA62, with larger acceptance to reach the c / b mass range

ECAL/HCAL
- Sandwich calorimeter w. scintillating bars+SiPM
- High-precision layers for directionality for ALP→γγ
- Test beam 2018

MUON
1. Scintilating bars+SiPM
2. Scintillatig tiles+SIPM
- Option 1 validated in test beam
- Option 2 in 2018

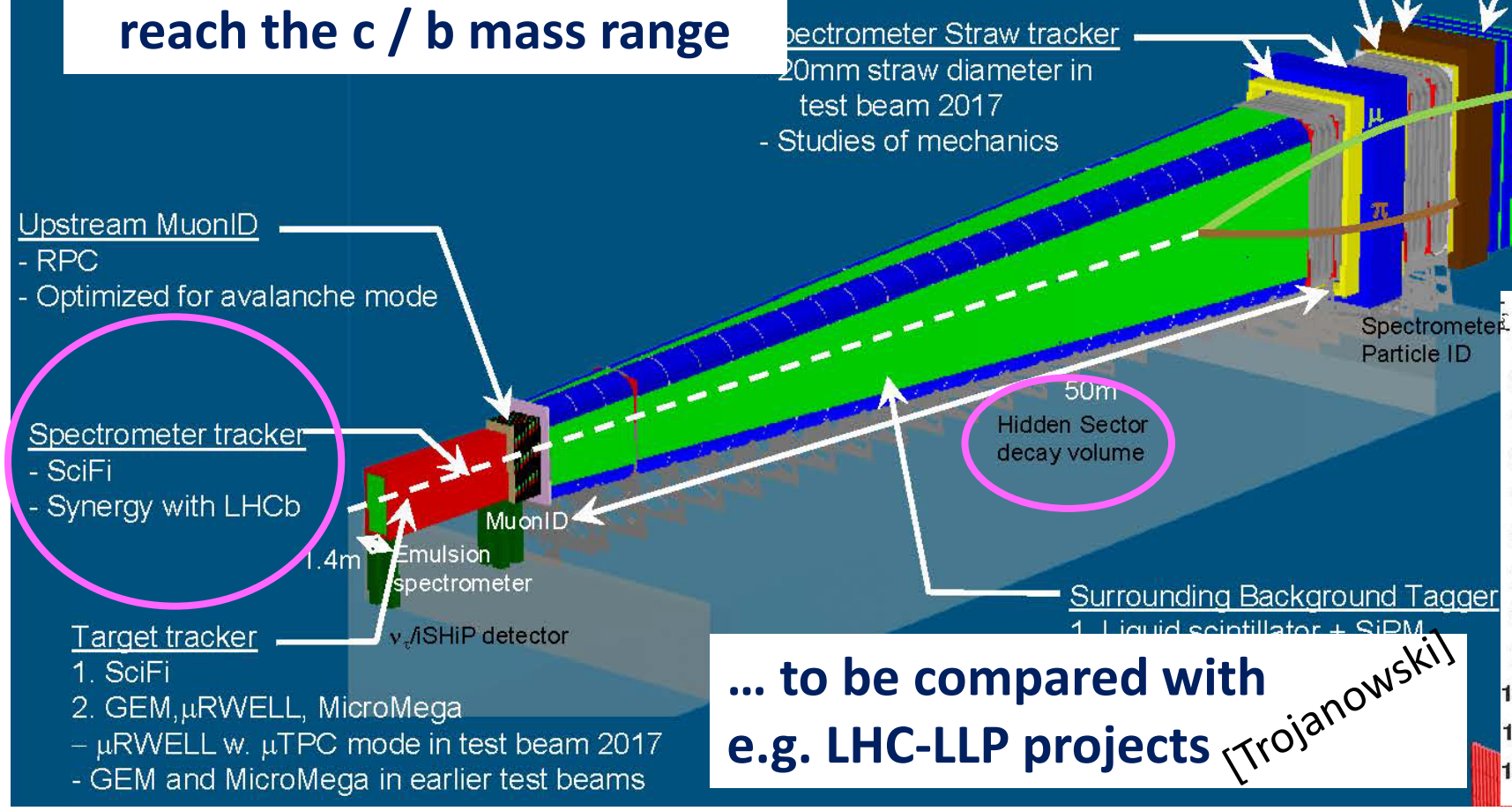
Timing Detector
1. Plastic scintillator +SIPM
2. MRPC
- Test beam 2017 w. electronics
- Demonstrated σ_t<100ps

pectrometer Straw tracker
20mm straw diameter in test beam 2017
- Studies of mechanics

Upstream MuonID
- RPC
- Optimized for avalanche mode

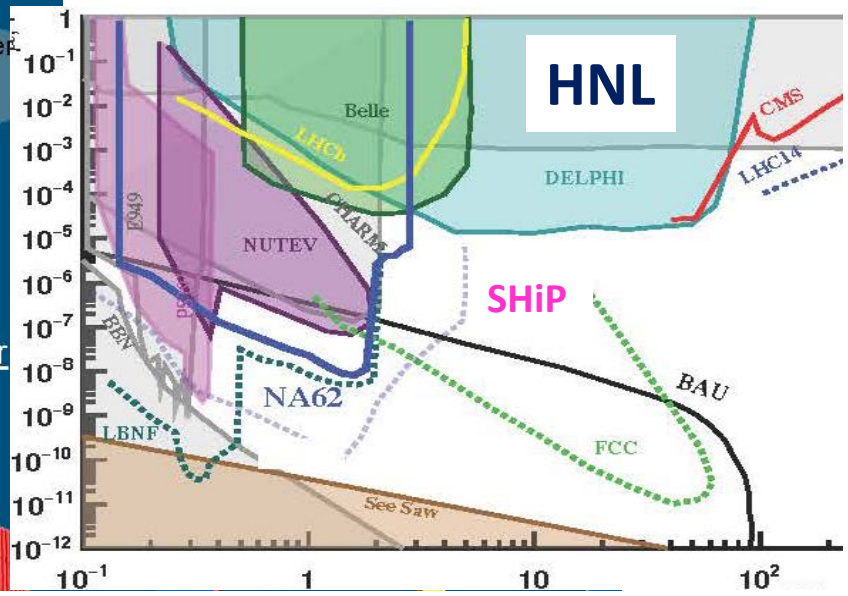
Spectrometer tracker
- SciFi
- Synergy with LHCb

Target tracker
1. SciFi
2. GEM,μRWELL, MicroMega
– μRWELL w. μTPC mode in test beam 2017
- GEM and MicroMega in earlier test beams

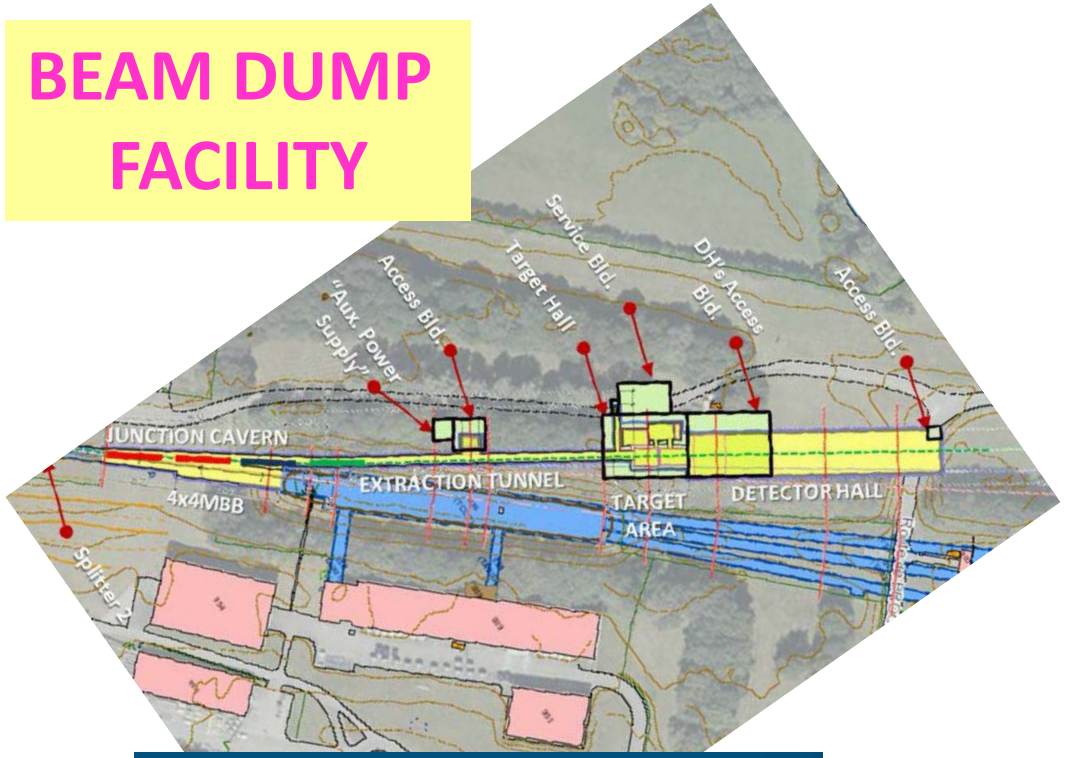


… to be compared with e.g. LHC-LLP projects [Trojanowski]

A unique reach for Heavy Neutral Leptons …

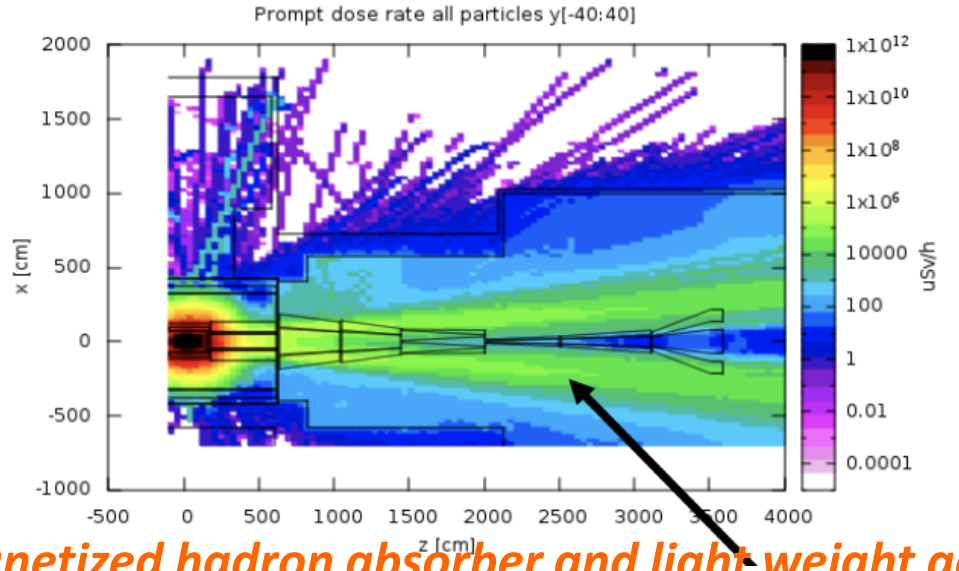


BEAM DUMP FACILITY



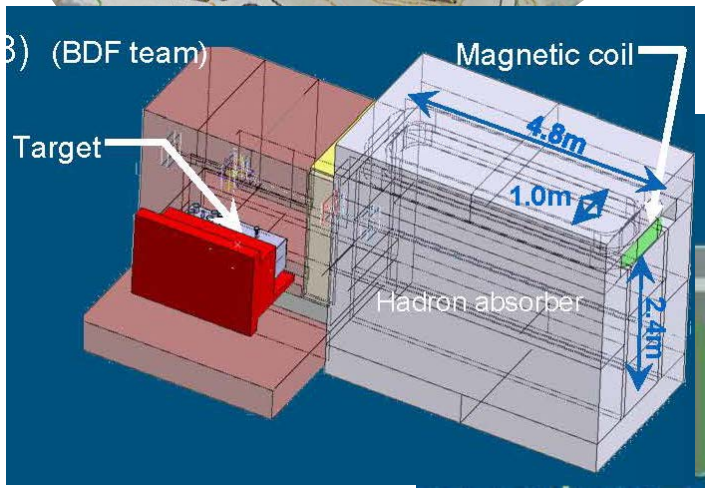
Foreseen to be sited close to the North Area

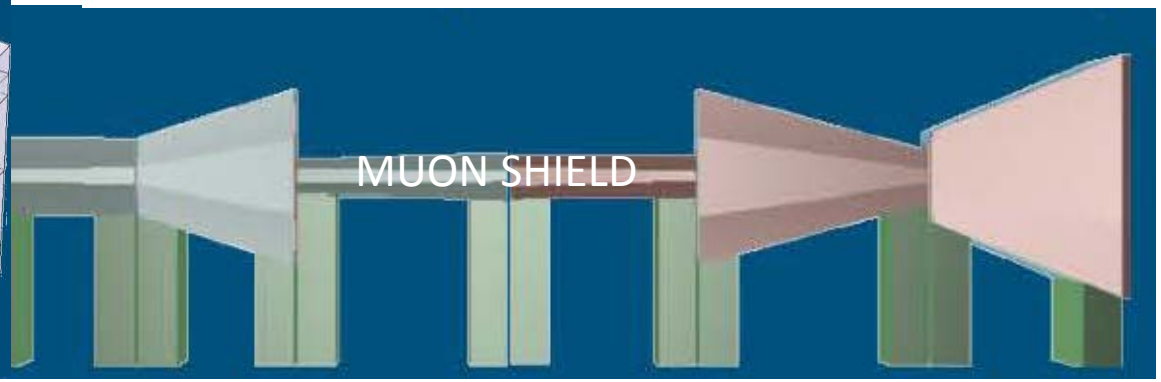
Conceptual design well advanced at CERN.



Magnetized hadron absorber and light weight active muon shield minimize punch through in decay volume

Muon yields and charm cross sections to be measured in test beams



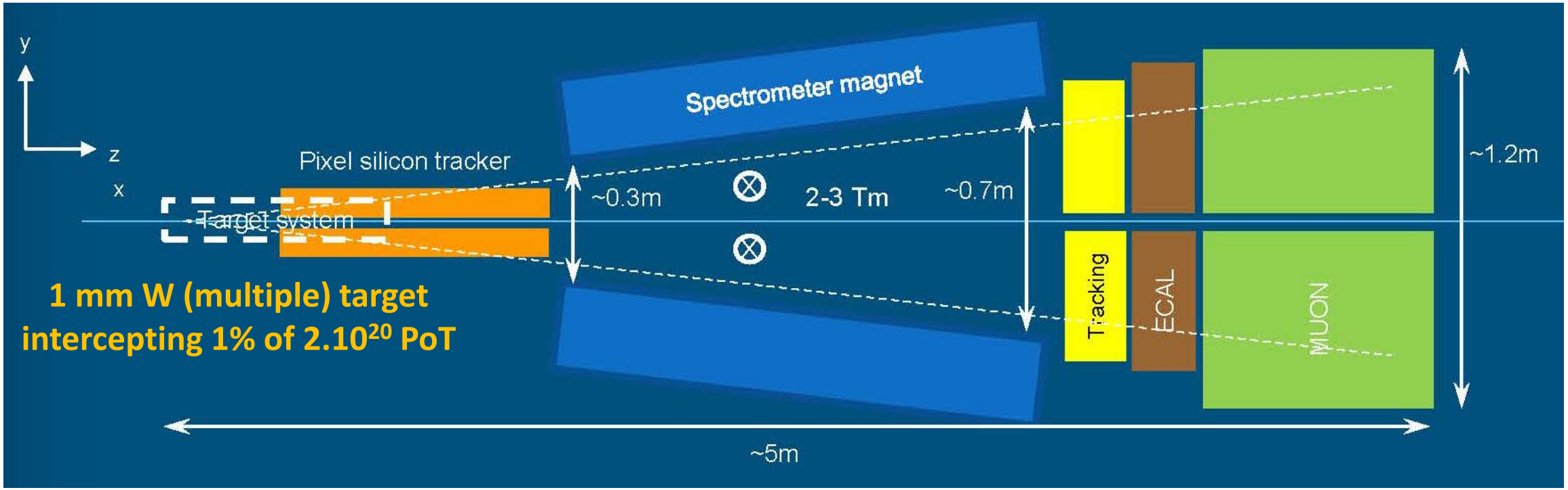


An opportunity for a new post-CNGS high intensity general facility at CERN

TauFV

Recently revived idea to intercept small BDF beam fraction to look for τ → 3μ decays

Could set limits on branching ratio better than 10^{-10} level (> BELLE-II reach)

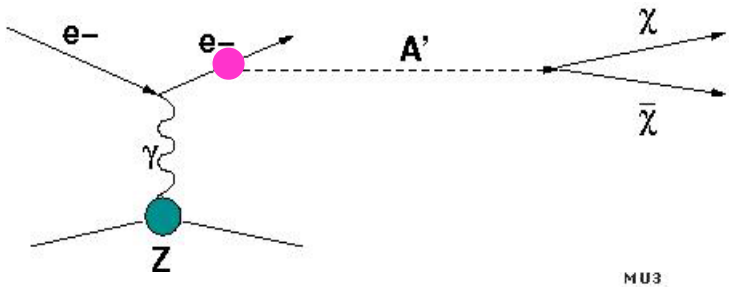


Implementation layout upstream of BDF target under study

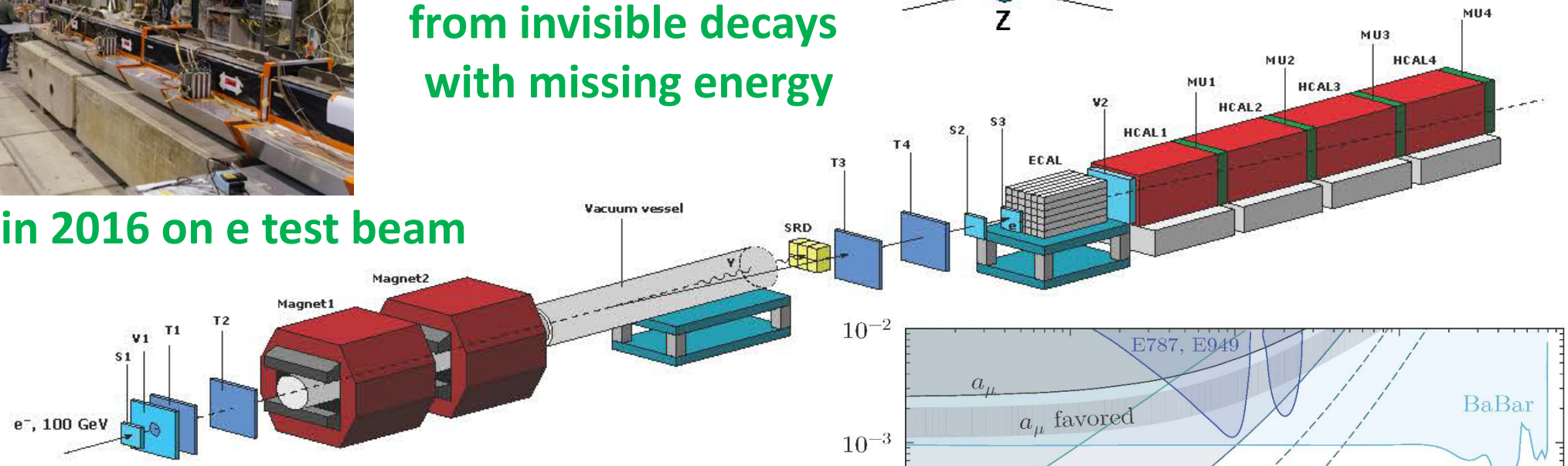
A promising option to maximize the physics reach of the Beam Dump Facility

NA64

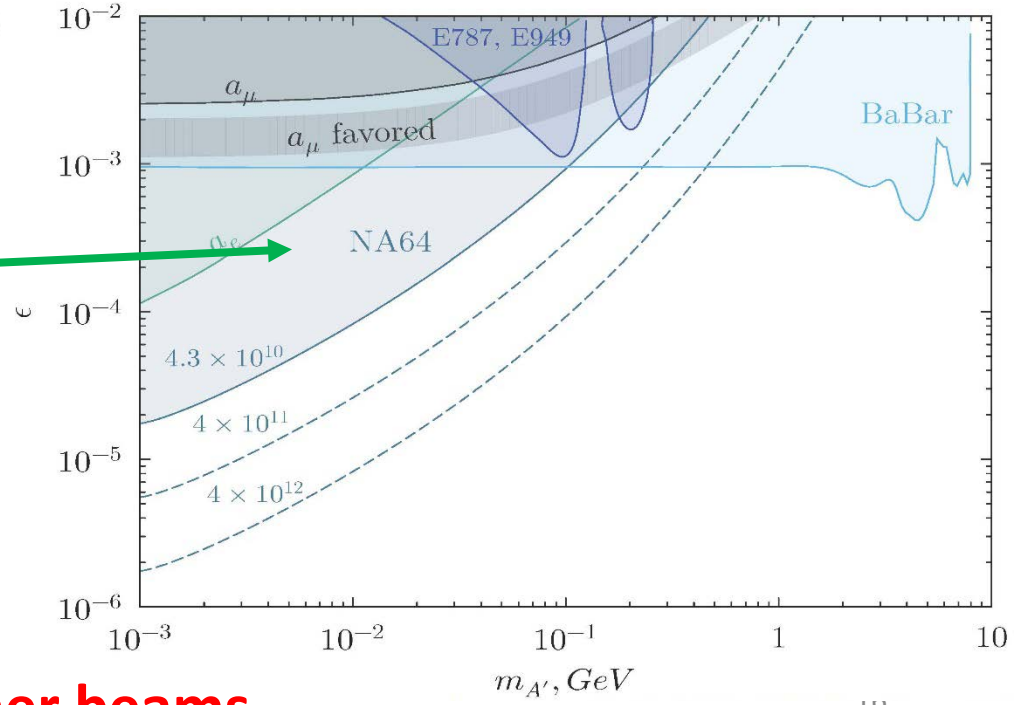
Hidden sector search from invisible decays with missing energy



Implemented in 2016 on e test beam



Fast analysis excluding $(g-2)_\mu$ interpretation confirms the potential of the method

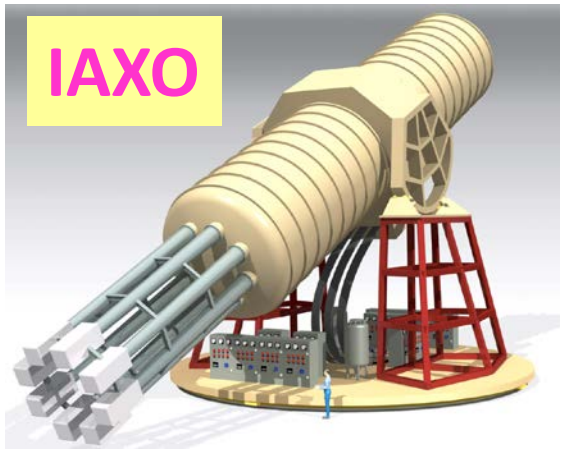


AFTER LS2:

Wish to extend the method to higher e intensity and μ / π / K / p beams

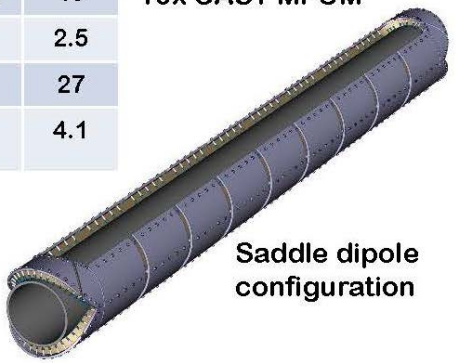
Main issues: e beam intensity and CERN siting for other beams

Next generation Axion Helioscope beyond CAST

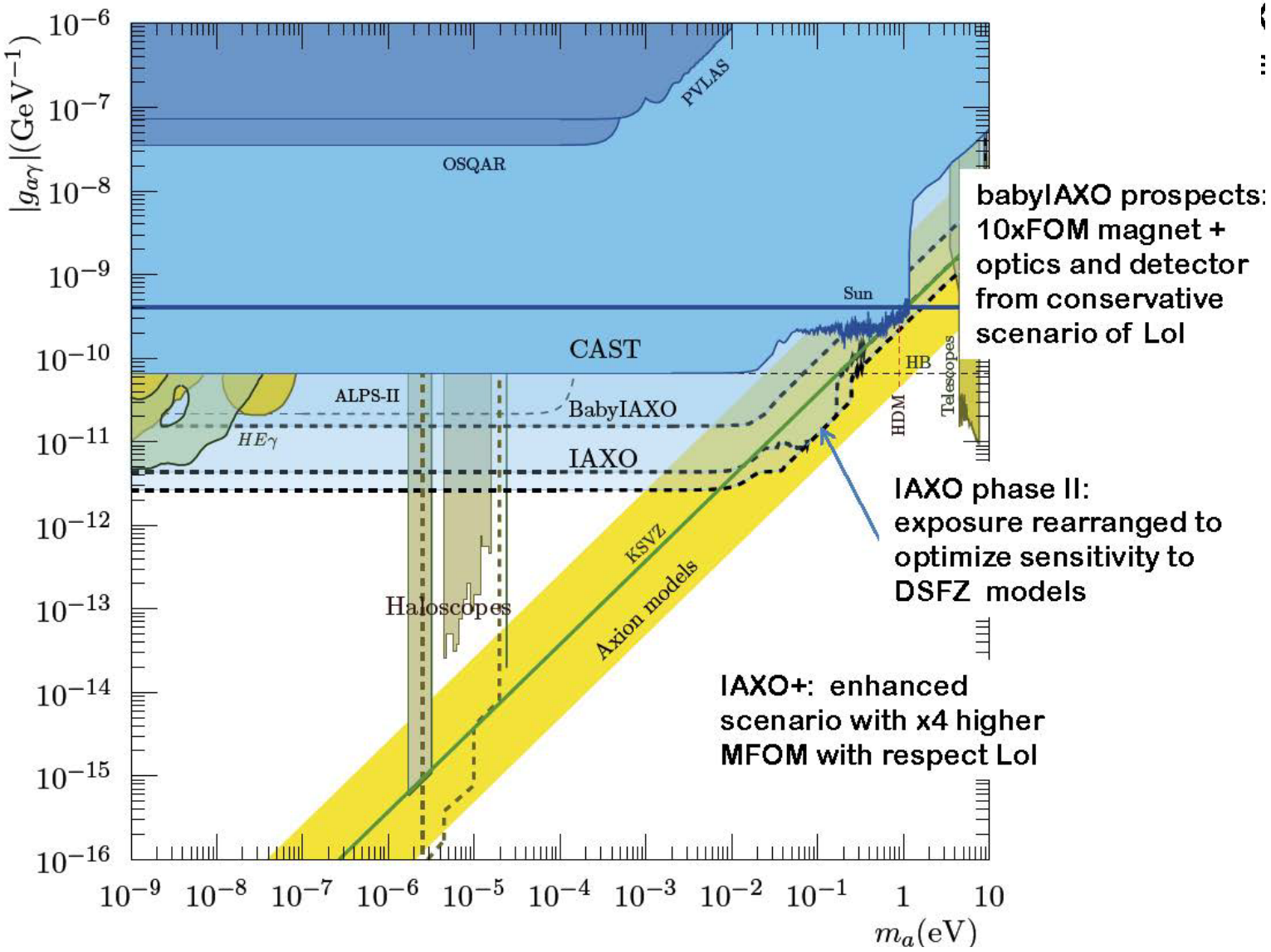


Free bore [m]	0.6
Magnetic length [m]	10
Field in bore [T]	2.5
Stored energy [MJ]	27
Peak field [T]	4.1

10x CAST MFOM



Saddle dipole configuration

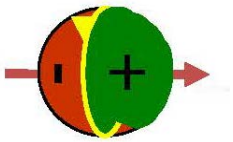


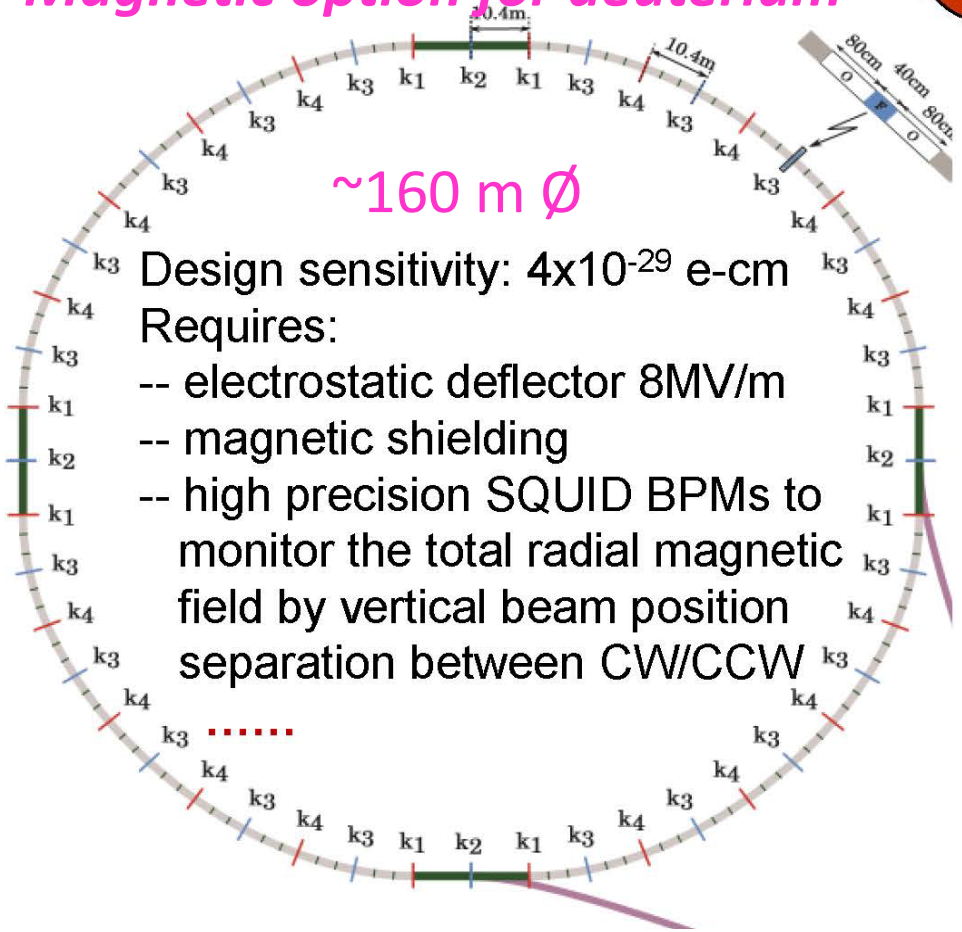
Support from CERN for magnet design within PBC

DESY considered as candidate site

Storage Ring for proton/deuterium EDM

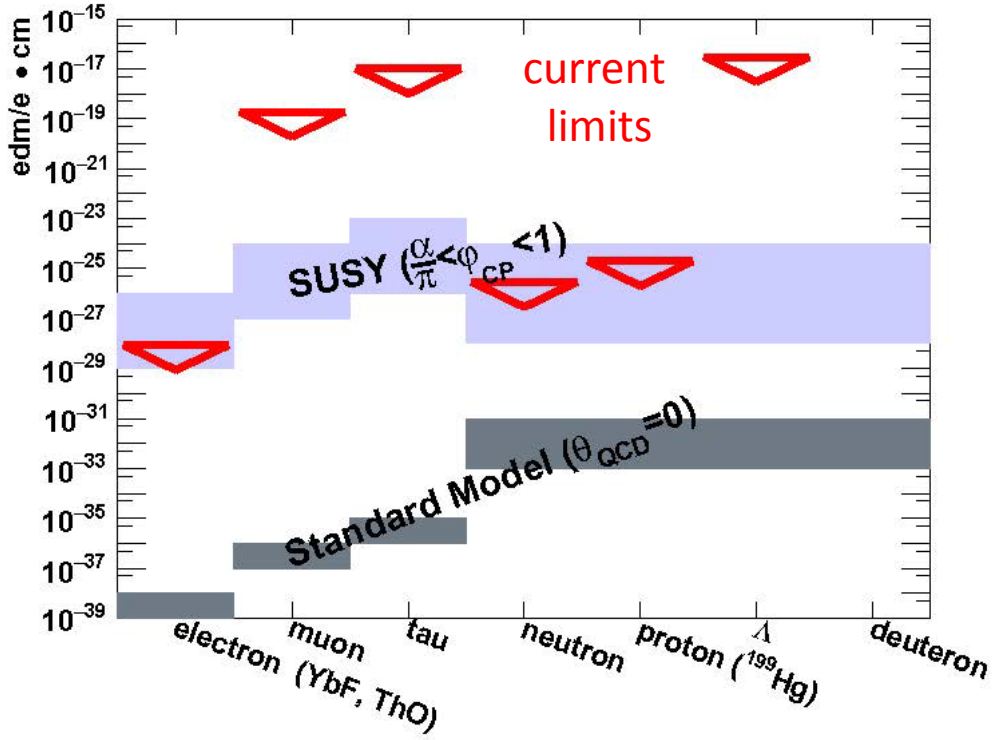
Electrostatic option for proton
Magnetic option for deuterium





10^{-29} e-cm sensitivity would correspond to 100 TeV for new physics energy scale

+ recent idea to look for axion DM through oscillating EDMs



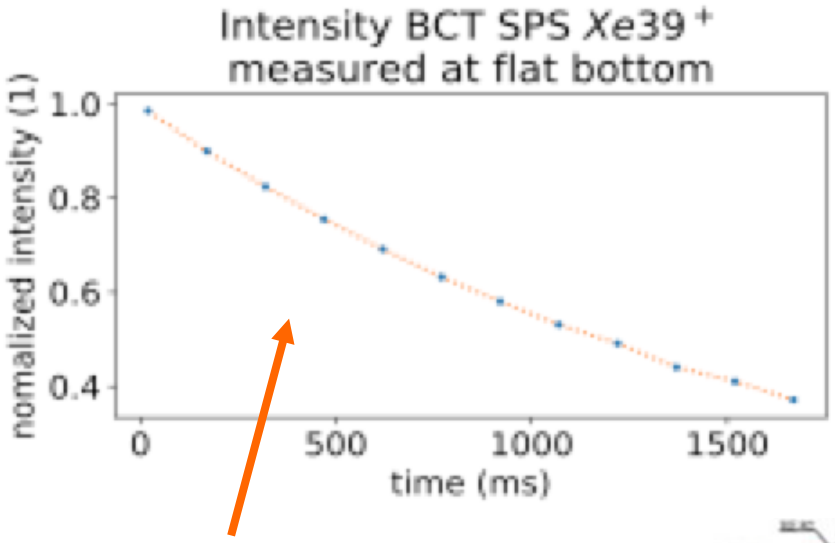
Ring design ongoing with CERN, srEDM and JEDI collaborations

<u>Main issue</u>: control of systematic effects (e.g. B fields)

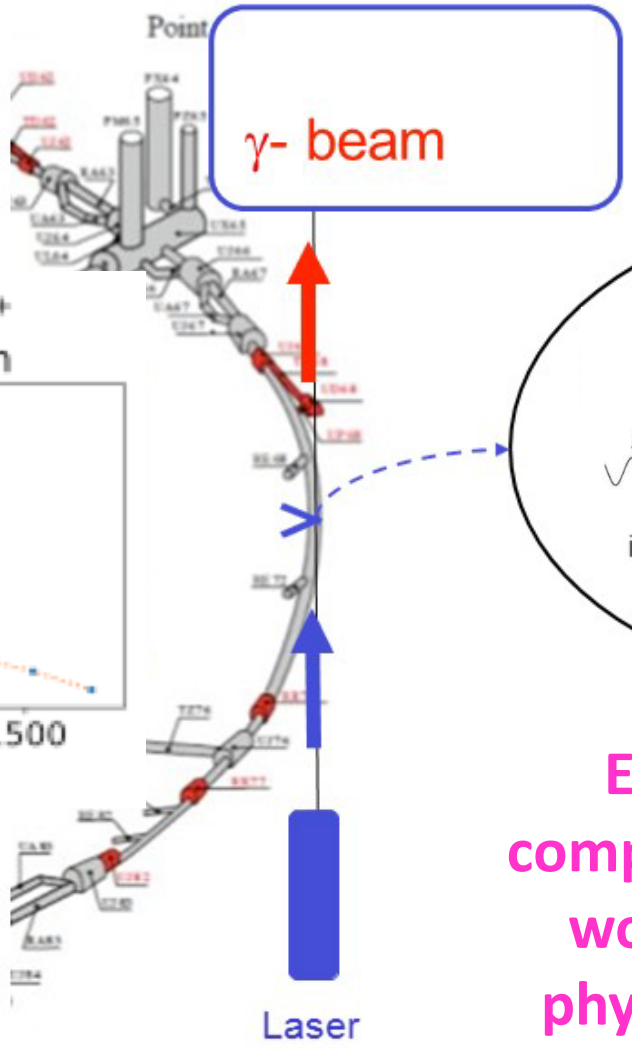
Gamma Factory

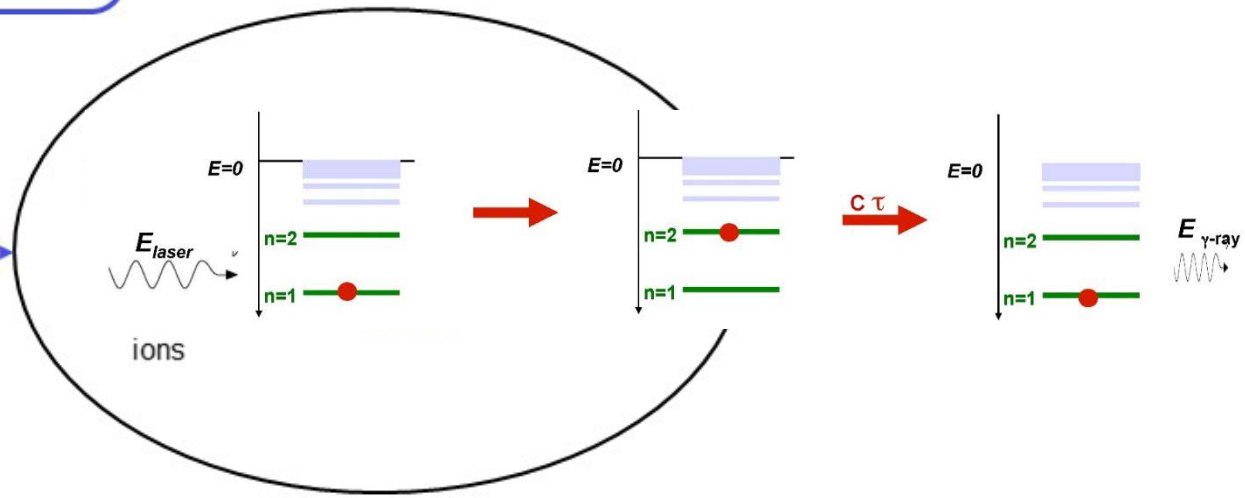
New idea to use LHC to convert laser photons into 0.1 - 400 MeV γ rays

LHC filled with Partially Stripped Ions



NB: encouraging lifetime > 1s measured in SPS for 39+Xe PSI

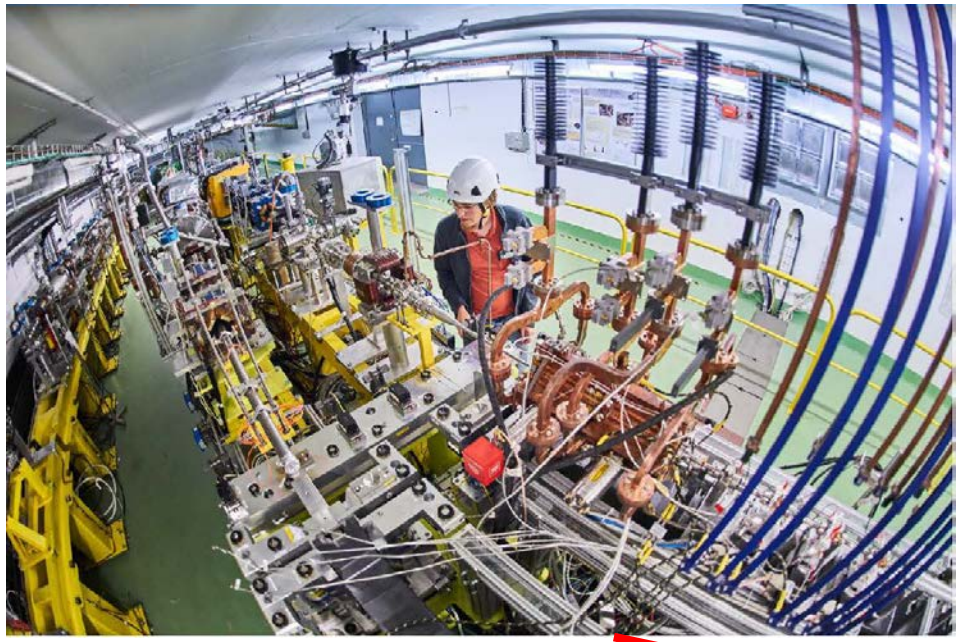




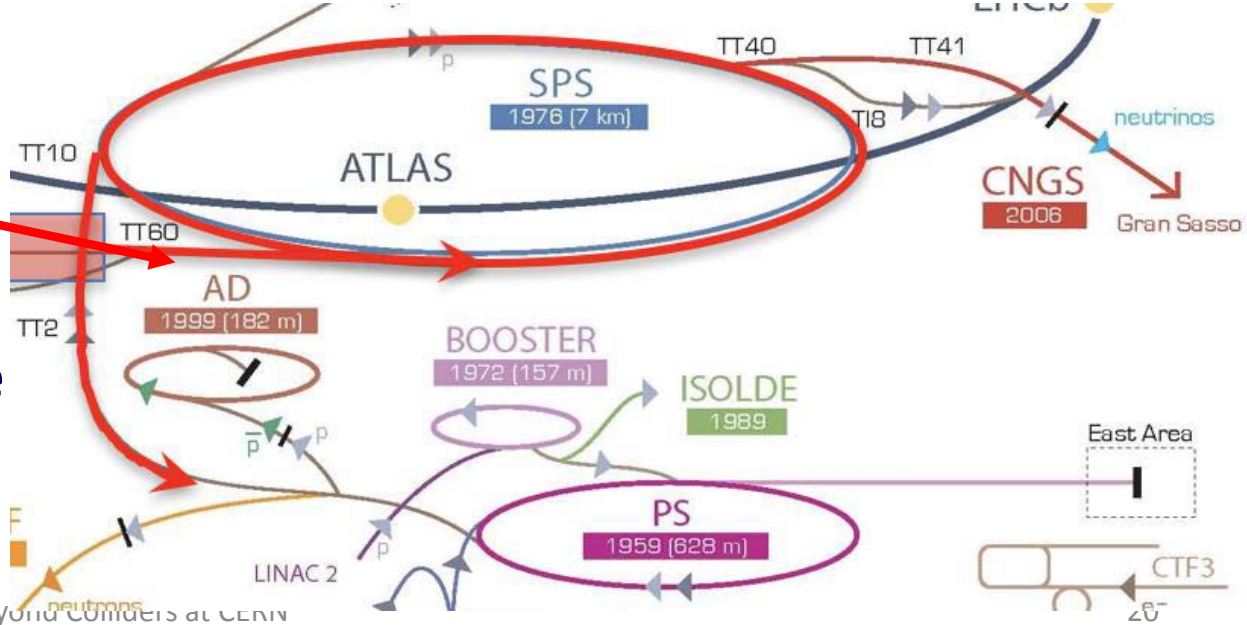
Expect factor 10^7 intensity increase compared to present e-driven γ ray beams, would open a completely new field of physics measurements and applications.

eSPS

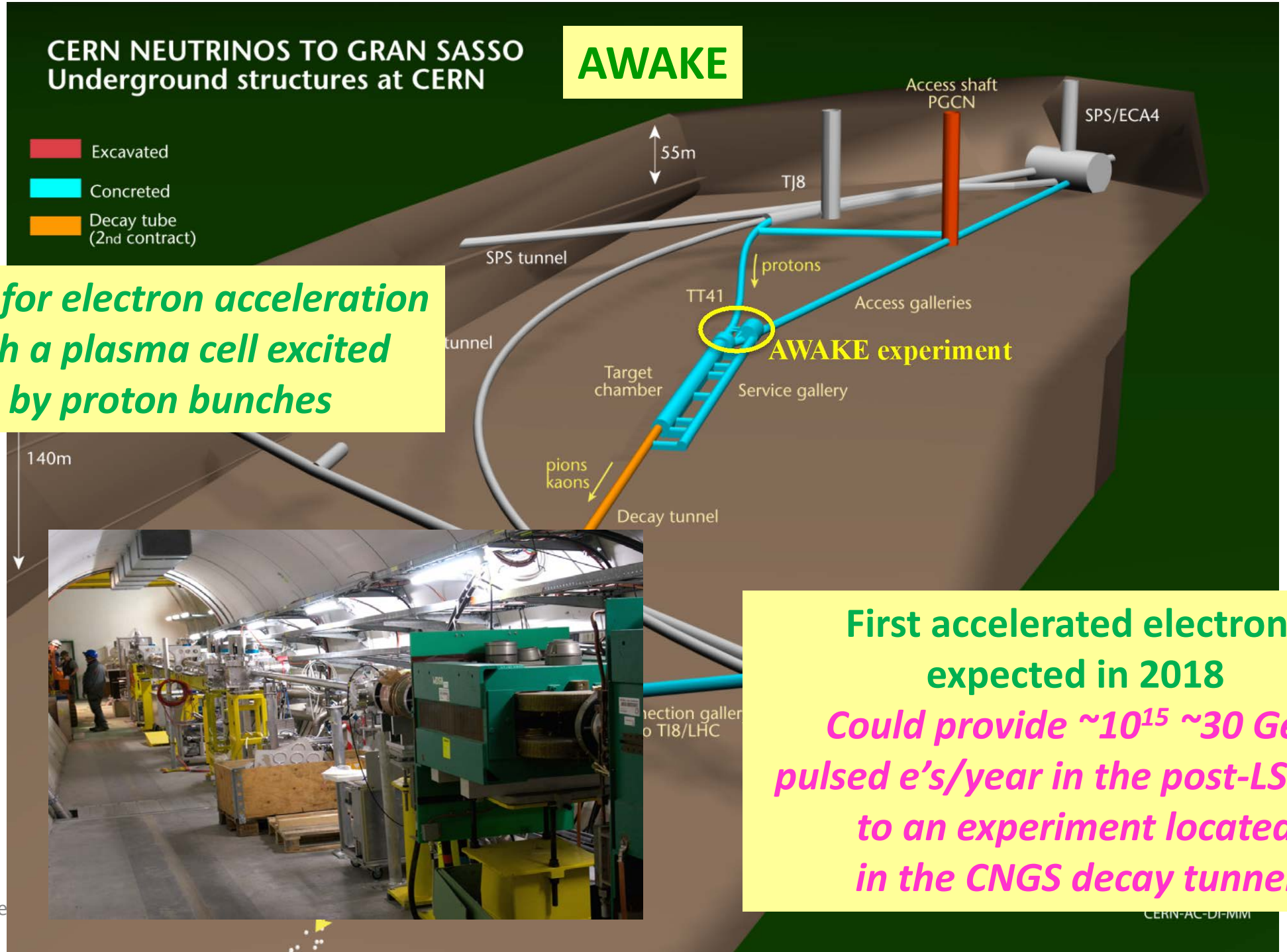
3 GeV e-LINAC with CLIC technology connected to SPS for acceleration to ~10 GeV



Would provide a unique testbed for R&D on linear acceleration techniques



Slow extraction from SPS would allow hidden sector searches in the invisible mode (~10^{16} e/year to expts à la NA64/LDMX)



R&D for electron acceleration with a plasma cell excited by proton bunches

First accelerated electrons expected in 2018

Could provide ~10^{15} ~30 GeV pulsed e's/year in the post-LS3 era to an experiment located in the CNGS decay tunnel

PBC DELIVERABLES

One main overview document supplemented by BSM/QCD context documents
and project CDR/CDS at a level of details matched to the maturity of the projects.
To be submitted end 2018 as input to the next European Particle Physics strategy update

NB: no arbitration between projects to be done by PBC
Guidelines will come later from the Strategy update

One of the main added values of PBC: a forum for exchanges
between communities with similar motivations, under CERN "umbrella":
SHiP/NA62/LHC-LLP, COMPASS/LHC-FT, COMPASS/MUonE,
NA60/NA61/LHC-FT, JEDI/srEDM, OSQAR/ALPS, etc…