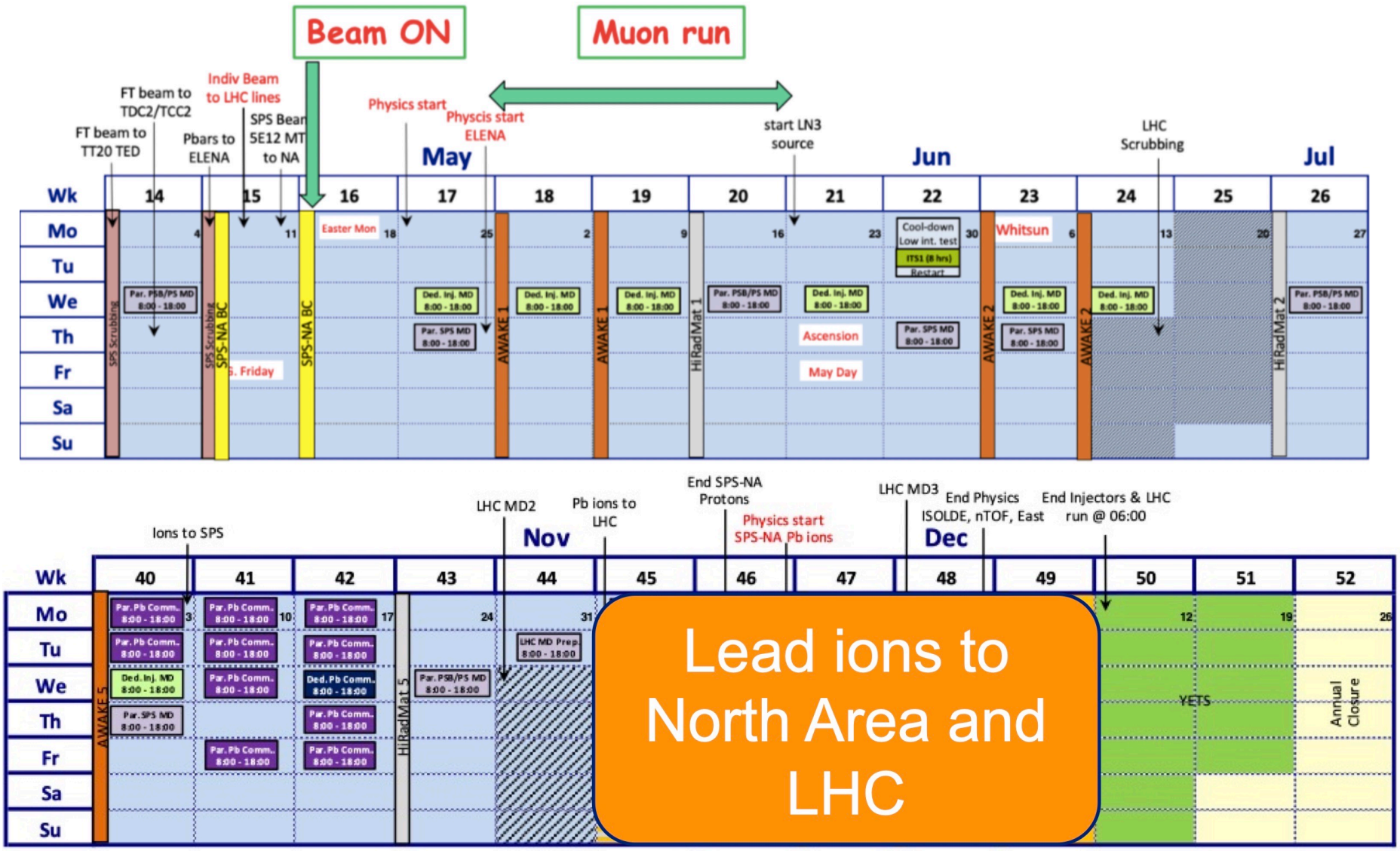
Discussion on M2 Beam Line Usage

J. Bernhard , M. Bona, L. Cunqueiro, M. Contalbrigo,
L. Eklund, E.B. Holzer, A. Milov, U. Wiedemann, W. Vogelsang

144th SPSC Meeting, January 18 2022

SPS Schedule



Proton run lasts from 25-04 till 14-11 for a total of 203 days (29 weeks)

Beam Request

SPS North Area M2 beamline

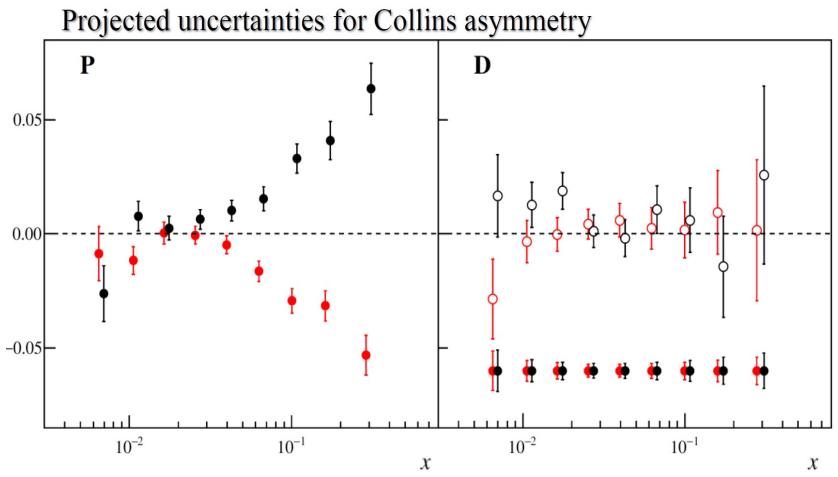
- Conflicting requests for **SPS M2 beamline**
  → SPSC working group

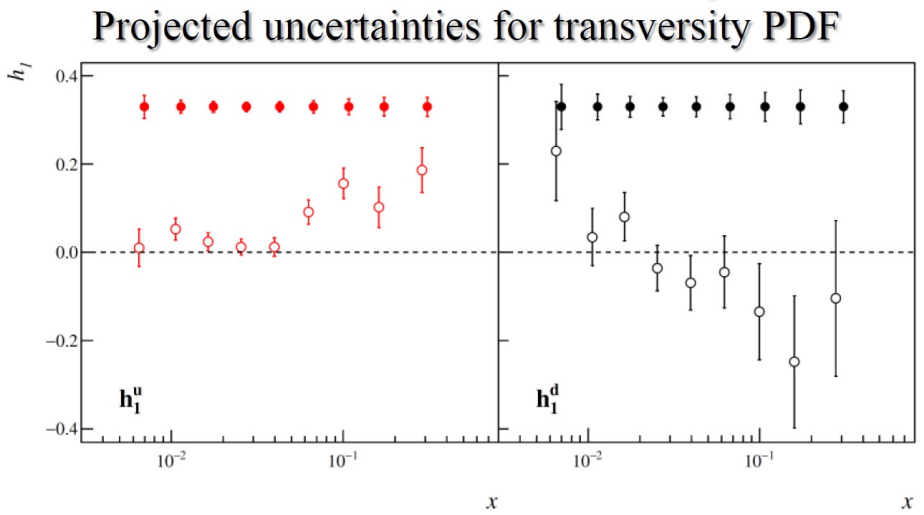
	Weeks requested main user	*Weeks requested parasitic user*
COMPASS NA58	26	5.5
NA64mu	3.5	0
MUonE	4.5	2.5
AMBER NA66	3.5	2

Clear overbooking requires prioritization

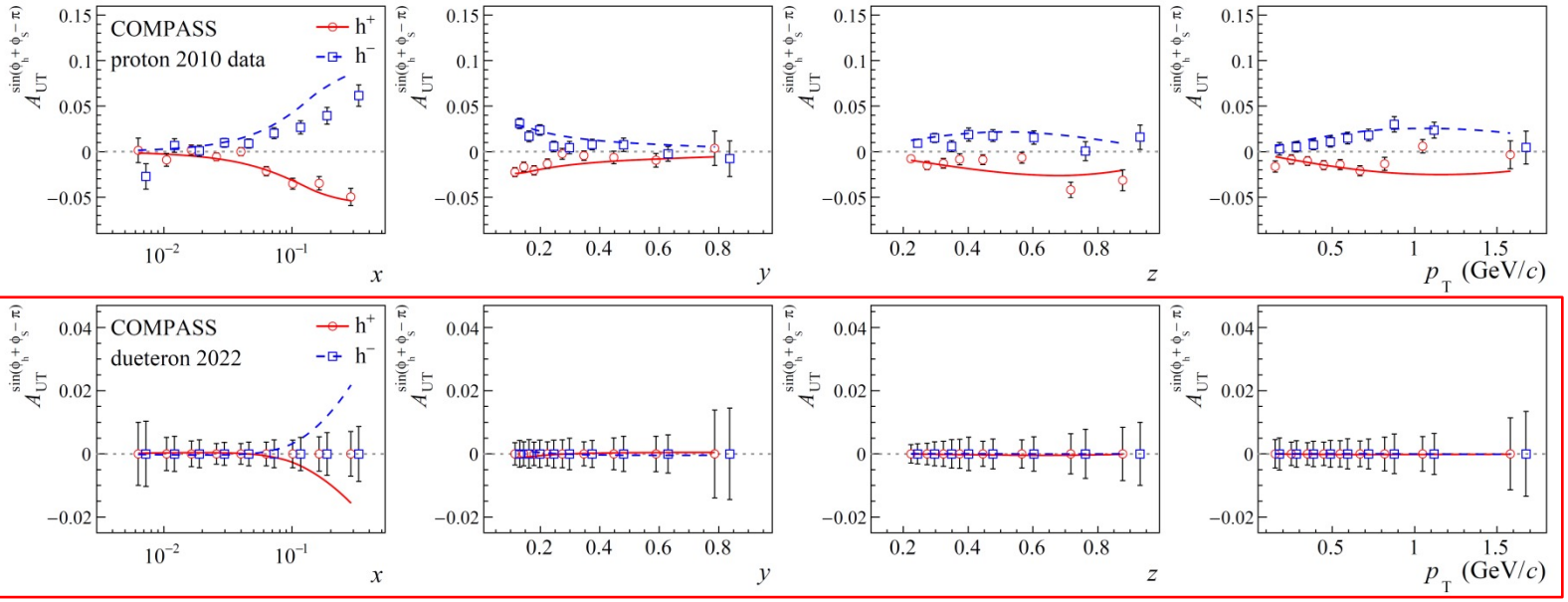
COMPASS and NA64mu apparatuses are in place and largely commissioned

There are still uncertainties on the hardware readiness for MuonE and AMBER





COMPASS considers critical to collect a typical 1-year run statistics to reach its physics goals



Parametrizations from:
JHEP 06 (2019) 007
by S. Bastami, H. Avakian, A. Efremov, A. Kotzinian, B. Musch, B. Parsamyan, A. Prokudin, M. Schlegel, G. Schnell, P. Schweitzer and K. Tezgin

All detectors operational in 2021, after a long commissioning

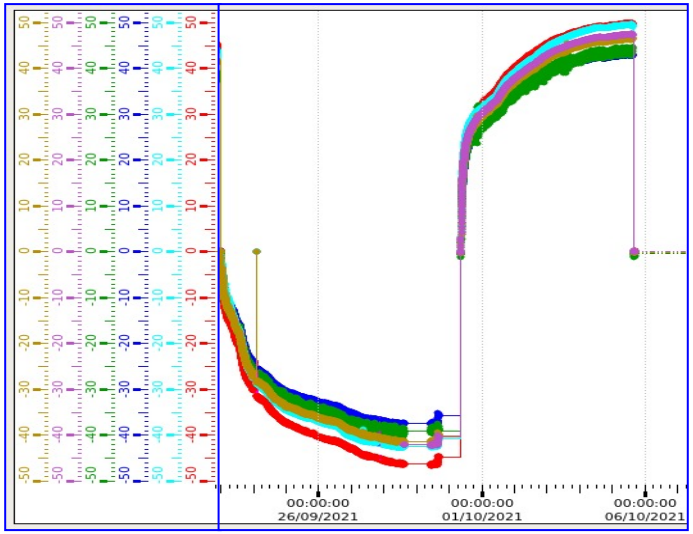
Severe problems during 2021, mostly not under COMPASS responsibility

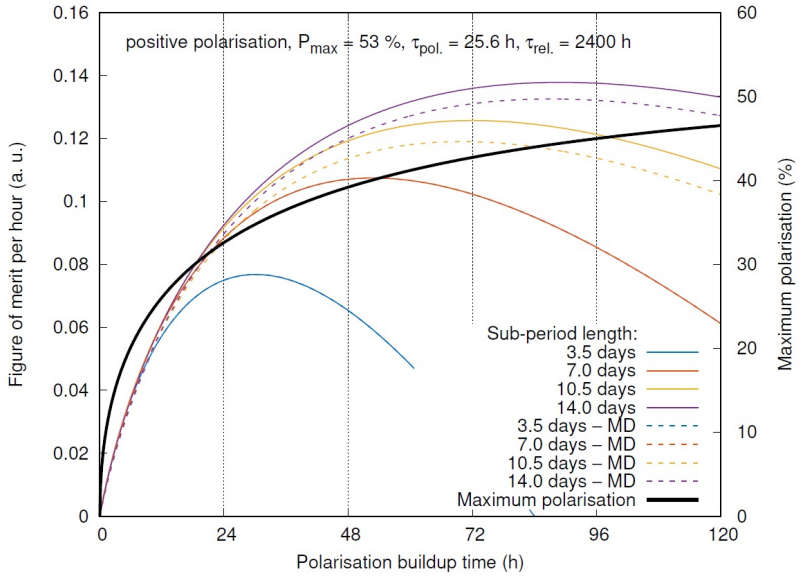
Vacuum leak due to missing expertise during assembling, ^{3}He pipe accident, beam instability

26 days were dedicated to target commissioning in 2021 instead of the programmed 42 days

COMPASS is highly confident that the target is ready for the 2022 run

The average polarization is expected to approach 45% within ~3 days (vs anticipated 50% in ~2 days)





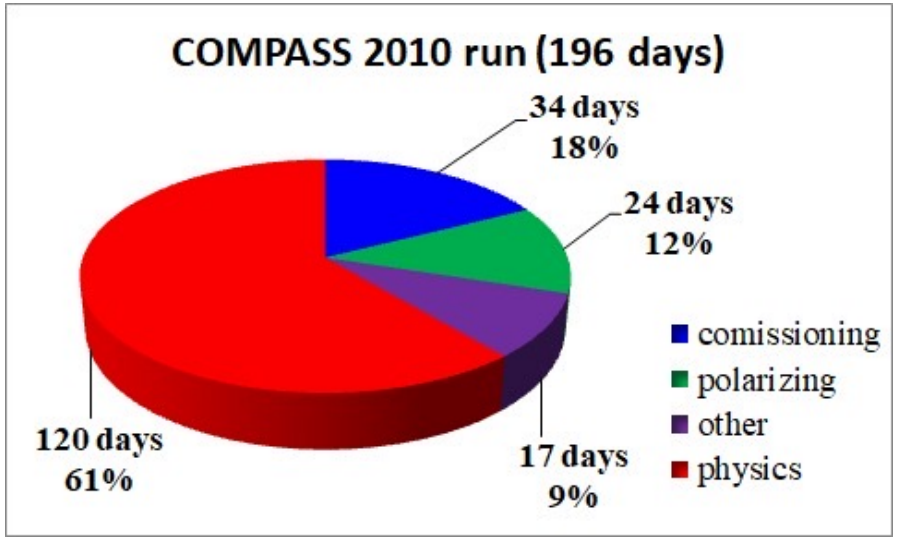
The Polarised Target needs important preparatory and concluding operations (temperature change, loading, ^{3}He, TE calibration, …) that should be better performed outside the physics run

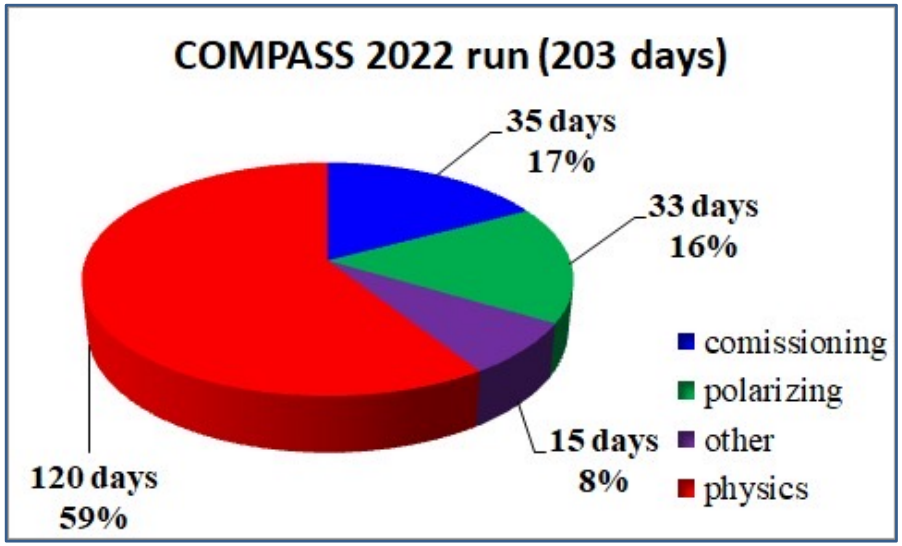
It should be operated in periods of about 2 weeks (polarization build-up and data-taking)

2022 is the last year for COMPASS, while the 1-year delay of LS3 is likely beneficial for others

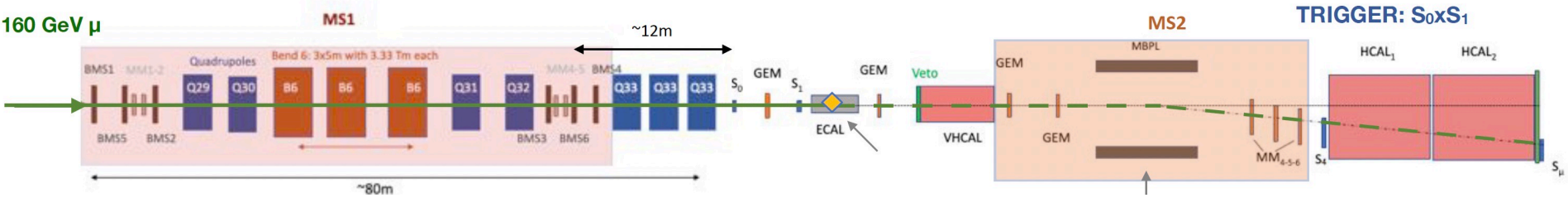
SPSC meeting
April 2018

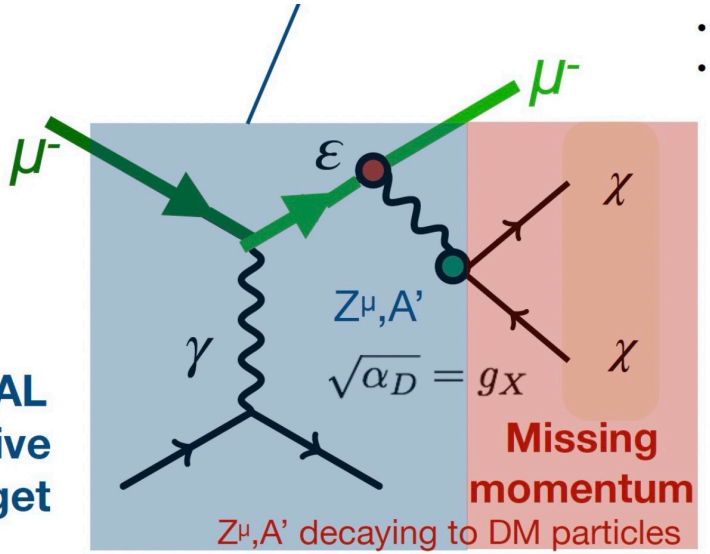
The SPSC recognises the physics case of measuring transversity for obtaining new information on the tensor charge, described in the first part of the addendum.
The Committee considers that the proposed deuteron run of about 150 days, which requires minimal changes to beam line and the experiment, represents a good case for a COMPASS operation in the first year after long shutdown LS2. The SPSC recommends approval of this run at the Research Board.





Needs to think with ~2 weeks target cycles → here ~10 cycles assumed
Statistics is critical to ensure a sensible run
Significant time is available for parassitic/alternative beam usage



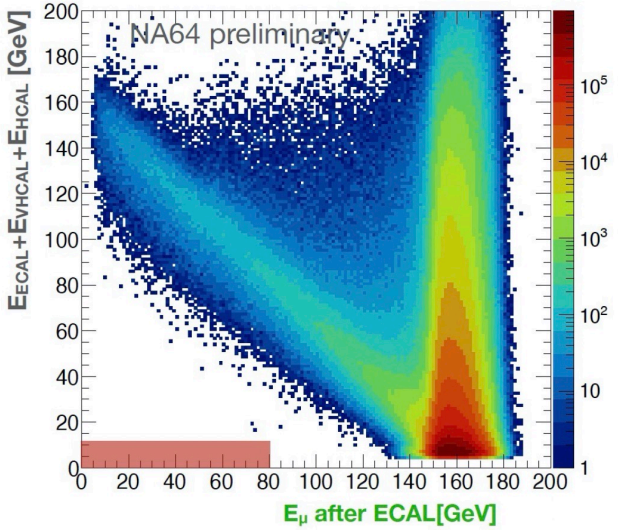


ECAL active target

- Trigger based on scattered muon deflection.
- Muon momentum mis-measurements level down to $\lesssim 10^{-12}$.

Signature

- Deflected μ- energy <80 GeV
- Energy on ECAL, VHCAL and HCAL compatible with a muon energy deposit.



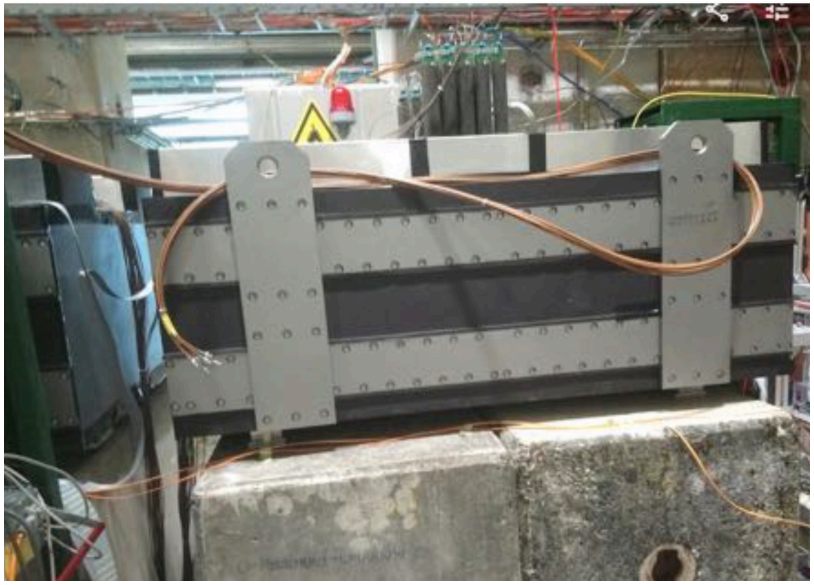
Impact on cross-section phase space approximations on muon Bremsstrahlung:
D. Kirpichnikov et al. arXiv:2107.13297
Accepted in PRD!

All detectors for electron and muon runs in 2022 are ready.

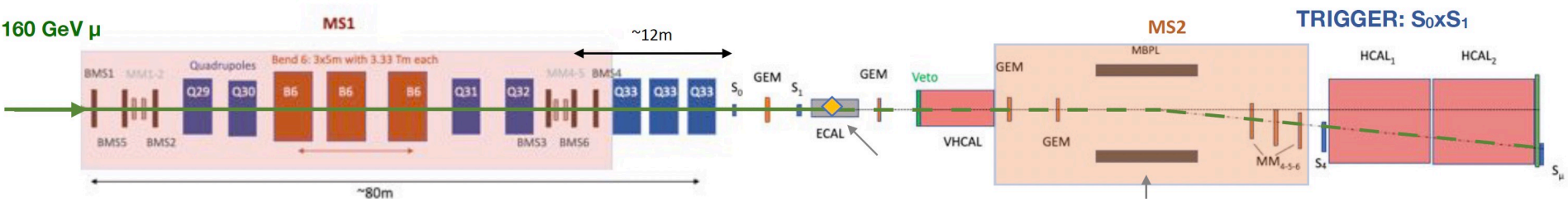
- The preparation of new detectors for muon beam:
  - First veto hadron calorimeters, VHcal; ready
  - Second veto hadron calorimeter, VHcal2; assembly in this year
  - Ecal, matrix 5x6 counters; ready and tested on the muon beam
  - 2 hadron modules, Hcal0 and Hcal1; ready and tested on the muon beam
  - Third hadron module, Hcal2; ready
  - Fourth hadron module, Hcal3; ready at the next week

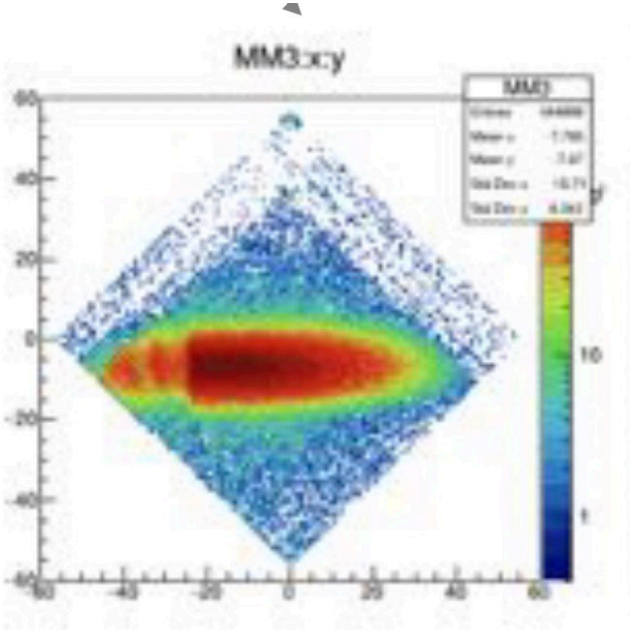
VHCAL veto

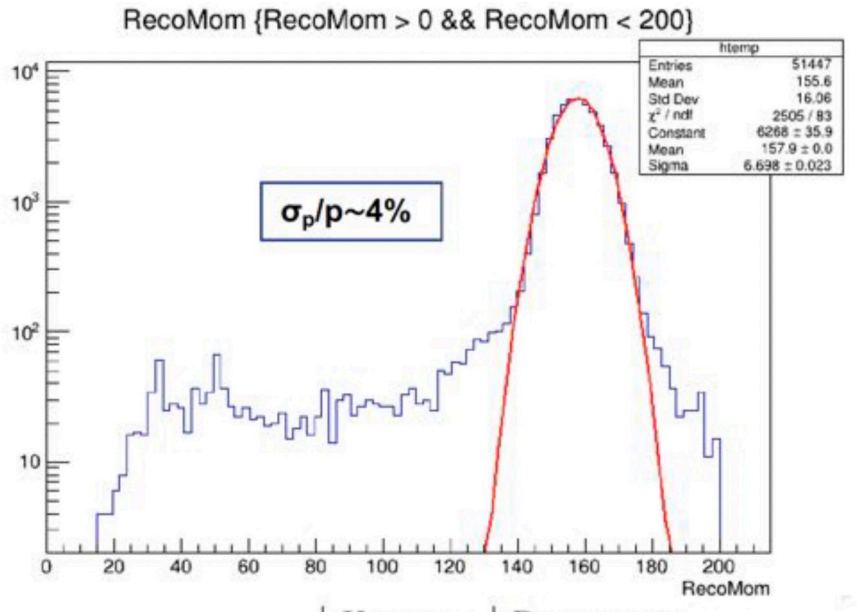
Hadron calorimeter



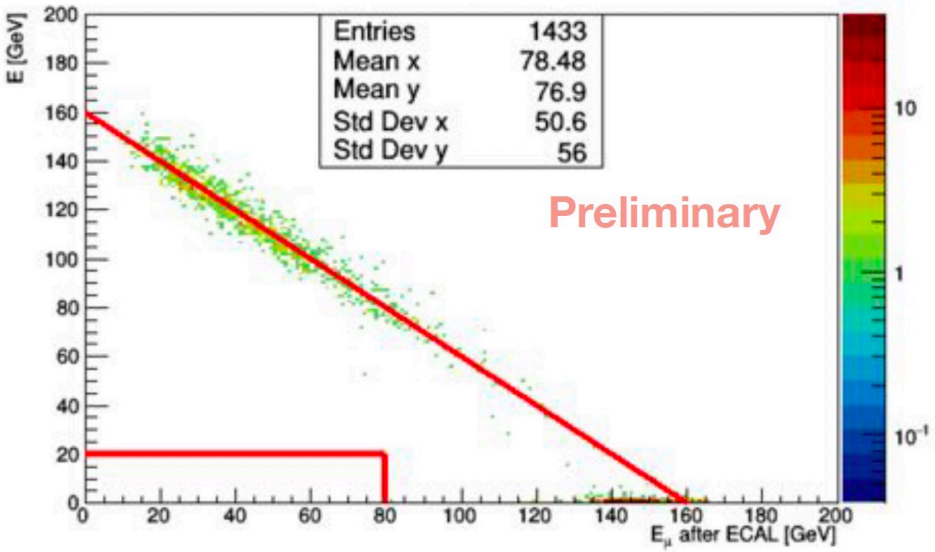
Shashlick em-calorimeter

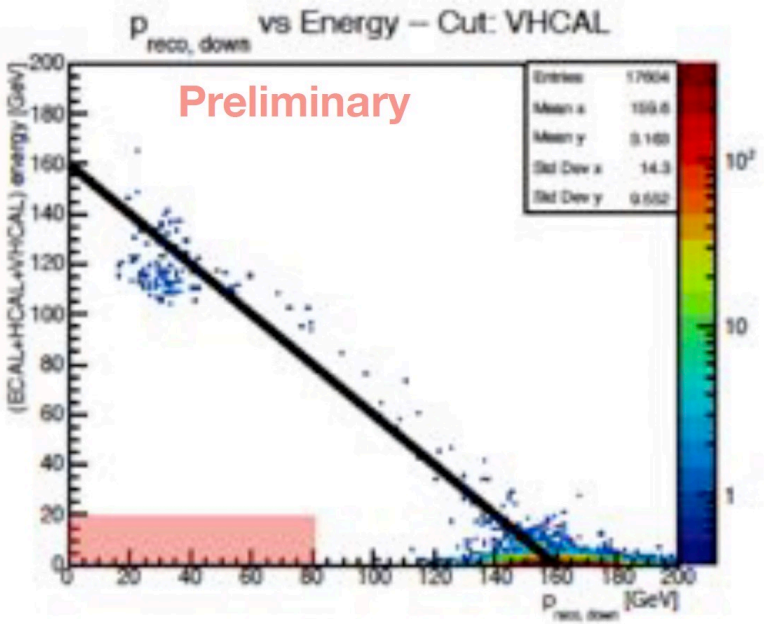






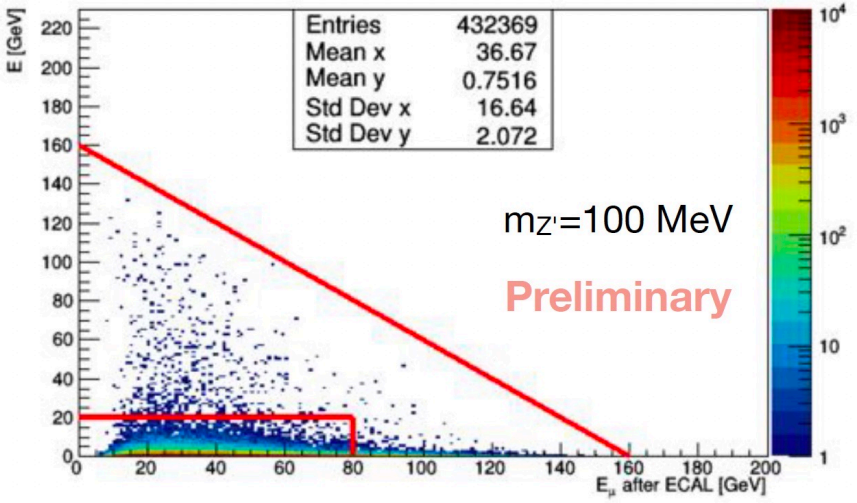
Preliminary study of the beam optics, detector resolution and hermeticity





So-far no indication of unexpected background

Source of background	Level per MOT
Hadron in-flight decay	$\lesssim 10^{-11}$
Momentum mismatch	$\lesssim 10^{-12}$
Detector non-hermeticity	$\lesssim 10^{-12}$
Single-hadron punch-through	$\lesssim 10^{-12}$
Dimuon production	$< 10^{-12}$
Total (conservatively)	$\lesssim 10^{-11}$



- **The 2021 NA64μ run was successful, ~5 x 10^9 MOT accumulated**
  - commissioning of the new beam and detector
  - preliminary results from the analysis of data sample are encouraging

- **The muon run at M2, PPE211,**
  23 days starting 25.04, ~160 GeV mu+.
  Agreed with COMPASS (on their request).
  - 3-4 days detector calibration, beam, trigger tuning
  - 6x10^4 spills (2.5 weeks) for data taking, 100-160 GeV mu+
  - primary goal is to accumulate ~a few10^{10} MOT, to study feasibility of the technique, and to optimize the setup in sensitivity for the first physics run
  - potential risk for the run is due to pandemic situation

$$a_\mu^{E821} - a_\mu^{SM} \sim (26.8 \pm 7.6) \times 10^{-10} (3.5\sigma)$$

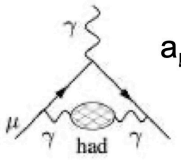
Current discrepancy limited by:

- Experimental uncertainty→ New experiments at FNAL and J-PARC **x4** accuracy
- Theoretical uncertanty→ limited by hadronic effects

$$a_\mu^{SM} = a_\mu^{QED} + a_\mu^{HAD} + a_\mu^{Weak}$$

G. Venanzoni, PSI Colloquium, 28 March 2019

Hadronic Vacuum polarization (HLO)

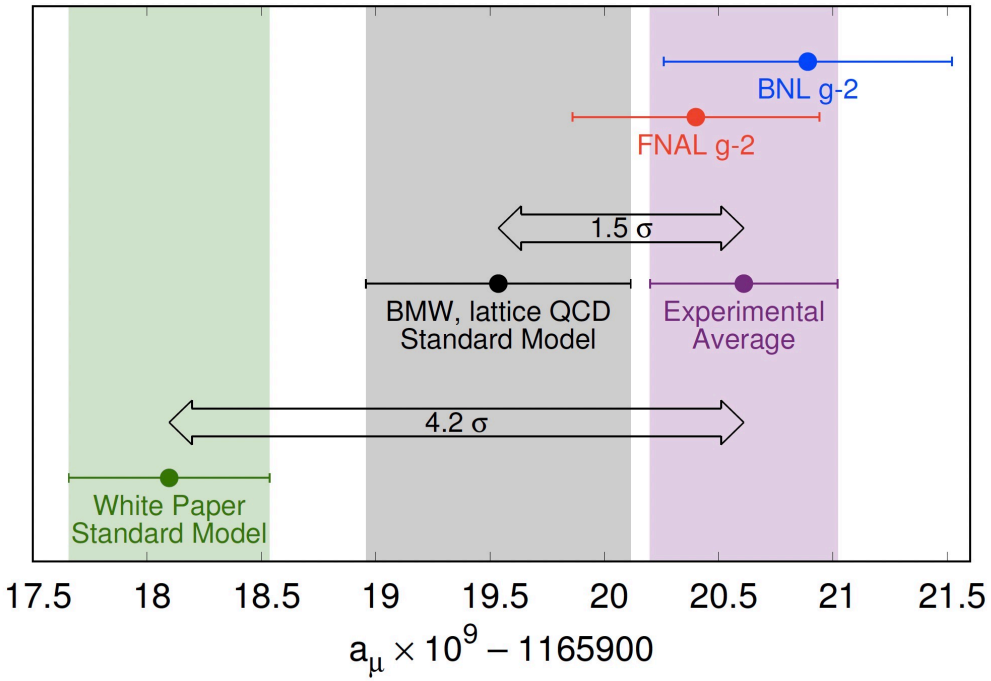


$a_\mu^{HLO} = (689.5 \pm 3.3) 10^{-10}$

F. Jegerlehner 17

$\delta a_\mu^{HLO} / a_\mu^{HLO} \sim 0.4\%$

Muon g-2



- **only 1 tracking station, partially equipped, was available at the end of 2021** *(two 2S modules instead of 6 composing a full station)*

  MUonE therefore proceeded to run a joint test with CMS, behind COMPASS, parasitically to NA64 (located upstream COMPASS). Two more 2S planes were in front of the station.

Aims:

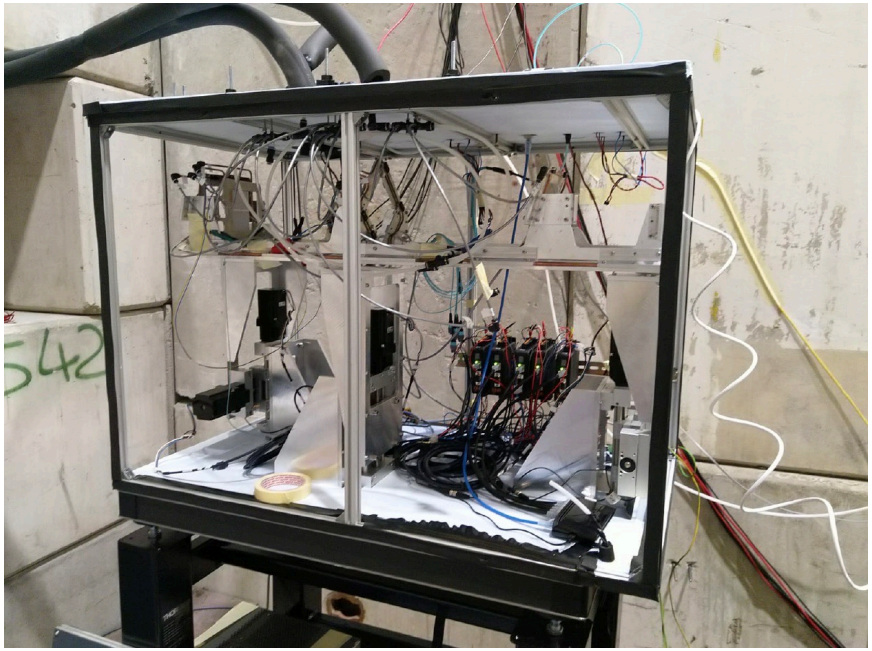
a. to test the CMS electronics and DAQ
b. to validate the design of the mechanics of the housing and services of the tracker planes

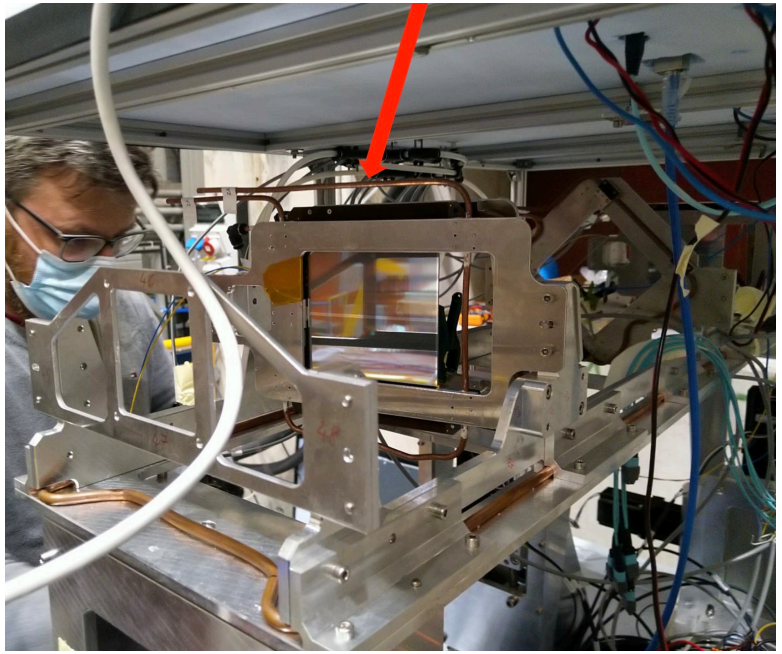
Nov'21 TB provided an important proof of concept for the MUonE readout chain

- The first time modules in beam were read out through a Serenity
- First time stub data from beam has been streamed at 40 MHz to disk
  - Recall : this is not envisioned in the CMS data model
- Prima facie - CMS modules & DAQ performed reliably throughout the TB

On the other hand, collected data does however appear to be of good quality

- Around 1TB of skimmed data to now analyse offline
- Opportunity to learn about system reliability, configuration & operation of the apparatus, and DAQ/DQM needs in 2022





MuonE

Following up on the sharing of the M2 beam line by AMBER, NA64-mu and MUonE, the Committee **recommends** that beam time for the MUonE test run to evaluate the angular precision and efficiencies in preparation of a proposal should be postponed from 2021 to 2022. This will ensure that a minimum of two detector stations are available allowing for a more decisive measurement.

- **in january 2022 MUonE will have more information about the procurement of 2S modules during 2022.**

  Seems reasonable to have:

  2 stations for summer (total 12 modules) ➡ 2 weeks of running

  3 stations for end of 2022 (total 18 modules) ➡ 1 week of running

  …. not yet clear if in time to perform a testrun with all 3

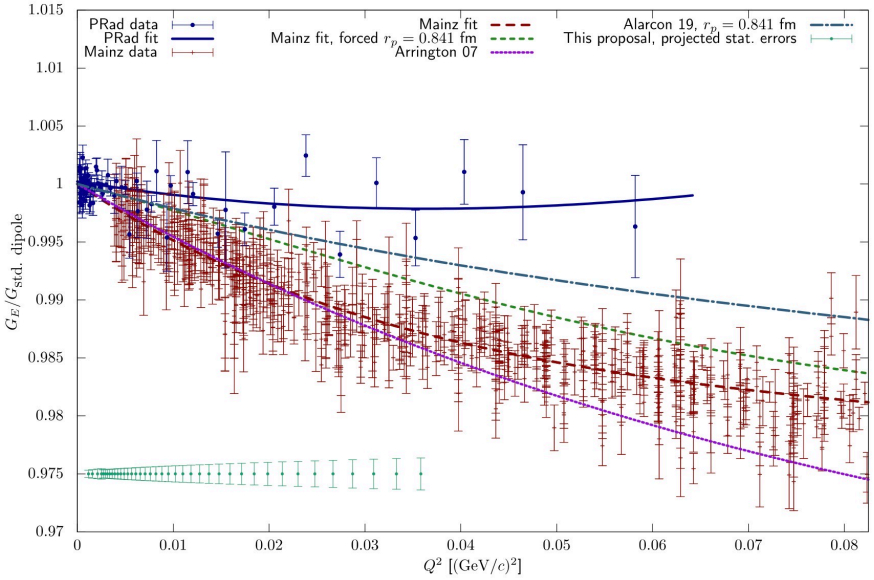
  (but anyway run with 2 stations if 3 are not there)

- **calorimeter modules will be calibrated and commissioned in the East Hall and ready to be put on M2 in may 2022**

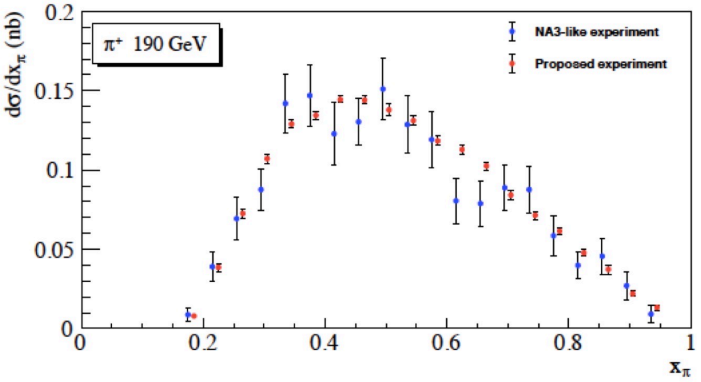
COMPASS proposed to leave MUonE as main user in the intervals of 3 days every 2-3 weeks, while they change target polarization.

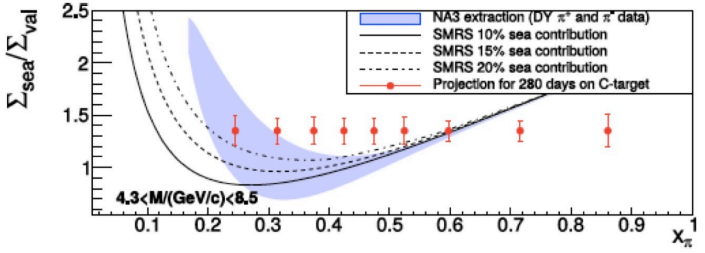
MUonE is exploring if there are the conditions to exploit these periods of time: (for subsystem commissioning)

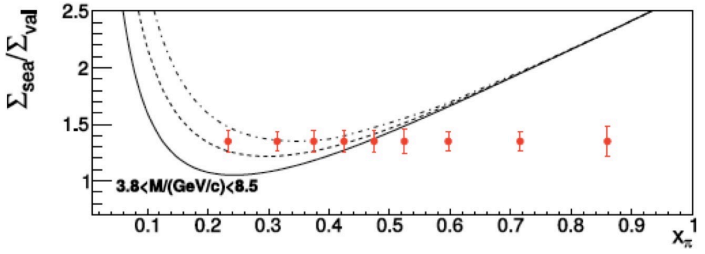
Proton radius



Pion structure

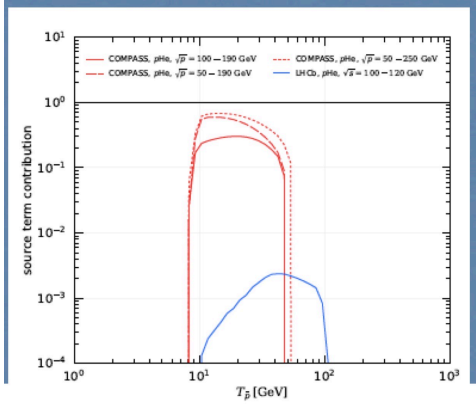


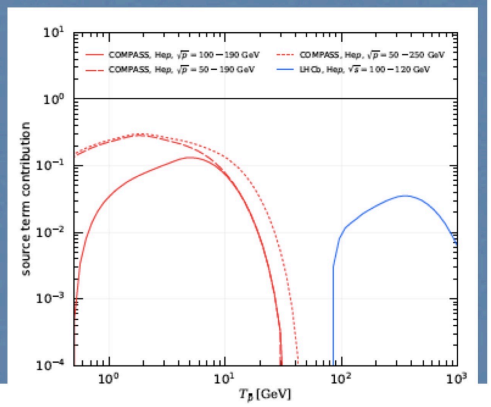




Antimatter production

p-He and He-p channels



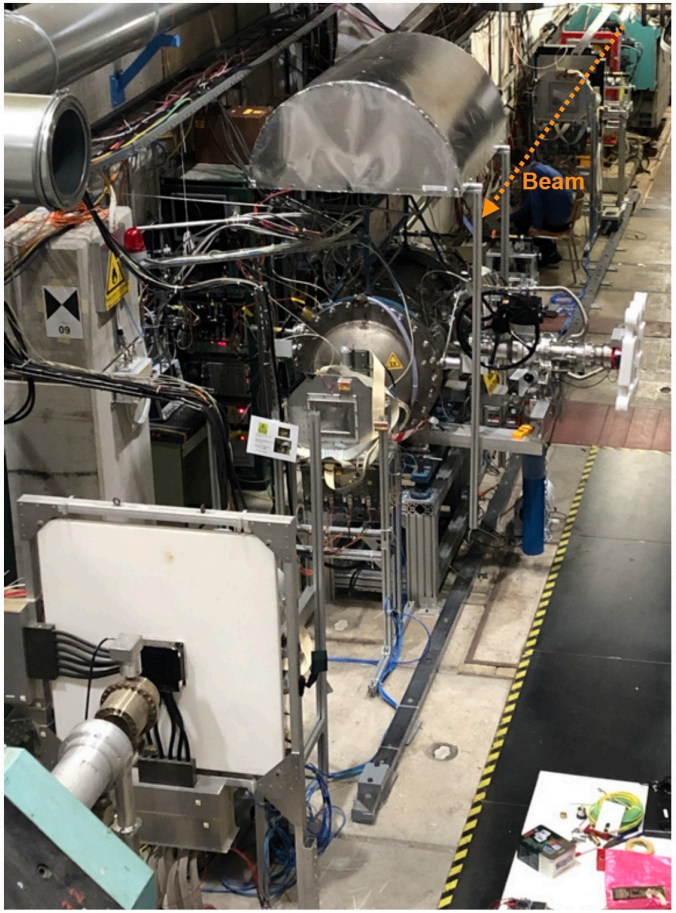


AMBER PRM - Pilot Run in October 2021

Goals for the pilot run for the PRM setup
Preparations with close-to-final layout of the measurement to study overall properties of the setup in the test beam location in the M2 beam line.

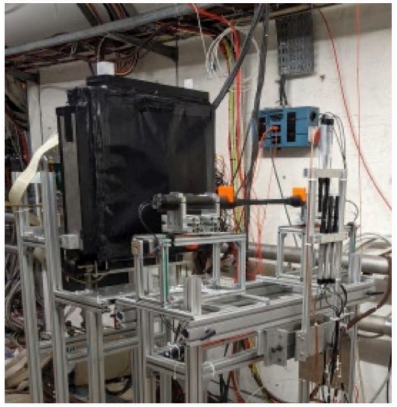
- 21 days dedicated data taking (06.10. — 27.10.)
- Comparable geometry and beam settings

- TPC — downscaled version with 2 chambers (IKAR):
  → Study beam-induced noise for different beam rates
  → Examine pressure and temperature effects
  → Evaluate anode structure
- Tracking — existing sci-fis, silicons and spectrometer
  → Provide tracking along TPC for studies
  → Produce data set for muon-proton event matching
  → Evaluate spectrometer performance in different running mode (only one magnet)

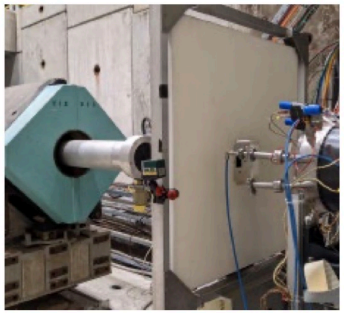


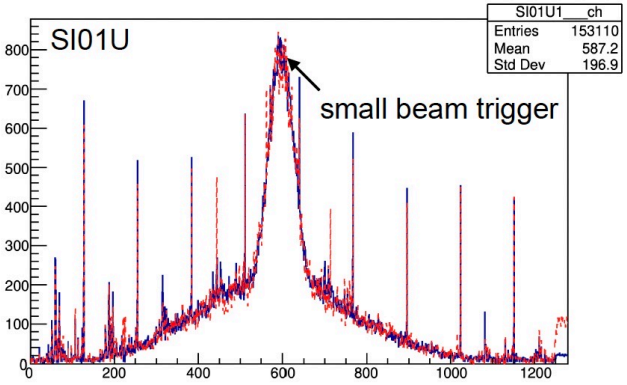
Tracking & alignment

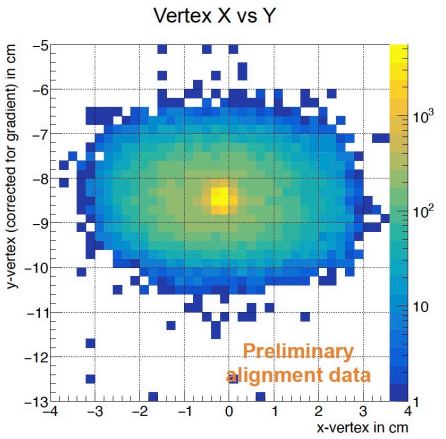
SF1



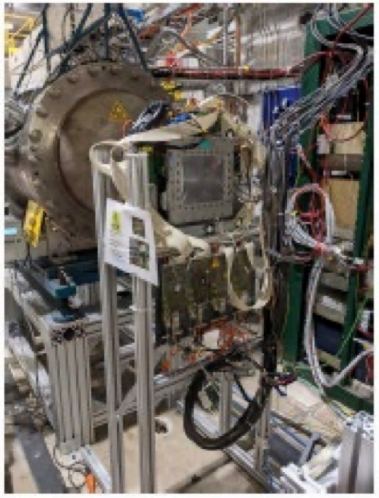
SF2



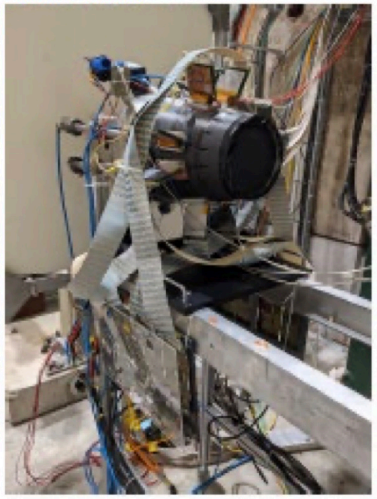


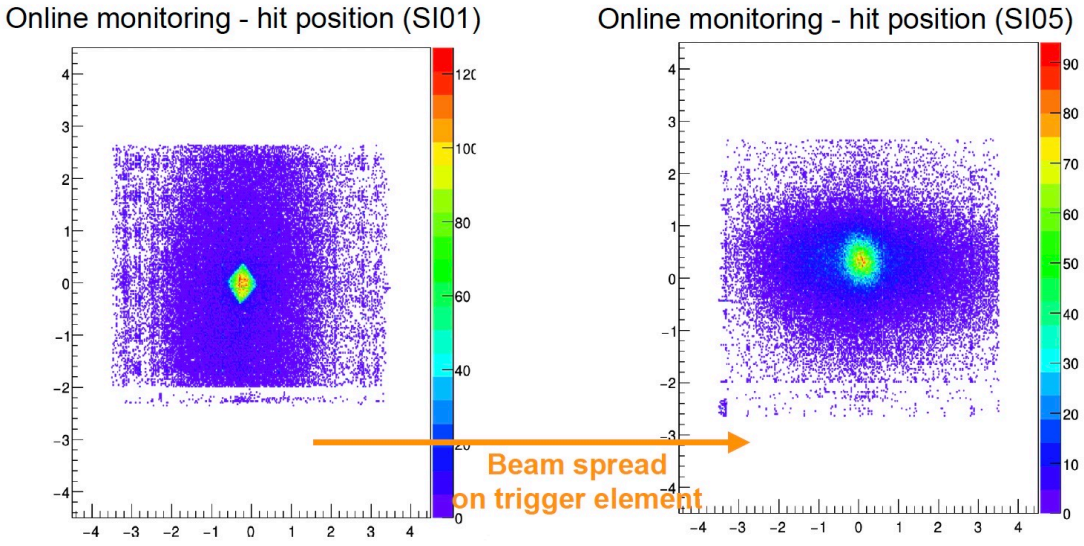


SI02



SI04 + SI05

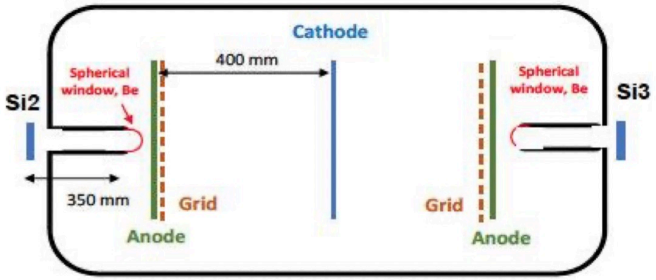


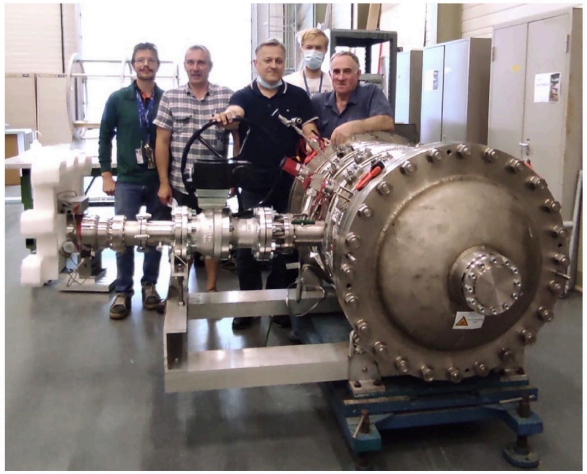


Active-target high-pressure TPC

IKAR as prototype version for final TPC.

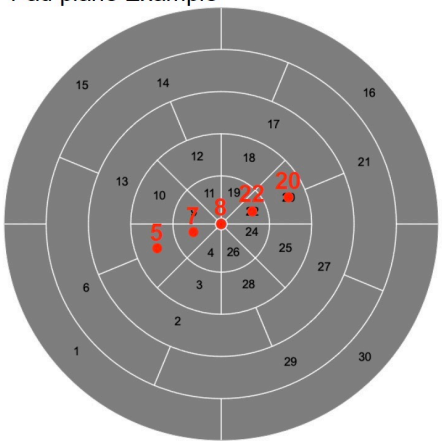
- First operation in NA8 (CERN, 1977 — 1987)
  → Already used for elastic μ-p and p-p scattering
- Inner part completely refurbished:
  → Two drift cells with 40 cm length each
  → New readout plane installed for testing
- Operation pressure for hydrogen: 8 bar (max)
  → Hydrogen operation permit difficult
  → Dedicated gas system with PLC control



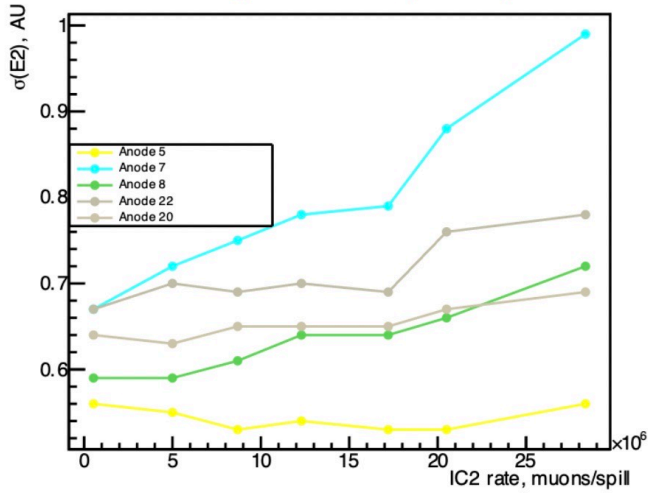


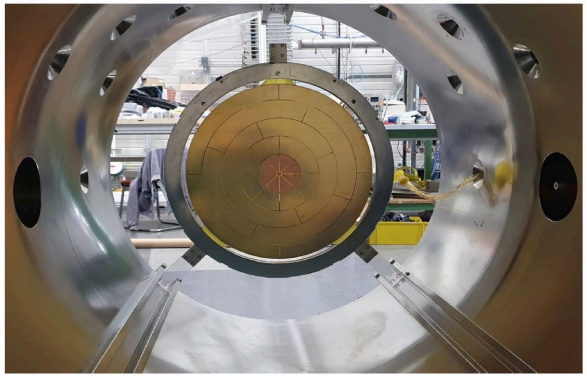
IKAR TPC

Pad plane Example

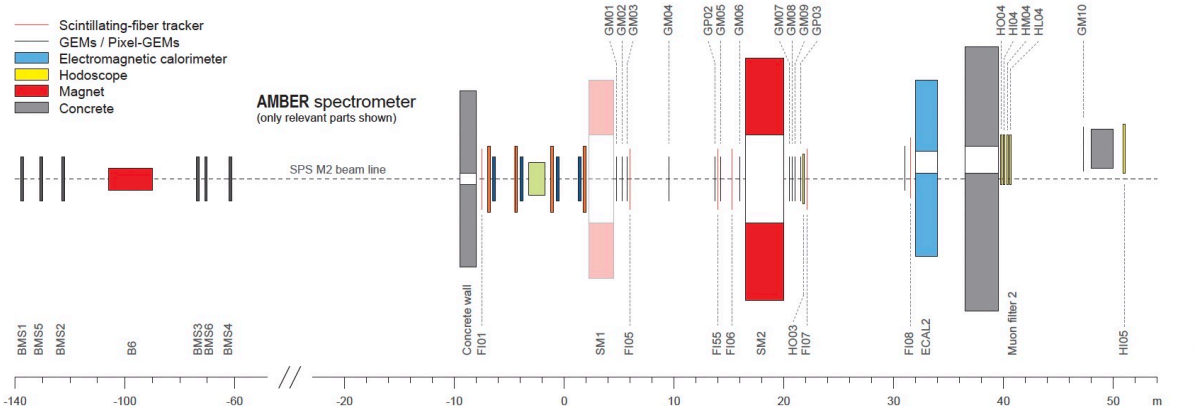


Energy resolution (4.3 bar)



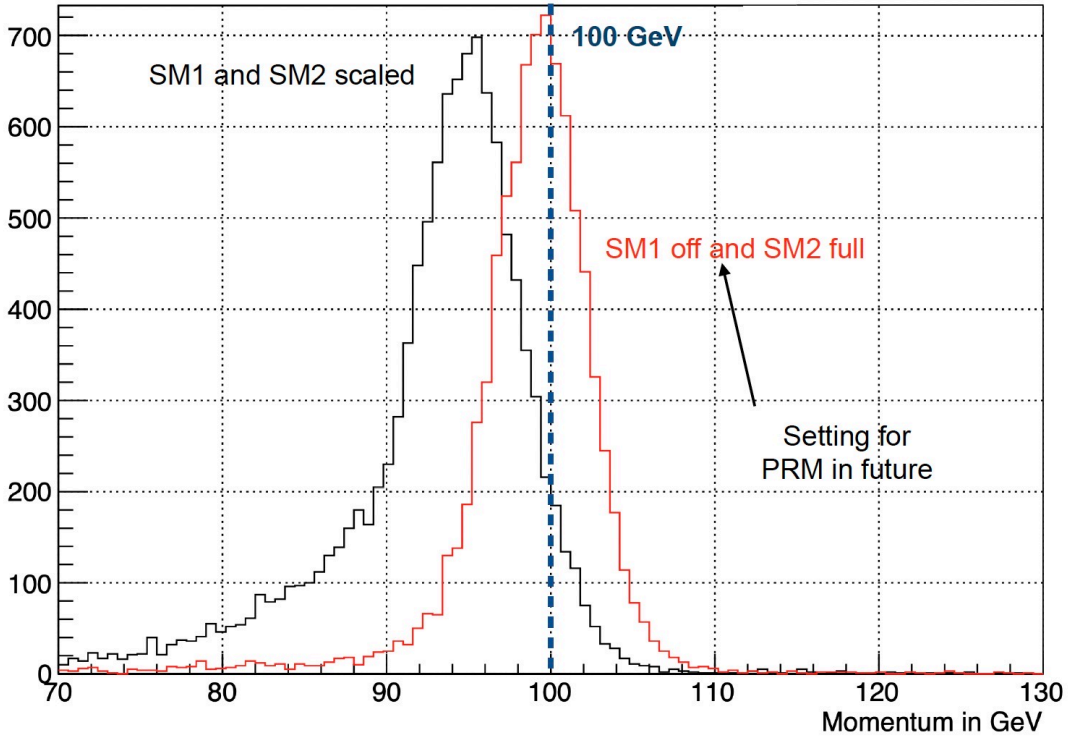


IKAR TPC Pad Plane

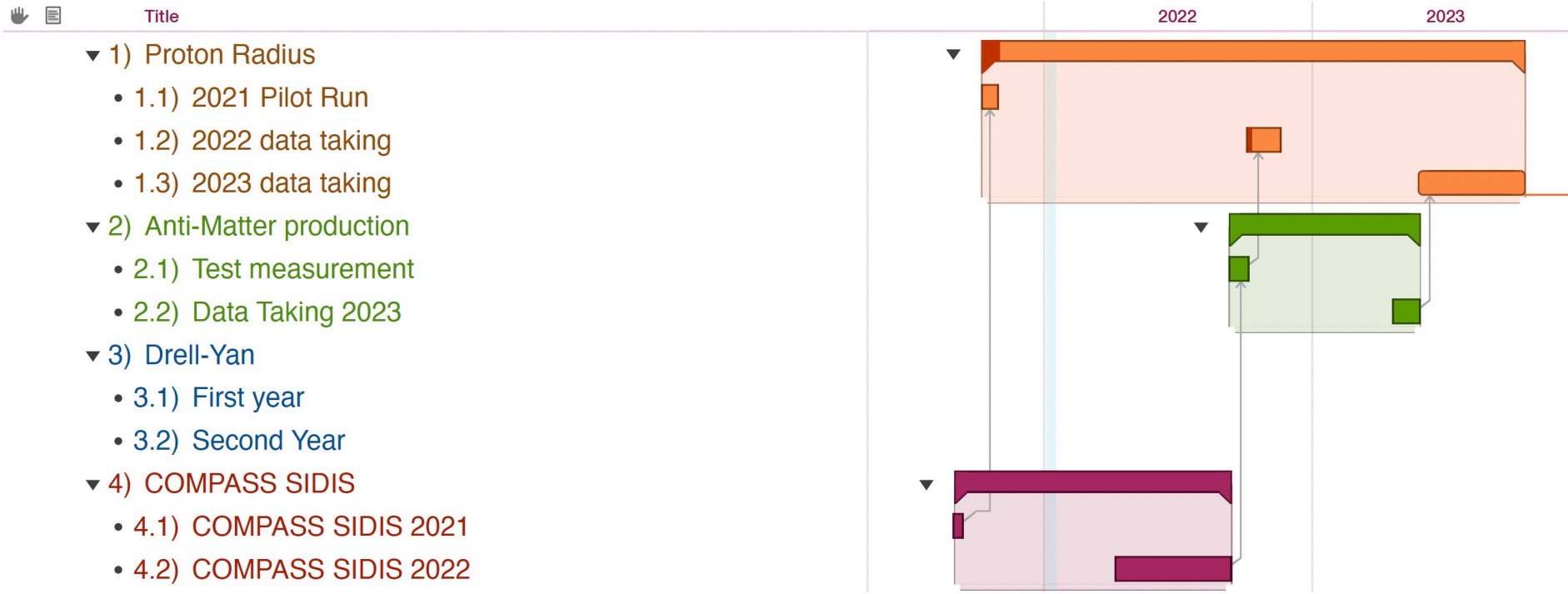


Momentum reconstruction

Adapt spectrometer settings to compensate reduced beam momentum to 100 GeV
Scale magnet currents



AMBER



It is a formal request which was submitted to the SPS coordinator:

PRM: 14 days parasitic, 15 days as a main user, desired time slot: Sep.-Nov.

Xsec: 10 days as a main user, desired time slot: Sep.-Nov.

Change over time (preliminary): SIDIS ➔ Xsec - 13 days; Xsec ➔ PRM 24 days
In the hypothesis of no parallel running, PRM set-up is constructed in the main experimental area

Anti-p based on the current DAQ. Wants He target for realistic yield/back (material budget)

Detector preparation: 2 days

- Set up of the Beam killer scintillators and tuning
- Set up of the upstream beam telescope

Data taking period: 8 days

- 3 days beam and spectrometer commissioning
- 2 days data acquisition at 190 GeV/c (test trigger configurati
- 2 days data acquisition at 50 GeV/c (play with beam intensity spectrometer acceptance)
- 1 days data acquisition at high energy end (280 GeV/c ?)

RPM moving to th new streaming mode also required for future DY.
2022 pilot run focus on tracking stations + new DAQ in the real beam spot

Main goals for PRM test run in 2022 looks like follows:

- we want to get the new DAQ system tested, with as much of the new tracking systems as can be obtained until autumn;
- as many as it possible existing tracking detectors has to be equipped with new DAQ compatible electronics and tested (Fibers/MWPCs/GEM). This will provide training data for monitoring, decoding and reconstruction
- we expect 2 or 3 partially equipped UT stations to be ready - this will become clear only until April; (delays: licence issue for ALPIDEs)

SIDIS dismounting ~ 4+4 days

Total duration of the Change-over (SIDIS set-up dismantling, no beam during day time):

- PT operation
  1. He3 removal - 1 day
  2. He4 filling - 1 day
  3. TE calibration data taking - 3 days
  4. He4 removal - 2 days
  5. DR warming up - 1 day
  6. PT material unloading – 1 day
  7. Best telescope + trigger platform removal – 2 days (during 4-5)

Pbar setup ~ 5 days

Total duration of the Change-over (AP set-up installation) (no beam in the area during day time):

- PT operation
  1. PT cell dismantling from the target holder and He3 line cleaning-up - 1 day
  2. Target holder installation and DR cooling down - 1 day
  3. He4 filling up - 1 day
  4. Building up beam telescope and trigger platform (veto & Sci/Fi) + survey - 2 days

COMPASS target post-calibration is critical for run validation

Target material change-over introduce some risk

With LiD target, trigger and signal yield might be impacted

however, the test can be done enytime with minimal impact on COMPASS

Pbar dismounting ~ 3 days

Total duration of the Change-over (AP set-up dismantling):

- PT operation
  1. He to be removed - 1 day
  2. (Warm up PT - 30 days)
  3. (DR un-cabling un-piping - 3 days)
  5. (PT platform rotation - 2 days)
- Beam telescope removal
  1. Silicons? + SciFi + N pipes? – 2 days

RPM setup ~ 3 weeks

- Beam telescope (experience from 2018 beam test):

4. Safety inspection - 3 days
5. Survey of the set-up - 1day
6. Change of the DAQ/FE running mode to triggerless (in parallel to other activities at least partially) 3 – weeks

(DAQ hardware is completely different)

New tracking stations cuold find space in COMPASS target area

DAQ upgrading can possibly proceed in stages

Beam Request

SPS North Area M2 beamline

- Conflicting requests for **SPS M2 beamline**
  → SPSC working group

	Weeks requested main user	*Weeks requested parasitic user*
COMPASS NA58	26	5.5
NA64mu	3.5	0
MUonE	4.5	2.5
AMBER NA66	3.5	2

NA64 can run in parallel with COMPASS commissioning

MuonE will deserve a pilot run (2-3 weeks) if ready (2 stations) in time

AMBER has focused on anti-p cross-section measurement as proton-radius TPC will not be ready in 2022. Proton beam, spectrometer response to antiproton, new tracking stations and DAQ could be commissioned in an opportunistic mode.

AMBER request to change COMPASS target material seems not enough justified

Minutes

The Committee notes with satisfaction the promising indications of the 2021 test runs of NA64μ, AMBER and MuonE.

The SPSC recommends that the experiments planned in the M2 beam line collaborate to maximize the usage of the beam for physics data-taking with complete apparatuses, by staging their activity in synergy and avoiding un-necessary setup modifications.

The Committee welcome the proposal to have the NA64μ data-taking at the beginning of the 2022 run, in parallel to the COMPASS spectrometer and target commissioning.

The Committee encourages the experiments to find opportunistic ways to commission new hardware elements prior of dedicated pilot runs and prioritize the essential tests in preparation of the physics runs.