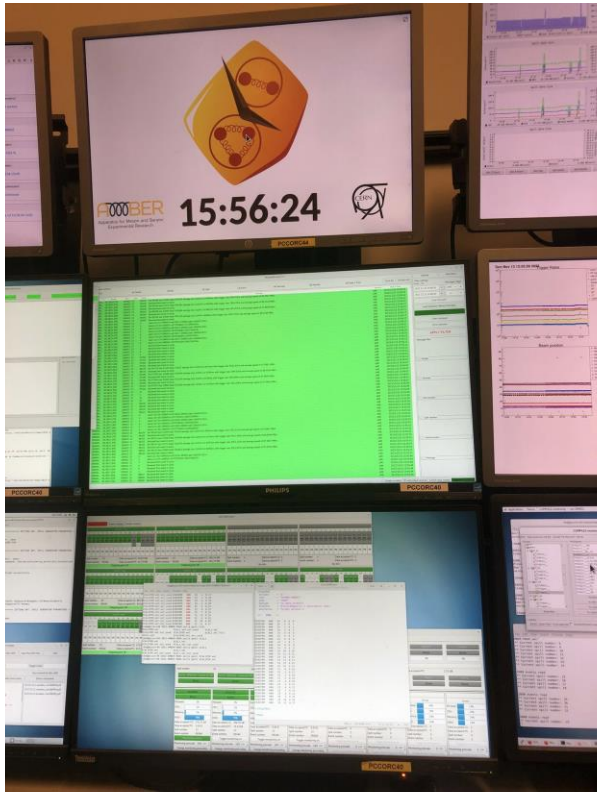
AMBER Annual Status Report
05/09/2023

Apparatus for Meson and Baryon Experimental Research

AMBER – status of 2023 data taking and beam time request 2024

Outlook

1. Introduction
2. Run 2023:
   - Antimatter Production cross-section (APX)
   - Proton Radius Measurement (PRM) tests 2021-2023
   - Drell-Yan high intensity CEDARs test (DY)
3. New hardware developments
4. Run 2024:
   - APX (LH target) – 2 months
   - DY – further CEDARS testing (few days)
   - PRM Test Run – 1 month
5. Summary



Introduction/news

Collaboration is growing up : New group from Giessen

- Group leader Prof. Kai-Thomas Brinkmann
- Lab is experienced in instrumentation, for example lead lab PANDA EMC barrel construction and PANDA PWO crystal development, participating in PANDA micro-vertex detector development
- Interests in physics:
  - feasibility studies in nucleon structure, complementary to CLAS TMD studies; contributions to DY program
  - simulations, e.g. GPDs in DVCS, DVMP

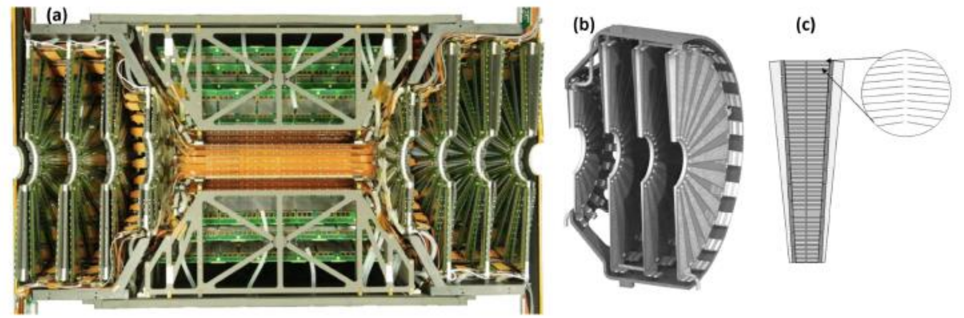
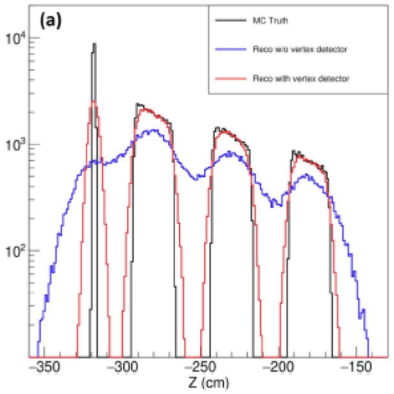


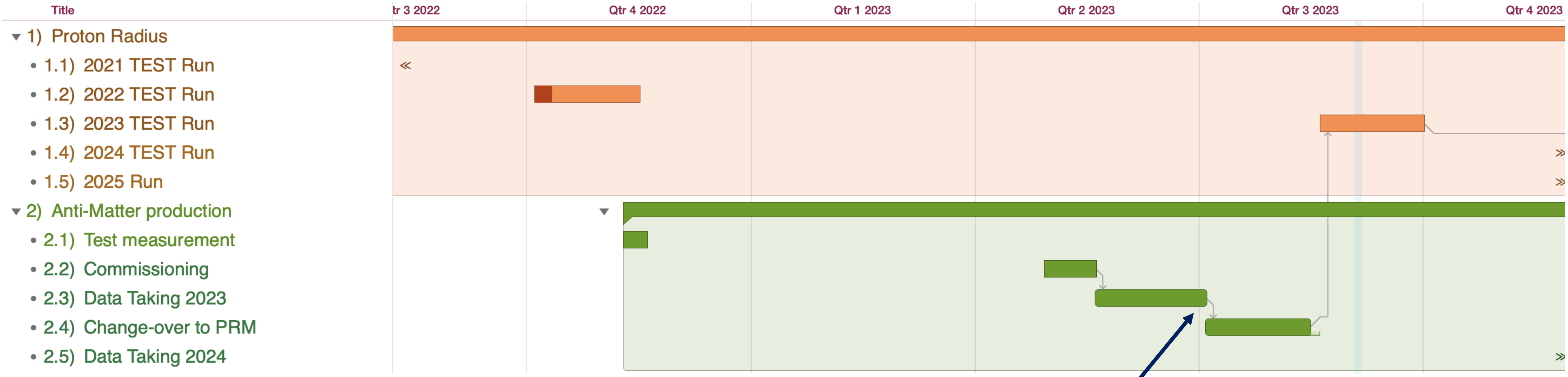
Figure 7 **(a)** A completed half FVTX detector, with sensors, frontend electronics, supporting structures, and cooling system. Two half FVTX endcaps are shown on either end. The overall length is about 80 cm. **(b)** A structural illustration of one endcap of the FVTX. One small disk and three large disks are included in one endcap. **(c)** A segment (wedge) of the FVTX sensor. Each wedge holds two columns of the silicon strips as shown in the zoomed-in portion.



Great news from Los Alamos NL:

- Early career DOE award: the AMBER Drell-Yan vertex tracker project has been selected for funding starting FY24
- This is a key detector for the AMBER Drell-Yan program which we intend to start after LS3.

Approved AMBER Running Plan 2023

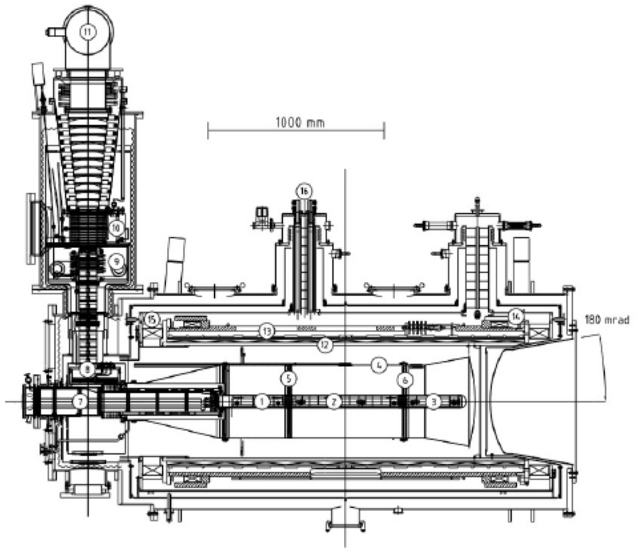


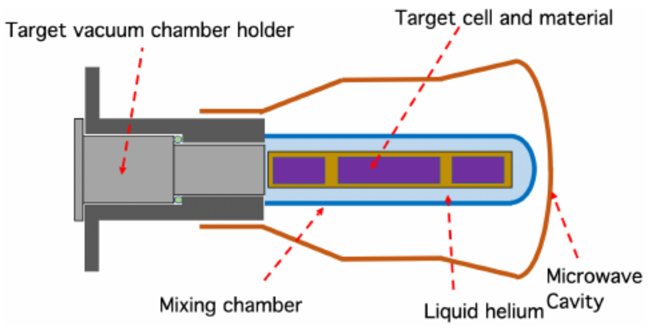
High intensity hadron beam CEDAR test (Drell-Yan)

APX 2023 Run (LHe target)

Apparatus for Meson and Baryon Experimental Research

Hardware preparations

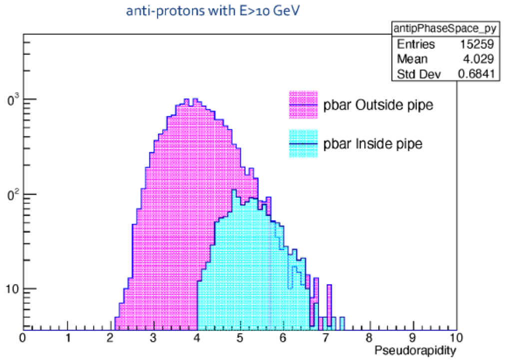




Target Status:

- Polarized target was successfully adapted as liquid He target   Cooling started on March 21st , Filling with He March 19th
  → reached 1.1 K on April 21st
- PT Magnet was tested on April 18th prior to hibernation

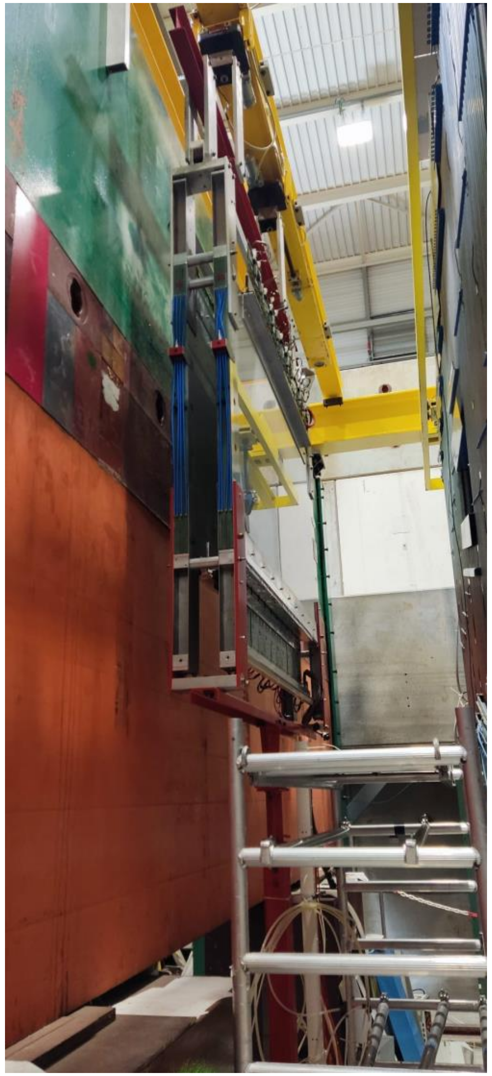
RICH Beam Pipe Removal:



- On March 28th the TB recommended the removal of the RICH beam pipe requested by the physics group
- We prepared a procedure document which was discussed and approved by CERN EP Safety
- The RICH was flushed with N2 before April 4th
- On April 19th the operation was successfully performed

APX 2023 Run

- Beam line commissioning started on April 17th and was concluded 27th
- Some problems with the CEDAR detector installation (alignment, gas system, readout)
  → Performance check for 60 GeV is planned for next week
- One MWPC was refurbished (exchange of mylar windows)
- RW throughout investigation of the readout problems
  → Improved but still not fully under control
- BeamKiller installation was improved.
- RICH filling with radiator gas on May 10th
- First part of electron calibration for calorimeters was performed last weekend



In general commissioning of the spectrometer went quite smooth with no major problems

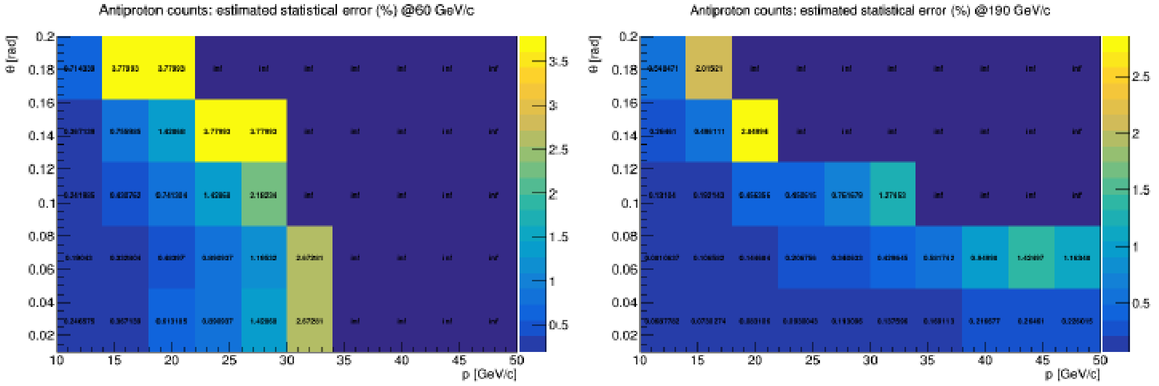
Physics data taking has been started on May 19th !

APX 2023 Run

We have successfully completed our program on liquid Helium target, 6 incoming beam energy measurements were performed. For each beam energy specific configuration of the spectrometric magnets bending power were used.

Table 2: Conducted measurements during the 2023 physics run.

Beam momentum (GeV/c)	Collision energy ($\sqrt{s_{\mathrm{NN}}}$) (GeV)	Start Date	End Date	Number of spills
60	10.7	24.05	30.05	37000
80	12.3	17.06	25.06	13400
100	13.8	01.06	11.06	13700
160	17.3	14.06	17.06	8500
190	18.9	19.05	24.05	11000
250	21.7	11.06	14.06	7300



(a) 60 GeV/c (b) 190 GeV/c

Fig. 9: Exemplary statistical precision of the recorded datasets at 60 GeV/c and 190 GeV/c.

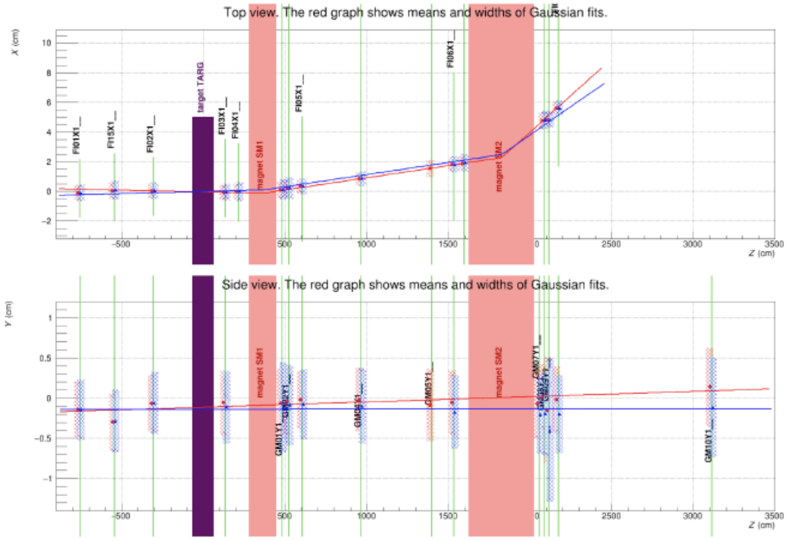
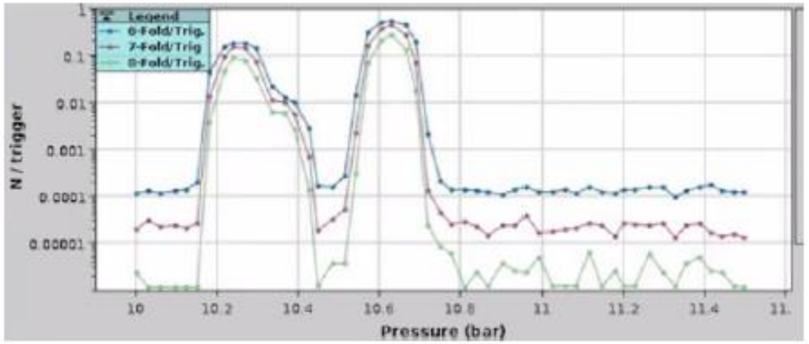


Fig. 10: Measured beam trajectory through the AMBER spectrometer for two different beam momenta. In red, 160 GeV/c is shown, and in blue, 190 GeV/c.



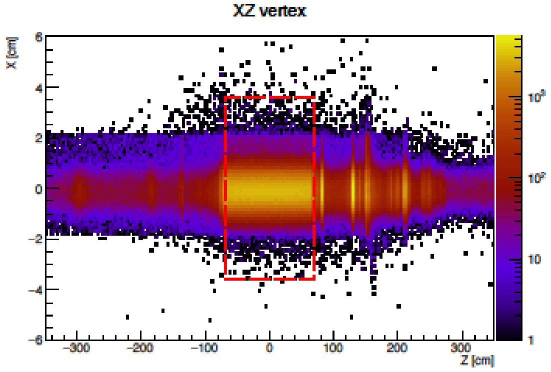
Important we were perfectly able to use CEDAR at 60 GeV/c beam mom. which is beyond its design specifications

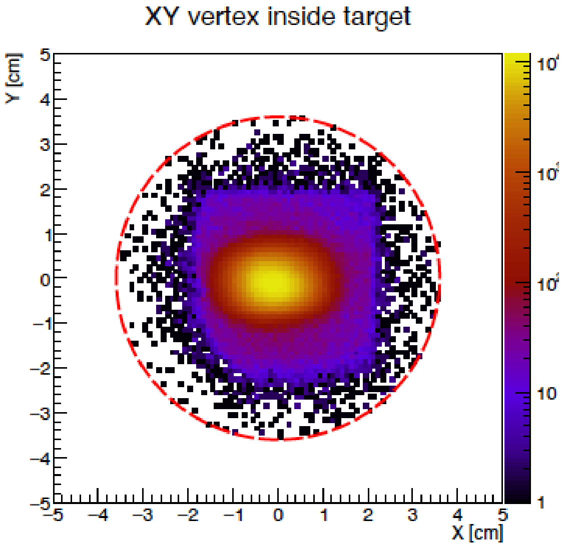
AMBER SPSC 2023

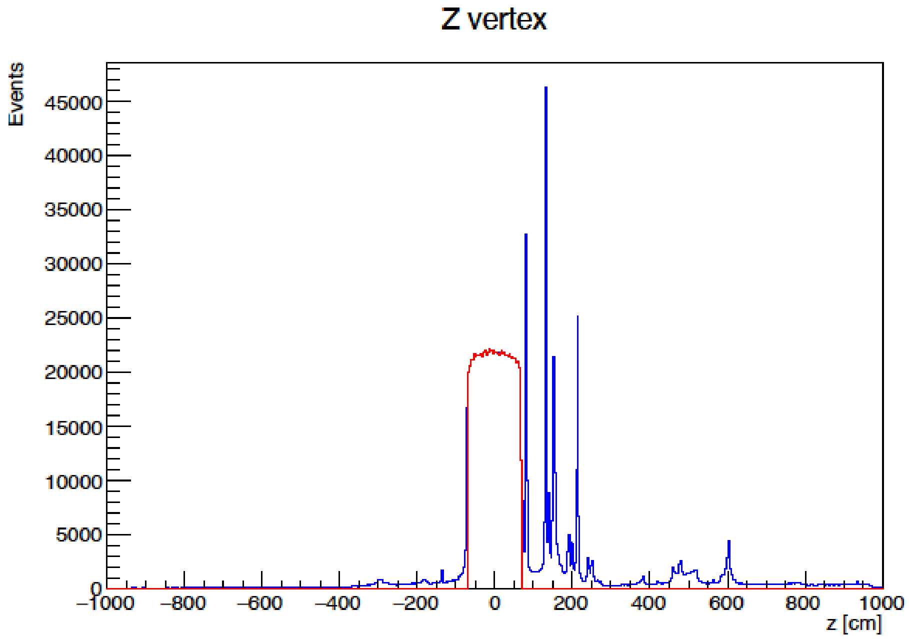
APX 2023 Run
Alignment and first look at the collected data

After the first round of alignment basic kinematical parameters of reconstructed data were examined, no strong anomaly found so far.

190 GeV/c data set. Preliminary, work in progress.







Davide Giordano at Quark Matter’23 (04-08/09)

APX 2023 Run
Alignment and first look at the collected data

After the first round of alignment basic kinematical parameters of reconstructed data were examined, no strong anomaly found so far. Here the RICH-1 response for different type secondary particles is shown together with Armenteros-Podolanski plot for particles coming our from the identified secondary vertex (K_S or Λ)

Preliminary, work in progress.

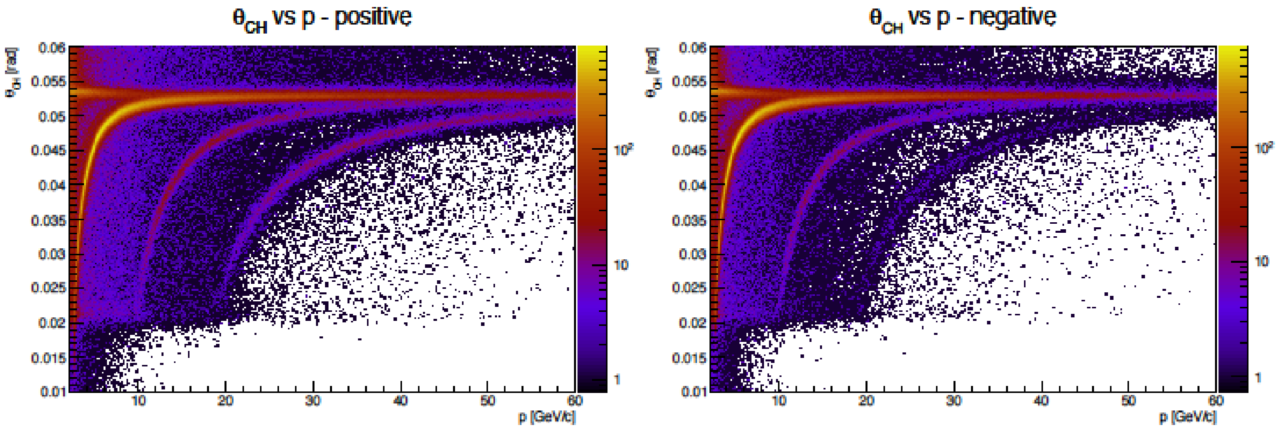


Fig. 14: Cerenkov angle in RICH-1 produced by positive particle (left) and negative particles (right) as a function of momentum. Very preliminary, not for public use.

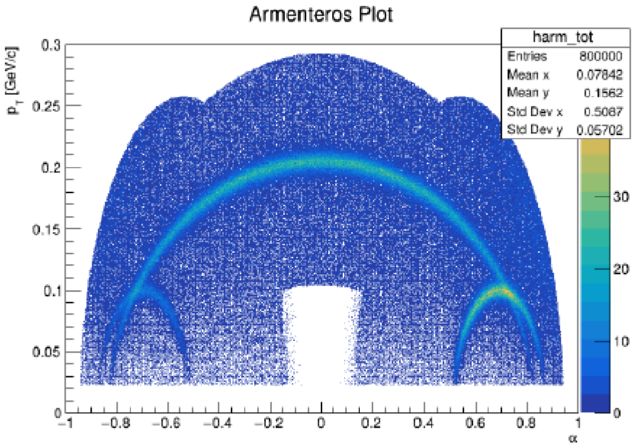
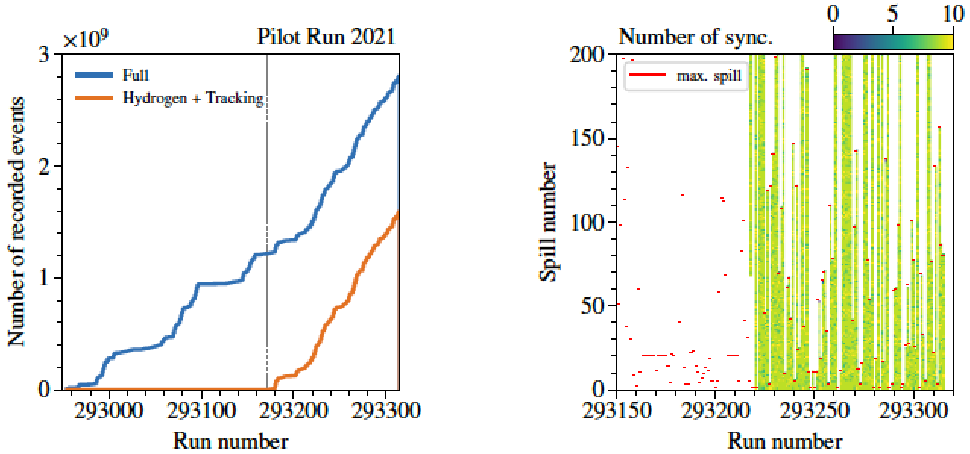


Fig. 15: Armenteros-Podolanski plot: on the y-axis the p_T of one daughter particles from the V0 decay vs the longitudinal momentum asymmetry. The main arc band represents the population of K0s and the two smaller arcs are the Λ and $\bar{\Lambda}$. Very preliminary, not for public use.

Davide Giordano at Quark Matter’23 (04-08/09)

PRM – update on a data analysis from 2021 Pilot Run

Apparatus for Meson and Baryon Experimental Research

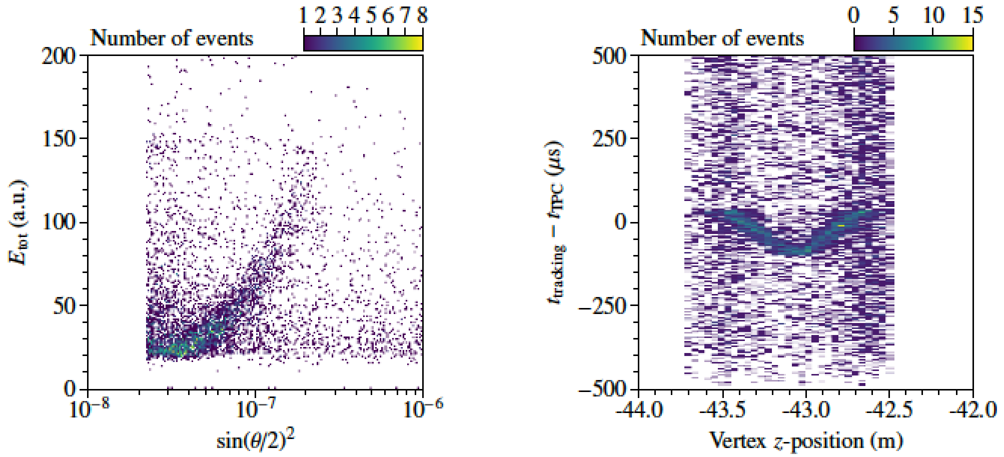


(a) (b)

Fig. 17: The integrated number of events during the pilot run is shown in (a). In (b) the number of synchronisation ticks used for the TRLO time stamp is presented. [8]

PRM Pilot Run 2021 conditions:

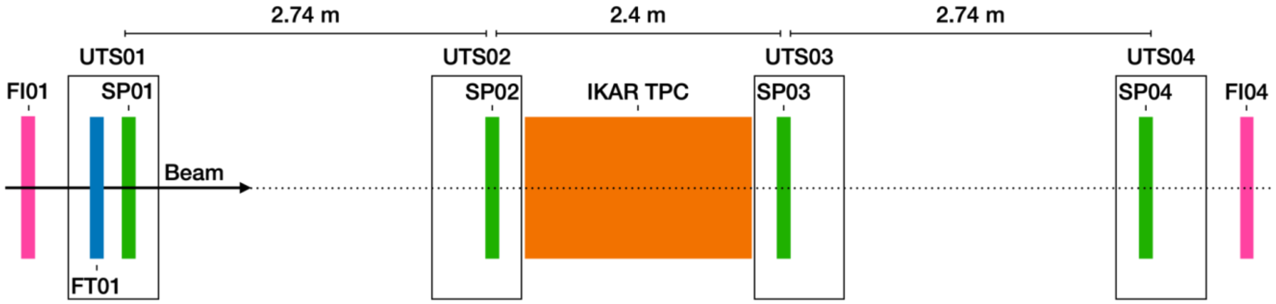
- “CEDARs M2 beam line area”
- “Downgraded with respect to final ” IKAR TPC, 8 bar hydrogen data
- ”Old” beam telescope
- Two independent DAQ systems, common time stamp
- Up to 7 MHz muon beam intensity



(c) (d)

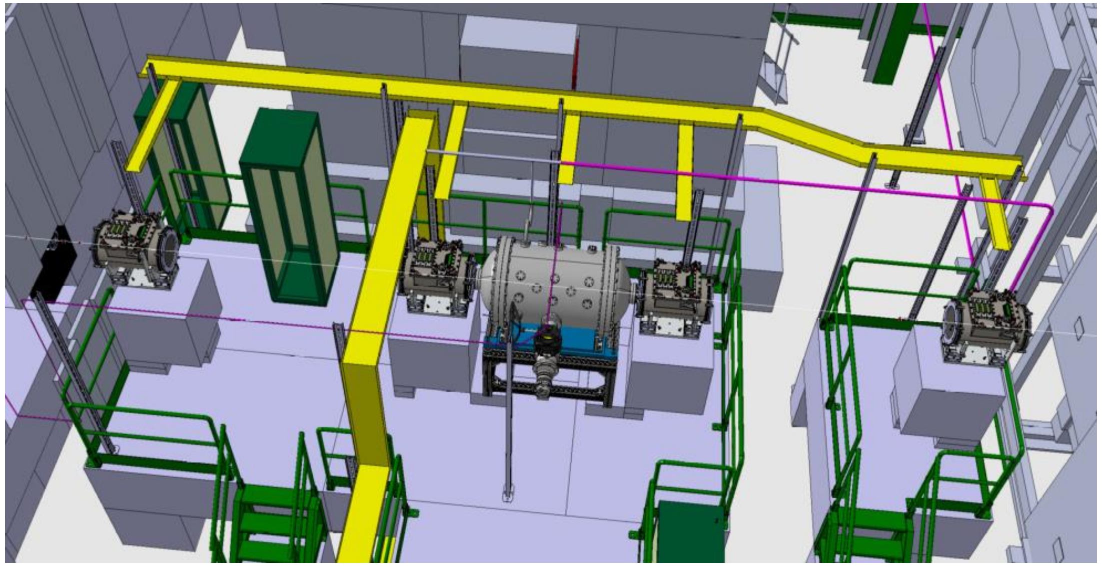
Fig. 18: In (a) the extracted TPC energy spectrum is shown. The TRLO time stamp difference between the tracking and TPC system is shown in (b) with the resulting correlations in energy and vertex position shown in (c) and (d). [8]

PRM 2023 Test Run – general lay-out and main components



PRM Test Run 2023 conditions:

- Final position wrt AMBER spectrometer
- "Downgraded with respect to final " IKAR TPC, 8 bar hydrogen data
- New partially equipped Unified Tracking Stations (UTS) with Scintillating Fiber Hodoscopes (SFH) and Silicon Pixel Detectors (SPD)
- New triggerless FriDAQ system



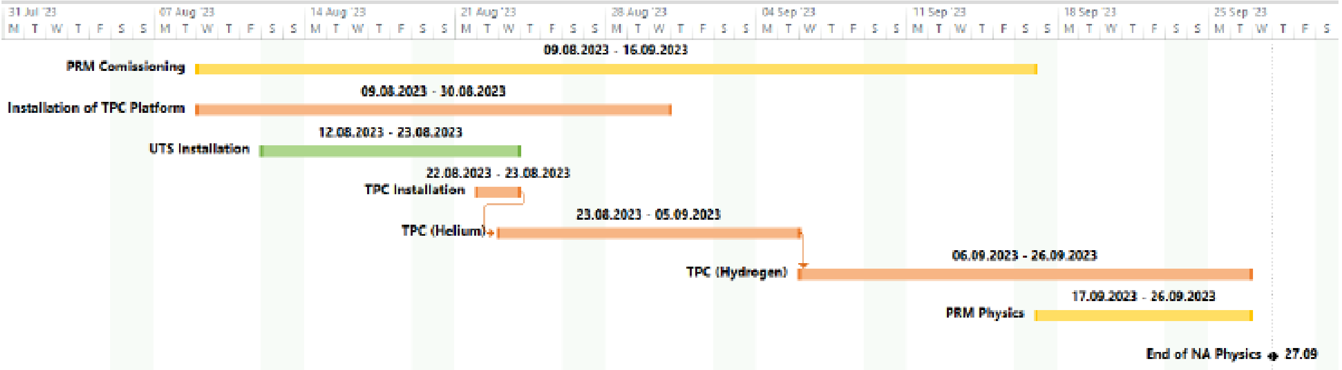
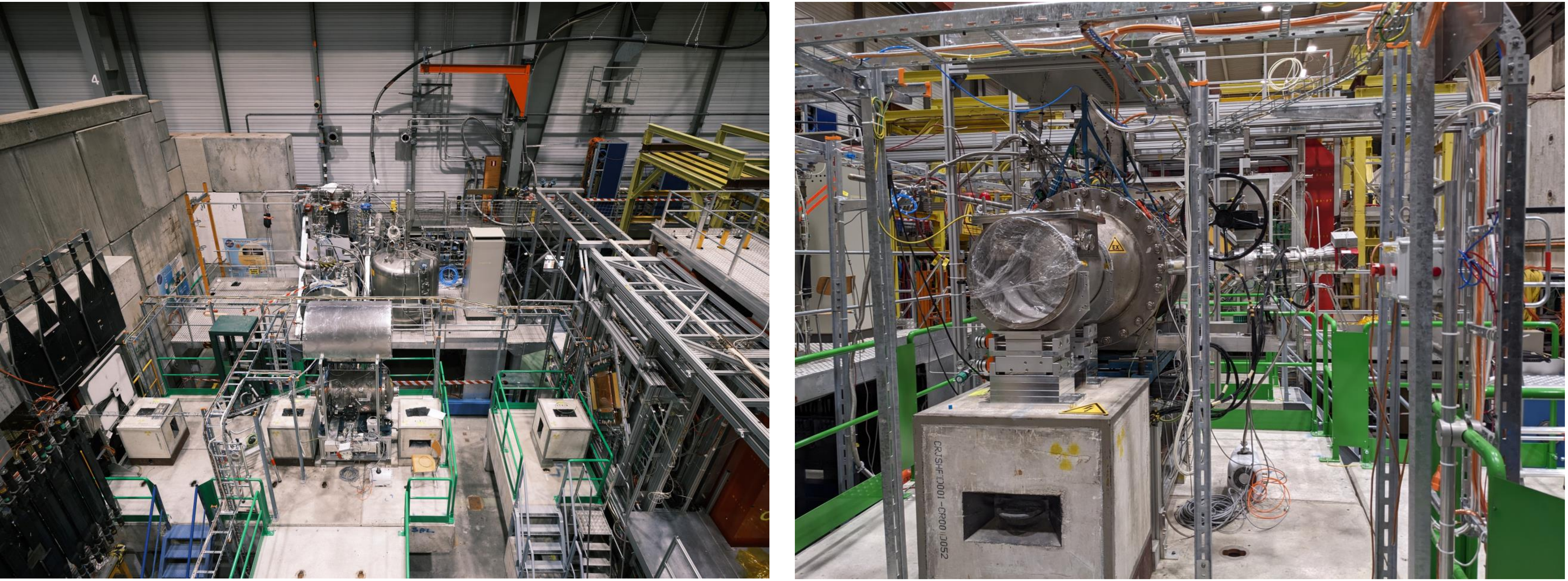


Fig. 20: Anticipated timeline for the PRM beam test preparation in 2023. TPC and UTS installation and the operation times are indicated.

PRM 2023 Test Run – current status of the installation



Goals of the 2023 PRM Test Run

The goals for the beam test focus mainly on the new components and their combination and can be summarised as follows:

1. Installation and commissioning of TPC infrastructure
2. Installation and commissioning of new UTS vessels including SFH and SPD detector with their new readout electronics
3. Commissioning of new streaming DAQ together with new detector front-end electronics
4. Verification of monitoring tools and calibration processes for DAQ and detector components
5. Data reconstruction in the new data format of the streaming DAQ
6. Study of detector efficiencies and resolutions at different beam rates up to 10 MHz

CEDARs detector test with high intensity hadron beam (DY)

As presented in the previous report [2022], the CEDAR detectors are a crucial element of the Drell-Yan (DY) setup.
We had some difficulties to make pion/kaon separation in COMPASS Drell-Yan run of 2018.
We believed that the main reason was our SciFi-based beam telescope we used to recontract beam track which was then back propagated to the CEDARs area.

In order to address all this issues a 4 days long test has been performed in 2023, right after the end of APX run:
- **Hadron beam intensity of 3,5x10^8 particles/spill**

– 4 nights (~30 hours total of non-continuous operation), negative and positive beam 190 GeV/c
– Beam telescope with 3 Silicon detectors included (4 planes each) + SciFIs (7 planes in total)
– Measurements varying pressure in the CEDARs

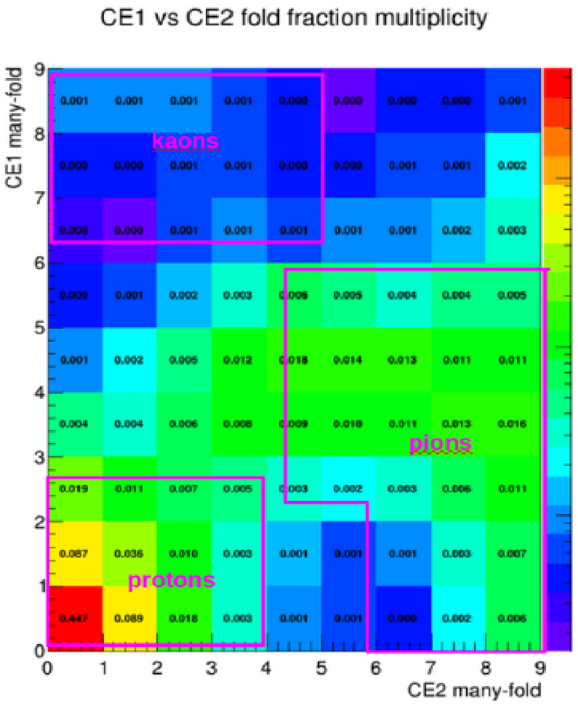
Prior to the start of this test RP conditions were studied and all precautions were taken.

CERDARs detector test with high intensity hadron beam (DY)
First results of the DY CEDARs test

Data was acquired for several conditions:

– Positive and negative hadron beams at intensity of 7x10^{7} and 3.5x10^{8} particles per spill at 190 GeV

– Negative hadron beam at 160 GeV


CE1 vs CE2 fold fraction multiplicity

0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.001
0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.001	0.002
0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.003
0.000	0.001	0.002	0.003	0.006	0.005	0.004	0.004	0.005
0.001	0.002	0.005	0.012	0.018	0.014	0.013	0.011	0.011
0.004	0.004	0.006	0.008	0.009	0.010	0.011	0.013	0.016
0.019	0.011	0.007	0.005	0.003	0.002	0.003	0.006	0.011
0.087	0.036	0.010	0.003	0.001	0.001	0.001	0.003	0.007
0.447	0.089	0.018	0.003	0.001	0.001	0.000	0.002	0.006

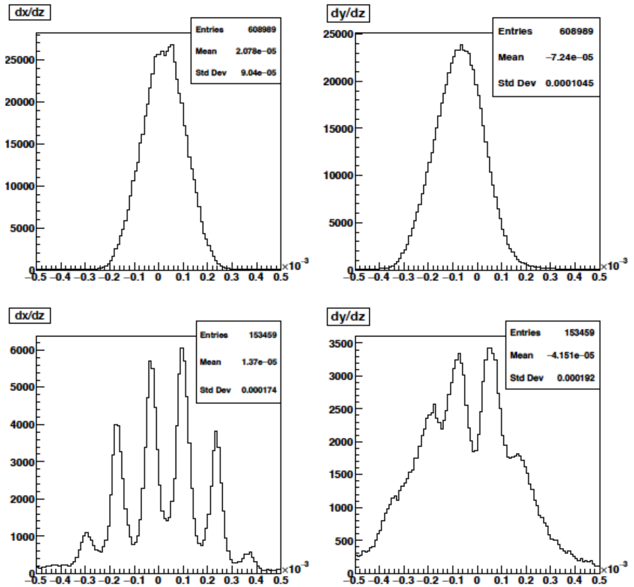


Fig. 26: Comparison of the beam angles dx/dy and dy/dz (in rad) at the beam telescope (Z = between 2023 DY test (top) and 2018 COMPASS DY (bottom). Preliminary, work in progress.

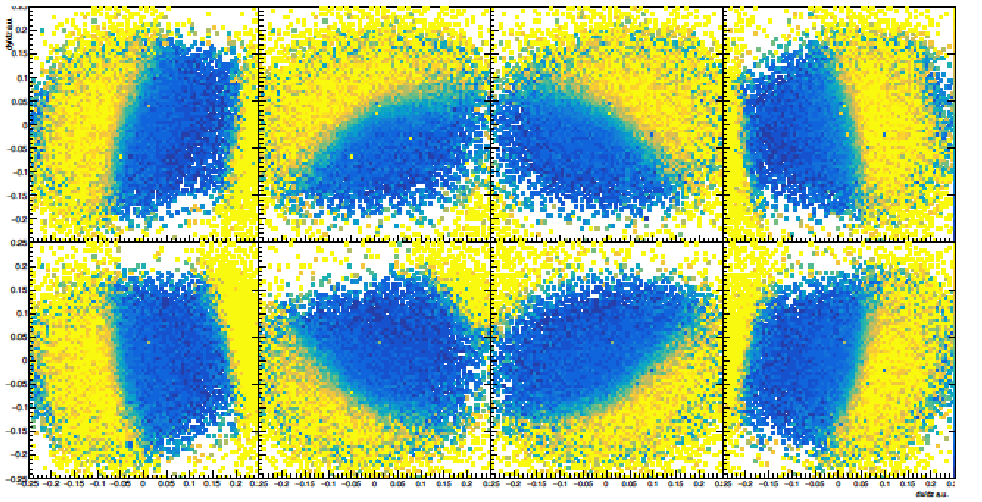


Fig. 27: Response of the CEDAR2 PMTs normalized to the beam flux in bins of beam slope when having 190 GeV positive hadron beam at intensity of 44×10^{6} particles/spill, and the CEDAR tuned on the kaon peak. Color scale from 0 (dark blue) to 0.25 (yellow). Preliminary, work in progress.

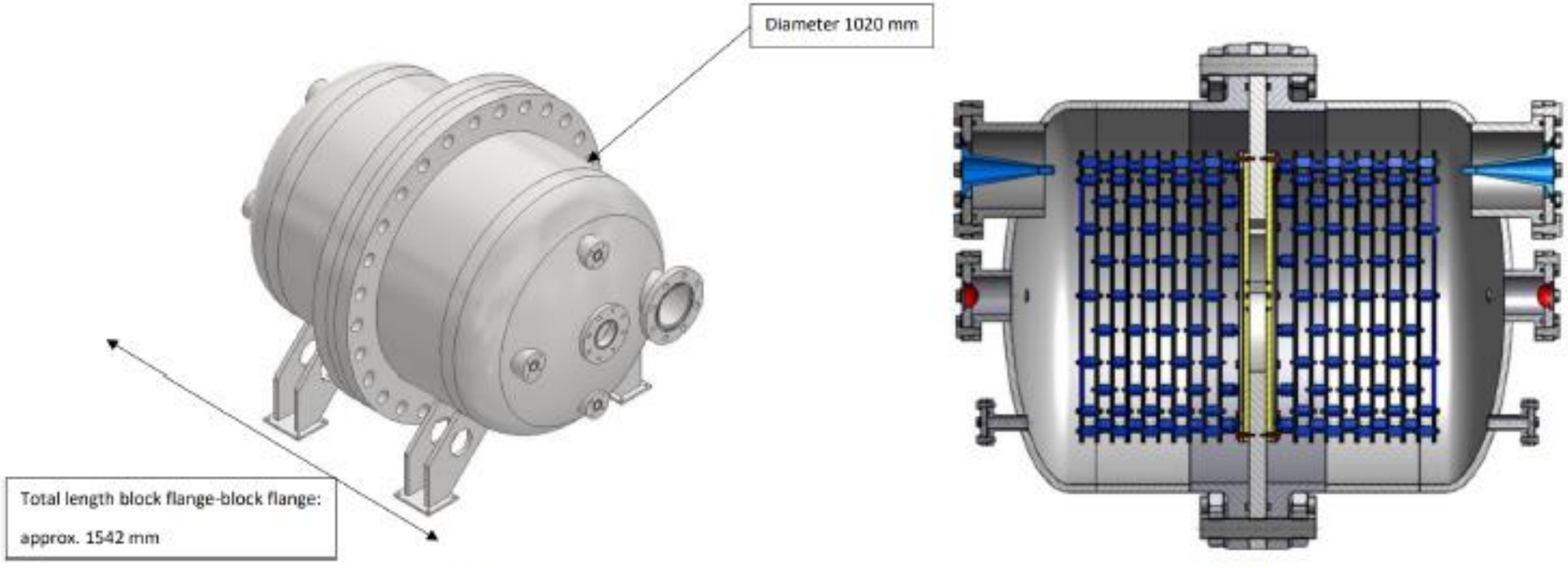
Thanks a lot to BE dep. for help, still major improvement is needed on CEDARs positioning System and CEDARs diaphragm opening control system, we intend to perform second short test in 2024

AMBER SPSC 2023

New Hardware developments
PRM Preparations - TPC

AMBER TPC (2024+)

- Hydrogen, max 20 bar
- Design phase of vessel is completed
- Several contacts with HSE/EP Safety during design phase
- Currently in production, expected delivery time is 2023

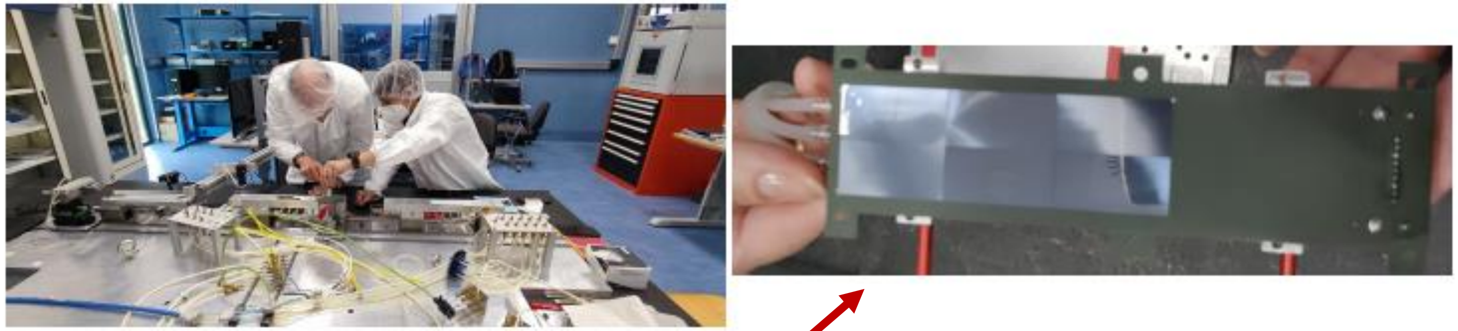


(a) (b)

Fig. 31: In (a) a 3D model of the new extendable 2-cell version of the TPC is shown with a sketch of the inner electrodes shown in (b).

AMBER TS Report May 2023

New Hardware developments
UTS (SPD) detector activity in 2023



(a)

(b)

Fig. 39: Photographs of the ALPIDE assembly tests at INFN Turin. In (a) the CMM and assembly rigs used to position the ALPIDE chips on the flex PCBs are shown. The adjacent figure (b) depicts six successfully glued ALPIDE chips on a flex PCB..

AMBER ALPIDE detectors
Assembly

The ALPIDE chips are currently being tested using the ALICE quality standard, out of 414 chips tested, 20.3 % fulfil the Gold standard, 31.6 % the Silver standard, 7.8 % the Bronze standard, with 40.2 % deemed unusable in the experiment, but still useful for practicing the assembly and performing mechanical tests..

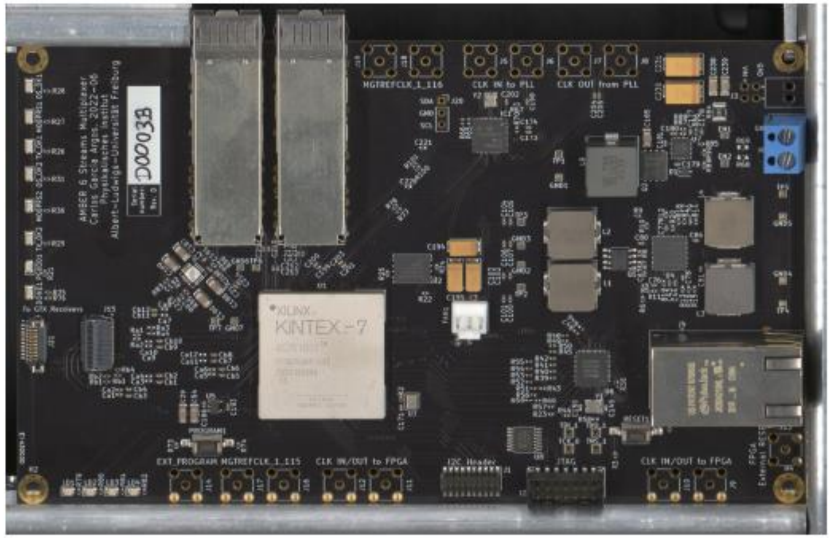


Fig. 40: Prototype of the ALPIDE Detector Specific DAQ Board (CMUX).

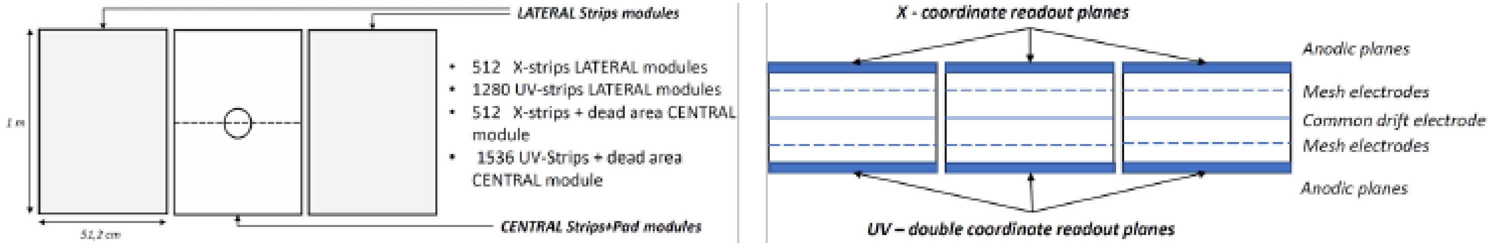
The firmware implementations (CMUX) include the following features:
– Control of the clock generator to configure the frequencies for the FPGA transceivers.
– Data readout from the transceiver lines coming from the ALPIDE chips, and processing for further transmission.
– Clock generator (40 MHz) and control interface to the ALPIDE chips, for register read/write.
– Data output to SFP+ transceivers, with various protocols: UDP on 10 GbE or UCF on Aurora 8b10b.
– IPBus interface to control the FPGA or the ALPIDE chips, and read out their statuses.
– Debug blocks using Virtual I/O and Integrated Logic Analyser.

AMBER SPSC 2023

New Hardware developments
New large Area MICRO-MEsh GAS (MM) detectors

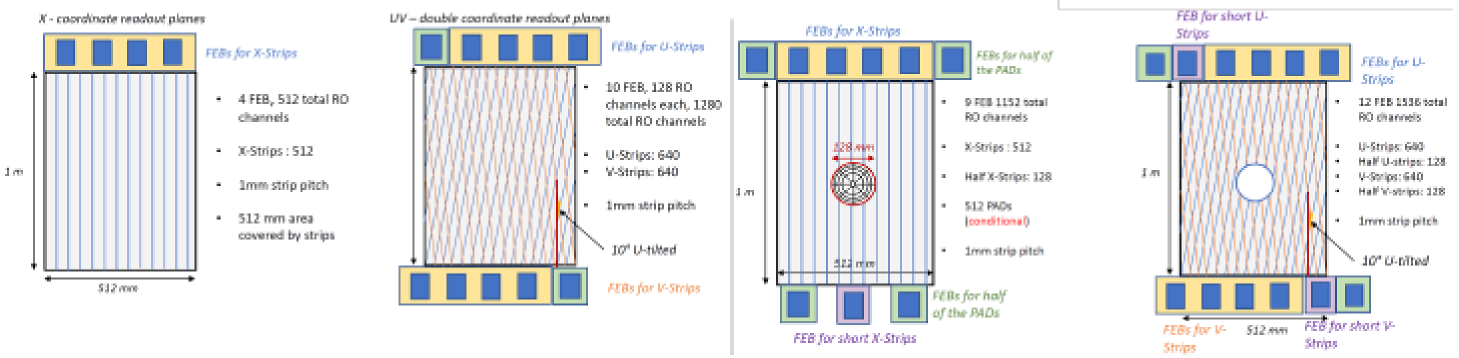
Apparatus for Meson and Baryon Experimental Research

Before the start of the Drell-Yan (2027/8) run we plan to substitute at least 3 stations of MWPCs which are old (>40 years) and shows numerous ageing problems.



- 512 X-strips LATERAL modules
- 1280 UV-strips LATERAL modules
- 512 X-strips + dead area CENTRAL module
- 1536 UV-Strips + dead area CENTRAL module

Fig. 41: A frontal and top view of the MM concept that is presently undergoing the design phase



- 4 FEB, 512 total RO channels
- X-Strips : 512
- 1mm strip pitch
- 512 mm area covered by strips

- 10 FEB, 128 RO channels each, 1280 total RO channels
- U-Strips: 640
- V-Strips: 640
- 1mm strip pitch

- 9 FEB 1152 total RO channels
- X-Strips : 512
- Half X-Strips: 128
- 512 PADs (conditional)
- 1mm strip pitch

- 12 FEB 1536 total RO channels
- U-Strips: 640
- Half U-strips: 128
- V-Strips: 640
- Half V-strips: 128
- 1mm strip pitch

(a) (b)

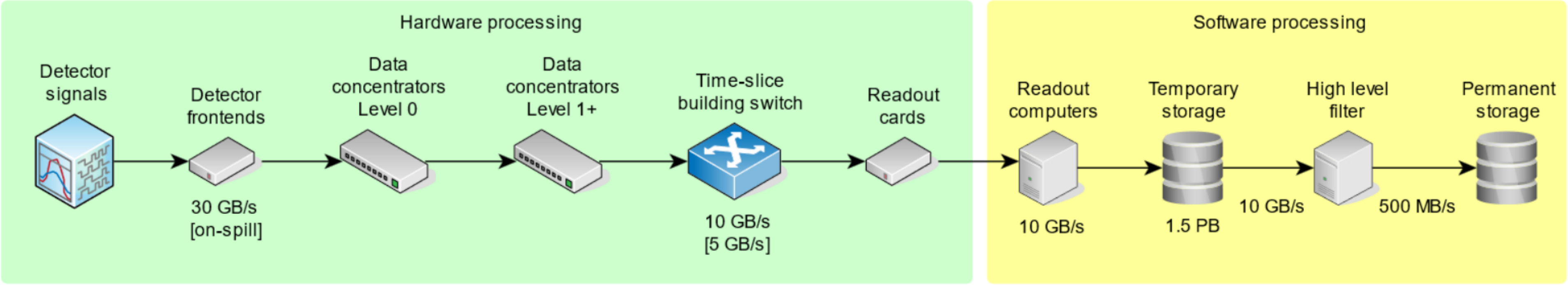
Fig. 42: RO electrodes conceptual configuration. In (a) the lateral module configuration is presented. On the figure (b) the central element is presented.

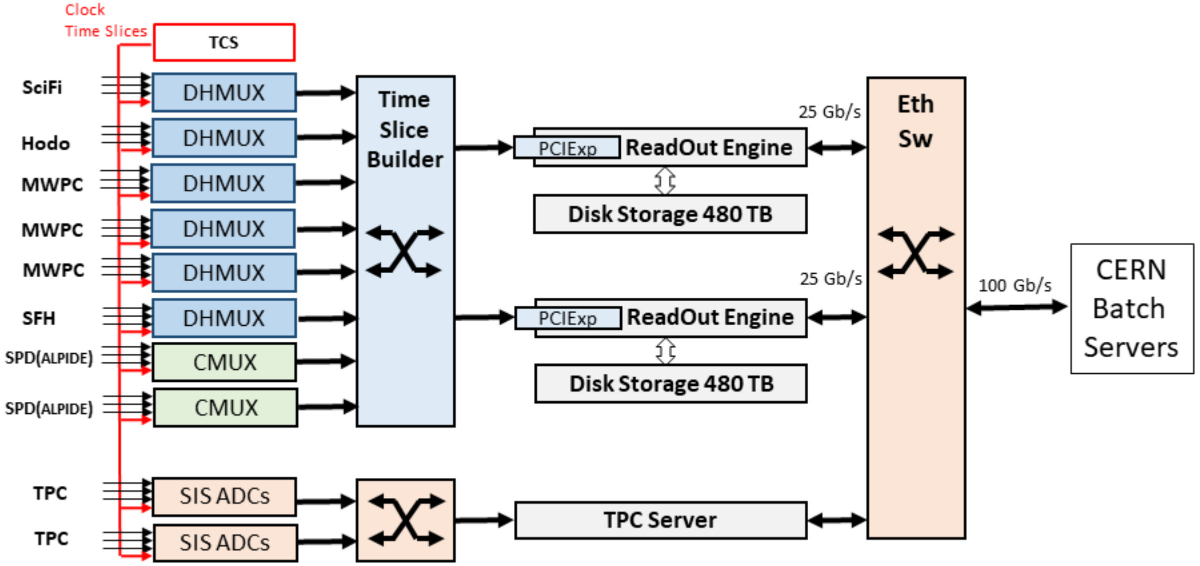
Main parameters of the future detector:
– Size: 130x100 cm2;
– Rates per channel: <500 MHz/strip (passivated centre);
– Spatial resolution: 600 um;
– Time resolution: 1 ns.

In parallel with the MM detector full scale prototype development a new ASIC chip is now under design in Torino Micro Electronics Laboratory, we intend to design in universal (based on the ToASt architecture developed in Torino) and usable as well by other gas detectors like MWPCs and Straws.

New Hardware developments
New Streaming DAQ

For the upcoming measurements, AMBER developed a new streaming data acquisition system (see AMBER SR 2022).





Objectives for this year PRM test run:
– validation of data flow with real detectors from front-end electronics up to HLT and CTA;
– verification of time synchronisation between detectors;
– verification of real amount of data generated by detectors in streaming mode with the expected one;
– collect data for offline verification and commissioning of fine time synchronisation algorithm.

New Hardware developments
New High Level Trigger (HLT) System

In the AMBER acquisition system, unwanted data is removed by the high-level filter (also known as HLT). The HLT is a distributed computational framework that is detached from the online DAQ system by a huge local disk storage.

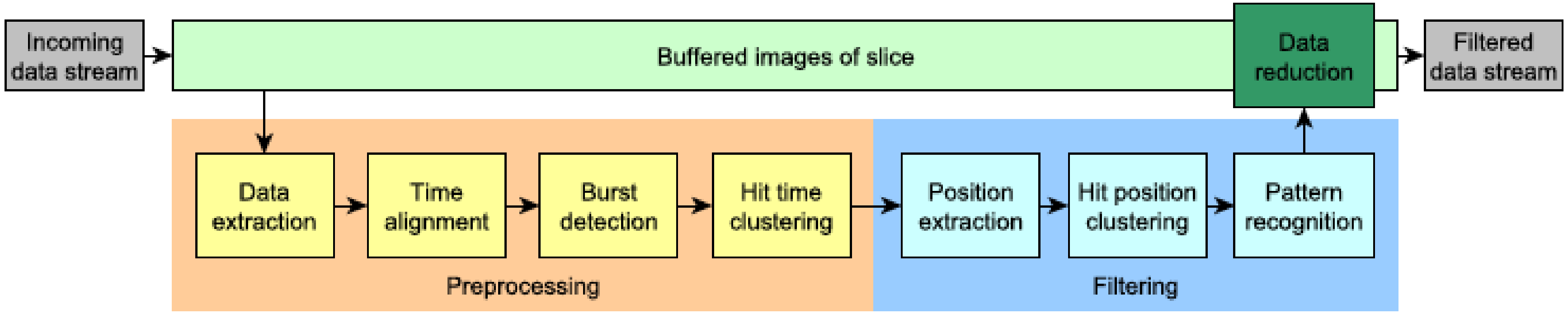


Fig. 44: Filtering pipeline representing a single filtering thread.

Thanks to collaborative attitude by CERN network group, Beam Department and CERN IT department we came to a solution which provides a dedicated 100 Gbps network link between the experimental area in 888 and the CERN data centre (commissioning in Aug. 2023). The high speed link provides sufficient bandwidth to transmit unfiltered data to the CERN data centre and allows us to operate the HLT framework on shared batch service. In 2022 we discussed this option with the IT department a received full support. The HLT framework will run on batch system and may use up to 1000 CPU cores during physics run.

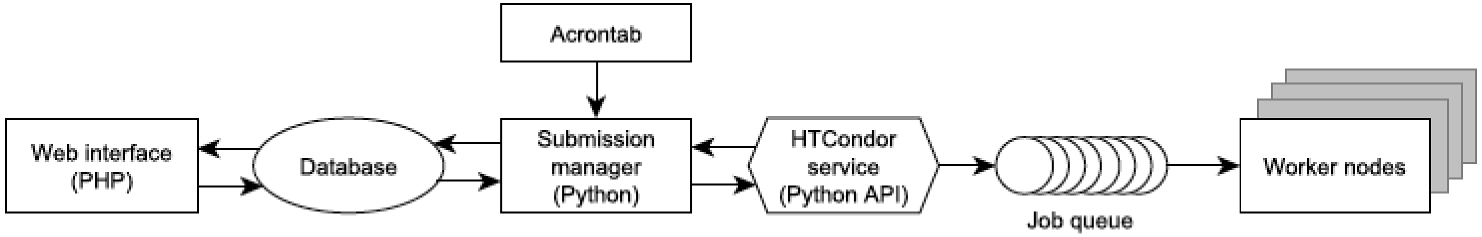


Fig. 45: Architecture of the HLT system running on the Batch service.

AMBER SPSC 2023

Beam Time request for 2024 Run (LH/LD target)

Measurement of $\bar{p}$ production cross-section in proton-proton collisions (was already a part of the AMBER Phase-1 Proposal approved by CERN RB.

As we have already reported AMBER collected this year unique data set on p + **He^4** → $\bar{\text{p}}$ + X in the unexplored beam momentum range of 60–250 GeV, which is with no doubt the signature contribution of our approved proposed Program (complementary data to LHCb with much larger kinematic coverage in the range of interest).

More data sets and results are available on p + **p** → $\bar{\text{p}}$ + X, the most recent ones from the NA61 collaboration at 20, 31, 40, 80 and 158 GeV. Nevertheless the new measurement by AMBER would be very important because:

- Consistent set of measurements in pp and p^{4}He will reduce systematic effects because we will be able to compare AMBER pp data to the data collected before by NA49 and NA61
- Extension of kinematic coverage in rapidity and p_T wrt previous experiments
- Extension to higher beam momentum

- p + **D** → $\bar{\text{p}}$ + X [under investigation], studies of cross-section scaling with nuclei size

- p + **p** → γ (2γ) + X in the π^0 production channel [under investigation]. γ–flux measurements by the Fermi Large Area Telescope with unprecedented precision, the flux from point-like sources (supernova etc.) or dark matter has to be separated from contribution from the nuclear interactions background

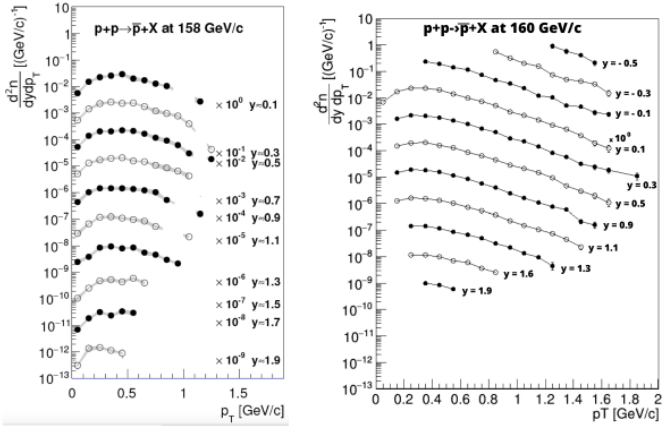


Fig. 16: Transverse momentum $\bar{p}$ spectra in rapidity slices produced in $p+p$ inelastic interactions at 158 GeV by NA61 (left figure) [4]. For comparison the expected results obtainable by AMBER in $p + p \to \bar{p} + X$ at 160 GeV are shown (right figure).

and the rapidity y is defined by

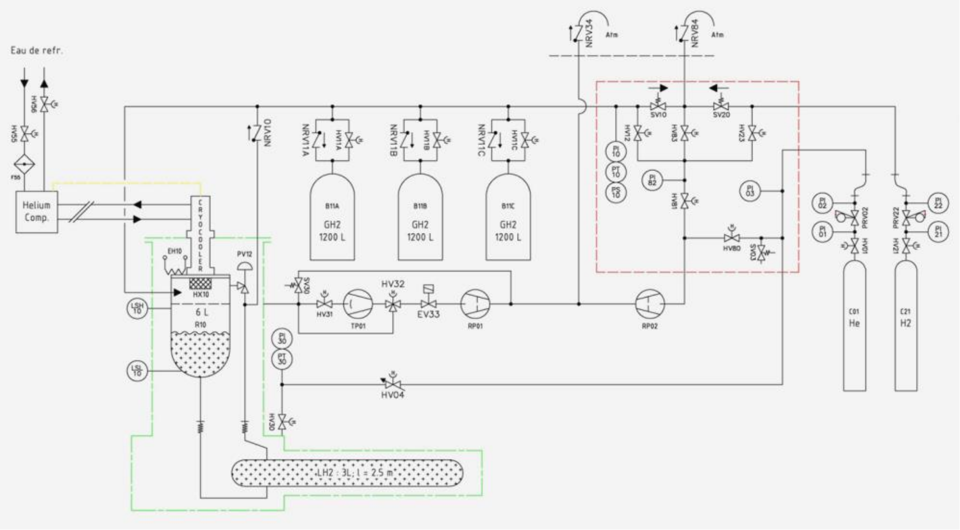
$$y = \frac{1}{2}\ln\left(\frac{E+p_z}{E-p_z}\right)$$

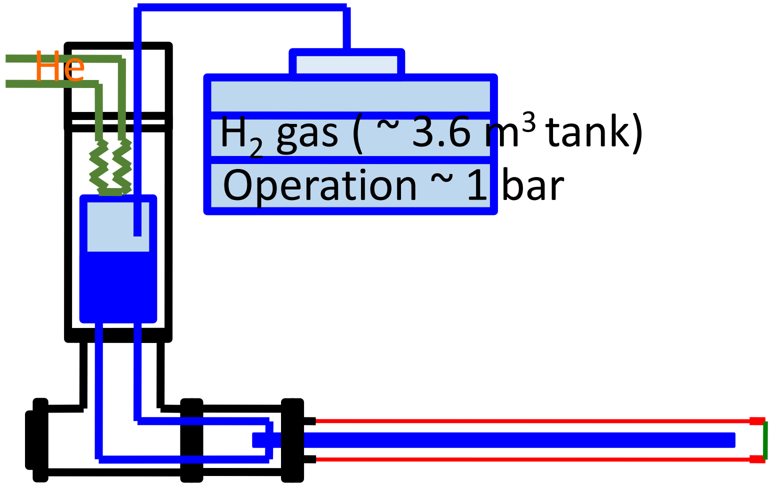
Beam Time request for 2024 Run (LH/LD target)

Hardware requirement and beam time request

Hardware modifications:

- Implementation of LH target used in 2016/17 for COMPASS DVCS measurement into AMBER set-up.
- Construction of the new target cell (TE-CRG should be involved, construction time ~6 months), will be compatible with LD
- Additional RICH radiator material C_4F_{10} has to be procured (delivery time ~ 6 months, available on the market)




He

H_2 gas (~ 3.6 m^3 tank)

Operation ~ 1 bar

Two months of data taking (comparable to 2023) would be sufficient to collect data with positive hadron beam at at least four different momenta (80, 160, 190, 250 GeV) impinging on a Liquid Hydrogen (Deuterium) Target 140 cm long.

AMBER SPSC 2023

PRM – Test Run 2024

- We aim to **complete the PRM setup** for test running at the end of the 2024 SPS proton beam time

- The **new TPC** is under construction: the vessel will be completed until the end of 2023. The inner structure is planned as Russian contribution; its realization depends on the possibility of further collaboration

- The goal is to demonstrate the **readiness of the setup for the full-statistics data taking in 2025** with a test data sample (at low Q^2) that allows to check the full analysis chain and a (low-statistics) result on the proton radius

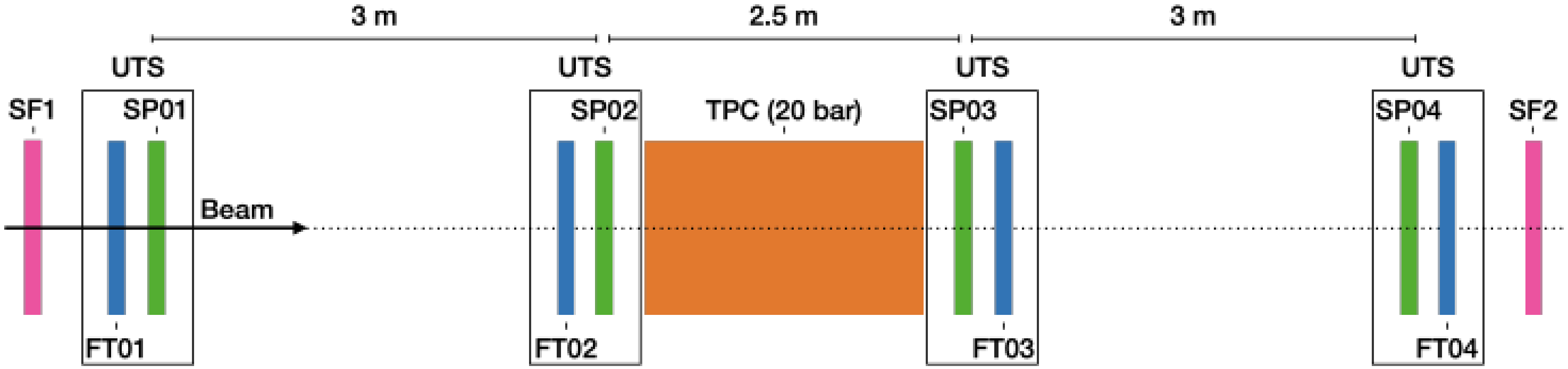


Fig. 23: Sketch of the foreseen 2024/2025 setup with the final TPC and all four UTS equipped.

Beam time request is 1 month

AMBER SPSC 2023

Summary

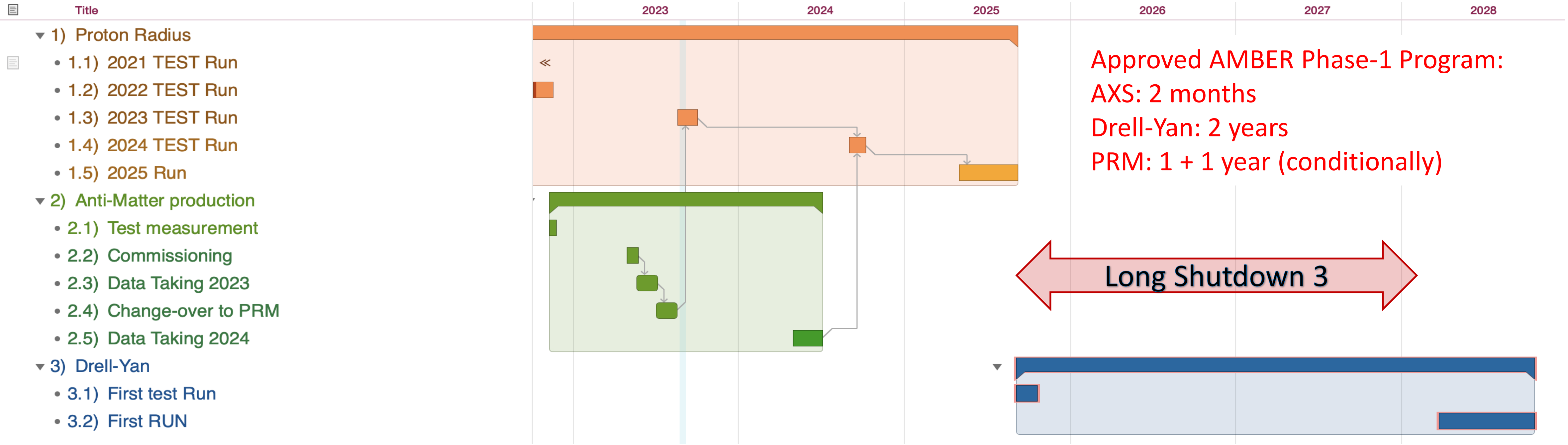
1. We have very successful data taking in 2023 so far advancing on all three approved experiments in a framework of the AMBER Phase-1 Proposal:
    - First Physics Run was completed for APX program (Liquid Helium data)
    - CEDARs test run with high intensity hadron beam (Drell-Yan)
    - First part of detector test data for PRM (parasitically with APX Physics Run)
2. We ask for scheduling in 2024:
    - second APX Physics Run with Hydrogen target (~2 months, scheduling must be known at least 6 months in advance)
    - PRM test run with the final detector configuration in the end of 2024 SPS Proton Run (~ 1 month)
3. We are progressing well with the new hardware developments for PRM and Drell-Yan Physics Runs (various detector systems compatible with new Streaming AMBER DAQ)

AMBER Phase-1 running plan

Apparatus for Meson and Baryon
Experimental Research

Milestones:

1. May 1st 2023 – Antimatter production Run (Std. DAQ)
2. Sep. 1st 2023 – PRM pilot (FreeDAQ, very limited setup)
3. May 1st 2024 – PRM Run (FreeDAQ, limited setup)
4. Sep. 1st 2025 – DY Pilot (FreeDAQ, all trackers + mu id)
5. May 1st 2028 – DY Run (Full Spectr. Ex. RICH, Calorimeters)



Approved AMBER Phase-1 Program:
AXS: 2 months
Drell-Yan: 2 years
PRM: 1 + 1 year (conditionally)

Spares

PRM – update on a data analysis from 2021 Pilot Run

Apparatus for Meson and Baryon Experimental Research

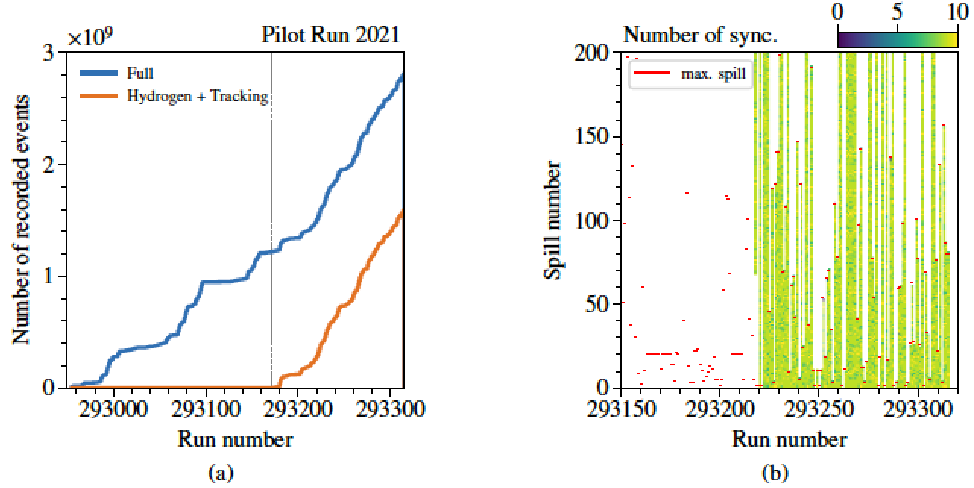
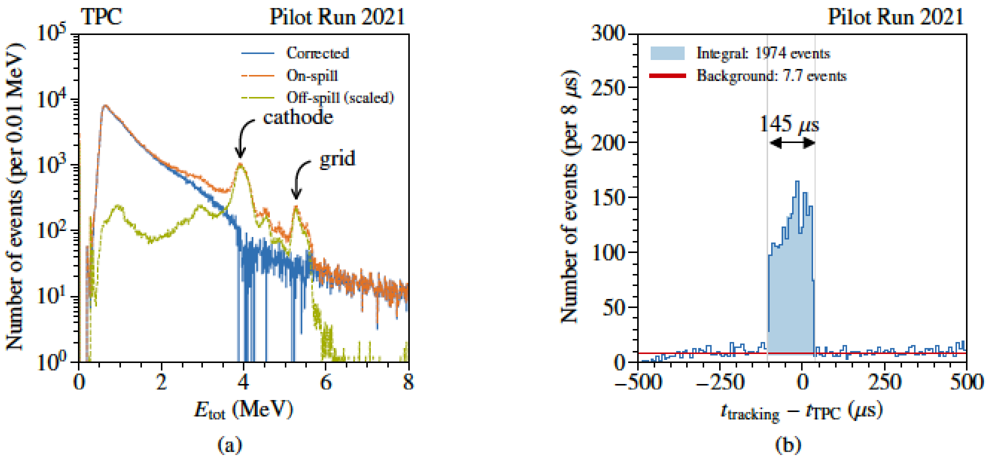


Fig. 17: The integrated number of events during the pilot run is shown in (a). In (b) the number of synchronisation ticks used for the TRLO time stamp is presented. [8]

PRM Pilot Run 2021 conditions:

- "CEDARs M2 beam line area"
- "Downgraded with respect to final " IKAR TPC, 8 bar hydrogen data
- "Old" beam telescope
- Two independent DAQ systems, common time stamp
- Up to 7 MHz muon beam intensity



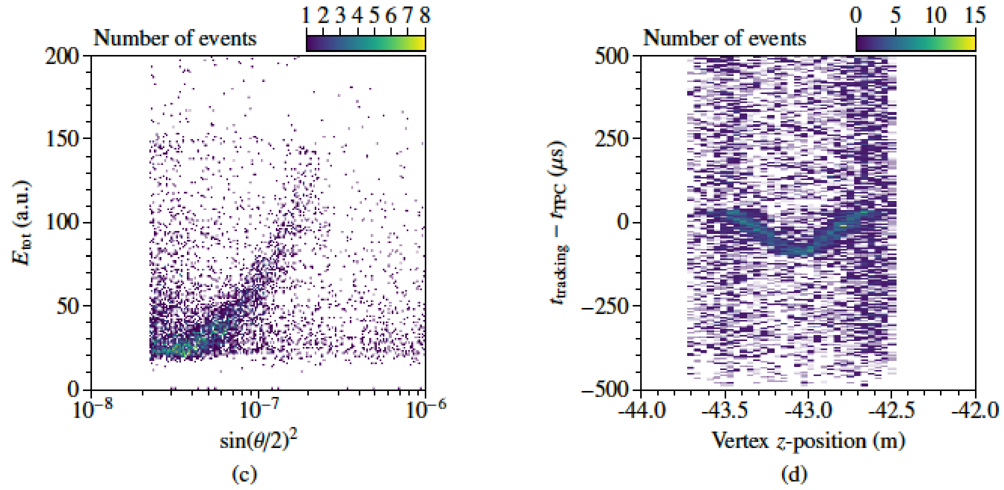


Fig. 18: In (a) the extracted TPC energy spectrum is shown. The TRLO time stamp difference between the tracking and TPC system is shown in (b) with the resulting correlations in energy and vertex position shown in (c) and (d). [8]

PRM 2023 Test Run – general lay-out and main components

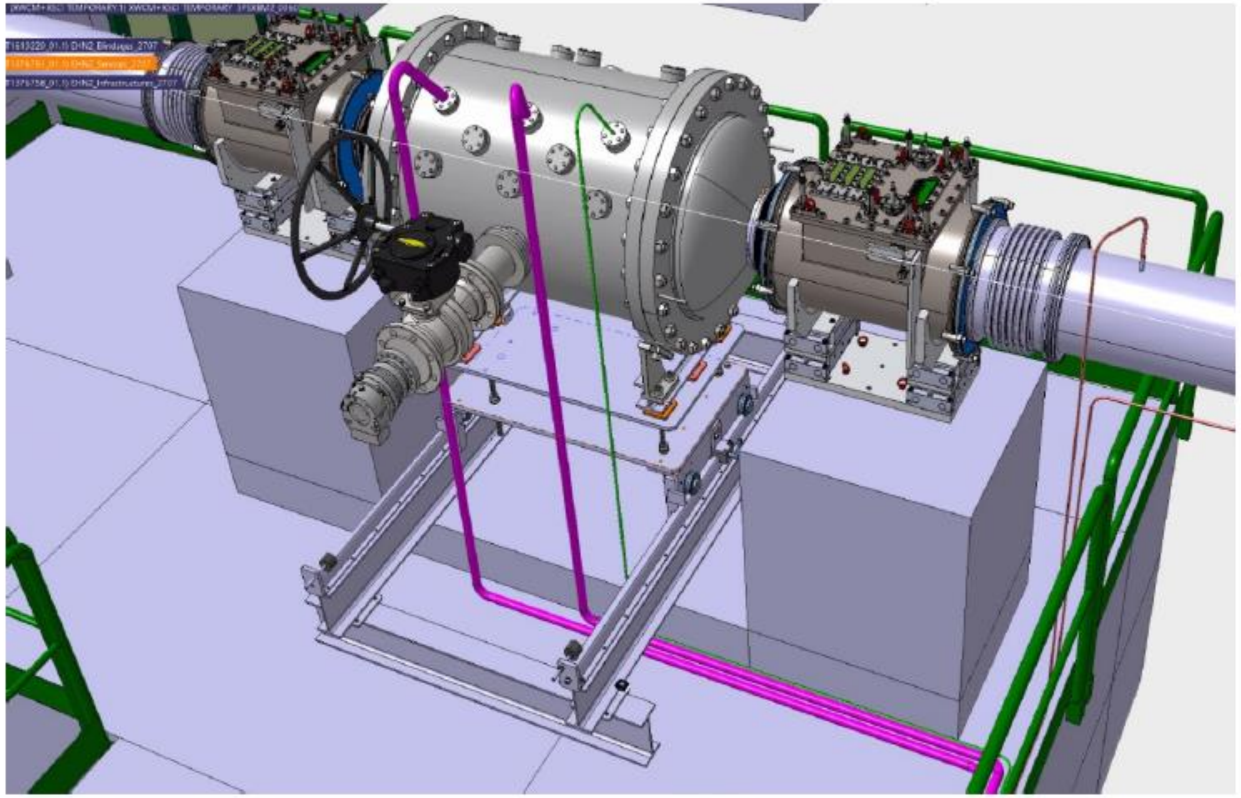


Fig. 29: Sketch of the foreseen IKAR TPC preparations in the target area sandwiched between two UTS. Hydrogen lines are indicated in purple.

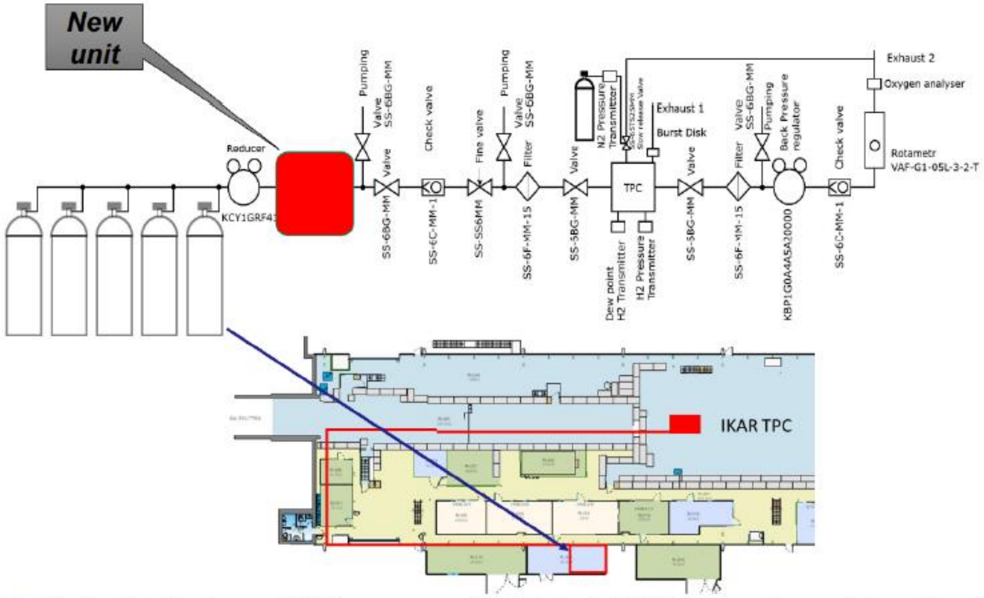


Fig. 30: Sketch of the foreseen IKAR gas system and installation in EHN2. The gas lines are indicated in red together with the new purification unit.

UTS (SPD) detector test in 2022

Apparatus for Meson and Baryon Experimental Research

The SPD system consisted out of 6 single ALPIDE monolithic active-pixel sensors (MAPS) 30 x15 mm^2 each and the SFH was equipped with 4 planes, each with 32 fibers partially readout out on both sides and partially mirrored to study an enhancement of the light yield.

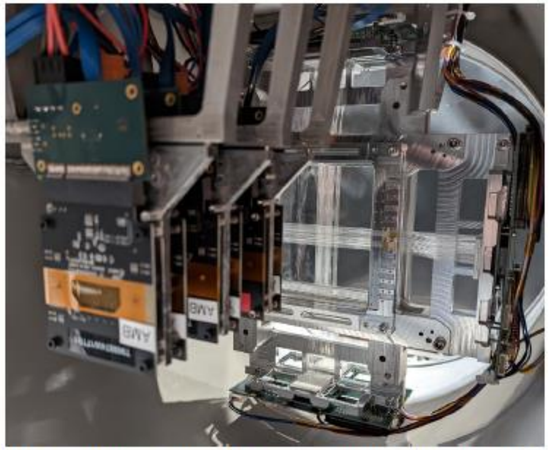


Fig. 32: Inner view of the UTS vessel during the 2022 beam test with six single ALPIDE chips (front) and SFH prototype (back).

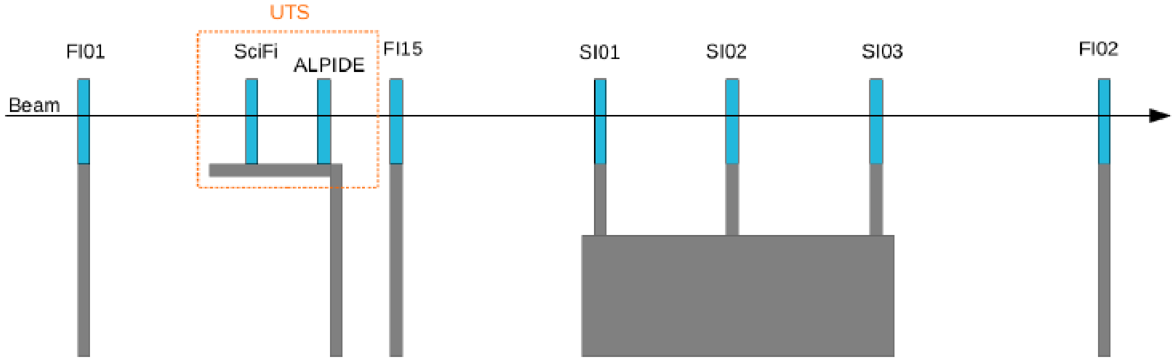


Fig. 33: Sketch of the 2022 UTS beam test setup placed in the beam telescope of the spectrometer.

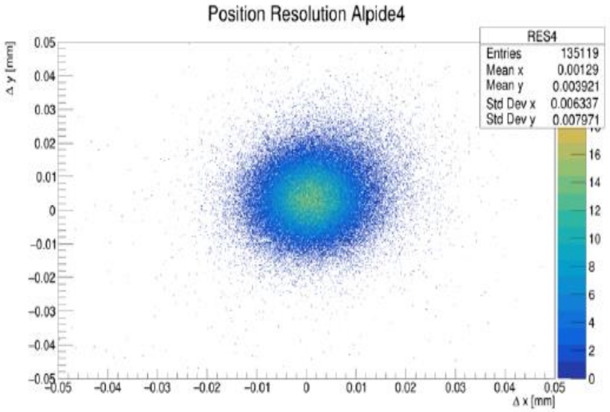


Fig. 34: Position resolution of one ALPIDE detector using tracks measured by the other 5 detectors.

ALPIDE position resolution ~6 um

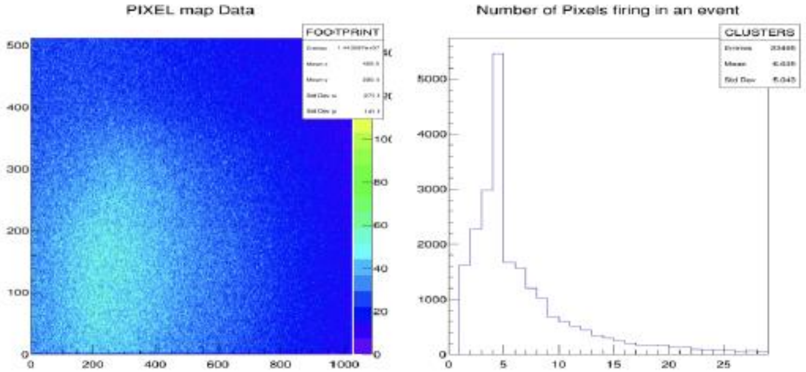


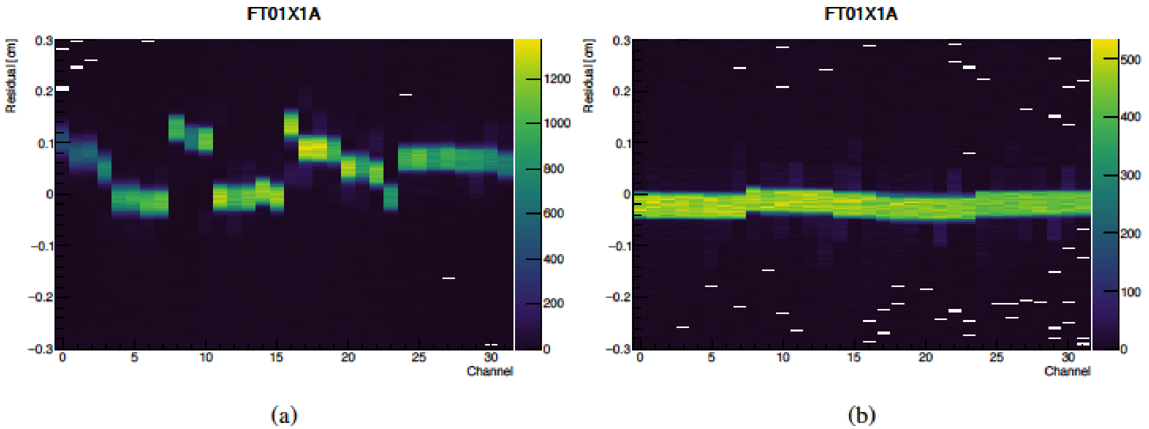
Fig. 35: Left: Beam profile on single ALPIDE chip. Right: Cluster size distribution in ALPIDE detector.

AMBER SPSC 2023

UTS (SFH) detector test in 2022/2023

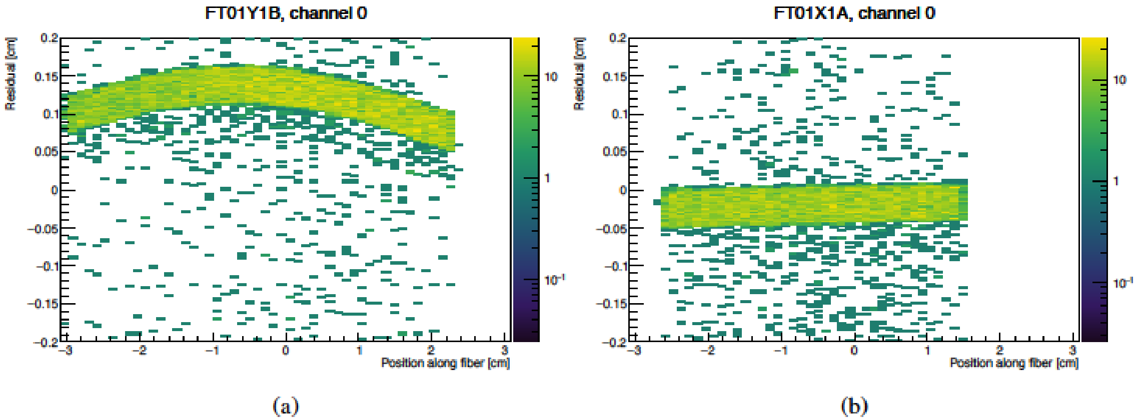
The SFH consists out of four dense layers of single squared 500µm thick fibers, individually read out on both ends with SiPMs. A crucial point is the alignment of individual fibers within the active area of the detector. Clear shifts and jumps between single fibers were observed in 2022 so in 2023 the new fibers fixation method was applied.

This dedicated for UTS SFH measurement was done in 2023 parasitically to APX data taking.



(a) (b)

Fig. 36: Panel (a) shows the alignment of individual fibers for the X1A plane during the 2022 beam test, with large fiber-to-fiber variations clearly visible. Panel (b) shows an improved version of the same plane tested in 2023. [11]



(a) (b)

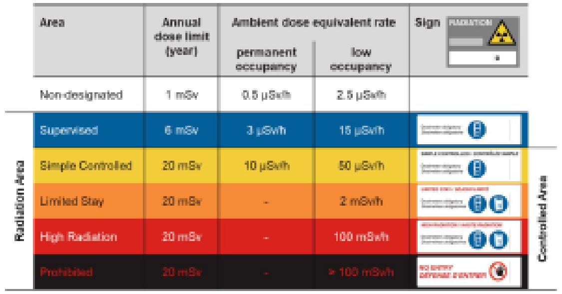
Fig. 37: Using the tracks obtained from surrounding silicon detectors, the difference of the track position and the reconstructed SFH hit position along the fiber was measured during the 2023 beam test. Panel (a) shows an example of one of the planes that were not improved after the test in 2022. Panel (b) shows the improved version of the X1A plane. For both plots, the same cuts were applied on the time and amplitude of the SiPM signals. [11]

AMBER SPSC 2023

CERDARs detector test with high intensity hadron beam (DY)
All results are by Claudia Ahdida HES/RP

Apparatus for Meson and Baryon Experimental Research

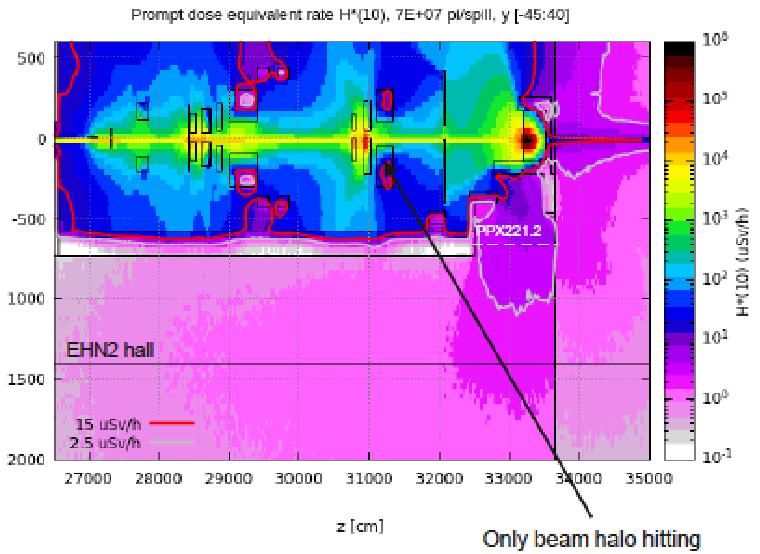
Results – reduction + shielding



Area	Annual dose limit (year)	Ambient dose equivalent rate		Sign
		permanent occupancy	low occupancy	
Non-designated	1 mSv	0.5 µSv/h	2.5 µSv/h	
Supervised	6 mSv	3 µSv/h	15 µSv/h	
Simple Controlled	20 mSv	10 µSv/h	50 µSv/h	
Limited Stay	20 mSv	-	2 mSv/h	
High Radiation	20 mSv	-	100 mSv/h	
Prohibited	20 mSv	-	> 100 mSv/h	

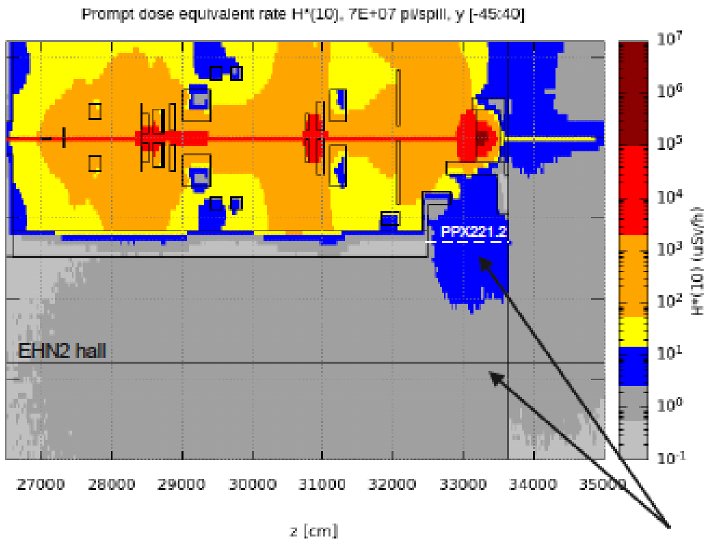
Prompt dose equivalent rate H*(10)
7E+07 pions/spill, 2 spills, 28.8 s supercycle

Beam height



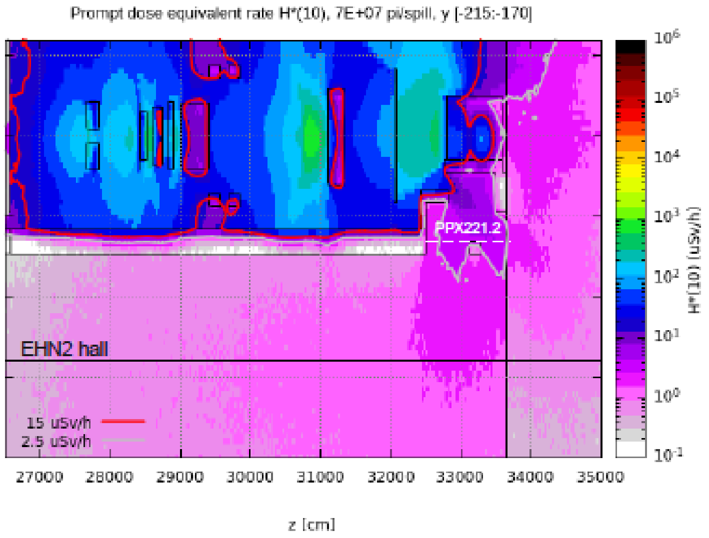
Only beam halo hitting detector

Beam height w/ different color scale



Area classification inside EHN2 and outside is met

Working height

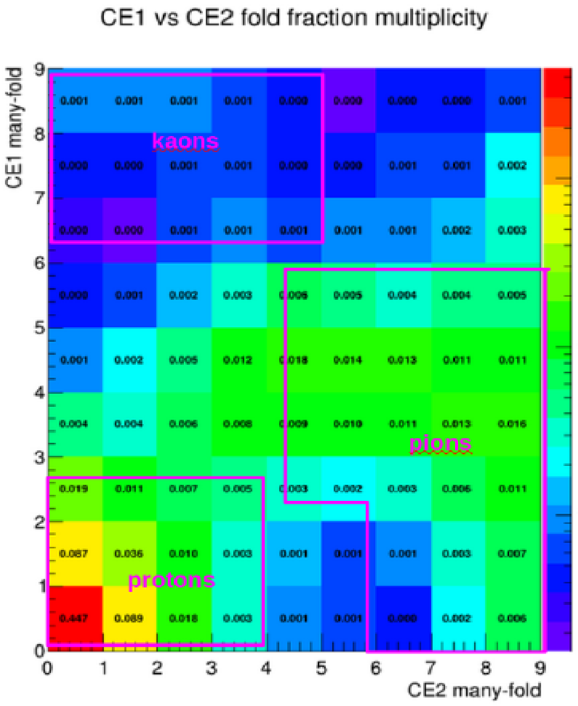


CERDARs detector test with high intensity hadron beam (DY)
First results of the DY CEDARs test

Data was acquired for several conditions:

– Positive and negative hadron beams at intensity of 7x10^7 and 3.5x10^8 particles per spill at 190 GeV

– Negative hadron beam at 160 GeV



0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.001
0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.001	0.002
0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.003
0.000	0.001	0.002	0.003	0.006	0.005	0.004	0.004	0.005
0.001	0.002	0.005	0.012	0.018	0.014	0.013	0.011	0.011
0.004	0.004	0.006	0.008	0.009	0.010	0.011	0.013	0.016
0.019	0.011	0.007	0.005	0.003	0.002	0.003	0.006	0.011
0.087	0.036	0.010	0.003	0.001	0.001	0.001	0.003	0.007
0.447	0.089	0.018	0.003	0.001	0.001	0.000	0.002	0.006

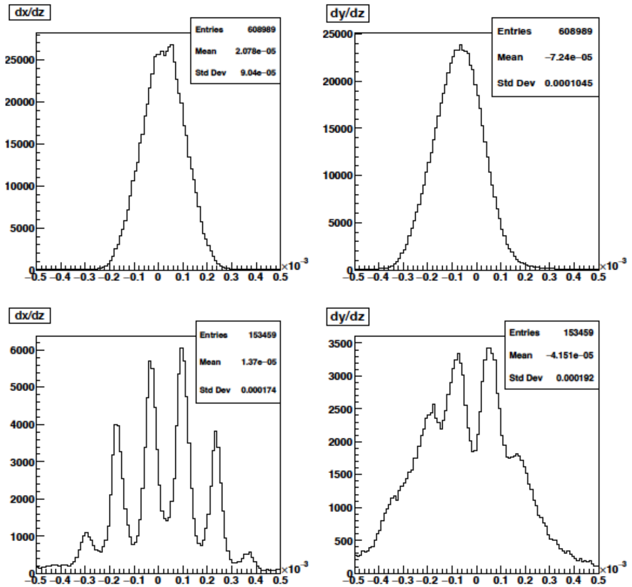


Fig. 26: Comparison of the beam angles dx/dy and dy/dz (in rad) at the beam telescope ($Z = -440$ cm) between 2023 DY test (top) and 2018 COMPASS DY (bottom). Preliminary, work in progress.

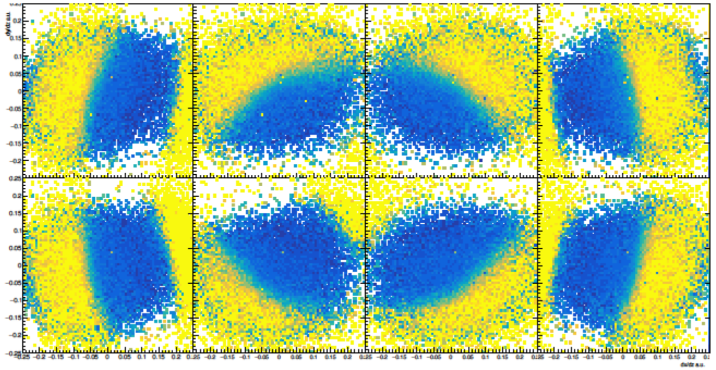


Fig. 27: Response of the CEDAR2 PMTs normalized to the beam flux in bins of beam slope when having 190 GeV positive hadron beam at intensity of 44×10^6 particles/spill, and the CEDAR tuned on the kaon peak. Color scale from 0 (dark blue) to 0.25 (yellow). Preliminary, work in progress.

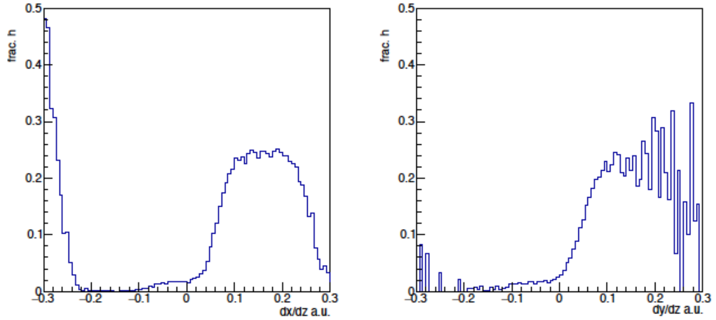


Fig. 28: CEDAR2 particle identification, when having 190 GeV positive hadron beam at intensity of 44×10^6 particles/spill, and the CEDAR tuned on the kaon peak (only 2 of the PMTs used here). Preliminary, work in progress.

Thanks a lot to BE dep. for help, still major improvement is needed on CEDARs positioning System and CEDARs diaphragm opening control system, we intend to perform second short test in 2024

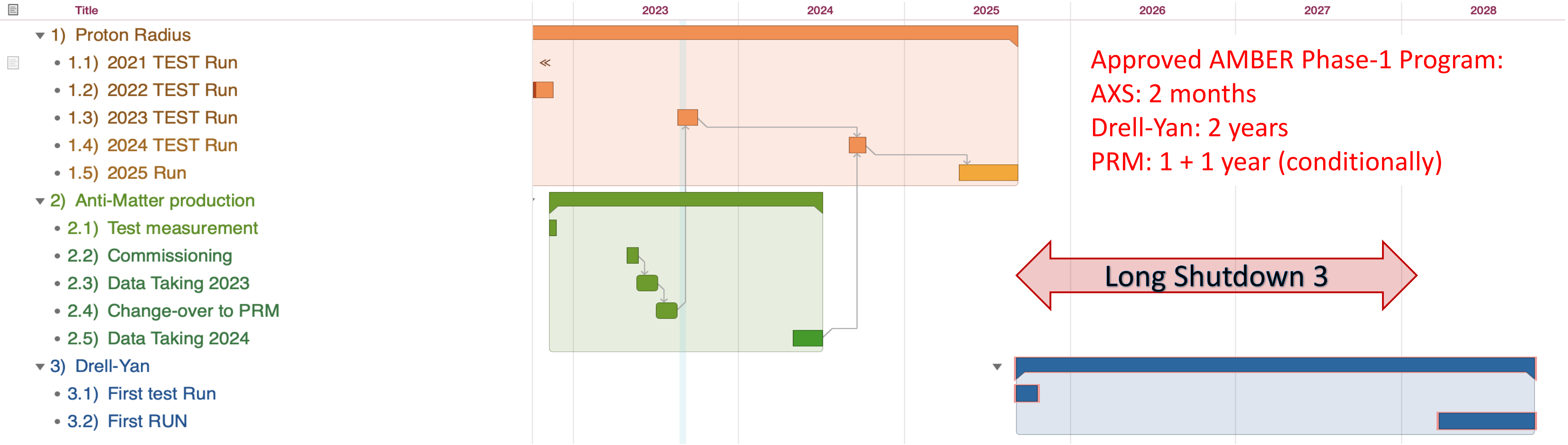
AMBER SPSC 2023

AMBER Phase-1 running plan

Apparatus for Meson and Baryon
Experimental Research

Milestones:

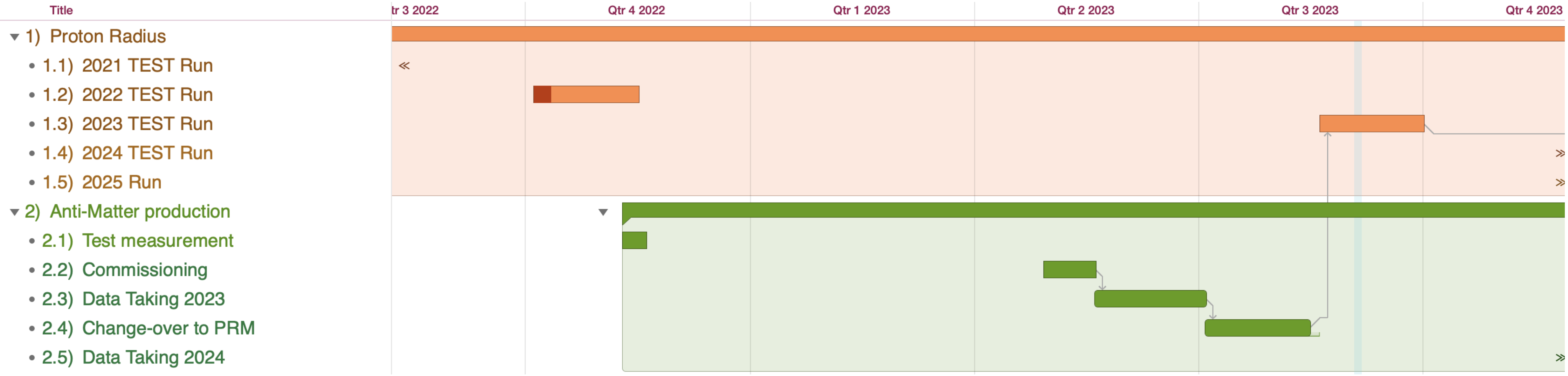
1. May 1st 2023 – Antimatter production Run (Std. DAQ)
2. Sep. 1st 2023 – PRM pilot (FreeDAQ, very limited setup)
3. May 1st 2024 – PRM Run (FreeDAQ, limited setup)
4. Sep. 1st 2025 – DY Pilot (FreeDAQ, all trackers + mu id)
5. May 1st 2028 – DY Run (Full Spectr. Ex. RICH, Calorimeters)



- 1) Proton Radius
  - 1.1) 2021 TEST Run
  - 1.2) 2022 TEST Run
  - 1.3) 2023 TEST Run
  - 1.4) 2024 TEST Run
  - 1.5) 2025 Run
- 2) Anti-Matter production
  - 2.1) Test measurement
  - 2.2) Commissioning
  - 2.3) Data Taking 2023
  - 2.4) Change-over to PRM
  - 2.5) Data Taking 2024
- 3) Drell-Yan
  - 3.1) First test Run
  - 3.2) First RUN

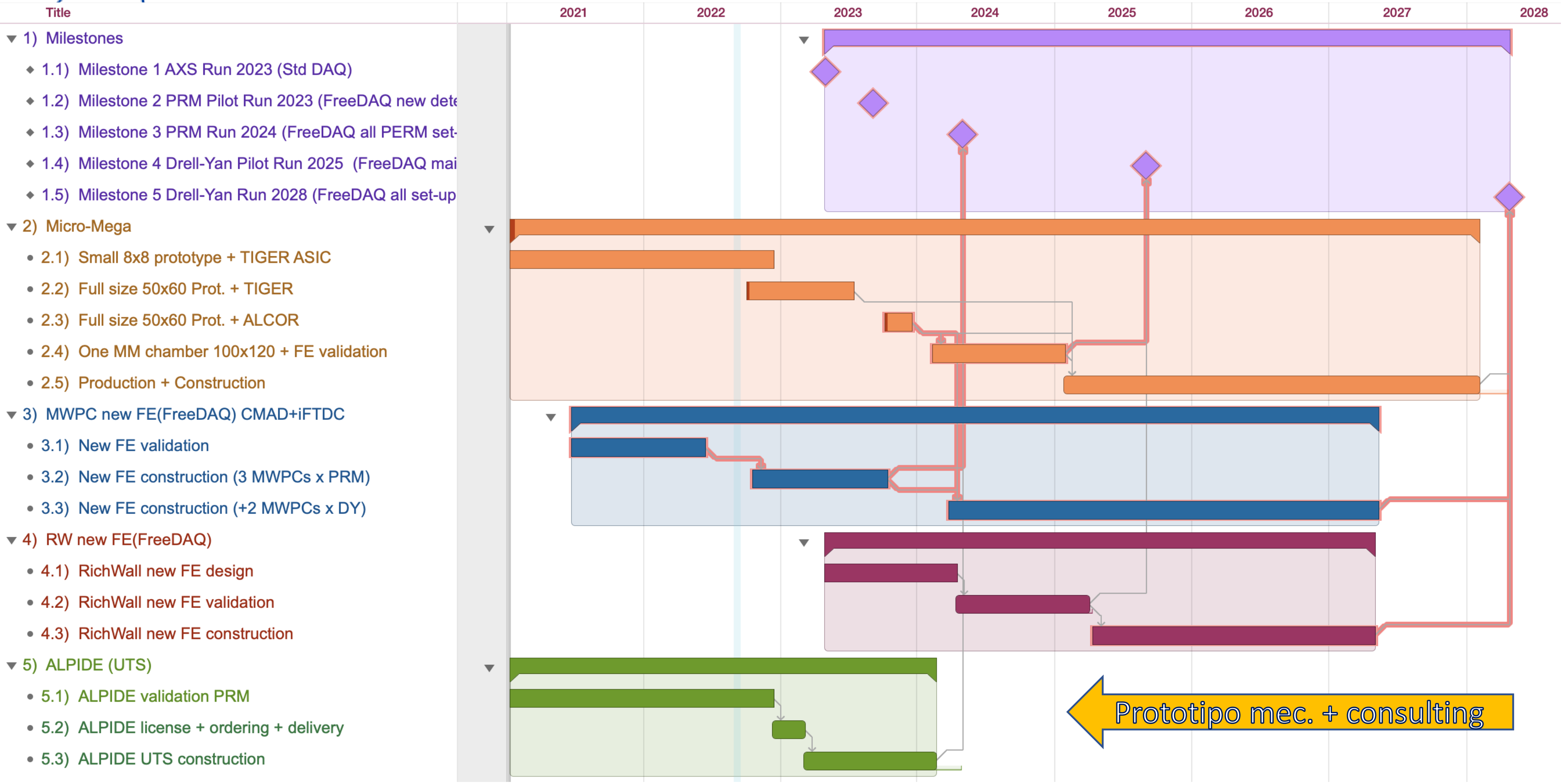
Approved AMBER Phase-1 Program:
AXS: 2 months
Drell-Yan: 2 years
PRM: 1 + 1 year (conditionally)

Approved AMBER Running Plan 2023



AMBER Phase-1 Torino construction plan

Apparatus for Meson and Baryon Experimental Research



- 1) Milestones
  - 1.1) Milestone 1 AXS Run 2023 (Std DAQ)
  - 1.2) Milestone 2 PRM Pilot Run 2023 (FreeDAQ new dete
  - 1.3) Milestone 3 PRM Run 2024 (FreeDAQ all PERM set-
  - 1.4) Milestone 4 Drell-Yan Pilot Run 2025 (FreeDAQ mai
  - 1.5) Milestone 5 Drell-Yan Run 2028 (FreeDAQ all set-up
- 2) Micro-Mega
  - 2.1) Small 8x8 prototype + TIGER ASIC
  - 2.2) Full size 50x60 Prot. + TIGER
  - 2.3) Full size 50x60 Prot. + ALCOR
  - 2.4) One MM chamber 100x120 + FE validation
  - 2.5) Production + Construction
- 3) MWPC new FE(FreeDAQ) CMAD+iFTDC
  - 3.1) New FE validation
  - 3.2) New FE construction (3 MWPCs x PRM)
  - 3.3) New FE construction (+2 MWPCs x DY)
- 4) RW new FE(FreeDAQ)
  - 4.1) RichWall new FE design
  - 4.2) RichWall new FE validation
  - 4.3) RichWall new FE construction
- 5) ALPIDE (UTS)
  - 5.1) ALPIDE validation PRM
  - 5.2) ALPIDE license + ordering + delivery
  - 5.3) ALPIDE UTS construction

Prototipo mec. + consulting