AMBER Status Review

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Meeting with spokespersons on June 8, 2021

142nd SPSC Meeting, June 11 2021

News and Progress in Formation of the AMBER Collaboration

- Election and nomination of
  - Physics Program Coordinators
  - CB chair
  - Technical Board
  - **Spokesperson election** just finished. Oleg Denisov and Jan Friedrich in charge for the initial mandate as AMBER spokespersons

- Collaboration name fixed to **AMBER** (resp. NA66/AMBER)

- **MoU drafting** ongoing since 15 April (bi-weekly) Chaired by Andrea Bressan

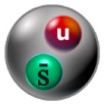
- First **Collaboration Meeting** took place May 6 and 7
- Stimulating two-days meeting with about 80 participants
- Current collaboration strength 189 (voting members)

Caveat: not all the funding to start the physics run has been secured yet

Pion

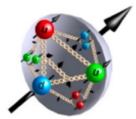
- $M_\pi \sim 140$MeV
- Spin 0
- 2 light valence quarks

Kaon

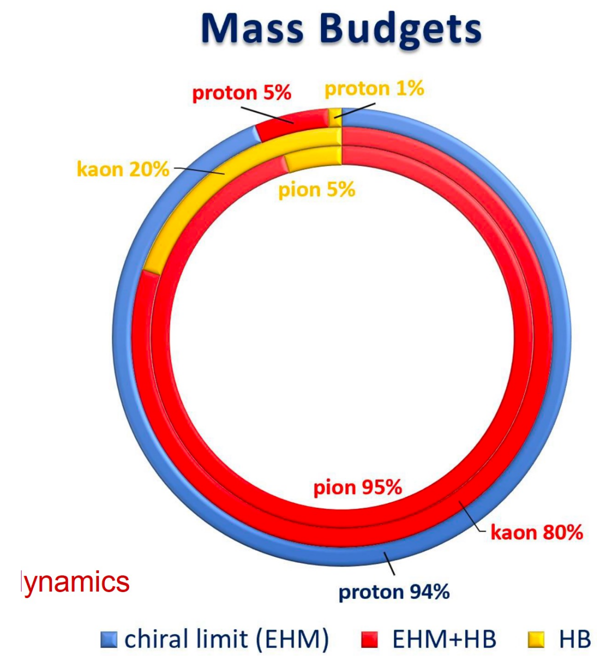


- $M_K \sim 490$MeV
- Spin 0
- 1 light and 1 "heavy" valence quarks

Proton

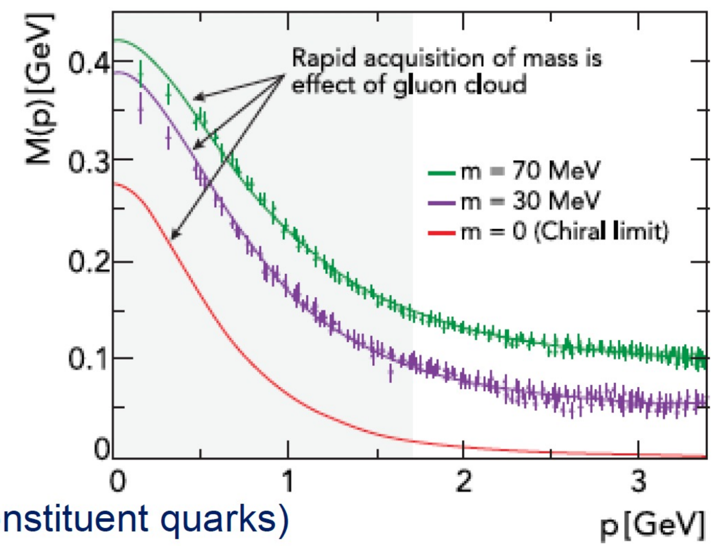


- $M_p \sim 940$MeV
- Spin 1/2
- 3 light valence quarks



Higgs generated masses of the valence quarks:

$M_{(u+d)}$~7 MeV $M_{(u+s)}$~100 MeV $M_{(u+u+d)}$~10 MeV



(Constituent quarks)

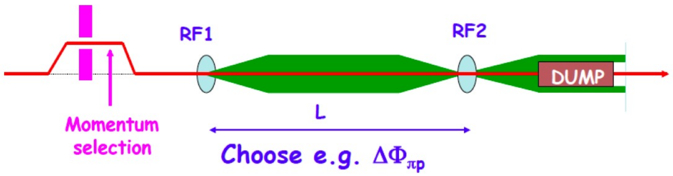
Dressed-quark mass function M(p)

<u>In order to "prove" that QCD underlies the EHM phenomenon to compare Lattice and Continuum QCD calculations with experimental data by measuring:</u>

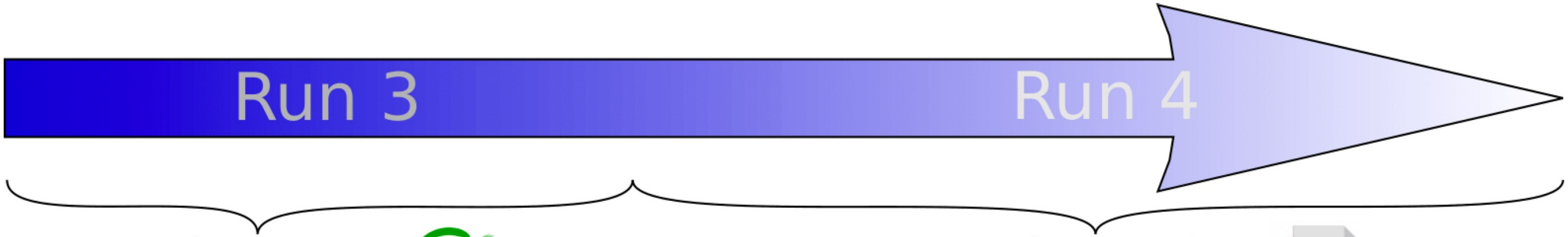
1. <u>Quark and Gluon PDFs of the pion/kaon/proton</u>
2. <u>Hadron's radii (confinement)</u>
3. <u>Excited-meson spectra</u>

AMBER Long Range Plan

Conventional muon/hadron M2 beams



$\Delta\Phi = 2\pi\,(L\,f\,/\,c)\,(\beta_1^{-1} - \beta_2^{-1})$ with $\beta_1^{-1} - \beta_2^{-1} = (m_1^2 - m_2^2)/2p^2$



Phase-1

Proton Radius Measurement
Antimatter production cross section
Pion structure (PDFs) via DY and charmonia

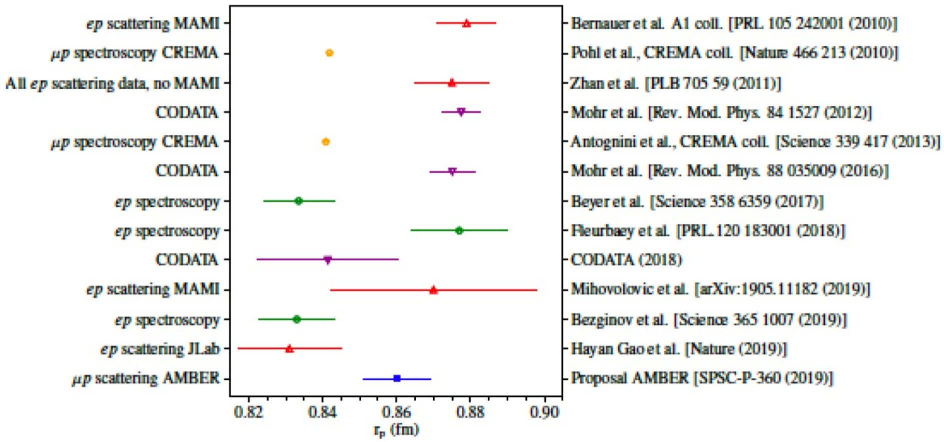
Phase-1 Proposal approved by RB on 02/12/2020

Phase-2

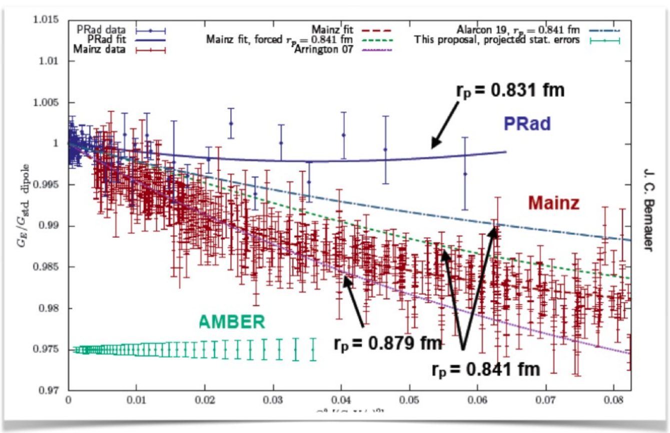
Kaon and pion structure (PDFs and PDAs)
High precision strange-meson spectrum
Kaon and pion charge radius
Kaon induced Primakoff reaction

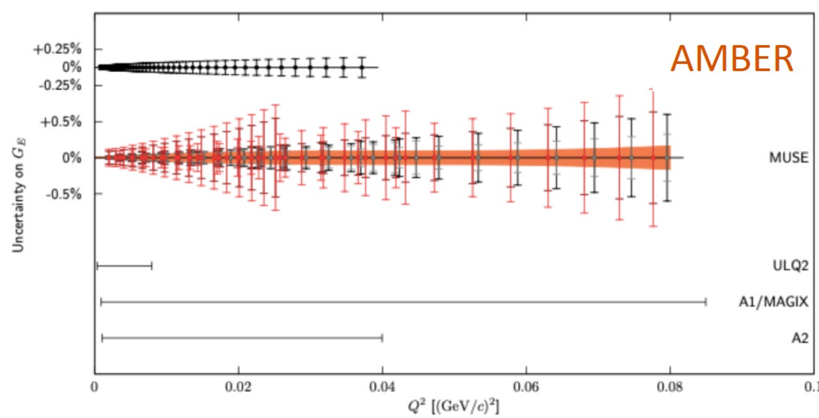
Phase-2 Proposal submission in the beginning of 2022

Proton Radius



	ep	μp
Spectroscopy	New measurements with ▪ lower systematics ▪ new transitions	✔
Scattering	New measurements with ▪ lower systematics ▪ reaching lower Q^2 ProRAD, ULQ2, ISR @ MESA, PRad	No data yet. MUSE at PSI coming soon AMBER





statistical precision of the proposed measurement, down to Q^2 = 0,001 GeV^2/c^2, Cross section is normalised to the G_D - dipole form factor

AMBER:
Pure muon beam + magnetic form factor contribution suppression at high E

The impact of the proposed p + p measurements on constraining the production of cosmic anti-protons versus their kinetic energy. Each curve represents the fraction of anti-proton production phase space as constrained by AMBER cross section measurements in p-p, p-He and He-p channels, compared to NA61 (p-p) and LHCb (p-He) measurements

p-H channel, in three different energy ranges

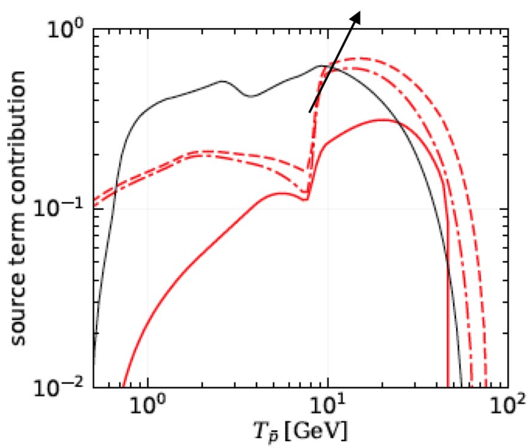
100-190 GeV/c

50-190 GeV/c

50 - 250 GeV/c

AMBER

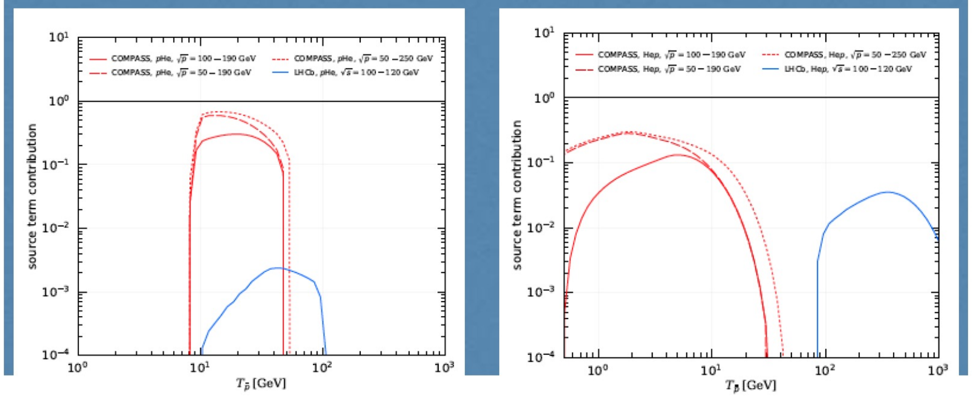
NA61 (20-158 GeV/c)



AMBER

LHCb

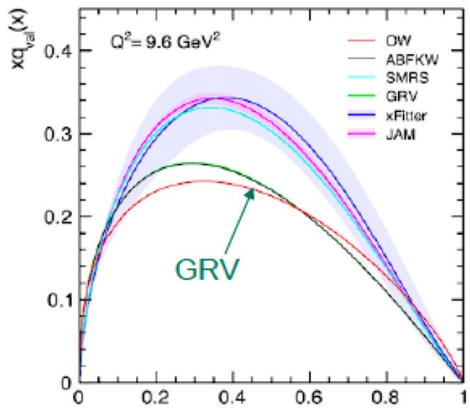
p-He and He-p channels



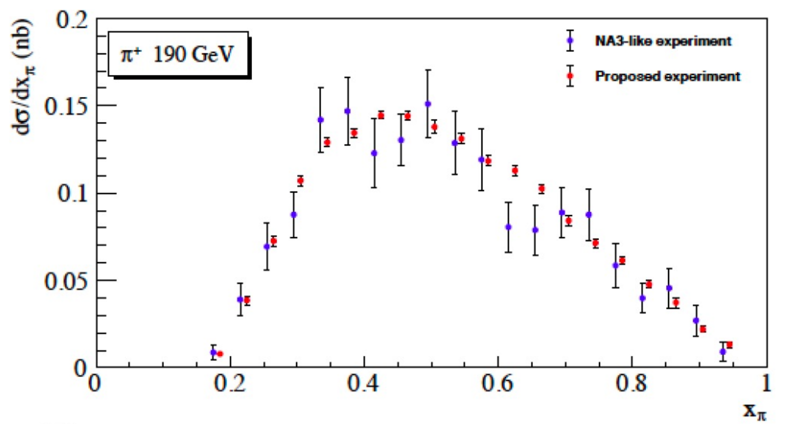
https://indico.cern.ch/event/820869/

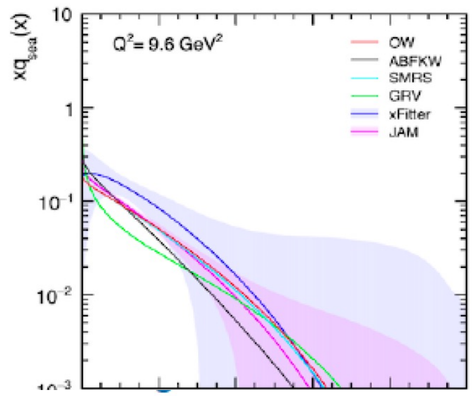
10/06/2021

Pion Structure

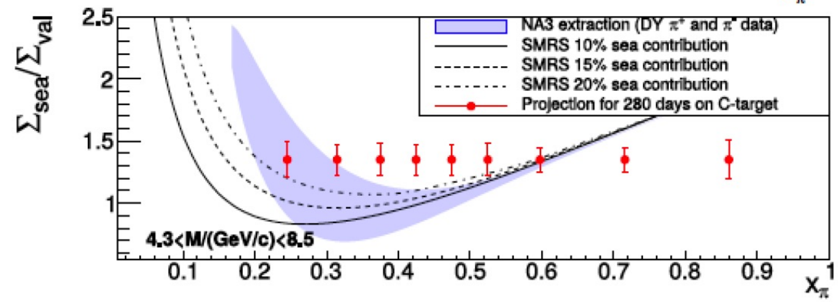


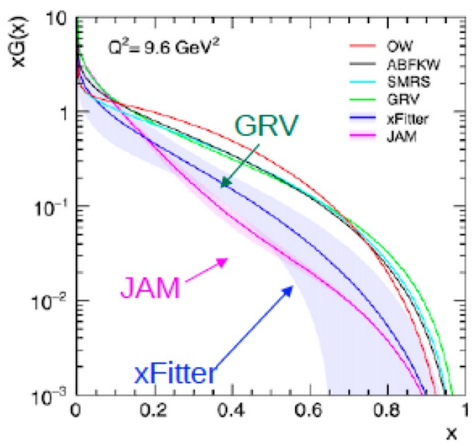
Valence



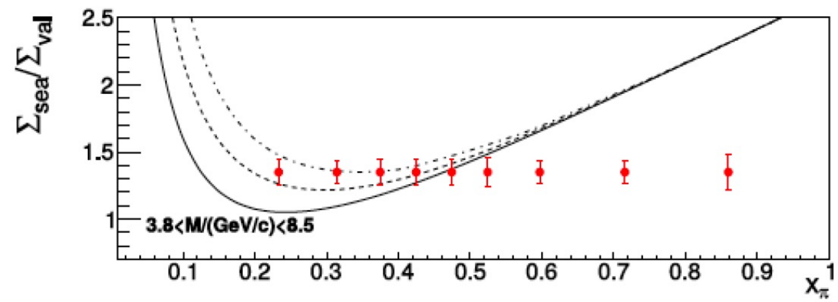


Sea





Gluons

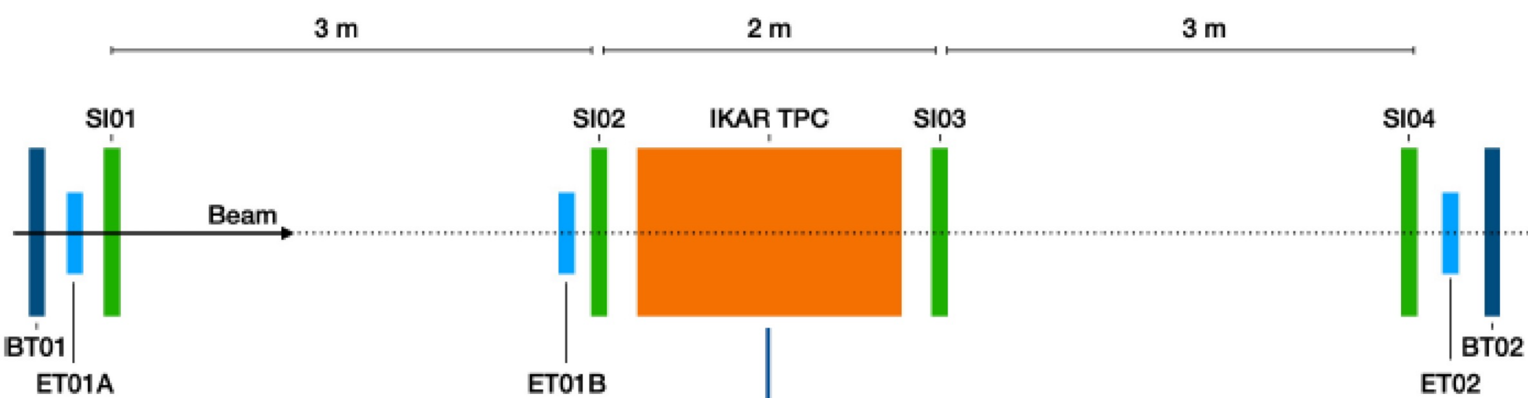


Sea quark content of pion can be accurately measured at AMBER for the first time

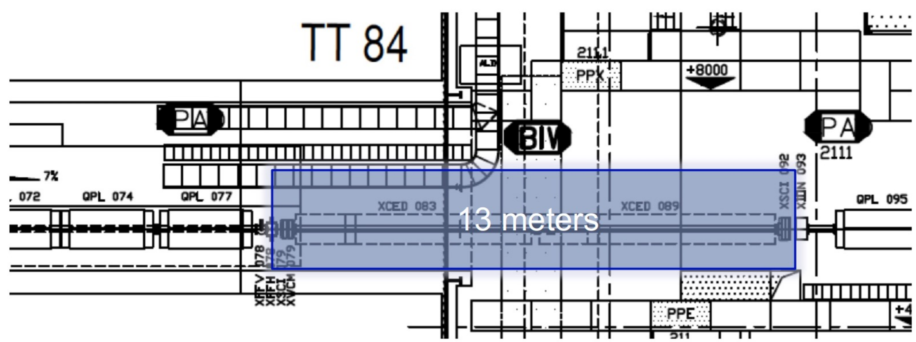
AMBER Pilot Run

Main Goal to be reached: **Proof-of-principle of all new detector equipment**

- Test the IKAR TPC in dedicated 20 days of beam (CEDAR position)
  - determine the **noise/background induced by the muon beam**, detect proton recoils correlated with scattered muons
- Test of the unified tracking detector station
  - operate one detector station with prototypes of both the **silicon-pixel detector** and the **scintillating-fibre hodoscope**
- Test of the new DAQ system (possible for TPC in park position)
  - operate new **free-running DAQ** system for readout for all new detector components



M2 beam line
CEDAR postion
Upstream of COMPASS



AMBER Pilot Run

Need to be complemented with a tracking system for the scattered muon

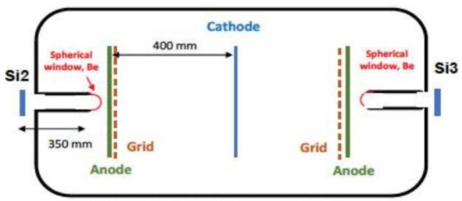
Licence issue with ALPIDE detectors
Negotiation pursued by ALICE
Likely not ready for the pilot run
Parasitic test assumed

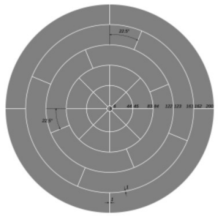
IKAR TPC (currently at CERN):

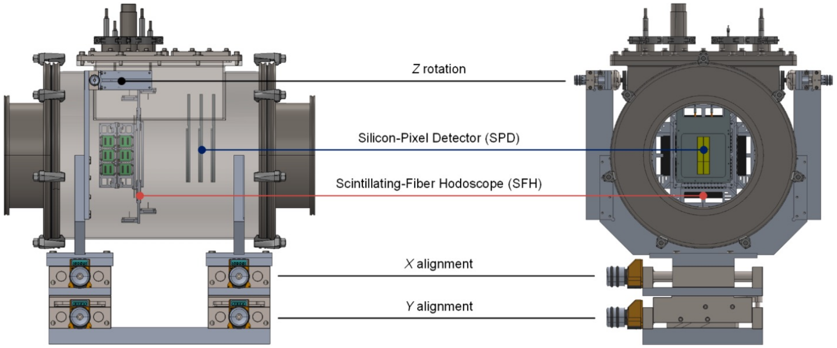
- → 2x drift cells with 400 mm length
- → New adapted field-shaping rings
- → Anode structure: identical structure, but with smaller diameter wrt final TPC
- → Operation pressure of max. 10 bar
- → New power-supplies and front-end electronics
- Ready for first pressure test
- Dedicated gas-purification system will be used

Combined Silicon-Fibre tracking station:

- → 2x+2y planes of 500 μm scintillating fibre 9.6x9.6 cm^2
- → 3 planes of pixel-silicons 9x9 cm^2 (pixel size 28x28 μm)
- → Operation pressure of max. 10 bar
- → New power-supplies and front-end electronics
- Small distance between the Silicon-pixel detectors and the Scintillating-Fibre Hodoscope
- Allow for independent access and cooling infrastructure
- Compatible with beam line elements for the He volume





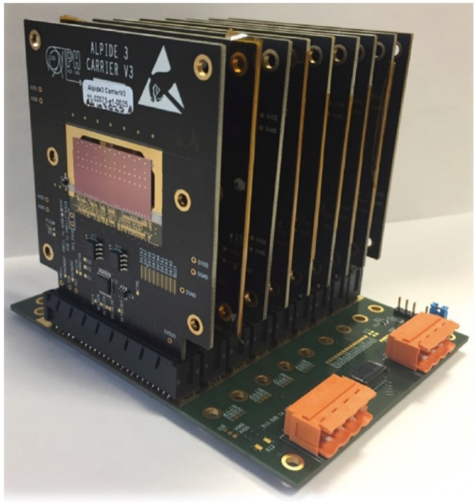


Pilot Run Tracking

Several options available for tracking available

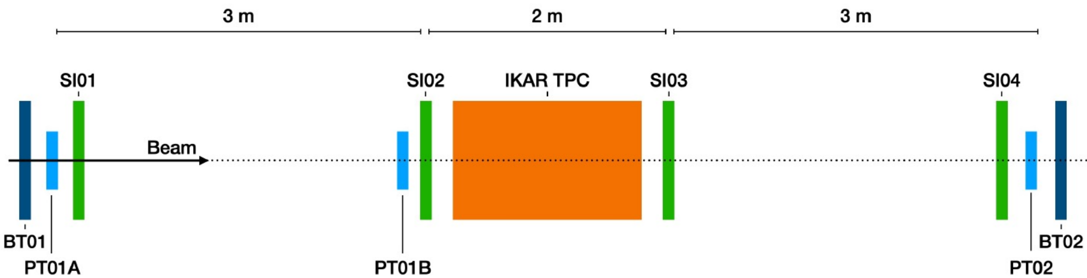
Tracking required to evaluate TPC response in the high-intensity muon beam and correlation of events.

- Option 1: ALPIDE telescope:
  - → Same technology as in the main run
  - → 9-plane telescopes are available
  - → Dedicated DAQ system based on EUDAQ
  - → Requires hit-time information due to time-resolution or delicate tracking algorithm



BTTB5, 26/01/2016 J.W. van Hoorne, CERN

- Option 2: COMPASS Silicon-strip detectors:
  - → Comparable hardware as in 2018
  - → Based on existing COMPASS DAQ, event definition and reconstruction
  - → No additional timing detectors required



- Under investigation: Possibility of an additional "physics" trigger to enrich correlated events

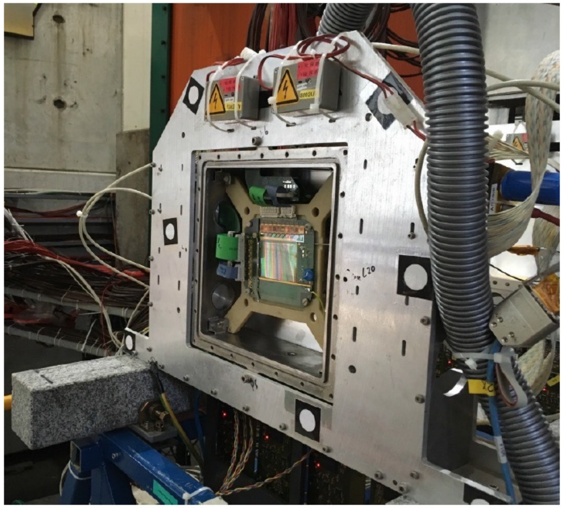
Both options are under discussion and evaluation to find the best option in terms of reconstruction, time schedule and man power

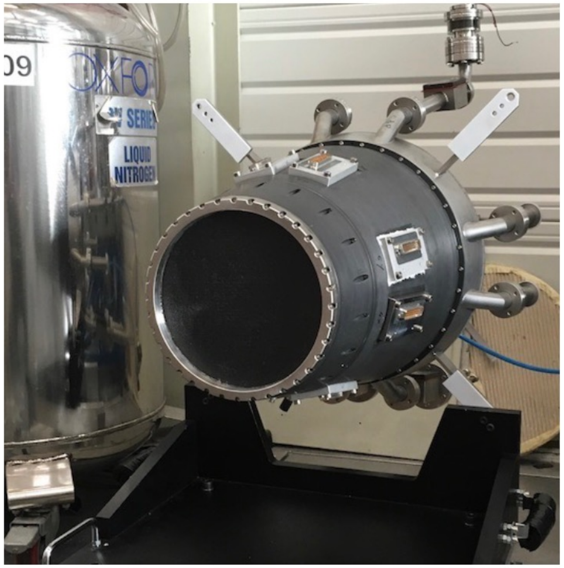
Pilot Run Tracking

Usage of silicon-strip tracking detectors

Previous model of the new cryogenic COMPASS silicon-strip tracking detector from 2004.

- Used in test measurement in 2018
- Characteristics:
  - → 300 µm wafer with an active area of 70x50 mm^2
  - → 1280 (1024) readout strips per projection and utilisation of charge sharing between strips
  - → Four single projections: X,Y and U,V (rotated by 5°)
  - → Time resolution: σ = 1.5 ns, spatial resolution: σ = 5 - 10 um (depending on cluster size)
  - → Triggered readout based on APV25 chips
- Disadvantages:
  - No experience with ALPIDE / tracking for main run
  - Trigger rate limited at 40 kHz
- Advantages:
  - Fully available and working system
- Todo:
  - “Minor” work: check equipment and prepare spares etc.

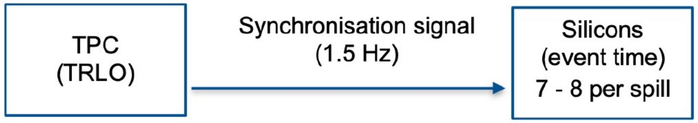




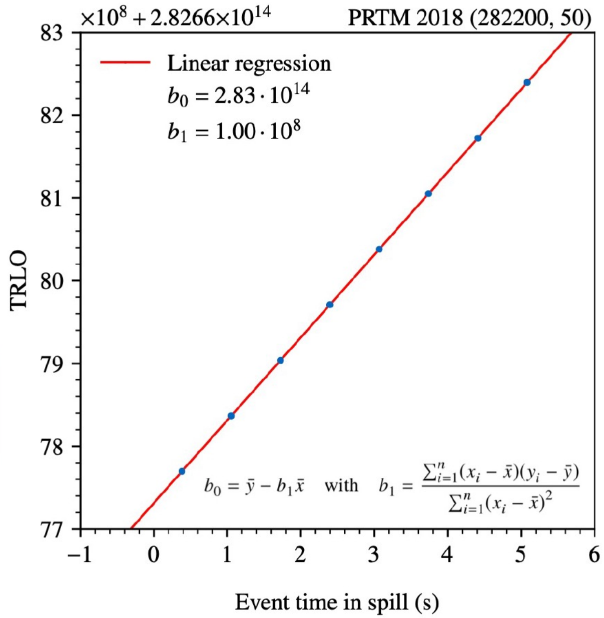
No cryogenic but part of the services from in-operation COMPASS silicon

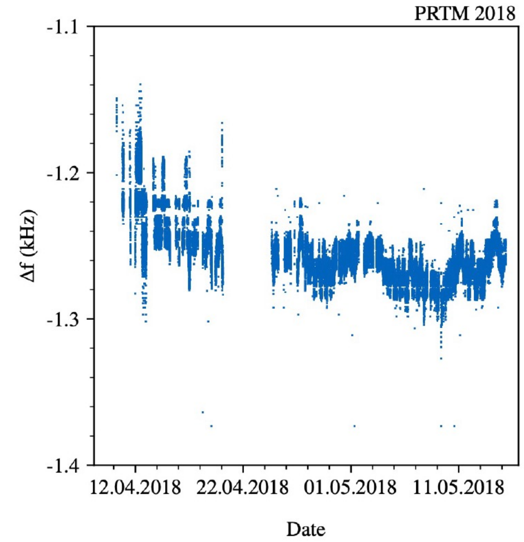
Synchronisation using time stamps
Events from separate TPC and silicon DAQ tagged with time stamp.

- TRigger LOgic (TRLO) time stamp with 100 MHz resulting in a time resolution of 10 ns
- Synchronisation of time stamps during SPS spill

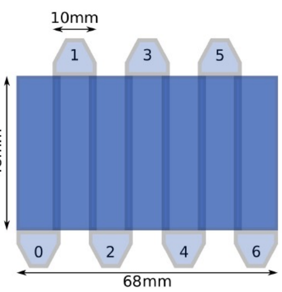


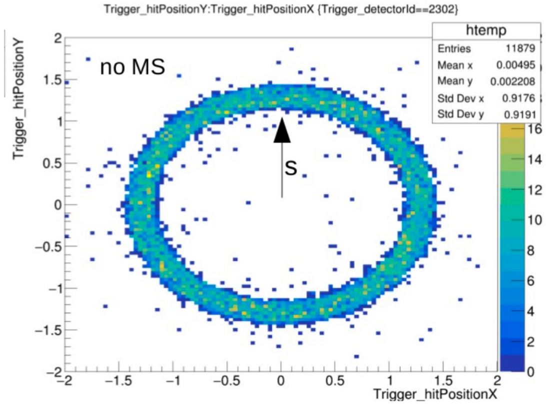
- Linear interpolation between synchronisation time stamps for calibration
- Match TPC and silicon events via TRLO time

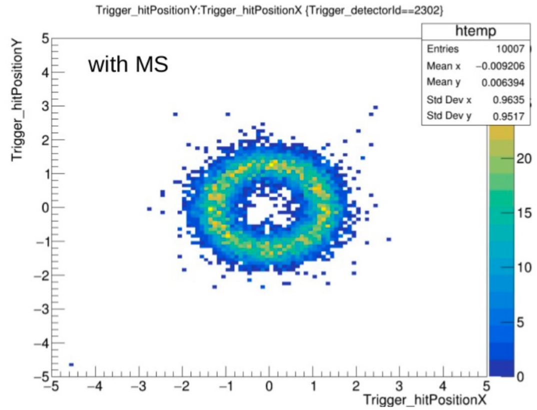




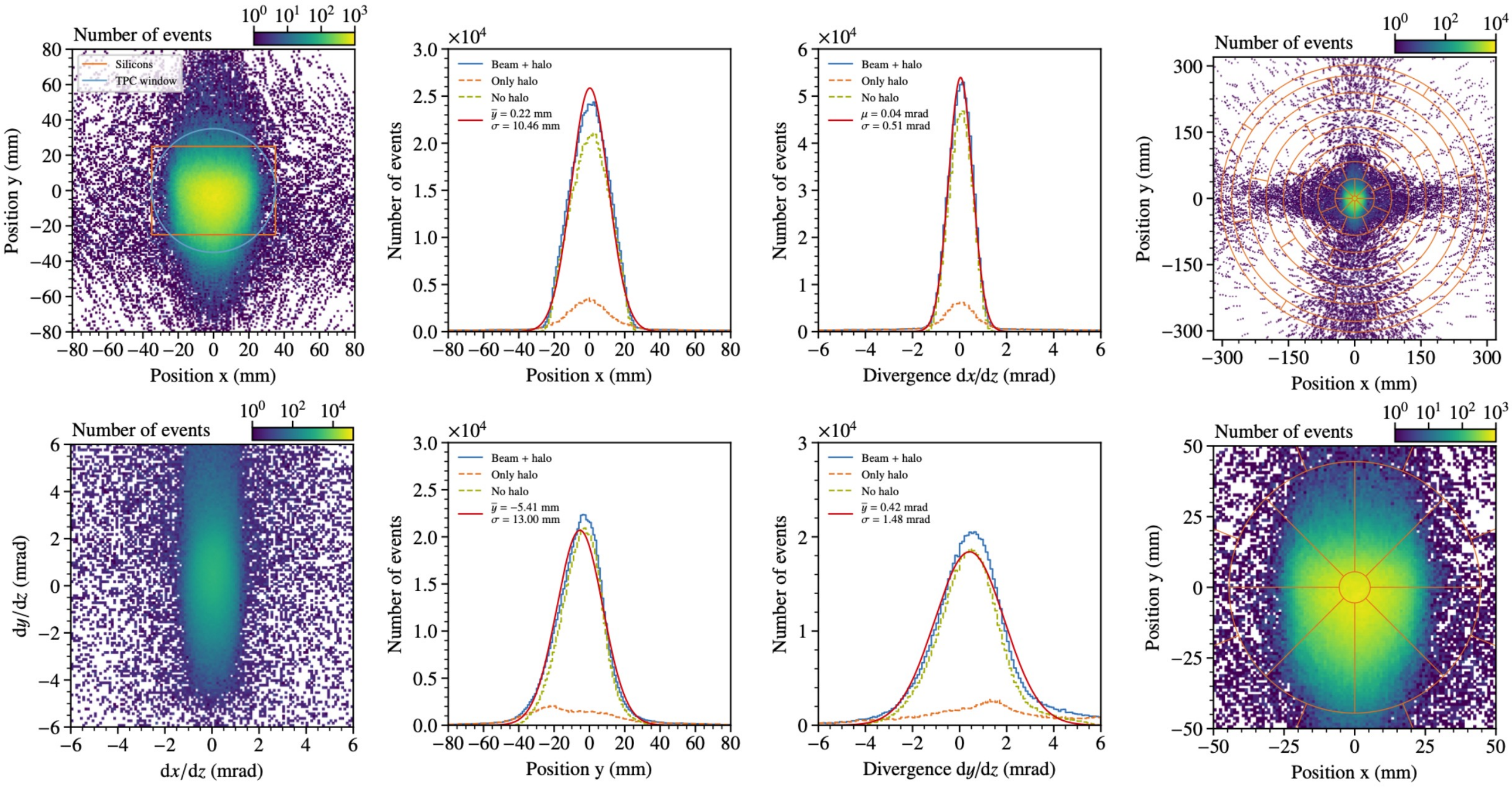
Beam Trigger



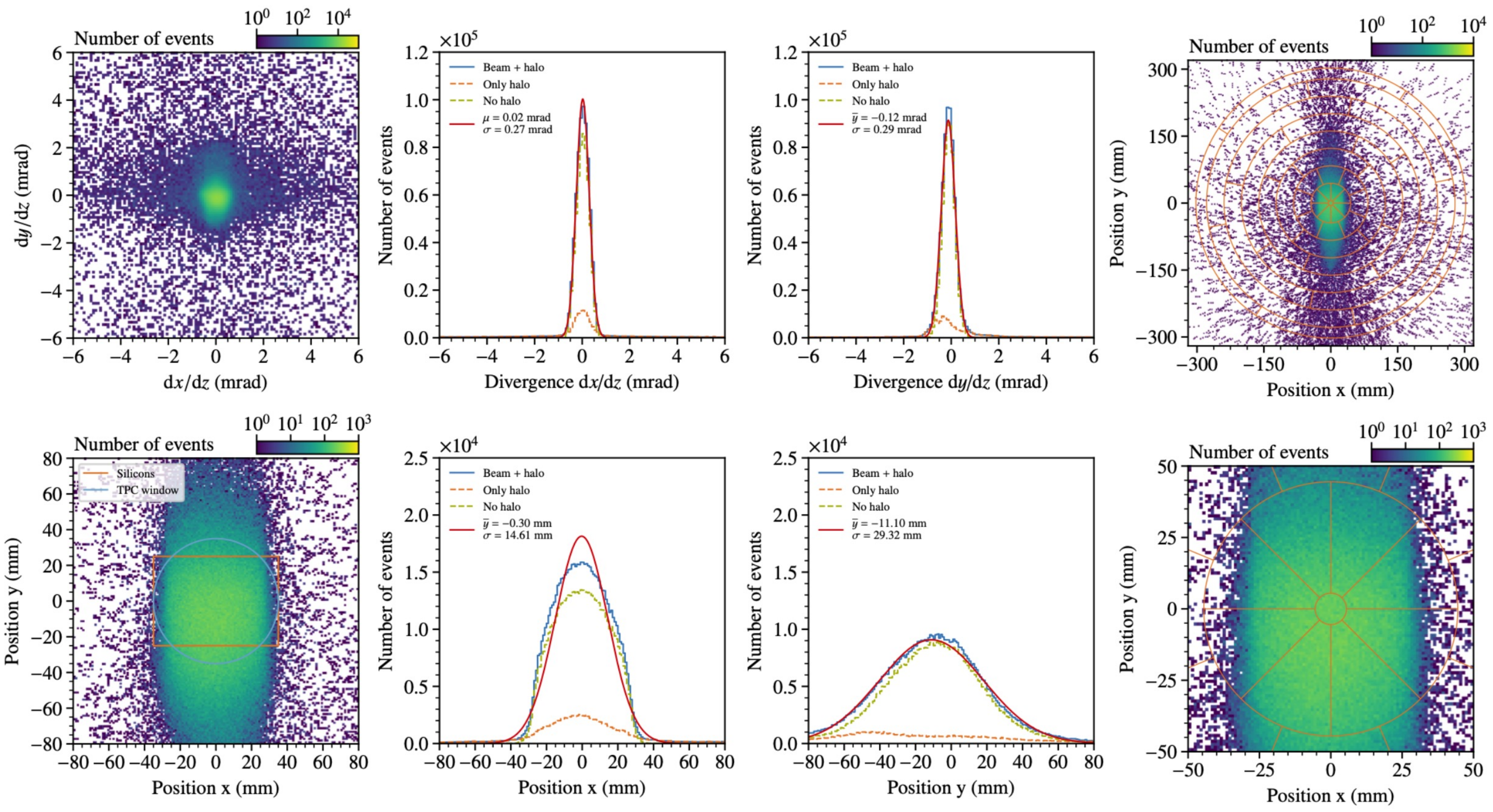




Beam Optics - Focused Beam (M2 Test Beam Area)



Beam Optics - Parallel Beam (M2 Test Beam Area)



Minutes

139th SPSC Meeting:

The Committee **recommends** approval of the proposal SPSC-P-360 by the AMBER Proto-Collaboration to use the M2 beam-line before LS3 to perform measurements related to:

(i) Drell-Yan and J/Psi production using the conventional M2 hadron beam;
(ii) proton-induced antiproton production cross sections for dark matter searches;
(iii) the proton charge radius using muon-proton elastic scattering.

The proton-radius program is contingent on a successful pilot run previously approved for the first year of SPS operation after the Long Shutdown LS2.

The SPSC **emphasises** that the beam time allocated to AMBER for any of the measurements is subject to the available time, and to annual discussions in the Committee on the use and sharing of the M2 beam line.

……

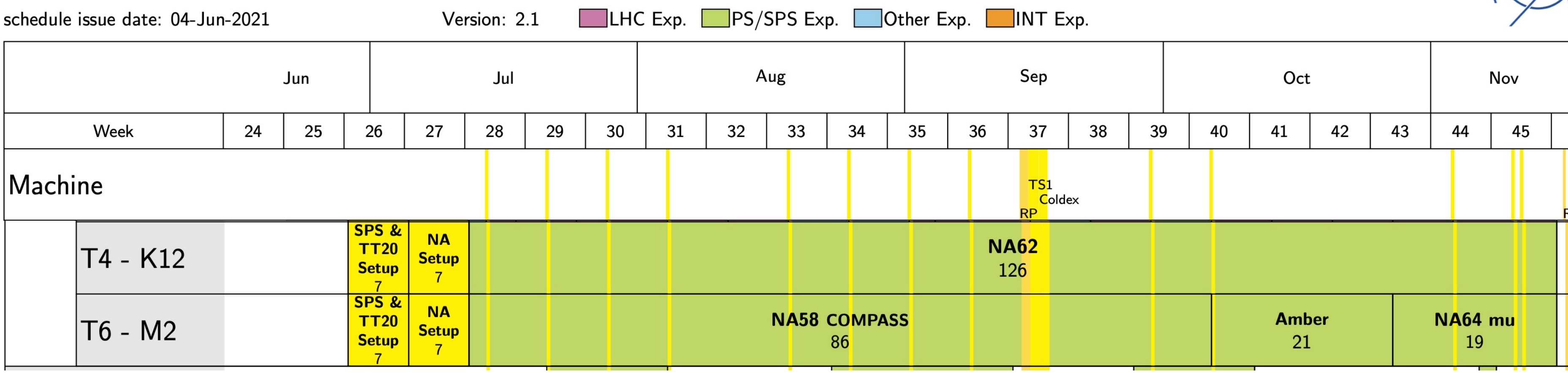
Suggested minutes of the 142th SPSC meeting:

The SPSC **recognizes** the physics interest of the AMBER program and **is looking forward** to the consolidation of the Collaboration structure.

The SPSC **aknowledges** the progress in preparation of the AMBER pilot run dedicated to the validation of the proton radius measurement and encourages the Collaboration to concentrate on the most viable option in complementing the TPC tracking.

M2 Schedule in 2021

SPS user schedule for 2021



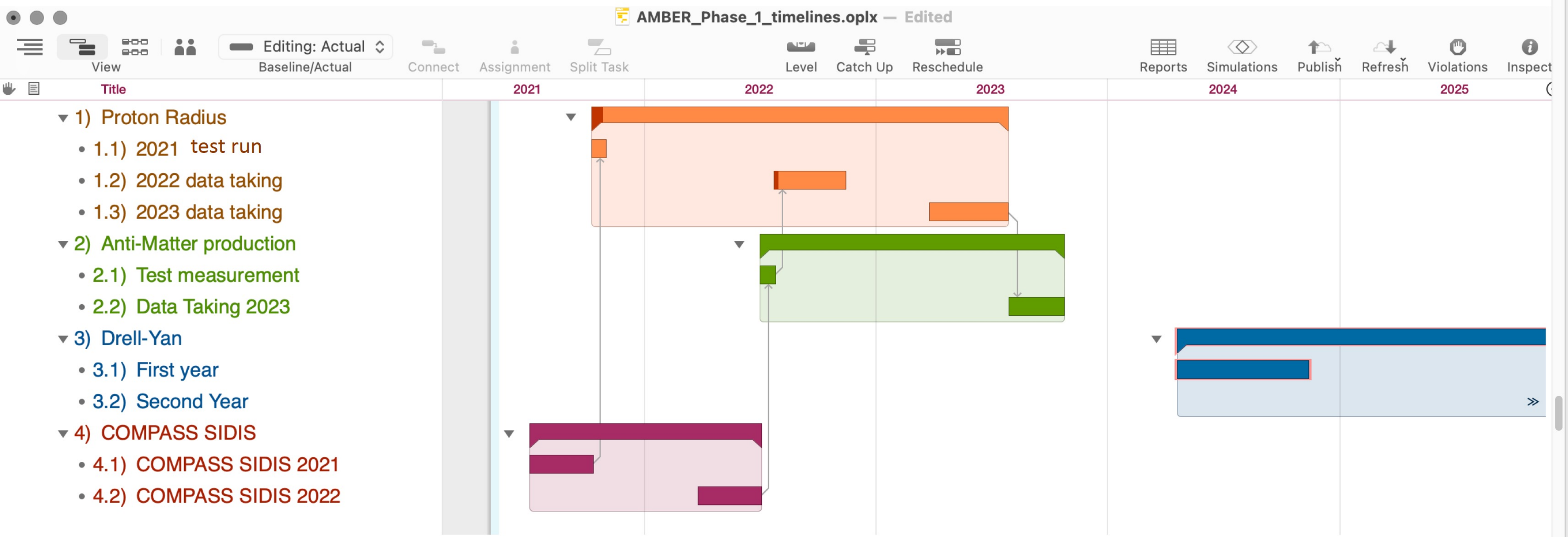
COMPASS minimum run to justify a meaninful data-taking
(3 weeks for spectrometer commissioning assumed to happen in July anyway)
2 weeks for target commissioning
2 weeks for each target polarization cycle (x3 minimum)
ends up to a bare minimum of 8 weeks = 56 days

AMBER and NA64mu pilot runs are crucial for the timely start of their RUN3 physics program

A beam schedule change request is possible but too premature to be considered at this time
COMPASS and AMBER Collaborations largely overlap and might eventually negotiate a compromise
A request for beam time compensation might impact 2022 beam schedule.

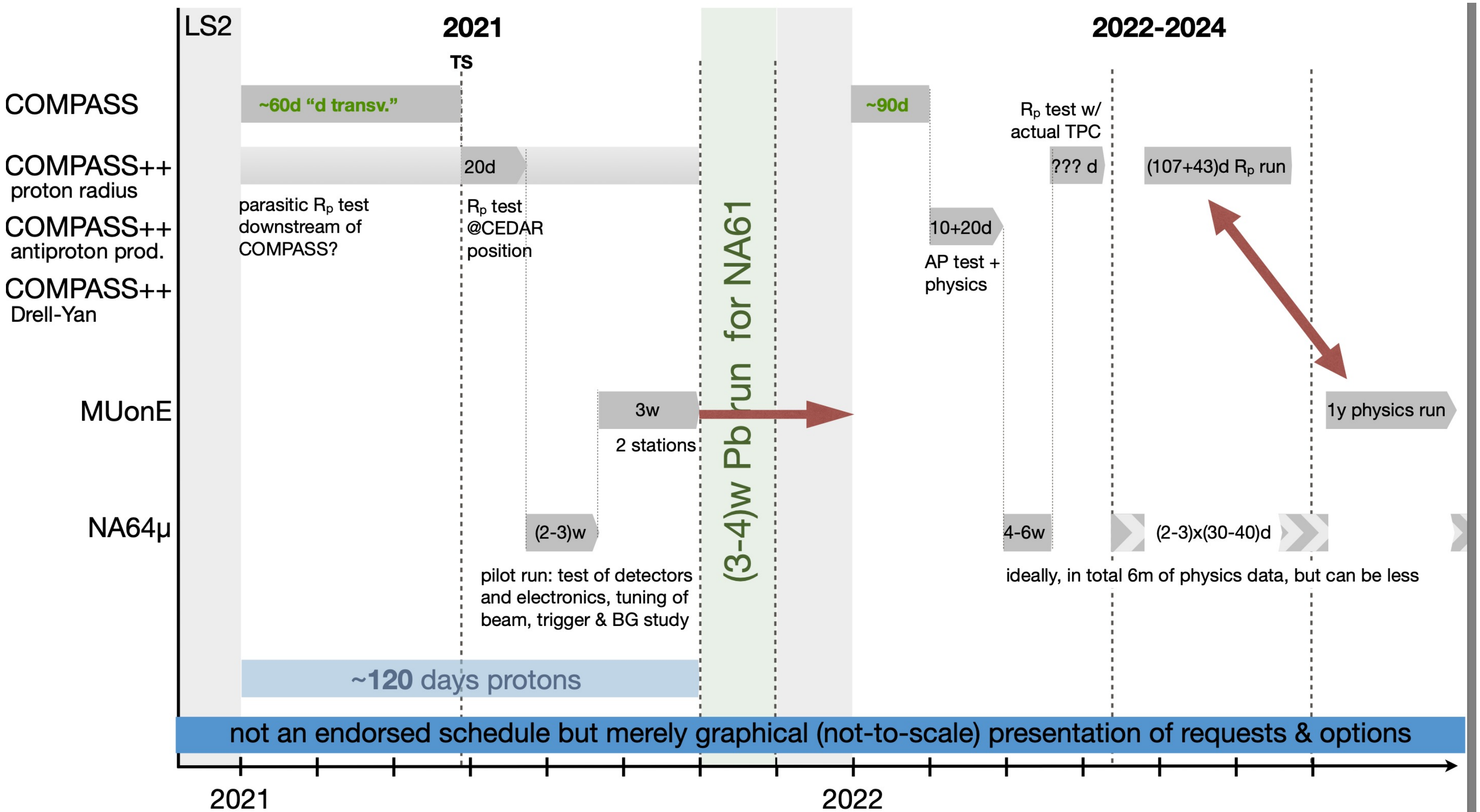
Not clear SPSC role if a decision has to be taken before fall meeting

O. Denissov presentation at the open session:



Starting point depends of the semiconductors availability on the market

SPSC Discussion in October '20



2022 schedule still in jeopardy

Pending information on readiness from COMPASS (polarized taregt), AMBER (ALPIDE telescope) MuonE (tracking stations), on potential 3 weeks start delay and Pb ion run length….

Need to keep trace with the experimetn for an extensive discuiion in fall meeting