AMBER Hardware:
Proton Radius Measurement

Technical Board Meeting 20.9.2022

Report by Physics Coordinator
Proton Radius Measurement – Plans and Developments (status April 2022)

• Active-target TPC
  • Main structure ready to be ordered (GSI/German groups), depends on funding grants (pending)
  • Work on the gas system further pursued at PNPI
  • Subject to further development concerning Russian group
  • Due to delays with production of main TPC: possible fallback for a physics running in 2023 is to reuse existing IKAR TPC (limited $Q^2$ range, $\frac{1}{4}$ of statistics)

• Muon tracking
  • Unified Tracking Station (UTS) design being finalized
  • Precise timing: Scintillating Fiber Hodoscope (SFH)
  • Precise space resolution: ALPIDE silicon pixel detectors
  • New FriDAQ free-running data acquisition system
  • Plan: full proof-of-principle until this autumn
We foresee several parasitic tests of the tracking detectors during the 2022 beam time, in the downstream test area.

Install and operate the new FriDAQ for the available detector components.

We plan dedicated tests in beam, at the end of the beam time, for testing the tracking detectors in realistic conditions and with new FriDAQ compatible electronics.

- 100 GeV beam
- Nominal PRM intensity $2 \cdot 10^6$ muons per second
- Focused beam

Goal: get one station characterized (space & time resolution, efficiencies, noise level etc), in combination with spectrometer scintillating fibers.

Two possible places: Upstream the polarized target (between FI01 and FI15/FI02) or downstream SM2 (between FI07 and FI08).
News from TPC: Carbon fiber window

(slides Oleg Kiselev, Joachim Weinert, Sandra Schwab, Kalliopi Dermati, Rainer Heseitl, GSI Darmstadt)

- Window simulated with ANSYS
- Flanges for testing produced
- Two windows made, 1.0 and 1.6 mm
- Carbon fabric 200 g/m² (style 452-5 Aero, twill weave), for the supporting parts in aircraft construction, motorsports, marine construction
ANSYS simulations for variable-thickness windows

- Weak area: fixation to the flange
- Thicker window (4 mm) at the fixation area and thinner (1 mm) in the middle should be more stable
- Difficult to make
Pressure test at MPA Darmstadt

- The Center for Construction Materials - Staatliche Materialprüfungsanstalt Darmstadt (MPA) and the Department and Institute of Materials Science (IfW) at the Technical University of Darmstadt
- Short pressure tests
- Long-term pressure tests
- Proved and certified laboratory
- Up to 30 samples can be tested in parallel
- Pressure up to 100 bar (distilled water)
Pressure test at MPA Darmstadt

- Setup with 8 cameras
- One professional high-speed camera (up to 5000 fps)
- Z deformation measured in the middle, precision 0.01 mm
## Pressure test at MPA Darmstadt

<table>
<thead>
<tr>
<th>Pressure, bar</th>
<th>Deformation in the middle Z, mm (Fully uniform thickness, 1 mm)</th>
<th>Deformation in the middle Z, mm (homogeneous, 1-4 mm)</th>
<th>Deformation in the middle Z, mm (inhomogeneous, 1-4 mm)</th>
<th>Measured deformation in the middle Z, mm (Fully uniform thickness, 1 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.04</td>
<td>0.04</td>
<td></td>
<td>0.02 / 0.04</td>
</tr>
<tr>
<td>20</td>
<td>0.08</td>
<td>0.08</td>
<td></td>
<td>0.06 / 0.08</td>
</tr>
<tr>
<td>30</td>
<td>0.09</td>
<td>0.12</td>
<td>0.11</td>
<td>0.10 / 0.12</td>
</tr>
<tr>
<td>40</td>
<td>0.16</td>
<td>0.15</td>
<td></td>
<td>0.14 / 0.19</td>
</tr>
<tr>
<td>50</td>
<td>0.20</td>
<td>0.19</td>
<td></td>
<td>0.19 / 0.25</td>
</tr>
<tr>
<td>60</td>
<td>0.24</td>
<td>0.23</td>
<td></td>
<td>0.24 / 0.32</td>
</tr>
<tr>
<td>70</td>
<td>0.28</td>
<td>0.27</td>
<td></td>
<td>0.31 / 0.39</td>
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<tr>
<td>80</td>
<td>0.32</td>
<td>0.31</td>
<td></td>
<td>0.37 / 0.45</td>
</tr>
<tr>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td>0.42 / 0.49</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td>0.49 / 0.495</td>
</tr>
</tbody>
</table>

Measured deformation while increasing pressure and then while decreasing Both windows, 1.6 mm (7 layers) and 1.0 mm (4 layers) did not break up to 100 bars!
Carbon fiber window: further plans

- Vacuum test of both windows
- New windows with a gas-stop foils
- Pressure test in November 2022
- Long-term pressure test in December 2022
IKAR refurbishment and operation in 2021

→ main parameters and details presented by Evgeny
Plans for the new TPC as of March 2021

Time Projection Chamber

Construction of a new TPC
New TPC vessel and readout parts required.

- New TPC construction:
  - 4x drift cells with 400 mm length
  - Maximal operation pressure: 20 bar
  - Segmented anode plane: 600 mm diameter
- Construction of TPC about 1.5 years in total
  - Split work and construction to be on time

\[ d = 600 \text{ mm} \]

10 MeV
20 MeV
1 MeV
5 MeV

Optimisation of geometry ongoing:
- Material budget, beam noise and proton ranges
  - optimal pressure settings for \( Q^2 \)-range
  - optimal internal geometry
  - optimal read-out plane segmentation
  - optimal beam-window size

Test run: IKAR TPC (2-cell version with smaller radius)

Christian Dreisbach | 10th March 2021 | EHN2 Working Group - AMBER: PRM
Plans for the new TPC in 4-cell geometry

- **Drift cells**: four, 400 mm long
- **Pressure**: 20 bar operational, 31 bar test
- **Anode plane**: 600 mm diameter
- **Signal outputs**: 8 x 16-channels SubD vacuum feedthroughs
- **HV inputs**: 1 pair of 10 kV and 50 kV vacuum feedthroughs (might be 2 pairs)
- **20 field shaping rings**: special profile stainless steel rings on the MACOR or PEEK
- **Anode structure**: 32 ring/sector structure similar to the modified IKAR TPC
Plans for the new TPC in 4-cell geometry

**Drift cells:** four, 400 mm long  
**Pressure:** 20 bar operational, 31 bar test  
**Anode plane:** 600 mm diameter  
**Signal outputs:** 8 x 16-channels SubD vacuum feedthroughs  
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**20 field shaping rings:** special profile stainless steel rings on the MACOR or PEEK  
**Anode structure:** 32 ring/sector structure similar to the modified IKAR TPC
Plans for the new TPC: 2 cells

- Two sections instead of four
- Same construction, diameter, gas pressure
- Endcaps are the same
- Smaller and lighter – less expensive
- To be investigated: impact on physics (less hydrogen, shorter track extrapolation)
2-cell Time Projection Chamber

- Same deformation-free mounting of the electrodes
- Two pairs of HV feedthroughs instead of four
- Beam windows, gas connectors are the same
Production of the pressure vessel

- Preliminary drawings and description of the 2-cell TPC is a basis of the tendering documents
- Funds from GSI, TUM, Bonn and Mainz are collected and will be used for the order
- EU-wide tender is opened, will go up to November
- 6 companies are contacted up to now
- Engineering phase – up to the end of 2022
- Production phase – up to the middle of 2023
TPC: 100 kV feedthroughs

- No feedthroughs certified up to 30 bar are available on the market
- The idea is to test those are potentially robust and should stand high pressure
- One sample (from CeramTech) is obtained
- Flange will be constructed, feedthrough welded and tested
ALPIDE tests in 2022

Slides/Team: Martin Bajzek, Oleg Kiselev, Bastian Löher, Valerii Panin, Luke Rose, Jose Luis Rodriguez Sanchez

- Designed by ALICE for ITS2
- 512 x 1024 pixels → 1 pixel: 29x27μm² → Active area of 1.5x3cm²
- 50 μm thick
- Radiation hard
- ALICE quote >99% detection efficiency → To be measured/confirmed for AMBER/R3B purposes
- One ALPIDE detector
- Readout: 1x MOSAIC board
- Continuous readout
- Parasitic mode
  - Minimal beam discrepancy?
- Deuteron at 1 GeV/u, 800 MeV/u, 200 MeV/u
ALPIDE tests Jülich/COSY: Results

- Read out with the MOSAIC board works.
- Noisy pixels if not removed before readout can dominate.
- ALICE/ITS2 DAQ is obsolete and needs to be modified.
- Further analysis macros must be prepared.

DAQ is fully redesigned and meanwhile changed
Triggering:
- internal trigger / continuous readout
- external trigger from Compass (latency ~2 µs)
- external trigger from trigger module (pulser) for quasi-continuous readout
- MOSAIC trigger to ALPIDE with variable delay

Timestamp protocols:
- Rataclock
- Ratatime
- Heimtime speaking clock

Timestamp source can accept CERN Whiterabbit timestamp for real UTC time
ALPIDE PC

- Start/stop synchronisation
  - DIM messages sent from COMPASS DAQ to TPC computer
  - Not yet implemented

- Readout
  - R3B DAQ (drasi)
  - Data format: GSI LMD with timestamps
  - Data rate: 1 GBit/s per MOSAIC, >100 kHz trigger rate with low hit occupancy
ALPIDE tests 10/2022

- Rio4 VME controller configers pulser.
- VULOMB 4B (reprogrmmable FPGA board) generates pulse trigger signal.
- EXPLODER (desktop FPGA module) ->Timestamping, WhiteRabbit.
- ECL to NIM convertor
- FiFo->distributes trigger and trigger signals to MOSAICs.
Goals for test beam November 1-3

- Verify new DAQ works and pixel masking improves efficiency under beam conditions.
- Sync DAQ with SciFi Detectors and COMPASS/AMBER DAQ.
- Measure position resolution of APIDE telescope setup + SciFi.

11 ALPIDEs and 9 MOSAIC boards are available and working
# SPS planning

## SPS: October 2022

<table>
<thead>
<tr>
<th>Machine</th>
<th>Week 39</th>
<th>Week 40</th>
<th>Week 41</th>
<th>Week 42</th>
<th>Week 43</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2 - H2</td>
<td>CMS HGCAL</td>
<td>LHCb</td>
<td>LHCb ECAL</td>
<td>NA64e</td>
<td>NA65</td>
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<tr>
<td></td>
<td>ATLAS ITK PIXEL</td>
<td>ATLAS AFG</td>
<td>MONO LITH</td>
<td>M.R. Jäkel, E. Oliveri</td>
<td>GIF RD51</td>
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<td>T2 - H4</td>
<td>V. Grinerov</td>
<td>A. Rummel</td>
<td>A. Rummel</td>
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<td>A. Rummel</td>
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<tr>
<td></td>
<td>ATLAS AFG</td>
<td>ATLAS AFG BCM</td>
<td>ATLAS ITK PIXEL</td>
<td>ATLAS AFG BCM</td>
<td>ATLAS AFG BCM</td>
</tr>
<tr>
<td>T4 - H8</td>
<td>U. Gabrion</td>
<td>W. Scandale</td>
<td>H. Schindler, N. Neri</td>
<td>H. Schindler, N. Neri</td>
<td>LHCb (Seldon)</td>
</tr>
<tr>
<td>T4 - K12</td>
<td>H. Danielsson</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6 - M2</td>
<td>COMPASS / MuonE (polarization periods)</td>
<td>MuonE tbc (AMBER 2d)</td>
<td>COMPASS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For further information contact the PS/SPS Coordinator. Email: Spc.Coordinator@cern.ch, Tel: +41 75 431 5275.

The latest version of the schedule are available here: [https://cern.ch/sp-sps-coordination](https://cern.ch/sp-sps-coordination)

This schedule is synchronized with injector schedule v1.2.

No beam to the North Area during Technical Stop (TS), Coales and Machine Developments (MD).

For TS a RP cool down time is needed and will be announced in the days preceding the stop.


## SPS: November 2022

<table>
<thead>
<tr>
<th>Machine</th>
<th>Week 44</th>
<th>Week 45</th>
<th>Week 46</th>
<th>Week 47</th>
<th>Week 48</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHCb ECAL</td>
<td>ALICE FOCAL</td>
<td>ALICE FOCAL</td>
<td>SNDF</td>
<td>NA61 setup 150 AGeV/c</td>
<td>NA61</td>
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<tr>
<td></td>
<td>ATLAS ITK PIXEL</td>
<td>ATLAS ITK PIXEL</td>
<td>CMS ECAL</td>
<td>CMS ECAL</td>
<td>CMS ECAL</td>
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<tr>
<td>NA62</td>
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<td>A. Rummel</td>
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<td>NA62</td>
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<td>E. Hiepke</td>
<td>X. Wu</td>
<td>X. Wu</td>
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<tr>
<td>T4 - K12</td>
<td>H. Danielsson</td>
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<tr>
<td>T4 - K12</td>
<td>H. Danielsson</td>
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Unified Tracking Station: Installation planning (from April)

- Setup and cabling of UTS in the spectrometer position: 2 days
- Readout tests with the new detectors: 2 days
Ongoing work on the UTS

• The UTS has arrived at CERN on Sunday 18.9.

• Installation of the ALPIDEs is ongoing

• SFH detector status and plans: Karl’s talk
Proposed 2023(+) setup

- The actual simulation of the 2023 setup (M. Hoffmann) includes as active detector components:

<table>
<thead>
<tr>
<th>Component</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMS</td>
<td>Beam momentum</td>
</tr>
<tr>
<td>IKAR TPC (8 bar)</td>
<td>Recoil proton</td>
</tr>
<tr>
<td>4 Pixel Silicons (SP, 3 planes)</td>
<td>Vertexing</td>
</tr>
<tr>
<td>4 SciFi Tracker (FT, 2 XY planes)</td>
<td>Timing</td>
</tr>
<tr>
<td>8 Compass SciFis (FI)</td>
<td>Timing (vertexing, momentum)</td>
</tr>
<tr>
<td>3 GF</td>
<td>Momentum</td>
</tr>
<tr>
<td>MWPCs (PB, PA06, PA11)</td>
<td>Momentum and muon Id.</td>
</tr>
<tr>
<td>HI05, HL, HM04/5Y</td>
<td>Muon Identification</td>
</tr>
<tr>
<td>ECAL2</td>
<td>Radiative corrections</td>
</tr>
</tbody>
</table>

- Magnet setting: SM1 off, SM2 on
- GF: Same as GM, active dead zone
- Material, not used in reconstruction: ST, DC, W45, RICH, ECAL1, HCAL1, HCAL2, MWPCs (PA01-05, PS), MW1, MW2, HI04, HO, HM04/5X, HG, 3 GF
Backup
Timelines for the Detector Developments in 2022

- **SIPM Lab Tests**: 07.03.2022 - 09.08.2022 (112 dys)
- **Signal Level Measurement**: 07.03.2022 - 06.05.2022 (45 dys)
- **Prototype Detector**: 21.03.2022 - 29.07.2022 (95 dys)
- **SFH Detector**: 01.08.2022 - 14.10.2022 (55 dys)
- **License Preparation**: 01.04.2022 - 31.05.2022 (43 dys)
- **ALPIDE Chips available**: 01.06.2022 - 15.08.2022 (54 dys)
- **Production of one Prototype ALPIDE Plane**: 15.08.2022 - 14.10.2022 (45 dys)
- **UTS ready**: 14.10
- **UTS Beam Test**: 17.10.2022 - 02.11.2022 (13 dys)
Fiber Hodoscopes – Tests in 2022

Detailed timelines have been worked out, input for TB
TPC: IKAR as in the 2021 test

• Pressure vessel inner diameter: 740 mm
• Pressure vessel length: 1600 mm
• Total volume 0.55 m$^3$
• Maximal operating pressure: 10 bar
• Spherical Be windows: 70 mm diameter, 0.5 mm thickness
• Total weight with the support: ~1500 kg
• Drift cells: two 400 mm drift cells
• Anode plane consists of a 10 mm diameter central pad surrounded with six rings
• The outer diameter of the largest ring is 480 mm