Reply to the SPSC questions on

Addendum CERN-SPSC-2018-008 entitled
Study of Hadron-Nucleus and Nucleus-Nucleus Collisions
at the CERN SPS:
Early Post-LS2 Measurements and Future Plans
by NA61/SHINE at the CERN SPS

By the NA61/SHINE Collaboration
http://na61.web.cern.ch/

Abstract

This document presents answers of the NA61/SHINE Collaborations to the SPSC questions on the addendum CERN-SPSC-2018-008 [1] (referred to as “Addendum”) to the NA61/SHINE proposal. Addendum requests an extension of the NA61/SHINE measurements beyond the Long Shutdown 2 and approval of the first physics data taking in 2022. The SPSC requested NA61/SHINE to consider a possibility to start the first physics data taking in 2021. NA61/SHINE concludes that this is possible and requests beam time in 2021 for detector commissioning and tests as well as for data taking with hadron (for neutrino physics) and Pb (for open charm measurements in Pb+Pb collisions) beams. The critical issue is timely flow of financial resources needed for the hardware of the detector upgrade.

June 5, 2018
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1 Comments and questions from the SPSC

The comments and questions of the SPSC to Addendum were sent to the NA61/SHINE spokesperson by the NA61/SHINE SPSC referees on April 23, 2018. They read as follows:

We had a long discussion about the NA61 addendum for running in 2021/22 during the closed session.

The committee expressed strong support regarding the proposed physics programme. However there was considerable opposition to approving 2022 running, especially in view of clarifications that have been received regarding the memo from Eckhard Elsen, that early post-LS2 means 2021. The chair of the committee promised to discuss the question with the research board, which immediately precedes the next SPSC.

In preparation for the continued discussion, we would like to get a better understanding about the foreseen time line for the upgrade and commissioning. Could you tell us more about:

(i) the upgrade time-line and the resources that are needed. Are there ways to accelerate the schedule by prioritising some items?

(ii) the CERN resources that will be needed, for infrastructure in the area (scaffolding etc), the magnetic field map (demineralised cooling water for the magnets may not be available during LS2) and the low energy beam studies (this may require new magnets). This will need to be worked out with the experimental areas team (Lau Gatignon et al.); we understood that you have started discussing these items with them recently.

(iii) how you plan the commissioning. What are the critical items; what determines the time scale for commissioning?

Regarding 3, one question that came up was whether a faster commissioning schedule could be envisaged in 2021. It was suggested that NA61/SHINE could consider asking specifically for more commissioning time in 2021, even if not all that time involves use of beam (e.g. if you need to fix a problem that manifests itself during the commissioning). People also asked whether, in such a scenario, it could also be realistic to envisage part of the Pb+Pb running at the end of 2021.

The minutes will read The SPSC received with interest the addendum concerning NA61/SHINE running in 2021 and 2022, SPSC-P-330-ADD-10, and will further review the proposal.

Best,
Sandra, Marco and Gavin

ps: We also raised the question of an presentation in the open session. However, given that there is already strong support for the physics goals it was felt that there wasn’t a specific need for an open session presentation
Table 1: Timeline of financial resources needed for hardware to complete the NA61/SHINE detector upgrade in 2021. Already covered expenses are shown in green.

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<tr>
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<td>..187.5k</td>
<td>34.5k</td>
<td>18k</td>
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<tr>
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<td>..21k</td>
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<td>Total</td>
<td>15k+30k</td>
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<td>10k</td>
<td>487k+37k</td>
<td>274k+37k</td>
<td>101k</td>
<td>71k</td>
<td>75k</td>
<td>18k</td>
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</tbody>
</table>

2 NA61/SHINE conclusion on the possibility to run in 2021

NA61/SHINE concludes that it is possible to collect physics data, in particular on charm production in Pb+Pb collisions and hadron production in h+A collisions needed for neutrino physics, in the second half of 2021. The critical issues is timely flow of financial resources needed for the detector upgrade. Table 1 presents the resources needed for the hardware. Details concerning the resources and the work schedule are provided in the following section.

Applications to national funding agencies for the funding of the NA61/SHINE detector upgrades are in preparation. NA61/SHINE proposes a strong physics program, but obtaining grants without recommendation from CERN is unlikely. Thus the grant application will be submitted to the agencies as soon as the NA61/SHINE first physics measurements are recommended by the SPSC. A typical time needed for grant approval is 6-12 months. Thus the first financial resources from dedicated grants will be available at the earliest at the beginning of 2019. The financial resources needed in 2018 are 35k CHF and can be covered by the common fund. In the first half of 2019 about 761k CHF (not including collaboration manpower) is needed.

The following sections answer detailed questions related to the readiness for data taking in 2021 asked by the SPSC. The last section presents the NA61/SHINE beam request for 2021 which includes beam periods needed for the detector commissioning and tests as well as physics data taking.

3 Schedule of upgrade activities and necessary funding

**the upgrade time-line and the resources that are needed. Are there ways to accelerate the schedule by prioritising some items?**
3.1 Time Projection Chambers

Figure 1 presents the schedule of the TPC read-out upgrade. The total hardware cost of 483k does not include 150k for a possible air conditioning upgrade.

(i) 2018: development of adapters, 25k:
   - Q2: 5k,
   - Q3: 10k,
   - Q4: 10k.

(ii) 2019 Q1:
   (a) ALICE electronics transfer fee: 100k.
   (b) Production of adapters for ALICE electronics, 274k:
      (1) production of input adapter cables chambers-FEC (HW): 150k,
      (2) production of readout cables/adapters (HW): 110k,
      (3) production of new mounting hardware for FECs (HW): 14k.
   (c) March: ALICE electronics removal and transport: 2k.
(d) Production of access platform, VTPCs and GAP TPC removal from the VER-TEX magnets.
(e) NA61/SHINE electronics removal.

(iii) 2019 Q2:
(a) ALICE electronics installation.
(b) Cooling upgrade (CERN help needed), 43k:
   (1) modification of cooling plates: 13k,
   (2) upgrade of cooling plants: 15k,
   (3) mounting of cooling plates and new cooling lines: 15k.
(c) Optical fibres, 25k:
   (1) optical fibres for clock/trigger and readout: 15k,
   (2) mounting of optical fibres: 10k.
(d) Low Voltage, 112k:
   (1) LV power supplies (8 pc): 87k,
   (2) LV cables and bus bars: 15k,
   (3) installation of LV cables and bus bars: 10k.

(iv) 2019 Q3:
(a) DAQ: 78 RCUs → 12 C-RORC → 6 nodes 5k each = 30k.

(v) After successful electronics test: VTPC and GAP TPC installation in the magnets.

3.2 Vertex Detector

The cost estimate assumes free transfer of incomplete ALPIDE staves from ALICE to NA61/SHINE.

(i) 2019 Q3–Q4: Component production, hardware cost 70k,
(ii) 2020: Detector installation when VTPCs are inserted back into the magnets. Read-out rack server: 2k,
(iii) 2021: Commissioning on the first beam available.

3.3 Projectile Spectator Detector

The PSD upgrade is based on the agreement between NA61/SHINE, INR (Moscow) and the CBM experiment at FAIR. The cost of the construction will be covered by INR instead of the INR CF contribution. Total hardware cost: 24k.

(i) 2018 Q2:
(a) Installation test of 8 modules of F-PSD (successful test run in May).

(ii) 2019 Q1–Q2:
(a) Construction of a long central module for F-PSD: 24k,
(b) Delivery of 4 CBM tapered modules for M-PSD and a long central module for F-PSD to NA61/SHINE,
Figure 2: DAQ upgrade schedule.

(c) March–April: dismounting M-PSD.

(iii) 2019 Q3–Q4:
   (a) Order of new FEE electronics and new MPPCs,
   (b) October–November: Full assembly of M-PSD and F-PSD with new FEE and readout electronics.

(iv) 2020:
   (a) Before April: Integration of upgraded PSD readout in common NA61/SHINE readout and commissioning on cosmic rays.

### 3.4 Beam Position Detectors

We consider two technologies for new BPD detectors:

(i) Scintillating Fibres (fibres: 10k, readout electronics: 40k, total: 50k, including spares, not including readout infrastructure),

(ii) Micromegas (cost still not estimated).
3.5 Trigger and Central DAQ

3.5.1 Trigger

(i) 2018 Q2:
   (a) Central trigger development: CAEN VME FPGA logic board: 5.2k; CFD 4.6k; Total 9.8k.

(ii) 2018 Q3–Q4:
   (a) Development and tests on beam during NA61/SHINE runs. The resulting system will be sufficient for tests during LS2.

(iii) 2020 Q4:
   (a) VME crate 6k,
   (b) Spare CAEN FPGA logic board and CFD 10k,
   (c) Trigger server 2k.

3.5.2 Data acquisition system

Figure 2 presents schedule of the DAQ upgrade. Total hardware cost: 238.5k.

(i) Central DAQ hardware 187.5k:
   (a) 2019 Q1–Q2:
      (1) 1 GbE switches: 20k (2×10k),
      (2) 100 GbE switches: 20k (2×10k),
      (3) 100 GbE NICs: 50k (50×1k),
      (4) 100 GbE AOCs: 22.5k (30×750),
      (5) Event builder servers: 75k (15×5k),
   (b) 2020 Q1:
      (1) Intel Optane Like Cards: 19.5k (30×650),
      (2) Switch to connect NA61/SHINE DAQ with EOS: 15k.

(ii) Infrastructure
   (a) 2019 Q1
      (1) Racks for high level trigger and event processing: 12k (2×6k),
      (2) Water cooling for the racks: price not estimated yet,
      (3) Electrical line for the racks: 4.5k.

3.6 DRS4 readout

(i) Table 2 lists prices to produce the DRS4-based readout with the following requirements:
   (a) BPD: 768 channels, 3 VME crates
   (b) PSDs: 512 channels, 1 crate
   (c) ToF-F: 64 channels, 1 crate together with trigger
Table 2: Cost of the DRS4-based read-out upgrade. Numbers in green show already covered costs.

<table>
<thead>
<tr>
<th>components</th>
<th>needed</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 CHF/ch</td>
<td>1408 ch</td>
<td>50k</td>
</tr>
<tr>
<td>production</td>
<td>15 CHF/ch</td>
<td>21k</td>
</tr>
<tr>
<td>VME crates</td>
<td>6 kCHF/pc</td>
<td>30k</td>
</tr>
<tr>
<td>Backplanes</td>
<td>5 pc</td>
<td>30k</td>
</tr>
<tr>
<td></td>
<td>5+3 pc</td>
<td>30k</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td><strong>69k+51k</strong></td>
</tr>
</tbody>
</table>

(d) beam counters and trigger: 64 channels

(ii) 2018: Test of prototype boards before we start mass production in 2019.

(iii) 2019:
   (a) 3 months to procure the components,
   (b) 6 months to produce the boards.

(iv) 2020:
   (a) Tests of complete system: Dell rack server (6k), 8 USB cards (1k), cables and accessories (1k+), 5 VME crates (5×6k = 30k). Total ~40k.

(v) University of Pittsburgh has 30 kUSD for 8 custom VME backplanes (including 3 spares, in production as of 2018 Q2)

(vi) UniGe has almost all components to produce 3000 ch (equivalent of ~100k)

(vii) We consider two DAQ integration solutions:
   • USB DAQ: 5 4PCI servers (3k/pc = 15k), 4 8PCI servers (5k/pc = 20k) (ToF RPC); 45 USB cards 120 CHF/pc = 6k; cables etc. 1–2k; Total: 43k
   • Custom FPGA DAQ: 13 FPGA cards 15k (total); 3 4PCI servers (3k/pc = 9k), 2 8PCI servers (5k/pc = 10k); cables etc. 1–2k; Total: 34k + manpower

4 CERN resources that will be needed

The requested a CERN technical support to NA61/SHINE presented below during the Long Shutdown 2 and needed due to the planned detector upgrades is comparable to the support provided by CERN to NA61/SHINE during the last years. Details are listed below.
4.1 VTPC removal from the magnets

(i) Beam pipe removal (CERN experts, crane),
(ii) Removal of the liquid hydrogen target and beam detectors in the target area (crane),
(iii) Removal of concrete block shielding, and possibly target area support (crane),
(iv) Reconstruction of walking platform for access to the VTPC electronics.

4.2 TPC electronics installation

(i) EN-CV help needed to organise dismounting of the existing cooling plates safely, connect new copper cooling covers in VTPCs, close unused water lines.

4.3 TPC electronics tests

(i) Cooling water:
   (a) TPC electronics will be cooled by already existing NA61/SHINE chiller,
   (b) Low voltage power supplies cooling with local chiller producing “raw” water equivalent at 18 °C, removing up to 5.2 kW of heat. The chiller is to be borrowed from EN-CV.

(ii) Magnets:
   (a) Before the VTPCs are inserted in the magnets we would like to perform measurement of the magnetic field map. This requires:
      (1) New magnetic field map measurement device from EP-DT-EF,
      (2) The power converter and the cryogenic installation upgrades to be completed,
      (3) Cryogenic installation ready: magnets need to be cooled down a month in advance, raw water needed,
      (4) Power converters require demineralised water,
      (5) The NA61/SHINE activities related to TPC electronics installation needs to be completed or temporarily interrupted.
   (b) After the VTPCs are inserted back in the magnet another test is needed to make sure the detector is ready for operation in magnetic field.

4.4 Possible upgrade of the air conditioning system in the TPC huts

(i) Upgrade was discussed with EN-CV. NA61/SHINE will investigate in 2018 whether improving insulation of the huts could be sufficient, in which case upgrade is not needed.
4.5 **Projectile Spectator Detector upgrade**

(i) Upgrade of both Forward and Main PSD requires crane to move the calorimeter modules.

4.6 **Radiation shielding**

Operation with a high intensity beam will require improved shielding in the PSD calorimeters area.

(i) EN-EA-LE will simulate radiation and shielding requirements,
(ii) RP performs measurements during the NA61/SHINE high beam intensity tests. Last test is planned for December 2018.

4.7 **Detector area clean-up**

(i) We may need CERN transport group help in removing pixel ToF-L/R and grid ToF-L/R from the MTPC hut.

4.8 **DAQ upgrade**

(i) Installation of high level trigger computers in the counting house requires new electrical and water cooling (raw water) lines
(ii) Connection of DAQ with EOS. Depending on technologies used by CERN IT we will need $2 \times 100$ GbE or $4 \times 40$ GbE, single-mode fibres and long range QSFP+ transceivers on both ends.

5 **NA61/SHINE beam request for 2021**

5.1 **Critical items and commissioning plan in 2021**

*how you plan the commissioning. What are the critical items; what determines the time scale for commissioning?*

Increase of the data taking rate to 1000 events/s necessitates the upgrades of the TPC read-out, trigger and DAQ, and the modification of the Projectile Spectator Detector calorimeter so that it can handle the high beam rate. TPC readout upgrade and TDAQ are the most critical. They require timely funding and following many steps of hardware installation. Delays would delay readout tests and integration with TDAQ.

We request the following beam time for commissioning:

(i) April 2021: two weeks of a hadron beam for the detector commissioning,
(ii) May 2021: one week of access for fixing uncovered issues,

(iii) June 2021: three weeks of a hadron beam for the detector commissioning and calibration runs.

Time between the three periods will allow us to prepare solutions in case any problems are discovered.

5.2 Beam request for physics data taking in 2021

Based on the information presented in Addendum [1] and this document NA61/SHINE requests the following beam periods in 2021:

(i) October/November 2021: 5 weeks of proton beam at 31 GeV/c for data taking for neutrino physics,


The requested 5 weeks of data taking for neutrino physics are needed to improve measurements of hadron flux from the T2K replica target (28 days) and measurements of hadron production on a Super-Sialon thin target (7 days) as discussed in Addendum in Secs. 8.1.1 and 8.1.3 [1].

The requested 4 weeks of data taking for heavy ion physics are needed for measurements of charm production in Pb+Pb collisions at 150A GeV/c as discussed in Sec. 4 of Addendum [1]. The run will allow to record about 30% (about 150M events) of the total statistics of events for this reaction (Pb+Pb at 150A GeV/c) requested in the Addendum. This would allow to get key results on charm hadron production in central and mid-central collisions, see Table 3 in Addendum [1]. The collection of the remaining event statistics will be the subject of a subsequent request to the SPSC for running in later years. It will allow to obtain important results for peripheral Pb+Pb collisions, see Table 3 in Addendum [1].
References