Report from the Inner Detector Integration Task Force (ID-ITF)

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B. Azmoun, M. Chiu, K. Dehmelt, P. Giannotti, D. Lynch, R. Nouicer, R. Pisani, R. Ruggiero, W. Sondheim, G. Stephans

We report on the conclusions from a task force set up to consider the integration of the four inner detectors of sPHENIX: the MB trigger detector, the TPC, the MVTX (formerly MAPS), and the INTT. The required cabling for services, such as power, cooling, and signals from each detector is summarized, as could best be determined from each group. A first plan for the cable routes in the detector inner region is proposed that attempts to minimize conflicts and the materials impact on physics measurements. Several open issues are identified, particularly regarding the integration of the MVTX and INTT detectors.

1. Inner Detector Integration

The integration of the inner detectors into sPHENIX requires a comprehensive plan to optimize the performance of the detectors while preventing interference between them. A task force was set up by E. O'Brien to come up with such a plan, with M. Chiu and B. Azmoun as co-chairs, and expertise supplied by D. Lynch and R. Ruggiero for mechanical engineering, R. Pisani on cooling and gas, P. Giannotti on electrical (see Appendix A). The detector representatives were M. Chiu for the MB detector, K. Dehmelt for the TPC, R. Nouicer for the INTT, and W. Sondheim and G. Stephans for the MVTX.

The task force members, together with other experts, have held several meetings since early March in an effort to gather all pertinent information to answer the charge put forth by Ed. Once this information was compiled, the possibility to integrate the four inner sPHENIX subsystems was evaluated, resulting in the identification of several critical issues. Most notably, interference between the MVTX and INTT detectors was a main focus of the task force, along with the requirement that the INTT cables must be extended to the endcaps of the TPC. Ultimately, these concerns, along with other identified conflicts, are being resolved through the cooperative efforts of the task force. The purpose of this report then, is to elaborate on these issues and to describe some proposed solutions.

A general set of guidelines was proposed in the task force to facilitate the optimization of the performance of these detectors when integrated into sPHENIX. These guidelines are

- Ensure that each subsystem gets the required space it needs to operate fully, without interfering with other subsystems
- Require that any integration of the detector allows it to meet the requirements of the baseline sPHENIX physics program
- Minimize material that may affect any part of sPHENIX's physics program through increased albedo or direct interference
- Consolidate material for services such as cables into de facto dead areas, to reduce the effect of the material
- Take into consideration the possibility of future possible upgrades (fsPHENIX and ePHENIX), where feasible
- Allow for reasonable access to critical components of each subsystem for maintenance, where feasible

The task force finds that while many details still need to be worked out, such as engineering drawings for the detector supports, great progress has been made in determining whether the four inner subsystems can be reasonably integrated into sPHENIX and satisfy all of the above guidelines. More work needs to be done in the design of the support structures and the routing of the cables to ensure that the added materials do not interfere in the physics program.

Overall, the TPC and MB detector integration does not seem to pose much of a concern, but the INTT and MVTX currently have major conflicts with each other since there is a spatial overlap between the two detectors and their services. As detailed below, the task force believes the conflict can be overcome, but we are waiting on an official declaration that the solutions proposed are feasible. Besides this spatial conflict, there is another challenge, which is being addressed by present INTT R&D, concerning the length of the extender cable (1.2 m required) connecting the HDI cable and readout card (ROCs) assumed to be located at the TPC endcap. The final major concern identified by the task force is the small clearance (1.3 mm) between the innermost MVTX layer and the beam-pipe, which creates a challenge in the installation since any mistake may rupture or damage the pipe.

2. Subsystem Reports

This section enumerates the input from each subsystem regarding the basic mechanical and electrical support that each subsystem will require within sPHENIX. Don Lynch has requested detailed system specifications from each subsystem group in order to define these requirements and has compiled this information into an Excel spreadsheet, which may be found in the appendix. The following is an overview of this information.

2a. Minimum Bias Trigger Detector (MB)

The PHENIX BBC will most likely be re-used in sPHENIX, serving nearly the same purpose but placed at z between 250 and 300 cm from the interaction point on the north and south sides. The signal cables are just long enough to reach from the FEE rack to the BBC if the FEE rack is placed along the mid-line of sPHENIX. The cables add up to a cross-sectional area of 4.5 sq. in (29 cm^2), on each arm, for a total of 9 sq in (58 cm^2) combined.

Mechanical Support: The weight of each arm is just 34 lbs (15.5 kg). A detailed design for the support has not been done. In sPHENIX at 250 cm < |z| < 300 cm there is ample clearance to place the supports so mounting should not be an issue. However, the BBC ID is 3.94" (10 cm), which directly interferes with the north beam-pipe used in PHENIX which has an OD of 5" (12.7 cm). In the south the beam-pipe OD is 3" (7.62 cm) at the proposed MB detector locations, but it then transitions to a 5" (12.7cm) beam-pipe at z = -330 cm. If sPHENIX moves on its rails southward more than about 30-80 cm, it will cause the BBC to crash into the south beam-pipe. Thus, there is a good chance the south beam-pipe may also need to be modified, to allow for southward movement of sPHENIX. Ideally a 3" (7.62 cm) OD aluminum beam-pipe should be extended from the central Be beam-pipe to as far as needed on both the north and south sides.

Signal: There are 64 channels on each side. Andrews air core cables are used to bring the signal to the FEE rack. At the PMTs, and at the rack, short (12 in) RG174 cables are used to patch to the Andrew's cable. The signal cables cover a cross-sectional area of 3.2 sq in (20.6 cm^2) for each side.

HV: 4 RG58 HV cables are needed for each arm, requiring a bundle of at least 0.2 sq in (1.3 cm^2) on each side.

LV: No LV cables are needed to the detector.

Peripheral sensors: 26 thermocouples in each arm monitor the PMT temperatures to protect against overheating, requiring a cable bundle of at least 0.32 sq in ().

Cooling: The total heat load is 384W, or about 3W per phototube. As in the early years of PHENIX, the cooling will be provided by 250 lpm of cooled air from the C-A supply. This should keep the temperature cool and constant to within the design spec of ±2 deg C. Eight ½" polyflow hoses will be used to bring the air to the detector, requiring at least 0.8 sq inches (5.2 cm^2) in a bundle. Note that in the later years of PHENIX nitrogen was used for the BBC cooling due to an incident where water came through the C-A air supply. A safety system is currently in place to prevent that from happening, so in the future it should be safe to use the C-A air supply.

Calibration: Two small fibers, one for each arm, bring laser (or possibly LED) flashes for gain monitoring and calibration during running. They occupy 0.1 sq (0.64 cm^2) on on each side.

Maintenance/service needs: While not necessary, the location of the sPHENIX BBC may be conducive to access during maintenance days, so it would be beneficial if that can be designed in.

Integration: There are no foreseen integration issues regarding the MB trigger detector, except that both portions of the detector will be mounted inside the steel doors of the magnet. In the baseline sPHENIX design there are no other subsystems in this area, we anticipate that there should be ample room available.

Other known issues: The placement of the MB detector may interfere with the forward magnet piston in the fsPHENIX upgrade, as well as other possible future upgrade detectors. The BBC is likely to be removed for ePHENIX, and thus does not pose a problem during the EIC era.

2b. Time Projection Chamber (TPC)

Mechanical Support: The TPC will consist of

1. Outer Field Cage, length 83.1” (211.1 cm), outer radius 30.7” (78 cm)

2. Inner Field Cage, length 83.1” (211.1 cm), inner radius 7.87” (20 cm)

3. Two end plates closing the outer and inner field cage and equipped with a total of 72 readout modules; maximum longitudinal extension 4.25” (10.8 cm), maximum radial extension 31.7” (80.5 cm)

4. Front End Electronics (FEE) Cards attached to the readout modules; 300 cards per end plate, extending to about 4” (10.2 cm) from the end plate. Since it was recently decided to equip the innermost readout modules (R1) with rectangular pads of size 1 mm x 10 mm (r-phi x radial) it would require to double the FEE cards in R1. However, if the decision will be made not to connect the pads in the innermost 10 cm (radial direction) the number of FEE cards would remain the same.

Two brackets will be mounted to either end plate which is attached to either outer ring of the inner HCAL (see Figure 2.1).

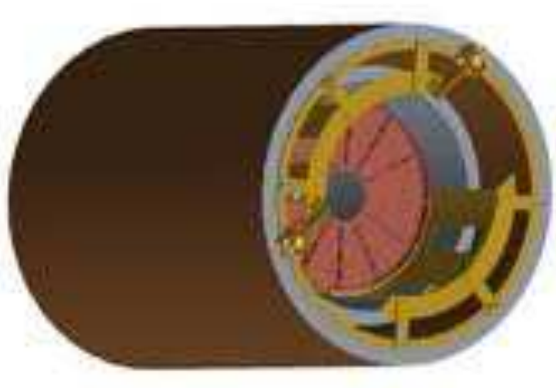


Figure 2.1: TPC mounted to the end rings of the inner HCAL. The red area depicts one of the TPC endplates, the yellow brackets are attached to the end plate and to the end ring of the inner HCAL.

Signal: 24 pre-terminated MTP (F) 48F - MTP (F) 48F trunk fiber cables will be connected to each end plate. Thus, a total of 48 cables will come from the FEE cards attached to the modules on the end plates with a length of about 20' (610 cm) each to the patch panels.

HV: Three different types of HV cables are needed for the TPC.

1. One RG-58/CU cable with SHV connectors on either side will be connected to each module (36 per end plate) with a total length of 27' (823 cm) from the end plate to the on-carriage rack (position TBD).

    a. Alternatively, the HV power supplies can be in form of DC-DC converter modules on the module backplane. This requires a LV PS with #10 AWG double stranded cables connected to each module (36 per end plate) with a total length of 27' (823 cm) from the end plate to the on-carriage rack (position TBD).

2. Two RG-58/CU cables will be connected through each end plate to the inside of the outer field cage and with an SHV connector to a HV module in the on-carriage rack (position TBD). The length of these cables will be 27' (823 cm) each.

3. One #18 AWG with an outer diameter of 0.4" (1 cm) will be connected through one end plate to the inside of the outer field cage up to the central membrane. The other side of the cable will be 27' (823 cm) long and connected to the on-carriage rack (position TBD).

LV: 98 times #10 AWG double stranded cables per end plate, with an outer diameter of 0.42" (1 cm) will be connected to the FEE with total length of 27' (823 cm) from the end plate to the on-carriage rack (position TBD).

Peripheral sensors: Possible peripheral sensors are expected to be

1. 80 thermocouples per end plate, 72 to be positioned on the modules and 6 to be fed through the end plate toward the gas volume. Four multi-pair (3 x 24 pairs + 1 x 6 pairs) cables per endplate, length 27' (823 cm) each will be routed from the end plate to the on-carriage rack (position TBD).

2. 16 Hall sensors over the surface of the outer field cage, with cables TBD. Each Hall probe will have to be connected via an extension cable of length 27'+ (823 cm +) from the place on the field cage to the on-carriage rack (position TBD).

Cooling: The detector total heat load comes predominantly from the FEE + optical module + LV power supplies with ~4.7kW per endplate. The plan is to use a water or water/glycol mixture to remove the heat generated at the endplates. They system will run at slightly below ambient (~20C +/- 3C). It will be remotely monitored and fully interlocked to maintain optimal operating conditions and prevent damage to the detector. The system will also be manifolded based on endplate segmentation to improve temperature uniformity across the encaps and isolation in case of need.

Detector Gas: The gas mixture will be based upon Neon; the present candidate is Ne-CF_4 90-10. The gas flow rate is expected to be six volume exchanges per day (1 m^3/hr), in a closed loop. Six ¼” (0.6 cm) NPT fittings with each 3.5’ (107 cm) SS flexible tubes connected to one manifold per end plate with a manifold adapter six times ¼” (0.6 cm) to 1.5” (3.8 cm). Output is then 1.5” (3.8 cm) SS flexible tube with an outer diameter of 2” (5.1 cm) of 30’ (914 cm) length from the end plate region to the patch panel.

Slight overpressure (~1-2 mbar {0.8-1.5 Torr}) relative to ambient pressure will be controlled, i.e., absolute gas pressure is varying. Temperature is requested to be held constant, possibly +/- 3K.

Calibration: A laser calibration system is foreseen. Opto-couplers will be attached to predefined feed-throughs on each end-plate which will be connected to optical fibers. System TBD.

Maintenance/service needs: In case of any failure of any part of the readout module (hardware, FEE, cables, etc.) we need to access the end plate under consideration.

Integration: The planned TPC cylindrical envelope poses no interference issues with respect to the surrounding detectors. However, we stipulate that no subsystem may use any part of the TPC structure (including the aluminum endcap wheel) for the purpose of structural support, since the TPC structure was designed to sustain itself, without regard for additional load. We also propose to have the services from all surrounding subsystems “shadow” the spokes of the aluminum TPC endcap wagon wheels whenever possible, in an effort to consolidate as much service material into this de facto dead area.

Other known issues:

Hall probes will be mounted and cabled on the surface of the outer field cage. Tie rods and tie rod scallops break the envelope, but are approved by sPHENIX engineering. This broken envelope layer will fit all Hall probes. Thermocouples will be attached to the end plates.
It was recently decided to equip the innermost readout modules (R1) with rectangular pads of size 1 mm x 10 mm (r-phi x radial) it would require to double the FEE cards in R1. This would increase the also the number of cables (LV, fibers) accordingly. If the decision will be made not to equip the innermost pads (r = 20 cm - 30 cm) the issue would be resolved.

Comment: The end plate will have spokes and each will be “equipped” with a number of threaded holes. These holes will serve as attachment support for 3D printed cable trays in which all cables for the TPC will be distributed.

2c. Intermediate Silicon Strip Tracker (INTT)

As shown in figure 2.2, the INTT consists of four layers of barrel (layers 0, 1, 2 and 3) silicon semiconductor strip detectors with the following radii: 6, 8, 10 and 12 cm. The acceptance of the INTT tracker for layers 0, 1, 2 and 3 is 2π in azimuth each, and for a vertex at 10 cm the coverage in pseudorapidity is ±1.12, ±1.27, ±1.10, and ± 0.95, respectively.

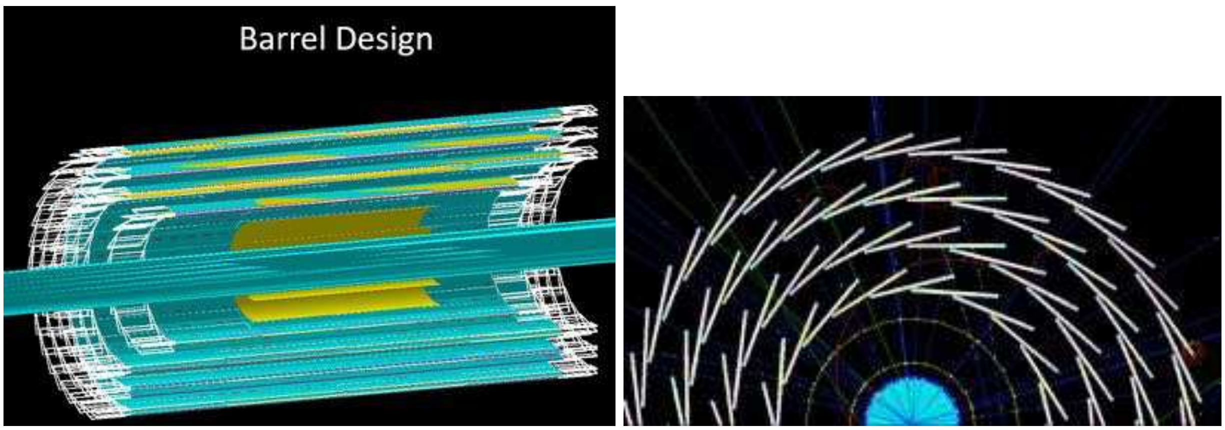


Figure 2.2: Side and front Views of the four INTT layers of barrels silicon strip detectors.

As shown in the figure 2.3, each layer of barrel silicon strip detector is composed of several ladders. Barrels 0, 1, 2 and 3 consist of 20, 26, 32, and 38 ladders, respectively. Each ladder is made of two half ladders mounted on the same Carbon-Fiber-Composite stave. Each half ladder is read out from one side and is composed of: (1) Two AC coupled, single-sided silicon strip sensors produced by Hamamatsu Photonics Co. (HPK). (2) One flexible circuit board, called High Density Interconnect (HDI); each HDI provides power, and bias input lines as well as slow control and data output lines. The HDI was manufactured and tested by Yamashita Company. (3) On top of each HDI, twenty six FPHX chips are mounted. The FPHX chip consists of a 128-channel front-end ASIC, and was designed by Fermilab for the FVTX detector. The chip was optimized for fast trigger capability, a trigger-less data push architecture, and low power consumption (64 mW/chip). Each ladder is 40 cm (layer 0) or 50 cm (layers 1-3) long, and has 36.464 cm (layer 0) and 46.452 cm (layers 1-3) of silicon. The ladders form the rigid part of the system, leaving flex HDI cable on the outer ends of the ladder. There will be some connectors, such as the barbs for the cooling inlets, which will extend the ladders beyond their currently known size by a few cm. The HDI ends will be connected to an extender cable which is connected at the other end to a FVTX ROC used in PHENIX. The extender has to be at least 1.2 m long (and possibly longer) to reach the ROCs, which are in a “big wheel” arrangement on the inner part of the TPC endcap.

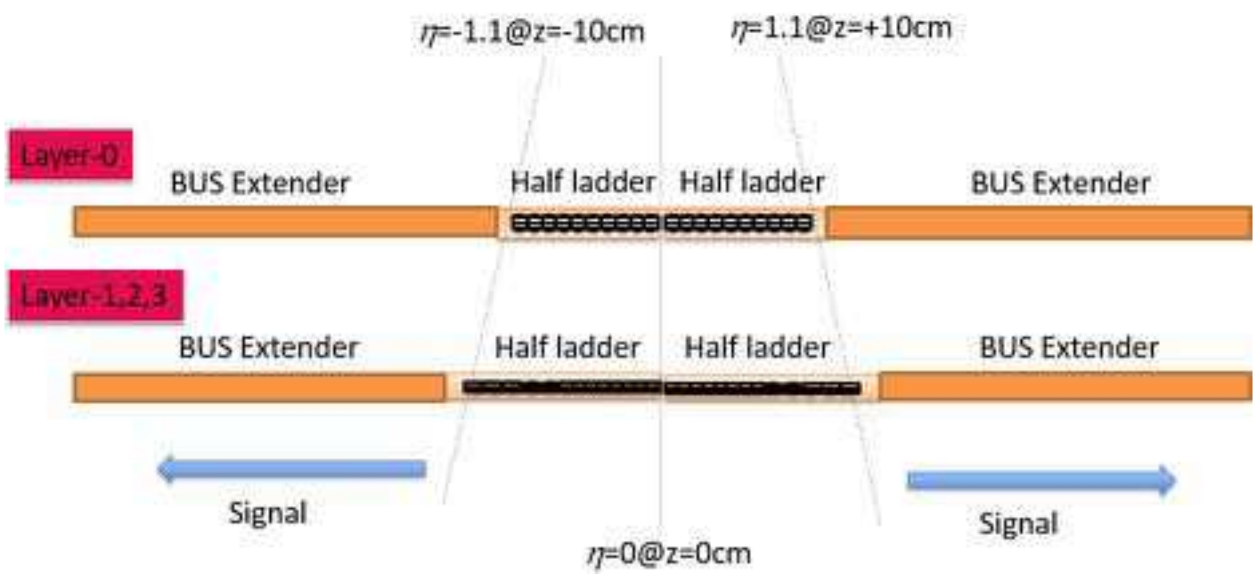


Figure 2.3: INTT ladder configuration for layers of barrels silicon strip detectors.

Mechanical Support: The INTT will be integrated into a dual hemisphere support frame (upper and lower). Each frame hemisphere will have a 3 point support onto a dual rail and bearing system in which the bearings will slide along pathways on the rail which allows the upper and lower frames to ride in separately and move away from the beam pipe until the frames have cleared the beam pipe flanges. The lower frame is positioned first, then the rail is adjusted in 3 dimensions to achieve the alignment precision required. Then the upper frame is brought into position and is mated to the lower frame by kinematic mounts. It is almost certain that the same external supports and rail system will need to hold both the INTT and the MVTX. As a result, it will not be possible to install or remove either detector while the other is already installed. However, the support system should allow installing either of the detectors alone in the absence of the other.

Signal: The signal is carried out from each ladder through the extender cable to the Read Out Card (ROC). Each ROC can read twenty ladders simultaneously. From each ROC to patch panel located at the IR, the signals are carried out by 4 x 12 fiber optical data cables. The length of each fiber optical cable is 10 m.

Bias voltage (HV) for each half ladder: Each ladder requires a bias voltage, and it is supplied through one bias voltage cable 1.5 mm thick, 10 m long and with hirox coaxial connectors at each end. The HV cable connects the HDI bus to the bias voltage power supply. We need 116 x 2 = 232 bias voltage cables.

LV for each half ladder: The low voltage of each half ladder is provided by the ROC through the extender cable. From each ROC to the low voltage power-supply, we need 4 cables with 16 pin connectors each. The length of each LV cable is 10 m, and we need 4 x 24 cables in total.

LV for the ROC: Each ROC requires one low voltage cable with 22 pin connectors. Total thickness of the cable is 8.8 mm, and the length is 10 m from the ROC to the power supply in the IR. We need 1 cable x 24 ROCs = 24 cables in total.

Slow Control: Each ROC is required to have one duplex fiber optical cable for slow control. The total length of the cable is 10 m and 1 x 24 cables are needed.

Clock Cable (ROC to clock board): From each ROC to the clock board, we need one cable with 8 pin connectors. The length of this cable needs to be determined because it depends upon the clock board location which should not be far from the ROC (less than 5 m).

Temperature sensor: Each ladder contains two thermistors (NCP15XH103D03) allowing us to read the temperature of each half ladder. The thermistors are part of the HDI (built in) and they are read out from the edge of the HDI. From each HDI, we will have one cable going to a readout board. The thermistors and readout board have been determined by Stephen Boose for sPHENIX and he is using them currently.

Cooling: Each ladder is mounted on one Carbon-Fiber-Composite (CFC) stave.The ladder contains a graphite sheet which carries out the heat of each ladder to the top edges of the stave. Each edge of the stave is connected to a Ring which is cooled down. The temperature of each ladder should be at 10 degrees Celsius during operation. The heat load expected from each half ladder is: 390 uW x 128ch x 26 chips = 1.3 W ≃ 2 W (including power). The total heat load over the entire INTT is ~300 W.

Calibration: No cables are needed for calibration.

Maintenance/service needs: Maintenance (or repair) is needed in case of failure of any INTT tracker components located on the TPC endcap such as the ROCs, cables, or clock boards. However, the task of repair will be planned and scheduled well ahead of a maintenance day.

Integration: See below in section 5 Mechanical Support/Integration.

2d. MAPS Vertex (MVTX)

The MVTX detector consists of 48 detectors ladders (staves) arranged in 3 layers of 12, 16, and 20 staves each. Services for each stave are routed through a conical fanout structure to a patch panel at one end of the detector. Figures 2.4 and 3.1 show some of these inner structures. In the following, only the cabling and other services after that patch panel are listed.

Fig. 2.4: ALICE MAPS enclosure (yellow sheath), and the detector staves fanned out to service cone supported by patch panel. On the far right is a single stave connected to a "service cable", which feeds into the patch panel.

Mechanical Support: The plan is to use a modified version of the support system used for the MAPS detector in ALICE. All mechanical support is cantilevered from one end. The ALICE system uses a conical structure, called the "service cone", which connects to the support ring at the end of the fanout cone (outer support of fanout shown at the left of Fig. 2.4, with some inner details for one detector layer shown in the center). This service cone, as well as the scheme of routing cables along its inner surface, will need to be redesigned to accommodate the other inner detectors in sPHENIX.

Signal: Data and control signals are carried by flexible shielded-twisted-pair flat cables, one per stave for a total of 48 cables. Each cable has 9 data lines (one per Si detector on the ladder) plus 3 control lines. Commercial cables similar to Samtec Twinax will be used. Exact dimensions are not yet know but a conservative upper estimate is that they will be no more than 4 mm thick by 30 mm wide.

HV: None.

LV: The Si detectors do not require high voltage but do have a low bias voltage. There is one RS bias cable per stave for a total of 48 cables. These will be single-line shielded cables. Exact dimensions are not yet known but a conservative upper estimate is that they will have an OD no more than 3 mm.

Power: The Si detectors and on-board electronics require both digital and analog power lines. The digital power input and output lines will most likely run in two individual shielded wires per stave for a total of 96 cables. Exact dimensions are not yet know but a conservative upper estimate is that they will have an OD no more than 3 mm.

The analog power input and output lines will most likely run in 2-wire twisted-pair shielded cables for a total of 48 cables. Exact dimensions are not yet know but a conservative upper estimate is that they will have an OD no more than 4 mm.

Note that the total power for the MVTX is not very high, only 120W, 2.5W per stave.

Peripheral sensors: None.

Cooling: Each stave will have a separate cooling inlet and outlet tube, for a total of 96 plastic tubes (Elastollan). Near the fanout patch panel, these tubes will have a 4 mm outer diameter. Details remain to be worked out but it is likely that before they exit the inner bore of the TPC, the tubes will need to transition to 6 mm OD for the inlet and 10 mm OD for the outlet. Flow requirements are modest, a total of 144 L/hr of water at 20 degrees C (3 L/hr in each tube). The detector will also require air cooling, the current ALICE design specifies 10-15 m^3/hr of dry air at 20^o C.

Calibration: None.

Maintenance/service needs: TBD.

Integration: The ALICE design for the fanout cone interferes with the INTT (see below).

Other known issues: The radial location of the inner MVTX layer will be very close to the beam pipe, probably as close as CAD safety requirements will allow. The Al section of the beam pipe, and especially the flange at the end of the Al section, prevent the installation of the full MVTX around the beam pipe outside of the TPC bore. As a result, the detector will need to be maneuvered into place as two separate pieces that come together only very close to the final detector location surrounding the center of the interaction region. A rail system similar to that described above for the INTT will be used.

3. MVTX/INTT Integration Issues

Early on it was recognized that the MVTX and INTT detectors interfere severely with one another. The main issue is illustrated by the following sketch in Fig. 3.1, which shows the active region of the 4 detector layers of the INTT interfering with the service-fanout cone of the MVTX detector. The ladders (rigid portions) of the INTT are 40 cm (layer 0) and 50 cm (layers 1-3) long. Note, however, that clearance has to be allocated beyond the ladders for the INTT. This is required to make space for cables, and also the not yet designed support structures and cooling barbs to the ladders. It is estimated that perhaps 5 cm, but maybe more, will be needed.

One proposal to create this clearance is to simply move the fanout cone for the MVTX further out along Z by about 15-20 cm, which will be enough for the MVTX services to clear the envelope for the INTT. This will provide a further benefit since the MVTX cone runs right along the angle for $|\eta| \sim 1.1$ emanating from points close to the end of the specified 10 cm interaction region along the beam line. Along this angle there is a lot of integrated material from the cone and thus provides a potentially large source of background for events near the edges of the sPHENIX fiducial kinematic acceptance.

Moving the cone southward requires lengthening by about 15 cm the patch cables that connect the data, power, and cooling services to the MVTX ladders from the patch panel at the end of the cone (see the two views shown in Fig 3.2 below). This allows the fanout cone to be pulled out of the way of the INTT envelope while also minimizing the material in front of the fiducial acceptance of the TPC. The cables connect to the edge of the MVTX staves and run to the panels at the endcap of the cone. If enough space is cleared, the INTT HDI cables, which are flexible, can then run around the outside of the MVTX fanout cone and lead to the outside, using the radial space between 12 and 20 cm. However, at the time of this report it is not known whether these patch cables can be extended.

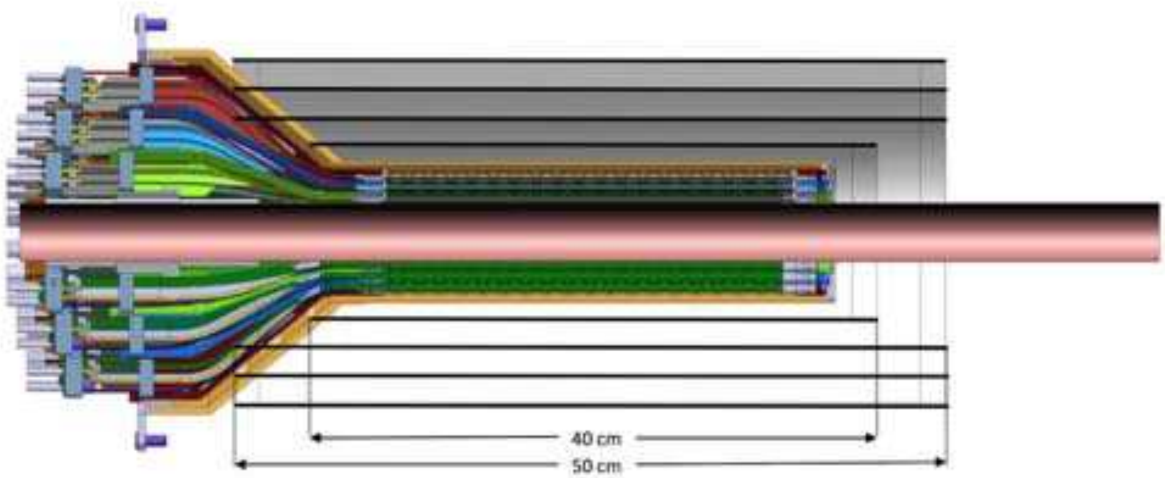


Fig. 3.1: Cross-sectional views of ALICE MAPS detector (to be modified for sPHENIX), shown with the proposed INTT active area for the four barrel layers (in gray). The 4 INTT layers are 40 cm (layer 0) and 50 cm (layers 1-3) long and represented in the thick black horizontal lines. The left side clearly conflicts with the ALICE MAPS cone.

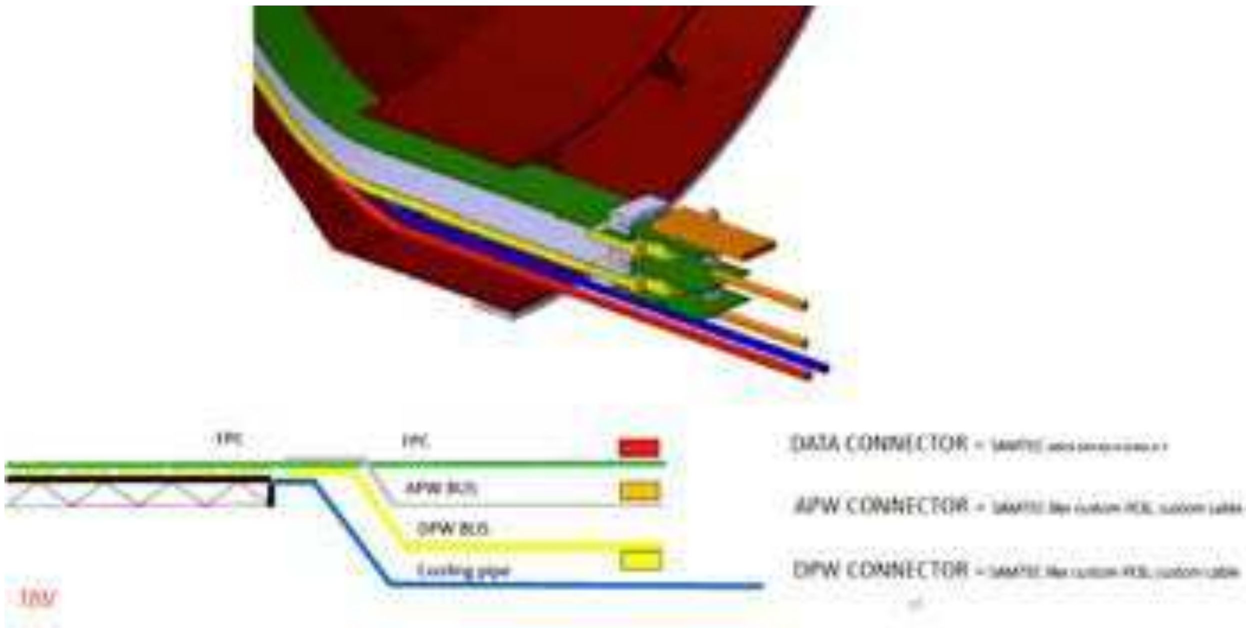


Fig. 3.2: Zoomed in view of service cable supporting data, power, and cooling to/from the detector. These services feed directly from the ladder to the patch panel.

A second option for solving the INTT-MVTX interference would be to extend the cylinder of the main MVTX section out to z = -50 cm, and then fan out to the patch panel. In other words, the new cone would start at z = -50 cm, and have an abrupt angle of 60^{o} from there, instead of the current 45^{o}. Since the cables already fit inside the MVTX cylinder (as seen from the left end of the MVTX ladders in fig 3.1), they should be able to be squeezed in a longer cylinder for another 15 cm. Still to be determined is whether the cables can then be fanned out from there in an abrupt cone and still reach the patch panel. One could attempt to reduce the size of the patch panel to make the fan-out more feasible, and the possibility of this is being studied by W. Sondheim.

As mentioned previously, the MVTX provides very little clearance to the beam-pipe. The closest point of the innermost MVTX layer is only 1.3 mm from the beam-pipe. This can be compared to the 3 mm clearance that ALICE has designed into their system. The 1.3 mm may be beyond the tolerance of any reasonable mechanical scheme for positioning within the inaccessible region inside the center of sPHENIX. In addition, while no one has consulted C-AD, they may complain about placing a detector so close to the Be beam-pipe, with the danger of breaking the pipe. At present, W. Sondheim is looking into whether the inner layer of the MVTX can be repositioned radially outward by 1-2 mm to provide more clearance to the beam-pipe. If this is not possible, either a mechanical solution must be devised to place the silicon-tracking assembly with 100 um tolerance from a 1.5 m distance, or a new beam-pipe will need to be procured.

4. INTT Extender Cable issue

The length of the extender cable connecting the HDI cable and readout card (ROCs) located on the TPC endcap is required to be at least 1.2 m, and possibly up to 1.4 m. Previously with the FVTX, the cables from the ladder to the ROCs were only ~0.3 m, so this is an untested configuration. It should be pointed out that this concern is already being addressed by present INTT R&D, where the INTT group is exploring using alternate cables which they believe provide adequate transmission of the LVDS signals over the 1.2+ m required length. A similar problem was solved using standard FPC cables by the PHENIX MPC-EX detector for even greater lengths than 1.2 m. The extender cable for the INTT will need to bring all signals from the HDI to the ROC board and power from the ROC board to the half ladder, and have a similar stack-up design to the HDIs.

5. sPHENIX Mechanical Support

5a. Envelope and Interface Control

In order to set boundaries and stay clear regions to be adhered to by all detector subsystems and support services infrastructure, the sPHENIX engineering group has established an sPHENIX Envelope Control drawing. Any changes to the envelope drawing requires sPHENIX management and sPHENIX engineering approval and require a revision to this drawing. A pdf copy of sPHENIX drawing number SP00-000-000 is attached as Appendix B to this report. This drawing will require revision to fully reflect the Inner detectors' envelopes.

In addition, each detector subsystem will have an Outline/Interface drawing that describes the pertinent external dimensions and specifications for physical interfaces, structural support, and services. The Outline/Interface drawings for the Inner detector subsystems are in progress. A preliminary version of the TPC Outline/Interface drawing is attached to illustrate a typical layout for such a drawing. The envelopes are graphically represented as shown below.

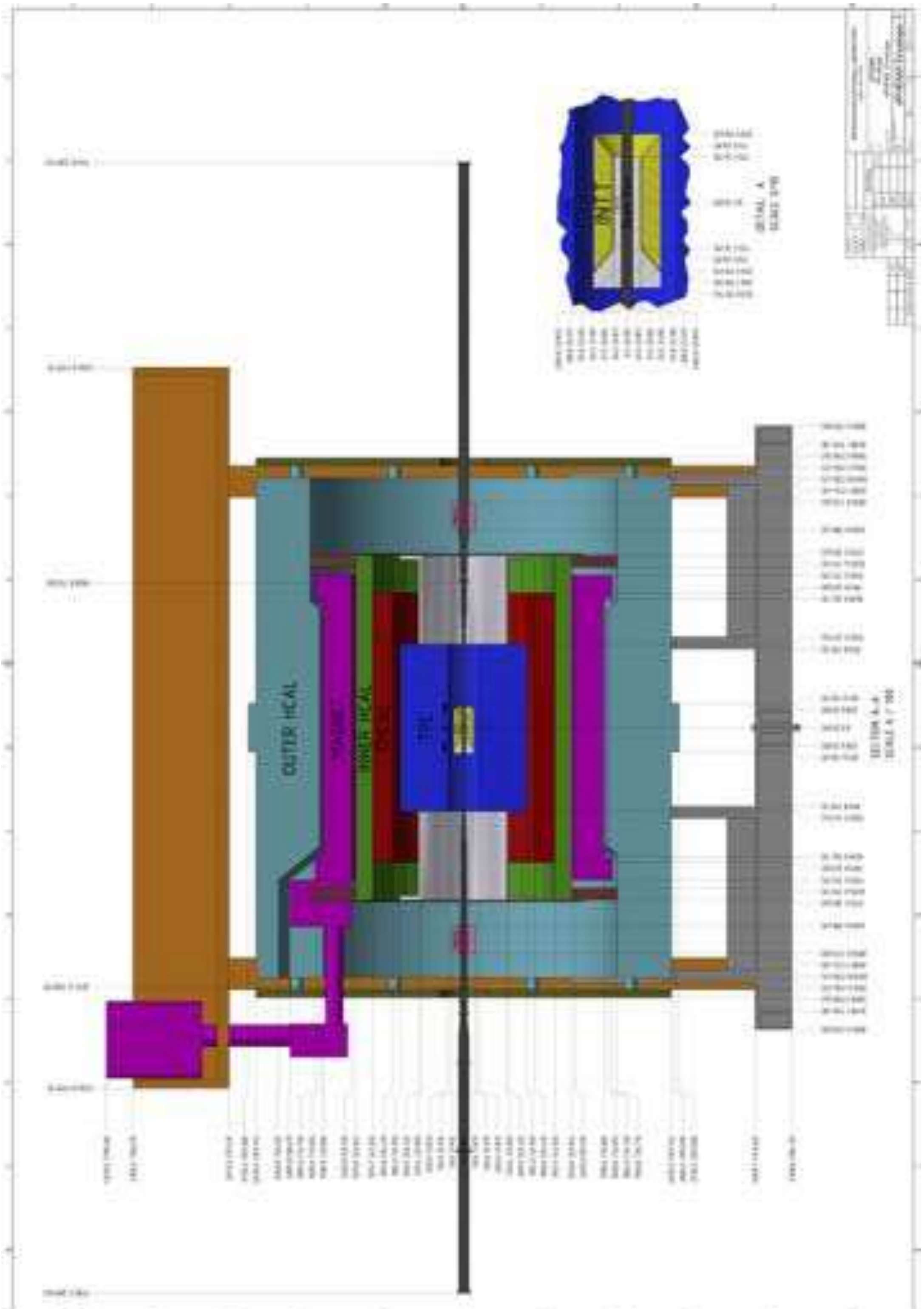


Fig 5.1 (a) sPHENIX Envelope Control Drawing, sheet 1

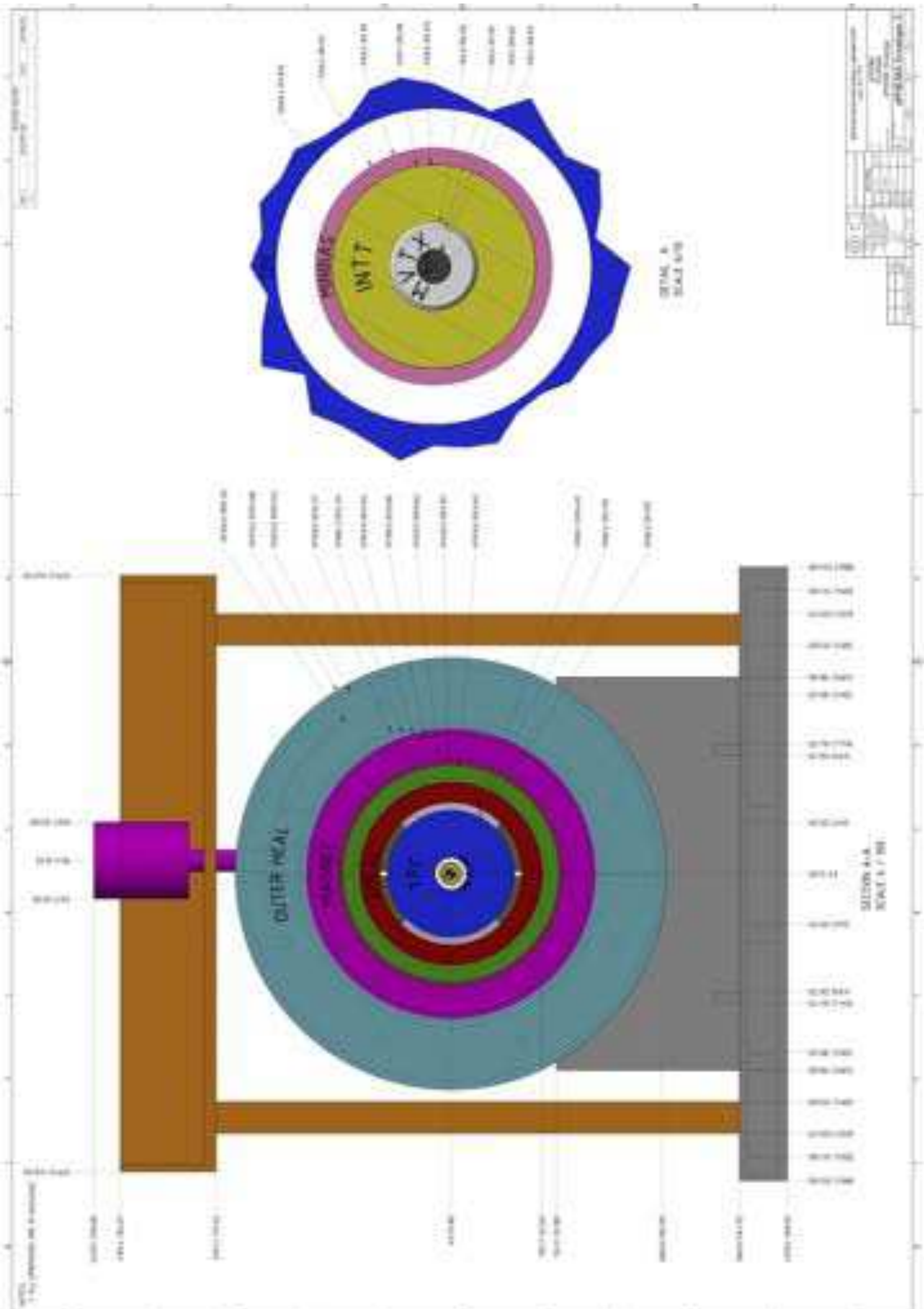


Fig 5.1 (b) sPHENIX Envelope Control Drawing, sheet 2

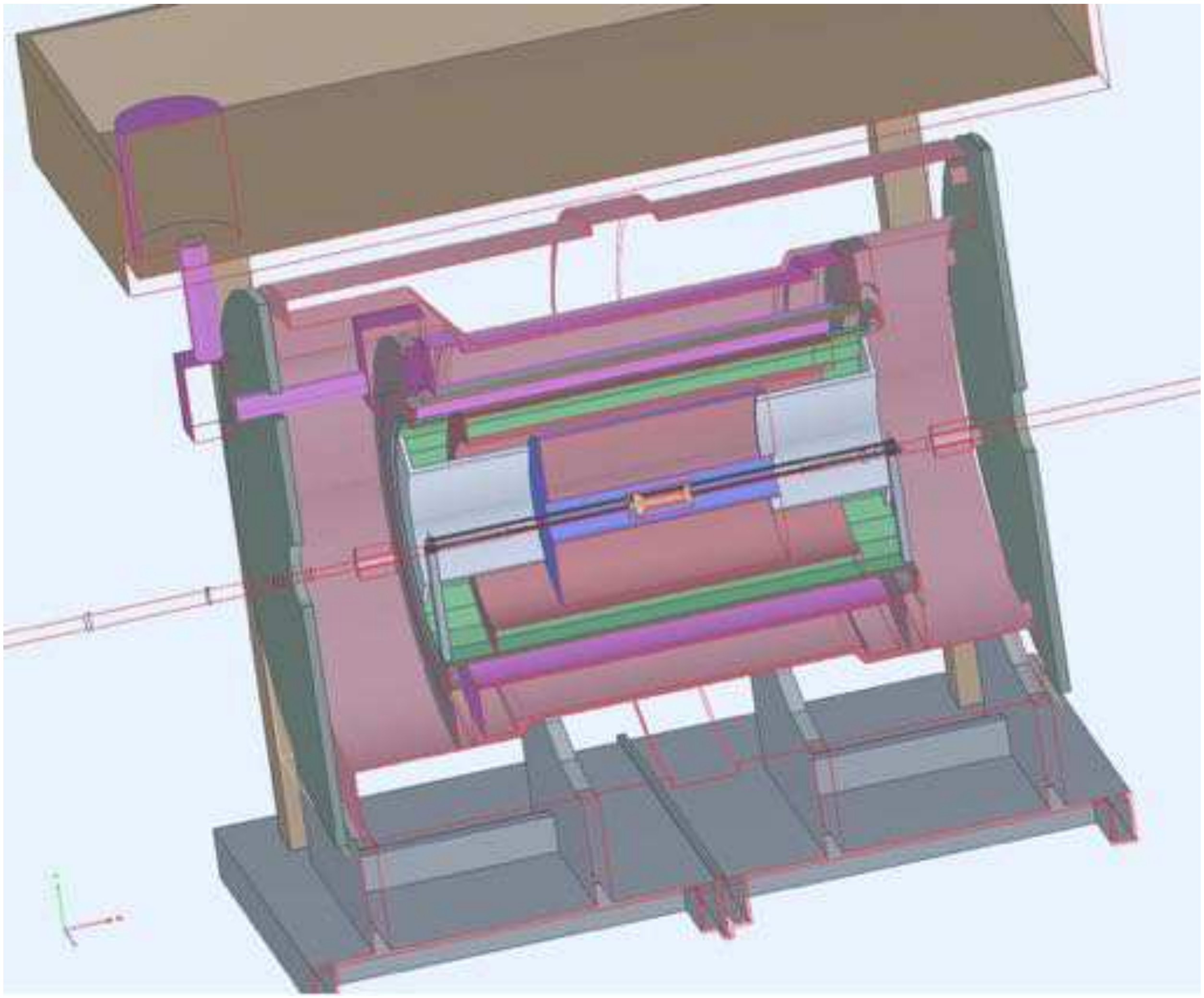


Figure 5.2 Cutaway of sPHENIX detectors, installed.

5b. TPC Support structure

The TPC will be supported by 2 ¼ “tophat” bracket, which in turn will be attached to the Inner HCal support ring. Detailed mechanical design of these items is in progress.

5c. MVTX + INTT support structure:

The MVTX and INTT detectors will be mounted to a common support structure, so that they will move in and out of the TPC bore together. However, it is essential that the mount allow the possibility of installing either of the two detectors alone if the other one is not present. In the case that the MVTX is not installed but the INTT is, this mount should not place inert material in the acceptance of the INTT. There were some requests to have a mount which allows the separate installation and/or removal of the INTT and MVTX detectors into the bore-hole. This is extremely difficult, and adds unnecessary complication with little benefit. We do not foresee any operational or maintenance issue which would make it undesirable if the mounting scheme required the two detectors to move into and out of the TPC bore together.

5d. Min Bias support structure:

The Min Bias support structure will be similar to the support structure of the BBC in the PHENIX detector experiment. Details of this structure have not yet been designed.

Figure 5.3 is an early concept of the mounting structures for the sPHENIX inner detectors.

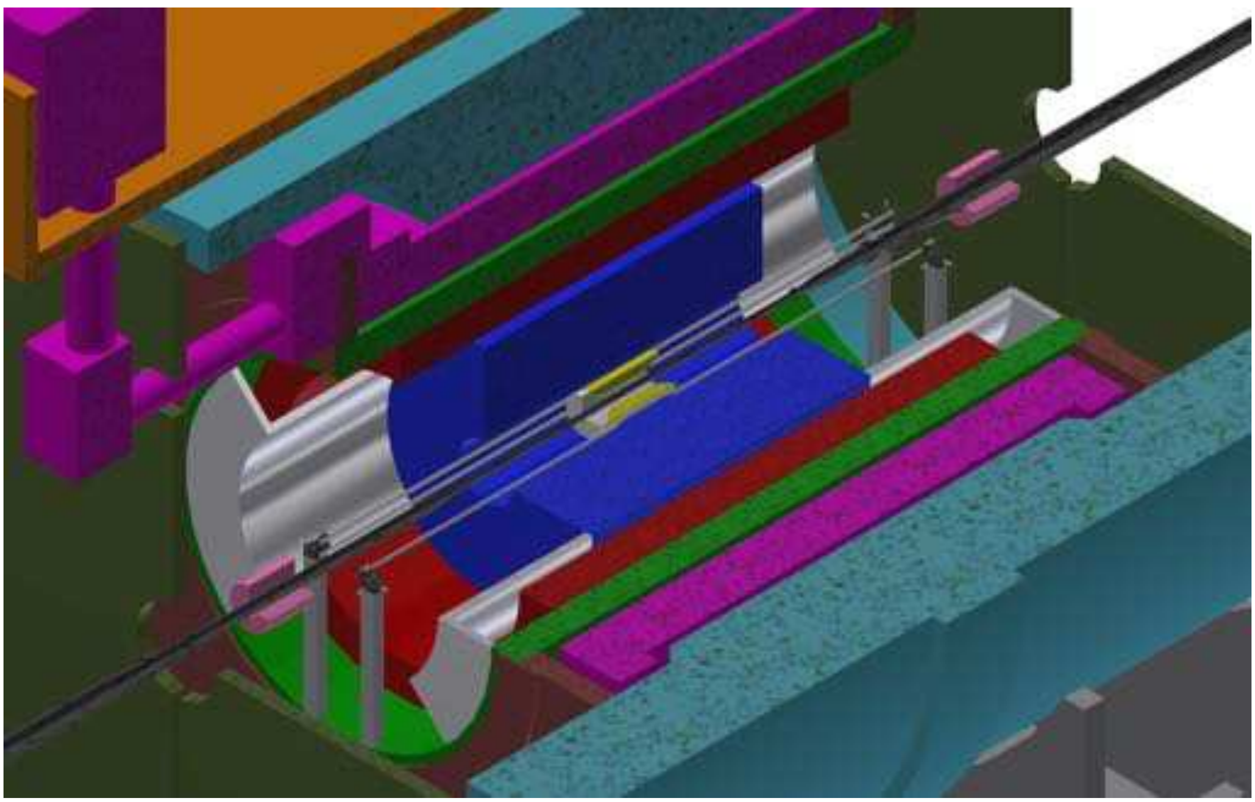
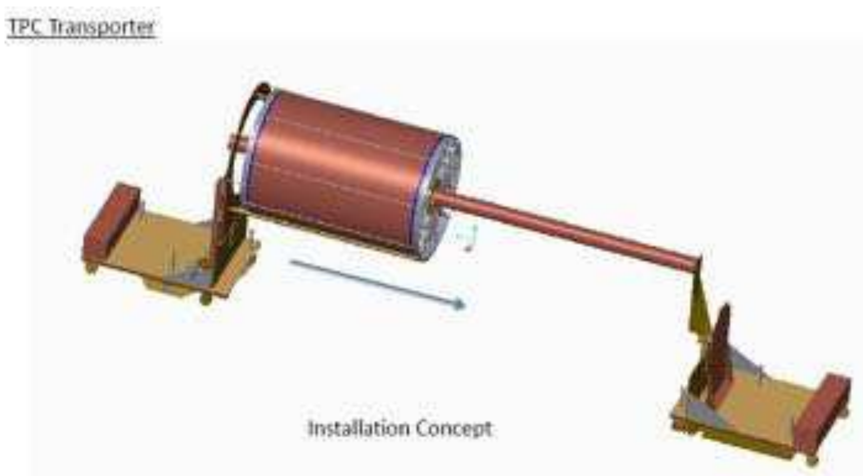


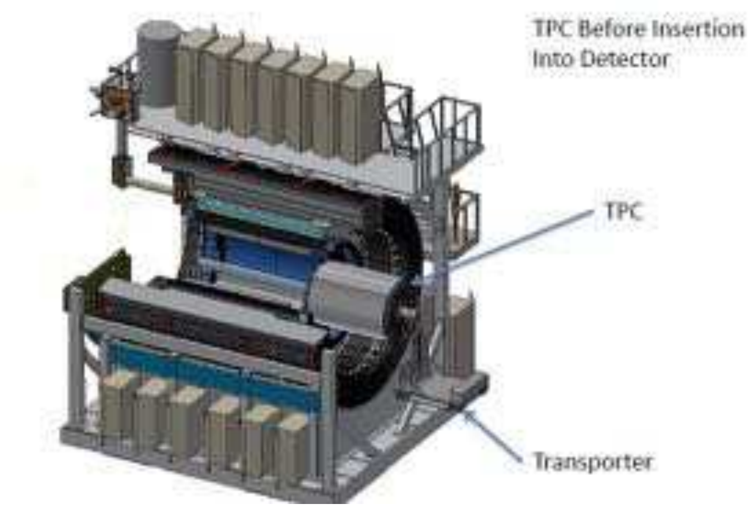
Figure 5.3 Inner Detector Support Structures

6. Installation

Installation of the sPHENIX Inner detectors will take place in 2 locations as follows:

1. The TPC will be installed while the the sPHENIX cradle carriage (“CC”) is in the sPHENIX Assembly Hall (AH). This will take place after the sPHENIX EMCal detector has been installed and aligned and after EMCal services are installed. The TPC will have an independent support structure consisting of 4 brackets connecting the TPC end plates to the Inner HCal support rings beyond the north and south ends of the SC magnet. These brackets will incorporate alignment features capable of aligning the TPC detector in all 6 degrees of freedom to the precision required by the subsystem. Once the precision required is achieved, the alignment features will be locked in place.





2. After alignment, the services for the TPC will be installed. These services will have independent support and strain relief so as not to adversely affect the TPC alignment. The services will be installed in the shadow of the spokes of the TPC endplates so as to minimize material in the remaining regions for future detectors.

3. Next, the entire CC is moved west on the sPHENIX rail system to the IR until its nominal axis is coaxial with the nominal RHIC beam axis then north until the CC assembly's nominal center point coincides with the sPHENIX nominal interaction point ("IP"). Survey and built in adjustments to the CC assembly are used to bring the entire assembly into tolerance as required.

   The following installation and alignment tasks take place after the cradle carriage is moved into the Interaction Region (IR).

4. The beampipe is installed and surveyed into place by using the beampipe survey fixture and making adjustments on the beampipe stands. The MVTX and INTT will be integrated into a dual half-cylinder support frame (upper and lower) with the upper and lower halves relatively aligned on the bench prior to installation such that the mating kinematic mounting features are fully adjusted in a simulated installation. Each frame will have a 3 point support onto a dual rail and bearing system in which the bearings will slide along pathways on the rail which allows the upper and lower frames to ride in separately and maintain separation from the beampipe until the frames have cleared the beampipe flanges. The lower frame is positioned first then the rail is adjusted in 3 dimensions to achieve the alignment precision required. Then the upper frame is brought into position and is mated to the lower frame by kinematic mounts.

5. The final detector to be installed and aligned is the Min Bias detector. It will be mounted on alignment rails which in turn mounted to horizontal and vertical brackets anchored to the Outer HCal inboard of the end caps/pole tips. These will allow X-Y-Z and angular adjustments as required.

6. All services to the detectors are routed from the north or south of the overall experimental assembly to service distribution points at the north and south end of each subassembly component. From that point services are routed to source points (e.g. electronics racks, cooling manifolds, etc.) which will be generally segmented into quadrants at each end (for the MVTX all services are routed to the south end). All manifolds and patch panels will be rack mounted on the Cradle Carriage platforms outside of the detector areas. In general, the services will be layered such that the outermost detector (Outer HCal) has the inner most services routes, with the Inner HCal on top of those, then the EMCal services then the TPC, The INTT, the MVTX and finally the Min Bias services.

7. Maintenance

Maintenance for the sPHENIX Inner detectors is divided into 3 categories:

1. Scheduled Maintenance on (usually) pre-determined maintenance days, generally limited to a single 8 hour period either weekly or bi-weekly during a run
2. Unscheduled maintenance of varying time length. These are in response to an unexpected event or failure which requires cessation of a run until the event is over or the failure is repaired or otherwise mitigated.
3. Annual shutdown maintenance of longer duration (generally 3-6 months, usually spanning the summer months)

The types of maintenance that can be performed on sPHENIX Inner detector subsystems depends on the category of maintenance:

During a scheduled maintenance period there is no access to the detector itself, as that would require opening of the end caps/pole tips, installing temporary access platforms and equipment safety barriers (e.g to prevent contact with Be beampipe), temporarily removing and/or relocating services, possible bypassing/disabling of safety systems, etc. It is simply not feasible to accomplish all of these tasks, perform maintenance on the detector subsystem and restore all items to pre-access conditions in a single 8 hour shift. More likely this would require a minimum of 3-5 days depending on the subsystem components to be addressed. Maintenance of electronics and services outside of the central region (e.g. in electronics racks, distribution/patch panels etc.) and remote testing of inner detector performance characteristics are possible during a scheduled maintenance period. No special equipment is anticipated for a scheduled maintenance period.

During an unscheduled maintenance period of modest length (1-2 weeks perhaps) some access to inner detector components may be possible. In such a case equipment protection barriers and access platforms would need to be erected and later removed. During such periods electronic modules, defective cables, and any failed components that would not require removal of the beampipe might be removed and replaced, including individual TPC GEM and Min Bias modules, and possibly a hemisphere or other portion of either the the MVTX or the INTT. It would also be possible to perform in-situ maintenance of some other detector components on the Inner Detectors as determined by the individual Inner Detector subsystem groups. Appropriate quick assembly access platforms and equipment protection barriers will need to be designed to support this category of maintenance.

During annual shutdown maintenance any other detector maintenance, upgrade or repair work is feasible up to and including completely disassembling the entire sPHENIX detector (for which a very long shutdown would be required.) This category of maintenance includes the ability to do scheduled and unscheduled category maintenance where the beampipe need not be removed and the sPHENIX carriage remains in its run position, maintenance requiring removal of the beampipe but not requiring movement of the carriage, up to and removal of the beampipe and moving the carriage to the sPHENIX assembly hall. Moving the cradle carriage to the Assembly Hall requires first removing the Beampipe, Min Bias, MVTX and INTT in reverse order as described in the Assembly section of this report. No additional special support equipment is needed for this category of maintenance as the equipment used in the initial assembly and the equipment required for interior access during an unscheduled maintenance together provide for all possible needs.

In all cases it should be noted that access to inner detectors, in general, is more difficult as the detectors move out from the center. That is because the general construction procedure is to assemble the outermost detector (Outer HCal) first then successively install subsystems from the outside in (SC Magnet, Inner HCal, EMCal, TPC, INTT, MVTX and Min Bias, in that order with each successive detectors services layered over the previous detectors (although there may be some interleaving, to be determined). The exception to this is that the INTT and MVTX are expected to be installed on a common support structure, although it is also proposed that either one of theses detectors could be installed without the other if required. Consequently, access to any given detector is expected to require at least some temporary removal or relocation of services to all detectors installed after (i.e. inboard).

8. Survey

Each of the sPHENIX Inner detectors will require externally visible fiducial references in order to position and align the detectors with the SC Magnet center and centerline and the nominal RHIC beam-path. In general, it is sufficient to have 3 non collinear fiducials at either axial end of the detector to adequately align it. It is the detector subsystem group’s responsibility to reference internal features of the detector to these fiducials as required by the subsystem. Appropriate adjustment features are to be designed into the support structures for each of the detector subsystems to achieve the required alignment precision.

It is expected that BNL survey will make use of its laser alignment system to perform survey and assist sPHENIX mechanical technicians with alignment adjustments. This survey system generally requires ¼ inch precision holes at each fiducial point in which the laser targets are placed.

9. Summary and Recommendations

In general the task force finds the state of the integration to be as expected for the level of maturity in a conceptual design stage. Mostly the integration does not pose a problem beyond the standard ones from a complicated collider detector experiment, but a few really big open questions remain with regard to integrating the two silicon tracking systems, Additionally, much of the task force conclusions were based on estimates of what the detector design, support structures, and cable connectors, etc, looked like. Detailed engineering designs were often lacking, and would need to be produced to come to final conclusions. Other stated requirements, like a hermetic seal around the silicon detectors to control their ambient humidity and temperature, aren't at the level that one could even think of figuring out how to design that in. Thus, this report should be seen only as a work in progress.

The main findings of the task force are that:

1. There are relatively few concerns regarding the integration of the TPC and MB detectors, though care will have to be taken to arrange cables to reduce their effect on measurements.
2. Care should also be taken to ensure that the various detectors do not electrically interfere with each other. For example, their grounding should remain distinct enough that there is no cross-talk, and no noise from one subsystem propagates to another.
3. There remains quite a large uncertainty when it comes to integrating the MVTX and INTT with the current designs of their detectors and support systems. The MVTX and INTT overlap physically and therefore cannot co-exist in their current configurations.
4. The MVTX clearance to the beam-pipe is only 1.3 mm, which poses a concern to the safety of the Be beam-pipe.
5. The INTT uses an electronics system based on the FVTX using FPHX chips sending data to the re-used FVTX ROCs. While the FVTX only had to send their data a short distance from the FPHX chips to the ROCs, in the INTT case they will need to send their data over 1.2 m minimum, since the ROCs cannot fit inside the 40 cm diameter opening of the TPC bore. This transmission needs to be tested.
6. There will be large additional volumes of material placed in sPHENIX, from cabling for the detectors but also from the support structures needed. Care is being taken to define the cable routes so that they minimize the impact on physics; for instance, to go out along the radial direction the subsystems intend to follow the spokes of the TPC endcap supports, which are already thick areas. The cabling for the inner silicon detectors will run out in the 20 cm radius inside the TPC and at present do not shadow any other sPHENIX subsystems. They may, however, interfere with fsPHENIX or ePHENIX subsystems but this was not evaluated by the task force. The INTT cables run out both north and south and terminate at the FVTX ROCs, which will be arranged in a "big wheel" on the inner edge of the TPC end-cap (and leaving clearance for the TPC so that they do not interfere). From the ROCs, cables will run out along the TPC spokes to racks. The MVTX cables run south inside the TPC, and will then run out radially to the racks, again following the TPC spokes.
7. The TPC will generate 10 kW of heat inside the enclosed volume of sPHENIX. Care is being taken to remove that heat, but that is a large source of heat and care needs to be taken that the cooling system is effectively designed.
8. Maintenance to the inner detectors will not be possible during access days, but will be possible during shutdowns.

The task force urges follow up to a few important questions, particularly to address how to find a configuration that allows the MVTX and INTT to coexist in sPHENIX. Some of these action items that remain to follow up on are

1. Can the patch cables from the MVTX be made longer than their current 18 cm? If so, by how much? As little as 10-15 cm additional length might be enough to allow for pushing the MVTX service cone southward enough so that the INTT has clearance for their cables.
2. If the MVTX patch cables cables cannot be extended, then how far can the one modify the MVTX service cone to provide clearance for the INTT?
3. Will the MVTX be able to move the inner-most layer radially outward by 1-2 mm to provide enough clearance with the beam-pipe?

The above action items are considered the main open questions that need to be answered in order to determine whether there are relatively easy ways to solve the conflict between the MVTX and INTT, and the possible conflict of the MVTX and the beam-pipe.

One caveat to this report is that the task force looked largely into reducing conflicts from the material that will be introduced with respect to the sPHENIX baseline. However, while considered, there was not a detailed study of possible conflicts with detectors that are not in the baseline, such as those in fsPHENIX and ePHENIX. It would be good for the proponents of these future upgrades consider the impact from the additional material that has been catalogued in this report.

Appendix A: Charge to the sPHENIX Task Force for Inner Detector Integration
February 14, 2016

Dear sPHENIX Colleagues,

The design of the sPHENIX detector has reached a state where it is becoming increasingly important to devise a comprehensive plan that addresses the various external mechanical and electrical requirements of the subsystems, especially the Inner detector subsystems, in order to facilitate their integration into the detector and prevent interferences. I am forming a task force to collect all the pertinent integration information associated with the Inner detectors, the ***TPC, INTT, MVTX (formerly MAPS) and Min Bias Detector****, and asking the committee to produce a report that both summarizes the information for use by the Project Management team, and recommends potential solutions to any integration challenge that they might identify. The task force should collect all relevant service information for the aforementioned Inner detectors including cable/fiber type and number, power needs, cooling needs, other services requirements including gas, lasers, other calibrations, electronics board counts with dimensions and locations. The integration report should include the current plan for external support, installation, survey and maintenance access.*

The Task Force report will be the initial step toward an optimized integration of the sPHENIX detector. As sPHENIX moves from conceptual design to preliminary design and eventually to final design, I expect that the report will get regularly updated to include the latest information. Once the Task Force report is submitted I expect that
the Task Force will evolve into a standing Inner Detector Integration Committee that will have a role in anticipating and solving integration issues as sPHENIX is being built. The integration job is complex but essential to the project success.

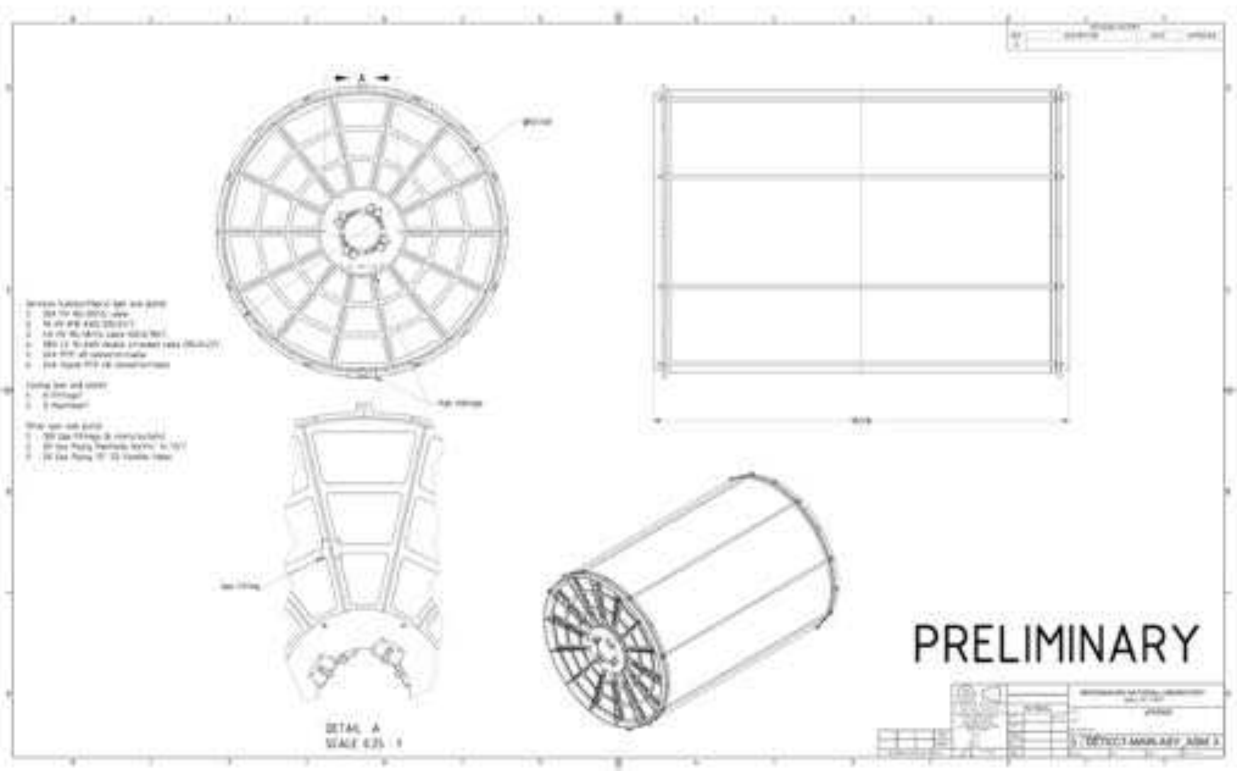
Mickey Chiu has kindly agreed to chair the Task Force. Bob Azmoun will be his deputy. The sPHENIX Chief Mechanical engineer, Don Lynch will be a member of the committee along with Rich Ruggiero. There will be one representative on the Task Force from each of the Inner Detectors. I would like to have a draft of the report by April 14, with the final report due May 1. Thank you for agreeing to participate in this important activity.

Ed O'Brien

Appendix B: sPHENIX Inner detector Outline/Interface control drawings

(Note: these drawings will provide detailed dimensional information for the actual external form dimensions of the detector and for all mechanical support, electrical, electronic, optical and fluid connectors/ports which interface with the rest of sPHENIX outside the subsystems.)

B.1 TPC Outline/Interface Drawing



B.2 INTT Outline/Interface Drawing

(1st draft in progress)

B.3 MVTX Outline/Interface Drawing

(1st draft in progress)

B.4 Min Bias Outline/Interface Drawing

(1st draft in progress)

Appendix C: Detailed requirements for services and detector envelopes from each subsystem

TPC

Mechanical Requirements

Item	Description	Quantity/Value	units	Notes
Envelope inner limit	radius/longitudinal length	7.87/98.4	inches	
Envelope outer limit	radius/longitudinal length	31.69/98.4	inches	
Axial location relative to IP		0	inches	TPC centered around IP
Weight (without external connected services)		?	kg	Not yet determined
Envelope precision (axial)		1/5	inches	
Envelope precision (radial)		1/50	inches	
Envelope precision (roll)		-		irrelevant due to rotational symmetry
Envelope precision (pitch)		0.5	mrad	
Envelope precision (yaw)		0.5	mrad	
Envelope stability (axial)		1/25	inches	
Envelope stability (radial)		1/50	inches	
Envelope stability (roll)		-		irrelevant due to rotational symmetry
Envelope stability (pitch)		0.5	mrad	
Envelope stability (yaw)		0.5	mrad	
Envelope repeatability (axial)		?		Once TPC is installed: no repeatability needed (?)
Envelope repeatability (radial)		?		Once TPC is installed: no repeatability needed (?)
Envelope repeatability (roll)		?		Once TPC is installed: no repeatability needed (?)
Envelope repeatability (pitch)		?		Once TPC is installed: no repeatability needed (?)
Envelope repeatability (yaw)		?		Once TPC is installed: no repeatability needed (?)

Services (cables/fibers)

Item	Description	Quantity/Value	units	Notes
HV Size/type	RG-58/CU cable	0.57/0.196	inches	SHV connectors (OD=0.57"), cable (OD=0.196") min. bend radius 2", weight 1/40 lbs/ft
HV number		72	each	36 per end-plate
HV length		25	ft	
HV Size/type	#18 AWG (OD=0.4")	0.4	inches	weight TBD
HV number		1	each	
HV length		27	ft	
HV Size/type	RG-58/CU cable (OD=0.196")	0.196	inches	SHV connector (OD=0.57") at rack, naked at end-plate, min. bend radius 2", weight 1/40 lbs/ft
HV number		4	each	
HV length		27	ft	
LV Size/type	10-AWG double stranded cable (OD=0.42")	0.42	inches	weight 1/8 lbs/ft
LV number		196	each	98 per end-plate
LV length		27	ft	
Signal Size/type	MTP 48 connector/cable	0.38/0.15	inches	MTP connector (OD=0.38"), cable (OD=0.15") bending radius: 7.5", weight 1/18 lbs/ft
Signal number		48	each	24 per end-plate
Signal length		20	ft	approximate; need to be all of equal length due to timing
Control Size/type	(temperature, other)	?		TBD
Control number		?		TBD
Control length		?		TBD
Other Size/type	(laser, other)	?		TBD
Other number		?		TBD
Other length		?		TBD

Cooling

Item	Description	Quantity/Value	units	Notes
Detector total heat load	FEE+optical module+LV PS GEM-HV	9.4	kW	4.7 kW per end-plate
Coolant spec	liquid	?		1.5ton@10C/end plate
# coolant circuits at detector				
Fittings at detector	(fitting size/spec)	?		TBD
Coolant flow rate		?		TBD
Coolant temperature at inlet		?		TBD
Coolant temperature stability		+/-2	K	
Coolant pressure at inlet		?		TBD
Coolant pressure drop		?		TBD

Other

Item	Description	Quantity/Value	units	Notes
Laser requirements	spec	?		TBD
# Racks (on-carriage)		?		TBD
Rack dimensions (on-carriage)	[width x depth x height]	?		TBD
# Racks (rack room)		?		TBD
Rack dimensions (rack room)	[width x depth x height]	?		TBD
# patch panels (on-carriage)		?		TBD
Patch panels dimensions (on-carriage)	[width x depth x height]	?		TBD
# patch panels (rack room)		?		TBD
Patch panels dimensions (rack room)	[width x depth x height]	?		TBD
Fittings at detector	1/4" NPT	12	each	6 gas inlet/outlets
Gas flow rate	1 m^3/hr	Ne-based		At present: Ne-CF4 90-10
Gas piping size/length	1/4" SS flexible tubes (OD=0.235")	3.5	ft	6 gas inlet/outlets; min. bend radius: 4", weight: 1/6 lbs/ft
Gas piping number	1/4" SS flexible tubes	12		
Gas piping manifold	6x1/4" to 1.5"	2	each	weight: 10 lbs each
Gas piping size/length	1.5" flexible tube (OD=2")	30	ft	min. bend radius: 12", weight: 1-1/4 lbs/ft
Gas piping number	1.5" SS flexible tubes	2	each	

MinBias

Mechanical Requirements				
Item	**Description**	**Quantity/Value**	**units**	**Notes**
Envelope inner limit		50	mm	Taken from PHENIX Drawing https://www.phenix.bnl.gov/~ruggiero/details.php?sid=1962
Envelope outer limit		150	mm	Taken from PHENIX Drawing https://www.phenix.bnl.gov/~ruggiero/details.php?sid=1964
Axial location relative to IP		250-300	cm	Still finalizing the position, but it will likely be between 250-300 cm
Weight (without external connected services)		68	lbs	Each quadrant is 17 lbs
Envelope precision (axial)		0.5	mm	
Envelope precision (radial)		0.2	mm	
Envelope precision (roll)		1	mrad	
Envelope precision (pitch)		1	mrad	
Envelope precision (yaw)		1	mrad	
Envelope stability (axial)		0.1	mm	Not sure if the numbers below seem reasonable, but we want as stable and repeatable as possible, within reason
Envelope stability (radial)		0.1	mm	
Envelope stability (roll)		0.5	mrad	
Envelope stability (pitch)		0.5	mrad	
Envelope stability (yaw)		0.5	mrad	
Envelope repeatability (axial)		0.1	mm	
Envelope repeatability (radial)		0.1	mm	
Envelope repeatability (roll)		0.5	mrad	
Envelope repeatability (pitch)		0.5	mrad	
Envelope repeatability (yaw)		0.5	mrad	

Services (cables/fibers)

Item	**Description**	**Quantity/Value**	**units**	**Notes**
HV Size/type	RG58 cables	0.25	in	
HV number		8		
HV length		7	m	
LV Size/type				
LV number				
LV length				
Signal Size/type	Andrew FSJ1RN-50B cables	0.25	in	
Signal number		128		
Signal length		6.75	m	
Control Size/type	Thermocouple	0.125	in	
Control number		52		
Control length		7	m	
Other Size/type	Laser Fibers	0.125	in	
Other number		2		
Other length		7	m	

Cooling

Item	**Description**	**Quantity/Value**	**units**	**Notes**
Detector total heat load		384	W	3 W per tube
Coolant spec	Chilled air			
# coolant circuits at detector		4		
Fiittings at detector	0.5" Swagelock	8		
Coolant flow rate		250	liters/min	
Coolant temperature at inlet		ambient		Using air source from CAD
Coolant temperature stability		ambient		
Coolant pressure at inlet		5	psi	
Coolant pressure drop		N/A		

Other

Item	**Description**	**Quantity/Value**	**units**	**Notes**
Laser requirements	spec			
# Racks (on-carriage)		1		
Rack dimensions (on-carriage)	[width x depth x height]			Need full height 19" rack
# Racks (rack room)		0		
Rack dimensions (rack room)	[width x depth x height]			
# patch panels (on-carriage)		3		
Patch panels dimensions (on-carriage)	[width x depth x height]			
# patch panels (rack room)		1		
Patch panels dimensions (rack room)	[width x depth x height]			

INTT

Mechanical Requirements

Item	Description	Quantity/Value	units	Notes
Envelope inner limit		5.4	cm	Inner ladder is at 6 cm. Ladders are tilted
Envelope outer limit		16	cm	Outer ladder is at 12 cm. Tilted/Readouts
Axial location relative to IP		50	cm	To HDI cable end
Weight (without external connected services)		TBD		
Envelope precision (axial)		± 2	mm	
Envelope precision (radial)		± 1	mm	
Envelope precision (roll)		± 2	degrees	
Envelope precision (pitch)		± 2	mm	
Envelope precision (yaw)		± 2	mm	
Envelope stability (axial)		± 2	mm	
Envelope stability (radial)		± 1	mm	
Envelope stability (roll)		± 1	mm	
Envelope stability (pitch)		± 1	mm	
Envelope stability (yaw)		± 1	mm	
Envelope repeatability (axial)		± 1	mm	
Envelope repeatability (radial)		± 1	mm	
Envelope repeatability (roll)		± 1	mm	
Envelope repeatability (pitch)		± 1	mm	
Envelope repeatability (yaw)		± 1	mm	

Services (cables/fibers)

Item	Description	Quantity/Value	units	Notes
HV Size/type	Each half ladder needs 1 HV cable	1.5	mm	Connection is at HDI end
HV number	Each half ladder needs 1 HV cable	116 x 2 = 232 cables		116 cables each side
HV length		10	m	from ladder to Local Power/Rack at IR
LV Size/type for the ROC	1 cable with 22 pin connectors	8.8	mm	Each ROC needs one LV cable
LV number for the ROC	1 cable at each ROC	1 cables x 24 ROCs = 24 cables		12 cables each side
LV length for the ROC	From the ROC to local Power Rack Room	10 each	m	Depends on the location of the Local Power ROC at IR
LV Size/type for the ladder at the ROC	4 cables in each ROC	9.5 each cable	mm	
LV number for the ladder at the ROC	4 cables in each ROC	4 cables x 24 ROCs = 96 cables		48 cables in each side
LV length for the Ladder at the ROC	From the ROC to local power Rack Room	10 each		Depends on the location of the Local Power ROC at IR
Data Signal Size/type	4 x 12 fibers optical cables data each ROC	3	mm	Connection is at the ROC
Data Signal number	4 x 12 fibers optical cables data each ROC	4 cables x 24 ROCs = 96 cables		48 cables in each side
Data Signal length	From the ROC to patch panel to rack room	10 + 70 = 80	m	From the ROC to patch panel to rack room
Slow Control Size/type	1 duplex fibers optical cable	1.3 each	mm	
Slow Control number	1 duplex fibers optical cable	1 duples x 24 ROCs = 24	m	12 each side
Slow Control length	From the ROC to patch panel to rack room	70	m	From the ROC to patch panel to rack room
Clock Cable (ROC to clock board): Size/type	Clock cable with 8 pin connector	5	mm	
Clock Cable (ROC to clock board): number	Each ROC has one clock cable	1 cable x 24 ROCs		12 each side
Clock Cable (ROC to clock board): length	From ROC to cloack board	2	m	
Clock Cable (clock board to patch panel): Size/type	1 duplex fiber optical cable	1.3 each	mm	
Clock Cable (clock board to patch panel): number	1 duplex fiber optical cable serve 6 ROCs	24/6 = 4		2 each side
Clock Cable (clock board to patch panel): length	1 duplex fiber: from clock board to patch panel	10	m	
Clock Cable (clock board to patch panel): Size/type	power cable: clock board to patch panel	0.5	mm	
Clock Cable (clock board to patch panel): number	Each cloack board serve 6 ROCs	24/6 = 4		2 each side
Clock Cable (clock board to patch panel): length	power cable: clock board to patch panel	10	m	
Temperature Cable Size/type	One cable from HDI end to readout board at IR	1.5	mm	
Temperature Cable number	One cable from HDI end to readout board at IR	116 x 2 = 232 cables		116 cables each side
Temperature Cable length	One cable from HDI end to readout board at IR	10	m	

Cooling

Item	Description	Quantity/Value	units	Notes
Detector total heat load	390 uW x 128ch x 26 chips x2 x 116 ladders = 301 W	500 W		
Coolant Temperature at ladder		5 to 10 degrees celsius	degrees celsius	
Coolant flow rate		TBD		
Coolant temperature at ROC big wheel		10 degree celsius		
Coolant temperature stability		± 1 degree celsius		

Other

Item	Description	Quantity/Value	units	Notes
Laser requirements	Not applicable (Laser not needed)	NA		
# Racks (on-carriage)	1 Rack for patch pannels: data signal and slow controle			
# Racks (rack room)	2 Racks: Using existing FVTX Racks for FEMS and DCMs			

MVTX

Mechanical Requirements	MVTX detector			
Item	**Description**	**Quantity/Value**	**units**	**Notes**
Envelope inner limit diameter	BNL	Beryllium 41.53	mm	OD of beampipe
Envelope outer limit diameter	BNL	120.0 mm	mm	ID of INTT layer 0
Axial location relative to IP	BNL	12.52/318.0	inches/mm	Axial envelope from sPhenix envelope drawing
Weight (without external connected services)	LANL/ALICE		kgrams	Total weight of IB detector service barrel 13.6 kgrams
Envelope precision (axial)	LANL-MVTX	l=271.2	mm	ALICE ITS ladder length, active area, 9 MAPS chips
Envelope precision (radial)	LANL-MVTX	r=22.0	mm	Current MVTX model, inadequate delta from beampipe
Envelope aluminum ext to Be beampipe	BNL	OD = 43.21	mm	length including 2.75" conflat 888.29mm each
Envelope outer shell MVTX	LANL-MVTX	OD = 100.0	mm	Outer diameter of MVTX shell, straight section
Envelope precision (roll)				
Envelope precision (pitch)				
Envelope precision (yaw)				
Envelope stability (axial)				
Envelope stability (radial)				
Envelope stability (roll)				
Envelope stability (pitch)				
Envelope stability (yaw)				
Envelope repeatability (axial)				
Envelope repeatability (radial)				
Envelope repeatability (roll)				
Envelope repeatability (pitch)				
Envelope repeatability (yaw)				

Services (cables/fibers)

Item	Description	Quantity/Value	units	Notes
Analog Power size/type	OD .444 mm	2	per stave	shielded twisted pair/stave, pl=3.97 g/m (xStave)
Twisted sense wire		2	per stave	
Shielded mesh		1	per stave	
RS Bias	OD 1.8 mm	1	per stave	pl= 7.5 g/m (xStave)
Analog Power number				
Analog power length				
Digital Power Size/type	OD .977 mm	2	per stave	pl= 15.8 g/m (xStave)
Twisted sense wire		2	per stave	
Digital Power number				
Digital Power length				
Signal Size/type	Data cables	12/stave	each	Samtec, pl= 64g/m (xStave)
Signal number				
Signal length				
Control Size/type	(temperature, other)			
Control number				
Control length				
Other Size/type	laser, other)			
Other number				
Other length				

Cooling - internal to MVTX

Item	Description	Quantity/Value	units	Notes
Cooling pipe off ladder	1.7 & 2.0 mm OD	1 each/ladder	each	total 96 tubes/48 ladders, length 366 mm
Cooling pipe off patch panel in service	4.0 mm OD	2/ladder	each	total 96 tubes/48 ladders, length 2000mm
Detector total heat load	120 watts, 2.5 watts/stave			
Coolant spec	negative pressure water			
# coolant circuits at detector		96		
Fiittings at detector	(fitting size/spec)			
Coolant flow rate	144 liters/hour, 3 liters/hour in each tube			
Coolant temperature at inlet	20 degrees C			
Coolant temperature stability				
Coolant pressure at inlet				
Coolant pressure drop				
Dry air/gas flow in enclosure	10-15 m**3/hour @ 20 deg C			

Other

Item	Description	Quantity/Value	units	Notes
Laser requirements	Possibel need for positioning			Designed metrology points in service barrel and cone
# Racks (on-carriage)				
Rack dimensions (on-carriage)	[width x depth x height]			
# Racks (rack room)				
Rack dimensions (rack room)	[width x depth x height]			
# patch panels (on-carriage)				
Patch panels dimensions (on-carriage)	[width x depth x height]			
# patch panels (rack room)				
Patch panels dimensions (rack room)	[width x depth x height]			