Interface Control Document

TPC

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Summary	The TPC interfaces to SiECAL, SET, SIT and VDET are described. After a light description of the TPC, this document provides detailed information on the matters which concern interactions or possible conflicts with other subdetectors: space occupation, power flow, matter budget, vibrations, support. Many of the issues are not decided yet. This document also lists several solutions and options to be studied.
Annexes	

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Distribution	***See Distribution list at the end of this document***

Template V1.0

- Table of Contents -

1. INTRODUCTION

1.1. Scope of the document

The purpose of this version of the document is to assemble all elements that may be relevant for the TPC. The document doesn't claim however either exactness or completeness at this stage. Unless explicitly mentioned, this document does not address software interfaces.

Very preliminary

1.2. Applicable Documents (AD)

Applicable Documents (AD)			
AD	**Title**	**Reference**	**Version**
DBD	ILD DBD	arxiv: 1306.6329	v1
XML 2017	Change in size and small option		
ICR	ILD Conventions and Rules		

1.3. Reference Documents (RD)

Reference Documents (RD)			
RD	**Title**	**Reference**	**Version**
TDD	TPC Technical Design Document (to be written)		

1.4. Details of changes to the previous design

To study performance vs cost effects, a small ILD model has been established, to be compared with the baseline. One of the changes on this model is the change of the TPC outer radius from 1808 mm to 1460 mm. The length is unchanged.

Due to the increase of the SiEcal thickness from 185 mm to 223 mm, the TPC barrel (ie outer radius) was decreased to 1769 .8 for the baseline model and 1426.8 mm for the small model in order to compensate for that effect (in the latter case, it is accepted that the outer pad-row is in a region of slightly degraded field.

One additional change concerns the material budget of the wall. Even though in the DBD it is mentioned that the field cage material for the inner and outer wall are respectively 1% and 3%, in the DD4HEP model it was initially 0.9% for both walls. This has now been altered and the material budget for the inner and outer field cage walls are 0.9% and 2.7% respectively.

1.5. List of abbreviations

List of Abbreviations			
ISS	Internal Support Structure	**VHV**	Very High Voltage (Cathode polarization)
FC	Field Cage		
LV	Low voltage		
HV	High voltage for detectors		

1.6. Nomenclature

Nomenclature			
Module	Module with its electronics	**Field Cage**	Gas-tight double cylinder equipped with a voltage degrader to ensure a uniform electric field (figure)
Web	The endplate frame support of the endcap detector modules	**Patch panel**	Panel to receive cables/fibres from the detectors and to the concentrators, and from the HV and LV supplies to the detectors
Membrane	Thin metallized film stretched in the middle of the field cage to serve as a cathode for the drift electric field	**Endplate**	Readout device closing the gaseous chamber at both ends, composed of modules supported by a web
Ribbon	Carbon Fibre (or metal) part mechanically connecting the TPC to its support (coil or HCAL)	**Wheel**	Set of modules covering a 360 degree azimuthal range and 1 module height in the radial direction.

2. GENERAL DESCRIPTION OF SUBSYSTEM

The TPC is a gas-tight vessel at atmospheric pressure closed by 2 endplates carrying the detector modules. A Technical Design Document will describe it in more detail.

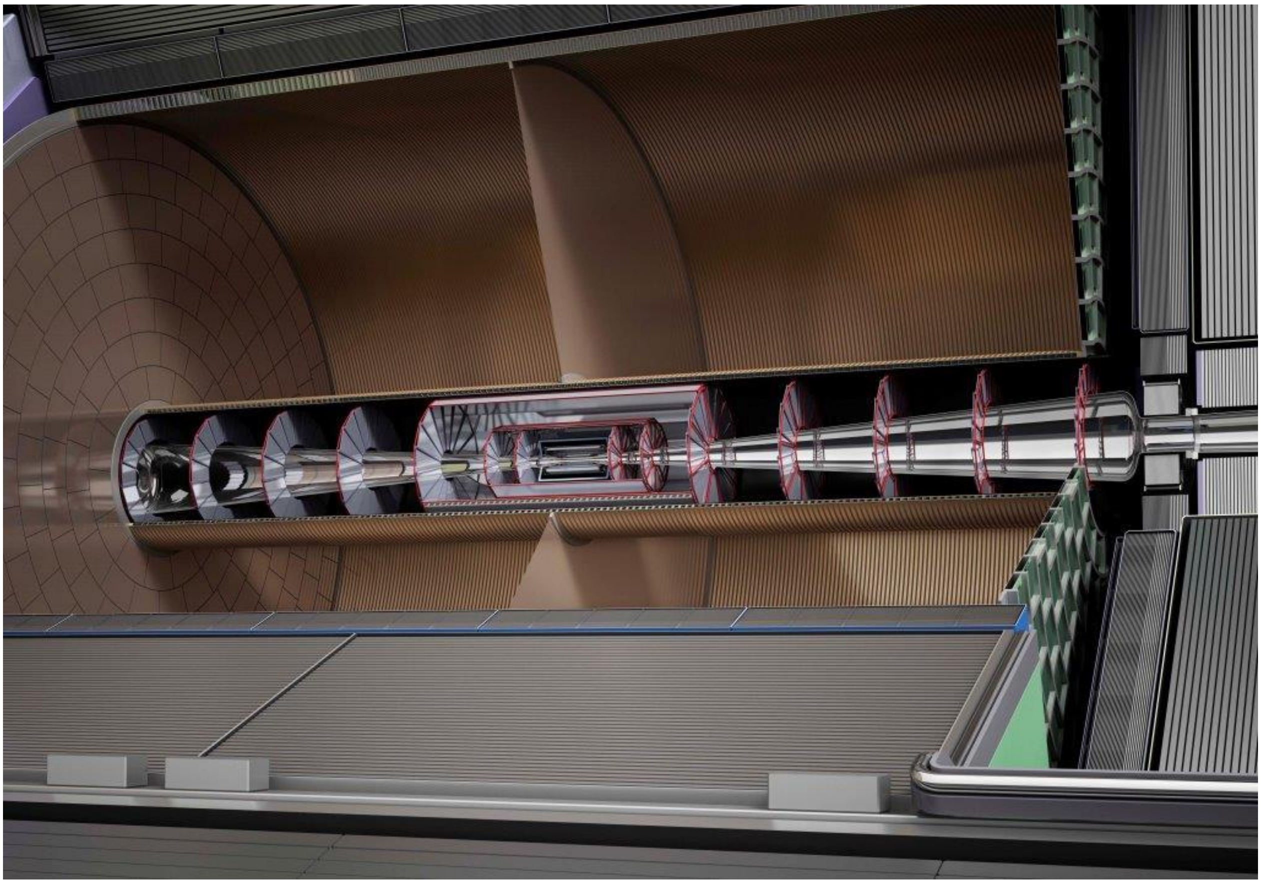


Fig. 1 : Artist's view of the TPC inside the calorimeter

Several options are retained during the R&D and costing periods, for the large model (baseline) as well as the small model. The segmentation of the baseline model can be in 4 to 8 "wheels" depending on how large the modules are, and 3 to 6 wheels for the small option. For the time being, the baseline is with 8 wheels, as this corresponds to module sizes comparable to those tested so far during the R&D phase. Several technologies are under study : Micromegas with a resistive anode, GEM and digital pixels.

3. GENERAL INTERFACE DESCRIPTION

The operation of the TPC can interfere in several ways with the other subdetectors. The various ways the TPC can affect its environment are listed here and detailed in the rest of the document.

Space occupation : most of the TPC bulk is contained in a cylinder, but fastening devices and services necessarily take some space outside this cylindrical 'bounding box' or 'envelope'.

Mechanical interface: the TPC has to be supported and has to support the ISS.

Though kept to a minimum, the material of the TPC partially obstructs the calorimeters, by the thickness of the FC in the barrel region, and even more by the endplate in the forward-backward regions.

The operation of the readout electronics generates heat which has to be taken away from the

detector to avoid temperature rise and non-uniformities.
Services (cooling, LV and HV supplies, signal) are conveyed by a system of pipes and cables which generates complication and space has to be shared with other subdetectors. They can also produce or carry their part of heat.
More specific to the TPC are the use of a high purity gas mixture, in which a flammable component is unavoidable, and a Very High Voltage for the field cage (probably 60 kV).
Also, a detailed knowledge of the magnetic field in the TPC region will be needed, which will require a special tool to map it precisely before installation. The calibration of the TPC will be achieved with the help of two laser systems which are described below.
The readout electronics, the gas amplification devices and some sensors will be part of the detector. Most of the supplies, compressors, gas mixers and purification devices will have to be off-detector. There are four classes of location, in increasing order of scarcity and requirements : the surface, the service cavern at more than 50 m, the gallery at about 50 m and the platform. For the latter, no vibration is authorized.

4. MECHANICAL INTERFACE

4.1 Coordinate system

The global coordinate system is defined in the ICR document on the ILD 'confluence' site. Two 2-D systems of local coordinates are used to position items in a module:
- a simple Cartesian system (*x*,*y*) with the origin in the center of the module: the *y* axis, radial, divides the module symmetrically in two and the *x* axis is the tangent to the circle centered on the detector axis and passing by the middle of the *y* segment extending from the inner to the outer border of the module.
- a (r,ϕ) system with r the distance from the beam axis and ϕ the angle The TPC is fastened to the HCAL structure or to the coil cryostat. It supports the Inner Silicon Subdetectors and the vertex detector (Fig. 3). (Fig. III-5.8 of DBD – Vol.4 of the ILC TDR 2013).

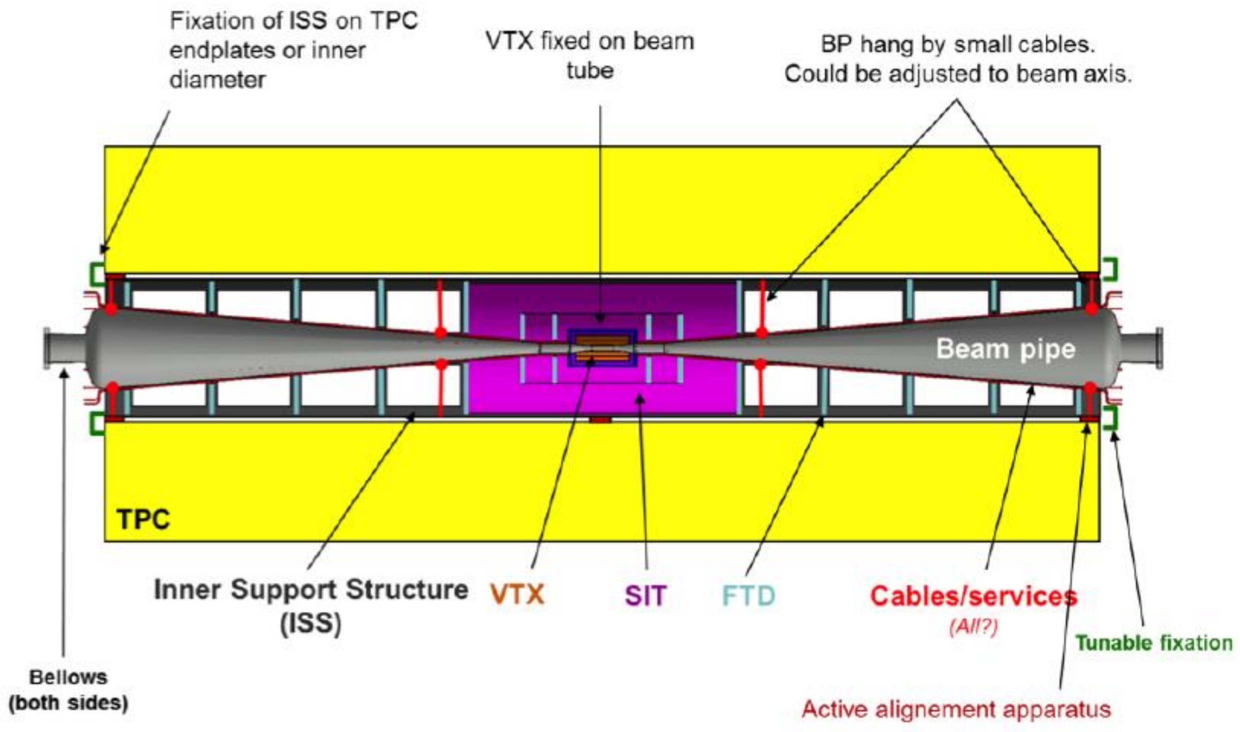


Figure 2 : Inner Support Structure (taken from the DBD,xxxxx)

In both cases (HCAL or coil supporting) there can be 2 to 4 supports, which can be ribbons or bars, or thick plates. The mechanical structure of the ECAL is thought to be too light to bear the weight of the TPC and ISS (roughly 2 tons). So far there is no official design of the SET. It could be fasten to the TPC or to the ECAL.
In the case where the TPC would be supported by the HCAL, the support ribbons would be shorter, which would provide a more rigid fastening and limit the vibration amplitude. Detailed calculations are needed to assess this point numerically, but the accuracy of the positioning will be better if HCAL is used as an anchorage.

In both cases, the question of where to choose the fixing points has been studied. Fig. 3 shows the two possibilities with 3 (blue) and 4 (red) anchorage points. The 4-point anchorage provides a better stability under seismic events.

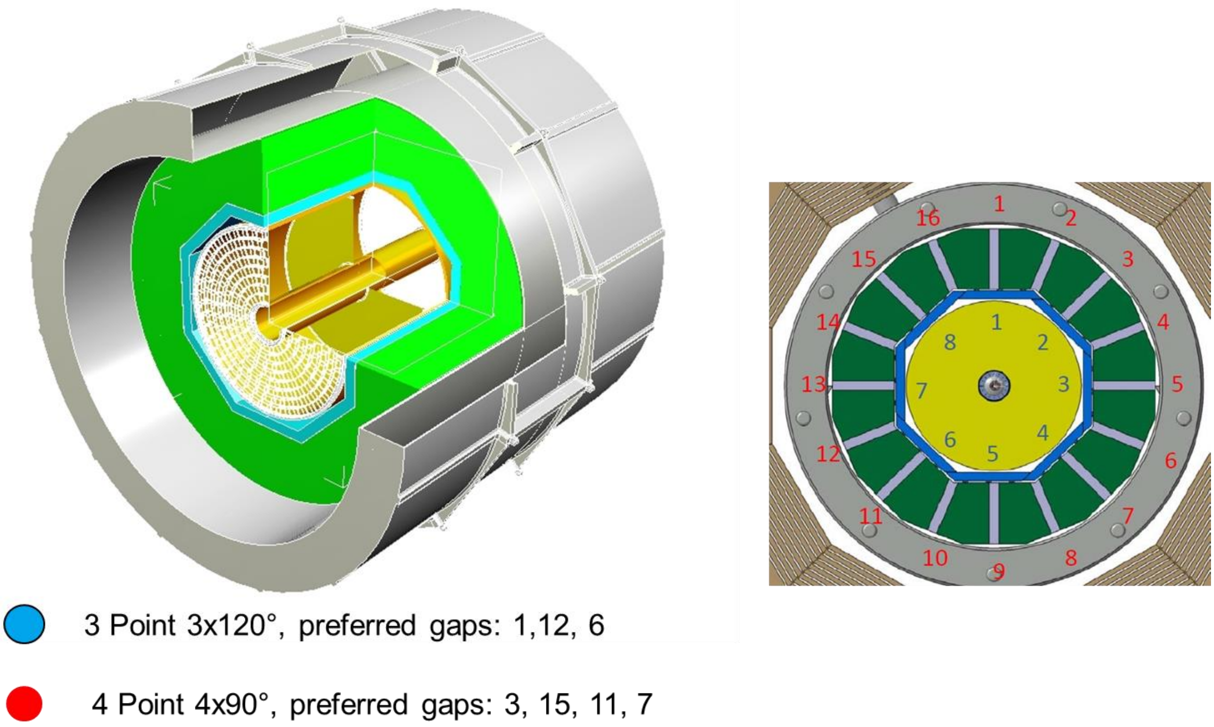


Figure 3 : possible positions of the TPC fixation points.

The support structure has to fulfill several requirements : it must be non-magnetic, robust in the three dimensions, and stable with temperature, which calls for a carbon-fiber structure. The accuracy is required to be better than 100 micrometers for the internal silicon detectors.

4.2 Critical dimensions.

The bulk of the TPC is contained in a cylindrical bounding box (or envelope) of 4700 mm length and 1770 mm radius (large version) or 1427 mm (small version), with a bore of 329 mm radius for the ISS bearing the vertex detector and the silicon tracker. However gas pipes, cooling pipes, LV cable, HV and VHV cables and signal optical fibers have to pass in the gap between the barrel and endcap calorimeters, where also sit the TPC supports. This gap is critical, especially for the VHV cable which should have a 26 mm diameter.

Another critical dimension is the distance of grounded parts to components polarized at the VHV. At the level of the membrane, the voltage might reach 60 kV, which makes this minimum distance 6 cm in dry air.

4.3 Weights

The total weight of the TPC with the ISS and its content is ca. 2 tons. The FC weight is estimated to be 265 kg according to the Large Prototype design. The two webs are 350 kg each (this is for a 4-wheel design in Aluminium), and they carry each 45 kg of PCB. These add up to 1055 kg. Such a structure has been shown to deform by less than 200 µm under its weight and an internal overpressure of 10 mbar.

4.4 Positioning and alignment constraints

The alignment of the TPC with respect to the internal trackers have been estimated in an ILD technical note 2016-001: it has to be well below 10 µm. Such an accuracy can only be obtained by software. The initial mechanical alignment should be within 100 µm- 200µm, which is also the order of magnitude of the deformations under the weight and the inner overpressure of a few mbar.

5. ELECTRICAL INTERFACE

The guiding line for the TPC is to have as few connections to the outside world as possible. There will be one or a few HV and LV cables per module, and optical fibres for the signal and the electronics settings. To ease the separation of the detector from the supplies and concentrators, there will be patch panels on each side (A and B). Available space for such patch panels is represented in Fig.4 by 6 grey 10x30 cm² rectangles each side.

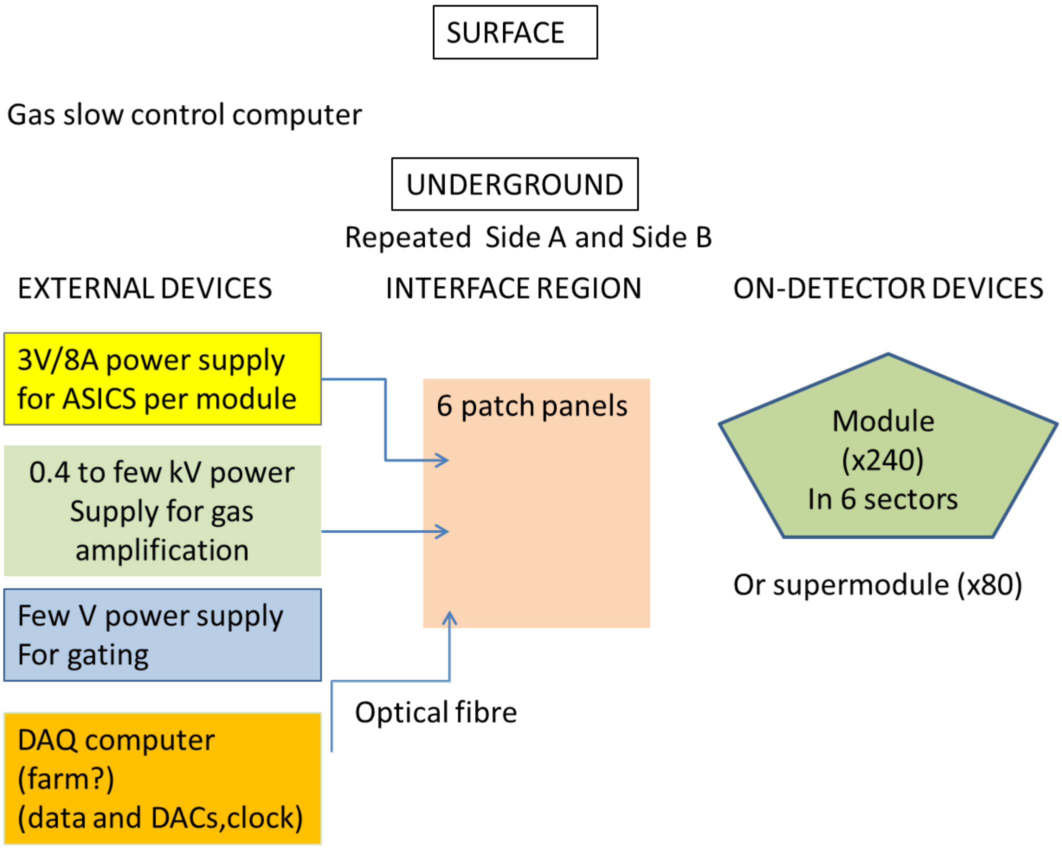


Figure 3 : Schematic view of power distribution and distribution and concentration of other relevant signals and data for one TPC endplate.

5.1 Block diagram

Figure shows a primitive block diagram for one module of TPC

The cables that arrive or leave from the patch panels have the following purpose:

- Low voltage power supply for the readout electronics and the powering of the active hubs
  - In-going cables and their feedback sense
  - 3 V/ 32 A power supply. In total there would be 480 channels of low-voltage supplies, brought by 6 bundles of 10 32-A-cables each side (one 32-A cable supplies a supermodule, which is an ensemble of 4 modules). This is 2 sets of 10 units, the total volume is 0.03 m^3, which should be placed on the platform or on the top of the yoke, to mitigate the dissipation in the cables.
- High voltage power supply for the gaseous amplification.
  - Standard “red” HV cables (few 100 V, few nA, in going), with SHV connectors, or a thinner version. These power supplies can be in the gallery, as the distance is not critical and a safe access for maintenance is needed.
  - A pulsed voltage has to be provided to the gating device. This has to be studied.
- Optical fibers for data transmission and detector control
  - Out-going and in-going fibers (2 per module, minimum curvature radius of 200 mm).

- The readout backend and the computers could be located in the gallery, where access is easy and space is available, at ~50 m distance from the detector.
- Clock distribution

5.2 Very high voltage

Special to the TPC is the need for a Very High Voltage supply to provide the drift electric field over 2.2 m. The optimum drift field depends on the gas choice. For the baseline choice of an Ar:CF_4:isobutane mixture 95:3:2 the maximum drift velocity is attained at a field of 280 V/m. This is optimum for the drift velocity stability over changes of the drift field, and would require a 62 kV stabilized power supply.
More R&D is needed to decide among several possibilities:
- where can be the VHV power supplies (there should be also a spare)?
- is it possible to make the VHV locally, to avoid a very cumbersome cable?

In the following the interfaces are described:

- Power (the type of power [regulated, unregulated, heating-, number of lines for each type):
  At the patch panel the power arrives directly from supplies sitting in the electronics trailer, Low voltage (~3V, 8 A) for the operation of the readout system. The power should be adequately tuned to avoid useless dissipation in the regulators.
  High voltage (few 100V, few nA) for the gaseous amplification device (technology dependent)
- Remote control: control type (relays, digital ...), the number of each type of control:
  Modules will be switched off by remote control, in principle the modules should be part of a GPIB bus system of which the master card is integrated. Each master card receives commands via Ethernet. (to be corrected by a specialist)
- Insulation:
  Standard HV cables.
- Photoelectric laser source:
  Illuminates the cathode with UVs to produce photoelectrons to study and monitor distortions
- Calibration laser:
  Provides a UV beam for alignment purposes
- Photoelectric UV light source:
  Enlights the cathode with UVs to produce photoelectrons to study and monitor distortions, Deuterium lamp with 160nm - 400nm of the wavelength as UV light source and smooth Aluminium film as cathode.
  To mimic the bunch structure & the ions distortion with UV light lamp by the specific time structure shine controller
  (Huirong Qi, please correct : there seems to be a confusion with the prototype)
    - To create more than about 10000 electrons/s.mm^2
    - Fused silica as the shine window: ~99% light trans.@266nm
- Calibration laser beams:

Provides a UV laser beam for calibration and alignment purposes to monitor the drift velocity, operation gas, gain uniformity and electric field.

- The ionization in the gas volume along the laser path occurs via two photon absorption by organic impurities
- Nd:YAG laser device with 266nm of wavelength (~4.68eV)
- Laser power : ~10 μJ/mm^2 to equal ~10MIP
- Fused silica as the laser mirrors: ~99% light transmission and reflection@266nm

- Gas analysis
- P and T monitoring

For convenience the original instructions are listed below:
It should indicate all electrical interfaces, including redundancies:

- power: the type of power (regulated, unregulated, heating), number of lines for each type;
- remote control: control type (relays, digital ...), the number of each type of control
- insulation;

Other interfaces: clock, other instruments, ...

5.2 Connection diagram

For convenience the original instructions are listed below:
This is a general wiring diagram showing the names of cables, connectors, equipment, ...

5.3 List of Connectors

- USB type Connector
- Standard HV Connector
- Standard Ethernet Connector
- Standard HDMI Connector

For convenience the original instructions are listed below:
This is a general wiring diagram showing the names of cables, connectors, equipment, ...
For each connector on should indicate:

- The location (eg equipment A);
- the name of the connector;
- type (manufacturer's name + complete reference);
- the general function (eg power ...)
- coded pins, keying;
- the precise limits of the respective supplies;
- the principle of shield connections and grounding policy.

5.4 Cabling and connecting sheets

For every connector and every pin it will be specified:

- the signal type (analog, digital, power, RF, ...),
- the waveform (period, duty cycle, maximum value, minimum value)
- a graphical representation for complex signals (ramp, modulation ...),
- the category (transmitter or receiver)
- the reference of the pining of the connector,
- the electrical diagram of the interfaced circuit.

5.5 Electrical grounding scheme

A diagram will indicate how are connected or isolated mechanical grounds, shieldings ...
The maximum contact resistance will be defined.

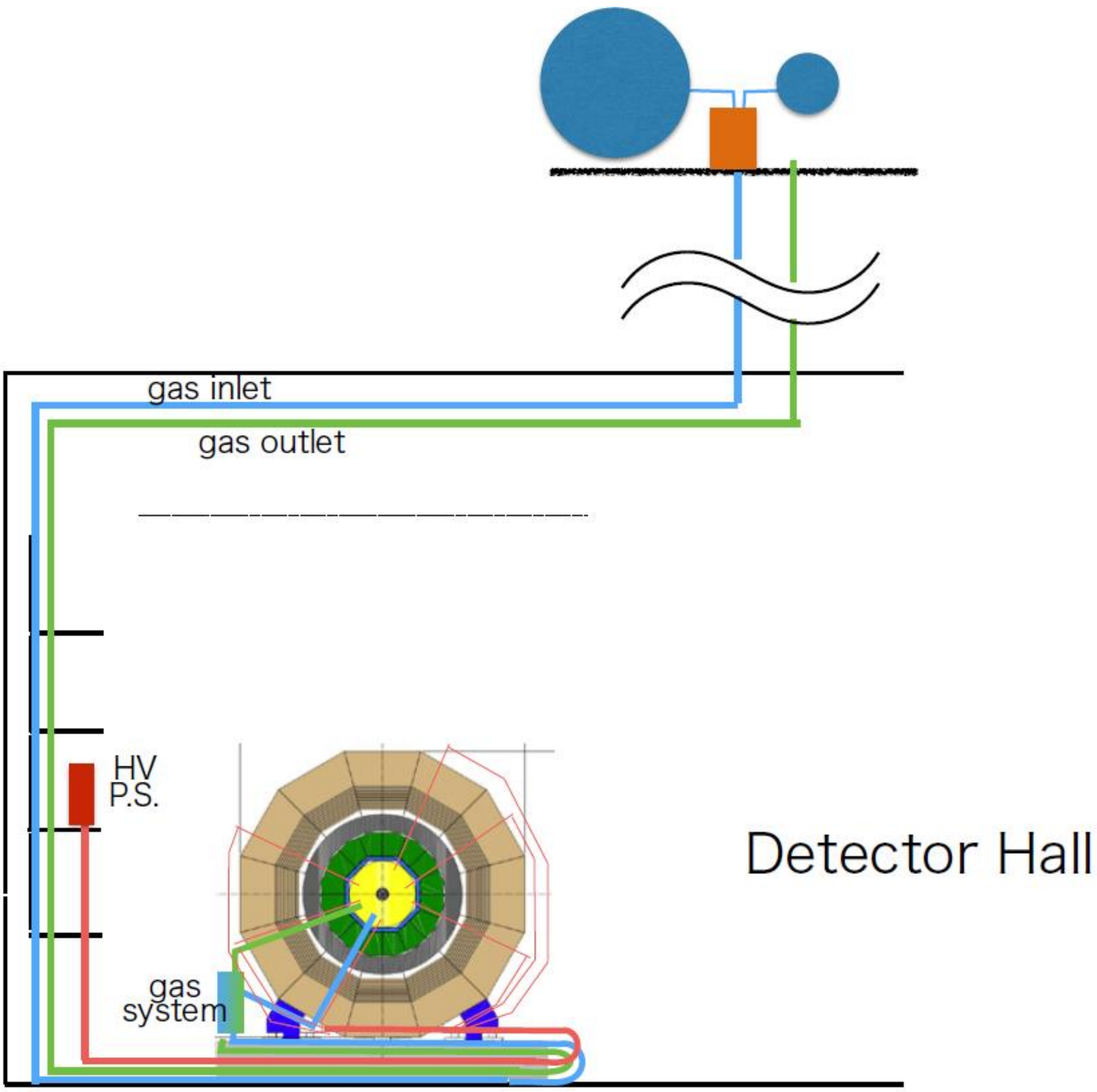
5.6 Power Consumption

The principle of power pulsing implies that the currents at the ASICs and module cards are enabled with a duty cycle of 1%.

The total power consumption with the present electronic designs (assuming 1.5 10^6 channels per endplate) is 6 kW per endplate (about 4 mW per channel). This can be reduced by a factor of 50 to 100 if the duty cycle of 0.5% can allow switching off the electronics between bunch crossings. The decision to do so also involves assessment of the need to be able to take cosmic data, for alignments purposes, and consideration of possible mechanical effects of power switching within an intense magnetic field. The power dissipated by the electronics could be reduced by a factor of two by limiting the voltage supply. The gas amplification system consumption is negligible.

In the pixellised option, the consumption is as much as 50 kW per endplate. Then, a reduction by a factor of 50 should be possible, thanks to power pulsing, and the cooling system and the diphasic CO_2 cooling system should be able to extract the remaining kW.

Power will also be dissipated in the cables bringing the low voltage (32 A copper cables, with 6 mm^2 section). If it turns out to be the case, a solution might be studied by bringing the current at higher voltage and making use of DC-DC converters to obtain the operational voltage. The low-voltage racks will be as close as possible to the detector, thus the power supplies will have to be cooled without producing vibrations. Available cooling from the detector can be used for this.



5.7 Other electrical interfaces

For the moment we use this section to describe what is inside the electronic trailer.

- HV power supplies
- 16 LV power supplies (type Lambda devices)

- Computer Farm (typically 16 DELL Poweredge),
- Connected to central storage of Central DAQ system for event building?

For convenience the original instructions are listed below:
This section defines all other electrical interfaces (clock s, other instruments ...).

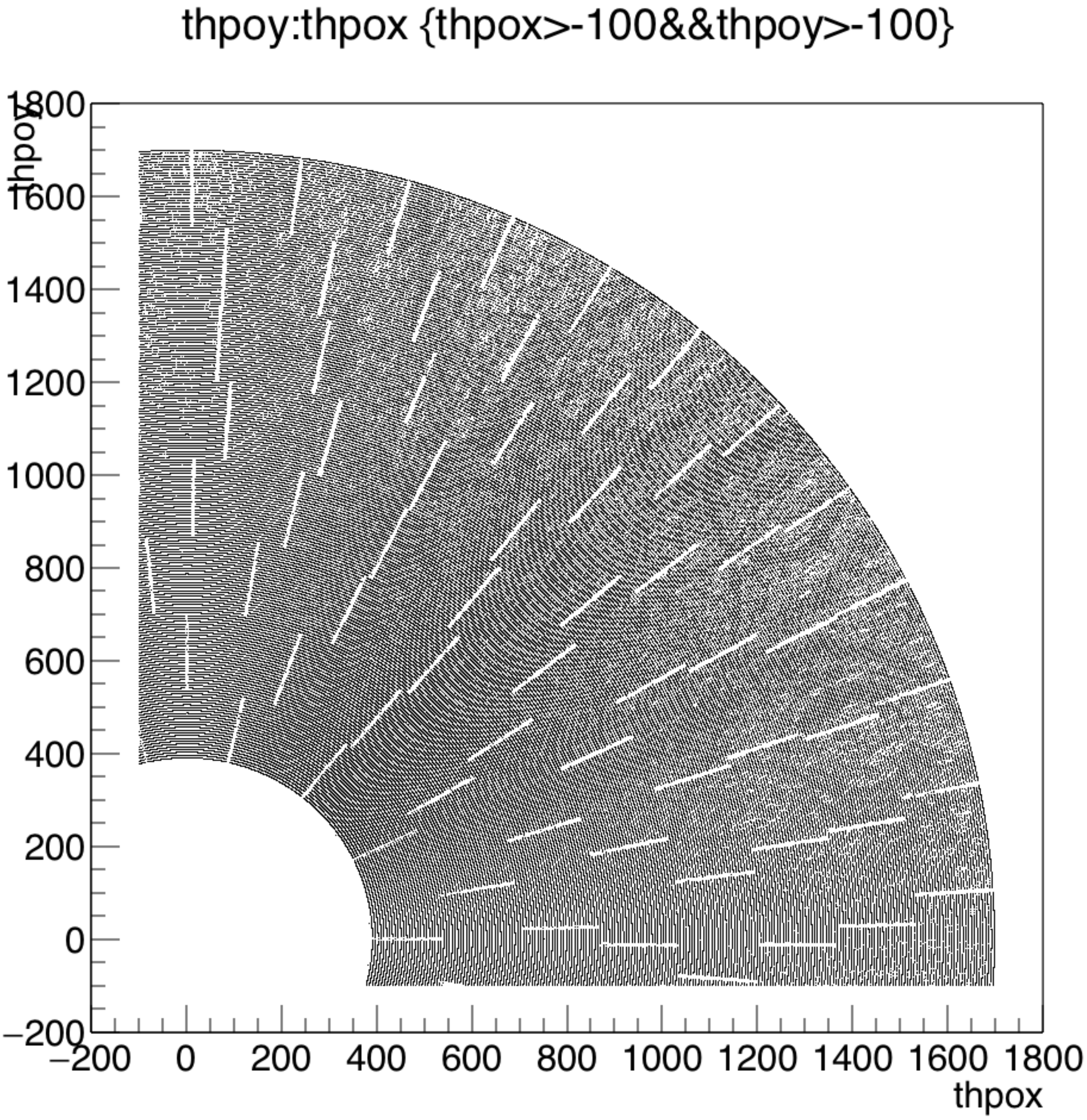


Figure 1. . Sketch of a TPC end plate	

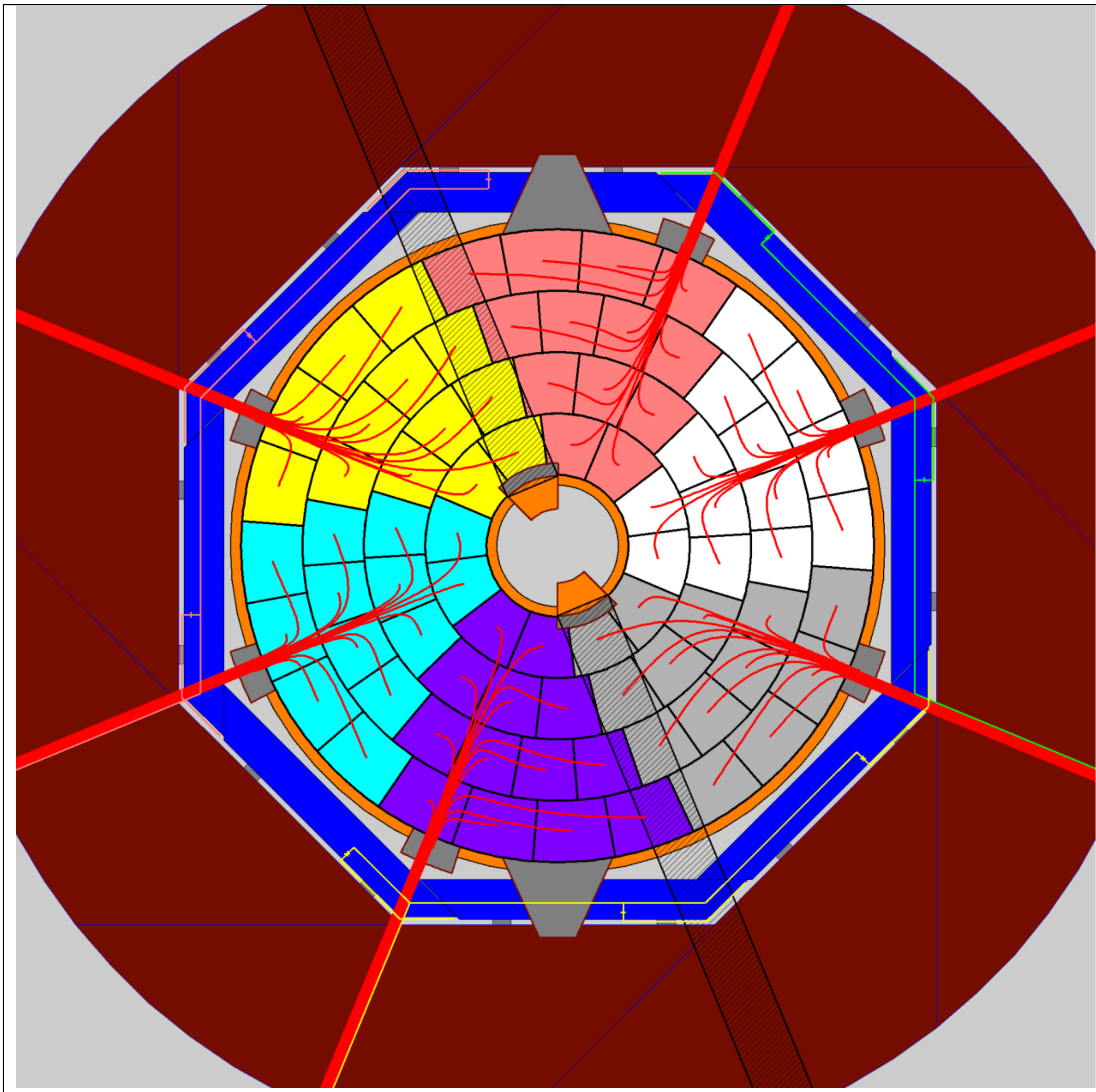


Figure 3. The TPC is shown hanging from the HCal. The ECal barrel is also represented with its rails.

6. FLUID INTERFACE

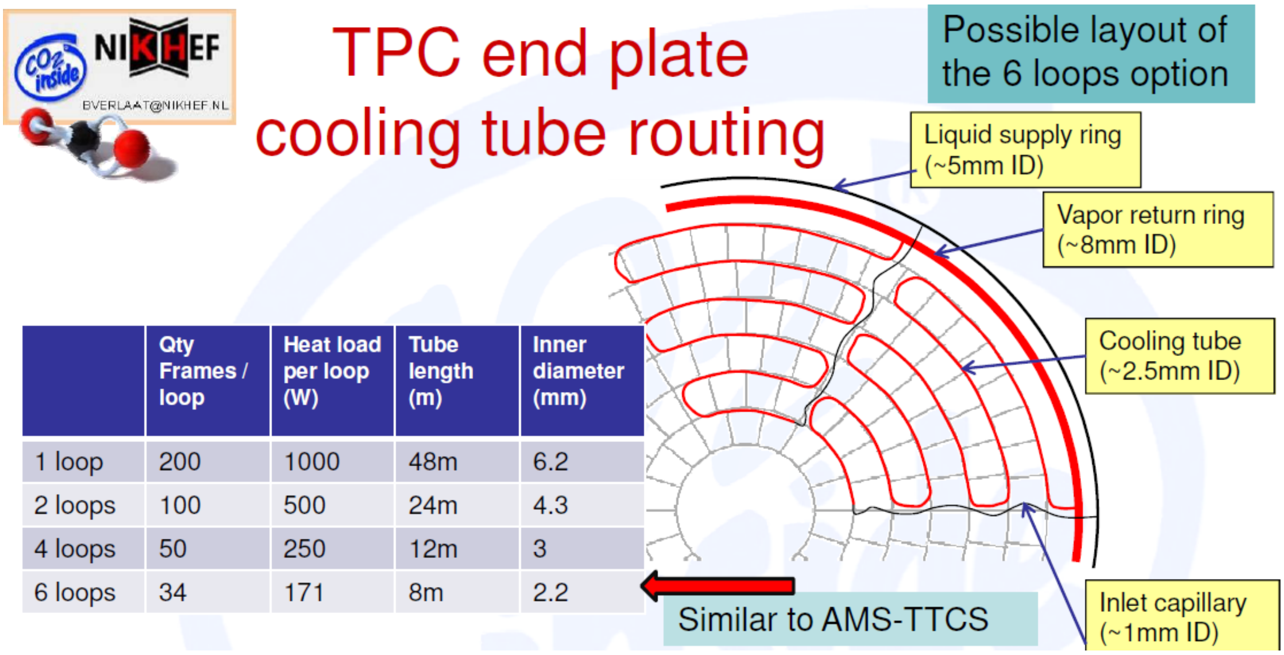
To avoid inhomogeneity of its properties, the temperature gradient has to be kept at a minimum, which implies taking the heat generated by the readout electronics while keeping the endplate at room temperature. For this, a 2-phase CO_2 cooling solution has been studied. The cooling fluid composed of co-existing gas and liquid CO_2 will be circulated in 2.5 mm diameter pipes in the modules (or the PCB will be equipped with microchannels), under a pressure of 50 to 100 bars. For instance, each endplate can be equipped by 6 loops, each 8 m long, with a 3.0 g/s mass flow of the 2-phase fluid. This allows 170 W to be removed per such loop. The diphasic fluid can be supplied by a 5 mm circular pipe around the endplate. The gaseous CO_2 can be collected from the 6 sextants by an 8-mm diameter circular pipe around the endplate.

6.1 Gas system Interface

Though the baseline gas contains isobutane, the mixture is not flammable. Thus the gas components have to be stored at the surface and the mixture has to be brought to the cavern. The storage will consist of a large Argon supply and a smaller battery of isobutane and CF4 cylinders.
The detector gas mixture will be brought and expelled by several 2 cm diameter pipes. The purity has to be kept at the 10^{-5} level to avoid electron capture during the drift. The 40 m^3 volume (30 m^3 in the small version) has to be renewed about twice a week. The detector gas is circulated at a rate of a few volumes per day. The chamber gas is premixed and buffered in large containers, which have a volume of approximately 200 m3, on the surface of the installation.

6.2 Cooling fluid system Interface

The information here and in Sec. 8 is extracted from a detailed study of the cooling system that is available under [xxx].
The TPC will be cooled by a diphasic CO2 system. A compressor is located in the gallery about 50 m from the ILD detector and the cooling fluid will be brought to and away from each endplate. From there it is further distributed to the individual modules by manifolds. Possibly several modules (maybe four?) can be served in series. Fig.5 shows the general concept of the cooling system. The heat is removed by 6 loops per endplate. Each loop is made of a 1mm diameter inlet capillary feeding a serpentine of 10 m stainless-steel pipe with an inner diameter of 2.5 mm. A peripheral 8-mm inner diameter exhaust ring returns the vapor to the CO_2 compressor. Each such loop can remove 200 W.



	Qty Frames / loop	Heat load per loop (W)	Tube length (m)	Inner diameter (mm)
1 loop	200	1000	48m	6.2
2 loops	100	500	24m	4.3
4 loops	50	250	12m	3
6 loops	34	171	8m	2.2

Figure 4 : sketch of the 2-phase CO_2 cooling, assuming one loop per sector.

7. THERMAL INTERFACE

For the subsystems:

- Thermal dissipation: in and out of operation

The TPC will evacuate all its produced heat by means of the cooling system. The only sources of heat dissipation are the cooling pipes in which CO_2 will undergo phase transition from around 21°C to 22 °C.

- Limit temperatures: during standby mode, for switching power, in operation. In any case, the temperature at the level of the readout ASICs should never exceed 60°C.

8. INTERFACES FOR DETECTOR TESTING

These are the specific interfaces related to the test equipment:

- MSE interfaces: mechanical assembly test ... ;
- ESE interfaces: electrical interfaces with the test and verification systems;
- OSE interfaces: reference cubes, or targets for the surveys ...

The laser system would be used for calibration and for distortion measurement in the prototype with one module as readout or large, A Nd:YAG laser with a wave length of 266 nm shall be used to study the track distortions. An additional UV-lamp could generate additional ions. The complete optical path and the laser power will be split into 6-7 laser tracks. The laser map coupling into the chamber and the planned laser tracks could be designed. The UV laser beam for calibration and alignment purposes to monitor the drift velocity, operation gas, gain uniformity and electric field. Nd:YAG laser device with 266 *nm* wavelength could make the ionization in the gas volume along the laser path occurs via two photon absorption by organic impurities. The laser power should be reach ~10μJ/mm^2 to equal ~10MIP,

HQ, Please revise this sentence:

and the laser transmission and reflection mirrors will create the laser map along the drift length.

The laser would be located in the cavern, in a barrack as required by security imperatives, and brought on the detector by an optical fiber.

9. GLOBAL REQUIREMENTS FOR THE SERVICES

The total AC power needed (dominated by electronics and computing) is about 40 kW in the baseline version of the TPC. This corresponds to a total volume

TO DO LIST

Actions	Who ?	When ?
Add photoelectric laser source and calibration laser (Section 8)	Huirong Qi	Week 41 (done)
Power dissipation in electronics and module weight; description of cables	Leif Jönsen	
Numbers for bounding box, clarification of 38 mm increase of ECAL thickness, local module coordinate system	Dimitra Tsionou	

DISTRIBUTION LIST

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