DRAFT **FP420 NOTE 2008-001**

FP420, High voltage bias and low voltage power supply

Henning E. Larsen, Univ. Torino and INFN (henning.e.larsen@gmail.com)

Revision information:

Initial version 1.0 dated 06/04/2007.
Version 2.0 dated 20/05/2007. Addition of commercial solutions. and QUARTIC/GASTOF support
Version 2.1: table page break disabled
Version 3.0: 24/3/2008. Major rewrite of the solutions sections adding the option of placing LV supplies in alcoves and inclusion of an all-in-counting-room solution.
Version 3.1: 1/4/08 Corrected figures which did not print and did not show up in non-windows platforms!

Introduction

This document describes the requirements for biasing the Silicon detectors and power their associated front-ends. In addition there are considerations for also supplying power and bias for the QUARTIC/GASTOF detectors and for temperature monitoring of the front-ends. We start by presenting the general specifications. Various solutions based on supplies from *CAEN S.p.A.* and *Wiener, Plein & Baus GmbH.* Finally a summary of the studied solutions and their cost is presented.

Definition of terms and overview

We will start from the broadest view and gradually focus down on individual details.
In Figure 1 is a top view of the context in which the FP420 proposal should be seen.

The Silicon pixel, QUARTIC/GASTOF detectors are grouped into 4 locations in the tunnel: 420m before and after CMS and Atlas interaction points as illustrated in Figure 1. In this discussion we nominate those locations: *FP420 station*s or simply *stations*.

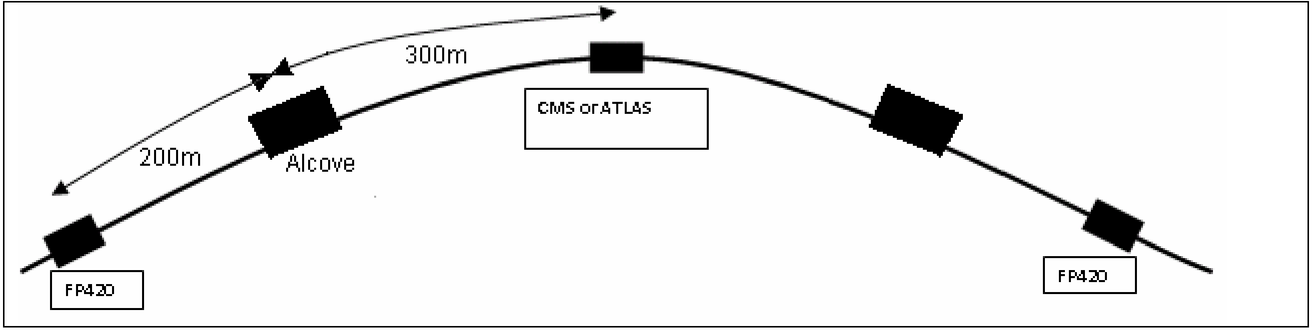


Figure 1: Top view of the FP420 setup showing that FP420 stations are located at the LHC downstream beam, 420m away from the CMS and the Atlas interaction points measured along the beam-pipe. The distances on the drawing is the approximate cable distances between FP420 station, alcove (RR17/13 for Atlas and RR57/53 for CMS) and counting room.

As can be seen, the FP420 detector's are all located in the LHC tunnel close to the downstream beam-pipe, with a distance along the beam of 420m to the interaction point, but the distance to the counting room is longer; up to 500m has to be accounted for. Obviously this is depending on the exact cable route and where in the counting room the electronics will be located. But both CMS and Atlas specialists have confirmed these lengths as being realistic estimates. Between the interaction point and FP420 stations is an alcove (RR17/13 for Atlas and RR57/53 for CMS) where a rack with service electronics could be placed (Ref: Detlef SWOBODA).

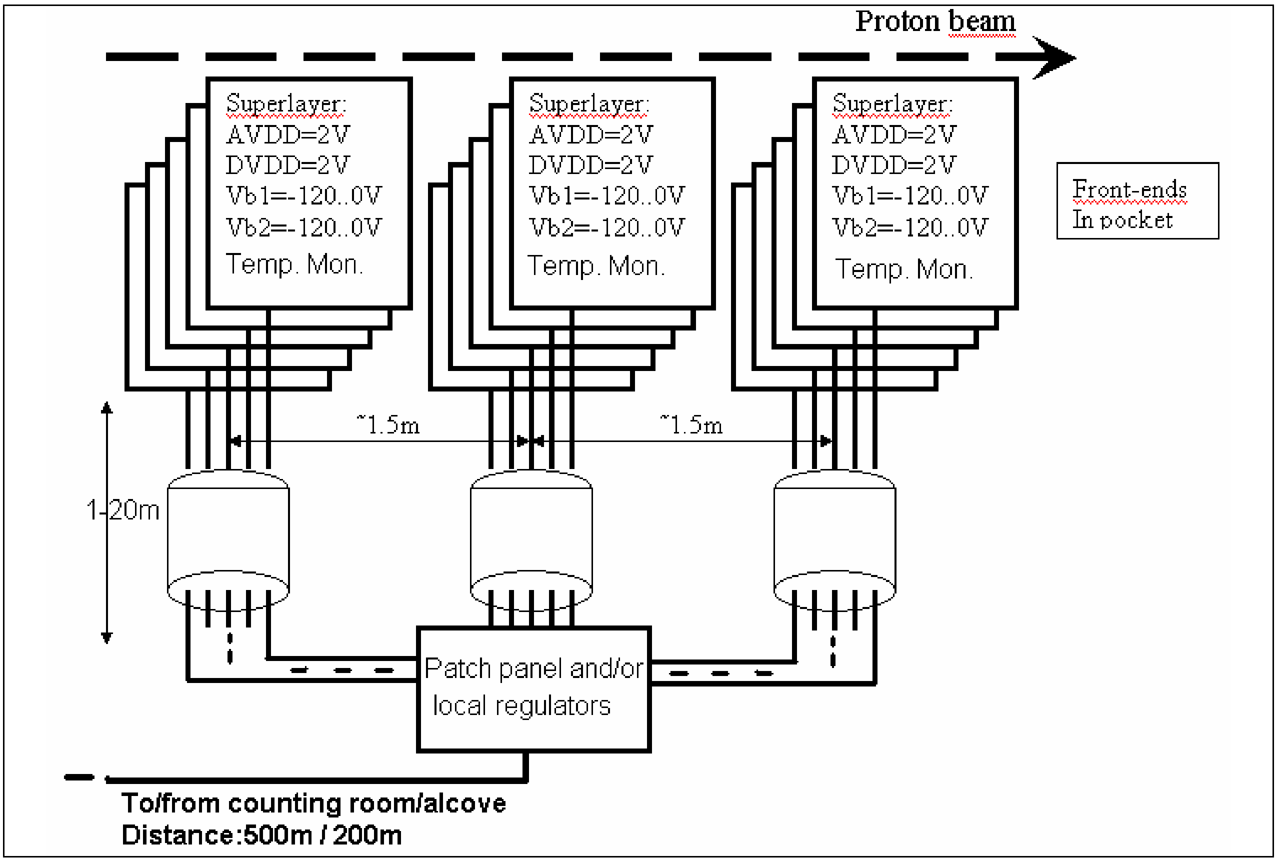


Figure 2: Overview of one of four FP420 stations highlighting the power and monitor items. It also illustrates how the front-ends are physically distributed at a station. Each station is built around a cryostat. This drawing shows a typical station with 3 pockets and 5 superlayers in each pocket. Each superlayer require 2 low and 2 high voltage supplies and a temperature monitor.

In Figure 2 is an overview of one of four FP420 stations. One station has up to 3 pockets each with up to 5 detector Superlayers. The detector assembly in a pocket is illustrated in Figure 3.

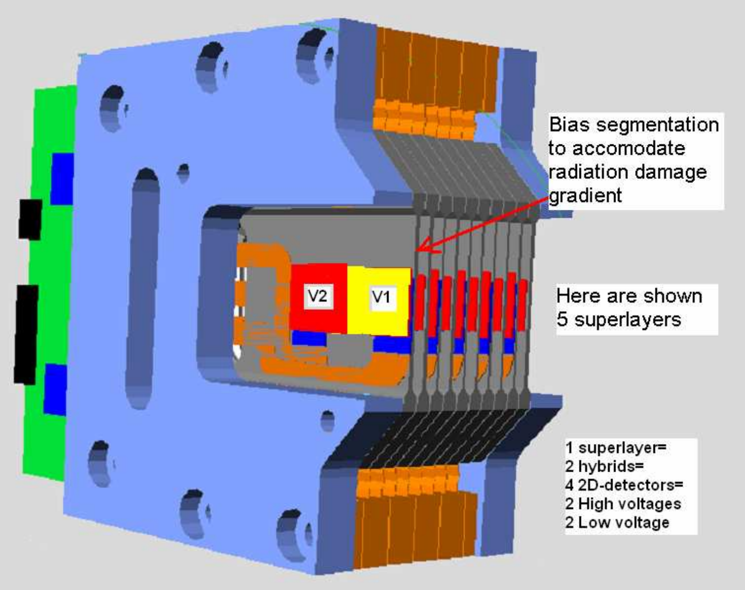


Figure 3: Illustration of one detector assembly located in a pocket. This shows how the detector is made out of individual hybrids (also called blades) stacked up in pairs. Each pair is called a Superlayer. The drawing is not to scale and only illustrates the concepts and nominations.

One Superlayer consists of 4 detectors and associated readout electronics. Physically a Superlayer consists of two hybrid planes, but for this discussion this is irrelevant because the low voltage and high voltage supply is shared between the two planes in a Superlayer.

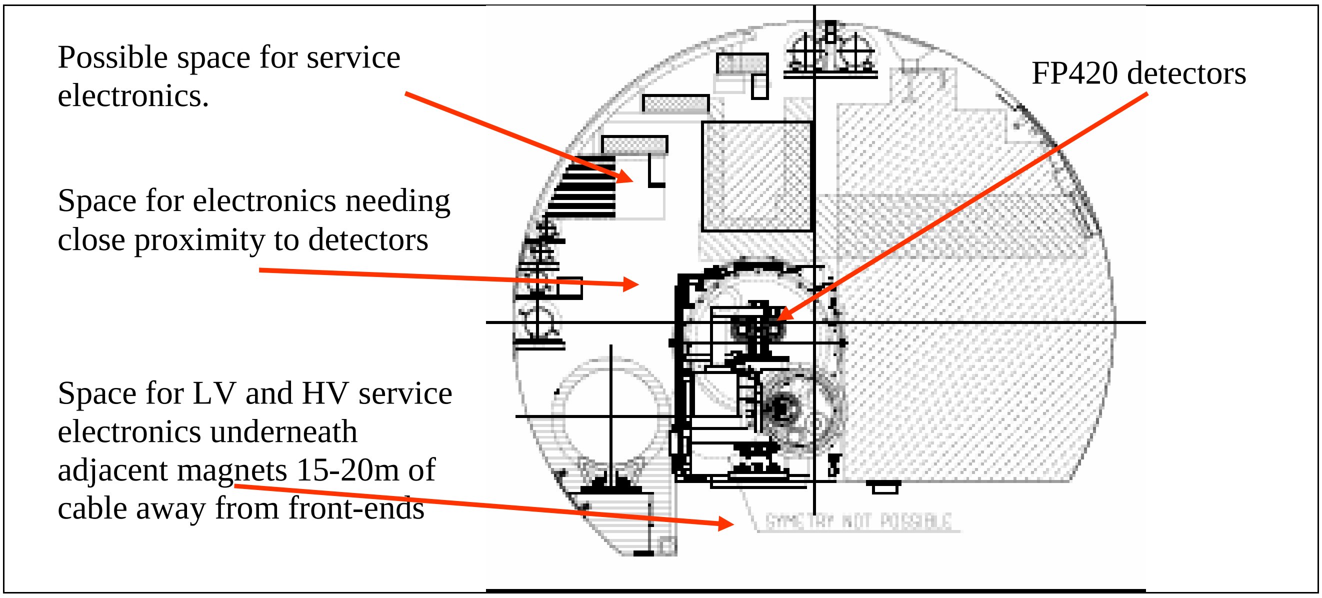


Figure 4: Crossection of the LHC tunnel at the locations of FP420

In Figure 4 is a cross sectional view of the LHC tunnel at the location of the FP420 detectors. The tunnel is 3.80 m in cross section diameter. Underneath adjacent magnets there is room for electronics which can sustain the radition. Here the height is limited to <400mm. This is enough for an 9U standard crate (482,6mm (incl. 19" rack-mounting profile) x 352mm (9U) x 553mm (WxHxD). The radiation field at the location of the service electronics is estimated to 15Gy(Si)/year=1.5kRad(Si)/year. (Ref: LHC-PM-ES-0006-00-10, edms 565013 and **LHC Project**

Note 296, 27 May 2002 and **LHC Project Note 295,** 27 May 2001) The field is a mixture of neutrons, protons and gamma radiation. We expect a lifetime of 10 years.
There is no significant magnetic field in the location underneath the adjacent magnets.

Segmentation

The system has to be segmented into reasonable size of units. There are many criteria to consider when selecting the partition. The most important ones are the goal to

1. Minimize electromagnetic interference (ground loops).
2. Minimize the impact of failing supplies on the performance of the total detector system. It is an advantage that in case of failure in a supply only a small part of the system will be out of operation. To full-fill this is obviously a question of how many resources are put into play.
3. Make maintenance simple and replacement of modules fast.
4. Minimize cost of support cables, connectors and electronics.

In practice one has to make a pragmatic choice based on the various requirements which are often contradicting of each other.
We recommend to keep the supplies for the Superlayers as one segment of supply. This allows for keeping each Superlayer electrically isolated from the other, even within a pocket. This also stems from the fact that the readout of one Superlayer is done by one chip. I.e. a readout chip is common for two hybrids which makes splitting of the supplies into even smaller segments covering a hybrid less relevant.
Now if we should do as we preached in the list of goals above, we would like to have a separate power supply with low voltage and high voltage for each Superlayer, but here we are faced with the limitations imposed by the products available on the market. There is no commercial product available which has both high voltage and low voltage in the mix we would like. This would require a custom design to meet this specification. We have considered this option but it has been abandoned due to lack of resources. In stead we suggest the use of standard multi-channel commercial supplies for the high voltage and similar modules for the low voltage supplies. This means in practice that each supply module will support several Superlayers, and it is thus possible that a failure inside such a module can bring down several super layers. But as mentioned this is choice based on a balance between requirements and resources.

Superlayer chips and detectors

The detectors are 2D detectors also used in Atlas. (??**CINZIA could add a few lines here??).** The amplifier and readout chips are the PixelChip (**REFERENCE**) and MCC (**REFERENCE**). Obviously the requirements are derived from reports on these chips. As mentioned, each Superlayer has four 2D-detectors and thus four PixelChips and they are read out with one MCC chip. This architecture is illustrated in Figure 5

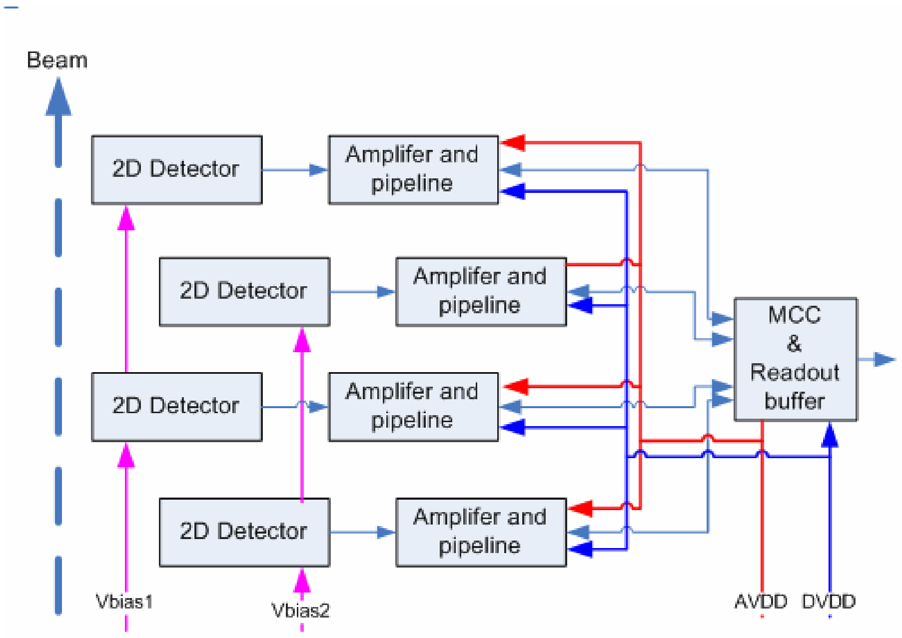


Figure 5: Block diagram of the supply for one Superlayer. Vbias1=Vb1 is for the pair of detectors closest to the beam and Vbias2=Vb2 is for the pair further away. AVDD is the analogue supply and DVDD is the digital supply for readout chips.

Superlayer supplies for FP420

The low voltage supply to a Superlayer should be floating relative to any other Superlayer.

Each Superlayer requires two low voltage supplies, preferably floating with minimum 1V compliance range relative to each other:

- Analogue AVDD nominal 1.6V
- Digital VVD nominal 2.0V.

In addition a Superlayer requires

- Two high voltage bias supplies Vbias1 and VBias2 with remote controlled voltage in the range 0V to minus 120V.
- These 2 different bias supplies Vbias1 and VBias2 for do not have to be floating relative to each other within a superlayer.

Low voltage power supplies specifications

From the specifications of the Atlas FE-I3 front end chip we get the requirements for one chip as listed in Table 1

One Pixel FE-I3 chip	Voltage range	Voltage nom	Current	Current limit
Analog AVDD	1.6-2.0V	1.6V	5-70mA	100mA
Digital VDD	1.5-2.5V	2.0V	1% occupancy: 40-50mA 10% occupancy: 60-70mA	100mA

Table 1: Low voltage requirement for one Atlas FE-I3 front end chip.

Notice that the required digital supply current depends on the detector occupancy. High occupancy results in higher current. The supply and its cables should take this into account.
In Table 2 are the requirements for one readout controller chip MCC.

One MCC	Voltage	Current	Current limit
Digital (VDD)	1.8-2.5V	120mA-150mA	170mA

Table 2: Supply requirement for one Atlas MCC chip

As each Superlayer has 4 detectors end 4 FE-I3 chips plus one MCC chip sharing the digital supply with the front-end we can sum up the total requirement per Superlayer as shown in Table 3.

4 FE-I3 + 1 MCC+ Read-out driver	Voltage range	Voltage nominal	Current	Current limit
Analog (AVDD)	1.6-2.0V	1.6V	20-280mA	310mA
Digital (VDD)	1.8-2.5V	2.0V	1% occ 280mA-350mA 10% occ 360mA-430mA	480mA
Monitor resolution	<20mV		<10mA	

Table 3: Overall specification for a Low voltage supply segment for one Superlayer consisting of 4 PixelChips FE-I3 and one MCC chip. Remote monitor should enable observation of the voltage and current.

There will be decoupling capacitors close to the load.

Note: At very high occupancy the Digital part of the FE and the MCC chip can go into a mode of latch-up. The chip does no longer work when in this state, but the supply should have a current limit set such that it does not damage the chip. It is currently assumed that a simple current limit for the collective supply of four FE-I3 plus 1 MCC chip combined with a means to monitor remotely the current consumption and to take corrective actions, will be sufficient to avoid damage to the chip.

The voltages may need adjustments in the course of the lifetime of the system due to radiation effects. It is an advantage if this can be done remotely.
The low voltage supply may need to have remote sense feedback to compensate for voltage drop. The wire and connector resistance and current variation determines if this is necessary.
There must be a current limit which can be set either locally or remotely at the value indicated in Table 3. It would be an advantage if its value can be set remotely as this will allow a more flexible system capable of dealing with changes due to for instance radiation damage. The current limiting can be either of a saturating type or a fold-back with latching action. The latter obviously requires some means of reset from the remote control system.
Currents and voltages must be monitored and results provided remotely with accuracy as mentioned in Table 3. Sample rate in the order of 1 Hz is sufficient.
Each Superlayer low voltage supply should be individually on/off controllable from remote.

High voltage power supplies specifications

The high voltage bias supply to a Superlayer should be floating relative to any other Superlayer.

Each Superlayer has two individual bias supplies in order to better cope with radiation damage. The closer the detector is to the beam, the higher its radiation damage is likely to be. As the bias voltage for depleting the detector increases with radiation damage, it is an advantage to segment the supply into two: One for the pair closest to the beam (Vb1) and one for the pair away from the beam (Vb2). To simplify matters it is not required to separate the GND between Vb1 and Vb2.
There will be passive RC low-pass filtering close to the load.

4 detectors 2 voltages	Voltage	Current	Current limit
Vb1	0 to -120V	<1mA	1mA
Vb2	0 to -120V	<1mA	1mA
Monitor Accuracy	<1V	1µA ~ 12 bit res.	
Setting Resolution	<3V ~ 6 bit res.		

Table 4: Specifications for the high voltage bias supplies for one Superlayer consisting of four detectors segmented onto a supply of two independent voltages. The voltage and current should be monitored from remote with at least the specified accuracy. The voltage should be controllable from remote with a resolution of better than 3V.

There must be a current-limit which should be set at the indicated value. To increase flexibility, it would be an advantage if its value can be adjusted, preferably from remote. The limiting can be a simple saturating current-source type of limit. Currents and voltages must be monitored and results provided remotely. Sample rate in the order of 1 Hz is sufficient.

The high voltage supply has to be remotely controllable to set the voltage in the range 0 to minus 120V.
The high voltage supply does not require remote-sense feedback on the wires to the load as the current-induced voltage drop is negligible in relation to the required accuracy.

In Figure 6 is a block diagram illustrating the connection of the bias supply to the front-end. This setup is used in the Atlas On-detector setup. Notice that the bias is connected to the detector anode and is thus negative and that the other terminal of the bias is referred to the analogue AVDD and not to GND. R1, R3 and C1 are included for filtering of noise. The purpose of R2 as reported by Atlas, is to enable measurement of the bias current in a test setup. If the supply has built-in current monitoring capabilities, R2 should not be required.
Notice that due to the construction of the input stage of the Front-end FE-I3 chip any decoupling locally on the hybrid, should be returned to AVDD and not GND. This actually means that if R2 is included in the layout, its resistance value should be a small as possible because this improves the filtering efficiency of C1.

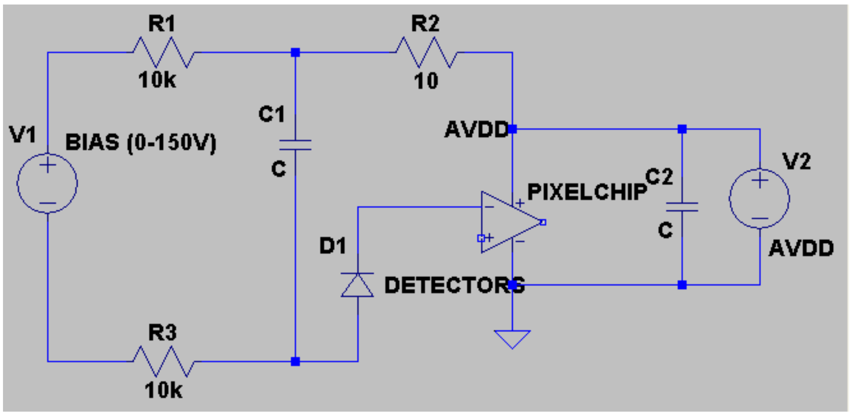


Figure 6: Connection diagram for the high voltage bias supply and for AVDD as suggested by the Atlas group. Notice that the bias is referred to the analogue AVDD and not to GND. The purpose of R2 is to enable measurement of the bias current in a test setup where the supply is not offering current measurement features. R1, R3 and C1 are for noise filtering.

Power budget

In Table 5 is listed and summed the power dissipated in the front-end. This scenario is for a worst case setup where the occupancy is 10% and the voltages are at a maximum. Notice that for cooling design the power from the radiation and the thermal flux from the ambient will have to be added to this list.

One Superlayer	Voltage [V]	Current [A]	Power [W]
AVDD	2.0	0.28	0.56
VDD	2.5	0.43	1.08
Vbias1	120	0.001	0.12
Vbias2	120	0.001	0.12
Total per Superlayer			1.88
		# SL's	
Total per pocket		5	9.38
		# Pockets	
Total per station		3	28.13

Table 5: Power dissipated in the front-end electronics assuming 5 superlayers per pocket. Numbers are worst case values with 10% occupancy and maximum voltages and currents. For other values see Table 3 and Table 4.

Low and high voltage channel count

# channels	One Superlayer	One pocket	One station	Fp420 experiment
	4 det.+ FE+1MCC	with 5 Supelayers	with 3 pockets	with 4 stations
Low voltage	2	10	30	120
High voltage	2	10	30	120

Table 6: Number of channels of Low and high voltage supplies.

Table 6 counts the channels needed in the nominal configuration of the Silicon detector setup. The final count may differ from this.

Temperature monitoring

The temperature in the front-ends need to be monitored. It will probably be a good solution to have a probe on each Super layer. Temperature sensors of NTC type are known to be radiation tolerant and are used in other detectors at LHC. For instance LHCb (Velo repeater board, Low Voltage Card) using NTC 103KT1608-1P from Semitec. They are available in many resistive values and form factors, including tiny surface mounted SMD packages. They are passive resistive types which need an excitation current in order to operate. Due to their relatively large resistance (kohms) they can be operated on two wires, as long as the wire resistance is only a small fraction of the probes resistance. With very long and thin wires, compensation of the wire drop can be necessary. The selection of the most appropriate device will require a later study. It is however given that there will be the need of both excitation circuitry and an ADC to read the values. It is an advantage if this excitation and measurement system can be integrated into the power supply crates. Assuming one detector per Superlayer the channel count will be as listed in Table 7

Temperature channels	One Superlayer	One pocket with 5 Superlayers	One station with 3 pockets of 5 SL

Channel count	1	5	15

Table 7: Temperature monitor channel count. This number is only an approximate number.

QUARTIC/GASTOF detectors high and low voltage supplies

The QUARTIC/GASTOF modules have different requirements as the Silicon detectors. At this moment the specifications per station are rather loosely set as described in Table 8:

QUARTIC/GASTOF detector	Number of channels	Voltage nominal	Current	Current limit
High voltage	4	-3.5kV	TBD	TBD
AVp12	1	12V	TBD	TBD
AVm12	1	-12V	TBD	TBD
DVp5	1	5V	TBD	TBD
DVp3.3	1	3.3V	TBD	TBD
Monitor resolution	TBD		TBD	

Table 8: Preliminary specifications for QUARTIC/GASTOF detectors power supply for one station.

Discussion about solutions considered

Originally a couple of solutions were studied based on commercial power supplies (CAEN S.p.A., Easy3000 series and Wiener, Plein & Baus GmbH, MPOD and Maraton series) being located in the tunnel next to FP420 stations stowed underneath the adjacent magnets. This setup is illustrated in Figure 7.

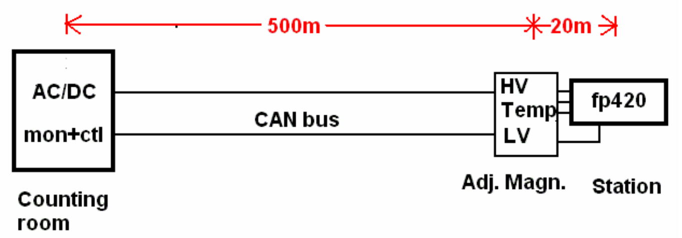


Figure 7: All power supplies and monitoring located in the tunnel adjacent to the station. Only communication and raw power pass over the 500m

The big advantage of these solutions is the low cable cost combined with options for extensive remote control and monitoring. The major drawback is the sensitivity to radiation combined with difficult access for maintenance.
A study of the radiation tolerance by Thijs Wijnands (CERN-TS) of a solution as in Figure 7 proposed by CAEN (see Table 12) concludes that this will exhibit 0.1 SEU (Single Event Upsets)/module/day if placed in the tunnel close to the stations. This will be the case from day-one of operation. This means that there will be several SEU's per day to deal with. In addition to this, there will be the usual effect of radiation damage gradually accumulating over time.
With these considerations in mind we have studied alternative solutions as the one in Figure 7.

Inspired by Totem Roman Pot detectors it is being considered to place the power supplies in the Alcove area's RR17/13 for Atlas and RR57/53 for CMS and use long cables (Figure 1). (**NEED WORKING ON:** IT IS UNCLEAR HOW MUCH THE RADIATION WILL BE IN THE ALCOVE AREA, GIVEN THAT THE LOCATION AVAILABLE IS ABOVE THE BEAMPIPE)
Finally we have also considered solutions where all critical power supply electronics is in the counting room and only very simple linear radiation hard regulators are located in the tunnel next to the station.
Common for these solutions with low voltage supply cables of 200m or more is that they require local regulators next to the load. Without such regulators it will not be possible to maintain a stable load voltage.

These alternative solutions are described below. The description It mainly focuses on the cable infrastructure which is a significant part of the total cost when using solutions with many long cables.
The solutions described, with long cables between power supply and detectors are all having the high voltage in the counting room. This is considered a good solution because radiation is no more a concern. The wires for high voltage can have a small cross section due to the small current (<1mA) and need no remote sense. The high voltage cables must be well shielded and with a noise filter at the detector.

Linear regulators next to the front-ends

Cables of 200m to 500m of length will have to be with rather large cross section in order to limit the voltage drop to the level required in the low voltage supplies (roughly <200mV). Remote sensing, which is the classical way of overcoming this, is not effective due to the long delay in the cable. The phase shift at the frequency f due to the cable delay τ is $2\pi f \tau$. At 500m of cable, the phase shift will be 45^o at 25kHz but to this has to be added the phase lag due to the capacitive load which is required to high frequency stability. This rapidly makes the total phase shift approaching 180 degree and instability. The only cure is to lower the loop bandwidth correspondingly but at the cost of the response time for dynamic load changes. So the cable delay will limit the obtainable bandwidth of the regulation control loop. Tests with the Wiener MPOD power supplies shows that it is not possible with this equipment to stabilize the voltage sufficiently.

We therefore suggest to place linear regulators next to the load to stabilize the voltage and to lower the requirements for the stability at the end of the long cable. This solution is shown in Figure 8.

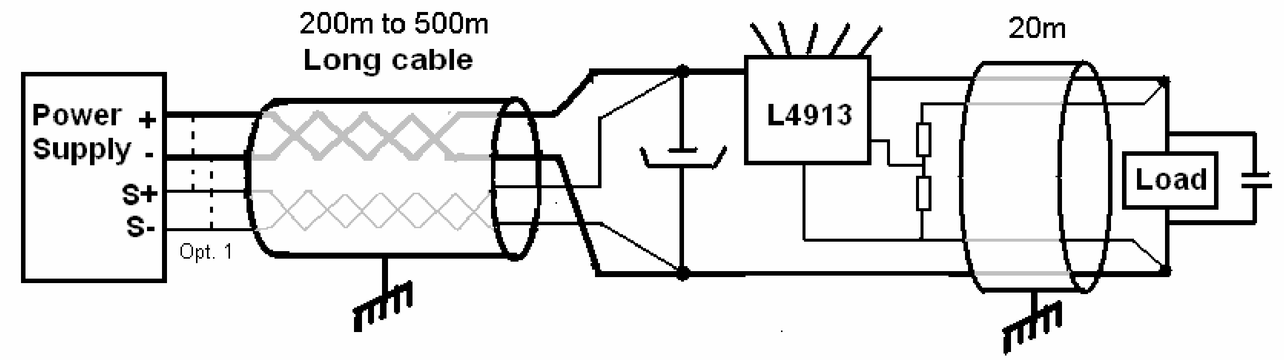


Figure 8: Block diagram showing the principle of using a local radiation hard linear regulator. Here for a positive voltage. A remote sense at the regulator input will compensate for the slow varying voltage variations there. It may not be needed however if the cables have a sufficient cross section. In that case connect at Opt. 1. A similar circuit exists for negative supplies using LHC7913-4.

Such setups, al be it with much shorter cables, are used in many LHC detector systems, such as Totem Roman Pot and Vertex Locator (VELO) of LHCb. A pair of radiation hard linear regulators has been developed in the framework of RD-49. The regulators are LHC4913 for positive voltages (SCEM: 08.57.56.011.7; 1.23V to 9V at 3A) and for negative voltages LHC7913-4 (SCEM: 08.57.56.111.4; -1.2V to -7V at 3A). Both types are available from CERN stores at around 15CHF a piece.

A setup as in Figure 8 will not allow monitoring of the actual load voltage. Only the load current can be monitored. In addition it is not possible to adjust the voltage remotely.

In other LHC experiments using a linear regulator, a separate monitoring system for the voltage is put in operation. This obviously has to be radiation hard. For instance CMS's central tracker use a system of FEC, DOHM and CCU's. The main issue with this solution is that it is highly specialized for these experiments and not easily adapted to FP420's requirements. Added to this is the difficulty of finding the components. Queries has shown that the parts are not available so new batches would have to be produced.

As an alternative solution we suggest the setup in Figure 9 which allows remote monitoring of the load voltage.

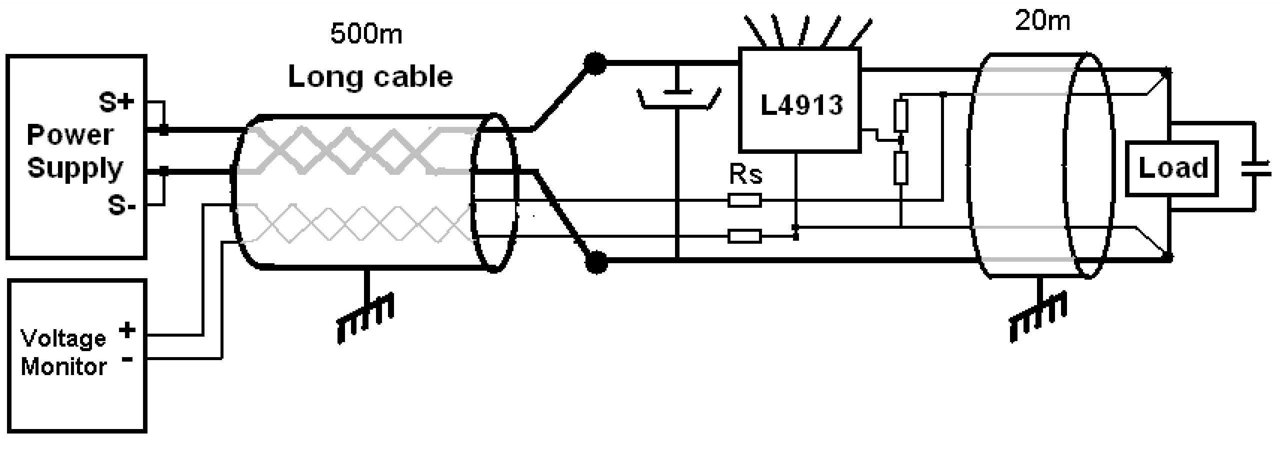


Figure 9: Block diagram showing the principle of using a local radiation hard linear regulator. Here for a positive voltage. Here is the option of remote monitor of the load voltage via isolation resistors R_s

The voltage at the load is fed back to the location of the power source via pairs in the same cable as the power source. A major issue is to avoid injection of noise into the regulation loop of the linear regulator. Putting an operational amplifier would be an option but it will be cumbersome because it need power itself and need to be a radiation hard. What we propose in stead is to put isolation resistors in series with the sense wires (R_s in Figure 9). As long as the ADC's at the acquisition end has high impedance and low leakage and bias current, the average current and thus the voltage drop across the sense resistors R_s will be small. This means that the average voltage measured at the acquisition end will equal the average voltage at the load. Rs should then be chosen sufficiently large compared to the impedance level in the regulator loop to avoid injection of noise and disturbance into the regulation. It is clear that the monitor will only give a correct measure at low frequencies. The bandwidth will be given by the cable capacity C and by R_s. With roughly C=50nF/500m and a typical R_s =10kOhm the upper 3dB cutoff frequency will be $1/(2\pi R_s C)$= 160Hz.

The cost of such modules with linear regulators is estimated to be 1500€ per station of FP420 i.e. 6000€ for Atlas+CMS.

In Figure 10 is a table listing the required voltage range at the input to the linear regulator. Lower bound on the voltage (column: "Regulator In Minimum") is established at the maximum current and the upper bound of the load voltage plus the minimum regulator drop-out voltage. The maximum input voltage to the regulator (column: "Regulator In Maximum") is given by the operating range of the regulator, here LHC4913. This leaves an absolute maximum cable drop in the long cable supplying the regulator of 12V-4.7V=7.3V. In practice however it is better to stay below this limit. The upper voltage limit will have to be somewhat less than 12V in order to avoid voltage overshoots from oscillations on the long cable.

Supply name	Load voltage	Property of cable between regulator and load					Regulator V drop	Regulator In	Regulator In
	max	length	wire cross sect	wire resistance	current	total V drop	Minimum	Minimum	Maximum
	Volt	m	mm2	Ohm/km	A	Volt	Volt	Volt	Volt
VDD	2.5	20	0.25	74	0.48	1.42	0.70	4.62	12.00
AVDD	2	20	0.25	74	0.31	0.92	0.70	3.62	12.00

Figure 10: Required voltage range at the input to the linear regulator for the low voltage supply for the silicon detector front ends. This result is independent on the cable length from the power supply to the regulator.

Special issues when employing linear regulators for QUARTIC/GASTOF

QUARTIC/GASTOF's preliminary supply requirements are listed in Table 8: Preliminary specifications for QUARTIC/GASTOF detectors power supply for one station. As seen there, these detectors require 3V, 5V and +-12V. The linear regulators LHC4913 (Vout = 1.23V to 9V at 3A, Vin<12V) and LHC7913-4 (Vout = -1.2V to -7V at 3A, -Vin <9V) will **not** support the voltage +12V and -12V. Practical limits using these regulators would probably be in the range -6V to +8V. We will have to await the exact requirement from the QUARTIC/GASTOF to elaborate on further solutions.

Low voltage in Alcoves, High voltage and temperature monitor in counting room. Local regulators at load

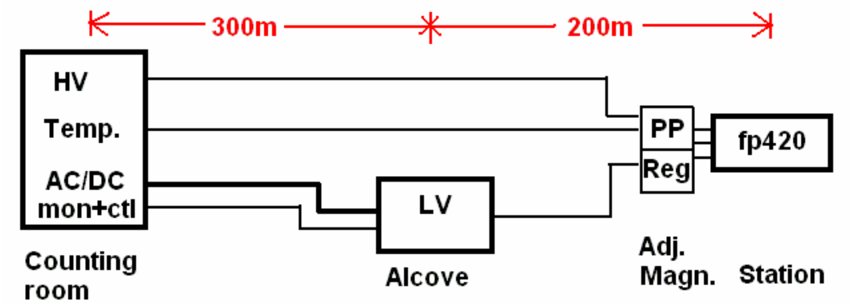


Figure 11: Low voltage in alcoves, rest in counting room using 200m cables from alcove to station. "PP" is a patch panel. "Reg"are linear regulators next to the load.

This solution is based on the use of Weiner Maraton low voltage supply placed in the alcove. CAEN also has radiation tolerant power supplies, but the Wiener Maraton has the best proven radiation tolerance of the systems studied here: CAEN, Wiener MPOD and Wiener Maraton.
The Wiener Maraton are used in Totem Roman pot detectors and placed in the Alcoves, although placed at a different location in the alcove as the one available to FP420.
The Wiener Maraton modules have been radiation qualified to 722Gy, and 8 10^{12}n/cm2. Their good radiation tolerance is partly obtained by moving the digital part of the control and monitoring circuitry away from the radiation zone. This results however, in less flexibility compared to the CAEN and the Wiener MPOD solutions. So in the Wiener Maraton system the output voltage and current limit can not be adjusted from remote, and monitoring is via analogue differential wires. One pair is required per measurement value (voltage and current) resulting in the requirement of a fair amount of monitor wires. The ADC's for this will need to be in a low radiation environment, i.e. in the counting room. For improved radiation tolerance, mains supply AC to DC conversion is done in the counting room. The cabling listed below takes account of this scenario.

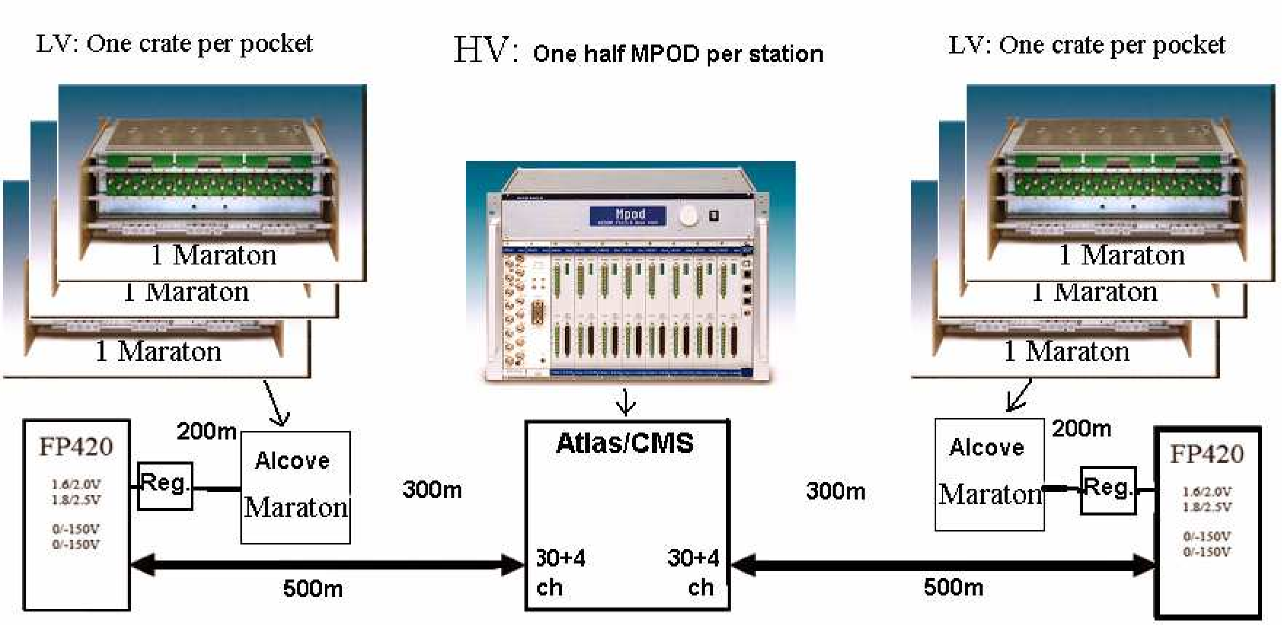
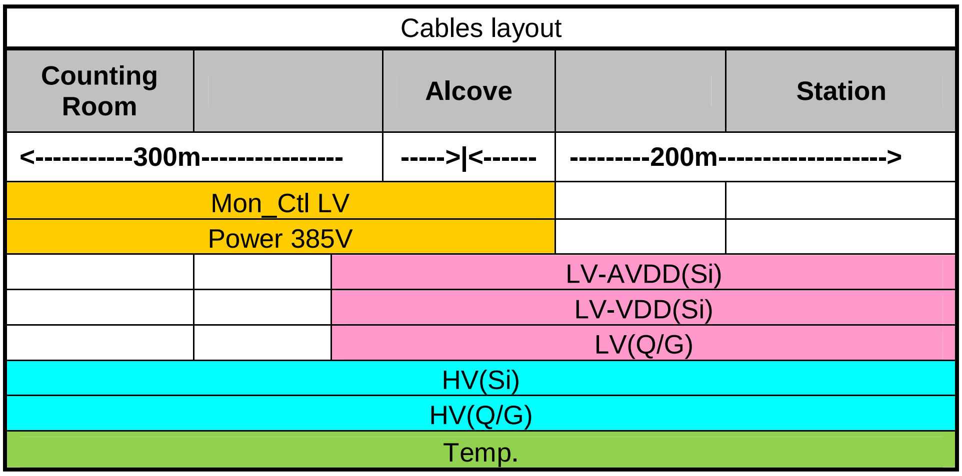


Figure 12: Low voltage Wiener Maraton supplies in the alcoves. High voltage MPOD type supplies in the counting room. The Wiener Maraton system is qualified for the radiation environment we have with a large margin. Here illustrated for either Atlas or CMS part

This solution requires a customization of Wiener Maraton low voltage modules in order to optimize it for low currents. The length of the monitor cable of 300m is beyond the specification in the data sheet, so this length of cable need further qualification. Cost for the Wiener modules has not been discussed. As shown in Figure 11 andFigure 12 a linear voltage regulator is placed next to the frontend to ensure the voltage stability at the load. The voltage drop in the long cables from power supply to regulator has been set to not exceed 3V meeting the requirements in the table in Figure 10 with a large margin.



Cables layout				
Counting Room		**Alcove**		**Station**
<-----------300m----------------		**----->|<------**	**---------200m------------------>**	
Mon_Ctl LV				
Power 385V				
		LV-AVDD(Si)		
		LV-VDD(Si)		
		LV(Q/G)		
HV(Si)				
HV(Q/G)				
Temp.				

Figure 13: Cable routing using the Wiener Maraton low voltage power supply in the alcove. Each colour corresponds to a cable function. "Mon_Ctl LV" is monitor and remote control for low voltage. Power_385V is DC raw supply for the Wiener Maraton crates. LV-AVDD(Si) is low voltage AVDD and LV-VDD(Si) is low voltage VDD for Si detectors LV(Q/G) is low voltage for QUARTIC/GASTOF. HV(Si) and HV(Q/G) is high voltage for Silicon and for QUARTIC/GASTOF. Temp is for remote monitor of temperatures.

The list of cables with the electrical and mechanical properties is tabulated in Figure 14. Total cable cost for ATLAS+CMS is estimated at 4*39,380CHF=160kCHF=100k€. This does not include the cables from the linear regulators to the frontend which is roughly 20m of length.

Cables for one arm of FP420

Cable usage	Channels (1)	SCEM	Type	Area each wire □	Wires per cable	Nr. of cables	Cable segments	Cable unit cost	Cable cost	Diam of one cab. (3)	Current per channel	Power pairs per channel	Monitor pairs per	One wire resitance	Total voltage drop	Cable length	Total wires	Spare nr. of wires	Notes
(7)				mm2				CHF/m	CHF	mm	A	(5)		Ω/km	V	m			
Mon_Ctl LV	108	04.21.52.145.9	NE36	0.50	36	6	3	4.70	8,460	18.5	0.001	1	0	37.0	0.022	300	216	0	
Power 385V	3	04.08.82.060.3	3*6.0 CEM	6.00	3	2	1	5.80	3,480	14	1	1	0	3.1	1.850	300	6	0	
LV-AVDD(Si)	15	04.21.52.228.7	NG28	1.00	28	6	3	6.30	7,560	20	0.3	1	1	18.5	2.220	200	60	48	(6)
LV-VDD(Si)	15	04.21.52.228.7	NG28	1.00	28			6.30		20	0.4	1	1	18.5	2.960	200	60		
LV(Q/G)	6	04.21.52.228.7	NG28	1.00	28	3	1	6.30	3,780	20	2	4	1	4.6	3.700	200	60	24	(4)
HV(Si)	30	04.21.52.140.4	NE26	0.50	26	3	3	5.20	7,800	16.5	0.001	1	0	37.0	0.037	500	60	18	
HV(Q/G)	4	04.31.51.555.2	HTC-50-3-2	0.50	2	4	1	1.00	2,000	6	0.001	1	0	37.0	0.037	500	8	0	
Temp.	15	04.21.52.020.1	ND26	0.25	26	3	1	4.20	6,300	14	0.001	1	1	74.0	0.074	500	60	18	
Total cable cost per station (arm):									**39,380**	**CHF**									

Legend and notes:

(1): Number of individual channels per FP420 arm

(2): Cable count is a multple of this number. Used to ensure each pot has its own cables

(3): Diameter of one cable

(4): Q/G detectors need +-12V. The LHC4913 only goes to +9V and LHC7913 to -7V, which means that it is not useful for long wire

LHC4913: Vin=3 to 12V, Vout = 1.25 to 9V, Vdropout<0.7V LHC7913: Vin=-3 to -9V, Vout -1.21 to -7V, VdropOut<0.8V

(5): Change this collumn's value to explore different configurations of cable count and cable drop

(6): AVDD and VDD wires share the same cable

(7): Maraton has up to 12 LV channels per crate. We need 3 crates in this setup

LV AVDD(Si): Low voltage Silicon detector analogue supply

LV VDD(Si): Low voltage Silicon detector digital supply

HV(Si): High voltage Silicon detector

LV(Q/G): Low voltage Quartic/Gastof

HV(Q/G): High voltage Quartic/Gastof

Figure 14: Cable inventory for a solution using Wiener Maraton LV supply in the alcove to supply both Silicon and QUARTIC/GASTOF over 200m low voltage cables but having additional linear regulators next to the load. All cables are standard CERN stores items. High voltage, monitor and temperature monitor is in the counting room. Total cable cost for ATLAS+CMS estimated at 4*39,380CHF=160kCHF=100k€

Low and high voltage and temperature monitor in counting room. Local regulators at load

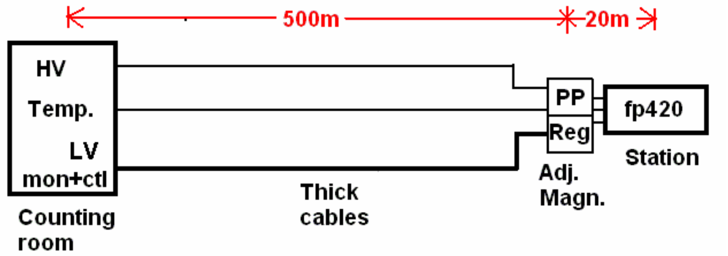
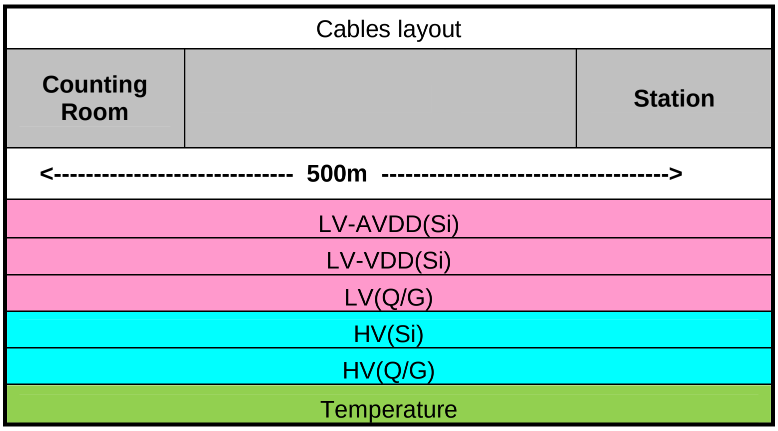


Figure 15: Low and high voltage in counting room using 500m cables to a patch panel with regulators next to the station. “PP” is a patch panel. “Reg” is linear regulators next to the load.

The low voltage need to be regulated at the load as mentioned. This can use either the solution in Figure 8 and Figure 9.



Cables layout		
Counting Room		**Station**
<----------------------------- **500m** ----------------------------------->		
LV-AVDD(Si)		
LV-VDD(Si)		
LV(Q/G)		
HV(Si)		
HV(Q/G)		
Temperature		

Figure 16: Cable routing, showing the different cables and the colour code used in Figure 17

Cables for one arm of FP420

Cable usage	Channels (1)	SCEM	Type	Area each wire □	Wires per cable	Nr. of cables	Cable segments (2)	Cable unit cost	Cable cost	Diam of one cab. (3)	Current per channel	Power pairs per channel	Monitor pairs per channel	Wire resitance	Total voltage drop	Cable length	Total wires	Spare nr. of wires	Notes
				mm2				CHF/m	CHF	mm	A	(5)		Ω/km	V	m			
LV-AVDD(Si)	15	04.21.52.228.7	NG28	1.00	28	9	3	6.30	28,350	20	0.31	2	1	9.3	2.868	500	90	12	(6)
LV-VDD(Si)	15	04.21.52.228.7	NG28	1.00	28			6.30		20	0.48	4	1	4.6	2.220	500	150		
LV(Q/G)	6	04.21.52.228.7	NG28	1.00	28	4	1	6.30	12,600	20	2	8	1	2.3	4.625	500	108	4	(4)
HV(Si)	30	04.21.52.140.4	NE26	0.50	26	3	3	5.20	7,800	16.5	0.001	1	0	37.0	0.037	500	60	18	
HV(Q/G)	4	04.31.51.555.2	HTC-50-3-2	0.50	2	4	1	1.00	2,000	6	0.001	1	0	37.0	0.037	500	8	0	
Temp.	15	04.21.52.020.1	ND26	0.25	26	3	1	4.20	6,300	14	0.001	1	1	74.0	0.074	500	60	18	

Total cable cost per station (arm): **57,050** **CHF**

Legend and notes:

(1): Number of individual channels per FP420 arm

(2): Cable count is a multple of this number. Used to ensure each pot has its own cables

(3): Diameter of one cable

(4): Q/G detectors need +-12V. The LHC4913 only goes to +9V and LHC7913 to -7V, which means that it is not useful for long wire

LHC4913: Vin=3 to 12V, Vout = 1.25 to 9V, Vdropout<0.7V

LHC7913: Vin=-3 to -9V, Vout -1.21 to -7V, VdropOut<0.8V

(5): Change this collumn's value to explore different configurations of cable count and cable drop

(6): AVDD and VDD wires share the same cable

LV AVDD(Si): Low voltage Silicon detector analogue supply

LV VDD(Si): Low voltage Silicon detector digital supply

HV(Si): High voltage Silicon detector

LV(Q/G): Low voltage Quartic/Gastof

HV(Q/G): High voltage Quartic/Gastof

Figure 17: Cable inventory for a solution with both low and high voltage supplies for both Silicon and QUARTIC/GASTOF located in the counting room and supplying over 500m cables, There are linear regulators next to the load. All cables are standard CERN stores items. High voltage, monitor and temperature monitor is in the counting room. Cost does not include pulling and connector mounting.

The maximum cable drop in the low voltage cables for LV(Si) detectors listed in Figure 17 is up to 2.8V. Total cable cost for ATLAS plus CMS is 4*57kCHF=228kCHF=144k€

Allowing a higher drop of up to 5.7V which is still within the requirements calculated in Figure 10, the number of LV(Si) cables can be lowered to 6 per station giving a total cost of 190kCHF=120k€. Hardware tests will have to be done in order to determine if a voltage drop of 5.7V is adequate or not.

In summary, the big advantage of this solution is that the power supplies are not exposed to radiation. This widens the field of power supply candidates significantly and lowers their cost and makes it simpler to maintain. The major drawback is the cable cost and the need for local regulators.

Commercial solutions having power supplies next to the stations

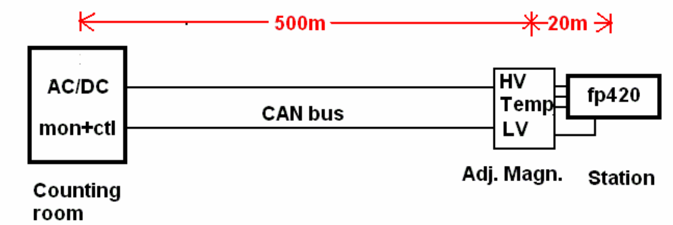


Figure 18: All supplies in the tunnel, adjacent to the station

For this setup we have got solution suggestions from two companies CAEN and Wiener based on our preliminary specifications. The suggested solutions still need some refinements and qualifications. Below is a listing of these proposals. The CAEN solution has more details presented, but this is not indicative of any preference of this solution just that this has been elaborated the most for the time being. Only the CAEN solution suggest putting the high voltage supplies in the tunnel.

Commercial solution, CAEN

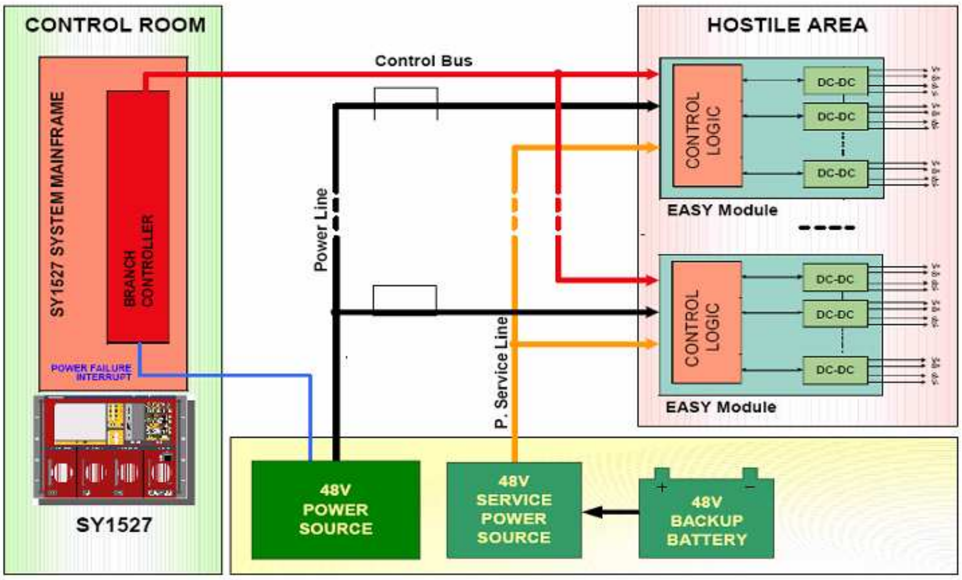


Figure 19: Generic block diagram of the CAEN system setup

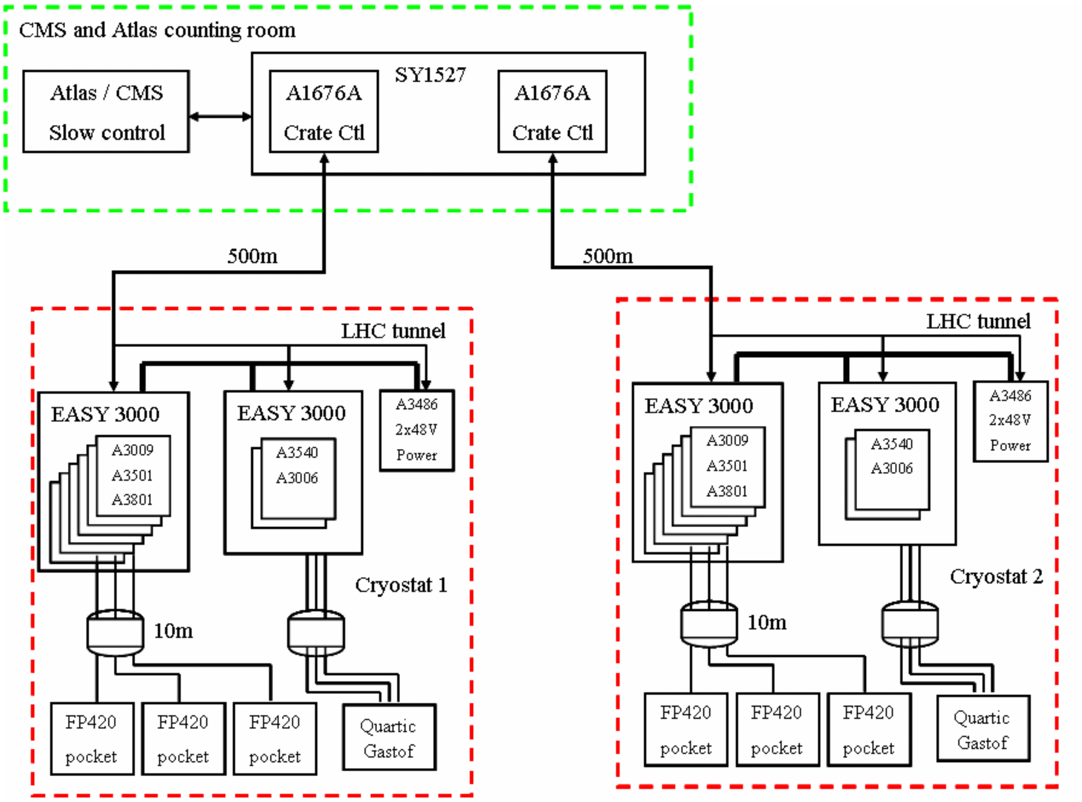


Table 9: Block diagram of the solution suggested by CAEN. This shows the supply of half of the FP420 setup i.e. two stations. The number of pockets illustrated is 3 per station. Shown are also the system for temperature monitoring (A3801) and the supplies for QUARTIC/GASTOF detectors A3540 and A3006

		One module		One station			
	CAEN module type	Slots	Channels	Number of modules	Number of slots	Number of EASY3000	Spare channels
Silicon detectors	LV supply A3009	4	12	3	12		6
	HV supply A3501	2	12	3	6		6
	Temp mon A3801	2	128	1	2		?
	Total				20	1	
QUARTIC GASTOF detectors	Quartic HV A3540	2	12	1	2		?
	Quartic LV A3006	4	6	1	4		?
	Total					1	

Table 10: Channel and module count for the CAEN solution for one station, including QUARTIC/GASTOF and temperature monitoring. Notice that there are 6 spare channels of high and low voltage in the Silicon detector crate in this configuration. Fully exploited, this configuration could supply up to 18 Superlayers, which could be distributed as 6 Superlayers in 3 pockets for instance. Alternatively the Silicon detector supplies could also occupy space in the QUARTIC/GASTOF crate giving even more extra space.

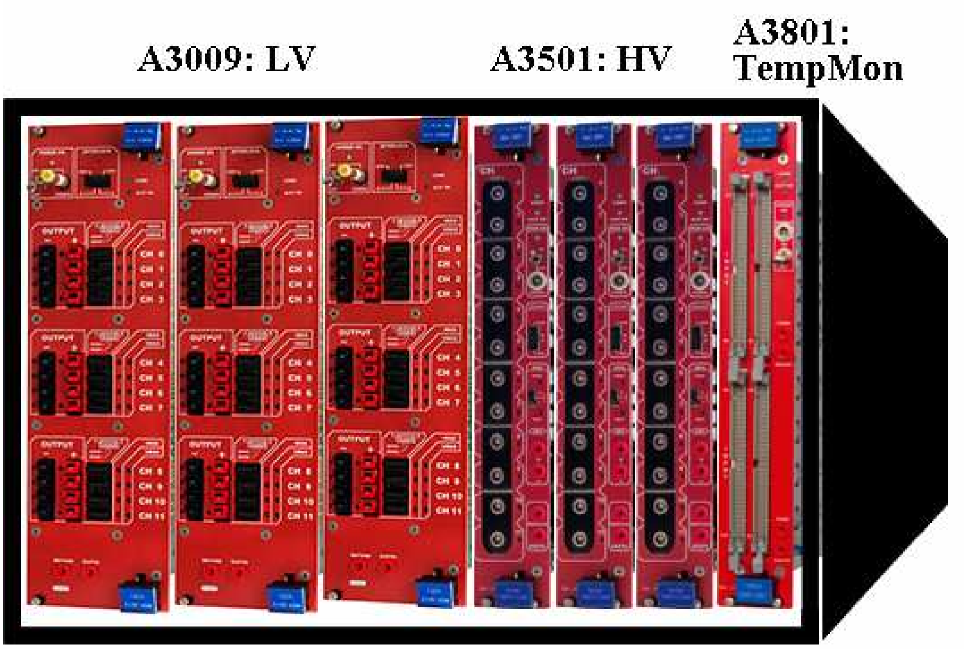


Figure 20: Silicon detector supply crate. CAEN's EASY3000 crate with low voltage A3009, high voltage A3501 supplies and ADC A3801 for temperature monitoring for one station with up to 18 Superlayers.

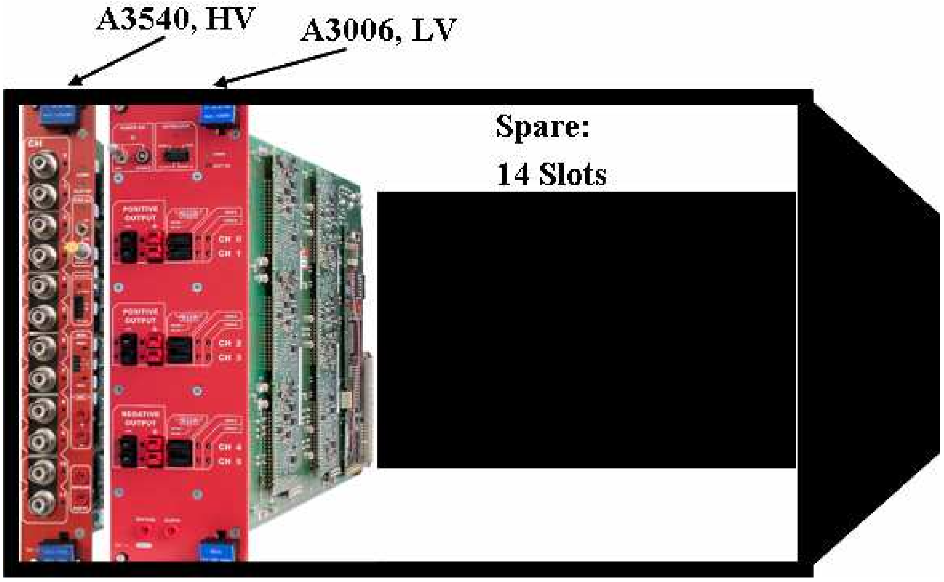


Figure 21: CAEN's EASY3000 crate with high voltage (A3540) and low voltage (A3006) supplies for QUARTIC/GASTOF detectors. 14 spare slots are available in this configuration.

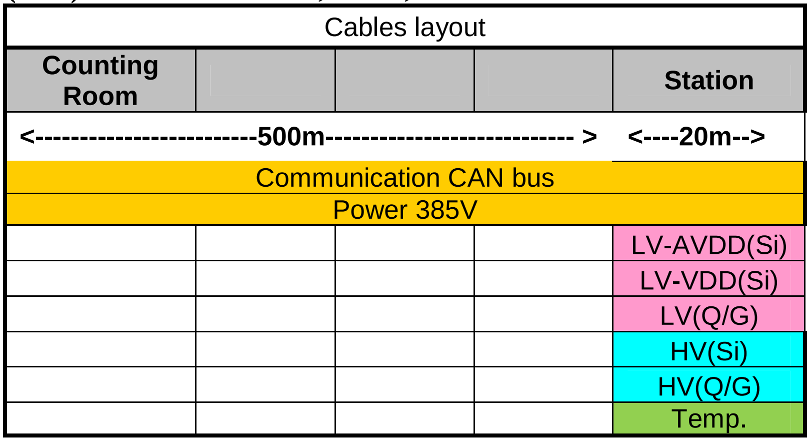
Notice that the A3006 low voltage supply is adjustable in the 4 to 16V range and may thus not be able to cover all the way down to 3.3V without additional modification.

Figure 22: A3486 dual channel power supply needed adjacent to the EASY crate's in the tunnel.

Cost of CAEN solution

	Module	Function	Unit cost	Units	Cost	
Silicon detector	A3501n	0-100V	3,621 €	12	43,457 €	
	Sy1527	Controller	9,183 €	2	18,365 €	
	A3009	LV	3,554 €	12	42,646 €	
	A3486	Power	3,942 €	4	15,769 €	
	A1676A	Branch ctl	842 €	4	3,369 €	
	A3801	ADC 128ch	4,000 €	4	16,000 €	
	EASY3000	Crate	942 €	4	3,767 €	
	Sub total				143,373 €	143,373 €
QUARTIC GASTOF	EASY3000	Crate	942 €	4	3,767 €	
	A3540	4kV	4,000 €	4	16,000 €	
	A3006	4-16V/6A	4,000 €	4	16,000 €	
	Sub total				35,767 €	35,767 €
	Total for CAEN modules					179,140 €

Table 11: Cost of standard CAEN modules for the solution with 3 pockets per station with up to 6 Superlayers per pocket. Includes both Atlas and CMS. This is excluding spares, cables and cost of customization of CAN bus (10k€). The modules A3540, A3006, A3801 are listed with estimated costs.



Cables layout				
Counting Room				**Station**
<------------------------500m-------------------------- >				**<----20m-->**
Communication CAN bus				
Power 385V				
				LV-AVDD(Si)
				LV-VDD(Si)
				LV(Q/G)
				HV(Si)
				HV(Q/G)
				Temp.

Figure 23: Cable routing and color code for use on the following Figure 24.

Cables for one arm of FP420

Cable usage	Channels (1)	SCEM	Type	Area each wire □	Wires per cable	Nr. of cables	Cable segments (2)	Cable unit cost	Cable cost	Diam of one cab. (3)	Current per channel	Power pairs per channel	Monitor pairs per channel	One wire resitance	Total voltage drop	Cable length	Total wires	Spare nr. of wires	Notes
				mm2				CHF/m	CHF	mm	A	(5)		Ω/km	V	m			
CAN bus	13	04.21.52.140.4	NE26	0.50	26	1	1	5.50	2,750	16.5	0.001	1	0	37.0	0.037	500	26	0	
Power 385V	3	04.08.82.060.3	3*6.0 CEM	6.00	3	2	1	5.80	5,800	14	1	1	0	3.1	3.083	500	6	0	
LV-AVDD(Si)	15	04.21.52.228.7	NG28	1.00	28	6	3	6.30	756	20	0.3	1	1	18.5	0.222	20	60	48	(6)
LV-VDD(Si)	15	04.21.52.228.7	NG28	1.00	28			6.30		20	0.4	1	1	18.5	0.296	20	60		
LV(Q/G)	6	04.21.52.228.7	NG28	1.00	28	3	1	6.30	378	20	2	4	1	4.6	0.370	20	60	24	(4)
HV(Si)	30	04.21.52.140.4	NE26	0.50	26	3	3	5.20	312	16.5	0.001	1	0	37.0	0.001	20	60	18	
HV(Q/G)	4	04.31.51.555.2	HTC-50-3-2	0.50	2	4	1	1.00	80	6	0.001	1	0	37.0	0.001	20	8	0	
Temp.	15	04.21.52.020.1	ND26	0.25	26	3	1	4.20	252	14	0.001	1	1	74.0	0.003	20	60	18	
Total cable cost per station (arm):									**10,328**	**CHF**									

Legend and notes:

(1): Number of individual channels per FP420 arm

(2): Cable count is a multple of this number. Used to ensure each pot has its own cables

(3): Diameter of one cable

(4): Q/G detectors need +-12V. The LHC4913 only goes to +9V and LHC7913 to -7V, which means that it is not useful for long wire

LHC4913: Vin=3 to 12V, Vout = 1.25 to 9V, Vdropout<0.7V LHC7913: Vin=-3 to -9V, Vout -1.21 to -7V, VdropOut<0.8V

(5): Change this collumn's value to explore different configurations of cable count and cable drop

(6): AVDD and VDD wires share the same cable

LV AVDD(Si): Low voltage Silicon detector analogue supply

LV VDD(Si): Low voltage Silicon detector digital supply

HV(Si): High voltage Silicon detector

LV(Q/G): Low voltage Quartic/Gastof

HV(Q/G): High voltage Quartic/Gastof

Figure 24: Cable cost for solution with all CAEN supplies in the tunnel. Total cost for CMS plus Atlas is 4*10kCHF=27k€

Required CAEN module customizations

CAN speed

The CAEN standard module solution is not guaranteed to work over 500m of cable. The CAEN CAN bus as standard is operated at 250kbit/s. 250kbit/s has been verified to work over cable SCEM 04.21.52.140.4 what signal integrity concerns, but due to the cable delay it violates the timing requirements of the CAN bus's arbitration protocol. Lowering the bit rate to 125kbit/s would make the cable of 500m meet the specifications of signal integrity and arbitration protocol.
Arbitration is only brought in play when more than one module attempts to talk onto the bus at a time. Therefore, depending on the software protocol implemented, it is in principle possible for the 250kbit/s to work despite the long cable delay.
CAEN has, at an additional cost, offered to modify the modules such that they will operate at 125kbit/s, but the modules will no longer be exchangeable with the rest of LHC's CAEN equipment of similar model.

Silicon high voltage bias supply

The CAEN module A3501 is designed for 0 to 100V, whereas FP420 may need the ability to go to minus 120V as specified above. It is however possible that this will not be necessary. Further radiation tests on the detectors should determine this. However, in case the 120V is needed, CAEN is able to modify the modules at an additional cost to meet the minus 120V specification.

CAEN module radiation qualification

<table>
<tr><th>Module CAEN</th><th>Function</th><th>Used by</th><th></th><th>Tested ok to</th><th>References</th></tr>
<tr><td rowspan="2">A3009</td><td>Low Voltage</td><td>Atlas RPC, LVL1, CMS</td><td>Certified for Atlas (1)</td><td>140Gy or 2x10^{11} p/cm2
By CERN POOL. See link below</td><td>Agostino Lanza, Anghinolfi and Fontaine</td></tr>
<tr><td colspan="5">http://lhcb-muon.web.cern.ch/lhcb-muon/electronics/Irad-Uppsala.pdf (non conclusive)</td></tr>
<tr><td rowspan="2">A3486</td><td>2 x 48V base Power</td><td>Atlas RPC, LVL1, CMS</td><td>Certified for Atlas (1)</td><td>140Gy or 2x10^{11} p/cm2
By CERN POOL</td><td>Agostino Lanza (INFN Pavia)</td></tr>
<tr><td colspan="5">http://lhcb-muon.web.cern.ch/lhcb-muon/electronics/Irad-Uppsala.pdf (non conclusive)
http://lhcb-muon.web.cern.ch/lhcb-muon/electronics/HV_TB_04.06.pdf</td></tr>
<tr><td>A3501</td><td>-100V bias</td><td></td><td>Not certified. But equivalent to A3540 below</td><td>Has not been tested.</td><td></td></tr>
<tr><td rowspan="2">A3540</td><td>4kV</td><td></td><td>Certified for Atlas</td><td>See links below</td><td>Agostino Lanza</td></tr>
<tr><td colspan="5">http://www.pv.infn.it/~servel/atlas/hv/hv_sys/casaccia_report.ppt (^{60}Co)
http://www.pv.infn.it/~servel/atlas/hv/hv_sys/index.html (proton, 159MeV)
http://lhcb-muon.web.cern.ch/lhcb-muon/electronics/HV_TB_04.06.pdf</td></tr>
<tr><td rowspan="2">A3801</td><td>128ch ADC</td><td></td><td>?</td><td>147Gy (proton)</td><td>A. Lanza, G. Iuvino, G. Passuello</td></tr>
<tr><td colspan="5">http://www.pv.infn.it/~servel/atlas/hv/hv_sys/tsl-report_jan-2006.ppt (proton, 159MeV)</td></tr>
<tr><td>A3006</td><td>4-16V</td><td></td><td>?</td><td>?</td><td></td></tr>
</table>

Table 12: Status of qualification for radiation as of this date (May 2007). ***Note*** **1: The certification limit, as agreed in ATLAS, is: 2 x 10^{11} p/cm2, corresponding to 140 Gy TID. A3006 could maybe be replaced by A3016 which has been tested.**

Commercial solution from Wiener

Note that a solutions for temperature monitoring has not been worked out in detail using Wiener's equipment.

Wiener, Solution 1, MPOD LV next to station, MPOD HV in counting room

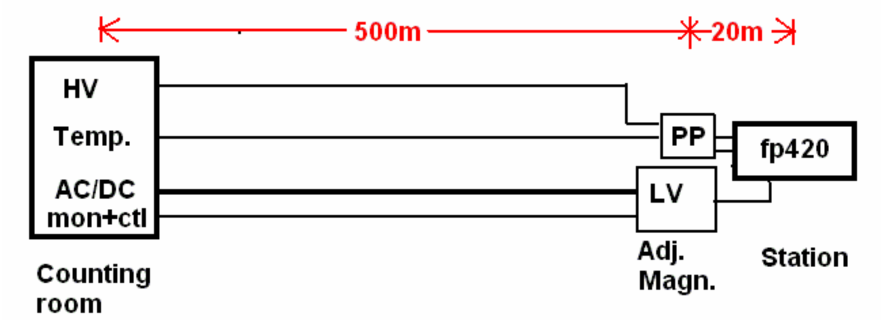


Figure 25: Overview of this solution illustrating one stations supply.

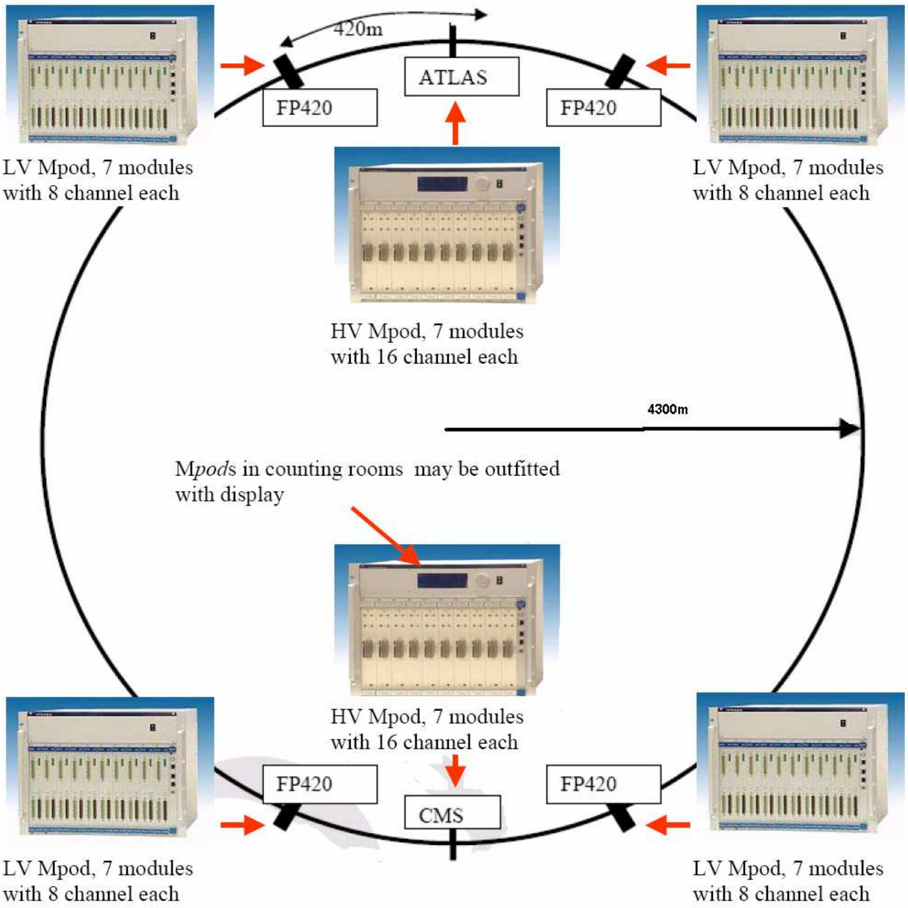
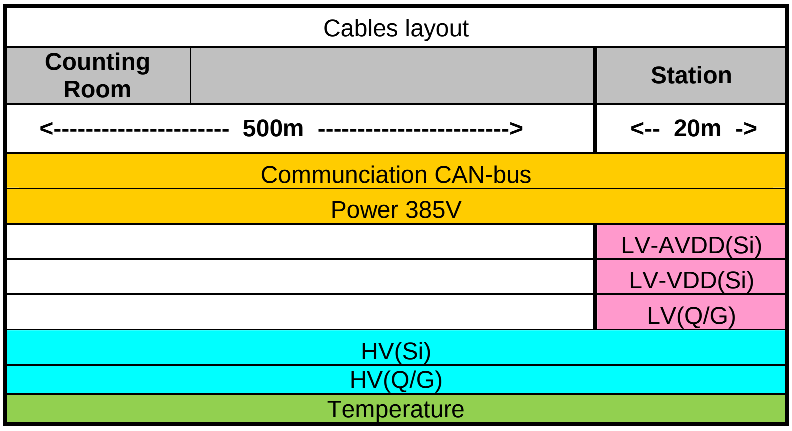


Figure 26:Wiener solution with LV supplies in the tunnel and high voltage supplies in the counting room, delivering the bias via 500m cables. The Mpod will require custom -120V modules.

This solution based on Wiener MPOD modules suggests putting only the low voltage part in the tunnel. One crate at each location will be needed for the Silicon detector supplies. The high voltage is supplied from MPOD modules in the counting room via 500m cable. Notice that no auxiliary power crate is needed in the tunnel as opposed to the case with the CAEN solution.
Note that the MPOD modules have never been radiation tested. This is a serious issue. According to the company they are made in a way which is likely to qualify them to the level we require. It will however be necessary to test the modules in both proton and gamma fields to qualify their use.



Cables layout

Counting Room		**Station**
<---------------------- 500m ------------------------>		**<-- 20m ->**
Communciation CAN-bus		
Power 385V		
		LV-AVDD(Si)
		LV-VDD(Si)
		LV(Q/G)
HV(Si)		
HV(Q/G)		
Temperature		

Figure 27: Cable routing and colour code for use in Figure 28

Cables for one arm of FP420

Cable usage	Channels (1)	SCEM	Type	Area each wire □	Wires per cable	Nr. of cables	Cable segments (2)	Cable unit cost	Cable cost	Diam of one cab. (3)	Current per channel	Power pairs per channel	Monitor pairs per channel	Wire resitance	Total voltage drop	Cable length	Total wires	Spare nr. of wires	Notes
				mm2				CHF/m	CHF	mm	A	(5)		Ω/km	V	m			
CAN bus	1	04.21.52.155.7	NF2	0.75	2	1	1	0.88	440	6.8	0.02	1	0	24.7	0.493	500	2	0	
Power 385V	3	04.08.82.060.3	3*6.0 CEM	6.00	3	2	1	5.80	5,800	14	1	1	0	3.1	3.083	500	6	0	
LV-AVDD(Si)	15	04.21.52.228.7	NG28	1.00	28	6	3	6.30	756	20	0.31	1	1	18.5	0.229	20	60	18	(6)
LV-VDD(Si)	15	04.21.52.228.7	NG28	1.00	28			6.30		20	0.48	2	1	9.3	0.178	20	90		
LV(Q/G)	6	04.21.52.228.7	NG28	1.00	28	2	1	6.30	252	20	2	3	1	6.2	0.493	20	48	8	(4)
HV(Si)	30	04.21.52.140.4	NE26	0.50	26	3	3	5.20	7,800	16.5	0.001	1	0	37.0	0.037	500	60	18	
HV(Q/G)	4	04.31.51.555.2	HTC-50-3-2	0.50	2	4	1	1.00	2,000	6	0.001	1	0	37.0	0.037	500	8	0	
Temp.	15	04.21.52.020.1	ND26	0.25	26	3	1	4.20	6,300	14	0.001	1	1	74.0	0.074	500	60	18	

Total cable cost per station (arm): **23,348** **CHF**

Legend and notes:

(1): Number of individual channels per FP420 arm

(2): Cable count is a multple of this number. Used to ensure each pot has its own cables

(3): Diameter of one cable

(4): Q/G detectors need +-12V. The LHC4913 only goes to +9V and LHC7913 to -7V, which means that it is not useful for long wire

LHC4913: Vin=3 to 12V, Vout = 1.25 to 9V, Vdropout<0.7V LHC7913: Vin=-3 to -9V, Vout -1.21 to -7V, VdropOut<0.8V

(5): Change this collumn's value to explore different configurations of cable count and cable drop

(6): AVDD and VDD wires share the same cable

LV AVDD(Si): Low voltage Silicon detector analogue supply

LV VDD(Si): Low voltage Silicon detector digital supply

HV(Si): High voltage Silicon detector

LV(Q/G): Low voltage Quartic/Gastof

HV(Q/G): High voltage Quartic/Gastof

Figure 28: Cable inventory for a solution with MPOD low voltage supplies for both Silicon and QUARTIC/GASTOF located next to the station. High voltage, monitor and temperature monitor is in the counting room. All cables are standard CERN stores items.

Total cable cost for this solution for ATLAS+CMS is 4*24k CHF=96kCHF=60k€. The cost of the MPOD modules has not been discussed in detail nor the temperature monitor modules in the counting room.

Wiener, Solution 2, Maraton LV crates, next to station, MPOD HV in counting room

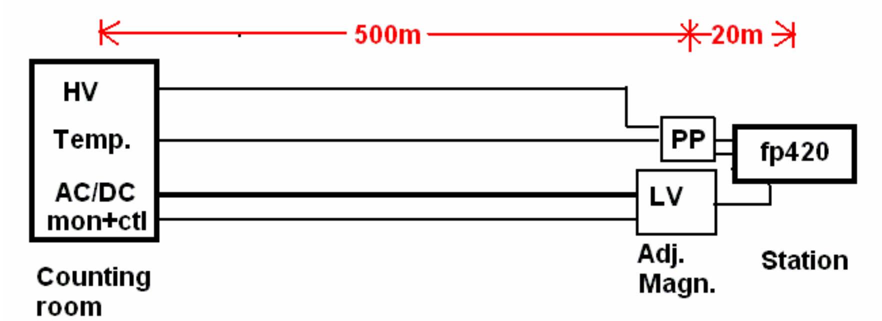


Figure 29: Overview of this solution illustrating one stations supply. Wiener Maraton is located next to the station in the tunnel

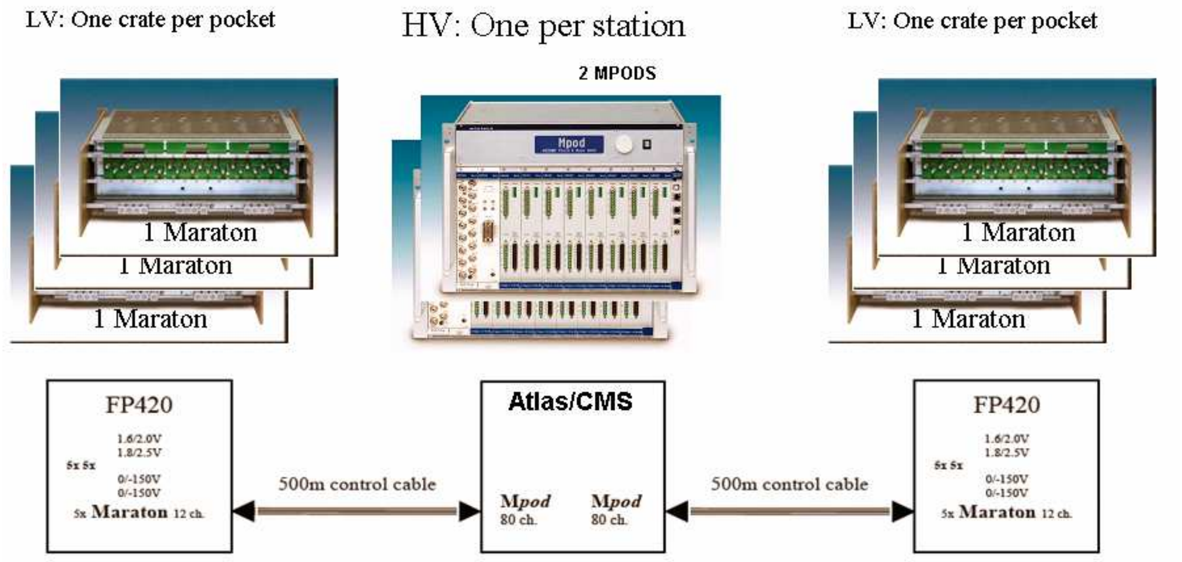
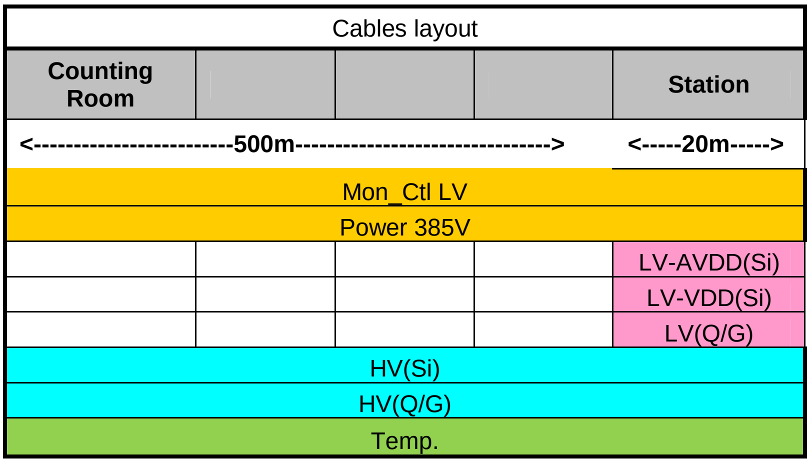


Figure 30: Low voltage supplies in the tunnel. High voltage *MPOD* type supplies are located in the counting room. The Wiener Maraton system is qualified for the radiation environment we expect in the tunnel under the adjacent magnets. The illustration shows the setup for either Atlas or CMS.

This solution has the low voltage supplies housed in Wiener Maraton crates in the tunnel next to the station. One crate will be needed per pocket. The high voltage is supplied over 500m of cable from an MPOD module in the counting room. This solution requires a customization of Wiener Maraton low voltage modules in order to optimize it for low currents. The monitoring of the Wiener Maraton is with individual twisted pairs from each channel. The ADC's for this will need to be in a radiation free environment, i.e. in the counting room. The length of the monitor and control cable of 500m is beyond the specification in the data sheet, so this length of cable need further qualification. Cost has not been discussed. In Figure 31 and Figure 32 is a listing of the required cables and their cost.



<table>
<tr><td colspan="5">Cables layout</td></tr>
<tr><td>Counting Room</td><td></td><td></td><td></td><td>Station</td></tr>
<tr><td colspan="4"><------------------------500m--------------------------------></td><td><-----20m-----></td></tr>
<tr><td colspan="5">Mon_Ctl LV</td></tr>
<tr><td colspan="5">Power 385V</td></tr>
<tr><td></td><td></td><td></td><td></td><td>LV-AVDD(Si)</td></tr>
<tr><td></td><td></td><td></td><td></td><td>LV-VDD(Si)</td></tr>
<tr><td></td><td></td><td></td><td></td><td>LV(Q/G)</td></tr>
<tr><td colspan="5">HV(Si)</td></tr>
<tr><td colspan="5">HV(Q/G)</td></tr>
<tr><td colspan="5">Temp.</td></tr>
</table>

Figure 31: cable routing for the Wiener Maraton solution next to the stations

The advantage of this solution is that it will fit the QUARTIC/GASTOF requirements without much modification. The disadvantages being the exposure to radiation and difficult access for maintenance. In addition, the Wiener Maraton only allow the voltage setting and current limits to be adjusted manually using potentiometers on the modules. No remote tuning is possible.

Cables for one arm of FP420

Cable usage	Channels (1)	SCEM	Type	Area each wire □	Wires per cable	Nr. of cables	Cable segments (2)	Cable unit cost	Cable cost	Diam of one cab. (3)	Current per channel	Power pairs per channel	Monitor pairs per channel	One wire resitance	Total voltage drop	Cable length	Total wires	Spare nr. of wires	Notes
(7)				mm2				CHF/m	CHF	mm	A	(5)		Ω/km	V	m			
Mon_Ctl LV	108	04.21.52.145.9	NE36	0.50	36	6	3	4.70	14,100	18.5	0.001	1	0	37.0	0.037	500	216	0	
Power 385V	3	04.08.82.060.3	3*6.0 CEM	6.00	3	2	1	5.80	5,800	14	1	1	0	3.1	3.083	500	6	0	
LV-AVDD(Si)	15	04.21.52.228.7	NG28	1.00	28	6	3	6.30	756	20	0.3	1	1	18.5	0.222	20	60	48	(6)
LV-VDD(Si)	15	04.21.52.228.7	NG28	1.00	28			6.30		20	0.4	1	1	18.5	0.296	20	60		
LV(Q/G)	6	04.21.52.228.7	NG28	1.00	28	2	1	6.30	252	20	2	2	1	9.3	0.740	20	36	20	(4)
HV(Si)	30	04.21.52.140.4	NE26	0.50	26	3	3	5.20	7,800	16.5	0.001	1	0	37.0	0.037	500	60	18	
HV(Q/G)	4	04.31.51.555.2	HTC-50-3-2	0.50	2	4	1	1.00	2,000	6	0.001	1	0	37.0	0.037	500	8	0	
Temp.	15	04.21.52.020.1	ND26	0.25	26	3	1	4.20	6,300	14	0.001	1	1	74.0	0.074	500	60	18	
Total cable cost per station (arm):									**37,008**	**CHF**									

Legend and notes:

(1): Number of individual channels per FP420 arm

(2): Cable count is a multple of this number. Used to ensure each pot has its own cables

(3): Diameter of one cable

(4): Q/G detectors need +-12V. The LHC4913 only goes to +9V and LHC7913 to -7V, which means that it is not useful for long wire

LHC4913: Vin=3 to 12V, Vout = 1.25 to 9V, Vdropout<0.7V LHC7913: Vin=-3 to -9V, Vout -1.21 to -7V, VdropOut<0.8V

(5): Change this collumn's value to explore different configurations of cable count and cable drop

(6): AVDD and VDD wires share the same cable

(7): Maraton has up to 12 LV channels per crate. We need 3 crates per station in this setup

LV AVDD(Si): Low voltage Silicon detector analogue supply

LV VDD(Si): Low voltage Silicon detector digital supply

HV(Si): High voltage Silicon detector

LV(Q/G): Low voltage Quartic/Gastof

HV(Q/G): High voltage Quartic/Gastof

Figure 32: Cable inventory for a solution with low voltage supplies (Wiener Maraton) for both Silicon and QUARTIC/GASTOF located next to the station. High voltage and temperature monitor is in the counting room. All cables are standard CERN stores items. Total cable cost for Atlas plus CMS is 4*37 kCHF=148kCHF=95k€

Summary of solutions

This table summarizes the solutions discussed for installation of FP420 in Atlas plus CMS experiments.

Description of solution				Cable cost	Module cost	Notes
LV		HV				
Near station	CAEN Easy3000	Near station	CAEN Easy3000	27k€	180k€+ 10k€	• Maintenance access, radiation and SEU issues
	Wiener MPOD	Counting room	TBD	60k€	TBD	• Maintenance access, radiation and SEU issues. • Need further radiation tolerance qualifications
	Wiener Maraton		TBD	95k€	TBD	• Maintenance access issues • No voltage tuning from remote.
Alcove	Wiener Maraton		TBD	100k€	TBD	• Maintenance access issues. • Need linear regulator. • No voltage tuning from remote. • Radiation field is unclear. • QUARTIC/GASTOF's +-12V issues
Counting room	TBD		TBD	144k€	TBD	• Lowest module cost. • High cable cost. • Need linear regulator. • No voltage tuning from remote. • Little or no radiation or access issue. • QUARTIC/GASTOF's +-12V issues

Figure 33: Summary of cable and module cost for various solutions covering both Atlas and CMS. Custom module with linear regulator is estimated to cost a total of 6k€. The cost of cable pulling and connector mounting is not included. TBD means that no particular manufacturer stand out as the best choice based on the investigations done so far. "QUARTIC/GASTOF's +-12V issues" refers to the problem that the LHC4713/ LHC7913 regulators will not be suitable to regulate +-12V. Other solutions will have to be found for that case.