

IDEA Drift Chamber

cost analysis

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The 2019 CEPC Detector cost-performance optimization
Beijing, November 20, 2019

An ultra-light Drift Chamber with Particle Identification capabilities

F. Grancagnolo

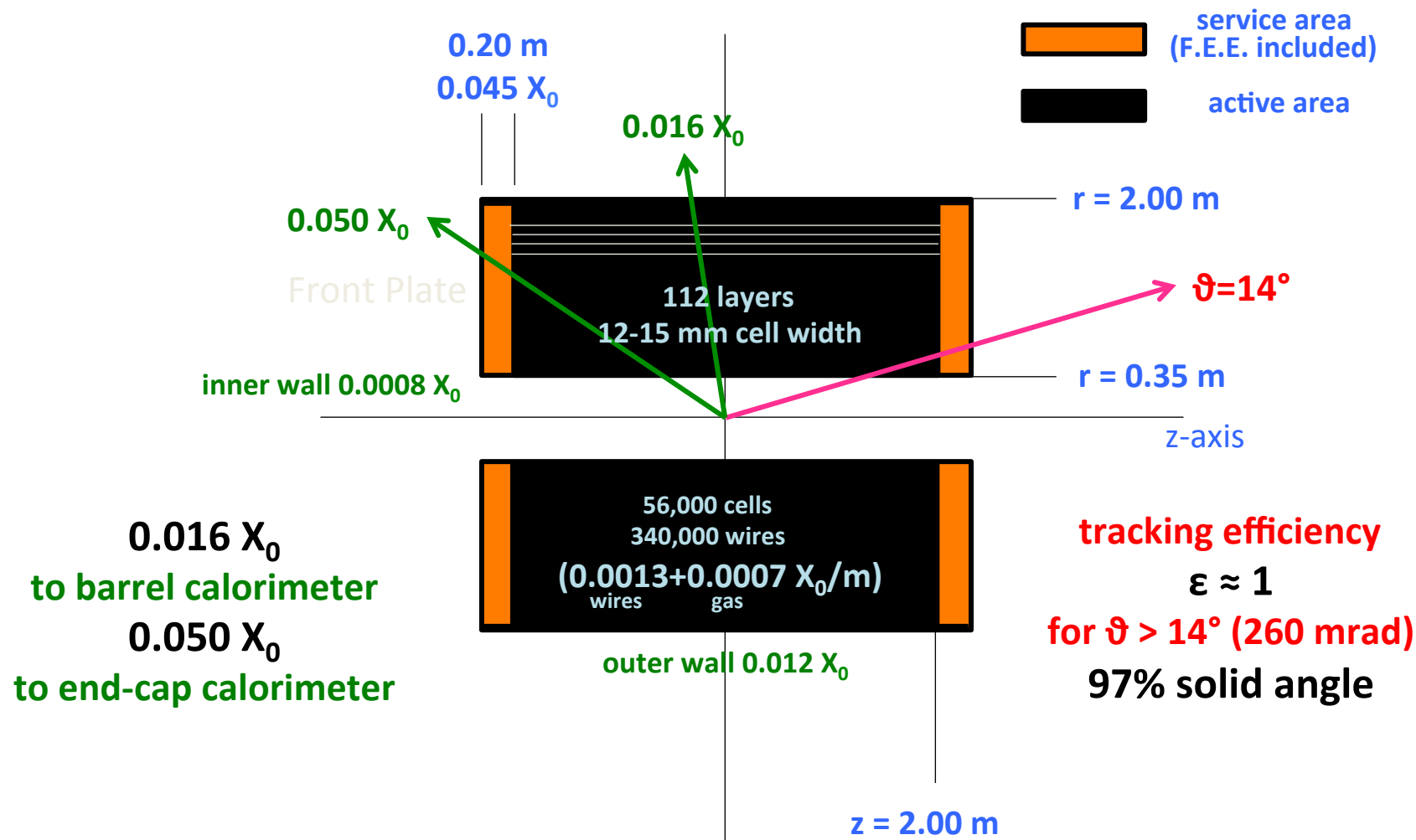
INFN – Lecce, ITALY



CEPC CDR International Review

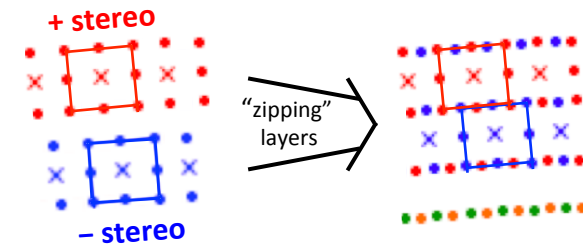
IHEP Beijing, Sept. 14, 2018

IDEA DCH Angular coverage

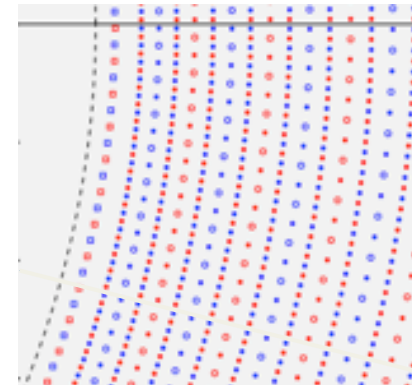


IDEA DCH Layout

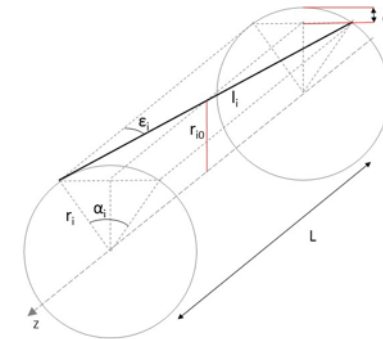
- 12÷15 mm wide square cells 5 : 1
field to sense wires ratio 56,448 cells



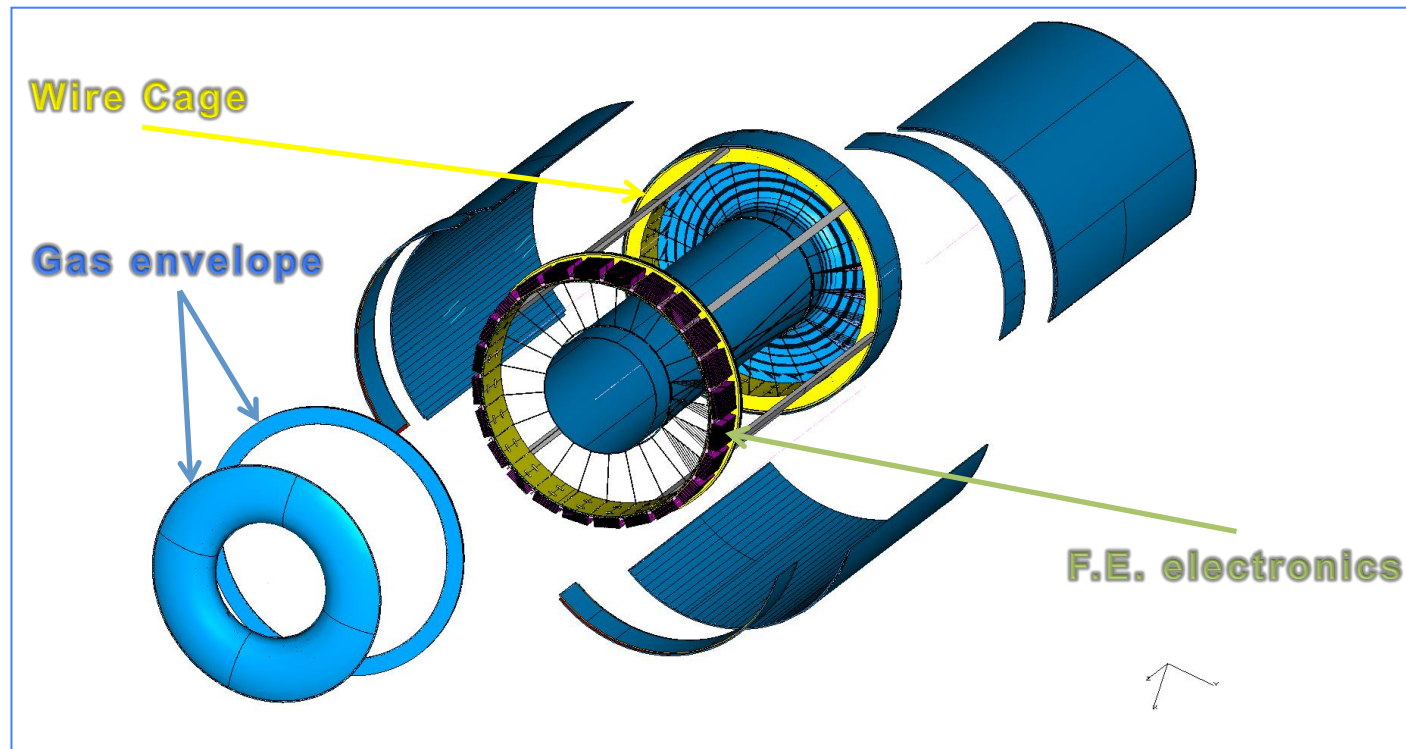
- 14 co-axial super-layers, 8 layers each
(112 total) in 24 equal azimuthal (15°)
sectors ($N_i = 192 + (i - 1) \times 48$)



- alternating sign stereo angles ranging
from 50 to 250 mrad



Gas containment and Wire support



Gas containment **Gas envelope** can freely deform without affecting the internal wire position and tension.

Wire support **Wire cage** structure not subject to differential pressure can be light and feed-through-less.

Summary of costs

	parts	outsourcing manpower	parts total	engineer manpower	engineer hours	engineer years	technician manpower	technician hours	technician years	operator manpower	operator hours	operator years	GRAND TOTAL
GAS ENVELOPE	611.458	270.200	881.658	153.600	1.920	1,11	174.080	4.352	2,52	0	0	0,00	1.209.338
WIRE CAGE	4.805.076	33.040	4.838.116	153.600	1.920	1,11	238.080	6.072	3,51	0	0	0,00	5.229.796
ASSEMBLY OPERATIONS	1.410.100	4.550	1.417.450	307.200	3.840	2,22	960.720	23.738	13,74	1.966.080	65.536	37,93	4.651.450
ELECTRONICS	12.902.000	262.500	13.164.500	883.200	11.040	6,39	402.400	10.060	5,82	0	0	0,00	14.450.100
HV/LV SYSTEM	621.600	0	621.600	32.000	400	0,23	96.000	2.400	1,39	0	0	0,00	749.600
GAS SYSTEM	389.500	0	389.500	32.000	400	0,23	86.400	2.160	1,25	0	0	0,00	507.900
TOTAL	20.739.734	570.290	21.312.824	1.561.600	19.520	11,30	1.957.680	48.782	28,23	1.966.080	65.536	37,93	26.798.184

engineer cost = 80 euro/h
 technician cost = 40 euro/h
 operator cost = 30 euro/h
 outsourcing manpower = 70 euro/h

Parameterization of costs

$$\text{Cost} = A + B \quad \text{with } B = C/\text{ch} \times \#\text{ch}.$$

	A [M€]	B[M€]
Gas Envelope	1.0	0.2
Wire Cage	0.7	4.5
Assembly operations	2.3	2.3
Electronics	1.4	13.1
HV/LV System	0.8	0
Gas System	0.5	0
TOTAL	6.9	19.9

Optimization of costs

	savings [M€]	note
shorten chamber by 10%	0.5 (1.8%)	minor loss of coverage
reduce outer radius by 10%	4.2 (15%)	20% degradation of p
increase cell size by 10%	4.2 (15%)	10% degradation of p
use carbon monofilament	3.2 (12%)	improve low momentum
man power	5.5 (20%)	

Back up slides

Gas Envelope

1.0	GAS ENVELOPE														
		engineering design	80	man hours	24	80	153.600								
1.1.0	End plate (2)						outer electronics panels								
1.1.1.1		unidirectional prepreg	12,5	m^2	160	40	80.000		materials skin	3,5	Kg	28	150	14.700	
1.1.1.2		materials core (Rohacell)	5	Kg	5	900	22.500		material core (Rohacell)	0,3	Kg	28	900	7.560	
1.1.1.3		metallized mylar film	12,5	m^2	40	20	10.000	1.4.1.4		metallized mylar film	0,6	m^2	28	20	336
1.1.1.4		consumables	250	m^2	1	20	5.000			consumables	0,5	m^2	28	20	280
1.1.2.1		tooling	1	#	1	30000	30.000			manufacturing (outsourcing)	160	man hours	1	70	11.200
1.1.3.1		manufacturing (outsourcing)	320	man hour	5	70	112.000			drilling/countersinking/inserting	1	machine hours	28	40	1.120
		tooling for machining	1	#	1	20000	20.000		panel inner struts						
1.1.3.2		drilling/finishing inner/outer edges	600	machine hours	4	40	96.000		materials	2	Kg	30	150	9.000	
	outer plate reinforcements (2)						1.4.1.4		metallized mylar film	0,5	m^2	30	20	300	
1.2.1.1		materials	22,0	Kg	4	200		17.600		consumables	0,4	m^2	30	20	240
1.2.3.2		manufacturing	80	man hours	4	70		22.400		manufacturing (outsourcing)	2	man hours	30	70	4.200
		steel bolts and inserts	400	#	4	4		6.400		cutting, milling and drilling	2	machine hours	30	40	2.400
										threaded inserts for bolts	440	#	24	3	31.680
1.3.0	inner plate reinforcements (4)							steel bolts (M8)	440	#	24	2,5	26.400		
1.3.1.1		materials	1,0	Kg	6	200	1.200	1.4.1.4	end panel insert						
1.3.3.1		manufacturing	48	man hours	6	70	20.160			materials	0,5	Kg	32	150	2.400
1.3.4.1		C studs and bolts	120	#	6	20	14.400			metallized mylar film	0,1	m^2	32	20	64
1.4.0	Inner cylinder								consumables	0,3	m^2	32	20	192	
1.4.1.1		materials skins (2)	5	m^2	32	40	6.400			manufacturing (outsourcing)	2	man hours	32	70	4.480
1.4.1.2		materials core (Rohacell)	15	Kg	4	30	1.800		cutting, milling and drilling	2	machine hours	32	40	2.560	
1.4.1.3		metallized mylar film	5	m^2	4	20	400		threaded inserts for bolts	200	#	24	3	14.400	
1.4.1.4		consumables	7	m^2	2	20	280		steel bolts (M8)	200	#	24	2,5	12.000	
1.4.2.1		tooling	1	#	1	6000	6.000	gas manifold ring							
1.4.3.1		core cutting and shaping	40	man hours	1	70	2.800	1.4.1.4		materials	45	Kg	3	150	20.250
1.4.3.1		manufacturing (outsourcing)	40	man hours	8	70	22.400			metallized mylar film	4	m^2	3	20	240
1.4.3.3		machining/drilling ends	40	machine hours	4	40	6.400			consumables	20	m^2	3	20	1.200
1.5.0	outer barrel panels								manufacturing (outsourcing)	80	man hours	3	70	16.800	
		materials skin	48	Kg	16	150	115.200			drilling	80	machine hours	3	40	9.600
		material core (Rohacell)	3,5	Kg	16	900	50.400		threaded inserts for bolts	1000	#	3	3	9.000	
		metallized mylar film	18	m^2	16	20	5.760		steel bolts (M8)	1000	#	3	2,5	7.500	
		tooling	1	#	1	15000	15.000		drilling/threading for gas	40	machine hours	3	40	4.800	
1.4.1.4		consumables	6	m^2	16	20	1.920	miscellanea							
		manufacturing (outsourcing)	48	man hours	16	70	53.760		gas connectors	144	#	2	12	3.456	
		drilling and countersinking	80	machine hours	16	40	51.200		adhesive					25.000	
									gaskets					15.000	

Wire Cage

2.0	WIRE CAGE							
		engineering design and drawings	80	man hours	24	80	153.600	
	"L" shaped outer ring (2)							
1.4.1.4		materials	90	Kg	4	150	54.000	
		consumables	50	m^2	4	20	4.000	
		tooling	1	#	1	12000	12.000	
		manufacturing (outsourcing)	120	man hours	3	70	25.200	
		jig for drilling spokes/stays holes	1	#	1	10000	10.000	
		drilling and surveying holes	40	machine hours	3	40	4.800	
		drilling holes/orings for e.p. ring	720	machine hours	3	40	86.400	
		drilling slots for Digitizer Cards	480	machine hours	3	40	57.600	
		threaded inserts for bolts	480	#	3	3	4.320	
		st. steel bolts	4800	#	3	2,5	36.000	
		stay pulling seal box/reinforcement	48	#	3	40	5.760	
		threaded holes/orings for stay box	96	machine hours	3	40	11.520	
		spokes						
			materials	0,33	Kg	100	200	6.600
		precision milling and drilling	4	machine hours	72	40	11.520	
	spokes retainers							
		materials	0,05	Kg	100	200	1.000	
		positioning inserts	48	#	3	4	576	
		precision milling and drilling	4	machine hours	72	40	11.520	
	stays							
		materials	1	m	1500	4	6.000	
		stay retainer crimp ring	800	#	3	2	4.800	
		stay pulling device	800	#	3	5	12.000	
	struts (6)							
1.4.1.4		materials	16	Kg	14	150	33.600	
		consumables	1,5	m^2	14	20	420	
		tooling	1	#	1	4000	4.000	
		manufacturing (outsourcing)	8	man hours	14	70	7.840	
		finishing edges and drilling	8	machine hours	14	40	4.480	
		wiring spacers						
			plastic for orinting (average spacer)	0,1	dm^3	20.000	8	16.000
			tooling for machining to size	1	#	120	200	24.000
			milling, cutting and drilling	8	machine hours	112	40	35.840
		wire boards						
			field and guard wires (30 mm)	12000	#	2	15	360.000
			sense wires (50 mm)	6000	#	2	25	300.000
			HV resistors	70000	#	2	1	140.000
			termination resistors	120000	#	2	1	240.000
		HV capacitors	60000	#	2	1,5	180.000	
	wires							
		sense wire (20 micron W)	300000	m	1,25	0,8	300.000	
		field/guard wire (40/50 micron Al)	1500000	m	1,25	1,6	3.000.000	
	miscellanea							
		tools	1	#	1	50000	50.000	

Assembly Operations

ASSEMBLY OPERATIONS

engineering and drawings	80	man hours	48	80	307200
clean room	1	#	1	800000	800.000
clean room consumables	1	#	2	50000	100.000
assembling and wiring jig					
rotating wheels	150	Kg	3	150	67.500
finishing edges and drilling	120	machine hours	2	40	9.600
support structure for wiring	600	Kg	2	20	24.000
support structure for wiring	160	machine hours	2	40	12.800
roll and ball bearings	120	#	1,5	20	3.600
roll and ball bearings mounting	160	man hours	1	40	6.400
rotation shaft	1	#	1	5000	5.000
synchronized step motors system	1	#	2	7000	14.000
encoding system	1	#	2	2500	5.000
transmission system	1	#	2	4000	8.000
tools and parts preparation	640	man hours	1	40	25.600
*system assembly	640	man hours	1	40	25.600
*surveying and alignment	160	man hours	1	80	12.800
wire cage assembly					
*tools preparation	160	man hours	1	40	6.400
*fixing spokes to "L" ring	4	man hours	48	40	7.680
*gluing spokes retainers to spokes	4	man hours	96	40	15.360
*position stays and tension tuning	8	man hours	48	40	15.360
*surveying and repositioning	160	man hours	1	80	12.800
strain gauges	800	#	2	5	8.000
strain control system	1	#	2	10000	20.000
strain gauges assembly	0,5	man hours	800	40	16.000
wires transport system					
wire card pick up extension (2)	60	machine hours	4	40	9.600
3-axis system (complete)	1	#	1	15000	15.000
vacuum suction caps set	2	#	1	2000	4.000
vacuum system	1	#	2	3000	6.000
support system for 3-axis	80	machine hours	2	40	6.400
wire card transfer system	40	machine hours	2	40	3.200
parts cleaning					
*spacers	0,02	man hours	20000	30	12.000
*wire boards	0,04	man hours	18000	30	21.600
*cleaning agents	200	liters	1	10	2.000
*ultra-sound cleaner (1,0 m)	2	#	1	2000	4.000
*tools and miscellanea	1	#	1	10000	10.000

wiring system

winding drum material	50	Kg	2	150	15.000
winding drum machining	40	machine hous	1	70	2.800
wire cards insert	25	machine hous	1	70	1.750
synchronized step motor system	1	#	2	8000	16.000
encoding system	1	#	2	3000	6.000
x-phi axis	1	#	2	4000	8.000
wire transmission system	1	#	2	5000	10.000
microscope	1	#	2	4000	8.000
torquemeter + tensionmeter	2	#	2	3000	12.000
brakes and clutches	2	#	2	2000	8.000
IR soldering arm	1	#	2	25000	50.000
ADC/DAC DAQ	1	#	2	12000	24.000
power supplies	6	#	2	1000	12.000
control system and DCS	1	#	2	5000	10.000
tools and parts preparation	40	man hours	2	40	3.200
system assembly	40	man hours	2	40	3.200
calibrations	40	man hours	2	40	3.200
miscellanea parts	1	#	1	5000	5.000
tension measuring resonant system	1	#	4	2500	10.000
electronics for above	80	man hours	1	80	6.400

wire laying operations

winding all layers	2	man hours	12000	30	720.000
quality checks	2	man hours	12000	30	720.000
placing wire layers	2	man hours	8208	30	492.480
stays tuning	8	man hours	342	40	109.440
layer tolerance checking	8	man hours	342	40	109.440
overall survey	2	man hours	768	80	122.880
consumables	1	#	1	50000	50.000

chamber closure

mounting struts/removing shell	80	man hours	4	40	12.800
mounting signal cables/holders	0,5	man hours	7000	40	140.000
mounting HV cables/holders	0,25	man hours	7000	40	70.000
mounting preamp cards/LV	1	man hours	7000	40	280.000
mount outer panels	8	man hours	24	40	7.680
inner cylinder insertion tool	1	#	1	10000	10.000
insertion tool machining	40	machine hours	1	70	2.800
mount insertion tool	32	man hours	2	40	2.560
mount end plates envelope	32	man hours	4	40	5.120
mount gas manifold ring	16	man hours	4	40	2.560
remove insertion tool	32	man hours	2	40	2.560
mount electronics outer panels	4	man hours	24	40	3.840
rotating chamber vertical	32	man hours	4	40	5.120
sealing end plates	160	man hours	2	40	12.800
sealing material	1	#	1	20000	20.000
support and transpost structures	1	#	2	40000	40.000

Electronics

ELECTRONICS

engineering and drawings/preamp	40	man hours	48	80	153.600
engineering and drawings/digitizer	40	man hours	48	80	153.600
engineering and drawings/ASIC	40	man hours	48	80	153.600
engineering and drawings/ROC	40	man hours	24	80	76.800

preamplifiers/digitizer

ASIC runs	4	#	1	50000	200.000
channels for test	1000	#	1,4	100	140.000
channels production	120000	#	1,2	50	7.200.000
16 ch card test stand	4	#	1	2500	10.000
16 ch card test	7500	man hours	0,5	70	262.500
HV, LV and signal cables + connect.	7500	#	1,2	100	900.000
installation cards + cables	1	man hours	7500	40	300.000

read out controller

protocol with DAQ	40	man hours	16	80	51.200
design, program FPGA	40	man hours	16	80	51.200
FPGA card (64 ch)	2000	#	1,25	1000	2.500.000
test FPGA	40	man hours	48	40	76.800
fiber optics select	40	man hours	16	80	51.200
test ROC	4	#	1,5	2000	12.000
ROC	2000	#	2,2	400	1.760.000
ROC test	2000	man hours	1	80	160.000

cooling

engineering design	40	man hours	10	80	32.000
coolong system (chillers, piping, cntl)	3	#	1,2	50000	180.000
cooling system installation	40	man hours	16	40	25.600

HV and Gas Systems

HV/LV SYSTEM

engineering and drawings	40	man hours	10	80	32.000
HV commercial mainframes (256 ch)	16	#	1,2	20000	384.000
patch panels + distribution + cables	16	#	1,5	3000	72.000
HV distribution	80	man hours	10	40	32.000
LV power supplies (12KW)	24	#	1,2	2000	57.600
distribution + cables	24	#	1,5	3000	108.000
LV distribution	80	man hours	20	40	64.000

GAS SYSTEM

engineering and drawings	40	man hours	10	80	32.000
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gas mixing

mixing controller	1	#	1	12000	12.000
mass flowmeters	8	#	1,5	3000	36.000
pressure controller	4	#	1,5	6000	36.000
pressure transducers	4	#	1,5	4000	24.000
proportional valves	4	#	1,5	4000	24.000
infrared hydrocarbon	2	#	1	15000	30.000
infrared water vapor	2	#	1	15000	30.000
infrared oxygen	2	#	1	15000	30.000
plumbing	1	#	1	20000	20.000
gas system assembly	80	man hours	10	40	32.000
gas connectors + miscellanea	1	#	1	10000	10.000
gas monitoring system (rad. source)	1	#	2	20000	40.000
gas monitoring system	40	man hours	10	40	16.000
mass spectrometer	1	#	1,5	25000	37.500
Residual gas analyzer	1	#	1,5	20000	30.000
DCS controls and sensors	1	#	1,5	20000	30.000
DCS controls	40	man hours	24	40	38.400