

Contents

1	Executive Summary	9
2	Science	14
2.1	Introduction	14
2.2	Acceleration and propagation of cosmic rays	17
2.2.1	Acceleration	17
2.2.2	Propagation and the GZK Cutoff	21
2.3	Recent theoretical work	26
2.3.1	Shock acceleration in extended sources	27
2.3.2	Association with gamma-ray bursts	30
2.3.3	Exotic sources	32
2.3.4	Astrophysical Neutrinos	35
2.3.5	Summary Comments on Source Models	36
2.4	Observational capabilities needed for the Auger Observatory	37
2.4.1	Composition resolution.	37
2.4.2	Energy resolution	39
2.4.3	Arrival direction resolution	40
2.4.4	Neutrino Astronomy	45
3	Observations of the Highest Energy Cosmic Rays	49
3.1	Background	49
3.2	Energy measurements	52
3.2.1	Energy spectrum	53

3.3	Direction measurements	61
3.3.1	Anisotropy	61
3.3.2	Point sources	63
3.3.3	Magnetic spectrometry with event pairs	64
3.4	The Immediate Future	67
3.5	The Physics and Astrophysics Potential of the Auger Project	68
4	Air Shower Measurement Techniques	70
4.1	Properties and Development of Air Showers	70
4.1.1	The Electromagnetic and Muon Components	71
4.1.2	Spatial Structure of the Shower	71
4.1.3	Time Structure of the Shower Front	74
4.1.4	Fluctuations in Shower Development	75
4.2	Determination of Shower Parameters	76
4.2.1	The Shower Direction and Axis	76
4.2.2	Energy	77
4.2.3	Primary Mass	78
4.2.4	New Particle Physics	80
4.3	Surface Array Methods	82
4.3.1	Water Čerenkov lateral distribution function	83
4.3.2	Event Reconstruction	86
4.3.3	Energy Assignment Parameter	86
4.4	Fluorescence Detection	89
4.4.1	Air Fluorescence	90
4.4.2	Čerenkov production and scattering	91
4.4.3	Detection Technique	94
4.4.4	Finding Shower Trajectories	97
4.4.5	Shower Shape and Energy	99
5	Simulated Performance of the Reference Design	102

5.1	Numerical simulations	102
5.1.1	The MOCCA Simulation Program	103
5.1.2	The SIBYLL Interaction Generator	104
5.1.3	Nucleus-Nucleus Interactions	106
5.1.4	Comparison to Data	106
5.1.5	Ongoing studies	108
5.2	Surface Detector Simulation	109
5.2.1	Detector description	110
5.2.2	Air Shower Structure	110
5.2.3	Detector Simulation	113
5.2.4	Comparison of Simulation and Data	118
5.2.5	Reconstruction of simulated events	126
5.3	Hybrid Detector Simulation	133
5.3.1	Methods	133
5.3.2	Simulation of Fluorescence Detector Response	134
5.3.3	Simulation of Ground Array Response	136
5.3.4	Hybrid Geometric Reconstruction Method	137
5.3.5	Energy and X_{max} Resolution	140
5.3.6	Results	141
5.4	Summary of Reconstruction Resolution	144
6	Surface Detector Array Design	151
6.1	The reference design	152
6.2	Detector geometry and array spacing	152
6.3	PMT positioning and detector uniformity	154
6.4	Mechanical realization and prototypes	157
6.5	Water purification and stability	160
7	Fluorescence Detector Design	163
7.1	The site layout	164
7.2	The telescope design	166

7.3	Alternative Designs	168
7.3.1	The Dual Mirror Concept	168
7.3.2	Wide angle Schmidt telescopes	168
8	Electronics Systems and Software	170
8.1	Station Electronics Packaging	170
8.2	Front End Electronics	171
8.3	Station Controller	175
8.4	Timing	176
8.5	Communications	178
8.5.1	Licensing Issues	179
8.5.2	Propagation	179
8.5.3	Performance Analysis of Frequency-Hopped Spread Spectrum.	182
8.5.4	Link Budget	184
8.5.5	Network Topology	186
8.6	Solar Power	187
8.7	Data Acquisition and Archives	189
8.8	Trigger	190
9	Site Survey	193
9.1	Introduction	193
9.2	Site Requirements	194
9.3	Site Visits and Relevant Data	194
9.4	Argentina	195
9.4.1	Laguna Blanca:	195
9.4.2	La Humada:	197
9.4.3	Monte Coman:	197
9.4.4	Nihuil:	198
9.4.5	Somuncura:	199
9.5	South Africa	200
9.5.1	Vaalputs:	200

9.6	Australia	201
9.6.1	Woomera	201
9.7	Spain	202
9.7.1	Tierra de Campos	203
9.8	Mexico	204
9.8.1	El Barreal	204
9.9	United States of America	205
9.9.1	Engle, NM:	205
9.9.2	Grand Canyon, AZ:	206
9.9.3	Lamar, CO:	207
9.9.4	Millard, UT:	208
10	Central Station	210
10.1	Central Station	210
10.1.1	The Office Building	210
10.1.2	The Dormitory	211
10.1.3	The Shed	211
10.2	Civil Engineering	211
11	Organization, Cost, and Schedule	213
11.1	Introduction	213
11.2	Organization	213
11.3	Construction Cost Estimate	216
11.4	Operating Cost	217
11.4.1	Project Schedule	222
A	Auger Project Participants	224
A.1	Auger Collaboration Membership	224
A.2	Auger Project Contributors	233