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AD Consolidation for operation beyond 2010

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Abstract

The Antiproton Decelerator (AD), which started up for physics in 2000 and today supplies low-energy antiprotons to the ATRAP, ALPHA, ASACUSA and ACE experiments is based on the ACOL machine from which it still retains most of the components. ACOL construction was completed in 1986 at a total cost of approximately 80 MCHF (excluding infrastructure) which today would correspond to a value of around 160 MCHF. During recent years, a reduction of maintenance and modernisation has been unavoidable due to budgetary restraints.

In order to identify the resources needed for continued AD operation beyond 2010 with a reasonably low risk of failures and to avoid increasing maintenance and repair costs, a study has been conducted involving groups from the AB, AT and TS departments. Analysis of breakdown risks, identification of items and costs for consolidation has been done as well as a risk score classification. To be noted is the relatively modest cost of the proposed items in view of the value of the facility and in comparison to the cost of the manpower necessary for running AD.

The two scenarios under consideration are (1): Continued operation until the end of 2012 with no major modifications to the AD machine and (2): Operation until the end of 2016 with the possibility to implement the proposed ELENA upgrade.

In both scenarios, AEGIS can carry out the measurement that it has proposed to make. The success-oriented timeline of the AEGIS proposal, which foresees installation of the experiment in 2009 and 2010, commissioning and first data taking in 2011 and carrying-out of a first gravitational measurement with antihydrogen in the following year is compatible with a scenario of AD operation only until the end of 2012. However, running the AD until 2016 would in addition allow going beyond the initial validation of the technique and would permit a more thorough investigation of the systematic errors in order to reach the initial physics goal (a measurement of the gravitational interaction of antihydrogen to 1%) and perhaps improve on it, as well as a number of ancillary physics measurements which are interesting and publishable in their own right.

Geneva, Switzerland
October, 2008

1. Executive summary

Identification of AD consolidation items was accomplished in collaboration with the AB, AT and TS departments. For each item, analysis of risk and implication of breakdowns was done using the method described in chapter 3. In chapter 4, a brief description of each item is given along with the estimated risk scores for the present state and for after the proposed consolidation. Also included are estimations for required manpower and materials budgets.

Also included in this report are AD running cost estimates (manpower and materials), short descriptions and cost estimates for the 2 proposals AEGIS and ELENA as well as considerations for running AD beyond 2016.

Three tables are presented in this summary:

Table1 “AD risk score classification” contains items classified according to their present risk score (RS). Total Personell and Materials budgets are given along with running summaries for the two closedown scenarios. Whether an item is to be considered for consolidation in the case of closedown in 2012 or 2016 respectively is indicated in the “1=Needed” columns.

For some items, a risk analysys is not appropriate. These are commented and grouped at the bottom of the table.

Table 2 and 3 show for the two closedown scenarios respectively the money spending profiles during 2008 – 2012 containing only the items which are considered for each scenario.

Table 1

AD risk score classification

Item	Group	RS	RS after	P	M	2012	2016	ΣP	ΣM	ΣP	ΣM	Remarks
						1=Needed		2012	2012	2016	2016	
				MY	kCHF			MY	kCHF	MY	kCHF	
AD Main bending magnets	AT-MCS	**15**	**6**	2.4	1030	0	1	0	0	2.4	1030	
AD power converter spares	AB-PO	**15**	**3**	0.25	95	1	1	0.25	95	2.65	1125	
AD MWPC:s	AB-BI	**15**	**2**	2	600	1	1	2.25	695	4.65	1725	ccc op&AEGIS
AD ring quadrupole QFC54	AT-MCS	**10**	**6**	0.3	60	1	1	2.55	755	4.95	1785	
AD inj. line pulsed power converters	AB-PO	**10**	**3**	4.3	1180	1	1	6.85	1935	9.25	2965	
AD e-cooling magnet spares	AB-BI	**10**	**6**	0.2	200	0	1	6.85	1935	9.45	3165	
AD target area spare magnets	AT-MCS	**10**	**4**		25	1	1	6.85	1960	9.45	3190	
AD vacuum ion pumps	AT-VAC	**9**	**6**	0.8	96	1	1	7.65	2056	10.25	3286	
AD kicker vacuum tanks	AB-BT	**9**	**2**	0.25	100	0	1	7.65	2056	10.5	3386	
AD Stoch.cooling p/u&kicker movement	AB-RF	**9**	**2**	1	50	1	1	8.65	2106	11.5	3436	
AD horn pulser ignitrons	AB-BT	**9**	**3**	0.5	400	0	1	8.65	2106	12	3836	Safety
AD vacuum cryo system	AT-VAC	**8**	**4**	0	80	1	1	8.65	2186	12	3916	
AD ring Q-trim power converters	AB-PO	**8**	**3**	1	175	1	1	9.65	2361	13	4091	
AD C02 system	AB-RF	**8**	**3**	1	160	1	1	10.65	2521	14	4251	
AD kicker oil system	AB-BT	**8**	**3**	0.75	60	0	1	10.65	2521	14.75	4311	
AD horn pulser electronics	AB-BT	**8**	**3**	0.5	100	0	1	10.65	2521	15.25	4411	
AD vac.ion pump power supplies&ctrls	AT-VAC	**8**	**2**	0.4	350	1	1	11.05	2871	15.65	4761	
AD target area ventilation & interlocks	AB-OP	**8**	**3**	1	100	1	1	12.05	2971	16.65	4861	
AD Stochastic cooling electronics	AB-RF	**6..9**	**2**	0.5	100	1	1	12.55	3071	17.15	4961	
AD ring corrector dipoles	AT-MCS	**6**	**4**	0.3	60	1	1	12.85	3131	17.45	5021	
AD magnet ancillary equipment	AT-MCS	**6**	**2**	0.3	135	0	1	12.95	3176	17.75	5156	
AD electron cooler power converters	AB-PO/BI	**6**	**3**	0.35	150	1	1	13.3	3326	18.1	5306	
AD cooling/ventilation	TS-CV	**6**	**3**	0	60	1	1	13.3	3386	18.1	5366	
AD target water cooling	AB-OP	**6**	**4**		50	1	1	13.3	3436	18.1	5416	
AD ejection line power converters	AB-PO	**4**	**2**	0.25	90	0	1	13.3	3436	18.35	5506	
AD Stochastic cooling power amplifiers	AB-RF	**4**	**2**	1.5	2500	0	0	13.3	3436	18.35	5506	2020
AD C10 system	AB-RF	**4**	**2**	0.2	75	1	1	13.5	3511	18.55	5581	
AD kicker power supply/ctrls upgrade	AB-BT	**4**	**2**	0.25	125	0	1	13.5	3511	18.8	5706	
AD orbit measurement system	AB-BI	**3**	**1**	0.1	65	1	1	13.6	3576	18.9	5771	
AD beam current transformers	AB-BI	**3**	**1**	1	230	1	1	14.6	3806	19.9	6001	
AD Instrumentation SW + FSU	AB-BI	**3**	**1**	1	80	1	1	15.6	3886	20.9	6081	
AD main quadrupole magnets	AT-MCS	**3..4**	**N.A.**			0	0	15.6	3886	20.9	6081	No suggestions
AD injection&ejection septa	AB-BT	**3**	**N.A.**			0	0	15.6	3886	20.9	6081	No suggestions
AD Stochastic cooling vacuum tanks	AB-RF	**5**	**N.A.**			0	0	15.6	3886	20.9	6081	No suggestions
Items without risk score rating:												
AD controls	AB-CO	**N.A**	**N.A**	5	700	1	1	20.6	4586	25.9	6781	CO program
AD septa controls	AB-BT	**N.A.**	**N.A.**	0.4	25	1	1	21	4611	26.3	6806	with AD controls
AD beam control	AB-RF	**N.A.**	**N.A.**	2.35	100	0	1	21	4611	28.65	6906	R.O.I.
AD target area remote manipulation	AB-ATB	**N.A.**	**N.A.**	0.75	45	1	1	21.75	4656	29.4	6951	R.O.I.
AD schottky analysis	AB-RF/BI	**N.A.**	**N.A.**	1.8	100	0	1	21.75	4656	31.2	7051	R.O.I.
Total (MY / kCHF)								**21.7**	**4656**	**31.2**	**7051**	

Table 2

Spending profile 2012 closedown

Item	Group	RS	RS after	ΣP	ΣM	M08	M09	M10	M11	M12
				MY	kCHF	kCHF	kCHF	kCHF	kCHF	kCHF
AD power converter spares	AB-PO	15	3	0.25	95		47	48		
AD MWPC:s	AB-BI	15	2	2	600		300	300		
AD ring quadrupole QFC54	AT-MCS	10	6	0.3	60		60			
AD injection line pulsed power converters	AB-PO	10	3	4.3	1180		120	530	530	
AD target area spare magnets	AT-MCS	10	4		25		25			
AD vacuum ion pumps	AT-VAC	9	6	0.8	96	24	24	24	24	
AD Stochastic cooling p/u & kicker movement	AB-RF	9	2	1	50		50			
AD vacuum cryo system	AT-VAC	8	4	0	80	20	20	20	20	
AD ring Q-trim power converters	AB-PO	8	3	1	175		25	150		
AD C02 system	AB-RF	8	3	1	160			80	80	
AD vacuum ion pump power supplies&controls	AT-VAC	8	2	0.4	350	50	150	150		
AD target area ventilation & interlocks	AB-OP	8	3	1	100			100		
AD Stochastic cooling electronics	AB-RF	6..9	2	0.5	100		50	50		
AD ring corrector dipoles	AT-MCS	6	4	0.3	60			60		
AD magnet ancillary equipment	AT-MCS	6	2	0.1	45		45			
AD electron cooler power converters	AB-PO/BI	6	3	0.35	150		150			
AD cooling/ventilation	TS-CV				60		60			
AD target water cooling	AB-OP	6	4		50		50			
AD C10 system	AB-RF	4	2	0.2	75			75		
AD orbit measurement system	AB-BI	3	1	0.1	65			65		
AD beam current transformers	AB-BI	3	1	1	230				230	
AD Instrumentation SW + FSU	AB-BI	3	1	1	80			40	40	
Items without risk score rating:										
AD controls	AB-CO	N.A	N.A	5	700			500	200	
AD septa controls	AB-BT	N.A.	N.A.	0.4	25			25		
AD target area remote manipulation	AB-ATB	N.A.	N.A.	0.75	45			45		
Yearly total (kCHF)						**94**	**1176**	**2262**	**1124**	**0**
Grand total (kCHF)					**4656**					

Table 3

Spending profile 2016 closedown

Item	Group	RS	RS after	ΣP	ΣM	M08	M09	M10	M11	M12
				MY	kCHF	kCHF	kCHF	kCHF	kCHF	kCHF
AD Main bending magnets	AT-MCS	15	6	2.4	1030		10	420	300	300
AD power converter spares	AB-PO	15	3	0.25	95		47	48		
AD MWPC:s	AB-BI	15	2	2	600		300	300		
AD ring quadrupole QFC54	AT-MCS	10	6	0.3	60		60			
AD injection line pulsed power converters	AB-PO	10	3	4.3	1180		120	530	530	
AD e-cooling magnet spares	AB-BI	10	6	0.2	200			80	120	
AD target area spare magnets	AT-MCS	10	4		25		25			
AD vacuum ion pumps	AT-VAC	9	6	0.8	96	24	24	24	24	
AD kicker vacuum tanks	AB-BT	9	2	0.25	100				50	50
AD Stochastic cooling p/u&kicker movement	AB-RF	9	2	1	50		50			
AD horn pulser ignitrons	AB-BT	9	3	0.5	400					400
AD vacuum cryo system	AT-VAC	8	4	0	80	20	20	20	20	
AD ring Q-trim power converters	AB-PO	8	3	1	175		25	150		
AD C02 system	AB-RF	8	3	1	160			80	80	
AD kicker oil system	AB-BT	8	3	0.75	60			30	30	
AD horn pulser electronics	AB-BT	8	3	0.5	100					100
AD vacuum ion pump power supplies&controls	AT-VAC	8	2	0.4	350	50	150	150		
AD target area ventilation & interlocks	AB-OP	8	3	1	100			100		
AD Stochastic cooling electronics	AB-RF	6..9	2	0.5	100		50	50		
AD ring corrector dipoles	AT-MCS	6	4	0.3	60			60		
AD magnet ancillary equipment	AT-MCS	6	2	0.3	135		45	45	45	
AD electron cooler power converters	AB-PO/BI	6	3	0.35	150		150			
AD cooling/ventilation	TS-CV				60		60			
AD target water cooling	AB-OP	6	4		50		50			
AD ejection line power converters	AB-PO	4	2	0.25	90				90	
AD C10 system	AB-RF	4	2	0.2	75			75		
AD kicker power supply/controls upgrade	AB-BT	4	2	0.25	125				62	63
AD orbit measurement system	AB-BI	3	1	0.1	65			65		
AD beam current transformers	AB-BI	3	1	1	230				230	
AD Instrumentation SW + FSU	AB-BI	3	1	1	80			40	40	
Items without risk score rating:										
AD controls	AB-CO	N.A	N.A	5	700			500	200	
AD septa controls	AB-BT	N.A.	N.A.	0.4	25			25		
AD beam control	AB-RF	N.A.	N.A.	2.35	100			50	50	
AD target area remote manipulation	AB-ATB	N.A.	N.A.	0.75	45			45		
AD schottky analysis	AB-RF/BI	N.A.	N.A.	1.8	100		15	60	25	
Yearly total (kCHF)						**94**	**1201**	**2947**	**1896**	**913**
Grand total (kCHF)					**7051**					

2. Risk analysis of the AD systems

A risk analysis has been performed for each item partly using the standard method of the AB department. Since this analysis reflects AD-only consolidation needs, the coefficient defining the importance of the AD physics program in relation to the other CERN programs has been omitted.

The risk analysis includes the following data:

1. Probability of failure (P)
- Rare (once in 10 to 25 years) = **1**
- Possible (once in 5 to 10 years) = **2**
- Likely (once in 2 to 5 years) = **3**
- Frequent (once a year) = **4**

2. Impact on CERN scientific objectives (Io)
- Insignificant (loss of 1 day of physics or less) = **1**
- Moderate (between 1 day and 1 week of physics lost) = **2**
- Major (up to 1 month of physics lost) = **3**
- Catastrophic (no more operation, failure to meet objectives for the year) = **5**

3. Impact on CERN's (AB department's) reputation (Ir)
- Insignificant = **1**
- Moderate (problem dealt with inside AB) = **2**
- Major (problem discussed at Executive Board or Governing bodies) = **3**

4. Financial impact of failure (If)
- Insignificant (<0.5% of AB annual budget or less than 120 kCHf) = **1**
- Moderate (between 1% and 4% of AB annual budget or 0.25 – 1 MCHf) = **2**
- Major (additional budget essential for repair i.e. >1MCHf) = **3**
- Catastrophic (report to council, could jeopardize CERN's future) = **5**

5. Safety impact in case of failure (Is)
- Insignificant (i.e. no injury or environmental consequence) = **1**
- Moderate (i.e. injury requiring medical attention but no loss of working days) = **2**
- Major (i.e. serious injury requiring medical attention and loss of working days)= **3**
- Catastrophic (i.e. loss of life) = **5**

The risk score is calculated as: **RS = P*max(Io,Ir,If,Is)**

3. Items considered for consolidation

3.1. AD Magnets

Money made available via consolidation projects for a total sum of 1.29 Mo CHF over the next 4 to 5 years. This will cover the purchase of spare magnet components, coils etc... And to rebuild the magnets, as well as the occasional routine maintenance which exceeds the frame of paragraph 1.Hereunder is the proposed baseline for a possible forthcoming AD consolidation program.

An inventory of the spare situation for the transfer line magnets is near completion. With a few exceptions, spares are available.

Conclusion: There are 177 magnets in operation in the AD Ring and its TL. Only a fraction (~ 80) of these magnets could be assessed in a relatively correct way due to the limited resources available. However the recommendations drafted in the present document should prevent the major foreseeable failures.

Item:	<u>AD Main bending magnets BHN/BHW/BHS</u>
Responsible:	AT/MCS
Description:	Supply of 5 sets of spare coils (2N, 2W, 1S) Supply of tools to machine open the magnets Overhaul of 4 magnets in 2010, 10+10 magnets in 2011/2012
RS:	15 (P=3, Io=5, Ir=2, If=2, Is=1)
RS after cons.:	6 (P=2, Io=3, Ir=2, If=1, Is=1)
Total budget:	1030 kCHF + 2.4 MY 2010-2012

The 24 BHN/BHW/BHS dipoles constitute the main magnets of the AD ring. The coil shimming of these dipoles shows an abnormal degradation, which tends to indicate that the coils are moving inside the magnet yokes during the pulsed cycle. It is therefore recommended to undertake the replacement of the internal shimming for some or all of the 24 dipoles. This entails the complete disassembly of the magnets. If such a program is undertaken it is advisable to also assess the coil insulation quality, as well as the possibility of the magnetic properties of the magnets. Such an important overhaul can be achieved within a 3-years program (Shutdown 2009/10 to 2011/12). Spare coils will be required in case of failure during the tests, and if the overhaul of the magnets is not conducted should be seen as a minimum requirement.

Note: A breakdown of one of the main dipoles cannot be excluded in the coming years. There are no spare BHN/BHW/BHS magnets available. The tooling required to replace a damaged coil is not available. There are no spare Coils available.

Note 2: Further evaluation of the Risk Score based on coil movement measurements and stress analysis of the coil connection pieces will be done during the 2008/9 shutdown. This might change the estimated RS downwards.

Item:	<u>AD Main quadrupole magnets QN(15/17/19 turns) & QW(20/22/26 turns).</u>
Responsible:	AT/MCS
Description:	None
RS:	3/4 (P=1/2, Io=2/3, Ir=2, If=2, Is=1)
RS after cons.:	N.A.
Total budget:	N.A.
Remark:	*Item for information on risk analysis*

The main ring quadrupoles (27 QN / 28 QW) are in an assessed good state and should not require a specific consolidation program in the near future. Spare magnets and coils are available for most types. A risk analysis has been drafted in the annex for information. Although, two minor issues have been identified that could possibly justify future actions:

- The possible movement of the upper coils (in case of accelerated ageing of the coil shimming) could overstress the straight and rigid interconnection between the coils and lead to the failure of the cooling circuit. Such phenomenon's have already been observed in the past, and a modification was undertaken several years ago (extra shimming) that might still be require further attention in the long term;
- The quadrupole coil tensioning rods made of conductive material are in contact with the coil insulation. In case of coil movement, this setup could eventually damage the coil insulation and lead to ground shorts.

Item: AD ring corrector dipoles
Responsible: AT/MCS
Description: Design and supply of correctors (functionality upgrade for DVD/DHZ 2904 and DVT/DHZ 2917). Supply of spare coils
RS: 6 (P=2, Io=3, Ir=1, If=1, Is=1)
RS after cons.: 4 (P=2, Io=2, Ir=1, If=1, Is=1)
Total budget: 60 kCHF + 0.3 MY 2010

Correctors are in much worse state and are probably much less reliable than any other element of the magnetic system of AD. The AD section has already expressed their wish to upgrade the correctors upstream and downstream the electron cooler (DHZ2904 / DHZ2917). In addition it is recommended either to renovate some other correctors in place in the ring and in the TL with new coils or to develop new correctors. The later program would require further studies.

Item: AD ring quadrupole QFC54
Responsible: AT/MCS
Description: Supply of 1 set of spare coils
RS: 10 (P=2, Io=5, Ir=2, If=1, Is=1)
RS after cons.: 6 (P=2, Io=3, Ir=2, If=1, Is=1)
Total budget: 60 kCHF + 0.3 MY 2009

The recent breakdown of the QFC054 magnet has imposed its overhauling and the replacement of its original coils with the only spare coils available. During the refurbishment, it has been noticed that the design of the cooling junctions has not been optimized for the very high speed of the water in this region (endoscopic examination inside the coil). It was also noticed that the old coils had already undergone several repairs at this junction before its complete wreckage during 2007 run. It is clear that the spare set of coils that is now put in place will suffer similar fast erosion in this region. It is recommended to manufacture a set of spare coils with an improved design in case this magnet is supposed to run for an extended period of time.

Item: AD magnet ancillary equipment
Responsible: AT/MCS
Description: Installation of filters + flow measurement on 80 main magnets
Replacement of 300 water hoses
RS: 6 (P=3, Io=2, Ir=2, If=1, Is=1)
RS after cons.: 2 (P=1, Io=2, Ir=1, If=1, Is=1)
Total budget: 135 kCHF + 0.3 MY 2009-2011

Most of the magnet ancillary equipment is in relative good shape and as such would not require any specific consolidation.

It is noted that water hoses have a limited lifetime (usually 10-15 years). In absence of information amongst AT/MCS, the age of the existing hoses could not be evaluated. The replacement of the hoses might have to be foreseen in the coming years. According to AD machine experts these hoses could already be aged between 10 and 15 years. If such is the case a replacement should be foreseen within 5 years if AD is to be run beyond 2012.

It is noted that no water filters equip the dipoles and quadrupoles in the AD Ring. Although not mandatory, filters guarantee that no impurity can enter and clog the magnet cooling circuits. Being given the spare situation of the main magnets, it might be safe to foresee the installation of filters on the magnets.

Estimated cost for filters & flow measurement is: 15kCHF HW + 30 kCHF FSU + 0.1 MY in 2009.

Cost for water hoses is: 70 kCHF HW + 20 kCHF FSU+ 0.2 MY spread over 2010 & 2011.

Item:	AD measured B-train
Responsible:	AT/MEI
Description:	Re-commissioning of existing system
RS:	N.A.
RS after cons.:	N.A.
Total budget:	0.2 MY 2009

This system has been used mainly for diagnostic purposes and for machine studies as well as a backup for the synthetic B-train system which is normally used for regular operation.

Since some time, the system is no longer operational.

In view of further development of the AD facility, it is important to bring this system back to operational status. Apart from a small effort in manpower, a new interface to the control system needs to be defined and implemented. The CO-part can be integrated in the global controls upgrade mentioned elsewhere in this report.

3.2. AD power converters

Item:	AD injection line pulsed power converters
Responsible:	AB/PO
Description:	Replace existing pulsed converters with up-to-date
RS:	10 (P=4, Io=2/3, Ir=2, If=1, Is=1)
RS after cons.:	3 (P=3, Io=1, Ir=1, If=1, Is=1)
Total budget:	1180 kCHF + 4.3 MY 2009-2011

The existing 2/4 kA converters are of the capacitive discharge type which employs large numbers of electrolytic capacitors. With an age of around 30 years, fault rates are increasing and faults cause long delays. A new design is proposed which retains some of the existing electronics. Design and prototyping will require 120 kCHF and 0.5 MY during the first year. Production of the 12 + 1 spare units is budgeted at 13* 70 kCHF + 30% (for controls, electricity supply and FSU:s).Manpower needs are 3.5 man-months per unit spread over the two following years.

Total budget of 1180 kCHF + 4.3 MY over 3 years 2009-2011.

Item:	AD ring Q-trim power converters
Responsible:	AB/PO
Description:	Q-trim converters upgrade/simplifying.
RS:	8 (P=4, Io=2, Ir=2, If=1, Is=1)
RS after cons.:	3 (P=3, Io=1, Ir=1, If=1, Is=1)
Total budget:	175 kCHF + 1 MY 2009-2010

Modification of existing Danfysik converters (Q-trim 1-2-3-5 and B-trim) to ensure future serviceability. Prototyping/tests of 1 unit foreseen in 2009 and installation of remainder as of 2010. At a price of 25 kCHF each , cost is 125 kCHF.

Replacement of ageing Q-trim4 with a new unit = 50 kCHF.

Manpower needs of 1 MY over 2 years.

Item:	AD power converter spares
Responsible:	AB/PO
Description:	BTI274S spare components and cabling, B/Q spares
RS:	15 (P=3, Io=5, Ir=2, If=1, Is=1)
RS after cons.:	3 (P=3, Io=1, Ir=1, If=1, Is=1)
Total budget:	95 kCHF + 0.25 MY 2009-2010

No spare unit exists for the BTI247S switching dipole converter (TT2 to AD target). The proposed soultion consists of using a similar converter installed in B.355 via new cables, modification of this converter to comply with the high inductance of the magnet and also the purchasing of spare components. A budget of 70kCHF has to be foreseen.

Also included is the purchase of spare parts for B-main and Q-main converters at a cost of 25kCHF.

Total budget is 95kCHF + 3 MM during 2009-2010.

Item:	AD ejection line power converters
Responsible:	AB/PO
Description:	Replacement of ageing converters.
RS:	4 (P=2, Io=2, Ir=2, If=1, Is=1)
RS after cons.:	2 (P=2, Io=1, Ir=1, If=1, Is=1)
Total budget:	90 kCHF + 0.25 MY 2011

10 of the converters for the ejection line magnets are old and are getting difficult to maintain in a good operational state. Foreseen is the replacement with new units at a total budget of 90 kCHF + 3 MM in 2011.

Item:	AD electron cooler power converters
Responsible:	AB/PO, AB/BI
Description:	New power converters/ctrls interface + HV upgrade
RS:	6 (P=3, Io=2, Ir=1, If=1, Is=1)
RS after cons.:	3 (P=3, Io=1, Ir=1, If=1, Is=1)
Total budget:	150 kCHF + 0.35 MY in 2009 (*)

The existing electron beam trajectory corrector supplies are obsolete and with uncertain spare parts situation. The proposed consolidation consists of replacing the existing supplies with modern units also capable of switching polarity during the machine cycle and of upgrading to current PLC-based controls interface.

The new controls interface also permits upgrade of the interlock system to the same type as is used in LEIR at a relatively small cost. Also included is the replacement of an obsolete oil-filled 40kV isolation transformer with a standard unit of the same type as is used in LEIR as well as simplification of the Faraday cage and the purchase of missing spare parts.

This will bring the system in line with the LEIR electron cooler meaning simpler and more efficient maintenance and sharing of spare parts.

Budget is 150 kCHF + 0.35 MY over one year.

More details can be found in document: http://edms.cern.ch/document/974805/1

(*) Some items have already been ordered in 2008 using the existing AD consolidation budget.

3.3. AD beam cooling:

Item: <u>AD electron cooler magnet spares</u>
Responsible: AB/BI
Description: Manufacture of 3 spare coils
RS: 10 (P=2, Io=5, Ir=3, If=2, Is=1)
RS after cons.: 6 (P=2, Io=3, Ir=2, If=1, Is=1)
Total budget: 200 kCHF + 0.2 MY 2010-2011

Since no spare units exist for some of the magnetic elements, a major breakdown would cause up to 1 year stop of physics. Consolidation consists of manufacture of 1 toroid, 1 collector solenoid and 1 gun solenoid. Replacement of any of these units require dismantling of the e-cooler and subsequent vacuum bakeout, hence the rather high RS after consolidation.

Budget is 200 kCHF + 2 MM over 2 years (2010/2011).

Item: <u>AD Stochastic cooling power amplifiers</u>
Responsible: AB/RF
Description: Construction of new power amplifiers & power supplies
RS: 4 (P=4, Io=1, Ir=1, If=1, Is=1)
RS after cons.: 2 (P=2, Io=1, Ir=1, If=1, Is=1)
Total budget: 2.5 MCHF + 1.5 MY 2011-2012
Remark: *Only in the case of AD running beyond 2016*

This item concerns the 48 semiconductor power amplifiers. It is estimated that with the present failure rate of approximately 10/yr and taking into account the present spare component stock and maintenace scheme that the system can be maintained until 2016. AD physics will stop if a large number of these 3GHz bandwith amplifiers drop out. For the period 2016 until 2020, one can expect increasing failure rates and depletion of the spare component stock. In this case, a renovation of the system should be considered including the design and construction of new amplifiers and power supplies. Required budget amounts to 2.5 MCHF + 1.5 MY spread over 2011 and 2012. Yearly maintenance which requires 10 kCHF HW + 15 kCHF FSU + 0.1 MY would be halfed.

Item: <u>AD Stochastic cooling vacuum tanks</u>
Responsible: AB/RF
Description: N/A
RS: 5 (P=1, Io=5, Ir=3, If=3, Is=1)
RS after cons.: N.A.
Total budget: N.A.
Remark: *Item for information on risk analysis*

In 1999 one of the kicker tanks water cooling circuits sprung a leak (inside the vacuum tank). This was successfully repaired with liquid epoxy and has been in service since then. For further possible faults of the same nature, similar repairs could be considered. In case of failed repair attempts, the implications would be very serious. All 4 tanks are required for AD operation and no spares exist at CERN. A possible solution would be requesting the return of the remaining 8 tanks (out of the 12 that were originally built for the ACOL project) from Germany and Japan and refurbish them with new technology. This would still imply high costs and manpower needs. For comparison, the 1986 price for the 12 tanks was in the order of 10 MCHF.

Item: <u>AD Stochastic cooling electronics</u>
Responsible: AB/RF
Description: Replacement of modified CAMAC-equipment with up-to-date
RS: 6/9 (P=3, Io=2/3, Ir=2, If=1, Is=1)
RS after cons.: 2 (P=2, Io=1, Ir=1, If=1, Is=1)
Total budget: 100kCHF + 0.5 MY 2009-2010

The switching of 12/24V 1A signals for system parameter control employs modified CAMAC-equipment. A replacement with up-to-date with solid-state units with standard controls interface is foreseen. The requirement is for a control with a precision of better than 100 ms with respect to the machine timing. A choice on the technical implementation has not been made yet. A PLC based system seems the most economic solution. However, it must be shown that the timing constraints can be fulfilled by a PLC. It is urgent to replace the obsolete CAMAC equipment, preferably during the 2009/10 shutdown.

Item: AD Stochastic cooling p/u & kicker movement
Responsible: AB/RF
Description: Replace motor driver electronics.
RS: 9 (P=3, Io=3, Ir=2, If=1, Is=1)
RS after cons.: 2 (P=2, Io=1, Ir=1, If=1, Is=1)
Total budget: 50 kCHF + 1 MY 2009

Consolidation of the movement system consists of development or purchase of new motor driver electronics and associate electronics to interface with the Controls System. The requirement is for a control with a precision of better than 100 ms with respect to the machine timing. A choice on the technical implementation has not been made yet. A PLC based system seems the most economic solution. However, it must be shown that the timing constraints can be fulfilled by a PLC. Spare mechanical parts for this system are presently available from de-commissioned units. This work could be done in 2009.

3.4. AD RF equipment:

Item: AD C10 system
Responsible: AB/RF
Description: Replacement of 1kW amplifiers.
RS: 4 (P=4, Io=1, Ir=1, If=1, Is=1)
RS after cons.: 2 (P=2, Io=1, Ir=1, If=1, Is=1)
Total budget: 75 kCHF + 0.2 MY 2010

Several of the consolidation items from previous consolidation program have already been done. Major remaining item is replacement of the 1kW amplifiers which have caused sveral stops in recent years. During 2008, validation tests on an existing amplifier design will be done. Purchase of 3 units at 25 kCHF/pce is planned for 2010 and installation foreseen for the 2010/2011 shutdown. Note that the risk factor is low due to redundance. Two C10 cavities are installed. In case of breakdown of one cavity, the AD will run at approximately 75% of nominal beam intensity.

Item: AD C02 system
Responsible: AB/RF
Description: Upgrade of obsolete equipment
RS: 8 (P=4, Io=2, Ir=2, If=1, Is=1)
RS after cons.: 3 (P=3, Io=1, Ir=1, If=1, Is=1)
Total budget: 160 kCHF + 1 MY 2010-2011

The existing cavity tuning system (amplifier, power supply and associated equipment) is around 40 years old and frequently causes stops and repairs. A new design has been launched in the PS and validation for use of this design in the AD could be done in about 1 year. Estimated cost is 65 kCHF.

The C02 consolidation also includes new HT supply (35 kCHF) + gap capacitors and electronics to a cost of approximately 60 kCHF. Budget is spread over 2 years 2010-2011.

Item: AD beam control
Responsible: AB/RF
Description: Upgrade of obsolete equipment
RS: **N.A.**
RS after cons.: **N.A.**
Total budget: 100 kCHF + 2.35 MY 2010-2011

Upgrade of existing analog beam control system to a standard digital low-level RF system similar to the one used in LEIR. The technical solution will depend on the future AD cycle generation/timing system.

Risk analysis is not meaningful since the objective here is standardisation and to have better remote control/analysis possibilities. Return on investment = reduced risk of long down time, no need for time consuming maintenance & repair of obsolete modules (a guess would be 0.1 FTE/year of operation).

Total budget is 100 kCHF and 2.35 MY spread over 2010 and 2011. A reduction in manpower needs compared to an earlier consolidation plan has been obtained since part of the development can be shared with other consolidation activities.

3.5. AD beam transfer equipment:

Item: AD kickers oil system
Responsible: AB/BT
Description: Oil system consolidation
RS: 8 (P=4, Io=2, Ir=1, If=1, Is=1)
RS after cons.: 3 (P=3, Io=1, Ir=1, If=1, Is=1)
Total budget: 60 kCHF + 0.75 MY 2010-2011

Replacement of obsolete kicker oil system as part of an ongoing campaign. Requires 60 kCHF + 0.75 MY during 2010/2011.

Item: AD kicker vacuum tanks
Responsible: AB/BT
Description: Refurbishment of existing tanks
RS: 9 (P=3, Io=3, Ir=2, If=1, Is=1)
RS after cons.: 2 (P=1, Io=2, Ir=1, If=1, Is=1)
Total budget: 100 kCHF + 0.25 MY 2011-2012

Based on previous AD experience of a leak followed by successful repair, the proposed consolidation consists of refurbishment of the 3 existing tanks in machine sectors 35,55 and 56. Structural improvements will allow for 300 degrees bakeout instead of 150 and also lower the risk of failure. A budget of 100 kCHF for HW + FSU and 0.25 MY is foreseen for 2011/12.

Item: AD kicker power supply/controls upgrade
Responsible: AB/BT
Description: Replacement of obsolete equipment
RS: 4 (P=4, Io=1, Ir=1, If=1, Is=1)
RS after cons.: 2 (P=2, Io=1, Ir=1, If=1, Is=1)
Total budget: 125 kCHF + 0.25 MY 2011-2012

Replacement of the power supplies including controls interface for the 10 kicker modules with up-to-date equipment (PCI-crate based). Budget is 125 kCHF + 0.25 MY in 2011/12.

Item: <u>AD horn pulser ignitrons</u>
Responsible: AB/BT
Description: Replacement of aging mercury ignitrons with semiconductor switches.
RS: 9 (P=3, Io=2, Ir=1, If=2, Is=3)
RS after cons.: 3 (P=3, Io=1, Ir=1, If=1, Is=1)
Total budget: 400 kCHF + 0.5 MY 2012
Remark: ***Safety***

Phasing out of the mercury ignitrons with semiconductor based technology. Due to the environmental impact of a failure, this item has high priority. A budget of 400 kCHF + 0.5 MY is required during 2012 or earlier if BT resources will be available. The scheduling of this item is linked with the "horn pulser electronics" upgrade below.

Item: <u>AD horn pulser electronics</u>
Responsible: AB/BT
Description: Replacement of obsolete purpose built equipment
RS: 8 (P=4, Io=2, Ir=2, If=1, Is=1)
RS after cons.: 3 (P=3, Io=1, Ir=1, If=1, Is=1)
Total budget: 100 kCHF + 0.5 MY 2012 (*)

Consolidation of the trigger generation system, HV supply and electrical distribution should be made at the same time as the ignitron upgrade (see above). A budget of 100 kCHF + 0.5 MY is planned during 2012 (or possibly earlier).

(*) Replacement of the controls interface & electronics with standard PLC-based equipment is underway and planned to be done during 2008 using the existing AD consolidation budget (75 kCHF + 0.5MY).

Item: <u>AD injection & ejection septa spares</u>
Responsible: AB/BT
Description: None
RS: 3 (P=1, Io=3, Ir=1, If=1, Is=1)
RS after cons.: N.A.
Total budget: N.A.
Remark: *Item for information on risk analysis*

1 spare injection unit exists. The installed ejection septum is presently used without water cooling due to a leak. It will be dismounted during the 2008/9 shutdown and refurbished. Spare coils exist. In the case of ejection septum breakdown, 3 weeks downtime can be expected due to vacuum bakeout.

Item: <u>AD injection & ejection septa controls</u>
Responsible: AB/BT
Description: Upgrade of controls interface
RS: 2 (P=2, Io=1, Ir=1, If=1, Is=1)
RS after cons.: 2 (P=2, Io=1, Ir=1, If=1, Is=1)
Total budget: 25 kCHF + 0.4 MY

To be considered within a global AD controls consolidation.

3.6. AD vacuum:

Item: AD vacuum ion pump power supplies & controls
Responsible: AT/VAC
Description: Replacement of old supplies + upgrade to up-to-date controls
RS: 8 (P=4, Io=2, Ir=2, If=1, Is=1)
RS after cons.: 2 (P=2, Io=1, Ir=1, If=1, Is=1)
Total budget: 350 kCHF + 0.4 MY 2009-2011

Replacement of aging Ion pump power supplies including controls (PLC/profibus based). With an age of 25 – 30 years, these supplies break down frequently. Only a few spare units exist and soon broken units will have to be repaired instead of replaced with long delays as result. For the risk analysis, AD is considered down when 1 vacuum sector is out. Budget is spread over 2009-2011.

Item: AD vacuum ion pumps
Responsible: AT/VAC
Description: Replacement of pumps and connectors
RS: 9 (P=3, Io=3, Ir=2, If=1, Is=1)
RS after cons.: 6 (P=2, Io=3, Ir=1, If=1, Is=1)
Total budget: 96 kCHF + 0.8 MY 2008-2011

Simultaneous problems with leaking connectors and/or internal short circuits on 2-3 ion pumps in the same vacuum sector will stop AD physics. Consolidation includes progressive replacement of all pumps after current measurement and replacement of connectors (10 per sector). Note that the risk score after consolidation remains fairly high due to bake-out time. Program will run over 4 years 2008-2011.

Item: AD vacuum Cryo compressors
Responsible: AT/VAC
Description: Purchase of spare units
RS: 8 (P=4, Io=2, Ir=1, If=1, Is=1)
RS after cons.: 4 (P=2, Io=2, Ir=1, If=1, Is=1)
Total budget: 80 kCHF (manpower needs are negligible) 2008-2011

Progressive (over 4 years) purchase of spare compressors.

3.7. AD diagnostics:

Item: AD orbit measurement system
Responsible: AB/BI
Description: Purchase of spare network analyser & construct spare multiplexer
RS: 3 (P=1, Io=3, Ir=2, If=1, Is=1)
RS after cons.: 1 (P=1, Io=1, Ir=1, If=1, Is=1)
Total budget: 65 kCHF + 0.1 MY 2010

Spare part situation is satisfactory except for the multiplexer which is of an old design with obsolete components. A re-design & construction of a spare unit is foreseen (15 kCHF + 0.1MY). Included is also purchase of a spare network analyzer at 50 kCHF.

Item: AD beam current transformers
Responsible: AB/BI
Description: Reconstruction of sensor and electronics of TFA6006 & TFA5302
RS: 3 (P=1, Io=3, Ir=2, If=1, Is=1)
RS after cons.: 1 (P=1, Io=1, Ir=1, If=1, Is=1)
Total budget: 230 kCHF + 1 MY 2011

Mechanical study for reconstruction of 2 TFA:s. TFA6006 is situated immediately downstream of the production target and has thus received large doses of radiation. Design includes shielding issues. For both TFA:S, the electronics is out of date and needs to be replaced. Cost is 160 kCHF for 6006 and 70 kCHF for 5302 out of which a large portion is used by the design office. A total of 1 MY is required for both units.

Item:	AD MWPC:s (Multi Wire Proportional Chamber)
Responsible:	AB/BI
Description:	Replace existing MWPC:s with GEM-detectors + new electronics
RS:	15 (P=3, Io=5, Ir=3, If=2, Is=1)
RS after cons.:	2 (P=2, Io=1, Ir=1, If=1, Is=1)
Total budget:	600 kCHF + 2 MY 2009-2010
Remark:	*Needed for AD operation from CCC.*

This is an essential tool frequently used for position and profile measurements in the AD ejection lines. Consolidation consists of upgrading the existing monitors while retaining the old vacuum chambers plus replacement of the obsolete in-house developed readout electronics with standard VME-based equipment. Using MWPC:s for the low-energy AD beams causes erratic measurements in one of the two planes. The new GEM-technology will remedy this. The present spare part situation is also critical with no spares remaining for several of the electronic modules. The proposed system will make use practical from the CCC thanks to adequate remote control and acquisition.

N.B. The AEGIS cost estimate assumes that this MWPC upgrade is to be done since the existing MWPC system does not allow for additional channels.

Item:	AD Schottky analysis
Responsible:	AB/BI
Description:	Replacement of non-standard and obsolete HW+SW (*)
RS:	N.A.
RS after cons.:	N.A.
Total budget:	100 kCHF + 1.8 MY 2009-2011
Remark:	*In the case of AD running beyond 2012*

Schottky analysis is used in the AD is the only means to measure circulating beam intensity with sufficient precision and is also used for tune measurements during the ramps. Intensity measurements throughout the deceleration cycle are extensively used and vital for the operation – it would be impossible to set up or run the machine without this. The present system employs obsolete hardware and software and should therefore be replaced with standard up-to-date equipment. The consolidation proposed here is valid for running AD until 2016 or beyond.

For the 2012 case, a minimal solution would be adopted consisting of adapting the existing software to FESA and finalizing the system (since the tune measurement part is not yet fully functional). This would require 0.3 FTE in 2009 and some additional effort for the finalizing.

(*) An alternative solution for intensity measurements would be to integrate it in the proposed system for RF beam-control consolidation owing to the experience gained with the development and operation of the current AD intensity measurement system and with the LEIR beam control system. Tune measurements would not be covered in this solution. The estimated cost is 30 kCHF and 1MY.

- Instrumentation software + other:	To the above items one has to add 1 MY for software development/adaption + 80 kCHF (FSU) 2010-2011
-MTV/Cameras,	AB/BI: PS-complex wide consolidation of HW & FESA compatible controls has recently been done. AD equipment is up-to-date.
-Emittance measurement,	(scrapers + stepping motors), AB/ATB: Ctrls upgrade done. Motor drivers to be replaced in 2009 (3kCHF+0.5MM).
	(photomultipliers + acquisition), AB: Some sw effort needed for FESA compatibility. 5kCHF for spare acquisition module.

3.8. AD target area and associated equipment:

Item: AD target area spare magnets
Responsible: AB/MCS
Description: Assessment/refurbishment of FTA.BHZ6024 spare
RS: 10 (P=2, Io=5, Ir=3, If=1, Is=1)
RS after cons.: 4 (P=2, Io=2, Ir=1, If=1, Is=1)
Total budget: 25 kCHF 2009

The target area magnet spare situation is satisfactory except for FTA.BHZ6024. The spare unit for BHZ6024 and 6025 is currently installed in the 6024 location and the condition of the original magnet is not known. An assessment will be made ASAP. Depending on the condition, it might be necessary to fabricate spare coils.

Item: AD target area ventilation & interlocks
Responsible: AB/ATB
Description: Renovation of ventilation & safety interlock system
RS: 8 (P=4, Io=2, Ir=2, If=1, Is=1)
RS after cons.: 3 (P=3, Io=1, Ir=1, If=1, Is=1)
Total budget: 100 kCHF + 1 MY 2010

The frequency of failures has increased during the last few years. The equipment is getting obsolete and lacks spare parts and documentation. Proposed consolidation includes: development of new PLC-based interlock system (20 kCHF), replacement of the ventilation controls cupboard (60 kCHF) and doubling of the controlled leak ventilator and controls (20 kCHF). Total manpower needs is around 1 MY.

Item: AD target water cooling
Responsible: AB/ATB
Description: Purchase of new sealed water pump & controls improvement
RS: 6 (P=3, Io=2, Ir=2, If=1, Is=1)
RS after cons.: 4 (P=2, Io=2, Ir=1, If=1, Is=1)
Total budget: 50 kCHF 2009

Purchase of sealed water pump: 20 kCHF. New controls: 30 kCHF

N.B. either of the 2 above items could be done during the 2008/9 shutdown, the other the following year.

Item: AD target area remote manipulation
Responsible: AB/ATB
Description: Improvement of remore manipulation equipment
RS: N.A.
RS after cons.: N.A.
Total budget: 45 kCHF + 0.75 MY 2010

The state of the equipment used for remote movements of the target, horn and associated equipment is degraded. In order to bring it back up to an acceptable state, the following actions should be considered:
Improvement of the cameras used for visual observation (15 kCHF)
Rejuvenation of manipulation equipment/electronics (20 kCHF)
Installation of a GSM antenna (10 kCHF)

3.9. AD control system:

Item: <u>AD control system</u>
Responsible: AB/CO
Description: Upgrade to comply with the rest of the PS-complex
RS: N.A.
RS after cons.: N.A.
Total budget: 700 kCHF + 5 MY

In order to comply with the ongoing rejuvenation of the injector controls according to the new Inca standard, the AD control system could profit from this resource investment and be upgraded with a relaitively small additional manpower effort. Continued operation with the old system is a problem since AB/CO can not afford to support all the legacy systems. The gain in manpower and also the quality of service would be much higher after renovation. For the HW, a complete upgrade of all FrontEnds is foreseen.

Major budget items:
FE:s HW including crates, modules, cabling and FSU:s: 700 kCHF + 2 MY of CERN manpower.
Central timing upgrade: 8 MM.
Inca DB configuration: 1.5 – 2 MY
DB support: 3 MM

N.B. HW cost could be reduced by 200 kCHF if one decides to keep existing G64 crates

3.10. AD infrastructure:

Item: <u>AD cooling water</u>
Responsible: TS/CV
Description: spares + cooling tower repair
RS: 6 (P=3, Io=2, Ir=2, If=1, Is=1)
RS after cons.: 3 (P=3, Io=1, Ir=1, If=1, Is=1)
Total budget: 60 kCHF 2009

Consolidation consists of structural repairs of the cooling station and purchase of spare parts. CERN manpower needs are minimal.

4. Maintenance & Operation

The following estimations have been done for actual yearly maintenance of the systems which are considered for consolidation:

Equipment	Responsible	Cost(kCHF)/yr	FTE/yr
AD magnets	AT/MCS	65	0.1
AD e-cooler	AB/BI	15	0.3
AD power converters	AB/PO	50	0.7
AD stochastic cooling	AB/RF	25	0.1
AD C10 system	AB/RF	0	0.1
AD C02 system	AB/RF	0	0
AD kickers	AB/BT	12	0.5
AD horn pulser	AB/BT	5	0.1
AD septa	AB/BT	8	0.2
AD vacuum	AT/VAC	35 (*)	0.8 to 1.0
AD target area	AB/ATB	20	0.1

(*) not from AT/VAC budget

Actual maintenance/operation budget (from APT). This is what the groups are actually spending and not necessarily what is needed.

Manpower:

FTEs	2007	2008	2009	2010	2011	Grand Total
AB-ABP	0.30	0.45	0.45	0.45	0.45	**2.10**
AB-ATB	0.45	0.45	0.45	0.45	0.10	**1.90**
AB-BI	1.05	2.55	2.55	2.65	2.65	**11.45**
AB-BT	0.75	0.69	0.85	0.80	0.80	**3.89**
AB-OP	4.09	4.10	4.10	3.81	4.10	**20.20**
AB-PO	0.70	0.70	0.70	0.70	0.70	**3.50**
AB-RF	1.58	1.63	1.60	1.70	1.70	**8.21**
AT-MEL	0.30					**0.30**
AT-VAC	0.80					**0.80**
Grand Total	**10.03**	**10.56**	**10.70**	**10.56**	**10.50**	**52.35**

Material:

kCHF	CET extractions of real cost						APT forecast			
	2003	2004	2005	2006	2007 Likely	2007 Initial	2008	2009	2010	2011
AB-ABP					0	50	50	50	50	50
AB-ATB	8	4		4	10	35	35	35	35	20
AB-BI				8	15	25	25	25	25	25
AB-BT					0	20	26	26	26	26
AB-OP				14	1	15	15	15	15	15
AB-PO	28	54	18	19	50	50	50	50	50	50
AB-RF				15	125	140	165	165	170	170
AT-VAC	156	112	32	45	10	80	80	80	80	80
Grand Total	**192**	**170**	**50**	**105**	**211**	**415**	**446**	**446**	**451**	**436**

5. AEGIS

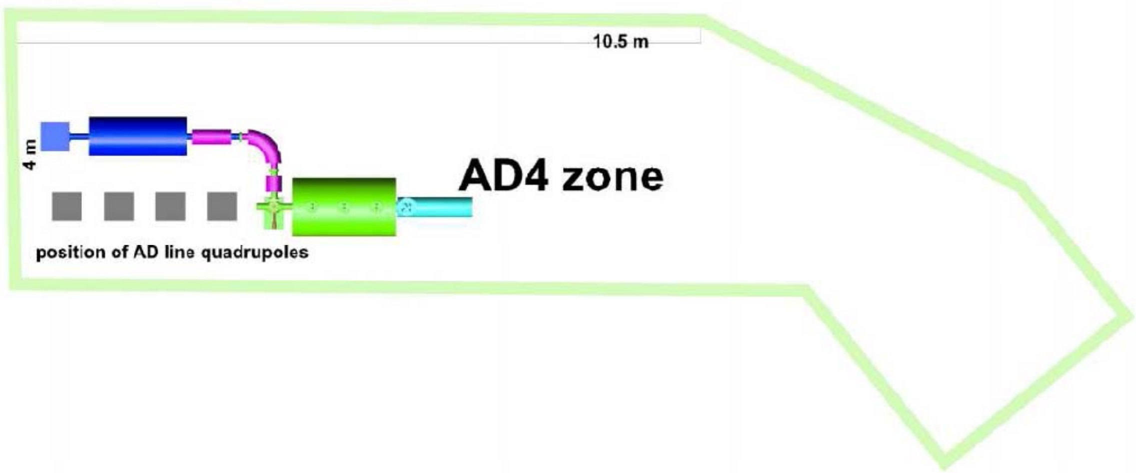
The proposed AEGIS (Antimatter Experiment: Gravity, Interferometry, Spectroscopy) experiment can be installed in the existing DEM-zone which they would share with the present ACE collaboration. Composed of approximately 60 users, AEGIS will use the 100 MeV/c Pbar beam from AD and perform gravitational studies on Hbars produced in flight.

The extension of the existing ACE beamline requires manufacturing and installation of 2 quadrupoles, 1 dipole, 3 combined H/V corrector magnets and 3 bpms as well as vacuum chambers and equipment.

N.B. Since the existing bpm-system (MWPC) is used to its maximum capacity and electronic modules are unavailable, this estimate assumes that the MWPC to GEM-detector consolidation mentioned in chapter 2 will be done.

Layout in the existing DEM-zone:

(Based on the existing AD layout. If ELENA is to be built, this and the cost estimate would need to be reviewed)



Cost estimate for extension of the existing DEM-line:

	Cost (kCHF)	Manpower (MY)
Beamline magnets	**75**	**0.33**
Magnet power converters	**100**	**0.2**
Vacuum equipment	**30**	**0.1**
Vacuum chambers	**85**	**0.1**
Diagnostics	**60**	**0.2 (*)**
Total	**350**	**1.0 (*)**

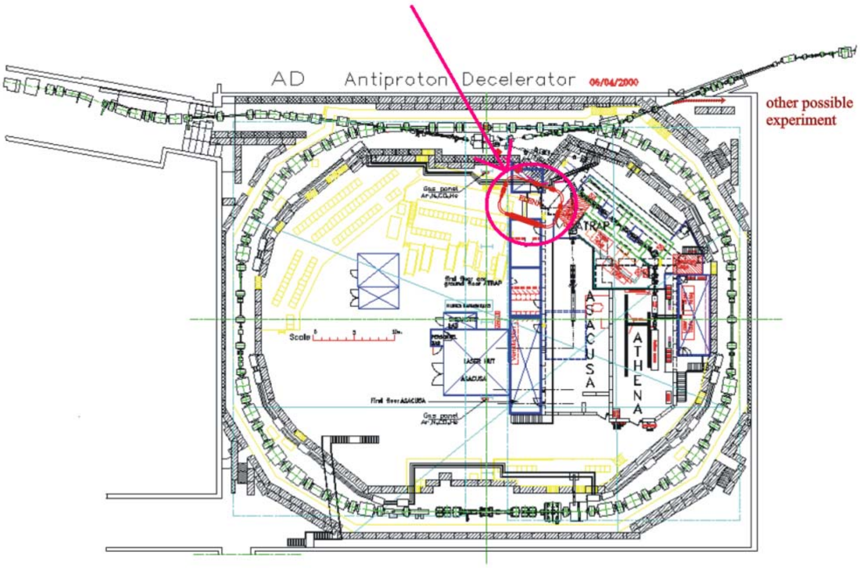
(*) cost of 3 additional channels added to the AD MWPC consolidation program.
If no AD MWPC consolidation is done, one can consider a reduced program (only replacing readout electronics/ctrls) for the MWPC:s in use (or find another solution):

Diagnostics **(in case of no AD MWPC consolidation)**	**440**	**1.5**

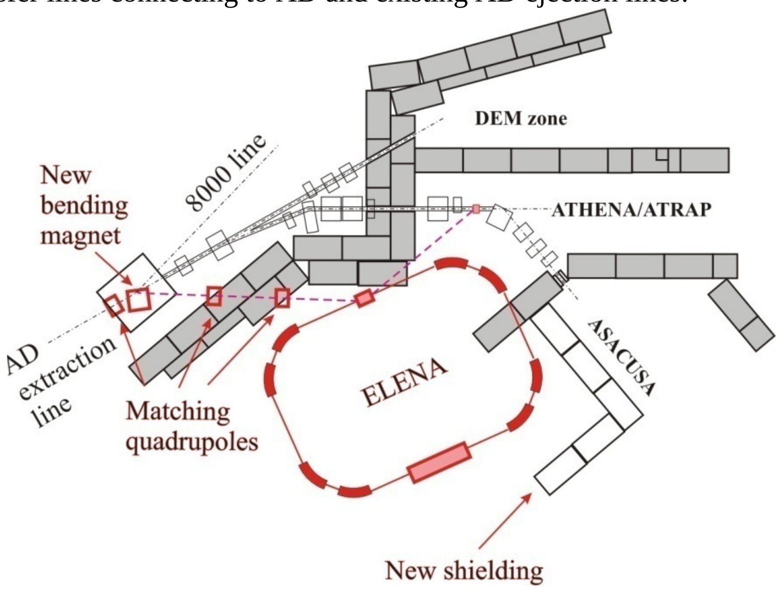
6. ELENA

In order to improve the trapping efficiency at the main AD experiments, a small additional decelerator & cooling ring has been proposed. Thanks to increased phase-space density and larger number of pbars available at low energy due to use of much thinner degrader foils, an increase in trapping efficiency of up to two orders of magnitude can be expected. ELENA is situated in the existing AD-Hall between the AD ring and the experimental area.

Proposed layout of ELENA In the existing AD hall:



ELENA with transfer lines connecting to AD and existing AD ejection lines:



The estimated time to design, construct and build ELENA is approximately 3.5 years.

A summary of the required resources can be found below. Further details can be found in the ELENA preliminary cost and feasibility study: http://documents.cern.ch/cgi-bin/setlink?base=preprint&categ=cern&id=ab-2007-079

Item	Material (kCHF)	Manpower FSU (kCHF)	Manpower FTE (MY)
Magnets (ring+inj. line)	**885**	**160**	**3.2**
Power converters	**857**		**1.5**
Injection/ejection septa	**220**		**2.9**
Injection/ejection kickers	**830**		**4.8**
Electron cooler	**1350**		**6.5**
Vacuum	**1175**	**27**	**5.0**
RF + Schottky diagnostics	**303**	**10**	**3.3**
B-trains	**80**		**0.7**
Diagnostics	**620**	**85**	**2.4**
Controls	**682**		**0.7**
H- source	**400**		**0.5**
Experimental area	**2245**		**3.0**
Mech. Design/Drawings			**17.0**
Div.	**290**		**6.5**
Total (MCHF/MY)	**9.937**	**.282**	**58.0**
Grand Total (MCHF/MY)	**10.219**		**58.0**

7. Implications of running AD beyond 2016

The present location of the AD building and target area is not easily compatible with the location of the planned PS2. To continue running the existing AD at its present location, a new transfer line looping back through the existing PS-ring tunnel or similar scheme would have to be built. Alternatively, one could either move the existing AD to a new location near PS2 or build a completely new, upgraded antiproton machine there.